XIV Science Team Meeting
Woods Hole, MA, USA

PROCEEDINGS OF THE GHRSST XIV SCIENCE TEAM MEETING

Woods Hole Oceanographic Institution (WHOI), Woods Hole, USA, 17th – 21st June 2013

ISSN 2049–2529

Issue 2 Revision 1 – September 2014

Edited by: The GHRSST Project Office

Meeting hosted by:

Woods Hole Oceanographic Institution

GHRSST International Project Office

Gary Corlett, Project Coordinator
gpc@ghrsst.org

Silvia Bragaglia-Pike, Project Administrator
gpa@ghrsst.org

www.ghrsst.org

Table of Contents

INDEX

EXECUTIVE SUMMARY

The Fourteenth Group for High Resolution Sea Surface Temperature (GHRSST) Science Team Meeting (G–XIV) was held at Woods Hole Oceanographic Institution (WHOI) Quisset Campus, in Woods Hole, MA, USA, from 17th-21st June, 2013. The meeting was supported by WHOI and local arrangements were organised by Carol Anne Clayson and Alec Bogdanoff. In total ~ 70 people participated in the meeting throughout the week.

The format of the Science Team Meeting broadly followed that of prior meetings. Monday morning began with introductions Susan Avery (Director of WHOI) and Peter Minnett (Chair of the GHRSST Science Team), which were followed by progress reports from the many agencies that contribute to GHRSST. On Monday afternoon the agenda for the week was reviewed and this was followed by a poster session. Tuesday was designated for the many GHRSST Technical Advisory and Working Groups (TAGs/WGs) and all had a very long day. Wednesday began with the first plenary scientific sessions and was followed in the afternoon by the annual team-building event and by the meeting dinner in the evening. Presentations were made to two retiring GHRSST Science Team members at the dinner, namely Richard Reynolds and David Llewellyn-Jones, in recognitions of their outstanding contribution to the field of sea surface temperature. Thursday was spent in plenary along with the first part of Friday morning. The meeting concluded with a wrap-up session, including reports from the Tuesday breakouts, and thanks were said to all involved, particularly the team at WHOI for what had been an excellent meeting.

This document contains a written summary of the meeting, including summary reports of each plenary session, the Tuesday breakouts, as well as extended abstracts submitted by the meeting participants. In addition to this report, all public presentations, reference and background documents can be accessed via the GHRSST website (*http://www.ghrsst.org*).

In addition to the main scientific session, side meetings were held by the VIIRS, MISST and S3VT projects. The GHRSST Advisory Council met on Thursday evening, and a meeting of the CEOS SST-VC took place on Friday afternoon.

Five new GHRSST Science Team members were nominated and subsequently elected: Carol Anne Clayson, Gutemberg Franca, Robert Grumbine, Eileen Maturi and Jonah Roberts-Jones.

The next GHRSST Science Team meeting, G-XV, will be held in Cape Town, South Africa, as decided at G-XIII.

SECTION 1: GHRSST XIV AGENDA WITH LINKS TO PRESENTATIONS

MONDAY, 17TH JUNE 2013		
08:30-09:00	Registration	
Plenary Session I: Introduction and review (Room 507) ***Chair:*** *Anne O'Carroll* ***Rapporteur:*** *Craig Donlon*		
09:00-09:30	**Welcome and logistics**	
Welcome to GHRSST		*Peter Minnett*
Welcome address from Woods Hole Oceanographic Institution		*Susan Avery (Director of WHOI)*
Logistics		*Carol Anne Clayson* *Gary Corlett*
09:30-10:30	**Reports from GHRSST Americas**	
NOAA/NESDIS/NODC LSTRF		*Ken Casey*
NOAA/NESDIS/STAR		*Alexander Ignatov*
NOAA/NESDIS/STAR		*Eileen Maturi*
NOAA/NESDIS/NCDC		*Viva Banzon*
NOAA/NWS/NCEP		*Bob Grumbine*
NAVO		*Jean-Francois Cayula*
10:30-11:00	**Tea/Coffee Break**	
11:00-11:30	**Reports from GHRSST Americas (Continued)**	
NASA GDAC		*Ed Armstrong*

MONDAY, 17TH JUNE 2013		
	NASA L2P & L4	*Mike Chin*
	MISST/RSS	*Chelle Gentemann*
11:30-12:30	**Reports from GHRSST Europe/Africa**	
	ESA	*Craig Donlon*
	Medspiration/Ifremer	*Jean-Francois Piollé*
	EUMETSAT	*Anne O'Carroll*
	OSI-SAF	*Pierre Le Borgne*
	MyOcean2	*Francoise Orain*
12:30-13:00	**Reports from GHRSST Asia/Pacific**	
	Australian Bureau of Meteorology	*Helen Beggs*
	JAXA	*Misako Kachi*
	JMA	*Shiro Ishizaki*
13:00-14:00	**Lunch**	
	Plenary Session II: Preparations for week ahead (Room 507) ***Chair:*** *Peter Minnett* ***Rapporteur:*** *Gary Corlett*	
14:00-14:15	*Summary of GPO activities*	*Gary Corlett*
14:15-14:30	*Remarks from the ST Chair*	*Peter Minnett*
14:30-15:30	*Discussion – Identification of main issues for meeting*	

MONDAY, 17TH JUNE 2013	
15:30-16:00	**Tea/Coffee Break**

16:00-18:00	**POSTER SESSION**	
1	*SQUAM Updates: progress since GHRSST-13 and future work*	Prasanjit Dash
2	*The Sentinel-3 mission: SLSTR technical overview*	Craig Donlon
3	*The Sentinel-3 mission: SLSTR data products*	Craig Donlon
4	*The sentinel-3 mission: performance and status*	Craig Donlon
5	*Night time detection of Saharan dust using infrared window*	Pierre Le Borgne
6	OSI-SAF operational NPP/VIIRS sea surface temperature chain	Pierre Le Borgne
7	*Evidence that SST signals are related to changes in the Atlantic meridional overturning circulation*	Yang Liu
8	L2 and L3 products from the ESA CCI project	Christopher Merchant
9	*GMES-PURE: Shaping the marine GMES/Copernicus user requirements*	Anne O'Carroll
10	*IASI L2Pcore sea surface temperature*	Anne O'Carroll
11	*New method in estimating Inter Sensor Sea Surface Temperature Biases using DINEOF analysis*	Francoise Orain
12	*Coastal diurnal warming study through in-situ and satellite data*	Xiaofang Zhu

MONDAY, 17TH JUNE 2013

16:00-18:00	VIIRS Side Meeting (Room 509)

Special session in VIIRS SST retrieval and validation

SST algorithm - 40min

SST QFs - 1hr 20min

For further information please contact: Alexander Ignatov (NOAA)

18:00-21:00	MISST Side Meeting (Room 507)

MISST project meeting

For further information please contact: Chelle Gentemann (RSS)

<table>
<tr><td colspan="3">TUESDAY, 18TH JUNE 2013</td></tr>
<tr><td>07:30-08:00</td><td colspan="2">Registration desk open</td></tr>
<tr><td colspan="3">GHRSST Parallel Breakouts for TAGs/WGs</td></tr>
<tr><td>08:00-10:00</td><td>EARWIG (507)</td><td>ICTAG (509)</td></tr>
<tr><td></td><td>• Agenda
• Bouali – Mitigation of striping in ACSPO clear-sky radiances and SST products
• Ignatov – Pattern recognition enhancements to NOAA ACSPO clear-sky mask
• Koner – Skin SST physical retrieval from GOES using modified total least square method
• Harris – Physical retrieval for MODIS
• Le Borgne – Using numerical weather prediction model profiles to improve SST calculations: application to Metop/AV
• Saha – Quantifying the effect of ambient cloud on clear-sky ocean brightness temperatures and SSTs
• Beggs – A consistent day/night SST regression algorithm based on 3-channel AVHRR
• Merchant – Improved optimal estimation retrieval using spatially smoothed input</td><td>8:00-8:10: Introduction
8:10-8:50: Analysis methods and development of L4 SST products
Presentations (10 min each):
• Sea surface temperature by Barnes' interpolation: current stage (Gutemberg França)
• Recent updates to the near real time OSTIA system (Jonah Roberts-Jones)
Brief update (5 min):
• NOAA Geo-Polar 5km Global SST Analysis for day & night, night-only, and diurnal correction plans (Eileen Maturi)
• Discussion (15 min)
8:50-9:35: Inter-comparison of L4 SST products
Presentations (10 min each):
• A comparison of SST gradients and the impact of going to higher resolution (Jorge Vazquez)
• L4 comparison using Reynolds/Chelton spectrum test (Michael Chin)
Discussion (25 min), including:
• Plans for the IC-TAG-wide inter-comparison based on Reynolds/Chelton approach
9:35-9:45: GMPE plans discussion (lead by Gary Corlett and Jonah Roberts-Jones)
9:45-10:00: General discussion and plans for the next year</td></tr>
<tr><td>10:00-10:30</td><td colspan="2">Tea/Coffee Break</td></tr>
</table>

TUESDAY, 18TH JUNE 2013		
10:30-12:30	*STVAL (507)*	*R2HA2 (509)*
	10:30: Introduction and ST-VAL Report (Helen Beggs) *10:40: Status of in situ SST Quality Monitor (iQUAM) (Alexander Ignatov for Feng Xu)* *10:50: Preliminary analyses of Metop AVHRR, MODIS and VIIRS SST products in SQUAM (Prasanjit Dash)* *11:00: Initial Validation of VIIRS Skin SST Retrievals with Shipboard Radiometers (Peter Minnett)* *11:10: High Latitude SST Cal/Val Activities at DMI (Jacob Høyer)* *11:20: Multi-Sensor Match-up Database for ESA SST_CCI (Gary Corlett)* *11:30: BoM Efforts to Improve SSESs for AVHRR SST Level 3 Products (Helen Beggs for Chris Griffin)* *11:40: General discussion and questions based on presentations.* *11:55: Discussion and feedback on the future of the GHRSST MDB, MMDB and HR-DDS through the Felyx System (Led by Jean-Francois Piollé).* *12:10: Other ST-VAL Issues (Led by Helen Beggs).*	*R2HA2 Breakout Summary Report*
12:30-13:30	**Lunch**	

12:30-13:30	**GPO Meeting**

<table>
<tr><th colspan="3">TUESDAY, 18TH JUNE 2013</th></tr>
<tr><td>13:30-15:30</td><td>DVWG (507)</td><td>DASTAG (509)</td></tr>
<tr><td></td><td>Brief Presentations/Updates:
• Outline
• Update on the GHRSST Tropical Warm Pool Diurnal Variability (TWP+) Project (Helen Beggs)
• Comparison of Diurnal Warming Estimates from Unpumped Argo Data and SEVIRI Satellite Observations (Sandra Castro)
• A diurnal warming dedicated matchup database: Examples and preliminary validation results (Pierre Le Borgne)
• SST diurnal variability: Regional extent & implications in atmospheric modeling (Ioanna Karagali)
• Application and evaluation of diurnal warming models forced with GFS model inputs (Gary Wick)
• SST sensitivity and its relevance to measuring diurnal variability (Chris Merchant)
• Impact of DW on Flux Climatology (Carol Anne Clayson)
Discussion Topics:
• Group goals and priorities
• Membership</td><td>1. Emerging trends in metadata (Ted Habermann, remote)
2. PO.DAAC integrated web services (Ed Armstrong)
3. Reconciling GHRSST archive integrity and data flows (Ken Casey)
4. A Hadoop framework for data mining and analyses of large datasets (Jean Francois Piollé)
5. Proposals for new GHRSST dataset policies (Ed Armstrong and Gary Corlett)</td></tr>
<tr><td>15:30-16:00</td><td colspan="2">Tea/Coffee Break</td></tr>
<tr><td>16:00-18:00</td><td>HLTAG (507)</td><td>AUSTAG (509)</td></tr>
<tr><td></td><td>• Outline
Brief Updates:
• Cloud and Ice masking issues (Steinar Eastwood)
• IST status and utility, from Earthtemp (Jacob L. Høyer)
• Arctic SST and Sea ice anomalies (Pierre Le Borgne)
Identify ongoing work within High latitudes:
• SST
• MIZ</td><td>• 16:00: GMES-Pure (Anne O'Carroll)
• 16:10: Results from NASA sponsored GHRSST Webinar (Jorge Vazquez)
• 16:40: Overview of SQUAM and demo (Prasanjit Dash)
• 17:10 Overview of fisheries habitat prediction (Ed Armstrong)
• 17:20 General Discussion on key topics (Gary Corlett)

1. Users – who are they?
2. Possible user symposium – we should have a good discussion on the what,</td></tr>
</table>

TUESDAY, 18TH JUNE 2013		
	• *ICE* *Discussion Topics:* • *Sea ice GMPE* • *Sea Ice CCI results*	*why, when etc.* 3. *Expansion into new areas – coordinating our efforts into South America and Asia etc.*
18:00-18:30	**Tea/Coffee Break**	
18:30-20:30	*IWWG (509)*	*CDRTAG (507)*
	IWWG Breakout Summary Report	• Presentations: – *Outline* – *The generation of SST climate data records using shipboard radiometers (Peter Minnett)* – *A long term satellite based data record of sea surface temperature from ESA's climate change initiative (Chris Merchant for Nick Rayner)*

WEDNESDAY, 19TH JUNE 2013		
08:00-08:30	**Registration desk open**	
Plenary Session III: Focus on topics relating to data and user services (Room 507) ***Chair:*** *Jorge Vazquez* ***Rapporteur:*** *Toshio M Chin*		
08:30-08:50	*CEOS SST-VC: update on progress*	*Craig Donlon*
08:50-09:10	*Felyx: A generic tool for EO data analytics*	*Jean-Francois Piollé*
09:10-09:30	*Data life cycle policy*	*Edward Armstrong*
09:30-10:00	*Open discussion led by session chair*	
10:00-10:30	**Tea/Coffee Break**	
Plenary Session IV: Focus on key topics relating to estimation, masking and validation (Room 507) ***Chair:*** *Helen Beggs* ***Rapporteur:*** *Werenfrid Wimmer*		
10:30-10:50	*Progress in sea surface temperature retrieval and future directions*	*Christopher Merchant*
10:50-11:10	*METOP-A/AVHRR derived SST over the Arctic: Five year (2007-2012) results*	*Pierre Le Borgne*
11:10-11:30	*AMSR2 SST GCOM-W1*	*Misako Kachi* *Chelle Gentemann*
11:30-12:00	*Open discussion led by session chair*	
Afternoon Team Building and GHRSST Dinner in the evening		

THURSDAY, 20TH JUNE 2013		
08:30-09:00	**Registration desk open**	
Plenary Session V: Focus on key topics relating to Level 4 (Room 507) ***Chair:*** *Alexey Kaplan* ***Rapporteur:*** *Edward Armstrong*		
09:00-09:20	*High Resolution Daily Sea Surface Temperature Analysis: the 2-stage OI*	*Richard Reynolds*
09:20-09:40	*Evaluation of GHRSST products for studies of short term climate variability - a comparison between OSTIA and NCDC OI2 analyses*	*Dudley Chelton*
09:40-10:00	*SST data impact in global HYCOM*	*Jim Cummings*
10:00-10:30	*Open discussion led by session chair*	
10:30-11:00	**Tea/Coffee Break**	
Plenary Session VI: Focus on key topics relating to climate (Room 507) ***Chair:*** *Christopher Merchant* ***Rapporteur:*** *Jon Mittaz*		
11:00-11:20	*ESA SST CCI L4 reanalysis using the OSTIA system*	*Jonah Roberts-Jones*
11:20-11:40	*A multi-sensor SST reanalysis for the arctic ocean*	*Jacob Høyer*
11:40-12:00	*Sampling errors in satellite derived sea surface temperature for climate data records*	*Yang Liu*
12:00-12:30	*Open discussion led by session chair*	

THURSDAY, 20TH JUNE 2013	
12:30-13:00	**S3VT Special Session (Room 507)**
Special session on Sentinel 3 Validation Team Welcome and overview of S3VT-T (10 min) Summary slides from team members/groups (10 min) Questions/issues for discussion (10 min) For further information please contact: Anne O'Carroll (EUMETSAT) or Craig Donlon (ESA)	

13:00-14:00	**Lunch**	
Plenary Session VII: Physical oceanography and SST (Room 507) ***Chair:*** *Peter Cornillon* ***Rapporteur:*** *Jonah Roberts-Jones*		
14:00-14:20	*Biases in global mean SST estimates obtained from gridded data sets*	*Alexey Kaplan*
14:20-14:40	*Statistical analysis of sub-mesoscale processes from satellite SST observations*	*Emmanuelle Autret*
14:40-15:00	*SEVIRI and VISSR SST front and gradient datasets*	*Peter Cornillon*
14:00-15:30	*Open discussion led by session chair*	
15:30-16:00	**Tea/Coffee Break**	

THURSDAY, 20TH JUNE 2013		
Plenary Session VIII: SST in ocean-atmosphere interaction (Room 507) ***Chair:*** *Carol Anne Clayson* ***Rapporteur:*** *Gary Wick*		
16:00-16:20	*Impact of diurnal warming on assimilation of satellite observations of sea surface temperature*	*Charlie Barron*
16:20-16:40	*Relating of sea surface temperature and color to carbon dioxide partial pressure and flux*	*Timothy Liu*
16:40-17:00	*Mid-latitude sea surface temperature signal in the upper troposphere*	*Xiasou Xie*
17:00-17:30	*Open discussion led by session chair*	

18:00-20:00	**Advisory Council (Room 507)**
Meeting of the GHRSST Advisory Council For further information please contact: Helen Beggs (ABoM)	

FRIDAY, 21ST JUNE 2013		
08:00-08:30	**Registration desk open**	
	Plenary Session IX: Coupled data assimilation and SST (Room 507) **Chair:** *Jim Cummings* **Rapporteur:** *Andy Harris*	
08:30-08:50	*Direct assimilation of satellite SST radiances*	*Jim Cummings*
08:50-09:10	*Evaluating the diurnal variability of sea surface temperature in a global initialised couple model*	*Jose Rodriguez*
09:10-09:30	*Sea surface temperature estimates and coupled forecasting*	*Christopher Merchant*
09:30-10:00	*Open discussion led by session chair*	
10:00-10:30	**Tea/Coffee Break**	
	Closing Session (Room 507) **Chair:** *Peter Minnett* **Rapporteur:** *Gary Corlett*	
10:30-10:45	*GHRSST and possible future developments*	*David Llewellyn-Jones*
10:45-11:00	*Report from Advisory Council*	*Helen Beggs*
11:00-11:50	**Summary of breakout groups**	
1	*AUS-TAG*	*Jorge Vazquez*
2	*CDR-TAG*	*Christopher Merchant*

FRIDAY, 21ST JUNE 2013		
3	*DAS-TAG*	*Ed Armstrong*
4	*DVWG*	*Gary Wick*
5	*EARWiG*	*Andy Harris*
6	*HL-TAG*	*Bob Grumbine*
7	*IC-TAG*	*Alexey Kaplan*
8	*IWWG*	*Bob Grumbine*
9	*ST-VAL*	*Helen Beggs*
10	*R2HA2*	*Peter Cornillon*
11:50-12:30	Review of action items	
12:30-13:15	Identification of priorities for following 12 months	
13:15-13:30	*Wrap-up/closing remarks*	
Close of GHRSST XIV		
13:30-14:30	**Box lunch to go**	

14:00-17:00	**CEOS SST-VC (Room 507)**
Meeting of the CEOS SST Virtual Constellation For further information please contact: Kenneth Casey (NOAA) or Craig Donlon (ESA)	

WELCOME FROM THE SCIENCE TEAM CHAIR:

Welcome to the 14th Science Team Meeting of GHRSST!

It has been an interesting and busy year since we last met in Tokyo, with new satellite measurements becoming available and the promise of more to come. There have been personnel changes within GHRSST, and positive developments with the GHRSST data streams. On a less uplifting note, the effects of budget contraction here in the US, and elsewhere, are becoming felt and the situation does not show any signs of improving in the near future.

At the last Science Team Meeting, the data from VIIRS were very fresh and the initial impressions were very promising. Now, a year later, we can report that these promises have been fulfilled; the VIIRS infrared bands are very clean and the derived skin SSTs are of high quality. All indications are that VIIRS will not only continue the long time series of wide-swath SSTs that include those from the AVHRRs and the two MODIS's, but will also bring improved spatial resolution and absolute accuracies. Also at the Tokyo meeting we heard of the first data from the AMSR-2 on GCOM-W1 and at this meeting we anticipate hearing more about the characteristics and accuracies of the microwave measurements. EUMETSAT has two additional earth observation satellites: MetOp-B in polar orbit carrying an AVHRR/3 and an IASI, and METEOSAT-10 (MSG-3) in geosynchronous orbit with a SEVIRI. Both AVHRR and SEVIRI are tried-and-tested sensors and we look forward to their data streams continuing over the next many years. We also look forward to the launches into polar orbit of the SGLI (Second generation GLobal Imager) on the Japanese GCOM-C1 and SLSTR on the European Sentinel-3a, and the Advanced Baseline Imager (ABI) on GOES-R into geostationary orbit. These are exciting times!

Another exciting development in the past year has been the signing of a Memorandum of Understanding between EUMETSAT and the National Satellite Ocean Application Service (NSOAS) of China. This bodes well for a wider use of data from Chinese satellites.

On the data front, the GDS-2 is being adopted by data providers, and a new processing of (A)ATSR data is underway. Similarly a reprocessing of the MODIS SSTs is anticipated in the next several months. The GDAC has adopted a "data life-cycle" policy that will ensure critical GHRSST data streams will continue to the served to the user community through the JPL PO.DAAC. Compliance with the new data policy is to the benefit of all in GHRSST.

As you know, Gary Corlett took over from Andrea Kaiser-Weiss as the GHRSST Project Coordinator in October and has taken up the reins in an admirable fashion. We also thank Silvia Bragaglia-Pike for her continued valuable contributions to the GHRSST Project Office. GHRSST is in safe hands.

A lot of effort goes on behind the scenes in preparing for the Science Team meetings, and in addition to the work done through the Project Office the local organizers at Woods Hole have also been busy. We thank Carole-Anne Clayson and her team.

So, again, welcome to the 14th GHRSST Science Team Meeting. I am looking forward to a stimulating and exciting week, and I hope you are too.

Peter Minnett

Peter Minnett

(Chair of the GHRSST Science Team)

SECTION 2: PLENARY SESSION SUMMARY REPORTS

SESSION I: INTRODUCTION AND REVIEW

Chair: Anne O'Carroll[1]; Rapporteur: Craig Donlon[2]

(1) EUMETSAT, Eumetsat-Allee 1, Darmstadt, 64295, Germany, Email: Anne.Ocarroll@eumetsat.int
(2) ESA/ESTEC, Keplerlaan 1, 2201 AZ, Noodwijk, The Netherlands, Email: craig.donlon@esa.int

Welcome to GHRSST: Peter Minnett

- Welcomed everyone to a busy and exciting week – lots of new data.
- VIIRS & AMSR2 are looking good and we look forward to SLSTR being launched and the new GCOM-C Imager. The new Metop and Meteosat satellites provide data to bring into the GHRSST fold.
- Welcomed Dr Susan Avery, WHOI.

Welcome address from Woods Hole Oceanographic Institution: Susan Avery

- Expressed pleasure to have everyone here.
- Gave an overview of the Woods Hole institution which was founded in 1930 by a Grant from Rockerfella, as a counterpart to Scripps.
- Mission: "To know the Ocean" – all aspects including climate.
- There is a strong integration of Science and the development and use of tools to access the ocean (deepest parts).
- There are two campuses here and another campus close to the water.
- There are 1100 people working at WHOI including 130 Graduate students and 80-100 joint Masters and Doctorate students with MIT.
- The annual budget is 200 Million dollars, 80% from competitive grants and awards. 20% from philanthropy.
- WHOI run 3 ships, HF radar, and 2 global class ships – a new Alvin certification is underway.
- Ocean Observatory initiative – will start to give networks and platforms and sensors to get full operational coverage of the ocean.
- New opportunities then to look at the temporal perspective of oceanography.
- There are 5 departments – interdisciplinary – including climate, conservation science, coastal issues, and deep ocean exploration.
- Have now the "deep sea challenger" - the Jim Cameron sub that went to the Mariana's trench.
- In discussion with congress on the importance of the ocean in long term perspective.
- Ocean acidification and impacts (fisheries, food web corals)
- Microbiology: fundamental component of the ocean – and we need to understand their role and importance.
- WHOI do not have a dedicated satellite laboratory but have an increase in interest that is growing.
- Right from the beginning of the USA foundation there is a culture of "giving back" (Fords. Scripps, Rockerfellas etc) to example libraries, universities etc. This is a

deep seated culture in the USA. It is difficult for environmental issues to receive the money.

- WHOI is the largest independent ocean laboratory in the USA.

Logistics: Gary Corlett

Thanks to all who have helped to prepare the meeting (Silvia, Carol-Anne, Alec and Kathy).

Reports from GHRSST Americas

NOAA/NESDIS/NODC/LSTRF: Ken Casey

- NODC components include the long-term archive (LTSRF) and RDAC for Pathfinder.
- LTSRF progress: 2.5Million files – services and data are all increasing significantly. There are lots of different mechanisms to access data. User numbers keep rising and more people are using the data.
- Working with CEOS SST-VC: provide data to CEOS and GEO via integrated Data Catalog and CWIC.
- Discovery and access has been a focus and has delivered new human interfaces and restful interfaces. 60 data sets and 53 with search at granule level. These are new services allowing people to develop applications that can query and access data.
- Browse graphic generation is back up and running and this is a good check to ensure all is well with the data files.
- RDAC for Pathfinder: Key aspects: 2012 data created and about ready to be released. V5.3 will be available by the end of the year – more consistent. Next year a full version 6.0 to full GHRSST GDS standard.

NOAA/NESDIS/STAR: Alexander Ignatov

- NOAA has 2 products from VIIRS: IDPO and ACSPO. Work on SST algorithms, QC flags and VIIRS sensor checks is underway.
- ACSPO Overview: Experimental version in 2012 (VIIRS and MODIS) and 2.2 operational in May 2013 with AVHRR GAC and FRAC. Later this year it will be GDS2.0 compliant.
- MICROS: looking at double differences. Show large period where MODIS RTM was not correct leading to cool biases. The RTM needs to be sorted out.
- SQUAM: All operational – system is now adding more functionality. All products are in the family except the IDPS (Commercial official products).
- iQUAM: Cal/Val activities. Progressing to Version 2 including Argo floats and temporal range to 1981.
- GDS2 implementation: VIIRS and AVHRRs from October 2013.

NOAA: Eileen Maturi

- Operational products for SST: retrieval and provision of GDS2.0 data, using GOES-13/14, MTSAT, and MSG-SST. There is also a blended analysis.
- Improvements: increased number of RTM layers; adding aerosol products to improve over climatology; improved Bayesian cloud screening based on satellite specific PDF's.

- 5km blended products include only EO GEO + PO data. The products preserve the mesoscale features well. Global L4 analysis now running. 1/20 deg analysis coming soon.
- Operational teams are now producing new contour charts based on the new 5km analysis – good user progress.
- Planned improvements: include 1km VIIRS 2013; METOP-B OSTIA is now the reference; include PM data in 2014.
- Some SST products are available from CLASS (e.g. 5km) and some others are being pulled by PO.DAAC.

NOAA/NESDIS/NCDC: Viva Banzon

- As an RDAC of GHRSST they have recently developed a "Temperature Portfolio" together with Land people.
- NCDC have heritage OI daily L4 Reynolds operational. AVHRR+AMSR 2002-2011 are no longer operational.
- R&D: Completed the HR daily OI 1/24 degree product which will go online soon (not going operational until there are users).
- Have other GHRSST related products: ICOADS transitioned to NCDC (underfunded). Trying to increase international participation and update.
- A NOAA-GCOS activity is providing a metric to decide where buoys are needed – not a perfect measure (NOAA-GCOS activity). Helps to understand where we need buoys. Simple way to communicate why we need a buoy array.
- 2015: expect to be GDS 2.0 compliant.

NASA GDAC: Ed Armstrong

- The GDAC functions with ~30Gb/Day GHRSST 6000 files per day. This will increase with high-volume data anticipated from VIIRS and Metop.
- On a monthly basis, user statistics reports are sent to RDACs. Improvement of the infrastructure to report these statistics is on-going.
- GDAC: Software handlers at ingest to check metadata. Read software is available. Good communication with RDACs is needed to improve tools and correct errors.
- Operational ingest of GDS2.0 L2P, L3C, L4 data has started (e.g. OSTIA, DMI, NAVO VIIRS).
- GDS2 implementation issues include reprocessing schedules, governance, lifecycle implementation. A User Working Group needs to be looked at.

NASA L2P & L4: Mike Chin

- MURL4 and G1SST L4 are both daily L4s at 1km. For MODIS L2P, the coefficients have been updated again – Franz et al are producing data.
- MUR has issues with over smoothing at high-latitudes. There is still active work on the products to use more data (daytime – so we need to look at DV issues).
- MODIS: new LATBAND approach is under test runs.
- MUR is ready for GDS2. MODIS moves to GDS2 in 2013 but for G1SST there are no plans.

MISST/RSS: Chelle Gentemann

- URI: HRPT data extends the time series over E&W coasts (1982-2016). These are high value data sets which have not been released before. Frontal maps will also be produced.
- Cummings: Adjoint of HYCOM to improve forecast errors. Miami: VIIRS data very good, SST's drifters radiometers etc. Uni Maryland: Methodology to use AATSR to understand AVHRR accuracy and calibration. U. Utah (Erik Crossman): Looking at Lake Temperature Algorithms (Climate community with S. Hook).

Reports from GHRSST Europe/Africa

ESA: Craig Donlon

- ESA has and continues to provide support to GHRSST (Project Office, Medspiration Evolution) and has several projects that make extensive use of GHRSST data. GHRSST is important to ESA as the Agency has successfully flown several SST missions and is developing new satellite SST capability.
- Sentinel Series of Missions in partnership with the EU are progressing well. Sentinel-3 provides the follow-on capability for ENVISAT AATSR.
- The third re-processing of the (A)ATSR archive is progressing well and the data are expected for release after Summer 2013 following validation work. A fourth reprocessing will bring the (A)ATSR archive into alignment with new Sentienel data format specifications (L2P will still be produced) by Q4 2014.
- Sentinel-3 Sea and Land Surface Temperature Radioameter (SLSTR) performance predictions remain stable at this time with good NEdT for Thermal Infrared Channels of ~50 mK.
- Follow on projects are now in progress to develop new ideas for Passive Microwave SST missions (MICROWAT). These include a study to refine the MICROWAT conical scanning antenna concept, !D interferometric approaches and a study to look at pushbroom narrow swath approaches.
- The Medspiration SST project has been extended as Medspiration Evolution (reported in the next paper).
- The GPO has been funded for 2 more years at the University of Leicester UK with Gary Corlety at the helm.
- A new ESA project called GlobCurrent has been initiated that will make full use of GHRSST data sets to develop innovative methods and products for ocean surface currents.
- The ESA CCI programme considers GHRSST as the Authoritative Scientific Body for SST issues. A Phase-II project is now in preparation building and extending the activities of Phase-I SST_cci. Phase-II will include more work on early AVHRR data records and improvements to SSTs derived from Passive Microwave satellite instruments especially in high latitude regions where IR data are limited due to persistent cloud cover.
- Following detailed discussions with many GHRSST Science Team members, ESA has initiated a new project to develop a Diagnostic Data Set called Felyx (reported in a follow on paper at this meeting). Felyx will allow other organizations and Agencies to host their own DDS/MDB systems in a distributed but federated manner. This will form a powerful tool for GHRSST activities.

- ESA also supports international coordination of SST activities through the CEOS SST-VC and through contributions to the International Space Science Institute with a dedicated activity to improve Satellite SST climate data records.

Medspiration/Ifremer: JF-Piolle

- Extension to Medspiration: Outreach, analytics, user apps, Sustaining and developing new products.
- Applications: Looking at changes in Mediterranean at local level for climate and also looking at strong events.
- Analytics: tools to allow processing of large data volumes working on cloud solution.
- Regional products L4 production and a new Global 2km analysis based on same methodology (ODYSSEA).
- Will try to develop new archives and a complete L2P archive at IFREMER in neCDF4 format.
- NAIAD is still going and supporting GHRSST as a front end.
- Still pushing for user demonstration and reach out to new communities.

OSI-SAF: Pierre Le Borgne

- New product: NPP VIIRS for the NAR area. L3C in GDSv2 netCDF4 is in Beta testing. Full operations planned for September 2013.
- SDI is produced from NPP, which is compared to NAAPS AOD estimates.
- IASI SST from EUM is being ingested and converted to full L2P. An MDB is being produced: looking at the first results.
- Have new data from Metop-B. Currently the chaing is being tested. Eventually the new products will replace Metop-A (only one produced operationally at any time).
- High latitude products are available twice daily. High latitude cloud/ice masking is a difficult problem. The Arctic SST is the most difficult region. All aspects of SST in the Arctic are problematic.
- GDSv2.0: All polar orbiter products will be in GDS2. Plan to switch on 3rd July to replace the old GDSv1.7. Double delivery is in progress now but this will stop. VIIRS and IASI will be produced in GDSv2.0 from the beginning.
- New NWP outputs are used in OSI-SAF – this will help reduce regional biases.

EUMETSAT: Anne O’Carroll

- Operational Oceanography: Meteosat and EPS looking towards MTG and EPS-SG.
- Hans Bonekamp is giving a presentation on GHRSST this week at a EUMETSAT/SOA/NSOAS bi-lateral meeting.
- Geostationary data reprocessing with the Climate Monitoring SAF (CM-SAF) underway.
- IASI L1c reprocessing 2014-2015. Within the CCI Phase II there are activities to bridge the gap using IASI data. User requirements for reprocessed IASI SST were not articulated so it is currently not part of the reprocessing plans.
- Gave an update on S3VT and the EUMETSAT Sentinel-3 marine centre.

MyOcean2: Francoise Orain/Herve Roquet

- The MyOcean project progressed to MyOcean2 from April 2012 to September 2014.
- MyOcean2 will simplify the big project and the SST, SI and Wind are now in a single OSI-TAC. Every Centre in MyOcean has a responsibility: Production Unit and Dissemination Unit.
- OSTIA: New version from UKMO updated the background and new bias corrections based on Metop-A and increased the number of GEO SST's.
- Lake ice has been added and a new SST climatology has been added. In GDS2 format. CMS: production of L3C and L3S over EU seas has stopped.
- CMS R&D blacklist of buoys: Look for bad buoys or anomalies using an automated scheme working on 10 day periods based on METOP, NOAA18/19. Coordinated with UKMO blacklists. There are more blacklisted buoys when more satellites are used.
- BESST: Belgium U. Liege – methodologies and estimations of bias in SST (Igor Tomazic). Use of DINEOF method with operational context and application/analysis.

Reports from GHRSST Asia/Pacific

Australian Bureau of Meteorology: Helen Beggs

- Locally retrieved HRPT gives much improved all round SSTs.
- Geostationary: MTSAT-1R using 2-channel algorithm much better and useable – data are here on red disk.
- GAMSSA and RAMSSA – GDS1.7 not sure if there is enough time to go to GDS2.0 (can't promise) but now have WindSat SST's in March 2012 – now are being used.
- Validation in 18 IMOS ships met and air-sea flux data, mooring, and 3 research vessels.
- Using AVHRR in ReefTemp NextGeneration Coral bleaching Nowcast System.
- Tested use of WindSat into SST's into Operational ocean model systems.

JAXA: Misako Kachi

- AMSR-2 release for L2 from May 17th. Data Policy does not allow for redistribution of data.
- AMSRE: 2pm data sets now being processed. Not distributed yet – used for calibrations.
- JAXA GHRSST Server – GDS2 is implemented on AMSR2 Windsat and VIRS ongoing
- Cal/Val is ongoing – AMSR2 standard product available on Web site of server.
- Want all users to reregister for new web site and close the old web site by end of year (gives access to new GDS2.0) format.
- Delay of GCOM-1C launch – JFY 2016 trying to keep schedule – fiscal situation is challenging.

JMA: Shiro Ishizaki

- MTSAT-1&2: 1D var approach with simple RTM to get SST in operations for 9 years. There is now a new scheme in test mode – regional analysis with AVHRR/MTSAT/AMSR2. MTSAT new system at 0.1 deg resolution.
- A new regional SST system is in preparation now. There is a need to improve some areas but so far it is very good.
- GDS2.0 Implementation: Plan to create netCDF GDS2.0 - several issues to be resolved. No fixed schedule is defined as yet.
- Plan to launch the next satellite Himawari-8 in FY2014.

SESSION III: FOCUS ON TOPICS RELATING TO DATA AND USER SERVICES

***Chair*: Jorge Vazquez[(1)]; *Rapporteur*: Toshio M. Chin [(2)]**

(1) Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA,
Email: jorge.vazquez@jpl.nasa.gov
(2) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
Email: toshio.m.chin@jpl.nasa.gov

ABSTRACT

The plenary session consisted of three talks followed by a discussion. Three talks presented included:

CEOS SST-VC: update on progress (Craig Donlon)

Felyx: A generic tool for EO data analytics (Jean-Francois Piolle)

Data life cycle policy (Edward Armstrong)

The following are summary notes from each session.

1. Summary

CEOS SST-VC: update on progress (Craig Donlon)

Goals, activities, and future visions for the SST Virtual Constellation (VC) are presented. Symbiotic relationships between the SST-VC and GHRSST are emphasized. SST-VC can promote and communicate the GHRSST activities to the traditional GHRSST sponsors especially the space agencies around the world. SST-VC can achieve these by publicizing societal benefits of GHRSST (and other SST) products. In the current SST-VC membership, GHRSST is well-represented; several membership slots are open. A discussion is made whether SST-VC could act to forward GHRSST requests on (future) space-based sensor equipment to the space agencies; an appropriate channel to communicate such requests seems to be in the form of a “white paper”.

Felyx: A generic tool for EO data analytics (Jean-François Piollé)

Felyx is a general tool for inter-comparison and validation of L1 and L2 data. Its applicability is not limited to SST or even ocean parameters. For GHRSST, it is a re-design of the HR-DDS effort. Felyx consists of a “back-end” module for subsetting and a “front-end” module for statistical package for inter-comparison analysis. There are a variety of flexible and customizable functionalities applicable to multiple match-up databases. An SST demonstration of Felyx is planned over a 6-month period starting February 2014. The name Felyx (and its logo too?) is provided by ESA, which is the sponsor. More details can be found in **www.felyx.org**. During the discussion period, a concern for computer system overloading is raised.

Data life cycle policy (Edward Armstrong)

Origin, goals, and components of data life cycle policy are described, and implementation of “GHRSST Data Life Cycle Policy” is encouraged. Goals of data life cycle policy include ensuring integrity, consistency, availability, visibility, and usability of data sets. They are driven by the frequent requests by the PO.DAAC users to connect them with the appropriate data sets and are not meant to be barriers to innovation in the side of data producers (i.e.

not meant to contradict with the GHRSST goal to provide the best quality SST products). Main components of data life cycle policy are: Quality Gate, Policy, and Users. Example of the latter ("Users") is a user working group (UWG) that provides feedback to effectiveness of the data life cycle policy. The "Policy" component of the data life cycle policy is a "document driven" procedure to ensure consistency in the whole process. Example of such a document is the PO.DAAC "Submission Agreement". Discussion has taken place to draft and adopt a GHRSST version of Submission Agreement and Quality Gatekeeper when introducing a new product as a GHRSST product. The GHRSST management recognizes the need of GHRSST to act as the gatekeeper. There has also been a discussion on forming a GHRSST User Working Group, with several volunteers and nominations for such group. Other topics of discussion include: retirement procedure for a data set, which really doesn't mean deletion of the data set but to control of version updates and visibility of the data set as already performed at LTSRF and PO.DAAC (which need to coordinate each others' procedures for consistency); data size and cost of delivering the data; ITAR of US Government.

The GHRSST Science Team was in agreement that the Data Set Lifecycle Policy should be adopted by GHRSST.

SESSION IV: FOCUS ON KEY TOPICS RELATING TO ESTIMATION, MASKING AND VALIDATION

Chair: ***Helen Beggs***[(1)]*; Rapporteur:* ***Werenfrid Wimmer***[(2)]

(1) CAWCR, Bureau of Meteorology, Australia, Email: h.beggs@bom.gov.au
(2) University of Southampton, UK, Email: w.wimmer@soton.ac.uk

Chris Merchant: "Progress in SST retrievals and future direction"

Lessons learnt from ARC: radiative transfer (RT) requires more work, but results show improvements to SST sensitivity.

Merchant presented SEVIRI work on NLSST/OE and sensitivity.

CCI multisensory matches have been done at BT stage not SST stage.

Recognition of RT approach needs to be built into future missions. SLSTR L1b file definition includes ECMWF NWP profiles.

Challenges:

- Uncertainty estimation
- Bringing MW SST into consistency of IR
- Obtaining NWP outputs to use in OE of SST
- Pinatubo style eruption – tropospheric aerosols , especially if no dual view sensor. Need to be prepared!

Questions:

Minnet: Ship-borne radiometer could help in no dual-view period

Merchant: Need to check statistical power of RADS.

Reynolds: Try out post period by looking at pre-AATSR period.

Gentemann: MW did reference sensor matchup, now MW is done to RTM. Use the environment to get simulated BT and than calibrate MW sensor to simulated BT. RTM is common sensor.

Merchant: But you need an SST to make it work. Best in situ is ARC for CCI. Have to be careful to not use a field which has trends, because you get trends in your data.

Harris: Idea of matching to RTM solves one sensor drifting

Merchant: But needs SST for your forward model!

Merchant: before 1991 you need an SST source. An ensemble is better than just a single source.

Donlon: Be ready for Pinatubo events: VC – GEOS wants white paper, to justify dual view.

Minnett: Also an argument for MW.

Pierre Le Borgne: "SST in the Arctic"

Why Arctic? It's challenging.

Validation with buoys: Most are between Greenland and Norway + ECWMF data.

Day time validation: Positive bias -> atmospheric correction problem (t11-t12).

Significant Cloud contamination, errors are depended on the shape of the atmospheric profile, errors can be simulated well -> OE or bias correction can be developed.

Correction for the simulated BT needed in DV areas (too low) – permanent day-time conditions.

Understanding DW in all day conditions is difficult.

Determining SST anomalies of monthly means – Are they linked with ice concentration anomalies?

Presented results of 5 years of METOP-A data in the Arctic.

Big question is: What is the foundation SST in the Arctic during summer when sun does not set?

Misako Kachi: "Cal-Val of GCOM-W1"

AMSR2 – Presented BT inter-calibration to AMSR-E and TMI. Calibration differences were investigated and found to be related to BT differences. It was not clear which of the SST data sets (AMSR-2, AMSR-E or TMI) was truth.

Validation of AMSR-2 SSTs against GTS buoys gave:

Bias = -0.09 K, Standard deviation = 0.552 K. This is considered very good as "required" SD is 0.8 K.

JAXA also compared AMSR-2 SSTs with R/V Mirai SST data.

Japanese Coast guard wants 10GHz SST (only available for SST >12 deg C), Standard AMSR-2 SST is 6 GHz.

AMSR-2 sea ice concentration will be integrated into JAXA long-term data set. They are planning to process AMSR-2 10 GHz SST to obtain 12 km resolution near the coast, but this is only available for SST > 12 deg C.

Questions:

Beggs: what is the spatial resolution from 10GHz.

MK: For 6 GHz resolution is 50km and 12km for 10 GHz.

Donlon: Can you tell us about the AMSR-2 sea-ice and wind data please?

MK: Still needs more data in all possible concentrations and seasons.

Donlon: Steinar is an expert on sea-ice.

MK: Wind speed, buoy data might be not be as good as possible.

Chelle Gentemann: "AMSR-2"

We have observed jumps in position in orbit but not scan time. We compared NOAA and JAXA data.

For the 6.9 and 7.3 channels, most of the RFI is in the 7.3 channel.

We performed a 3 point collocation of AMSR2, MODIS and buoy SSTs.

AMSR-2 appeared to have approximately -0.8 K bias at the moment. It has much better stability than AMSR-E and much better hot load stability (10% of AMSR-E hot load problems).

Calibration should be fairly straightforward. We are using Windsat and RTM. Expect to release geophysical retrievals in Fall 2013.

We learned a lot from Aquarius, can model for side lobe contamination and can get up to 20km to land. We can also make sun glint retrievals.

AMSR-2 – in situ: Bias = -0.80 K

SD = 0.57 K

Questions:

Donlon: There is the issue of the response function. Can JAXA help with that? It is needed to remove the side lobe contamination.

CG: Info needed from Mitsubishi / JAXA.

General Questions:

DLJ: Will L1 data from SLSTR have NWP data?

CM: At the tie point the SLSTR files will have profiles (air temperature, water vapour).

TN: full geolocation

CM: forecast in real time

DLJ: This is to make RTM easier

CM: Yes

DLJ: Slight bug. This should to be independent. Atmospheric data should be from different data stream to keep it independent.

Donlon: Is it still valid in the future? Use the best available NWP data for reanalysis, so NWP data in L1 should be thrown away.

CM: It does not have to be the best. RT should not be dependent on the best data.

Donlon: But what about the cost of archiving?

TN: at reprocessing stage there is no need for profile data.

Sasha Ignatov: We could start archiving profile data with SSTs as well.

Minnett: AMSR-2 is brilliant and thank you JAXA.

DLJ: Comment on use of words: bias correction should be bias adjustment.

Show of hands regarding use of “bias correction” of “bias adjustment” was inconclusive.

Conclusion: Use as appropriate.

SESSION V: FOCUS ON KEY TOPICS RELATING TO LEVEL 4

***Chair: Alexey Kaplan*[1]*, Rapporteur: Edward Armstrong*[2]**

(1) Lamont-Doherty Earth Observatory of Columbia University, Palisades Ny 10964, USA, Email: alexeyk@ldeo.columbia.edu
(2) Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove, Pasadena, CA 91109, USA,Eemail: edward.m.armstrong@jpl.nasa.gov

1. Session schedule

This session included three 20-minute talks on the outstanding issues of production and interpretation of Level 4 (L4) SST products. The talks were followed by the 30-minute open discussion.

2. Talks

In the talk "High Resolution Daily Sea Surface Temperature Analysis: the 2-stage OI" Richard Reynolds presented his new two-stage OI method for producing high-resolution L4 SST products. This new analysis uses as its first stage already established NCDC 0.25^o Daily AVHRR+AMSR OI (one of the GHRSST current L4 products) and corrects each daily field it with the three days of Pathfinder SST data (v 5.2) to produce an interpolated analysis on the Pathfinder's $1/24^o$ spatial grid. The research version of the product is already available for the entire AMSR period: 1 June 2002 – 4 October 2011. This analysis method was tested according to the Reynolds et al. (2013) approach, which involves repeating this analysis with the synthetic SST data, obtained by sub-sampling the SST output from a high-resolution ocean model simulation and adding noise to it. Results of the analysis applied to the synthetic data then are compared with the full model fields ("truth"). Tests showed that the two-stage interpolation method indeed was successfully reducing the noise that was present in the synthetic high-resolution data. It was found that theoretical error estimates produced during the 2^{nd} stage of the new analysis, especially their normalized version, were strongly tracking the presence of the high-resolution SST observations: statistics that may be useful in interpreting high-resolution SST fields for weeding out cases where high-resolution features appear in the absence of high-resolution data.

Dudley Chelton gave a talk "Evaluation of GHRSST products for studies of short-term climate variability" in which he presented a comparison between monthly averages of two GHRSST L4 products: OSTIA and NCDC Daily 0.25^o AMSR+AVHRR OI. The comparison was done in terms of wavenumber spectra, Eastern Pacific El Nino indices (NINO3 and NINO3.4), North Pacific EOFs and PDO, global EOFs, and standard deviations of differences between monthly averages of the two products. Wavenumber spectra of monthly fields of the two products were very similar (and similar to the spectra of their daily fields, as presented by Reynolds and Chelton, 2010), with the OSTIA having slightly weaker variance features with 50-500 km spatial scales, suggesting lighter relative weighting of the microwave data in the OSTIA compared to the NCDC product. Large scale patterns and their indices (El Nino, PDO, EOFs and PCs) for the two data sets were very similar (although the patterns looked slightly noisier in the NCDC OI case). Standard deviations of the difference between the products were larger than the speaker expected: they approached ~1°C in the western boundary current extensions and were commonly 30-80% of the local SST anomaly magnitudes in the open ocean. Reasons for most differences could not be determined, except for a few cases: in areas where ice is present, infilled SST values are computed differently in the two products; cold bias in the AATSR data (not used by the NCDC OI) apparently dominated the 2^{nd} global EOF of the OSTIA-NCDC monthly difference;

possible aerosol and/or cloud errors in the tropical Atlantic. Overall conclusion was that despite the differences, OSTIA and NCDC OI yielded very similar climate variability, although slightly noisier in the NCDC case.

Jim Cummings, in the talk “SST data impact in global HYCOM” put the task of producing L4 SST products into the context of data assimilation, the way it is done in the Navy Coupled Ocean Data Assimilation (NCODA) system (Cummings 2005) that produces, in particular, the FNMOC 6-hourly 9km SST analysis (one of the GHRSST L4 products). This SST analysis is an outcome of the multivariate OI system cycled together with a high-resolution (1/12^{o}) ocean model, HYCOM, so that the analysis system provides initial conditions for model forecasts, whereas short-term model forecasts or previous analyses are used to generate first-guess fields for the next analysis. The measure of the observational impact proposed in this talk is model forecast error reduction due to a given observation. These can be estimated using the adjoint methodology developed by Langland and Baker (2004) and implemented in NCODA. Maps of observational impacts show that while the effect of most observations is to reduce forecast error (beneficial observations), some observations do increase the error in the forecast (non-beneficial observations). The presence of non-beneficial observations points towards a problem in either data QC, or instrument calibration, or model error, or adequacy of calculated assimilation statistics (observation error, background error). Maps and time series of impacts were shown for November 2012 SST observations from NOAA-18, NOAA-19, METOP-A, GOES, buoys, and ships. In one example lack of coherent structure in error reduction due to NOAA-18 SST as compared to the same from NOAA-19 were interpreted as an indication of problems with the aging NOAA-18 sensor. This data impacts calculation system cannot be used in HYCOM operational runs, because data for the last 12 days are assimilated there every day there, so that data impact estimates are not interpretable. But in pre-operational runs, where each observation is assimilated only once, all sources of the SST data were found to be reducing, on average, HYCOM 48-hour forecast error: NOAA-19 and METOP-A more so than NOAA-18 and GOES, moored buoys more than drifting buoys, and among ship observations hull contact sensor produced more beneficial observations than engine room intake and bucket measurements.

3. Discussion

The talks were followed by a vigorous open discussion, with most comments driving at the issues of utility of individual observations, their GHRSST-mandated Single Sensor Error Statistics (SSES) supplied with all L2P products, and how/if they are used for producing GHRSST L4 products. Talk by Jim Cummings on the estimation of data impact in the NCODA system, without presenting explicit comparisons with the SSES values, made it very clear that the actual benefit of the analysis system from a given observation is a complicated concept that cannot possibly be simply equivalent to the SSES or even to the reduction in the OI theoretical error estimate due to an assimilation of that observation with the error assumed to obey the supplied SSES. For example, the observational impact evaluated in the NCODA system can be either beneficial or not (resulting in the reduction or increase of the model forecast error, respectively), and this is not something that can be described within the SSES paradigm. Craig Donlon asked L4 producers if they are actually using the GHRSST-supplied SSES in their analysis systems. The response was not uniform; it appeared that only some producers actually used SSES from the L2P products they ingest, and even in those cases the SSES were used not at their face values. The SSES bias estimates were used more often than SSES standard deviations.

Craig Donlon pointed out, in effect, that the GHRSST community spent tremendous amount of time to come to an agreement with regards to the structure and content of the SSES fields in GHRSST products, that the SSES values were currently deemed important enough to be produced and included in all level 2 data files, and that it is disappointing to see them not used (or to be underused) in the higher level products. He requested to poll L4 producers on the ways they are currently using the SSES values. Helen Beggs said that better communication is necessary between IC-TAG, EARWiG, and ST-VAL. In particular, she requested that at the future GHRSST Science Team meetings the breakout sessions for these three groups, due to the important cross-cutting issues, were never scheduled to overlap (this year IC-TAG and EARWiG breakout sessions did overlap). Craig suggested that these groups need their own workshop to sort out these issues. Due to the time limitations, the discussion period ended before positions of discussants and further plans for the work in this direction could be finalized.

4. References

Cummings, J.A., 2005: Operational multivariate ocean data assimilation. Q.J.R. Meteorol. Soc., 131: 3583–3604. doi: 10.1256/qj.05.105

Langland, R.H. and N.L.Baker, N.L., 2004: Estimation of observation impact using the NRL atmospheric variational data assimilation adjoint system. Tellus A, 56: 189–201. doi: 10.1111/j.1600-0870.2004.00056.x

Reynolds, R.W., and D.B.Chelton, 2010: Comparisons of daily sea surface temperature analyses for 2007–08. *J. Climate*, **23**, 3545–3562.

Reynolds, R.W., D.B.Chelton, J.Roberts-Jones, M.J.Martin, D.Menemenlis, and C.J.Merchant, 2013: Objective determination of feature resolution in two sea surface temperature analyses. J. Climate, **26**, 2514-2533. doi: http://dx.doi.org/10.1175/JCLI-D-12-00787.1.

SESSION VI: FOCUS ON KEY TOPICS RELATING TO CLIMATE

*Rapporteur: **Jonathan Mittaz**(1); Chair: **Christopher Merchant**(2)*

(1) University of Maryland, College Park, MD, USA, Email: Jon.Mittaz@noaa.gov
(2) University of Reading, Reading, UK. Email: c.j.merchant@reading.ac.uk

ABSTRACT

Report on the session "Focus on key topics relating to climate" held for GHRSST XIV.

1. Introduction

The session was focused on key topics relating to climate.

2. The ESA CCI L4 reanalysis using the OSTIA system

Jonah Roberts-Jones gave a talk on the new OSTIA reanalysis system. He described a new L4 analysis which is a daily high resolution product from 1991-09 to 2010-12. Uses data from the SST CCI project with no in-situ data, with NOAA and MetOp AVHRR is cross-calibrated to (A)ATSR observations. Therefore validation is against an independent dataset, which was not possible with the earlier reanalysis. Also this is an analysis at depth (20cm) so it will contain a diurnal signal with data adjusted to 10:30 and 22:30 local time so giving a mean SST during the day. They also used the OSI-SAF reprocessed and operational sea ice concentration and include associated sea ice errors. They use new background error covariances which are seasonally varying at two scales at mesoscales and synoptic scales and the scales are anisotropic. The new analysis improves both the statistics as well as improving (tightening) the SST gradients. Some issues with NOAA satellites with biases esp. NOAA-12 with large spikes, but OSTIA is robust to these biases (awaiting final validation). Work to be done – awaiting full validation using drifters and top-level ARGO data, and do an inter-comparison with other reanalysis products.

3. A multi-sensor SST reanalysis for the Arctic ocean

Jacob Høyer gave a talk on a multi-sensor SST reanalysis for the arctic ocean climate data record. Uses Pathfinder, ARC, ICOADS and OSI-SAF ice concentration over the period 1982-2010. The spatial resolution is 0.05 degrees produced daily. There is a dedicated artic bias correction using artic derived error statistics and scale lengths etc. and has been shown to improve the analysis relative to the ARC data. Validation was done against in-situ observations which were not included in the analysis – overall bias <0.1K, stddev ~0.6K. Drifters and buoys were better than ship observations, but the 1980s is mostly ships, 2000s mostly buoys. There does seem to be a small negative summer bias with good performance in the regions within 50km of the ice edge. There was also a negative bias seen within 50km of the ice edge that was not present in pathfinder for example, so the OI is being looked at. Trends have been looked at and there were +ve or zero trends on the arctic with the largest variability in Baffin Bay and Chukchi sea. The spatial patterns agree between ARC, Pathfinder and the new OI. Future work is to produce a climatology for the Artic, more analysis of trends and consistency and a check on the marginal ice zone performance. They would also like to rerun with the new CCI SST data.

4. Satellite derived sea surface temperature for climate data records

Yang Liu gave a talk on sampling errors in satellite derived sea surface temperature for climate data records. She showed the error sources from the interim SST White Paper but she concentrated on level 4 errors. Sources of uncertainties in level 4 data were described concentrating on cloud error and sampling errors. She used G1SST to do the analysis. The cloud mask used was the MODIS 4km cloud mask. The data is taken on 4km scales using the cloud mask and sampled onto 12,25,50,100,250km and 1,3,7,14 day and 1 month timescales and compared to the reference (original) cloud free 4km sampled SST, Initial results – 12 km 1d difference is trivial but becomes apparent as reduced spatial resolution and temporal resolution. The distribution is close to zero with a slight shift to +ve in going from one day to one month. The histogram tend to become more spiked with increasing spatial resolution. The plots relating space and time resolution were shown. Then a global mean analysis was shown showing that the differences are largest at high latitude. A study of global maps chowing spatial and temporal variations was then shown. In summary, sampling errors caused by clouds are large and cannot be neglected – to get to < 0.1K sampling errors use L4 fields with low resolutions. The actual spatial distribution is complex but real L4 fields have additional errors together with errors caused by gap filling. Future work – seasonal analysis, use of MODIS data, regional analysis, AATSR and VIIRS.

Questions: Harris – any other analysis to be used other than G1SST? G1SST has cloud artifacts embedded in it. Beggs – what are you trying to get from this study from L4 producers? The project was just to assess cloud impact on L4 – maybe this can be used to generate new metrics for additional error studies/SSES. It's how to fill gaps from satellite data – applied to a monthly L3 just as much.

5. General discussion

Each speaker gave 1 or 2 headlines from each talk. Speaker 2: Key findings trends from OI agree from ARC. Q: Why to produce special OI in Artic? – Artic is special region including satellite errors so need specific bias correction. Maybe should compare with global analysis to have same performance. 1: Initial impact of using consistency reprocessed data with a framework having a feedback. 3: Sampling errors are important.

Poulter: Wondered about bias pattern level 4 products – do different sampling of L4 could explain some of the bias patterns and if has some spatial coherence that looks geophysical but isn't. Take model fields to investigate this with a sampling study. Liu: Bias in Level 4 has cloud problems which are geophysical. For larger volumes you can see 'though cloud' so preferentially have bias in larger area with cloud where there are only a few data point are equally weighted so you will preferentially get a cold bias in that case. Difference in how you weight the different regimes, Points towards looking into this (0.1K is not small).

Merchant to Høyer: any thoughts on sampling effects in Arctic, since you don't have as much data as you'd like. Didn't look too hard a sampling effects. Do you think sampling effect may cause some of the trends you see. Høyer was a little surprised that ARC and OI agree – sampling didn't seem to be that large an issue.

Harris: If you get large areas on long timescale – heat content issue. Some of bias due to how clouds are sampled – preferentially sampled areas. On global scales the bias is surprising.

Craig: Jacob – if you're not using microwave, limited data – microwave would be a real benefit. But, in terms of looking at trends, MW is SST is only in last 10 years – dataset is over 30 years.

Merchant: Two examples of perfect data studies in session, to look at effect of issues, particularly sampling errors, effects of procedural issues – i.e., structural uncertainty issues.

General agreement that this is an area that needs more activity to understand unknown effects of structural issues.

SESSION VII: PHYSICAL OCEANOGRAPHY AND SST

Rapporteur: Jonah Roberts-Jones[(1)]; Chair: Peter Cornillon[(2)]

(1) Met Office, Fitzroy Rd, Exeter, UK. Email: jonah.roberts-jones@metoffice.gov.uk
(2) University of Rhode Island, Narragansett Rhode Island, USA Email: pcornillon@me.com

Presentations and discussion

Alexey Kaplan presented 'Biases in global mean SST estimates obtained from gridded data sets' in which he discussed the differences (in global mean SST) between in-situ observations, interpolated in-situ analyses (eg HadISST) and SST analyses which use satellite data. Within the context of producing an analysis Ship SST observations are generally corrected to a standard SST (which is generally buoy observations) which can only be done in the recent period, this introduces a discontinuity in the SST time series. AK asked what should be used as a standard of SST 'truth' (which can be carried back to the historical period)? Peter Minnett raised the combined archive database that he is compiling of ship-borne radiometers. This will provide independent measurements of the skin SST which could be used to assess other in situ observations and skin satellite measurements. Chris Merchant raised the fact that the top-level ARGO observations provide an independent measurement of the SST. Viva Banzon noted that they (as well as HadISST3) currently carry out adjustments on a platform by platform basis using an ensemble approach.

Emmanuelle Autret presented 'Statistical analysis of sub-mesoscale processes from satellite SST observations' in which she is concerned with scales between 1 and 80 km. Reconstructing using Eulerian approach a global map of SST spectral slope from high resolution MODIS and AMSRE data she noted steep slope in transition zones and in the core of major current systems. MODIS had more homogeneous spatial distribution of spectral slopes than AMSRE and showed SST anomalies along the SST gradients. The technique was able to reconstruct fine-scale structure in the SST, part of the small-scale variance is underestimated due to lack of noise in the transformation.

Peter Cornillion presented 'SEVIRI and VISSR SST front and gradient datasets'. He uses gradient based and population based algorithms (which are complementary) to produce the maps which are now publicly available. Climatologies of fronts have also been calculated. In certain regions (eg the Agulhas retroflection) the probability of finding a front can be low despite the fact that fronts are always present due to the fact that the fronts are not static.

SESSION VIII: SST IN OCEAN-ATMOSPHERE INTERACTION

Rapporteur: Gary A Wick

NOAA ESRL/PSD, 325 Broadway, R/PSD2, Boulder, CO 80302, USA.
Email: gary.a.wick@noaa.gov

1. Overview

The plenary session VIII on SST in ocean-atmosphere interaction was comprised of two presentations and subsequent discussions. The talks were given by Charlie Barron and Tim Liu. The third presentation originally scheduled for the session was not given. No further general discussion occurred after the two presentations.

2. Impact of diurnal warming on assimilation of satellite observations of sea surface temperature

The first presentation entitled "Impact of diurnal warming on assimilation of satellite observations of sea surface temperature" was given by Charlie Barron. The talk focused on the impact of data assimilation in regional ocean models in two basins: the Mediterranean and the Gulf of Mexico. Assuming that forecasts should be improved by more data and more capable assimilation methods, the analysis compared different assimilation methods. Traditional variational assimilation functions by balancing estimated errors to minimize a cost function. The alternate approach presented here is "first guess at appropriate time" or FGAT which measures differences at the observation time and interpolates these differences to the model time. Through the FGAT technique one obtains better representation of the phase of diurnal variability and eliminates the aliasing of diurnal warming into bias.

Several experiments were conducted with the assimilation of polar and/or geosynchronous data with FGAT on or off. Biases were computed relative to an analysis from drifting buoy data. The results generally showed that with FGAT, model forecasts do simulate the mean diurnal signal, but there tends to be a cold forecast bias as time progresses. There was less ambiguity of the benefits of the FGAT technique in the Mediterranean than in the Gulf of Mexico. Both regions showed the best results with AVHRR data only. Impacts on the estimation of the air-sea heat flux were also considered. Overall, the results were said to confirm the importance of minimizing bias, bias inconsistency, and the importance of model forecast skill.

Questions addressed why the AVHRR results were better than for MSG – one speculation was a potential small bias in MSG. Andy Harris asked about diurnal warming in the model and Charlie replied that it was just from a prognostic term as a function of fluxes giving the warming of the upper most model layer. The diurnal cycle was 0.5 to 0.75 degrees averaged over the summer. In response to a further question from Andy if something "better" was desired, Charlie replied that the model does fine with the mean signal, but a better boundary layer representation was possible.

3. Ocean-atmosphere coupling over mid-latitude oceans

The second presentation was "Ocean-atmosphere coupling over mid-latitude oceans" given by Tim Liu. The focus of this presentation was a simple example of using SST to do a coupling study. Coupling in the mid-latitude regions was said to be controversial. Generally the lapse rate is believed to be to week to generate deep convection as over the tropical ocean. In contrast to other studies claiming solar heating was unimportant to previously observed record warming, this study claimed that solar radiation does follow the SST anomaly and that ~30% of the warming could be contributed by solar radiation. Teleconnections were claimed to be visible where temperatures in the tropics affected the midlatitudes. Citing measurements from AIRS, SST influences were claimed to extend up through the atmosphere and not just the boundary layer. SST was said to be very central in the coupling.

Several questions challenged fundamental elements in this study. The columnar structure in the air temperature was said to be hard to believe. Tim defended the results saying that TRMM rain patterns also support his ideas, but the unambiguity of these results was also challenged.

SECTION 3: BREAKOUT SESSION SUMMARY REPORTS

EARWIG[1] BREAKOUT SUMMARY REPORT

Chair: Andrew Harris

NOAA-CICS, ESSIC, Univ. Maryland, College Park, MD, USA, Email: Andy.Harris@noaa.gov

ABSTRACT

This is a summary of the issues discussed during the breakout session of the Estimation And Retrievals Working Group (EARWiG) at the 14th GHRSST Science Team Meeting held in Woods Hole, MA. The session consisted of eight presentations and much lively discussion. This demonstrates that the field is very active and progress is encouraging, although much work remains to be done. In particular, several presentations demonstrated that there are significant gains to be made from the use of radiative transfer, and that such techniques are now comfortably achievable on an operational basis, providing the ability to fully exploit the data from "next-generation" sensors such as VIIRS and MODIS. Issues that remain include the perennial ones of cloud detection and aerosol contamination, although the availability of 3-d aerosol information from various operational centres raises the prospect of direct inclusion into radiative transfer models. The loss of Envisat has deprived the community of a valuable IR reference sensor (AATSR) which had demonstrated robustness to aerosol contamination, providing additional impetus for mitigating this problem for single-view IR sensors. Since the SST retrieval field is very active, there is little prospect for (nor benefit in) prescribing consensus algorithms in the near-term. Instead, the working group will expend effort in drafting improved validation metrics to encompass all aspects of retrieval algorithm characteristics that may feasibly be quantified and are deemed of benefit to the community.

1. Introduction

GHRSST's primary mission has focused on the characterization of uncertainty in existing products, combined with a unified data format to convey the relevant information to end-users. Actual algorithmic issues related to data products were initially eschewed by the GHRSST project, being regarded as the preserve of data providers. However, it became increasingly clear that scientists desired a forum for the sharing of ideas to overcome problems which were recurrent in one form or another in many SST products. Thus, the Estimation and Retrievals Working Group (EARWiG) was instituted with the express purpose of addressing issues relating to the retrieval of sea surface temperatures from radiances observed by satellite instruments.

It should be noted that EARWiG is intended not only as a focus but also a liaison with other national and international activities, such as the European Research Network for SST (ERNESST) and the recently formed NASA SST Science Team.

What follows is a summary of both the EARWiG breakout session and the report given during the final plenary session of the Science Team Meeting.

2. Breakout Session

The eight presentations for the breakout session can be found at:

1 EARWiG: GHRSST Estimation And Retrievals Working Group

https://www.ghrsst.org/documents/q/category/ghrsst-science-team-meetings/ghrsst-xiv-woods-hole/ghrsst-xiv-presentations/tuesday-18th-june-am-breakout-sessions/earwig/

A brief summary of the feedback for each presentation (in bullet form) is below.

A consistent day/night SST regression algorithm based on 3-channel AVHRR (Beggs)

- Lots of feedback!
- Consider correcting glint using 1.6 & 2.2 um
- Some concern about adding pixel-to-pixel noise
- Statistics show very small differences between different daytime algorithms
- Similarly, nighttime algorithms are better
- Note, there is a “hidden” quadratic term
- Basic feeling that one can’t conjure information “from nothing”

Mitigation of striping in ACSPO clear-sky radiances and SST products (Bouali)

- What about archive data? Transfer to Goddard?
- Re. above, need a user request. In principle would be OK to transfer algorithm
- Processing time is 30 seconds for a 5 min granule

Pattern recognition enhancements to NOAA ACSPO clear-sky mask (Petrenko)

- Matlab code being rewritten in Python. ~1 year time frame to include in ACSPO 2.4 (current version is 2.2, next is 2.3 [GDS 2 compliant])

Skin SST physical retrieval from GOES using modified total least square method (Koner)

- Comment made that OE should not be thought of as “statistical”
- However, MTLS is deterministic
- The technical elements of this discussion were moved offline

Physical retrieval for MODIS (Harris)

- Exact approach to initial implementation of MTLS for MODIS was clarified (all surface-sensitive thermal IR channels, but retaining 2-element state vector)
- What plans for aerosol?
- Include in state vector for retrieval
- How to deal with errors in air-sea temp diff?
- Make use of multiple lower atmospheric sounding channels + lapse rate in state vector

Using numerical weather prediction model profiles to improve SST calculations: application to Metop/AV (Le Borgne)

- Some concern about interplay between OSTIA and METOP
- What elements are used from NWP?
- 15 levels of ECMWF T, Q & O3, RTTOV 10.X
- Don’t you see jumps when systems change
- There is inertia in system but it doesn’t matter

Quantifying the effect of ambient cloud on clear-sky ocean brightness temperatures and SSTs (Saha)

- Is it mostly just the effect on water vapor profile in the vicinity of cloud (since 11 & 12 are affected but not so much for SST)?

Improved optimal estimation retrieval using spatially smoothed input (Merchant)

- Can it be done by regressing BT to local SST retrieval?
- This won't improve sensitivity but will reduce noise (assuming that you start with a regression SST)

Points raised during the short open discussion time were as follows

- Encouraging to see progress in algorithms, cloud, *etc*.
- Important to include SST sensitivity in metric for algorithms (how to do?)
- Some expressed a desire to cut down on the variants of NLSST, *etc.*, (not necessary to have 10 different flavors)
- It is not really looking to get consensus algorithm, since it would stifle the innovation that we have seen
    - N.B. It was subsequently clarified by the GHRSST-PO that consensus on algorithms was not really being sought at this stage
- Consensus on metrics is desirable (*e.g* see comment on SST sensitivity). Obviously this crosses into ST-VAL territory
- Regarding calibration, GSICS is operational for MSG. Other geostationary sensors are in the pipeline. Mechanism is really for geostationary sensors only (at least for now).

3. Report to Plenary

Eight presentations shows that there continues to be a lot of activity and interest in this field. (Not bad for a group whose very raison d'etre was questioned at the outset.) Key themes that emerged during the breakout are described in the following paragraphs.

Firstly, physical retrieval methodologies are coming to the fore. In this regard, accuracy of fast radiative transfer, instrument calibration and NWP input are issues. It is becoming increasingly desirable to obtain a good source of aerosol data to include (preferably 3-d, although such datasets are large, due to the numerous aerosol species, and not generally distributed). Metrics (based on physical retrieval methodologies in particular) which calculate quality of SST retrieval on a pixel-by-pixel basis have potential to improve SSES.

Again, for physical retrieval methods, the additional channels of new instruments offer prospect of improved retrievals (more complex state vector for the retrieval). Increase in computing power means we can now consider iterative methods. Smoothing inputs to physical retrieval related to 'atmospheric' parameters shows promise for reduced noise and increased sensitivity to SST.

There are also prospects for improvements to cloud detection. Recently introduced Bayesian gives ~20% cloud-free (*cf.* 'traditional' methods may only be ~10%). Based on evaluation of all data, implication is that a good retrieval is possible for ~30% of data (*i.e.* an increase of 50% over Bayesian methods).

As already mentioned, some asked if it is necessary to have many variations on certain algorithms (*e.g.* NLSST). Again, it is important to include an 'SST sensitivity' metric in assessment of algorithms, as part of a needed consensus on metrics is desirable. With regard to the latter, there is an obvious link to the activities of the STVAL working group, and liaison will continue (not least because many EARWiG participants are members of both groups).

4. Conclusion

Much progress has been made in the past year and even more exciting work is proposed. The working group will remain in contact throughout the year and hold another workshop prior to the next ST meeting. A key goal for this coming year is the drafting of proposed metrics for SST algorithm evaluation for presentation at the next Science Team Meeting in Cape Town.

ICTAG[2] BREAKOUT SUMMARY REPORT

Chair: Alexey Kaplan[(1)]; Vice-Chair and Rapporteur: T. Mike Chin[(2)]

(1) Lamont-Doherty Earth Observatory of Columbia University, Palisades NY 10964, USA, Email: alexeyk@ldeo.columbia.edu
(2) Jet Propulsion Laboratory, California Institute of Technology, 2800 Oak Grove, Pasadena, CA 91109, USA, Email: toshio.m.chin@jpl.nasa.gov

1. Membership Update

Dave Foley (NOAA and University of California at Santa Cruz) was added as an IC-TAG member, at his request. David Poulter, a former IC-TAG member who has developed the HR-DDS system and who is now working at Pelamis Scientific Software Ltd. on a contract with IFREMER, was asked and agreed to re-join the IC-TAG, since in his current job he is developing a system with the capabilities relevant to the IC-TAG goals.

2. The Status Update and Development Plans for the Constituent Inter-Comparison Systems

By its ToR, IC-TAG is focused on the inter-comparison systems for the L4 SST products, specifically GMPE, HRDDS, and SQUAM.

About 2 yrs ago HR-DDS became defunct, because of the funding problems. Now, however, David Poulter is developing a more advanced system, called Felyx, whose capabilities will include those of the HR-DDS. The project is funded by ESA and is being led by Jean-François Piollé. Felyx development plans had been presented at other sessions of G14.

For logistical reasons, in the last year the SQUAM development only involved work with the L2 and L3 SST products, not with L4. However, L4-SQUAM work is planned to restart in August 2013. Considerable progress of SQUAM on L2 and L3 inter-comparison was reported elsewhere at G14.

GMPE's funding situation and a new proposal for the further development was presented by Gary Corlett. The current funding of the GMPE system by MyOcean2 is coming to an end. However, the U.K. Met Office is willing to keep it running and to support its updates provided that the participating L4 producers agree to obey certain requirements regarding their products' attributes and their delivery, specifically to have all products entering the GMPE system to conform to the GDS 2.0 format, to be delivered daily by 1300UTC, all participating products to be global and of the spatial resolution no sparser than 0.25°, to be accessible through the PO.DAAC or, at a minimum, by the ftp elsewhere, and to satisfy certain requirements on the resilience and validation. L4 producers that were present had not objected to these requirements.

In addition, U.K. Met Office offered to provide the software and guidance for establishing: (1) Secondary GMPEs, for testing and evaluation of the new L4 products (e.g., at the GDAC, if they are interested) (2) Regional GMPEs, for regional L4 products (e.g., at the interested RDACs). The GPO is enthusiastic about these proposals. Present Data Centers' representatives were also cautiously interested, but concerned about the details, especially on the issues of redundancy in the GMPE analysis and as to whether and where the secondary GMPEs will be archived. Gary Corlett and other people relevant to this initiative will be settling these issues over email.

2 IC-TAG: GHRSST Inter-Comparison Technical Advisory Group

3. Analysis Methods and the Development of New L4 SST Products

This part of the session contained two formal 10-minute presentations

"Sea surface temperature by Barnes' interpolation: current stage" by Franca Gutemberg

"Recent updates to the near real time OSTIA system" by Jonah Roberts-Jones

and a 5-minute update

"NOAA Geo-Polar 5km Global SST Analysis for day&night, night-only, and diurnal correction plans" by Eileen Maturi

F. Gutemberg presented the new regional SST analysis product from Brazil's REMO network, which includes of the oil company Petrobras, Brazilian navy, and four public universities. This daily L4 SST product covers the continental shelf and slope area off Brazilian coast at 5 km resolution. It is based on the AVHRR and TMI data inputs and uses Barnes' interpolation method. A focus of current activities is the product validation against buoy data, using 11 moored and 23 drifting buoys.

J. Roberts-Jones summarized recent progress in the OSTIA system, including: a new background error covariance evaluation using deviations from the AATSR data; using a subset of the METOP data set for the bias correction over areas where the AATSR are not available; inclusion of the lake ice data with the input from the NCEP 1/12^{o} ice concentration product. Future plans for the OSTIA system include the development of the three-hourly skin temperature analysis, a more advanced data assimilation scheme for the analysis technique, and the use of the flow-dependent background error covariance matrix.

E. Maturi presented two new ("Day/Night" and "Night-time Only") NOAA daily global L4 products for the foundation SST based on the data from geo-stationary satellites (GOES-E/W and MTSAT-2) covering the period from 2004 to present. Plans for the diurnal corrections and for the retrospective analysis extending back to 1994 were discussed.

In the discussion that followed the presentations many issues were raised: impacts of ingesting the TMI data in the new REMO (Brazilian) SST analysis (authors were uncertain about that at this point); file format for the sub-daily, i.e., three-hourly and "diurnal corrections" L4 SST products and if the format standardization was necessary; methods to disclose the input data sets used in a given L4 analysis and if the currently provided meta data ("source" field as required by the GDS) was sufficient; overall need, for users' benefit, to document L4 products better and in a more transparent way, in particular, the plans to adapt for presentation on the GHRSST website tables from the GMPE and SQUAM SST inter-comparison papers published by the groups of IC-TAG members last year (Martin et al., 2012; Dash et al. 2012); the need for the OSSE-like comparisons as tests of the L4 analysis techniques and to what extent the currently planned Reynolds/Chelton tests (discussed in detail later in this session) would serve this purpose and if they could be upgraded in terms of the sophistication and realism of their synthetic data inputs.

4. Inter-comparison of L4 SST products

This part of the session contained two formal 10-minute presentations

"A comparison of SST gradients and the impact of going to higher resolution" by Jorge Vazquez

"L4 comparison using Reynolds/Chelton spectrum test" by Mike Chin

J. Vazquez compared the SST gradient-magnitudes near the Peruvian coast, in the Gulf Stream area, and in the Gulf of Callifornia from four L4 products: NCDC Daily AVHRR-only OI, OSTIA, REMSS, and MUR. While the higher resolution product (MUR, 1km) generally did identify spatial features of smaller scale than lower resolution products did, when sub-sampled without interpolation it yielded similar gradient magnitudes to the lower-resolution products, e.g. NCDC OI (25km). This was interpreted as a support for the MUR skill (in that it did not add discernible amount of noise compared to the lower-resolution products) and for the potential of high-resolution products in general.

M. Chin described the effort of PO.DAAC/JPL colleagues (including Michelle Gierach and Ed Armstrong), in collaboration with Dick Reynolds and Dudley Chelton to make the synthetic data used by *Reynolds et al.* (2013) and codes for their spectral analysis available through PO.DAAC: ftp://grhsst@podaac.jpl.nasa.gov (the password has to be requested by sending an email to Ed.Armstrong@jpl.nasa.gov). Mike Chin has examined these data and software, and applied this test to his own L4 analysis (MUR). In his presentation he described the structure of the test data set and how it should be used.

It followed from the extensive discussion that while at present any L4 producer could already download the package and perform the test, it seems that some streamlining of the procedure would make things easier to perform and to interpret. It is desirable to avoid (1) the need for re-gridding the L4 results on the "4km Pathfinder grid"); (2) the need for the L4 producers to accommodate the present L3-type input rather than the typically used L2 input format for observational data; (3) the ambiguity in the test data used in the experiments with regards to the observational error estimates, which are not prescribed in Reynolds et al. (2013) tests.

Craig Donlon suggested that all analysis results based on the common simulated L2 data inputs and presented at the standard resolution of individual L4 products (i.e., without further re-gridding) should be uploaded to PO.DAAC by L4 producers participating in this experiment. In this case the comparison procedures (e.g., spectral analysis) can be performed in a uniform way and also refined, if necessary, later. L4 producers were asked to send a brief email stating their interest in participation in this experiment and/or voice their concerns regarding the participation, so that an agreeable experiment procedure can be finalized soon and the actual participation could take place.

5. References

Dash, P., A. Ignatov, M. Martin, C. Donlon, B. Brasnett, R. W. Reynolds, V. Banzon, H. Beggs, J.-F. Cayula, Y. Chao, R. Grumbine, E. Maturi, A. Harris, J. Mittaz, J. Sapper, T. M. Chin, J. Vazquez-Cuervo, E. M. Armstrong, C. Gentemann, J. Cummings, J.-F. Piollé, E. Autret, J. Roberts-Jones, S. Ishizaki, J. L. Høyer, D. Poulter, Group for High Resolution Sea Surface Temperature (GHRSST) analysis fields inter-comparisons—Part 2: Near real time web-based level 4 SST Quality Monitor (L4-SQUAM), *Deep Sea Research Part II: Topical Studies in Oceanography*, Available online 17 April 2012, ISSN 0967-0645, 10.1016/j.dsr2.2012.04.002.

Martin, M., P. Dash, A. Ignatov, V. Banzon, H. Beggs, B. Brasnett, J.-F. Cayula, J. Cummings, C. Donlon, C. Gentemann, R. Grumbine, S. Ishizaki, E. Maturi, R. W. Reynolds, J. Roberts-Jones, Group for High Resolution Sea Surface temperature (GHRSST) analysis fields inter-comparisons. Part 1: A GHRSST multi-product ensemble (GMPE), *Deep Sea Research Part II: Topical Studies in Oceanography*, Available online 2 May 2012, ISSN 0967-0645, 10.1016/j.dsr2.2012.04.013.

Reynolds, R. W., D. B. Chelton, J. Roberts-Jones, M. J. Martin, D. Menemenlis, and C. J. Merchant, 2013: Objective determination of feature resolution in two sea surface temperature analyses. J. Climate, **26**, 2514-2533. doi: http://dx.doi.org/10.1175/JCLI-D-12-00787.1.

STVAL[3] BREAKOUT SUMMARY REPORT

Chair: Helen Beggs

CAWCR, Bureau of Meteorology, Australia, Email: h.beggs@bom.gov.au

ABSTRACT

This is the report of presentations and discussions that occurred during the Satellite SST Validation Technical Advisory Group break-out session on Tuesday 18th June 2013.

1. Introduction and ST-VAL Report (Helen Beggs, Chair ST-VAL)

Helen Beggs, as the new Chair of the ST-VAL TAG, thanked Gary Corlett for his many years as Chair of the ST-VAL. She then summarized activities of the ST-VAL TAG since the last Science Team Meeting (see ST-VAL TAG Report in these proceedings). Following input from Science Team members in the lead up to GHRSST-XIV and on Day 1 of the meeting, the GHRSST PO had requested that the ST-VAL discuss the following topics during the breakout session:

- Future of GHRSST MDB, MMDB and HR-DDS
- A virtual constellation of ship-borne SST radiometers?
- Validation Protocol Document (VPD)
- Approach for assessing resolution of products
- SSESs:
    - Are they being calculated correctly?
    - Are they being applied correctly?
    - Are they really appropriate?

Beggs proposed that these topics be discussed later in the session, following the short presentations.

2. Status of in situ SST Quality Monitor (iQUAM) (Sasha Ignatov for Feng Xu)

The new version of the NESDIS in situ SST Quality Monitor, iQUAM2, is now available via http://www.star.nesdis.noaa.gov/sod/sst/iquam/v2/.

New features:

- ARGO floats added (data source: USGODAE/GDAC, with available QFs + standard iQuam QC added)
- Time series extended back to September 1981 (from January 1991 in iQuam1)
- ICOADS data used from September 1981 - November 2007 (with ICOADS QF preserved + standard iQuam QC added); GTS from December 2007 onwards (note that iQuam1 was fully GTS-based)
- CMS black list QF added
- Data are in self-documented netCDF4 (change from HDF4 in iQuam1)

3 STVAL: GHRSST Satellite Sea Surface Temperature Validation Technical Advisory Group

- A new "performance history" QC check added to standard iQuam QC (aka "iQuam black list")

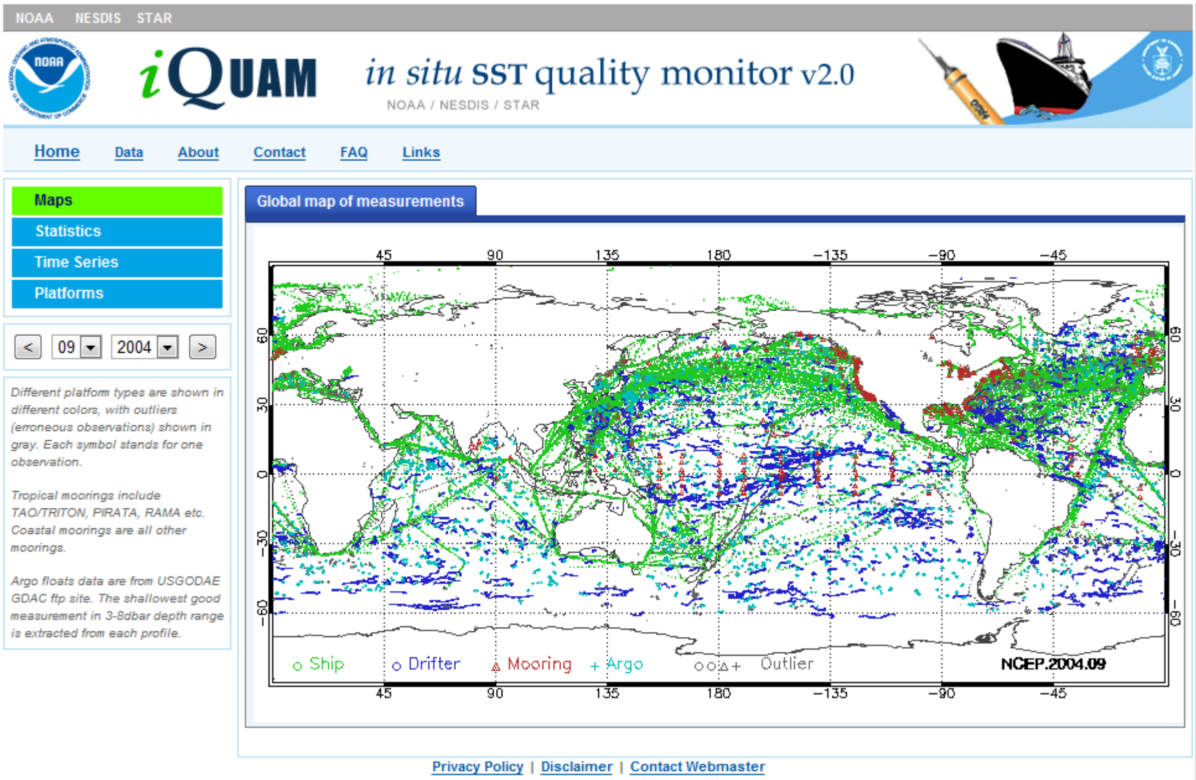


Figure 1: Example of NOAA NESDIS iQUAM2 in situ SST quality monitor web page.

Ignatov: I have a dream that iQUAM3 will contain ship radiometer SSTskin.

3. Preliminary analyses of Metop AVHRR, MODIS and VIIRS SST products in SQUAM (Prasanjit Dash)

Dash presented new features of NESDIS SST Quality Monitor (SQUAM) including monthly validation of satellite SST L2, L3 and L4 products with respect to drifting buoys. Future developments will include MSG, MTSAT and GOES L2P data and remaining L4 products.

4. Initial validation of VIIRS skin SST retrievals with shipboard radiometers (Peter Minnett)

Comparisons of VIIRS SST with M-AERI and ISAR skin SSTs from cruises indicate that VIIRS is a very accurate instrument with standard deviations of 0.2 K (RV Knorr cruise) and 0.4 K (MV Andromeda Leader cruise) when compared with MAER-I SSTskin data. See extended abstract in GHRSST-XIV proceedings for more details. Later this summer they will install a MAERI MkII on Allure of the Seas.

5. High Latitude SST Cal/Val Activities at DMI (Jacob Hoeyer)

DMI obtained an ISAR in June 2012 with the aim to obtain high latitude radiometer observations for cal/val of SST and Ice Surface Temperatures. The ISAR has been deployed for 7 weeks on an ice breaker cruise in northern Greenland in 2012. The plans are to mount the ISAR on Royal Arctic, providing high latitude SST validation.

6. GHRSST Validation Protocol Document (VPD) (Gary Corlett)

Proposal from GHRSST PO for a brief VPD that would contain:

a) Review of existing datasets
b) QC procedures
c) Future data requirements
d) Description of how to produce SSES's and quality levels via links to L2/L3 producers' documents

Donlon: This GVPD is an essential document and needs to include a test data set which can be run through data producer's match-up systems to test how they calculate SSES's.

Corlett: BVPD will not specify *how* in situ data is measured. The main document should be quite short but with supporting documents.

Volunteers to write sections to email Gary Corlett.

7. BoM efforts to improve SSESs for AVHRR SST Level 3 products (Helen Beggs for Chris Griffin)

The Bureau of Meteorology produces real-time HRPT AVHRR SSTskin and SSTskin files in GDS2 L2P, L3U, L3C and L3S formats (*http://imos.org.au/sstproducts.html*). The processing system has been significantly updated in the past 12 months to include a dynamic retuning of SST regression algorithms and dynamic estimates of sensor specific error statistics (SSES) based on drifting buoys, multi-swath, multi-instrument composites over time periods from single day to monthly, and a consistent evaluation of day/night SST.

The SSESs have been redesigned for gridding and merging multiple images from the same source as well as images from multiple sources that preserve the sense of the data sources. Important features of the new IMOS SSES method are:

- Inclusion of sses_count as a new experimental field corresponding to an indicative number of in situ measurements that contribute to SSES estimates in L2P (single swath, geolocated) files and an indicative number of incumbent pixels with SSES in L3U (single swath, gridded), L3C (single sensor, multiple swath, gridded) and L3S (multiple sensor, gridded) files.
- Inclusion of sst_count, sst_mean and sst_standard_deviation as new experimental fields in L3C files allowing the diurnal variation and composition of weighted standard error statistics to be separated, and aid in the combination of multiple L3C files into a single L3C files over a longer time period, as well as merging multiple L3C files into L3S multiple instrument composites

The meeting was in general agreement that it was sensible to include sses_count and sst_count as experimental fields and that Chris Griffin's approach was sound.

8. Discussion of ST-VAL issues

In Situ SST Radiometers:

Tim Nightingale and Werenfrid Wimmer proposed a common format and repository for shipborne SST radiometer data. Tim Nightingale was asked to email the CCI netCDF format for SST radiometer data to Beggs to disseminate to ST-VAL. NEODC (RAL) is willing to host SST the radiometric data. The question was posed, where do we need in situ SSTskin?

Minnett: Over the years we have covered most of the oceans but ships rarely go over the same route again. Even if they travel between the same ports they tend to adjust their tracks due to ocean conditions.

Merchant: CDR-TAG requirement: Need SSTskin along repeat transects within 100 km of each other and ideally at least once monthly.

Beggs: Do we have sufficient high latitude in situ SSTskin?

Hoeyer: DMI is obtaining Arctic ISAR SSTskin.

Beggs: RV Investigator to sporadically obtain Southern Ocean ISAR SSTskin from late-2014.

Do we need more ships at high latitudes with more repeating transects?

Black Body Calibration:

Craig Donlon presented details of the Calibration and Inter-calibration of CASOTS black bodies paper. Donlon emailed the "Protocols to maintain the S.I. traceability of the ship borne ISAR radiometer for satellite SST validation" document to members of ST-VAL and requested ST-VAL review these protocols and give feedback by end July 2013.

Sensor Specific Error Statistics:

Are they being calculated correctly?

Harris: Every L2/L3 producer does something different.

The meeting suggested that producers need to provide:

- SSES method description
- SSES validation

Are the SSES's appropriate for the application?

It was decided that ST-VAL should work with IC-TAG to determine what L4 producers need from SSES's. Some questions posed:

Do users need additional SSES fields such as sses_count and sst_count?

- sses_count = Number of *in situ* matches that contributed to the statistics
- sst_count = Number of satellite SST measurements that contributed to the "best typical" L3 SST grid value

The general consensus was that it was a good idea. CMS are all ready including the or_number_of_pixels experimental variable in their L3S files which gives the original number of pixels from the L2Ps contributing to the SST value in the L3S file. This variable appears to correspond to the Bureau of Meteorology's experimental sst_count field.

9. Actions

Action ST-VAL/14/1:

Tim Nightingale to email Helen Beggs the document describing proposed format for in situ radiometric SST data for circulation to ST-VAL group for comment and possible endorsement.

Action ST-VAL/14/2:

Chair ST-VAL to forward to ST-VAL Group the URL to periodically updated NCDC maps showing density of buoy and ship SST observations. (Closed)

Action ST-VAL/14/3:

ST-VAL Group to provide Craig Donlon with feedback on Protocols for using CASOTS Black Bodies document by end July 2013.

Action ST-VAL/14/4:

Chair ST-VAL group to provide to ST-VAL group with template for SSES method description.

Action ST-VAL/14/5:

L2/L3 producers to provide a document describing their SSES calculation method to Chair ST-VAL group for serving via GHRSST web site.

R2HA2[4] BREAKOUT SUMMARY REPORT

Chair: Peter Cornillon [(1)]; Hervé Roquet [(2)]

(1) University of Rhode Island, USA, Email: pcornillon@me.com
(2) Centre Météorologie Spatiale, MetéoFrance, France, Email: roquet@meteo.fr

1. Introduction

As a result of travel constraints and conflicting sessions, those members of the *Rescue and Reprocessing of Historical AVHRR Archives (R2HA2) Working Group,* responsible for the restructuring of acquired AVHRR archives were unable to attend the R2HA2 breakout. Those in attendance therefore focused on the acquisition of historical AVHRR archives with the chair simply reporting on progress made with regard to formalizing the L1p format.

2. R2HA2 membership/WG XIII attendees

The official members of the R2HA2 Working Group are:

- Peter Cornillon (Chair)
- Ed Armstrong
- Ken Casey
- Eileen Maturi
- Jon Mittaz
- Hervé Roquet (Vice-Chair)

Attending the GHRSST XIV R2HA2 Working Group Meeting were:

- Peter Cornillon (Chair)
- Ken Casey
- Christo Whittle
- Dave Foley
- Dan Iwanski

3. R2HA2 Working Group objectives

The objectives of the working group are to:

1) Identify historical archives[5] of AVHRR HRPT and LAC data.
2) Copy these archives to a central data repository.
3) Convert these data to a consistent L1P[6] format in netCDF4.
4) Reprocess these data in a consistent manner to GDS2.0 L2P and serve them via the GHRSST Regional/ Global Task Sharing Framework (R/GTS).

4 R2HA2: GHRSST Rescue & Reprocessing of Historical AVHRR Archives Working Group

5 The focus here will be on pre-2000 archives of HRPT and LAC data since a global 1km archive of MODIS data exists post-2000. However, post-2000 AHVRR HRPT and LAC data will be accepted if provided, they will simply not be the focus.

6 L1P is a level 1 format that will defined by the R2HA2 explicitly for AVHRR HRPT and LAC data.

4. Necessary steps

In order to accomplish its objectives, the working group will:

1) Identify and locate historical archives (pre-2000) of AVHRR HRPT and LAC data.
2) Copy data from historical archives to a central location.
3) Identify a central assembly center(s) (CAC).
4) Define a format (L1P) in which the data are to be stored.
5) Define if/how contributions are to be stitched together at the CAC.
6) Determine how to handle navigation information.
7) Identify where the reprocessing is to be performed.
8) Define the SST algorithm to be used for reprocessing.
9) Determine how to perform the navigation.

5. Progress

Progress has been made in two areas over the past year:

- **Acquisition of data from receiving stations and the transcription of these data to new media**. Peter Cornillon presented a short summary of progress to date in identifying AVHRR HRPT/ LAC archives and in copying the data from these archives to more stable media. The status of data retrieval is as follows:
    - ***CMS receiving station, Lannion, France -*** CMS has been acquiring all HRPT passes visible from its receiving station in Lannion, France since 1992. The data have been stored in two formats. One, they call ‘brut’ (sounds like a type of champagne, but, in fact it is very close to the standard NOAA format) and the other is their internal format call ‘fis’. We have copied all brut data to URI. These data date from 1996, fis data from 1993. The data are in good shape and waiting agreement on L1pCore.

      Action: Cornillon work to begin conversion to L1P when the software is available.

    - ***Hawaiian receiving station -*** HRPT data were acquired from a receiving station maintained in Hawaii for a number of years. The data were archived on DAT tapes written with a Hewitt Packard computer running either a 10.xxx or 11.xxx operating system. Operation of the receiving station ceased a number of years ago but the DAT tapes were retained. A decision was made to discard these tapes. This was brought to our attention so the University of Rhode Island (URI) agreed to take possession of the tapes and to try and copy them to newer media. The transfer was effectuated in May 2012 and staff at URI immediately began trying to read the tapes. Unfortunately, they appear to be DDS2 compliant hence not compatible with the DAT drives available at URI. A request was made to the audience at GHRSST XIII for information on a DDS2 compatible DAT drive. Several suggestions were made and Cornillon followed-up on these but with no success. The data are still at URI but a system capable of reading them has not yet been found.

      Action: Cornillon to pray for a solution.

    - ***Argentinian receiving station -*** The University of Miami acquired over 12,300 AVHRR HRPT passes from a receiving station in Argentina. These data were stored on 316 Sony optical disks and covered the period from July 1984 to

September 1999. These data were going to be discarded so, as part of the *R2HA2* effort, URI agreed to attempt to copy these data from Sony optical drives to magnetic disks. Required for this effort is a Sony optical drive reader, a DEC computer, an interface board between the DEC machine and the optical drive reader and software capable of reading the data as written at UMiami. Although URI had all of these components each failed as they tried to read the data. URI has worked with UMiami on another possible DEC computer but this one does not appear to be salvageable either. The data are still at URI but a system capable of reading them has not yet been found.

Action: Cornillon to pray for a solution.

- ***Earthnet data (ESA)* –** At GHRSST XIII, Olivier Arino suggested that R2D2 contact ESA with regard to their Earthnet data. This was done by Peter Minnett in April 2013 with the last follow-up in early July. We are awaiting progress at ESA with regard to this.

  Action: Cornillon to work with Minnett and then ESA on acquiring these data.

- ***Instituto del Mar del Perú* –** Contact has been established with Carlos Paulino Rojas with regard to the collected at a Peruvian receiving station starting in the late 1990s. Some of these data are on CV/DVD and some on tapes. Carlos will copy the CVs/DVDs to magnetic disk and ship to URI. He has tried to read the tapes so will send those as well. However, given our success in reading old tapes in the past we are not optimistic with regard to our ability to recover the data on tape. The tapes and magnetic disk will be sent in mid-September.

  Action: Cornillon work on securing the data once sent and then to begin the process of converting to L1P.

- ***South African Receiving Station***

  Action: Cristo Whittle will determine what is available and how to transfer to URI.

DVWG[7] BREAKOUT SUMMARY REPORT

Rapporteur: Gary A. Wick

NOAA ESRL/PSD,325 Broadway, R/PSD2, Boulder, CO 80302, USA
Email: gary.a.wick@noaa.gov

1. Overview

The diurnal variability working group (DVWG) breakout session consisted of several brief presentations by group members, a significant report on the potential for diurnal variability studies using Argo floats, and a discussion on desired approaches and requirements for diurnally resolved SST.

2. Desired Approaches/Requirements for Diurnally Resolved SST

To allow for sufficient time in the session, the discussion on priority requirements for the provision of diurnal information was held first before the individual presentations. This discussion is conducted annually to ensure that the focus of the DVWG is consistent with the broader requirements of GHRSST. Group chair Gary Wick presented a strawman list of priority topics and solicited feedback from the group. Additional requirements from Level 4 producers and other SST product users were particularly requested.

Through the discussion, five primary themes were identified. The first requirement is the provision of diurnal warming estimates. The provision of these estimates must take into account the desired temporal frequency, representative depth, and appropriate spatial resolution. Specific requirements in these areas may vary between users. The second requirement was for the direct provision of diurnal warming models and parameterizations. Several model development activities remain underway and the group was asked to facilitate access to the various routines and software elements. The third requirement was for the improved provision of uncertainty characteristics for existing models and predictions. Accurate estimation of uncertainties can, in some cases, be as important as the estimation of the diurnal warming values themselves. The fourth request was to work toward increasing the amount of available data for validation of diurnal warming estimates. The potential of Argo data has been central to these discussions. The final requirement was for a more general improvement in the understanding of the basic physics surrounding diurnal warming. Fundamental improvements in the models for diurnal warming are still desired.

3. Brief Presentations

Several short update presentations were given by various members of the DVWG. Since the group did not meet in between the GHRSST science team meetings this year, these updates were important to maintain the continuity of group activities.

The first presentation was an update on the Tropical Warm Pool Diurnal Variability Project (TWP+) by Helen Beggs. Significant new work at the Bureau of Meteorolgy in Australia included revised SST retrievals from MTSAT-1R with common day and night algorithms. With the resulting revised diurnal warming estimates, it is now desirable to proceed with the planned model comparisons.

A second presentation was given by Pierre Leborgne on the status of a dedicated diurnal warming matchup database based on SEVIRI satellite data. The dataset has been

7 DVWG: GHRSST Diurnal Variability Working Group

developed with the intent of providing a useful resource for diurnal warming studies. The content of the database was described along with highlights of types of studies that can be conducted. Notably, he showed observations suggesting persistence of a diurnal warming signal throughout the nighttime hours. For further information on accessing the database, one should contact Gerard.Legendre@meteo.fr. Broader use of the data is encouraged.

The next presentation, given by Sandra Castro, was entitled “Diurnal Warming from Unpumped Argo floats and SEVIRI.” This work compared estimates of diurnal warming from the two data sources to help assess the potential utility of near-surface data from unpumped Argo floats. The results showed very good agreement in estimates of subskin, foundation, and corresponding diurnal warming supporting the accuracy of both products and associated methodologies. This work is encompassed in a paper submitted to Remote Sensing of Environment which is now in press.

The third presentation was given by Ioanna Karagali on new work she has begun on a multi-faceted project related to SST diurnal variability. Key elements of the presentation included a comparison of SEVIRI and AATSR observations and an evaluation of potential different methods for deriving a foundation temperature estimate from SEVIRI data. Future work in the project is also to include model based studies using the Generalized Ocean Turbulence Model or GOTM.

Additional brief presentations were given by Chris Merchant, Gary Wick, and Carol Anne Clayson. Chris Merchant spoke to the relevance of SST sensitivity in satellite retrievals to studies of diurnal variability. Low sensitivities will lead to underestimates of diurnal variability demonstrating it is a practical concern that can impact comparisons with in situ observations. Gary Wick described recent progress in implementing new real-time diurnal warming estimates based on model calculations forced with numerical weather prediction model forecast fields (from the NOAA Global Forecast System model). The capability is being done as part of a broader NOAA effort to incorporate diurnal warming information into SST Level 4 analyses and is envisioned to be part of a resource for comparing modeled estimates of diurnal warming. Finally Carol Anne Clayson presented recent observations of turbulence fields of value for model evaluation. Most notably, turbulent kinetic energy dissipation measurements showed a very different relationship to diurnal warming observations than anticipated - sparking discussion and potential ideas for further study.

4. Diurnal Variability Studies with Argo Floats

A highlight of the session was a visit by Breck Owens of WHOI who discussed the potential for conducting a dedicated diurnal warming study with Argo floats. Breck is a member of the Argo Steering Team and has responsibility for US Atlantic activities. While such studies and broader interactions with the Argo community have been desired, the lack of dedicated funding has previously posed an obstacle. Opportunities now exist for a pursuing a study with existing Argo float technology. With more floats going out with Iridium communication capabilities it is possible to do many innovative things. Breck stated that a dedicated experiment was now “perfectly doable.” For a float in a region of expected diurnal warming, it would be possible to program the float to repeatedly sample the near-surface ocean over a period of 3-5 days. He felt that it would also be possible to explore sampling closer to the surface than in standard Argo observations where the pump is turned off at a depth of ~5 m, at least in regions away from the coast. Discussion considered possibilities for establishing forecasts of diurnal warming and an action was taken for the DVWG to develop plans for pursuing a future experiment of opportunity.

DAS-TAG[8] BREAKOUT SUMMARY REPORT

Chair: Edward Armstrong[(1)], Vice-Chair: Jean Francois Piollé[(2)]

(1) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
Email: edward.m.armstrong@jpl.nasa.gov)
(2) IFREMER, France, Email: Jean.Francois.Piolle@ifremer.fr

ABSTRACT

The DAS-TAG provides the informatics and data management expertise in emerging information technologies for the GHRSST community. It provides expertise in data and metadata formats and standards, fosters improvements for GHRSST data curation, experiments with new data processing paradigms, and evaluates services and tools for data usage. It provides a forum for producer and distributor data management issues and coordination.

1. Introduction

This year the DAS-TAG session had a number of presentations concerned with metadata standard reviews, new data processing capabilities and web services that allow users to apply large processing power and chained services directly to the data, GHRSST data coordination activities and proposals to improve data curation through data lifecycle policy implementation.

2. NASA Metadata Trends

Ted Habermann from the HDF Group presented an overview metadata “dialects” including the overlap of ISO 19115 metadata with the NASA ECHO and DIF standards. XML based processing methods have been developed such that 99% of both ECHO and GCMD metadata attributes can be mapped to their ISO counterparts. Metadata description of granules, data quality and lineage, and services are very well described in the ISO 19xxx standards and the community should move to unifying within that standard.

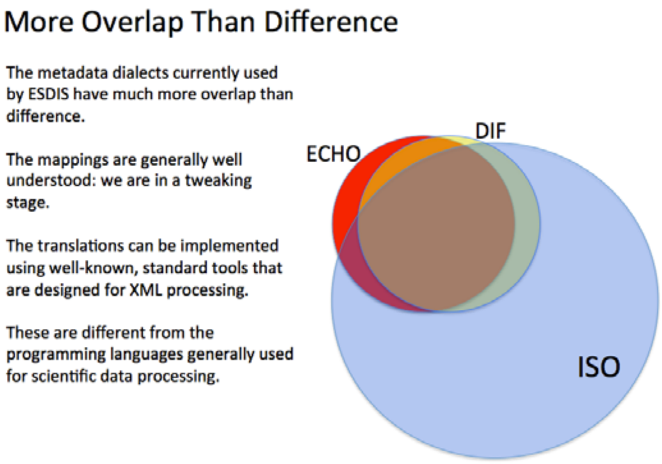


Figure 1. The overlap of metadata dialects used within NASA.

8 DAS-TAG: GHRSST Data Assembly And Systems Technical Advisory Group

3. Web Services For Earth Science Data

Ed Armstrong from the NASA Jet Propulsion Laboratory presented an overview of emerging based web services for earth science data that will be available in the very near future from the Physical Oceanography DAAC. The RESTful nature of these services allow access from any client the can formulate a URL such as web browser or programming script. These web services allow the following capabilities and can be “chained” in sequence to provide seamless input/output from one service to another:

- Search Dataset/Granule Web Service
- Metadata for Dataset/Granule Web Service
- Extract and Subset Granule Web Service
- Image Granule Web Service

A conceptual use case was presented for ASCAT L2 ocean vector wind data that started with dataset and ISO 19115 metadata discovery, a granule search on a specific time domain, data extraction and finally visualization (Fig. 2)

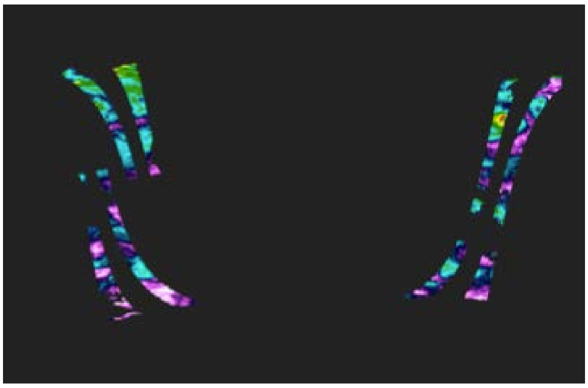


Figure 2. Visualization output after extracting an ASCAT ocean vector wind granule through web services “chaining”

4. HADOOP Usage in Medspiration

Jean François Piollé from Ifremer reported on the implementation of a processing framework based on Hadoop for Medspiration data. Hadoop is an open source processing paradigm based on a Map Reduce model that breaks tasks and data into smaller more modular components that can be rapidly executed independently in a distributed compute fashion. A data mining application developed in the context of Medspiration project is operated on the Ifremer/Cersat *Nephelae* platform which consists of 600 processing cores, 600 TB useful storage (1.5 PB physical storage) and 2.5 TB of memory. The computing application in this case was satellite data processing for derived products such as climatologies, anomalies and data statistics. For example, creating climatology and anomalies based on four years of regional L4 ODYSSEA SST data took 90 seconds. Processing 10 years of QuikSCAT data to retrieve daily wind speed min/max/mean took 2 minutes. This kind of computation will soon be accessible by users through a web interface.

The concept here is that putting data directly in proximity to powerful computing can be leveraged by users to quickly generate results and explore new ideas. It is a major complement, in future, to the traditional delivery of data to users.

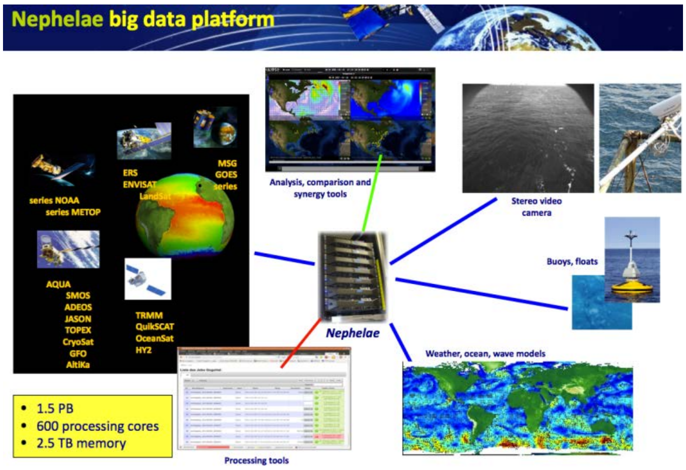


Figure 3. Concept of the Nephelae Hadoop based processing system

5. GDAC to LTSRF Data Flow

Ken Casey from the NOAA National Oceanographic Data Center (NODC) presented results from a short study on reconciling differences and inconsistencies between the GDAC and LTSRF. Some of these inconsistencies are due to missing or incomplete FGDC and DIF metadata. The LTSRF has refined its workflow to accommodate some of these issues and is now working through a backlog. In the future the transfer of GDS2 records should be easier since they do not contain external metadata records (e.g., the FR metadata records). It was also noted that the PO.DAAC metadata web service can be used to regenerate complete metadata records.

6. Dataset Lifecycle

Ed Armstrong reported on the Dataset Lifecycle Policy that the PO.DAAC has implemented for all of its new datasets including GHRSST. This Lifecycle is designed improve data stewardship and insure that datasets that enter into the PO.DAAC distribution and archiving system met standards with regard to data formats, metadata, and even data quality and maturity. Impacts on operations, tools and distribution are assessed through the collection of various metrics including through written documentation. Of primary concern to GHRSST data providers is a template for a “Memorandum of Understand” that includes sections for the provider to document the data uncertainty assessment and validation, and the processing lineage and algorithm history. This document is meant to be a first step to assess the dataset quality and will be eventually leveraged to improve GHRSST ISO metadata records as well. After some discussion it was agreed that “Submission Agreement” would be a more suitable name for this template. The lifecycle concepts were agreed to be ready to be presented to a GHRSST science team plenary session later in the week (see additional report for Thurs presentation).

7. Additional Discussion

The DAS-TAG considered the status of GDS2 production and governance of the GDS2 documentation. Some data producers have already produced GDS2 spec granules and these will be released publically in the near future. A spreadsheet was circulated for producers to enter their best estimates of the start dates of GDS2 datasets. The GDS2 is essentially frozen until the Project Office comes up with a plan for updates. An important future modification to the GDS2 is an extension for climate data records.

HLTAG[9] BREAKOUT SUMMARY REPORT

Chair: Robert Grumbine

NOAA/NWS/NCEP, Email: robert.grumbine@noaa.gov

1. Jacob Hoeyer Introduction/Overview of session

2. Steiner Eastwood – methods of ice and cloud classification and masking

2.1. This is still a complex issue, including how to objectively score classifiers

2.2. Martin Lange raised the possibility of using NWP model estimated clouds as a first guess, or other tool.

3. Jacob Hoeyer – Ice Surface temperature analysis

3.1. There are many sources for such temperatures

3.2. It is a question for HL-TAG and GHRSST at large whether IST is something to include under GHRSST umbrella. HL-TAG members seemed more inclined to do so than other GHRSST members

3.3. Match up data sets are needed, and are being developed

4. Pierre Le Borgne – Metop-A in the arctic, 2007-present

4.1. Showed some sizeable trends over this short period.

4.2. Parts of data analysis lead to some discussion, later picked up in more detail about what constituted an ice cover and how to define it or use it.

5. Discussion – Ice analysis intercomparison

5.1. Both OSI-SAF and NCEP apply a 15% minimum ice concentration in their analyses.

5.1.1. There is some desire among GHRSST users for values to be shown for all concentrations.

5.2. Helen Beggs noted that it is desirable to have the ice analysis, at least at/of the ice edge, to finer resolution than the ~10 km of the OSI-SAF and NCEP analyses.

5.3. Many-sided discussion lead to a desire for at least a verification statistic of P(ice in nature | ice in analysis) for each cell in total.

5.4. GMPE-lite re-mentioned.

6. Jacob Hoeyer Summary of Session

[9] HLTAG: GHRSST High Latitude Technical Advisory Group

Action Items:

- Steiner Eastwood and Robert Grumbine to proceed, perhaps with David Poulter assistance, on an ice GMPE-lite
- Robert Grumbine to schedule HL-TAG telecon at least once before end of calendar year

AUSTAG[10] BREAKOUT SUMMARY REPORT

Chair: Jorge Vazquez(1), V-Chair: Prasjanit Dash(2)

(1) Jet Propulsion Laboratory/California Institute of Technology, Pasadena, Ca,
Email: jorge.vazquez@jpl.nasa.gov
(2) National Oceanographic and Atmospheric Administration, College Park, Md.
Email: prasjanit dash@noaa.gov

ABSTRACT

The breakout session of the AUS-TAG consisted of a variety of reports including an application of GHRSST data to fisheries management. Other presentations included a report on a recent NASA sponsored GHRSST webinar, as well as a demo on SQUAM and a general discussion user support and future GHRSST symposiums. Conclusions about future symposiums were linked to future meetings in South Africa and South America. Other possibilities include having a user survey and/or questionnaire.

1. Introduction

Anne O'Carroll reported on a joint project and referred to her poster European Mission project (Maritime safety, environment, safety) Within the scope of this project, she is collecting expressions of interest for users' requirement (individual or agency). An action item that came out of her presentation referred to the need for a review of the User Requirement's document.

Action item: AUS TAG will provide user requirement information (or document) to Anne O'Carroll.

Jorge Vazquez reported on a recent NASA sponsored GHRSST webinar (May 29-30 2013). The webinar aimed at motivating users to learn more about GHRSST and learn how to use GHRSST data.

Webinar events (2 days in total):

Day-1:

- example of applications, e.g., GHRSST data for La Nina/El Nino studies, Gulf stream etc.
- Jorge showed summary of participants – webinar technology was based on Adobe Connect.
- 49 participants (NRT: 43.2%; coastal: 45.9%; climate: 40.5%; interdisciplinary. 48.6%; 13 countries besides USA; 12 gov 12 commercial 14 education)

Day-2:

- focused on tools and services
- 30 participants (NRT: 25…)

There were a total of ~100 registrations.

- Could be useful for expanding GHRSST data in SA, China, and India.
- There was lot of discussions on the technicality of the webinar.

10 AUSTAG: GHRSST Applications And Users Services Technical Advisory Group

- Ken Casey asked if it’s a good idea to have such seminars targeting a specific product.
- Ken Casey also mentioned about training material (generated by Pam Michael).— send this to Japanese GHRSST participant
- Lewis Gramer mentioned: “connectivity issue could be annoying for some locations.”
- Helen B. asked “is there a tool to get data for a particular lat/lon point and for longer time series”?

Live Access Server allows for subsetting of data for level 4 fields.

Action item: follow-up on questions.

Prasanjit Dash gave a SQUAM overview and an online demo of SQUAM.

Action item: Send email to Lewis Gramer on dependence against “proximity to land”, when available. Also, MICROS (a companion website at NOAA) has this feature (Korak Saha and Sasha Ignatov mentioned)- may be forward the link.

Ed Armstrong gave a presentation on fishery habitat prediction

Ed A. introduced the participants to a system, which NASA has assembled, that integrates satellite and model output with fishery data. Tools allow analyses of interaction between species and key environmental variables. (visit: www.phamlite.com).

Ed:

- suggested to visit www.runeasy.com
- explained Pelagic Habitat A. M. (PHAM) system
- spoke on stock assessment for: a) “Tuna of the EPO” and b) “Sharks of the California current”. Tuna is important commercial species ($2-3 b revenue)
- Fishery data: survey, commercial catch, vessel logbook, recreational fishing, tagging

Environmental characteristicsSatellite and other data

- Remote sensing data helps in finding correlated relationships between habitat and environment. Showed Easy Screen of PHAM; showed GHRSST SST, SeaWiFS Chlorophyll, NOAA CW Frontal probability, NASA ECCO2 ocean currents in relation to fishery.`
- Habitat prediction: showed relation between fish concentration between Chlorophyll, SST (e.g., Skipjack related to SST; Bigeye to both Chlorophyll and SST shown via 3-D contour diagrams.)
- Lewis Gramer asked: “if you collaborate with Southeast fisheries”

Action item: follow up with the Southeast fisheries and see if there is any area of commonality.

Craig Donlon gave a presentation a lesson-writing competition.

- briefly introduced to a lesson-writing competition initiated by ESA;
- details at: www.learn-eo.org/competition.php to join the lesson-writing competition (prize: 5000 euros, 3000 euros, 2000 euros).
- designed to teach people fundamentals but can also do powerful image calculations.
- How to participate: Becoming a lesson author (multi-lingual); any non-ESA employee can participate as long as at least one ESA data is used.

- topics covered: application of Earth observation (Geophysical, Social … welcome).

Action item: Craig D will ask Silvia to forward this info to GHRSST people.

Gary Corlett led a general discussion (brought up the issues from GPO):

A. Users: Who are they?

Gary C. spoke about requirements to gauge "user behavior".

- distinguished between Users, Power users, Small users, New users, One time users, Repeat users
- How many products are there?, spatial coverage?, temporal coverage?, what accuracy
- do RDAC's have information on this?
- Ed Armstrong spoke: "we have summary of usage".
- Lewis Gramer suggested: "in addition to analyzing users, also bring up a survey"

Action item: Ed Armstrong will provide some "Usage/user summary to Gary Corlett".

B. Possible user symposium

- Gary C. raised questions: "organize another user symposiums? – but then, who pays/hosts". Two broad possibilities have been identified towards this end:
    - : "organize session at major conferences?"
    - "is there any benefit to creating a user questionnaire"?
- Symposium was not favored, but user survey was. But D. Lewin Jones suggested to ask about "symposium" in the user survey itself.
- A. Carrol asked "how to send the survey request to users"? Gary C. said, inform users by encouraging them to join the mailing list.
- Alexey K. said, "asking for too much info from users could be annoying". So, how much information should be asked for, from the users.

C. Expansion into new areas

- for new countries: "hold science team meeting" OR "hold a GHRSST local workshop" ?
- the GPO favors the latter approach as ST meetings have specific requirements; or break the annual meeting to "2 days Science meeting" and "3 days users' symposium".

Action item for all AUS TAG members: read the URD (AUS TAG) members and provide feedback (by the end of October, 2013) to Gary C.

New membership request: Christo Peter Whittle, CSIR, SA, christo.whittle@gmail.com

IWWG[11] BREAKOUT SUMMARY REPORT

Chair: Robert Grumbine

NOAA/NWS/NCEP, Email: robert.grumbine@noaa.gov

Inland Waters Working Group

Lewis Gramer, Martin Lange, Erik Crossman, Eileen Maturi, Andy Harris, Jorge Vazquez, Robert Grumbine

Discussion highlights

This session had wide-ranging open discussion rather than presentations. Some highlights:

- Many of the issues which affect lake temperature analysis also affect coral (near shore) areas temperature analysis (Lewis Gramer)
- Erik Crossman working on a literature and validation review for lake temperatures
- Note of Xiaofeng Chu (RSMAS – NOAA) working on coastal diurnal warming

Actions:

- Recommend to GHRSST that group name be changed to Nearshore Waters Working Group.
- Robert Grumbine to establish shared document (Google Drive) listing off lakes with greatest distance to nearest land, lat-long of that point, and lake area. Other fields, including names, to be added by group as desired.
- Erik Crossman to provide links/copies of lake temperature climatologies and his literature review
- Martin Lange to provide verification statistics document on the use of FLAKE (lake model) in DWD NWP.
- Robert Grumbine to collect and share email addresses of lake-interested people.
- Schedule date for next NSWWG in ~September time frame.

[11] IWWG : GHRSST Inland Waters Working Group

CDR-TAG BREAKOUT SUMMARY REPORT

Vice-Chair: Jon Mittaz[(1)], Chair: Chris Merchant[(2)]

(1) University of Maryland, MA, US, Email: Jon.Mittaz@noaa.gov
(2) University of Reading, England, Email: c.j.merchant@reading.ac.uk

ABSTRACT

Report on the session help by the Climate Data Record Technical Advisory Group for GHRSST XIV.

1. Introduction

Introduced terms of references and pointed out several things of importance with the main emphasis on looking at the CDAF issues. It is important to give users some information and properties of different datasets so once we have CDAF in place one of the tasks of the TAG will be to maintain the outcomes of the CDAF reviews.

2. Talk on ship borne radiometers and their importance for CDRs

Peter Minnett gave a talk on the use of shipboard radiometers for climate data records as part of the ISSI Team (made up of people who have used such radiometers). He discussed the methodology of calibrating pre-launch data to an SI standard and then the on-board spacecraft radiances for satellites and then discussed a similar calibration chain for ship borne radiometers. He then discussed the connection between ship radiometer, satellite and buoy matches to try and reconcile the skin temperatures to a reference given the relatively small number of radiometer matches. Basically use radiometers to validate the uncertainties of the satellite SSTs relative to the ship radiometer derived SSTs. Current ship borne radiometers then provide a method of tracing to a standard for SST. There is a push to detail the complete uncertainty chain from standard through to SST from NPL to understand all error sources. It was pointed out that there are, however, many error sources such as blackbody emissivity, thermistors and the calibration sequence itself. Ship radiometers can then only realistically be used as a validating source to the satellite SSTs and you need to know the M-AERI error and the uncertainty of the collocation method as independent numbers to compare with satellite SSTs to try and get estimates of all the uncertainties. Multiple error transfer chains and procedures have been/are being developed to try this, and the work Peter discussed is trying to move towards the best procedure for obtaining the best estimate of uncertainty with some level of traceability to a standard.

3. ESA Climate Change Initiative and CCI

Chris Merchant presented work on obtaining CDRs via ESA CCI SST on behalf of Nick Rayner. He discussed using the (A)ATSR (from ARC) which has reduced spatial coverage to correct the AVHRR (for better spatial coverage). He then discussed the different sources of uncertainty (noise, synoptically correlated effects, large scale effect such as calibration). He then presented an L4 analysis derived from SST CCI ATSR and AVHRR SSTs (Level 4 derived from a depth temperature a 0.2m from a close to daily average). This new analysis should supersede the OSTIA reanalysis currently provided from the Met Office, once validated. The main point of the work is to have a consistent AVHRR record consistent to the (A)ATSR record as far as possible. Work is being undertaken for validation but there is also work to understand the impact of the new CDR on models, fronts and other products. The project is moving onto phase 2 of CCI and the plan is to create a system to reprocess and update easily, revise the product following user feedback and try and expand back to 1978. The current CCI products will be available soon for people on the CDR-TAG team to use (emails/links provided). There were questions raised about GDS 2.0 SSES fields: the new product does not give the usual statistical connection to drifting buoys, but is thought to be compatible with GDS 2.0. AVHRR data from 1991 will be available very soon using the most recent two satellites' GAC data for between 1991 and 2010.

4. Historical and In Situ Activities

Slides were shown showing the status of different CDR related projects showing the updates from the last GHRSST meeting. They can be viewed online.

ACTION CDR-TAG chairs to revise approach to summary graphic of projects, since there are now more than one project per sensor

5. Climate data assessment Framework and associated issues

Resulting from the action initiative at the CDR-TAG in 2012, Version 1 is in existence (v1.0.2). The purpose of document is to provide users with information on CDRs so they can work out if a given set is of use to their own application. The CDAF lays out how the CDR-TAG will accomplish this. Currently looking at the L2 and L3 – L4 will be later. There will be basic screen of a product, and then the product provider will provide evaluation information and then the CDR-TAG team will review the information and then approve and publish on a website. The CDR-TAG will not approve a dataset as an official GHRSST CDR.

SST datasets have to pass basic criteria - > 10 years, is it available etc. Then the provider has to provide assessment information. This is not meant to be overly prescriptive, yet consistent enough to enable comparisons between different datasets to be made sensibly. The general assessment information was then presented There are some that are qualitative such as what are the datasets strengths. Then there are quantitative information to be filled out This includes assessment against drifting buoys, against Argo and assessment of deseasonalised against GTMBA. In more detail, what are the systematic differences between a reference such as drifters (the reference must be independent to the SST retrieval algorithm). Then there are systematic uncertainties e.g. median bias which could be linked to more information (e.g. maps of bias). Then there are non-systematic uncertainty – essentially the noise though it not completely random. Then stability against the GTMBA. Then there is SST sensitivity. While many welcome this as an additional metric, groups not doing radiative transfer may not be able to provide this. Do we need a reference (simulated) dataset for those who do not use RTM as part of their process? It was agreed this could be an approach to solve this issue when it first arises. For the CCI, sensitivity is evaluated pixel by pixel, but not reported in the product. Users could be shown geographical variations in mean sensitivity on a map via a link.

Helen Beggs asked about regression based algorithm regarding the sensitivity of SST and how it is calculated in detail. She was pointed to Chris Merchant's EARWIG Talk (GHRSST XIV) and the solution of providing the derivatives to be used was raised. Peter Minnett raised a question of adjustment of RTM TOA radiances with adjustments to SST since the atmosphere responds. It was going to be talked about offline. Sasha Ignatov asked a question regarding SST sensitivity as to if it had to be done pixel by pixel or globally. The baseline is that it is a single number but the spatial information could be provided via a map, for example. Sasha also raised the issue to robust vs standard deviation and the current plan is to use robust standard deviation.

Chris raised Felyx (see JF Piollé talk, Thursday) as a possible way of standardizing CDAF metrics as a longer term solution. This is a user requirement fed into the Felyx user consultation. In terms of in-situ matches, maybe IQUAM could be used alternatively, but

Ken Casey noted it would be preferable to have tools to use it consistently and easily. Perhaps the first (few) CDR providers could make their code available. This was raised a maybe a necessary requirement to make it easy for people to put data into the system. It was suggested that a few datasets should be tried. CCI could provide access to GTMBA, and IQUAM/SQUAM may have code for buoys and matches via open source code. Sasha can provide access to some of this code. CCI will try the framework out but using their own matchup database. Chelle will also provide a product. Helen will also provide (financial year 14/15) may provide a product (after a year).

Two groups are setting similar things up officially within the CEOS WG climate context (SST and Ocean Colour) and SST (GHRSST) is more advanced. Other groups will look at the CDAF which could be used as a first start for them to follow. Peter raised the point that other groups have different goals so their methods (if enforced on us) may not be best practice for GHRSST. Discussion then moved onto which matchup dataset is best – perhaps IQUAM, perhaps ICOADS. Craig raised the possibility of a funded CCI project to setup such a matchup database. The suggestion is that the details will be worked out over the next year, but we need consistent in-situ data plus code a documents so that it can be done either locally by the provider or centrally (if funded).

ACTION: Discussion will move offline via a working group during year up to next GHRSST (Chris Merchant, Jon Mittaz, Sasha Ignatov, Craig Donlon, Ken Casey, Jean-Francois Piolle and Chelle Gentemann). Helen Beggs will seek future funding for CDAF assessment on her products.

How to describe traceability was raised by Peter Minnett, so (**ACTION**) the question is raised to STVAL to advise on how to address this in CDAF.

Conclusion: the CDR-TAG endorsed the CDAF v1.0.3 and recommends to the GHRSST ST that it is adopted and acted upon.

6. Historical satellite information

Archiving pre-launch and associated documentation of satellite calibration is an issue of long term importance to CDR-TAG interests.

ACTION: This will be raised in an open letter to CEOS and CGMS by the GHRSST Chair.

SECTION 4: INTRODUCTION AND REVIEW

GHRSST LONG TERM STEWARDSHIP AND REANALYSIS FACILITY (LTSRF) AT THE US NATIONAL OCEANOGRAPHIC DATA CENTER (NODC)

Kenneth S. Casey

NOAA National Oceanographic Data Center, USA, Email: Kenneth.Casey@noaa.gov

ABSTRACT

Since the 13th GHRSST Science Team Meeting, the Long Term Stewardship and Reanalysis Facility (LTSRF) at the US National Oceanographic Data Center (NODC) has made significant progress in the long-term stewardship of all GHRSST datasets. This report summarizes these accomplishments and provides an overview of the contribution the US NODC is providing to the international SST community.

1. Introduction

The US NODC serves as the long term stewardship for all GHRSST products provided to the Regional Global Task Sharing (R/GTS) Framework, illustrated in in Figure 1.

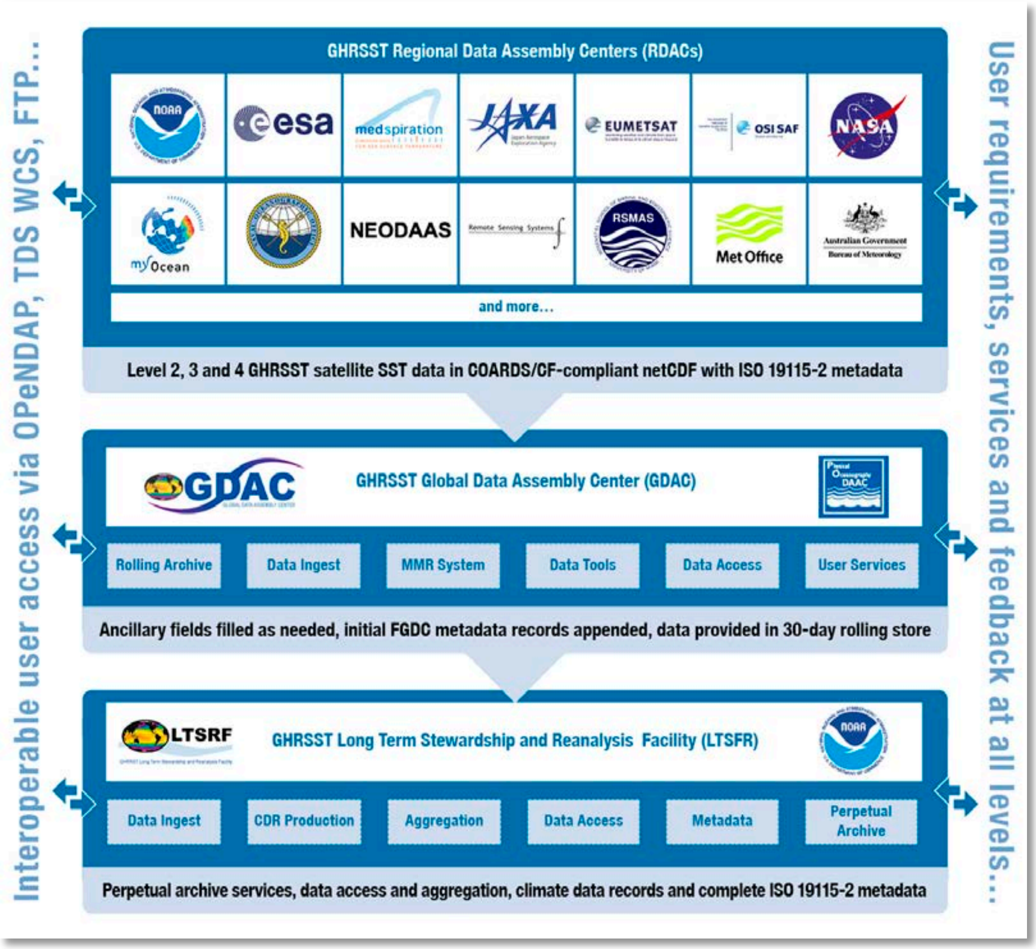


Figure 1: The GHRSST Regional Global Task Sharing Framework.

In addition to providing long term archival services, the NODC LTSRF also serves as a Regional Data Assembly Center (RDAC) for the SST climate data record, Pathfinder Version 5.2.

This report provides the current status on the both the LTSRF and Pathfinder RDAC activities.

2. LTSRF Progress Since GHRSST 13

Table 1 summarizes the progress made by the LTSRF since 2007. Each year, as the volume of the archive has grown the number of services available to these data has grown as well. At the time of this report, the NODC LTSRF is capable of providing all GHRSST products through FTP, HTTP (http://data.nodc.noaa.gov/ghrsst), OPeNDAP (http://data.nodc.noaa.gov/opendap), and the THREDDS Data Server (TDS). Gridded products are additional made available through the Live Access Server (LAS, http://data.nodc.noaa.gov/las) and a wide range of discovery services are enabled though the NODC Geoportal Server (http://data.nodc.noaa.gov/geoportal). NODC also ensures that GHRSST meets the expectations of the Committee on Earth Observing Satellites (CEOS) by providing both collection and granule level discovery to the CEOS WGISS Integrated Catalog (CWIC) system.

Table 1: Summary of LTSRF progress since 2007.

	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013***
Accessions		39,048	49,957	59,982	67,906	92,282	95,244
Files		679,000	993,580	1,352,901	1,662,004	2,459,724	2,535,291
Volumes (TB)		13	20	28	34	57	59
Services	ftp http	ftp http	ftp http DAP	ftp http DAP WMS WCS	ftp http DAP WMS WCS LAS	ftp http DAP WMS WCS LAS Geoportal	ftp http DAP WMS WCS LAS Geoportal Granules CWIC

	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013***
Files served per day	85	1130	1734	3413	21,956	14,896	28,807	15,869
GB served per day	0.2	1.8	3.9	18.8	66.3	115	73	84
Users served per day	3	7	8	8	11	19	19	21

Table 2: User accesses from the LTSRF.

Table 2 summarizes the user accesses to the GHRSST LTSRF at NODC. Overall growth has been seen every year since the LTSRF began serving GHRSST data in 2005. These results are also presented graphically in Figure 2 below.

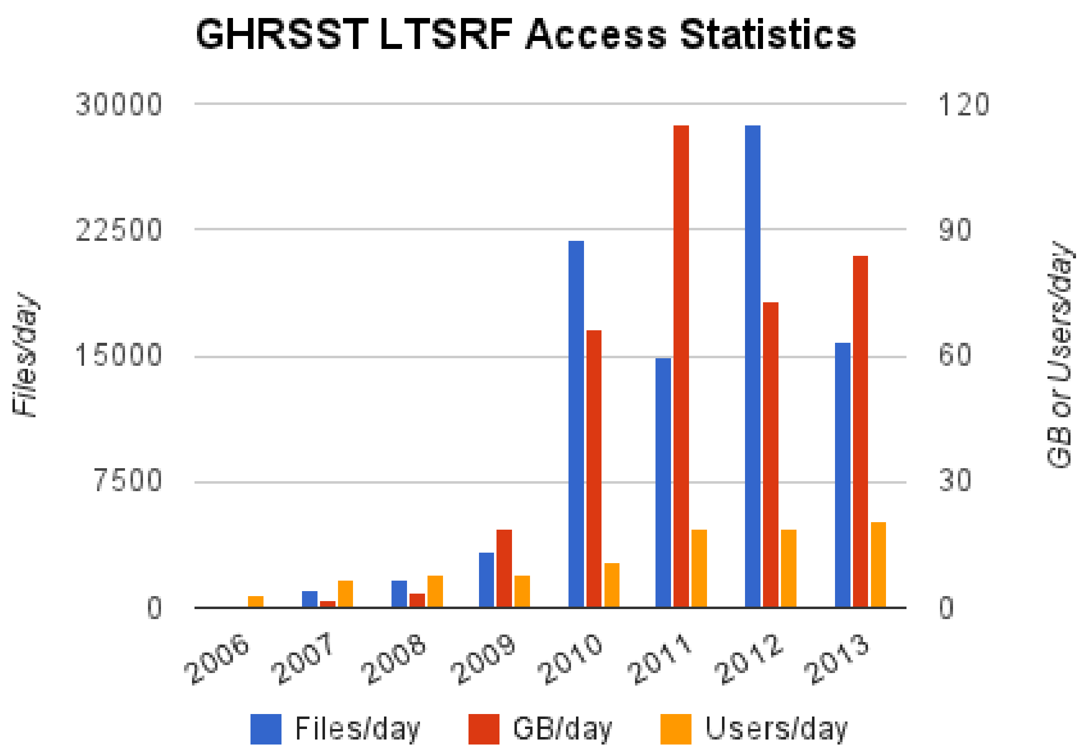


Figure 2: LTSRF user access statistics in graphical form.

A significant step forward in enhanced data discovery and access was achieved in the last year when the NODC enabled the seamless linking between collection level and granule level discovery. Once a user discovers a GHRSST collection, they can now jump directly to a granule (or file) level discovery process using a common look and feel interface. The granule discovery interface is shown below in Figure 3.

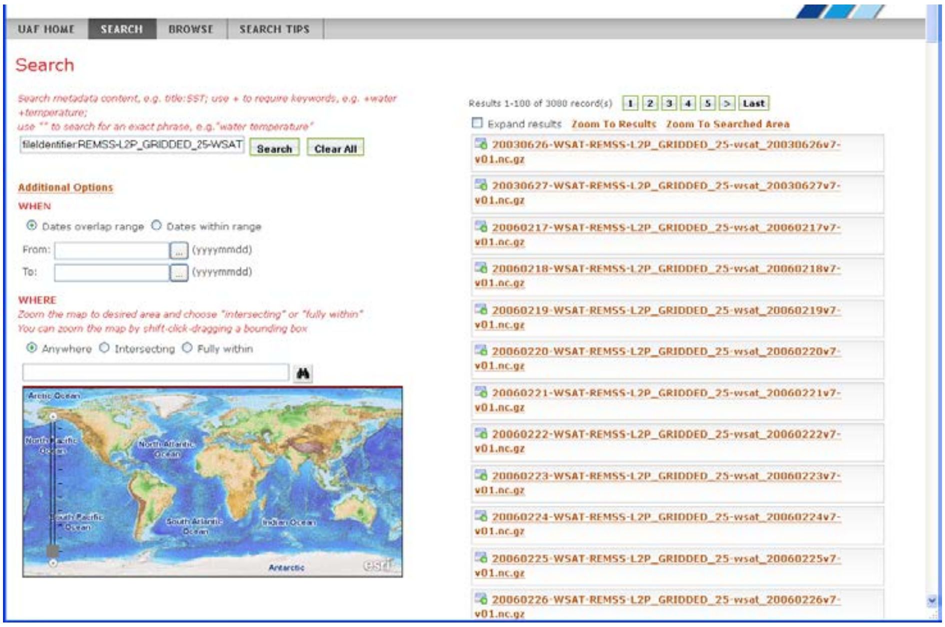


Figure 3: Screenshot of granule level discovery interface, enabling users to find individual data files within a collection.

Significant progress has been made in preparing for the GDS2 transition at the NODC LTSRF. Ingest and archive systems have been updated and awaiting final testing once real GDS2 files become available. As part of the GDS2 preparations, significant quantities of back-logged data files have been archived. These files arrived to the LTSRF originally with insufficient metadata or other problems that made their automatic archiving impossible. Complete clear out and full reconciliation of the data files ever sent to the GDAC and those archived at NODC is expected by September 2013.

In addition to these advances, the LTSRF still maintains automated status reporting and provides browse graphics for all ingested data files.

3. Pathfinder RDAC Activities

The goal of the Pathfinder climate data record RDAC is to provide the longest, most accurate, and most consistent SST record from the AVHRR sensor series. Currently, Pathfinder Version 5.2 in GDS2 L3C format is available for 1981-2011 (with 2012 expected in September 2013). Unfortunately, no SSES bias or standard deviation errors are available, nor is the RDAC able to provide GHRSST-compliant times for the L3C data. All of the data are available via TDS, FTP, HTTP, LAS, OPeNDAP, WCS, WMS, and the Geoportal Server. In addition, a 7-day climatology and gap-filled time series version of Pathfinder are made available in the Coral Reef Temperature Anomaly Database (CoRTAD v4, http://www.nodc.noaa.gov/SatelliteData/CoRTAD).

Looking forward, in summer 2013, Daily, 5-day, 7-day, and monthly V5.2 averages and climatologies in GDS2 L3C/L4 are expected to be available. By the end of 2013, a new V5.3

Pathfinder in GDS2 L2P, L3U, L3C is expected. PFV5.3 corrects several shortcomings in V5.2:

- SSTs will be available for all quality levels, including quality of 0 which was left out of V5.2 due to memory issue in the underlying code
- Sun glint regions will be better included in the data
- Cloud tree tests for NOAA-7 and NOAA-19 will be consistent now with the rest of the sensors. In v5.2 they were not.
- The L2P and L3U can now include SST_dtime.

Note, SSES bias/stdv still won't be available until Version 6 later in 2014/2015. Version 6 will include GDS2 L2P, L3U, and L3C, with uncertainties and times, 2000-present

4. Conclusion

The period since GHRSST 13 has been another successful one for the NODC LTSRF and Pathfinder RDAC.

NESDIS CENTRAL REPORT: POLAR SST PRODUCTS AND MONITORING AT NESDIS

Alexander Ignatov[1], John Sapper[2] and and Team
(Yury Kihai, John Stroup, Boris Petrenko, Xingming Liang, Prasanjit Dash, Feng Xu, Korak Saha)

(1) NOAA/STAR, 5830 University Research Court, College Park, MD 20740, USA,
Email: alex.ignatov@noaa.gov
(2) NOAA/OSPO, 5830 University Research Court, College Park, MD 20740, USA

Update to NOAA operational polar retrieval system, Advanced Clear-Sky Processor for Oceans (ACSPO) is presented. ACSPO was upgraded recently to version 2.20. New capabilities were added to facilitate RTM based physical retrievals, and optional SST bands (VIIRS M13 and M14, and MODIS 21, 22, and 29) added. Work on version 2.30 is underway which will report ACSPO in GDS2.0 compliant format. Work towards reprocessing AVHRR GAC data 2004-present (NOAA-15, -16, -17, -18, -19, and Metop-A and –B) underway.

Also reviewed are status and enhancements to three monitoring systems:

- SST Quality Monitor (SQUAM; *www.star.nesdis.noaa.gov/sod/sst/squam/*) – sustained monitoring of VIIRS, two MODIS, 3 NOAA AVHRRs, and 1 Metop-A AVHRR radiance products. Added product from newly launched Metop-B (Sep 2012). Validation of ACSPO GAC and Pathfinder against in situ added. Functional improvements to web page made.
- Monitoring of IR Clear-sky Radiances over Oceans for SST (MICROS; *www.star.nesdis.noaa.gov/sod/sst/micros/*) – sustained monitoring of VIIRS, two MODIS, 3 NOAA AVHRRs, and 1 Metop-A AVHRR radiance products. Added product from newly launched Metop-B (Sep 2012) – shows anomalies, work is underway with Calibration and CRTM Teams to resolve. Resolved MODIS anomaly, by working with CRTM Team – MODIS in family, except band 20 where Terra and Aqua differ by 0.3K. All other platforms are stable and in family. Work is underway to upgrade to MICROS v7 which will additionally monitor optional SST bands, reprocessed AVHRR data, and different cloud masks for BTs and SSTs.
- In situ SST Quality Monitor (*iQuam*; *www.star.nesdis.noaa.gov/sod/sst/iquam/*) continues to operate in near real time. Upgrades to version 2 are underway (reprocessing back to 1980, adding ARGO floats, adding OSI SAF and UK MO black lists).

NOAA GEOSTATIONARY AND BLENDED GHRSST PRODUCTS

Eileen Maturi [(1)]***, Andy Harris, Jonathan Mittaz, Prabhat Koner*** [(2)]

(1) NESDIS College Park, Maryland, U.S.A., eileen.maturi@noaa.gov
(2) University of Maryland/CICS College Park, Maryland, U.S.A. short address including country, andy.harris@noaa.gov, jon.mittaz@noaa.gov Prabhat.Koner@noaa.gov

ABSTRACT

The National Oceanic and Atmospheric Administration's (NOAA) office of National Environmental Satellite Data and Services (NESDIS) generates operational geostationary Level-2P (L2P) products in GHRSST GDS2.0 format and blended geostationary and polar orbiting Level 4 SST analysis to satisfy the requirements of the GHRSST users. NOAA provides full L2P SST products for GOES E/W as part of its operational processing. The L2P products are derived from ½-hourly GOES-East & West North & South sectors in native satellite projection and include the full L2P ancillary fields. NOAA provides full L2P SST products for MTSAT-2 and MSG-2 as part of routine operations. For MTSAT-2 the L2P product is produced every hour in native satellite projection whereas for MSG-2 the L2P product is produced every 15 minutes. Both the MTSAT-2 and MSG-2 L2P products contain the full L2P ancillary field as required by the GSD2.0 format. All the NOAA generated geostationary L2P products include diurnal warming estimates as part of their ancillary field.

Operational SST retrievals from NOAA's GOES and POES satellites are used to produce an operational daily global, high resolution 5km SST blended SST analysis and a global, high resolution 5km SST Night time Only Analysis in GSD2.0 format.

Within the next year a diurnally corrected operational daily global 5km SST analysis for day/night and night time only will be available in GHRSST L4. Shortly after this, we plan to incorporate the AMSR-2 SSTs into the daily global 5km SST analysis suite of products.

We have initiated a Reprocessing Geo-Polar Blended SST analyses in support of NOAA Coral Reef Watch. We are reprocessing both the 5km day/night and night time only blended SST analyses from September 2004 forward. We plan to have this completed a year from now. These data sets will be available in GHRSST L4 format.

SST ACTIVITIES AT NCDC

Viva Banzon[(1)], Eric Freeman[(2)], Boyin Huang[(2)], Huai-min Zhang[(2)]

(1) National Climatic Data Center, Asheville, NC, USA, Email: viva.banzon@noaa.gov
(2) same address, Emails: eric.freeman@noaa.gov, boyin.huang@noaa.gov, huai-min.zhang@noaa.gov

ABSTRACT

The NOAA National Climatic Data Center is one of the GHRSST Regional Data Centers in the USA. Here updates are provided about the ¼° Daily Optimum Interpolation Sea Surface Temperature analysis, routinely produced at NCDC. A summary is also provided of SST products still in development and other SST-related activities at NCDC. Issues to be addressed under GHRSST are also raised.

1. Introduction

The NOAA National Climatic Data Center (NCDC) is a GHRSST Regional Data Centers that routinely produces the ¼° Daily Optimum Interpolation SST (DOISST). In addition, two other SST analyses are under development: the Two-stage (2S) High-Resolution OISST and the night-like OISST. This report covers the SST products above, but also presents other SST-related activities that do not necessarily fall under GHRSST but may be of interest to the community.

2. DOISST

The ¼ DOISST is the main NCDC product (*http://www.ncdc.noaa.gov/oa/climate/research/sst/oi-daily-information.php*). At present, only the DOISST that uses SST data from the Advanced Very High Resolution Radiometer (AVHRR) is routinely updated daily. This product is also known as AVHRR-only. The AVHRR+AMSR DOISST time series uses additional data from the Advanced Microwave Scanning Radiometer on the Earth Observing Platform (AMSR-E). AMSR-E SSTs have not been available since October 2011, so AVHRR+ASMR production has stopped, but is being extended by including WindSat and AMSR2 (discussed below).

Reprocessing using the latest Pathfinder version 5.2 is planned but there is a gap in the new version due to missing level1B data for NOAA9 that was used in the previous v5.0 to fill in the gap between NOAA 11 and 14. Pathfinder preferentially uses afternoon satellites and Pathfinder processing of the morning satellite NOAA12 L1B data has not produced acceptable SSTs (R. Evans, Pers. comm.). Options on filling this gap are being discussed with the Pathfinder producers (U. Miami and NODC).

In the future, AMSR2 data will be used to revive the AVHRR+AMSR time series. WindSat data, from the non-civilian U.S. satellite Coriolis, has been found suitable to bridge the gap between AMSR-E and AMR-2, even though the viewing geometry and overpass time of WindSat is quite different from the other two microwave satellites, as discussed in a recent paper by Banzon and Reynolds (2013). Other than Pathfinder, AMSR SSTs have been upgraded to version 7, and WindSat data is available only as version7. Thus, the AVHRR+AMSR time series has to be reprocessed using the new versions of inputs. GDS2.0 compliance for the DOISST netCDF files is planned for next year but may occur earlier at the end of 2013.

3. 2S and Night-like OISST

The Two-stage (2S) High resolution OISST is a daily analysis performed at 1/24° resolution, and is done in two-stages. The first stage is the AVHRR+AMSR DOISST methodology. The second stage is designed to produce higher resolution features only where high resolution data are available. A recent paper by Reynolds et al. (2013) tested this methodology using simulated data. Plans are to release 2S OISST after the methodology has been applied to real data. For the Night-like OISST, the problem of insufficient data is being dealt with by using wind screened daytime satellite data.

4. Other SST activities

NCDC also has non-GHRSST activities that involve in situ SST observations. The Extended Reconstruction of Sea Surface Temperature (ERSST) is a monthly SST analysis on a 2°grid that uses only in situ data (http://www.ncdc.noaa.gov/ersst). It is available from the 1880's and is used for climate assessments. It also provides a historical context to more recent trends derived from satellite data. This product is updated monthly. Current activity is focused on developing ERSST version 4 with better uncertainty estimates and additional bias corrections, among other things.

The International Comprehensive Ocean-Atmosphere Data Set (ICOADS) is the authoritative source of all surface marine *in situ* observations collected worldwide (http://icoads.noaa.gov). Due to loss of funding, ICOADS is now transitioning to NCDC and is being enhanced through formal international partnerships. Due to budgetary constraints, the next major release, Release 3.0 or R3.0), is expected by the end of 2014.

The performance measure (PM) for SST, produced in compliance with the US Government Performance Regulations Act (GPRA), is used to monitor the global buoy array as a NOAA-GCOS activity. The SST PM is designed to answer the question on where to deploy more buoys, based on the number of in situ observations reported in the past three months on a 10° grid (Fig. 1). As the number of deployed buoys (or equivalent ship observations) increases in the gridbox, then the Potential Satellite Residual Bias Error becomes smaller and can satisfy the target of about 0.5 C for each 10° gridbox. NCDC send this product quarterly to the Climate Program Office (http://www.osmc.noaa.gov/).

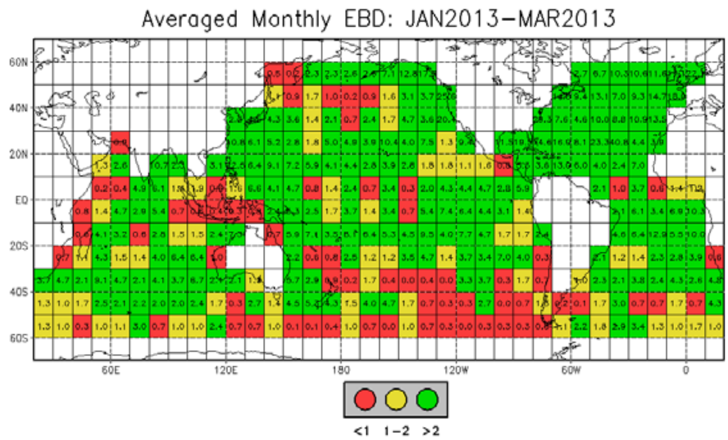


Figure 1: An example of how the GPRA SST performance measure is used to identify areas where observations are low expressed as equivalent buoy density (EBD)

5. Issues

NCDC is interested in finding out who will be the producer of AMSR2 SSTs, and if there will be any inter-comparison effort to evaluate the algorithms. For the Metop-B which will no longer follow heritage AVHRR procedures, what is the distribution, validation and archive plan? Similarly, for VIIRS, when will the SST algorithm be stabilized?

6. Conclusion

For GHRSST, NCDC's main activity is in producing SST analyses. Compliance with GDS2.0 is expected next year. DOISST is routinely maintained but reprocessing with updated inputs is a main concern because information is not always readily available about upcoming changes. There are other NCDC activities that involve the in situ observations, and support from GHRSST is always appreciated.

7. References

Reynolds, R. W., D. B. Chelton, J. Roberts-Jones, M. J. Martin, D. Menemenlis, and C. J. Merchant, 2013: Objective determination of feature resolution in two sea surface temperature analyses. J. Climate, 26. 2514-2533.

Banzon, Viva F., Richard W. Reynolds, 2013: Use of WindSat to Extend a Microwave-Based Daily Optimum Interpolation Sea Surface Temperature Time Series. J. Climate, 26, 2557–2562. doi: http://dx.doi.org/10.1175/JCLI-D-12-00628.1.

NASA GDAC[12] REPORT TO THE GHRSST SCIENCE TEAM

Edward Armstrong (1), Jorge Vazquez (1), Andrew Bingham(1), Michelle Gierach(1), Thomas Huang(1), Cynthia Chen(1), Chris Finch(1), Charles Thompson(1)

(1) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
Email: edward.m.armstrong@jpl.nasa.gov

ABSTRACT

In 2012-2013 the Global Data Assembly Center (GDAC) at NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC) continued its role as the primary clearinghouse and access node for operational GHRSST data streams, as well as its collaborative role with the NOAA Long Term Stewardship and Reanalysis Facility (LTSRF) for archiving. Our presentation reported on our data management activities and infrastructure improvements since the last science team meeting in 2012.

1. Introduction

The oral presentation reviewed the core functions of the GDAC and its contributions to the operation of GHRSST:

- Ingest, Quality Assurance, Metadata, Distribution, Discovery, Archive, LTSRF interface for +61 GHRSST datasets
- Support operational datastreams for L2P/L3/L4 data from 14 RDACs (30 GB/day; 6K granules/day)
- Maintain linkages to data providers and LTSRF archive
- Develop/improve tools and services for data usage including web services
- Report on user reports and distribution statistics
- User community engagement
- Curate dataset metadata and lifecycle

2. Accomplishments

The major accomplishments of the GDAC revolved around the themes of GDS-2 implementation, tools and services of existing GHRSST datasets, metadata improvements and user services. The highlights include

- GDS-2 tasks:
  - Data handler for ingest implemented
  - Python-based metadata compliance checking improved
  - NetCDF read software in R, IDL, Matlab, Python developed
  - 3 GDS2 datasets ingested (but not publically released)
- Dataset lifecycle implementation. A new "Submission Agreement" required from data providers will improve the capture of dataset quality
- GHRSST Project Office coordination through a joint Dec 2012 meeting at JPL

[12] GDAC: NASA Global Data Assembly Center

- Upcoming tools and services including new web services for discovery, extraction, and visualization
- GHRSST L4 spectral analysis "package" released
- NASA sponsored GHRSST webinar

3. Distribution metrics

The following figures show distribution metrics from the GDAC since 2011. Users, data volumes and number of files are all steady or have slightly increased.

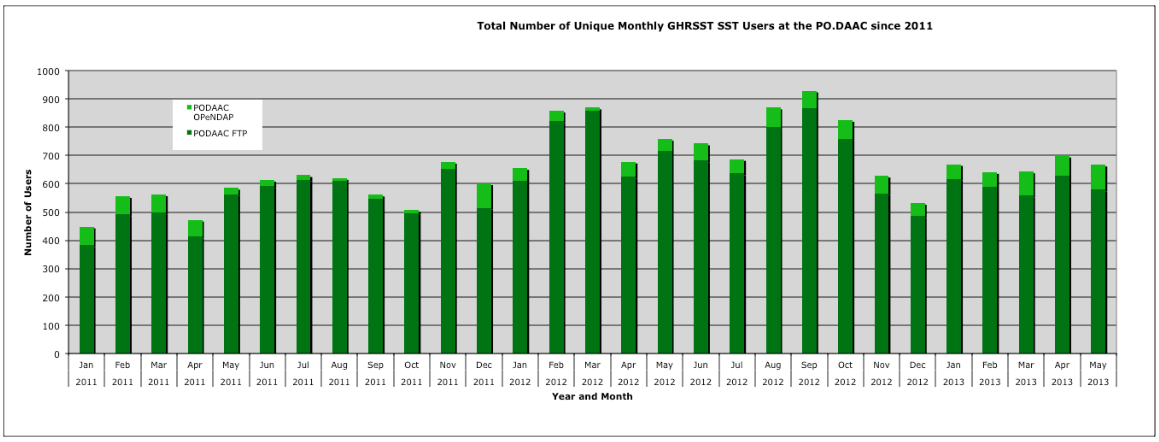


Figure 1. Number of unique monthly users via FTP and OPeNDAP

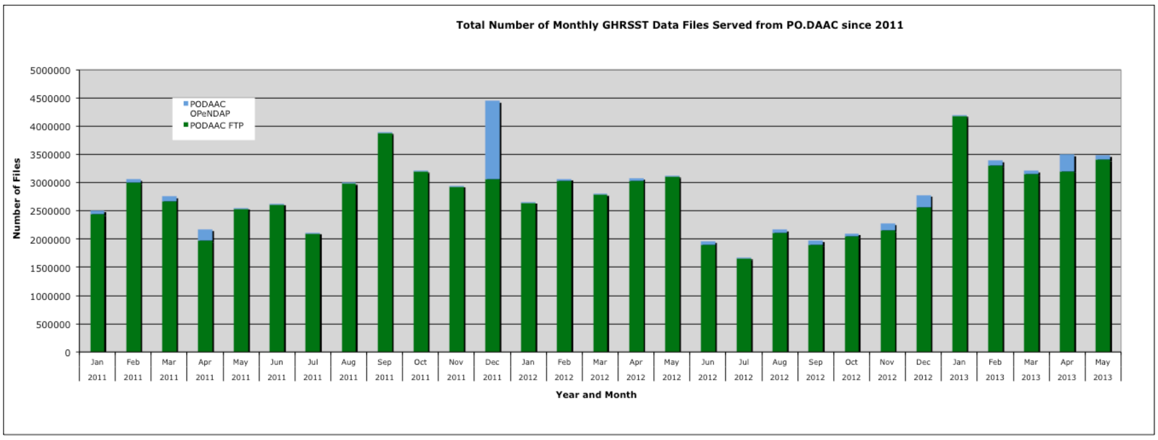


Figure 2. Number of monthly files distributed

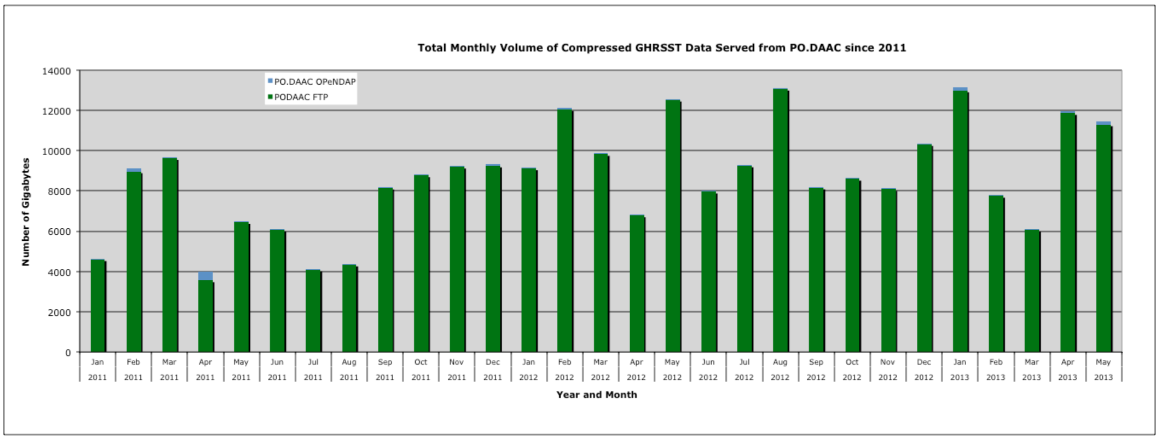


Figure3. Number of monthly files distributed

4. Issues

The following issues of concern were raised at the GDAC report on the first day and throughout the meeting

- GDS2 implementation and reprocessing schedules
- Dataset lifecycle implementation in conjunction with GHRSST User Working Group review
- Improved dataset quality documentation including provenance and lineage capturing
- GDS stewardship and governance
- Exchange of GDS2 datasets with the LTSRF
- Growth of SST datasets and guidance on SST dataset selection
- Forum usage

5. Acknowledgements

This work was carried out at the NASA Jet Propulsion Laboratory, California Institute of Technology. Government sponsorship acknowledged. Copyright 2013 California Institute of Technology. Government sponsorship acknowledged.

NASA GHRSST PRODUCTS (MODIS, MUR, G1): STATUS REPORT

T. Mike Chin

Jet Propulsion Laboratory, California Institute of Technology, U.S.A.,
Email: mike.chin@jpl.nasa.gov

ABSTRACT

Production statuses of three NASA GHRSST products are presented, including new and planned activities.

1. The Products

NASA GHRSST products include *MODIS* L2P, *MUR* L4, and *G1SST* L4.

The *MODIS* L2P data are SST retrievals from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors aboard Terra and Aqua satellites, covering the globe along polar orbits and featuring ultra-high 1-km resolution and wide swaths. Each GHRSST MODIS product contains SST retrievals from two channels (11 and 4 μm), both with their own single sensor error estimates and quality flags, with the 11-μm retrievals serving as the main "SST" data while the 4-μm retrievals being designated as the auxiliary "SST4" data.

Both the *Multi-sensor Ultra-high Resolution (MUR)* and *G1SST* L4 products are daily SST analyses at 1-km horizontal resolution. The key differences between the two products are in the input data sets, time coverage, and analysis technique used by each product. MUR uses a more selective set of input data, opting to ingest only night-time data (based on local time) from a smaller number of L2 and L3 data sets; while G1SST uses a wider range of input data sets including those from geo-stationary satellite. MUR has over a decade of coverage starting mid-2002 and continuing to present day with a 4-day production latency; while coverage of G1SST begins in 2010 and continues with a 1-day latency. Analysis techniques for both MUR and G1SST feature multiple stages of scale-dependent interpolations. MUR follows the energy-conserving *multi-resolution analysis (MRA)* expansion using the Battle-Lemarié wavelets (continuous basis functions), leading to approximately 10 scale-dependent stages of interpolation. G1SST performs its interpolation by applying a 2D-Var method at three scale-dependent stages.

2. Recent Activities

The recent production activities for the <u>*MODIS*</u> L2P product include delivery of an updated coefficient estimation algorithm and initiation of reproduction using it. The algorithm uses the LATBAND approach (6 zonal bands 20 degrees wide symmetric from the equator). The coefficients for Terra are available at present, with coefficients for Aqua expected within weeks. The Ocean Biology Processing Group (OBPG) at Goddard is implementing the updates into the SeaWiFS Data Analysis System (SeaDAS). Reprocessing is underway (e.g., 2009-2012 for both Aqua and Terra) to be followed by comparison/validation work.

For <u>*MUR*</u> L4, "Version 4" upgrades were performed recently and released on April 1, 2013. The new MUR version has corrected over-smoothing in the high-latitude basins around ice edges, added WindSat L3 and iQuam buoy data sets as its inputs, and updated inter-sensor bias estimation scheme. Retrospective upgrading from version 3 to 4 has been completed back to August 1, 2012. MUR (version 3) has been a popular product based on the delivery statistics at GDAC (PO.DAAC) for the year 2012, indicating potentially high user needs for ultra-high-resolution SST analysis products. In fact, user feedback has triggered the Version 4 upgrade activities for MUR.

For *G1SST* L4 production, Zhijin (Gene) Li has become the new contact person. The 2D-Var algorithm has been updated to suppress noise over areas where signal to noise ratios are relatively small, and the background covariances have been updated correspondingly. These updates have been completed before the previous GHRSST meeting (Tokyo, 2012).

3. Planned Activities (including GDS2.0 conversion)

For *MODIS* L2P, reprocessing using the new algorithm continues. GDAC (PO.DAAC) plans to transition to the GDS2.0 format in late autumn.

For *MUR* L4, upgrade to Version 4 continues retrospectively back to beginning of coverage (June 1, 2002). Completion of the upgrade is expected by the end of the year (2013). Transition to GDS2.0 will start by August 2013, and, thereafter, retrospective GDS2.0 format conversion will take place in conjunction with Version 4 upgrade.

For *G1SST* L4, no plan for production or GDS2.0 transition is announced.

4. Concluding Remarks (with issues raised for GHRSST)

Issue in the delivery of large products is raised. All three products reported here are large-volume products due to their ultra-high resolutions. In particular, the MODIS L2P product consists of approximately 300 granule files totaling 7.5 gigabytes each day (for each sensor) even after bzip2 compression has been applied. The MUR and G1SST L4 products are sized 200 to 300 megabytes each for each day also after compression. Communication cost of downloading these files is significant and sometimes prohibitive for users who require SST time-series and who lack access to internet with high enough bandwidth. However, since users of ultra-high-resolution products tend to be interested in regional SST, server-side subsetting is effective for most of these users. Indeed, the OPeNDAP protocol has demonstrated usefulness and popularity in delivery of the L4 products (MUR and G1) primarily for scientific users interested in regional oceanography. For L2P products, development of a new delivery tool is needed since geo-locations (e.g., longitudes and latitudes) are not apparent from the data grids upon which OPeNDAP bases its subsetting procedure.

MULTI-SENSOR IMPROVED SEA SURFACE TEMPERATURE (MISST) FOR (IOOS) 2013 SUMMARY REPORTS

Chelle Gentemann

Remote Sensing Systems, Santa Rosa, CA, USA, Email: gentemann@remss.com

Executive Summary of Report

Sea Surface Temperature (SST) is vital to coastal and marine spatial planning, global weather prediction, climate change studies, search and rescue, and ecosystem based management. SST is derived from measurements taken by numerous satellites carrying infrared and microwave radiometers, and measured from moored buoys, drifting buoys, and ships. This project focuses on completing research to improve the quality of the satellite SSTs from existing and new sensors, produce multi-sensor blended gap-free SSTs from US and international datasets, and successfully broaden the use of these products within specifically targeted coastal applications and the Integrated Ocean Observing System (IOOS).

The objectives of this project are to (1) improve and continue generation of satellite SST data and SST analyses in the IOOS DMAC and CF compliant Group for High Resolution Sea Surface Temperature (GHRSST) Data Specification GDS format; (2) distribute and archive these data; and (3) use this improved SST data in applications, many specifically targeted for the IOOS.

In the full proposal, each task has been assigned to one or more partners. This partnership consists of 28 scientists from industry, academia, and government with wide ranging experience spanning the initial calibration of satellite sensors, development of SST algorithms, assessment of SST uncertainties, production of NRT satellite data, research into data fusion methodologies and the production of blended data sets, research into diurnal warming and the cool skin effect which both affect satellite SST measurements, and applications that utilize SSTs.

The reports attached are from each partner and detail their progress in 2013. Key progress has been made in the following:

- Held webinar with representatives from the IOOS Regional Associations.
- Established accessibility via the Southwest Fisheries Science Center's ERDDAP server.
- Operational L2P SST production for GOES-13, GOES-15, MTSAT, and MSG.
- Advanced Clear-Sky Processor for Oceans (ACSPO) retrievals are made from AVHRRs onboard
- NOAA-18,-19 and Metop-A and –B, VIIRS, Terra and Aqua MODIS, and NOAA-16 (2008-on).
- NAVOCEANO is providing operational L2P GDS 2.0 VIIRS SST, preparing to transition to GDS 2.0 for N-18, N-19, METOP-A GAC, and N-19 LAC, and ready to ingest GDS 2.0 L2P data.
- All East/West US coast AVHRR HRPT data in CLASS for 1981-March 2013 acquired, processed to
- SST with U.Miami's Pathfinder SST algorithm and passed through the URI fronts/gradients workflow.

- NCDC has continued production of the 1/4° Optimally Interpolated Sea Surface Temperature
- (DOISST) analysis and is making preparations to incorporate VIIRS SSTs operationally.
- Implementation and operational production of version 4.0 of the Multi-scale Ultra-high Resolution
- (MUR) Sea Surface Temperature Data Set.
- All MISST data are operationally archived and made available through IOOS DMAC-compliant services by NODC, which has also enabled LAS access to gridded MISST data.
- A methodology was developed using the SI-traceable (A)ATSR instrument series as a reference to determine critical AVHRR calibration parameters in-orbit and a semi-deterministic methodology for assessing retrieval uncertainty on a pixel-basis.
- An evaluation of current lake temperature algorithms has been completed and will be presented at GHRSST 2013 in June 2013.
- GCOM-W AMSR2 initial calibration has been completed and geophysical retrievals produced. A triple-collocation validation study is being used to determine error statistics for AMSR-E and AMSR2.
- The first year of VIIRS SSTs has been produced and errors assessed through comparisons with drifting buoys and ship-based radiometers show that the VIIRS SSTs are of high quality.
- The capability for direct assimilation of satellite sea surface temperature (SST) radiances has been implemented in the three-dimensional variational Navy Coupled Ocean Data Assimilation system (NCODA 3DVAR).
- An adjoint-based procedure to determine the impact of assimilation of observations on reducing ocean model forecast error has been integrated into the Navy's global HYCOM ocean analysis/forecast system.
- Development and evaluation of diurnal warming models and corresponding uncertainty estimates, as well as the derivation of diurnal warming climatologies and characteristics from different sensors.
- A heat budget model for ocean warming over coral reefs of the Florida reef tract has been developed using MISST, reanalysis, and a Coastal Relief Model for reef bathymetry; the model matches annual cycles and extremes of in situ reef temperature at a variety of long-term coral reef monitoring sites.
- Case studies in the Gulf of Mexico and Mediterranean Sea were used to examine the impact of diurnal variations on assimilative SST analyses and forecasts.

MEDSPIRATION AND SST ACTIVITIES AT IFREMER

Jean-François Piollé[(1)], Nicolas Reul[(2)], Olivier Arino[(3)], Emmanuelle Autret[(4)]

(1) CERSAT / Institut Français de Recherche pour l'Exploitation de la Mer (France),
Email: jfpiolle@ifremer.fr
(2) CERSAT / Institut Français de Recherche pour l'Exploitation de la Mer (France),
Email: nicolas.reul@ifremer.fr
(3) European Space Agency, Email: olivier.arino@esa.int
(4) CERSAT / Institut Français de Recherche pour l'Exploitation de la Mer (France),
Email: eautret@ifremer.fr

ABSTRACT

A large effort and infrastructure at Ifremer/CERSAT are now dedicated to offering a full European GDAC service, in particular in support to projects such as Medspiration, MyOcean or OSI SAF. It enables providing resources for SST users and producers such as satellite to in situ match-up databases, data search and extraction (Naiad dataminer), data quality assessment tools (Felyx), interactive long-term data analysis, remote processing capabilities through cloud computing technology. In addition, Medspiration project has been extended for two more years by ESA in order to provide new products and longer-time series, and reach out a wider community through use cases demonstrating the use of data synergy over Mediterranean Sea.

1. Medspiration

The **Medspiration** Project is a European initiative, funded by ESA (in the frame of DUE program), to combine sea surface temperature (SST) data measured independently by several different satellite systems into a set of data products that represent the best measure of SST, presented in a form that can be assimilated into ocean forecasting models or used for various kinds of application. It has pioneered the implementation of operational services for SST following GHRSST project recommendation and standards.

Medspiration has been extended for two more years to sustain its current line of high resolution regional SST maps, but also develop new products, outreach services and demonstrations :

- a global 2km high resolution analysis based on the Odyssea processing chain used for regional analyses
- 3D animations demonstrating geophysical phenomena for general public audience, based on Medspiration products and the combination with other parameters
- an interactive tool for data analysis and mining, based on Hadoop technology
- scientific applications using Medspiration products and demonstrating the synergy of sensors over the Mediterranean sea
    - Local and regional indexes of the Mediterranean Sea warming
    - Interactions between sea surface temperature and strong atmospheric events (High Evaporation and Precipitation Events and cyclogeneses)

Information and data access are available on Medspiration pages http://www.medspiration.org.

2. GHRSST Satellite/In situ Match-up Database

The GHRSST in situ to satellite match-up database for sea surface temperature was developed in the context of Medspiration project. It is a unique tool to assess the quality of the satellite SST observations and estimate the respective sensor specific errors. The CERSAT continues to produce and to host for GHRSST community the available satellite to in situ match-ups. The match-ups are either processed at CERSAT or directly provided by another institution. They are ingested into a common database, and the content of this database is daily exported to NetCDF4 format and available through ftp (ftp://ftp.ifremer.fr/ifremer/cersat/projects/myocean/sst-tac/matchups/).

The GHRSST MDB is now being completely redesigned and will cover all the L2P products ingested by the European GDAC, using the iSQUAM buoy, ship and argo float database. It will also be extented later, in the context of ESA/felyx project, to provide multi-sensor match-up capability as well.

We will also host match-ups provided by OSI SAF for AVHRR/METOP-A, SEVIRI and GOES-13.

3. European Long-Term SST Archive

Initially for the needs of MyOcean project and the production of regional and global SST analyses, Ifremer maintains a online mirror of the a large selection of GHRSST data collections. It also converts to GHRSST format older data collections of O&SI SAF products. To optimize both storage and download performances, all files have been converted to NetCDF4, using its internal compression ability.

This archive is openly accessible at http://cersat.ifremer.fr/data/collections/ghrsst

The demonstration platform used to set-up this archive is based on a combination of Big Data and cloud computing technologies to offer to users co-located data collection and processing capabilities at the same facility. The deluge of SST historical and newly acquired data, together with the limited internet bandwidth or end-user's local storage capacity hamper large-scale analysis and revisiting of swath full resolution data. It is our ambition to demonstrate that today's technologies are changing the shape of long-term data centers and the way scientists make use of the data. The CERSAT archives now permits – on mutual agreements - users to also locally process the data through a custom virtual machine.

4. User-friendly access

We are continuing our efforts to provide advanced tools for the search, discovery, graphical display and data extraction of GHRSST products.

In particular, the Naiad datamining tool (http://www.naiad.fr) is being operated to provide data search & selection and visualization for GHRSST L2P swath products, either through a user interface or by direct scripting.

Another new application, Calypso (http://www.ifremer.fr/calypso) provides display and graphical feature extraction (time series, sections, hovmoller,...) for a set of GHRSST L3 and L4 products (geostationary products, supercollated and analyses produced for MyOcean). This new application is now being interfaced with Naiad tool to provide integrated access to any GHRSST product level.

EUMETSAT REPORT

Anne O'Carroll

EUMETSAT, Eumetsat-Allee 1, 64295 Darmstadt (Germany), Email: Anne.Ocarroll@eumetsat.int

ABSTRACT

The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) delivers operational weather and climate-related satellite data, images and products throughout all day and year. EUMETSAT also has commitments to operational oceanography and atmospheric composition monitoring. Activities over the next twenty years include the continuation of the Mandatory Programmes (MSG, EPS) and future (MTG, EPS-SG), which all include ocean observations of SST and sea surface winds.

EUMETSAT supervises and coordinates its Satellite Application Facility (SAF) network. The EUMETSAT Ocean and Sea-ice SAF is lead by Meteo-France with a consortium of institutes from EUMETSAT member states, and provides reliable and timely operational services related to meteorology, oceanography and the marine environment. The OSI-SAF Continuous Development and Operations Phase 2 began in March 2012.

1. Metop-B and MSG-3

Meteosat-10 was launched on 5th July 2012 giving continuation of the Meteosat Second Generation (MSG) series providing operational weather and climate monitoring services over Europe and Africa. In April 2013, Meteosat-9 took over the Rapid Scanning Service (RSS) from Meteosat-8, the first MSG satellite launched in 2002. Meteosat-9 and -10 form a two-satellite configuration, with Meteosat-10 providing full disc imagery of the European and African continents and adjacent seas every 15 minutes and Meteosat-9 delivering more frequent images every five minutes over Europe and North Africa.

Metop-B was launched on 17th September 2012, following on from the launch of Metop-A in 2006. The Metop satellites include the Advanced Very High Resolution Radiometer/3 (AVHRR) and Infrared Atmospheric Sounding Interferometer (IASI) instruments which include the capability of measuring surface temperature. Metop-B replaced Metop-A as EUMETSAT's prime operational polar-orbiting satellite following the end of its commissioning period on 24th April.

Level 2 SST products from Metop-B AVHRR will be delivered at a later date from the EUMETSAT OSI-SAF. Level 2 SST products from SEVIRI switched to Meteosat-10 from Meteosat-9 on 21st January 2013 without any noticeable impact for users.

2. IASI SST products at EUMETSAT

IASI L2Pcore SSTs have been continued to be supplied in GDS V2.0 (netcdf4) format as a demonstrational product, available via ftp from the EUMETSAT data centre. The SSTs are those contained within the operational EUMETSAT IASI L2 Product Processing Facility (PPF) product, available from EUMETSAT since April 2008. The IASI SST L2Pcore contains skin SSTs, flags, quality information and SSES plus an auxiliary wind-speed field, but no further auxiliary data. The IASI L2Pcore is a swath product available in near-real time, and the resolution of the IASI IFOV is 0.01465 radians [1].

The IASI L2 PPF underwent an operational upgrade to version 5 in September 2010. Although, there were no changes to the retrieval of SST in this version, there were changes to the cloud detection and characterisation methods in the IASI PPF. The next L2 PPF upgrade, version 6, is planned for later in 2013 to include a new cloud detection scheme and level 2 product quality flagging. Other issues to be considered soon include: improvements to address the slight angular dependency; the inclusion of band 3 (shorter wavelengths) in the retrieval at night-time; the use of OSI-SAF sea-ice edge information; and the detection of dust layers for flagging and possibly correction.

Validation over the period July 2012 to March 2013 against drifting buoys have shown the Metop-A IASI SST continue to have a cool bias of -0.25K (σ 0.32K), thought to be mainly due to the retrieval process. Early validation results for Metop-B IASI SSTs also show a similar cool bias at around -0.25K for an analysis over the period February to April 2013. Three-way collocations [2] have shown the Metop-A IASI SSTs to have an overall global accuracy of 0.24K. Recent Metop-A IASI SST validation results are shown in [3, 4].

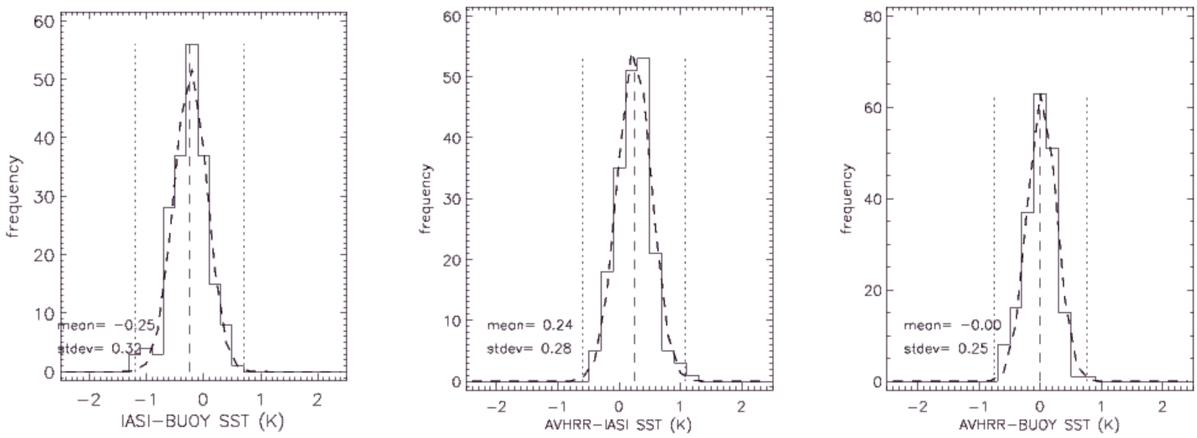


Fig 1. Histograms of IASI, AVHRR, and drifting buoy differences over the period July 2012 to March 2013.

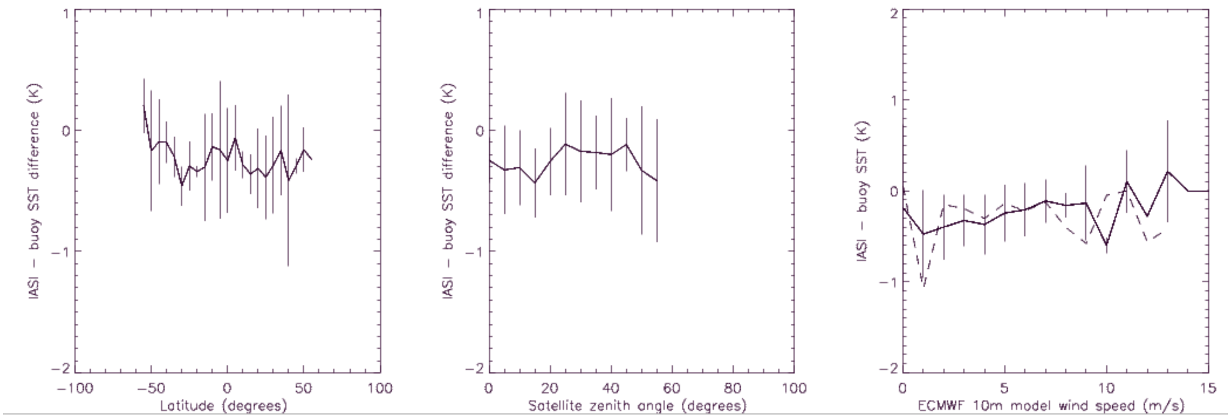


Fig 2. IASI minus drifting buoy SST differences versus latitude, satellite zenith angle and ECMWF wind speed over the period July 2012 to March 2013.

Within the Continuous Development and Operations Phase 2 of the EUMETSAT Ocean and Sea-Ice Satellite Application Facility (OSI-SAF) a full IASI L2P SST will be produced based on the IASI L2Pcore SST from EUMETSAT central facilities, with the addition of the necessary extra auxiliary data (e.g. aerosol, ice).

3. Sentinel-3 SLSTR

EUMETSAT is participating in GMES Sentinel-3 in partnership with ESA, where EUMETSAT will operate the satellite and will serve the marine user community. ESA leads the development of the Sentinel-3 space and ground components, with support from

EUMETSAT. ESA will serve the land user community. Dissemination of Level 1 and Level 2 near-real time and short-time critical products will be by EUMETCast.

Over the last twelve months work has continued on a joint ESA/EUMETSAT Cal/Val plan. Version 1 has been agreed and work is progressing towards a version 2. A joint ESA-EUMETSAT call to participate in the Sentinel-3 Validation team (S3VT) was initiated in late 2012, receiving a total of 80 submissions, with 10 on surface temperature. The team members receive no funds from ESA or EUMETSAT, and the call is rolling therefore new participants can join at any time. The first workshop is planned at ESRIN for 26 to 29 November 2013. The 'temperature' sub-group will be co-chaired by ESA and EUMETSAT.

4. Other ocean missions and third party agreements

A bilateral meeting between EUMETSAT with National Ocean Satellite Application Center (NSOAS) and State Oceanic Administration (SOA) took place at EUMETSAT from 17-21st June. Information on the GHRSST project was presented. The aim of the workshop was to present and highlight the EUMETSAT and European efforts and benefits in ocean-related activities and to assess/identify common grounds/possible areas for enhancing our cooperation with SOA/NSOAS.

The continuation of the EUMETSAT Ocean Surface Topography Mapping optional programme (Jason-3 and beyond) will contribute an uninterrupted sea level rise monitoring data set. Work towards access to relevant data from third-parties with the preparation of agreements with the Indian Space Research Organisation (ISRO) and SOA, will give EUMETSAT access to an enhanced ocean products catalogue.

5. Reprocessing activities at EUMETSAT

For geostationary reprocessing activities: work on the inter-satellite calibration of the complete Meteosat series referenced to IASI employing HIRS measurements is ongoing, with the first data expected in 2014. The EUMETSAT OSI-SAF will reprocess SEVIRI SST based on the already reprocessed SEVIRI L1.5 also using the NWC-SAF cloud mask data in full temporal resolution produced by the CM SAF. There are currently no activities planned for Meteosat First Generation.

The polar orbiting reprocessing activities include the IASI Level 1c reprocessing which is now planned for 2014/2015. Although it could be appended to the IASI L1C reprocessing, needs for reproduction of the IASI SST product were not stated and are currently not part of the EUMETSAT plan. EUMETSAT central facilities will support the ESA CCI SST project in phase 2 to use IASI to constrain drift in AVHRR, by 'predicting' stable AVHRR clear-sky BTs from IASI spectra. EUMETSAT will implement an IASI spectra extraction tool to provide match-up data for AVHRR clear sky data. The EUMETSAT CM SAF is part of a new SCOPE-CM project together with NOAA and RAL on the creation of an AVHRR L1b FCDR that will start in January 2014.

6. References

IASI Level2 Product Format Specification, EPS.MIS.SPE.980760, http://www.eumetsat.int/Home/Main/DataProducts/Resources/index.htm?l=en

O'Carroll, A.G., J.R. Eyre, and R.W. Saunders, 2008: Three-way error analysis between AATSR, AMSR-E, and in situ sea surface temperature observations, J. Atmos. Oceanic. Tech., 25, 1197-1207

O'Carroll, A.G., T. August, P. Le Borgne, A. Marsouin, The accuracy of SST retrievals from Metop-A IASI and AVHRR using the EUMETSAT OSI-SAF matchup dataset, RSE, 126 (2012), 184-194

August, T., et al, IASI on Metop-A: Operational Level-2 retrievals after five years in orbit, J. Quant Spectrosc Radiat Transfer (2012), doi:10.1016/j.jqsrt.2012.02.028

OSI-SAF SST ACTIVITIES IN 2012-2013

Pierre Le Borgne*[(1)]*, Gérard Legendre*[(1)]*, Anne Marsouin*[(1)]*, Sonia Péré*[(1)]*,
***Hervé Roquet*[(1)]*, Steinar Eastwood*[(2)]*, Jean-François Piollé*[(3)]**

(1)Météo-France/Centre de Météorologie Spatiale, Lannion, France Email*:* pierre.leborgne@meteo.fr
(2) Norwegian meteorological Institute, Oslo, Norway Email: steinar.eastwood@met.no
(3) IFREMER, Brest, France Email: Jean.Francois.Piolle@ifremer.fr

ABSTRACT

This presentation will report on the OSI SAF activities related to Sea surface temperature during the summer 2012 summer 2013 period.

As far as polar orbiters are concerned, two new operational products have been prepared:

- VIIRS SST made available twice a day over the North Atlantic Regional (NAR) area
- IASII SST which is produced at EUMETSAT central facility and converted into full L2P products at OSI-SAF/ CMS. Global full resolution granules will be delivered through IFREMER

These new products, as well as all polar orbiter derived OSI-SAF/CMS SST products are delivered in GDSV2.0 (netcdf 4) compliant format.

An upgrade of the polar orbiter SST processing chain is being prepared :

- A new cloud/sea Ice mask has been prepared at met.no
- A prototype METOP/AVHRR SST chain has been run for more than one year to use NWP model outputs in the processing, similarly to what is done at CMS geostationary satellite data processing
- METOP-A SST products have been extensively validated, especially over the Arctic, which is one of the most problematic area.

At HL OSI-SAF, a combined Ice Surface Temperature (IST) and SST product is in preparation.

Concerning geostationary SST processing, Meteosat-10 has replaced Meteosat-9 without noticeable problems. A Matchup Data Base, dedicated to Diurnal Warming (DW) studies has been prepared for summer 2012.

REPORT FROM AUSTRALIA – BLUELINK AND IMOS

Helen Beggs[(1)], Leon Majewski[(2)], Christopher Griffin[(2)], Ruslan Verein[(1)], Pavel Sakov(1), Xinmei Huang(2), Luke Garde[(2)] and Christopher Tingwell[(1)]

(1) Centre for Australian Weather and Climate Research, Bureau of Meteorology, Melbourne (Australia), Email: H.Beggs@bom.gov.au, R.Verein@bom.gov.au, P.Sakov@bom.gov.au, C.Tingwell@bom.gov.au

(2) Bureau of Meteorology, Melbourne (Australia), Email: Leon.Majewski@bom.gov.au, C.Griffin@bom.gov.au, X.Huang@bom.gov.au, L.Garde@bom.gov.au

ABSTRACT

Since June 2012 there have been a number of new and updated sea surface temperature (SST) products released by the Australian Bureau of Meteorology with support from the Bluelink Project and the Integrated Marine Observing System (IMOS). In addition to upgrades to the operational regional and global SST analyses (RAMSSA and GAMSSA) contributed to the GHRSST Global Data Assembly Centre (GDAC) and the GHRSST Multi-Product Ensemble Project, the Bureau is also producing operational real-time and reprocessed High Resolution Picture Transmission (HRPT) AVHRR SST in GDS v2.0 L2P, L3U, L3C and L3S formats which we intend to supply to the GDAC before December 2013. Other new products produced by the Bureau over the past year which may be of interest to the GHRSST community are the reprocessed MTSAT-1R skin SST L3 files for the GHRSST TWP+ Project, validation-quality, near real-time SSTdepth data from eighteen ships of opportunity and a high resolution, operational coral reef stress monitoring system, ReefTemp NextGen. This report summarises the advances made in the research and development of new SST products by Bluelink and IMOS from 1 June 2012 to 1 June 2013 and plans for the coming year.

1. Introduction

For the past ten years, the Australian Government, through the Australian Bureau of Meteorology (Bureau, *http://www.bom.gov.au*), Royal Australian Navy and CSIRO have contributed to Bluelink Ocean forecasting Australia (Brassington et al., 2007; *http://wp.csiro.au/bluelink*), a project to deliver ocean forecasts for the Australian region. Bluelink includes ocean model, analysis and assimilation systems, and provides timely information and forecasts on oceans around Australia. Phases I and II of the project have completed and Phase III will run until June 2014. Operational high resolution (0.1° horizontal resolution) ocean analyses and forecasts are available as maps from *http://www.bom.gov.au/oceanography/forecasts/* and netCDF files from *http://godae.bom.gov.au*.

One of the aims of Bluelink has been to provide the best possible SST products for ingest into and validation of research and operational Numerical Weather Prediction (NWP), ocean and atmosphere-ocean coupled models. To this end it was decided at the commencement of Bluelink I to align with many of the goals of the Group for High Resolution SST (GHRSST: *http://www.ghrsst.org*) and modify the Bureau's existing operational SST analysis and direct broadcast Advanced Very High Resolution Radiometer (AVHRR) SST processing systems to produce a range of products in GHRSST formats containing uncertainty estimates for each SST value. These satellite SST products have been produced in various GHRSST file formats ranging from geolocated SST from one satellite to gridded SST from multiple satellites (L2P, L3U, L3C, L3S and L4 – see Casey et al., 2011) at various spatial and temporal resolutions designed for a wide range of research and operational applications (Beggs, 2010; Beggs et al., 2011a; Garde et al., 2013).

Commencing in 2007, the Bluelink support for development of GHRSST products has been strongly augmented by funding from the Integrated Marine Observing System (IMOS, http://www.imos.org.au), a nation-wide collaborative program designed to observe the oceans around Australia, with guaranteed funding until September 2014, likely to be extended until June 2015.

The main Bluelink and IMOS contribution to GHRSST is through an Australian Regional Data Assembly Centre (RDAC) system based at the Bureau of Meteorology, delivering the following types of GHRSST data products:

- MTSAT-1R hourly, 1/20° resolution, SST L3U (gridded, single scene) files using different algorithms for day and night and reprocessed for the GHRSST TWP+ Project using the same algorithm for day and night (Section 3)
- Locally received High Resolution Picture Transmission (HRPT) Advanced Very High Resolution Radiometer (AVHRR) SST L2P (geolocated, single swath), L3U (gridded, single swath), L3C (gridded, single sensor) and L3S (gridded, multiple sensor) files using different algorithms for day and night and a recently improved method for deriving sensor specific error statistics (Section 4)
- L4 (gridded, gap-free) files from "RAMSSA", the operational, daily, 1/12° resolution, SST analysis over the region 20°N to 70°S, 60°E to 170°W (Section 5), and the operational, global, daily, 1/4° resolution SST analysis system ("GAMSSA") (Section 6).

Other SST-related contributions include:

- Quality assured *in situ* SST available via the GTS and IMOS Ocean Portal in near real-time from vessels of the Australian Volunteer Observing Fleet (AVOF) fitted with Automatic Weather Stations and other ships of opportunity and research vessels in the Australian region (Section 2)
- Quality assured meteorological, SSTdepth and calculated air-sea flux data available via the IMOS Ocean Portal (http://imos.aodn.org.au/webportal) from three research vessels in the Australian region (http://imos.org.au/airseaflux.html)
- Quality assured *in situ* meteorological, SSTdepth and calculated air-sea flux data available via the IMOS ocean portal in near real-time from a Southern Ocean mooring (http://imos.org.au/asfs.html)
- Provision of in situ and satellite SST and NWP and wave model forecasts for the GHRSST Tropical Warm Pool Diurnal Variability (TWP+) Project (https://www.ghrsst.org/ghrsst-science/science-team-groups/dv-wg/twp/; Section 7)
- Research into the frequency and amplitude of diurnal warming events over the Tropical Warm Pool using TWP+ data from multiple satellites (Section 7)
- Testing the impact of assimilating WindSat GHRSST-format L2P-gridded SSTsubskin data into the Bureau's Operational ocean model, OceanMAPS 2.1 (Huang, 2012) - decreased standard deviation of OceanMAPS analysis SST2.5m with respect to buoy SSTfnd by 0.1 to 0.2°C over region 90°E – 180°E, 70°S – 15°N
- Developing an operational coral reef stress monitoring system for the Great Barrier Reef, "ReefTemp NextGen", based on the GHRSST-format IMOS HRPT AVHRR L3S products (Garde et al., 2013)

- Ten years of global, daily, 1/10º resolution, Bluelink Ensemble-based SST (BESST) re-analyses (Beggs et al., 2012b)
- Regional hourly and Global 3-hourly skin SST analyses in a GHRSST L4-like format ("RAMSSA_skin" and "GAMSSA_skin": Beggs et al. 2009 and Beggs et al., 2011b) – available from http://godae.bom.gov.au
- Evaluating the use of hourly RAMSSA_skin SSTs in the data assimilation cycle of the Bureau of Meteorology's regional ACCESS NWP system (Puri et al., 2010). (It is hoped that the use of realistic diurnally varying SSTs will have a positive impact on the quality control of satellite radiance observations, and therefore on forecast skill.)

2. SST from Ships of Opportunity

Typically, SST observations from engine intake sensors on volunteer observing ships (VOS) in the Australian region are significantly noisier than those obtained from drifting buoys. Until recently, the more accurate SST observations from Australian research vessels have been difficult to access in a timely manner in consistent formats. Therefore, prior to 2010, ship SST observations in the Australian region have not been used for near real-time validation of satellite SST observations. From 2008, the IMOS Project has enabled accurate, quality controlled, SST data to be supplied in near real-time (within 24 hours) to the Global Telecommunications System (GTS) from VOS, passenger ferries and research vessels in the Australian region.

As part of IMOS, the Bureau of Meteorology (Bureau) has instrumented eight Australian commercial vessels with hull temperature sensors (Sea Bird SBE 48), supplying high-quality bulk SST observations every hour. In addition, the Bureau has provided near real-time access to one minute averaged SST and salinity data streams from seven research vessels (RV Southern Surveyor, RSV Aurora Australis, RV L'Astrolabe, RV Solander, RV Cape Ferguson, RV Tangaroa and RV Linnaeus), two tourist ferries (PV SeaFlyte and PV Fantasea One) and one commercial vessel (MV Pacific Celebes). In total, eighteen vessels have contributed near real-time data to IMOS and the GTS (Table 1 and Figure 1). Due to sales of vessels over the years, currently only 12 of these vessels provide data to IMOS and the GTS.

Table 1. *Details of IMOS Ship SST Data Available Via the GTS and IMOS Ocean Portal*

Vessel	Callsign	Data Start	SST Sensor
RV Southern Surveyor	VLHJ	4 Feb 2008	SBE 3
RV L'Astrolabe	FHZI	30 Dec 2008	SBE 38
RSV Aurora Australis	VNAA	12 Oct 2008	SBE 38
PV SeaFlyte (Rottnest Is Ferry)	VHW5167	30 Apr 2008	SBE 38
PV Fantasea One (Whitsunday Ferry)	VJQ7467	5 Nov 2008	AD590
PV Spirit of Tasmania (Bass Strait Ferry)	VNSZ	10 Dec 2008	SBE 48
MV Portland	VNAH	20 Jun 2009	SBE 48
MV Stadacona	C6FS9	10 Aug 2009	SBE 48
MV Highland Chief	VROB	30 Sep 2009	SBE 48

Vessel	Callsign	Data Start	SST Sensor
MV Iron Yandi	VNVR	10 Feb 2010	SBE 48
PV Pacific Sun	9HA2479	12 Dec 2010	SBE 48
RV Solander	VMQ9273	24 Feb 2010	SBE 38
RV Cape Ferguson	VNCF	5 Dec 2010	SBE 38
RV Tangaroa	ZMFR	27 Apr 2011	SBE 38
MV Pacific Celebes	VRZN9	11 May 2008	Aanderaa 4050
RV Linnaeus	VHW6500	21 Dec 2011	SBE 38
MV Xutra Bhum	HSB3402	3 Jul 2012	SBE 48
MV Wana Bhum	HSB3403	5 Aug 2012	SBE 48

All SST data are quality assured (Beggs et al., 2012a) and placed in real-time on the Global Telecommunications System (GTS) as either SHIP or TRACKOB reports. The quality controlled (QC'd) SST data are also available in netCDF format with QC flags and metadata via the IMOS ocean data portal (*http://imos.aodn.org.au/webportal*) or directly from *http://thredds.aodn.org.au/thredds/catalog/IMOS/SOOP/SOOP-SST/catalog.html* , *http://thredds.aodn.org.au/thredds/catalog/IMOS/SOOP/SOOP-ASF/catalog.html* or *http://thredds.aodn.org.au/thredds/catalog/IMOS/SOOP/SOOP-TRV/catalog.html*.

Comparisons between AATSR, AVHRR, buoy and IMOS ship SST observations indicate that at least twelve of the IMOS ship data streams, including all those from hull temperature sensors, have comparable errors to those obtained from drifting buoys (Beggs et al. 2012a). In waters with little or no coverage by buoys, satellite SST validation and bias-correction should be improved by using IMOS ship SST observations in addition to available drifting buoy SST data.

The IMOS ship SST data have been used in real-time SST analysis systems (including RAMSSA and GAMSSA) and for validation of satellite SST, SST analyses and ocean models (Beggs et al., 2012a).

There are plans to provide quality assured SSTskin data to IMOS from an autonomous "ISAR" SST radiometer to be installed in early 2014 on Australia's new research vessel, RV Investigator.

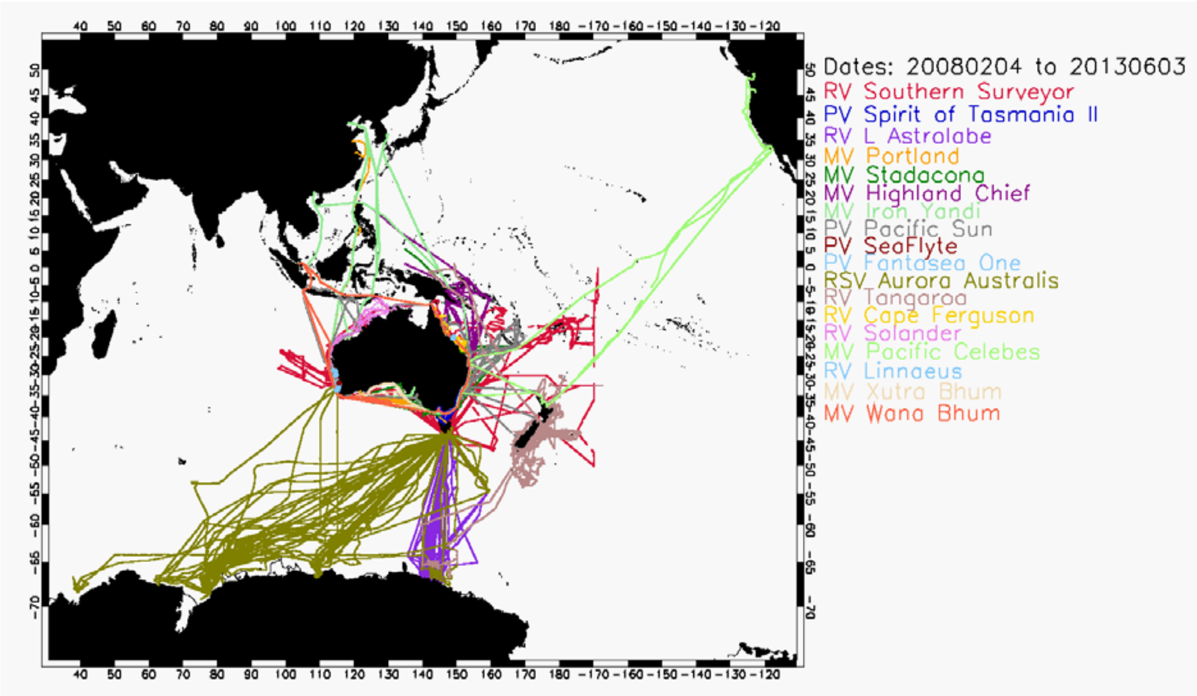


Figure 1. *Locations of all IMOS QC'd ship SST observations to 3 June 2013 from 18 vessels.*

3. Geostationary MTSAT-1R skin SST

The MTSAT-1R satellite is in geostationary orbit above 140°E and carries the Japanese Advanced Meteorological Imager (JAMI) on board. JAMI captured full-disc imagery on an hourly basis during the period 2005-2010 in five spectral channels (0.6-12.0 µm). The observations from spectral channels centred at 3.7, 10.8 and 12.0 µm were used to calculate SST. Since mid-2007, the Bureau has routinely generated SSTskin products from the MTSAT-1R, using the NOAA-developed Geostationary Satellite Derived Sea Surface Temperature Processing System (Maturi et al., 2008). The software has been modified at the Bureau to accept locally generated NWP fields, University of Edinburgh/NOAA Baysean cloud clearing and use regression against drifting buoy SST rather than physical retrieval to convert from brightness temperatures to SST (version 4).

The v4 MTSAT-1R SSTskin 0.05° x 0.05° gridded, single scene L3U files (Figure 2) back to June 2006 are available via *ftp://aodaac2-cbr.act.csiro.au/imos/GHRSST/L3U/ABOM-L3U_GHRSST-SSTskin-MTSAT_1R/*.

Initial comparison to the network of drifting buoys indicated that the difference between MTSAT-1R and buoy SST observations varied spatially and temporally, with biases on the order of ±0.2 K and standard deviations on the order of 0.8-1.2 K. Additionally, the use of different algorithms for day (2-channel) and night (3-channel) scenes introduced hour-to-hour differences in the bias of > 0.2 K. This order of uncertainty reduces the utility of the data for temporal studies of diurnal variability.

(a)

(b)

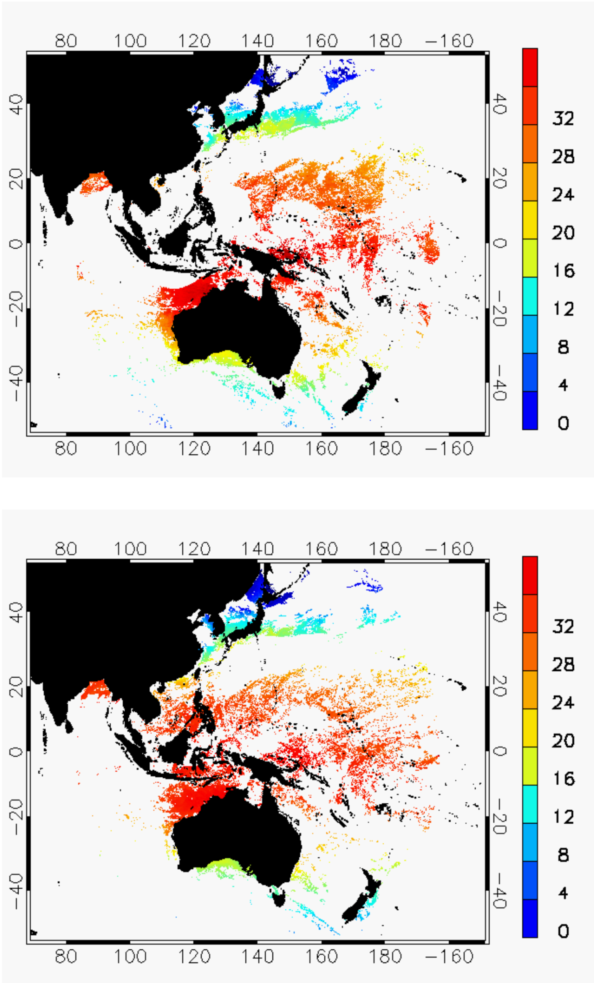


Figure 2. *An example of the output from the v4 MTSAT-1R processing system of L3U SSTskin for (a) 0530 UT (day) and (b) 1630 UT (night) on 10 April 2009. SST is plotted for cloud-free pixels (quality level = 3 to 5).*

In order to reduce the temporal and spatial biases in the MTSAT-1R SST data, the following correction factors were developed from a number of geometric and temporal properties, including pixel/line position, observation hour, solar declination and Earth-Sun distance.

$$Corrected\ \ SSTskin = SSTskin + GFAC + DFAC + TFAC \tag{1}$$

Where *DFAC* is the SST correction caused by the solar declination/earth sun distance, *TFAC* is a correction for the time of day and *GFAC* is a correction associated with the scan pattern and these various SST components are parameterised thus:

$$SSTskin = p_0 T_4 + p_1(T_4 - T_5) + p_2(T_4 - T_5)\sec\theta \tag{2}$$

$$GFAC = p_3(XIDX - p_4)^2 + p_5 YIDX^2 \tag{3}$$

$$DFAC = p_6 DECL + p_7(ESDIST - 1) \tag{4}$$

$$TFAC = p_8 \sin(\pi OBSHOUR/12) + p_9 \sin(2\pi OBSHOUR/12) \tag{5}$$

Where

T_4 = Brightness temperature of Channel 4 (11 micron channel)

T_5 = Brightness temperature of Channel 5 (12 micron channel)

θ = satellite zenith angle,

XIDX = pixel number in longitude direction

YIDX = pixel number in latitude direction

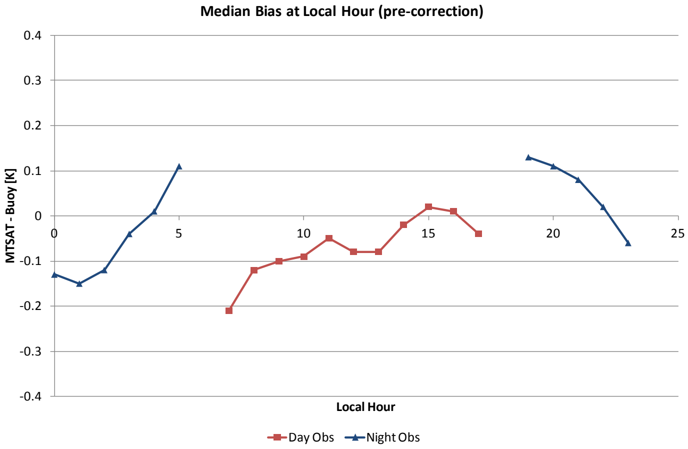
DECL = solar declination

ESDIST = distance between Earth and Sun

OBSHOUR = Integer hour of observation in UTC

The application of these correction factors reduced the spatial and temporal differences between buoy and MTSAT-1R SST observations (Figure 3). The resulting bias is < 0.1 K with a standard deviation of ~0.7 K and hour-to-hour differences < 0.1 K.

(a)



(b)

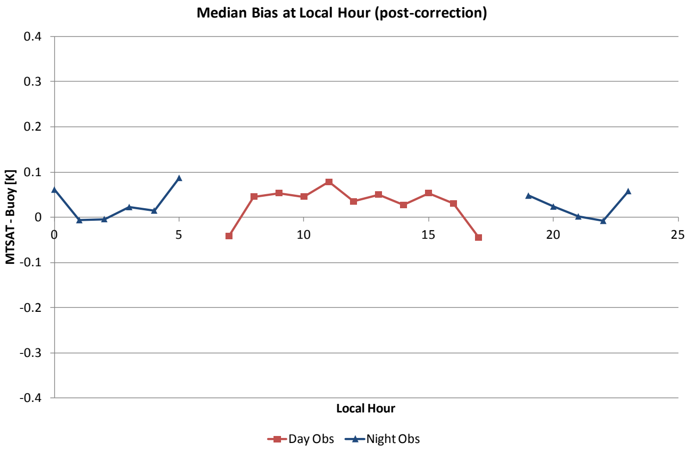


Figure 3. *MTSAT-1R SSTskin – buoy SSTskin versus local sidereal time in hours for the entire study period and MTSAT-1R domain (a) without correction and (b) with the correction described in equation 1. Note: The buoy SSTdepth measurements were converted to SSTskin by subtracting 0.17ºC.*

The corrected version 5 MTSAT-1R SSTskin values were converted to the GHRSST Tropical Warm Pool Diurnal Variability (TWP+) Project L3 format for the period 1 January to 30 April 2010 and released for testing by the TWP+ Project Team in January 2013. Preliminary results of their use to quantify diurnal warming in the Tropical Warm Pool region are described in Section 7.

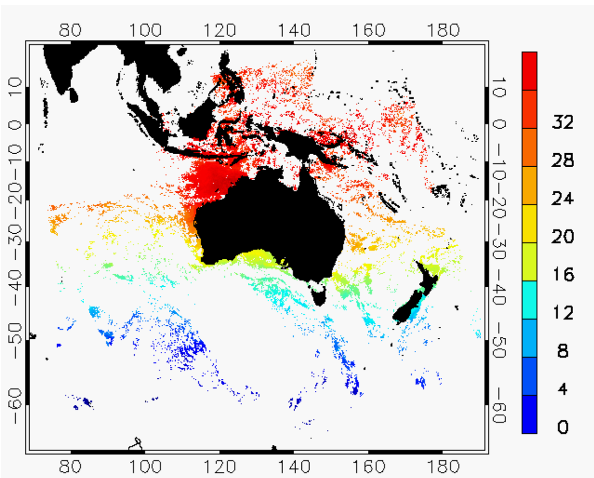
4. Locally Received AVHRR SST

The highest resolution (1.1 km) data from Advanced Very High Resolution Radiometer (AVHRR) sensors on the NOAA series of polar-orbiting meteorological satellites can only be obtained through receiving direct broadcast High Resolution Picture Transmission (HRPT) data from the satellite as these data are not stored onboard. In Australia HRPT data is received by a consortium of agencies (Bureau of Meteorology, WASTAC, AIMS and CSIRO) at ground-stations located in Darwin, Townsville, Melbourne, Hobart, Perth and Alice Springs and in Antarctica at Casey and Davis Stations. As part of the IMOS Project the Bureau of Meteorology, in collaboration with CSIRO Marine and Atmospheric Research, produces real-time, HRPT AVHRR SSTskin data (Paltoglou et al., 2010) from operational NOAA polar-orbiting satellites in the GHRSST GDS v2.0 L2P, L3U, L3C and L3S formats (Casey et al., 2011).

During the past 12 months, the Bureau has tested revised SST regression algorithms based on modified Non-Linear SST (NLSST – Walton et al., 1998) algorithms. The dataset has a number of features and processing methodologies which target a range of user expertise, and attempt to provide a consistent, accurate record. These features include a dynamic retuning of SST regression algorithms, dynamic estimates of sensor specific error statistics (SSES - based on matchups with SST from drifting buoys), multi-swath, multi-instrument composites over time periods from single day to monthly, and a consistent evaluation of day/night SST (Griffin et al., 2013).

The SSESs (bias and standard deviation of the median SST compared with drifting buoys) are a function of the estimated proximity to cloud in kilometers, latitude, longitude, satellite zenith angle and whether day or night, with daytime defined as sun zenith angle < 90º. Recently, the method used to calculate the SSES statistics for gridding and merging multiple SSTs from the same sensor as well as SSTs from multiple sensors has been modified to better reflect the matchup accuracy of the data sources (Griffin et al, 2013).

(a)



(b)

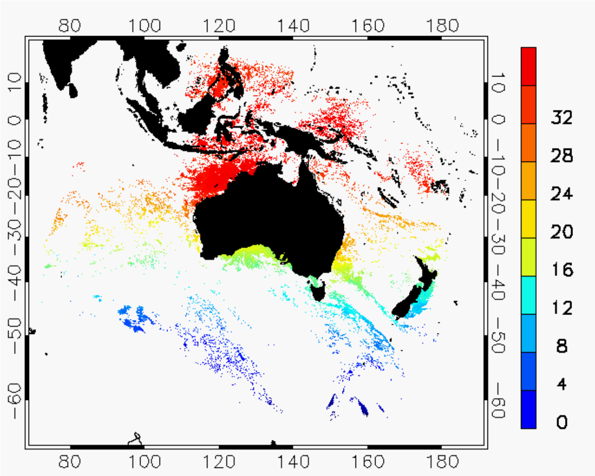


Figure 4. *Example of 1-day (a) day (~1330 LT) and (b) night (~0130 LT) 0.02° x 0.02° L3C SSTskin from NOAA-18 HRPT AVHRR SST data for 10 April 2009. SST is plotted for cloud-free pixels (quality level ≥ 3).*

Each L2P file is gridded to a cylindrical equidistant projection (0.02° latitude x 0.02° longitude) over the region 70ºE to 190ºE, 70ºS to 20ºN to form a GDS v2.0 format L3U file (Casey et al., 2011). These L3U files are in turn combined to form single sensor day/night L3C and Multiple sensor (one, three, six, fourteen and monthly) day/night and day+night L3S composite 0.02° x 0.02° resolution HRPT AVHRR SSTskin files in GHRSST GDS v2.0 formats (Casey et al., 2011) over the region 70ºE to 190ºE, 70ºS to 20ºN (eg. Figure 4). Each gridded cell contains the average of all the highest available quality SSTs that overlap with this cell, weighted by area of overlap. Only quality level ≥ 2 SSTs are included in the L3U, L3C or L3S products.

Using the Paltoglou et al (2010) methodology, HRPT AVHRR SSTskin GDS v2.0 L2P and L3U files from NOAA-15, 16, 17, 18 and 19 (back to 1998) are currently available from the IMOS FTP server (ftp://aodaac2-cbr.act.csiro.au/imos/GHRSST/) with L3C available back to 2009 and L3S files (from NOAA-15, 17, 18 and 19) available back to 2002. Using the new SST algorithms and SSES method described in Griffin et al. (2013), the archived raw HRPT AVHRR data from all operational NOAA polar-orbiting satellites over the Australian and Antarctic regions back to 1992 will be progressively reprocessed into day/night SSTskin L2P, L3U, L3C and L3S files, and day+night SSTfnd L3S files, by June 2014.

The IMOS AVHRR L2P products are being ingested into several SST analysis systems (Bureau's RAMSSA, GAMSSA, JPL OurOcean's G1SST and Medspiration's ODYSSEA Great Barrier Reef analysis). The L3U and L3S products are used for real-time mapping of meso-scale ocean currents in the Australian region (http://oceancurrent.imos.org.au/). The L3C products are being used in the GHRSST TWP+ project (https://www.ghrsst.org/ghrsst-science/science-team-groups/dv-wg/twp/). The L3S products are used within the Bureau for the ReefTemp NextGen coral bleaching nowcast system (Garde et al. 2013).

Future work for the period to June 2014 will include:

- Routinely validating HRPT AVHRR SST against drifting buoys and IMOS in situ SST data (eg. ships, Argo, seals)
- Providing real-time HRPT AVHRR SSTskin L3U files from Casey Antarctic station
- Providing reprocessed (back to 1992) HRPT AVHRR SSTskin L2P, L3U, L3C and L3S files incorporating Australian and Antarctic data via IMOS and the GHRSST

GDAC – already providing real-time files from Australian ground stations via IMOS and Bureau OPeNDAP servers

5. RAMSSA – Regional Australian Multi-Sensor SST Analysis

A real-time, high-resolution, Regional Australian Multi-Sensor Sea surface temperature Analysis (RAMSSA) system has been developed at the Australian Bureau of Meteorology as part of the Bluelink Ocean Forecasting Australia project, and has been operational since 13 June 2007. The pre-existing operational, 1/4° resolution, regional SST analysis system (*Smith et al., 1999*) was modified to produce 1/12° resolution, daily SST analyses over the Australian region (20°N - 70°S, 60°E - 170°W) (Figure 5).

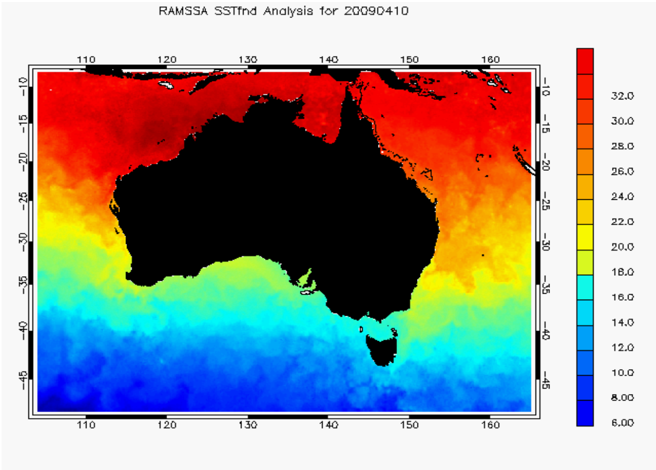


Figure 5. *An example of the RAMSSA v1.3 daily regional 1/12° resolution SST analysis for 10 April 2009.*

Over the years, the RAMSSA system has combined SST data from infrared (AVHRR and AATSR) and microwave (AMSR-E/WindSat) sensors on polar-orbiting satellites with in situ (ship, buoy, Argo and XBT) measurements to produce daily foundation SST estimates (SSTfnd), largely free of nocturnal cooling and diurnal warming effects (Beggs et al., 2011c). REMSS AMSR-E L2P stopped being ingested on 10 October 2011 and ESA AATSR L2 SST on 12 April 2012. On 11 December 2012, REMSS WindSat L2P-gridded SSTsubskin data started to be ingested into the operational RAMSSA analyses. The various data streams that have been used to form each daily RAMSSA analysis are listed in each L4 file header. By ~0400 UT each day, the operational analyses of the previous day's observations can be downloaded as GDS v1.7 netCDF3 L4 files from the GHRSST GDAC (via *ftp://podaac-ftp.jpl.nasa.gov/allData/ghrsst/data/L4/AUS/ABOM/RAMSSA_09km/*) or viewed as maps of SST and SST anomalies from *http://www.bom.gov.au/marine/sst.shtml*. Archived RAMSSA L4 files back to 12 June 2006 are available from *http://godae.bom.gov.au/* and back to 1 April 2008 from the GHRSST Long-Term Stewardship Facility at NODC (*ftp://ftp.nodc.noaa.gov/pub/data.nodc/ghrsst/L4/AUS/ABOM/RAMSSA_09km/*).

The RAMSSA analyses are used in real-time as the boundary condition for the Bureau's regional numerical weather prediction models (ACCESS-R, ACCESS-A and ACCESS-C) and to validate the Bluelink operational ocean model (OceanMAPS2) SST(2.5m) forecasts/analyses (Huang 2012). They are used experimentally in regional skin SST analyses (Beggs et al., 2009b) and the GHRSST TWP+ experiment.

Future work on RAMSSA in 2013/2014 will include updating the file format to GDS2 netCDF4 L4 (Casey et al., 2011) and investigating the ingestion of new GHRSST L2P and L3U files from AMSR-2 (on GCOM-W1), VIIRS (on S-NPP), AVHRR (on METOP-B) and possibly Himawari-8.

6. GAMSSA – Global Australian Multi-Sensor SST Analysis

A real-time Global Australian Multi-Sensor Sea surface temperature Analysis (GAMSSA) system was developed at the Australian Bureau of Meteorology as part of the Bluelink project, and has been operational since 2 October 2008. The operational, RAMSSA 1/12° resolution, regional SST analysis system (*Beggs, 2007*; Beggs et al., 2011c) was modified to produce 1/4° resolution, daily global foundation SST analyses (Beggs, 2008; Zhong and Beggs, 2008) (Figure 6).

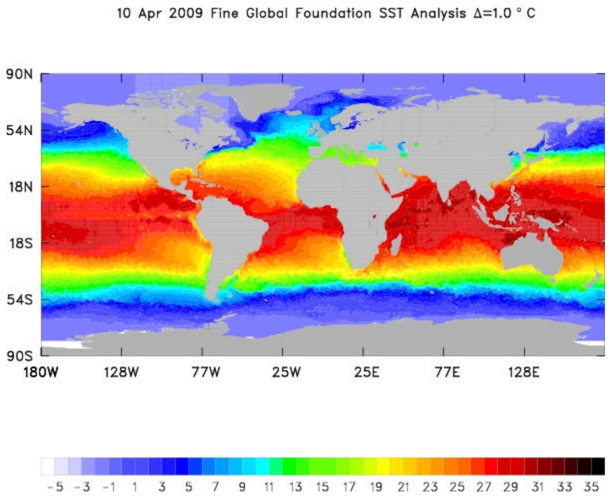


Figure 6. *An example of the GAMSSA v1.1 daily global 1/4° resolution SSTfnd analysis for 10 April 2009.*

The operational GAMSSA analysis system currently uses the following data streams

i. REMSS WindSat L2P-gridded SSTsubskin (since 11 Dec 2012)
ii. IMOS HRPT AVHRR L2P SSTskin from NOAA-18 and NOAA-19
iii. NAVOCEANO GAC AVHRR SSTblend from NOAA-18, NOAA-19 and METOP-A
iv. in situ SST from the GTS (ships and buoys)

By ~0500 UT each day, the operational analyses of the previous day's observations can be downloaded as GDS v1.7 L4 files from the GHRSST GDAC (via *ftp://podaac-ftp.jpl.nasa.gov/allData/ghrsst/data/L4/GLOB/ABOM/GAMSSA_28km/*). Archived GAMSSA L4 files back to 23 July 2008 are available from *http://godae.bom.gov.au/* and back to 24 August 2008 from the GHRSST Long-Term Stewardship Facility at NODC (*ftp://ftp.nodc.noaa.gov/pub/data.nodc/ghrsst/L4/GLOB/ABOM/GAMSSA_28km/*).

Prior to 11 December 2012, the input satellite SST data streams were corrected for global biases by subtracting the SSES_bias_error values from SSTs in the GDS v1.6 format files. However, it was unclear whether applying this bias correction was reducing errors, so since that date no bias correction has been applied to the operational GAMSSA (or RAMSSA) systems. Figure 7 shows the results of applying and not applying the bias-correction to the input data streams for the period 1 January to 30 April 2013. It would appear from this small study that applying the bias-correction reduces the bias in the NAVOCEANO GAC AVHRR

SST data streams but increases the bias in the REMSS WindSat SST data. It was reported at the 14th GHRSST Science Team Meeting that the calculation of SSES_bias_error in WindSat L2P-gridded files was modified in early June 2013. The Bureau intends to evaluate these updated SSES_bias_error values later in 2013 before applying the bias-correction to the WindSat SST values ingested into the GAMSSA and RAMSSA systems.

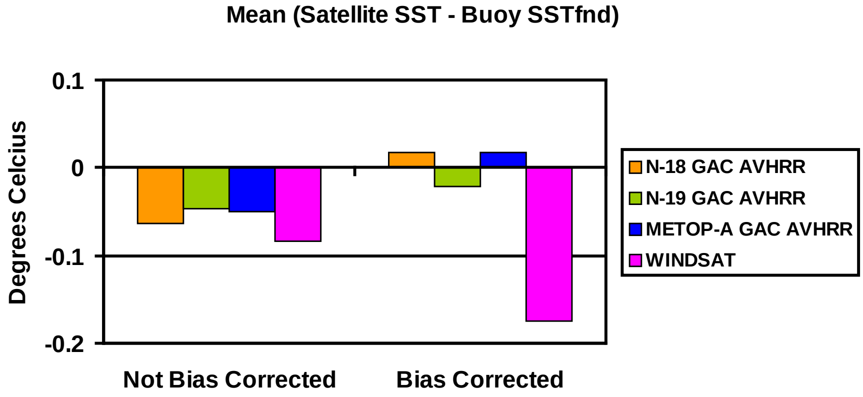


Figure 7. *Global satellite SST inputs to GAMSSA with and without applying the correction SST – SSES_bias_error for the period 1 January to 30 April 2013.*

Since 10 March 2009, GAMSSA analyses have contributed as one of 11 global SST analyses to the GHRSST Multi-Product Ensemble (GMPE: Martin et al., 2012) and Analysis Intercomparison Project (http://ghrsst-pp.metoffice.com/pages/latest_analysis/sst_monitor/daily/ens/index.html). During 2010, the GAMSSA SSTfnd analyses contributed the third highest percentage of SST values to the GMPE median SST (10.3%) compared with the Canadian Meteorological Centre (CMC) 0.2º SSTfnd analysis (12.9%) and Met Office OSTIA SSTfnd analysis (12.3%) (Martin et al., 2012). Global match-ups with independent SST observations from Argo floats indicate that during 2010 GAMSSA had a standard deviation of 0.49ºC compared with 0.46ºC from CMC and OSTIA analyses (Martin et al., 2012). Although globally GAMSSA was on average only 0.03°C colder than Argo SST during 2010, it was on average 0.13°C warmer than Argo SST over the Southern Ocean (Matthew Martin, pers. com., 2011).

Hovmöller diagrams of L4 minus L4 analyses produced by the NOAA SST Quality Monitor (L4-SQUAM: http://www.star.nesdis.noaa.gov/sod/sst/squam/L4/index.html) show that GAMSSA SSTfnd is on average between 0°C and 0.5°C warmer than the GMPE daily SSTblend analysis over the Southern Ocean (Dash et al., 2012). It has been shown that the AVHRR and AMSR-E L2P SST data streams ingested into GAMSSA are on average biased warm by between 0°C and 0.3°C south of 40°S between 60°E and 170°W (Beggs et al., 2011c).

The GAMSSA analyses are used in real-time as the boundary condition for the Bureau's operational global NWP model (ACCESS-G: Puri et al., 2010) based on the Met Office's Unified Model. They are also used to initialise the Bureau's seasonal forecast model (POAMA 2.0: http://poama.bom.gov.au).

Future work on GAMSSA in 2013/2014 will include updating the file format to GDS2 netCDF4 L4 (Casey et al., 2011) and investigating the ingestion of new GHRSST L2P and L3U files from AMSR-2 (on GCOM-W1), VIIRS (on S-NPP), AVHRR (on METOP-B) and possibly Himawari-8.

7. Using the TWP+ Data Set to quantify diurnal variation over the Tropical Warm Pool

A new comprehensive dataset, the TWP+, has been compiled by the Australian Bureau of Meteorology (BoM) in collaboration with the Group for High Resolution SST (GHRSST), Australian Integrated Marine Observing System (IMOS), Météo-France, University of Edinburgh (UoE) and Remote Sensing Systems (REMSS) for the study of diurnal variability over the Tropical Warm Pool region. The TWP+ data set comprises satellite and *in situ* SST observations and high-resolution model forecasts of ocean/atmospheric parameters at the ocean surface over the region 25°S to 15°N, 90°E to 170°E for the periods 1 January to 30 April 2009 and 1 January to 30 April 2010. The data set contains SST observations ranging in depth from 20 cm to several metres from drifting and moored buoys and ships, and the following gridded skin (~10 μm depth) or subskin (~ 1 mm depth) SST data from radiometers on polar-orbiting and geostationary satellites:

- UoE ATSR Reprocessing for Climate (ARC) AATSR on EnviSat (skin, 0.1° resolution)
- IMOS/BoM HRPT AVHRR on NOAA-17, NOAA-18 and NOAA-19 (skin, 0.02° resolution)
- EUMETSAT FRAC AVHRR on METOP-A (skin, 0.025° resolution)
- IMOS/BoM Imager on MTSAT-1R (skin, 0.05° resolution)
- REMSS AMSR-E version 7 on Aqua (subskin, 0.25° resolution)
- REMSS WindSat version 7 on Coriolis (subskin, 0.25° resolution)

Other SST products included are a gridded, daily, composite of “foundation” (pre-dawn) SST using night-time MTSAT-1R skin SST data for the hours 10 pm to 5 am LST (at native 0.05° resolution and regridded to 0.375° resolution), and a gridded, daily, gap-free analysis of satellite and *in* situ SST approximating a foundation SST (RAMSSA) (at native 1/12° resolution and regridded to 0.375° resolution). Forecast products included in TWP+ are the Bureau’s hourly, 0.375° resolution, ACCESS-R Numerical Weather Prediction forecasts of surface parameters (short-wave and long-wave flux, friction velocity, sensible and latent heat flux, wind stress, accumulated precipitation, winds, pressure, air temperature and humidity) (Puri et al., 2010), and the Bureau’s AUSWAM 12-hourly, 0.5º resolution forecast of sea state parameters (significant wave height and direction, wind speed and direction and peak wave period).

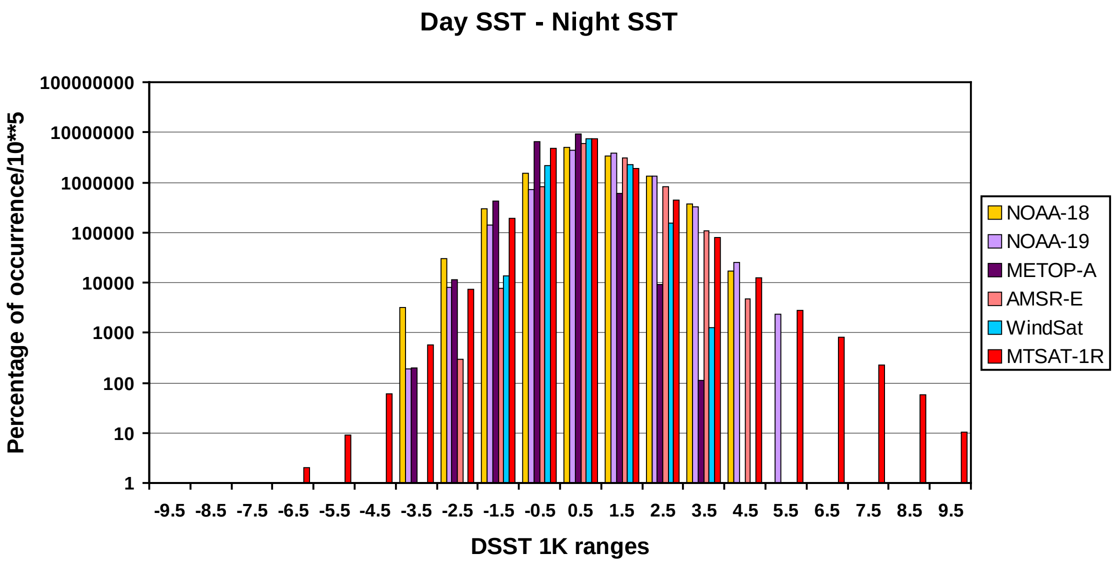


Figure 8. *Percentage occurrence/100,000 of 1°C ranges of daytime SST – night-time SST for the various TWP+ satellite data streams, for the period 1 January to 30 April 2010 over the region 25°S to 15°N, 90°E to 170°E. The data were filtered for 2 x 2 good SSTs using the proximity_confidence levels in each L2P, L3U or L3C file. A mininum proximity_confidence of 4 was used for SSTs from NOAA-18 and NOAA-19 AVHRR, 2 for AMSR-E/WindSat and 5 for MTSAT-1R.*

The TWP+ data are currently being used to quantify diurnal warming events and test diurnal variation models as part of the GHRSST Tropical Warm Pool Diurnal Variability (TWP+) Project (*https://www.ghrsst.org/ghrsst-science/science-team-groups/dv-wg/twp/*). Recent studies show that different satellite sensors measure different diurnal warming events due to differing spatial coverage and observation times. For the period 1 January to 30 April 2010 over the TWP+ domain daytime minus night-time SSTs of up to 6°C were measured using multiple satellite sensors for NWP wind speeds less then 3 m/s (Figure 8), implying that models need to be able to predict diurnal warming up to at least 6°C.

All TWP+ data are available to TWP+ project collaborators in netCDF format from the Bureau of Meteorology OPeNDAP server. Contact *h.beggs@bom.gov.au* for access.

8. Future Plans for Bluelink and IMOS SST Products (2012-2013)

8.5. SST Products

As part of the next phase of the IMOS and Bluelink-III Projects (June 2013 – June 2014), the Bureau of Meteorology aims to:

- Provide reprocessed (back to 1992) HRPT AVHRR SSTskin L2P, L3U, L3C and L3S files incorporating Australian and ***Antarctic*** data via IMOS and the GHRSST GDAC – already providing real-time files from Australian ground stations via IMOS and Bureau OPeNDAP servers
- Provide real-time HRPT AVHRR SSTskin L2P, L3U and L3C files from Casey Antarctic station
- Provide reprocessed hourly, 0.05º x 0.05º gridded, v5 MTSAT-1R SSTskin L3U files for 2006 to 2010
- Upgrade operational RAMSSA and GAMSSA to GDS2 L4 format and to incorporate new GHRSST L2P and L3U data streams as they become available

- Provide quality-assured SSTskin data from an autonomous radiometer on Australia's new research vessel, RV Investigator.

8.6. SST-related Research

Over the coming year the Bureau of Meteorology plan to:

- Evaluate hourly RAMSSA_skin SSTskin analyses for quality control of satellite sounder data being assimilated into ACCESS-R NWP analyses
- Write a paper on using the TWP+ satellite SST data set (AVHRR, AMSR-E, WindSat and MTSAT-1R) and ACCESS-R winds to quantify the frequency and extent of diurnal warming events over the TWP
- Write a paper on producing an HRPT AVHRR SST data set using a consistent 3-channel algorithm for day and night

9. Acknowledgments

The work was supported by both the Bluelink Ocean Forecasting Australia Project (a joint project between the Royal Australian Navy, CSIRO Marine and Atmospheric Research and the Australian Bureau of Meteorology) and the Integrated Marine Observing System (an initiative of the Australian Government being conducted as part of the National Collaborative Research Infrastructure Strategy and the Super Science Initiative).

10. References

10.1. Links to Web Pages, OPeNDAP and FTP Servers

Bureau of Meteorology Operational SST Analysis Web Page:
http://www.bom.gov.au/marine/sst.shtml

Bluelink Ocean Forecasting Australia Project Web Site: *http://wp.csiro.au/bluelink/*

Bluelink SST Products Research Web Page:
http://www.cawcr.gov.au/projects/SST/SST_external.html

Bureau of Meteorology GODAE OPeNDAP Server: *http://godae.bom.gov.au*

Bureau of Meteorology Seasonal Forecast Model (POAMA) Web Site:
http://poama.bom.gov.au.

Bureau of Meteorology Web Site: *http://www.bom.gov.au*

Group for High Resolution SST (GHRSST) Web Site: *http://www.ghrsst.org*

GHRSST Global Data Assembly Centre Web Page: *http://ghrsst.jpl.nasa.gov*

GHRSST Long-Term Stewardship Facility at NODC Web Site: *http://ghrsst.nodc.noaa.gov/*

GHRSST Multi-Product Ensemble (GMPE) and Analysis Intercomparison Project Web Page:
http://ghrsst-pp.metoffice.com/pages/latest_analysis/sst_monitor/daily/ens/index.html

GHRSST Tropical Warm Pool Diurnal Variability (TWP+) Project Web Page:
https://www.ghrsst.org/ghrsst-science/science-team-groups/dv-wg/twp/

Integrated Marine Observing System (IMOS) Web Site: *http://www.imos.org.au*

IMOS GHRSST SST Products Web Page: *http://imos.org.au/sstproducts.html*

IMOS Ocean Data Portal: *http://imos.aodn.org.au/webportal*

IMOS Remote Sensing Data Web Page: *http://imos.org.au/srs_data.html*

IMOS Remote Sensing FTP Server for GHRSST data: *ftp://aodaac2-cbr.act.csiro.au/imos/GHRSST*

IMOS Research Vessel Air-Sea Fluxes web page: *http://imos.org.au/airseaflux.html*

IMOS Research Vessel Meteorological, SST and Flux Data OPeNDAP site: *http://thredds.aodn.org.au/thredds/catalog/IMOS/SOOP/SOOP-ASF/catalog.html*

IMOS Ship of Opportunity SST web page: *http://imos.org.au/sst.html*

IMOS Ship of Opportunity SST Data OPeNDAP site: *http://thredds.aodn.org.au/thredds/catalog/IMOS/SOOP/SOOP-SST/catalog.html*

IMOS Southern Ocean Flux Station Web Page: *http://imos.org.au/sofs.html*

IMOS Tropical Research Vessel Data OPeNDAP site: *http://opendap-tpac.arcs.org.au/thredds/catalog/IMOS/SOOP/SOOP-TRV/catalog.html*

NOAA/NESDIS SST Quality Monitor Site (SQUAM): *http://www.star.nesdis.noaa.gov/sod/sst/squam/index.html*

10.2. Journals/Reports

Andreu-Burillo, Isabel, Gary Brassington, Peter Oke and Helen Beggs (2010) Including a new data stream in in Bluelink Ocean Data Assimilation System, *Australian Meteorological and Oceanographic Journal,* **59:**77-86.

Beggs, Helen (2007) A High-Resolution Blended Sea Surface Temperature Analysis over the Australian Region, *BMRC Research Report*, *Bureau of Meteorology*, *Melbourne, Australia, 43 pp.* *http://www.bom.gov.au/bmrc/pubs/researchreports/RR130.pdf*

Beggs, Helen (2008) GAMSSA – A New Global Australian Multi-Sensor SST Analysis, Submitted to Proceedings of the 9th GHRSST–PP Science Team Meeting, Perros-Guirec, France, 9-13 June 2008. *http://cawcr.gov.au/bmrc/ocean/BLUElink/SST/GHRSST9/9th_GHRSST-PP_Meeting_GAMSSA_paper.doc*

Beggs, H., R. Verein, H. Kippo, M. Underwood, I. Barton, C. Steinberg, E. Schulz, R. Hibbins, A. Thomas and G. Ball (2009a). Enhancing Ship of Opportunity Sea Surface Temperature Observations in the Australian Region, GHRSST 2009 International Users Symposium Conference Proceedings, Santa Rosa, USA, pp. 147-150. *http://imos.org.au/soopdoc.html*

Beggs, Helen, Chelle Gentemann and Peter Steinle (2009b) Real-time skin sea surface temperature analyses for quality control of data assimilated into NWP models, *extended abstract, The Fifth WMO International Symposium on Data Assimilation of Observations in Meteorology, Oceanography and Hydrology, Melbourne, Australia, 5-9 October 2009.* *http://cawcr.gov.au/projects/SST/5WMO_DASymp_Extended_Abstract_Beggs_Sep2009.pdf*

Beggs H. (2010) Use of TIR from Space in Operational Systems, In: Oceanography from Space Revisited, Ed. V. Barale, J.F.R. Gower and L. Alberotanza, Pub. Springer Science+Business Media B.V. p.249-271.

Beggs, H., R. Verein and G. Paltoglou (2010a) Calibration and validation of AVHRR sea surface temperatures using observations from ships of opportunity, *In: Proceedings "Oceans from Space" Venice 2010, 26-30 April, 2010, p. 37-38.*

Beggs H., L. Majewski, G. Paltoglou, E. Schulz, I. Barton and R. Verein (2010b) Report to GHRSST11 from Australia - Bluelink and IMOS, *In: Proceedings of the 11th GHRSST Science Team Meeting, Lima, 21-25 June 2010, p. 21-31.* https://www.ghrsst.org/documents/q/category/ghrsst-science-team-meetings/ghrsst-xi-lima/

Beggs H., P. Sandery, V. Barras and P. Steinle (2011a) Australian Bureau of Meteorology SST Requirements for NWP and Atmosphere-Ocean Coupled Models, *In: Proceedings of the GHRSST XII Science Team Meeting, Edinburgh, 27 June - 1 July 2011, p. 180-184.* https://www.ghrsst.org/files/download.php?m=documents&f=110927105711-Proceedings260911Final.pdf

Beggs H., L. Majewski, G. Paltoglou, R. Verein and A. Zhong (2011b) Report to GHRSST12 from Australia – Bluelink and IMOS, *In: Proceedings of the GHRSST XII Science Team Meeting, Edinburgh, 27 June - 1 July 2011, p. 90-105.* https://www.ghrsst.org/files/download.php?m=documents&f=110927105711-Proceedings260911Final.pdf.

Beggs, H., A. Zhong, G. Warrren, O. Alves, G. Brassington and T. Pugh (2011c) RAMSSA - An Operational, High-Resolution, Multi-Sensor Sea Surface Temperature Analysis over the Australian Region. *Australian Meteorological and Oceanographic Journal*, 61, 1-22. http://www.bom.gov.au/amoj/papers.php?year=2011

Beggs H., R. Verein, G. Paltoglou, H. Kippo and M. Underwood (2012a) Enhancing ship of opportunity sea surface temperature observations in the Australian region, *Journal of Operational Oceanography,* (ISSN: 1755-8778), **5**, 59-73. http://www.ingentaconnect.com/content/imarest/joo/2012/00000005/00000001/art00006

Beggs H, L. Majewski, G. Kruger, R. Verein, P. Oke, P. Sakov, C. Tingwell, V. Barras, P. Sandery and C. Griffin (2012b) Report to GHRSST13 from Australia - Bluelink and IMOS, *In: Proceedings of the GHRSST XIII Science Team Meeting, Tokyo, 4 – 8 June 2012, p. 149-163.* https://www.ghrsst.org/files/download.php?m=documents&f=121207144549-GHRSSTXIIIProceedingsIssue1Rev0.pdf

Brassington, G. B., Tim Pugh, Claire Spillman, Eric Schulz, Helen Beggs, Andreas Schiller and Peter R. Oke (2007) Bluelink Development of Operational Oceanography and Servicing in Australia, *J. Res. Practice in Information Technology,* **39**, 151-164.

Casey, K, C. Donlon and the GHRSST Science Team (2011) The Recommended GHRSST Data Specification (GDS) 2.0, Revision 4 [online], 7 November 2011, 123 pp. https://www.ghrsst.org/documents/q/category/gds-documents/operational/

Dash, P., A. Ignatov, M. Martin, C. Donlon, B. Brasnett, R. Reynolds, V. Banzon, H. Beggs, D. May, B. McKenzie, J-F. Cayula, Y. Chao, R. Grumbine, E. Maturi, A. Harris, J. Mittaz, J. Sapper, T. Chin, J. Vazquez, E. Armstrong, C. Gentemann, J. Cummings, F-F. Piolle, E. Autret, J. Roberts-Jones, S. Ishizaki, J. Hoyer, D. Poulter (2012) Group for High Resolultion SST (GHRSST) Analysis Fields Inter-Comparisons Part 2. Near real-time web-based Level 4 SST Quality Monitor (L4-SQUAM). *Deep Sea Research II,* **77-80**, 31–43. http://www.star.nesdis.noaa.gov/sod/sst/squam/documents/DSRII_2011_Revision/DSRII_IC-TAG_Part2_L4_SQUAM.pdf.

Garde L.A., C.M. Spillman, L. Majewski, C. Griffin, G. Kruger and H**.** Beggs (2013) ReefTemp Next Generation, CAWCR Technical Report, No. 63, 35 pp. http://cawcr.gov.au/publications/technicalreports/CTR_063.pdf

Griffin, C, L. Majewski and H. Beggs (2013) Computing sea surface temperatures and Sensor Specific Error Statistics for GHRSST compliant AVHRR products over the Australian region, http://imos.org.au/srsdoc.html

Huang (2012) Operational Implementation of OceanMAPS version 2.1 (BLUElink> Ocean Forecasting System), NMOC Operations Bulletin, Number 94, 17 pp. http://www.bom.gov.au/australia/charts/bulletins/apob94.pdf

Martin M., P. Dash, A. Ignatov, V. Banzon, H. Beggs, B. Brasnett, J-F. Cayula, J. Cummings, C. Donlon, C. Gentemann, R. Grumbine, S. Ishizaki, E. Maturi, R. Reynolds, J Roberts_Jones (2012) Group for High Resolution SST (GHRSST) Analysis Fields Intercomparisons: Part 1. A GHRSST Multi-Product Ensemble (GMPE). *Deep Sea Research II,* **77-80**, 21–30. http://dx.doi.org/10.1016/j.dsr2.2012.04.013.

Maturi E., A. Harris, C. Merchant, J.Mittaz, R. Potash, W. Meng and J. Sapper (2008) NOAA's Sea Surface Temperature Products from Operational Geostationary Satellites, *Bull. American Met. Soc.*, Dec 2008, 1877-1888.

Oke P. R, Brassington G. B., Griffin D. A. and Schiller A. (2008), The Bluelink ocean data assimilation system (BODAS). *Ocean Modelling*, **21**, 46-70.

Paltoglou, G., H. Beggs and L. Majewski (2010) New Australian High Resolution AVHRR SST Products from the Integrated Marine Observing System, *In: Extended Abstracts of the 15th Australasian Remote Sensing and Photogrammetry Conference, Alice Springs, 13-17 September, 2010.* http://imos.org.au/srsdoc.html

Puri, K., Dietachmayer, G., Mills, G.A., Davidson, N.E., Bowen, R.A. and Logan, L.W. 1998. The new BMRC Limited Area Prediction System, LAPS. *Aust. Met. Mag., 47,* 203–33.

Puri, K. et al. (2010) Preliminary results from Numerical Weather Prediction implementation of ACCESS. *CAWCR Research Letters 5,* 15–22. http://www.cawcr.gov.au/publications/researchletters/CAWCR_Research_Letters_5.pdf

Smith N. S., B. Ebert and G. Warren (1999) The Bureau of Meteorology SST Analysis System, An informal paper produced as background for the OOPC/AOPC Workshop on SST Analyses for Climate, International Research Institute, LDEO, Palisades NY USA, Nov 10-12, 1998. http://www.bom.gov.au/bmrc/ocean/BLUElink/SST/The_Bureau_of_Meteorology_SST_analysis_system.doc

Walton, C.C., Pichel, W.G., Sapper, J.F. and May, D.A. (1998) The development and operational application of nonlinear algorithms for the measurement of sea surface temperatures with the NOAA polar-orbiting environmental satellites. *J. Geophys. Res.* 103, No. C12, 27999-280.

Zhong, Aihong and Helen Beggs (2008) Analysis and Prediction Operations Bulletin No. 77 - Operational Implementation of Global Australian Multi-Sensor Sea SurfaceTemperature Analysis, 2 October 2008.

http://cawcr.gov.au/projects/SST/GAMSSA_BoM_Operational_Bulletin_77.pdf

REPORT TO GHRSST XIV FROM JAXA

Misako Kachi [(1)]***, Keiji Imaoka*** [(1)]***, Hiroshi Murakami*** [(1)]

(1) Japan Aerospace Exploration Agency (JAXA), Tsukuba (Japan), Email : kachi.misako@ jaxa.jp

ABSTRACT

Recent Japan Aerospace Exploration Agency (JAXA) activities are summarized and reported.

AMSR2 onboard the GCOM-W1 satellite was launched on 18 May 2012 (JST) from Tanegashima Space Center, Japan. AMSR2 Level 1 (brightness temperature) products have been released to public since 24 January 2013, and Level 2 (geophysical parameters including SST) will be available in May 2013. GCOM-C1, which carrying SGLI instrument, is currently scheduled to be launched in Japanese Fiscal Year of 2015. AMSR-E has restarted but in slow rotation of 2rpm since December 2012 to implement cross-calibration between AMSR2.

Renewal of JAXA GHRSST server (http://sharaku.eorc.jaxa.jp/ADEOS2/ghrsst/) will be completed in May 2013 to distribute L2P and L3C SST products of AMSR2, AMSR-E, WindSat and VIRS in GDS 2.0 format.

1. Introduction

JAXA developed the Ocean Color and Temperature Scanner (OCTS) as optical imagers to observe SST onboard the Advanced Earth Observing Satellite (ADEOS) operated from 1996 to 1997, the Global Imager (GLI) onboard the Advanced Earth Observing Satellite-II (ADEOS-II) operated from 2002 to 2003, and is developing the Second generation Global Imager (SGLI), which will be carried by the first generation of the Global Change Observation Mission (GCOM) - Climate (GCOM-C1) scheduled to be launched in Japanese Fiscal Year (JFY) of 2015.

JAXA also developed the Advanced Microwave Scanning Radiometer (AMSR) as passive microwave imagers to observe SST, onboard the ADEOS-II, AMSR for EOS (AMSR-E) onboard NASA's EOS Aqua satellite, which has been operating since 2002, and launched AMSR2 onboard the first generation of the GCOM - Water (GCOM-W1) in May 2012. C-band (6.9GHz/7.2GHz) channels on AMSR, AMSR-E and AMSR2 are indispensable for retrieving global sea surface temperature and soil moisture. All-weather and frequent measurements enables analyses of rapid changes of SST.

2. Current status of JAXA missions

2.1. AMSR-E

AMSR-E was launched in May 4, 2002, and halted its observation in 4 October 2011. Since the end of August 2011, the continuous increase of relatively large antenna rotation friction was detected twice, thus JAXA has been monitoring condition. At 0658UTC in 4 October 2011, the AMSR-E reached its limit to maintain the rotation speed necessary for regular observations (40rpm,) and the radiometer automatically halted its observation and rotation.

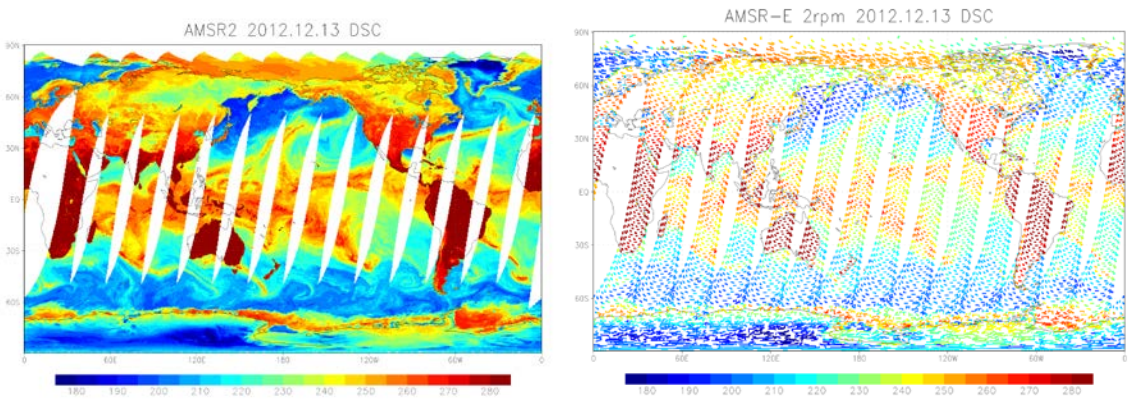


Figure 1. Examples of 23GHz V-pol brightness temperature of AMSR2 (left) and AMSR-E in 2rpm rotation (right).

Since AMSR-E hardware (both sensor and control) is expected in healthy condition except for its large friction with antenna rotation, and cross-calibration between AMSR-E and AMSR2 is very important, JAXA prepared a recovery plan with engineers and NASA. AMSR-E has restarted observation at 2-rpm since December 2012 to implement cross-calibration with AMSR2 (Fig. 1).

2.2. AMSR2 on GCOM-W1

AMSR2 is multi-frequency, total-power microwave radiometer system with dual polarization channels for all frequency bands. The instrument is a successor of AMSR and AMSR-E. The frequency bands include 6.925, 7.3, 10.65, 18.7, 23.8, 36.5, and 89.0-GHz.

AMSR2 onboard the GCOM-W1 satellite was launched on 18 May 2012 (JST) from Tanegashima Space Center, Japan. The early orbit checkout of GCOM-W1 satellite and AMSR2 instrument was performed for about three months after the launch. Since it took about 45 days to insert the satellite into “A-Train” orbit, the checkout tasks were carried forward between intervals of orbit control events. The GCOM-W1 satellite has joined A-train orbit since 29 June. After GCOM-W1 was inserted into the planned position on the A-Train orbit, AMSR2 was spun up to 40 rpm, and then set to “science mode” to start observation in 3 July. Initial checkout of the satellite and the instrument has completed in 10 August without major problem. The GCOM-W1 satellite was installed in front of the Aqua satellite to keep continuity of AMSR-E observations and provide synergy with the other A-Train instruments for new Earth science researches.

Standard products of AMSR2 is distributed through the GCOM-W1 Data Distribution Service system (http://gcom-w1.jaxa.jp) as well as AMSR-E and AMSR standard products. Level 1 brightness temperature product is released in January 2013, 8-month after the launch as scheduled, and Level 2 geophysical parameter products will be available in May 2013, 1-year after launch.

Currently, final evaluation activities of geophysical parameters are underway for the Data Release Review scheduled in May 2013. Early results show that all geophysical parameters satisfy their release accuracy, and will be ready for release as scheduled.

Fig. 2 is three-day average image of AMSR2 SST. AMSR2 SST product is validated by comparing with various buoy SST observations reported through the Global Telecommunication System (GTS) operated by World Meteorological Organization (WMO). Each match-up data will include AMSR2 footprints around buoy stations within radius of 30 km and 2 hours. Root mean square error (RMSE) between AMSR2 and Buoy SSTs from August to December 2012 is currently 0.56 °C and correlation coefficient (R) is 0.998 (Fig. 3).

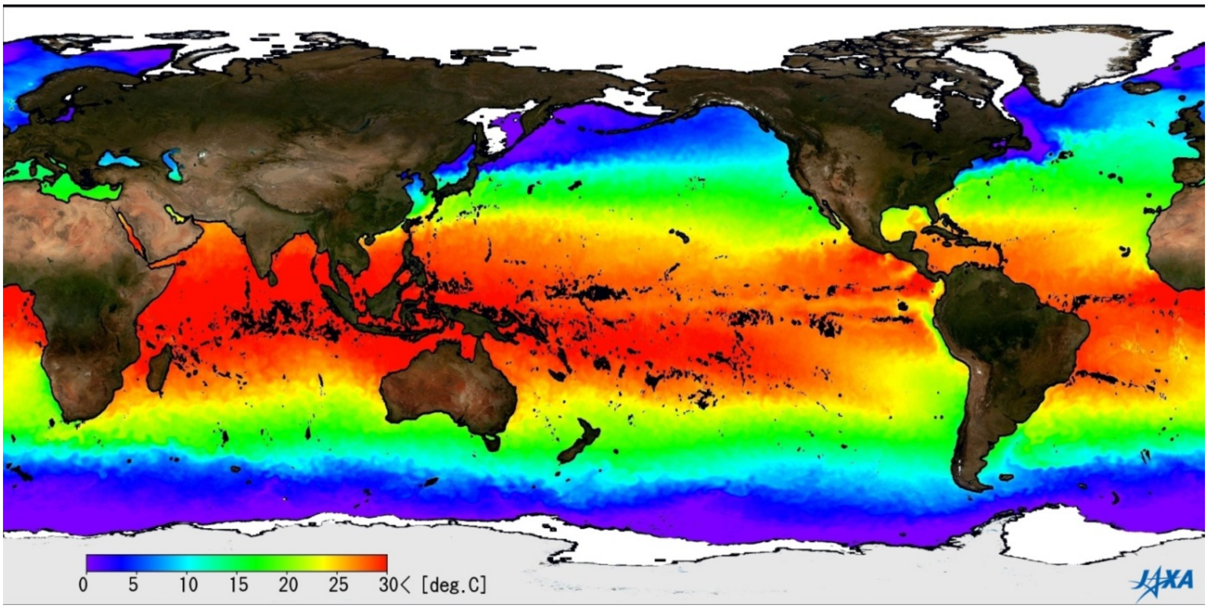


Figure 2. Three-day average of AMSR2 Sea Surface Temperature from 1 to 3 April 2013.

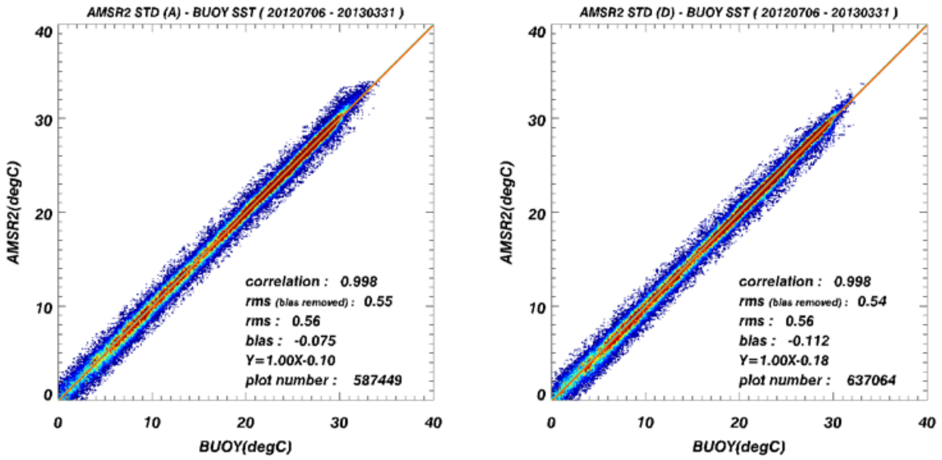


Figure 3. Scatter plots of AMSR2 SST and buoy SST from 6 July 2012 to 31 March 2013.
Left: Ascending orbit (noon). Right: Descending orbit (night).

2.3. SGLI on GCOM-C

SGLI is a versatile, general purpose optical and infrared radiometer system covering the wavelength region from near ultraviolet to infrared. SGLI system consists of two components; SGLI-VNR (Visible & Near infrared push-broom Radiometer); and SGLI-IRS (shortwave & thermal InfraRed Scanner) to optimize optics for each wavelength range. Two major new features are added to SGLI, they are 250 m spatial resolution for 11 channels and polarization/multidirectional observation capabilities. The GCOM-C1 satellite is currently scheduled to be launched in Japanese Fiscal Year of 2015.

The 250m resolution data of SGLI-VNR will enable to detect more fine structure in the coastal area such as river outflows, regional blooms, and small currents SST and ocean color products derived from SGLI will provide additional information to AMSR2 SST.

Currently, the System Critical Design Review (CDR) of SGLI was completed in April 2013, and Proto-Flight Models (PFM) of the satellite and SGLI are under construction.

3. Current status of JAXA GHRSST Server

Renewal of JAXA GHRSST server (http://sharaku.eorc.jaxa.jp/ADEOS2/ghrsst/) will be completed in May 2013. Web site includes information of available SST products produced by JAXA, registration form to download data, and near-real-time monitor of products (Fig. 4).

Simple registration is needed to access to password protected ftp site to download data. Several passive microwave imagers, such as AMSR2, AMSR-E, and NOAA's WindSat onboard the Colioris, and the Visible Infrared Scanner (VIRS) onboard the Tropical Rainfall Measuring Mission (TRMM) satellite are available. L2P and L3C SST products of those instruments will be available in GDS 2.0 format. Old GDS version of AMSR-E products (GDS 1.6) will be also available until the end of 2013.

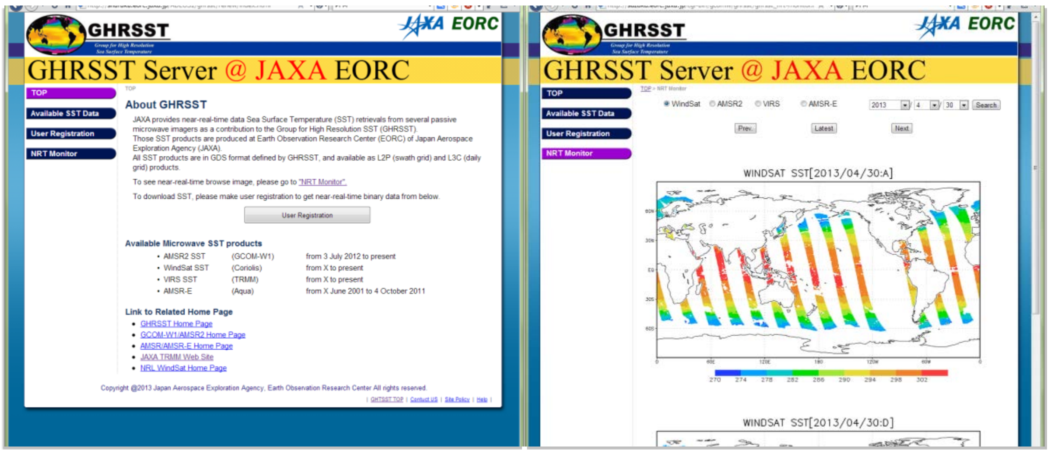


Figure 4. New JAXA GHRSST web site. Left: Top page. Right: NRT monitoring page.

4. Activities and Plan for 2013-2017

Currently, we're planning following activities during 2013 and 2017 as shown in Table 1.

Year	Activities and plans
2013	Release of AMSR2 L1 standard product to general users 8-month after launch. Release of AMSR2 L2 (including SST) standard product to general users 12-month after launch. Renewal of JAXA GHRSST web site/server. Release of AMSR2, AMSR-E, Windsat and VIRS SST in GDS 2.0 format. Apply AMSR2 algorithm to AMSR-E data to produce continuous data set. Consideration of extension of AMSR2 SST algorithm to other satellite microwave imagers.
2014	Update of AMSR2 SST algorithm (TBD). Release of consistent passive microwave SST products applying AMSR2 algorithm (TBD).

Year	Activities and plans
2015	Launch of GCOM-C1 satellite (TBD).
2016	Release of SGLI data products to public (TBD). Addition of SGLI SST to JAXA GHRSST server (TBD).
2017 or later	Launch of GCOM-W2 satellite (TBD).

Table 1. List of JAXA activities and plans from 2013 to 2017

5. Conclusion

Activities and plans of JAXA are described. Japanese GHRSST members, JAXA, JMA and Tohoku University, are working closely and sharing information regarding satellite instruments and SST data each other.

Both of GCOM-W1 satellite and AMSR2 instruments are in good condition after the launch in May 2012, and their performances are excellent.

Level 1 brightness temperature product is released in January 2013, 8-month after the launch as scheduled, and Level 2 geophysical parameter products will be available in May 2013, 1-year after launch. Currently, final evaluation activities of geophysical parameters are underway for the Data Release Review scheduled in May 2013. Early results show that all geophysical parameters satisfy their release accuracy, and will be ready for release as scheduled.

JAXA GHRSST server will be replaced by new system, and web site will also renew its contents. New SST data from AMSR2, Windsat and VIRS will be added to the JAXA GHRSST server in May 2013 in GDS 2.0 format.

REPORT TO GHRSST XIV FROM JMA

***Shiro Ishizaki*[(1)], *Yukio Kurihara*[(2)], *Mika Kimura*[(1)], *Udai Shimada*[(3)] and *Yoshiaki Kanno*[(1)]**

(1) Office of Marine Prediction, Japan Meteorological Agency, Tokyo (Japan),
Email : s_ishizaki@met.kishou.go.jp
(2) Meteorological Satellite Center, Japan Meteorological Agency, Kiyose (Japan)
(3) Meteorological Research Institute, Japan Meteorological Agency, Tsukuba (Japan)

ABSTRACT

After the 13th GHRSST Science Team Meeting, JMA has installed SST from WindSat and GCOM-W1/AMSR2 into global daily sea surface temperature (MGDSST) analysis. Using AVHRR Pathfinder Version 5.0 /5.1 SST and AQUA/AMSR-E SST, MGDSST is reprocessed for 1982-2006. In order to improve MTSAT SST, Meteorological Satellite Center (MSC)/JMA developed new processing system for MTSAT SST.

1. Introduction

JMA developed a SST analysis system to generate global daily SST data (Merged satellite and in-situ data Global Daily Sea Surface Temperature: MGDSST) in 2004. This SST analysis system produces 1/4° resolution, daily global SST analysis, using both satellite and in-situ SST observation. As an analysis scheme, the MGDSST analysis adopts optimal interpolation (OI) method which considered not only spatial correlation but also temporal correlation. JMA started to implement operational (real-time) analysis of the MGDSST in 2005 using GAC AVHRR SST (NOAA-15 and NOAA16) provided by NOAA, and AQUA/AMSR-E SST by JAXA. By 03UTC each day, the operational analysis of the previous day's (real-time analysis) becomes available through the NEAR-GOOS Regional Real Time Data Base (RRTDB: http://goos.kishou.go.jp/ registration is required prior to use). The MGDSST reproduces global SST field well, although high-frequency SST variation is underestimated (Iwasaki *et al*., 2008). The MGDSST analysis contributes to the GHRSST Multi-Product Ensemble (GMPE) median SST.

The MGDSST is used in various operational systems in JMA. In the regional ocean data assimilation system (Multivariate Ocean Variational Estimation system / Meteorological Research Institute Community Ocean Model for the Western North Pacific: MOVE/MRI.COM-WNP; Usui *et al.* (2006)), the MGDSST is used as observation data. MOVE/MRI.COM-WNP well reproduces the ocean states in the seas around Japan and provides better prediction of current and temperature field for one month.The MGDSST is also used as a lower boundary conditions in the numerical weather prediction models.

Because the OI method applied in the MGDSST analysis considers temporal correlation, this method requires the observation data after the target day in order to produce the more appropriate analysis. On the other hand, long term, consistent time series of the SST analysis is needed for climate research. For these reason, JMA implemented reanalysis (first version of reanalysis) of the MGDSST from 1985 to 2004 using AVHRR Pathfinder Version 4/5.0 SST in 2006, and the reanalysis MGDSST was extended to 2005 in 2007. For the purpose to incorporate the observation data after the target day into MGDSST, JMA has been reprocessed the MGDSST analysis (delayed analysis) in operation with about 5-month delay using GAC AVHRR SST and AQUA/AMSR-E SST since 2006.

After geostationary satellite MTSAT-1R was launched in 2005, Meteorological Satellite Center (MSC) /JMA had generated several types of products, including SST, using observation of MTSAT-1R. In 2009, in order to reduce biases of the MTSAT-1R SST, MSC/JMA developed a new processing system for MTSAT-1R SST based on a method of Maturi *et al.*, (2008). These SST products are included in Monthly Report of Meteorological Satellite Center (CD-ROM; see, http://mscweb.kishou.go.jp/product/library/report/index.htm). After MTSAT-2 became operational, MSC/JMA started generating SST product using MTSAT-2 observations instead of MTSAT-1R.

2. Current Status of the MGDSST Analysis

In October 2011, AQUA/AMSR-E SST was excluded from MGDSST analysis due to the completion of its observation. Since February 2013, SST observed by WindSat has been incorporated to the operational (real-time) analysis of MGDSST. After the launch of GCOM-W1/AMSR2 in May 2012, JAXA made great efforts to retrieve SST. In 27 May 2013, JMA started incorporating AMSR2 SST into MGDSST (Figures 1 through 4). Currently, JMA uses AVHRR SST (NOAA-18, NOAA-19 and MetOp-A), WindSat SST and AMSR2 SST to generate operational MGDSST data. AVHRR SST data are provided by NOAA/NESDIS for Global ocean (GAC data), as well as locally received by MSC/JMA for the western North Pacific (HRPT data). SST from both WindSat and AMSR2 are provided by JAXA.

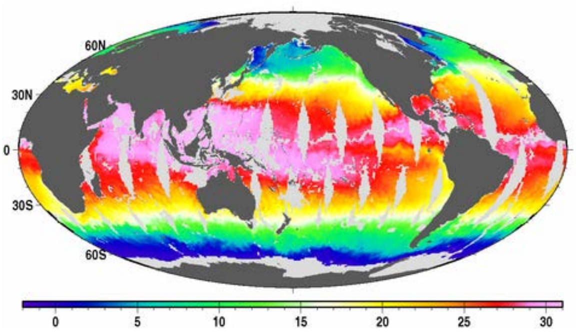


Figure 1: An example of daily SST from GCOM-W1/AMSR2 for 1 June 2013.

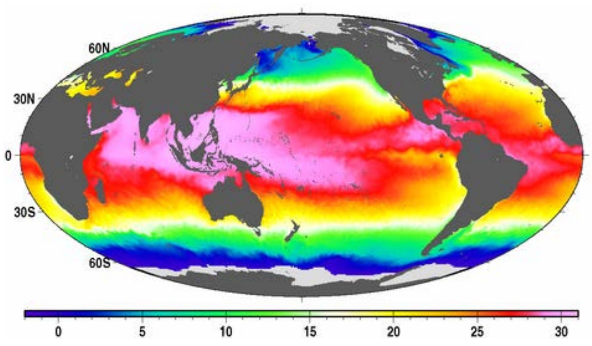


Figure 2: An example of MGDSST for 1 June 2013.

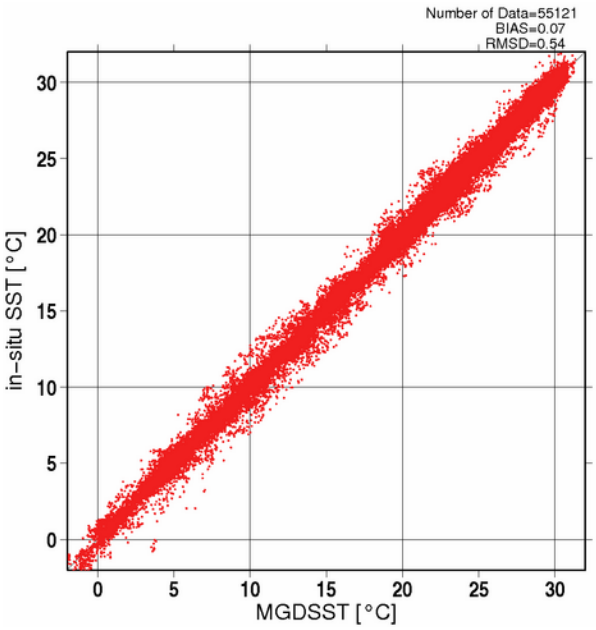


Figure 3: Scatter plot between MGDSST, where AMSR2 SSTs are ingested, and in-situ measurements for April 2013.

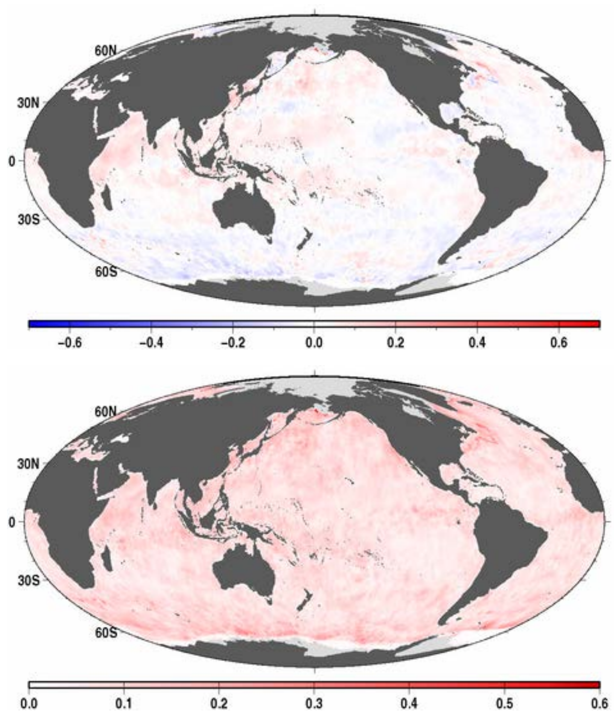


Figure 4: (Top) mean differences (with AMSR2 minus without AMSR2) and (bottom) standard deviations in MGDSST.

JMA implemented reanalysis (second version of the reanalysis) of the MGDSST from 1982 to 2006 using AVHRR Pathfinder Version 5.0 /5.1 SST and AQUA/AMSR-E SST (Figures 5 and 6).

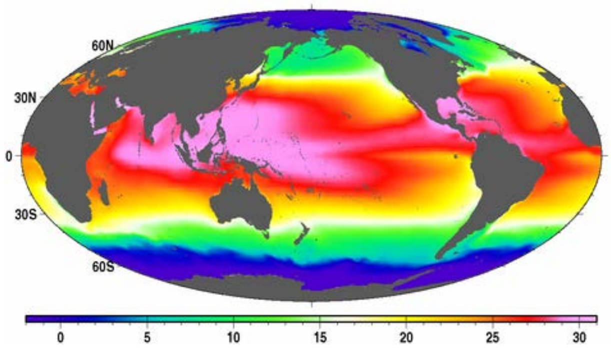


Figure 5: Monthly SST climatology for July calculated using second version of the reanalysis.

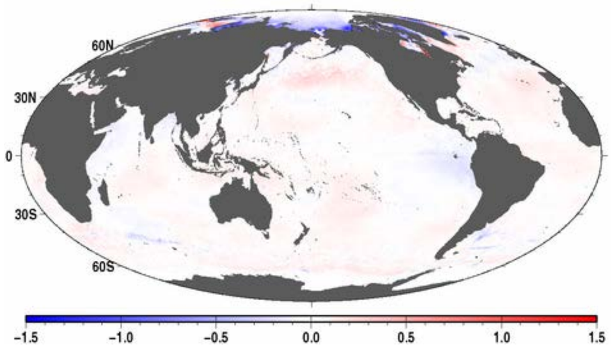


Figure 6: Differences in monthly SST climatology for July (second version minus first version).

3. Current Status of the MTSAT SST Product

SSTs from MTSAT-1R and MTSAT-2 observations show a good performance for monitoring ocean states. But additional efforts to reduce biases are required for incorporating into SST analysis, since the current method produces MTSAT SSTs with large negative biases in the areas where satellite zenith angles are larger than 50 degrees. MSC/JMA developed a new physical retrieve method for producing MTSAT SSTs using one-dimensional Variational (1DVAR) technique (Kurihara, 2012). The new method includes single layer radiative transfer calculation in order to take into account effects of water vapour absorption and sea surface emissivity. Based on MGDSST analysis system, JMA is now developing a regional SST analysis system (1/10° resolution) in which MTSAT SSTs are incorporated (Figure 7).

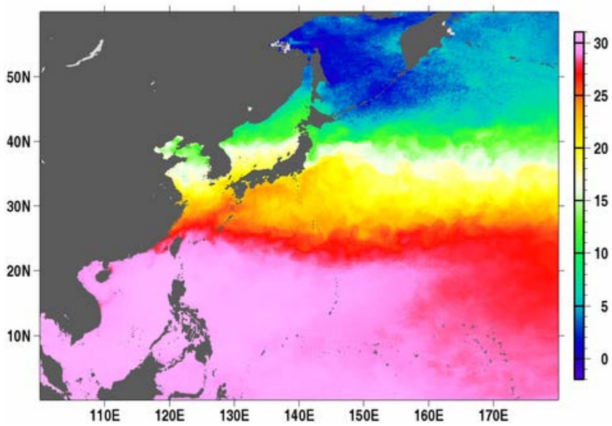


Figure7: An example of regional version of SST analysis for 1 June 2013.

4. Future Plan

1. The new method which improves SST retrieved from MTSAT observation will be applied to operational system in summer 2013.
2. JMA continues to develop a system to incorporate MTSAT SST into SST analysis aiming to increase the resolution of the analysis.
3. JMA is preparing *Himawari* 8/9, the successor to MTSAT, to be launched in 2014 and 2016 respectively.
4. NWP division and Office of Marine Prediction of JMA are having discussions about a design of a next generation SST analysis system. Through the discussions, requirements from SST users (e.g. NWP group) will be specified on developing the new analysis system.
5. JMA will develop a system to create and deliver MGDSST files of NetCDF version based on GDS-2.0 format.

5. References

Iwasaki S., M. Kubota and H. Tomita (2008) Inter-comparison and evaluation of global sea surface temperature products. *Int. J. Remote Sensing*, **29,** (21), 6263-6280.

Maturi E., A. Harris, C. Merchant, J.Mittaz, R. Potash, W. Meng and J. Sapper (2008) NOAA's Sea Surface Temperature Products from operational Geostationary Satellites, *Bull. American Met. Soc.*, Dec 2008, 1877-1888.

Usui, N., S. Ishizaki, Y. Fujii, H. Tsujino, T. Yasuda and M. Kamachi (2006) Meteorological Research Institute multivariate ocean variational estimation (MOVE) system : Some early results. *Advances in Space Research*, **37**, 806-822.

Kurihara, Y (2012) Optimal estimation technique for SST from MTSAT-2, Presented to the 13th GHRSST science team meeting, Tokyo, Japan, 5-8th July, 2012.

SECTION 5: FOCUS ON TOPICS RELATING TO DATA AND USER SERVICES

CEOS SST-VC: UPDATE ON PROGRESS

C. Donlon(1), K. Casey(2), M. Kachi(3), H. Beggs(4), C. Merchant(5), A. Bingham(6), H. Bonekamp(7),

(1) ESA/ESTEC, Keplerlaan 1, 2201 AZ, Noodwijk, The Netherlands, Email: craig.donlon@esa.int
(2) NOAA National Oceanographic Data Center, USA, Email: Kenneth.Casey@noaa.gov
(3) Japan Aerospace Exploration Agency (JAXA), Tsukuba (Japan), Email : kachi.misako@ jaxa.jp
(4) CAWCR, Bureau of Meteorology, Australia, Email: h.beggs@bom.gov.au
(5) University of Reading, Reading, UK. Email: c.j.merchant@reading.ac.uk
(6) JPL, USA, Email: Andrew.Bingham@jpl.nasa.gov
(7) EUMETSAT, Eumetsat-Allee 1, 64295 Darmstadt (Germany),
Email: Hans.Bonekamp@eumetsat.int

ABSTRACT

The key space segment capabilities providing Sea Surface Temperature (SST) measurements are extensive and are used by a large number of international Agencies. So far, several CEOS Agencies have invested a considerable amount of resources in activities related to SST, sometimes without full optimization. The SST-VC shall support the coordination consolidation and further development of satellite SST capability, products, user feedback and education/outreach activities using the recognized and well established GHRSST as the prime coordination mechanism. The emphasis is to reduce redundancy between the successful and functioning work of GHRSST (as an implementer of the SST-VC coordination) and the SST-VC (representing the activities of the Agencies).

FELYX: A GENERIC TOOL FOR EO DATA ANALYTICS

Jean-François Piollé[(1)], Dave Poulter[(2)], Jamie Shutler[(3)], Veronica Guidetti[(4)]

(1) CERSAT / Institut Français de Recherche pour l'Exploitation de la Mer (France), Email: jfpiolle@ifremer.fr
(2) Pelamis Scientific Software (UK), Email: david.poulter@pelamis.co.uk
(3) Plymouth Marine Laboratory (UK), Email: jams@pml.ac.uk
(4) European Space Agency (Italy), Email: veronica.guidetti@esa.int

ABSTRACT

Felyx is currently under development and is the latest evolution of a generalised High Resolution Diagnostic Data Set system funded by ESA. It draws on previous prototype developments and experience in the GHRSST, Medspiration, GlobColour and GlobWave projects.

Felyx is fundamentally a tool to facilitate the analysis of EO data: it is being developed by IFREMER, PML and Pelamis. It will be free open software written in python and javascript. The aim is to provide Earth Observation data producers and users with an open-source, flexible and reusable tool to allow the quality and performance of data streams from satellite, in situ and model sources to be easily monitored and studied. New to this project, is the ability to establish and incorporate multi-sensor match-up database capabilities. The systems will be deployable anywhere and even include interaction mechanisms between the deployed instances.

The primary concept of Felyx is to work as an extraction tool. It allows for the extraction of subsets of source data over predefined target areas (which can be static or moving). These data subsets, and associated metrics, can then be accessed by users or client applications either as raw files or through automatic alerts. These data can also be used to generate periodic reports or be used for statistical analysis and visualisation through a flexible web interface.

Felyx enables:

- subsetting - large local or remote collections of Earth Observation data over predefined sites (geographical boxes) or moving targets (ship, buoy, hurricane), storing locally the extracted data (referred as miniProds). These miniProds constitute a much smaller representative subset of the original collection on which one can perform any kind of processing or assessment without having to cope with heavy volumes of data.
- generation of statistics - computing statistical metrics over these miniProds using for instance a set of usual statistical operators (mean, median, rmse), which is fully extensible and applicable to any variable of a dataset. These metrics are stored in a fast search engine which can be interrogated by humans and automated applications.
- generate reports or warnings/alerts - based on user-defined inference rules, through various media (emails, twitter feeds,..) and devices (phones, tablets).
- analysing – analysis of miniProds and metrics through a web interface allowing the data to be explored and extracting useful knowledge through multidimensional interactive display functions (time series, scatterplots, histograms, maps).

There are many potential applications but important uses foreseen are :

- monitoring and assessing the quality of Earth observations (e.g. satellite products

and time series) through statistical analysis and/or comparison with other data sources
- assessing and inter-comparing geophysical inversion algorithms
- observing a given phenomenon, collecting and cumulating various parameters over a defined area
- crossing different sources of data for synergy applications

The services provided by felyx will be generic, deployable at users own premises, and flexible allowing the integration and development of any kind of parameters. Users will be able to operate their own felyx instance at any location, on datasets and parameters of their own interest, and the various instances will be able to interact with each other, creating a web of felyx systems enabling aggregation and cross comparison of miniProds and metrics from multiple sources.

The system will be fully implemented in February 2013. Initially two instances will be operated simultaneously during a 6 months demonstration phase, at IFREMER - on sea surface temperature (including most GHRSST products and climate datasets such as the (A)ATSR time series) and ocean waves datasets - and PML - on ocean colour.

DATA LIFE CYCLE POLICY

***Edward Armstrong* [(1)]*, Eric Tauer* [(1)]**

(1) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
Email: edward.m.armstrong@jpl.nasa.gov

ABSTRACT

The presentation focused on describing a new dataset lifecycle policy that the NASA Physical Oceanography DAAC (PO.DAAC) has implemented for its new and current datasets to foster improved stewardship and consistency across its archive. The overarching goal is to implement this dataset lifecycle policy for all new GHRSST GDS2 datasets and bridge the mission statements from the GHRSST Project Office and PO.DAAC to *provide the best quality SST data in a cost-effective, efficient manner, preserving its integrity so that it will be available and usable to a wide audience.*

1. Dataset Lifecycle Policy

The primary motivation for the PO.DAAC with respect to the implementation of the policy is to ensure consistency across the data holdings with regard to metadata and formats, data quality and maturity, and to ensure requirements for internal data management best practices are followed. Impacts on data, operations, tools and distribution are assessed through the collection of various metrics. The primary components of the lifecycle are defined by a series of documents designed to collect these lifecycle policy metrics (Fig. 1). Some of the metrics are related to internal procedures to document system requirements such as impacts on operations, and tools and distribution (e.g., the System Impact Assessment document), but of fundamental importance to the data provider is a document known as the Submission Agreement. This document is part of the lifecycle “quality gate” designed to improve the capturing of data quality and descriptions. Although the document contains sections to establish the respective expectations between the data provider and the PO.DAAC with regards to data latency, tools and services availability, support and distribution requirements, it more importantly contains sections for the provider to document and improve the quality characterization of their dataset including data uncertainty assessment and validation results, and well as the processing lineage and algorithm description. Components of these sections could come from published literature, project validation results, or project algorithm description documents.

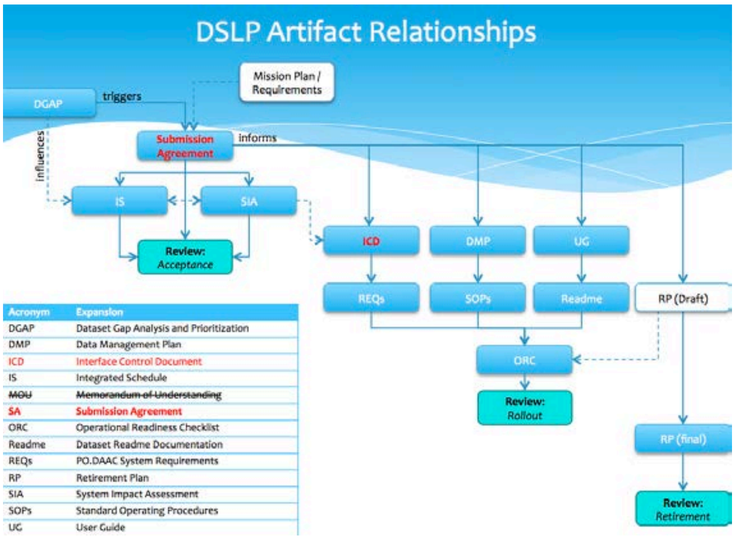


Figure 1. Example of the various facets and documents in the hierarchy of the PO.DAAC dataset lifecycle policy (DSLP). Of importance to a data provider is the Submission Agreement to document data quality.

An example of the populated data quality components in the Submission Agreement is seen in Figure 2 for a Oceansat-2 scatterometer dataset:

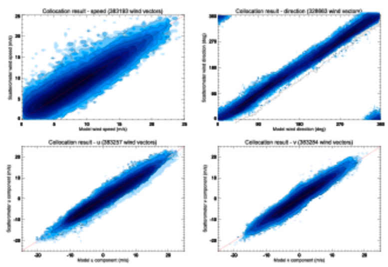
Validation and Uncertainty Estimate

The performance of the products issued by the OSI SAF are characterized by a wind component RMS error smaller than 2 m/s and a bias of less than 0.5 m/s in wind speed.

The figure below shows two-dimensional histograms of the retrieved winds versus ECMWF 10m wind background for the 50-km wind product, after rejection of Quality Controlled (KNMI QC flagged) wind vectors. The data for these plots are from 28 consecutive orbits from 9 and 10 February 2012.

The top left plot corresponds to wind speed (bins of 0.5 m/s) and the top right plot to wind direction (bins of 2.5°). The latter are computed for ECMWF winds larger than 4 m/s. The bottom plots show the *u* and *v* wind component statistics (bins of 0.5 m/s). The contour lines are in logarithmic scale. Note that the ECMWF winds are real 10m winds, whereas the scatterometer winds are equivalent neutral 10m winds, which are on average 0.2 m/s higher.

From these results, it is clear that the spread in the distributions is small. The wind speed bias is 0.16 m/s (close to the expected value of 0.2 m/s) and we obtain wind component standard deviations of 1.37 in *u* and 1.30 in *v* directions.



The wind products are also compared to in situ winds from moored buoys on a monthly basis. This is part of the regular OSI SAF product quality reporting.

Lineage

In scatterometer wind retrieval a Geophysical Model Function (GMF) is inverted. The radar backscatter of the ocean, as derived from the GMF, depends, besides on the wind vector w.r.t. the radar beam pointing, on radar wavelength (C-band or Ku-band) and vertical (VV) or horizontal (HH) polarization. The inversion step combines the backscatter measurements in a Wind Vector Cell (WVC) to compute the WVC-mean wind vector.

Since the scatterometer wind retrieval problem is over-determined, this opens up the possibility of quality control (QC) by checking the inversion residual (maximum likelihood estimator or MLE). The MLE value can be seen as the distance of a set of backscatter measurements to the GMF manifold in measurement space. It is found that the MLE is well capable of removing cases with extreme wind variability (at fronts or centers of lows), or with other geophysical variables affecting the radar backscatter, such as rain.

Scatterometer winds have multiple ambiguities and there are up to four local minima after wind inversion in each WVC. The ambiguities are removed by applying constraints on the spatial characteristics of the output wind field, such as on rotation and divergence. This is done using a Two-dimensional Variational Ambiguity Removal Scheme.

OSCAT uses a 1-meter dish antenna rotating at 20 rpm with two "spot" beams of about 25 km × 55 km size on the ground from both the HH beam and VV beam, at incidence angles of respectively 43° and 49°, that sweep the ocean surface in a circular pattern. Note that the egg-shaped beam footprints are divided into slices in range direction by applying a modulated chirp signal and resulting in fields of view of about 8 km by 25 km, which constitute the individual contributions to a WVC-mean backscatter value and where a set of up to four of those largely overlapping spatial averages determine the WVC-mean wind. Moreover, geophysical quality and spatial representation of the vector winds are finally determined by the filtering properties of the ambiguity removal scheme.

Figure 2. The Validation and Lineage sections describing the data quality for Oceansat-2 wind scatterometer (OSCAT).

2. Conclusion

This Submission Agreement as part of the dataset lifecycle policy is meant to be a first step to assess the dataset quality and can be eventually leveraged to improve GHRSST ISO

19115 metadata records (using data quality DQ_ and lineage LE_ objects) as well. It can also potentially be used to improve dataset selection from the user perspective. After plenary discussion it was agreed that new GHRSST datasets should strive to adopt this lifecycle approach including the Submission Agreement.

3. Acknowledgements

This work was carried out at the NASA Jet Propulsion Laboratory, California Institute of Technology. Government sponsorship acknowledged. Government sponsorship acknowledged.

SECTION 6: FOCUS ON KEY TOPICS RELATING TO ESTIMATION, MASKING AND VALIDATION

PROGRESS IN SEA SURFACE TEMPERATURE RETRIEVAL AND FUTURE DIRECTIONS

Christopher Merchant[(1)], Pierre Le Borgne[(2)]

(1) Dept. of Meteorology, University of Reading, Reading, UK, Email: c.j.merchant@reading.ac.uk
(2) Météo-France/Centre de Météorologie Spatiale, Lannion, France Email*: pierre.leborgne@meteo.fr*

ABSTRACT

The last five years have seen a modest flurry in new retrieval algorithms for infrared (IR) estimates of sea surface temperature (SST). These include: cross-sensor harmonized coefficients in the ATSR Reprocessing for Climate project; reduced state vector optimal estimation, with various forward model bias adjustments; traditional non-linear SST (NLSST) modified with simulation based bias adjustment; incremental regression (NLSST or other equations expressed in a "nudging" form); experiments with genetic algorithms (seemingly supporting the efficiency of NLSST among possible parametric forms); and, in this past year, an extension of optimal estimation which takes account of the long length scales of the atmosphere – "smoothed OE", which is described in reasonable detail below.

At the request of the GHRRST project office, this talk will review these developments and try to show how they relate, and what are their relative strengths and weaknesses. Many of the recent developments have as a common feature use of forward simulation of the retrieval situation to inform the SST estimate. This development has been motivated by the observation that "anomalous atmospheres" (which here really means conditions not appearing frequently in a global sample of retrieval situations) cause SST bias. These can be reduced by exploiting forward simulation, as directly evidenced with the adjusted NLSST method.

The position taken in the talk will be that variants of OE are most likely to give further progress, and smoothed OE will be presented as a direction for future research. Adopting OE shifts the point of progress from investigating "algorithms" to improving forward simulations of satellite observations. Sensor characterization, calibration, forward simulation and in-flight bias correction of brightness temperatures become the routine new challenges in SST retrieval.

More on smoothed OE:

Sea surface temperature (SST) can be estimated from day and night observations of the Spinning Enhanced Visible and Infra-Red Imager (SEVIRI) by optimal estimation (OE). We show that exploiting the 8.7 μm channel, in addition to the "traditional" wavelengths of 10.8 and 12.0 μm, improves OE SST retrieval statistics in validation. However, the main benefit is an improvement in the sensitivity of the SST estimate to variability in true SST.

In a fair, single-pixel comparison, the 3-channel OE gives better results than the SST estimation technique presently operational within the Ocean and Sea Ice Satellite Application Facility. This operational technique is to use SST retrieval coefficients, followed by a bias-correction step informed by radiative transfer simulation. However, the operational technique has an additional "atmospheric correction smoothing", which improves its noise performance, and hitherto had no analogue within the OE framework. Here, we propose an analogue to atmospheric correction smoothing, based on the expectation that atmospheric total column water vapour has a longer spatial correlation length scale than SST features. The approach extends the observations input to the OE to include the averaged brightness temperatures (BTs) of nearby clear-sky pixels, in addition to the BTs of the pixel for which

SST is being retrieved. The retrieved quantities are then the single-pixel SST and the clear-sky total column water vapour averaged over the vicinity of the pixel. This reduces the noise in the retrieved SST significantly. The robust standard deviation of the new OE SST compared to matched drifting buoys becomes 0.39 K for all data. The smoothed OE gives SST sensitivity of 98% on average. This means that diurnal temperature variability and ocean frontal gradients are more faithfully estimated, and that the influence of the prior SST used is minimal (2%). This benefit is not available using traditional atmospheric correction smoothing.

The technique should be applicable to other sensors, including dual-view observations such as the future Sea and Land Surface Temperature Radiometer (SLSTR). Adaptations to this and other cases will also be discussed.

MEOP-A/AVHRR DERIVED SST OVER THE ARCTIC: FIVE YEAR (2007-2012) RESULTS

Pierre Le Borgne[(1)], Anne Marsouin, Sonia Péré

(1) Météo-France/Centre de Météorologie Spatiale, Lannion, France Email: pierre.leborgne@meteo.fr

ABSTRACT

SST from METOP-A AVHRR has been produced from 2007 up to now at Centre de Meteorologie Spatiale (CMS) in the framework of EUMETSAT/OSI-SAF. SST has been produced globally, at full resolution. METOP-A/AVHRR derived SSTs have been validated against drifter measurements on an operational basis. A special validation effort has been made for the Arctic Ocean where the SST retrieval conditions are particularly difficult, see Poulter & Eastwood (2008) and Hoyer et al. (2012). These previous studies pointed out positive biases by day and negative biases by night. The daytime positive bias origin has been investigated by Le Borgne et al 2011 who tested a Numerical Weather model derived bias correction on AVHRR data in summer 2008. More recently, a specific bias correction method has been developed by Hoyer et al 2013.

The present study aims to provide an extensive overview of the METOP-A/AVHRR results after 5 years of routine operational production and before the switch to METOP-B, which became operational in April 2013. One of the main objectives of this study is to draw lessons from the METOP-A experience for application to METOP-B in the framework of an upgrade of the OSI-SAF polar orbiter SST chains.

The period studied starts on the 1st October 2007, after a few problems during the first summer of operational use have been solved. It ends on the 30th September 2012. “Arctic” in this study is defined as areas North of 60°N.

This presentation will present detailed validation results and analyze some elements of the SST variability in the Arctic from diurnal warming to seasonal and inter-annual variability.

References

Hoyer, J.L., Karagali, I., Dybkjaer, G. and R. Tonboe, Multi sensor validation and error characteristics of Arctic satellite SST observations, *Remote Sensing of Environment*, 121, 335-346, 2012

Hoyer, J.L., Le Borgne, P. and S. Eastwood, A bias correction method for Arctic satellite sea surface temperature observations, *Remote Sensing of Environment*, submitted, 2013

LeBorgne, P., S. Péré and H. Roquet, Errors and correction of METOP/AVHRR derived SST in Arctic conditions, *Proceedings of the 2011 EUMETSAT meeting*, Oslo, Norway, 2011

Poulter, D.J. and S. Eastwood, Validation of the OSI-SAF METOP SST products in Polar Regions, OSI SAF scientific report, available at http://www.osi-saf.org, 2008

CAL/VAL STATUS OF THE GCOM-W1/AMSR2

Misako Kachi[(1)], Keiji Imaoka[(1)], Takashi Maeda[(1)], Arata Okuyama[(1)], Kazuhiro Naoki[(1)], Masahiro Hori[(1)], Haruhisa Shimoda[(1)(2)] and Taikan Oki[(1)(3)]

(1) Japan Aerospace Exploration Agency (JAXA), Tsukuba (Japan), Email : kachi.misako@ jaxa.jp
(2) Tokai University Research and Information Center (TRIC), Tokai University, Tokyo (Japan)
(3) Institute of Industrial Science (IIS), The University of Tokyo, Tokyo (Japan)

ABSTRACT

AMSR2 onboard the GCOM-W1 satellite has started its continuous scientific observation since July 3, 2012. Inter-calibration of AMSR2 Tb with other passive microwave instruments showed that differences were found between the calibration of AMSR2 and TMI/AMSR-E. The differences seem to be Tb-dependent. Further inter-calibrations are in progress, including comparison with polar orbiting radiometers through TMI or by polar region match-ups, and direct comparison with AMSR-E Tbs obtained by slow rotation observation (from December 2012). Validation results of AMSR2 ocean parameters, such as SST, sea surface wind speed, and sea ice concentration showed that root mean square error (RMSE) of each parameter satisfied required release accuracy defined by user requirements.

AMSR2 Level 1 brightness temperature (Tb) products have been released to public since 24 January 2013, and Level 2 (geophysical parameters including SST) since May 17, 2013. Further calibration and validation activities will be continued toward future algorithm improvements. Latest calibration status is available at GCOM-W1 web site (http://suzaku.eorc.jaxa.jp/GCOM_W/) and L2 validation status is coming soon.

1. Introduction

The Advanced Microwave Scanning Radiometer 2 (AMSR2), which is a successor of AMSR for EOS (AMSR-E), onboard the Global Change Observation Mission – 1st Water (GCOM-W1) was launched on May 18, 2012, and has started scientific observation since July 3, 2012. C-band (6.9GHz/7.2GHz) channels on AMSR-E and AMSR2 are indispensable for retrieving global sea surface temperature and soil moisture. All-weather and frequent measurements enables analyses of rapid changes of SST.

Table 1 is a list of AMSR2 standard products and their required accuracies. Release accuracy should be achieved when data is released to general users. Algorithm version of released brightness temperature (Tb) products is Version 1.1, and that of geophysical parameters is Version 1.0. Calibration and validation results showed that all products showed better accuracy compared to the release accuracy defined in Table 1.

Products	Areas	Resolution	Accuracy			Range
			Release	Standard	Goal	
Brightness Temperature	Global	5-50km	±1.5K	±1.5K	±1.0K (systematic) ±0.3K (random)	2.7-340K
Integrated water vapor	Global, over ocean	15km	±3.5kg/m^2	±3.5kg/m^2	±2.0 kg/m^2	0-70kg/m^2
Integrated cloud liquid water	Global, over ocean	15km	±0.10kg/m^2	±0.05kg/m^2	±0.02kg/m^2	0-1.0kg/m^2

Products	Areas	Resolution	Accuracy			Range
			Release	Standard	Goal	
Precipitation	Global, except cold latitude	15km	Ocean ±50% Land ±120%	Ocean ±50% Land ±120%	Ocean ±20% Land ±80%	0-20mm/h
Sea surface temperature	Global, over ocean	50km	±0.8°C	±0.5°C	±0.2°C	-2-35°C
Sea surface wind speed	Global, over ocean	15km	±1.5m/s	±1.0m/s	±1.0m/s	0-30m/s
Sea ice concentration	Polar region, over ocean	15km	±10%	±10%	±5%	0-100%
Snow depth	Land	30km	±20cm	±20cm	±10cm	0-100cm
Soil moisture	Land	50km	±10%	±10%	±5%	0-40%

Table 1.List of AMSR2 standard products and their required accuracies

2. Calibration

2.1. Inter-calibration with TMI

AMSR2 Tbs (Version 1.1) were inter-calibrated with those of TMI. First, create collocation dataset from AMSR2 and TMI within 15 minutes in time in 0.1 degrees grid size. Second, compute differences between observed- and calculated-Tb (O-C) for both AMSR2 and TMI, over rainforest and cloud-free/calm ocean areas. Global analysis data and Radiative Transfer Model (RTM) are used to derive calculated-Tbs. Finally, create “double difference” to cancel out the differences in frequency and incidence angle. Therefore, comparison is done between AMSR2 (O-C) and TMI (O-C).

Inter-calibration coefficients (slope and intercept) were derived by linear regression. There is no physical meaning of straight-line approximation. Calibration differences at typical Tbs are also shown in Table 2 based on the inter-calibration coefficients. Characteristics of the difference sometimes differ for ocean/land and ascending/descending. Coefficients in Table 2 were determined by using both ocean and rainforests values, and averaged over ascending and descending.

Asc+Dsc	slope	intercept	TB@ocean	ΔT@ocean	TB@land	ΔT@land
10V	-0.01662	6.99952	179	+4.0	285	+2.3
10H	-0.00975	5.61573	91	+4.7	283	+2.9
18V	-0.05124	13.80014	205	+3.3	286	-0.8
18H	-0.01944	4.62348	131	+2.1	284	-0.9
23V	-0.03970	13.47956	237	+4.1	288	+2.0
23H	-	-	-	-	-	-
36V	-0.02711	9.66059	224	+3.6	285	+1.9
36H	-0.02108	7.84445	160	+4.5	284	+1.9
89AV	-0.00141	1.75392	270	+1.4	287	+1.3
89AH	-0.00975	4.97772	242	+2.6	287	+2.2
89BV	-0.00618	3.37024	269	+1.7	287	+1.6
89BH	-0.00545	3.80564	241	+2.5	287	+2.2

Table 2 Inter-calibration coefficients between AMSR2 and TMI.

2.2. Direct comparison with AMSR-E

Since the end of August 2011, the continuous increase of relatively large antenna rotation friction was detected twice in AMSR-E, thus JAXA has been monitoring condition. At 0658UTC in 4 October 2011, the AMSR-E reached its limit to maintain the rotation speed necessary for regular observations (40rpm,) and the radiometer automatically halted its observation and rotation. Since AMSR-E hardware (both sensor and control) is expected in healthy condition except for its large friction with antenna rotation, and cross-calibration between AMSR-E and AMSR2 is very important, JAXA prepared a recovery plan with NASA to avoid any influence to other on board instruments.

AMSR-E observations resumed from December 4, 2012 with 2-rpm rotation speed (Fig. 1). Geolocation and Tbs are computed by modified software. Observation is sparse, but reasonable for global-scale comparison. Calibration improvement of 2rpm mode data is underway.

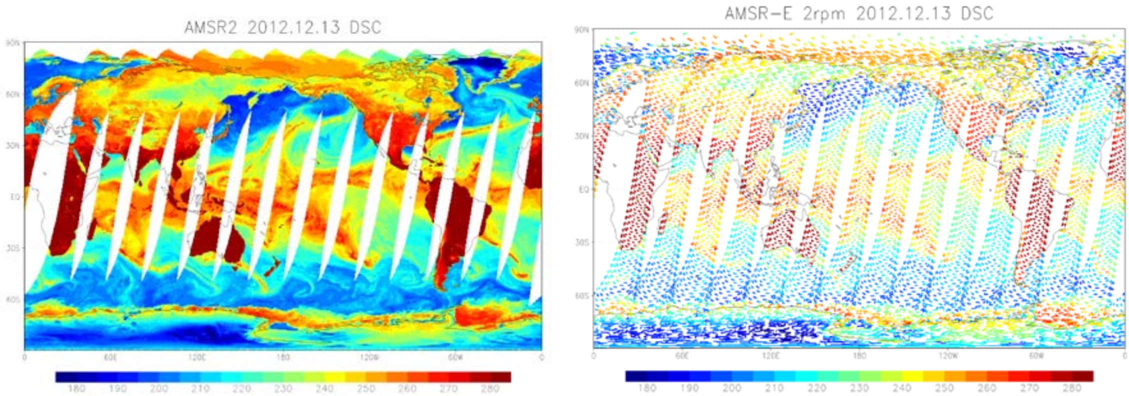


Figure 1. Examples of 23GHz V-pol brightness temperature of AMSR2 (left) and AMSR-E in 2rpm rotation (right).

2.3. Summary of calibration

Brightness temperatures (Tbs) of AMSR2 (Version 1.1) were inter-calibrated with those of TMI and AMSR-E. Differences were found between the calibration of AMSR2 and TMI/AMSR-E. The differences seem to be Tb-dependent. Inter-calibration coefficients (slope and intercept) were derived to compensate the calibration differences. Note that these coefficients are just to cancel out calibration differences. Differences originated from instrument's characteristics (e.g., center frequency and incidence angle) should be handled by users. Investigation of the causes of the calibration differences is underway. Further inter-calibrations are in progress, including comparison with polar orbiting radiometers through TMI or by polar region match-ups, and direct comparison with AMSR-E Tbs obtained by slow rotation observation. Further calibration result is available at GCOM web site (http://suzaku.eroc.jaxa.jp/GCOM_W/materials/w_productinfo.html).

3. Validation

For validation of AMSR2 standard products and development of some research products, JAXA implements two types of activities in cooperation with other researchers and projects. The first category is utilizing the existing ground observation networks maintained by operational agencies and instantaneous observations by other satellites and instruments. The other one is implementation of specific field campaigns and monitoring focusing on specific parameters in collaboration with other projects, especially for land surface variables, such as snow depth and soil moisture content.

In this abstract, we will show results of ocean parameters (SST, sea surface wind speed, and sea ice concentration) only.

3.1. Sea Surface Temperature

AMSR2 SST product is validated by comparing with various buoy SST observations reported through the Global Telecommunication System (GTS) operated by World Meteorological Organization (WMO). Each match-up data includes AMSR2 footprints around buoy stations within radius of 30 km and 2 hours. Root mean square error (RMSE) between AMSR2 and Buoy SSTs from July 6, 2012 to March 31, 2013 is 0.56 °C (Fig. 2) and satisfies required release accuracy defined in Table 1.

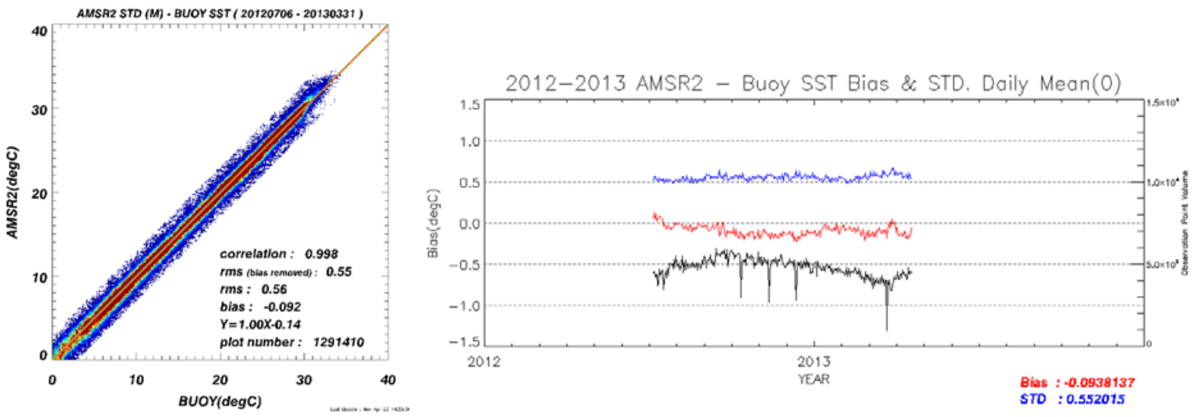


Figure 2. Validation results of AMSR2 with buoy SST. Scatter diagram (left) and time variation (right) of bias (red), standard deviation (blue and number of observation (black).

SST was also validated by campaign experiment. Under joint study between JAXA and Japan Marine Science and Technology (JAMSTEC), SST observation by Research Vessel (R/V) Mirai during its voyage around Pacific Arctic regions from September to October 2012. SST observation at ship bottom (7m depth), where mixing layer assumed to be deeper than 10m depth, was used for comparison. Figure 3 is scatter diagram between AMSR2 SST and ship observation SST from September 4 to October 15, 2012 (left) and passage route of R/V Mirai (right). RMSE of ascending orbit is greater than that of descending orbit (not shown), but RMSE of both ascending and descending orbits is 0.70 °C, which is lower than required release accuracy.

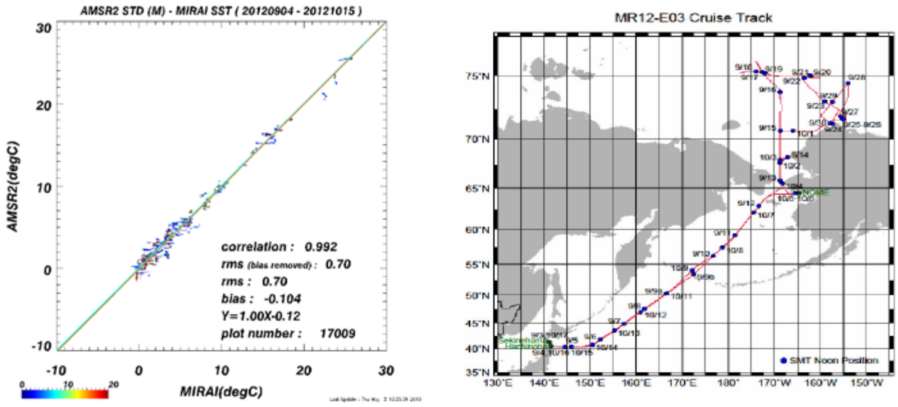


Figure 3. Validation results of AMSR2 with SST observation by R/V Mirai operated by JAMSTEC. Scatter diagram (left) and route of R/V Mirai during the experiment (left). Courtesy of JAMSTEC.

3.2. Sea Surface Wind Speed

AMSR2 sea surface wind speed product is also validated by comparing with buoy wind speed observations reported through GTS. Condition of match-up data is same as SST. RMSE between AMSR2 and buoy sea surface wind speed from July 6, 2012 to March 31, 2013 is 1.12 m/s (Fig. 4) and satisfies required release accuracy of Table 1.

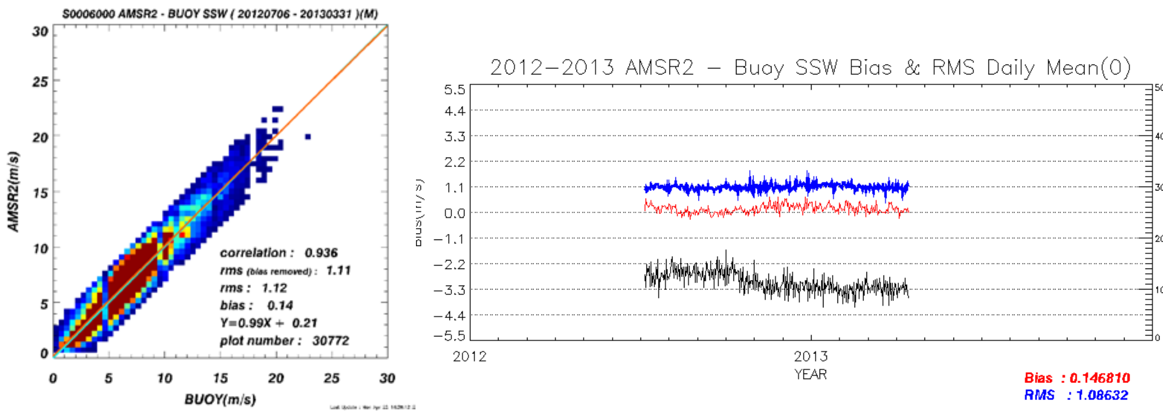


Figure 4. Validation results of AMSR2 with buoy sea surface wind speed. Scatter diagram (left) and time variation (right) of bias (red), standard deviation (blue and number of observation (black).

3.3. Sea Ice Concentration

AMSR2 sea ice concentration product is validated by comparing with the Moderate Resolution Imaging Spectroradiometer (MODIS) cloud product. MODIS onboard NASA's EOS Aqua satellite, which is also flies in A-train orbit, and an imaging spectroradiometer that provides imagery of the Earth's surface and clouds in 36 discrete narrow spectral bands from approximately 0.4 to 14.0 µm. The comparison used MODIS band 2 (0.841 to 0.876µm) where had highest resolution (250m). The MODIS images were acquired under mostly clear sky conditions and coordinated. A threshold technique was determined the ice concentration from the MODIS. The technique defines an ice–water reflectance threshold, allowing each MODIS grid cell to be classified as either ice or water. The 250-m ice grid cells were summed over each co-registered AMSR2 10-km grid cell to provide a 10-km resolution ice concentration. Four match-up cases, which have enough cloud-free view of sea ice concentration in MODIS observation on July 28, 2012, October 31, 2012, November 30, 2012, and March 5, 2013, were carefully selected. RMSE between AMSR2 and MODIS in all match-up cases is 9.38 % (Fig. 5), and it satisfies required release accuracy in Table 1. Right of Figure 5 is overlay of AMSR2 sea ice concentration (color) and MODIS band1 (grey scale) over Arctic Sea/Greenland Sea on July 28, 2012. AMSR2 sea ice concentration gives close agreement with MODIS image in high concentration area, and its ice edge roughly in accordance with MODIS image.

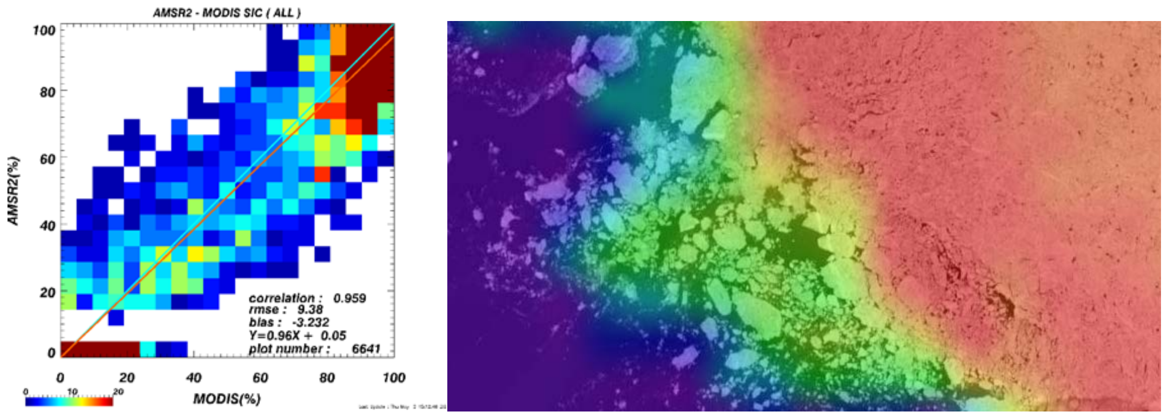


Figure 5. Validation results of AMSR2 with MODIS for sea ice concentration. Scatter diagram of four cases (left) and overlay of AMSR2 sea ice concentration (color) and MODIS band 1 (grey scale) on July 28, 2012.

4. Summary

All AMSR2 standard products have been released to public from GCOM-W1 Data Providing Service System (https://gcom-w1.jaxa.jp/). Level 1 and Level 3 brightness temperature products have been released to public since Jan. 24, 2013. All Level 2 geophysical parameter products satisfied release accuracy required, and Level 2 and 3 geophysical parameter products have been released to public since May 17, 2013. Further calibration and validation activities will be continued toward future algorithm improvements. Latest Level 1 calibration result is available at GCOM-W1 web site, and Level 2 validation results will be available soon (http://suzaku.eroc.jaxa.jp/GCOM_W/materials/w_productinfo.html).

Currently, we're working on introduction of AMSR2 Sea Ice Concentration to be integrated to JAXA long-term Sea Ice dataset (from 1978-present) produced from SMMR, SSM/I, AMSR-E and Windsat data. This dataset is available via JAXA Satellite Monitoring for Environmental Studies (JASMES) web site (http://kuroshio.eorc.jaxa.jp/JASMES/climate/).

For GHRSST users, AMSR2 SST in GDS 2.0 format is now available both near-real-time processing and past period from JAXA GHRSST server (http://suzaku.eorc.jaxa.jp/GHRSST/) along with AMSR-E, Windsat and TRMM/VIRS SSTs. Browse images are also available at the web site.

GCOM-W1 AMSR2 SST

Chelle L. Gentemann

Remote Sensing Systems, Santa Rosa, CA, USA, Email: gentemann@remss.com

ABSTRACT

The Advanced Microwave Scanning Radiometer-2 (AMSR2) carried on the Japan Aerospace Exploration Agency's (JAXA) Global Change Observation Mission – Weather (GCOM-W) satellite was launched on 18 May 2012. The GCOM-W satellite was put in the A-train satellite configuration, positioned directly in front of the Aqua satellite, and will provide global, daily coverage of the Earth with a 1:30 PM equatorial crossing time. AMSR2 is a conically scanning passive microwave radiometer with 14 channels and 7 frequencies. It is a modified version of the AMSR-E designed for NASA's AQUA satellite by the Mitsubishi Electric Corporation. The offset 2.0 meter parabolic reflector rotates a full revolution in 1.5 seconds and will be the largest rotating reflector in orbit. There are 7 feedhorns, one for each frequency, with horizontal and vertical polarizations measured separately at 6.925, 7.33, 10.65, 18.7, 23.8, 36.5, and 89.0 GHz. The cold sky mirror and hot load serve as calibration points for the earth scene brightness temperatures. The satellite will be at an altitude of 700 km measuring a swath width of 1440 km.

GCOM-W AMSR2 has several key differences from the AQUA AMSR-E that will affect the calibration and geophysical retrieval algorithm development. The AMSR-E instrument has a well-established problem with the hot load design which results in calibration errors. The AMSR-E calibration methodology addresses this by modeling the thermal gradients across the hot load. GCOM-W has a new hot load thermal control system which should eliminate the need for this modeling. Another key difference is the addition of a 7.3 GHz channel for possible Radio Frequency Interference (RFI) mitigation. Although RFI is not currently a large problem over the ocean, serendipitously, this channel should result in improved rain retrievals and rain flagging in the SST and wind speed products. Finally, the 2.0 meter reflector will increase the spatial resolution of all retrievals.

The differences between AMSR-E and AMSR2 will be discussed as well as early results producing SST from AMSR2 data.

SECTION 7: FOCUS ON KEY TOPICS RELATING TO LEVEL 4

HIGH RESOLUTION DAILY SEA SURFACE TEMPERATURE ANALYSIS: THE SECOND STAGE OI

Richard W. Reynolds

NOAA Cooperative Institute for Climate & Satellites (CICS,)
Asheville, North Carolina (USA), Email: Richard.W.Reynolds@noaa.gov

ABSTRACT

A two-stage optimum interpolation (OI) analysis processing system has been developed. The first stage uses satellite data from the Advanced Very High-resolution Radiometer (AVHRR) and microwave retrievals for the Advanced Microwave Scanning Radiometer (AMSR) satellite instruments on a 1/4° spatial grid. The second stage is a high-resolution analysis on a 1/24° grid using only AVHRR data. The second stage output is available from 1 June 2002 through 4 October 2011, the period that AMSR data were available. There are two output fields for the second stage: the high-resolution SST and the high-resolution normalized error variance (range 0-1).

1. Introduction

The high-resolution analysis described here is part of a two-stage processing system. Both stages use an optimum interpolation (OI) method. The first stage is carried out on a 1/4° grid using both infrared retrievals and microwave retrievals; the second stage is carried out on a 1/24° grid using only infrared data. The second stage is designed to produce high-resolution features only when high-resolution data are available. If high-resolution data are not available, the resolution of the second stage remains at the original lower resolution of the first stage.

The two-stage processing has several advantages. First the correlations error scales and noise-to-signal ratios can be separately designed for each of the two different grid resolutions. Second, the high-resolution normalized error indicates where high-resolution data were used locally in the high-resolution second stage.

2. First Stage OI, the 1/4° daily low-resolution analysis

The first stage analysis uses satellite data from the Advanced Very High-resolution Radiometer (AVHRR) and microwave retrievals for the Advanced Microwave Scanning Radiometer (AMSR) satellite instruments, the AMSR+AVHRR 1/4° OI. As discussed in (2) microwave instruments have excellent open ocean coverage compared to infrared instruments because microwave retrievals can be made in cloudy regions. Thus, a first stage analysis using AMSR will not have open ocean regions without retrievals for long periods as can occur with infrared retrievals in regions with persistent cloud cover. The retrievals from the AMSR instrument are available from 1 June 2002 through 4 October 2011 when the instrument failed. If AMSR or an equivalent microwave product is not used, the first stage would not be as solid a foundation for the second stage analysis in regions with persistent clouds.

3. Second Stage OI, the 1/24° daily high-resolution analysis

Although microwave has better coverage than infrared, microwave has lower resolution for its retrievals (~50 km) while infrared resolution can approach 1 km. Thus, the high-resolution second stage analysis is done using the OI with infrared satellite data only. The high-resolution second stage is designed to use AVHRR Pathfinder version 5.2 (1). These data are available as high resolution gridded fields on 1/24° grid. The analysis uses the same grid but only data with the highest Pathfinder quality flag (flag=7) are used. The analysis is presently limited to the period for which AMSR data were available for the first stage low-resolution analysis, 1 June 2002 through 4 October 2011. However, both stages of the analysis could be extended in real-time using other microwave and infrared data.

Before computing the high-resolution analysis it is necessary to define the spatial error correlations, C(x), and noise-to-signal variance ratio, V(x). For the low-resolution analysis these are defined in (2). When the method described there was applied to the high-resolution data, the results were noisy because of large gaps in the high-resolution data. Other statistical computations showed that parameter changes from low to high resolution can be expressed as

$$C_H(x) = C_L(x) / R \qquad \text{and} \qquad V_H(x) = V_L(x) * R$$

Here the subscripts H and L stand for high and low resolution and R is a factor which ranges from 1 to G_L/G_H where G_L= 1/4° and G_H= 1/24° are the spatial grid scales. Thus, G_L/G_H=6 and 1< R< 6. As R increases the high-resolution error correlation decreases, while the noise-to-signal ratio increases. The factor, R, was determined by experimentation. A value of R = 3 was selected as producing a good balance between resolution and noise.

The high-resolution first guess is a simply the low-resolution analysis (AMSR+AVHRR OI) interpolated to high resolution at the same time step. If the low-resolution analysis is linearly interpolated to a high-resolution grid without smoothing, high-resolution noise will be generated because the interpolated field will not have a continuous spatial first derivative. To correct this problem, the low-resolution analysis is first linearly interpolated to high resolution and then smoothed. The smoothing is done with equal weights (boxcar smoothing) over a sliding box of 11 by 11 high-resolution grid points. (At the equator the box size is 51 by 51 km.) The low-resolution analysis impacts the high-resolution analysis through the low-resolution first guess. However, the high-resolution analysis has no effect on the low-resolution analysis, i.e., the link between the two stages is only one way.

The low-resolution analysis includes a bias adjustment based on in situ data. However, that adjustment is done with spatial resolution of roughly 10° because of the sparse data density of in situ observations. The bias adjustment must be done on finer scales or the high-resolution analysis may show strong gradients between regions with and without high-resolution data. To avoid this, each day of daytime and night time high-resolution data is separately averaged to the low-resolution grid and analyzed on the low-resolution grid with the low-resolution analysis (AMSR+AVHRR OI) as a first guess. For both day and for night, the low-resolution analysis at the same time step is used as the first guess. The difference between each low-resolution analysis and the low-resolution first guess is defined as the low-resolution day and night bias. The bias is interpolated to the high-resolution grid and used to remove any biases in the high-resolution data. The interpolation uses the same method as described above to interpolate the low-resolution first guess to the high-resolution first guess. The bias corrected high-resolution data is used in the high-resolution analysis.

An example of the bias correction is shown in Figure 1 for 1 June 2002 with respect to the high-resolution first guess. The top panels show the uncorrected day and night observations differences; the bottom panels show the bias correction day and night observation differences. The differences are lower when the biases are corrected. It is also important to note the scarcity of the observations. In regions of persistent cloud cover, the coverage can only partially be improved by adding several days of data or using multiple infrared satellite instruments.

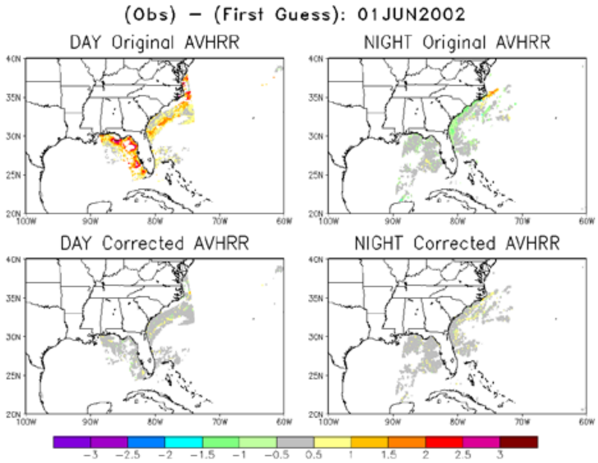


Figure 1. The difference between the high-resolution data and the low-resolution first guess interpolated to high resolution for 1 June 2002. The uncorrected and bias corrected differences are shown in the top and bottom panels, respectively. Day and night observations are in the left and right panels. The color scale is in °C.

At each grid point with nearby data, a solution is found as described in equations 3-5 in (2). The computational time for a local OI solution for each set of linear equation is proportional to the square of the number of data points, N, used. To reduce the solution time at a given data grid point, only data within a given radius, presently 15 km, are used. Furthermore, if the number N is greater that N_{max} , presently 21, only the most important N_{max} points are used. The importance is ranked by choosing data points with the largest diagonal terms in equation 5 in (2). If the noise-to-signal ratio is locally roughly constant, this method selects the closest data points to the solution point. The tendency for the analysis to focus on the closest grid points also tends to sharpen the high-resolution feature resolution beyond what could be expected from the correlation scales alone.

Because the high-resolution first guess is independent of previous high-resolution analyses, three consecutive days of data are used. If the analysis is done at time t, the three consecutive days are at times, t-1, t, and t+1. To provide a smoother temporal transition between analyses, the noise-to-signal standard deviation ratio was increased by a factor of 2 for times t-1 and t+1.

Even with the bias correction on low-resolution scales, strong spatial gradients occur in regions near the boundaries of sparse high-resolution data coverage. Furthermore, the high-resolution features tend to extend into the low-resolution regions. To allow the analysis to reduce the importance of regions with low data coverage, the noise-to-signal standard deviation ratio is increased by a factor, $F = N_{max}/N$ for $N<N_{max}$ or $F = 1$ for $N \geq N_{max}$. Here $N_{max} = 21$ and N is the number of points analyzed in each analysis solution. Thus, as N decreases below N_{max}, the noise-to-signal ratio increases by F.

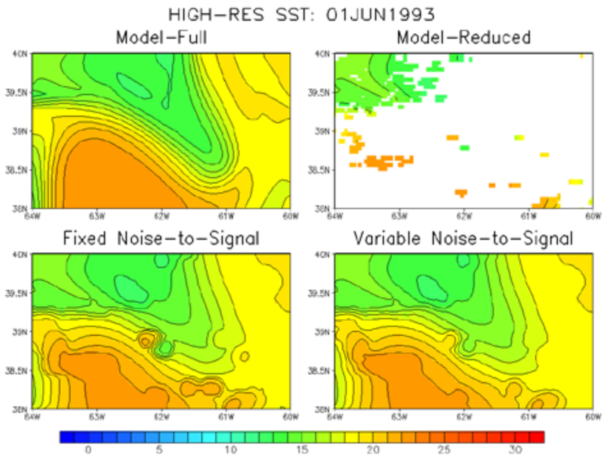


Figure 2. SST model data and SST analyses for 1 June 1993 for a region in the Gulf Stream. The top panels show the full high-resolution model data (left) and the reduced high-resolution model data (right). The reduced data are reduced by actual AVHRR sampling. The bottom panels show the high-resolution analyses. The left panel shows the analysis using a fixed noise-to-signal ratio; the right shows a variable noise-to-signal ratio. The color scale is in °C.

Using the full ocean model dataset discussed in (3), it is possible to see the impact of the variable noise-to-signal ratio. The left top panel in Figure 2 shows the full model field using a 3-day average for 1 June 1993. The right top panel shows how the data density is lowered when observations are reduced by actual AVHRR data coverage. In particular note the small dipole near 39°N and 62°W. The frontal gradient in the full dataset moved over the 3-day period. However, due to sparse sampling, an erroneous dipole was created that is not supported by the full dataset. In the bottom panel on the left, the high-resolution analysis is run with a fixed noise-to-signal ratio. In this case the analysis shows the dipole. However, in the bottom panel on the right the variable noise-to-signal ratio allows the analysis to reduce the impact of the dipole. However, other features with adequate data, e.g., in the northwest corner of the figure, are correctly resolved in both analysis versions.

4. Results

The high-resolution analysis was run from 1 June 2002 through 4 October 2011. There are two output fields, the high-resolution SST and the high-resolution normalized error. The normalized error variance is given by equation 6 in (2) when the analysis increment error, V_k^2, is set to 1. The normalized error variance is 1 when there are no data used locally in the analysis and decreases towards 0 as the local data density increases. Monthly averages of the normalized error are useful in determining where high-resolution features are likely.

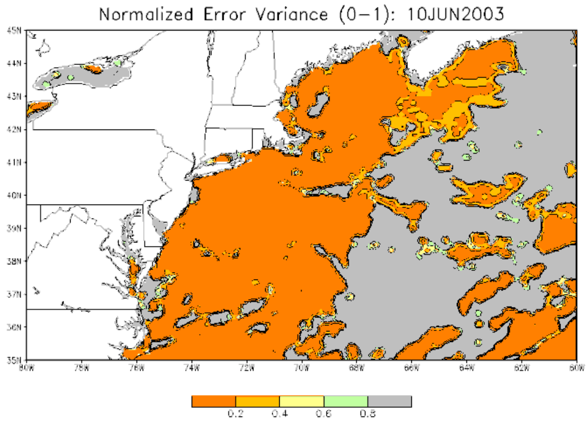


Figure 3. Monthly average normalized error variance for January (top) and July (bottom) 2003. The normalization error is 1 when there are no high-resolution data and reduces toward 0 as the local high-resolution data density increases.

The monthly averages suggest that daily high-resolution features would be unlikely in the Gulf Stream in winter but likely in summer. To investigate a summer pattern, the daily normalized error is shown for for 10 June 2003 in Figure 3. This example shows that the daily normalized error for the analysis is more binary than the monthly averages with regions with high-resolution data (normalized error <0.4) and those without (normalized error >0.4). In this example high-resolution features would be missing in roughly the eastern half of the region shown. The corresponding high-resolution first guess, interpolated from the low-resolution first guess, and the high-resolution analysis for the same region and date are shown in Figure 4. The results clearly show that high-resolution features only occur in regions with normalized error <0.4. The advantage of this two-stage analysis is that the high-resolution analysis can be adjusted to only show high-resolution features when high-resolution data are available. Thus procedure avoids generating high-resolution noise when there are no high-resolution data as discussed in (3).

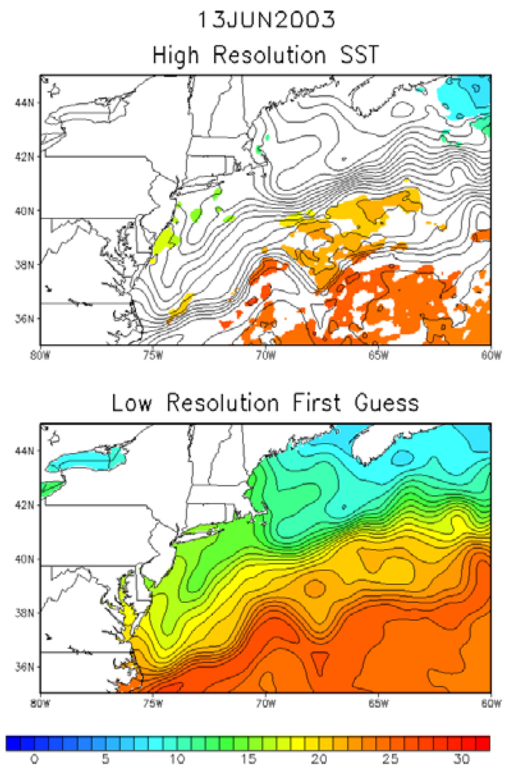


Figure 4. The high-resolution analysis (top) and low-resolution first guess interpolated to high resolution (bottom) for 10 June 2003. The shading and contours are 1°C. High-resolution features are only available when the normalized error in Figure 6 is <0.4; these regions are shaded in the high-resolution analysis (top).

Acknowledgement: The Pathfinder SST Climate Data Records used in this study was acquired from NOAA's National Climatic Data Center (http://www.ncdc.noaa.gov).

5. References

1. Casey, K. S., T. B. Brandon, P. Cornillon, and R. Evans, "The Past, Present and Future of the AVHRR Pathfinder SST Program", in *Oceanography from Space: Revisited*, eds. V. Barale, J. F. R. Gower, and L. Alberotanza, Springer, 2010 DOI: 10.1007/978-90-481-8681-5_16.

2. Reynolds, R. W., T. M. Smith, C. Liu, D. B. Chelton, K. S. Casey, and M. G. Schlax, "Daily high-resolution blended analyses for sea surface temperature", *J. Climate,* **20***,* 5473-5496, 2007.

3. Reynolds, R. W., D. B. Chelton, J. Roberts-Jones, M. J. Martin, D. Menemenlis, and C. J. Merchant, "Objective determination of feature resolution in two sea surface temperature analyses". *J. Climate*, **26**, 2514–2533, 2013

EVALUATION OF GHRSST PRODUCTS FOR STUDIES OF SHORT TERM CLIMATE VARIABILITY – A COMPARISON BETWEEN OSTIA AND NCDC 0I2 ANALYSES

Dudley B. Chelton and Craig M. Risien

Oregon State University, College of Earth, Ocean and Atmospheric Sciences,
104 CEOAS Administration Building, Corvallis, OR, 97331-5503, USA,
Email: chelton@coas.oregonstate.edu, crisien@coas.oregonstate.edu

ABSTRACT

Most of the emphasis of GHRSST is focused on improving the spatial and temporal resolution of SST analyses. Aside from the problem of temporal aliasing of poorly resolved high-frequency variability (e.g., the diurnal cycle), many applications of SST analyses do not require high spatial or temporal resolution. For example, short-term climate variability is often investigated from monthly averages. For such studies, resolution is generally of secondary concern; the primary concern is accuracy. SST anomalies from the seasonal cycle are typically only 0.4–0.6°C and seldom exceed 1.2°C. Since the magnitudes of SST anomalies are comparable to the accuracy of the satellite measurements themselves, it is crucially important that non-random components of measurement errors be very small. Identifying non-random errors in SST analyses is challenging since the true SST is unknown. However, the degree to which non-random errors are a concern can be assessed from cross comparisons between different GHRSST products.

An analysis of monthly averages of the OSTIA and NCDC OI2 SST products for the time period April 2006 through February 2013 reveals surprisingly large differences that often exceed 0.5°C over vast areas spanning thousands of kilometers. There does not appear to be any geographical preference for these differences; they occur at different times and locations throughout the World Ocean and they often persist for several months at a time. The differences appear to be attributable to a wide variety of causes, including aerosols over the eastern tropical Atlantic, clouds in southeastern tropical Pacific, ice around Antarctica and in the high-latitude North Pacific, differences in the details of the analysis procedures, and differences in the SST measurements that are incorporated in each analysis product.

The conclusions of this study are that GHRSST should focus at least as much attention on the accuracies of the SST measurements as on the resolution of the SST analyses.

SST DATA IMPACT IN GLOBAL HYCOM

James A. Cummings

Naval Research Laboratory, Oceanography Division, Monterey, California, USA 93943
Email: cummings@nrlmry.navy.mil

ABSTRACT

An adjoint-based procedure to determine the impact of assimilation of observations on reducing ocean model forecast error has been integrated into the Navy's global HYCOM ocean analysis/forecast system (Cummings and Smedstad, 2013). Adjoint sensitivity gradients and actual model-data differences are used to estimate the impact of each observation assimilated on a measure of model forecast error (Langland and Baker, 2004). It is not necessary for an observation to produce a large change in the model initial conditions to have a large impact on reducing model forecast error. Observations with small model-data differences can have large impacts when the observation influences a dynamically sensitive location. The method provides a feasible all at once approach for determining observation impacts. The procedure is computationally inexpensive and can be used for routine observation monitoring. Data impacts can be partitioned for any subset of the data assimilated: instrument type, observed variable, geographic region, vertical level, or platform with traceability to individual platforms based on call sign. Results presented here show the impact of assimilation of the various SST observing systems on reducing HYCOM 48-hour temperature forecast error.

1. Introduction

Data assimilation corrects the errors of a short-term model forecast with new observations in order to generate improved initial conditions for the next forecast run of the model. It is likely that observations assimilated do not have equal value in terms of correcting model forecast error. The challenge then is to determine which observations are best. Adjoint-based data impact systems provide an objective and quantitative method to determine the value of the data assimilated. It is not necessary to add or remove observations from the assimilation to estimate data impact as is done in data denial experiments. This is advantageous since ocean observing and assimilation/forecast systems are in continuous evolution requiring an efficient procedure that allows the impact of observations to be regularly assessed.

2. Progress

The adjoint of the Navy Coupled Ocean Data Assimilation (NCODA) 3DVAR has been integrated into the Navy global HYCOM analysis/forecast system. HYCOM is executed on a global 1/12° resolution grid and cycles with the 3DVAR every 24 hours. Observation impact requires a forecast error metric which is calculated here as the difference between 72 and 48 hour forecasts valid at the same time. Any difference between the two model trajectories is due entirely to the assimilation of observations and represents the impact of observations assimilated on reducing HYCOM 48 hour forecast errors. HYCOM forecast errors are calculated for full model temperature, salinity, and velocity fields and are assumed to be valid at the model initialization time. Data impacts are calculated for each observation assimilated. A negative value indicates a beneficial impact (forecast errors decreased from assimilation of the observation), while a positive value indicates a non-beneficial impact (forecast errors increased). Non-beneficial data impacts are not expected. If they occur, and are persistent, then it may indicate problems in the data quality control, instrument calibration, error statistics used in the assimilation, or model error. Thus, the adjoint-based data impact system can be used as an effective observing system monitoring tool.

Figure 1 gives an example of a HYCOM forecast error map for SST in the Gulf of Mexico on 24 July 2012. Considerable flow dependence is seen in the forecast errors associated with the loop current and a large eddy in the center of the Gulf. Figure 2 gives a time series of daily impacts of satellite SST observing systems averaged over the HYCOM Atlantic basin during October-November 2012. All sources of satellite SST assimilated reduce HYCOM forecast errors every day. Figure 3 shows the geographic variability of METOP-A and GOES data impacts averaged on the HYCOM grid during the same time period. In general, beneficial impacts are seen almost everywhere. However, some persistent non-beneficial impacts occur with the METOP-A data in the eastern tropical Atlantic likely associated with atmospheric dust, and in the eastern fringe of the GOES data probably due to scan angle dependent errors. Finally, Figure 4 gives rank histograms showing the relative importance of the satellite SST observing systems assimilated by global HYCOM in the Atlantic. METOP-A and NOAA-19 have nearly equivalent data impacts with GOES data the least important source of satellite SST data assimilated on a per observation basis. No discernible difference is found in the impacts of day vs. night and GAC vs. LAC retrieval types for METOP-A in HYCOM, although LAC data types are by far the most frequent.

3. Future Capabilities

In addition to global HYCOM, the NCODA 3DVAR adjoint has been integrated into the Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS) adjoint-based observation impact system. Here, atmospheric forecast error metrics (dry energy, moist energy, refractivity) and the adjoint of atmospheric forecast model are used to determine initial condition sensitivity gradients and quantify the impact of SST observations on high-resolution forecasts of atmospheric boundary layers. Thus, the NCODA adjoint-based data impact system can be used to determine the relative importance of the various satellite SST observing systems on both ocean and atmospheric forecast systems. This work is on-going.

4. References

Cummings, J. and O.M. Smedstad (2013). Variational Data Assimilation for the Global Ocean. In, *Data Assimilation for Atmospheric, Oceanic & Hydrologic Applications (Vol. II*). S. Park and L. Xu (eds). Springer, pp. 303-343.

Langland, R. and N. Baker (2004). Estimation of observation impact using the NRL atmospheric variational data assimilation adjoint system. Tellus 56A:189-201.

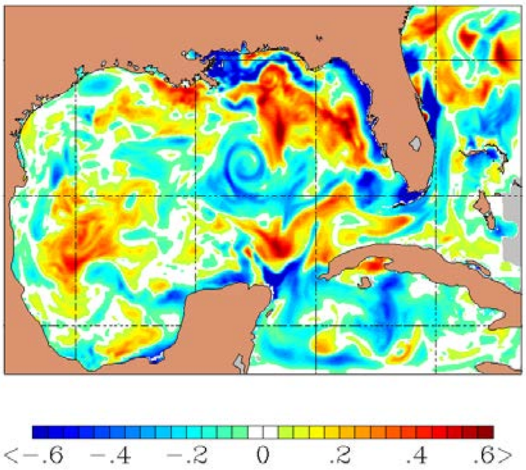


Figure 1. HYCOM SST forecast errors in Gulf of Mexico 24 July 2012. Negative values indicate forecast error reduction; positive value indicates forecast errors increase.

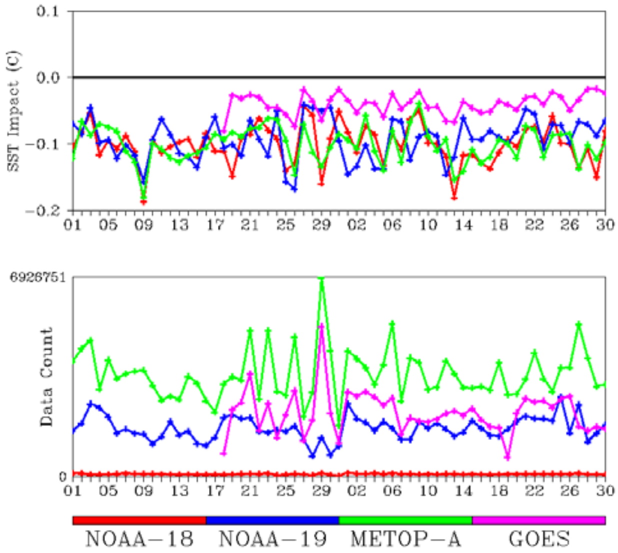


Figure 2. Daily satellite SST data impacts for HYCOM Atlantic basin: October-November 2012. Negative values indicate beneficial impacts.

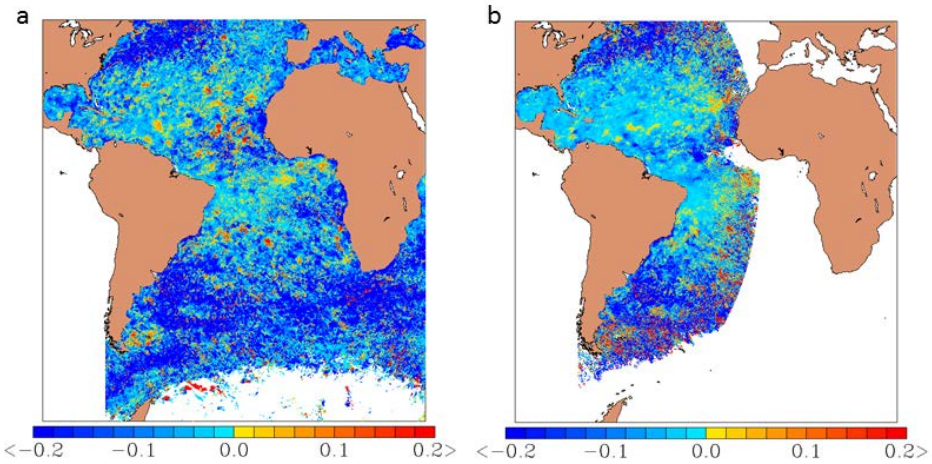


Figure 3. Geographic distribution of SST data impacts averaged on the 1/12° HYCOM Atlantic basin model grid for October-November 2012. (a) METOP-A, (b) GOES. Negative values (cool colors) indicate beneficial impacts.

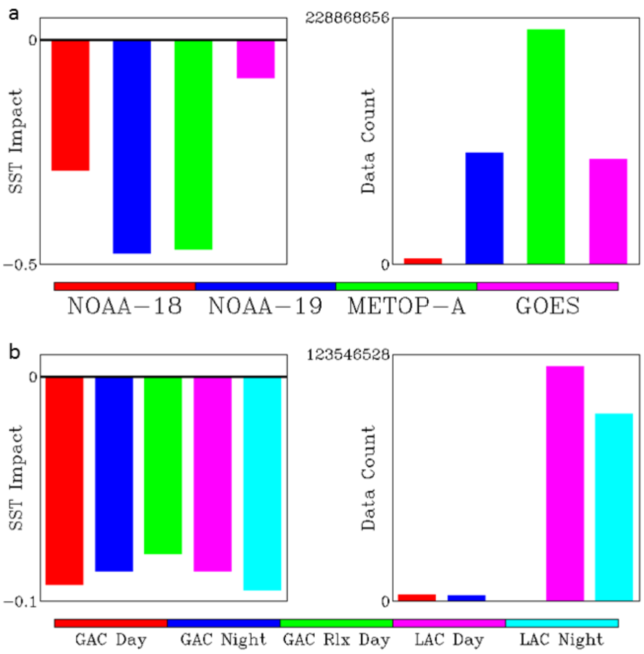


Figure 4. Rank order histograms of HYCOM Atlantic basin satellite SST data impacts and observation data counts for October-November 2012. (a) Satellite SST observing system data impacts; (b) METOP-A retrieval type data impacts. Negative values indicate beneficial impacts.

SECTION 8: FOCUS ON KEY TOPICS RELATING TO CLIMATE

ESA SST CCI L4 REANALYSIS USING THE OSTIA SYSTEM

Jonah Roberts-Jones[(1)], Emma Fiedler[(1)], Alison McLaren[(1)], Christopher Merchant[(2)]

(1)Met Office, Fitzroy Rd, Exeter, UK. Email: jonah.roberts-jones@metoffice.gov.uk
(2)University of Reading, Whiteknights, Berkshire, UK.

ABSTRACT

A high resolution L4 SST and sea-ice reanalysis has been produced as part of the European Space Agency SST Climate Change Initiative (ESA SST CCI) project using the Operational SST and sea Ice Analysis (OSTIA) system at the UK Met Office. The ESA SST CCI L4 reanalysis is a global, daily product produced on a 1/20° (~6km) grid running from 1st Aug 1991 to 31st Dec 2010. The observational data sources used are ATSR, NOAA AVHRR and METOP AVHRR data and have been generated specifically for the project using a new, consistent SST retrieval method. The observations retrieve SST at 20cm depth which has enabled, for the first time, the OSTIA system to produce a daily mean SST analysis at 20 cm. The L4 analysis is unique in using satellite observations only and thus the withholding of in-situ data enables validation using an independent data source for the full reanalysis period.

An overview of the L4 ESA SST CCI reanalysis system and will be presented with a focus on the improvements implemented compared to the previous OSTIA reanalysis. Results of the assessment of the L4 ESA SST CCI reanalysis will be shown which includes independent validation statistics for the full reanalysis period.

A MULTI-SENSOR SST REANALYSIS FOR THE ARCTIC OCEAN

Jacob L. Høyer, Eva Howe, Gorm Dybkjær & Rasmus Tonboe

(1) Center for Ocean and Ice, Danish Meteorological Institute, Denmark, Email:jlh@dmi.dk

ABSTRACT

Satellite sea surface temperature (SST) observations in the Arctic Ocean have been demonstrated to be a challenging task with the presence of sea ice, persistent cloud cover and large atmospheric variability. The construction of a level 4 SST reanalysis product does therefore require special treatment for the Arctic Ocean.

A new bias correction method has been developed specifically for the Arctic Ocean, with the aim of improving the L4 performance in high latitude regions (Høyer et al, 2013). The method applies regional and sensor specific statistics to take into account the error and sampling characteristics for the satellite sensors. This algorithm has been demonstrated to work well and has been used to construct a 30 year level 4 reanalysis with daily SST fields for the Arctic Ocean from 1982 to 2012. The reanalysis includes satellite observations from the ATSR Reprocessing for Climate (ARC) and the NOAA AVHRR pathfinder project. In addition, in situ observations from the ICOADS dataset are used for validation and the Eumetsat OSI-SAF sea ice reanalysis is included for ice masking.

An independent validation has been performed against independent in situ observations, revealing a stable performance throughout the time period, with a mean bias < 0.05 deg. C and standard deviations of 0.6 deg. C. The performance is better than the original uncorrected L2 observations from AVHRR. Trends in SST over the 30 years will be presented for the entire domain together with their statistical confidence. Comparisons will be presented with trends from the original L2P observations and in situ observations in areas with good data coverage. Regional examples of monthly SST variations throughout the time period will be given for Greenland waters and for areas in the Arctic Ocean where the decreasing ice cover has resulted in larger areas with open waters during summer. Special attention will be devoted to the performance of the reanalysis in the Marginal Ice Zone, as this is an area where a large discrepancy is found in the existing level 4 products.

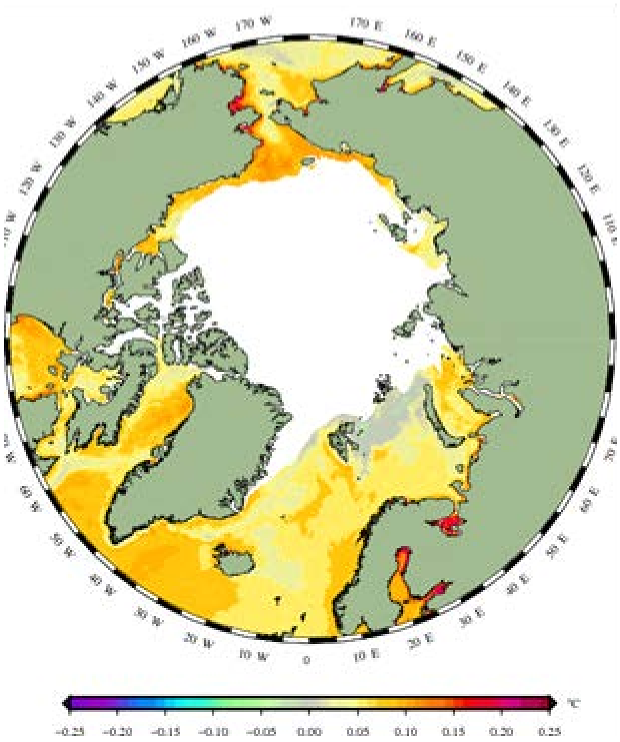


Figure 1: Linear trends in oC /year in SST from 1982 to 2012, estimated from monthly averages of the L4 fields.

References

Høyer, J. L., Le Borgne, P. and Eastwood, S., A bias correction method for Arctic satellite sea surface temperature observations, *Rem Sens. Env*., *In press,* 2013.

SAMPLING ERRORS IN SATELLITE DERIVED SEA SURFACE TEMPERATURE FOR CLIMATE DATA RECORDS

Yang Liu[(1)], Peter J. Minnett[(2)]

(1) Meteorology & Physical Oceanography, Rosenstiel School, University of Miami, USA
Email: yliu@rsmas.miami.edu
(2) Meteorology & Physical Oceanography, Rosenstiel School, University of Miami, USA
Email: pminnett@rsmas.miami.edu

ABSTRACT

Climate Data Records (CDR) have stringent requirements on the accuracies of satellite SST products. For Infrared SSTs, sampling uncertainties caused by cloud presence generate errors. In addition, for sensors having narrow swaths, the swath gap will act as another sampling error source. In this study, sampling performance of the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Terra satellite is investigated. To assess these errors, the sampling errors are assessed by sampling a reference Level 4 SST field (G1SST) using swath and cloud masks of MODIS. Global and regional SST uncertainties from the two sources are studied by assessing the sampling error propagating from high temporal and spatial resolutions to low (6 spatial resolutions from 4 kilometers to 2.5° and 5 temporal resolutions from daily to monthly).

1. Introduction

Satellite derived Sea Surface Temperature (SST) has contributed to numerous aspects of climate research. For the Climate Data Record (CDR) purposes (National Research Council, 2004), requirements on the accuracy of derived SST suggest an absolute temperature uncertainty of 0.1K and trend stability of better than 0.04K per decade (Ohring et al., 2005). Satellite IR sensors provide a relative high accuracy and therefore the measured IR SST acts as a credible source. To generate SST CDR with the high-level requirements, uncertainties in satellite IR SST products must be quantified. Various sources of uncertainties dominate in different IR SST production steps and are accumulated at successive data levels (Level 1 to Level 4). Gap-free Level 4 fields make them desirable for climate models and studies. However for IR SST, sampling errors resulting from the presence of clouds at level 2 that propagate into Level 4 needs to be quantified, since the presence of clouds will cause significant undersampling. In addition, the gap between successive swaths of some sensors also leads to sampling errors. For daily sampling, sensors with a broad swath width hold better potential to sample the earth's oceans than do sensors with narrow swaths. Sampling errors caused by both cloud mask and narrow swath width are propagated into level 4 and therefore act as uncertainties in generating SST CDRs. In this study, these sampling uncertainties are studied and assessed.

2. Data and Methods

MODIS cloud masks at 4km and daily resolution are used. G1SST is selected as our Level 4 reference, which is an 1km resolution SST analysis using SST observations from multiple sources. The study period includes 31 days from 2010.12.26 to 2011.1.25.

The G1SST fields are resampled into 4 kilometer basic resolution maps, The MODIS sampled G1SST is generated by eliminating the 4 kilometer G1SST pixels which are identified as cloudy or fall in a swath gap in the MODIS field. The sampled SST and the G1SST at the base resolution (4km×4km and daily), were aggregated into a range of discrete temporal (1day, 3days, 1week, 2weeks, and 1month) and spatial (4km, 12km, 0.25°, 0.5°, 1°, 2.5°) resolution:

$$\mathrm{SST}_{RT} = \frac{1}{\mathrm{n_R} \times \mathrm{n_T}} \sum_{\mathrm{i=1}}^{n_R} \sum_{\mathrm{j=1}}^{\mathrm{n_T}} \mathrm{SST}_0^{\mathrm{ref}} \tag{1}$$

$$\mathrm{SST}_{RT}^{ref} = \frac{1}{\mathrm{N_R} \times \mathrm{N_T}} \sum_{\mathrm{i=1}}^{\mathrm{N_R}} \sum_{\mathrm{j=1}}^{\mathrm{N_T}} \mathrm{SST}_0^{\mathrm{ref}} \tag{2}$$

where SST_0^{ref} is the G1SST at base resolution, $\mathrm{n_R}$ and $\mathrm{n_T}$ are the number of sampled reference SSTs for the R spatial resolution and T temporal resolution resampling box. $\mathrm{N_R}$ and $\mathrm{N_T}$ are the maximum number of reference SSTs in the resampling box.

Sampling errors $Diff_{RT}$ are represented by the differences between the sampled SST and the G1SST at each grid box at each spatial and temporal resolution.

$$Diff_{RT} = \mathrm{SST}_{RT} - \mathrm{SST}_{RT}^{ref} \tag{3}$$

A gap fraction is defined as the percentage of missing data in each resampling box.

$$Gap\_F_{RT} = 1.0 - \frac{n_r \times n_t}{N_r \times N_t} \tag{4}$$

3. Results

In global ocean, the root mean square error of the sampled SST shows relatively low values at both the highest and lowest resolutions, which is illustrated by the saddle shaped region in the first column of Figure.1. The global mean sampling error shows warm biases in the high spatial and low temporal resolutions and cold biases in the low spatial and high temporal resolutions. Besides, there is an apparent difference of 0.02 K between the day and night time biases (second column, Figure.1). At the highest downsized resolution (or base resolution) the sampled global mean SST has approximately +3.00K biases. But the accurate global mean SST (~0.10K bias) can be obtained by averaging the sampled SST to 2.5° and monthly resolution (third column, Figure.1). The global gap fraction distribution (last column, Figure.1) is closely related to the bias distribution of global mean SST, which indicates gaps due to clouds presence and swath width are responsible for significant global sampling errors.

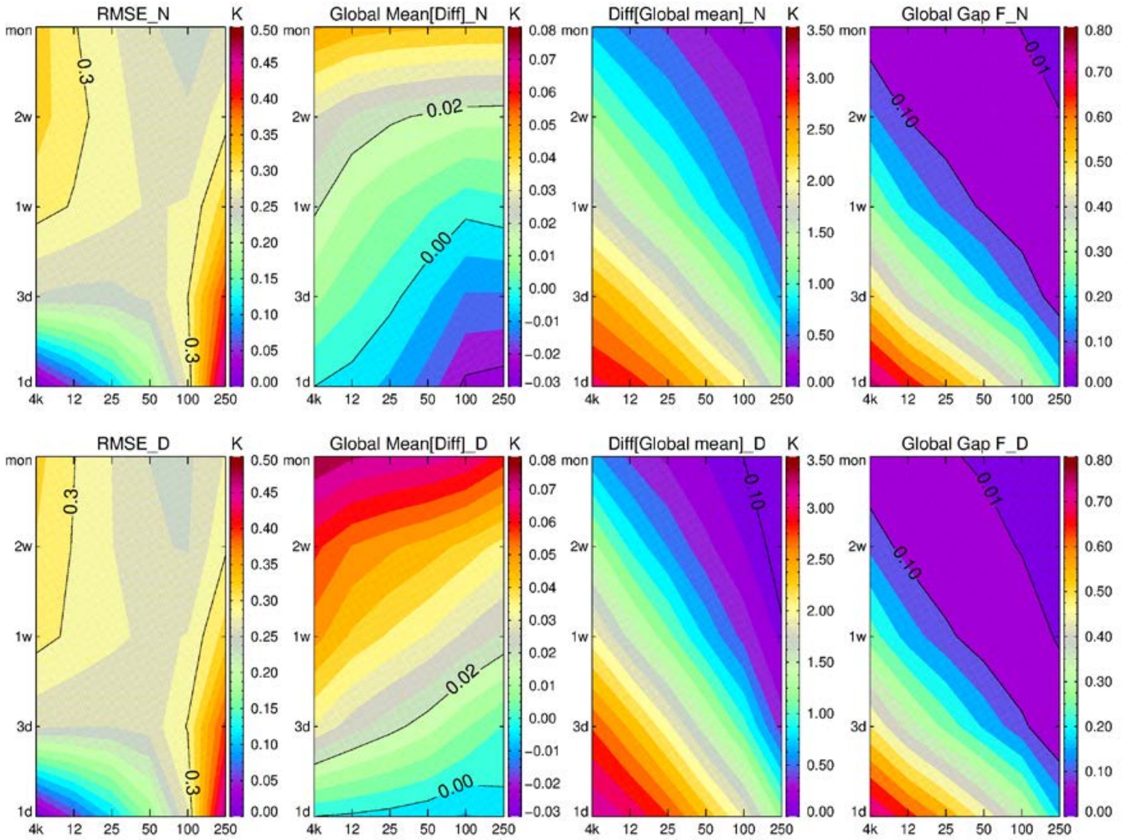


Figure 1. Global Statistics of sampling errors and gap fraction at all studied resolutions. Top: Night; Bottom: Day

Natural SST variability is also responsible for significant sampling errors. Figure.2 shows the comparison between the sampling error or difference (first column), gap fraction (second column) and the G1SST standard deviation at three resolutions for the global daytime sampling. The lowest sampling errors are more likely to occur in the middle of subtropical ocean gyre and at the northern boundary of the Indian Ocean. These areas are also characterized by relatively low gap fraction and SST standard deviation. However, regions characterized by large gap fraction and high SST standard deviation are prone to large sampling errors.

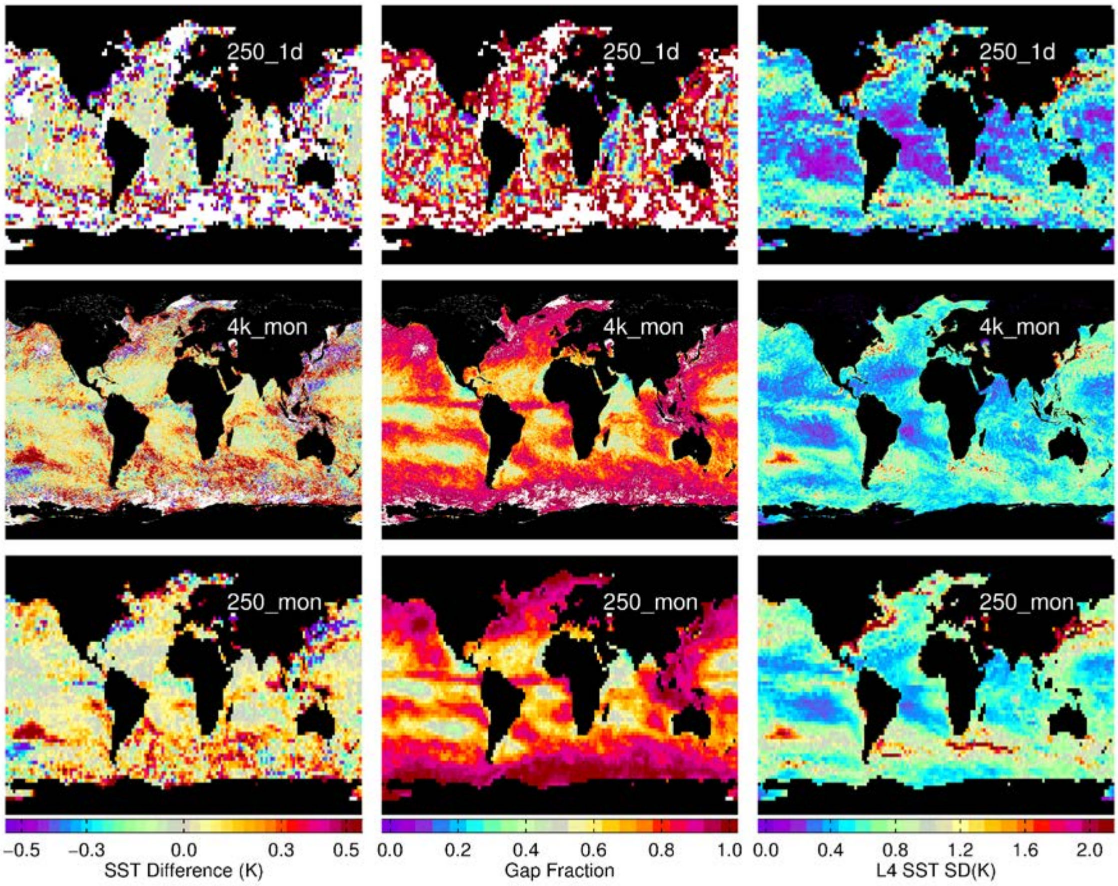


Figure.2. Global distributions of SST difference, gap fraction for daytime sampling and Level 4 SST standard deviation.

Noting the complex geographic distribution of sampling errors, some resemble the spatial or temporal variability of the SST field, some are more likely due to the cloud over, the magnitude of sampling errors is a combined consequence of both gaps (cloud cover) and SST variability. Figure.3 shows the sampling error increases significantly with either gap fraction or SST standard deviation when averaged to the lowest temporal or lowest spatial resolution. The mean error at the maximum gap fraction is about ±0.5K. But there are extreme cases when error exceeds ±5K.

4. Summary

Sampling errors caused by cloud and swath gap are significant and cannot be neglected when interpreting or using Level 3 and Level 4 fields. For sampling errors in global mean SST less than 0.1K, only resolutions at 1° and monthly, 2.5° and 2 weekly, or 2.5° and monthly data should be used. Sampling error distribution is related to both cloud and ocean properties, therefore regional statistics are needed for characterizing the errors. Real Level 4 fields include errors inherited from Level 2 and the additional complexity coming from sophisticated interpolation algorithms, which could either increase or decrease sampling error. But these cannot be simply assessed by using the method used in this study.

5. Future Work

Different seasons will be included in the statistics. Possible diurnal variation of sampling error will be investigated by comparing with the MODIS sampling on Aqua. Sampling error will be further quantified by characterizing either geography or cloud and ocean surface properties. In addition, AATSR and VIIRS data will be compared to assess the added issues of different swath widths.

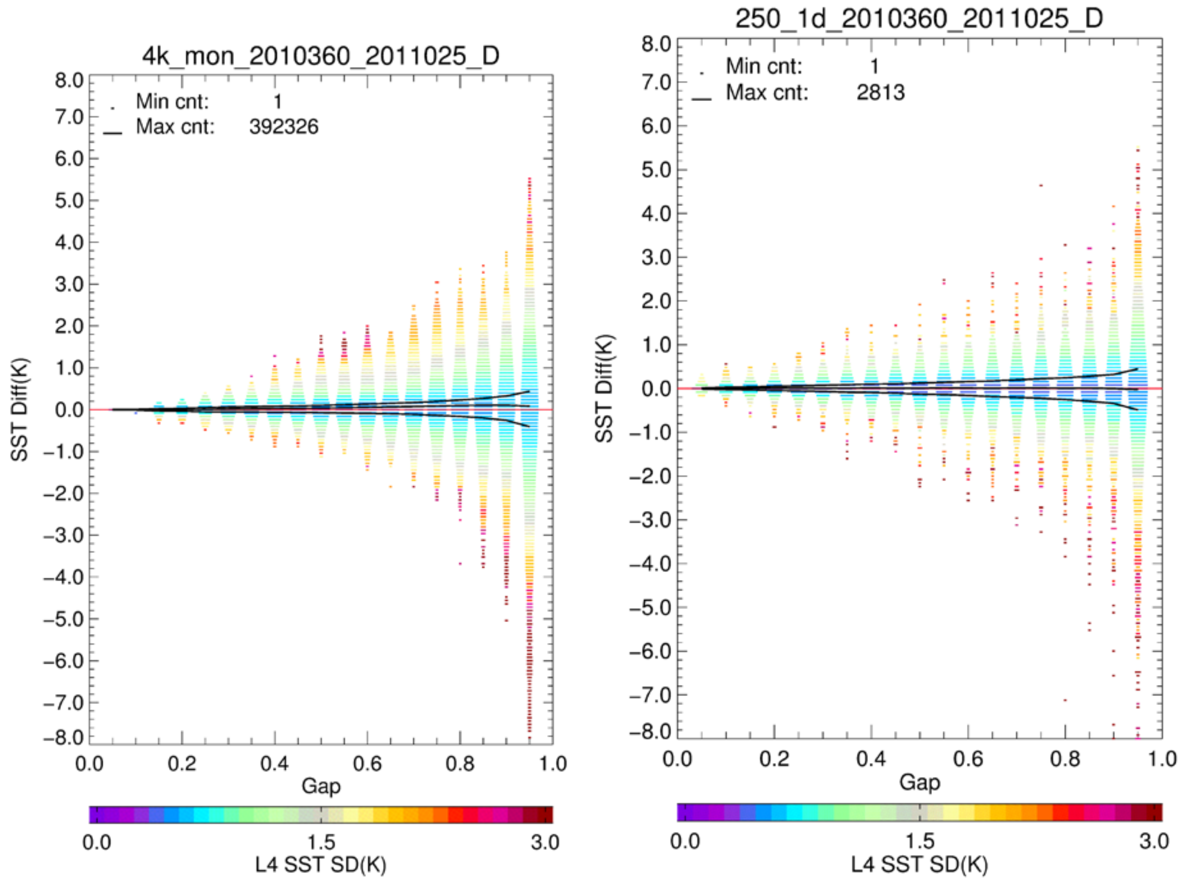


Figure.3. Global daytime sampling error magnitude (y axis) changes with change of gap fraction (x axis) and SST standard deviation (color). The width of each box shows how many grid cells fall into the gap fraction and sampling error range, and is logrithm scaled by the maximum and minimum number of grid cells shown in each upper left corner.

6. References

Ohring, G., B. Wielicki, R. Spencer, W. J. Emery, and R. Datla, 2005: Satellite instrument calibration for measuring global climate change: Report of a workshop. Bull. Amer. Meteor. Soc., 86, 1303–1313

ISSTST, ‘Sea Surface Temperature error budget: White paper.’ 18 Jun. 2010. <http://www.ssterrorbudget.org/ISS

SECTION 9: PHYSICAL OCEANOGRAPHY AND SST

BIASES IN GLOBAL MEAN SST ESTIMATES OBTAINED FROM GRIDDED DATA SETS

Alexey Kaplan[(1)]

(1) Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY 10964,
Email: alexeyk@ldeo.columbia.edu

ABSTRACT

Despite the efforts to correct inter-platform biases in the SST data used for producing gridded data sets, the remaining biases are significant enough to create easily discernible differences between global means estimated from such gridded data sets. For example, global means from annually averaged OSTIA SST is systematically colder than that from the NCDC Daily 0.25^o AVHRR-only OI data set by about 0.1^{o}C, while the latter is colder than the same estimated from the (older) NCEP monthly 1^o OI by approximately the same amount. While historical SST data sets that make use of the AVHRR data (HadISST1 and COBE SST) show very good consistency with the NCEP monthly 1^o OI, they are colder than the products that use only *in situ* data (ERSST v3b, HadSST2, HadSST3, ICOADS). The global mean difference between these two groups of gridded historical data sets becomes especially prominent after 2000, exceeding 0.1^{o}C in some years. All these differences are **not** due to differences in the domains of the data sets (they appear in co-located calculations as well) or can be reasonably explained by random error effects on global annual SST averages. Systematic differences between ship and buoy data and remaining cold biases in the AVHRR data seem responsible for the global mean differences between historical data sets during the satellite period. Global mean differences between individual L4 products have to be traced to their input data sets and their inter-platform bias removal procedures. Homogenization of historical data sets in terms of a common reference across satellite and pre-satellite periods is yet to be satisfactorily resolved in the community, even with regards to the annual global SST means.

STATISTICAL ANALYSIS OF SUB-MESOSCALE PROCESSES FROM SATELLITE SST OBSERVATIONS

Emmanuelle Autret[(1)], Bertrand Chapron[(1)]

(1) IFREMER, Plouzané, France, Email: emmanuelle.autret@ifremer.fr

ABSTRACT

Today, one important challenge is to resolve the smaller scales (1-50km) that are ubiquitous on high resolution optical, infrared and radar images. There is ample evidence that the mesoscale to sub-mesoscale variability is still not adequately resolved nor is its impact fully accounted for in the present ocean circulation models. The decay of mesoscale structures is generally too fast, and turbulent fluxes of tracer are systematically underestimated, especially in the vertical. These processes typically occur at horizontal spatial resolutions from order 100 m to several kilometers, but their ranges of influence can propagate to coarser spatial scales (10-50 km). The objective of this study is then to build on an optimal use of high-resolution satellite sensor synergy to possibly improve our understanding of processes at these finer scales (order kilometer), as adequate in-situ observations resolving these scales are still rare. In particular, we wish to propose the use of advanced statistical descriptors to help the characterization and interpretation of small scales and the underlying flow properties from combined instantaneous 2D observations of tracer. First, spectral analysis, as traditionally used in the statistical characterization of oceanic turbulence, is performed. Spectral slopes in the mesoscale and submesoscale range estimated from different SST datasets are compared and the sensitivity to resolution and noise level is investigated thoroughly. The global distribution of spectral slopes estimated from AVHRR Metop observations is then obtained. The analysis helps to reveal that variances at these scales can be quite different but follow very similar power-law distributions (in agreement with recent realistic high resolution numerical simulation). As spectral forms may only be weak constraints concerning the structure of the underlying flows, we also propose the use of more sophisticated measures of tracer variability than the spectrum. Indeed, coherent structures essentially sign in the phase information of the satellite snapshots, and we first propose the analysis of the spatial and temporal conditional variability of small scales relative to larger scales. A second approach is then applied to perform statistical analysis of the tracer level-set geometry, in particular the conditional statistics of small-scale isoline meanderings along larger scale fronts.

SEVIRI AND VISSR SST FRONT AND GRADIENT DATASETS

***Peter Cornillon*[1], *Pierre Le Borgne*[2]**

(1) University of Rhode Island, Narragansett Rhode Island, USA Email: pcornillon@me.com
(2) Centre de Météorologie Spatiale, Météo-France, Lannion, France Email: pierre.leborgne@meteo.fr

ABSTRACT

Sea surface temperature (SST) front and gradient datasets have been developed form the archive of SEVIRI and VISSR data acquired by Météo-France in Lannion France. These data sets cover the North and South Atlantic from 2001 for SEVIRI, the western half of the basins, and 2003 for MSG, the eastern half of the basins, through February 2011. The data are available in the 'space-view' projection as chunked netCDF4 files via OPeNDAP at http://www.sstfronts.org/opendap/hyrax/.

1. Introduction

Sea surface temperature front and gradient datasets derived from infrared radiometers carried on two sets of geostationary satellites are discussed. The first set of radiometers are the SEVIRI carried on the European Meteosat Second Generation (MSG) satellites, covering the period from 12 June 2003 through 28 February 2011. The second set of radiometers are the VISSR carried on the US Geostationary Orbiting Environmental Satellites (GOES) covering the period 20 February 2001 through 28 February 2011. Front and gradient datasets are derived from the hourly SST fields obtained from these sensors. Processing of the data is identical for both time series. First, only pixels for which the SST confidence level was greater than or equal to two were selected and the resulting fields were then median filtered with a 3x3 filter. Processing to obtain gradients and fronts was then undertaken as described below with the output datasets all stored in chunked netCDF4 allowing for easy extraction of image or front subsections.

2. The Gradient Datasets

Gradients were obtained by first convolving Sobel kernels in the along- and cross-scan directions with the median filtered fields and then correcting for the satellite geometry. Sobel gradients are available in Kelvin per pixel in the along- and cross-scan directions in one set of files and Sobel gradients in Kelvin per km in the eastward and northward directions in a second set of files. The latter also includes the gradient magnitude.

3. The Front Datasets

Fronts are obtained from the median filtered fields using the single image edge detection (SIED) algorithm developed at the University of Rhode Island4. Each output file from this algorithm includes three sets of variables. One set consists of variables that define front segments found in the image. A front segment is a set of contiguous front pixels found with the SIED algorithm. The second set consists of all front pixels in the image and the third set of the characteristics of the 32x32 pixel regions used to find front pixels. Of particular interest are those variables in the second set. Variables in this group include the longitude, latitude, along-scan and cross-scan location of the pixel, and the eastward- and northward-component of the Sobel gradient at the front and near, but not in the front - the background gradient. In addition, the SST values extending eight pixels on each side of the front and normal to it are available as a 17 pixel vector. This allows the user to examine the region around the front. Other variables are available as well and are described in the netCDF file.

SECTION 10: SST IN OCEAN-ATMOSPHERE INTERACTION

IMPACT OF DIURNAL WARMING ON ASSIMILATION OF SATELLITE OBSERVATIONS OF SEA SURFACE TEMPERATURE

Charlie N. Barron[(1)], Peter L. Spence[(2)], and Jan M. Dastugue[(1)]

(1) Naval Research Laboratory, Code 7321, Stennis Space Center, MS, 39529, USA,
Email: charlie.barron@nrlssc.navy.mil
(2) QinetiQ North America, Stennis Space Center, MS, 39529, USA

ABSTRACT

Sea surface temperature (SST) varies on a range of temporal scales according to variations in insolation, advection, and mixing. A prominent diurnal signal can frequently be identified in the SST of midlatitude to tropical regions, particularly under conditions of high insolation and low wind speed. Case studies in the Gulf of Mexico and Mediterranean Sea are used to examine the impact of such variations on assimilative SST analyses and forecasts. The scenarios provide infrared observations from polar-orbiting or geostationary satellites to an assimilative ocean model using a 24-hour update cycle. SST innovations are determined relative to the prior 24-hour SST forecast or using a first guess at the appropriate time (FGAT) approach which matches each observation to its corresponding time-varying forecast. It was anticipated that the FGAT would have its largest impact in the Gulf of Mexico summer, when the occurrence of the relatively large diurnal cycle maximum is nearly in phase with the nowcast. In contrast, FGAT was anticipated to have relatively little impact in the Mediterranean summer, where the diurnal maximum and nowcast are 90° out of phase. The impact of FGAT in the fall-spring seasons would be more affected by the skill in forecasts of the non-diurnal trend, as the diurnal signal is smaller in these seasons. FGAT is found to have its largest benefit in reduction in the mean error of the SST forecasts; its impact on standard deviation is mixed. It is also found to have larger impact in the cases assimilating observations from geostationary satellites, which give a broad sample of SST over all times of the day. Observations from the polar orbiter come at a sun-synchronous 10:00 AM or PM, sampling near the midpoints of the diurnal variation. The effectiveness of FGAT is dependent on model forecast skill and effective only if the model is able to adequately predict diurnal or other dominant variations between analysis times.

1. Introduction

The Mediterranean Sea and the Gulf of Mexico are similarly-sized semi-enclosed sea basins in the midlatitudes of the northern hemisphere, with the central latitude of the Mediterranean falling near 30˚N, close to the northernmost latitude in the Gulf of Mexico. Both encompass a range of sub-regional SST climates. The Gulf is dynamically divided into eastern and western regions, with the east dominated by the warm Loop Current and the west more strongly influenced by weather systems moving eastward off the coast and westward-propagating Loop Current eddies. The Gulf of Campeche to the west is somewhat sheltered from all but the southernmost eddy paths and dynamically distinct from the wind-driven circulation on broad shelf to the north. The northern boundary has strong freshwater inflow concentrated in centrally-located Atchafalaya and Mississippi River plumes. The Gulf domain in this study also extends into the northwestern Caribbean and Atlantic waters north of Cuba and east of Florida, adding to the diversity obscured within a single number measuring Gulf-wide performance.

The Mediterranean includes greater distinctions among an even wider range of subregions. The western Mediterranean includes regions west of Corsica and Sardinia. At the extreme southwest, the Alboran Sea is dominated by the Alboran gyres and exchange with the North

Atlantic through the Strait of Gibraltar. It is connected by the westward flowing Algerian Current to the Algerian Basin, which produces prominent regions of cool upwelling when it is pushed offshore. To the north, the Balearic Sea, Gulf of Lion, and Ligurian Sea also show episodic upwelling, most strongly evident when strong Mistral winds blow from the northwest across the Gulf of Lion. The central Mediterranean from Sardinia east to Greece includes Tyrrhenian, Adriatic, and Ionian Sea subdivisions with their own local characteristics. The eastern region tends to have the warmest Mediterranean SSTs. These occur under conditions of high insolation in the southeast, and conditions can be significantly cooler to the north in the Aegean Sea, a region exposed to cold continental wind outbreaks and inflow of cool, fresh Black sea water through the Turkish Straits. The diversity of conditions in the Mediterranean leads a larger range of SST variability with potentially higher uncertainty for SST predictions and verification.

Diurnal warming adds an additional complication to accurately analyzing and forecasting SST. Performance of daily SST predictions is assessed relative to independent *in situ* SST measurements matched to model fields interpolated to be valid at each observation time and location. If the SST field remains fairly constant between daily analyses, then observations at any time of the day are equally useful as measures of model-ocean difference, valid to estimate system performance to calculate model-ocean mismatches to be minimized through variational data assimilation. If diurnal variations are present, then the range of temperature over the course of the day often exceeds the difference from one daily analysis time to the next. Such diurnal and other sub-daily excursions increase the impact of non-uniform temporal sampling in the observations and representativeness errors associated with the analysis and performance increments.

2. Experiments

Experiments in the two domains from December 2009 to December 2011 are configured to evaluate satellite data streams and data assimilation approaches. In particular, three sets of source SST observations are defined in each domain: polar orbiting observations, geostationary observations, and combined satellite observations. The NOAA AVHRR sensors provide the polar satellite observations, while the NOAA Geostationary Operational Environmental Satellite (GOES-East) and the European Meteosat Second Generation (MSG) provide the geostationary observations for the Gulf of Mexico and Mediterranean, respectively. The AVHRR and GOES SST estimates are produced by the U.S. Naval Oceanographic Office, while the MSG SST estimates are produced by IFREMER/METEO-France.

These satellite data are assimilated into cycling NCOM/NCODA (Barron et all 2forecast models on a 3-km grid forced with COAMPS atmospheric fields. The models are run with the First Guess at Appropriate Time (FGAT; Massart et al., 2010) option on or off. With FGAT off, the assimilation interpolates the satellite observations to the analysis time and calculates an innovation based on the difference between the interpolated observed and model nowcast SSTs. With FGAT on, model-observation differences are calculated at the time and location of each observation and the differences are interpolated to estimate a nowcast innovation.

Model analyses and forecasts are output at three-hour frequency with forecasts to 72 hours after the 0:00 UTC analysis/nowcast time. To assess performance, model SST is interpolated in space and time to match corresponding independent SST observations from drifting buoys. While all in situ surface-only observations are withheld from the assimilative model forecasts and thereby offer independent estimates of the ocean state, only the surface drifters are used in the performance metrics reported in this article. Other, similarly withheld surface in-situ observations such as those from fixed buoy locations or shipboard observations might be used, but the drifting buoys are selected as having the best combination of broadly distributed geographic coverage, reducing geographic sampling bias, sampling bias, and accurate measurements at a fairly uniform near-surface depth. Results are compiled by local time of day and combined seasonally, annually, and multi-annually.

3. Results

Bias and standard deviation of the errors are evaluated for all cases, where standard deviation is the square root of the mean squared error after the mean differences are removed. In the Gulf of Mexico (Table 1), standard deviations of the analysis errors are near 0.50˚C for all satellite and FGAT combinations, with standard deviation of the forecast errors increasing to about 0.55˚C. FGAT tends to produce slightly larger deviations, near 0.57˚C, again similar among all satellite alternatives. Bias in the Gulf of Mexico differs significantly among the satellite options. With FGAT on (best case), AVHRR-based analyses show 0.03 ˚C bias (warm) while GOES-E gives -0.17˚C bias (cold) and -0.11 ˚C bias for the combined case. FGAT makes a significant impact, as the FGAT-off biases in these cases are about 0.10˚C cooler. Forecast adds an additional cold bias, near 0.23˚C cooling after 72 hours. In the Mediterranean (Table 2), the nowcast with FGAT bias is 0.03˚C cold for AVHRR-only and 0.15˚C warm for MSG, with a combined result near 0.04˚C. FGAT adds a warm bias near 0.05˚C, about half of the Gulf of Mexico impact. Model forecast has a cold bias of about half of the Gulf of Mexico case, near 0.10˚C cold after 72 hours. The FGAT forecast appears best in the MSG case, but this is misleading as the warm MSG bias counteracts the cold forecast bias.

Breaking the results down seasonally (Table 3), the impact of FGAT is unambiguously positive in summer but slightly negative in winter. This result reflects seasonal changes between the dominant processes causing temperature variations between successive analyses. If the model has no skill in representing variations on scales shorter than a day, our assimilation approach should ignore these sub-daily variations and treat the temporal mean of the observations as an estimate of the ocean state at the nowcast time, using the difference between the observation mean and the nowcast SST as the basis for calculating assimilation increments. On the other hand, when the model does have some skill in predicting sub-daily variations, then we can benefit from FGAT, calculating the observation-model differences at the time of the observations and averaging these differences to estimate the true model-observation increment at the analysis time. FGAT shows its most positive impact during the northern hemisphere spring and summer. These are times of maximum solar heating and corresponding diurnal warming. Thus, the model has skill in representing the diurnal variations and providing a sound basis for an FGAT approach. In the fall and winter, insolation and diurnal warming are smaller, allowing other contributors to sub-daily SST variations to increase in relative importance. The cold forecast bias, stronger in the Gulf of Mexico but also evident in the Mediterranean, reduces the fidelity of short-term SST forecasts. The effect of this bias and inadequate representation of the cumulative effects of short-time scale processes other than diurnal warming provide an insufficient basis for effective FGAT assimilation during the fall and winter.

	Gulf of Mexico 196,740 obs	Bias ˚C (model-ob)		Standard Deviation ˚C	
		FGAT on	FGAT off	FGAT on	FGAT off
Nowcast analysis - observation	Both Polar and Geostationary	-0.11	-0.21	0.54	0.5
	Polar only	**0.03**	-0.07	0.54	0.51
	Geostationary only	-0.17	-0.26	0.54	0.52
51-72 hr forecast - observation	Both Polar and Geostationary	-0.34	-0.41	0.57	0.55
	Polar only	**-0.25**	-0.30	0.57	0.55
	Geostationary only	-0.39	-0.46	0.57	0.57

Table 1: SST matchups between cycled NCODA analyses, NCOM forecasts, and independent drifting buoy observations in the Gulf of Mexico over years 2010-2011. NCODA analyses are daily at 0:00 UTC while forecasts are interpolated to the observation time from 3-hourly NCOM output spanning 51-72 hours after each nowcast.

	Mediterranean 95,179 obs	Bias ˚C (model-ob)		Standard Deviation ˚C	
		FGAT on	FGAT off	FGAT on	FGAT off
Nowcast analysis - observation	Both Polar and Geostationary	0.04	0.10	0.70	0.70
	Polar only	**-0.03**	**0.03**	0.71	0.71
	Geostationary only	0.15	0.18	0.72	0.72
51-72 hr forecast - observation	Both Polar and Geostationary	-0.06	**-0.01**	0.82	0.82
	Polar only	-0.12	-0.07	0.82	0.84
	Geostationary only	0.04	0.06	0.82	0.83

Table 2: SST matchups as in Table 1 but for Mediterranean Sea.

A significant cold bias reduces the skill of the forecast over the 51-72 hour range in the Gulf of Mexico, with bias in the best seasonal cases from -0.05 to -0.52˚C. The cold bias is less evident in the Mediterranean over most seasons, with 51-72 hour forecast bias in the best cases generally ranging from -0.05 to 0.03˚C. The best cases as determined over the 51-72 hour forecast range in the Mediterranean obscure the cold forecast bias by emphasizing runs relying on the geostationary MSG observations, observations that lead to a warm bias at the analysis time. Nevertheless, most seasons are found to have only a small forecast bias. However, comparisons with observations during Autumn 2013 indicate a Mediterranean 3-day forecast bias near to -0.3˚C, much colder than other months, This result appears to be a consequence of sampling bias. The surface drifters providing the matchups in this season (Fig. 1) are clustered in the southern parts of the western Mediterranean with a disproportionate presence in the cool upwelling north of Algeria. This sampling bias is identified as the likely cause of the apparent cold bias during the Autumn of 2011; prior seasons showed broader coverage across the sea an few observations immediately north of the Algerian coast.

	Season and years	Min Analysis Bias (model-ob)			Min 51-72 hr. Fcst Bias (mod-ob)			Number of obs
		Satellites	FGAT	˚C bias	Satellites	FGAT	˚C bias	
Gulf of Mexico	Winter 2010	AVHRR	same	±0.03	AVHRR+GOES	off	-0.12	4148
	Spring 2010	AVHRR	off	-0.01	AVHRR	on	-0.17	17764
	Summer 2010	AVHRR	on	0.07	AVHRR	on	-0.21	76562
	Autumn 2010	AVHRR	same	-0.03	AVHRR	off	-0.25	45052
	Winter 2011	GOES	off	-0.07	AVHRR+GOES	off	-0.25	23725
	Spring 2011	GOES	off	0.00	AVHRR	on	-0.05	16461
	Summer 2011	AVHRR	on	-0.15	AVHRR	on	-0.52	8796
	Autumn 2011	AVHRR+GOES	on	-0.16	AVHRR+GOES	on	-0.38	4956
	2010	AVHRR	same	±0.06	AVHRR	on	-0.24	146699
	2011	AVHRR	on	-0.04	AVHRR	on	-0.28	50041
	2010-2011	AVHRR	on	0.03	AVHRR	on	-0.25	196740
Mediterranean Sea	Winter 2010	AVHRR+MSG	off	-0.02	MSG	off	-0.01	5174
	Spring 2010	MSG	off	0	MSG	off	0.03	3113
	Summer 2010	AVHRR+MSG	on	0.03	MSG	off	-0.01	7653
	Autumn 2010	AVHRR	on	0.03	AVHRR+MSG	on	-0.01	28960
	Winter 2011	AVHRR	on	-0.01	AVHRR	same	±0.01	19100
	Spring 2011	AVHRR	on	-0.02	AVHRR+MSG	off	-0.05	11340
	Summer 2011	AVHRR+MSG	on	0.03	MSG	same	±0.02	11490
	Autumn 2011	MSG	off	-0.09	MSG	off	-0.29	8561
	2010	AVHRR	on	-0.01	AVHRR+MSG	on	-0.03	46714
	2011	AVHRR+MSG	on	0	MSG	off	-0.01	48465
	2010-2011	AVHRR	on	-0.03	AVHRR+MSG	off	-0.01	95179

Table 3: Seasonal SST matchups between cycled NCODA analyses, NCOM forecasts, and independent drifting buoy observations in the Gulf of Mexico over years 2009-2011. NCODA analyses are daily at 0:00 UTC while forecasts are interpolated to the observation time from 3-hourly NCOM output spanning 51-72 hours after each nowcast.

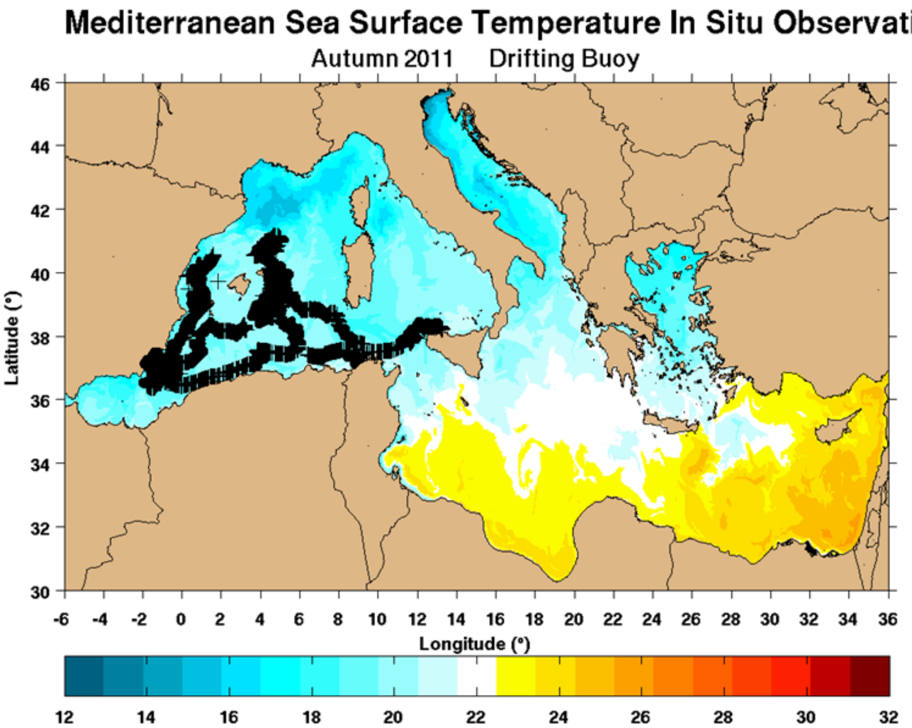


Figure 1: Locations of drifting buoy matchup observations superimposed on mean model sea surface temperature during Autumn 2011 in the Mediterranean Sea. The concentration of the observations in the western Mediterranean and in particular the cool upwelling along the coast of Algeria introduces as sampling bias relative to the true errors averaged over the entire Mediterranean domain.

4. Conclusion

Evaluations of regional NCOM forecasts using 3DVAR NCODA assimilation in the Gulf of Mexico and Mediterranean demonstrate the impact of diurnal variations on analyses and forecasts of sea surface temperatures. The FGAT approach mitigates the errors introduced by sub-daily variations if the model is able to skillfully forecast evolution over these time scales. It is shown that the models do have skill to sufficiently simulate the mean diurnal signals which are most important in the spring and summer seasons of maximum insolation. Differences between assimilation of observations from geostationary and polar-orbiting platforms are reduced by FGAT but problems associated with intra-sensor bias persist. Sampling bias introduces additional complexities to interpreting the statistics associated with matchups between model analyses and forecasts and independent SST measurements from surface drifters. An overall cold forecast bias is a persistent source of error that will be addressed in future research efforts.

5. References

Barron, C.N., A.B. Kara, P.J. Martin, R.C. Rhodes, and L.F. Smedstad, Formulation, implementation and examination of vertical coordinate choices in the global Navy Coastal Ocean Model (NCOM), *Ocean Modelling* **11**(3-4), 347-375, doi:10.1016/j.ocemod.2005.01.004, 2006.

Cummings, J.A., Operational multivariate ocean data assimilation. *Quart. J. Roy. Met. Soc.* **131**, 3583-3604, 2005.

Massart, S., B. Pajot, A. Piacentini, and O. Pannekoucke, On the merits of using a 3D-FGAT assimilation scheme with an outer loop for atmospheric situations governed by transport, *Mon. Wea. Rev*. **138**, 4509-4522, 2010.

RELATING OF SEA SURFACE TEMPERATURE AND COLOR TO CARBON DIOXIDE PARTIAL PRESSURE AND FLUX

W. Timothy Liu and Xiaosu Xie

Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA, USA
Email:w.t.liu@jpl.nasa.gov; xiaosu.xie@jpl.nasa.gov

A decade long time series of ocean surface carbon dioxide (CO2) partial pressure (fugacity) has been produced from spacebased measurements of sea surface temperature and color (chlorophyll) using a statistical model trained by over a quarter of a million cruise measurement coincident with satellite data. The partial pressure is a dominant factor that governs ocean as the source and sink of atmospheric CO2 content, and it reflects the biogeochemistry processes of the ocean. The changes of the partial pressure with sea surface temperature and with chlorophyll are examined. Their relative regional and seasonal dependence and the implications on ocean-atmosphere CO2 flux and ocean ecology will be discussed.

MID-LATITUDE SEA SURFACE TEMPERATURE SIGNAL IN THE UPPER TROPOSPHERE

Xiaosu Xie and W. Timothy Liu

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
Email: xiaosu.xie@jpl.nasa.gov, w.t.liu@jpl.nasa.gov

The ocean has long memory and its feedback to the atmosphere governs climate changes. The coupling of the small and slow processes of the ocean to the transient and large-scale processes of the atmosphere, particularly in the extratropical latitudes, has been controversial. The atmospheric lapse rate is believed to be too weak to generate deep convection to transfer the effect of oceanic processes high enough in the atmosphere to be effective on the coupling. Many studies on large-scale coupling and long-term climate changes, in the past, were based on numerical model simulation and analysis of model products. They did not show the effect of local sea surface temperature changes beyond the boundary layer particularly in long time scales. Over two western boundary layer current (Kuroshio and Agulhas) extension, we found spatial coherence between sea surface temperature anomalies measured by the Advanced Microwave Scanning Radiometer (AMSR) and cloud top temperature provide by the International Cloud Climatology Project (ISCCP). Over the sea surface temperature anomalies, temperature and rain profiles measured by the Atmospheric Infrared Sounder (AIRS) and Tropical Rainfall Measuring Mission (TRMM) are found to be coherent all the way to the top of the troposphere.

SECTION 11: COUPLED DATA ASSIMILATION AND SST

DIRECT ASSMILATION OF SATELLITE SST RADIANCES

James Cummings[(1)] and James Peak[(2)]

(1) Naval Research Laboratory, Oceanography Division, Monterey, California, USA 93943,
Email: cummings@nrlmry.navy.mil
(2) Naval Research Laboratory, Marine Meteorology Division, Monterey, California, USA 93943,
Email: peak@nrlmry.navy.mil

ABSTRACT

A capability for direct assimilation of satellite sea surface temperature (SST) radiances has been implemented in the three-dimensional variational Navy Coupled Ocean Data Assimilation system (NCODA 3DVAR). The SST radiance assimilation operator uses both forward and inverse modeling based on radiative transfer. The operator uses an incremental approach and takes as input prior estimates of variables known to affect SST: (1) SST, (2) air temperature, and (3) water vapor. The priors are obtained from ocean and numerical weather prediction (NWP) model forecasts. The forward model uses the Community Radiative Transfer Model (CRTM) to simulate top-of-the-atmosphere (TOA) brightness temperatures (BTs) for the various SST satellites and channel wavelengths. The inverse model is forced by differences between observed and predicted TOA-BTs and uses CRTM Jacobians (radiance derivatives with respect to the priors) to retrieve information about the priors from the radiance measurements. The SST inverse model effectively partitions the observed change in TOA-BT into a change in SST that takes into account the variable temperature and water vapor content of the atmosphere at the time and location of the satellite SST radiance measurement. The change in SST is then input as an innovation in the NCODA 3DVAR minimization. Proper characterization of the prior errors is critical to the success of the method. For this purpose, atmospheric ensemble products are used to provide uncertainty of the NWP priors, radiometric noise estimates of the channels are obtained from satellite monitoring statistics, and SST prior errors are estimated from a time history of ocean model variability and model-data differences. The method is a true example of coupled data assimilation, whereby an observation in one fluid (atmospheric radiances) creates an innovation in the other fluid (ocean SST).

1. Introduction

Satellite derived SSTs are often generated using empirical regression models that relate cloud cleared radiances to drifting buoy measurements of SST. The regression models are global (or nearly global), calculated once, and held constant. The coefficients represent a very broad range of atmospheric conditions with the result that systematic errors are introduced into the empirical SST when the method is uniformly applied to new radiance data. In the direct assimilation method, coefficients that relate radiances to SST are dynamically defined for each atmospheric situation observed. As a result, the method explicitly corrects for the overlying atmosphere and produces a more accurate and time consistent estimate of SST. The direct assimilation method has multiple applications. In one application it is used to compute atmospheric corrections to an existing SST using collocated NWP fields. The correction is applied at the time the SST is assimilated. This approach is being used as a post-processing step in the NAVOCEANO SST retrieval processing. Alternatively, the method is integrated directly into a variational analysis scheme as an observation operator. In this mode there is no need for an empirical SST derived from buoy matchups. The SST prior comes from the ocean model forecast and is used with the atmospheric forcing in the radiance assimilation. Ideally the ocean and atmospheric models have evolved in coupled mode.

2. Progress

Figure 1 gives a schematic of the satellite SST radiance assimilation observation operator. The operator was validated using METOP-A data for 2008-2010 obtained from the ESA Climate Change Initiative project. Here, priors from ECMWF atmospheric model fields were used with collocated satellite SST radiances and drifting buoy SST measurements to calculate atmospheric corrections to the SST lower boundary condition used by the ECMWF model. The corrected and uncorrected SSTs were compared to the drifting buoy SST. Table 1 shows that the atmospheric correction resulted in an 80% improvement in the fit of the lower boundary SST to the drifting buoy SST. The operator has been successfully applied to cloud cleared radiances from NOAA-18, NOAA-19, METOP-A, GOES-13, GOES-15, and NPP-VIIRS using operational NAVOCEANO empirical SSTs and Navy NWP model inputs. It was found with global Navy NWP model priors that a bias correction step is necessary due to the model fields being too moist in what otherwise should be cloud free areas. Satellite SST radiance data by definition are cloud free but the NWP priors can be from areas that are both cloudy and clear. The bias correction uses a sliding time window of cloud cleared radiances from the drifting buoy matchup database maintained by NAVOCEANO. The bias correction is routinely updated in an automated scheme to capture changes in the Navy NWP model and its water vapor distribution over time.

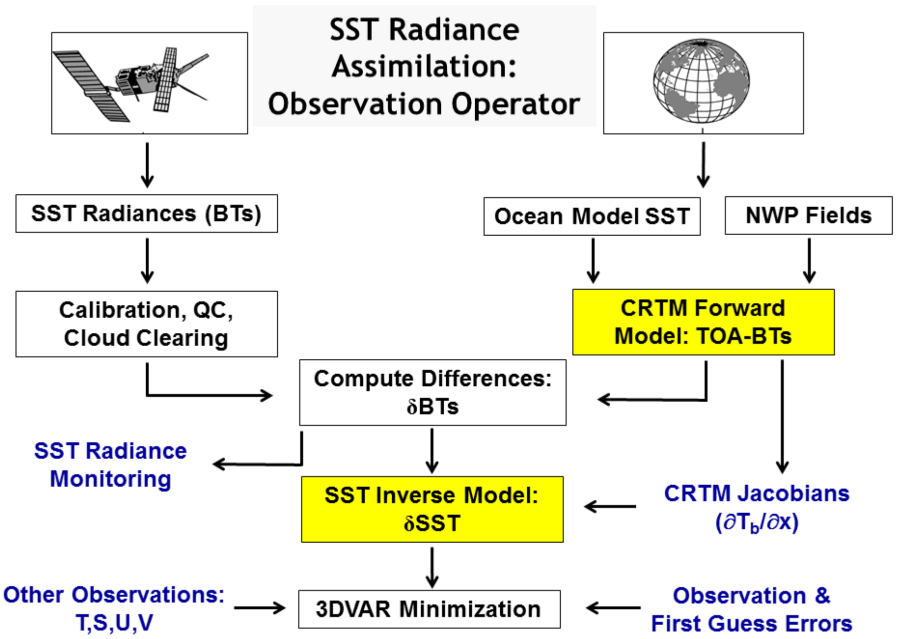


Figure 1. Flow chart of the SST radiance assimilation observation operator in NCODA. The CRTM forward and SST inverse models are highlighted in yellow.

Table 1. Verification statistics of SST radiance operator applied to METOP-A data using ECMWF NWP model priors.

METOP 2010 Data Count	Error Prior SST	Error Corrected SST	Per Cent Improvement
149,383	**-0.0314**	**-0.0062**	**80.2%**

3. Future Capabilities

The radiance assimilation operator is being evaluated in the NCODA 3DVAR analysis as part of the Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS). Here, SST radiances are used in direct assimilation mode to correct the ocean model forecast SST using the coupled model state. In addition, SST lower boundary conditions derived from atmospheric corrected NAVOCEANO SSTs are being evaluated in the four-dimensional Navy Atmospheric Variational Data Assimilation System (NAVDAS). Here, the metric is fewer rejections of radiances from lower tropospheric channels that peak at or near the surface. Currently, these channels are rejected by the NAVDAS 4DVAR because of inaccuracies and unrealistic temporal variability in the empirical SST retrievals.

Work is underway to extend the radiance operator to ice covered seas to provide estimates of ice surface temperature (IST). The Navy global HYCOM ocean forecast system is coupled to a sea ice model (CICE), and the combination of SST and IST data will provide a seamless analysis of surface conditions for the coupled model. Finally, aerosol optical depth from the Navy Aerosol Analysis and Prediction System (NAAPS) will be added as a prior variable in the forward and inverse modeling. The presence of atmospheric dust is known to produce a cold bias in infrared radiances and needs to be taken into account.

4. References

Cummings, J.A. (2011). Ocean Data Quality Control. In, *Operational Oceanography in the 21st Century*. A. Schiller, G. Brassington (eds), Springer, pp. 91-121.

Cummings, J. and O.M. Smedstad (2013). Variational Data Assimilation for the Global Ocean. In, *Data Assimilation for Atmospheric, Oceanic & Hydrologic Applications (Vol. II)*. S. Park and L. Xu (eds). Springer, pp. 303-343.

EVALUATING THE DIURNAL VARIABILITY OF SEA SURFACE TEMPERATURE IN A GLOBAL INITIALISED COUPLED MODEL

José M. Rodríguez, Peter Sykes, Tim Johns

Met Office, FitzRoy Road, Exeter, EX1 3PB, UK, Email: jose.rodriguez@metoffice.gov.uk

ABSTRACT

Air-sea interactions play a role in predictability on seasonal and inter-annual timescales. There is accumulating evidence that, by improving the representation of physical processes, they can also improve predictability at intra-seasonal timescales, particularly in the tropics. With the aim of studying the role of air-sea coupling in providing improving forecast skill in the 1-15 day timescale, a large set of initialised global coupled atmosphere-ocean-sea ice hindcasts has been completed, making use of a similar model version as in recent climate model assessments. Such experiments also provide a platform to analyse systematic errors and drifts in the model that are robust across forecast timescales. Here we present preliminary results of investigations into the representation of the diurnal cycle of sea surface temperatures by the coupled model. A comparison is made with observed data from moored buoys and MTSAT-1R SST skin datasets over the tropical Warm Pool (TWP+ data set). We also examine the sensitivity of model performance to frequency of air-sea coupling.

1. Introduction

Atmosphere and ocean prediction systems have reached a degree of maturity where it is natural to start investigating the importance of air-sea interactions at various timescales. Air-sea interactions have long been recognized to play a role in predictability on seasonal and inter-annual timescales. Evidence of their importance on shorter timescales is becoming more compelling, particularly in their capacity for enhancing predictability in the tropics. Predictability of the Madden Julian Oscillation, the main mode of tropical variability on timescales ranging from a few days to more than a month, may be improved with an accurate representation of air-sea coupled feedbacks. With the aim to explore the role of air-sea coupling in improving forecast skill on the 1-15 day timescale – for both atmosphere/land surface and ocean/sea ice forecasting purposes- a large set of initialised global coupled atmosphere-ocean-sea ice hindcasts has been completed, using a MetUM configuration at N216L85 atmosphere and ORCA025L75 ocean resolution (Johns et al, 2012). Details of the model configuration used are shown in Table 1. The ocean and atmosphere components have been initialised separately and the model ran freely, with no flux adjustment or bias corrections. Atmosphere and land components were initialised using operational NWP analyses and the ocean and sea ice initialisation was done with ocean analyses from FOAM-NEMOVAR model driven with operational NWP fluxes. For the study of the diurnal variability shown here, 5-day lead time coupled hindcasts were produced daily for Jan-April 2010, in accordance with the TWP+ diurnal variability model inter-comparison project.

	Initialised Coupled Model
Components and resolution	**A** – MetUM GA4.0, N216 L85 **O** – NEMO3.2, ORCA0.25º L75 **I** – CICE 0.5º
Air-sea boundary conditions	Interactively coupled every hour and also 3hours (resolving diurnal cycle)
Initialisation **All model components are initialised at 0z**	**A** – Operational NWP analysis interpolated to N216 L85 (with monthly mean climatological river state taken from climate model control run) **O, I** – FOAM NEMOVAR plus CICE ORCA025º L75 analysis.

Table 1: Coupled model configuration used to evaluate the diurnal variability of SST

2. Diurnal variability in SST

One of the fundamental modes of variability of sea surface temperature (and many atmospheric variables) is the diurnal cycle, associated with the daily variation in solar forcing. Changes in the solar heating of the surface due to cloud, mixing of heat to depth induced by wind and precipitation lead to large variations in the magnitude of the diurnal cycle of SST, as shown globally by Stuart-Menteth et al (2003) and Gentemann et al (2003). The simulation of amplitude and phase of this cycle provides a key test for the representation by a coupled model of the interactions between ocean surface, the boundary layer and the free atmosphere.

In situ analysis:

It has been found by Sykes 2011 (see also Bernie 2007) that to properly resolve the diurnal cycle of SST, at least 4 evenly spaced samples during the day are required. Following their analysis, we have made a comparison between model and in-situ data. We have used 1-hourly means of model data and observational measurements of SST from a set of 12 TRITON moored boys, located on the tropical West Pacific. Measurements are at various depths, typically 1 m. Model and observational data have been extracted and analysed for February 2010.

Two aspects of the diurnal cycle of SSTs have been assessed, the diurnal range and maxima and minima timing. To determine the range, maximum and minimum SST values need to be found on each day. For this, we have used an algorithm in which the multi-day time series is split into individual 1 day series on which the minimum and maximum are searched (Sykes et al, 2011). Several criteria are applied by the algorithm, including that the minimum value must occur between 01:00 and 11:00 local time, and the maximum value, between 11:00 and 21:00, to ensure that the minimum corresponds to night-time cooling and the maximum to solar heating.

Figure 1 shows and example of the daily time series of model and buoy data at 147E 5N, after the maximum/minimum algorithm was applied. There is a considerable variability in the magnitude of the diurnal range at this particular location. The model in general captures the large event present at the end of the month, which can be seen in the maxima and range of the diurnal variation, although it tends to overestimate the maxima. The modelled minimum values, on the other hand, exhibit a lower bias.

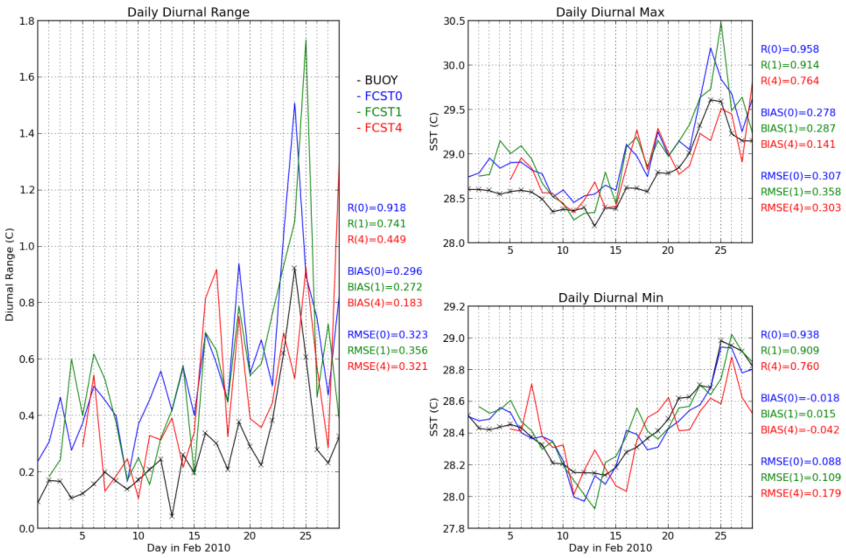


Figure 1: Daily time series of buoy and model diurnal maximum (top right), minimum (bottom right) and left, at a buoy location (147E 5N). Model data corresponds to 0, 1 and 4 day forecast.

Statistics across all buoys have been calculated. Anomaly correlations for the maximum and minimum comparisons were computed to assess the temporal correlation of model data to buoy data. Results are presented in Table 2. There is a warm bias of the order of 0.07 to 0.34 K in the model maximum diurnal SST values compared to the buoys. Bias in the model minimum is smaller (-0.04 to 0.01). As a consequence, the diurnal variability range is overestimated by the coupled model. As the forecast day increases, the overestimation decreases. However, the correlation also decreases rapidly with day forecast.

	MIN			MAX			RANGE		
FCST	R (ANOM)	BIAS	RMS	R (ANOM)	BIAS	RMS	R	BIAS	RMS
FCST 0	0.78	-0.03	0.18	0.86	0.34	0.44	0.79	0.37	0.46
FCST 1	0.69	0.01	0.23	0.78	0.33	0.48	0.69	0.31	0.45
FCST 4	0.53	-0.04	0.28	0.49	0.07	0.41	0.23	0.11	0.35

Table 2: Combined statistics of all buoys against model 0,1 and 4 day forecasts for diurnal maxima, minima and range. Bias and RMS error units are in Kelvin.

In addition to the amplitude of the diurnal cycle, we have also evaluated the phasing of maxima and minima, using the algorithm mentioned previously. Results vary from buoy to buoy. However, it can be said that the model maximum time is within better agreement with buoys than the minimum time. Minimum time is later in the model by approximately 3.5 hours .

Model Satellite comparisons:

In order to allow assessment of the model diurnal cycle at a much greater area than point measurements of buoys, we have used MTSAT-1R SST skin datasets over the Tropical Warm Pool (TWP+ dataset). The satellite data were gridded onto a regular 0.25º lat-lon grid and passed through the diurnal maximum/minimum algorithm. Figure 2 shows results of this evaluation. The top left pane displays a composite of monthly diurnal range averages that were calculated for every grid point of satellite data. The pane on the mid left shows coverage (N: number of days of data available at each grid point). Other panes show comparisons with the model first day forecast: diurnal range, model RMS error, bias and absolute error.

In most of the Tropical West Pacific domain the model overestimates the diurnal minima, with largest biases in coastal regions. The minimum temperature (not shown) is best represented in the region north of Papua-New Guinea (where the diurnal range shows a positive bias). On the other hand, the model reproduces relatively well the diurnal maxima, although, in general, it overestimates it. As a consequence, the diurnal range is underestimated in most of the Tropical West Pacific domain. This underestimation is exacerbated in the 5-day forecast.

There is a disagreement with the results from the in-situ evaluation, which suggest that the coupled model overestimates the diurnal range. The reasons for this discrepancy need to be investigated. One plausible explanation could be related to the fact that buoys measure temperature at approximately 1 m, whereas satellite data correspond to skin temperature. Since the diurnal variability of skin temperature tends to be larger than temperature at depth, the buoys' diurnal range is smaller than the satellite range.

The coupled model has also been run in a configuration with a 3 hr ocean-atmosphere coupling frequency. Buoy and satellite comparisons show that decreasing the model air-sea coupling frequency does not change significantly the amplitude of the diurnal variability. However, increasing the coupling frequency improves the timing of maxima and minima events.

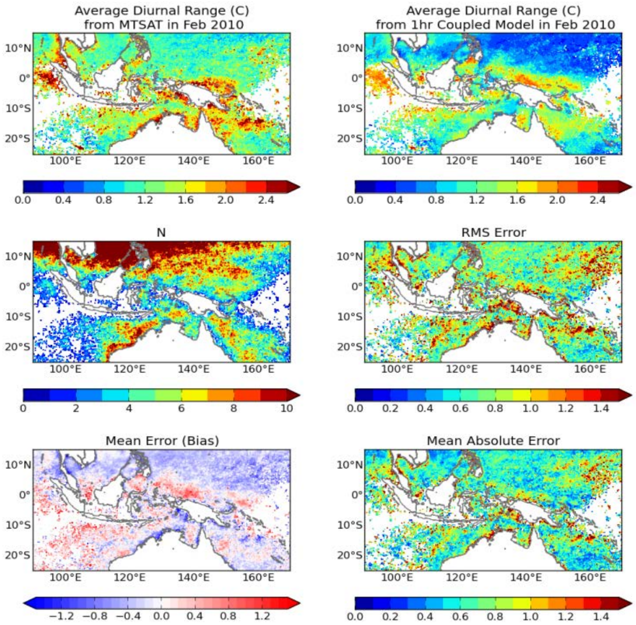


Figure 2: Comparison of satellite and model diurnal range (first day forecast, F0) using monthly average diurnal range values from the satellite (top left), and model (top right), number of days with 'valid' range (middle left), RMS error (middle right), mean bias (bottom left) and absolute error (bottom right). All values are in units of Kelvin.

3. Conclusion

Air-sea-ice coupling in the MetUM configuration shows promise for improving short to medium range forecasting skill, even without bias corrections – particularly in the tropics. In the extra-tropics skill is generally competitive in coupled versus uncoupled hindcasts. Careful diagnosis is required to investigate compensating systematic errors in the two systems – ocean and atmosphere. Coupled NWP shows potential as a framework for studying persistent systematic errors seen in climate models.

We are currently participating in ongoing work on the TWP+ project geared towards model-model and model-data assessment of the diurnal cycle of SST and air-sea fluxes. Future work will involve the introduction and test of a formulation of air-sea thermodynamic coupling that should improve the accuracy of surface fluxes.

4. References

Bernie, D., E. Guilyardi, G. Madec, J. Slingo and S. Woolnough, Impact of resolving the diurnal cycle in an ocean-atmosphere GCM. Part 1: a diurnally forced OGCM, *Climate Dynam,* 29, *575-590,* 2007.

Gentemann, C.L, C.J. Donlon, A. Stuart-Menteth, F.J. Wentz, Diurnal signals in satellite sea surface temperature measurements, *GRL*, 30(3), 1140-1143, 2003.

Johns, T., A. Shelly, J. M. Rodríguez, D. Copsey, C. Guiavarc'h, S. Milton, P. Sykes, Report on extensive coupled ocean-atmosphere trials on NWP (1-15 day) timescales, *Met Office technical report,* 2012.

Stuart-Menteth, A., I. Robinson and P. Challenor, A global study of diurnal warming using satellite-derived sea surface temperature, *J. Geophys. Res.-Oceans*, C5, 108, 2003.

Sykes, P. J. While, A. Sellar, M. Martin, Diurnal variability in sea surface temperature: observation and model assessment. *Met Office technical report,* 2011.

Walters, D. N., M. J. Best, A. C. Bushell, D. Copsey, J. M. Edwards, P. D. Falloon, C. M. Harris, A. P. Lock, J. C. Manners, C. J. Morcrette, M. J. Roberts, R. A. Stratton, S. Webster, J. M. Wilkinson, M. R. Willett, I. A. Boutle, P. D. Earnshaw, P. G. Hill, C. MacLachlan, G. M. Martin, W. Moufouma-Okia, M. D. Palmer, J. C. Petch, G. G. Rooney, A. A. Scaife, and K. D. Williams, The Met Office Unified Model Global Atmosphere 3.0/3.1 and JULES Global Land 3.0/3.1 configurations, *Geosci. Model Dev.*, 4, 919–941, 2011.

SEA SURFACE TEMPERATURE UNCERTAINTY ESTIMATES AND COUPLED FORECASTING

***Christopher Merchant*[(1)]*, Christopher Old*[(2)]*, Keith Haines*[(3)]* and Gary Corlett*[(4)]**

(1) University of Reading, Reading, UK. Email: c.j.merchant@reading.ac.uk
(2) University of Edinburgh, Edinburgh, UK. Email: Chris Old cold2@staffmail.ed.ac.uk
(3) University of Reading, Reading, UK. Email: k.haines@reading.ac.uk
(4) University of Leicester, Leicester, UK. Email: gkc1@leicester.ac.uk

ABSTRACT

Coupled data assimilation/forecasting is assimilation of sea surface temperature (SST) and other observed variables into a weather forecasting system that represents and couples the dynamics of both atmosphere and ocean (at least to a depth relevant to the forecast timescale).

In existing uncoupled assimilation/forecast systems, SST fields are prescribed typically by reference to an SST analysis (an “L4 SST”). L4 SSTs are spatially complete, but this is achieved by interpolation (in space and/or time) or other means that may be incompatible with the dynamics represented within the coupled model. To this extent these products, if assimilated, could unrealistically constrain the model. For coupled prediction, assimilation of swath (L2) or finely averaged (L3) SSTs is more appropriate (and ultimately, it may be preferable to assimilate the relevant radiances). Hereafter, both L2 and L3 products are referred to generically as ‘satellite SSTs’.

In order to be weighted appropriately within the coupled assimilation system, satellite SSTs need to be accompanied by realistic uncertainty estimates. Obviously, satellite SSTs from different sensors, etc, differ in their level of uncertainty. Moreover, within the satellite SST product stream for a particular sensor there is a significant variation in uncertainty. Within the Group for High Resolution SST (GHRSST) system, this variation is somewhat captured via flagging of data with different levels of confidence (on a scale from 1 to 5), and (in some products) stratification of sensor specific error statistics (SSES) by observational context and/or confidence.

We argue that efforts directed to attach observation-specific SST uncertainty information to each satellite SST need to be progressed and their results accommodated within GHRSST standards, in order to be ready for wide-spread adoption of coupled prediction systems.

SST uncertainty estimates should reflect factors such as:

- the level of radiometric noise in the radiance observations;
- how this noise propagates and is (usually) amplified through the retrieval process to generate ‘SST noise’;
- the degree of uncertainty arising from the retrieval algorithm’s inability to resolve the inherent ambiguity in the retrieval process (algorithmic uncertainty); and
- systematic uncertainty arising from the calibration of the sensor and the uncertainty in parameters used within the retrieval.

In general, these factors vary with the performance of the sensor, the combination of channels used for retrieval, and the observational context. Noise amplification is, for example, generally greater when observing regions with higher water vapour loading, and, consequently, lower atmospheric transmittance. For averaged/gridded (L3) SSTs, the

degree of sampling across the grid cell (representativity) is a further factor that affects the uncertainty in the grid-cell average SST. With good understanding of the instrument and the ability to simulate the retrieval process using radiative transfer modeling, a realistic observation-specific model for satellite SST uncertainty is achievable, although not yet common practice.

It is not sufficient, however, to estimate only the total uncertainty. Satellite SST errors are in general partly correlated in space and time, and without accounting for such correlation, the coupled assimilation system could be too strongly constrained towards the satellite observations. (The practice of “super-obbing” satellite observations when combining with in situ observations is a useful heuristic approach for avoiding over-confidence in the satellite SSTs in the absence of understanding of satellite SST error correlations.) As a minimum, it is likely that three components of uncertainty need to be distinguished:

1. Uncertainty from random effects: includes propagated sensor noise (if independent between measurements); if SSTs are averaged, this component of uncertainty reduces with the classic 1/root(n) dependence; in an observation error covariance matrix, this component contributes nothing to off-diagonal elements.

2. Uncertainty from partially correlated effects: includes algorithmic uncertainty, in which the retrieval error depends on the state of the atmosphere (particularly the vertical water vapor profile) and/or sea state; where the errors correlate on the spatial scales of atmospheric variability, this component could be described as “uncertainty from synoptically correlated effects”; this component of uncertainty does not reduce as fast as 1/root(n) when averaging SSTs on shorter spatial scales; in an observation error covariance matrix, this component contributes to off-diagonal elements, with greater covariance for observations that are closer in space and time.

3. Uncertainty from systematic effects: such as calibration uncertainty: this component is correlated between satellite SSTs from a given sensor and does not reduce in magnitude when satellite SSTs are averaged.

If the standard uncertainty in each is found, the total standard uncertainty is the root sum of squares of the components.

There is considerable effort required to estimate these uncertainty components, but we argue it should become a routine part of SST retrieval design by data producers. At present, little seems to have been done to quantify the correlation properties, such as length scales, of partially correlated errors. It is likely that the results are sensor specific, and quite different for infra-red compared to microwave SST observations.

The poster/presentation will show results of a simulation study to look at the degree of spatio-temporal correlation of errors in infra-red satellite SSTs, and the magnitude of these effects compared to random effects.

SECTION 12: CLOSING SESSION

GHRSST AND POSSIBLE FUTURE DEVELOPMENTS

David T Llewellyn-Jones[(1)]

(1) Space Research Centre, University of Leicester, LEICESTER, LE1 7RH, U.K., Email: dlj1@le.ac.uk

ABSTRACT

The substantial and unprecedented achievements of GHRSST are briefly reviewed. Some of the factors which have led to this success will be identified. As a particular example, the way in which the usage of data from one individual sensor, AATSR, has been facilitated will be cited. Possibilities for future developments for GHRSST are discussed, including the possibilities for analogous initiatives involving other parameters than SST. The future role of the Science team is also considered.

1. Introduction

GHRST has been a truly unprecedented success in the dissemination and hence the use of SST data by operational users and by some other classes of user. The keys to its success lie in several areas; firstly, the existence of a user community with well-established and defined needs; GHRSST's full acceptance and understanding of user requirements; coupled with the establishment and operation of a large-scale international scheme for data handling, processing, storage and dissemination. The tasks of defining, coordinating and, of course, establishing funding, comprise an enterprise which should not be underestimated and is a tribute to the many individual contributors

2. The Scope for Further Development of the GHRSST model

GHRSST will, almost inevitably continue to improve the SST service, both in terms of the quality and versatility of its product and also in the number of data-sources it will utilise, especially from countries not yet participating in GHRSST.

The question of whether or not to set up and incorporate parallel schemes for related marine observations is an important one, which can offer some scientific advantages. As with SST, the feasibility of such a scheme depends on the user need and on the existence of a user consensus on the definition of the product, which in the case of SST are well established, but not necessarily so for other parameters. However, this is a challenge that is worth careful consideration by GHRSST, because operational users will greatly appreciate and benefit from the standardisation of service quality that should result from a 'one-stop shop'.

Thus, there is a case to be made for GHRSST to be prepared to welcome proposals for the dissemination of other marine or, in some cases, atmospheric parameters, but will also need to be aware of the need for an established user community with some agreement on data-product definition.

SECTION 13: NON-PLENARY ABSTRACTS

ST-VAL REPORT TO GHRSST14

Helen Beggs[(1)], Peter Minnett[(2)], Gary Corlett[(3)], Jacob Høyer[(4)], Pierre Le Borgne[(5)], Alexander Ignatov[(6)], Prasanjit Dash[(7)], Feng Xu[(8)], Christopher Griffin[(9)]

(1) CAWCR, Bureau of Meteorology, Australia, Email: h.beggs@bom.gov.au
(2) Peter J. Minnett, Rosenstiel School, University of Miami, USA, Email: pminnett@rsmas.miami.edu
(3) Gary Corlett, University of Leicester, UK, Email: gkc1@leicester.ac.uk
(4) Jacob Høyer, Danish Meteorological Institute, Denmark, Email: jlh@dmi.dk
(5) Pierre Le Borgne, CMS, Meteo-France, France, Email: pierre.leborgne@meteo.fr
(6) Alexander Ignatov, NOAA, MD, USA, Email: Alexander.Ignatov@noaa.gov
(7) Prasanjit Dash, NOAA and Colorado State University, CO, USA, Email: Pransanjit.Dash@noaa.gov
(8) Feng Xu, NOAA/STAR and GST Inc, MD, USA, Email: Feng.Xu@noaa.gov
(9) Christopher Griffin, Bureau of Meteorology, Australia, Email: c.griffin@bom.gov.au

ABSTRACT

This report summarises advances made by members of the Group for High Resolution Sea Surface Temperature (GHRSST) Satellite SST Validation (ST-VAL) Technical Advisory Group (TAG) since the last GHRSST Science Team Meeting in June 2012.

1. Introduction

The ST-VAL TAG was established to look at all aspects of satellite SST validation: from the reference data itself, to the challenges which occur when comparing these locally representative reference observations to satellite data, to the ongoing refinement of the uncertainty estimates. During the past year the emphasis has been on the following:

- Upgrading the *In Situ* SST Quality Monitor (*i*Quam; Section 2)
- Validating the new Visible Infrared Imaging Radiometer Suite (VIIRS) SST products available from the Suomi National Polar-orbiting (S-NPP) satellite using SQUAM (Section 3) and *in situ* data from drifting buoys and shipboard radiometers (Section 4)
- High latitude validation of satellite SST using an *in situ* SST radiometer (Section 5)
- Development of a multi-sensor match up database for ESA's Climate Change Initiative (CCI) (Section 6)
- Efforts to produce improved sensor specific error statistics for AVHRR L2P, L3U, L3C and L3S products (Section 7)
- Comparisons of Meteo-France's Centre de Meteorologie Spatiale (CMS) and NOAA blacklists of *in situ* SST observations
- Testing impact of using GHRSST SSES bias corrections on various data streams ingested into the Bureau of Meteorology's operational global daily SST analysis system, GAMSSA (see Report from Australia to GHRSST14 – BLUElink and IMOS)

2. In Situ SST Quality Monitor (iQuam)

The *in situ* SST Quality Monitor (*i*Quam; www.star.nesdis.noaa.gov/sod/sst/iquam/) continues generating QC'd in situ SST data, and presents their monitoring statistics on the web. These data are used at NOAA to generate match-ups with satellite L2 and L3 products and L4 analyses, and monitor the corresponding validation statistics in the SST Quality

Monitor (SQUAM; www.star.nesdis.noaa.gov/sod/sst/squam/). JTECH manuscript submitted describing and documenting *i*Quam v1.

Development of *i*Quam version 2 is underway. The major enhancements in v2 include:

- adding Argo floats
- extending the iQuam time series back to ~1980 (current starting date is 1 Jan 1991)
- generating complete consistent time series of QCed in situ data off ICOADS input (currently, GTS is used)
- replacing the current GTS data source with ICOADS
- adding OSI SAF and UK Met Office black list flags to the iQuam Quality Flags.

3. Monitoring Metop/NOAA AVHRR, Terra/Aqua MODIS, and SNPP VIIRS SST Products in SQUAM

The NOAA SST Quality Monitor (SQUAM; *www.star.nesdis.noaa.gov/sod/sst/squam/*) sustained and expanded its functionality. This was particularly challenging, as in August 2012, NOAA Center for Satellite Applications and Research (STAR) relocated from its World Weather Building (WWB) office in Camp Springs, MD, to the new National Center for Weather and Climate Prediction (NCWCP) in College Park, MD.

SQUAM includes 3 major modules: L2, L3 and L4.

L2-SQUAM

- Sustained monitoring of several low-resolution (AVHRR GAC) SST products, including NOAA MUT, NOAA ACSPO, and NAVO SeaTemp, from NOAA-16, -18, -19, and Metop-A against several L4 products
- Sustained monitoring of several high-resolution SST products (Metop-A AVHRR ACSPO and OSI SAF, Terra and Aqua MODIS, and SNPP VIIRS – IDPS and ACSPO) against several L4 products
- Added Metop-B ACSPO product in SQUAM, following its launch in Sep 2012
- Added validation of ACSPO GAC SSTs against iQuam data
- Improved overall functionality of L2-SQUAM page
- Explored adding display of reprocessed ACSPO data

L3-SQUAM

- Added validation against iQuam data of PathFinder v5.0

Ongoing and work in SQUAM includes

- Improving and completing functionality of L4-SQUAM
- Adding MOD28/MYD28 products in L2-SQUAM
- Adding monthly validation statistics (currently, only daily stats are available)
- Adding monitoring of ACSPO-RAN (reanalysis) data
- Adding geostationary data

4. Validation of VIIRS Skin SST Retrievals using in situ SST and other satellite SST products

The Visible Infrared Imaging Radiometer Suite (VIIRS) on S-NPP is the first in a new series of visible and infrared radiometers to be flown on the Joint Polar Satellite System (JPSS).

Four of the infrared channels of VIIRS were designed to provide accurate retrievals of skin SST. The infrared detectors were cooled down in early 2012 and the data stream stabilized in early March. The following sections report on the validation of the VIIRS SSTs using drifting buoys and shipboard radiometers.

4.1. Data Collection

4.1.1. Drifting Buoys

Quality-controlled subsurface SSTs from drifters are used in generating matchups with the satellite data. The quality assurance is done through the NOAA iQUAM – *in situ* Quality Monitor, which is interrogated on a daily basis. The distribution of the of VIIRS-buoy matchups are shown in Figure 1

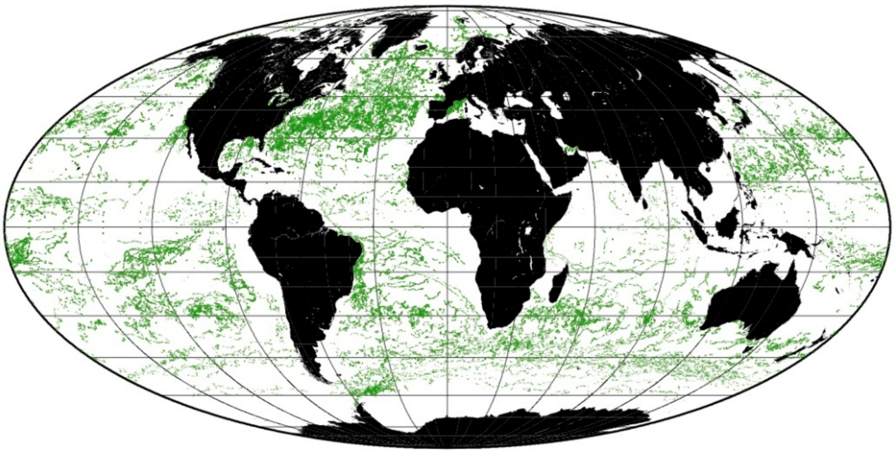


Figure 1. Distribution of VIIRS-buoy matchups

.

The new generations of drifters are being developed and deployed, with the ultimate goal of having accuracies of 0.01K. The first step was to add a second decimal place in the temperature values transmitted in real-time by satellite. The distribution of the VIIRS matchups with these buoys is shown in Figure 16.

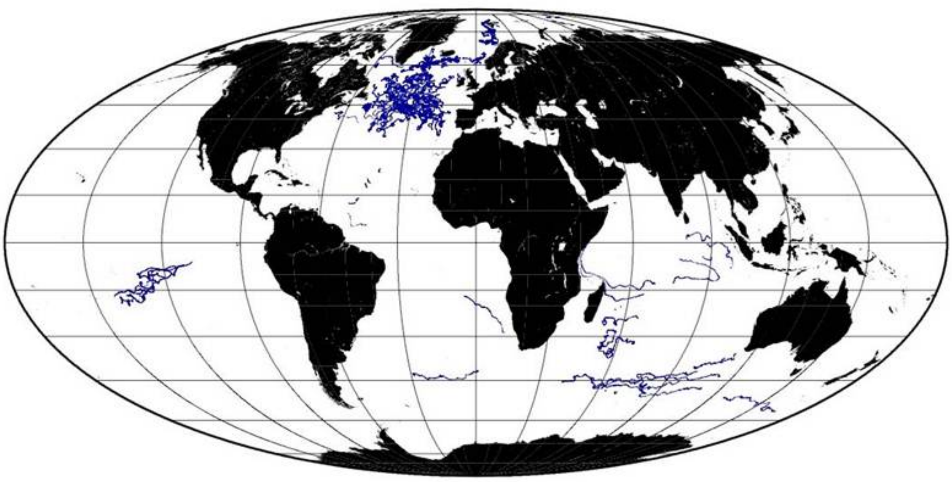


Figure 2. Distribution of of GHRSST drifting buoys.

4.1.2. Ship radiometers – M-AERI

The skin SST measurements for VIIRS validation have been taken by the Marine-Atmospheric Emitted Radiance Interferometers. Figure 17 shows skin SST measurements taken in the North Atlantic Ocean.

With separate funding from NASA, a second-generation M-AERI is being developed and one of the new design instruments was recently mounted together with an original M-AERI on a two month deployment on the R/V *Knorr*. Following post-cruise calibration, the skin SSTs are included in the generation of the VIIRS SST Match-Up Data Base.

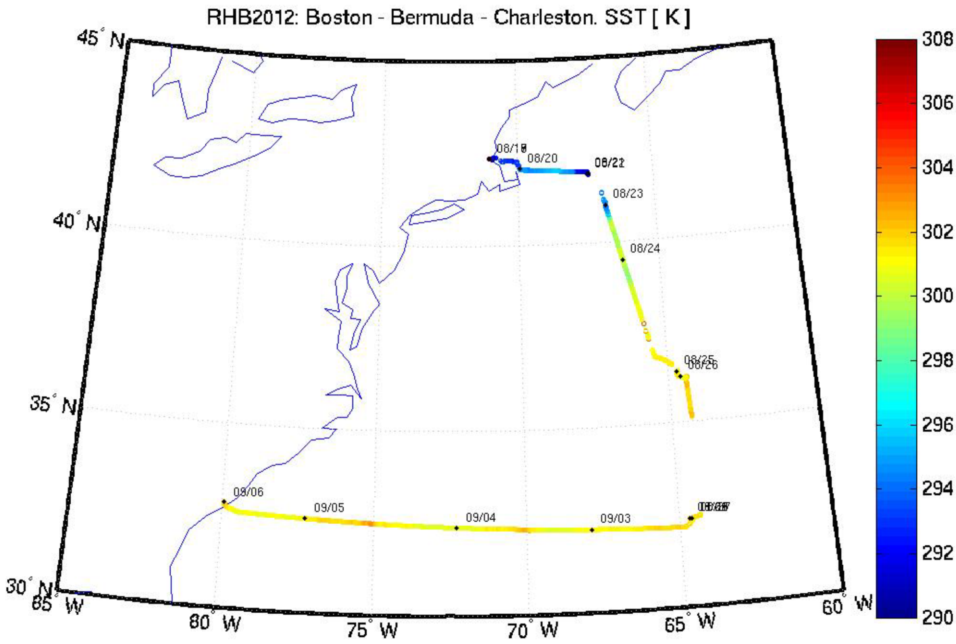


Figure 3. Measurements of the Skin SST from NOAA Ship Ronald H Brown, 18 August – 6 September, 2012. The color scale, on the right, is skin SST in K.

4.1.3. Ship radiometers - ISAR

A second type of ship-board instrument, the Infrared Sea surface temperature Autonomous Radiometer (ISAR) also provides skin SST for VIIRS validation. ISARs are autonomous filter radiometers with two internal blackbody calibration targets and, as with the M-AERIs, pre- and post-deployment laboratory calibration against NIST-traceable calibrators provides SI traceability. Data relayed in real-time by Iridium. We have two ISARs which have been deployed on commercial vessels since the VIIRS SST infrared data stream began. One is on the M/V *Andromeda Leader* which plies between Japan and the USA, with the round-trip taking about two months (Figure 4).

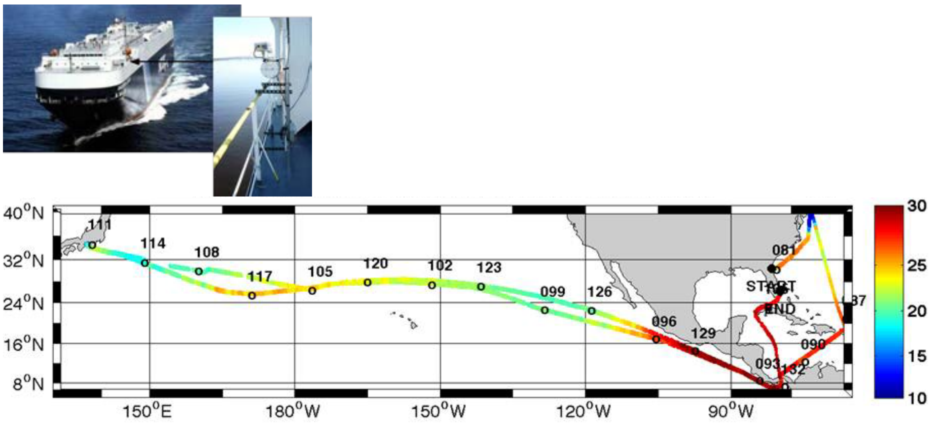


Figure 4. The skin SST measured by an ISAR on the M/V Andromeda Leader from 20 March to 14 April, 2012. The numbers of on the ship track are days of the year, and the colors indicate temperature as indicated at right in oC. Photographs of the ship and the ISAR are also shown.

The second ISAR was mounted on the M/V *Horizon Spirit* as part of the DoE MAGIC field campaign13. Starting in October, 2012, the ship sailed between Los Angeles, California, and Honolulu, Hawaii, taking two weeks for a round trip (Figure 5).

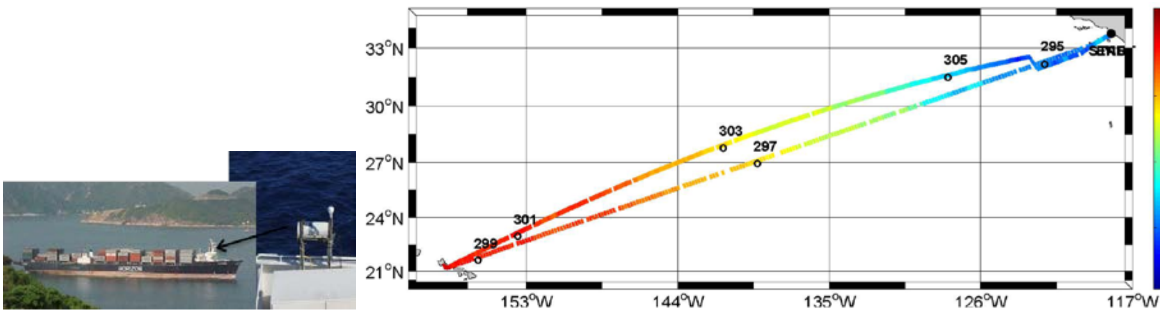


Figure 5. The skin SST measured by an ISAR on the M/V Horizon Spirit from 20 October to 1 November, 2012. The numbers on the ship track are days of the year, and the colors indicate temperature as indicated at right in ^{o}C. Photographs of the ship and the ISAR are also shown.

4.2. Evaluation

4.2.1. Spatial Distribution of Differences with Heritage Data

The evaluation of the integrity of the spatial distribution of the VIIRRS SSTs has been conducted by comparisons with independent fields. The first used is the daily, global SSTs derived from AVHRR data using Optimum Interpolation (OI) to produce regular, gap-free fields. These are frequently referred to as the Reynolds SST (Reynolds and Smith, 1994). An example of the difference field, VIIRS – Reynolds is shown in Figure 20. The VIIRS SSTs are derived using the 3-band night-time algorithm but with the Miami Decision-Tree cloud mask (see below). The data are from data day 2012-225 (August 12, 2012) and are limited

13 See http://www.arm.gov/sites/amf/mag/

to those with the best quality flag and to satellite zenith angles <55^o. The blue areas are where the VIIRS SSTs are likely to be influenced by the presence of atmospheric aerosols, and are therefore cooler than the correct SSTs. The Reynolds OI field is tied to *in situ* measurements and is therefore less influenced by the atmospheric conditions. The areas where VIIRS appears to be warmer than the Reynolds OI fields are more difficult to understand, and it is not clear whether the VIIRS SSTs are showing a warm bias, or whether the Reynolds SSTs have a cold bias.

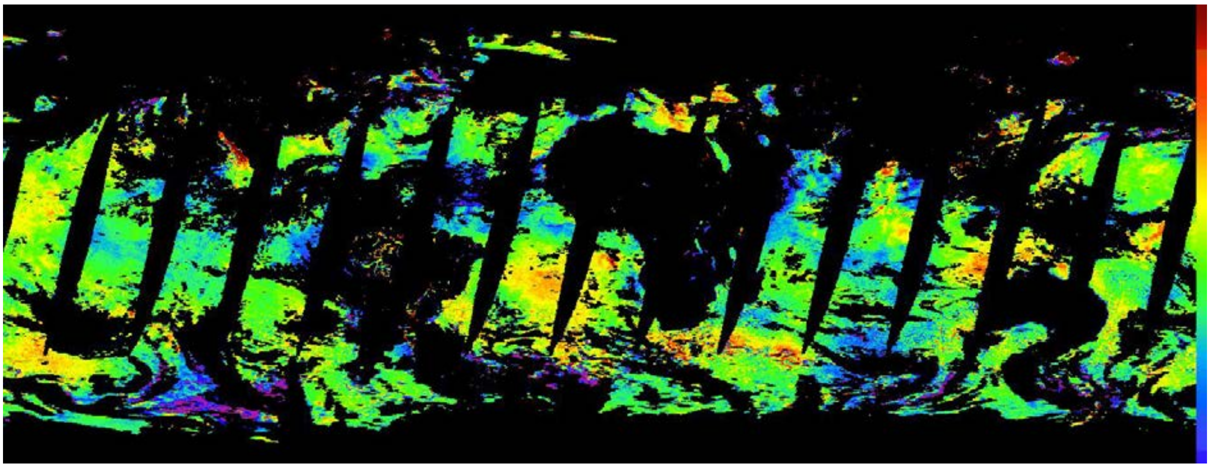


Figure 6. An example of the difference SST field, VIIRS – Reynolds OI. The color scale is ±5K. with red indicating VIIRS warmer than Reynolds OI, and blue cooler. Black indicates land, clouds, and gaps between adjacent swaths.

Figure 7 shows the comparison of VIIRS SSTs (as in Figure 20) with SSTs derived from the microwave radiometer WindSat on the US Navy Coriolis satellite. Because the sources of uncertainties in the microwave SSTs are different to those in the infrared SSTs, the uncertainties in the SSTs used to derive the differences shown in *Figure 21* are uncorrelated. A major source of error in microwave SSTs is the contamination of the measurements by land emission entering the radiometer through the antenna side lobes. Another concern about this comparison is that the geometry of the WindSat swaths requires the compiling of five-days of measurements to generate complete global fields. The terminator orbit of Coriolis means the overpass times are not close to S-NPP. But these concerns aside, the SSTs from WindSat are of good quality. The differences between VIIRS and WindSat SSTs (*Figure 21*) show the same cold bias in regions where we expect aerosol contamination of the VIIRS retrievals, but lack the areas that show a warm bias when compared to the Reynolds OI fields (Figure 20). Although not definitive, this is indicative of regional cold biases in the Reynolds OI fields, not warm biases in the VIIRS SST retrievals.

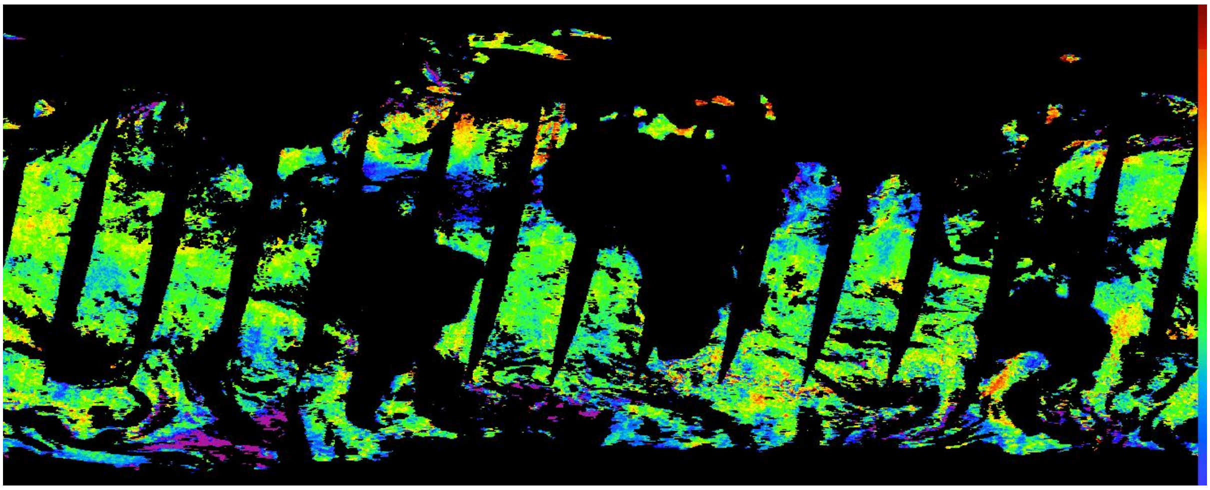


Figure 7. As Figure 6, but VIIRS infrared SST - WindSat microwave SST.

4.2.2. Comparison to In Situ Measurements

As an example of the results of comparisons with *in situ* measurements, *Figure* 22 shows the comparison of the VIIRS skin SSTs with skin SSTs measured by the ISAR in the Pacific Ocean from early February to late October, 2012. The comparison is shown as a time series of the temperature differences. The VIIRS SSTs are derived at night using the 3-band algorithm (Equation 4) using the Miami Cloud Mask, and retrieval coefficients also derived at Miami. The mean of these 267 matchups is 0.029K, with a standard deviation of 0.416K. These are very encouraging numbers. The causes of the outliers are being investigated.

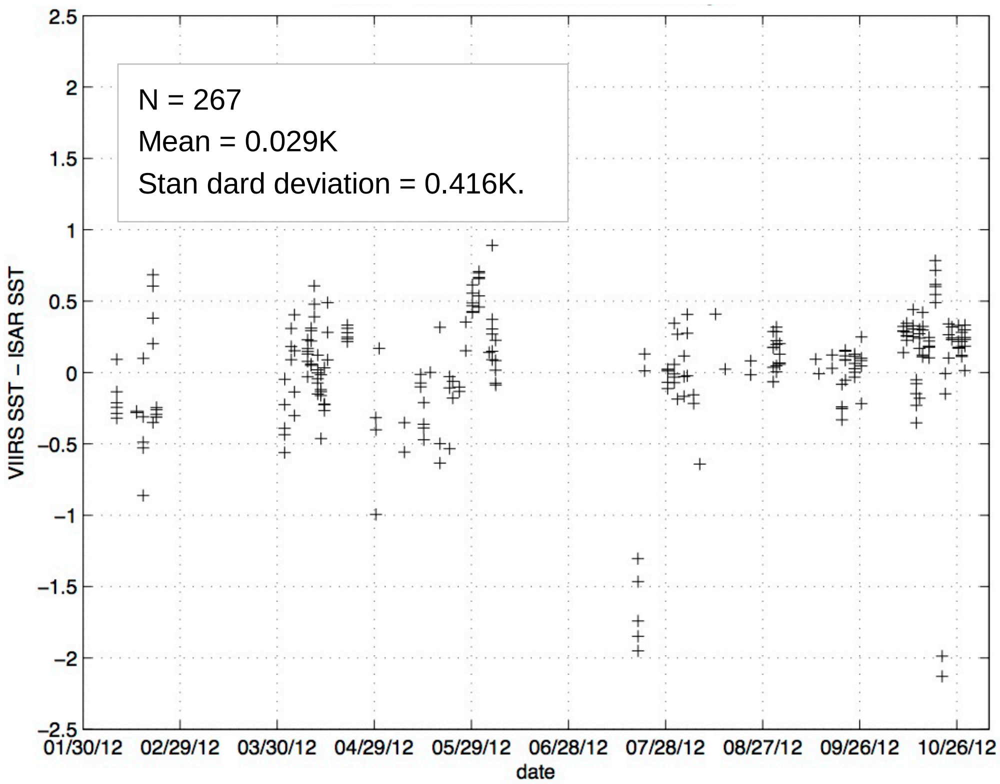


Figure 8. Time series of VIIRS night-time 3-band SST retrievals referenced to skin SST measured by the ISAR in K.

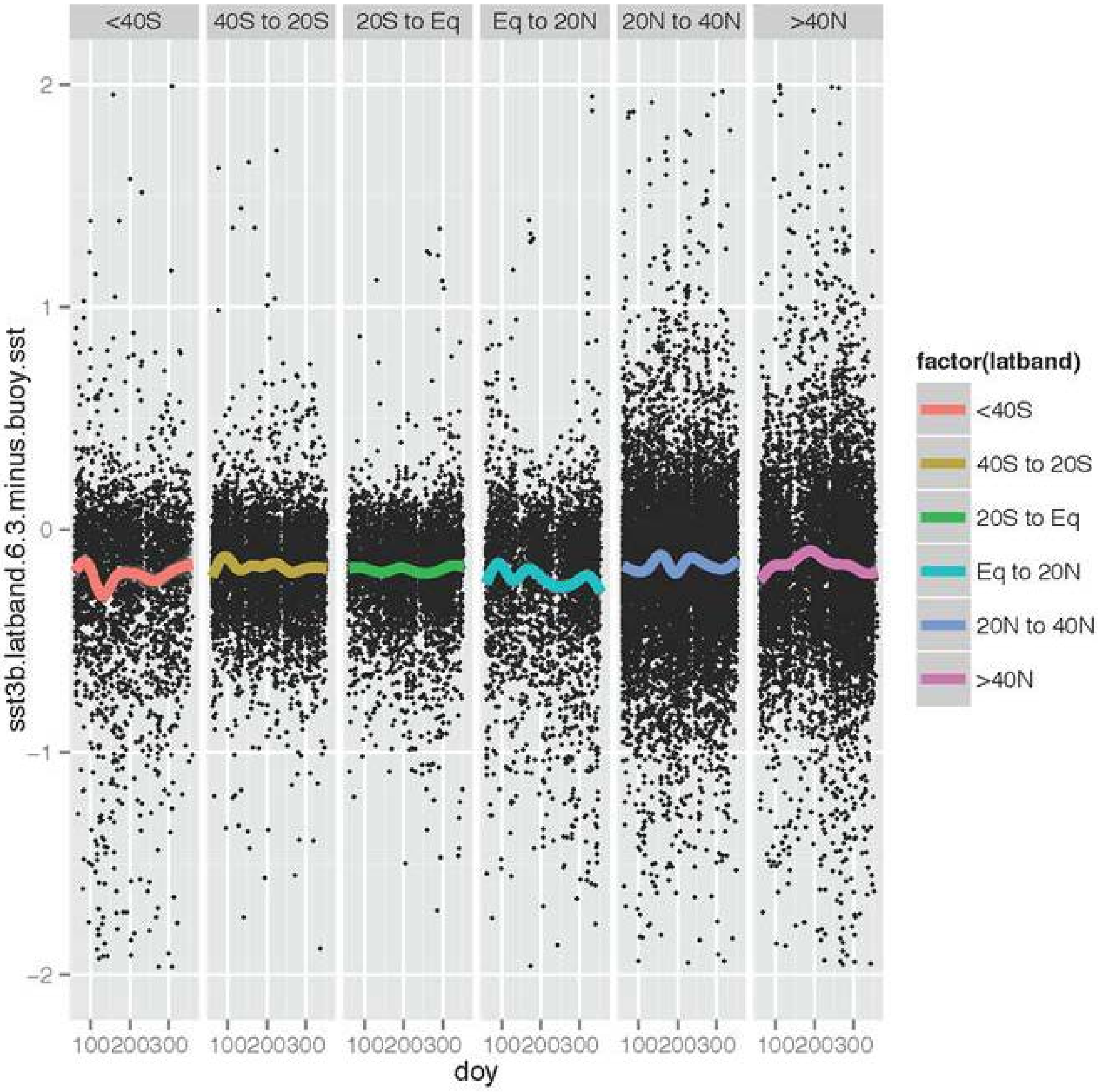


Figure 9. Time series of the median errors in latitudinal bands (colors) and the individual points (black). Day 100 is April 9, and 350 is December 15, 2012.

The time series of the median and standard deviations of the daily differences between the VIIRS skin SSTs derived with RSMAS algorithms using the 3-band night-time measurements and subsurface temperatures measured from drifting buoys are shown in Figure 9. These algorithms are based on our experience with the MODIS and AVHRR retrievals. This involves generating the coefficients for the NLSST algorithm using matchups in zonal bands in monthly intervals, with smoothing across the domain boundaries. The Miami Decision-Tree cloud mask has been used here (*Figure 10*).

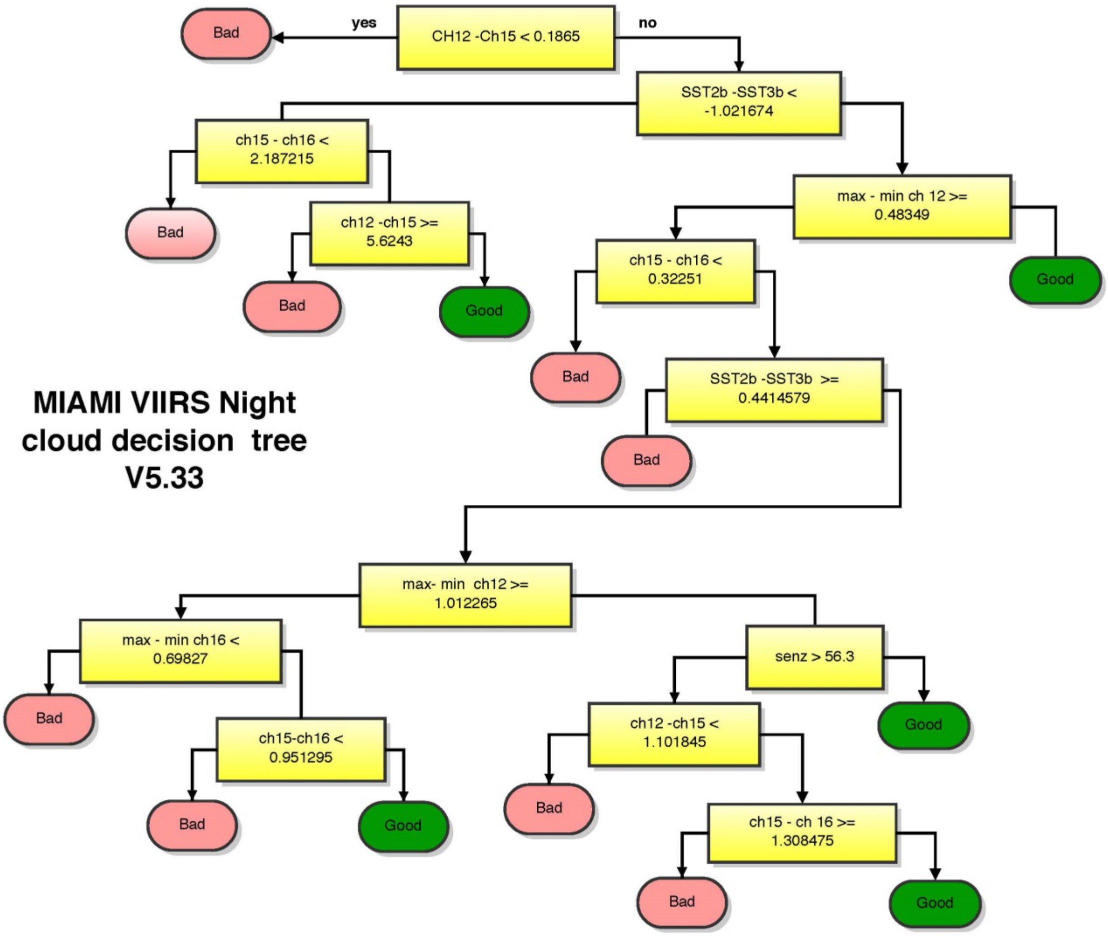


Figure 10. Miami Decision-Tree approach to the identification of cloud-free pixels. Each test is derived from physical expectations based on the radiometric measurements in different VIIRS bands, and on the measurement geometry. Only pixels that are designated "Good" provide high quality SSTs. This example is for night-time measurements.

5. DMI High Latitude SST Validation Activities

The Danish Meteorological Institute (DMI) has purchased an ISAR radiometer to be used for high latitude SST and Ice surface temperature validation studies. The current status is that the radiometer has been deployed as part of the LOMROG III expedition on an ice breaker going to areas north of Greenland. In addition, a field campaign has been carried out to Qaanaaq in western Greenland. DMI plan to mount the ISAR this summer on a regular vessel sailing from Denmark (Aalborg) to Greenland (Nuuk) every 3 weeks. The ISAR data will be used for high latitude validation of operational L2P observations entering the DMI OI processing system. Finally, DMI has been elected to the Sentinel 3 Cal/Val team, where the radiometer observations will also be used.

6. Multi-Sensor Match-up Database for ESA SST_CCI

A multi-sensor match-up dataset (MMD) is a set of temporal and spatial coincidences between multiple satellite datasets of both L1 and L2 retrievals and time series of corresponding measurements from various types of in situ instruments. The implementation of a multi-sensor matchup database (MMDB) is a fundamental requirement for the SST system of ESA's Climate Change Initiative (CCI), facilitating the continuous algorithm improvement cycle.

For the production of the SST-CCI round-robin data package (RRDP) an SST multi-mission match-up system (MMS) has been developed and implemented for the first time. The MMDB covers a period of 20 years and includes satellite datasets from (A)ATSR, NOAA AVHRR, MetOp AVHRR and SEVIRI, passive microwave AMSR-E and TMI, GOME-2, OSI SAF, analysis and forecast datasets from ECMWF, and in situ measurement time series recorded by drifting buoys, moorings and ships. In total, the MMDB includes more than 6 million match-up records.

The MMS runs on the Edinburgh Compute and Data Facility (ECDF) cluster and makes use of the Sun Grid Engine (SGE). It employs the ATSR Reprocessing for Climate (ARC) software to retrieve SST on arbitrary sets of match-up records. The database implementation is based on open-source PostgreSQL with PostGIS extension.

7. BoM Efforts to Improve Sensor Specific Error Statistics for AVHRR SST Level 3 Products

As a contribution to the Australian Integrated Marine Observing System (IMOS), the Australian Bureau of Meteorology produces operational SST products in the GHRSST GDS v2.0 formats from locally received High Resolution Picture Transmission (HRPT) AVHRR data from NOAA polar-orbiting satellites.

Bureau staff worked over the past 12 months to determine and document the Sensor Specific Error Statistics (SSES) for gridding and merging multiple images from the same source as well as images from multiple sources that preserve the sense of the data sources. SSES deviations and biases now better reflect current levels of matchup accuracy, advised by historical information.

Important features of the new IMOS SSES method are as follows:

- Inclusion of sses_count as a new experimental field corresponding to an indicative number of in situ measurements that contribute to SSES estimates in L2P (single swath, geolocated) files and an indicative number of incumbent pixels with SSES in L3U (single swath, gridded), L3C (single sensor, multiple swath, gridded) and L3S (multiple sensor, gridded) files.
- Inclusion of sst_count, sst_mean and sst_standard_deviation as new experimental fields in L3C files allowing the diurnal variation and composition of weighted standard error statistics to be separated, and aid in the combination of multiple L3C files into a single L3C files over a longer time period, as well as merging multiple L3C files into L3S multiple instrument composites

The four new experimental fields described above allow L3S and L3C files to be combined hierarchically, producing L3S files at an intermediate step that can be further combined. Longer term (climatological) products with many individual data sources can thus be produced recursively with the resulting SSES independent of the exact order in which the files were combined. For example, annual L3S SST could be generated by combining four quarterly L3S SST products which are in turn derived from three monthly L3S SST products, each of which are composed of daily L3S products, which are in turn composed of the L3C products from various source instruments on their respective days. The resulting L3S product would contain estimates of the diurnal variation as well as the in situ error, with biases corresponding to both, determined as if all of the original L3C files were processed in a single pass.

Further information on the new SSES computation methodology can be found at http://imos.org.au/srsdoc.html.

L4 COMPARISON USING REYNOLDS/CHELTON SPECTRUM TEST

T. Mike Chin[(1)], Michelle Gierach[(1)], Ed Armstrong[(1)], Jorge Vazquez[(1)]

(1) Jet Propulsion Laboratory, Pasadena, California USA, Email: mike.chin@jpl.nasa.gov

ABSTRACT

At the last GHRSST meeting (13th, in Tokyo), Dudley Chelton and co-authors presented preliminary results of a proposed test for evaluating the analysis procedures used by various GHRSST L4 datasets, which was later published in Journal of Climate as "Objective Determination of Feature Resolution in Two Sea Surface Temperature Analyses" by Reynolds, Chelton, Roberts-Jones, Martin, Menemenlis and Merchant; *http://dx.doi.org/10.1175/JCLI-D-12-00787.1*. In their presentation, the test was applied to the analysis procedures of the NCDC Two-Stage OI and OSTIA. There was an expressed interest among GHRSST L4 data producers to perform this test on their analysis procedures. To that extent, Dudley Chelton and Dick Reynolds have been working closely with the GDAC/PO.DAAC to provide this capability, which this presentation describes. Specifically, interested L4 producers can download the simulated SST data sets used in the paper by Reynolds et al., apply their analysis methods to the data, and then compute the auto-spectra and cross-coherence spectra to be compared to those evaluated in the paper.

The data sets and a tutorial are provided on the PO.DAAC ftp site *ftp://ghrsst@podaac.jpl.nasa.gov*; please contact Ed Armstrong (*Edward.M.Armstrong@jpl.nasa.gov*) in advance to receive your login/password.

MUR GLOBAL L4 SST ANALYSIS STATUS REPORT

***T. Mike Chin*[(1)], *Jorge Vazquez*[(1)], *Ed Armstrong*[(1)]**

(1) Jet Propulsion Laboratory, Pasadena, California USA, Email: mike.chin@jpl.nasa.gov

ABSTRACT

The Multi-scale Ultra-high Resolution (MUR) L4 data product is a daily SST analysis gridded at 1km horizontal resolution globally. The temporal coverage is from 1 June 2002 to present (with a 4-day latency). Its primary input data sets are MODIS (Terra and Aqua), AMSR-E, Wind-SAT, AVHRR-GAC, and in-situ (buoys). The technique for data fusion is the Multi-Resolution Variational Analysis (MRVA) method. The MUR project has just completed 5th year of production effort, and “Version 4” of the MUR SST product has just been released. The major updates in the latest version include correction on the SST value over areas with finite amount of ice and incorporation of Wind-SAT data to replace the microwave inputs formerly provided by AMSR-E. The webpages for the MUR product are: **http://podaac.jpl.nasa.gov/Multi-scale_Ultra-high_Resolution_MUR-SST** and **http://mur.jpl.nasa.gov**.

MULTI-SENSOR MATCH-UP DATABASE FOR ESA SST_CCI

Gary Corlett[1], Martin Boettcher[2], Ralf Quast[2], Thomas Storm[2], Chris Merchant[3], Craig Donlon[4]

[1]University of Leicester, United Kingdom
[2]Brockmann Consult GmbH, Germany
[3]University of Reading, United Kingdom
[4]ESA/ESTEC, The Netherlands

ABSTRACT

A multi-sensor match-up dataset (MMD) is a set of temporal and spatial coincidences between multiple satellite datasets of both L1 and L2 retrievals and time series of corresponding measurements from various types of in-situ instruments. The implementation of a multi-sensor matchup database (MMDB) is a fundamental requirement for the sea surface temperature (SST) system of ESA's Climate Change Initiative (CCI), facilitating the continuous algorithm improvement cycle.

For the production of the SST-CCI round-robin data package (RRDP) an SST multi-mission match-up system (MMS) has been developed and implemented for the first time. The MMDB covers a period of 20 years and includes satellite datasets from (A)ATSR, NOAA AVHRR, MetOp AVHRR and SEVIRI, passive microwave AMSR-E and TMI, GOME-2, OSI SAF, analysis and forecast datasets from ECMWF, and in-situ measurement time series recorded by buoys, drifters, moorings and ships. In total, the MMDB includes more than 6 million match-up records.

The MMS runs on the Edinburgh Compute and Data Facility (ECDF) cluster and makes use of the Sun Grid Engine (SGE). It employs the ATSR Reprocessing for Climate (ARC) software to retrieve SST on arbitrary sets of match-up records. The database implementation is based on open-source PostgreSQL with PostGIS extension.

PRELIMINARY ANALYSES OF METOP AVHRR, MODIS AND VIIRS SST PRODUCTS IN SQUAM

Prasanjit Dash[1,2], Sasha Ignatov[1], Yury Kihai[1,3], John Stroup[1,4], John Sapper[1]

(1) National Oceanic and Atmospheric Administration, MD, USA
(2) Colorado State Univ / Cooperative Inst for Research in the Atmosphere, CO, USA
(3) GST, Inc, MD, USA
(4) STG, Inc, VA, USA

ABSTRACT

The Suomi National Polar-orbiting Partnership (S-NPP) satellite serves as a bridge mission from the NOAA POES and NASA EOS programs toward the Joint Polar Satellite System (JPSS), a collaborative effort between US and European polar programs. The Visible/Infrared Imager/Radiometer Suite (VIIRS) sensor draws on the success of heritage AVHRR and MODIS sensors, flown onboard NOAA/Metop and Terra/Aqua satellites, respectively.

Global sea surface temperature (SST) products at VIIRS native resolution have been generated in near real-time since January 2012 by two NOAA systems: operationally, by the Interface Data Processing Segment (IDPS) developed and operated by the S-NPP contractor, Raytheon, and experimentally, by the Advanced Clear-Sky Processor for Oceans (ACSPO), developed at STAR. Additionally, the ACSPO system also processes data from several AVHRRs onboard NOAA (16, 18 and 19; GAC) and Metop (-A and- B; FRAC and GAC), and two MODISs, onboard Terra and Aqua. All SST products are routinely monitored and cross-evaluated in the SST Quality Monitor (SQUAM; ***www.star.nesdis.noaa.gov/sod/sst/squam/***) and their relative performances are reported online. Additionally, global Metop-A AVHRR SST generated by O&SI SAF/Eumetsat is also monitored in SQUAM. Several daily level-4 gap-free SSTs (such as OSTIA and Reynolds) and quality controlled *in situ* data from *i*Quam are used as references for relative evaluation of these level-2 products.

One and a half years of S-NPP VIIRS SSTs (from IDPS and ACSPO) and Terra/Aqua MODIS (ACSPO) SSTs, and longer time series of Metop-A AVHRR FRAC (from O&SI SAF and ACSPO) in SQUAM are presented. Preliminary results of correlated errors for different reference L4 SSTs are discussed. The performance of SST algorithms and cloud-masks will be shown, using established SQUAM metrics and additional exploratory analysis, and cross-comparisons of various high-resolution SSTs are discussed.

SQUAM UPDATES: PROGRESS SINCE GHRSST-13 AND FUTURE WORK

Prasanjit Dash[1,2], Sasha Ignatov[1]

(1) National Oceanic and Atmospheric Administration, MD, USA
(2) Colorado State Univ / Cooperative Inst for Research in the Atmosphere, CO, USA

ABSTRACT

With a range of SST products available from different systems and of different types (levels 2, 3 and 4), a desirable step in the SST community is validation and cross-comparison of these products to check for their relative merits, in a timely manner. To achieve this objective, the web-based near-real time SST Quality Monitor (SQUAM; *www.star.nesdis.noaa.gov/sod/sst/squam*) was developed at NOAA.

The major focus of this year was on L2-SQUAM, to support two major launches: S-NPP in October 2011 and Metop-B in September 2012. Two VIIRS SST data streams were included in L2-SQUAM, IDPS and ACSPO. Metop-A/B FRAC and GAC SST products have also been included. Also, validation against *in situ* data was added to L3-SQUAM (which currently only reports Pathfinder 5 data), and to L2-SQUAM ACSPO GAC modules. Despite these additions (level-2, 3), SQUAM also suffered from stagnation in some of its modules (level-4) because of unavoidable circumstances. For example, L4-SQUAM received a reduced priority, following the STAR office move from Camp Springs to College Park in August 2012. Work is underway to resume and complete L4-SQUAM, expand L3-SQUAM (by adding (A)ATSR ARC dataset 1991-2012) and L2-SQUAM by adding MOD28/MYD28 products. We also plan to upgrade SQUAM to include monthly in situ statistics for all the level-2 products.

THE SENTINEL-3 MISSION: PERFORMANCE AND STATUS

C. Donlon[1], B. Berruti[1], S. Mecklenberg[2], J. Nieke[1], H. Rebhan[1], U. Klein[1], A. Buongiorno[2], C. Mavrocordatos[1], J. Frerick[1], B. Seitz[1], P. Goryl[2], P. Féménias[2], and J. Stroede[1]

(1) European Space Agency ESA/ESTEC, Keplerlaan 1, 2201 AZ, Noordwijk, The Netherlands.
Craig.donlon@esa.int
(2) European Space Agency/ESRIN, via Galileo Galilei, Frascati Rome, Italy.

ABSTRACT

Global Monitoring for Environment and Security (GMES) is a joint initiative of the European Commission (EC) and European Space Agency (ESA), which aims at achieving an autonomous and operational Earth observation capacity. Two Sentinel-3 satellites are in development with the second satellite expected approximately 18 months after the first. The overall service duration is planned to be 20 years with several satellites. Currently, the launch of the first Sentienl-3 satellite is planned in mid 2014 and the second unit ~18 months later. This joint presentation will present an update on SLSTR Performance and with a focus on (a) application of SLSTR SST data as a reference mission for the International SST constellation. (b) Engaging the international community in Sentinel-3 calibration and validation activities.

SEA SURFACE TEMPERATURE BY BARNES' INTERPOLATION: CURRENT STAGE

Rosa Cristhyna de Oliveira Vieira Paes[(1)], Rodrigo Carvalho de Sousa[(1)], Gutemberg Borges França[(1)] and Igor Balteiro Pereira de Campos[(1)]

(1) Federal University of Rio de Janeiro, Department of Meteorology, Laboratory of Applied Meteorology, University City Campus, CEP: 21.941-916 Rio de Janeiro, RJ - Brazil., Email: rosa,rodrigo,gutemberg,igor@lma.ufrj.br

ABSTRACT

A simple system for daily cloud free sea surface temperature (SST) composition based on thermal AVHRR and microwave TMI data is presented here. Barnes' objective analysis (Barnes, 1964) is applied as an interpolator to merge these two data sources, which have different spatial and temporal resolutions in a daily SST composition and in a regular grid product. Three comparisons were carried out as follows. First, in situ SST (daily average) measurements from eleven PIRATA's buoys were compared. The correlation coefficients results varied from 0.89 to 0.99, and RMSE, MAE and MBE values have not exceeded 0.57 for period from 2002 to 2010. Second, comparisons between daily SST composition and average daily in situ SST collected from twenty three drifting buoys for the period from May 2008 to October 2010. The statistics results are 0.94, 0.25, 0.19 and -0.002 for correlation, RMSE, MAE and MBE, respectively. Third, SST (daily average) time series generated by OSTIA project was compared. The temporal and spatial RMSE (considering the study area) values ranged from approximately 0.21^{o}C to 1.50^{o}C and its average was 0.47^{o}C for the period from January 1st to May 31st, 2006. Validation results are quite consistent (with SST composition accuracy less than 1.0^{o}C). The idea of interpolated SST field uncertainty is obtained from the daily covariance matrix which is computed using ensemble approach for the period of four years from 2005 to 2008 and its results are compared with OISTA's one on 30th June 2012.

1. Introduction

This work is a complementary one of the França *et al*. (2011) presented in the GHRSST XII Science Team Meeting. The update SST improvements are basically as follows: the inclusion of the SST (blended AVHRR and TMI) daily uncertainty and comparison with OSTIA's product.

2. Study area and SST data

The study area lies between latitudes 45°S and 15°N and longitudes 70°W and 15°W, related to the data periods from 2002 to 2010. The composition SST is based on daily AVHRR data from NOAA 18 and 19 and TMI data form TRMM with spatial resolution of approximately 9 km and 25 km, respectively.

In order to validate results daily average in situ SST data collected at 1 meter depth from a set of 11 moored buoys of PIRATA (Pilot Research Moored Array in the Tropical Atlantic) project, 23 drifting buoys of PNBOIA project and OSTIA's SST were used.

3. Method

The methodology to produce the SST field is based composed of the three main steps as shown in Figure 1. The inputs data are cloud free AVHRR and TMI data input which Barnes interpolation is applied to produced the blended daily SST. The daily uncertainty field is estimated by the covariance matrix obtained via ensemble (Fu *et al.*, 2009). The ensemble is generated so that it contains variability of the ocean at the surface. This work has used forty four ocean states (members) from each day (2005 to 2008, considering 10 days before and after, 2-days interval) to produce the daily SST uncertainty which is make available with SST field (in the NetCDF format, GDSV2.0).

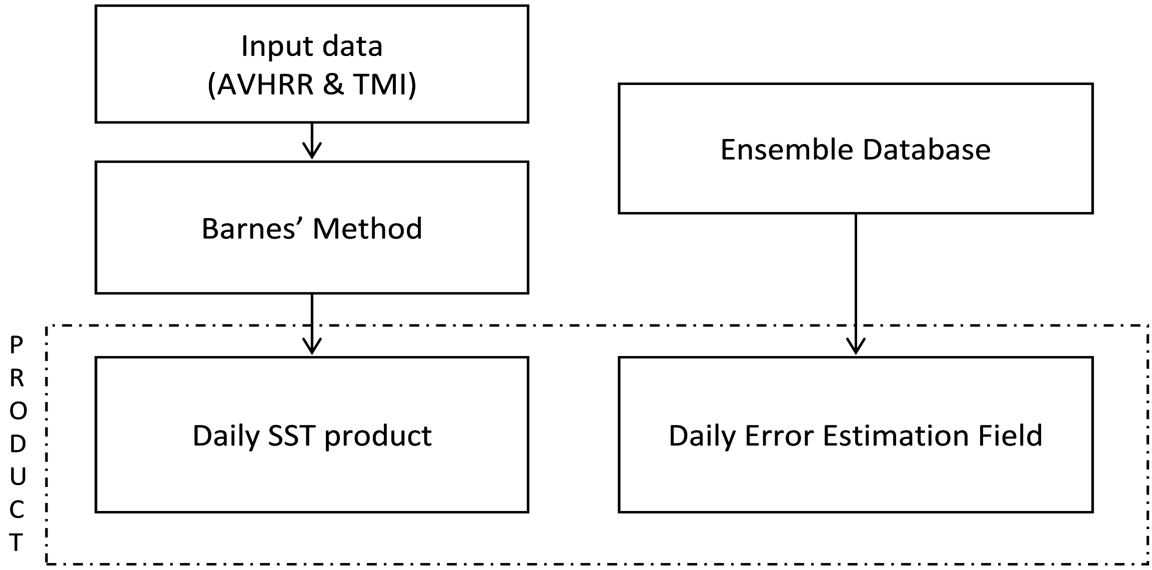


Figure 1. SST field estimation method and its uncertainties.

4. Validation

The SST validation were made by using 11 PIRATA's project buoys (taking its temperature approximately at 1 meter depth) and 23 drift buoys from National Buoys Program (PNBOIA) from Brazilian Navy for the period from September 2002 to December, 2010. Comparison between the daily analysis cloud-free SST and *in situ* SST measurements, the correlation coefficient (CORR) is higher than 0.85 and Root Mean Square Error (RMSE), MAE Mean Absolute Error (MAE) and Mean Bias Error (MBE) have not exceeded 0.6 for all *in situ* measurements. Additionally, comparison with SST drifting buoys has showed very consistent results, with values of RMSE and correlation of 0.250 and 0.944.

Figure 2 displays in the study area the RMSE between OSTIA and the SST produced in this work for the period from January 1st to June 30th, 2006. The RMSE varies approximately from 0.21^{o}C to 1.50^{o}C and its average is 0.47. The maximum RMSE value appears in Brazil-Malvinas current confluence region near Brazil and Uruguay borders and also in the regions of upwelling since those regions are characterized by considerable thermal gradient in time (Olson *et al.*, 1988; Piola *et al.*, 2000). In Figure 3 is spatially showed the error difference of standard deviation between OSTIA product and the one calculated from the error estimated in this work on 30th June 2012. In summary, the maximum differences are also presented in Brazil-Malvinas current confluence region as in Figure 2.

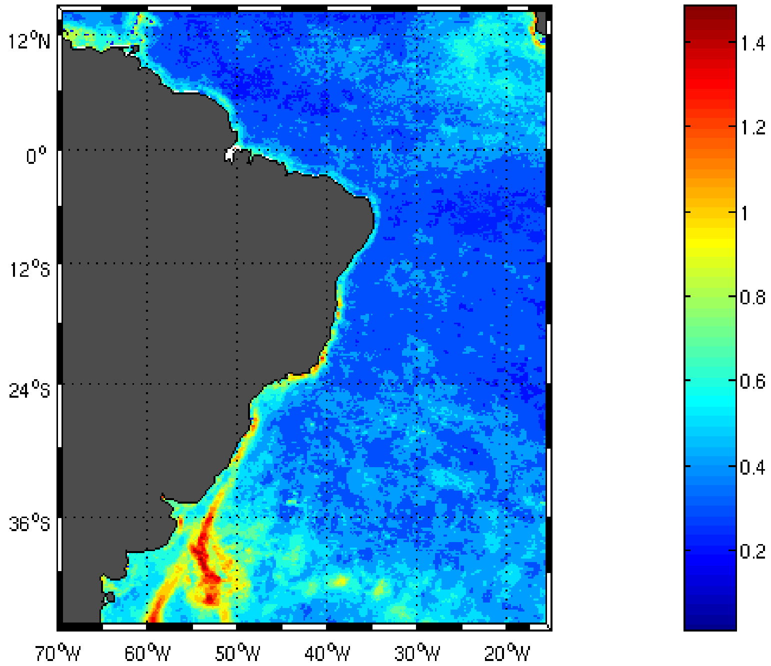


Figure 2 – RMSE field generated from SST estimated values considered in this work and SST estimated values of OSTIA project collected during the period from January 1st to June 30th, 2006.

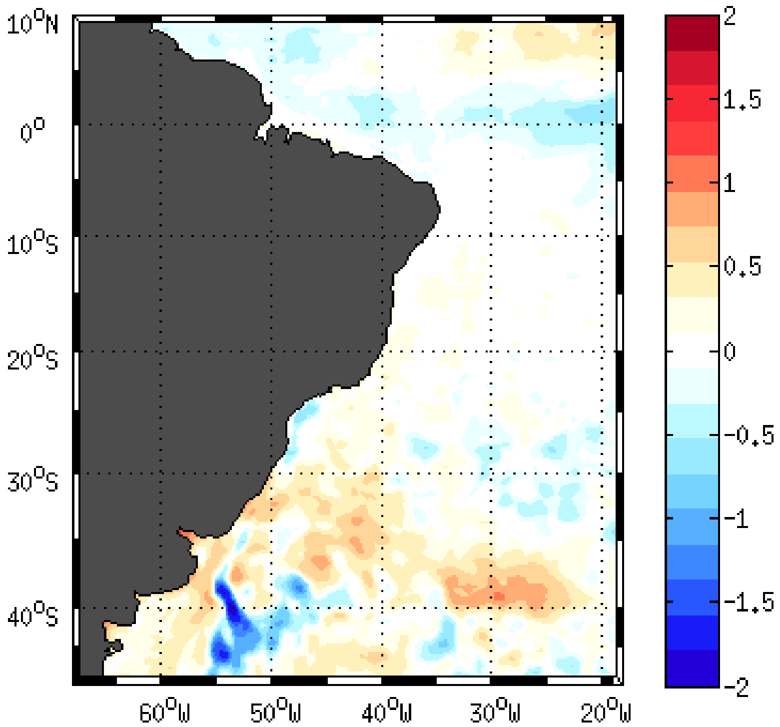


Figure 3 – Error estimation difference between OSTIA's SST and one estimated in this work on 30th June 2012.

5. Conclusion

This work presents a procedure for daily SST composition based on AVHRR and TMI SST using Barnes' approach and to present the current accuracy of the product by comparing it with in situ buoys near SST and OSTIA SST product. Overall, the results have revealed a good performance of the system. All comparisons carried out in this work between daily SST composition and in situ SST measurements from eleven PIRATA's buoys show that the correlation coefficients vary from 0.89 to 0.99 and RMSE, MAE and MBE values have not exceeded 0.57, considering time period from 2002 to 2010. Similar the latter, comparisons were realized between daily SST composition and average daily in situ SST collected from twenty three drifting buoys for the period from May 2008 to October 2010. The statistics results are 0.94, 0.25, 0.19, and -0.002 for correlation, RMSE, MAE and MBE, respectively.

Furthermore, a comparison with SST time series generated by OSTIA project shows results with good coherence since the RMSE values vary approximately from 0.21°C to 1.50°C and its average is 0.47 for the period from January 1st to May 31st, 2006. Besides, the difference of the field error estimation against one generated by OSTIA is quite coherent, as present in Figure 4. Although, further improvements probably may be gained by increasing the number of error samples.

Based on result analysis, it may be stated that the developed system can provide a daily SST cloud free product with absolute error less than 1.0°C. Although the results are reasonable, the validation activities are recommended and should be permanently carried out.

6. References

Barnes, S., -1964- A technique for maximizing details in numerical weather map analysis, Journal Applied Meteorology. 3: 395-409.

França, G. B. ; Oliveira, A. N. ; Ruivo, B. C. ; Paes, R. C. O. V. . Applying Barnes Technique for Daily SST (AVHRR and TRMM/Microwave) Images Composition. In: The Ghrsst XII Science Team Meeting, 2011, Edinburgh. The GHRSST XII Science Team Meeting, 2011. p. 209-212.

Fu W. W., Zhu J. e Yan C. X. A comparison between 3DVAR and EnOI techniques for Satellite altimetry data assimilation,. Ocean Modelling, v. 26, p. 206-216, 2009.

Olson, D. B., Podesta, G. P., Evans, R. H. & Brown, O. B., 1988, Temporal variations in the separation of Brazil and Malvinas Currents. Deep Sea Research Part A, Oceanographic Research, vol. 35, 12: 1971–1990.

Piola, A. R., Campos, E. J. D., Möller JR., O. O., Charo, M. & Martinez, C., 2000, Subtropical Shelf Front off eastern South America, Journal of Geophysical Research, vol. 105: 6565–6578, doi:10.1029/1999JC000300.

MONITORING OF IR CLEAR-SKY RADIANCES OVER OCEAN FOR SST (MICROS): RADIOMETRIC STABILITY AND CONSISTENCY OF AVHRRS, MODISS, AND VIIRS

XingMing Liang[1,2], Alexander Ignatov[1]

(1) NOAA/NESDIS, Center for Satellite Application and Research (STAR), College Park, MD 20740

(2) CSU, Cooperative Institute for Research in the Atmospheres (CIRA), Fort Collins, CO 80523

ABSTRACT

Monitoring of IR Clear-Sky Radiances over Oceans for SST (MICROS; *www.star.nesdis.noaa.gov/sod/sst/micros*) is NESDIS near-real time web-based radiance monitoring system. It analyzes Model (Community Radiative Transfer Model, CRTM) minus Observation (M-O) biases in brightness temperatures (BT) in three bands centered at 3.7 (IR37), 11 (IR11), and 12µm (IR12), for several AVHRR (NOAA-16, -17, -18, -19, and Metop-A, -B), V*IIRS (Suomi National Polar Partnership, S-NPP),* and MODIS (Terra, Aqua) sensors. Double-differences (DD) are employed to check BTs for radiometric stability and consistency. All sensors are stable, with the exception of two AVHRRs, onboard NOAA-16 and to a lesser extent NOAA-18, and generally consistent. VIIRS onboard S-NPP, launched in October 2011, is well in-family, especially after its calibration was fine-tuned on March 7, 2012. MODIS M-O biases were initially out-of-family by up to -0.6K, due to incorrect CRTM transmittance coefficients. Following MICROS feedback, CRTM Team updated coefficients and brought MODIS back in-family. Terra and Aqua BTs are very consistent in bands 31 (IR11) and 32 (IR12) but show cross-platform bias of 0.3K in band 20 (IR37), likely attributed to sensors. Work with MODIS Characterization Support Team is underway to resolve. Initial analyses of AVHRR onboard Metop-B launched in September 2012 suggest that its BTs are offset from Metop-A by up to ~0.3K, depending upon band. We conclude that MICROS DDs are well suited to evaluate sensors stability, but dedicated effort is needed to ensure consistent RTM calculations for various sensors before DDs can be used in Global Space-based Inter-Calibration System (GSICS) quantitative applications.

PATTERN RECOGNITION ENHANCEMENTS TO NOAA ACSPO CLEAR-SKY MASK

Irina Gladkova[1], Fazlul Shahriar[1], Yury Kihai[2,3], Boris Petrenko[2,3], Alexander Ignatov[2], Michael Grossberg[1]

(1) NOAA CREST, City College of New York
(2) NOAA/STAR
(3) GST, Inc

Determination of SST from VIIRS, MODIS and AVHRR imagers requires highly accurate clear sky mask (CSM). The current NOAA SST system, Advanced Clear-Sky Processor for Oceans (ACSPO), employs point-wise intensity thresholds, spectral consistency, and spatial uniformity checks for clear-sky detection. This study explores pattern recognition enhancements to ACSPO CSM. Generally, ocean is more uniform than cloud, resulting in slowly meandering flow-like patterns, whereas high frequency flaky structures come from cloud. We explore machine learning (pattern recognition) methods applied to satellite derived SST imagery, to statistically determine a highly sensitive cloud mask for use in the SST product. The algorithms should minimize “cloud leakage” and “false alarms”, be fast, robust, and globally applicable, 24/7.

The approach we will present uses a set of training examples, manually marked by experts, to build statistical models of “confident clear” and “confident cloud” in a high dimensional local feature space. Example of such mark-up is shown in Figure 1. Figure 2 (right panel) shows the confidence score computed by logistic regression algorithm on the per-pixel values of SST, VIIRS band M12 (3.7 micron), M15 (10.7 micron) and M16 (12.0 micron). The local feature space is based on a spatial-spectral window around the point being considered. Separate models are constructed for “confident clear” and “confident cloud” cases using component analysis. Potentially non-linear manifold analysis may be used should component analysis models not prove sufficient. Once these models are computed during the training phase, a similarity measure is applied to points in the product that need to be classified as cloud or clear. The similarity measure is used to determine whether a local model for the point to be determined is more similar to the clear or cloud model in production of the mask. The preliminary result of spectral-spatial score representing the normalized uncertainty is shown in Figure 2 (left panel). Figures 3-6 are showing the current acspo mask and the regression based mask.

The similarity measure can be calibrated using the marked training data to provide a score as to the confidence of classification. The score can then be written back into an HDF format to provide a cloud mask with confidence measure for use with the SST.

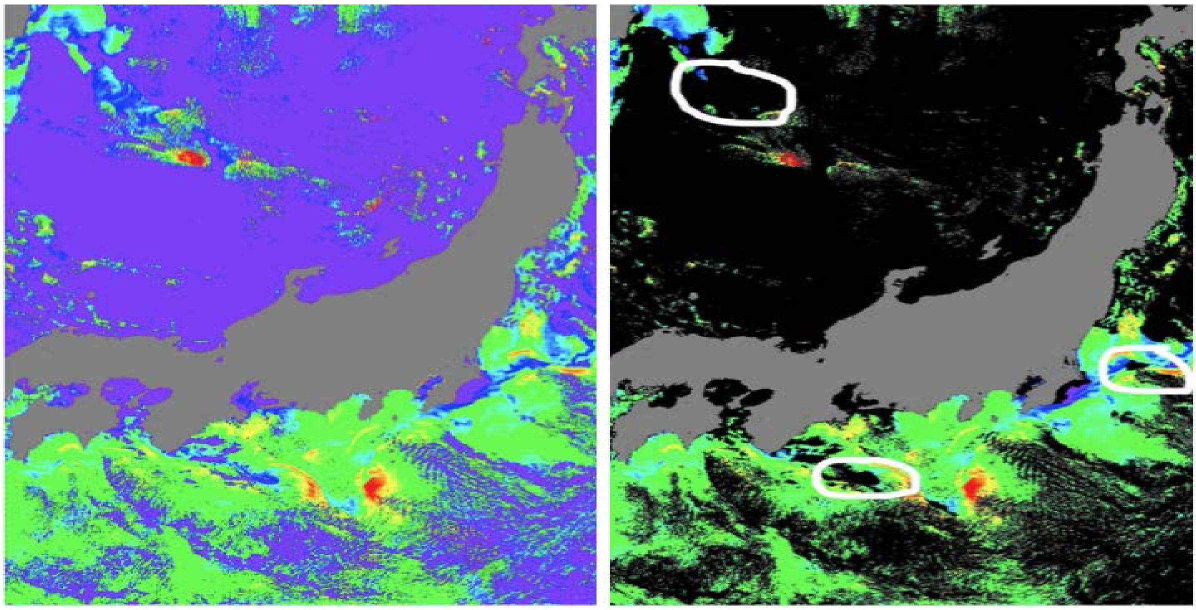


Figure 1: SST anomaly without cloud mask (left) and with the acspo cloud mask (right). Confident cloud is black and probably cloudy grey. Three "false alarm" cloudy regions were circled by STAR/SST experts indicating that current product overestimates cloud in these areas.

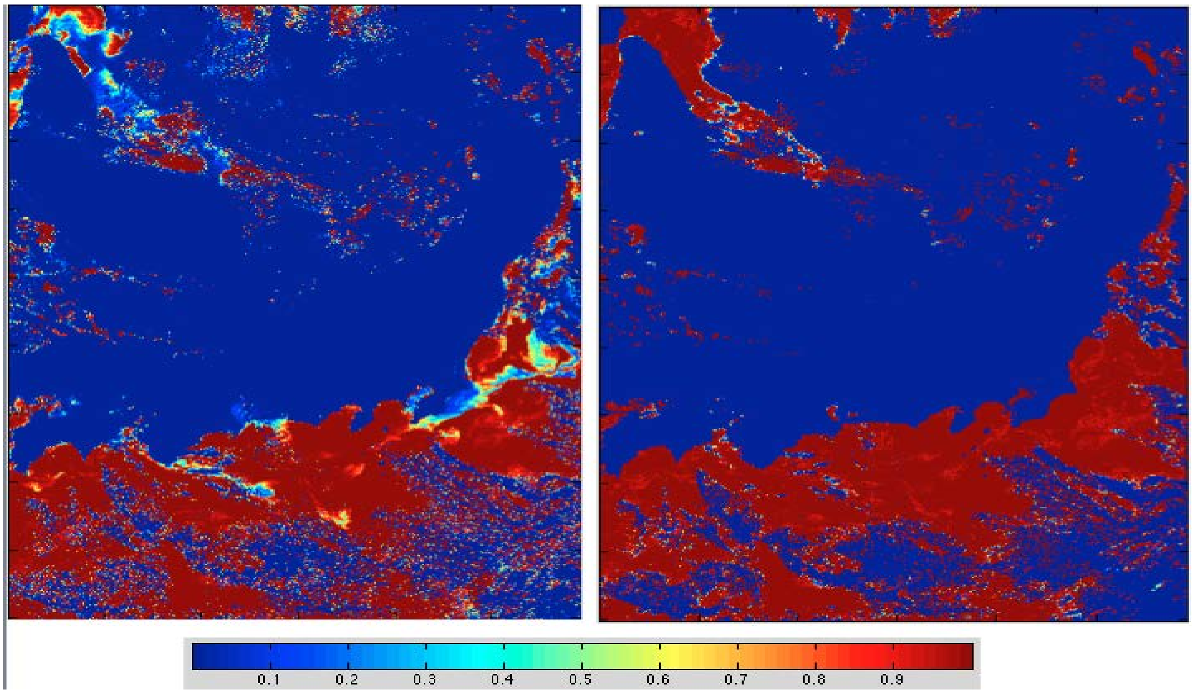


Figure 2: Image showing preliminary result of a logistic regression based confidence score trained on the current cloud mask. Pixels having scores close to 1 are considered "confident" water and pixels having scores close to 0 are considered "confident" cloud. Areas with uncertain scores in the point-wise multi-spectral data space by the regression (right) are improved in a spatial-spectral (window-based) feature space shown of the left.

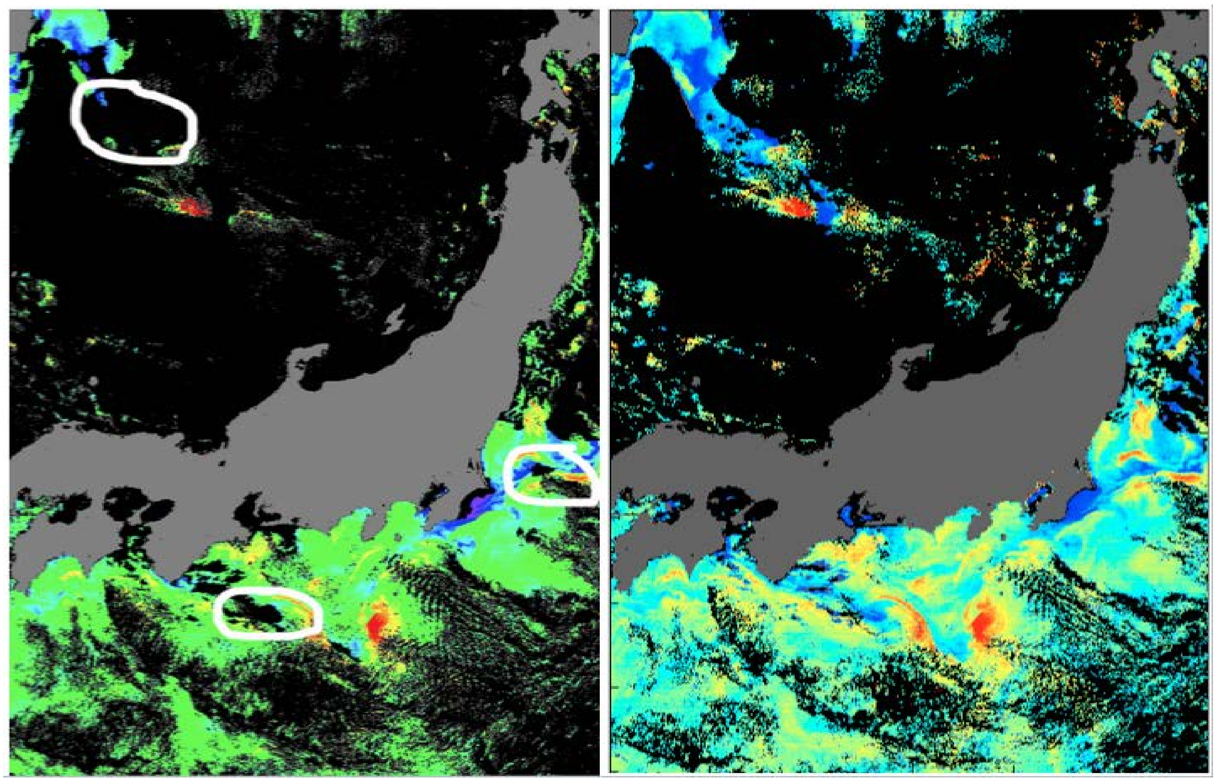


Figure 3: Image showing the SST anomaly with the current acspo mask (left) and the regression based (right).

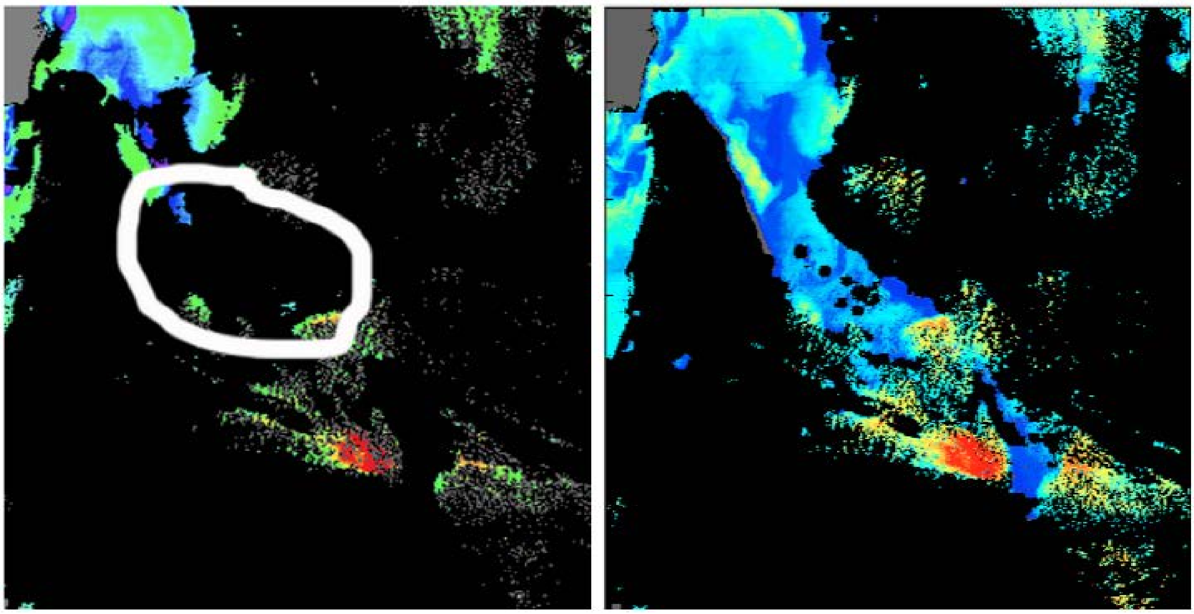


Figure 4: Zoomed into the top circled area of the Figure 3.

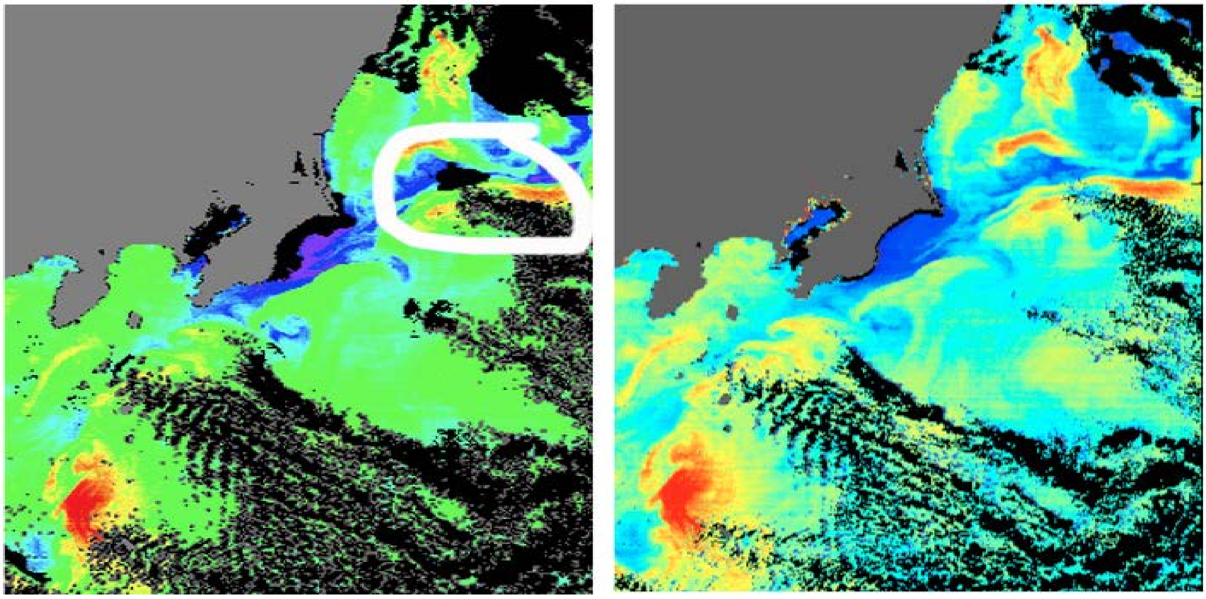


Figure 5: Zoomed into the bottom right circled area of the Figure 3.

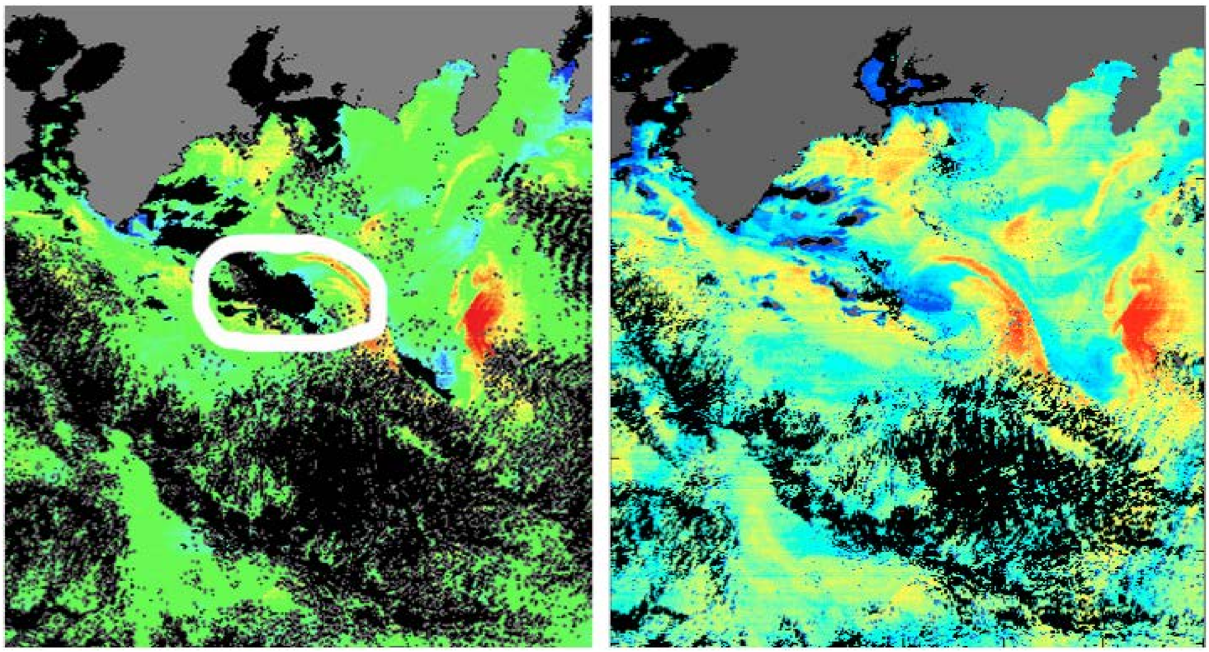


Figure 6: Zoomed into the bottom right circled area of the Figure 3.

STATUS OF S-NPP/VIIRS SENSOR AND SST

Sasha Ignatov[1], Peter Minnett[2], Bob Evans[2], Pierre Le Borgne[3], Hervé Roquet[3], Doug May[4], Jean-François Cayula[4,5], Bob Arnone[6,7], Prasanjit Dash[1,8], Xingming Liang[1,8], John Stroup[1,9], Boris Petrenko[1,10], Yury Kihai[1,10], Feng Xu[1,10], Marouan Bouali[1,8], Kay Kilpatrick[2], Walton McBride[7], John Sapper[11]

N (1) NOAA/STAR, 5830 University Research Court, College Park, MD 20740, USA;
Email: Alex.Ignatov@noaa.gov
(2) U. Miami/RSMAS, FL 33149
(3) EUMETSAT OSI SAF, Meteo France/CMS, Lannion, France
(4) NAVO, Stennis Space Flight Center, MS 39248, USA
(5) QinetiQ North America, Services & Solutions Group, MS 39248, USA
(6) NRL, Stennis Space Flight Center, MS 39248, USA
(7) U.Southtehrn Mississippi, Stennis Space Flight Center, MS 39248, USA
(8) CIRA, Ft Collins, CO 80523, USA
(9) STG, Inc, NCWCP, College Park, MD 20740, USA
(10) GST, Inc, NCWCP, College Park, MD 20740, USA
(11) NOAA/OSPO, 5830 University Research Court, College Park, MD 20740, USA

The Suomi National Polar-orbiting Partnership (NPP) satellite launched in October 2011 is a bridge mission between NOAA POES and NASA EOS Programs towards the Joint Polar Satellite System (JPSS). Visible/Infrared Imager/Radiometer Suite (VIIRS) onboard S-NPP and two follow-on JPSS satellites, J1 (~2017) and J1 (~2023), builds on MODIS heritage, and provides high radiometric accuracy and spatial resolution multispectral imagery. VIIRS sensor data records (SDR; L1b) are processed by Raytheon's Interface Data Processing Segment (IDPS) system, using algorithms developed by the Northrop Grumman Aerospace Systems (NGAS). In 2011, algorithm and Cal/Val responsibility have been transitioned from NPOESS private contractor, Northrop Grumman, to NOAA Center for Satellite Applications and Research (STAR). STAR coordinates JPSS SST Team, including U. Miami, NAVO, OSI SAF, and NRL/USM with the objective to ensure high quality IDPS SST Environmental Data Record (EDR; L2) product, by verifying the performance of VIIRS SDRs, cloud mask (VCM) and SST algorithms, and suggesting and implementing improvements. In addition, JPSS SST partners continue running their heritage SST systems, and process VIIRS SDRs into agency-unique L2 SST products, using different cloud masking and SST algorithms. In particular, STAR generates NOAA heritage Advanced Clear-Sky Processor for Oceans (ACSPO) product which will become operational later in 2013.

Past year efforts have been directed towards several objectives

1. Evaluate performance of IDPS SDR and EDR products, through sustained monitoring of
    a. VIIRS clear-sky ocean radiances in SST bands M12 (3.7µm), M15 (11µm), and M16 (12µm) in the Monitoring of IR Clear-sky Radiances over Oceans for SST (MICROS; www.star.nesdis.noaa.gov/sod/sst/micros/), and checking them for stability, continuity, accuracy and consistency with AVHRRs and MODISs
    b. IDPS and ACSPO SSTs in SST Quality Monitor (SQUAM; www.star.nesdis.noaa.gov/sod/sst/squam/). Other SST products monitored in SQUAM are Metop-A AVHRR FRAC produced by OSI SAF, and several ACSPO products from Metop-A and -B (both FRAC and GAC), two MODISs from Terra and Aqua, and three AVHRR GACs from NOAA-16, -18, -19. All

products are monitored in SQUAM, I near-real time, and evaluated for stability, continuity, accuracy and cross-platform and cross-product consistency.

   c. Quality controlled *in situ* data in *in situ* Quality Monitor (*i*Quam; www.star.nesdis.noaa.gov/sod/sst/iquam/).

2. Report sensor performance to VIIRS SDR Team, work with SDR and Community Radiative Transfer Model (CRTM) Teams to resolve anomalies, and test effects of improve calibration on clear-sky ocean radiances and SSTs.
3. Evaluate the IDPS EDR performance; work with JPSS partners and SDR and VCM Teams to resolve observed anomalies; make SST EDR product available to users via CLASS (declare SST EDR “beta”, mainly for users to familiarize themselves with data formats); and begin working towards “provisional” status (i.e., partially validated and useable for applications.)
4. Evaluate striping in VIIRS SST imagery, suggest remedies, develop fast and accurate “operational” destriping code (initially, to be applied in conjunction with ACSPO product).

It was concluded that the VIIRS is a good sensor for SST, and SDR performance has reached a stable status, and is now acceptable for SST production. Three major remaining issues with the IDPS SST EDR product are: (1) suboptimal performance of its VIIRS cloud mask (VCM), especially during daytime; (2) suboptimal SST regression algorithms proposed by the private contractors; and (3) suboptimal quality control (quality flags) in SST EDR product. Work is underway with the VCM Team to improve the cloud mask. SST Team came up with proposed SST regression algorithms. These formulations will be discussed at VIIRS break-out. Initial discussion of the SST QFs will also take place in the VIIRS break-out. Status of NOAA ACSPO VIIRS product is also briefly discussed.

STATUS OF IN SITU SST QUALITY MONITOR (*I*QUAM)

***Feng Xu*[1,2] *and Sasha Ignatov*[1]**

(1) NOAA/STAR, 5830 University Research Court, College Park, MD 20740, USA,
Email: alex.ignatov@noaa.gov
(2) GST, Inc, NCWCP, College Park, MD 20740

In situ SST Quality Monitor (*iQuam*; *www.star.nesdis.noaa.gov/sod/sst/iquam/*) continues generating QCed in situ SST data, and their monitoring on the web. These data are used at NOAA to generate match-ups with various satellite L2 and L3 products, and with various L4 analyses, and monitor corresponding validation statistics in SST Quality Monitor (SQUAM; *www.star.nesdis.noaa.gov/sod/sst/squam/*). Development of iQuam version 2 is underway. The major enhancements in v2 include

- add ARGO floats
- extend iQuam time series back to ~1980 (current starting date is 1 Jan 1991)
- replace current GTS data source with ICOADS
- add OSI SAF and UK MO black lists flags to iQuam Quality Flags

SST DIURNAL VARIABILITY: REGIONAL EXTENT & IMPLICATIONS IN ATMOSPHERIC MODELLING

Ioanna Karagali[(1)], Jacob L. Høyer[(2)]

DTU Wind Energy, Technical University of Denmark, Frederiksborgvej 399, Roskilde, 4000, Denmark, Email:ioka@dtu.dk
COI, Danish Meteorological Institute, Lyngbyvej 100, Copenhagen Ø, 2000, Denmark, Email:jlh@dmi.dk

ABSTRACT

The project Sea Surface Temperature Diurnal Variability: Regional Extent and Implications in Atmospheric Modeling (SSTDV: R.EX.- IM.A.M.) was initiated within the framework of the European Space Agency's Support to Science Element (ESA STSE). The main focus is twofold: i) to characterize and quantify regional diurnal warming from the experimental MSG/SEVIRI hourly SST fields, for the period 2006-2012. ii) To investigate the impact of the increased SST temporal resolution in the atmospheric model WRF, in terms of modeled 10-m winds and surface heat fluxes.

Withing this context, 3 main tasks have been identified. The first task includes the validation and inter-comparison of SEVIRI and AATSR data, the construction of the night-time foundation temperature fields and the characterization of the regional diurnal warming.

The second task focuses on modeling the diurnal SST variability using the General Ocean Turbulence Model (GOTM). The activities within this task include sensitivity tests on the GOTM set-up, comparison of GOTM, SEVIRI and buoys in point locations and a focus in the North Sea/Baltic Sea with comparisons of GOTM, SEVIRI and 3 diurnal variability schemes.

The impact of the diurnal SST variability on atmospheric modeling is the prime goal of the third and final task. This will be examined by increasing the temporal resolution of the SST initial conditions in WRF and by evaluating the WRF included diurnal scheme. Validation of the modeled winds will be performed against 10m ASAR winds and heat flux error estimates will be derived.

This study will briefly describe the overall project structure and focus on the first results from WP1. Validation results between the SEVIRI and AATSR Re-processing for Climate (ARC) datasets will be presented. In order to characterize and quantify regional diurnal warming over the SEVIRI disk, a SEVIRI derived reference field representative of the well mixed night-time conditions is required. Different methodologies are tested and the results are validated against SEVIRI pre-dawn SSTs and in situ data from moored and drifting buoys.

1. Introduction

During day time and under favorable conditions of low winds and solar heating, the upper few meters of the oceanic layer may experience an increase of temperature that can reach up to several degrees. This is most intense in the first few millimeters of the water column; the part observable from microwave and infra-red sensors on space-borne platforms. Diurnal SST variability has been observed in different areas of the global ocean including the Mediterranean (Merchant et al., 2008), western North Atlantic (Price et al. 1987), and the Gulf of California (Ward, 2006) using combinations of in situ and satellite observations. Recently, a preliminary study has revealed large diurnal warming signals when compared to drifting buoys in the inter-tropical Atlantic, when in other regions of the SEVIRI disc the agreement between drifters and the satellite diurnal signal was found to be around 0.5 K

(LeBorgne et al., 2012). Most of the studies mentioned above were limited in the Tropics and mid-latitude regions but recently diurnal warming has been reported at higher latitudes (Eastwood et al., 2011; Karagali et al., 2012).

The diurnal variability of SST is currently not properly understood. Atmospheric, oceanic and climate models are currently not adequately resolving the daily SST variability, resulting in biases of the total heat budget estimates (Webster et al.,1996; Ward, 2006; Bellenger & Duvel, 2009; Bellenger et al., 2010) and therefore, demised model accuracies. In addition, strong SST diurnal signals can complicate the assimilation of SST fields in ocean and atmospheric models, the derivation of atmospheric correction algorithms for satellite radiometers and the merging of satellite SST from different sensors (Donlon et al., 2007). Not accounting for the daily SST signal can cause biases in the scatterometer derived ocean wind fields and biases in the estimated net flux of CO_2, as the out flux of oceanic CO_2 is positively correlated with the increase of SST.

Thus, there is an increased need to understand and quantify the diurnal SST variability at different regions and resolve the vertical extend of the diurnal signal, in order to relate observations from different instruments and to remove trends from climate records. Part of the effort to create a long time series of stable SST fields consists of successfully modeling the diurnal cycle at a given location in order to correct for the inconsistent satellite overpass times. This can be achieved using either observational evidence from in situ and satellite-derived SSTs or, models able to resolve the daily SST cycle and its vertical extend. The success of such modeling attempts highly depends on the accuracy of the input fields, in particular the wind (typically obtained from atmospheric models). Consequently, there is a need to evaluate the impact of properly resolving the daily variability of SST in atmospheric models, in terms of momentum and heat fluxes.

The ESA STSE funded project SSTDV:R.EX.-IM.A.M. aims at characterizing the regional extend of diurnal SST signals and their impact in atmospheric modeling. The 6-year long SEVIRI (MSG) hourly SST fields will be used to perform a low, mid and high latitude evaluation of the diurnal cycle and identify regional patterns. Identifying areas where common diurnal warming patterns occur is important to better understand the conditions under which the diurnal cycle is formed. ENVISAT AATSR SSTs hold a key role for comparisons with the SEVIRI SSTs, especially in areas where drifting buoys are not available. In addition, the General Ocean Circulation Model (GOTM) will be implemented in order to establish the correlation patterns between diurnal variability and the upper ocean dynamics. This will serve as the link between the surface signals of the diurnal cycle, available by satellites, and the observational evidence from drifting and moored buoys. The second part of the project aims at characterizing how the diurnal SST signals impact atmospheric modeling. Hourly SST fields, when available, will be used to initialize the high resolution Weather Research & Forecasting (WRF) model, currently operational in DTU. Modeled 10-m wind fields will be compared with ENVISAT ASAR 10-m winds and in situ measurements at various atmospheric levels, from meteorological masts located offshore. Heat flux error estimates will be assessed and compared with the SEVIRI SSI & SLI products.

2. Data

2.1. AATSR

The AATSR Reprocessing for Climate (ARC) dataset v1.1 is used, for the period 01/2006-03/2010 and the v1.1.1 from 04/2010-2012. Data are obtained through the NERC Earth Observation Data Centre (http://www.neodc.rl.ac.uk/browse/neodc/arc). The selected file types are i) Day-time dual-view 2-channel and ii) Night-time dual-view 3-channel SST retrievals. The ENVISAT platform had the Local Equatorial Crossing Time (LECT) at 10:00.

The nominal orbit had a repeat cycle of 35 days and the satellite crossed from North to South during the descending orbit in day-time and from South to North during the ascending orbit in night-time. The daily files contain three different temperature measurements and in this study SST_{skin} is used.

2.2. SEVIRI

SEVIRI experimental hourly fields from CMS have been obtained for the period 2006-2012 in order to analyze the regional diurnal warming in the SEVIRI disk. The selected domain extends from 73 W-45 E and 60S-60N. MSG/SEVIRI SST retrievals are classified using a quality flag index that ranges from 0 (unprocessed), 1 (erroneous), 2 (bad), 3(acceptable), 4 (good) to 5 (excellent). In addition, a missing reason flag is available, which indicates the reason for the unprocessed data that are quality flagged with 0. The values of the missing reason flag range from 0 (no data), 1 (out of area), 2 (aerosol), 3 (cloud mask), 4 (cloud time variability), 5 (cloud climatology), 6 (ice), 7 (other) to 8 (quality control). SEVIRI SSTs are corrected for the cool skin bias by an addition of 0.2 K at CMS, before they are released.

2.3. Drifting Buoys

Temperature measurements from surface drifters are obtained from the Coriolis database (*http://www.coriolis.eu.org/*). The data are representative of 20-cm depth temperatures and are available for the entire Atlantic, from 2006 to 2011.

3. Methods

3.1. SEVIRI-AATSR Match-Ups

The spatial and temporal matching of the SEVIRI-AATSR SSTs is performed based on i) a maximum 30 minute difference between local times, ii) SEVIRI SST with quality flags>=3 and AATSR SST with uncertainty <=0.8 are selected, iii) SEVIRI-AATSR latitude and longitude difference <= 0.049°. To correct for the different reference level of the AATSR and SEVIRI SSTs, 0.2 K are subtracted from each SEVIRI retrieval, so both datasets are representative of SST_{skin}.

3.2. Test SST_{Found} Fields

In order to study the diurnal SST variability, a foundation SST field representative of well mixed conditions in the upper oceanic surface layer, is necessary. Test foundation fields (TFF) are composed from SEVIRI night-time SSTs, for the period January-December 2010 using a moving local time window and different ranges of the MSG quality flags (qf). Five different TFFs are composed:

1. TFF1: LT 00-03, QF 3-5, +/- 3 days
2. TFF2: LT 00-04, QF 3-5, +/- 3 days
3. TFF3: LT 00-04, QF 5, +/- 3 days
4. TFF4: LT 22-04, QF 3-5, +/- 3 days
5. TFF5: LT 22-06, QF 3-5, +/- 3 days

In addition, two types of validation fields (VF) are composed daily from the last pre-dawn value flagged with i) VF1: QF 3-5 and ii) VF2: QF 5. The difference TFF-VF is defined and the statistics are computed for each TFF-VF combination. The “successful” TFF must combine minimum standard deviation and maximum TFF-VF and TFF data availability. Karagali et al. (2012) used the TFF1 method but in this project it is sought to investigate the impact of the different moving time windows and quality flags with respect to latitude.

In addition, the Coriolis drifter data are used to create similar drifter foundation fields as the TFFs for the same test year. The SEVIRI TFFs are also compared against the drifter TFFs.

4. Results

4.1. Validation of SEVIRI-AATSR

The SEVIRI-AATSR match-ups have a mean bias (δSST) of -0.06 K, standard deviation (σ) 0.56 K, correlation coefficient (r) 0.996, estimated using 53393988 match-ups. To avoid the contamination of spurious SST values, a filter is further applied, defined as δSST+/-4*σ. Match-ups within this range are slightly reduced to 53127984 and have δSST=-0.07 K, σ= 0.51 K and r=0.997.

When match-ups are binned every 1° of latitude (Figure 1), biases are mostly zero for the mid-latitudes of both hemispheres and become negative in the Tropics, indicating that SEVIRI SSTs are colder compared to AATSR. Le Borgne et al. (2011) have shown such negative SEVIRI biases in the Tropics and relate them with the anomalous vertical distribution of water vapor that complicates the SST retrieval. The standard deviation is generally between 0.4 and 0.6 K and only slightly exceeds this upper threshold around the Equator. Correlation coefficients are relatively stable around 0.996 and only decrease between the Equator and 10^0 N. Most match-ups are between 30^0 and 40^0 N while the lowest match-up availability is found in the high latitudes of both hemispheres and between 5^0 and 10^0 N.

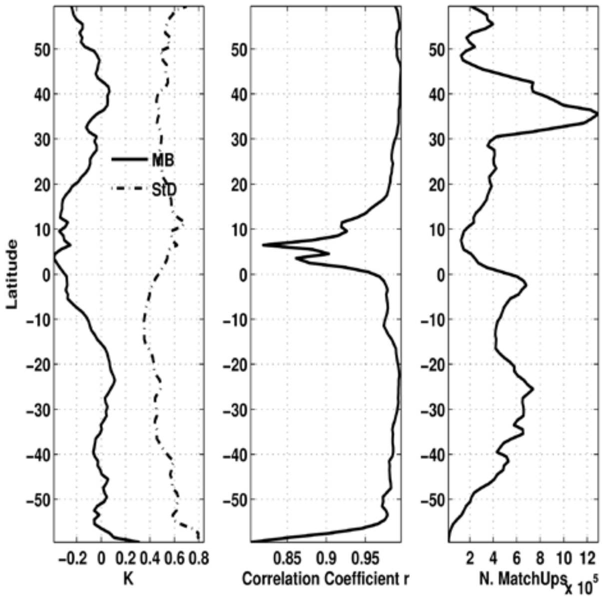


Figure 1: Latitude dependent statistics of the SEVIRI-AATSR match-ups.

4.2. Test SST_{Found} fields

Figure 2 shows the latitude dependent statistics of the SEVIRI TFFs vs the SEVIRI VF1 for 2010. All the TFFs have a similar behavior with latitude. A small positive bias is identified in the southern Atlantic which slightly increases at the Equator, without exceeding 0.05 K. Immediately north of the Equator the bias turns negative. An increase is observed around 5^o N, when the bias turns positive again followed by a decrease between 10^0 and 30^0 N, when the bias becomes negative. From 30^0 N and up, the bias is slightly positive without exceeding 0.05 K. This is a consistent behavior for all the TFF-VF1 biases, including TFF3 which nonetheless, shows larger positive amplitudes and does not turn negative. The standard deviation is fluctuating around 0.4 K with lowest values between 40^0 S and the Equator. From 0^0 to 25^0 N, standard deviations exceed 0.4 K and decrease again from 25^0 to 40^0. Data availability is similar for the TFFs that use the same type of quality flags but TFF3 has clearly lower data availability. Lowest data availability is observed for the high latitudes, more for the South compared to the North hemisphere. Maximum data availability for the mid-latitudes of both hemispheres.

Summarizing, the validation of the multi-day, night-time SST composites against single-day, pre-dawn SSTs which are assumed to represent the coldest SST during a day, shows almost zero biases and standard deviations around 0.4 K. Thus, the night-time fields can accurately represent cold, night-time foundation temperatures. Only using quality 5 SEVIRI data decreases the availability in the foundation field. Results on the statistics between the TFFs and VF2 (pre-dawn, quality 5 SST) show a lower data availability which also varies strongly with the latitude and this is associated with the quality of data used in the validation field. Thus, even if the TFF is composed from a range of qualities, a potential discard in estimated anomalies may occur when using only quality 5 to estimate the daily anomalies. In addition, a warm bias may be introduced using only quality 5 data (see blue line in Figure 2) for the night-time foundation field compared to the coldest, pre-dawn value, but current findings show this bias to be in the order of 0.1-0.2 K.

Figure 2: Latitude dependent statistics of the SEVIRI TFF minus pre-dawn Validation match-ups for 2010.

Using the same methodology as for the SEVIRI TFFs, night-time foundation fields are composed from drifter data. The latitude dependent statistics of SEVIRI-Drifter TFFs are shown in Figure 3, binned every 10^0. The mean biases are mostly negative indicating that the SEVIRI TFFs are colder than the drifter ones. Highest mean absolute biases are identified for the Tropics and especially the North Hemisphere between the Equator and 20^0 N. In this region standard deviations are also highest and the correlation r is lowest. Lower biases and standard deviation is found for TFF3 (dark blue line), which only has quality 5 SEVIRI SSTs but the data availability is significantly reduced. From the TFFs that include quality 3-5 SEVIRI SSTs, biases are similar for all. Standard deviations are slightly different in 3 regions. In the southern latitudes (40^0-60^0 S), standard deviations are significantly lower for TFF1 and TFF2 compared to TFF4, TFF5. In the Tropics, between 10^0 S-5^0 N, TFF4 and TFF5 have marginally lower standard deviation. Above 40^0 N, all standard deviations increase but TFF5 has a slightly higher standard deviation. The latitudinal extend of the

SEVIRI-Drifter TFFs biases is similar to the one of SEVIRI-AATSR but has a higher amplitude.

Figure 3: Latitude dependent statistics of the SEVIRI TFF minus Drifter TFF for 2010.

When the spatial distribution of the biases is examined (not shown), it is found that large negative biases occur mainly between the Equator and 20^0 N and in the North Atlantic, indicating colder SEVIRI foundation fields. Positive SEVIRI biases in the South Hemisphere are associated with major regions of cold currents (Malvinas, Benguela). Strong positive biases are also found in the Bay of Biscay and the Mediterranean Sea.

5. Discussion

This study describes the preliminary results of the ESA SSTDV:REX-IMAM project. At this phase, the aim is to characterize SEVIRI regional accuracies against AATSR SSTs. An AATSR product reprocessed for climate studies (ARC) was used. Embury et al. (2012) demonstrated that the ARC dataset has well documented and low biases in the order of 0.3 K compared to in situ measurements. Current findings indicate overall SEVIRI-AATSR biases are around -0.1 K and the standard deviation is 0.51 K. The spatial extend of the SEVIRI-AATSR biases show strong positive signals around the cold surface currents like the Portugal, Canary, Benguela and Malvinas. The latter is also at the edge of the SEVIRI disk where accuracy is reduced. Strong negative biases are found around the Equator and the North Atlantic, related to the complicated vertical profiles of water vapor.

Day-time vs. night-time SEVIRI-AATSR match-ups (not shown) indicate that for local times extending 5 hours around the AATSR equatorial crossing time (thus also for retrievals near the sub-satellite track) that negative biases are mostly occurring at night-time. Finally, when the biases are binned according to the SEVIRI quality flags it is found that it is the quality 3 and 4 data that contribute to the larger biases and standard deviations. When only quality 5 data are considered, the bias is zero and the standard deviation does not exceed 0.4 K.

The SEVIRI processing chain has recently been updated to accommodate retrieval biases at some of the problematic areas mentioned above. The new processing started in 2011 and up to now no re-processing of the SEVIRI archive is being performed, thus this study uses the old dataset. Some of the well documented biases found in this study are compensated for in the new dataset.

Regarding the test foundation fields, different methodologies have been examined that utilize different quality flags and night-time windows. Validation of this test foundation fields against SEVIRI pre-dawn values, indicates that on average the test foundation fields may be warmer by a maximum of 0.4 K when quality 3-5 data are used. Using only quality 5 data may increase this bias by an additional 0.1—0.2 K. These results are in accordance with findings from the SEVIRI-AATSR validation, which showed that quality 5 SEVIRI data are warmer than quality 3 and 4. This is associated with the SEVIRI cloud masking scheme where lower quality data have higher chances of cloud contamination, which will lower the pixel SST.

6. Conclusion

This study has focused on the preliminary results on the regional extend of diurnal warming in the SEVIRI disc. Prior to the estimation of diurnal signals from the geostationary platform a validation of the 6-year long dataset with AATSR derived SSTs is performed. The mean SEVIRI-AATSR bias is -0.07 K and its standard deviation 0.51 K. While in the mid-latitudes of both hemispheres SEVIRI-AATSR biases are almost zero and the standard deviation shows minimum values, in the Tropics and high latitudes the bias becomes negative and the standard deviation increases

Prior to the estimation of diurnal signals, test foundation SST fields are composed from SEVIRI night-time SSTs and are validated against SEVIRI pre-dawn SSTS and night-time composites from drifting buoys. While the validation of SEVIRI night-time composites with pre-dawn SSTs shows almost zero biases and standard deviations of 0.4 K indicating a good description of night-time, mixed conditions. When the SEVIRI composites are validated with drifter composites it is found that they are, on average, colder by approximately 0.2 K in the extra-Tropics and by 0.4-0.6 K in the Tropics. An impact of the SEVIRI quality flags is also identified, where quality 5 data are warmer and show better statistics with drifter composites. Thus, the SEVIRI-Drifter differences are partly associated with the potential partial cloud coverage of SEVIRI pixels for qualities of 4 and lower. Another bias contribution arises from the reference depth of drifting buoys (~20 cm) and SEVIRI SSTs (sub-skin estimated as skin+0.2 K).

7. References

Bellenger, H., Y. N. Takayabu, T. Ushiyama, and K. Yoneyama, Role of diurnal warm layers in the diurnal cycle of convection over the tropical Indian Ocean during MISMO, *Mon. Wea. Rev.* **138**, 2426-2433, 2010.

Bellenger, H., and J. P. Duvel, An analysis of ocean diurnal warm layers over tropical oceans. *J. Climate,* **22***,* 3629-3646, 2009.

Donlon C, Robinson I, Casey KS, Vazquez-Cuervo J, Armstrong E, Arino O, and co-authors, The Global Ocean Data Assimilation Experiment High-resolution Sea Surface Temperature Pilot Project, *Bull. Am. Met. Soc.* **88(8)**, 1197-1213, 2007.

Eastwood, S., LeBorgne, P., Péré, S., and D. Poulter, Diurnal variability in sea surface in the Arctic. *Rem. Sens. Environ.* **115***,* 2594-2602, 2011*.*

Embury, O., Merchant, C.J., and G. K. Corlett, A reprocessing for climate of sea surface temperature from the along-track scanning radiometers: Initial validation, accounting for skin and diurnal variability effects, *Rem. Sens. Env.,* **116**; 62-78, 2012.

Karagali, I., Hoeyer J., and C. B. Hasager, SST Diurnal Variability in the North Sea and the Baltic Sea, *Rem. Sens. Env.* **112** (513), 1195-1225, 2012.

Le Borgne, P., Legendre, G., and S Péré, Comparison of MSG/SEVIRI and drifting buoy derived diurnal warming estimates. *Rem. Sens. Env.* ***124****,* 622-626, 2012.

Merchant, C. J., Filipiak, M. J., Le Borgne, P., Roquet. H., Autret. E., et al.. Diurnal warm-layer events in the western Mediterranean and European shelf seas. *Geophysical Research Letters,* **35**, L04601, 2008.

Price, J., Weller, R. , Bowers, C. , and M. Briscoe, Diurnal Response of Sea Surface Temperature Observed at the Long-Term Upper Ocean Study (34^{o} N, 70^{o} W) in the Sargasso Sea. *J. Geophys. Res.,* **92(C13)***,* 14480-14490*,* 1987.

Webster P. J., Clayson C. A., and J. A. Curry, Clouds, radiation, and the diurnal cycle of sea surface temperature in the Tropical Western Pacific, *J. Clim.* **9***,* 1712-1730, 1996.

Ward B, Near-surface ocean temperature, *J. Geophys. Res.* **111***,* C02004, 2006*.*

SKIN SST PHYSICAL RETRIEVAL FROM GOES USING MODIFIED TOTAL LEAST SQUARES METHOD

Prabhat K. Koner and Andy R. Harris

CICS/ESSIC, University of Maryland, College Park, College Park, Maryland

Abstract

Sea surface temperature (SST) retrieval from satellite measurements is dominated by regression based inverse, however, it is understandably inadequate to attempt to characterize global geophysical conditions (atmospheric and oceanic states) for SST retrievals using only a few regression coefficients. Thus, we introduce a total least squares(TLS) method for SST retrieval, which implicitly determines the optimal regularization strength to be applied to the normal equations for 1^{st} order Newtonian retrieval using all of the noise terms embedded in the residual vector. However, the standard TLS technique does not include any constraint to prevent noise enhancement in state space parameters from the existing noise in measurement space for an inversion with an ill-conditioned Jacobian. To achieve a stable solution, we introduce additional regularization empirically and it is referred to as the modified total least squares method (MTLS). We have applied this method for SST retrievals from GOES-13 measurements and collocated with buoy temperatures. Our results for a time series of twenty six months show a significant improvement in the SST retrieved with the MTLS algorithm over the operational regression-based products by the Office of Satellite Products and Operations (OSPO), NOAA, (~50% reduction in root mean square error for validation against buoys). Finally, we will present a new algorithm for error masking including cloud, which is based on the dynamic thresholds of spectral differences. Results show that this new algorithm can increase the data coverage by 50% as compared to NOAA's operational Bayesian cloud detection.

A DIURNAL WARMING DEDICATED MATCHUP DATA BASE EXAMPLES AND PRELIMINARY VALIDATION RESULTS

Sonia Péré, Anne Marsouin, Gérard Legendre, Pierre Le Borgne

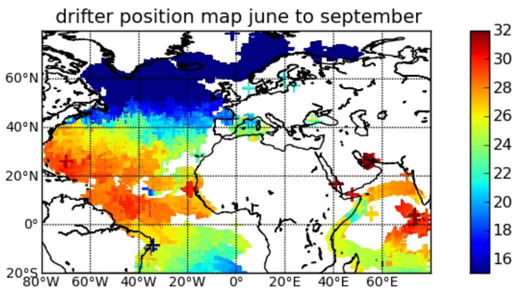
Météo-France/Centre de Météorologie Spatiale, Lannion, France, Email: sonia.pere@meteo.fr

ABSTRACT

The Meteo-France Centre de meteorology Spatiale (CMS) has made available in November 2012 a matchup database (MDB) dedicated to diurnal warming (DW) studies. This MDB is based on METOSAT-9 SEVIRI data. It includes in situ Sea Surface Temperature SST measurements, SEVIRI products (SST and radiative fluxes) and ECMWF forecast model outputs collected from June till end of September 2012. The MDB main inputs are the Ocean and Sea Ice Satellite Application Facility (OSI-SAF) processing chain work files, which are processed in near real time and archived at CMS. The MDB has been built offline. The 2012 MDB covers METEOSAT disk north of 20S (see map) and four months, June to September 2012.

The MDB files are daily files in netCDF4 format. A month of data corresponds to 1.1G to 1.3G, depending on the month. A tar file compressed by bzip2 containing the 4 months has a size of 1.1G.

This presentation aims to give some examples of the MDB content and present first diurnal warming cycle intercomparison results.



DW MDB drifting buoy measurement position map from June to September 2012

OSI-SAF OPERATIONAL NPP/VIIRS SEA SURFACE TEMPERATURE CHAIN

Pierre Le Borgne, Gérard Legendre, Anne Marsouin, Sonia Péré, Hervé Roquet

Météo-France/Centre de Météorologie Spatiale, Lannion, France Email: pierre.leborgne@meteo.fr

ABSTRACT

Data of the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard Suomi National Polar-orbiting Partnership (NPP) have been acquired at Centre de Météorologie Spatiale (CMS) in Lannion (Brittany) in direct readout mode since April 2012. CMS is committed to produce sea surface temperature (SST) products from VIIRS data twice a day over an area covering North-East Atlantic and the Mediterranean Sea in the framework of the EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI-SAF). A cloud mask has been developed and cloud mask control techniques have been implemented. SST algorithms have been defined, as well as quality level attribution rules. Since mid October 2012 a VIIRS SST chain, similar to that used for processing METOP AVHRR has been run in a preoperational mode. The corresponding bias and standard deviation against drifting buoy measurements (mid October 2012 to mid March 2013) are -0.05 and 0.37 K for nighttime and -0.13 and 0.46 K for daytime, respectively. VIIRS derived SST production is expected operational by mid 2013. The OSI-SAF VIIRS derived SST products are compliant with the Group for High Resolution SST (GHRSST) GDS V2.0 format.

USING NUMERICAL WEATHER PREDICTION MODEL PROFILES TO IMPROVE SST CALCULATIONS : APPLICATION TO METOP/AVHRR

Pierre Le Borgne[1], Sonia Péré[2], Hervé Roquet[3]

(1) Météo-France/Centre de Météorologie Spatiale, Lannion, France Email: pierre.leborgne@meteo.fr
(2) MF/CMS, Email: sonia.pere@meteo.fr
(3) MF/CMS, Email: herve.roquet@meteo.fr

ABSTRACT

The European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) Ocean and Sea Ice Satellite Application Facility (OSI-SAF) has been producing full resolution METOP-A /Advanced Very High Resolution Radiometer (AVHRR) derived Sea Surface Temperature (SST) data at a global scale since July 2007.Two algorithms, one for nighttime and one for daytime conditions have been used with constant coefficients since 2007. Yearly global statistics obtained by comparison with drifter measurements are satisfying, with an absolute bias against drifters within 0.1 K and standard deviations better than 0.6 K by day and 0.5 K by night. Nevertheless, like any other multispectral algorithm derived SST, METOP/AVHRR SST data show regional biases.

The practical solutions adopted at present to correct for regional biases rely on using real time simulated Brightness Temperatures (BTs), either in Optimal Estimation (OE) methods or Bias Correction methods. BTs are simulated in the adequate Infrared window channels by applying a Radiative Transfer Model (RTM) to Numerical Weather Prediction (NWP) atmospheric profiles, using a guess SST field as surface temperature.

In the framework of the EUMETSAT OSI-SAF, Météo-France/Centre de Météorologie Spatiale (CMS) in Lannion has developed a geostationary satellite SST chain using simulated BT which became operational in August 2011.

CMS has been running a prototype chain since November 2011 for testing the same approach on METOP/Advanced Very High Resolution Radiometer (AVHRR) data. The prototype is run in near-real time, to be as close as possible to operational conditions and uses OSTIA as surface temperature, ECMWF forecast profiles and the Radiative Transfer for TIROS Operational Vertical (RTTOV) Sounder model version 10.

This presentation aims to present the main results of this prototype after more than one year of run.

A LONG-TERM SATELLITE BASED DATA RECORD OF SEA SURFACE TEMPERATURE FROM ESA'S CLIMATE CHANGE INITIATIVE

***Nick Rayner*[(1)]*, Simon Good*[(1)] *and Chris Merchant*[(2)]**

(1) Met Office Hadley Centre, Exeter, EX1 3PB, U.K., Email: nick.rayner@metoffice.gov.uk
(2) University of Reading, Reading, U.K., Email: c.j.merchant@reading.ac.uk

ABSTRACT

The study of climate change demands long-term, stable observational records of climate variables such as sea surface temperature (SST). ESA's Climate Change Initiative was set up to unlock the potential of satellite data records for this purpose. As part of this initiative, 13 projects were established to develop the data records for different essential climate variables - aerosol, cloud, fire, greenhouse gases, glaciers, ice sheets, land cover, ocean colour, ozone, sea ice, sea level, soil moisture and SST. In this presentation we present new prototype data products that are available now for users to trial.

The SST project began in 2010 and has now produced two prototype products. The first is a long-term product (covering mid-1991 - 2010 currently, but with a view to update this in the future), which prioritises length of data record and stability over other considerations. It is based on data from the Along-Track Scanning Radiometer (ATSR) and Advanced Very-High Resolution Radiometer (AVHRR) series of satellite instruments. The product aims to combine the favourable stability and bias characteristics of ATSR data with the geographical coverage achieved with the AVHRR series. Uncertainty information is included with the SSTs, split into components with different spatio-temporal correlation structures. The second data product demonstrates the coverage that can be achieved using the modern satellite observing system including, for example, geostationary satellite data. Six months worth of data have been processed for this demonstration product.

The prototype SST products are being made available to users to trial in their work. Data are made available in GDS2.0 compatible NetCDF files - allowing ease of use by users - with a number of extra data fields included, e.g. uncertainty estimates split into components. We briefly summarise how this additional information was incorporated into the files.

We are very keen for people to test the products out and to provide feedback to the project. This feedback will be used to improve the products in the future. Please contact us (nick.rayner@metoffice.gov.uk) or visit the project website at *http://www.esa-sst-cci.org*.

EUROPEAN SPACE AGENCY CLIMATE CHANGE INITIATIVE FOR SEA SURFACE TEMPERATURE (SST CCI): STATUS UPDATE

Christopher Merchant

Dept. of Meteorology, University of Reading, Reading, UK, Email: c.j.merchant@reading.ac.uk

ABSTRACT

The ESA SST CCI is in the final year of its first three-year phase. A principal objective in phase 1 has been to prototype a system for developing a sea surface temperature (SST) dataset for climate, based on Along Track Scanning Radiometers (ATSRs) and Advanced Very High Resolution Radiometers (AVHRRs) in combination. The approach is to break the usual dependence of AVHRR SSTs on drifting buoy matches by cross referencing AVHRR brightness temperatures (BTs) to ATSR-series BTs. This should give both independence and stability to AVHRR SSTs derived using a consistent approach to ATSR SST retrieval. Progress on this will be reported. In addition, there are a set of deliverables from the project in the form of documents which may be relevant to advancing GHRSST objectives, perhaps particularly for the Climate Data Records TAG, but also more widely. An overview of these deliverables will be given to guide those interested to relevant reading. Lastly, another objective of the project has been to specify a system for routine generation of an SST CDR to be built in SST CCI phase 2. The outlines of this specified system will be explained.

OPTIMAL ESTIMATION OF SEA SURFACE TEMPERATURE ASSUMING SPATIALLY SMOOTH WATER VAPOUR

***Christopher Merchant*[(1)]*, Pierre Le Borgne*[(2)]**

(1) Dept. of Meteorology, University of Reading, Reading, UK, Email: c.j.merchant@reading.ac.uk
(2) Météo-France/Centre de Météorologie Spatiale, Lannion, France Email: pierre.leborgne@meteo.fr

ABSTRACT

Sea surface temperature (SST) can be estimated from day and night observations of the Spinning Enhanced Visible and Infra-Red Imager (SEVIRI) by optimal estimation (OE). We show that exploiting the 8.7 μm channel, in addition to the “traditional” wavelengths of 10.8 and 12.0 μm, improves OE SST retrieval statistics in validation. However, the main benefit is an improvement in the sensitivity of the SST estimate to variability in true SST.

In a fair, single-pixel comparison, the 3-channel OE gives better results than the SST estimation technique presently operational within the Ocean and Sea Ice Satellite Application Facility. This operational technique is to use SST retrieval coefficients, followed by a bias-correction step informed by radiative transfer simulation. However, the operational technique has an additional “atmospheric correction smoothing”, which improves its noise performance, and hitherto had no analogue within the OE framework. Here, we propose an analogue to atmospheric correction smoothing, based on the expectation that atmospheric total column water vapour has a longer spatial correlation length scale than SST features. The approach extends the observations input to the OE to include the averaged brightness temperatures (BTs) of nearby clear-sky pixels, in addition to the BTs of the pixel for which SST is being retrieved. The retrieved quantities are then the single-pixel SST and the clear-sky total column water vapour averaged over the vicinity of the pixel. This reduces the noise in the retrieved SST significantly. The robust standard deviation of the new OE SST compared to matched drifting buoys becomes 0.39 K for all data. The smoothed OE gives SST sensitivity of 98% on average. This means that diurnal temperature variability and ocean frontal gradients are more faithfully estimated, and that the influence of the prior SST used is minimal (2%). This benefit is not available using traditional atmospheric correction smoothing.

The technique should be applicable to other sensors, including dual-view observations such as the future Sea and Land Surface Temperature Radiometer (SLSTR). Adaptations to this and other cases will also be discussed.

INITIAL VALIDATION OF VIIRS SKIN SST RETRIEVALS WITH SHIPBOARD RADIOMETERS

Peter J Minnett[(1)], R. Michael Reynolds[(2)], Miguel A Izaguirre[(3)] & Elizabeth J Williams[(4)]

(1) Meteorology & Physical Oceanography, Rosenstiel School, University of Miami USA, Email: pminnett@rsmas.miami.edu
(2) Remote Measurement & Research Co., Seattle, USA Email: michael@rmrco.com
(3) Meteorology & Physical Oceanography, Rosenstiel School, University of Miami USA, Email: mizaguirre@rsmas.miami.edu
(4) Meteorology & Physical Oceanography, Rosenstiel School, University of Miami USA, Email: ewilliams@rsmas.miami.edu

ABSTRACT

The Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi National Polar-orbiting Partnership satellite (Suomi-NPP), launched on October 28, 2011, is the first in a new series of visible and infrared radiometers to be flown on the Joint Polar Satellite System (JPSS). Four of the infrared channels of VIIRS were designed to provide accurate retrievals of skin Sea-Surface Temperature (SST). The infrared detectors were cooled down in early 2012 and the data stream stabilized in early March. Infrared radiometers have been deployed on commercial and research vessels to provide skin temperature measurements for the validation of the VIIRS SST retrievals. Initial results will be presented from ship data taken in the Pacific and Atlantic Oceans, which confirm good accuracies of the VIIRS SSTs.

THE GENERATION OF SST CLIMATE DATA RECORDS USING SHIPBOARD RADIOMETRY

Peter J Minnett[(1)], Gary K. Corlett[(2)] & ISSI International Team on SST CDRs*

(1) Meteorology & Physical Oceanography, Rosenstiel School, University of Miami USA, Email: pminnett@rsmas.miami.edu
(2) Physics and Astronomy, University of Leicester, UK, Email: gkc1@leicester.ac.uk

ABSTRACT

The generation of a Climate Data Record of Sea-Surface Temperature requires a thorough assessment of the measurement uncertainties in the derived temperatures, and traceability of the temperatures and their uncertainties to national SI reference standards. This can best be achieved by using SI-traceable ship-board radiometers to provide the reference validation data for the satellite retrievals. We have been doing this for over a decade using, primarily, Marine-Atmospheric Emitted Radiance Interferometers (M-AERIs) on a large number of ships in a wide range of environmental conditions and Infrared Sea-surface Temperature Autonomous Radiometers (ISARs) on commercial vessels. SI traceability is achieved through a series of international workshops that have been held at the Rosenstiel School, University of Miami, that have included NIST participation with the Earth Observing System Transfer Radiometer (TXR), and as part of the Third Workshop in 2008, the National Physical Laboratory in the UK compared a number of laboratory blackbody calibrators used by collaborating European groups using the AMBER (Absolute Measurements of Black-body Emitted Radiance) transfer radiometer. Thus the necessary requirements for CDRs of SST are fulfilled. Her we present the steps in a rigorous approach to generate SST CDRs.

*Researchers who have attended the ISSI International Teams in Space Science on the “Generation of Climate Data Records of Sea-Surface Temperature from current and future satellite radiometers” include:

Dr Peter Minnett (Team Leader)

Dr Gary Corlett (Co-leader)

Dr Sandra Castro, University of Colorado, USA

Dr Craig Donlon, ESA-ESTEC, NL

Dr Lei Guan, Ocean University of China, CN

Dr Andy Jessup, University of Washington, USA

Dr Tim Nightingale, Rutherford Appleton Laboratory, UK

Dr Anne O’Carroll, EUMETSAT, DE

Dr Theo Theocharous, National Physical Laboratory, UK

Dr Gary Wick, NOAA ESRL, USA

Dr Werenfrid Wimmer, University of Southampton, UK

Dr Chris Wilson, NASA JPL, USA

RECENT UPDATES TO THE NEAR-REAL TIME OSTIA SYSTEM

Jonah Roberts-Jones, Emma Fiedler, Alison McLaren

Met Office, Fitzroy Rd, Exeter, UK. Email: jonah.roberts-jones@metoffice.gov.uk

ABSTRACT

The UK Met Office Operational SST and sea Ice Analysis (OSTIA) system generates a daily combined foundation SST and sea ice concentration product on a 1/20° (~6 km) grid. The system assimilates infrared and microwave satellite SST observations in addition to in-situ observations. All input data is passed through an automatic quality control system and a bias correction on satellites using a reference dataset is carried out. OSTIA then uses a multi-scale optimal interpolation scheme to assimilate observations onto a first guess field provided by the previous analysis with a relaxation to climatology. The sea ice concentration is obtained from the EUMETSAT OSI-SAF daily ice concentration product.

Recent updates to the near-real time (NRT) OSTIA system will be highlighted. The background error covariances used within the assimilation scheme have recently been re-estimated within the ESA SST CCI project. The methodology and resulting estimates will be presented as will the impact of implementing them in the NRT OSTIA system. A further change was necessitated by the loss of the AATSR instrument which resulted in the OSTIA system using in-situ data alone as a reference in the bias correction of the other satellite data. The results of including a high quality subset of METOP AVHRR data to the reference dataset used in the bias correction will be presented. The addition of lake ice will also be discussed. This has recently been added to the OSTIA product to complement the lake surface water temperatures which have been included since November 2011. The lake ice fields are obtained using a combination of NCEP ice concentration data and ice cover based on the OSTIA lake surface temperature analysis. The impact of all these updates on the accuracy of the OSTIA product will be described.

QUANTIFYING THE EFFECT OF AMBIENT CLOUD ON CLEAR-SKY OCEAN BRIGHTNESS TEMPERATURES AND SSTS

Korak Saha[1,2] and Alexander Ignatov[1]

(1) NOAA/NESDIS, Center for Satellite Application and Research (STAR), Camp Springs, MD 20746
(2) CSU, Cooperative Institute for Research in the Atmospheres (CIRA), Fort Collins, CO 80523

ABSTRACT

Advanced Clear Sky Processor for Oceans (ACSPO) is NESDIS operational system which produces clear-sky ocean brightness temperatures (BTs) in three bands centered at 3.7, 11 and 12 µm, and Sea Surface Temperatures (SST) as functions of these BTs and view zenith angle (VZA). In this presentation, we quantify the effect of ambient cloud on the clear-sky BTs and SSTs. The pixels identified in ACSPO as cloud free, may be still affected by their cloudy neighbors. Threshold based ACSPO cloud tests may be triggered (or not) on pixels with elevated aerosols and/or water vapor (cloud-halos), surrounding clouds. Since such transient states are difficult to classify using a threshold-based clear-sky-mask, it will affect the ACSPO clear-sky BTs and SSTs. We use a number of clear-sky ocean pixels (NCSOP) around each pixel identified in ACSPO as clear-sky, calculated using sliding window technique, as (an inverse) proxy of ambient or residual cloud. SST and BT differences are calculated in each clear-sky ACSPO pixel, by subtracting the expected (first guess) SST and BTs (simulated using the community radiative transfer model, CRTM). It was shown earlier using one week of global data that the SST and BT differences decrease exponentially with NCSOP, and asymptotically approach their “confidently clear-sky” limits, when NCSOP is large enough. To verify this observation on longer time scales, the NCSOP dependencies of SST and BT differences have been routinely calculated and published in near-real time web-based Monitoring of IR Clear-Sky Radiances over Oceans for SST (MICROS; *www.star.nesdis.noaa.gov/sod/sst/micros/*) system since March 2012. In this study, we fit an exponential curve with three fit parameters using a Levenberg-Marquardt least-square minimization, using an IDL based code named MPFIT. The stability of the fitting is investigated by trending the fit parameters with time. Results of this study are used to more accurately validate CRTM and its first guess input fields, and quantify residual cloud contamination in ACSPO products.

STUDYING DIURNAL WARMING IN SHALLOW COASTAL SEAS THROUGH IN-SITU DATA ANALYSIS

Xiaofang Zhu(1), Peter Minnett(2), J. Hendee(3), C. Manfrino(4) and R. Berkelmans(5)

University of Miami/RSMAS; xiaofang.zhu@rsmas.miami.ed
University of Miami/RSMAS; pminnnett@rsmas.miami.edu
NOAA/ AOML; Jim.Hendee@noaa.gov
Central Caribbean Marine Institute;manfrino@reefresearch.org
Australian Institute of Marine Science; R.Berkelmans@aims.gov.au

ABSTRACT

A good understanding of diurnal warming phenomenon is important for satellite sea surface temperature (SST) validation against in-situ buoy data and satellite data merging. For the coastal region, it also helps to improve the satellite data application to predict ecosystem health such as coral reef bleaching. Compared to its open ocean counterpart which has been studied extensively and modeled with good success, coastal diurnal warming has more localized characteristics including coastline geometry, bathymetry, water types, tidal and wave mixing properties, and is researched much less.

The goal of this study is to characterize coastal diurnal warming using two extensive in-situ temperature and weather datasets from Caribbean and Great Barrier Reef, Australia. Results showed that clear daily warming patterns were present in most of stations from both datasets. For the three Caribbean stations where solar radiation is main cause of daily warming, the mean warming amplitudes were around 0.4K at deeper depths of 4 to 7m and 0.6-0.7K warming at shallower depths of 1 to 2m, while the largest warming value of 2.1K. For sea bottom temperature dataset from the Great Barrier Reef, 20% of days had warming amplitude larger than 1K, with the largest warming amplitude over 4K. The averaged daily warming was found to be closely related to daily average wind speed and maximum insolation, also it depended on coastal geographic features including water depths, locations on a reef (reef flat vs. reef slope), the relative locations from the barrier reef chain (coast vs. lagoon stations vs. inner lagoon sites vs. outer rim sites); and the proximity to the tidal inlets. In addition, the influences of tides on daily temperature changes and its relative importance compared to solar radiation have been studied. It was possible to quantify the influence of tide versus solar radiation by calculating the ratio of power spectrum densities of M2 tide versus 24-hour insolation cycle, i.e., ($PSD_{12.42hr}/PSD_{24hr}$) from a temperature spectrum analysis. Despite the fact that Great Barrier Reef stations are generally located at regions with large tidal changes, the tidal effects were modest: 80 percent of stations showed value of ($PSD_{12.42hr}/PSD_{24hr}$) of less than 10%.

APPENDICES

APPENDIX 1 – PARTICIPANTS LIST

Last Name	First Name	Affiliations	Email
Armstrong	Ed	NASA JPL, PO.DAAC, USA	edward.m.armstrong@jpl.nasa.gov
Autret	Emmanuelle	IFREMER, France	emmanuelle.autret@ifremer.fr
Banzon	Viva	NOAA/NESDIS/ NCDC, USA	viva.banzon@noaa.gov
Barron	Charlie	Naval Research Laboratory, USA	charlie.barron@nrlssc.navy.mil
Barton	Ian	Australia	ian.barton@ozemail.com.au
Beggs	Helen	CAWCR, Australia	H.Beggs@bom.gov.au
Bingham	Andrew	JPL, USA	Andrew.Bingham@jpl.nasa.gov
Bogdanoff	Alec	WHOI, USA	alecb@whoi.edu
Bouali	Marouan	NOAA/CIRA, USA	marouan.bouali@noaa.gov
Bragaglia-Pike	Silvia	GHRSST Project, University of Reading, UK	gpa@ghrsst.org
Brasnett	Bruce	Environment Canada	Bruce.Brasnett@ec.gc.ca
Casey	Ken	NOAA/NESDIS/ NODC, USA	Kenneth.Casey@noaa.gov
Castro	Sandra	University of Colorado, USA	sandrac@colorado.edu
Cayula	Jean-Francois	Qinetiq North America, USA	j.cayula@ieee.org
Chelton	Dudley	OSU, USA	chelton@coas.oregonstate.edu
Chin	T. Mike	JPL, USA	mike.chin@jpl.nasa.gov
Clayson	Carol Anne	WHOI, USA	cclayson@whoi.edu
Corlett	Gary	University of Leicester, UK	gpc@ghrsst.org
Cornillon	Peter	University of Rhode Island, USA	pcornillon@me.com
Crosman	Erik	University of Utah, USA	erik.crosman@utah.edu

Last Name	First Name	Affiliations	Email
Cummings	James	Naval Research Laboratory, USA	cummings@nrlmry.navy.mil
Dash	Prasanjit	NOAA NESDIS / CSU CIRA, USA	prasanjit.dash@noaa.gov
de Sousa	Rodrigo Carvalho	AML/UFRJ, Brazil	rodrigo@lma.ufrj.br
Donlon	Craig	European Space Agency, The Netherlands	craig.donlon@esa.int
Eastwood	Steinar	Norwegian Meteorological Institute	s.eastwood@met.no
Evans	Robert	RSMAS/MPO, USA	revans@rsmas.miami.edu
Foley	Dave	Institute of Marine Sciences, UCSC, USA	dave.foley@noaa.gov
Foti	Gregg	NODC, USA	gregg.foti@noaa.gov
França	Gutemberg	Federal University of Rio de Janeiro - UFRJ, Brazil	gutemberg@lma.ufrj.br
Gentemann	Chelle	Remote Sensing Systems, USA	gentemann@remss.com
Gramer	Lewis	University of Miami CIMAS, USA	lgramer@rsmas.miami.edu
Grumbine	Robert	NOAA/NWS/NCEP, USA	robert.grumbine@noaa.gov
Harris	Andrew	ESSIC, UMD, USA	andy.harris@noaa.gov
Høyer	Jacob	Danish Meteorological Institute	jlh@dmi.dk
Ignatov	Alexander	NOAA/NESDIS/STAR, USA	Alex.Ignatov@noaa.gov
Ishizaki	Shiro	Japan Meteorological Agency	s_ishizaki@met.kishou.go.jp
Iwanski	Dan	University of Rhode Island, USA	diwanski@gso.uri.edu
Kachi	Misako	JAXA, JAPAN	kachi.misako@jaxa.jp
Kaplan	Alexey	LDEO of Columbia University, USA	alexeyk@ldeo.columbia.edu
Karagali	Ioanna	DTU Wind Energy - Technical University of Denmark	ioka@dtu.dk
Koner	Prabhat	ESSIC, USA	prabhat.koner@noaa.gov

Last Name	**First Name**	**Affiliations**	**Email**
Lange	Martin	German Weather Service	martin.lange@dwd.de
Le Borgne	Pierre	Météo-France	pierre.leborgne@meteo.fr
Liu	W. Timothy	Jet Propulsion Laboratory, USA	w.t.liu@jpl.nasa.gov
Liu	Yang	RSMAS, University of Miami, USA	yliu@rsmas.miami.edu
Llewellyn-Jones	David	University of Leicester, UK	dlj1@le.ac.uk
Maturi	Eileen	NOAA/NESDIS, USA	eileen.maturi@noaa.gov
Merchant	Christopher	University of Reading, UK	c.j.merchant@reading.ac.uk
Minnett	Peter	University of Miami, USA	pminnett@rsmas.miami.edu
Mittaz	Jonathan	University of Maryland, USA	Jon.Mittaz@noaa.gov
Nightingale	Tim	STFC Rutherford Appleton Laboratory, UK	tim.nightingale@stfc.ac.uk
O'Carroll	Anne	EUMETSAT, Germany	Anne.Ocarroll@eumetsat.int
Orain	Françoise	Météo-France CMS R&D	francoise.orain@meteo.fr
Petrenko	Boris	NOAA/GST, Inc., USA	boris.petrenko@noaa.gov
Piolle	Jean-François	IFREMER, France	jfpiolle@ifremer.fr
Poulter	David	Pelamis Scientific Software Ltd, UK	david.poulter@pelamis.co.uk
Reynolds	Richard	CICS-NC, USA	Richard.W.Reynolds@noaa.gov
Roberts-Jones	Jonah	UK Met Office	jonah.roberts-jones@metoffice.gov.uk
Rodríguez	José	UK Met Office	jose.rodriguez@metoffice.gov.uk
Saha	Korak	NOAA/NESDIS/STAR and CIRA/CSU, USA	korak.saha@noaa.gov
Salter	John	University of Rhode Island, USA	John_salter@my.uri.edu
Vazquez	Jorge	JPL/Cal Tec, USA	jorge.vazquez@jpl.nasa.gov

Last Name	First Name	Affiliations	Email
Whittle	Christo	Council for Scientific and Industrial Research (CSIR), ZA	cwhittle@csir.co.za
Wick	Gary	NOAA/ESRL/PSD, USA	gary.a.wick@noaa.gov
Wimmer	Werenfrid	University of Southampton, UK	w.wimmer@soton.ac.uk
Xie	Xiaosu	Jet Propulsion Laboratory, USA	xiaosu.xie@jpl.nasa.gov
Yoder	James	WHOI, USA	jyoder@whoi.edu
Zhu	Xiaofang	RSMAS, University of Miami, USA	xiaofang.zhu@noaa.gov

APPENDIX 2 – PHOTO

APPENDIX 3 – SCIENCE TEAM 2013/14

Olivier Arino	European Space Agency, Italy
Ed Armstrong	NASA JPL, USA
Viva Banzon	NOAA/NESDIS, USA
Ian Barton	CSIRO Marine Research, Australia
Helen Beggs	Bureau of Meteorology, Melbourne, Australia
Kenneth S Casey	NOAA/NODC, USA
Sandra Castro	University of Colorado, Boulder, USA
Mike Chin	NASA JPL, USA
Carol Anne Clayson	WHOI, USA
Peter Cornillon	University of Rhode Island, USA
Craig J Donlon	European Space Agency, The Netherlands
Steinar Eastwood	Met.no, Norway
Bill Emery	University of Colorado, Boulder, USA
Bob Evans	RSMAS, University of Miami, USA
Gutemberg França	Federal University of Rio de Janeiro - UFRJ, Brazil
Chelle Gentemann	Remote Sensing Systems Inc., USA
Robert Grumbine	NOAA/NWS/NCEP, USA
Lei Guan	Ocean University of China, China
Andrew Harris	NOAA/NESDIS, USA
Jacob Høyer	Danish Meteorological Institute, Denmark
Simon Hook	NASA JPL, USA
Alexander Ignatov	NOAA/NESDIS/STAR, USA
Shiro Ishizaki	Japan Meteorological Agency (JMA), Japan
Misako Kachi	Japan Aerospace Exploration Agency (JAXA), Japan
Alexey Kaplan	Lamont–Doherty Earth Observatory of Columbia University, USA
Hiroshi Kawamura	Tohoku University, Japan
Pierre Le Borgne	Metéo France OSI–SAF, France
W Timothy Liu	NASA JPL, USA
Matthew Martin	MetOffice, UK
Eileen Maturi	NOAA/NESDIS, USA
Doug May	Naval Oceanographic Office, USA
Christopher Merchant	University of Edinburgh, Scotland, UK
Peter Minnett (Chair)	**RSMAS, University of Miami, USA**
Jonathan Mittaz	NOAA, USA
Tim Nightingale	Rutherford Appleton Laboratory, UK
Anne O'Carroll	EUMETSAT, Darmstadt, Germany
Jean–François Piollé	IFREMER, France

David Poulter	Pelamis Scientific Software Ltd
Nick Rayner	MetOffice Hadley Centre, UK
Jonah Roberts-Jones	MetOffice, MetOffice, UK
Ian S Robinson	National Oceanography Centre, UK
Christo Whittle	CISR, South Africa
Jorge Vazquez	NASA JPL,USA
Gary Wick	NOAA ETL, USA
Werenfrid Wimmer	University of Southampton, UK

Last page

XIV Science Team Meeting
Woods Hole, MA, USA

GHRSST XIV

Woods Hole, MA, USA
17th – 21th June 2013

Final Agenda – 19th June 2013

Meeting hosted by:

Woods Hole Oceanographic Institution

Contents

1. Welcome to GHRSST XIV

Welcome to the 14th Science Team Meeting of GHRSST!

It has been an interesting and busy year since we last met in Tokyo, with new satellite measurements becoming available and the promise of more to come. There have been personnel changes within GHRSST, and positive developments with the GHRSST data streams. On a less uplifting note, the effects of budget contraction here in the US, and elsewhere, are becoming felt and the situation does not show any signs of improving in the near future. As a result of budgetary constraints it is very likely that several GHRSST stalwarts will not be in attendance at Woods Hole, and we will miss their contributions.

At the last Science Team Meeting, the data from VIIRS were very fresh and the initial impressions were very promising. Now, a year later, we can report that these promises have been fulfilled; the VIIRS infrared bands are very clean and the derived skin SSTs are of high quality. All indications are that VIIRS will not only continue the long time series of wide-swath SSTs that include those from the AVHRRs and the two MODIS's, but will also bring improved spatial resolution and absolute accuracies. Also at the Tokyo meeting we heard of the first data from the AMSR-2 on GCOM-W1 and at this meeting we anticipate hearing more about the characteristics and accuracies of the microwave measurements. EUMETSAT has two additional earth observation satellites: MetOp-B in polar orbit carrying an AVHRR/3 and METEOSAT-10 (MSG-3) in geosynchronous orbit with a SEVIRI. Both AVHRR and SEVIRI are tried-and-tested sensors and we look forward to their data streams continuing over the next many years. We also look forward to the launches into polar orbit of the SGLI (Second generation GLobal Imager) on the Japanese GCOM-C1 and SLSTR on the European Sentinel-3a, and the Advanced Baseline Imager (ABI) on GOES-R into geostationary orbit. These are exciting times!

Another exciting development in the past year has been the signing of a Memorandum of Understanding between EUMETSAT and the National Satellite Ocean Application Service (NSOAS) of China. This bodes well for a wider use of data from Chinese satellites.

On the data front, the GDS-2 is being adopted by data providers, and a new processing of (A)ATSR data is underway. Similarly a reprocessing of the MODIS SSTs is anticipated in the next several months. The GDAC has adopted a "data life-cycle" policy that will ensure critical GHRSST data streams will continue to the served to the user community through the JPL PO.DAAC. Compliance with the new data policy is to the benefit of all in GHRSST.

As you know, Gary Corlett took over from Andrea Kaiser-Weiss as the GHRSST Project Coordinator in October and has taken up the reins in an admirable fashion. We also thank Silvia Bragaglia-Pike for her continued valuable contributions to the GHRSST Project Office. GHRSST is in safe hands.

A lot of effort goes on behind the scenes in preparing for the Science Team meetings, and in addition to the work done through the Project Office the local organizers at Woods Hole have also been busy. We thank Carol Anne Clayson and her team.

So, again, welcome to the 14th GHRSST Science Team Meeting. I am looking forward to a stimulating and exciting week, and I hope you are too.

Peter Minnett

Peter Minnett

(Chair of the GHRSST Science Team)

2. Organisation

2.1. Oral Presentations

Presentation should be made according to the time allotted in the Agenda; please allow a few minutes for questions.

Each presenter is requested to provide an **extended abstract** of their presentation **by the end of the meeting, or by the 30th June at the latest** in Microsoft Word format for inclusion in the GHRSST proceedings. This will help get the proceedings published efficiently and quickly after the meeting ends.

A template for your extended abstracts is provided at:

https://www.ghrsst.org/files/download.php?m=documents&f=121129121900-yoursurnameabstract.dot

2.2. Poster Presentations

The poster session is on Monday evening from 16:00 in the coffee break area. The poster boards are roughly 47” by 47” in size.

2.3. Session Chairs

The main tasks of a session Chair are to briefly introduce each speaker, keep the presentations to the time allowed, and to lead/moderate the discussion. The Chair should work closely with the rapporteur to prepare a **short summary of the session**.

Each **breakout session Chair** is responsible for:

- Preparing the breakout session in advance in order to focus on the key issues for GHRSST
- Arranging short overview presentations and timetabling these to allow as much discussion as possible
- Reporting the session back to plenary on Friday morning
- Reporting the session formally (based on notes from the rapporteur) in a written **session summary report**

Both **plenary and breakout *session summary reports*** should be suitable for publication in the proceedings and are to be **delivered to the GPO (gpa@ghrsst.org) before the end of the meeting**.

2.4. Rapporteurs

The purpose of the rapporteurs is to capture important information during the session for the follow-up of the workshop by the GHRSST-PO and Science Team. In preparing your session reports, you should avoid making lengthy summaries of the presentations and discussions.

Please concentrate on issues which relate directly to the objectives of the workshop, the mandate of GHRSST and the future development of GHRSST ocean products and services and provide a general overview of the main session outcomes/conclusions.

As a template for your session report please use:

https://www.ghrsst.org/files/download.php?m=documents&f=121129121900-yoursurnameabstract.dot

3. Agenda

3.1. Sunday 16th June 2013

We will gather in Falmouth on Sunday evening for a meal and maybe a few drinks to ward off the jet lag. For those that wish to come along we will get together at 18:00 in the foyer of the *Inn on the Square*.

3.2. Monday 17th June 2013

Monday, 17th June 2011

08:30-09:00	**Registration**

Plenary Session I: Introduction and review (Room 507)

Chair: *Anne O'Carroll* ***Rapporteur:*** *Craig Donlon*

09:00-09:30	**Welcome and logistics**
Welcome to GHRSST	*Peter Minnett*
Welcome address from Woods Hole Oceanographic Institution	*Susan Avery (Director of WHOI)*
Logistics	*Carol Anne Clayson Gary Corlett*

09:30-10:30	**Reports from GHRSST Americas**
NOAA/NESDIS/NODC LSTRF	*Ken Casey*
NOAA/NESDIS/STAR	*Alexander Ignatov*

Monday, 17th June 2011

NOAA/NESDIS/STAR	*Eileen Maturi*
NOAA/NESDIS/NCDC	*Viva Banzon*
NOAA/NWS/NCEP	*Bob Grumbine*
NAVO	*Jean-Francois Cayula*

10:30-11:00	**Tea/Coffee Break**

11:00-11:30	**Reports from GHRSST Americas (Continued)**
NASA GDAC	*Ed Armstrong*
NASA L2P & L4	*Mike Chin*
MISST/RSS	*Chelle Gentemann*

11:30-12:30	**Reports from GHRSST Europe/Africa**
ESA	*Craig Donlon*
Medspiration/Ifremer	*Jean-Francois Piolle*
EUMETSAT	*Anne O'Carroll*
OSI-SAF	*Pierre Le Borgne*
MyOcean2	*Francoise Orain*

Monday, 17th June 2011

12:30-13:00	**Reports from GHRSST Asia/Pacific**	
Australian Bureau of Meteorology		*Helen Beggs*
JAXA		*Misako Kachi*
JMA		*Shiro Ishizaki*

13:00-14:00	**Lunch**

Plenary Session II: Preparations for week ahead (Room 507)

Chair: *Peter Minnett* ***Rapporteur:*** *Gary Corlett*

14:00-14:15	*Summary of GPO activities*	*Gary Corlett*
14:15-14:30	*Remarks from the ST Chair*	*Peter Minnett*
14:30-15:30	*Discussion – identification of main issues for meeting*	

15:30-16:00	**Tea/Coffee Break**

16:00-18:00	**Poster Session**	
1	SQUAM Updates: progress since GHRSST-13 and future work	Prasanjit Dash
2	The Sentinel-3 mission: SLSTR technical overview	Craig Donlon
3	The Sentinel-3 mission: SLSTR data products	Craig Donlon

Monday, 17th June 2011

4	The sentinel-3 mission: performance and status	Craig Donlon
5	Night time detection of Saharan dust using infrared window	Pierre Le Borgne
6	OSI-SAF operational NPP/VIIRS sea surface temperature chain	Pierre Le Borgne
7	Evidence that SST signals are related to changes in the Atlantic meridional overturning circulation	Yang Liu
8	L2 and L3 products from the ESA CCI project	Christopher Merchant
9	GMES-PURE: Shaping the marine GMES/Copernicus user requirements	Anne O'Carroll
10	IASI L2Pcore sea surface temperature	Anne O'Carroll
11	New method in estimating Inter Sensor Sea Surface Temperature Biases using DINEOF analysis	Francoise Orain
12	Coastal diurnal warming study through in-situ and satellite data	Xiaofang Zhu

16:00-18:00	VIIRS Side Meeting (Room 509)

Special session in VIIRS SST retrieval and validation

SST algorithm - 40min

SST QFs - 1hr 20min

For further information please contact: Alexander Ignatov (NOAA)

18:00-21:00	MISST Side Meeting (Room 507)

MISST project meeting

For further information please contact: Chelle Gentemann (RSS)

3.3. Tuesday 18th June 2013

Tuesday, 18th June 2013

07:30-08:00	Registration desk open

GHRSST Parallel Breakouts for TAGs/WGs

08:00-10:00	EARWIG (507)	ICTAG (509)
	Awaiting final agenda – session will include 10 min presentations on: 1. *Mitigation of striping in ACSPO clear-sky radiances and SST products (Marouan Bouali)* 2. *Pattern recognition enhancements to NOAA ACSPO clear-sky mask (Boris Petrenko for Irina Gladkova)* 3. *Skin SST physical retrieval from GOES using modified total least square method (Prabhat Koner)* 4. *Using numerical weather prediction model profiles to improve SST calculations: application to Metop/AV (Pierre Le Borgne)* 5. *Quantifying the effect of ambient cloud on clear-sky ocean brightness temperatures and SSTs (Korak Saha)*	*8:00-8:10: Introduction* *8:10-8:50: Analysis methods and development of L4 SST products* *Presentations (10 min each):* *Sea surface temperature by Barnes' interpolation: current stage (Gutemberg France)* *Recent updates to the near real time OSTIA system (Jonah Roberts-Jones)* *Brief update (5 min):* *NOAA Geo-Polar 5km Global SST Analysis for day & night, night-only, and diurnal correction plans (Eileen Maturi)* *Discussion (15 min)* *8:50-9:35: Inter-comparison of L4 SST products* *Presentations (10 min each):* *A comparison of SST gradients and the impact of going to higher resolution (Jorge Vazquez)* *L4 comparison using Reynolds/Chelton spectrum test (Michael Chin)* *Discussion (25 min), including:* *Plans for the IC-TAG-wide inter-comparison based on Reynolds/Chelton approach* *9:35-9:45: GMPE plans discussion (lead by Gary Corlett and Jonah Roberts-Jones)* *9:45-10:00: General discussion and plans for the next year*

10:00-10:30	Tea/Coffee Break

Tuesday, 18th June 2013

10:30-12:30	STVAL (507)	R2HA2 (509)
	10:30: Introduction and ST-VAL Report (Helen Beggs) 10:40: Status of in situ SST Quality Monitor (iQUAM) (Alexander Ignatov for Feng Xu) 10:50: Preliminary analyses of Metop AVHRR, MODIS and VIIRS SST products in SQUAM (Prasanjit Dash) 11:00: Initial Validation of VIIRS Skin SST Retrievals with Shipboard Radiometers (Peter Minnett) 11:10: High Latitude SST Cal/Val Activities at DMI (Jacob Hoeyer) 11:20: Multi-Sensor Match-up Database for ESA SST_CCI (Gary Corlett) 11:30: BoM Efforts to Improve SSESs for AVHRR SST Level 3 Products (Helen Beggs for Chris Griffin) 11:40: General discussion and questions based on presentations. 11:55: Discussion and feedback on the future of the GHRSST MDB, MMDB and HR-DDS through the Felyx System (Led by Jean-Francois Piolle). 12:10: Other ST-VAL Issues (Led by Helen Beggs).	**Awaiting final agenda**

12:30-13:30	**Lunch**

12:30-13:30	**GPO Meeting**

Tuesday, 18th June 2013

13:30-15:30	*DVWG (507)*	*DASTAG (509)*
	Brief Presentations/Updates: • *Update on the GHRSST Tropical Warm Pool Diurnal Variability (TWP+) Project (Helen Beggs)* • *Comparison of Diurnal Warming Estimates from Unpumped Argo Data and SEVIRI Satellite Observations (Sandra Castro)* • *A diurnal warming dedicated matchup database: Examples and preliminary validation results (Pierre Le Borgne)* • *SST diurnal variability: Regional extent & implications in atmospheric modeling (Ioanna Karagali)* • *Application and evaluation of diurnal warming models forced with GFS model inputs (Gary Wick)* • *SST sensitivity and its relevance to measuring diurnal variability (Chris Merchant)* • *Carol Anne Clayson* ***Discussion Topics:*** • *Group goals and priorities* • *Membership*	*1. Emerging trends in metadata (Ted Habermann, remote)* *2. PO.DAAC integrated web services (Ed Armstrong)* *3. Reconciling GHRSST archive integrity and data flows (Ken Casey)* *4. A Hadoop framework for data mining and analyses of large datasets (Jean Francois Piolle)* *5. Proposals for new GHRSST dataset policies (Ed Armstrong and Gary Corlett)*

15:30-16:00	**Tea/Coffee Break**

16:00-18:00	*HLTAG (507)*	*AUSTAG (509)*
	Awaiting final agenda	• *16:00: GMES-Pure (Anne O'Carroll)* • *16:10: Results from NASA sponsored GHRSST Webinar (Jorge Vazquez)* • *16:40: Overview of SQUAM and demo (Prasanjit Dash)* • *17:10 Overview of fisheries habitat prediction (Ed Armstrong)* • *17:20 General Discussion on key topics (Gary Corlett)* *1. Users – who are they?* *2. Possible user symposium – we should have a good discussion on the what, why, when etc.* *3. Expansion into new areas – coordinating our efforts into South America and Asia etc.*

18:00-18:30	**Tea/Coffee Break**

Tuesday, 18th June 2013

18:30-20:30	*IWWG (509)*	*CDRTAG (507)*
	Awaiting final agenda	***Awaiting final agenda – session will include 10 min presentations on:*** • *The generation of SST climate data records using shipboard radiometers (Peter Minnett)* • *A long term satellite based data record of sea surface temperature from ESA's climate change initiative (Chris Merchant for Nick Rayner)*

3.4. Wednesday 19th June 2013

Wednesday, 19th June 2013

08:00-08:30	**Registration desk open**

Plenary Session III: Focus on topics relating to data and user services (Room 507)

Chair: *Jorge Vazquez* ***Rapporteur:*** *Ed Armstrong*

08:30-08:50	*CEOS SST-VC: update on progress*	*Craig Donlon*
08:50-09:10	*Felyx: A generic tool for EO data analytics*	*Jean-Francois Piolle*
09:10-09:30	*Data life cycle policy*	*Edward Armstrong*
09:30-10:00	*Open discussion led by session chair*	

10:00-10:30	**Tea/Coffee Break**

Wednesday, 19th June 2013

Plenary Session IV: Focus on key topics relating to estimation, masking and validation (Room 507)

Chair: *Helen Beggs* ***Rapporteur:*** *Bob Grumbine*

10:30-10:50	*Progress in sea surface temperature retrieval and future directions*	*Christopher Merchant*
10:50-11:10	*METOP-A/AVHRR derived SST over the Arctic: Five year (2007-2012) results*	*Pierre Le Borgne*
11:10-11:30	*GCOM-W1 AMSR2 SST*	*Misako Kachi* *Chelle Gentemann*
11:30-12:00	*Open discussion led by session chair*	

12:00-18:00	**Afternoon Team Building**
See section 5 for further details	

19:00-22:00	**GHRSST Dinner**
See section 5 for further details	

3.5. Thursday 20th June 2013

Thursday, 20th June 2013

08:15-08:45	**Registration desk open**

Thursday, 20th June 2013

Plenary Session V: Focus on key topics relating to Level 4 (Room 507)

Chair: *Alexey Kaplan* ***Rapporteur:*** *Mike Chin*

08:45-09:05	*High Resolution Daily Sea Surface Temperature Analysis: the 2-stage OI*	*Richard Reynolds*
09:05-09:25	*Evaluation of GHRSST products for studies of short term climate variability - a comparison between OSTIA and NCDC OI2 analyses*	*Dudley Chelton*
09:25-09:45	*SST data impact in global HYCOM*	*Jim Cummings*
09:45-10:15	*Open discussion led by session chair*	

10:15-10:45	**Tea/Coffee Break**

Plenary Session VI: Focus on key topics relating to climate (Room 507)

Chair: *Christopher Merchant* ***Rapporteur:*** *Jon Mittaz*

10:45-11:05	*ESA SST CCI L4 reanalysis using the OSTIA system*	*Jonah Roberts-Jones*
11:05-11:25	*A multi-sensor SST reanalysis for the arctic ocean*	*Jacob Hoeyer*
11:25-11:45	*Sampling errors in satellite derived sea surface temperature for climate data records*	*Yang Liu*
11:45-12:15	*Open discussion led by session chair*	

Thursday, 20th June 2013

12:15-12:45	S3VT Special Session (Room 507)

Special session on Sentinel 3 Validation Team

Welcome and overview of S3VT-T (10 min)
Summary slides from team members/groups (10 min)
Questions/issues for discussion (10 min)

For further information please contact:
Anne O'Carroll (EUMETSAT) or Craig Donlon (ESA)

12:45-14:15	**Lunch**

Plenary Session VII: Physical oceanography and SST (Room 507)

Chair: *Peter Cornillon* ***Rapporteur:*** *Jonah Roberts-Jones*

14:15-14:35	*Biases in global mean SST estimates obtained from gridded data sets*	*Alexey Kaplan*
14:35-14:55	*Statistical analysis of sub-mesoscale processes from satellite SST observations*	*Emmanuelle Autret*
14:55-15:15	*SEVIRI and VISSR SST front and gradient datasets*	*Peter Cornillon*
15:15-15:45	*Open discussion led by session chair*	

15:45-16:15	**Tea/Coffee Break**

Thursday, 20th June 2013

Plenary Session VIII: SST in ocean-atmosphere interaction (Room 507)

Chair: Carol Anne Clayson **Rapporteur:** Gary Wick

16:15-16:35	*Impact of diurnal warming on assimilation of satellite observations of sea surface temperature*	*Charlie Barron*
16:35-16:55	*Relating of sea surface temperature and color to carbon dioxide partial pressure and flux*	*Timothy Liu*
16:55-17:15	*Mid-latitude sea surface temperature signal in the upper troposphere*	*Xiasou Xie*
17:15-17:45	*Open discussion led by session chair*	

18:00-20:00	**Advisory Council (Room 507)**

Meeting of the GHRSST Advisory Council

For further information please contact: Helen Beggs (ABoM)

3.6. Friday 21st June 2013

Friday, 21st June 2013

08:00-08:30	**Registration desk open**

Plenary Session IX: Coupled data assimilation and SST (Room 507)

Chair: Jim Cummings **Rapporteur:** Andy Harris

08:30-08:50	*Direct assimilation of satellite SST radiances*	*Jim Cummings*
08:50-09:10	*Evaluating the diurnal variability of sea surface temperature in a global initialised couple model*	*Jose Rodriguez*
09:10-09:30	*Sea surface temperature estimates and coupled forecasting*	*Christopher Merchant*
09:30-10:00	*Open discussion led by session chair*	

10:00-10:30	**Tea/Coffee Break**

Closing Session (Room 507)

Chair: Peter Minnett **Rapporteur:** Gary Corlett

10:30-10:45	*GHRSST and possible future developments*	*David Llewellyn-Jones*

10:45-11:00	*Report from Advisory Council*	*Helen Beggs*

11:00-11:50	**Summary of breakout groups**	
1	*AUS-TAG*	*Jorge Vazquez*
2	*CDR-TAG*	*Christopher Merchant*
3	*DAS-TAG*	*Ed Armstrong*
4	*DVWG*	*Gary Wick*
5	*EaRWiG*	*Andy Harris*
6	*HL-TAG*	*Bob Grumbine*
7	*IC-TAG*	*Alexey Kaplan*
8	*IWWG*	*Bob Grumbine*
9	*ST-VAL*	*Helen Beggs*
10	*R2HA2*	*Peter Cornillon*

11:50-12:30	*Review of action items*

12:30-13:15	*Identification of priorities for following 12 months*

13:15-13:30	*Wrap-up/closing remarks*

Close of GHRSST XIV

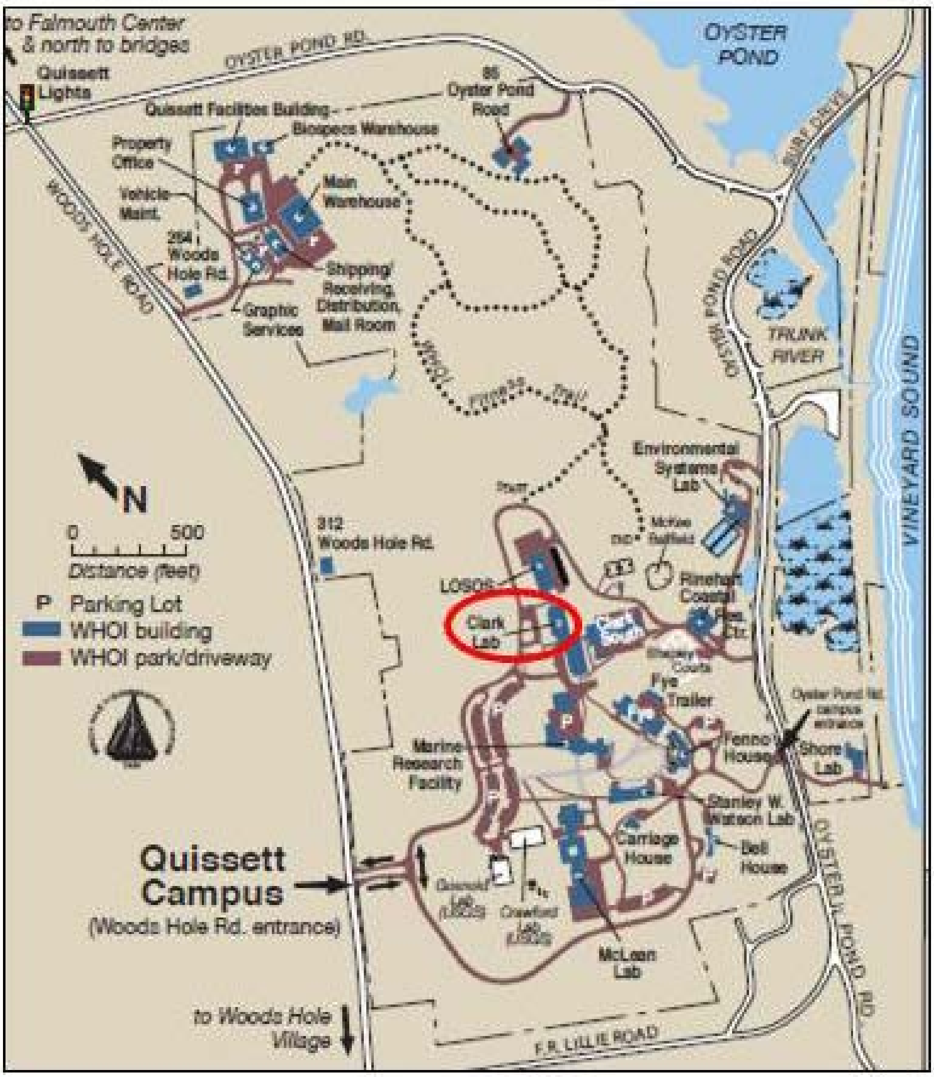
13:30-14:30	**Box lunch to go**

14:00-17:00	CEOS SST-VC (Room 507)
	Meeting of the CEOS SST Virtual Constellation For further information please contact: Kenneth Casey (NOAA) or Craig Donlon (ESA)

4. Meeting venue

All of the meeting sessions will take place in the **Clark Building, Quissett Campus,** at WHOI. WHOI has a comprehensive visitor website for general information here: http://www.whoi.edu/main/visitor-information.

Quissett Campus



4.1. Parking notice

Parking permits will be available at the GHRSST meeting check in desk (Clark Building, 5th floor foyer, outside Room 507) for those who have cars. Parking is available anywhere on the Quissett campus.

4.2. Local transport

There may be a number of participants who have rental cars and are willing to offer transport to other people staying at the same hotels. A car-sharing scheme is being investigated and more information will be made available locally.

If not we advise you use the following mode of transport:

The Breeze: Woods Hole Trolley
The Woods Hole Trolley runs between Falmouth Mall and Woods Hole along Route 28 and Woods Hole Road, seven days a week. Visit Website

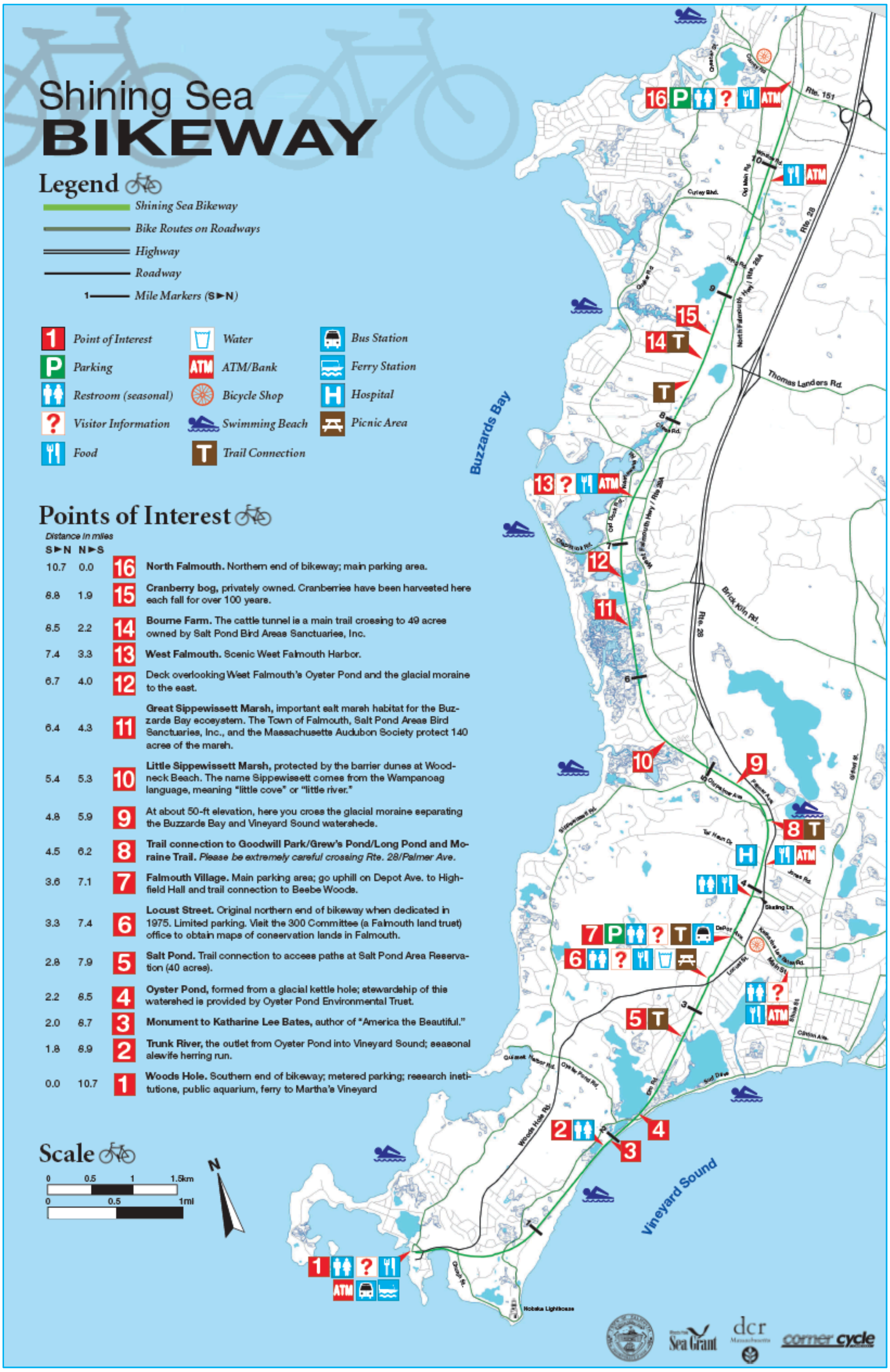
The Breeze: b-bus
b-bus is convenient, low-cost public transportation from Cape Cod and back. The Cape Cod Regional Transit Authority provides this door-to-door, ride-by-appointment service for people of all ages for trips for any purpose, including school, work, shopping, college, doctor's appointments, visiting friends and even Boston medical trips. Enrolment required. Visit Website

Taxis:

- Falmouth Taxi can be reached at either 01-508-540-7214, 508-548-3100, or info@falmouthtaxi.com.
- All Seasons Taxi: (508) 548-9990
- Upper Cape Taxi: (508)-540-1290

Finally, a possible further alternative for those staying at the Inn on the Square could be to either hire bicycles or even walk!

The Shining Sea Bikeway runs right past Inn on the Square and the Quissett Campus (1.8 miles). On the map on the following page the Inn on the Square is right at stop 7, and stop 2 is right about at the WHOI campus, although there is not a sign on the bikeway pointing up the hill to the Quissett campus. If you would like further information please let the WHOI hosts know and they can provide more information.


Shining Sea
BIKEWAY
Legend
Shining Sea Bikeway
Bike Routes on Roadways
Highway
Roadway
Mile Markers (S►N)
Point of Interest
Parking
Restroom (seasonal)
Visitor Information
Food
Water
ATM/Bank
Bicycle Shop
Swimming Beach
Trail Connection
Bus Station
Ferry Station
Hospital
Picnic Area
Points of Interest
Distance in miles
S►N N►S
10.7 0.0 16 North Falmouth. Northern end of bikeway; main parking area.
8.8 1.9 15 Cranberry bog, privately owned. Cranberries have been harvested here each fall for over 100 years.
8.5 2.2 14 Bourne Farm. The cattle tunnel is a main trail crossing to 49 acres owned by Salt Pond Bird Areas Sanctuaries, Inc.
7.4 3.3 13 West Falmouth. Scenic West Falmouth Harbor.
6.7 4.0 12 Deck overlooking West Falmouth's Oyster Pond and the glacial moraine to the east.
6.4 4.3 11 Great Sippewissett Marsh, important salt marsh habitat for the Buzzards Bay ecosystem. The Town of Falmouth, Salt Pond Areas Bird Sanctuaries, Inc., and the Massachusetts Audubon Society protect 140 acres of the marsh.
5.4 5.3 10 Little Sippewissett Marsh, protected by the barrier dunes at Woodneck Beach. The name Sippewissett comes from the Wampanoag language, meaning "little cove" or "little river."
4.8 5.9 9 At about 50-ft elevation, here you cross the glacial moraine separating the Buzzards Bay and Vineyard Sound watersheds.
4.5 6.2 8 Trail connection to Goodwill Park/Grew's Pond/Long Pond and Moraine Trail. Please be extremely careful crossing Rte. 28/Palmer Ave.
3.6 7.1 7 Falmouth Village. Main parking area; go uphill on Depot Ave. to Highfield Hall and trail connection to Beebe Woods.
3.3 7.4 6 Locust Street. Original northern end of bikeway when dedicated in 1975. Limited parking. Visit the 300 Committee (a Falmouth land trust) office to obtain maps of conservation lands in Falmouth.
2.8 7.9 5 Salt Pond. Trail connection to access paths at Salt Pond Area Reservation (40 acres).
2.2 8.5 4 Oyster Pond, formed from a glacial kettle hole; stewardship of this watershed is provided by Oyster Pond Environmental Trust.
2.0 8.7 3 Monument to Katharine Lee Bates, author of "America the Beautiful."
1.8 8.9 2 Trunk River, the outlet from Oyster Pond into Vineyard Sound; seasonal alewife herring run.
0.0 10.7 1 Woods Hole. Southern end of bikeway; metered parking; research institutions, public aquarium, ferry to Martha's Vineyard
Scale
0 0.5 1 1.5km
0 0.5 1mi
N
Buzzards Bay
Vineyard Sound
Rte. 151
Rte. 28
Thomas Landers Rd.
Brick Kiln Rd.
Nobska Lighthouse
dcr
Sea Grant
corner cycle

4.3. The meeting

You will find the GHRSST XIV Reception Desk in the foyer outside Room 507 (main meeting room) on the 5th floor of the Clark Building.

Plenary Sessions (Monday, Wednesday, Thursday and Friday) will be in room 507 and Breakout Sessions (Tuesday) will take place in Room 507 and in Room 509 on 5th floor (see agenda for further details).

Meeting coordinators

- Local coordinators:
  - Carol Anne Clayson (850-321-9300; cclayson@whoi.edu)
  - Alec Bogdanoff (508-444-2532)
  - Kathy Ponti (508-289-3806)
- GHRSST Project Office
  - Gary Corlett (0044-789-420-4135; gpc@ghrsst.org)
  - Silvia Bragaglia-Pike (gpa@ghrsst.org)
- In case of emergency:
  - To report an emergency on the WHOI campus: Dial 2911 (or 508-289-2911 from your cell phone).
  - To reach local emergency services when off campus: Dial 911.

Coffee breaks and meals during the meeting

- Coffee Breaks: in foyer outside Room 507
- Lunches: On Monday, Tuesday and Thursday they will be available in the foyer outside room 507. On Friday there will be box lunches.

  Details of lunch on Wednesday are provided in the Special Events section.

Dinners

Information on local restaurants and opening times will be available at the venue.

5. Special Events

5.1. Sunday 16th June

- Where: Inn on the Square foyer
- When: 18:00 hours
- How to get there: See information in the Accommodation section

5.2. Wednesday 19th June (afternoon team building)

For the Wednesday afternoon team building activity we are considering two options to allow for changes in weather:

1. Sports: This will be a team event and we are currently looking at a couple of different sports so please some appropriate clothing for a bit of activity. There may be a small charge for equipment hire (to be advised at registration) and we will meet at WHOI at 13:00.
2. Martha's Vineyard: This will be a visit to Martha's Vineyard, travelling by ferry to and from Woods Hole, with guidance to be provided on what to do once there. There will be a small cost for the ferry and for transport on the Vineyard. Please note that you will need to be at WHOI ready to go by 12:30.

Obviously the success of these activities will very much depend on the local weather on Wednesday afternoon and a final decision will be made nearer the time.

Please note that Lunch on Wednesday is not included in the registration fee and you buy your own. If the sport option is selected then we will likely order in some take away food.

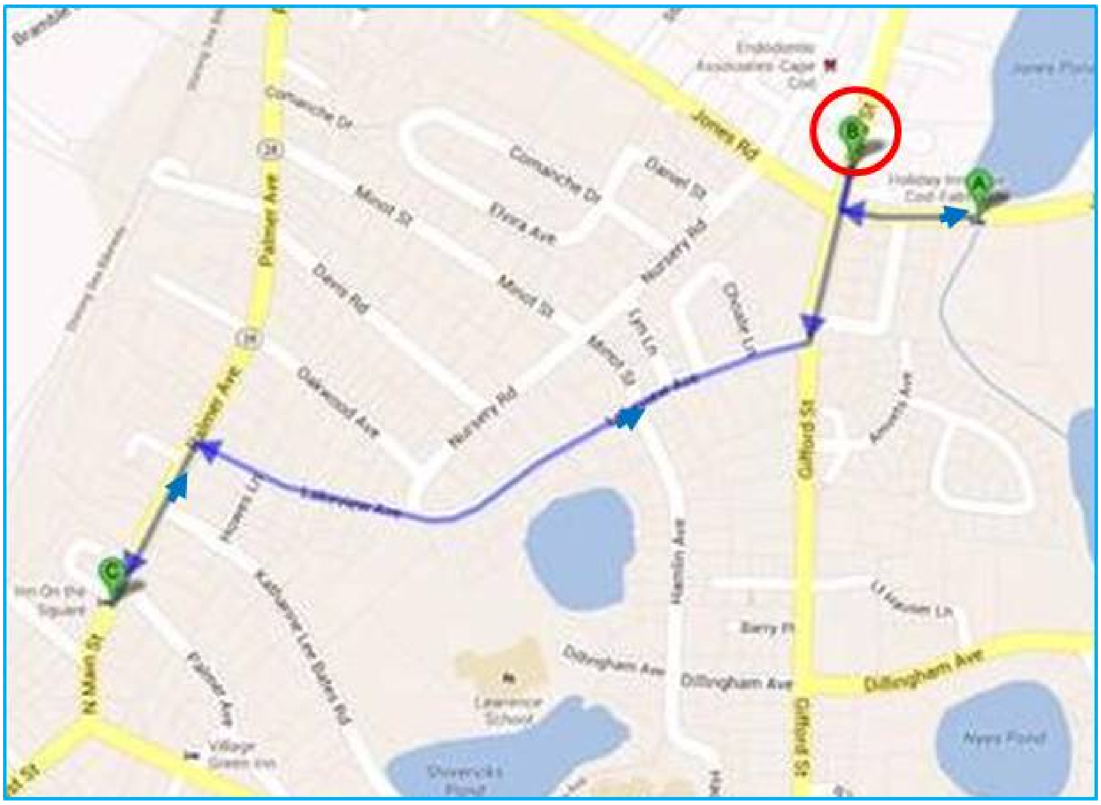
5.3. Wednesday 19th June (evening)

The meeting dinner will be at the Coonamessett Inn on Wednesday, June 19. The cost for the dinner is $40 per person. There will be a cash bar available during the dinner. We highly suggest that all meeting attendees join us for this year's dinner. **Please note that if you wish to attend you must have registered your interest by Thursday 13th June at the latest.**

The Coonamessett Inn is located at 311 Gifford Street, Falmouth, MA 02540. The Coonamessett Inn is located 0.1 miles from the Holiday Inn and 0.8 miles from the Inn on the Square.

Both hotels are a walkable distance to/from the location of the dinner:

Holiday Inn (A) to Coonamessett Inn (B) = ~0.1 mi
Inn on the Square (C) to Coonamessett Inn (B) = ~0.8 mi



6. Travel information

6.1. Travel to Woods Hole

The Woods Hole Oceanographic Institution is located on beautiful Cape Cod. It is roughly 75 miles southeast of Boston, MA. Woods Hole is about equidistant from the Providence-TF Green Airport and Boston-Logan Airport; however, it is much easier to get from Boston to Woods Hole via public transportation.

Travel information to WHOI can be found here: http://www.whoi.edu/directions/.

6.2. Flying into Boston-Logan Airport (BOS)

- **Car Rental:** You can rent a car at the airport and drive to Woods Hole. Direction to the Quissett Campus are available here: http://www.whoi.edu/directions/
- **Bus:** The best option is Peter Pan Bus service from the airport directly to Falmouth or Woods Hole. You can purchase tickets online on the Peter Pan website: www.peterpanbus.com.

6.3. Flying into Providence-TF Green Airport (PVD)

- **Car Rental:** You can rent a car at the airport and drive to Woods Hole. Direction to the Quissett Campus are available here: http://www.whoi.edu/directions/
- **Public transportation** is quite difficult from PVD to Woods Hole.

6.4. AMTRAK Northeast

- If you are in New England and want to take Amtrak, you can take the train to South Station in Boston and then take the Peter Pan Bus down to Falmouth. You can purchase tickets online on the Peter Pan website: www.peterpanbus.com.

6.5. Northeast Bus Service

- Peter Pan Bus provides service (via connections) to Falmouth/Woods Hole from several New England metropolitan areas. You can purchase tickets online on the Peter Pan website: www.peterpanbus.com.

Note to travelers: There are only two bridges to Cape Cod, and can get backed up during the summer. In addition, the buses to and from the Cape can fill up. **We recommend spending the couple extra dollars on "Reserved Seats" for a specific schedule, date and time of departure.**

7. Hotel information

Both hotels that had rooms reserved for participants to GHRSST XIV are located far enough from the Quissett Campus that a rental car may be desired. If you stay at Inn on the Square, you can take the Peter Pan Bus from the airport to within a very short walking distance from the hotel. We can help those who desire to carpool. In addition, you can walk or rent a bike for the week (http://www.cornercycle.com) - it is a nice 2 mile walk or bike ride along the Shining Sea Bike Path (http://www.woodshole.com/documents/bikewaymap.pdf) from Inn on the Square to the Quissett Campus.

7.1. Inn on the Square

40 North Main Street, Falmouth, MA 02540 - www.innonthesquare.com.

Phone: 508-457-0606 or 800-676-0000for reservations.

All room rates subject to state/occupancy taxes, currently 9.7%. $15 per person charge for more than 2 adults in a guest room

Note: Cancellations must be placed 72 hours prior to the date of arrival, or guests will be billed for one night's rate plus tax.

Roughly 2 miles from WHOI, and next door to the Falmouth Peter Pan Bus terminal. For those not planning to rent a car, this hotel will be the best option.

7.2. Holiday Inn Falmouth

291 Jones Road, Falmouth, MA 02540, http://www.holidayinn.com/hotels/us/en/falmouth/fmhma/hoteldetail,

Phone: Skype 508-540-2000 or 508-540-2000 FREE.

All rooms have two double beds and are non-smoking.

All room rates subject to state/occupancy taxes, currently 9.7%

Note: Cancellations must be placed 48 hours prior to the date of arrival, or guests will be billed for one night's rate plus tax.

Roughly 3.15 miles from WHOI

8. Provisional list of Participants

Last Name	First Name	Affiliations	Email
Armstrong	Ed	NASA JPL, PO.DAAC, US	edward.m.armstrong@jpl.nasa.gov
Autret	Emmanuelle	IFREMER, France	emmanuelle.autret@ifremer.fr
Banzon	Viva	NOAA/NESDIS/ NCDC	viva.banzon@noaa.gov
Barron	Charlie	Naval Research Laboratory, US	charlie.barron@nrlssc.navy.mil
Barton	Ian	Australia	ian.barton@ozemail.com.au
Beggs	Helen	CAWCR, Australia	H.Beggs@bom.gov.au
Bingham	Andrew	JPL, US	Andrew.Bingham@jpl.nasa.gov
Bogdanoff	Alec	WHOI, US	alecb@whoi.edu
Bouali	Marouan	NOAA/CIRA, US	marouan.bouali@noaa.gov
Bragaglia-Pike	Silvia	GHRSST Project, University of Reading, UK	gpa@ghrsst.org
Brasnett	Bruce	Environment Canada	Bruce.Brasnett@ec.gc.ca
Casey	Ken	NOAA/NESDIS/ NODC	Kenneth.Casey@noaa.gov
Castro	Sandra	University of Colorado, US	sandrac@colorado.edu
Cayula	Jean-Francois	Qinetiq North America, US	j.cayula@ieee.org
Chelton	Dudley	OSU, US	chelton@coas.oregonstate.edu
Chin	T. Mike	JPL, US	mike.chin@jpl.nasa.gov
Clayson	Carol Anne	WHOI, US	cclayson@whoi.edu
Corlett	Gary	University of Leicester, UK	gpc@ghrsst.org
Cornillon	Peter	University of Rhode Island, US	pcornillon@me.com

Last Name	First Name	Affiliations	Email
Crosman	Erik	University of Utah, US	erik.crosman@utah.edu
Cummings	James	Naval Research Laboratory, US	cummings@nrlmry.navy.mil
Dash	Prasanjit	NOAA NESDIS / CSU CIRA, US	prasanjit.dash@noaa.gov
de Sousa	Rodrigo Carvalho	AML/UFRJ	rodrigo@lma.ufrj.br
Donlon	Craig	European Space Agency, The Netherlands	craig.donlon@esa.int
Eastwood	Steinar	Norwegian Meteorological Institute	s.eastwood@met.no
Evans	Robert	RSMAS/MPO, US	revans@rsmas.miami.edu
Foley	Dave	Institute of Marine Sciences, UCSC, US	dave.foley@noaa.gov
Foti	Gregg	NODC	gregg.foti@noaa.gov
França	Gutemberg	Federal University of Rio de Janeiro - UFRJ, Brazil	gutemberg@lma.ufrj.br
Gentemann	Chelle	Remote Sensing Systems, US	gentemann@remss.com
Gramer	Lewis	University of Miami CIMAS, US	lgramer@rsmas.miami.edu
Grumbine	Robert	NOAA/NWS/NCEP	robert.grumbine@noaa.gov
Harris	Andrew	ESSIC, UMD, US	andy.harris@noaa.gov
Hoeyer	Jacob	Danish Meteorological Institute	jlh@dmi.dk
Ignatov	Alexander	NOAA/NESDIS/STAR	Alex.Ignatov@noaa.gov
Ishizaki	Shiro	Japan Meteorological Agency	s_ishizaki@met.kishou.go.jp

Last Name	First Name	Affiliations	Email
Iwanski	Dan	University of Rhode Island, US	diwanski@gso.uri.edu
Kachi	Misako	JAXA, JAPAN	kachi.misako@jaxa.jp
Kaplan	Alexey	LDEO of Columbia University, US	alexeyk@ldeo.columbia.edu
Karagali	Ioanna	DTU Wind Energy - Technical University of Denmark	ioka@dtu.dk
Koner	Prabhat	ESSIC, US	prabhat.koner@noaa.gov
Lange	Martin	German Weather Service	martin.lange@dwd.de
Le Borgne	Pierre	Météo-France	pierre.leborgne@meteo.fr
Liu	W. Timothy	Jet Propulsion Laboratory, US	w.t.liu@jpl.nasa.gov
Liu	Yang	RSMAS, University of Miami, US	yliu@rsmas.miami.edu
Llewellyn-Jones	David	University of Leicester, UK	dlj1@le.ac.uk
Maturi	Eileen	NOAA/NESDIS, US	eileen.maturi@noaa.gov
Merchant	Christopher	University of Reading, UK	c.j.merchant@reading.ac.uk
Minnett	Peter	University of Miami, US	pminnett@rsmas.miami.edu
Mittaz	Jonathan	University of Maryland, US	Jon.Mittaz@noaa.gov
Nightingale	Tim	STFC Rutherford Appleton Laboratory, UK	tim.nightingale@stfc.ac.uk
O'Carroll	Anne	EUMETSAT, Germany	Anne.Ocarroll@eumetsat.int
Orain	Françoise	Météo-France CMS R&D	francoise.orain@meteo.fr
Petrenko	Boris	NOAA/GST, Inc., US	boris.petrenko@noaa.gov

Last Name	First Name	Affiliations	Email
Piolle	Jean-François	IFREMER, France	jfpiolle@ifremer.fr
Poulter	David	Pelamis Scientific Software Ltd, UK	david.poulter@pelamis.co.uk
Reynolds	Richard	CICS-NC	Richard.W.Reynolds@noaa.gov
Roberts-Jones	Jonah	UK Met Office	jonah.roberts-jones@metoffice.gov.uk
Rodríguez	José	UK Met Office	jose.rodriguez@metoffice.gov.uk
Saha	Korak	NOAA/NESDIS/STAR and CIRA/CSU, US	korak.saha@noaa.gov
Salter	John	University of Rhode Island, US	John_salter@my.uri.edu
Vazquez	Jorge	JPL/Cal Tec, US	jorge.vazquez@jpl.nasa.gov
Whittle	Christo	Council for Scientific and Industrial Research (CSIR), ZA	cwhittle@csir.co.za
Wick	Gary	NOAA/ESRL/PSD, US	gary.a.wick@noaa.gov
Wimmer	Werenfrid	University of Southampton, UK	w.wimmer@soton.ac.uk
Xie	Xiaosu	Jet Propulsion Laboratory, US	xiaosu.xie@jpl.nasa.gov
Yoder	James	WHOI, US	jyoder@whoi.edu
Zhu	Xiaofang	RSMAS, University of Miami, US	xiaofang.zhu@noaa.gov