PROCEEDINGS OF
THE GHRSST XV SCIENCE TEAM MEETING

Cape Town, South Africa
2nd – 6th June 2014

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EXECUTIVE SUMMARY

The Fifteenth Group for High Resolution Sea Surface Temperature (GHRSST) Science Team Meeting (G–XV) was held at the Cape Town Aquarium and University of Cape Town (UCT) Graduate School of business, in Cape Town, South Africa, from 2nd – 6th June, 2014. The South African National Space Agency (SANSA), as well as ESA and EUMETSAT, supported the meeting. Local arrangements were organised by Christo Whittle and Emlyn Balarin from UCT. In total ~ 60 people participated in the meeting throughout the week.

The format of the Science Team Meeting broadly followed that of prior meetings. Monday morning began with introductions from Frank Shillington (Director, Nansen-Tutu Centre, Cape Town) and Peter Minnett (Chair of the GHRSST Science Team). These were followed by talks from Michel Verstraete, Christo whittle and Stewart Bernard on remote sensing activities in South Africa. The rest of Monday was taken up with progress reports from the many agencies that contribute to GHRSST. On Tuesday was again designated for the many GHRSST Technical Advisory and Working Groups (TAGs/WGs). Wednesday began with the first plenary scientific sessions and was followed in the afternoon by the annual team-building event and by the meeting dinner in the evening. A presentation was made to Pierre Le Borgne to mark his retirement and contribution to GHRSST. Thursday was mainly spent in plenary. However, in the afternoon a new activity took place where interactive displays of key GHRSST data systems were given. The last plenary session took place on Friday morning, and the meeting concluded with a wrap-up session, including reports from the Tuesday breakouts, and thanks were said to all involved, particularly the team at UCT for what had been another excellent meeting. In particular, Peter Minnett thanked the many local scientists that turned up and contributed.

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

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

Three new GHRSST Science Team members were nominated and subsequently elected: Ioanna Karagali, Hervé Roquet and Keith Willis.

Three venues were nominated for G-XVI, ESA ESTEC, Qingdao and Rio de Janeiro. Following a show of hands vote, it was decided that the next GHRSST Science Team meeting, G-XVI, will be held at ESA ESTEC, in The Netherlands.

SECTION 1: AGENDA

WELCOME FROM THE SCIENCE TEAM CHAIR

Welcome to the 15th Science Team Meeting of GHRSST - a highlight of the year.

This event marks an important milestone as it is the first time we come to Africa for a Science Team Meeting, and it will be a pleasure to see so many new faces amongst the more established GHRSST members in Cape Town. It is no accident that this venue was chosen as it offers an excellent opportunity to extend the reach of GHRSST to a new continent and to a new group of both young and more established oceanographers and forecasters using satellite measurements. We hope this will result in South African researchers and practitioners maintaining future involvement in the global community facilitated by GHRSST.

A new event this year is a two-day Summer School in the week before the Science Team Meeting. This is intended for local students and others wishing to learn more about satellite remote sensing of the ocean surface temperature. We acknowledge the support of the University of Cape Town by making facilities available for this educational activity.

The agenda this year largely follows those of previous years, being a mixture of plenary and break-out sessions. We have had feedback from some of the Science Team Members arguing for fewer parallel sessions, but it is simply not possible to avoid this given the need to have all of the components of GHRSST represented in a meeting less than a week in length. I hope you will agree with me that the agenda developed by Gary and Silvia is a good compromise, giving us the opportunity to hear many stimulating scientific presentations in plenary, and to have the chance for more detailed discussions in the breakout sessions.

Securing travel funds to attend the Science Team Meetings remains difficult, but it is good that so many have registered to attend, especially those who have to make long journeys. But many familiar faces will be absent, alas. And it is pleasing that there are so many local people involved in this year's meeting.

It is a pleasure to acknowledge the support from the SANSA, ESA and EUMETSAT, without which this Science Team Meeting could not happen. Special thanks are due to Christo Whittle, Emlyn Balarin and colleagues at UCT here in Cape Town for doing so much behind the scenes to ensure the meeting will be a success. The continuing commitments of many national and international funding sources that support the research and practice of many of us involved in GHRSST also deserves acknowledgment.

So, I look forward to seeing you all in Cape Town and anticipate an exciting, stimulating and rewarding meeting. I hope the same goes for you too!

Peter

Peter Minnett

(Chair of the GHRSST Science Team)

MONDAY

Monday, 2nd June 2014	
Plenary Session I: Introductions ***Chair: Peter Minnett Rapporteur: Gary Corlett***	
Welcome and logistics	
Welcome to GHRSST XV	*Peter Minnett*
Welcome address from UCT	*Professor Frank Shillington (Director, Nansen-Tutu Centre, Cape Town)*
Logistics	*Gary Corlett/Christo Whittle*
Remote sensing activities in South Africa	
Defining South Africa's next EO mission	*Michel Verstraete*
OceanSAfrica and SST	*Christo Whittle*
IOCCG and OCR-VC	*Stewart Bernard*
Tea/Coffee Break	
Plenary Session II: Review of activities (Part 1) ***Chair: Anne O'Carroll Rapporteur: Werenfrid Wimmer***	
SST-VC	*Craig Donlon*
GDAC	*Ed Armstrong*
LTSRF	*Ken Casey*
SQUAM and iQUAM	*Alexander Ignatov*
FELYX	*Jean-François Piollé*
Lunch	
Plenary Session II: Review of activities (Part 2) ***Chair: Ken Casey Rapporteur: Dave Poulter***	
ABoM	*Ian Barton/Helen Beggs*
ESA	*Craig Donlon*
EU GDAC	*Jean-François Piollé*
EUMETSAT	*Anne O'Carroll*

Monday, 2nd June 2014	
JAXA	*Yukio Kurihara/Misako Kachi*
JMA	*Shiro Ishizaki*
MISST	*Gary Wick/Chelle Gentemann*
Tea/Coffee Break	
Plenary Session II: Review of activities (Part 3) ***Chair: Alexander Ignatov Rapporteur: Prasanjit Dash***	
MyOcean	*Hervé Roquet*
NASA	*Ed Armstrong*
NAVO	*Jean-François Cayula/Doug May*
NOAA	*Ken Casey*
NESDIS/STAR GHRSST SST Products	*Eileen Maturi*
EarthTemp Arctic Workshop	*Jacob Hoeyer*

TUESDAY

<table>
<tr><th colspan="2">Tuesday, 3rd June 2014</th></tr>
<tr><td colspan="2"><u>GHRSST Parallel Breakouts for TAGs/WGs</u></td></tr>
<tr><td>STVAL</td><td>DASTAG</td></tr>
<tr><td>

Overview of ST-VAL activities since GHRSST-XIV - Presented by Pierre LeBorgne (5 mins)
Validation:

Monitoring and Validation of HR L2 SSTs in SQUAM (Prasanjit Dash) (10 mins)
Questions/discussion on validation (5 mins)

SSES Methods

ABoM SSES (Chris Griffin - via telecon) (10 mins)
NOAA/STAR SSES (Boris Petrenko) (10 mins)
NAVOCEANO SSES (Jean-Francois Cayula) (10 mins)
MODIS/VIIRS SSES Hypercube (Peter Minnett) (10 mins)
IASI SSES (Anne O'Carroll) (10 mins)
OSI-SAF SSES (Pierre LeBorgne) (10 mins)
Discussion on SSES (10 mins)

In Situ Data for Validation:

Fiducial Reference Measurements for Thermal Infrared Satellite Validation (FRM4-CEOS) - Craig Donlon (10 mins)
Shipborne Radiometer data format and common repository - Tim Nightingale (10 mins)
Discussion on in situ data (5 mins)

Election of new ST-VAL Deputy Chair (5 mins)

</td><td>

Issues related to L2P specification for dual-view sensors (Anne O' Carroll)
Quality, Quantity, Continuity, Latency use cases for GHRSST data (Ed Armstrong)
Proposal for a GHRSST Ship-borne Radiometer Format, “L2i” (Tim Nightingale)
Evolution of the GHRSST Regional/Global Task Sharing (R/GTS) Framework (Ken Casey)
Issues related to GDS 2.0 for Climate Products (Owen Embury)

Discussion topics:

R/GTS reorganization
Dataset relevancy, ranking and maturity
GDS 2.0 change policy

</td></tr>
<tr><td colspan="2">Tea/Coffee Break</td></tr>
<tr><td>DVWG</td><td>AUSTAG</td></tr>
<tr><td>Awaiting final agenda – session will include 10 min presentations on:</td><td>

Lessons learned from the GHRSST Ocean Science Booth and recommendations (Gary Corlett with inputs from Silvia, Jorge, Prasanjit

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</table>

<table>
<tr><th colspan="2">Tuesday, 3rd June 2014</th></tr>
<tr><td>An analysis system for diurnal Sea Surface Temperature (Jonah Roberts-Jones)
Regional SST diurnal warming from SEVIRI (Ioanna Karagali)</td><td>and all) 20 min
Review of AUS-TAG Strategic Plan - overview of activities and users' statistics & future plans (Jorge Vazquez and Prasanjit Dash with any further inputs) 20 min
Validation of a hybrid coordinate ocean model (HYCOM) on the Agulhas Bank shelf south of Africa using GHRSST MUR and 1km MODIS data (Christo Whittle and Bjorn Backeberg et al.) 20 min
What products to use? – A VIIRS case study: NAVO vs. ACSPO (Prasanjit Dash and Alex Ignatov with any further inputs) 10 min
Which in situ products are available to use? – A technical overview of iQuam data (Alex Ignatov with any further inputs) 10 min
Which in situ products are available to use? – An overview of shipboard radiometers (Peter Minnett) 10 min
Interactive discussions on GHRSST archive (Led by Alex Ignatov) 20 min
From the perspective of data producers (e.g., L2/L4 users who push their data to PO.DAAC): Efficient archival – how to backfill missing data, archive L3 version of L2p, how to best provide and promote information about a product (web-page, inter-comparison documents etc).
From the perspective of data users (e.g., L4 producers seeking L2 data): Efficient access to archive (feedback that access to NOAA ftp is 2x faster that PO.DAAC ftp); bandwidth, number of users etc.
Demos/Overviews of GHRSST GDAC/LTSRF Tools & Services, Data usage Are they adequate to meet user needs? (Jorge Vazquez, Gary Corlett, all) 20 min</td></tr>
<tr><td colspan="2">Lunch</td></tr>
<tr><th>HLTAG</th><th>CDRTAG</th></tr>
<tr><td>Latest report on high latitude work at CMS (Pierre LeBorgne)
VIIRS algorithm performance at high latitudes (Sasha Ignatov)
Temporal Sea ice Cover in the Baltic Sea (Martin Lange)</td><td>Results from trials of the CDAF (Chris Merchant)
Review of Status Report on International Reprocessing Efforts (Jon Mittaz)
Updates on CORE-CLIMAX and Maturity Matrices (Chris Merchant)</td></tr>
</table>

<table>
<tr><th colspan="2">Tuesday, 3rd June 2014</th></tr>
<tr><td>Sea ICE GMPE – Definitions and development (Steinar Eastwood)
Follow up actions and developments from the Earthtemp meeting in Exeter (Jacob Høyer)
Discussion of the justification for the HL-TAG (All)</td><td>FIDUCEO, a proposal to EU H2020 (Jon Mittaz)
Discussion: funding GHRSST climate activities (Chris Merchant)
CDR-TAG Chair/Vice Chair succession (Chris Merchant)</td></tr>
<tr><td colspan="2">Tea/Coffee Break</td></tr>
<tr><td>EaRWiG</td><td>ICTAG</td></tr>
<tr><td>Agenda/purpose (chair)
Discussion/agree agenda
Algorithm bias correction
Regional biases in operational SST retrieval (LeBorgne)
Discussion
SST Sensitivity
Intro (chair)
Information content analysis for physical SST retrieval (Koner)
Discussion
Cloud detection
Evaluation of performance of different cloud schemes using long-term Geo-SST matchup database (Koner)
Discussion
EARWiG activities for coming year
Proposed Workshop @Reading (vice-chair)
Discussion</td><td>16:00-16:10 Introduction
16:10-17:15 Talks and discussion on inter-comparison of L4 SST products and their validation
Talks (10 min each) followed by a discussion (15 min total):
16:10-16:20: Biases between In Situ and Remotely-Sensed Data Sets around the Coast of South Africa (Albertus Smit)
16:20-16:30: REMO SST GROUP: Status & Updates (Gutemberg Franca)
16:30-16:40: Validation of Sea Surface Temperature Analyses in the Arctic Ocean Using UpTempO Buoys (Sandra Castro)
16:40-16:50: A Review on the Application of High Resolution SSTs in a Coastal Upwelling Region: The test case off Peru (Jorge Vazquez)
16:50-17:00: An intercomparison of long-term SST reanalyses using the GHRSST multi-product ensemble (GMPE) system (Jonah Roberts-Jones)
17:00-17:15: Discussion
17:15-17:45: Discussion of major IC-TAG issues
Topics:
Conversion of inter-comparisons to user recommendations (i.e., answering questions: “Why do all these products differ?” and “Which SST should I use?”)
Inter-comparison results to date and uncertainty in L4 products
Inter-comparison systems (GMPE, SQUAM, FELYX)
Suggestions/Recommendations for further inter-comparisons
17:45-18:00: General discussion and plans for the next year</td></tr>
</table>

WEDNESDAY

Wednesday, 4th June 2014	
Plenary Session III: SST in African waters ***Chair:*** *Gutemberg Franca* ***Rapporteur:*** *Jonah Roberts-Jones*	
Time series of SST anomalies off Western Africa	*Charlie Barron*
Coastal change and variability around Southern Africa	*Mathieu Rouault*
Characterization of Agulhas Bank upwelling variability from 1km MODIS Aqua/Terra data	*Christo Whittle*
Tea/Coffee Break	
Plenary Session IV: Diurnal variability ***Chair:*** *Gary Wick* ***Rapporteur:*** *Sandra Castro*	
A diurnally corrected high-resolution SST analysis	*Andy Harris*
Using a 1-D model to reproduce diurnal SST signals	*Ioanna Karagali*
Validation of SST and diurnal warming in Lake Vaenern, Sweden	*Steinar Eastwood*
Afternoon Team Building and GHRSST Dinner	

THURSDAY

Thursday, 5th June 2014	
Plenary Session V: L4 analyses ***Chair:*** *Alexey Kaplan* ***Rapporteur:*** *Ed Armstrong*	
Biases Versus Variability in Differences Between Gridded SST Products	Alexey Kaplan
A validation of the error estimates in SST analyses	*Jonah Roberts-Jones*
Producing gap-free analysed sea surface temperature data from L3 products using web-based Data INterpolation Empirical Orthogonal Functions (DINEOF) technique	*Igor Tomažić*
Tea/Coffee Break	
Plenary Session VI: Impact of clouds on SST retrievals ***Chair:*** *Andy Harris* ***Rapporteur:*** *Owen Embury*	
Bayesian Cloud Detection for AVHRR instruments	*Owen Embury*
Extension of ACSPO VIIRS SST domain using pattern recognition analyses	*Irina Gladkova*
Sea surface temperature characterization using a high-resolution ocean model	*Ed Armstrong*
Lunch	
Plenary Session VII: New data streams ***Chair:*** *Craig Donlon* ***Rapporteur:*** *Tim Nightingale*	
Evaluation of SST products from HY satellites	*Lei Guan*
Update on VIIRS	*Alexander Ignatov*
SSTs from GCOM-W1 AMSR2	*Chelle Gentemann/Gary Wick*
Future NOAA/NESDIS/STAR GEO Dataset	*Eileen Maturi*

FRIDAY

Friday, 6th June 2014		
Plenary Session VIII: Climate Data Records ***Chair:*** *Chris Merchant* ***Rapporteur:*** *Jon Mittaz*		
SST algorithms in ACSPO reanalysis of AVHRR GAC data		*Boris Petrenko*
ESA's Sea Surface Temperature Climate Change Initiative: Outcomes from Phase I and Plans for Phase II		*Chris Merchant*
SST CCI trail-blazer users: engagement and results		*Chris Atkinson*
Tea/Coffee Break		
Closing Session ***Chair:*** *Peter Minnett* ***Rapporteur:*** *Gary Corlett*		
Report from Advisory Council		*Anne O'Carroll*
Summary of breakout groups		
1	*AUS-TAG*	*Jorge Vazquez*
2	*CDR-TAG*	*Christopher Merchant*
3	*DAS-TAG*	*Ed Armstrong*
4	*DVWG*	*Gary Wick*
5	*EaRWiG*	*Andy Harris*
6	*HL-TAG*	*Jacob Hoeyer*
7	*IC-TAG*	*Alexey Kaplan*
8	*ST-VAL*	*Pierre Le Borgne/Helen Beggs*
Review of action items		
Identification of priorities for following 12 months		
Wrap-up/closing remarks		
Close of GHRSST XV		

SECTION 2: PLENARY SESSION REPORTS AND ABSTRACTS

PLENARY SESSION II: REVIEW OF ACTIVITIES I

SESSION REPORT

Chair: Anne O'Carroll(1), Rapporteur: Werenfrid Wimmer(2)

(1) EUMETSAT, Darmstadt, Germany, Email: Anne.Ocarroll@eumetsat.int
(2) University of Southampton, UK, Email: w.wimmer@soton.ac.uk

1. SST-VC: Craig Donlon

Status and Issues

- Terms of Reference and Implementation
- CEOS Radiometer inter-calibration
- SST-VC paper

Implementation Targets:

- Wider participation of CEOS Agencies
- User community
- Better product service, access interoperability
- Value for money
- Reduce duplication of coordinating activities

Maturation:

- - New SIT chair (J-L Fellous) new CEOS lead (P. Ultra-Gerrad)
- - CEOS 2014-2016 work plan
- - GHSST as an example for VC
- - Terms of Reference for all VC

Status and Issues:

- Space segment
    - No dual view IR
    - Passive MW SST not secure
    - Fiducial Reference Measurements (FRM)still a challenge
- Strong international collaboration
- Needs CEOS member state participation
- LTSRF registered all data at CEOS
- WGCV shipborne radiometer inter-comparison 2014/1015
- Essential elements for VC

There is a need for a requirement based white paper (based on ocean ops 2009). Technical Reference series IOCCG is a good example; we should do the same for GHRSST. VC white paper could be the first reference paper.

Plans for an ITT for Shipborne Radiometer inter-comparison were presented and potential routes for SI tractability for Argo, GTMBA, drifting buoys discussed.

2. GDAC: Ed Armstrong

Highlights

- GDS1 maintenance
- GDS2 ingestion
- Link to LTSRF
- Tools
- User community
- Data management and lifecycle

Users use mainly FTP, OpenDAP and threads gain a share recently.
New webportal has been launched, http://podaac.jpl.nasa.gov/ .
Tools for processing and accessing data can be found at http://podaac.jpl.nasa.gov/podaac_labs.

PO.DAAC web services are chained so one can use them to make a processing chain.
Webification (a JPL development) is similar to OpenDAP, but more powerful : Subsetting by variable range in url! -> virtual Quality Screening Service.
Four GDS2 datasets have been released (lifecycle of datasets becomes more important).
A demonstration of the PO.DAAC tools will be held on Thursday afternoon.

Lifecycle quality information, data relevance information on GHRSST data sets has to be improved, Data policy for data sets is needed; This will be discussed in the DAS-TAG.

PO.DAAC new manager: Rob Toaz (Dec 2013)

- GHRSST is ‘mission’ under NASA-ESDIS

Q: Monthly statistics, Can user location be identified?
A: Currently not, but should be possible in the future
Casey: Using google analyses, but still new so might be able to do that in the future.

Q: Webification service; code opensource?
A: JPL technology; Ed can put people in contact with author, but its open source.
Casey: New DAP has the same filtering capability.
Demo on Thursday!

3. LTRSF: Ken Casey

Flowchart on the data flow chain RDAC->GADC-LTSRF
No new service since last year put improvement on the new services from last year.
From the RDACs a comma separated monthly user files would be great; NODC will accumulate them and display the information.
The GHRSST holding at CEOS is seconded highest user product holding.

Major PO.DAAC reconciliation project completed (less reliant on xml files)

Improvements on the data ingestion include GDS2 operations (More checks possible with netcdf4), Browse/kml Graphics automated generation and automated status reporting.

Issues:

- (A)ATSR tapes: LTSRF needs in writing that no longer needed.
- SST Climatology’s in GDS2; This needs a GHRSST decision
- GCOS SST inter-comparison: is it still needed

- Growing volumes – ok at the moment; but are multiple version of products really needed?
- *Digital Object Identifier* (DOI) can be issued at LTSRF now; Need some coordination if implemented for GHRSST.
- NODC can directly receive data, for reprocessed data sets, however the data should go thorough GDAC first. Its best to contact the GDAC and LTSRF if you are submitting reprocessed data to check on procedure.

Q: Issues on climatology's in GDS2 format
A: No technical issues; no explicit format in GDS; needs some formalization

Q: Newer technologies for data access: New users; or old users using new technology.
A: Good question; but currently not known.

4. SQUAM & IQUAM: Alexander Ignatov

SQUAM: community system.

- Deviations from reference SST
- Showed example of two Metop Products (OSI-SAF; ACSPO) with cloud contamination. Comparison with CMC (climatology), Reynolds (no metop assimilation), OSTIA (OSI-SAF assimilation) L4. Also vs. iQuam.
- Improved stability and efficiency of the system
- Filled in more SST L2 products
- Future:
  - Complete L4 and L2 IR products
  - Setup geo-Squam
  - New knowledge and understanding

iQuam:

- Objectives: QC, Monitoring, Data serving
- version 1 2009; version 2 later in 2014
- Monthly statistics, by drifters, GMTBA, coastal moorings, ships; individual platforms
- IQuam 2: add argo, time series to 1982 using ICOADS; CMS blacklist; trackop Ship, GHRSST buoys …
- Main data volume form drifters.

A: Argo, flag on windspeed
Q: wind speed is saved (not saved) with iQuam; uses the top AGRO measurement, highest quality measurements (6 to 8 m). Depth is reported in iQuam.

5. Felyx: Jean-François Piollé

Free open-source software to analysis large EO data sets (github)

- different processing algorithms
- dataset inter-comparisons
- data download and subsetting
- diagnostic report productions
- distributed processing
- networked production sites

- social media
- file format and domain agnostic

Felyx is based miniprods (static sites or trajectories) and a searchable JSON file index. Data input is via an agnostic third party tool. The access to Felyx is either via a RESTful interface (web) or a python API. A workflow concept is implemented and operations can be done on the fly. Automated report generation and bookmarking (i.e.: generate the same report monthly) are supported. Also there is a user configurable anomaly detection and alert implemented. Test system is based on the meditation sea and the GHRSST MDB. The Felyx system is open source and users can have their own instance either installed from source or as a linux container (LXC).

Status:

- Backend almost finished
- Interfaces and bug fixes needed
- Better administration and API still to be implemented
- Starting full scale tests soon
- First release in Sept 14 with 6month demonstration and bug fix phase.

Q: do you know research gate
A: Yes, but not implemented yet, but I can be added (or you add it yourself). Tools are not finished yet.

Q: Batch mode?
A: Operation can be automatically (as new data arrives); or can be run in batch mode (reprocessing)

Q: Band width limitation?
A: Extraction is statistical values; data has already been processed; System is scalable, disk storage and processor load configurable;

REPORT FROM THE CEOS SST-VC

Craig Donlon[(1)], Kenneth S. Casey[(2)]

(1) European Space Agency, the Netherlands, Email: craig.donlon@esa.int
(2) Kenneth Casey, NOAA NODC, USA, Email: kenneth.casey@noaa.gov

ABSTRACT

1. Introduction

The SST-VC exists to foster the best quality sea surface temperature data and their availability for applications across all relevant spatial and temporal scales in the most effective and efficient manner through international collaboration, scientific innovation, and rigor.

The SST-VC addresses the following strategic objectives to address this aim:

- Maintain a strong and mutually supportive relationship and interface between CEOS and the activities of the Group for High Resolution SST (GHRSST);
- Foster better engagement by Nations operating or preparing satellite SST sensors;
- Work to assure the long term continuity of all necessary space-based components including passive microwave and dual-view, high quality IR reference-sensor SST data;
- Synthesize the driving requirements for SST measurements from space;
- Support outreach, education and development of new SST practitioners;
- Promote GHRSST standards for satellite SST;
- Advocate priority areas for funding of SST activities;
- Promote the sharing of data.

2. Characterisation of the measurements and data collections within the SST-VC scope

The geophysical parameter concerning the SST-VC is Sea Surface Temperature measured by infrared and passive microwave satellite sensors supported by in situ measurements required for quality control.

The SST-VC works with GHRSST to publish technical guidelines for GHRSST compliant datasets known as the GHRSST Data Specification (GDS). CEOS Agencies wishing to contribute their datasets to GHRSST and the SST-VC conform to the GDS. GHRSST and the SST-VC maintain data discovery and access to all GHRSST-formatted products, using the GHRSST Global Data Assembly Centre, the GHRSST Long Term Stewardship and Reanalysis Facility, GHRSST Regional Data Assembly Centres, and the CEOS-WGISS Integrated Catalogue as appropriate.

3. Characterisation of the space segment concerned

The SST-VC addresses all SST-capable space-based platforms as well as relevant in situ platforms, including but not limited to polar and geostationary orbiting platforms, infrared and microwave-based sensors, in situ radiometers, surface drifters, moored buoy arrays, and near-surface profiling instruments – implicating a large number of CEOS agency missions. The core missions that are currently the priority for coordination efforts by the SST-VC are:

- Metop series (AVHRR/IASI);
- NOAA POES series (AVHRR);
- Suomi NPP (VIIRS);

- GCOM-W series (AMSR2)
- TRMM (VIRS/TMI)
- TERRA/AQUA (MODIS/AMSR-E)
- Coriolis (WindSat)
- METEOSAT series (SEVIRI/MVIRI)
- GOES series (Imager)
- MTSAT series (IMAGER)
- HY series (COCTS/RAD)
- FY series (Imager)
- INSAT-3D series (Imager)
- COMS series (Imager)

With the following future missions being of particular importance: Sentinel-3 (SLSTR), GCOM-C (SGLI), JPSS (VIIRS), GOES-R (Imager), MTG (FCI), FY-4 (MCSI). SST-VC activities include coordination of capabilities of a much broader range of CEOS agency missions and instruments.

Other SST-VC activities include the coordination of homogenous SST climate data records from past space-based sensors (dating from the early 1970s), better specification of uncertainty estimates within SST products, better use of reference sensors (e.g., ENVISAT AATSR and the Sentinel-3 SLSTR) within the Constellation, and efforts to assure the long-term continuity of passive microwave SST data.

The CEOS Missions, Instruments and Measurements database (available at http://database.eohandbook.com/) provides a comprehensive reference for SST missions. Not all of these missions are currently contributed to GHRSST and the SST-VC.

4. Activities, outcomes and deliverables

The SST-VC has identified the following high-level outcomes and deliverables on 3- and 5-year horizons. Annual activities leading toward these longer-term outcomes are identified and updated each year in the separate SST-VC Implementation Plan document.

	3-year horizon	**5-years or more horizon**
Space Segment	▪ Documented plan for the required virtual constellation ▪ The 2015 constellation will have many of the core elements required to satisfy the main user requirements (with the planned launch of the first Sentinel-3 (with SLSTR) closing the current gap in dual-view IR capability).	▪ It is hoped that sustained effort will sustain C-band passive microwave SST products and develop a real aperture capability approaching 10 km. ▪ Dual-view IR reference sensor is expected to be reinstated with the launch of Sentinel-3 SLSTR. ▪ An optimistic launch schedule suggests that the IR imaging capability is well supported.
Ground Segment & Information Systems	▪ 100% of GHRSST Products Discoverable through the CEOS IDN and CWIC system	▪ 100% of GHRSST Products Discoverable through the CEOS IDN and CWIC system

	3-year horizon	**5-years or more horizon**
Products & Services	▪ GDS2.0 specification in widespread use; Fully developed Climate Data Assessment Framework (CDAF) ▪ International exchange of common-specification data sets in place for many (but not all) SST satellite sensors ▪ Basic uncertainty information attached to some data sets	▪ SST Climate Data Assessment Framework (CDAF) implemented routinely for all GHRSST data designated as ECV products. ▪ International exchange of all SST satellite data sets using common specifications. ▪ Uncertainty estimates attached to all SST data sets

Reports to SIT from the SST-VC will emphasize progress towards achievement of these outcomes and deliverables and the issues and obstacles for SIT attention.

5. The current SST-VC schedule

Activity	**Milestone**	**Target Date**
1. Develop and optimize the SST constellation	Develop a White Paper describing and justifying the SST- Virtual constellation.	Sept. 2015
2. Develop and implement metrics for SST services, products, and users	Focus discussion at 2014 GHRSST/SST-VC workshop Preparation of position paper	June 2015 September 2015
3. Coordinate consensus SST reference documents	Publish updated GHRSST Data Specification 2.0 (GDS2).	Annually
4. Encourage timely access to products	62/62 GHRSST fully integrated in IDN/CWIC (WGISS)	Complete by Sept. 2014
5. Develop and improve the satellite SST ECV	Complete and publish the SST Climate Data Assessment Framework (CDAF)	2014/15
6. Improve SST calibration, inter-calibration, and validation	Hold an IR radiometer inter-comparison exercise building on the ISSI focus group conclusions	2015

SST-VC meets normally once per year in conjunction with the annual GHRSST Science Team Meeting.

More details of the SST-VC schedule of activities and milestones is maintained and updated annually in the separate SST-VC Implementation Plan document.

6. Membership and leadership

The current SST-VC Co-Leads are:

- NOAA, Kenneth S. Casey (Kenneth.Casey@noaa.gov)
- ESA, Craig Donlon (Craig.Donlon@esa.int)

And the following CEOS agencies are actively involved in SST-VC:

JAXA	Misako Kachi (Kachi.Misako@jaxa.jp)
NASA	Andrew W Bingham (Andrew.W.Bingham@jpl.nasa.gov)
EUMETSAT	Hans Bonekamp (Hans.Bonekamp@eumetsat.int)
UKSA	Chris Merchant (C.J.Merchant@reading.ac.uk)
CSIRO	Helen Beggs (H.Beggs@bom.gov.au)
SANSA	Jane Olwoch (JOlwoch@sansa.org.za)
G. Corlett	WGCV representative and GHRSST Project Office (ex officio)
P.J Minnett	GHRSST Science Team Chair (ex officio)

7. Resources

The SST-VC leverages existing contributions by participants in GHRSST and on a volunteerism basis with additional resources provided by member Agencies (e.g. ESA Climate Change Initiative, Support to the GHRSST Project Office, NASA PO.DAAC, NOAA NODC data stewardship)

8. Implementation and coordination issues

Achievement of the SST-VC objectives requires the following implementation and coordination issues to be addressed by SIT:

1. The necessary CEOS agency participation in the generation of SST data products and coordination activities.
2. CEOS agency participation in Satellite SST metrics to assess, monitor and improve the collective SST capability for user communities.
3. Support to the SST-VC activities striving to achieve and maintain standards based traceability for on-orbit validation activities (i.e. in situ radiometer round-robin activity).
4. Endorsement of the SST-VC white paper describing and justifying the overall scope and components of the CEOS SST- Virtual constellation.

GLOBAL DATA ASSEMBLY CENTER (GDAC) REPORT

Edward Armstrong[(1)], Jorge Vazquez[(1)], Rob Toaz[(1)], Michelle Gierach[(1)], Thomas Huang[(1)], Cynthia Chen[(1)], Chris Finch[(1)], Charles Thompson[(1)]

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ABSTRACT

In 2013-2014 the Global Data Assembly Center (GDAC) at NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC) continued its role as the primary clearinghouse and access node for operational GHRSST data streams, as well as its collaborative role with the NOAA Long Term Stewardship and Reanalysis Facility (LTSRF) for archiving. Our presentation reported on our data management activities and infrastructure improvements since the last science team meeting in 2013.

1. Accomplishments

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

- Ingesting and distributing GDS2 datasets
  - Four new GDS2 datasets were brought online via the dataset lifecycle policy, others added for FTP distribution only
- Supported operational datastreams for L2P/L3/L4 data from 14 RDACs
  - Maintained existing GDS1 datastreams
  - Maintained linkages to data providers and LTSRF archive
- Developed tools and services for data usage
  - Web services, Subsetting, Visualization, Data Aggregation
- User community engagement
  - GHRSST webinar and supported GHRSST Ocean Sciences booth.
- Data management and lifecycle implementation

2. Distribution metrics

The following figures show distribution metrics from the GDAC since 2005. Users, data volumes and number of files are all steady or have slightly increased. Users are leveraging interfaces and services such as OPeNDAP, THREDDS and LAS more so than in the past. The LTSRF report will present the GHRSST project summary statistics.

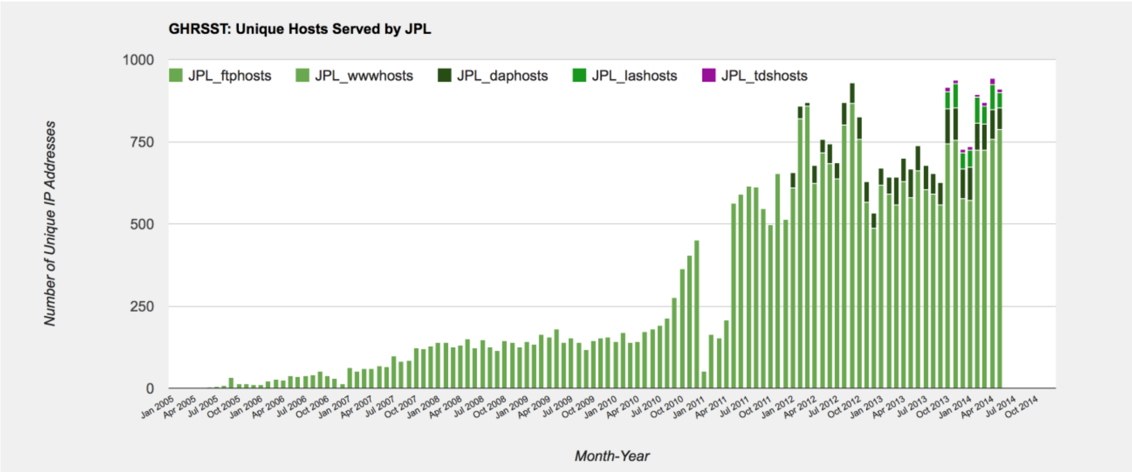

Figure 1: Number of unique monthly users via FTP, OPeNDAP, LAS and THREDDS

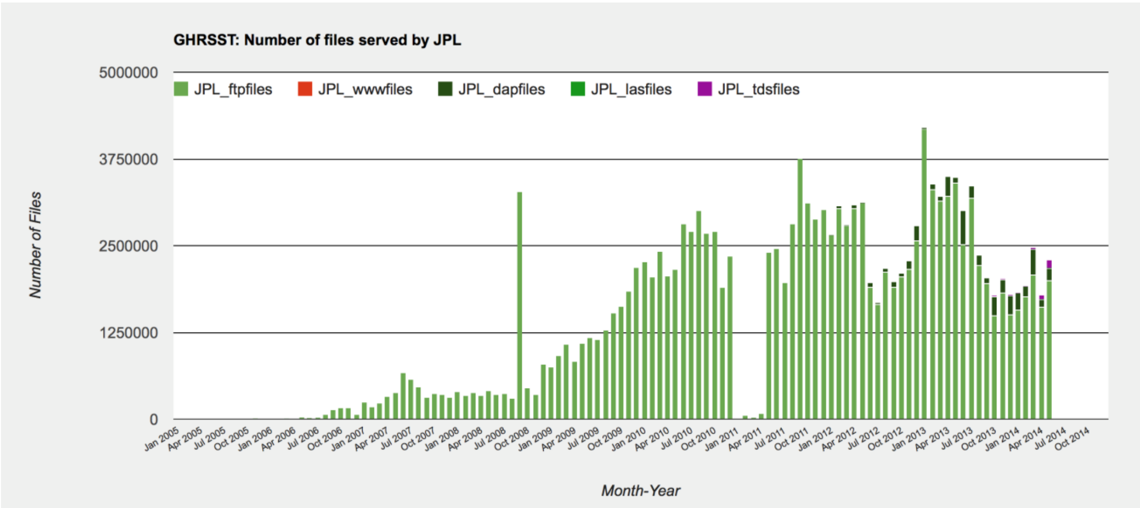

Figure 2: Number of monthly files distributed

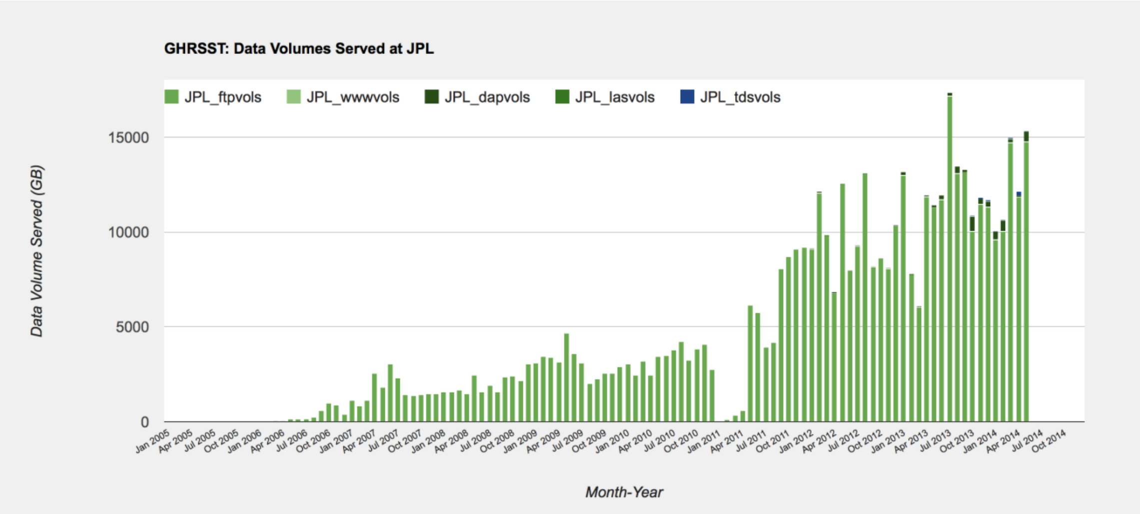

Figure 3: Volume of monthly files distributed

3. GDS2 Datasets status

The following GDS2 specification datasets are now available via FTP and OPeNDAP at a minimum. Those marked as "Released" have generally completed the PO.DAAC dataset lifecycle policy requirements. More GDS2 datasets are expected in the coming months.

Dataset(s)	RDAC	Status
L4 OSTIA	UKMO	Released
L4 DMI_OI	DMI	Released
L4 CMC0.2deg	CMC	Released
L2p VIIRS	NAVO	Released
L2P VIIRS	OSPO	Ingested and Accessible
L2P AVHRR18, 19, MTA, MTB	NAVO	Ingested and Accessible
L2P GOES 13, 15	OSPO	Ingested and Accessible
L2P MSG	OSPO	Ingested and Accessible
L2P MTSAT2	OSPO	Ingested and Accessible
LC3 AVHRR19, MTA	OSISAF	Ingested and Accessible
L2P AVHRR MTA	OSISAF	Ingested

4. Tools and Services

Many new tools or improvements to existing tools can be found in the "PO.DAAC Labs" (http://podaac.jpl.nasa.gov/podaac_labs

- **SOTO2D**: visualization including GHRSST MODIS L2P, Windsat L3, G1SST L4
- **PO.DAAC Web Services**: search, discovery, metadata, extract as "chained" services. ISO metadata generation service
- **HiTIDE**: GUI based L2 subsetting
- **Webification (w10n)**: Arbitrary data store exposed as URLs. Subset by value (see example below)

- **Coastal Marine Discovery Service**: GIS interface for satellite data
- **Datacasting**: RSS Informed earth science data availability
- **Live Access Server** (LAS) for L3/L4 subsetting
- **Virtual Quality Screening Service:** Upcoming NASA funded technology project to implement quality screening web service for GHRSST and SMAP data

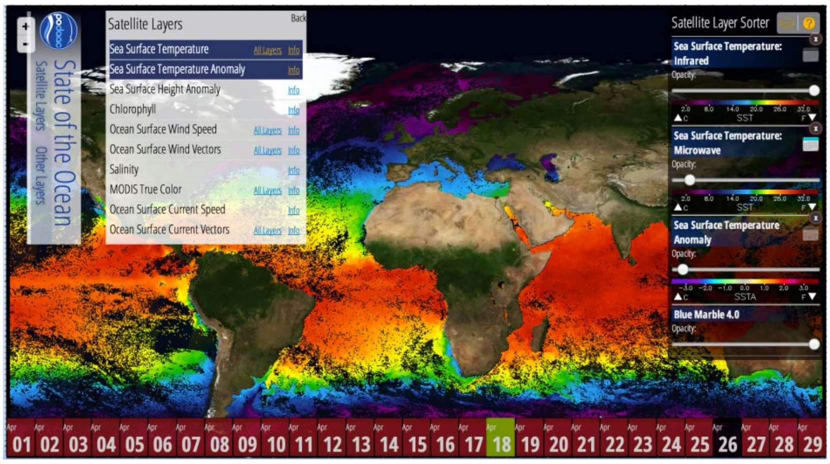

Figure 4: State of the Ocean (SOTO) 2D: An improved interface for exploring satellite visualizations including GHRSST data

Examples of webification service invocations depicting advance SST screening and subset by value for a MODIS L2P granule.

- Subset a L2P granule (by latitude and longitude value)
  - http://host:port/path/2013/123/20130503-MODIS_T-JPL-L2P-T2013123065500.L2_LAC_GHRSST_N-v01.nc.bz2/sea_surface_temperature[**-130<lon<-120,35<lat<45**]?output=format
- Apply a quality filter
  - http://host:port/path/2013/123/20130503-MODIS_T-JPL-L2P-T2013123065500.L2_LAC_GHRSST_N-v01.nc.bz2/sea_surface_temperature[**quality_flag>=4**]?output=format
- Quality filter, wind screen, subset all in one step:
  - http://host:port/path/2013/123/20130503-MODIS_T-JPL-L2P-T2013123065500.L2_LAC_GHRSST_N-v01.nc.bz2/sea_surface_temperature[**quality_flag>=4,wind_speed>6,-130<lon<-120,35<lat<45**]?output=format

5. Summary

- GHRSST has a stable and growing user community
- GDS2 datasets online, discoverable, available via tools and services
- New PO.DAAC tools and services implemented for subsetting, discovery, dataset and granule web services.
- Issues for concern and consideration raised at the GDAC report on the first day and throughout the meeting

a. Dataset lifecycle implementation to collect improved data quality information
b. GHRSST dataset relevancy and selection is an issue for many users
c. Evolution of R/G Task Sharing framework

6. Acknowledgements

This work was carried out at the NASA Jet Propulsion Laboratory, California Institute of Technology. Government sponsorship acknowledged. Copyright 2014 California Institute of Technology. Government sponsorship acknowledged.

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

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ABSTRACT

Since the 14th GHRSST Science Team Meeting, the Long Term Stewardship and Reanalysis Facility (LTSRF) at the US National Oceanographic Data Center (NODC) has made significant progress in the long-term stewardship of all GHRSST datasets. This report summarizes these accomplishments and provides an overview of the contribution the US NODC is providing to the international SST community.

1. Introduction

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

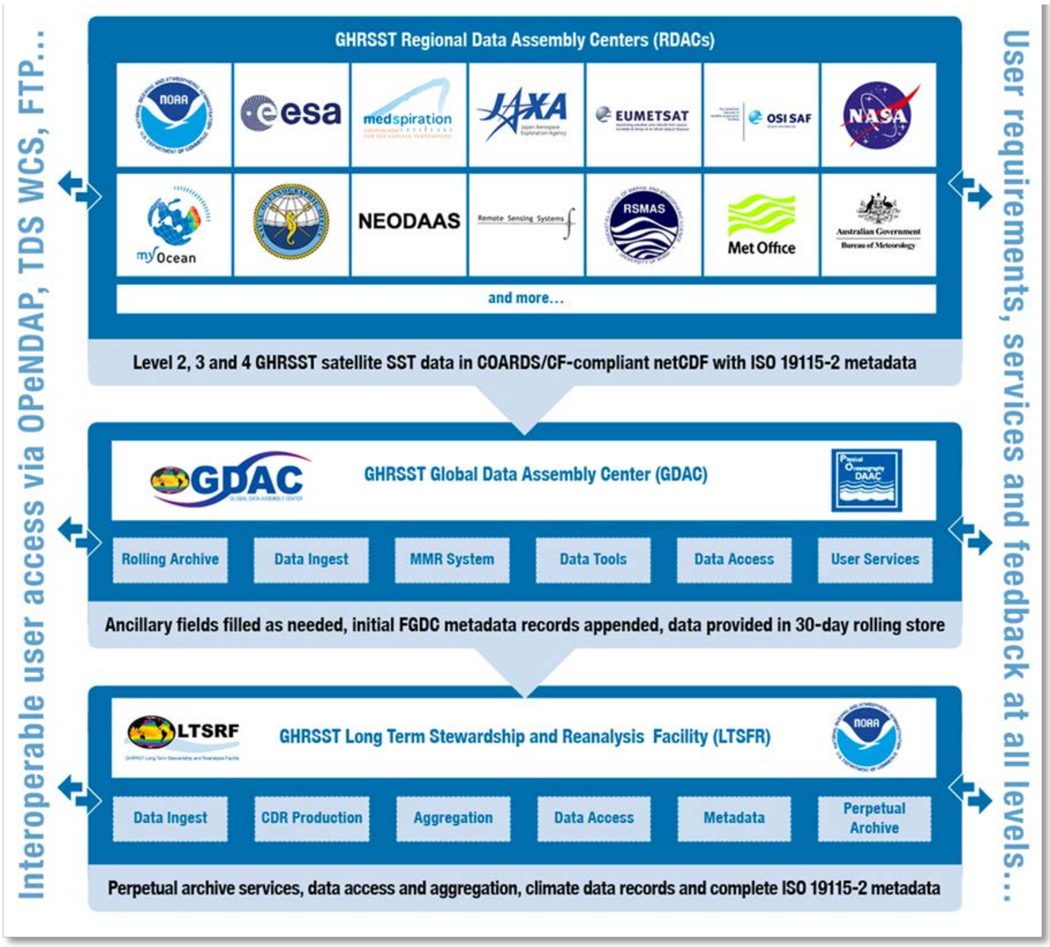


Figure 1: The GHRSST Regional Global Task Sharing Framework.

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

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

2. LTSRF Progress Since GHRSST 14

Table 1 summarizes the progress made by the LTSRF since 2007. Each year, as the volume of the archive has grown the number of services available to these data has grown as well. At the time of this report, the NODC LTSRF is capable of providing all GHRSST products through FTP, HTTP (http://data.nodc.noaa.gov/ghrsst), OPeNDAP (http://data.nodc.noaa.gov/opendap), and the THREDDS Data Server (TDS). Gridded products are additional made available through the Live Access Server (LAS, http://data.nodc.noaa.gov/las) and a wide range of discovery services are enabled though the NODC Geoportal Server (http://data.nodc.noaa.gov/geoportal). NODC also ensures that GHRSST meets the expectations of the Committee on Earth Observing Satellites (CEOS) by providing both collection and granule level discovery to the CEOS WGISS Integrated Catalog (CWIC) system. In the last year, no new services were added but the level of completeness in each of the green-bolded text areas was increased dramatically. For example, in 2013, only some L4 products were in the NODC LAS. Now, all gridded products included gridded L2P, L3, and L4 are available.

Table 1: Summary of LTSRF progress since 2007. 2014 numbers are based on the status as of 01 June 2014.

	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014***
Products		22	26	27	40	59	60	62
Accessions		39,048	49,957	59,982	67,906	92,282	105,046	107,925
Files		679,000	993,580	1,352,901	1,662,004	2,459,724	3,290,806	3,428,238
Volumes (TB)		13	20	28	34	57	69	72
Services	ftp http	ftp http	ftp http DAP	ftp http DAP WMS WCS	ftp http DAP WMS WCS LAS	ftp http DAP WMS WCS LAS Geoportal	ftp http DAP WMS WCS LAS Geoportal Granules CWIC	ftp http DAP WMS WCS **LAS** **Geoportal** **Granules** **CWIC**

Table 2: User accesses from the LTSRF. 2014 numbers are projected based on January – April statistics.

	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014***
Files served per day	85	1130	1734	3413	21,956	14,896	28,807	20,056	13,826
GB served per day	0.2	1.8	3.9	18.8	66.3	115	73	145	117
Users served per day	3	7	8	8	11	19	19	24	40

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

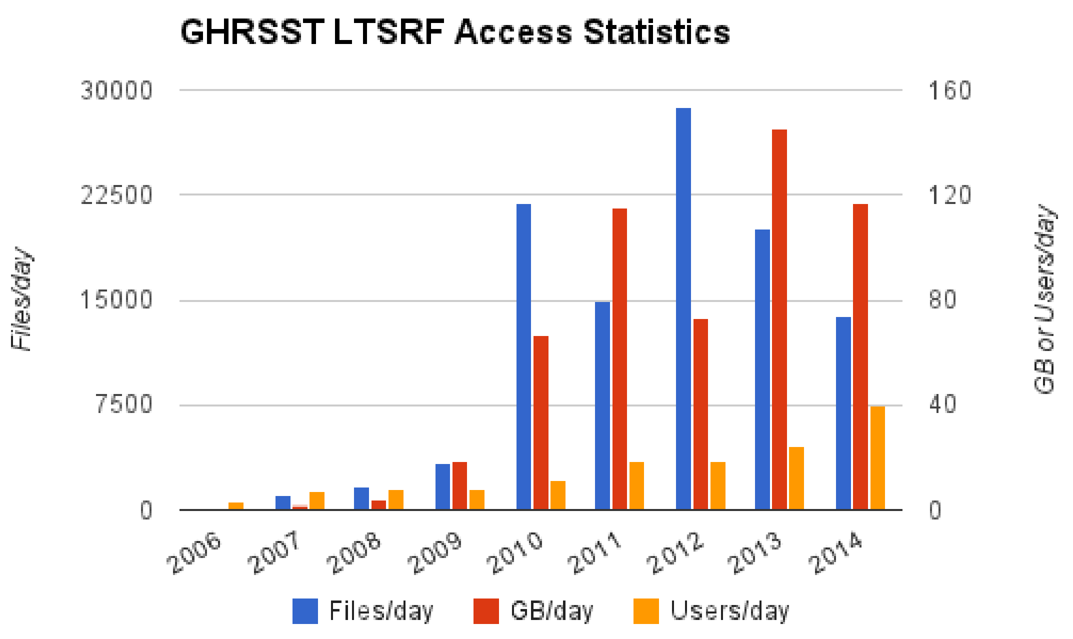
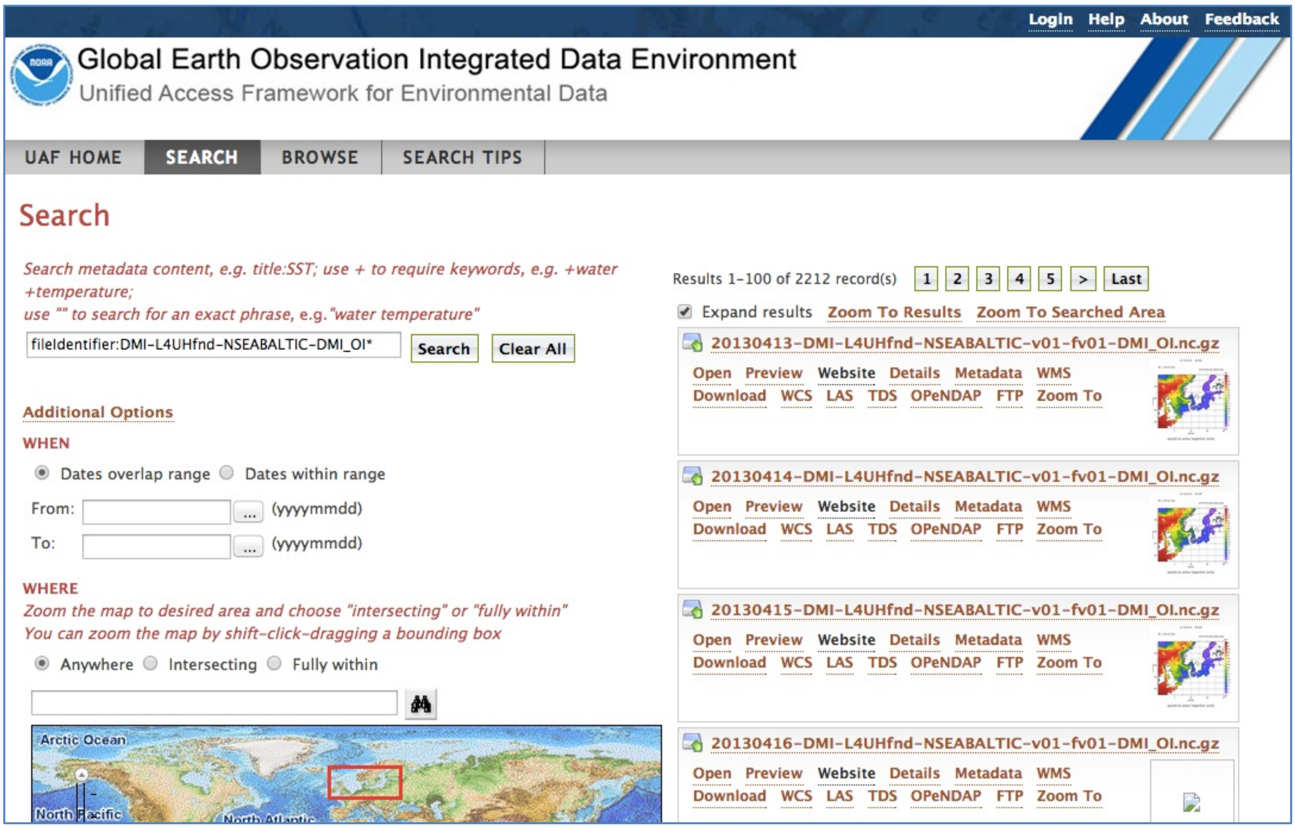


Figure 2: LTSRF user access statistics in graphical form.

The progress made in linking collections of GHRSST products and the discovery of their constituent granules was continued over the past year. At the time of last year's report, 53 of 60 GHRSST GDS1 products had granule discovery enabled. In the last year, NODC has now improved that metric to 60 of 60 GDS1 products, and the completeness of the granule inventories is nearing 100% for each individual product.

Once a user discovers a GHRSST collection, they can now jump directly to a granule (or file) level discovery process using a common look and feel interface. The granule discovery interface is shown below in Figure 3 and has been improved since the last report to include on-demand browse graphic generation for any product found in the NODC LAS.

Figure 3: Screenshot of granule level discovery interface with on-demand browse graphics generated automatically as the results list is displayed, enabling users to find individual data files within a collection.



Since the last meeting, NODC completed a significant archive reconciliation effort between the NODC LTSRF and PO.DAAC GDAC holdings. Over the years since GHRSST data began arriving at NODC in 2005, a large number of files were quarantined because of insufficient metadata or other problems that made their automatic archiving impossible. This backlog was systematically processed into the archive through improved procedures that are less reliant on the presence of File Record metadata records for each data file and through significant human effort to analyze issues and resolve them on a case by case basis.

The NODC LTSRF also completed its preparations to archive GDS2 products and began the automated archive of the new GHRSST data in May of 2014. The first GDS2 product archived was the NAVO L2P data from VIIRS. As part of the new archive procedures, range checking is performed on the latitude-longitude values and an email alert sent to the RDAC, GDAC, and NODC LTSRF staff to when files are detected with anomalous values.

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

3. Pathfinder RDAC Activities

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

Looking forward, in summer 2014, Daily, 5-day, 7-day, and monthly V5.2 averages and climatologies in GDS2 L3C/L4 are expected to be available. By the end of 2014, a new V5.3 Pathfinder in GDS2 L2P, L3U, L3C is expected. PFV5.3 corrects several shortcomings in V5.2:

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

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

4. Issues

Two issues identified in the report to GHRSST-14 were resolved in the past year and have been mentioned previously in this report. These issues were the NODC-PO.DAAC reconciliation and the GDS2 readiness. Other previous issues remain, however, and a few new issues have arisen as well. These issues are summarized in Table 4 below.

Table 4: Summary of issues and concerns at the NODC LTSRF.

NODC Issue or Concern	Comment
GDS2 Readiness	COMPLETE – now archiving GDS2!
PO.DAAC-NODC Reconciliation	COMPLETE – can track ongoing sync at http://www.nodc.noaa.gov/SatelliteData/ghrsst/remaining.txt
Archive of ATSR-1, ATSR-2, AATSR L2P data from RAL	UPDATE – Last meeting NODC received verbal confirmation NOT to archive these data. Can that statement be put in writing? (email ok, perhaps from the existing CEDA-NEODC Help Desk ticket?)
SST Climatologies in GDS2	UPDATE – Questions arose again this year on this topic, so still timely. NODC has them, what should be done with them? RDACs making them too?
GCOS SST Intercomparison site and common-input comparison study	Should NODC turn it off, rely just on LAS? Anyone going to complete the study?
Growing volumes	No immediate concern, but changes could be coming. Would RDACs be open to deletion of older versions of data when newer ones exist in the archive? No analysis yet.

NODC Issue or Concern	Comment
Digital Object Identifiers (DOI)	Ready to mint them for GHRSST collections. Need authorship list for each product. Need to coordinate if RDACs already have a DOI so we can cross-reference.
Direct receipt of data at NODC vs. existing GDAC channel (e.g., new ATSR series reprocessing)	How to maintain comprehensive catalog?
30-day delay too long. Could we shorten or perhaps mirror?	Would like to explore possibilities for sake of user experience.

5. Conclusion

The period since GHRSST 14 has been another successful one for the NODC LTSRF and Pathfinder RDAC.

SQUAM AND IQUAM PROGRESS AT NOAA

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ABSTRACT

NOAA has developed a comprehensive online SST monitoring system. Satellite and analysis SST products are monitored in the SST Quality Monitor (SQUAM, www.star.nesdis.noaa.gov/sod/sst/squam/; Dash *et al*., 2010, 2012). *In situ* SSTs used in Cal/Val of satellite/analysis SSTs are quality controlled, monitored and served to external users in the *in situ* SST Quality Monitor (*i*Quam, www.star.nesdis.noaa.gov/sod/sst/iquam/; Xu and Ignatov, 2014). Progress with SQUAM and iQuam since the 14th GHRSST Meeting in Woods Hole was summarized in this presentation. The 3rd element of the NOAA monitoring system, Monitoring IR Clear-sky Radiances over Ocean for SST (MICROS), is not discussed here, but is accessible at www.star.nesdis.noaa.gov/sod/sst/micros/; Liang and Ignatov, 2011).

1. SST Quality Monitor (SQUAM)

SQUAM monitors three types of SST products – swath (L2), gridded (L3), and analysis (L4). SQUAM was initially set up to monitor only NOAA SST products, but then evolved to include other community polar SST products from GHRSST partners. Analyzed in SQUAM are deviations of a product from its expected state (reference). The differences are checked if small, close to a Gaussian shape, and have a small fraction of outliers. Two types of reference SSTs are used: *in situ* data and several high quality global L4 fields. The quality of raw *in situ* SSTs available *via* GTS stream is suboptimal and non-uniform. This problem is mitigated in SQUAM by using uniformly QCed data from iQuam. Also, *in situ* data are scarce and not available globally. Therefore SST products are additionally checked against global L4 fields. A list of L2 products, which are monitored in, or are being added to, SQUAM is shown in Fig. 1.

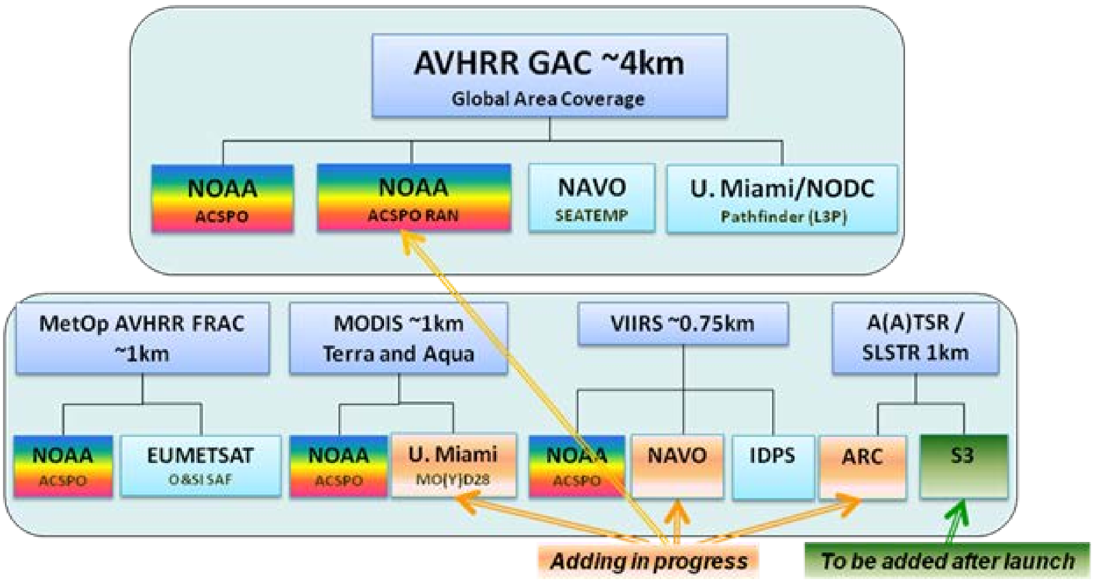

Figure 1: Level 2 SST products in SQUAM. All products are monitored on a daily basis, stratified by day and night. The focus of past year has been on adding ACSPO Reanalysis, NASA/U. Miami MO(Y)D28, NAVO VIIRS, and (A)ATSR Reprocessing for Climate (ARC L2P; to get ready for analysis of SLSTR data following Sentinel 3 launch). Consolidation of the new additions into SQUAM is currently underway.

Since GHRSST-14 in Woods Hole, our focus in SQUAM has been on adding the remaining L2 products. The community has also requested to include monthly monitoring, in addition to the current daily. The new capability is demonstrated in Fig. 2 for the two SST products from Metop-A AVHRR FRAC, produced at NOAA and at the O&SI SAF, Lannion, France.

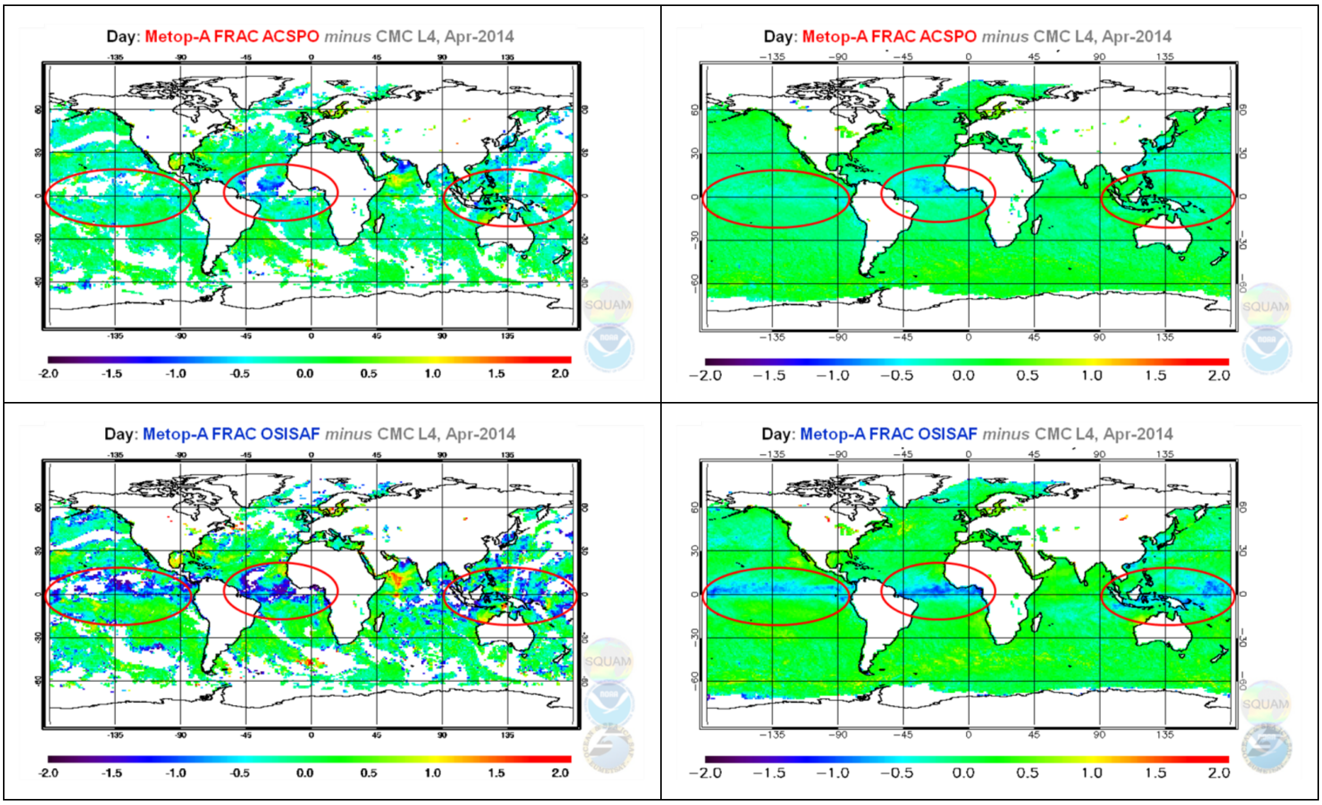

Figure 2: Examples of (left) current daily and (right) new monthly monitoring in SQUAM. Monthly monitoring is currently being implemented. It will facilitate identification of persistent product anomalies such as the areas of suppressed SST in the tropics seen in O&SI SAF product, due to the effect of residual cloud or specifics of the SST retrieval algorithm.

Monitoring of L2 products from several AVHRR, MODIS, and VIIRS instruments continued in SQUAM. Fig. 3 shows example time series of STDs wrt two reference L4 fields, Reynolds and OSTIA. There are some discontinuities wrt both L4s, due to changes in their real time production, but overall STDs are smaller and less noisy with respect to OSTIA, suggesting a smaller level of “spatial and temporal noise” in OSTIA L4. Wrt Reynolds, O&SI SAF L2 shows larger STD than ACSPO, but comparable wrt OSTIA, likely due to the fact that O&SI SAF L2 product was assimilated in OSTIA L4, whereas ACSPO L2 was not assimilated in either.

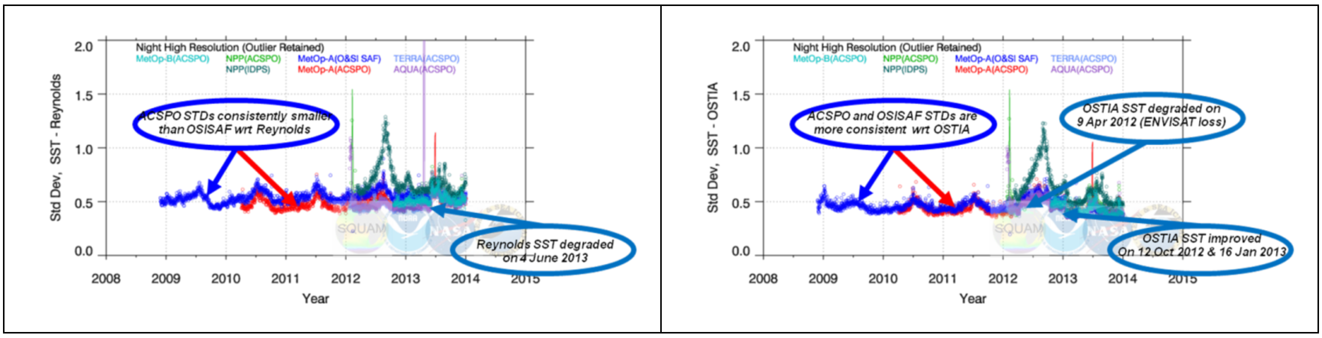

Figure 3: Time series of nighttime STD wrt two reference L4 fields: (left) Reynolds and (right) OSTIA. Of relevance to this discussion are two curves, both for Metop-A FRAC SSTs, one produced by the O&SI SAF (blue) and the other by the NOAA ACSPO system (red).

Fig. 4 shows monthly time series of STDs wrt *in situ* data from iQuam. Both time series show seasonal variations, but in all cases, the red curves go below the blue curves, suggesting smaller STDs wrt in situ data in ACSPO product.

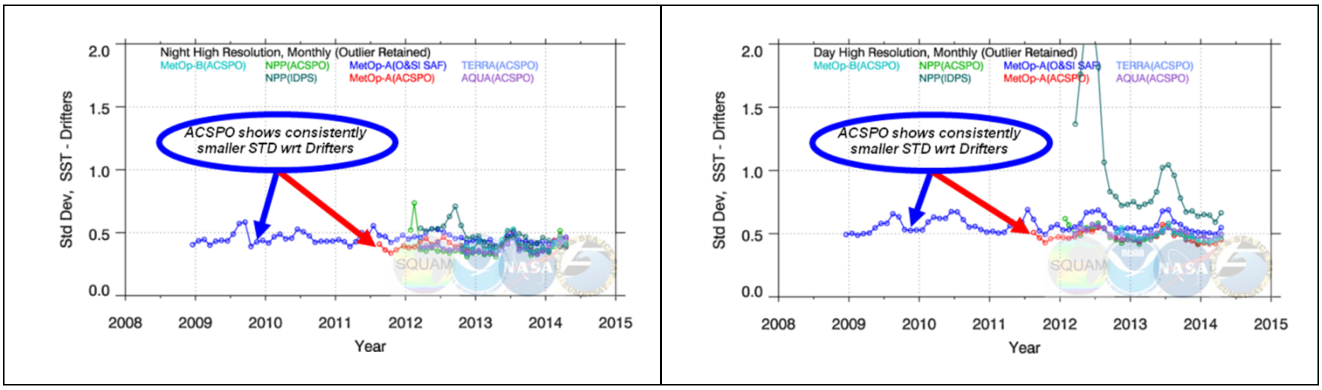

Figure 4: Time series of monthly STD wrt iQuam in situ data: (left) night and (right) day.

2. *In situ* SST Quality Monitor (*i*Quam)

*i*Quam performs 3 functions: 1) quality control of in situ GTS data using community consensus uniform QC procedures; 2) near-real time web display of QCed data online at www.star.nesdis.noaa.gov/sod/sst/iquam/; and 3) serving QCed data online for external users.

The past year effort was directed towards redesigning *i*Quam and creating version 2. The major enhancements of iQuam2 are extending time series back to 1981 (from 1991 in iQuam1) using ICOADS data and blending them with NRT GTS data; and adding ARGO floats and black list flag produced by O&SI SAF. Beta iQuam2 was released in September 2013 and feedback from GHRSST community was solicited. Two additions were proposed: 1) trackob ships (Helen Beggs, Australian BoM); and 2) DBCP-GHRSST drifters (Gary Corlett, U. Leicester). Implementation of these two requested inclusions is underway.

Figures below demonstrate some new capabilities in iQuam2. Fig. 5 shows an example global distribution of *in situ* data for the month of November, 2013.

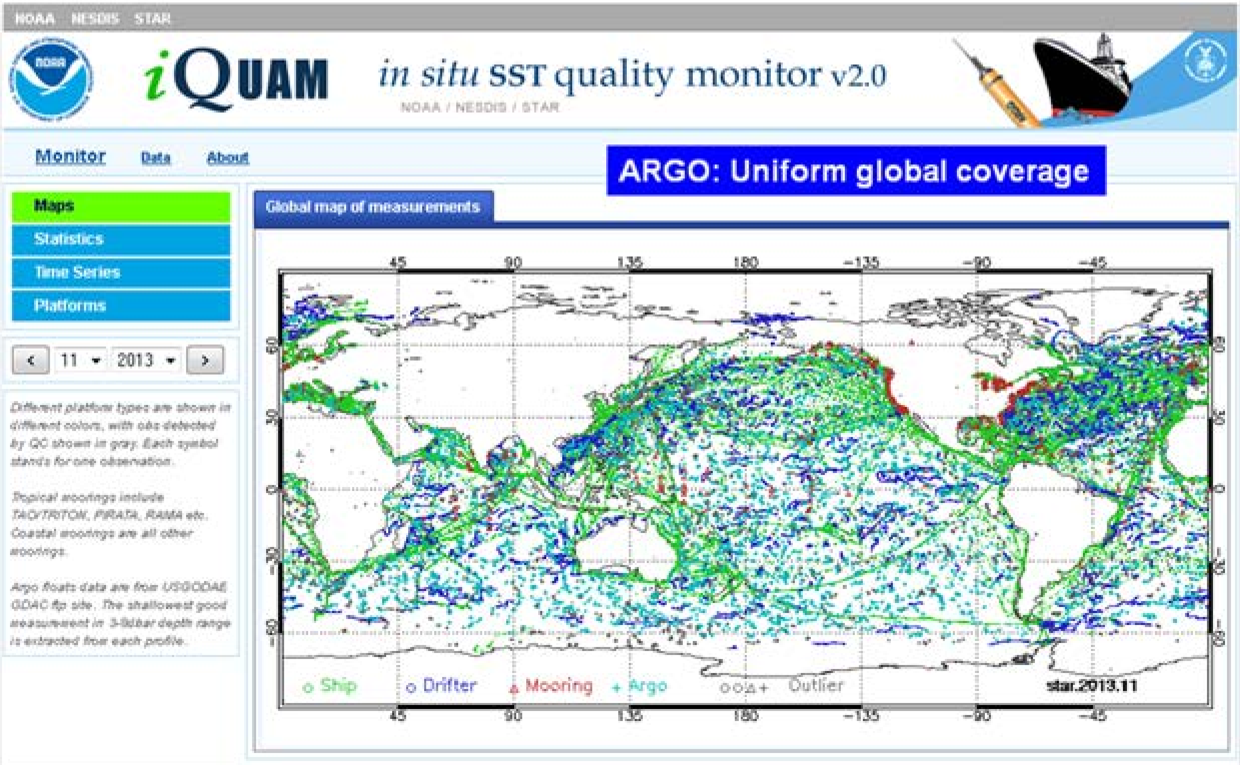

Figure 5: New interface of iQuam2. Note more complete and globally uniform coverage by ARGO floats.

ARGO floats provide most complete and uniform global coverage. Fig. 6 shows time series of unique IDs in iQuam2. Number of ARGO floats has grown very quickly after 2000, but they contribute a relatively small fraction of in situ measurements, compared to buoys and ships, due to their 10 day profiling cycle.

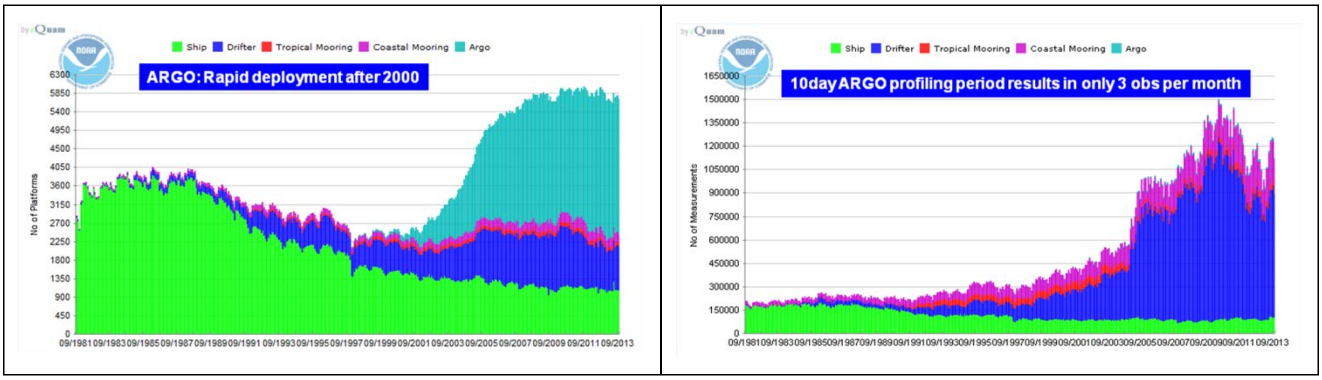

Figure 6: Time series of unique IDs in iQuam2 and number of corresponding monthly measurements in November 2013.

Fig. 7 shows time series of mean biases and STDs of *in situ* minus Reynolds. For ARGO floats, the mean difference is very consistent with that for drifters and tropical moorings, whereas STD is larger, likely due to the fact that drifters and moorings have been assimilated in Reynolds L4 whereas the ARGO floats have not.

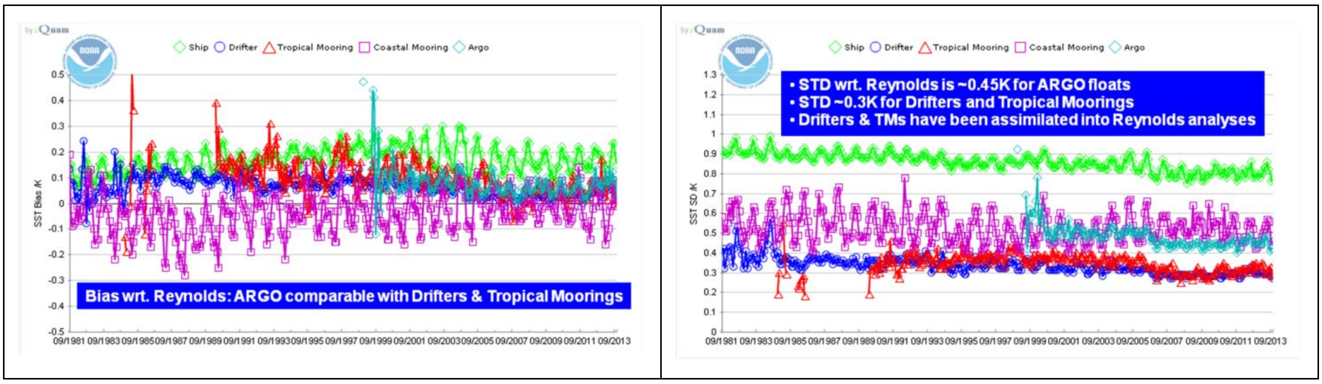

Figure 7: Time series of mean bias and STD wrt Reynolds in iQuam2 in November 2013.

3. Summary and Future Work

Future work in SQUAM will be directed towards completion and consolidating of ARC, NAVO VIIRS, ACSPO RAN, and MO(Y)D28, uniform implementation of monthly monitoring, and catching up with the L4 monitoring which has been unstable since GHRSST-14. We will work towards complete inventory of polar IR L2 and analysis L4 products and setting up a GEO-SQUAM. We believe that SQUAM is approaching a point where it can be used to start building a newer understanding and generalizations.

We will work towards completion of iQuam2. Specifically, we will cross-evaluate heritage QC available in USGODAE ARGO and ICOADS dataset, to gain more confidence in iQuam NRT QC. We will complete adding trackob ships, and DBCP-GHRSST buoys, and their evaluation for satellite Cal/Val. iQuam2 will be presented at the CLIMAR4 workshop (June 2014, Asheville, NC) and published in peer-reviewed literature.

4. Acknowledgments

We thank GHRSST colleagues for help and advice. The views, opinions, and findings are those of the authors and should not be construed as an official NOAA or US Government position, policy, or decision.

5. References

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FELYX : FREE OPEN-SOURCE SOFTWARE TO ANALYSE LARGE DATASETS OF EARTH OBSERVATION DATA

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1. Overview

Felyx is a project funded by ESA and implemented by a consortium led by Ifremer including PML and Pelamis.

It aims at bringing to the user community an open source solution for the analysis and intercomparison of datasets, for application such as :

- sensor calibration & validation
- products or algorithm intercomparison
- analysis of long time series of multiple parameters (climate change, trends, ...)

The basic concept of felyx is shown on figure 1: felyx extracts subsets from larger datasets over predefined areas. These subsets are referred to as "miniprod". Felyx therefore build stacks of these miniprods over each selected site. It also computes statistical or qualitative metrics metrics for each extracted miniprods, stored in an search engine (ElasticSearch) so that time series of these metrics can be queried later by users. This data processing can be done in NRT (triggered whenever a new file is incoming) or as a background task when reprocessing a full archive.

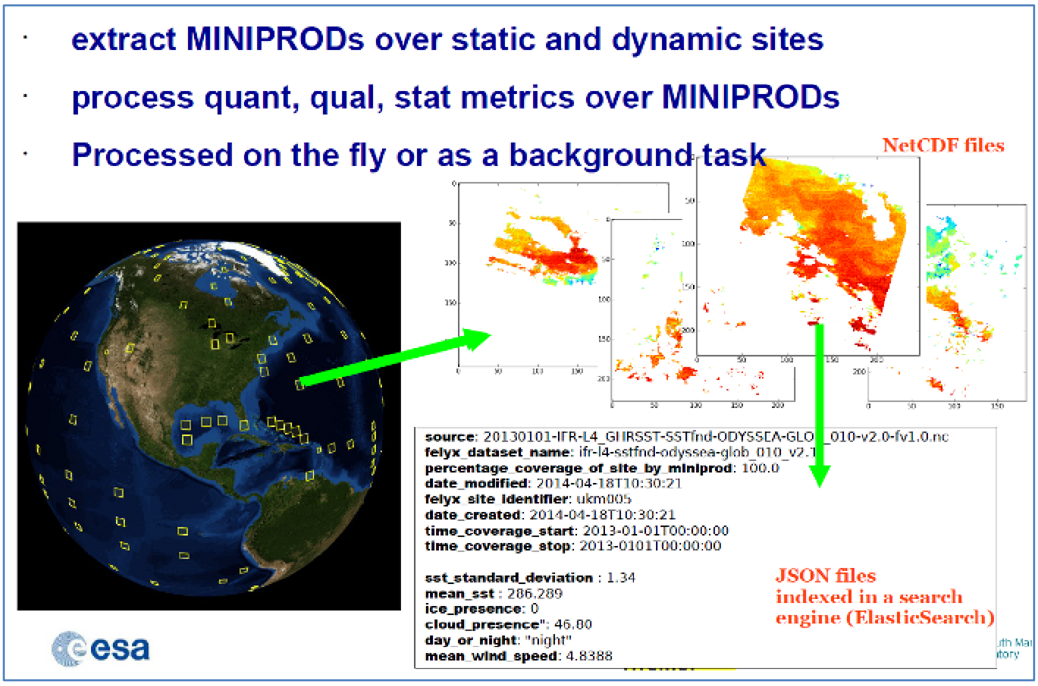

Figure 1: extraction of miniprods and metrics over static sites in felyx

The sites over which miniprods and metrics are extracted can be either static or moving targets such a buoy trajectories, as shown in figure 2. Typically this allows to build satellite to in situ matchups by feeding the system with the trajectories of drifters, Argo floats or ships.

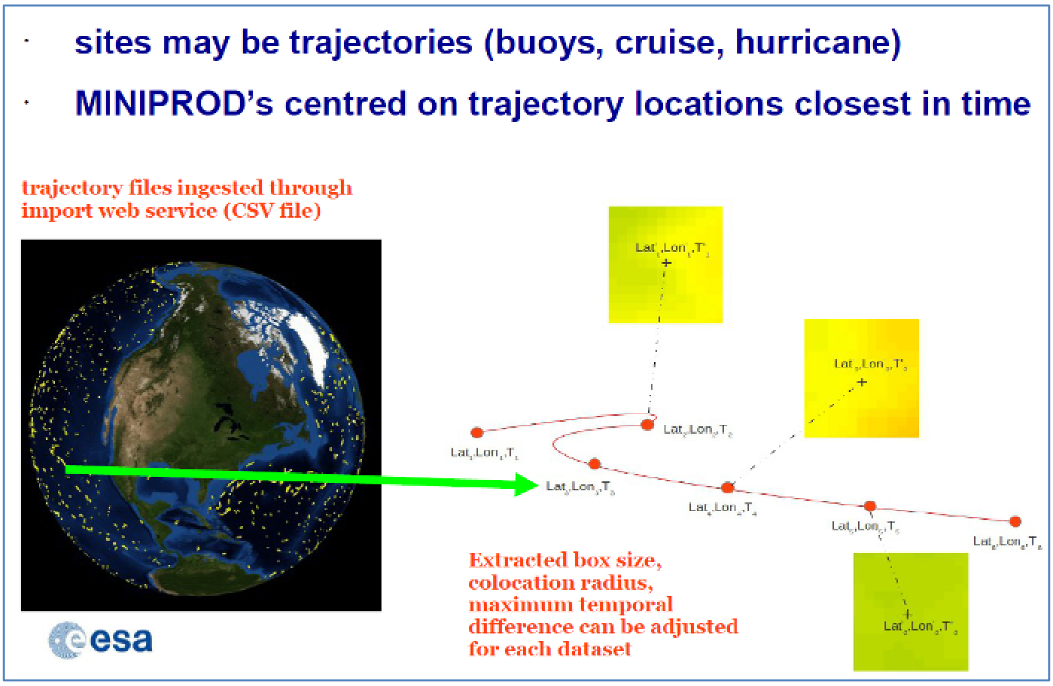

Figure 2: extraction of miniprods over dynamic sites

The extracted miniprods and metrics can be queried by users in many ways: miniprods can be made available through a ftp or OpenDAP server. Note that the miniprods are stored in NetCDF format.

- a RESTful web service allows to interrogate the system and select the data to be returned. It includes a complete workflow mechanism to perform complex requests (see further).
- These RESTful services can be accessed directly from a web application (a default web interface is provided with felyx) or a user script using whatever language. A python client API is provided by the project to perform standard queries.

Figure 3: examples of queries with RESTful API (top left) and python API (bottom right)

2. GUI

A default web interface will also be provided with felyx : it will allow to select and query metrics and miniprods, to display them through a choice of plotting tools (time series, histogram, scatterplot, ...). It will allow users to build their own data report (selection of plots) and to eventually automate it. All plots and reports can be shared though social media such as Twitter or Facebook.

The web interface is designed to be displayed on smartphone, tablet or desktop.

Figure 4: example of data display with felyx default GUI

3. Extensibility

Felyx is a client/server system. Several instances of felyx servers or clients can be deployed and they can be interconnected to each other (but it is not mandatory): this means that different felyx servers can process and serve independently miniprods and metrics over their respective datasets (but sharing the same list of extraction locations). A user or web application can then query and intercompare data from these different instances, as illustrated on figure 5, taking advantage of this network of felyx instances. This widely extends the range of possible queries to the system.

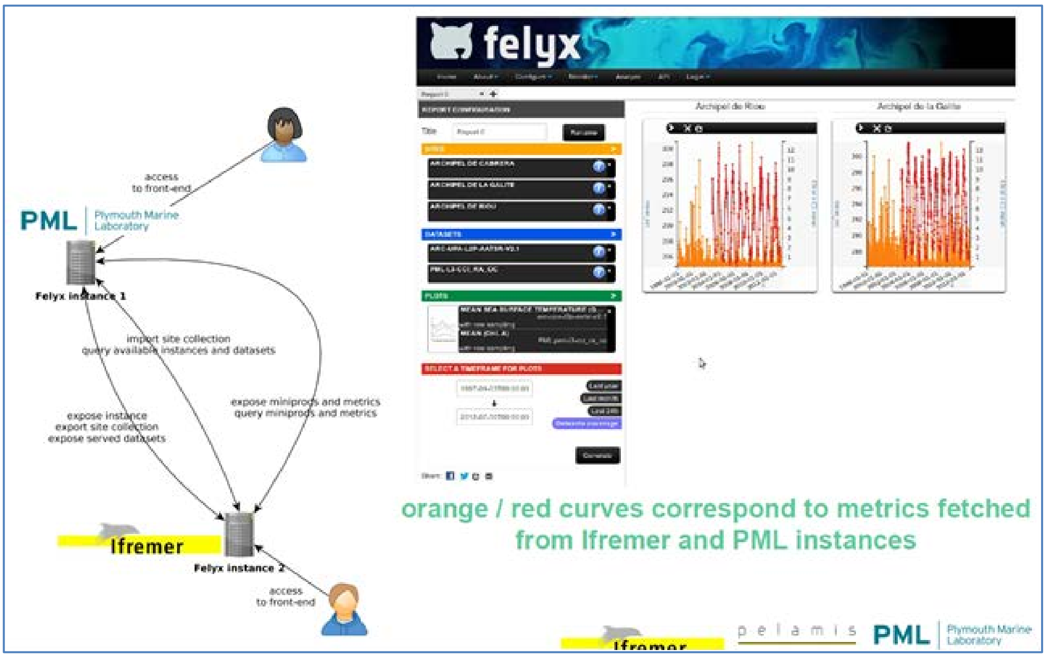

Figure 5: cross query over multiple instances, concept (left) and example (right)

The data selection query can range from very simple selections to complex workflows, including colocation or on the fly computation of new metrics, remapping/resampling of the miniprods, format conversion, etc.... The felyx workflow engine is fully extensible thanks to to the addition of plugins. Every owner of a felyx instance is then free to implement its own plugins.

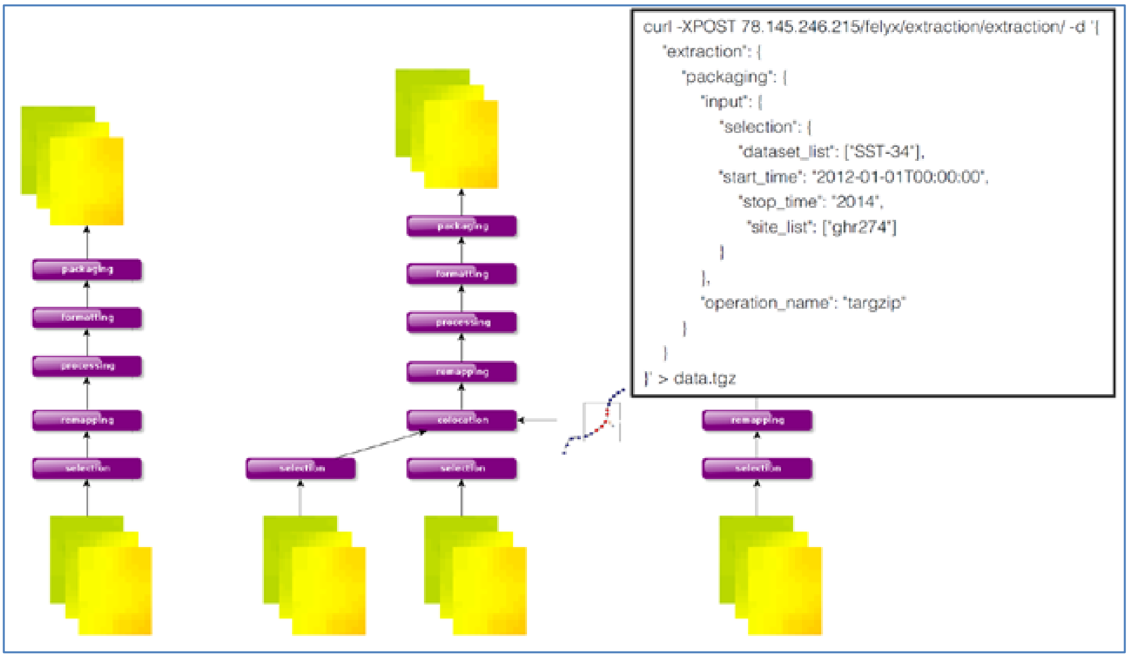

Figure 6: examples of complex workflows

By design, felyx is domain and format agnostic. It means it can apply to science domain and any geophysical parameters (ocean, land, atmosphere,...) provided the related data match the acquisition patterns that have defined in felyx (swath, grid, trajectory, ...), and that it does not require input data to be in a single format (new formats can be handled through plugins).

Last, the list of metrics operator can be also extensible by implementing plugins.

Felyx back-end is fully implemented in python and therefore plugins must be written in python too (or have python wrappers).

4. Next steps

The implementation of felyx is well advanced and a release of the first deployable version of the system is planned for September 2014.

In order to demonstrate the system and assess its reliability, a 6 month demonstration period will take place starting immediately after the software release. It will focus mostly on sea surface temperature and wave data collections on a Ifremer instance, and on ocean colour on an instance at PML. Specific use cases for each parameter will be run, working closely with a selection of end-users. This includes for instance:

- demonstration of a GHRSST insitu and multi-sensor match-up database for a wide list of L2P and L3 products
- long-term assessment of climate change over small and medium islands in Mediterranean Sea (PIM Initiative).

The system will be released to the users community in GPL-v3 license. This means that users can freely modify the code and develop commercial applications. Users are therefore encouraged to develop their own applications and services.

Felyx will be distributed with source code, installers but also pre-installed within a Linux container offering therefore a wide range of installation possibilities to users. It is all written in python (back-end) and javascript (front-end).

PLENARY SESSION II – REVIEW OF ACTIVITIES II

SESSION REPORT

Chair: Kenneth S. Casey[1], Rapporteur: David Poulter [2]
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ABSTRACT

On the afternoon of Monday, 02 June 2014, several agencies and organizations from around the world reported to the plenary gathering of the 15th GHRSST Science Team Meeting. This report provides a very brief overview and summary of those presentations, which were given in the second half Plenary Session II – Review of Activities. Kenneth Casey (NOAA/NODC) served as the session chair and David Poulter (Pelamis Scientific Software Ltd) served as the rapporteur.

1. Schedule

The schedule of speakers and their organizations is shown below in Table 1.

Table 5: The schedule of speakers and their organizations during the Monday afternoon plenary session.

Presentation Time	Organization	Speaker
14:00-14:15	ABoM	Ian Barton
14:15-14:35	ESA	Craig Donlon
14:35-14:45	EU GDAC	Jean-François Piollé
14:45-15:05	EUMETSAT	Anne O'Carroll
15:05-15:20	JAXA	Yukio Kurihara
15:20-15:35	JMA	Shiro Ishizaki
15:35-15:55	MISST	Gary Wick

2. Summary of Presentations

2.1. Australian Bureau of Meteorology (ABoM), Ian Barton

Ian Barton spoke on behalf of Helen Beggs, who could not attend the meeting in person. Barton described the highlights of the work completed in the last year, specifically the reprocessing of Australian HRPT AVHRR data from 1992, which is nearly complete.

The processing chain has been upgraded and is now using an NLSST algorithm, which can produce SSTs without the use of a background L4. BoM are now also producing L3S products, over an extended 'Southern Ocean' region, which extends the original Australian region. It was noted that there is a gap around South

Africa, and so Helen is looking for South African HRPT stations to fill this gap. Please contact Helen or see IMOS website to get access to this data. Feedback on these products would be most welcome.

It was reported that the BlueLink analysis now ingests GHRSST L4 products.

COSPPac was described in some detail. This effort is an AUSAID program to help Pacific Island governments to use BOM data to assist fisheries management and other maritime activities. They are examining the methods to find the 'best' SST for fisheries applications, along with delivery mechanisms. This service is also using MUR L4 products along with NAVO GAC L2P from METOP-B.

BoM are collaborating with NOAA NESDIS to produce a L2 and L3 product, with the code to be provided to NESDIS for testing. This collaboration aims to promote the use of VIIRS outside of US.

Future plans in BoM include the installation of an ISAR on *RV Investigation*, the use of AMSR2 and VIIRS into BOM operation SST, and to produce IMOS direct broadcast GHRSST products from these instruments.

2.2. European Space Agency (ESA), Craig Donlon

Donlon welcomed Olivier back to GHRSST, after his recent absence. He described the importance of GHRSST, in terms of the importance of SST, to ESA. He also described both Copernicus and S3 as a source of information for policy makers; specifically when utilized in the face of natural disaster, climate change, and to ensure civil security.

Copernicus has a long-term perspective with contract negotiations underway to produce 20+ satellites up to the 2030s. Modification to the S3 program will begin with S3-e, as the beginning of the improved second version. Donlon reported that S3-a was injected into orbit 8km low, and is lifted, but that involves repeated SAR refocusing and so may take some time.

S3 launch is now planned for late 2015, and Donlon reported that the launcher has been purchased. The differences between AATSR and SLST were described, focusing on the new mechanical components, and describing the improved swath width and other instrument improvements. The new optical pathways, including the newer half speed mirrors and detector clusters, were described, highlighting the increase in complexity for this instrument over the ATSR series. S3 data will be here soon, and we must ensure that we are ready.

SLSTR has new bands optimized for fire detection and other new applications. There are some issues with calibration of fire channels as the on board black bodies cannot achieve a high enough temperature for full calibration.

The revisit time with 2 satellites is under a day globally, and will remain so above 30 degrees N / S with only one satellite. Fire channel sensitivity on SLSTR is not fully known, and is subject to some revision. The S3 B unit and preflight model are being built together, and will be swapped just before launch.

Donlon described briefly the S3 High Resolution (10m) imager. It was noted that the thermal bands only go out to SWIR, and so it is of limited use for SST. However, the instrument will have at least twice the swath of Landsat / SPOT series of satellites. It will ensure that high-resolution imagery will be produced over every island over of greater area than 100 sq kilometers.

The second S3 symposium is planed for 2015 in Frascati, although no date is confirmed yet. It was requested that GHRSST seek a greater involvement in the S3VT. The offer of hosting GHRSST 2015 in Frascati after the S3 meeting was made.

Donlon described the Earth Observation Envelope Program EOEP 5 (2017-2021) to fund science driven R&D; and the continuation of the Data User Element (DUE) which is still on going. The Call For Innovators III program is open to all domains of EO applications and open to all bidders, and bids are encouraged.

Continued funding of GPO is provided by ESA (thanks were given to Corlett and Pike); and the Medspiration Evolution is ongoing with TV5 as the prime users. It was reiterated that the science team must provide web site content to the GPO to improve our web presence. Donlon proposed a discussion about the future of the RGTS and the reintegration of the EUGDAC and the GDAC; this will be discussed by the DAS-TAG at this meeting. The ESA SST-CCI has been extended tor another 3 years. The SST-CCI is pushing new products to NEODC, with a view to move the data to more flexible repositories such as CERSAT or GDAC. Donlon made a note of described the CCI user requirements as a good example of a URD.

The audience was encouraged to look at the oceanflux-ghg project.

Donlon welcomed the inclusion of SANSA to the GHRSST fold.

Finally, Donlon noted that whilst the GDS2 is a complete document, it is not a complete guide to the development of a working GHRSST component service, such as a new RDAC. This is a gap in the documentation, which should be addressed.

2.3. European Global Data Assembly Center (EU GDAC), Jean-François Piollé

Piollé described the EUR-GDAC and related activities. It historically served MyOcean or Medspiration, or other European partners, but the scope was widened significantly recent years.

Piollé introduced several new services to assist in the smart dissemination of data, instead of simple FTP push activities. The system incorporates Naiad and Felyx, but also new crowd sourcing systems like the OceanFlux project as well as the implementation of cloud computing. The system has 2 PB of storage, 1600 cores and 2.5 TB of RAM. It combines short and long term storage. It was noted that there is no backup for non-critical datasets, although there is some redundancy for all datasets. Some datasets are not available at other DACs.

Piollé described the issues in the DAC organization. Some data exist at one or other GDAC only, and some are variably complete at different centres. There are also some datasets that are only distributed via individual RDACs, and GDACs may not have permission to ingest or to disseminate them.

Piollé described the current GDAC system as not efficient for all needs. He felt there should be a central repository (virtual or otherwise) with distributed archives, however we should not abandon geographic redundancy or duplication of data. Finally, Piollé described the PIM imitative, which aims to assist government of very small Mediterranean Islands. Specifically, PIM provides data in formats that they are familiar with (Excel etc.).

IFREMER will provide new interpolation and assimilation scheme for Medspiration L4 products in august this year.

2.4. EUMETSAT, Anne O'Carroll

O'Carroll described the roll of EUMETSAT in operational oceanography, and the breakdown of responsibility between EUMETSAT and the SAFs for both METOP and MSG; namely, that EUMETSAT proved L1 data and the OSI-SAF provides.

METOP IASI and AVHRR are being improved, with the inclusion of NeDT in AVHRR products.

The IASI SST product includes skinSST, SSES and ECMWF wind as an L2PCore format, available via EUMETSAT FTP. A new chain with new retrieval based on PWLR and 1D-VAR planned for July 2014.

The full L2P format data for IASI should be available this summer form the OSI-SAF. Analysis shows a slight cool bias in SST but errors of only 0.3 - 0.4 K. The product will begin to use a tailored training set for skin SST and aerosol flagging in the next few months.

GSICS continue to perform bias monitoring with RT-TOV and identified a significant error on July 2013 on 3.9 channel. This error is thought to be caused by thin ice on instrument.

There will be a full MSG reprocessing end 2015, and a full METOP reprocessing and 2014. Ice surface Temperature processing will be transferred form DMI to OSD-SAF at end 2014.

The relation between EUMETSAT and Copernicus was explained, where in effect EUMETSAT will provide the ground segment for marine observations. S3 data will be available on one month rolling archive, and the full archive via FTP. EUMETCAST will provide L2 data only, although that will be reconsidered in the event of a delegation request. All data will be in stored in the U-MARF.

S3VT is still operating a rolling call for projects, with next meeting for late 2014 / early 2015. The excellent initial meeting in Frascati 2013 was praised.

The OSI-SAF and EUMETSAT-Central will produce an SLSTR MDB as a joint activity. S3 will provide individual algorithm SSTs to cal/val teams, but only a ‘best’ SST to the public. The main product is L1B – which will contain cosmetic pixels due to re-gridding; however, tools will be provided to convert L1B to L1A (no information will be lost on conversion to L1B prior to dissemination). There was a call for GHRSST feedback on this design choice. S3 SST algorithms will be based on Merchant / ARC algorithm, lake surface temperature will also be provided. A future upgrade to Bayesian cloud clearing is planned. Example data will be provided before S3 launch, but no timescale is in place yet.

EUMETSAT is collaborating with NOAA to provide Suomi NPP SST, with the first data disseminated on 8th May 2014. Some content is removed from the disseminated files to reduce volume data volume.

EUMETSAT also have bilateral agreement with NSOAS to process and disseminate from HY-2a and have initiated contact with ISRO to distribute Indian SSTs in HDF format.

The EUMETSAT meeting in September 2014 (Meteorological Satellite Conference) and Climate Symposium 2014 in Darmstadt on October 2014 were both highlighted.

2.5. Japanese Space Exploration Agency (JAXA), Yukio Kurihara

Speaking for Misako Kachi, who could not attend, Yukio Kurihara described JAXA instruments and joint missions, plus the JAXA contribution to GHRSST in the form of the Japanese RDAC. It was noted that JAXA data policy has recently changes to allow third party distribution and commercial use of JAXA satellite data, this was strongly welcomed.

AMSR2 NRT data is now available from Japan’s RDAC, and AMSRE L1B data in slow rotation mode is available though GCOM-W research product site - http://gcom-w1.jaxa.jp. AMSRE was restarted in slow rotation mode in December 2012.

The GMP Core Observatory has been launched in February and is showing good performance so far. The data will soon be released. GCOM-C/SGLI is to be launched JFY2016.

A GCOM-W follow on mission is in discussion, but is not yet committed to.

JAXA is releasing data in GSD2 format from AMSR2, WindSAT, AMSRE and VIRS (TRMM), although VIRS is currently deactivated.

GCOM-W was inserted into the A-Train, and is providing good quality data. L1, L2 and L3 data reprocessing is expected later this year. The instrument shows excellent matchup statistics against buoys, with < 0.1 K bias and < 0.7K error.

Kurihara showed use of 10 GHz SST as a research product; although it cannot detect SST under 10 deg C it is showing some interesting results and the exploration of this product is encouraged. Finally. It was noted that GPM data will be released soon from both NASA and JAXA. GMI data is already released (and one month ahead of schedule).

2.6. Japan Meteorological Agency (JMA), Shiro Ishizaki

Ishizaki described the MGDSST global ¼ analysis, which is now using AMSR2. The data available from NEAR-GOOS

It was shown that MTSAT is now being processed with a 1D-VAR model and single layer RTM. This shows good comparison with *in situ* observations.

JMA provides a Western Pacific 1/10 analysis, and is now testing the operational implementation of this service. There is a marked improvement in SSTs in the wake of typhoons (e.g. Man-Yi) the new analysis as it responds to shock far quicker, performing significantly better than the global analysis.

JMA committed to distribute all future data in GDS2 – but the schedule has not been agreed yet.

Finally, Ishizaki described Himawari-8/9 satellites. These have a vast increase in the number of available channels (5 to 16) and resolution (2km to 500m). Data volume is increased 50 times. Launch of Himawari-8 will be in 2015 and Himawari-9 in 2016. Operations are expected to continue to 2028 (15 years) at 140 E with in orbit spare. Himawari is the Japanese word for sunflower.

JMA data policy has not yet changed even though JAXA data policy has, as previously reported. Discussions are ongoing, and will be modified to increase 'public data use', but this is not defined yet.

2.7. Multi-sensor Improved SST for IOOS (MISST), Gary Wick

Wick quickly described the key highlights of the MISST2 program in the last year. These were identified as:

- University of Rhode Island: Cornillon continues data recovery efforts to convert AVHRR HRPT from 1982 on into GDS2.
- Naval Research Laboratory: Cummings has implemented an adjoint based procedure to understand assimilation impacts Miami
- University of Miami: Minnett and Evens have demonstrated improvements in cloud screening, and indicate that VIIRS to be a good instrument.
- University of Maryland: Mittaz and Harris have demonstrated improved Geo-SST, with improvement in bias in GEOS.
- Jet Propulsion Laboratory: JPL continues with MUR production and MUR cross validation, and will soon integrate AMSR2 and VIIRS into this stream. They will focus on improving inland SST.
- University of Utah: Crossman has worked on improving lake SST, with a JTECH publication. Will continue to work with the United States Navy to validate lake SST.
- NAVOCEANO: VIIRS products have been transformed to GDS2. Work continues to include ice concentration into K10. Further work will include lake SST (Crossman). NAVO will produce regional L3 in specific regions of interest. The delay in S3 launch was highlighted as a problem.
- REMSS: Highlights include the publication of a validation paper, and testing GDS2 format products. It was noted that MWOI-fusion and MWIR-fusions products will soon be released in V4 and in GDS2 format. Please email Gentemann for details. Future efforts will focus on the revision AMSR2 water vapor effect processing.
- NOAA/NESDIS: GOES13, GOES15, MTSAT and MSG now in GDS2 format. NESDIS are also producing L4 5km analysis in GDS2
- NOAA/PFEG: Work largely paused due to tragic death of Dave Foley. Cara Wilson is in process of hiring a new person to carry on Dave's work.
- NCDC Banzon: Extensive refactoring of OISST code expected to be complete summer 2014, this should make future improvements far easier and quicker to implement.
- Colorado University: Castro has completed a L4 inter-comparison with specific performance evaluation of performance at high latitude. This will be reported at HL-TAG.
- MOAA AOML: An analysis of SST performance during bleaching events was described, which showed good agreement with in situ in extreme conditions.

3. Conclusion

The session provided a useful overview of the significant contributions being made to GHRSST from numerous agencies and organizations around the world.

ESA SUPPORT TO GHRSST

Craig Donlon[1], Olivier Arino[2]

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ABSTRACT

The European Space Agency (ESA) has provided sustained support for to GHRSST since 2001. A variety of mechanisms and activities are used, together with other space agencies, to ensure that GHRSST remains the primary international science team for matters relating to SST. ESA, in partnership with the European Commission is currently developing the Copernicus Sentinel missions – of which Sentinel-3 is planned to provide continuity of dual-view SST measurements from 2015 until 2020+. In additions, through the Climate, Science and Application program elements of the fourth ESA Earth Observation Envelope Program (EOEP-4) ESA financially supports the GHRSST Project Office and a number of European science and exploitation projects that fully utilize GHRSST data. This paper provides a summary report of relevant ESA activities for GHRSST.

1. Introduction

The European Space Agency (ESA) considers GHRSST top be the primary international science team for matters relating to SST: GHRSST is the body that defines international consensus for practical and scientific issues raised by national SST science teams, projects and contributing space agencies. As an example of this, the GHRSST Data processing Specification (GDS) is formally applied to the SST products that will be derived from the Copernicus Sentienl-3 Sea and Land Surface Temperature Radiometer (SLSTR) thorough an operational near-real-time service. The relationship between GHRSST and the CEOS SST Virtual Constellation (SST-VC) provides a formal mechanism to ensure that international scientific and operational consensus achieved through the endeavors of GHRSST are coordinated across Space Agencies and is fully supported by ESA. ESA welcomes the South African Space Agency (SANSA), who has recently joined GHRSST, and notes that GHRSST continues to grow in its role as the international science team for SST.

2. Satellites

ESA has been engaged in developing satellites and instruments that can measure SST from space since the late 1970's (Figure 1) staring with the geostationary Meteosat satellites operated by EUMETSAT. Since then, a steady and evolving stream of new satellites have been launched to support numerical weather forecasting via dedicate meteorological satellites operating in geostationary and polar orbits, European research and development missions (such as ERS and ENVISAT) and today, in partnership with the European commission, the Copernicus Sentinel satellites (see http://sentinel.esa.int for a complete overview).

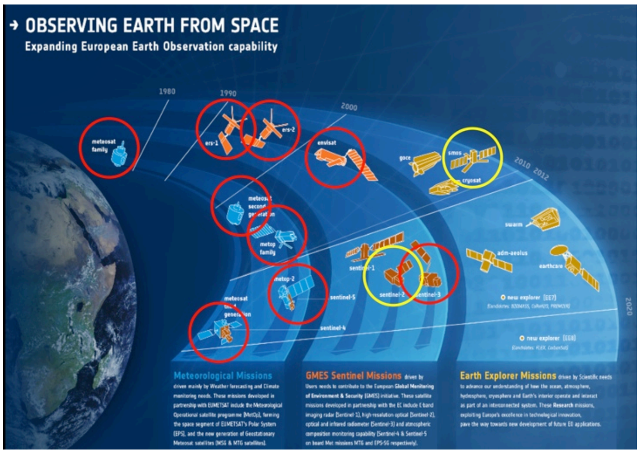

Figure 1: The Expanding European Earth Observation Capability highlighting those missions relevant to SST.

Copernicus (see http://www.copernicus.eu/) is a user driven programme and a major space investment by Europe to deliver a new integrated (i.e. combination of space-based, ground-based measurements with earth system models) operational earth observation infrastructure including a fleet of complementary satellites and instruments that provide a unique source of information for policymakers, scientists, business and public use. Satellite measurements are translated into knowledge by operational services and scientific applications that constitute a European response to global issues including long-term environmental management, understanding and mitigating the effects of climate change and to ensure civil security (amongst others).

Copernicus has a long-term operational perspective with 16 satellite launches committed up until 2020 and a further ~16 launches planned in the 2020-2030 period. Sentinel-1, carrying a C-band synthetic aperture imaging radar, was successfully launched on 3rd April 2014 heralding the start of Copernicus satellite missions. Sentinel-3 is planned for launch in late 2015 and is of most relevance to the GHRSST community.

3. Section Heading

Sentinel-3 is an operational mission in high-inclination, low earth orbit for the provision of observational data to marine and land monitoring services. These services include the generation of sea, ice and land surface altimetry products, land and ocean colour products, sea and land surface temperature products, and vegetation products. The operational character of the mission implies a high level of availability of the data products and fast delivery time, which have been important design drivers for the mission. The Sentinel-3 spacecraft accommodates a topography payload consisting of a SAR Radar Altimeter (SRAL) and a Microwave Radiometer (MWR) plus a suite of instruments for precise orbit determination (POD). In addition, two large optical instruments - the Ocean and Land Colour Instrument (OLCI) and the Sea and Land Surface Temperature Radiometer instrument (SLSTR). These instruments will ensure the continuation of important data streams established with ESA’s ERS and ENVISAT satellites. Full performance will be achieved with a constellation of two identical satellites, separated by 180 degrees in the same orbital plane.

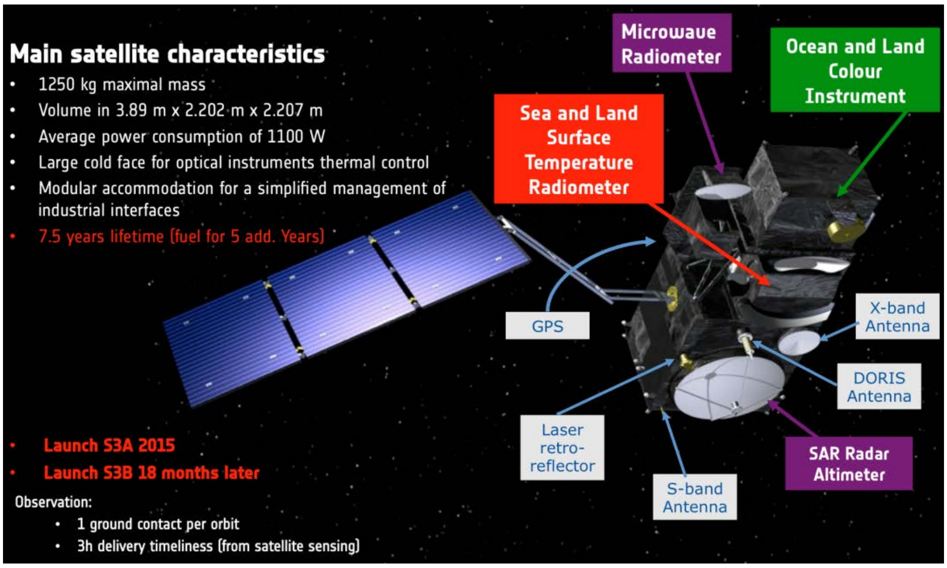

Figure 2: The Copernicus Sentinel-3 satellite.

Two Sentinel-3 satellites are in development with the second satellite launch expected approximately 18 months after the first. The overall service duration is planned to be 20 years and is expected to be fulfilled by a series of several satellites. Currently, the launch of the first Sentinel-3 satellite is planned in late 2015.

The main objective of the Sentinel-3 SLSTR instrument is to maintain continuity with the ENVISAT (A)ATSR series of instruments (e.g., Edwards et al, 1990; Llewellyn-Jones et al, 1984) that provide a reference sea surface temperature data set for other satellite missions (Donlon et al, 2010). Consequently, wherever possible, the SLSTR design is based on the reuse of AATSR concepts, supported by existing and qualified technologies (Coppo et al, 2010). SLSTR will retrieve global coverage SSTskin with zero bias and an uncertainty of ± 0.3 K (1σ) for a 5 x 5 degree latitude longitude area, having a temporal stability of 0.1 K/decade in support of Copernicus climate monitoring and operational ocean and weather forecasting applications. In addition, SLSTR using a suite of visible and infrared radiance measurements will provide land surface temperature, active fire monitoring, ice surface temperature cloud, atmospheric aerosol, land surface, forestry and hydrology products in support of Copernicus services.

Following ENVISAT AATSR, the SLSTR instrument is a conical scanning imaging radiometer employing the along-track-scanning dual view technique (Edwards et al, 1990) to provide robust atmospheric correction over the dual-view swath (see Table 1). The wide nadir view swath is offset to the west of the nadir point to overlap with the OLCI instrument swath (which is inclined to avoid sun-glint contamination). The main areas of improvement over heritage (A)ATSR instruments include wider swath coverage, more spectral bands, and a spatial resolution of 0.5 km for visible bands.

		ATSR-1	ATSR-2	AATSR	SLSTR
		ERS-1	ERS-2	ENVISAT	Sentinel3
Swath [km]	Nadir oblique	500 500	500 500	500 500	1400 740
SSI [km] VIS/SWIR	Resolution at sub sat point	1	1	1	0.5
SSI [km] IR		1	1	1	1
Band 1[12]	Chlorophyll	-	0.555	0.555	0.555
Band 2	Veg. Index	-	0.659	0.659	0.659
Band 3	Veg. Index	-	0.865	0.865	0.865
Band 4	Cloud clearing	-	-	-	1.375
Band 5	Cloud clearing	1.610	1.610	1.610	1.610
Band 6	Cloud clearing	-	-	-	2.250
Band 7	SST	3.740	3.740	3.740	3.740
Band 7 F	Fire	-	-	-	3.740
Band 8	SST	10.850	10.850	10.850	10.850
Band 8 F	Fire	-	-	-	10.850
Band 9	SST	12.000	12.000	12.000	12.000
Life time [years]	As designed As flown	3 1991-2000	3 1995-2008	5 2002 2012	7.5

Table 1: comparison between (A)ATSR instruments and Sentinel-3 SLSTR.

The complete suite of AATSR and ATSR-2 spectral channels (0.55, 0.66, 0.85, 1.6, 3.7, 10.8 and 12 µm) is included in order to maintain continuity with the previous sensors. Additional channels at 1.378 µm and 2.25 µm are included to enhance thin cirrus cloud detection (Gao et al, 1993). Each VIS channel pixel sample achieves a high signal-to-noise ratio (SNR ≈ Δ600) at 30% Earth albedo signals and each IR pixel sample a low noise equivalent temperature difference NEΔT < 30 mK (Coppo et al, 2010). The design also includes the capability to derive active fire measurements (e.g., Wooster et al 2005) using an extended dynamic range of the 3.7 µm channel and dedicated optimized detectors at 10.8 µm although this capability is secondary to the primary SST retrieval capability.

The SLSTR uses a new scanning system compared to the (A)ATSR instruments allowing a wider swath in both nadir and oblique views. SLSTR uses two independent optical scanning chains each having a scan mirror (scanning at a constant velocity of 200 rpm), an off-axis paraboloid mirror and a fold mirror which focus the energy into a prime focus Instantaneous Field Of View (IOFV) of the Earth. An innovative recombination optical “flip” mirror alternately relays one of the optical beams into a common field plane at the entrance to the instrument detector assembly where there is a cold baffle. This configuration increases the swath width in both views with an oblique view swath of ~740 km centred at the SLSTR nadir point and a nadir swath of ~1400 km that is asymmetrical with respect to the nadir point to provide coverage identical and contemporaneous with OLCI ocean/land colour measurements.

The Focal Plane Assembly (FPA) is a box composed of a base-plate and an aluminium dome containing the IR and visible optical benches. Two element photo conductive detectors are used for the TIR channels actively cooled to ~80 K using a Stirling cycle cooler (Matra Marconi, 1996). Small multi-element arrays of Photo Voltaic detectors are used for the other channels. The Ground Sampling Distance (GSD) at nadir for the TIR channels is ~1 km, and 0.5 km for Visible and SWIR channels. As the scan rate is half that of AATSR, each scan will measure 2 along-track pixels of 1 km (and 8 pixels at 0.5 km resolution) simultaneously and view the calibration black body cavities every second scan. The SLSTR scan arrangement means that both oblique and nadir views share common focal plane optics and detectors in such a way as to ensure spectral and radiometric integrity of the design and the resulting data. The scan design is also a consequence of accommodation restrictions at the spacecraft and will not have any impact on product quality.

The current best prediction of SLSTR performance is provided in Table 2 that is based on bench tests using Flight detector units with the engineering model front-end-electronics (i.e. not flight electronics). For channels

S1/2/3/4/5/6 the reflectivity is 3% for a ground sampling distance (GSD) of 500m. For S7/8/9 channels the GSD is 1 km and figures are quoted for end-of-life. The SLSTR will be fully calibrated in late 2014 at Rutherford Appleton Laboratories, UK at which point a full end-to-end performance budget at instrument level will be available.

SLSTR Band	λcenter [μm]	Δλ [μm]	NEdR@3% / [W m^{-2} St^{-1}] NEdT [mK]	SSD [km]
S1	0.555	0.02	**9.68 x10^{-4}**	0.5 x 0.49
S2	0.659	0.02	**9.38 x10^{-4}**	0.5 x 0.49
S3	0.865	0.02	**9.09 x10^{-4}**	0.5 x 0.49
S4 *	1.375	0.015	**3.57 x10^{-4}**	0.5
S5 *	1.61	0.06	**1.76 x10^{-4}**	0.5
S6 *	2.25	0.05	**4.17 x10^{-4}**	0.5
S7	3.74	0.38	**60 mK**	1.0
S8	10.95	0.9	**26 mK**	1.0
S9	12	1.0	**28 mK**	1.0
F1	3.74	0.38	**225 mK**	1.0
F2	10.95	0.9	**45 mK**	1.0

AATSR Heritage
SLSTR New Bands

Table 2. Best estimate of performance predictions for Sentinel-3A SLSTR.

The Sentiennl-3A satellite is now in full Assembly Integration and Testing (AIT) at Thales Alenia Space, Cannes, France and an SLSTR instrument has been fully integrated into the satellite. The Flight Model is now being calibrated and will be replace the unit currently integrated prior to final testing.

4. SST Applications, Scientific Research and Development.

The ESA Medspiration Project is a Data User Element (DUE) European initiative to combine sea surface temperature (SST) data measured independently by several different satellite systems into a set of data products that represent the best measure of SST, presented in a form that can be assimilated into ocean forecasting models or used for various kinds of application. It has pioneered the implementation of operational services for SST following GHRSST project recommendation and standards. Medspiration is currently developing ner L4 analysis products and climate indicators in the Mediterranean Sea. See http://cersat.ifremer.fr/thematic-portals/projects/medspiration for more details.

The ESA Felyx project is to provide an open-source, flexible and reusable software system that can be used to research and monitor the quality and performance of Earth observation (EO) data streams. The input data streams can be from sensors mounted on satellites, generated by models, or collected in-situ. The Felyx system is being developed to support both producers and users of EO data and will fully exploit the GHRSST data streams. Felyx will replace the pilot GHRSST HR-DDS. See http://hrdds.ifremer.fr/ for more information.

The ESA Climate Change Initiative (CCI) SST project focuses on the development of climate-quality SST products derived from infrared and passive microwave satellite data sets. The primary data sets are derived from the (A)ATSR and AVHRR series of IR instruments and R&D work is exploring the application of C-band passive microwave SST data. SST_cci is developing and validating algorithms to meet GCOS Essential Climate Variable (ECV) requirements for (consistent, stable, error-characterized) global satellite data products from multi-sensor data archives. Within an R&D context, SST_cci will produce the most complete and consistent possible time series of multi-sensor global satellite data products for climate research and modeling. See http://www.esa-sst-cci.org/ for more information.

Other ESA projects exploiting GHRSST data include:

- www.microwat.org (New Microwave mission concept)

- www.globcurrent.info (Ocean surface currents)
- www.storm-surge.info (Storm Surges)
- www.oceanflux-ghg.org/ (Ocean Carbon Flux)

5. GHRSST Project Office.

ESA has maintained financial support to the GHRSST project office for several years. Currently based at the University of Leicester UK and staffed by Dr Gary Corlett and Silvia Bragaglia-Pike (based at the University of Reading, UK), the GHRSST-PO provides a focal point for the GHRSST project. ESA will continue to fund the GPO at current levels until the end of 2016.

6. Conclusions.

The European Space Agency (ESA) considers GHRSST top be the primary international science team for matters relating to SST: GHRSST is the body that defines international consensus for practical and scientific issues raised by national SST science teams, projects and contributing space agencies. GHRSST data sets are utilized across the applications and research activities of ESA. In addition, ESA is developing the next generation of dual-view polar orbiting infrared radiometers to continue the successful legacy of the (A)ATSR series in the form of the Copernicus Sentinel-3 SLSTR instruments.

THE EU-GDAC AND OTHER RELATED SEA SURFACE TEMPERATURE ACTIVITIES AT IFREMER

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ABSTRACT

This report describes the status of the European GHRSST GDAC, addressing also new challenges for GHRSST system, as well as progress on Medspiration project.

1. The EU-GDAC

Ifremer hosts a European GHRSST GDAC, in order to serve the needs of European users as well as internal projects requiring continuous access to SST data and processing resources.

1.1. T Current GDAC capabilities C

The EU-GDAC combines the short term storage and NRT availability of the US-GDAC with the long-term capabilities of the LTSRF at NODC, keeping online complete archive of the majors SST data collection. The long term data preservation, involving daily data duplication on a tape library, is only ensured for datasets for which Ifremer has an archiving and dissemination responsibility: this includes in particular all SST data collections from Ocean & Sea-Ice SAF and MyOcean2 project.

The catalogue of GHRSST products and download links are available on IFREMER/CERSAT web site:

- http://cersat.ifremer.fr/data/collections/ghrsst

The data are available freely and openly, through ftp and OpenDAP. It is only requested to register to get the access credentials. Note that some datasets, for which third party distribution is not approved by the original producer, may be available for local access only (internal Ifremer users or external users accessing the CERSAT cloud). A redundant ftp access is also available for near real time datasets for which a high level of availability is required, such as O&SI SAF datasets.

Ifremer/CERSAT set up a cloud computing platform for the analysis and processing of massive archives of earth observation data. The current storage capability is about 2 PB, embedded within a cluster of about 1600 cores. All GHRSST data are stored within this platform, together with large collections of other EO data (satellite, model, in situ) allowing for fast access and processing to local users or to remote users connecting to this platform. This prevents users from downloading the data, which can not be considered for large data collections such as GHRSST datasets (10s of Tbytes of data) by processing them directly at their storage location. Access to this platform can be obtained on-demand,as long as processing resources availability allows it (contact Jean-François Piollé, jfpiolle@ifremer.fr).

The rationale and motivation behind this EU-GDAC is:

- to serve European user needs by mirroring datasets available in US-GDAC. This is not critical anymore, though it also brings more robustness to GHRSST system by providing a backup access to GHRSST data in case one GDAC is down. The access to the EU-GDAC is not restricted to European users and also allows to deal with restrictions that may apply to some countries on another GDAC for internal policy issues.
- To provide access to datasets that may not be available in another DAC or GDAC. Because the mirroring of all existing datasets is a task beyond the capability of any GDACs, because it takes time to agree and set up with the provider, this tends to lead to closer interactions of a GDAC with some

data providers. As a result, some datasets are available at US-GDAC and not at EU-GDAC, and vice versa (for instance O&SI SAF and MyOcean datasets are almost exclusively available at EU-GDAC). The figure 1 provides the current list of products hosted at EU-GDAC, underlined in blue are the datasets solely available at EU-GDAC (or with a more complete archive). This clearly shows that US-GDAC and EU-GDAC are complementary regarding the extent of their data collections.

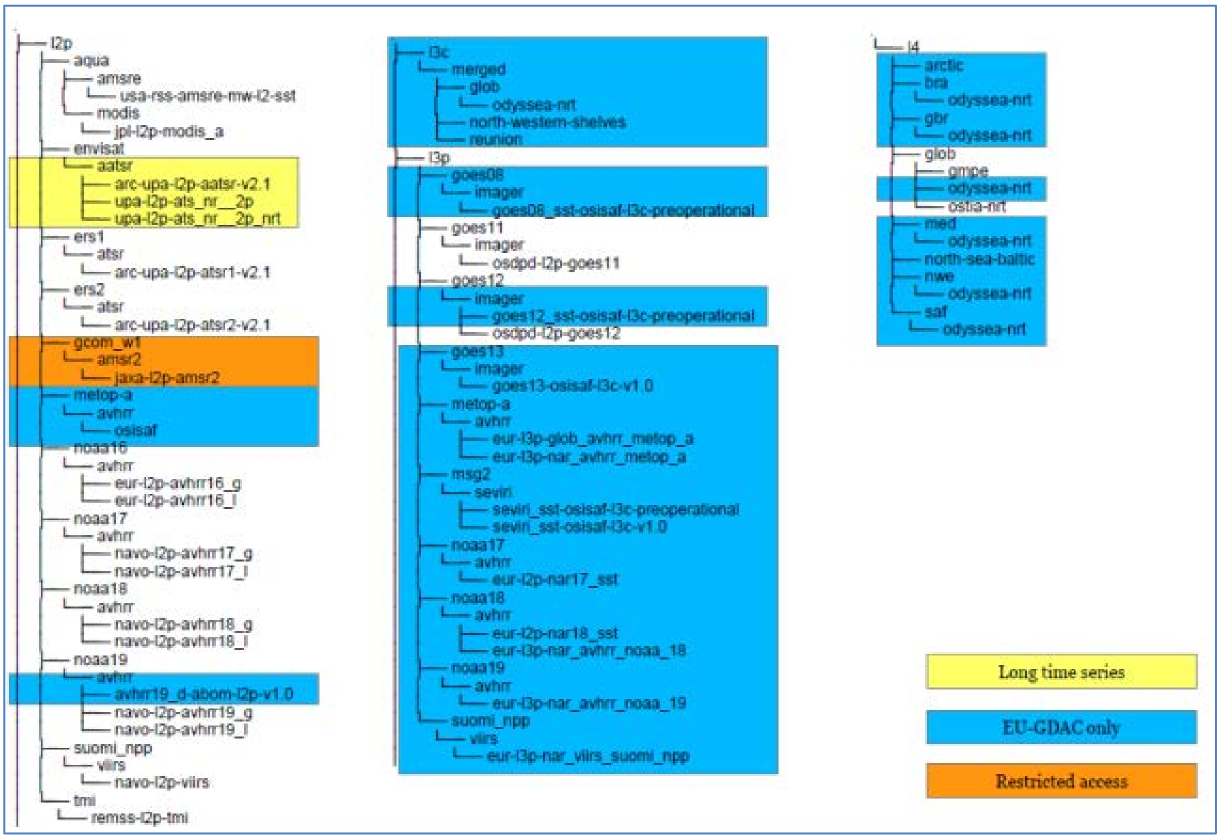


Figure 1: list of GHRSST products at EU-GDAC (in color datasets complementary to US-GDAC)

- As shown on figure 2, Ifremer is developing a set of projects aiming at data synergy, combining SST with other parameters to evaluate new quantities such as ocean gas fluxes, ocean heat fluxes, ocean acidification, salinity and high wind speeds from SMOS, ocean surface currents. Most of these project are funded by ESA which is therefore a strong sponsor for the EU-GDAC. They require a permanent access to large collections of data. Similarly Ifremer is engaged in several project to implement tools and validation resources, such as Felyx (ESA, see dedicated report in GHRSST XV) which will be used to generate match-up databases (with in situ) for GHRSST products and diagnostic datasets for intercomparison over regional areas: this require direct access to the source data collections, to extract subsets from these massive datasets. This led to assemble a large SST data archive, building de facto a new GDAC at Ifremer. Not to mention other processing activities, such as the Odyssea reanalysis (see in next section).

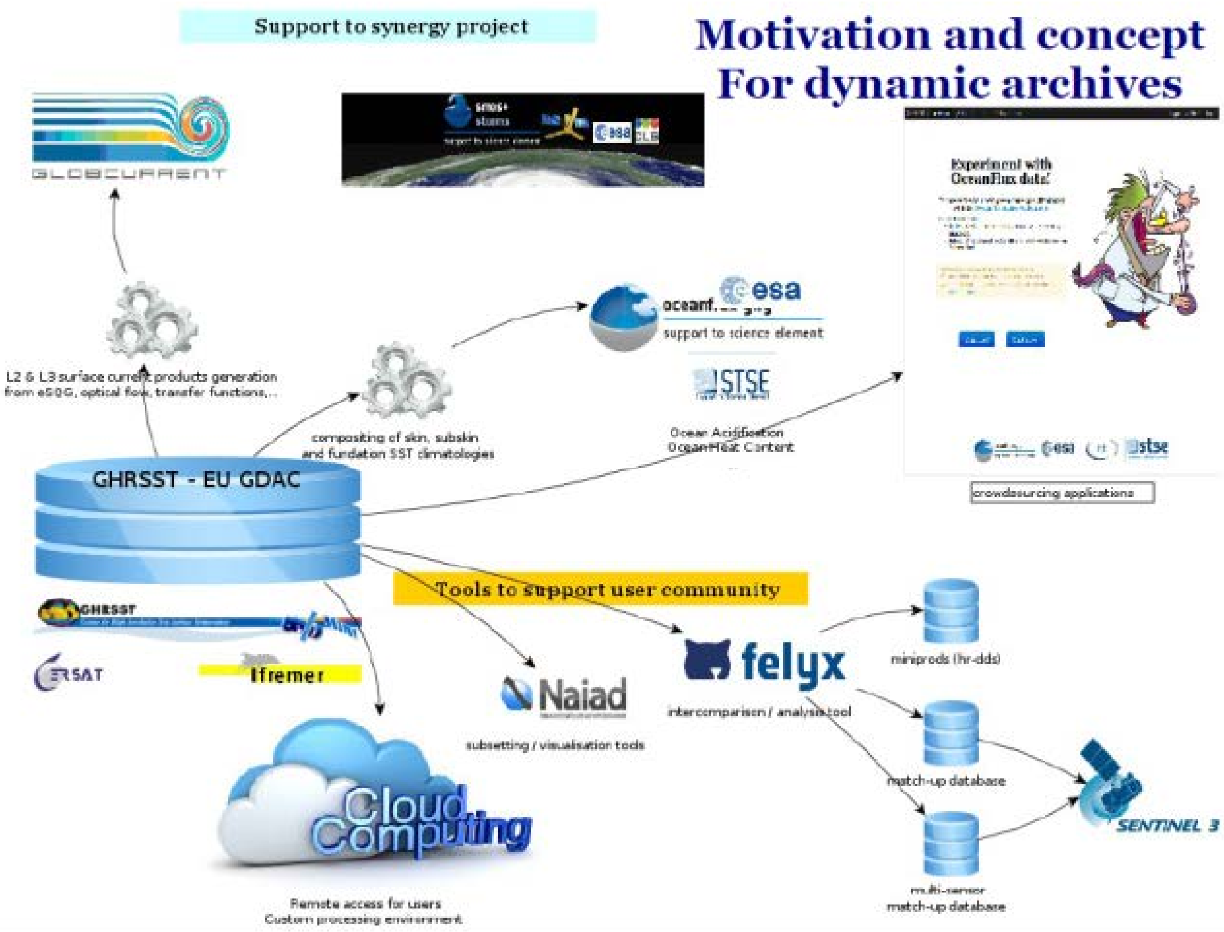


Figure 2: projects and tools graviting around the GHRSST EU-GDAC archive for a dynamic exploitation of this archive

1.2. Towards an evolution of GHRSST model?

For all the reasons mentioned above, the traditional GHRSST model (multiple RDAC and a single GDAC) is no longer valid:

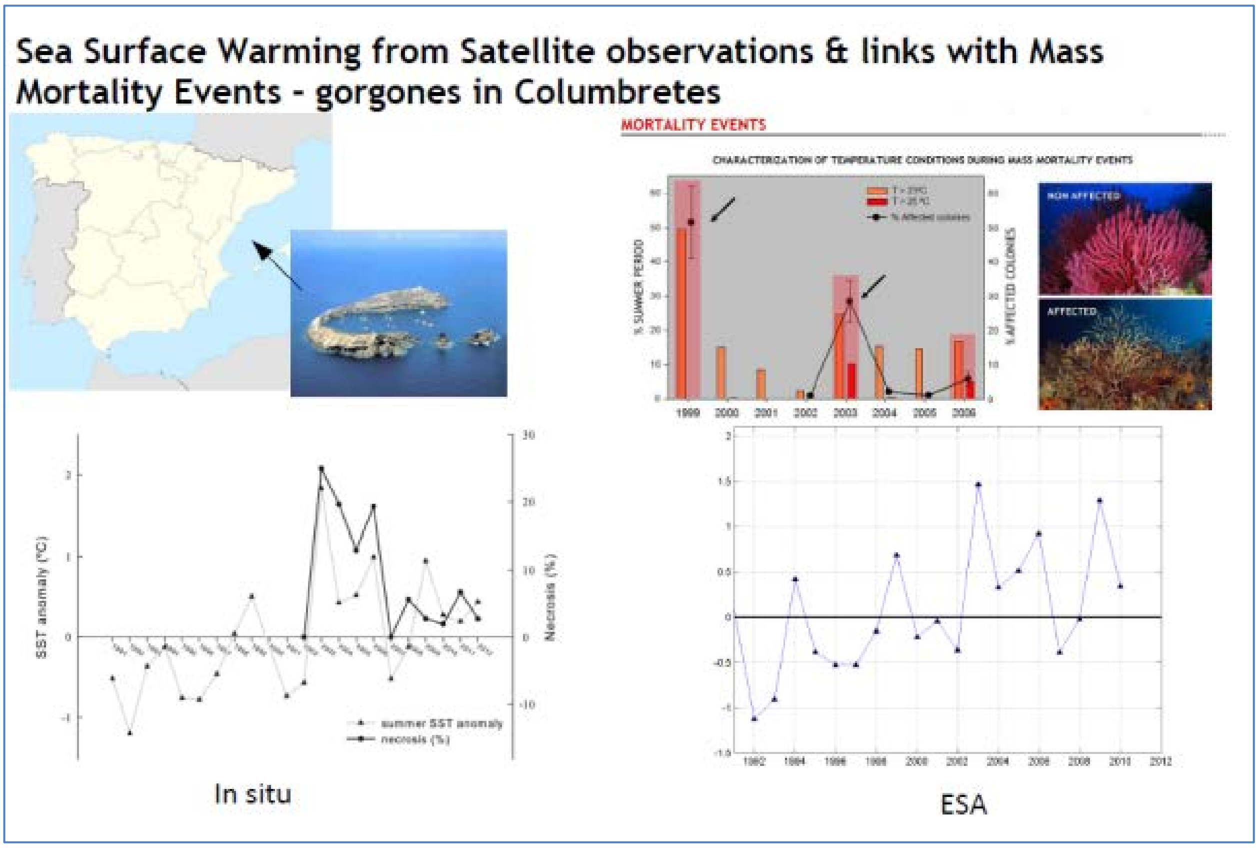
- some datasets are distributed exclusively by RDACs because of strong data policy which may take time to smooth out.
- none of the current GDACs provides all the available GHRSST datasets, they are actually complementary
- replication and redundancy between RDACs/GDACs adds reliability to the overall GHRSST system and should be considered as an asset
- this reliability applies also to funding which is not secured for ever at any GDAC. Replication allows to face such possible issues in future too.
- Data transfer over the network is no longer the ideal data paradigm. Users will analyse and work with data over dedicated platforms remotely. This will necessary involve copying datasets at different locations.
- Even in the traditional data access model (dowwnload by a user from a remoite server), there is no nowdays any real need for physically centralized data archives, as this can be virtualized as when you download your latest TV series episode.

For all these reasons, we think the GHRSST system model should be revised. A centralized catalogue and access should replace the physical centralized storage, allowing for multiple access points to the same datasets. This would make the overall system more comprehensive (instead of interrogating each GDAC in current system to compare available products) and more reliable.

Lastly, crowdsourcing tools should also be investigated to build the users community, allow data quality assessment by the users, build and feedback knowledge from and to the users (preferred products, etc...).

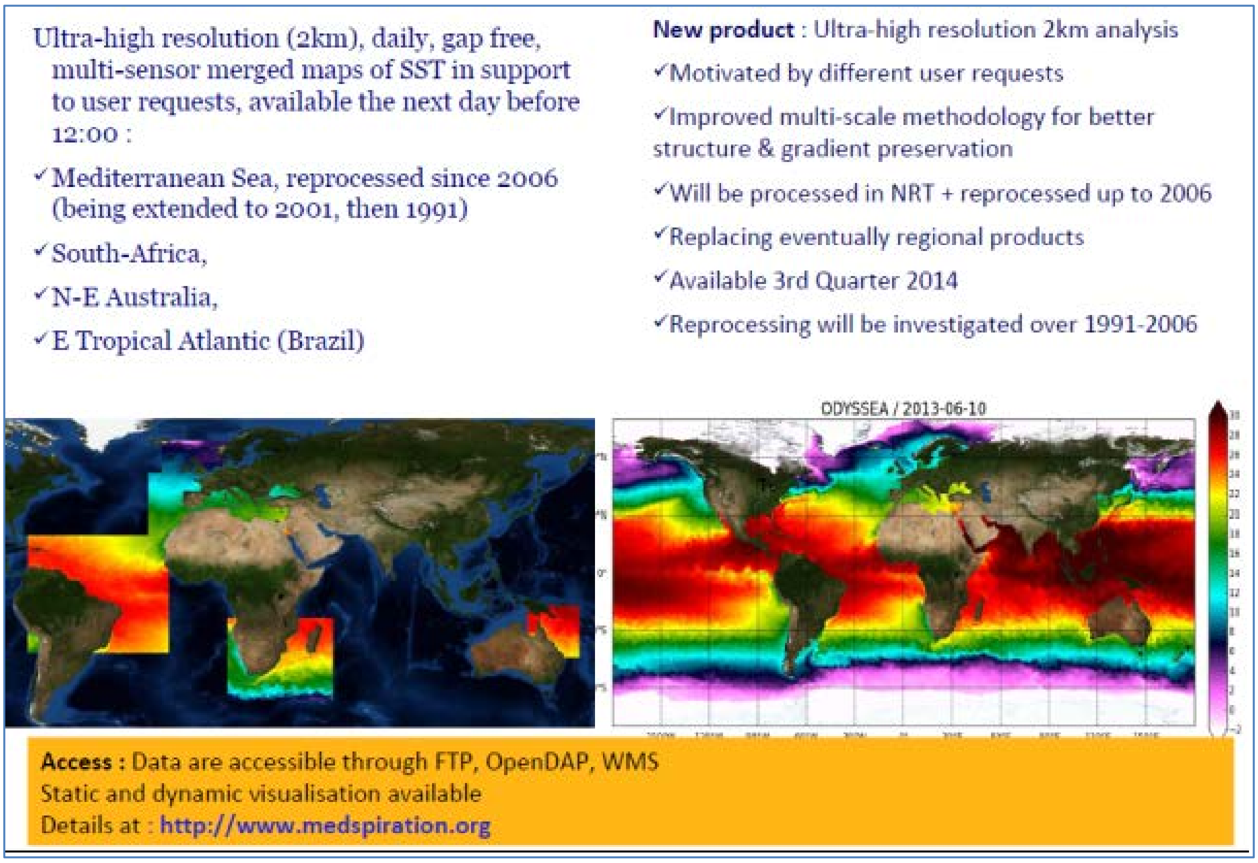
2. Medspiration +

Medspiration “Plus” is an ESA initiative and a 2 year extension to the former Medspiration project (http://www.medspiration.org). It aims at bridging the gap with new user communities that may not be fully aware of the potential of satellite observation or may lack the resources or tools to manipulate them. It aims at achieving this by developing shared studies in two different communities and organizing dedicated user workshops. A particular domain of interest is the evaluation and monitoring of climate change over small and medium islands in Mediterranean Sea. This is done in the context of an international initiative (PIM project, http://initiative-pim.org/en) which gathers several Med Sea countries and a large community of experts from different domains. It addresses critical issues such as the understanding of mass mortality events (here gorgones, in figure 4) clearly related to sea surface temperature anomalies).



In parallel, we are sustaining the production of Medspiration high resolution analysis (2km) over Mediterranean Sea, South-Africa, Brazil & tropical Atlantic and Great Barrier Reef in Australia (see figure 5).

We have also implemented a new global high resolution analysis from a large collection of data. This product will replace the regional analysis. It is based on the same methodology (Odyssea processing chain) with improvements including multi-scale processing for better rendering of small scale features and gradients. It will be available at the end of 2014, both in NRT and reprocessed back to 2006. Further reprocessing back to 1991 will be then investigated but not available before next year.



EUMETSAT AND OSI-SAF REPORT FOR GHRSST

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ABSTRACT

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

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

1. SST at EUMETSAT

EUMETSAT operational services from Metop-B (AVHRR, IASI) and Meteosat-10 (SEVIRI) continue. Launches related to oceanography planned for 2015 include MSG-4 (SEVIRI) in July 2015; and the 3rd party/optional programmes of Copernicus Sentinel-3 SLSTR from July-September 2015; and Jason-3 planned for March 2015. Further ahead, Metop-C is planned for 2018; EPS-SG (MetImage, IAS) around 2020; and MTG-I1 (FCI) in 2018 and MTG-S1 (IRS) in 2020.

A recent update to the Metop-AVHRR Level1b products includes NeDT. SSTs from IASI continue to be available from the EUMETSAT data centre in L2Pcore format, with Metop-B data available from January 2014 in addition to Metop-A. A new version 6 of the IASI level-2 processor is planned to be operational summer 2014, and will include a new SSES scheme for IASI L2Pcore. The OSI-SAF produces IASI L2P in full GDS2 format (including auxiliary data), with the pre-operational release planned for summer 2014. Figures 1 and 2 show recent validation results of IASI SST against drifting buoy and AVHRR SSTs from a matchup dataset produced by the OSI-SAF. Version 5 IASI SSTs continue to have a slight cool bias with respect to drifting buoys. Preliminary validation results using version 6 IASI SSTs (with a new 1D-Var retrieval) indicate this cool bias is reduced to less than -0.1K (compared to drifting buoys) for the highest quality results.

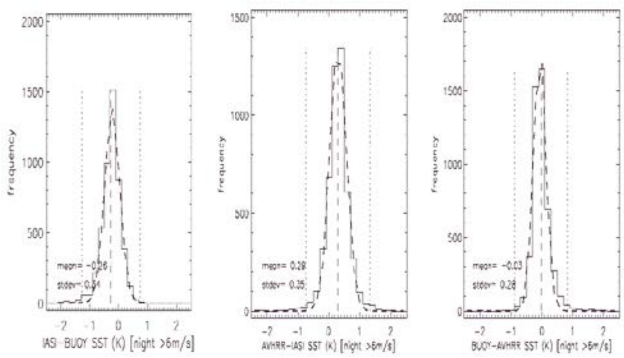

Figure 1: Histogram of IASI, AVHRR, buoy SST differences (night-time, wind over 6m/s, with quality control) over the period April 2013 to December 2013.

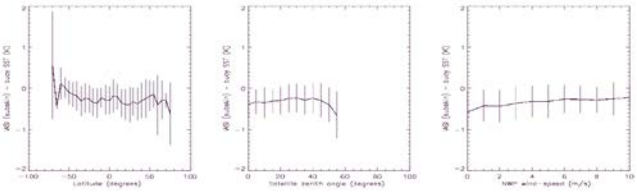

Figure 2: IASI minus drifting buoy SST differences versus latitude, satellite zenith angle and ECMWF wind-speed over the period April 2013 to December 2013.

2. EUMETSAT Ocean and Sea-Ice Satellite Application Facility

The OSI-SAF Continuous Development and Operations Phase 2 began in March 2012, and preparations are beginning for the start of CDOP-3 in March 2017.

New developments in 2013/2014 include: lake validation (Eastwood et al, GHRSST, 2014), Arctic studies, and a new LEO (Metop/NPP) chain in pre-operational mode (Le Borgne et al, GHRSST, 2014). Activities in preparation include: reprocessing of MSG archive (end 2015); Metop-A to Metop-B and new chain (end 2014); and introduction of Ice Surface Temperature in the high latitude SST product (end 2014).

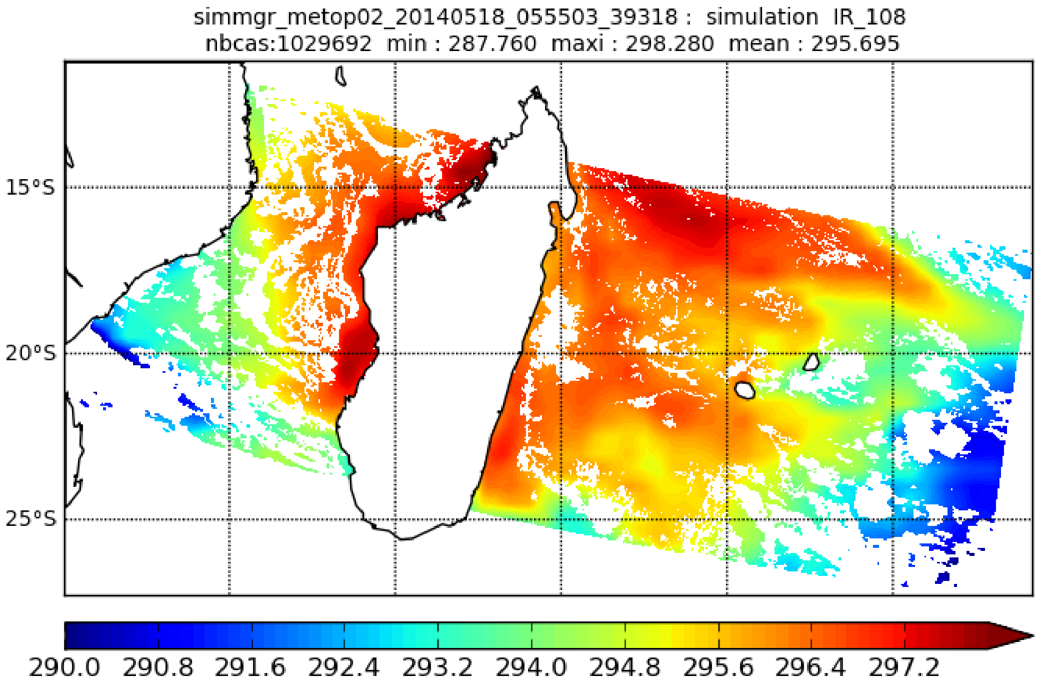

Figure 3: Full resolution BT simulation in channel 10.8micron in a Metop-A granule on the 18th May 2014

3. Copernicus Sentinel-3 SLSTR

EUMETSAT is participating in the European Commission's Copernicus Sentinel-3 programme in partnership with ESA, where EUMETSAT will operate the satellite and will serve the marine user community. ESA is responsible for the development of the Sentinel-3 space and ground components and will serve the land user community. The first meeting of the ESA-EUMETSAT Sentinel-3 Validation team meeting took place in November 2013, and contributed to the preparation of the S3VT implementation plan. The development of SLSTR operational processors with industry is progressing. The Sentinel-3 satellite is currently planned to be launched on 30th June 2015 (with a July to September launch window). The satellite will have on board the

Sea and Land Surface Temperature radiometer (SLSTR), a dual-view sensor, and is a successor to the ATSR series but with a wider swath and updated instrument characteristics.

Level 0 and Level 1 data and products will be generated at both EUMETSAT and ESA. EUMETSAT will be the Sentinel-3 marine centre and are responsible for the production and distribution of the level-2 marine products. Data will be distributed through EUMETCast and the EUMETSAT data centre as currently demonstrated for other EUMETSAT satellite data such as from the Metop's, MSG and JASON-2.

4. Third party data activities

Work towards access to relevant sea surface temperature data from third-parties continues including the agreements with ISRO, SOA and JAXA. The SNPP4C project has begun whose purpose is to demonstrate the provision of real time Suomi-NPP data to the Copernicus services using existing infrastructure. The project builds on the established EUMETSAT/NOAA relationship. SST from VIIRS (ACSPO 2.3) is now being sent to MyOcean2. The project also includes atmospheric composition from VIIRS, OMPS and CrIS (MACC-II). The first dissemination of SST products began on 8th May 2014. They are first processed at EUMETSAT to reduce their volume by 50% before redistribution by EUMETCast, by the removal of experimental brightness temperatures data.

In addition to its own satellite data and meteorological products, EUMETSAT also distributes data and products from partner organisations as part of an international cooperation, some of which is made available via EUMETCast, direct dissemination and the internet. Distributions relevant to SST include: receiving microwave SST from HY-2a from NSOAS; the process of receiving GHRSST AMSR-2 products from JAXA has started; sample SST data in HDF format from Insat-3D from ISRO and contact established. More information on third party data activities can be obtained from EUMETSAT's third party data manager, Simon Elliott, simon.elliott@eumetsat.int.

5. References

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Le Borgne, P., G. Legendre, A. Marsouin, S. Pere, H. Roquet, S. Saux-Picart, Regional biases in operational SST retrieval, GHRSST, 2014.

REPORT TO GHTSST XV FROM JAXA

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ABSTRACT

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

AMSR2 onboard the GCOM-W satellite was launched on 18 May 2012 (JST) from Tanegashima Space Center, Japan. AMSR2 Level 1 (brightness temperature) products have been released to public since 24 January 2013, and Level 2 (geophysical parameters including SST) have been available in May 2013. GCOM-C, which carrying SGLI instrument, is currently scheduled to be launched in Japanese Fiscal Year of 2016. AMSR-E has restarted but in slow rotation of 2-rpm since December 2012 to implement cross-calibration between AMSR2. VIRS on the TRMM satellite has turned off due to satellite bus battery anomalies since 21 March, 2014. JAXA-NASA joint mission Global Precipitation Measurement (GPM) Core Observatory was launched on 28 February 2014 (JST) and GMI L1 data was released to public on 16 June, 2014.

Renewal of JAXA GHRSST server (http://suzaku.eorc.jaxa.jp/GHRSST/) has been completed in May 2013 to distribute L2P and L3C SST products of AMSR2, AMSR-E, WindSat and VIRS in GDS 2.0 format. AMSR2 near-real-time (3-6 hours after observation) SST in GDS 2.0 is available in April 2014.

JAXA data policy regarding environmental satellite data, including GCOM and GPM, was changed and accepts free distribution to third parties and commercial use without restriction, and products in JAXA GHRSST server can be provided to GDAC and LTSRF.

1. Introduction

JAXA developed the Ocean Color and Temperature Scanner (OCTS) as optical imagers to observe SST onboard the Advanced Earth Observing Satellite (ADEOS) operated from 1996 to 1997, the Global Imager (GLI) onboard the Advanced Earth Observing Satellite-II (ADEOS-II) operated from 2002 to 2003, and is developing the Second generation Global Imager (SGLI), which will be carried by the Global Change Observation Mission (GCOM) - Climate (GCOM-C) scheduled to be launched in Japanese Fiscal Year (JFY) of 2016.

JAXA also developed the Advanced Microwave Scanning Radiometer (AMSR) as passive microwave imagers to observe SST, onboard the ADEOS-II, AMSR for EOS (AMSR-E) onboard NASA's EOS Aqua satellite, which has been operating since 2002, and launched AMSR2 onboard the GCOM - Water (GCOM-W) in May 2012. C-band (6.9-GHz/7.3 -GHz) channels on AMSR, AMSR-E and AMSR2 are indispensable for retrieving global sea surface temperature and soil moisture. All-weather and frequent measurements enables analyses of rapid changes of SST.

2. Current status of JAXA missions

2.1. AMSR-E

AMSR-E was launched in May 4, 2002, and halted its observation in 4 October 2011. Since AMSR-E hardware (both sensor and control) is expected in healthy condition except for its large friction with antenna rotation, and cross-calibration between AMSR-E and AMSR2 is very important, JAXA prepared a recovery plan with engineers and NASA. AMSR-E has restarted observation at 2-rpm (in slow rotation) since December 2012 to implement cross-calibration with AMSR2. Details about slow rotation AMSR-E operation are available from the AMSR-E web site (http://sharaku.eorc.jaxa.jp/AMSR/products/amsre_slowdata.html).

Currently, AMSR-E L1B data in 2-rpm mode is distributed to public through the GCOM-W Research Product web page (http://suzaku.eorc.jaxa.jp/GCOM_W/research/terms.html).

2.2. AMSR2 on GCOM-W

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

AMSR2 onboard the GCOM-W satellite was launched on 18 May 2012 (JST) from Tanegashima Space Center, Japan. The GCOM-W satellite has joined A-train orbit since 29 June. After GCOM-W was inserted into the planned position on the A-Train orbit, AMSR2 was spun up to 40-rpm, and then set to “science mode” to start observation in 3 July. Initial checkout of the satellite and the instrument has completed in 10 August without major problem. The GCOM-W satellite was installed in front of the Aqua satellite to keep continuity of AMSR-E observations and provide synergy with the other A-Train instruments for new Earth science researches.

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

AMSR2 SST product is validated by comparing with the quality controlled buoy SST observations of the iQUAM version 1 provided by NOAA/NESDIS. Each match-up data will include AMSR2 footprints around buoy stations within radius of 30 km and 2 hours. Root mean square error (RMSE) between AMSR2 and buoy SSTs from May to December, 2013 is currently 0.57 °C, which is including both ascending (noon) and descending (night) orbits, and correlation coefficient (R) is 0.998 (Table 1).

AMSR2 SST is also operated in near-real-time (NRT) basis, 3-6 hour after observation. Differences between NRT and standard processes are input ancillary data. NRT product uses forecast of surface atmospheric fields instead of global analysis data and daily MGDSST of previous day instead of current day as ancillary data. Comparison of statistics calculated from both AMSR2 NRT SST products with buoys are also summarized in Table 2.

	Standard AMSR2 SST [°C]		
	Ascending + Descending	Ascending (noon)	Descending (night)
Bias	0.071	0.093	0.051
RMSE	0.57	0.58	0.56
Correlation Coefficient	0.998	0.998	0.998

Table 1. Comparison of AMSR2 standard SST with buoys (iQUAM V1).

	Near-Real-Time AMSR2 SST [°C]		
	Ascending + Descending	Ascending (noon)	Descending (night)
Bias	0.065	0.080	0.051
RMSE	0.57	0.59	0.56
Correlation Coefficient	0.998	0.998	0.998

Table 2. Comparison of AMSR2 near-real-time SST with buoys (iQUAM V1).

AMSR2 SST algorithm uses 6.9-GHz channels to retrieve SST, but has a weak point that horizontal resolution of 6.9-GHz is the worst in the AMSR2 channel set. The 10-GHz channel also has sensitivity to SST higher than 10-12 °C, and can provide SST with finer horizontal resolution, and less missing areas along the coast lines. AMSR2 SST using 10-GHz channel is one of research product candidate for future release. Currently, JAXA is processing AMSR2 10-GHz SST as test product and evaluating its accuracy by buoy SST. Figure 1 is scatter plots of AMSR2 10-GHz SST versus buoy observation, and Table 3 is a summary of statistics. Please note that SST under 10 °C is not excluded during the comparison with buoys. Therefore, scatter plot shows bad accuracy in SST range under 10 °C. When providing this SST data, SST under 10 °C should be missing or, at least, flagged.

	AMSR2 10 GHz SST [°C]		
	Ascending + Descending	Ascending (noon)	Descending (night)
Bias	0.193	0.221	0.168
RMSE	0.87	0.85	0.89
Correlation Coefficient	0.991	0.992	0.990

Table 3. Comparison of AMSR2 10-GHz SST with buoys (iQUAM V1).

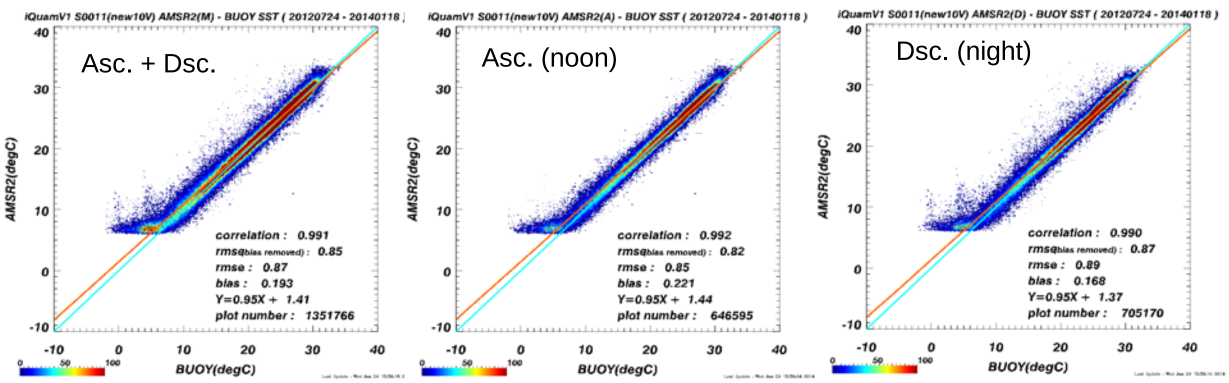

Figure 1: Scatter plots of AMSR2 10-GHz SST and buoy SST (iQUAM V1) from 24 July 2012 to 18 January 2014. Left: Ascending and descending orbit. Middle: Ascending orbit (noon). Right: Descending orbit (night).

2.3. VIRS on TRMM

TRMM is a joint mission between JAXA and NASA, which was launched in November 1997 and still in iperation. The Visible Infrared Scanner (VIRS), which was developed by NASA, on board the TRMM satellite has turned off since 21 March, 2014, due to satellite bus battery anomalies and considering operational priority within the mission. Currently, battery is normal status, but the TRMM Science Team has made the decision that for the time being, the VIRS instrument will remain off for safety.

2.4. GMI on GPM Core Observatory

The GPM Core Observatory, a joint mission between JAXA and NASA, was launched from JAXA Tanegashima Space Cenrter on 28 February, 2014 (JST). GPM Microwave Imager (GMI) was developed by NASA as a successor of TMI on board the TRMM satellite, and its Level 1 brighness temperature data was released to public in 16 June, 2014.

GMI has 10-GHz channel same as TMI, and has a capability to measure SST higher than 10-12 °C. Currently, JAXA is working on developing GMI SST for release in JAXA GHRSST server.

2.5. SGLI on GCOM-C

SGLI is a versatile, general purpose optical and infrared radiometer system covering the wavelength region from near ultraviolet to infrared. SGLI system consists of two components; SGLI-VNR (Visible & Near infrared push-broom Radiometer); and SGLI-IRS (shortwave & thermal InfraRed Scanner) to optimize optics for each wavelength range. Two major new features are added to SGLI, they are 250 m spatial resolution for 11 channels and polarization/multidirectional observation capabilities. The GCOM-C satellite is currently scheduled to be launched in Japanese Fiscal Year of 2016.

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

3. Current status of JAXA GHRSST Server

Renewal of JAXA GHRSST server (http://suzaku.eorc.jaxa.jp/GHRSST/) has been completed in May 2013. Web site includes information of available SST products produced by JAXA, registration form to download data, and near-real-time monitor of products.

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

Distribution of AMSR2 SST in near-real-time basis, available within 3-6 hours after observation, was started at April, 2014 from the JAXA GHRSST server.

JAXA data policy regarding environmental satellite data, including GCOM and GPM, was changed and accepts free distribution to third parties and commercial use without restriction, and products in JAXA GHRSST server can be provided to GDAC and LTSRF.

4. Activities and Plan for 2014-2018

Currently, we're planning following activities during 2014 and 2018 as shown in Table 4.

Year	Activities and plans
2014	Update of AMSR2 SST algorithm. Release of GMI SST data to public. Addition of AMSR2 10-GHz SST to JAXA GHRSST server (TBD). Update of AMSR-E Level 1B reflecting AMSR2 knowledge.
2015	Release of consistent passive microwave SST products applying AMSR2 algorithm.
2016	Launch of GCOM-C satellite (TBD).
2017	Release of SGLI data products to public (TBD). Addition of SGLI SST to JAXA GHRSST server (TBD).
2018 or later	Launch of AMSR2 follow-on (TBD)

Table 4. List of JAXA activities and plans from 2014 to 2018

5. Conclusion

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

Both of GCOM-W satellite and AMSR2 instruments are in good condition after the launch in May 2012, and their performances are excellent. All AMSR2 standard products were released to public, and distributed through the GCOM-W Data Providing Service System (https://gcom-w1.jaxa.jp).

The GPM Core Observatory and its instruments are also in good condition after the launch in February 2014. Currently, JAXA is working on developing GMI SST algorithm and processing system to distribute data through the JAXA GHRSST server.

JAXA GHRSST server was replaced by new system, and web site also renewed its contents (http://suzaku.eorc.jaxa.jp/GHRSST/). SST data from AMSR2, Windsat and VIRS are available from the JAXA GHRSST server in GDS 2.0 format. In addition, AMSR2 SST in near-real-time basis has been distributed through the server since April 2014. Recent change of JAXA data policy accepts distribution of JAXA products from GDAC and LTSRF, and we expect wider utilization of SST products in various user communities.

REPORT TO GHRSST XV FROM JMA

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ABSTRACT

After the 14th GHRSST Science Team Meeting, JMA has started to use global daily sea surface temperature (MGDSST) analysis for surface boundary condition of One-month Ensemble Prediction System (EPS). In order to increase the resolution of SST analysis, JMA is developing a regional SST analysis system (1/10° resolution), in which MTSAT SSTs are incorporated.

1. Introduction

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

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

Because the OI method applied in the MGDSST analysis considers temporal correlation, this method requires the observation data after the target day in order to produce the more appropriate analysis. On the other hand, long term, consistent time series of the SST analysis is needed for climate research. For these reasons, JMA conducted reanalysis (first version of reanalysis) of the MGDSST from 1985 to 2004 using AVHRR Pathfinder Version 4/5.0 SST in 2006, and the reanalysis MGDSST was extended to 2005 in 2007. For the purpose to incorporate the observation data after the target day into the MGDSST, JMA has been reprocessed the MGDSST analysis (delayed analysis) in operation with about 5-month delay using GAC AVHRR SST and AMSR-E/AMSR2 SST since 2006.

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

2. Current Status of the MGDSST Analysis

In October 2011, AQUA/AMSR-E SST was excluded from the MGDSST analysis due to the completion of its observation. After the launch of GCOM-W1/AMSR2 in May 2012, JAXA made great efforts to retrieve SST. In 27 May 2013, JMA started incorporating AMSR2 SST into the MGDSST. Currently, JMA uses AVHRR SST (NOAA-18, NOAA-19 and MetOp-A), WindSat SST and AMSR2 SST to generate operational MGDSST data. AVHRR SST data are provided by NOAA/NESDIS for Global ocean (GAC data), as well as locally received by MSC/JMA for the western North Pacific (HRPT data). SST from both WindSat and AMSR2 are provided by JAXA. In 2013, JMA performed reanalysis (second version of the reanalysis) of the MGDSST from 1982 to 2006 using AVHRR Pathfinder Version 5.0 /5.1 SST and AQUA/AMSR-E SST.

For providing one-month forecasts, JMA operates One-month Ensemble Prediction System (EPS), which consists of 50 members of numerical atmospheric prediction models. The EPS used COBE-SST, which is 1° resolution analysis using in-situ SST measurements alone, for surface boundary conditions. Since March 2014, JMA started to use the MGDSST for the EPS.

3. Current Status of the MTSAT SST Product

SSTs from MTSAT-1R and MTSAT-2 observations show a good performance for monitoring ocean states. But additional efforts to reduce biases are required for incorporating into SST analysis, since the current method produces MTSAT SSTs with large negative biases in the areas where satellite zenith angles are larger than 50 degrees. MSC/JMA developed a new physical retrieval method for producing MTSAT SSTs using one-dimensional variational (1DVAR) technique (Kurihara, 2012). The new method includes single layer radiative transfer calculation in order to take into account effects of water vapor absorption and sea surface emissivity. MSC/JMA is preparing operational system to generate MTSAT SSTs using the new retrieval method.

Based on the MGDSST analysis system, JMA is now developing a regional SST analysis system (1/10° resolution), in which new MTSAT SSTs are incorporated. In the regional analysis system, smaller and shorter scale features are considered in optimal interpolation procedure. Figure 1 show an example of the analysis in the case of rapid SST decrease due to passing of typhoon Man-Yi, in 2014. SSTs generated from regional analysis system captures rapid SST decrease after passing the typhoon (from 15th to 17th Sep.), whereas the MGDSST shows a little decrease during the same period.

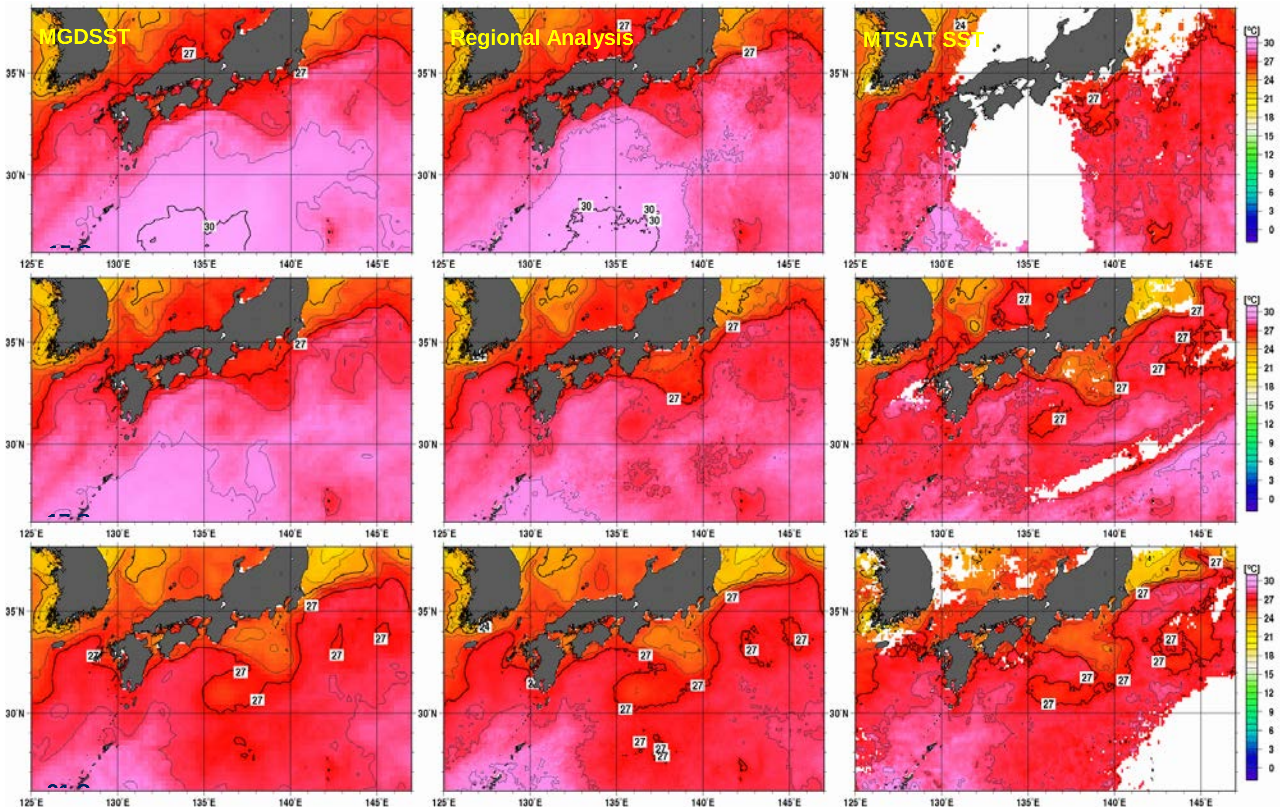

Figure 1: SST field from the MGDSST(left), from regional analysis (middle) and MTSAT-2(right). Typhoon Man-Yi was located at around 20N135E in 15th September (white area south of Japan in top right panel).

4. Himawari 8/9

Himawari 8/9 are the successor to MTSAT-1R/2, Geostationary Meteorological Satellite of JMA. There are several improvements including:

- Increased number of spectral bands from 5 to 16
- Increased spatial resolution for VIS and IR channels (from 4km to 2km for IR)
- Increased measurement frequency (from every hour to every ten minutes for entire region).

Himawari 8 is scheduled for launch in Japanese Fiscal Year of 2014 (Himawari 9 no earlier in JFY2016).

5. Future Plan

1. The new method which improves SST retrieved from MTSAT observation will be applied to operational system in 2014.
2. JMA continues to develop a system to incorporate MTSAT SST into SST analysis aiming to increase the resolution of the analysis.
3. JMA is preparing *Himawari* 8, the successor to MTSAT, to be launched in 2014.
4. JMA will develop a system to create and deliver MGDSST files of NetCDF version based on GDS-2.0 format.

6. References

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PLENARY SESSION II: REVIEW OF ACTIVITIES III

SESSION REPORT

Chair: Alexander Ignatov[2]; Rapporteur: Prasanjit Dash[2]

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ABSTRACT

The session featured six speakers representing five organizations.

Summary of Speakers and Organizations

1. My Ocean – Hervé Roquet
2. NASA – Ed Armstrong
3. NAVO – Jean-François Cayula
4. NOAA – Kenneth Casey
5. NOAA – Eileen Maturi
6. DMI – Jacob Høyer

Summary of presentations

The highlights for each talk are given below.

1. MyOcean RDAC Progress Report – Hervé Roquet

Points: (1) transition of Copernicus to operational phase, (2) MyOcean2 progress, and (3) new and future products and services.

1.1.

Background was given on the overall environment and status of the current transition from MyOcean research to operational phase. Research phase planned to complete by Feb 2014 was extended to Mar 2015, when operations will be delegated to “entrusted entities”. Land and emergency and security services will be provided under direct management through EC services and EU agencies, whereas the Atmosphere, Marine and Climate services are competed. Requests for expression of interest were issued in Feb 2014; potential operators selected in Mar 2014; direct negotiations with potential operators are underway from Apr-Oct 2014; contracts with selected operators will be negotiated by Nov 2014; contractors selected by Mar 2015; and the operational efforts ramped up by Jun 2015. Negotiations are underway with ECMWF for Atmosphere and Climate Services and with the Mercator Ocean for Marine Services. In Marine Services, EC requested continuity with MyOcean, open completion for implementing, and Europeanization of the services.

1.2.

MyOcean2 progressed to v3.1 which offers 4 new satellite products (NRT sea level over the Mediterranean; L4 Hi-Res SST over Baltic, L4 Hi-Res SAR sea ice over Arctic; and global NRT wind from Metop-A/B ASCAT and OSCAT ¼º. Main updates include new reanalysis from 1993-2011; ocean color (MODIS-A and VIIRS) – global and Baltic, and aggregation of bio-model from hindcast to forecast – Mediterranean. Other updates include OC L3/4 products over Black Sea; monthly/seasonal means of OSTIA SSTs; assimilation of ARGO floats in the model over Black Sea; tuning model over Arctic; and hourly resolution for the model product over the NW shelf. MyOcean2 v4 will offer 124 products (instead of current 111). 30 new products will be added (including 6 model, 23 satellite and 1 in situ). 38 products will be updated (13 model, 25 satellite and in situ obs).

1.3.

Examples were given of the new products in v 3.1 (Baltic SST reanalysis from 1983-2009, DMI), v 4.0 (regional 3-hourly diurnal SST analyses, M-F/CMS), v 4.1 (sea and ice surface temperature, DMI), and MyOcean2FO (global diurnal SST analyses, Met Office).

2. NASA RDAC Progress Report – Ed Armstrong

Points: (1) MODIS ST team meeting last month, (2) NASA Physical Ocean program and the SST Science Team, (3) CEOS COVERAGE Program, (4) NASA funded GHRSST datasets, (5) ESDIS GIBS.

2.1. MODIS SST Team Meeting report

a. 5 earth science missions launches this year: OCO-2, ISS-RapidSCAT (PO.DAAC), ISS-CATS, SMAP, SAGE-III ON ISS
b. MODIS Terra Aqua continue to operate normally
c. Terra lifetime until 2022! Similar or longer for Aqua
d. GHRSST MODIS datasets presented to community
e. Collection 6 reprocessing for both T/A. Improved SST coefficients and cloud mask
f. Collection-6 reprocessing will generate new GHRSST L2P datasets; netCDF4, lots of effort
g. Time series in PO.DAAC will extend back in time to cover full T/A missions

2.2. Physical Oceanography program (Eric Lindstrom)

a. OS Topo, vector wind, salinity, SST
b. PO R&A (including SST) ~10 M USD
c. SST as % of PO program: a little bit less (15-30 % between 2009-2014)
d. ISS SST White paper covers 3 points (requirements on sat SST, framework of characterization of error budget, recommendation for tasks that will improve products)
e. Perspectives, Issues, Discussions
    - How best to interface with other NASA Science Teams including Ocean Salinity and Ocean Vector Winds
    - Recognize that multi-sensor activities are required
    - Integrate/link to GHRSST

2.3. CEOS COVERAGE program

a. why produce multi variable ocean product
b. individual applications using a single variable may be enhanced by other ocean data (e,g. fish tracker)
c. recent application poll from GHRSST webinar

2.4. NASA funded products

a. MUR L4: users are requesting NRT. May 2014 started interim- productions at 3-2-1 day latency
b. Ongoing/Future: QC/adjustment of Arctic SST, prep for ingestion of VIIRS

2.5. ESDIS browse enhancements examples from the Global Imagery Browse Service (GIBS)

This statement attributed to Eric Lindstrom lead to some discussion: “It is time to define the NASA/Science Team relationship to GHRSST. How best to make the most of the commonalities and complementarities?”

Comments: **Peter** NASA is a little late in the game. Not to undermine but there is some effort being duplicated. **Craig** agrees. Craig: Eric’s activities do not undermine GHRSST and *vice versa* but what we need to do is an “active collaboration” and benefit.

3. NAVOCEANO RDAC Progress Report – J-F. Cayula

Points: (1) L2P production; (2) NAVO K10 L4; (3) NAVO VAL stats; (4) GDAC downloads; (5) MCSST processing; (6) Future plans.

3.1. L2P Production:

a. N18 global 9km (dgs1/2), N19 same
b. L2p inputs: N18/19, Metop-A/B: cal earth located AVHRR HIRS 1B from OSPO, NPOESS S-NPP VIIRS M-Band, NAAPS AOD, land/sea mask (low & high res), climatology, analyzed fields (100 km, 10 km), SST match up database
c. L2p file content for GDSv1.0: standard + BTs
d. L2p GDS2: all standard with BT non L2P core fields
e. Showed stats stratified by quality levels, between levels 5 and 3, sharp contrast

3.2. NAVO K10 L4 analysis

a. Updated 4 times daily. Lots of inputs including S-NPP. May 2014: RMS=0.5K, Bias=-0.08K, # of obs=11,876

3.3. Production stats

a. # of obs for GAC: 0.4M/day
b. # of HR SST obs per day: 15M/day, NPP about 23M/day
c. MCSST daytime RMSD wrt. drifters pretty stable.

3.4. Showed download statistics from GDAC, March 2014

3.5. NAVOCEANO improvements

a. Improvement to NCM
b. Evaluating modification of coverage/cloud detection, daytime, VCT test

3.6. Future work

a. Turn off dissemination of L2P in GDSv1.0 depending on users’ feedback
b. Continue improve NCM

c. Investigate switch to OSI SAF equations
d. Add day/night indicator to GDSv2 L2P
e. Investigate: using full swath, full resolution, accuracy of sat retrieval to profiling float data, lake SST, obtain Sentinel-3, K10 GDSv2.0 better update cycle

Comments: **Ed Armstrong** # of obs is higher for Metop-A – why? **J-F:** Unsure, but may be due to the fact that it's a morning platform.

4. NOAA contributions to GHRSST – Ken Casey

Points: (1) background; (2) contributions from NOAA line offices and subdivisions; and (3) key NOAA highlights.

4.1. Background

a. RDAC/GDAC framework: RDACs – NCDC; NODC; OSPO. STAR will become RDAC soon
b. NOAA is making contributions all across GHRSST – key players in the science team, and working groups
c. Showed general diagram of NOAA – where are NOS, NMFS, NESDIS, etc

4.2. Background Contributions

a. IOOS: funds MISST project. Integrated Ocean Observing Fisheries Science Center
b. SWFSC: SW fisheries. Fisher applications, IOOS regional association, tailored across to fisheries
c. ESRL: Gary Wick, ST and DVWG member, DV model
d. AOML: Atlantic Oceanographic and Meteorological Lab – coral application
e. NCEP: improving weather and ocean prediction using GHRSST data, improving lake temperature
f. NODC: CEOS SST VC, Long term archive, RDAC for PathFinder
g. NCDC: RDAC for two products (AVHRR OI L4, AVHRR AMSR OI L4), ST member, replacing AMSR with Windsat
h. OSPO: operational L2P/L4: GOES, MTSAT, MSG2/3, NOAA-19, Metop-A, L4
i. STAR: NPP/JPSS and GOES-R leadership, works with OSPO, NOAA's newest RDAC, retrieval WG chair. Online tools
j. ICOADS: latest status from NOAA, NOAA/NCDC and NCAR active in US, partnership expanded to include UK and Germany, New blended NRT product in development, will be updated to v3 in 2015 (now v2.5)

4.3. Key NOAA highlights

a. STAR: ACSPO VIIRS GDS2 L2P, 2× res 3× coverage of NAVOD VIIRS, will go into CMC, 3 VIIRS SSTs monitored in SQUAM (ACSPO, NAVO, IDPS)
b. NODC: archival of GDS2 products commenced (NAVO VIIRS, CMC L4)
c. STAR: 5km POES-GOES blended analysis, Coral Reef users, will include DV, funding received
d. Physical Retrieval for Geo SST products (MTLS)
e. ongoing "consolidation trend"

5. NOAA STAR Geo and Blended SST Products – Eileen Maturi

Points: (1) geostationary products; (2) geo-polar SST blended.

5.1. Geo products and enhancements

a. GOES-13 /15, MTSAT 2, Meteosat 10
b. Aug 2013, went operational with physical retrievals – works better than regression SST
c. Example of Meteosat10 around Cape Town area
d. Improved bias and scatter plots for GOES 13/15 MTLS
e. Summary of product accuracy for different GEO
f. Improved CRTM input – number of layer increased from 16 to 26

5.2. Geo polar blended

a. 5km SST analyses (day/night combined, and nighttime only)
b. Data-adaptive 3 different correlation length scales
c. Preserves fine scale features without introducing excessive noise
d. Inputs: polar (ACSPO N19, Metop-B) and geo (GOES E/W, MTSAT-2, Meteosat-10)
e. 1km ACSPO VIIRS will be included in Jul 2014
f. Improve bias correction scheme (replace RTG with OSTIA)
g. Include AMSR-2 SST to improve regional biases
h. Diurnally Corrected 5km SST Analysis available in Nov 2014
i. Reprocessing of Geo-Polar Blended SST will be done in two phases.

6. EarthTemp Arctic Workshop – Jacob Høyer

EarthTemp is a UK funded network, led by Chris Merchant. First Met in Copenhagen from 12-14 June 2013 and had a follow-up Arctic meeting in Exeter from 18-19 2013, UK, focusing on hi-lat SST. Points: (1) presentations in 3 sessions, major discussion topics – Algorithm issues, SST analysis problems, and diurnal variability; (2) proposed solutions.

6.1. Presentations

a. Cloud/ice detection (Steiner)
b. NRT SST (Pierre)
c. Arctic algo val (Jacob)
d. Experience from CCI (Owen)
e. Physics based SST (Chris Merchant) - Val of AVHRR for physical retrievals improves performance compared to operational products, daytime negative biases, issues with masking out data in CCI AVHRRs due to 4deg cold OSTIA. Also, "lack of reference sensors: stable bias" was discussed. No consensus about reference sensors, inter-comparison of biases may be way forward, e.g., monthly mean July difference between: AATSR and PathFinder seems quite consistent
f. SST algorithms in CCI project (Owen + Chris)
g. SST fnd SST in Arctic (Sonia)

h. Emma presented the challenges of L4 analysis particularly at ice edge. DMI method spreads cold observations too far into ocean. OSTIA method too warm in the ice peak. UKMO: try and use anisotropic ice edge methods. What to use as reference for DV where no nighttime exists? Very few night obs > 7m/s wind speed. Interesting topic and hard to define

i. SST variability in Arctic Diurnal warming in Lake Vaenen (Steiner Eastwood). Stratification during day and collapse during night, Residual warming trend

6.2. Solutions

a. Consensus that increased cooperation is the way forward

b. publish results (Jacob/Pierre)

c. small projects 2-4 partners (students) to address atmospheric profile data (Jacob/Herve/Steiner/Cristina), SST and ice concentration

d. Collaboration with external projects: NACLIM, ICE-ARC, IAOOS, Arctic ROOS, HadlSST, ACCESS, OSI SAF, NAACOS, NORMAP, SST CCI 2, MyOcean2, MERCATOR and corresponding point-of-contacts were shown

e. More information: wiki was set-up wiki.met.no/arctic-sst/start/, come to HL-TAG, visit EarthTemp website

Comments: **Craig**: question about screening data strategy corresponding to polar areas – do we need it?

PROGRESS AT THE NAVAL OCEANOGRAPHIC OFFICE REGIONAL DATA ASSEMBLY CENTER

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ABSTRACT

NAVOCEANO processes several satellite data streams into sea surface temperature (SST) in real time for direct assimilation into operational ocean analyses and forecast models. The SST data are also converted into the GHRSST L2P file format and provided to the GHRSST GDAC for real time dissemination worldwide. This paper describes the current status of NAVOCEANO SST processing, recent progress, and plans for future improvements.

1. Introduction

NAVOCEANO participation in GHRSST includes the delivery of several L2P SST data sets in near real time to the GHRSST GDAC, the acquisition and use of several GHRSST L2P SST files in operational ocean analyses and forecasts, and the delivery of an L4 SST analysis product to the GDAC. The following sections detail the status and progress of NAVOCEANO L2P and L4 production; metrics of L2P SST quantity, accuracy and utilization; and recent processing improvements and plans for the coming year.

2. L2P and L4 Production

NAVOCEANO is providing four GDSv1 formatted L2P SST data sets to the GHRSST GDAC. These include NOAA-18 Global Area Coverage (GAC), NOAA-19 GAC, NOAA-19 Local Area Coverage (LAC), and MetOp-A GAC. Each of these data sets is also now delivered to the GHRSST GDAC in L2P GDSv2 format. In addition, MetOp-B and S-NPP VIIRS SST data sets have also been added as GDSv2 deliveries to the GDAC. All data sets include the infrared channel brightness temperatures associated with each SST retrieval. NAVOCEANO provides an L4 satellite SST only analysis product that is generated by assimilating SST retrievals from seven polar orbiting, one microwave and three geostationary satellites that are available either through NAVOCEANO or GHRSST.

3. NAVOCEANO SST Retrieval Metrics

NAVOCEANO L2P SSES statistics are presented in Table 1. The majority of NAVOCEANO SST retrievals for each data set are Proximity Confidence level 5. The accuracy for each satellite data set at this level is around 0.40 to 0.45 C. These accuracies have been consistently within this range for several years for all satellites.

Product	Proximity Confidence 5		Proximity Conf. 4		Proximity Conf. 3	
	RMS	Bias	RMS	Bias	RMS	Bias
NOAA-18 GAC	0.40 (97% of data)	-0.07	0.69	0.34	1.52	1.03
NOAA-19 GAC	0.40 (96% of data)	-0.01	0.79	0.30	1.81	0.95
NOAA-19 LAC	0.45 (95% of data)	-0.11	0.84	-0.03	2.04	-0.22

Product	Proximity Confidence 5		Proximity Conf. 4		Proximity Conf. 3	
	RMS	Bias	RMS	Bias	RMS	Bias
MetOp-A GAC	0.40 (98% of data)	-0.04	0.70	0.25	2.03	-0.42
MetOp-B GAC	0.43 (98% of data)	-0.04	0.72	0.31	1.98	0.84
S-NPP VIIRS	0.39 (93% of data)	-0.03	0.76	0.02	2.01	-0.54

Table 1: NAVOCEANO L2P SSES.

NAVOCEANO GAC SST retrieval quantities have averaged more than 400,000 confidently clear observations per day for several years (Figure 1). In addition, generation of SSTs from high resolution LAC, FRAC and S-NPP VIIRS data average about 15 million observations per day per satellite (not shown).

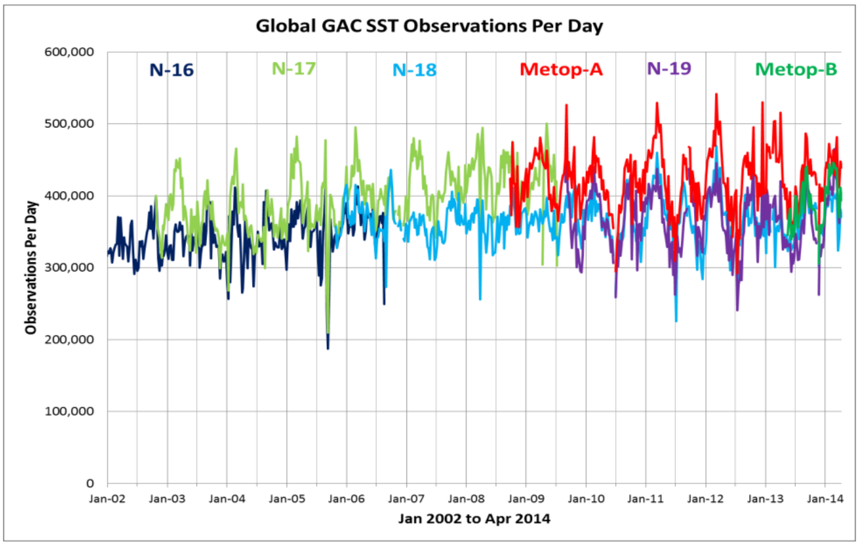

Figure 1: NAVOCEANO global GAC SST observations per day 2002-2014.

Analysis of the GDAC NAVOCEANO product download statistics shows that most users are still dependent upon use of the GDSv1 products (Table 2). The NAVOCEANO K10 L4 and NOAA-19 L2P products show the highest number of users. Use of the S-NPP VIIRS L2P product in GDSv2 has increased. NAVOCEANO desires to discontinue dissemination of the GDSv1 products in the near future which necessitates users to switch to the new GDSv2 data sets as soon as possible.

Satellite	Product	Format	Users	GB	Files
NOAA-18	GAC L2P	GDSv1	11	125.5	7328
NOAA-18	GAC L2P	GDSv2	12	339.3	12410
NOAA-19	GAC L2P	GDSv1	40	125.6	7717
NOAA-19	GAC L2P	GDSv2	9	335.2	12364

Satellite	Product	Format	Users	GB	Files
NOAA-19	LAC L2P	GDSv1	47	177.3	9818
NOAA-19	LAC L2P	GDSv2	8	367.2	13413
MetOp-A	GAC L2P	GDSv1	11	67.8	3522
MetOp-A	GAC L2P	GDSv2	4	86.2	3909
MetOp-B	GAC L2P	GDSv2	5	61.6	6286
S-NPP	VIIRS L2P	GDSv2	16	5391.5	725006
Multiple	K10 L4	GDSv1	155	1.0	1130

Table 2: NAVOCEANO product downloads from the GDAC.

4. NAVOCEANO SST Processing Improvements and Future Plans

NAVOCEANO is investigating improvements to the NAVOCEANO Cloud Mask tests used in operational VIIRS SST processing. A recent improvement addressed coverage and cloud detection artifact issues in nighttime SST by switching to a higher resolution field SST. Cloud detection and coverage has also been improved in the daytime VIIRS SST processing by more selective use of the Visible Cloud Threshold test.

NAVOCEANO continues to investigate improvements to VIIRS daytime cloud detection. Switching to the OSI-SAF SST algorithm is also being evaluated for VIIRS SST processing. NAVOCEANO intends to add a day/night indicator to the VIIRS GDSv2 L2P data using the l2p_flags array. Because of the constant spatial resolution across the entire swath of VIIRS, NAVOCEANO is investigating production of SSTs for full swath. Comparison of SSTs to profiling float surface layer temperatures is planned to be investigated along with alternative algorithms for inland lakes.

5. Conclusion

NAVOCEANO continues to actively participate in GHRSST by providing several L2P SST data sets in near real time, providing a L4 SST analysis product, and using several L2P SST data sets provided by other GHRSST providers. Each of the SST data sets provided by NAVOCEANO maintain high accuracy relative to in situ SST measurements and are consistently used by numerous online users via the GHRSST GDAC. NAVOCEANO continues to improve on its SST processing, most recently the VIIRS cloud detection processes.

NOAA/NESDIS/STAR
GHRSST SEA SURFACE TEMPERATURE PRODUCTS

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ABSTRACT

The National Oceanic and Atmospheric Administration's (NOAA) office of the National Satellite Data and Services (NESDIS) generates operational geostationary Level-2P (L2P) sea surface temperature (SST) products in GHRSST GDS2.0 format from GOES-E/W, MTSAT-2, and MSG-3 and blended Level 4 SST analyses to satisfy the requirements of the GHRSST users.

1. Introduction

NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) generate Sea Surface Temperature (SST) products from Geostationary (GOES) East (E) and West (W) satellites on an operational basis in both gridded and GHRSST format and he capability was extended to permit the generation of operational SST retrievals from the Japanese Multi-function Transport Satellite (MTSAT) and the European Meteosat Second Generation (MSG) satellite, thereby extending spatial coverage. The four geostationary satellites (longitudes 75°W, 135°W, 140°E, and 0°, respectively) provide high temporal SST retrievals for most of the tropics and mid-latitudes, with the exception of a region between ~60°E and ~80°E. A process of continual development has produced steady improvements in the SST product accuracy with most recently the implementation of a physical retrieval algorithm based on a Modified Total Least Squares algorithm (Koner et al. 2014). These operational geostationary SST products are then blended with the polar operational SSTs to produce daily global, high resolution SST analyses in GHRSST L4 format.

2. Geostationary Sea Surface Temperature Products

GHRSST L2P SST

NOAA provides full L2P SST products for GOES E/W as part of its operational processing. The L2P products are derived from ½-hourly GOES-East & West North & South sectors in native satellite projection, and include the full L2P ancillary fields. NOAA provides full L2P SST products for MTSAT-2 and MSG-3 as part of routine operations. For MTSAT-2 the L2P product is produced every hour in native satellite projection whereas for MSG-3 the L2P product is produced every 15 minutes. Both the MTSAT-2 and MSG-3 L2P products contain the full L2P ancillary field as required by the GSD2.0 format. All the NOAA generated geostationary L2P products include diurnal warming estimates as part of their ancillary field. Table 1 lists the NOAA GHRSST operational geostationary SST L2P products with their area of coverage and frequency.

Figure 1 shows an Image of the gridded Meteosat-10 (MSG-3) SST product.

Table 1: NOAA GHRSST Operational Geostationary SST L2P data sets for GOES-E/W, MTSAT, and MSG,

SATELLITE	AGENCY	AREA	FREQUENCY
GOES-EAST	NOAA	N-HEM Sector S-HEM Sector	Every 30 min Every 30 min
GOES-WEST	NOAA	N-HEM Sector S-HEM Sector	Every 30 min Every 30 min
MTSAT-2	JAPAN(JAXA)	Full Disk	Every hour
MSG-3	EUROPE (EIUMETSAT)	Full Disk	Every 15 Minutes

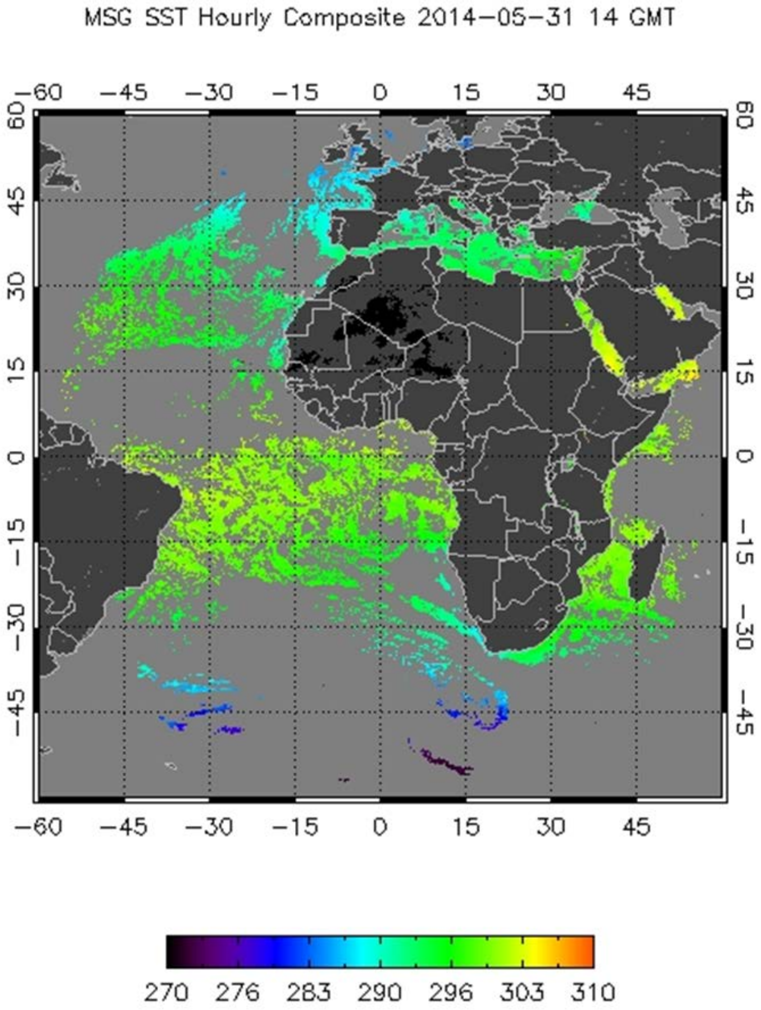

Figure 1. This is an example of the NOAA MSG-SST product.

Improved SST Algorithm

The old regression based algorithm to generate sea surface temperatures from geostationary satellites has been updated and a physical retrieval based on Modified Total Least Squares has been implemented (Koner et al. 2014). This new algorithm was made operation on the 1st August 2013. Figures 2 and 3 show the improved bias and scatter for GOES-13 and GOES-15, respectively. Note the significant improvement around day 214 (2014/08/01). Figure 4 shows the summary of product accuracy for MTSAT-2 and Meteosat-10 (MSG-3).

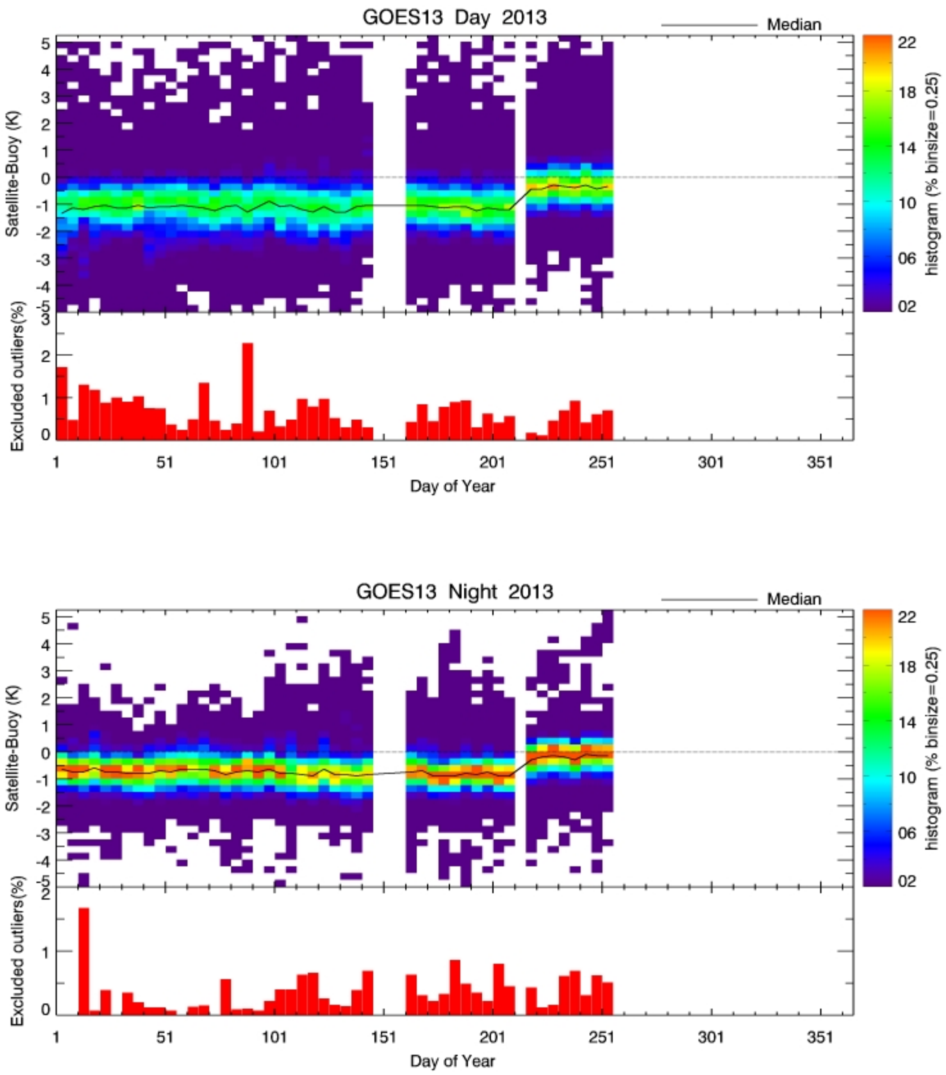

Figure 2 shows the improved bias and scatter for GOES-13 for daytime and nighttime with physical retrieval based on Modified Total Least Squares.

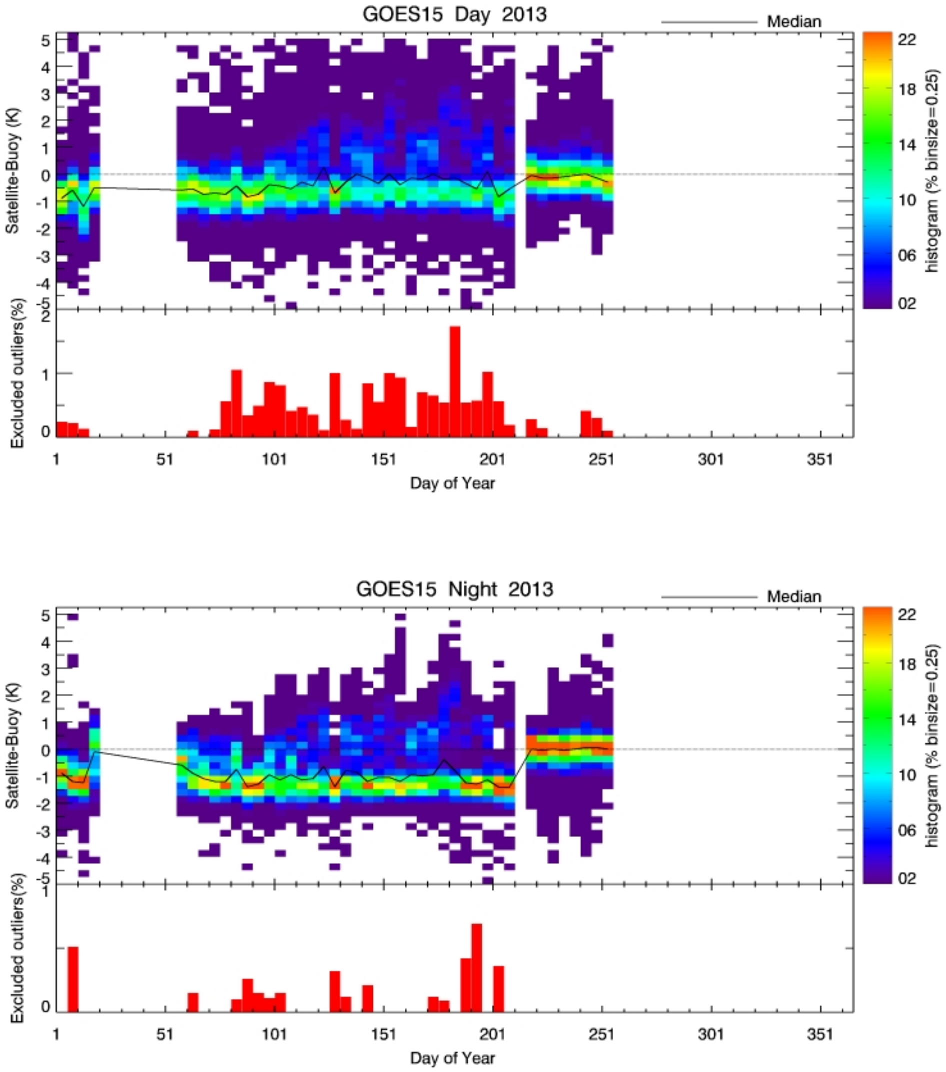

Figure 3 shows the improved bias and scatter for GOES-15 for daytime and nighttime with physical retrieval based on Modified Total Least Squares

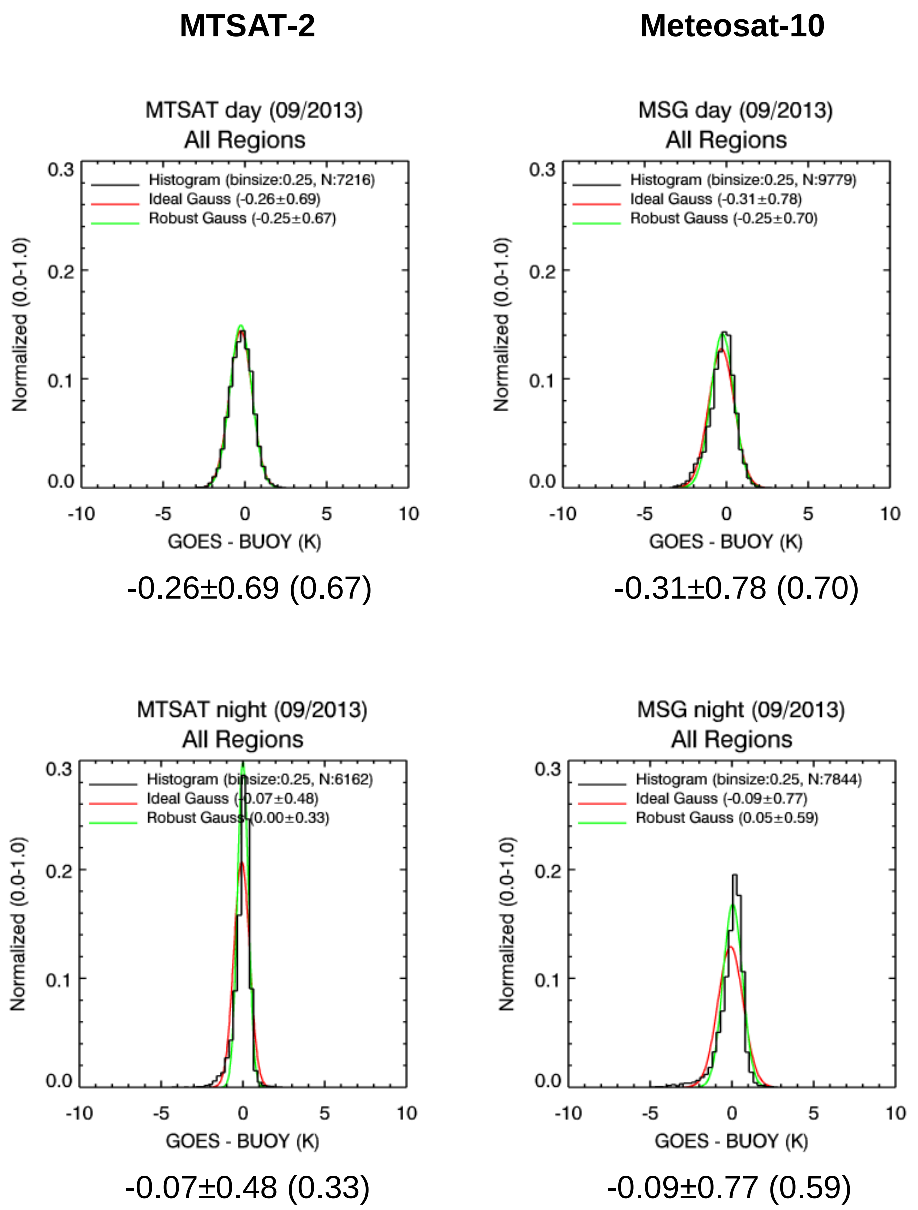

Figure 4 shows a summary of the product accuracy for MTSAT-2 and Meteosat-10 for daytime and nighttime with the implementation of the physical retrieval algorithm based on Modified Total Least Squares. The robust standard deviations from approximately 1 year earlier with the old SST algorithm was MSG: day=0.82 MSG: night=0.52 and MTSAT:day=0.78 MTSAT:night=0.52 which shows the general improvement in statistics.

Future Improvements

Future GHRSST geostationary L2P SST data sets will be generated from, Himawari-8/9 and INDSAT-3D and MSG-4. There will also be a diurnally corrected 5km global day/night SST Analysis produced in GHRSST L4 format which is scheduled to be operational in November 2014. Then in December 2014 the product should include the AMSR2-SST to acquire SSTs in regions of high clouds where there are no infrared data available.

3. Blended SST Analyses

Operational SST retrievals from NOAA's GOES and POES satellites are used to produce an operational daily global, high resolution 5km SST blended SST analyses and a global, high resolution 5km SST Nighttime Only Analysis. These analyses are both generated in HDF and GHRSST L4 in GSD2.0 format. Figures 5 shows the GHRSST L4 analysis product forday and night. Nighttime only is available and will show a difference in coverage.

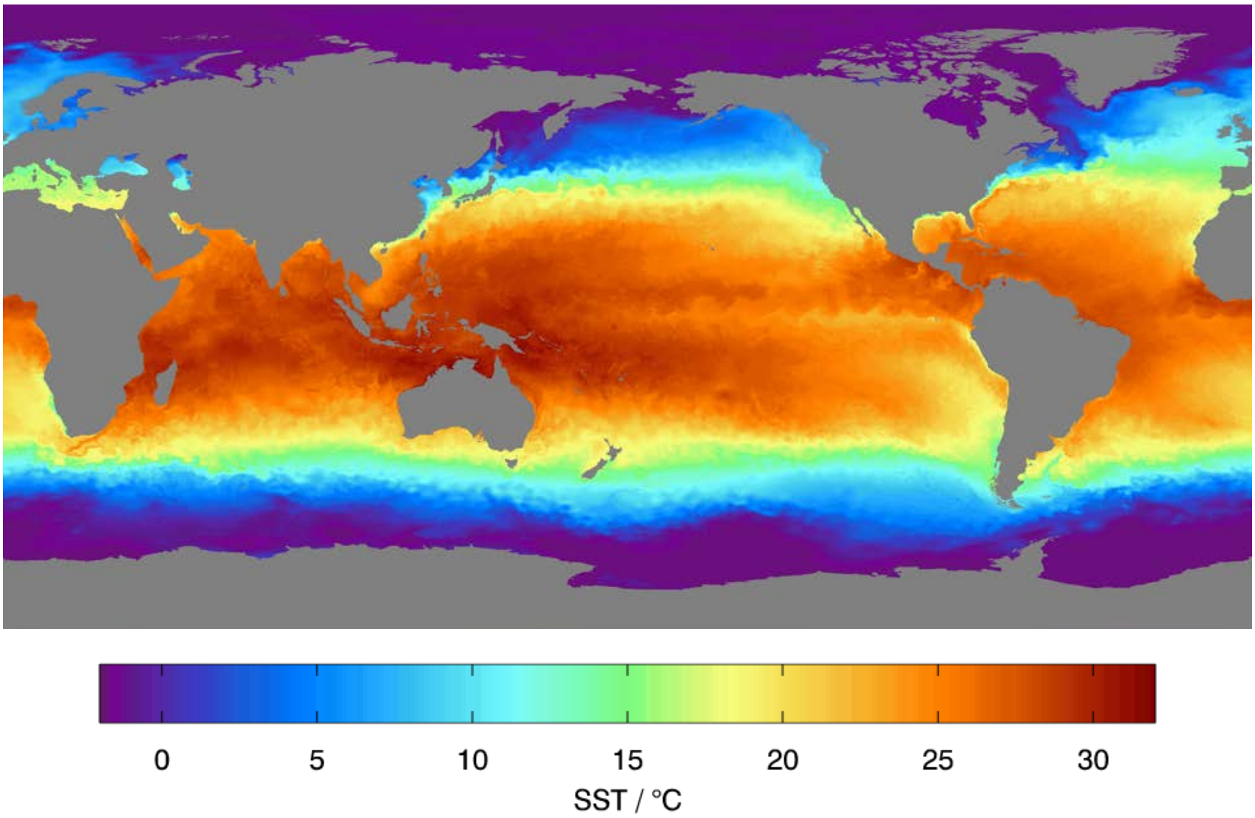

Figure 5 shows the daily 5-km global blended SST analysis for day and night.

These 5km blended SST analyses are produced daily from 24 hours of polar and geostationary sea surface temperature satellite retrievals (NOAA-19, Metop-B, GOES-E.W, MTSAT-2 and Meteosat-10) and it does not use buoy data only satellite data. VIIRS data will be included from August 2014.

Product Accuracy for Blended SST Analysis

The product accuracy summary in Figure 6 was generated using the distribution of buoys shown in Figure 7. The Median bias (analysis – buoy) is -0.02 K. The Robust Standard Deviation is 0.29K. The Robust Standard Deviation = (75% - 25%)/1.349.

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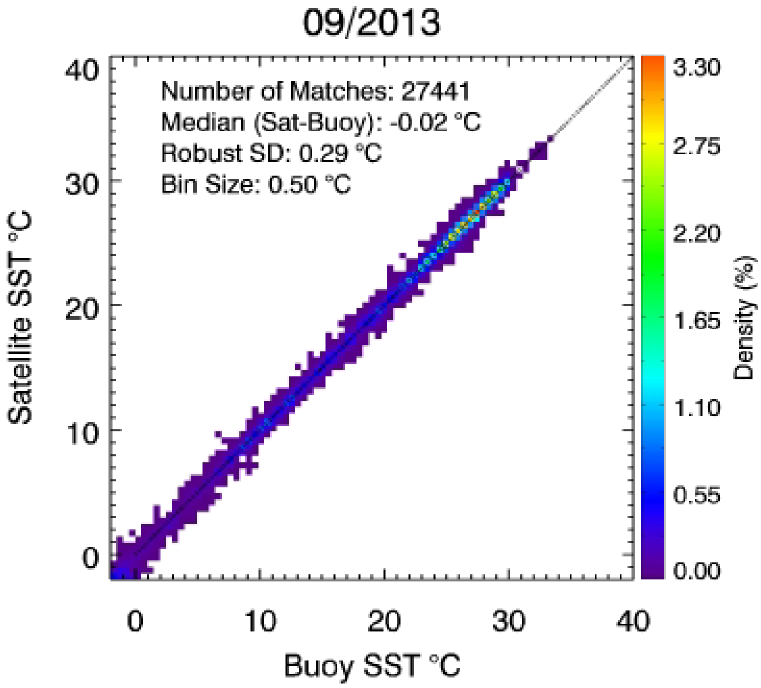

Figure 6 shows the summary of the product accuracy for the blended SST Analysis product

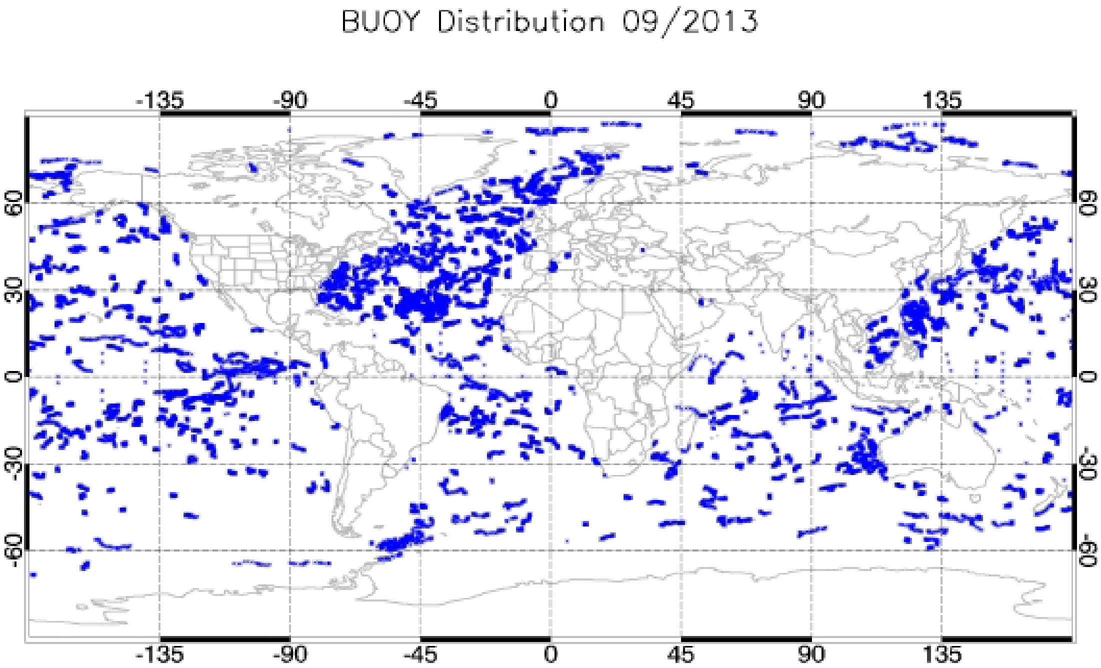

Figure 7 shows the distribution of buoys used to generate Figure 6 plot.

Reprocessed GHRSST L4 products

We are reprocessing both the 5km day/night and nighttime only blended SST analyses. There will be two phases. Phase I will reprocess GEO-Polar Blended SSTs in both HDF and GHRSST-L4 format from September 2004 forward. We plan to have this completed by December 2014. Phase II will start the reprocessing 5km day/night and nighttime only blended SST analyses for 1994 to 2004. We plan to have this completed by December 2015.

4. Conclusion

The GHRSST geostationary SST and blended SST Analyses products provide to the GHRSST user community a uniquely powerful data set for studying SST and makes it possible to study such effects as diurnal warming of the ocean surface and the evolution of mesoscale features such as fronts and eddies. The temporal and increased data coverage of the geostationary satellites and the gap free SST analyses provides reliable, accurate data coverage in important oceanographic, meteorological, and climatic regions.

5. References

Koner, P. et al., 2014, “A physical deterministic inverse method for operational satellite remote sensing: an application for SST retrievals, submitted IEEE-TGRS.

PLENARY SESSION III: SST IN AFRICAN WATERS

SESSION REPORT

Chair: Gutemberg Franca[1], Rapporteur: Jonah Roberts-Jones[2]

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Session Summary Report

The session contained three presentations on SST in South African Waters. Charlie Barron presented "Time series of SST anomalies off Western Africa". He showed how assimilative ocean models provide a tool to understand SST variability around southern Africa. Results were presented that showed RELO NCOM, a nested assimilative model, was reasonably accurate around southern Africa. It was able to capture both diurnal warming events and upwelling regions.

Mathieu Rouault presented "Coastal change and variability around Southern Africa" in which he discussed several pieces of research. He highlighted the shortcomings of using both course resolution model data and SST analyses to investigate climate trends. He also showed how the flagging in satellite data sets removed strong gradients in coastal upwelling regions.

Christo Whittle presented "Characterization of the Agulhas Bank upwelling variability from 1km MODIS Aqua/Terra data". He presented results correlating satellite data of both SST and Chlorophyll with users in the fishery industry in mind. The region of study is a complex oceanic region influenced by wind-driven coastal upwelling, as well as dynamic current driven upwelling. He showed that during periods of seasonally high variability flagging in SST data led to overly smooth SST variability in regions of interest. The variability in SST analyses was also underestimated. By using satellite data of different quality levels he could get cleaner match of SST and Chlorophyll variability.

Discussion

Discussion again mentioned again that in SST analyses true feature resolution is different to grid resolution. This has been widely discussed in the IC-TAG and work is being undertaken to address this. The user requirements of scientists working on African SST were discussed. It was stated that the onus is on a user to look at the data to inform their choice of products. Archives and publications can inform this choice but there is a need for GHRSST to present its many tools better which may aid users in data discovery. The take up of social media and its use within GHRSST was also discussed, which was a running theme through GHRSST 15.

TIME SERIES OF SST ANOMALIES OFF WESTERN AFRICA

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ABSTRACT

An assimilative ocean forecast model encompassing the southern tip of Africa is examined to evaluate the impact of alternate satellite data streams and to demonstrate the use of such forecast systems to understand the processes and evolution of regional ocean environments. Assimilative ocean forecast systems are a product of three pillars of oceanographic research: models, observations, and data assimilation. A regional model on a 3-km grid portrays evolving conditions around the southern tip of Africa in response to boundary, atmospheric, and riverine inputs. It is guided by satellite observations, comparing its performance when provided NOAA 18/19 AVHRR and/or Suomi-NPP VIIRS SST. Guided by assimilation of these observations, a model provides one avenue to understand the balances and processes controlling the African ocean environment; the degree to which such simulations correspond to reality is assessed in part by comparisons with independent ocean observations. In situ and remote observations provide irregularly distributed glimpses of the true ocean state. As in situ observations are fairly sparse in the region around southern Africa, particularly in real time, relatively greater reliance is placed upon satellite SST and other types of remote observations. A system of data assimilation uses the varied observations to guide the ocean forecasts, transforming the realistic ocean simulations into forecasts of likely conditions in the real ocean with accompanying estimates of forecast uncertainty. Assimilative ocean forecast around South Africa are evaluated from January to April 2014, investigating the impact of alternative SST data streams and reserving in situ observations of SST as an independent reference for validating the forecast ocean state. In addition to a regional overview, we consider in more detail time series of SST anomalies, primarily off western Africa, examining the evolution within sections through upwelling zones and predicted instances of relatively large diurnal warming. The prominent band structure evident in diurnal warming is found to appropriately correspond with regions of high insolation and low wind stress aligned with atmospheric fronts. SST variability off the west coast is highest on the edges of the persistent upwelling. On the east coast, SST shows the signals of episodic upwelling in the southeast and possible combined upwelling trends and riverine effects farther north in Maputo Bay.

1. Introduction

An assimilative ocean forecast model encompassing the southern tip of Africa is examined to evaluate the impact of alternate satellite data streams and to demonstrate the use of such forecast systems to understand the processes and evolution of regional ocean environments. Demonstrated agreement between the forecasts and independent ocean observations bolsters confidence in the insights drawn from the modeled dynamics and provides a reference for assessing model fidelity.

Assimilative ocean forecast systems are a product of three elements: models, observations, and data assimilation. Ocean models endeavor to numerically represent the physical processes that maintain or change the ocean state. A model quantifies how an ocean would be expected to transition from an initial state under the influence of specified constraints and exchanges with the surrounding environment. The model can be expected to deviate from the real ocean due to errors in the initial state, errors in the constraints, and processes that are non-deterministic on the scales resolved. While the model gives a consistently complete view that approximates a real ocean, in situ and remote observations give irregularly distributed glimpses of the true ocean state. Data assimilation unites these two elements, endeavoring to draw the simulated ocean toward a more accurate representation of its true state.

A regional model implemented on a 3-km represents evolving ocean conditions in response to boundary, atmospheric, and riverine inputs. It is guided by satellite observations, and we evaluate the relative effect of assimilating alternative satellite data streams by comparing its performance when provided NOAA 18/19 AVHRR and/or Suomi-NPP VIIRS SST. Since the in situ observations are relatively sparse in the region around southern Africa, particularly in real time, ocean assimilation relies on the more abundant satellite SST and other types of remote observations for guidance and reserves surface in situ samples for validation. Guided by assimilation of the remote observations, the model provides an avenue to understand the balances and processes controlling the African ocean environment. The degree to which such simulations correspond to reality is assessed by comparisons with the independent in situ observations.

2. Experiments

The baseline capabilities developed by the Naval Research Laboratory (NRL) for US Navy ocean predictions begin with the global Hybrid Coordinate Ocean Model (HYCOM; Chassignet *et al*., 2007) within the Global Ocean Forecast System (GOFS 3.0; Metzger et al., 2008; Metzger et al., 2012). With its representation of the ocean on a 9 km grid, GOFS 3.0 is adequate as an initial source of assessment for many applications. In other circumstances where greater detail is needed, the operational forecasters at the Naval Oceanographic Office (NAVOCEANO) will configure a higher resolution nested implementation of the Navy Coastal Ocean Model (NCOM; Barron *et al*., 2006).

As an example of this rapidly relocatable capability, NCOM is implemented on a 3 km grid to examine the sea surface temperature (SST) around South Africa (Figure 1a). It uses atmospheric inputs from the Navy Global Environmental Model (NAVGEM 1.1; Pauley *et al.*, 2013; Metzger *et al*., 2013). Assimilation uses 3DVar Navy Coupled Ocean Data assimilation (NCODA; Cummings, 2005) with the FGAT option (Massart *et al.,* 2010). Lateral boundaries are interpolated from GOFS 3.0, and rivers are included following the available climatology (Barron and Smedstad, 2002).

Following standard operational practices, the forecast systems are guided by assimilation of available real-time data streams including satellite altimetry (Altika, Jason-2, Cryosat), satellite SST, and in situ observations. In the three cases shown here, the standard satellite SST observations are limited to three sources produced by NAVOCEANO: 1) Advanced Very High Resolution Radiometer (AVHRR) on NOAA 18, 19; 2) Visible/Infrared Imager Radiometer Suite (VIIRS) on Suomi-NPP; and 3) combined AVHRR and VIIRS. Of the variety of in situ observations that would be assimilated under standard operational conditions, only profile observations, those extending below the surface (i.e. Argo, gliders, XBT, etc.) are assimilated; surface ship and buoy observations are reserved as a source of independent confirmation data. Assimilation distributes insertion of analysis increments over a 24-hour update cycle for daily 00:00 UTC nowcasts and three-hourly forecasts extending to 72 hours. For the matchup comparisons, model SST is interpolated in space and time to match corresponding independent SST observations from drifting buoys.

Figure 1b shows matchup locations of the validating surface drifting buoys from January-April 2014 superimposed over SST. The collective data set extends from the warm Mozambique Channel and Agulhas Current into the cool Antarctic Circumpolar Current. Unfortunately, the drifters cover neither the upwelling zones nor diurnal warming bands off western Africa that are the focus of this paper. Extension of the in situ matchups to include ship engine intake or hull sensor would broaden coverage, but the high standard errors and potential biases of these additional data cause us to restrict matchups to the relatively high quality surface drifter observations.

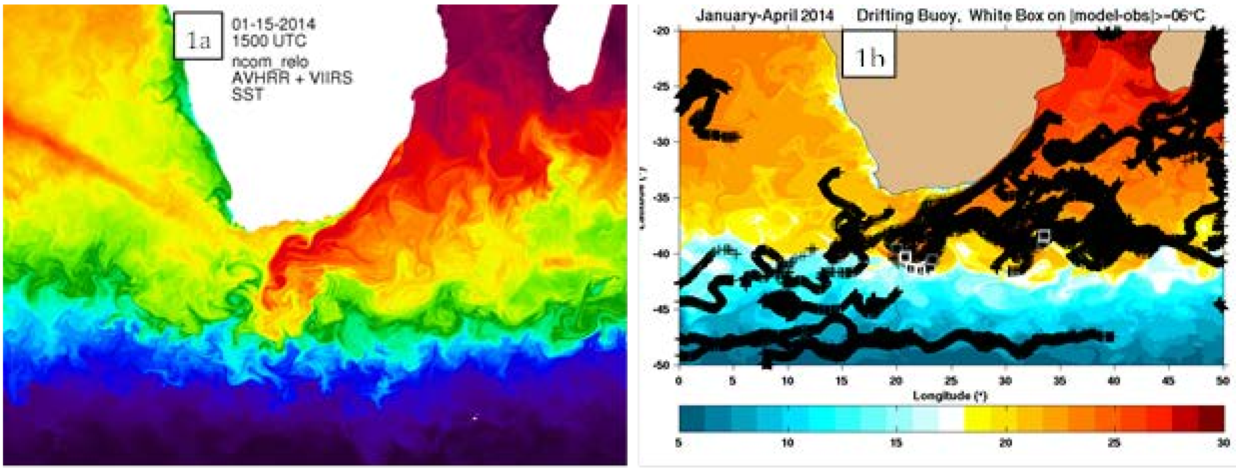

Figure 1: a) Forecast SST valid on 15 January 2014, 1500. Notable features on this day include cool upwelling along much of the western coast and points along the eastern coast in addition to the signature of diurnal warming in a band west of South Africa extending west-northwest from the vicinity of the Cape. b) Locations of surface drifting buoys over January-April 2014 superimposed over SST. These provide the independent in situ SST observations used for validation.

Comparison among the simulations differing by the satellite alternatives show reasonable agreement with the in situ observations, with some improvement gained by using VIIRS over AVHRR and slight additional improvement derived from their combined use. Biases and standard deviations relative to the independent surface drifter observations from January-April 2014 are shown in figure 2. Both the analysis and forecasts have a forecast bias of 0.01°C or less. Root mean squared (RMS) errors are smallest for the case assimilating both AVHRR and VIIRS, increasing from about 0.7°C for the analysis (and 3-24 hour forecasts, not shown) to about 0.9°C in the 72 hour forecasts. Around 2100 matchups are available per local hour, as shown by the inset plots placed in each plots upper right corner. Agreement between the model and observed SSTs in the case assimilating both AVHRR and VIIRS, the most accurate scenario, is further quantified in the scatter plots of Figure 3.

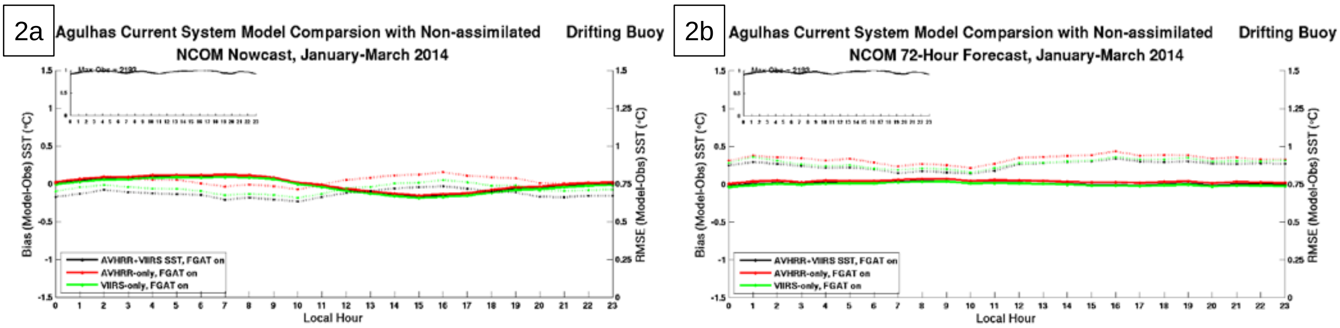

Figure 2: Comparisons of (a) 0000 UTC analysis and (b) 51-72 hour forecast SST analysis fields with corresponding observations valid at the range of local hours over the day. The comparisons with the static analysis nowcast over the same day reveals mean diurnal signal with amplitude of ~0.3˚C.This diurnal signal is not evident in comparisons of the forecast fields, indicating that the model is capturing an accurate mean diurnal cycle.

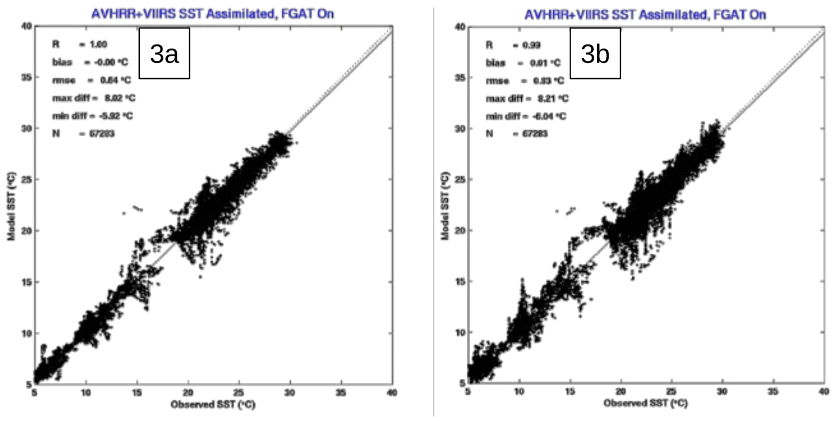

Figure 3: Comparison of SST observations and matching values from NCOM (a) analyses and (b) 51-72 hour forecasts using South Africa regional NCOM assimilating AVHRR and VIIRS. The largest RMSE tend to occur within the interface between bimodal warm and cold distributions. NCOM has a warm bias in this cap. Overall the simulations show little (<0.005˚C amplitude) analysis bias and slightly warm (~0.01˚C) 72-hour forecast bias

3. Results

Simulations from the case assimilating both AVHRR and VIIRS, the case in best agreement with the independent observations, are used to investigate variability in SST around South Africa, particularly on the western side. We focus on two aspects well represented in the region: diurnal warming and upwelling.

The context of diurnal warming events evident on 15 January 2014 in Figure 1 is examined in more detail in Figure 4. Regions of peak diurnal warming are associated with the combined effects of low wind stress over the hours of high solar flux. The low wind stress magnitude allows the heating to be retained within a stratified, near-surface layer rather than distributed over a thicker mixed layer. The narrow swath of high diurnal warming is typical of the forecast events in this region corresponding to regions of low wind stress and high insolation aligned with patterns of atmospheric fronts in this region. Similar diurnal warming patterns were found by Gentemann et al. (2008) through analysis of microwave and infrared SST retrievals around the world. The bands of diurnal warming are a product of the solar flux and wind stress and are not a product of data assimilation, as the bands are not evident in the 00:00 UTC assimilative analyses.

Upwelling is examined in 4 sections off South Africa (Figure 5). Upwelling is strongest to the west, where broad bands of cool water are persistent from St. Helena Bay to Luderitz and farther north. Narrow episodes of upwelling do occasionally emerge along the east coast, leading to a dip in mean SST and a peak in SST temporal standard deviation near the Great Kei River at 32.5°S. Evidence of upwelling is scant moving north along the east coast, and only in April (not shown) are the nearshore temperatures in Maputo Bay (26°S) relatively cool. Maputo Bay does have sharply fresher water inshore associated with the climatological inflow from the Limpopo, Incomati, Maputo, and Umbeluzi Rivers in southern Mozambique. As discussed by Smit (2014), riverine and other very nearshore SST can differ significantly from the slightly offshore values observable through satellite remote sensing, further increasing the uncertainty of temperatures applied to model river inflows and their influence on the nearshore temperature forecasts.

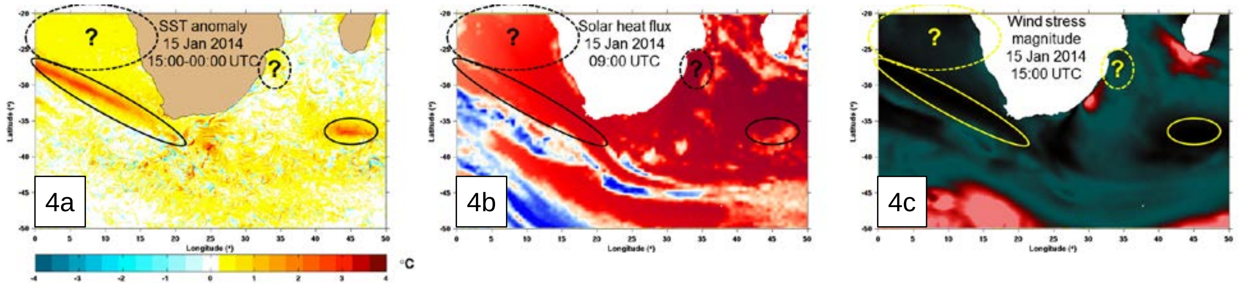

Figure 4: The diurnal warming SST anomaly (a) and corresponding solar flux (b) and wind stress magnitude (c) at various times on 15 January 2014. Peak diurnal warming near 3°C within the solid ellipses is associated with high solar flux and uniformly low wind stress over the preceding hours, while the dashed ellipses identify areas of only moderate diurnal warming where intervals of moderate wind stress have mixed warming associated with similarly high solar flux.

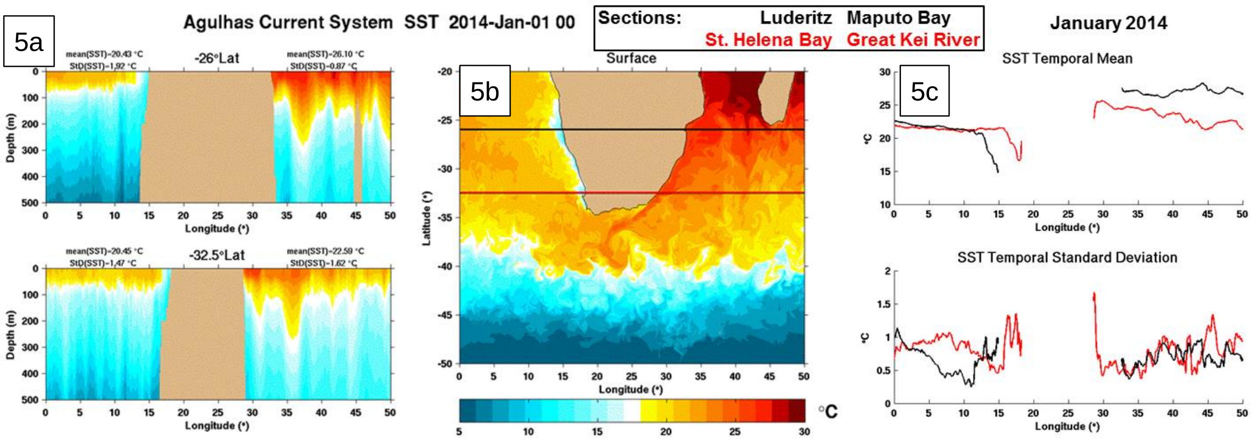

Figure 5: 01 January 2014 0000 UTC snapshot of (a) temperature sections and (b) SST showing cool upwelling regions along the west coast of Africa. (c) January mean and standard deviations of SST reflect episodic upwelling near the Great Kei River through the local nearshore mean SST minimum and high standard deviation.

4. Conclusion

Implementation of relocatable NCOM nest around South Africa provides SST forecasts of low bias and reasonable accuracy. Patterns of diurnal warming and coastal upwelling are consistent with the dominant dynamic balances and similar to observations from remote sensing. The model provides a useful tool for investigating local characteristics and confirms the positive impact of assimilating both AVHRR and VIIRS as processed by NAVOCEANO.

5. Acknowledgements

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RECENT COASTAL CLIMATE CHANGE AROUND SOUTH AFRICA

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1. Data

We used 1°×1° resolution Optimally Interpolated SST (Reynolds SST, Reynolds *et al*. 2002). Reynolds SST is derived from daily merged, *in situ*, It has been used successfully in southern Africa to represent coastal SST, for instance in describing the 1999/2000 extreme oceanographic event in the southern Benguela and Benguela *Niño*s. Those successes were attributable to the offshore and alongshore extent of those severe perturbations. Even if the Reynolds SST does not represent accurately all features of the Agulhas Current system or coastal area because of the resolution of the data and the interpolation scheme, it can be used satisfactorily when averaged over a large domain. We also used two satellite-derived SST products: (i) The Ocean Pathfinder SST and the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the NASA Terra satellite has been collecting data since 2000. Level-2 MODIS data were downloaded from the Ocean Color website) and processed at a 4 km resolution using the SeaWiFS Data Analysis System. Only the daytime passes were processed, allowing us to use the cloud flag (CLDICE). We also used several other SeaDAS flags (ATMFAIL, LAND, HILT, HISOLZEN, LOWLW, MAXAERITER, ATMWARN, NAVFAIL, FILTER) but not the SST quality flags (SSTWARN, SSTFAIL). The daily data were then averaged to obtain monthly data.

2. Comparison between Pathfinder SST and Modis SST

2.1. Warm bias in Pathfinder data over EBUS

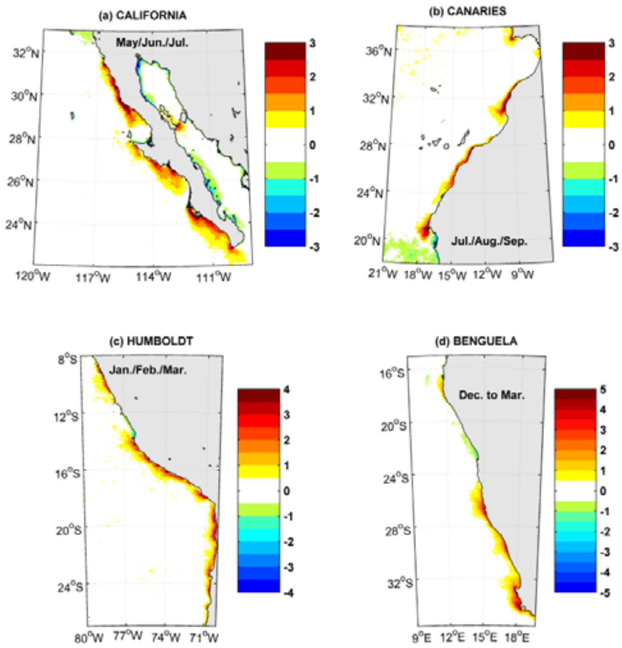

Figure 1: SST difference (°C) between Pathfinder and MODIS from 2000 to 2009 in the four main EBUS: (a) California during May/Jun./Jul., (b) Canary during Jul./Aug./Sep., (d) Humboldt during Jan./Feb./Mar. and (d) Benguela during Dec./Jan./Feb./Mar..

In order to assess the bias present in the Pathfinder monthly data at a larger scale and for the four main Eastern Boundary upwelling system (EBUS), we calculated the monthly climatological value for both Pathfinder and MODIS SST products over their common period: 2000-2009. The two products have been systematically compared in the four systems for each month. Firstly, it appeared that no significant biases were observed between the two products during winter time within the four main EBUS. However, during summer, warm nearshore biases up to 5 °C are present on the Pathfinder SST climatology over the four EBUS (Figure 1). The extent of the geographic regions on Figure 1 was determined by the area where a warm bias was found (i.e. no significant bias was found outside the limits of the four maps). In more detail, the California system has a warm bias of up to 3 °C in Pathfinder SSTs mainly from May to July and only between 22 and 32° N (Figure 1a). North of this region, the spatial SST gradients are weaker even during the summer, and no important biases are induced by spurious flagging. Within the Canary system, a warm SST bias of up to 3 °C is found in Pathfinder climatological SST from July to September (Figure 1b). During June, October and November, a weaker warm bias is found further south between 18 and 22° N (not shown). In the Humboldt system, a warm bias of up to 4 °C in the Pathfinder climatology is found nearshore from January to March all along the coasts of Chile and Peru. In the Benguela system, a warm bias of up to 5 °C is found in the Pathfinder climatology from December to March, mostly south of 24° S. For these four EBUS, the warm bias is not found exactly at the same period. The warm monthly bias is found when high horizontal SST gradient exists. This gradient is maximum during summer time, when surrounding waters are warmed up by solar fluxes while cold upwelled waters are present at the coast. The strength of the gradient within the EBUS is also strongly dependant on the peak of upwelling season, which varies for each specific region. Results are detailed in Dufois et al (2011) and Dufois et al 2012

2.2. Data evaluation over the Benguela system

Pathfinder monthly data were compared with MODIS monthly SST and in-situ data off Cape Town. On Figure 2, the MODIS monthly SSTs (bold black line) is highly correlated (92 %) with the in-situ time series (dashed bold gray line). A Root Mean Square Error (RMSE) of 0.5 °C and a bias of 0.01 °C is found when comparing MODIS to the in-situ monthly SSTs. Daily Pathfinder SST (gray circles on Figure 2) is in relative agreement with the in-situ monthly data only during winter. Thus, during winter months (from June to September) the monthly Pathfinder data are well correlated (84 %) with monthly in-situ data (over only two common years), whereas there is no correlation if considering all seasons (-26 %). The RMSE of 0.37 °C and the bias of 0.2 °C also confirm the good match found during winter. During summer, only a few warm Pathfinder daily data values are used to compile the monthly data. This spurious behaviour is a result of the threshold tests implemented when selecting a quality level of four for the final Pathfinder Data Product that results in the flagging of most of the accurate nearshore data values.

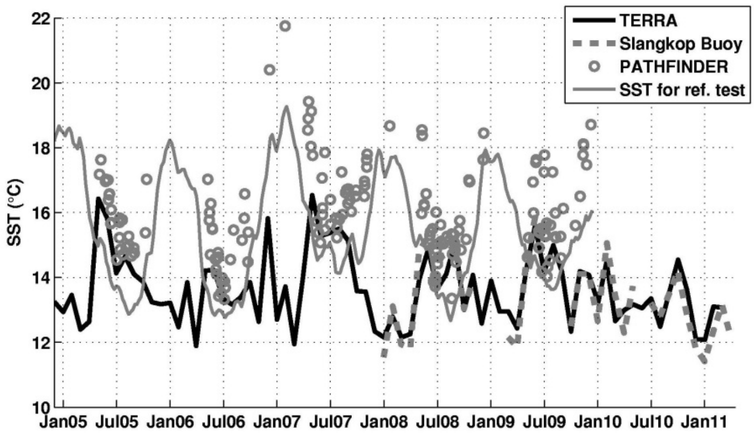

Figure 2: Comparison between monthly MODIS SST (bold black line), monthly in-situ SST data (bold dashed gray line) and the daily Pathfinder SST (gray circles) at position 34°12'14.40"S; 18°17'12.01"E. The gray line corresponds to the threshold of acceptable values for Pathfinder SSTs with a quality level of 4.

This particular flagging procedure is based on the "Reference Test": if the absolute difference between daily SST and a 3 week mean center based on the 1-degree resolution Reynolds Optimally Interpolated SST (OISST, Reynolds et al., 2002) is lower than or equal to 2 °C, then the SST quality is considered to be low and a quality flag lower than or equal to 3 (suspect value) is set (Kilpatrick et al., 2001). Quoting Kilpatrick et al. (2001), this test is known to "occasionally bias quality flags in coastal areas [...] and regions having large SST gradients in time or space". In the Benguela region, large SST gradients over short spatial scales are often encountered during the upwelling-favourable austral summer period. This ultimately induces a systematic flagging of the strongest and coldest upwelling events as bad quality data. The minimum value used for the reference test of the SST (gray line in Figure 2) is calculated from a lower resolution dataset (OISST), which does not resolve the high gradient seasonally encountered in our domain. Thus, only the warm events are kept (i.e. no or low upwelling associated with weak SST gradients) inducing an artificial warm bias in the monthly data in summer. A similar reference test, based on the difference between MODIS SST and an OISST reference value (although a higher absolute threshold of 3 °C is used during the test), can be optionally used to process MODIS SST with SEADAS.. Using this flag (SSTFAIL) leads to the same result (not shown here): for satellite-derived monthly data, flagging using a reference test based on OISST value is excessive in areas with strong SST gradients, which could lead to a warm bias. Results are detailed in Dufois et al (2011) and Dufois et al 2012

3. Recent coastal oceanic climate change around South Africa

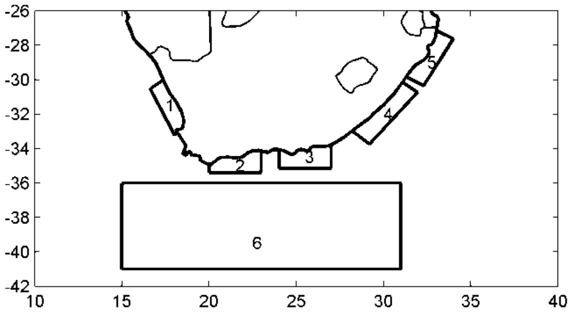

Figure 3: The domain used in this study. The Reynolds SST is averaged in the following domains to construct monthly time-series from 1982 to 2009 – 1, West Coast; 2, South Coast; 3, Port Elizabeth/Port Alfred; 4, Transkei; 5, KwaZulu–Natal; 6, Agulhas Current system

Figure 3 shows the domain used for the time-series analyses. The regions we studied were: (1) West Coast, (2) South Coast, (3) Port Elizabeth/Port Alfred, (4) Transkei and (5) KwaZulu–Natal (5). Each coastal time-series is derived by averaging data in a domain 3° wide along the coast and extending 1° offshore, so that they have the approximately the same size. We also used a region (6) encompassing the Agulhas Current system averaged from 36 to 42°S and from 15 to 30°E. The Reynolds SST data use high-resolution morning and evening AVHRR satellite estimates and all available observations.

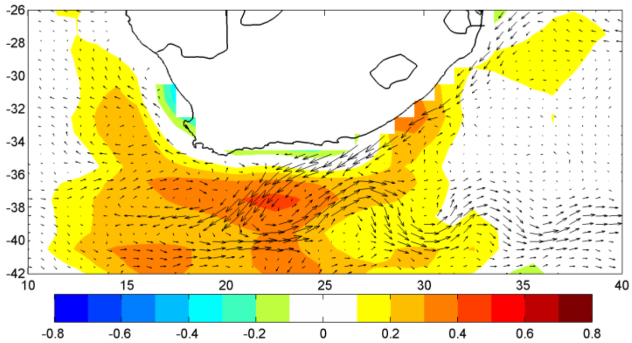

Figure 4: Linear trend of 1°×1° resolution Reynolds SST from 1985 to 2009. Mean AVISO absolute geostrophic velocity vectors derived from the mean dynamic topography (Rio et al, 2005) are superimposed)

Figure 4 shows the linear trend in SST using 1°×1° resolution Reynolds SST from 1982 to 2007. Superimposed is the mean 1993–2007 absolute geostrophic current vector derived from merged altimetry (Rio et al, 2005). Considerable difference exists when using pathfinder SST which is of concern (Blamey et al, in preparation). Figure 2 also shows the main features of the Agulhas Current system. The main loop is south of the continent, and the retroflection located in the domain delimited by the area 10–20^{o}E and 37–42^{o}S. Eddies shed from the Agulhas Current are usually formed in the retroflection area and move mostly in a northwest direction towards Brazil. The Agulhas Return Current flows eastwards and meanders. The Agulhas Current system has warmed by up to 1.5 °C since the 1980s, argued by Rouault *et al.* (2009) to have resulted from an intensification of the Agulhas Current system in response to an augmentation of wind-stress curl in the South Indian Ocean. The increase in the wind stress itself is attributable to an increase in trade winds and a poleward shift in the westerly wind at the relevant latitude. A regional ocean model is able to reproduce the observed SST relatively well, was used to derive quantities such as transport, fluxes of heat and salt, and temperature trends at depth. It showed that the transport of the Agulhas Current system has increased since the 1980s, leading to the warming. Coastal cooling of up to 0.55°C per decade is also apparent (Figure 4), mainly along South Africa's west coast. Changes have been of lesser magnitude along the south coast (from Cape Agulhas to Cape St Francis), as well as in the dynamic upwelling cell around Port Elizabeth/Port Alfred. The cooling in the West of the country is continuous from Cape Agulhas to the Namibian border. Next, we looked at SST linear trends in the five coastal regions around South Africa and in the Agulhas Current system. Figure 5 shows the 1982–2009 trends for all months of the year in the six regions defined. Although a bit short to study a trend, this series still represents changes over a 28-year period. Statistically significant trends at the 95% level according to Spearman's rank correlation test are marked in the Figure with a dashed line. There is a negative trend of up to –0.55°C per decade for the West Coast from January to August, up to –0.35°C per decade for South Coast from May to August and up to –0.4°C per decade for Port Elizabeth/Port Alfred, mostly from May to August. There is no change for the months September–December for all three regions, and no change in summer for either the South Coast or Port Elizabeth/Port Alfred. A warming of up to 0.55°C per decade is observed in the Transkei domain and for the Agulhas Current for all months of the year, but little change in the KwaZulu–Natal domain except for a statistically significant trend of up to 0.25°C per decade from December to February. Change in the Agulhas Current system is more marked in the retroflection area itself, and deceases to the east . The winter change is the most robust signal across the region, with cooling for the West Coast, the South Coast and Port Elizabeth/Port Alfred, and warming for the Agulhas Current system to the south.

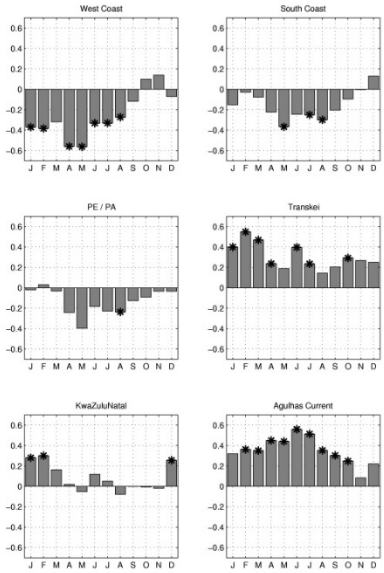

Figure 5: From left to right and from top to bottom: linear trend in °C per decade for each month of the year derived using the Reynolds SST from 1982 to 2009 for the domains West Coast, South Coast, Port Elizabeth/Port Alfred, Transkei, KwaZulu–Natal and the Agulhas Current system. Statistically significant trend are highlighted with a star.

4. Acknowledgement

WRC, Nansen Tutu Center, NRF and ACCESS

5. References

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PLENARY SESSION IV: DIURNAL VARIABILITY

SESSION REPORT

Chair: Gary Wick[1], Rapporteur: Sandra L. Castro[1]

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ABSTRACT

The Diurnal Variability Plenary Session was held on the morning of Wednesday, 4 June. The session consisted of three brief presentations, followed by discussion time at the end. Gary Wick chaired the session for Carol Anne Clayson who was unable to attend.

1. Brief Presentations

Three short presentations were given by group members updating on key areas of progress over the past year.

Andy Harris: A Diurnally Corrected High Resolution SST Analysis:

Andy Harris talked about changes to the diurnally-corrected version of the daily, 5 km, NOAA Geo-Polar blended SST analysis. This SST analysis is a satellite-only data driven, multi-scale optimal interpolation that blends data from polar (AVHRR SSTs on MetOp B, and NOAA 19, and preoperational VIIRS SSTs, soon to replace NOAA19) and geostationary (GOES E/W, MTSAT-2, SEVIRI) orbiters. Prime customers for the new product are the NOAA Coral Reef Watch for coral bleaching monitoring. Recent changes to the analysis include successful incorporation of VIIRS super-obs in the 5 km product and implementation of a diurnal warming adjustment based on the Kantha-Clayson turbulence model with Stokes drift and Langmuir circulations, forced with NWP and Wave fields. The diurnal warming correction is applied at the super-obs stage. Preliminary comparisons (Gulf Stream, Agulhas current) indicate that the 5-km Geo-Polar blended analysis compares well to the existing 11-km version. Peak diurnal warming events of the order of 4 – 5K are being observed, with averaged daily mean warming of ~ 1K with respect to 5-m depths.

The code for the Kantha-Clayson turbulence model with Stokes drift was provided by Gary Wick, and was translated into operational mode by Jon Mittaz. Currently, the code has been optimized for operational use (it runs 2.5 times faster, making it possible to run the full turbulence scheme on a global scale under 1 hour) and is being debugged (there are discrepancies on the order of 0.5 – 1.5 K in 1% of cases due to differences in double vs. single floating-point precision. In these cases, round-off errors are causing the salinity profiles to become unstable). It is expected that the code will be fully operational by October of 2014, after which it will be made available for collaborative work with either Gary Wick or Jon Mittaz.

Standing issues:

- Diurnal warming uncertainties need to be revised since uncertainties in forcing NWP fluxes are likely to be significant.
- The diurnal warming correction can be different for enclosed seas due to the lack of wave information in these areas.
- Coral bleaching is an issue in tidal areas. There is a need to characterize tides in the model, but questions remain as how to treat the depth of the reef.

A question was raised about why the Stokes drift is important for the diurnal warming calculations? A.H. thinks this is because it gives more reasonable mixing.

Ioanna Karagali and Jacob Hoyer: Using a 1-D Model to Reproduce Diurnal SST Signals. ESA STSE Project "SSTDV: R.EX. – IM.A.M."

The ESA STSE Project "SSTDV: R.EX. – IM.A.M." is an ESA-funded project to look at the diurnal warming from SEVIRI, using the GOTM 1-D turbulence model, with an oceanic and atmospheric modelling component. The General Ocean Turbulence Model (GOTM) is an open-source software that computes solutions for the 1-D transport equations of heat, salt and momentum. It can be driven with NWP fluxes or it can be setup to internally compute fluxes. It is highly customizable with various options for the turbulence closure scheme as well as the light extinction and longwave radiation computation.

Karagali presented preliminary sensitivity tests on GOTM's ability to reproduce diurnal warming events using different configurations of the forcing radiative fluxes and light absorption schemes at three buoy locations with known heating. Results were presented for an Arctic buoy from Met.NO, an array of moorings from the Marine Light-Mixed Layer Experiment 91 (MLML91), and a PIRATA buoy.

Arctic Case: This sensitivity study used a diurnal warming event, documented in Eastwood et al. 2008, that was observed in the Barents Sea during June 20-22, 2008, and had a peak amplitude of 3K. The objective was to try to reproduce the observed peak amplitude with GOTM using different configurations for the shortwave radiation, with and without climatological temperature profiles from WOA09 and MetNo, and light extinction (LE) schemes. The heat and momentum fluxes were both prescribed and calculated within GOTM using NWP fields from HIRLAM (MetNo). GOTM best reproduced the 3K-peak diurnal amplitude using shortwave fluxes computed within GOTM with profiles from MetNo.

MLML91 Experiment and Pirata Buoy Comparisons: The code was modified to include a new longwave (LW) radiation flux parameterization and a 9-band absorption scheme. Sensitivity tests were done running GOTM with calculated and prescribed incoming LW radiative fluxes and different LE schemes (2-band and the new 9-band absorption model). The outcomes from the GOTM runs were compared against moored buoys from the MLML91 experiment. GOTM was able to reproduce some of the observed peak amplitudes at 2-m depth, but not others. The 9-band LE scheme had marginal improvements over the 2-band, and prescribed LW fluxes lead to slightly better statistics than calculated ones. Looking at the impact of the 2 vs. 9-band LE schemes on the GOTM temperature profiles, interpolated over time, the only significant differences are observed above 5-m depth, with the 9-band predicting more heating for largest event.

Pirata Buoy (15N, 38W): The same LW vs. LE sensitivity tests from the case above, but compared against more recent records (August and September 2006) from a Pirata buoy at 1-m depth showed better agreement between GOTM and the buoy, especially for LW fluxes calculated within GOTM. The 2-band scheme, however, was slightly better than the 9-band for the two separate instances of diurnal warming observed with the Pirata buoy. SEVIRI-observed warming, collocated with the Pirata buoy (for a single cell, and averaged over 4 grid cells), showed poor agreement with the GOTM-derived warming at 1.5 cm, regardless of the SEVIRI confidence flags used in the analysis.

Steiner Eastwood, Cristina Luis, Lars-Anders Breivik: Diurnal Warming in Lake Vänern.

S. Eastwood described validation activities of OSI SAF SST products in lakes, using a MetNo buoy deployed in Lake Vänern, Sweden, from May to October, 2013. A close look was given to an extreme diurnal warming (DW) event observed on June 1, 2013.

Lake Vänern is the third largest in Europe, with an average depth of 27 m and maximum depth of 106 m. The MetNo moored buoy (59N, 13E) measures SSTs at 20 cm below the surface (other thermistors are at 30 cm, 42 cm, 45 cm, 65 cm, 115 cm, and 240 cm depths) and reports observations every 30 minutes. Initial comparisons with OSI SAT products (METOP-A, NOAA-19, and VIIRS), using confidence flags 3 – 5, indicates a nighttime bias in METOP-A (-0.23K). Other comparisons have biases less than 0.1K and standard deviations less than 0.7K. Characterization of the mean monthly diurnal cycle, constructed using all days in a month for which the SST at 3 pm was greater or equal than the SST at 6am and 11pm, shows the largest peak DW amplitudes occurring in the month of June, with a monotonic decrease in peak amplitude for the rest of the summer months.

Monthly timeseries of DW indicate the presence of a three-day warming event from May 31st – June 1st, 2013, with peak amplitudes of 2°C, 4°C, and 6°C. The 6°C-warming event, although quite large, is not unprecedented at high latitudes, as indicated by buoy observations reported by Sonia Pere at the Bering Sea (70N) and Eastwood at Barents Sea (73N). The last week of June also shows 5 DW events with 3 – 4°C peak amplitudes.

NWP winds (HIRLAM 8) at the buoy location for June 1st indicated that during the extreme event the wind speeds were about 1 m/s. A closer inspection of the timeseries of buoy temperatures with depth, shows the expected lag in the penetration of heat with depth. The foundation temperature is ~1.15 m – 2.40 m-depth. Characterization of the mean daily diurnal cycle with depth, using all the profiles with DW>1.0°C from May to October and DW = SST max – SST-at-6am, indicates that the mean peak amplitude is ~1.5°C at 30 cm, 1.0°C at 115 cm, and ~0.5°C at 240 cm. Modelling studies using GOTM with 2 m/s-wind and Jerlov 1 extinction coefficient (Pere and LeBorgne) show that GOTM is able to simulate the DW amplitudes at different depths reasonably well.

Lake Vänern, thus, is a great laboratory for the study of extreme DW events, especially during June when diurnal heating is frequent and strong. Also, its turbidity makes it a good test bed for the study of light extinction models. Because of this, there is now a permanent MetNo buoy (since April 2014), equipped with an anemometer and data loggers at 5- and 10m depths, which will be used for validating satellite lake SSTs, testing equipment, and DW studies. This buoy will be left to freeze during the winter.

2. Discussion

DW models work fine, but are tuned regionally. They are limited by the availability and accuracy of the forcing information. There is a need for high resolution forcing parameters, especially high temporal resolution NWP fields. Hourly NWP winds are better suited for DW studies. A request was raised about the possibility for the DVWG to solicit these products on behalf of GHRSST scientists.

Other wind products that are desirable for the GHRSST scientists with an interest in DW, are:

- Hourly integrals of wind mixing energy
- Wind stress
- Integrated fluxes
- Cloud information
- Better peak solar radiation

USING A 1-D MODEL TO REPRODUCE DIURNAL SST SIGNALS

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ABSTRACT

The diurnal variability of SST has been extensively studied as it poses challenges for validating and calibrating satellite sensors, merging SST time series, oceanic and atmospheric modelling. As heat is significantly trapped close to the surface, the diurnal signal's maximum amplitude is best captured by radiometers. The availability of infra-red retrievals from a geostationary orbit allows the hourly monitoring of the diurnal SST evolution. When infra-red SSTs are validated with in situ measurements a general mismatch is found, associated with the different reference depth of each type of measurement. A generally preferred approach to bridge the gap between in situ and remotely obtained measurements is through modelling of the upper ocean temperature. This ESA supported study focuses on the implementation of the 1 dimensional General Ocean Turbulence Model (GOTM), in order to resolve the diurnal signals identified from SEVIRI SSTs and in situ measurements. GOTM is a model solving the basic hydrodynamic and thermodynamic processes related to vertical mixing in the water column. From previous analysis it was shown that the data used to initialise the model, especially the temperature profiles, along with the selection of the coefficients for the 2-band parametrisation of light's penetration in the water column, hold a key role in the agreement of the modelled output with observations. To improve the surface heat budget and the distribution of heat, the code was modified to include an additional parametrisation for the total outgoing long-wave radiation and a 9-band parametrisation for the light extinction. New parametrisations for the stability functions, associated with vertical mixing, have been included. GOTM is tested using experimental data from the Woods Hole Oceanographic Institution Upper Ocean Processes Group archive. The successful implementation of the new parametrisations is verified while the model reproduces the diurnal signals seen from in situ measurements. Special focus is given to testing and validation of different set-ups using campaign data from the Atlantic Ocean, to establish a model set-up applicable to different regions.

1. Introduction

The diurnal cycle of SST occurs during day-time and under cloud-free conditions and is driven the concurrent occurrence of low enough wind (~<6 m/s) and strong solar heating. Due to lack of wind that promotes mixing, heat is trapped in the upper ocean layer creating a stratified, warm layer which extends from the surface to a few meters depth with temperature increased by potentially several degrees. Diurnal warming has been extensively identified with the use of SST retrievals obtained from radiometers on space-borne platforms, which correspond to skin and sub-skin temperatures, i.e. in the upper mm of the water column. It has been identified in various locations in the global ocean (Stuart-Menteth et al., 2003) and more recently, at the higher latitudes of the North Hemisphere (Karagali et al., 2012) and the entire Atlantic Ocean including the enclosed basins (Karagali and Høyer, 2014).

Diurnal variability of SST can cause complications in various research areas. For example, in an attempt to create long and stable temperature records for climate studies, merging SST time-series from different satellite sensors typically occurs but these have different overpass times therefore capture different parts of the diurnal cycle which needs to be known. When developing retrieval algorithms for radiometers, diurnal variability should be removed from buoy observations that are used for validation purposes. Diurnal changes in SST will drive variations in the instantaneous values of the air-sea heat fluxes (Clayson and Bogdanoff, 2013) and the atmospheric stability, and since this effect is typically not taken into account in ocean and atmospheric models, forecast skill may be reduced. In an attempt to understand and predict diurnal variability, modelling efforts have been undertaken by the community, developing various physical mixed layer models and parametrisations; an extensive review of such activities is available from Kawai and Wada

(2007). Karagali and Høyer (2013) tested some parametrisations in the North and Baltic Seas and compared them with SEVIRI derived diurnal warming estimates, highlighting the dependence of the parametrisations on their input fields, typically from NWP models which do not resolve the diurnal SST cycle.

This study utilises the General Ocean Turbulence Model (GOTM) for the purpose of reproducing the diurnal signals seen from in situ instruments and satellite SSTs. Sensitivity tests were performed in order to investigate the impact of the various GOTM parameters in the model's skill to reproduce the daily SST cycles. Section 2 gives a description of the model, the experimental set-up and the data sets used for the model tests. The results are presented in section 3 and main conclusions are drown in section 4.

2. Experimental Set-Up

GOTM is a 1 dimensional turbulence model that describes the basic thermodynamic and hydrodynamic processes related to the vertical mixing by solving the 1-d equations for the transportation of heat, salt and momentum (Umlauf et al.). Surface fluxes can be either prescribed from NWP models or calculated by GOTM with the use of bulk flux algorithms which require the input of meteorological variables such as the 10-m wind components, the air temperature, pressure, humidity and cloud cover. The model includes a 2-band parametrisation for the light extinction inside the water column but has been modified to also include a 9-band parametrisation. Additional options have been included for i) the calculation of the net long-wave radiation by means of a Brunt type formula and ii) the prescription of the down-welling long wave radiation from measurements. New stability functions, i.e. dimensionless quantities involved in the expressions for the diffusivity of heat and momentum, have also been added. The vertical grid extends down to a depth of 150 m, using 150 vertical layers of which approximately 70 are in the upper 10 m. For this study, the model is assessed at 3 different locations, shown in Figure 1. Depending on the location at which the model is assessed, different set-up options were investigated as shown in Table 1.

Parameter	Options
1. Down-welling Long-wave Rad.	1. Clark et al., 1974 2. Hastenrath & Lamb, 1978 3. Bignami et al., 1995 4. Berliand & Berliand, 1952 6. User prescribed
2. Light Extinction Scheme	1. 2-band (J I) 2. 2-band (J I, upper 50 m) 3. 2-band (J IA) 4. 2-band (J IB) 5. 2-band (J II) 6. 9-band (Paulson & Simpson, 1981) 7. 9-band (Paulson & Simpson, 1981 and COART) 8. 9-band (Paulson & Simpson, 1981 and MODTRAN)

Table 1: GOTM set-up options evaluated in this study.

2.1. Arctic Diurnal Warming

In Eastwood et al. (2011), a diurnal warming event in the order of 3 degrees was identified in the Arctic, around 74.4 N and 44.5 E, during the 21st to 22nd of June 2008. According to evidence from satellite SSTs, the foundation temperature was 3^{o}C and reached up to 6^{o}C at mid-day. This event was modelled using fluxes calculated with the Fairall algorithm (embeded in GOTM), from meteo-files obtained from the HIRLAM NWP model which were provided by the Norwegian Meteorological Institute (metNo). Climatological temperature profiles from the World Ocean Atlas 09 (WOA09) were used to initialise the model, along with temperature profiles from an ocean model available at metNo. The WOA09 dataset was obtained through the National Oceanic Atmospheric Administration (NOAA) National Oceanographic Data Center (NODC) and can be found at http://www.nodc.noaa.gov/OC5/WOA09/pr_woa09.html.

2.2. Marine Light – Mixed Layer 1991 Experiment (MLML91)

The MLML91 experiment took place during the spring and summer of 1991, when a buoy was moored at 59.5 N and 20.82 W at 2822 m of water, measuring meteorological variables such as temperature, humidity, pressure, wind, down-welling long-wave and short-wave radiation and water temperature down to a depth of 325 m. The data were obtained from the Woods Hole Oceanographic Institute Upper Ocean Processes working group and are publicly available at http://uop.whoi.edu/archives/mlml91/mlml91.html. A period of 4 days, from the 29th of June to the 2nd of July 1991, during which a 1 degree event occurred was modelled using the buoy meteo and ocean measurements as input fields. During the modelling experiment, two methods for the down-welling long-wave radiation were tested and 8 methods for the calculation of the light extinction within the water column (see Table 1).

2.3. PIRATA Moored Buoy

The PIRATA mooring is located at 15^{o}N, 38^{o}W. The buoy is equipped with instrumentation for measuring various meteorological parameters such as air temperature, humidity, pressure, wind, down-welling long-wave and short-wave radiation and water temperature at different depths. Approximately 1 year of measurements were obtained from the Pacific Marine Environmental Laboratory (PMEL) through the Tropical Atmosphere Ocean (TAO) project and are available at http://www.pmel.noaa.gov/tao/disdel/disdel-pir.html. The event occurring on the 24/8/2006, reached 1.5 degrees amplitude, and in this study the period from the 22nd to the 25th of August was modelled using the different options shown in Table 1.

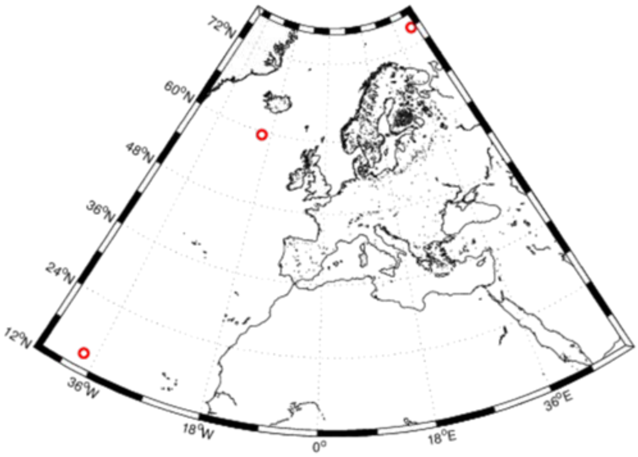

Figure 1: Locations used for the GOTM runs. Starting from the top right, the diurnal warming event identified in Eastwood et al. 2008, in the middle is the MLML91 moored buoy and bottom left the moored PIRATA buoy.

3. Results

The diurnal warming event in the Arctic, identified in Eastwood et al. (2011), had an amplitude of 3 degrees at the warmest spot, and occurred on the 22nd of June 2008. For this study, the temperature at the location 74.4 N, 44.5 E was modelled using NWP meteorological parameters, allowing for the calculation or prescription of the short-wave radiation, different parametrisations for the long-wave radiation, different temperature profiles and LE schemes. Figure 2 shows the test runs, where the 1st day is used as spin-off period. In the left panel, the coloured lines show the top layer GOTM temperature estimated using calculated (solid) versus prescribed (dashed) short-wave radiation and parametrisation 2 (red) versus 4 (cyan) for the long-wave radiation calculation. For these 4 curves, one initial temperature profile from the World Ocean

Atlas 09 dataset was used. What is generally seen is that there is a mismatch in the timing of the diurnal cycle, associated with the difference reference time of the HIRLAM input field. A very small difference between the long-wave radiation parametrisations is identified. Moreover, it is found that the WOA09 profile has a lower top layer temperature than what was observed from the satellite SSTs (3^{o}C) and that the runs using this profile, had an amplitude of approximately 2^{o}C. The black solid line shows the GOTM temperature modelled by calculating the short-wave radiation, using parametrisation 1 for the long-wave radiation and a temperature profile from the metNo ocean model. The red and cyan dashed-dotted lines use the same methods for the short-wave radiation and temperature profile but different parametrisations for the long-wave radiation. The main finding from this comparison is that with the appropriate initial temperature profile, the amplitude of the diurnal event is better resolved reaching up to 6 ^{o}C. Moreover, parametrisations 1 and 4 for the long-wave radiation produce the same result. The black dashed line has the same set-up as the black solid line, except that it uses a modified WOA09 profile in that the top level has been adjusted to the value of the metNo profile. By comparing the black solid and dashed curves, it is found that it is not only the top layer of the initial temperature profile that regulates the modelled temperature, but also the deeper layers. The right panel of Figure 2 shows the temperature evolution for GOTM runs using a calculated short-wave radiation, parametrisations 1.1 (red lines) and 1.3 (cyan lines) for the long-wave radiation, and LE schemes 2.1 (solid), 2.2 (dashed), 2.3 (dashed-dotted) and 2.4 (diamonds). It is shown that for a given colour, i.e. long-wave radiation parametrisation, the highest amplitude arises when using the LE 2.1 scheme, representative of open ocean waters. Moreover, for any given LE scheme option the long-wave parametrisation 1.1 yields higher temperatures compared to 1.3. In addition for a given colour, all LE schemes provide temperature curves that differ in amplitude during the warming and peak amplitude phase but collapse on each other during the night-time cooling period, except option 2.3 which yields lower temperatures consistently throughout the modelling period.

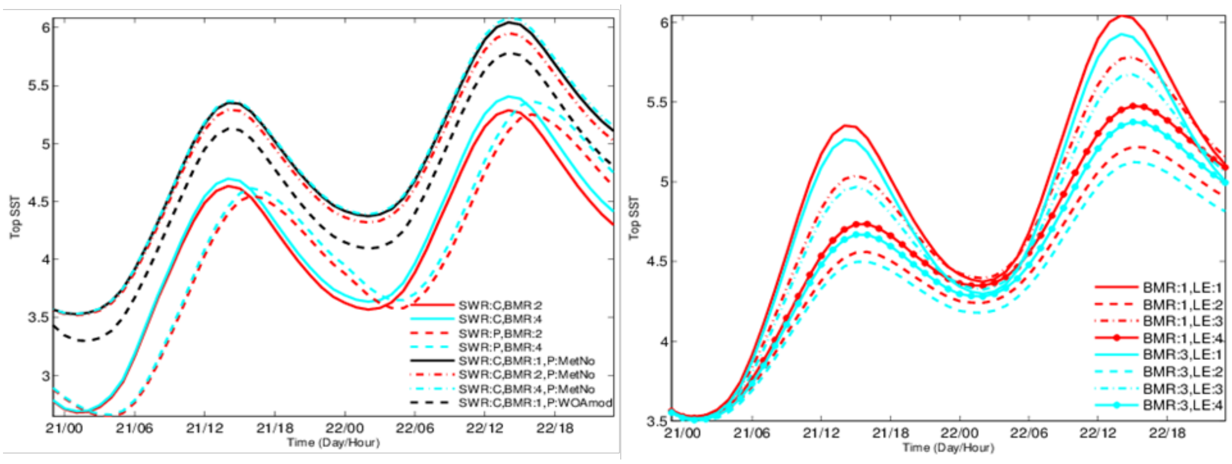

Figure 2: Temperature evolution for the 2 day period of the Arctic warming event, using different methods for the fluxes and different profiles (left), different light extinction schemes (right).

A warming event of 1 K was identified in the 2m temperature time-series of the MLML91 measurements and was used as a test case for the GOTM set-up. The evolution of temperature between the 29th of June and the 2nd of July 1991 from the buoy (black crosses) and the GOTM runs (coloured lines) using different LE schemes are shown in Figure 3. It is found that while GOTM reproduces rather well the diurnal variability of the first 2 days, it generally fails to reproduce the much smaller variability seen in the last 2 days of measurements. Prescribing the long-wave radiation (option 1.2, right panel) adds more variability in the daily cycle, particularly in the last day. The amplitude of the main event, on the 2nd day, is well captured particularly from the 9-band model (blue lines). The statistics between the GOTM and buoy temperature at 2m are shown in Table 2, for the various GOTM set-ups. Generally, lower mean biases (μ) and standard deviations (σ) and higher correlation coefficients (r) were estimated for the GOTM runs using the prescribed long-wave radiation (option 1.6). When examining the differences due to the light extinction schemes, the lowest μ is found for option 2.8 (the 9-band model with coefficients from Paulson and Simpson (1981) and attenuation lengths from the MODTRAN model while the lowest σ and highest r values are found for 2.5 (the 2 band model with Jerlov II type water). Nonetheless, the difference in the σ between LE schemes is in the order of 0.03 degrees.

At the PIRATA site, the 1m buoy and GOTM temperatures for the 2 options of the long-wave radiation and the different LE schemes are shown in Figure 4. GOTM reproduces the diurnal variability seen in the measurements, independent of the long-wave radiation method or the LE scheme. Minor differences between the amplitudes reached using the various LE schemes are identified, but they are mostly in the order of 0.2-0.3 K. The 9-band model (blue lines) performs better at capturing the amplitude of the peak event but does slightly overestimate the warming during the first two days and the last.

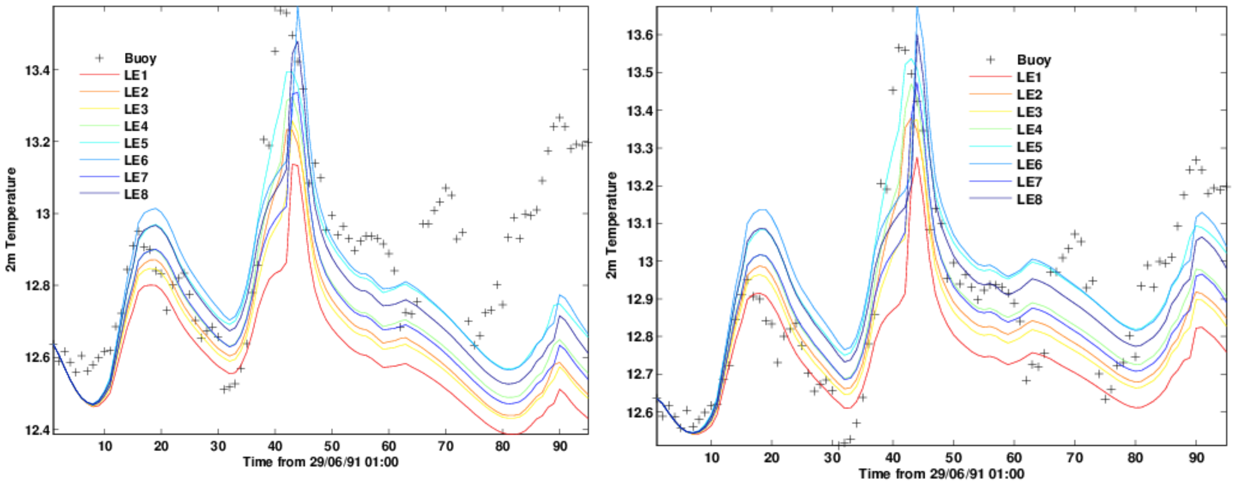

Figure 3: Temperature evolution for the 4 day period of the MLML91 warming event, using 2 different methods for the down-welling long-wave radiation, i.e. the Berliand and Berliand (1952) parametrisation (left) and the measurements from the buoy (right). The coloured lines represent different LE schemes and the crosses are the buoy measured temperature at 2m.

LE	Mean Bias (μ)		Stand. Dev. (σ)		Corr. Coef. r	
	1.4	1.6	1.4	1.6	1.4	1.6
2.1	-.29	-.15	.23	.18	.41	.71
2.2	-.23	-.07	.22	.15	.53	.81
2.3	-.25	-.10	.22	.16	.51	.78
2.4	-.19	-.04	.20	.14	.59	.83
2.5	-.11	.05	.19	.13	.66	.85
2.6	-.10	.05	.21	.16	.59	.76
2.7	-.20	-.05	.22	.16	.53	.76
2.8	-.14	.01	.21	.16	.59	.77

Table 2: Statistics of the GOTM-Buoy 2m temperature for the different runs. The rows represent different LE schemes from 1 to 8, while the internal columns are for the GOTM runs with options 4 and 6 for the down-welling long-wave radiation.

The statistics between the buoy and GOTM temperatures are shown in Table 3, indicating generally lower μ and σ and higher r values for option 1 of the long-wave radiation (the parametrisation of Berliand and Berliand, 1952). Nonetheless, the differences in the statistics between the 2 options are minor and in the order of 0.08 K. When examining the statistics due to the different LE schemes, option 3 (2-band model using the Jerlov IA type) shows the lowest μ and σ and highest r value when the long-wave radiation is parametrised using the Berliand & Berliand, 1952 formula (option 1.4) and option 1 (2-band model using Jerlov I type) when the long-wave radiation is prescribed (1.6). When the top layer temperature from GOTM (1.5 cm) is compared to the SEVIRI extracted temperature, shown in Figure 5, it is found that SEVIRI shows much colder temperatures during night-time (almost 2 degrees difference) and higher day-time temperatures (by approximately 1 degree) during the 1st day. The night-time cooling at the beginning of the 2nd day is approximately 1 degree larger in the SEVIRI SST, but the 2nd day peak is reasonably resolved. Unfortunately, the 3rd day large diurnal warming event is absolutely missed by SEVIRI. This highlights the difficulty of collecting appropriate datasets with full observations from in-situ and satellite sensors for the purposes of calibrating the GOTM model.

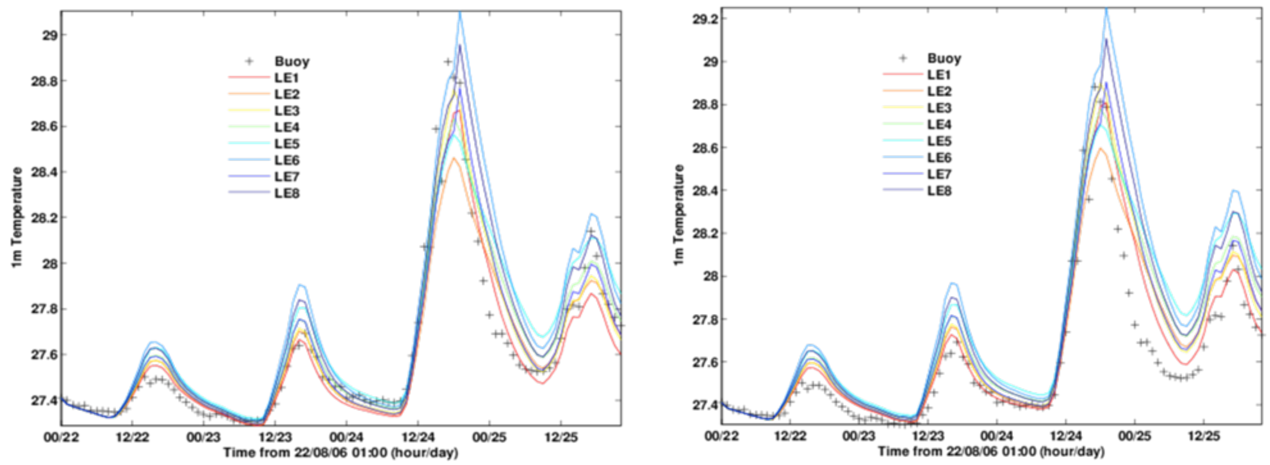

Figure 4: Temperature evolution for the 4 day period of the PIRATA warming event, using 2 different methods for the down-welling long-wave radiation, i.e. the Berliand and Berliand (1952) parametrisation (left) and the measurements from the buoy (right). The coloured lines represent different LE schemes and the crosses are the buoy measured temperature at 1m.

LE	Mean Bias (μ)		Stand. Dev. (σ)		Corr. Coef. r	
	1.4	1.6	1.4	1.6	1.4	1.6
2.1	-.03	.05	.08	.09	.97	.97
2.2	-.01	.06	.11	.11	.96	.94
2.3	.01	.09	.08	.12	.97	.96
2.4	.03	.11	.10	.13	.96	.95
2.5	.07	.15	.13	.16	.93	.92
2.6	.11	.19	.15	.19	.95	.94
2.7	.02	.09	.10	.13	.96	.95
2.8	.07	.15	.12	.16	.95	.96

Table 3: Statistics of the GOTM-Buoy 1m temperature for the different runs during the period 22-25/8/2006 at the PIRATA buoy location. The rows represent different LE schemes from 1 to 8, while the internal columns are for the

GOTM runs with options 1 and 2 for the down-welling long-wave radiation.

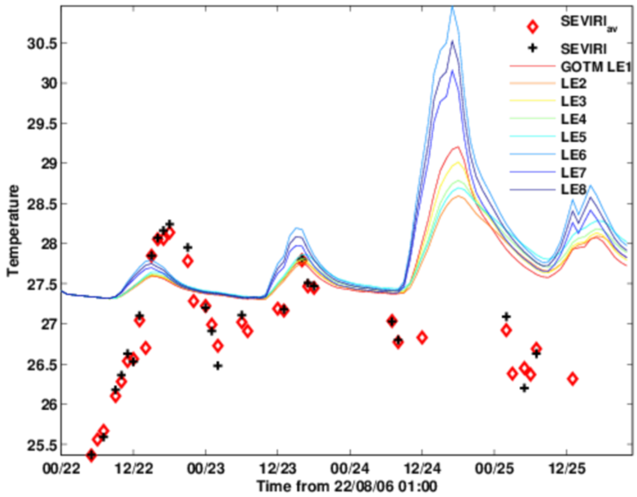

Figure 5: Top layer GOTM modelled temperatures using the prescribed long-wave radiation and different LE schemes (coloured lines) and SEVIRI retrieved SST from the grid cell (black crosses) containing the PIRATA buoy and from the average of 4 grid cells around the PIRATA location (red diamonds).

4. Conclusion

This study has focused on applying a 1 dimensional ocean turbulence model for the purpose of reproducing diurnal signals in the sea surface temperature as seen from in situ measurements and satellite SST fields. A variety of tunable model parameters were tested and their impact in GOTM's skill to reproduce sea water temperatures comparable to the observations was evaluated in terms of the mean bias, standard deviation and correlation coefficient.

Three different locations representative of different latitudinal bands were tested, including the Arctic Ocean, the mid/high latitudes and Tropics of the Atlantic Ocean. Regarding the parametrisation for the short-wave radiation, it was found from sensitivity tests that certain options yield almost the results (1 and 4) while others (2 and3) show a small reduction in the amplitude of the diurnal signal in the order of 0.1-0.2 degrees, at least in the Arctic case. Prescribing the long-wave radiation from measurements does not always yield the best results, likely due to errors in the measurements themselves, but such data are not always available.

Regarding the different light extinction schemes, it was found that the 9-band model, which is thought to be more representative of the physical conditions that occur when light enters the water column, did not always yield better results compared to the 2 band model. Nonetheless, the error statistics for the 9-band modle were only approximately 0.05 degrees higher compared to the selection with the lowest bias and standard deviation and the highest correlation coefficient.

It has been shown that GOTM reproduces very well the diurnal signals seen from measurements and that further refinements can improve the model's performance. So far, the model has been driven with in situ measurements and the results are promising, but when the model is initialised with NWP fields, its performance against in situ data may degrade.

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VALIDATING SATELLITE SST AND OBSERVATIONS OF DIURNAL WARMING IN LAKE VÄNERN

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ABSTRACT

A buoy for observing the surface temperature and temperatures down to 2.4 meters have been deployed Lake Vänern by the Norwegian Meteorological Institute (MET). This was done for the purpose of validating Ocean and Sea Ice Satellite Application Facility (OSI SAF) sea surface temperature (SST) products over this lake and also study diurnal warming, both at the surface and the profile of the diurnal temperature cycle. Results from 2013 are presented.

1. Introduction

Observations of surface temperatures in lakes are spares and often not reported through “normal” channels such as the Global Telecommunication System (GTS). To validate the OSI SAF SST products over lakes, a typical drifting buoy was moored on a fixed position in Lake Vänern (at 59N 13E, 20m depth). The buoy had been equipped with an eye bolt for mooring, to prevent it from drifting ashore. Lake Vänern was chosen because it is large (Europe's third largest, 5650km2), not to deep (average depth 27m, maximum depth 106m) and easily accessible. The water is quite turbid in Lake Vänern with a Secci depth of 3-5m according to measurement from Swedish University of Agricultural Sciences (http://info1.ma.slu.se/db.html). So diurnal warming can potentially have large amplitudes.

The buoy has a temperature sensor situated about 20cm below the water surface. Underneath the buoy a series of water proof temperature loggers were attached (of type Hobo Water Temperature Pro v2, http://www.onsetcomp.com). They were measuring at depths of 30, 42, 45, 65, 115 and 240cm. The loggers at 45, 65, 115 and 240cm were shielded from direct sunlight with a thin, white disk. The logger at 30cm was shielded by the buoy itself.

2. Validation of lake surface temperature

The lake buoy observations have been collocated with the SST fields from the OSI SAF North Atlantic Region (NAR) SST product, using the closest satellite pixel to the observation and a time window of +/- 1 hour. The operational NAR SST product is available for METOP-A and NOAA-19 AVHRR, and in demonstration mode for NPP VIIRS.

The validating results are shown in Table 1, and shows that the validation statistics are as expected. The bias is low and so is the night time standard deviation. For daytime the standard deviation is higher, but still within expected range. VIIRS performed better that METOP-A and NOAA. The higher daytime is partly due to the higher variability during diurnal warming at daytime.

	Night time (> 95)			Daytime (< 85)		
	bias	std	num	bias	std	num
METOP-A	-0.23	0.49	55	0.00	0.67	146
NOAA-19	0.06	0.45	82	0.03	0.68	108
NPP VIIRS	0.04	0.34	68	-0.02	0.53	90

Table 1: Validation results comparing the OSI SAF NAR SST products for METOP-A, NOAA-19 and NPP VIIRS against the moored buoy in Lake Vänern. Data from 3rd May to15th October 2013.

3. Observed cycle of diurnal warming events

From time series of observations from the buoy, as seen in Figure 1, it is obvious that there are daily temperature cycles on several of the days. These vary from small amplitudes to strong diurnal warming events. The event on 1st June is quite extreme and has an amplitude of around 7 deg C. The diurnal warming case for 1st June is especially strong, and has been studied in more details. In Figure 2 SST fields from the OSI SAF AHL SST product are shown, illustrating how the spatial distribution of SST field is evolving on the 1st June. The strongest DW amplitude are in the two northern bays of Lake Vänern, where the water is partly sheltered from the weak northerly winds. The NWP wind field from the HIRLAM model run at MET Norway had weak winds of about 1m/s in these areas on 1st June (not shown).

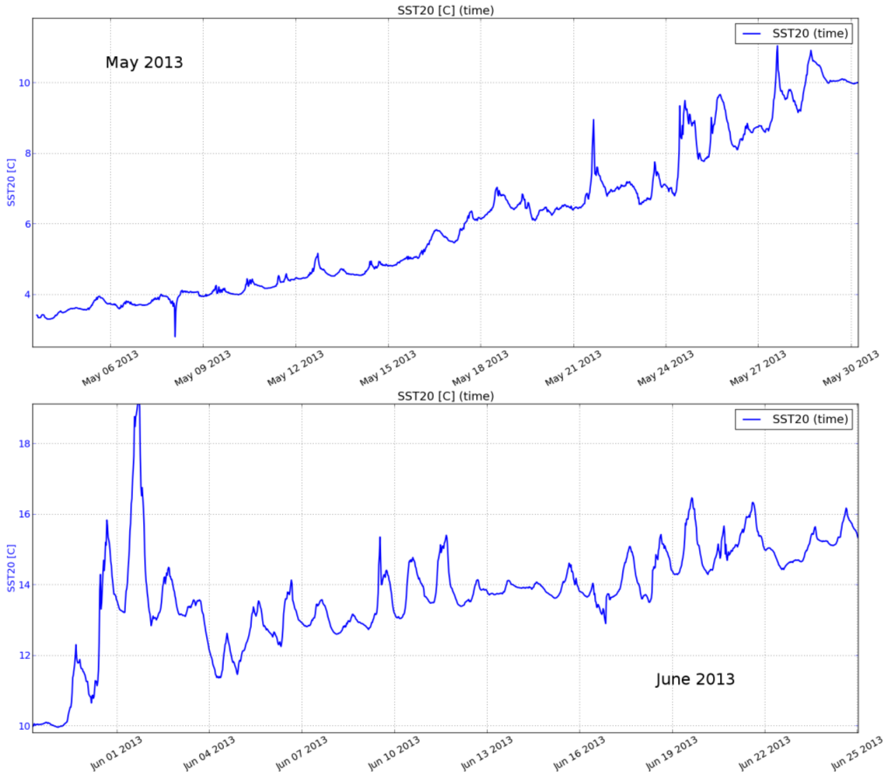

Figure 1: Time series of SST at 20cm depth for May and June 2013 for the Lake Vänern buoy.

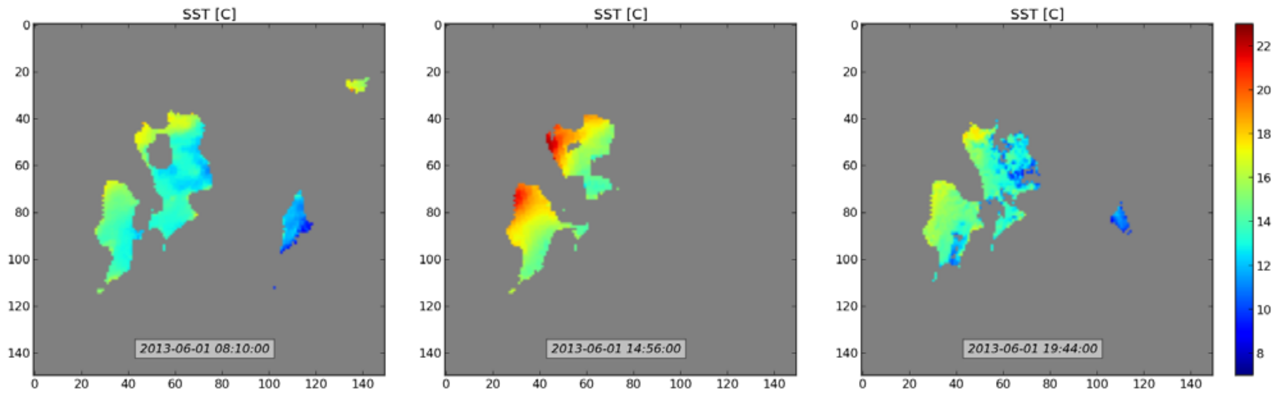

Figure 2 Subsets of OSI SAF AHL SST covering Lake Vänern based on AVHRR data, on 01.06.2013. Grey is land and cloud covered areas.

4. Observed profile of diurnal warming events

The observations from Lake Vänern also includes temperature loggers at different depths, and these observations can be used to study the vertical structure of the diurnal warming events. In Figure 3 this is shown for the 1 June case, including 31st May also. The DW amplitude is strongest at 30cm and decreasing with amplitude. The maximum amplitude is also occurring later in the day at the deeper layers. At 240cm there is no clear diurnal cycle, indicating that the foundation temperature is somewhere between 115cm and 240cm. The temperature at 240cm raises to the same temperature as the other layers at the end of 1st June, when the wind is increasing and the water column is mixed.

In Figure 4 the average diurnal temperature cycles at different depths for all DW cases are shown. There is a clear DW signal for the upper layers down to 115cm, with a weaker signal at 240cm. The amplitude delay with depths is also apparent.

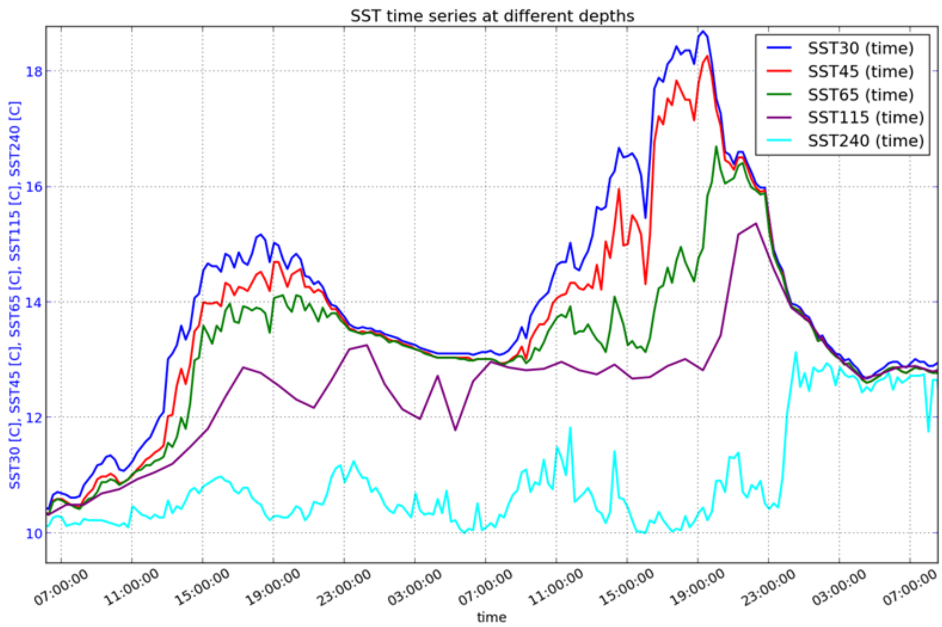

Figure 3: Temperature at depths between 30cm to 240cm on 31st May and 01st June 2013 at buoy location in Lake Vänern. Hours are in local time.

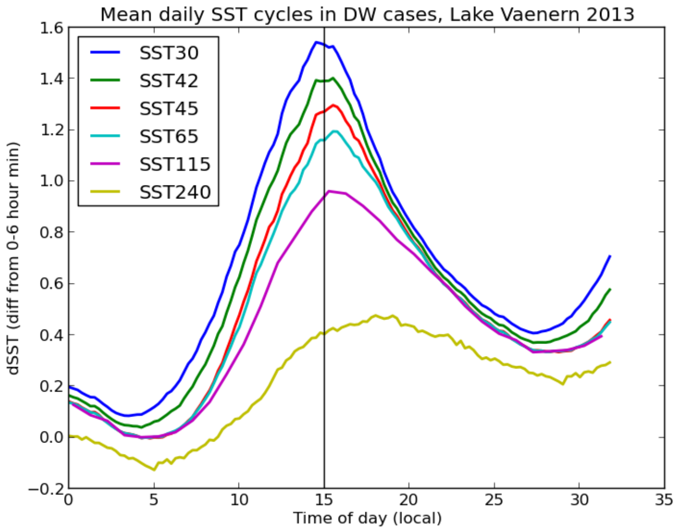

Figure 4: Mean daily temperature cycles at different depths for events with diurnal warming (DW at surface >= 1.0°C).

5. Conclusion

A surface drifting buoy was moored at a fixed position in Lake Vänern, Sweden, for May-October 2013. The observations were compared with OSI SAF satellite SST products and they validate as expected in this lake, with performance which is comparable to validation at sea. There is a higher standard deviation at daytime caused partly by a stronger variability due to diurnal warming. Diurnal warming was frequent at the buoy location and very strong events of DW (up to 7°C) were observed in lake Vänern.

Lake Vänern has proved to be a good location for validating satellite lake temperatures, testing measuring equipment and study diurnal warming. The work will continue and the same buoy has been deployed for the 2014 season, including temperature loggers down to 10m and a wind speed logger.

PLENARY SESSION V: L4 ANALYSES

SESSION REPORT

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

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1. Session schedule

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

2. Talks

In the talk “Biases Versus Variability in Differences Between Gridded SST Products” Alexey Kaplan demonstrated that despite significant community efforts to correct inter-platform biases in the SST data that are used for producing gridded data sets, the remaining biases are significant enough to create easily discernible differences between global means estimated from such gridded data sets, even from those that are interpolated to be globally complete (L4 data sets). While historical SST products that make use of the AVHRR data (HadISST1 and COBE SST) show very good consistency with each other and with the NCEP weekly 1^o OI product, they are colder than data sets that use only in situ data (ERSST v.3b, HadSST3, and ICOADS). High-resolution interpolated SST products, which make more extensive use of the satellite data (OSTIA and NCDC OI), are even colder (by about 0.3^oC in the 1985-2000 period). These differences are not due to different spatial coverage of the data sets (they appear in co-located calculations as well) and cannot be reasonably explained by random error effects on the global annual SST means. However, (1) the differences seem to decrease after 2001; (2) NCDC Daily 0.25^o OI version that uses microwave data in addition to the AVHRR has smaller differences with the in situ data; (3) newer CCI version of the OSTIA data set is closer to the in situ data as well. Therefore, remaining cold biases in the AVHRR data and, possibly, systematic differences between ship and buoy data as well, seem responsible for the global mean differences between historical data sets during the satellite period. Homogenization of historical data sets in terms of a common reference data type across satellite and pre-satellite periods is yet to be satisfactorily resolved, even with regards to the estimates of annual global SST means.

Jonah Roberts-Jones gave a talk “A Validation of the Error Estimates in SST Analyses” in which he presented a comparison of uncertainty estimates of the L4 SST products that constitute the GMPE ensemble. The uncertainty estimates used in this comparison are those given by the *analysis_error* fields in the GHRSST data sets under GDS 2.0 standard. Estimation of the analysis uncertainty in the OSTIA product of the U.K. MetOffice was presented as a combination (with tunable coefficients) of the background error variance values and “observational weights”, found as a complementary OI solution to the input data set where all observations are given a value of 1, and background estimates are 0. Recently implemented change in the OSTIA background error estimates resulted in smaller analysis uncertainty estimates that show seasonal changes and match well analysis minus ARGO floats’ SST differences. Other GMPE members also showed a good agreement between their differences with ARGO SST and their uncertainty estimates, despite significant differences in the average magnitudes of their analysis error estimates. Most of inter-compared products didn’t show seasonal dependence of their uncertainty estimates.

Igor Tomažić, in the talk "Producing Gap-Free Analysed Sea Surface Temperature Data From L3 Products Using Web-Based Data Interpolation Empirical Orthogonal Functions (DINEOF) Technique" presented a brief description of the DINEOF method for a non-parametric infilling of data sets with missing data (gaps). This method has been developed and is being actively promoted by GeoHydrodynamics and Environmental Research (GHER) Group of the University of Liège (Liège, Belgium). The software for this method is freely available on the Web, and it is being used for the production of a few publicly available products, namely

- BESST: Inter-sensor Bias Estimation in Sea Surface Temperature, described at *http://www.gher.ulg.ac.be/ BESST/*
- OCEANCOLOUR_BS_CHL_L4_NRT_OBSERVATIONS_009_045 distributed through *myocean.eu.*

Recently the group developed a web interface for performing the DINEOF analyses of user-selected data sets. Use of this web interface was illustrated by examples. Answering questions, the speaker said that Google indicated an interest in the web application; he also explained that because of the need to perform the full-domain Singular Value Decomposition, the DINEOF method is more suitable for regional analyses of satellite data, rather than for the global domain.

3. Discussion

The talks were followed by a vigorous open discussion, with most comments pointed at the need to help users with the interpretation of the results of L4 analyses, for which an adequate description of their error is the necessary first step. The discussion quickly moved to the problem of finding out what are typical users' requirements for the L4 SST products, and what recommendations on selecting the most appropriate L4 product can be made to a user. In particular Chris Merchant announced that an ESA Climate Change Initiative SST User Workshop on Uncertainties was being organized by Nick Rayner, to be held in the U.K. Met Office in November 2014 (*http://www.esa-sst-cci.org/PUG/workshop.htm*) and encouraged wide participation and advertising among SST users.

BIASES VERSUS VARIABILITY IN DIFFERENCES BETWEEN GRIDDED SST PRODUCTS

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1. Motivation

Despite the significant progress in achieving consistency between different kinds of sea surface temperature (SST) measurements, some problems remain. These become apparent when an inter-comparison of independently produced data sets is undertaken, especially when satellite-based data sets need to be reconciled with in situ data sets. For example Figure 2.18 of a recent IPCC report (Hartmann et al. 2013a), re-plotted for readability here in Figure 1, shows globally averaged annual means of SST and night marine air temperatures (NMAT) for several state-of-the-art data sets. While there is a very good consistency between different curves going back to the 19th century, a strange “separation” of these five curves into two groups occurs in the period after 2000, when, in general, the SST data is more abundant than before. It turns out that the two colder data sets in this period are the only two that blend-in some satellite data (AVHRR) into the analysis of the in situ data sets (HadISST1 and COBE SST), while the warmer data sets are those of NMAT (HadNMAT2) and SST (ERSST and HadSST3) that use in situ data exclusively (see Hartmann et al., 2013b for details of these data sets). Differences between global annual averages of SST from these two groups of data sets are beyond what could be explained by random error or incomplete data coverage in this period (and they appear in co-located calculations as well). More comprehensive homogenization of satellite and in situ SST that takes into account surface processes and depth and measurement type differences is needed to overcome this difficulty.

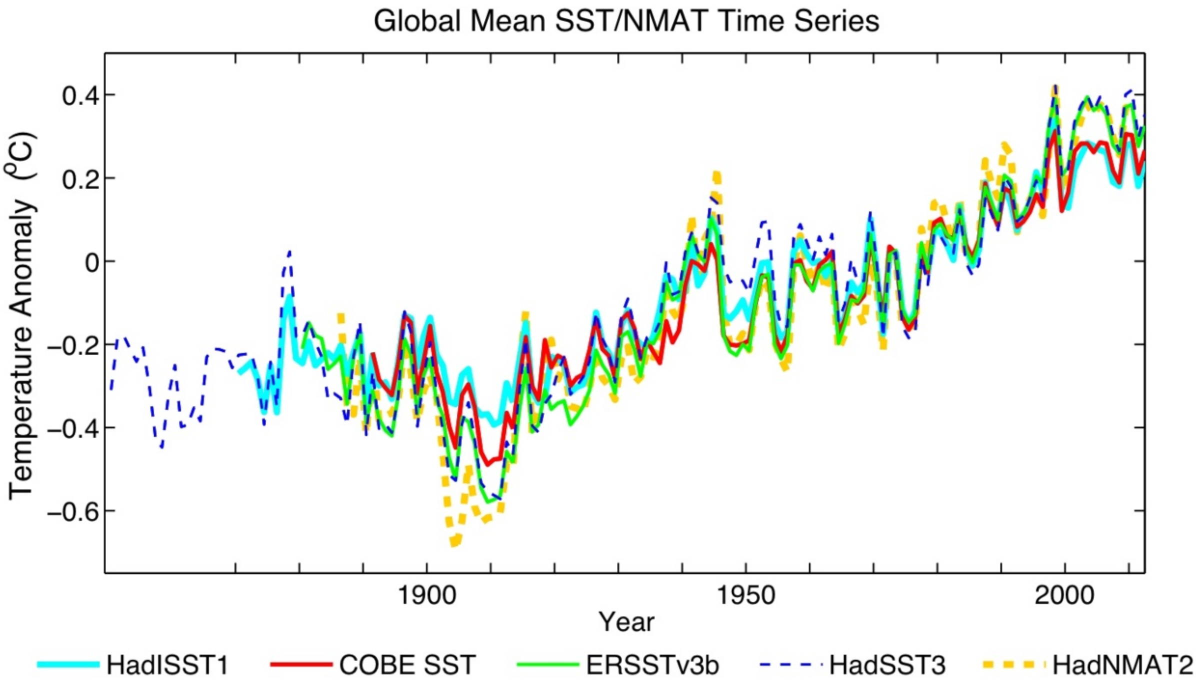

Figure 1: Global means of annually averaged SST and Night Marine Air Temperature (NMAT) anomalies relative to each data set’s individual 1961-1990 climatology. (Re-plotted for readability Figure 2.18 of the IPCC WG1 contribution to AR5, Hartmann et al., 2013a).

For further analysis, in order to deal with more straightforward comparison, we replace HadNMAT2 data set with the SST from ICOADS, Release 2.5, 2^ox2^o enhanced monthly summaries, and calculate all anomalies with regards to a common climatology (NCEP OI, 1961-1990). Results are presented in Figure 2. Large differences between ICOADS and other data sets before 1940 are expected: these are due to the need for bias corrections of bucket SST measurements, which are not applied in the ICOADS data set. But the differences after 2000 are similar to those shown in Figure 1, and, naturally, ICOADS takes place in the warmer, in situ only "group".

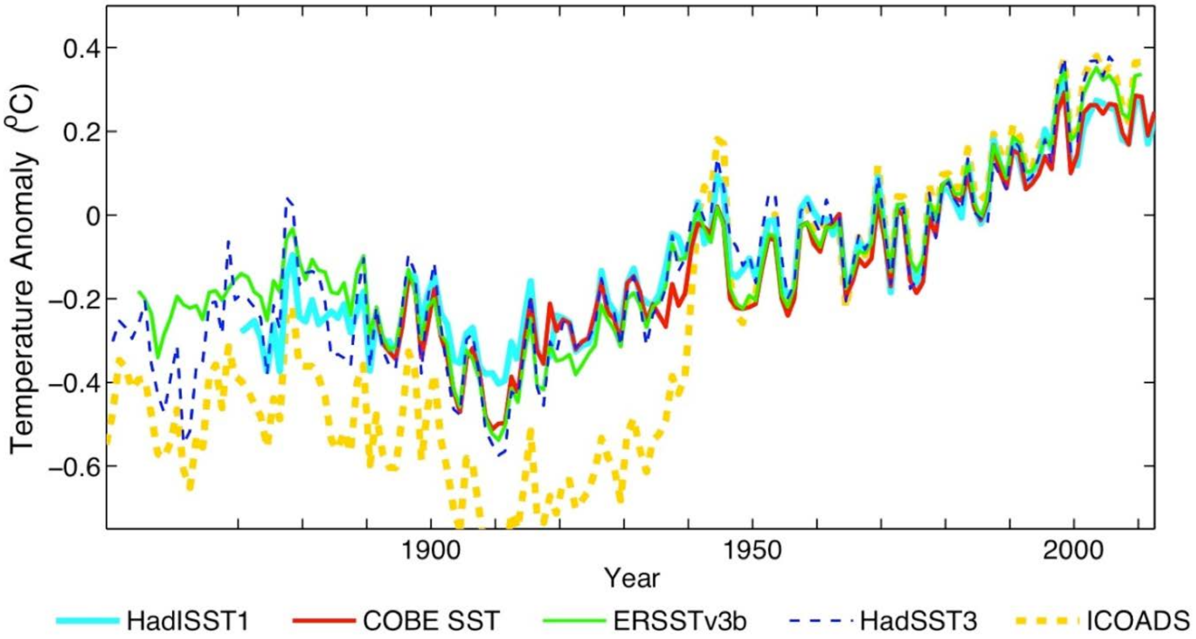

Figure 2: Global means of annually averaged SST anomalies relative to a common climatology (1961-1990 climatology from NCEP OI, Reynolds et al., 2002). Compared to Figure 1, 2^ox2^o enhanced monthly summaries of SST observations from ICOADS, Release 2.5, replaced the HadNMAT2 data set. (See Hartmann et al., 2013a for brief descriptions and primary references for individual data sets).

2. Focus on the Satellite Period

In order to understand better differences between satellite and in situ SST observations, we re-plot ICOADS and HadISST1 curves from Figure 2 for the period after 1980 together with satellite-period data set: legacy NCEP weekly 1^ox1^o OI, v.2, data set (Reynolds and Smith, 1994; Reynolds et al. 2002) and three GHRSST L4 products, and Pathfinder night SST, v.5.0 (Figure 3). While NCEP OI shows excellent consistency with HadISST1, all other data sets are significantly colder, Pathfinder being colder by about 0.3^{o}C. Precise reasons for that require more detailed investigation, but it is encouraging that the NCDC product that uses both IR and MW data is warmer than the IR-only product and has smaller differences with ICOADS SST and HadISST1. Also differences between GHRSST L4 products shown in Figure 3 (two NCDC versions and OSTIA) and HadISST1 become smaller after 2001 than before.

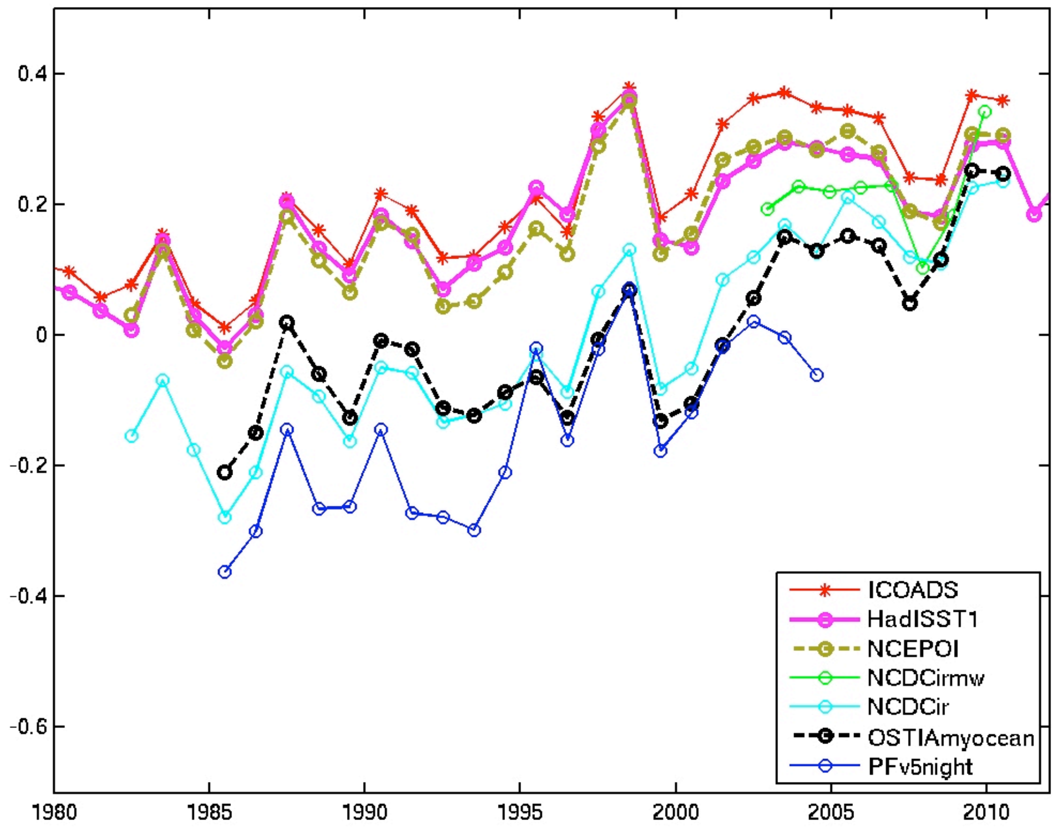

Figure 3: Global means of annually averaged SST anomalies relative to a common climatology (1961-1990 climatology from NCEP OI) for the period after 1980. ICOADS and HadISST1 curves are as in Figure 2, other curves are NCEPOI - NCEP OI, v.2 (Reynolds et al., 2002), NCDCirmw and NCDCir are NCDC Daily 0.25^o OI based on IR+MW data and on IR data only, respectively (Reynolds et al, 2007), OSTIAmyocean - OSTIA SST as retrieved from myocean.eu in September 2013, and PFv5night - Pathfinder v.5.0 night SST.

Finally, recently produced ESA CCI version of OSTIA, based on the L2P AVHRR and ATSR input data sets, re-processed within the ESA CCI project (Good and Rayner, 2013), shows smaller differences with HadISST1 (Figure 4, thick black curve). Precise reasons for this improvement are yet to be established and would require a careful comparison of input L2P data sets used by different OSTIA versions. T-Y diagram of zonally averaged differences between two OSTIA versions show sharp transitions between a few data segments and the variability dominated by the seasonal cycle within individual segments (Figure 5).

3. Preliminary Conclusions

There are easily discernible differences between global mean SST estimates obtained from different gridded products, even between those that are interpolated to be globally complete. While historical SST products that make use of the AVHRR data (HadISST1 and COBE SST) show very good consistency with each other and with the NCEP weekly 1^{o}x1^o OI product, they are colder than data sets that use only in situ data (ERSST v3b, HadSST3, and ICOADS).

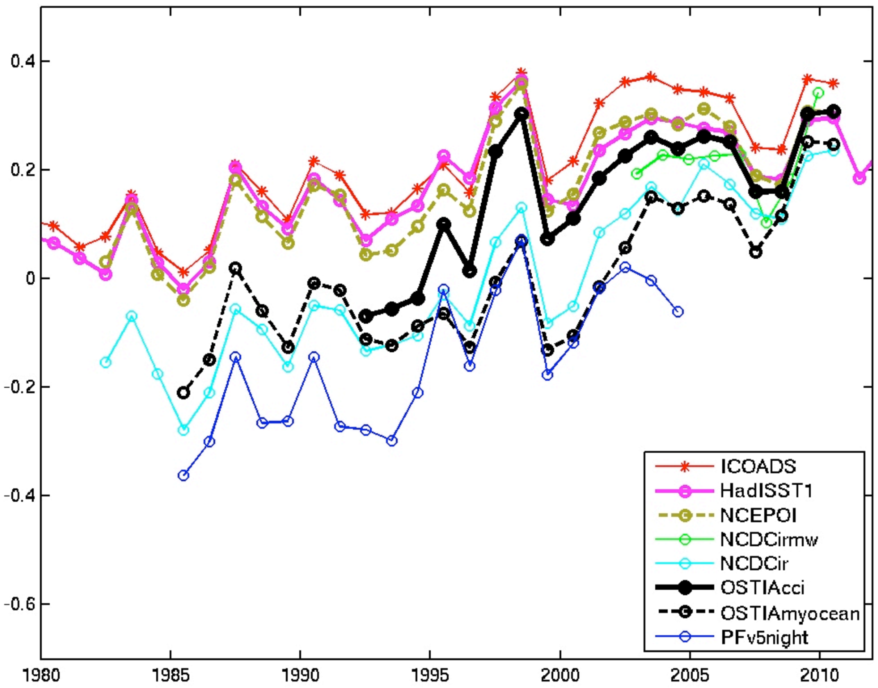

Figure 4: Same as Figure 3, but with an added line for the ESA CCI OSTIA pre-release version (thick black curve). This is the long-term satellite-only product created by the OSTIA system from the SST CCI STSR and SST CCI AVHRR data (Good and Rayner, 2013).

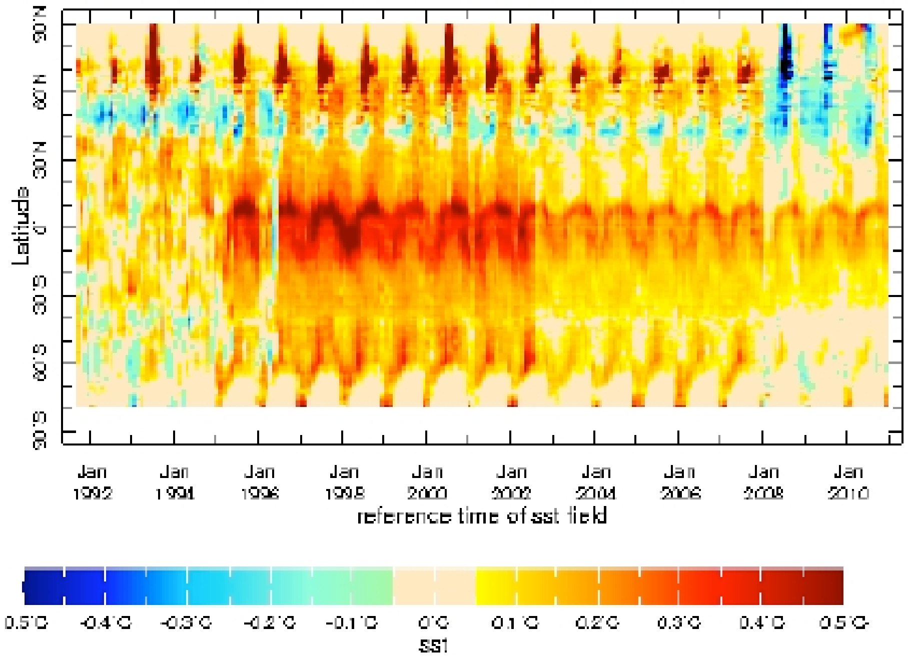

Figure 5: Zonal mean monthly difference (OSTIA_CCI – OSTIA_myocean).

High-resolution interpolated SST products, which make more extensive use of the satellite data (OSTIA and NCDC OI), are even colder yet (by about 0.3°C in 1985-2000 period). These differences are not due to different spatial coverage of the data sets (they appear in co-located calculations as well) and cannot be reasonably explained away by random error effects on the globally averaged annual SST means.

However, (1) NCDC OI version that uses microwave data in addition to the AVHRR has smaller differences with the in situ data, and (2) CCI version of the OSTIA, which is based on consistently re-processed ATSR and AVHRR data is closer to the in situ data than the original (*myocean.eu*) OSTIA version. Therefore, it might be that the remaining cold biases in the AVHRR data and, possibly, systematic differences between the ship and buoy data as well, are responsible for the global mean differences between historical data sets during the satellite period. Homogenization of historical data sets in terms of a common reference data type across satellite and pre-satellite periods is yet to be satisfactorily resolved, even with regards to the estimates of annual global SST means.

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A VALIDATION OF THE ERROR ESTIMATES IN SST ANALYSES

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ABSTRACT

SST analyses generated in the GHRSST data format contain estimates of the analysis uncertainty in the L4 products. An accurate analysis uncertainty estimate is required by users who require information on the confidence to place in the analysed SST at a grid box level.

The formulation of the analysis uncertainty estimates in the Operational Sea surface Temperature and sea Ice Analysis (OSTIA) system will be presented. These estimates were validated against the 'true' error of the OSTIA SST analysis, assessed using independent Argo data. An inter-comparison of SST analysis uncertainty estimates produced by other analysis production centres was carried out within the framework of the GHRSST Multi-Product Ensemble (GMPE) system.

It is desirable to have consistency within the GHRSST Inter-Comparison TAG in how the analysis error estimates are made across different L4 products to help users make informed decisions as to which product is appropriate. The aim of this presentation is to stimulate this discussion.

1. Introduction

Gap-free SST analyses (termed L4 products) are produced by a variety of agencies within GHRSST in both near-real time (NRT) and long-term (LT) reanalysis modes. These analyses have a diverse user community and generally assimilate both in-situ and satellite SST data onto a background based on persistence. Each analysed SST value is accompanied by an uncertainty estimate (the 'analysis error' in GHRSST Data Specification). These uncertainty estimates are vital to users who require information on the confidence to place in the SST value or may require a quantitative estimate of the uncertainty to use the SST analysis in assimilation or validation studies.

2. Uncertainty estimation in OSTIA

Operational Sea surface Temperature and sea Ice Analysis (OSTIA) is run daily in NRT and reanalysis modes at the UK Met Office. The analysis errors in the OSTIA SST analysis are estimated by first calculating the observational weight (ε^o) for each analysis grid point. An additional Optimal-Interpolation (OI) analysis is carried out where all observations are given a value of 1, background is set to 0. The background and observation error covariances are the same as those used in the SST analysis. Background error covariances are specified a priori and parameterised into error variances and error length scales. Observation errors are assumed uncorrelated and variances are estimated for satellite data by taking the single-sensor error statistics (SSES) standard deviation which are provided with the data.

$$\varepsilon_i^a = \sqrt{B_i[\alpha + \beta(1-\varepsilon_i^0)]} \quad \text{(equation 1)}$$

The uncertainty in the SST analysis (ε^a) is estimated by combing the observational weight (ε^o) with the background error variance (B) within each analysis grid point i, (equation 1). This formulation contains two tuneable parameters α (which is currently set to 0.5) and β (which is currently set to 4). In this estimation the majority of the flow dependence in the estimated analysis uncertainty is determined by the daily observational coverage but uncertainty estimates are heavily constrained by the background error variances.

To validate the uncertainty estimates provided in OSTIA the best estimate of the true error in the analysis is obtained by using Argo observation-minus-analysis differences (o-a). The top-level (between 3-5m) Argo observations have been shown to provide an independent estimate of the foundation SST. These Argo observations are not assimilated by the analysis. A comparison of the true analysis error as estimated by Argo o-a standard deviation, hereafter referred to as the Argo analysis error, and the uncertainty estimates provided with the analysis showed that the uncertainty estimates represent in the main the spatial pattern of the Argo analysis errors, this is dependent on the Argo o-a variability being captured in the background error covariances. The OSTIA uncertainty estimates are an over-estimate of the Argo analysis errors both globally and regionally (figure 1). The seasonality exhibited by the OSTIA uncertainty estimates and the Argo analysis errors differ (figure 1). This is due to the fact that the seasonality in the uncertainty estimates (magnified in DJF) is primarily due to seasonal maximum in the sea ice extent in the Northern Hemisphere. The seasonality in the Argo analysis errors (magnified in JJA) is caused by the Northern Hemispheric bias in the Argo network. The observed seasonality is due to a more variable SST caused by shallower mixed layer during summer and possible contamination by diurnal warming.

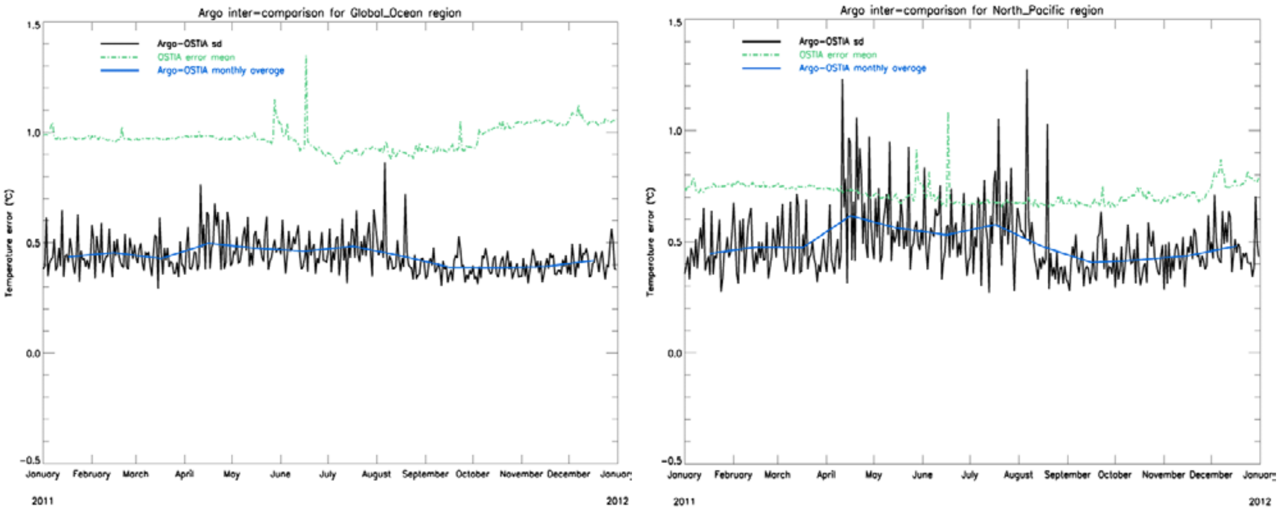

Figure 1: Comparison of the OSTIA analysis daily uncertainty estimates (green)with the daily (black) and monthly average (blue)analysis error estimated from Argo observation-minus-analysis difference standard deviations for 2011 averaged (a) globally and in the (b) North Pacific..

3. Inter-comparison of uncertainty estimates in SST analyses using the GMPE system

The GHRSST multi-product ensemble (GMPE) system is produced at the UK Met Office. Within the GMPE framework the analysis uncertainties from OSTIA (Met Office, UK), AVHRR-OI (NCDC/NOAA, USA), CMC (Canadian Met Center, Canada), GAMSSA (BOM, Australia) and NAVO K10 (Naval Oceanographic Office, USA) have been inter-compared. These estimates are generated using different methodologies by each individual analysis producer.

Monthly average SST uncertainty estimates for each of the analyses for July 2012 are shown in Figure 2 to illustrate both the commonalities and the differences between the uncertainty estimates in the different products. Most analyses have an increased uncertainty estimate in SST frontal regions such as in the Gulf stream, Agulhas retroflection and the Kuroshio current region. Most of the uncertainty estimates exhibit an seasonally enhanced error in the Summer Hemisphere, here discerned in Northern Hemisphere. The moored-buoy array can be discerned as points of reduced error in the AVHRR-OI and GAMSSA uncertainty estimates. The OSTIA and NAVO K10 uncertainty estimates have increased error under the sea ice field whilst the other analyses set either low or zero errors under sea ice.

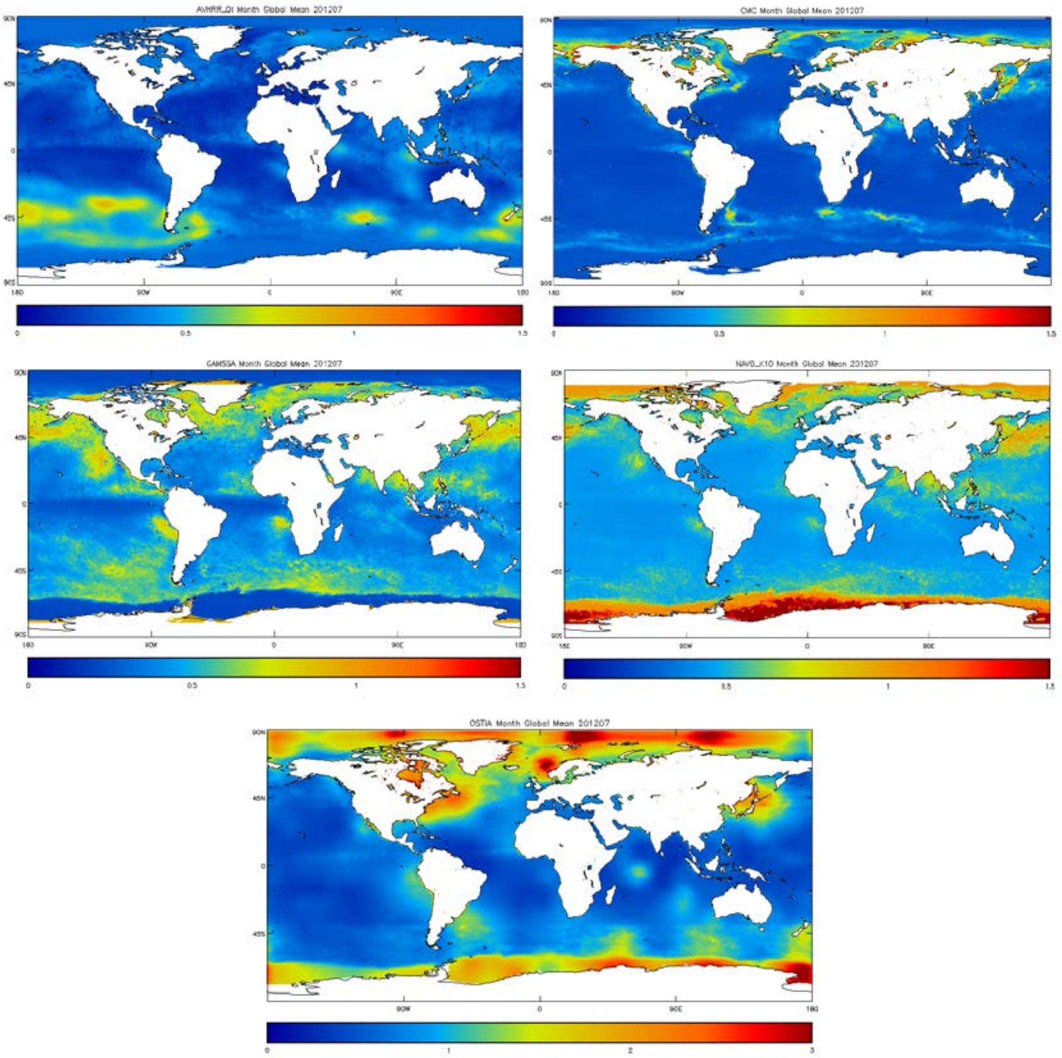

Figure 2: Monthly average SST uncertainty estimates for July 2012 from (a) AVHRR-OI, (b) CMC, (c) GAMSSA, (d)NAVO K10 and (e)OSTIA.

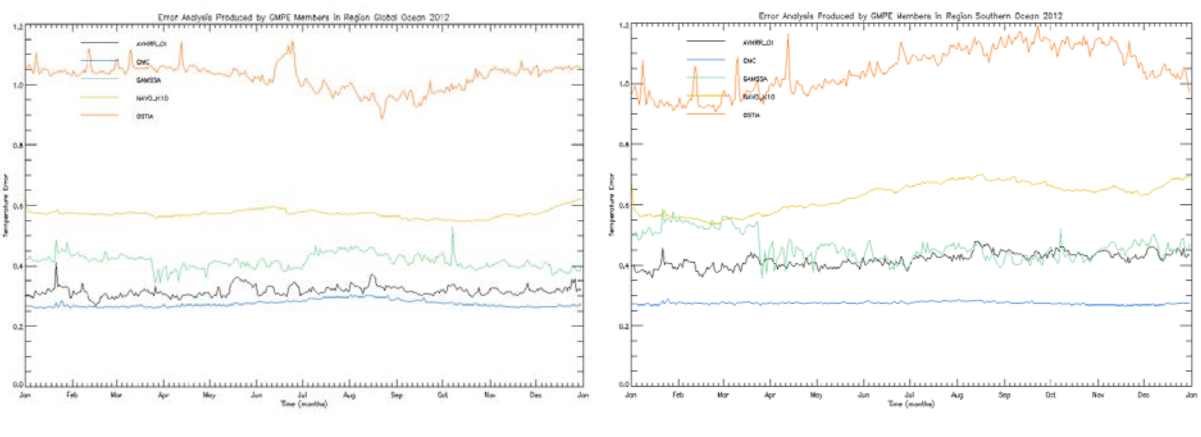

Figure 3:Inter-comparison of the uncertainty estimates in different SST analyses in 2012 averaged (a) globally and in the (b) Southern Ocean.

Figure 3 shows an inter-comparison of the (a) global and (b) Southern Ocean uncertainty estimates in the different SST analyses for 2012. Uncertainty estimates produced by OSTIA are considerably higher than those of the other GMPE members in all regions. As the uncertainty estimates in both OSTIA and NAVO K10 are magnified by expanding sea ice fields, greater seasonality can be observed in their error estimates compared to those of the other analyses. The uncertainties in the CMC analysis are consistently lowest (~0.26K), this result is very robust across all the different regions. A step change in GAMSSA analysis errors in Southern Ocean in March 2012 (figure 3(b)) can be observed to affect the global statistics (figure 3(a)).

The uncertainty estimates for each individual analysis can be validated using the Argo analysis error, (not shown). It was found that none of the uncertainty estimates calculated for the analyses exhibited the seasonality observed in the Argo analysis errors. Most of the analyses (AVHRR-OI, GAMSSA, CMC) under-estimate the Argo analysis errors whilst OSTIA and NAVO K10 are over-estimates, this will partly be due to the effect of the sea ice. Although it doesn't capture the seasonality the CMC uncertainty estimates are closest to the Argo analysis errors relative to the other analyses.

4. Updates to the OSTIA uncertainty estimates

Updated background error covariances in the OSTIA system in Jan 2013 led to changes in the uncertainty estimates. An increase in the number of analysis iterations (to ensure convergence) resulted in increased observational weight going into the uncertainty estimates, this in led to a reduction in the magnitude of the uncertainty estimates. A bug in this implementation meant that between Jan 2013 and Jan 2014 the updated background error variances were used in the OI analysis to calculate the observational weight but old variances were used in the uncertainty estimation equation (equation 1)

Using correct background error variances in error estimation equation leads to significant change in both magnitude of analysis errors and in the spatial structure. The magnitude of the uncertainty estimates is at least halved in all regions. The result of this update was uncertainty estimates much closer to Argo analysis error in magnitude and fields with a much improved spatial structure. This brings OSTIA uncertainty estimates in line with the best of the other GMPE analyses.

5. Conclusion

Validation using Argo data showed that the uncertainty estimates in OSTIA were over-estimated. An inter-comparison of the uncertainty estimates from a subset of GMPE members and validation using Argo data was carried out. This showed that the large OSTIA errors are an outlier compared to the other SST analyses used in GMPE. Other GMPE members tend to under-estimate the Argo analysis error but the CMC uncertainty estimates are closest to the Argo analysis errors.

A bug during implementation of the updated background error variances meant that although new variances were used in observational weight analysis they were not used in the error calculation itself. Fixing this bug resulted in changes to the magnitude and spatial structure of the uncertainty estimates considerably and brings them closer to the Argo estimates and the uncertainty estimates of the best of the GMPE members.

More work is required within the GHRSST IC-TAG on the uncertainty estimates generated by SST analysis producers to address the following questions;

- Should we try and standardise how the analysis uncertainty estimates are calculated within the L4 GHRSST community?
- Is it wise to tune these uncertainties where possible to match the errors estimated from Argo-analysis differences?
- Should the community be worried that most analyses underestimate uncertainties regionally and don't capture the seasonality observed in the Argo-analysis differences?
- Can the data producers provide correlation information with the analysis error standard deviations? Is this information of use to users?

PRODUCING GAP-FREE ANALYSED SEA SURFACE TEMPERATURE DATA FROM L3 PRODUCTS USING WEB-BASED DATA INTERPOLATION EMPIRICAL ORTHOGONAL FUNCTIONS (DINEOF)

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ABSTRACT

DINEOF (Data INterpolating Empirical Orthogonal Functions) is a powerful tool based on EOF decomposition developed at the University of Liege/GHER for the reconstruction of missing data in satellite datasets, as well as for the reduction of noise, detection of outliers and EOF analysis. DINEOF is openly available as a series of Fortran 90 routines to be compiled by the user, and as binaries (that can be run directly without any compilation) both for Windows and Linux platforms.

In order to facilitate the use of DINEOF analysis and increase the number of interested users, we developed a web-based application for DINEOF analysis with the necessary parameters available to run high-quality analysis. This includes choosing a variable within selected dataset, defining a domain, time range, filtering criteria based on available variables in the dataset (e.g. quality flag, satellite zenith angle …) and defining necessary DINEOF parameters. Results, including reconstructed data, associated errors and calculated EOF modes are disseminated in NetCDF format over OpenDAP server allowing easy visualisation and analysis.

Currently, we included several available daily sea surface temperature L3 Collated products (Eumetsat OSI-SAF SEVIRI, Metop-A/AVHRR and Pathfinder 4 km v5.2) obtained from MyOcean and NOAA/NODC to be used in the web-based analysis. Later, based on users' request, we plan to extend number of datasets and variables available for reconstruction and analysis.

1. Introduction

DINEOF (Data Interpolating Empirical Orthogonal Functions) is a technique to interpolate missing data in satellite datasets using an EOF decomposition [*Alvera-Azcárate et al.*, 2005; *Beckers and Rixen*, 2003]. It has been developed within the GeoHydrodynamic and Environmental Research (GHER) group at University of Liege as an open-source software under GPL license.

Prior to the analysis, the temporal and spatial average is removed from the data and the missing data are set to zero. The first EOF mode is calculated from this dataset (using Lanczos decomposition method) until convergence is reached, and this procedure is repeated for subsequent EOF modes. Cross-validation is used to estimate the optimum number of calculated EOF modes, by setting aside a small percentage (~1-5%) of valid data and calculating the root-mean square difference between the reconstructed data and the initial data set. The number of modes that minimizes the error is considered optimal. The method performs also noise reduction since it uses a truncated EOF series to reconstruct missing data.

Error maps can be calculated for the reconstructed data set based on an Optimal Interpolation approach (Daley, 1991) using the EOF basis obtained by DINEOF to construct variance field [*Beckers et al.*, 2006].

The quality of the reconstruction can be improved by using DINEOF in a multivariate approach [*Alvera-Azcárate et al.*, 2007] and taking into account the correlation between variables included in the reconstruction.

To reduce the noise in the temporal EOFs and improve the reconstruction for cases with non-uniform time steps (e.g. due to prolonged cloudiness), a Laplacian filter has been applied to the temporal covariance matrix [*Alvera-Azcárate et al.*, 2009] producing more realistic reconstructions. A methodology to detect outliers in satellite data using DINEOF analysis has been performed by applying three tests [*Alvera-Azcárate et al.*, 2012], analyzing information rejected by EOF basis derived using DINEOF technique, and by performing two additional tests that examine the proximity to clouds or land and the departure from a local median value.

Finally, a methodology to improve the interpolation of multi-scale processes by using a succession of simpler interpolations has been developed [*Beckers et al.*, 2014]. This methodology showed improvement when the large-scale analysis of hourly SEVIRI data using DINEOF was combined with a local optimal interpolation using a Gaussian covariance.

DINEOF has been developed in Fortran 90 and users can download application directly from this page: http://modb.oce.ulg.ac.be/mediawiki/index.php/DINEOF

2. Web-based DINEOF application

To reach out a larger user community and to show the capacity of DINEOF technique to a wide audience we created a new version of DINEOF (v4) with a web user interface. Several SST L3 datasets were downloaded from MyOcean (SEVIRI, METOP_A) and NOAA/NODC (Pathfinder SST) datasets but the list of datasets can be easily extended to other NetCDF-based data, depending on the user requests.

The new version consists of three modules (Figure). A) *Core DINEOF* is the main application written in Fortran 90 that performs the analysis (described in previous chapter), B) *engine DINEOF* is a set of routines written in Octave/Matlab and used for preparing data, calculating errors and outliers and performing basic post processing, and C) the user interface is a web application that collects all user information necessary to perform the DINEOF analysis. Results are distributed in NetCDF format over OpenDAP server for simple access and analysis.

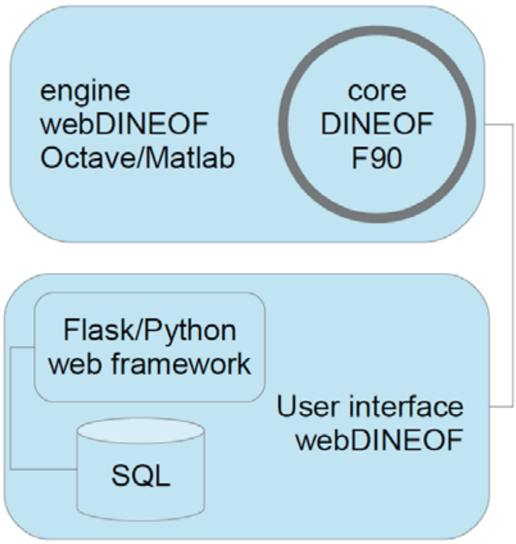

Figure 1: Schematic functionality of DINEOF application consisting of three modules (core, engine and user interface).

Engine DINEOF can be used separately from user interface and is prepared for advanced users who want to perform intensive and long term analyses in their local environment and on their custom dataset. The user has to define several input parameters: name of the product dataset, variable name, start and end date, grid size (in degrees), area name and bounding box, filtering criteria (filters the chosen variable based on available criteria within the dataset, eg. quality flag, wind speed, satellite zenith angle, etc…), correction criteria (applying conversion to the variable before performing analysis, e.g. converting kelvins to degree Celsius, or skin to subskin temperature, or applying any other custom function), and finally, DINEOF parameters.

To define a new dataset not included in the pre-defined list of datasets the user simply has to define the location of the files inside the dataset, the filename pattern and how to extract the date from the filename, grid size and corresponding grid name (longitude, latitude and landmask) and new dataset is prepared for analysis.

This module is available as an open source Octave/Matlab toolbox that is used to prepare the data for the first module (core DINEOF analysis).

The third module, DINEOF web user interface (*Figure*) is created to allow a fast and easy access to the DINEOF analysis without the hurdle of installing the core DINEOF application or actually downloading datasets. The web application front end is developed in Python (Flask web framework) with SQL database serving as a backend to store input and output parameters as well as configuration parameters (available dataset and corresponding variables). Upon dataset selection, available variables within the dataset are displayed and users can select the variable on which the analysis will be performed, select grid size (in degrees and as a multiplier of the grid size of the selected dataset), select region, define start and end time and DINEOF parameters regarding the number of modes to be computed and the strength of the temporal covariance matrix filter [*Alvera-Azcárate et al.*, 2009]. The parameter *nev* defines maximum number of modes to be computed if the cross validation approach does not find the optimal number of modes. The maximum number of iterations (*nitemax*) defines the number of iterations if convergence is not reached, and finally *min_clear* defines minimum percentage of clear pixels within each file used in the analyses.

Upon starting the analysis, user is informed by email about the selected initial parameters. When the analysis is finished the results are available in NetCDF format over OpenDAP or as a direct link to download) and the user receives another email with basically the same information as in the results page.

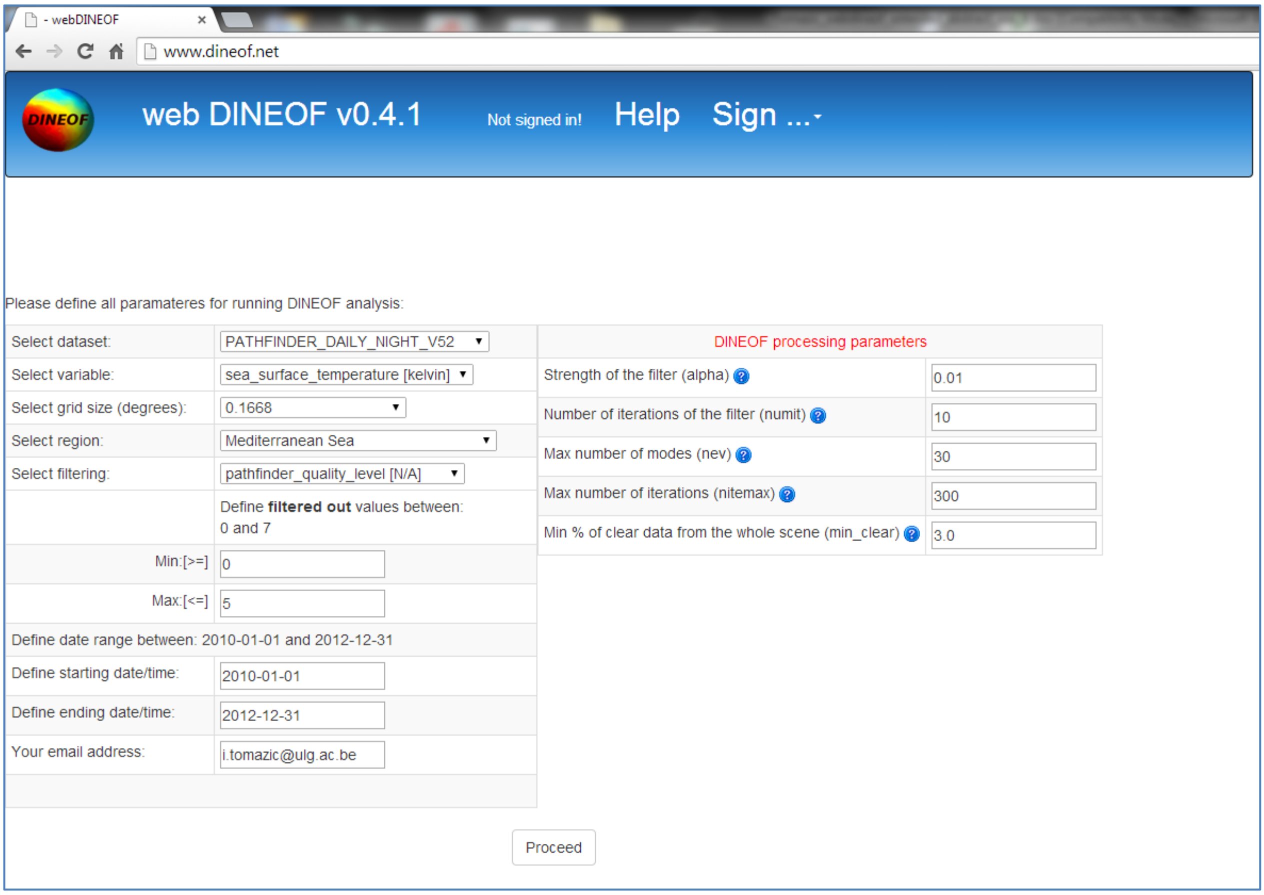

Figure 2: DINEOF web application user interface.

Here, we show one example of L4 DINEOF analyses for Pathfinder v5.2 nighttime SST over the Agulhas current. DINEOF reconstruction was done for a period of two years (2010-2011) with the grid size 4 times coarser (subsampled) than the original grid (~0.17 deg). We excluded all pixels with Pathfinder quality flags below or equal to 6 (users are free to experiment on these parameters) and over the whole period, and considering this criteria, analysis were performed only on 7.2% of data (92.80% of missing data). An example of the reconstruction and the associate error field for the 22 January 2010 is shown in Figure and Figure, respectively, while two main EOF modes (out of 30) are show on Figure . The first two modes explain 98.5% of variability and in the first mode (93.75%) it is clearly visible the persistence of the Agulhas current and of the upwelling region on the west African coast throughout these two years. The second mode (4.76% of explained variability) shows seasonality in the signal influencing (among other things) a front position.

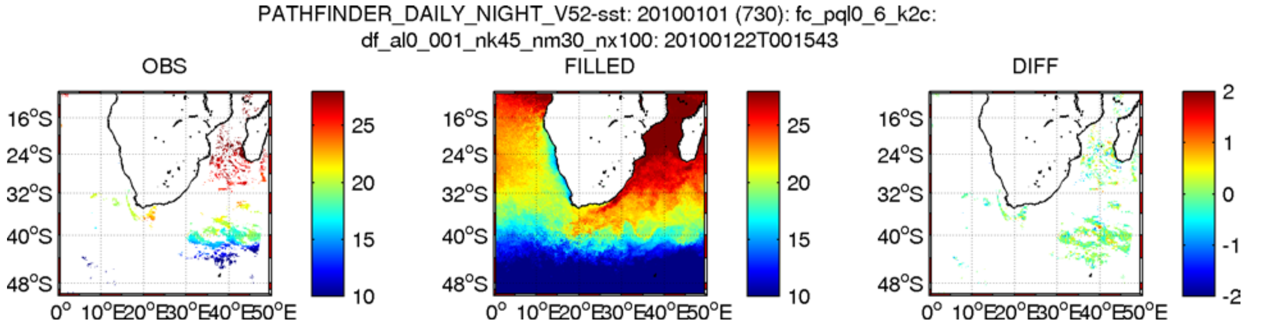

Figure 3: DINEOF reconstruction of the Agulhas current for the 22.01.2010. Left panel shows the observed SST, middle panel shows the reconstructed SST and the right panel shows the difference between the reconstruction and the original observations.

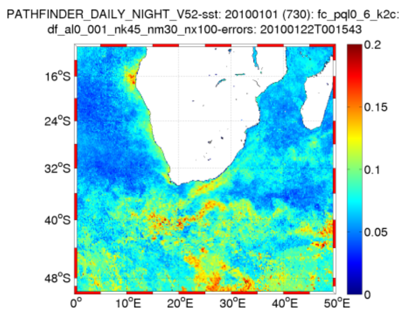

Figure 4: Error field for the analysis shown n Figure 3 (22.01.2010).

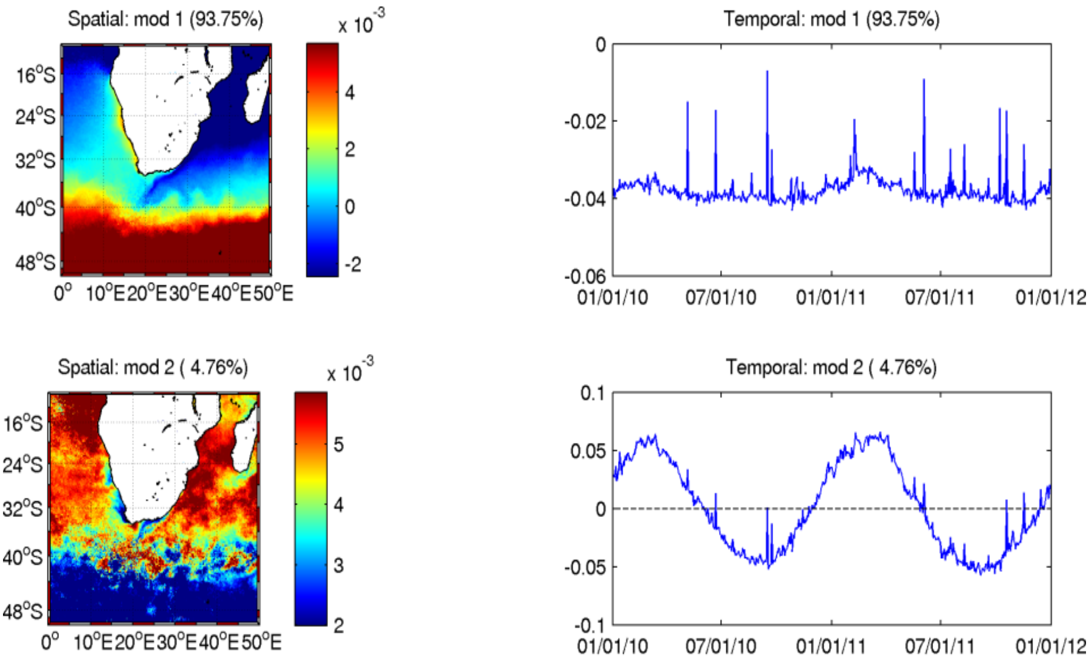

Figure 5: First two EOF modes obtained with DINEOF analysis describing 98.5% of variability.

3. Summary

DINEOF is a powerful tool for producing gap free (L4) datasets using an EOF decomposition. It is well established and used in numerous publications [e.g. *Ganzedo et al.*, 2011; *Nechad et al.*, 2011, …].To reach out a wider user community we developed a new version that includes a web based user interface. Beside web application, we developed an engine module that allows full scale analysis of custom datasets over long term periods.

Forum is established at the following address: http://groups.google.com/group/dineof.

The new version is available at the following web address: http://www.dineof.net.

4. Acknowledgments

This work was realized in the context of the DINEOF-on-web and BESST (Inter-sensor Bias Estimation in Sea Surface Temperature) - SR/12/158 projects funded by the Belgian Science Policy (BELSPO) in the frame of the Research Program For Earth Observation "STEREO II".

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PLENARY SESSION VI: IMPACT OF CLOUDS ON SST RETRIEVALS

SESSION REPORT

Chair: Andy Harris[(1)], Rapporteur: Owen Embury[(2)]

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(2) Department of Meteorology, University of Reading, UK, Email: o.embury@reading.ac.uk

1. Introduction

This session included three talks which are briefly summarized here, for full refer to the corresponding presentation on the GHRSST website or the extended abstract in these proceedings.

2. Bayesian Cloud Detection for AVHRR instruments – Owen Embury

This talk briefly described the Bayesian Cloud Detection scheme used in the ATSR Reprocessing for Climate (ARC) project and recent work to adapt the scheme for AVHRR instruments. The key aspect of the adaption was modifying the ATSR specific lookup tables so they could be used for instruments with different viewing geometry and spectral response functions. For reasons that were not entirely clear, the scheme was not able to distinguish low fog in one of the scenes shown. This may have been due to overly large uncertainties assigned to the 1.6 micron channel to prevent flagging of sunglint as cloud. In the case of low fog, T_{11} and T_{12} are both consistent with clear-sky conditions; while the 1.6 micron reflectance is higher, it may fall within the tolerance the scheme allows for sun-glint

3. Extension of ACSPO VIIRS SST domain using pattern recognition analyses – Irina Gladkova

The ACSPO system includes cloud detection for VIIRS, the system is generally conservative as it is intended for SST retrieval resulting in some false alarms where clear-sky is incorrectly flagged as cloud. Affected regions are typically colder than surrounding SSTs (e.g. upwelling regions). This talk presented a pattern recognition technique designed to detect the falsely flagged regions and reclassify them as clear-sky. The technique is applied to the retrieved SSTs and not the BTs. There was some discussion as to why this limitation had been imposed upon the technique.

4. Sea surface temperature characterization using a high-resolution ocean model – Ed Armstrong

This talk introduced a very high resolution (1/48 ° horizontal, 25 s temporal) ocean model developed at NASA, running on the Pleiades supercomputer at NASA AMES. This has the potential to be used to investigate various aspects of satellite data assimilation using realistic synthetic data. For example, the model could be used to generate synthetic L2P products which could be ingested into a L4 analyses system. The resulting L4 product could then be compared against the SST field from the high resolution model to determine how details are retained.

5. Discussion

Cloud detection algorithms developed for cloud retrievals are not always appropriate for SST retrievals, this is due to the intended use of the screened pixels. In one case the mask is used to identify cloudy pixels suitable for cloud retrievals, in the other case it is used to identify clear-sky pixels suitable for SST retrievals.

Pixels which are unsuitable for either purpose (e.g. partially cloudy, dust, or aerosol affected) are problematic as their classification in a “cloud” mask will depend whether the algorithm developers were trying to detect “cloudy” or “clear-sky” pixels.

Water vapour may look like cloud (especially in the vicinity of cloud where haloes may form) and lower the brightness temperature even though the atmosphere is clear and SST may still be retrieved. Fundamentally, we need to define cloud as “where the retrieved SST will not be valid”.

It can be difficult to test cloud detection algorithms as we do not have a reference or “true cloud mask” to compare them against. Two options were discussed:

A library of expertly screened satellite imagery would be useful for testing and comparing cloud detection algorithms. However, creating such a library would take a significant amount of time as manually screening imagery is difficult and labour intensive.

The Cloudsat satellite carries a cloud detecting radar. This can be used for testing the cloud detection for instruments in the A-Train (e.g. MODIS-Aqua), for other satellites the testing is limited to overlaps between different satellite orbits. Attractive though this is, getting precise matchups with the A-train is not that easy (experience of Heidinger *et al.*).

Many cloud detection algorithms used for SST retrieval will incorrectly flag ocean fronts as cloud, either due to the strong gradient or the cold side of the front being rejected as “cold cloud” by the algorithm. This has impacts both on SST products (by rejecting cold SSTs more than warm SSTs) and on derived products such as ocean front analyses (as the fronts may have been screened out).

Some users have requested an ocean front product. This was discussed and thought to be too difficult at this stage due to the cloud screening issue and large range of front detection techniques which can produce very different results. Instead, adding the SST gradients (calculated over a 3×3 window) should be considered as this is a pre-requisite to an ocean front product.

PATTERN RECOGNITION ENHANCEMENTS TO CLEAR SKY MASK FOR VIIRS SST

Irina Gladkova[1,2], Yuri Kihai[2,3], Alexander Ignatov[3], Fazlul Shahriar[1,4], Boris Petrenko[2,3]

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ABSTRACT

Discriminating clear from cloudy ocean areas, particularly at night, is difficult task. The clear-sky mask of the NOAA Advanced Clear-Sky Processor for Oceans (ACSPO) from the Visible and Infrared Imager/Radiometer Suite (VIIRS) onboard the Suomi National Polar-orbiting Partnership (S-NPP) satellite employs comparisons of retrieved SST with L4 analyses, reflectance threshold tests and spatial uniformity tests [1]. Although ACSPO clear sky mask (ACSM) performs well on a global scale, it tends to overestimate the cloud cover in highly dynamic areas with strong currents and cold upwelling as well as coastal areas. It is those highly dynamic and coastal waters that are of most interest to the SST users for fishing, ship navigation, climatology and marine biology studies, etc. Thus a clear sky identification that is good in a global-average sense, but systematically and consistently erroneous in some, perhaps geographically small, but critically important to users regions, may seriously limit trustworthiness and use of the satellite SST products. This study seeks to more fully explore VIIRS superior radiometric and imagery performance, and open such interesting ocean areas to SST users.

Visual inspection of the retrieved SST in typical clear sky ocean regions, misclassified by the ACSM as cloud, suggests that such problematic areas are contiguous, with well-defined boundaries, and they are typically located in the vicinity of ocean thermal fronts. Expert users can often visually distinguish cloud patterns from SST, in the non-screened satellite imagery. The distinction usually relies on the wider context, taking into consideration the surrounding patterns and textures.

We present an automated pattern recognition algorithm is explored, which attempts to mimic some intuitive visual perception of SST imagery by human operators to distinguish the patterns typical of ocean versus cloud. Generally, ocean is more uniform and contiguous. Even when it is dynamic, it shows slowly meandering flow-like patterns as opposed to more geometrically complex structures indicative of clouds. Difference between ocean and cloud patterns is more pronounced in the SST gradient magnitude domain. Viewed as a terrain, the dynamic areas of the ocean appear as sharp mountain ridges (corresponding to ocean thermal fronts) towering over flat valleys (corresponding to slowly changing ocean temperatures). In the proposed algorithm, we first identify such SST gradient ridges and adjacent contiguous areas with similar SST values, and then make clear-sky versus cloud decision based on the statistics of the whole region, rather than on a per pixel basis.

We have analyzed four days of global ACSPO SST imagery. Forty-eight cropped images representative of typical ACSM misclassifications have been selected, visually inspected and hand-marked, to identify improvements resulting from the proposed algorithm as well cases, when it has mistakenly added cloudy pixels (created new cloud leakages) or failed to restore the clear pixels (i.e., failed to fix the ACSM false alarms). Figure 1 shows a representative example of improvement, near the coast of South Africa. The retrieved SST values for all pixels in the scene are shown on the left, and with ACSPO mask overlaid is on the right. Land is rendered in brown and black pixels correspond to out-of scale cold SST values. The ACSM masks out grey and magenta areas, combined. In the magenta pixels, the ACSM and the pattern recognition algorithms both agree and say “cloud”, whereas the grey pixels are restored by the proposed algorithm into the SST domain. The areas of cold upwelling off the West Coast Peninsula, as well as the shore waters of Cape Town, have been successfully detected. The left panel suggests that all grey areas are indeed cloud-free, and the new SST domain is more complete and informative.

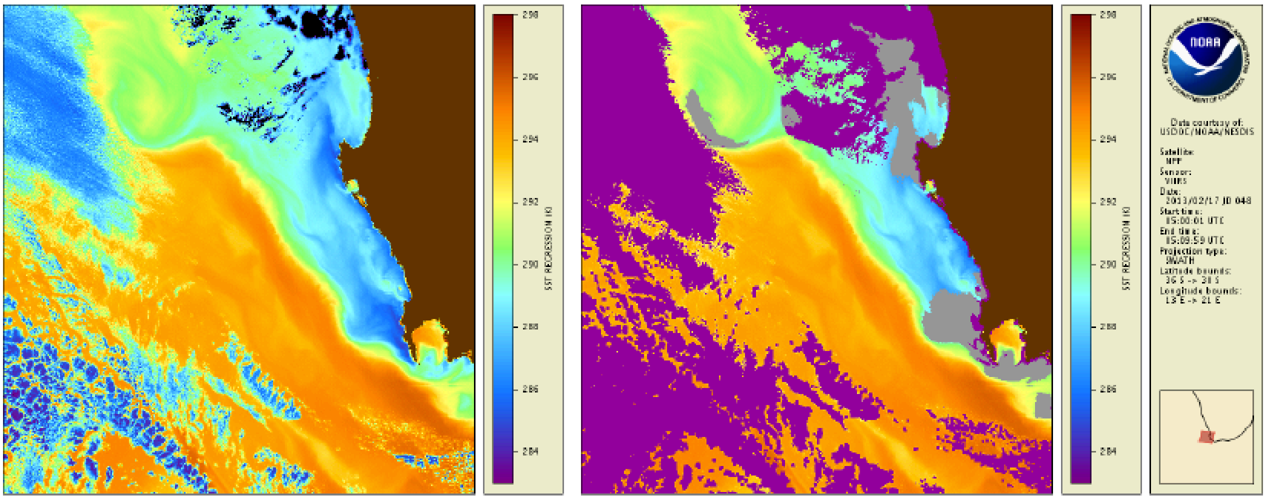

Figure1: South Africa, 17 Feb 2013, night overpass. Cold upwelling (gray) is misclassified by ACSM as cloud and restored by the pattern recognition algorithm.

The analyses are performed with SST's derived from destriped VIIRS radiances, which is instrumental for this type of approach. Striping in the VIIRS data leads to artifacts in the gradient field, poses spatial discontinuities, and affects the statistics of high frequency components. The current implementation of the algorithm does not use any information other than patterns in the VIIRS retrieved SST field. In particular, albedo channels in the daytime data are very informative, but they were reserved for an independent verification of the algorithm. This is intentional and aimed at facilitating the desired consistency and continuity at day-night transition.

The approach is currently considered as a supplementary step to the existing ACSPO Clear-Sky Mask. We will consider redesigning the current ACSM, based on the new pattern recognition principles. It will be first implemented and extensively tested with the VIIRS SSTs, and later extended to also include AVHRR and MODIS data. We will also consider generating an ocean front product at the stage of cloud masking, and outputting in the SST files, as an additional layer.

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SEA SURFACE TEMPERATURE CHARACTERIZATION USING A HIGH-RESOLUTION OCEAN MODEL

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ABSTRACT

We will report on the use of simulated sea surface temperature (SST) from a highly instrumented (hourly output of full 3D fields), high-resolution (0.75 to 2.2 km horizontal grid spacing and 90 vertical levels) global ocean configuration of the Massachusetts Institute of Technology general circulation model (MITgcm) to investigate SST L2P matchups, and sampling issues in the generation of Level-4 analyses. The simulation is particularly well suited to carry out these exercises because it has thin vertical levels (1 m) near the surface and includes tidal forcing and realistic diurnal forcing from latest 0.14-degree European Centre for Medium-Range Weather Forecasts (ECMWF) analysis. In the first exercise we use the model near-surface output from one month to investigate the temporal evolution of model SST relative to geostationary SST observations in the South Atlantic and Indian Ocean. Goals of the comparisons include investigating the diurnal signature of SST in cloudy regions, determining how to use model SST as a proxy for foundation temperature, and gauging the accuracy and realism of the model itself using the satellite SST observations. For the second exercise, we review the use of the model fields themselves as sources of high-resolution synthetic data for Level-4 analysis experiments.

PLENARY SESSION VII: NEW DATA STREAMS

SESSION REPORT

Chair: Craig Donlon[(1)], Rapporteur: Tim Nightingale[(2)]

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(2) STFC Rutherford Appleton Laboratory, UK, Email: tim.nightingale@stfc.ac.uk

1. Evaluation of SST products from HY satellites: Lei Guan

Introduced Haiyang (NSOAS/SOA) and Fengyun (NSMC/CMA) satellites (ten, to date) and their instruments (COCTS vis/ir, RM uwave, VIRR vis/ir, S-VISSR vis/ir). Data policy : authorised users, general access via online form (most requests approved). See http://satellite.cma.gov.cn. Preliminary results from HY-1B validated against GOOS (?) buoys. High biases and noise. New NLSST and MCSST algorithms regressed against buoys. HY RM comparisons with Windsat, AMSR2 and iQuam. Discussed wind speed dependence of SST.

CD: Passive microwave. How can GHRSST help with biases, SDs?

KC: Instrument intercomparisons. What happens if you compare Windsat/AMSR2? Do you get similar problems?

AH: Stripe noise in IR can be reduced with Sea Space (?)

2. Update on VIIRS: Alexander Ignatov

NOAA STAR is coordinating JPSS SST team. Thanks to users for feedback.

Three algorithms:

- IDPS (Interface data processing segment) SST EDR to be phased out.
- ACSPO (Advanced Clear Sky Processor for Oceans). Became optional 03/2014. Processes all pixels, full swath. Reported in 10 minute granules. RTM and de-striping capabilities.
- NAVO – SEATEMP builds on pre-ACSPO heritage. Operational 03/2013. 86 second granules. Conservative cloud mask.

Two VIIRS L2P products: NAVO & ACSPO. Which to use? Comparisons with CMC L4 and iQUAM.

L2P vs. L4: very good agreement though some Saharan aerosol signal. NAVO cloud screening kills equatorial band, ACSPO doesn't. ACSPO good Gaussian statistics (mean 0.02, SD 0.38).

AH: Does you product report 1SD per block? AI: Yes.

L2P vs. L4: NAVO statistics very similar to ACSPO.

L2P vs. in situ: Limited matchups. ACSPO: mean -0.02, SD 0.28. NAVO: mean 0.02, SD 0.29.

Summary: IDPS statistics slightly degraded compared with NAVO, ACSPO.

Imagery examples shown.

Report from Bruce Brasenett (?)

BB assimilates ACSPO, NAVO, compares with Argo.

AH: Turn off bow tie correction? Irena – data not missing.

3. GCOM-W1 AMSR2 SST: Chelle Gentemann

RSS work on AMSR2. GCOM1-W1 Launched 05/1012, data from 07/2012.

AMSR2 calibration: large L1 biases reported at JAXA meeting. Retrieval approach: RTM used as calibration reference. Windsat SST, wind vapour, cloud input into RTM to simulate TOA radiances, AMSR2 calibration adjusted to fit. Variables then retrieved from (re-)calibrated AMSR2 radiances. Derived non-linearity corrections often quite different from JAXA corrections.

Retrieval validated against in situ (high deviation observations excluded). Bias -0.04, SD 0.56. Compared ascending/descending retrievals with Reynolds. Can see signatures of hot load and of sun, moon on cold mirror. Will be filtered out. No significant structure compared with buoys.

RFI from ground and from geostationary satellites a big problem. Filters used in active regions. GDS 2.0 this month.

AH: GDS 2.0 this month. Will RSS distribute it? CG: Yes, RSS and GDAC

AH: Calibration differences worst at 150K. Very bad for SST. CG: Less of a problem for regression. Bad for physical retrievals.

CD: RTM description? GG: In Meissner & Wentz 2012 (IEEE)

4. Future NOAA/NESDIS/STAR GEO Dataset: Eileen Maturi

Showed current geostationary satellite coverage – gap over Indian Ocean. Himawari-8 will replace MTSAT-2. Full disk images every 10 minutes. Regions every 2.5 minutes. Products operational on 11, 12/2015.

INSAT launched 12/2013. Negotiations to use data (Indian ocean)

MSG-3 replaced by MSG-4 in analysis.

HR: Do you use GOES-R? IM: Nope.

KC: Will India produce GHRSST data? GC: Israel keen to cooperate. Beijing too.

5. Discussion

CD: New uwave capability. (To LG) Chinese data in GHRSST?

HR: Frequency protection important. How can GHRSST help? CD: Problem is telecoms – very powerful. 999 vs. general ocean measurements a difficult argument to make.

PM: Satellite broadcast is big problem. ESA study – rapid sampling, segmentation helps to avoid burst data. Extra burden if done on board, alternatively high download bandwidth.

AH: Frequency regulation a losing battle, but technology can help.

CD: Formal recommendation from GHRSST to CEOS-VC (on regulation of passive microwave bands) would be good.

PM: Tropical Atlantic wiped out by Ascension Island radar.

CD: SMOS experience – L band operators thought they were compliant, just retuning needed to come into spec.

EVALUATION OF SST PRODUCTS FROM HY SATELLITES

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ABSTRACT

The Haiyang (HY) series satellites operated by the National Ocean Satellite Application Center (NSOAS) of the State Oceanic Administration (SOA) of China were designed with the capability of Sea Surface temperature (SST) observations from space. The HY-1A was launched in May 2002 and HY-1B was launched in April 2007. The HY-2 was launched in August 2011. The Chinese Ocean Color and Temperature Scanner (COCTS) onboard HY-1 satellites has thermal infrared split window channels for SST observations and the Scanning Microwave Radiometer (RM) onboard HY-2 has low-frequency microwave channels for SST observations. The accuracy of the HY-1B COCTS SST products in the northwest Pacific and the HY-2 RM global SST products are investigated. The results of the evaluation of the SST products are discussed.

1. Introduction

Sea Surface temperature (SST) is an essential indicator for climate change (Donlon et al., 1993). The SST products have been available from a number of operational and experimental satellites. The Haiyang (HY) series satellites were designed with the capability of SST observations from space. The HY-1A was launched in May 2002 and HY-1B was launched in April 2007. The Chinese Ocean Color and Temperature Scanner (COCTS) onboard HY-1A and HY-1B have thermal infrared split window channels for SST observations (Liu et al., 2003). The rms error of SST from HY-1A COCTS compared with GTS in-situ SST data was 1.26 ºC (Wang et al., 2006). The HY-2 satellite was launched in August 2011 which carries four instruments including the Scanning Microwave Radiometer (RM) (Jiang et al., 2012). The microwave radiometer has low frequency channels at 6.6 GHz and 10.7 GHz which are capable of SST measurements. The preliminary assessment of the HY-2 SST products with NCEP re-analysis data from 10 October to October 20, 2011 shown an rms error of about 2 ºC (Jiang et al., 2012). The assessment of the products with NDBC and Argo SST measurements in the first half year of 2012 shown the accuracy of the initial SST products is about -0.49 ± 1.63 ºC and -0.28 ± 1.68 ºC respectively (Zhao et al., 2013). And the comparison of the HY-2 SST with WindSat SST data in the same period indicated an error of 1.8 ºC. In this study, the HY-1B and HY-2 SST products are evaluated by in situ measurements and satellite data.

2. Evaluation of SST from HY-1B COCTS

The HY-1B COCTS L2B SST products are developed and distributed by the National Satellite Ocean Application Service (NSOAS) of the State Oceanic Administration (SOA). The products are distributed in HDF format. The L2B SST products in the region of Northwest Pacific in February, May, August and November during the period of 2008 to 2011 are compared with in-situ SST data from the North-East Asian Regional GOOS (NEAR-GOOS) Regional Delayed Mode Data Base (RDMDB). The SST data from buoy measurements are selected from RDMDB and quality control is applied to buoy data. The matchups of COCTS L2B SST products and buoy SST data are generated with spatial window of 0.01º and temporal window of one hour. The location of the matchups is shown in figure 1a and the statistics of the comparison is shown in figure 1b. The total number of matchups is 764. The bias of the difference between COCTS L2B and buoy SST is 1.22 ºC and the standard deviation of the difference between COCTS L2B and buoy SST is 1.78 ºC. The results show large positive error of HY-1B COCTS L2B SST products than HY-1A COCTS SST data.

3. Evaluation of SST from HY-2 RM

The HY-2 RM L2A products are also developed and distributed by NSOAS and distributed in HDF format. The HY-2 RM L2A SST products from August 2012 to March 2014 are compared with in situ measurements from NOAA iQuam system and SST products from WindSat and AMSR2. The L2A SST products are projected to daily ascending and descending equal-angle map with a grid size of 0.25 degree. The AMSR2 L3 products are provided by JAXA. The spatial reclusion of the daily products is 0.25 degree. The daily WindSat gridded data are provided by Remote Sensing Systems with the grid size of 0.25 degree. Figure 2 shows the statistics of the comparisons between RM, Windsat and AMSR2 SST daily data. The results show that the bias between Windsat and HY-2 RM ascending SST is from -1.17°C to 1.63°C and averagely is 0.04°C. The standard deviation is from 1.37°C to 3.86°C and averagely is 2.14°C. The bias between Windsat and HY-2 RM descending SST is from -1.75°C to 0.84°C and averagely is -0.23°C. The standard deviation is from 1.25°C to 4°C and averagely is 2.27°C. The bias between AMSR2 and HY-2 RM ascending SST is from

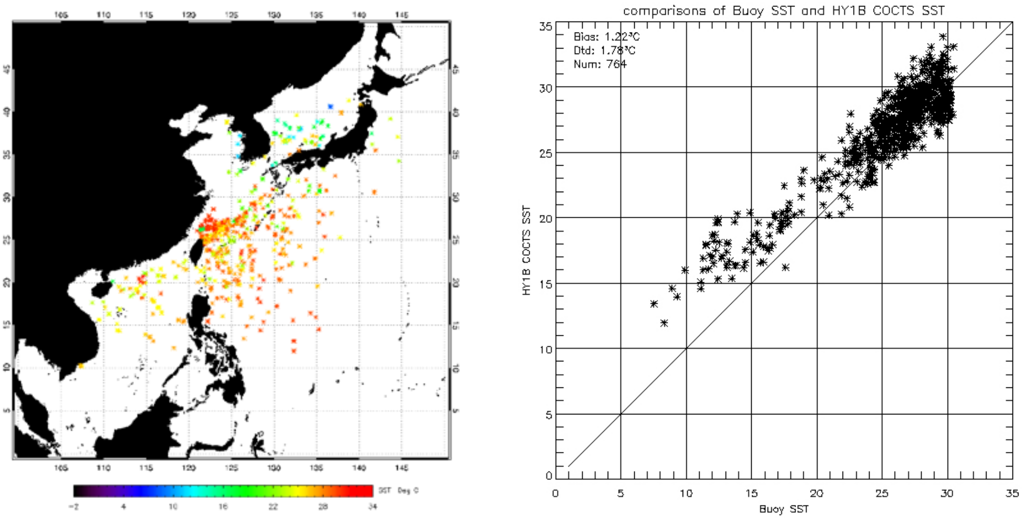
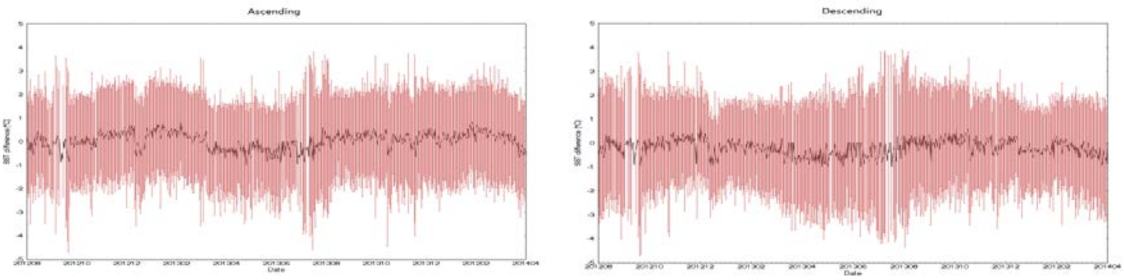
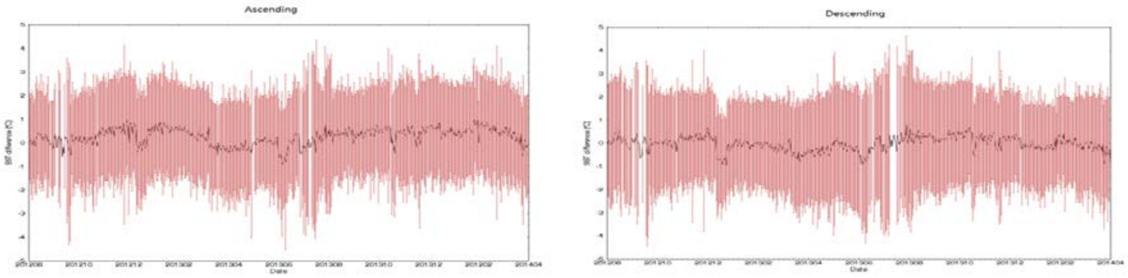


Figure 1: Comparison of HY-1B COCTS L2B SST products with buoy SST data.
(a) Location of the matchups; (b) Statistics of the matchups.



(a) (b)



(c) (d)

Figure 2: Comparisons of HY-2 RM SST with WindSat and AMSR2 SST.
Daily statistics of the difference between (a) WindSat and RM, ascending passes; (b) WindSat and RM, descending passes; (c) AMSR2 and RM, ascending passes; (d) AMSR2 and RM, descending passes.

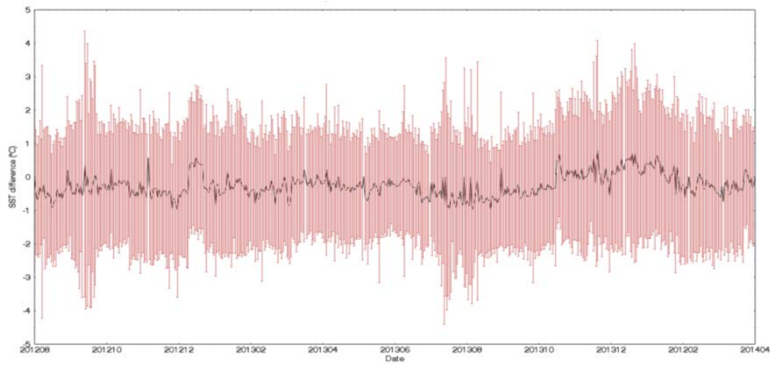


Figure 3: Comparisons of HY-2 RM SST with buoy SST.

-0.92°C to 1.44°C and averagely is 0.28°C. The standard deviation is from 1.53°C to 3.85°C and averagely is 2.20°C. The bias between AMSR2 and HY-2 RM descending SST is from -1.35°C to 0.79°C and averagely is -0.04°C.The standard deviation is from 1.63°C to 3.94°C and averagely is 2.33°C. The spatial distribution of difference between monthly SST from AMSR2 and HY-2 RM is similar to the SST difference between RM and Windsat. But the SST difference between AMSR2 and RM is larger than that between RM and Windsat. The equator crossing time of HY-2 and Coriolis is almost the same, ascending at 18:00 local time, descending at 1:00. While GCOM-W1 ascending time is 13:31 and descending time is 1:31. The time difference may cause relatively larger error between RM and AMSR2 SST. Secondly, SST products from HY-2 RM are evaluated by in situ buoy measurements from NOAA iQuam system (Xu and Ignatov, 2010). The matchups are generated with the temporal window of 1 hour and the spatial window of 0.25 degree. The results of the daily comparison are shown in figure 3. The bias between daily HY-2 RM and buoy SST is from -1.45°C to 0.79°C and averagely is -0.27°C. The standard deviation is from 1.30°C to 3.98°C and averagely is 1.97°C.

4. Summary

The HY-1B COCTS L2B SST products in the Northwest are evaluated by buoy measurements. The HY-2 RM L2A SST products are compared with WindSat and AMSR2 SST products as well as buoy data. The results show relatively large error in the SST products. The error sources are being investigated.

5. References

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VIIRS SST PRODUCTS

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ABSTRACT

Joint Polar Satellite System (JPSS) is a follow-on mission to the NOAA Polar Orbiting Environmental Satellites (POES). The first JPSS satellite, the Suomi National Polar-orbiting Partnership (S-NPP) was launched in October 2011 with the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard. NOAA is responsible for the JPSS mission and corresponding data products, including SST. Beginning in January 2012, NOAA has been producing an experimental VIIRS SST product using its heritage Advanced Clear-Sky Processor for Oceans (ACSPO) system, while the official operational VIIRS SST product was produced by the Interface Data Processing Segment (IDPS) of the former National Polar-orbiting Operational Environmental Satellite System (NPOESS). The IDPS product was handed over to NOAA in 2010 as a part of the NPOESS restructuring, for maintenance, archival and enhancements. To improve cost efficiency and to facilitate JPSS data utilization, NOAA management worked to consolidate the two SST systems. Based on extensive relative performance analyses and feedback from NOAA and external users, the ACSPO system was selected to produce the official JPSS SST product. Following this decision in January 2014, the ACSPO SST product became operational in March 2014. It is now archived at the PO.DAAC and NODC in GHRSST Data Specification version 2 (GDS2) netcdf4 format while the IDPS product, currently archived at CLASS in HDF5 format, will be phased out. In the meantime, NAVOCEANO started generating its version of the VIIRS GDS2 SST product, building on the NAVO (and pre-ACSPO NOAA) AVHRR heritage. NAVO VIIRS SST product is also archived at the PO.DAAC/NODC. This presentation overviews the current status of ACSPO and NAVO products and assesses their relative merits, to facilitate the choice of more appropriate VIIRS SST L2 product for individual users' applications.

1. ACSPO, IDPS and NAVO VIIRS SST Products

ACSPO is the operational SST system at NOAA. It was initially employed with data from 4km AVHRR GAC on NOAA satellites and later with 1km AVHRR FRAC onboard Metop satellites. Following the opening of the VIIRS cryoradiator doors on S-NPP on 18 January 2012, experimental production of ACSPO VIIRS SST product commenced on 22 January 2012. Simultaneously, NOAA STAR began an experimental ACSPO production of MODIS SST from Terra and Aqua, in support of NOAA VIIRS SST Cal/Val efforts and consistency analyses. ACSPO VIIRS and MODIS SST products have been monitored in the SST Quality Monitor (SQUAM; www.star.nesdis.noaa.gov/sod/sst/squam/; *Dash et al., 2010*) and validated against QCed in situ data from the in situ SST Quality Monitor (*i*Quam; www.star.nesdis.noaa.gov/sod/sst/iquam/; *Xu and Ignatov, 2014*).

In 2010, the privately developed and owned NPOESS system was restructured, and the new JPSS system established. NOAA was asked to assume ownership and is now responsible for the full suite of JPSS products, including the NPOESS Interface Data Processing Segment (IDPS) products. Continuous monitoring of IDPS SST in SQUAM commenced on 8 March 2012. Based on 2+ years of cross-comparisons and users' feedback, NOAA JPSS management recommended in January 2014 that the JPSS SST Team concentrate on ACSPO support and development and withdraw from maintenance of the IDPS SST product. Following this decision, the NOAA ACSPO product became operational in March 2014, and is now archived at PO.DAAC and NODC. As of today, ACSPO is the only official NOAA JPSS SST product.

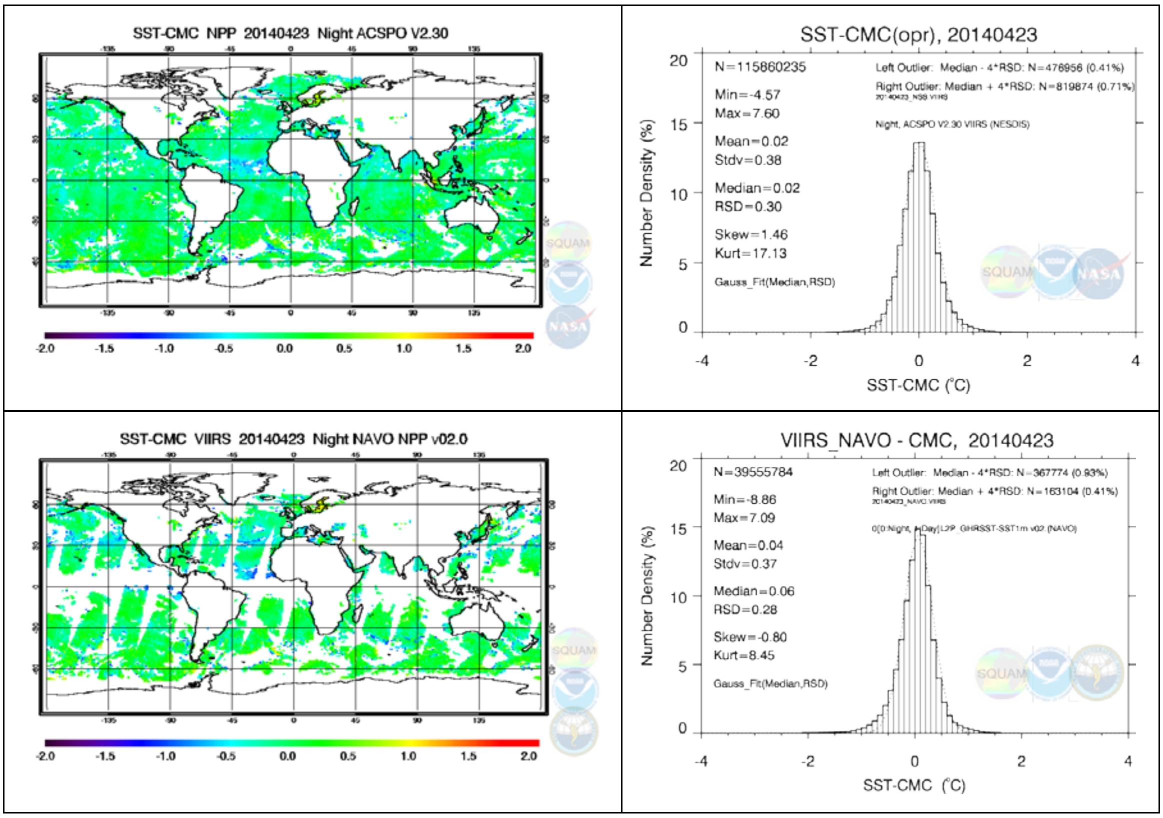
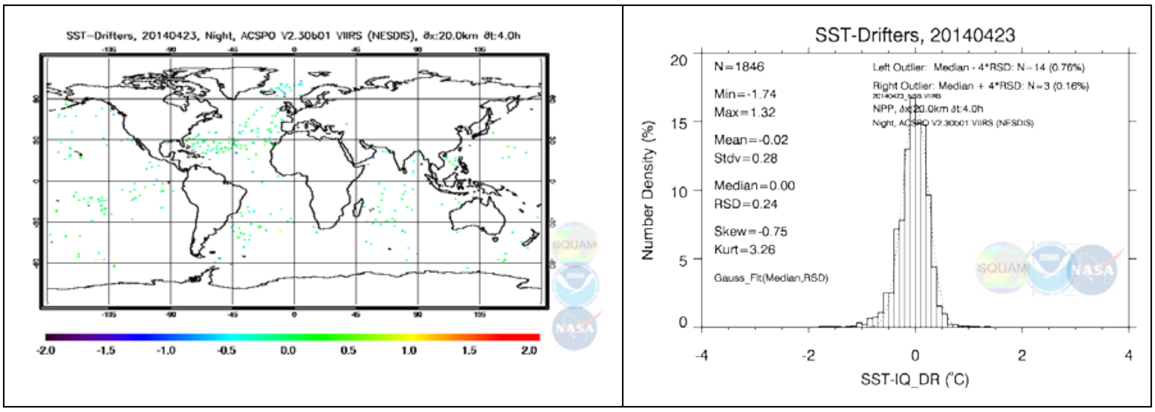


Figure 1: ACSPO and NAVO VIIRS SSTs wrt CMC L4. For mapping, data have been aggregated to 1º resolution, whereas histograms were produced from pixel level data.



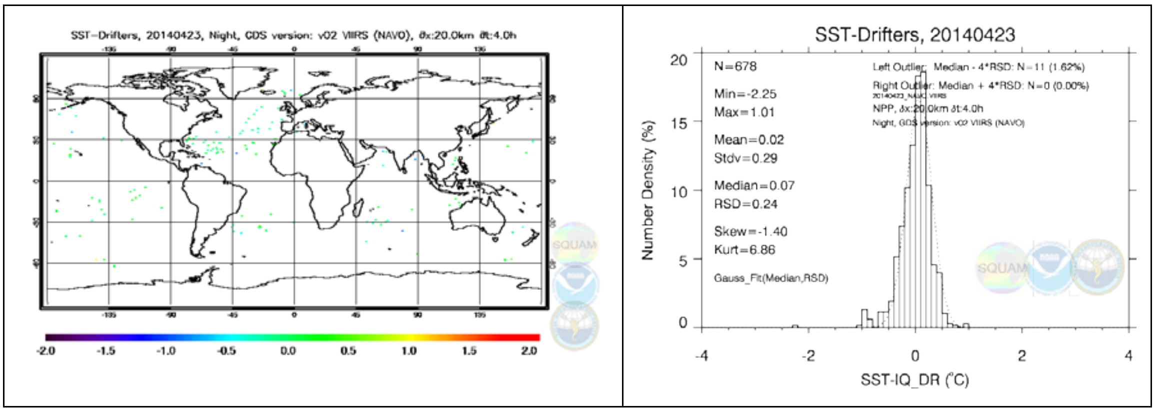


Figure 2: Same as in Fig.1 but wrt quality controlled drifters from iQuam.

Building on its heritage AVHRR SEATEMP SST system, NAVO started generating a VIIRS SST product in March 2013. The specifics of the NAVO SST product is that it only makes retrievals in a narrow swath (within ±54º view zenith angle), processes data by 2×2 arrays (effectively reducing the product resolution to 1.5km at nadir), and uses a conservative cloud mask (to satisfy the stringent requirements of the Navy modeling community). In contrast, the ACSPO and IDPS systems process every clear-sky VIIRS pixel at native sensor resolution (0.75km at nadir), make retrievals in a full sensor swath (up to ±68º), and attempt to balance the clear-sky mask with the needs of more complete coverage of the global ocean. The NAVO VIIRS SST product has been archived at PO.DAAC/NODC since May 2013.

NIGHT – Summary

ΔT = "VIIRS minus CMC" SST (expected ~0)

	NOBS (%ACSPO)	Min/ Max	Mean/ STD	Med/ RSD
IDPS	116.8M (101%)	-13.1/+12.6	-0.04/0.46	-0.00/0.31
ACSPO	115.9M (100%)	- 4.6/+7.6	-0.02/0.38	-0.02/0.30
NAVO	39.5M (34%)	- 8.9/+7.1	+0.04/0.37	+0.06/0.28

- *IDPS: SST domain is +1% larger than ACSPO, All stats degraded*
- *NAVO: SST domain is factor of ×3 smaller than ACSPO, stats improved*

ΔT = "VIIRS minus in situ" SST (expected ~0)

	NOBS (%ACSPO)	Min/ Max	Mean/ STD	Med/ RSD
IDPS	2,082 (113%)	-2.9/+5.6	-0.06/0.43	-0.01/0.26
ACSPO	1,846 (100%)	-1.7/+1.3	-0.02/0.28	-0.00/0.24
NAVO	678 (37%)	-2.3/+1.0	+0.02/0.29	+0.07/0.24

- *IDPS: SST domain is +13% larger than ACSPO, All stats degraded*
- *NAVO: SST domain is factor of ×3 smaller than ACSPO, stats comparable*

Figure 3: Nighttime ΔT_S statistics on 23 April 2014 wrt CMC L4 and iQuam in situ data for three VIIRS SST products.

DAY – Summary

ΔT = "VIIRS minus CMC" SST (expected ~0)

	NOBS (%ACSPO)	Min/ Max	Mean/ STD	Med/ RSD
IDPS	120.4M (100%)	- 28.7/+10.4	+0.20/0.77	+0.24/0.45
ACSPO	121.0M (100%)	- 5.4/+ 9.2	+0.29/0.59	+0.21/0.41
NAVO	41.3M (34%)	- 8.2/+ 7.5	+0.28/0.56	+0.22/0.40

- IDPS: SST domain is comparable with ACSPO, All stats degraded
- NAVO: SST domain is factor of ×3 smaller than ACSPO, stats comparable

ΔT = "VIIRS minus in situ" SST (expected ~0)

	NOBS (%ACSPO)	Min/ Max	Mean/ STD	Med/ RSD
IDPS	1,758 (105%)	-5.3/+2.7	-0.06/0.77	+0.10/0.48
ACSPO	1,680 (100%)	-1.4/+2.8	+0.07/0.42	+0.06/0.37
NAVO	510 (30%)	-1.2/+2.1	+0.12/0.35	+0.07/0.35

- IDPS: SST domain is +5% larger than ACSPO, All stats degraded
- NAVO: SST domain is factor of ×3 smaller than ACSPO, stats improved

Figure 4: Daytime ΔT_S statistics on 23 April 2014 wrt CMC L4 and iQuam in situ data for three VIIRS SST products.

2. ACSPO vs. NAVO VIIRS SST global comparisons

Fig. 1 shows global coverage by ACSPO and NAVO VIIRS data on 23 April 2014 (night), and corresponding histograms of VIIRS minus CMC L4 SSTs. The number of SST pixels in the NAVO product is about one-third of those in ACSPO. When data are aggregated into 1º grids for mapping in Fig. 1, the difference in coverage is less dramatic. Still, there are no NAVO data in some areas, e.g. in the Tropics and in the Arctic. Additional analyses show that some of these areas may remain uncovered for extended periods of time up to a month or even more. The shape of the histograms is close to Gaussian. NAVO shows slightly improved standard deviations compared to ACSPO (0.37K vs. 0.38K for conventional and 0.28K vs. 0.30K for robust standard deviations).

Fig. 2 shows same results as in Fig. 1 but wrt quality controlled drifters from iQuam. Although coverage by drifters may not be fully uniform or globally representative, validation against in situ data is viewed in the community as the "gold standard". Similar to CMC L4 comparisons, the number of ACSPO match-ups is larger than NAVO by a factor of ~3, with comparable validation statistics.

Fig. 3 summarizes nighttime NOBS and SST performance statistics wrt L4 and in situ SSTs from Figs. 1-2. The IDPS product is also included, for completeness. NOBS are comparable in IDPS and ACSPO products, with inferior performance statistics for IDPS. On the other hand, the NAVO product has a factor of 3 smaller NOBS, whereas the performance statistics are comparable for the two products.

Fig. 4 summarizes daytime NOBS and SST performance statistics. Daytime observations are largely consistent with the nighttime in Fig. 3, except that the IDPS statistics are more significantly degraded compared to ACSPO and NAVO, and the margin between the ACSPO and NAVO standard deviations is now a little wider.

3. ACSPO vs. NAVO VIIRS SST imagery

Fig. 5 shows a typical example of ACSPO and NAVO SST imagery. Larger coverage by ACSPO product is generally consistent with the global analyses above.

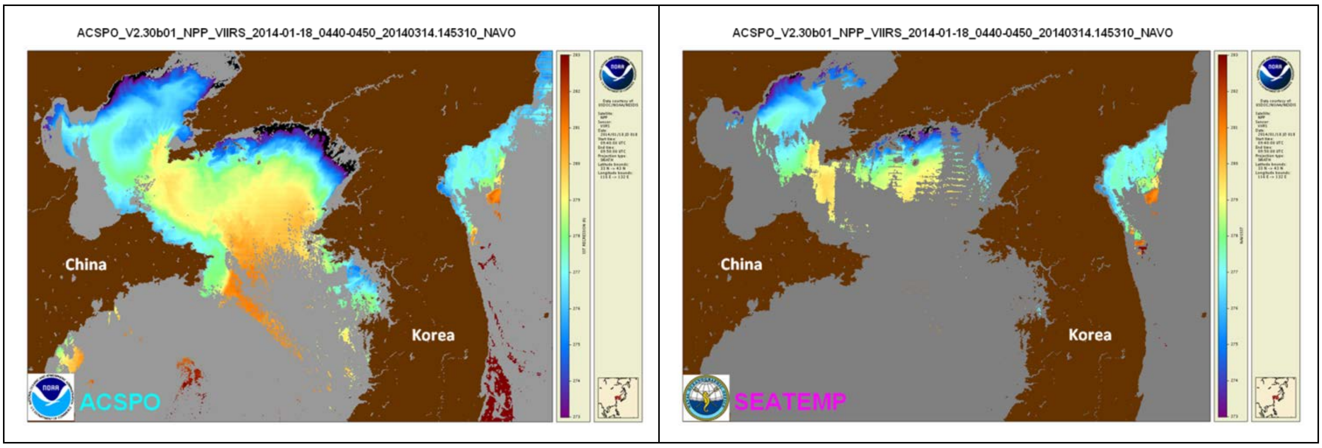


Figure 5: Example ACSPO and NAVO SST imagery on 18 January 2014.

4. Assimilation of NAVO and ACSPO VIIRS SSTs in CMC L4

The NAVO VIIRS L2 SST product has been evaluated for assimilation in CMC L4. Additionally, Bruce Brasnett performed several test runs with ACSPO data, for 2 periods: from 1 Jan – 31 Mar 2014, and 15 Aug – 9 Sep 2013. ARGO floats have been used to independently verify the resulting CMC L4 product.

Fig. 6 shows an example CMC L4 run with NAVO and ACSPO VIIRS SSTs as inputs, for a period from 1 Jan – 5 Feb 2014, when data of both products were available. Independent validation against ARGO floats suggests that ACSPO provides an improved CMC L4 analysis, in all zonal bands. Based on test runs, CMC plans to assimilate ACSPO VIIRS L2P product in CMC analysis as soon as it becomes available to CMC.

5. Summary

ACSPO is the official JPSS VIIRS SST product. The IDPS product will be discontinued. An alternative VIIRS SST product is produced by NAVO. Comparisons of ACSPO and NAVO SSTs suggest that their performance is comparable, with ACSPO coverage being a factor of ~3 larger compared with NAVO product. The differences in coverage are due to three reasons: narrow swath <±54º, 2×2 pixel processing, and conservative cloud mask. Largest differences in coverage appear to be in the Tropics and in the Arctic.

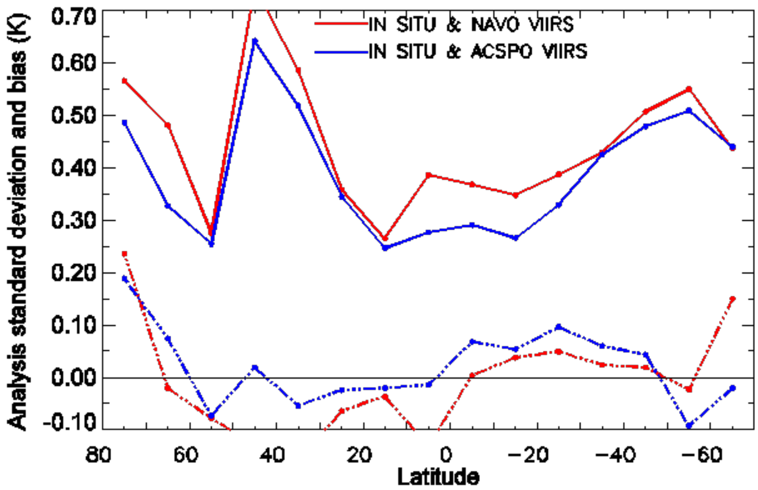


Figure 6: Standard deviation of CMC L4 minus ARGO floats as a function of latitude. (Note that the Northern Hemisphere is on the left and the Southern Hemisphere on the right). In red is shown the control run with NAVO VIIRS SST assimilated. In blue is shown a test run when ACSPO SST was used instead of NAVO SST.

6. Future Work

Future ACSPO work will focus on improved coverage and performance in the dynamic and coastal areas, based on pattern recognition analyses (*Gladkova, et al., 2014*). High latitudes and better separation of cold water from ice is our next focus area. Destriping algorithms currently under testing in experimental ACSPO chain will be implemented in NOAA operations (*Bouali and Ignatov, 2014*). Following several users requests, we plan to generate ACSPO L3 product and archive at PO.DAAC/NODC. Work is underway with the Australian BoM group to test out their gridding code in ACSPO VIIRS processing chain. We will reprocess and back-fill all ACSPO VIIRS data from January 2012 – onward and archive at PO.DAACNODC.

Our ultimate priority will be on working with users to ensure that the ACSPO product fully meets their needs. We welcome their feedback and will work on all necessary fixes and improvements.

7. Acknowledgments

The views, opinions, and findings are those of the authors and should not be construed as an official NOAA or US Government position, policy, or decision.

8. References

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FUTURE NOAA/NESDIS/STAR GEO DATASETS

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ABSTRACT

The current NOAA operational geostationary sea surface temperatures are generated using a physical retrieval algorithm (Modified Total Least Squares). This algorithm will be applied to the Himawari 8/9 which will replace MTSAT-2, INDSAT3D (Indian Satellite) and MSG-4 which will replace MSG-3.

1. Introduction

The National Oceanic and Atmospheric Administration's satellite office generates sea surface temperature (SST) retrievals on an operational basis from a suite of satellites, the NOAA GOES-East and West satellites, the European Meteosat Second Generation (Meteosat-10) satellite, and the Japanese Multi-functional Transport Satellite (MTSAT-2).

Cloud masking is based on a probabilistic (Bayesian) approach and is implemented for improved retrieval accuracy and provides a probability of clear sky. The confidence level of the cloud detection is included as a separate variable in the product, allowing end-users the option of choosing the cloud threshold level to suit their requirements. The SST is then generated using a physical retrieval methodology based on the Modified Least Squares technique (MTLS, Koner et al. 2014) which replaced the older regression based retrieval method in August 2013. The code has been generalized to allow data from any geostationary satellite instrument to be easily ingested.

Future geostationary sea surface temperatures will be generated from Himawari8/9, INDSAT3D and MSG- 4. These future satellite SSTs will be produced in gridded and GHRSST L2P.

2. Current NOAA Geostationary SST Products

Table 1 list the current satellite geostationary sea surface temperatures products and an example of a merged dataset using all operational geostationary datasets is shown in Figure 1. Note the gap in coverage around the Indian subcontinent where we currently have no geostationary coverage which will be filled by the INSAT-3D satellite.

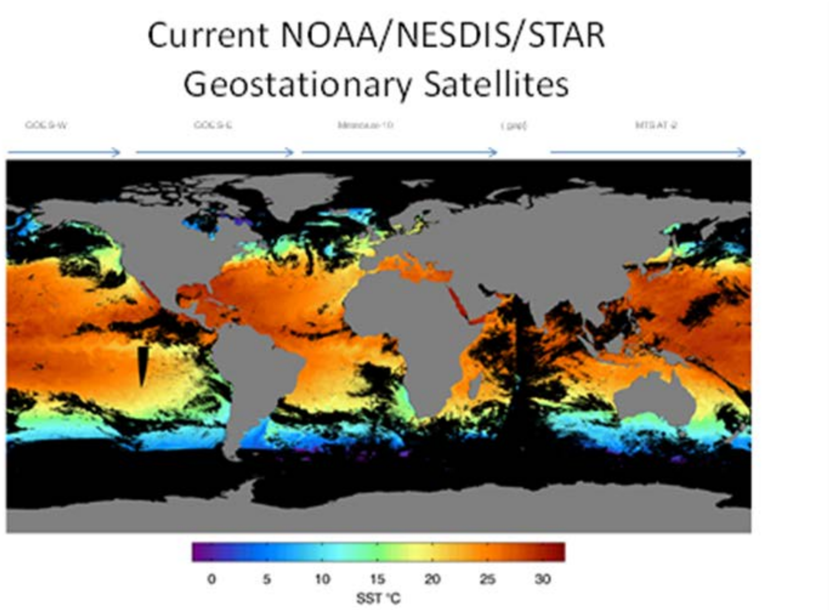

Figure 1: The current NOAA NESDIS STAR Geostationary sea surface temperatures.

SATELLITE	AGENCY	AREA	FREQUENCY
GOES-EAST	NOAA	N-HEM Sector S-HEM Sector	Every 30 min Every 30 min
GOES-WEST	NOAA	N-HEM Sector S-HEM Sector	Every 30 min Every 30 min
MTSAT-2	JAPAN(JAXA)	Full Disk	Every hour
MSG-3	EUROPE (EIUMETSAT)	Full Disk	Every 15 Minutes

Table 1: NOAA GHRSST Operational Geostationary SST L2P data sets for GOES-E/W, MTSAT, and MSG,

3. Future NOAA Geostationary SST Products

Himawari-8/9

The Japanese Multifunctional Transport Satellite (MTSAT)-2 will decommission at the end of December 2015. Himawari-8 will replace MTSAT-2. The Advanced Himawari Imager (AHI) will generate full-disk images every 10 minutes and regional images for the area around Japan every 2.5 minutes. Himawari-9 will then replace Himawari-8. The AHI is similar to the Advanced Baseline Imager on the GOES-R satellite. Figure 2 shows the launch and operational schedules for Himawari-8/9. Himawari-8 is to launch in 2014 and become operational in early 2015. Himawari-9 is to launch in 2016 and become operational in 2017.

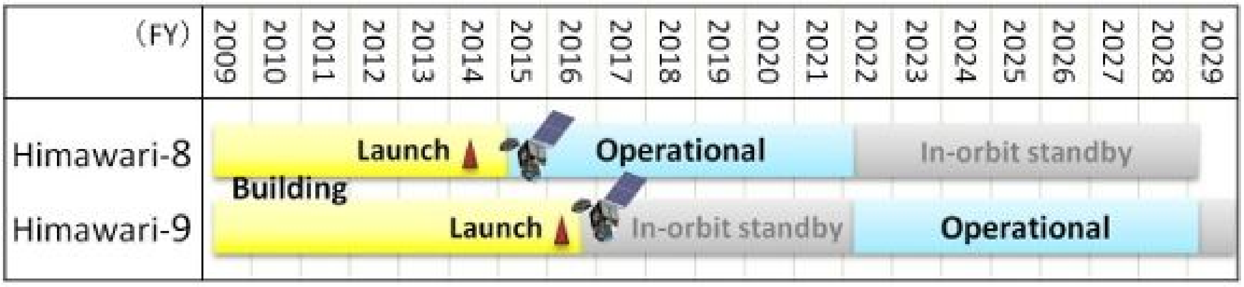

Figure 2: the launch and operational dates for Himawari-8/9

The physical retrieval methodology will be applied to Himawari-8 to generate gridded and GHRSST L2P SST retrievals. These retrievals will be included into the geo-polar blended GHRST L4 SST analyses. There will also be an opportunity to explore the use of extra channels for improving the retrieval and cloud detection.

INSAT-3D

The Indian satellite INSAT-3D is a meteorological; satellite developed by the Indian Space Research Organization and was launched successfully on 26 July 2013 using an Ariane 5 ECA launch vehicle from French Guiana and INSAT-3D is positioned at 82 Degrees East Longitude. Its payloads include an Imager and Sounder with the Imager having similar characteristics to the GOES Imager together with the addition of a SWIR (1.6µm) channel. The physical retrieval methodology will be applied to INSAT-3D to generate gridded and GHRSST L2P SST retrievals. These retrievals will be included into the geo-polar blended GHRST L4 SST analyses.

Meteosat Second Generation -11 (MSG-4)

The fourth in a series of Meteosat Second Generation-11 is planned for launch in 2015 and operational in 2016. This will replace MSG-3. The physical retrieval methodology will be applied to MSG-4 to generate gridded and GHRSST L2P SST retrievals. These retrievals will be included into the geo-polar blended GHRST L4 SST analyses.

4. Conclusion

In the near future three new satellites (Himawari-8/9, INSAT-3D and MSG-4) will be added to the NOAA Geostationary SST product suite. The improvements to the production of sea surface temperatures from the current geostationary satellite sensors can also be applied to the next-generation GOES-R Advanced Baseline Imager which is due for launch in 2016.

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PLENARY SESSION VIII: CLIMATE DATA RECORDS

SST ALGORITHMS IN ACSPO REANALYSIS OF AVHRR GAC DATA FROM 2002-2013

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ABSTRACT

4 km resolution GAC data from NOAA and MetOp AVHRRs are being reprocessed at NOAA/NESDIS to create a long-term L2 SST product as input for the NOAA geo-polar blended L4 SST and potentially other L4 products. In the first stage of reanalysis (RAN1), the ~12 years time series of matchups (2002-2013) were created and used to select and tune up the retrieval algorithms for the second stage (RAN2),with emphasis on minimizing spatial biases, close reproduction of true SST variations, and maximizing temporal and spatial stability as well as the cross-platform consistency. This paper describes the explored SST algorithms.

1. Introduction

Following a request from the NOAA Coral Reef Watch Program, 4km AVHRR GAC data from NOAA and MetOp satellites are being reprocessed at NOAA/NESDIS STAR with the Advanced Clear-Sky Processor for Oceans (ACSPO, Ignatov et al., 2012). The objective is to create a long-term, L2 SST product, consistent with NOAA operations, for the use in the NOAA geo-polar blended L4 SST and potentially other L4 analyses. During the first stage of reprocessing (RAN1) the L2 datasets were generated from NOAA-15, -16, -17, -18, -19, Metop-A and -B from 2002-2013 with operational ACSPO v.2.2. The clear-sky AVHRR brightness temperatures (BT) were selected with the ACSPO Clear-Sky Mask (ACSM, Petrenko et al., 2010) and matched with *in situ* SSTs from the *in situ* Quality Monitor (*i*Quam, Xu and Ignatov, 2014). These multiyear matchup datasets have been used to train and cross-evaluate the SST algorithms for the next stage of reanalysis (RAN2). This paper presents the explored SST algorithms and main results of their evaluation. More details on the exploration of the RAN2 algorithms can be found in (Petrenko et al., 2014a).

2. SST algorithms

The first type of explored algorithms has been a conventional regression, most often used in the operational setting. Based on results of the recent analysis (Petrenko et al., 2014a), in the latest ACSPO versions 2.30 (operational) and 2.31 (RAN2), the regression equations were adopted in the EUMETSAT OSI-SAF formulations (Lavanant et al. 2012) :

Day: $$T_S = a_0+(a_1 + a_2 S_\theta) T_{11} + [a_3 + a_4 T_S^0 + a_5 S_\theta] (T_{11}- T_{12}) + a_6 S_\theta, \quad (1)$$

Night: $$T_S = b_0+(b_1 + b_2 S_\theta) T_{3.7} + (b_3 + b_4 S_\theta) (T_{11}- T_{12}) + b_5 S_\theta. \quad (2)$$

Here, $T_{3.7}$, T_{11}, and T_{12} are BTs observed in the AVHRR channels 3b, 4 and 5; $S_\theta = sec(\theta)-1$; θ is satellite view zenith angle (VZA); T_S^0 is the first guess SST (in Celsius); a_i and b_i are regression coefficients, derived from matchups of satellite BTs with *in situ* SST, $T_{in\ situ}$.

The second type of the algorithms is the Incremental regression (IncR). It has been developed at NOAA during preparations for the GOES-R ABI mission scheduled for launch in 2015 (Petrenko et al., 2011). Several possible formulations of IncR equations were tested during RAN1 and the following equations have been adopted for RAN2:

Day: $$T_S = T_S^0 + c_0 + c_1(T_{11} - T_{11CRTM}) + c_2[(T_{11} - T_{11CRTM}) - (T_{12} - T_{12CRTM})]\, T_S^0 + c_3 S_\theta + c_4 W + c_5 W^2 + c_6\theta + c_7\varphi + c_8\varphi^2 \quad (3)$$

Night: $$T_S = T_S^0 + d_0 + d_1(T_{3.7} - T_{3.7CRTM}) + d_2(T_{12} - T_{12CRTM}) + d_3 S_\theta + d_4\theta + d_5 W + d_6\varphi + d_7\varphi^2 \quad (4)$$

Here, $T_{3.7CRTM}$, T_{11CRTM}, and T_{12CRTM}, are BTs simulated in ACSPO using the Community Radiative Transfer Model (CRTM,Liang et al., 2009), in conjunction with first-guess SST (Canadian Meteo Centre, CMC) and atmospheric profiles from the National Center for Environmental Prediction Global Forecast System (GFS). The regression coefficients, c_i and d_i, are derived from matchups of observed BT increments, T_λ- $T_{\lambda CRTM}$, with *in situ* SST increments, $T_{in\ situ}$ - T_s^0. The procedure of derivation of the IncR coefficients includes scaling, aimed at maintaining a sufficient sensitivity to true SST variations. Eq. (3) and Eq. (4) include a number of terms independent of BT increments but dependent from S_θ, VZA, TPW W and latitude φ. This role of these terms is to correct for non-uniform biases in T_λ- $T_{\lambda CRTM}$. More details on the IncR algorithm can be found in (Petrenko et al., 2014a).

In order to reduce the effect of calibration instabilities, coefficients of the conventional and incremental regressions were recalculated on a daily basis using 3 months of matchups (current day±45 days) running window. In the next Section, three algorithms are compared: 1) Regression algorithms with constant coefficients (RCC, a benchmark to measure further improvements); 2) The conventional regression with variable coefficients (RVC); and 3) The IncR with variable coefficients.

3. Main results

Fig. 1 shows time series of monthly global mean biases and standard deviations of NOAA-17 SST retrieved with three algorithms, with respect to *in situ* SST and CMC. The constant coefficients for RCC were derived from all NOAA-17 matchups in 2005. Fig. 1 also shows time series of the corresponding mean sensitivities. All statistics in Fig. 1 were produced by averaging within a 31 day running window (current day±15 days). In Fig. 1a global biases of RCC SST with respect to *in situ* SST vary within ±0.2 K, whereas for the algorithms with variable coefficients, RVC and IncR, they are well within ±0.05 K. This is a benefit of using variable coefficients. Variations in RVC and IncR global biases with respect to CMC (Fig. 1b) follow variability of *in situ* SST biases. Fig.1c shows that global SDs wrt *in situ* SST are somewhat smaller for the IncR compared with the RCC and RVC, but IncR SDs wrt CMC are larger than for both regression algorithms. (Fig.1d). This is a consequence of the higher sensitivity of the IncR SST to true SST.

The analysis of annual biases of retrieved SST with respect to *in situ* SST has shown (Petrenko et al., 2014a) that using variable coefficients significantly reduces the interannual variability of RVC biases and makes the biases of SSTs produced for different satellites more consistent compared with RCC. However, the RVC biases remain essentially non-uniform as functions of VZA, TPW and latitude. The IncR further flattens out the dependencies of biases from these variables compared with RVC.

The non-uniformity of SST biases as functions of observational conditions gives rise to non-uniform regional SST biases. We estimated regional biases of SST retrieved with three SST algorithms as median annual biases of T_S - $T_{sin\ situ}$ within 10º×10º lat/lon boxes:

$$B_A = \text{median}\,(T_S - T_{sin\ situ}) \quad (5)$$

The multiyear median biases B_{IA} were estimated for those lat/lon boxes in which B_A's estimates were available for all full years of operation of a given satellite:

$$B_{IA} = \text{median}\,(B_A) \quad (6)$$

Fig. 2 shows maps of B_{IA} for NOAA-17, -18 and Metop-A produced with the three daytime algorithms. All algorithms show large cold biases in the areas of Saharan dust. RCC and RVC produce large warm biases in the high latitudes of the Southern oceans and, to some extent, also in the North. For RCC, the high-latitude biases are always larger than for RVC. For the IncR, there are no high-latitude negative biases. However, there are some consistent negative biases up to -0.4K over the Arabian Sea, and warm biases up to +0.4 K in some parts of the Eastern Tropical Pacific. This may be a side effect of the bias correction terms in Eq. (3), which compensate for the cold biases in the areas of the Saharan dust but may result in artificially warm biases elsewhere in the tropics. A temporary fix to this problem, before the aerosol attenuation is reliably accounted for in CRTM, would be excluding matchups collected in the areas affected by dust, and retraining the dataset.

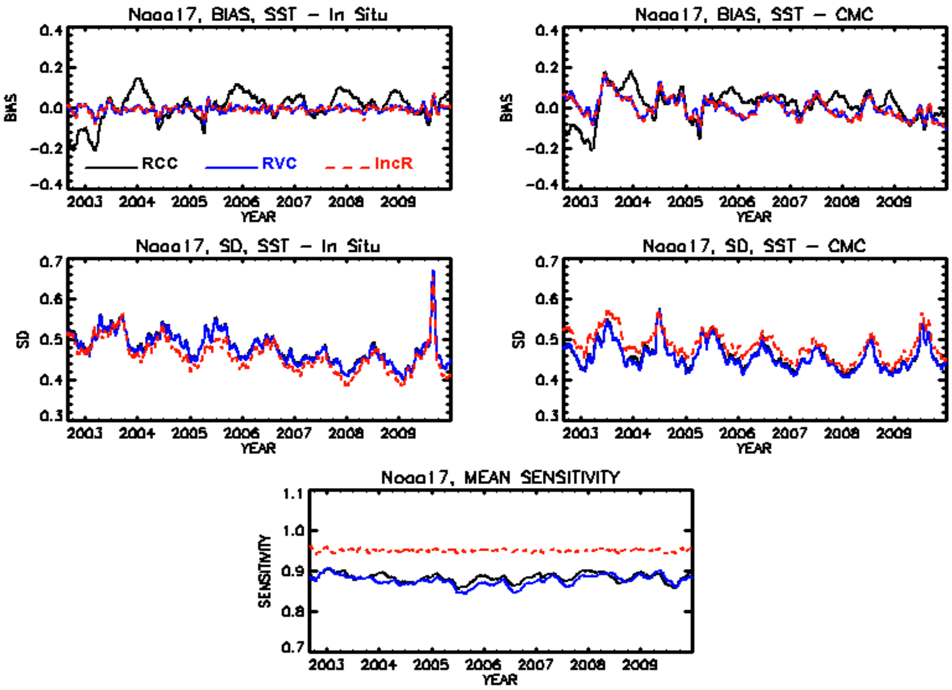

Fig. 1: Time series of global statistics of NOAA-17 SSTs.

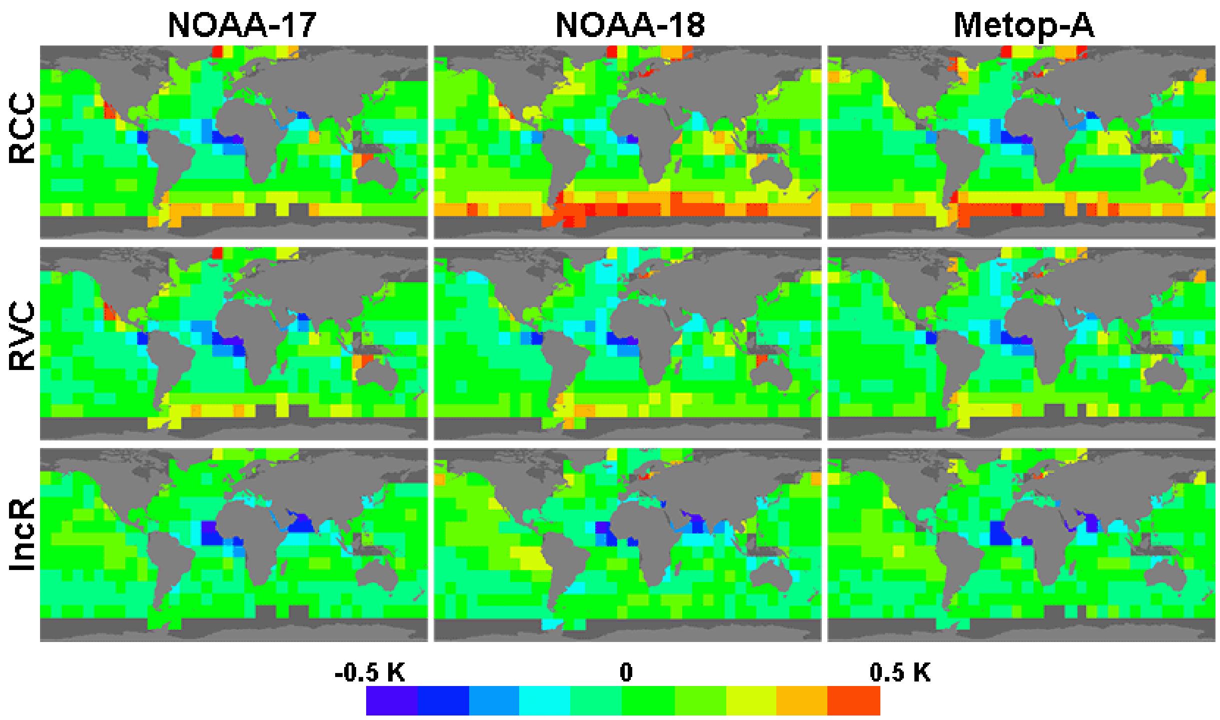

Fig. 2: Maps of mean multiyear biases averaged over 10º×10º lat/lon boxes for three algorithms and three satellites.

4. Summary

Two ways of minimizing variations in temporal and spatial biases in the L2P SST produced from satellite infrared data have been explored during RAN1. Temporal trends in global regression SST biases were reduced by using variable coefficients recalculated on a daily basis. Regional variations in SST biases have been further reduced by replacing the regression equations with incremental equations (IncR). Eventually, the IncR algorithm produced the smallest, most uniform and stable regional SST biases.

On the second stage of reanalysis (RAN2), ACSPO version 2.31 will be employed, which incorporates all three SST algorithms analyzed in this study. We also plan to further elaborate a set of metrics used to characterize the quality of L2P SST time series and, in particular to explore the methodology of GHRSST Climate Data Assessment Framework (Merchant et al., 2013).

The results of RAN1 have shown that the existing AVHRR sensors have very different stability. The AVHRRs onboard NOAA-17, -18, and Metop-A are most stable, whereas the AVHRRs of NOAA-15, NOAA-16 since mid-2004, and NOAA-18 since mid-2011 are least stable (Ignatov et al., 2014). Work is underway to improve the AVHRR radiances. The improvement is expected to be most dramatic for the unstable sensors and periods but it is also likely to improve the more stable sensors.

5. Acknowledgments

This work was conducted under the Ocean Remote Sensing Program funded by NOAA. We thank Program Manager, Paul DiGiacomo, and Deputy Program Manager, Marilyn Yuen-Murphy, for support and encouragement. Thanks go to our SST colleague, Xingming Liang, and to Coral Reef Watch and Geo-Polar blended teams for helpful discussions and feedback. The views, opinions, and findings contained in this paper are those of the authors and should not be construed as an official NOAA or US Government position, policy, or decision.

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ESA'S SEA SURFACE TEMPERATURE CLIMATE CHANGE INITIATIVE: OUTCOMES FROM PHASE I AND PLANS FOR PHASE II

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ABSTRACT

In early 2014, the ESA Sea Surface Temperature Climate Change Initiative concluded Phase I and commenced Phase II. In Phase I, 20 years of data from Along Track Scanning Radiometer and Advanced Very High Resolution Radiometer measurements were processed to SST. The SSTs are independent of in situ measurements at all levels, including the level-4 SST CCI Analysis, which is satellite-only. In the unblended satellite products, skin estimates are provided at the time of satellite observation (the fundamental data) and depth of 20 cm at a standardised local time of day (data mediated by a diurnal-cycle model to avoid aliasing of diurnal cycle as orbit times change). The SST CCI Analysis (which is a no-in-situ run of the OSTIA system using SST CCI inputs) is an SST depth product, considered to represent a daily average estimate.

Active engagement of trail-blazer users with the Phase I data has led to useful feedback on the products, particularly the SST CCI Analysis, and given examples of applications where SST CCI products seem to be particularly useful.

Plans for Phase II will be presented. SSTs will be generated back to 1981 and up to 2015 from ATSRs and AVHRRs. We will attempt to preserve independence in the periods not covered by ATSRs by harmonising the AVHRR radiance products using overlap periods. Some fundamental work into the possible use of microwave SST within the climate data record will be undertaken. A critical aspect here is whether this can be achieved to improve coverage and precision for the periods covered by microwave sensors, without compromising the stability of the time series relative to the earlier infra-red only period. Bayesian cloud detection, previously applied only to ATSRs, will be developed and applied to the AVHRR record. Additional effort will be invested to stabilise the time series during periods of elevated stratospheric aerosol. The estimation of uncertainty for each SST value will also be further developed, and a user workshop to establish better dialogue with users about uncertainty information is planned in November 2014.

As well as developments in the methodology of deriving SSTs, the system for generating data will be further developed. The system will be integrated at a single data and processing centre, including the elements that in Phase I were distributed (namely, OSTIA and SEVIRI and Metop data). The system will also be prepared for Sentinel 3 data. The multi-sensor match-up system will be more fully automated, and a facility for download of "bespoke" match-up datasets will be made available to the GHRSST community.

1. Introduction

In early 2014, the ESA Sea Surface Temperature Climate Change Initiative concluded Phase I and commenced Phase II. In Phase I, 20 years of data from Along Track Scanning Radiometer (ATSR) and Advanced Very High Resolution Radiometer (AVHRR) measurements were processed to SST. The ATSR products are L3U products at 0.05 deg latitude-longitude resolution. The AVHRR products are L2P (although, being from GAC, there is averaging of the brightness temperatures in the L1 input) at a nadir resolution ~4 km. The ATSR and AVHRR streams are then combined into an SST CCI Analysis products, at 0.05 deg grid resolution, daily.

The SSTs are independent of in situ measurements at all levels, including the level-4 SST CCI Analysis, which is satellite-only. This is achieved briefly as follows: retrievals are based on radiative transfer, with tuning of the radiative transfer done for each sensor in a way intended to give consistency with independent ATSR-derived SSTs.

In the unblended satellite products, skin estimates are provided at the time of satellite observation (the fundamental data) and depth of 20 cm at a standardised local time of day (data mediated by a diurnal-cycle model to avoid aliasing of diurnal cycle as orbit times change). The SST CCI Analysis (which is a no-in-situ run of the OSTIA system using SST CCI inputs) is an SST depth product, considered to represent a daily average estimate.

Active engagement of trail-blazer users with the Phase I data has led to useful feedback on the products, particularly the SST CCI Analysis, and given examples of applications where SST CCI products seem to be particularly useful. For details see the paper in this volume by Chris Atkinson.

2. SST CCI results in Phase I

Figure 1 is a summary of the results from SST CCI so far (end of Phase I).

Requirement	GCOS (2011)	SST CCI URD L3/L4 breakthrough’	SST CCI Ph 1 result	SST CCI Ph2 target
Accuracy / demonstrated on scale	0.1 K / 100 km	0.02 K / 100 km	Generally ~0.2 K / regionally	0.1 K / 1000 km ATSR era, 0.2 K 1980s.
Precision	None	0.05 K / 100 km	Varies, quantify it	Varies, quantify it
Stability (retrospectively assessable against tropical moorings only, using current methods)	0.03 K / decade	0.02 K per decade; 0.05 K seasonally, diurnally	Mostly <0.05 K per decade for 1996 – 2010; seasonal stability generally ~0.2 K, locally greater	<0.05 K per decade for 1991 to present; ~0.1 K / decade overall
Spatial resolution	1 km	0.1 deg	0.05 deg	0.05 deg
Temporal resolution	Daily	Day/night (UTC)	Day/night on standardized local time (L2, L3); daily (L4)	Day/night standardized on local time; new adjustments (e.g., UTC daily mean)
Uncertainty information	None	Total uncertainty	Total and components	Total and components, corr. length scales
Type of SST	Blended	Skin & buoy-depth	Skin and buoy-depth	Skin and buoy-depth (R&D on sub-skin)
Period		~1980 - now	1991 - 2010	1981 - 2016

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Figure 1: Summary of achievements of Phase I and targets for Phase 2 of SST CCI, relative to statements of requirement. GCOS = Global Climate Observing System. URD = User Requirements Document from the SST CCI project, available at http://www.esa-sst-cci.org/PUG/documents.

Validation results are available in a Product Validation and Intercomparison Report available at http://www.esa-sst-cci.org/PUG/documents.

The datasets generated to date by ESA's Climate Change Initiative project for Sea Surface Temperature are available from the Centre for Environmental Data Archival via the page www.neodc.rl.ac.uk. Possibly it is most useful to go to the dataset pages using the DOIs of the datasets, which are, for version 1.0:

- For SSTs derived only from the Advanced Very High Resolution Radiometers: http://dx.doi.org/10.5285/782305d4-1ded-43f9-a0ed-40cb41ff0a43
- For SSTs derived only from the Along-Track Scanning Radiometers: http://dx.doi.org/10.5285/fe7a9d81-cfc0-4023-90da-0be37b803bc7 (This points to v1.0. A v1.1 update, addressing a few problems in v1.0, is linked below.)
- For a gap-filled, daily blend ("SST CCI analysis") of the above datasets (with good feature resolution): http://dx.doi.org/10.5285/878bef44-d32a-40cd-a02d-49b6286f0ea4
- A bug-fixing upgrade to the SST CCI ATSR data is now available from the data centre. Relative to v1.0, the newly released v1.1: completes the record up to the end of the AATSR mission (April 2012, cf. Dec 2010 for v1.0); fixes persistent holes from missing data after midnight; restores missing files; fixes various metadata bugs. http://dx.doi.org/10.5285/79229cee-71ab-48b6-b7d6-2fceccead938

To get data, you need to register just your e-mail address with the data centre. If you try to access data without logging in, you may get a page that says "access to the dataset is restricted". This is misleading: **there is no restriction on obtaining SST CCI data**, you simply need to be logged in to the data centre.

Figure 2 is an example day from the SST CCI analysis. This image represents the sea surface temperature (SST) across the global oceans on 5th January, 2010. It is made by blending satellite-derived estimates of SST and filling gaps by an optimal interpolation -- a process referred to as 'analysis'. This SST analysis was created using data from the Along-Track Scanning Radiometers (ATSR) and Advanced Very High Resolution Radiometers (AVHRR), analysed using the Met Office OSTIA system.

The particular value of the SST CCI dataset is that it has relatively high feature resolution, refers to a well-defined type of SST (temperature at 20 cm depth, daily average) and, unlike most satellite SSTs, is independent of in situ observations. The full dataset covers 1991 to 2010 and was created in Phase 1 of ESA's SST Climate Change Initiative (SST CCI).

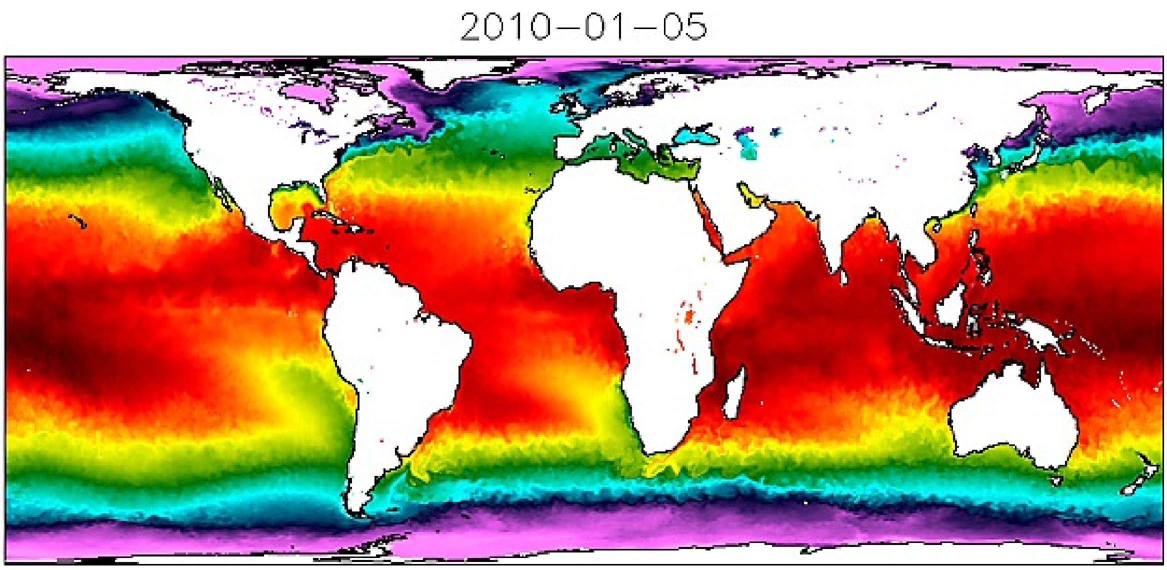

Figure 2: This is an estimate of the sea surface temperature (SST) across the global oceans on 5th January, 2010. It is made by blending satellite-derived estimates of SST and filling gaps by sophisticated interpolation -- a process referred

to as 'analysis'. This SST analysis was created using data from the Along-Track Scanning Radiometers (ATSR) and Advanced Very High Resolution Radiometers (AVHRR), analysed using the Met Office OSTIA system. The particular value of this SST dataset is that it has relatively high feature resolution, refers to a well-defined type of SST (temperature at 20 cm depth, daily average) and is independent of in situ observations. The full dataset covers 1991 to 2010 and is publicly available (see link below). It was created in Phase 1 of ESA's SST Climate Change Initiative (SST CCI).

Comprehensive documentation is available, including the following:

- Product User Guide and Quick Start Guide
- Uncertainty Characterisation Report
- Climate Assessment Report
- Product Validation and Inter-comparison Report
- User Requirements Document
- Algorithm Theoretical Basis Document
- Product Specification Document

These are linked from the dataset DOIs and also are available at: http://www.esa-sst-cci.org/PUG/documents.

3. Plans for SST CCI Phase II

Some of the targets for Phase II are shown in Figure 1.

Figure 3 is a schematic of the plans for Phase II in terms of data products and the time periods covered.

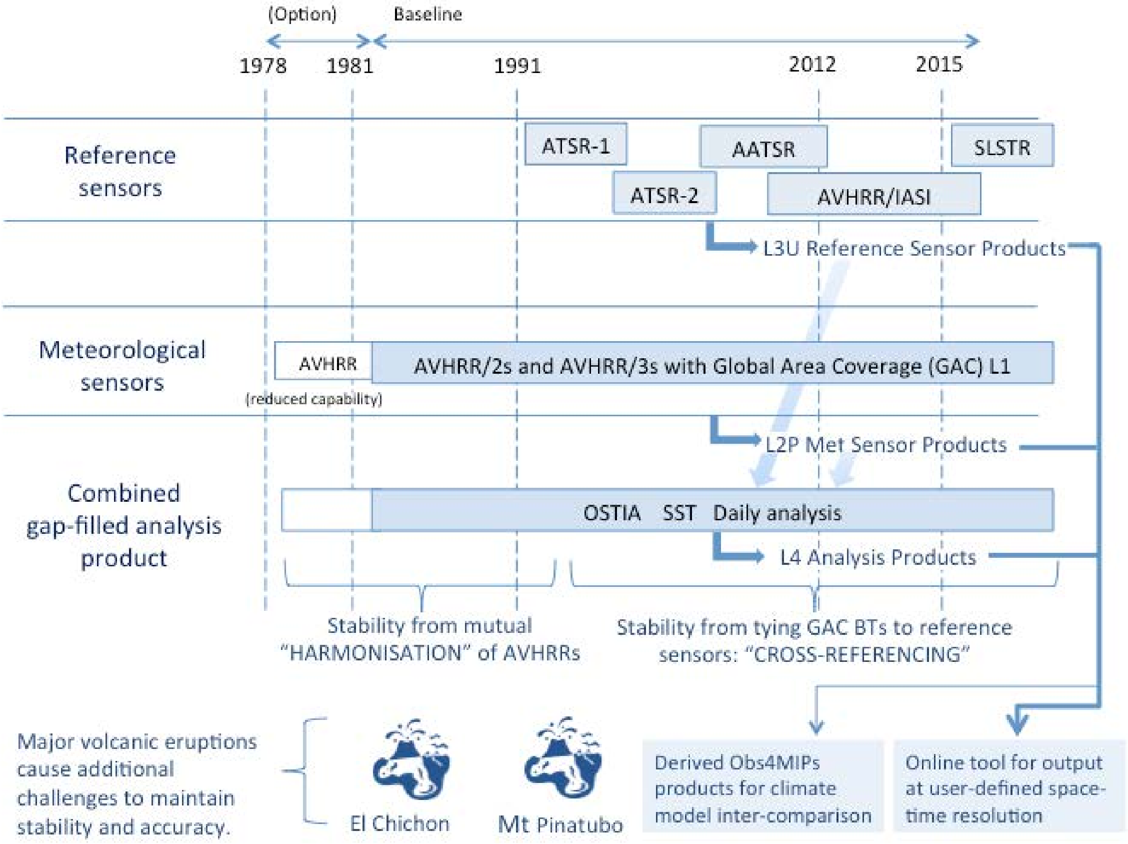

Figure 3: Plans for Phase II products from SST CCI. Reference sensor products will be produced from full resolution L1b data from ATSRs and the Metop-A AVHRR, and preparations will be made to link to SLSTR. AVHRR sensors will be tied

to reference sensors (post 1991) and L2P products developed from GAC. There will be a 0.05 deg OSTIA-based SST CCI analysis, a version of the data derived for Obs4MIPs, and an online tool for obtaining data aggregated to user-defined space time resolution.

The primary aims for the Phase II project are listed below:

- Make ATSR SSTs that improve upon the ARC (Merchant et al., 2012) dataset in terms of bias and stability
- Reduce ATSR-1 residual trend of ~0.1 K/yr post-Pinatubo
- Develop and test cloud detection for GAC using Bayesian
- Smooth-atmosphere optimal estimation with aerosol robustness for single-view SST
- Pre-ARC harmonisation of AVHRRs
- Stabilise AVHRR-A vs IASI to act as bridging reference sensor
- SLSTR preparation
- Develop and test an optimal estimator for AMSR-2
- Switch to NEMOVAR analysis system and integrate with satellite processing chains, and additionally
- Optimise configuration of analysis system in terms of data sub-sampling
- Introduce background error co-variances with adaptive correlation length scales based on SST gradients and/or data density
- Develop and test methods for use of uncertainty components from L2 and L3 data, accounting for correlation length scales (to be developed)

4. Conclusion

SST CCI Phase II is extremely challenging, and ultimately has the aim to develop a prototype SST climate data service that is:

- sustainable in the long term
- able to harness the best scientific SST R&D
- able to provide necessary performance: a 'nimble' improvement cycle for reprocessing high-performance capacity to store and process relevant data flows now and in the coming era of Sentinel missions

The strategy is to build this at the Facility for Climate and Environmental Monitoring from Space (CEMS) in the UK, and actively seek mechanisms for operating the system beyond SST CCI Phase II.

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SST CCI TRAIL BLAZER USERS: ENGAGEMENT AND RESULTS

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ABSTRACT

The ESA CCI SST project engaged a small number of trail blazer users to test out the pre-release products and to provide feedback. This is documented in the Climate Assessment Report (CAR), available via http://www.esa-sst-cci.org/PUG/documents. Here we present a selection of results from two of the CAR's main strands: an assessment of trends and variability in the SST CCI products and comparison with other SST products, and the use of the SST CCI products in climate modeling and by trail blazer users. The interested reader is referred to the CAR documentation where detailed information and many more results can be found.

Some of the key messages from the trail blazer users highlighted in this presentation are:

- Daily mean SST is more useful than foundation SST for evaluating model simulations of heat transport by tropical instability waves;
- The standard deviation of the surface temperature error in a reanalysis of shelf seas was lower when SST CCI products were used, relative to the period when Pathfinder data were assimilated;
- The use of the SST CCI uncertainties gave a significant reduction in the RMS errors of the shelf seas reanalysis;
- An Arctic analysis showed improvements (lower RMS difference from reference data) when SST CCI data were used for 2006-2008 instead of precursor data;
- Different SST datasets were used to force the same global general circulation model at different resolutions. Several differences in the simulated mean state seem to be influenced by differences between the datasets, including the Indian monsoon rainfall and some aspects of surface temperature. Tropical cyclone climatologies are also affected;
- SST CCI analysis seems more strongly related to precipitation and cloud in some locations than some other analyses.

1. Introduction

The ESA CCI SST project produced three long term products:

1. ATSR. SSTs from ATSR instruments in L3U format at 0.05° latitude by 0.05° longitude resolution covering 1991 – 2010. (Hereafter, SST CCI ATSR.)
2. AVHRR. SSTs from AVHRR instruments in L2P format at Global Area Coverage (GAC) resolution covering 1991 – 2010. (Hereafter, SST CCI AVHRR.)
3. Analysis. Satellite-only SST-depth L4 daily analysis created by OSTIA system from SST CCI ATSR and SST CCI AVHRR products at 0.05° latitude by 0.05° longitude resolution covering 1991 – 2010. (Hereafter, SST CCI analysis.)

These products were assessed within the SST CCI project, including in the Climate Assessment. The findings from this are documented in the Climate Assessment Report (CAR), available via http://www.esa-sst-cci.org/PUG/documents. The products assessed were pre-release versions that do not differ from version 1.0 products in any way that affects the results depicted here. There were three main strands to the Climate Assessment:

- An assessment of trends and variability and comparison to other SST products, including an assessment of stability of the SST CCI products in comparison to reference data
- An assessment of the impact of the SST CCI products on climate modelling, for example in model evaluation and in driving atmosphere-only models, and the use of the SST CCI products in other applications (see below).
- An assessment of the consistency of the SST CCI products with other Essential Climate Variables

In addition to our own analysis, we invited a number of voluntary trail-blazer users to test the SST CCI products in their own applications. They supplied reports summarising their use of the data, including what they had learned from them, in addition to recommendations for future products. This is documented in the CAR under other applications.

Here we present a selection of the key findings from the first two main strands of the CAR. In Section 2 we show that the SST CCI products provide an apparently good representation of variability and are quite stable. Then, armed with this knowledge, Section 3 presents an assessment of the Met Office Hadley Centre coupled climate model by comparing to the SST CCI and Reynolds et al. (2007) Daily OI analyses, whilst Section 4 presents a selection of results from the trail-blazer users.

The interested reader is referred to the CAR documentation where detailed information and many more results can be found.

2. Assessment of trends and variability and comparison with other SST products

There are many precursor SST climate data sets and analyses. We compared the SST CCI products to a large number of them. Figure 1 shows how the global mean SST anomaly in the SST CCI products compares to those of the comparison data sets. The comparison data sets are shown by the thin grey lines and the SST CCI data sets by the coloured lines. There are some outliers among the comparison data sets, some of which have limited spatial coverage. The cool biased outlier is the AVHRR Pathfinder data set. The bias in the SST CCI AVHRR data set on the global average is about 0.2K less than in the Pathfinder data, despite using the same cloud-clearing scheme, indicating the improvement achieved by the new retrievals and the tying to ATSR. There is a relative bias between the SST CCI products of order 0.1-0.2K, although we also see some short periods of anomalously large bias in the early 1990s and in 1996. Generally though, the SST CCI products provide a picture of variability that is consistent with that seen in the comparison data.

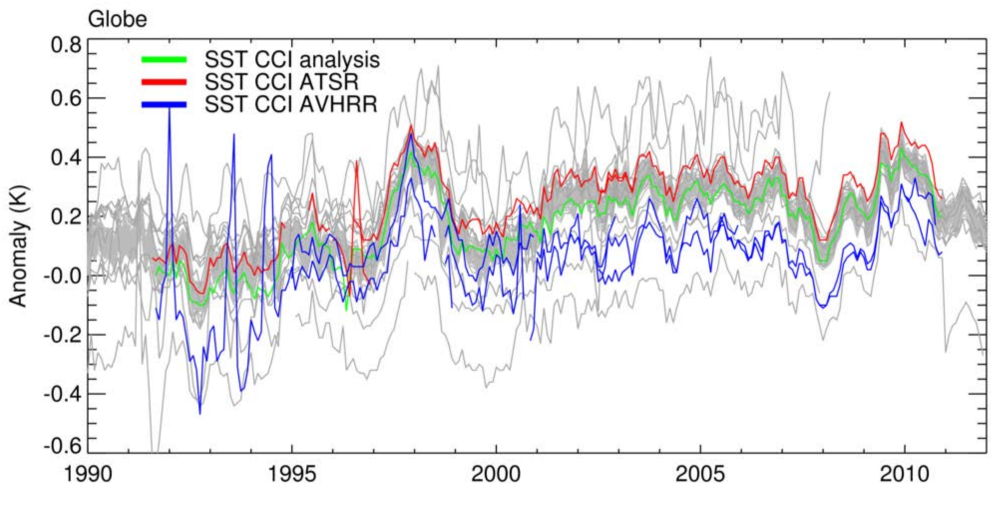

Figure 1: Global average SST anomaly (K, relative to MyOcean OSTIA reanalysis climatology) for each of the comparison data sets (grey) and the SST CCI products.

In preparing the CAR, we calculated time series like those in Figure 1 for many areas of the world's oceans and linear trends in those regions are displayed there for the SST CCI products and the comparison data.

While in the global mean and in some regions of the world's oceans, SST CCI products are biased relative to each other and the comparison data, in others they are not and represent a clear improvement over precursor data sets.

One example of a climatically important phenomenon where this happens is the Dipole Mode Index (DMI) in the Indian Ocean, shown in Figure 2. Here we see much of the peak-to-trough variability is larger in the SST CCI products than in the comparison data (though not in all cases, for example in 2010). A more detailed investigation of the 1997 event shows that this is due to improved resolution of a cold anomaly off Indonesia in the SST CCI products. One thing to note is that the relatively narrower spread of estimates for the DMI, as compared with the global mean SST anomalies in Figure 1, is in part because the variability is higher and because the index is calculated as the difference between two areas (taking differences will tend to reduce the effect of systematic offsets between data sets).

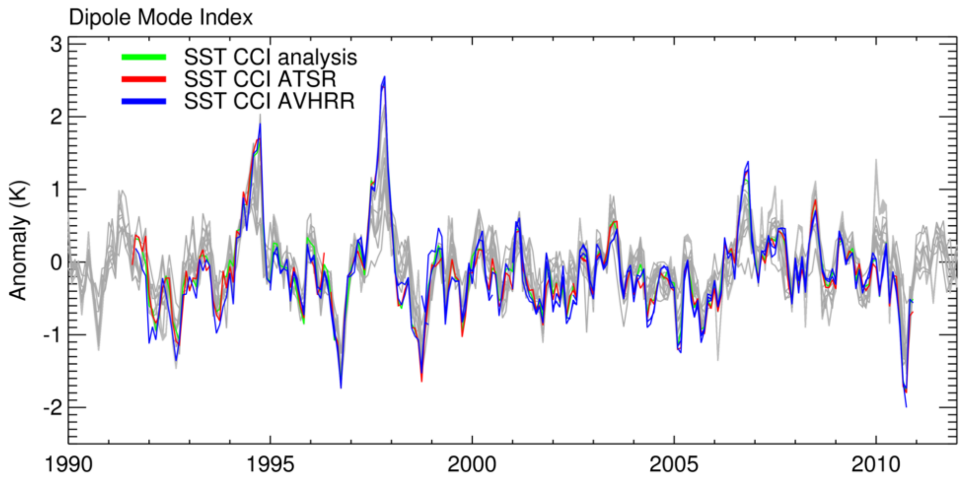

Figure 2: Dipole Mode Index (K) for each of the comparison data sets (grey) and the SST CCI products. Units are in K because the indices are calculated as the difference between two simple area averages of temperature.

An assessment of major EOF patterns in the (independent) satellite-only SST CCI analysis and gridded in situ data (contributed by one of our trail-blazer users) also confirms that large-scale variability in the SST CCI products is as expected.

The stability in the SST CCI products was also assessed relative to a series of reference data from the Global Tropical Moored Buoy Array (the GTMBA). In practice, because we require match ups between the SST CCI products and the GTMBA measurements in at least 75% of months over the period of analysis, we can only assess the products' stability in the tropical Pacific. Figure 3 shows differences between the SST in the SST CCI products and in the GTMBA measurements over the whole period of record. We see there are two distinct periods:

- 1991-1995, when the record contained data from the troubled ATSR-1 instrument and the AVHRR on board NOAA-12 which was also beset by problems. During this period we can see large changing differences from the reference; and
- 1995-2010, then the more stable ATSR-2 and AATSR instruments were available. We see much smaller differences from the reference and less change over time.

The GCOS stability requirement is a stringent 3mK per year. None of the SST CCI products meet this over the 1991 to 1995 period, as we would expect. However, over the period 1995-2010, the SST CCI night time AVHRR product meets this comfortably and the SST CCI ATSR daytime and analysis products fall only marginally outside. The SST CCI night time ATSR product is stable to within 6mK per year, which is inside the previous GCOS stability requirement.

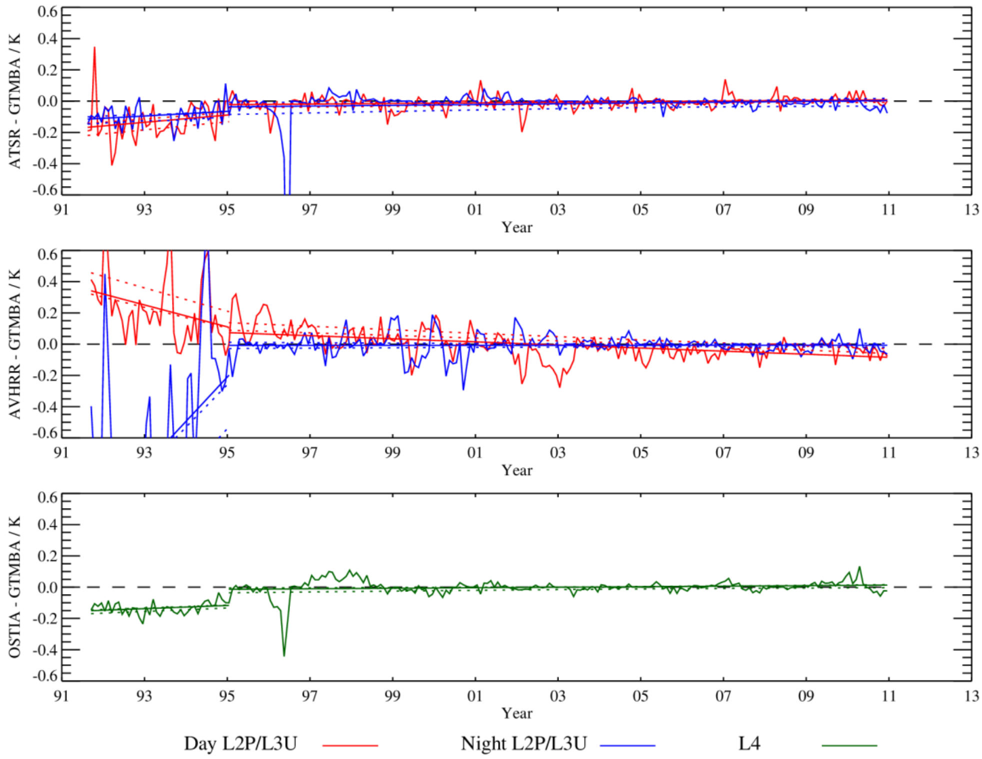

Figure 3: Time series of deseasonalised composite monthly mean differences (K) between the SST CCI products and the GTMBA. Separate day and nighttime series are provided for the SST CCI AVHRR and ATSR products. Also plotted are the results of a least squares linear fit (solid lines) for the 1991 to May 1995 and June 1995 to 2010 periods and their 95% confidence bands (dashed lines). OSTIA/L4 refers to SST CCI analysis, L2P to SST CCI AVHRR and L3U to SST CCI ATSR.

3. Use in climate modeling

When we assess the mean state of the Met Office Hadley Centre coupled climate model by comparing to the SST CCI and the Daily OI analyses, we see no discernible impact of the SST CCI analysis because the model errors can be large, especially in the Southern Ocean. However, when we assess simulated *daily* variability, we draw different conclusions about the model depending on the observed analysis used. Figure 4 shows zonal mean plots comparing daily variability in the surface temperature from the coupled model control simulation to the Daily OI analysis at the top and to the SST CCI analysis in the middle. The two observed analyses are compared at the bottom. The Daily OI contains generally greater daily variability than the coupled model, whereas the variability in the SST CCI analysis is closer to that in the model, with the exception of the mid latitudes. We believe the daily variability in the SST CCI analysis is more reliable than that given in the Daily OI because the input data are better quality and are adjusted to consistent reference times, which averaged together give a good approximation to the daily average. The Daily OI, on the other hand, does not attempt to adjust its input data for diurnal effects, so spurious variability will result.

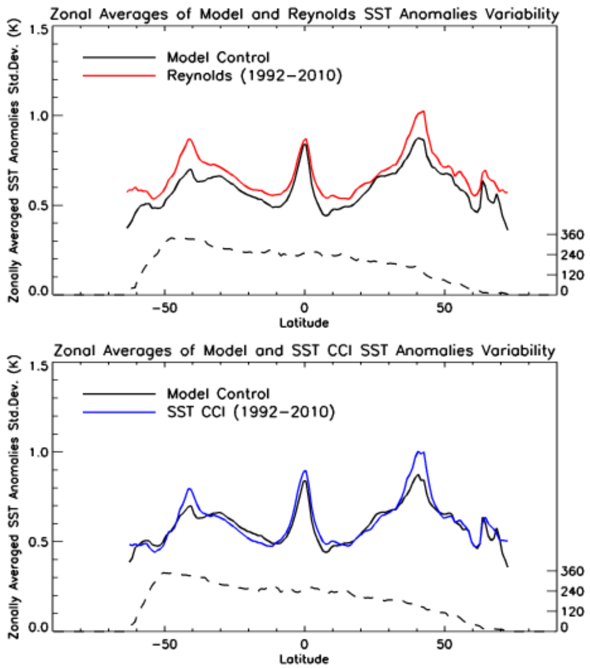

Figure 4: Zonal averages of daily SST anomaly variability (standard deviations, K) in a HadGEM3 model control run, the SST CCI analysis, and the Reynolds Daily OI. All datasets have been regridded to a 1° grid. Comparisons are: (top) model with Daily OI; (bottom) model with SST CCI analysis. Dotted lines denote the number of grid cells used to create the zonal averages.

If we consider global maps (not shown) comparing the daily variability in the coupled model simulation separately with the Daily OI and SST CCI analyses, the areas where we might wish to investigate model performance more closely generally differ. However, the Arabian Sea is seen, in both cases, as an area where the coupled model has lower variability than the observations. It is likely here that this has a lot to do with problems in the observations. Figure 5 shows SST anomalies averaged over the North Indian Ocean for the SST CCI products and comparison datasets. The SST CCI AVHRR retrievals in this region contain intermittent biases arising from episodes of desert dust over the ocean, which adds extra noise to the observations and hence to the analyses. Because this region is very important for accurate modelling of the Indian Monsoon, close attention will need to be paid to retrievals here in the SST CCI Phase II.

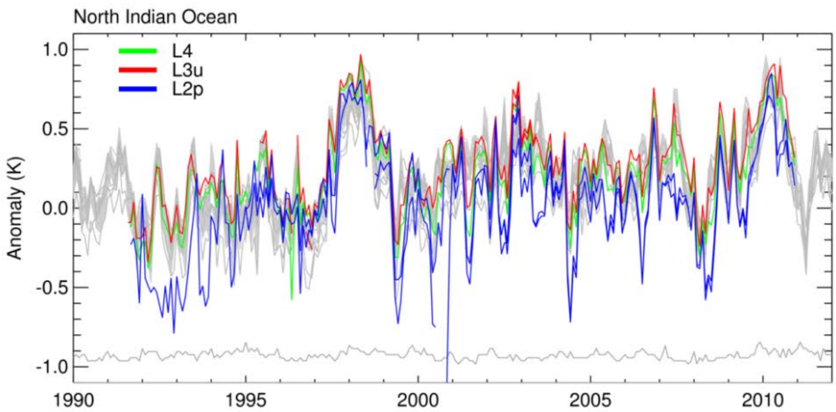

Figure 5: Average SST anomaly in the North Indian Ocean (K, relative to MyOcean OSTIA reanalysis climatology) for each of the comparison data sets (grey) and the SST CCI products. L4 refers to SST CCI analysis, L3U to SST CCI ATSR and L2P to SST CCI AVHRR.

Exploring the analyses more closely, we also see an apparent positive impact in the Arabian Sea of the use of microwave observations in the Daily OI (not shown). Prior to the introduction of AMSR data, the variability in the Daily OI is enhanced relative to the SST CCI analysis. Thereafter, it is reduced and more comparable to that of the SST CCI. We also hope to be able to explore more fully the impact of the inclusion of microwave data in such sensitive regions in Phase II.

4. Use by trail-blazer users

Some of the results from five of our trail-blazer user studies are now presented:

(1) An exploration of heat transport in ocean models via tropical instability waves (courtesy Tim Graham). An ocean model was forced using atmospheric information from 1994 to 1998 with the aim of exploring the transport of heat by tropical instability waves in a 1 degree resolution ocean model and a 0.25 degree resolution ocean model; to determine whether or not the higher resolution model was more realistic. Simulated daily SST was compared to three observed analyses: the MyOcean OSTIA reanalysis, the Reynolds et al. (2007) Daily OI and the SST CCI analysis. An example of the comparisons is shown in Figure 6. The OSTIA reanalysis aims to represent foundation SST. We can see that it tends to be cooler than the higher resolution ocean model simulation. The Daily OI tracks the higher resolution model simulation, except during the peak of the El Niño event. The SST CCI analysis is also close to the higher resolution simulation, except when it is biased prior to 1996. We also see much closer agreement of the SST CCI analysis to the forced simulation during the peak of the El Niño event, which is another indication that peak-to-trough variability seems to be higher in the SST CCI analysis. Apart from the anomalous variability in May 1996, the daily variability is also reduced in the SST CCI analysis.

The provision of daily mean information in the SST CCI analysis is a better natural comparator to the simulated daily data than foundation SST or the daily 'means' provided in the Daily OI. The conclusion of whether or not the higher resolution model is more realistic is dependent on the observational analysis used.

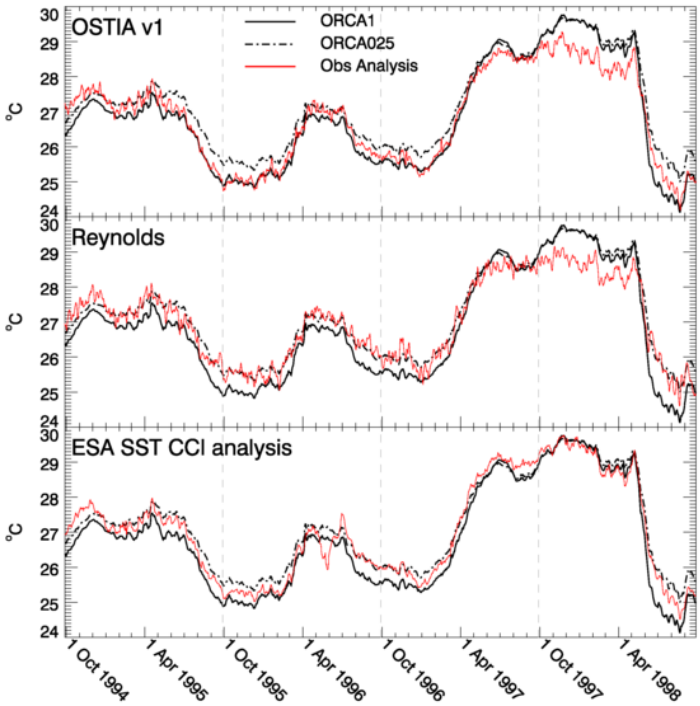

Figure 6: Mean SST (°C) over region [110–150°W, 4°S-4°N], 1st October 1994-30th September 1998. Dark lines are repeated in each panel and show the time series as simulated in the ORCA1 and ORCA025 models. Each panel additionally shows the observational time series from: (top) OSTIA Reanalysis v1.0; (middle) Reynolds Daily OI and (bottom) ESA SST CCI analysis.

(2) Assimilation of SST CCI AVHRR product into North-West Shelf Seas reanalysis (courtesy Robert King). A 7km resolution reanalysis of the European North West Shelf Seas has been produced by assimilating SST observations from satellite and in situ platforms into an ocean forecasting model. Figure 7 shows an improvement in performance of that reanalysis when the AVHRR source is switched from Pathfinder to SST CCI from 1996 onwards. The mean observation-minus-model difference has fewer outliers after the switch, indicating that it is more stable then and the standard deviation of observation-minus-model difference is closer to zero and also more stable. This reanalysis has made use (from 1996 onwards) of a component of the uncertainty estimates provided with each pixel of the SST CCI AVHRR product, as opposed to the single value provided in the Pathfinder product (used prior to 1996). This has also led to an improvement in the skill of the reanalysis, as measured by comparison to in situ data.

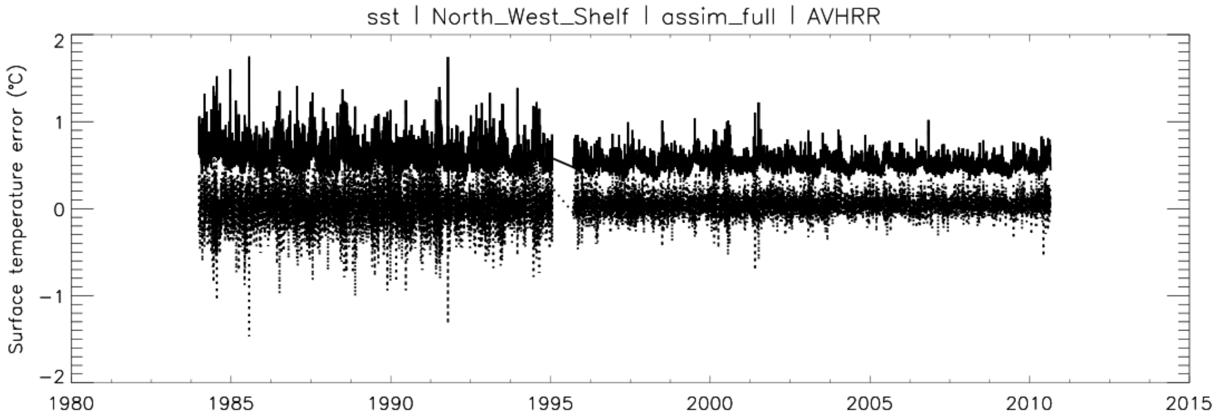

Figure 7: Surface temperature error (°C) for AVHRR observations over the full reanalysis: i.e. the mean (bottom, dashed lines) and standard deviation (top, solid lines) of the observation-model differences for the assimilative run. The observations come from Pathfinder v5.2 from 1984 to 1995 and from ESA CCI SST pre-release version from 1996 onward.

(3) Use in an analysis for the Arctic (courtesy Jacob Høyer). This study aimed to assess the impact of the SST CCI AVHRR product on an Arctic L4 analysis. A test analysis was produced for 2006-2008 and compared with an Arctic L4 analysis based upon Pathfinder AVHRR observations. The Arctic analysis produced using the SST CCI AVHRR dataset showed smaller overall RMS differences when compared against independent in situ observations from drifting buoys, moored buoys and ships. The standard deviation of the difference between the Arctic analysis and drifting buoys is also seen to improve when using the SST CCI AVHRR dataset, although this difference is seen to vary through the year.

(4) Use in simulation of tropical storm track density (courtesy Malcolm Roberts). The SST CCI analysis has been used, along with two other analyses, to drive an atmosphere-only model at both 130km resolution and 25km resolution. The impact of the SST CCI analysis on the modelling of tropical storms has been analysed and is illustrated in Figure 8. In the 130km resolution simulation, cyclone frequency is low in the western Pacific when compared to HURDAT observations when all three analyses are used. When the model resolution is increased to 25 kilometres, the simulation forced by the Reynolds et al. (2007) Daily OI maintains this frequency here, but the cyclone tracks spread out over more of the north Pacific. When the SST CCI analysis is used, the cyclone frequency in the west Pacific is increased, but the tracks are more tightly constrained. In both cases, south Pacific cyclones are too frequent compared to HURDAT. By making use of multiple SST analyses, model biases can be put into context compared to the model response to different forcing datasets.

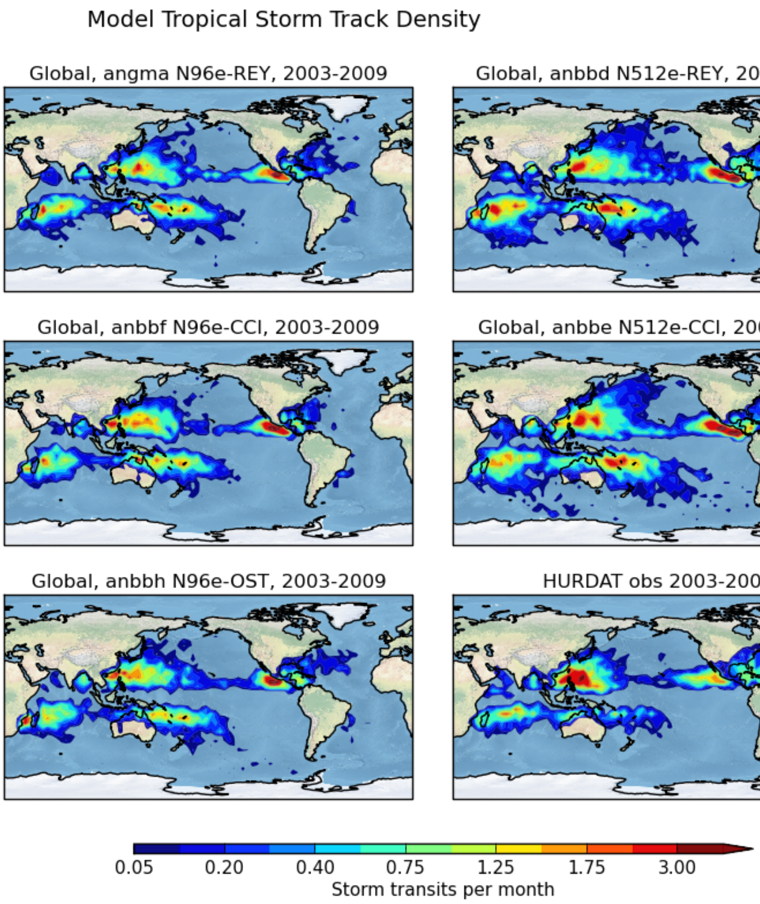

Figure 8: Tropical storm track density in different model simulations and observations. Left hand column: Model simulations at ~130km resolution. Right hand column: Model simulations at ~25km resolution and HURDAT observations (bottom right). Atmosphere-only model simulations were driven by different SST analyses. Top: Reynolds et al. (2007) Daily OI. Middle: SST CCI analysis. Bottom: OSTIA v1.0 reanalysis.

(5) Relationships between SST and precipitation (courtesy Katie Brown). Various aspects of the relationship between SST and clouds and precipitation were explored. Figure 9 shows contemporaneous correlations between SST anomalies and precipitation anomalies from the Global Precipitation Climatology Project. The relationships with the SST CCI analysis at the bottom are compared to those with the AMIP SST at the top and with the Reynolds et al. (2007) Daily OI in the middle. We can see broad similarities between the plots but, for example, concentrating on the Indian Ocean we see a stronger relationship between SST and precipitation when the SST CCI analysis is used. The relationship with the AMIP data set is almost as strong here, but that with the Daily OI is weakest. Looking at time series of SST and precipitation anomalies in this region, we see that it is the enhanced peak to trough variability in the SST CCI analysis that is responsible for the strong relationship.

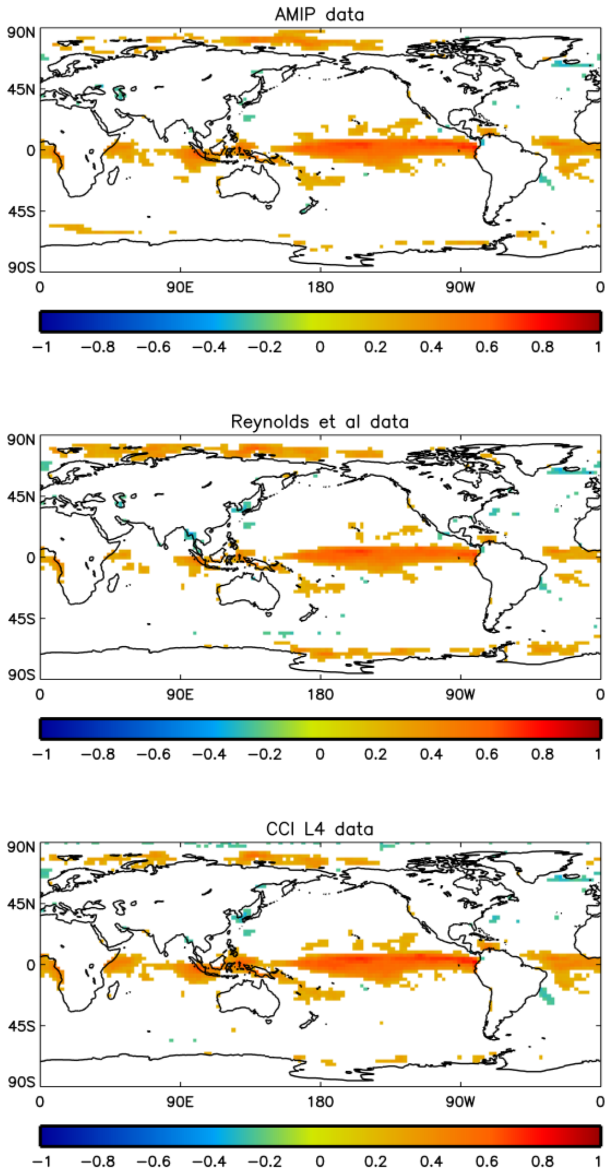

Figure 9: Correlations (significant at 5% level) between precipitation anomalies and SST anomalies from (top) AMIP; (middle) Daily OI; (bottom) SST CCI analysis.

5. Key Messages

A few key messages arising from the use of the SST CCI products in various applications are highlighted below, some of which were presented in Sections 2-4. As mentioned in the introduction, the interested reader is referred to the CAR documentation where a helpful summary of **all** the key findings is presented, along with detailed information and many more results than those selected here.

- Variability in AVHRR SSTs may be exaggerated in the Gulf of Arabia/Arabian Sea due to biases from intermittent desert dust. Here the SST CCI analysis is up to 0.6 K cooler than some other datasets in JJA. This causes a significant reduction in the simulated Indian monsoon rainfall when used to drive a 25 km model, magnifying an existing model bias. There is some evidence that there could be a positive impact of the use of passive microwave data in this region

- Daily mean SST data provided by the SST CCI analysis is more useful than foundation SST data for the purpose of evaluating model simulations of heat transport by tropical instability waves. The daily mean SST CCI analysis is more comparable to simulated daily mean SSTs.
- Surface temperature error in a reanalysis of shelf seas (assimilating only SST) was markedly lower when SST CCI products were used, relative to the earlier period when Pathfinder data were assimilated. Use of the newly developed SST CCI uncertainties gave a significant reduction in the RMS errors of the shelf seas reanalysis when compared to in situ observations.
- Different SST datasets were used to force the same global atmosphere-land general circulation model at low (~130 km) and high (~25 km) resolutions. Several differences in the simulated mean state seem to be influenced by differences between the SST datasets, including the Indian monsoon rainfall and surface temperature differences over North America. It is not clear whether this is due to the superior resolution of the SST CCI analysis, or due to other differences between data sets (e,g, in their relative biases). Tropical cyclone climatologies are also affected, particularly in the Eastern and Western Pacific regions.
- It is important to have a range of forcing datasets, e.g. through provision of an ensemble, so that model biases can be put into context compared to the model response to different forcing datasets.

6. Acknowledgements

The results presented in the SST CCI CAR are a synthesis of many people's efforts including those of the trail-blazer users. We present work here courtesy of John Kennedy, Gary Corlett, Simone Morak, Tim Graham, Robert King, Jacob Høyer, Malcolm Roberts and Katie Brown. Many other authors contributed to the full CAR.

7. References

Reynolds, R. W., T. M. Smith, C. Liu, D. B. Chelton, K. S. Casey and M. G. Schlax, *J. Clim.* **20**, 5473-5496, 2007, doi:http://dx.doi.org/10.1175/2007JCLI1824.1.

SECTION 3: BREAKOUT SESSION REPORTS AND ABSTRACTS

SUMMARY OF BREAKOUT GROUPS

THE APPLICATIONS AND USER SUPPORT TECHNICAL ADVISORY GROUP (AUS-TAG) BREAKOUT MEETING REPORT

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

1. Effective agenda

1 Intro (Jorge Vazquez)
2 Overview of GHRSST Booth @ OSM 2014 – lessons learned (Gary Corrlett)
3 Validation of a hybrid coordinate ocean model (HYCOM) on the Agulhas Bank shelf south of Africa using GHRSST MUR and 1km MODIS data (Bjorn Backeberg)
4 Large biases between in situ and remotely sensed datasets along the South African Coast (A J Smit)
5 An overview of shipboard radiometers (Peter Minnett)
6 Interactive discussion on GHRSST archive (Sasha Ignatov)

2. GHRSST Booth @ OSM 2014 – Gary

Highlights:

- We managed on a limited budget
- Met with quite a broad spectrum: power users, small scale, and who knew nothing about GHRSST. Most users asked: what is “High Resolution” SST ?
- The fact that GHRSST data is free and accessible was surprising to many.

Learnings:

- People like free things (memory sticks). Chocolates are even more popular!
- People NEED HELP in choosing products; simply too many products !
- Many people did not know what GHRSSRT is : we need to work on this
- SST movies are popular
- Don’t trust the Wi-Fi: demonstrating access to GHRSST services was impractical

Recommendations:

- Please a better mailing strategy
- Need to start recommending a product for specific cases – this will be somewhat controversial.
- Need to improve our help material. (may be add tutorial videos)
- Social Media presence is required: many people did not know what GHRSST is!

3. HYCOM on Agulhas bank using GHRSST MUR and 1KM MODIS – Bjorn

- EnOI model: truth is between Model and Obs & depending on what you trust more, modelling is done. Problems: observations sparse, accuracy unknown, correction (3 big problems)
- System developed (EnOI) is still in infancy

- The model, on an average, degrades the SST pattern. Incorrect correlation between SSH and SST and distribution. Reported problems in the system that needs to be fixed.

Charlie Barron: commented on the flat relation between SSH/SST and said it may not be representative everywhere.

Peter Minnett: Please provide feedback when you use GHRSST SST on QL and error characterization.

4. Large biases between in situ and remotely sensed measurements along SA coast – AJ Smit

- Presented "a good example of bad usage of remotely sensed data": What happens when you use sat SST in the coast, where you are not supposed to do (up to 400 mts).
- Point measurements confirm that sat SST is warner by a few degrees (PF more, MODIS less). Coastal measurements are hand-held human effort accurate within 0.1 degree Celsius. 84 or 85 sites or so along the SA coastline and future plans include 140 more by 2016-end.
- Different causes of these biases: atmospheric influences, reflect underlying oceanographic processes, instrumental differences, bulk vs skin, surface winds, inshore hydrodynamics, turbulence.
- Suggested that GHRSST should warn people using the data at the coastal areas.
- Coastal Temperature Network: scientific steering and technical coordination.

Charlie Barron: I have seen this problem before. If you go to near-shore region, covariance to do the assimilation doesn't acknowledge the truth. Your average tend to be biased towards open ocean. Transition from land to sea is not easy as you get incorrect wind stress. Comment: Very interesting approach and very challenging.

Sasha Ignatov: Which product has larger bias? PF (v5) up to 6, MODIS up to 3 deg Celsius. Match-up criterion ? (ans: in situ inside a pixel)

Christo: (comment): East coast and West coast have different effects. East coast Agulhas has heavy effects. Also, you compared with climatology, that might also affect the stats a bit.

Gary Corlett: How does the variability compare between sat and in situ. **AJ**: the variability in situ data is slightly higher, i.e., in situ is able to detect much more variability than satellite data.

5. Overview of ship borne radiometers – Peter Minnett

- •Showed an informative table of all known shipborne radiometers and focused on a subset.
- M-AERI: from 1996, 54 cruises of radiometers; JPL NNR – Simon Hook; ISAR- by Craig, Fred Wimmer; BESST – just entering service now (Ship or UAV)
- View of the world with radiometers: over a range of time we can sample a large environmental condition with a rather small number of radiometers. SISTER- showed continental boundaries Australia etc – don't hurt your eyes
- For climate related studies, we need to have SI-traceable calibration as Craig pointed out this morning (NIST EOS TXR). They are also used in aircrafts.
- Referred to Tim's presentation abt proposed document of GDS2.0 radiometer data.

Peter Minnett: Repository: one candidate is British Oceanographic Data center- does not have to be unique, can be mirrored.

Ken Casey: rationale for BODC is fine but we talk at DAS TAG that US NODC could be effective as well for us.

Sasha Ignatov: I'd offer to include it in iQUAM. We really appreciate the step in formulating this. Also, should the iQUAM go to NODC/ JPL as STAR is not operational.

6. Interactive discussion on GHRSST archive – led by Sasha Ignatov

Discussions from two perspectives: Data producer perspective and User perspective.

6.1. Data Producer Perspective:

Sasha Ignatov: should we send data to Ed or to Ken ?

Ken Casey: this has been done many times by many RDACS, a normal process is to send to EdArmstrong and then to NODC. Data with prospect will go through this process. There are other questions also coming up, like ESA CCI etc. some of then may not go to GDAC.

Sasha Ignatov: okay, it sounds like we coordinate with JPL and Ed Armstrong agreed and updated on the status of ACSPO VIIRS archival.

Ken Casey: coordination should be done ahead of time especially when e data volume is high.

Sasha Ignatov: the other question. We had request about L3 data. So how do we archive, do we have precedence to archive both L3 and L2 data?

Ken Casey: L3 is a new thing now. It's completely normal and reasonable to have both L2 and L3 because some users need L2 and some need L3, so both arte fine.

Sasha Ignatov: sometime users ask for customized product. E.g., Helen wants 2 km VIIRS product. So it's like two flavors of L3 VIIRS data. I am unsure how to handle these two different streams. Is it possible to create customized L3 on the fly if we provide S/W at the repository?

Ken Casey: we discussed that as a possibility but we are not doing this yet, it's not that straightforward (SSES etc issues). So for now we cannot do it on the fly.

Sasha Ignatov: several flavors of same data, e.g., OSI SAF Metop A and ACSPO MetopA, ACSPO VIIRS and NAVO VIIRS. Should we do some comparison and put ppt on JPL website.

Craig: that should be on GHRSST website.

6.2. Data User Perspective:

Sasha Ignatov: I've heard from Bruce Brasnett that JPL ftp site was twice slower as compared to NOAA. And Helen also had similar concerns. Have you guys done any study?

Ken Casey: these are anecdotal concerns and should be documented before taking concrete step.

Jorge Vazquez: do we have the tools that are needed by the users". ?

We need feedback on whether we have the right tools. How to better communicate with the users? How do we get a tool to provide the user with means to have a custom made dataset for a given region. E.g., choosing the QF and providing the custom-made data.

Craig Donlon: Where is this type of discussion captured at GHRSST?

Jorge Vazquez gave a case study where a power user does not use GHRSST data because he needs a custom cloud mask. He always asked Jorge why GHRSST does not do this.

Craig Donlon: lets capture the user requirement and bring this issue up. That's how you can do this.

Ed Armstrong: the point you hit on, (QL sub-select etc.) is a general problem for satellite data. We are working on this technology. We don't have S/W developers to attack this issue but NASA Earth Science WG promoting new technologies and we can present that and say, "GHRSST wants something like this, can you help us?".

Charlie Barron: another important issue is gradient issue. E.g., what if I want high gradient areas for fishery etc. and I want to have data only for those areas.

Gary Corlett: We will talk to our users again

Christo Whittle: the summer school was useful and positive feedback. But yet, they thought it was not easy to choose which products to use. We should have summer schools in general for SST. If you want to reach the community and young scientists, hold summer schools/trainings etc.

Alexey Kaplan: showed some objection against Summer school idea.

Charlie Barron: you are targeting young scientists but we talk about user base. It’s like teaching parents how to use cell phones.

Ken Casey: GHRSST is a coalition of the willing and not a corporation. That’s why AUS TAG is critical in collecting these User Requirements.

7. Action item/Summary of SSES:

- Strengthen the outreach (spread message, social media). Setup Twitter Feed through JPL PO.DAAC. Jorge and Ed
- Survey of users (GHRSST-PO with Jorge and Prash)
- People need help in choosing products. There are too many. (try to come up with a recipe, tutorial videos etc.)
- Seek feedback from users, such as Bjorn, on GHRSST’s SST Quality level and SSES. Incorporate into user survey.
- Seek feedback from users if they are happy with tools to deal with GHRSST data (Jorge) . Incorporate into user survey.
- Explore if it is required issuing some warning on where not to use satellite SSTs (based on AJ Smit’s talk where sat SSTs within 400m of SA coast have a warm bias). Part of guide on choosing data product.
- Further talks on repository for in situ radiometer data (as they progress).
- Collect documented evidence on ftp performance (PO.DAAC/NODC), in case of a sub-optimal connection. This will help to take concrete action. Jorge and Ed

THE CLIMATE DATA RECORDS TECHNICAL ADVISORY GROUP (CDR-TAG) BREAKOUT MEETING REPORT

Chair: Chris Merchant[1] ; Rapporteur: Jon Mittaz[1,2]

(1) University of Reading, Reading, UK, Email: c.j.merchant@reading.ac.uk
(2) National Physical Laboratory, Teddington, UK

The session started with a discussion of the attempts to implement the Climate Data Assessment Framework as a trial to assess its usability (following the agreement to do so at GHRSST-XIV). Of the three proposed datasets to be put through the CDAF process only one dataset (CCI Phase I) was actually put through the process by Gary Corlett, who presented his experience of filling out the CDAF template. In general the process was found to be fairly easy, but there were a number of entries that needed clarification in the CDAF document and more guidance was needed and would be added. Hyperlinks to relevant documents should be included.

It was then agreed that the CDAF would be updated with clarifications. In terms of the difficulty of filling out the CDAF template in general it was found to be fairly simple, although the data was well set up to calculate all the required statistics. The one part that required some thinking was the systematic uncertainty portion and there was some discussion regarding the stability calculation where it was pointed out that the stability is not a measured trend but the stability of the underlying measurement itself. In terms of the amount of time it took to fill out the template, the calculation of the required statistics took a few hours (though the CCI programme is well set up to generate such statistics) and the form filling itself took about half an hour. The possibility of pre-filling the form using met-data was raised.

Action: CM to clarify the present version of the CDAF at the points identified by GC.

Then the status of the international reprocessing efforts was reviewed. In general things are progressing for most of the projects. A few extra projects were proposed to be included such as the tools provided by the GHRSST LTSRF under Tools.

At the end of the review there was discussion around the summary slides and it was pointed out that there are four L2/L3 datasets which could be put into the CDAF process in the next year (Pathfinder, IMOS AVHRR, ACSPO-RAN and NOAA GEO reprocessing) and the relevant people would be contacted to ensure that this happens. It was also pointed out that many of the L4 datasets had a temporal length consistent with the CDAF process and it was agreed that the CDAF would be updated to include extra fields (such as feature resolution)/guidance for creating a Level 4 CDFA process, and this would be circulated when updated. The GHRSST LTSRF at NOAA NODC also said they might be able to help with generating some of the statistics using the GHRSST archive which is already resident there, which should help in the filling out of the CDAF template.

Action: JM to work with teams for Pathfinder, IMOS AVHRR, ACSPO-RAN, SST CCI and NOAA GEO reprocessing to ensure their CDAF assessments are available for review at GHRSST-XVI.

Then there was a presentation about the CORE-CLIMAX project and the update to the Maturity Matrix concept. CORE-CLIMAX is an EC Framework 7 project that is creating a system to help users understand the maturity and usability of different climate datasets. It is creating a simple colour coded matrix that can rank different climate datasets relative to several criteria to help the user compile a list of possible datasets which may be applicable to his or her application. There was discussion regarding if such a matrix should be used and if it should be up to individual scientists to make their own determination. However, it was pointed out that the intention of the CORE-CLIMAX Matrix was just to guide and help both scientists and non-scientists to order the list of climate data records to speed up their own assessment of which data record is best for them and was not intended to define which they should use. It was also pointed out that the CORE-CLIMAX model would likely be something that the GHRSST project would have to deal with in the future and this was why the CORE-CLIMAX project had been presented to the CDR-TAG at this time.

A presentation was then given on a proposed project called FIDUCEO that intends to bring metrological methods and uncertainty traceability to Level 1 datasets (with new FCDRS from Meteosat First Generation/AVHRR/HIRS/Microwave humidity sounders) and Level 2 datasets including SST, upper tropospheric humidity, surface albedo and aerosol.

Finally, the current chair of the CDR-TAG (Chris Merchant) is standing down this year and a request for nominations for both the Chair and vice-Chair were requested. The current vice-Chair (Jonathan Mittaz) has indicated that he is willing to stand as the Chair if there are no other nominations. [Post meeting note: no other nominations were received.]

The next steps for the CDR-TAG were discussed. The CDAG will be extended to be appropriate for L4 products. This involves establishing a consensus metric for feature resolution in SST analyses.

Action: CM will co-ordinate upgrading to CDAF v2, applicable also to L4 products.

THE DATA ASSEMBLY AND SYSTEMS TECHNICAL ADIVSORY GROUP (DAS-TAG) BREAKOUT MEETING REPORT

Edward Armstrong[1], Jean-François Piollé[2]

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(2) IFREMER, France, Email: Jean.Francois.Piolle@ifremer.fr

ABSTRACT

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

1. Introduction

This year the DAS-TAG session at the 15th GHRSST Science Team Meeting had a number of presentations concerned with recommendations to the GDS2 specifications to deal with complex L2 and climate data, new data formats proposed for *in situ* SST radiometers, new data management concepts based on quality/quantity/latency/continuity use cases and evolution of the GHRSST Regional/Global Task Sharing framework (R/G TS). Below is an overview and summary of each presentation.

2. L2P specifications for dual view sensors -- Anne O'Carroll

a. SLSTR on Sentinel 3 has a extended suite of SST algorithms
b. EUMETSAT originally requested extra 32 bytes/pixel (64 bytes/pixel total experimental) to implement more SST variables
c. Consensus was to keep L2P "light" for baseline product. Other five SST algorithms will be separate products with restricted access.

3. Proposal for increased GDS flexibility for climate datasets -- Owen Embury

a. SST Climate Change Initiative (CCI) outputs numerous additional variables beyond the 32 byte experimental limit for uncertainties, diurnal adjustments, SST adjusted to different depths or times
b. Group consensus was to not aggregate SST as depth in a single variable because this will lose the definition of CF standard names like sea_surface_skin_temperature
c. DAS-TAG agreed that there should be a waiver process for 64 bytes/pixel. A waiver was submitted to Advisory Council and approved (see Summary).

4. Proposal for GHRSST format for *in situ* radiometers -- Tim Nightingale

a. From an outcome of 4 workshops recommendations were developed for data and metadata formats for *in situ* radiometer data. Concerned with accessibility and standardization of radiometer data
b. GDS2 netCDF/CF/ACDD data and metadata model adapted in a 50pg document
c. Science team to recommend adoption of document after tech review by DAS-TAG
d. Where will data be accessible? NODC and Ifremer are potential homes.

5. Quality, Quantity, Continuity, Latency use cases for GHRSST data -- Ed Armstrong Dataset Lifecycle

a. Conceptual use cases for new potential tools, services, capabilities for management of GHRSST data and data streams at PO.DAAC
b. Presented 9 use cases
    i. Quality assessment: Data accuracy, completeness, usability
    ii. Metadata assessment: Completeness and veracity
    iii. Latency and Continuity: Data latency and provenance
c. Stakeholders identified for each use case: producer, user, data management operations etc.

6. Evolution of the GHRSST Regional/Global Task Sharing (R/GTS) Framework – Ken Casey

a. Reviewed current Regional/Global Task Sharing framework (R/G TS): RDACS → GDAC → LTSRF. The current data management and delivery system is not broken, but the Sentinal3 mission and others may not fit in this model.
b. New avenues of data delivery and discovery need to be investigated:
    i. Options for "virtually" consolidating GHRSST holdings to maintain the existing user expectations on completeness, integrity, and reliability
    ii. Common discovery must be maintained.
    iii. CEOS WGISS Integrated Catalog (CWIG) is one way forward. Both NOAA and NASA are already contributing.
c. New proposals beyond the R/G TS framework to be explored and developed by next GHRSST ST meeting

7. Summary

DAS-TAG applied for GDS2 revisions to Advisory Council with regard to experimental 64 bytes/pixel waiver (and minor adjustments to solar_zenith_angle and satellite_zenith_angle variables). This was approved by the AC and they agreed DAS-TAG will implement future minor revisions to GDS2. Next revision will be GDS2 release 6. DAS-TAG agreed to review *in situ* radiometer format document and will develop proposals for new concepts for the R/G TS evolution by 2015 science team meeting. Jean Francois Piolle agreed to be new chair for DAS-TAG. Ed Armstrong will remain as interim vice-chair.

THE DIURNAL VARIABILITY WORKING GROUP (DVWG) BREAKOUT MEETING REPORT

Gary A. Wick

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ABSTRACT

The Diurnal Variability Working Group (DVWG) met during a breakout session for 2-hours on the morning of Wednesday, 4 June. The session consisted of three brief presentations by group members and discussion of priority group activities, potential intersession activities, and group leadership. Gary Wick chaired the meeting for Carol Anne Clayson who was unable to attend.

1. Brief Presentations

Three short presentations were given by group members updating on key areas of progress over the past year. An additional planned "around-the-room" session to give other members a chance to briefly state their current activities did not occur due to insufficient time.

The first presentation entitled "An Analysis System for Diurnal Sea Surface Temperature" was given by Jonah Roberts-Jones on behalf of James While who is leading the activities. The presentation described initial work at the Met Office to produce an analysis of diurnal variations in skin and subskin SST. The project would produce ~3 hourly SST analyses to complement existing foundation SST products. The system incorporates models for the cool skin (Artale et al., 2002) and warm layer (Takaya, 2010) along with observations of diurnal warming and data assimilation. Preliminary results from the models forced with numerical weather prediction inputs were shown and compared with available observations. Observations are employed from available infrared satellite data. The diurnal warming observations are computed as the difference between the SST observation and a foundation estimate where the foundation product is derived for each sensor using an OSTIA-like system. Assimilation of the observations is performed using a 4D Var approach. An example of the analyzed peak diurnal SST from the presentation is shown in Figure 1. It was emphasized that the current work is still preliminary and much remains to be done. Discussion following the presentation suggested that the resulting analysis could potentially be used to validate modeled wind fields.

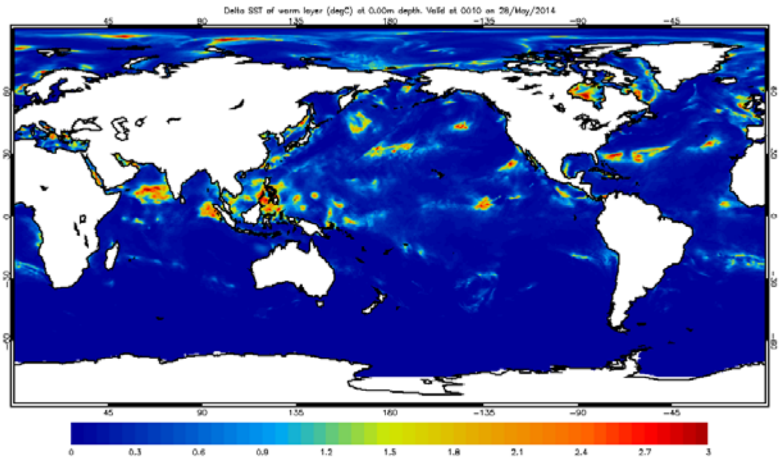

Figure 1: Peak analysed warm layer temperature on 29/5/14 taken from presentation of While et al.

The second presentation was given by Ioanna Karagali on the regional extent of observations of diurnal variability as derived from SEVIRI. The work from this presentation is one component of a larger project for

Ioanna. Additional modeling activities were presented in the Thursday plenary session. The first portion of the presentation reviewed test foundation SST fields from SEVIRI following up on a presentation given at last year's meeting. Results were shown next for monthly mean warming and occurrence of large events in excess of 1 K. Discussion highlighted the lack of observed extreme warming in the tropical Atlantic where low wind speeds suggest more might be expected. Final results included graphics on annual distributions of diurnal warming and typical timing of the diurnal cycle for different regions within the SEVIRI domain. A paper is currently available in Ocean Sciences Discussions on these results.

The third presentation was given by Jon Mittaz describing the work he has led on the conversion of a version of the Kantha-Clayson diurnal warming model into a form suitable for operational use within NOAA NESDIS. The model is to be used to adjust SST observations with diurnal warming present to a "foundation" value for use in the NOAA NESDIS blended GOES-POES SST analysis. The model has been re-coded in F90 and ~2.5 times speed improvements have been achieved. Through the code conversion and testing some features (bugs) were identified in its extension for application to global grids. The impact was on a very small number of points but was not insignificant. A significant impact was also shown for running the code in double as opposed to single precision.

2. DVWG Priority Activities

Group discussion focused on priority activities for the group and potential intersession meetings.

A key activity to be followed up on is a dedicated experiment with Argo floats with Iridium communication capabilities. During the DVWG breakout at GHRSST XIV, an opportunity for developing a an experiment to reprogram a float or floats for a period of 3-5 days to study diurnal variability was discussed. This opportunity has not yet been fully achieved and it was agreed that the DVWG still wanted to pursue this activity. A subgroup was formed to coordinate planning. Carol Anne Clayson was nominated (in her absence) to lead this task and additional volunteers included Ioanna Karagali, Sandra Castro, and Gary Wick.

Discussion emphasized that one of the key services the DVWG can provide to GHRSST is recommendations on what diurnal warming models to use and their associated limitations and uncertainties. Diurnal warming model evaluations and intercomparisons are underway and should continue. Gary Wick volunteered to be a focal point for these activities and interested participants included Chris Merchant, Sandra Castro, Ioanna Karagali, and David Poulter.

Analyses of diurnally resolved SST are beginning to emerge (as evidenced by the presentation from the Met Office) and are a valuable addition to the GHRSST product suite. The DVWG agrees to promote their development. Broader intercomparison and evaluation activities may be desirable at some future point.

Discussion also highlighted issues with use of the concept of the foundation temperature, particularly in high latitude regions during the summer season. While a useful concept, the quantity is hard to directly measure in practice. At high latitudes where the sun is up nearly continuously, warming can continue for multiple days and a foundation value is hard to define. While outside the direct purview of the group, the DVWG recommended that discussions continue within GHRSST on use of the foundation temperature. Reference to SST values at a specific depth (e.g. drifting buoy depth) might be more useful in practice.

Opportunities for some sort of formal intersession meeting were discussed. While more formal interaction with L4 producers on use of diurnal warming information was viewed as valuable, there was not sufficient interest to justify scheduling a formal meeting. Better communication amongst the group will be emphasized during the coming year. An informal meeting of those involved with diurnal warming model evaluation activities may be attempted depending on how work progresses and travel opportunities.

Following the presentation of the breakout session during the Friday plenary session Craig Donlon noted that the DVWG should take a more active role in interacting and providing feedback to the drifting buoy and Argo community. While such interactions have occurred in the past, it is important that those groups continue to receive feedback on the value of their observations to DVWG activities to ensure continued collaboration and responsiveness in the future.

3. Group Leadership

Gary Wick advised that Carol Anne Clayson had officially taken over as chair of the DVWG during the past year. While Gary has been serving informally as vice-chair in the interim, he noted that his current commitments were such that he could not likely continue efficiently in this role and a new vice-chair should formally be elected. Nominations were solicited from those in attendance at the breakout but none were provided during the meeting. The nominations remain open and the position will be filled through remote election during the intersessional period.

THE ESTIMATION AND RETRIEVALS WORKING GROUP (EARWIG) BREAKOUT MEETING REPORT

Chair: Andy Harris[(1)], Rapporteur: Owen Embury[(2)]

(1) Earth System Science Interdisciplinary Center, University of Maryland, College Park, USA, Email: Andy.Harris@noaa.gov
(2) Department of Meteorology, University of Reading, UK, Email: o.embury@reading.ac.uk

1. Introduction

The breakout included three presentations on SST retrieval, and a discussion of a workshop on seasonal biases to be held April 2015.

2. Regional biases in operational SST retrieval – Pierre Le Borgne

Pierre presented the operational SST retrieval method used at Météo-France. They use a NLSST formulation to retrieve the SST, then estimate the retrieval bias by applying the retrieval to simulated BTs from a forward model (RTTOV) driven by NWP fields. After subtracting the simulated retrieval bias from the initial SST the final SST estimate shows very little regional variation. This method has been used operationally for the geostationary satellites for some time and has recently been under testing for Metop AVHRR.

The Meteo-France processing scheme also includes a radiance bias correction step. This is especially important for Meteosat-10 where the 3.9 µm channel shows large simulation – observation differences.

Q Has the cause of the biases been investigated?

A No, priority has been to remove biases

Q Have you compared the biases with GSICS work?

A Yes, they are broadly consistent. But haven't tried applying the GSICS adjustment up front.

Q Do the forward model simulations include aerosol?

A No, current simulations are clear-sky only. Including aerosol may improve simulation-observation agreement off Africa and Australia where the simulated bias is warmed than the observed bias

Q Are the forward model simulations time consuming?

A No. In the Metop prototype the RTTOV model was run for every pixel but did not account for the majority of the processing time (~3 minutes per granule) so further optimizations were not required.

3. Information content analysis for physical SST retrieval – Prabhat Koner

Prabhat presented a brief overview of physical retrieval methods, an information content analysis, and a short comparison of two physical retrieval methods: Modified Total Least Squares (MTLS) and Optimal Estimation Method (OEM) applied to GOES-13 and MTSAT. For the two sensors considered the OEM performed badly, with the OEM retrieved SST being of lower quality (higher error) then the first guess, while MTLS was effective in these tests.

Q Does this method include radiance bias correction?

A No, radiance bias correction is not required. MTLS includes a regularization parameter which depends on the difference between observations and first-guess simulations. In effect, when the first guess was good the MTLS will return the first guess without adding any instrument noise. In cases where the first guess was wrong, MTLS will use the observations to return an improved SST.

Q Chris Merchant implemented the MTLS and could not reproduce the results (bias-corrected OEM appeared to perform slightly better than MTLS)?

A Evidence for an incomplete expression for MTLS regularization in Merchant presentation at EarthNet Arctic SST Workshop (https://wiki.met.no/_media/arctic-sst/meetings/arctic-sst-earthtemp-merchant.pdf) - missing normalization by L2-norm of residual. We need to compare implementations.

Q Is there a systematic way to determine the regularization expression?

A Not yet. The regularization expression may be expected to include appropriate terms such as exponential or logarithms

Q The results here show MTLS produces a lower RMSE which is the desired outcome in many situations, but is it appropriate for climate where low bias and independence from the *a priori* are more important

A As the regularization is based on the departure from the first guess it only returns close to *a prior*i in cases where it was a correct guess.

4. Cloud Detection Verification – Prabhat Koner

Prabhat presented a short comparison of the Bayesian cloud mask implemented for geostationary satellites at NOAA against a new cloud mask based on dynamic thresholds. The new cloud mask resulted in 50% more coverage while increasing the amount of cloud detected. Including radiance bias correction (RBC) resulted in a significant decrease in SST retrieval skill.

Q Is this an instrumentation issue – the effect may correspond to the switch between MTSAT 1 and 2.

5. Proposed EARWiG Workshop – Owen Embury

Owen proposed an EARWiG workshop to investigate seasonal biases in SST retrievals. Many SST retrievals show evidence of seasonal biases which is often seen in plots of satellite – L4 analyses differences (see Figure 1 for example). Similar bias patterns are produced from simulations indicating that physical retrievals or bias correcting methods should help. However, biases may also exist in the L4 analyses as comparisons of IR and MW SSTs do not show the same seasonal biases. A workshop will be held in April 2015 at the University of Reading to investigate causes and corrections for seasonal biases.

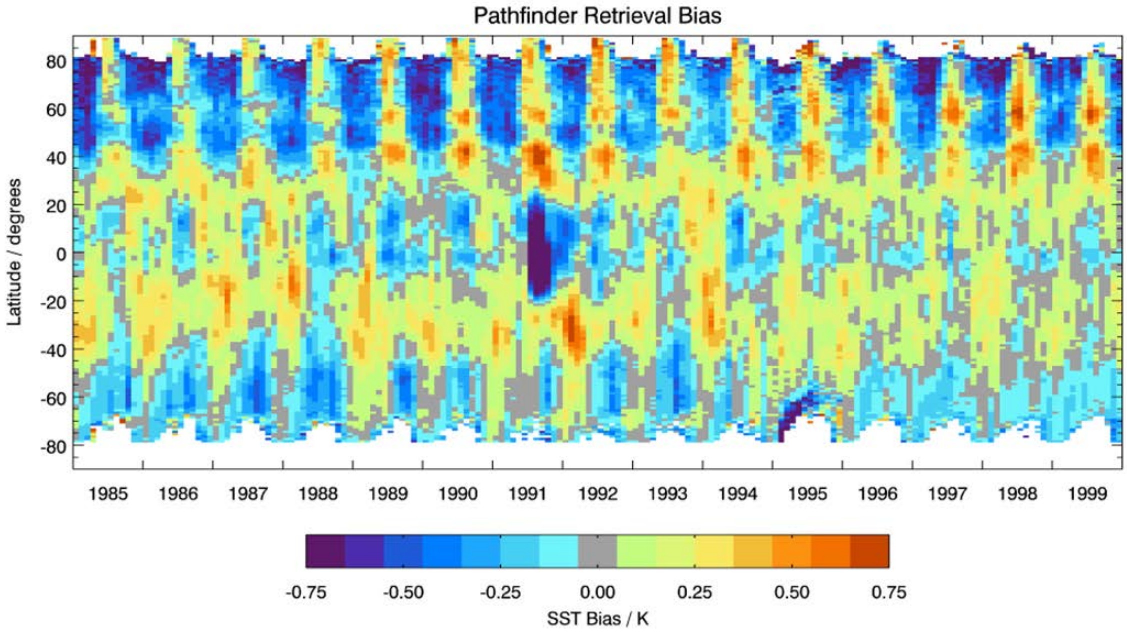

Figure 1: Pathfinder v5 - Daily OI ¼ ° SST different. Seasonal cycle in difference is present in both hemispheres, Pinatubo aerosol in 1991 causes a large cold bias.

THE HIGH LATITUDE TECHNICAL ADVISORY GROUP (HL-TAG) BREAKOUT MEETING REPORT

Prepared by Jacob L. Høyer[(1)], on behalf of the HL-TAG[2]

(1) Centre for Ocean and Ice (COI), Danish Meteorological Institute (DMI), Email: jlh@dmi.dk

(2) Current members of the HL-TAG: Robert Grumbine (Chair), Jacob L. Høyer (co-chair), Andy Harris, Anne O'carroll, Chelle Gentemann,, Christopher Merchant, Emma Fiedler, Helen Beggs, Leon Majewski, Nick Rayner, Peter Minnett, Sonia Peré, Steinar Eastwood, Fred Wimmer, Alex Ignatov, Sandra Castro, Owen Embury, Martin Lange.

1. Introduction

In the absence of Bob Grumbine, Jacob Høyer was leading the HL-TAG breakout meeting. The agenda for the 2 hour meeting was:

- Diurnal warming in Lake Vänern, using GOTM — Pierre Le Borgne
- VIIRS algorithm performance at high latitudes — Sasha Ignatov
- Temporal Sea ice Cover in the Baltic Sea — Martin Lange
- Sea ICE GMPE – Definitions and development — Steinar Eastwood
- Review of the HL-TAG — All

2. Report from the presentations

2.1. Diurnal warming in Lake Vänern, using GOTM

Pierre Le Borgne presented recent results from Météo France, where the 1-d ocean turbulence model, GOTM has been applied to Lake Vaenern in Sweden. The figure below shows examples of modeled and observed temperature variations in the upper meters of the ocean.

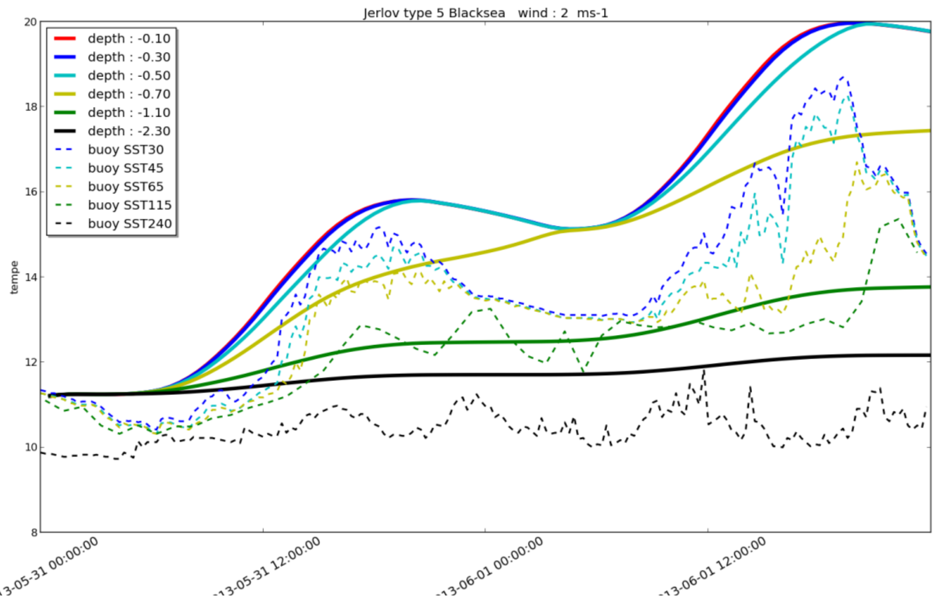

Figure 1: Observed (dashed) and modeled ocean temperature from Lake Vaener at different depths.

The main conclusions from the talk are:

- This was the first attempt using raw ECMWF outputs. They depend on the light extinction coefficient profiles
- The amplitude of the temperature at 30cm is very sensitive to wind values between 1 and 3 m/s
- Increasing absorption in surface layers (0-1 m) leads to unrealistic vertical temperature gradients (and amplitudes)
- The light extinction with depth in the first meter (code & local conditions) must be further investigated
- Future work will include the application of fine resolution Hirlam outputs

2.2. VIIRS algorithm performance at high latitudes

Sasha Ignatov gave a presentation on the performance of the ASCPO VIIRS product, with special emphasis on the high latitude performance. The conclusions from the talk are listed below:

- ACSPO VIIRS provides superior coverage at high latitudes
- Including the data in a level 4 analysis gives a positive impact on the L4 product from CMC
- Maybe tendency to cold bias in Arctic, when the ASCPO VIIRS product is compared against buoy observations
- However, statistically significant validation at HL remains challenging, due to limited in situ data

2.3. Temporal Sea ice Cover in the Baltic Sea

Martin Lange reported on a comparison he has made on different sea ice products. As the Ocean atmosphere fluxes changes drastically with an ice cover, he was looking towards improving the NWP products using global sea ice masks. As a first step, an intercomparison was performed during winter 2012/2013 in the Baltic Sea, between the operational products of operational sea ice products from BSH, Ostia data (OSI-Saf) and the NCEP product. He found some temporally large jumps in the ice concentration from OSI-SAF and NCEP. The figure below shows the different products over the same region.

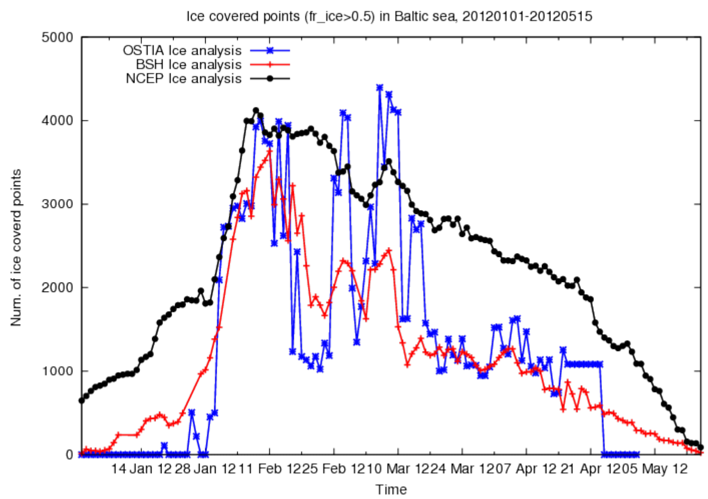

Figure 2: Ice covered area in the Baltic Sea for the OSI-SAF (OSTIA), the BSH and the NCEP sea ice concentration products during the winter 2012.

The cause of these large jumps was discussed, concluding that it was due to land contamination effects in the passive microwave data. There was consensus that the OSI-SAF and NCEP global product could be improved in Coastal and enclosed seas by including information from regional high resolution sea ice products

2.4. Sea ICE GMPE – Definitions and development

In relation to the previous talk, Steinar Eastwood led the discussion on setting up an intercomparison site for different sea ice products. This is a topic that has been debated for some time within the HL-TAG. In order to speed up the progress, a subgroup was established, consisting of:

- Steinar Eastwood (lead)
- Bob Grumbine
- Jacob Høyer
- Martin Lange
- Sandra Castro
- Sasha Ignatov

The task of the group will be to:

- Establish the requirements
- Define a common grid and regridding tools
- Define comparison statistics
- Determine how to display the results

A report on the progress of the subgroup will be given on GHRSST 16 science team meeting

3. Discussion on the purpose of the HL TAG

The high latitude TAG is a group with about 20 members but the number of active members working with high latitude SST issues is closer to 5, where most of these come from Europe. In addition to the little intrasessional activity within the HL-TAG group, Jacob led the discussion about the relevance of the HL-TAG. The discussion also included a review of the terms of reference. There was general consensus that the terms of reference still was applicable to the work in the group and that the main problems were still to be solved. Despite the overlap with several of the other groups, it was agreed that having a HL-TAG group hels in putting the high latitude challenges in focus. Several members asked for the intersessional communication to be increased within the group should through teleconferences. For the coming year, the Sea Ice GMPE collaboration, which includes people from several continents, is a first step towards increased communication and collaboration.

THE INTER COMPARISON TECHNICAL ADVISORY GROUP (IC-TAG) BREAKOUT MEETING REPORT

Chair: Alexey Kaplan[1], Vice-Chair: T. Mike Chin[2]

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(2) Jet Propulsion Laboratory, California Institute of Technology, 2800 Oak Grove, Pasadena, CA 91109, USA, Email: toshio.m.chin@jpl.nasa.gov

1. Membership Update

It was noted with deep sadness that Dr. David G. Foley of NOAA and University of California at Santa Cruz, who joined the IC-TAG group at the previous GHRSST Science Team meeting (G14), has passed away on December 8, 2013. In Dave Foley IC-TAG lost a valuable colleague.

2. Update of the IC-TAG Terms of Reference

First item in the IC-TAG Terms of Reference lists existing inter-comparison systems on which the group should focus their efforts for inter-comparing L4 SST products. However, the High Resolution Diagnostic Data Set (**HRDDS**) became defunct and is being replaced by a new, more advanced system **Felyx** (developed by David Poulter on a project funded by the ESA and lead by Jean-François Piollé). Therefore the first item of the Terms of References has been edited to read:

> "1.To coordinate existing inter-comparison activities for L4 analyses within GHRSST, including the GHRSST Multi-Product Ensemble (**GMPE**), and the comparison of L4 analyses and lower level data including the SST Quality Monitor (**SQUAM**), and the advanced data stream monitoring system called **Felyx**. "

3. Talks and discussion on inter-comparison of L4 SST products and their validation

This part of the session contained four formal 10-minute presentations that engendered a lively discussion:

> *"REMO SST GROUP: Status & Updates"* by ***Gutemberg Franca,***
>
> *"Validation of Sea Surface Temperature Analyses in the Arctic Ocean Using UpTempO Buoys"* by ***Sandra Castro,***
>
> "*A Review on the Application of High Resolution SSTs in a Coastal Upwelling Region: The test case off Peru* by ***Jorge Vazquez***,
>
> *"An intercomparison of long-term SST reanalyses using the GHRSST multi-product ensemble (GMPE) system*" by ***Jonah Roberts-Jones.***

G. França presented an update on the activities of his group related to the Barnes interpolation scheme merging together several SST data sources to generate a regional analysis field (REMO SST). Comparisons between interpolated daily SST fields and *in situ* SST measurements were performed. When the coastal upwelling regime set up near Brazilian coast in January – February 2014, striking differences exceeding 4^{o}C occurred between REMO SST and the IEAPM buoy moored at 22.994^{o}S and 42.187^{o}W, 7km from the coast. OSTIA values showed essentially the same differences from these buoy data. These biases in L4 products during the coastal upwelling periods were traced to L2 and L3 products that were used as the input data for the L4 products' respective interpolation schemes. SST values from SEVIRI, GOES-13, NOAA-18, and NOAA-19 all were warmer by about 4^{o}C than the buoy SST during the upwelling period in January and February 2014.

A similar problem (warm satellite SST bias occurring during the coastal upwelling regime) has been observed by Albertus Smit in his presentation at the AUS-TAG breakout session. Irina Gladkova and David Poulter offered a possible explanation: too conservative a cloud mask could be removing all data pixels with upwelled water, thus leaving in the L2 products only warm water temperatures from places nearby where the upwelling was not occurring at the time.

While the L2 data error is not really the IC-TAG domain, these biases probably were observed especially clearly because of the visualization ease that L4 products provide. Therefore a **suggested action** was formulated**:** for G.Franca to provide details (the actual data granules used, buoy temperature values, etc.) to I.Gladkova and D.Poulter, and discuss them in order to substantiate the explanation for these biases. Having done that, the problem could be referred to the ST-VAL WG or EaRWiG.

The following three talks directly informed the discussion of the main focus of this session: answering a user's question "Which SST data set should I use?" S.Castro used Taylor diagrams and other skill scores w.r.t. Arctic UptempO buoy observations to evaluate L4 SST products, since these observations are not used in the presently available L4 SST products. J.Vazquez evaluated the reality of high magnitudes of SST gradients in high-resolution L4 products by comparing of SST gradient magnitudes derived from 2km ECCO2 model simulations and two L4 SST products of vastly different resolution: 1km MUR and 0.25^{o} NCDC. J.Roberts-Jones used GMPE, Argo floats, and feature resolution evaluation to inter-compare L4 products. When the statistics or ranking of different L4 products with respect to these different criteria are put together into the same table, it can give a user an idea of relative performance of SST products in various respects. However, neither these performance measures nor their ranks are intended to be summed up and used as an overall "score" inter-comparing L4 products in any "universal" way. Instead, the goal should be to identify the most suitable product to a given user's need, based on the criteria that are most important for the user's proposed application.

In the discussion that followed, it was concluded that to help answering a user's question "Which SST data set should I use?" IC-TAG should collect on a single webpage:

(1) Tables with the formal description of L4 products, like the updatable versions of those that were published in the 2012 two-part GMPE-SQUAM paper (Martin et al., 2012; Dash et al., 2012);

(2) Links to papers like these and presentations like those given in this IC-TAG breakout session;

(3) Tables with actual comparisons of data sets with ARGO floats, like GMPE currently presents, for global and regional statistics (i.e., mean bias and std). The statistics should be given as averages over different periods of time (no less than a few months), and should be updatable;

(4) Some simple examples of possible users' reasoning, while perusing these materials, towards selecting L4 products that are adequate to their purposes.

4. References

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THE SATELLITE SEA SURFACE TEMPERATURE VALIDATION GROUP (ST-VAL) BREAKOUT MEETING REPORT

Pransanjit Dash[1], Helen Beggs[2] and Pierre LeBorgne[3]

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ABSTRACT

The Satellite SST Validation Technical Advisory Group met for two hours during the 15th GHRSST Science Team Meeting in Cape Town on the 3rd June 2014. Themes of presentation and discussions were:

- Advances in satellite SST Validation over the past year
- Sensor Specific Error Statistics (SSES) Methods from various producers of GHRSST level 2 and level 3 SST products
- In Situ SST data for satellite validation

1. Introduction

The meeting was chaired by ST-VAL Deputy Chair, Dr Pierre Le Borgne, with the ST-VAL Chair, Dr Helen Beggs, participating via teleconferencing. The session was rapporteured by Dr Prasanjit Dash. The agenda followed during the meeting was:

Overview of ST-VAL activities since GHRSST-XIV (Pierre Le Borgne)

Validation

- Monitoring and Validation of HR L2 SSTs in SQUAM (Prasanjit Dash)
- Questions/discussion on validation

SSES Methods

- ABoM SSES (Chris Griffin - via telecon)
- NOAA/STAR SSES (Boris Petrenko)
- MODIS/VIIRS SSES Hypercube (Peter Minnett)
- IASI SSES (Anne O'Carroll)
- OSI-SAF SSES (Pierre LeBorgne)
- Discussion on SSES

In Situ Data for Validation

- Fiducial Reference Measurements for Thermal Infrared Satellite Validation (FRM4-CEOS) - Craig Donlon
- Shipborne Radiometer data format and common repository - Tim Nightingale
- Discussion on in situ data

Election of new ST-VAL Deputy Chair

All presentations are available for download from https://www.ghrsst.org/documents/q/category/ghrsst-science-team-meetings/grsst-xv-cape-town-south-africa/g-xv-presentations/tuesday-3rd-june-2014/stval/.

2. Satellite SST Validation

Monitoring and Validation of High Resolution Level 2 SSTs in HR-SQUAM (Prasanjit Dash):

- Presented monthly validation of 11 HR SSTs against drifters including VIIRS and ARC
- Sensitivity to space-time window in matchups: 20 km/hr, 10 km/hr, 5 km/hr – not very sensitive on a global scale (except # of matchups)
- Many L2 products show high correlation among their residuals, esp. same sensors but different processors. This should be considered by L4 producers in their assimilation to reduce redundant inputs.

No major concerns or action items. Seems straightforward.

3. Sensor Specific Error Statistics (SSES) Methods

ABoM AVHRR SSES (Chris Griffin):

- Quality Levels = f(proximity to cloud)
- Adaptive error statistics: Uses rolling 1 year window adjusted every 1 to 6 days. Smoothly varying bias and S.D. inc at edges of swaths. SSES model = f(swath cpt, geographic cpt)
- SSES (swath component) = f(sat zen angle, time of day, QL)
- SSES (geographic component) = f(lat, lon, time, QL)
- Modelled bias and SD considered against binned in situ measurements.

Chris Merchant: Had an issue with SSES: quality level should not be correlated to uncertainty estimate. They should be more independent.

Peter Minnett agrees and thinks SSES needs to be revisited. What is the right way of conveying?

Craig Donlon: Practical and Pragmatic way.

ACSPO SSES (Boris Petrenko):

- Quality Levels = f(clear sky values)
- SSES (bias, S.D.) = f(sat zen angle, TPW)
- Future SSES: account for other factors, eg. Aerosol, coastal proximity, ambient cloud, calibration

Sasha Ignatov: mentioned "we need feedback from L4 community and currently there is a disconnect. Many users use QL.

Bruce Brasnett: did not find any added value in ACSPO SSES and found it not to be of any use."

Craig Donlon mentioned "it was formulated to link quality to in situ data in a pragmatic way". There is a need to do something more forcefully – this is not just in context of ST VAL".

MODIS/VIIRS SSES Hypercube (Peter Minnett):

- Currently only for MODIS
- Hypercube SSES = f(lat, season, sat zen angle, etc) on a pixel-by-pixel basis
- Stable statistics require about > 150 matchups per cell
- Future: exploring "functional dependencies" to avoid step changes in cell boundaries

Pierre Le Borgne: mentioned about receiving complaints from users that there is a discontinuity in QL and liked **Peter Minnett's** suggestion to explore continuous/functional SSES.

IASI SSES (Anne O'Carroll):

- Quality Level: based on binned TPWV from IASI L2 sounding data (0 to 5). Usable quality starts from QL = 2. Documentation can be found in the EUMETSAT web site – updated v5.2.3
- March 2013: SSES redefined to be in line with OSI-SAF QL definitions.
- SST uncertainty derived from 1D-VAR.
- IASI Version 6 this summer.

Craig Donlon raised the question whether ST-VAL ever defined QL.

Pierre LeBorgne said: "we have tried several times when Andy was trying to find the proper words. That all led to nowhere. Then we tried a quantitative way like Anne did. This is also relative to sensors and one cannot have a uniform approach.

Peter Minnett: Pierre's comment that it's specific to specific sensor is exactly right. So it may not be useful to have something generalized, may become vague.

Chris Merchant: That gives rise to another confusion. All (cloud masks, etc) are all correlated. So what QL really tells about? "About uncertainty" or "how confident we are about our uncertainties"?

Craig Donlon: QL is more related to the process. The problem is how people use QF as there is no specification.

Andy Harris: One could use just SSES (and not QL). If you want a continuous characterization, use SSES – quality flags are going to change with time.

OSI-SAF SSES (Pierre Le Borgne):

- Two axes related to cloudiness and algorithm.
- Two risk factors and QL are mapped into the two axes to get numerical value for SSES

Pierre LeBorgne: "It was not meant as the definition of SSES but was a pragmatic way". We have two visions for SSES: (a) based on MDB (b) as Chris said

Chris Merchant: "Should uncertainty be related to QL? Huge uncertainty can still be of best quality.

Sasha Ignatov: QF and Q Indicator. E.g., when QL is linked to latitude, it is not a good idea as we end up throwing away data. How to decouple continuous from discontinuous factors is the questions.

Craig Donlon: How many people model in a functional form their uncertainty will be interesting.

Chris Merchant: Error retrieval schemes and propagation of error.

Alexey Kaplan: Fitting functional form is interesting for research but not necessarily useful for error modeling. Everybody now is discussing on how to model error but Pierre asked "how to avoid discontinuity in the QL". One could interpolate between centers of bins and create a continuous number range and avoid discontinuity (Multilinear interpolation). But Pierre said this will create problem between highly populated and thinly populate bins and also at edges. But, "people who complaint about discontinuity do not understand the details, so once we fix this, they will complain about something else.

Pierre LeBorgne: "we have to decouple in our mind QL and SSES. We have to get rid of binning to get continuous definition of errors. That would be a step forward and after that we can give an error level"

Action item/Summary of SSES:

- - SSES needs to be re-visited – open focused discussion when appropriate
- - SSES and QL should be de-coupled
- - QL also should be more continuous rather than a step function

SSES Discussion:

- Many L4 users use QL in preference to SSES as find little or no added value from SSES (Note: NAVOCEANO sses_bias has been very useful for BoM systems)
- It is difficult to have a uniform approach to defining QL as sensor specific
- QL related to data processing (such as cloud identification) whereas SSES may be better for L4 producers to use as SSES will change in time with sensor quality
- Q) Should SSES be related to QL? Huge uncertainty can still be of best quality (ie. clear of cloud)

Action Items/Summary of SSES:

- SSES need to be revisited – open focused discussion when appropriate
- SSES and QL need to be de-coupled
- QL should be more continuous rather than a step function

4. In Situ SST Data for Satellite Validation

Fiducial Reference Measurements for Thermal Infrared Satellite Validation (FRM4-CEOS) – Craig Donlon:

- Fiducial Reference Measurements are a suite of independent ground measurements that provide the maximum ROI by delivering to users the required confidence in data products, in the form of independent validation results and satellite uncertainty estimates, over the entire end-to-end duration of the satellite mission
- All FRMs must be traceable to SI standards

Discussion:

- Within a certain time scale sensors can be traceable but degrade with time
- Drifters though not traceable give a great distributed reference
- Not all drifters degrade equally – not a straight forward issue

Chris Merchant: "I'm not sure that it is right to say that in situ should be traceable to SI. Within a certain time scale things could be traceable but degrade with time.

Jon Mittaz: "I think is almost a language issue".

Craig Donlon: "yes, but a critical one".

Jon Mittaz: "It's okay to have a traceable number with huge error ? People at NPL say: "there are times when you don't know uncertainty so you put a threshold"… so I don't think it's true that metrological organization would object. There is an element of educating".

Craig Donlon: "So far, they object".

Chris Merchant: "Drifters even not traceable give a great distributed reference". **Craig**: but we see buoys degrade.

Peter Minnett: (comment): "not all drifters are created equal and not all degrade equal. Also depends on how it is built, where its deployed. So it's not so straight forward an issue.

Shipborne Radiometer data format and common repository – Werenfrid Wimmer and Tim Nightingale:

- Objective: Develop a common radiometer data format
- Proposal: A GHRSST shipborne radiometer format (L2i)
- Feedback sought on draft L2i format document (email Tim Nightingale)

Sasha Ignatov: offered to archive L2i radiometer data as part of iQuam

Craig Donlon: suggested that BUFR tables should be used for non-radiometer in situ SST data as require data to be in BUFR format for GTS

Action items/Summary of In Situ Data for Validation:

- “Fiducial Reference Measurement” is a new terminology to attract government funding as “in situ” creates some resistance

Action ST-VAL/15/1: Those who are interested obtain the L2i GDS2.0 document from Tim Nightingale and provide feedback.

Action ST-VAL/15/2: Where to host the radiometer data is not finalised – follow-up in the next ST-VAL meeting

5. Election of new Deputy Chair of ST-VAL TAG

Dr Pierre Le Borgne’s impending retirement from Météo-France and the GHRSST Science Team meant that it was necessary to elect a new Deputy Chair of the ST-VAL TAG. One nomination was received by Pierre Le Borgne, being Dr Werenfrid Wimmer. Dr Wimmer was therefore elected unopposed.

ABSTRACTS

WHICH VIIRS PRODUCT TO USE? NOAA ACSPO VS. NAVOCEANO SEATEMP

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ABSTRACT

The Suomi-NPP satellite, launched in October 2011 with the VIIRS instrument onboard, serves as a bridge mission from POES/EOS towards the JPSS. The NOAA JPSS SST team is tasked to generate SST products meeting or exceeding the mission specifications. This paper discusses and compares two operational VIIRS SST products, produced by the NOAA Advanced Clear-Sky Processor for Oceans (ACSPO) and the NAVOCEANO SEATEMP systems. The third product generated by the Interface Data Processing Segment (IDPS) system will be discontinued in the future, but it is also included in the comparisons for completeness. Relative merits and performances of these VIIRS SST products are provided to assist users in choosing a product suitable for their intended applications.

1. Introduction

A set of three VIIRS SST products – from ACSPO (Petrenko *et al.*, 2010), NAVOCEANO and IDPS – are monitored in the high-resolution (HR) module of SQUAM (Dash *et al.*, 2010), along with ACSPO products from NOAA-16, -18, -19 and Metop-A and -B AVHRRs, Aqua and Terra MODIS, and O&SI SAF SST from Metop-A. Radiances in VIIRS SST bands have been sufficiently stable since January 2012 and are consistent with AVHRR and MODIS radiances in similar bands (Liang and Ignatov, 2013). SSTs from VIIRS have gradually stabilized and are generally consistent with SSTs from other sensors. The availability of several SST sensors in orbit (five AVHRRs, two MODIS, and VIIRS) assists in consistency checks and product improvements. Comparisons with other non-VIIRS products are available online at *http://www.star.nesdis.noaa.gov/sod/sst/squam/HR/*.

The status of two operational VIIRS SST products, ACSPO and NAVOCEANO, along with the IDPS that is being phased out, is discussed. Employing established SQUAM metrics, these L2 VIIRS SSTs, along with other HR SSTs, are inter-compared to assess their relative performances using several daily L4 gap-free SSTs (OSTIA, Reynolds, CMC) and quality controlled *in situ* data from *iQuam* (*Xu and Ignatov, 2014*).

2. VIIRS SST products: IDPS, ACSPO, NAVOCEANO

2.1 NOAA/NGAS IDPS

The IDPS VIIRS SST system was developed by Northrop Grumman Aerospace Systems (NGAS) and the ownership has been transferred to NOAA.

2.2 NOAA ACSPO

The ACSPO system is the NOAA heritage SST system. Experimental SST products for S-NPP VIIRS and Terra/Aqua MODIS have been generated since early 2012, and ACSPO VIIRS became operational in March, 2014. The SSTs are reported in native spatial resolution (~ 0.75 km) and in the full satellite swath. In January, 2014, ACSPO was designated as the official JPSS SST product.

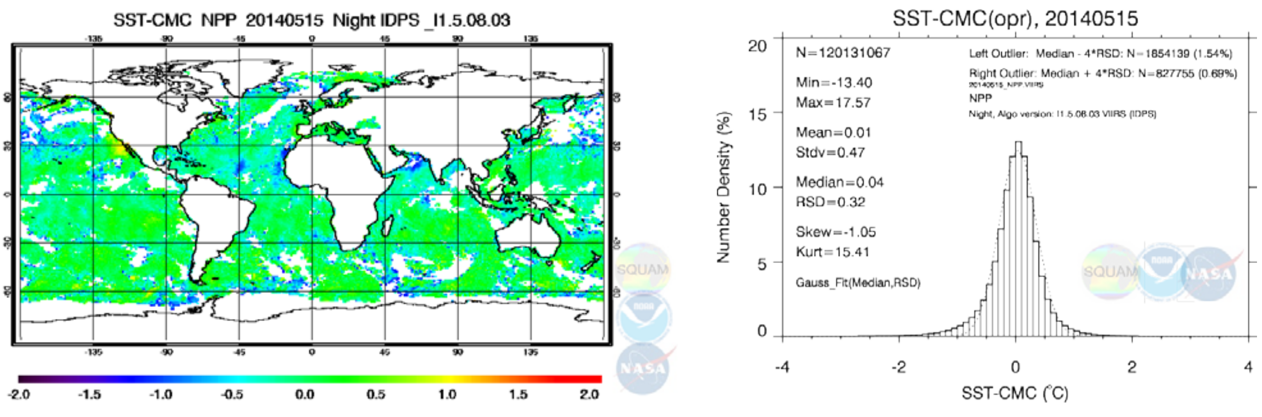
2.3 NAVOCEANO SEATEMP

The NAVOCEANO VIIRS system builds upon the NOAA AVHRR pre-ACSPO heritage, transitioned to NAVO in mid-1990. NAVOCEANO VIIRS SST became operational in May, 2013. The NAVOCEANO SSTs are processed in 2x2 arrays and are reported at a reduced spatial resolution (~ 1.50 km) and within a limited satellite swath of less than 54° view zenith angle.

3. Monitoring of VIIRS SSTs in HR-SQUAM

The SQUAM system checks satellite products for self- and cross-consistency. Analyzed are the differences between satellite (T_S) and reference SSTs (T_R), $\Delta T_S = T_S - T_R$. Several different reference fields (T_R) are used, including gap-free Level 4 (L4) analysis fields (Reynolds, CMC, OSTIA) and quality controlled *in situ* measurements (drifters, moorings and ships). Monitoring is performed daily, using a pre-defined diagnostic-set: ***Maps*** (spatial distribution of ΔT_S), ***Histograms*** (probability density function, PDF, of ΔT_S), ***Time-series*** of statistical parameters (viewgraphs), ***Dependence*** of ΔT_S on geophysical conditions (daily) and the corresponding time-series in ***Hovmöller*** space.

Figure 1 shows an example of maps and histograms for ACSPO, NAVOCEANO and IDPS VIIRS SSTs on 15-May-2014, compared against L4 gap-free CMC field. Maps are used to check global L2 products for their coverage as well as possible cold anomalies indicating leaked cloud and/or unaccounted aerosols. The related histograms of ΔT_S (right panel) check for proximity to a Gaussian shape. The annotated parameters are trended in time to check for stability of products and to evaluate their relative performances.



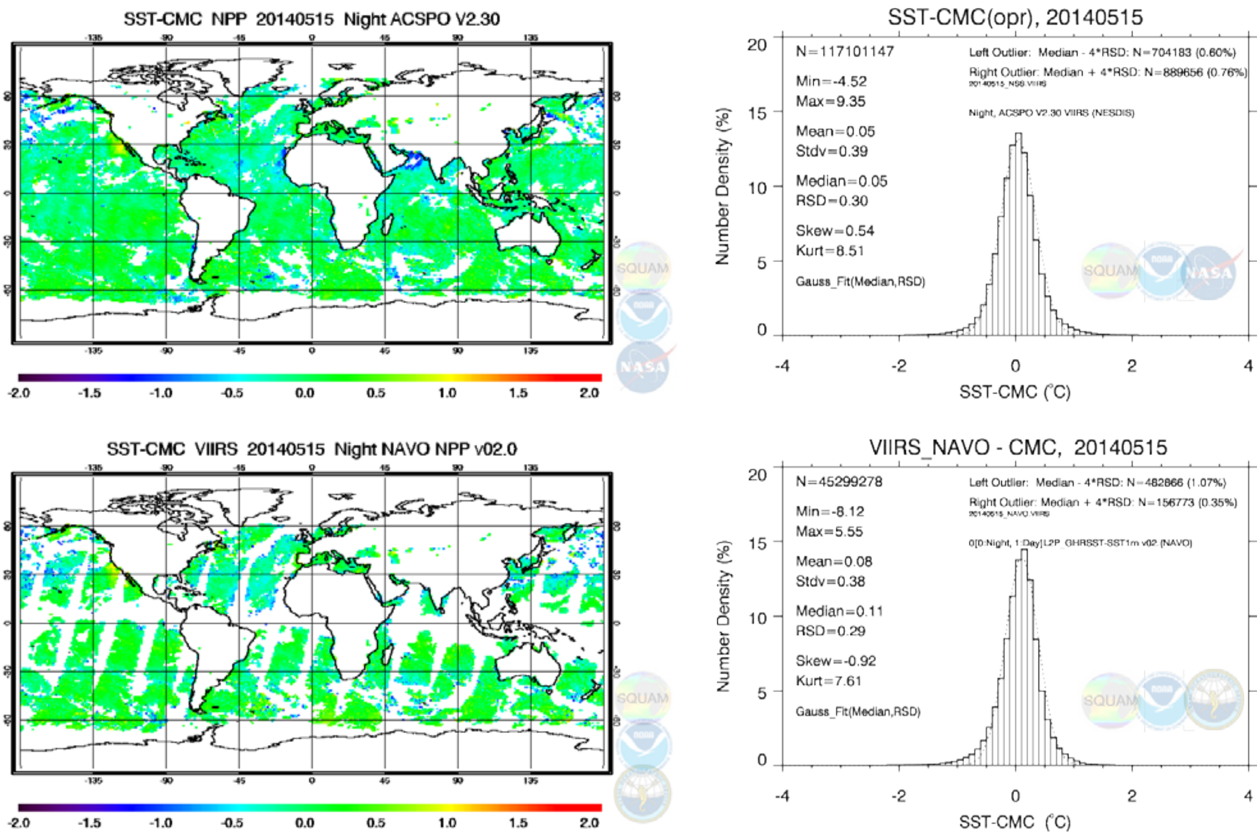


Figure 1: Left panel: Distribution of night VIIRS SSTs minus CMC SST (15-May-2014). Right panel: corresponding histograms. Statistical parameters are annotated on the left. Top: IDPS, Middle: ACSPO, Bottom: NAVOCEANO.

Retrieval domains for ACSPO and IDPS are comparable but ACSPO performance statistics are superior. More cold anomalies indicative of larger cloud/aerosol leakages are noticed in IDPS SST. NAVOCEANO retrieval domain is ~2.6 times smaller than ACSPO, while performances are comparable. Table 1 summarizes statistics of ΔT_S for CMC L4 reference field.

VIIRS Products	# of matches (% ACSPO)	Min / Max (◦C)	Mean / Median	Std Dev / RSD	Skew / Kurt
ACSPO	117M (100%) – night 111M (100%) – day	-4.5 / 9.4 -5.7 / 8.8	0.05 / 0.05 0.24 / 0.16	0.39 / 0.30 0.61 / 0.41	0.54 / 8.51 1.95 / 11.25
NAVO	45.3M (38.7%) 36.1M (32.6%)	-8.1 / 5.6 -7.9 / 7.7	0.08 / 0.11 0.18 / 0.13	0.38 / 0.29 0.54 / 0.41	-0.92 / 7.61 0.67 / 8.14
IDPS	120.13 (102%) 111.96 (101%)	-13.4 / 17.6 -27.4 / 14.0	0.01 / 0.04 0.17 / 0.21	0.47 / 0.32 0.79 / 0.45	-1.05 / 15.41 -0.56 / 10.11

Table 1: Statistics of VIIRS SSTs wrt. L4 CMC. (Daily, 15th May, 2014).

4. Validation against quality-controlled drifters

Figure 2 shows monthly night time-series of median, robust standard deviation and number-of-matches for the three VIIRS SSTs compared against drifters, with a 20 km and 4 hour space-time window for match-up.

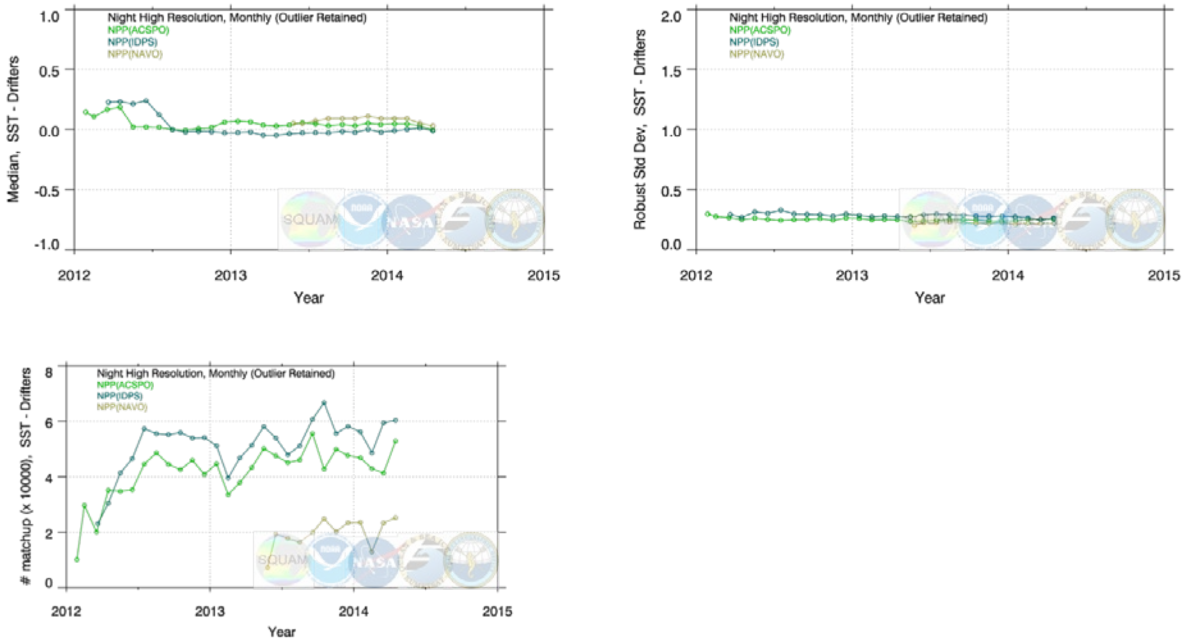


Figure 2: Monthly nighttime time series of three VIIRS SST products validated against quality controlled drifters. The median and robust standard deviation (RSD) values of residuals (SST minus Drifters' temperatures) closely track each other. The number of NAVO matches is about one-third of ACSPO. RSD values for NAVO are slightly but consistently better.

Table-2 summarizes monthly validation of VIIRS SSTs against quality controlled drifter SSTs.

VIIRS Products	# of matches (% ACSPO)	Min / Max (◦C)	Mean / Median	Std Dev / RSD	Skew / Kurt
ACSPO	42.9K (100%) – night 42.6K (100%) – day	-2.6 / 5.9 -2.8 / 4.1	-0.03 / 0.04 0.06 / 0.06	0.39 / 0.25 0.42 / 0.33	2.77 / 35.04 0.35 / 4.46
NAVO	12.9K (30.1%) 10.1K (23.6%)	-2.6 / 2.2 -1.8 / 4.3	0.06 / 0.09 0.05 / 0.03	0.29 / 0.22 0.38 / 0.32	-0.97 / 7.51 0.58 / 5.89
IDPS	48.6K (113%) 46.2K (109%)	-6.6 / 2.8 -8.0 / 6.4	-0.06 / 0.00 -0.07 / 0.02	0.42 / 0.26 0.65 / 0.42	-2.00 / 15.51 -1.68 / 11.23

Table 2: Statistical summary for monthly validation of VIIRS SSTs wrt. Drifters, Feb 2014.

5. Persistent features in monthly maps

To detect persistent features, monthly anomaly maps will be added in SQUAM. Figure 3 shows an example.

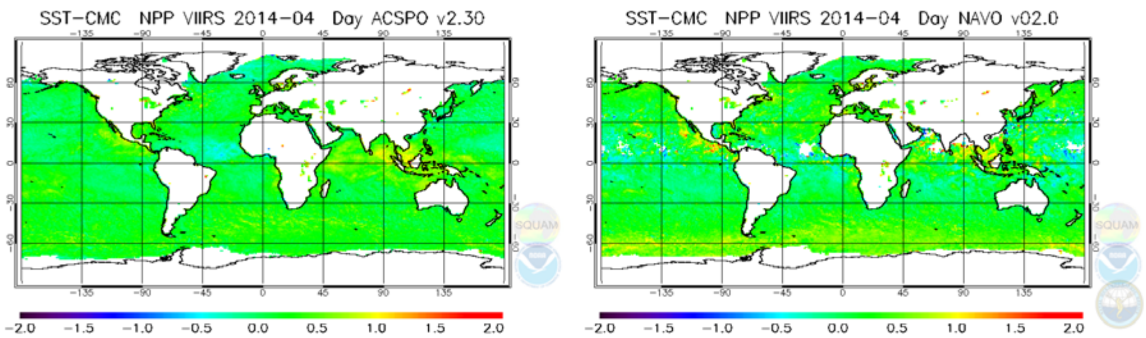


Figure 3: Monthly daytime maps of VIIRS minus L4 CMC. Left: ACSPO. Right: NAVOCEANO. Some persistent cold residuals indicate possible leakages of clouds or aerosols. Positive residuals (due to diurnal warming or specifics of the NLSST regression algorithm) are more pronounced in NAVOCEANO SST. Some areas of the oceans are not covered in NAVO product even at a monthly interval.

6. Performance of ACSPO and NAVOCEANO SST across the swath

The NAVO VIIRS product shows slightly better standard deviations than the corresponding ACSPO SSTs. Figure 4 shows time-series of standard deviation as a function of view zenith angle (VZA).

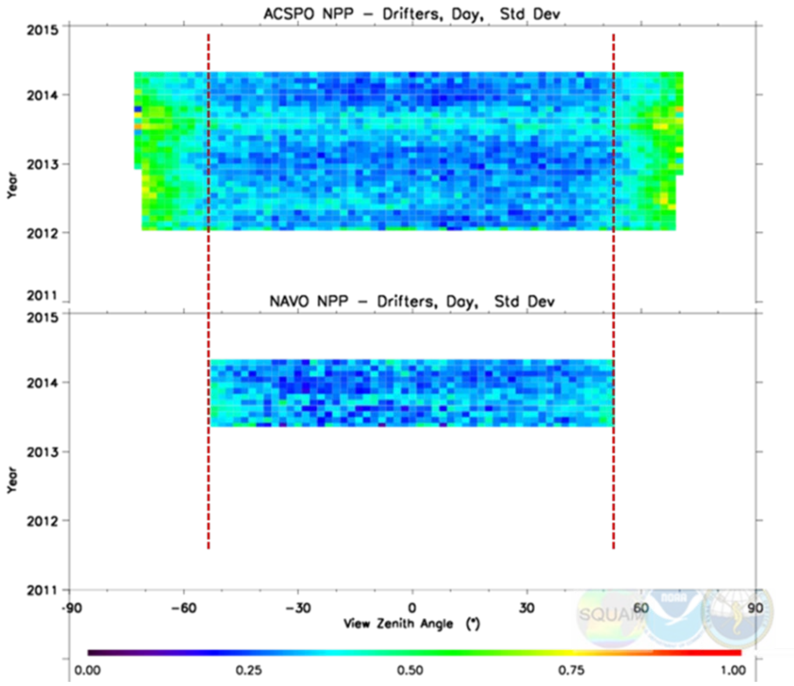


Figure 4: Time series (y-axis) of standard deviation as a function of view zenith angle (x-axis). Top: ACSPO NPP, bottom: NAVOCEANO.

The observations from Fig. 4 suggest that:

- ACSPO makes retrievals in full swath whereas NAVOCEANO at VZA<54°.
- Within the limited VZA domain, ACSPO and NAVOCEANO standard deviation values are comparable.
- ACSPO standard deviation values degrade towards swath edges. This degradation is more complex than merely a function of VZA, and shows some seasonality.

7. Summary

There are two global VIIRS products, NOAA ACSPO and NAVOCEANO SEATEMP. Both are archived at the JPL PO.DAAC / NODC in GDS2 format. The IDPS product is being discontinued due to suboptimal performance and lack of users. It is currently archived at CLASS in HDF5 and will be wiped off once a complete record of ACSPO VIIRS from Jan 2012-on is archived. The relative merits of ACSPO and NAVOCEANO VIIRS SSTs are:

- NAVO global coverage is about 1/3 of ACSPO. As a result, some areas of the ocean remain uncovered by the NAVOceano product for extended periods, up to a month.

- Measured in their corresponding full retrieval domains, NAVOCEANO outperforms ACSPO by a narrow (day) to moderate (night) margin.
- However, in the VZA "intersection" domain, both products show comparable performances. Therefore, the users can choose either product depending on their coverage requirements.

8. Acknowledgments

We thank many of our SST colleagues for their help. The views, opinions, and findings are those of the authors and should not be construed as an official NOAA or US Government position, policy, or decision.

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MONITORING AND VALIDATION OF HIGH-RESOLUTION LEVEL 2 SSTS FROM AVHRR FRAC, MODIS, (A)ATSR AND VIIRS IN SQUAM

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ABSTRACT

The NOAA SST Quality Monitor (SQUAM) was designed as a community tool for monitoring and validation of global SST products and providing their diagnostics online. SQUAM is organized in several modules, following the GHRSST classification of products into level 2, 3 and 4 (L2, L3, L4). The high-resolution (HR) module (*www.star.nesdis.noaa.gov/sod/sst/squam/HR/*) provides diagnostics for HR L2 SSTs. Currently, several products from different sensors generated by NOAA ACSPO and IDPS, EUMETSAT O&SI SAF, ESA ARC and NAVOCEANO are ingested and analyzed in HR-SQUAM. This paper gives an overview of the HR L2 SST diagnostics reported by HR-SQUAM.

1. Introduction

Several global high-resolution (1km or better) SST products are currently generated by different countries and organizations using various sampling and SST algorithms. NOAA is responsible for VIIRS SST products from S-NPP and JPSS satellites. VIIRS SST should be cross-evaluated and used in concert with the heritage SST products from AVHRR, MODIS and (A)ATSR sensors, for improved understanding of SST spatial and temporal variability, at various scales. A majority of satellite SST products are monitored, validated against *in situ* SSTs, and cross-evaluated to ensure their accuracy and consistency in the NOAA SST Quality Monitor (SQUAM) system (Dash *et al.*, 2010). A special HR-SQUAM module was set up to specifically monitor the high-resolution SST products.

In addition to sustained monitoring of NOAA ACSPO (Petrenko *et al.*, 2010) products (from Metop-A and -B AVHRR FRAC, S-NPP VIIRS, and Terra/Aqua MODIS), IDPS VIIRS, and the O&SI SAF Metop-A AVHRR FRAC, recently the following products were also included in HR-SQUAM: EUMETSAT/Univ. of Reading (A)ATSR Reprocessing for Climate (ARC) and NAVO VIIRS. Efforts are underway to include MO(Y)D28. Employing an established SQUAM metric, these L2 SSTs are inter-compared using several daily L4 gap-free analyses (*e.g.*, OSTIA, Reynolds, CMC) and quality controlled *in situ* data from *iQuam* (Xu and Ignatov, 2014). Results of monitoring are presented, along with some preliminary analysis of product independence and error characterization.

2. Example Monitoring of Level 2 (L2) SST

The SQUAM system performs statistical self- and cross-consistency checks of satellite products. Analyses are performed on the differences between satellite (T_S) and reference SSTs (T_R), $\Delta T_S = T_S - T_R$. Several different reference fields (T_R) are used, *e.g.*, optimally interpolated blended satellite/in situ gap-free Level 4 (L4) analysis fields (Reynolds, CMC, OSTIA) and quality controlled *in situ* measurements (including drifters, moorings and ships). The premise is that the probability density functions (PDF) of global ΔT_S are close to a Gaussian shape. Statistical moments of a Gaussian distribution can thus be used to quality control (QC) the satellite SSTs and monitor them for stability and cross-platform consistency. All the analyses are performed using a pre-defined diagnostic-set: ***Maps*** (spatial distribution of ΔT_S), ***Histograms*** (PDF of ΔT_S), ***Time-series*** of statistical parameters (viewgraphs), *Dependence* of ΔT_S on geophysical conditions (daily) and the corresponding time-series in *Hovmöller* space.

Figure 1 (left panel) shows an example monitoring of ACSPO Metop-A SST, compared against Canadian Meteorological Centre's L4 gap-free field. Such maps are used to check global L2 products for their coverage as well as possible cold anomalies due to the effects of leaked cloud and unaccounted aerosols. The corresponding histograms of ΔT_S (right panel) check for proximity to a normal distribution. The annotated parameters are trended in time to check for stability of products and to evaluate their relative performances.

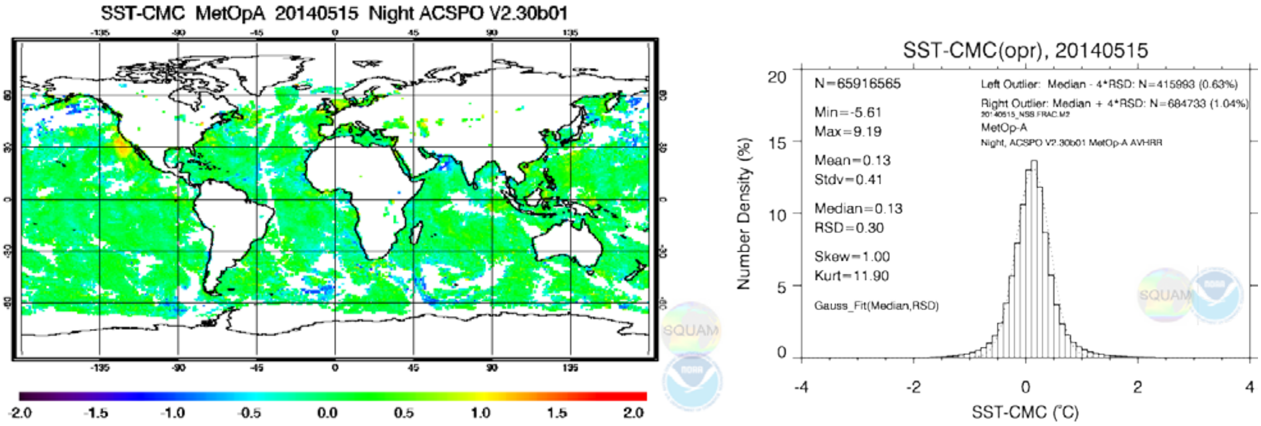
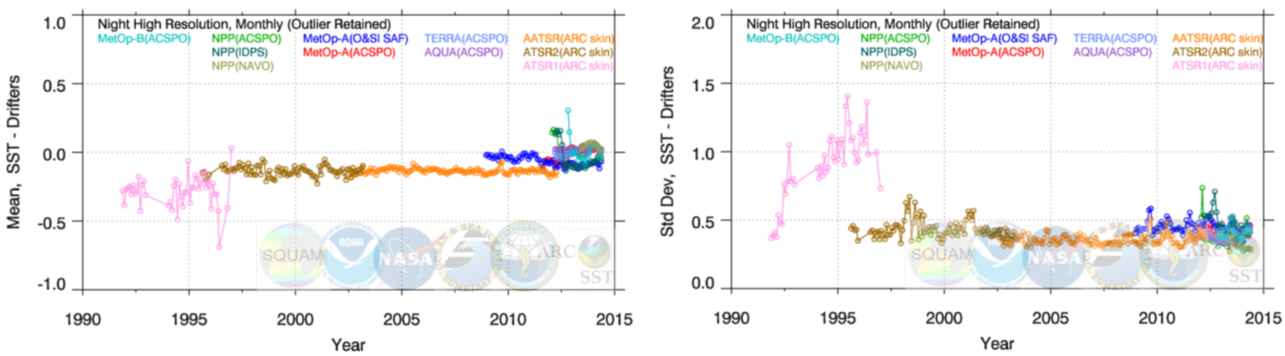


Figure 1: Left panel: Global distribution of nighttime ACSPO Metop A AVHRR SST minus CMC L4 SST, for 15-May-2014. Right-panel: PDF corresponding to the left panel. The statistical parameters are annotated on the PDF.

Figure 1 (left panel) shows some negative residuals (more than a degree) implying possible cloud leakage beyond the "roaring forties". Such diagnostics are available for various products and also against multiple references to minimize the odds that such anomalies are caused by the reference field itself.

3. Time-series validation against quality controlled drifters

The statistics shown in Figure 1 are available against multiple references including quality-controlled *in situ* data. In situ validation statistics are available aggregated over both daily and monthly intervals. Figure 2 shows monthly nighttime time series of mean, standard deviation and number of corresponding "L2 vs. *in situ*" match-ups, for eleven different HR products. A *20 km and 4 hour* space-time window is used in SQUAM for match-up.



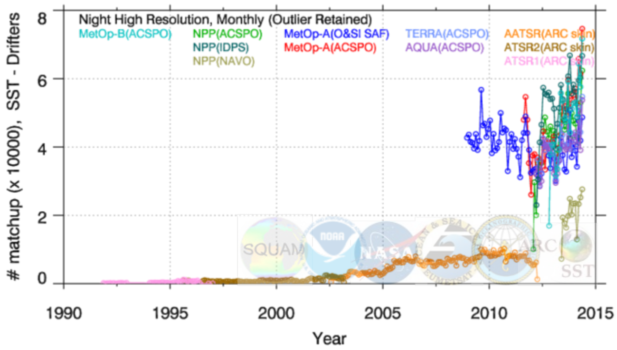
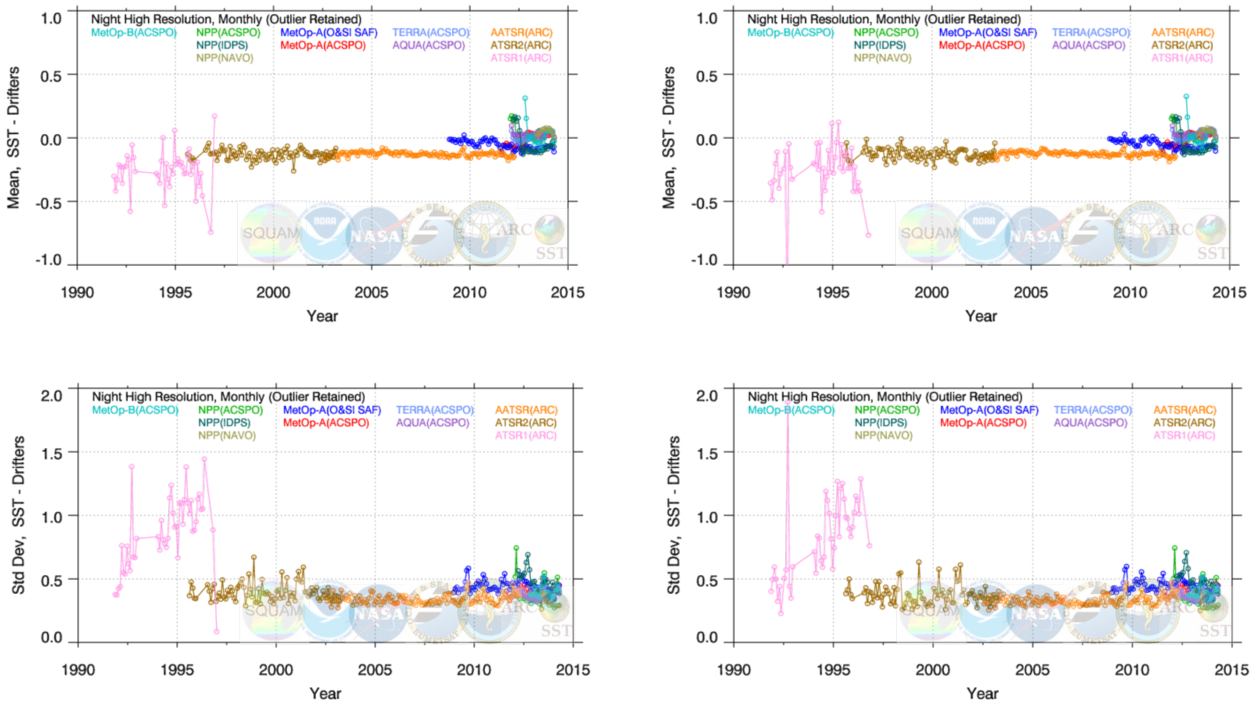


Figure 2: Monthly nighttime time series of high resolution satellite SSTs validated against quality controlled drifters from iQuam. Products are listed in the legend. Most products show comparable performance (except ARC ATSR1, whose SST had large anomalies due to sensor issues). Most products shown here are bulk (or between bulk and skin) whereas the ARC product was generated as a skin temperature. This explains somewhat colder mean biases in ARC skin SST minus bulk SST for drifters.

3.1. Sensitivity to space-time window for monthly statistics

So far, there is no SST community consensus on the space-time window for creating *in situ* match-ups. Therefore, a case study of sensitivity to space-time window was performed and is shown in Figure 3. Comparing Figure 2 and Figure 3 suggests that for progressively more conservative match-up criteria (20km/4hr *vs.* 10km/2hr *vs.* 5km/1hr), the validation standard deviations decrease but only slightly and the validation results are not significantly sensitive to the size of the window, at least globally.



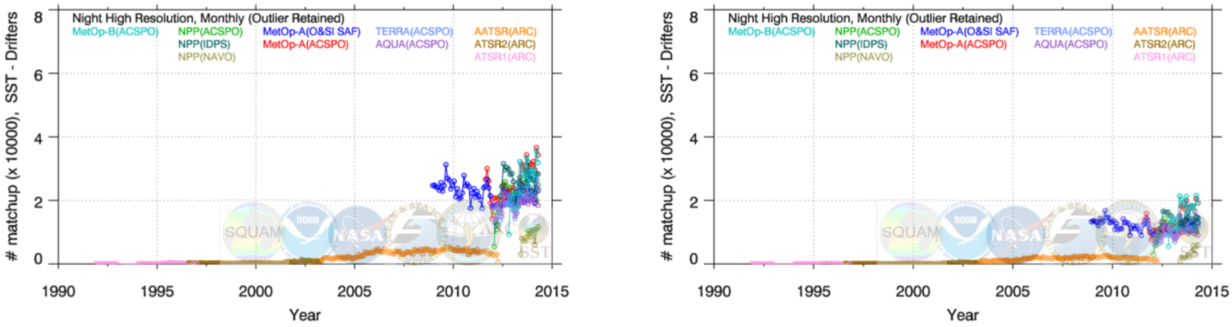


Figure 3: Sensitivity of validation statistics to space-time window. Left panel: 10 km 2 hr threshold. Right panel: 5 km 1 hr threshold. Top panels; mean; middle panels: standard deviation; bottom panel: number of match-ups.

3.2. Representative summary statistics of validation against drifters

Table 1 summarizes validation statistics of ten SSTs, grouped based on their equatorial crossing time (ECT).

Products	~ECT	# of matches	Min / Max (◦C)	Mean / Median	Std Dev / RSD	Skew / Kurt
ACSPO NPP	13:30	42917 (night)	-2.61 / 5.92	-0.03 / 0.04	0.39 / 0.25	2.77 / 35.04
		42586 (day)	-2.82 / 4.12	0.06 / 0.06	0.42 / 0.33	0.35 / 4.46
NAVO NPP		12912	-2.58 / 2.20	0.06 / 0.09	0.29 / 0.22	-0.97 / 7.51
		10063	-1.80 / 4.31	0.05 / 0.03	0.38 / 0.32	0.58 / 5.89
IDPS NPP		48638	-6.62 / 2.83	-0.06 / 0.00	0.42 / 0.26	-2.00 / 15.51
		46208	-8.04 / 6.43	-0.07 / 0.02	0.65 / 0.42	-1.68 / 11.23
ACSPO Aqua		40728	-3.18 / 6.07	0.05 / 0.06	0.41 / 0.28	2.22 / 24.69
		42083	-3.18 / 3.91	0.12 / 0.10	0.44 / 0.38	0.28 / 2.76
ACSPO Metop-A	9:30	52591	-2.33 / 6.60	0.03 / 0.04	0.44 / 0.28	2.84 / 31.62
		46594	-2.43 / 4.99	0.00 / 0.01	0.42 / 0.37	-0.10 / 2.91
OSISAF Metop-A		34215	-4.24 / 5.60	-0.08 / -0.01	0.43 / 0.29	-1.19 / 10.79
		40430	-3.68 / 5.13	0.10 / 0.16	0.51 / 0.39	-0.63 / 4.12
ACSPO Metop-B	9:30	48837	-2.83 / 7.21	0.05 / 0.06	0.42 / 0.29	2.09 / 27.67
		44574	-2.39 / 4.71	0.03 / 0.04	0.43 / 0.38	0.11 / 2.56
ACSPO Terra	10:30	40285	-2.19 / 5.84	0.06 / 0.06	0.41 / 0.28	1.94 / 22.74
		39385	-2.29 / 4.46	0.06 / 0.06	0.45 / 0.41	0.28 / 3.54
ARC AATSR	10:00	5533	-4.04 / 2.19	-0.16 / -0.12	0.41 / 0.25	-1.89 / 14.16
		7446	-3.93 / 2.28	-0.12 / -0.10	0.49 / 0.34	-1.22 / 8.89
ARC ATSR2	10:30	1591	-3.11 / 1.63	-0.11 / -0.12	0.36 / 0.27	0.04 / 5.39
		1957	-4.88 / 2.38	-0.18 / -0.16	0.52 / 0.39	-0.74 / 6.17

Table 1: Validation of satellite SSTs against drifters for Mar-2014, except AATSR for Feb-2012 and ATSR2 for Feb-2003.

4. Persistent features in monthly maps

To detect persistent features, monthly maps of ΔT_S are being considered to be included in SQUAM. An example is shown in Figure 4 below.

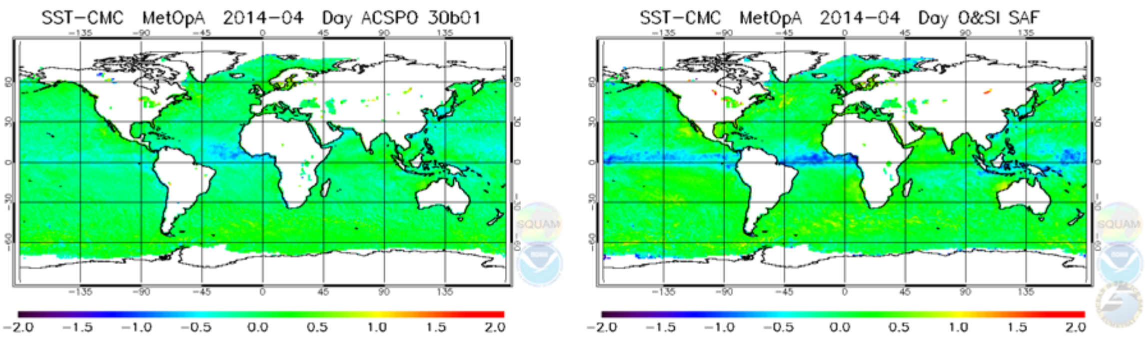


Figure 4: Monthly daytime aggregated maps of Metop-A AVHRR minus L4 CMC. Left: ACSPO. Right: O&SI SAF. Persistent cold residuals are observed for both products, to a larger degree in O&SI SAF, indicating possible leaked clouds/aerosols or deficiencies of SST algorithm. Such maps will be included in future versions of SQUAM.

5. Correlation between residuals for different SST products

In order to preliminarily investigate independence of the various products, correlations between the residuals (product minus reference) were analyzed and are summarized in Table 2.

Residuals (SST – Drifters)	~ECT	ACSPO NPP	IDPS NPP	NAVO NPP	ACSPO Metop-A	OSISAF Metop-A	ACSPO Metop-B	ACSPO Terra	ACSPO Aqua
ACSPO NPP	13:30	1.00 (Night) 1.00 (Day)	0.69 0.67	0.49 0.41	0.24 0.21	0.13 0.15	0.22 0.20	0.27 0.21	0.36 0.38
IDPS NPP			1.00 1.00	0.54 0.37	0.21 0.20	0.17 0.19	0.28 0.19	0.25 0.19	0.31 0.32
NAVO NPP				1.00 1.00	0.22 0.18	0.18 0.10	0.21 0.15	0.24 0.15	0.29 0.23
ACSPO Metop-A	9:30				1.00 1.00	0.47 0.46	0.31 0.38	0.27 0.31	0.18 0.19
OSISAF Metop-A						1.00 1.00	0.20 0.27	0.19 0.22	0.09 0.13
ACSPO Metop-B	9:30						1.00 1.00	0.16 0.19	0.25 0.33
ACSPO Terra	10:30							1.00 1.00	0.28 0.27
ACSPO Aqua	13:30								1.00 1.00

Table 2: Correlations between residuals of different SSTs. Analyzed were gridded ΔT_S data (1º×1º latitude longitude), separated by day night.

The figures from Table 2 suggest that correlations are higher for different products from the same sensor (*e.g.*, NPP from ACSPO, IDPS and NAVO; Metop-A from ACSPO and O&SI SAF) and lower for the same product from different sensors (*e.g.*, ACSPO product from Terra and Metop-A).

6. Summary and future work

Most high resolution L2 SSTs analyzed in SQUAM show comparable performances. A significant sensitivity to space-time window on monthly match-up is not seen except for reduced number of matches. However, many products show a high degree of correlation in residuals indicating that the products may not be providing independent information about the state of the sea surface, and that needs to be further investigated.

7. Acknowledgments

We thank many of our SST colleagues for their help. The views, opinions, and findings are those of the authors and should not be construed as an official NOAA or US Government position, policy, or decision.

8. References

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REGIONAL SST DIURNAL WARMING FROM SEVIRI

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ABSTRACT

Diurnal warming of the upper ocean layer typically occurs under clear skies when the wind is low and the solar heating high. This diurnal signal has been extensively studied as it poses challenges for validating and calibrating satellite sensors, merging SST time series, oceanic and atmospheric modelling. As heat is significantly trapped close to the surface, the diurnal signal's maximum amplitude is best captured by radiometers. The availability of infra-red retrievals from a geostationary orbit allows the hourly monitoring of the diurnal SST evolution. SEVIRI SSTs from 2006 to 2011 were used in this study to i) construct a foundation temperature field (SST_{found}) representative of well mixed conditions and to ii) quantify the day-time warming signal at different regions. In order to construct a representative SST_{found} sensitivity tests were performed using multi versus single day averages of night time SSTs of different quality flags. It was found that the bias against a single day validation field consisting of the last pre-dawn, quality 5 SST ranged from -0.1 to 0.1 K and the standard deviation was mostly between 0.2 and 0.3 K. Using a single day composite of night-time (local time 00-04), quality 3-5 SST, the day-time (from 08-20 local time) anomalies, δSST, were estimated as quality 5 SST_{day}- SST_{found}. It was shown that δSST exceeding 1K are found in the enclosed basins such as the Mediterranean, Black, Baltic and Arabian Seas but also in the coastal areas of western Africa and Madagascar as well as in the central North and South Atlantic (Figure 1, left panel). Such occurrences coincided well with concurrent low winds and high surface heat fluxes from ECMWF (Figure 1, right panel). A regional analysis of the diurnal warming characteristics in terms of the mean daily cycle, the annual distribution of warming exceeding various thresholds and the local time of occurrence was performed for 8 domains. These were categorised in 2 mid-latitude domains in the north and south Atlantic, 3 sub-Tropical domains, 1 domain in the Tropics and 2 domains covering the Mediterranean and Black Sea and the Baltic and North Sea. Consistent patterns identified in all domains included the seasonal spring and summer signal, a peak of occurrences in the early afternoon between 13 and 16 local time, the early morning cooling and the residual warm layer of the mean daily cycle. Differences between domains were noted in the amount of identified warming exceeding different thresholds, the width of the annual distributions indicating the occurrence of warming throughout the year or only during some months, the peak local time of occurrence shifting earlier or later depending on the domain, the occurrence or not of warming at certain periods of the day, the peak mean amplitude and rate of warming and cooling (Figure 2). For a detailed description of the study, see the manuscript from Karagali and Høyer, *Characterisation and quantification of regional diurnal SST cycles from SEVIRI*, in Ocean Sciences Discussion, 11, 1093-1128, 2014.

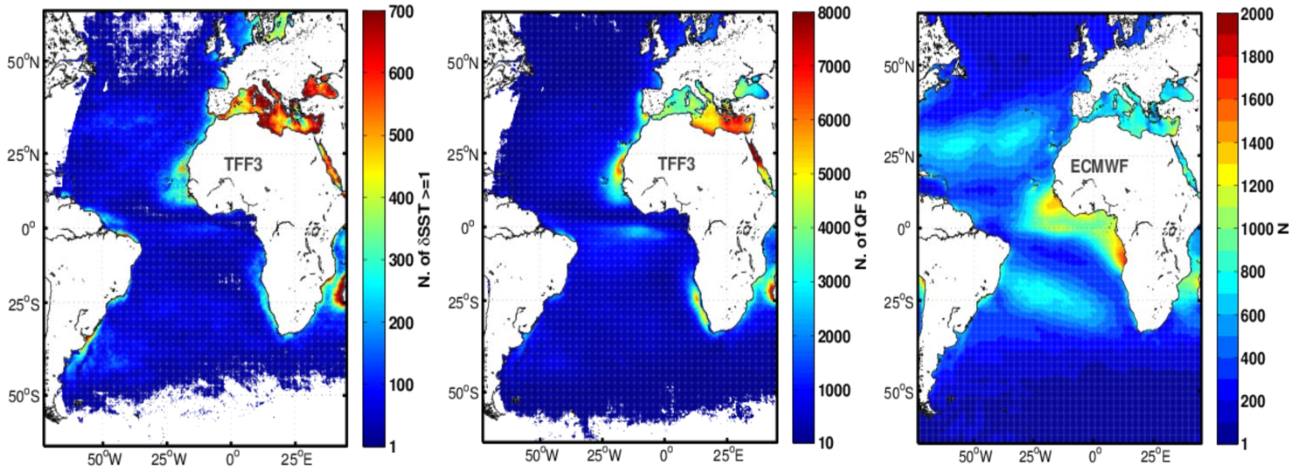

Figure 1: Number of cases for δSST greater or equal to 1 K (left), quality 5 day-time SST (middle) during 2006-2011 and simultaneous low wind (less than 6 m/s) and high surface heat flux (more than 400 W/m²) cases (ECMWF, 2009-2011).

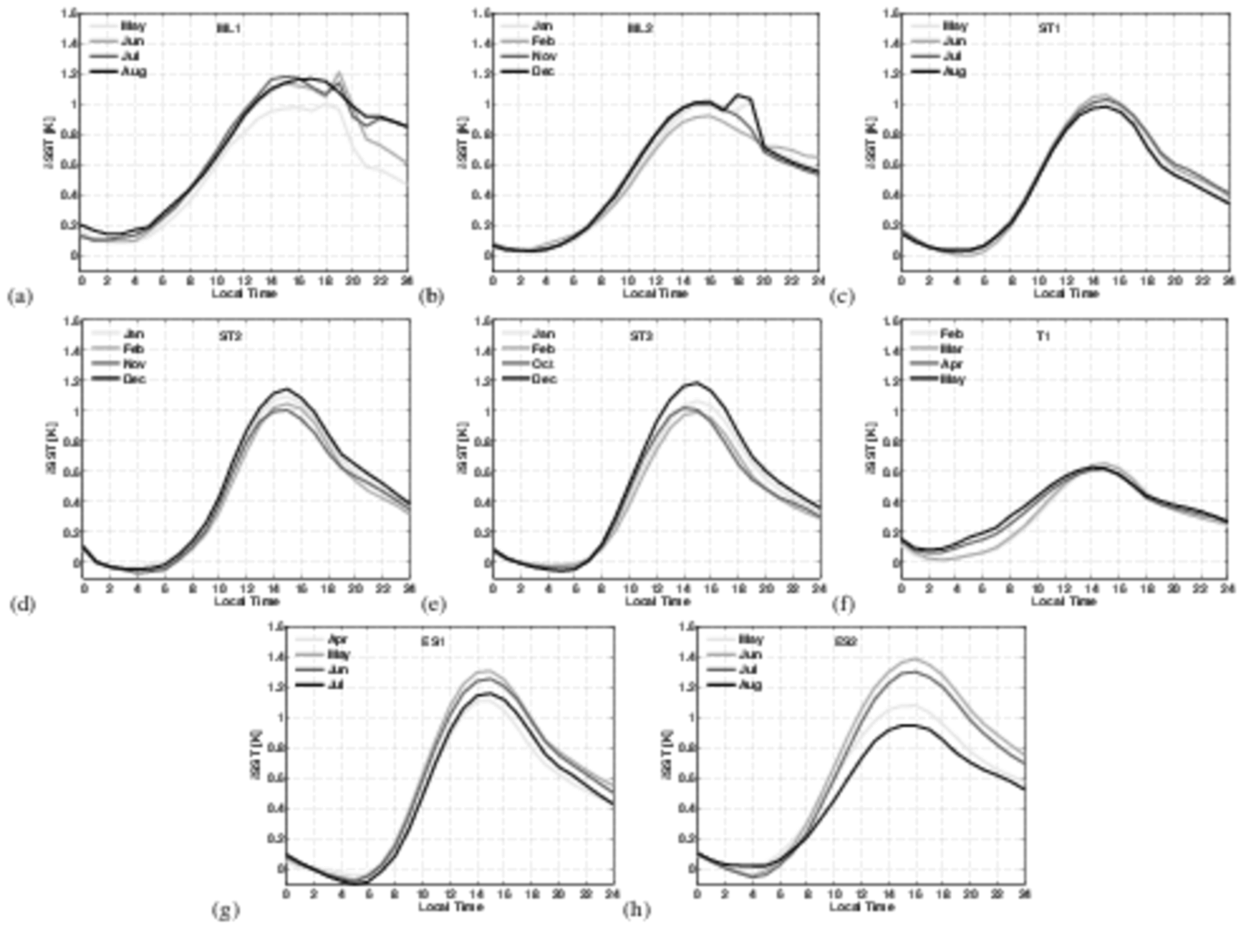

Figure 2: The monthly averaged daily cycle at 8 different domains of the SEVIRI disk, for the months with the peak amplitude. The daily cycles are based on grid cells that show warming exceeding 0.5 K at least once during the day.

TEMPORAL VARIATIONS OF SEA ICE COVER IN THE BALTIC SEA

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ABSTRACT

Sea ice cover is a crucial parameter for surface fluxes of heat and moisture over water areas. The isolating effect and the much higher albedo strongly reduces the turbulent exchange of heat and moisture between the oceans' surface and the atmosphere, and allows for cold and dry air mass flow with strong impact on the stability of the whole boundary layer, and consequently on cloud formation as well as on precipitation in the downstream regions.

Numerical weather centers as ECMWF, MétéoFrance or DWD use external products to initialize SST- and sea ice cover in their NWP models. To the knowledge of the author there are mainly two global sea ice products well established with operational availability, one from NOAA NCEP that combines measurements with satellite data, and the OSTIA sea ice product, based on OSI-SAF derived from SSMI/S sensors. DWD additionally uses a regional product for the Baltic sea provided by the federal service for shipping and hydrography which combines observations from ships (and icebreakers) for the German part of the Baltic Sea and model analysis from the hydrodynamic HIROMB model of the Swedish meteorological service for the rest of the domain.

The temporal evolution of the three different products is compared, problems in Ostia are illustrated and suggestions for a harmonization of strong day to day jumps over large areas are made.

REMO SST GROUP: STATUS & UPDATES

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ABSTRACT

This is an update of the SST activities of our group related to BARNES' interpolator to merge several data sources (e.g., AVHRR, TMI, GOES and MSG) and generate a daily composition with uncertainty in a regular grid product. The SST validation is continuously made by using PIRATA's project buoys and drifting buoys from National Buoys Program (PNBOIA) from Brazilian Navy. The results are very consistent considering the period from 2002 to 2014. Furthermore, a study case related to the upwelling event, which occurred in the region corresponding to the interval of latitudes and longitudes of 20°S to 27°S, and 48°W to 40°W, respectively, from January to February 2014, has been analyzed. The comparisons of SST *in situ* measurements (buoy located at coordinates 22.994°S and 42.187°W) and some SST products available have overestimated SST in about 4°C during the aforementioned period. Therefore, in order to try to solve such local SST estimation, Ensemble Optimal Interpolation (EnOI) approach with *in situ* measurements assimilation is being tested and developed. We intend to discuss alternatives for that during the meeting.

1. Introduction

A simple system for daily cloud free sea surface temperature (SST) composition, named REMO SST, based on thermal AVHRR data from NOAA 18 and 19 and microwave TMI data from TRMM is provided by REMO's group. Barnes' objective analysis (França *et al.*, 2013) is applied as an interpolator to merge these two data sources, which have different spatial (NOAA: ~9km, TMI: ~25km) and temporal resolutions in a daily SST composition and in a regular grid product (0.05°). Validation has been continuously carried out with moored and drifting buoys and also against GHRSST products. The results are quite good in open ocean, but near the coast during the upwelling event the differences between SST analysis and SST from the buoy located approximately 6km from the coast are high. The present challenge is to develop a better SST analysis during an upwelling event in Campos and Santos basins as it follows in Figure 1.

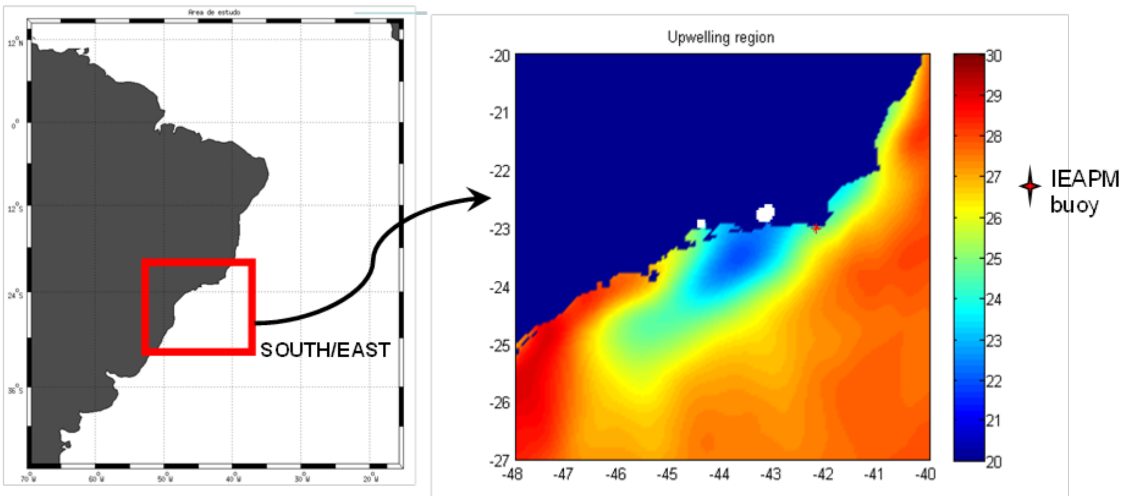

Figure 1: Upwelling region.

2. Applied data and Challenge

A study case related to upwelling event from January 14th to February 14th, 2014 was analyzed. The upwelling study area lies between latitudes 20°S and 27°S and longitudes between 48°W and 40°W where a strong upwelling event was recorded by the buoy (IEAPM buoy) located near the Brazilian coast.

Figure 2 depicts the differences registered by the buoy and SST analysis from REMO, OSTIA and the buoy SST measurements during the no-upwelling period.

The problem is during the upwelling period. The comparisons between *in situ* SST from this buoy and all SST products (REMO and OSTIA) and SST estimations (from NOAA, MSG and GOES) have overestimated SST from the buoy in about 4°C for the period aforementioned (during the summer) as it follows in Figure 3. The reason for it is unknown and is being investigated.

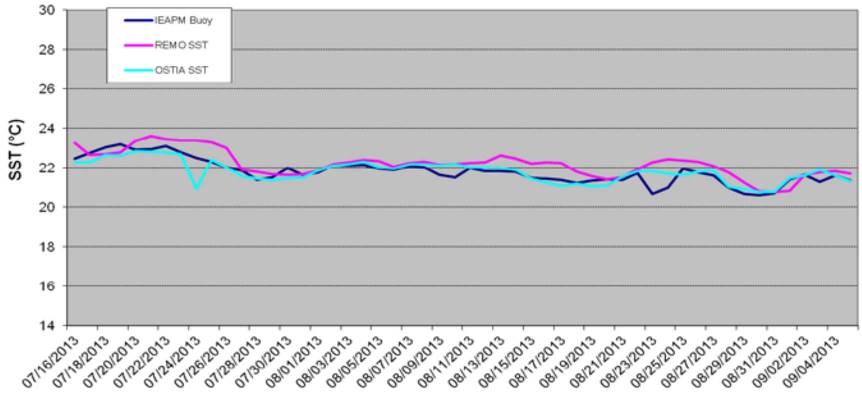

Figure 2: Comparison between buoy and SST products for no-upwelling period.

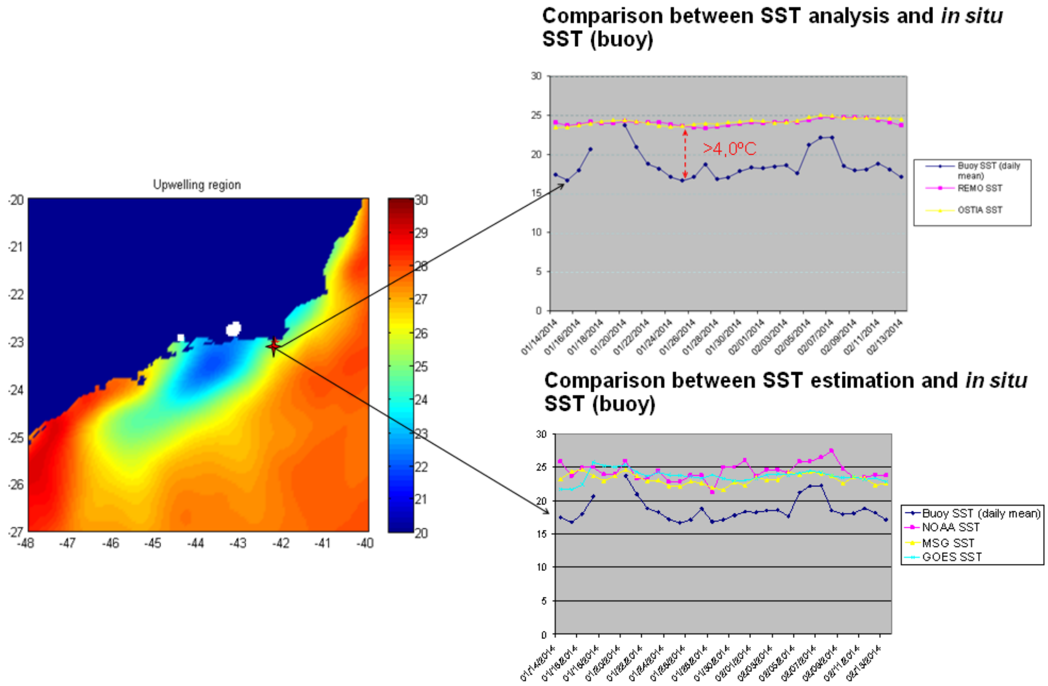

Figure 3: Comparison between buoy and SST products (upper right) and buoy and SST estimation (bottom right) for no-upwelling period.

In order to try to solve this problem, EnOI (Oke *et al.*, 2002, 2005), which is an optimal interpolation method, was tested assimilating *in situ* (IEAPM buoy) measurements. The buoy SST was not represented in the ensembles, then the buoy information was discharged during the assimilation and in this case, a gain regarding the overestimation has not been obtained.

3. Considerations and way-forward

REMO L4 SST has been produced routinely at LMA/UFRJ since 2008 and its results are compared with *in situ* SST from moored and drifting buoys and GHRSST analysis. The results are quite good, excepted near the coast during the upwelling period, as observed this year. Trying to solve this problem, some strategies are currently under development for the REMO SST product in the upwelling region, as it follows: 1) an optimal interpolation scheme using EnOI; 2) additions to the cloud detection scheme; and 3) development of local atmosphere correction algorithm.

Regarding to EnOI method, we intend: 1) to ingest METOP-A and VIIRS data aiming to evaluating if the buoy measurements are represented; and 2) to create synthetic ensembles ingesting *in situ* SST data from the buoy for upwelling region and use them since buoy gives the signal.

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SSES IN ACSPO

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ABSTRACT

The current implementation of Single Sensor Error Statistics (SSES) within the Advanced Clear-Sky Processor for Oceans (ACSPO) is described.

1. Estimation of SSES in ACSPO

According to GDS 2.0 Technical Specifications (https://www.ghrsst.org/ghrsst/tags-and-wgs/stval-wg/sses-single-sensor-error-statistics/), “the Single Sensor Error Statistics are a key component of all GHRSST L2P data files”. The Advanced Clear-Sky Processor for Oceans (ACSPO) is a processing system currently used at NOAA/NESDIS to operationally produce L2P SST from all NOAA and MetOp AVHRRs as well as NPP VIIRS. The latest version 2.30 of ACSPO exploits regression SST algorithms in the EUMETSAT OSI-SAF formulation (Lavanant et al., 2012) and the ACSPO clear-sky mask (ACSM, Petrenko et al., 1010). The output of ACSPO v.2.30 is optionally provided either in heritage HDF5 or in GDS2 formats and includes estimates of bias and standard deviation (SD) of SST for all ocean pixels.

The estimates of SSES in ACSPO are based on significant dependencies (Petrenko et al., 2014) of accuracy and precision of regression SST from two variables, satellite view zenith angle (VZA) and total precipitable water vapor content in the atmosphere (TPW). The ACSPO output in the heritage format includes pixel values of VZA and TPW produced by interpolation of VZAs from L1B SDRs and gridded TPWs from the NOAA Global Forecast System (GFS, http://www.nco.ncep.noaa.gov/pmb/products/gfs/). The dataset of matchups, which is continuously maintained and replenished from the ACSPO output files and *in situ* Quality Monitor (*i*Quam, Xu and Ignatov, 2014) includes VZA and TPW among other supporting information. This dataset of matchups is used to recurrently recalculate the regression SST coefficients and to generate 2D lookup tables (LUT), in which SSES are represented as functions of VZA and TPW. When processing L1B data, the pixel values of SSES are produced by interpolation of the LUT SSES values to the pixel values of VZA and TPW.

2. Future development

Although the way of representing SSES statistics described above adequately reflects the major dependencies of SST accuracy and precision from atmospheric attenuation, a number of essential factors are still to be taken into account. This includes the effects of aerosol, ambient cloud, proximities to coast and ice. For regression SST algorithms, it is important to explore the statistical properties of a set of matchups used for calculation of regression coefficients. It is expected that the SSES methodology will evolve in the future ACSPO versions towards accounting for the aforementioned factors.

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NEARSHORE BIASES BETWEEN SATELLITE SST AND IN SITU SEAWATER TEMPERATURES ALONG SOUTH AFRICA

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ABSTRACT

Gridded SST products are increasingly being applied close to the coast for biogeographical applications. We report here the dangers of doing so through a comparison of MODIS Terra and Pathfinder v5.2 SSTs with instrumental *in situ* temperatures taken within 400 m from the littoral zone. Biases of up to +6 ºC between satellite-derived and *in situ* climatological temperatures exist at 95 sites spanning the *ca*. 2,700 km long South African coastline (see Smit *et al*., 2013 for the full study). Although biases are predominantly warm (i.e. the satellite SSTs being warmer), smaller or even cold biases also appear in places. We demonstrate the presence of gradients in temperature biases along shore-normal transects — generally SSTs extracted close to the shore exhibit smaller biases with respect to the *in situ* temperatures. Contributing towards the magnitude of the biases are factors such as SST data source, proximity to the shore, the presence/absence of upwelling cells or coastal embayments.

1. Introduction

There is a global paucity of temperature measurements for the coastal zone, here defined as a band of nearshore water within 400 m from the littoral (Pearce et al., 2006; Blanchette *et al*., 2008; Smale and Wernberg, 2009; Tittensor *et al*., 2010; Couce *et al*., 2012). When SST data are needed for this region in support of biological enquiry, authors often extrapolate data derived from satellite SST products (Blanchette *et al*., 2008; Broitman *et al*., 2008; Tyberghein *et al*., 2011) without requiring validation that they in fact represent the nearshore thermal environment. Increasingly, satellite-derived SSTs are being used to understand effects of climate change on the coastal marine biota (Müller *et al*., 2009; Selig *et al*., 2010; Hilbish *et al*., 2011; Bartsch *et al*., 2012).

Satellite-derived temperature measurements near the coast may differ from *in situ* measurements at the same location (Katsaros, 2003; Leichter *et al*., 2006; Castillo and Lima, 2010), yet how widespread the problem is has not been well documented. The purpose of this paper is to demonstrate the dangers inherent in using remotely sensed SST data for local (small-scale) applications, particularly at the coast. Our aims are twofold: i) to compare two commonly used satellite SST products for the South African marine coastal zone to temperature data obtained *in situ* (climatologies only) and ii) to provide the most reliable and spatially complete coastal seawater temperature climatology that is possible using existing *in situ* data for the entire South African coast.

2. Approach

Full details of the analysis are provided by Smit *et al*. (2013). Basically, our approach is to compare existing 'point source' *in situ* temperatures with satellite-derived SSTs. We use four *in situ* data sources. One set is collected by the South African Weather Service (SAWS) using hand-held mercury thermometers at sites along the coast. A second source is electronic underwater temperature recorders (UTRs) managed by the South African Departments of Environmental Affairs (DEA) and Agriculture, Forestry and Fisheries (DAFF), and Ezemvelo KwaZulu-Natal Wildlife (EKZNW). The third set is also comprised of UTR data and was supplied by the South African Environmental Observation Network (SAEON). The fourth is KwaZulu-Natal Sharks Board (KZNSB) measurements taken using hand-held alcohol thermometers at sites on the

KwaZulu-Natal (KZN) coast. These daily time series data represent 95 unevenly spaced localities along the entire length of the South African coast (*ca*. 2,700 km). The *in situ* data set is compared with three sources of gridded SSTs: the AVHRR Pathfinder v.5.2 and the MODIS Terra (1 km and 4 km) products. We deliberately discriminate between SST obtained by orbiting infrared radiometers and *in situ* seawater temperature because the former is a measure of surface temperature anywhere on Earth within the 10–20 μm of the ocean's surface [37] (here we used temperatures sampled at 5, 10, 15 and 20 km from the land-sea margin) and the latter a measure of temperature in the bulk water column representing the upper mixed layer of the nearshore region. It is our intent for the data to undergo further validation and refinement through the continual addition of more point-source data, so that this inshore temperature dataset may be adopted and used by the marine scientific community for diverse nearshore applications.

3. Results and Discussion

Detailed outcomes of the research are presented by Smit *et al*. (2013). Large biases — up to +6 ºC in places — exist between *in situ* and satellite-derived climatological temperatures for 95 sites spanning the entire *ca*. 2,700 km of the South African coastline, from the Benguela Current dominated west coast to the Agulhas Current influenced east coast. Biases are predominantly warm (*i.e*. satellite SSTs being warmer than corresponding *in situ* temperatures), although smaller or even cold biases also appear in places, especially along the southern and western coasts of the country.

The large spatial heterogeneity of the biases reflects largely the underlying oceanographic processes that determine the coastal seawater temperature regime. Along the east coast of South Africa the effect of the Agulhas Current is more-or-less constantly felt at the coast and upwelling is largely absent. Along the south coast upwelling is strongly localised and intermittent, and is of a type that often occurs inshore of western boundary currents. Along the west coast upwelling is a seasonal feature of the nearshore, clearly evident at the shoreward edge of the Benguela Current. This juncture between upwelling (west and south coasts) and no upwelling (east coast) has a large influence on the variability and magnitude of the SST bias — it is clear that along the east coast biases are large and always positive. The seasonality of upwelling, which is strongly felt along the west coast and to a lesser extent along the south coast, is also very visible in the biases, such that cold biases are felt when upwelling is most intense during the austral summer (*ca*. September to March). The presence of embayments also influences the bias, and in this instance result in colder SSTs relative to the *in situ* temperatures.

Both sets of satellite data indicate an offshore (shore-normal) gradient in SST bias with the greatest bias seen at 20 km from the coast and least at the coast. This gradient is more marked in the summer. The AVHRR biases are greater than those of MODIS Terra; in the latter, the magnitude of the bias further decreases with increasing resolution from 4 km to 1 km pixels.

4. Conclusion

Concerns about temperature changes in the oceans make the accurate monitoring of seawater temperature a priority. In the light of our findings, above, the GHRSST community should prioritise studies into the validation of SSTs for coastal applications. Until SST products suitable for coastal applications can be developed, users should instead use directly measured seawater temperatures in shallow, inshore marine environments.

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A REVIEW ON THE APPLICATION OF HIGH RESOLUTION SSTS IN A COASTAL UPWELLING REGION: THE TEST CASE OFF PERU

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ABSTRACT

Comparisons are performed between Sea Surface Temperature Gradients (SST) derived from three sources:

1) the 0.25 degree resolution National Climatic Data Center Optimally interpolated AVHRR+in-situ data set
2) the 1km gridded Multi-Scale Ultra High Resolution Sea Surface Temperature Data Sea Surface Temperature Data Set (MUR)
3) a 2km version of the Estimating the Circulation and Climate of the Ocean (ECCO2) Model

A covariability analysis is applied between the ECCO2/MUR and ECCO2/NCDC magnitudes of SST gradients. Results indicate that MUR is closer to model in representing possible mesoscale variability as well as changes in the upwelling scale.

1. Introduction

Previous results (Vazquez et al., 2013) have shown that a comparison of four different gridded GHRSST data sets off the Peruvian Coast indicate differences arise with respect to the resolvability of SST gradients and their relationship to coastal upwelling scales. Further analysis indicates that at the lower resolutions results compare well between the 0.25 degree resolution National Climatic Data Center (NCDC) SST product and the sub-sampled 1km gridded Mult-Scale Ultra-High Resolution (MUR) SST data. The central question then becomes is higher resolution data a better respresentation of coastal areas associated with major upwelling zones. Even with the limitation of cloud coverage is high resolution infrared data adding information in these coastal areas. Are predicted changes in upwelling scales as defined by Marchesiello and Estrada (2010) consistent with results presented here.

2. Methodology

SST gradients from Oct-Nov 2011 were calculated in an area off the South American Coast between 35S to 0S and 90W to 70W.

Covariability modes of the magnitude of the SST gradients were calculated between a high resolution run of the (2km) Estimating the Circulation and Climate of the Ocean (ECCO2) model and gradients derived from the 1km gridded Multi-Scale Resolution Sea Surface Temperature Data (MUR) set and the 0.25 degree National Climatic Data Center (NCDC) SST data.

Longitude sections of SST gradients were calculated at 18S and 30S to identify possible upwelling scales. Additionally, as a reference, the maginitue of SST gradients for the same area were also derived from the WINDSAT satellite for the same period of time and area.

3. Mean SST Gradients

Figures 1 and 2 show the average magnitude of the SST gradient for Oct-Nov 2011 for ECCO2, M&R, NCDC, and WINDSAT. Clearly both ECCO2 and MUR show similar magnitudes, perhaps indicative of mesoscale and sub-mesoscale variability.

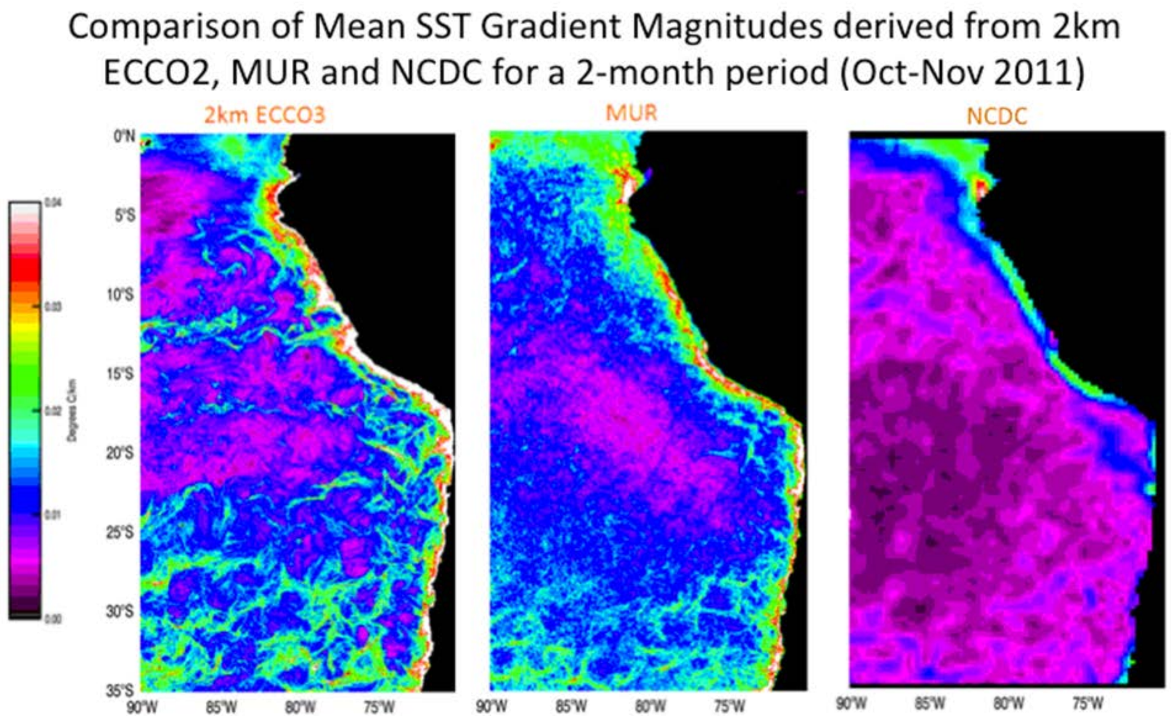

Figure 1: Mean of the magnitude of SST gradients derived from ECCO2, MUR, nd NCDC for Oct-Nov 2011.

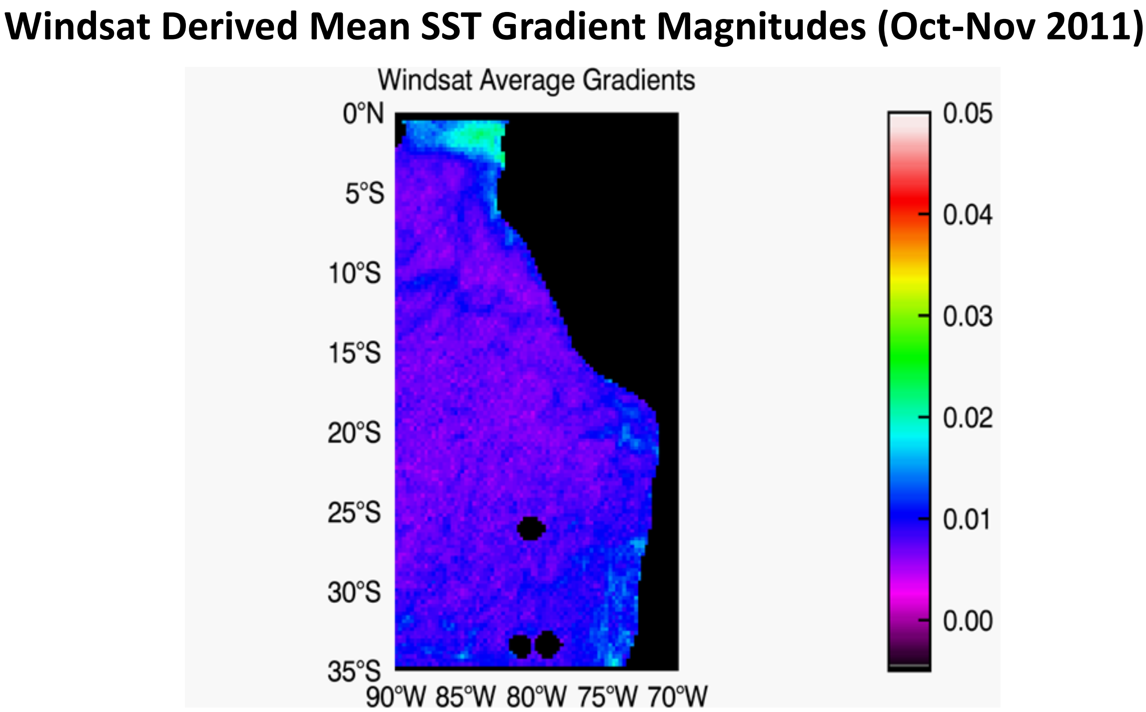

Figure 2: Mean of the magnitude of SST gradients derived from WINDSAT for Oct-Nov 2011.

4. Longitudinal Sections

Longitudinal sections of the magnitude of the SST gradients were dervied at 18S and 30S. The results shown are for the first mode of covariability between ECCO2/MUR and ECCO2/NCDC.Overlaid are also the WINDSAT SST gradient magnitudes for the same latitudes. Figure three and four shows the SST gradients at 18S. Figure 5 and 6 show the same for 30S.

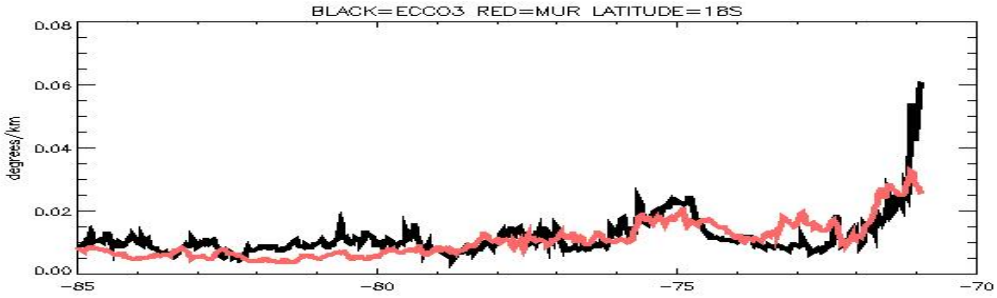

Figure 3: SST gradients at 18 for the first mode of covariability between ECCO2/MUR. Black=ECCO2 Red =MUR

Clearly MUR is doing a better job of representing the magnitude of the SST gradient, especially near the coastal upwelling region. However the NDDC derived gradients also are representative of a coastal upwelling region. Figure 4 shows the same results as igure 3 except at 30S.

SST gradients along 18S for Covariability (Mode 1) ECCO2 and MUR and NCDC

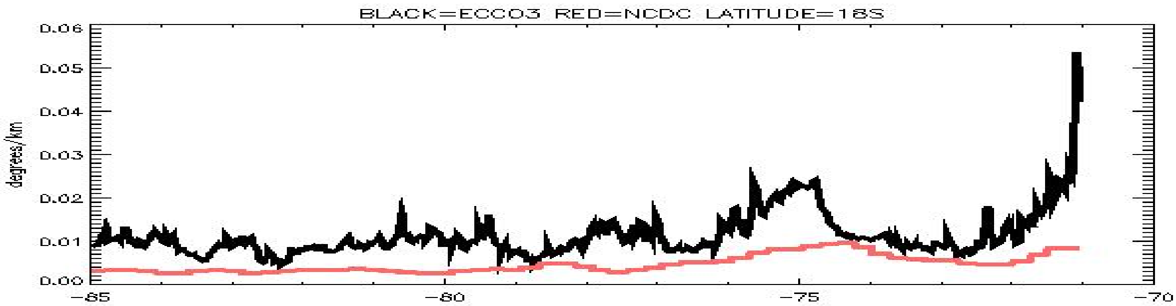

Figure 4: SST gradients at 18S for the first mode of covariability between ECCO2/NCDC. Black=ECCO2 Red=NCDC.

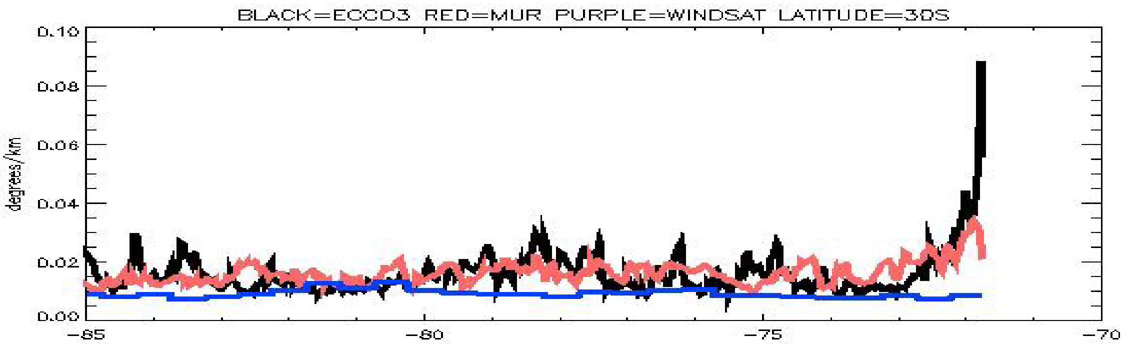

Figure 5: SST gradients at 30S for the first mode of covariability between ECCO2/NCDC. Black=ECCO2 Red=NCDC. Windsat (blue) is included as a reference.

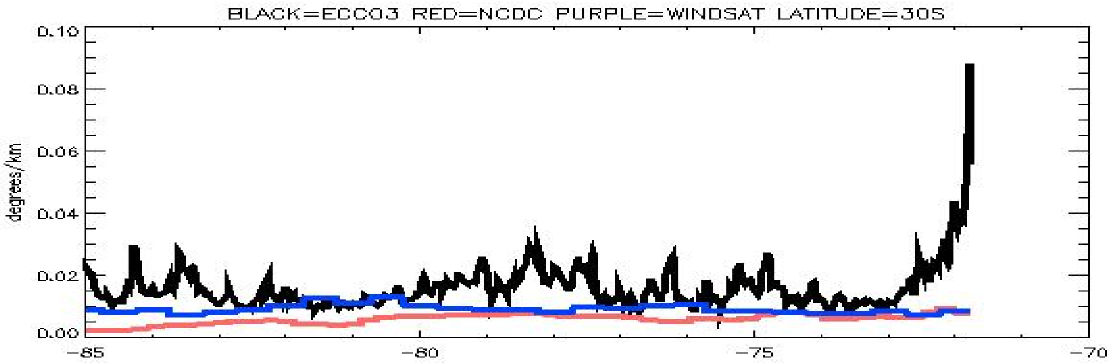

Figure 6: SST gradients at 30S for the first mode of covariability between ECCO2/NCDC. Black=ECCO2 Red=NCDC. Windsat (blue) is included as a reference.

5. Conclusion

A covariability analysis of SST gradient magnitudes derived from a 2km ECCO2 model output and MUR and NCDC level 4 products indicates much smoother gradients found in the 0.25 NCDC product that do not resolve the upwelling scales seen along the South American Coast.

Correlations of 2km ECCO2 and MUR are consistently higher for the first mode of covariability than for ECCO2 and NCDC.

Comparisons with SST gradients from WINDSAT indicate that MODIS and AVHRR are adding critical high resolution information for resolving upwelling scales, especially

Results seem to indicate that South of 25S the lower resolution SST products are not resolving smaller scale upwelling features. Windsat microwave data alone is not resolving upwelling scales along the South American Coast. Future work will focus on confirming scales and connection

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APPENDIX 2 – PHOTO

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