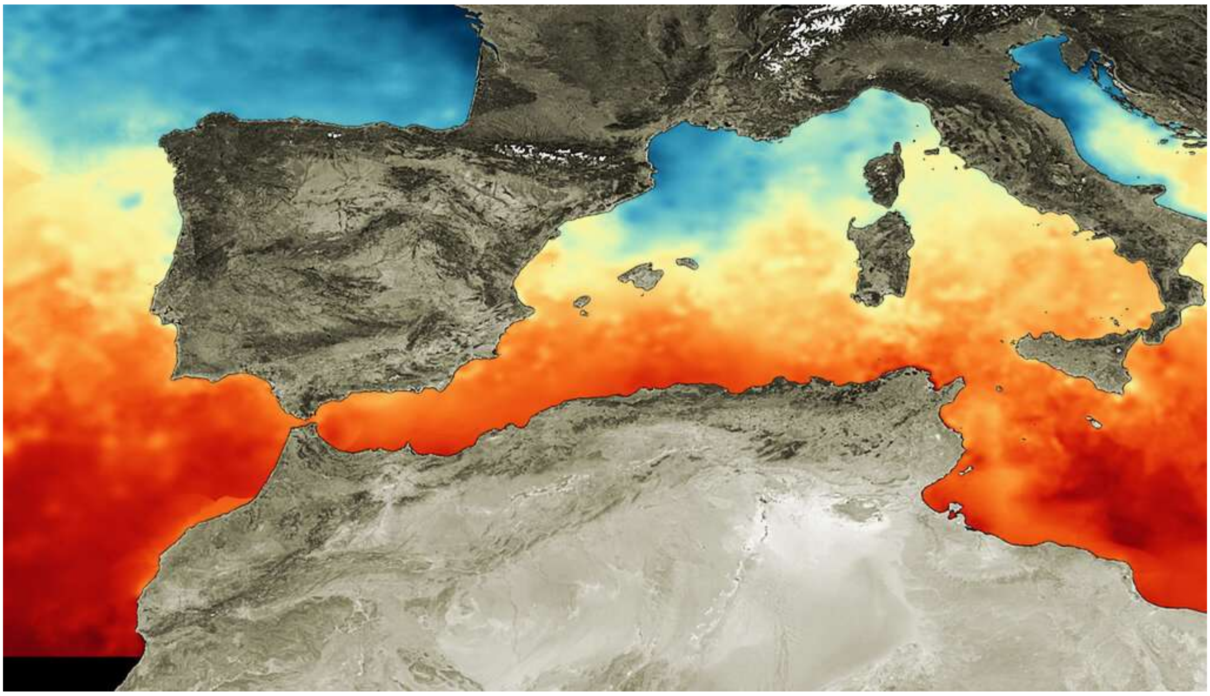
Proceedings

23rd International GHRSST Science Team Meeting

27 June-1 July 2022



Cover: Mediterranean sea surface temperature. Credits: ESA, https://www.esa.int/ESA_Multimedia/Images/2008/10/Mediterranean_sea_surface_temperature

The GHRSST Project Office is funded by the European Union Copernicus Programme and is hosted by the Danish Meteorological Institute, Lyngbyvej 100, 2100 Copenhagen (DK)

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The GHRSST23 International Science Team meeting has been sponsored by:

Contents

Welcome to the 23rd GHRSST Science Team meeting

Anne O'Carroll, GHRSST Science Team Chair, EUMETSAT

Welcome to the 23rd International Science Team meeting of the Group for High Resolution Sea-Surface Temperature (GHRSST23, GHRSST XXIII).

This year we will be holding both a fully-virtual meeting and in-person meeting in Barcelona, with joint aspects, for the first time. Even though the Pandemic conditions continue, and travel is still difficult or impossible for many participants, we received strong feedback last year to organise an in-person event in 2022. The in-person event is kindly hosted by the Institut de Ciències del Mar –ICM (CISC) in Barcelona, with the support of Cristina González Haro and Jordi Isern-Fontanet. It has been 3 years since we last met in person, so the collaborative opportunities and live discussions will be much welcomed. For those of you unable to travel to Barcelona, the virtual meeting will follow the same organisation as the last two years, hosted on the EUMETSAT Moodle, with the support of the EUMETSAT training team and on gather.town.

This will be the first meeting organised by the new Copernicus GHRSST Project Office (GPO), which transitioned in July 2021, led by Chiara Bearzotti (GPO coordinator), Pia Wind (GPO administrator), supported by Jacob Høyer and Ioanna Karagali from the Danish Meteorological Institute (DMI). I hope you have all had a chance to interact with them in preparation for the meeting, and some of you will have a chance to meet them in-person at the end of June. I would like to welcome them all to this new role, and thank them for the excellent coordination over the last year. New communication tools and methods have been introduced by the GPO over the last year, including introducing Slack channels and Github, in addition to the EUMETSAT Moodle.

The provision of high-quality Sea Surface Temperature (SST) data from a broad satellite constellation has continued, including the launches of FY-4B (GEO) in June 2021, FY-3E (LEO) in July 2021 and GOES-18 in March 2022 in the last year. In the next year, launches are planned for MTG I1, JPSS-2 and Oceansat-3. Commissioning and ongoing validation activities also continue for several missions, and we look forward to hearing about all the updates at this meeting. We will also hear about updates from future missions such as the continuity of microwave SST with AMSR-3 planned for launch by JAXA, Sentinel-3 C/D, Metop-SG A1, Sentinel-3 Next Generation Optical by ESA, and the Copernicus Imaging Microwave Radiometer (CIMR) planned for approx. 2029, plus others.

We have an interesting agenda for the week covering sessions on user applications and climate; Processing and Products; Calibration, Validation and Product Assessment; Algorithms and Computing and Products. Highlights will include: comparisons of SST analyses using Saildrones; evaluation of diurnal warming estimates; hearing about the new Felyx release for a distributed and cloud-ready multi-matchup dataset production framework; and the 2nd NOAA AVHRR GAC SST reanalysis.

There will be live discussions on the Task Teams progress with dedicated Zoom sessions each day, focusing on a few Task Teams at a time, supplemented by the Moodle forum and discussions. An important Task Team presentation will be an update on the evolution of the Regional/Global Task Sharing by the R/GTS team, including information on upcoming implementation of GHRSST data discovery and cataloguing on the GHRSST web-site. We will also have a dedicated session on the

Wednesday including developing training plans and formats on SST, discussing the GHRSST 25th anniversary plans for 2024, and re-evaluating the GHRSST priorities. This will address GHRSST's user driven priorities as presented in our OceanObs19 white paper, covering: improving data quality in the Arctic; improving coastal SST data quality; and improving SST feature resolution. For those attending in person in Barcelona we will have a few specific collaboration events with focus including on dynamical information from high-resolution SST, coastal and inland waters, open science on the cloud, and infrared sea surface temperature retrieval.

I hope you all have an enjoyable and productive meeting and have a great week!

Anne O'Carroll

Opening Session

Rapporteur: Ioanna Karagali (1)

Chair: Anne O'Carroll (2)

(1) Danish Meteorological Institute, Denmark, Email: ika@dmi.dk

(2) EUMETSAT, Germany, Email: Anne.Ocarroll@eumetsat.int

This report summarises the key points from the opening session of GHRSST23, which took place on Monday June 27th 2022.

Welcome by Antonio Turiel, Chair of the Barcelona Expert Centre (BEC)

A first welcome was given by Antonio Turiel, the chair of the Barcelona Expert Centre (BEC), on behalf of the director of the Institute of Marine Sciences (ICM), one of the largest marine science institutes in Europe, with approximately 250 employees.

The institute serves as the logistics base for research vessels and the Spanish base in Antarctica. Furthermore, ICM hosts the Barcelona Expert Centre (BEC), a SMOS mission laboratory, active in the production and distribution of satellite products related to sea surface height and other oceanographic variables.

Keynote Lecture: "On the role of SST fronts in setting up SST statistics"

A keynote lecture was given by one of the GHRSST meeting hosts, Jordi Isern-Fontanet (CSIC-ICM) on the role of thermal fronts and how to characterise high resolution SST. While using spectral slopes is a common tool for assessing the effective spatial resolution of SST products, which typically exhibit a drop in power following a k-2 slope, there are limitations. A common approach in turbulence-related studies is to use structure functions which also exhibit power laws, with e.g. the 2nd order structure function being the spectral slope. A characteristic of turbulent flows is the anomalous scaling, i.e. the departure from a straight line, consistent for various order functions (2nd, 4th, 6th, 8th). Thus, singularity exponents are proposed as a proxy measure for front intensity. The spatial distribution of fronts characterises the scaling of the structure functions. Anomalous scaling is proportional to the intensity of the strongest front; this is robust result that can be theoretically predicted and it implies that if front intensity changes with season, anomalous scaling will also change, thus SST products need to be coherent with this feature. In summary, ocean fronts determine the scaling properties of structure functions, with most intense fronts controlling the anomalous scaling of structure functions. This has a direct practical use in the validation of SST products.

For further material and reading, see González-Haro et al, poster S2-35 and manuscript in the Geophysical Research Letters entitled "On the seasonal cycle of the statistical properties of Sea Surface Temperature" by Isern-Fontanet et al, 2022, GRL 49(8), 10.1029/2022GL098038.

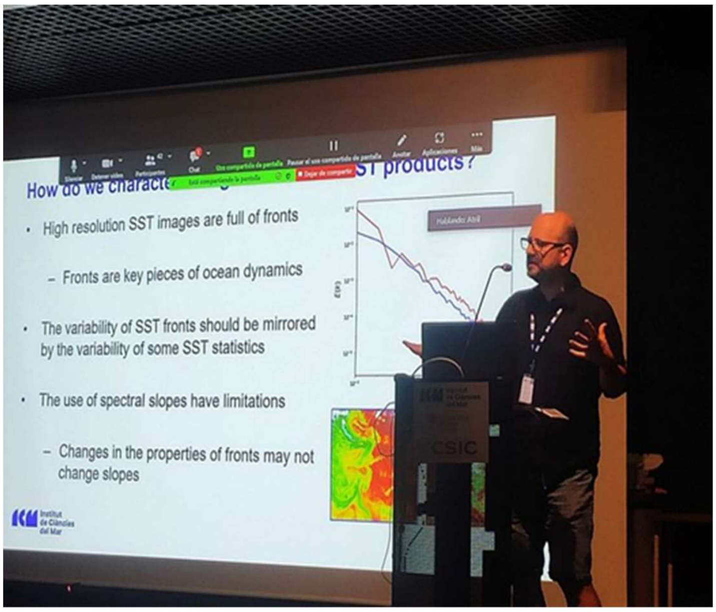


Figure 1: Jordi Isern-Fontanet keynote talk.

Welcome by GHRSST Science Team Chair

The GHRSST Science Team chair Anne O'Carroll followed with an introductory presentation on GHRSST as the framework for SST knowledge and data, provision of best practices, processes and uncertainties. Furthermore, the Chair summarised the mission of GHRSST for meeting user needs by improving data quality in the Arctic, coastal SST data quality and SST feature resolution as summarised in the OceanObs'19 white paper.

A short introduction was provided on the importance of SST for atmospheric and oceanic circulation, ocean biogeochemistry and climate change monitoring, along with a review of the first SST measurements, starting in 1770 by Benjamin Franklin and Timothy Folger in their efforts to chart the Gulf Stream.

The Chair also provided a short summary of the various methods for measuring SST from space referred to geostationary Infra-Red (IR) and IR hyper-spectral sensors as well as polar orbiting IR and Passive Microwave (PMW) sensors.

The importance of space-based SST retrievals was highlighted through the presentation of modern in-situ measurements obtained by buoys (moored and drifting) which are fundamental for development and validation of algorithms yet sparse.

In light of the different methods to retrieve SST, the GHRSST definitions of SST were provided, i.e. SST_{skin}, $SST_{sub\text{-}skin}$, SST_{depth} and $SST_{foundation}$ (see Figure below).

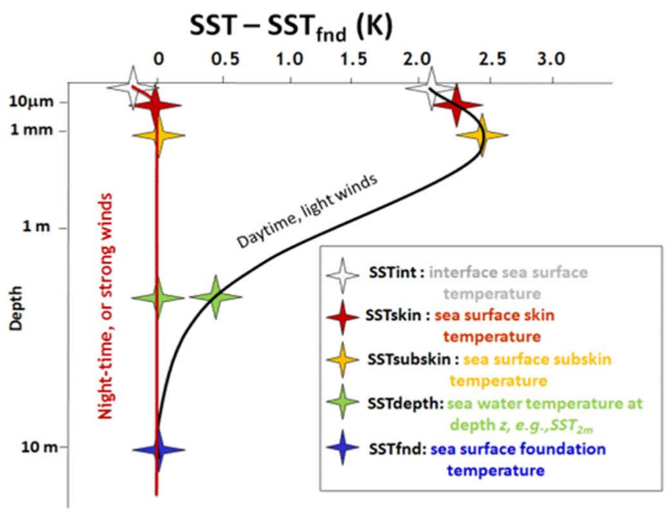


Figure 2: SST definitions as in https://www.ghrsst.org/ghrsst-data-services/products/

Finally, a short historical summary was provided on how GHRSST grew out of a GODAE PP 1997-2008 project, its structure encompassing the Science Team, the Technical Advisory Groups and the various Task Teams along with the Regional Task Sharing activities for cataloguing and data discovery.

The list of GHRSST patrons and sponsors is available on the GHRSST website: https://www.ghrsst.org/about-ghrsst/patrons-and-sponsors/ All of them have supported many Science Team meetings around the world and throughout the years.

The GHRSST project office (GPO) has been located at the Danish Meteorological Institute (DMI) since Summer 2021. The website is supported and maintained by NOVELTIS while the overall funding is provided by Copernicus through EUMETSAT. The main activities of the GPO relate to the support of the Science Team and its chair, the website and users. GPO is also involved with the coordination of SST Virtual Constellation, i.e. team of experts to ensure continuity of SST missions.

Practical information for physical meeting participants

Christina Gonzalez-Haro (BEC/ICM) welcomed the participants in Barcelona and ICM. Information on how to navigate around Barcelona was provided. She also further described the social activities scheduled for Wednesday afternoon.

Figure 3: Welcome by Cristina Gonzalez Haro.

Resources

zenodo https://zenodo.org/record/7259164

vimeo https://vimeo.com/showcase/9536986/video/727718567

Agencies' Presentations and Discussions

Rapporteur: Andy Harris (1)

Chair: Jean-Francois Cayula (2)

(1) NOAA/NESDIS ORA, USA andy.harris@noaa.gov

(2) Vencore, Inc, Stennis Space Center, Mississippi, USA jf_cayula@yahoo.com

The 23rd GHRSST meeting included a session where representatives of 16 participating agencies have contributed with reports of their agency's activities over the last year. Some of the agencies reported to the plenary with specific highlights. These are briefly listed below.

The other agencies have reported on the status of their progress with specific slides. Links to their slides is reported in this section of the proceedings.

Highlights of the Agencies

Australian Bureau of Meteorology (BoM)

Presenter: Helen Beggs

BoM contributes to GHRSST with Satellite SST products in GHRSST GDS2.0 format and in-situ SST data for satellite Cal/Val and L4 ingestion. There has been significant progress since 2021 in developing new products and applications with regards to BoM/IMOS GDS2 L2P, L3U, L3C, L3S and L4 products, BoM/IMOS Ship of Opportunity SST Sensors Sub-Facility and ISAR SSTskin from RV Investigator. The highlight was the release of new reprocessed Himawari-8 L3C and Geo-Polar Multi-sensor L3S products, in collaboration with the SST CCI Team at University of Reading. Activities have also been implemented to help users, for instance:

- A book chapter to inform Australian users of satellite SST products. Ref: Beggs, Helen (2021) Temperature. Chapter 14 in Earth Observation: Data, Processing and Applications. Volume 3B-Surface Waters. CRCSI, Melbourne. pp. 245–279. https://www.eoa.org.au/earthobservation-textbooks) and
- A podcast to inform Australian farmers about how SST is measured and used: https://agriculture.vic.gov.au/support-and-resources/podcasts/my-rain-gauge-is-busted-podcast-series

Additional plans for 2022-2023 were also highlighted in the presentation.

Link to presentation: https://zenodo.org/record/7259212

NOAA/NESDIS/STAR 2

Presenter: Eileen Maturi

NOAA/NESDIS/STAR 2 is currently developing the following activities: Geostationary SSTs, reprocessed Geostationary SSTs 1995-2002, operational Geo-Polar Blended SST Analysis, incorporation of MetOp-C into all the Geo-Polar Blended SST analyses, reprocessing Blended SSTs 1995-2002, OISST (Optimum Interpolation Sea Surface Temperature), operational Oceanic Heat

Content Products. Under the EUMETSAT/NOAA joint science agreement for the period 2020-2024, a joint product development for the following activities is being implemented: calibration/validation activities of SST, High Latitude (Arctic SST Analysis) and lake-surface water temperature.

Link to presentation: https://zenodo.org/record/7259206

NASA

Presenter: Ed Armstrong

PO.DAAC continues to migrate GHRSST data holdings to the NASA Earthdata Cloud (AWS-west). The migration is nearly finalised. The new cut-off date for on premise data access is on 30 September 2022. Two presentations can be looked up in the proceedings, both are related to context capabilities, features and opportunities in the PO.DAAC cloud data paradigm.

- ID 015: PO.DAAC Cloud Data Ecosystem – Part 1: Search, Access and Services
- ID 022: PO.DAAC Cloud Data Ecosystem - Part 2: Moving Science to the Cloud

During the brief highlight, statistics on the GHRSST Data Usage Metrics were provided.

The highlight contains as well information on the MISST (Multi-sensor Improved SST) follow-on activities.

Link to presentation: https://zenodo.org/record/7259216

NOAA/NCEI

Presenter: Huai-Min Zhang

During this short presentation, Huai-Min Zhang provided information related to the goal of the collection and Stewardship of the World's Marine Surface Meteorological and Oceanographic Data, the generation of High Level Blended Products, and the provision of Customer Service. The scope ranges from foundational datasets (e.g. The International Ocean Atmosphere Data Set - ICOADS, the Pathfinder Sea Surface Temperature Climate Data Record data set) to high level authoritative gridded, blended and merged datasets (e.g. the Extended Reconstructed Sea Surface Temperature - ERSST, the Optimum Interpolation Sea Surface Temperature - OISST and the Blended Sea Surface Winds product) (tiered scientific data stewardship).

Link to presentation: https://zenodo.org/record/7259220

NOAA/ACSPO

Presenter: Alexander Ignatov

ACSPO (*Advanced Clear-Sky Processor for Ocean),* the NOAA enterprise SST system V2.61 VIIRS products have been discontinued. 3rd JPSS VIIRS Reanalysis ('VIIRS RAN3') have been completed with ACSPO V2.80. Full-mission Level 2P/3U products from NPP (Feb'2012-pr) and N20 (Jan'2018-pr) have been uniformly reprocessed and archived in PO.DAAC.

Three other reanalyses with ACSPO v2.80 have been performed:

- full-mission Metop-FG AVHRR RAN1, including 6 datasets (L2P/3U) from Metop-A (Dec'2006-Nov'2021); Metop-B (Oct'2012-pr), and Metop-C (Dec'2018-pr) fully archived in PO.DAAC;
- two L3S-LEO RAN1 datasets (AM, from 3 Metop-FG satellites, Dec'2006-pr, and PM, from 2 JPSS satellites, Feb'2012-pr) archived in PO.DAAC; and
- NOAA AVHRR GAC RAN2 datasets (L2P/3U) from 10 NOAA satellites (N07, N09, N11, N12, N14, N15, N16, N17, N18, N19) produced and archived at NOAA CoastWatch system.

Future plans include: the ACSPO support for 4 new launches/satellites (GOES-18 in Mar'2022, NOAA-21 in Nov'2022, Himawari-9 and Meteosat-12 in Dec'2022), the reprocessing of all 3rd generations GEO data (GOES-16/17/18, Himawari-8/9, and MTG), Terra/Aqua MODISs, and L3S-LEO SSTs (to include N21 and Terra/Aqua MODISs).

Link to presentation: https://zenodo.org/record/7259224

Japan Aerospace Exploration Agency, JAXA

Presenter: Misako Kachi

JAXA's GDS2.0 datasets are available both from JAXA Himawari Monitor for AHI SST and from JAXA GHRSST server for other SSTs (AMSR2, SGLI, etc.). GCOM-C/SGLI (IR) SST Version 3 was released in November 2021 with further improved cloud masking. Himawari-8/AHI (IR) SST version 2.1 was released in June 2021 to fix bug in QC flag. Due to a planning switch-over of Himawari satellites by JMA, Himawari-8/AHI SST will be replaced by Himawari-9/AHI SST in Dec. 2022. The distribution of both Himawari-8 and -9 data during the overlap period after Sep. 2022 is currently being considered. After switching-over, JAXA plans to recalibrate Himawari-8/AHI SST to be consistent with Himawari-9 including correction of decreasing trends found in Himawari-8/AHI SST. GCOM-W/AMSR2 (microwave) SST Ver.4.1 will be released in summer 2022 to correct decreasing trends in Northern hemisphere and retrieve SST under windy/light-rainy conditions. JAXA also released AMSR2 sea ice motion vector products in Mar. 2022. JAXA is currently developing GOSAT-GW/AMSR3 to be launched in JFY2023. AMSR3 products will be released to public one year after the launch.

Link to presentation: https://zenodo.org/record/7265090

European Space Agency, ESA

Presenter: Paolo Cipollini

The legacy of Sentinel-3 SLSTR for operational and climate-quality SST is being continued and enhanced. An overview of the SST Mission in the Copernicus Context was presented with information related to current generation sentinels, next generation sentinels and the planned Copernicus extension.

Link to presentation: https://zenodo.org/record/7265102

Naval Oceanographic Office, NAVO

Presenter: Bruce McKenzie

NAVOCEANO GHRSST data are provided to JPL PODAAC. GHRSST data are acquired for assimilation in Navy Global Ocean Forecast System. Additional NAVOCEANO GHRSST data are available and can be provided upon request: NOAA-20 VIIRS global 750 m L2P and MetOp-B/C global 1 km L2P.

Link to presentation: https://zenodo.org/record/7265118

Additional updates provided by following agencies

EUMETSAT Sea-Surface Temperature activities, by Anne O'Carroll: https://zenodo.org/record/7265124#.Y16GmHaZOHs

CMC Sea Surface Temperature activities, by Dorina Surcel Colan:

https://zenodo.org/record/7265139

Progress update from the Met Office, by Chongyuan Mao:

https://zenodo.org/record/7265141

Report from Ifremer /CERSAT, by Jean-François Piollé:

https://zenodo.org/record/7265145

Report from NSOAS, by Ljian SHI, Xiaomin Ye, Wu Zou, Mingsen Lin and Qimao Wang:

https://zenodo.org/record/7265135

Report from Japan Meteorological Agency, by Sakurai Toshiyuki:

https://zenodo.org/record/7265147

Update by CMA, Chinese National Satellite Meteorological Center (National Center for Space Weather), by Sujuan Wang:

https://zenodo.org/record/7265151

Satellite Application Facility on Ocean and Sea Ice (OSI SAF), by Stéphane Saux Picart:

https://zenodo.org/record/7265128

Resources

Links to all presentations are provided above

Recording of the session with the highlights of the presentations below (8 agencies): https://vimeo.com/showcase/9536986

Starting at 2:05:45

In-person collaborative workshops

Workshop W1: What dynamical information can we extract from High Resolution Sea Surface Temperatures?

Organiser 1: Jordi Isern-Fontanet, Institut de Ciències del Mar (ICM) Barcelona Expert Center (BEC), jisern@icm.csic.es

Organiser 2: Cristina González Haro, Institut de Ciències del Mar (ICM) Barcelona Expert Center (BEC), cgharo@icm.csic.es

Organiser 3: Christopher Merchant, University of Reading, c.j.merchant@reading.ac.uk

Short abstract

Satellite infrared radiometers have provided high resolution (~1 km) measurements of the ocean surface during the last forty years. The existence of such a time series enables us to investigate different dynamical regimes of the upper ocean and monitor potential changes related to global warming. The main problem, however, is to extract the dynamical characteristics of the upper ocean. This is motivated by two types of difficulties: data related limitations (cloud coverage, noise level, failure of cloud mask algorithms, etc.) and the availability of tools to extract information (statistical tools, dynamical frameworks, etc.)

In this session, we proposed to review some of these tools based on the multifractal theory of turbulence and other approaches, and to discuss how they are impacted by data limitations.

Outcomes of the workshop

The workshop considered what spatial fields of SST, obtained as "slices" in time, reveal about ocean dynamics.

Peter Cornillon presented a machine learning technique that dynamically identifies unusual SST patterns from global data, and showed that cloud detection problems can influence results unfavourably. He also raised that pixel centre locations may have patterns that can bias the calculated gradients by treating images as if they were regular and square.

Christopher Merchant presented simulations of how SST gradients are not necessarily represented at full strength (in K/km) in satellite SSTs, explaining why. He also presented the effects that SST noise has in reducing the gradient-signal-to-noise ratio, sometimes significantly.

Cristina Gonzalez-Haro presented singularity exponent distributions of several GHRSST L4 analysis products and discussed their shapes in comparison with expectations. It appears that different gap-filling methodologies applied to such analyses distort these distributions. The result consists in distributions which do not plausibly represent turbulent processes, to varying degrees. Some open questions remain about how the singularity distributions relate to the methodological choices made by producers.

Jordi Isern-Fontanet discussed the physical importance of singularity exponent distributions and the impacts of observational problems such as under- or over-masking of clouds on the distributions.

During the discussions, the following points arose:

- The importance of optimizing better cloud masking was re-emphasized.
- Different instruments have quite different feature fidelity and noise characteristics, giving a variety of impacts on dynamical information between different sensors.

Therefore there is work to be done in quantifying impacts on gradients and singularity exponents.
Sensitivity and noise are sometimes traded off against each other in retrievals, and the impact on gradient-signal-to-noise needs to be quantified.

Resources

The following presentations are available:

Issues for GHRSST to Consider, https://zenodo.org/record/7265175

What dynamical information can we extract from High Resolution Sea Surface Temperatures? (Part 1) https://zenodo.org/record/7265184

What dynamical information can we extract from High Resolution Sea Surface Temperatures? (Part 2*)* https://zenodo.org/record/7265190

Workshop W2: Coastal and inland waters 60m-100m resolution SST products challenges

Organiser 1: Emmanuelle Autret, IFREMER, emmanuelle.autret@ifremer.fr
Organiser 2: Jean-Francois Piollé, IFREMER, Jean.Francois.Piolle@ifremer.fr

The objective of this in-person collaborative event was to initiate discussions and interactions on coastal and inland waters ultra-high resolution SST products related challenges: SST-retrieval algorithm, land/water discrimination, cloud masking, possible modification of emissivity, reference dataset definition and construction for algorithm optimization and validation, availability of ancillary data.

Outcomes of the workshop

During this session, the discussions were mainly driven by the on-going work carried out in the frame of the TRISHNA mission, since one of the primary scientific objectives of this mission consists in providing high-quality SST imagery in coastal zones and inland waters at 60m resolution.

Thermal infrared imagery on board land dedicated satellite missions - and also covering coastal areas - has been around since 1984 with Landsat series, and today it offers a 100m resolution with a revisit time of 16 days. This wealth of data has not been exploited until today, or only through limited and very localized demonstrations, mainly because of low revisiting times and relatively poor radiometric performances. Still, they are invaluable for many applications ranging from forecasting system improvement to coastal process understanding and monitoring, and in support of many economic activities such as aquaculture.

Besides, new missions (ECOSTRESS on ISS, TRISHNA in 2025, SBG in 2027, Copernicus LSTM in 2028) that are now available or on their way will provide better radiometric performances, higher spatial resolution and temporal sampling, and will increase the value and operational capacity of this source of observations.

Workshop W3: Open science on the cloud for GHRSST

Organiser 1: Chelle Gentemann, Farallon Institute

Organiser 2: Ed Armstrong, Jet Propulsion Laboratory, edward.m.armstrong@jpl.nasa.gov

Science is becoming more collaborative and open and moving rapidly to the cloud. How we access and use data is changing what questions we can ask and what science is possible. This requires a new set of skills for scientists.

This workshop was meant to be a collaborative hands-on workshop. We talked about the tools of open science: Git, GitHub, and Jupyter and discuss powerful python libraries for GHRSST scientists, such as Xarray, SciPy, and SatPy. The goal of the workshop was to show how these tools make science more efficient, more collaborative, and more fun.

Outcomes of the workshop

At the workshop, the following topics were covered:

- The tools of open science: Introduction to Git, GitHub, and Jupyter. How to create a GitHub repository and make a pull request?
- Powerful Python libraries: Xarray, SciPy, SatPy.
    - Xarray – cloud access to GHRSST datasets. SciPy – anomaly analysis in seconds on large global datasets.
    - SatPy – fast collocations of L2 and in-situ data using kd-tree algorithms.

Issues related to data in the cloud are:

- The licensing.
- The usage statistics may not be straightforward for all clouds. These have to be better captured. Also, finding who is using the data is difficult, but statistics per dataset can be currently obtained by NASA from AWS.
- Having data ready in Cloud optimized data containers such as Zarr with appropriate chunking.
- Zarr emulation services like Kerchunk can be used without modifying the original NetCDF GHRSST granules and without duplicating/reformatting the entire archive. However it requires computing resources for creation and maintenance.
- Recommendations for appropriate chunking (10-100 MB) should be added in the GDS data specifications[1], but should be confirmed with the Pangeo project. Chunk sizes are also processing level dependent in some cases (e.g., L2P vs L3/L4).

[1] https://www.ghrsst.org/resources/ghrsst-project-documents/

Workshop W4: Outstanding problems in infrared sea surface temperature retrieval

Organiser 1: Christopher Merchant, University of Reading NCEO, c.j.merchant@reading.ac.uk

Organiser 2: Andy Harris, NOAA-CISESS, University of Maryland, andy.harris@noaa.gov

While SST product accuracy has improved in the past decade, new technologies and methodologies are yet to realize their full potential. Traditional regression methods benefit from improved calibration, lower noise and greater degrees of freedom that modern instruments provide, and thus have delivered progress.

But what greater potential do modern instruments provide, and in combination with which retrieval approaches?

There are some areas where physical retrieval methods provide demonstrable advantages (e.g., reduced regional biases), while significant reductions in other components of uncertainty are not fully realised. We have discussed why this may be the case, and consider potential ways forward. As a matter of priority, we have also looked at the performance of SST products at high latitudes, particularly in terms of bias and coverage, since L4 analyses exhibit the most deviation in this critical region.

Outcomes of the workshop

The workshop had two foci:

- Biases in sea surface temperature (SST) in high latitudes;
- Steps to advance physical retrieval methods.

Chris Merchant (CM) introduced the session, noting that the objective for progress in SST retrieval is to address simultaneously systematic errors, random errors and SST sensitivity together (not trading sensitivity for noise suppression, for example).

Jacob Høyer (JH) and Andrew Harris (AH) opened the high latitude topic, showing biases arising from retrieval (causes not fully understood) and biases in gap-filled products from differential false masking of SSTs.

In discussing high latitude retrieval biases in plenary, the following points arose:

- Could neglecting the relative freshness of Arctic waters cause a bias of ~0.5 K against latitude, as notably observed in the SST climate change initiative (CCI) data? Emissivity variations with respect to wind speed, angle and temperature are generally accounted for in retrievals (empirically or by physical modelling), but indeed, salinity variations may not be considered because it is a smaller term. However, it is worthwhile to double-check what the SST retrieval impact might be. *Action: Reassess neglecting of salinity impact on emissivity. Action owner: Owen Embury (University of Reading).*
- Matches to Saildrone cruises are a rich and promising resource, particularly when the Saildrone has an upward looking PAR or IR measurement to help segment matches into cloudy or clear independently of the satellite cloud mask (validating screening and retrieval steps in case of residual cloud contamination is a bias source, specifically in high latitudes). *Action and action owner: Chong Jia (Rosenstiel School of Marine, Atmospheric, and Earth Science, University of Miami) to advise on how to segment Saildrone radiometric measurements into clear/cloudy.*
- Comparisons of L2 with the 2019 Saildrone Arctic cruises revealed that there were slightly more pixels within ±1 K of the SBE temperature that were flagged as bad than flagged as good. The implication is that a lot of acceptable SST observations may have been screened out. The majority of such points occurred during the summer melt/ice retreat conditions.

- Is numerical weather prediction (NWP) a source of such bias in the case of physical retrievals? A systematic error in temperature profile could be an error source, for example. *Action and action owners: Gary Wick (NOAA) and Jacob Høyer (Danish Meteorological Institute) volunteered to look into this possibility, for example by comparing high resolution and standard resolution NWP.*
- Cloud mask validation is important since residual cloud may be a source of bias. *Action and action owner: Steinar Eastwood (*MET Norway) *is interested in looking carefully at this, which could include expert inspection of imagery from the affected regions.*
- For daytime cases, comparison with the cloud mask of an ocean colour sensor on the same platform is another potential source of information. No specific action defined for this last item.

Christopher Merchant introduced the issues facing physical retrieval (defined as making use of radiative transfer modelling in inversion). These are post-coefficient bias adjustment, optimal estimation (maximum a posteriori, maximum likelihood, with smoothing of atmospheric correction, with bias awareness) and modified total least squares. OE and similar methods are well established as generic, easily adapted to multiple sensors and low error for “split window” (typical daytime, two channel) retrievals. However, for triple and other channel combinations, it is less clear-cut for reasons that are not fully understood.

During the discussions, the following points arose:

- The simplified treatment of atmospheric profile uncertainty may be a fundamental limit, but it should be addressable particularly for instruments with more wavelengths available for solution. This is an open research question for GHRSST.
- Promote collaboration on bias-aware methods of physical retrieval (Action: CM).
- Investigation into the use of more accurate fast-RTM to reduce the noise input in the retrieval (Action: AH).

Workshop W5: Open Science is the future, how does GHRSST evolve?

Organiser 1: Tasha Snow, Colorado School of Mines, USA, tsnow@mines.edu

Organiser 2: Chelle Gentemann, Farallon Institute

Open science - opening up the scientific process from idea inception to result — increases access to knowledge and expands opportunities for new voices to participate. Sharing the data, code, and knowledge associated with the scientific process lowers barriers to entry for historically-underrepresented communities, enables findings to be more easily reproduced, and generates new knowledge at scale. Success, however, depends on all of us working to change the paradigms and frameworks from which we operate.

Outcomes of the workshop

How we do science is undergoing massive transformation. Open-source tools that easily enable reproducible science are becoming the default for science. Data is moving onto the cloud, increasing accessibility. Software is being shared openly and developed collaboratively.

- What will GHRSST products and collaborations look like in 5 years?
- How will these changes affect how we do science and produce data products?
- How could the GHRSST community adapt to the evolving context and what changes need to be made?

The following topics were addressed during the workshop:

- The introduction to open-source collaborations and open science;
- Where is GHRSST along the open-science road?
- How can we create products together?
- What does the science team organization look like?

Finding the datasets

This is still a major issue. The GHRSST catalogue is going to provide access points for each dataset in the near future: https://www.ghrsst.org/ghrsst-data-services/ghrsst-catalogue/

How to help users with the right dataset for their usage? Intake allows to build community, thematic catalogues with a selection of products that can be shared.

Other GHRSST frameworks should also help to sort out the different product qualities, accessibility, and documentation to the users. For instance the Climate Data Assessment Framework (CDAF)[2] and the Matchup Database Standards (MDB)[3] task teams could support these tasks with fair and common metrics, transparency and information.

Harmonization of access across different cloud platforms

Through its stakeholder agencies GHRSST should recommend more harmonization, e.g. on free download capabilities. GHRSST should also recommend and demonstrate existing standards for increased harmonization of data access that can be easily interpreted on top of the existing services. Intake, STAC- demo notebook of multi-cloud access should be set up.

Additional notes are also available from the other in-person workshop on the GHRSST open data (W3).

[2] https://www.ghrsst.org/about-ghrsst/task-teams/task-team-on-climate-data-assessment-framework/
[3] https://www.ghrsst.org/about-ghrsst/task-teams/task-team-on-matchup-database-standards-mdb-tt/

Workshop W6/PD3: GHRSST priorities

Results of the in-person workshop (W6) and Panel Discussion (PD3)

Organiser: Anne O'Carroll, EUMETSAT

Rapporteur: Jacob Høyer, Danish Meteorological Institute, jlh@dmi.dk

The goal of two sessions at the GHRSST23 meeting, one in-person workshop and one online panel discussion, was to define GHRSST progress and to assess the next priorities in the upcoming years regarding data access and usage, high-latitudes, feature resolution / coasts / diurnal variability, L3/L4 applications and microwave SST and what still needs to be done.

Key considerations

- There is a strong mandate to focus on spatial and temporal high resolution to resolve coastal processes and the complexity related to the Arctic and the sea surface and sea ice interplay.
- As NWP is expected to drive evolutions towards higher spatiotemporal resolution, GHRSST needs to define what "high resolution" means for SST, especially with the upcoming launches of LSTM, TRISHNA and future missions.
- In relation to the Arctic, Sea Ice Surface Temperature needs to be homogenised with SST as a uniform variable in order to define the boundaries between ocean/sea-ice and land. Furthermore, existing Arctic SST/IST analyses need to be connected with the global L4 SST counterparts.
- With respect to Passive Microwave (PMW), since no absolute calibration exists, requirements need to be defined given that not all future PMW missions have SST-sensitive channels.
- GHRSST needs to maintain and advance its tradition of progressiveness and inclusiveness, and consider how to open up to the scientific community through sharing tools, including such common tools for specific analyses, e.g. for spatial resolution assessment.
- With the use of cloud services, many GHRSST datasets are now spread across platforms. Therefore, there is a need to redefine and harmonise standards and format specifications, and GHRSST needs to promote free usage of various platforms. Yet as it is not always easy to use the data, there is also a need for experts with scientific background.
- In order to enlarge the user community, GHRSST needs to expand on the "user/application" driven examples of how to utilise GHRSST data, including for NWP applications. Also GHRSST needs to expand to more L4 inter-comparison exercises, including Diurnal Analysis products, to better inform users on which products can be more relevant to their applications.
- GHRSST can provide a recommended methodology to deal with cloud and bow-tie effects (MODIS) when doing gradients' analysis, and encourage data producers to provide more guidelines to users with respect to handling improved quality fields that may be included in GHRSST products.

The following topics were discussed in more details, and they should be addressed by GHRSST.

High latitudes

- More work needs to be done on the correction of MW data close to coast and sea ice, to improve MW coverage in high latitudes.
- More Cal/Val data are needed in the high latitudes.
- A question to be addressed is: How do lessons in the Arctic translate to Antarctic?
- There is the need for additional and complementary in-situ observation such as ship-borne radiometers to measure skin SSTs.
- Both MCSST and ICPS have issues with cloud detection algorithms at high latitudes.

L4 and L3 applications

- Assess appropriate bias correction reference for L4 in high latitudes.

- Assess impact of "clear-sky" sampling bias in IR using MW/IR comparisons.
- Investigate optimizing length scales for anomaly correlation in L4.
- Improve consistency between SST and IST and SST-SIC in marginal ice zone How to get ice and SST producers to be consistent.

Microwave SST

- Adopt an integrated approach to improve SST uncertainties.
- GHRSST should work on integrating IST and SST products and promote that SST and IST is same domain.
- There is no absolute calibrations for MW, thus there is a need for inter-calibrations and inter-comparisons between e.g. AMSR3 and CIMR.
- More and better CDRs in the high latitudes.
- Determine the cause L4 differences in the high latitudes.

Additional priorities to be considered

Redefinition of High Latitudes: GHRSST needs to focus on what now is meant by "high resolution SST" and user needs for high-resolution SST. Should we start to tailor products for these new emerging requirements for coupled NWP and coastal applications? This is an important focus for GHRSST in the coming years, to take on board in the different task teams too.

Additionally, new cloud optimized storage formats have to be considered by GHRSST producers.

Data access and usage

- Important to have free access to data, including from cloud infrastructure.
- Easier user access to data can be obtained by chunking or packing data user specified formats and sizes.
- The preferred ways of access to data ranged from API clients, to cloud data.
- Important that the developed GHRSST data catalogue assist users in their work with SST data.

Coastal /diurnal variability and feature resolution

A number of issues where raised in the discussion:

- In some locations (e.g., in-land fjords), complex coastlines and land contamination make the resolution inadequate for the near-shore applications (e.g., aquaculture in fjords and inlets).
- Use for new missions such as the TRISHNA mission: scientists studying VHR processes may want up to cm spatial resolution, but this is very user/application-dependent.
- There is a need for a better synergy for exploitation of coincident OC and SST.
- Clouds: some errors occur - would they be reduced by using time series instead of single image detection? This has been done before, but it is also application dependent.
- Compatibility between ECVs remains an issue, for example in simultaneous observations in the thermal and visible spectrum, with similar resolution.

- It is important to determine the link between the horizontal, vertical, and, temporal scales of the ocean temperature, in relation to the use of higher resolution satellite observations.
- Unrealistic gradients when multisensor data (IR and microwave info) are merged, due to some places only having observations from the latter.
- Process studies based on numerical modelling - e.g., eddies inside eddies - indicate that it would be very useful to have both near-shore and open-ocean samples to disclose small scale processes.
- There's also the issue of the spatial-vs-temporal resolution: right now we cannot have high temporal resolution in both dimensions, but having sub-daily measurements would be useful for the daily cycle.

Challenges for the community

- How can GHRSST become a more open community?
- A good solution would be the creation of a GitHub community, especially to bring new early career to GHRSST and create new collaborations.
- GHRSST should be redefined as an open science platform.
- GHRSST needs to provide more support to the weather prediction.

Actions and arising recommendations

- GHRSST should focus on the very high resolution SST observations and the upcoming THRISHNA and LSTM missions in the coastal regions and processes.
- Consistency should be improved between SIC and SST for L2 and L4 as well as for IR vs. MW.
- GHRSST should incorporate IST and SST in the products and promote that SST and IST belong to the same domain.
- The access and use of large satellite datasets are changing and GHRSST should facilitate the new ways of working through the data catalogue and formats.
- GHRSST needs to expand on the “user/application” driven examples of how to utilize GHRSST data.
- GHRSST should strive for calibration and improvement of MW and IR products in coastal and Arctic regions.

Resources

miro https://miro.com/app/board/uXjVOw7npQU=/

vimeo https://vimeo.com/725342802

Panel Discussions (PD)

PD1: Training formats on SST, an interactive discussion and co-design session

Chair: Hayley Evers-King

Panellists: Hayley Evers-King, Ioanna Karagali, Ben Loveday, Ana Ruescas, Peter Minnett, Sandra Castro, Chelle Gentemann

Rapporteur: Benjamin Loveday, Innoflair UG, Germany (On behalf of EUMETSAT), ben.loveday@external.eumetsat.int

This session consulted the GHRSST science team on experiences and future needs for training for both the GHRSST itself, and the wider SST user community, both existing and prospective. The session included a panel of experts with experience in delivering training on SST and related topics, as described below. Short presentations from the panel were followed by an interactive session. This included elements of co-design using tools such as Miro, and focussed on the planning of future training resources and the development of events.

Panellists

Hayley Evers-King, Marine applications expert at EUMETSAT, hayley.eversking@eumetsat.int
Chelle Gentemann, Programme Scientists, NASA Tops, former member of the GHRSST Science Team, cgentemann@faralloninstitute.org
Peter Minnett, Professor Meteorology and Oceanography, University of Miami, member of the GHRSST Science Team, pminnett@rsmas.miami.edu
Sandra Castro, scientist, member of the GHRSST Science Team, University of Colorado, sandra.castro@colorado.edu
Ana Ruescas, Brockmann Consult / University of Valencia, ana.ruescas@brockmann-consult.de
Ioanna Karagali, scientist, member of the GHRSST Science Team, Danish Meteorological Institute, ika@dmi.dk

Introduction

The PD1 discussions session focussed on the need to develop training for the SST community. There are multiple audiences to consider in this regard, including; those in the room (experts), those outside the GHRSST community who work with SST, and new users.

The session had three primary aims, each of which is addressed via a different approach, as detailed below:

- Aim 1: exchange thoughts and experiences on training (SST and beyond). This was addressed through panel discussion.
- Aim 2: gather experiences and needs from the community present at the meeting. This was done using the Sli.do online polling and Q&A tool.
- Aim 3: begin planning activities, both courses and resources. This was achieved using Miro online whiteboard tool.

Each of the interactions is discussed in the sections below. Key points are highlighted and possible actions are presented at the end of the document. Alongside the in room discussion, remote attendees were given the option to raise points via a secondary Sli.do Q&A forum, or using the meeting's Moodle page. Neither platform was used in this discussion, with all points coming from those present.

The discussion

Panellists for the discussion session are Hayley Evers-King (Chair), Sandra Castro, Peter Minnett, Ana B. Ruescas, Chelle Gentemann, Ioanna Karagali. Their contact details are listed above.

Hayley Evers-King

EUMETSAT Marine Application Expert, User Support Division

Hayley delivers user engagement and training to ocean users that exploit EUMETSAT's marine data streams. This includes SST products from SLSTR. She does not have formal training in teaching, but has been extensively involved in various training activities for EUMETSAT and beyond.

Sandra Castro

Member of the GHRSST Science Team, University of Colorado, CCAR

Sandra Castro is a data user. She regularly fields requests from the user community at large about which SST products are most suitable to use. She does not have formal training in teaching. Sandra raised the following considerations in the discussion:

- Firstly, that it would be very useful to have some online guidance for which product to use. She suggests that the **GHRSST catalogue is a great online platform to convey this information,**
- It would also be very useful to provide a list of prompt questions that help to refine the most suitable product for a given use case. She suggests an "online shopping" type approach where the product suite can be narrowed down by specific user needs, for example resolution, coverage, application etc.
- It would be useful to ask GHRSST users to also evaluate the products they use (e.g. on a scale of 1-5), in order to give us more candid reviews than we receive from our colleagues.
- The GHRSST science team should provide an "SST for dummies" manual.
- Statistics from user feedback could be used to highlight the things that the science team should prioritise.
- We should provide examples/options to facilitate a "Just plot" type approach where users can pick a region and zoom in and compare. This is a good initial check to see weaknesses in products associated, for example, with low spatial resolution.
- The "ARMS" ACSPO tool is very useful place to show different SST products to new users.
- New users are virtual by nature. Training should accommodate an online audience.
- New users assume that Level-4 products are "real", but some judgement will be required in answering associated questions such as "How complete is and uncertain is the underlying data coverage?".

Peter Minnett

Member of the GHRSST Science Team, Professor Emeritus in Meteorology and Oceanography, RSMAS, University of Miami

Peter has no formal training in teaching, but 25 years of experience in teaching graduate students and non-specialists about SST. He was involved in the GHRSST training efforts in both Qingdao and Cape Town. A summary of some of Peter's slides can be found in figure 1. Peter raises the following points:

- Interactivity is key. Putting technology, in this example instrumentation, in people's hands, provides a good focus point for teaching. PowerPoint can be quite boring, and physical examples of hardware, or the use of video helps to enliven learning.
- Utilising image processing exercises (e.g. via SNAP & SeaDAS) is a good way to get trainees to the data early on, helping them quickly apply start on their own analyses.

- Exploring online data access centres should be part of the training landscape.
- Covering the fundamentals of measurement is necessary. For example, most trainees do not understand how orbit impacts measurement.
- There is a need to explain strengths and weakness of L1, L2, L3, L4 fields.
- One of the best ways to gain and keep trainees attention is to focus on the use of data in locally relevant, real-world cases. For example, how SST evolves alongside hurricane formation in California.
- The best barometer to see what students have learned is to see how they use their knowledge in their own applications of interest. This is sometimes hard to track.
- More short courses should be provided alongside the GHRSST science team meeting.
- We should offer mote recorded lessons and Q&A sessions to the wider community, acknowledging that this does not replicate the classroom experience.
- Curricula should be designed in tandem with university programmes (e.g. SOLAS University of Ireland).

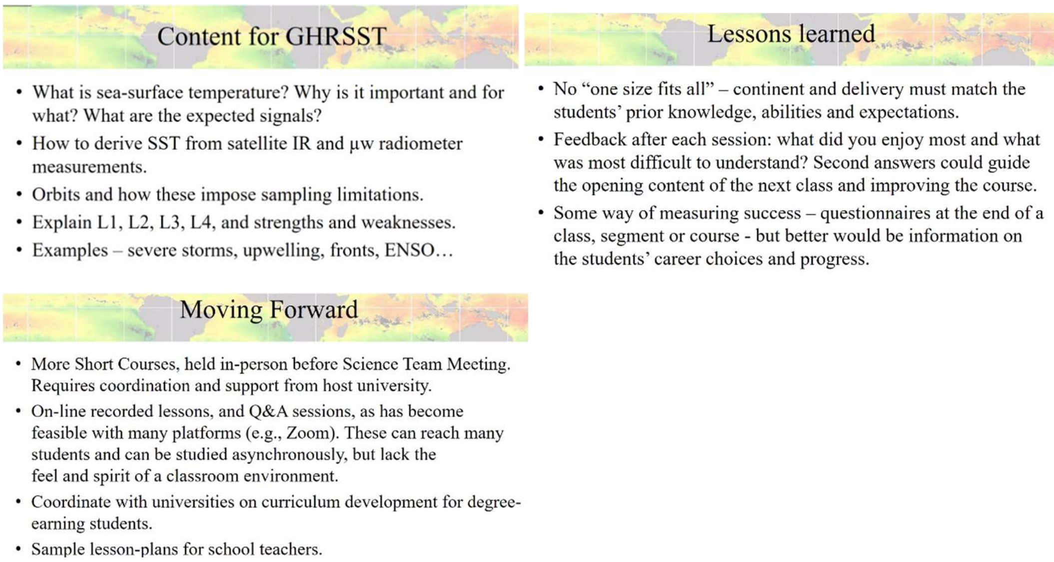


Figure 1: Key slides from Peter Minnett's panel presentation

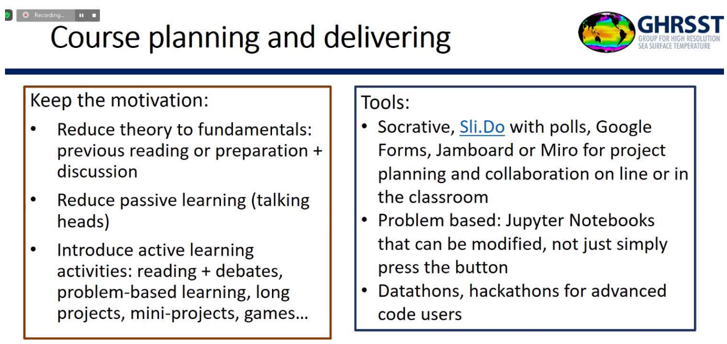


Figure 2: Key slide from Ana Ruescas' panel presentation

Ana B. Ruescas

Associate Professor of Geography at University of Valencia. Representing the Copernicus Marine Training Service)

Ana provides training on the ESA STEP SNAP package, but also develops learning methodologies and pedagogical approaches via teaching about geo-spatial data, with a primary focus ways to retain motivation. Ana is interested to see what the GHRSST community requires from EUMETSAT Copernicus Marine Training Service (CMTS) in terms of support for SST training. Ana gives a short overview of the role of the CMTS, who deliver courses on the fundamentals of marine Earth observation, specific courses on SST, engage in collaborative events and support "train the trainer" activities. Ana raises the following points:

- Keeping motivation is key to any training activity, and we need a variety of approaches and tools to do this.
- We should reduce theory to fundamentals.
- We should reduce passive learning, promoting active learning alternatives. This approach is as valid online as it is in person.
- To support this, we should use tools such as Socrative, Sli.do, Miro, Google forms, Jamboard to facilitate interaction and assessment.
- Where we use Jupyter Notebooks, these should feature exercises and not just be a series of sequential "button pushes".
- We should remember that new learners are digital natives!
- However, our field is complex and we should not incentivise short attention spans.
- Above all, we should stay open and approachable, remembering that we were also early-career researchers once. At some point we all knew nothing!

Chelle Gentemann

Project Scientist for the NASA TOPS programme, and member of the GHRSST Science Team

Chelle is not an academic, her background is in the private sector, as well as working for non-profit organisations and federal agencies. Chelle is a software carpentry instructor. She has extensive experience in online learning. She often trains at conferences and regularly participates in hackathons. More recently, Chelle organised a crash course on how to use Massively Open Online Courses (MOOCs) to reach an audience of thousands of people. Chelle raised the following points:

- The most important this is to get trainees trying something as quickly as possible.
- We have a lot of people asking what SST they should use. However, while this is a basic question, we have the opportunity to design different learning approaches, for example by using executable Jupyter Notebooks.
- We should also reach out to users interested in Level-4 data. GHRSST is well positioned to support these users, especially when it comes to data access.
- Things move fast. It is likely that two months after authoring any training code, it is old, broken or defunct. Consequently, we should consider the sustainability of our training projects, and what long term plan is for resources developed as part of them.
- In response, Hayley Evers-King makes the suggestion that we should target some specific areas and come up with guidance and communities of practice to help maintain our content in the simplest ways possible.

Ioanna Karagali

Member of the GHRSST Science Team, Danish Meteorological Institute

Ioanna has a background in academia, but now works in the GHRSST project office. She has experience in designing short courses, spanning 2-3 days, on SST and other variables, and supervises undergraduate and PhD students. Ioanna raises the following points:

- GHRSST users often ask the project office “which dataset should I use?”. However, they also regularly ask “Can you please give me the data?” or even “Can you tell me about the temperature for the last three years?”. Being asked these questions suggests that maybe this information is not easy enough for users to find, and perhaps users don’t know what our role is. In this context, improved products guides and tutorials are key to clarifying the answers to these questions
- GHRSST should focus more on inexperienced users who are using Level-4 products. These are the users we are trying to attract. Experienced data scientists are more skilled and more likely to find an answer to their questions, independently. The less experienced, day-to-day user needs more direct support.

Sli.do discussion

To gather information on the experiences and needs of the community, a series of Sli.do questions were presented to the audience. The results of these questions are shown in Figure 3. A brief summary of the discussions around these questions follows below.

Q1: Hayley Evers-King highlights that we learn about remote sensing in various ways and on different career pathways. This echoes in our own approaches to learning, and therefore our approaches to training.

Q2: Hayley Evers-King summarizes that our priorities cover a broad range. Selecting the SST is clearly an important focus, but we can’t ignore the need for training on cloud processing.

Q3: Hayley Evers-King notes that it is not surprising to see in-person format come out on top. However, there is still interest in online approaches. Chelle reinforces here earlier panel discussion points, outlining good methodologies to make online learning more compelling by focussing on practical and interactive approaches using, for example, Jupyter Notebooks. Ioanna adds that network development is much more challenging in an online context, recalling her early GHRSST meetings where she was able to meet and discuss papers of interest with the actual authors.

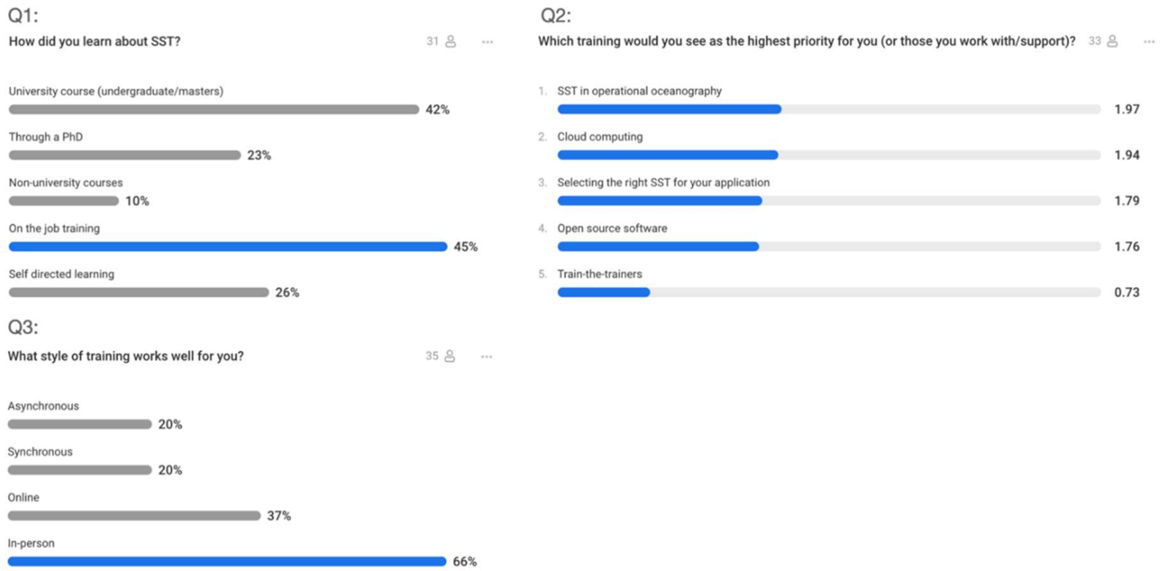
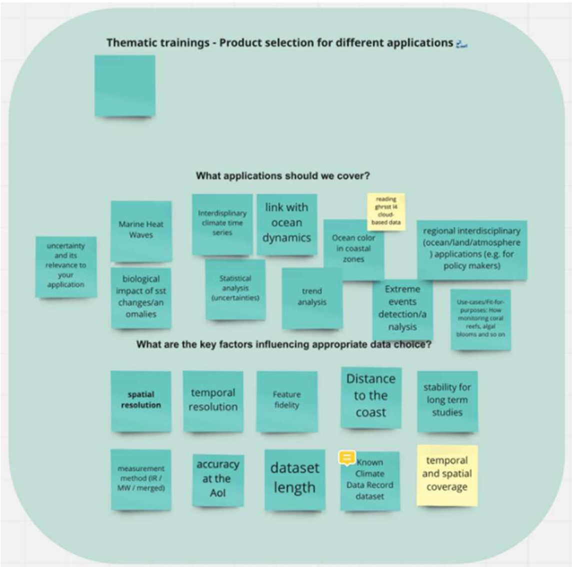


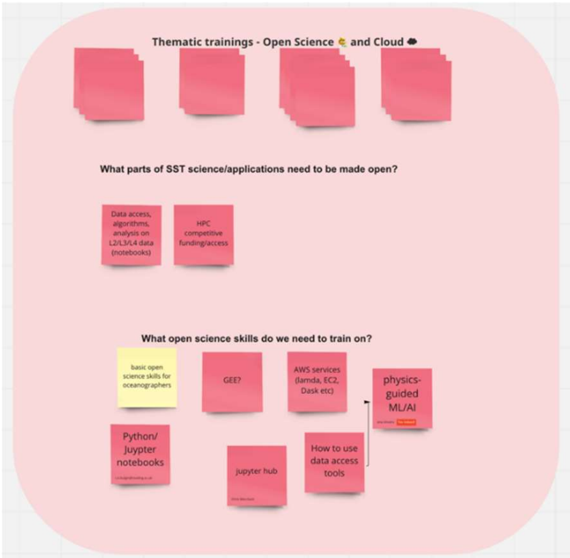
Figure 3: Sli.do results for the 3 questions asked in the session

Miro discussion

The outcomes of the Miro session can be found in Figure 4. Some final points were made after the session.

- Ana Ruescas notes that we should not just deliver training in English.
- Hayley Evers-King suggests that if there are volunteers for translation, these should be identified.
- Chelle Gentemann reminds us that we should consider the sustainability of our training material in this context. Translating course material needs to be "live": when the material, presumably in English, evolves and the translation does not, we face problems. It is, therefore, better to focus on core material being translated and sustainable in the long term.
- Jorge Vazquez points out that we already had partners in Latin America. These partners could be directly involved if they already had translated content. This would remove the need to translate material from scratch.
- Christo Whittle notes that for training purposes, it is important to be aware of who the target audience is. We often engage very different stakeholders, such as small-scale fishers, environmental managers and undergraduates. We should focus on the provision of high-level information. Partnerships with tertiary institutes, as well as initiatives like GMES, could help to address training at different stakeholder levels, as they have experience in this regard. Being more strategically aware of which target audience we are trying to train helps to get the best people involved in the right places.





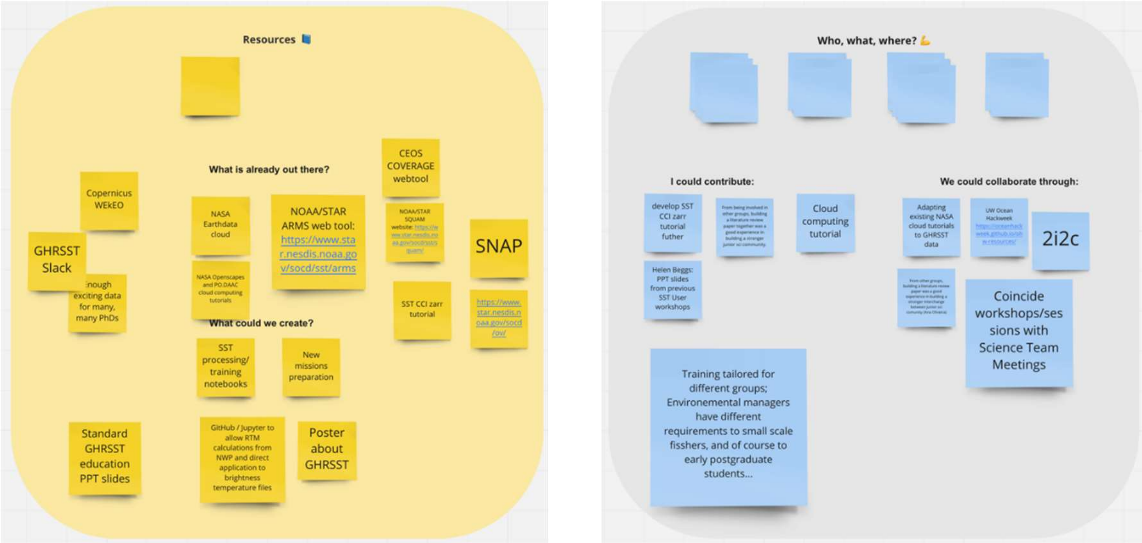


Figure 4: Results from the Miro session.

Actions and arising recommendations

The GHRSST international Project Office should collaborate with the EUMETSAT training service to translate the feedback above into plans for **training courses (or similar user-engagement events) that can address different audiences, the data selection and cloud/open source topics.**

A hybrid training course could be proposed, with an online component and then an in-person phase associated with the next GHRSST meeting. This could be paired with the inclusion of early-career researchers/new users in a mentoring/support scheme (creation of an ambassadors' network).

Further activities could combine training approaches with other activities in the science team, such as developing a Jupyter Hub/GitHub collaboration for algorithm intercomparison/feature fidelity investigations. This would meet scientific objectives while allowing GHRSST community members to learn new skills in open science.

A collation of the available learning resources in the form of a list should be made available on the GHRSST website.

Potential development of new tools to support users/training should be explored, for instance:

- A decision tool linking characteristics of different datasets to various applications.
- A number of case studies with examples of SST use in different applications, with the inclusion of text and Jupyter notebooks for example.

References

Beggs, Helen. Temperature. Chapter 14 in Earth Observation: Data, Processing and Applications. Volume 3B—Surface Waters. CRCSI, Melbourne. pp. 245–279. https://www.eoa.org.au/earth-observation-textbooks, (2021).

Resources

miro	https://tinyurl.com/474jjs6e
vimeo	https://vimeo.com/725342802

PD2: GHRSST 25th anniversary activities

Chair: Anne O'Carroll, EUMETSAT

Panellists: Anne O'Carroll, Jacob Høyer, Ioanna. Karagali

Rapporteur: Chiara Bearzotti, Danish Meteorological Institute, GPO chb@dmi.dk

This session consulted the GHRSST community on activities for the 25th GHRSST anniversary. As GHRSST celebrates its 25 years in 2024, a discussion on various activities to communicate this achievement occurred during a dedicated panel on Wednesday 29th June 2022.

An overview of the inputs received throughout the discussion is available on the Miro board used during the panel discussion, together with inputs collected from the audience. Inputs were grouped around categories, with suggestions on how to:

- Gain visibility at major events,
- Offer interactive formats,
- Involve the users of GHRSST products,
- Explore potential new formats.

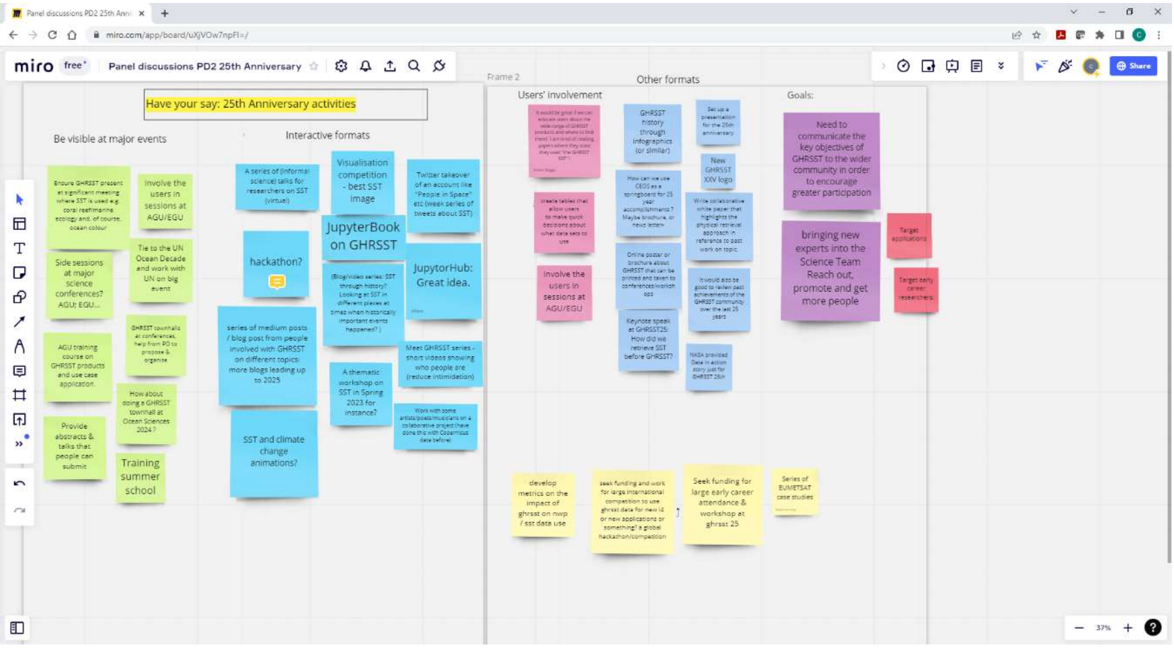


Figure 1: Suggestions collected on the 25th anniversary activities.

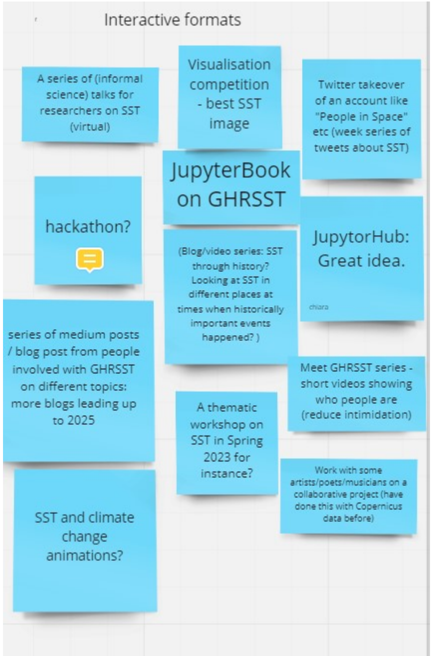


Figure 2: Suggestions on interactive formats.

In particular, when it comes to the users of the GHRSST products:

- There is the visible need to offer more information to the users about the GHRSST products, where to find them, how these can be used.
- GHRSST should put users in the position to make quick decisions about what datasets are to be used.
- Users should be involved in GHRSST organised sessions on GHRSST products, alongside larger events such as EGU and AGU.

A number of interactive formats could also be used to improve the transfer of know-how to the users (Figure 2).

Actions and arising recommendations

The main outcome is the need to attract new experts and early-career scientists and to reinforce the link with users.

To achieve this a range of activities was suggested, including:

- The offer of interactive/online formats such as meet & greet, hackathons, talks, tweets, collaboration with artists, blogs, and visualization competitions.
- The participation in physical meetings such as the UN Decade for a Sustainable Ocean, AGU, EGU, and Ocean Sciences where users can be involved and training provided.

These have to be implemented together with the members of the Science Team and within the limits of capacity of the GPO resources.

Resources

miro https://tinyurl.com/474jjs6e

vimeo https://vimeo.com/725342802

PD3: GHRSST priorities

Chair: Anne O'Carroll, EUMETSAT

Panellists: Chunxue Yang, Peter Cornillon, Chelle Gentemann, Jean-Francois Piollé, Kachi Misako, Ioanna Karagali

Rapporteur: Jacob Høyer, Danish Meteorological Institute, jlh@dmi.dk

The results of the panel discussion are reported together the following section of these proceedings: Workshop W6/PD3: GHRSST priorities (see page 28 of this document)

Resources

miro	https://miro.com/app/board/uXjVOw7npQU=/
vimeo	https://vimeo.com/725342802

Task Teams Progress

Sessions chairs:

Anne Ocarroll, EUMETSAT, Germany

Stephan Saux-Picart, Meteo-France, France

Ed Armstrong, JPL/NASA, United States

Sessions rapporteurs:

Bruce McKenzie, NAVOCEANO, United States

Steinar Eastwood, MET Norway, Norway

Jean-Francois Piollé, IFREMER, France

GHRSST Task teams are set up to address particular issues identified by the GHRSST Science Team. Task teams (TTs) are proposed and agreed at the annual Science Team Meetings (STM).

Each task team has a chair and a team of volunteers, the task team members.

Each chair is asked to appoint an early-career scientist as co-chair to encourage participation in GHRSST and ensure continuation of knowledge.

The task teams report their findings at the annual Science Team Meetings and the Science Team decides if the task team has completed its task or should continue.

The following task teams have reported to the plenary during the GHRSST23 meeting:

- Climatology and L4 Inter-Comparison (IC),
- Evolution of the Regional/Global Task Sharing (R/G TS),
- Feature Fidelity (F2T2),
- Shipborne Radiometry (ISFRN),
- High Latitude SST (HLSST),
- Single Sensor Error Statistics and L4 (SSESL4),
- Matchup Database Standards (MDB),
- HRSST Drifters for Satellite SST Validation (HRSST).

Evolution of the Regional/Global task sharing (R/G TS)

TT Chair and Presenter: Jean-François Piollé, IFREMER

Regional GHRSST Task Sharing Task Team updates and activities were presented by Jean-François Piollé (Ifremer). These included:

- The Task team objectives and membership.
- The list of GDP and GDAC entities.
- The deliverables for 2022 – 2023.
- The GDS Data Specifications version 2.1.
- The description of the GHRSST Central catalogue and federated open search.
- The responsibilities of GDP, DAC, and project office.
- A schedule and work plan for the coming year.

The meeting discussions provided clarification that non-DAC GDP data can be catalogued. An initial version of the catalogue should be ready by next GHRSST meeting, depending on DAC/GDP input. GDS 2.1 will be released soon with a data checker. The open search link will be updated. Three beta testers volunteered for reviewing the documentation (manual) and the catalogue functions.

Objective of this task team

Specification of GHRSST system, interface and architecture

- Format specifications
- To define the roles and interactions between GHRSST entities
- To define the minimum services and interfaces to be implemented to serve GHRSST data
- To ensure the overall GHRSST system operates according to specifications
- To support GHRSST partners to implement the required services and interfaces

Team Members of the TT

Senior researchers: JF Piollé, Ed Armstrong, Wen-Hao Li, Yongsheng Zhang, Huai-min Zhang, Korak Saha.

One contact point per GDP or DAC: Sheekela Baker, Helen Beggs, Kenneth Casey, Mitsuhiko Fuda, Pallavi Govekar, Jacob Høyer, Sasha Ignatov, Bruce McKenzie, Kachi Misako, Hideyuki Muramatsu, Korak Saha, Igor Tomazic, Cristina Tronconi, Yongsheng Zhang.

Unfortunately, we do not have early-career researcher in the team, and they are very welcome!

GDS Table of GHRSST Entities

Deliverables Scheduled 2022-2023

- GHRSST GDS 2.1 and dynamic tables: 07/2022
- GHRSST R/G TS System Architecture GSA (https://doi.org/10.5281/zenodo.4926440)
- GHRSST Central Catalogue: 09/2022
- GHRSST Central Catalogue User Manual: 10/2022
- Opensearch federated search service: 07/2022
- Opensearch example notebook: 07/2022

GHRSST Central Catalogue and Opensearch service implementation was funded by Copernicus through EUMETSAT

Shared documentation, software and results

- Your slack channel (not used so far): https://ghrsstworkspace.slack.com/archives/C024GTYJABH

- Github: https://github.com/GHRSST/ghrsst-opensearch
- Moodle page (not used out of GHRSST meeting): https://training.eumetsat.int/course/view.php?id=368&section=2
- Zenodo for GHRSST documents: https://zenodo.org/communities/ghrsst/

GDS Data Specification new version 2.1

We have a new GDS (2.1): https://www.ghrsst.org/ghrsst-news/updated-ghrsst-data-specification-2-1-now-available-for-download/ This version includes changes discussed before but properly accessible from GHRSST web site. In this new version, we have also removed inconsistencies in the format description.

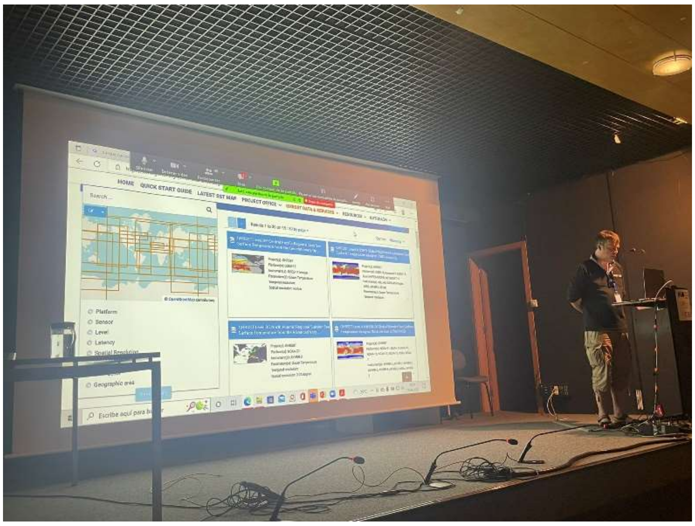
Few considerations for a future update:

- Removing scaling (replace with float / significant digits).
- New cloud optimized format (NetCDF, Zarr).
- Chunking.
- Object storage.
- On the fly data transformation (e.g. internal cloud storage to GDS NetCDF).
- Intake / STAC.

GHRSST Central Catalogue

https://www.ghrsst.org/ghrsst-data-services/ghrsst-catalogue

This test version is currently password protected until public release.



What we still need to do:

- Populate initial catalogue from PO.DAAC harvesting (repeated because of changes, e.g. cloud migration) [Ifremer].
- Freeze harvest from PO.DAAC, no more import possible [Ifremer].
- Clean: remove duplicates (merge information), obsolete products, mismatched information [Ifremer, R/G TS Team].
- Update GDS table of dataset identifiers [GDPs/DACs].
- Cross GDS table of dataset identifiers with catalogue [R/G TS Team]
- Add complementary information from NOAA catalogue: missing datasets, additional access points, and manual editing [NOAA].
- Update dataset description [GDPs/DACs].

GHRSST Central Catalogue: editing workflow

One contact point per GDP or DAC. Each GDP responsible for editing and updating its own dataset (can be delegated to DAC). Each DAC responsible for editing the access information (can be the same as GDP):

- URLs for FTP, HTTP, OpenDAP, etc… accesses.
- Opensearch end-point (when existing) and product identifier.

Request account for catalogue editing at: chb@dmi.dk

Receive login and password for editing and receive instructions (User Manual) for editing.

Connect to https://www.ghrsst.org/ghrsst-data-services/ghrsst-catalogue

Sign in with account. Use a new form or duplicate existing dataset / edit. DOI can be requested online (but you can provide your own). When editing a new dataset, send to review board once the form is completed. When updating an existing dataset, review and approval is not required

Federated Opensearch service https://opensearx.ifremer.fr/

Final URL: https://opensearch-ghrsst.ifremer.fr

- Connected to OSI SAF (at Ifremer) and PO.DAAC end points.
- Opensearch configuration is connected to the GHRSST catalogue: it is important to keep the catalogue metadata accurate and up-to-date.
- Subject to changes in July (testing phase) as we are refining the initial GHRSST Central Catalogue.
- Example notebook on GHRSST Github: https://github.com/GHRSST/ghrsst-opensearch/blob/main/opensearx.ipynb

Responsibilities of GHRSST Data Producers

GHRSST data producers are responsible for the compliance of their products to GHRSST GDS specifications. Data producers have to run the format checker and provide results to GPO for publication in catalogue. Data producers are responsible for creating, editing and keeping up to date the description of the datasets they produce for GHRSST.

Responsibilities of GHRSST Data Assembly Centres

GHRSST data assembly centres (DACs) are responsible for creating, editing and keeping up to date the description of the data access services they offer for the datasets they host and distribute for GHRSST; and for providing HTTP(S), FTP, OpenDAP etc. access, and for providing Opensearch end-point to be plugged to GHRSST Opensearch entry point. The current DACs are listed in the tables below:

Entity Code	GHRSST RDAC Name	GDP	DAC	Other distribution DAC	Contact
ABOM	Australian Bureau of Meteorology	Y	Y	JPL	Pallavi.Govekar@bom.gov.au Helen.Beggs@bom.gov.au
CMC	Canadian Meteorological Centre	Y		JPL	dorina.surcel-colan@canada.ca
DMI	Danish Meteorological Institute	Y	Y	JPL CMEMS	jlh@dmi.dk
IFR	Ifremer	Y	Y		jfpiolle@ifremer.fr
JPL	JPL Physical Oceanography Distributed Active Archive Center	Y	Y		edward.m.armstrong@jpl.nasa.gov
METNO	Norwegian Meteorological Institute	Y	Y		steinare@met.no
CMEMS	Copernicus Marine Service	Y	Y		cristina.tronconi@artov.ismar.cnr.it
NAVO	Naval Oceanographic Office	Y		JPL	bruce.mckenzie@navy.mil
NCEI	National Centers for Environmental Information	Y	Y		yongsheng.zhang@noaa.gov
OSPO	NOAA Office of Satellite and Product Operations	Y		JPL NCEI	sheekela.baker-yeboah@noaa.gov
OSISAF	EUMETSAT Ocean and Sea Ice Satellite Applications Facility	Y	Y		jfpiolle@ifremer.fr

Entity Code	GHRSST RDAC Name	GDP	DAC	Other distribution DAC	Contact
REMSS	Remote Sensing Systems, CA, USA	Y		JPL	brewer@remss.com
RSMAS	University of Miami, RSMAS	Y			
STAR	NOAA Center for Satellite Applications and Research	Y		JPL NCEI	alex.ignatov@noaa.gov
UKMO	UK Meteorological Office	Y		JPL CMEMS	Good, Simon <simon.good@metoffice.gov.uk>
ESACCI	ESA SST Climate Change Initiative	Y	Y		Chris Merchant ?
JAXA	Japan Aerospace Exploration Agency	Y	Y		Mr. Mitsuhiko Fuda (fuda.mitsuhiko@jaxa.jp) Mr. Hideyuki Muramatsu (muramatsu.hideyuki@jaxa.jp) Cc: kachi.misako@jaxa.jp
MAR	EUMETSAT	Y	Y		igor.tomazic@eumetsat.int

GHRSST Project Office Responsibilities

The GHRSST Project Office, together with the support of the Science Team technical task team, should be responsible for:

- Implementing, operating and sustaining the central catalogue and its search and discovery services (on whatever host) – currently funded by Copernicus.
- Verifying the compliance of provided dataset and metadata. Approving the publication of any submitted dataset, verifying the metadata accuracy and completeness, the result of the format checker and for supporting the R/G TS core team.

Proposed Schedule for completion of activities

- Last harvesting of metadata from PO.DAAC catalogue: end July 2022 – import will be then not possible.
- Initial internal version (pre-populated, not public): end July 2022.
- Correction/update of pre-populated information (R/G TS testing team: Ifremer, PO.DAAC, NOAA, EUMETSAT): end July to end October 2022.
- Release to public (with approved datasets): mid-September 2022.
- All DACs and GDPs able to edit datasets and add new datasets: mid-September 2022.

Work plan for next year

2022 (second half):

- To complete initial population of catalogue – update outdated information.
- To open to public GHRSST central catalogue and Opensearch services.
- To complete the GHRSST central catalogue with missing and new products.
- Federated granule search service for datasets with Opensearch endpoint.

2023 (first half):

- To operate the GHRSST R/G TS system verification of new datasets and metadata.
- To verify and support the implementation of the required GHRSST services by each DAC, in particular Opensearch.

Conclusions

The GHRSST R/G TS team has well defined objectives that can be accomplished with support from the GDPs, DACs, and GPO.

Link to this presentation:

This presentation is available in the Moodle only:

Log into the Moodle of the 23rd GHRSST INTERNATIONAL SCIENCE TEAM MEETING (G-XXIII)

And download the presentation from this link: https://training.eumetsat.int/pluginfile.php/45479/course/section/4564/0627-RGTS-TT%20Report%20v3-Piolle.pdf?time=1657189511229

vimeo https://vimeo.com/showcase/9536986/video/727718567
starts at 1:07

Climatology and L4 Intercomparison (IC-TT)

TT Chair and presenter: Helen Beggs, Australian Bureau of Meteorology

There is an active group with about 15 contributors working around three main tasks, including:

- Intercomparison of L4 products.
- Understanding differences between the different L4 products.
- Comparing ocean features in L4 products.

Significant local differences between different L4 products are observed, these need more studies to understand these differences fully. Prominent differences are shown in some regions like the Arctic, but small differences in other. Several publications are available on the work done in the IC-TT: https://www.ghrsst.org/resources/publications/

The last year the work has focused mostly on task 3, including several posters presented at GHRSST23.

Work plan for the next year:

The task team will focus on the Task 3 issues. A new task 3.6 has been introduced by Chunxue Yang to compare SST gradients represented in various L4 products. In this task the team will try to include all available products, so the team will be in contact with the producers and will do this comparison on a coarser resolution, but the team will calculate the gradient before reducing the resolution.

Q&A with the presenter

What is the best way to compare time series of different gradient products?

A simple difference will not be optimal if the position of the gradient fronts are slightly shifted between products, while amplitudes are the same.

Also, for the variability of a front, how to best calculate this, using a point position or a region, and how to define the regions?

The best way might be to calculate the angle between the gradients and then do the PDF of the angle, which will tell you if the gradients are aligned or not.

For gradient comparison, is there a way to verify? Are buoy data useful?

Drifting buoys will just drift with the currents, but moored buoys like coastal moored buoys could be useful (can see their location in iQuam). Maybe ferry data can be used, as they monitor the same track over several years.

Additional remarks:

- Since the L4 products are on different resolution, this is a good opportunity to look at effect of resolution differences.
- Seasonal differences might be due to seasonal differences in cloud cover in different input products, since some of the L4 products do not use the same input data.
- Deliverables on T3.1 and T3.5 are due in June 2023, other tasks have not planned deliverables yet.
- There are plans to meet online once every 2 months.
- It is easiest for people with related funded projects to contribute, as we all are usually fully booked.
- We wish to ask for an extension beyond completion date, at least one more year.
- New interested people are invited to join the IC-TT.

Link to this presentations:

This presentation is available in the Moodle only: 23rd GHRSST INTERNATIONAL SCIENCE TEAM MEETING (G-XXIII)

Direct links:

Updated presentation (Version 30 June 2022) and previous presentation (Climatology and L4 Inter-Comparison)

https://vimeo.com/727700672
start from minute 16:55

High Latitude SST (HLSST TT)

TT Chair and presenter: Michael Steele, University of Washington

In the past year, we have worked on validating and improving the retrieval at high latitude (HL) and facilitating and extending the in-situ observations. The Task team HLTT counts on a good number of members.

The upcoming initiative for 2022-2023 are the following:

- Establish an HL in-situ SST database.
- Get better use of HL in-situ in iQuam.
- Keep on working on the SST / IST integration.
- Implement a new Arctic-focused reanalysis (RARE).
- Use Arctic Saildrone data from 2019, 2021 and 2022; for 2022 in cooperation with DBO (Dist. Bio Observatory) for specific lines.
- Focus on Arctic marine heatwaves: these are increasing, as sea ice retreats.
- Recent Arctic SST increase: global warming versus local internal variability, and increasing importance of cloud cover as sea ice retreats.

Q&A with the presenters

Really nice to hear about the dedicated Arctic reanalysis, is the HLTT only looking at Arctic or also looking at Antarctic?

This task team want to look at the Antarctic, but there are very few in-situ observations. OSI SAF has products for the Southern Hemisphere, both operational and CDR. In-situ is very limited at Southern Hemisphere, but some data are available from Petra Heil. There is also available in-situ data from the NOAA NCEI SUMD. The UpTempO buoy database with Arctic in-situ profiling data will be updated soon, including SST. EUMETSAT and DMI will launch a SLSTR IST product, including a matchup dataset, which will be available for all. We could also possibly be extended with VIIRS and Metop. EUMETSAT and DMI are also looking into building a dedicated IST buoy, but this is currently only in the design phase.

Do we have a community recommended grid to use for gridding high latitude data?

The EASE/EASE2 and polar stereographic are the most commonly used. In the context of CIMR, ESA is defining an EASE-like grid, which could be a template for GHRSST.

In-situ observations from sensors on marine mammals, how close to the surface does these observations go, that is, do they provide proper SST observations?

There are quite some data in the Southern Ocean, and we would expect them to provide useful SST data as the animals go to the surface for air.

Link to this presentation:

This presentation is available in the Moodle only: [23rd GHRSST INTERNATIONAL SCIENCE TEAM MEETING (G-XXIII)](https://training.eumetsat.int/course/view.php?id=449)

https://training.eumetsat.int/course/view.php?id=449

vimeo https://vimeo.com/726969260

Matchup Database Standards (MDB TT)

TT chair and presenter: Igor Tomazic, EUMETSAT

The objective of this task team is to suggest the way forward towards common SST MDB production method and assessment metrics and protocols. Some of the tasks have been completed, others will be completed in 2023 and 2024. An overview is provided in the picture below.

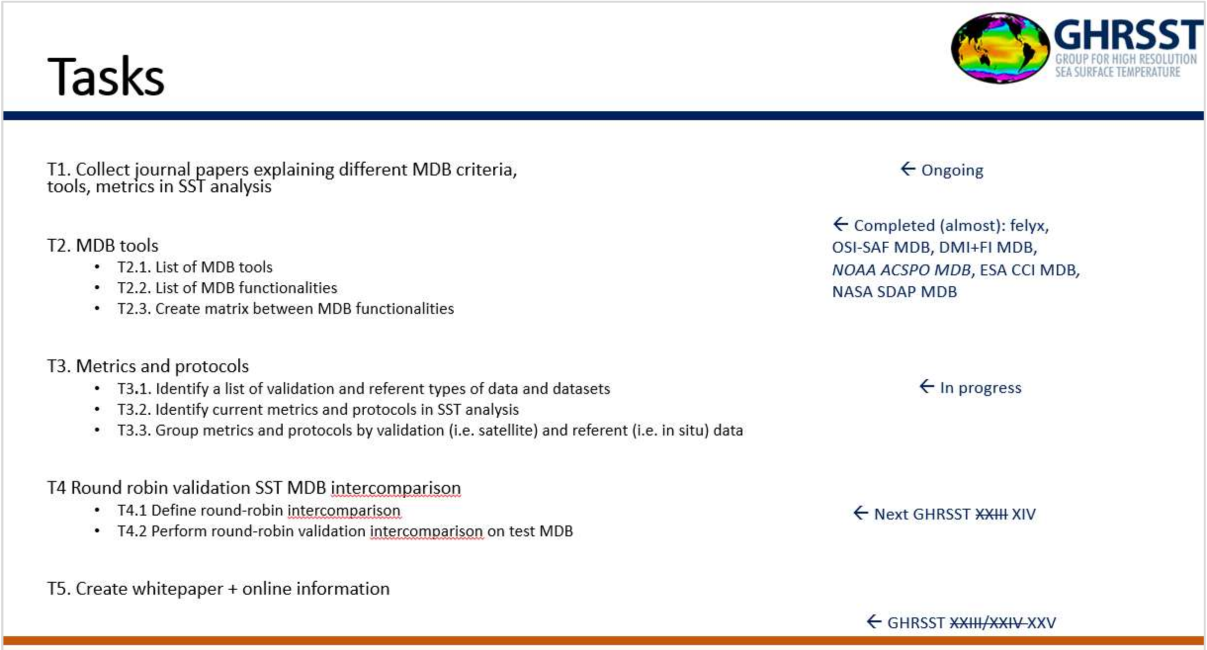


Figure 1: Progress in the MDB tasks. Credits: Igor Tomazic.

The MDB tools are felyx, CCI MDB, NOAA ACSPO MDB, JPL SDAP-CDMS, OSI SAF, DMI and FI. The task team is working on an online spreadsheet with a map of these tools and their functionalities to identify currently used methods and criteria in matchup analysis. There is a delay in the development/implementation of new felyx MDB (intercomparison) framework.

Link to this presentation:

This presentation is available in the Moodle only: [23rd GHRSST INTERNATIONAL SCIENCE TEAM MEETING (G-XXIII)]

Direct links to the presentations:

- Presentation on the TT progress and task
- Presentation for discussion at the plenary (28 June 2022)

vimeo

https://vimeo.com/724976580
from the start to minute 18:42

Feature Fidelity (F2T2 TT)

TT chair and presenter: Peter Cornillon, University of Rhode Island

The objective of this task team is to address issues of uncertainty of SST fields in relation to the study of oceanographic features at mesoscale and smaller, i.e. < O(100km).

The activities of this task team have been broken down into tasks:

- Task 1 Classification of types of problems contributing to uncertainties at different spatial scales.
- Task 2 Identification of effects giving rise to these problems.
- Task 3 Outline approaches to quantifying the uncertainties of interest.

A report was set up in 2021: https://zenodo.org/record/7263467#.Y10oX3bP2Hs

The spatial scales associated with various categories of problems have been discussed within the task team:

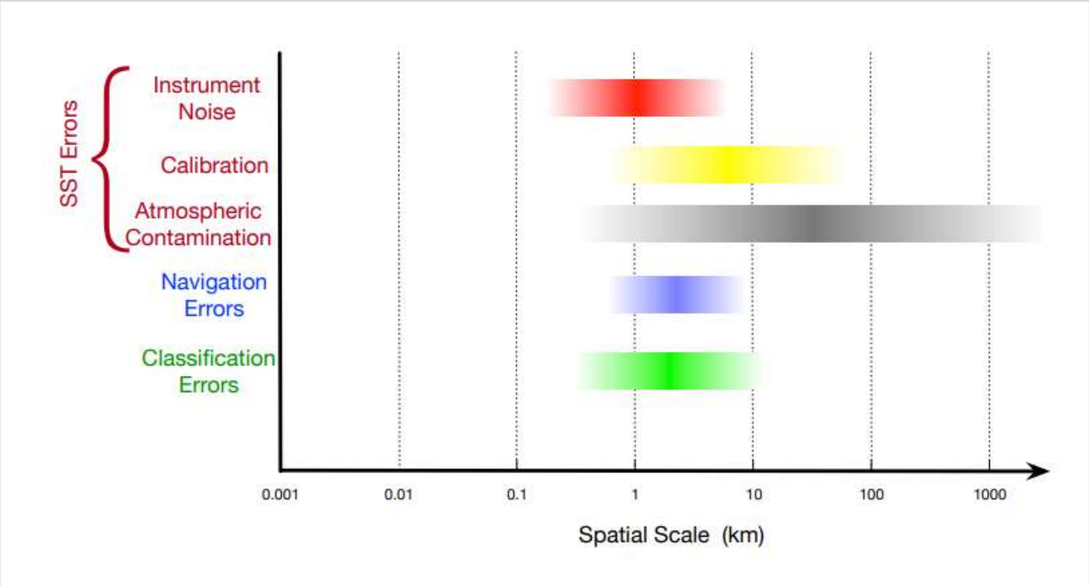


Figure 2: Spatial Scales of SST Errors Associated with Cause. Credits: Peter Cornillon.

Two approaches will be investigated:

- Metrological approach: propagation of errors through the processing steps.
- Determine uncertainty from the variance of the SST fields.

A manuscript on the "The Fidelity of Features in Satellite-Derived Sea Surface Temperature Field" with focus on issues related to the fidelity of SST features is being prepared. This manuscript would include instrument and retrieval-related issues:

- Instrument-related issues:
    a. Instrument noise.
    b. Scanner geometry, e.g., The Bow-Tie Effect.
- Retrieval-related issues:
    a. Calibration.
    b. Structure of the equation used for retrieval, e.g., spatially averaging the nonlinear term in a nonlinear algorithm vs not doing so.

c. Atmospheric contamination, e.g., the imprint of atmospheric phenomena on the SST field.
d. Classification errors, e.g., cloud-contaminated pixels flagged as clear or Front pixels flagged as bad.

Link to this presentation:

This presentation is available in the Moodle only: 23rd GHRSST INTERNATIONAL SCIENCE TEAM MEETING (G-XXIII)
Direct links to the presentations:

- Presentation on the update of the TT work
- Presentation of 28th June 2022 for discussion

vimeo

https://vimeo.com/724976580
From minute 18:42 to the end

Shipborne Radiometry (ISFRN TT)

TT chair and presenter: Werenfrid Wimmer, University of Southampton

The goals of this task team are to:

- Facilitate coordination of Fiducial Reference Measurement, such as Shipborne Radiometry.
- Develop a community of in-situ radiometer builders, operators and data users to promote good practice in the construction and operation of in-situ radiometers, agree and establish protocols, formats and standards for quality assurance of data, share knowledge and coordinate activities between network members, inform the wider community about the Network's activities.
- Provide a single access point for the collection and dissemination of radiometer data, Support satellite radiometer operators in the long-term validation of satellite products.
- Create a common date format and archive for Fiducial Reference Measurement.

The major achievements so far are the following:

- The network has been set up.
- Protocols and procedures – on webpage www.ships4sst.org
- Updates to deployment protocols: https://ships4sst.org/instruments/deployments
- Updates on the manuals: https://ships4sst.org/documents
- Inter-comparison.
- NPL and Pier, which has just been finished.

Resources:

- https://www.ships4sst.org/
- https://www.ships4sst.org/services/ships4sst-data
- https://twitter.com/ships4sst

Link to this presentation:

This presentation is available in the Moodle only: 23rd GHRSST INTERNATIONAL SCIENCE TEAM MEETING (G-XXIII)

Direct link to the presentation: https://training.eumetsat.int/pluginfile.php/45479/course/section/4564/0626-ShipborneRadiometer-WerenfridWimmer.pdf

vimeo https://vimeo.com/724979637

Single Sensor Error Statistics and L4 (SSES-L4 TT)

TT chair and presenter: Andy Harris, NOAA

Sensor-Specific Error Statistics (SSES) represent one of the primary "value-added" components of GHRSST L2P/L3x products. The question arises as to how much value the current SSES information is adding. Within the GHRSST community, an obvious application is in the production of L4 SST analyses. Three main sub-tasks have been identified:

- Establishment of the usefulness of the SSES bias and standard deviation.
- How best to use the current SSES.
- Set up of a forum on the future evolution of SSES.

The plans for the second half of 2022 are to analyze and characterize SSES schemes based on L2P/L3x producer inputs already provided, and seeking additional clarifications as needed.

In the first half of 2023, the plan is to devise and conduct diagnostic experiments based on anticipated behaviour/performance of different L2P/L3x SSES schemes

Link to this presentation:

This presentation is available in the Moodle only: 23rd GHRSST INTERNATIONAL SCIENCE TEAM MEETING (G-XXIII)

Direct link:
https://training.eumetsat.int/pluginfile.php/45479/course/section/4564/SSES_L4_GHRSST_XXIII_TemplateTT-Requirements-aoc-Accessible.pdf

vimeo

https://vimeo.com/724979637
Starting at minute 13:25

HRSST drifters for satellite SST validation (HRSST TT)

TT chair and presenter: Gary Corlett, EUMETSAT

The objective of this task team is to coordinate HRSST drifter activities with the drifting buoy community.

The plans for the next twelve months include the following activities:

- Continue performance evaluation of HRSST2 drifters.
- Refine minimum metadata standard with GDP.
- Draft a journal article.

The revised HRSST specification are expected to be available by December 2022.

Link to this presentation:

This presentation is available in the Moodle only: 23rd GHRSST INTERNATIONAL SCIENCE TEAM MEETING (G-XXIII)

Direct link:

https://training.eumetsat.int/pluginfile.php/45479/course/section/4564/HRSST-GaryCorlett.pdf?time=1655195129287

Report from the GHRSST Advisory Council to the Science Team

Presenter: Jorge Vazquez (1)

Rapporteur: Chiara Bearzotti (2)

Chair: Anne O'Carroll (3)

1) JPL /Caltech, USA, Email: jorge.vazquez@jpl.nasa.gov

2) Danish Meteorological Institute, Email: chb@dmi.dk

3) EUMETSAT, Email: Anne.Ocarroll@eumetsat.int

The Advisory Council (AC) met on 28th June 2022. At the AC meeting, the members had useful discussion with respect to updates and activities to be implemented in the upcoming months. The meeting was attended by representatives of major agencies: ESA; NOAA NCEI, NASA, EUMETSAT, OSI-SAF, IFREMER/GDAC, Met Office (UK); JAXA, JMA, NAVO, Australian BOM, DMI, CMA China, CEOST SST-VC, Copernicus C3S. The outcome of the discussions and the **actions to be implemented by GHRSST Science Team (ST) and GHRSST Project Office (GPO)** are summarized in this session report.

Collaborations

At the AC meeting progress was reported on the following activities:

- CEOS SST-Virtual Constellation: with activities related to the CEOS analysis-ready data, the contribution from other disciplines such as the Precipitation Virtual Constellation, and activities linked to the United Nations Decade of Ocean Science for Sustainable Development (2021-2030).
- Cross-cutting collaborative effort on the CEOS COVERAGE activity involving different CEOS Ocean Virtual Constellations, with phase B finished and phase C expected to move into 2023, with interagency data products from 4 Ocean Virtual Constellations and implementation of 0.25 degrees (L4) http://coverage.ceos.org
- Collaborations on other opportunities were discussed, notably with in-situ data including Saildrones, International Tropical Tuna Commission, Sargasso Sea Commission, and Univ. of South Florida which is implementing NetCDF files of harmful algal blooms (Sargassum Density).

Actions to be implemented by the Science Team and the GPO

A number of actions are to be implemented by the Science Team and the GPO in the upcoming months:

- **What is the best way to move forward with the update of the GDS 2.0 tables with respect to the current data activity of the data providers and producers, and the transition of the central catalogue** as presented by the Task Team on R/G TS at the GHRSST23 meeting ([4])? Much work is planned for the integration with the catalogue, so that in the future it is easier for data providers to follow a process and distribute data to the GHRSST project. The action indicates that instructions (manual, tested by beta testers) and a checker code to be updated for the new GDS2.1 are to be prepared for the agencies. This action is incumbent upon the Task team, the agencies and the GPO, with a supporting role in this transition.

[4] Direct link to the presentation: https://training.eumetsat.int/pluginfile.php/45479/course/section/4564/0627-RGTS-TT%20Report%20v3-Piolle.pdf?time=1657189511229

- **GHRSST official data policy**: with the need of a simple process to confirm if a new dataset is GDS compliant.
- A new action for the GPO is to **revise partly the set-up of the GHRSST annual meeting, in order to attract more early-stage researchers (ESR**), including user forum session to include user applications. This is very critical for the future of GHRSST: integrate ESR in the community, increase user interactions and share network, transfer expertise.
- A key point for the AC is the adoption of actions to increase the participation of early-stage researchers in GHRSST activities, with a number of **new formats for engaging with ESR**, for instance "ghrSST talks" for younger professionals to share resources and results, the set-up of a thematic workshop in May 2023 with a larger participation of ESR, and the creation of an ambassador network of early-career researchers. This action is incumbent upon the GPO but the ST members need to support the implementation of these activities. The creation of SST training formats should also allow a greater participation of ESR in the future.
- The AC tasked the ST, with the support of GPO, with the action to **make GHRSST activities and data more visible:** share more resources, but also get more engaged in events such as AGU, EGU, UN Ocean Decade and Ocean Science, and be more active in these fora and consider how GHRSST can be more active in science policy. The agencies are requested to provide Outreach officers' contacts to allow more interactions with the GPO and grow the network within the GHRSST community. The 25^{th} anniversary activities should include a roadshow of GHRSST at major events to show what GHRSST has done and achieved. GHRSST needs more participations and greater lead, but also **availability of ST members to join and take the lead** in organizing sessions at major events
- **Increasing accessibility of GHRSST presentations**: a must for next year, by ensuring the compliance of presentations, captioning videos, and making them mandatory for all speakers. This is a key item. Thanks to the chair for making this a priority! This is an action for the GPO to collect resources for accessibility guidelines and to create accessible templates to be used in future meetings.

Conclusion

A number of actions need to be taken up in the following months, before the 2023 meeting takes place. Thanks to the GPO for its support in setting up the GHRSST23 meeting with all the necessary technology to allow interactions and make it easier for people to attend this meeting remotely.

References

- United Nations Decade of Ocean Science for Sustainable Development
- http://coverage.ceos.org
- Jorge Vazquez, AC chair Report from GHRSST XXIII Advisory Council meeting to the plenary https://www.ghrsst.org/wp-content/uploads/2022/07/202206-GXXIII-AC-report-to-ST-web.pdf

Resources

vimeo https://vimeo.com/726045498

Final Session

Rapporteur: Ioanna Karagali (1)

Chair: Anne O'Carroll (2)

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The GHRSST meeting ran very successfully over 5 days as a hybrid meeting, accessible for both in-person and online participants. There were 18 science presentations and 37 posters with 99 online participants and 50 in-person participants. There were 3 panel discussions, 6 in-person collaborative workshops and 7 task team reports.

This report summarises the main discussion points during the final session of the GHRSST23 meeting, which took place on Friday 1 July from 10:00-11:30. The session summarised the main outcomes of the GHRSST week including the main achievements and salient discussion points and actions.

The agenda of the session included a summary and outcomes of the GHRSST meeting, a presentation about task teams planning, review of actions from the GHRSST project office and practical information on science team nominations and memberships along with a call for updates to the website. Finally, reports from the three panel discussions which took place on Wednesday afternoon were given.

Task Team Planning

Rapporteur: Chiara Bearzotti, Danish Meteorological Institute, GPO

Task team planning and activities up to the next meeting include updates on publications, reporting of new task team members, progress and results.

Many platforms used for GHRSST23 and many will be obsolete but Moodle will remain active, along with Miro boards pre-recorded presentations and meeting sessions will be available on Vimeo.

Slack and Github are the points for year-round discussion and code sharing, if access is needed, the contact point is the GHRSST Project Office (GPO).

Key considerations

A list of actions, as defined by the Advisory Council (AC), includes:

- **The update and maintenance of GDS tables**, official data policy and the transition to central GHRSST catalogue as organised by the GPO with the shared effort of the Science Team (ST) and DACs. Instructions (manual to be tested by beta testers) and checker code to be updated for new GDS2.1 and prepared for DACs and data producers who want to implement the GDS. The manual will also include a simple process, e.g. a checklist, to confirm/verify if datasets are GDS compliant. This needs to be checked by R/G TS review board. To transition to the central catalogue, DACs without OpenSearch capabilities can have a catalogue entry but not a search entry. This may be modified in the future.
- **Re-think the GHRSST meeting format in order to attract early-career researchers** (ECR or ESR[5]) and new users and to be more content driven (AC/22/03). Action to be initiated by the GPO.

[5] Early-Career Researcher (ECR) means an individual currently undertaking an honours, Masters or PhD degree, or otherwise postdoctoral researchers within 5 years of attaining their PhD.

- **Increase the participation of ECR/ESRs in GHRSST** (AC/22/04). Suggestions for this activity include a series of informal virtual talks for the younger professionals to present results to senior GHRSST scientists, virtual workshop in May 2023 especially for early-career researchers, an ambassador network of ESRs, GPO to ask feedback from ESR participating in GHRSST23, SST training plan.
- **Make GHRSST activities and data more visible, an activity shared by the ST members and the GPO** (AC/22/05). To achieve this, it is advised to target major scientific events such as AGU, EGU, Ocean Sciences meetings, UN Decade for Sustainable Oceans and science-policy events with proposed sessions and GHRSST booths in the corresponding exhibitions. ST members, with the support of the GPO, should become more active in taking the lead on this. Especially for the GHRSST 25th anniversary it is suggested to establish a roadmap of GHRSST contents at major events (see previous examples). Finally, it is suggested to investigate if agencies can provide/support part of the outreach activities by providing contact points for their Outreach Officers.
- **Make GHRSST presentations accessible, through compliance with international standards**, e.g. by captioning presentations, communicated by the GPO and ensured by the presenters (AC/22/06).

Training Formats Panel Discussion

Rapporteur: Ben Loveday, Innoflair UG

The aim of this panel discussion was to exchange thoughts and experiences on training of SST and beyond, gather experiences and needs from the community and begin planning of activities. Interactivity and motivation are key components, the use of video, physical props, demos is advised along with different tools (sli.do, Miro), yet the most important to activate trainees and reduce passive learning is to get them to try activities such as plotting.

Key considerations

With respect to available resources:

- Jupyter notebooks need to be sustainable and interactive. A solution is to get the GHRSST community to help maintain such resources up-to-date.
- SST for dummies course/manuals along with product level guides and tutorials are key. Consider translating tutorials to other major languages beyond English – with the help of existing partnerships, ST members.

With respect to audiences and platforms used, suggestions included to focus on inexperienced L4 users, more training alongside meetings, more recorded lessons and Q&A sessions, possibly participation in curriculum design in collaboration with universities, and updated GHRSST catalogue for online guidance.

Questions on training formats, posted in sli.do, showed a clear trend for the need to consider diverse learning backgrounds and diverse application priorities while a clear advantage to in-person interaction was reported, even more so because of the better networking opportunities this format offers.

Suggestions on the Miro Board indicated that there are many applications to cover (marine heat waves, uncertainties, climate time series, link with ocean dynamics, biological impact of SST anomalies, detection/analyses of extreme events) and many factors to consider (spatiotemporal resolution and coverage, feature fidelity, distance to coast, stability, measurement method, CDR) when matching applications to products. The most important parts of the SST science/applications that need to be made open include access to data, algorithms and analyses on L2/L3/L4 along with HPC competitive access. Open science skills are recommended (code sharing platforms, open source code/programming language) and even though lots of tools are available, there are still gaps where we can create GHRSST branded tools, i.e. Jupyter books/notebooks.

Finally a collection of known tools and training formats (GHRSST Slack, SNAP, Copernicus Wekeo and CMEMS, SST CCI Zarr tutorial, NOAA/STAR SQUAM, NOAA/STAR ARMS web tool, NASA EarthData cloud, NASA Openscapes and PO.DAAC cloud computing tutorials) highlighted the possibilities of what GHRSST can add (SST processing/training notebooks, standard education slides, GHRSST poster, training tailored to specific groups – students, managers/policy makers, companies) and where the ST and GHRSST23 participants could contribute (develop SST CCI tutorial further, enhance/develop slides from previous SST User workshops, create cloud computing tutorial, adapt existing NASA cloud computing tutorials to GHRSST products, coincide workshops/sessions with ST meetings, 2i2c, write review paper together with ESRs).

GHRSST 25th Anniversary Panel Discussion

Rapporteur: Chiara Bearzotti, Danish Meteorological Institute, GPO

As GHRSST celebrates 25 years in 2024, a discussion on various activities to communicate this achievement occurred during a dedicated panel on Wednesday June 29th 2022.

Key considerations

The main outcome is the need to attract new experts and early-career scientists and to reinforce the link with users. To achieve this a range of activities was suggested, including interactive/online formats (meet & greet, Hackathons, talks, tweets, collaboration with artists, blogs, visualization competitions) and participation in physical meetings, for instance UN Decade for a Sustainable Ocean, AGU, EGU and Ocean Sciences, where users can be involved and training provided.

GHRSST Priorities Panel Discussion

Rapporteur: Ioanna Karagali, Danish Meteorological Institute, GPO

This panel discussion focused on the priorities for GHRSST as achieved so far and to be tackled in the next years.

Key considerations

There is a strong mandate to focus on spatial and temporal high resolution to resolve coastal processes and the complexity related to the Arctic and the sea surface and sea ice interplay.

As NWP is expected to drive evolutions towards higher spatiotemporal resolution. GHRSST needs to define what high resolution means for SST, especially with the upcoming launches of LSTM, TRISHNA and other missions.

There is a strong need for high resolution, good quality SST in the coastal zone (LSTM, TRISHNA and other future missions).

Especially in relation to the Arctic, Sea Ice Surface Temperature needs to be homogenised with SST as a uniform variable in order to define the boundaries between ocean/sea-ice and land. Furthermore, existing Arctic SST/IST analyses need to be connected with the global L4 SST counterparts.

With respect to Passive Microwave (PMW), since no absolute calibration exists, requirements need to be defined given that not all future PMW missions have SST-sensitive channels. GHRSST needs to maintain and advance its tradition of progressiveness and inclusiveness, and consider how to open up to the scientific community through sharing tools, including such common tools for specific analyses, e.g. for spatial resolution assessment.

With the use of cloud services, many GHRSST datasets are now spread across platforms. Therefore there is a need to redefine and harmonise standards and format specifications, and GHRSST needs to promote free usage of various platforms. Yet as it is not always easy to use the data, there is a need for experts with scientific background.

In order to enlarge the user community, GHRSST needs to expand on the "user/application" driven examples of how to utilise GHRSST data, including for NWP applications. Also GHRSST needs to expand to more L4 inter-comparison exercises, including Diurnal Analysis products, to better inform users on which products can be more relevant for their applications.

There should be more user / application driven examples of how to utilise GHRSST data, including for NWP applications.

GHRSST can provide a recommended methodology to deal with cloud and bow-tie effects (MODIS) when doing gradients' analysis, and encourage data producers to provide more guidelines to users with respect to handling improved quality fields that may be included in GHRSST products.

Practical information for upcoming actions

The GPO is planning updates for the GHRSST website:

- A blog will be launched and embedded into the website. Volunteers from the Science Team are needed, so please contact the GPO to be involved.
- The profiles of Science Team members will be updated with pictures, bio, LinkedIn/Tweeter, ORCID. Please contact the GPO to send your updates.
- The web page about SSES on the GHRSST website is to be updated with inputs provided by Andy Harris.
- Links to the Vimeo showcase will be added to the Media Center.
- The GHRSST Catalogue & manual will be included in the website on this page: https://www.ghrsst.org/ghrsst-data-services/ghrsst-catalogue/
- The pages of Task teams will be updated with latest news as reported during the GHRSST23 meeting.
- The current Proceedings of GHRSST23 will be saved to Zenodo with links pointing to the records from the website page. The materials will continue to be available on the Moodle for all the participants.

A kind reminder to the Science team members: please be frequently involved in GHRSST activities, provide leadership, and attend the annual Science Team meetings.

Future meetings

- A thematic workshop to be organised in May 2023 should encourage early-career scientists to join GHRSST.
- The next meeting, the GHRSST24 meeting (GHRSST XXIV), will take place in Ahmedabad (India) in October 2023, from Monday 16 October to Friday 20 October 2023.
- The GHRSST25 meeting (GHRSSTXXV) will take place in 2024. It will be hosted by our Canadian partners.

Resources

vimeo https://vimeo.com/726045498

Appendix 1 Proceedings of the Science Sessions

Science Session S1 Applications

S1 Applications: Highlights of the Science Sessions

The Highlights of the Science Sessions included a number of five-minute talks based on the full recorded presentations followed by a short discussion period.

ID 024: Using deep supervised machine learning to explore and identify patterns within sea surface temperature data

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Short abstract

Sea Surface Temperature (SST) datasets contain vital information on the Earth's climate and on the ocean's dynamical processes. This information is difficult to extract due to its complexity and the size of the associated datasets with current oceanographic methods failing to deal effectively with them. A new direction with great promise is the use of deep learning techniques applied to the datasets. Prochaska et al (2021) developed a machine-learning algorithm, known as ULMO, to discover complex or extreme events in the SST fields. Their focus shifted as they noticed that ULMO proved to work for much more, consistently identifying patterns, not only in the extremes but, within larger portions of the dataset as well. In the work discussed in this presentation, we applied the ULMO algorithm to the nighttime portion of the global Visible Infrared Imaging Radiometer Suite (VIIRS) SST dataset, ~2.4x105 granules requiring ~40 TB of storage. VIIRS is the operational version of MODIS and the next-generation visible and infrared sensor flown by NOAA. We compared the machine learning decomposition of VIIRS to that of MODIS and further analyzed the mesoscale patterns within images from the VIIRS dataset. On a global scale, we saw that ULMO was able to consistently recognize similar, but not identical, patterns within the VIIRS dataset and that the output of ULMO is an excellent discriminator over the whole dataset, again not just for extreme events.

Link to this presentation:

zenodo https://zenodo.org/record/7120393

vimeo https://vimeo.com/717963173

ID 059: Recent upper Arctic Ocean warming expedited by summertime atmospheric processes

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Short abstract

The observed upper (0–50 m) Arctic Ocean warming since 1979 has been primarily attributed to anthropogenically driven changes in the high latitudes. Here, using both observational and modeling analyses, we demonstrate that a multiyear trend in the summertime large-scale atmospheric circulation, which we ascribe to internal variability, has played an important role in upper ocean warming in summer and fall over the past four decades due to sea ice-albedo effect induced by atmospheric dynamics. Nudging experiments in which the wind fields are constrained toward the observed state support this mechanism and suggest that the internal variability contribution to recent upper Arctic Ocean warming accounts for up to one quarter of warming over the past four decades and up to 60% of warming from 2000 to 2018. This suggests that climate models need to replicate this important internal process in order to realistically simulate Arctic Ocean temperature variability and trends.

Q&A with the author

Why can't use high resolution at high latitudes?

I agree that summer time is when we get SSTs in the Arctic and it's a very challenging season due to cloudiness, and that is why it is exciting to get the benefits of the future MW mission. In terms of the internal Arctic Rossby radius of deformation in the Arctic Ocean, 10 km is a nice average value for the Arctic as a whole, but given the strong surface stratification in many areas, it can be as small as 1 km. This is a very complex issue.

How were you able to discern the impacts of anthropogenic vs. natural causes?

Climate modellers frequently do an ensemble of runs where the initial conditions are changed slightly to delineate the internal variability. This can then be subtracted from the total variability. I believe his approach was consistent with other similar type studies and was a standard method.

When you say that 40% of the variability was due to one cause, was the rest to the other or are there other unknown components?

The sum usually does not add to one as the model doesn't reproduce the observations perfectly. For our ice results, the sum was close to one, but for SST the sum only approached around 70%. An additional component to Arctic warming was from currents from south to north.

Link to this presentation:

zenodo https://zenodo.org/record/7120430

vimeo https://vimeo.com/724360789

S1 Applications: Interactive (Posters)

ID 002: Comparing Global Marine Cold Spells (MCS) and Marine Heatwaves (MHW)

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Short abstract

Global warming is causing extreme climate events to become more frequent and more severe. Marine Heat Waves (MHW) and Marine Cold Spells (MCS) are prolonged, discrete periods of anomalously high/low SSTs with wide ranging impacts from dramatic shifts in biodiversity to changes in fishery yields. Previous research has found that MHW are increasing in frequency and intensity but MCS remain less well understood.

We compared the global MCS and MHW intensities and trends in their frequency over the period 1982-2020. These events were also assigned a category from 1 (moderate) to 4 (extreme). Our findings show that in much of the ocean, MCS have become less frequent by around one event every five years while MHW have become more frequent by around one event every five to ten years.

Most of these changes are due to increases in category I and II MHW, and decreases in category I and II MCS. However, events in parts of the Southern Ocean go against these trends with MHW becoming slightly less frequent and MCS becoming more frequent. Category III and IV MHW remain less common than the milder events, and at individual locations they are occurring at a roughly constant rate. However, these events are becoming more widespread. Category III and IV MCS are rare but are continuing to occur at a near constant rate in much of the ocean.

Access the poster in PDF:

zenodo https://doi.org/10.5281/zenodo.6840556

ID 009: Intercomparison of High-Resolution SST Climatologies Over the Australian Region

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Short abstract

Sea surface temperature (SST) climatology datasets provide the reference for observations of ocean anomalous events, which may have significant effects on the local marine ecosystem. The representativeness of the SST climatologies of the historical and current ocean surface states is essential to identify and predict anomalous events. Here we compare five high-resolution SST climatology datasets around the Australian coast to investigate the uncertainty introduced by the reference SSTs to current estimates of SST anomalies. The datasets studied are: (i) 0.05-degree global daily climatology calculated by this study from the ESA SST Climate Change Initiative (CCI) Analysis v2.0 product (1981-2016); (ii) 0.25-degree global daily climatology for 1981-2016, derived from the NCEI daily AVHRR_OI SST; (iii) 0.02-degree SST Atlas of the Australian Regional Seas (SSTAARS), a pixel-wise daily climatology for 1992-2016; (iv) 0.05-degree NOAA Coral Reef Watch (CRW) global monthly climatology for 1985–2012 and (v) 0.1-degree global daily climatology for 1994-2016, derived from the BRAN_2016 ocean reanalysis. The climatology datasets formed from SST CCI analysis v2.0 data are used as the reference to compare datasets (ii)-(v) based on the same reference time period and central year. This study indicates that climatologies (i) and (v) would be suitable for use as a reference over the Australian region. However, for smaller spatial scales, or where a night-only SST climatology is required, the 2 km daily SSTAARS would also be suitable. The feature resolution of the climatology datasets (i) and (v) is significantly coarser than SSTAARS climatology.

Access the poster in PDF:

zenodo https://doi.org/10.5281/zenodo.6840566

ID 012: On the equivalence between Singularity Exponents and Finite Size Lyapunov

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Short abstract
Exponents in remote sensed images of the ocean. Horizontal transport and mixing processes are key to properly understand changes in the global ocean. Finite Size Lyapunov Exponents characterise the rate of separation of infinitesimally close trajectories and therefore provide information of the dispersion processes and the Lagrangian Coherent Structures (i.e. transport barriers and fronts). In order to estimate the Finite Size Lyapunov Exponents (and also Finite Time Lyapunov Exponents), a sequence long enough of the velocity field is required. The Singularity Exponents are a dimensionless measure of the degree of regularity or irregularity of a function at each point of its domain. The estimation of the Singularity Exponents is related to the multifractal properties of any ocean scalar satellite image and then no velocity field is required. Numerical estimations of Singularity Exponents show evidence that different ocean scalars present the same Singularity Exponents and that they coincide with the streamlines of the fow. This in particular means that we can estimate the streamlines from the Singularity Exponents derived from Sea Surface Temperature maps. Here we explore the possibility of computing the Finite Size Lyapunov Exponents without the need of any velocity field. For this we numerically analyse one year of satellite ocean images of Absolute Dynamic Topography and Sea Surface Temperature. Numerical estimations show a linear relationship between the Singularity Exponents and the Finite Size Lyapunov Exponents which is more robust in the case of the Singularity Exponent from Sea Surface Temperature than in the case of the Absolute Dynamic Topography. In the talk, we plan to discuss the causes of these differences and the steps forward to address this equivalence from a theoretical point of view.

Access the poster in PDF:

https://doi.org/10.5281/zenodo.6840754

ID 018: Increased marine heat waves, a major impact of climate change in the Mediterranean

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Short abstract

Mediterranean Sea has suffered an accelerated warming in the most recent 40 years. This warming has brought higher temperatures especially in the extended summer season in the Western Mediterranean (WMED), not only higher extremes but also persistent high values. Alongside, an increase has also be seen in the frequency and intensity of marine heat waves. From the analysis of satellite sea surface temperature (SST) data from GHRSST Level 4 AVHRR_OI Global Blended Sea Surface Temperature Analysis (GDS2) database main characteristics and specially trends of marine heatwaves have been analysed in the Western Mediterranean.

Marine heatwaves' characteristics and trends for the whole WMED and subregions, previously defined by the authors in a former publication, have been studied. A global positive/increasing trend has been found for the occurrence, duration and intensity of marine heatwaves in the WMED, but relevant regional differences arise. Northern and central areas of the WMED show the highest increase of duration and intensities while the Alboran Sea area shows the lowest values in all analysed magnitudes. The area between the Gulfs of Lion and Genoa stands out as a hotspot in the for marine heat waves occurrence in the region. Differences appear not only from a regional point of view but also between seasons with clearly higher trend values for the extended summer season.

Access the poster in PDF:

zenodo https://doi.org/10.5281/zenodo.6840682

ID 021: Use of a high resolution satellite-derived Sea Surface Temperature (SST) climatology for the initialization of a real-time weather forecast model

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Short abstract

The NOAA/NASA Advanced Very High Resolution Radiometers (AVHRR) Oceans Pathfinder Project was used to conduct a daily climatology in order to produce initial SST conditions for the operation of a regional real-time Weather Forecast System (WFS) based on the Regional Atmospheric Modelling System (RAMS). Previous studies have evaluated the importance of a well-defined SST for the simulation and forecast of heavy rainfall events, both in terms of the precipitation distribution and intensity. Therefore, an appropriate representation of this parameter should improve the prediction of these weather events. RAMS uses global monthly climatological data at 1 degree resolution (about 100 km) by default. To improve this spatial and temporal resolution, the AVHRR 4 km SST product was used to substitute the original SST field used by RAMS. The current methodology used this dataset to obtain a daily value for each grid point within the whole simulation grid, computed as the climatological mean of the whole time series, considering a 25-year period. An SST map for the simulation region and for each day of the year is then created, being accessible at any time. The corresponding map is then formatted to be directly incorporated into RAMS before a new simulation-cycle starts. The methodology has been developed to be flexible enough to permit not only a continuous update of the climatological database when more data becomes available, but also to implement other SST data sources, such as GHRSST products.

Access the poster in PDF:

zenodo https://doi.org/10.5281/zenodo.6564169

ID 029: Application of Nonstationary Extreme Value Analysis to Satellite-Observed Sea Surface Temperature Data for Past Decades

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Short abstract

This study provides the recent ISAR observations in the seas surrounding the Korean Peninsula, the Indian Ocean, and the Northwest Pacific Ocean. To understand the characteristics of the sea surface temperature (SST) and its overall vertical structure, we collocated the ISAR temperatures and those from satellite SST, surface drifter, ARGO float, and shipborne thermosalinograph of R/V ISABU. The skin temperature was mostly lower than that of the satellite, and the difference between the two temperatures indicated a diurnal variation. Similar to the results of previous studies, the skin-bulk temperature differences tended to be amplified in the low wind speed. The amplitude of the diurnal fluctuation was inversely proportional to the wind speed, so it was more positively amplified during the day and a relatively small negative bias at night. The differences between surface drifter temperatures and ARGO temperatures also exhibited a diurnal variation with a bias of –0.05K before 9 AM, reaching its highest peak of about 0.2K around 3 PM, and gradually decreased at night. The amplitudes of these temperature differences showed a seasonality with bimodality of the first maximum value in March-April and the secondary peak in September-October. Under low wind condition, the drifter-ARGO temperature differences also showed dominant skin-bulk temperatures differences. The analyses of the temperature differences enabled to understand the comprehensive characteristics of vertical temperature structure and roles of wind speed and stability on diurnal/seasonal variations. More ISAR observations are needed for a substantial understanding of ocean warming in response to climate change.

Access the poster in PDF:

https://doi.org/10.5281/zenodo.6840726

ID 031: Resolution of fronts: comparison of ECOSTRESS 70-m scale L2 to GHRSST L2, L3 and L4 products

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Short abstract

The ECOSTRESS L2 surface temperature pixel scale of 70m provides an opportunity for comparison of gradient intensity and spatial resolution of frontal features observed in GHRSST L2, L3, and L4 products. We carried out our analysis in the Alboran Sea frontal region of the western Mediterranean because of the intensity of the gradients associated with the basin-wide eddies. In all of the GHRSST products, gradients were well resolved using the Sobel 3×3 kernel. However, it was not possible to resolve gradients in ECOSTRESS L2 scenes with the Sobel kernel because of the high noise levels, but gradients were resolved with an 11×9 smooth noise robust gradient kernel proposed by Holoborodko. As expected, SST gradient intensities scaled inversely with both pixel size and the size of the gradient operator. Spatial position of gradients differed substantially among products, with the best fidelity in L2P products, followed by L3. L4 products varied in spatial fidelity as a result of the time scale of temporal averaging, and varied in resolution of gradient intensity depending on pixel size. ECOSTRESS, because of its much smaller pixel scale, provides added value to GHRSST products by identifying more precisely the locations and intensities of the steepest gradients.

Access the poster in PDF:

zenodo https://doi.org/10.5281/zenodo.6840745

ID 037: Assessment of Sea Surface Temperature products over the Baltic Sea

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Short abstract

In the context of the ESA Baltic+ Salinity Dynamics project, the first SMOS (Soil Moisture and Ocean Salinity) sea surface salinity (SSS) dedicated products over the Baltic Sea have been developed. A first prototype of these SSS products evidenced the sea surface temperature (SST) as one important driver of the SSS errors. Considering the low sensitivity of brightness temperatures to SSS changes in cold waters (with a mean value below 3 degrees C in winter in the Baltic Sea), it is crucial to use the most accurate SST product for the salinity retrieval. Besides, SST is used as a template when using multifractal fusion techniques to increase the spatial resolution of these SSS products.

In order to identify the most suitable SST product over the Baltic Sea, we have analysed the state-of-the-art EO-based SST products (OSTIA, CMC, REMSS, CCI) [Woo and Park, 2020], by comparing them with the collocated in-situ temperature measurements provided by SeaDataNet. This analysis has revealed that the best quality salinity product over the Baltic Sea is the CCI SST, with a standard deviation of the difference with in-situ of 0.62 degrees C, , which is still large compared to open ocean regions. Therefore, EO SSS products would benefit from improvements in SST products over the Baltic Sea.

Access the poster in PDF:

zenodo https://doi.org/10.5281/zenodo.6840754

ID 047: Marine Heatwaves in the North Atlantic: Climatology and Trends

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Short abstract

The North Atlantic is characterised by dipole sea surface temperature (SST) differences that result from the regional segments of the global thermohaline circulation: While such Sea Surface Temperature (SST) patterns are well documented, more recently, attention has also been drawn to the urgency of detecting and predicting marine heatwaves (MHW). Like their atmospheric counterparts, MHWs have been associated with anthropogenic climate change, impacting both the marine fauna (e.g., coral bleaching, megafauna mortality, species-range shift) and flora (e.g., dieback of kelp forests, harmful algal blooms). In this study, 39 years of remotely sensed SST observations are used to identify spatio-temporal patterns of MHWs in the N. Atlantic (1982-2020 period). The 0.25˚ spatial resolution data is subject to MHW detection using the deviation from the climatological 90th percentile during at least 5 days as the criteria to measure pixel-wise anomalies. Results show that MHW events are becoming more frequent in the westernmost North Atlantic region, particularly in the Gulf Stream - this zonal pattern agrees with the typical N. Atlantic dipole SST gradient, which is shown to be increasing. Conversely, MHW intensity trends – both mean magnitude and maximum amplitude – reveal the polar amplification signal, i.e., the greatest increases are detected in the northernmost region, where the mean rate of intensity reaches up to 1ºC change, per decade.

Access the poster in PDF:

zenodo https://doi.org/10.5281/zenodo.6840772

ID 053: Assessing the spatiotemporal variability of Sea Surface Temperature in Delaware Bay, USA, Using the GHRSST Data Product

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Short abstract

Studies of Sea Surface Temperature (SST) are essential to understanding the response of the bay's environmental and ecological system to a changing climate, given the imminent effects of climate change. The aim of this study is to assess the spatial and temporal variability of Sea Surface Temperature (SST) in Delaware Bay, USA during the period between 2003 and 2020. In the current study, two datasets consisting of in-situ daily SSTs from six stations operated by the National Data Buoy Center (NDBC) and a 17-year Group for High Resolution Sea Surface Temperature (GHRSST) dataset of 0.01° × 0.01° spatial resolution are employed. GHRSST data were evaluated against long-term in-situ measurements using the Normalized Root-Mean-Square-Error (NRMSE), Normalized Bias (NB), Kling-Gupta Efficiency (KGE), and a comparison of the data probability distribution, revealing strong agreement between the data sets. Non-parametric trend analysis and a change point detection method were used to assess the temporal variability of daily and annual mean SST. Results revealed a statistically significant upward trend of SST series within the study area. The rate of change of the 95th percentile SST and the 5th percentile SST were computed to investigate the temporal evolution of extreme SSTs. An analysis of the correlation between streamflow temperature anomalies at the downstream of Delaware River and SST anomalies in the study area were conducted. A strong correlation was observed in the estuary outlet of the Delaware River. Teleconnections with climate indices showed that the variability in SST patterns was significantly affected by the Western Hemisphere Warm Pool (WHWP), and the North Atlantic Oscillation (NAO) indices.

Access the poster in PDF:

zenodo https://doi.org/10.5281/zenodo.6840830

ID 055: Importance of Ocean Heat Content to the Global Climate System

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Short abstract

Ocean Heat Content is an important component of the Global Climate System. The Ocean Heat Content is largely responsible for precipitation or lack thereof (agricultural impacts), tropical cyclone formation and intensity, coral reef bleaching, and ecological forecasting (e.g. Fish stock). This poster will provide examples of how Ocean Heat Content impacts the global climate system.

Access the poster in PDF:

zenodo https://doi.org/10.5281/zenodo.6840842

Science Session S2 Processing and products

S2 Processing and products: Highlights of the Science Sessions

The Highlights of the Science Sessions included a number of five-minute talks based on the full recorded presentations followed by a short discussion period.

ID 020: Deep-learning models for Single Image Super Resolution: applications to Mediterranean Sea SST products and SST gradients within the Copernicus Marine Service

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Short abstract

In the framework of the Copernicus Marine Service, the Italian National Research Council (CNR) – Institute of Marine Sciences (ISMAR) is responsible for producing and distributing operational near-real-time (NRT) Sea Surface Temperature (SST) products over the Mediterranean and Black Seas. The CNR-ISMAR SST processing chain, which includes several modules, from data extraction and preliminary quality control to cloudy pixel removal and satellite images merging, provides daily (night-time) merged multi-sensor (L3S) and optimally interpolated (L4) foundation SST fields at high (HR) and ultra-high (UHR) spatial resolution (i.e., over 1/16° and 1/100° regular latitude-longitude grids, respectively).

However, the effective resolution of UHR L4 products strictly depends on the availability of high-resolution cloud-free measurements. The Optimal Interpolation algorithm makes use of HR L4 data remapped onto a 1/100° regular grid as first-guess (which means UHR SST features are already filtered out) and it is not able to reconstruct small scale features unless valid L3 observations are present within a short temporal window.

For this reason, CNR is presently working to improve the MED NRT SST products' effective resolution and SST gradients' accuracy through the development of deep learning models. In particular, the application of Convolutional Neural Networks (CNN) in the process of reconstructing high-resolution images from low-resolution ones, the so-called single image Super Resolution (SR) technique, has demonstrated an impressive potential. Here we present preliminary results on the achievements and the limitations in applying this specific class of artificial intelligence techniques to improve the effective resolution (and SST gradients) of our MED-NRT-L4-UHR product.

Q&A with the author

Were there objective ways of comparing the different attempts to preserve features with gap filling? I have noted that you showed convincing figures, but I wondered if there were more objective approaches.

We included RMS error figures in the full presentation.

I noted that there is a challenging issue with ground truth, is there any other possible approach?

Yes, Cristina Gonzalez Haro's metrics might also be another possible approach.

Peter Cornillon followed up adding that he utilizes a log likelihood measure. It serves as another different way of comparing fields that can indicated where a model or satellite is not doing something right.

Link to this presentation:

zenodo https://zenodo.org/record/7120450

vimeo https://vimeo.com/717978093

ID 025: Latest Improvements and Future Plans of the JAXA GHRSST Datasets of MW, LEO-IR and GEO-IR

Submitting author/speaker (Name and Surname): Misako KACHI

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Short abstract

JAXA operationally produces and distributes various satellite-based SST datasets by using passive microwave, polar-orbital InfraRed and geostationary InfraRed imagers in GDS2.0 format from the JAXA GHRSST server (https://suzaku.eorc.jaxa.jp/GHRSST/) and Himawari Monitor (https://www.eorc.jaxa.jp/ptree/) in near-real-time basis and archives past period data since June 2002. We have updated SGLI SST Ver.3 to improve cloud masks in November 2021 and plan to update AMSR2 SST Ver.4.1 soon. Due to the improved cloud masking, SGLI SST V3.0 in the daytime are retrieved from the SGLI measurements only with pre-calculated RTM-based coefficients and Baysian-based PDFs and are 100% independent from any other in-situ and analysed data. AMSR2 SST Ver.4.1 will correct underestimation trends versus in-situ observations over Northern low- and mid-latitudes since 2019 and provide SST retrievals under high-wind and weak precipitation conditions, which are set to missing in previous versions. We also prepare tuning of Himawari SST algorithm corresponding to planning change-over of the Japanese geostationary satellite from Himawari-8 to -9 scheduled in late 2022. Overlap operations of Himawari-8 and -9 are planned by Japan Meteorological Agency (JMA) for a couple of months to inter-calibrate two SST products. We are also preparing multiple SST products for the AMSR3 onboard the GOSAT-GW satellite to be launched in JFY2023. Those products will succeed SST datasets of AMSR-E and AMSR2 and improve robustness of SST retrievals and spatial resolution by adding new channels in 10-GHz. We will introduce the latest status of SST datasets and future plans for AMSR3.

Link to this presentation:

zenodo https://zenodo.org/record/7258981

vimeo https://vimeo.com/725228558

ID 034: OSPO GDP: Cloud Migration of Satellite Sea Surface Temperature Products

Submitting author/speaker: Sheekela Baker-Yeboah

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Short abstract

The NOAA/NESDIS/Office of Satellite and Product Operations (OSPO) processes operational Sea Surface Temperature (SST) products in collaboration with NOAA/NESDIS/Center for Satellite Applications and Research (STAR). GHRSST products include Level-2,3 Advanced Clear-Sky Processor for Oceans (ACSPO) and Level-4 Geo-Polar Blended SST products. These operational products are provided by OSPO through the Product Distribution and Access (PDA) system to domestic and international users. OSPO is working with the Office of Satellite Ground Services (OSGS) within NESDIS to transition product processing and distribution of SST products into an Amazon Web Services (AWS) cloud environment, called the NESDIS Common Cloud Framework (NCCF). Advanced Very High Resolution Radiometer ACSPO 2.8 SST product generation was transitioned in January 2022 and Visible Infrared Imaging Radiometer Suite ACSPO 2.8 SSTs in April 2022. Geo-Polar Blended SST product production is scheduled for transition in February 2023. Products will continue to be distributed via the PDA until the NCCF product distribution component is implemented. An overview will be provided.

Link to this presentation:

zenodo https://zenodo.org/record/7259011

vimeo https://vimeo.com/719093789

ID 045: Overview of the Arctic SST/IST activities for the Copernicus Marine Service at DMI

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Short abstract

Accurate estimates of sea surface (SST) and sea-ice surface temperatures (IST) are crucial for understanding, monitoring and predicting climate change in the Arctic. The Danish Meteorological Institute releases a suite of Pan-Arctic L3 and L4 products in Near-Real-Time and as Multi-Year datasets, as a Production Unit (PU) for the Copernicus Marine Monitoring Service Sea Ice (SI) Thematic Assembly Center (TAC).

Within this framework, the first gap-free (L4) combined SST and IST climate dataset of the Arctic (>58°N) for the period 1982-2021, has been released. Optimal interpolation was used to combine multiple infrared satellite observations to daily, gap-free fields with a spatial resolution of 0.05 degrees. The combination of SST and IST provides a consistent climate indicator which can be used to monitor day-to-day variations as well as climate trends in the Arctic Ocean; sea and sea-ice surface temperature increased about 4.5°C over the period 1982-2021, with the largest warming exceeding 10°C in the north-eastern Barents Sea.

The aim of this presentation is to provide an overview of the existing suite of Copernicus Marine Service Pan-Arctic products for the SST and IST along with the improvements and new products planned for the new phase, including the new version of the L4 Multi-Year climate dataset and its associate Ocean Monitoring Indicators (OMI) which will be released by the end of 2022.

Link to this presentation:

zenodo https://zenodo.org/record/7259036

vimeo https://vimeo.com/719086702

ID 048: Facilitating the Use of the MODIS Aqua L2 SST Dataset

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Short Abstract

The MODIS Aqua L2 SST dataset obtained from the PO-DAAC for the period 2002-2021 is being modified to improve its usability. To begin with the L2 field is being regridded to correct for the bow-tie effect. The bow-tie effect gives rise to an irregular spacing of along-track pixels with the effect increasing away from nadir and, for MODIS, resulting in a non-monotonic ordering of the pixels at distances of about 400 pixels from nadir. This makes estimates of the SST gradient problematic at best. Furthermore, the data are provided in 5 minute granules, resulting in seams every 2030 scan lines. To avoid these seams, the regridded granules are combined into complete orbits starting at 75°S. The starting location minimizes ocean areas exposed to orbit-to-orbit seams.

In addition to geometric modifications, pixels mistakenly flagged as bad are unmasked. Such pixels are found in high-gradient regions and dynamic regions where the retrieved values differ by more than 2°C from that of the reference field. To address the high gradient problem, the mask is divided into objects and each object is examined to determine whether or not the associated SST values are reasonable. To address the reference temperature issue the min/max of SSTs in 5°x5° regions were determined from the complete masked dataset and retrieved values >10% below the minimum and <10% above the maximum were retained.

Link to this presentation:

zenodo https://zenodo.org/record/7259038

vimeo https://vimeo.com/717969600

S2 Processing and products: Pre-recorded talks

ID 007: The 2nd NOAA AVHRR GAC SST Reanalysis (1981-2022)

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Short abstract

The 2nd SST reanalysis (RAN2) was created from 4km GAC data of the AVHRR instruments, flown onboard ten NOAA satellites from September 1981 – present, with the NOAA Advanced Clear-Sky Processor for Oceans (ACSPO) enterprise system. A number of features of the RAN2 SST make it different from existing AVHRR GAC reanalyzes. The data set includes "Subskin" SST, highly sensitive to true skin SST, and "Depth" SST, agreeing much closer with in-situ SST. Both SSTs are retrieved in a full ~3,000 km AVHRR swath. The long-term AVHRR calibration trends are compensated for by daily recalculation of the regression coefficients using matchups with in-situ SSTs collected within moving time windows; shorter-term biases are minimized on a monthly basis by correction of the regression offsets from 31-day windows. Calibration coefficients from L1B data, corrupted by Sun impingements on the sensor, are corrected by interpolation between the unaffected parts of the orbit. Stray light in the Earth view pixels is detected by the nighttime signal in the AVHRR band 2 and screened out. Regional cold SST biases, caused by volcanic aerosol after major eruptions, are mitigated by more conservative cloud screening, only applied in the affected latitudinal bands. The RAN2 SST is available at NOAA CoastWatch, https://coastwatch.noaa.gov/cw/satellite-data-products/sea-surface-temperature/acspo-avhrr-gac.html in swath L2P (144 10-min granules per 24hr interval), and two 0.02° gridded formats: uncollated (L3U; also 144 granules/24hr) and collated (L3C; two global maps per 24hr, for day and night). The presentation describes the major features of the RAN2 SST and evaluates its performance.

Link to this presentation:

zenodo https://zenodo.org/record/7259046

vimeo https://vimeo.com/717904606

ID 044: A 40-year Sea Surface Temperature Climate Data Record from the ESA Climate Change Initiative

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Short abstract

ESA's Climate Change Initiative (CCI) will soon release the third major version of the SST CCI Climate Data Record (CDR) which will cover a 40-year period using data from Advanced Very High Resolution Radiometer (AVHRR), Along Track Scanning Radiometer (ATSR), Sea and Land Surface Temperature Radiometer (SLSTR) instruments, Advanced Microwave Scanning Radiometer (AMSR)-E and AMSR2. The dataset includes both single-sensor products at L2P, L3U, and L3C; plus a Level 4 SST analysis generated using the Met Office Operational Sea Surface Temperature and Ice Analysis (OSTIA) system. Version 3 of the SST CCI CDR will be the first to make use of data from AVHRR/1 instruments carried on board NOAA-6, -8, and -10 platforms. This will increase the data coverage in the 1980s and allow the dataset to extend back to 1980. The quality of the AVHRR retrievals has been improved by using a new biasaware optimal estimation (BAOE) technique and updated radiative transfer modelling including tropospheric dust which significantly reduces the SST biases due to dust aerosols seen in previous CDRs. Passive microwave AMSRE and AMSR2 data were previously available as an experimental produce from SST-CCI, but are now included in the main CDR for the first time. In comparison to the previous CDR, this new release will also use of full resolution MetOp data and include the dual-view SLSTR sensors. Complementary to the ESA CCI, the Copernicus Climate Change Service (C3S) is producing an Interim CDR (ICDR) to proving an ongoing extension in time of the SST-CCI CDR. The C3S ICDR is algorithmically equivalent to the CCI CDR and will switch from extending the current version 2 record to extending CCI version 3 during 2022.

Link to this presentation:

zenodo https://zenodo.org/record/7259054

vimeo https://vimeo.com/719081007

ID 046: Overview of the Baltic Sea and North Sea SST activities for the Copernicus Marine Service at DMI

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Short abstract

The Danish Meteorological Institute serves as a Production Unit (PU) for the Sea Surface Temperature (SST) Thematic Assembly Center (TAC) of the Copernicus Marine Monitoring Service. Within this framework, a suite of L3 and L4 SST products for the Baltic and North Sea are produced daily and as multi-year products. Having entered a new phase of the project in 2022, a range of activities are planned for the next three years, from releases of new products to improvements on existing ones. An example of a new product is the hourly L4 SST resolving the diurnal cycle in the North and Baltic Seas, currently under development. It is based on single-sensor satellite SST, aggregated hourly and optimally interpolated to generate gap-free hourly fields. Upon release, the product will allow monitoring of the daily SST variability, especially relevant for algal blooms and marine heatwaves. An improvement of the existing daily L4 SST product is related with its associated uncertainties as analysis showed them to be higher than those observed from comparisons with drifting and moored buoy in-situ sensors. The aim of this presentation is to provide an overview of the existing SST products and their quality, along with a summary of the improvements planned for the ongoing Copernicus Marine Service phase, especially those to be implemented by the end of 2022; preliminary results for the generation and validation of the new L4 diurnal SST product and the validation of modelled uncertainties of the daily L4 SST for the North/Baltic Seas will be presented.

Link to this presentation:

zenodo https://zenodo.org/record/7259067

vimeo https://vimeo.com/719081983

S2 Processing and products: Interactive (Posters)

ID 004: Towards a daily Gridded Super-Collated SST Product from Low Earth Orbit Satellites (L3S-LEO-D) at NOAA

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Short abstract

NOAA provides 0.02° gridded super-collated (L3S) SST products from low earth orbit (LEO) satellites, produced using its Advanced Clear-Sky Processor for Ocean (ACSPO) enterprise SST system. The L3S-LEO family comprises two lines: PM (from afternoon satellites; currently using 2 VIIRS instruments onboard NPP/N20) and AM (from mid-morning satellites; currently using 2-3 AVHRR FRAC instruments onboard Metop-A/B/C). Both L3S-LEO PM/AM products are reported twice daily, one for day and one for night, resulting in four files per day, sampling the diurnal cycle at approximately 1:30am/pm (LEO-PM) and 9:30am/pm (LEO-AM) local times. Complete archives of ACSPO L3S-LEO PM/AM products are available at PO.DAAC and CoastWatch, with new data added in near-real-time.

Access the poster in PDF:

zenodo https://zenodo.org/record/7119761

ID 010: Naval Oceanographic Office Sea Surface Temperature Processing and Products

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Short abstract

The Naval Oceanographic Office (NAVOCEANO) Data Collection Division is responsible for providing near-real-time sea surface temperature (SST) measurements to the US Navy and national/international partners. The Naval Research Lab (NRL) at Stennis Space Center provides the research and development of the SST processing for numerous satellite data sets that are operationally processed at NAVOCEANO. This SST data is assimilated in the Navy's Global Ocean Forecast System (GOFS) and Global Environmental Model (NAVGEM) and soon in the Navy Global Earth System Prediction Capability (ESPC). NAVOCEANO is a member of the Group for High Resolution SST (GHRSST) science group operationally providing and acquiring GHRSST datasets.

NAVOCEANO operationally processes satellite-derived SSTs, which are ingested into GOFS and NAVGEM to provide forecasts at both the global and regional scale, and is a Regional Data Assemble Center (RDAC) for GHRSST. The intent of our presentation is to go into further detail on the products we create, the satellites we use (and will use in the future), our contributions to the GHRSST community, and show graphics of some recent events, such as the Hunga Tonga–Hunga Ha'apai volcanic eruption.

ID 016: Recent updates to the NCEP SST analysis and comparison with OSTIA and CMC products

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Short abstract

The NCEP Near-Surface Sea Surface Temperature (NSST) has been operational since 2017. It has been integrated within the operational Global Data Assimilation System, utilizing foundation temperature as the analysis variable. Products from OSTIC and CMC similarly use foundation temperature, but integrate more observation into the production of their SST analyses.

An upgrade to NSST has been prepared that targets expanded observational coverage by including additional satellites and reducing the thinning mesh utilized for data selection for SST-sensitive satellite data. Additional changes to the background error correlations have been tested to further constrain data impacts locally. A tighter quality control for AVHRR radiance with cloud flag in the data set is included in this update as well. The combined upgrade package shows better fit to both in-situ and satellite observations. As expected, the changes have also resulted in resolving higher resolution spatial structures and improved the representation of the diurnal variability of the foundation temperature for related areas.

An inter-comparison among L4 products from NCEP NSST, OSTIO, and CMC has been performed and includes calculation of RMS and bias relative to OSTIA for specific areas. Overall, OSTIA and CMC products are closer to each other than to NSST. However, for some local areas, any of the three can be the outlier. The evaluation suggests that the individual analysis can be improved by exploring root causes for the differences among products.

Access the poster in PDF:

https://zenodo.org/record/7119908

ID 023: Copernicus Sentinel-3 Sea (and sea-Ice) Surface Temperature: product status, evolutions and projects

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Short abstract

The first Copernicus Sentinel-3 satellite was launched on 16th February 2016 and the second on 25th April 2018. The Sentinel-3A/B satellites observe high quality Sea Surface Temperature (SST) from the Sea and Land Surface Temperature Radiometer (SLSTR). These accurate SSTs provide a reference satellite SST dataset and time-series for other satellite SST missions and are important for climate monitoring.

Operational SLSTR SST products have been distributed from the EUMETSAT marine centre since 5th July 2017. EUMETSAT performs ongoing validation activities for SLSTR SST, together in coordination with the Sentinel-3 validation team, and real time monitoring is shown from the link to metis.eumetsat.int. Validation results show the products performing extremely well, and dual-view SSTs recommended to be used as a reference SST source, with some users already using SLSTR SST reference data.

EUMETSAT began activities in 2021 towards revised and improved algorithms for SLSTR SST and sea-ice Surface Temperature (ST) with the intention of the operational implementation of SLSTR day-2 SST and day-1 sea-ice ST by 2025. This includes improvements to the Bayesian cloud-screening, retrieval coefficient updates, inclusion of depth SST in addition to skin SST, potential evolution to include full nadir grid, and the first operational implementation of sea-ice ST for SLSTR. Shorter term improvements, planned by 2023, include revised SST coefficients, updates to ADI and DDI tests, and updates to SSES scheme. A demonstrational sea-ice ST prototype processor has been implemented on the Copernicus WEkEO platform. Recent results and information on further ongoing projects and evolutions relating to Sea Surface Temperature at EUMETSAT will be presented.

Ongoing validation activities are important for assessing and maintaining SLSTR SST product quality. In addition to inter-comparisons with other satellite SST, key components are collocations and analyses with drifting buoy SSTs. A Copernicus-funded EUMETSAT project called 'Towards Fiducial Reference Measurements (FRM) of Sea-Surface Temperature by European Drifters' (TRUSTED) is now in its fifth year. Over 150 high-resolution drifting buoys (HRSST-2), plus calibration per sensor, have been deployed so far. A service of measurements will continue at a rate of additional 25 buoys per year, with a focus at higher latitudes and other priority regions. Activities have also begun towards the requirements, design and prototype of sea-ice surface temperature drifting buoys needed for the validation of Copernicus satellite sea-ice surface temperature products. Activities continue to assess and validate these reference buoys as FRM for SLSTR together in coordination with the GHRSST HRSST Task Team.

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zenodo https://zenodo.org/record/7119783

ID 032: Evaluation of sea surface temperatures derived from the HY-1C and HY-1D satellites

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Short abstract

As one of the key payloads on the Chinese HaiYang (HY)-1C and HY-1D satellites, the Chinese ocean colour and temperature scanner (COCTS) was designed for global sea surface temperature (SST) and ocean colour detection. Global sea surface temperatures (SSTs) have been detecting by the COCTS instruments since September 2018. The SSTs derived from the COCTS on the HY-1C (COCTS/HY-1C) and HY-1D satellites (COCTS/HY-1D) and the nonlinear SST algorithm with corresponding coefficients will be introduced. The retrieval SSTs from Jan. 1, 2019 to Mar. 31, 2020 were evaluated by the in-situ measurements from iQuam with root mean square errors (RMSEs) of 0.84 °C for daytime and 0.97 °C for nighttime and robust standard deviations (RSDs) of 0.73 °C for daytime and 0.72 °C for nighttime, respectively. RMSEs of 0.65 °C and 0.71 °C and RSDs of 0.51 °C and 0.47 °C were obtained for the daytime and nighttime SSTs of the COCTS/HY-1D recorded from April 26 to August 31, 2021, using a spatiotemporal matching window of 4 hours and 2.5 km. Daily gridded retrieval SSTs from COCTS on both HY-1C and HY-1D were compared with SSTs from the moderate-resolution imaging spectroradiometer (MODIS) on Terra satellite and the visible infrared imaging radiometer (VIIRS) on the Suomi National Polar-orbiting Partnership (S-NPP) satellite. Both daytime and nighttime SSTs from COCTS are consistent with those from MODIS and VIIRS.

Access the poster in PDF:

zenodo https://zenodo.org/record/7119951

ID 035: Evaluation and intercomparison of GHRSST products at a global scale

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Short abstract

Sea Surface Temperature (SST) plays an important role in the production of satellite based Sea Surface Salinity (SSS) observations. On the one hand, it is used as an auxiliary parameter for SSS retrieval from brightness temperature to produce L2 and L3 datasets. On the other hand, it is used as a template to increase spatial resolution using multifractal fusion techniques (L4 product).

Traditionally, Soil Moisture and Ocean Salinity (SMOS) SSS datasets produced at the Barcelona Expert Center were based on OSTIA SST product. In this work, we revisit this election and assess different sources of satellite-derived SST products. The assessment will consist of:

- comparison with in-situ data (ARGO floats);
- performing a correlated triple collocation analysis [González- Gambau et al., 2020] between the different products to decide which one presents the lower uncertainty;
- spectral and singularity analysis to assess the spatial resolution of each SST product [Hoareau et al. 2018].

Access the poster in PDF:

zenodo https://zenodo.org/record/7258969

ID 054: Single channel and split-window SSTs from Landsat in Antarctica

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Short abstract

Landsat recently released its Collection 2 Level 2 Surface Temperature product, marking the first comprehensive calculations of surface temperatures from the four-decade-long Landsat mission sequence. Producing surface temperatures requires complex integration of Landsat imagery with external atmospheric datasets and model outputs, to compensate for the lack of dual thermal bands (Landsat 4/5/7) and other bands required for atmospheric correction (Landsat 4/5/7/8/9). Although this work provides a reliable surface temperature product, gaps still exist for sea surface temperature (SST) retrievals: the algorithm is optimised for acquiring land surface temperatures (i.e., not SST), and surface temperatures are not produced at night or around Antarctica.

Here, we develop Landsat single-channel and split-window SST algorithms that will allow for integration with GHRSST products and will also be developed as an on-demand, cloud-based, user-customizable data product. The single channel algorithm uses coincident atmospheric profiles from reanalysis data for temperature, relative humidity, and geopotential height as inputs into a radiative transfer model to account for the atmospheric effects on thermal retrievals. The Non-Linear SST algorithm for split-window Landsat data (Landsat 8/9) will use the Canadian Meteorological Center Global Foundation SST product as a SST reference, and radiative transfer model-based simulations of at-sensor brightness temperatures to derive the algorithm coefficients. Our cloud-based workflow—modelled after the ICESat-2 SlideRule project—will provide a framework for on-demand data product generation and serving, allowing users to specify algorithms and atmospheric data inputs and models to retrieve Landsat SSTs optimised for their scientific needs.

Access the poster in PDF:

zenodo https://zenodo.org/record/7258965

Science Session S3 Calibration, Validation and Product Assessment

S3 Calibration, Validation and Product Assessment: Highlights of the Science Sessions

The Highlights of the Science Sessions included a number of five-minute talks based on the full recorded presentations followed by a short discussion period.

ID 006: Comparison of GHRSST SST analysis in the Arctic Ocean and Alaskan coastal waters using saildrones: Application to a use case in the Y-K Delta

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Short abstract

There is high demand for complete satellite SST maps (or L4 SST analyses) of the Arctic regions to monitor the rapid environmental changes occurring at high latitudes. Although there is a plethora of L4 SST products to choose from, satellite-based products evolve constantly with the advent of new satellites and frequent changes in SST algorithms with the intent of improving absolute accuracies. The constant change of these products, as reflected by the version product, make it necessary to do periodic validations against in-situ data. Eight of these L4 products are compared here against saildrone data from two 2019 campaigns in the western Arctic, as part of the MISST project. The accuracy of the different products is estimated using different statistical methods, from standard and robust statistics to Taylor diagrams. Results are also examined in terms of spatial scales of variability using spectral analysis. The three products with the best performance at this point and time are used in a case study of the thermal features of the Yukon-Kuskokwim delta. Comparisons are also made with Salinity data from NASA's Soil Moisture Active Passive Mission. Overall, the statistical analyses show that two L4 SST products had consistently better relative accuracy when compared to the saildrone subsurface temperatures. Those are the NOAA/NCEI DOISST and the RSS MWOI SSTs. Results will also be presented on comparing the spectral variance and feature resolution. Comparisons are all done using Saildrone as the reference.

Q&A with the author

You are showing very significant differences among the L4 SST products in the Arctic. How do we go from documenting to understanding these differences?

SST maps are worth a hundred words. We need to improve the documentation of the data sets and their regional differences; global validation does not apply to recommendations of what should be used regionally and particularly for the Arctic region.

On what spatial scales do the new sensors need to resolve dynamics in the Arctic? About the 10-km spatial scale mentioned, was that level of skill due to the microwave sensor limitation?

We already resolved many scales with current satellite products, as indicated by the Yukon River discharge being resolved. About the second question, the answer is due to the lack ok high resolution IR data at high latitudes.

Huai-Min Zhang commented that the NOAA/NCEI OISSTs better performance is related to the new sea ice concentration to SST conversion (Banzon et. Al 2021) which was implemented in OISST v2.1, overcoming the Arctic warm biases in OISST v2.0. The better performance was also verified independently by NOAA/PMEL scientists against their Saildrone data.

Link to this presentation:

zenodo	https://zenodo.org/record/7259071
vimeo	https://vimeo.com/717998613

ID 057: Constructing sampling and measurement error models for ICOADS SST from ships based on ESA CCI SST analysis

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Short abstract

Taking advantage of high resolution, reliable uncertainty estimates, and in-situ data independence of daily fields of the European Space Agency (ESA) Climate Change Initiative (CCI) SST Analysis product (hereinafter, CCI SST), versions 1, errors of 1°x1° monthly bin averages of ship SST observations from International Comprehensive Ocean-Atmosphere Data Set (ICOADS), Release 3.0, were modelled as a sum of random effects, once their systematic biases were approximated and removed as their climatologically-averaged differences from similarly binned CCI SST. For 1992-2010 period, in more than 66% (50%) of locations with temporal coverage exceeding 50% (66%) for 1°x1° monthly bins containing more than one observation, the error magnitude agrees within 20%(10%) with the estimates, based on the random error model. These error estimates were also split into sampling and measurement error components. Seasonal variations in the total error magnitude were traced to the sampling error component, which is driven by seasonal changes in the intra-bin SST variability, while the seasonality of measurement error estimates appears not significant (by Levene's test for variance). Random measurement error estimates for different measurement methods used on ICOADS ships compared well with previously published estimates. Improved error estimates were constructed by recombining all-season measurement error estimates with sampling error estimates based on the full data sample from the CCI SST data set.

Link to this presentation:

zenodo https://zenodo.org/record/7259086

vimeo https://vimeo.com/720612527

S3 Calibration, Validation and Product Assessment: Pre-recorded talks

ID 005: High Latitude Sea-Surface Skin Temperatures Derived from Saildrone Infrared Measurements

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Short abstract

From 15th May to 11th October 2019, six Saildrone autonomous surface vehicles (ASVs) were deployed for 150-day cruises collecting a suite of atmospheric and oceanographic measurements from Dutch Harbor, Alaska, transiting the Bering Strait into the Chukchi Sea. Two Saildrones funded by NASA (the National Aeronautics and Space Administration), SD-1036 and SD-1037, were equipped with infrared pyrometers in a “unicorn” structure on the deck for the determination of the ocean sea-surface skin temperature (SSTskin). We present an algorithm to derive SSTskin from the downward- and upward-looking radiometers and estimate the main contributions to inaccuracy of the SSTskin. After stringent quality control of data and eliminating measurements influenced by sea ice and precipitation, and restricting the acceptable tilt angle of the ASV based on line-by-line radiative transfer model (LBLRTM) simulations, SSTskin can be derived to an accuracy of 0.12 K. The error budget of the derived SSTskin is developed and the largest component comes from the instrumental uncertainties assuming the viewing geometry is adequately determined. Thus, Saildrones equipped with these sensors could provide sufficiently accurate SSTskin retrievals for studying the physics of the thermal skin effect, in conjunction with accurate sub-surface thermometer measurements, and for validating satellite-derived SSTskin at high latitudes.

Link to this presentation:

zenodo https://zenodo.org/record/7259096

vimeo https://vimeo.com/718309135

S3 Calibration, Validation and Product Assessment: Interactive (Posters)

ID 011: Validation of FY-3E/MERSI-LL Sea Surface Temperature

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Short abstract

The FengYun-3E(FY-3E) satellite is the first early-morning orbit satellite in China's polar orbiting meteorological satellite family. It was launched from the Jiuquan Satellite Launch Center of China on July 5, 2021. Its local time at descending node is 5:30 AM. The split window data of Medium Resolution Spectral Imager-Low Light (MERSI-LL) onboard FY-3E is used to estimate SST. Bias and RMSE of FY3E/MERSI-LL SST from January to February 2022 are -0.02 and 0.47 by comparison with in-situ buoy data (iQUAM). Further validation against in-situ and CMC will be discussed during the GHRSST XXIII.

Access the poster in PDF:

zenodo https://zenodo.org/record/7119349

ID 027: Retrieval of Sea Surface Temperature from HY-1C COCTS

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Short abstract

The Haiyang-1C (HY-1C) satellite is the first operational ocean colour satellite of the Chinese HY-1 series satellites, launched in September 2018. The Chinese Ocean Colour and Temperature Scanner (COCTS) on board HY-1C satellite has two thermal infrared channels with the spectrum range of 10.30-11.40 μm and 11.40-12.50 μm for sea surface temperature (SST) observations. The Bayesian cloud detection and optimal estimation (OE) SST retrieval were applied to COCTS data in this study. The Bayesian cloud detection algorithm that has been developed is based on the Bayes' theorem and used simulation of COCTS observations. The MODerate resolution atmospheric TRANsmission (MODTRAN) model was used for simulation of COCTS brightness temperatures. Global SSTs were retrieved from COCTS by OE from July 2019 to August 2019 and were validated using iQuam buoy SST and Sea and Land Surface Temperature Radiometer (SLSTR) SST. Comparison of COCTS OE SST with buoy SST showed that the COCTS SSTs are cooler than buoy measurements by −0.16 ºC on average, and the standard deviation (SD) of differences was 0.46 ºC. The mean difference of COCTS OE SST with matched skin temperatures from the SLSTR is -0.02 ºC, with a SD of 0.45 ºC. These validation results of COCTS OE SST demonstrated that Bayesian cloud detection and OE SST retrieval algorithm worked well for HY-1C COCTS.

Access the poster in PDF:

zenodo https://zenodo.org/record/7119788

ID: 028 Application of Nonstationary Extreme Value Analysis to Satellite-Observed Sea Surface Temperature Data for Past Decades

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Short abstract

Extreme value analysis (EVA) has been extensively used to understand and predict long-term return extreme values. This study provides the approach to EVA using satellite-observed sea surface temperature (SST) data over the past decades. Representative EVA methods were compared to select an appropriate method to derive SST extremes of the East/Japan Sea (EJS). As a result, the peaks-over-threshold (POT) method showed better performance than the other methods. The Optimum Interpolation Sea Surface Temperature (OISST) database was used to calculate the 100-year-return SST values in the EJS. The calculated SST extremes were 1.60–3.44 °C higher than the average value of the upper 5th-percentile satellite-observed SSTs over the past decades (1982–2018). The monthly distribution of the SST extremes was similar to the known seasonal variation of SSTs in the EJS, but enhanced extreme SSTs exceeding 2 °C appeared in early summer and late autumn. The calculated 100-year-return SSTs were compared with the simulation results of the Coupled Model Intercomparison Project 5 (CMIP5) climate model. As a result, the extreme SSTs were slightly smaller than the maximum SSTs of the model data with a negative bias of –0.36 °C. This study suggests that the POT method can improve our understanding of future oceanic warming based on statistical approaches using SSTs observed by satellites over the past decades.

Access the poster in PDF:

zenodo https://zenodo.org/record/7258958

ID 040: Assessing the Ability of Satellites to Resolve Sea Surface Temperature Variability – The ATOMIC Region

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Short abstract

Direct measurements of the SST from multiple platforms deployed during the Atlantic Tradewind Ocean-Atmosphere Mesoscale Interaction Campaign (ATOMIC) field campaign are used to evaluate the ability of satellite products to accurately represent the spatial SST variability. In-situ SST measurements from the Research Vessel Ronald H. Brown, Saildrones, and drifters were collocated with five leading daily Level 4 SST analyses and two Level 3 single-sensor SST products during the period from January 1 to February 24, 2020. The absolute accuracy of the satellite products was generally good with random errors on the order of 0.2 K or less, though most exhibited a small cool bias of ~0.1 K. Sub-grid SST variability in the ATOMIC region was small (< 0.03 K) in relationship both to other regions and to uncertainties in the satellite products. Despite their absolute accuracy, the satellite products were unable to provide a reliable representation of SST spatial gradients within the ATOMIC domain on the scale of their respective grid resolutions. Correlations between satellite-derived and observed cell-to-cell SST differences were low, as the uncertainty in the satellite products dominated over small cell-to-cell variability in the region. The products better represented the spatial SST variability on scales of 1° or more. Simulations demonstrated that a satellite product precision of 0.05 K or less would be needed to successfully reproduce the observed SST spatial variability at the grid cell level, but this is challenging with current capabilities. Independent observations from the Arctic showed greater variability and a relaxed accuracy requirement.

Q&A with the author

Is there already a warming model in the GFS? Is this something you to consider and are you potentially doing a double correction?

We did not explicitly looked at GFS. We just focused on this particular model and all the tuning nobs in there. Need to look at what is already in the GFS model. We can look at other models like GOTM, but there are current activities underway to integrate this particular model within NOAA. I don't think there is anything double counted. There might be some consistency issues in the fluxes. A sensitivity of the fluxes to the evolution of the SSTs was not done. This is something I would like to look at with you in the future.

I noticed that you use a wave model forcing in your experiments. What happens if you just use winds?

In one of the multiple configurations we looked at the model without any dependence on the wave parameters. These tests indicated that the inclusion of the waves had a positive impact. Did not have wave parameters for all the regions like the Mediterranean. In a global sense, inclusion of wave effects had a positive impact on the average global statistics.

Access the poster in PDF:

zenodo https://zenodo.org/record/7119985

ID 042: NOAA STAR SOCD OceanView: The Level-4 thermal fronts module

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Short abstract

The NOAA STAR SOCD OceanView (OV) v1.0 was publicly released in May-2021 at *https://www.star.nesdis.noaa.gov/socd/ov/*. The OV is a web-based application delivering an integrated display of remote sensing, *in-situ*, and model data over oceans, polar areas, coastal and inland waterways. It incorporates products primarily from NOAA and some from NASA and other sources, spanning satellites, aircraft, and models. This visualization tool is still evolving and has several modules, including an experimental thermal front module capable of deriving and interactively visualizing level-4 fronts. The overall long-term activities of GHRSST Climatology and L4 Inter-comparison Task Team (IC-TT) 3 are to:

1. Validate L2, L3, and L4 SST gradients in highly variable regions using SailDrones
2. Produce an online visualization tool for L4-SST gradients
3. Develop the science to calculate fronts and intercompare
4. Validate SST gradients/fronts with other independent but related data, e.g., salinity gradients or altimeter currents
5. Compare feature resolution and its spatial consistency across marine regions
6. Compare SST gradients over seasonal and interannual time scales

The OceanView tool contributes explicitly to #2 above, will potentially contribute to #3 and #4, and for general visualization purposes. It offers an interactive visualization with various filters to sub-select fronts and a profiler to analyze individual fronts. Currently, it has only one L4 SST front (NOAA GOES-POES blended). However, the system is scalable and will be expanded depending on identified needs and the path forward. This preliminary presentation aims to gauge features of interest and potential extension to meet GHRSST TT objectives.

Access the poster in PDF:

zenodo https://zenodo.org/record/7119199

ID 058: T-MEDNet observation network: a ground truth for ultra-high resolution satellite SST in the Mediterranean nearshore and coastal ocean

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Short abstract

Since nearly two decades, the T-MEDNet initiative (www.t-mednet.org) aims to develop an operative and cost-effective climate change observation network in Mediterranean coastal ecosystems based on collaborative approaches. In T-MEDNet, seawater temperature is sampled continuously at hourly-frequency using data loggers (accuracy ±0.21°C) deployed by divers at standard depths, every 5m from the surface down to 40m depth. To date, the temperature network gathers 23 Marine Protected Areas and 17 Research Institutions from eight Mediterranean countries, from Gibraltar straight to the West, to the Eastern Levantine Sea. Sustained observations are conducted in 80 coastal sites, among which 40 with near surface sampling, across spatial and temporal scales (multi-decadal for the longest). The high-frequency multi-year time series are managed in a centralized way and regularly updated, resulting in a harmonized and quality-checked database of over 20 million *in-situ* samples.

T-MEDNet observations have proved key for a range of studies including the validation of gridded satellite sea surface temperature (SST) products, the analysis of coastal dynamics, decadal warming trends, and the assessment of marine heatwaves ecological impacts. Due to its unique features, T-MEDNet observation network can be considered as a ground truth for satellite SST in the Mediterranean nearshore and coastal ocean, with strong potentialities for the validation of, then joint use with, ultra-high resolution SST (<100m) from the TRISHNA and SENTINEL missions. In that sense T-MEDNet is seeking for support and cooperation at all levels for building satellite-*in-situ* synergies to guide evidence-based climate change coastal adaptation strategies.

Following multiple users' requests for a reduced L3S-LEO temporal resolution and data size, with increased coverage and improved performance metrics, this presentation discusses the newly produced L3S-LEO-D product, created by collating the L3S-LEO AM/PM Day/Night products into a single daily SST. The main challenges in creating the L3S-LEO-D SST are systematic biases between individual L3S-LEO SSTs due to diurnal warming, and movement of SST features over the course of the 24-hour collation window. In the ACSPO L3S-LEO-D algorithm, the inter-satellite biases due to

diurnal warming are mitigated by debiasing/harmonising individual L3S-LEO products to night-time L3S-LEO-PM using a statistical model based on modelled wind speed and mean solar insolation. After diurnal debiasing is applied, individual L3S-LEO SSTs are combined using an iterative method, focusing on preservation of features and minimization of residual cloud leakages.

Access the poster in PDF:

zenodo https://zenodo.org/record/7258942

Science Session S4 Algorithms

S4 Algorithms: Highlights of the Science Sessions

The Highlights of the Science Sessions included a number of five-minute talks based on the full recorded presentations followed by a short discussion period.

ID 001: Improving the atmospheric correction algorithms for sea surface skin temperature retrievals from MODIS using machine learning methods

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Short abstract

Satellite retrievals of sea surface skin temperature (SST_{skin}) have become necessary for many near-real time applications. The missions of the two MODISs have provided continuous measurements for more than twenty years and have played a significant role in generating time series of quantitative estimates of SST_{skin}. This study used four machine learning approaches: eXtreme Gradient Boosting (XGBoost), support vector machines (SVM), random forests (RF), and artificial neural networks (ANN), to develop improved atmospheric correction algorithms for satellite-derived SST_{skin} in the Caribbean region. A set of satellite and in-situ measurements, including SST, the atmospheric state and surface radiation, taken on research cruises, from surface moorings and drifting buoys was used to train the machine learning models. Finally, the reliability and shortcomings of various machine learning methods were assessed through comparisons with SST_{skin} derived from shipboard and other in-situ measurements. Overall comparisons show encouraging results: the biases of various machine learning approaches vary between -0.076 K to 0.013 K; with the XGBoost showing the best correlation in a statistical analysis of in-situ SST measurements. This study contributes to improving our understanding of the key environmental properties and will reduce uncertainty in earth science and climate research.

Q&A with the author

This is a limited geographical area using other radiometer transects around the world. The study is limited by the radiometers. Why not do a simulation study globally? That way they could assess the method independently of where the radiometers are.
We checked the performance globally, but decided to focus on the study area.

Did you trained the NLSST coefficients with the global data set or the limited training data set?
We used MODIS matchups to compare with the machine learning because MODIS uses a NLSST algorithm.

Obviously, you got good results with different methods. Which method do you recommend?

Vector Machine method is powerful. Already used by ocean colour community. Time costs are important.

Link to this presentation:

https://zenodo.org/record/7259108

https://vimeo.com/717898530

ID 039: Evaluation of Modeled Diurnal Warming Estimates for Use in Producing SST Analyses

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Short abstract

The blending of SST retrievals from different times and representative depths in the generation of Level 4 SST analyses requires compensation for variability associated with processes like diurnal warming. A version of the Kantha-Clayson one-dimensional turbulence closure model with wave effects has been modified to simulate diurnal warming at arbitrary times and depths based on forcing data obtained from global numerical weather prediction and wave models. The model has been integrated into the NOAA NESDIS GOES-POES Blended SST analysis and shared with EUMETSAT. The model performance using these forcing data, however, has not yet been thoroughly evaluated, particularly in instances of large diurnal warming which are of the greatest importance for application to SST analysis generation.

Here, we evaluate the model performance over four seasons using observations of diurnal warming derived from operational geosynchronous satellite SST retrievals. The model is forced with 6-hourly data from the NOAA Global Forecast System (GFS) and Wave Watch III models and the simulated diurnal warming amplitudes are compared with estimates derived from the Meteosat-11, GOES-16, and Himawari-8 satellites. Multiple model configurations and "tunable" parameters are evaluated to identify the best achievable performance. Results from direct point-to-point comparisons and derived distributions of diurnal warming amplitudes provide a recommended model configuration and demonstrate that the model can yield realistic predictions with uncertainty levels sufficient for application to SST analyses. The identified model configuration is also shown to produce accurate estimates of diurnal warming observed from multiple research cruises, lending additional confidence in the model performance.

Link to this presentation:

zenodo https://zenodo.org/record/7259110

vimeo https://vimeo.com/717888931

S4 Algorithms: Pre-recorded talks

ID 019: Impact on sea-surface-temperature feature detection from improved daytime cloud detection for SLSTR

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Short abstract

The Sea and Land Surface Temperature Radiometer (SLSTR) has a complex dual viewing geometry, with near-nadir thermal observations with a spatial footprint around 1 km, and non-co-registered reflectance channels at 0.5 km spatial resolution. A preprocessor has been developed that optimises the averaging of reflectances onto a grid matching the infrared image grid, giving better reflectance-IR compatibility for purposes such as cloud detection. The preprocessor also enables use of sub-IR-pixel reflectance variability as a cloud detection metric, replacing thermal standard deviation as a spatial coherence metric.

The impact of this alternative day-time detection on the ability to observe sea surface temperature (SST) thermal features is presented. The thermal standard deviation metric is sensitive to local thermal gradients, aiding detection of cloud edges and scattered cloud particularly at night, but has the disadvantage of often masking frontal features. We show that such problems are significantly reduced during the day when using sub-pixel standard deviation of a suitable reflectance channel as a substitute. At night, the thermal standard deviation remains essential to avoid excessive failures to detect cloud.

S4 Algorithms: Interactive (Posters)

ID 008: MW / IR intercomparison campaign for the establishment of a SST skin – subskin relation

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Short abstract

Temperature rise and the immediate effect it has over the Arctic calls for increased monitoring of sea surface temperature (SST), which demands the highest possible synergy between the different sensors orbiting Earth, both on present and future missions. One example is the possible synergy between Sentinel-3's SLSTR and the future Copernicus Imaging Microwave Radiometer (CIMR), which is currently in development phase. To achieve that, there is a need to establish a relation between skin and subskin SST, which are measured by infrared and microwave sensors respectively. That could lead to the creation of better datasets that could be assimilated into climate models.

To address the aforementioned issue, the Danish Meteorological Institute (DMI) and the Technical University of Denmark (DTU) did, on June 2021, a week-long intercomparison campaign between Denmark and Iceland, where they collected data by simultaneously deploying microwave and infrared sensors side-by-side. DMI is a part of the International Sea Surface Temperature Fiducial Reference Measurement Radiometer Network (ISFRN) and has experience on shipborne radiometer deployments in the North Sea, and DTU has long experience in microwave radiometer deployment campaigns. In this particular campaign, two ISARs (Infrared Sea Surface Temperature Autonomous Radiometer), measuring on the 9.6 – 11.5 µm spectral band, were deployed alongside two recently refurbished EMIRADs, namely EMIRAD-C and EMIRAD-X, measuring on C and X band respectively. The intercomparison campaign and the corresponding research are funded by ESA as part of the SHIPS4SST Phase 2 project.

This study aims at demonstrating the methodology applied to retrieve SST from the microwave brightness temperature using Optimal Estimation techniques, and present a first attempt to establish a relationship between skin and subskin SST, as well as the overall research progress so far.

Access the poster in PDF:

zenodo https://zenodo.org/record/7258934

ID 017: Application of Deep Neural Network in Estimating Sea Surface Temperature from INSAT-3D Imager

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Short abstract

Sea surface temperature (SST) is one of the important essential climate variables. The continuous monitoring of the SST is required to study the Earth's climate change. Additionally, SST information is necessary to understand many oceanic processes and meteorological events. In the present study, a machine learning technique based on deep neural network (DNN) is exploited to estimate the SST from infrared Imager on-board India's geostationary satellite INSAT-3D. To establish the DNN, a matchup dataset is prepared by collocating the split-window observations of INSAT-3D Imager and in-situ measurement of SST for the years 2017-2020. Further, 70% of the matchup data is randomly selected for training the DNN, whereas, the rest 30% is used for testing. The assessment of the trained DNN is performed in terms of the standard statistical quality indicator viz., bias and root-mean-squared error (RMSE), etc. A negligible bias with RMSE of ~0.5K is observed in both the training and testing datasets. To examine the robustness of the developed DNN, it is further applied on the independent dataset of January 2021 of INSAT-3D Imager and is validated against the in-situ SST measurements. The validation shows the RMSE of ~0.6K in the estimated SST throughout the month.

Access the poster in PDF:

zenodo https://zenodo.org/record/7120008

ID 026: Impact of Volcanic Eruptions on Sea Surface Temperature products

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Short abstract

The eruptions of the Raikoke volcano on 22 June 2019 and the Tonga volcano on 15 January 2022 sent plumes of volcanic ash to the stratosphere and higher with the potential to affect the reliability and accuracy of satellite derived Sea Surface Temperature (SST) retrievals. The current study looks at the impact of the eruptions on SST retrievals produced by the Naval Oceanographic Office (NAVOCEANO) using SST software developed at the Naval Research Laboratory (NRL) and using legacy GOES-13 SST software updated by NRL for compatibility with the Electro-optical Infrared Weather System Geostationary (EWS-G1) imager. Emphasis is on SST products distributed to the Group for High Resolution SST (GHRSST). We used Suomi National Polar-Orbiting Partnership (Suomi NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) measurements over a higher latitude region that received a significant sulfur dioxide injection into the stratosphere from Raikoke. The NRL SST software produced fewer retrievals with moderately higher standard deviation following the Raikoke eruption compared to a previous year with low volcanic contamination. The plume from the Tonga volcano had a relatively low sulfur dioxide content, so its effects were more limited in time and space. In the Tonga case, the EWS-G1 SST retrievals using the legacy software are more affected by volcanic contamination than those produced by the NRL SST software using other satellites. In general, this study finds that the NRL SST software successfully excludes SST retrievals under higher volcanic contamination while allowing retrievals, with mild consequences, under conditions of lower contamination.

Access the poster in PDF:

zenodo https://zenodo.org/record/7120029

ID 030: Cloud detection based on deep neural network for HY-1C COCTS

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Short abstract

The Haiyang-1C (HY-1C) satellite is the first operational ocean colour satellite of the Chinese HY-1 series satellites. The Chinese Ocean Colour and Temperature Scanner (COCTS) onboard the HY-1C satellite has 10 channels for ocean colour and sea surface temperature (SST) observations. Cloud detection is one of the key pre-processing steps of SST retrieval. Deep learning algorithm can combine spectral information and spatial information and has strong ability of feature extraction. The U-Net is one of useful convolutional networks for image segmentation, consisting of the encoder and the decoder. We use the deep learning model U-Net to identify the cloud over the ocean in HY-1C COCTS images. The HY-1C COCTS cloud detection dataset is composed of HY-1C COCTS L1B global area coverage data in August 2019. The dataset is randomly divided into training set, eval set and test set with the ratio of 7:2:1. The ground truth of dataset using to train the U-Net model is constructed by Bayesian cloud detection method and manual mask. The overall accuracy on test dataset of the deep learning method is 0.95. The SST retrieval based on Optimal Estimation (OE) algorithm for clear pixels detected by U-Net is conducted. The COCTS OE SSTs are compared with iQuam in-situ SST. The bias and standard deviation of the COCTS minus in-situ SST difference are -0.1 K and 0.53 K, respectively. The ratio of matchups with SST difference lower than -1.67 K is 1.11%, indicating that the missed cloud detection is not obvious. In addition, the brightness temperature images after cloud detection show that the performance of cloud detection over the ocean front works well. In general, the cloud detection based on deep learning algorithm performs well for HY-1C COCTS.

Access the poster in PDF:

zenodo https://zenodo.org/record/7120034

ID 050: Blended analysis of FY-3C sea surface temperature data based on oriented elliptic correlation scales

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Short abstract

Sea surface temperature (SST) is critical to global climate change analysis and research. This study the quality-controlled in-situ sea surface temperature (SST) and Visible and Infrared Scanning Radiometer (VIRR) SST data from Fengyun-3C (FY-3C) satellite processed by bias correction were used, and the Kalman filtering methods with oriented elliptic correlation scales were applied to construct SST fields. Firstly, the model of oriented elliptic correlation scale was established for SST analysis, then the observation observation errors from each type of SST data source were estimated using the optimal matched datasets, and the background field errors were calculated by using the model of oriented elliptic correlation scale. Finally, the blended SST analysis product using the Kalman filtering methods was obtained. Besides, in order to validate these SST results, the SST fields using the optimum interpolation (OI) method were chosen for comparions. The SST data quality analysis of 2016 revealed that the Kalman analysis has a better performance than those of the OI analysis with the root-mean-square errors (RMSEs) of 0.3911 and 0.3243 °C, respectively,which was more closer to the OISST product's RMSE of 0.2897 °C. The results demonstrated that the Kalman filtering method with dynamic observation error and background error estimation was significantly superior to the OI method in SST analysis for FY-3C SST data.

Access the poster in PDF:

zenodo https://zenodo.org/record/7258914

ID 051: Sea surface temperature retrieval from HY-1D COCTS observations

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Short abstract

The Haiyang-1D (HY-1D) satellite is an operational ocean satellite, and the Chinese Ocean Colour and Temperature Scanner (COCTS) onboard it can be used for sea surface temperature (SST) observations. In this study, the SST retrieval algorithm was based on atmospheric radiative transfer modelling using 11µm and 12µm channel brightness temperature (BT). Representative ERA5 profiles containing SST and atmospheric state information were selected, which were used as the inputs for the BT simulation by MODerate resolution atmospheric TRANsmission (MODTRAN). The COCTS BT were inter-calibrated with the Visible Infrared Imaging Radiometer Suite (VIIRS) BT before applying to the SST retrieval algorithm. The cloud detection was performed using COCTS visible and infrared channel data, retrieved COCTS SST, and the reference SST. The global COCTS SST was retrieved in this study. The comparisons between the retrieved SST and Infrared Sea surface temperature Autonomous Radiometer (ISAR) as well as the buoy data were carried out. The results are analysed to investigate the accuracy of the algorithms.

Access the poster in PDF:

zenodo https://zenodo.org/record/7258880

Science Session S5 Computing and Products

Science Session S5 Computing and Products: Highlights of the Science Sessions

The Highlights of the Science Sessions included a number of five-minute talks based on the full recorded presentations followed by a short discussion period.

ID 036: felyx – new release of the distributed and cloud-ready multi-matchup dataset production framework

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Short abstract

Felyx is a generic open-source community software initially funded by ESA to produce satellite-to-in-situ matchups or systematic satellite data extraction over predefined areas, in order to support instrument Cal/Val activities and monitoring of geophysical quantities. After several years of operation, such as for Sentinel-3 SLSTR Sea Surface Temperature (SST) in EUMETSAT, and applications in many different contexts and parameters (wind, altimetry, etc.), it has been redesigned under European Union's Copernicus programme funding and managed by EUMETSAT, to add new functionalities, and much improved installation, robustness, configuration and monitoring. It comes with a distributed processing framework allowing to run the processing more efficiently over HPC infrastructure or cloud environment in containerised manner. It works natively with all GHRSST products and can use a variety of in-situ measurements (drifters, Argo floats and moored buoys from CMEMS, TRUSTED buoys, radiometers from ship4sst, Saildrone) including profile data, to produce matchup dataset files with flexible content and full traceability to source measurements.

Q&A with the author

What level of expertise is needed for someone to pick up Felyx and start using it for their own objectives?

In the re-design, it is easily installable. Chris comments that if he can use it, they have done a fantastic job.

Does it have a public API to make requests or to interactively query the system?

Felyx has a front-end (RESTful) API to request data in single http request (json query). You can extract matchups through an open command line.

Link to this presentation:

zenodo https://zenodo.org/record/7259123

vimeo https://vimeo.com/723950103

Science Session S5 Computing and Products: Pre-recorded talks

ID 022: PO.DAAC Cloud Data Ecosystem - Part 2: Moving Science to the Cloud

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Short abstract

As the PO.DAAC (and the rest of the NASA earth science data portfolio) migrates GHRSST and other datasets to the AWS cloud with its enterprise level data discovery, access and services capabilities (see abstract: Li et al., PO.DAAC Cloud Data Ecosystem - Part 1: Search, Access and Services) new opportunities (and challenges) are emerging for the scientific and applications user community. In this presentation we detail some of the emerging science analysis capabilities that a user in the cloud can leverage. This will be demonstrated through a series of jupyter notebook workflows that run and manipulate data directly in the cloud using many of the capabilities and services from Part 1, and other standard python/AWS/Pangeo project utilities and customized code. Examples include workflows that perform spatial/temporal matchups of satellite SST to in-situ data, interdisciplinary matchups at the land/sea coastal boundary (e.g., Amazon River outflow), long time series ECCO ocean model analyses and several others that are made available as ready-to-run tutorials from the public PO.DAAC github site. These tutorials have been developed over the past year in support of various NASA cloud data workshops and hackathons to introduce the concept of performing scientific analysis directly in the cloud with little need to download input data; only the results after cloud computation. Examples of cloud computing costs will also be presented as this should not be a significant blocker for usage of cloud data.

Link to this presentation:

zenodo	https://zenodo.org/record/7119632
vimeo	https://vimeo.com/724565044

Science Session S5 Computing and Products: Interactive (Posters)

ID 014: CEOS Ocean Variable Enabling Research & Applications for GEO (COVERAGE): An Initiative and Prototype Platform to Simplify and Expand the Accessibility and Usage of Inter-agency Satellite and in-situ Oceanographic Data in Support of Interdisciplinary Applications

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Short abstract

There is a growing imperative to better marshal available ocean observations of different types in support of interdisciplinary marine science and ecosystem management applications for societal benefit. There is also a related to develop improved data infrastructures and services for a more digitally integrated ocean observing system, one providing more seamless access to diverse observations for the oceans to enable their synergistic and efficient use also amongst emerging user communities and applications. COVERAGE is an international effort and 3 year pilot project within the Committee on Earth Observation Satellites (CEOS) involving interagency participation and engagement of the four CEOS Virtual Constellations including SST-VC that seeks to address these challenges. Its goal is to provide improved access to multi-agency, multidisciplinary remote sensing data for the oceans that are also better integrated with in-situ observations, also biological, that pose additional data interoperability challenges. COVERAGE focuses on implementing technologies, including emerging cloud-based solutions, to provide an advanced yet accessible data rich, web-based platform for integrated ocean data delivery and access: multi-parameter observations, easily discoverable and usable, organized thematically, and complemented by a set of integrated, value-added data services including data search, visualization and analytics. COVERAGE development is characterized by a phased, user-driven, open source approach organized around priority application use cases identified by agency partners. Here we provide an overview of the initiative and the status of current our Phase-C project, and showcase some of the COVERAGE's core data service capabilities.

Access the poster in PDF:

zenodo https://zenodo.org/record/7119272

ID 015: PO.DAAC Cloud Data Ecosystem – Part 1: Search, Access and Services

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Short abstract

PO.DAAC has pioneered the NASA earth data cloud migration to the Earthdata Cloud (Amazon Web Service – AWS) since January 2021. Today, almost all of the GHRSST datasets archived at PO.DAAC have been successfully migrated. The migration effort includes not just the datasets, but also the access tools/services, together forming the new PO.DAAC Cloud (POCLOUD) data ecosystem – new cloud paradigm, which brings challenges to the users with many new features and opportunities. A new Cloud Data page on PO.DAAC website has been created as a collective information center to help guide data users in discovering, accessing, and utilizing cloud data. In the new cloud paradigm, the traditional PO.DAAC data search web portal will be preserved to continually serve as the main data discovery platform. In addition, NASA has designed a new Earthdata search portal for discovering the earth science datasets across 12 NASA data centers. To access the POCLOUD data, most of the on-premise tools and services are (will be) made available except the PO.DAAC Drive, which will be retired after the cloud data migration. Currently, the data direct download (https), OPeNDAP, the Level 2 subsetting tool HiTIDE, and the visualization tool SOTO have been added to POCLOUD datasets. A collection of Harmony APIs, which are a common family of services discovering and accessing the Earth observation data from different NASA data centers, are also made available to most POCLOUD data, including services for subsetting, Zarr reformatting, and regridding. Users are encouraged to find helpful tutorials, demos and recipes from Cloud Data page, such as, the powerful and efficient data subscriber script, tutorials on OPeNDAP, Amazon s3 bucket direct access, and cloud data applications.

Access the poster in PDF:

zenodo https://zenodo.org/record/7119594

ID 041: Monitoring coastal events and changes using satellite data and contextual information: towards a CEOS COAST application knowledge hub

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Short abstract

Significant differences in land *versus* sea characteristics and shallow-water response to remotely sensed signals pose challenges in satellite-based coastal monitoring. Highly variable weather systems (*e.g.*, monsoons), boundary currents (*e.g.*, Gulf Stream), oceanic dipoles, upwelling and downwelling, and dust/aerosol effects further enhance the challenge. Nevertheless, the coastal areas are critical as they hold the most extensive human base. Despite known limitations in satellite capabilities for coastal applications, the improving resolutions and sensor characteristics render them attractive for such studies. Consequently, a growing focus is on coastal applications using satellite data and other available information to get the best value from an integrated approach. Towards this end, the Satellite Oceanography and Climate Division (NOAA/STAR/SOCD) and NOAA Fisheries are actively pursuing an effort to ease visualization and provide a knowledge base for coastal events. We are conceptualizing the Committee on Earth Observation Satellites (CEOS) COAST Application Knowledge Hub (AKH) to enable simultaneous displaying of:

- [1] satellite-based ocean parameters (SST, Chlorophyll, etc.),
- [2] social data and indicators (e.g., population, vulnerability),
- [3] shoreline characteristics,
- [4] seabed properties,
- [5] station measurements (e.g., precipitation gauge),
- [6] a set of base maps to provide context,
- [7] waterways, [8] elevation, and
- [9] a set of curated major coastal events that caused significant damage (storms, HABs, etc.).

Story maps corresponding to individual events will enable further deep-dive, and IPCC projections will provide a future outlook. As we conceptualize the CEOS COAST AKH, this preliminary presentation aims to assess the study potential, interactively solicit suggestions, and gauge features of interest.

Access the poster in PDF:

zenodo https://zenodo.org/record/7119481

ID 052: Access to Copernicus marine data from EUMETSAT is changing. Are you ready?

Submitting author/speaker (Name and Surname): Benjamin Loveday (Hayley Evers-King, listed below, will be the on-site speaker/presenter)

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Short abstract

As the size and complexity of the Earth observation data catalogue grows, the ways in which we interface with it must adapt to accommodate the needs of end users, both research-focussed and operational. Consequently, since 2020 EUMETSAT have introduced a suite of new data services to improve the ability of users to view, access and customise the Earth observation data catalogue they provide. These services, which are now operational, offer both GUI- and API- based services and allow fine grained control over how users interact both with products, and the collections they reside in. From early 2022, these services will also support the dissemination of the EUMETSAT Copernicus Marine Data Stream, including the Level-1 and Level-2 marine products from both the Sentinel-3 and Sentinel-6 missions at both near real-time and non-time-critical latency.

Here, we give an overview of the capability of these data services, with examples of how to use them. In addition, we will outline the tools and resources that are available to assist users in incorporating these services into their workflows and applications. These include online user guides, python libraries and command line approaches to facilitate data access, and a suite of self-paced training resources and courses. This poster presentation will include demonstrations of the services, information on plans and schedules for the inclusion of future data streams, and the opportunity for new and experienced users to ask questions and give feedback.

Access the poster in PDF:

zenodo https://zenodo.org/record/7119090

Science Session S6 Future Missions

Science Session S6 Future Missions: Highlights of the Science Sessions

The Highlights of the Science Sessions included a number of five-minute talks based on the full recorded presentations followed by a short discussion period.

ID 049: Future ESA Missions for SST: Providing Enhanced Continuity for Copernicus

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European Space Agency

Short abstract

Sustained observations in the visible and infrared domain are one of the pillars of the Copernicus Programme. For SST, the vast amount of data collected by the current Sentinel-3 Sea and Land Surface Temperature Radiometer (SLSTR) provide crucial input to a number of Services including the Copernicus Marine Environment Monitoring Service (CMEMS). Here we present three highly-synergistic missions currently in preparation that will continue and extend the space-based SST record. The **Next Generation of Sentinel-3 Optical**, to be launched in 2032, will address the evolution of the optical payloads OLCI and SLSTR. The primary Sentinel-3 NG Optical mission objective for SST is to achieve enhanced continuity for Copernicus, at least at the level of the quality of the current generation of Sentinel-3 SLSTR. We will illustrate the advanced technical concepts that are currently being evaluated as part of Phase 0 of the mission development, in particular those for the technical evolution of SLSTR and of the SST products. This in turn leads to enhanced services or new services, and also enables R&D into new applications.
The coastal zone has also been identified as one of the complementary mission objectives of the Copernicus Expansion **Land Surface Temperature Monitoring (LSTM)** Mission (launch planned in 2028). The key observational requirements of the LSTM mission are systematic global acquisitions of high-resolution (50 metres) observations over land with a high revisit frequency of 2 days. Coastal waters are covered within 100 km from the shoreline, plus the full Mediterranean Sea and Caspian Sea, and coral reef areas. We will illustrate the main technical features of the instrument and the expected applications in the coastal zone.
SST is also crucial in the Arctic. Monitoring SST with an all-weather instrument in the Arctic is key for the operational monitoring and forecasting by CMEMS, and is one of the two primary objectives of the **Copernicus Imaging Microwave Radiometer (CIMR)** mission, whose launch is also planned for 2028. We will describe the key requirements for CIMR SST, the expected SST products and their application to monitoring the melting of sea ice and ocean dynamics.

Q&A with the author

We will have near all-weather observations to 15 km, and within 15 km from coastal zones, from CIMR. Obviously, SLSTR has cloud limitations. There are gaps in the coasts, but the 50-m resolution from LSTM will help fill those gaps. Very transformative combination of sensors for the Arctic. Is ESA already thinking about studies with an Arctic focus that use the synergy between these types of instruments?

We will initiate and carry out these studies in the next couple of years. The synergy for SST in the Arctic follows on other Arctic Copernicus expansion missions for the polar oceans like CRISTAL (Ku band radar for polar ice and snow topography altimetry mission) and ROSE-L (L band radar). I'll promote those discussions. Nice to bring the high-resolution SST from SLSTR to look at synergies with CIMR and the other Copernicus expansion missions in the coastal zones. Something we discussed already with THRISNA; useful extension for the cryosphere. CM: Good news is in your mind.

There are other upcoming missions that look at coastal areas and the Indian Ocean for high resolution SST retrievals, such as the French-Indian TRISHNA and ESA's Harmony missions. Is there any action foreseen between agencies to maximize high-resolution observations from overlap areas, even in the open ocean, and compare the fields seen by the different missions?

To my knowledge there is no common action yet on high-resolution overlap areas. To digress for a moment let me explain how this is done in the SEASTAR mission where a radar was used to measure total surface currents at 1 km resolution in coastal regions, but sub-mesoscale happens in the middle of the ocean too. We are now aliasing the scientific community to discuss ocean regions of special interest where small-scale activity happens. An advisory group need to identify areas with small activity of interest. No discussions yet. Perhaps the SST community needs to select a small number of areas to look at these synergies at very high resolution. This is not tenable everywhere in the world in terms of data volume, but agree that the community needs to focus on a multi-mission high-resolution intercomparison for a handful of regions.

Link to this presentation:

zenodo	https://zenodo.org/record/7259129
vimeo	https://vimeo.com/725757387

Science Session S6 Future Missions: Interactive (Posters)

ID 013: The ESA Earth Explorer 10 Candidate Mission: applications on the retrieval of SST gradients from L1 observations

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Short abstract

The ESA Harmony Earth Explorer 10 candidate mission science objectives cover applications spanning from upper oceans dynamics to air-sea interactions, cryosphere and solid-Earth. The mission is designed primarily to study the coupled atmosphere-ocean dynamics. The focus is on air-sea interactions and small-scale upper ocean processes in the sub-mesoscale to mesoscale dynamical regimes, which are crucial for the vertical transport of momentum, heat, carbon, nutrients and marine organisms. These processes have a clear signature in Sea Surface Temperature (SST). Intense SST gradients are indeed actively involved in the ocean-atmosphere coupling. Their relation with local changes in sea surface roughness, surface winds up to the modulation of storm tracks has been extensively documented.

The Harmony mission concept tackles these issues providing co-located observations of high-resolution surface roughness, currents and SST. Based on the characteristics of the Harmony Thermal-InfraRed payload, we focus on the retrieval of relative SST gradients from Top Of Atmosphere (TOA) Brightness-Temperature (BT) observations as obtained from a broadband (8-13 µm) Panchromatic channel (PAN). This approach, compared to the SST-gradient estimates from L2 geophysical retrievals, is expected to reduce the retrieval's sensitivity to radiometric noise and mitigates the impact of inter-channel co-registration errors.

Based on L1 and L2 GHRSST SST data, we mimic PAN-derived Harmony observations and show that SST gradients are correctly located in the TOA observations. Analytical studies, as well as simulations based on the Atmospheric Radiative Transfer Simulator (ARTS) also enabled to quantify the detrimental effect of co-registration and radiometric noise on the space-based SST gradients retrieval.

Access the poster in PDF:

zenodo https://doi.org/10.5281/zenodo.6840906

ID 038: The Indo-French TRISHNA satellite mission: high resolution and high revisit surface temperature for land and coastal ocean

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Short abstract

The TRISHNA mission (Thermal infraRed Imaging Satellite for High-resolution Natural resource Assessment) is a cooperation between the French (CNES) and Indian (ISRO) space agencies, for a satellite to be launched in 2025 for a 5-year lifetime, to measure approximately twice a week the visible, near infrared and thermal infrared signal of the surface-atmosphere system globally and at 60 m resolution for the continents and coastal ocean, with a resolution of 1000 meters over deep ocean. Level 2 products –free and open data policy- include Sea Surface Temperature, visible and near infrared surface reflectances as well as cloud mask, aerosol optical thickness and data quality flags.

Design drivers of the mission: (i) monitoring of ecosystem stress and water use, focusing on agriculture and water content of vegetation, through evapotranspiration; and (ii) coastal and inland waters: characterization of the dynamics of the shallow bathymetry; monitoring of exchanges in estuaries and intertidal zones; sea surface temperatures and winds; sub-mesoscale activity in coastal areas and in the high seas; oil spills, thermal pollutants, effluents and wastewater discharges.

Interactions are needed with the experts and future users: definition of monitored coastal areas and polar zones, algorithms for SST and optical surface variables computation, cloud mask, product content: variables, auxiliary and ancilliary data.

The synergy (orbits, products, algorithms, CAL/VAL) between TRISHNA and future operational high-resolution thermal infrared missions (Surface Biology and Geology (SBG, 2027) from NASA/JPL, Land Surface Temperature Monitoring (LSTM, 2029) from ESA) is also a key element of the preparation of TRISHNA.

Access the poster in PDF:

https://doi.org/10.5281/zenodo.6840921

ID 056: Sea surface temperature in coastal ocean with different data: application for the TRISHNA mission

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Short abstract

Sea surface temperature (SST) at the ocean-atmosphere interface represents a key variable for understanding, monitoring and predicting heat, momentum and gas fluxes as well as ocean dynamics over a wide range of spatio-temporal scales. In coastal areas, the intense exchanges between the ocean/atmosphere/continent generate a very high variability of the surface temperature both in time and space, which makes the data of the future TRISHNA mission suitable for many applications. We are interested in the study of sub-mesoscale structures (100 m -1 km) in the coastal environment, having an impact on productivity and ocean-atmosphere fluxes.

We study thermal infrared (TIR) signals for the determination of SST in the coastal environment using different data and methods that are complementary in terms of their spatio-temporal resolution and coverage in order to prepare the TRISHNA mission: airborne measurements, satellite measurements and in-situ measurements. SAFIRE airborne flights equipped with infrared cameras took place in the Gulf of Lion off Banyuls/Mer in the Mediterranean Sea in September 2019.

We then compared the SST deduced from airborne data, LANDSAT images and in-situ data. The results show a good agreement between the 3 types of data (temperature difference <1°C) demonstrating: 1) the good quality of the airborne TIR data 2) the usefulness of the larger scale spatialized information of the LANDSAT TIR data and 3) the importance of the in-situ data. The situation in September 2019 in the coastal environment off Banyuls/Mer presents an upwelling regime forced by a major wind event (Mistral and Tramontane) at the scale of the Gulf of Lion, a process well monitored by the 3 types of SST data, especially their spatio-temporal complementarity. These results illustrate an example of a very high spatial resolution SST application for the future TRISHNA mission.

Access the poster in PDF:

zenodo https://doi.org/10.5281/zenodo.6840936

Appendix 2 Extended abstracts of the Science Sessions

Extended abstracts: Science Session S1 Applications

Recent upper Arctic Ocean warming expedited by summertime atmospheric processes

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Abstract

The observed upper (0–50 m) Arctic Ocean warming since 1979 has been primarily attributed to anthropogenically driven changes in the high latitudes. Here, using both observational and modeling analyses, we demonstrate that a multiyear trend in the summertime large-scale atmospheric circulation, which we ascribe to internal variability, has played an important role in upper ocean warming in summer and fall over the past four decades due to sea ice-albedo effect induced by atmospheric dynamics. Nudging experiments in which the wind fields are constrained toward the observed state support this mechanism and suggest that the internal variability contribution to recent upper Arctic Ocean warming accounts for up to one quarter of warming over the past four decades and up to 60% of warming from 2000 to 2018. This suggests that climate models need to replicate this important internal process in order to realistically simulate Arctic Ocean temperature variability and trends. After the presentation, a discussion occurred about how anthropogenic vs. natural climate variability is determined; the answer is that it is a two-stage process: (1) anthropogenic change is determined by finding the mean of an ensemble of runs with slightly different initial conditions: this averages out the natural climate variability and leaves only the greenhouse gas-forced change. Then (2) some aspect of the natural climate variability is determined by running additional experiments; here we strongly nudged model winds to observed winds to determine this effect which previous work indicates (i) is ultimately forced by tropical Pacific variability (e.g., El Nino) that propagates to the Arctic via Rossby waves and (ii) represents a large fraction of natural climate variability-forced sea ice and upper ocean change.

Introduction

Recent global warming fuelled by increasing anthropogenic greenhouse gases is most prominent in the Arctic with significant atmospheric and oceanic warming and pronounced sea ice and land ice melting (Steele et al., 2010; Steele & Dickinson, 2016). Warming of the upper ocean in the Arctic is contributing to sea ice loss and changes of ocean circulation. However, our understanding of Arctic upper ocean temperature variability in the past decades and its main drivers remains limited, with previous studies mainly focusing on two processes. The primary one is due to recent sea ice reduction, which allows the ocean to gain more heat. The secondary one involves ocean advection with heat transported into the Arctic Ocean by the time-mean northward-flowing currents.

While the above processes have been extensively examined in the context of anthropogenic warming, the role of internal variability in Arctic Ocean warming is unclear. In the past decades, a strengthened cyclonic oceanic circulation in the Eurasian sector has been observed as well as a stronger Beaufort Gyre in the American sector. However, it is unknown to what degree these are the result of anthropogenic forcing, internal variability, or a combination of both. In particular, the Arctic has exhibited a trend toward higher summertime pressure anomalies since 1979. One explanation links these anomalies to a teleconnection from the tropics which propagates northward via an atmospheric wave train, exerting a warming effect that melts sea ice by regulating temperature, humidity, clouds, and downward longwave radiation in the Arctic atmosphere (Ding et al., 2017;

2019). This process arises from internal variability and explains 40% of the trend in sea ice loss in September since the 1980s. It is reasonable to expect that this process also has an impact on upper ocean temperature either via the ice-albedo effect or via potential impacts on the northward transport of oceanic heat. However, the detailed processes linking this atmospheric internal variability with upper ocean temperature remain unexamined. Because interactions between anthropogenically forced and internally generated processes and feedbacks are complex, it is often difficult to identify a clear cause-and-effect relationship. Given the importance of upper ocean temperature in stabilizing and shaping the high-latitude climate in the Arctic, a better understanding of the relative roles of each forcing in recent Arctic Ocean warming is desirable.

Results

The Arctic Ocean exhibits strong warming trends and year-to-year variability of the upper 50 m in the last four decades in summer and fall (Fig. 1a). This layer, defined as the upper ocean in this study, resides above the Pacific Waters (PW) located between 50 and 150 m depth and Atlantic Waters (AW) located between 200 and 800 m. Thus, its temperature variability impacts the overlying sea ice and the efficiency of the heat exchange between the ocean and atmosphere. To understand upper ocean temperature variability related to summertime atmospheric and sea ice processes, we focus on the area confined by the long-term mean (1979–2018) June–July–August (JJA) Arctic sea ice extent (approximated by black line in Fig. 1b). Within this area, the upper ocean is fully covered by sea ice for large parts of the year but has some exposure to the atmosphere from June to October with the maximum in September when the sea ice reaches its minimum extent. Thus, an interaction between the atmosphere and the upper ocean is expected during these ice-free months. Atmospheric warming during summer first melts sea ice, and then warms the resulting open water in the following months. Downwelling longwave radiation is the key component of the surface energy balance in late summer warming.

First, we examine the response of CESM1 to anthropogenic forcing by examining the 40-member ensemble mean of the historical simulation. The 40-member ensemble is considered sufficient to largely remove the effect of internal variability and thereby only reflects the external forcing. We examine upper tropospheric (300 hPa) winds as an indicator of the larger scale circulation. Unlike the observed upper tropospheric wind trend in ERA5, the wind trend due to anthropogenic forcing is very weak and only accounts for a small part of observed trends. This suggests that the observed upper air wind trend in the past four decades is primarily due to internal variability of the climate system.

We next conduct a set of nudging experiments to quantify the effect of the atmospheric circulation on upper ocean temperature in the Arctic. In this experiment we nudge the winds of the Community Climate System Model 1 (CESM1, which provides a nudging capability) to reanalysis while anthropogenic forcing is fixed at the level of year 2000 (CO_2 = 367 ppm), which is very close to the observed mean CO_2 concentration over the past 40 years (CO_2 = 369 ppm; see Methods). The goal of this experiment is to assess the contribution of wind forcing on sea ice melting and upper ocean warming by comparing the nudging experiment with the historical simulations of the same model and the observational evidence. The nudging experiment consists of five 40-yr historical runs from 1979 to 2018, in which simulated winds within the Arctic (north of 60°N) are nudged to the corresponding 6-hourly ERA5 winds (see Methods). The five members are initiated with different atmosphere, sea ice and oceanic conditions on 1979/1/1 (see Methods) and the ensemble mean of the five realizations is analyzed hereafter to remove impacts of initial conditions in the simulations. The climatology of sea ice concentration, ocean temperature, and salinity in the Arctic in the ensemble mean of these 40-yr nudging runs exhibits roughly similar patterns and magnitude as the observations.

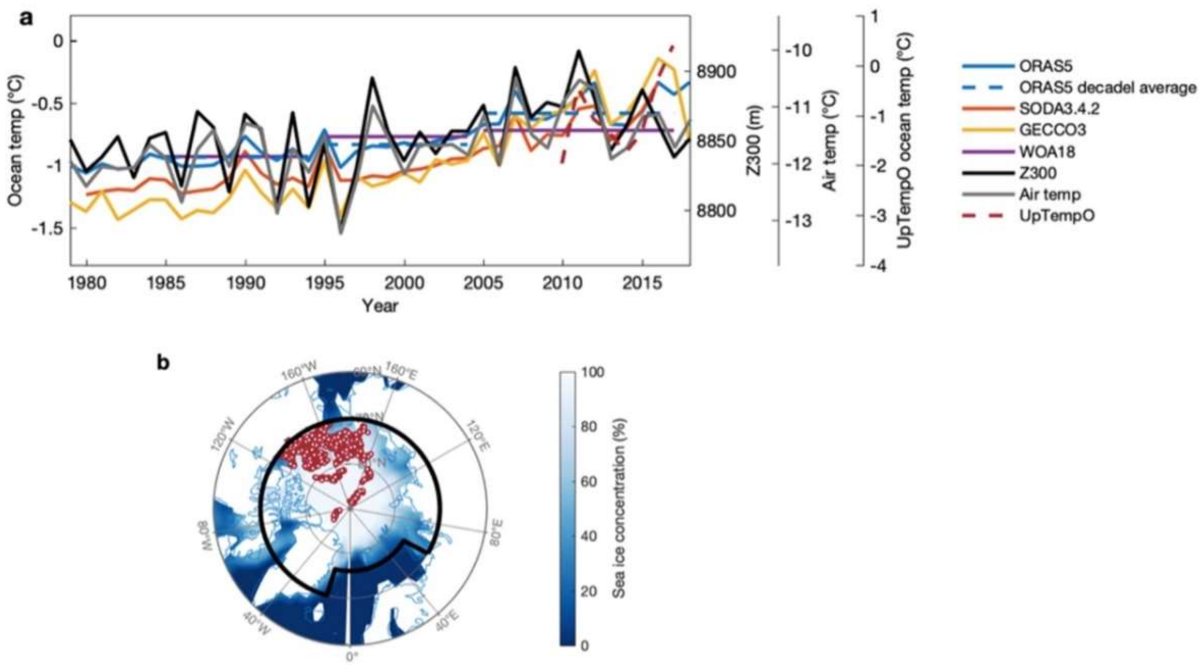

Figure 1. The Arctic Ocean domain-average time series for fall (SON) upper (0–50 m average) ocean temperature (°C) using three different reanalysis data (ORAS5, SODA3.4.2, and GECCO3) and observation data (WOA18), summer (JJA) Z300 (m), and JJA tropospheric (surface to 300 hPa average) air temperature (°C) over the region circled by the black contour in **b** using the ERA5 reanalysis, and upper (0–50 m) ocean temperature (°C) using UpTempO buoy data (Banzon et al., 2020; data marked by red dots in **b**). **b** Climatology of JJA sea ice concentration from the National Snow and Ice Data Center (NSIDC) Nimbus-7 SMMR and DMSP SSM/I-SSMIS passive microwave monthly sea-ice product version 1 for the period 1979–2018. The area enclosed by the solid black line in **b** indicates the domain used for the following calculations. Red dots are UpTempO buoy data positions.

Conclusions

The mean trend in the simulated upper ocean temperature in the five nudging runs is 0.04 °C per decade, while that in the ensemble mean of the 40 CESM-LEN members is 0.09 °C per decade. The combined upper ocean temperature trend due to the two forcings is 0.13 °C per decade, which is slightly lower than the trend of 0.17 °C per decade in ORAS5 over the last 40 years, suggesting that the sum of these two forcings can explain most of SON upper ocean warming. Based on their contributions to the warming in ORAS5 (0.04/0.17 and 0.09/0.17), we estimate that the internal, wind-driven variability accounts for 24% of upper ocean warming while anthropogenic forcing accounts for 53% of upper ocean warming over the past 40 years.

For the period 2000–2018, we find that internal wind-driven variability has become even more important and over the Pan-Arctic Ocean, explaining about 60% of the Pan-Arctic Ocean warming trend from 2000 to 2018. A caveat is that anthropogenic warming likely has an imprint on the reanalysis winds which are used to drive the nudging run, although this part appears to be small. This means that our estimates of the role of internal variability on SON upper ocean warming (24% over 1979–2018 and 60% over 2000–2018) are likely upper bounds.

References

Banzon, V., Smith, T. M., Steele, M., Huang, B. & Zhang, H.-M. Improved Estimation of Proxy Sea Surface Temperature in the Arctic. J. Atmospheric Oceanic Technol. 37, 341–349 (2020).

Ding, Q. et al. Fingerprints of internal drivers of Arctic sea ice loss in observations and model simulations. Nat. Geosci. 12, 28–33 (2019).

Ding, Q. et al. Influence of high-latitude atmospheric circulation changes on summertime Arctic sea ice. Nat. Clim. Change 7, 289–295 (2017).
Steele, M. and S. Dickinson, The phenology of Arctic Ocean surface warming, J. Geophys. Res., 121, doi:10.1002/2016JC012089, (2016).
Steele, M., Zhang, J. & Ermold, W. Mechanisms of summertime upper Arctic Ocean warming and the effect on sea ice melt. J. Geophys. Res. 115, C11004 (2010).

Extended abstracts: Science Session S2 Processing and products

Deep-learning models for Single Image Super Resolution: applications to Mediterranean Sea SST products and SST gradients within the Copernicus Marine Service

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Abstract

In the framework of the Copernicus Marine Service, the Italian National Research Council (CNR) – Institute of Marine Sciences (ISMAR) is responsible for producing and distributing operational near-real-time (NRT) Sea Surface Temperature (SST) products over the Mediterranean and Black Seas. The CNR-ISMAR SST processing chain, which includes several modules, from data extraction and preliminary quality control to cloudy pixel removal and satellite images merging, provides daily (night-time) merged multi-sensor (L3S) and optimally interpolated (L4) foundation SST fields at high (HR) and ultra-high (UHR) spatial resolution (i.e., over 1/16° and 1/100° regular latitude-longitude grids, respectively). However, the effective resolution of UHR L4 products strictly depends on the availability of high-resolution cloud-free measurements. The Optimal Interpolation algorithm makes use of HR L4 data remapped onto a 1/100° regular grid as first-guess (which means UHR SST features are already filtered out) and it is not able to reconstruct small scale features unless valid L3 observations are present within a short temporal window.

For this reason, CNR is presently working to improve the MED NRT SST products' effective resolution and SST gradients' accuracy through the development of deep learning models. In particular, the application of Convolutional Neural Networks (CNN) in the process of reconstructing high-resolution images from low-resolution ones, the so-called single image Super Resolution (SR) technique, has demonstrated an impressive potential. Here we present preliminary results on the achievements and the limitations in applying this specific class of artificial intelligence techniques to improve the effective resolution (and SST gradients) of our MED-NRT-L4-UHR product.

Introduction

The Sea Surface Temperature (SST) is one of the essential oceanic variables to investigate air-sea interactions, climate variability, ocean dynamics and to monitor marine ecosystems (see e.g. Deser et al., 2010; Rio et al., 2018; Yang et al., 2021). Hence, the ability to accurately estimate global SST is crucial for a wide variety of users. Satellite-derived measurements are the main source of such extended datasets for scientific applications. However, SST images provided by infrared and/or microwave satellite measurements are often affected by invalid data and, therefore, further processing is needed to obtain gap-free images (for a review of SST see e.g. Minnett et al., 2019).

Within the Copernicus Marine Service (see e.g. Le Traon et al., 2019), the Italian National Research Council - Institute of Marine Sciences (CNR-ISMAR) is responsible for producing and distributing operational near-real-time merged multi-sensor (L3S), and gap-free (L4) SST products over the Mediterranean and Black Seas (Buongiorno Nardelli et al., 2013). In this context, CNR-ISMAR is currently working to improve the NRT SST products' effective resolution and SST gradients' accuracy through the development of deep learning models. In the last decades, it has been widely shown that deep learning-based methods have the ability to obtain high quality results in the field of computer vision. Among the image processing techniques, Convolutional Neural Networks (CNNs) turned out to be crucial for reconstructing High-Resolution (HR) images from Low-Resolution (LR) ones, the so-called single image Super Resolution (SR) problem, proving successful in a wide range of applications. Particularly, the availability of large satellite-derived datasets for ocean remote sensing, as well as the increasing need of deriving high resolution images of sea surface dynamics, brought the ocean research community to explore the benefits that could derive from SR-CNN methods applied to remote sensing images (e.g., Ducournau and Fablet, 2016; Liu and Wang, 2020; Buongiorno Nardelli et al. 2022). Here we present preliminary results on the potential of applying these methods to recover high resolution SST features over the Mediterranean Sea.

Data and Methods

The CNR-ISMAR SST processing chain, which includes several modules, from data extraction and preliminary quality control to cloudy pixel removal and satellite images merging, provides daily (night-time) L3S (https://doi.org/10.48670/moi-00171) and L4 (https://doi.org/10.48670/moi-00172) foundation SST fields at high (HR) and ultra-high (UHR) spatial resolution (i.e., over 1/16° and 1/100° regular latitude-longitude grids, respectively). The final L4 product is obtained by means of a two-step algorithm that allows to interpolate SST data at high and ultra-high spatial resolution. This two-step process is necessary to take into account the range of space-time covariance scales spanned by the surface processes revealed by the SST, while keeping the estimation computationally feasible. In practice, the UHR Optimal Interpolation (OI) scheme makes use of HR L4 data as first-guess (after remapping them onto a 1/100° regular grid). HR SST data are obtained by optimally interpolating L3S data at 1/16° using a larger space-time decorrelation scales and wider observation search radius than the one adopted at UHR. As such, UHR SST features are clearly filtered out in the first guess map and related SST gradients also significantly “blurred” unless valid L3 observations are present within a very short temporal window (2 days). In this context, we are currently investigating the potential of applying CNNs to improve the effective resolution/gradients of our NRT L4 UHR product, retrieving those high resolution features when L3 UHR data are missing.

The application of CNNs to the Super Resolution problem is based on a network that directly learns an end-to-end mapping between low resolution and high resolution images. These networks proved successful for processing remote sensing gridded data in practical applications since they have shown an impressive capacity to capture small scale features exploiting the self-similarity property of natural images (Ducournau and Fablet, 2016). However, particular attention has to be made to the depth of the network, that has to be deep enough to produce an accurate output without increasing dramatically the computational cost, as well as to the generalization issue (in particular, to avoid under and overfitting). The CNNs implemented here learn from a ground-truth UHR L3S SST dataset how to reconstruct small scale features in optimally interpolated first guess maps. Both original datasets are mapped on a regular grid at 1/100° spatial resolution over the Mediterranean Sea for the year 2020. The data are then selected considering overlapping patches of dimensions 100 km x 100 km, chosen by extracting all the tiles containing at least 95% of valid pixels. SST values are then transformed into anomalies to get rid of seasonal variability and normalized between -1 and 1. The test dataset is selected separating the 15% of the days available after the preprocessing (chosen randomly) for a fully independent dataset, and it is composed of ~18000 tiles. The training dataset consists of ~112000 pairs of tiles, of which 15% is used by the network in the validation phase.

A powerful baseline SRCNN was proposed by Dong et al. (2016) and consists of three 2D convolutional layers with different kernel size. Here, we show the preliminary results obtained from a more sophisticated architecture, firstly proposed by Buongiorno Nardelli et al. (2022), called *dilated Adaptive Deep Residual Network for Super-Resolution* (dADR-SR). In the dADR-SR network (schematized in Figure 1) the low resolution input dataset is initially fed to three parallel dilated convolutional layers with the same number of filters but increasing dilation factor, which are more suitable to extract information at different scales. After this first stage, the data pass through a sequence of twelve Multiscale Adaptive Residual Blocks (M-ARB), each one including two sets of convolutional layers and a Squeeze-and-Excitation (SE) module, which are designed to further exploit multi-scale information and more efficiently combine residual features, thus modeling complex interdependencies, before being summed up to produce the final high resolution output. Finally, as benchmarking/validation references we also applied the *Enhanced Deep Residual Network for Super Resolution* (EDSR; Lim et al., 2017) and the *Adaptive Deep Residual Network for Super Resolution* (ADRSR; Liu et al., 2019). All codes are written in Python using the deep learning framework *Keras*.

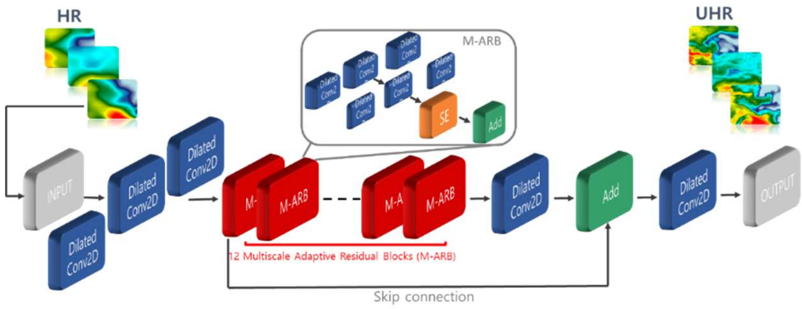

Figure 1: Sketch of the dADR-SR used to reconstruct SST fields.

Results

Here we present preliminary results of the application of the dADR-SR (compared to the other networks mentioned) to the optimally interpolated first guess maps used in the production of our NRT L4 UHR SST data. The left panels in Figure 2 show the SST daily map of September 4, 2020 reconstructed by the dADR-SR at 1/100° over the Mediterranean Sea. Smaller panels correspond to zoomed areas of the same map with the corresponding SST Sobel gradients for the L3S UHR ground-truth data, the first guess approximation and dADR-SR reconstruction (from left to right). We can observe that the SST field estimated by the CNN appears much sharper than the one approximated by the low resolution map, showing a good ability of the network to reconstruct dynamical features with a RMSE = 0.37 °C and the best mean Peak-Signal-to-Noise-Ratio (PSNR) among the networks. As we can see in Table 1, all networks present lower RMSE than the low resolution approximation, with different number of epochs needed to verify the early stopping condition and produce the high resolution output. Moreover, the SST gradients' maps suggest that the dADR-SR is clearly able to capture high magnitude patterns with a superior accuracy with respect to the first guess map (which tends to severely smooth SST structure when ground-truth data are missing). This is confirmed from the error maps shown in the right panels in Figure 2. We can observe the difference between the error made by the low resolution approximation and the dADR-SR model with respect to the original UHR image averaged on 1°x1° boxes, where the red shades represent an improvement of the CNN with respect to the low resolution image and the blue shades a degradation. The comparison shows an alternated behavior in the case of SST fields but reveals an outstanding performance of the CNN in terms of SST gradients' reconstruction. The presence of several blue zones in the SST field is probably due to the choices made during the creation of the training and test datasets, which excluded some particularly dynamic areas near the coast. Considering a wider spatial variability and increasing the time series for the training we are confident that the improvement on the CNN output would be apparent also for the SST field.

Conclusions

The wide availability of global satellite-derived datasets for ocean remote sensing and the value of providing high resolution images of sea surface dynamics combined with the requirement to improve the computational efficiency brought the ocean research community to explore the benefits that could derive from Deep Learning Methods applied to Earth Observation. In particular, Convolutional Neural Networks for Super Resolution have shown impressive results training with satellite-based observation due to the ability to exploit self-similarity properties.

In our preliminary results, the SST fields estimated by the CNNs appear much sharper than the low resolution maps, but the best results are achieved in the estimation of SST gradients (especially for high magnitude patterns which are generally smoothed out by interpolation techniques). This is likely due to technical choices made during the creation of the datasets, which is a crucial step in this field. For this reason, we are working on improving our results, increasing datasets time series, creating training and test datasets in different ways and making different choices of CNN parameters.

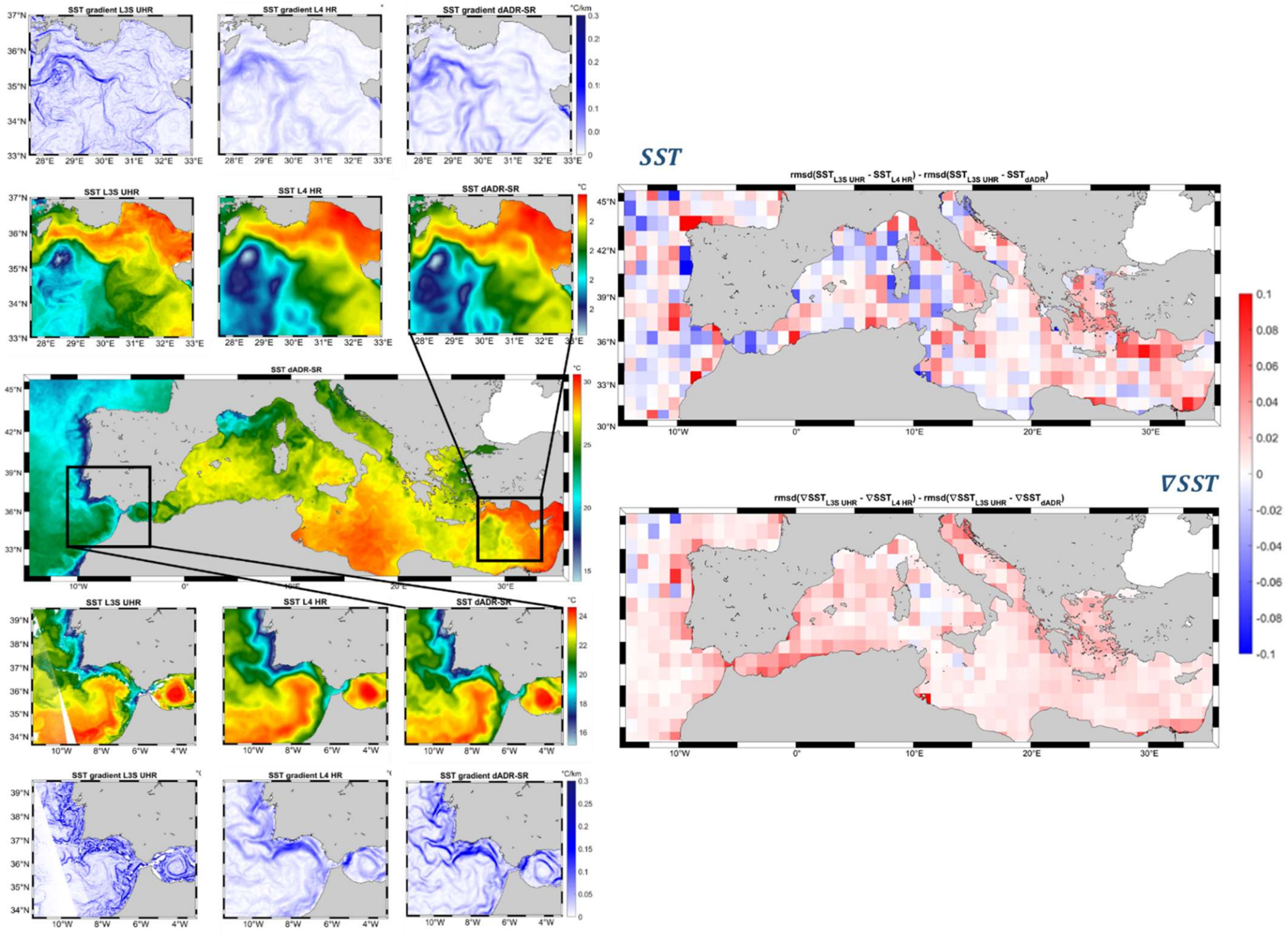

Figure 2: (left) SST daily map of September 4, 2020 reconstructed by the dADR over the Mediterranean Sea. Smaller panels correspond to zoomed areas of the same map with the corresponding SST gradients for the UHR ground-truth data, the LR approximation and dADR reconstruction (from left to right). (right) Difference between the error made by the low resolution approximation and the dADR model with respect to the original UHR image for SST values (top) and SST gradients (bottom) averaged on 1°x1° boxes.

Model	RMSE (°C)	PSNR	#epochs
SRCNN	0.34	36	99
EDSR	0.35	36	40
ADRSR	0.35	36	21
dADRSR	0.37	36.1	9
Low Resolution	0.4	35.9	-

Table 1. Comparison between approximations.

References

Buongiorno Nardelli, B., Tronconi, C., Pisano, A., & Santoleri, R., High and Ultra-High resolution processing of satellite Sea Surface Temperature data over Southern European Seas in the framework of MyOcean project. Remote Sensing of Environment, 129, 1-16, 2013.

Buongiorno Nardelli, B., Cavaliere, D., Charles, E., & Ciani, D., Super-Resolving Ocean Dynamics from Space with Computer Vision Algorithms. Remote Sensing, 14(5), 1159, 2022.

Deser, C.; Alexander, M.A.; Xie, S.P.; Phillips, A.S. Sea surface temperature variability: Patterns and mechanisms. Annu. Rev. Mar. Sci., 2, 115–143, 2010.

Dong, C., Loy, C. C., He, K., & Tang, X., Image super-resolution using deep convolutional networks. IEEE transactions on pattern analysis and machine intelligence, 38(2), 295-307, 2015.

Ducournau, A., & Fablet, R., Deep learning for ocean remote sensing: an application of convolutional neural networks for super-resolution on satellite-derived SST data. In 2016 9th IAPR Workshop on Pattern Recognition in Remote Sensing (PRRS), 1-6. IEEE, 2016.

Le Traon, P. Y., Reppucci, A., Alvarez Fanjul, E., Aouf, L., Behrens, A., Belmonte, M., ... and Zacharioudaki, A. From observation to information and users: The Copernicus Marine Service perspective. Frontiers in Marine Science, 6, 234, https://doi.org/10.3389/fmars.2019.00234, 2019.

Lim, B., Son, S., Kim, H., Nah, S., & Mu Lee, K., Enhanced deep residual networks for single image super-resolution. In Proceedings of the IEEE conference on computer vision and pattern recognition workshops, 136-144, 2017.

Liu, S., Gang, R., Li, C., & Song, R., Adaptive deep residual network for single image super-resolution. Computational Visual Media, 5(4), 391-401, 2019.

Liu, X., & Wang, M. (2020). Super-resolution of VIIRS-measured ocean colour products using deep convolutional neural network. IEEE Transactions on Geoscience and Remote Sensing, 59(1), 114-127.

Minnett, P. J., Alvera-Azcárate, A., Chin, T. M., Corlett, G. K., Gentemann, C. L., Karagali, I., ... and Vazquez-Cuervo, J. . Half a century of satellite remote sensing of sea-surface temperature. Remote Sens. Environ., 233, 111366, https://doi.org/10.1016/j.rse.2019.111366, 2019

Rio, M. H., and Santoleri, R.. Improved global surface currents from the merging of altimetry and sea surface temperature data. Remote Sens. Environ., 216, 770-785, https://doi.org/10.1016/j.rse.2018.06.003, 2018

Yang, C., Leonelli, F. E., Marullo, S., Artale, V., Beggs, H., Nardelli, B. B., ... and Pisano, A.. Sea Surface Temperature Intercomparison in the Framework of the Copernicus Climate Change Service (C3S). J. Climate, 34(13), 5257-5283, https://doi.org/10.1175/JCLI-D-20-0793.1, 2021.

The 2nd NOAA AVHRR GAC SST Reanalysis (1981-2022)

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Abstract

The 2nd SST reanalysis (RAN2) was created from 4km GAC data of the AVHRR instruments flown onboard ten NOAA satellites from September 1981 – present, using the NOAA Advanced Clear Sky Processor for Ocean (ACSPO) enterprise SST system. The AVHRR GAC RAN2 data set reports two SSTs: 'Subskin' (highly sensitive to true skin SST) and 'Depth' (agreeing closer with in-situ SST, at the expense of reduced sensitivity). Both SSTs are retrieved in the full ~3,000 km AVHRR swath. The long-term SST trends are mitigated by daily recalculation of the regression coefficients, using matchups with *in-situ* SSTs collected within moving time windows. Shorter-term biases are additionally minimized by correcting the regression offsets within 31-day windows. Special measures are taken to mitigate the effects of Sun impingement on AVHRR in terminator zones. Impingements on the black body are corrected by interpolating the calibration coefficients between the unaffected parts of the orbit, whereas stray light in the Earth view pixels is detected by the nighttime signal in the AVHRR band 2 and screened out. Regional cold SST biases, caused by volcanic aerosol following the three major eruptions, are mitigated by more conservative cloud screening in the affected areas. The RAN2 SST is available in swath L2P (144 10-min granules per 24hr interval), and two 0.02° gridded formats: uncollated (L3U; also 144 granules/24hr) and collated (L3C; two global maps per 24hr, for day and night). The presentation describes the major features of the RAN2 SSTs and evaluates their performance.

The RAN2 SST products

The 2nd NOAA AVHRR GAC SST reanalysis (RAN2) data set was created at NOAA using its Advanced Clear Sky Processor for Ocean enterprise SST system. The goal was to produce an SST record in an optimal retrieval domain and maximally consistent with in-situ data. This document provides a brief description of the RAN2 products and their validation results. More detailed descriptions on the features and validation of the RAN2 data set can be found in [1-3], along with comparisons with two other existing AVHRR SST data sets [4-5].

The RAN2 data are available at https://coastwatch.noaa.gov/cw/satellite-data-products/sea-surface-temperature/acspo-avhrr-gac.html in the following three formats:

- L2P: 4km/nadir swath, 144 10-min files/satellite/24hr;
- 0.02°L3U: Gridded Uncollated, 144 10-min files/satellite/24hr;
- 0.02°L3C: Gridded Collated (L3C), 2 files/satellite/24hr (day and night).

All available AVHRR L1b data were processed maximally completely and consistently. As of today, the data set covers the period from 1 Sep 1981 – 30 Jun 2022 with SSTs retrieved from 4 km AVHRR GAC data of ten NOAA satellites, N07, 09, 11, 12, 14, 15, 16, 17, 18 and 19. AVHRRs onboard N15, 18 and 19 are still functional, and their L1B data are processed and added to the RAN2 with ~6 months latency.

The AVHRR GAC RAN2 data set reports two SST products. The 'Subskin' SST is produced with global regression. It is highly sensitive to 'skin' SST and de-biased with regard to *in-situ* SST. The 'Depth' SST is produced with piecewise regression. It is more precise and accurate with regard to *in-situ* SST, but less sensitive to skin SST. The retrievals use three AVHRR thermal bands (3.7, 10.8 and 12 µm) at night and two bands (10.8 and 12 µm) during daytime, with the algorithms switched at SZA=90° (SZA defined in-pixel). The regression algorithms are trained against *in-situ* data. For N11 and subsequent satellites, drifters and tropical moored buoys are used. For the earlier N07 and N09, ship data had to be added, because drifters and tropical moorings were too scarce in the early to mid-1980s. The ACSPO uses first-guess SST in the SST algorithms and in the Clear-Sky mask. Customarily, the ACSPO uses L4 SST from the Canadian Meteorology Center (CMC) [6]. In RAN2, the CMC SST was used since its beginning on 1 Sep 1991. Prior to that period, L4 SST from the Climate Change Initiative v.2.1 (CCI) was employed [5].

Compensation for long-term SST trends

The orbits of the NOAA satellites are not corrected in flight, leading to significant changes in the equator crossing times during the missions, which in turn modifies the relationships between satellite and *in-situ* data. Another issue related to the orbital drifts, is that the AVHRRs may periodically become more exposed to sunlight in the twilight zones, giving rise to warm and cold SST outliers. The satellites flying in the early-morning orbits, N12 and N15 suffered the most. In conjunction with other AVHRR instrumental instabilities, the orbital drifts introduce trends in retrieved SSTs. In RAN2, such trends are mitigated by daily retraining of the regression coefficients using matchups collected within moving windows of 91 days for 'Subskin', and 361 days for 'Depth' SST. The regression offsets are additionally adjusted based on 31-day windows. As a result, the biases with respect to *in-situ* SST are minimized and flattened out as a function of time.

Correction for Sun impingements on AVHRR

The sunlight impingements on the sensor often occur when the satellites approach the terminator from the dark side of the orbit. The effect of such events on retrieved SST is twofold. First, stray light in the Earth view gives rise to warm SST outliers. Second, Sun impingement on the sensor's black body results in corruption of the calibration coefficients, recorded in the L1B data, which results in filling the affected scans with cold SST outliers. In RAN2, the corrupted calibration coefficients are corrected by a linear interpolation between the unaffected parts of the orbit. The stray light in the Earth view is detected and filtered out based on the reflectance signal in channel 2.

Mitigation of the effects of volcanic aerosols

Major volcanic eruptions affected SST retrievals from N07 (Mt. El Chichon, Apr 1982), N11 and N12 (Mt. Pinatubo, Jun 1991; Mt. Hudson, Aug-Oct 1991). The attenuation by volcanic aerosol cooled down AVHRR SSTs, within specific latitudinal bands. In order to mitigate the effects of the volcanic aerosols, the ACSPO clear-sky mask was modified to automatically become more conservative within the affected latitudinal bands, when the number of cold SST outliers increases within those bands.

Collation and coverage

The RAN2 SSTs are available in three formats: 1) L2P (swath; 144 10-min granules daily); 2) gridded L3U with 0.02° spatial resolution (also 144 files daily); and 2) collated 0.02° L3C format (2 files daily, one for day and one for night). The L2P and L3U data cover from 12-18% of all ocean pixels, within each corresponding 10-min granule. The collation improves the global coverage, due to many L3U granules overlapping, and thus increases the retrieval domain in the L3C format by 30-60% (to 20-25% total, compared with 12-18% in the L2P and L3U data).

Validation

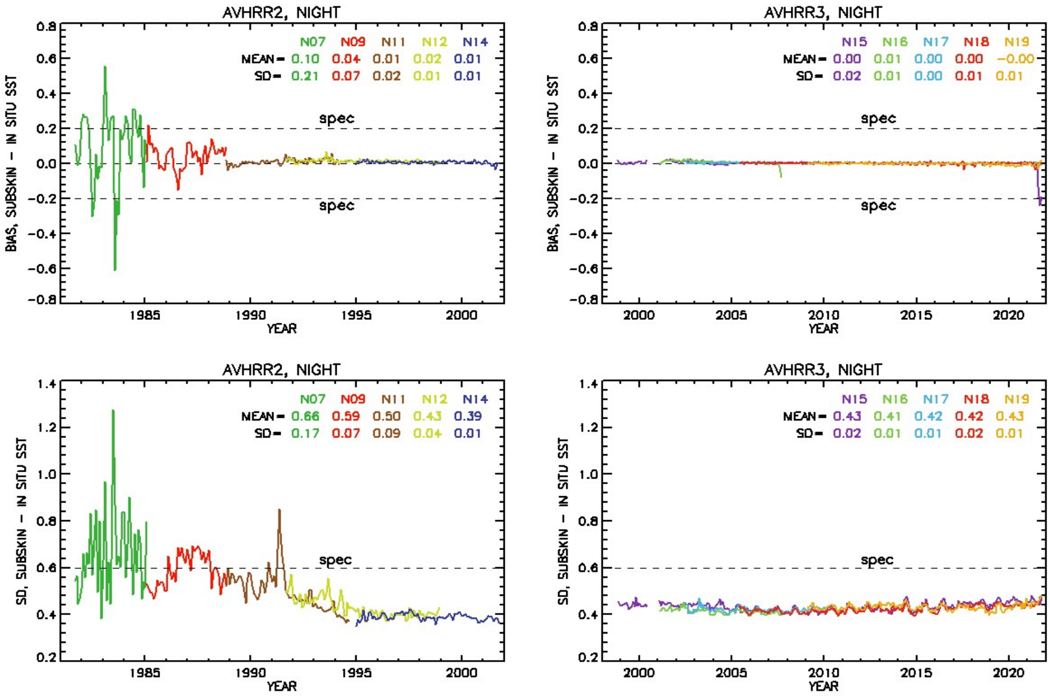

Figure 1. Time series of (top panels) biases and (bottom panels) standard deviations of 'Subskin' – in-situ SST for (left panels) N07-N14 carrying AVHRR2 and (right panels) N15-N19 carrying AVHRR3 sensors.

Figure 1 shows the time series of global monthly biases and standard deviations (SDs) of RAN2 'Subskin' SST with respect to drifting and tropical moored buoys. The biases for N11 and subsequent satellites are practically flat. The biases for N07 and N09 are variable, because their SSTs were trained against a combination of drifters, tropical moorings and ships, but validated against drifters and tropical moorings only. The SDs are largest for N07 and N09, due to two factors: a small number of drifters and tropical moorings, and suboptimal quality of the first AVHRR/2 sensors and in-situ data during this earlier period of satellite era. For the N11, the SDs significantly reduce after 1 Sep 1991, when the first guess switched from CCI to CMC, and remained close to ~0.4K for 'Subskin' and 0.3K for 'Depth' SSTs thereafter. The origin of the SD spike in the N11 SST in Apr-Jun 1991 (prior to Mt Pinatubo and Mt Hudson eruptions), remains unclear and is being investigated. Outside of this period, the statistics of RAN2 'Subskin' SST for N11-N19 are well within the NOAA specifications (±0.2K for biases and 0.6K for SDs). The SDs for RAN2 'Depth' SST are close to those of 'Subskin' SST for N07-N09, and lower by 0.08–0.10K for N11-N19. The SSTs from N16-N19 AVHRR/3s were also validated against independent Argo floats (not shown). (Note that independent validation of the earlier AVHRR/2 SSTs Argo floats is impossible, due to the lack of AF data in the 1980s-1990s.) The results of this independent AF validation are consistent with validation against drifters and tropical moorings shown in Figure 1.

Summary

The AVHRR GAC RAN2 SST data set covers the period from Sep 1981 – Jun 2022 with SST retrieved from 5 AVHRR/2s (N07/09/11/12/14) and 5 AVHRR/3s (N15/16/17/18/19). The data were reprocessed as fully and consistently as possible with the NOAA ACSPO enterprise system. The main features of the RAN2 SST are:

- The data set reports two SST products (both retrieved in the full AVHRR swath)
    - 'Subskin' SST is highly sensitive to true skin SST, de-biased with regard to in-situ SST
    - 'Depth' SST is more precise with regard to in-situ SST, but has reduced sensitivity to true SST

- SST biases are minimized (with regard to SH+D+TM for N07/N09 and with regard to D+TM for all other satellites)
- Sun impingements on the AVHRR black body are mitigated by correcting L1B gains and offsets
- Stray light in Earth view pixels is filtered out, based on the residual reflectance in AVHRR Ch2
- The validation statistics with respect to drifters and tropical moored buoys are well within the NOAA specifications for N11-N19, and may exceed these specs for the earliest N07 and N09 due to the inclusion of ship data in the training data sets of matchups
- The retrieval domain is from 12-18% in the L2P/3U data and increases to 20-25% in L3C data.

Future work

Future work on AVHRR GAC RAN data will include

- Continue extending the RAN2 dataset w/N15/N18/N19 data, with ~6 month latency;
- Explore improvements to the nighttime calibration (particularly for the early N07/09/11);
- Explore improvements to N07/09 retrievals, by excluding the 3.7µm data when suboptimal;
- Explore improvements to the daytime calibration and correction of navigation problems;
- Adjust/Improve the SST and cloud masking algorithms, to minimize regional biases;
- Explore iterative creation of the L4 analysis from the RAN2 SST for using in RAN3 as a first guess;
- Work with NOAA and external users and iteratively improve all elements of RAN processing.

Disclaimer

The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the author(s) and do not necessarily reflect those of NOAA or the Department of Commerce.

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References

1. Petrenko, B., V. Pryamitsyn, A. Ignatov, O. Jonasson and Y. Kihai, AVHRR GAC Sea Surface Temperature Reanalysis Version 2, Remote Sensing, 14, 3165, 2022, https://doi.org/10.3390/rs14133165.
2. Petrenko B., V. Pryamitsyn, A. Ignatov and Y. Kihai, Mitigation of the AVHRR instrumental issues in historical SST retrievals during NOAA AVHRR GAC SST RAN2. Proc. SPIE 12118, Ocean Sensing and Monitoring XIV, 1211803 (2022), https://doi.org/10.1117/12.2619361.
3. Pryamitsyn, V., Petrenko B., A. Ignatov, O. Jonasson and Y. Kihai, Evaluation of the NOAA AVHRR GAC RAN2 SST dataset. Proc. SPIE 12118, Ocean Sensing and Monitoring XIV, 1211802 (2022), https://doi.org/10.1117/12.2619357.
4. Saha, K., X. Zhao, H. Zhang, et al., AVHRR Pathfinder version 5.3 level 3 collated (L3C) global 4km sea surface temperature for 1981-Present, https://doi.org/10.7289/v52j68xx (2018).
5. Merchant, C. J., Embury, O., Bulgin, C. E. *et al.*, Satellite-based time-series of sea-surface temperature since 1981 for climate applications, Scientific Data, 6(1), 223 (2019), https://www.nature.com/articles/s41597-019-0236-x
6. CMC, GHRSST Level 4 CMC0.2deg Global Foundation Sea Surface Temperature Analysis (GDS version 2), NASA Physical Oceanography DAAC, 10.5067/GHCMC-4FM02, http://podaac.jpl.nasa.gov/dataset/CMC0.2deg-CMC-L4-GLOB-v2.0 (2012).

Latest Improvements and Future Plans of the JAXA GHRSST Datasets of MW, LEO-IR and GEO-IR

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Abstract

JAXA operationally produces and distributes various satellite-based SST datasets by using passive microwave, polar-orbital InfraRed and geostationary InfraRed imagers in GDS2.0 format from the JAXA GHRSST server (https://suzaku.eorc.jaxa.jp/GHRSST/) and Himawari Monitor (https://www.eorc.jaxa.jp/ptree/) in near-real-time basis and archives past period data since June 2002. We have updated SGLI SST Ver.3 to improve cloud masks in November 2021 and plan to update AMSR2 SST Ver.4.1 soon. Due to the improved cloud masking, SGLI SST V3.0 in the daytime are retrieved from the SGLI measurements only with pre-calculated RTM-based coefficients and Baysian-based PDFs and are 100% independent from any other in-situ and analysed data. AMSR2 SST Ver.4.1 will correct underestimation trends versus in-situ observations over Northern low- and mid-latitudes since 2019 and provide SST retrievals under high-wind and weak precipitation conditions, which are set to missing in previous versions. We also prepare tuning of Himawari SST algorithm corresponding to planning change-over of Japanese geostationary satellite from Himawari-8 to -9 scheduled in late 2022. Overlap operations of Himawari-8 and -9 are planned by Japan Meteorological Agency (JMA) for a couple of months to inter-calibrate two SST products. We are also preparing multiple SST products for the AMSR3 onboard the GOSAT-GW satellite to be launched in JFY2023. Those products will succeed SST datasets of AMSR-E and AMSR2 and improve robustness of SST retrievals and spatial resolution by adding new channels in 10-GHz. We will introduce the latest status of SST datasets and future plan for AMSR3.

Introduction

SST observations by MW, LEO-IR, and GEO-IR

JAXA operationally produces various satellite-based sea surface temperature (SST) dataset by using passive microwave (MW), Low Earth Orbit InfraRed (LEO-IR) and Geostationary InfraRed (GEO-IR) imagers. SST from the Advanced Microwave Scanning Radiometer 2 (AMSR2) onboard the Global Change Observation Mission – Water (GCOM-W) has advantage of “cloud-free” while its spatial resolution is coarse (about 30-50km) than that of IR imager. IR imager cannot observe SST under the clouds unlike MW imager but has big advantage in spatial resolution. SST from the Second-generation Global Imager (SGLI) on board the Global Change Observation Mission – Climate (GCOM-C) has advantage of “high-resolution” – its minimum spatial resolution is 250m and coverage is global area including Polar region. SST from the Advanced Himawari Imager (AHI) on board the Hiamwari-8 satellite has advantage of “frequent”. Its spatial resolution is 2km and temporal resolution is 10 min for full-disc area with coverage of one third of Earth’s surface except the Polar.

List of the JAXA GHRSST datasets

Table 1 shows a list of MW, LEO-IR and GEO-IR SST datasets provided by JAXA in GDS2.0 format. All SST datasets except Himawari-8/AHI SST are distributed from the JAXA GHRSST server (https://suzaku.eorc.jaxa.jp/GHRSST/) and AHI SST dataset is available from the JAXA Himawari Monitor (https://www.eorc.jaxa.jp/ptree/) after simple registration.

Satellite/ Sensor	Processing Type	Product	Archive Period	Latency	Version
Aqua/ AMSR-E	Standard	L2P L3C	from June 2002 to October 2011	N/A	Ver.8
GCOM-W/ AMSR2	Near RealTime	L2P L3C	latest 7 days (10GHz SST is available from V3.0.)	4 hours	Ver.4.1 (updated in Jul. 2022)
	Standard	L2P L3C	from 3 July 2012 to present (10GHz SST is available from V3.0.)	1 day	
GPM/ GMI	Near RealTime	L2P L3C	latest 7 days	4 hours	Ver.5 (updated in May 2022)
	Standard	L2P L3C	from 4 March 2014 to present	1 day	
Coriolis/ WindSat	Near RealTime	L2P L3C	from 3 August 2011 to 19 October 2020	N/A	Ver.8
GCOM-C/ SGLI	Near RealTime	L2P	1km: from 1 January 2020 to present 250m: latest 7 days	1 day	Ver.3000
Himawari-8/ AHI	Near Realtime	L2P L3C	latest 4 days	25 minutes	Ver.2.0
	Standard	L2P L3C	from 7 July 2015 to present	4 days	

Table 1: List of the JAXA GHRSST Datasets

Update of AMSR2 SST

Standard product of AMSR2 SST (Shibata, 2004, 2006, 2007) is retrieved by using 6.9GHz channels. Its spatial resolution is about 50km, depending on Field of View (FOV) of 6.9GHz, but it is robust in all temperature ranges. JAXA also produces additional AMSR2 SSTs as research product -- 10GHz SST and multi-band SST. Advantage of 10GHz SST is its spatial resolution (30km) but less accuracy in low temperature range, less than 10degC, due to poor sensitivity of 10GHz to low temperature SST. Multi-band (MB) SST uses 6.9, 7.3 and 10GHz channels to retrieve SST to reduce missing areas due to Radio Frequency Interferences (RFIs).

Current AMSR2 SST version (as of June 30, 2022) is Ver.4.0, which was released in October 2020. AMSR2 6GHz SST Ver.4.0 showed decreasing trends versus quality-controlled match-up buoy in the Northern sub-tropics since 2019. This decreasing trend is not shown in both 10GHz and MB SST, and it may be due to overcorrection of positive trends found in 6GHz TB since the launch.

To correct this, we prepared Ver.4.1 algorithm for AMSR2 SST. Major improvements in Ver.4.1 are; 1) more detailed calculation of land emission; 2) modified wind correction to retrieve SST over windy region; 3) modified atmospheric correction to retrieve SST over weak rain region; 4) correction of TB trends; and 5) revision of RFI detection method. Figure 1 shows comparison of AMSR2 6GHz SST Ver.4.0 and Ver.4.1. In Ver.4.1, there are less missing area due to retrieval of windy/rainy pixels with "acceptable quality", improved RMSE and bias in 10N-40N regions, and nearly equal accuracy in global area compared to Ver.4.0. AMSR2 SST Ver.4.1 was released to public on July 27, 2022.

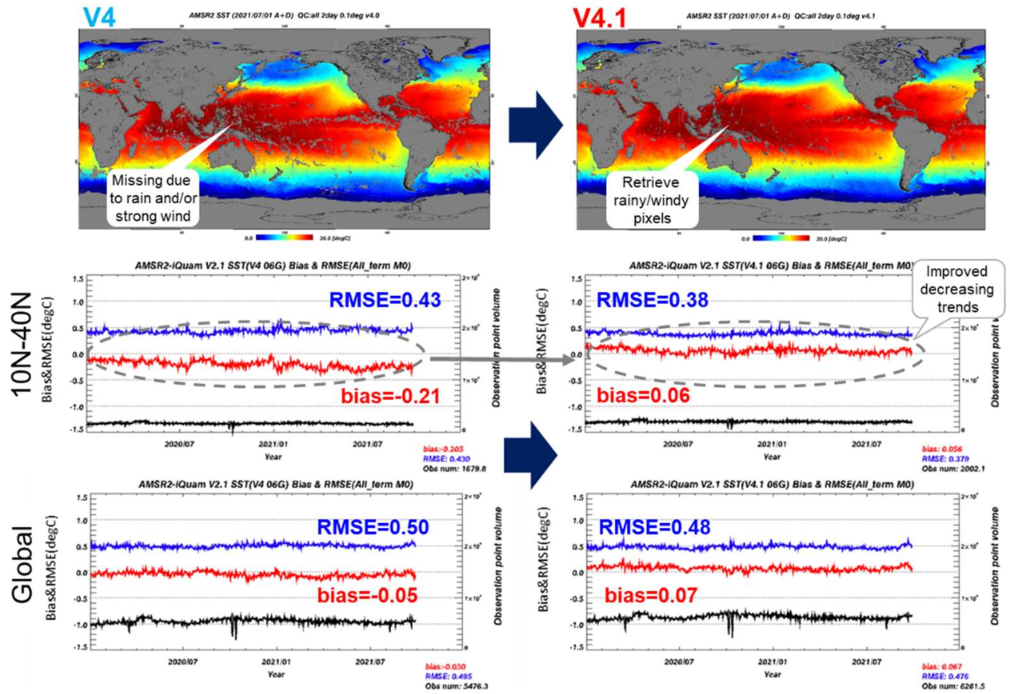

Figure 1: Comparison of AMSR2 6GHz SST Ver.4.0 (left) and Ver.4.1 (right). Upper: SST average during July 1-2, 2021. Middle: Temporal variation of daily statistics versus buoy averaged over 10N-40N; Lower: Same but over global area.

Update of SGLI SST

The latest SGLI SST (Kurihara *et al.*, 2021) is Ver.3 and released to public in November 2021. Improvements in Ver.3 are; 1) stripe- and random-noises by introducing a new split-window data filter; 2) daytime cloud masking above turbid waters by using 1.6 um data, around SST fronts by improved SST front detection, and above inland waters by using NDWI; 3) nighttime cloud masking by changing the quality level classification and thresholds. There is no change on the SST method (Q-method).

SGLI SST Ver.3 shows good accuracy over the Arctic region. Figure 2 shows monthly Probability Density Function (PDF) and statistics of differences between SGLI SST Ver.3 (quality level >= 4) and buoy SST over the area higher than 70N latitude from June to September 2021. SGLI SST Ver.3 shows good accuracy around 0.3-0.4K.

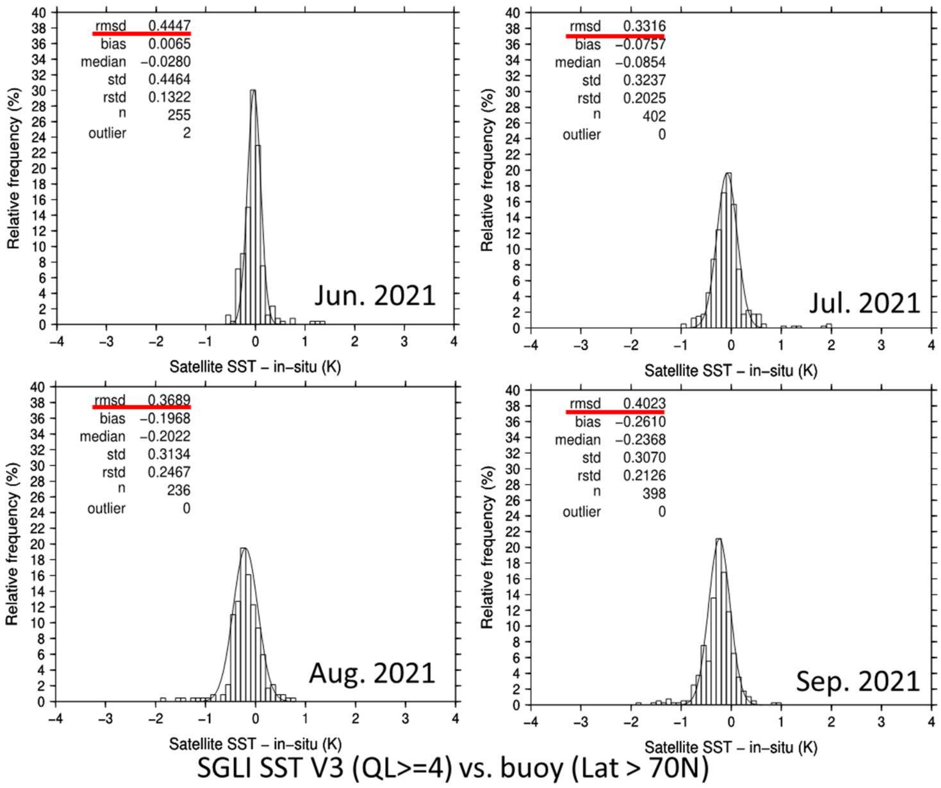

Figure 2: PDFs of differences between SGLI SST Ver.3 and buoy SST.

Update of Himawari SST

JAXA applies SST retrieval algorithm developed for SGLI to the Himawari-8/AHI (Kurihara *et al.*, 2016) to produce consistent IR SSTs in both LEO and GEO. The latest Himawari-8 SST product is Ver.2. There is a significant long-term trend in bias in the current Himawari-8 SST as shown in Figure 3. This trend will be corrected in producing the Climate Data Record (CDR) after the satellite transfer from the Himawari-8 to Himawari-9, planned by JMA.

JMA will replace the Himawari-8 satellite to the Himawari-9 satellite in December 2022 with some overlap period. JAXA plans replace Himawari-8 SST to Himawari-9 SST at the same time to continue the Himawari SST product

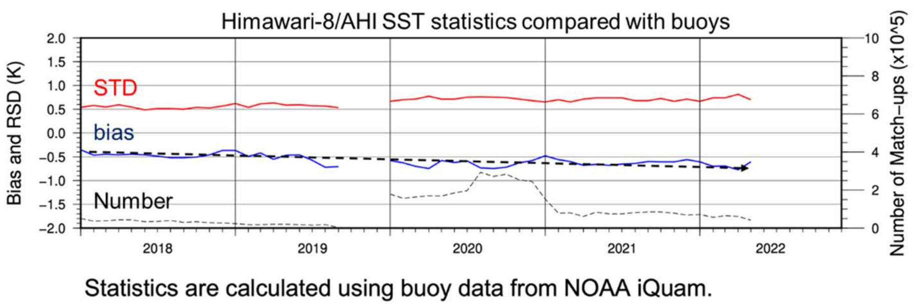

Figure 3: Temporal variation of statistics of Himawari-8 SST versus iQuam buoy SST from 2018 to 2022.

Highlights of recent SST events

Unusual high SST in the Japan Sea in July 2021

In the summer of 2021, we experienced unusual high SST over the Japan Sea. Figure 4 indicates SST in July 2021 is anomalous during the past 20-year. Both daytime (ascending orbit) and nighttime (descending orbit) SSTs are increased from the middle of July and reached to peak in late July, and it is 8-9 degreeC higher than normal years in daytime. AMSR2 wind speed showed calm state over the region during this period and SGLI SST has less impacts of clouds (not shown). It indicates less wind and less cloud condition in weather in July 2021. When the Typhoon No.9 has passed the area on August 8-9, 2021, AMSR2 SST was dropped down to normal state, and it indicates ocean temperature under the skin surface may not be warmed up.

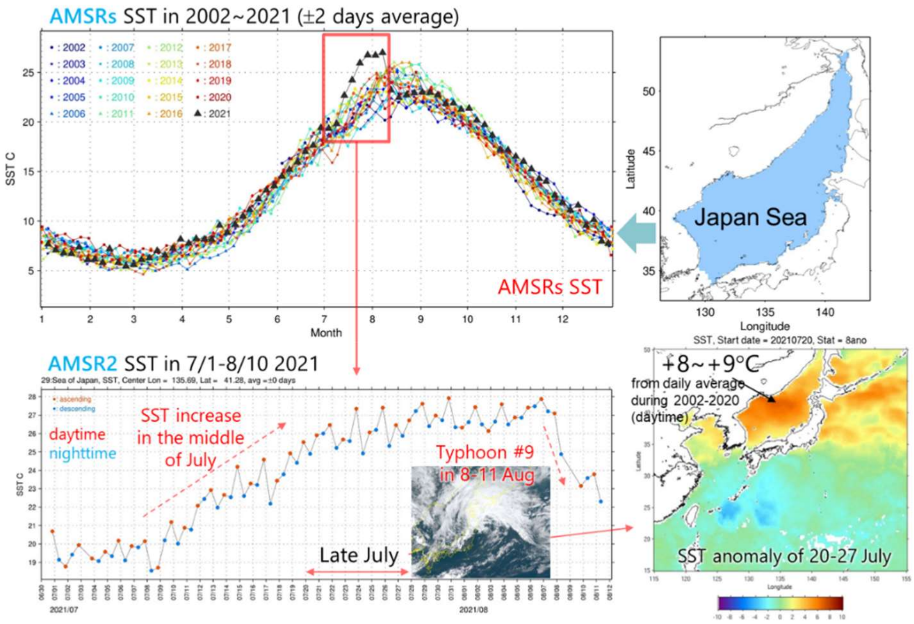

Figure 4: Seasonal variation of AMSRs SST (using both AMSR-E and AMSR2) over the Japan Sea. Upper right: area of average (Japan Sea) is shown in light blue. Upper left: seasonal change of 5-day running mean AMSRs SST from 2002 to 2021. Lower left: close-up of AMSR2 SST variation from July 1 to August 10, 2021. Lowe right: AMSR2 SST anomaly around Japan in July 20-27, 2021.

Collaboration with ocean model community

To merge the MW, LEO-IR and GEO-IR SSTs, JAXA collaborates with model developing community, especially in satellite-based SST data assimilation to ocean models.

JAXA and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) collaborates in this area by assimilating AMSR2, SGLI, and Himawari SSTs into their 3-km grid ocean model around Japan in near-real-time basis to produce short-term forecast of ocean status, called JCOPE-T DA (Miyazawa *et al.*, 2017 & 2021). The system assimilates satellite SST data high-frequently, and outputs temperature, salinity, ocean currents in 46-layer and sea-level height. Operational processing is conducted by JAMSTEC to produce analysis and forecast of ocean state, and model output images and SST are distributed from the JAXA Himawari Monitor. The same system is also used in transfer simulation of pumice by ocean volcanic eruption using location of identified pumice stones by SGLI, ALOS-2.

JAXA also collaborates with RIKEN to develop eddy-resolving local ensemble transform Kalman fileter (LETEKF)-based ocean research analysis (LORA) for the western North Pacific and Maritime Continent regions with satellite-based SST assimilation (Ohishi *et al.*, 2022a, 2022b, 2022c). The system is developed on the JAXA supercomputer to produce long-term ocean dataset for geoscience research applications as well as for fisheries, marine transport, and environment consultants. We plan to distribute ocean dataset with ensemble mean and spread of past period data since 2015 in near future.

Summary

JAXA produces and distributes various MW, LEO-IR, and GEO-IR SST products as GHRSST Dataset. Those datasets are available from two web sites -- Himawari/AHI SST in GDS2.0 format is available at the JAXA Himawari Monitor (https://www.eorc.jaxa.jp/ptree/) and other SSTs in GDS2.0 format is available at the JAXA GHRSST server (https://suzaku.eorc.jaxa.jp/GHRSST/).

AMSR2 SST Ver.4.1 was recently released with improved RMSE and bias in the Northern subtropics and introduction of retrievals of windy or light-rainy pixels. Currently we are preparing algorithms for AMSR3 onboard the GOSAT-GW satellite, to be launched in Japanese Fiscal Year of 2023.

SGLI SST Ver.3 was released in Nov. 2021 with improved cloud masking and reduced random noises. There are some remained issues, including high bias under high WV, negative bias caused by aerosol or volcanic ash, and sea ice mask.

The Himawari-8 satellite will be replaced by the Himawari-9 satellite in December 2022 and resultingly AHI SST produced by JAXA will be also replaced. Current long-term trends in Himawari-8 SST will be corrected in future CDR processing after the satellite transfer.

There are some research activities that use multi-satellite SST data in multi-disciplinary areas. JAXA has worked with JAMSTEC and RIKEN, ocean model developing institutes, in development of the ocean data assimilation systems to use satellite-based SST data directly to the ocean models. Those 3-dimensional and frequent ocean datasets without missing areas can be used for several applications, such as fishery and simulation of the pumice stones.

References

Kurihara, Y., H. Murakami, K. Ogata and M. Kachi, A quasi-physical sea surface temperature method for the split-window data from the Second-generation Global Imager (SGLI) onboard the Global Change Observation Mission-Climate (GCOM-C) satellite, Remote Sens. Environ., DOI: 10.1016/j.rse.2021.112347, 2021.

Kurihara, Y., H. Murakami and M. Kachi, Sea surface temperature from the new Japanese geostationary meteorological Himawari-8 satellite, Geophys. Res. Letters. DOI: 10.1002/2015GL067159, 2016.

Miyazawa, Y., S. M. Varlamov, T. Miyama, Y. Kurihara, H. Murakami, M. Kachi, A Nowcast/Forecast System for Japan's Coasts Using Daily Assimilation of Remote Sensing and In-situ Data. Remote Sens., 13, 2431, 2021. DOI:10.3390/rs13132431.

Miyazawa, Y., S. M. Varlamov, T. Miyama, X. Guo, T. Hihara, K. Kiyomatsu, M. Kachi, Y. Kurihara, H. Murakami, Assimilation of high-resolution sea surface temperature data into an operational nowcast/forecast system around Japan using a multi-scale three-dimensional variational scheme, Ocean Dyn., 67, 713-728. DOI: 10.1007/s10236-017-1056-1, 2017.

Ohishi, S., T. Hihara, H. Aiki, J. Ishizaka, Y. Miyazawa, M. Kachi and T. Miyoshi, An ensemble Kalman filter system with the Stony Brook Parallel Ocean Model, submitted to Geoscientific Model Development, 2022a.

Ohishi, S., T. Miyoshi and M. Kachi, An EnKF-based ocean data assimilation system improved by adaptive observation error inflation (AOEI), submitted to Geoscientific Model Development, 2022b.

Ohishi, S., T. Miyoshi and M. Kachi, LORA: A local ensemble transform Kalman filter based ocean research analysis, submitted to Ocean Dynamics, 2022c.

Shibata A., AMSR/AMSR-E SST algorithm developments: removal of ocean wind effect, Italian J. Remote Sensing, 30/31: 131-142, 2004.

Shibata, A., Features of ocean microwave emission changed by wind at 6 GHz, J. Oceanogr., 62(3), 321-330, 2006.

Shibata, A., Effect of air-sea temperature difference on ocean microwave brightness temperature estimated from AMSR, SeaWinds, and buoys, J. Oceanogr., 63(5), 863-872

Overview of the Arctic SST/IST activities for the Copernicus Marine Service at DMI

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Abstract

Accurate estimates of sea surface (SST) and sea-ice surface temperatures (IST) are crucial for understanding, monitoring and predicting climate change in the Arctic. The Danish Meteorological Institute releases a suite of Pan-Arctic L3 and L4 products in Near-Real-Time and as Multi-Year datasets, being a Production Unit (PU) for the Copernicus Marine Monitoring Service Sea Ice (SI) Thematic Assembly Center (TAC). Within this framework, the first gap-free (L4) combined SST and IST climate dataset of the Arctic (>58°N) for the period 1982-2021, has been released. Optimal interpolation was used to combine multiple infrared satellite observations to daily, gap-free fields with a spatial resolution of 0.05°. The combination of SST and IST provides a consistent climate indicator which can be used to monitor day-to-day variations as well as climate trends in the Arctic Ocean; sea and sea-ice surface temperature increased about 4.5°C over the period 1982-2021, with the largest warming exceeding 10°C in the north-eastern Barents Sea.

In this paper, an overview of the existing suite of Copernicus Marine Service Pan-Arctic products for the SST and IST is provided, along with the improvements and new products planned for the new phase, including the new version of the L4 Multi-Year climate dataset and its associate Ocean Monitoring Indicators (OMI) which will be released by the end of 2022.

CMEMS SST/IST products

The Near-Real-Time (NRT) product SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_008 is available from 2018 onwards and consists of a daily, gap-free PanArctic SST and IST field of 0.05 degrees resolution, covering surface temperatures in the ocean, the sea ice and the marginal ice zone. Input data include infra-red observations from AVHRR on Metop-A (SST+IST), VIIRS_NPP (SST+IST), NOAA 20 (SST) and SLSTR SST from Sentinel 3A/B. SST products are currently adjusted to the VIIRS_NPP SST observations in a dynamical way. The satellite observations are processed at DMI for high latitudes. The level 2/3U data are processed using an IST, SST or MIZ algorithm and the observations contain information about what algorithm is used and the cloud mask quality (Dybkjær et al., 2012; 2014).

The reprocessed Multi-Year (MY) SEAICE_ARC_PHY_CLIMATE_L4_MY_011_016 product, from 1982 to 2021, consists of a daily, gap-free field with a 0.05 degrees resolution, and covers surface temperatures in the ocean, the sea ice and the marginal ice zone. The corresponding L3S super-collated product SEAICE_ARC_PHY_CLIMATE_L3S_MY_011_021 will be released in 2022; it consists of a daily field at a 0.05° resolution, with gaps due to data unavailability, and covers surface temperatures in the ocean, the sea ice and the marginal ice zone. For more details on all products, see the corresponding Copernicus Marine Service Product User Manual (2021; 2022) respectively.

DMIOI Processing System

The processing system uses the optimal interpolation method (Høyer & She, 2007; Høyer et al., 2014), operating on anomalies from a first guess field. A persistence-based method is applied, which uses the previous analysis field as the first guess field. The SST and IST observations from the current day are therefore interpreted as anomalies with respect to the first guess field. The errors on the guess field are derived from the analyses, both for SST and IST. Each SST analysis value is accompanied by an uncertainty estimate which is a result of the Optimal Interpolation algorithm.

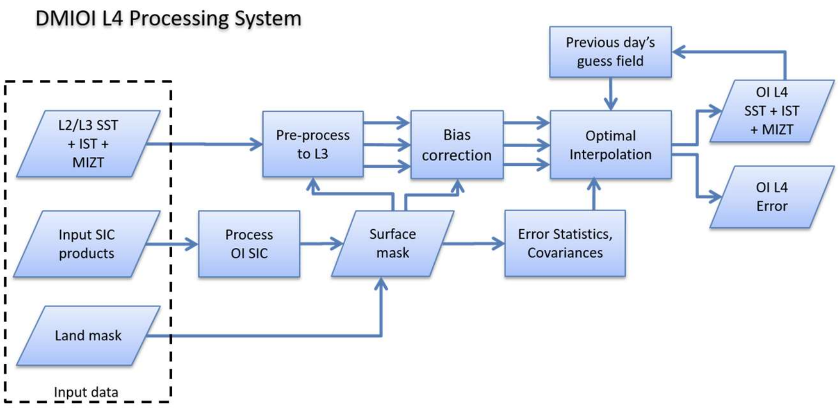

Figure 1: Schematic representation of the Optimal Interpolation system at DMI (DMIOI).

The statistical parameters, such as first guess variance and error correlation functions are different for SST and IST. In the construction of the combined OI field, the sea ice concentration (SIC) field is used to construct the full field such that for SIC<15 the SST statistical parameters are used. For 15<SIC<70, the Marginal Ice Zone, a linear weighting of both SST and IST statistical parameters are used. For SIC>70, the IST statistical parameters are used.

Validation of NRT L4 product

The sparse in-situ data coverage in the Arctic has made validation of the IST component for product SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_008 challenging and in 2022 routine validation using in-situ data from SIMB3 stations was initiated. Although one year of statistics was produced, results are improved compared to previous validation studies typically using 2-m air temperature measurements from drifting buoys stations, see Copernicus Marine Service Quality Information Document (2021).

In-situ	Type	Mean	Standard Deviation	RMS	N. Obs
SIMB3	IST	-3.52	3.63	5.05	621

Table 1: Validation statistics (in Kelvin) of the L4 IST component with in-situ observations from SIMB3 stations.

Validation of MY L4 and L3S products

An example of the MY L3S, corresponding L4 SST/IST product and its associated uncertainty field is provided in Figure 2. Validation of both products is routinely performed at every regular temporal extension or update using a suite of in-situ observations, separately for SST (drifting and moored buoys, Argo floats) and IST (drifting buoys and Operation IceBridge flights). Especially for the IST component, validation is not straightforward as direct IST in-situ measurements are almost never available and typically 2-m air temperature (T2m) is used instead. Table 1 shows the statistics from the validation on the L4 with a constant bias correction of 0.16°C applied, and the L3S product in parentheses, against in-situ measurements for the period 1982-2020, separately for the SST and IST components, see Nielsen-Englyst et al.(2022) for more details.

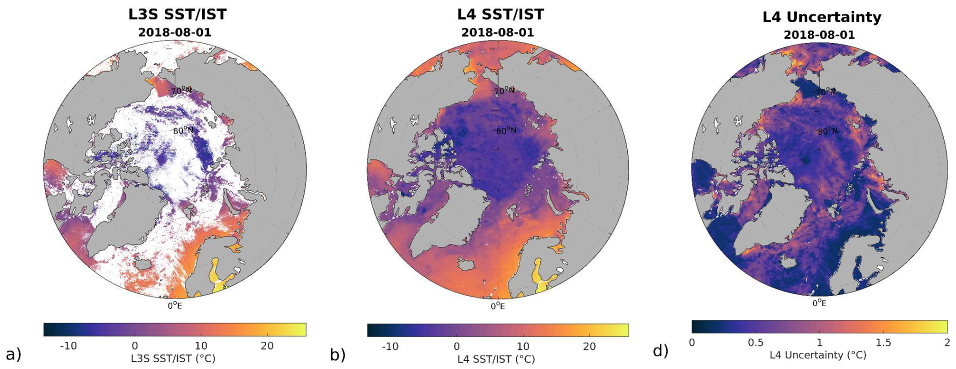

Figure 2: Examples of L3S (left), L4 (middle) and L4 Uncertainty (right) for August 1, 2018.

In-situ	Type	Mean	Standard Deviation	RMS	N. Obs
Drifting buoys	SST	0.00 (0.07)	0.54 (0.43)	0.54 (0.44)	3062549 (876709)
Moored buoys	SST	0.03 (0.10)	0.56 (0.53)	0.56 (0.54)	76052 (29946)
Argo floats	SST	0.03 (0.12)	0.51 (0.40)	0.51 (0.41)	32953 (10312)
NP Drifting Ice Stations (T2m)	IST	-2.35 (-1.81)	3.12 (2.51)	3.91 (3.09)	7665 (1183)
Drifting buoys ECMWF (T2m)	IST	-3.21 (-3.22)	3.34 (3.36)	4.63 (4.65)	55288 (26502)
Drifting buoys CRREL (T2m)	IST	-2.87 (-2.69)	3.36 (3.38)	4.42 (4.32)	22979 (11149)
IceBridge KT-19 (IST, SIC>=15%)	IST	1.52 (0.69)	3.12 (3.11)	3.48 (3.18)	36638 (33057)

Table 2: Validation statistics (in Kelvin) of the L4 and L3S, in parentheses, product's SST and IST components with in-situ observations.

Ocean Monitoring Indicators

The multi-year product SEAICE_ARC_PHY_CLIMATE_L4_MY_011_016 is used for the first -time estimation and and release, through the Copernicus Marine Service, of Ocean Monitoring Indicators (https://marine.copernicus.eu/access-data/ocean-monitoring-indicators?category=112&region=21&search=), defined as monthly mean anomalies and trends from a multi-year climatology, currently 1993-2014, starting from 1993 and updated annually. The 2021 anomalies and trends are being calculated and will be released in the next Copernicus Marine Service EiS (Entry into Service), scheduled for November 2022. The estimated anomalies and trends for 2020, not publicly released, are shown in Figure 3. The combined SST and IST trend for the period 1993-2020 was 0.131±0.008°C/yr, indicating an overall warming of more than 3.5°C over the last 28 years, with the highest trends occurring on the Eurasian side, i.e. Barents, Kara, Laptev and East Siberian Seas.

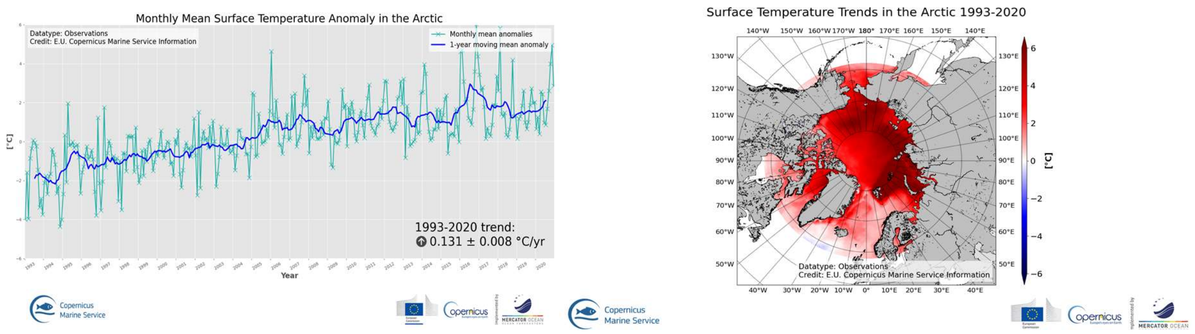

Figure 3: Monthly mean combined SST and IST anomaly (left) and cumulative trends for 1993-2020 (right).

Conclusion

The new Copernicus Marine Service Phase, 2022-2024, ensures the continued production and improvement of existing and new SST L4 and L3S products covering surface temperatures of the open ocean, sea ice and marginal ice zone, specifically developed for the Arctic.

References

Copernicus Marine Service, Product User Manual for Arctic Sea and Ice surface temperature product SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_008, V1.6, 2021. https://catalogue.marine.copernicus.eu/documents/PUM/CMEMS-SI-PUM-011-008.pdf

Copernicus Marine Service, Quality Information Document for Arctic Sea and Ice surface temperature product SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_008, V1.6, 2021. https://catalogue.marine.copernicus.eu/documents/QUID/CMEMS-SI-QUID-011-008.pdf

Copernicus Marine Service, Product User Manual for SEAICE_ARC_PHY_CLIMATE_L4_MY_011_016 and SEAICE_ARC_PHY_CLIMATE_L3S_MY_011_021, V2.0, 2022. https://catalogue.marine.copernicus.eu/documents/PUM/CMEMS-SI-PUM-011-016-021.pdf

Dybkjær, G., R. Tonboe and J.L. Høyer, Arctic surface temperatures from Metop AVHRR compared to in-situ ocean and land data. Ocean Sci. 8, 959–970, 2012. doi:10.5194/os-8-959-2012.

Dybkjær, G., J.L. Høyer, R. Tonboe and S. Olsen, Report on the documentation and description of the new Arctic Ocean dataset combining SST and IST, NACLIM Deliverable D32.28, 2014.

Høyer, J.L. and J. She, Optimal interpolation of sea surface temperature for the North Sea and Baltic Sea, J. Mar. Sys. 65, 1-4, 2007.

Høyer, J.L., P. Le Borgne and S. Eastwood, A bias correction method for Arctic satellite sea surface temperature observations, Rem. Sens. Environ. 146, 201-213, 2014.

Nielsen-Englyst P., J.L. Høyer, W.M. Kolbe, G. Dybkjær, T. Lavergne, R. Tonboe, S. Skarpalezos and I. Karagali, A combined sea and ice-surface temperature climate dataset of the Arctic 1982-2021, Rem. Sens. Environ., under review, 2022.

Overview of the Baltic Sea and North Sea SST activities for the Copernicus Marine Service at DMI

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Abstract

The Danish Meteorological Institute serves as a Production Unit (PU) for the Sea Surface Temperature (SST) Thematic Assembly Center (TAC) of the Copernicus Marine Monitoring Service. Within this framework, a suite of L3 and L4 SST products for the Baltic and North Sea are produced daily and as multi-year products. Having entered a new phase of the project in 2022, a range of activities are planned for the next three years, from releases of new products to improvements on existing ones. An example of a new product is the hourly L4 SST resolving the diurnal cycle in the North and Baltic Seas, currently under development. It is based on single-sensor satellite SST, aggregated hourly and optimally interpolated to generate gap-free hourly fields. Upon release, the product will allow monitoring of the daily SST variability, especially relevant for algal blooms and marine heatwaves. An improvement of the existing daily L4 SST product is related with its associated uncertainties as analysis showed them to be higher than those observed from comparisons with drifting and moored buoy in-situ sensors. The aim of this presentation is to provide an overview of the existing SST products and their quality, along with a summary of the improvements planned for the ongoing Copernicus Marine Service phase, especially those to be implemented by the end of 2022; preliminary results for the generation and validation of the new L4 diurnal SST product and the validation of modelled uncertainties of the daily L4 SST for the North/Baltic Seas are presented.

CMEMS SST products

The L4 Near-Real-Time SST product SST_BAL_SST_L4_NRT_OBSERVATIONS_010_007_b is a daily, multi-sensor, level 4 optimally interpolated product from the daily processing of the night time SST at high resolution (0.02°), covering the Baltic and North Sea. It is produced with the operational Optimal Interpolation system at DMI (DMIOI) which uses various satellite SST level 2 data as input, that have passed a significant number of quality controls, and are inter-calibrated and bias corrected.

The L4 Multi-Year SST product SST_BAL_SST_L4_REP_OBSERVATIONS_010_016 is a daily, multi-sensor, level 4 optimally interpolated product using infra-red satellite observations from the ESA CCI and Copernicus C3S projects and high resolution sea ice information from SMHI and CMEMS SI TAC. The product covers the period from January 1982 to May 2021, while it undergoes regular time extensions and re-processing with newer versions of the ESA CCI and Copernicus C3S SST datasets.

The L4 Near-Real-Time Diurnal SST product SST-BAL-PHY-SUBSKIN_L4-NRT-010-034 is a gap free satellite sub-skin SST analysis created by the DMIOI system, using L2P and L3 single-sensor SST data as input. The product will be available from May 01 2022 on a regular latitude/longitude grid at 0.02° resolution, providing an estimate of the hourly sub-skin SST with uncertainty estimates, which is the SST including diurnal variability.

Optimal Interpolation System

The Operational Sea Surface Temperature and Ice Analysis (DMIOI) system uses upstream L2 and L3 satellite data along with ice concentration information for the production of L3S and L4 SST. Figure 1 shows the different steps for the creation of the DMI level 3S and 4 products at DMI. Depending on if the system is used for the daily NRT production of SST_BAL_SST_L4_NRT_OBSERVATIONS_010_007_b and SST_BAL_SST_L3S_NRT_OBSERVATIONS_010_032 or the reprocessing for the Multi-Year SST_BAL_SST_L4_REP_OBSERVATIONS_010_016 and SST_BAL_PHY_L3S_MY_010_040 products, different input data are used.

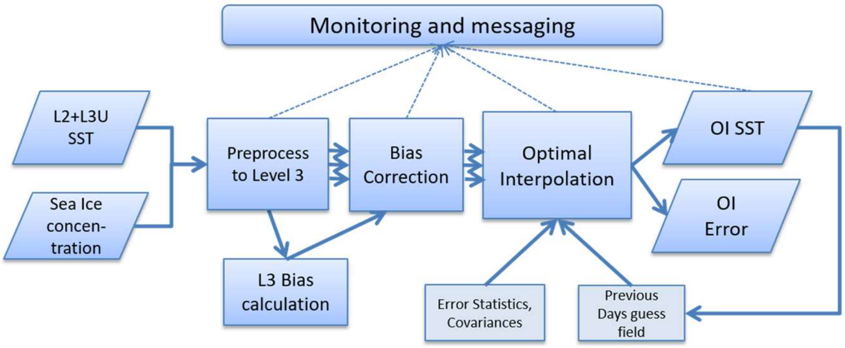

Figure 1: Schematic representation of Optimal Interpolation system at DMI (DMIOI).

The SST OI system uses a persistence-based approach utilising the previous analysis field as a first guess. The SST observations from the current day are therefore interpreted as anomalies with respect to the first guess field. The errors on the guess field are derived from the data. The pre-processing steps consist of a collation of each of the different products on a L3 grid. The time scale for the aggregations is the analysis +- 12 hours. For further details see the corresponding CMEMS Product User Manuals ([1] and [2], respectively) and [3]. For the production of the diurnal SST_BAL_PHY_SUBSKIN_L4_NRT_010_034 product, all satellite data valid for a particular day and hour, within 24 hours from the analysis are considered. The input L2/L3U SST data undergo various QC and processing steps to generate separate level 3 products and single-sensor hourly files are bias-corrected to ensure consistency. Hourly anomalies, dSST, from the SST foundation temperature of the same day (SST_BAL_SST_L4_NRT_OBSERVATIONS_010_007_b) are estimated as SST_{hour} minus $SST_{foundation}$. The OI is then applied to the hourly anomaly field, to produce gap-free hourly dSST and the $SST_{foundation}$ is subsequently added to the hourly dSST.

Validation of uncertainties for L4 NRT SST 010_007b

Assessing the provided error estimates was performed with the use of drifting and moored buoys for 2021, in the North Sea (drifters) and Baltic Sea (moored buoys), from the Copernicus Marine Service (INSITU_GLO_NRT_OBSERVATIONS_013_030, INSITU_BAL_NRT_OBSERVATIONS_013_032). The estimated L4 uncertainty was compared against the observed one, defined as the standard deviation of the L4 SST minus in-situ (not shown). An overestimation of the modelled uncertainties that are provided with the daily L4 analysis was observed, both against drifting and moored buoys, manifested as a relatively stable standard deviation of L4 SST minus in-situ (vertical black lines) although the modelled uncertainties increased from 0.2 and up to 0.85 K (drifters) or 1 K (moored buoys). In order to reduce the modelled error estimates provided with the L4 SST daily analysis, an assessment of the 1st-guess variance used was performed. A new 1st-guess variance field was estimated using daily SST analyses fields from 2017 to 2021. The new 1st-guess variance field was lower than the standard one used currently for the operational production, by up to 0.5° especially obvious in the northern and southern parts of the Baltic Sea basin and extended areas of the North Atlantic. The new 1st-guess variance field was used to re-calculate the L4 SST and associated error fields for the test year of 2021 and the modelled uncertainties were validated again using the drifting and moored buoys.

Figure 2 shows the uncertainty analysis using the newly calculated L4 SST and error fields with the implementation of the new 1st-guess variance field against drifting and moored buoys, respectively. The theoretical curves which should be followed are indicated by the dashed lines. An overall reduction of modelled errors by approximately 0.1 degrees is observed compared to the original modelled errors, manifested as a decrease in the range of values in the x-axis, both for drifting and moored buoys; previous maxima were 0.86 K and 1.02 K, respectively. Furthermore, the standard deviation (vertical lines) of the L4 SST vs in-situ observations increases with increasing error estimates following better the theoretically expected dashed lines, in particular for the range 0.2°-0.4° of error estimates, which is where most match-ups are observed (blue lines). To assess the impact of the new vs the old 1st-guess variance field on the daily SST analysis, validation of the SST produced using the old and new 1st-guess variance field, for 2021, was performed against the moored and drifting buoys. The results (not shown) indicated almost no change in the statistics for the L4 SST between the two versions, beyond a negligible reduction of the bias, standard deviation and RMS observed at the 3rd decimal, e.g. 0.318 K and 0.530 K RMS for drifting and moored buoys respectively for the new estimates from 0.320 K and 0.533 K for the original.

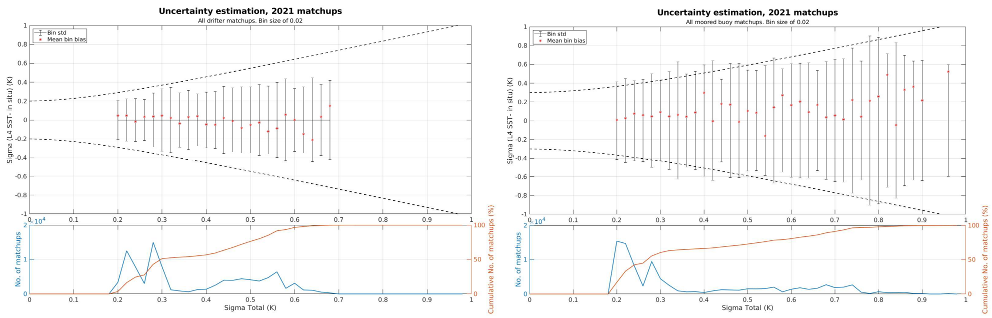

Figure 2: Uncertainties (x-axis) provided with the daily L4 analysis, using the newly derived 1st guess variance, against the estimated standard deviation of the L4 SST analysis minus in-situ SST from buoys (y-axis), drifting (left) and moored (right). The bottom panels show the availability of match-ups (blue) and cumulative availability (orange).

Ocean Monitoring Indicators

The multi-year product SST_BAL_SST_L4_REP_OBSERVATIONS_010_016 is used routinely for the estimation and release, through the Copernicus Marine Service, of Ocean Monitoring Indicators (https://marine.copernicus.eu/access-data/ocean-monitoring-indicators?category=112&region=21&search=), defined as monthly mean anomalies and trends from a multi-year climatology, currently 1993-2014, starting from 1993 and updated annually. Currently, the 2021 anomalies and trends are being calculated and will be released by the next Copernicus Marine Service EiS (Entry into Service), scheduled for November 2022.

Diurnal product L4 NRT SST 010_034

The new product is currently being validated for the test period May-August 2021 using the in-situ drifting and moored buoys. An example of an hourly SST L4 gap-free field for June 01, 2021 16:00 can be seen in the middle panel of Figure 3 below. The left panel, shows the night-time foundation SST, computed as the mean SST during 00:00-04:00. The right panel, shows dSST, i.e. the difference $SST_{16:00}$-$SST_{foundation}$, where differences of 2 degrees can be seen in large parts of the Baltic Sea basin.

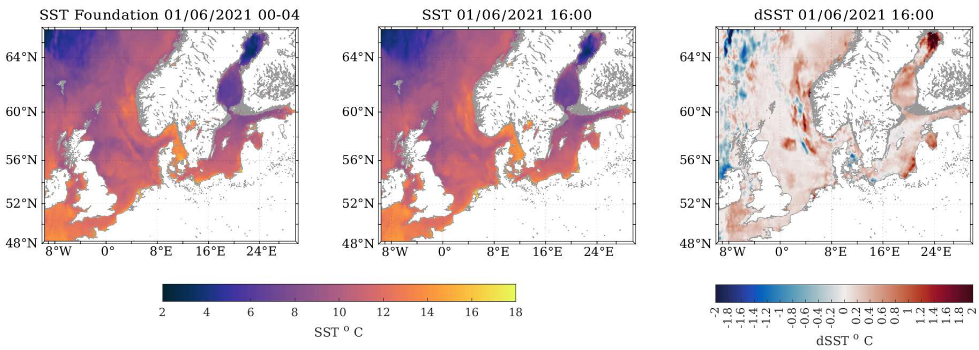

Figure 3: Foundation SST temperature (left), SST at 16:00 (middle), dSST (right).

Using experience from the uncertainty analysis of the L4 NRT SST product, a sensitivity analysis was carried out using the standard and newly calculated 1st-guess variance fields along with the standard option to bias-correct the input L2/L3 SST data or not. Four sample datasets covering the period May-August 2021 were generated and compared with drifting buoys. Results from the three are shown in Table 1, separated into all day match-ups, day-time (06:00-19:00) and night-time (>19:00 and <06:00). Bias-correcting the input data results in better comparisons with the drifters for all cases (all day, day-time and night-time) while using the newly derived 1st-guess variance (see previous section) further improves the comparisons through lowering of the standard deviation and RMSE. Overall, statistics are comparable to what is found for the NRT SST L4 product 010_007_b (Copernicus Marine Service, 2019).

L4 NRT SST (All, Day, Night)	Bias-corrected (BC), standard 1st-guess			No BC (NBC), standard 1st-guess			BC, new 1st -guess		
Mean	-.174	-.203	-.136	-.223	-.252	-.186	-.174	-.203	-.136
Standard Dev.	.553	.557	.546	.566	.570	.559	.549	.553	.541
RMSE	.580	.593	.563	.609	.623	.589	.576	.589	.558
N. Obs	34690	19869	14821	34690	19869	14821	34690	19869	14821

Table 1: Validation statistics (in Kelvin) of the L4 diurnal SST sample datasets with in-situ observations from drifting buoys.

References

[1] Copernicus Marine Service, Product User Manual SST_BAL_SST_L4_REP_OBSERVATIONS_010_016, V1.3, 2017, https://catalogue.marine.copernicus.eu/documents/PUM/CMEMS-OSI-PUM-010-016.pdf.

[2] Copernicus Marine Service, Product User Manual SST_BAL_SST_L4_NRT_OBSERVATIONS_010_007_b, SST_BAL_SST_L3S_NRT_OBSERVATIONS_010_032, V2.7, 2019, https://catalogue.marine.copernicus.eu/documents/PUM/CMEMS-SST-PUM-010-007-032.pdf.

[3] Høyer, J. L. and Karagali, I. (2016). Sea surface temperature climate data record for the North Sea and Baltic Sea. Journal of Climate, 29 (7), 2529-2541.

Extended abstracts: Science Session S3 Calibration, Validation and Product Assessment

Comparison of GHRSST SST analysis in the Arctic Ocean and Alaskan coastal waters using saildrones

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Abstract

The rapid environmental changes occurring at high latitudes. Although there is a plethora of L4 SST products to choose from, satellite-based products evolve constantly with the advent of new satellites and frequent changes in SST algorithms with the intent of improving absolute accuracies. The constant change of these products, as reflected by the version product, make it necessary to do periodic validations against in-situ data. Eight of these L4 products are compared here against Saildrone data from two 2019 campaigns in the western Arctic, as part of the MISST project. The accuracy of the different products is estimated using different statistical methods, from standard and robust statistics to Taylor diagrams. Results are also examined in terms of spatial scales of variability using spectral analysis. The three products with the best performance at this point and time are used in a case study of the thermal features of the Yukon-Kuskokwim delta. Comparisons are also made with Salinity data from NASA's Soil Moisture Active Passive Mission.

Overall, the statistical analyses show that two L4 SST products had consistently better relative accuracy when compared to the Saildrone subsurface temperatures. Those are the NOAA/NCEI DOISST and the RSS MWOI SSTs. Results will also be presented on comparing the spectral variance and feature resolution. Comparisons are all done using Saildrone as the reference.

Introduction

- There is high demand for complete satellite SST maps (or L4 SST analyses) of the Arctic regions to monitor the rapid environmental changes occurring at high latitudes. Although there is a plethora of L4 SST products to choose from, satellite-based products evolve constantly with the advent of new satellites and frequent changes in SST algorithms with the intent of improving absolute accuracies. The constant change of these products, as reflected by the version product, make it necessary to do periodic validations against in-situ data.
- Eight of these L4 products are compared here against Saildrone data from two 2019 campaigns in the western Arctic, as part of the MISST project. The accuracy of the different products is estimated using different statistical methods, from standard and robust statistics to Taylor diagrams. Results are also examined in terms of spatial scales of variability using auto- and cross-

spectral analysis. The three products with the best performance at this point and time are used in a case study of the thermal features of the Yukon-Kuskokwim delta.

Results

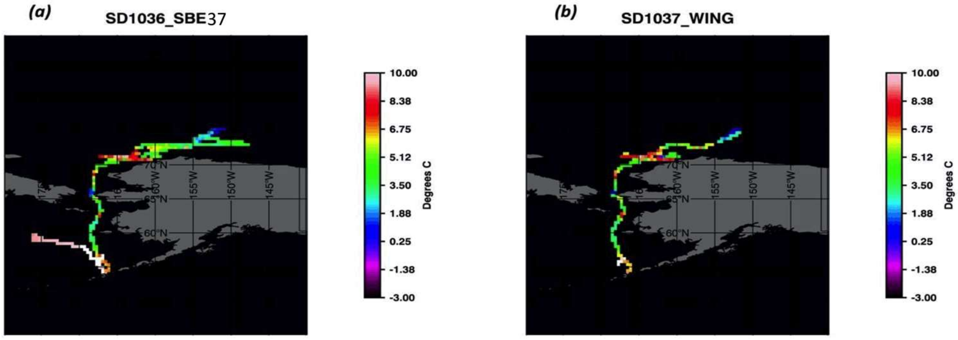

Figure 1: SST along the two NASA Saildrone deployments SD1036 and SD1037

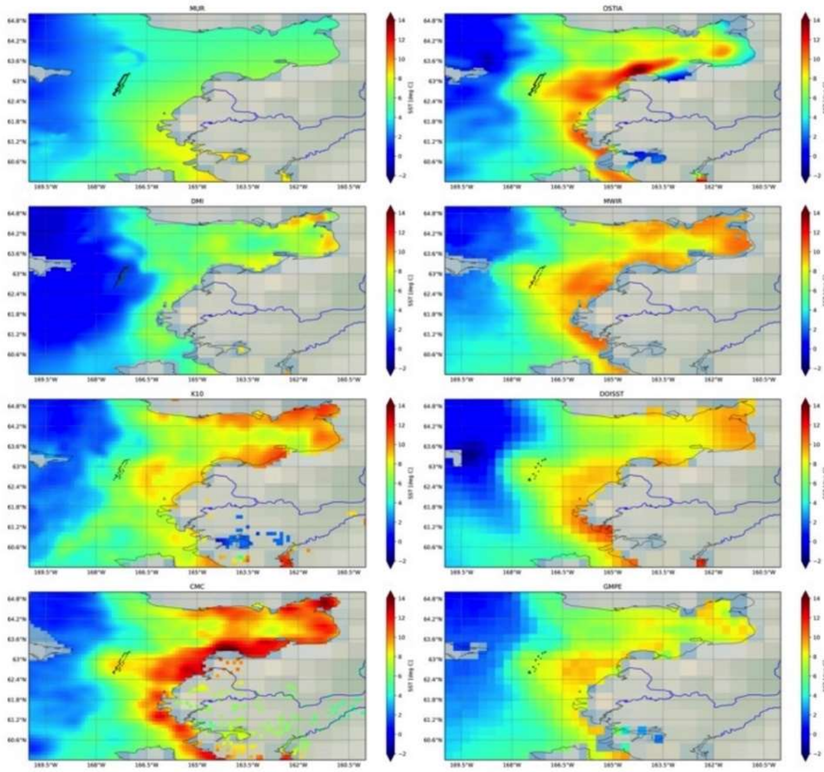

Figure 2: Mean SST for the 8 GHRSST level 4 products. The mean is derived over the time period of the Saildrone deployments.

The top two figures show the location of the two MISST Saildrone Deployments. SD1036 and SD1037. The locations of the Saildrone deployments are color coded with the SST values. The eight lower figures show the mean SST during the Saildrone deployment for the 8 GHRSST Level 4 products zooming in on the area of the Yukon River discharge and the Y-K delta. The 8 data sets show clear differences in the magnitude of the warmer water associated with the Y-K delta.

Conclusion

- The statistical analyses show that two L4 SST products had consistently better relative accuracy when compared to the Saildrone subsurface temperatures. Those are the NOAA/NCEI DOISST and the RSS MWOI SSTs (see Taylor Diagrams below)
- In terms of the spectral variance and feature resolution, the UK Met Office OSTIA product appears to outperform all others at reproducing the fine scale features, especially in areas of high spatial variability such as the Alaska coast. It is known that L4 analyses generate small-scale features that get smoothed out as the SSTs are interpolated onto spatially complete grids. However, when the high-resolution satellite coverage is sparse, which is the case in the Arctic regions, the analyses tend to produce more spurious small-scale features.
- The analyses here indicate that the high-resolution coverage, attainable with current satellite infrared technology, is too sparse due to cloud cover to support very high resolution L4 SST products in high latitudinal regions. Only for grid resolutions of ~9-10 km or greater, does the smoothing of the gridding process balance out the small-scale noise resulting from the lack of high-resolution infrared data. This scale, incidentally, agrees with the Rossby deformation radius in the Arctic Ocean (~10 km).

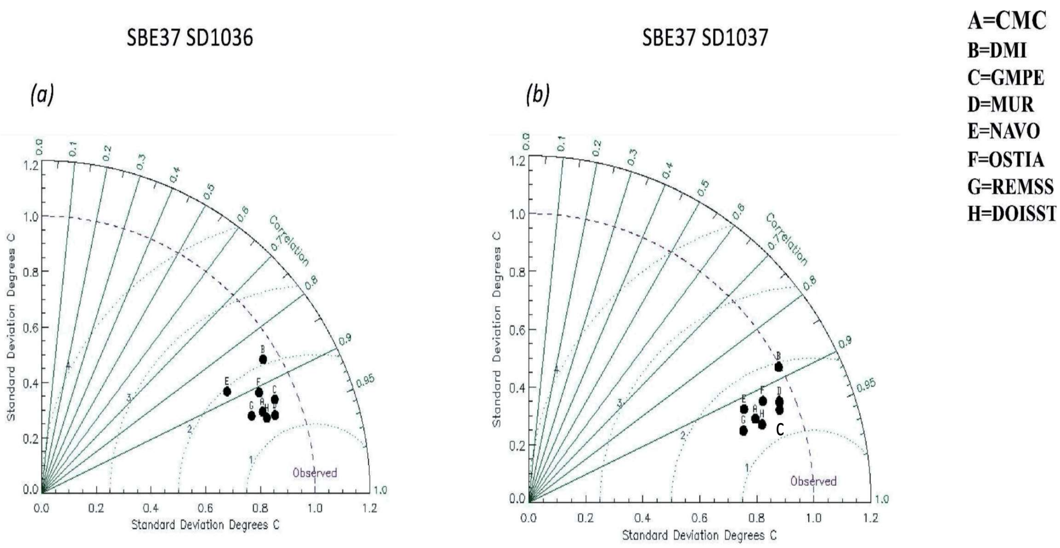

Figure 3: Taylor Diagrams summarizing the results of the comparisons of the 8 GHRSST Level 4 products with the two NASA Saildrone deployments.

References

Vazquez-Cuervo, Jorge, S. L. Castro, M. Steele, C. Gentemann, J. Gomez-Valdes, and W. Tang. "Comparison of GHRSST SST Analysis in the Arctic Ocean and Alaskan Coastal Waters Using Saildrones" Remote Sensing 14, (3) : 692. 2022. https://doi.org/10.3390/rs14030692

Validation of FY-3E/MERSI-LL Sea Surface Temperature

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Abstract

The Medium Resolution Spectral Imager-Low Light (MERSI-LL) onboard FY-3E has 7 channels, of which the 2 infrared split window channels' spatial resolution is 250m at nadir, the others are 1km.The split window data of MERSI-LL is used to estimate SST. At present, only 1 km granule SST retrieval and temporally composited daily SST (0.05°lat/lon grid, 00UTC and 12UTC centered) are ready. It will be released from http://satellite.nsmc.org.cn/PortalSite/Data/Satellite.aspx mid of this July to register for free. The 250m granule SST retrieval near China region is undergoing.

Introduction

The FengYun-3E (FY-3E) satellite is the first early-morning orbit satellite in China's polar orbiting meteorological satellite family (Zhang et al. 2022). It was launched from the Jiuquan Satellite Launch Center of China on 5 July 2021. Its local time at descending node is 5:30 A.M. The split window data of MERSI-LL is used to estimate SST which is sub skin SST and is highly sensitive to skin SST.

FY-3E/MERSI-LL SST

FY-3E/MERSI-LL sensor's brightness temperature and quality-controlled buoy SST (iQUAM V2.1) pairs are included in the matchup database (MDB) if they are coincident within 1km in space and 1 hour in time. Least-Square Regression is used for estimating the coefficients of NLSST. First guess SST is daily OSTIA V2.0 (0.05° × 0.05 °).

Validation

Validate SST against in-situ data

Monthly MDB with monthly SST coefficients from October 2021 to April 2022 is used to assess the accuracy of FY-3E/MERSI-LL SST (hereafter FY-3E SST). Table 1 shows the monthly global mean biases and standard deviations (SDs) of FY-3E SST minus in-situ (drifters and tropical moorings) and corresponding correlation coefficient and number of matchups, separately by day and night. Figure 1 shows time series of monthly global mean biases and SDs of table 1, separately by day (Red) and night (Black). Figure 2 shows histograms and scatter plots of FY-3E SSTs with respect to in-situ SSTs of January 2022 (a,c: Day b.d: Night).

	Day						Night					
Date	Bias (K)	Median (K)	SD (K)	RSD (K)	R	Nobs	Bias (K)	Median (K)	SD (K)	RSD (K)	R	Nobs
2021.10	0.05	0.06	0.43	0.4	0.998	17508	0.04	0.05	0.43	0.4	0.998	20217
2021.11	0.03	0.02	0.41	0.35	0.998	11466	-0.02	0	0.42	0.4	0.997	23918
2021.12	-0.01	-0.02	0.45	0.38	0.998	11373	-0.01	0	0.41	0.39	0.997	25058
2022.1	-0.01	0	0.46	0.41	0.997	19319	0	0.02	0.43	0.4	0.997	25260
2022.2	0.01	0.02	0.46	0.38	0.998	29683	-0.01	0	0.4	0.36	0.998	28049
2022.3	0	0.02	0.42	0.38	0.998	34016	-0.02	0.02	0.41	0.37	0.998	21341
2022.4	-0.05	-0.02	0.48	0.47	0.996	47630	-0.06	-0.05	0.49	0.46	0.998	13064

Table 1: Monthly global mean biases and SDs of FY-3E SST minus in-situ and corresponding correlation coefficient and number of matchups.

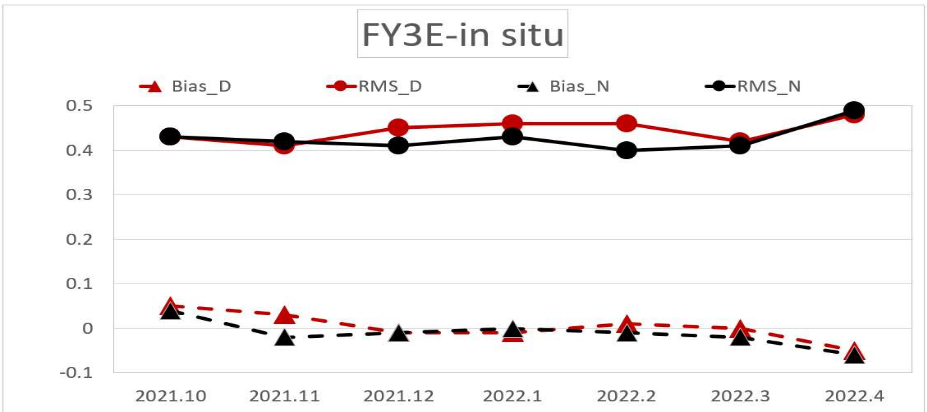

Figure 1: Monthly global mean biases and SDs of FY-3E SST minus iQUAM (D+TM) SSTs.

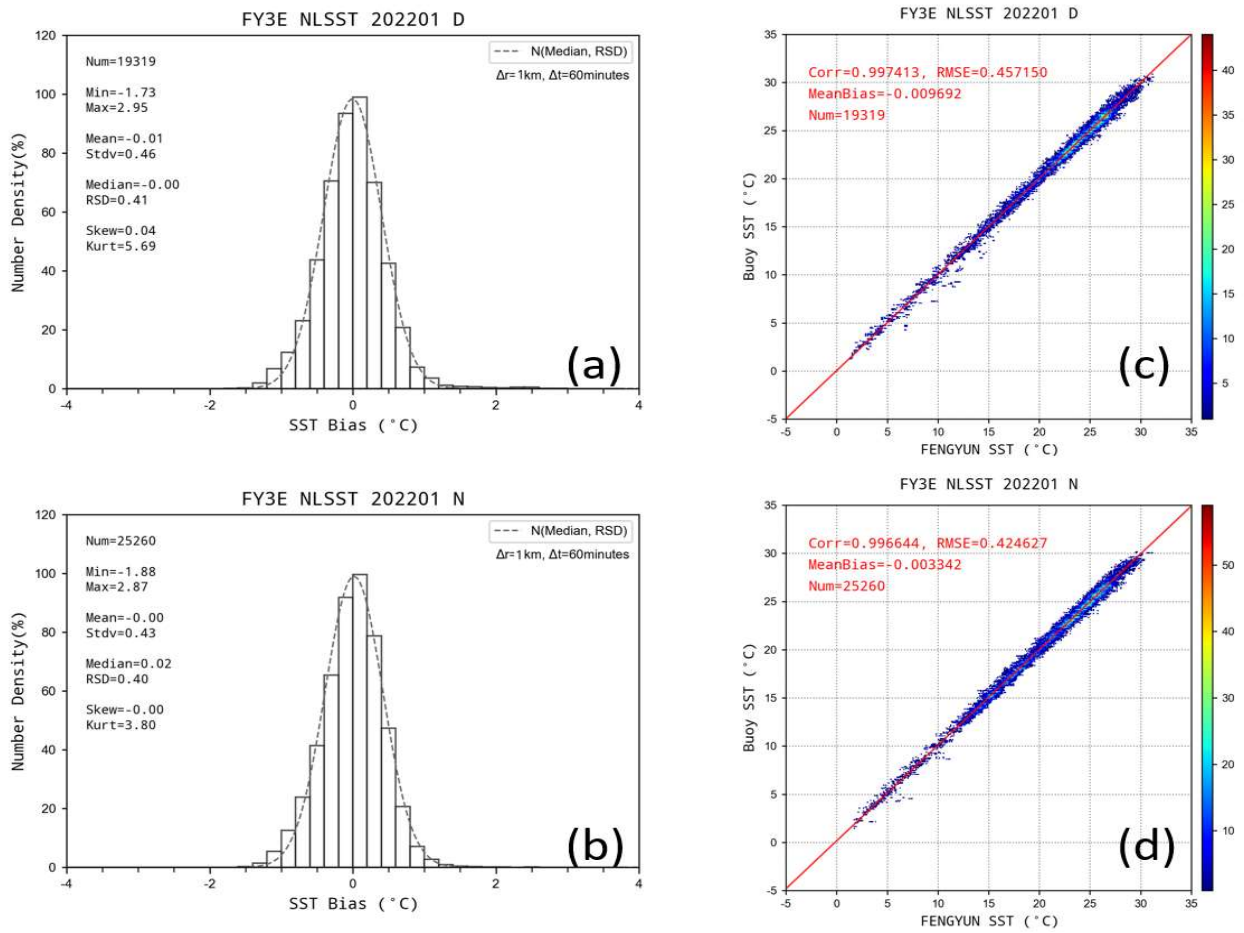

Figure 2: Histograms and scatter plots of FY-3E SSTs with respect to in-situ SSTs of Jan. 2022 (a, c: Day b, d: Night).

Validate SST against Global gridded L4 SST

Daily CMC V3.0 (0.1° × 0.1 °) is bi-linearly interpolated to MERSI-LL 1km pixels at nadir, L2P SST analysis is based on the 5-minute granule of FY-3E SST minus CMC. Figure 3 shows the time series of anomaly statistics of FY-3E SST for QL 5 from 7 September 2021 to 30 June 2022, separately by day (a, c) and night (b, d), ascending (red) and descending (black) node.

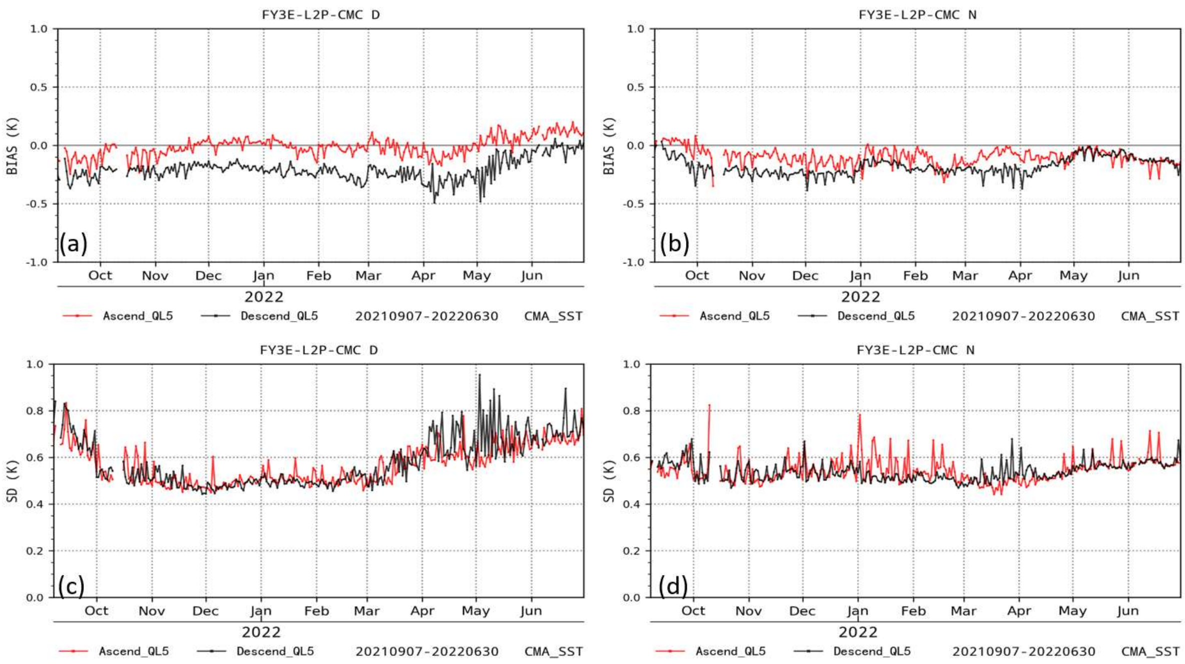

Figure 3: Daily global mean biases and SDs of FY-3E minus CMC

(a, c: Day. b, d: Night. Red: Ascending Black: Descending).

In order to investigate the capability of FY-3E SST for climate applications, monthly L3C SST is composited and monthly SST anomalies with respect to SST climatology (OISST_MonthClim_1982-2011.nc) are derived. Monthly OSTIA SST anomalies with respect to the same SST climatology are derived as reference. The FY-3E/MERSI monthly nighttime SST anomalies maps from October 2021 to April 2022 are shown in Figure 4 top panel, bottom panel shows the corresponding monthly OSTIA SST anomalies.

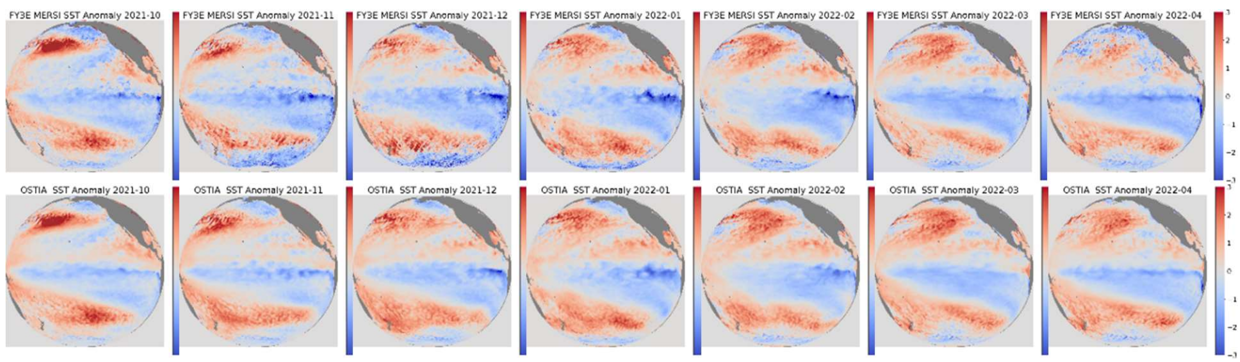

Figure 4: Evolution of Oct.2021-Apr.2022 La Niña revealed by FY-3E/MERSI monthly nighttime SSTAs. Top: FY-3E minus 1981-2010 monthly OISST. Bottom: monthly OSTIA minus 1981-2010 monthly OISST.

Conclusion

Based on monthly MDB from October 2021 to April 2022 the global mean biases are ranging from -0.06K to 0.05K and the SDs are ranging from 0.4K to 0.49K by comparison with in-situ buoy data. Comparison with FY-3E 5-minute granule SST (1km at nadir) and daily CMC from 7 September 2021 to 30 June 2022, the monthly global mean biases of daytime are ranging from -0.31K to 0.06K and the SDs are ranging from 0.48K to 0.7K, the monthly global mean biases of nighttime are ranging from -0.25K to 0.01K and the SDs are ranging from 0.49K to 0.59K.

Acknowledgements

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References

Zhang, P., X. Q. Hu, Q. F. Lu et al.FY-3E: The first operational meteorological satellite mission in an early morning orbit. Adv. Atmos. Sci., 39(1), 1-8, 2022

High Latitude Sea-Surface Skin Temperatures Derived from Saildrone Infrared Measurements

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Abstract

With NASA (National Aeronautics and Space Administration) funding, two Saildrone uncrewed surface vehicles (USVs) equipped with infrared (IR) pyrometers in a “unicorn” structure on the deck for the determination of the ocean sea-surface skin temperature (SST_{skin}) were deployed for 150-day cruises, from 15th May to 11th October 2019. The cruises were from Dutch Harbor, Alaska, going north through the Bering Strait into the Chukchi Sea, and back. An algorithm to derive SST_{skin} from the downward- and upward-looking radiometers is presented with an estimate of the uncertainty budget. After stringent quality control of data and eliminating measurements influenced by sea ice and precipitation, and limiting the range of tilt angles of the USV, based on the results of line-by-line radiative transfer model (LBLRTM) simulations, SST_{skin} can be derived to an accuracy of ~0.12 K. If the measurement geometry is well determined, the largest contribution to inaccuracies in the derived SST_{skin} is from instrumental uncertainties. Thus, Saildrones equipped with these sensors in this configuration could provide sufficiently accurate SST_{skin} retrievals for studying the physics of the thermal skin effect and for assessing the accuracy of satellite-derived SST_{skin} at high latitudes.

Introduction

Infrared (IR) satellite remote sensing [1] can provide frequent, long-term, global coverage of the sea surface skin temperature (SST_{skin}). To better assess errors in the satellite SST_{skin} retrievals, accurate in-situ measurements are required as validation data. IR radiometers mounted on ships or other platforms have been recognized as providing appropriate, accurate SST_{skin} measurements for the validation procedures, without needing to consider the cool skin effect and possible diurnal warming required when using data from drifting buoys or Argo floats, which measure the subsurface temperature at depths of several centimeters to meters. Over the past several decades, there are several ship-borne IR radiometer systems that have been proven to be successful in collecting SST_{skin} data, such as the Scanning Infrared Sea surface Temperature Radiometer (SISTeR) [2], the Marine Atmospheric Emitted Radiance Interferometer (M-AERI) [3], and the Infrared Sea surface temperature Autonomous Radiometer (ISAR) [4]. However, the available SST_{skin} validation data are limited in number and spatio-temporal extent, especially at high latitudes. The main challenge for acquiring more data is that the deployment and maintenance of accurate radiometers is both difficult and expensive. Here, we introduce a simple system with two

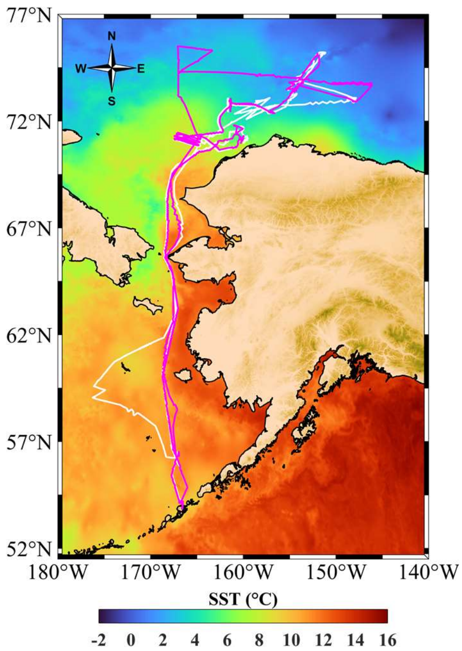

Figure 1: Cruise tracks for SD-1036 (white) and SD-1037 (magenta). The background SSTs on 16th Sept 2019 are from MUR Level 4 SST analysis data produced by GHRSST.

IR radiation pyrometers on Saildrone uncrewed surface vehicles (USVs) deployed in 2019.

Saildrone is a capable USV platform, operating on sustainable energy, using wind-power for propulsion and a suite of solar-powered meteorological and oceanographic sensors. The sensors are connected to onboard computers and deliver data in real time via satellite communications, making possible adaptive sampling and real-time data analysis. From 15th May to 11th October 2019, a fleet of Saildrone vehicles made a 150-day round-trip cruise from Dutch Harbor, Alaska. This deployment of six Saildrones included two NASA-funded vehicles, SD-1036 and SD-1037, whose trajectories are plotted in Figure 1. These two Saildrones carried a pair of IR pyrometers at the same nadir angle and zenith angles on the deck for the SST_{skin} retrieval. Additionally, there was a single down-looking sensor mounted on the spar of the sail at 2.25 m above the ocean surface. The pyrometers, manufactured by Heitronics Inc, were CT15s for the sea-view and CT09s for the sky-view.

Methodology

Figure 2 shows the geometry of the spectral radiance measurements which must be considered when deriving SST_{skin}. Due to the low installation height, 0.8 m, of the instruments, the atmospheric transmittance in the H layer can be taken as unity in the 8-14 µm wavelength spectral interval. Also, since the emissivity (ε) of seawater is slightly less than unity, a small portion of downwelling atmospheric radiation is reflected at the air-sea interface into the field of view of the sea-viewing radiometer. Thus, we have the relationship:

$$\int_{\lambda_0}^{\lambda_1} \sigma(\lambda) B(T_{sea}, \lambda)\, d\lambda = \int_{\lambda_0}^{\lambda_1} \sigma(\lambda) \left[\varepsilon(\lambda,\theta) B(T_s,\lambda) + \left(1-\varepsilon(\lambda,\theta)\right) B\left(T_{sky},\lambda\right)\right] d\lambda \quad (1)$$

where T_{sea} and T_{sky} are the radiometric temperatures measured by CT15 and CT09, T_s is the SST_{skin}. $\sigma(\lambda)$ is the relative spectral response (RSR) function of CT15, defining the limits of integration shown in Eq. (1). Note that the RSR function of CT09 significantly differs from the CT15s, the inaccuracies introduced will be discussed later.

To derive the SST_{skin}, it is important to know accurately the ε for the spectral intervals. The emissivity is sensitive to zenith angles (θ), especially >50º, and the viewing geometry changes with the tilt of vehicle. Therefore, to determine θ for each measurement, we established the three-dimensional rotation matrix, involving the three Euler angles: yaw, roll and pitch. Given the viewing geometry, we calculated ε using a fast radiative transfer model, RTTOV, which has a built-in IR sea surface emissivity model (IREMIS).

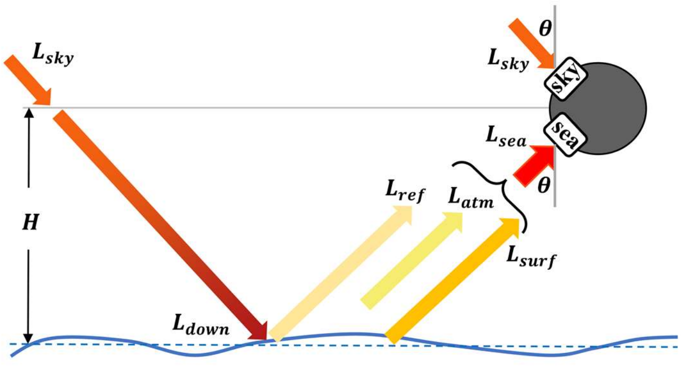

Figure 2: Sketch of radiative components considered for deriving the SST_{skin} with IR radiometers mounted at height H above the sea surface viewing the sea surface and sky at angles θ.

Error Budget Analysis

For the error budget of Saildrone derived SST_{skin}, there are three main components: inaccuracies in ε, and uncertainties in both sea- and sky-viewing radiometric measurements. The error in ε is very small due to the well-considered viewing geometry required for an accurate retrieval, and the well-established model. For the sky measurements, the errors are the instrumental uncertainty, the different viewing angle and RSR function from the sea-viewing sensor. While for the sea measurements, the only contribution is from the instrumental uncertainty. The SST_{skin} uncertainty budget is:

$$\epsilon_{skin}^2 = \epsilon_{sea}^2 + \epsilon_{sky}^2 + \epsilon_{angle}^2 + \epsilon_{RSR}^2 \qquad (2)$$

Based on the instrumental uncertainty given by the manufacturer (Table 1), and numerical simulations using line-by-line radiative transfer model (LBLRTM), T_{sky}contributes inaccuracies in the SST_{skin} retrievals ≤ 0.024 K for SD-1036 and ≤ 0.036 K for SD-1037 under clear skies. However, the accuracy of the sea-viewing CT15 is 0.5 K (Table 1), which is believed to be very conservative. An alternative way to make the first order approximation of the instrumental accuracy based on the field data. Considering that SD-1036 and SD-1037 were close, within 10 km, at times during the cruise, analyzing the subsurface SSTs from high-accuracy Sea-Bird SBE 56 thermometers at a depth of 0.3 m provides information on the geophysical variability of SST over these short separations. The uncertainty of SST_{skin} can be evaluated by comparing the ΔSST_{skin}, including an uncertainty term and the term due to difference in geophysics in Eq. (3), with the corresponding $\Delta SST_{0.3\ m}$, which only contains the geophysical variability (Eq. (4)), from two Saildrones assuming consistent upper ocean thermal structure given in Eq. (5). For this hypothesis to hold, diurnal warming signals in the measurements must be removed to eliminate the effects of thermal stratification patterns. The uncertainty of SST_{skin} is thus estimated to be about 0.12 K at a confidence level of 95% using the statistics of robust standard deviation in Eq. (6), and assuming that the uncertainties for SD-1036 and SD-1037 are identical. This assessment demonstrates that the accuracy of the CT15s on the Saildrones is much better than 0.5 K given in the manufacturer's specification.

$$\Delta SST_{skin} = SST_{skin\_1036} - SST_{skin\_1037} = u_c + \delta(SST_{skin}) \qquad (3)$$

$$\Delta SST_{0.3\ m} = SST_{0.3\ m\_1036} - SST_{0.3\ m\_1037} = \delta(SST_{0.3\ m}) \qquad (4)$$

$$\delta(SST_{skin}) = \delta(SST_{0.3\ m}) \qquad (5)$$

$$u_c = \sqrt{u_{1036}^2 + u_{1037}^2} = 1.96 * RSD(\Delta SST_{skin} - \Delta SST_{0.3\ m}) \qquad (6)$$

	CT09 (Sky)	CT15 (Sea)
Manufacturer's stated accuracy	± 1.0 K plus 0.6% of the difference between target and instrument temperature	± 0.5 K plus 0.7% of the difference between target and instrument temperature

Table 1: Manufacturer's stated accuracy for Heitronics IR pyrometers CT09 and CT15.

Conclusion

To obtain accurate ε for SST_{skin} derivations, the viewing geometry of sensors must be constrained to limit the effects of the vehicle's pitching and rolling. The errors of SST_{skin} retrievals are mainly from the inaccuracies of the sea and sky radiometric temperatures and the larger is in the sea-viewing CT15 measurements. The instrumental uncertainty of CT15 is << 0.5 K given in the manufacturer's specifications. The SST_{skin} derived from the infrared pyrometers on the hull of Saildrones have an uncertainty of ~0.12 K, which is sufficiently accurate for studies of the upper-ocean thermal skin layer, air-sea heat exchanges, oceanic thermal front patterns and to validate satellite-retrieved SST_{skin}. More details are given by [5]

References

[1] P. J. Minnett *et al.*, "Half a century of satellite remote sensing of sea-surface temperature," *Remote Sensing of Environment,* vol. 233, p. 111366, 2019.

[2] C. J. Donlon, T. Nightingale, L. Fiedler, G. Fisher, D. Baldwin, and I. S. Robinson, "The Calibration and Intercalibration of Sea-Going Infrared Radiometer Systems Using a Low Cost Blackbody

Cavity," *Journal of Atmospheric and Oceanic Technology,* vol. 16, no. 9, pp. 1183-1197, 1999.

[3] P. J. Minnett, R. O. Knuteson, F. A. Best, B. J. Osborne, J. A. Hanafin, and O. B. Brown, "The Marine-Atmospheric Emitted Radiance Interferometer: A High-Accuracy, Seagoing Infrared Spectroradiometer," *Journal of Atmospheric and Oceanic Technology,* vol. 18, no. 6, pp. 994-1013, 2001.

[4] C. Donlon *et al.*, "An Infrared Sea Surface Temperature Autonomous Radiometer (ISAR) for Deployment aboard Volunteer Observing Ships (VOS)," *Journal of Atmospheric and Oceanic Technology,* vol. 25, no. 1, pp. 93-113, 2008.

[5] C. Jia, P. J. Minnett, M. Szczodrak and M. Izaguirre, High Latitude Sea Surface Skin Temperatures Derived From Saildrone Infrared Measurements. IEEE Transactions on Geoscience and Remote Sensing (Accepted). 2022.

Extended abstracts: Science Session S4 Algorithms

Improving the atmospheric correction algorithms for sea surface skin temperature retrievals from MODIS using machine learning methods

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Abstract

Satellite retrievals of sea surface skin temperature (SSTskin) have become necessary for many near-real time applications. The missions of the two MODISs have provided continuous measurements for more than twenty years and have played a significant role in generating time series of quantitative estimates of SSTskin. This study used four machine learning approaches: eXtreme Gradient Boosting (XGBoost), support vector machines (SVM), random forests (RF), and artificial neural networks (ANN), to develop improved atmospheric correction algorithms for satellite-derived SSTskin in the Caribbean region. A set of satellite and in-situ measurements, including SST, the atmospheric state and surface radiation, taken on research cruises, from surface moorings and drifting buoys was used to train the machine learning models. Finally, the reliability and shortcomings of various machine learning methods were assessed through comparisons with SSTskin derived from shipboard and other in-situ measurements. Overall comparisons show encouraging results: the biases of various machine learning approaches vary between -0.076 K to 0.013 K; with the XGBoost showing the best correlation in a statistical analysis of in-situ SST measurements. This study contributes to improving our understanding of the key environmental properties and will reduce uncertainty in earth science and climate research.

Extended Abstracts

Infrared imaging radiometers in geostationary or polar orbits have provided measurements for the retrieval of SST for a half-century (Minnett et al. 2019). The MODISs on TERRA and AQUA have taken nearly continuous measurements for more than twenty years, with an unprecedented spectral resolution, and they are being extended into the future by the VIIRS on the S-NPP and NOAA20, and on subsequent satellites. As with all measurements, it is not only important to endeavor to improve the accuracy of the SSTskin retrievals, including in challenging situations, but also to quantify their errors and uncertainties (Donlon et al. 2007; Kumar et al. 2021) as this facilitates the appropriate use of the fields in all applications, especially in forecast model assimilation schemes.

Since these early pilot studies, more ML methods have demonstrated their capabilities in remote sensing applications: a scalable end-to-end gradient boosting tree (XGBoost; (Chen and Guestrin 2016)) approach has been used to handle nonlinear satellite product estimations such as the Chlorophyll-a (Cao et al. 2020; Chen et al. 2019) and SST (Wolff et al. 2020). Support vector machine (SVM) and artificial neural network (ANN), approaches were tested in atmospheric correction for satellite ocean colour sensors (Cao et al. 2020; Fan et al. 2021; Fan et al. 2017; Frouin et al. 2019), water quality retrieval (Balasubramanian et al. 2020), and oceanic particulate organic carbon concentrations (Liu et al. 2021). Our goal is to use various ML approaches to develop improved atmospheric correction algorithms to derive SSTskin in NRT; the applications above underscore the potential of ML in the proposed study. To achieve this goal, we used a sufficient number of factors in the training dataset in order to result in a statistically meaningful model. In-situ Ocean and atmospheric data measured from ships, surface buoys were used in the study, augmented with simulated data derived with radiative transfer models.

Figures

Our goal is to improve the atmospheric correction algorithms for SSTskin retrievals from MODIS using ML methods and devise versions that will be applicable in NRT. The goal can be divided into tasks given below. Some components can be conducted in parallel while others will be sequential. One of our initial objectives will be the generation of MUDBs; then we will use radiative transfer simulations, including through abnormal atmospheres to derive simulations of satellite brightness temperatures and retrieved SSTskin. The contents of the MUDBs and the simulated variables was used with ML methods, including to assess their validity and accuracy. The overall framework is illustrated in Figure 1.

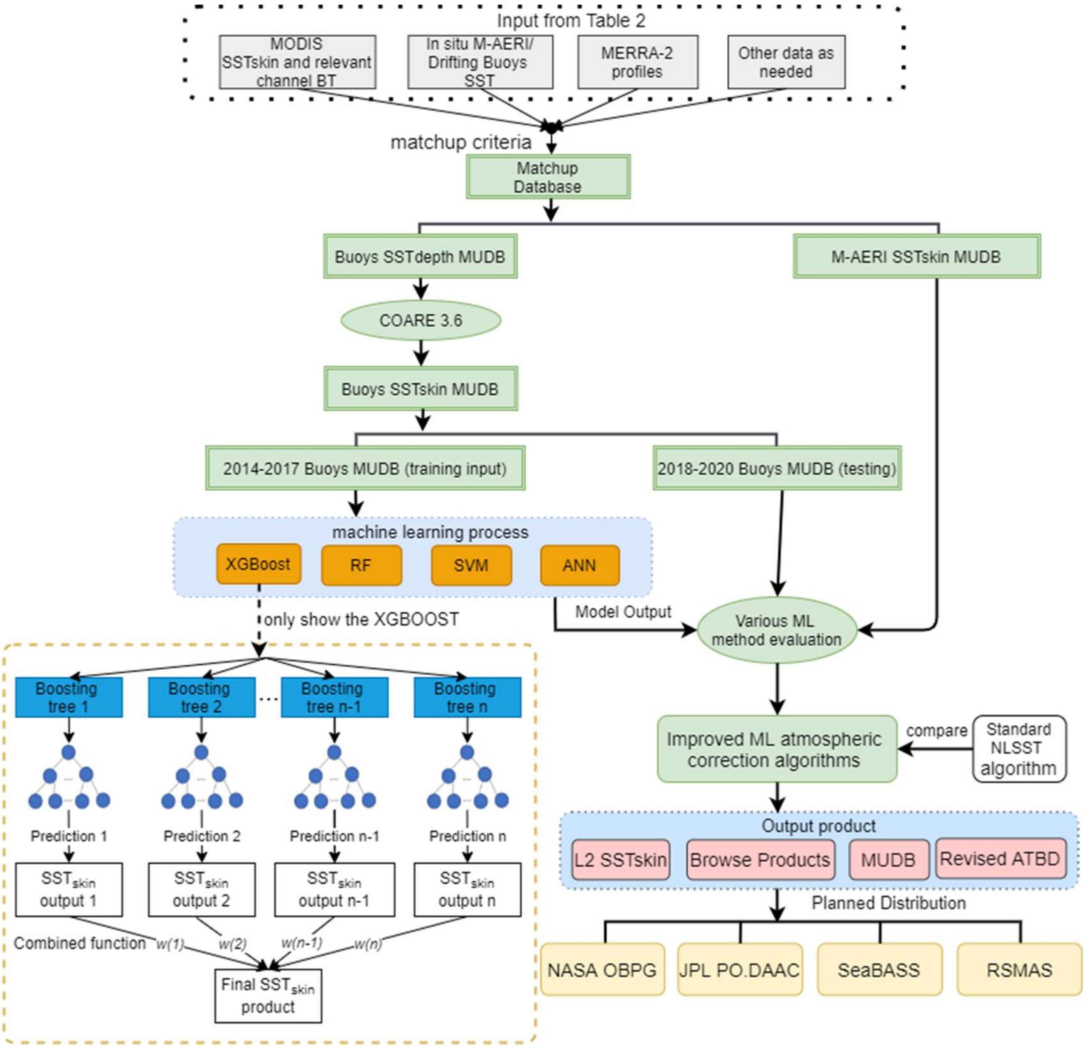

Figure 1: Overall framework of the proposed study. The yellow dot box shows a schematic diagram illustrating the process of the XGBoost algorithm, an optimized distributed gradient boosting method.

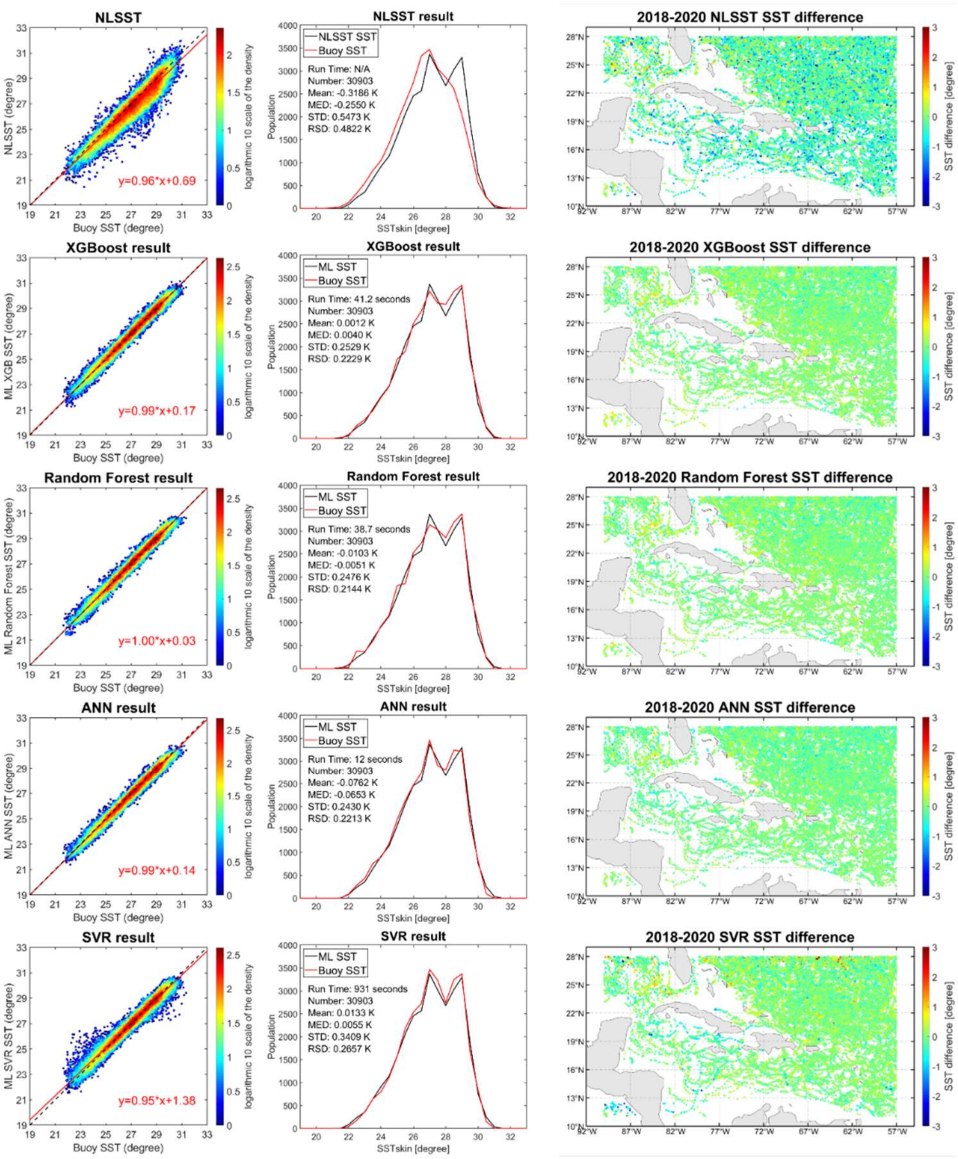

Figure 2: Left: Scatter plot of ML output SST against the drifting buoy measured SST. The dashed line is the 1:1 line and the red line is the least-squares linear fit. Middle: Histograms of ML output and measured SST as a function of the measured SST. Right: Differences between the ML output and measured SST. The colors indicate the difference, as shown on the right in degree.

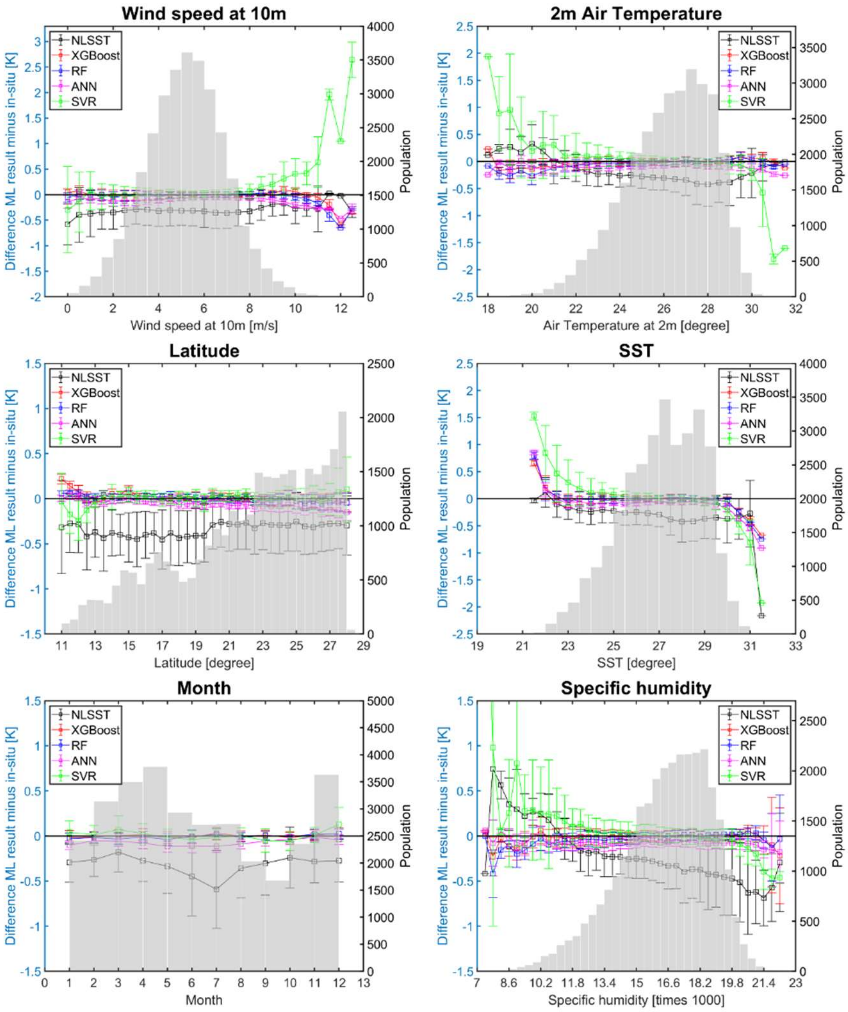

Figure 3: ML output minus drifting buoy measured SST as functions of wind speed (a), 2m air temperature (b), latitude (c), SST (d), month (e), and relative humidity (f). The error bars indicate the variance of the difference, and the error dot is the mean of the difference. The gray bars show the population within each x-axis interval.

Conclusion

A set of satellite and in-situ measurements, including SST, the atmospheric state and surface radiation, taken on research cruises, from surface moorings and drifting buoys was used to train the machine learning models. The reliability and shortcomings of various machine learning methods were assessed through comparisons with SSTskin derived from shipboard and other in-situ measurements. Overall comparisons show encouraging results: the biases of various machine learning approaches vary between -0.076 K to 0.013 K; with the XGBoost showing the best correlation in a statistical analysis of in-situ SST measurements. This study contributes to improving our understanding of the key environmental properties and will reduce uncertainty in earth science and climate research. The impact of other factors, such as different kinds of aerosol layers, sea salt sprays, etc. should be further explored with ML method. Such approaches as developed here can be applied to infrared satellite radiometers such as VIIRS on the Suomi-NPP and NOAA-20, SLSTR on Copernicus Sentinel-3 A/B satellites to improve the SSTskin retrievals.

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References

Balasubramanian, S.V., Pahlevan, N., Smith, B., Binding, C., Schalles, J., Loisel, H., Gurlin, D., Greb, S., Alikas, K., & Randla, M. (2020). Robust algorithm for estimating total suspended solids (TSS) in inland and nearshore coastal waters. Remote Sensing of Environment, 246, 111768.

Cao, Z., Ma, R., Duan, H., Pahlevan, N., Melack, J., Shen, M., & Xue, K. (2020). A machine learning approach to estimate chlorophyll-a from Landsat-8 measurements in inland lakes. Remote Sensing of Environment, 248, 111974.

Chen, S., Hu, C., Barnes, B.B., Xie, Y., Lin, G., & Qiu, Z. (2019). Improving ocean color data coverage through machine learning. Remote Sensing of Environment, 222, 286-302.

Chen, T., & Guestrin, C. (2016). Xgboost: A scalable tree boosting system. In, Proceedings of the 22nd acm sigkdd international conference on knowledge discovery and data mining (pp. 785-794)

Donlon, C.J., Robinson, I., Casey, K.S., Vazquez-Cuervo, J., Armstrong, E., Arino, O., Gentemann, C., May, D., LeBorgne, P., Piollé, J., Barton, I., Beggs, H., Poulter, D.J.S., Merchant, C.J., Bingham, A., Heinz, S., Harris, A., Wick, G., Emery, B., Minnett, P., Evans, R., Llewellyn-Jones, D., Mutlow, C., Reynolds, R.W., Kawamura, H., & Rayner, N. (2007). The global ocean data assimilation experiment high-resolution sea surface temperature pilot project. Bulletin of the American Meteorological Society, 88, 1197-1213. https://doi.org/10.1175/BAMS-88-8-1197

Fan, Y., Li, W., Chen, N., Ahn, J.-H., Park, Y.-J., Kratzer, S., Schroeder, T., Ishizaka, J., Chang, R., & Stamnes, K. (2021). OC-SMART: A machine learning based data analysis platform for satellite ocean color sensors. Remote Sensing of Environment, 253, 112236.

Fan, Y., Li, W., Gatebe, C.K., Jamet, C., Zibordi, G., Schroeder, T., & Stamnes, K. (2017). Atmospheric correction over coastal waters using multilayer neural networks. Remote Sensing of Environment, 199, 218-240. 10.1016/j.rse.2017.07.016

Frouin, R.J., Franz, B.A., Ibrahim, A., Knobelspiesse, K., Ahmad, Z., Cairns, B., Chowdhary, J., Dierssen, H.M., Tan, J., Dubovik, O., Huang, X., Davis, A.B., Kalashnikova, O., Thompson, D.R., Remer, L.A., Boss, E., Coddington, O., Deschamps, P.-Y., Gao, B.-C., Gross, L., Hasekamp, O., Omar, A., Pelletier, B., Ramon, D., Steinmetz, F., & Zhai, P.-W. (2019). Atmospheric Correction of Satellite Ocean-Color Imagery During the PACE Era. Frontiers in Earth Science, 710.3389/feart.2019.00145

Kumar, C., Podestá, G., Kilpatrick, K., & Minnett, P. (2021). A machine learning approach to estimating the error in satellite sea surface temperature retrievals. Remote Sensing of Environment10.1016/j.rse.2020.112227

Liu, H., Li, Q., Bai, Y., Yang, C., Wang, J., Zhou, Q., Hu, S., Shi, T., Liao, X., & Wu, G. (2021). Improving satellite retrieval of oceanic particulate organic carbon concentrations using machine learning methods. Remote Sensing of Environment, 256, 112316.

Minnett, P.J., Alvera-Azcárate, A., Chin, T.M., Corlett, G.K., Gentemann, C.L., Karagali, I., Li, X., Marsouin, A., Marullo, S., Maturi, E., Santoleri, R., Saux Picart, S., Steele, M., & Vazquez-Cuervo, J. (2019). Half a century of satellite remote sensing of sea-surface temperature. Remote Sensing of Environment, 233, 111366. https://doi.org/10.1016/j.rse.2019.111366

Wolff, S., O'Donncha, F., & Chen, B. (2020). Statistical and machine learning ensemble modelling to forecast sea surface temperature. Journal of Marine Systems, 103347.

Extended abstracts: Science Session S5 Computing and Products

PO.DAAC Cloud Data Ecosystem - Part 2: Moving Science to the Cloud

Session: S5 Computing and Products

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Abstract

As the PO.DAAC (and the rest of the NASA earth science data portfolio) migrates GHRSST and other datasets to the Amazon Web Services (AWS) cloud with its NASA enterprise level data discovery, access and services capabilities (see Li et al., *PO.DAAC Cloud Data Ecosystem - Part 1: Search, Access and Services*[1]) new opportunities (and challenges) are emerging for the scientific and applications user community. In this presentation we detail some of the emerging science analysis capabilities that a user in the cloud can leverage. This will be demonstrated through a series of Jupyter notebook workflows that run and manipulate data directly in the cloud using many of the capabilities and services from Part 1[1], and other standard python/AWS/Pangeo project utilities and customized code. These examples include workflows that perform spatial/temporal matchups of satellite SST to in-situ data, interdisciplinary matchups at the land/sea coastal boundary (e.g., Amazon River outflow), long time series ECCO ocean model analyses and several others that are made available as ready-to-run tutorials from the public PO.DAAC GitHub site. These tutorials have been developed over the past year in support of various NASA cloud data workshops and hackathons to introduce the concept of performing scientific analysis directly in the cloud with little or no need to download input data before performing computations.

NASA Data in the Cloud

As NASA's Earthdata archive continues to grow and is expected to increase exponentially with new emerging missions such as SWOT (whose data the PO.DAAC will archive and manage) and NISAR, the entire NASA ingest, archive and distribution system with its commensurate enterprise level services is being migrated to the AWS cloud (known colloquially as the NASA Earthdata Cloud). The PO.DAAC dataset migration to the cloud is still ongoing but new missions are now going directly to cloud storage vs on premise storage. The PO.DAAC has migrated over 50% of its data to the cloud already including the vast majority of GHRSST datasets.

As shown in Figure 1, one result of this new paradigm will be that the vast collections of Earth observation data are "close to compute," meaning that besides finding it easier to discover, access, and manage data, a user will be able to compute on and analyze large data sets more efficiently using AWS cloud compute resources, thereby enabling a broader range of interdisciplinary research. Although the "download the data to analyze locally" model is still expected to be a dominant user experience in the short term (and this model is well supported, see Figure 1) eventually the scale of scientific analysis will require developing cloud computing expertise. The purpose of this presentation is to introduce some of these new capabilities via python based Jupyter Notebook tutorials.

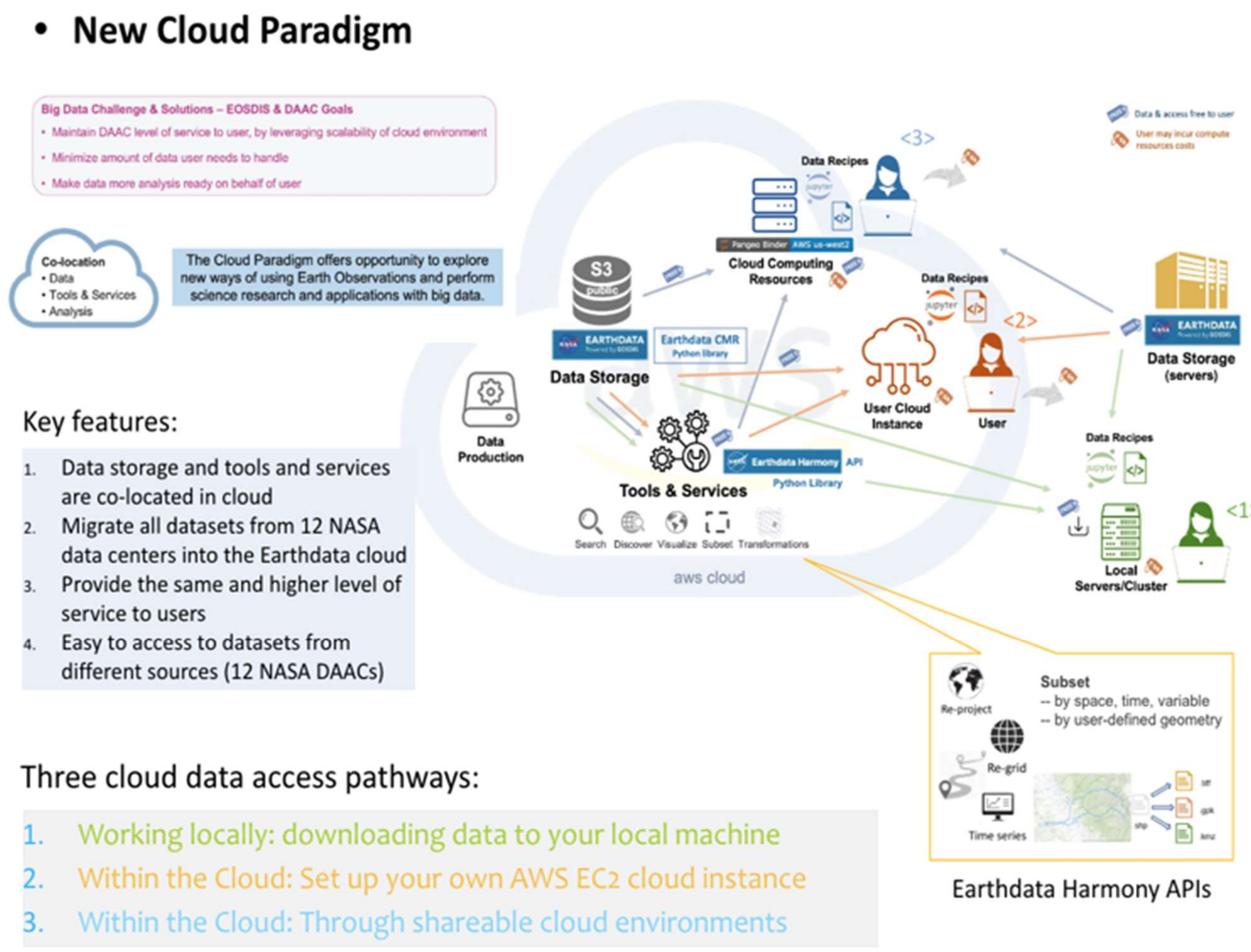

Figure 1. The emerging NASA Cloud Data Ecosystem and User Experience

Cloud Tutorials

This section contains examples of ready-to-run cloud tutorials that have been developed by the PO.DAAC to support its community. They are freely available on the PO.DAAC GitHub site: https://github.com/podaac/tutorials/tree/master/notebooks. Many of them use GHRSST datasets in some manner but all require a AWS cloud account. NASA has developed documentation to assist new users with understanding the details and workflow for establishing new AWS accounts that can be found on the following website: https://www.earthdata.nasa.gov/learn/webinars-and-tutorials/cloud-primer-amazon-web-services

ECCO SSH/SST correlation

The first example uses several NASA harmony services from the harmony-py python module including the netcdf-to-zarr service to simplify the granule discovery, temporal subsetting and the transformation to Zarr (a cloud optimized data format) for the ECCO SSH and Potential Temperature datasets. In fact the code to invoke the netcdf-to-zarr service transformation request for all ECCO granules is contained in the single line:

ecco_request = Request(collection=ecco_collection, temporal=time_range, format='application/x-zarr', concatenate='False')

Once a ephemeral Zarr ECCO output is created in the cloud, it can be accessed and operated on using other python packages like s3fs, xarray and numpy to perform the analysis which is to spatially and temporally correlate the SSH and SST model outputs to investigate the Indian Ocean Dipole. All the operations run 100% in the AWS cloud with no local download. The tutorial can be found here:

https://github.com/podaac/tutorials/blob/master/notebooks/meetings_workshops/workshop_osm_2022/ECCO_ssh_sst_corr.ipynb

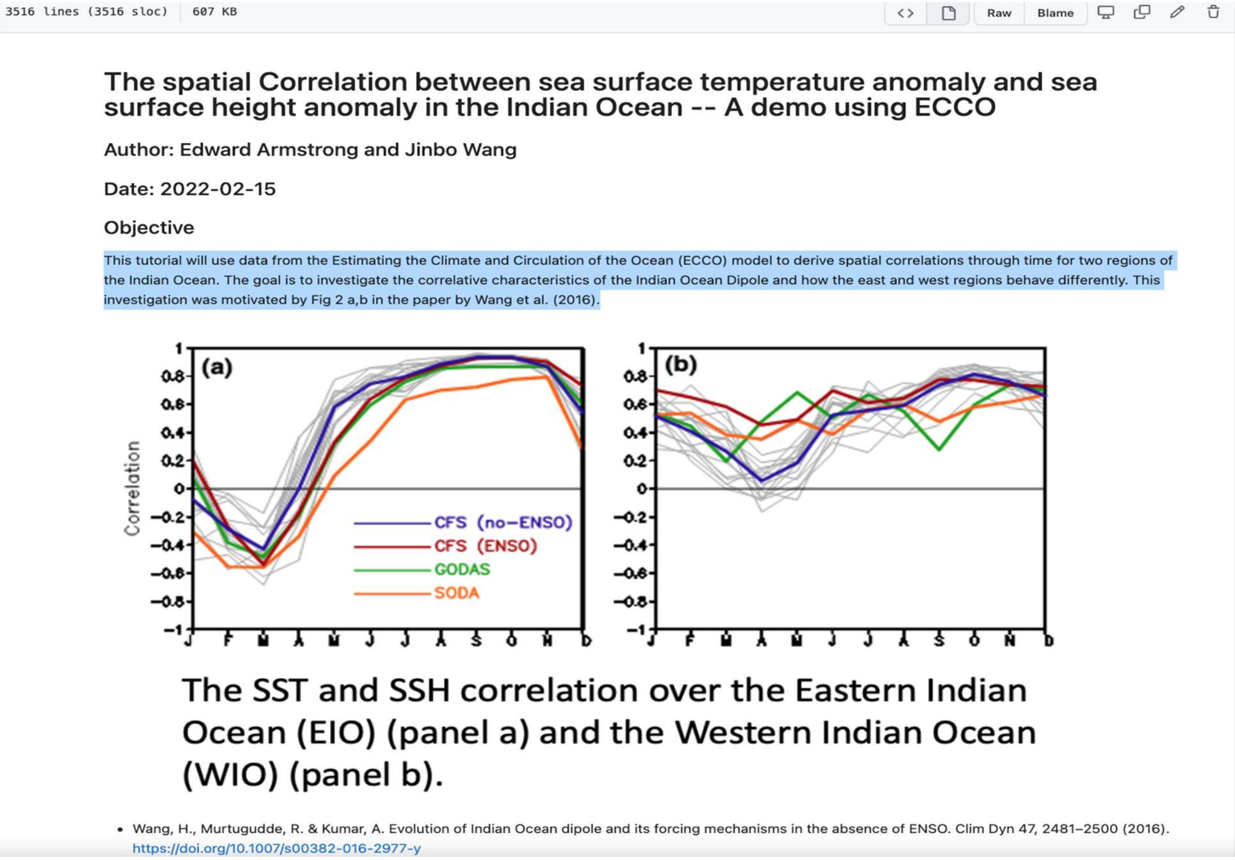

Figure 2. The ECCO cloud analysis Jupyter Notebook

Amazon River exploration

The second tutorial explores the relationships between river height, land water equivalent thickness, sea surface salinity, and sea surface temperature in the Amazon River estuary and coastal region from multiple datasets including GRACE-FO (water storage), MODIS (SST), SMAP (salinity), pre-SWOT hydrological (water extent) datasets. Using this tutorial a number of time series from the different measurements can be plotted and visually explored for co-variability and phase relationships:

https://github.com/podaac/tutorials/blob/master/notebooks/meetings_workshops/workshop_osm_2022/CloudAWS_AmazonRiver_Estuary_Exploration.ipyn

```
Out[27]: Text(0, 0.5, 'River Height (m)')
```

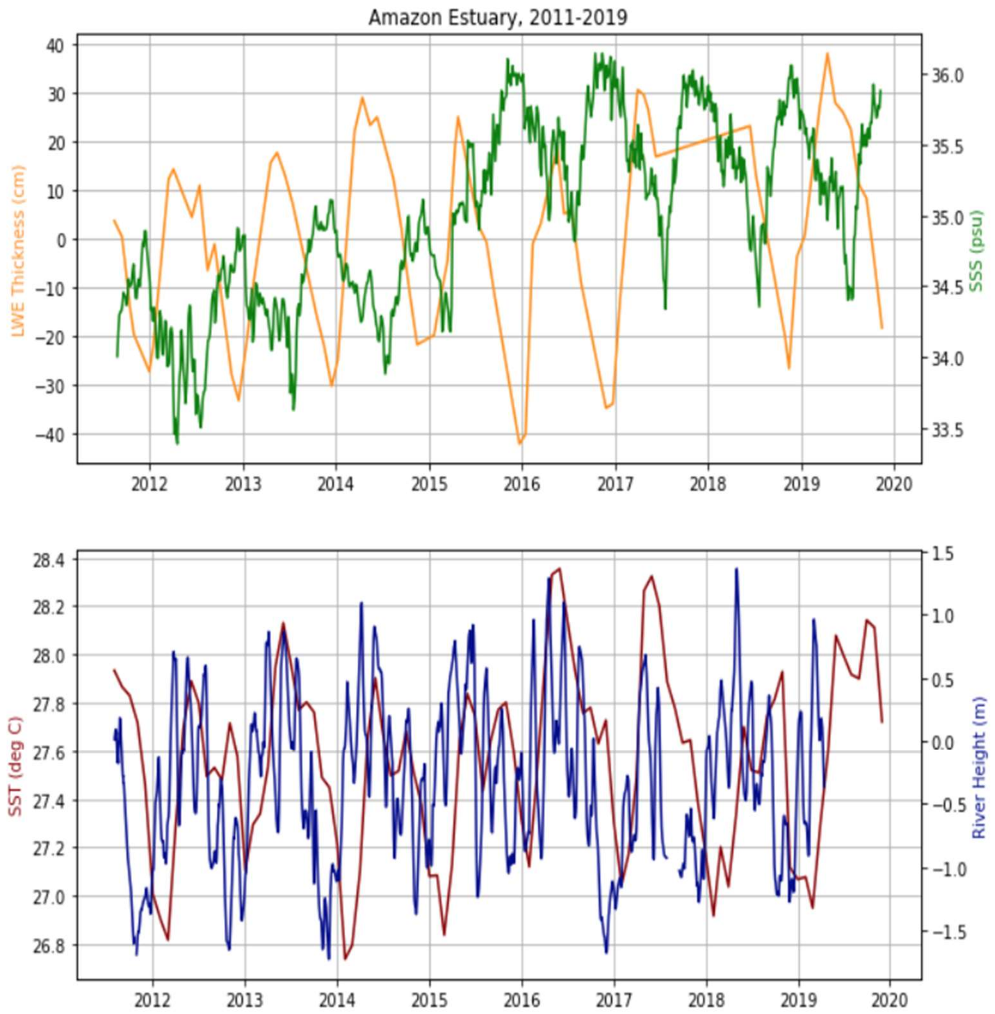

Figure 3. Exploring geophysical signals in the Amazon River basin

Satellite/ In-situ matchups

The third tutorial is another exercise using a variety of datasets to explore temporal and spatial relationships. The use case in this example is matchup of SST values from different sources including L2 and L4 satellite data to in-situ observations from the Argo profiling drifters. The novel application of this tutorial is that it uses some datasets from outside the PO.DAAC domain, including the MUR L4 SST dataset in the public AWS Registry of Open Data, and the netCDF Argo data accessible via its project API. The workflow accesses and quality controls regional MODIS L2 data from the NASA Earthdata Cloud (AWS), and then spatially/temporally matches those values to the MUR and Argo SST measurements. This tutorial can be found here: https://github.com/podaac/tutorials/blob/master/notebooks/SWOT-EA-2021/Colocate_satellite_insitu_ocean.ipynb

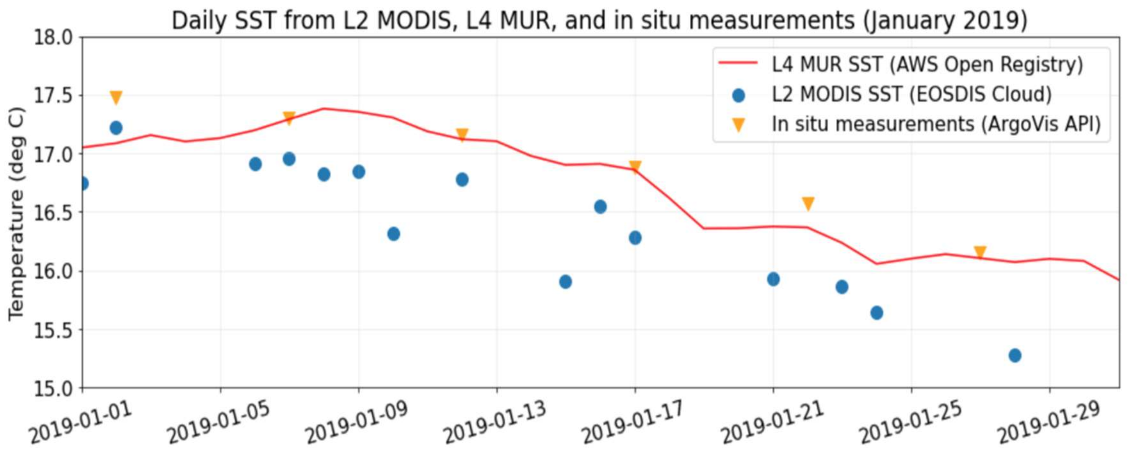

Figure 4. Using AWS derived SST datasets and external Argo in-situ data for matchups

Conclusion

For the present, most users will continue to implement the "download the data to analyze locally" mode of operation even with cloud native data, and the PO.DAAC has command line tools to meet this need, including the *podaac-data-subscriber.py* and *podaac-data-downloader.py* available from https://github.com/podaac/data-subscriber/. However, as data volumes continue to grow from emerging missions such as SWOT, the need for more performant capabilities to execute scientific analyses and data processing will increase as well. This is where leveraging scalable cloud computing directly on the data hosted in AWS is expected fulfil this need. Some further expected benefits of cloud computing include more easily supporting interdisciplinary use cases, promoting open and repeatable science, and providing new ways of working with Earth Observation data using Machine Learning and Artificial Intelligence. However, bottlenecks to adoption remain including the learning curve for the variety of available AWS compute services (but AWS provides many free trial services and reasonable documentation), understanding how to budget and control costs (costing tools and alerts are readily available in AWS), and the fact that there are other cloud providers (e.g., Google Cloud and Microsoft Azure) that represent an additional challenge to collaborating across different cloud platforms. Nevertheless, the opportunities for increasing science return using cloud computing are extremely attractive. How best the GHRSST community can take advantage of these emerging cloud capabilities including GHRSST cloud training and capacity building should be a goal of the Science Team in the near future.

References

[1] Wen-Hao Li et al., *PO.DAAC Cloud Data Ecosystem - Part 1: Search, Access and Services.* 23rd GHRSST Science Team Meeting, Session: S5 Computing and Products

Ref: ID 015: PO.DAAC Cloud Data Ecosystem – Part 1: Search, Access and Services

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GHRSST23 participants (online and in-person)

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