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16th Nov	Comments from Craig Donlon	Tables of activities inserted for all chapters	0.6.3	
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22nd Nov	Chris Merchant's comments from 15th Nov	Executive Summary, ESA CCI, Validation framework, Incorporating frontier SST science	0.6.4	Andrea elaborated the GDIP according to Chris Merchant's comments, Silvia included all other changes suggested by Chris
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19 Jan 2012	Craig Donlon	ECV terminology, Tracability matrix, priority of DPF	1.1	Andrea elaborated accordingly

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Executive Summary

Sea-Surface Temperature (SST) measured from satellites make key contributions to operational oceanography, numerical weather prediction, climate studies and other applications including marine biology. GHRSST partners operate a Regional/Global Task Sharing (R/GTS) system delivering real-time SST derived from satellite measurements to users. In addition to the operational service, GHRSST aims to support and develop best practice in development of the Climate Data Record (CDR) of SST, an Essential Climate Variable (ECV) for global change studies. GHRSST strives to ensure SST data product continuity and provides a link between research and operations with dedicated sub-groups on SST research issues, on data formats and data stewardship, and on user interaction.

Six main strategic themes of GHRSST result from the GHRSST Terms of References, i.e., from the necessity to maintain the data flow which GHRSST users rely on (Strategic Aim I), together with quality estimates (Strategic Aim II) as well as from the necessity to nurture the science (Strategic Aim III) which allows the users to make full use of the information. The interaction between operational, scientific and user communities is a crucial driver for progress, reflected in complimenting Strategic Aim IV (develop and maintain user interaction). Further, GHRSST strives for strengthening links with the international community (Strategic Aim V) and gives recommendations for the future (Strategic Aim VI).

The strategic themes planned to be addressed 2012-2022:

I. Maintain the Regional/Global Task Sharing system

The R/GTS: a resilient system of data exchange and storage in which GHRSST partners complement each other's capabilities to generate and deliver SST data for the many GHRSST objectives and applications. We should say something about pulling through the frontier science here and the validation work – especially monitoring of uncertainties.

II. Expand validation framework

For satellite observations to form climate data records, a stable validation system is required to determine the uncertainty characteristics. This calls for increased in-situ coverage (i.e., sampling all regions with higher frequency) and improved accuracy and resolution of in-situ measurements. Especially promising is the improvement in accuracy of the drifting buoys according to the specifications of the GHRSST-DBCP-PP as we expect a large increase in high quality global sampling. Further, the extension of the Argo network with near-surface capability will give in-situ observation of the diurnal variability profile; especially promising is the inclusion of a second set of unpumped sensors to the second-generation Argo profilers that allow measurements as the sensors break surface. Current ship-borne SST measurements show improvement in accuracy, too. Finally, the development of a global, sustained network of ship-borne radiometers for satellite SST validation can provide an unbroken chain of measurements to SI standards, thereby underpinning the generation of CDRs for the ECV SST. Increased accuracy and traceability to SI standards of the in-situ networks will allow improvements to the design and calibration of satellite borne radiometers to be verified.

III. Incorporate frontier SST science

Derived from the users' applications and needs, GHRSST has identified the following priorities for future developments related to SST measurements from space: (1) improved cloud and sea-ice discrimination, particularly at high latitudes, and at night (2) provide high spatial resolution fields (1 km) together with information on feature resolution, (3) algorithm improvement for both infra-red and microwave, (4) improved error characterisation, (5) lake surface temperature and ice cover and (6) consistent data sets over multiple missions. These issues are of particular importance at high latitudes, due to the sparseness of both satellite and in-situ observations, and due to the variability of the atmosphere. GHRSST Working Groups (WGs) and Technical Advisory Groups (TAGs) strive for progress with the above issues and welcome new participants.

A long term goal of GHRSST is to draw on the expertise of its members to improve scientific understanding of the ocean and air-sea interactions, concerning the above open research questions and emerging new ones.

IV. Develop and sustain user interaction

Through continuous dialogue with the users about their requirements, GHRSST adapts tools to facilitate the efficient use of SST products. User requirements cover many aspects including maintaining continuity of products and developing new ones to meet the needs of operational meteorology and climate monitoring services, operational oceanography centres, addressing environmental issues, and interactions between oceanography, meteorology and climate. GHRSST is driven by user requirements and provides guidance to users, recognising that they may require help to identify research relevant to their applications. GHRSST plans to assist decision making by delivering and explaining uncertainty and science behind the data, particularly with regards to climate data and forecasts. Better educational tools to guide the correct choice, interpretation and application of SST products are envisaged for the next decade.

V. Strengthen international collaboration and promotion of GHRSST

In addition to nurturing partnerships with users, GHRSST plans to strengthen international collaboration in the space sector via its enrolment as the CEOS (Committee on Earth Observation Satellites) Virtual Constellation (VC). Through CEOS-VC SST, GHRSST envisages acquiring new members and initiating collaboration with countries which develop their SST observing systems. Through the CEOS SST-VC mechanism, GHRSST will advise on the most useful cross-Agency satellite constellation of missions (the virtual constellation) for SST to meet user requirements in a similar manner to that currently in operation for altimetry.

GHRSST plans to strengthen its engagement with in-situ SST community via the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) with the Argos, the Data Buoy Cooperation Panel (DBCP) and the Ship Observation Team (SOT). GHRSST will keep in close contact with international stakeholders of ocean observation like the World Meteorological Organisation (WMO), the Intergovernmental Oceanographic Commission of UNESCO (IOC), the World Climate Research Program (WCRP), and many more.

GHRSST will continue to promote satellite-based SST products to earth system scientists and the general public through web-sites.

VI. Recommendations for the future

Drawing on more than 10 years' experience, GHRSST recommends increased efforts to ensure continuous SST coverage from satellite, covering both the complementary IR and MW spectral regions. GHRSST encourages instrument designs and calibration which are traceable to SI standards, match user requirements and have the highest possible resolution in space and time, while maintaining accuracy and radiometric resolution. GHRSST recommends the production of uncertainty estimates based on understanding of instrumental and sampling properties as well as auxiliary fields. GHRSST advocates a resolution preserving processing of merged SST products, and real-time inter-comparison. GHRSST encourages specifications of SST error correlations to facilitate the application of SST data in data assimilation systems.

Scope of the Document

This document is a management tool for the Group for High Resolution Sea Surface Temperature (GHRSST) International Project Office (GPO). This version (2011) covers the Strategic Aims for 2012-2022. It is a living document that will be reviewed and updated yearly, in connection with the annual GHRSST ST meetings.

The document starts with a short overview of GHRSST, outlining the GHRSST mission and the GHRSST organisational structure. In the subsequent chapters it is explained how GHRSST plans to implement its six Strategic Aims, which are:

(I) to maintain the Regional/ Global Task Sharing system,

(II) to expand validation activities

(III) to incorporate frontier SST science,

(IV) to develop and sustain user interaction,

(V) to strengthen international collaboration and promotion of GHRSST, and

(VI) to give recommendations for the future.

Applicable and Reference Documents

[GDS2]	The Group for High Resolution Sea Surface Temperature Science Team, The Recommended GHRSST Data Specification (GDS) 2.0 revision 4, 2011 https://www.ghrsst.org/files/download.php?m=documents&f=111107150103-GDS20r4.pdf
[OO9]	Donlon, C. J., Casey, K. S., Gentemann, C., LeBorgne, P., Robinson, I. S., Reynolds, R. W., Merchant, C., Llewellyn-Jones, D., Minnett, P. J., Piollé, J. F., Cornillon, P., Rayner, N., Brandon, T., Vazquez, J., Armstrong, E., Beggs, H., Barton, I., Wick, G., Castro, S., Hoeyer, J., May, D., Arino, O., Poulter, D. J., Evans, R., Mutlow, C. T., Bingham, A. W. and Harris, A. (2009a): Successes and Challenges for the Modern Sea Surface Temperature Observing System, Community whitepaper for OceanObs09, Venice, Italy, 21-25 September, 2009.
[SOW]	ESA, Statement of Work (SoW), Group for High Resolution Sea Surface Temperature (GHRSST) International Project Office, ESA Reference: EOP-SM/1957/CD-cd, 2009
[WPN]	White paper on Sea Surface Temperature Error Budget from the NASA Interim Sea Surface Temperature Science Team 18th June 2010
[PRO-E]	Proceedings Edinburgh GHRSST XII

Relevant Web sites

[URL-1]	GHRSST Web site: https://www.ghrsst.org

Acronyms and abbreviations

AATSR	Advanced Along Track Scanning Radiometer
ABOM	Australian Bureau of Meteorology RDAC
AC	Advisory Council
AHL	Atlantic High Latitude
AMSR	Advanced Microwave Scanning Radiometer
AMSR-E	Advanced Microwave Scanning Radiometer - Earth Observing System
ARC	ATSR Re-analysis for Climate
ARC-Lake	ATSR Reprocessing for Climate: Lake Surface Water Temperature & Ice Cover
ASIP	Air-Sea Interaction Profiler
ATOVS	Advanced TIROS Operational Vertical Sounder
ATSR	Along-Track Scanning Radiometer
AUS-TAG	Applications and User Services Technical Advisory Group
AVHRR	Advanced Very High Resolution Radiometer
BODC	British Oceanographic Data Centre
CAC	Central Assembly Center(s)
CAF	Central Application Facility (EUMETSAT)
CASSTA	Composite Arctic Surface Temperatures
CDOP	Continuous Development and Operations Phase
CDR	Climate Data Record
CEOS	Committee on Earth Observation Satellites
CEOS SIT	CEOS Strategic Implementation Team
CF	Climate Forecast (convention of netCDF)
CMS	Centre de Météorologie Spatiale
CNR	Consiglio Nazionale delle Ricerche (I)
COMS	Communications, Oceanography and Meteorology Satellite
CRED	Coral Reef Ecosystem Division
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTD	Conductivity, Temperature, Depth (in situ ocean measurements)
DAP	Data Access Protocol
DAS-TAG	Data Assembly and Systems Technical Advisory Group
DBCP	Data Buoy Coordination Panel
DMI	Danish Meteorological Institute
DPF	Data Processing Framework
DUE	Data User Element
DVWG	Diurnal Variability Working Group
EAR	Ecological Acoustic Recorder
EARS	EUMETSAT ATOVS Retransmission Service
EARWiG	Estimation and Retrievals Working Group
EB	Equivalent buoy
ECMWF	European Centre for Medium-range Weather Forecasting
ECV	Essential Climate Variable
EEZ	Exclusive economic Zone
ENVISAT	Environmental Satellite
EO	Earth Observation
EOP	Earth Observation Programme
EOSDIS	NASA Earth Observing System Data and Information System
EPS	EUMETSAT Polar System
ERNESST	European Research Network for Estimation from Space of Surface Temperature
ESA	European Space Agency

ESA CCI	European Space Agency Climate Change Initiative
EUM	EUMETSAT
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUR	European RDAC
fCDR	fundamental Climate Data Record
FNMOC	Fleet Numerical Meteorology and Oceanography Center
FTP	File Transfer Protocol
FY	Feng Yun satellites
GAMSSA	Global Australian High-Resolution SST analysis
GCOM	Global Change Observation Mission
GCOM-W	Global Change Observation Mission – Water GHRSST
GCOS	Global Climate Observing System
GDAC	Global Data Assembly Centre
GDIP	GHRSST development and implementation plan
GDS	GHRSST Data Specification
GDSV	Generic Data Structure Viewable
GEO	Group on Earth Observation
GHRSST	Group for High Resolution Sea Surface Temperature
GMPE	GHRSST Multi Product Ensemble
GODAE	Global Ocean Data Assimilation Experiment
GOES	Geostationary Operational Environmental Satellite
GOMS	Geostationary Operational Meteorological Satellite
GOOS	Global Ocean Observing System
GPM	Global Precipitation Mission
GPO	GHRSST Project Office
G-POD	ESA Grid Processing on Demand
GSICS	Global Space-based Intercalibration System
GTS	Global Telecommunications System
HDF	Hierarchical Data Format
HI	Haiyang satellites
HIRLAM	High Resolution Limited Area Model
HL	High Latitude
HL-TAG	High Latitude Technical Advisory Group
HRDDS	High Resolution Diagnostic Data-set
HRPT	High Resolution Picture Transmissions
HTTP	Hypertext Transfer Protocol
IASI	IR Atmospheric Sounding Interferometer
ICOADS	International Comprehensive Ocean-Atmosphere Data Set
IC-TAG	Inter comparison Technical Advisory Group
IFREMER	Institut français de recherche pour l'exploitation de la mer
IMOS	Integrated Marine Observing System
iQuam	In situ SST Quality monitor
IOC	Intergovernmental Oceanographic Commission
IOOS	Integrated Ocean Observing System
IMPF	Image Processing Facility
IR	Infrared
ISAR	Infrared Sea surface temperature Autonomous Radiometer
IST	Ice Surface Temperature
IWWG	Inland Waters Working Group (was LSWT-WG)
JAXA	Japan Aerospace Exploration Agency

JCOMM	WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology
JMA	Japan Meteorological Agency
JPL	Jet Propulsion Laboratory
JPL_OurOcean	NASA Jet Propulsion Laboratory
JPSS	Joint Polar Satellite System
KML	Keyhole Markup Language
L2	Level-2 data products
L2P	Level-2 Pre-processed data product
L3	Level 3 data products
L3C	Level 3 collated data product
L3S	Level 3 super-collated product
L3U	Level 3 un-collated data product
L4	Level 4 data product
LAC	Local Area Coverage
LAS	Live Access Server
LEO	Low Earth Orbiter
LML	Low and midlatitude
Ln	Level n of data processing, n=0, 1, 2, 3 or 4
LST	Local Sun Time
LTSRF	Long Term Stewardship and Reanalysis Facility
LSWT-WG	Lake Surface Water Temperature Working Group (now IWWG)
M-AERI	Marine-Atmospheric Emitted Radiance Interferometer
MDB	Matchup Data Base
METNO	Norwegian Meteorological Institute
MetOp	Meteorological Operational Satellite
MFC	Monitoring and Forecast Center
MGDSST	Merged satellite and in situ data Global Daily Surface Temperatures
MISST	Multi-Sensor Improved Sea-Surface Temperature
MIZ	marginal ice zone
MMR	Master Metadata Repository
MMS	Multi-sensor match-up system
MODIS	Moderate Resolution Imaging Spectroradiometer
MSG	METEOSAT Second Generation
MTSAT	Multi-functional Transport Satellite
µ-wave	Microwave
MW	MicroWave
MWRI	Microwave Radiation Imager µ-wave
MYO	MyOcean
MyOcean	EU-GMES project for Ocean Monitoring and forecasting
NAR	North Atlantic Region
NASA	National Aeronautics and Space Administration
NASA-SST	The NASA Sea Surface Temperature Science Team
NAVO	US Naval Oceanographic Office
NCDC	NOAA National Climatic Data Center (US)
NEODAAS	NERC Observation Data Acquisition and Analysis Service
NESDIS	National Environmental Satellite, Data and Information Service (US)
netCDF	Network Common Data Format
NGSST-O	New Generation SST for Open Ocean
NIR	Near Infrared
NIRST	New IR Sensor Technology

NIST	National Institute of Standards and Technology
NLSST	Non-linear SST
NMP	New Millennium Program
NOAA	National Oceanic and Atmospheric Administration (US)
NOAA ETL	NOAA Environmental Technology Laboratory
NOC	National Oceanography Centre, Southampton
NODC	NOAA National Oceanographic Data Center (US)
NODC LAS	NODC Live Access Server
NOP	Numerical Ocean Prediction
NOPP	National Oceanographic Partnership Program (US)
NPL	National Physical Laboratory
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	National Polar-orbiting Operational Environmental Satellite System Preparatory Project
NRL	Naval Research Laboratory
NRT	Near-real-time
NSIDC	National Snow and Ice Data Center
NWC SAF	Nowcasting and Very Short Range Forecasting
NWP	Numerical Weather Prediction
OA	Objective Analysis
OceanSITES	A worldwide system of long-term, deepwater reference stations
OCG	JCOMM Observations Programme Area Coordination Group
ODYSSEA	Multi-Sensor Merged High-Resolution SST over Global Ocean at 0.1° Geographical Grid
OE	Optimal estimation
OMP	Office of Marine Prediction (JMA)
OPeNDAP	Open-source Project for a Network Data Access Protocol
OSDPD	NOAA Office of Satellite Data Processing and Distribution
OSE	Observing system experiments
OSISAF	EUMETSAT Ocean and Sea Ice Satellite Applications Facility
OSSE	Observing System Simulation Experiments
OSTIA	Operational Sea Surface Temperature and Sea Ice Analysis
PFV	Pathfinder version
PMEL	Precision Measurement Equipment Laboratory
PNG	Portable Network Graphics
PO.DAAC	Physical Oceanography Distributed Active Archive Centre (US)
POES	Polar Operational Environmental Satellite
PP	Pilot Project
PSBE	Potential Satellite Bias Error
PVP	Product Validation Plot
QA4EO	Quality Assurance for Earth Observation data
QC	Quality Control
QCed	Quality Controlled
QI	Quality Indicator
R&D	Research & Development
R/GTS	Regional/Global Task Sharing framework of GHRSST
R2HA2	Rescue & Reprocessing of Historical AVHRR Archives
RAMSSA	Regional Australian Multi-sensor SST analysis
RAN-TAG	Reanalysis Technical Advisory Group
RD	Reference document
RDAC	Regional Data Assembly Centre
REMSS	Remote Sensing Systems, CA, USA

RFI	Radio Frequency Interference
RMS	Root Mean Square
RSD	Relative Standard Deviation
RSMAS	Rosenstiel School of Marine and Atmospheric Science, University of Miami
RTM	Radiative Transfer Model
RTTOV	Radiative Transfer for TOVS
SAF	Satellite Applications Facility
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SGLI	Second generation GLobal Imager
SI	System International
SLSTR	Sea and Land Surface Temperature Radiometer
SOOP	Ship-of-Opportunity Programme
SOT	JCOMM Ship Observing Team
SOTO	State of the Ocean
SoW	Statement of Work
SPURS	Salinity Processes in the Upper Ocean Regional Study
SQUAM	SST Quality Monitor
SSES	Single Sensor Error Statistics
SSI	Surface Solar Irradiance
SSM/I	Special sensor microwave imager
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
STS	Surface Temperature and Salinity
STVAL	Sea Surface Temperature Validation Working Group
TAC	Thematic Assembly Center
TAG	Technical Advisory Group
TB	Brightness Temperature
TDS	THREDDS Data Server
THREDDS	Thematic Realtime Environmental Distributed Data Services
TIR	Thermal Infrared
TMI	TRMM Microwave Imager
TOVS	TIROS Operational Vertical Sounder
TRMM	Tropical Rainfall Measuring Mission
TWP	Tropical Warm Pool
UKMO	UK Met Office
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNOLS	University-National Oceanographic Laboratory System
UPA	United Kingdom Multi-Mission Processing and Archiving Facility
URD	User Requirements Document
URL	Uniform Resource Locator
US	United States
UTC	Coordinated Universal Time
VC	Virtual constellation
VIIRS	Visible/IR Imager Radiometer Suite
WCRP	World Climate Research Program
WCS	Web Coverage Service
WG	Working Group
WHOI	Woods Hole Oceanographic Institution
WindSat	WindSat is a satellite-based polarimetric microwave radiometer
WMO	World Meteorological Organization

WMS	Web Mapping Service
WPN	White paper on Sea Surface Temperature Error Budget from the NASA Interim Sea Surface Temperature Science Team
WWW	WMO World Weather Watch

Table of Contents

The GHRSST Science Team 2011/12:

Olivier Arino	European Space Agency/ESRIN, Italy
Ed Armstrong	NASA JPL, USA
Viva Banzon	NOAA/NESDIS, USA
Ian Barton	CSIRO Marine Research, Australia
Helen Beggs	Bureau of Meteorology, Melbourne, Australia
Kenneth S Casey	NOAA/NODC, USA
Sandra Castro	University of Colorado, USA
Mike Chin	NASA JPL, USA
Gary Corlett	University of Leicester, UK
Peter Cornillon	University of Rhode Island, USA
Craig Donlon	European Space Agency/ESTEC, The Netherlands
Steinar Eastwood	Met.no, Norway
Bill Emery	University of Colorado, USA
Bob Evans	RSMAS, University of Miami, USA
Chelle Gentemann	Remote Sensing Systems Inc., USA
Lei Guan	Ocean University of China, China
Ted Habermann	NOAA/NODC, USA
Andrew Harris	NOAA/NESDIS, USA
Jacob Hoeyer	Danish Meteorological Institute, Denmark
Shiro Ishizaki	Japan Meteorological Agency (JMA), Japan
Alexey Kaplan	Lamont-Doherty Earth Observatory of Columbia University, USA
Misako Kachi	Japan Aerospace Exploration Agency (JAXA), Japan
Hiroshi Kawamura	Tohoku University, Japan
Pierre Le Borgne	EUMETSAT OSI-SAF, France
W Timothy Liu	NASA JPL, USA
David Llewellyn-Jones	University of Leicester, UK
Matthew Martin	MetOffice, UK
Doug May	Naval Oceanographic Office, USA
Christopher Merchant	University of Edinburgh, Scotland, UK
Peter Minnett (Chair)	RSMAS, University of Miami, USA
Jonathan Mittaz	University of Maryland, USA
Tim Nightingale	Rutherford Appleton Laboratory, UK
Anne O'Carroll	EUMETSAT, Darmstadt, Germany
Jean-François Piollé	IFREMER, France
Dave J Poulter	National Oceanography Centre, UK
Nick Rayner	MetOffice Hadley Centre, UK
Richard Reynolds	NOAA CDC, USA
Ian S Robinson	National Oceanography Centre, UK
Jorge Vazquez	NASA JPL,USA
Gary Wick	NOAA ETL, USA

Introduction

Sea-surface temperature (SST) data are a key input for weather and ocean forecasting and climate research (*e.g., Donlon et al., 2009a*). The Group for High Resolution Sea Surface Temperature (GHRSST) provides a framework for establishing best practices for data processing and sharing of data at the international level (*Donlon et al., 2009b*). Also, GHRSST serves as a forum for scientific dialog. GHRSST offers SST data sharing and delivers SST to the users - see https://www.ghrsst.org for an overview. GHRSST is an international project with a global following. Regional Data Assembly Centres (RDACs) follow the GHRSST recommendations for best practice in data processing and deliver to the GHRSST Global Data Archiving Centre (http://ghrsst.jpl.nasa.gov/) and the GHRSST Long-term Stewardship and Reanalysis Facility (http://www.nodc.noaa.gov/sog/ghrsst/), from where, more than 1000 unique visitors per month access a variety of SST data. 100 million files have been downloaded since the start of the Regional/ Global Task Sharing Framework. GHRSST provides user guidance and software tools for accessing the SST products relevant for specific applications (https://www.ghrsst.org)

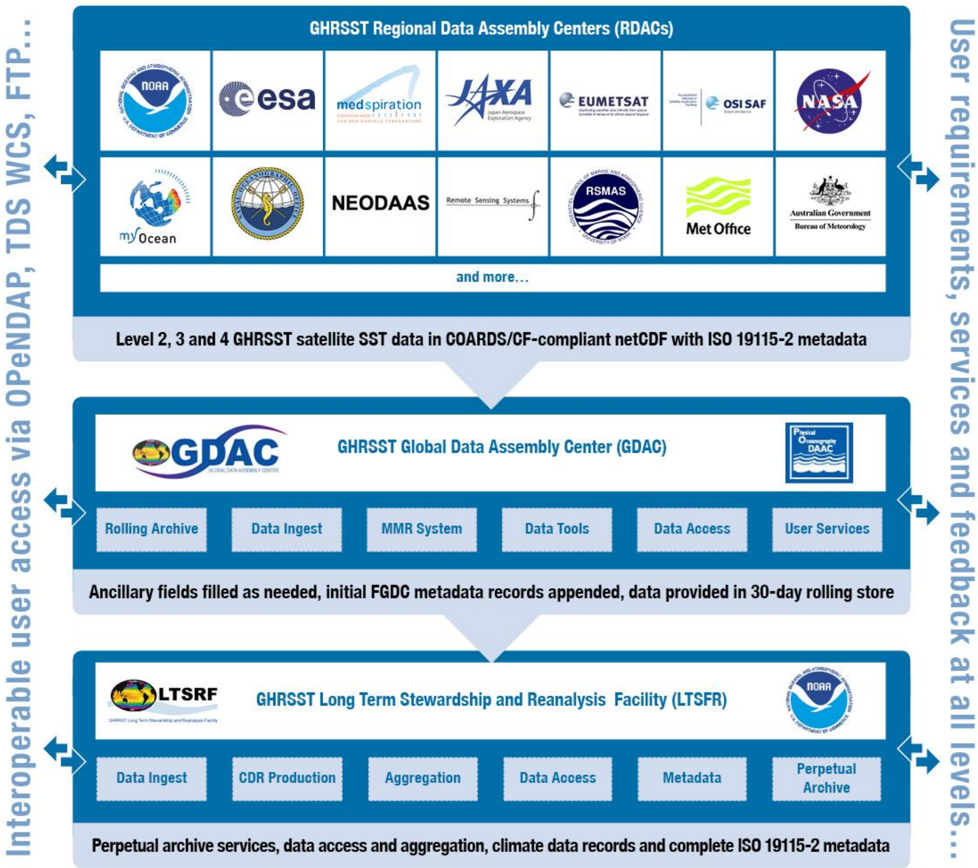


Figure 1: The GHRSST data flow from the Regional Data Assembly Centres to the collection point at the Global Data Assembly Centre, and from there to the Long Term Stewardship and Reanalysis Faculty.

User requirements drive the GHRSST data production. The GHRSST Science Team responds to those through the activities of dedicated Working Groups (WGs) and Technical Advisory Groups (TAGs). These groups concentrate on specific science issues or areas of interest. The diagram below gives the currently active GHRSST sub-groups. With support of the GHRSST Project Office, the Science Team ensures the cross linking of the sub-groups and encourages knowledge exchange with the users. The GHRSST Project Office maintains the formal communication within GHRSST, promotes GHRSST in the international landscape and takes advice given by the International Stakeholder Advisory Council.

GHRSST provides a mechanism to nurture a Virtual Constellation of satellite missions for SST within the framework of the Committee on Earth Observation Satellites (CEOS), see Appendix 1 for details.

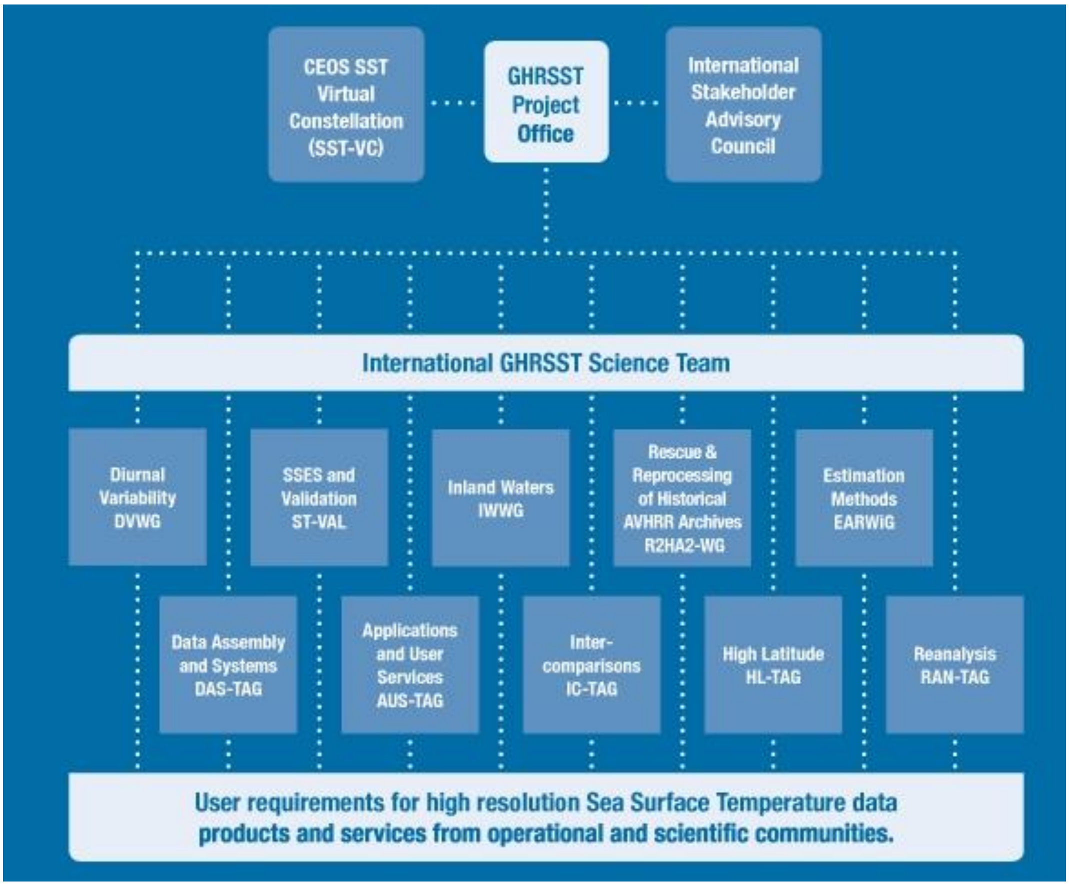


Figure 2: GHRSST is led by the International GHRSST Science Team. It is supported by the GHRSST Project Office, which also provides the link to the International Stakeholder Advisory Council and the CEOS SST Virtual Constellation. Drivers for GHRSST are the user requirements, and dedicated working groups are concentrating on scientific or technical issues.

The GHRSST Development and Implementation Plan (GDIP, this document) characterizes the plans and anticipated activities for the next 10 years. In 2009, a general vision on future developments was documented in *Successes and Challenges for the Modern Sea Surface Temperature Observing System*, a Community whitepaper for OceanObs09, Venice, Italy, 21-25 September, 2009 by Donlon et al., 2009 which is included as section 6 in this document and referred to in the following as [OO9]. The general direction of GHRSST is defined by the GHRSST Terms of References (Appendix 1), which have been agreed to by the GHRSST Science Team and are reviewed as required at the annual GHRSST Science Team meetings.

Similarly, this document is intended to be updated annually, based on the reports to the Science Team meetings and subsequent discussions. This document mirrors the matrix structure of GHRSST: the first dimension of the structure is given by the data flow (Figure 1) within the Regional/Global Task Sharing Framework (R/GTS). These are based on national and international funding and thus are compliant to the mandate of the funding agencies. The second dimension of the GHRSST structure is given by the professional interaction: GHRSST Technical Advisory Groups and Working Groups, which investigate specific issues within the Science Team (Figure 2).

The Strategic Aims result from the GHRSST Terms of References, i.e., from the necessity to maintain the data flow which GHRSST users rely on (Strategic Aim I), together with quality estimates (Strategic Aim II) as well as from the necessity to nurture the science (Strategic Aim III) which allows the users to make full use of the information. The interaction between operational, scientific and user communities is a crucial driver for progress, reflected in complimenting Strategic Aim IV (develop user interaction). Further, GHRSST strives for links with the international community (Strategic Aim V) and gives recommendations for the future (Strategic Aim VI).

In the following chapters, it is explained how GHRSST plans to implement its five Strategic Aims which are to:

(I) maintain the Regional/ Global Task Sharing system,

(II) expand validation activities

(III) incorporate frontier SST science,

(IV) develop user interaction,

(V) strengthen international collaboration and promotion of GHRSST and

(VI) give recommendations for the future.

1 Strategic Aim I: Maintain the Regional/Global Task Sharing framework

The backbone for GHRSST is the Regional/Global Task Sharing (R/GTS) framework: data production and collection, as illustrated in Figure 1, according to community standards. To maintain this is the strategic goal number one. Thus the recent (2011) acceptance of GHRSST as the CEOS-Virtual Constellation SST formation (see Appendix 1) which are expected to result in strengthening and expanding the R/GTS. The Data Assembly and Systems Technical Advisory Group (DAS-TAG) is instrumental in achieving this goal. In the section below, the elements of the R/GTS (regional contributions and the overarching activities) are described together with their future plans for development.

1.1 Data Assembly and Systems Technical Advisory group (DAS-TAG)

The GHRSST Data Assembly and Systems TAG is responsible for the day-to-day operational specification and management of GHRSST data products and services. In practice, this involves the specification and control of all aspects of data archive, dissemination, file level and discovery metadata, international standards conformance, quality control and assurance issues, product content, amongst many others. The DAS-TAG is a dynamic team drawing on the collective resources of an international membership that is actively involved in satellite and in situ data management issues.

Future plans: support R/GTS, develop GDS through community consensus.

1.2 The GHRSST Data Specification (GDS)

A pre-requisite for sharing data and for making ingestion of SST data in operational systems economical, a common data format is indispensable. Under the leadership of DAS-TAG, considerable effort was spent in the previous years to develop and document the data formats and operating principles of GHRSST that are captured in the GDS documentation. The GDS is defined in accordance with international conventions that maximise benefit for users. The result in 2011 is the GDS version 2.0 revision 3 [GDS2]. This document has been extensively reviewed and endorsed by the Space Agencies and international data providers that constitute the backbone of GHRSST through an open peer review process managed by the GHRSST Project Office and the DAS-TAG.

Future plan: It is planned to collect any issues, together with resolutions, in an amendments tracker on the web-site, for public access. The GDS2 documentation is planned to be updated according to those, the release dates to be agreed on at the annual GHRSST Science Meetings. Special care in the preparation of the GDS aspires not too many changes to the format, facilitating the work of the RDACs.

1.3 Overview of Regional Activities

Having evolved from a Pilot Project of the Global Ocean Data Assimilation Experiment (GODAE) to address an emerging need for accurate high resolution sea surface temperature (SST) products in support of operational ocean forecasting, GHRSST today utilises all of the SST datastreams used by Numerical Ocean Prediction (NOP), Numerical Weather Prediction (NWP) and ocean/atmosphere sciences. Data are passed in a logical manner starting at the national or regional data producers, the so-called Regional Data Assembly Centers (RDACs).

In Europe, Medspiration (an ESA DUE project) pioneered the implementation of an operational service for a combined level 4 SST product, using as input the level 2 inputs from a variety of Agency regional data centres. In parallel, EU funded projects (e.g. MERSEA and today MyOcean) extended the developments of new level 3 and level 4 and other products compliant to GHRSST specifications. Other activities at national weather centres developed new activities to take advantage of the new products and services offered by GHRSST in Europe. The Japanese GHRSST server is hosted by the Earth Observation Research Centre of JAXA; the products are developed by JAXA, JMA, and Japanese universities, with a focus on NWP, NOP and fisheries. The Australian contribution to GHRSST, through collaboration between BoM and CSIRO grew to meet the needs of NOP and NWP around Australia. The Australian national waters are a priority, but research extends to the Antarctic region as well as the tropical warm pool in the Pacific Ocean, in addition to serving the coastal communities of Australia (for recreational purposes). Academic, government, military and industry researchers from the US (NASA, NOAA, Naval Research Laboratory, Naval Oceanographic Office, Remote Sensing Systems, and collaborating universities) have been involved in GHRSST directly as well as through the project USGODAE, the MISST project, and in collaboration with the NASA-SST Science Team.

RDAC logo	RDAC code	Name of Institution	Country
Australian Government Bureau of Meteorology	ABOM	Australian Bureau of Meteorology	Australia
	ESACCI (ESA Climate Change Initiative)	University of Edinburgh, UK Met Office, University of Leicester, OSI-SAF, DMI, Met No, Brockmann Consult, Space Connexions	Europe

RDAC logo	RDAC code	Name of Institution	Country
	ESA	European Space Agency	Europe
	EUM	EUMETSAT	Germany
	EUR	Ifremer (Institut français de recherche pour l'exploitation de la mer)	France
	JAXA	Japan Aerospace Exploration Agency	Japan
	JPL	NASA Jet Propulsion Laboratory	USA
	JPL_OurOcean	NASA Jet Propulsion Laboratory	USA
	MYO	MyOcean (for CNR, DMI, Metéo France, Norwegian Meteorological Institute, UK Met Office)	EU (Italy, Denmark, France, Norway, UK)
	NAVO	US Naval Oceanographic Office	USA
	NCDC	NOAA National Climatic Data Center	USA
	NEODAAS	NERC Observation Data Acquisition and Analysis Service	UK
	NODC	NOAA National Oceanographic Data Center	USA

RDAC logo	RDAC code	Name of Institution	Country
	OSDPD	NOAA Office of Satellite Data Processing and Distribution	USA
	OSISAF	EUMETSAT Ocean and Sea Ice Satellite Applications Facility	France, Norway
	REMSS	Remote Sensing Systems Inc., CA, USA	USA
	RSMAS	University of Miami	USA
	UKMO	UK Met Office	UK

Table 1: Overview over of the Regional Data Assembly Centers (RDACs) producing the GHRSST data.

1.4 Future RDAC plans in the US

In addition to the GHRSST Global Data Assembly Centre (GDAC) hosted at the NASA JPL PO.DAAC, and the GHRSST Long-term Stewardship and Reanalysis Facility (LTSRF) hosted at NOAA NODC, there are several regional data production activities at NASA and NOAA and other organizations. The US Navy, through the Naval Oceanographic Office, is a major data producer. NOAA activities include GOES-related GHRSST products, the SST Quality Monitor SQUAM, and further activities are performed under the NOAA Climate Data Record Program. NASA activities are scientifically linked within the NASA SST Science Team. MISST2 (details below) is a collaborative US project funded through the National Oceanographic Partnership Program.

1.4.1 NASA SST Science Team

The NASA SST ST continues to address issues associated with the SST error budget as outlined in the NASA SST ST White Paper (http://www.sstscienceteam.org/white_paper.html) in this document referred to as [WPN], as well as to develop scientific applications of satellite-derived SST data. Specific topics include:

1) The physical basis of SST measurements,

2) Radiative transfer modelling and SST retrieval algorithm development,

3) Calibration, instrument characterization, and measurement validation,

4) Data merging and gridding, and

5) Applications making use of SST fields such as the generating the Climate Record: reprocessing, data access, and stability of the climate record. Feature studies include fronts, eddies, currents, heat flux studies, and others.

The collaborative work of the NASA SST ST resulted in contributions in three areas:

1. Requirements placed on satellite-derived SST products
2. A framework for the characterization of the error budget for satellite-derived SST products
3. Recommendations for tasks that need to be undertaken to improve satellite-derived SST products.

The resulting recommendations (approximately 70 in total) of the WPN cover a very broad range of activities.

Thus, the NASA SST ST activities are focused on research concerning improved retrieval algorithms, data classification, instrument development, improved merging, gridding, and objective analysis, and on characterizing the uncertainties.

1.4.2 MISST2

MISST2 is a five-year project (2012-2016) that is the follow-on to the successful MISST project (Gentemann et al. 2009) that served to coordinate US activities that were directed to achieve the aims of GHRSST. As with many research activities, those of MISST2 will depend on the level of funding, but planned activities include:

Produce all data in new GDS 2.0 format (L2P, L3, and L4). Research into improved lake temperatures, ancillary data, diurnal modelling, skin effect, error estimates, and L4 analysis. Distribution & Long-term stewardship of data through the GDAC and LTSRF. Improved access and education for IOOS partners. Applications within IOOS to improve decision making, e.g. coral health, outreach and education.

- Task 1. Improved, sustained generation of GHRSST data
  - Task 1.1. Continue production of existing data streams
  - Task 1.2. New GDS 2.0 products
  - Task 1.3. Improved lake temperatures
  - Task 1.4. Improved ancillary data
    - Task 1.4.1. Improved diurnal modelling
    - Task 1.4.2. Cool skin effect
  - Task 1.5. Improved error estimates
  - Task 1.6. L4 analysis
    - Task 1.6.1 Update existing data to GDS 2.0
    - Task 1.6.2. New L4 data to GDS 2.0
      - Task 1.6.2.1 Validation of high-resolution features
      - Task 1.6.2.2 Formal analysis error estimates for hypothesis testing
- Task 2. Distribution & Long-term stewardship
  - Task 2.1. GDAC
  - Task 2.2. LTSRF
  - Task 2.3. Improved SST access for IOOS partners
- Task 3. Applications within IOOS to improve decision making

Task 3.1. Coral health

Task 3.2. Outreach to IOOS Regional Associations and Users

Task 3.3. Ocean fronts

Task 3.4. Ocean Forecasts

Task 3.5. NWP

Task 3.6. Coupled Modelling and data impact studies

1.5 Future RDAC plans in Europe

1.5.1 EUMETSAT OSI-SAF

The SST R&D and production activities in the EUMETSAT OSI-SAF are described in the Continuous Development and Operations Phase (CDOP) documents. The present phase (CDOP1) will conclude in March 2012. The second phase (CDOP2) document was approved in June 2011 and is the reference document that defines the SST activities till 2017. After mid 2012, all OSI-SAF products will be delivered in GDSV2.0 format.

NRT Production in CDOP2

For NRT products the target timeliness is two hours after reception of the last contributing satellite brightness temperature at the production centre.

SST production includes the following basic steps:

- cloud mask creation
- cloud mask application
- SST calculations
- validation

The cloud masks used in this context are the NWC SAF masks and, for METOP/AVHRR processing, the MAIA mask developed for this purpose.

Several studies led by the OSI SAF during CDOP-1 have demonstrated that:

- current multi-spectral algorithms show seasonal/regional biases
- the use of simulated brightness temperatures calculated from NWP profiles can improve significantly the results, either by determining a local correction term for the multi-spectral algorithms, or by deriving SST by Optimal Estimation

At the beginning of CDOP-2 only the geostationary (GEO) SST chain will use NWP model outputs. This will be extended to the Low Earth Orbiter (LEO) chains at CMS and met.no during CDOP-2. Nevertheless, all SSTs will be derived first by multi-spectral techniques, and the NWP derived correction term or optimal estimation will be used if proven successful in operations. Each SST product is delivered with quality indices (on a scale from 1 to 5) at pixel level, as recommended by GHRSST. Only pixels with quality index 3 and higher are recommended for quantitative use; index 1 (cloudy) pixels are not usable and index 2 data are restricted to qualitative studies.

The current Atlantic High Latitude (AHL) SST product produced at met.no is a dedicated product to take into account the specific conditions in the Arctic. It is defined as a continuation of the NAR products north of 60^{o}N, with an overlapping area for comparisons. It takes advantage of the good EARS data coverage at high latitudes.

The Atlantic High Latitude product will be extended to cover the Antarctic including ice surface temperature estimates, becoming the High Latitude (HL) SST product. There is a seamless transition between the algorithms used over open water, across the marginal ice zone and over sea ice. The NWC SAF cloud mask is used over both ice and water.

The CDOP-2 SST product main characteristics are given in the table below.

SST	Product id	Production Center	Coverage	Projection/ resolution	Input satellite data	Central time or frequency	Target accuracy (1)
NAR SST	OSI-202	LML	European seas	Polar stereo/ 2km	Metop + NOAA /AVHRR + NPP / VIIRS	At least 4 times a day	Bias: 0.5K Std Dev.: 0.8K
HL SST and IST	OSI-203	HL	Atlantic High Latitudes	Polar stereo/ 2km	NOAA + Metop + NPP/VIIRS	Twice daily	SST: Bias: 0.5K Std Dev.: 0.8K IST: bias 1K, Std Dev.: 2K
Full resolution Metop SST	OSI-204	LML	global	Swath projection/ 1 km	Metop/AVHRR	N/A	Bias: 0.5K Std Dev.: 0.8K
Full resolution AVHRR SST and IST	OSI-205	HL	Poleward of 50N/50S	Swath projection/ 1 km	NOAA/EARS + METOP	N/A	SST: Bias: 0.5K Std Dev.: 0.8K IST: bias 1K, Std Dev.: 2K
GLB SST	OSI-201	LML	global	Isolat, isolon/ 0.05°	Metop/AVHRR	2 times a day	Bias: 0.5K Std Dev.: 0.8K
Meteosat SST	OSI-206	LML	60S-60N 60W-60E	Isolat, isolon/ 0.05°	MSG	0000,0100 ,… UTC	Bias: 0.5K Std Dev.: 1K
GOES-E SST	OSI-207	LML	60S-60N 135W-15W	Isolat, isolon/ 0.05°	GOES-E	0000,0100 ,… UTC	Bias: 0.5K Std Dev.: 1K

SST	Product id	Production Center	Coverage	Projection/ resolution	Input satellite data	Central time or frequency	Target accuracy (1)
IASI SST	OSI-208	LML	global	Swath: 12 to 40 km	METOP/IASI	N/A	Bias: 0.5K Std Dev.: 0.8K

Table 2: CDOP2 SST product main characteristics. Target accuracy (1) is defined for a monthly basis, for the whole product coverage, against drifter measurements

IASI L2P core SSTs have been available from the EUMETSAT data centre since March 2011, with the SSTs derived from the global IASI level 2 product processing facility at EUMETSAT. The delivered products are only in the L2P core format, i.e. without auxiliary fields such as sea-ice and aerosol requested by the GHRSST. CMS will add to the IASI derived SST products the missing variables. A validation phase will take place once the system is in place, with the building of a Match-up Data Base. SST retrieved from IASI has the potential for improved atmospheric correction over other sensors using commonly used multi-spectral techniques. IASI SSTs therefore provide a complementary SST data source; they can be used to examine and correct for regional biases in other SST sources; and they provide a long-term and stable contribution to the range of global SST products available from different sensors, important for inter-sensor error characterisation.

Within the IASI level 2 processing at EUMETSAT, there are plans to upgrade the cloud detection scheme to utilise a method based on artificial neural networks (2011). Further possible developments influencing the SST retrieval over the next few years include: improvements to address the slight angular dependency; the inclusion of band 3 (shorter wavelengths) in the retrieval at night-time; the use of the OSI-SAF sea-ice edge information; and the detection of dust layers for flagging and possibly correction.

Reprocessed products in CDOP2

During the CDOP-2 the OSI-SAF will re-process the MSG/SEVIRI SST products from the start of the MSG mission. The re-processed MSG/SEVIRI data set is required for climate activities, because of their high temporal sampling rate, in particular for many investigations related to the diurnal warming cycle.

The main drivers for this re-processing activity are, considering the original MSG/SEVIRI products which were processed by the OSI SAF in near real-time since 2004:

- the MSG/SEVIRI level 1.5 re-processing at EUMETSAT CAF, aiming in particular at correcting the IR calibration error in the IMPF processing during the first years of the MSG mission
- the new near real-time OSI SAF MSG/SEVIRI SST processing chain at CMS, which was declared operational in August 2011, and which brings a significant improvement in terms of products quality
- the results from the first phase of the ESA CCI project on SST, which CMS is contributing to, and which will inter-compare different SST algorithms and make recommendation for the SST re-processing activities

The characteristics and format of the re-processed MSG/SEVIRI SST data set (OSI-250) will be similar to the ones of the (new) near real-time OSI SAF products (0.05° horizontal resolution, every hour, compliant with the GHRSST GDS V2.0 format specification).

Without anticipating the results from the ESA CCI activities, it can be stated that the SST retrieval will be based on radiative transfer modelling, using RTTOV and ECMWF atmospheric profiles.

1.5.2 MyOcean

The MyOcean SST TAC activities should be continued and enhanced in the framework of the MyOcean-2 project (2012-2014), which is currently under negotiation with the European Union.

The main SST TAC activities and products upgrades planned in the framework of the current MyOcean project, due to end in March 2012, are:

- transition to GDS V2
- preparation activities for the SST TAC operational acceptance as part of MyOcean V2 system (technical evolution of central systems : web site, OpenDAP/THREDDS servers, central catalogue etc…), which should be opened to external users in December 2011
- resolution increase of regional SST analyses over the Baltic Sea (from 0.03° to 0.02°) and the Arctic Ocean (from 0.05° to 0.03°)
- near real-time operational processing and delivery of new SST TAC products : daily multi-sensor (L3S) products over the Mediterranean Sea and the Black Sea at 0.01° horizontal resolution, daily global SST analysis at 0.1° horizontal resolution (ODYSSEA)

During MyOcean-2 (2012 - 2014), the SST activities will continue focus on quality monitoring and inter-calibration of level 2 satellite SST products, and on operational processing and continuous improvement of L3/L4 global and regional satellite SST products. In addition, the following evolutions are planned:

- use of new input L2P SST sources, in particular Sentinel-3A SLSTR L2P SST products processed centrally at EUMETSAT, according to the agreement between EUMETSAT and ESA. The SLSTR data will provide continuity for current ENVISAT AATSR SST data, which are used as reference SST data by the SST TAC in the current satellite SST inter-calibration approach.
- development of an Ice Surface Temperature analysis, which will complement the SST analyses in the high latitude areas
- increase in the time sampling of L3/L4 satellite SST products, to provide information on the SST diurnal variations
- production of several SST re-analyses at global and regional scales

The MyOcean-2 proposal has been submitted in November 2010. It has been evaluated positively by the European Union, and is now in its negotiation phase.

1.5.3 Medspiration

The Medspiration project aims to provide high resolution regional products over a selection of regional areas, to support specific user demands to ESA or ongoing environmental, geophysical or mission-support projects. The current production of 2km resolution L4 products over the Mediterranean Sea, South-Africa (Agulhas), Australian Great Barrier Reef and Western Tropical Atlantic (Brazil) will be sustained at least up to 2012. The objective is to continue this production beyond this date as long as users request them.

As such Ifremer has set up a very flexible processing and archiving framework able to address any future demand, but also reprocessing of past data. A large effort has been dedicated in implementing this effort, using the latest cloud computing and big data technologies, in order to minimize in future the cost and resources to cope with new user demands.

Reprocessing activities have been also undertaken over Mediterranean Sea, starting from 2006. This reprocessing will be completed by the end of 2011 but we will seek in 2012 to extending this reanalysis back to 1991 once AATSR reprocessing is completed.

1.5.4 ESA-RDAC for (A)ATSR

AATSR processing is suggested to improve by switching to an upgraded processing (improvements had been demonstrated with the ARC project) for L2P. Funding has not yet been assured as of Nov 2011.

1.5.5 ESA SST CCI

The ESA Climate Change Initiative (CCI) in SST is presently funded (2010 to 2013) by ESA for a phase of scientific consultation and detailed specification of a system proposed to be potentially implemented in 2013 to 2016.

ESACCI has slightly different aims as an RDAC in that the emphasis is on climate and is associated with the GHRSST Reanalysis Technical Advisory Group. Therefore, ESACCI (i) will define a short-delay (not near real time) product delivery system, enabling use of NWP analyses and other short-delay auxiliary information to maximise climate quality, and (ii) will maintain consistency between the short-delay delivery and the corresponding full-mission archives – i.e., the short-delay operations will at all times be a seamless extension of an available climate data record.

The present phase includes prototyping of CDRs defined by a Product Specification Document. (For current versions of all ESACCI documents, refer to www.esa-sst-cci.org.)

The long-term prototype will create for 1991 to 2010:

- ATSR-series L3C at daily (day-night separate) 0.05° resolution
- AVHRR-GAC based L2P (orbit files)

by methods yet to be selected via an open algorithm selection procedure, presented at GHRSST XII. In both cases, products will include

- SST-skin at time of observation from the “best” available retrieval, the primary SST product
- SST-20 cm inferred for a standardised time of day (10.30 and 22.30 local solar time)
- total uncertainty (in the equivalent of the SSES standard deviation field)
- components of uncertainty with different spatio-temporal correlation properties

The ESACCI product format is compatible with GDS2.0. The L2P and L3C products will be used to generate a satellite-only SST-depth daily L4 analysis using a modified version of the UK Met Office’s OSTIA system. A tool to generate L3 at alternative coarser resolutions with properly propagated uncertainty estimates will be developed.

In addition, there will be a demonstration prototype of a number of further products:

- AMSRE-v7 and TMI-v7 L2P with modified uncertainty information
- Metop AVHRR L3C at 0.05° resolution
- SEVIRI L3C at 0.05° resolution
- AATSR L2P at full resolution (1 km)
- L4 analysis with a wider inclusion of sensors than the long-term prototype

The ESACCI products will be systematically assessed against a Product Validation Plan that will also be publicly available on the website once approved. This PVP includes the protocol for objective algorithm selection, product verification, independent product validation using reserved data (including independent validation of L4), and assessment of utility for climate applications. The products will be openly available once the product validation and climate assessment reports are approved (2013). Assuming phase 2 is commissioned, routine short-delay delivery will commence during 2013 to 2016, precise time to be determined.

Although not a product, an aspect of the present work in ESACCI of wider relevance in GHRSST is the creation of a multi-sensor match-up system (MMS) at level 1b (geolocated, cloud-screened brightness temperatures). This comprises coincidences of in situ with multiple satellite observations, being used to address consistency between sensors and the relative uncertainties of different sensors.

1.6 RDAC Plans in Japan

JAXA, JMA and Tohoku University are working closely and sharing information regarding satellite instruments and SST data each other.

The JAXA GHRSST server has been operating, and continues updating in order to meet requirements from the GHRSST science team. Satellite-based SST data from future missions such as AMSR2 on GCOM-W1 and SGLI on GCOM-C1 will also be distributed to the community.

JMA incorporated several satellite SST observations to their MGDSST analysis. In order to improve MTSAT SST, they are testing modified processing system for MTSAT SST.

Tohoku University continues the production of New Generation SST for Open Ocean (NGSST-O) that began in 2003.

Currently, JAXA is planning following activities during 2011 to 2016 as shown in Table 3.

Year	Activities and plans
2011	Release of AMSR-E SST in GDS v2.0 format. Addition of VIRS SST to JAXA GHRSST server. Start new GCOM-W1 Data Distribution Service for test operation (AMSR-E and AMSR standard products are available).
Late 2011 or Early 2012	Launch of GCOM-W1 satellite.
2012	Release of AMSR2 products to collaborative organizations (L+3month) and general user (L+1year) through GCOM-W1 Data Distribution Service. Update of AMSR2 SST algorithm and apply it to AMSR-E data to produce a long-term data set. Addition of AMSR2 SST to JAXA GHRSST server.
2013	Launch of Global Precipitation Measurement (GPM) core satellite. Consideration of extension of AMSR2 SST algorithm to other satellite microwave imagers (TBD).
2014	Launch of GCOM-C1 satellite (TBD).

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

Table 3: List of JAXA activities and plans

OMP/JMA is implementing reanalysis of MGDSST for the period from 1981 to 1984 using AVHRR Pathfinder Version 5.2 SST. OMP/JMA will replace climatologies of SST for the period of 1981 to 2010 after the implementation. Developing a system to create and deliver MGDSST files of NetCDF version based on GDS-2.0 format is one of the issues to be discussed in these years.

As a follow-on to the MTSAT series, JMA plans to launch next-generation satellite Himawari-8 in 2014 and the launch of a second follow-on satellite, Himawari-9, into orbit, standby is also scheduled for 2016.

1.7 RDAC Plans in Australia

As part of the next phase of the Integrated Marine Observing System (IMOS) and BLUElink-III Projects (July 2011 - June 2013), the Australian Bureau of Meteorology aims to:

- Provide reprocessed (back to 1992) HRPT AVHRR SSTskin L2P, L3U, L3C and L3S files incorporating Australian and Antarctic data via IMOS and the GHRSST GDAC (June 2011) – all ready providing from real-time back to 2002 L2P files from Australian ground stations via ftp://aodaac2-cbr.act.csiro.au/imos/ GHRSST/
- Provide real-time HRPT AVHRR SSTskin L2P files from Davis and Casey Antarctic stations (June 2013)
- Provide real-time and reprocessed hourly, 0.05º x 0.05º gridded, MTSAT-2 SSTskin L3U files to IMOS (December 2011) - all ready provided reprocessed MTSAT-1R SSTskin L3U files via ftp://aodaac2-cbr.act.csiro.au/imos/GHRSST/
- Equip two additional SOOP vessels with hull-contact temperature sensors and provide real-time, quality assured ship SST data streams from these vessels plus CSIRO's RV Linnaeus to the GTS and IMOS (June 2012) - all ready providing SST from 14 vessels via http://opendap-tpac.arcs.org.au/thredds/catalog/IMOS/ SOOP/
- Upgrade operational RAMSSA and GAMSSA to incorporate new GHRSST L2P data streams for enhanced accuracy/resolution (HRPT AVHRR and possibly MTSAT-2, AATSR and WindSAT) (December 2011)
- Collaborate with the GHRSST DV-WG in the TWP+ Project to quantify diurnal warming events and test diurnal variation models in the Tropical Warm Pool region
- Test RAMSSA_skin SSTskin analyses for both the quality control of satellite sounder data being assimilated into ACCESS-R NWP analyses and as a boundary condition for ACCESS-R forecasts (June 2012)
- Assess the impact of incorporating a DV model in the BLUElink coupled limited area model (CLAM) (June 2012).

In the longer term, the Bureau aims to incorporate new GHRSST L2P data streams such as those from AMSR-2 and SLSTR into its operational SST analysis and ocean forecast systems and will work with GHRSST to improve the quality and availability of in situ SST data in the Australian region.

1.8 GHRSST Global Tasks

1.8.1 GDAC

The Global Data Assembly Center (GDAC) at NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC) is the primary clearinghouse and access node for operational GHRSST data streams, in collaborative role with the NOAA Long Term Stewardship and Reanalysis Facility (LTSRF) for archiving.

Future Plans: The Global Data Assembly Center (GDAC) continues to meet its requirements to distribute increasing numbers of GHRSST datasets and volumes, foster data discovery, maintain meaningful metadata records, implement robust data stewardship practices, and build new data utilization tools and services. GHRSST data-streams can now leverage off an improved and scalable data management system that has recently been put into place at the PO.DAAC as well as new subsetting, visualization, data discovery, web services and metadata tools. NASA has recognized the importance of GHRSST data (with the recent 2011 NASA Physical Oceanography proposal call emphasizing these products) while supporting the concept that leading edge research cannot be fostered without strong data management principles and infrastructure. In conjunction with the NOAA Longterm Stewardship and Reanalysis Facility, the GDAC is committed to maintaining GHRSST data for all users well into the future.

1.8.2 LTSRF

Active Archive Efforts at NODC LTSRF are continuing, with annual reviews of GHRSST version 1 product metadata and feedback provided to RDACs on inconsistencies and issues with their products. With the final approval of the new GHRSST Data Specification Version 2 (GDS2) in the fall of 2010, NODC staff are also actively working to update automated ingest procedures and prepare ISO 19115-2 metadata for all GHRSST products. Browse graphic images continue to be created and have been extended to include every GHRSST netCDF file regardless of processing level. The process of generating a browse graphic forces the LTSRF archive to confirm and verify the contents of every package of data arriving into the archive. Currently, a PNG browse graphic is automatically generated for every L2P, L2P_GRIDDED and L4 data file arriving at the LTSRF. An accompanying KML wrapper is also generated, which allows the PNG graphic to be viewable in Google Earth. In addition to quality assurance, browse graphics increase the discoverability of GHRSST data holdings at the LTSRF. Users can quickly see the differences in spatiotemporal coverage and resolution among the various GHRSST products, helping them to choose which product is the best for their particular application. Increasing the discoverability of and access to GHRSST data continues to be a major focus of the NODC LTSRF. In addition to HTTP and FTP, GHRSST data continue to be made available online from the LTSRF using the Data Access Protocol (DAP) via OPeNDAP's Hyrax server, and through the DAP, Web Coverage Service (WCS), and Web Mapping Service (WMS) via Unidata's THREDDS Data Server (TDS). Virtual aggregations making the gridded GHRSST products appear as single, 3-dimensional "cubes" of data in space and time instead of a discrete collection of 2-dimensional slices were made available through the NODC LAS this year (http://data.nodc.noaa.gov/las). The collection-level metadata records generated by NODC for each GHRSST product that are now accessible not only via Google searches but have also now been published to Geospatial One Stop (http://www.geodata.gov) and Data.gov (http://data.gov).

Future Plans: The past year has been a highly active one for the LTSRF. The large data management system has been maintained and improved, and progress made toward creating high resolution, multi-sensor reanalysis products. Preparations for the receipt of GDS2 data at the LTSRF have been made, and it is anticipated that the new GHRSST standards will further enhance the usability of the GHRSST collection for climate-related applications. Growing numbers of users continue to access more and more GHRSST data every year. The GHRSST LTSRF archive continues to improve its level of quality assurance of the data as it flows into the archive and is working with RDACs to remedy problems that are found. The coming year looks even more promising, with longer time series of data being made available to a wider range of users in GHRSST GDS2 format from projects like Pathfinder and the ESA CCI. Improvements to the SST intercomparison facility for understanding key differences in the available data continue including dynamic subsetting and analysis through the NODC LAS.

1.8.3 Matchup database (MDB)

The GHRSST systems match satellite SST and SST analysis products to in situ observations and store these matchup pairs in a relational database. The GHRSST Matchup Data Base (MDB) is then used to validate data products and to generate the Sensor Specific Error Statistics (SSES) required by L2P data products.

Future plans: a community consensus in situ data and match-up procedures has been recommended by the NASA SST ST [WPN] as follows: '*A "Best Practices" guideline should be developed that identifies data sets (NCEP GTS, FNMOC, ICOADS, ...), data types (ships, drifters, tropical & coastal buoys) and QC procedures (more sophisticated & consistent with meteorological community). Unified match-up procedures (space-time windows, selection criteria) should be developed and adopted. Shared databases of skin SSTs and in situ bulk SSTs should be developed and made available to the community. These guidelines should provide a baseline validation approach, and not be used to restrict additional, innovative approaches.'*

Ifremer is currently acting as the central GHRSST match-up database (MDB), storing into a relational database match-ups either directly produced by SST providers (such as OSI SAF for Metop, Seviri or GOES-13, or the University of Miami for MODIS) or directly produced at Ifremer for the available L2P (AMSRE, TMI, AVHRR, GOES11) using CORIOLIS as in situ data source. These match-ups come in a variety of format, content, production or quality control procedures and it is an objective in the coming years, in the context of GHRSST, to unify the production of these match-ups, following the recommendations by most space agencies or cal/val groups. In particular, the following points shall be addressed:

a) in situ data: define and set up a unified source for in situ data, as extensive as possible, providing reliable metadata and classification, and applying consistent and agreed quality control and filtering procedures
b) define consistent and homogeneous procedures for the match-ups processing, using unified time and space criteria or search/selection procedures, as well as confidence criteria and quality control
c) define unified format and content: it is acknowledged that some content shall be specific to a sensor but common parameters and metadata shall be identified and specified within GHRSST framework.
d) agree and set up exchange protocols between match-up providers and the GHRSST central MDB

1.8.4 GMPE, SQUAM and HR-DDS

Intercomparison tools have been developed within IC-TAG and are now provided for public access:

- The GHRSST Multi-Product Ensemble (GMPE) system (http://ghrsst-pp.metoffice.com/pages/latest_analysis/sst_monitor/daily/ens/index.html)
- The High Resolution Diagnostic Data-set (HRDDS) system (http://www.hrdds.net)
- The SST Quality Monitor (SQUAM) system (http://www.star.nesdis.noaa.gov/sod/sst/squam/)

GMPE future plans: The work for GMPE is currently funded by the MyOcean European project and by UK funding. It is hoped that this support will continue in the follow-on project to MyOcean (called MyOcean2) which is currently under negotiation. Funding from ESA will also be available to begin work on a longer-term GMPE product.

HR-DDS Diagnostic Data Set: Diagnostic Data Sets are produced from satellite data every day for a number of globally distributed sites as part of the GHRSST data product monitoring system. In some cases, satellite winds, ocean colour, operational NWP and ocean forecast model outputs are also available. These data products and associated analysis tools are aimed at groups interested in verification of satellite data sets (including L2P and L4 GHRSST products).

Further future plans for 2012 and beyond: The HR-DDS system at NOC will be maintained at NOC under the MyOcean project until the end of that project in early 2012. In November 2011 the developer currently responsible for the system left NOC, handing responsibility for maintaining the system to Maureen Pagnani at the British Oceanographic Data Centre in Southampton. Dr Helen Snaith will retain overall responsibility for managing the system. Resources are required for further development of the system, or for formal maintenance of the system, after the end of the MyOcean project (April 2012). However, BODC will continue to maintain the service on a best effort basis for as long as possible given other resource constraints.

SQUAM future plans: The work for L2 SQUAM is currently funded under US GOES-R and JPSS Projects. L3-SQUAM work was not funded but was accomplished “at will”. L4-SQUAM was partially supported by the US Joint Center for satellite data Assimilation in FY11, and this support continues into FY12. Long-term sustained funding for L4-SQUAM support is yet to be identified.

Recommended by the NASA-SST-ST:

- To develop systematic approaches to L4 product intercomparison and validation, including validation of uncertainty estimates; judicious approaches to selection of data to use in L4 products vs data to be withheld for validation; to consider more sophisticated validation studies, e.g. OSSE.
- To develop systematic approaches to clarifying and communicating the actual smoothness of individual L4 products versus their nominal grid resolution; to investigate the influence of these parameters on the data set error.

1.9 Actions for Strategic Aim I: Maintain the Regional/Global Task Sharing system

Action	Priority	Key groups	Related [OO9] recommendations, (See Appendix 3)	Milestones	Risks
I-1 Support	high	DAS-TAG,	46, 47	GHRSST	

Action	Priority	Key groups	Related [OO9] recommendations, (See Appendix 3)	Milestones	Risks
R/GTS		GDAC, LTSRF		meetings	
I-2: Maintain GDS	high	DAS-TAG	42, 43, 45	GHRSST meetings	
I-3: Develop and maintain GHRSST MDB's	high	ST-VAL, RAN-TAG, Ifremer, MeteoFrance, NOAA	28		
I-4: Develop and maintain tools matching in-situ and satellite data, both for historic data and near real-time like the HRDDS, like iQUAM	medium	ST-VAL, BODC Southampton (HRDDS), NOAA (SQUAM iQuam)	29c, 29d, 33		HRDDS: End of funding April 2012 iQuam funding
I-5 Maintain and extend GMPE	high	IC-TAG, UK MetOffice	32, 34		

Table 4: Actions for Strategic Aim I – Maintain the Regional/Global Task Sharing system

2 Strategic Aim II: Expand Validation Framework

Major improvements to satellite SST validation are expected to result from increased accuracy and resolution of in situ SSTs from ships and data buoys and independent data from a global, sustained network of ship-borne radiometers to validate the RTM retrievals. Such validation is essential to challenge the retrievals properly and independently. Furthermore, such process studies using accurate in situ radiometry underpin our fundamental understanding of the air-sea interface: ultimately allowing us a reality insight from which we may then expand to a more general framework with a model based approach.

Especially in high latitudes, more in-situ measurements are required.

In the past, GHRSST has discussed the possibility of establishing community consensus datasets and data-bases, sampling methodologies and QC procedures concerning the use of in situ SST for satellite calibration and validation. , Progress has been limited by the availability of funding. This goal was also identified by the NASA SST ST. In 2011/2012 the GPO plans to develop together with the Science Team the “GHRSST verification, validation and calibration report” [SOW], collecting the ongoing validation activities and establishing a framework for sharing equipment, datasets and methodologies. Below, the planned calibration and validation activities are summarized as output from the ST-VAL breakout session in Boulder 2011.

2.1 Drifting buoys for SSES estimation

The current GHRSST reference source for providing Single Sensor Error Statistics (SSES) are drifting buoys, and all groups who provide SSES (or do any type of validation with drifting buoys) use a method of quality control that is unique to their processing system. Good quality control of drifting buoys is vital as this can have an effect on calculated difference to satellites of up to 0.2 K. Several issues were discussed at the Boulder 2011 workshop by Pierre Le Borgne (CMS) and Sasha Ignatov (NOAA), including their current blacklist approach, should blacklisted buoys be reused, and should a master blacklist be maintained by GHRSST. Clearly more work is needed on this issue.

A pilot project in collaboration with DBCP was started in 2010 for upgrading drifting buoys, i.e., to improve pre-and post-deployment sensor calibration, improved sensor installation and additional meta-data. GHRSST required 2010:

Variable	Accuracy	Resolution	Drift
SST	0.05 K	0.01 K	0.01 K/decade
Location	0.5 km	0.5 km	
Obs time	5 mins	5 mins	

Table 5: GHRSST recommendations for upgraded drifting buoys

The progress of this pilot project is monitored by ST-VAL, see: https://www.ghrsst.org/ghrsst-science/science-team-groups/stval-wg/dbcp-ghrsst-pilot-project/

2.2 The use of Argo as a reference dataset

A key aim of the ST-VAL group is to create a global reference dataset that is solely used for validation and is not used in producing the L2P or higher products offered by GHRSST. The current choice for SSES is drifting buoys, but drifting buoy data are also used in retrievals and in bias correction for the analysis products. Other possible reference datasets include ship-borne radiometers, which are traceable to SI national temperature standards such as those maintained by NIST and NPL, and are therefore essential for constructing climate data records, and the moored buoy network. However, additional data sources, such as the ARGO profilers can complement the limited number of ship-borne radiometers and limited coverage of moorings. Initial work initiated by the GHRSST DV-WG with DBCP collaboration and executed by Chris Merchant (University of Edinburgh) has shown that Argo near-surface measurements offer great potential to provide this data; this initial work was promoted by a DV-WG talk from Stephen Riser during GHRSST IX who demonstrated high accuracy before and after deployment from several recovered floats. In addition, recent work by Castro et al. (2010) has demonstrated the use of research grade sub-surface measurements in providing improved retrievals.

Initial comparisons to the AATSR sensor on Envisat has shown the intrinsic high accuracy of an Argo float (S. Riser reported ~ 0.0005 K at GHRSST IX) means the total match-up uncertainty from comparing Argo SST-depth to AATSR SST-skin is comparable to that of ship-borne radiometers (which is an SST-skin to SST-skin comparison) assuming any residual thermal stratification of the ocean surface has been mixed away. Fundamental physical differences remain between the SSTskin and SSTdepth data reported by ARGO and despite the high accuracy of ARGO SSTdepth data, unequivocally accounting for these differences remains a fundamental challenge. Statistically, the point measurements offered by ARGO show considerably lower uncertainty than drifters during the day. A summary of the match-up statistics is shown in the Table 6 below.

Retrieval	Drifters			Argo		
	Number	**Median (K)**	**RSD (K)**	**Number**	**Median (K)**	**RSD (K)**
Day time	40074	+0.02	**0.32**	822	+0.03	**0.28**
Night time	50790	+0.00	**0.35**	701	+0.00	**0.29**

Table 6: Comparison of AATSR operational SSTs versus drifting buoys and Argo near-surface match-up results. Drifting buoy data from ICOADS; Argo data from Met Office EN3; match-ups limited to wind speeds > 6 ms^{-1}; robust statistics; match-ups are nearest pixel within ±2hrs

The results in Table 6 show consistent median differences using both drifters and Argo, but a significant reduction is seen for the ICOADS for both day and night match-ups. This reduction is equivalent to removing ~ 0.2 K from the match-up process, which is currently our best estimate of the drifting buoy uncertainty (the Argo uncertainty is ~ 0.005 K as reported by S. Riser at GHRSST IX).

The high accuracy Argo data, together with statistical analyses and assumptions regarding the connections between SSTskin and SSTdepth, allows us to better understand the statistical uncertainty of comparing a single point in situ measurement to a 1-km satellite pixel. Although the above match-ups are not exactly coincident, their relatively similar global distribution and median differences allows us to adopt the approach of approach to O'Carroll et al. (2008) and use multi-way statistics to estimate the uncertainty of comparing a single point in situ measurement to a satellite pixel.

At the GHRSST XII (Edinburgh 2011), the GHRSST Science Team agreed on the use of Argo near-surface temperature measurement as a reference data set.

2.3 Ship observations

A further useful dataset for ST-VAL are in situ ship measurements. Currently the GHRSST community has a very limited requirement for ship-borne underway hull thermometry or Thermosalinograph SST data due to their geographical coverage and usually high measurement uncertainty. However, recent advances led by the Australian Bureau of Meteorology (Beggs et al., at DV-HL-STVAL workshop at Boulder, 2011) have shown that modern in situ ship measurements, when carefully managed, can provide comparable accuracy to current drifting buoys.

The ST-VAL group is coordinating with the JCOMM Ship Observations Team (SOT) to better articulate the GHRSST requirements for ship SSTs and Ian Barton gave a presentation on behalf of GHRSST at the recent SOT meeting in Hobart.

2.4 Radiometers on ships

Over the past decade and more, ship-based radiometers have made important contributions to the validation of satellite-derived SSTs. The measurements of the surface emission, corrected for the small contribution of the reflected sky emission, leads to a retrieval of the skin SST, which is the temperature that gives rise to the signal that is detected in space. The discrepancy between the ship-based and satellite based skin temperatures is free of the effects of the near-surface temperature gradients that are present in the comparisons with subsurface thermometers, and gives a better indication of the errors introduced by the imperfections of the atmospheric correction algorithms. Other sources of error, such as introduced by the spatial variability of the SST fields, resulting from the comparison of a spatially averaged satellite-derived SST and a spot-sample of the validation measurement are common to validation by radiometers and buoys, but for radiometers on a moving ship a linear average of many independent samples can be made over length scales comparable to the spatial resolution of the satellite SST fields.

The ship-based radiometers are self calibrating as they include two internal black-body targets at different, known temperatures. The calibration chain to SI standards is achieved by calibration of the radiometers before and after deployment against laboratory black bodies that have been characterized by the NIST reference radiometer, the TXR, or similar devices.

To be valuable for the validation of satellite-derived SSTs, the matchups with ship-based radiometers must encompass the range of natural variability of the atmosphere and ocean surface. This has been achieved by installing radiometers on commercial ships that ply routes that cover a wide range of conditions, such as the trans-Pacific section of freighters of NYK lines, or ice-breakers that resupply Antarctic bases. Long-term deployments on ships that sample a smaller range of conditions is useful to assess the regional stability of the SST retrievals round the seasons, such as Royal Caribbean Cruise Lines ships in the Caribbean and western north Atlantic, and P&O Ferries between the UK and Spain. Additional geographic areas can be covered by installing radiometers for shorter periods on research ships that go to regions rarely visited by commercial vessels.

2.5 Future Validation Activities

The following categories of future SST validation activities resulted from the Boulder workshop in 2011:

1. Ship-borne SST Radiometers

More countries should be persuaded to operate SST radiometers on ships.

The CEOS requirement for the generation of CDRs (or estimate for ECVs) is for an unbroken chain of comparison from the satellite measurements to SI standards, and with can be done for SST using radiometers on ships. Repeatedly recalibrated radiometers also provide long-term consistency between satellite SST sensors. M-AERI has been logging SSTskin since 1995. Therefore prior to the mid-90's we cannot provide the basis to ensure the satellite SST form a consistent climate record with SI traceability. As a minimum, each satellite sensor should be validated once in an ocean region during its lifetime, although more frequent sampling is strongly desired.

2. Argo

A detailed study of the utility of Argo floats for validating satellite SSTs should be carried out within GHRSST (see recommendations to Argo). The "thermal recharging floats" which are under development, and which have a potential near-indefinite lifetime for relatively rapidly repeating profiles near the surface, require a few degrees temperature differential to operate, so will not likely achieve this poleward of 50° so may not be useful at high latitudes (Yi Chao) . But they do have a potential to provide useful data over much of the oceans. The cost per thermal recharging float would be around $40k to $50k.

3. Drifters

Thermistors should be better calibrated as currently drifting buoy thermistors are not individually calibrated prior to deployment. The data transmission format should also be changed to allow SST measurements to be reported at 0.01K resolution (see GHRSST recommendations to DBCP and JCOMM OCG). The addition of thermistor chains to measure diurnal heating would be of use to relate the surface measurements to temperatures at depth.

4. Ships

The possibility of using hull-contact sensors on VOS-Clim ships installed with automatic weather stations should be explored. We should also push for the periodic recalibration of engine intake sensors on volunteer observing ships (see GHRSST recommendations to JCOMM OCG)

5. Animals

Increasing numbers of good thermometers that transmit measurements by satellite are being attached to animals, including large marine mammals and birds, Evidence is accumulating that these measurements are of sufficient quality to be used for the validation of satellite-derived SST. At present these data are not readily available; most of the sea lion CTD data is not available in real-time on the GTS (Yi Chao).

6. Existing campaigns

There are often opportunities for SST validation cruises. In the coming year there are:

- Aquarius Mission – Salinity Validation Cruises

Yi Chao is a project scientist on the Aquarius mission, which was launched in June 2011. Aquarius SSS derivation requires SST to an accuracy of 0.5 K. The Salinity Processes in the Upper Ocean Regional Study (SPURS) Field Experiment is planned for 2012 in the sub-tropical North Atlantic (25°N, 28°W) and will have a seven day repeat. They will collect subsurface and surface observations. See http://spurs.jpl.nasa.gov

- March 2012 cruises:
  WHOI flux buoy (Bob Weller)
  PMEL mooring (x2)

Seagliders (x3)
Wave Gliders (x2)
STS floats (x25) – Steve Riser profiling floats
SSS drifters (x75)
ML floats (x2)
Microstructure Profiler
ASIP (used to be called SkinDeEP)
Flux bow mast

- July 2012: French cruise
- Fall 2012: UNOLS cruise
- Spring 2013: UNOLS cruise

Yi Chao suggested that an SST radiometer could go on one of these cruises. All cruise data will be available in near real-time to the public.

7. Dynamo Campaign (Indian Ocean)
   - US ship is the *Roger Revelle*.
   - Japanese ship is the *Mirai*, which is equipped with an ISAR.
8. Repeating cruises
   - PIRATA and TRITON refurbishment cruises: Peter Minnett will contact PI's to have an ISAR or M-AERI to be installed on these vessels.
   - Helen Beggs suggested the possibility of having an ISAR or M-AERI installed on the MV Whana Bhum or Xutra Bhum.
   - A document summarising the ship requirements for a M-AERI or ISAR deployment is required (Peter Minnett and Werenfrid Wimmer).
9. How do we deal with combined skin/bulk SSTs?

Ancillary surface forcing variables can be obtained from the following:

- AWSs on ships that are well-maintained
- Scatterometer winds
- NWP assimilation fields
- Met flux moorings (see OceanSites web site)

2.6 Actions for Strategic Aim II

Action	**Priority**	**Key groups**	**Related [OO9] recommendations (See Appendix 3)**	**Milestones**
II-1 Establish defined terminology concerning errors/ uncertainties	high	ST-VAL, ESA CCI		2012 GHRSST meeting

Action	Priority	Key groups	Related [OO9] recommendations (See Appendix 3)	Milestones
II-2 Influence in-situ development system to improve accuracy, SI traceability, meta-data stewardship, and to increase temporal resolution and global coverage.	high	ST-VAL, HL-TAG, RAN-TAG, DVWG	6, 8,9, 20, 21, 22, 24, 26, 27,	GHRSST meetings
II-3 Formulate a Calibration and Validation Framework	high	RAN-TAG, ST-VAL, ST	25	Melbourne workshop 2012, GHRSST meetings
II-4 Assessing quality of upgraded drifters	high	ST-VAL		Melbourne workshop 2012, GHRSST meetings
II-5 Using Argo near-surface profiles for diurnal model validation	high	DVWG		Melbourne workshop 2012, GHRSST meetings
II-6 Assessing Argo near surface measurements as independent reference source	high	ST-VAL		GHRSST meetings

Table 7: Actions for Strategic Aim II – Expand validation framework

3 Strategic Aim III: Incorporate pioneering SST science

The following priorities for future developments related to SST measurements from space have been identified: (1) improved identification of contaminated measurements, e.g., cloud, aerosol and sea-ice discrimination, particularly at high latitudes and at night in the infrared, and rainfall, rfi and side lobe effects in the microwave; (2) provide high spatial resolution fields (1 km) together with information on feature resolution; (3) algorithms that reduce regional biases in the derived SSTs; (4) improved error characterisation; (5) lake surface temperature and ice cover and (6) consistent data sets over multiple missions. These issues are of particular importance at high latitudes, due to the sparseness of both satellite and in-situ observations, and due to the variability of the atmosphere. GHRSST Working Groups (WGs) and Technical Advisory Groups (TAGs) strive for progress with the above issues and welcome new participants.

GHRSST Working Groups (WGs) and Technical Advisory Groups (TAGs) search for progress with the above issues: EARWiG and HL on (1), DV for (2), EARWiG for (3), ST-VAL and EARWiG (4), IWWG (5), IC-TAG for (6), R2HA2 and RAN-TAG for (7). In this chapter, the plans of the groups are compiled, drawing on the TAG and WG reports of the groups for the GHRSST XII meeting in Edinburgh, and the GHRSST XII breakout session reports (*Kaiser-Weiss (ed.), 2011*).

Below, the issues of overarching relevance are explained, followed by the detailed plans of the respective groups.

1) **Improved Detection of Contaminated Pixels:** Clouds, ice and water differ in the probability distribution of the relation of reflectances and brightness temperatures at different wavelengths (*S. Eastwood, GHRSST XII, Edinburgh 2011*). Thus a Bayesian approach to masking ice/clouds in the Arctic is applied at the OSI SAF during the processing of SST from the AVHRR (Advanced Very High Resolution Radiometer). The method is found to work well during day time. There are continuing efforts in the ESA SST Climate Change Initiative (CCI) project to improve cloud and ice masking at high latitudes, including the challenging night time cases.
2) **High spatial resolution fields:** Increasing the spatial resolution and frequency of observations not only reduce the effects of clouds obscuring the surface. High resolution observations (1km) are required to capture sub-mesoscale SST variability over the global ocean and particularly in the shelf sea regions. Higher resolution (1km, hourly) SST data allow better detection of SST diurnal variability features and fronts. It was shown that in numerical weather prediction models, the atmospheric moisture uptake is resolution dependent. For instance, the rain rate is sensitive to the resolution of the SST boundary condition (*Minobe et al., 2008*).
3) **Algorithm improvements to reduce SST biases:**

   For the infrared measurements, the contamination from uncorrected variability in atmospheric moisture content remains a major error source.

   Recent developments in algorithms include the incremental nudging method, optimal estimation developed by several groups, the NRL retrieval method (a variant of optimal estimation) and improved water-vapour banded coefficients.

   For instance, regional biases in SST can be reduced by modelling the effect of the atmospheric moisture and temperature on the measured brightness temperatures in the channels used to derive SST. When a NWP field is used to calculate this bias, the regional SST bias can be significantly reduced (see Figure 3 in *LeBorgne, 2011)*, how the METOP summer positive bias can be corrected by using HIRLAM profiles).

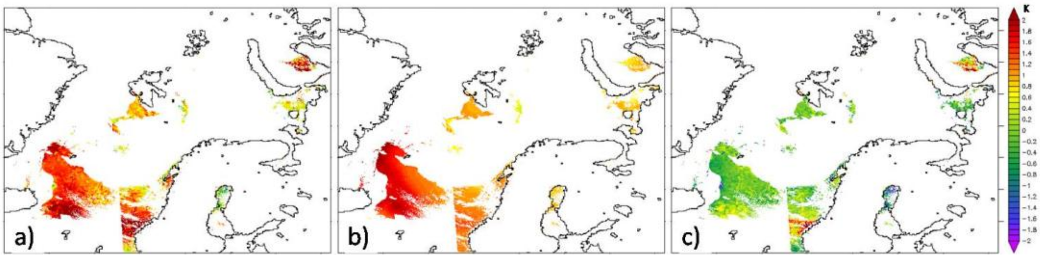


Figure 3: Case of 5th July: (a) Operational METOP/AVHRR – OSTIA SST difference (b) simulated error; (c) corrected SST – OSTIA (P. Le Borgne et. al, this conference)

An alternative method to reduce regional biases in infrared satellite SST, particularly at high southern latitudes, has been developed at the Australian Bureau of Meteorology (*Paltoglou et al., 2010*). In order to reduce biases in AVHRR SST over the Southern Ocean, a simple model of atmospheric depth as a function of latitude has been folded into the airmass term in the daytime non-linear SST (NLSST) regression algorithm that converts AVHRR brightness temperatures to SST (*Paltoglou et al., 2010*). In addition, due to the much greater number of drifting buoy SST observations available at mid-latitudes compared with high southern latitudes, those at high latitudes were given a greater weighting when calculating both the night-time and daytime regression coefficients for the NLSST calibration algorithms. These methods appear to have largely eliminated the latitudinal bias south of 40ºS in the AVHRR SST from NOAA-17, 18 and 19 satellites observed in data sets calibrated using the standard NLSST algorithms (*Beggs et al., 2011*).

4) **Improved uncertainty (i.e., error) characterisation**: This is vital for development of generally all applications, see section 3.1. Currently, several terms are used to describe errors and uncertainties in GHRSST. A thorough definition of those, and documentation on how the uncertainty (or error) estimates are derived, is the first step for achieving harmonisation across the GHRSST products in the near future. In this document, the terms “error” and “uncertainty” are used interchangeably, i.e., covering both the systematic and the random error component, thus including the bias, the uncorrelated as well as the correlated errors.

5) **Lake and other inland waters surface temperature and ice cover:** A dedicated working group IWWG has been formed 2012, see section 3.6.

6) **Progress in merging techniques (data assimilation):** Future assimilation of SST data into (coupled) atmosphere/ocean models is anticipated. For this estimates of uncertainty are required, and in addition also the error co-variance matrices. The data assimilation compares observation, models and analyses, and statistics on their differences can be generated automatically, This so-called ‘feedback statistics’ can give valuable information on the data quality, validity of error estimations, and error correlations, for instance the ‘feedback statistics’ can show if any observing system has a drift compared to all other observation and model information, Also, the observation impact of a particular observation on the analysis is a by-product of several data assimilation methods.

7) **Ensuring continuity over missions:** Although there are currently ten satellites with sensors capable of measuring SST, some elements of the in-flight constellation are fragile. Four of the 10 satellites are geostationary (GOES-E, GOES-W, MTSAT, MSG) and measure the partial earth disk centred on the sub-satellite point). Several instruments are past their expected lifespan, and the situation is especially severe for the passive microwave instruments. This is underscored by the recent loss of the AMSR-E instrument after 9 years of operation leaving the SST constellation with a significant gap (AMSR-E provide a near-all-weather capability with global coverage) until GCOM-W is launched (expected in 2012). Continuity of missions is absolutely crucial for the applications in weather and ocean forecasting, and other marine applications, and especially climate research. A major research priority of GHRSST is to ensure consistent data sets over multiple missions.

3.1 Satellite Sea Surface Temperature Validation group (ST-VAL)

The development of the Sensor Specific Error Statistics (SSES) is one of the activities of the Satellite Sea Surface Temperature Validation (ST-VAL) group. This group was established to look at all aspects of satellite SST validation: from the reference data itself, to the challenges which occur when comparing these locally representative reference observations to satellite data, to the ongoing refinement of the uncertainty estimates.

ST-VAL Workplan 2011-2016 (from ST-VAL Breakout session Edinburgh):

- SSES
  - Adoption of ‘Common Principles’
  - Improvement of validation methods

  - Definition of uncertainties
  - QC of drifter data
  - DBCP pilot project
- Continued evaluation of Argo
  - as reference data source for independent validation of SSTs and their uncertainty estimates
- Continued interaction with in situ providers
  - Requirements for SOT data
  - Attempt to develop a coordinated network
  - Argo near-surface profiles
  - Thermistor chains
- Exploitation of forthcoming campaigns
  - For example SPURS
  - See report from Boulder in ST-VAL Edinburgh report (also included in *Kaiser-Weiss (ed.), 2011*)
- Calibration
  - Where should this sit in GHRSST?
- Next generation SSES (uncertainties)
  - From first principles
  - Presented in a form useful for climate research
- SST Reference network
  - Composition and capability
  - Coordinate with RAN-TAG
- Documentation

3.2 Diurnal Variability Working Group (DVWG) Priorities and Plans

The DVWG priorities are centred on providing the GHRSST community and users with improved estimates of diurnal warming both for individual satellite retrievals and on global grids to complement current foundation SST analyses. Significant progress has been made in improving the understanding and modelling of diurnal warming, and now it is important to apply these results to better convey diurnal warming estimates and associated uncertainties in a cohesive manner. Specific priorities include:

- Development, validation, and production of diurnal warming analyses
- Continued model development and evaluation
- Provision of guidance on recommended/consensus approaches
- Improved web presence facilitating access to diurnal warming models, estimates, and uncertainties
- Connecting ARGO SSTdepth with SSTskin measurements using appropriate modelling techniques

A key product missing from the GHRSST suite is global/regional fields of estimated diurnal warming at specified times and depths for users requiring information on diurnal warming in their applications. While some information is present in individual retrievals, our analyzed fields focus on providing daily average or foundation values. Provision of either initial operational fields or recommended methodologies is perhaps the single greatest priority of the group. Further user input on the ideal information content of these products is still being pursued.

To support these analyses, as well as provision of information on the amount of diurnal warming present in individual L2P products, model development and evaluation activities will continue. A necessary component of this work is to develop better estimates of uncertainties in predictions of diurnal warming.

As model development continues, it is important for the DVWG group to convey information on the applicability and capabilities of the different available models. While it is unlikely there is a single diurnal warming model that GHRSST should endorse, we will utilize our collective experience to highlight our recommendations on what the models can and cannot do and what models work best under different circumstances.

One way the DVWG will achieve this objective is through improvement of the information content of the DVWG web pages. Through these pages we will facilitate improved access to the different available models, test scripts for their application, information on their associated uncertainties, and available validation data. Activities have begun in this area but will be a continuing process as new models and results become available.

A key resource for the evaluation of diurnal warming models and analyses is the newly compiled Tropical Warm Pool (TWP+) data set, which combines high-resolution numerical weather prediction model output fields with direct SST observations from multiple satellite sensors. Coupled with similar previous data in the Mediterranean region, application of the TWP+ data will be a key focus of DVWG activities in the coming year to pursue these objectives.

A common theme that has emerged from the various model development and testing activities is that there is still relatively limited direct observational data of large diurnal warming events with which the models can be validated. Several group members have cited the need for additional accurate observations accompanied by a full set of coincident environmental data with which the different models can be forced. The possibility of calling for or endorsing a dedicated experiment to collect the required observations has been discussed. The group is planning to pursue preparation of a white paper to document our requirements, provide justification for our needs, and explore possible experimental concepts. As this is completed, the DVWG will work to circulate the document and look for opportunities to include the concepts in ongoing or upcoming field programs.

Interaction with other communities with interests in diurnal warming will be pursued to ensure that the products emerging from GHRSST and the DVWG will meet the spectrum of user needs. The NASA SST Science Team has specifically recommended developing and enhancing links with the ocean colour and meteorological communities.

The activities of the DVWG are largely performed on a best-effort basis under broader support for SST related research activities. Few within the group have funding dedicated specifically to diurnal warming research. The group remains highly dedicated, but progress will remain constrained by available time and resources.

3.3 High Latitude Technical Advisory Group (HL-TAG)

Improved error characterization: The error characterization in high latitudes is more difficult than elsewhere because of the lack of in-situ measurements (see Figure 4 for an illustration of drifting buoy coverage).

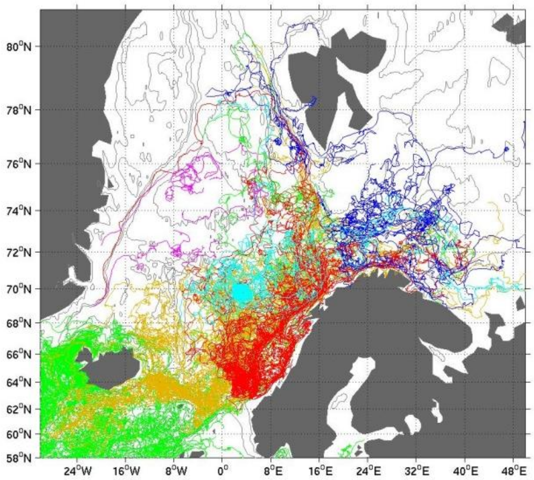


Figure 4: Scarcity of in-situ data: Tracks of all deployed drifting buoys 1991- 2009. Each buoy is individually colour-coded (image provided by I Koszalka, University of Oslo).

Furthermore, the atmospheric moisture content is highly variable in high latitudes making its effects difficult to correct. Discriminating between cloud and ice is crucial. Comparing the SST errors of specific satellite instruments in the Arctic shows that there is significant correlation between the error estimates of the infrared (IR) instruments, but low correlation between the errors from the microwave (MW) and IR instruments Also, dense coverage is desirable for deriving statistically significant results (Figure 4). The spatial correlation scales of satellite errors were found to be typically 300-500 km, the temporal correlation scales were found to be a few days (*Høyer et al., 2011*).

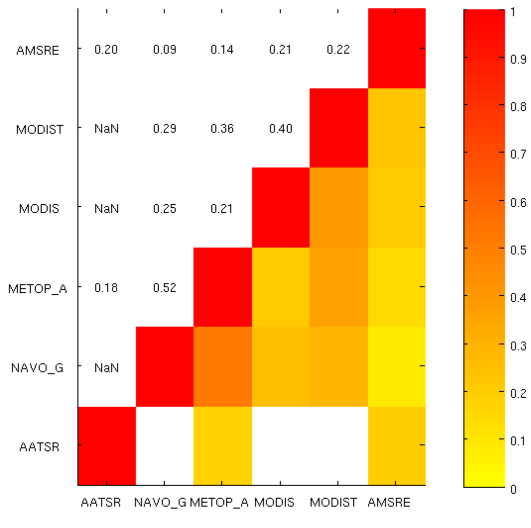


Figure 5: Validation of L2P in the Arctic: Significant error correlation exists between different IR SSTs, low correlation between AMSRE (MW) and IR SSTs (Høyer et al., 2011).

The high latitude regions are characterized by a lack of in situ observations, decreasing ice cover and strong sensitivity to the forcing that drives climate change. It is therefore important to secure the availability of accurate and reliable satellite SST observations in the high latitudes, which are the main objectives for the GHRSST High Latitude Technical Advisory Group (HL-TAG). The dry atmosphere, presence of sea ice in the Marginal Ice zone, the extended periods with cloud cover and the lack of in situ observations makes the retrieval of sea surface temperature observations from satellite a challenging task. The HL-TAG focuses upon validating and improving the satellite retrievals in the High latitude region. In addition, the HL-TAG facilitates the use of existing in situ observations and encourages the community to deploy new drifting buoys and other in situ observations.

Future planned work within HL-TAG

- SST:
  - Develop and validate several retrieval algorithms for the high latitudes
  - Validated performance in Marginal Ice zone.
  - Improve on cloud and ice detection
  - L4 Arctic multisensor bias adjustment method tested.
- IST
  - Improve operational 1 km L2 Metop-A IST, develop Metop-B IST
  - Combine MW and IR using modelling results.
  - Develop L4 IST product
  - Need for quality controlled validation data
- Sea Ice
  - Assess reprocessed NSIDC sea ice fields
  - Updated OSI-SAF reanalysis
  - Lake ice products
  - Intercomparisons of sea ice products
- In situ
  - Radiometer for high latitude field work (SST and IST).
  - Ice mass balance buoys (with floating device)
  - Wave glider
  - IMOS: new observation techniques

3.4 The Inter-Comparison Technical Advisory Group (IC-TAG)

The aim of the IC-TAG is to develop international collaboration in this field in order to assess and inter-compare the different L4 analyses, and to provide uncertainty estimates on both the analyses and observational products, and to give appropriate guidance to users. There are currently three systems used for inter-comparing the various L4 analyses within the IC-TAG:

- The GHRSST Multi-Product Ensemble (GMPE) system (http://ghrsst-pp.metoffice.com/pages/latest_analysis/sst_monitor/daily/ens/index.html)
- The High Resolution Diagnostic Data-set (HRDDS) system (http://www.hrdds.net)
- The SST Quality Monitor (SQUAM) system (http://www.star.nesdis.noaa.gov/sod/sst/squam/)

Short-term plans

In the short-term, a number of activities are planned including:

- Obtaining the remainder of the summary information on the L4 systems and writing an overview for the GHRSST web-site, aimed at users;
- completing the two-part paper on GMPE and SQUAM;
- transferring the GMPE web-pages across to a new site, with a re-design of the pages;
- producing GMPE files which include anomaly and gradient information for each analysis;
- introducing new L4 products into GMPE and SQUAM;
- adding consistent validation against QCed in situ data for all products in SQUAM;
- adding remaining L2 SST products, including geostationary (GOES, MSG, MTSAT) and polar (MODIS, VIIRS, (A)ATSR, AMSR-E)

Longer-term plans

A number of issues have been raised over the past year with regard to the estimation of analysis error in the L4 products. A project should be started within the IC-TAG aimed at investigating the way error estimation is currently done with a view to improving and potentially attempting to standardise it.

The GMPE system will contribute to the ESA SST Climate Change Initiative project. In this context, available long-term L4 SST products will be combined into a version of GMPE.

Analyses will be conducted in SQUAM towards reconciliation of various SST products monitored in this system, through accounting for diurnal cycle and improving sensor calibration and characterization from which L2 SST products are derived.

Adding ARGO floats to iQuam, and extending time series from current 1991 to at least 1981 (AVHRR/2 era) are considered. Once accomplished, validation in SQUAM will be extended back in time for those products available prior to 1991 (Reynolds, OSTIA Reanalysis), and validation against QCed ARGO floats will be consistently added for all products.

Funding

The work for GMPE is currently supported by the MyOcean European project and by UK funding. It is hoped that this funding will continue in the follow-on project to MyOcean (MyOcean2) which is currently under negotiation. Funding from ESA will also be available to begin work on a longer-term GMPE product.

The work for L2 SQUAM is currently funded under US GOES-R and JPSS Projects. L3-SQUAM work was not funded but was accomplished “at will”. L4-SQUAM was partially supported by the US Joint Center for Satellite Data Assimilation in FY11, and this support continues into FY12. Long-term sustained funding for L4-SQUAM support has to be identified.

3.5 Estimation and Retrievals Working Group (EARWiG)

The Estimation and Retrievals Working Group (EARWiG) is exploring the interaction of cloud detection and retrieval techniques, as well as other known issues such as geographical and aerosol related effects. These regional varying aerosol and moisture contents add errors (biases) to the SST estimate. EARWiG compares and develops different retrieval methods, with the objective to generate more accurate GHRSST L2P products.

EARWiG envisages working on best practice recommendation to data providers:

- Instrument calibration (at L1b)

- Cloud detection (IR)
- The inverse problem
- Effects of aerosols (IR)
- Side-lobe, RFI & precipitation contamination (MW)
- Lake surface temperature
- Uncertainty estimates for the above

EARWiG priorities:

SST retrieval is not a "done deal":

- Especially when considering <0.05K/decade stability requirement
- Simulations show that the main biases in current products are due to algorithmic limitations
- Despite this, it is hard to obtain algorithm/product improvement funded

Radiance calibration is another priority of EARWiG.

Feedback should be given to providers, CEOS CalVal, and the SST Virtual Constellation

SST retrieval is a vibrant activity and EARWiG should lead the way with:

- Best practice recommendations
- Exploitation of Multi-sensor Matchup Dataset concepts
- Themed workshop (joint-WG) in Melbourne, March 2012

3.6 Inland Waters Working Group (IWWG)

Adaptation of SST techniques to inland waters can give lake surface water temperature and ice cover for lakes (Figure 6 and Figure 7). High northern latitudes have a high prevalence of glacial-origin lakes, many of which are large (hundreds of square kilometres in area) and uninstrumented. Even for larger lakes, high (~1 km) resolution observations are required to account for the complex shapes of many glacial-origin water bodies. Lake temperatures have a material impact on regional scale weather in northern high latitudes (*Balsamo et al, 2011*) and require observations. Within GHRSST, projects such as "ARC-Lake" (www.geos.ed.ac.uk/arclake) aim to address the current observational deficit.

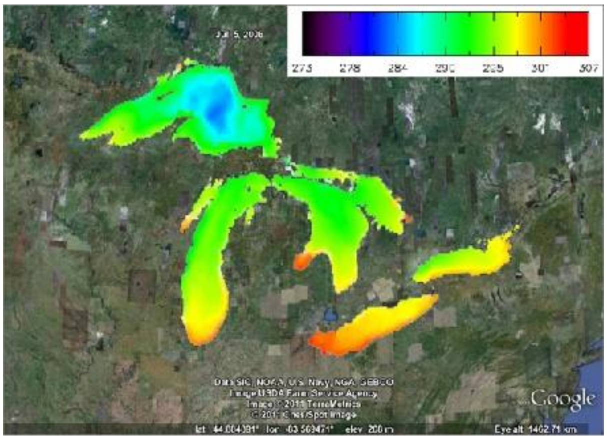


Figure 6: Great Lake Surface Water Temperature (colour-coded) from ATSR as developed in the ARC Lake project (S. McCallum et al., GHRSST XII, Edinburgh 2011).

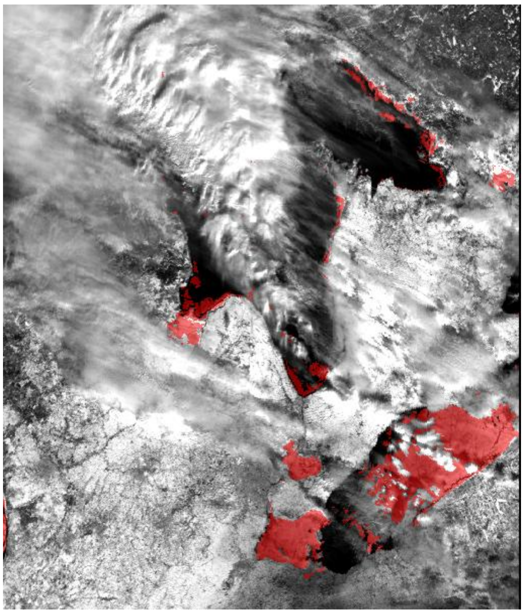


Figure 7: Lake Ice-Cover (ice marked red) from ATSR as developed in the ARC Lake project (S. McCallum et al., GHRSST XII, Edinburgh 2011).

The GHRSST IWWG coordinates international activities related to the treatment of Lake Surface Water Temperature and lake/land masks in GHRSST data products. The interaction of the atmosphere with the underlying surface is strongly dependent on the surface temperature and its time-rate-of-change. Most NWP systems assume that the water surface temperature can be kept constant over the forecast period. The assumption is dubious for small-to-medium size relatively shallow lakes, where the diurnal variations of the surface temperature reach several degrees. A large number of such lakes will become resolved features as the horizontal resolution of the NWP models is increased. Apart from forecasting the lake surface temperature, its initialization is also an issue. Lakes strongly modify the structure and the transport properties of the atmospheric surface layer above.

Inland waters temperatures are of interest for:

1. Met-offices: (e.g. Weather warning, information for fishermen) with a near-real time requirement, including ice. ECMWF states 10 km resolution.

2. Climate scientists require long series, high stability, the onset of melting and freezing

Following issues are expected and have been discussed to find ways to address:

Inland waters definition and respective land mask (the latter might vary over time) are of high priority. Further issues to be addressed include:

Retrieval issues - because of the varying height of different lakes, atmospheric effects, errors because of land contamination, small amount of in-situ data, collaboration with EARWiG is required.

Cloud mask - is optimized for application over ocean and may fail over inland waters.

In-situ validation – currently done case-by-case.

Uncertainty estimates for Inland waters temperature. IWWG needs to decide: For what size of lakes/ inland waters can we reasonably provide a temperature?

Ice information is also required.

3.7 Rescue & Reprocessing of Historical AVHRR Archives (R2HA2-WG) Working Group

Five Advanced Very High Resolution Radiometers (AVHRR) have been flying on NOAA polar-orbiting satellites (and more recently the European polar-orbiting satellite, Metop) since 1981. Because there was no encryption of the down-linked data, anyone with a receiving station could acquire these data. As a result a number of organizations have set up HRPT receiving stations over the years and collected a subset of the passes seen by the station. These data have been archived in a variety of formats and on a variety of media ranging from 9-track tape to DVDs. Many of these receiving stations are situated in coastal areas, acquiring passes covering shelf and slope waters that are of general interest to the oceanographic community. The Rescue & Reprocessing of Historical AVHRR Archives (R2HA2) Working Group has been founded to locate these distributed data, re-process with a community-consensus algorithm and store in a consistent format on modern media, to rescue them for research on long-term SST changes.

Necessary steps

To accomplish its objectives, the working group will:

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

Short term (1-2 years)

In the coming year, the group intends to accomplish three primary goals. The first is to establish the group formally by collecting a list of official members. The Chair will contact interested parties in order to accomplish this goal.

The second goal is to identify historical archives of AVHRR HRPT and LAC data, and to begin to copy those data to a central location. The group agreed that because a global 1km archive exists for the post-2000 period, its priority objective is to rescue and reprocess pre-2000 data. A list of known historical archives was generated at the GHRSSTX meeting, and working group members will add to this list as necessary. The Chair will contact parties identified for each historical archive, ask if they are willing to make their data part of this effort, and if so, work with those parties to copy their data to a central location. Though ultimately the working group intends to identify a Central Assembly Center (CAC) where the data will be collected and converted to a common format, identifying that CAC is not a priority initially.

The third goal for the next one to two years is to define a common output format, to which all the historical data will be converted. The group agreed that the scientific format for this should be netCDF4, and that it should be called L1P. Several questions arose related to the output format, including if and how to stitch the data together, how to handle navigation information, and how to handle calibration coefficients. The group discussed these issues in some detail, but ultimately selected a subgroup to resolve them and define the output format. This subgroup consists of Hervé Roquet, who will lead the subgroup, Jon Mittaz and Ed Armstrong, and intends to look at the GDS2.0 Technical Specifications document as a starting-place for defining the L1P products. It was suggested that this subgroup invite Bob Evans of UMiami and George Paltoglou of the Australian Bureau of Meteorology to participate in their activities. Both have extensive experience with regard to issues related to level 1 data but were not at the meeting or in this breakout session.

Longer-term considerations

After identifying, copying, and reformatting a significant collection of historical AVHRR HRPT and LAC data, the group intends to reprocess this collection using an existing/vetted algorithm and generate a consistent L2P product in GDS2.0 format, to be served via the GHRSST R/GTS. This will provide a way to check the validity of the original conversion to L1P, and will give users confidence in the group's efforts, as well as a point of comparison for other products.

Reprocessing within the GHRSST framework will also facilitate archive of both the L2P products and the lower-level L1P products at the NOAA National Oceanographic Data Center (NODC), as the GHRSST Long Term Stewardship and Reanalysis Facility, has a standing agreement to archive GHRSST products. The group also discussed the archival of the original recovered historical data (pre-conversion to L1P). Though this issue will most likely not be addressed in the next couple of years, the group acknowledged that at a minimum, the NOAA Archive would likely act as the deep archive for these data, and will pursue any required negotiation with NOAA (most likely through the NODC) to that end. In addition, to facilitate archival in the future, communication with potential data providers should explicitly state the group's intent to archive and distribute openly all data recovered. The volume of the recovered archives is estimated to be less than, but on the order of 100 TB. In line with archive considerations, the group discussed the need for thorough metadata, documentation and documented code throughout this process.

Finally, the group discussed potential synergies with existing reprocessing and data rescue efforts. One of these efforts is led by George Paltoglou of the Australian Bureau of Meteorology. The group will reach out to George in an effort to coordinate. The NOAA Climate Data Record Program is funding work to reprocess historical AVHRR GAC data, and could potentially provide a source of funding to the R2HA2 working group after the group has performed a proof of concept by producing L1P products from the historical archives. The group acknowledged that these L1P products would represent a success in and of themselves, and be useful to other climate applications such as cloud, ice and land product generation. Meanwhile, the group will enhance its visibility through existing connections such as the Data Archiving and Access Requirements Working Group in the U.S.

3.8 Reanalysis Technical Advisory Group (RAN-TAG)

The GHRSST Reanalysis Technical Advisory Group (RAN-TAG) coordinates the global production of Climate Data Records (CDR) for the Essential Climate Variable SST extending back to 1981. Through interactions with the GCOS SST and Sea Ice Working Group, ESA's Climate Change Initiative, the NOAA CDR Program, and members of the global climate SST community, the RAN-TAG has developed an over-arching SST Essential Climate Variable (ECV) Framework for SST. This framework reflects the fact that no single SST CDR product can meet all users' needs and illustrates the requirement for a coordinated suite of SST CDR products instead. The RAN-TAG works to ensure that all GHRSST operational and delayed mode data sets are archived and made available at the NODC LTSRF, and that the many groups developing CDRs around the world work together smoothly and efficiently, minimizing unnecessary duplication of effort and sharing scientific advances and product development experience.

Reanalysis Product Developments: Significant progress continues to be made in the development of single-sensor and merged reanalysis SST products. Demand for these more accurate, consistent, and longer-term products continues to grow, with users ranging from fisheries scientists to numerical modellers interested in longer data sets than the GHRSST forward-mode operational data streams can provide. Requests for data continue to escalate rapidly at the LTSRF, providing clear evidence that users need more and longer SST data sets to achieve a range of societal benefits. Progress continues in the new ESA Climate Change Initiative (CCI) project for SST to improve both the AVHRR and (A)ATSR sensor series data. The ATSR Reprocessing for Reanalysis for Climate (ARC) project concluded with the creation of a CDR v1.0 from the ATSR series of sensors (1991 to 2010).

A major step forward for the AVHRR Pathfinder SST effort was just made with the public release of the AVHRR Pathfinder Version 5.2 (PFV5.2) data set in June of 2011 (http://pathfinder.nodc.noaa.gov). This new version of Pathfinder is available in L3C format and is nearly 100% compliant with the GDS2 specifications (it is missing only the pixel-by-pixel time specification and the SSES bias/standard deviations). It is a significant stepping stone on the way to the future Pathfinder Version 6, which will include L2P, L3-uncollated (L3U), and L3-collated (L3C) products generated using a new and improved coefficient scheme. Work to reprocess HRPT data from the AVHRR series is also underway at the Australian Bureau of Meteorology and the University of Rhode Island, and the 12th GHRSST Science Team Meeting will include a breakout session for a new GHRSST Working Group focused on those data.

In 2011-2012, specifying a new Data Processing Framework (DPF) for the SST Climate Data Records will be a priority for the RAN-TAG, and efforts will continue to make GHRSST products more usable for the archive user community. As always, and above all else, international collaboration will continue to be the means by which the ambitious goals of GHRSST Reanalysis will be achieved.

3.9 Actions for Strategic Aim III

Action	Priority	Key groups	Related [OO9] recommendations (See Appendix 3)	Milestones
III-1 Improving uncertainty estimates	high	ST-VAL, RAN-TAG, EARWIG, IC-TAG, HL-TAG, IWWG	7	Is based on II-1,
III-2 Adaption of common principles for SSES	medium	ST-VAL	24	GHRSST meetings
III-3 Development of diurnal warming models and production if diurnal warming analyses	high	DVWG	19	GHRSST meetings
III-4 improved SST, ice and cloud products in High Latitudes	high	HL-TAG	37, 39	GHRSST meetings
III-5 Inland water surface temperature products (and ice coverage)	high	IWWG	40, 41,	GHRSST meetings

Action	Priority	Key groups	Related [OO9] recommendations (See Appendix 3)	Milestones
III-6 Rescue and reprocessing of historical AVHRR archives	high	R2HA2-WG		GHRSST meetings
III-7 Specifying a Data Processing Framework (DPF) for SST Climate Data Records in support of the development of the ECV SST	high	RAN-TAG	11, 14, 15,	2012
III-8 Development of error estimates for L3 and L4	high	IC-TAG	29e	GHRSST meetings
III-9 Algorithm development (instrument calibration, cloud detection, aerosol effects, side-lobe abd precipitation contamination MW) and error estimates	high	EARWiG, HL-TAG, RAN-TAG	16, 35, 36, 38	GHRSST meetings
III-10 Communicate scientific advancements to the users	high	AUS-TAG		GHRSST meetings

Table 8: Actions for Strategic Aim III – Incorporate frontier SST science

4 Strategic Aim IV: Develop and sustain user interaction

Within GHRSST, the Project Office and the AUS-TAG hold special responsibilities for user interaction. The data producing centres have their own and very important communication pathways with the users. GHRSST data providers are encouraged to provide a short description advertising their data. GHRSST as a whole plans to serve its users with documents for user guidance, data miners and data access tools, as well as free code for reading data into common programs (Fortran, C, IDL, Matlab)

User feedback is collected via the GPO and the GDAC, the latter is committed to maintain a catalogue of user questions and answers, and a forum for users.

User Requirements are compiled in collaboration with the users, resulting in an annually updated User Requirement Document by GPO.

4.1 Applications and User Services Technical Advisory Group (AUS-TAG)

The main goal of the AUS-TAG is to facilitate usage of GHRSST products across a broad user spectrum. In addition to answering the user questions directly on an individual basis, AUS-TAG also maintains the GHRSST User's Manual, including data access and descriptions. Another responsibility of the AUS-TAG is to maintain and develop methods for data discovery.

Users of GHRSST data continue to increase in number. With the emergence of the historically reanalyzed products, there has been a significant increase in using GHRSST data for scientific research. Near-real time capabilities continue to emerge, specifically in numerical weather forecasting and fisheries. Challenges still remain which must be addressed for maximizing the use of GHRSST data. In response to these challenges, new tools are implemented to allow for Level 2 and Level 3 subsetting capabilities at the GDAC. Additional tools such as the

THREDDS (Thematic Realtime Environmental Distributed Data Services) are being implemented to allow users to aggregate data sets with a large number of files. The State of the Ocean (SOTO) near real time visualization tool allows for overlaying different parameters that includes SST and other parameters such as sea surface height The GDAC maintains a GHRSST forum which allows users and science team members to interact efficiently on science and technical issues. The GDAC also plans to incorporate tables that will allow users to quickly decide on what data set best fits their usage.

Future plans include development more robust metrics that will incorporate level 2 subsetting and THREDDS. Additionally a dashboard is available which needs to be populated with the GDAC and RDAC status such that users can get near real time information on the status of data streams.

The plan is to optimize and add to the already existing facilities (User Guide, User Forum, Example Code, Data Mining portals).

4.2 GPO user interaction plans

The GHRSST Project Office interacts directly with users. It maintains connections with the SST power users, directs user questions to the respective experts and plans to ensure user involvement in the GHRSST annual meetings. The GPO plans to publish and to update user relevant documents and keeps the web-site interesting for users.

4.3 Science Team user interaction

GHRSST recognises that users need to be pointed to the research relevant to their application by experts. GHRSST plans to develop "environmental intelligence" which is more than simply supplying environmental data and forecasts. For certain applications, and for choosing the optimum data, users need to be made aware of how the SST data were generated, which feature resolution can be expected, what quality flags and auxiliary information need to be regarded for the correct interpretation. In future, it will become important to be able to explain to stakeholders the significance, uncertainty and science behind the data, particularly with regards to climate data and forecasts. Better education regarding the choice, interpretation and application of SST products is envisaged for the next decade.

4.4 Actions for Strategic Aim IV

Action	Priority	Key groups	Related [OO9] recommendations (see Appendix 3)	Milestones
IV-1 Develop and maintain user friendly tools for data access and analysis	high	AUS-TAG GDAC	13	GHRSST meetings
IV-2 Maintain user forum and FAQ catalogue	high	AUS-TAG, GDAC	29b	ongoing
IV-3 Create material for User guidance	high	AUS-TAG,RDACs, GPO	31	Review annually
IV-4 Collect User requirements	high	AUS-TAG, GPO		Review on demand

Table 9: Actions for Strategic Aim IV – Develop user interaction

5 Strategic Aim V: Strengthening international collaboration and promotion of GHRSST

5.1 GHRSST serving as CEOS VC SST

A proposal to serve as CEOS VC SST was developed in 2010 and 2011 and submitted to CEOS in November 2011.

The CEOS Virtual Constellation on SST (SST-VC) shall support the coordination consolidation and further development of satellite SST capability, products, user feedback and education/outreach activities using the recognized and well established GHRSST as the prime implementation mechanism. Initially SST-VC group members will be those representing CEOS Agencies, the GHRSST Science Team Chair and selected members of the GHRSST Science Team involved in relevant SST activities. The emphasis on this structure is to reduce duplication between the successful and functioning work of GHRSST (as an implementer of the SST-VC) and the SST-VC representing the co-ordination activities of the Agencies. The following members confirm that their Agency will participate in the SST-VC:

SST-VC Co-leads:

1) Kenneth S. Casey, National Oceanic and Atmospheric Administration (NOAA), USA
2) Craig Donlon, European Space Agency (ESA), Netherlands

SST-VC members

1) Hans Bonekamp, European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), Germany
2) Andrew Bingham, Jet Propulsion Laboratory, National Aeronautics and Space Administration (NASA), USA
3) Misako Kachi, Japan Aerospace Exploration Agency (JAXA), Japan
4) Peter Minnett (GHRSST ST Chair), University of Miami, USA.

This collective group would form the leadership of the SST-VC."

The proposal as presented to CEOS SIT 2011 can be found in Appendix 1.

5.2 Engagement with the in-situ community

This section outlines how GHRSST plans to engage with the in-situ community to strengthen international collaboration, in the near future and up to the next 10 years.

To maintain the high quality of the satellite SST products provided by GHRSST it is essential that the group has access to in situ ocean surface data provided by a range of accurate instruments located on diverse platforms, over a wide range of climate conditions. In order to attain this goal GHRSST will continue and enhance its engagement with the following groups:

1 JCOMM Observations Programme Area Coordination Group (OCG) (see https://www.ghrsst.org/files/download.php?m=documents&f=110524144221-GHRSSTSubmissionJCOMMOCG4revised.doc)

2 JCOMM Ship Observations Team (SOT) (see Ian Barton's presentation: https://www.ghrsst.org/documents/q/category/ghrsst-science-team-

meetings/ghrsst-xii-edinburgh/ghrsstxii-presentations/breakout-sessions-2011/stval-breakout/)

3 JCOMM Data Buoy Coordination Panel (DBCP) (see https://www.ghrsst.org/ghrsst-science/science-team-groups/stval-wg/dbcp-ghrsst-pilot-project/)

4 OceanSITES Science Steering Team

5 Argo Science Team (see http://www.ghrsst.org/documents.htm?parent=852)

Concerning point 2, the following specific recommendations from GHRSST in relation to in-situ observations were included in the GHRSST Recommendations to JCOMM OCG document (https://www.ghrsst.org/files/download.php?m=documents&f=110524144221-GHRSSTSubmissionJCOMMOCG4revised.doc) and presented to both the Sixth Meeting of the IOC/UNESCO JCOMM Ship Observations Team SOT-VI - dealing with ship observations only (11-15 April 2011) and the Fourth Session of the JCOMM Observations Coordination Group - OCG-IV dealing with all ocean observation platforms (18-20 April 2011):

a. Adding the provision of radiometric skin SST data to the JCOMM OCG portfolio of VOS measurements. Ships that participate in such a measurement programme should also maintain a radiosonde capability.
b. Ensure that ships and other platforms currently providing high quality in situ data where possible expand their provision of meteorological meta-data. Wind speed, history of wind speed, air temperature and local humidity are the most important. Measurements of near-surface temperature profiles should also be encouraged.
c. Enhance the capability of Argo floats, drifting buoys and moorings to measure temperature profiles in the top 2 meters of the ocean.
d. Where possible a regular accurate calibration of in situ data instrumentation is carried out, preferably against a standard that is traceable to an SI measurement.
e. Establishing a JCOMM SOT working group to collaborate with GHRSST to better define requirements for measurements of SST from ships, and to identify new opportunities that may assist with a more uniform coverage of the global oceans.
f. Planning to obtain ship of opportunity participation in future SST measurement inter-comparison experiments.
g. Encourage JCOMM data providers to use the GHRSST data set to assess the accuracy and performance of their SST measurement instruments.

Concerning point 3, a pilot project in collaboration with DBCP has started to improve pre-and post-deployment sensor calibration, improved sensor installation and additional meta-data. The progress of this pilot project is monitored by ST-VAL, see: https://www.ghrsst.org/ghrsst-science/science-team-groups/stval-wg/dbcp-ghrsst-pilot-project/

Concerning point 5, GHRSST recommended to Argo a specification of vertical resolution of 10 cm from 0 to 3 m and 50 cm resolution from 4m to 10 m. In addition to the diurnal warming studies the Argo near surface profiles allow, GHRSST recognises the special value of Argo as an independent in-situ reference system.

Short term plans:

During 2011/2012 a working group will be set up comprising members of the JCOMM SOT and GHRSST to better define requirements for measurements of SST from marine platforms and to identify new opportunities that may assist with more uniform in situ SST coverage of the global oceans."

ST-VAL plans assessing the new improved drifters and will feedback to GHRSST and to DBCP.

Argo near surface temperature (NST) profiles are planned to be assessed by DVWG and ST-VAL.

5.3 GHRSST Promotion and Capacity building through the GPO

Promotion objectives are to: 1) present information to users, potential users, scientists, space agencies, national and international funding bodies, and to the general public, 2) to increase demand for GHRSST data and to 3) differentiate the GHRSST products with respect to usage from each other, and from non-GHRSST products.

Media of GHRSST promotion include: the web-site with GHRSST News service, emails, brochures, conference attendance and collaboration in shared projects.

Promoting GHRSST to users: Promoting GHRSST will be pursued by attending conferences, and encouraging all GHRSST members to do similarly. First priority are conferences where power users are (related to Operational Ocean Forecasting, Numerical Weather prediction, Climate Science, Oceanography, Remote Sensing Community, Space agencies).

The network of people with access to GHRSST news will be planned to increase. This way, reminders on GHRSST are paired with useful information. More GHRSST news are aimed to advertise new products, or advances in GHRSST related science.

Promoting GHRSST to scientists: International collaboration and in fact many personal overlaps with ERNESST and NASA SST Science Team will ensure highest level of research is maintained and fostered.

The best advertisement for GHRSST is the highly valued data GHRSST provides to the users. This should be eased as much as possible by convenient data access, and a broad presence of references to GHRSST.

Promoting GHRSST to data producers: A strong relationship with GHRSST users and scientists will make GHRSST attractive to the data producers. Sometimes, new data producers are approached when new satellite instruments have been successfully launched, as the new producers would greatly benefit from the GHRSST potential.

Existing data producers will be approached when necessary for discussion about potential national limitations on distributing data.

Contact with data producers will be via CEOS-VC (when CEOS-SST-VC is in place), GOOS, Space agencies and National Research bodies and Met Services.

Promoting GHRSST to national and international programs, space agencies and funding bodies: By establishing contact and informing about the progress of GHRSST in terms of data production, standardization, GHRSST data usage, GHRSST user support, science and achievements in defining community best practises.

Promoting GHRSST to the public (interested laymen): Through webpages and brochures

Capacity building in GHRSST: Generally, capacity building refers to the concept as actions that enhance an organizations ability to work towards its mission, which is for GHRSST: "*To develop and nurture cooperation and progress at the world scale in the subject area of satellite Sea Surface Temperature",* as has been agreed by the GHRSST Science Team at the 9th International GHRSST Science Team meeting, Perros Guirrec, June, 2008.

Capacity development in GHRSST: Special emphasis will be given in GHRSST to develop the Community Capacity which brings benefits in terms of:

- the increase in skills and competencies on the part of members of such communities;

- gain from synergies, research crossfertilization, knowledge transfer and collaboration
- the more effective, efficient and sustainable delivery of services
- increase in sustainability of the GHRSST service, and quality assurance of GHRSST data

Capacity building (users, scientists, producers): Capacity building will be started by expanding national contacts to span the majority of the global groups. Currently, the US, the UK, and France are well incorporated within GHRSST. Special effort goes to foster relations with Japan and South American groups, follow up the link to Korean groups and to build up links with China and India. Currently missing links to, for example, Canada, Germany and former Eastern Europe and Russia, South Africa, Kenya need investigation. The user statistics of the GHRSST web site according to country will give clues where to direct activities. Good sources of contact points for new patrons representing missing countries are with GODAE-OceanView, JCOMM, WMO, and the national space agencies.

Plans for capacity building development in new nations: Capacity building includes the development of collaboration with, and transfer of knowledge to, nations not yet involved. In special focus are nations with a strong interest in SST, and with thriving activities in the space observation segment. Contact will be established and common interest and potential for collaboration explored. These groups will be invited to join the GHRSST activities (collaboration with GHRSST Technical Advisory Groups, Working Groups, and offer to review of documents, participation in Science Team Meetings and user symposia).

Plans to include other regions: The GHRSST is in the process of developing links to Brazil, Canada, China, India, Peru, and South Korea, and any national teams are warmly invited to join or collaborate.

5.4 Actions for Strategic Aim V

Action	Priority	Key groups	Related [OO9] recommendations (See Appendix 3)	Milestones	Risks
V.1 CEOS-VC SST implementation plan	medium	SST-VC		Dec 2011	
V.2 Communication of SST user needs to CEOS members	High	SST-VC	1,2,3,4,5,10,12,17,18, 44		
V.3 Maintain links to GHRSST related international groups	medium	SST-VC, ST chair, GPO	30, 44		
V.4 Influencing bodies responsible for in-situ measurements such as to consider GHRSST needs	High	ST, GPO, SST-VC	23, 29a,		
V.5 Communicating quality of upgraded drifters to DBCP	High	ST-VAL		Melbourne workshop 2012, GHRSST meetings	

Action	Priority	Key groups	Related [OO9] recommendations (See Appendix 3)	Milestones	Risks
V.6 Communicating the use of Argo near-surface profiles for diurnal model validation, and independent reference source	Medium	DVWG and STVAL		Melbourne workshop 2012, GHRSST meetings	

Table 10: Actions for Strategic Aim V – Strengthen international collaboration and promotion of GHRSST

6 Strategic Aim VI: Recommendations for the future

The OceanObs White paper [OO9] provides a core contribution to address the OceanObs09 theme "Developing technology and infrastructure" under Session 4B "Satellite data integration and products". It has been prepared for those implementing and working with the modern sea surface temperature (SST) observing system. The purpose of [OO9] is threefold: (1) to highlight key developments of the modern era SST observing system over the last 10 years (2) to discuss the principal challenges for the observing system in the next 10 years and (3) to propose an ideal plan for the global integrated high resolution SST observing system. In the tracability matrix below the recommendations of the OceanObs White paper [OO9] paper (see Appendix 3) are related to the Strategic Aims of GHRSST.

Recommendations from [OO9], see also Appendix 3	Key groups	Implementation with Strategic Aim
1.	SST-VC	V
2.	SST-VC	V
3.	SST-VC	V
4.	SST-VC	V
5.	SST-VC	V
6.	STVAL	II
7.	ST-VAL, IC-TAG, RAN-TAG	III
8.	STVAL	II
9.	STVAL	II
10.	RAN-TAG, SST-VAL	V
11.	RAN-TAG	III
12.	HL-TAG, RAN-TAG	III
13.	AUS-TAG, GDAC	IV
14.	RAN-TAG	III
15.	RAN-TAG	III
16.	RAN-TAG, EARWiG	III
17.	SST-VC	V
18.	SST-VC	V

Recommendations from [OO9], see also Appendix 3	Key groups	Implementation with Strategic Aim
19.	DVWG	III
20.	DVWG	II
21.	ST-VAL, RAN-TAG, DVWG	II
22.	ST-VAL	II
23.	SST-VC	V
24.	ST-VAL	II, III
25.	RAN-TAG, ST-VAL, ST	II
26.	ST-VAL	II
27.	ST-VAL	II
28.	RAN-TAG, ST-VAL	I
29.a	AUS-TAG	V
29.b	AUS-TAG	IV
29.c	ST-VAL	I
29.d	ST-VAL, RAN-TAG	I
29.e	IC-TAG	III
30.	SST-VC	V
31.	AUS-TAG, RDACs	IV
32.	IC-TAG	I
33.	ST-VAL, RAN-TAG	I
34.	IC-TAG	III
35.	EARWiG, HL-TAG	III
36.	EARWiG, HL-TAG	III
37.	HL-TAG	III
38.	EARWiG	III
39.	HL-TAG	III
40.	LWST	III
41.	LWST	III
42.	DAS-TAG	I
43.	DAS-TAG	I
44.	SST-VC	V
45.	DAS-TAG	I
46.	DAS-TAG	I
47.	DAS-TAG	I

Table 11: Tracability matrix relating the GHRSST Actions to the 47 [OO9] recommendations

APPENDIX 1: The CEOS Constellation for Sea Surface Temperature (SST-VC)

Full Proposal: September 2011

Craig Donlon (ESA) and Kenneth S Casey (NOAA)

Executive Summary

The key space and *in situ* measurement capabilities providing Sea Surface Temperature (SST) measurements are extensive and are used by a large number of Agencies. So far, several CEOS Agencies have invested a considerable amount of resources in activities related to SST, sometimes without full optimization. An ***actual*** SST in-flight Constellation does exist but could be optimised further through:

- **Better use of reference sensors (e.g., ENVISAT AATSR and the Sentinel-3 SLSTR) within the Constellation,**
- **Assured long-term continuity of passive microwave SST data,**
- **Response to climate users and climate services requirements,**
- **Better and more homogeneous SST products and services to users,**
- **Better international consensus product and service specification within controlled and approved documentation,**
- **Better specification of uncertainty estimates within SST products,**
- **Improved collaboration within the Constellation,**
- **Improved coordination, consolidation and development of the collective SST capability,**
- **Improved SST products, homogenization of products, services and product dissemination with better user engagement.**

Since 2000, significant development has taken place through the activities of the Group for High Resolution SST (GHRSST) in these areas. The mature GHRSST structures have developed and evolved as the CEOS Virtual Constellation (VC) concepts have developed themselves serving over 72,000 users that have accessed SST products in near real time and delayed mode, accessing over 100 million files amounting to over 232 Tb of information. GHRSST has an origination structure that has both fixed and flexible components allowing it to respond effectively and efficiently to new and emerging challenges. GHRSST, through its extensive international coordination activities, has often been cited as a model for other VCs. In fact the GHRSST Science Team, its International Project Office and associated Project Office Management Advisory structure has developed with the proposed CEOS SST-VC clearly in mind. In this context, the current implementation of GHRSST already provides an SST-VC function but is not formally connected to CEOS. The SST-VC, with GHRSST as the implementation mechanism, will deliver real coordination in space-based Earth observations for societal benefit through the prioritized CEOS SST-VC activities.

This document is the full proposal for a CEOS Sea Surface Temperature Virtual Constellation (SST-VC), designed to further optimize SST observation and data production. It is proposed to implement a CEOS SST-VC using the existing Group for High Resolution Sea Surface Temperature (GHRSST, see http://www.ghrsst.org) as the implementation mechanism. The proposed SST-VC will:

Strengthen CEOS Agency SST activities and improve coordination, consolidation and development of the collective SST capability through better synergy and communication in a global framework to encourage wider participation of all Agencies,

Improve SST products, services, interoperability, data access and data dissemination building on the strengths of CEOS Agencies with better user engagement,

Avoid unnecessary duplication of existing coordination activities and provide CEOS Agencies with **value for money** by capitalising on the already committed investments made to GHRSST and allow a **rapid spin up of SST-VC** activities.

This proposal is fully compliant with the CEOS paper on establishing new Virtual Constellations and has been fully endorsed by the GHRSST Science Team.

Mission Statement and Anticipated Outcomes

In support of the Group on Earth Observations (GEO) objectives and as a space component of the Global Earth Observation System of Systems (GEOSS), the Committee on Earth Observation Satellites (CEOS, see http://www.ceos.org/) has developed the concept of virtual, space-based "CEOS Constellations for GEO". CEOS Virtual Constellations (VCs) exist for Ocean Surface Vector Wind, Ocean Colour Radiometry, Ocean Surface Topography, Atmospheric Composition, Land Surface Imaging, and Precipitation.

CEOS Agencies recognize Virtual Constellations as a means to better address space-based Earth observation needs on a global basis – without eroding the independence of individual agencies. In particular to *take account of international users and their requirements from the outset of satellite projects* in planning processes. The Virtual Constellations are a highly effective 'brand' and vehicle for CEOS and its Members. The concept is widely known and discussed as an illustration of the more focused and effective nature of CEOS activities in the GEO-era. CEOS recognizes that national/regional observing requirements will continue to dominate space agency spending and that any grand design for implementation of global observing systems will always be dependent on individual agency funding priorities. The Constellations are seen within the community as having significant promise as a vehicle for focused discussions on harmonization of programmes and plans of participating agencies in support of a common goal – be that continuity of observations for a particular operational community or in support of a particular Essential Climate Variable (ECV) over many years and decades. To realize its full potential, the Constellations concept must embrace inclusion of the physical results of coordination – the 'sharp end', such as the ECVs and data products themselves. These are the currency and language of the policy-makers, of governments and the treaties and protocols they use to define common information needs.

So far, several CEOS Agencies have invested a considerable amount of resources in activities related to sea surface temperature (SST), sometimes without full optimization. This document is a full proposal for a CEOS Virtual Constellation for Sea Surface Temperature (SST-VC). The aim of the SST-VC is:

> ***To ensure the best quality sea surface temperature data for applications in short, medium, and decadal time scales in the most cost effective and efficient manner through international collaboration and scientific innovation.***

The SST-VC defines a set of prioritized strategic objectives to address this aim:

- Better use of reference sensors (e.g., ENVISAT AATSR and the Sentinel-3 SLSTR) within the Constellation,
- Assured long-term continuity of passive microwave SST data,
- Response to climate users and climate services requirements,
- Better and more homogeneous SST products and services to users,
- Better international consensus product and service specification within controlled and approved documentation,
- Better specification of uncertainty estimates within SST products,
- Improved collaboration within the Constellation,
- Improved coordination, consolidation and development of the collective SST capability,

Improved SST products, homogenization of products, services and product dissemination with better user engagement.

The key space segment capabilities applicable to a SST-VC are shown in 0 (page 18). Assuming that most or all of the sensors listed are successfully launched the potential impediments to success are:

1) Lack of timely access to and sharing of data, including Level-1 and higher product satellite data;

2) Lack of developing and sharing *in situ* data bases, and derived products of sufficient quality to use for calibrating and validating satellite data products;

3) Difficulty of sustaining projects for coordination of data products and user feedback across satellite sensors to support global and regional scientific data products;

4) Limited outreach, education and development of new SST practitioners.

5) Incomplete engagement by Nations operating or preparing satellite SST sensors,

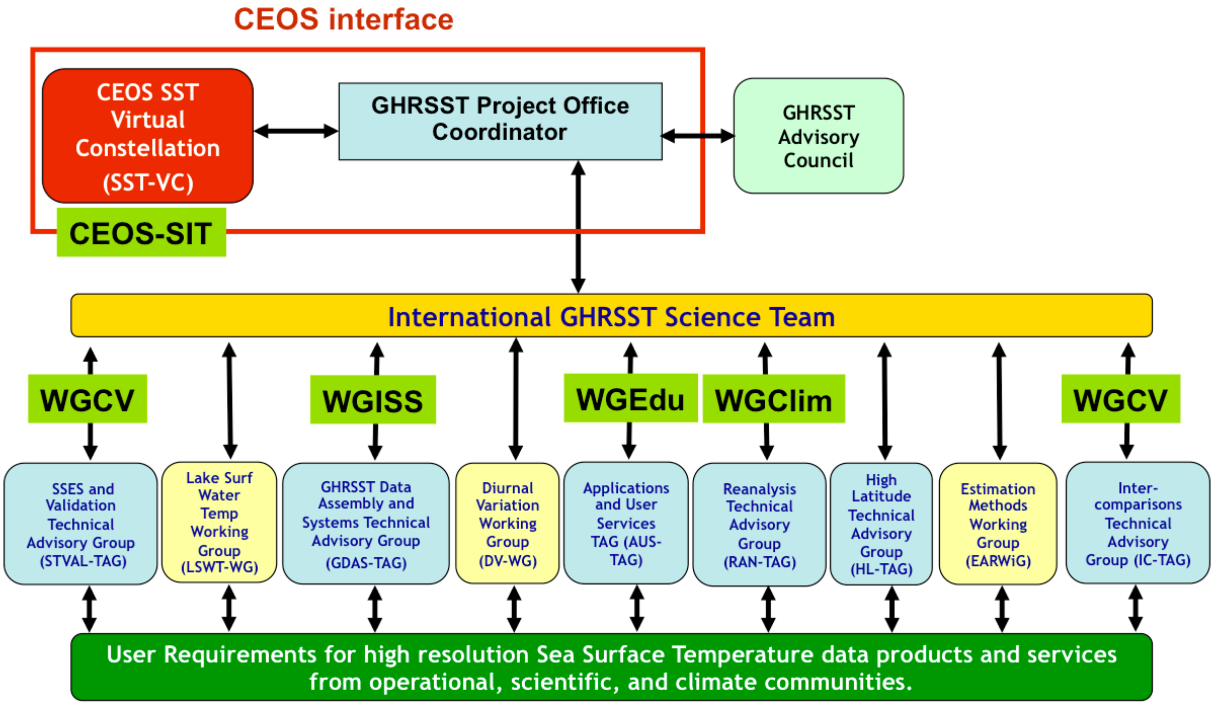
CEOS can help avoid these impediments by encouraging member Agencies to promote timely access to and sharing of data, through better cooperation (5) to establish appropriate linkages required to overcome impediments (2) and (3) and to support focused activities to address (4) as listed above.

In the last decade, satellite Agencies, science, operational user/producer and SST practitioner communities have come together within the Group for High Resolution SST (GHRSST) to create a new framework for generation, delivery and application of improved common format high-resolution (~1-10 km) satellite SST datasets for the benefit of society. The GHRSST data system is a mature, robust, and highly reliable near real time and delayed mode data system known as the GHRSST Regional/Global Task Sharing framework (R/GTS) and has operated in NRT since 2006. It consists of distributed Regional Data Assembly Centers (RDACs) around the world that submit their data to a Global Data Assembly Center (GDAC) maintained at the NASA Jet Propulsion Laboratory Physical Oceanography Distributed Active Archive Center (JPL PO.DAAC), where all the data are available for 30 days. After that they are transferred to the GHRSST Long Term Stewardship and Reanalysis Facility (LTSRF) at the U.S. National Oceanographic Data Center (NODC) for long-term preservation and distribution. The extensive user base includes many operational meteorological services, the scientific community, industry and Government. Since the R/GTS has operated, statistics show over 72,000 users have accessed the R/GTS in NRT, accessing over 100 million files amounting to more than 232 Tb of information.

The GHRSST structures (A1-Figure 1) have developed and evolved as the CEOS VC concepts have developed themselves. GHRSST has an organisation structure that has both fixed and flexible components allowing it to respond effectively and efficiently to new and emerging challenges. GHRSST has often been cited as a model for other VC and the current implementation of GHRSST already provides an SST-VC function. Clearly marked on (A1-Figure 1) are the mapping between CEOS Working Groups (WG) and the Strategic Implementation Team (SIT) (green boxes) where interactions between GHRSST and CEOS are strongest. Co-ordination between the SST-VC and the GHRSST-Science Team will largely take place through a relationship with the GHRSST International Project Office (which formally works on behalf of the GHRSST Science Team (the formal entity of GHRSST itself) and the Project Office Advisory Council (providing stakeholder advice to the Project Office)) and the various working groups of GHRSST itself. The long-standing GHRSST Technical Advisory Groups (TAG) and ad hoc Working Groups (WG) are typically at the "cutting edge" of international SST

activities delivering real coordination in space-based Earth observations for societal benefit through the prioritized CEOS SST-VC/GHRSST activities.

The purpose of the CEOS SST-VC proposal presented here is not to duplicate or to replace the activities of GHRSST but rather, to ensure effective communication and coordination between CEOS Agencies on practical issues related to SST using GHRSST as the 'implementation' of the CEOS SST-VC. In this way the investments committed by CEOS Members will be optimised for the benefit of Society through better numerical weather and ocean forecasting, production and management of climate data records in support of climate services and, scientific applications in oceanography, climate and meteorology.



A1-Figure 1: Currently active GHRSST structures and proposed interface to the SST-VC. Standing Technical Advisory Groups (TAG) and task oriented Working Groups (WG) are highlighted. The mapping of GHRSST structures to CEOS structures are shown as green boxes: this is where CEOS SST-VC<>GHRSST interactions are expected to take place. Co-ordination between the SST-VC and the GHRSST-Science Team will largely take place through a formal relationship with the GHRSST International Project Office.

GHRSST functions internationally based on national and Agency support that today amounts to in excess of $25M over a period of nearly 10 years. GHRSST processes and services, implemented via many CEOS Agencies and National infrastructures, support on a daily basis, in near real time, the continued development and management of critical SST datasets and have attained a significant level of operational maturity. The extensive user base that depends on GHRSST includes operational agencies and scientific institutions, climate groups and media services. The level of maturity attained now calls for a formal relationship with CEOS, which coordinates the activities of Agencies for the sustained cost-effective collection of the satellite measurements on which GHRSST bases its work. It is proposed that this formalism be expressed as a CEOS SST Virtual Constellation (SST-VC).

The expected outcomes of our proposed approach include:

- Continued support to an extensive user community with established and functional systems and services,
- Stronger CEOS Agency SST activities through better synergy and communication;

- Wider participation of CEOS Agencies in SST related activities;
- Better SST product and service interoperability building on the strengths of CEOS Agencies;
- Better data access and product applications by CEOS Agencies;
- Value for money to CEOS Agencies by capitalising on the already committed investments made to GHRSST;
- Reduced duplication of coordinating activities; and
- A stable and secure rapid spin up of SST-VC activities.

This proposal is fully compliant with the CEOS paper on establishing new Virtual Constellations and has been fully endorsed by the GHRSST Science Team at the 12th GHRSST Science team Meeting, Edinburgh, 27th June – 1st July 2011.

Proposed activities for the SST-VC

The proposed SST-VC shall support the coordination consolidation and further development of satellite SST capability, products, user feedback and education/outreach activities using the recognized and well established GHRSST as the prime implementation mechanism. Eleven key actions and activities are proposed for the SST Virtual Constellation (SST-VC) in the table below.

ID	Action	Activity	Measure	Status
1	Minimise duplication of existing activities. Act as a conduit for feedback between CEOS and the international SST science and operational community at all levels by formal reporting of SST-VC activities to CEOS SIT.	Maintain a close dialogue between GHRSST and CEOS agencies by reporting GHRSST, GEO and CEOS activities regularly to CEOS-SIT. Develop a CEOS SST-VC Portal (in line with other CEOS VC). Participation on Annual GHRSST Science Team meetings.	Reports prepared and presented to SIT. Regular update of Portal content SST-VC membership participation on GHRSST ST annual meetings.	Initiated through SST-VC proposal.
2	Development and optimization of the SST constellation Advocate and promote the development and optimization (reduced redundancy and improved continuity and overlap among missions) of a virtual constellation of satellites (defined in A 1-Table 1A 1-Table 2) that satisfy key ongoing GEOSS and GCOS requirements for SST	Develop a paper describing an optimised constellation for SST building on the feedback from the GHRSST Regional/Global task Sharing (R/GTS), Users and Agencies. Contribute to the CEOS response to the 2010 GCOS Implementation Plan.	Paper prepared and presented to CEOS. Peer reviewed journal paper prepared and submitted to Journal	Initiated by SST/GHRSST Ocean Obs 09 White Paper.

ID	Action	Activity	Measure	Status
	measurements based on international consensus[1] that shall build on the strengths of each CEOS Agency to sustain an effective constellation			
3	Develop and implement metrics for SST services, products and users. Develop and implement processes, based on an agreed set of metrics, that ensure the SST Constellation will satisfy the relevant community needs making full use of existing statements of requirements	Continue to develop and maintain an International GHRSST User Requirements document for an SST constellation.	GHRSST URD updated annually by GHRSST Project Office	URD in place
4	Coordinate consensus SST reference documents. Coordinate the GHRSST Data Specification (e.g. GDS[2]) document for the benefit of CEOS Agencies and GEOSS tasked with implementing GHRSST recommendations (e.g., formalism, feedback and reviews)	Maintain the GDS documentation for the benefit of CEOS agencies	GDS Documentation reviewed and under revision control.	GDS reviewed internationally and v2.0 in place and under version control.
5	Encourage timely access to products. Foster and encourage timely access to CEOS agency satellite SST data products in GHRSST GDS-2.0 format	Continue to liaise with data providers within the GHRSST R/GTS especially agencies that are not well connected	Develop new collaborations with CEOS agencies under the GHRSST R/GTS	On-going
6	Develop and improve satellite SST Essential	Continue to coordinate the international efforts for re-	Develop active collaborations	On-going

1 Donlon, C. J., K. S Casey, C. Gentemann, P. LeBorgne, I. S. Robinson, R. W Reynolds, C. Merchant, D. Llewellyn-Jones, P. J. Minnett, J. F. Piolle, P. Cornillon, N. Rayner, T. Brandon, J. Vazquez, E. Armstrong, H. Beggs, I. Barton, G. Wick, S. Castro, J. Hoeyer, D. May, O. Arino, D. J. Poulter, R. Evans, C. T. Mutlow, A. W. Bingham and A. Harris, Successes and Challenges for the Modern Sea Surface Temperature Observing System, in Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 1), Venice, Italy, 21-25 September 2009, Hall, J., Harrison, D.E. & Stammer, D., Eds., ESA Publication WPP-306. White paper available from http://www.ghrsst.org/modules/documents/documents/OO-ModernEraSST-v3.0.pdf and http://www.oceanobs09.net/blog/?p=227

2 The GDS is the Detailed Processing Model used by the GHRSST data producers and has now matured to a v2.0 based on 6 years of sustained activity. Details are available at http://www.ghrsst.org/documents.htm?parent=50

ID	Action	Activity	Measure	Status
	Climate Variable. Foster the development, improvement, production and wide application of CEOS agency satellite SST Essential Climate Variable (ECV) satellite data products for climate applications and services.	analysis of SST products (e.g. NOAA, NASA, JAXA, EUMETSAT and ESA CCI, activities, GCOS SST/SI Working group, GOOS, OOPC) to minimise duplication and maximise international partnerships. Coordinate CEOS implementation actions through GCOS Action O7 [IP-04 O9]: “provision of best possible SST fields”.	between Agency activities for the SST ECV.	
7	Improve SST calibration, inter-calibration and validation. In partnership with data providers and the international science community, improve calibration, inter-calibration and validation of each satellite system contributing to the VC, including the definition and implementation of appropriate near-real-time uncertainty estimates for CEOS agency satellite SST data products working within the framework of CEOS QA4EO	Develop QA4EO processes and implement these within the GHRSST R/GTS.	Install QA4EO processes into GHRSST R/GTS and products	In progress
8	Improve user feedback to CEOS Agencies. In partnership with data providers, coordinate SST user feedback for the benefit of CEOS Agencies	Actively seek user feedback at GHRSST user consultations/symposia on an annual basis	Conduct an annual user assessment for SST products at the GHRSST Science Team Meeting	On-going
9	Develop training activities for satellite SST practitioners. Develop and implement specific development and training activities to foster a next generation of satellite SST practitioners	Develop training materials and support international workshops (e.g., ESA Summer schools, GHRSST training workshop) using existing tools and products to promote a new generation	Number of training events and resources supported and/or made available through SST-VC activities	New activity building on existing capabilities.

ID	Action	Activity	Measure	Status
		of SST practitioners		
10	Liaise with the other Virtual Constellations Liaise with the other Virtual Constellations (e.g., Ocean Vector Winds, Ocean Surface Topography, Ocean Colour Radiometry) to enable cross-fertilization among the communities and to create synergy	Attend other VC meetings to better coordinate activities and synergies	Useful collaboration established across VC	New Activity
11	Prepare an Implementation Plan, to be approved by CEOS.	Prepare plan, review plan with GHRSST community and submit to CEOS	Submit plan to CEOS	New Activity

A 1-Table 1: Proposed activities for the SST-VC.

Climate Requirements Addressed

Sea-surface temperature (SST), together with air temperature over land, is a fundamental indicator of the climate system on a variety of time scales. Long-term historical climate data sets of "SST" have been traditionally based upon a blend of *in situ* SST data at varied depths and in the latter years, satellite SST measurements. To meet GCOS SST requirements, integrated analysis products are needed that take advantage of the synergy between SST derived from EO infra-red and passive microwave instruments and SST derived from sparse sample *in situ* measurements at different vertical depths. The diurnal cycle in SST can be >5 K magnitude in certain regional-local low-wind conditions and can be aliased into lower frequencies if not sampled properly: accounting for regional diurnal SST variability within EO data is a significant challenge to be addressed when blending SST data.

GCOS SST-ECV Target Requirements 2011[3]

Climate products must make best use of our understanding of the limitations of each data stream provide uncertainty estimates from region to region depending on the final application requirements of the derived products. The GCOS[3] requirements for the SST Essential Climate Variable are as follows:

A climate quality blended analysis SST product that provides a measure of the SST at depth that makes use of in situ, satellite infra red and satellite passive microwave SST measurements

The GHRSST Science Team and the SST-VC leads have been extensively involved in the development of the GCOS 2011 Update to "Systematic Observation Requirements For Satellite-Based Products For Climate , Supplemental details to the satellite-based component of the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)".

[3] Update to GCOS-107 (WMO/TD No.1338) August 2011 (in final edit following public review) "Systematic Observation Requirements For Satellite-Based Products For Climate , Supplemental details to the satellite-based component of the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (GCOS-92)" http://www.wmo.int/pages/prog/gcos/index.php

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
SST	10km	N/A	Daily	0.1 K over 100 km scales	Less than 0.03 K over 100 km scales

The international consensus target requirements derived by the GHRSST Reanalysis Technical Advisory Group (RAN-TAG) for long-term satellite SST records have been set as: 0.01K/decade stability, <0.3 K absolute accuracy, 0.1 K relative.

Rationale: Global-average surface warming trends (combined land-surface air temperatures and SST) are estimated to be ~0.165 K decade^{-1} when computed from data between 1979-2005 but with significant hemispheric differences: N. Hemisphere ~0.235 K/decade, S. Hemisphere ~0.09 K/decade (IPCC AR4, Ch3). Trends computed for the period 1901-2005 yield estimates <0.1 K/decade, with little difference between hemispheres. Assuming a global surface temperature change signal of 0.1 K/decade, a global average temperature time series should be stable to much better than 0.1 K/decade in order to distinguish the signal from the instability of the time series. To detect such slow and small but significant changes it is prudent to aim for a stability of at least 0.03K/decade and, if funds and technology allow it, ideally 0.01 K/decade. It is understood that this level of stability is not achievable by current measurement systems, but it remains the target. SST stability should be sought at local spatial scales of ~100-1000 km in addition to global averages. The requirements have been set to resolve decadal changes on global and regional scales.

Currently achievable performance (indicative values)

- IR-derived SST: 0.16 K at 25 km (ENVISAT AATSR)
- Passive microwave-derived SST: 0.42 K at 25 km gridded (EOS AQUA AMSRE)
- *In situ* buoys: 0.23 K
- SST blended analyses: ~0.2-0.5 K with regional variation

Requirements for satellite instruments and satellite datasets

- FCDRs of appropriate IR (polar orbiting and geostationary) and 'near all weather' PM satellite measurements capable of supporting climate accuracy are required in a sustained manner adhering to GCOS satellite Climate Monitoring Principles (GCOS IP-10: Action C6 and C8).
- The long-term future of PM SST observations remains uncertain at present and must be properly addressed.
- Stable well-calibrated high-accuracy and high-temporal stability SST measurements from at least one AATSR-class instrument are required. These measurements can be used to monitor variability and tie together wider SST coverage measurements from complementary IR and PM instruments.

Supplemented by:

- Sea-ice edge and concentration observations are required in high latitude regions by SST analysis systems.
- Additional information is required to account for atmospheric aerosol contamination of IR satellite data sets.
- Surface wind measurements are required near contemporaneously with SST measurements for diurnal variability estimation.
- Surface wind vector observations are required for the retrieval of PM SST.
- For all products high-quality *in situ* SST observations are required on a continuous basis.

Calibration, validation, and data archiving needs

- There is a need to improve instrument calibration of IR and PM sensors.
- Work to improve accuracy and the use of a variety of *in situ* observations for instrument calibration and more general SST validation, for cloud, aerosol, side lobe contamination, and other impact characterization is required. Comparison of products from independent measurements and analyses remains a priority.
- Routine reporting of the depth of observation from all *in situ* SST data is essential to improve the quality of satellite SST holdings. The ability to exploit historical and contemporary datasets is affected by the limited amount of metadata typically available.
- *In situ* [ship mounted] radiometers that are accurately calibrated before and after each deployment to traceable national standards must be maintained as a truly independent reference data set for inter-calibration of follow-on satellite missions. This is particularly important where gaps in data exist between follow on missions. A moderate global array of ~10 repeat lines in different atmospheric regimes is required. *In situ* radiometer sampling strategies must consider the variable nature of SST skin dynamics.
- Argo floats that are capable of resolving thermal stratification in the upper 5 m of the ocean are required to comprehensively sample thermal stratification and provide a calibration to drifting buoy observations used in satellite validation and quality monitoring.
- Further steps should be taken to strengthen SST data stewardship activities for the satellite SST data record, including tools that provide easy access to multiple source satellite and *in situ* data. Tools should also be provided for the regular processing and analysis of combined data sets.

Adequacy/inadequacy of current holdings

- SST data holdings are extensive and widely used, but further reprocessing is required to address known problems, such as regional biases, cloud, rain, side-lobe, and aerosol contamination, and consistently analysed geostationary and polar orbiting data to resolve the diurnal cycle.

Immediate action, partnerships, and international coordination

- Satellite SST data providers should take steps to make their calibrated radiance observations available for use in the SST reprocessing and re-analysis community.
- A concerted and immediate effort should be made to ensure the sustained continuity of passive microwave SST using a ~6.9 GHz channel. Steps should be taken to ensure that better accuracy and high spatial resolution are key design goals for future passive microwave satellite radiometers.
- Maintain and enhance coverage by geostationary instruments sufficient to resolve diurnal variability, and improve mechanisms for geostationary SST data exchange.
- A concerted effort is required to develop a framework to provide robust uncertainty and bias estimates for *in situ* SST data sets that are used for satellite instrument calibration and product validation.
- Cloud screening of IR data is remains a significant challenge, despite nearly 30 years of activity, and failure to detect sub-pixel clouds remains the source of substantial uncertainty in IR satellite data sets. Further development of cloud clearing approaches is urgently required to improve the quality of IR SST FCDR.
- The performance of IR satellite SST atmospheric corrections in aerosol rich atmospheres must be improved.
- More effort must be given to the definition and implementation of ice masking procedures and techniques in polar regions for satellite SST observations.
- The performance of IR satellite SST atmospheric corrections in polar atmospheres must be improved
- Steps should be taken to improve the treatment of side-lobe, ice, and rain contamination of PM measurements in the coastal zones.
- Continue reprocessing of satellite data for providing a homogeneous global SST climate data record, in particular for all PM data sets and for geostationary and polar orbiting IR data sets (AVHRR data from 1981 to present requires reprocessing). A systematic framework in which

satellite SST data sets can be regularly re-processed and uncertainty estimates provided is required (GOCS IP-10: Action C11). The system should foresee multiple re-processing at all levels from engineering data through to geophysical products to produce the best FCDR for each satellite sensor.

- Sustain and augment the Argo profiling drifter network with better capability to resolve diurnal thermal stratification in the surface ocean. Argo profiling floats should be equipped with a capability to make detailed SST vertical profile measurements in the top 10 m of the ocean.

The GCOS Satellite Supplement[3] specifically notes:

> *"Continuing support is needed for efforts such as the international Group for High-Resolution SST (GHRSST) Project (and associated CEOS SST Virtual Constellation that is now emerging), which attempts to make optimum use of satellite and in situ observations at the highest feasible space and time resolution whilst continuing to support efforts to improve the absolute accuracy of satellite SST measurements and our understanding of the characteristics of the uncertainties."*

This proposal underlines the importance of strong interaction and partnerships with the CEOS WG-Climate. The SST-VC was represented at the first meeting of CEOS WG-Climate and has already made submissions on priority areas for action. It is anticipated that this partnership will develop and mature as the SST-VC and CEOS WG-Climate themselves develop.

GEO Requirements Addressed

SST impacts many GEO climate, weather, ecosystem and agriculture SBA tasks e.g. aquaculture, fisheries, ocean prediction and monitoring, climate and seasonal prediction amongst other applications. Furthermore, the GHRSST structures are working within the Infrastructure components of GEO and demonstrate GEOSS in action. Today the GHRSST Multi-Product Ensemble (GMPE) system that is used to monitor the relative differences between global operational SST analysis systems), forms part of the core work on ensemble techniques under GEO DA-09-02: Data Integration and Analysis. Considering the emerging GEO 2012-2015 work-plan (Version 1 August 2011) we identify the main areas where GEO and the SST-VC may interact are I the following activities:

- Infrastructure:
  - **IN-01: GEOSS Common Infrastructure (The GHRSST R/GTS is an excellent example of GEOSS in action)**
  - **IN-02: Earth Observing systems**
  - **IN-03: Earth Data Sets**
  - **IN-04: GEOSS Communication Networks**
  - **IN-05: Gap Analyses**
- Institutions and Development
  - **ID-01: Data Sharing**
  - **ID-03: Developing Institutions and Individual Capacity**
  - **ID-04: Building Communities and Awareness**
  - **ID-05: Ensuring GEOSS Sustainability**
- Information Services
  - **DS-02: High Impact Weather Forecasting**
  - **DS-03: Climate Information**
  - **DS-04: Ocean Monitoring, Forecasting and Resource Development**
  - **DS-09: Global Agricultural Monitoring and Early Warning**
  - **DS-12: Global Carbon Observations and Analysis**
  - **DS-13: Global Ecosystem Monitoring**

As the new Work Plan matures, steps will be taken to ensure consolidated activities will have mutual benefit between GEO and CEOS. One of the SST-VC co-leads is a member of the GEO Science and Technology Committee and this linkage will be further consolidated as the SST-VC moves forward.

Programmes of Direct Relevance

- NASA JPL Physical Oceanography Distributed Active Archive Center (PO.DAAC) GHRSST GDAC services for SST (http://ghrsst.jpl.nasa.gov/)
- NOAA National Oceanographic Data Center (NODC) Long Term Stewardship and Reanalysis Facility for GHRSST SST (http://ghrsst.nodc.noaa.gov)
- EUMETSAT Ocean and Sea Ice Application facility (OSI-SAF http://www.osi-saf.org/) and EUMETSAT Central Facilities.
- JAXA data server for GHRSST (http://sharaku.eorc.jaxa.jp/ADEOS2/ghrsst/)
- European Space Agency Climate Change Initiative (CCI http://earth.eo.esa.int/workshops/esa_cci/intro.html)
- NASA SST Science Team (http://depts.washington.edu/uwconf/sst2010/)
- GODAE Ocean View (http://www.godae.org/oceanview.html)
- NOAA GOES-R project (http://www.goes-r.gov/)
- Global Monitoring for Environment and Security (GMES) Marine Core Service (http://www.myocean.eu.org/)
- Australian Integrated Marine Observing System (IMOS) Project (http://imos.org.au/)
- All services and projects within the scope of GHRSST (http://www.ghrsst.org)

We anticipate that other groups will be part of the SST-VC activities as the Constellation becomes established.

SST-VC Strengths, Weaknesses, Opportunities and Threats (SWOT) assessment analysis

The following matrix provides a SWOT analysis of the proposed SST-VC.

Strengths	Weakness
Existing and functioning International coordination through GHRSST is established	Not all relevant Space Agencies are currently engaged in SST-VC/GHRSST activities
Effective NRT data access to EO SST, mature long-term data archive and data stewardship services are in place that will form the basis for climate work.	*In situ* data are limited in their accuracy and thus their ability to demonstrate the performance and improve EO SST sensors to a climate standard. Better coordination is required.
Extensive scientific user community in place that are actively engaged with SST-VC/GHRSST.	Sustained Passive Microwave SST continuity is fragile.
Extensive operational community in place and community are actively engaged with SST-VC/GHRSST.	There is a lack of performance metrics for the SST constellation today. It is thus difficult to demonstrate the full scope of user uptake and applications of CEOS member capability.
Leadership of SST EO climate activities through the GHRSST mechanism and CEOS WG-Climate including response to GCOS requirements in place.	While Agencies do provide EO SST uncertainty estimates according to a common specification their comparability and application is currently sub-optimal.
Systematic user feedback at all levels within the SST-VC/GHRSST Regional/Global task sharing framework	Consolidated documentation of user feedback and queries is currently sub-optimal.
International data format, operations and development consensus documentation in place	

and actively maintained.

International project office in place and fully functioning on the international stage.

SST-VC/GHRSST is actively addressing CEOS QA4EO requirements

Demonstrated improvements in operational capability with clear societal benefit (e.g. weather forecast, ocean forecasting, climate services).

Opportunities	**Threats**
Better participation by CEOS Members having an EO SST capability in SST-VC activities.	Sustained funding for SST-VC/GHRSST activities remains a threat.
Better coordination of in situ SST activities (e.g. new drifting buoys with accurate sensors for EO validation is now being piloted through GHRSST) leading to EO improvements.	Loss of key people leading SST-VC/GHRSST activities.
Coordinate the sustained provision of passive microwave SST data within the SST Constellation.	Loss of EO Passive microwave capability from the current SST constellation will lead to a degradation of SST services and data quality.
Develop more widespread awareness and utility of CEOS Member SST data sets beading to improved societal benefit (e.g. better weather and ocean forecasts)	
There is much work to be done to improve, through better re-processing and re-analysis activities, EO SST data holdings to address climate services.	
Using the new GEO work-plan, strengthen and further formalize contributions to GEO.	
Strengthen and formalize contributions to GCOS through the CEOS WG-Climate, GHRSST and other projects (e.g. ESA CCI)	
Develop a set of metrics for the SST constellation activities to satisfy the relevant community needs making full use of existing statements of requirements.	
Make better use of QA4EO tools and implement improved QA4EO processes	
Harmonize and improve estimates of uncertainty in all EO SST products.	

Description and Timelines of Current and Future Satellite Programmes

A 1-Table 2: summarises current and future satellite programs from 1991 to 2025 that include instruments capable of measuring SST.

Mission Name Short	Launch Date	End of Life (EOL) Date	Mission Status	Mission Instruments
Meteosat series	20 November 1993	31 January 2021	Currently being flown	MVIRI: 6, 7 SEVIRI: 8, 9, 10, 11
ERS series	1991	31 December 2011	Currently being flown	ATST-1 and ATSR-2
POES series	01 May 1981	01 March 2016	Currently being flown	AVHRR/2: 7,9, 11, 14 AVHRR/3: 15, 16, 17, 18, 19
TRMM	28 November 1997	?	Currently being flown	TMI, VIRS
INSAT series	03 April 1999	10 April 2013	Currently being flown	VHRR: 2E, 3A
OCEANSAT-1	26 May 1999	31 December 2009	Currently being flown	MSMR: 1
Terra	18 December 1999	30 September 2011	Currently being flown	MODIS
GOES series	03 May 2000	01 January 2028	Currently being flown	ABI: R, S Imager: 11, 12, 13, O, P Sounder: 11, 12, 13, O, P
NMP series	21 November 2000	30 September 2011	Currently being flown	ALI: 1 Hyperion: 1
Envisat	01 March 2002	31 December 2013	Currently being flown	AATSR
Aqua	04 May 2002	30 September 2011	Currently being flown	AIRS, AMSR-E, MODIS
FY-1 series	15 May 2002	31 December 2009	Currently being flown	MVISR (10 channels): 1D
Coriolis/Windsat	06 January 2003		Currently being flown	Windsat

Mission Name Short	Launch Date	End of Life (EOL) Date	Mission Status	Mission Instruments
KALPANA-1	12 September 2002	09 December 2012	Currently being flown	VHRR
FY-2 series	19 October 2004	31 December 2016	Currently being flown	IVISSR (FY-2): 2C, 2D, 2E, 2F
MTSAT series	26 February 2005	28 June 2015	Currently being flown	IMAGER/MTSAT-2: 2 JAMI/MTSAT-1R: 1R
EPS series	19 October 2006	01 December 2021	Currently being flown	AVHRR/3: 1, 2, 3 HIRS/4: 1, 2 IASI: 1, 2, 3
HY-1 series	11 April 2007	01 January 2013	Currently being flown	COCTS: B, C, D
FY-3 series	27 May 2008	31 December 2024	Currently being flown	IRAS: 3A, 3B, 3C, 3D, 3E, 3F, 3G, MVIRS: 3F, 3G, VIRR: 3A, 3B, 3C, 3D, 3E, 3F, 3G
Meteor series	18 September 2009	31 December 2015	Currently being flown	IKFS-2: N2 MSU-MR: N1, N2 MTVZA: N1, N2
COMS series	26 June 2010	01 November 2016	Currently being flown	MI: 1
GOMS/ELECTRO series	31 December 2009	31 December 2021	Approved	MSU-GS: N1, N2, N3
HY-2 series	01 January 2010	01 January 2011	Currently being flown	RAD: A
SAC series	22 May 2010	22 May 2015	Currently being flown	NIRST: D/Aquarius
NPP	25 October 2011	02 June 2015	**VII. Approved**	VIIRS
GCOM-W series	01 February 2012	01 February 2025	Approved (W1) Planned (W2,W3)	AMSR-2: W1, W2, W3
Sentinel-3 series	01 August 2013	01 July 2026	Approved	SLSTR: A, B, C
FY-4 series	31 December 2012	31 December 2024	Planned	MCSI: O/A, O/B, O/C, O/D, O/E

Mission Name Short	Launch Date	End of Life (EOL) Date	Mission Status	Mission Instruments
GCOM-C series	January 2014	January 2020	Approved (C1) Planned (C2,C3)	SGLI: C1, C2, C3
JPSS series	2017	01 January 2027	Approved	MIS: 2, 3, 4 VIIRS: 1, 2, 3, 4
MTG-I (imaging) series	15 December 2016	15 December 2037	Approved	FCI: 1, 2, 3, 4

A 1-Table 2: Key space segment capabilities for SST 1981-2025

Recommendations for the formation of the Constellation Study Team and identification of Constellation Co-Leads

The proposed SST-VC shall support the coordination consolidation and further development of satellite SST capability, products, user feedback and education/outreach activities using the recognized and well established GHRSST as the prime implementation mechanism. Initially SST-VC group members will be those representing CEOS Agencies, the GHRSST Science Team Chair and selected members of the GHRSST Science Team involved in relevant SST activities. The emphasis on this structure is to reduce duplication between the successful and functioning work of GHRSST (as an implementer of the SST-VC) and the SST-VC representing the co-ordination activities of the Agencies. The following members confirm that their Agency will participate in the SST-VC:

SST-VC Co-leads:

1) Kenneth S. Casey, National Oceanic and Atmospheric Administration (NOAA), USA
2) Craig Donlon, European Space Agency (ESA), Netherlands

SST-VC members

3) Hans Bonekamp, European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), Germany
4) Andrew Bingham, Jet Propulsion Laboratory, National Aeronautics and Space Administration (NASA), USA
5) Misako Kachi, Japan Aerospace Exploration Agency (JAXA), Japan
6) Peter Minnett (GHRSST ST Chair), University of Miami, USA.

This collective group would form the leadership of the SST-VC. Our plan is to select 2 people from the leadership group to serve as the co-chairs with a rotation every 3-5 years. We note that this group is of a manageable and functional size and at this stage we are keen to maintain a moderate group size to ensure effective management and coordination of the SST-VC in the early days. We anticipate that others will join as well and additions to this list will be made in due course. ***We specifically identify the following Space Agencies and other entities whose participation could be solicited:***

1. Comision Nacional de Actividades Espaciales (CONAE), Argentina.
2. Indian Space Research Organisation (ISRO)
3. Korea Aerospace Research Institute (KARI)
4. Chinese Academy of Space Technology (CAST)
5. National Remote Sensing Center of China (NRSCC)
6. National Satellite Meteorological Center/Chinese Meteorological Administration (NSMC/CMA)

7. Russian Federal Service for Hydrometeorology and Environmental Monitoring (ROSHYDROMET)
8. Russian Aviation and Space Agency (Roskosmos)
9. Global Climate Observing System (GCOS)
10. Group for Earth Observation (GEO)
11. Other CEOS members with an interest in SST

This is a non-exhaustive list that notes key Agencies with EO SST measurement capability/interests and other CEOS members are invited to consider participation on the SST-VC.

Requirements and guidelines for contributors

As required by the CEOS VC paper, the following sections outline requirements and guidelines for contributors to the SST-VC.

Technical measurement criteria

Contributors to the SST-VC shall:

- Work towards establishing an EO Constellation of satellite assets that collectively address SST climate requirements as set out in Section 3 of this document.
- Prioritize the sustainability of (a) passive microwave EO missions that provide continuity to existing capability and (b) reference sensors (e.g. the ENVISAT AATSR).
- Work together to optimize the configuration of the collective EO SST measurement capability (e.g., instruments, orbits, channels, calibration)
- Work with other implementation agencies to ensure that adequate in situ SST data are available for the proper assessment of EO SST accuracy and quality.
- Work towards consensus solutions to monitor the performance and quality of EO SST data products and services.
- Participate in GHRSST TAG and WG activities that will move forward SST-VC measurement priorities.

Inter-comparison and calibration/validation targets

Contributors to the SST-VC shall:

- Participate in relevant GHRSST TAG and WG inter-comparison activities (e.g., the GHRSST Inter-comparison Technical Advisory Group – IC-TAG).
- Participate in relevant GHRSST TAG and WG calibration/validation activities (e.g., the GHRSST Validation Technical Advisory Group - STVAL).
- Agree to share performance results of inter-comparison activities between relevant parties for the sole purpose of understanding and improving EO SST products and services.
- Agree to share EO and in situ data products for the purpose of understanding the quality and performance of EO SST data products in order to further their application in climate applications and services.

Data access and format guidance

Contributors to the SST-VC shall:

- Make their SST measurements available to the community.
- Be engaged in EO SST activities and work towards implementing and evolving the GHRSST Data Processing Specification version 2.0 (GDS-2.0, see: https://www.ghrsst.org/files/download.php?m=documents&f=GDS2.0_TechnicalSpecifications_v2.0.pdf).
- Actively participate in the GHRSST Regional/Global Task sharing Framework (R/GTS) described at https://www.ghrsst.org/ghrsst-science/what-is-ghrsst/

Assessment of compliance to GCOS GCMP

Contributors to the SST-VC shall:

- Within operational and political constraints, agree implement GCOS GCMP for EO SST measurements.
- Periodically report an assessment of compliance with GCOS GCMP.
- Participate in relevant GHRSST TAG and WG inter-comparison activities (e.g., the GHRSST Reanalysis Technical Advisory Group – RAN-TAG).
- Work towards a system that is capable of providing accurate and relevant uncertainty estimates with every EO SST measurement.
- Work effectively with the requirements and guidance of the CEOS WGClimate.
- Endeavour to use periodic re-analysis activities to improve compliance to GCOS GCMP.

Coordination and management

Contributors to the SST-VC shall:

- Participate in relevant GHRSST TAG and WG inter-comparison activities.
- Attend the annual International GHRSST Science Team Meeting that provides a forum and space for international coordination of EO SST activities
- Participate in CEOS WG as required.
- Collectively develop and support outreach and training activities (building on existing opportunities) to further the application and development of EO SST data products and services.

Schedule

In accordance with the CEOS paper for new Constellations, the SST-VC leadership group will begin to prepare an implementation plan and Study Report following approval of this proposal. The will take a similar approach to the lead set by the OST-VC as it produced its 15-year plan taking into consideration the GHRSST Development and Implementation Plan (GDIP) and the OceanObs-09 Community While Paper.

Costs

The cost of ***establishing*** the SST-VC constellation is minimal given the commitments already made to GHRSST (approximately $25M over a period of nearly 10 years). In terms of ***operating*** the SST-VC the following resources are in hand:

- ESA continues to fund the GHRSST International Project Office until 2013,
- NASA funds the GDAC and NASA SST-Science Team activities,
- NOAA funds the GHRSST LTSRF and operational production of GHRSST data from GOES platforms,
- EUMETSAT funds the OSI-SAF contributions to GHRSST,
- JAXA funds their activities within GHRSST,
- Additional funds contribute from National agencies supporting the activities of the SST-VC (via GHRSST),
- GHRSST international Science Team meetings provide an obvious annual focal point for the SST-VC. Traditionally, costs associated with hosting the GHRSST meetings are met by *sponsorship* with travel and subsistence costs covered at National level (except for students where sponsorship is required).

In terms of ***developing*** the SST-VC, additional CEOS Agency support will be required to support specific SST-VC activities including: development and publication of promotional and educational materials (web pages, course materials); organization and hosting of SST-VC training workshops; attendance of CEOS meetings and other specific meetings as required by the activities of the SST-VC.

Conclusions and way forward

This full proposal paper sets out the background, priorities and proposed activities to be implemented by the CEOS SST-VC working with GHRSST and an implementation body. It is clearly evident that while much has been achieved through the activities of GHRSST, there is more to do in order to optimize and take full advantage of the SST virtual constellation to further benefits to society. An important aspect of the SST-VC will be the focus on climate SST, working with GCOS and CEOS WGClimate. Using the leverage of international collaboration, a common purpose and consensus documentation to secure domestic budgets underpinning GHRSST activities is evidently successful. Continuing this philosophy we expect the SST-VC/GHRSST partnership, working with WGClimate, to emerge as a key instrument in the space segment of the climate architecture, and a mechanism for delivery of coordinated SST ECV products and services. For example: the GHRSST Re-ANalysis Technical Advisory Group (RAN-TAG) is coordinating with the GCOS SST/SI WG and many members are actively involved in ECVs; an SST- ECV framework is being developed to address the inputs a requirements of many organisations; a reanalysis activity and inter-comparison work is underway at LTSRF; a concerted effort is being made to federate the SST user/producers and deliver consensus recommendations to CEOS and GCOS.

We propose a lean and efficient approach, consistent with the view of CEOS, that builds on existing activities and services in order to maintain coordination of SST activities and provide value for money. Currently ESA, NASA, NOAA, CSIRO, JAXA and EUMETSAT play prominent roles in the SST-VC: we prioritise the inclusion of other “SST Agencies” in SST-VC activities.

Today, GHRSST activities have made a real tangible difference to the way that EO SST are provided, documented and used through the development and implementation of consensus community approached documented in the GHRSST Data Processing Specification version 2.0 (GDS-2). This has resulted in a significant increase in user uptake and engagement of CEOS Agency products. Priorities now include the complete specification of uncertainty estimates (at the pixel level) for all SST measurements the promotion and community awareness of how to interpret and apply these estimates. Challenges to move forward include reaching consensus on how to include lake water surface temperatures within SST data sets as requested by weather forecasting agencies.

According to the CEOS Virtual Constellations paper the next steps to move forward will be develop an implementation plan that will bring focus and expert leadership on the specific challenges and opportunities presented in this proposal.

APPENDIX 2: GHRSST Terms of Reference

1. The aim of the Group for High Resolution Sea Surface Temperature

It was agreed by GST-IX that the main aim of the international Group for High Resolution Sea Surface Temperature (GHRSST) is:

> ***To develop and nurture cooperation and progress at the world scale in the subject area of satellite Sea Surface Temperature***

2. GHRSST Terms of Reference

Terms of Reference for the Group for High Resolution Sea Surface Temperature (GHRSST) were developed at GST-IX as follows:

2.1 To develop consensus within the international SST community about key issues of satellite-SST science and technology, and to communicate the collective view to those who design and operate satellite SST sensors and those who develop, distribute and archive SST data products. Activities to achieve this include:

a. Construct and maintain a partnership, at the international level, between the space agencies and the users of satellite-SST data to develop and coordinate data utilization. The priorities and activities of the partnership are embodied in the evolving GHRSST Development and Implementation Plan (GDIP).

b. Manage, develop and monitor the GHRSST Regional/Global Task Sharing (R/GTS) framework in cooperation with other bodies and systems according to the principles of subsidiarity[4]

c. Maintain an international Science Team of experts in all aspects of SST;

d. Maintain the GHRSST Data Specification (GDS) documentation which is the foundation for the R/GTS. This implies a requirement to:

   i. Encourage agencies to agree on common formats for data exchange, common data products and algorithms.

   ii. Facilitate provision of common tools to access data in different formats.

   iii. Provide assessments of data quality and work to identify and eliminate errors and uncertainties of measurements.

e. Create and maintain working groups and technical advisory groups, as required, to support the GDS and R/GTS framework and to promote international best practice on all aspects of SST including data merging and integrated use for the applications, scientific and operational user communities. Recommend workshops to address issues relevant to data merging and integrated use.

f. Build capacity and awareness of the GHRSST, its activities, data products and services including the coordination and facilitation of scientific and user workshops and symposia as appropriate for the GHRSST Development and Implementation Plan (GDIP).

[4] The subsidiarity principle is based on the idea that decisions must be taken as closely as possible to the most appropriate expertise and existing infrastructure: GHRSST should not undertake action (except on matters for which it alone is responsible) unless GHRSST action is more effective than action taken at national, regional or local level (i.e. GHRSST should not duplicate or re-invent existing capability and structures).

2.2 To enhance the flow of relevant knowledge, information, recommendations and decisions throughout the international community of SST data providers, users and scientists. Ways in which GHRSST can accomplish this include the following.

To distribute and promote all GHRSST related research, information, and recommendations to international, national, and regional sponsors and funding bodies.

a. To serve as a communication and coordination channel between data providers and the global, user community of satellite-SST data, and so to maximize the benefits that accumulate from international investments in science, operations, and technology related to SST.

b. To work closely with the appropriate international bodies, international scientific programs, satellite-SST-mission offices and other agencies to harmonize the international effort and advance SST science, operations and applications by maintaining a GHRSST international user requirement document for SST, noting the need to work effectively with other agencies in this activity.

c. To act as an interface and thus integrate the GHRSST within other global systems and projects as appropriate (e.g., GODAE, COOP, GOOS, CLIVAR, GWEX etc.).

d. To coordinate, enable and facilitate, on behalf of the GHRSST Science Team, the open exchange of relevant satellite and in situ data streams for use within the GHRSST. In particular, the GHRSST Science Team should prepare and submit specific data access proposals, negotiate with data providers (e.g., in situ observations from the commercial sector), and oversee the correct application of any associated data policy requirements and agreements.

e. To develop appropriate information systems such as a web site, newsletter, home page and data access networks to show the importance of SST data to the global community.

2.3 To promote the long-term provision for continuity of satellite SST data sets and the development of new generations of SST sensors that support the growth of operational SST data services, with an emphasis on encouraging the integration/merging of data from complementary SST data sets for use in applications ranging from short term weather and ocean forecasting to climate prediction and monitoring (GCOS Essential Climate Variables).

2.4 To facilitate access to SST data and related ancillary data (wind, atmospheric aerosol, etc.) and encourage the provision of in situ data by relevant agencies where such data are required for verification, interpretation, validation and/or calibration of SST products and the derivation of secondary products. This will include activities such as:

Encourage the combined use of same source satellite and in situ data within the international data system in common data-exchange formats.

a. Recommend data-collecting strategies to fill existing gaps in time and space, of key variables.

b. Support the coordination of satellite instrument validation activities focussed on the development of a user community service for the reporting and exchange of validation results and information relating to the operational activities of satellite platforms and data delivery in near real time.

2.5 To encourage and assist the pull-through of SST science into operational systems and to maintain appropriate documentation and frameworks to nurture better collaboration between SST science and operational centres.

a. Organize workshops and conferences targeted at potential users of the data (e.g. climate, weather and ocean forecasting, seasonal and decadal prediction, climate science, fisheries, coastal resource agencies).

b. Promote demonstration projects that involve both providers and users of ocean-colour data.

2.6 To foster expertise in using SST data worldwide and broaden the user community for SST, particularly in developing and emerging countries, by activities such as :

a. Training courses, user outreach and application support material and workshops.

b. Facilitate development of data systems in these areas to support and sustain the user communities.

c. Promote international cooperation in research and application development through international symposia, provision of data and software for user communities, scientific research and scientific exchange programs.

d. Develop training materials that provide the user community with the tools and the capability to utilize real data, both in the course of instruction and after the completion of the course material.

2.7 To encourage the formation of an international calibration and validation network for SST (distinct from 2c which refers to instrument and sensor validation) This is needed to,

a. Ensure that sea-truth measurements conform to accepted international protocols, and that sensor calibrations be traceable to (inter-)national calibration standards.

b. Encourage the development of an international protocol for satellite sensor characterization, quality assurance of data, and exchange of validation data.

c. Facilitate the formation of a distributed calibration and validation archive and database network.

APPENDIX 3: Recommendations from the OceanObs White paper [OO9]: Successes and Challenges for the Modern Sea Surface Temperature Observing System

The following recommendations are made within the OceanObs White paper [OO9]:

1. We recommend that steps should be taken to increase the accuracy and spatial resolution of passive microwave SST data sets through innovative satellite design. These improvements would enable better coverage of the coastal zones and better discrimination of mesoscale structures that are closely coupled to the surface wind field improving SST climate data records and numerical weather forecasts.
2. A concerted effort should be made to ensure the sustained continuity of passive microwave SST using a ~6.9 GHz channel in an operational (redundant) context. Steps should be taken to ensure that better accuracy and high spatial resolution are key design goals for future passive microwave satellite radiometers.
3. A capability for satellite infrared dual view along track scanning radiometry should be sustained in an operational context with redundancy.
4. Future single view satellite infrared radiometer systems developed for accurate SST retrieval should include channels at ~8.6, 3.9 and 4.05 μm.
5. The capability for high-quality satellite infrared multi-frequency radiometry in geostationary orbit should be sustained. Ideally a constellation of 6 geostationary instruments is required to provide global coverage at satellite zenith angles amenable to quantitative SST estimation. We note that continuity of both IR and passive microwave SST observations on polar and geostationary platforms is considered essential for an accurate and robust SST Climate Data Record (CDR).
6. All SST observations are reported together with a depth of observation and that adequate transmission codes are provided for in situ radiometers and other instruments to report their SST data in near real time via operational communication systems. Special efforts should be made to improve the quantity and documented calibration of all in situ SST measurements – especially those made by ships – so that they can be used in satellite validation activities. Finally improvements to the sampling of the global drifting buoy array in the Southern Ocean and Arctic Ocean should be implemented, building on existing legacy systems, to achieve better sustained sampling in these regions.
7. Observing system experiments (OSE), sampling studies and, error analyses (such as the Potential Satellite Bias Error, PSBE) should be an integral part in the design, development and operation of an integrated SST observing system suited to both near real time operations and climate data record production.
8. We strongly recommend that all Argo floats are equipped with a capability to make high vertical resolution measurements of SST in the upper 10m of the ocean surface and that shallow-water Argo floats be developed and deployed. Evidence should be gathered and presented to Argo float manufacturers highlighting the applications and benefit of providing high resolution temperature sensors on all Argo floats for the investigation of SST diurnal variability.
9. A concerted effort is required to develop a framework to provide robust uncertainty and bias estimates for *in situ* SST data sets based on the use of satellite, model, and climatological reference data sets in collaboration with JCOMMOPS and other Agencies.
10. We fully endorse the Global Climate Observing System (GCOS, 2006) climate monitoring principles, which are all relevant to an integrated (satellite plus in situ) SST

observing system, and urge agencies to take steps to implement these principles in their short and long term planning for the future of satellite SST data sets.

11. We recommend that a systematic framework in which satellite SST data sets can be re-processed is developed and operated. The system should foresee multiple re-processing of L0 (engineering) data through to L2 (geophysical) products to produce the best Climate Data Record for each satellite sensor. Furthermore, developments achieved for climate re-analyses should be quickly integrated into operations.
12. The Group for High Resolution SST/GCOS SST & Sea Ice Working Group modern-era SST inter-comparison activity is sustained and enhanced to include other satellite data sets in order to identify systematic biases between complementary SST Climate Data Record.
13. Further steps should be taken to strengthen data stewardship activities for the modern era SST data record including tools that provide easy access to multiple source satellite and in situ data. Tools should also be provided for the regular processing and analysis of combined data sets (e.g., the ESA Grid Processing on Demand (G-POD) system).
14. A consensus approach is obtained and documented to produce sensor specific SST climate data records (one per sensor/series) in an optimized end-to-end high-resolution global coverage SST measurement system. Also, that an appropriate international cooperative data service is implemented that will develop, maintain and provide SST Climate Data Records.
15. We recommend that an optimal level of diversity in approach and competition to achieve the best result is encouraged when implementing SST Essential Climate Variable processing systems.
16. Further research must be conducted to develop and refine SST optimal estimation techniques that maximize the error reduction from having multiple complementary observing systems in space.
17. Satellite developers should include better (two calibration targets) on-board calibration systems for satellite infrared and passive microwave sensors, ensure that adequate data are collected on board the spacecraft to characterise instrument calibration, and that these data are telemetered to ground. We also recommend, based on 17 years of experience, that the along-track scanning technique provides an excellent approach to measuring accurate SST from satellites and should be more widely adopted for operational systems.
18. Future satellite and in situ SST observing systems should provide a measurement of contemporaneous wind stress in order to understand the context of SST measurements (e.g., cool skin and thermal stratification), to help blending of SST measurements made by different methods under moderate wind stress and to facilitate the application of SST measurements in scientific and operational systems.
19. A systematic data gathering exercise should be performed to identify and catalogue diurnal SST warming events across the global ocean using satellite and in situ measurements in order to better understand the spatial and temporal variability of such events and their impact at daily, monthly seasonal, annual and multi-annual timescales.
20. Steps should be taken to secure high temporal resolution (ideally at an hourly resolution) wind fields over the global ocean for use in diurnal SST variability modelling.
21. Single Sensor Error Statistics (SSES) describing SST uncertainty for individual satellite sensors on a pixel-by-pixel basis should be stratified by season and region and include a variety of auxiliary data that can be used to derive the SSES in a hypercube (multi-dimensional) matchup database approach.
22. We note the need for better in situ SST observations and supporting data and metadata (including depth of observation and calibration history) for use in Single Sensor Error

Statistic derivation schemes. We recommend that (1) operators of in situ radiometer systems are encouraged to share their observations in order to maximize the benefit to the satellite SST community and (2) all in situ observations when reported should include depth, calibration history, measurement method and a meaningful estimate of uncertainty.

23. The Committee on Earth Observation Satellites (CEOS) Quality Assurance for Earth Observation data (QA4EO) approach should be used by Space Agencies working together with inter-Governmental agencies, in situ data providers and the scientific SST community when defining, implementing and operating a sustained SST validation program.
24. We recommend that a concerted effort to develop better Single Sensor Error Statistics uncertainty and error estimates for all satellite and in situ data sets should be a priority and urge agencies and scientists to devise new schemes that can be implemented in an operational manner. We recommend that uncertainty estimation follows and, where appropriate, contributes to the Quality Assurance for Earth Observation data (QA4EO) approach both for satellite data and for in situ data.
25. We endorse the approach in which well characterised and accurate satellite sensors may act as a reference data source for bias correction and Single Sensor Error Statistics derivation but note that steps should be taken to assure the sustained provision of such data (e.g., the ESA Sentinel-3 Sea and Land surface Temperature Radiometer (SLSTR) that will follow the Advanced along Track Scanning Radiometer (AATSR) due for launch in 2012). We further recommend that new satellite infrared radiometer systems make full use of additional channels in the 3-12 μm spectral region.
26. Space Agencies working together with inter-Governmental agencies, in situ data providers and the scientific SST community take steps to define, implement and operate a sustained validation program for all satellite radiometers producing SST for the lifetime of the mission. We also recommend that Space Agencies and in situ data providers include sustained validation of their SST products as a fundamental component of each satellite mission and in situ platform for the entire mission/instrument duration.
27. We recommend that an optimum number of in situ high-quality infrared radiometer systems are maintained for the purpose of infrared and passive microwave satellite validation building on the demonstrated capability during the last 10 years. Such systems should be augmented by better aircraft measurements that have the additional benefit of covering large transects although care should be taken to ensure that atmospheric attenuation of the sea surface signal does not compromise the accuracy of data when flying at altitude.
28. An international reference match-up database that applies the same control and process methodologies to the match-up process between satellite and in situ SST measurements and supporting input data is developed, maintained and operated in order to allow a fair, consistent and up-to-date estimation of errors on satellite SST retrieval. We note such a common database is best constructed following the systematic re-processing of satellite data as part of a Climate Data Record development activity and should be consistent with the CEOS QA4EO process.
29. We recommend that the SST community of producers and users establish and maintain:-
    a. A programme of *in situ* measurements, both thermometers on buoys, ships and subsurface vehicles and radiometers on ships and platforms that can be used for validating the different products. For the sake of efficiency it is desirable that this be a fully collaborative programme shared between all the agencies

responsible for SST products. There is also a need to specify the requirements for new *in situ* data acquisition systems to support data integration, including wider coverage by ship-based radiometers, diurnally resolving moorings, Argo with additional sensors for near-surface sampling and the OceanSites approach.

b. A forum in which sets of quality metrics relevant to specific uses of SST data are defined and regularly reviewed (consistent with QA4EO). Different metrics will need to be defined for different applications, for example timeliness and reliability of error statistics may be more important than accuracy for assimilation into forecasting models, whereas absolute accuracy and stability are most important for climate datasets.
c. Tools such as the high-resolution diagnostic dataset (HRDDS) described above, that facilitate comparisons between different SST data products. New developments should include automated comparisons between different SST products to alert producers when inconsistencies are detected.
d. Match-up databases (MDB) which relate satellite-derived SST products with in situ measurements of SST. It is essential to preserve independence between those *in situ* observations used for calibration of SST products and those used for validation of the sensor specific error statistics attached to each data product, for which a new set of tools needs to be developed. Moreover, for long term climate monitoring it will be important to establish a “protected MDB” that can be preserved as an independent validation reference for future generations of SST product re-analyses. Ideally such data should not be allowed to influence the evolution of product algorithms in order to preserve their independence.
e. A generic system to acquire better feedback from data assimilation systems (e.g., observation weights rejection statistics) in order to ascertain how much influence different SST observational products have on the observing system models. Such information will identify targets for the quality of satellite SST data products, necessary for them effectively to constrain ocean models.

30. The ocean SST (GHRSST) community work effectively with the Global Space Based Satellite Inter Calibration System (GSICS) and establish if and how it may assist GSICS for the benefit of improved SST measurements by working together (e.g., using the High Resolution Diagnostic Data Set (HR-DDS) and GHRSST Multi Product Ensemble (GMPE) tools).
31. SST analyses producers should provide a user oriented document (to a standard template) that describes each analysis product and the choices and assumptions that have been made for the analysis procedure. The document should highlight the strengths and weaknesses of the analysis output in order to help users use the data in the most appropriate manner.
32. The GHRSST Multi Product Ensemble (GMPE) capabilities should be extended to provide quantitative data outputs in a GHRSST format for use by the general ocean community, consider higher spatial resolutions for the system grid specification, the inclusions of automated procedures for statistical analysis of the ensemble and the creation of regional GMPE tools for specific and challenging regions (e.g., Tropical Pacific, Bay of Bengal and Indian Ocean, Indonesia, Arctic Ocean, Great Lakes). These services could be distributed across multiple centres.
33. The GHRSST High Resolution Diagnostic Data Set (HR-DDS) should be extended to include user defined quantitative analysis and event driven monitoring capabilities in near real time to monitor the quality and performance of the SST observing system. Reports should be automatically sent to data providers and users when an event of interest is encountered by the HR-DDS system. Furthermore, the HR-DDS should be

expanded to include long time series of SST data sets to be visualised for reanalysis purposes.

34. A high resolution inter-comparisons group should be established under GHRSST that would be similar to the SST inter-comparison group already established for historical SSTs within the framework of GCOS. This group would include representatives of each of the major centres creating high resolution SST analyses with terms of reference established by the GHRSST science team.
35. As cloud screening of infrared satellite data is remains a significant challenge, despite nearly 30 years of activity, and failure to detect sub-pixel clouds remains the source of substantial uncertainty in satellite data sets, we recommend that a systematic review of cloud clearing approaches is undertaken with the purpose of properly documenting the strengths and weakness of each approach. Such a review should identify and prioritise a set of activities that should be undertaken to ensure that the best possible methods of cloud clearing are identified and used by satellite data providers. The review should also assess the severity of cloud detection to the degree of tolerable SST impact for unscreened clouds in the context of user applications.
36. We recommend that further development of probabilistic cloud detection and flagging algorithms should be undertaken to potentially improve the quality of satellite SST data sets from infrared sensors.
37. More effort must be given to the definition and implementation of ice masking procedures and techniques in polar regions for infrared satellite observations.
38. Satellite SST data providers using infrared systems should review the performance of their atmospheric correction algorithms in polar atmospheres and take steps to develop more appropriate algorithms for these regions.
39. Further efforts should be undertaken to continue the SST time series with more reliable in situ and radiometer observations in the Arctic Ocean.
40. Producers of L2 SST products discuss and agree on a common definition of global lakes for which Lake Water Surface Temperature (LWST) shall be retrieved routinely from satellite data ideally as part of the SST processing systems.
41. Satellite SST navigation techniques should be improved to allow confident delineation of lake and coastal shores, tidally exposed wet/dry areas and improvement in the retrieval of LWST and SST in complex coastal regions. Pixel classification flags should be revised and improved in a consistent manner so products use/share a common flag set (at a minimum the definitions should be agreed) to assist in these activities.
42. The netCDF Climate Forecast (CF) convention is used by satellite and in situ data providers to manage metadata and interoperability of the modern-era SST data record. We urge other satellite SST data providers to adopt the GHRSST L2P, L3, and L4 netCDF format approach to providing SST data to user communities.
43. Satellite SST data providers should take steps to make their L1b data available for use in the SST CDR re-analysis community and as part of NRT GHRSST products.
44. The adoption of a standards based approach to metadata and file formats has been one of the foundations of success for GHRSST and we recommend that the approach is strengthened and extended to other satellite and in situ SST data providers using appropriate mechanisms.
45. We recommend that the GHRSST Data Specification (GDS), in a revised and updated format, and the GHRSST Regional/Global Task sharing Framework (R/GTS) are strengthened and sustained in order to maintain and develop the strong user-producer collaboration that has enabled a new generation of SST data products and services to develop over the last 10 years.

46. GHRSST Regional Data assembly Centres (RDAC) should be sustained and strengthened following the subsidiarity principle in order to provide the maximum benefit to each region, to ensure that feedback from national and regional users is gathered, and that the modern era SST record and services develop according to user requirements.
47. The GHRSST Global Data Assembly Centre (GDAC) service should continue to develop and collaborate with RDACs and the Long Term Stewardship and Re-analysis Facility (LTSRF) to actively monitor the status of the R/GTS, data products and work with users.

Scientific References

Balsamo, G., Salgado, R., Dutra, E., Bousetta, S., Stockdale, T. And Potes, M. (2011) On the contribution of lakes in predicting near-surface temperature in a global weather forecasting model. http://www.ecmwf.int/publications/library/do/references/list/14 Technical Memorandum No. 648.

Barton, I.J., 2007a: Satellite-derived sea surface temperatures – a case study of error variability, Proc. ' ENVISAT Symposium 2007', Montreux, Switzerland, 23-27 April 2007 (ESA SP-636, July 2007).

Barton, I. J., P. J. Minnett, K. A. Maillet, C. J. Donlon, S. J. Hook, A. T. Jessup, and T. J. Nightingale, 2004: The Miami2001 infrared calibration and intercomparison. Part II: Shipboard results. J. Atmos. Oceanic Technol., 21, 268–283.

Beggs, H., Zhong, A., Warren, G., Alves, O., Brassington, G. and Pugh, T. (2011): RAMSSA – An Operational, High-Resolution, Multi-Sensor Sea Surface Temperature Analysis over the Australian Region, Australian Meteorological and Oceanographic Journal, 61, 1-22.

Casey, K.S., R .Evans, K.A. Kilpatrick, E.J. Kearns, T.B. Brandon, R.W. Vazquez, and J. Vazquez (2009). Toward the sea surface temperature climate data record from space: An improved Advanced Very High Resolution Radiometer Pathfinder dataset, in preparation for Journal of Climate.

Castro, S.L., Wick, G.A., Minnett, P.J., Jessup, A.T., Emery, W.J., 2010. The impact of measurement uncertainty and spatial variability on the accuracy of skin and subsurface regression-based sea surface temperature algorithms, Remote Sensing of Environment, 114, 2666-2678Cayula, J.-F. and P. Cornillon, 1996, Cloud Detection from a sequence of SST images, *Remote Sens. of Environ.,* **55**, 80-88.

CEOS, 2008, The Earth Observation Handbook: Climate Change Special Edition 2008, available at http://www.eohandbook.com/

CEOS 2009, The Earth Observation Handbook online database available at http://database.eohandbook.com/

Chelton, D. B., M. G. Schlax, and R. M. Samelson, Summertime Coupling between Sea Surface Temperature and Wind Stress in the California Current System, 2007: J. Phys. Oceano, 37 (3), 495-517.

Corlett, G. K., I.J. Barton, C.J. Donlon, M.C. Edwards, S.A. Good, L.A. Horrocks, D.T. Llewellyn-Jones, C.J. Merchant, P.J. Minnett, T.J. Nightingale, E.J. Noyes, A.G. O'Carroll, J.J. Remedios, I.S. Robinson, R.W. Saunders and J.G. Watts, 2006. The accuracy of SST retrievals from AATSR: An initial assessment through geophysical validation against in situ radiometers, buoys and other SST data sets, Adv. Space Res., 37 (4), 764-769.

Curry, J. A. and A. Bentamy, M. A. Bourassa, D. Bourras, E. F. Bradley, M. Brunke, S. Castro,S. H. Chou, C. A. Clayson, W. J. Emery, L. Eymard, C. W. Fairall, M. Kubota, B. Lin,W. Perrie, R. A. Reeder, I. A. Renfrew, W. B. Rossow, J. Schulz, S. R. Smith,P. J. Webster, G. A. Wick, And X. Zeng, Seaflux, Bull. Am. Soc., (3), 85, 2004, DOI: 10.1175/BAMS-85-3-409.

Donlon, C. J., Casey, K. S., Gentemann, C., LeBorgne, P., Robinson, I. S., Reynolds, R. W., Merchant, C., Llewellyn-Jones, D., Minnett, P. J., Piolle, J. F., Cornillon, P., Rayner, N., Brandon, T., Vazquez, J., Armstrong, E., Beggs, H., Barton, I., Wick, G., Castro, S., Hoeyer, J., May, D., Arino, O., Poulter, D. J., Evans, R., Mutlow, C. T., Bingham, A. W. and Harris, A. (2009a): Successes and Challenges for the Modern Sea Surface Temperature Observing System, Community whitepaper for OceanObs09, Venice, Italy, 21-25 September, 2009.

Donlon, C., Casey, K., Robinson, I., Gentemann, C., Reynolds, R., Barton, I., Arino, O., Stark, J., Rayner, N., Le Borgne, P., Poulter, D., Vazquez-Cuervo, J., Armstrong, E., Beggs, H., Llewellyn-Jones, D., Minnett, P., Merchant, C. and Evans, R., (2009b) The GODAE High-Resolution Sea Surface Temperature Pilot Project, Oceanography, 22, 34-45.

Donlon, C. J., P. J. Minnett, C. Gentemann, T. J. Nightingale, I. J. Barton, B. Ward, and J. Murray, 2002: Toward improved validation of satellite sea surface skin temperature measurements for climate research. *Journal of Climate*, **15,** 353-369

Donlon, C, J., T. J. Nightingale, L. Fiedler, G. Fisher, D. Baldwin, and I. S. Robinson, 1999: The calibration and intercalibration of sea-going infrared radiometer systems using a low cost blackbody cavity. J. Atmos. Oceanic Technol., 16, 1183–1197.

Donlon C, Robinson I S, Reynolds M, Wimmer W, Fisher G, Edwards R, Nightingale T J., 2008. An Infrared Sea Surface Temperature Autonomous Radiometer (ISAR) for Deployment aboard Volunteer Observing Ships (VOS). Journal of Atmospheric and Oceanic Technology 25 (1): 93-113.

Donlon, C. J., I. Robinson, K. S Casey, J. Vazquez-Cuervo, E Armstrong, O. Arino, C. Gentemann, D. May, P. LeBorgne, J. Piollé, I. Barton1, H Beggs, D. J. S. Poulter, C. J. Merchant, A. Bingham, S. Heinz, A Harris, G. Wick, B. Emery, P. Minnett, R. Evans, D. Llewellyn-Jones, C. Mutlow, R. Reynolds, H. Kawamura1 and N. Rayner. The Global Ocean Data Assimilation Experiment (GODAE) high Resolution Sea Surface Temperature Pilot Project (GHRSST-PP), 2009: Oceangraphy Magazine in press.

Donlon, C. J., I. Robinson, K. S Casey, J. Vazquez-Cuervo, E Armstrong, O. Arino, C. Gentemann, D. May, P. LeBorgne, J. Piollé, I. Barton1, H Beggs, D. J. S. Poulter, C. J. Merchant, A. Bingham, S. Heinz, A Harris, G. Wick, B. Emery, P. Minnett, R. Evans, D. Llewellyn-Jones, C. Mutlow, R. Reynolds, H. Kawamura1 and N. Rayner. The Global Ocean Data Assimilation Experiment (GODAE) high Resolution Sea Surface Temperature Pilot Project (GHRSST-PP), 2007: *Bull. Am. Meteorol. Soc*., 88 (8), 1197-1213, (DOI:10.1175/BAMS-88-8-1197)

Donlon, C.J. and the GHRSST-PP Science Team, 2006: *The GHRSST-PP data processing specification version 1.6*., 241 pp. [Available online at www.ghrsst-pp.org.]

Flament, P., J. Firing, M. Sawyer, and C. Trefois (1994), Amplitude and horizontal structure of a large diurnal sea surface warming event during the coastal ocean dynamics experiment, J. Phys. Oceanogr., 24(1), 124– 139.

Gentemann C. L., P. J. Minnett, P. Le Borgne and C. J. Merchant (2008), Multi-satellite measurements of large diurnal warming events, Geophys. Res. Lett, 35, L22602, doi:10.1029/2008GL035730.

Gentemann, C. L., P. J. Minnett, J. Sienkiewicz, M. DeMaria, J. Cummings, Y. Jin, J. D. Doyle, L. Gramer, C. N. Barron, K.S. Casey, and C. J. Donlon (2009). MISST: The Multi-Sensor Improved Sea Surface Temperature Project. Oceanography, 22(2), 76-87.

Global Climate Observing System (GCOS), 2006: Systematic Observation Requirements for Satellite-based Products for Climate Supplemental details to the satellite-based component of the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC GCOS-107, WMO/TD No. 1338, available from http://www.wmo.ch/pages/prog/gcos/index.php?name= publications

Group for High Resolution Sea Surface Temperature Science Team, The Recommended GHRSST Data Specification (GDS) 2.0 revision 4, 2011 https://www.ghrsst.org/files/download.php?m= documents&f=111107150103-GDS20r4.pdf

Guan, L. and H. Kawamura, 2003: *SST* availabilities o satellite infrared and microwave measurements. J. Oceanogr., Vol. 59, No. 2, 201-209.

Haarpaintner, J., R. T. Tonboe, D. G. Long, and M. L. Van Woert, 2004: Automatic detection and validity of the sea-ice edge: an application of enhanced-resolution QuikScat/SeaWinds data. *Geoscience and Remote Sensing, IEEE Transactions on*, **42,** 1433-1443

Hook, S.J., F.J. Prata, R.E. Alley, A. Abtahi, R.C. Richards, S.G. Schladow, and S.O. Pálmarsson, 2003: Retrieval of Lake Bulk and Skin Temperatures Using Along-Track Scanning Radiometer (ATSR-2) Data: A Case Study Using Lake Tahoe, California. *J. Atmos. Oceanic Technol.*, **20**, 534–548.

Høyer, J. L, Karagali, I., Dybkjær, G. and Tonboe, R. T. (2011) Multi sensor validation and error characteristics of Arctic satellite sea surface temperature observations, Submitted to Remote Sensing of Environment.

Jessup, A. T., R. A. Fogelberg, and P. J. Minnett, 2002: Autonomous shipboard radiometer system for in situ validation of satellite SST. Proc. Int. Symp. of Optical and Scientific Technology, Seattle, WA, SPIE.

Kaiser-Weiss, A. K. (ed.) (2011), Proceedings of the GHRSST XII Science Team Meeting Edinburgh 2011, available from the GHRSST Project Office or from https://www.ghrsst.org/files/download.php?m=documents&f=111006165323-Proceedings260911Final.pdf.

Kelliher, H., G. corlett and I. S. robinson, 2007: SST Data Continuity Final Report, ICP2.SCL.REP.001 under contract CSSPA/0705, available from: http://www.pinkbox.space.qinetiq.com/icp2/exploitation/Space_Connexions_Final_Web.pdf, 201 pp .

Kilpatrick, K.A., G.P. Podesta and R. Evans (2001). Overview of the NOAA/NASA Advanced Very High Resolution Radiometer Pathfinder algorithm for sea surface temperature and associated matchup database. J. Geophys. Res., 106 (C5), 9179-9197.

LeBorgne, P., Péré, S. and Roquet, H. (2011), Errors and correction of METOP/AVHRR derived SST in Arctic conditions, Extended Abstract, EUMETSAT Conference Oslo, 2011.

May, D. A., M. M. Parmeter, D. S. Olszewski, and B. D. McKenzie, 1998: Operational processing of satellite sea surface temperature retrievals at the Naval Oceanographic Office. *Bulletin of the American Meteorological Society*, **79,** 397-407.

Merchant C J and Harris A R (1999), Toward the elimination of bias in satellite retrievals of skin sea surface temperature. 2: Comparison with in situ measurements, J Geophys Res, 104, C10, 23579-23590.

Merchant C J, Harris A R, Maturi E and MacCallum S (2005), Probabilistic physically-based cloud screening of satellite infra-red imagery for operational sea surface temperature retrieval, Quart. J. Royal Met. Soc., 131, 2735-2755.

Merchant C J, P Le Borgne, A Marsouin and H Roquet (2008a), Optimal estimation of sea surface temperature from split-window observations, Rem. Sens. Env., 112 (5), 2469-2484. doi:10.1016/j.rse.2007.11.011

Merchant C J, D Llewellyn-Jones, R W Saunders, N A Rayner, E C Kent, C P Old, D Berry, A R Birks, T Blackmore, G K Corlett, O Embury, V L Jay, J Kennedy, C T Mutlow, T J Nightingale, A G O'Carroll, M J Pritchard, J J Remedios and S Tett (2008b), Deriving a sea surface temperature record suitable for climate change research from the along-track scanning radiometers, Adv. Sp. Res, 41 (1), 1-11. doi:10.1016/j.asr.2007.07.041

Merchant, C. J., M. J. Filipiak, P. Le Borgne, H. Roquet, E. Autret, J.-F. Piolle, and S. Lavender (2008c), Diurnal warm-layer events in the western Mediterranean and European shelf seas, Geophys. Res. Lett., 35, L04601, doi:10.1029/2007GL033071.

Minnett, P. J., R. O. Knuteson, F. A. Best, B. J. Osborne, J. A. Hanafin, and O. B. Brown, 2001: The Marine-Atmosphere Emitted Radiance Interferometer: A high-accuracy, seagoing infrared spectroradiometer. J. Atmos. Oceanic Technol., 18, 994–1013.

Minobe, S., Kuwano-Yoshida, A., Komori, N., Xie, S.-P. and Small, R. J. (2008): Influence of the Gulf Stream on the troposphere. Nature, 452**,** 206-209.

National Research Council (NRC), 2008: Ensuring the Climate Record from the NPOESS and GOES-R Spacecraft: Elements of a Strategy to Recover Measurement Capabilities Lost in Program Restructuring Committee on a Strategy to Mitigate the Impact of Sensor Descopes and Demanifests on the NPOESS and GOES-R Spacecraft, National Research Council, ISBN-13: 978-0-309-12184-2 190 pages available from http://books.nap.edu/catalog.php?record_id=12254#orgs.

O'Carroll, A. G., Eyre, J.R., Saunders, R.W., (2008). Three-way error analysis between AATSR, AMSR-E, and in situ sea surface temperature observations. Journal of Atmospheric and Oceanic Technology, 25, 1197-1207Oesch, D. C., J.-M. Jaquet, A. Hauser, and S. Wunderle, 2005: Lake surface water temperature retrieval using advanced very high resolution radiometer and Moderate Resolution Imaging Spectroradiometer data: Validation and feasibility study, *J. Geophys. Res.*, 110, C12014, doi: 10.1029/2004JC002857.

Oesch, D. C., A. B. Hauser, and S. Wunderle , 2004: Operational application of NOAA-AVHRR data for mapping lake surface temperatures in an alpine environment: feasibility and validation, Remote Sensing for Agriculture, Ecosystems, and Hydrology V. Edited by Owe, Manfred; D'Urso, Guido; Moreno, Jose F.; Calera, Alfonso. Proceedings of the SPIE, Volume 5232, pp. 284-292 (2004).

O’Carroll, A.G., J.R. Eyre, and R.W. Saunders, 2008: Three-Way Error Analysis between AATSR, AMSR-E, and In Situ Sea Surface Temperature Observations. *J. Atmos. Oceanic Technol.*, **25**, 1197–1207.

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

Robinson, I. S. and C. J. Donlon (2003) Global Measurement of Sea Surface Temperature from Space: Some New Perspectives, J. Atm. Ocean Sci. (previously The Global Atmosphere and Ocean System), 9, (1), 19-37. (Note revised bibliographic reference to make it accessible electronically)

Roemmich D. and the Argo Steering Team, 2009: Argo: the challenge of continuing 10 years of progress, Submitted to Proceedings of the Final GODAE Symposium.

Saunders, R. W., N.R.Ward, C.F.England and G.E.Hunt, Satellite observations of sea surface temperature around the British Isles. Bull. Am. Met. Soc. 63 267-272 (1982).

Smith, N.R. and Koblinsky, C., 2001: The ocean observing system for the 21st Century, a consensus statement. In: Koblinsky, C. and Smith, N.R. (Eds.), Observing the Oceans in the 21st Century, pp 1-25, GODAE Project Office, Bureau of Meteorology, Melbourne, Australia.

Stammer, D, F. J. Wentz, and C. L. Gentemann, 2003, Validation of microwave sea surface temperature measurements for climate purposes, Journal of Climate, 16, 73-87.

Stark, J. D., C. J. Donlon, M. J. Martin and M. E. McCulloch, 2007, OSTIA : An operational, high resolution, real time, global sea surface temperature analysis system., Oceans '07 IEEE Aberdeen, conference proceedings. Marine challenges: coastline to deep sea. Aberdeen, Scotland. IEEE.

Vazquez-Cuervo, J., E. Armstrong, K. Casey, R. Evans, and K. Kilpatrick, 2009: A comparison between the Pathfinder Version 5.0 and Version 4.1 Sea Surface Temperature Data Sets: A Case Study for High Resolution, submitted to J. of Climate.

Vincent, R. F., R. F. Marsden, P. J. Minnett, and J. R. Buckley, 2008b: Arctic Waters and Marginal Ice Zones: Part 2 - An Investigation of Arctic Atmospheric Infrared Absorption for AVHRR Sea Surface Temperature Estimates. *Journal of Geophysical Research*, **113,** C08044.doi:10.1029/2007JC004354.

Vincent, R. F., R. F. Marsden, P. J. Minnett, K. A. M. Creber, and J. R. Buckley, 2008: Arctic Waters and Marginal Ice Zones: A Composite Arctic Sea Surface Temperature Algorithm using Satellite Thermal Data. *Journal of* Geophysical Research, 113, C04021.doi:10.1029/2007JC004353.

Walton, C. C., W. G. Pichel, J. F. Sapper, and D. A. May, 1998: The development and operational application of nonlinear algorithms for the measurement of sea surface temperatures with the NOAA polar-orbiting environmental satellites. Journal of Geophysical Research, 103, 27,999-28,012.

Wentz, F. J.,, C. Gentemann, D. Smith, and D. Chelton, 2000: Satellite Measurements of sea surface temperature through clouds. Science,288, 847–850.

Zhang, H.M., R.W. Reynolds, R. Lumpkin, R. Molinari, K. Arzayus, M. Johnson, and T.M. Smith, 2009: An Integrated Global Observing System For Sea Surface Temperature Using Satellites and in Situ Data: Research to Operations. *Bull. Amer. Meteor. Soc.*, **90**, 31–38.

Zhang, H.-M., R. W. Reynolds, and T. M. Smith, 2006: Adequacy of the in situ observing system in the satellite era for climate SST. *J. Atmos. Oceanic Techol*., 23, 107–120.