2017 JPSS SST Progress Report

Sasha Ignatov

Yury Kihai, Boris Petrenko, Irina Gladkova, Yanni Ding, Xinjia Zhou, Kai He, Olafur Jonasson, Matthew Pennybacker, Maxim Kramar, Paul DiGiacomo, John Sapper

NOAA Center for Satellite Applications and Research (STAR)

Summary

1. **Users**
   - Continue supporting STAR (Coast Watch, Geo-Polar Blend, CRW), CMC, Met Office
   - Significant progress with NCEP (RTG/NCODA), Australian Bureau of Meteorology, Danish Met Institute
   - Working with NOS/WCOFS, NCEI, JMA
2. **ACSPO Data**
   - Real-time L2P (May'14-pr) and L3U (May'15-pr): podaac.jpl.nasa.gov and www.nodc.noaa.gov
   - Reprocessed (RAN1) L2P/L3U + rotated (2-week) buffer of real-time data: coastwatch.noaa.gov
3. **ACSPO Development**
   - 2.41 (Aug 2016; delivered): improved mask/SST, handling H8. Implementation delayed due to NDE freeze
   - v2.50 (Sep 2017; in testing): improved SST imagery/algorithms; processes GOES-R (G16); Redesigned L3U
   - v2.60 (in development): pattern recognition, ocean fronts, geo "collated" (Mar 2018; Will be used in RAN2)
4. **Web Monitoring Upgrades**
   - ACSPO Regional Monitor for SST (ARMS; www.star.nesdis.noaa.gov/sod/sst/arms/) → to v1.40
   - SST Quality Monitor (SQUAM; www.star.nesdis.noaa.gov/sod/sst/squam/) → to v2
   - *In situ* SST Quality Monitor (*i*Quam; www.star.nesdis.noaa.gov/sod/sst/iquam/) → to v2
   - Added new data & functionality. Improved data stability, web interface, and efficiency.
5. **J1 Readiness (Scheduled Launch: Oct 2017)**
   - ACSPO v2.50 will be ready to process J1 (code may require updates; LUTs will need to be updated)
   - SQUAM and ARMS: J1 control buttons created, ready to be populated

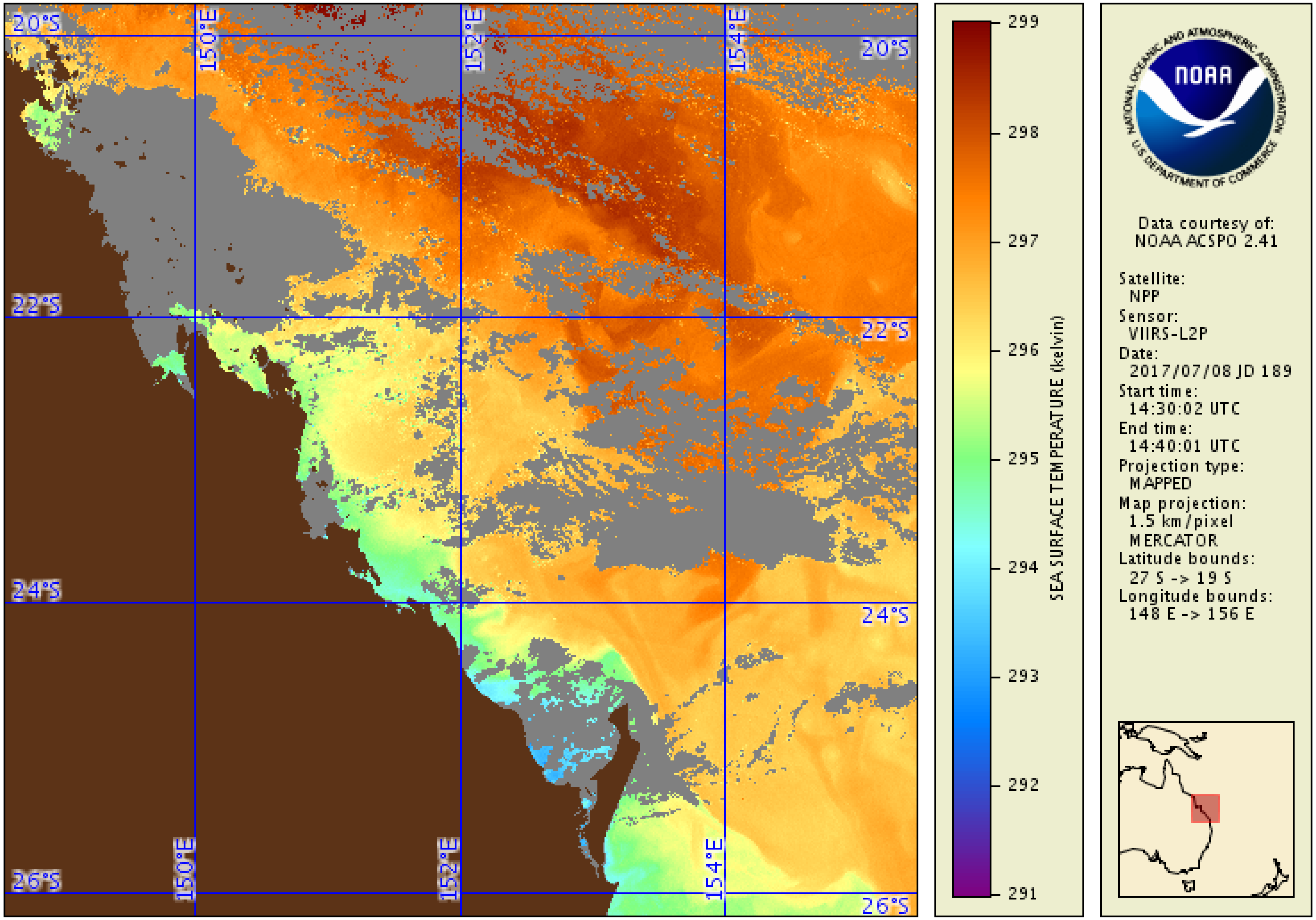
Users

1. **Continue Supporting Existing Users**
   - STAR Coast Watch (Paul DiGiacomo, Veronica Lance)
   - STAR Geo-Polar Blended Team (Eileen Maturi, Andy Harris)
   - Coral Reef Watch Team (Mark Eakin)
   - CMC L4 (Dorina Surcel-Colan)
   - Met Office (Simon Good, Emma Fiedler, Chongyuan Mao)
2. **Significant Progress with Several New Users' Groups**
   - NCEP RTG Team (Bob Grumbine, Bert Katz)
   - Australian Bureau of Meteorology (Helen Beggs, Chris Griffin, Pallavi Govekar)
   - Danish Meteorological Institute (Jacob Høyer)
3. **Emerging Users**
   - NOS West Coast Ocean Forecast System (Alexander Kurapov)
   - NCEP NCODA Team (Ilia Rivin, Jim Cummings)
   - NCEI/STAR (Tom Smith, Viva Banzon)
   - JMA (Toshiyuki Sakurai)

Many ACSPO Users Assimilate L3U Product

- L3U (Uncollated) = gridded L2P (~2 orders smaller size)
- ACSPO L3Us were requested by Met Office, ABoM, and JMA
- Initially in ACSPO v2.40, BoM L3U was employed (thanks to Chris Griffin and Helen Beggs for sharing BoM L3U code)
- New bilateral algorithm (weights are functions of distance and SST deviation from a typical SST) was employed in v2.41
- ACSPO v2.50 will also produce L3U for AVHRR (operationally) and MODIS (experimentally)
- L3U compares well w/L2P (preserves spatial features) & *in situ*
- L3U is a first step towards L3C ("collated" – multiple overpasses of the same satellite are collated) and L3S ("super-collated" – all overpass from all platforms collated together)

L2P: Southern Great Barrier Reef, Australia
SNPP VIIRS 8 July 2017



L3U: Southern Great Barrier Reef, Australia
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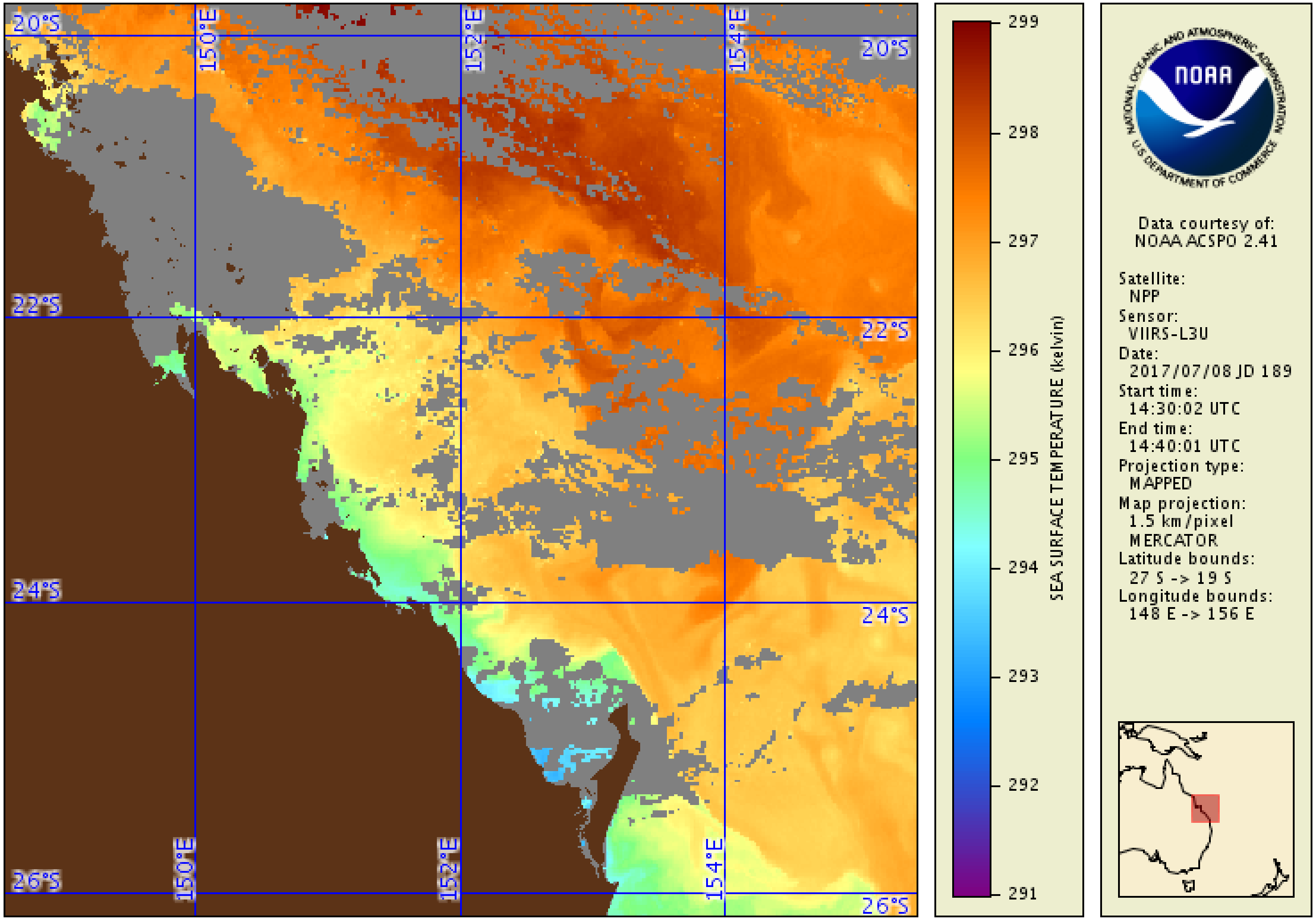
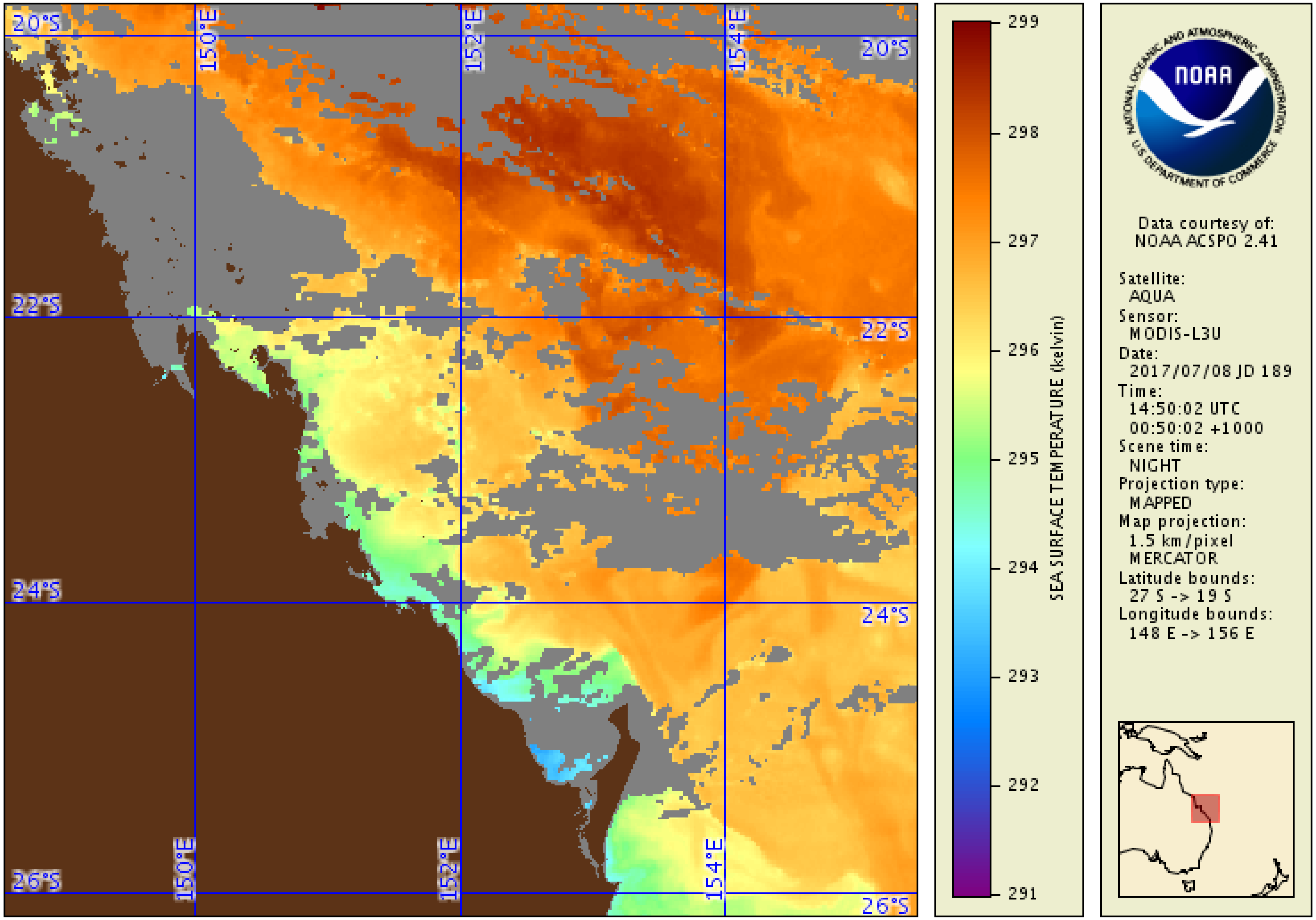
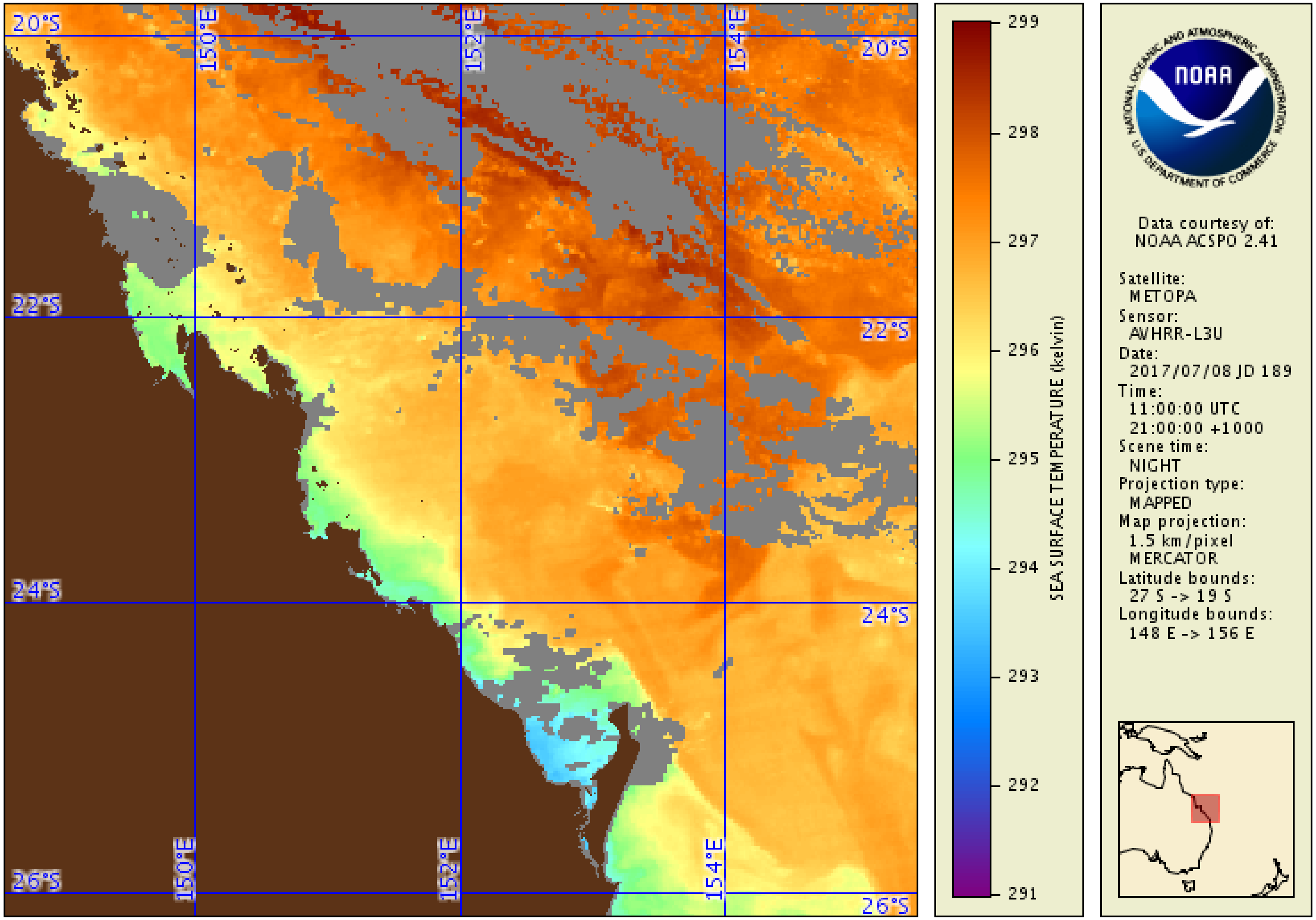


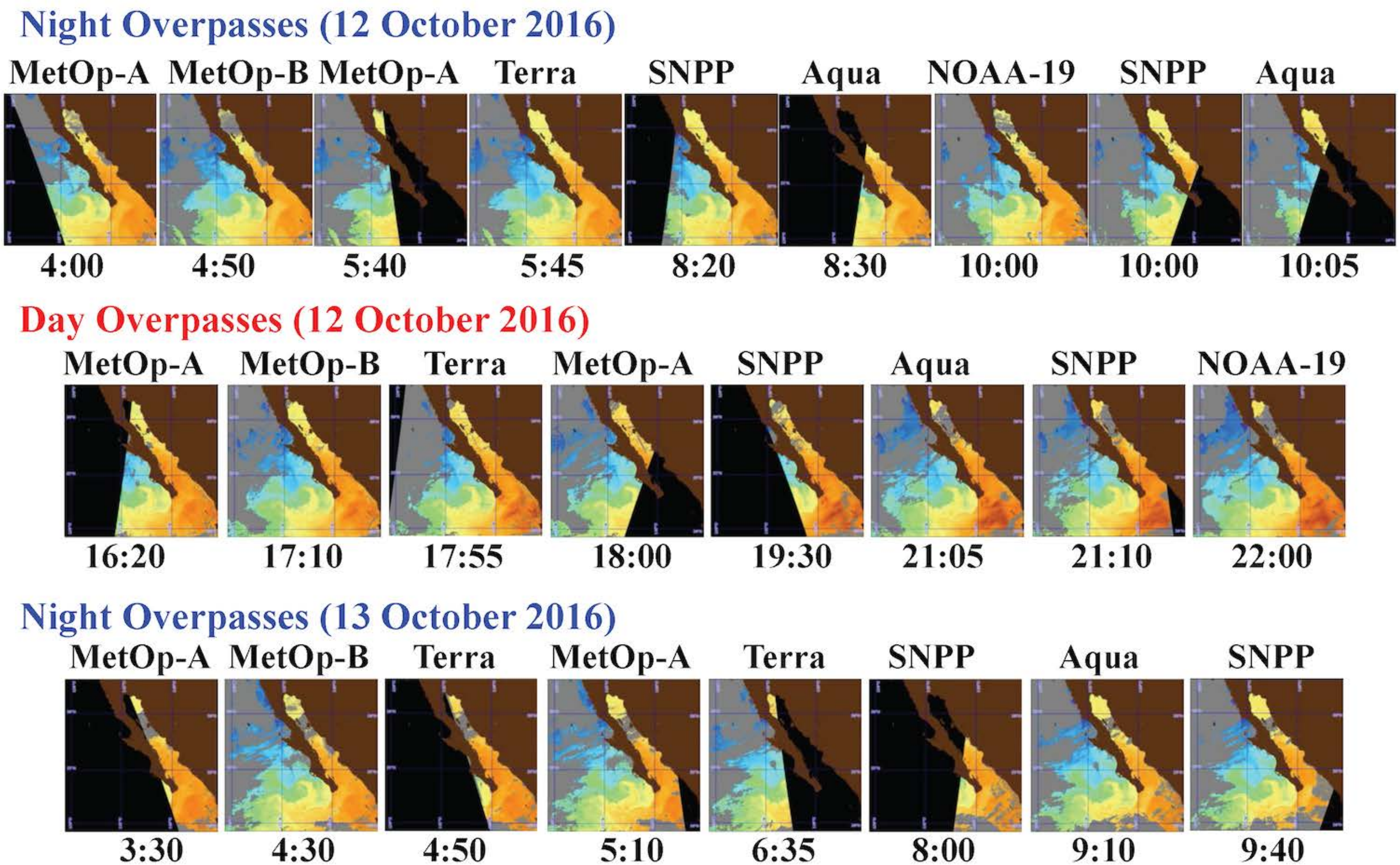
L3U: Southern Great Barrier Reef, Australia
Aqua MODIS 8 July 2017



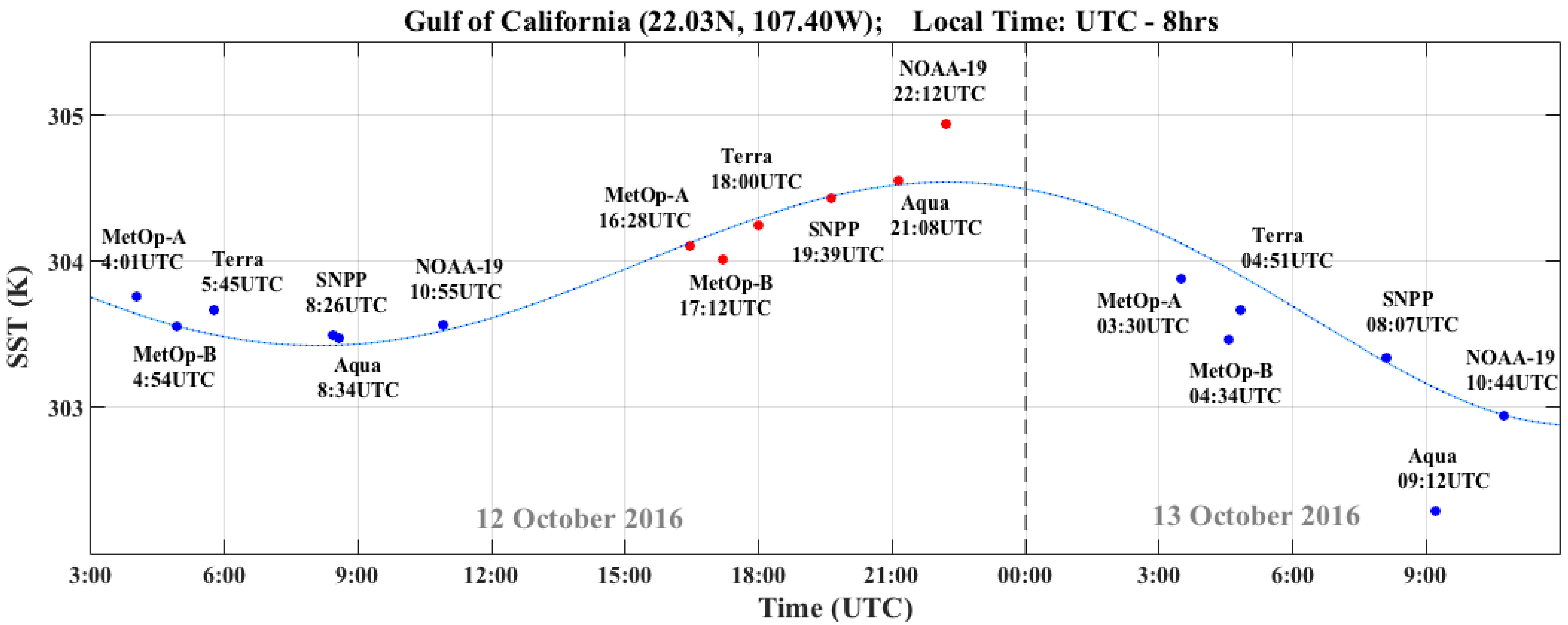
L3U: Southern Great Barrier Reef, Australia
Metop-A AVHRR 8 July 2017



Towards L3C/L3S Products: Example over Gulf of California in Oct 2016



Future ACSPO L3C/L3S Products



- L3C/L3S should resolve the diurnal cycle (not simply average different L3Us together)
- Individual L3Us should be de-biased and weighed in inverse proportion to their RMSEs
- Need to understand users' needs & requirements, leverage BoM L3C/L3S experience

ACSPO Data Products & Distribution

- NDE/OSPO produce ACSPO L2P/L3U SST from VIIRS (SNPP; soon to be also J1), AVHRR GAC (N19, Metop-A/B) and FRAC (Metop-A/B) operationally
- Operational Products are distributed via OSPO “Product Distribution & Access” (PDA)
- STAR processes MODIS-A and -T experimentally, and has generated GAC and SNPP VIIRS Reanalyses-1 (“RAN1”)
- The plan is keep on Coast Watch (CW; coastwatch.noaa.gov) a rotated (~2-week) buffer of VIIRS/AVHRR and ABI/AHI operational, and MODIS experimental L3U products, and supplement them with science-quality L3U RANs. L2Ps will be only served by special request, due to data size
- The CW will work with NCEI to archive RAN products
- Things are in flux now, work underway to shape them up by Aug 2018
- Contact A. Ignatov with any questions

ACSPO L2P Products

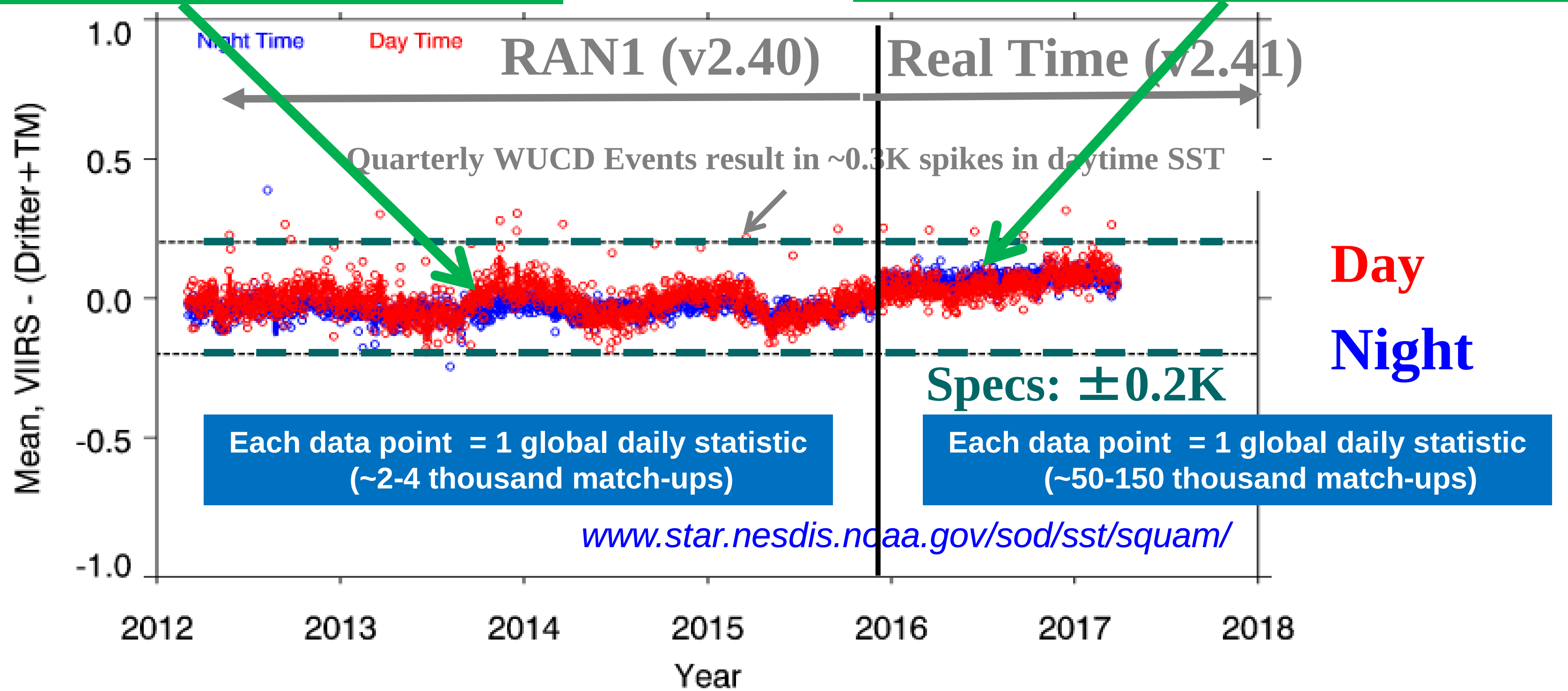
- ACSPO files are in GHRSST Data Specification v2 (GDS2) NetCDF format
- Data organized into 10min (VIIRS, AVHRR FRAC), 1hr (AVHRR GAC), and 5min (MODIS) granules
- Daily data size: 27GB (VIIRS), 10GB (FRAC/MODIS), and 0.8GB (GAC)
- BTs in all SST bands, and “sub-skin” SST (derived by a regression algorithm) are reported in all ocean pixels (including cloud, ice, etc.) up to 10km inland
- Clear-sky mask & QLs provided in each pixel (we only recommend using QL=5)
- Single Sensor Error Statistics (SSES) Bias & SD are reported in each pixel. They were derived from match-ups with *in situ* data using Piece-Wise Regression (Petrenko et al, 2016) and represent expected SST errors wrt. *in situ* in each pixel
- Subtracting SSES bias from “regression sub-skin SST” reconciles it with *in situ* SSTs (minimizes regional biases, by minimizing residual cloud/aerosol, VZA/TPW dependent errors in regression algorithms, and diurnal effects)
- We recommend correcting for SSES biases in data assimilation/analysis applications, especially those aimed at “bulk” (foundation) SST

ACSPO L3U 0.02º Products

- ACSPO files are in GHRSST Data Specification v2 (GDS2) NetCDF format
- Data organized as L2P: 10min (VIIRS, AVHRR FRAC), 1hr (AVHRR GAC), and 5min (MODIS) granules
- Daily data size: 0.7GB (VIIRS, FRAC, MODIS, GAC)
- “Sub-skin” SST are only reported in clear-sky pixels with QL=5
- BTs are not reported
- As in L2P, SSES bias and SD are reported in each pixel.
- As in L2P, we recommend correcting for SSES biases in data assimilation/analysis applications especially aiming bulk/foundation L4s

Validation of VIIRS L2P SST Vs. Drifters + Trop. Moor. Global Bias (No SSES Bias Correction)

One-to-One Matchups (10km,30min) | **One-to-Many Matchups (10km,30min)**



- Overall, product meets specs & users' requirements – except the WUCD events
- Quarterly spikes are due to Warm-Up Cool-Down exercises – working with SDR to resolve
- Biases are more consistent during RAN1 (Mar'12 – Dec'15). In NRT, a warming trend is seen
- **Working w/SDR to fix WUCD and set up infrastructure in STAR for RAN2 (in FY18)**

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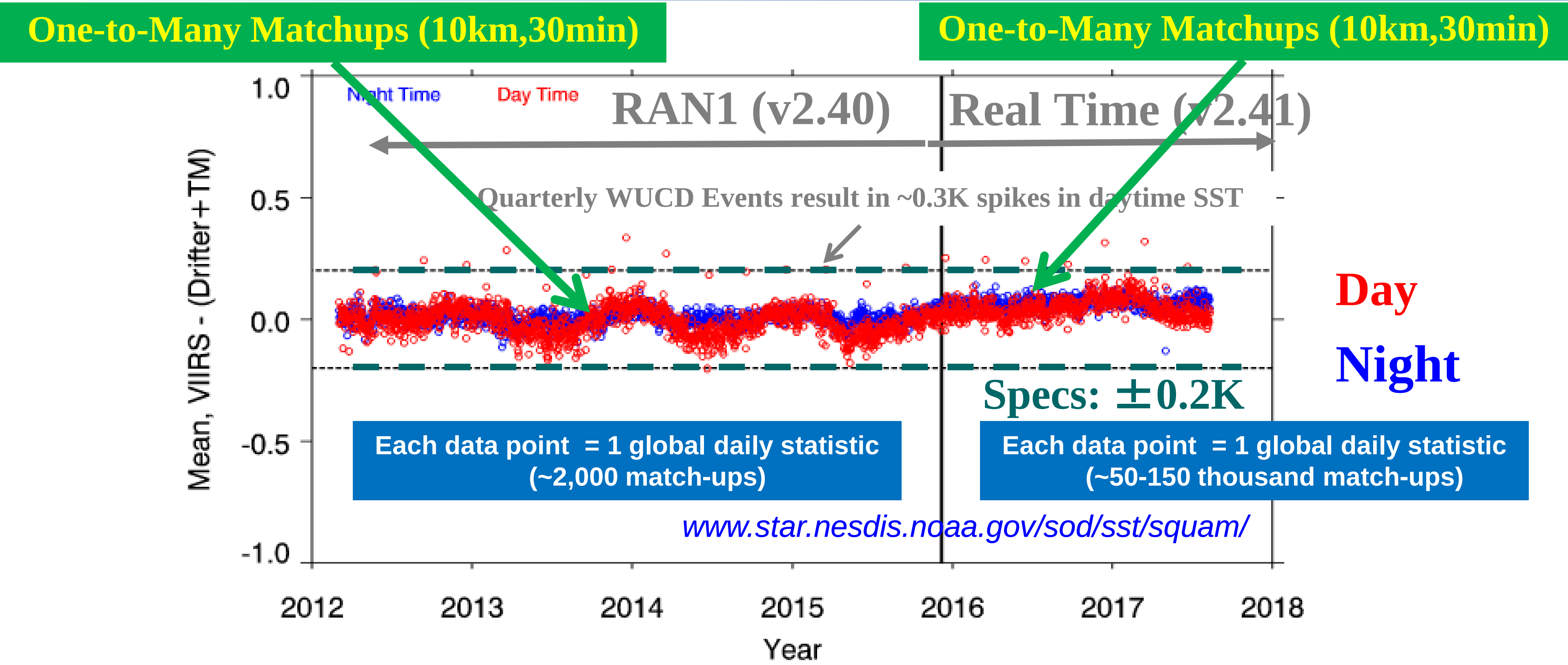

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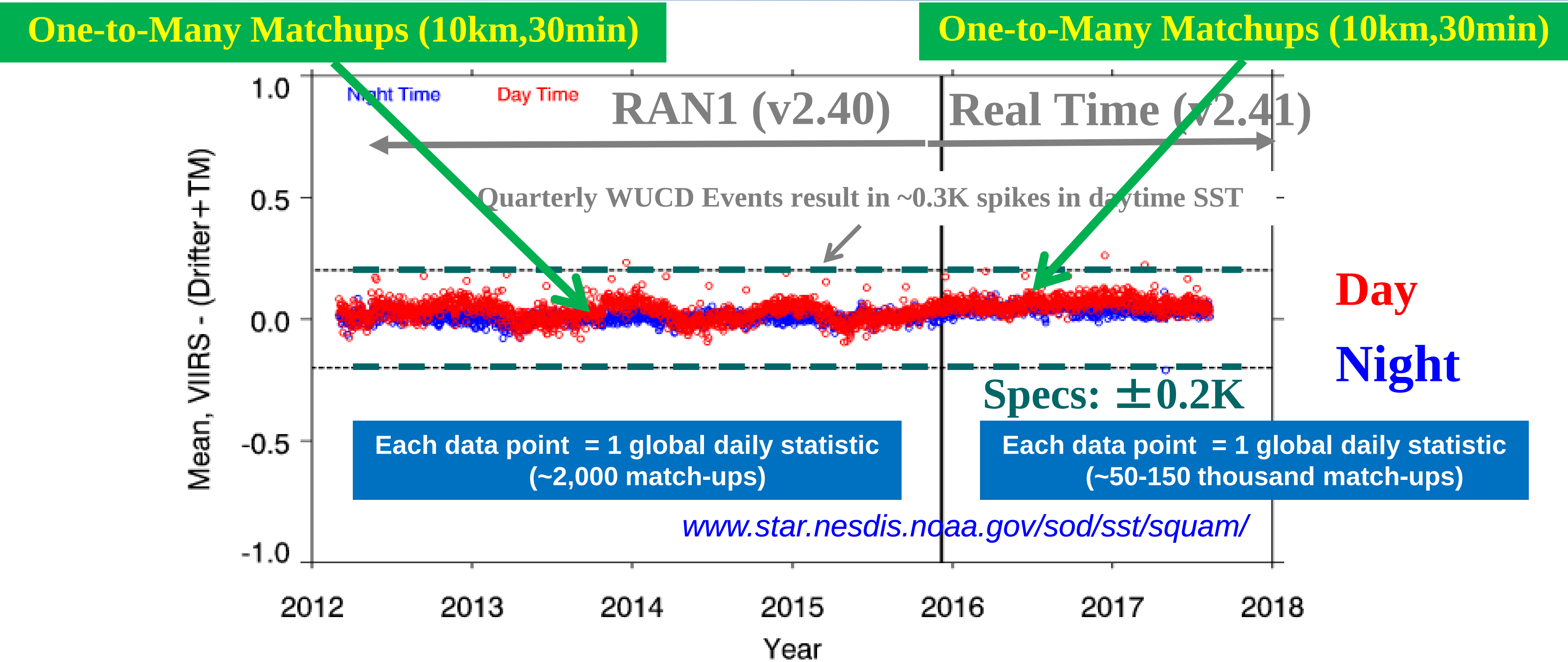

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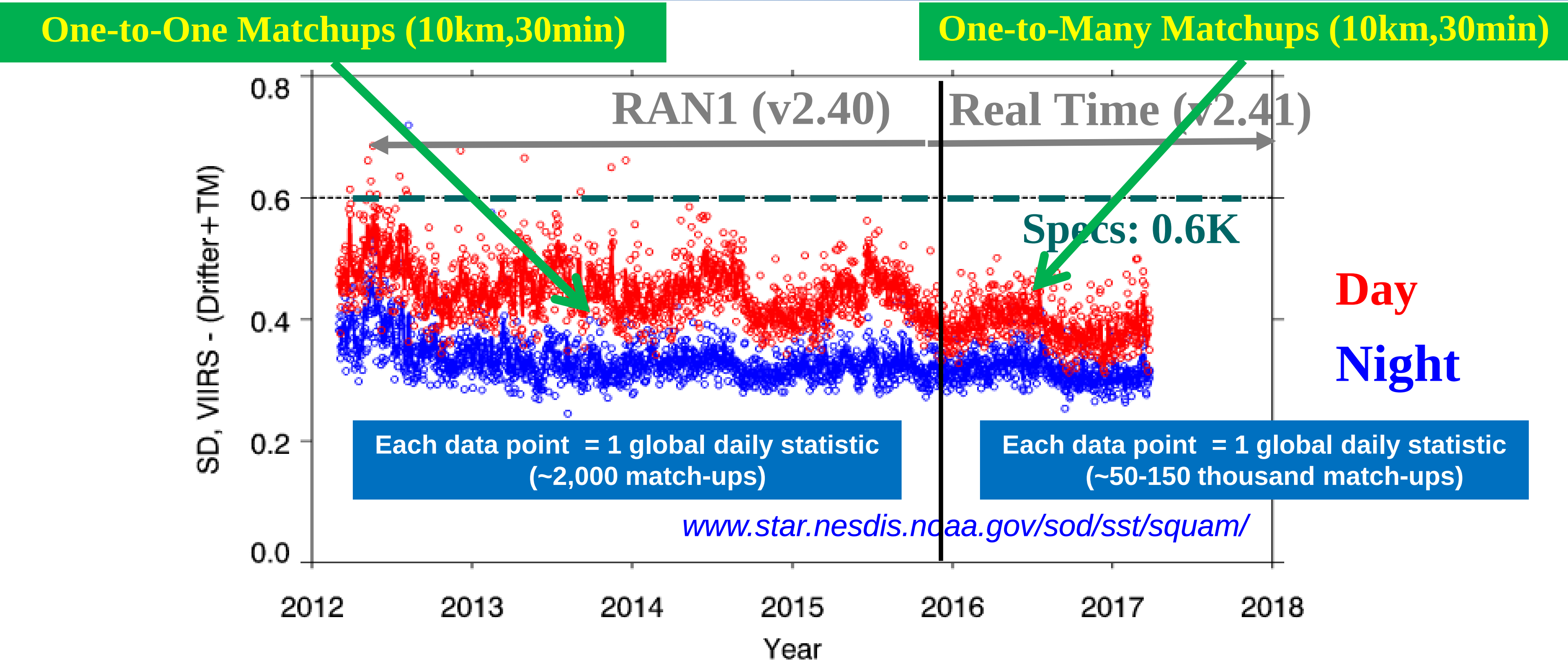
Validation of VIIRS L2P SST Vs. Drifters + Trop. Moor. Standard Deviation (No SSES Bias Correction)



- Current SDs ~0.30K (Night) and ~0.40K (Day). Both meet specs & users' requirements
- SDs smaller @night (skin VIIRS SST is closer to buoy bulk SST) and larger during daytime
- ACSPO v2.41 appears less noisy, compared to previous version 2.40 used in RAN1
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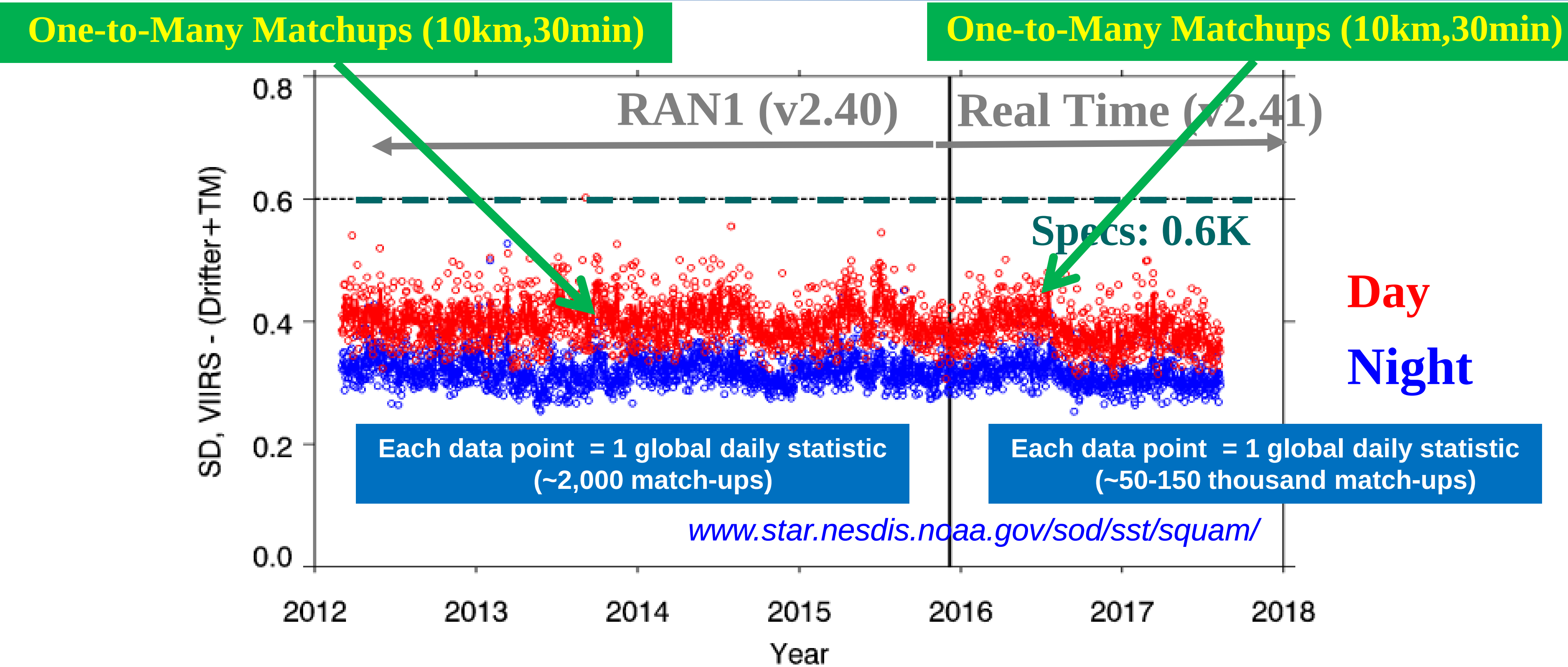

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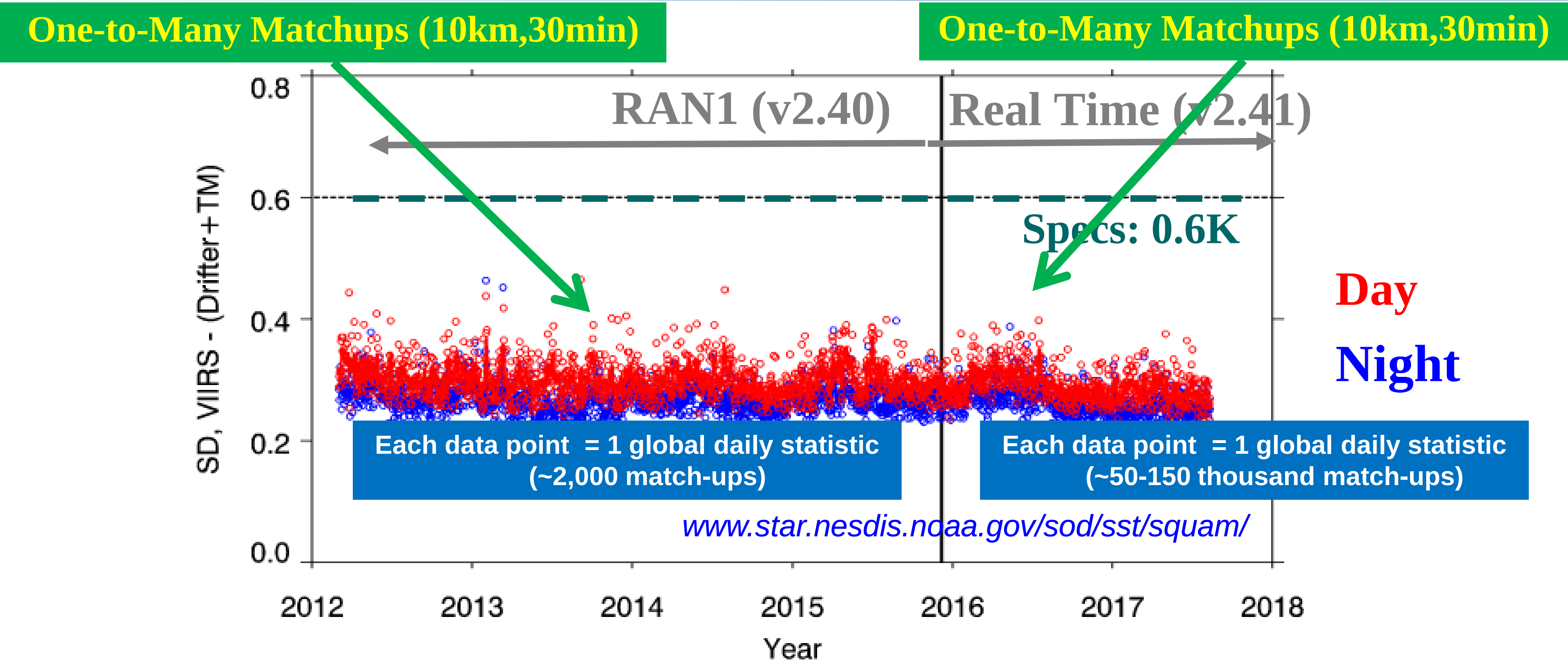

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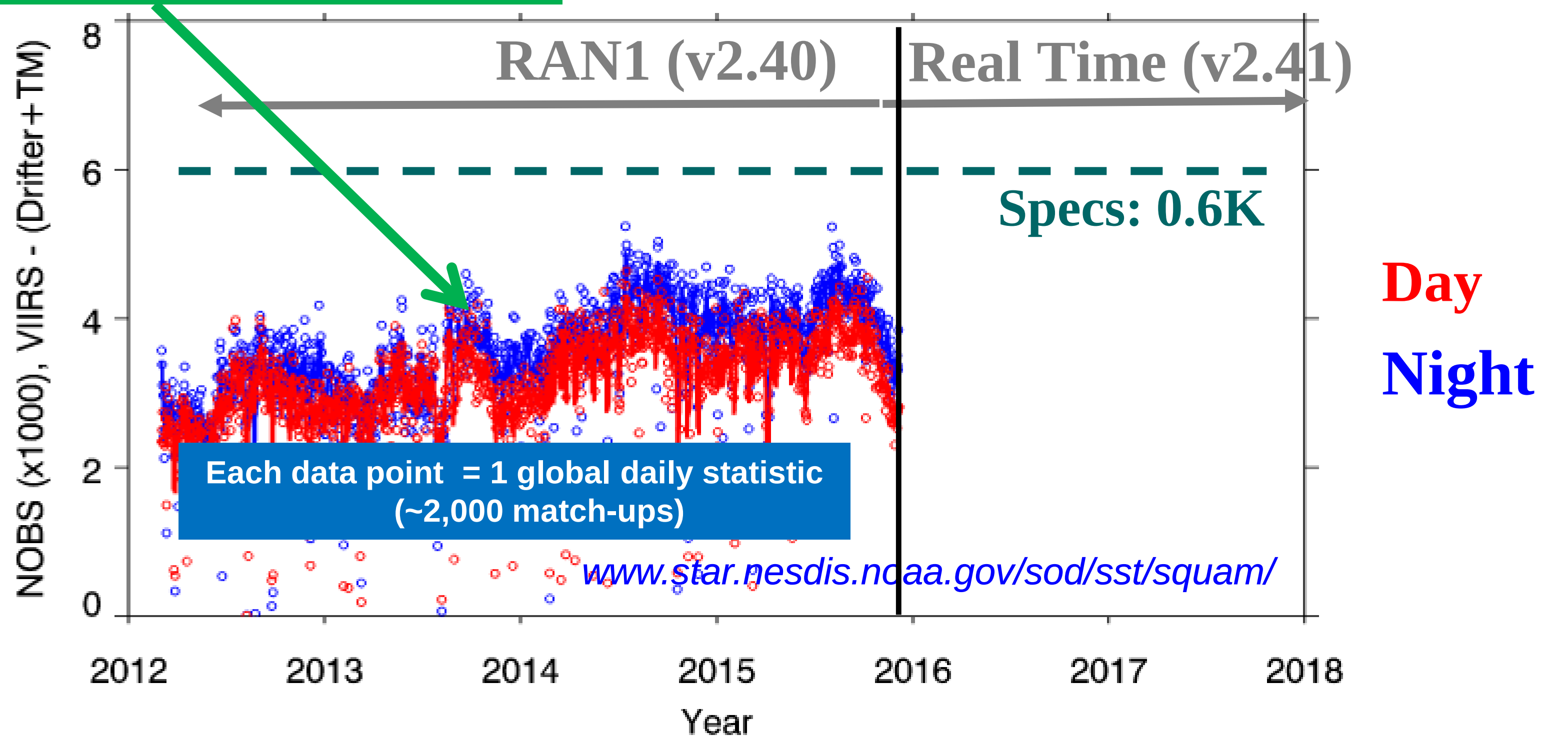

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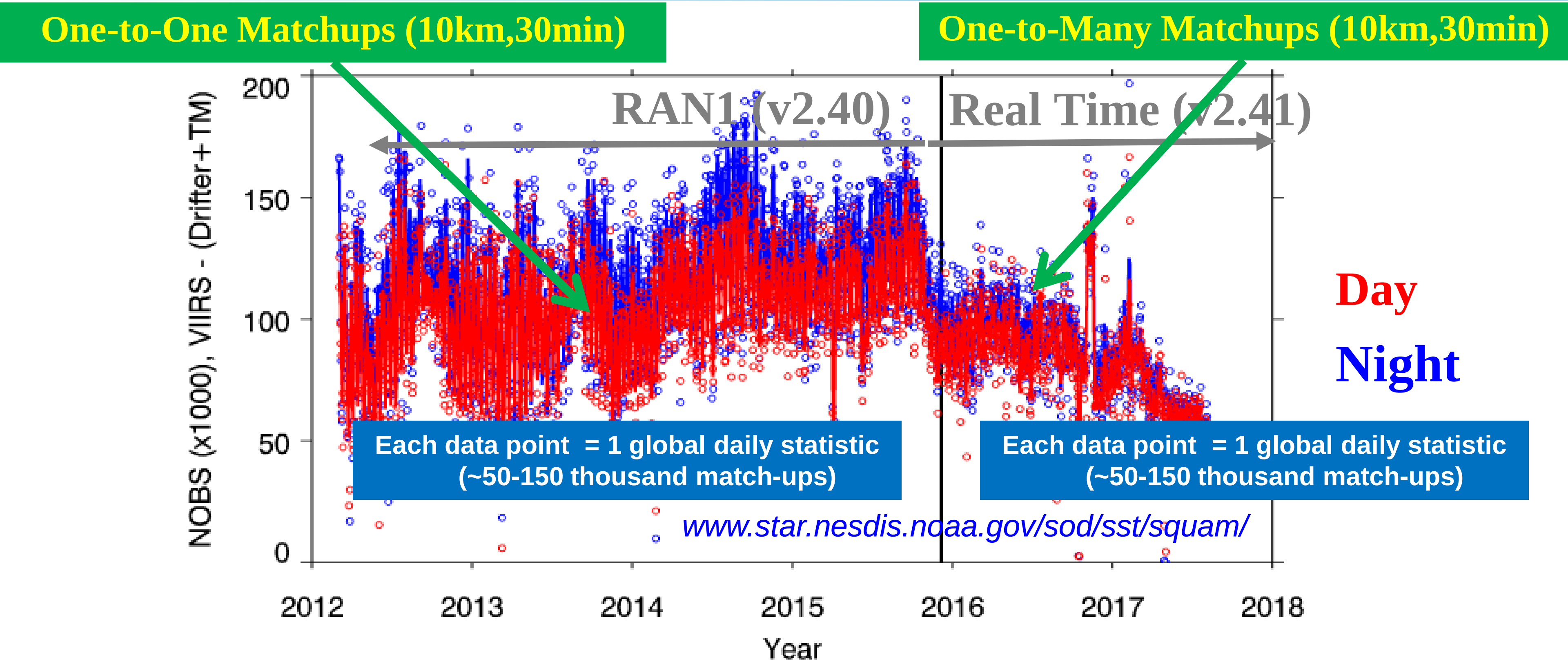

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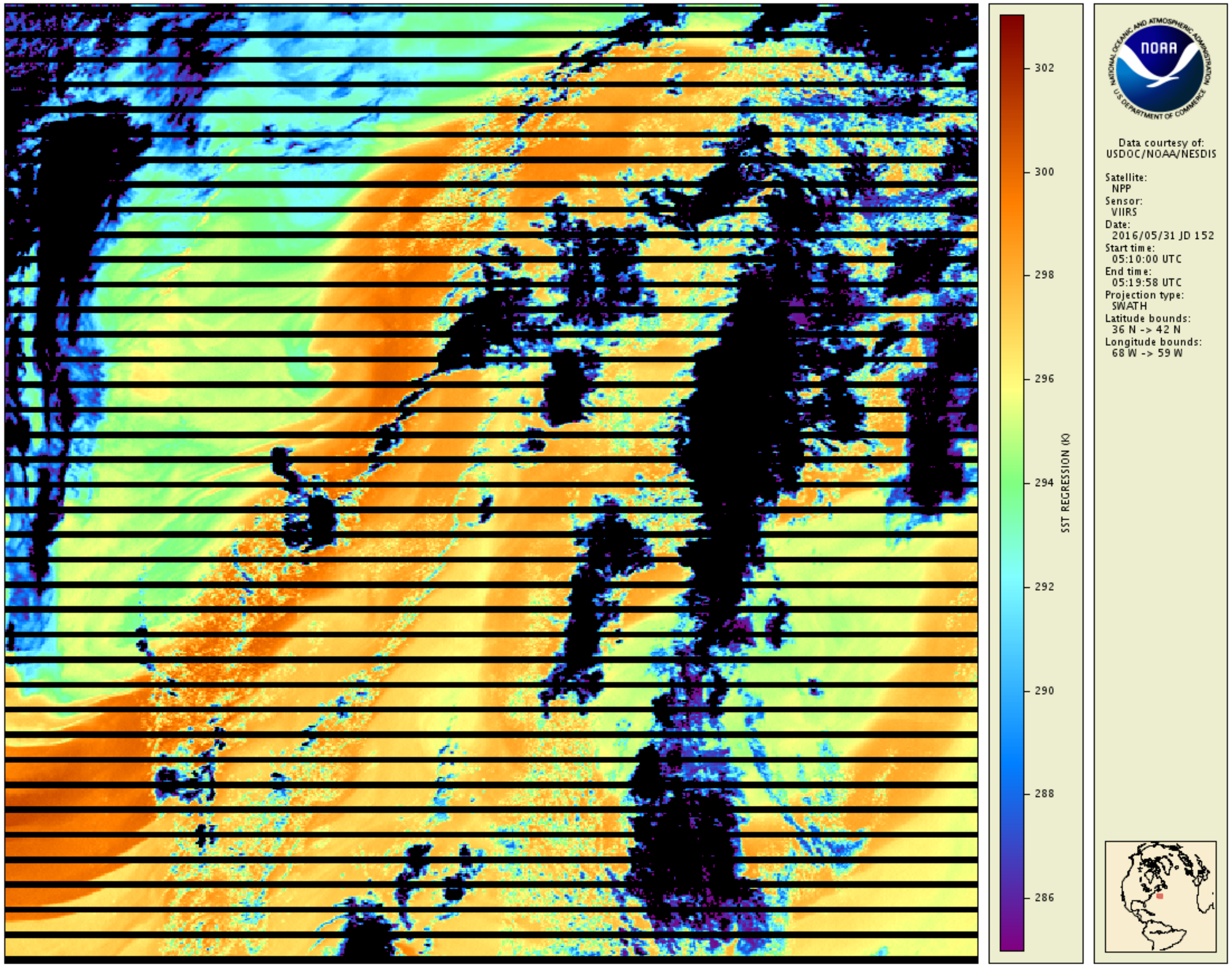
ACSPO Versions 2.50 and 2.60

1. ACSPO 2.50 (Sep 2017) will improve brightness temperature (BT) and SST imagery in the full VIIRS swath, using special **resampling** algorithms to (a) minimize geometrical distortions; and (b) fill in the bow-tie deleted pixels.

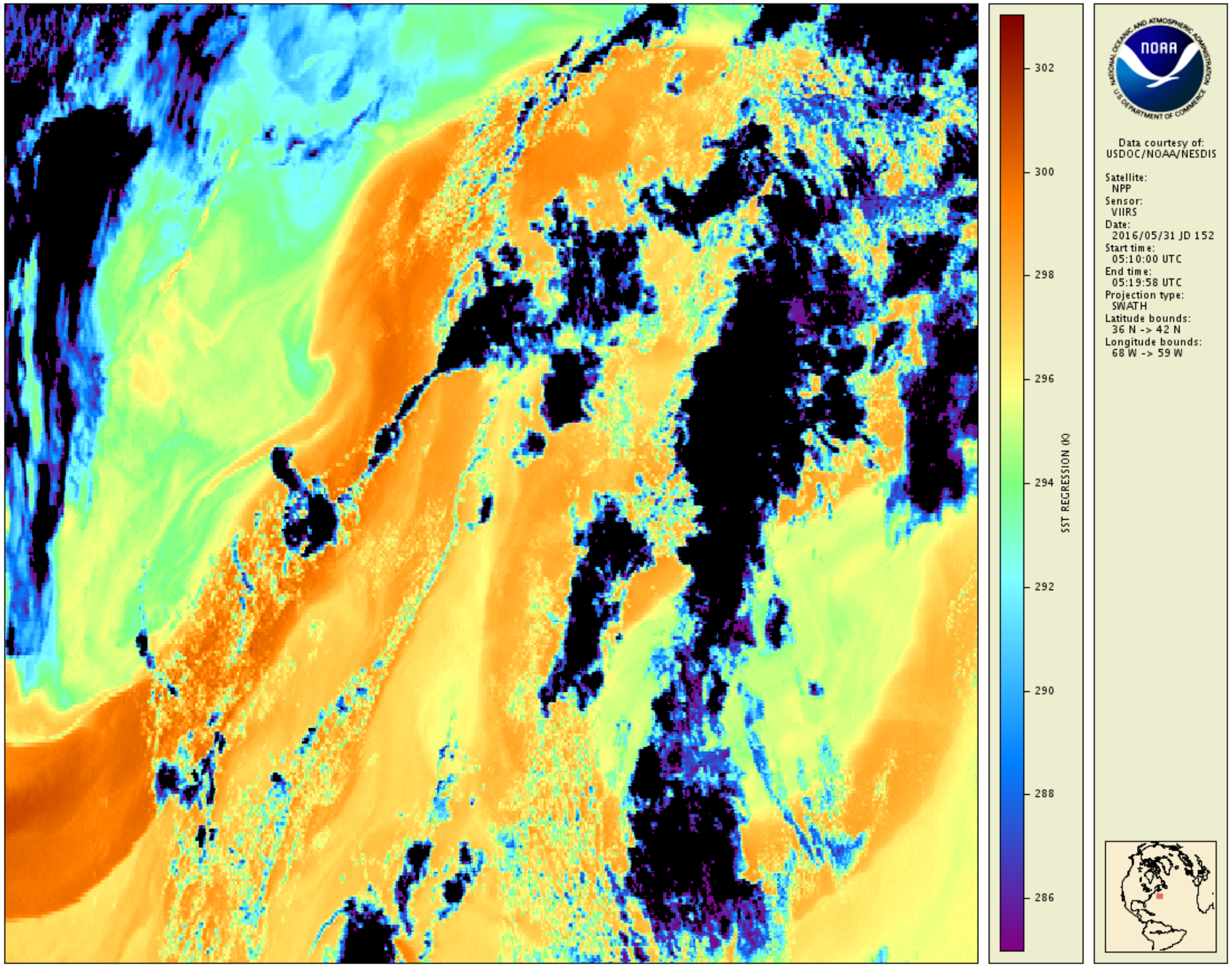
2. ACSPO 2.60 (Mar 2018) will (a) derive **ocean fronts**; and (b) improve **clear sky identification** in dynamic, coastal, and high-latitude areas of the ocean.

For SST Improvements in v2.50, see presentation by Petrenko et al (this breakout)

VIIRS SST Imagery in ACSPO v2.41



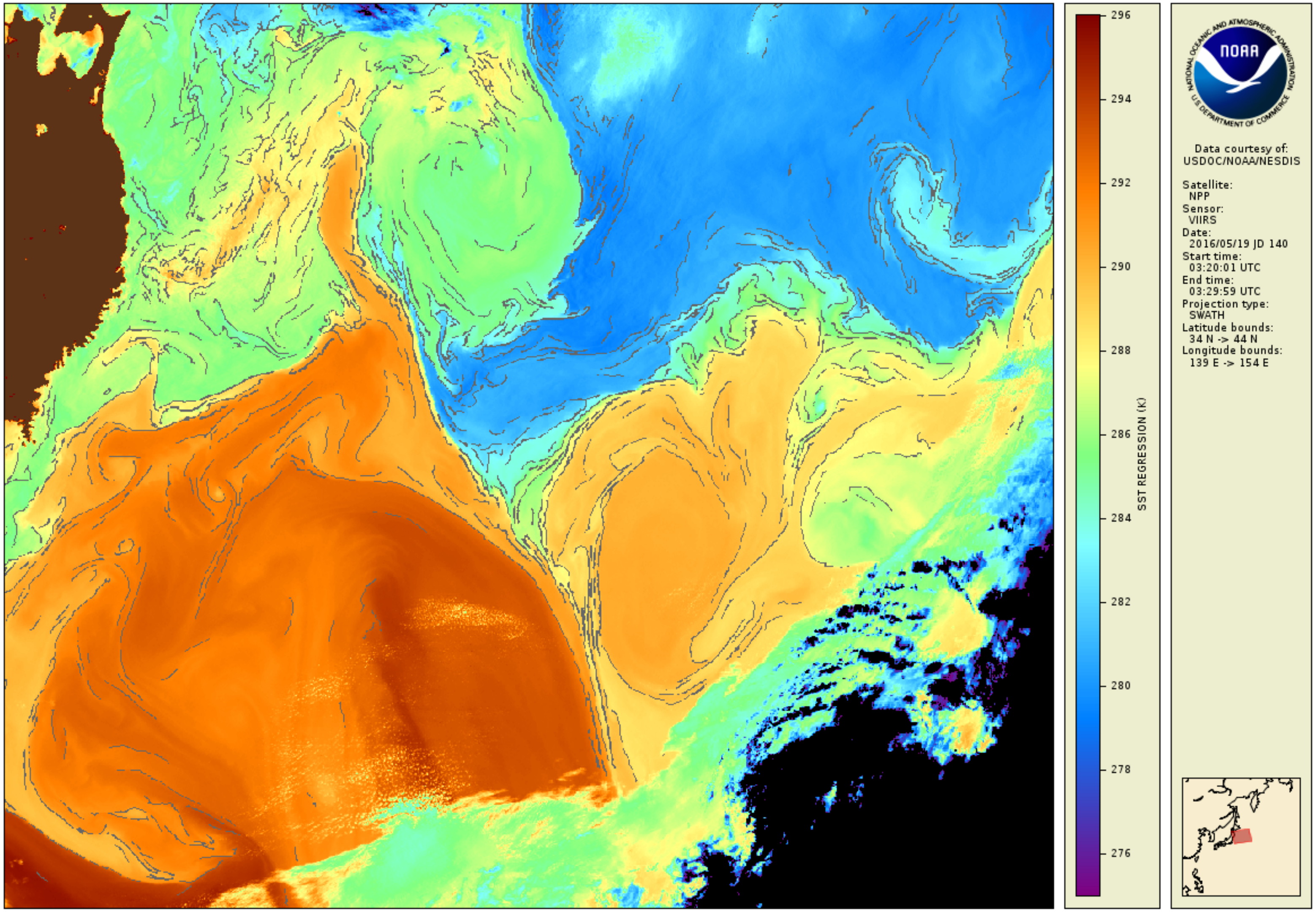
VIIRS SST Imagery in ACSPO v2.50 – on



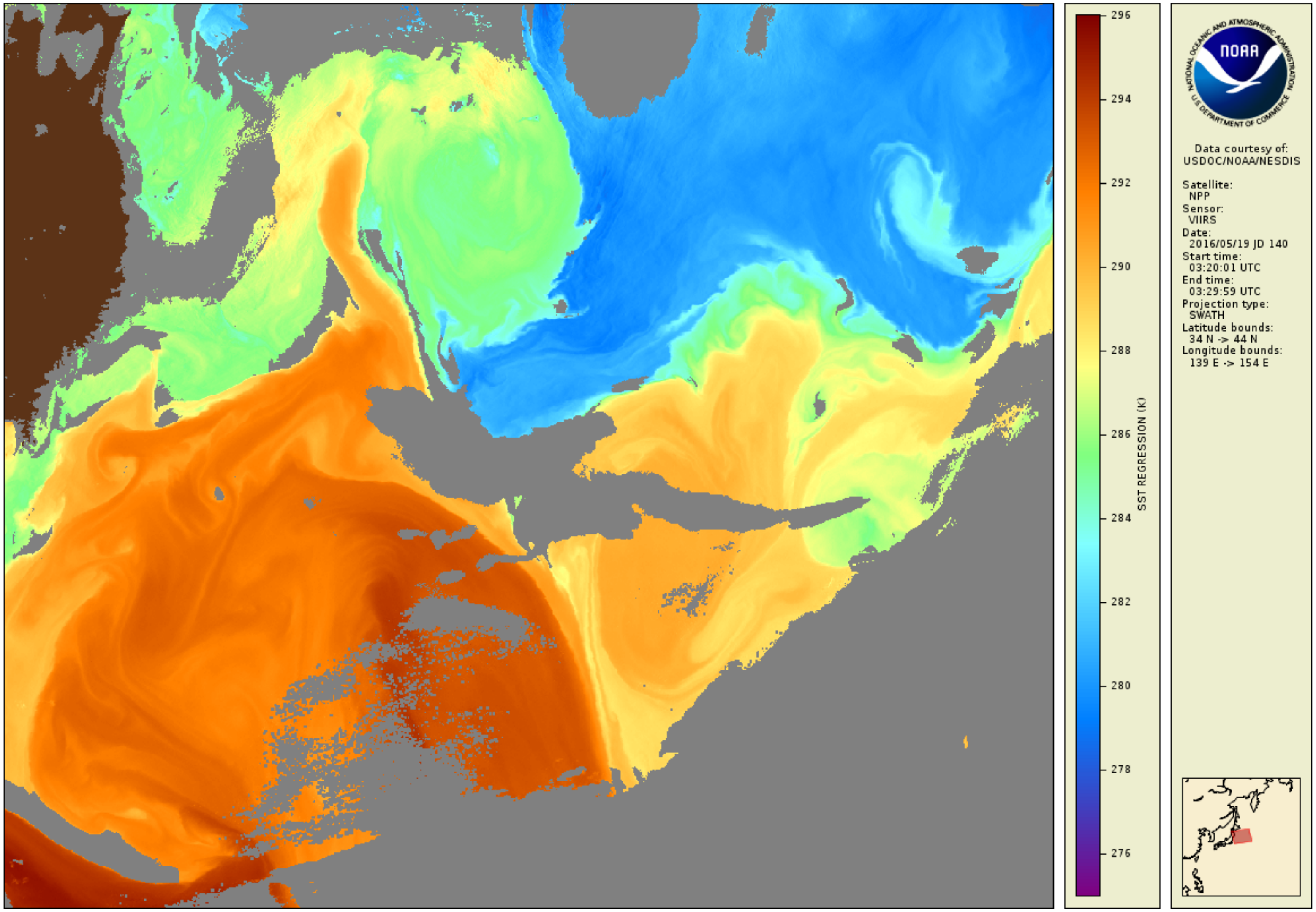
Clear-Sky Identification for SST: Current Practices and Limitations

- All existing clear-sky masks are subject to 2 types of misclassifications: “false alarms” and “cloud leakages”
- False alarms often occur in dynamic areas (currents, eddies, upwellings), costal zones, and sea-ice transitions
- Misclassifications are often persistent from one overpass to another
- Result in loss of data in interesting areas and day/night inconsistency
- Cloud leakages can lead to false front detection
- Traditional front detection algorithms assume availability of external clear-sky mask

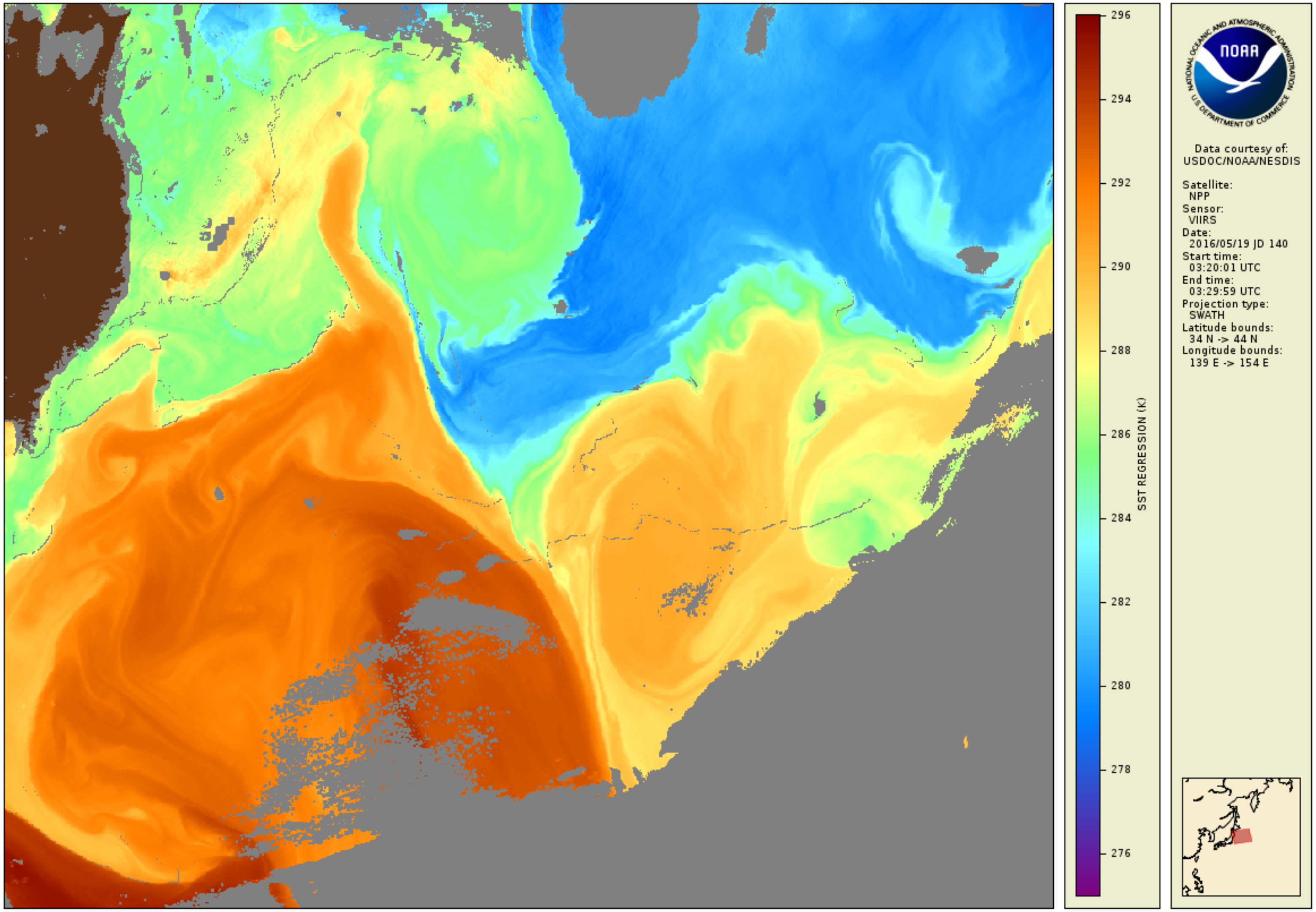
All-Sky SST with Thermal Fronts Overlaid: Kuroshio Current 19 May 2016



Example of False Alarms: Kuroshio Current 19 May 2016



SST with Corrected Clear-Sky Mask: Kuroshio Current 19 May 2016



Motivation for SQUAM Redesign

- Challenging data volumes and demand for computing resources
  - New gen polar: VIIRS onboard SNPP and future J1 – J4; AVHRR FRAC onboard Metops; MODIS onboard Terra and Aqua
  - New gen geo: ABI onboard G16 and future GOES-S/T/U, AHI onboard Himawari-8/9
  - Reanalyses (RAN): AVHRR GAC and VIIRS, future FRAC, MODIS, etc.
- Need for new functionalities
  - SSES bias correction
  - Variable regression coefficients (for ACSPO RAN SSTs)
  - SQUAM processing improvements: time aggregation, match-up, etc
- Need for updating the web interface
  - Room for improvement with new web tech (graphic, interactivity, speed, etc.)
- Development of SQUAM2 started in 2016

He et al, SQUAM2 (this breakout)

Enhancements in *i*Quam2

As *i*Quam user community grows, it requested several enhancements

- ❑ Extend time series to full satellite era (Sep 1981 – on)
- ❑ Improve QC, by adding
  - the 2nd reference SST (CMC)
  - performance history check (*i*Quam check similar to the UKMO/CMS "black lists")
  - CMS black list; and individual QFs from data producers (ICOADS, ARGO, IMOS)
- ❑ Improve web interface
  - Redesign web engine (from flash player to High Charts)
  - Add daily (hourly) statistics
  - Enhance graphics (interactive display, and print/save functions)
- ❑ Add new *in situ* data
  - ARGO Floats (in NRT and post-processing modes)
  - High-Resolution Drifters
  - IMOS Ships
  - Coral Reef Watch buoys
- ❑ Change output data files to NetCDF4. (Maximally reconcile with GHRSST GDS2 satellite L2/L3 format).

Zhou et al, SQUAM2 (this breakout)

What is ARMS?

1. **A part of the NOAA SST Monitoring system, focusing on challenging areas, most interesting to data users & producers**
   - Coastal/Internal waters
   - Dynamic areas
   - High latitudes
   - Cloudy regions
2. **Monitors regional performance of ACSPO SST & clear-sky mask**
3. **Checks for image quality & consistency**
4. **Compares polar vs. geo ACSPO SSTs**
   - Himawari-8 AHI
   - GOES-16 ABI
5. **Compares ACSPO L2/L3 SSTs with several hi-res L4 SSTs**
   - 0.01° JPL MUR
   - 0.05° Met Office OSTIA
   - 0.05° NOAA Geo Polar Blended
   - 0.10° Canadian Met Centre CMC

Ding et al, SQUAM2 (this breakout)

Main Take-Home Messages

- Users are key NOAA priorities. We are committed to product services and improvements to meet users' needs and expectations
- VIIRS L3U product finds a good traction with VIIRS SST users. We encourage whose users who still use L2P data, to consider L3U
- ACSPO L3U line of products is being extended to include other polar (AVHRR FRAC/GAC, MODIS) and geo (ABI/AHI) sensors
- This will provide a uniform line of high quality / small size ACSPO products to users, from all US polar sensors
- Also, it will set the stage for collated/super-collated ACSPO products
- NOAA Coast Watch will serve ACSPO RAN products, supplemented by rotated buffers of near-real time data (to complement NOAA PDA and JPL PO.DAAC), and transition to NCEI for archival
- NOAA Monitoring and Validation systems are being continuously upgraded to best serve needs of ACSPO users & producers

Future Work

- Support J1 launch
  - NOAA ACSPO system and Monitoring tools are ready
- Two coming ACSPO deliveries to operations
  - V2.50 (Sep 2017): Improved SST imagery & SST algorithms
  - V2.60 (Mar 2018): Improved cloud mask and thermal fronts
- Perform SNPP RAN2 (v2.60), archive w/Coast Watch (2018)
- Release new versions of monitoring systems and document (2018)
  - SQUAM v2
  - *i*Quam v2
  - ARMS v1.40
- Work with STAR/JPSS/GOES-R Management to define path to L3 collated (L3C) and super-collated (L3S) ACSPO products (TBD)


Thank You!

JPSS Annual Meeting

17 August 2017, College Park, MD

Current status and upcoming changes in ACSPO VIIRS SST

Boris Petrenko[1,2], Alexander Ignatov[1] , Yury Kihai[1,2], Xinjia Zhou[3], Kai He[3], Maxim Kramar[1,2]

(1) NOAA STAR, USA; (2) GST, Inc., USA; (3) CSU CIRA, Inc., USA

Current ACSPO 2.41 VIIRS SST products

Product	**Global Regression (GR) SST**	**Piecewise Regression (PWR) SST (aka De-biased SST)**
Representation in ACSPO GDS2 file	"sea_surface_temperature"	"sea_surface_temperature" -"SSES_bias"
Algorithm	Two regression equations, (one for day and one for night)	Piecewise regression with multiple sets of coefficients for separate segments of the SST domain
Bands used	Night: M12 (3.7 µm), M15 (10.76 µm) and M16 (12.01 µm) Day: M15 and M16	
Coefficients training	Least-squares method: best fit of *in situ* SST	
Precision wrt *in situ* SST	Night: ~0.3 K Day: ~0.4 K	Night: ~0.25 K Day: ~0.3 K
Mean sensitivity to SSTskin	Night: ~0.97 Day: ~0.9	Not controlled

- GR SST is sensitive to "skin" SST – "subskin" SST
- PWR SST precisely fits *in situ* SST - proxy for "depth" SST

Changes in VIIRS SST algorithms in ACSPO v.2.50

Change	Expected improvement
1. VIIRS band M14 (8.55 µm) is involved in SST retrieval, along with bands M12, M15 and M16	✓ Improved precision with respect to *in situ* SST
2. The PWR SST equation accounts for GFS wind speed and Local Solar Time	✓ Improved precision of PWR SST with respect to *in situ* SST ✓ Improved reproduction of diurnal cycle in "depth" SST
3. The definition of SSES SD changes from SD of GR SST-*in situ* SST to SD of PWR SST – *in situ* SST	✓ Improved assimilation of PWR SST in L4 analyses (potentially)
4. PWR "skin" SST is implemented for internal testing	✓ Improved "skin" SST retrieval (compared with GR SST)

VIIRS GR SST equations in ACSPO v.2.50

Night:

$$T_S = a_0 + a_1 T_{11} + a_2(T_{11}-T_{3.7}) + a_3(T_{11}-T_{8.6}) + a_4(T_{11}-T_{12}) +$$
$$+[a_5 + a_6 T_{11} + a_7(T_{11}-T_{3.7}) + a_8(T_{11}-T_{8.6}) + a_9(T_{11}-T_{12})]S_\vartheta +$$
$$+ [a_{10}(T_{11}-T_{3.7}) + a_{11}(T_{11}-T_{8.6}) + a_{12}(T_{11}-T_{12})]T_S^0$$

Day:

$$T_S = a_0 + a_1 T_{11} + a_3(T_{11}-T_{8.6}) + a_4(T_{11}-T_{12}) +$$
$$+[a_5 + a_6 T_{11} + a_8(T_{11}-T_{8.6}) + a_9(T_{11}-T_{12})]S_\vartheta +$$
$$+ [a_{11}(T_{11}-T_{8.6}) + a_{12}(T_{11}-T_{12})]T_S^0$$

$T_{3.7}, T_{8.6}, T_{11}, T_{12}$	observed BTs
$S_\vartheta = 1/\cos(\vartheta) - 1$	ϑ is VZA
T_S^0	L4 SST in °C (currently by Canadian Meteorological Center – CMC)
a’s	regression coefficients, trained against drifters and mooring buoys

- New equations include regressors of the conventional types, which can be constructed from 3 or 4 radiometric bands
- The coefficients are stabilized by cutting off the least informative dimensions in the space of regressors instead of dropping some regressors *(Petrenko et al., SPIE,2016)*
- The SST noise is reduced by smoothing the differential regressors without the loss of sensitivity *(Petrenko et al., SPIE, 2015)*

Expected improvement of SST precision because of using VIIRS band M14

SST	SD wrt in situ SST	
	Without M14	With M14
Day		
Global Regression	**0.41**	**0.39**
Piecewise Regression	**0.28**	**0.25**
Night		
Global Regression	**0.34**	**0.33**
Piecewise Regression	**0.26**	**0.23**

- Band M14 (8.55 µm) improves precision, especially for PWR SST

Modification of PWR SST equation

- The current ACSPO PWR SST fits *in situ* SST with SD≈0.25 K
- The further improvement of precision requires accounting for new sources of errors
- One of such error sources is the bias between *in situ* SST and “skin” SST.
- Two of the variables driving the skin/depth bias, available during the SST retrieval **wind speed *(V)*** and **Local Solar Time (LST)**

Day:

$$T_S = a_0(LST) + a_1 T_{11} + a_3(T_{11}-T_{8.6}) + a_4(T_{11}-T_{12}) +$$

$$+[a_5 + a_6 T_{11} + a_8(T_{11}-T_{8.6}) + a_9(T_{11}-T_{12})]S_\vartheta +$$

$$+ [a_{11}(T_{11}-T_{8.6}) + a_{12}(T_{11}-T_{12})]T_S^0 + a_{13}V$$

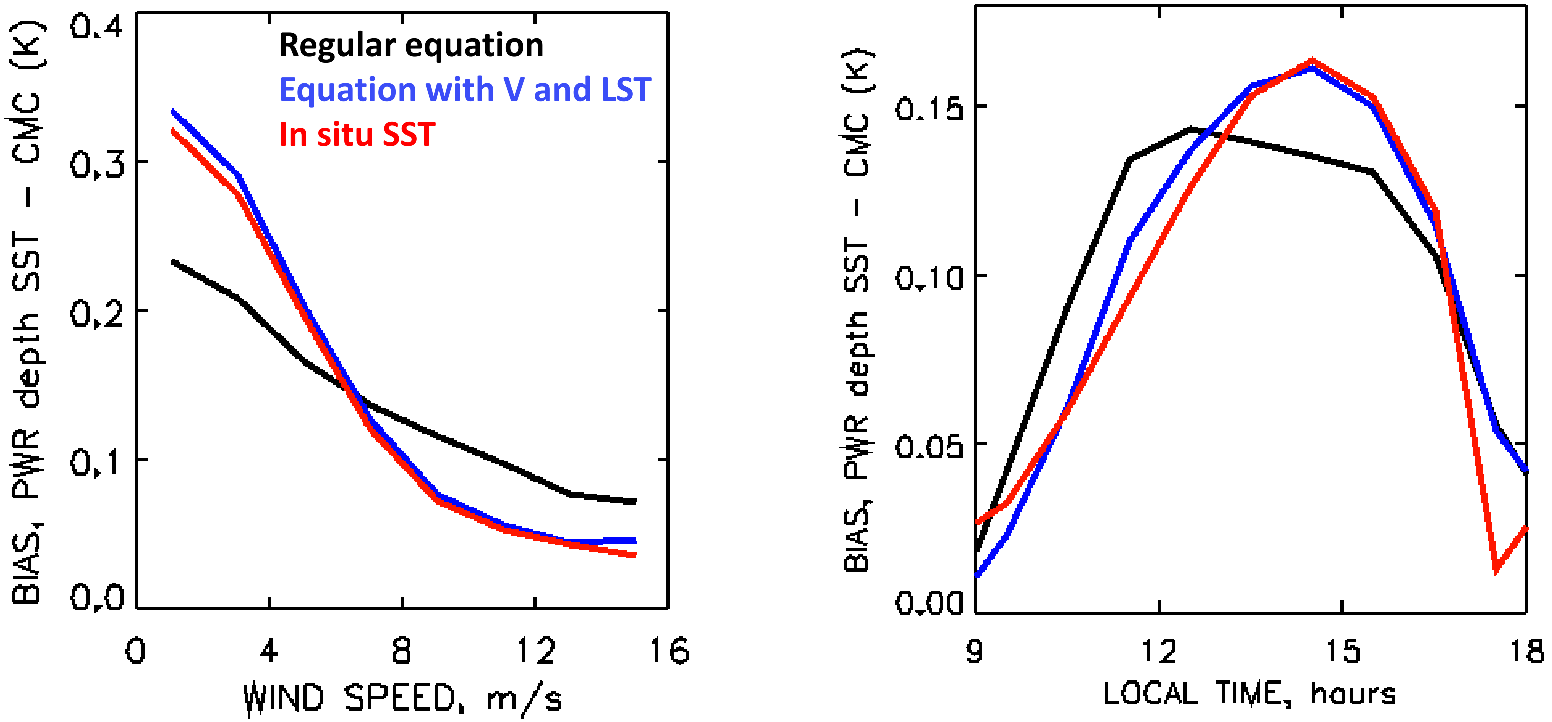
- LST is accounted for by correcting the offsets in the SST equations for every LST hour. During L2 processing, the offsets are interpolated to actual LST
- GFS Wind speed is added to the equation as an additional regressor

Expected improvement of daytime PWR SST precision wrt *in situ* SST due to accounting for *V* and LST

Dataset of matchups	*V* and LST are not accounted for	*V* and LST are accounted for
Training (January – December 2016)	**0.25**	**0.24**
Validation (January-June 2017)	**0.26**	**0.25**

- Accounting for wind speed and LST reduces daytime SD wrt *in situ* SST

Daytime PWR SST bias wrt CMC
as function of wind speed and local time



- Accounting for *V* and LST in the PWR SST equations:
  - ✓ Improves the reproduction of dependencies of *in situ* SST-CMC bias from V and LST
  - ✓ Shifts the maximum of the diurnal warming signal from ~12:30 to ~14:30, consistently with *in situ* SST

Experimental Piecewise Regression “skin” SST

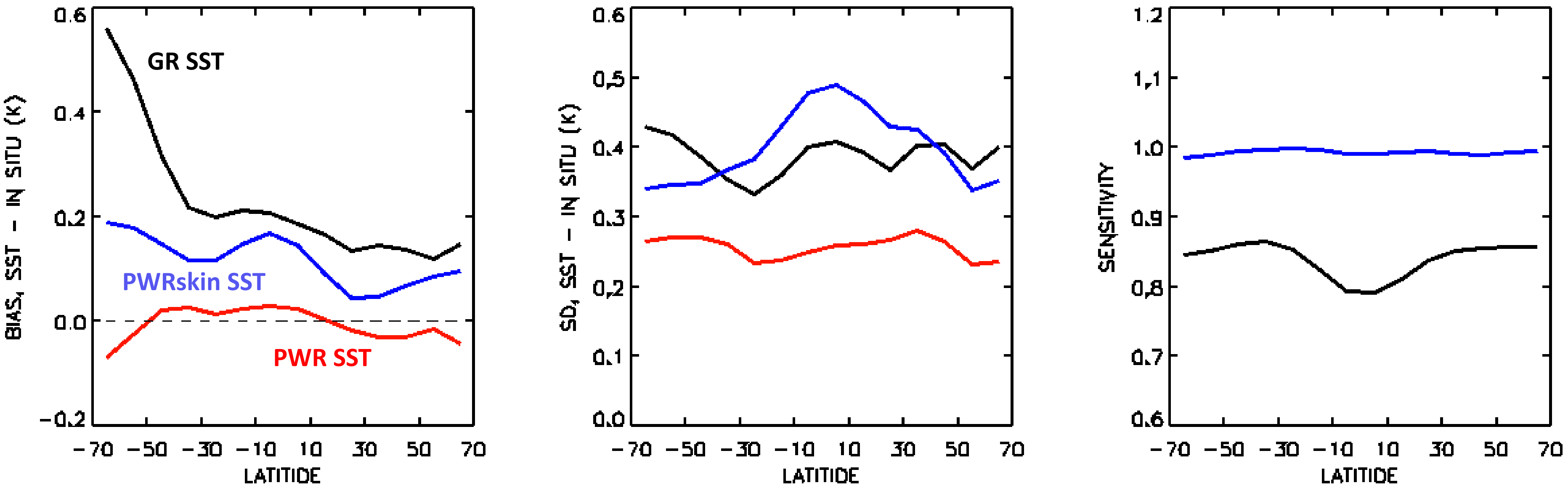
- The goals of the **Piecewise Regression “skin” SST (PWRskin SST)** are :
  - ✓ To reduce regional SST biases (compared with the GR SST);
  - ✓ To bring the sensitivity closer to 1 and to make it more uniform
- The **PWR skin SST** uses the segmentation of the SST domain in the space of regressors, like it is done in the current PWR SST
- **PWRskin SST** coefficients are trained under the constraint “mean sensitivity =1”

SD wrt in situ SST and sensitivity for GR SST and PWR skin SST

SST	Day		Night	
	SD wrt *in situ* SST	Sensitivity	SD wrt *in situ* SST	Sensitivity
GR SST	**0.37**	**0.85±0.08**	**0.33**	**0.90±0.04**
PWR skin	**0.38**	**1.00±0.05**	**0.31**	**1.00±0.03**

- PWRskin brings the mean sensitivity to 1 and reduces its variations

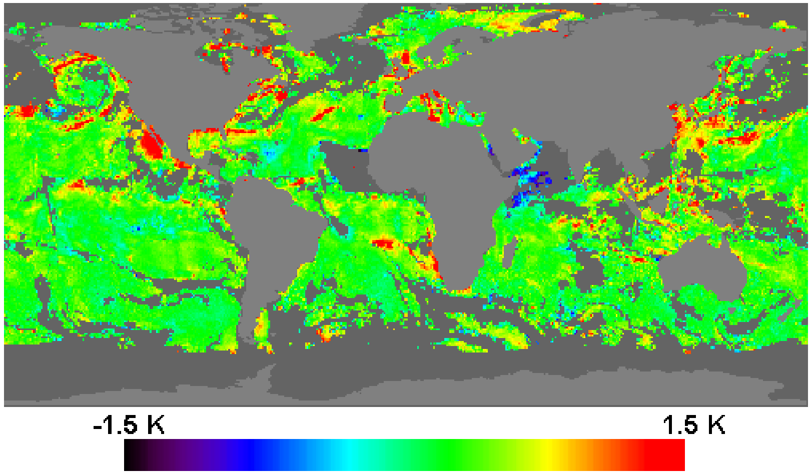
Daytime biases and SDs of SST- *in situ* SST and sensitivities as function of latitude



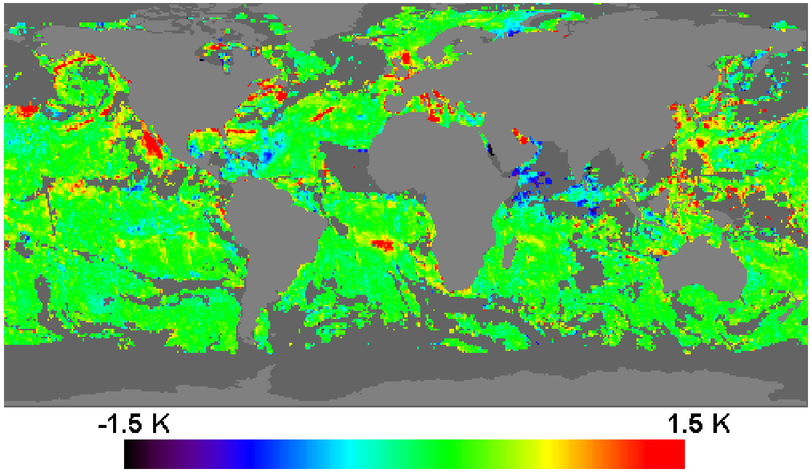
- GR SST produces large biases at high latitudes in the South
- PWRskin SST biases and SDs are maximum at low latitudes (expected)
- The biases and SDs for PWR are the smallest and the most uniform
- Sensitivity of GR SST is minimum at low latitudes, whereas the sensitivity of PWRskin SST is more uniform and closer to 1

Daytime maps of GR SST-CMC, PWR "skin" SST-CMC and GR SST-PWR "skin" SST (5 July 2017)

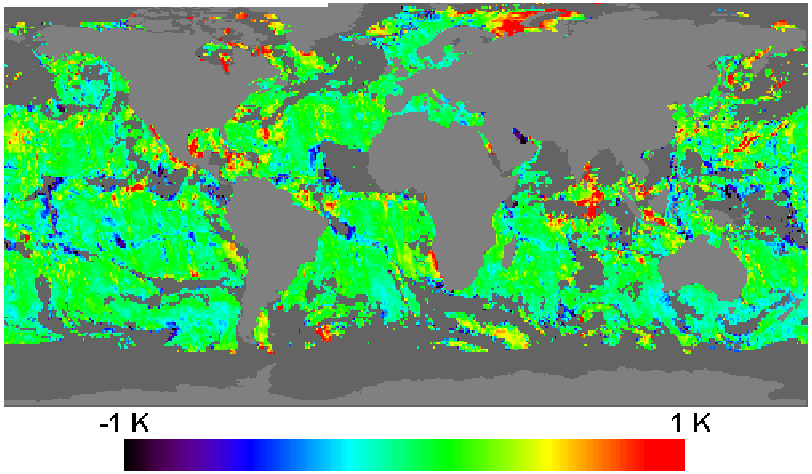
GR SST – CMC: Bias=0.46K, SD=0.50 K



PWRS SST – CMC: Bias=0.32K, SD=0.50 K



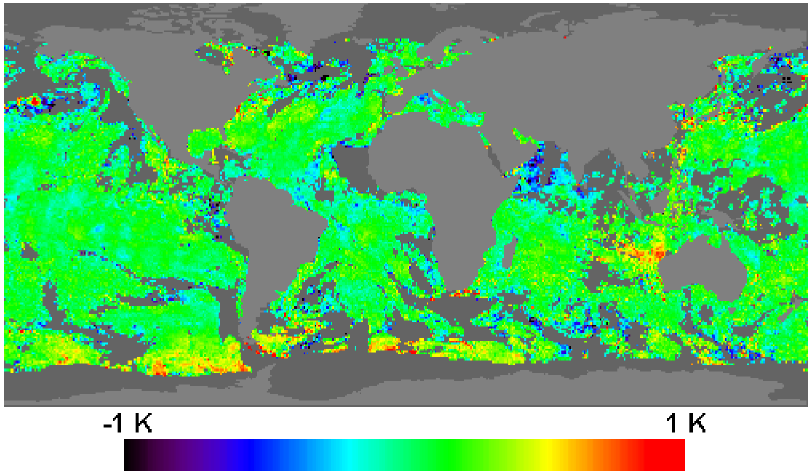
GR SST - PWRS SST



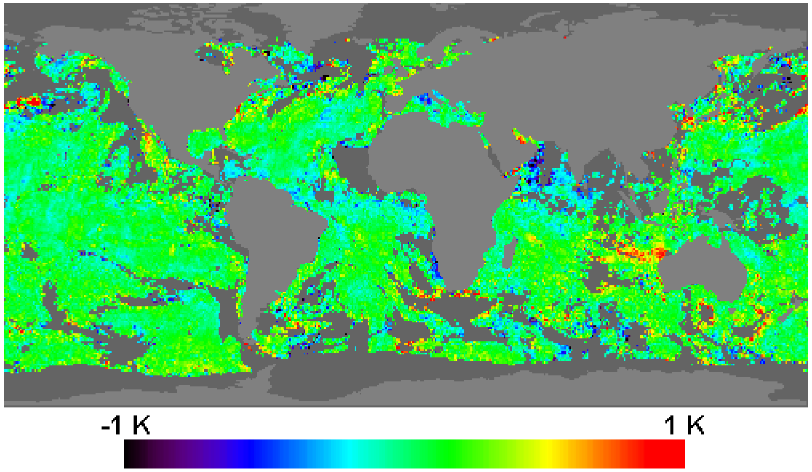
- PWRskin SST reduces warm biases in high latitudes

Nighttime maps of GR SST-CMC, PWR “skin” SST-CMC and GR SST-PWR “skin” SST (5 July 2017)

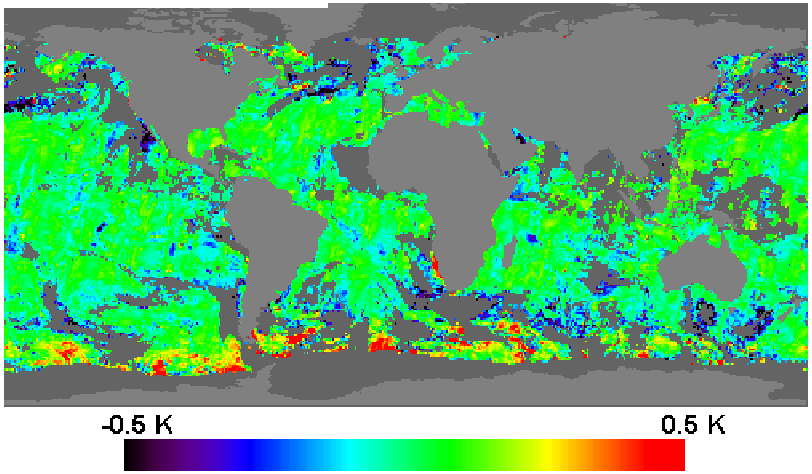
GR SST – CMC: Bias=0.11K, SD=0.32 K



PWRS SST – CMC: Bias=0.06K, SD=0.33 K



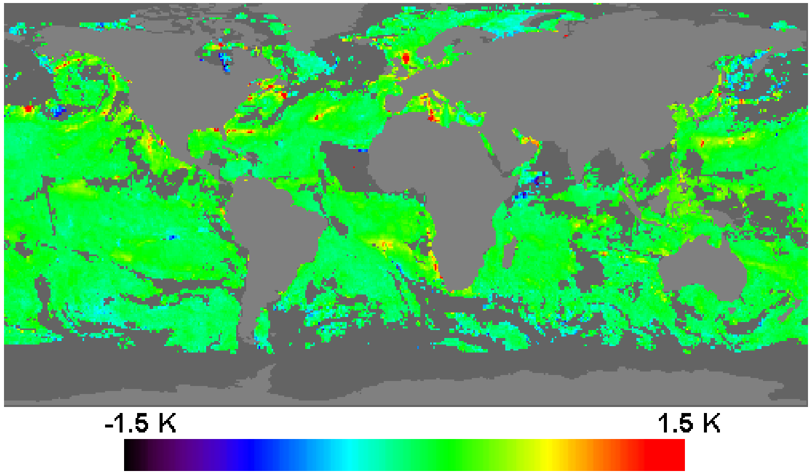
GR SST - PWRS SST



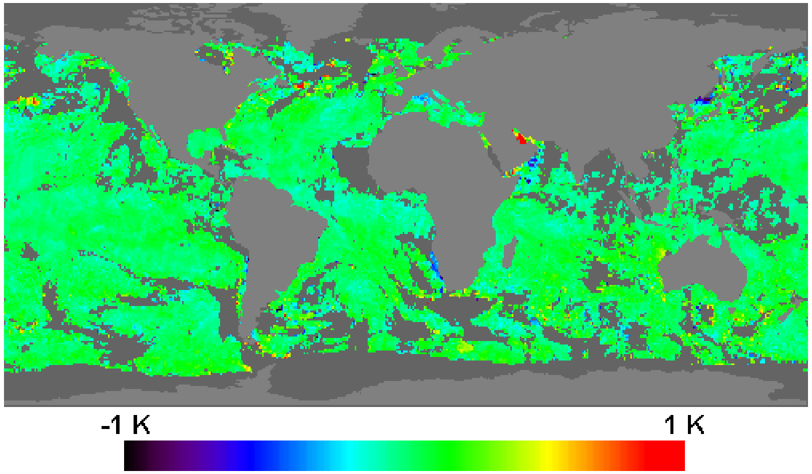
At night, the PWRskin SST reduces warm biases in high latitudes in the South

PWR SST minus CMC (5 July 2017)

PWR SST – CMC, DAY: Bias=0.18K, SD=0.27 K



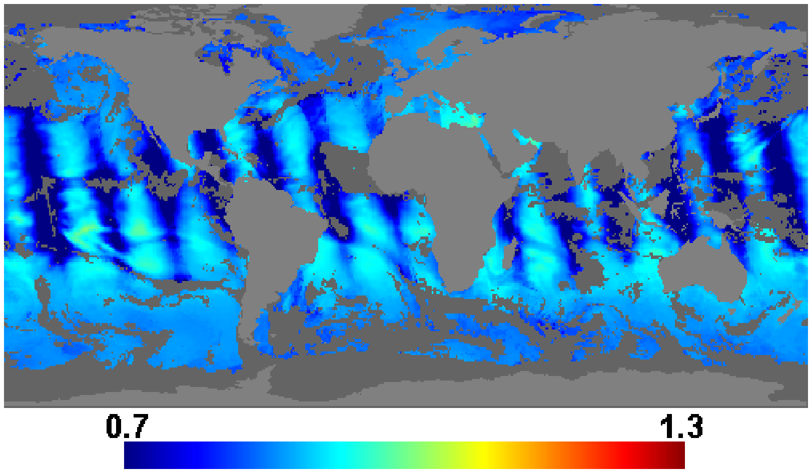
PWR SST – CMC, NIGHT: Bias=0.02K, SD=0.17 K



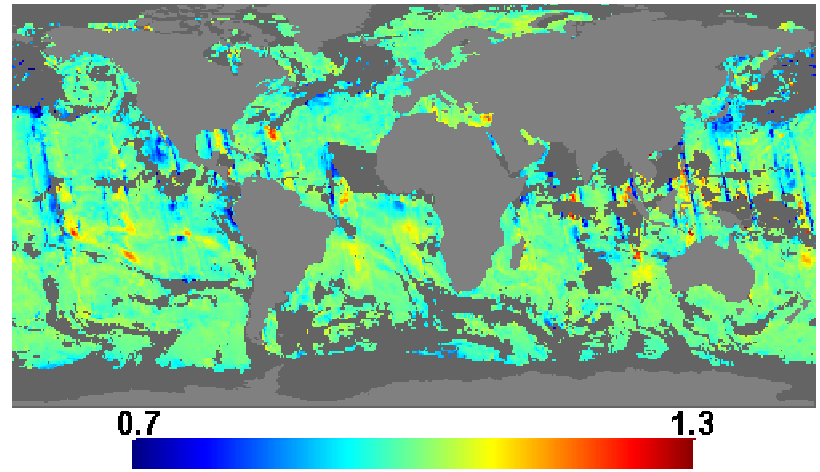
PWR SST is highly precise with respect to CMC

Sensitivities for GR SST and PWR skin SST

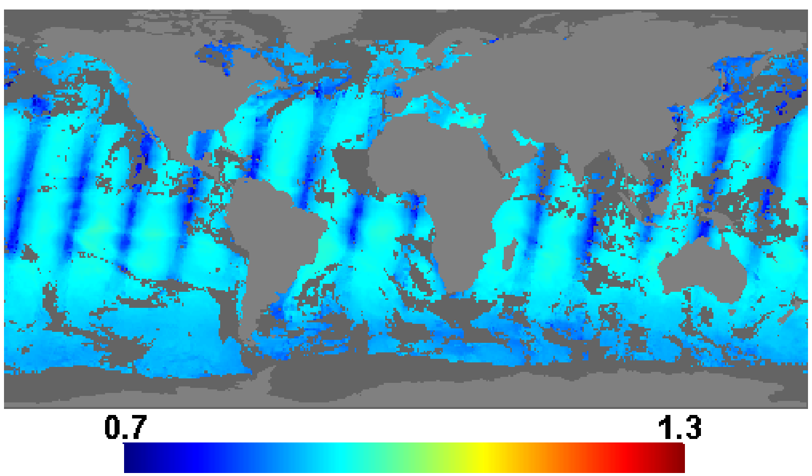
GR SST, DAY: mean=0.85, SD=0.08



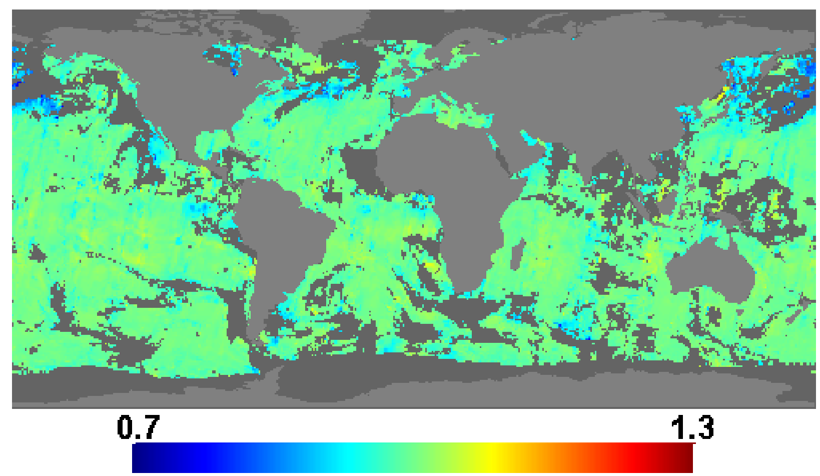
PWR skin SST, DAY: mean=0.99, SD=0.05



GR SST, NIGHT: mean=0.91, SD=0.03



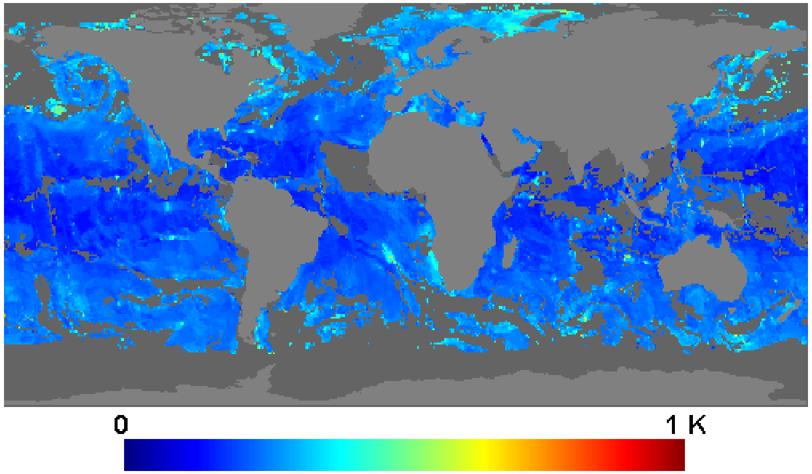
PWR SST, NIGHT: mean=0.99, SD=0.02



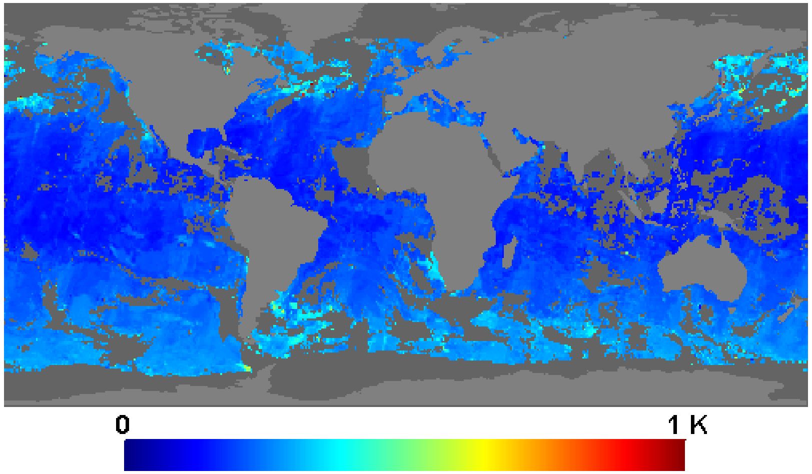
- Sensitivities for PWR skin SST are closer to 1 and more uniform

SSES Standard Deviation

SSES SD, DAY



SSES SD, NIGHT



- In ACSPO v. 2.50, SSES SD represents SD of PWR SST - *in situ* SST and may be used for optimal weighting of PWR SST with other products during L4 analyses

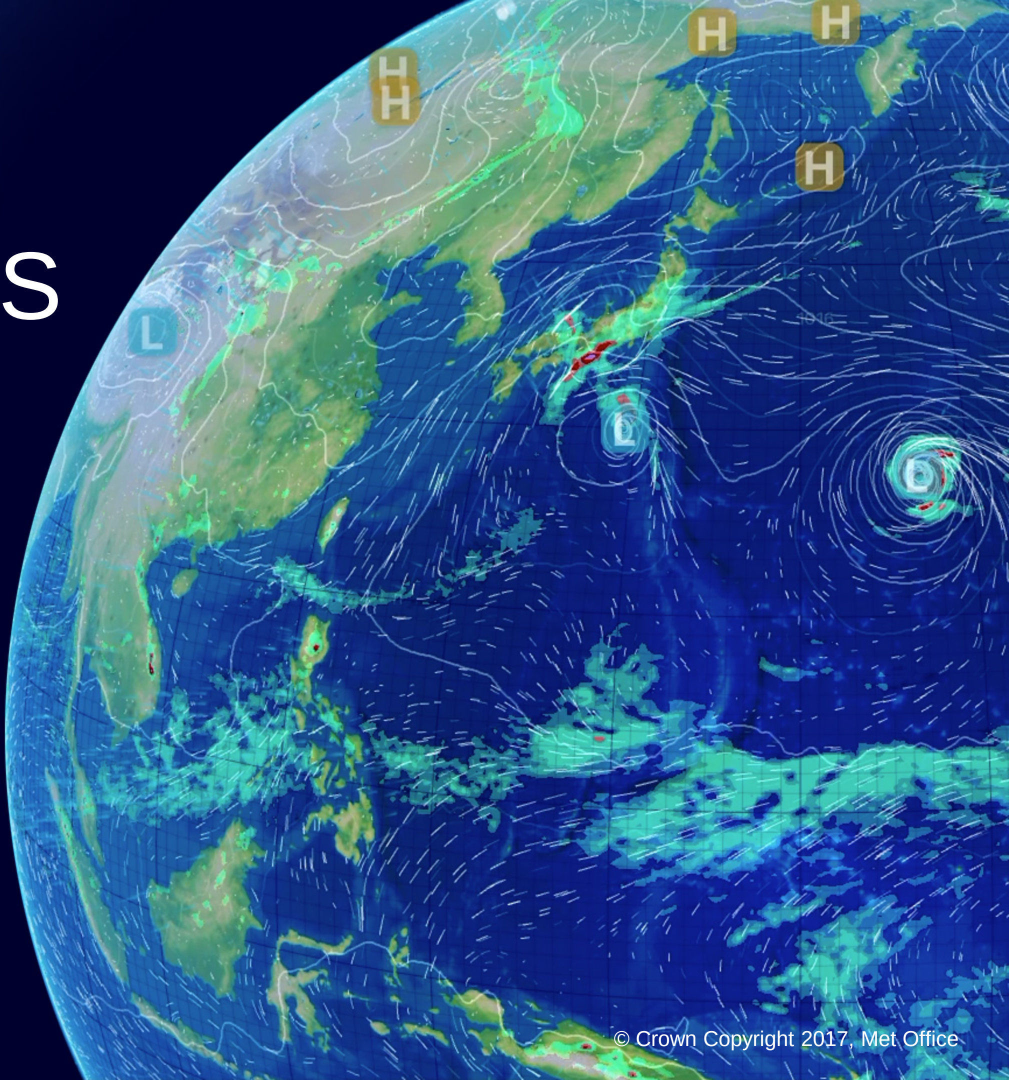
Summary of improvements

- Using the VIIRS band M14 (8.55 µm) for SST, in addition to the previously used bands will improve the precision of ACSPO SST products wrt *in situ* SST
- The precision of the PWR SST will be further improved by accounting for GFS wind speed and local solar time in the regression equations
- The new experimental product, Piecewise Regression "skin" SST will be tested and is expected to become a better proxy for SSTskin than the current Global Regression SST
- SSES SD will represent SD of PWRdepth SST wrt *in situ* SST to facilitate the assimilation in L4 analyses.

THANK YOU

Met Office

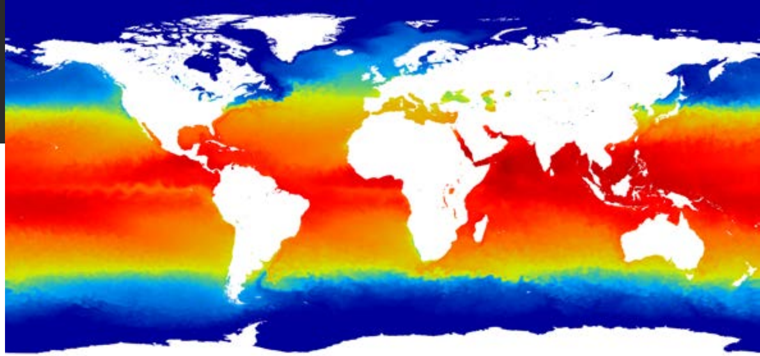
Use of ACSPO VIIRS L3U SST in the OSTIA system



The OSTIA team: Simon Good, Emma Fiedler, Chongyuan Mao, Rebecca Reid

August 17, 2017

Met Office



Introduction

OSTIA is the Met Office Operational SST and Ice Analysis system

- L4 (global, gap-free analysis), produced daily at 1/20º grid resolution
- Foundation SST (uses all nighttime observations and daytime observations only when wind speed >6 m s^{-1} to remove diurnal warming effects)
- Validates well against other analyses (compared to independent near-surface Argo observations)
- Available from http://marine.copernicus.eu/services-portfolio/access-to-products/?option =com_csw&view=details&product_id=SST_GLO_SST_L4_NRT_OBSERVATIONS_010_001

Met Office

SST data used in OSTIA

- ACSPO VIIRS
- AMSR2 (from Remote Sensing Systems)
- NOAA-18 and -19 AVHRR (from NAVO)
- MetOp AVHRR (from OSI SAF)
- SEVIRI (from OSI SAF)
- GOES-E (from OSI SAF)
- In situ (ships, drifters, moored buoys) (from GTS)

Change in the last year

OSTIA performs a bias-correction of satellite data to a reference dataset of all in situ data and high-quality satellite data

- Prior to November 9, 2016, the reference satellite data was a subset of MetOp-A AVHRR (nighttime, max satellite zenith angle 48 degrees, QL4+)
- From November 9, 2016 onwards the reference satellite data was ACSPO VIIRS nighttime data

Prior testing of the impact of the change

Before proceeding with the change, testing was carried out. Two runs were conducted for the period 09 Dec 2015 – 11 Jan 2016:

- Control: MetOp-A AVHRR (nighttime, max satellite zenith angle 48 degrees, Q4+) used as the reference dataset
- VIIRSG_ref: Nighttime VIIRS QL5 data used as the reference dataset

Validation used Argo observations (shallowest observations between 3-5 m depth have been shown to be representative of foundation temperature and they are not used in the analysis) from the Met Office Hadley Centre EN4 database (www.metoffice.gov.uk/hadobs)

Near-surface Argo minus OSTIA analysis statistics for a test period of 9 Dec 2015 – 11 Jan 2016

Region (CMEMS definitions)	Mean diff to Argo (K)		RMS diff to Argo (K)	
	control	VIIRSG_ref	control	VIIRSG_ref
Global	0.12	0.06	0.45	0.40
North Atlantic	0.22	0.05	0.48	0.42
Tropical Atlantic	0.17	0.11	0.28	0.24
South Atlantic	0.08	0.08	0.46	0.44
North Pacific	0.20	0.09	0.51	0.45
Tropical Pacific	0.08	0.07	0.26	0.22
South Pacific	0.03	0.07	0.32	0.30
Indian Ocean	0.03	0.09	0.29	0.28
Southern Ocean	0.07	0.04	0.45	0.42

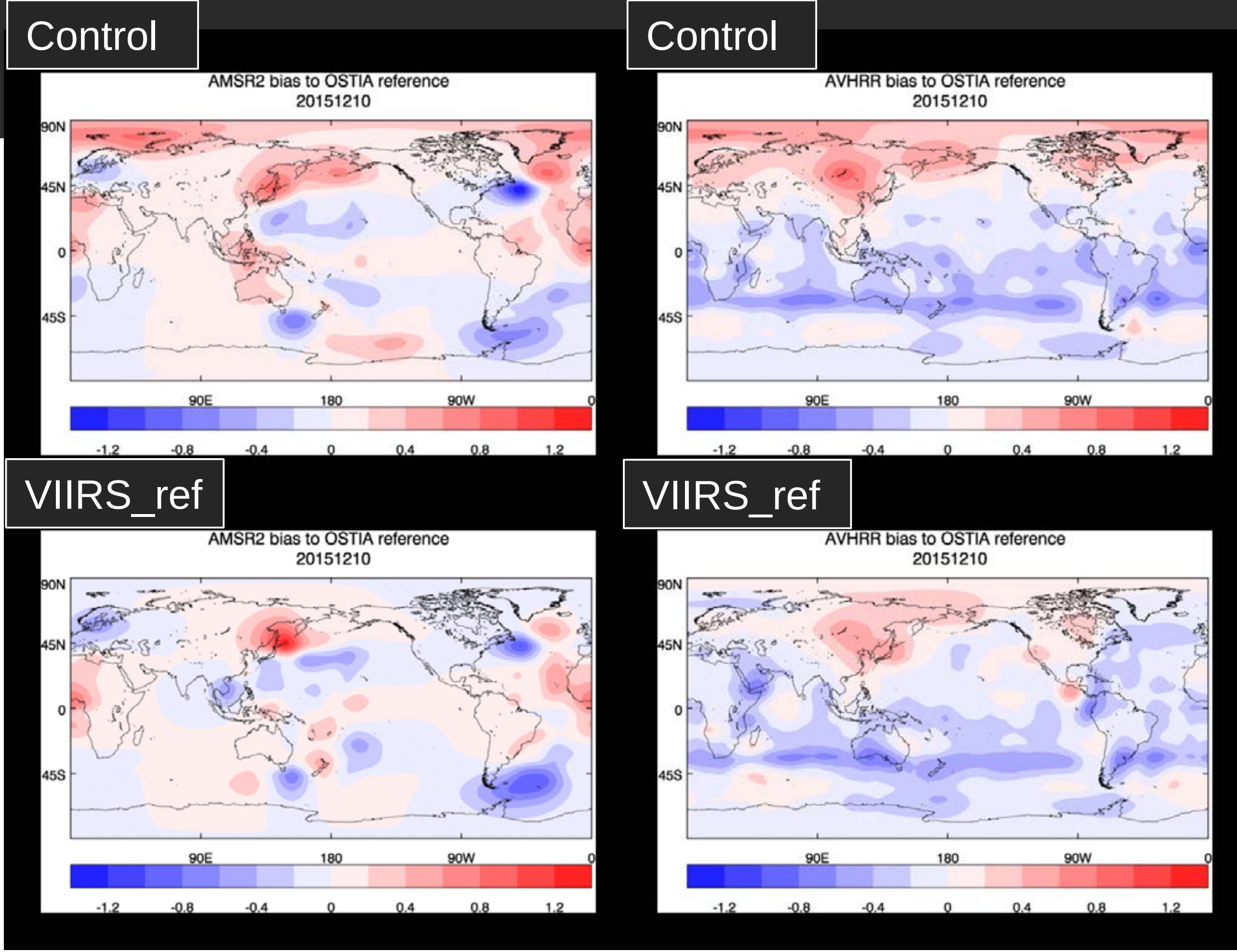
Results from prior testing

- Sizable improvement of 0.05 K global RMS difference to Argo using VIIRS as a reference and improvements in RMS consistent across all regions
- Similar results were seen for a second test period of 01 to 31 May 2016
- Improvements of mean difference to Argo in most ocean regions
  - Largest magnitude decrease of 0.16 K in North Atlantic
  - Smallest magnitude decrease of 0.01 K in Tropical Pacific
  - Detriments to mean difference seen in South Pacific (0.04 K) and Indian Ocean (0.06 K)

Animations of daily bias fields:

REMSS AMSR2 and NOAA -18 and -19 AVHRR minus the two reference datasets, control (MetOp-A AVHRR) and VIIRS

Observations have already been filtered to remove daytime measurements where wind speed < 6 m s^{-1}, and SSES biases have been removed



Results from prior testing

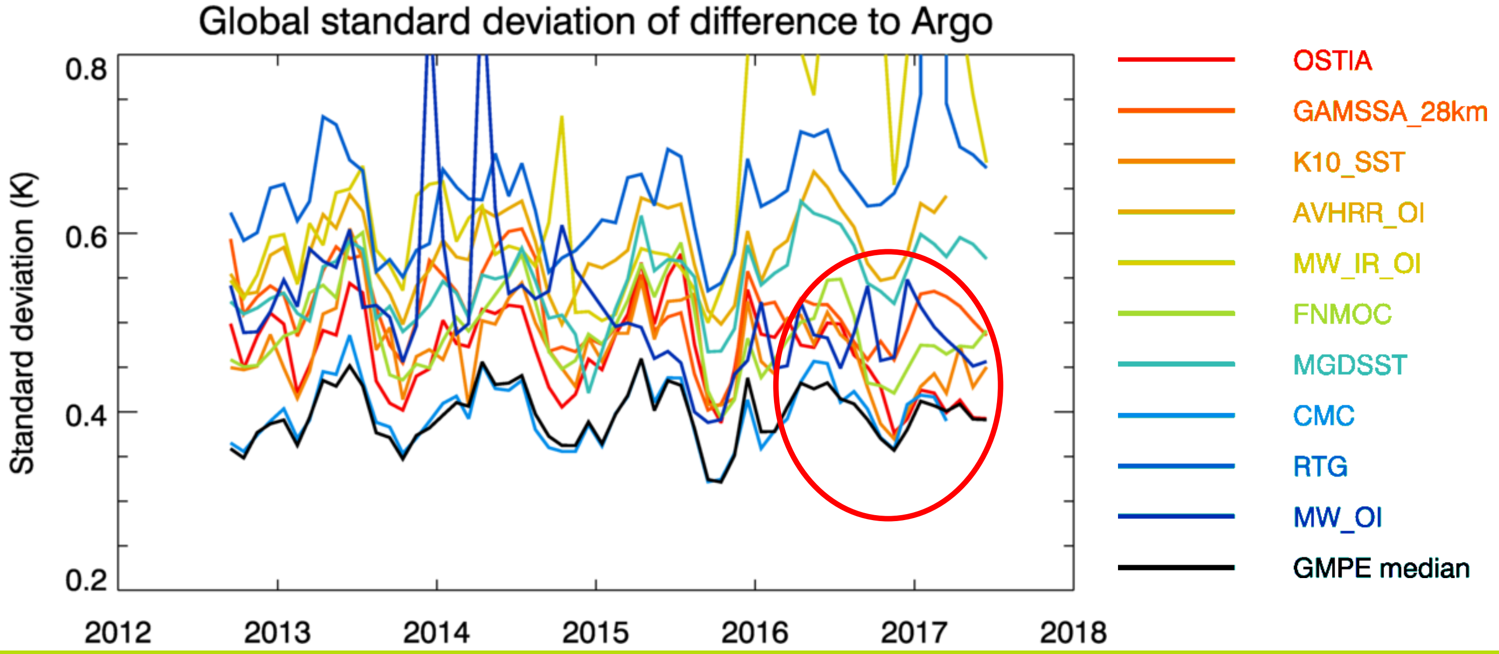
- The bias fields show the magnitude of the correction removed from the observations by the OSTIA system
- The run using VIIRS as a reference has eliminated the warm bias seen in the Arctic, so this “correction” is no longer being applied to the data
- The magnitude of the biases is generally smaller for the run using VIIRS as a reference, meaning the observations are in closer agreement with the reference data
- Note the unusual band of cold bias for combined NAVO AVHRR-18 and -19 along 30-40S compared to both reference datasets

Impact on the operational system - GMPE

- Near-surface temperature observations from Argo profiling floats are used to validate various global SST analyses and their daily ensemble median, known as the GMPE (GHRSST Multi-Product Ensemble) median product
- These statistics are updated on the first of the month for the previous-but-one month using Argo data from the Met Office Hadley Centre EN4 database
- Plots can be seen at http://ghrsst-pp.metoffice.com/pages/latest_analysis/sst_monitor/argo/
- GMPE data are available from http://marine.copernicus.eu/services-portfolio/access-to-products/?option=com_csw&view=details&product_id=SST_GLO_SST_L4_NRT_OBSERVATIONS_010_005

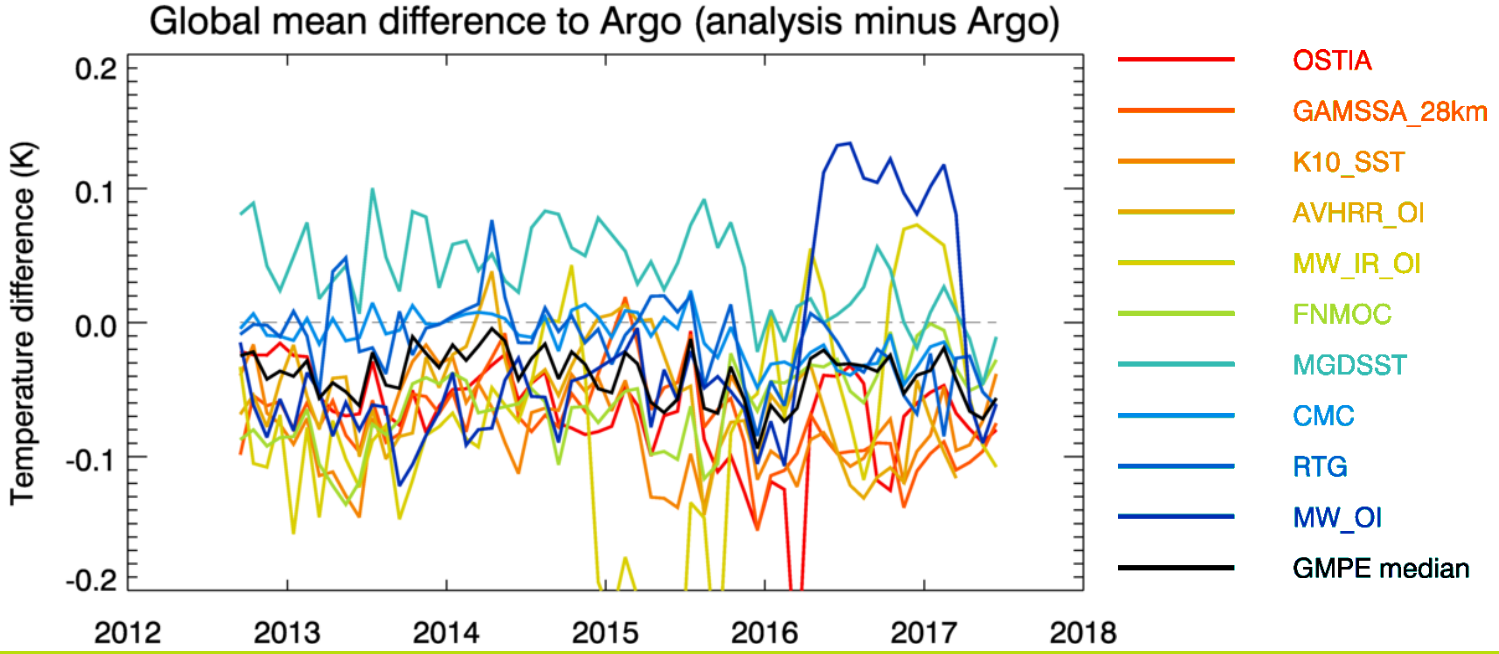
Impact on the operational system - GMPE

There is a clear improvement in standard deviation of differences from the time of the upgrade



Impact on the operational system - GMPE

However, global mean differences are variable and do not show a clear change



Summary

- OSTIA is a near real time, operational SST analysis run daily at the Met Office
- In November, the system was upgraded to use nighttime ACSPO VIIRS data as the reference used to correct for biases in other satellite data
- Prior testing indicated that this change should improve mean and standard deviation of differences to reference Argo data
- Monitoring since the upgrade has shown a clear improvement to standard deviation of differences; however this is not clear in mean differences

- Thanks for making your excellent data available!

VIIRS in RTG SST HR

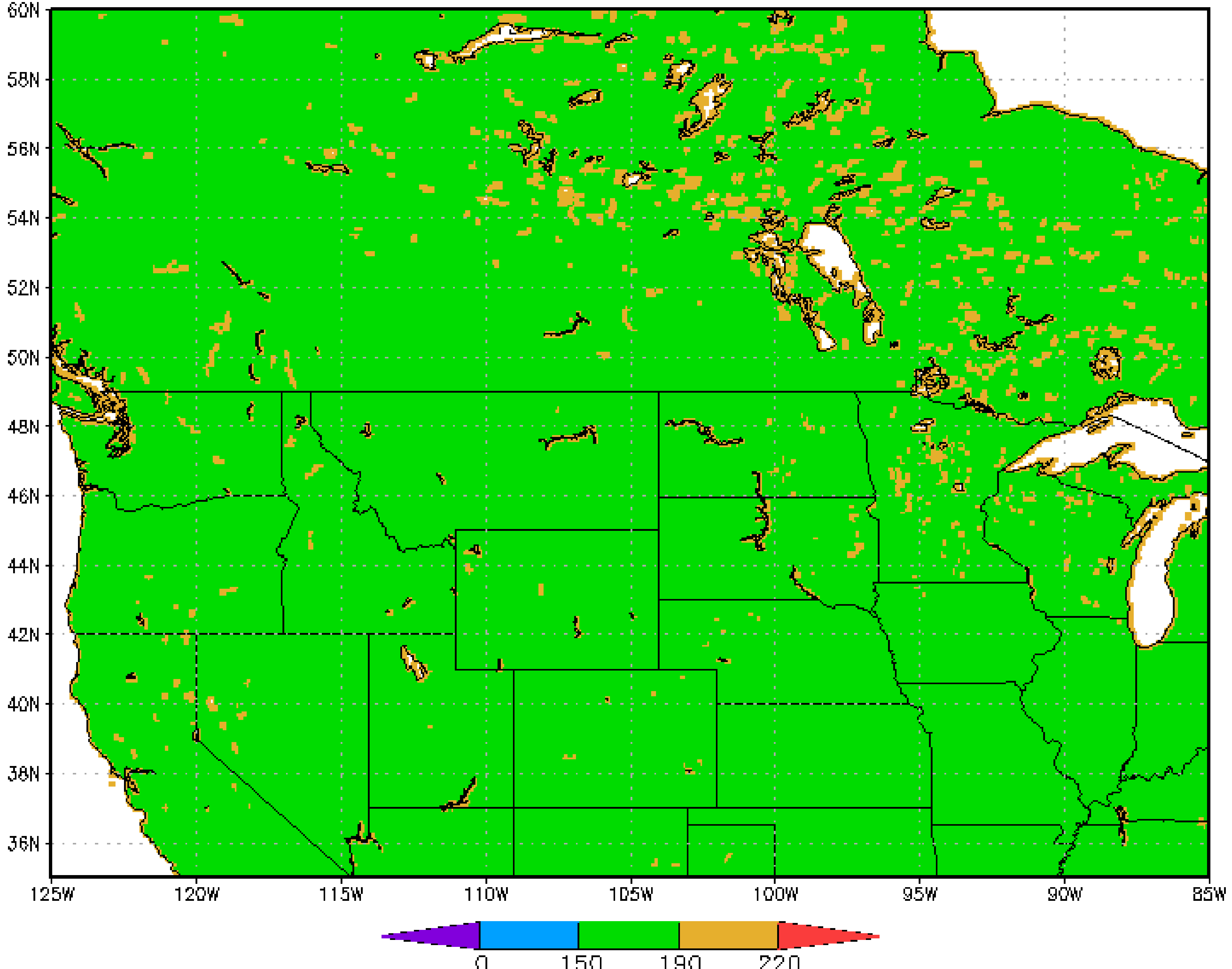
Robert Grumbine, Bert Katz

RTG Data Sources

- In Situ
  - Buoys, Ships, CMAN, (to come: ARGO, Walrus,)…
- Satellite
  - AVHRR — L1b — physical retrievals (NOAA-18, 19; Metop A, B)
  - GOES-13,15 — L3 — NESDIS composited retrievals
  - VIIRS — L2 (to come) — High resolution retrievals (~1 km)
  - AMSR2 — L2 (to come+1) — Microwave (large footprint, but see through clouds)

RTG Analysis Grids

- Being retired — half degree
- Operational — 1/12th degree, 5 arcmin, ~10 km
  - Future — N. America at 2.5 km?
- Masking via bounding curves to arbitrary target
- Daily average, buoy depth
  - Future — buoy depth and ?skin temperature
  - Future — resolve diurnal cycle (6 hrs or more frequent analysis)



60N
58N
56N
54N
52N
50N
48N
46N
44N
42N
40N
38N
36N
125W
120W
115W
110W
105W
100W
95W
90W
85W
0
150
190
220

VIIRS

- L2 ACSPO -- SST Retrievals
  - GHRSST (CF 2.0) NetCDF
    - Rely on SSES
  - BUFR
    - NWS Operations
    - Challenges of volume + format

Verification

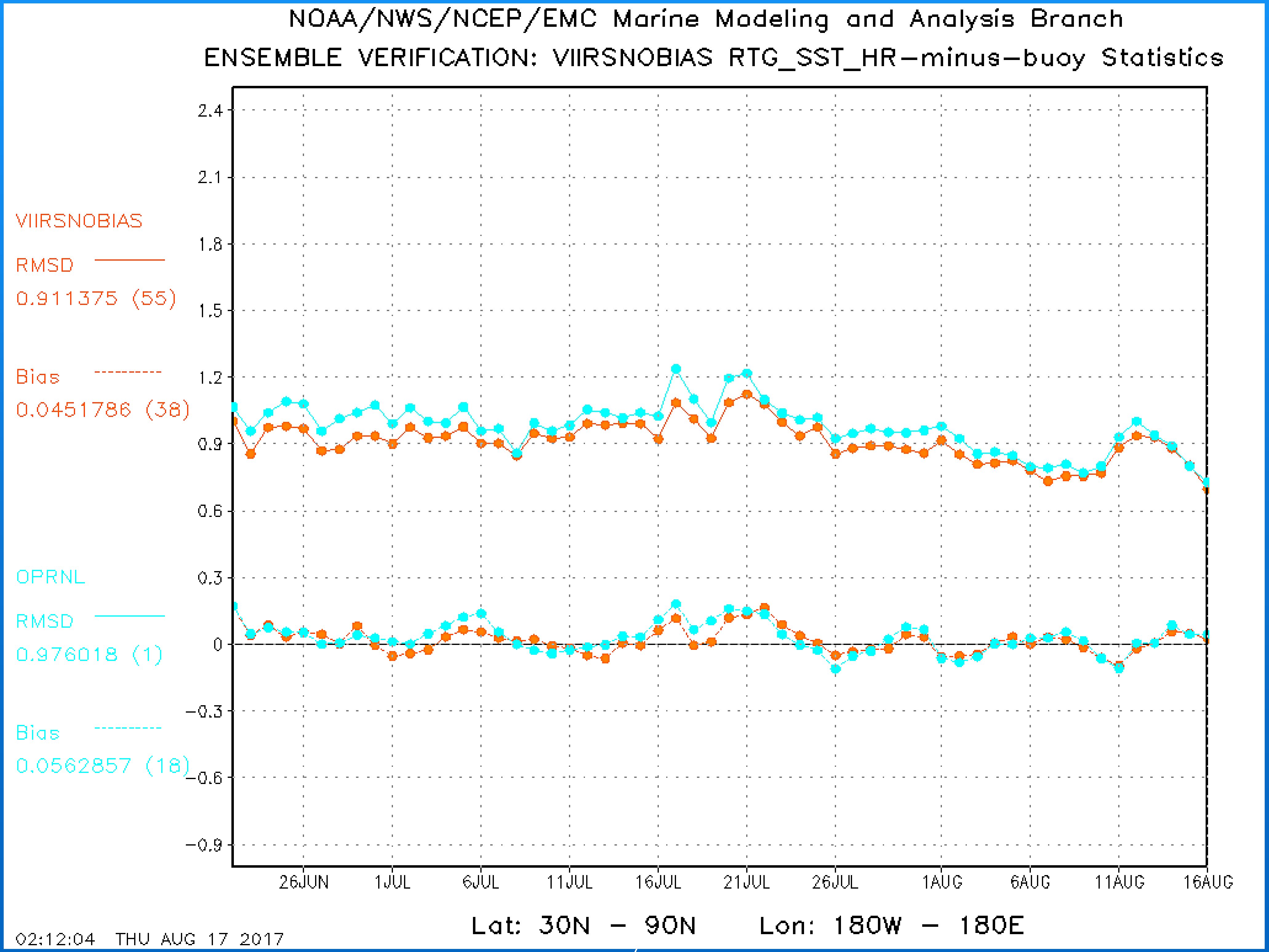
33 subdomains

5 repeated, independent, analyses with 20% of in situ withheld

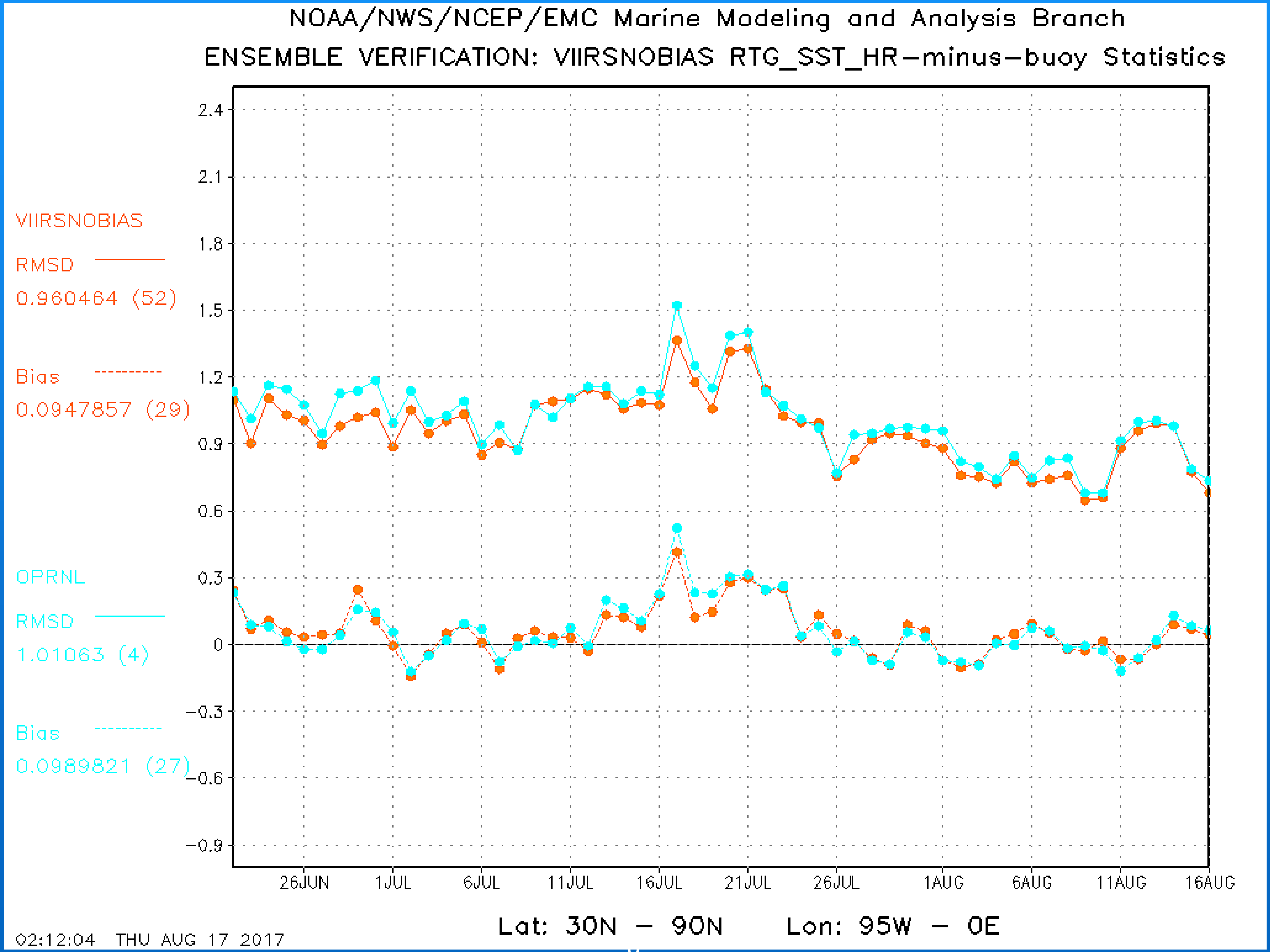
Score against withheld data

Bernoulli trial assessment

Verification -- NH extratropical



N. Atlantic



NOAA/NWS/NCEP/EMC Marine Modeling and Analysis Branch
ENSEMBLE VERIFICATION: VIIRSNOBIAS RTG_SST_HR–minus–buoy Statistics
VIIRSNOBIAS
RMSD
0.960464 (52)
Bias
0.0947857 (29)
OPRNL
RMSD
1.01063 (4)
Bias
0.0989821 (27)
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
–0.3
–0.6
–0.9
26JUN
1JUL
6JUL
11JUL
16JUL
21JUL
26JUL
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6AUG
11AUG
16AUG
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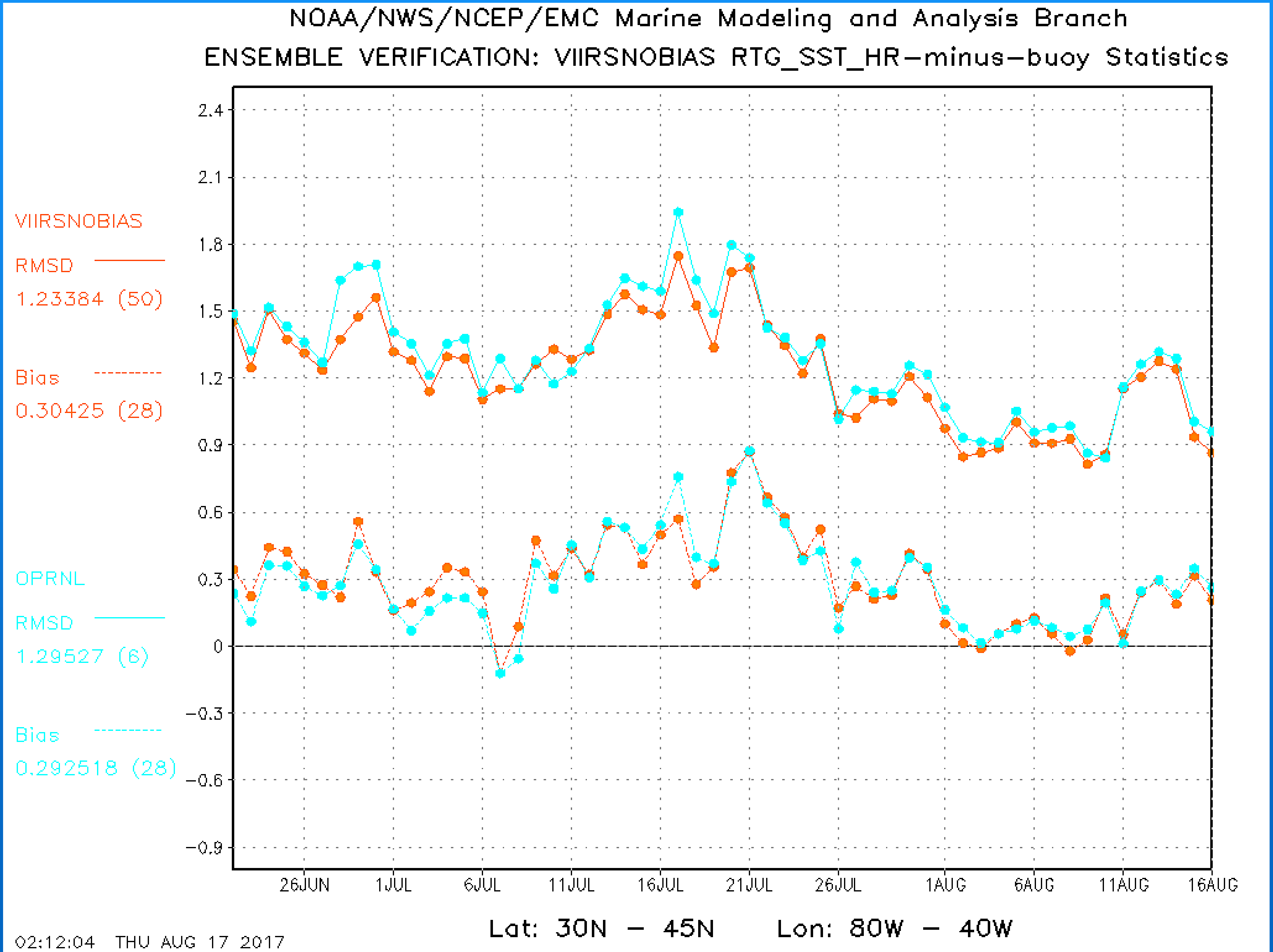
02:12:04 THU AUG 17 2017

NW Atlantic



NOAA/NWS/NCEP/EMC Marine Modeling and Analysis Branch
ENSEMBLE VERIFICATION: VIIRSNOBIAS RTG_SST_HR–minus–buoy Statistics
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Bias
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OPRNL
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Bias
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2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
–0.3
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26JUN
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6JUL
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16JUL
21JUL
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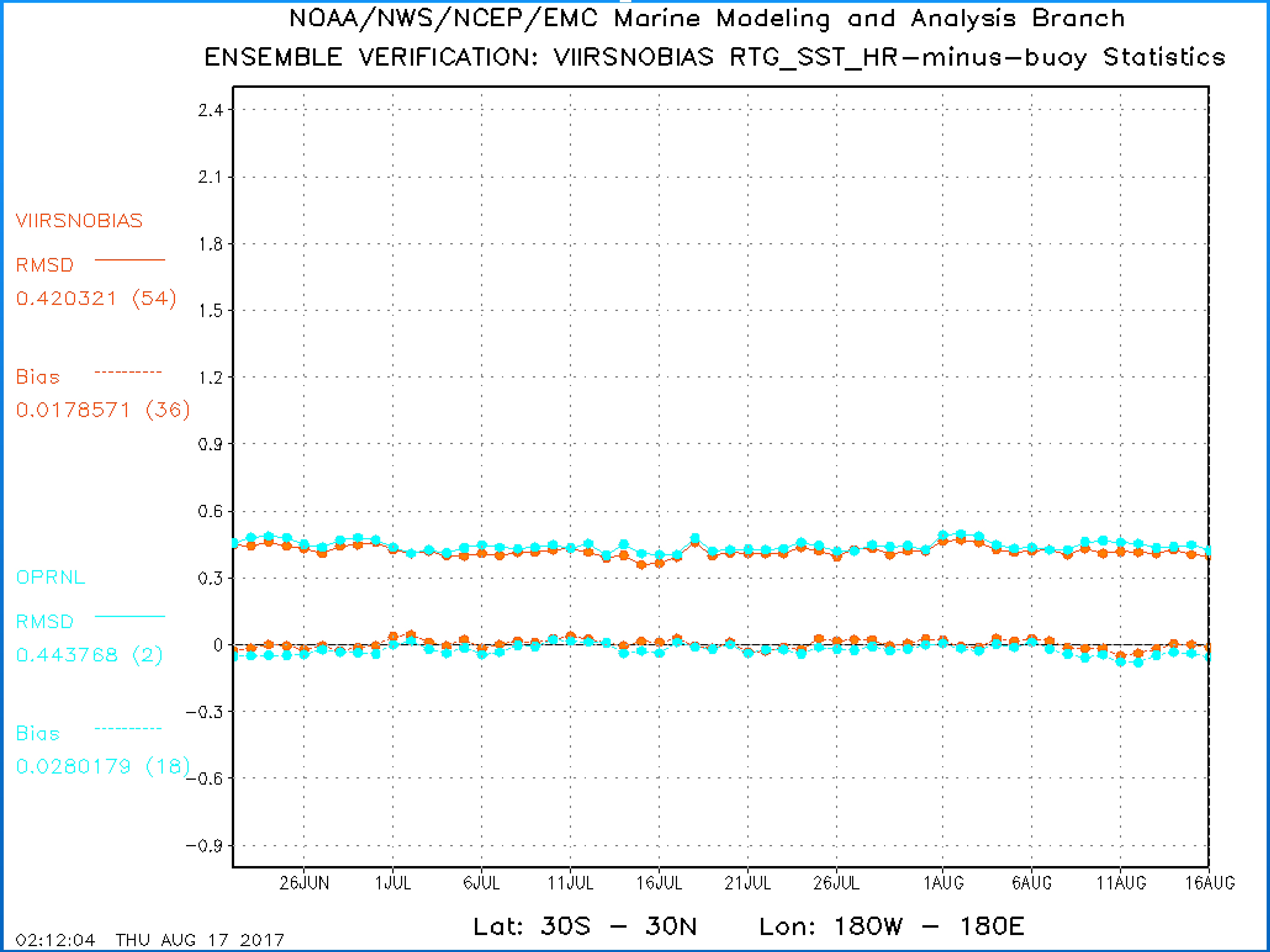
Tropics



NOAA/NWS/NCEP/EMC Marine Modeling and Analysis Branch
ENSEMBLE VERIFICATION: VIIRSNOBIAS RTG_SST_HR-minus-buoy Statistics
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Bias
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OPRNL
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Bias
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2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
−0.3
−0.6
−0.9
26JUN
1JUL
6JUL
11JUL
16JUL
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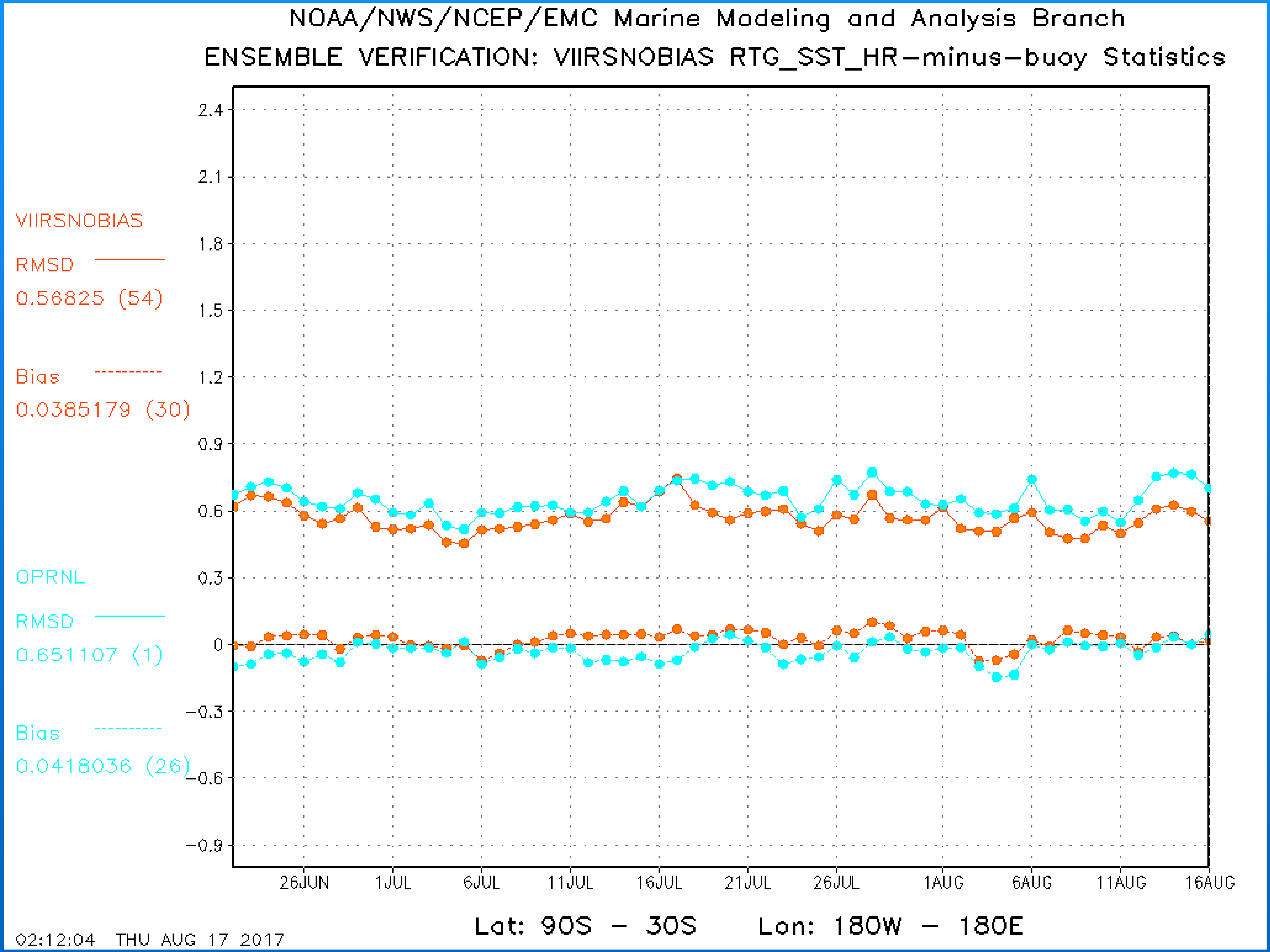
02:12:04 THU AUG 17 2017

SH Extratropical



Conclusions

Clear winner

Implementation ~Fall 2017

Thank you

Use of ACSPO VIIRS L3U SST in the Australian Bureau of Meteorology

Helen Beggs, Pallavi Govekar, Chris Griffin, Pavel Sakov and Leon Majewski

Bureau of Meteorology, Melbourne, Australia

STAR JPSS 2017 Annual Science Team Meeting, College Park, MD, USA, 14th – 18th August 2017

Background

- BoM currently uses NAVOCEANO's 9 km x 4 km global AVHRR SST data from NOAA-18/19 and METOP-A/B in operational SST analyses and ocean models
- BoM produces GHRSST L2P, L3U, L3C and L3S products from HRPT AVHRR SST data from NOAA satellites for IMOS Project and operational BoM systems
- Need Suomi-NPP and JPSS VIIRS SSTs for above systems as a follow-on to NOAA-19 AVHRR SST
- Unable to access VIIRS L2P SST via FTP in real-time due to high volumes so requested ACSPO produce lower resolution VIIRS L3U files
- NOAA/STAR produces ACSPO VIIRS 0.02º L3U SST (0.2m) product with rectangular grid aligned with IMOS 0.02º L3U product
- BoM currently testing these products for operational systems (IMOS L3U/L3C/L3S, SST analyses and ocean forecasts).

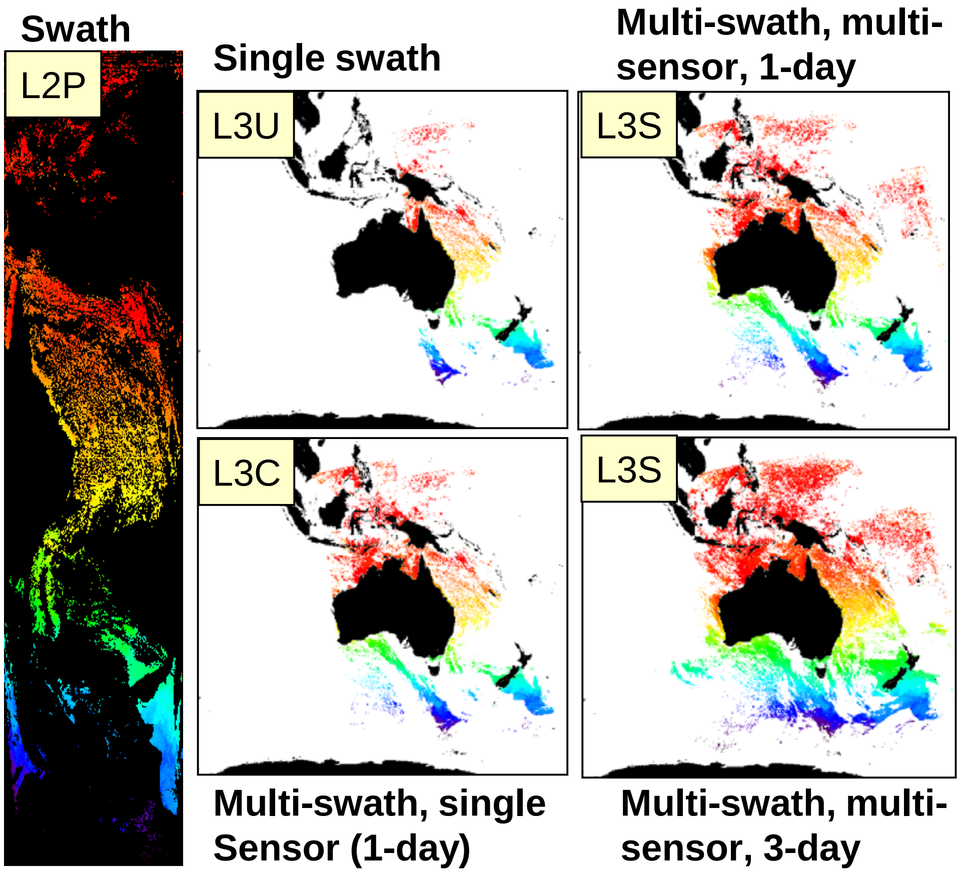
Australian Government
Bureau of Meteorology

IMOS HRPT AVHRR GHRSST products

http://imos.org.au/sstproducts.html

IMOS

- BoM and CSIRO have 1.1 km (at nadir) HRPT AVHRR data from NOAA-11 to NOAA-19 from reception stations in Australia and Antarctica back to mid-1980's
- For IMOS, BoM has produced GHRSST products (0.02º L3U, L3C, L3S) over two domains (Australia and Southern Ocean) from 1992 to present using the "stitched" HRPT AVHRR SST archive
- Can IMOS use ACSPO VIIRS SST data to continue the IMOS SST data set and improve spatial coverage?



Constructing IMOS VIIRS L3U product

- NOAA/STAR produces "ACSPO" VIIRS_NPP 0.02º single swath, composite "L3U" SST product (on IMOS grid)

- In order to merge with IMOS AVHRR L3U SSTs, ACSPO VIIRS L3U files are modified such that the quality_level is redefined as the minimum of the original VIIRS_NPP ACSPO_v2.40 quality_level and quality level, q_s, calculated using Sensor Specific Error Statistics (SSES), using sses_bias (μ_{sses}) and sses_standard_deviation (σ_{sses}) estimates, thus:

$$q_{\mathrm{sses}} = \frac{1}{\sqrt{2}}\sqrt{\max\left(\left(\frac{\sigma_{\mathrm{sses}}}{\sigma_0}\right)^2 + \left(\frac{\mu_{\mathrm{sses}} - \mu_0}{\sigma_{\mathrm{sses}}}\right)^2 - 1, 0\right)}$$

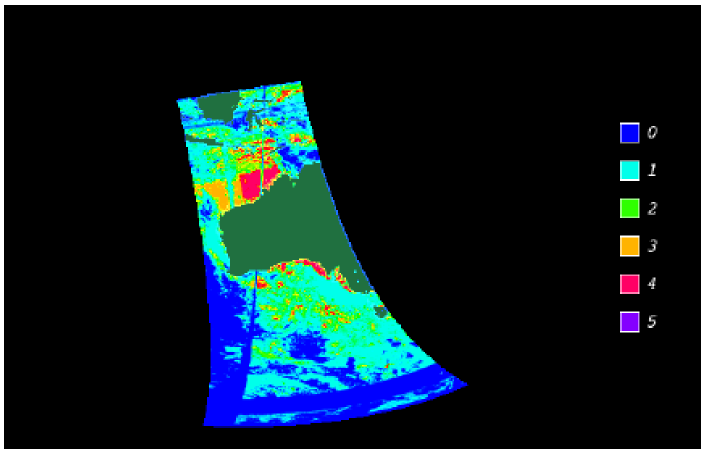
$$q_s = \lfloor 5 \exp^{\eta q_{\mathrm{sses}}} \rceil$$

- Different data sources can then be combined using q_s, *provided that* η/σ_0 = constant

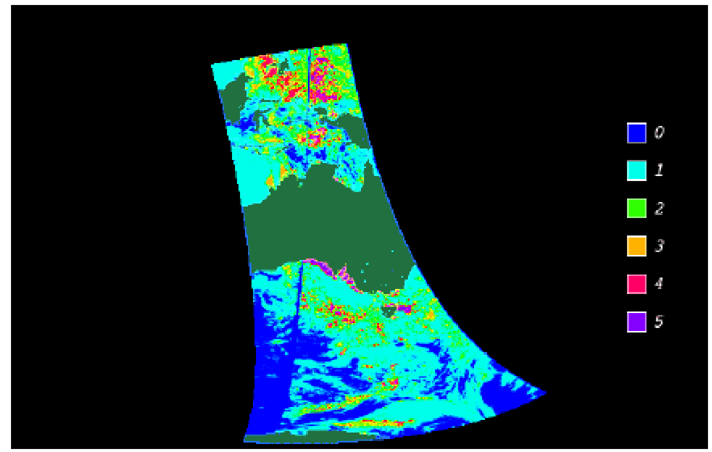
Australian Government
Bureau of Meteorology

"Remapped Quality Level"
min(quality_level, q_s)

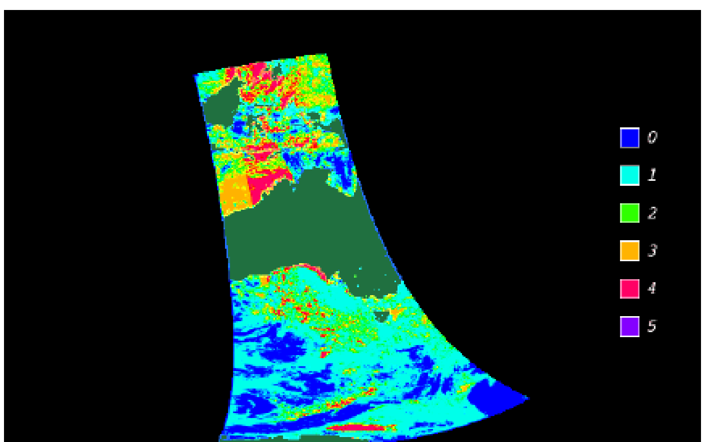
IMOS



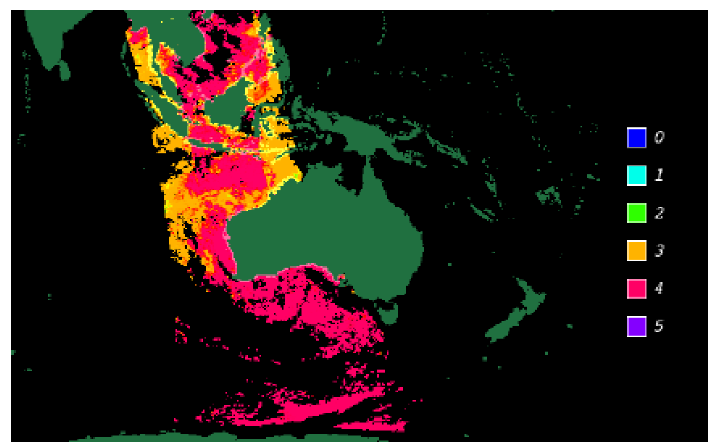
NOAA-15 fv01 L3U



NOAA-18 fv01 L3U



NOAA-19 fv01 L3U



L3U NPP VIIRS

Why adjust the quality level in this way?

Bureau compositing algorithms use sses_bias, sses_standard_deviation and degrees of freedom as parametric quality assessments, and quality_level as a non-parametric measure. Only highest non-parametric quality data are combined parametrically. Thus we need a good way to compare in absolute terms the quality of data streams from a non-parametric standpoint.

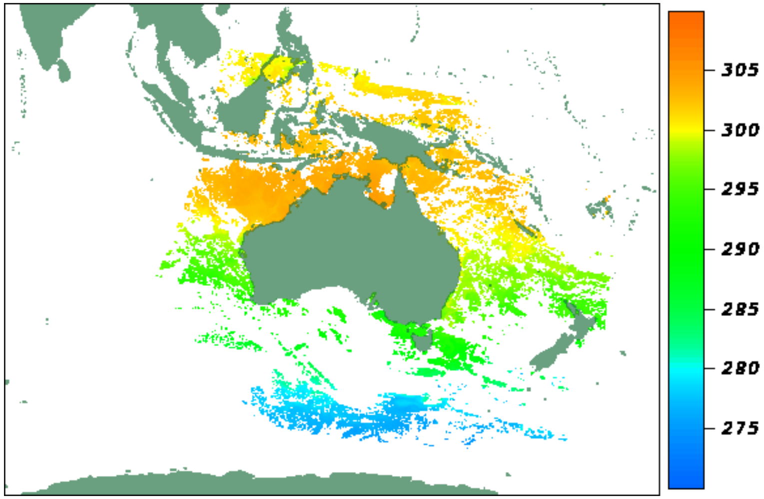
Remapping the quality level allows us to:

- track degradation in quality over each platform life
- combine "**old**" platforms with "**new**" platforms with appropriate quality assessment
- reflect the greater uncertainty of measurement and degraded quality as the uncertainty and deviation from in situ measurement increases
- provide supplier quality assessment based on other metrics

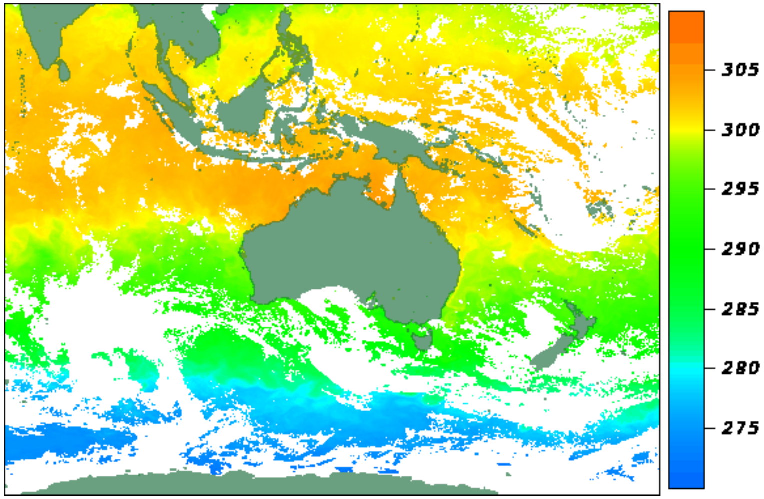
IMOS VIIRS L3C product

- We composited VIIRS_NPP L3U data to construct our new VIIRS L3C product

1-day night L3C (QL=4, 5) from NOAA-19



1-day night L3C (QL=4, 5) from VIIRS



Sea surface temperatures with quality level 4 and 5 For L3C-1day night file from (a) NOAA-19 and (b)VIIRS_NPP for 22nd February 2016.

IMOS "Multi-sensor" L3S product

Australian Government
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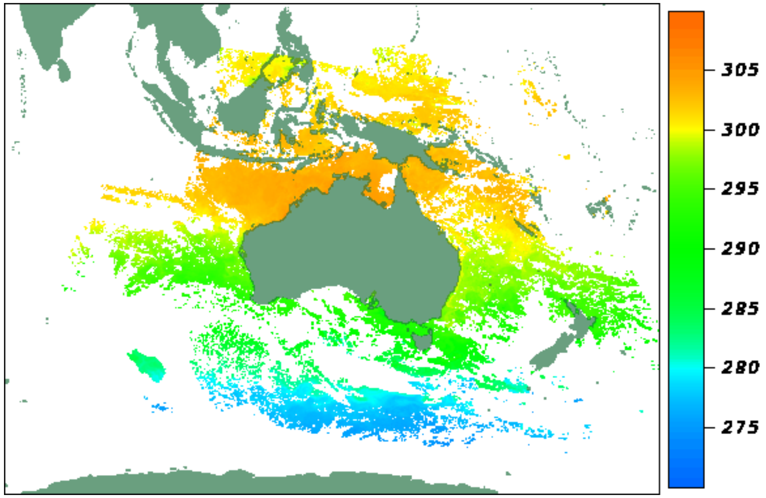
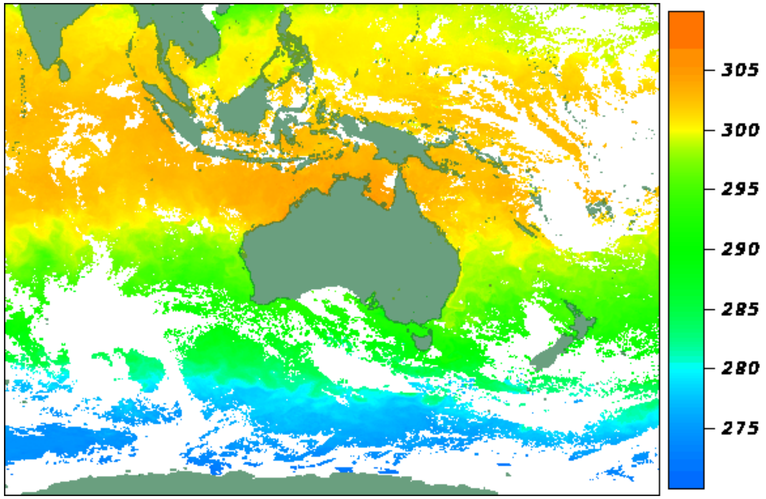
- We composited NOAA-15, NOAA-18, NOAA-19 and VIIRS_NPP data to construct our new "Multi-sensor" L3S product
- Note that in this example Multi-sensor L3S has greater spatial coverage than VIIRS L3C alone, for remapped quality level ≥ 4

1-day night L3S (QL=4, 5) from NOAA-18/19



1-day night L3S (QL=4, 5) from N-15/18/19 and VIIRS



Sea surface temperatures with quality level 4 and 5 For L3S-1day night file from (a) NOAA-18/19 and (b) Multi-sensors (NOAA-15/18/19 and VIIRS_NPP) for 22nd February 2016.

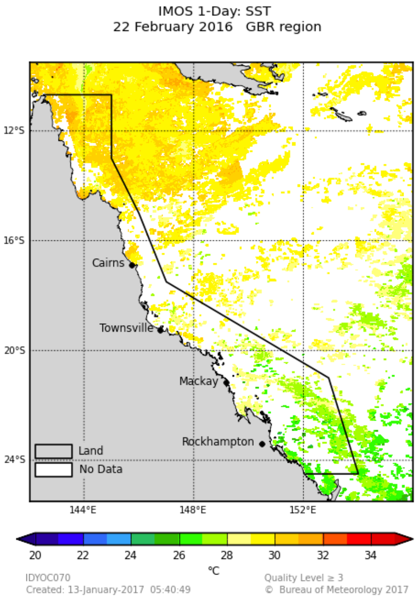
VIIRS L3C/L3S Validation

Compared QL ≥ 4 SST(0.2 m) from IMOS AVHRR and VIIRS L3C/L3S files with drifting and tropical moored buoy foundation SSTs for 1 Mar – 30 Jun 2017 over Australian domain (70ºE – 190ºE, 70ºS – 20ºN). Data collocated if within 6 hours and same 0.02º grid cell, and winds > 6 m/s (day), > 2 m/s (night).

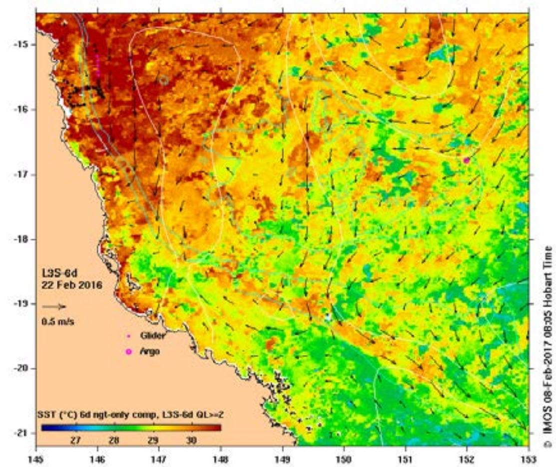
L3C/L3S Product	Day Matchups	Day Bias (K)	Day SD (K)	Night Matchups	Night Bias (K)	Night SD (K)
N-15 L3C	107	-0.10	1.14	2298	-0.03	0.69
N-18 L3C	846	0.04	0.66	4769	-0.01	0.65
N-19 L3C	2741	0.06	0.65	3835	0.02	0.44
VIIRS L3C	15355	0.21	0.36	20092	0.04	0.35
N-18/19 L3S	3958	-0.01	0.69	7123	0.00	0.57
Multi L3S	20901	0.23	0.45	24447	0.03	0.44

Use of VIIRS SSTs
- Level 3 SST

Due to enhanced spatial coverage and agreement with buoys, the IMOS multi-sensor L3S SST products are expected to provide better input for applications such as BoM's ReefTemp NextGen Coral Bleaching Nowcasting system and IMOS OceanCurrent.



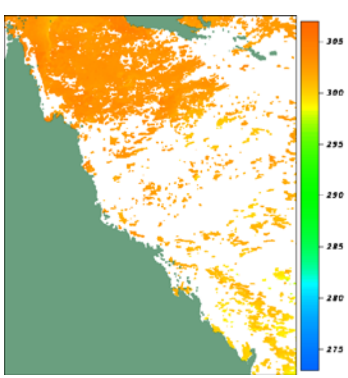
BoM ReefTemp NextGen map of the 2 km SST for 22 Feb 2016, generated using IMOS night-only 1-day L3S SSTs. Image source: http://www.bom.gov.au/environment/activities/reeftemp/reeftemp.shtml



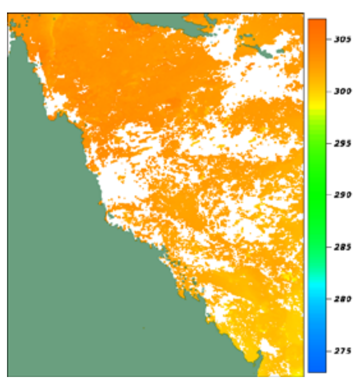
IMOS *OceanCurrent* map of the 2 km SST and surface ocean current vectors for 22 Feb 2016, generated using IMOS night-only 6-day L3S SSTs. Image source: http://oceancurrent.imos.org.au/sst.php

L3S-1night quality>=4 for 22 Feb 2016

AVHRR



Multisensor



Use of VIIRS SSTs
- Level 4 SST

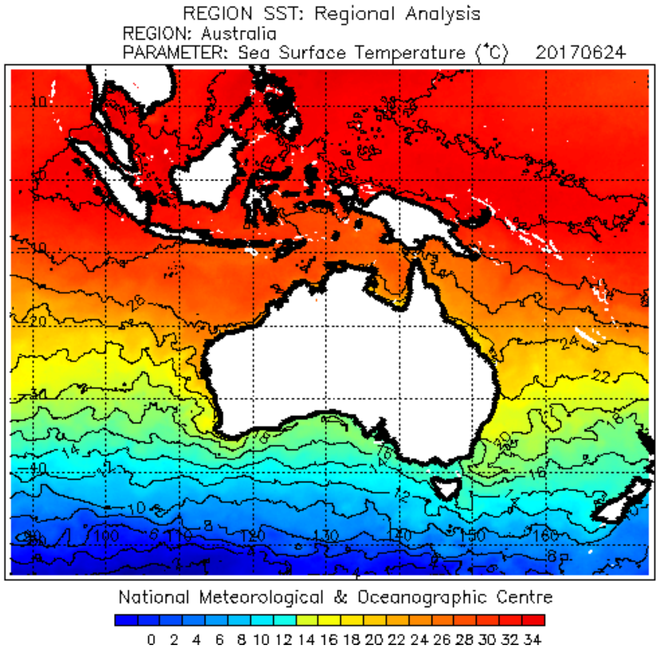
Australian Government
Bureau of Meteorology

IMOS

- ACSPO VIIRS L3U SST data is being tested for ingestion into the Bureau's operational daily SST analyses (1/12º RAMSSA and 1/4º GAMSSA)

- Pre-processing system converts ACSPO VIIRS L3U data to IMOS VIIRS L3U format (QL changed) then collates to daily 1/12º and 1/4º L3C SSTfnd data
  - Using only SSTs for daytime ACCESS-G NWP analysis winds ≥ 6 m/s, nighttime winds ≥ 2 m/s
  - Will be optimally interpolated along with HRPT AVHRR, GAC AVHRR, AMSR-2 and in situ SSTfnd data into SST analyses

RAMSSA SST Analysis for 24th June 2017

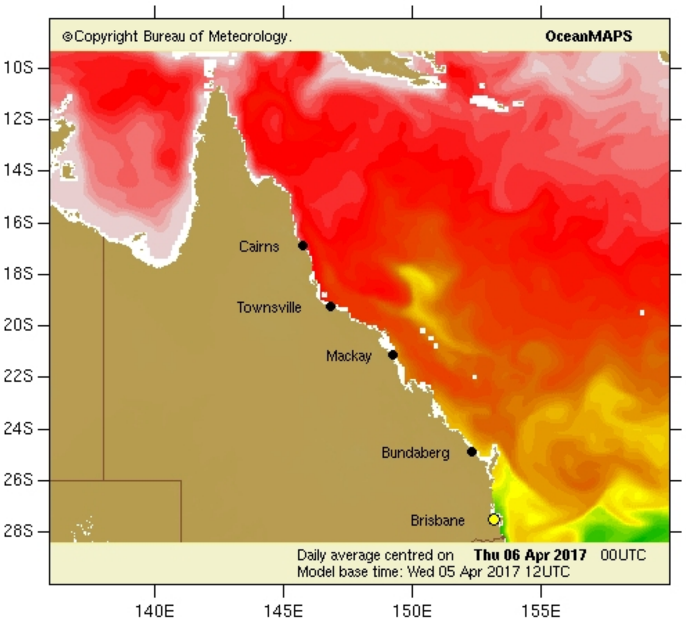


Use of VIIRS SSTs
- Ocean Forecast SST

Australian Government
Bureau of Meteorology

- By end of 2017 ACSPO VIIRS L3U SST data will be ingested into the Bureau's operational 10 km global ocean model, OceanMAPS v3.2, and 4 km Great Barrier Reef ocean model, eReefs
- Pre-processing system collates VIIRS L3U data to 6-hourly 0.04º L3C data
- Collated obs: (quality level = 5) AND (nighttime OR winds ≥ 6 m/s)
- Assimilating VIIRS L3C SST into eReefs resulted in marginal improvement in SST forecast error, with no major effect on other state variables
- Assimilating VIIRS significantly increased IR SST data coverage cf NAVO GAC AVHRR L2P

OceanMAPS forecast SST(2.5m)



Summary

- The high spatial resolution (0.75 km) of VIIRS SST data results in significant improvement in spatial coverage of IMOS multi-sensor L3S SST products and infrared SST inputs into ocean models and SST analyses at BoM
- Initial validation (March-June 2017) indicates that QL ≥ 4 multi-sensor L3S SSTs have significantly lower standard deviation than AVHRR-only L3S SSTs, when compared with buoy SSTs
- The improved L3S SST products are likely to provide better input for applications such as ReefTemp NextGen Coral Bleaching Nowcasting and IMOS OceanCurrent.
- Maps of pre-operational IMOS 1-day Multi-sensor L3S SST available in test ACSPO Regional Monitoring System (ARMS: https://www.star.nesdis.noaa.gov/sod/sst/arms_dev/arms_test2)

Future work

Over the coming 12 months, we aim to:

- Implement download of ACSPO VIIRS L3U files from operational NOAA FTP server rather than PO.DAAC
- More extensively validate VIIRS L3C/L3S files
- Provide operational, real-time IMOS fv01 VIIRS 2 km L3U, L3C and multi-sensor L3S files via the IMOS OPeNDAP server
- Reprocess IMOS fv02 AVHRR L3U/L3C/L3S and fv02 VIIRS L3C and multi-sensor L3S files for the period 1 Jan 2015 to 31 Dec 2016 using reprocessed ACSPO v2.4 VIIRS L3U files
- Test ingesting VIIRS L3C SSTfnd into RAMSSA/GAMSSA SST analyses
- Include ACSPO VIIRS L3U SST in operational general circulation ocean models – OceanMAPS v3.2 and eReefs

Australian Government
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IMOS

Thank You!

Contact: helen.beggs@bom.gov.au

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IMOS

Supplementary Slides

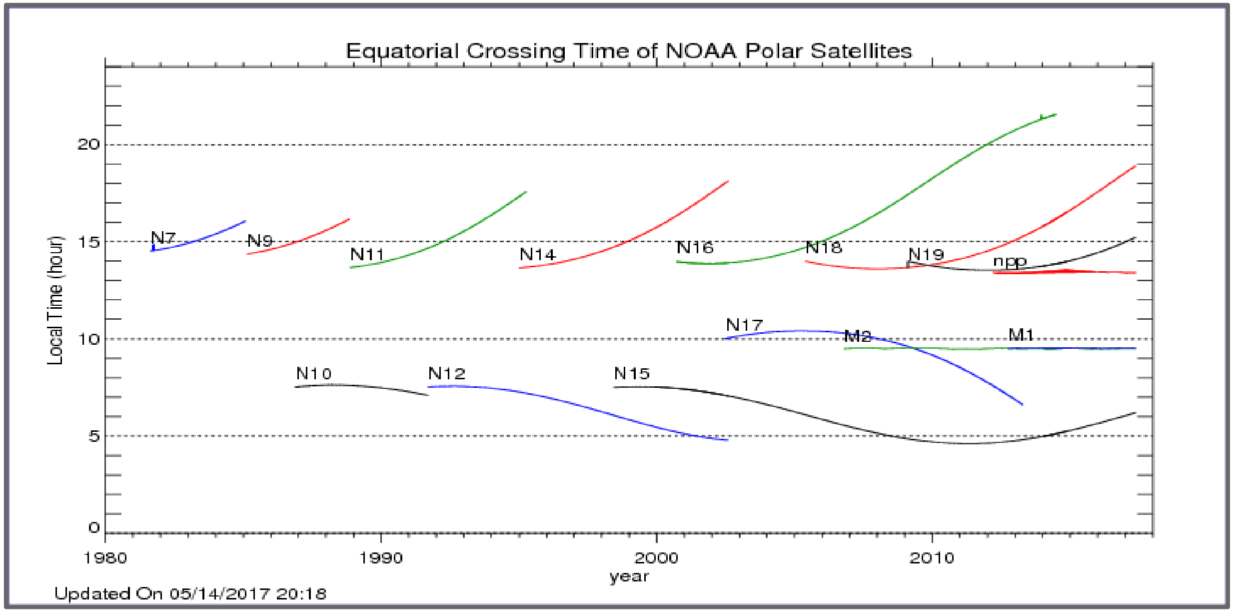
Constructing IMOS VIIRS L3U product

- Only the ACSPO VIIRS L3U files that have data on IMOS grid are processed further.
- ACSPO VIIRS L3U files are modified by adding ancillary fields to match up with standard IMOS L3U files (e.g. sea ice, winds, dt_analysis)
- l2p_flags are redefined using modified ancillary fields.
- The variable 'or_number_of _pixels' in the NOAA's VIIRS_NPP ACSPO_v2.40 L3U file indicates the original number of pixels from the L2Ps contributing to the SST value. VIIRS spatial resolution is 742m while AVHRR spatial resolution is 1.1km, almost double.
- To ensure that the pixel density is consistent between VIIRS with AVHRR at NADIR, we divided 'or_number_of_pixels' in OSPO VIIRS L3U file by two to get 'sses_count' in our new VIIRS L3U file.

Equatorial Crossing Times for NOAA Polar Satellites

The satellites NOAA-15, NOAA-18, NOAA-19 and Suomi-NPP have different equatorial crossing times. Currently, the daytime equatorial crossing time for

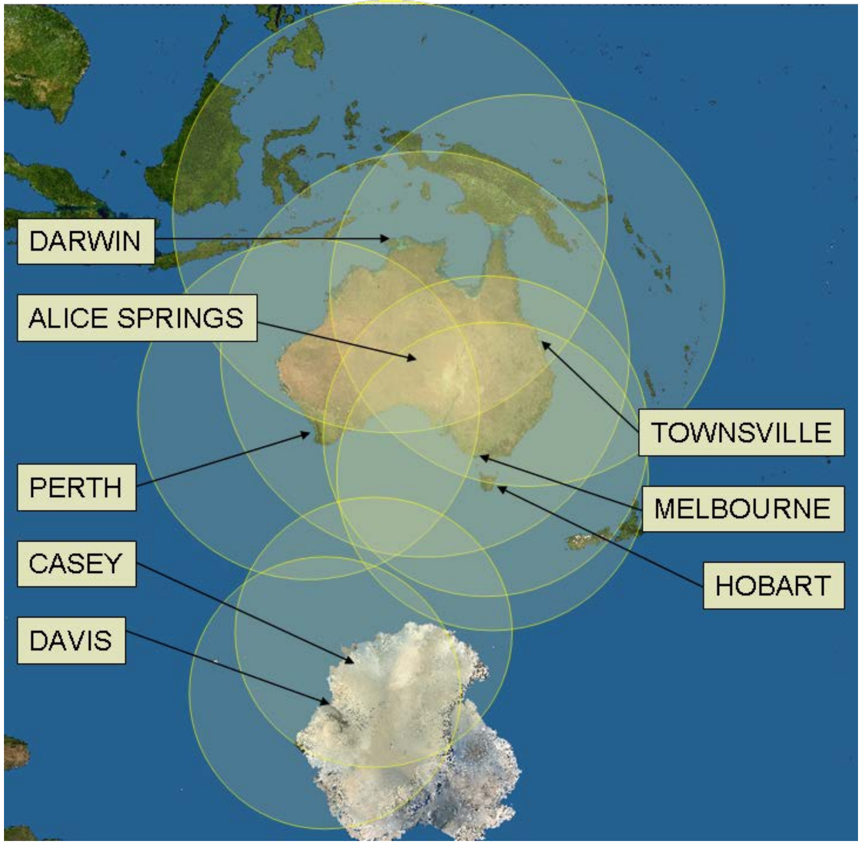
- NOAA-15 is ~ 18:00 LST (around sunset)
- NOAA-18 is ~ 19:00 LST (around sunset)
- NOAA-19 is ~ 15:00 LST (close to peak diurnal cycle)
- Suomi-NPP is ~13:30 LST (early afternoon)



Equatorial Crossing Time for NOAA Polar onboarding Satellites.
Image Source: https://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_avhrr_ect.php

Introduction

- Passive infra-red sensors on polar-orbiting satellites provide the highest resolution SST observations from space (~1 km) but cannot sense SST under cloud.
- Pre-2002 (MODIS) the only wide swath, 1 km resolution, satellite SSTs available were direct-broadcast AVHRR SST from NOAA polar-orbiters.
- BoM and CSIRO have 1.1 km (at nadir) "HRPT" AVHRR data from NOAA-11 to NOAA-19 from reception stations in Australia and Antarctica back to mid-1980's



OceanMAPS v3.1 SST Analyses and Forecasts

Lead: Gary Brassington; Contact: Xinmei Huang

http://www.bom.gov.au/oceanograpy/forecasts

Australian Government
Bureau of Meteorology

Depth: Top cell depth 5 m so SST(2.5 m)

Resolution: Daily, 0.1º Global

Available: 9 Jun 2016 to real-time

Method: sequential, multi-variate, data assimilation based ensemble optimal interpolation

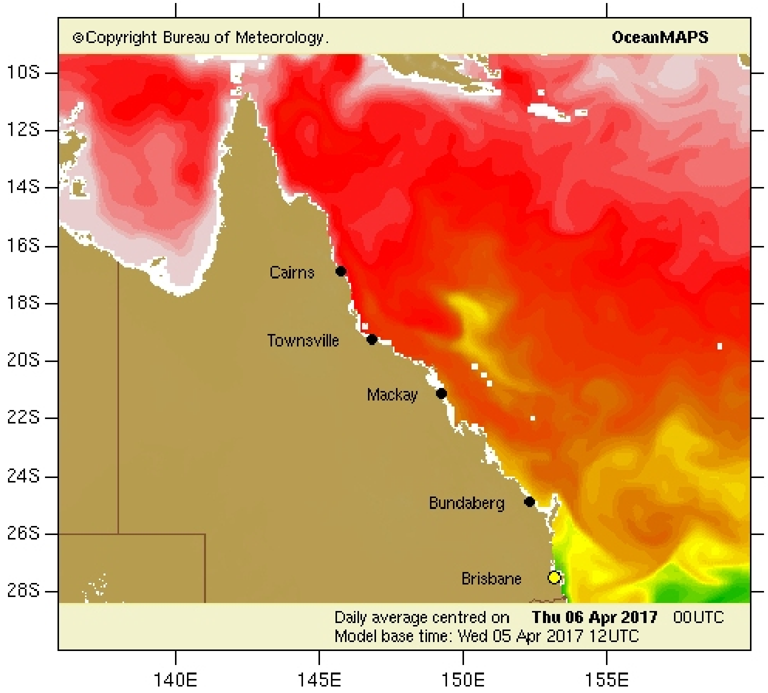
- Multivariate assimilation includes - altimetry, sat-SST, in situ T/S and XBT's

SST inputs:

- 9 km NAVOCEANO GAC AVHRR (NOAA-18/19, METOP-A/B) **L2P** SST1m
- ~50 km JAXA AMSR-2 (GCOM-W) **L2P** SSTsubskin
- Argo, XBT, CTD, mooring in situ SSTdepth (GTS, Coriolis, US-GODAE)

Uses: Defence, Search & Rescue, Oil Spills, shipping, etc

OceanMAPS forecast SST(2.5m)

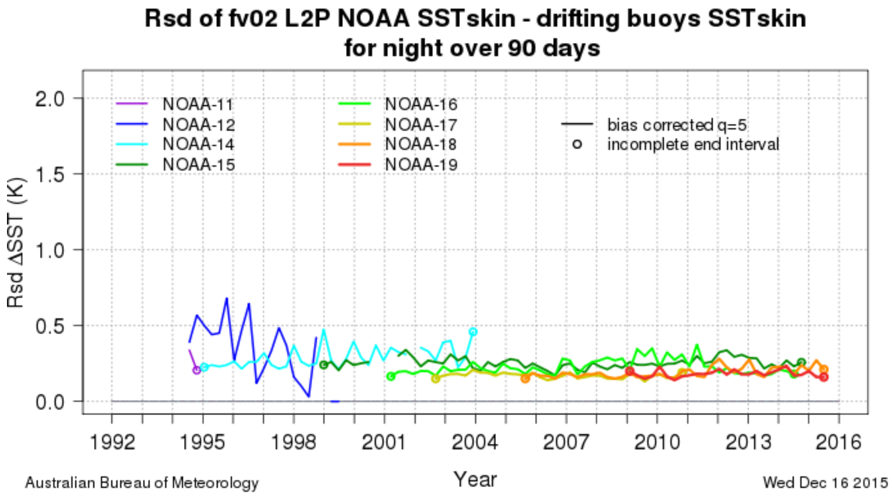


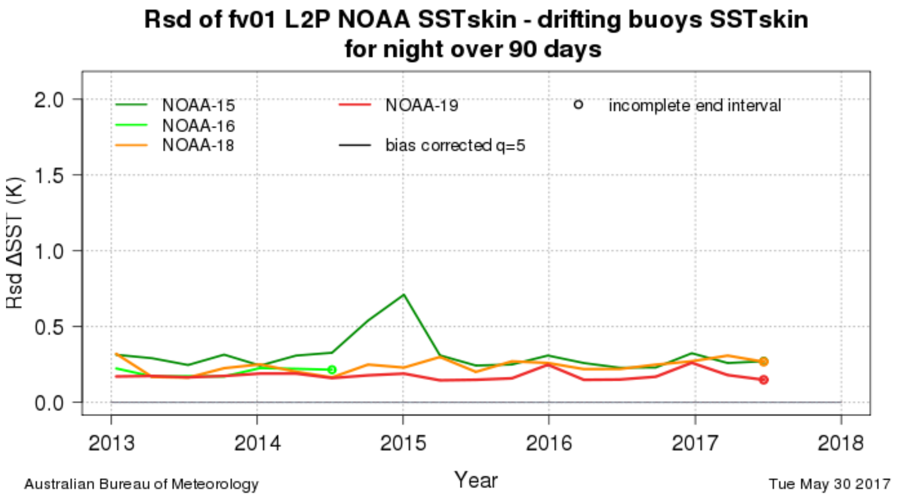
Data availability

IMOS AVHRR-only 2 km L3U, L3C and L3S files are available by Thredds server from 1992 to present at http://rs-data1-mel.csiro.au/thredds/catalog/imos-srs/sst/ghrsst/catalog.html

The online operational validation of IMOS AVHRR L2P products is available at http://imos.org.au/sstdata_validation.html

The pre-operational real-time IMOS VIIRS L3U/L3C and multi-sensor L3S files from 1 March 2017 to present are available by request (contact: helen.beggs@bom.gov.au)





DMIs use of NPP-VIIRS SST data from ASCPO

Jacob L. Høyer
Danish Meteorological Institute
Denmark

DMI
Danish Meteorological Institute

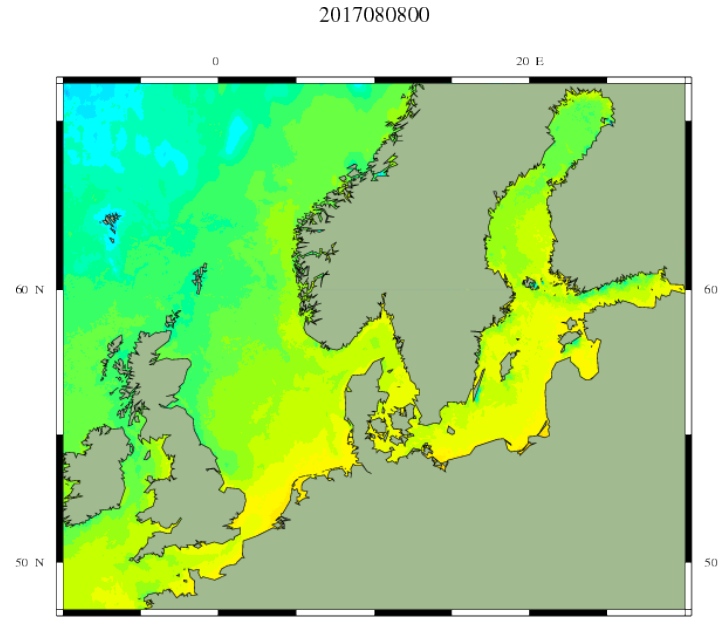
Scope

- Talk will focus upon Level 4 SST products:
  - North Sea-Baltic Sea
  - Global
- And show the inclusion of the VIIRS_NPP product

DMI
Danish Meteorological Institute

DMI_OI for the North Sea and Baltic Sea

- Part of the Copernicus Marine Environmental Monitoring Service (CMEMS) OSI-TAC project
- Daily operational rproduct
- Spatial resolution of 0.02 degrees
- Uses North Sea-Baltic Sea area
- Ingests NPP-VIIRS data in 0.02 degrees
- Used operationally in the DMI ocean and atmosphere models for the Danish Seas
- Available at:
  - CMEMS web site (*marine.copernicus.eu/*)
  - PoDAAC (podaac.jpl.nasa.gov/)



DMI
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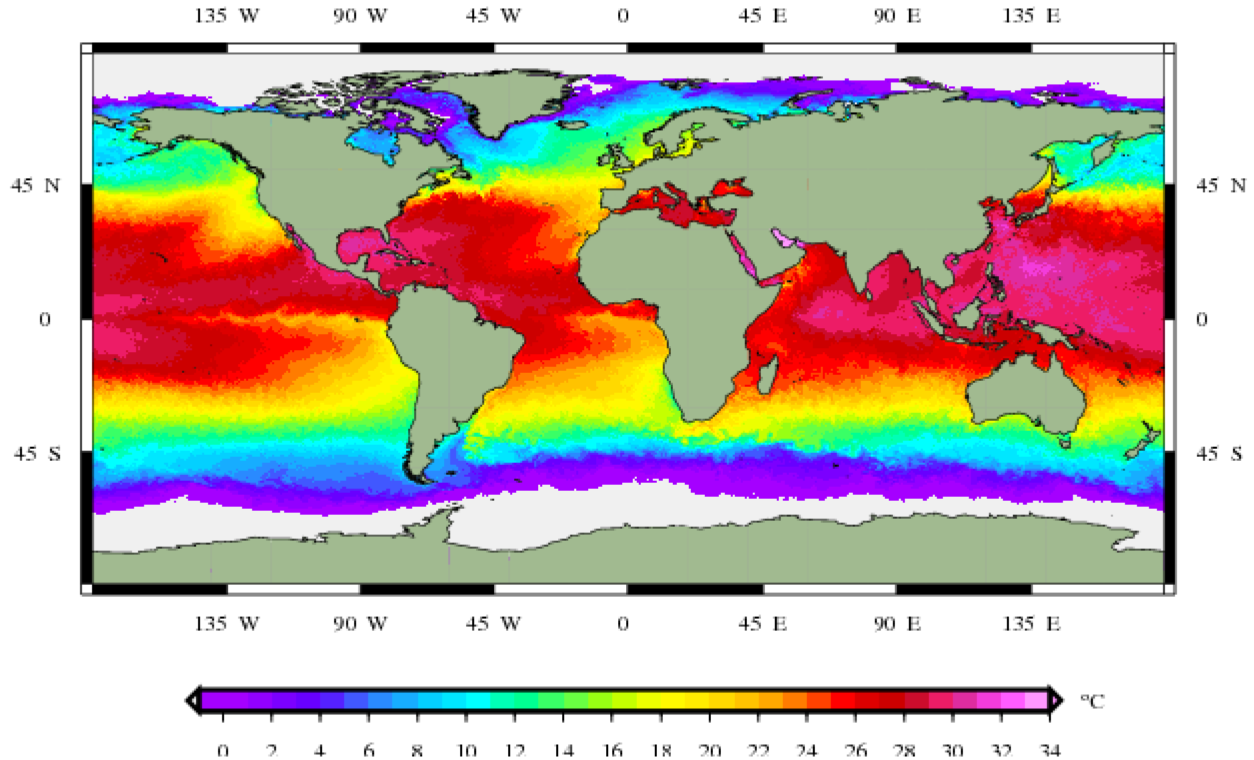
Global DMI_OI product

- Daily operational product
- Spatial resolution: 0.05 degrees lat and lon
- Part of the new GMPE product
- Included in Squam
- Used for DMIs Arctic Ocean and Atmosphere models.
- Available at:
    - PoDAAC (podaac.jpl.nasa.gov/)



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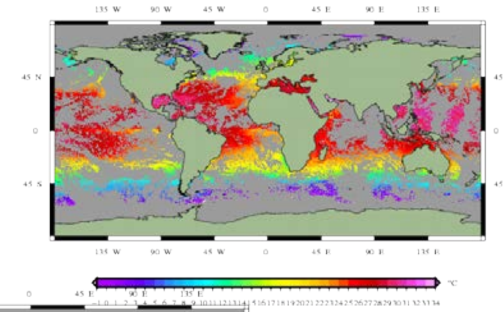
Satellite data included in the DMI_OI

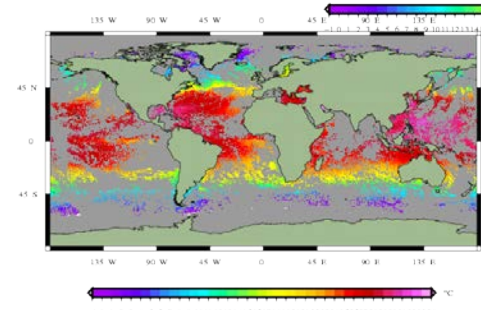
Level 2 and 3 operational SST products included in the DMI_OI

- From PODAAC:
  - VIIRS_NPP-OSPO-L3U-v2.4
  - AVHRR19_G-NAVO-L2P-v1.0
  - AVHRR19_L-NAVO-L2P-v1.0
- From OSI-SAF:
  - OSI-203 Operational AVHRR, NOAA/AVHRR L3
  - OSI-204-b Operational Metop-B/AVHRR L2P
  - OSI-206 Operational MSG/SEVIRI L3C
  - OSI-207 Operational GOES-E/IMAGER L3C
  - **Sea Ice:** OSI-401-b Operational DMSP/SSMIS L3
- From Jaxa:
  - Jaxa AMSR2 SST

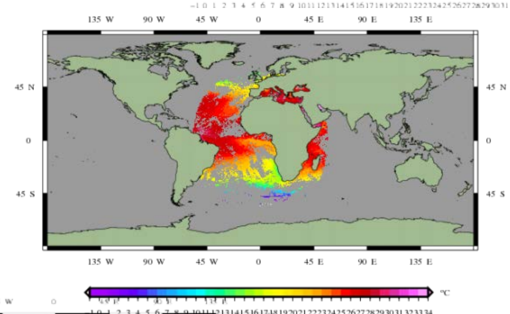
VIIRS_NPP



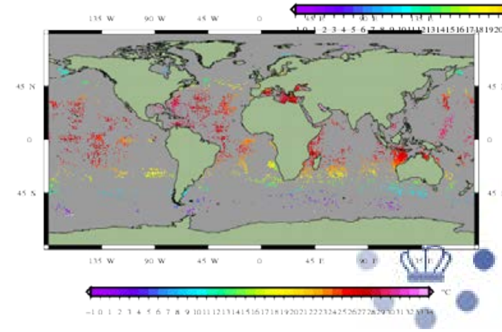
Metop-B



MSG



AVHRR GAC



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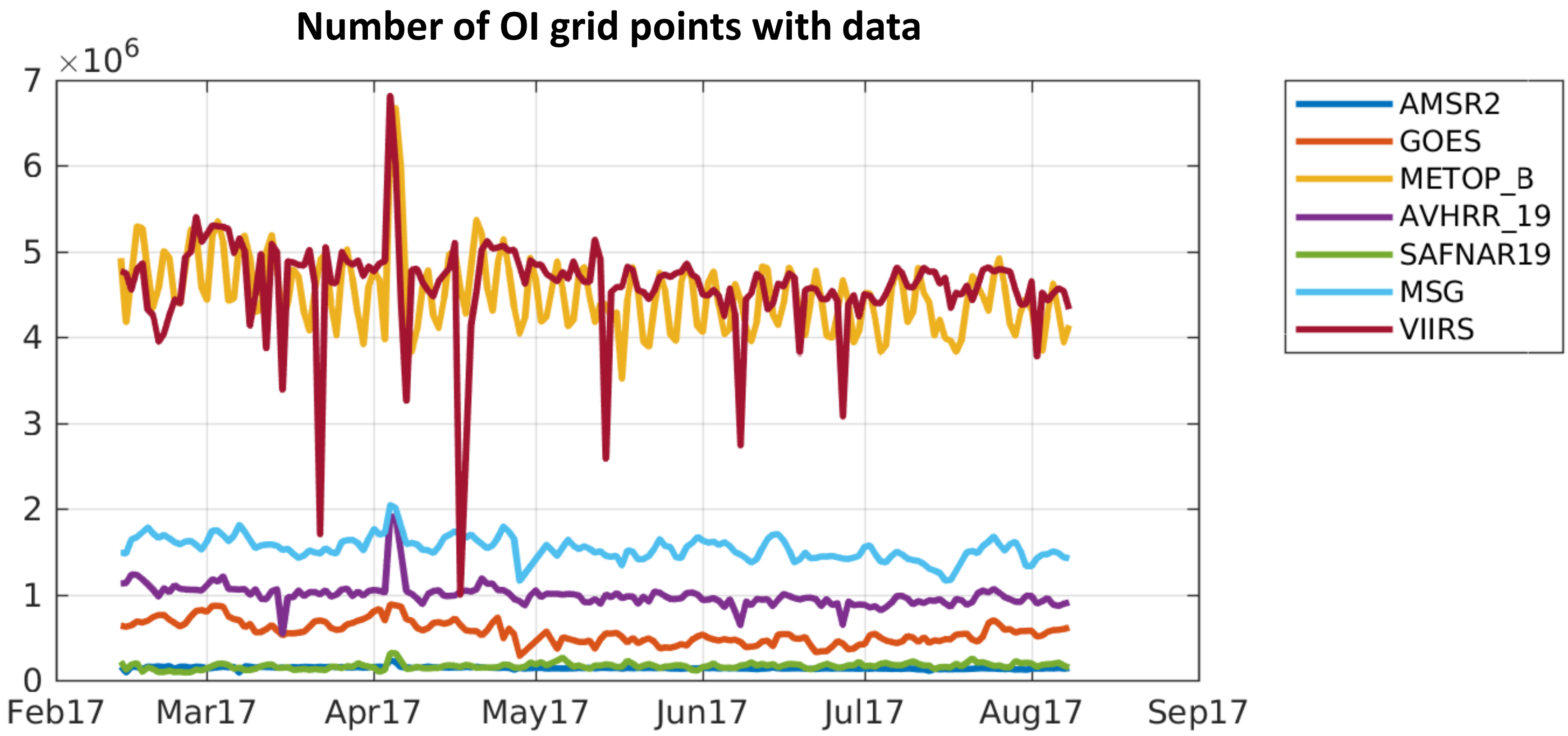
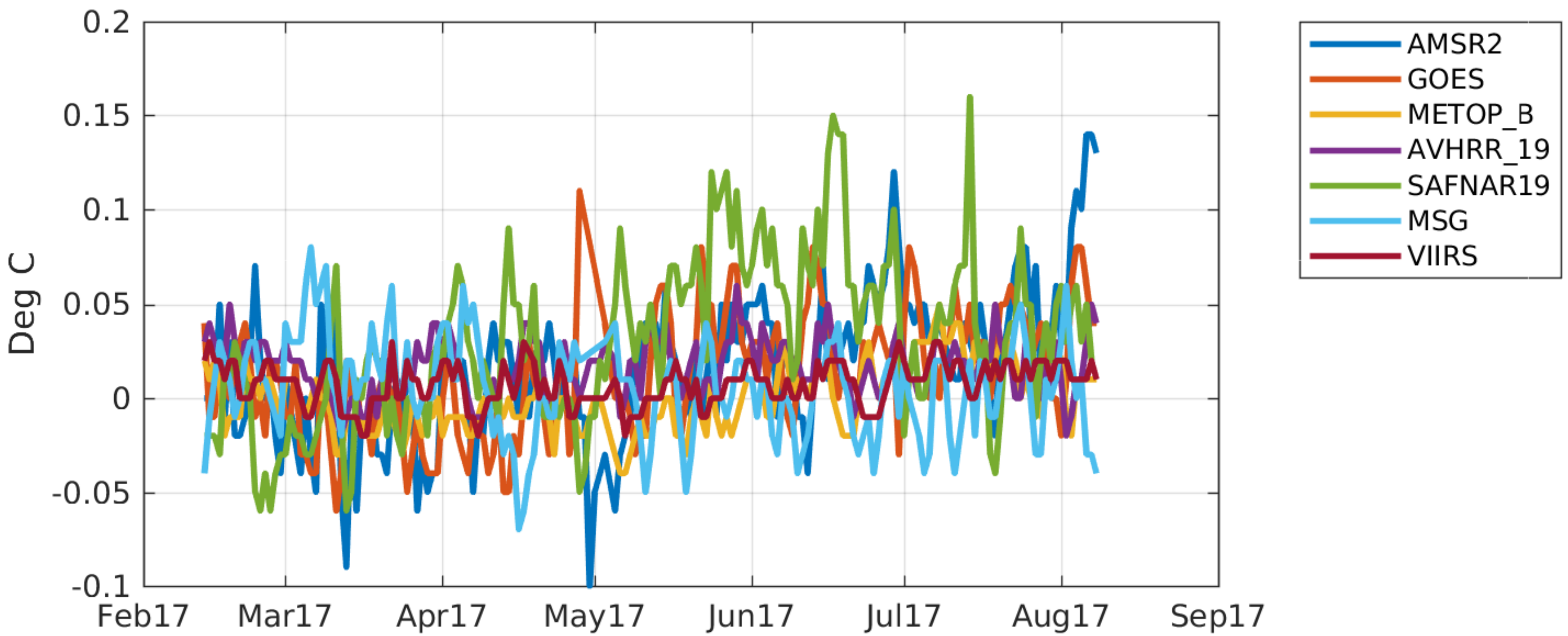
L2 SST aggregation, number of data

- Temporal window of +-24 hours from analysis
- VIIRS_NPP product with largest data amount



Mean difference to first guess

- Global statistics of aggregated L3 products against first guess field (previous day analysis)
- Mean VIIRS_NPP difference with respect first guess field is small.



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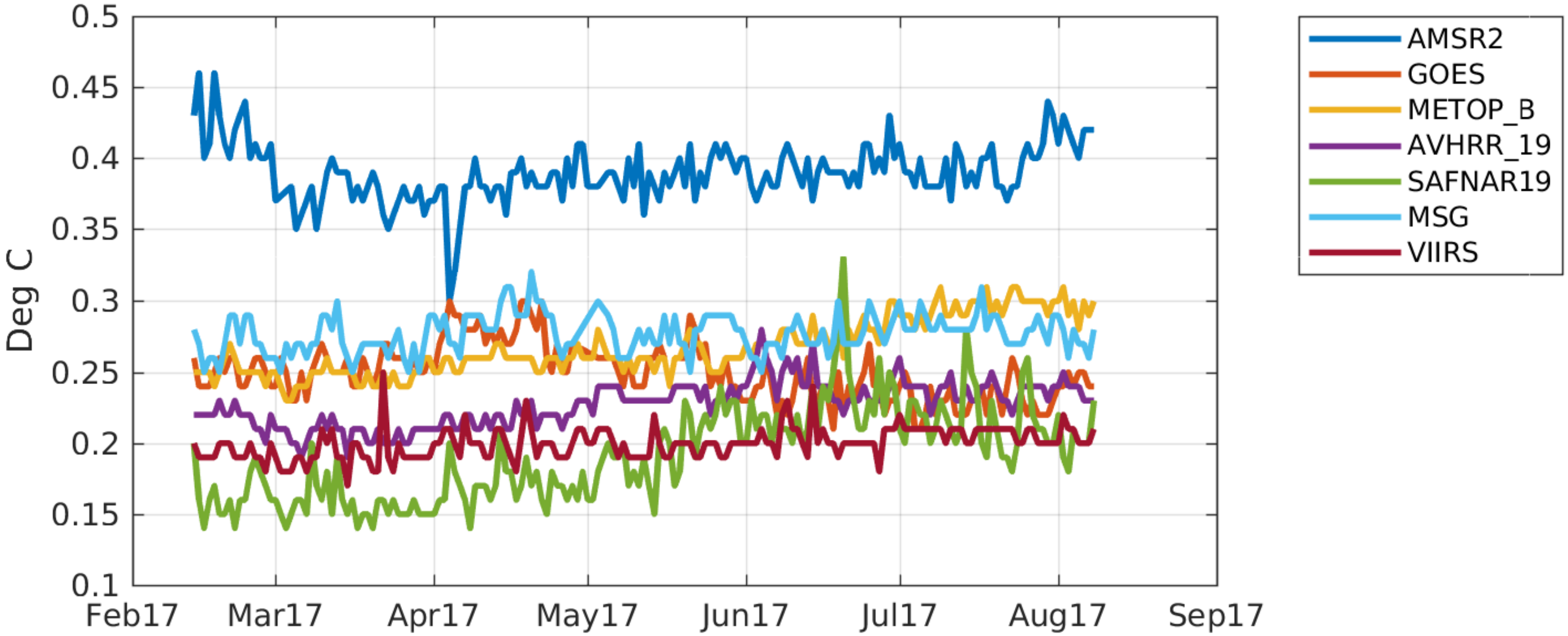
Std dev of anomalies wrt first guess

- Same as previous slide, but with stddev
- VIIRS_NPP among the products with low stddev and stable performance



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Conclusion

- We are very happy with the timeliness and accuracy of the S-NPP VIIRS product
- Data coverage of Viirs data is very high
- Compared with first guess fields, the VIIRS_NPP show good accuracy and stable performance
- VIIRS-NPP product very important for the global performance of the level 4 DMI_OI

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Thanks and keep up the good work !

DMI
Danish Meteorological Institute

NOAA's Geo-Polar Blended SST Analysis

Andy Harris[1], Jonathan Mittaz[1,4], Gary Wick[3], Eileen Maturi[2], John Sapper[5], Mark Eakin[2]

[1]NOAA-CICS, University of Maryland

[2]NOAA/NESDIS/STAR

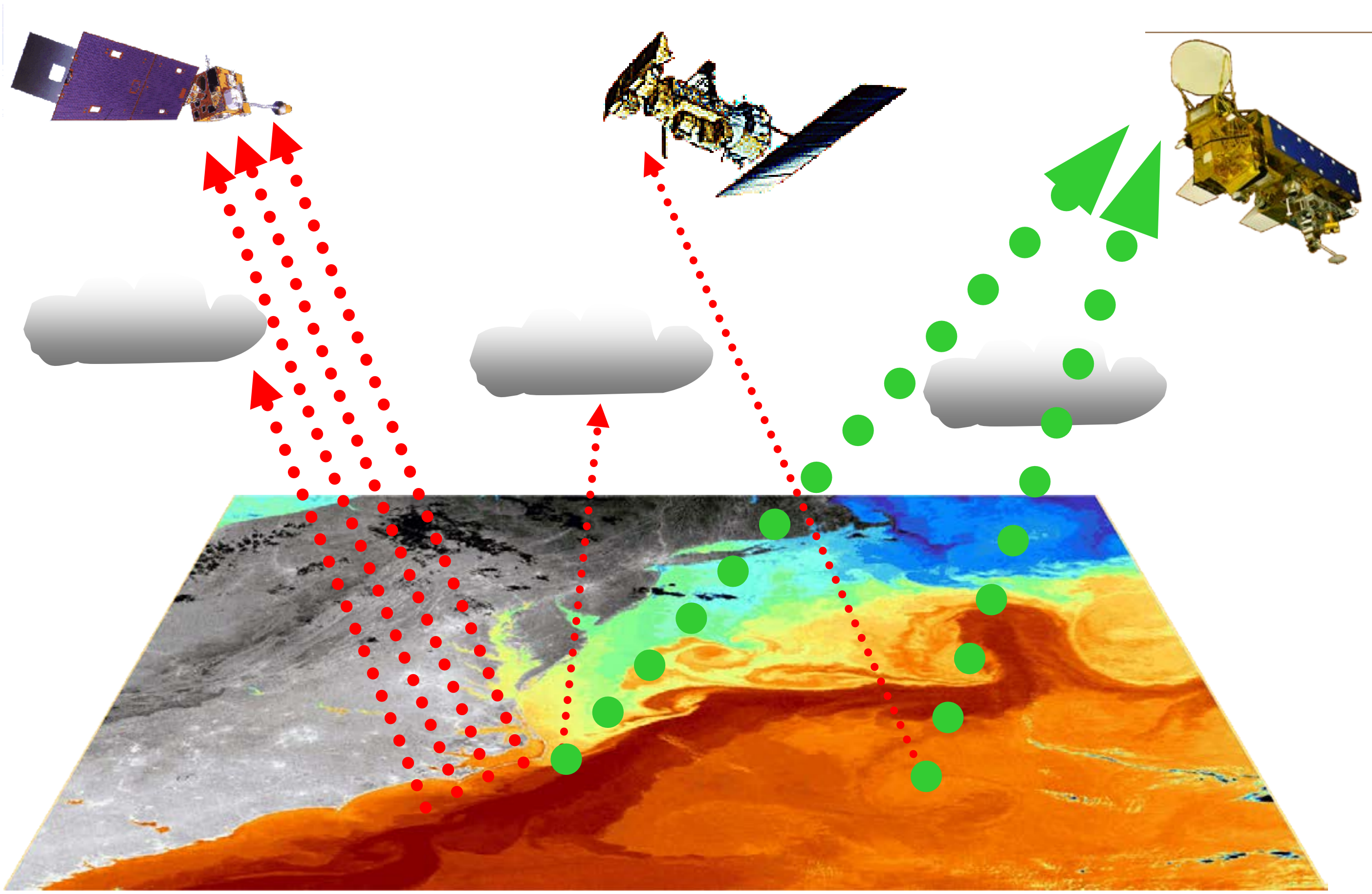
[3]NOAA/OAR/ESRL

[4]University of Reading, UK

[5]NOAA/NESDIS/OSPO

JPSS Annual Meeting, 14 – 18 August, 2017

Maximize strengths – minimize weaknesses



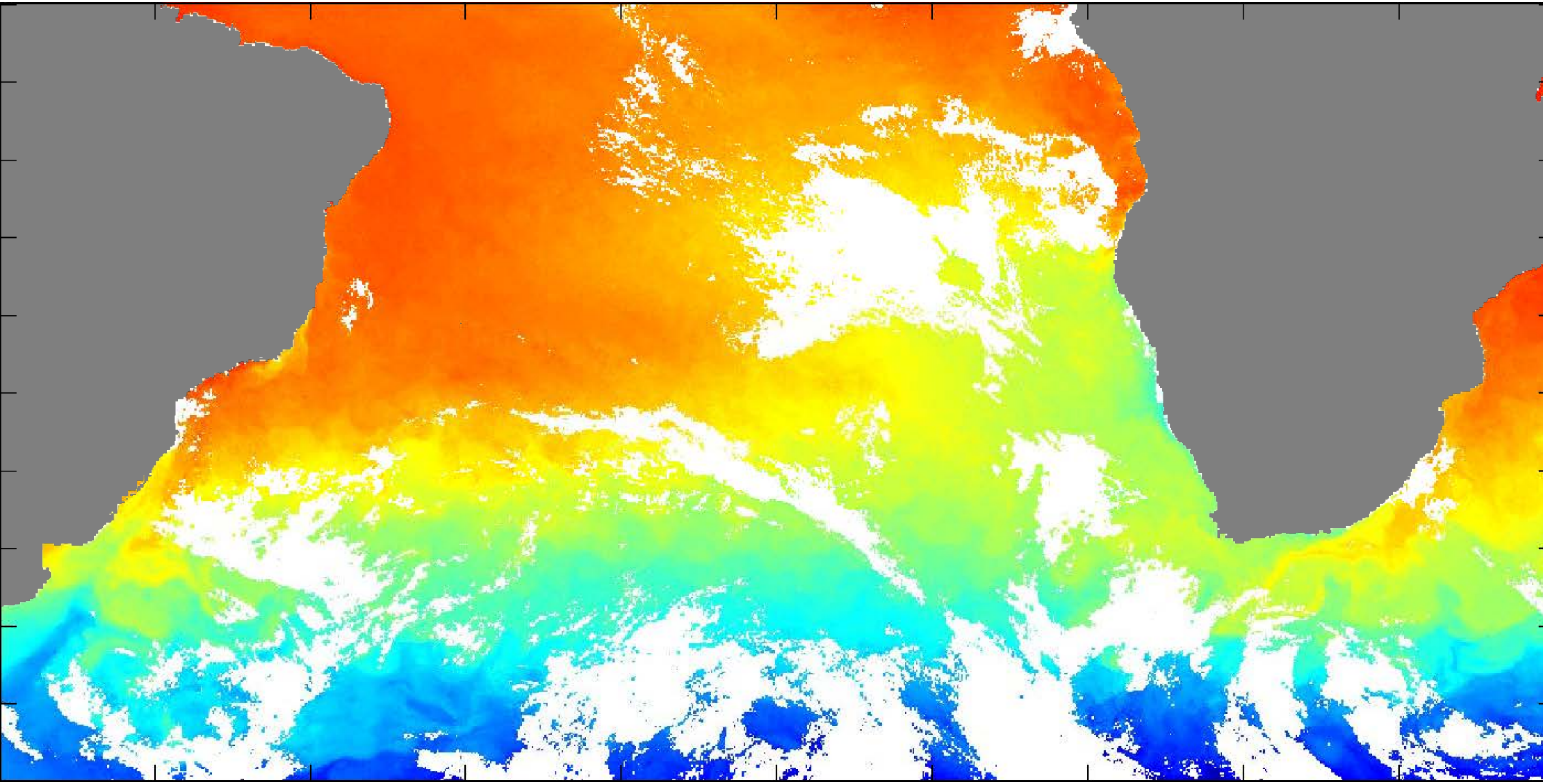
POES IR has **high spatial resolution**

GOES IR has **high temporal resolution**

Microwave has **all-weather capability**

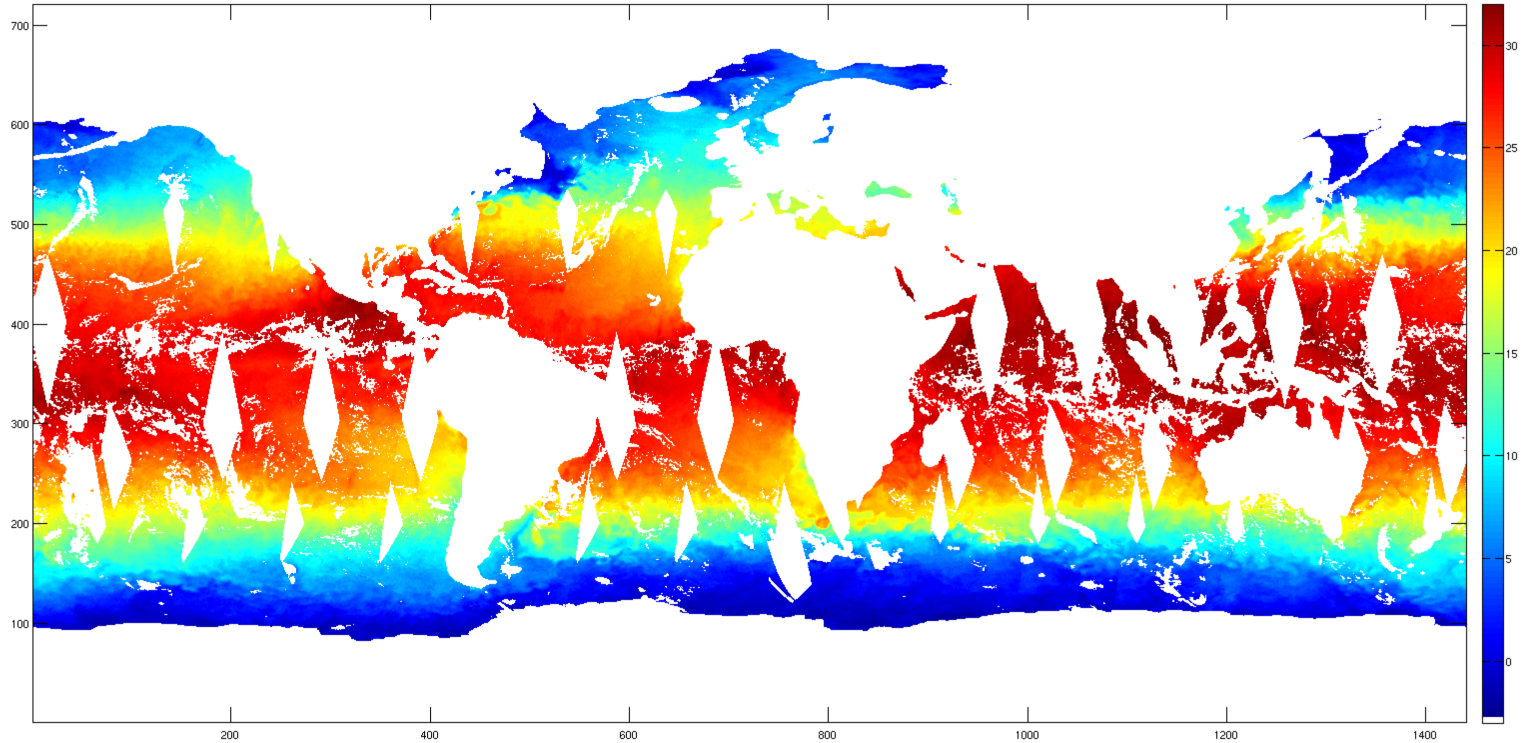
Combine to obtain the **optimal SST analysis**

Combined coverage



Geo-SST dominates low-to-mid latitudes

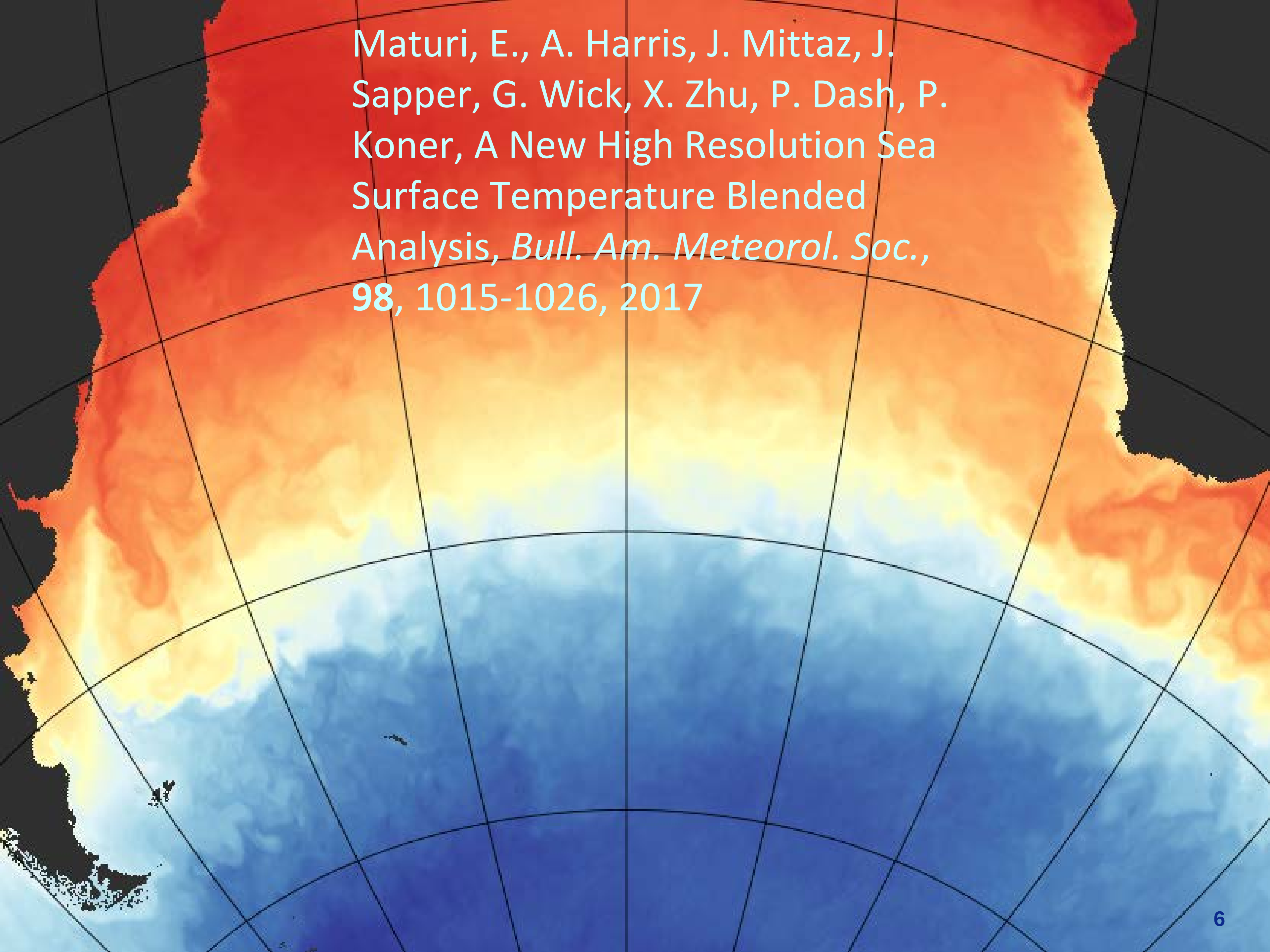
Data Coverage – AMSR-2



- Valid SST data coverage from AMSR-2 for 2014-05-01
  - » Improved coverage in both Tropics and High Latitudes
  - » 3 days gives almost complete coverage away from land & ice

5-km Blended SST Analysis

- **Produced daily from 24 hours of Polar- & Geo-SST**
  - MetOp-B
  - GOES-E/W Imager
  - Meteosat-10 SEVIRI [Meteosat-8 over Indian Ocean]
  - Himawari-8 Imager
  - VIIRS
  - [AMSR-2]
  - **Does <u>not</u> use buoy data**
- **Multi-scale OI**
  - Mimics Kalman Filter **(***Khellah et. al., 2005***)**
- **3 stationary priors**
  - Short, intermediate and long correlation lengths
  - Mimic non-stationary prior while preserving rigor
  - Interpolation of resultant analyses based data density
    - ➢ **<u>Allows fine resolution where possible without introducing noise</u>**

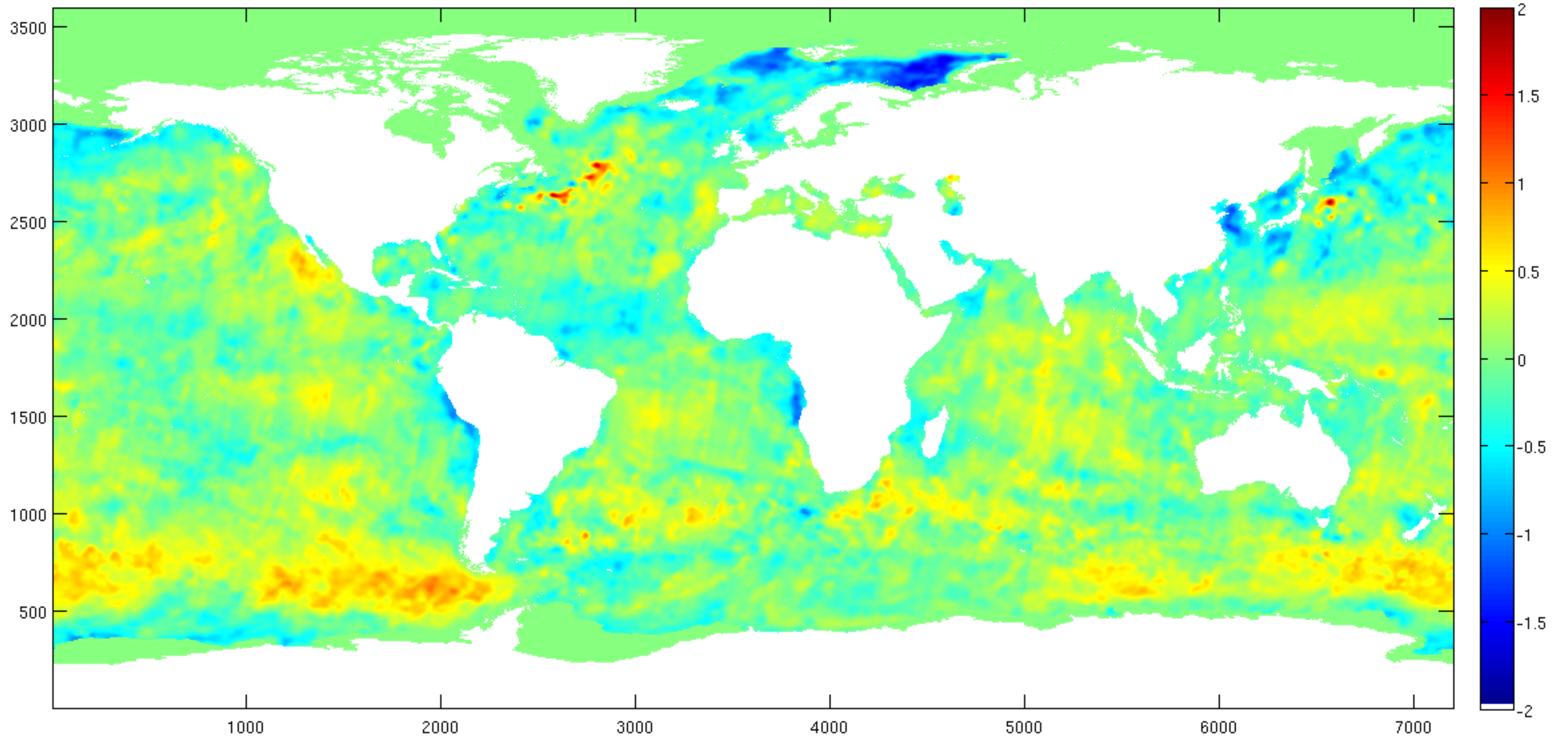


Maturi, E., A. Harris, J. Mittaz, J. Sapper, G. Wick, X. Zhu, P. Dash, P. Koner, A New High Resolution Sea Surface Temperature Blended Analysis, *Bull. Am. Meteorol. Soc.*, **98**, 1015-1026, 2017

AMSR-2 SSES Bias

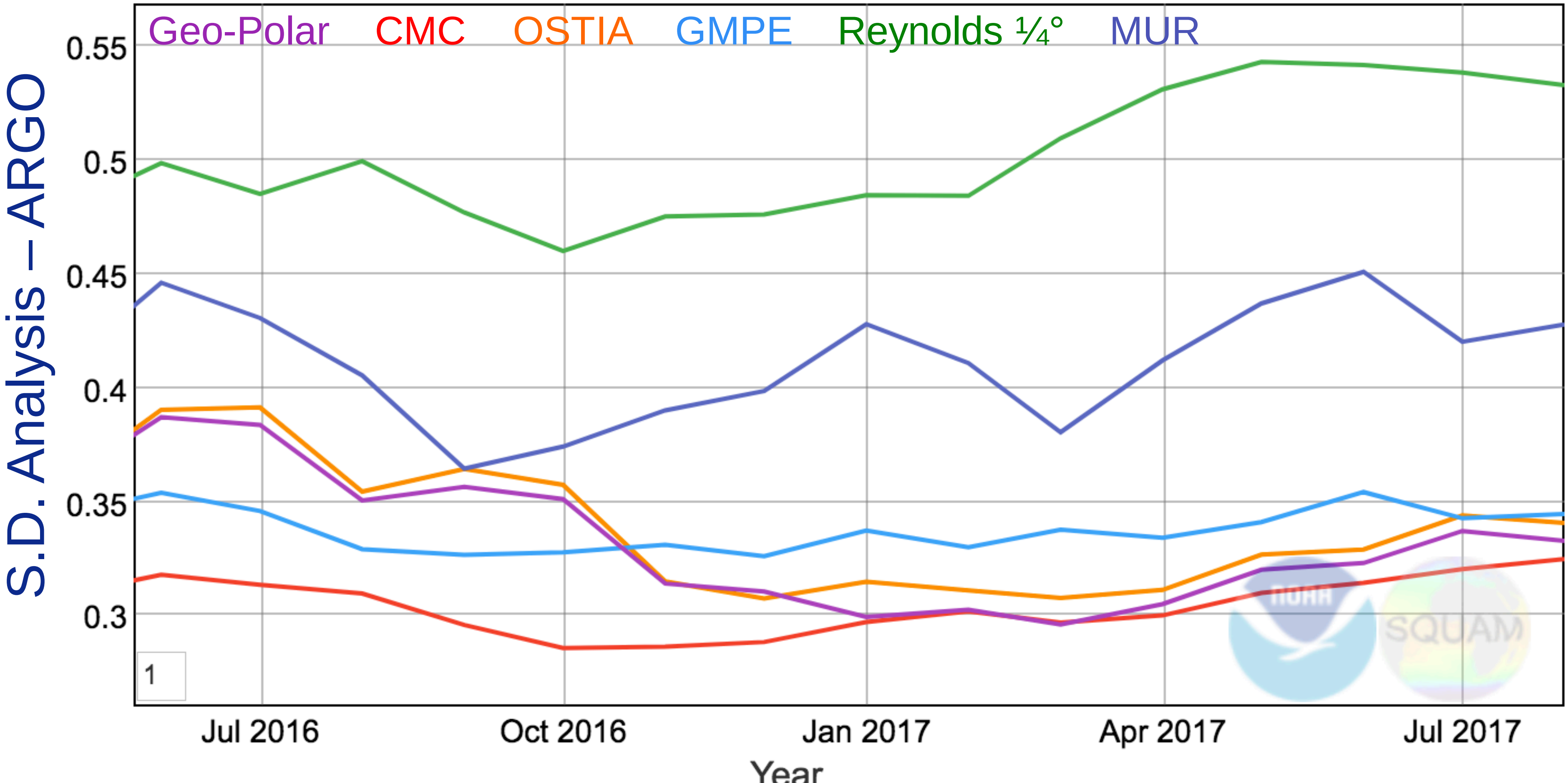
- **Lookup table based on incidence angle**

With SSES Bias Adjustment



VIIRS data

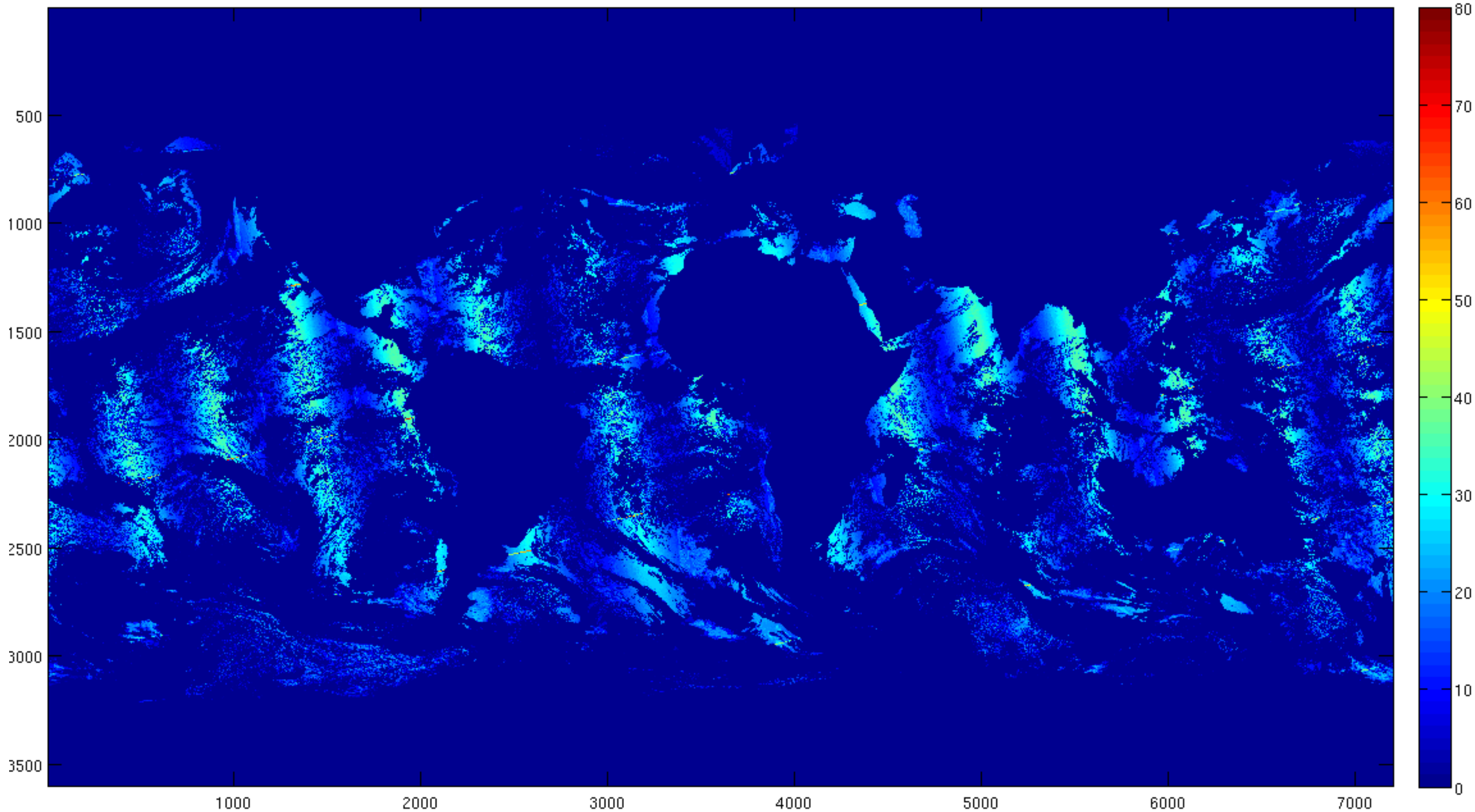
- **VIIRS incorporated into Geo-Polar Blended 5-km global SST analysis**



Significant impact on accuracy *cf.* <u>independent</u> ARGO data

VIIRS coverage

- **Coverage is improved w.r.t. MetOp AVHRR**



ACSPO AVHRR coverage
ACSPO VIIRS coverage

NOAA Coral Reef Watch

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

DOC > NOAA > NESDIS > STAR > CRW

Coral Reef Watch

CRTF | CRCP | CREIOS | CoRIS

CRW Home

Products Overview

Near-Real-Time Data
(5-km Resolution)

Bleaching Alert Area

Degree Heating Week

HotSpot

Sea Surface Temperature

SST Anomaly

Virtual Stations/Gauges

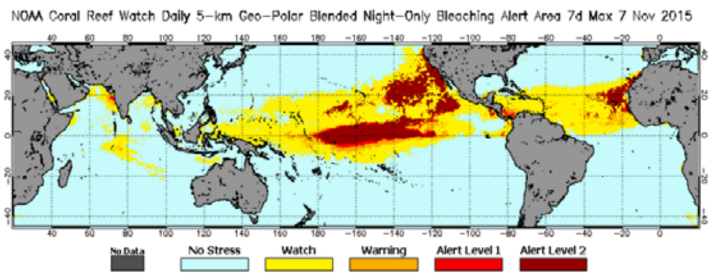
Near-Real-Time Data
(50-km Resolution)

Coral Reef Watch Satellite Monitoring

NOAA Coral Reef Watch is pleased to announce the release of its new Daily 5-km Satellite Coral Bleaching Thermal Stress Monitoring Product Suite. The 5-km products are accessible directly below, in the left navigation bar, and throughout this website. Access to our heritage suite of operational 50-km satellite monitoring products will still be possible for the next several months. We encourage all of our users to look over the new 5-km products and provide feedback to us at coralreefwatch@noaa.gov.

Click on buttons below image to change parameter; click on image to navigate to parameter's web page.

Switch to 50-km products ►



Alerts | HotSpot | DHW | SST | Anomaly | SST Trend | Outlook | Doldrums | Virtual Stations

El Niño bleaching patterns web page

The NOAA Coral Reef Watch program's satellite data provide current reef environmental conditions to quickly identify areas at risk for coral bleaching, where corals lose the symbiotic algae that give them their distinctive colors. If a coral is severely bleached, disease and partial mortality become likely, and the entire colony may die.

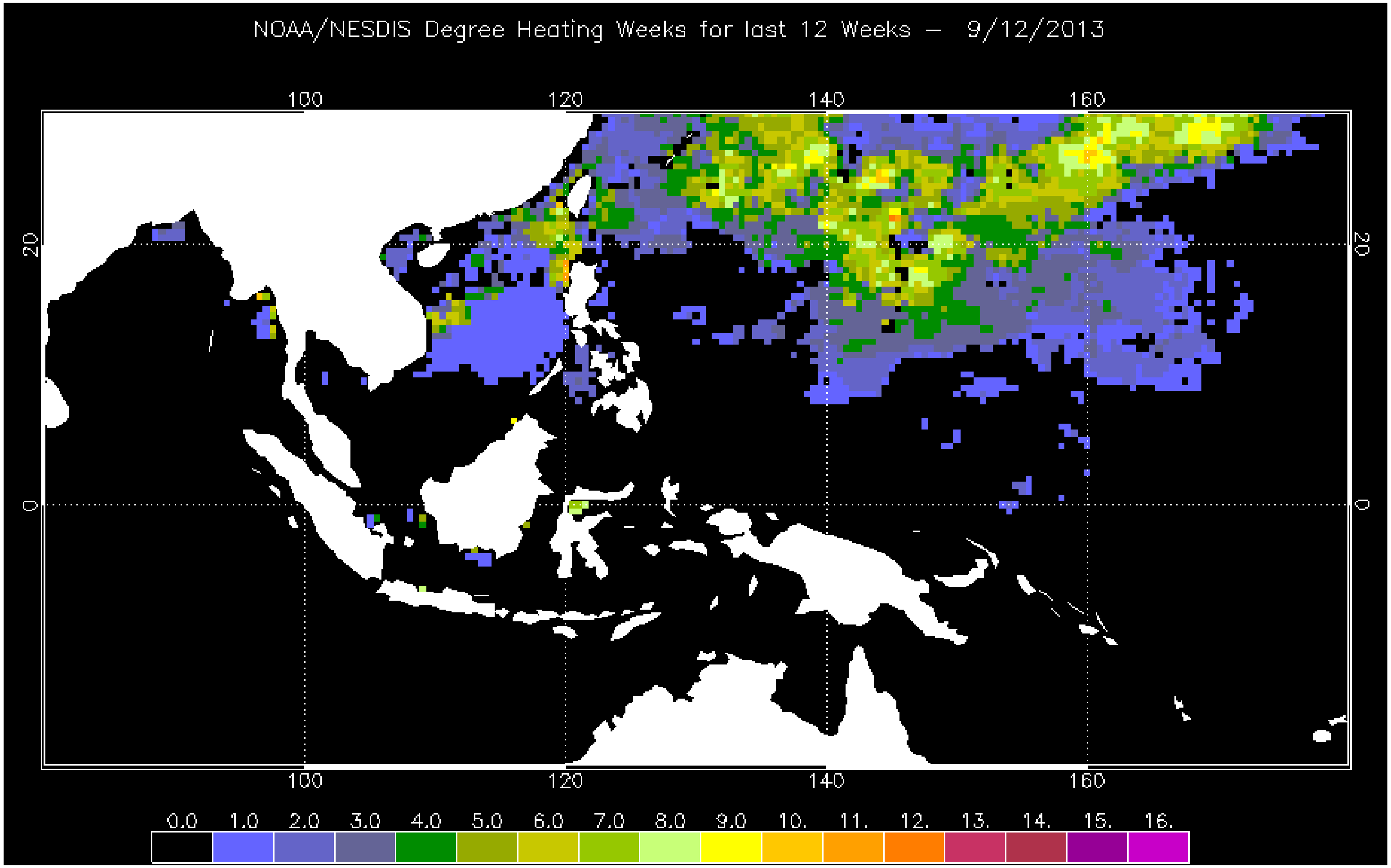
Continuous monitoring of sea surface temperature at global scales provides researchers and stakeholders with tools to understand and better manage the complex interactions leading to coral bleaching. When bleaching conditions occur, these tools can be used to trigger bleaching response plans and support appropriate management decisions.

Announcements

October 8, 2015:
NOAA announces third ever global coral bleaching event on record! Read the NOAA press release here.

Coral Reef Watch Products

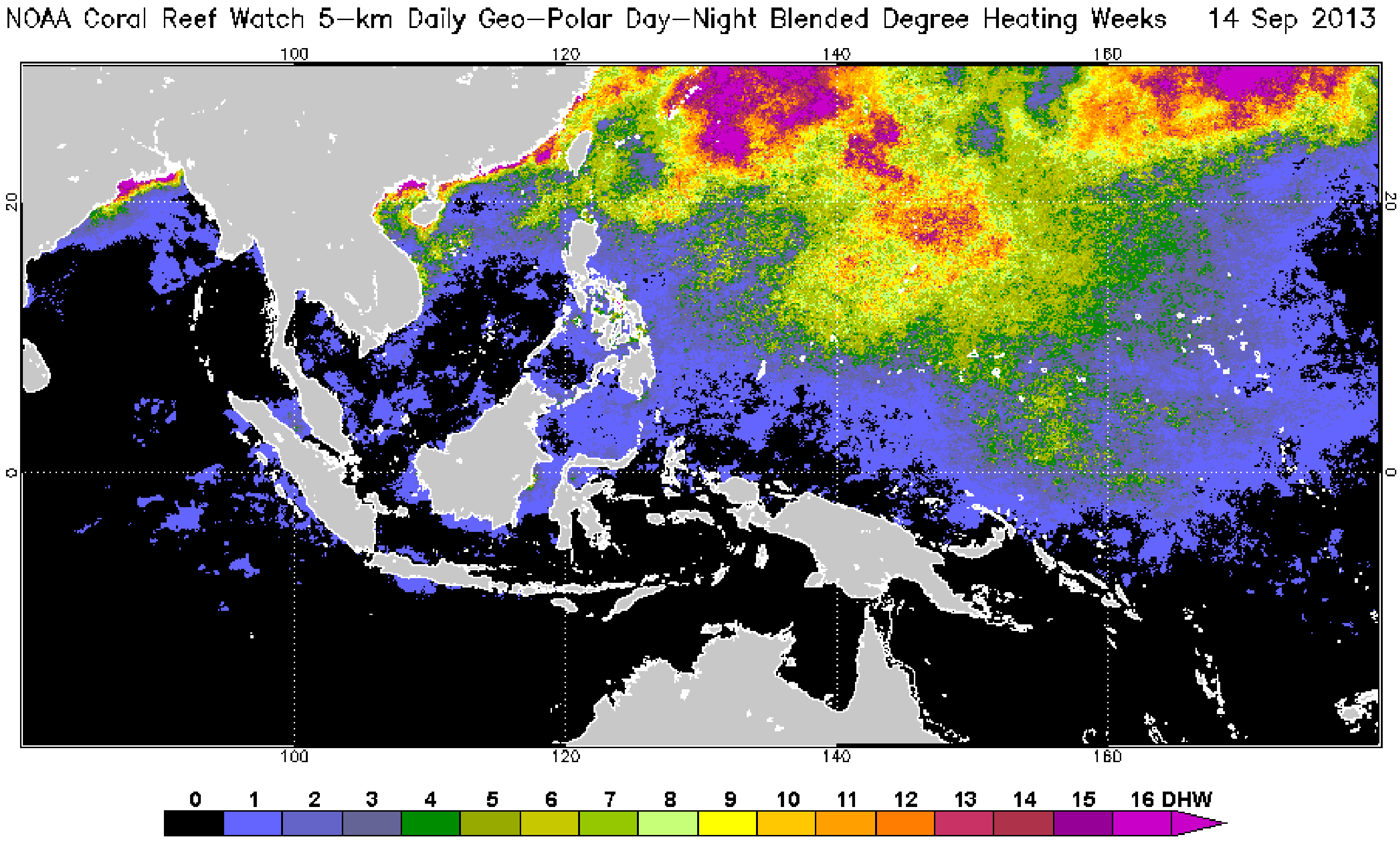
"Coral Triangle"



- **Accumulated thermal stress is predictor of bleaching risk**

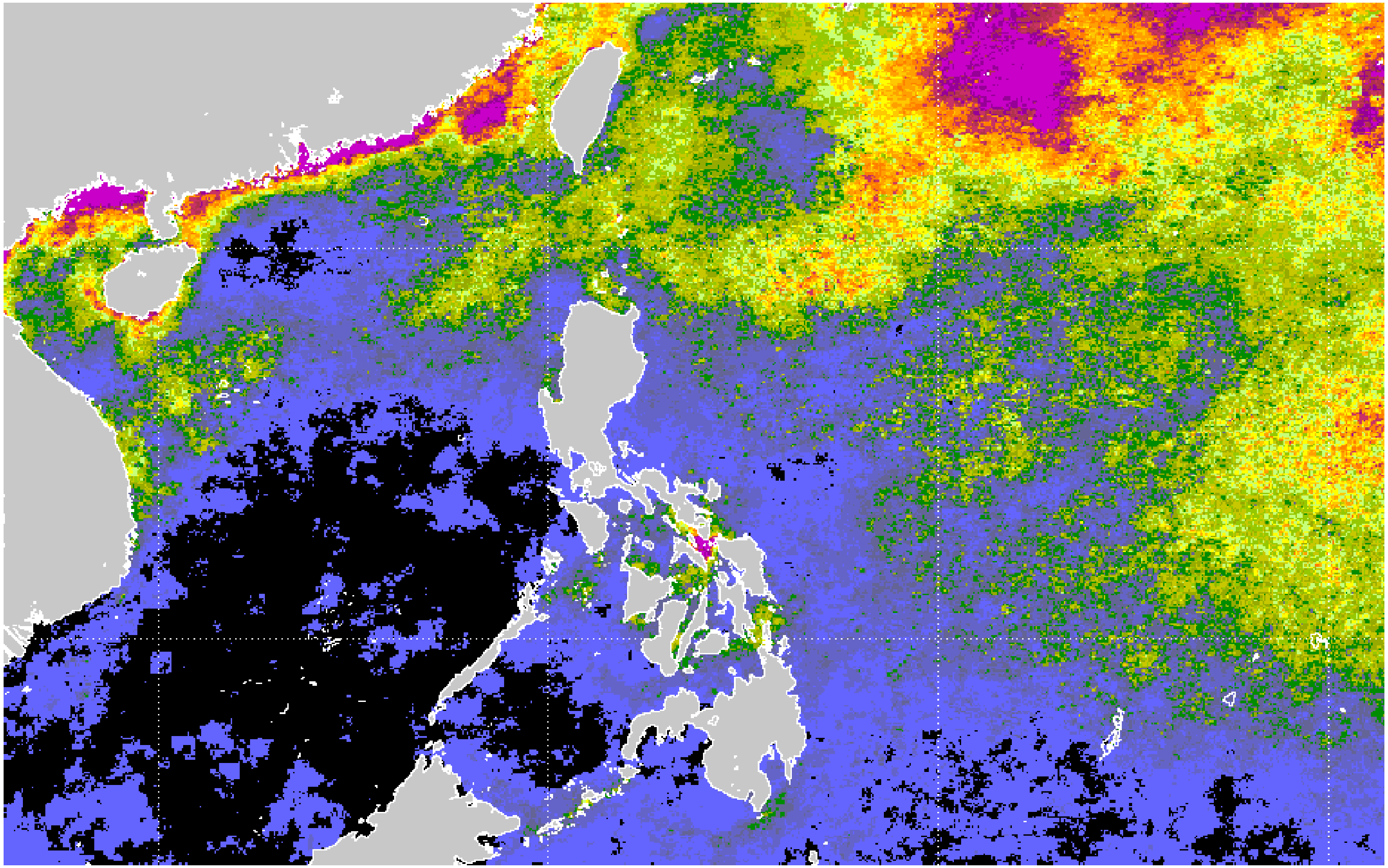
CRW Products based on 5-km SST

“Coral Triangle”

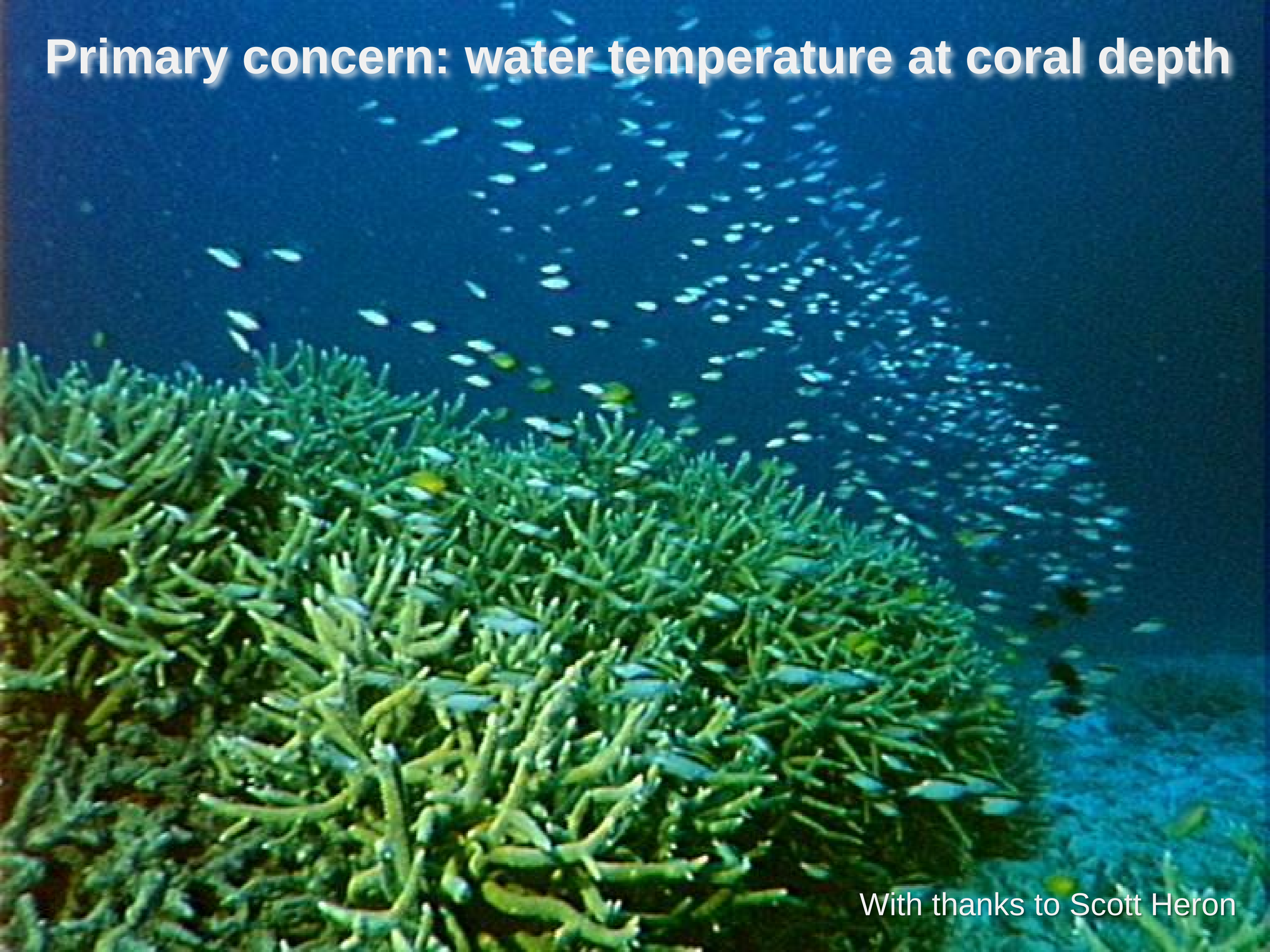


CRW Products – 5-km detail

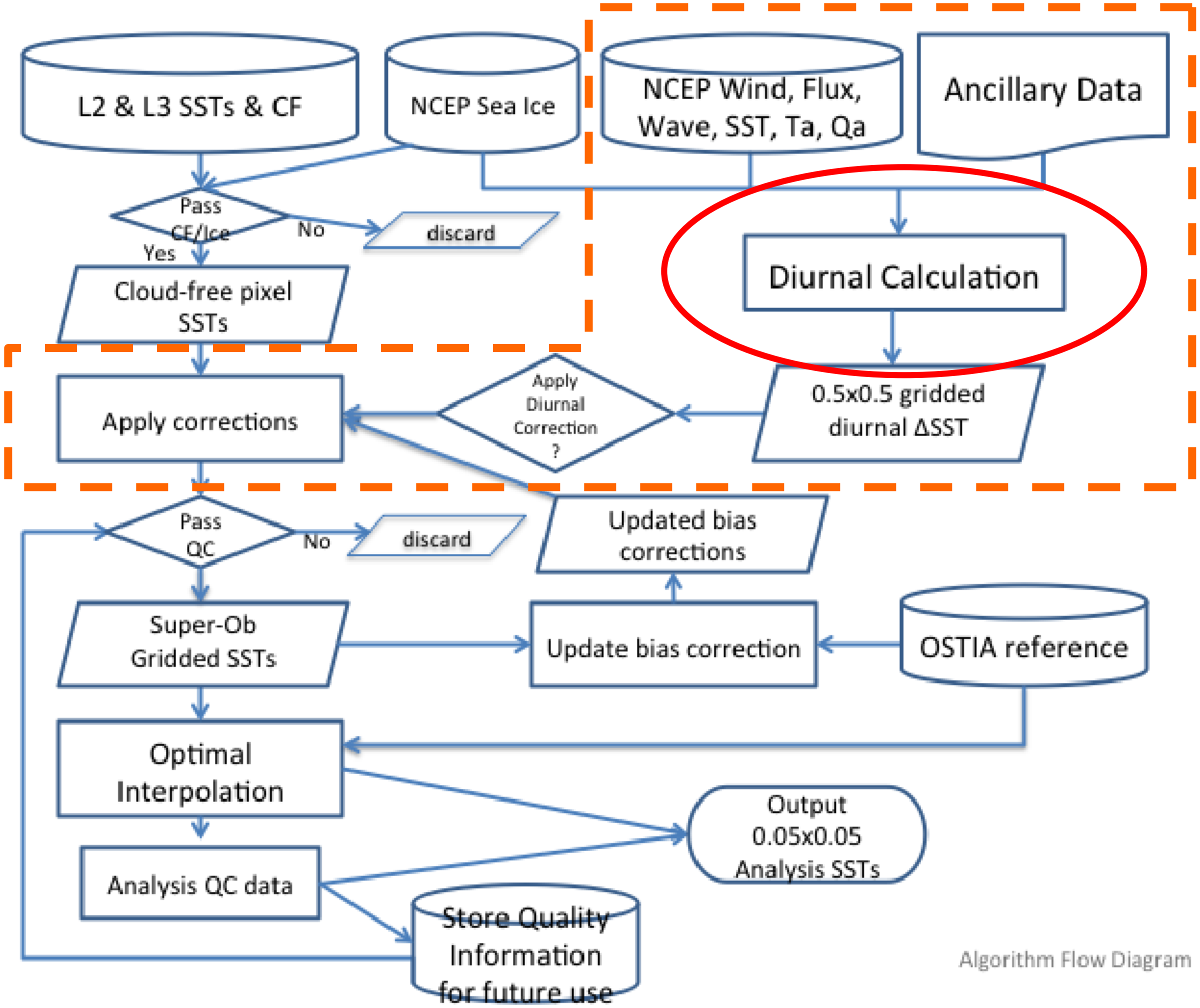
"Coral Triangle"



- **New analysis enables much greater precision, *e.g.* small fringing reefs**
- **However, <u>climatology is not derived from same dataset</u>**

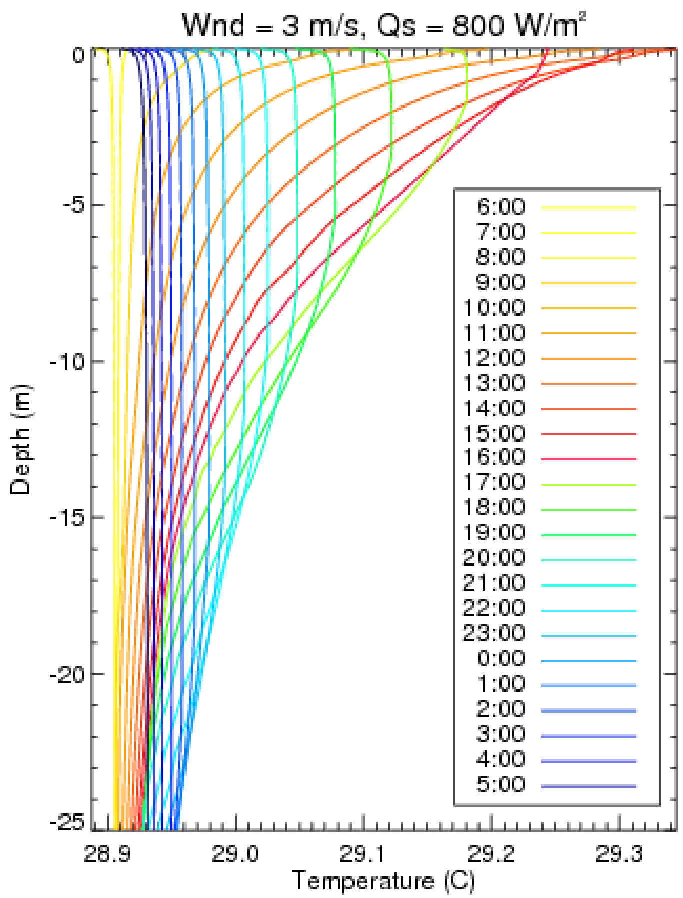

Primary concern: water temperature at coral depth
With thanks to Scott Heron

Including diurnal warming correction in SST analysis



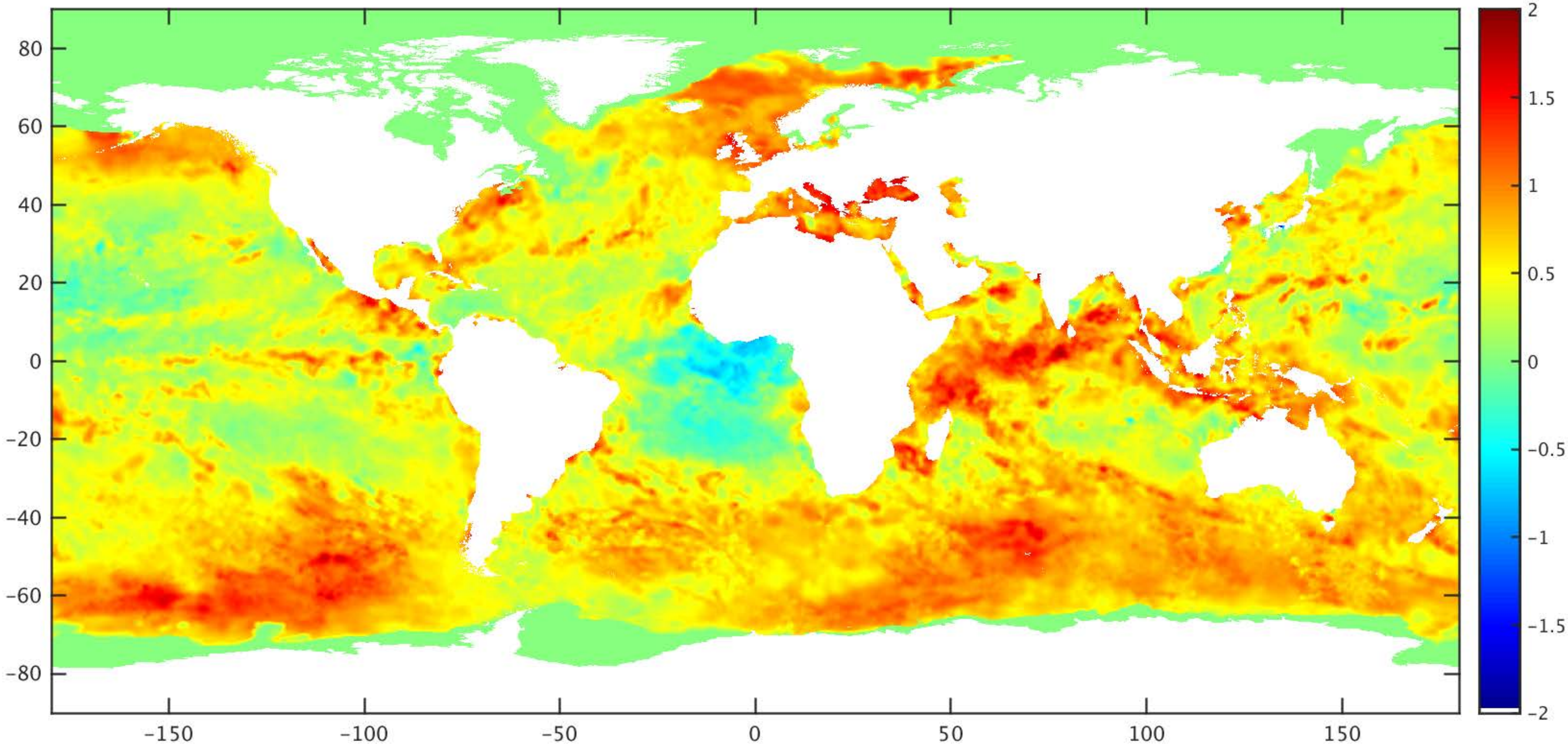
Diurnal Warming Correction – Sample Model Profile of Warming with Depth

- **Model simulates full vertical profile of warming**
  - Enables estimation of warming at arbitrary depth
  - Model presently run to a depth of 50 m
- **Time evolution of vertical temperature profile shown here for idealized forcing with a constant wind speed of 3 m/s and a peak insolation of 800 W/m²**



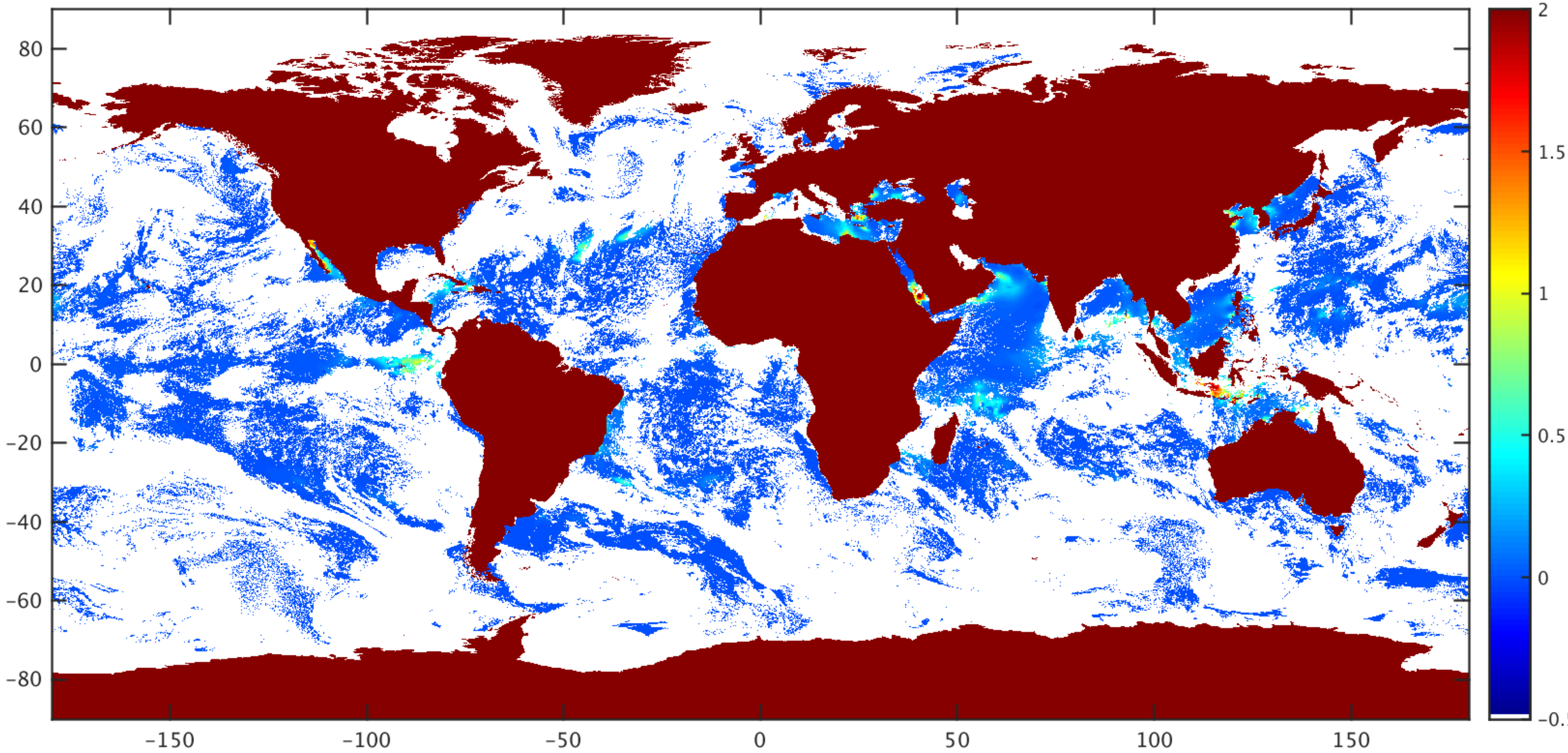
Magnitude of warming

Example bias correction field VIIRS daytime



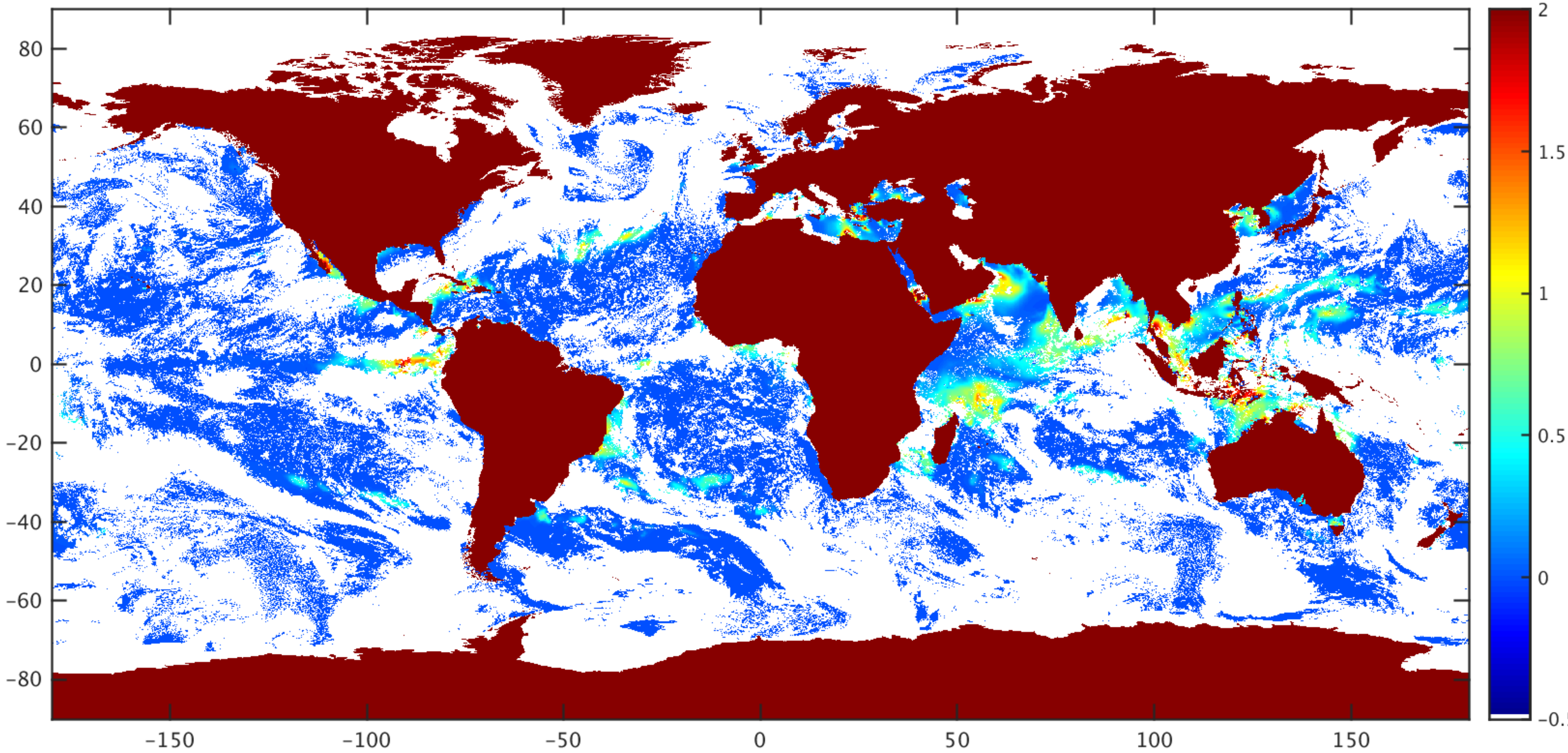
- **Bias correction usually <2 K**
- **Model response damped by including <u>gustiness parameterization</u>**
- **Why might the <u>observed</u> diurnal excursion be damped?**

Effect of diurnal adjustment on input data



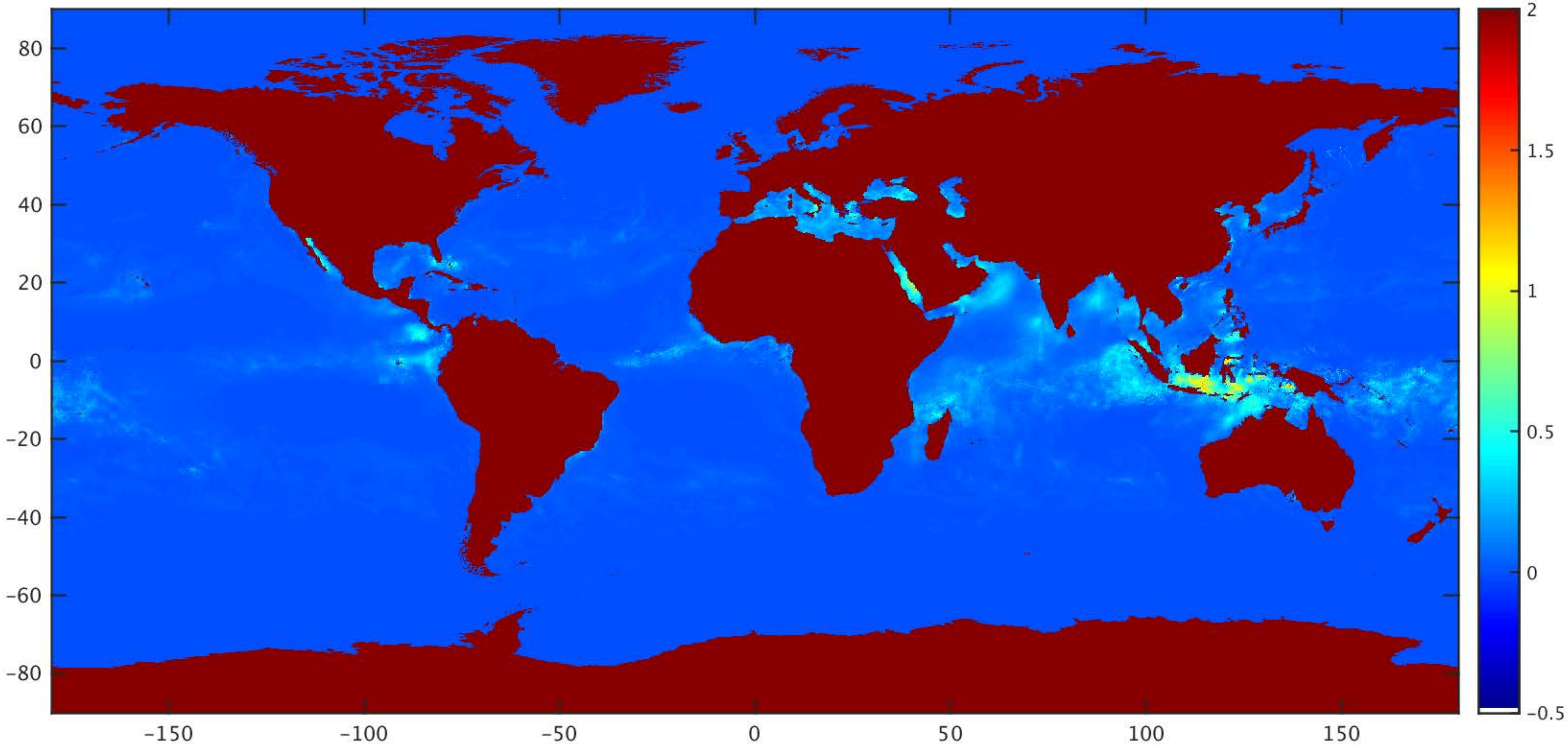
- **METOP adjustments are fairly modest**

Effect of diurnal adjustment on input data



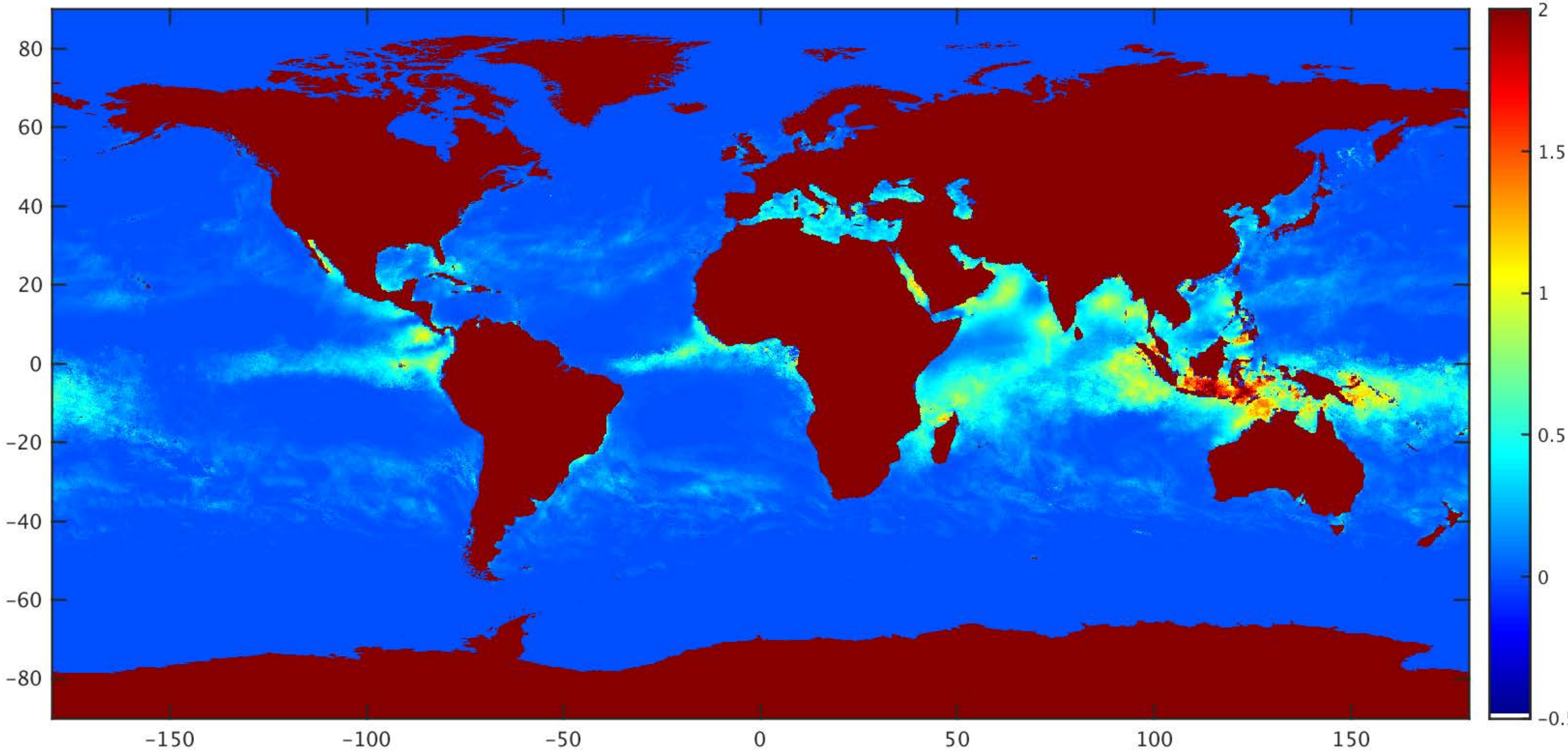
- **VIIRS adjustments are more significant**

Effect of diurnal adjustment on input data



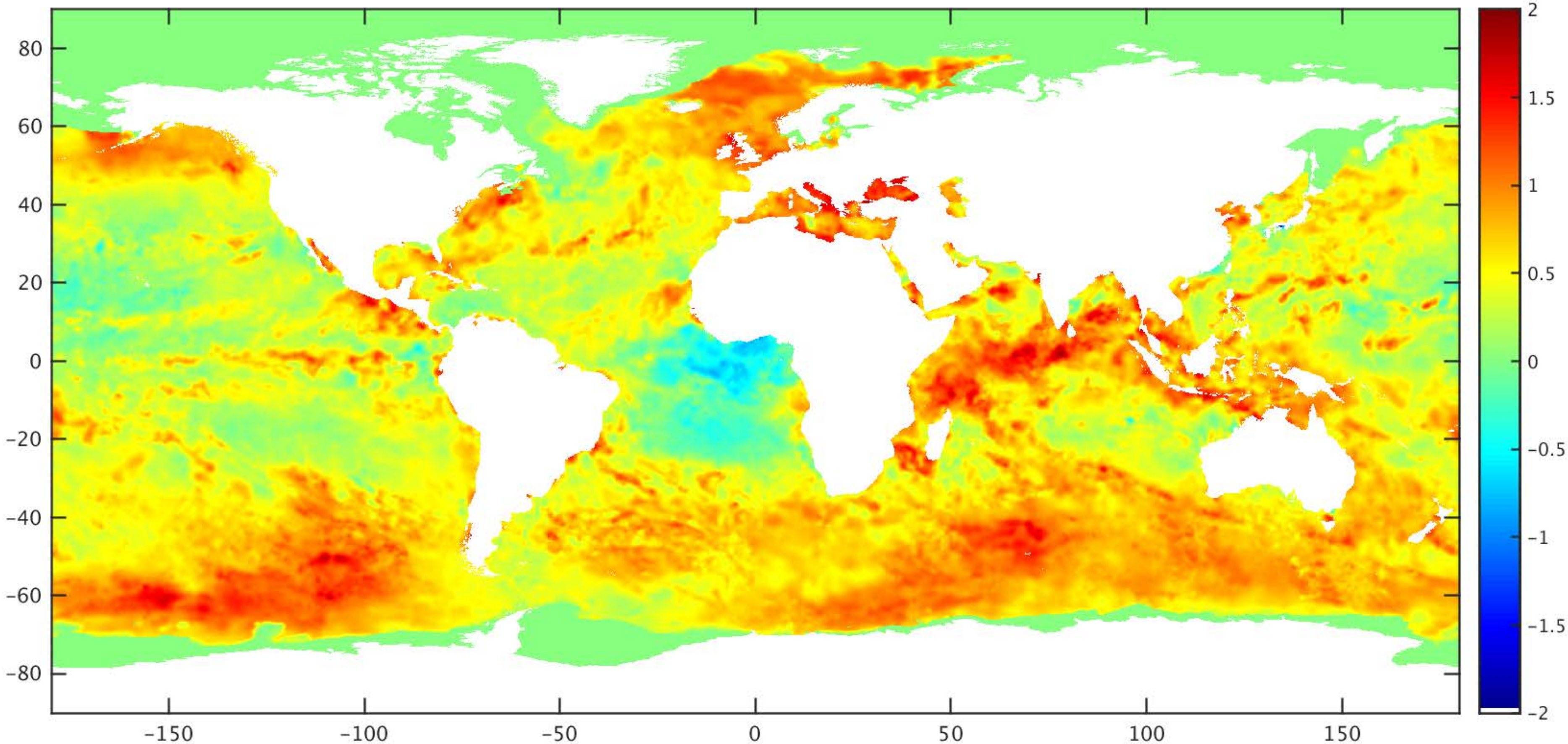
- **METOP monthly average for March 2016**

Effect of diurnal adjustment on input data



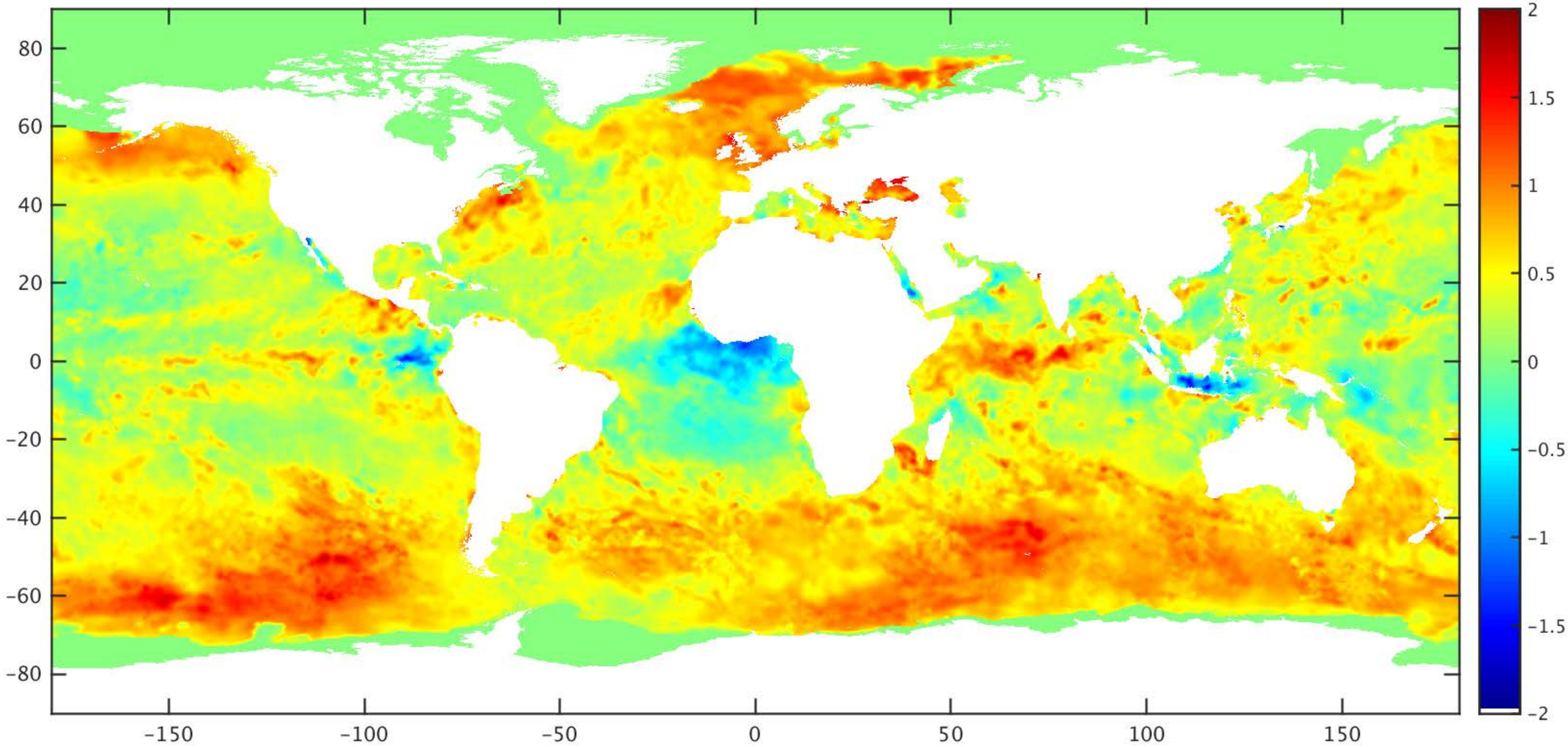
- **VIIRS monthly average for March 2016**

Effect of diurnal adjustment on bias correction



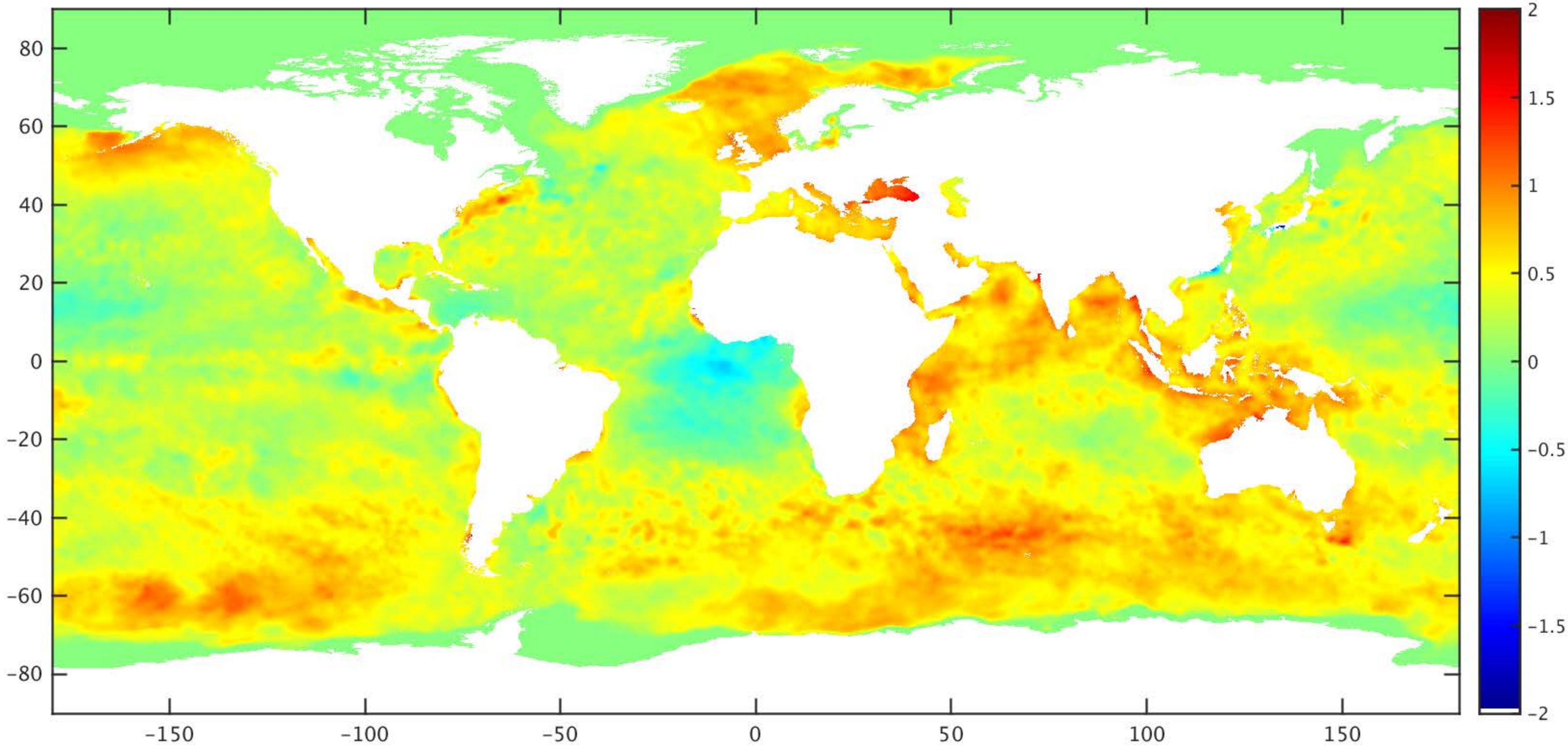
- **Unadjusted VIIRS (2016-03-21)**

Effect of diurnal adjustment on bias correction



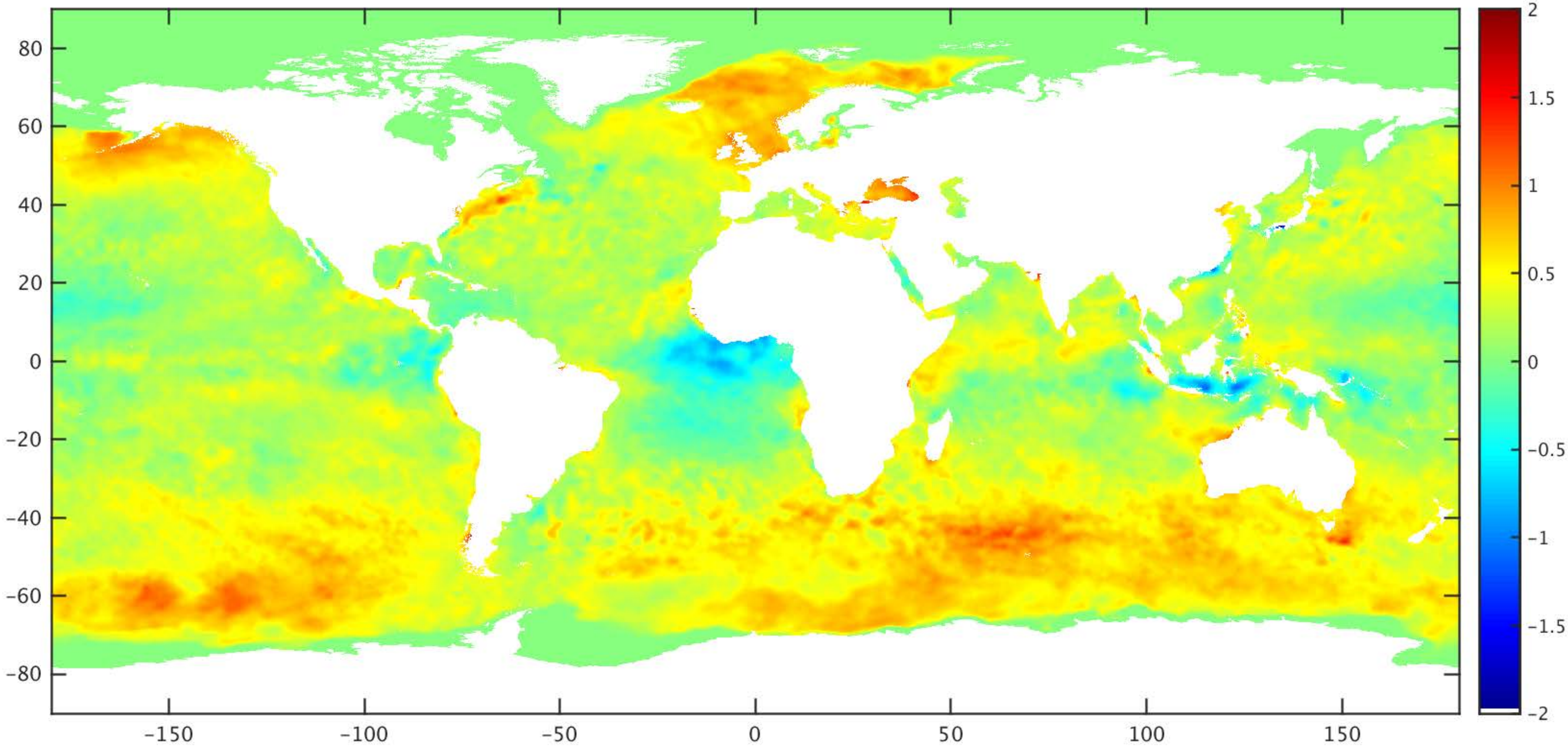
- **Diurnally adjusted VIIRS (2016-03-21)**

Effect of diurnal adjustment on bias correction



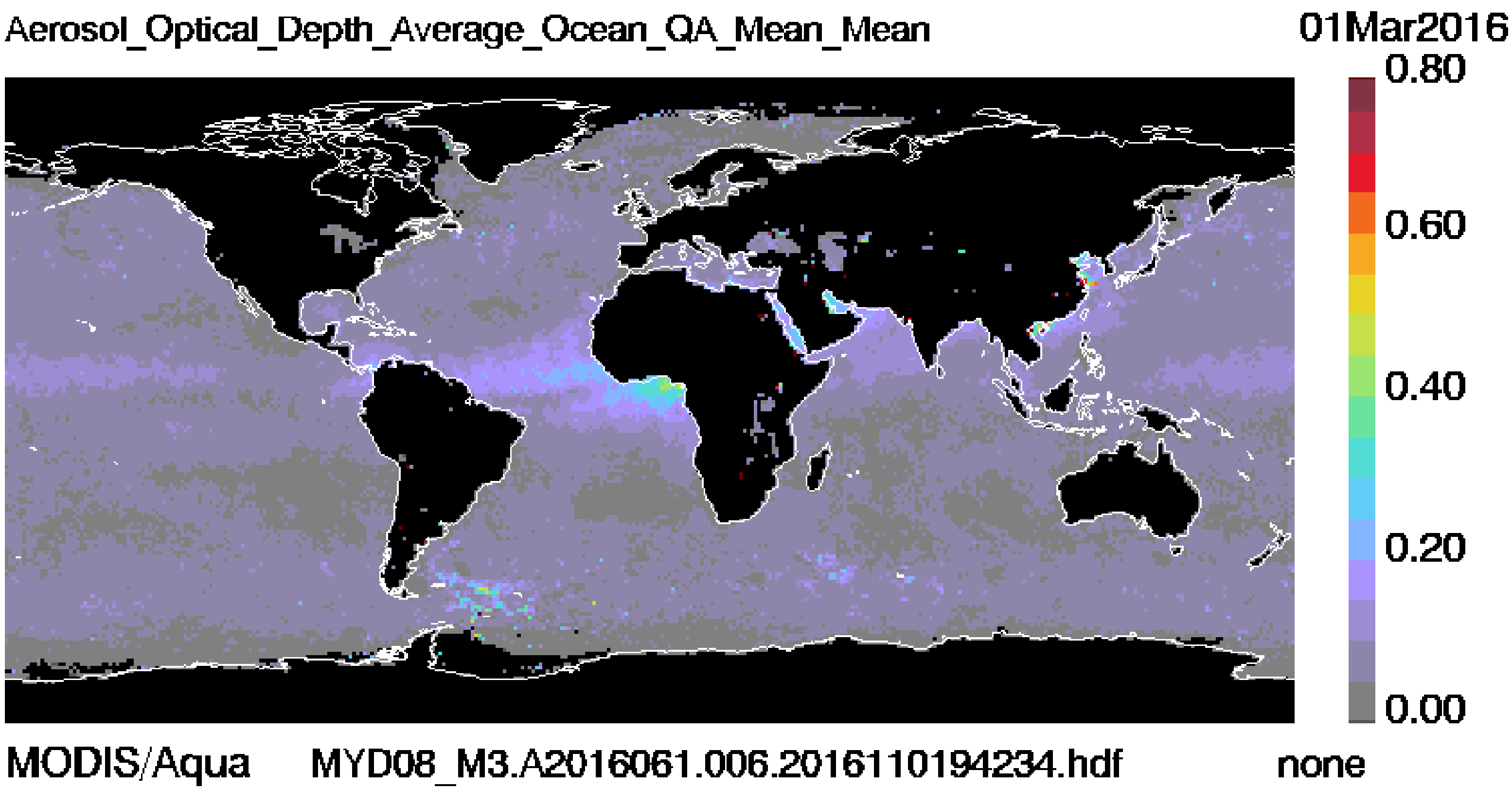
- **Unadjusted monthly average VIIRS**

Effect of diurnal adjustment on bias correction



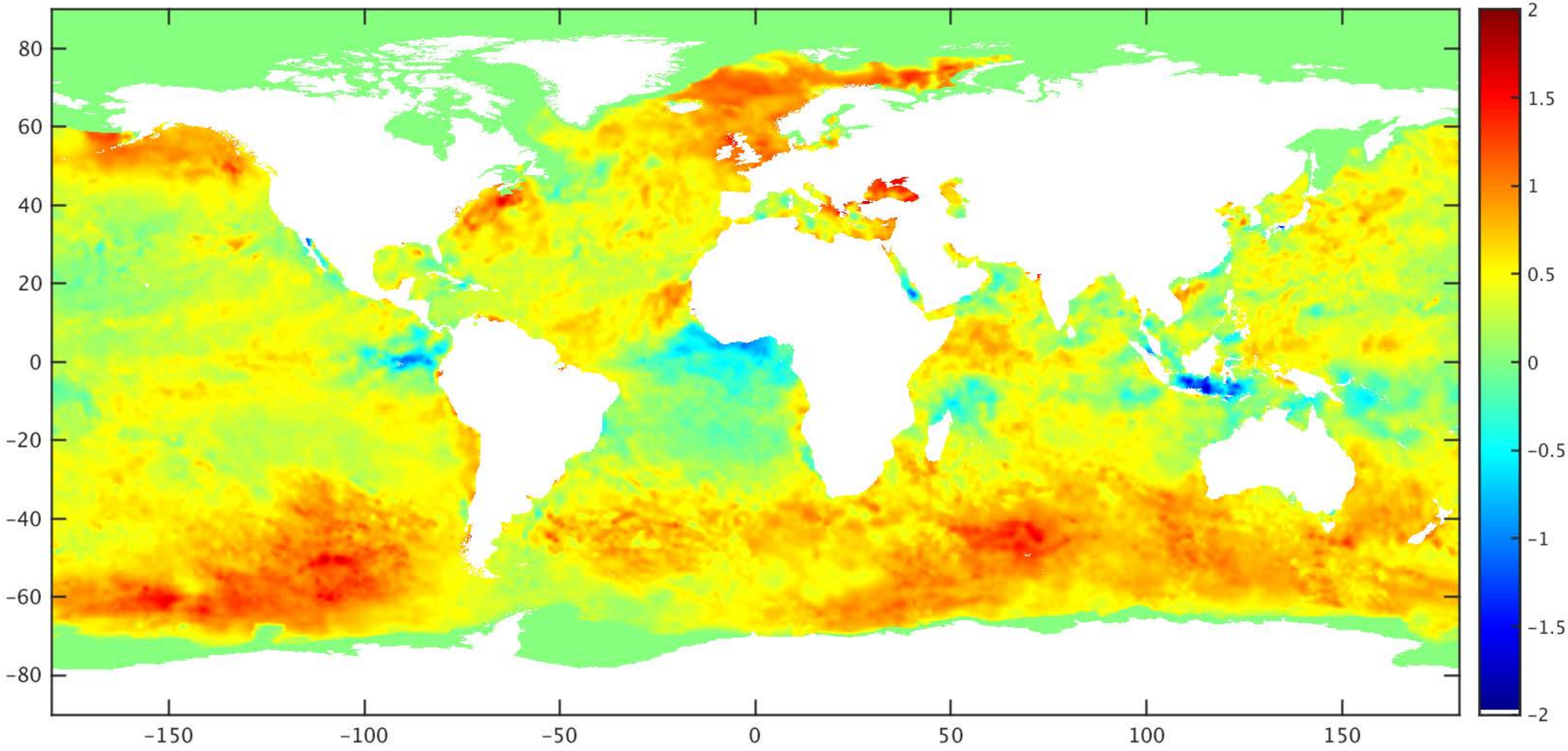
- **Diurnally adjusted monthly average VIIRS**

Retrieval biases – aerosol?



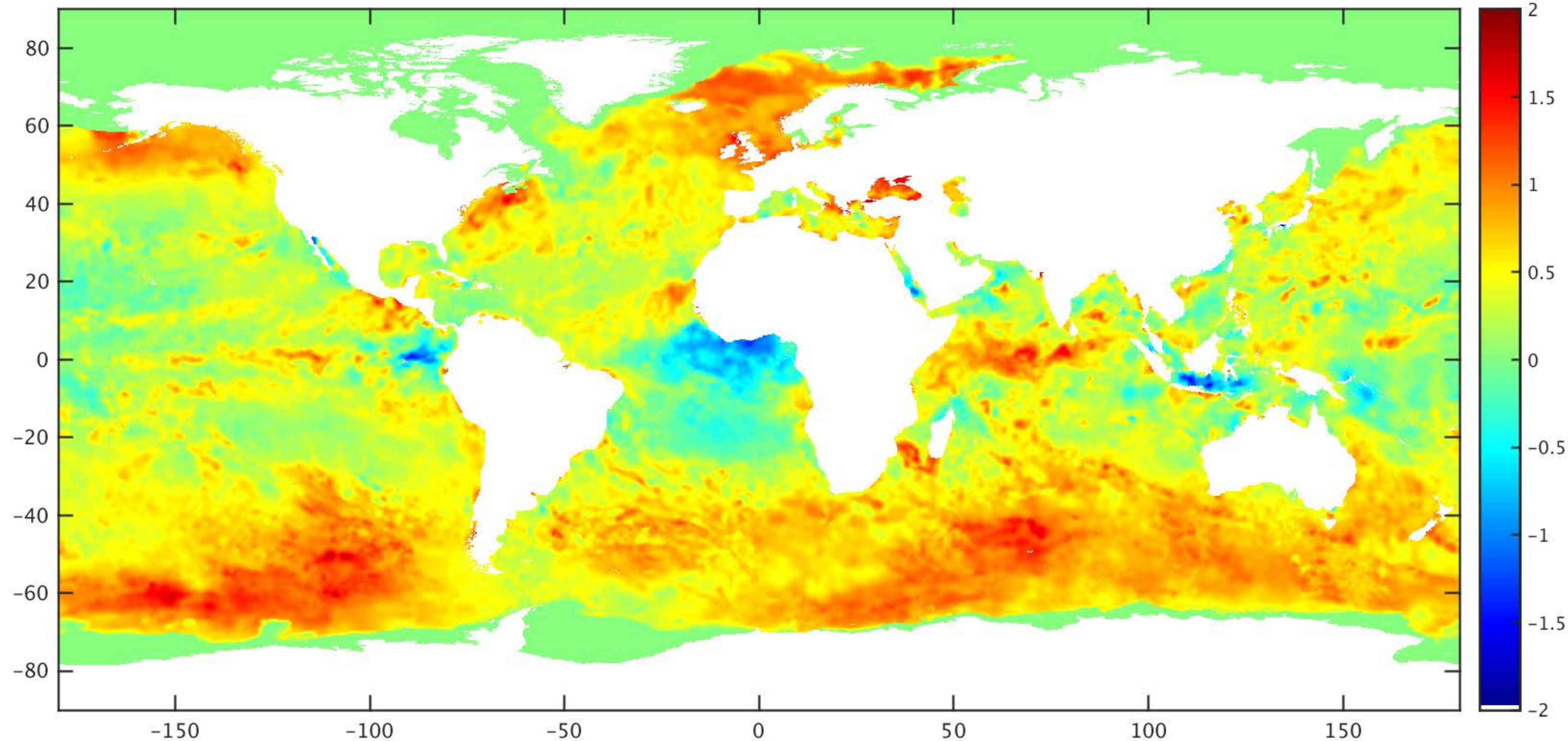
- **MODIS-A mean aerosol, Mar 2016**
- **Other atmospheric factors, *e.g.* water vapour loading**

Effect of diurnal adjustment on bias correction



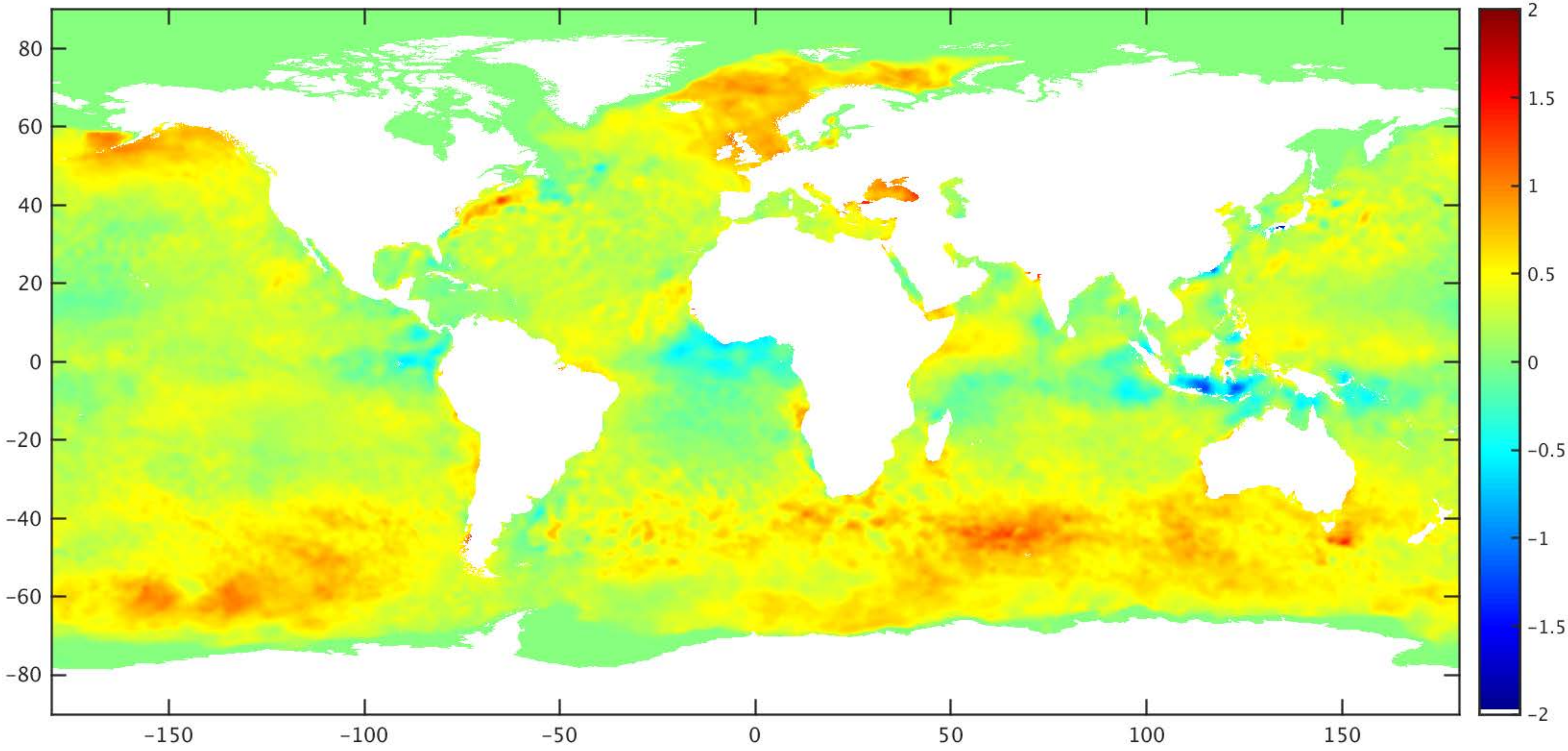
- **Diurnally adjusted VIIRS + SSES Bias (2016-03-21)**

Effect of diurnal adjustment on bias correction



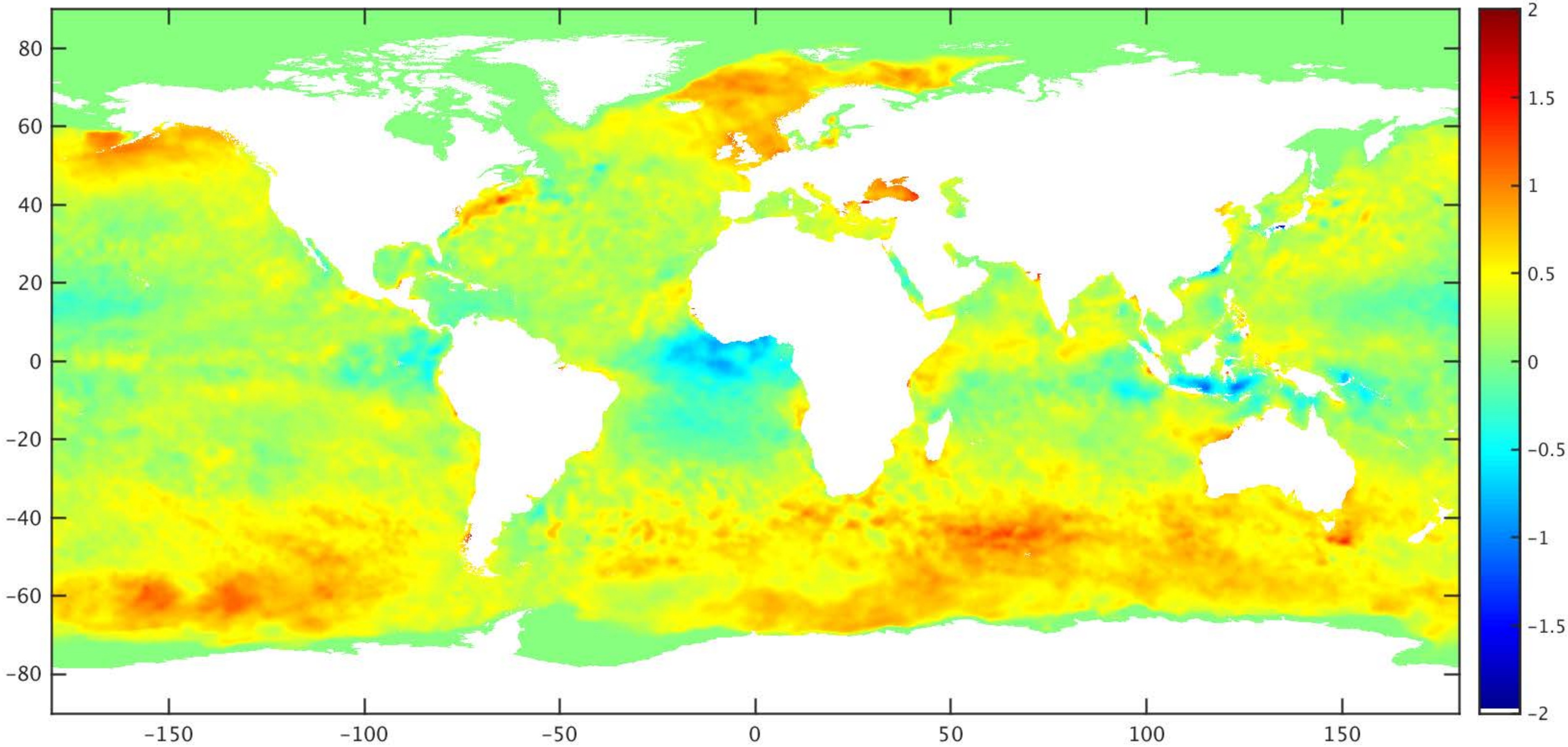
- **Diurnally adjusted VIIRS (2016-03-21)**

Effect of diurnal adjustment on bias correction



- **Diurnally adjusted monthly average VIIRS + SSES Bias**

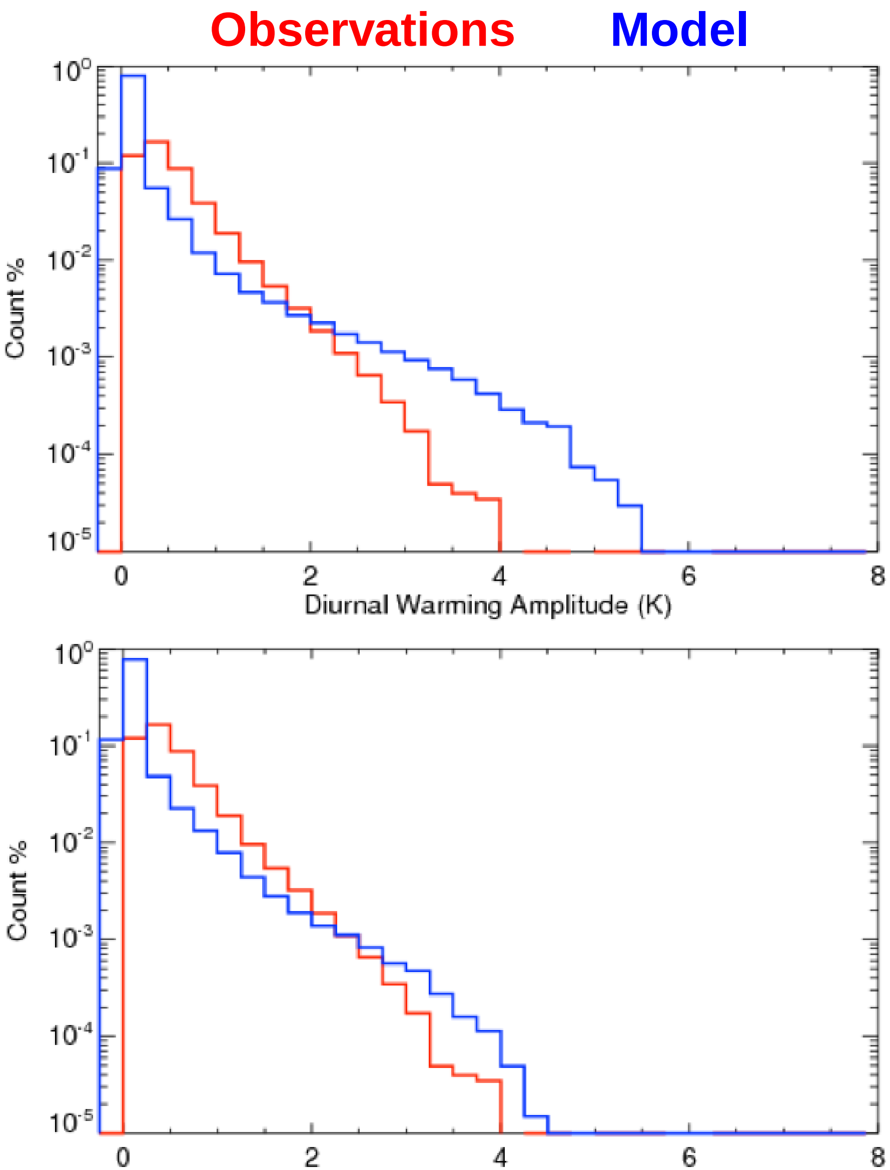
Effect of diurnal adjustment on bias correction



- **Diurnally adjusted monthly average VIIRS**

Improve Diurnal Adjustment

- **Difficult to model the observed distribution of warming**
  - Especially in tropics
- **New parameterization + wind gustiness**
  - Substantially improved distribution of modeled warming



Validation vs ARGO

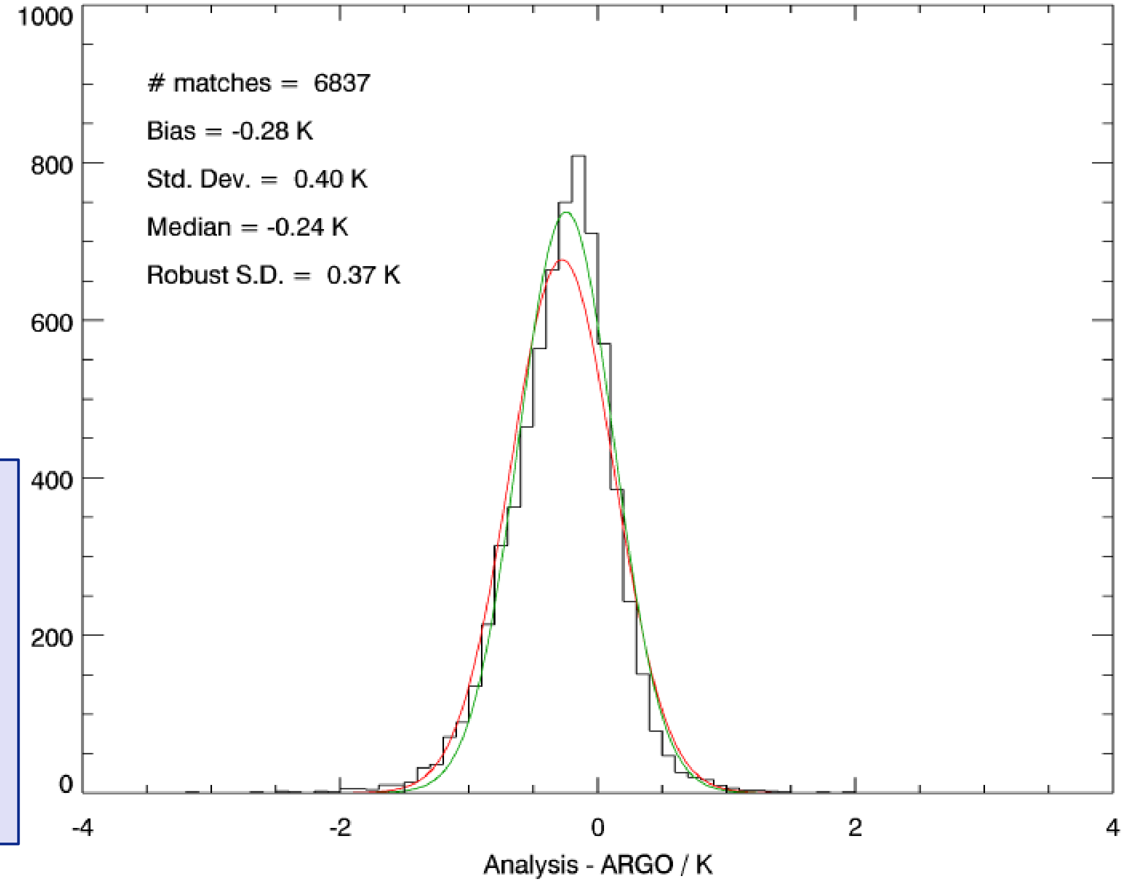
- March 2016
- iQuam QC
- 3 – 7 m depth

Global: -0.28±0.40 (0.37)

30+°N: -0.40±0.46 (0.36)

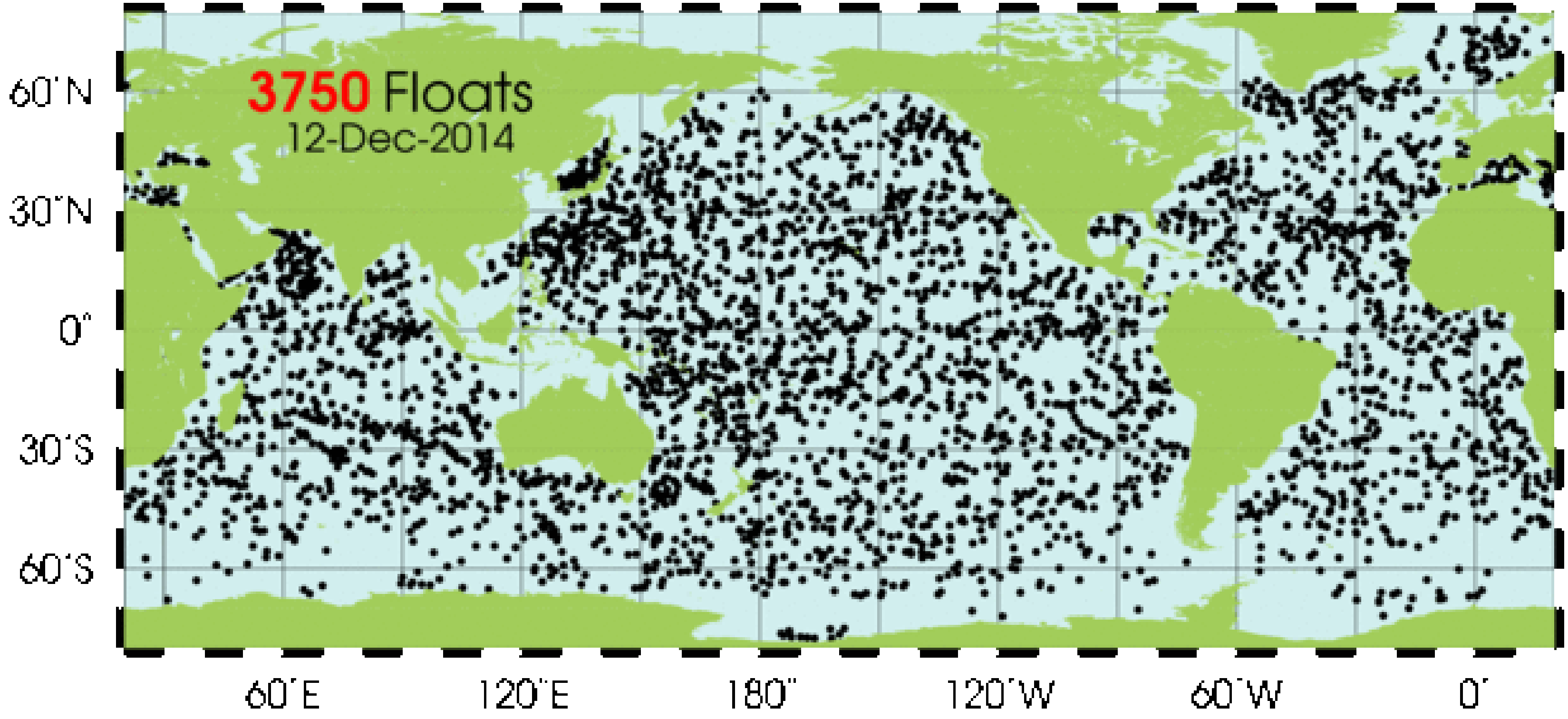
<|30°|: -0.18±0.36 (0.30)

30+°S: -0.40±0.41 (0.37)

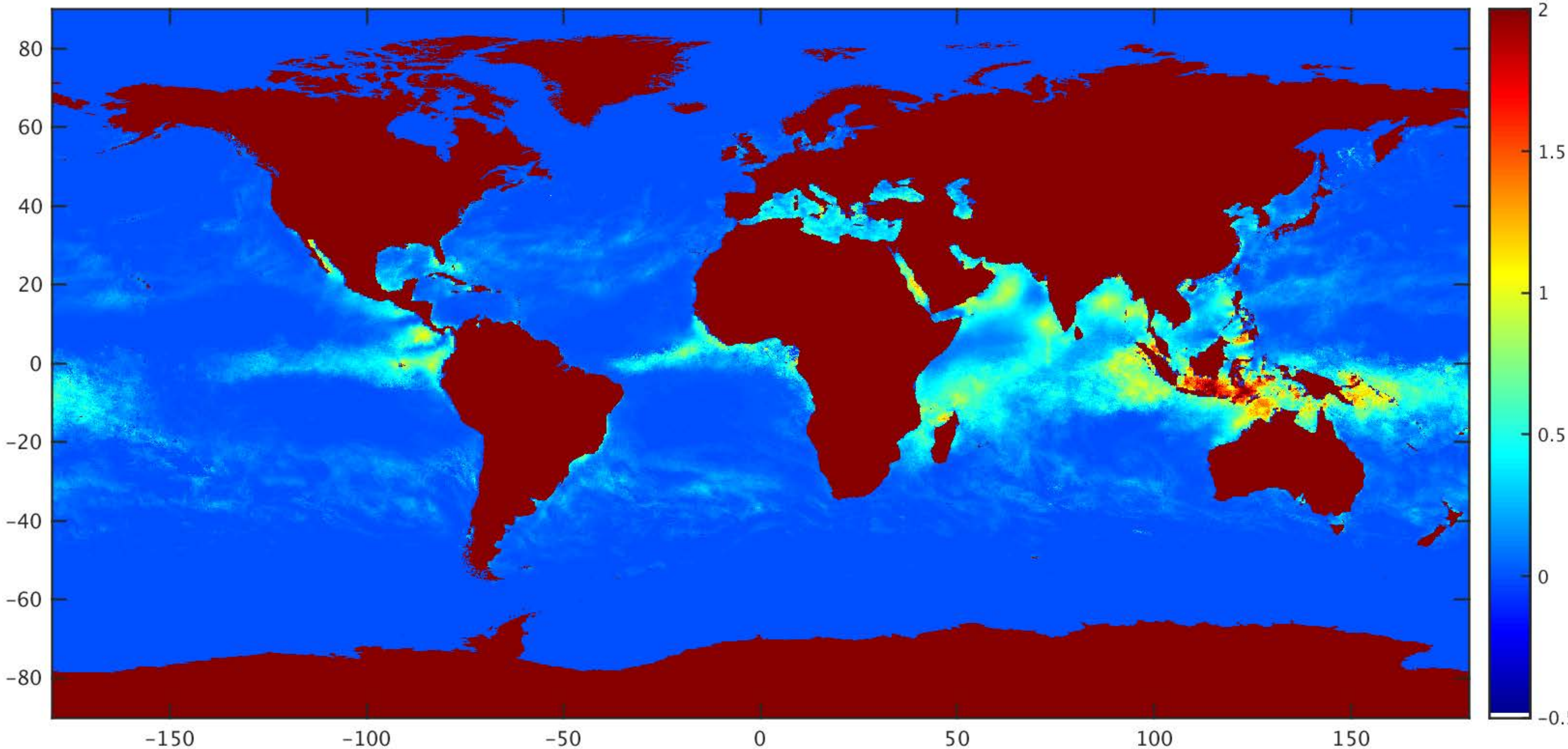


N.B. **Virtually identical statistics to uncorrected analysis!**

Locations of currently active ARGO floats



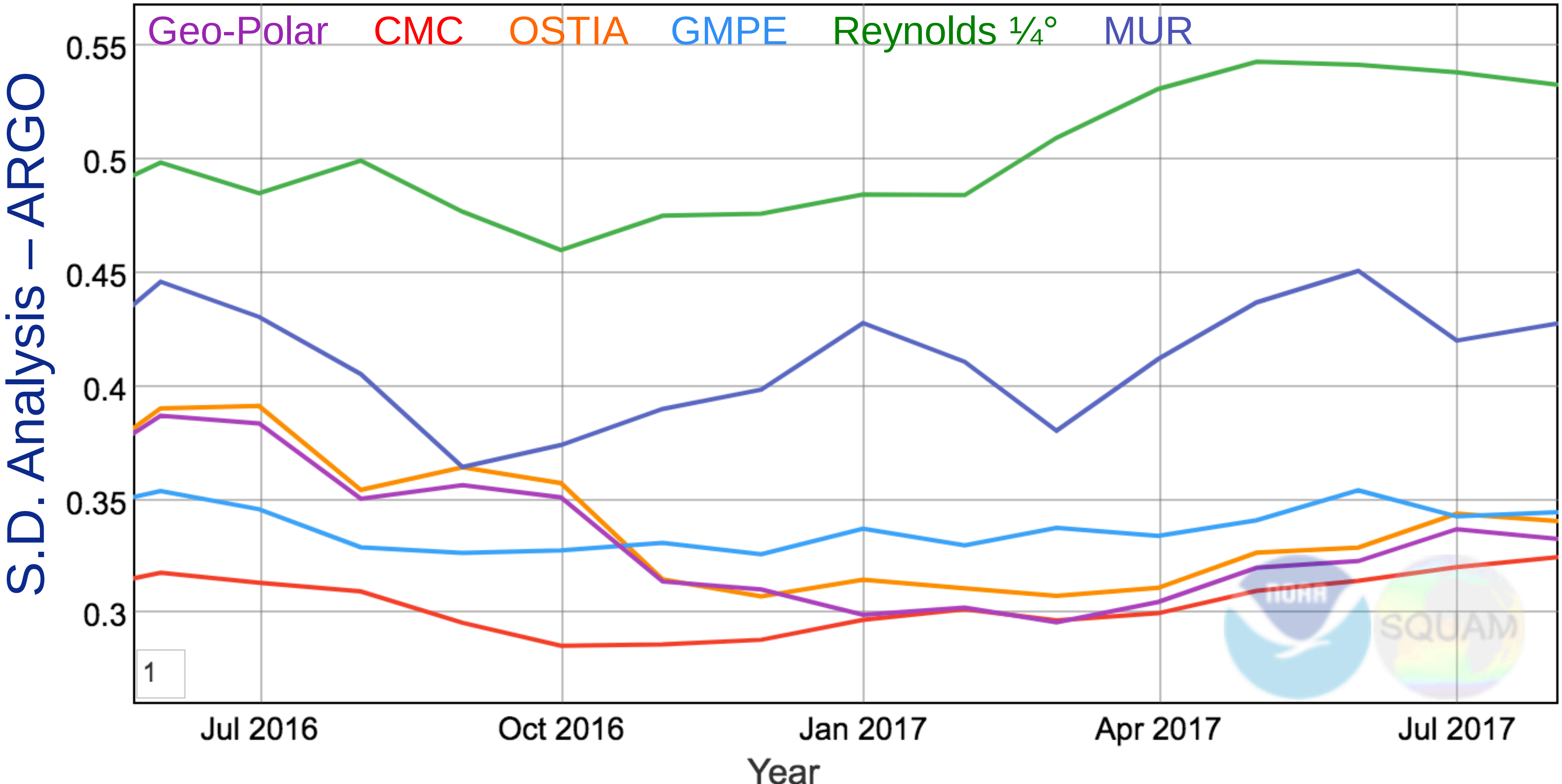
Effect of diurnal adjustment on input data



- **VIIRS monthly average for March 2016**

VIIRS data

- ***N.B.*** **VIIRS now used as bias correction reference for OSTIA**



Significant impact on accuracy *cf.* <u>independent</u> ARGO data

Summary

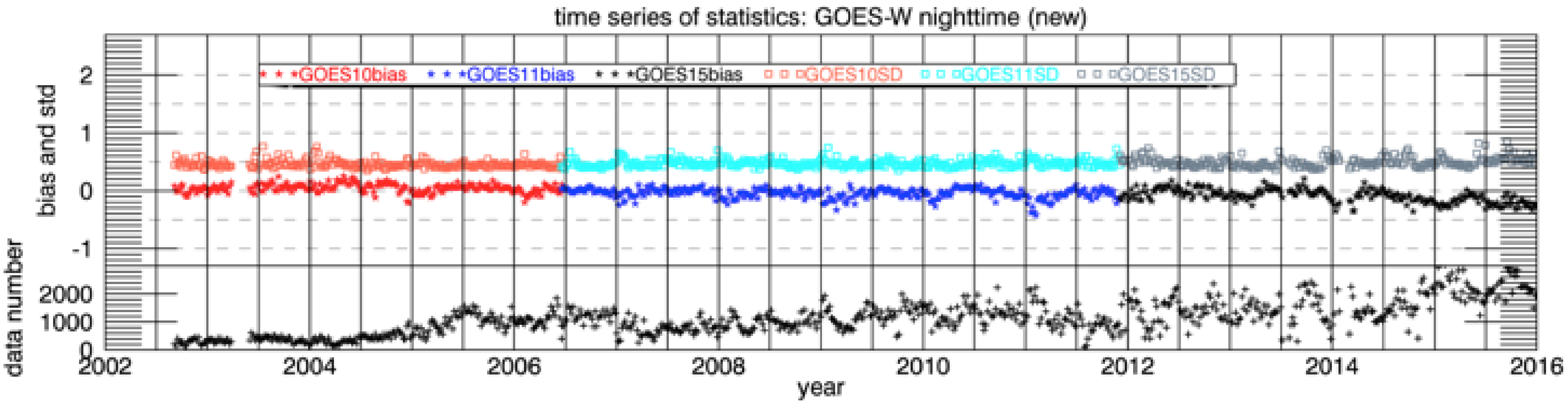
- **NOAA produces all the L2 data that go into the analysis**
  - Polar data – ACSPO regression SST
  - Geostationary – Bayesian cloud + MTLS Physical retrieval
  - *N.B.* Convergence on ACSPO means Himawari-8 is ACSPO
  - AMSR-2 SST is processed with NOAA GAASP algorithm
    - Initial SSES scheme **based on incidence angle**
- **L4 SST analysis continues to be improved**
  - Bias correction against OSTIA
    - OSTIA has improved *cf.* independent ARGO
    - Therefore Geo-Polar Blended 5-km Analysis has also improved
  - Analysis bias correction scheme due for overhaul
    - ACSPO VIIRS [+Sentinel-3 SLSTR]

Summary cont'd

- **Diurnal correction with turbulence model & Stokes' Drift**
  - Beneficial for applications that depend on SST at depth (*e.g.* CRW)
  - Daytime SST retrieval may not see full scope of DW, especially in tropics
  - Gustiness parameter damps warming (too much?)
    - Partly a work-around for above issue
  - New parameterization **substantially improves warming distributions**
    - Should be incorporated in next update to model
  - Other regional algorithm biases
    - On balance, using SSES bias + diurnal adjustment is better

Summary cont'd

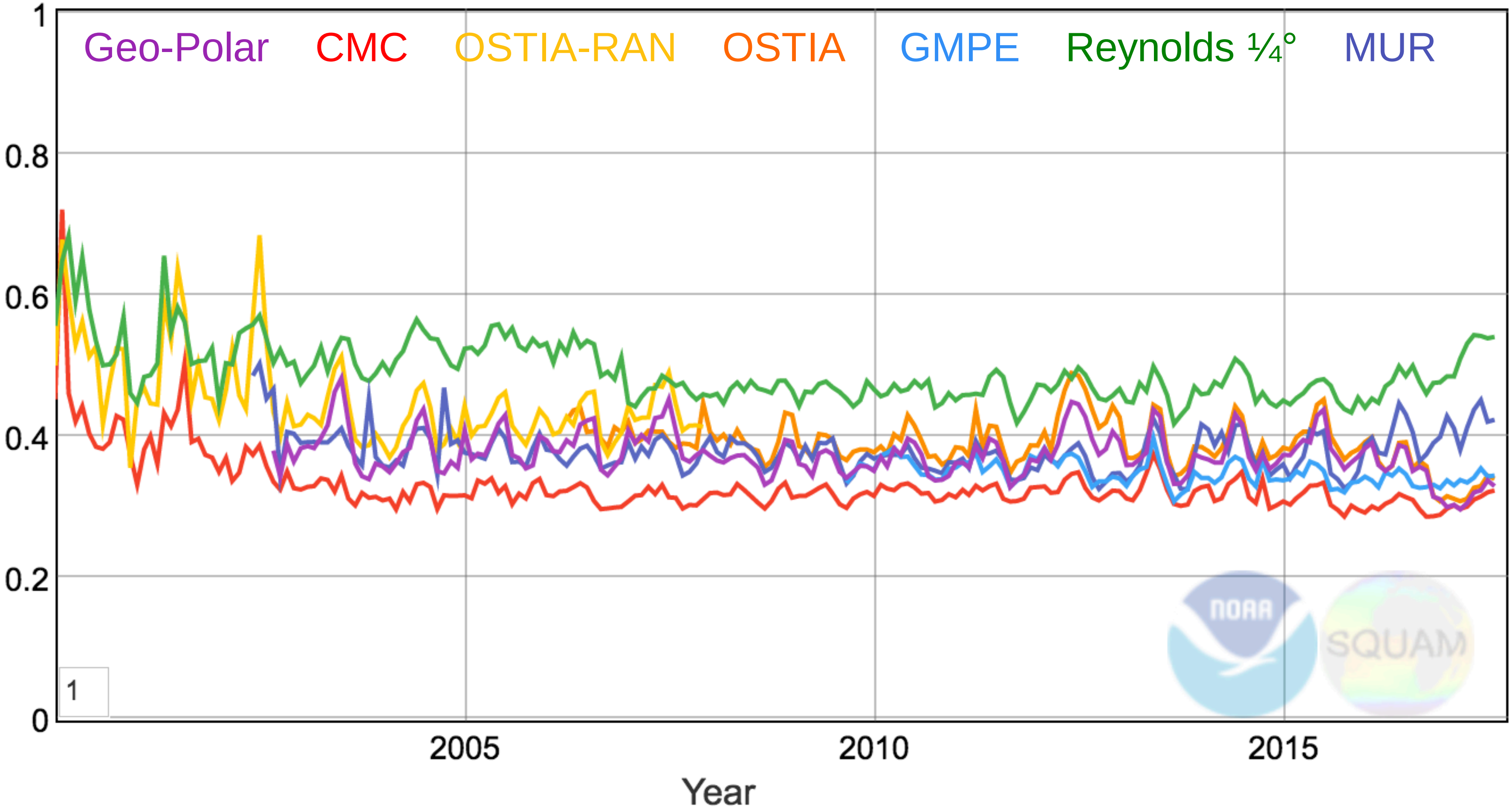
- **Reprocessing 2002 – 2016**
  - Improved baseline for CRW
    - ➢ ACSPO GAC AVHRR + Geo-SST (Physical+Bayesian) [*N.B.* no VIIRS]
    - ➢ OSTIA RAN + OSTIA Operational



Reprocessed GOES-W

Summary cont'd

- **Reprocess again using ACSPO nighttime 3-chan + SSES as reference?**



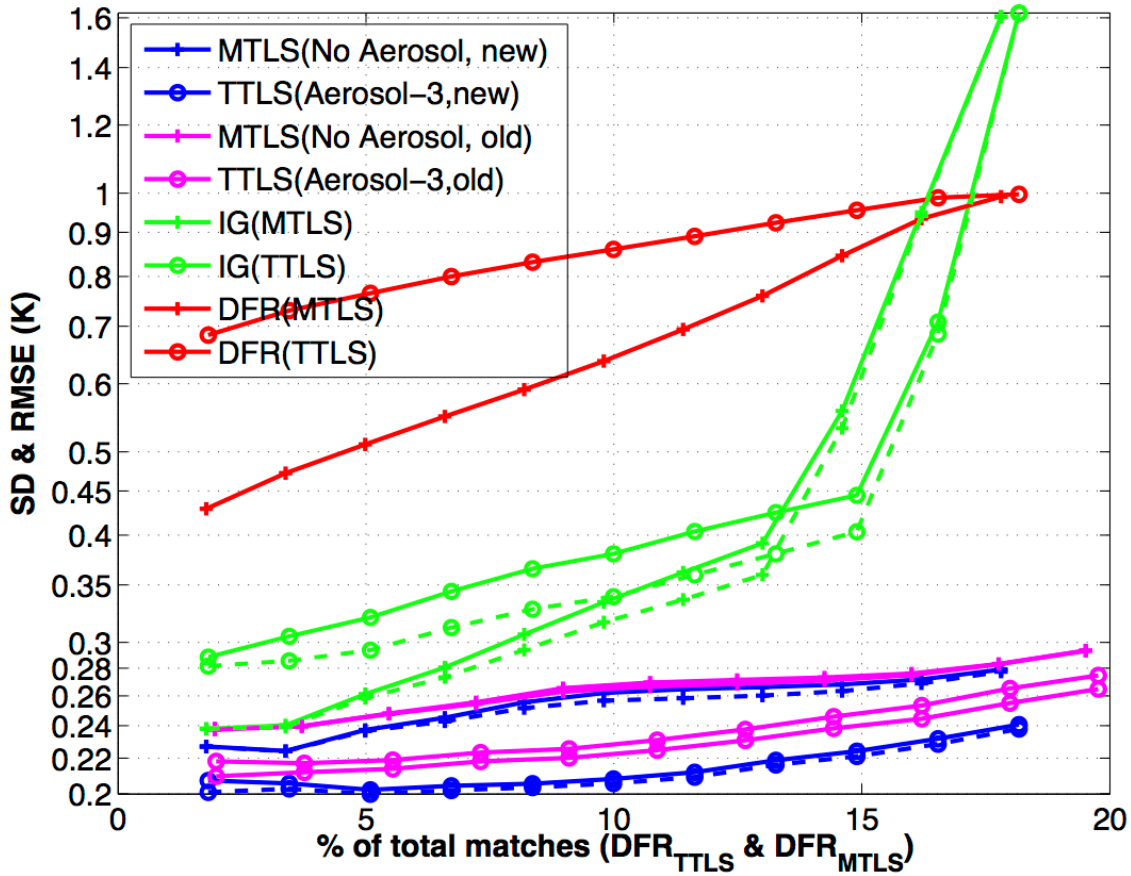
Backup slides

MODIS: Addition of aerosol

- **Put aerosol information in the CRTM**
  - NGAC profiles, multiple species (dust, salt, sulfate, soot)
  - Improve match of RTM to observation
  - Does this improve retrieval?
- **Put aerosol in the retrieval vector**
  - Allow Total Column Aerosol to vary
  - $\boldsymbol{x}$ = [SST, WV, TCA]^T
  - Jacobian now includes ∂T/∂TCA for each channel
  - Does this improve retrieval?
- **MTLS developed for 2-parameter retrieval**
  - Try different regularization operator since problem is now more ill-conditioned: **Truncated Total Least Squares (TTLS)**

$$|\Delta \boldsymbol{y}| \leq 1: \; \lambda = (\sigma_{end-1})^2 \qquad |\Delta \boldsymbol{y}| > 1: \; \lambda = (\sigma_{end-1}/\log(|\Delta \boldsymbol{y}|))^2$$

Inclusion of aerosol



- **Accuracy with TTLS & joint [SST, WV, TCA] ~0.2 K**
- **Algorithm sensitivity is also improved *cf.* MTLS**

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Using ACSPO VIIRS data in CMC SST analyses

Dorina Surcel Colan

National Prediction Development Division, Meteorological Service of Canada, Environment and Climate Change Canada, Canada

4th STAR JPSS Annual Meeting

14-18 August 2017, College Park, MD, USA

Introduction

- In 2016 CMC run 2 SST analyses using Suomi-NPP VIIRS retrievals:
  - 0.2° analysis assimilating 3 AVHRR, VIIRS and AMSR2 (v2)
  - 0.1° analysis assimilating 4 AVHRR, VIIRS and AMSR2 (v3)
- Both analyses assimilate in situ observations (ships, drifting buoys and moored buoys) and ice data
- SST analysis refers to a depth temperature (foundation SST) without diurnal variability
- CMC SST analyses were available on PO.DAAC

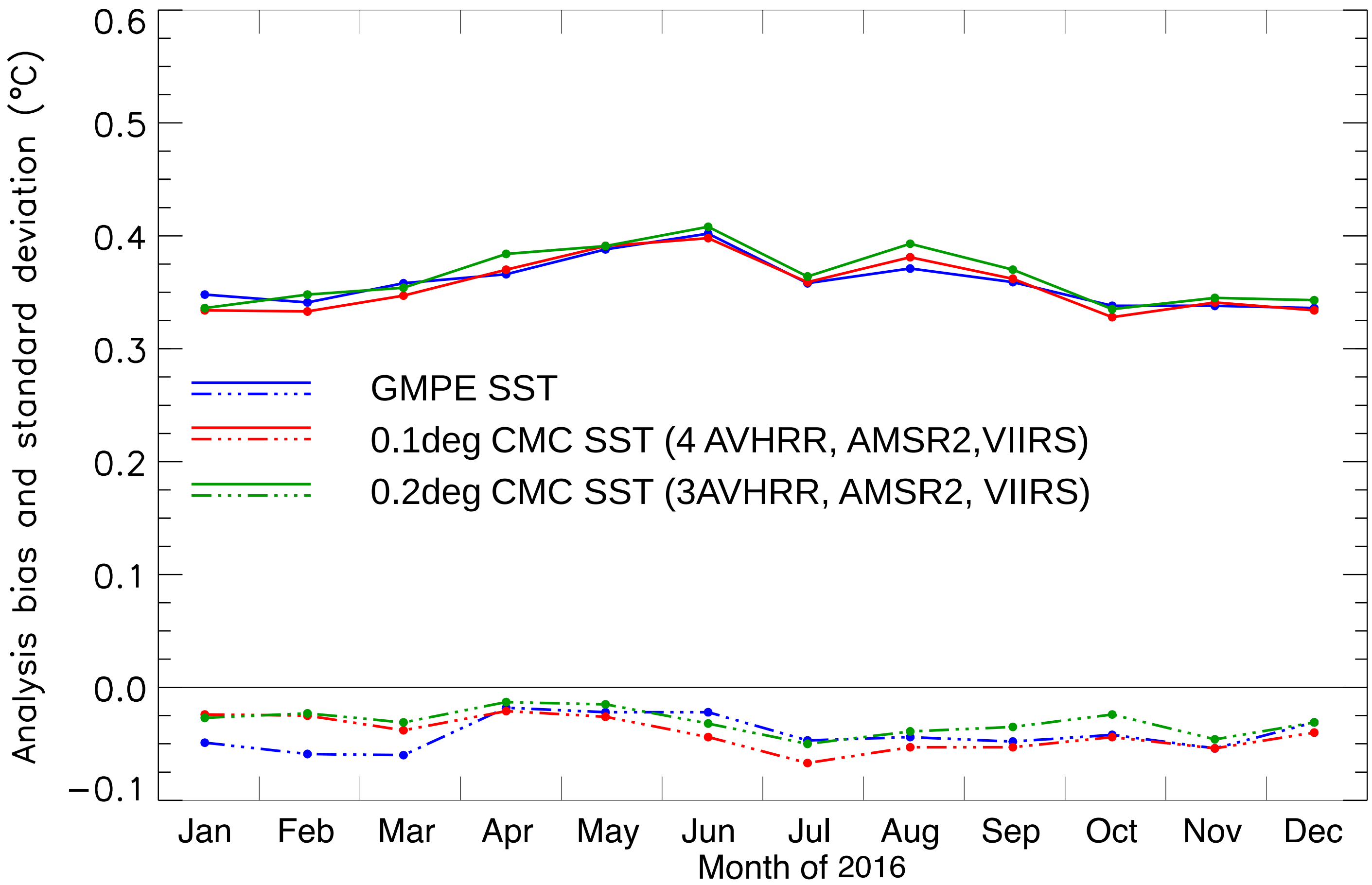
VIIRS SST Product

- VIIRS dataset used in SST products is produced by NOAA/NESDIS using Advanced Clear-Sky Processor for Oceans - ACSPO (Petrenko et al. 2014)
- ACSPO VIIRS retrievals: L2P format – 21G/day – until October 2016 and L3U data (~2.4 G/day) afterwards
- No SSES bias and standard deviation from ACSPO VIIRS are used, the analysis has his own satellite bias correction algorithm.

Evaluation of CMC SST for 2016

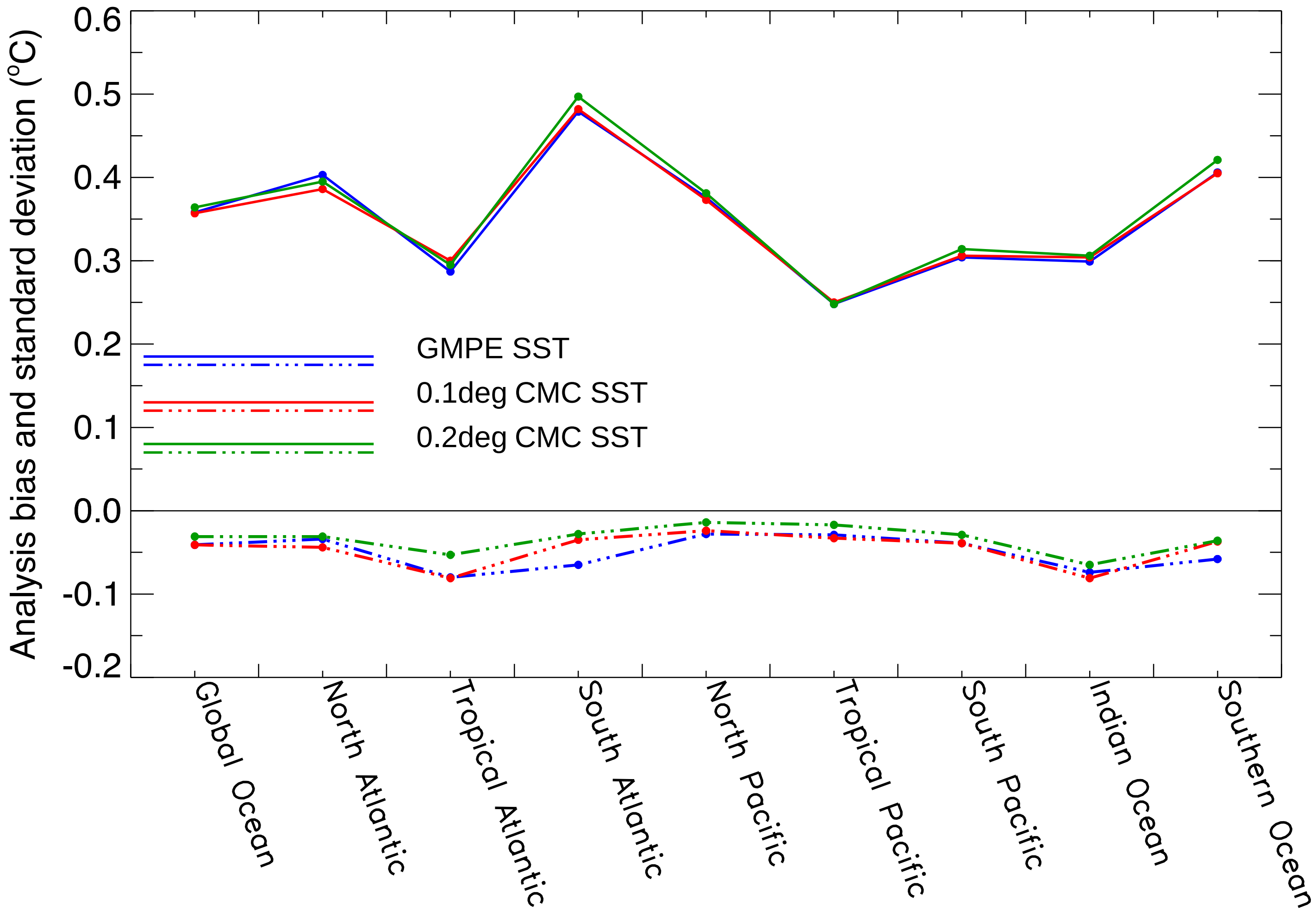
- All verifications are done against independent measures from Argo floats
- Observations are used only if they are between 3 m and 5 m and within four standard deviations of the climatology

Performance of CMC SST



The 0.1deg analysis performed better than 0.2 deg. analysis in 2016.
GMPE product improved in April 2016 (VIIRS used in OSTIA?)

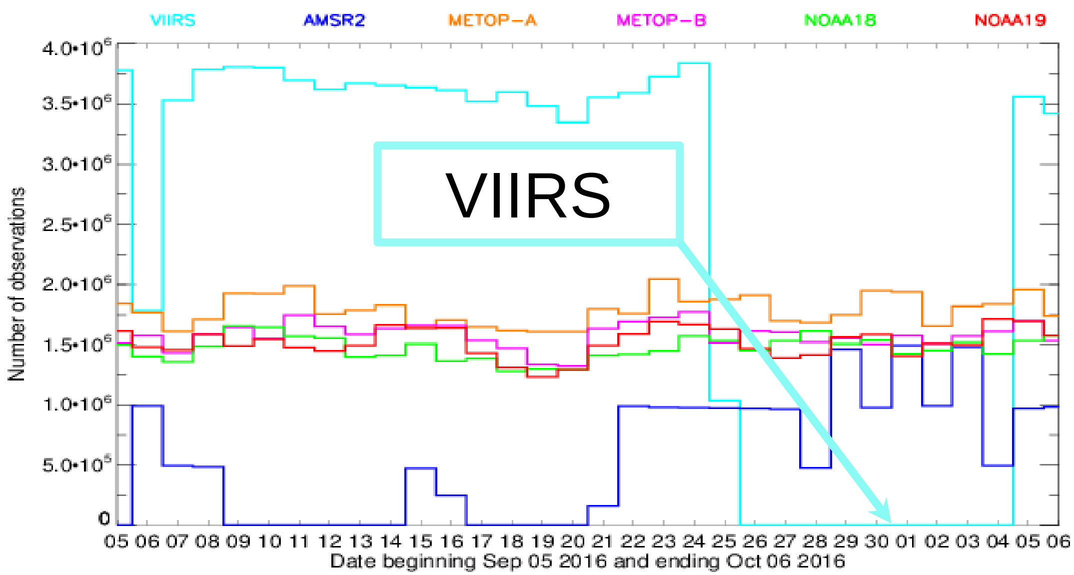
Performance of CMC SST



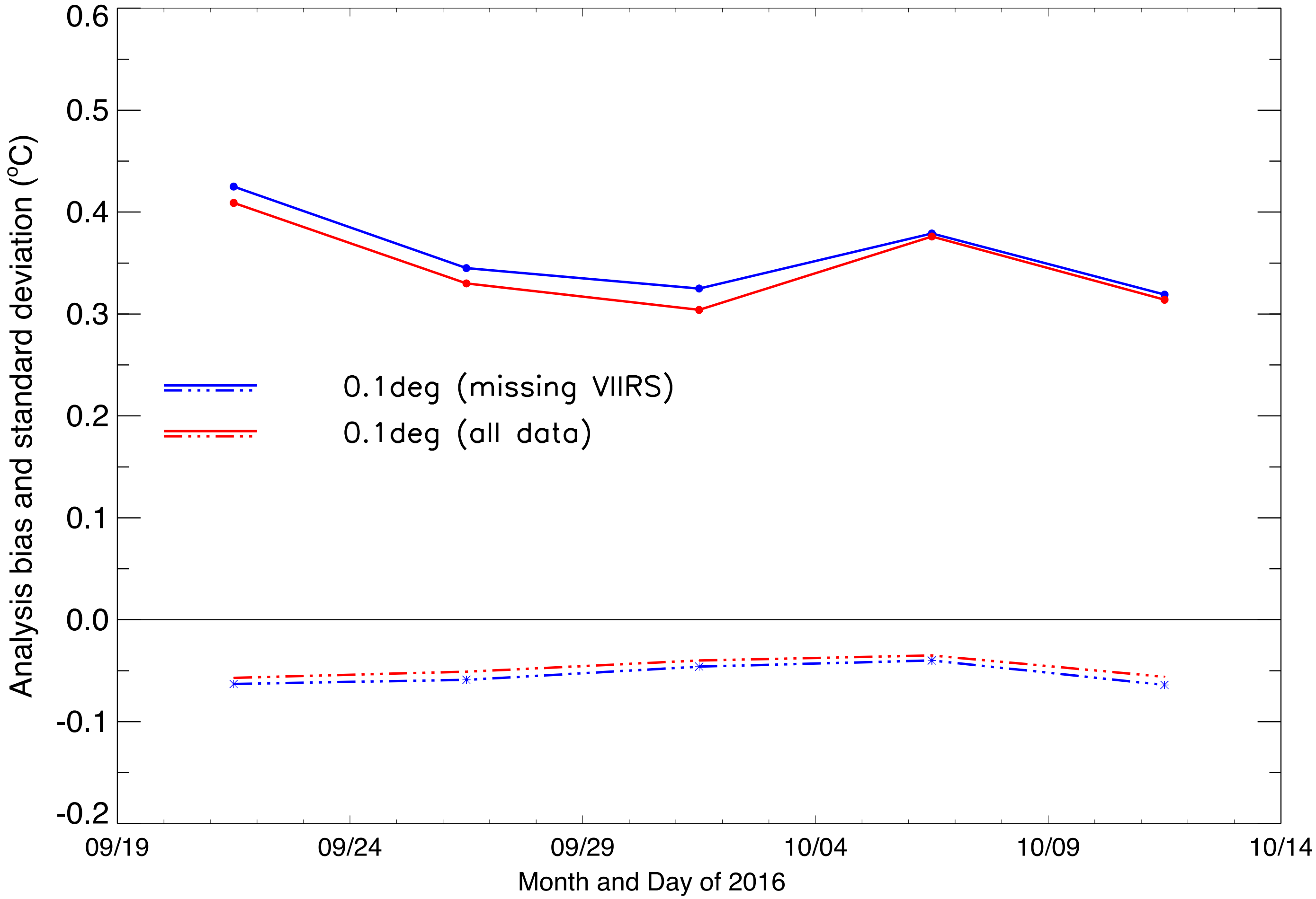
In 2016 GMPE product used 0.2deg CMC SST but not 0.1deg CMC SST

ACSPO VIIRS from PO.DAAC

- NOAA/NESDIS provided VIIRS 2.40 L2P and L3U format
- CMC SST analyses had used ACSPO VIIRS in L2P format since 2014.
- From 26 Sept. to 4 Oct. 2016 data feed for ACSPO VIIRS L2P from PO.DAAC had been interrupted

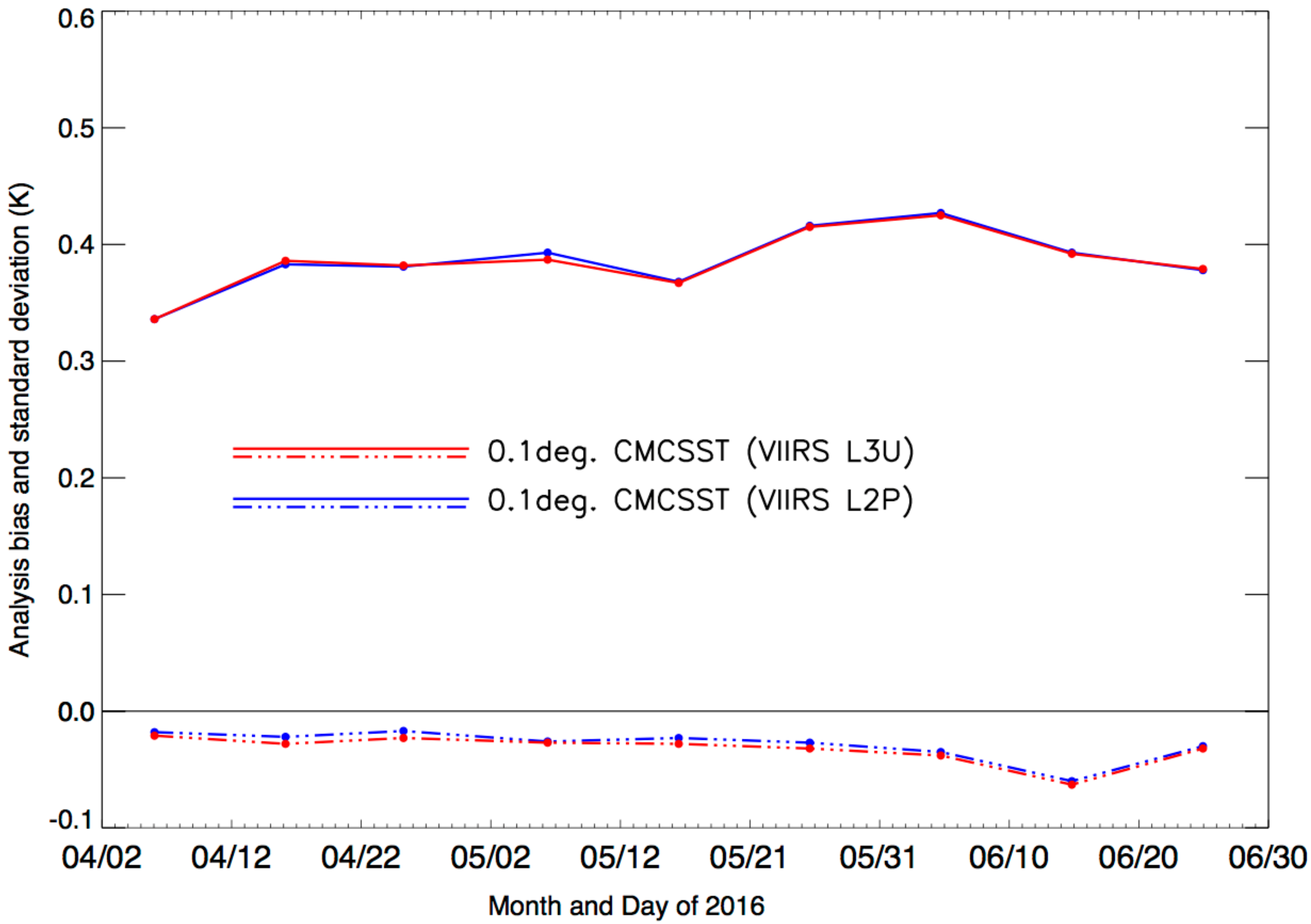


ACSPO VIIRS from PO.DAAC



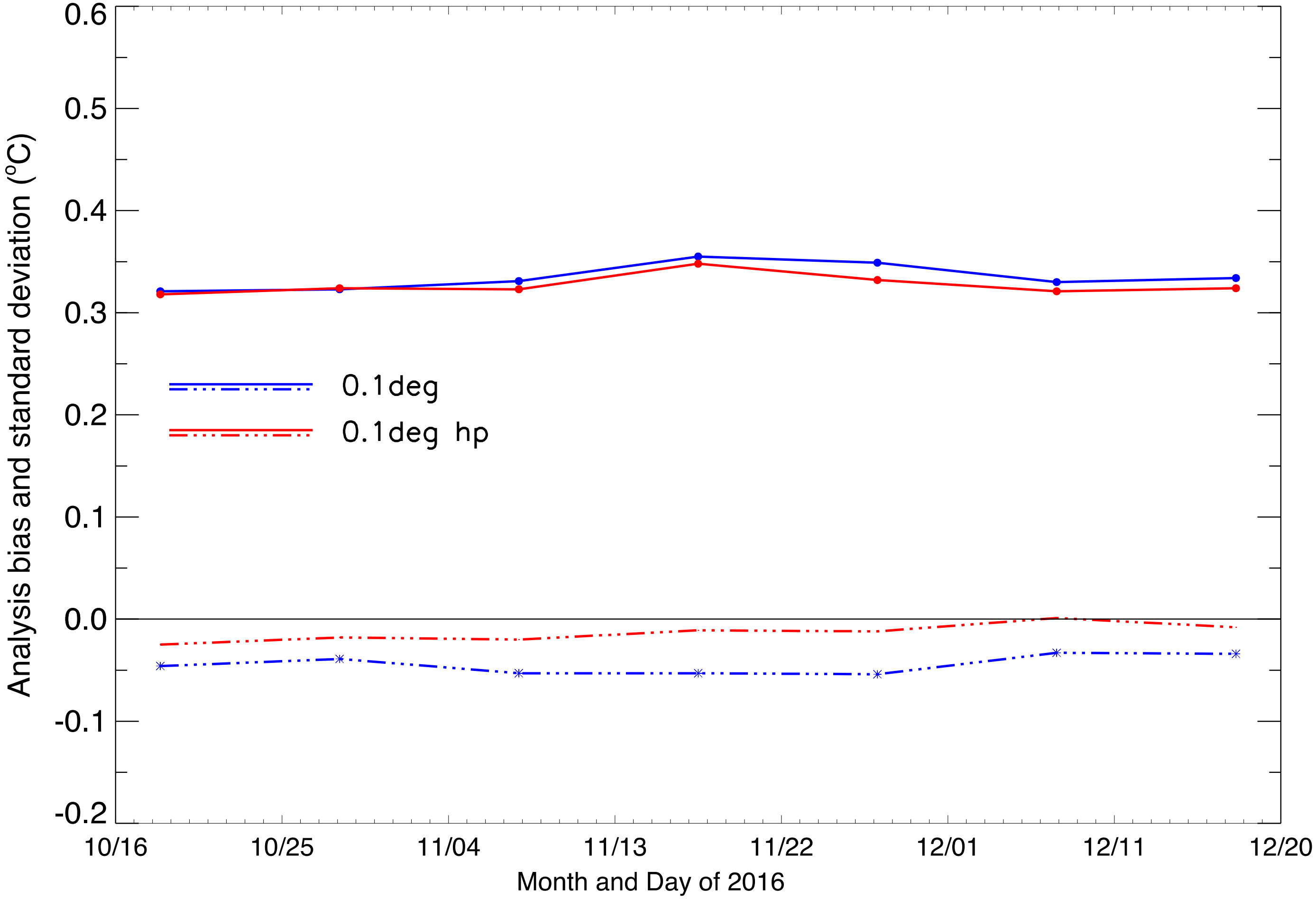
Without VIIRS data CMC SST has larger standard deviation compared to ARGO; VIIRS L3U have been used after Oct.4

ACSPO VIIRS 2.40 L2P vs L3U



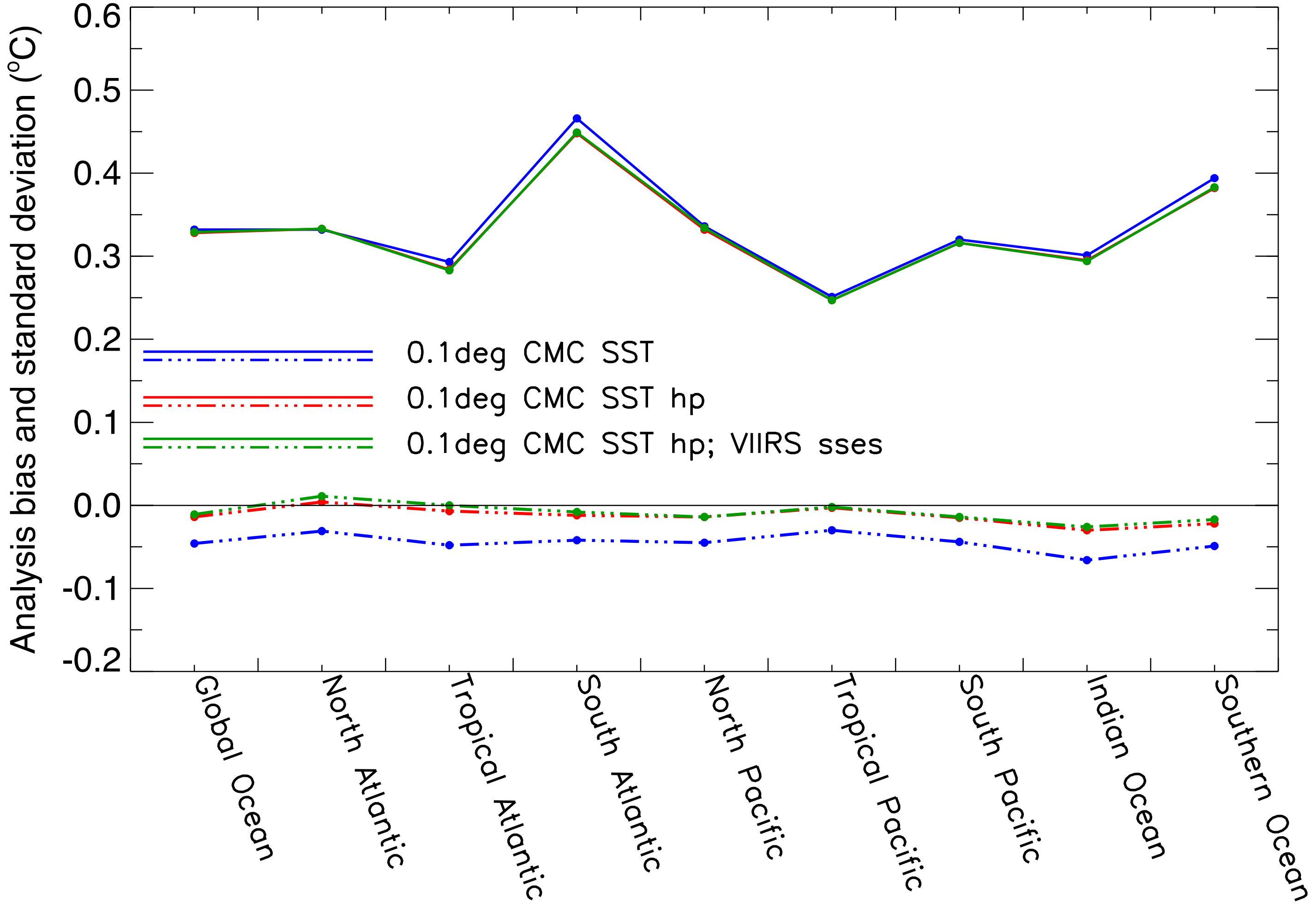
Similar performance for 0.1 deg. CMC SST when VIIRS ACSPO in L3U format are used

Changes in CMC SST in 2016



Smaller bias and standard deviation when using observational data with higher precision (two decimals instead of one decimal)

ACSPO VIIRS 2.40 L3U with SSES



Using SSES only for ACSPO VIIRS L3U has very small impact in the analysis bias

Conclusions and future plans

- CMC SST analyses continue to perform well in 2016
- As 0.1 deg. CMC SST has better performance than 0.2 deg. CMC SST (v2) and is an operational product, 0.2 deg. analysis using VIIRS has been discontinued in March 2017
- At this moment no CMC SST is used in GMPE, 0.1 deg. analysis to be introduced soon
- Using VIIRS L3U data does not affect the quality of the analysis and the data are easier to handle (2.4G/day compare to 21G/day)
- A new version of 0.1 deg. CMC SST using higher precision for the observational data and an improved ice analysis will be implemented early in 2018
- This new version will be reprocessed for the last 5 years (at the beginning) and the data will be made available early in 2018.

From STAR's Geo-Polar Blended SST to the 2014-17 Global Coral Bleaching Event and Beyond:

A Coral Reef Watch Report

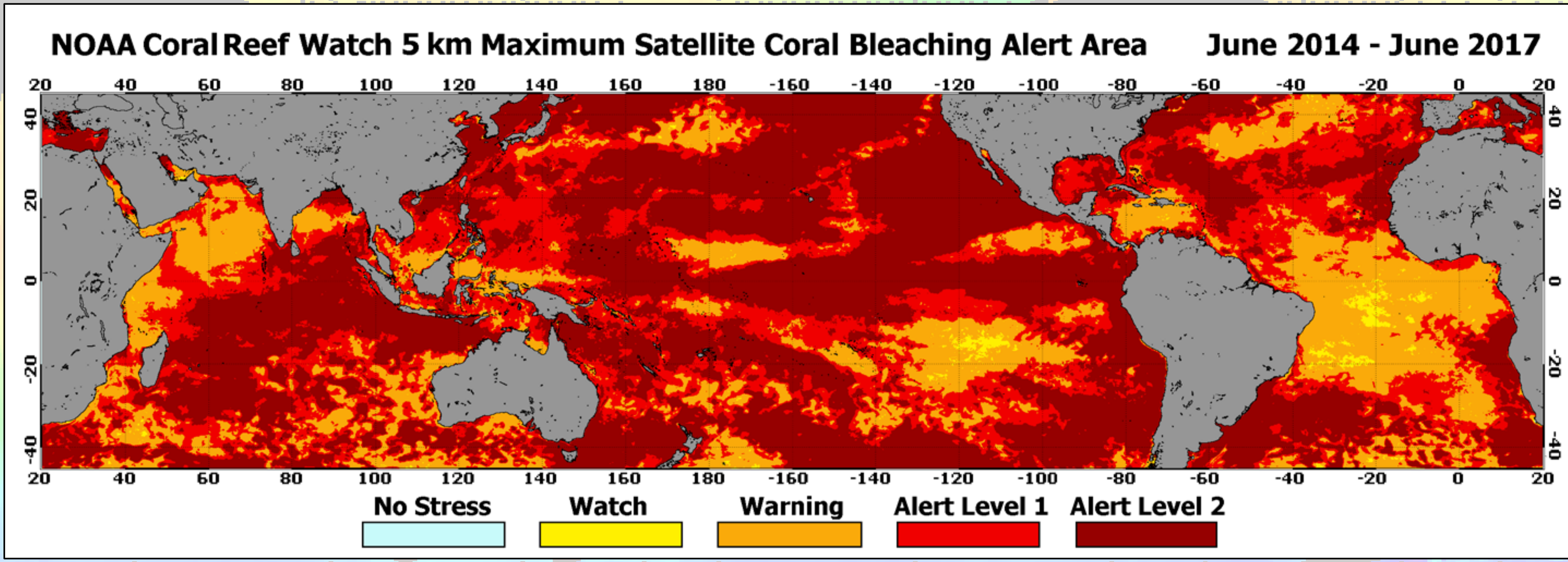
Jacqueline De La Cour (Jacqueline.Shapo@noaa.gov) with the Coral Reef Watch team and collaborators

https://coralreefwatch.noaa.gov

Third Global Coral Bleaching Event: 2014-17

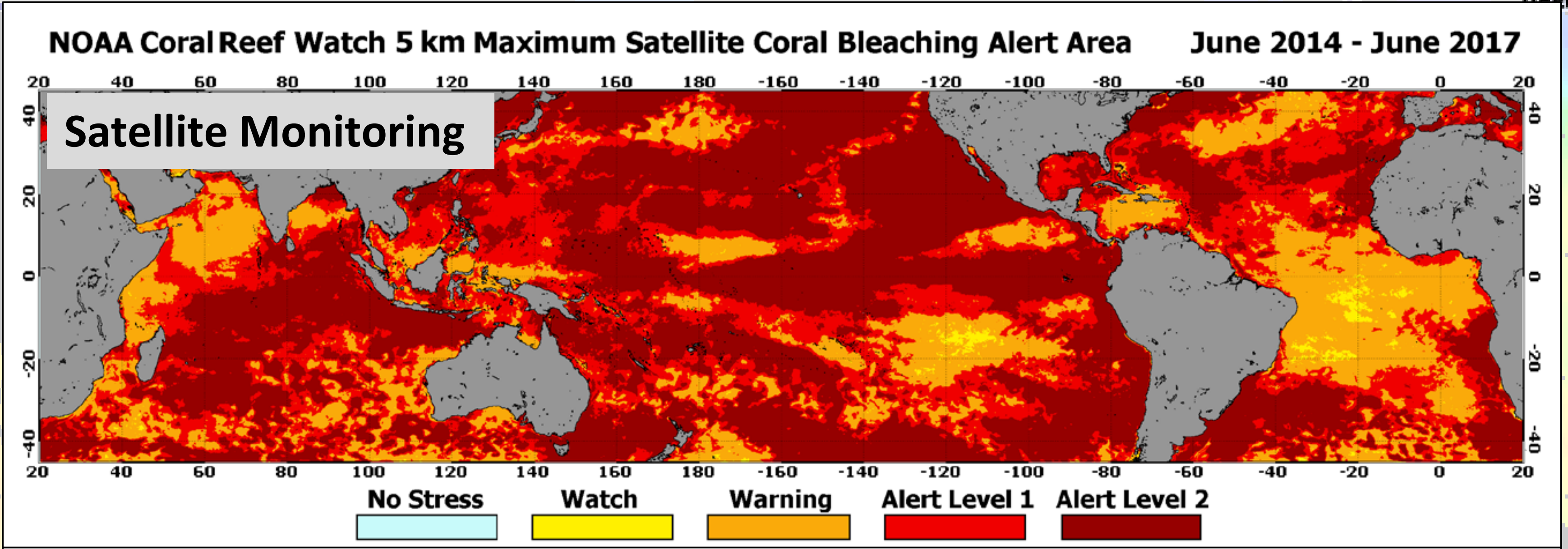
NOAA

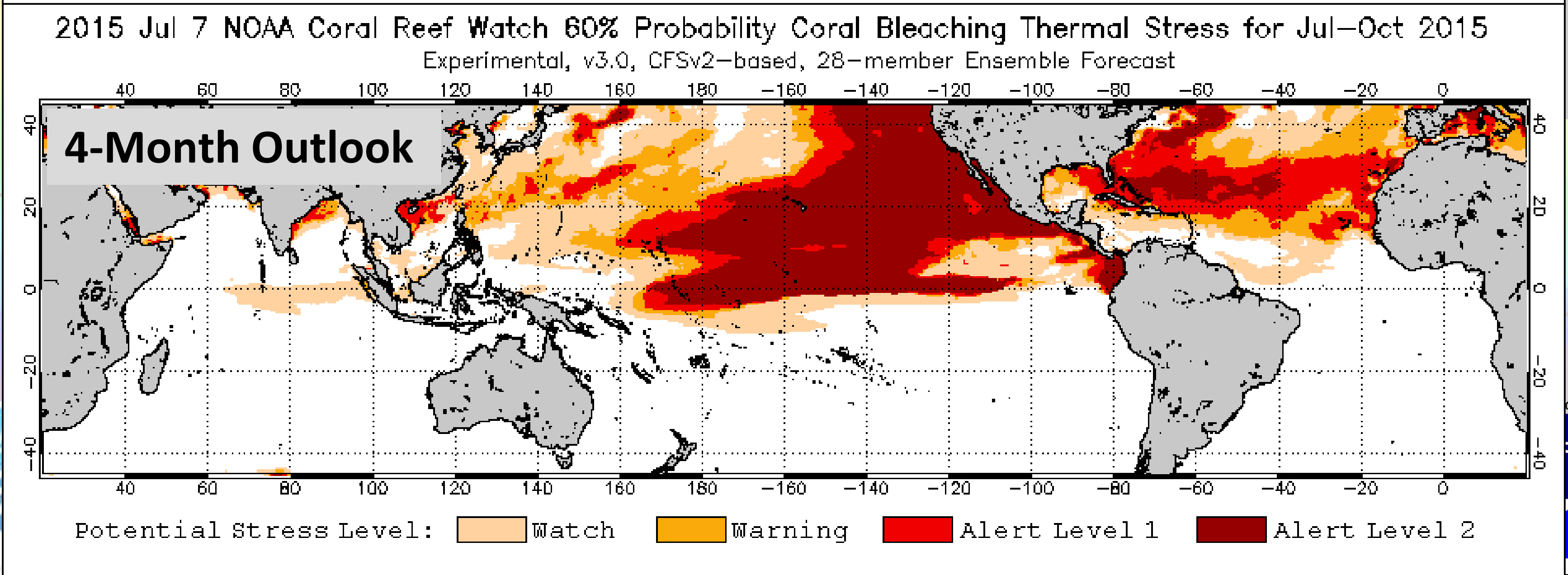
- Declared start of third-ever global bleaching event (**Oct 2015**)
- Announced likely ending of the event (**June 2017**)



Coral Reef Watch's satellite monitoring and modeled outlooks led to first-ever, well-coordinated monitoring, research, and management of a global bleaching event

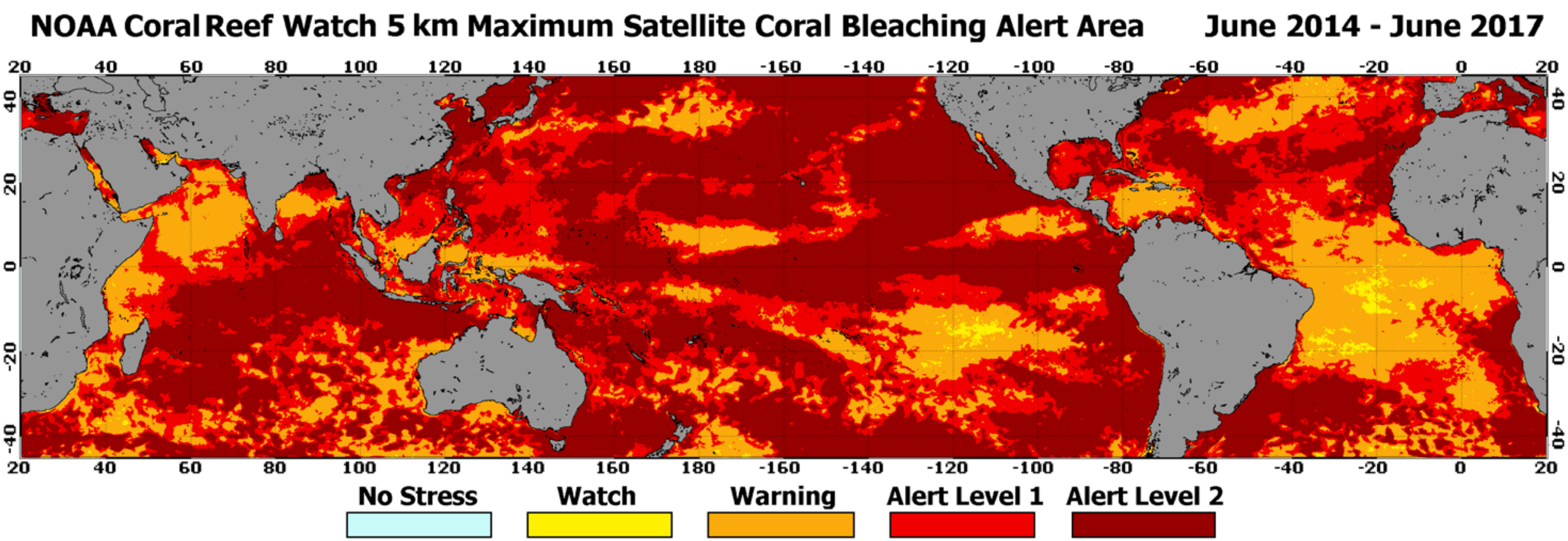
Third Global Coral Bleaching Event: 2014-17



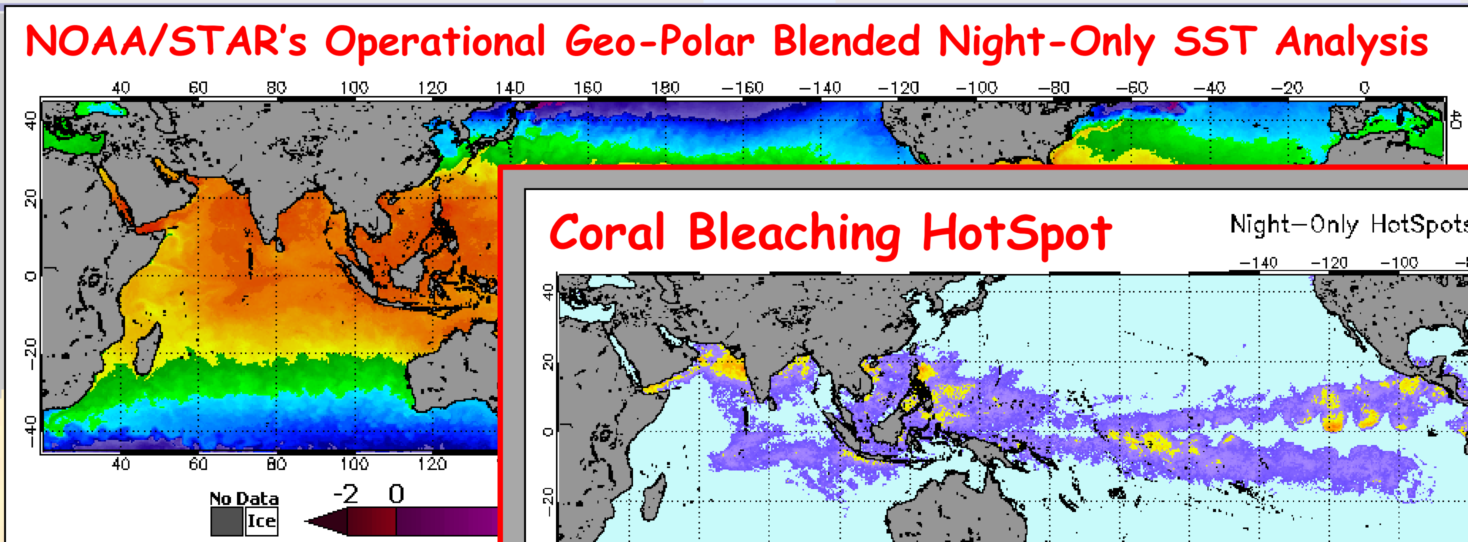


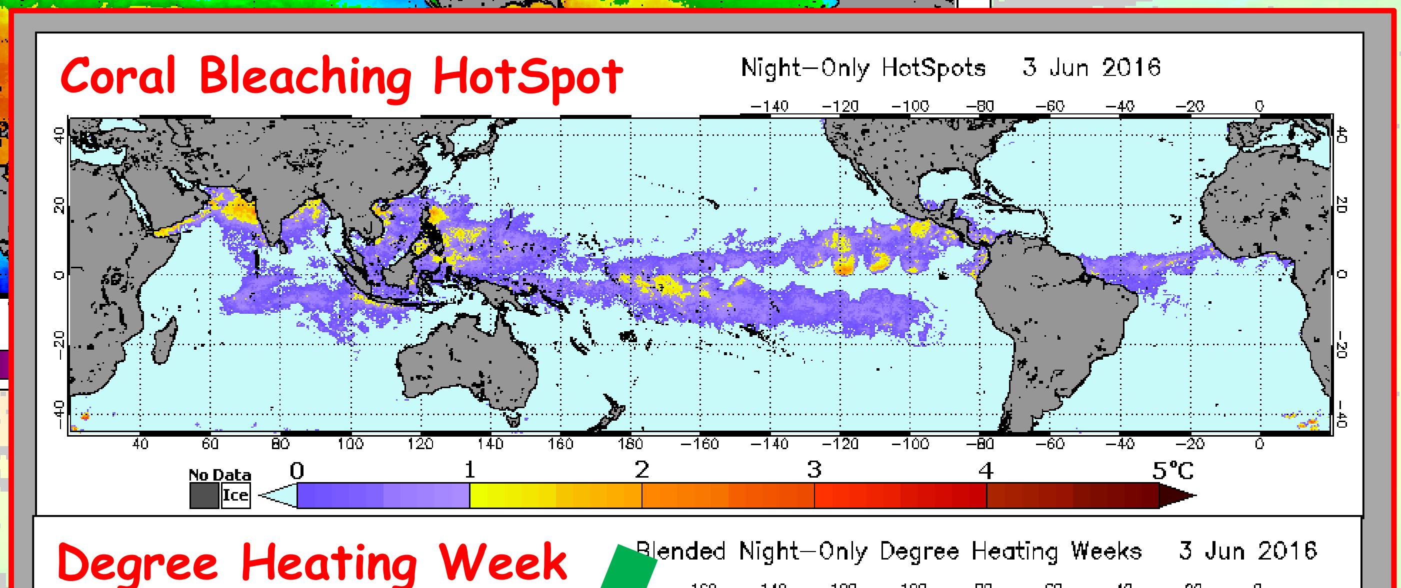
Third Global Coral Bleaching Event: 2014-17

- Longest global bleaching event ever (3-years)
- Most widespread global bleaching event ever
- Over ½ exposed twice (Guam: 4 years in a row)
- ~100% coral reefs stressed worldwide ; 64% of reefs with bleaching level heat stress

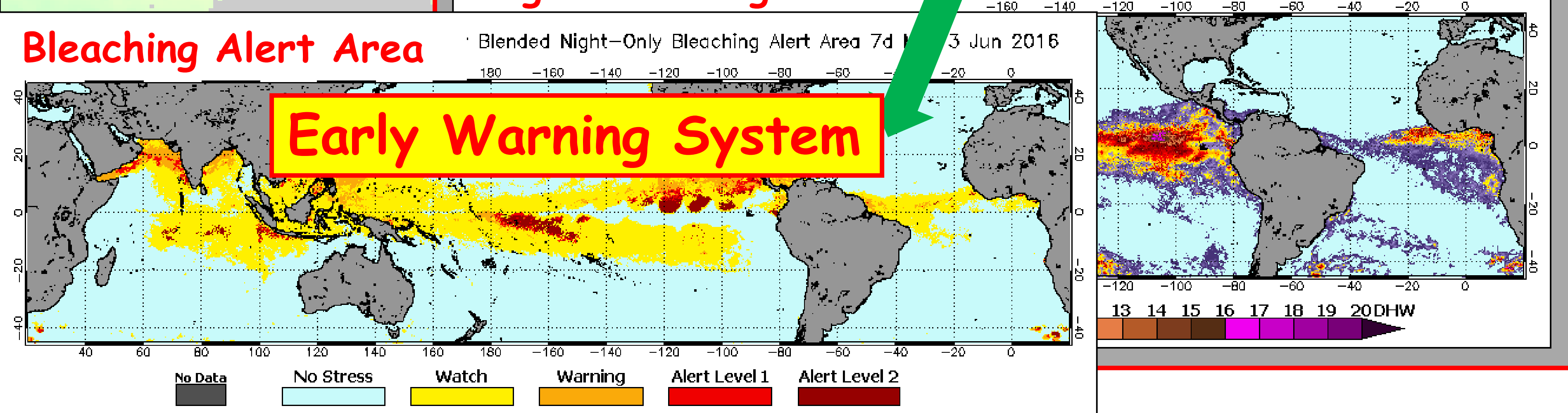


Coral Reef Watch 5 km Satellite-Based Products



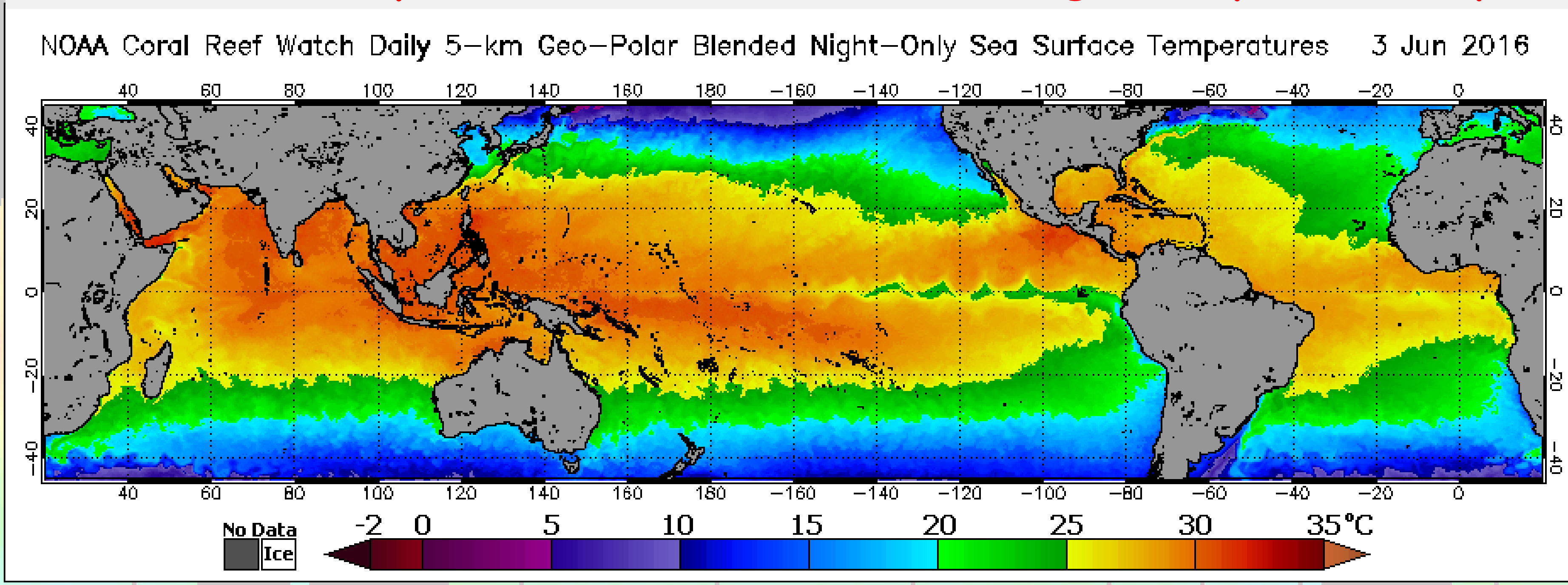


- Global, 5 km
- Updated daily
- Posted online



Coral Reef Watch 5 km Satellite-Based Products

NOAA/STAR's Operational Geo-Polar Blended Night-Only SST Analysis



Polar: S-NPP (VIIRS), METOP-B

Geo: GOES-E, GOES-W, METEOSAT-10, HIMAWARI-8

https://coralreefwatch.noaa.gov

Advances in Coral Reef Watch's 5 km Products

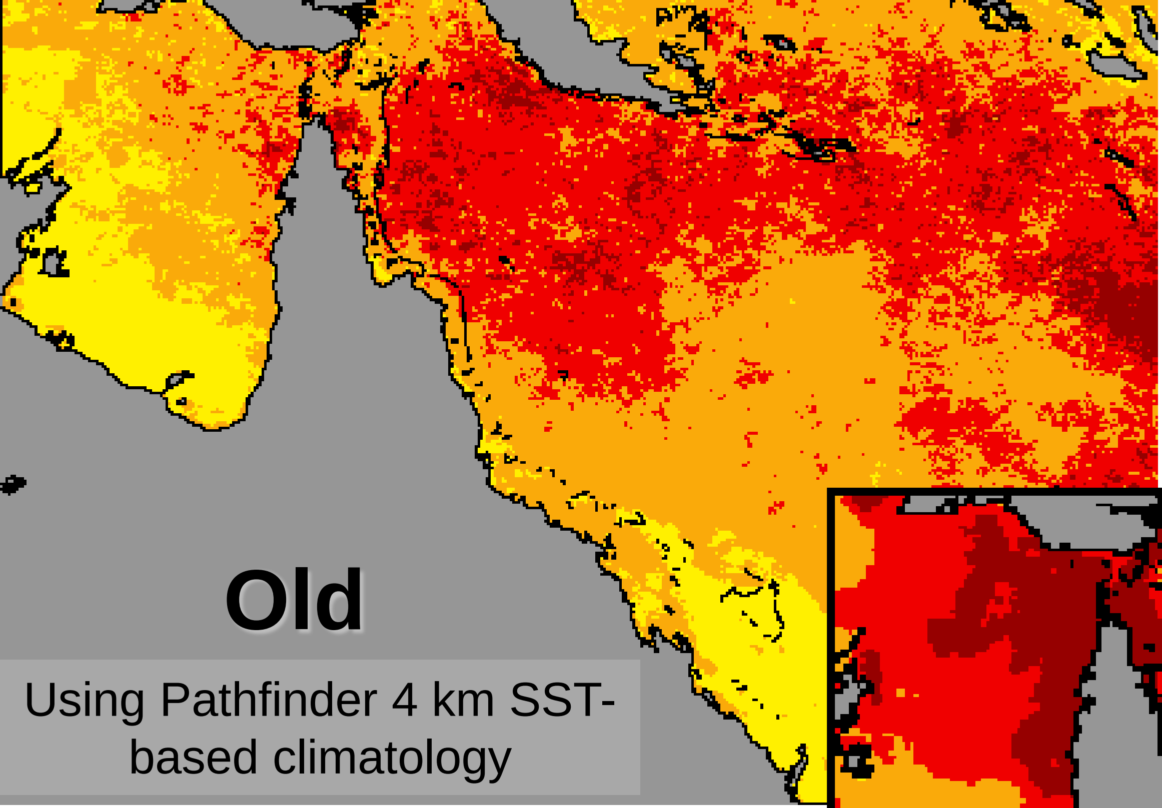
Development & implementation of a new climatology:

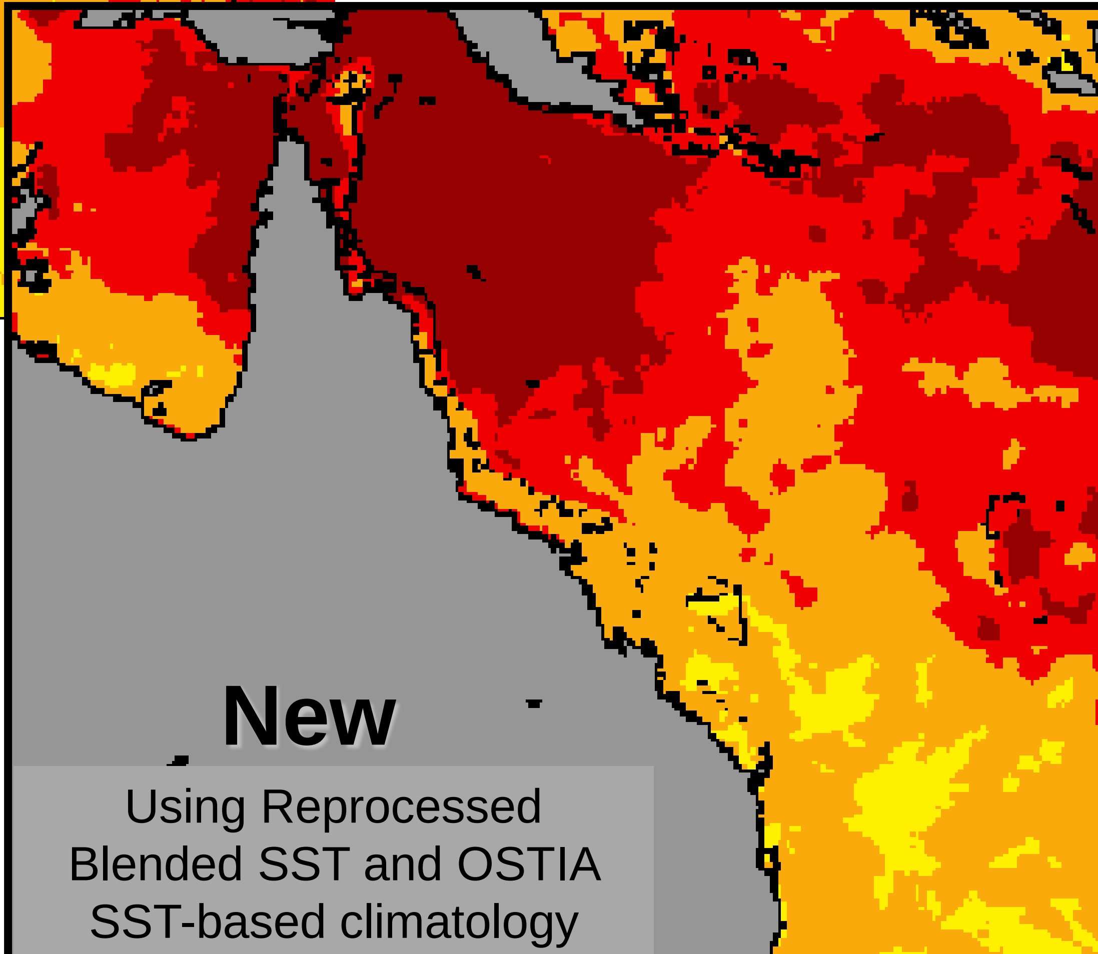
- STAR's Reprocessed Blended SST (2002-2015)
- OSTIA Reanalysis (1985-2002)

Development & implementation of Version 3 product suite:

- Significant improvement in accuracy (initial testing)

Heat Stress using Improved 5 km Climatology





Advances in Coral Reef Watch's 5 km Products

Development & implementation of a new climatology:

- STAR's Reprocessed Blended SST (2002-2015)
- OSTIA Reanalysis (1985-2002)

Development & implementation of Version 3 product suite:

- Significant improvement in accuracy (initial testing)

Development: 1985-present dataset ("CoralTemp")

- **1985-2002: OSTIA Reanalysis**
- **2002-2016: STAR's Reprocessed Blended SST**
- **2017-present: STAR's near-real-time operational Blended SST**

50reefs.org

CRW - Member of Scientific Steering Group

Future plans

STAR's Reprocessed 5 km Blended SST:

- **Delivered:** **2002 Sept-2016**
- **In processing:** **1994-2002 August**

- **VIIRS SST**
  - **Not available for current version**
  - **To be included in future version**

Higher resolution satellite SST-based monitoring products

- **High quality SST available (including VIIRS L2U, L2C)**
- **Experiments showed gaps in daily data = challenge**
- **Higher resolution (>2 km) Blended SST is desired**

Delayed Science-Quality Geo-Polar Blended SST Analysis??
(CRW's monitoring accumulates heat stress over three months)

Key Messages

Geo-Polar Blended data (incorporating VIIRS)

- **Just in time for 2014-17 Global Coral Bleaching Event**
- **Higher-resolution, better global & regional products**
- **Excellent use by scientists and resource managers worldwide**

New satellite data needs:

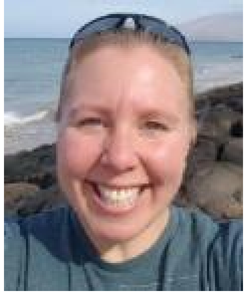
- **High-resolution polar & geostationary data needed for blended SST and coral bleaching heat stress products**
- **JPSS provides needed sub-km SST with global coverage**
- **High quality reprocessing needed for climatology**

@CoralReefWatch **CoralReefWatch**

coralreefwatch@noaa.gov

Thank you from the NOAA Coral Reef Watch Team!!

Mark Eakin



Jacquie De La Cour (GST)

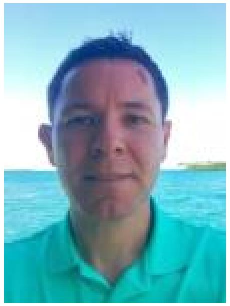
Gang Liu (GST)

Erick Geiger (GST)

Ben Marsh
(GST & ReefSense)

Kyle Tirak (GST)

Andrea Gomez
(CCNY & NOAA-CREST)



William Hernandez Lopez
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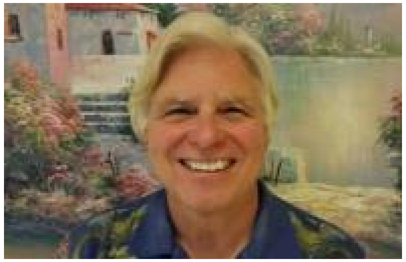
William Skirving
(GST & ReefSense)

Scott Heron (GST & ReefSense)



Rob Warner (NOAA/NOS)

Al Strong (GST & SR)

- **Over 1000 media stories (print, online, radio, TV)**
- ***Chasing Coral* – feature length documentary**
  - **Premiered at Sundance Film Festival, January 2017**
  - **Won Audience Award for Best US Documentary**

Use of ACSPO VIIRS L3U SST in MGDSST (delayed analysis)

Japan Meteorological Agency

Toshiyuki SAKURAI*, Yukio KURIHARA, Akiko SHOJI, Hiromu KOBAYASHI, Ayako TAKEUCHI(Office of Marine Prediction)

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Introduction

- MGDSST (Merged satellite and in-situ data Global Daily Sea Surface Temperature)
  - Global, 0.25 x 0.25 grid resolution, daily GPV
  - Biases of satellites' data are corrected using in situ SSTs
  - Scale decomposed space-time optimal interpolation

Prompt analysis: conducted within JMA's NWP System

Input: AVHRR (NOAA-18, 19, MetOp-A) [GAC and LAC around Japan], AMSR2, WindSat, In-situ

Delayed analysis: conducted five-months later in principle

Input: AVHRR (NOAA-18, 19, MetOp-A) [GAC], AMSR2, In-situ

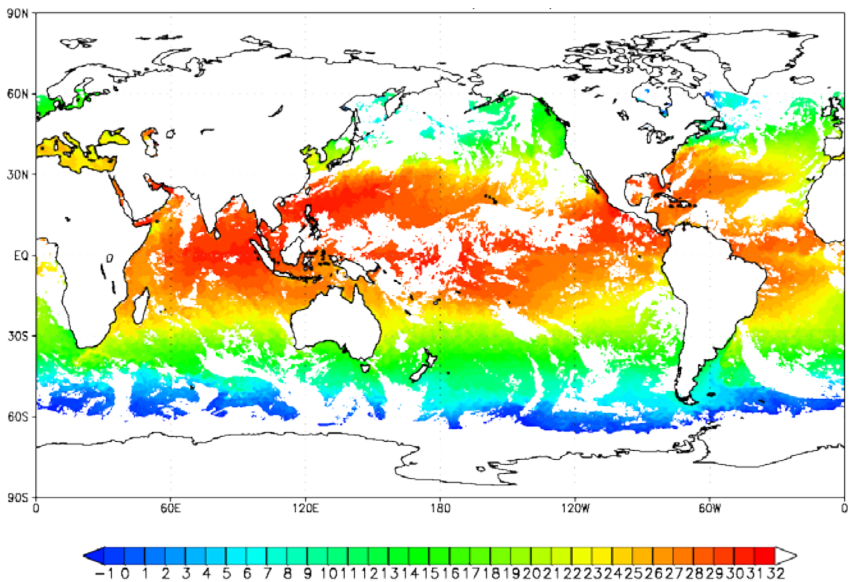
Reanalysis: reprocessed for 1982-2006 with Pathfinder SST v5.0/5.1 and other data

We conducted an impact test for delayed analysis.

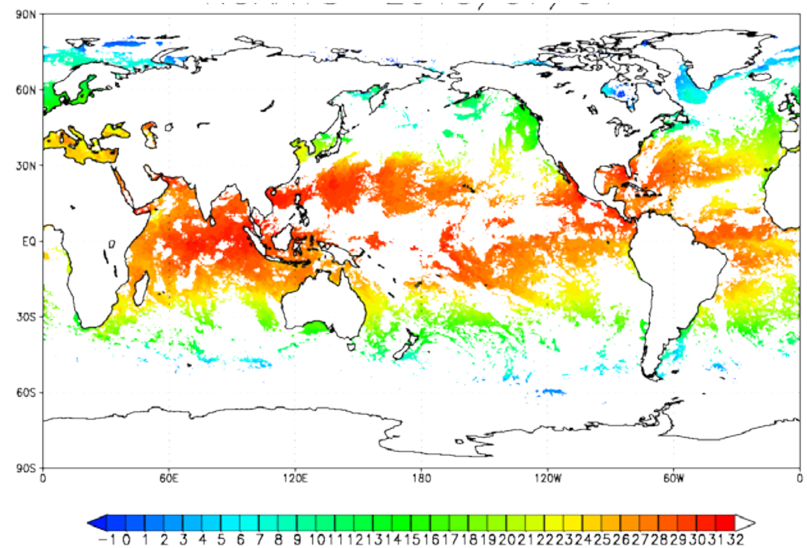
ACSPO VIIRS L3U SST

- JMA has routinely acquired ACSPO VIIRS L3U SST (ver.2.40) from NOAA Server.
- The coverage of VIIRS SSTs are superior to that of AVHRR.

sNPP/VIIRS SSTs 2015/07/01



NOAA18/AVHRR SSTs 2015/07/01



Daytime and nighttime data are combined on a 0.25 ° grid

Method of impact test

- Impact of assimilation of VIIRS SSTs for the delayed-mode MGDSST analysis was tested against a control run (i.e. routine analysis) for the period from 02 Feb. 2016 to 30 Jun. 2016.

- The configuration of test run was the same as the control , except that VIIRS SSTs are used in place of NOAA18/AVHRR data. The SSES bias was removed from the VIIRS L3U SSTs.

- The observational error of VIIRS SSTs in optimal interpolation was set equal to 0.57 times of that of NOAA18/AVHRR SSTs by calculating the ratio of the both RMSEs against buoy SSTs.

Method of validation

- Validation was conducted against (1) in-situ observation and (2) daily VIIRS SSTs.

(1) Comparison against In-situ observation

Moored/drifting buoy and Argo data were used. Those were not independent to analysis because they were also used for bias correction of satellites' data.

(2) Comparison against daily VIIRS SSTs

To confirm VIIRS SST were ingested into analysis, we also compare with daily VIIRS SSTs.

- Both data were daily-averaged and converted into 0.25 deg. X 0.25 deg. grids for comparison.
- Validation Period : from 02 Feb. 2016 to 30 Jun. 2016.

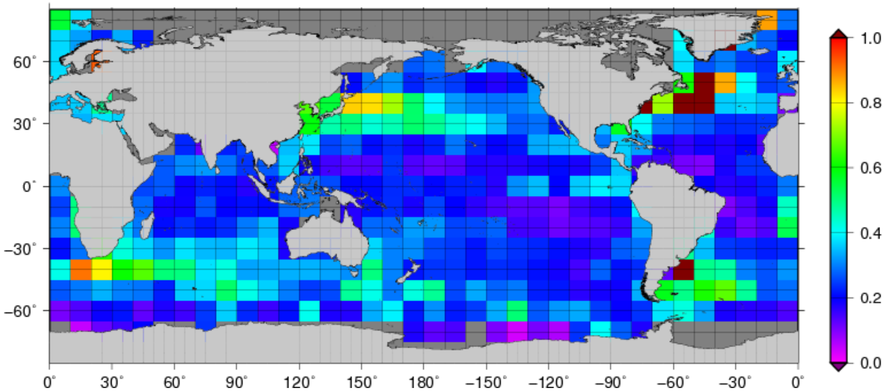
Results (1) : Validation by in-situ data

- RMSE for Test run is improved by 0.016 K in global region.
- Improvement of RMSE is relatively large in the southern mid- and high- latitude.
- Bias for Test run is generally comparable with that of Control.

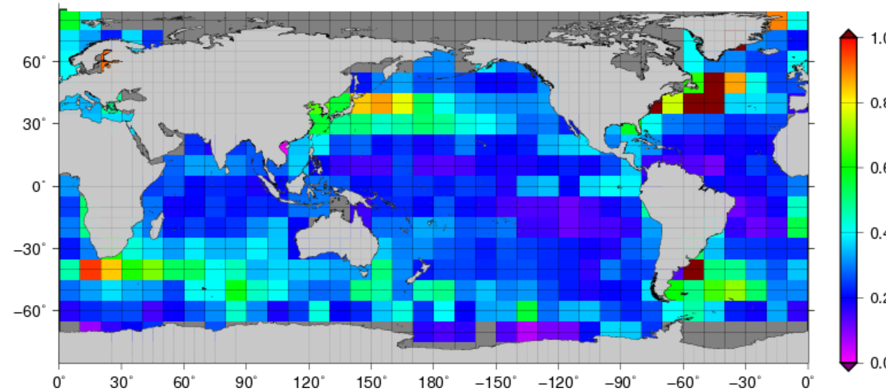
Area	BIAS (K)		RSME(K)		Number of Observations
	Control	Test	Control	Test	
Global	0.021	0.020	0.409	0.393	381420
60N-90N	0.001	0.008	0.364	0.355	8886
30N-60N	0.035	0.034	0.575	0.554	80554
30S-30N	0.020	0.021	0.271	0.265	175876
60S-30S	0.013	0.009	0.450	0.427	113138
90S-60S	-0.002	-0.020	0.254	0.225	2966

RMSE map against In-situ data

RMSE for Test (+ VIIRS) 【K】

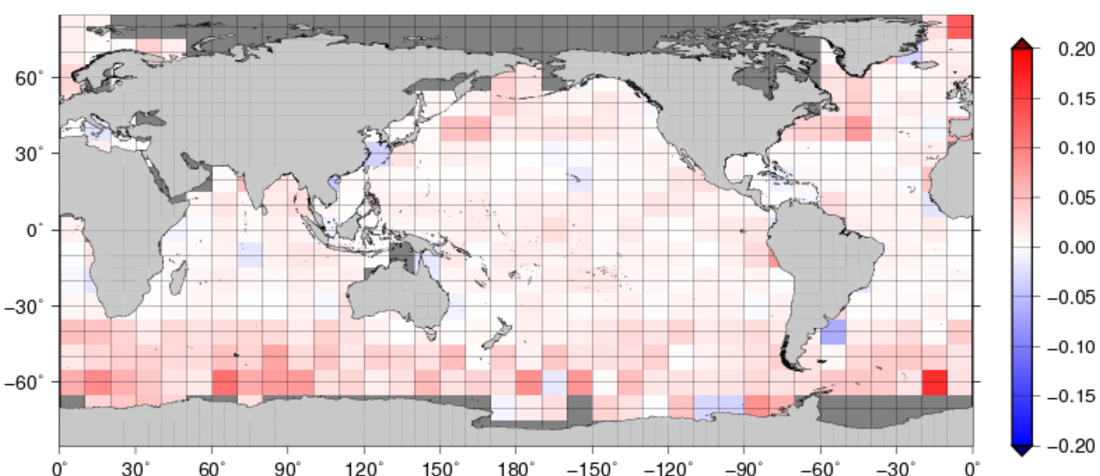


RMSE for Control 【K】



[Above figures] RMSE for 10x10 degree grids

RMSE difference between Control and Test

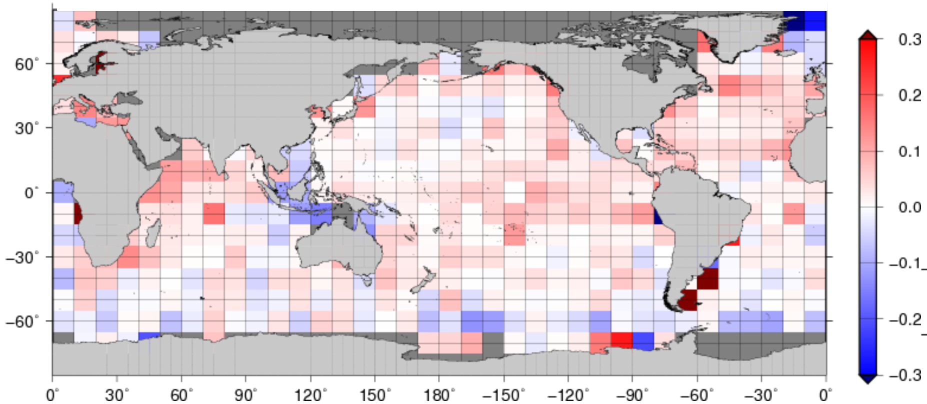


[Left figure]
Warm color indicates RMSE(Test) is smaller than RMSE(Control).

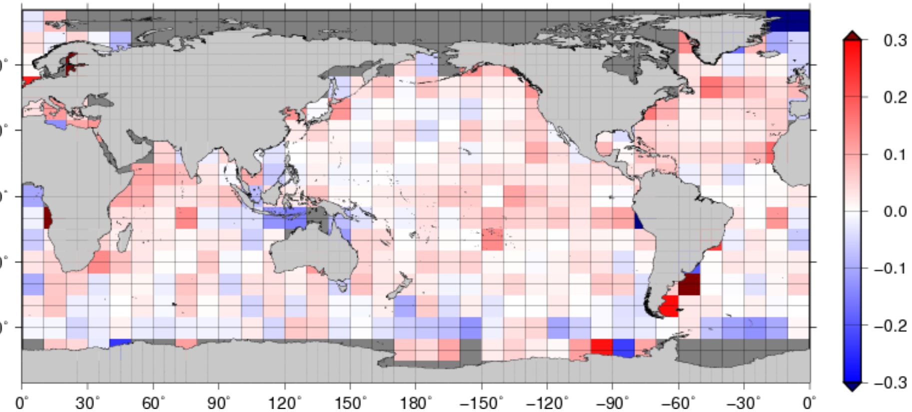
- RMSE for Test is generally improved in almost all areas.
- Improvement is relatively large in the mid- and high-latitude.

Bias map against In-situ data

Bias for Test (+ VIIRS) 【K】

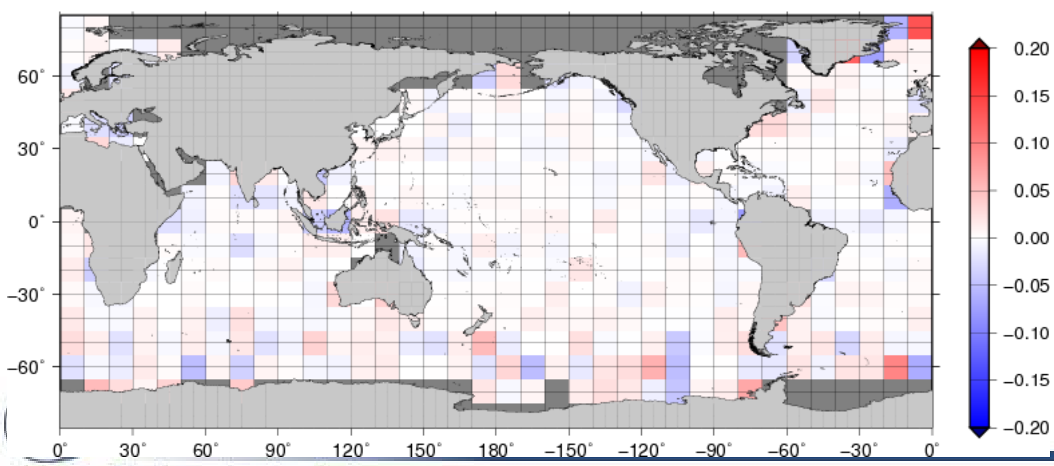


Bias for Control 【K】



[Above figures] Bias for 10x10 degree grids

Difference in absolute value of bias (abs (bias)) between Control and Test

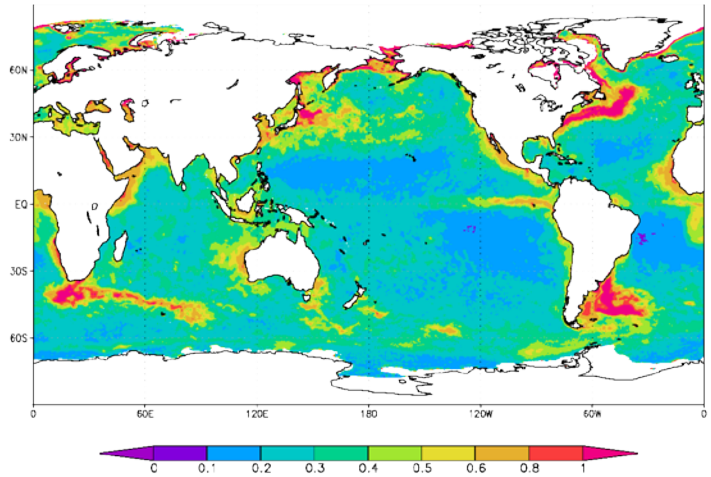


[Left figure]
Warm color indicates abs (bias) (Test) is smaller than abs (bias) (Control).

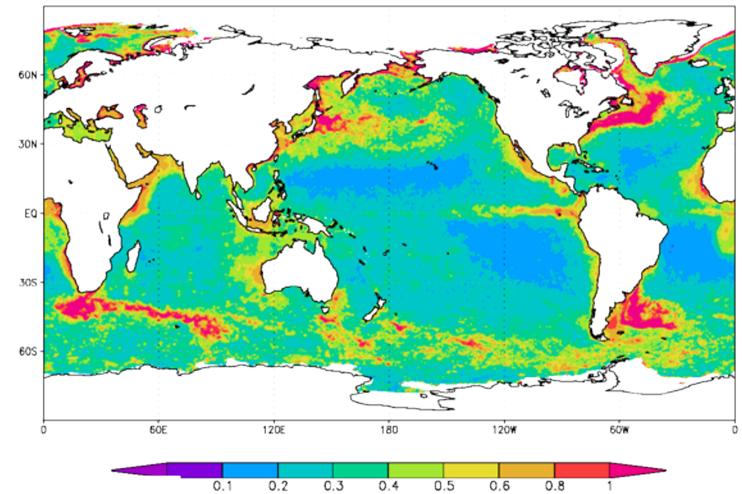
- Both Test and Control have a positive bias in almost all areas.
- Abs (bias) for Test is comparable with that of Control.

Results (2) : Validation by daily VIIRS SSTs
RMSD map against daily VIIRS SSTs

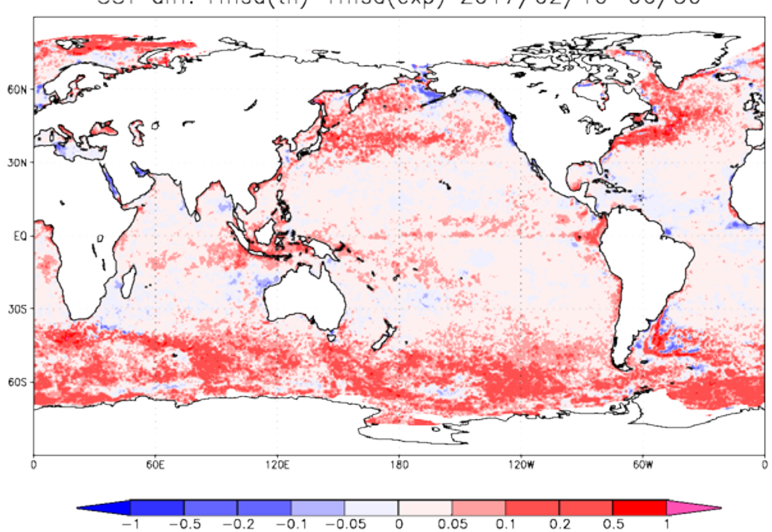
RMSD for Test (+ VIIRS) 【K】



RMSD for Control【K】



RMSD difference between Control and Test

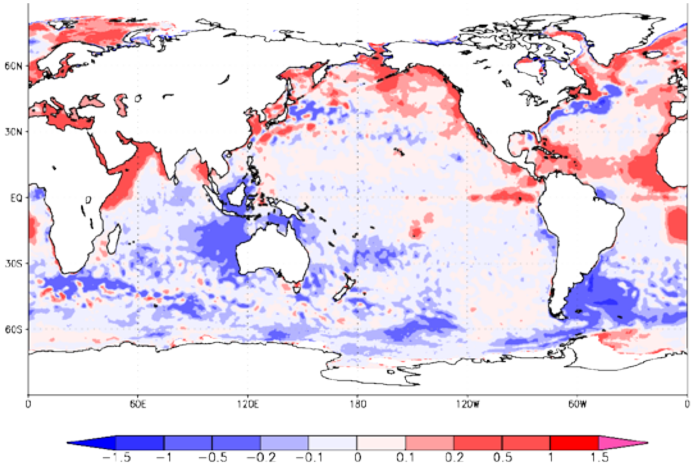


[Left figure]
Warm color indicates RMSD (Test) is smaller than RMSD (Control).

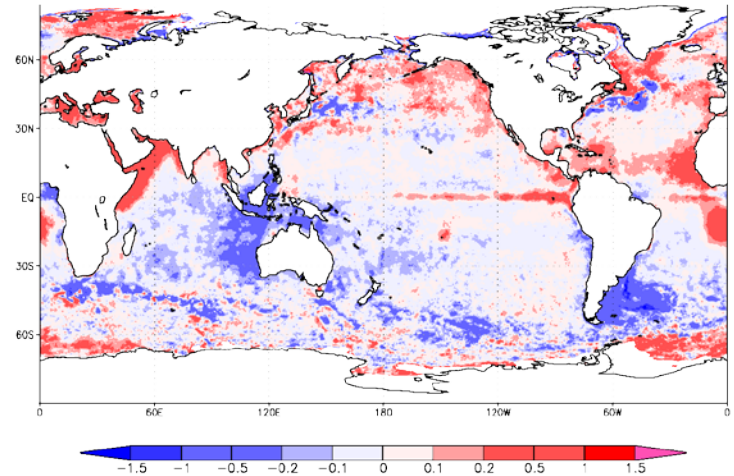
- RMSD for Test is smaller in the mid- and high-latitude and around sea ice area.
- RMSD for Test is degraded along west coast of the North America, in seas off Alaska and the Red sea.
  => It might be caused by some unknown issues with our analysis system.

Bias map against daily VIIRS SSTs

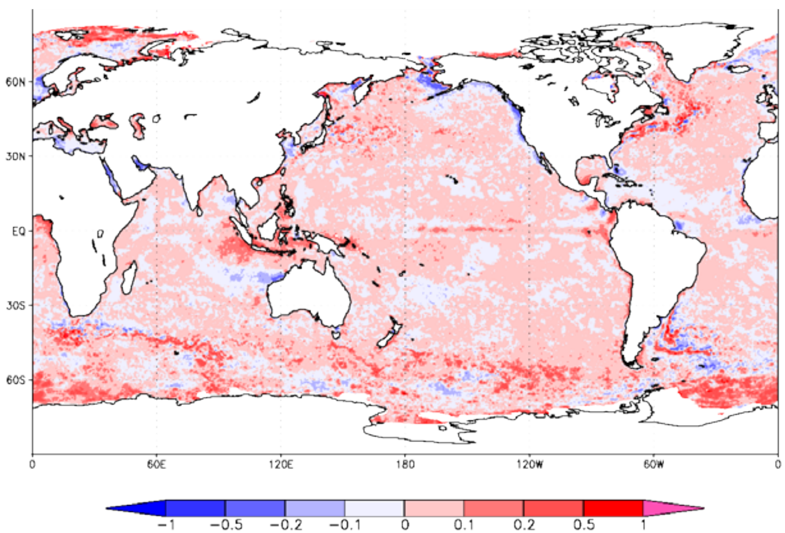
Bias for Test (+ VIIRS) 【K】



Bias for Control 【K】



Difference in absolute value of bias (abs (bias)) between Control and Test



[Left figure]
Warm color indicates abs(bias) (Test) is smaller than abs(bias) (Control).

Abs(bias) is generally improved, however, not so large except around the Antarctic.

Summary & Future Work

- Impact of assimilation of VIIRS SSTs for the delayed-mode MGDSST analysis was tested.
- From the validation results against in-situ data, RMSE for Test run was improved by 0.016 K in global region.
- The improvement is relatively large in the southern mid- and high- latitude. This might be caused by better coverage of VIIRS SSTs in these areas, and by better accuracy of VIIRS SSTs.
- We will make an impact test for prompt analysis of MGDSST and HIMSST in current year.

NOAA CoastWatch/ OceanWatch Sea Surface Temperature Data Dissemination

Veronica P. Lance* and
Paul M. DiGiacomo
and the NOAA CoastWatch/OceanWatch Team

*Global Science & Technology, Inc.

2017 STAR/JPSS Annual Science Meeting
College Park, MD, 14-18 August 2017

STAR Center for Satellite Application and Research
National Environmental Satellite, Data, and Information Service (NESDIS)

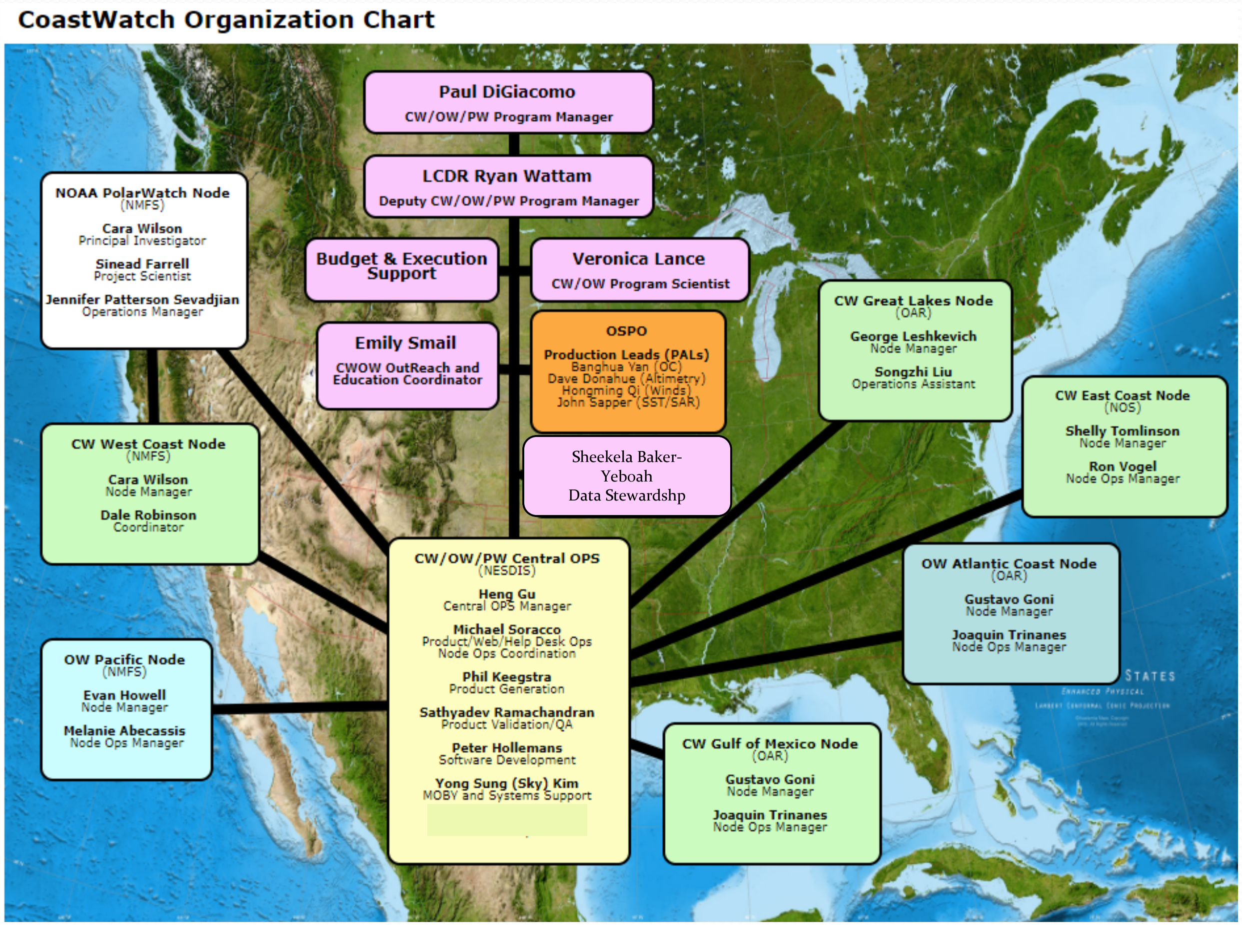
NOAA CoastWatch/OceanWatch Team

Paul DiGiacomo – Program Manager

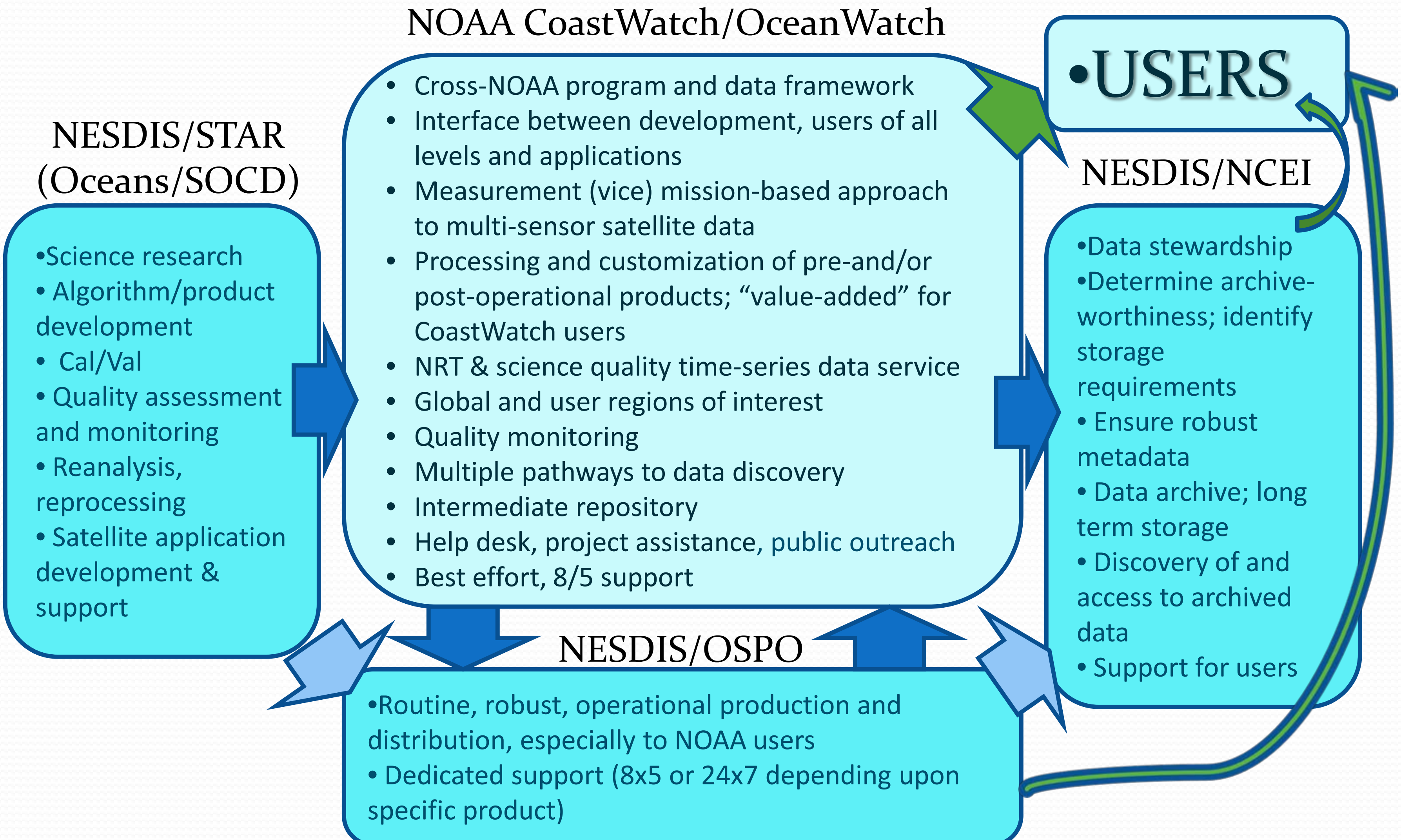
Full Time "CW Central" Technical Team	With Support From
Heng Gu	Veronica Lance
Phil Keegstra	Emily Smail
Sathya Ramachandran	Sheekela Baker-Yeboah
Michael Soracco	Ryan Wattam

And PolarWatch
and 5 Regional Nodes

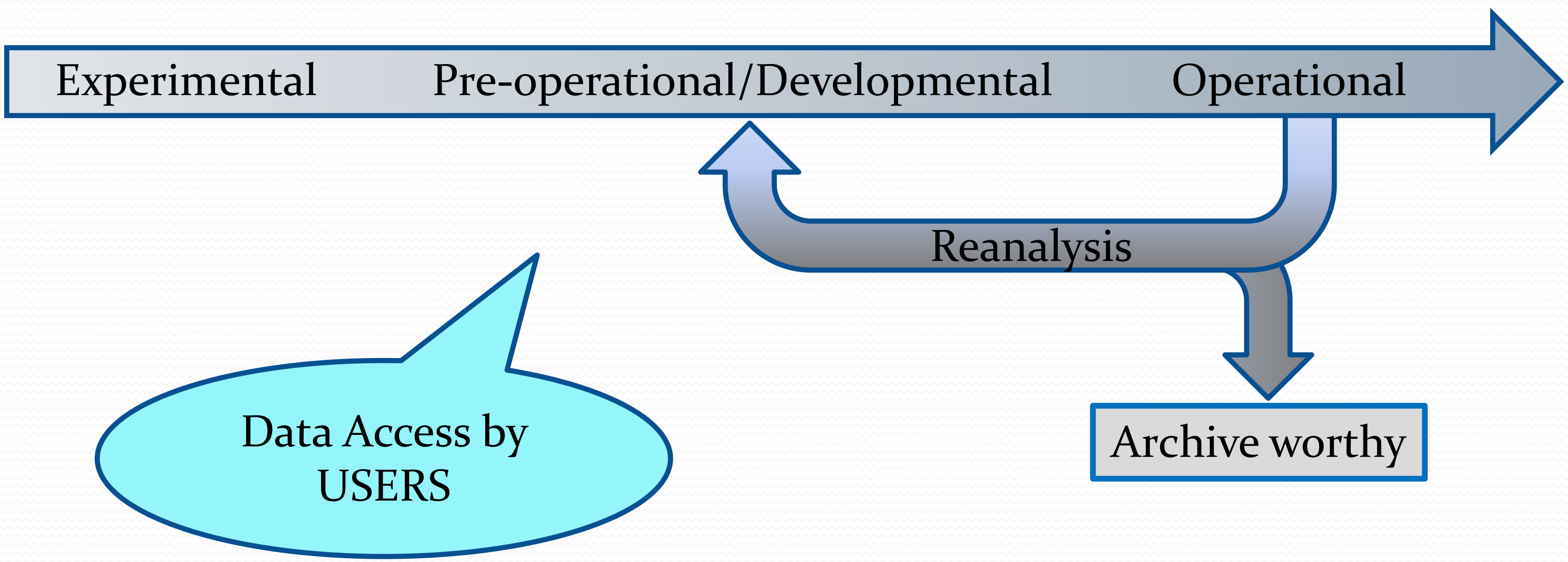
NOAA CoastWatch/OceanWatch/PolarWatch



Role of NOAA CoastWatch/OceanWatch



Typical Product Lifecycle



Current SST at NOAA CoastWatch/OceanWatch

Processing	Program	Latency	Temporal Availability	Spatial Coverage	Spatial Resolution	Data format(s)	Direct Source to CWOW
Ctera*	AVHRR	NRT	Daily, rolling 2 weeks	CW heritage regions		HDF, GeoTIFF	OSPO
ACSPO	**VIIRS**	**NRT**	**Daily, rolling 2 weeks**	**CW heritage regions**	**Nominal 750 m**	**HDF, GeoTIFF**	**OSPO**
GOES-SST*	Geo-Stationary	NRT	4x per day	Geo Basins	6 km	HDF, GeoTIFF	OSPO
Blended	Geo-Polar Blended	NRT	Daily	Global	5 km	HDF, GeoTIFF	OSPO
ACSPO	**VIIRS RAN-1 L2P, L3U**	**Delayed Mode**	**2002 to 2015****	**Global**	**4 km GAC**	**NetCDF**	**STAR/SST team**
ACSPO	AVHRR RAN-1, L2P	Delayed Mode	2002 to 2015**	Global	4 km GAC	NetCDF	STAR/SST team

*transitioning to ACSPO

**will be backfilling from 2015 through to present

SST at NOAA CoastWatch/OceanWatch

Processing	Program	Latency	Links to Browse Images	Links to Data
Ctera	AVHRR	NRT	https://coastwatch.noaa.gov/cw_html/NearRealTimeSearch.html?region=ALL&product=sst&sensor=AVHRR&daysback=1&desc=sat	https://cw2.espc.nesdis.noaa.gov/data/avhrr/ ftp://ftpcoastwatch.noaa.gov/pub/data/products/avhrr/
ACSPO	**VIIRS**	NRT	http://coastwatch.noaa.gov/cw_html/NearRealTimeSearch.html?region=ALL&product=sst&sensor=VIIRS&daysback=1&desc=sat	https://cw2.espc.nesdis.noaa.gov/data/viirs/ ftp://ftpcoastwatch.noaa.gov/pub/data/products1/viirs/
GOES-SST	Geo-Stationary	NRT	https://coastwatch.noaa.gov/cw_html/NearRealTimeSearch.html?region=ALL&product=sst&sensor=Imager&daysback=1&desc=sat	https://cw2.espc.nesdis.noaa.gov/data/goes/ ftp://ftpcoastwatch.noaa.gov/pub/data/products1/goes/
Blended	Geo-Polar Blended	NRT	https://coastwatch.noaa.gov/cw_html/NearRealTimeSearch.html?region=ALL&product=sst&sensor=Multi&daysback=2&desc=sat	https://cw2.espc.nesdis.noaa.gov/data/goespoes/ ftp://ftpcoastwatch.noaa.gov/pub/data/products/goespoes/
ACSPO	**VIIRS** RAN-1 L2P	Delayed Mode	Being incorporated into Data Discovery Tools with browse PNG's	https://www.star.nesdis.noaa.gov/thredds/catalog/swathSNPPVIIRSSCIENCEL2PWW00/catalog.html ftp://ftp.star.nesdis.noaa.gov/pub/socd2/coastwatch/sst/ran/viirs/snpp/l2p/
ACSPO	**VIIRS** RAN-1 L3U	Delayed Mode	Being incorporated into Data Discovery Tools with browse PNG's	https://www.star.nesdis.noaa.gov/thredds/catalog/swathSNPPVIIRSSCIENCEL3UWW00/catalog.html ftp://ftp.star.nesdis.noaa.gov/pub/socd2/coastwatch/sst/ran/viirs/snpp/l3u/
ACSPO	AVHRR RAN-1	Delayed Mode	Being incorporated into Data Discovery Tools with browse PNG's	ftp://ftp.star.nesdis.noaa.gov/pub/socd2/coastwatch/sst/ran/avhrr_gac/ https://www.star.nesdis.noaa.gov/thredds/socd/coastwatch/acspo/catalog_sst_acspo_avhrrgac.html

Website Revamp v.1.2 in Progress

SST Product Pages

National Oceanic and Atmospheric Administration
U.S. Department of Commerce

NOAA CoastWatch • OceanWatch

Sea Surface Temperature ACSPO VIIRS RAN1 Level 2P, 3U

Search
CoastWatch NOAA

Need Help?
(301) 683-3335

Description | Information | Data Access | Documentation | Data Citation

L2P data are available through the following servers

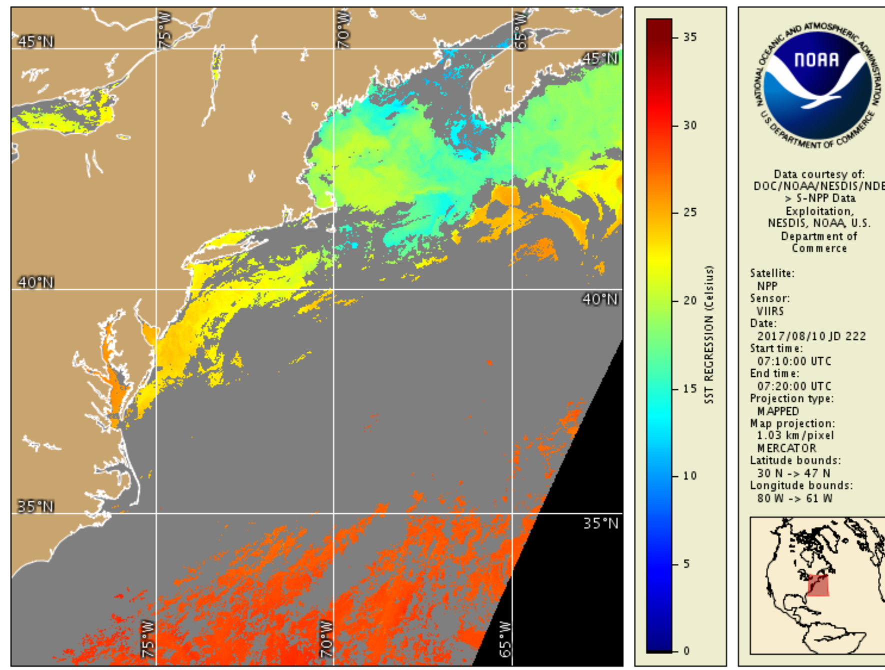
Service	Resource Locator
FTP	ftp://ftp.star.nesdis.noaa.gov/pub/socd2/coastwatch/sst/ran/viirs/snpp/l2p/
THREDDS	https://www.star.nesdis.noaa.gov/thredds/catalog/swathSNPPVIIRSSCIENCEL2PWW00/catalog.html

L3U data are available through the following servers

Service	Resource Locator
FTP	ftp://ftp.star.nesdis.noaa.gov/pub/socd2/coastwatch/sst/ran/viirs/snpp/l3u/
THREDDS	https://www.star.nesdis.noaa.gov/thredds/catalog/swathSNPPVIIRSSCIENCEL3UWW00/catalog.html

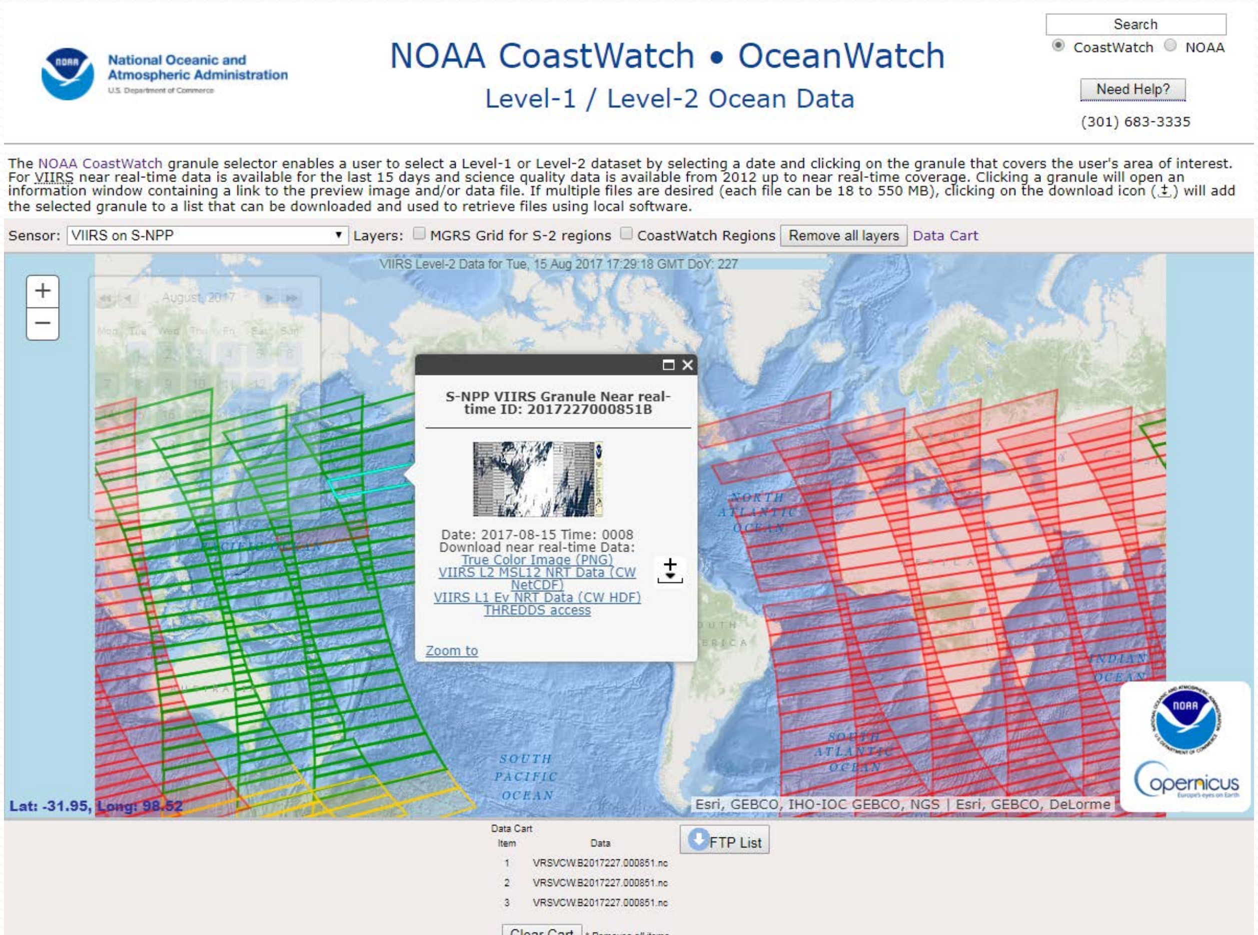
[Please acknowledge "NOAA CoastWatch/OceanWatch" when you use data from our site and cite the particular dataset DOI as appropriate.]

NRT Search



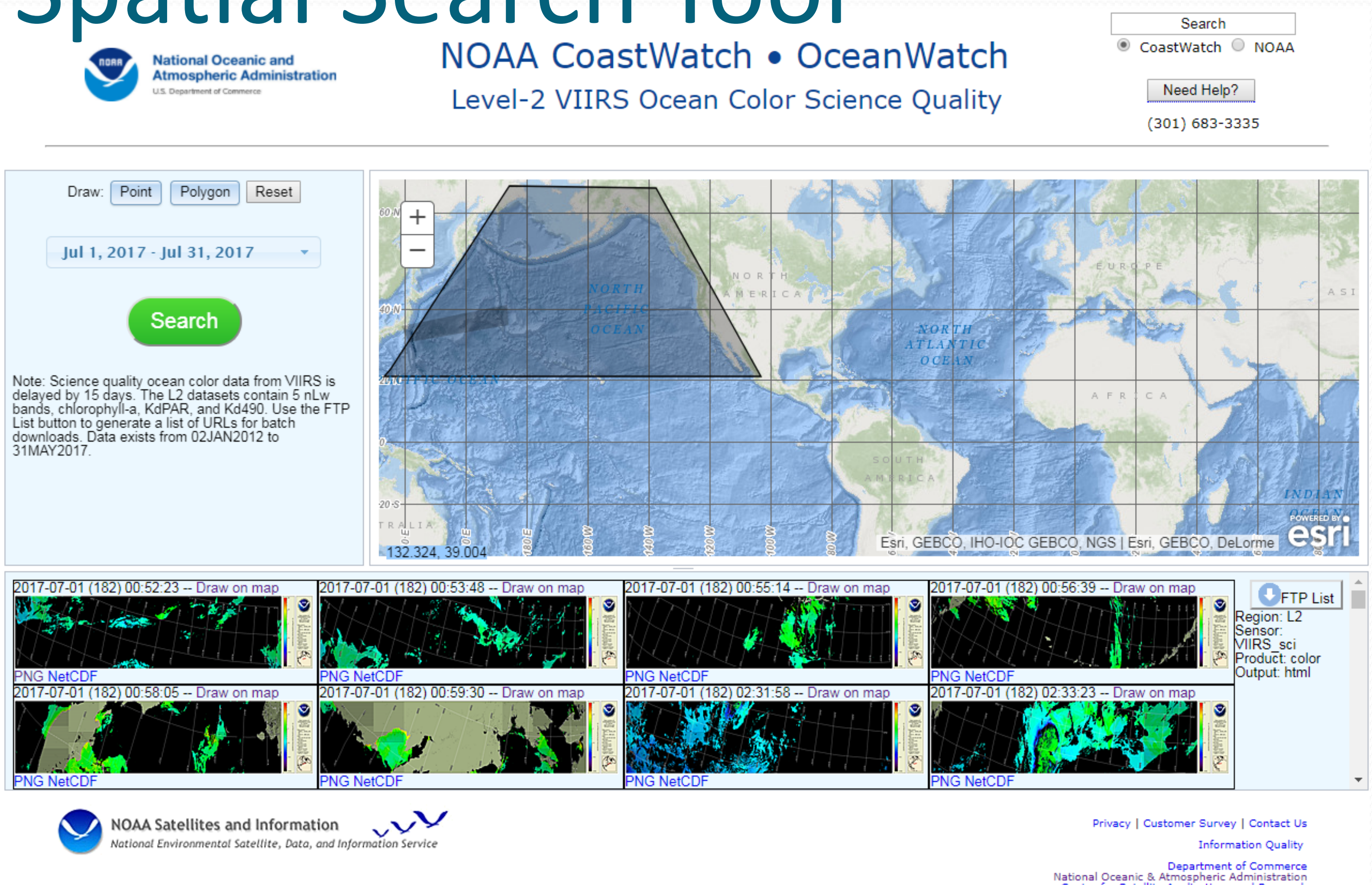
https://coastwatch.noaa.gov/cw_html/NearRealTimeSearch.html

L2 Granule Selector



https://coastwatch.noaa.gov/cwn/cw_granule_selector.html

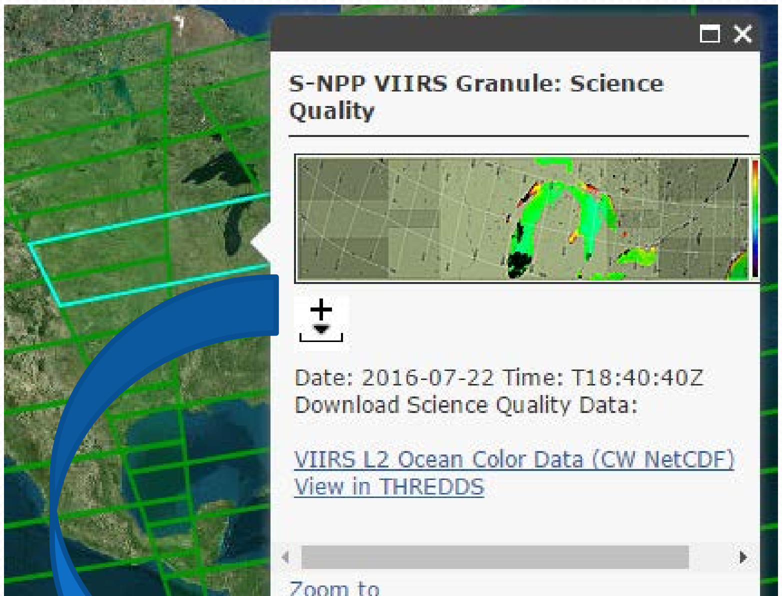
L2 Spatial Search Tool



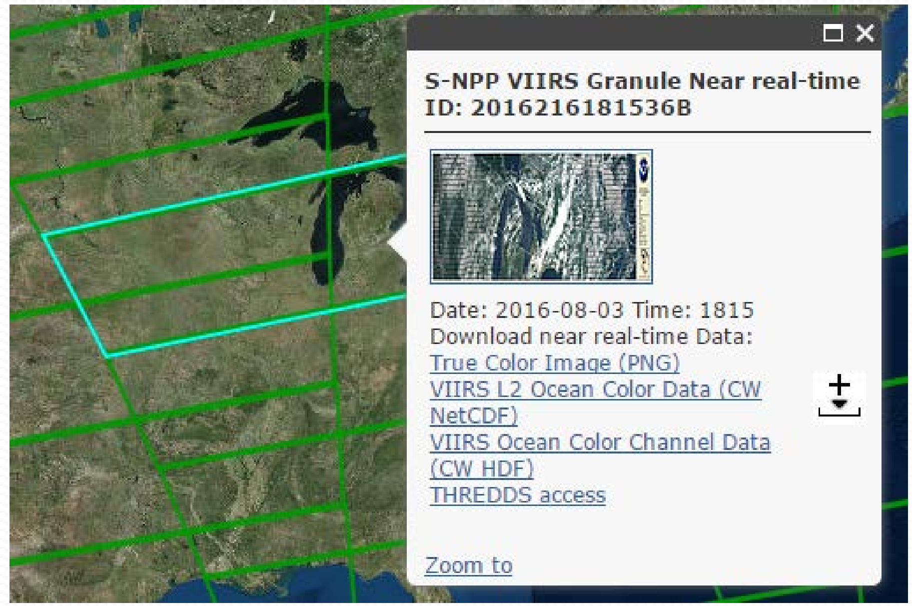
https://coastwatch.noaa.gov/cw_html/cw_polygon_search.html#searchbox

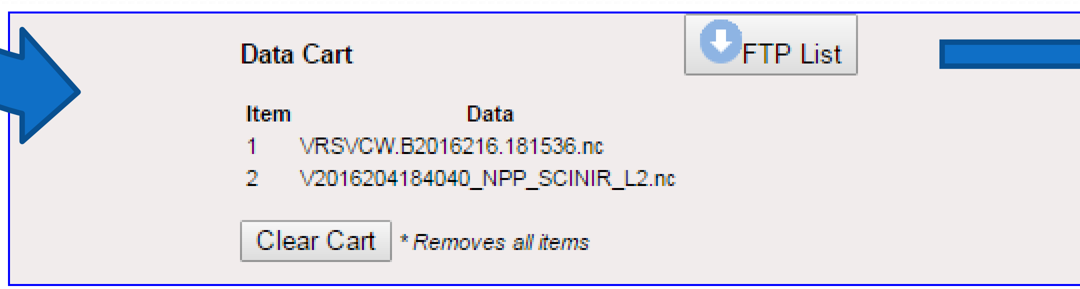
Example of VIIRS Data Cart

Science Quality RAN

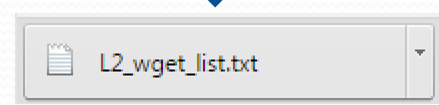


Near real-time





For batch download



Data Stewardship and Long-Term Archive by NCEI

- NOAA CoastWatch/OceanWatch is prepared to deliver ACSPO VIIRS RAN1 GAC data for data stewardship and long-term archiving by NCEI (GHRSST; Tier 1, 2).
- Arrangements between STAR (via CoastWatch) and NCEI are back in progress after some delays.

Sentinel-3A

- A Cooperative Arrangement between the United States and the European Commission and technical arrangements between NOAA and EUMETSAT (and NOAA and ESA for S1 and S2) are all complete.
- EUMETSAT NRT data transfer via terrestrial multicast to NOAA/STAR is now routine. S3 marine data (OLCI, SLSTR and SRAL). CoastWatch is routinely serving OLCI L1b and L2. SLSTR and SRAL will be coming online.
- NOAA CoastWatch/OceanWatch is the primary US data distributor of S3 marine data
- S3 data complement VIIRS SNPP:
  - 300m spatial resolution (vs. 750m)
  - Morning orbit (vs. afternoon)

NOAA's Optimum Interpolation SST and Updates Needed

Thomas Smith[1], Viva Banzon[2], Sasha Ignatov[3], and Huai-Min Zhang[2]

1. NOAA/NESDIS/STAR & CICS-MD, 2. NOAA/NESDIS/NCEI, 3. NOAA/NESDIS/STAR

The contents of this presentation are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of NOAA or the U.S. Government

NOAA Satellites and Information
National Environmental Satellite, Data, and Information Service

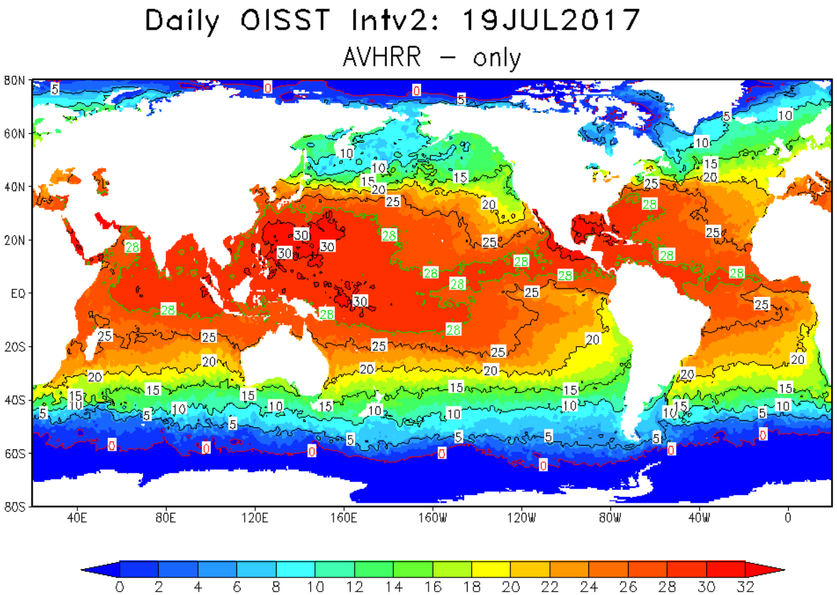
cics-md
Cooperative Institute for Climate & Satellites
UNIVERSITY OF MARYLAND

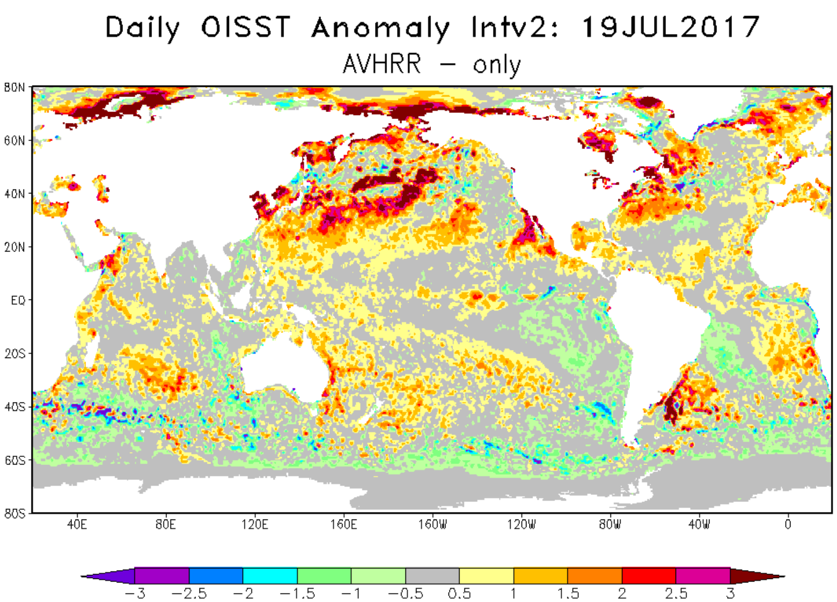
Outline

- OISST: stable analysis, widely used for multi-decade study and monitoring
- Updates needed:
  - VIIRS data need to be incorporated, requiring testing
  - Processing updates needed
- Without attention the analysis could become less reliable

The OI 0.25° Daily Analysis

- Example mean and anomaly for 1 day, using Navy AVHRR data
- Bias adjustments for cloud & aerosol contamination
- Large to mid scale features resolved and error estimates available
- Long record (since late 1981)
- Widely used for long-term monitoring and study





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Satellite SSTs and Testing Needed

- SSTs estimated from radiation
  - Atmospheric corrections for clouds and aerosols
  - Compared to older algorithms, ACSPO SSTs have greater sampling: need to evaluate changes from using ACSPO SSTs
  - First: compare ACSPO AVHRR-based analysis to current AVHRR-based analysis
  - Next: compare ACSPO AVHRR-based OISST to ACSPO VIIRS-based OISST

ACSPO Data Improvements

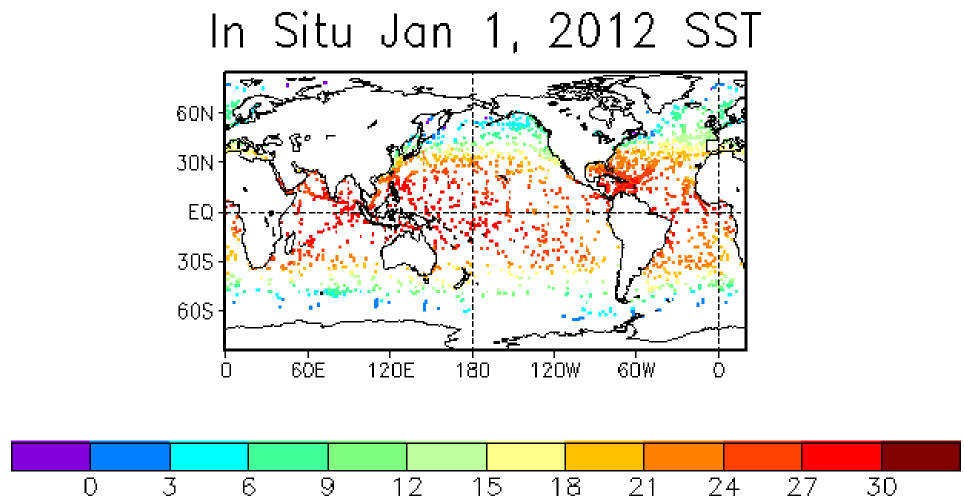
- Current status:
  - AVHRR Navy SST used after 2005
  - AVHRR Pathfinder SST used for historical period (1981-2005)

- New ACSPO operational AVHRR-based SST
  - More advanced algorithm, better coverage, less resolution loss
  - Becoming easier to use for operations

- ACSPO VIIRS data
  - continues infrared time series after AVHRR era ends
  - need to be tested for 0.25° long-period analysis and for a higher-resolution analysis

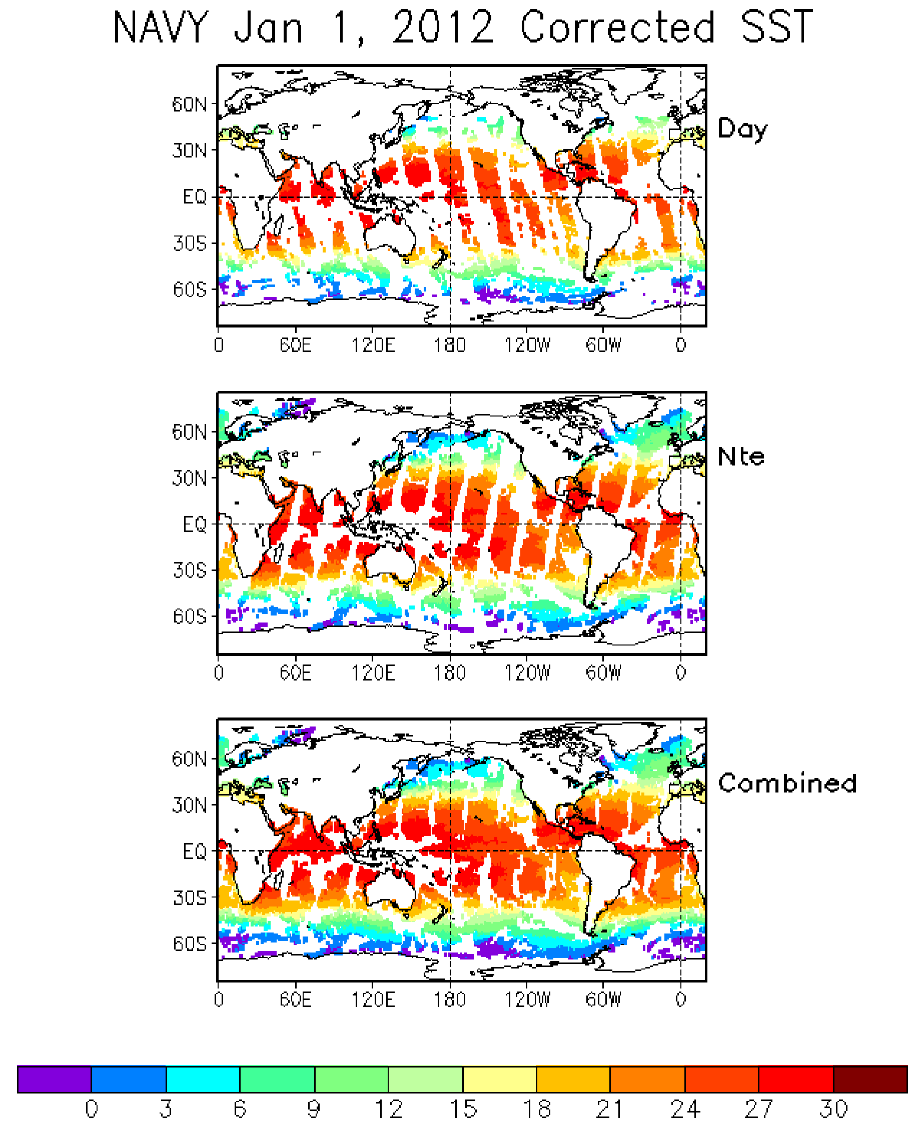
In Situ Data

- One day: 1 Jan 2012
- Ship & Buoy combined sampling typical for the year
- Mostly used for correcting satellite biases
  - Not enough sampling for high-resolution analysis
- Here averaged to 1° grid to more clearly show sampling



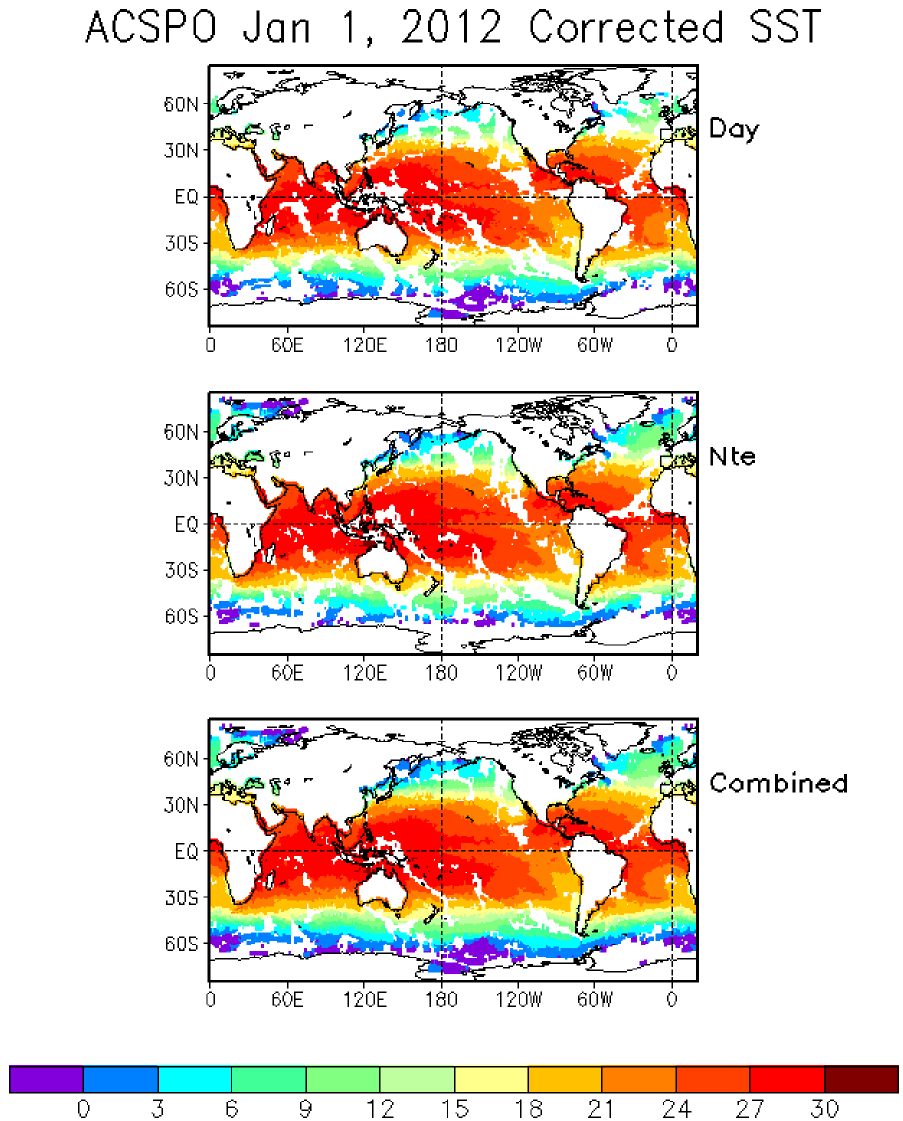
NAVY AVHRR Daily

- One day: 1 Jan 2012
- Day & Night show satellite passes
- Combined sampling for daily analysis



ACSPO AVHRR Daily Data

- Same day: more sampling
- Expanded data reduces sampling errors
- Data errors need more evaluation



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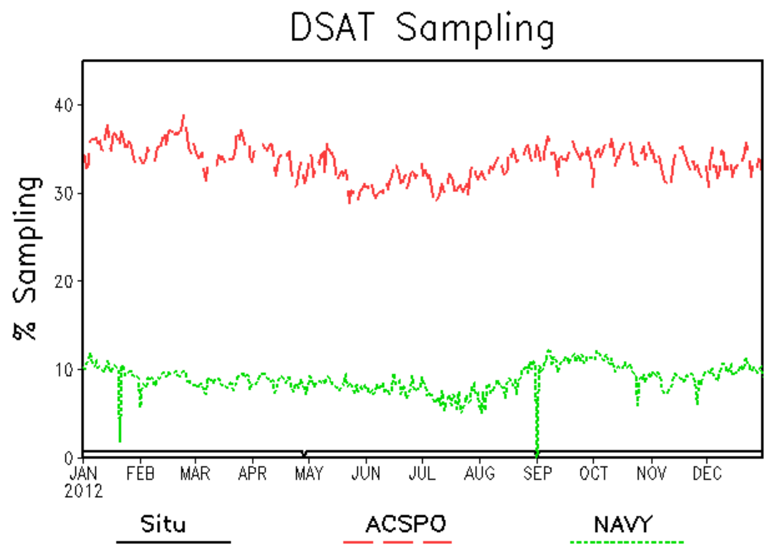
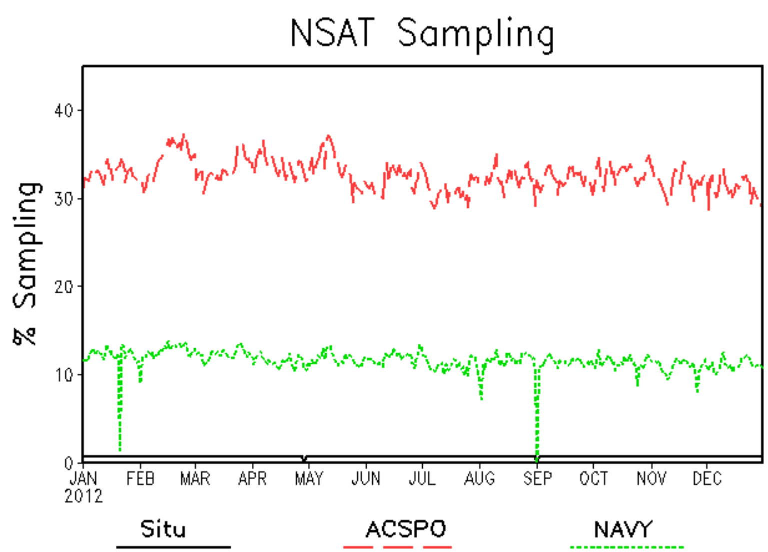
Sampling Comparisons

- ACSPO sampling about 3 times NAVY sampling of 0.25° grid squares

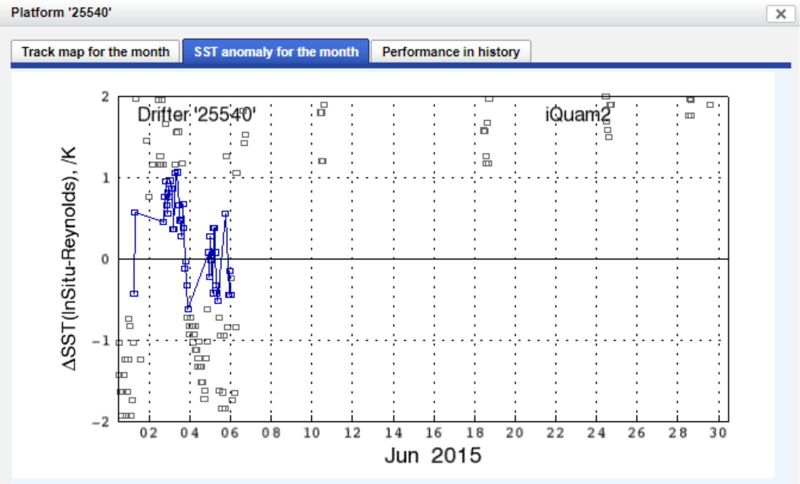
Averages	ASCPO	NAVY	In Situ
DSAT	33.5	8.9	0.7
NSAT	32.6	11.6	0.7





Arctic Problem: 1 Buoys

Buoys can get trapped in melt pond or on top of ice: careful QC needed



Plot of single buoy over time (lat=84.4, lon=-21.2) shows acceptable values in blue, questionable in gray

From https://www.star.nesdis.noaa.gov/sod/sst/iquam/v2/index.html

- Ice-mass balance buoy (front): SLP, SAT, SST, ice T, snow depth, ice thickness
- Balls (background) SVP-B common drifters
- Arctic buoys began after 2010, QC delayed so not used in current OISST
- Could use iQuam (STAR) criteria for screening

Picture courtesy of Ignatius Rigor, U. Washington, and US Interagency Arctic Buoy Program and International Arctic Buoy Program

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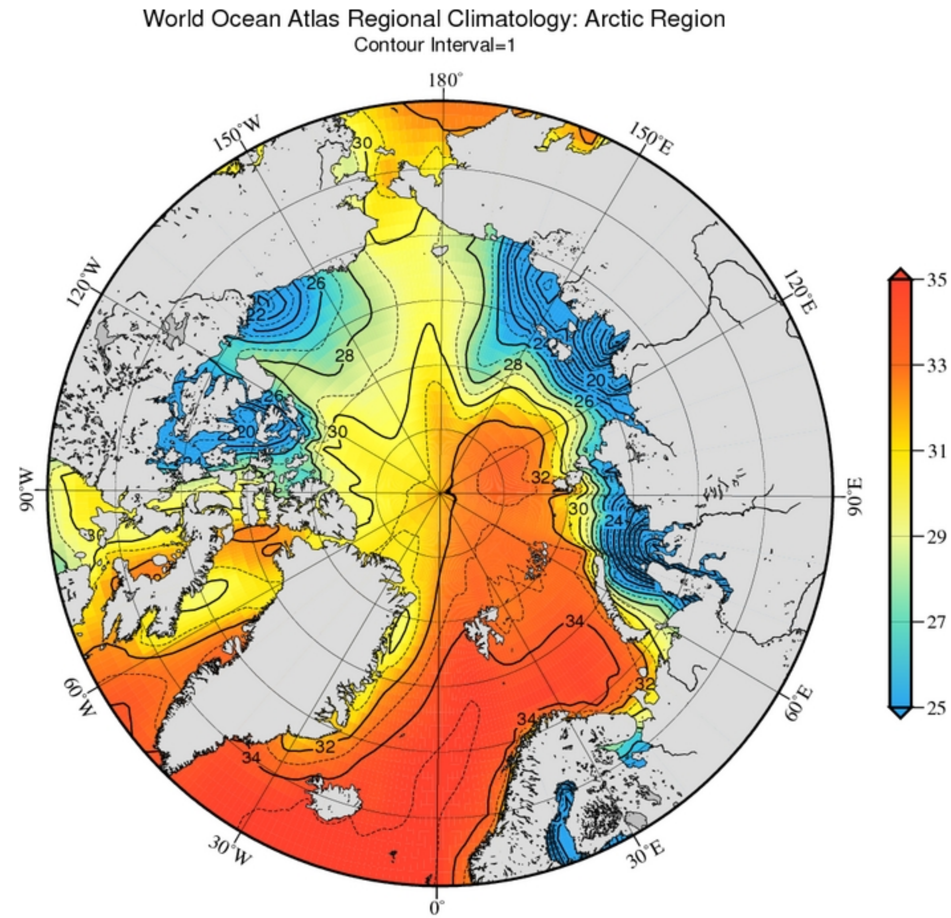
Arctic Problem: 2 Salinity Variations

- OISST assumes constant ocean freeze temperature -1.8C (S about 33)
- Actual freeze temperature changes due to salinity
- OI smoothing spreads errors in the sparse-data Arctic

S	Tf (°C)
20	-1.08
25	-1.36
30	-1.64
35	-1.92



Summer (Jul.-Sep.) salinity [PSS] at the surface (one-degree grid)

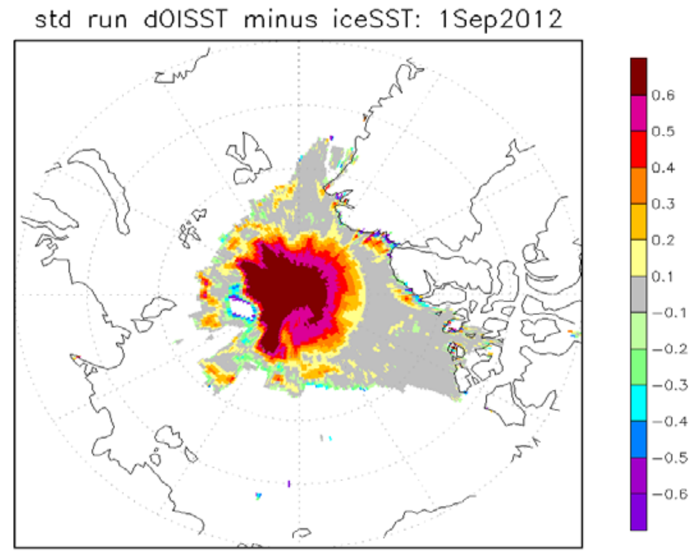
Arctic Problem: 3 Analysis

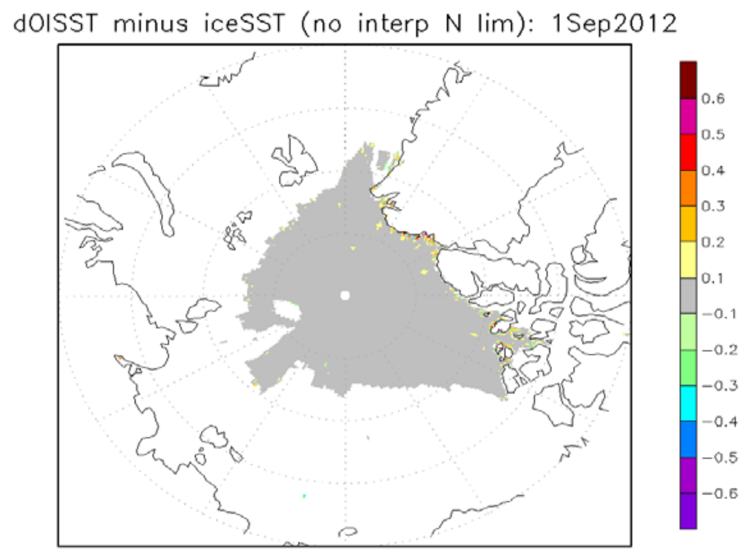
Too much smoothing & extrapolation to the pole in Arctic, spreading sparse warmer temperatures

Analysis with Smoothing – IceSST (upper)

Analysis without smoothing difference (lower)

More testing and validation needed





Improved Analysis Statistics

Weekly 1° OI Average Scales

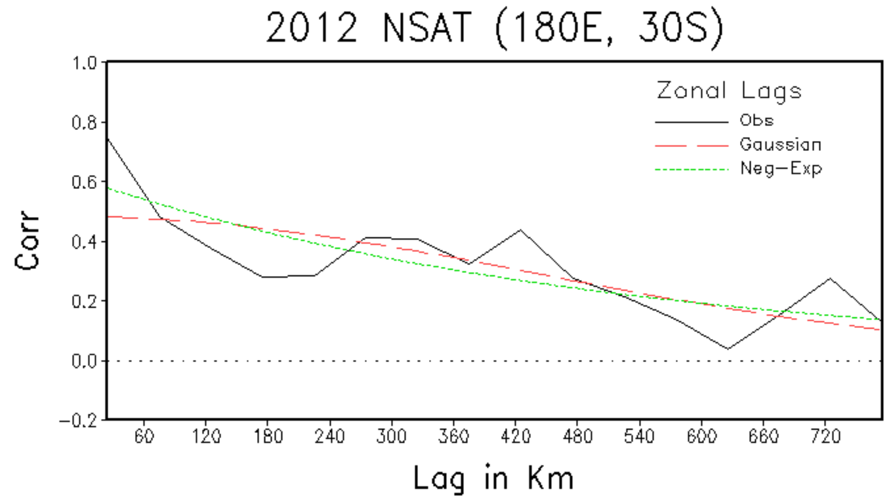
Zonal	859 km
Meridional	608 km
Noise/Signal Variance	0.77-2.13

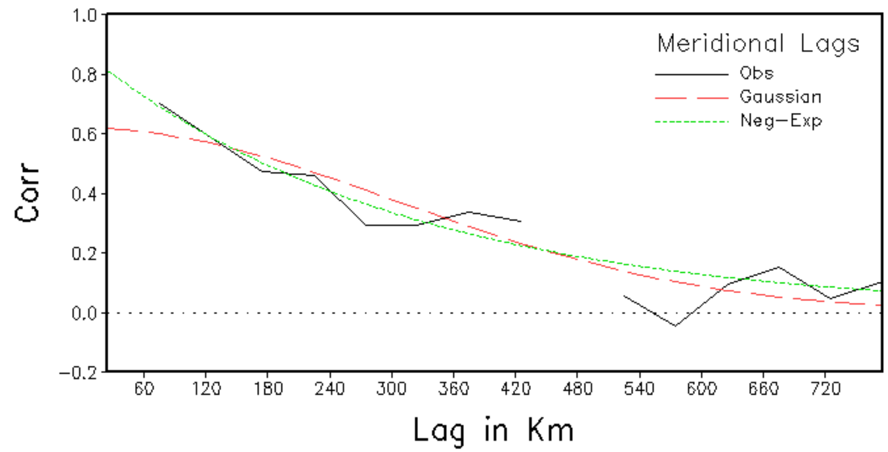
Daily 0.25° OI Average Scales

Zonal	151 km
Meridional	155 km
Noise/Signal Variance	0.25

ACSPO Daily 0.25° Preliminary Estimates

Zonal	270 km
Meridional	240 km
Noise/Signal Variance	0.15-0.29





Resolution Improvements

- VIIRS Available for about 6 years, allows better resolution
- ACSPO SSTS also available for AVHRR from 2002
- Higher spatial resolution possible for the VIIRS period
  - Separate HR analysis to continue into future
  - Longer record 0.25° analysis still needed
- Due to greater sampling from ACSPO processing, may be possible to use it to estimate daily cycle for longer record

Summary

- Long-record OISST is needed: AVHRR era is ending
- Analysis needs updating for continued high-quality operations
- New data needs testing: ACSPO AVHRR, ACSPO VIIRS, updates of Pathfinder and ICOADS
- New higher-resolution analyses are possible for a shorter period
- Without additional resources testing and updates are likely to be delayed

JPSS SST assimilation in the US West Coast Ocean Forecast System (WCOFS)

Alexander Kurapov
College of Earth, Ocean, and Atmospheric Sciences,
Oregon State University /
Visiting Scientist at NOAA (NOS, NESDIS)

In collaboration with NOAA partners: E. Bayler (JCSDA), E. Myers (NOS/CSDL), A. Ignatov (NESDIS/STAR), L. Miller, E. Leuliette (NESDIS/STAR)

Academic partners: A. Moore (UCSC), J. Wilkin (Rutgers U.), S. Erofeeva (Oregon State U.)

WCOFS domain & dynamics (3D & nonlinear):

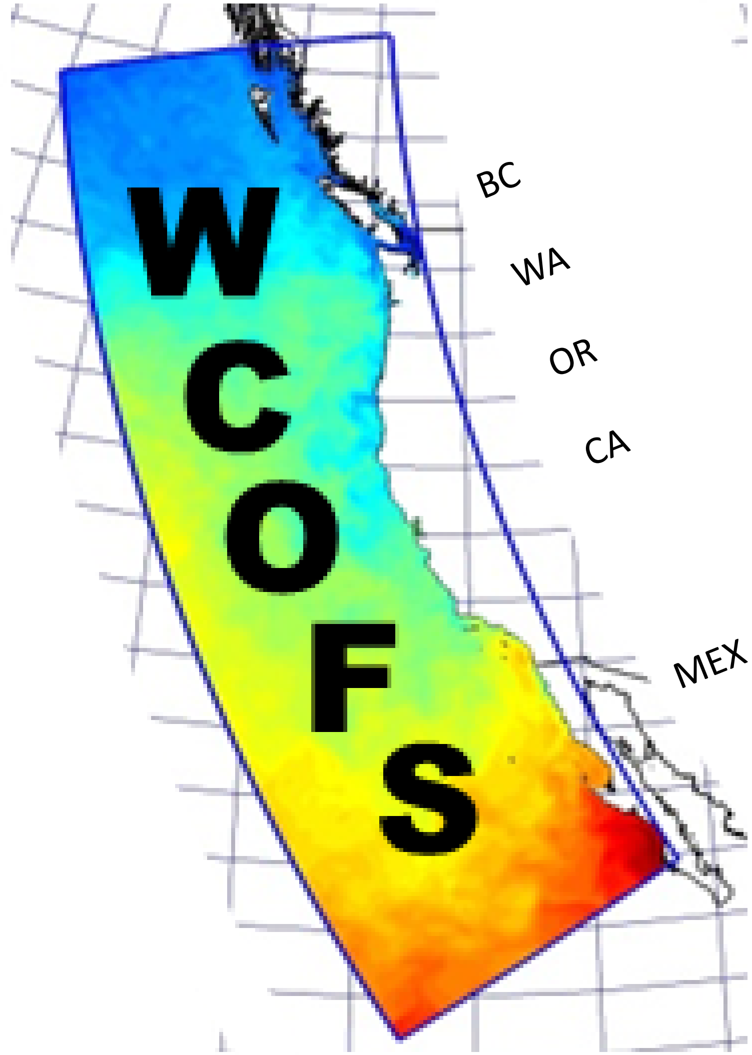
- North Pacific Current enters the domain between 45-50N (off OR-WA) and splits into the southward flowing California Current System and northward flowing Alaskan Stream

- Shelf (CA-OR-WA): seasonal wind-driven upwelling and downwelling

- Coastal currents instabilities and separation into the adjacent interior ocean

- Coastally trapped waves propagating from south to north

- River influences



Goal: 3-7 day forecasts of oceanic conditions (coastal sea level, currents, oceanic fronts, etc.), constrained by data assimilation (DA)

Data assimilation: Optimally combine a 3D ocean dynamical model and available observations from different platforms

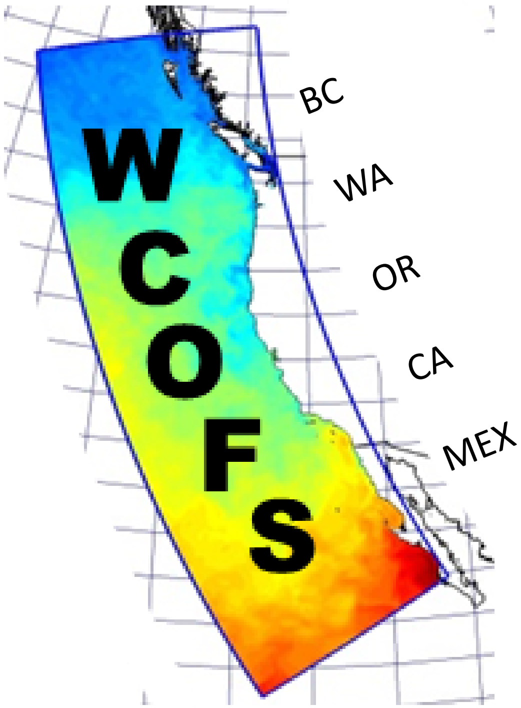
=> Improved initial conditions for the forecasts

Motivation for operational prediction (shelf currents, coastal sea level, SST, fronts):

- national security,
- navigation,
- search and rescue,
- environmental hazard response (oil spills, marine debris, etc.),
- fisheries,
- coastal weather prediction,
- beach erosion,
- recreation,
- new business opportunities,
- public health,
- education,
- local community involvement,
- new technology development, etc.

Credit : Eric Mortenson, Doug Beghtel /The Oregonian, www.naturalbuy.com, USCG, http://i.livescience.com/, Grantham et al. (2002)

WCOFS:



Model dynamics are based on the Regional Ocean Modeling System (ROMS): 3D, fully nonlinear, primitive equations, hydrostatic & Boussinesq approximations, vertical turbulence parameterization scheme

Horizontal resolution: 2-km
Vertical resolution: 40 terrain-following layers

Forcing:

- Surface winds and heat flux (12-km NOAA NAM)
- @open boundary: global model (HYCOM/RTOFS)
  + tides (Oregon State Tidal Inverse Soft.)
- River inputs: Columbia R., Fraser R., small rivers in Puget Sound

(Assimilation: at 4 km horizontal resolution, interpolate correction to the 2-km grid for forecasts)

WCOFS development, focus areas:

1. Skill assessments for the hindcast solution (2009-2014), improvements in the model formulation:

   Kurapov, A.L., S. Y. Erofeeva, and E. Myers, 2017: Coastal sea level variability in the US West Coast Ocean Forecast System (WCOFS), Ocean Dynamics, 67: 23. doi:10.1007/s10236-016-1013-4

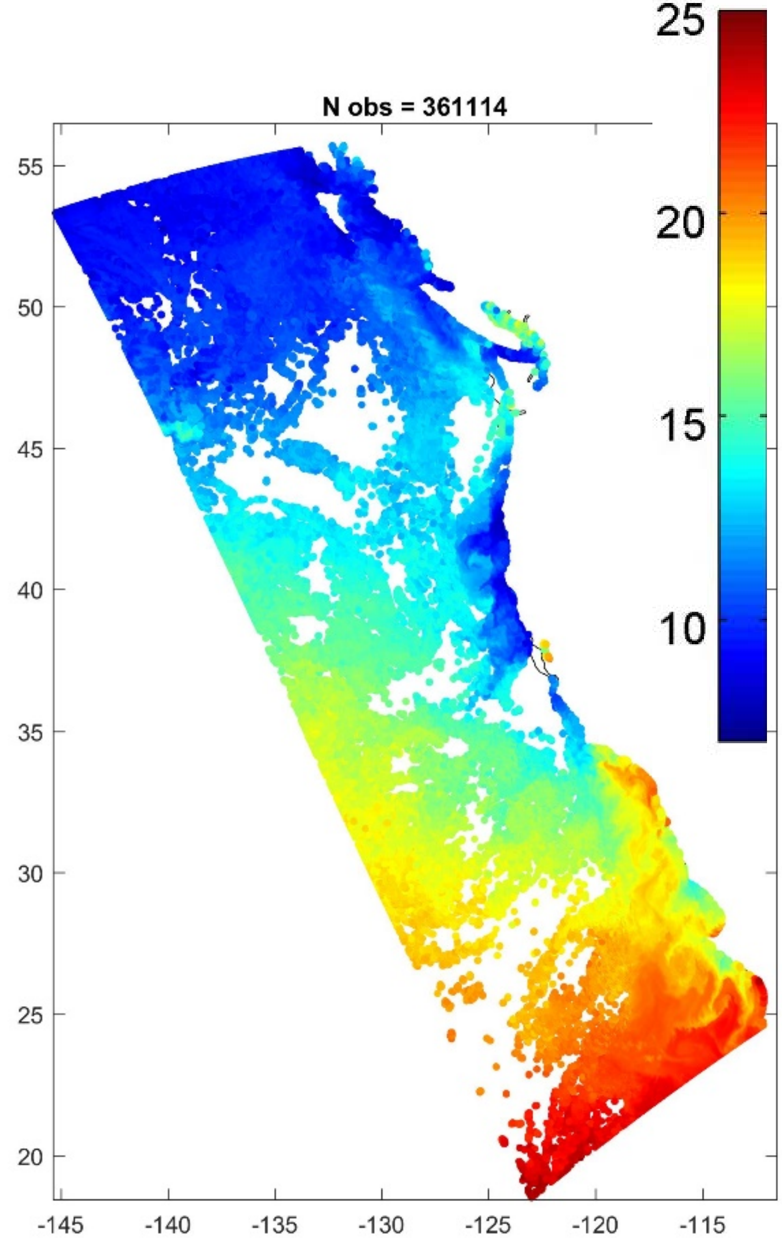
   Kurapov, A. L., N. Pelland, and D. L. Rudnick, 2017: Seasonal and interannual variability in oceanic properties along the US West Coast continental slope: inferences from a high-resolution regional model, J. Geophys. Res., in press

2. Real-time WCOFS without assimilation (w/ Jiangtao Xu, CO-OPS)
3. Data assimilation, hindcast experiments (feasibility, forecast metrics, cost-benefit analyses)

Jets and eddies are observable:

- Satellite SST
- Satellite altimetry
- Land-based HF radar surface currents

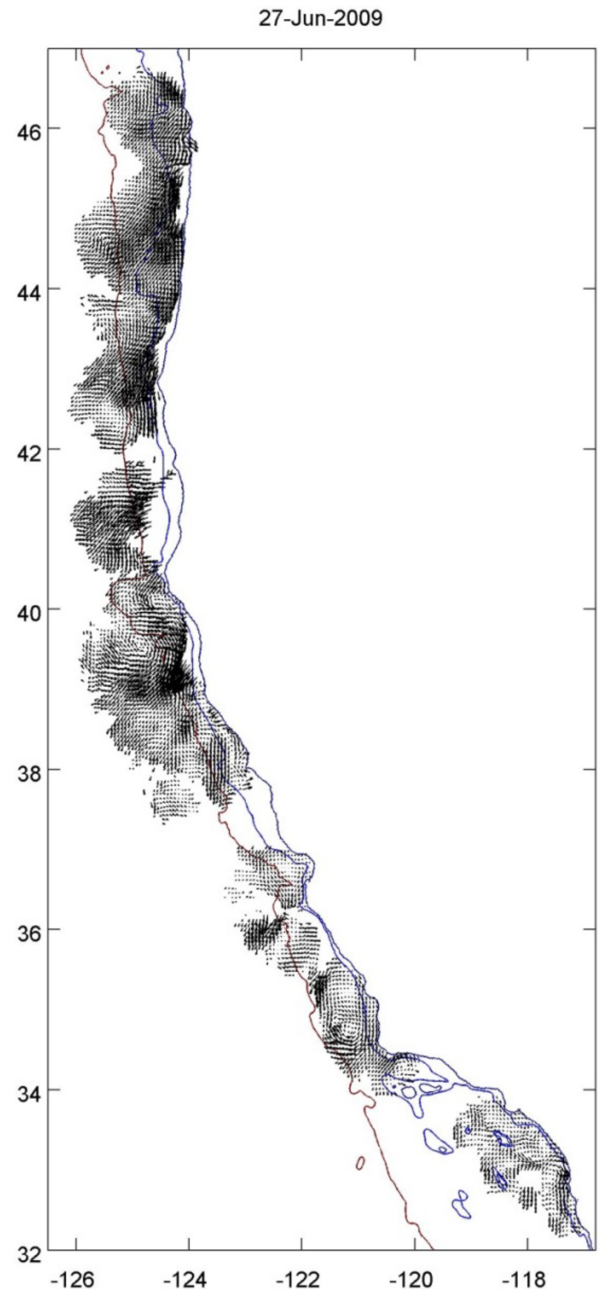
+ glider T & S vertical sections, Argo T & S profiles



JPSS L3U, 1-3 Jun 2014

HF radar surface currents (can be used for assimilation or forecast verification)

(we have tried assimilation of hourly data maps, 6-km resolution)



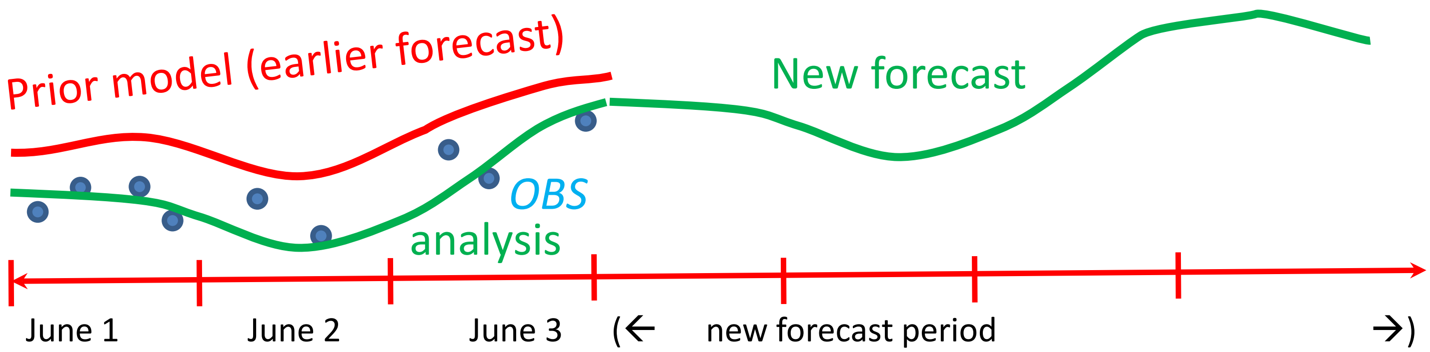
WCOFS4 DA Test, 3-day assimilation window

Observations:

- SST: JPSS VIIRS L3U (Ignatov et al., NOAA/NESDIS/STAR)
- SSH: Alongtrack altimetry, (1Hz/6 km alongtrack resolution, Jason, Cryosat, etc.)

Assimilation methodology, 4DVAR:

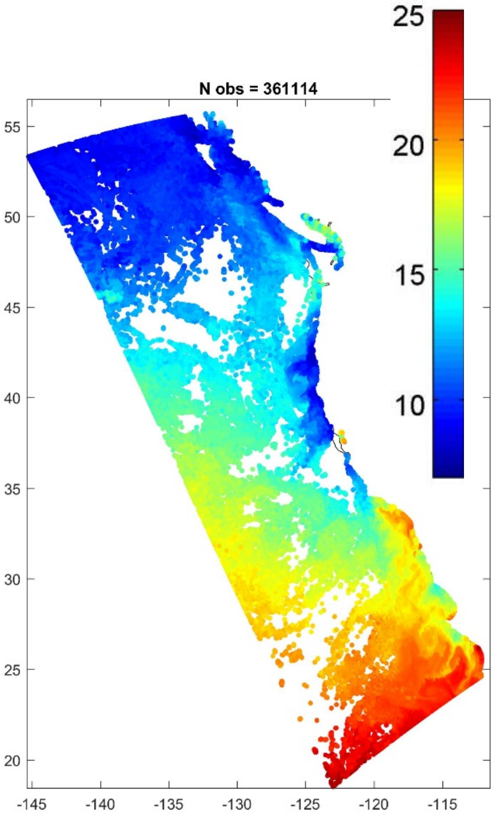
Cost function = || model deviation from prior ||^2 + || model – obs ||^2 → min



(a) Over a given time interval (here, 3 days: June 1-3) use available observations and **the adjoint model** to correct initial conditions for the analysis (here, at the beginning of June 1)

(b) The analysis provides improved initial conditions for new forecast (6/4-7)

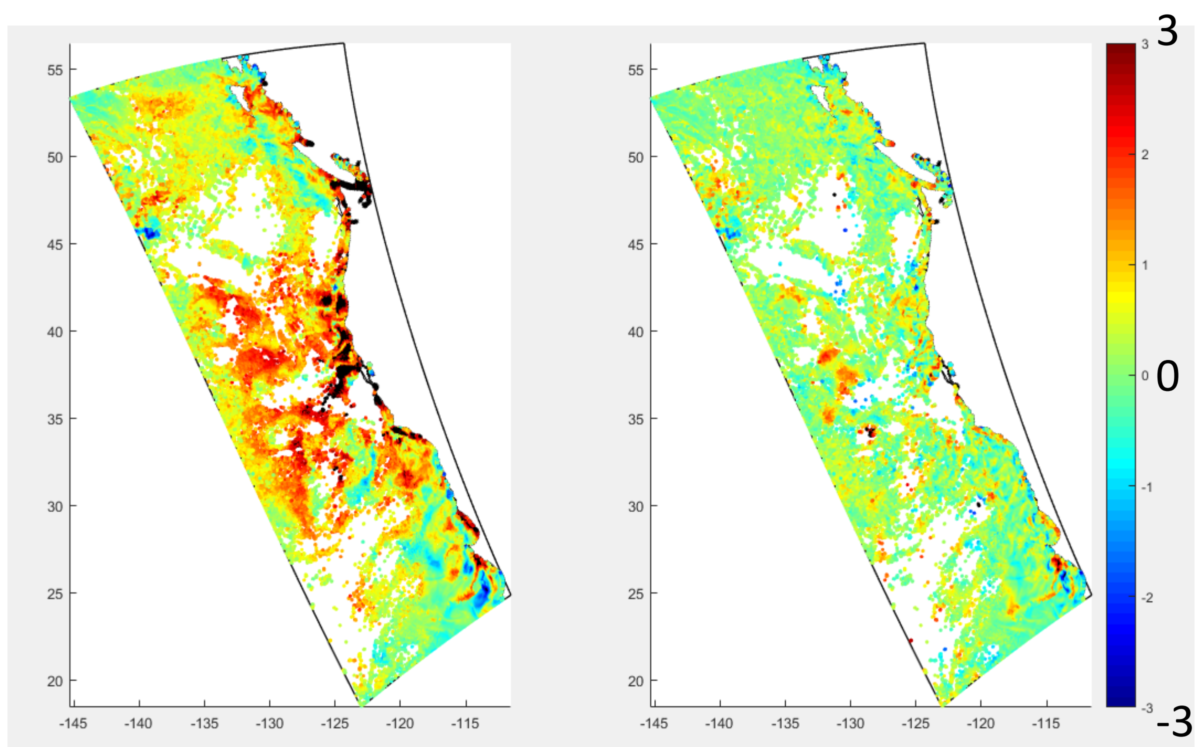
SST: All obs in the 3-day interval



Data fit, SST (model-observation difference, degrees C)

Before DA (rmse=1.19)

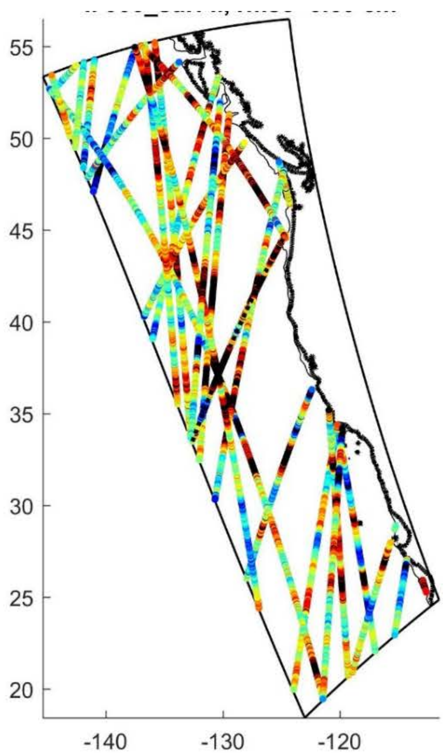
After DA (rmse = 0.55°C)



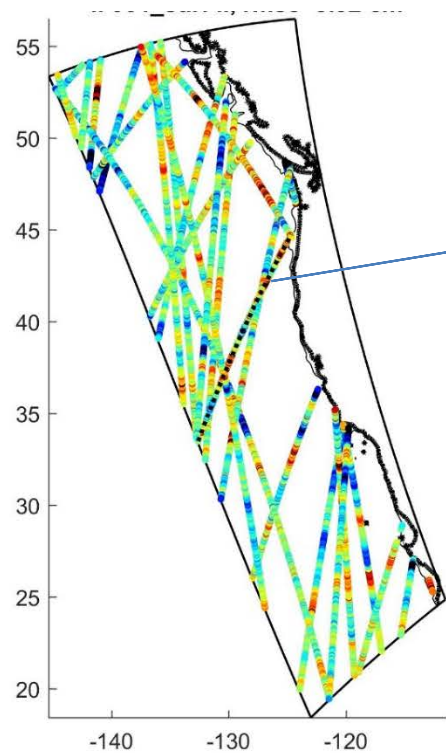
DA: Cooling at the surface. Correction of the SST front locations

Data fit, SSH (non-tidal, model-observation difference, m)

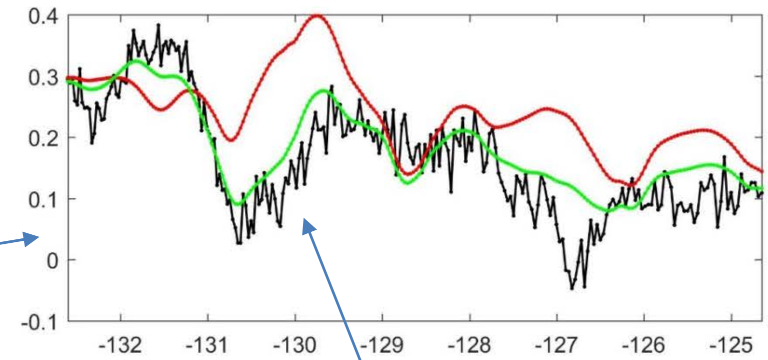
No DA (rmse=6.60 cm)

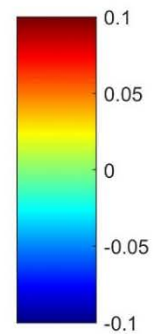


DA (rmse = 3.92 cm)



Alongtrack SSH (m): ***OBS***, ***no DA***, ***DA***





DA: improved representation of the slope of the ocean surface => surface eddies and jets

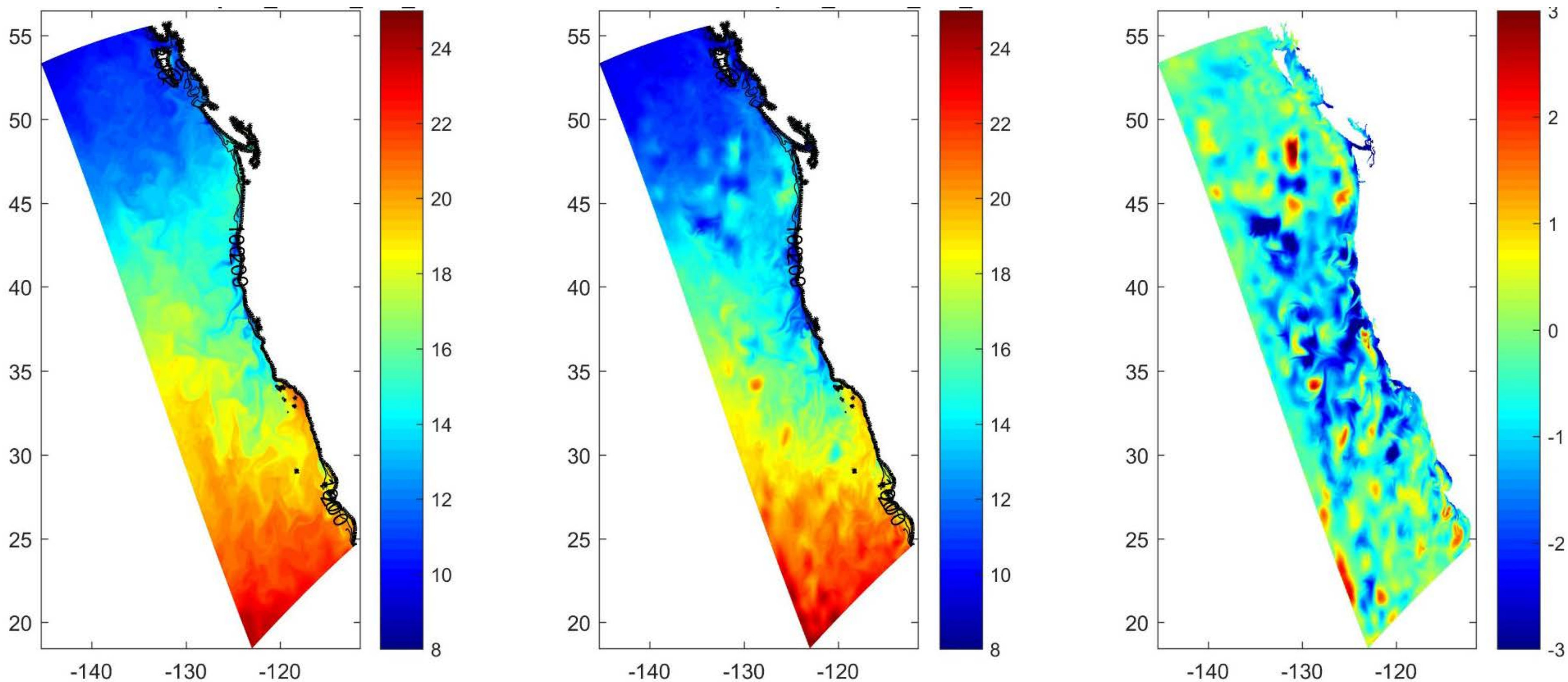
(All the tracks in the 3-day exp.: color shows model-obs difference)

DA IMPACT: SST

cooling the surface (compensate to weaker than observed upwelling)

(SST, 6/3/2014 00UTC:

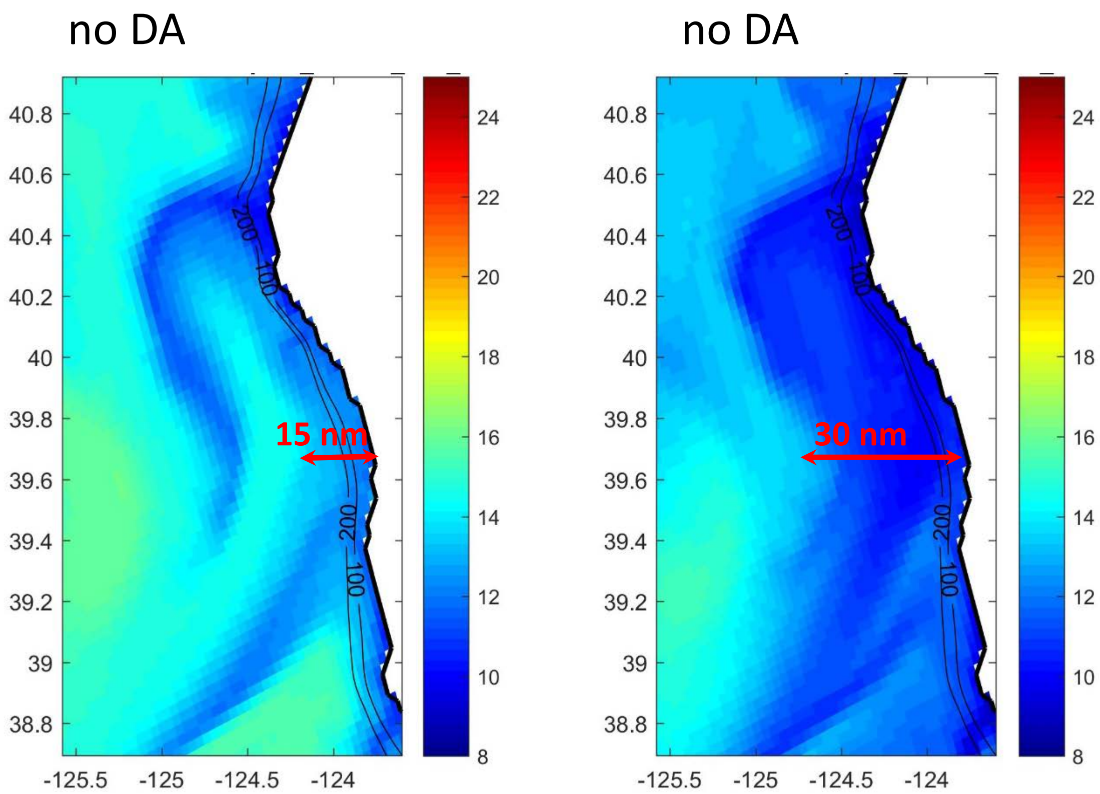
no DA DA difference: DA – no DA, degr C



Impact of SST assimilation, front location of C. Mendocino (CA)

Fishermen have been using SST forecasts to guide their operations… the SST front is where tuna are likely

In the figure: model without assimilation will suggest a 2 hour trip to the front, while the actual front is much farther, a 4 hour trip (at traveling at a speed of 7.5 knots)



Note: the offshore front location changes appreciably over 2-3 days. 3-day forecasts will be valuable.

Strongest currents are along the front (up to 2 knots): use to optimize routes

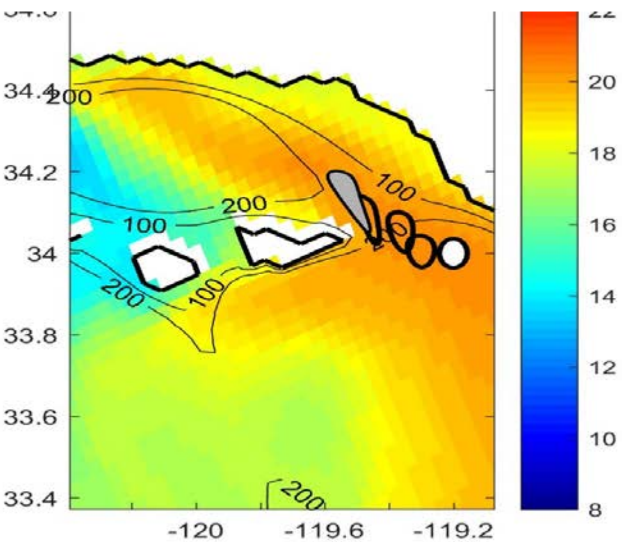
DA Impact, "oil slick" dispersion in Santa Barbara Channel

Background color*: *<u>SST</u> (shown on Jun 3, 2016)

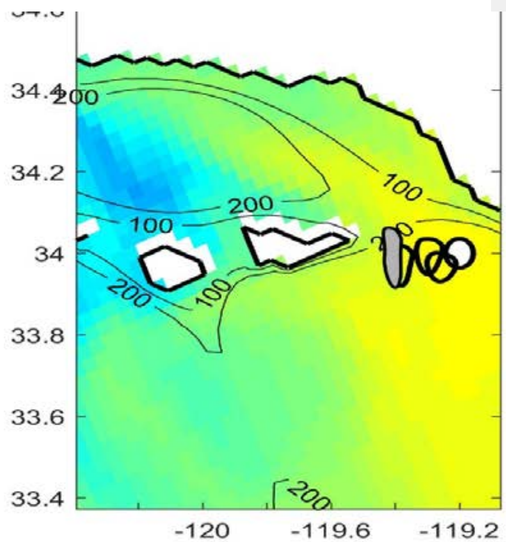
A patch is released on the surface and its contour is tracked using model (uv) for 2 days (6/2-3)

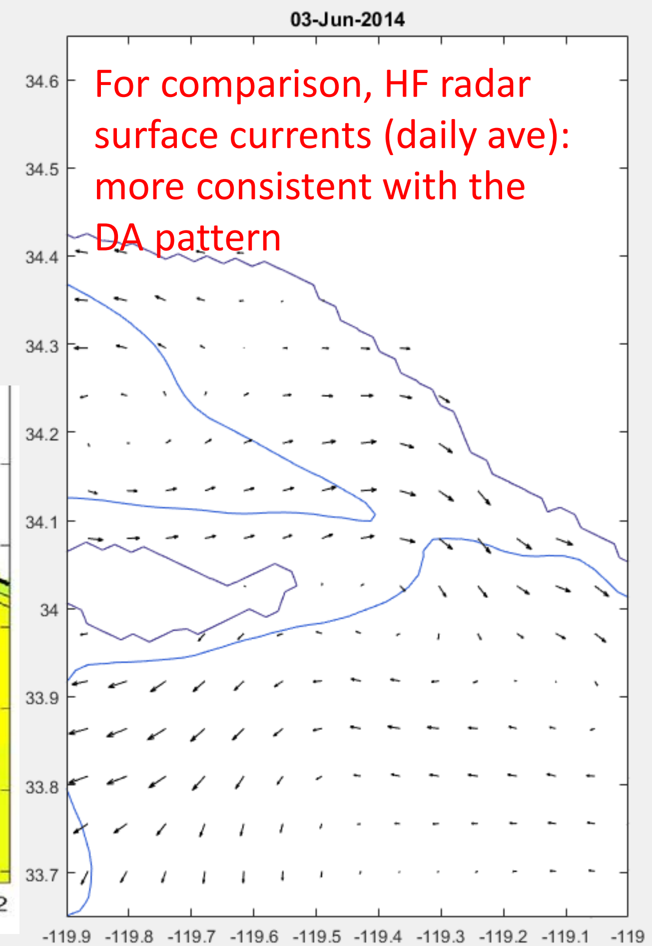
WHITE: beginning (4-km radius disk), GRAY: 48 hours later

No DA



DA





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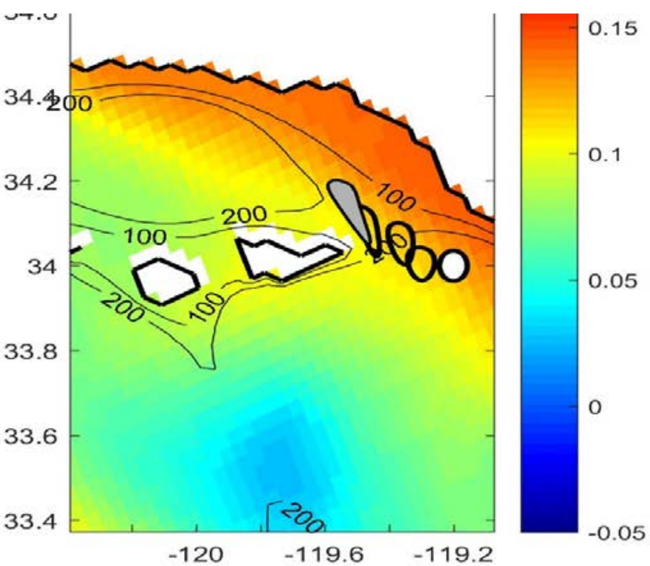
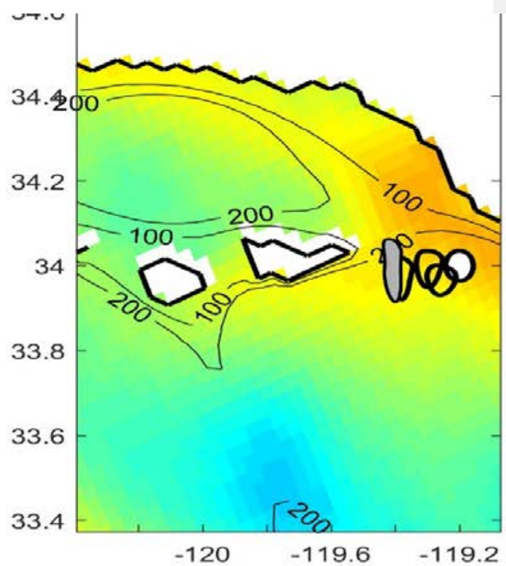
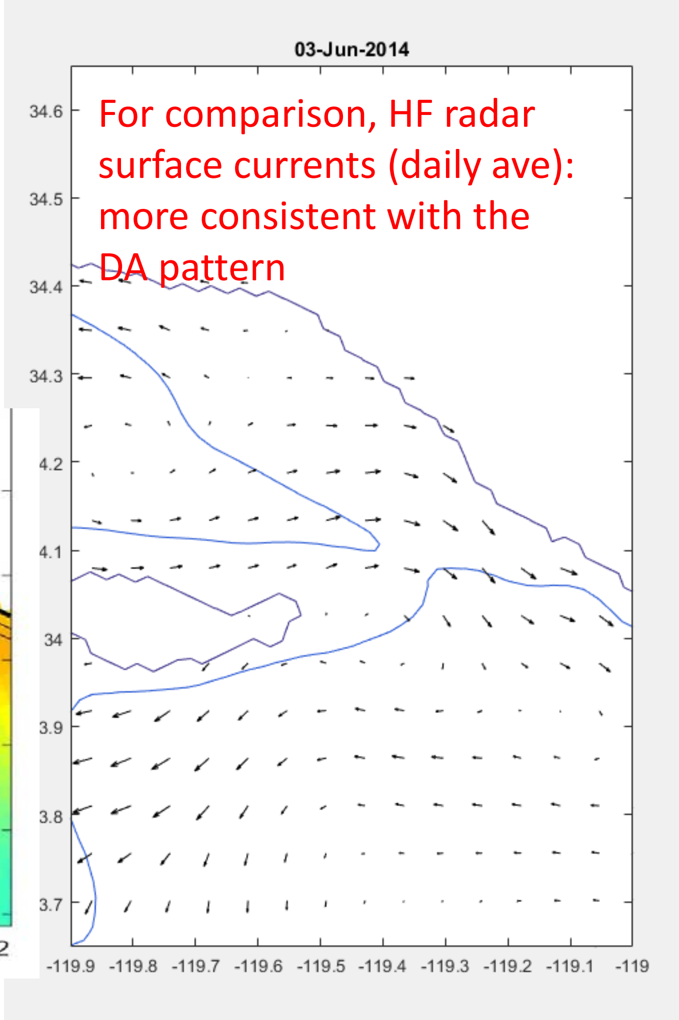


DA





SUMMARY:

JPSS L3U SST will be assimilated into the WCOFS using 4DVAR, providing

- Improved 3-day forecasts of SST and other oceanic variables
- Synthesis of SST with other observational data
- Gap-free maps of SST (dynamically based time and space interpolation of the SST data)

Initial assimilation tests using JPSS L3U SST show impact on the front location and surface material transports, relevant for navigation, fisheries, and environmental hazard response

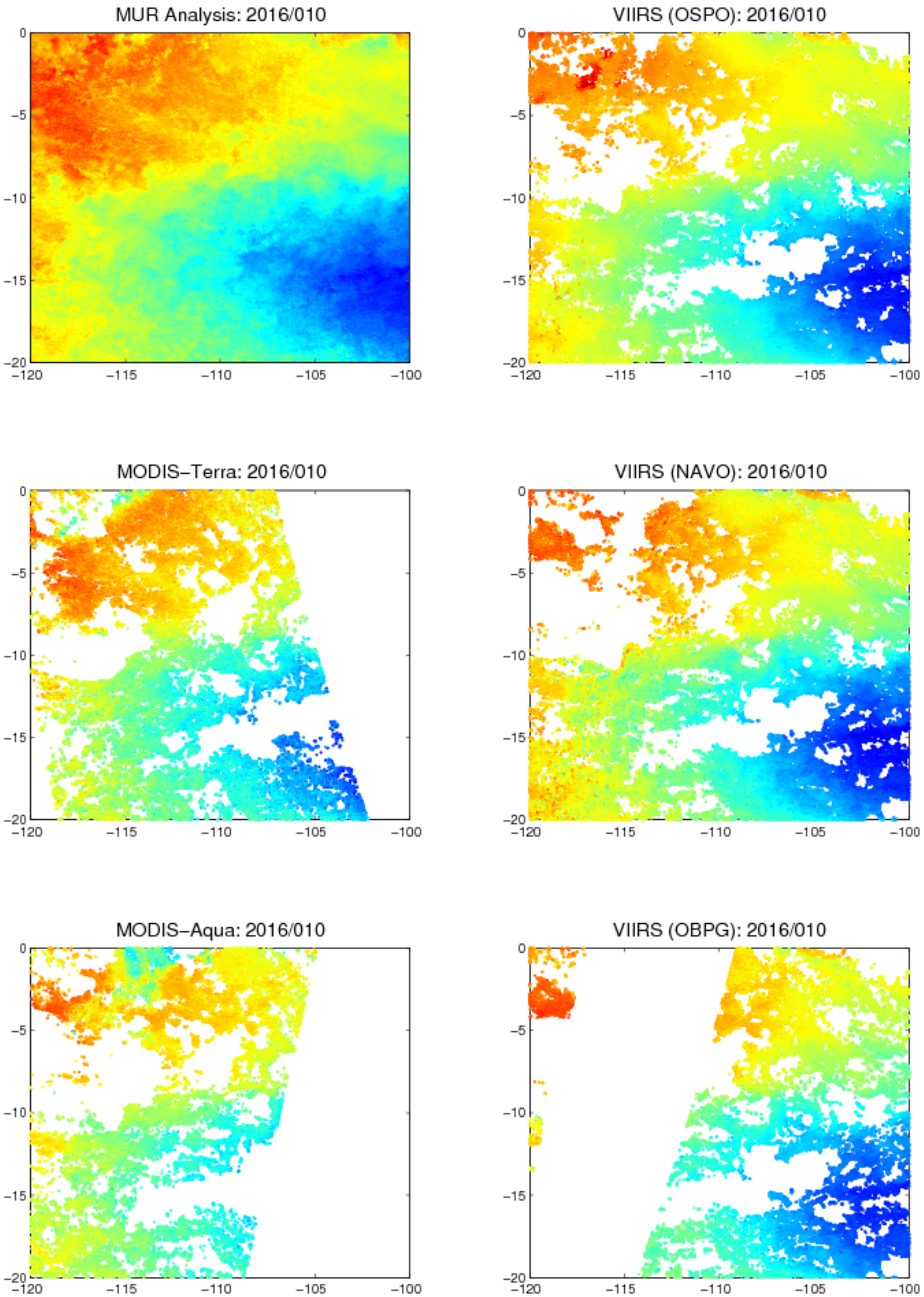
Users & uses of WCOFS forecasts:
- Search & rescue
- Environmental hazard response (e.g., NOAA ORR)
- Fisheries (industry, management)
- Onshore pathogens transport
- Navigation

Plans to assimilate VIIRS SST in JPL Multi-scale Ultra-high Resolution (MUR) L4 analysis

Mike Chin, JPL

“MUR” Gridded SST Analysis

- *Multi-scale Ultra-high Resolution (MUR)* SST analysis uses a **1-km grid**.
- MODIS is the source of high-resolution SST retrievals; no VIIRS ingested at present.
- VIIRS is the **best option** for independent data to *validate* the **spatial patterns at fine scales**.
- MUR plans to ingest VIIRS in the future.



- We welcome availability of multiple products which allow us to qualify the VIIRS features before comparing to MUR.
- The three existing VIIRS L2P products (ACSPO, NAVO, NASA-OBPG) are different in quality pixel flagging as well as subtle differences in the SST values/features.
- Spatial registration of the pixels would pose some challenges in comparing VIIRS against MUR, or MODIS which are ingested by MUR, due to the differences in the sampling patterns and relatively fast (sub-daily) evolution of the small features that we are interested in.
- Registration issue also exists for comparison between Himawari-8 and MUR since H8 contains data voids (cloud) and MUR does not match high frequency sampling of geostationary satellites.
- Work is underway to develop space-time registration techniques for both VIIRS and Himawari8 for validation of the MUR product.

Validation of 1~5-km scale SST features and plans for new data sets to be ingested in MUR

- Comparison at that scale is very difficult because differences in larger-scale features could "mask" the small features of interest.
- The closer agreement between OSPO VIIRS and MUR (RMS difference of ~0.3C globally) gives us hope that we can somehow isolate the fine scale features from these two for comparison.
- The next version of MUR will ingest RAN1 AVHRR SST data from NOAA-17 to replace older version of Pathfinder AVHRR SST used by the current MUR. The L2 data (RAN1) are preferred since they preserve the geolocations (lat, lon) without truncation, which often takes place during gridding of L3 data like Pathfinder.
- The next version of MUR will finally ingest VIIRS data. The NASA (OBPG) product receives priority; two other products are still invaluable for pre-ingestion quality control (as stated above). Due to the availability of multiple products, the situation is different from the MODIS products which were difficult to evaluate through comparison.
- Again, from user's perspective, having multiple products is positive.

ARMS: Advanced Clear-Sky Processor for Ocean (ACSPO) Regional Monitor for SST

www.star.nesdis.noaa.gov/sod/sst/arms/

Yanni Ding[1,2], Alexander Ignatov[1],
Michael Grossberg[3], Irina Gladkova[1,3], Calvin Chu[3]

[1]*STAR, NOAA Center for Weather and Climate Prediction (NCWCP), USA*
[2]*CIRA, Colorado State University (CSU), USA*
[3]*City College of New York, USA*

ACSPO Regional Monitor for SST (ARMS)

Global Monitoring and Validation of satellite & blended SST products has been established in NOAA SQUAM in 2009

However, satisfactory global performance does not guarantee uniform & accurate regional performance

Complementing global analyses with more regional focus was recommended by the Joint Polar Satellite System (JPSS) Program Office

In 2016, ACSPO Regional Monitor for SST (ARMS) was launched *www.star.nesdis.noaa.gov/sod/sst/arms/*

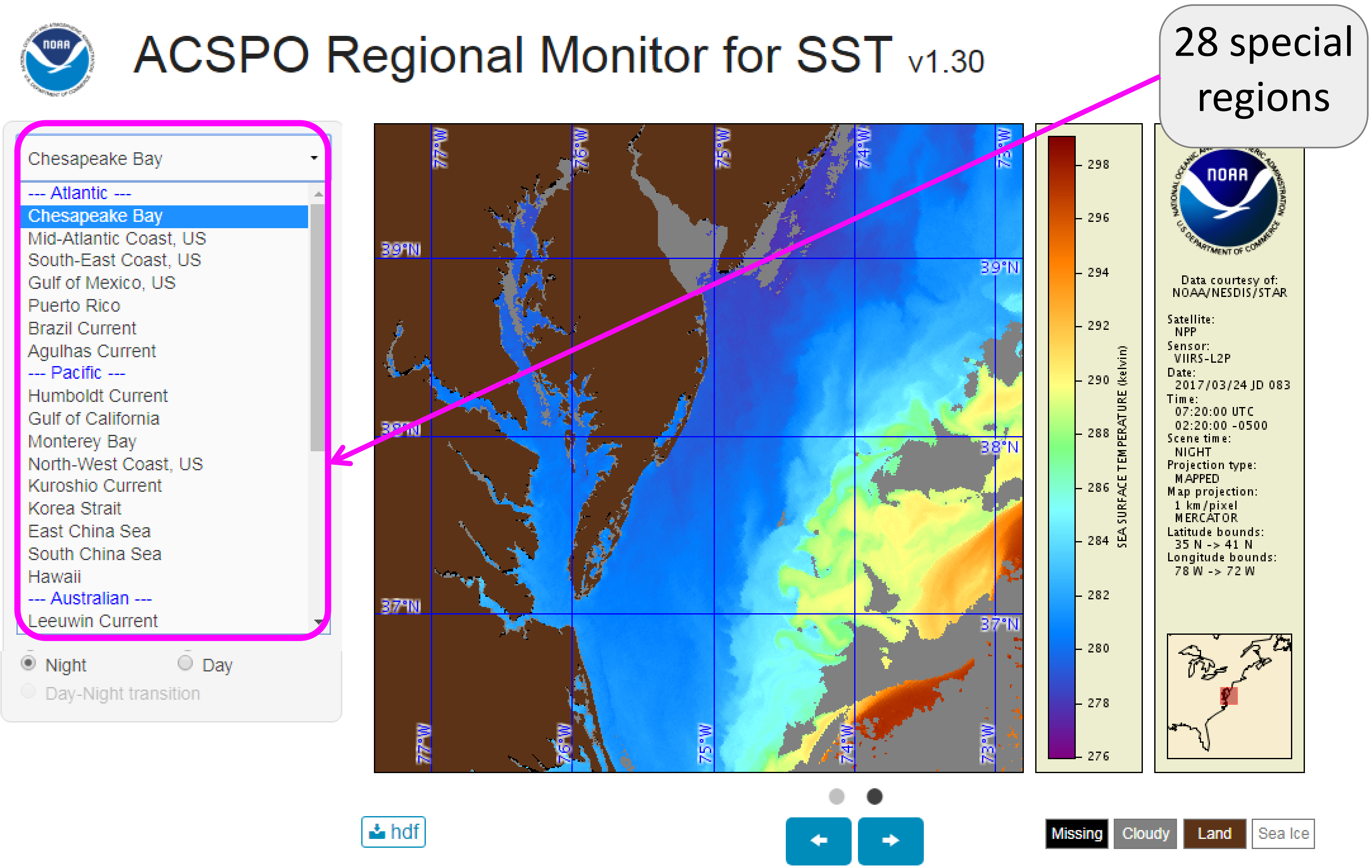
What is ARMS?

1. **A part of the NOAA SST Monitoring system, focusing on challenging areas, most interesting to data users & producers**
   - Coastal/Internal waters
   - Dynamic areas
   - High-latitudes
   - Cloudy regions
2. **Monitors regional performance of ACSPO SST & clear-sky mask**
3. **Checks for image quality, accuracy & consistency**
4. **Compares polar vs. geo ACSPO SSTs**
   - Himawari-8 AHI
   - GOES-16 ABI
5. **Compares ACSPO L2/L3 SSTs with several hi-res L4 SSTs**
   - 0.01° JPL MUR
   - 0.05° Met Office OSTIA
   - 0.05° NOAA Geo Polar Blended
   - 0.09° RAMSSA
   - 0.10° Canadian Met Centre CMC

Regions in ARMS

Regions in ARMS

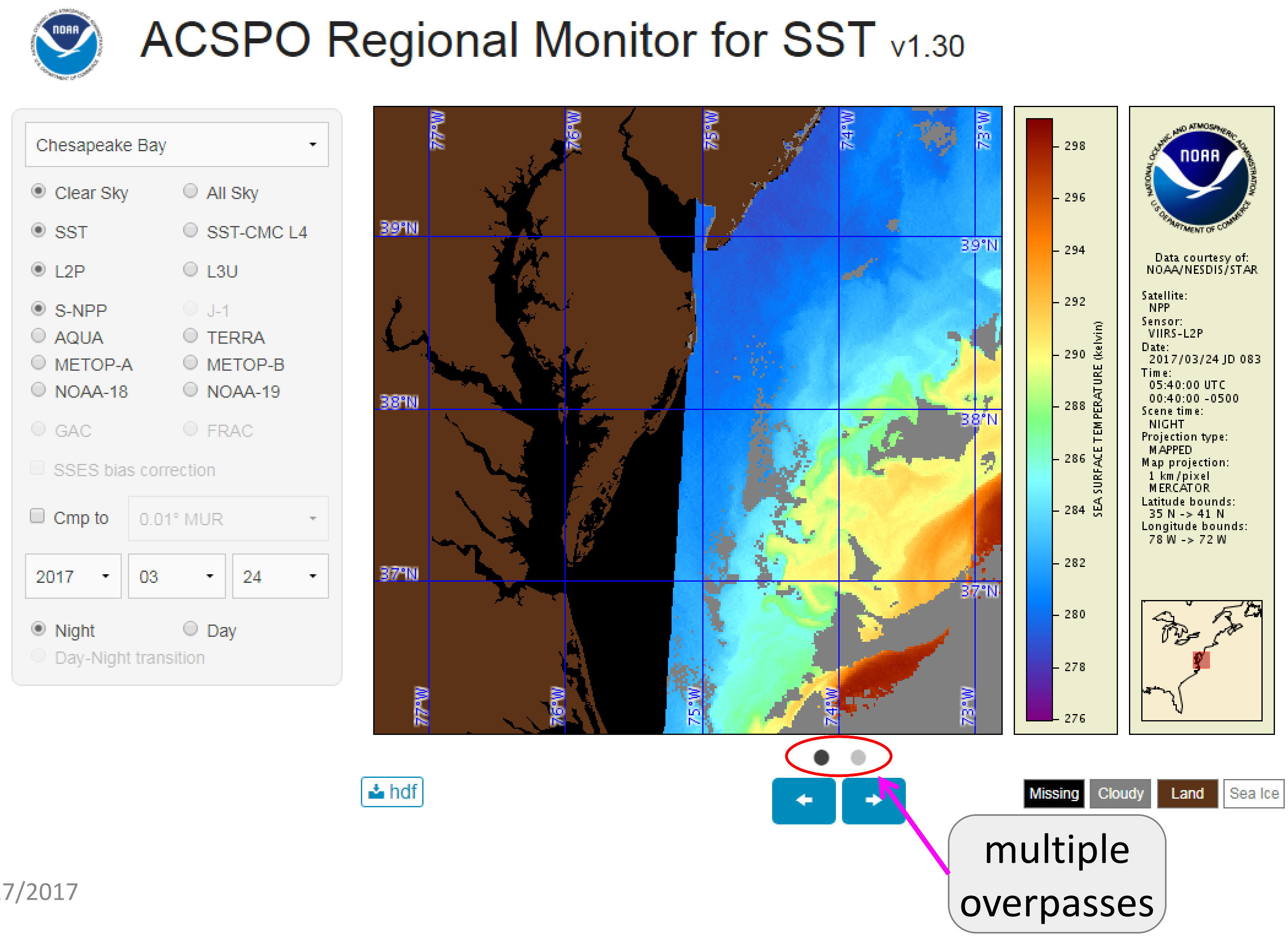
- ✓ Currently, ARMS includes 20 special regions (can be changed/expanded based on users needs)



Multiple Overpasses

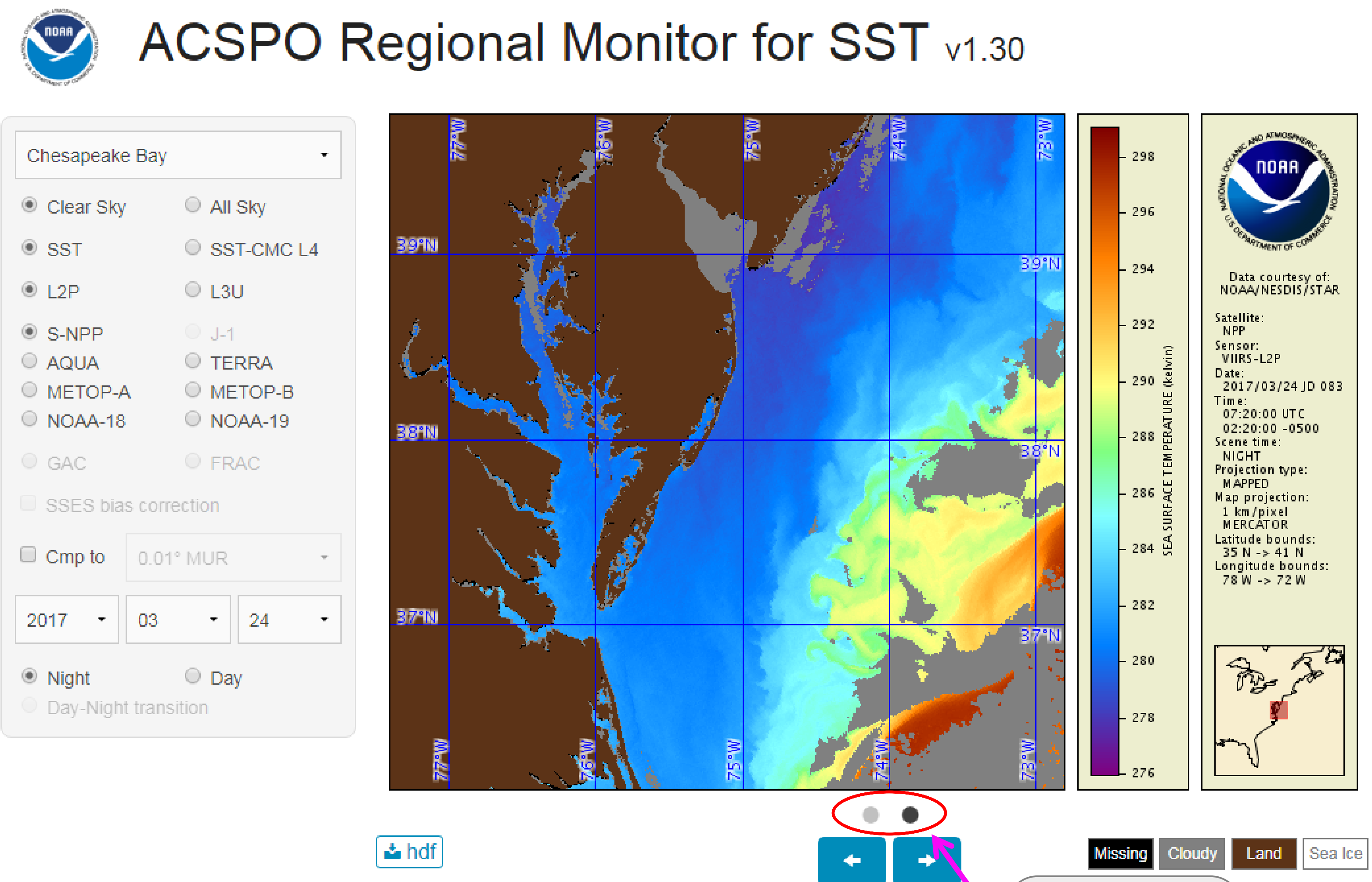
Multiple Overpasses

✓ Polar satellite may overfly the same region twice per day/night (or more, in high latitudes)



Multiple Overpasses

✓ Display different overpasses; aggregating different overpasses → L3C products

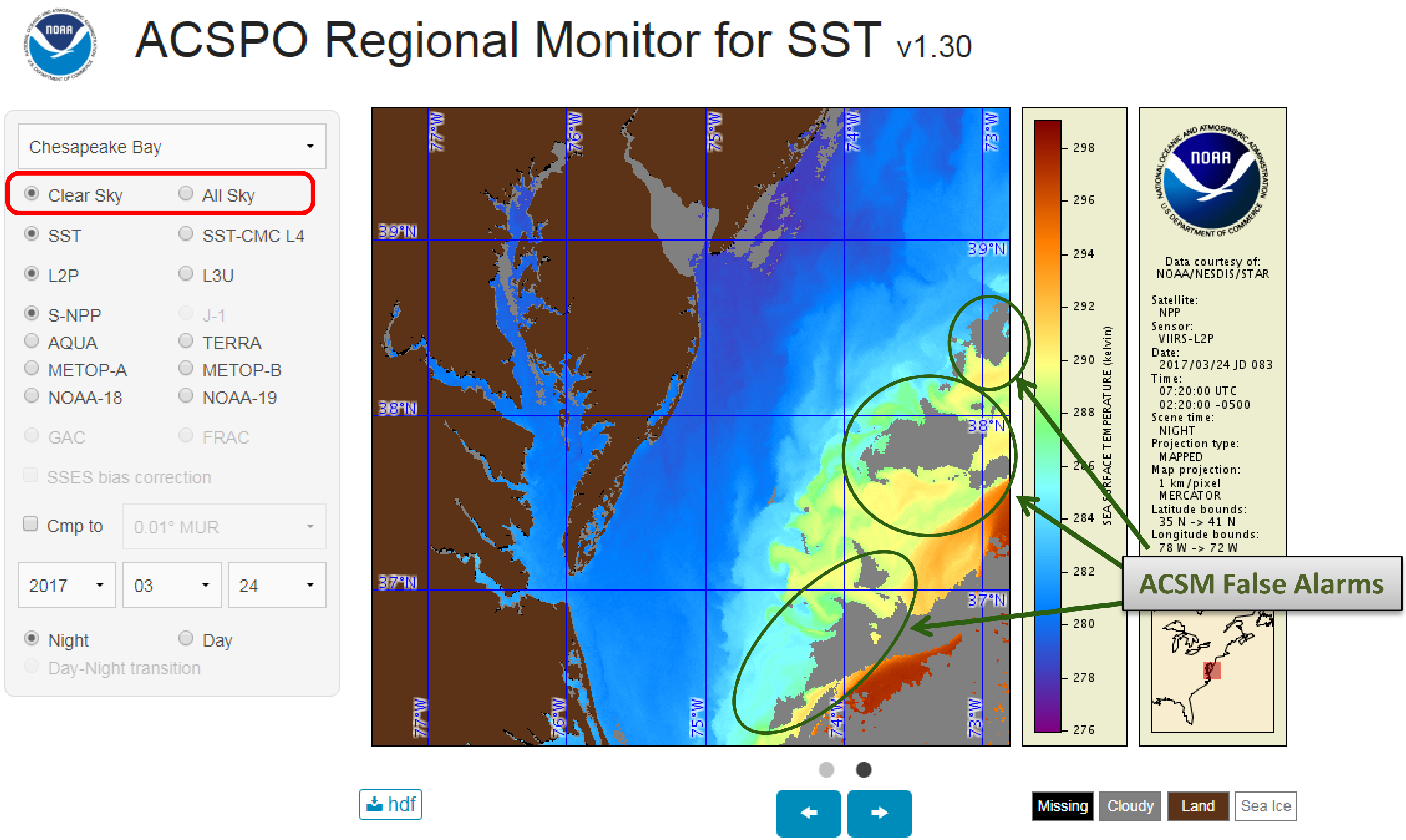


multiple overpasses

Clear-sky and All-sky SSTs/ΔSSTs

ARMS Interface: Clear-sky and All-sky SSTs/ΔSSTs

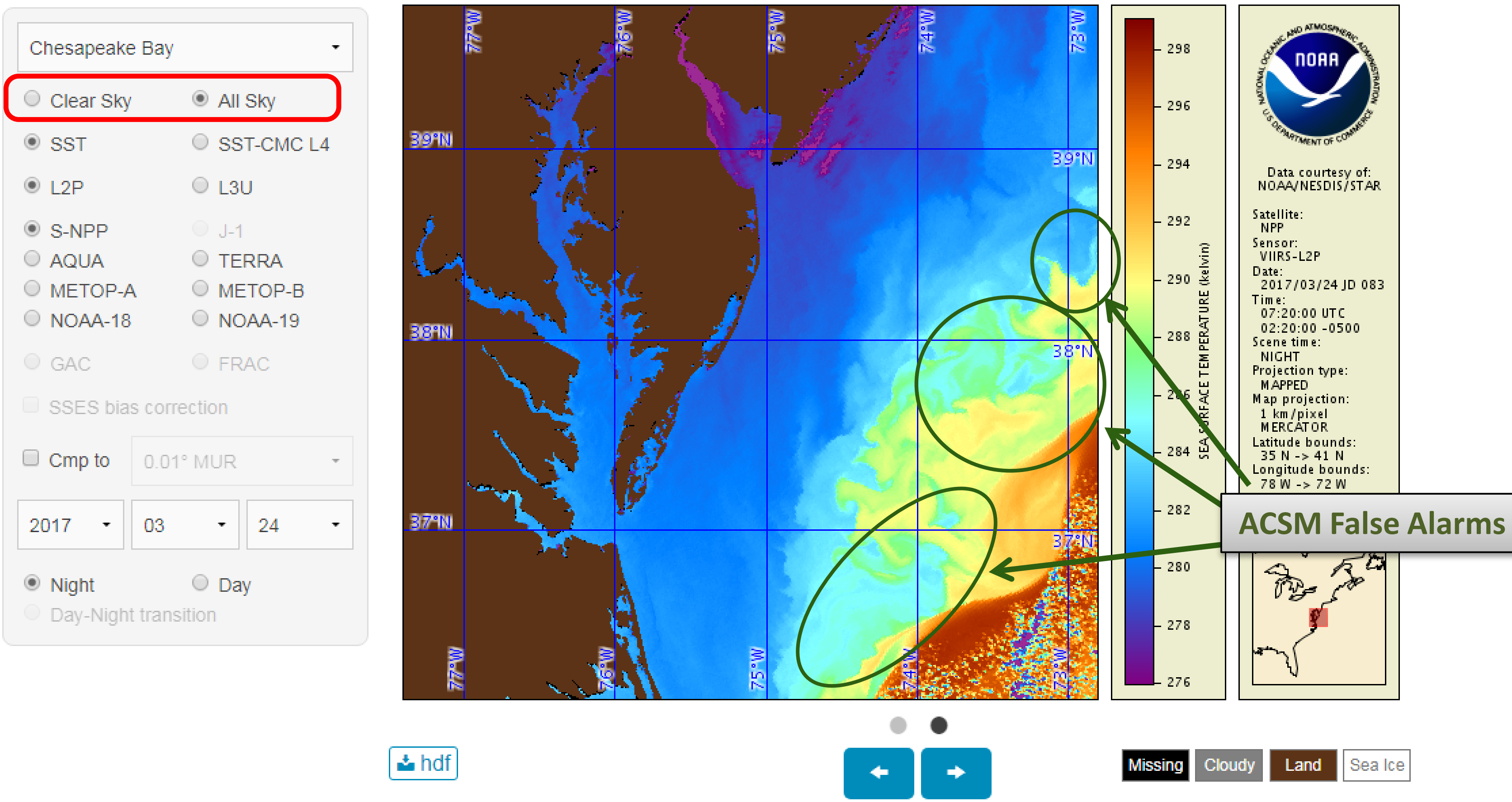
✓ Monitoring: Clear-sky and All-sky SSTs and ΔSSTs=SST-Ref. SST (CMC L4)



ARMS Interface: Clear-sky and All-sky SSTs/ΔSSTs

✓ All-sky SST helps to identify over-screening of clouds

ACSPO Regional Monitor for SST v1.30



ARMS Interface: Clear-sky and All-sky SSTs/ΔSSTs

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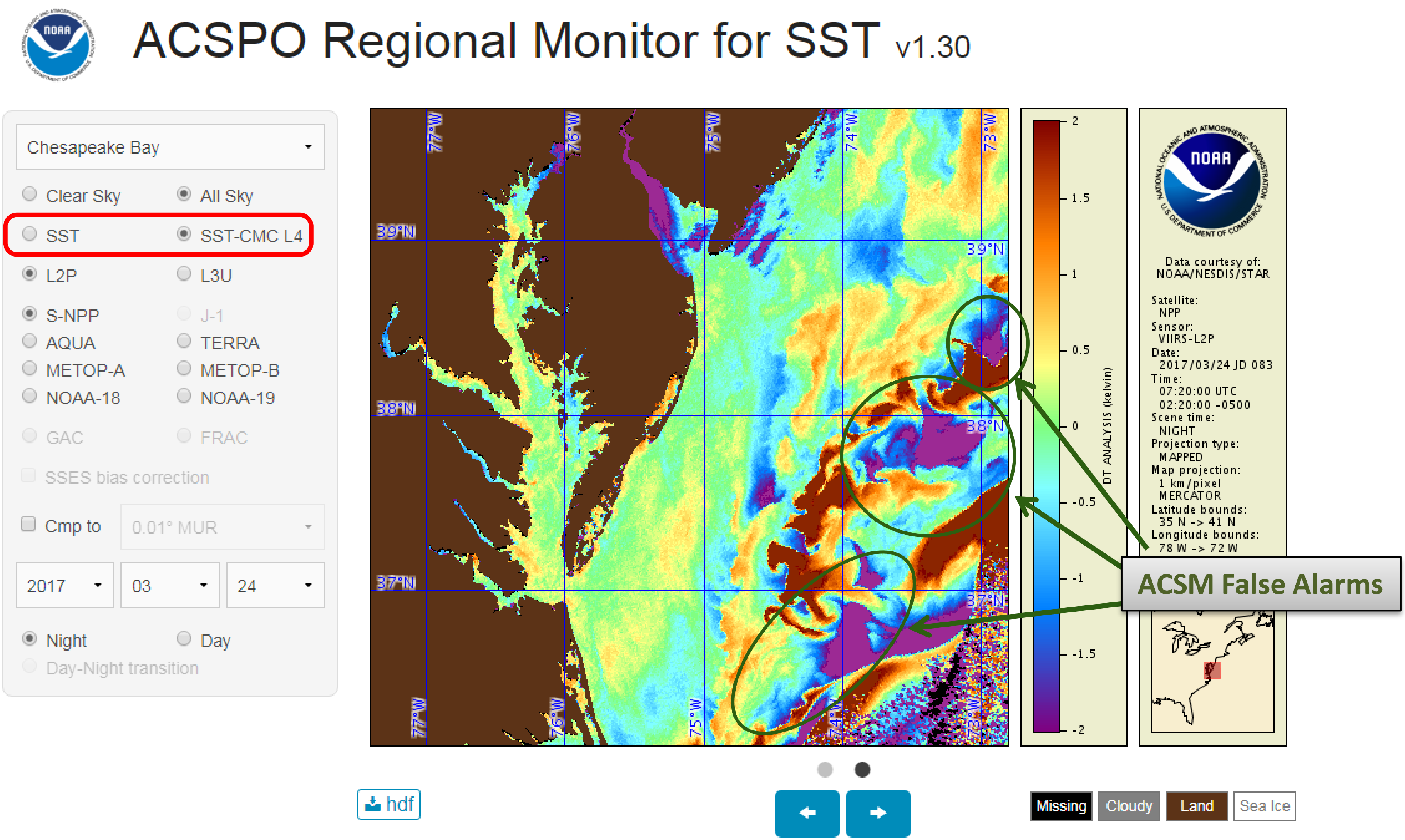
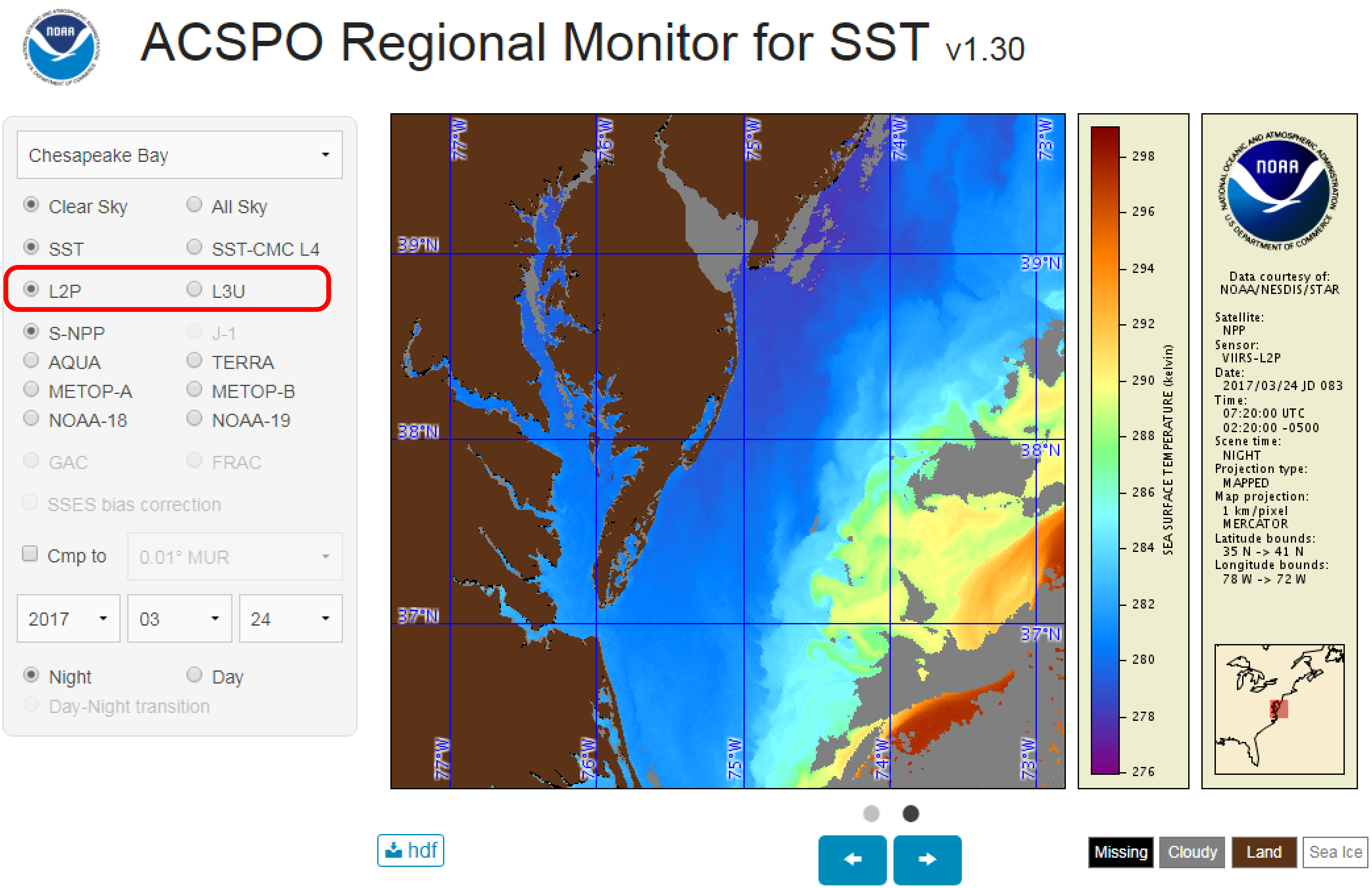


Data Levels

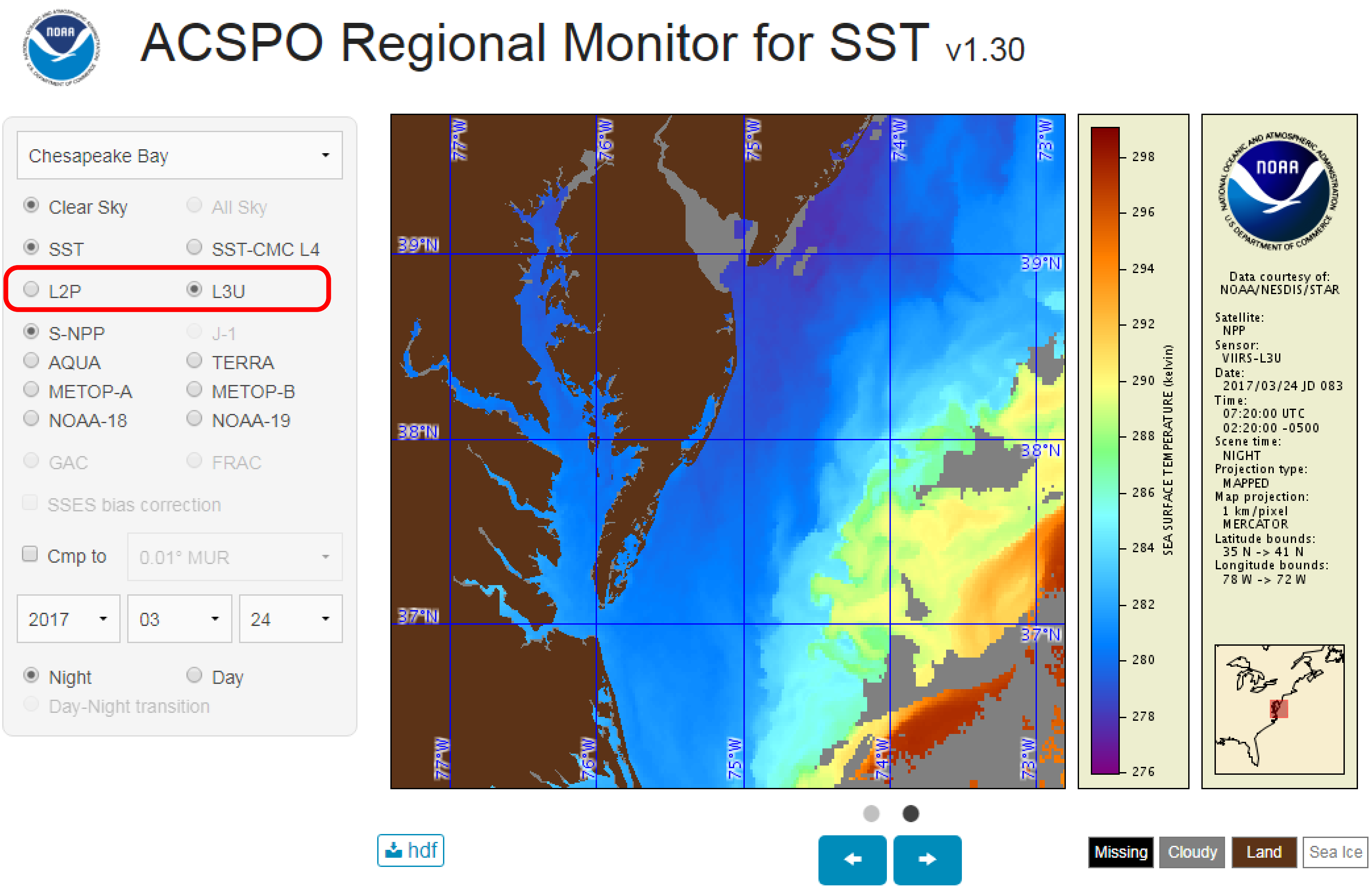
ARMS Interface: L2P

For visualization in ARMS, L2P is remapped to equal-grid (resolution is region specific; always 512×512)



ARMS Interface: L3U (un-collated)

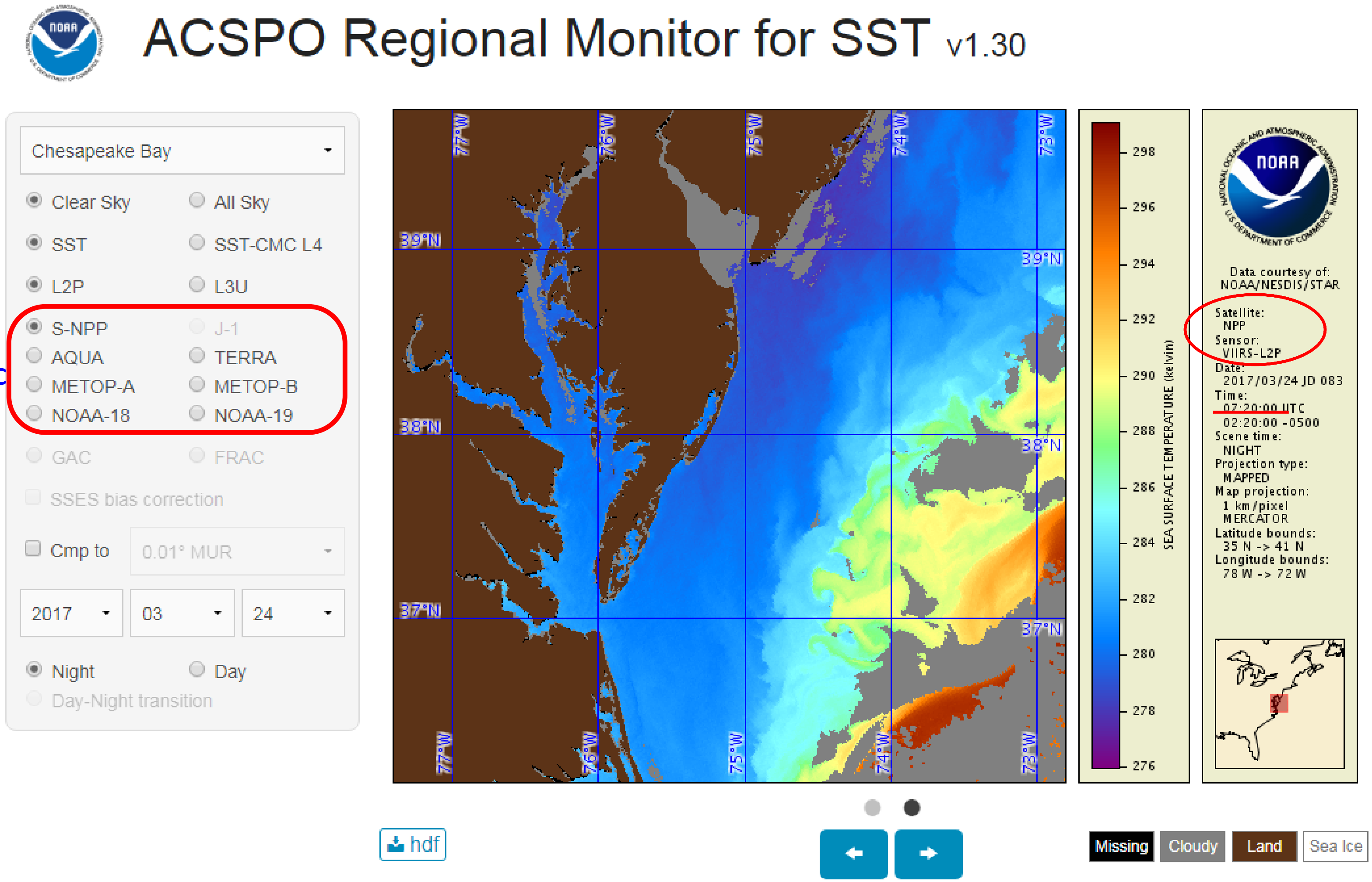
L3U is also remapped to a projection/resolution consistent with re-projected L2P



Platform / Sensor Selection

ARMS Interface: Product Selection

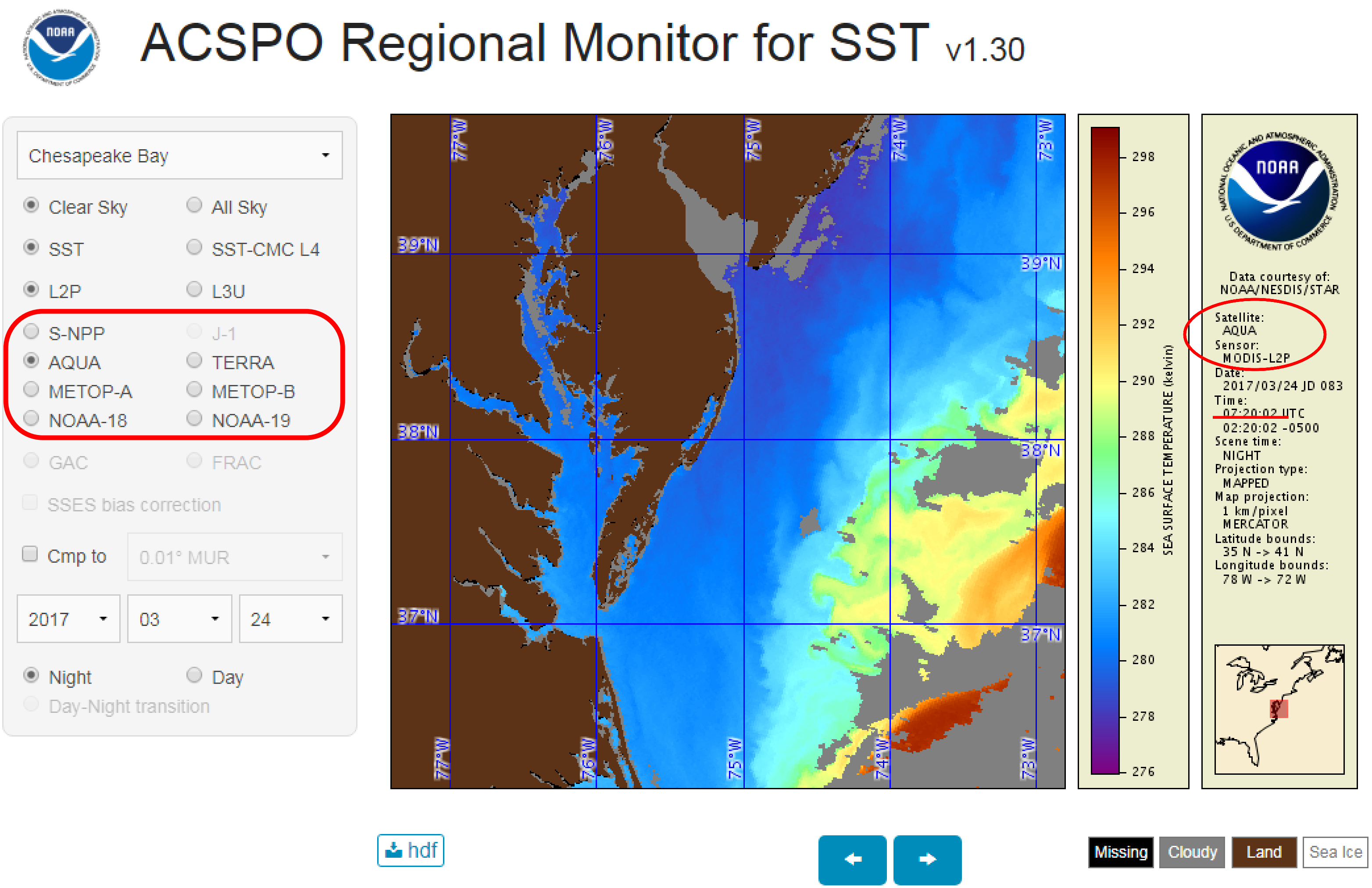
✓ Monitoring: VIIRS onboard NPP, MODIS onboard Aqua/Terra, AVHRR onboard Metop-A/B, NOAA-18/19



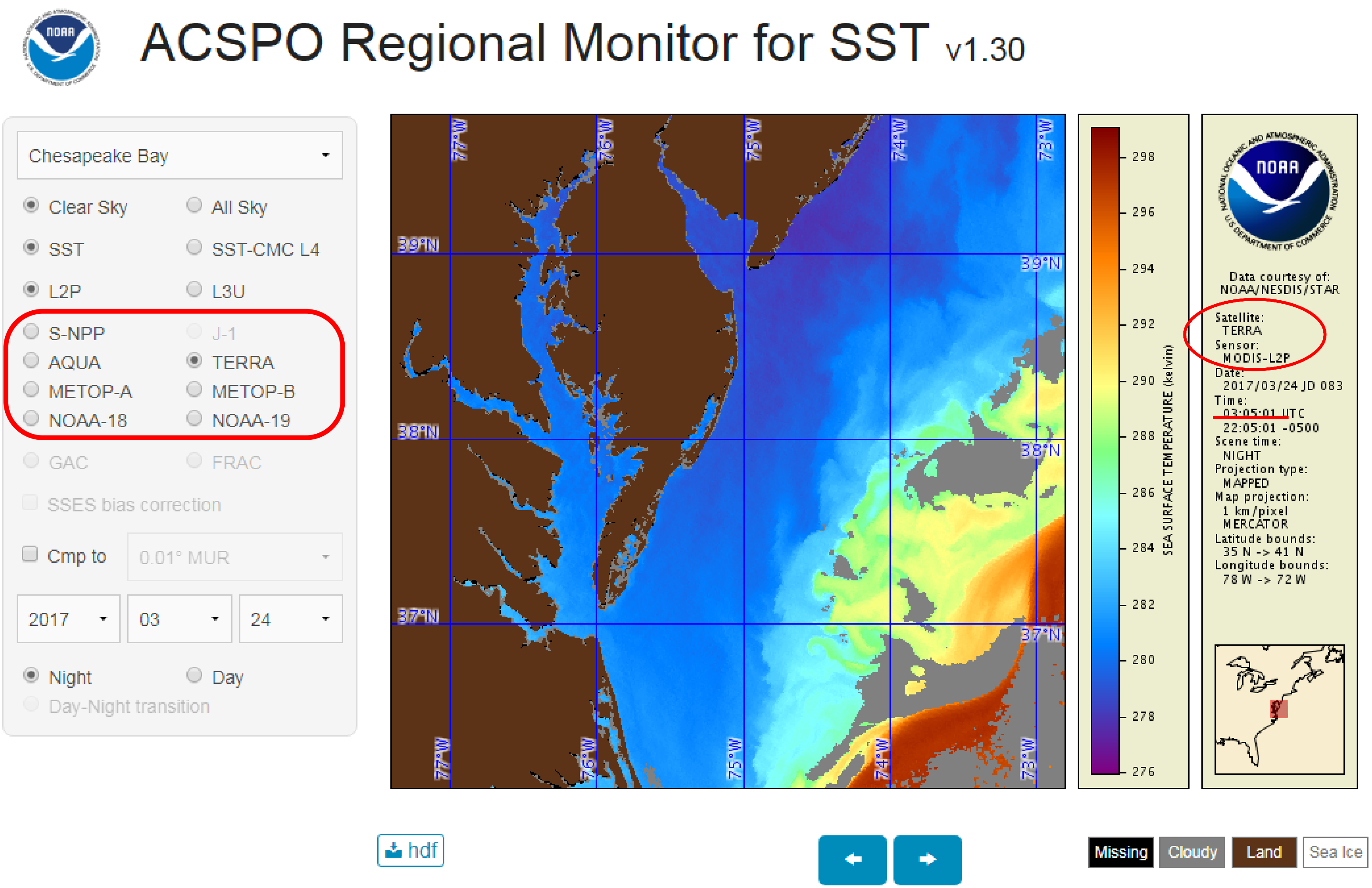
VIIRS
MODIS
AVHRR FRAC
AVHRR GAC

ARMS Interface: Product Selection

✓ Similar pass-time for NPP & Aqua; slightly different data coverage/cloud mask

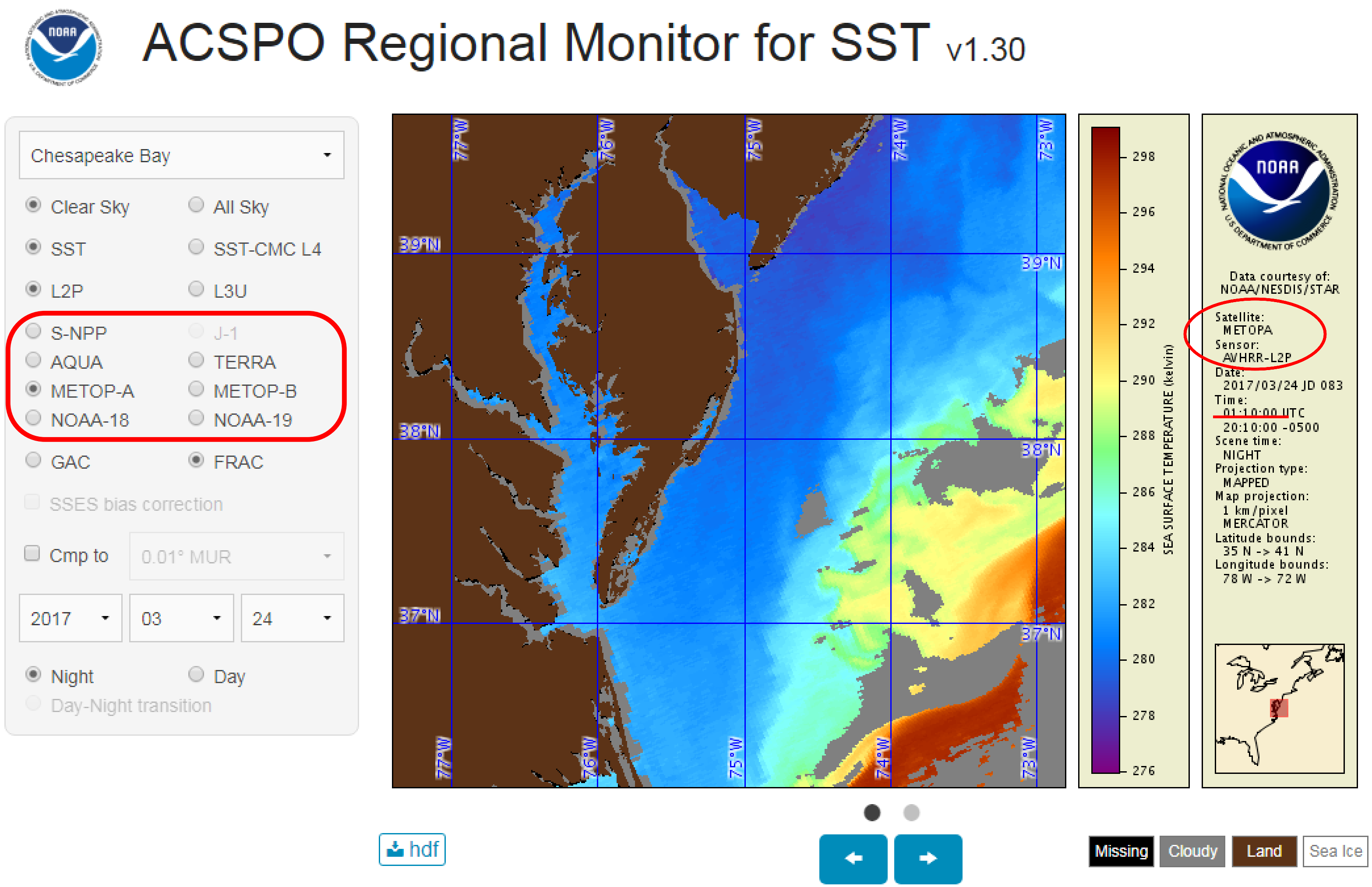


ARMS Interface: Product Selection



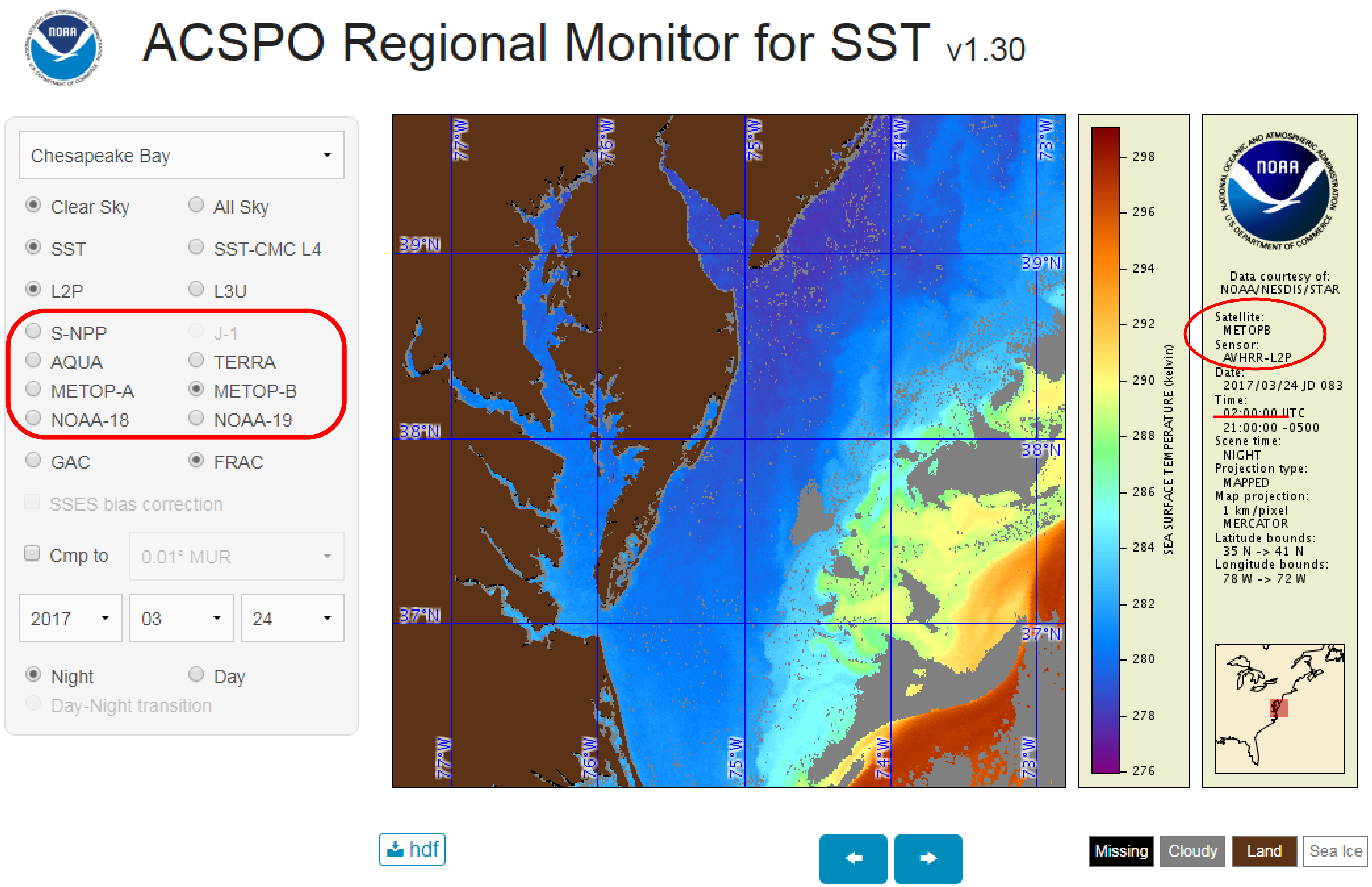
ARMS Interface: Product Selection

✓ FRAC Metop-A has warmer temperature compared to MODIS Aqua and FRAC Metop-A



ARMS Interface: Product Selection

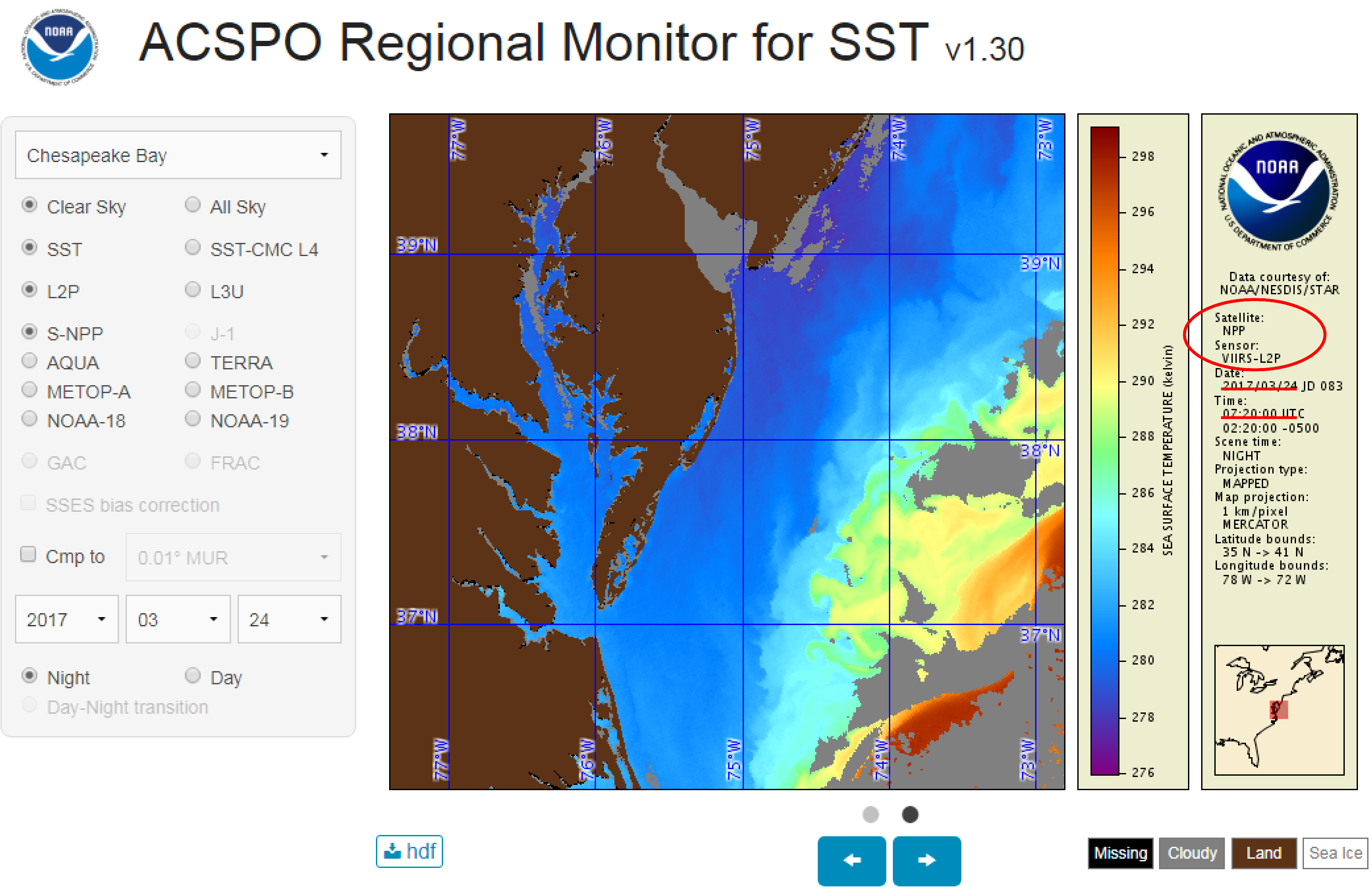
- ✓ Multiple overpasses of different platforms → L3S (super-collated) product



Comparison to L4 SSTs

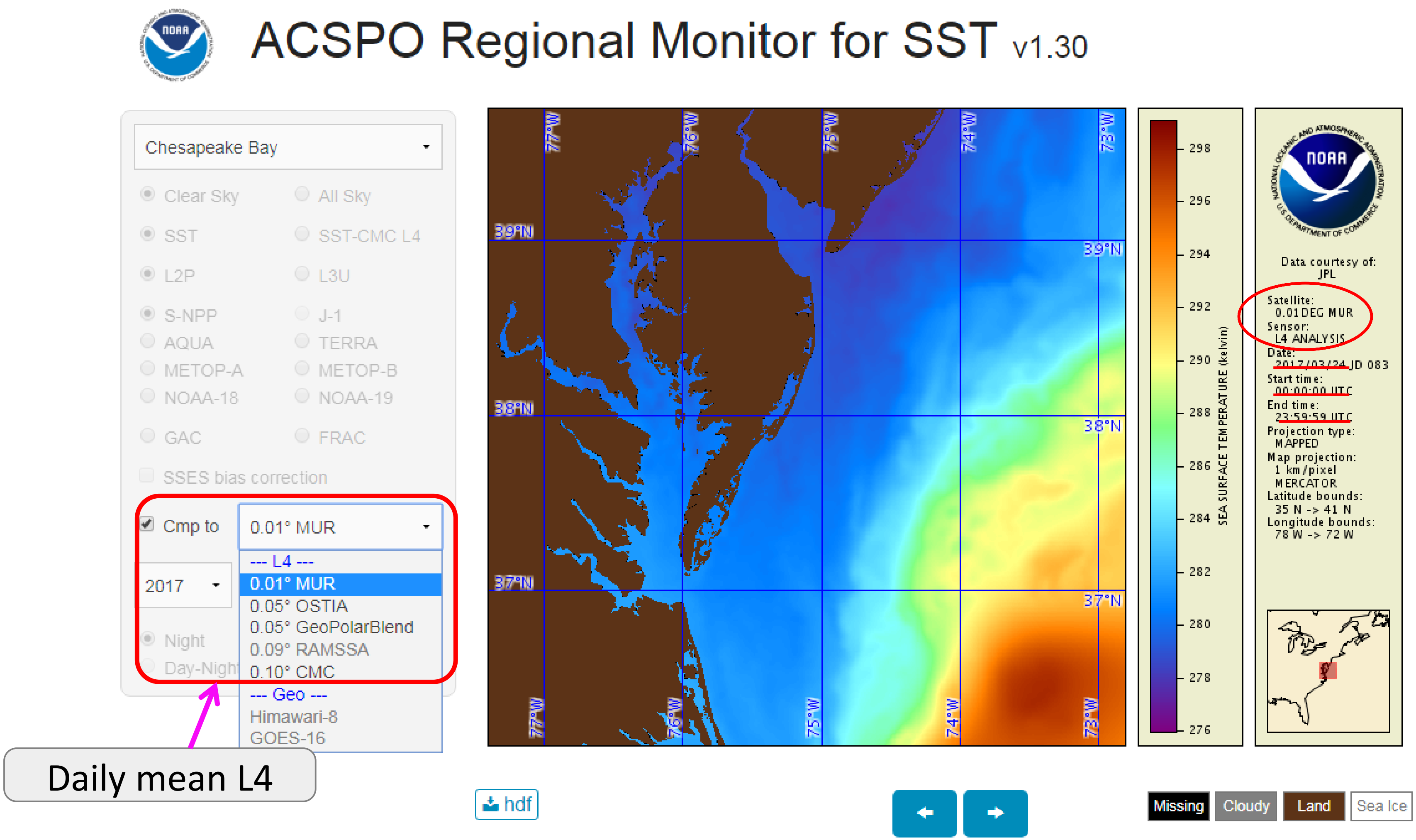
ARMS Interface: Comparison to L4 SSTs

✓ Including four L4 SSTs: 0.01° MUR, 0.05° OSTIA, 0.05° Geo_Polar_Blended, 0.09° RAMSSA, 0.10° CMC

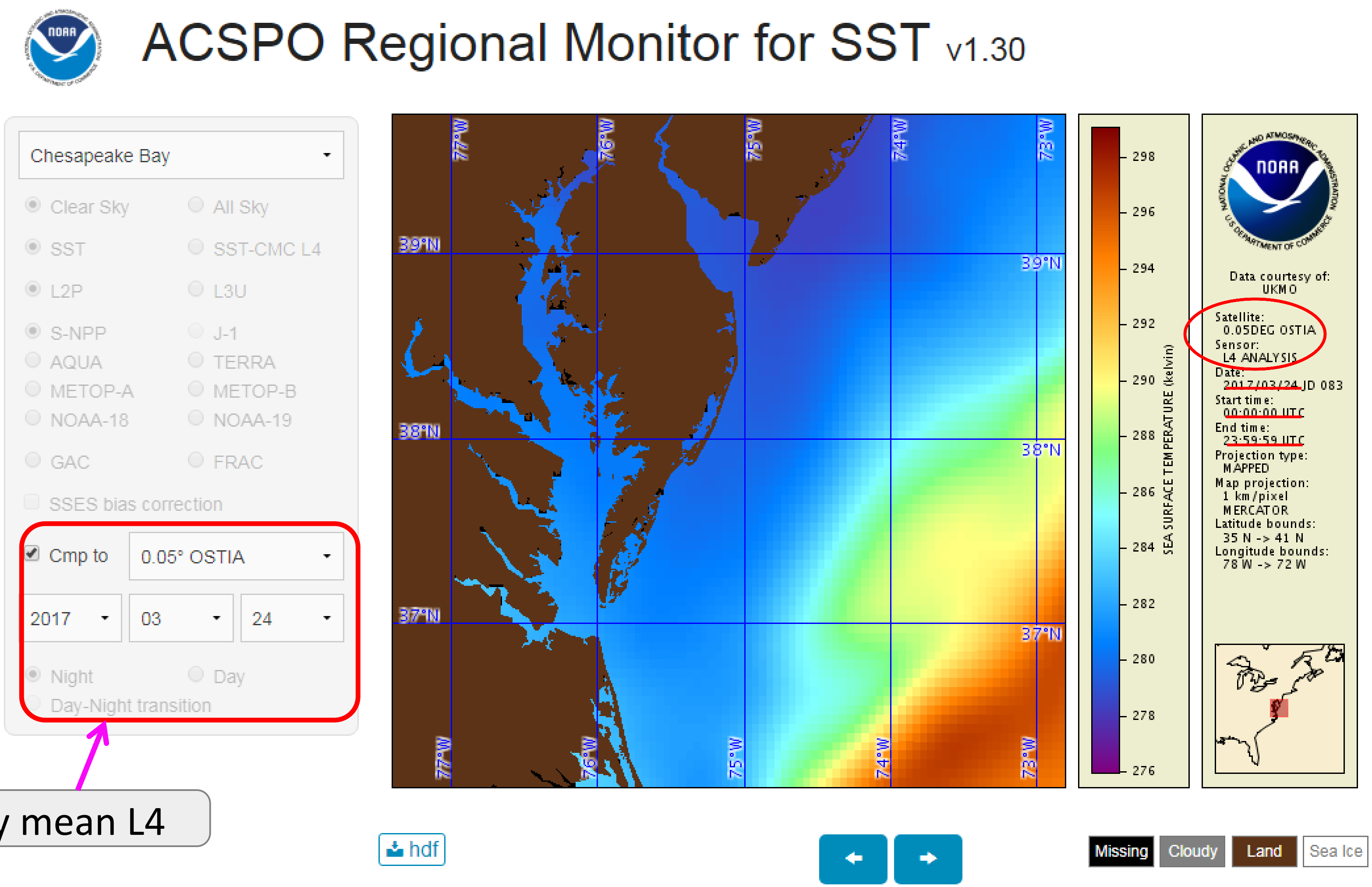


ARMS Interface: Comparison to L4 SSTs

- ✓ 0.01° MUR shows more details where VIIRS_NPP data are available



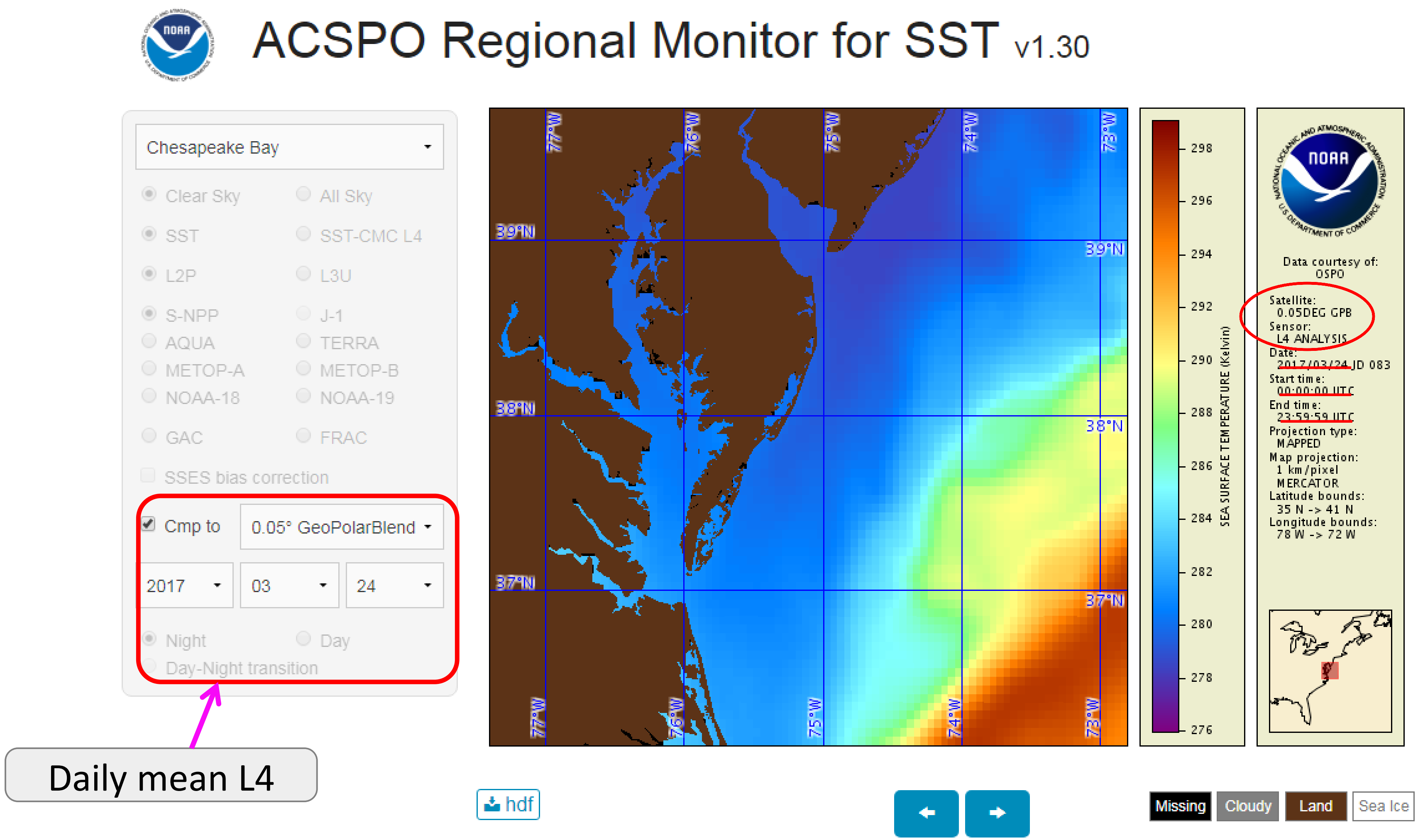
ARMS Interface: Comparison to L4 SSTs



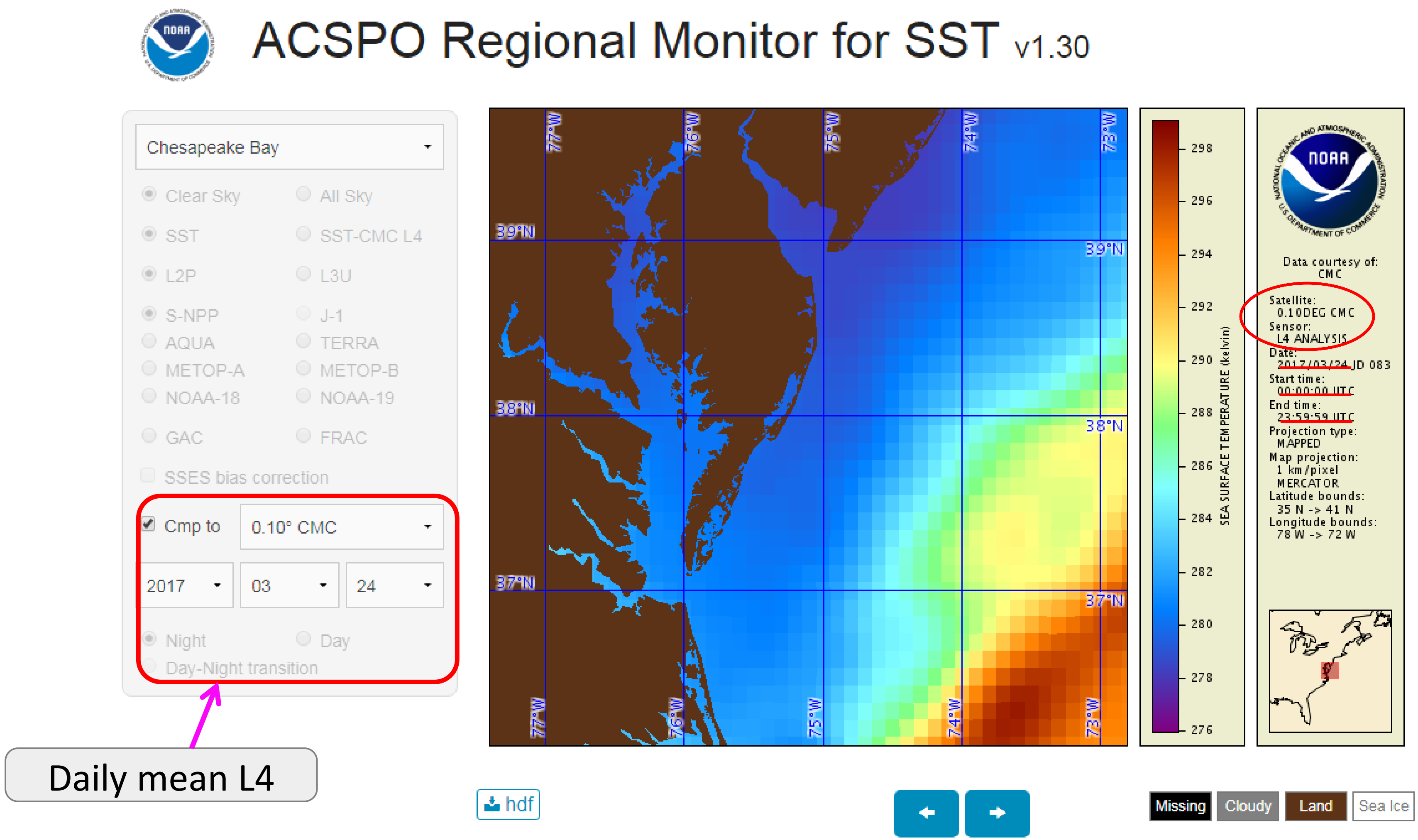
Daily mean L4

Comparison to L4 & Geo SSTs

✓ 0.05° Geo_Polar_Blended reserves more details than OSTIA



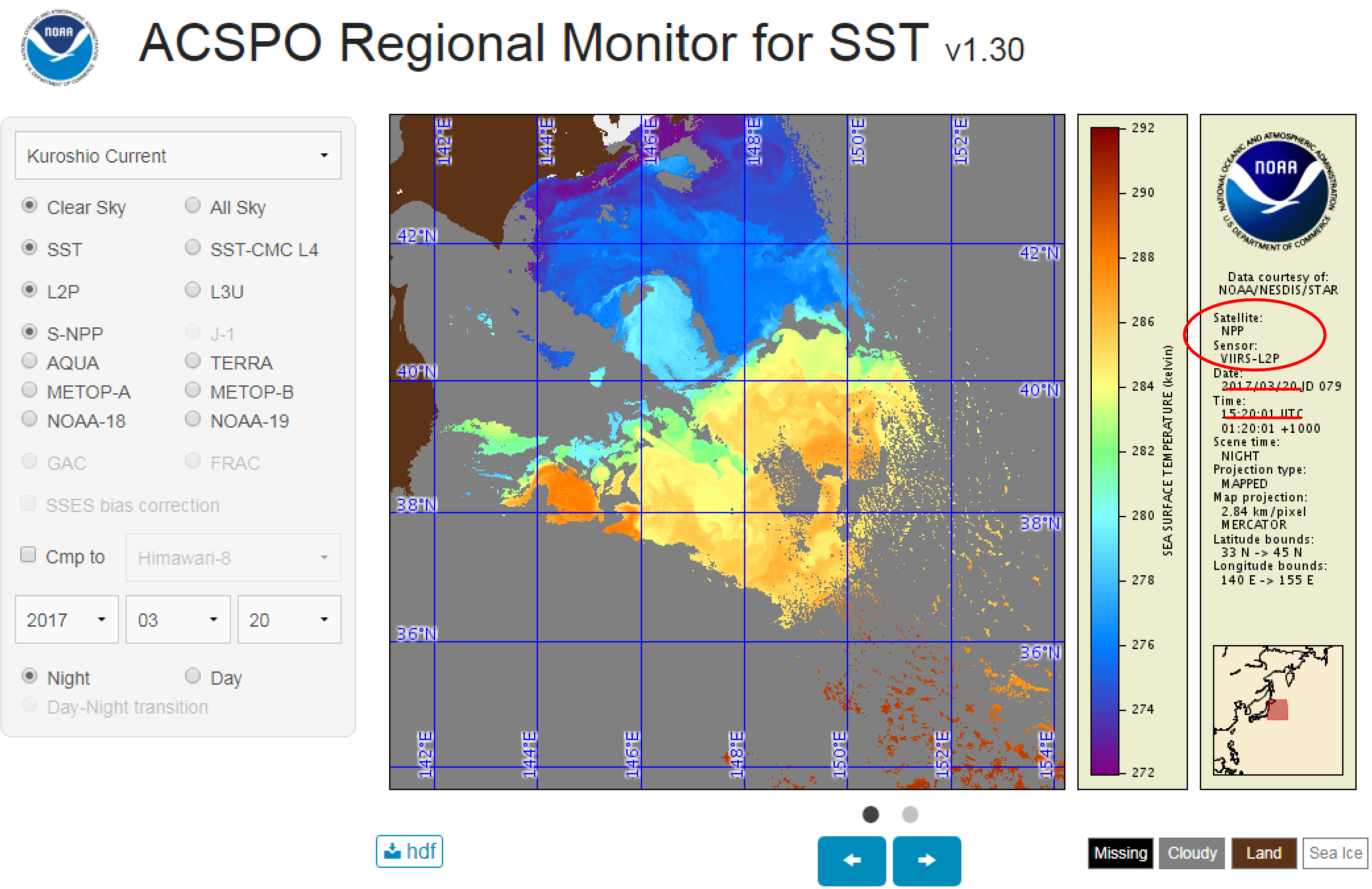
ARMS Interface: Comparison to L4 SSTs



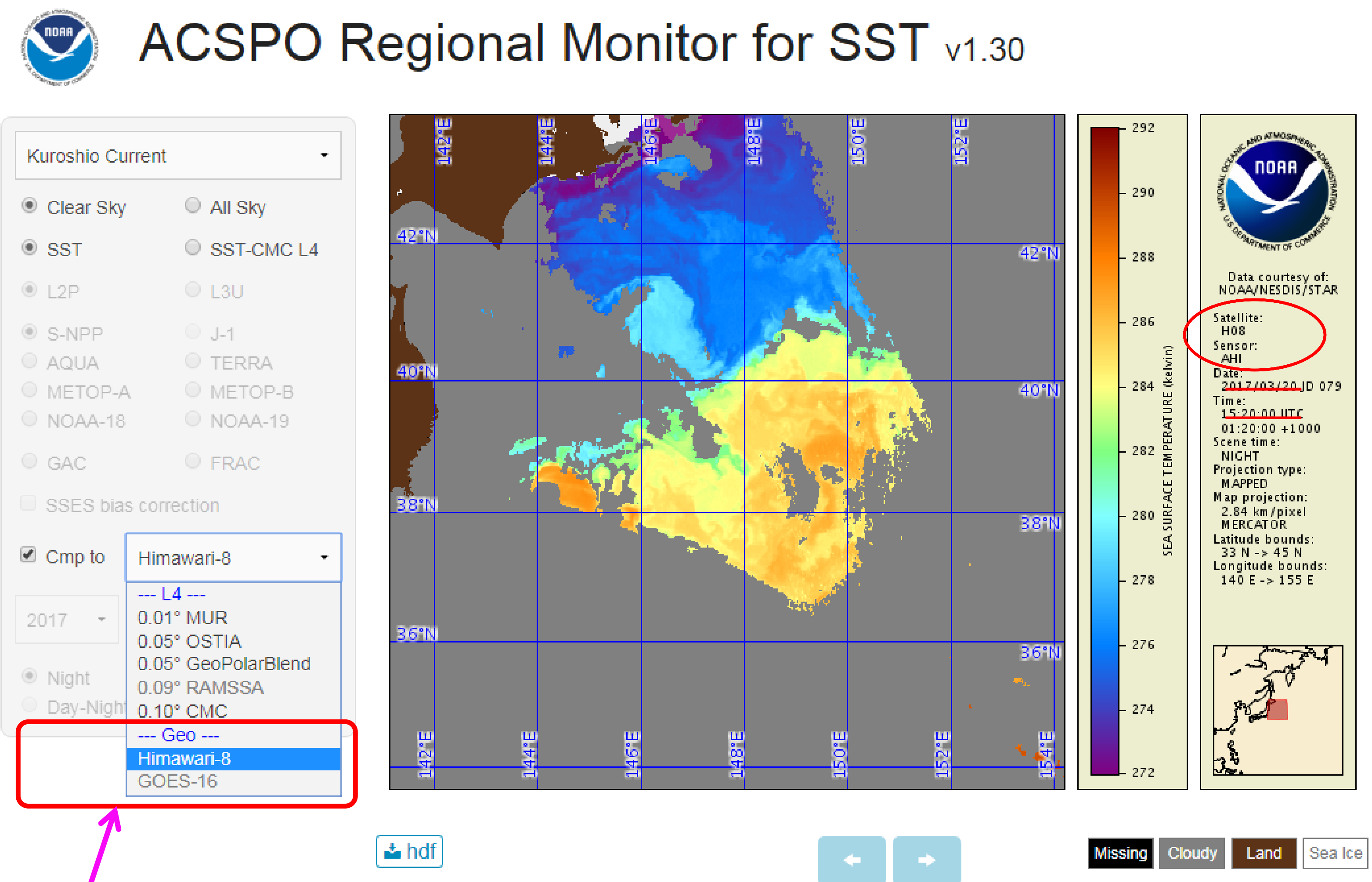
Comparison to Geo SSTs

ARMS Interface: Comparison to Geo SSTs

- ✓ Including geostationary SSTs: AHI onboard Himawari-8, ABI onboard GOES-16 (internal view only)
- ✓ AHI is available for three regions: Kuroshio Current, Korean Strait, and South China Sea



ARMS Interface: Comparison to Geo SSTs

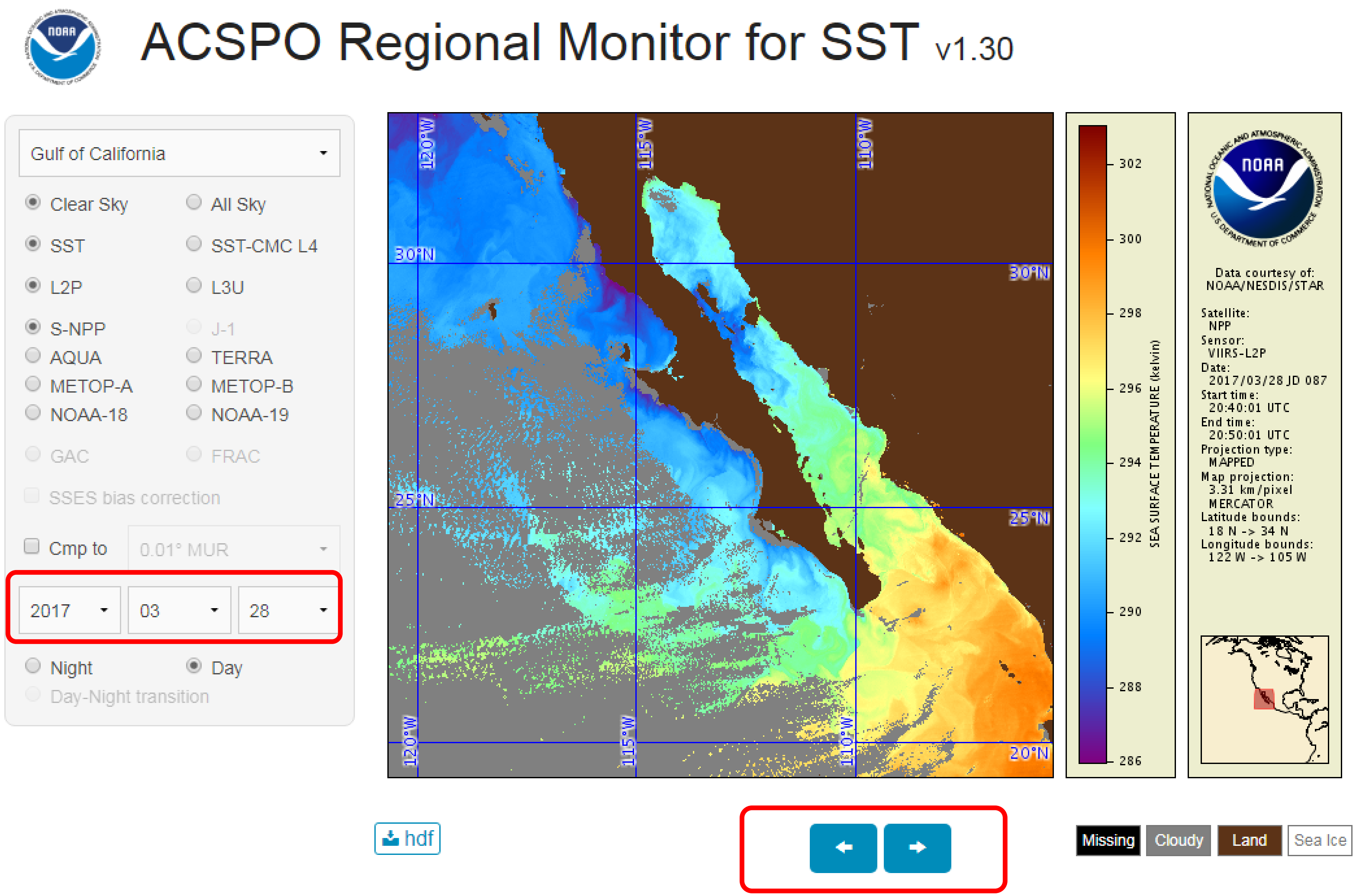


Closest in time geo

Date Selection

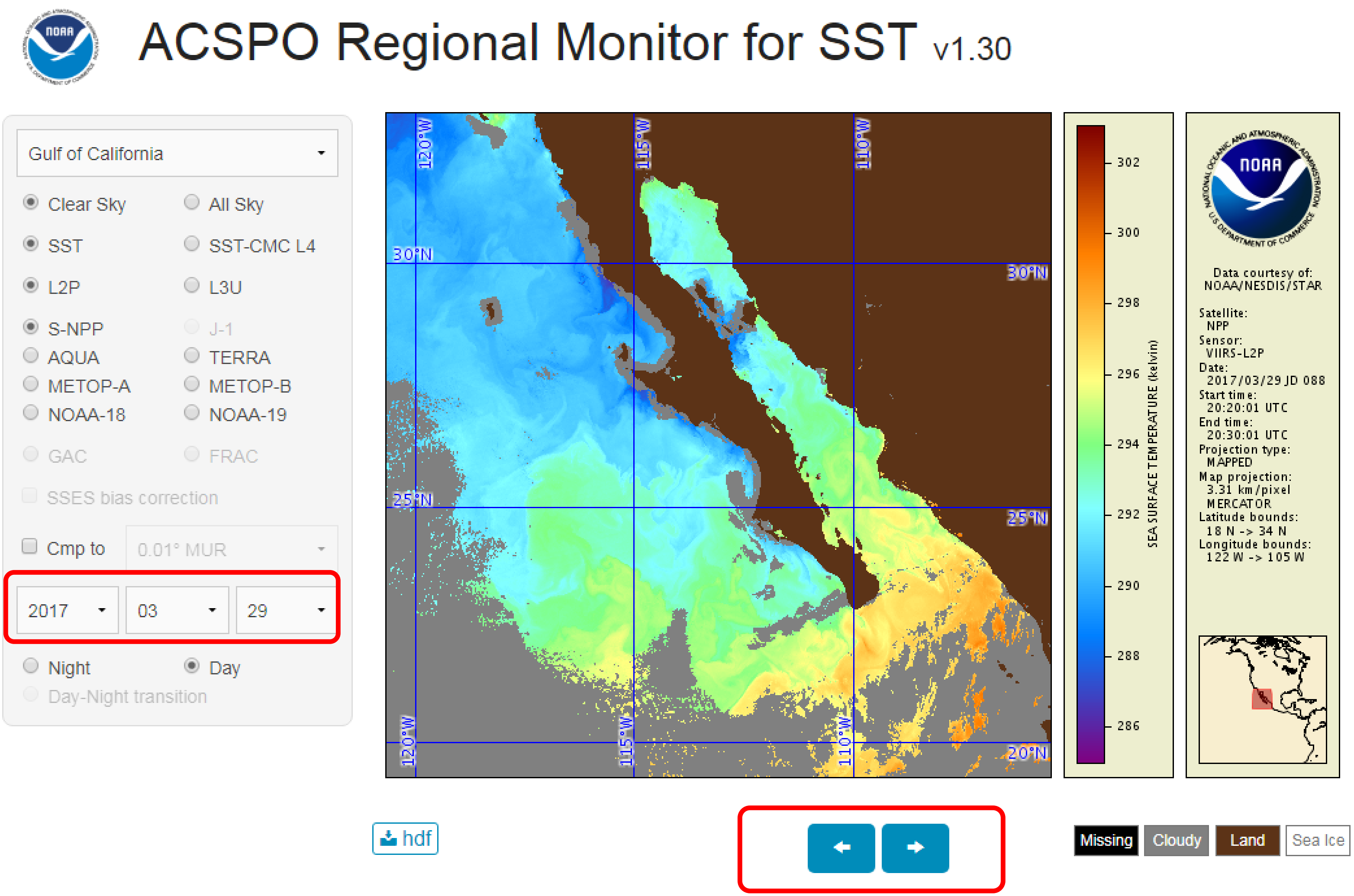
ARMS Interface: Date Selection

- ✓ Starting date: July 18th 2015



ARMS Interface: Date Selection

- ✓ Starting date: July 18th 2015



ARMS Interface: Date Selection

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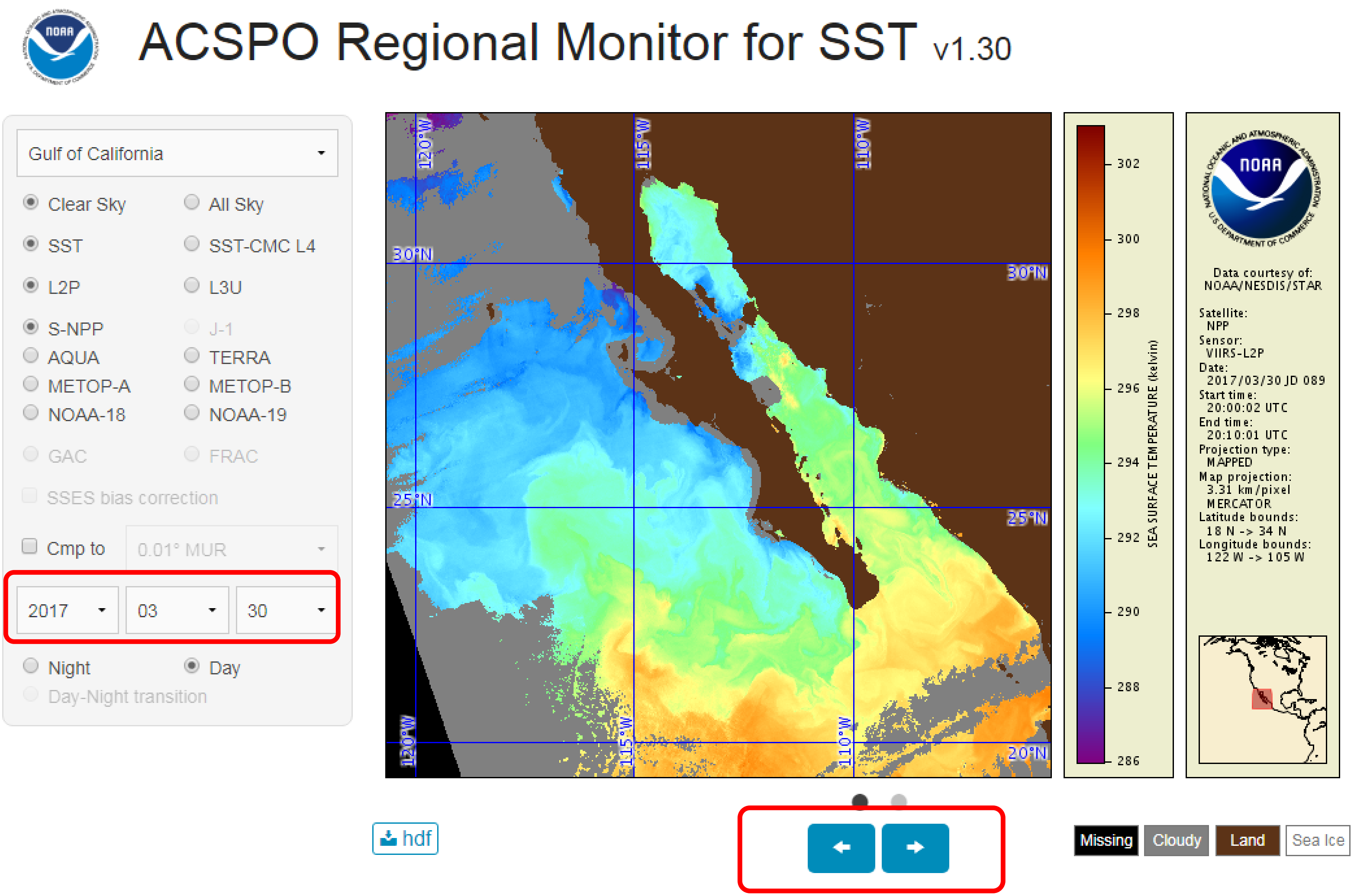
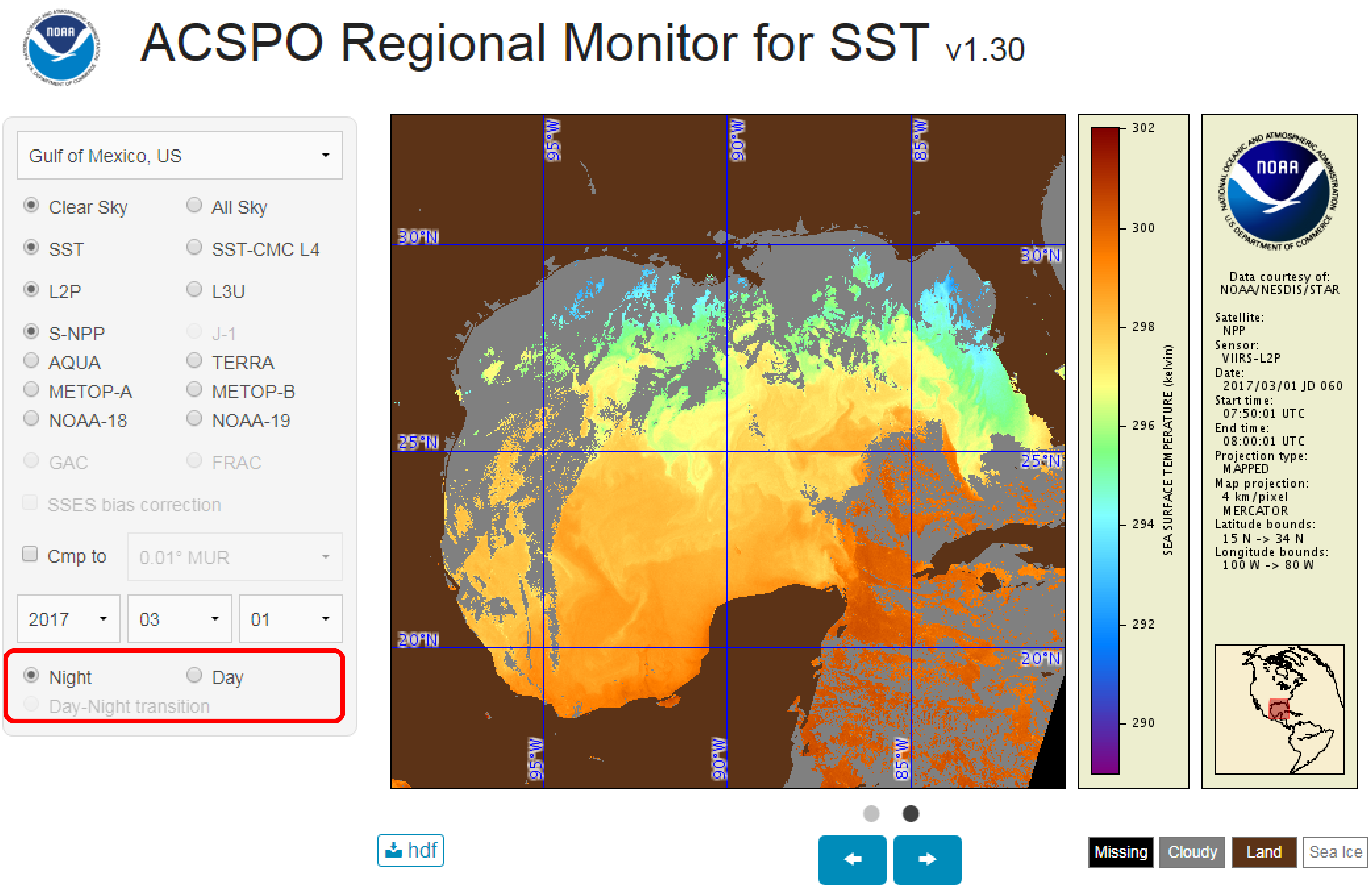


Day/Night Data

ARMS Interface: Day/Night Data

✓ Scene time options: nighttime, daytime, region crossing the day-night transition zone (high-lats)



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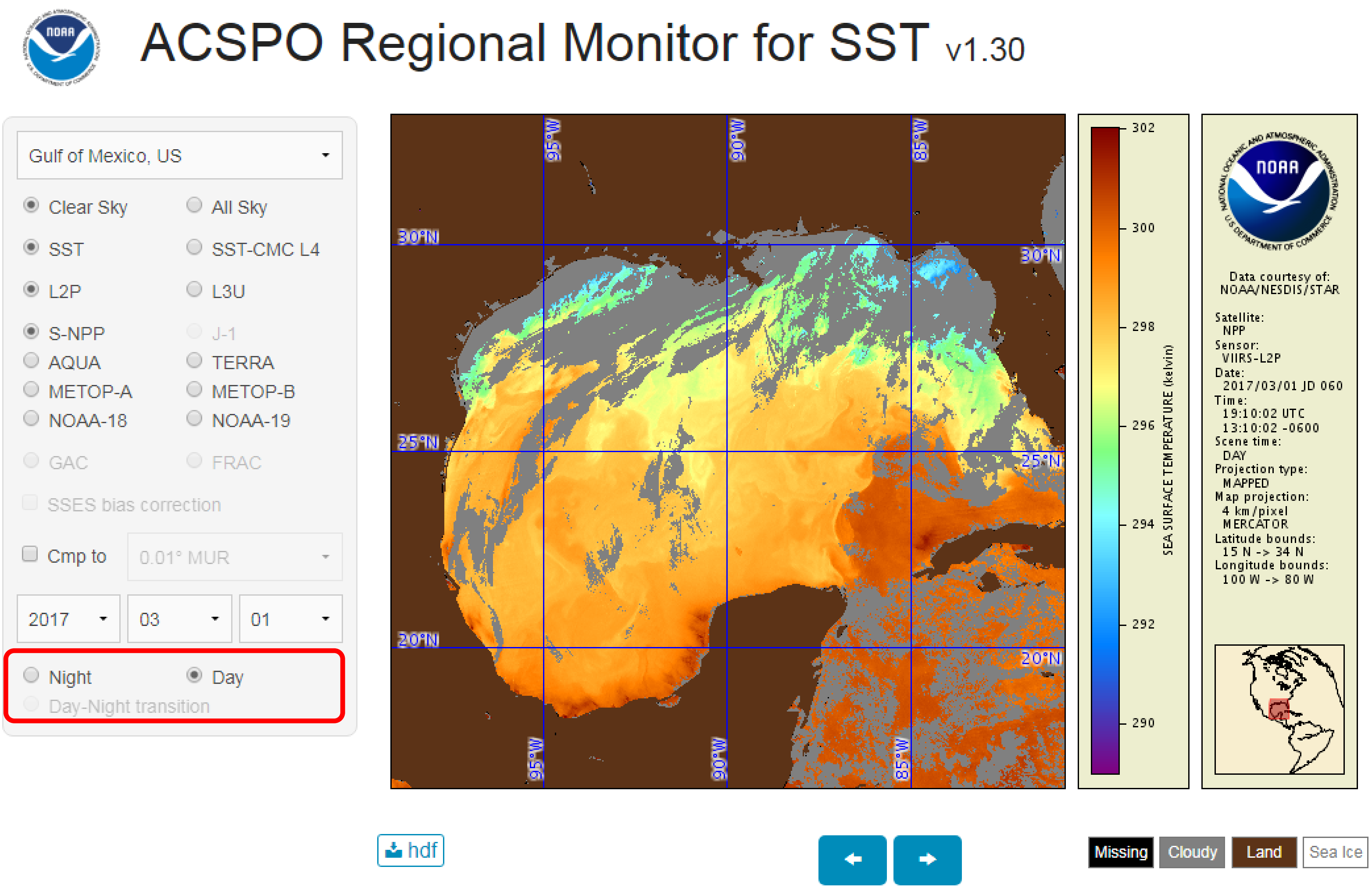

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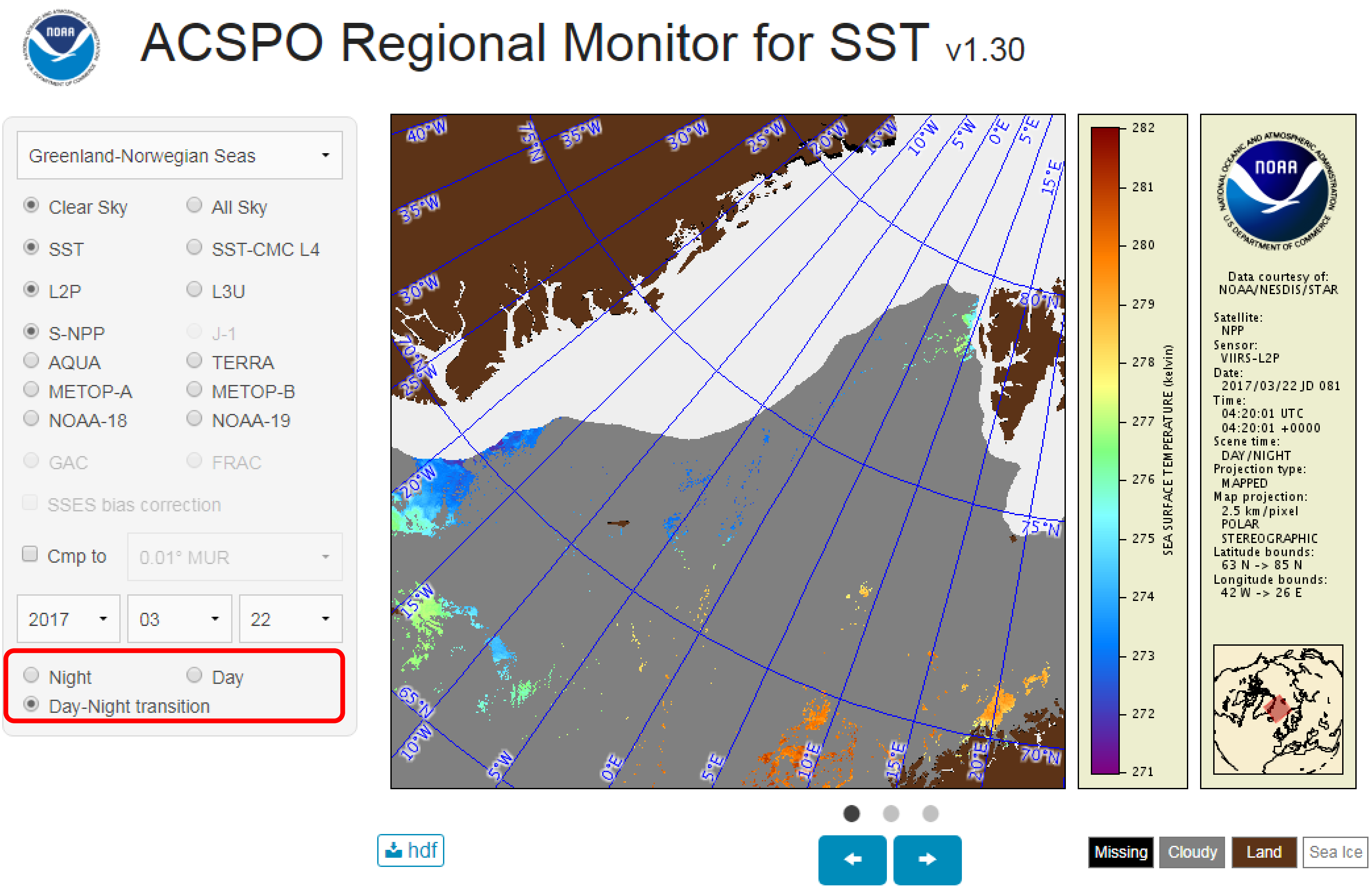
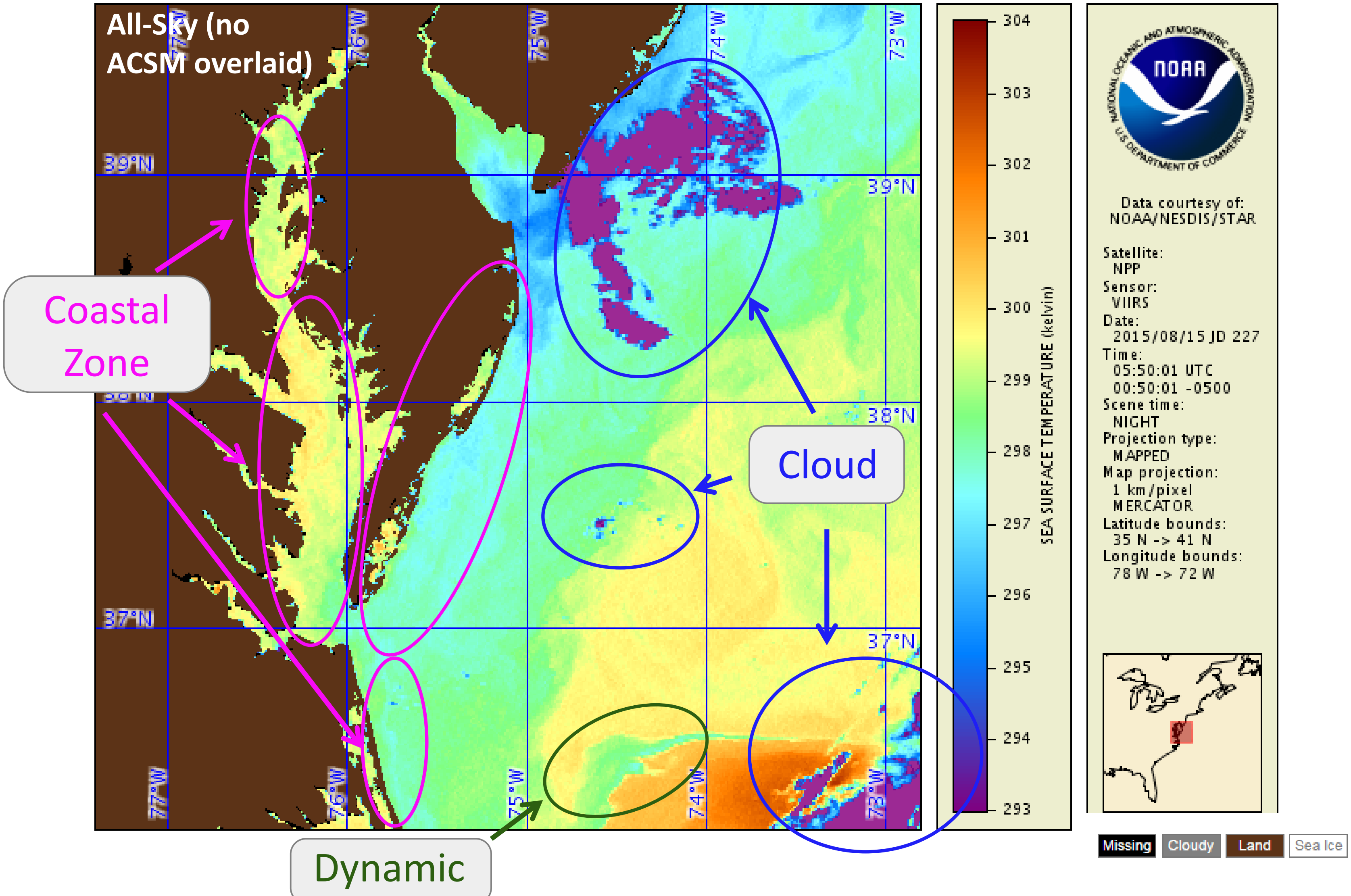


Examples of Using ARMS for ACSPO Diagnostics

- ✓ Validate Clear-Sky Domain
- ✓ Validate Clear-Sky Mask and SST for day/night consistency
- ✓ Check the sea-ice mask in ACSPO (currently taken from CMC)

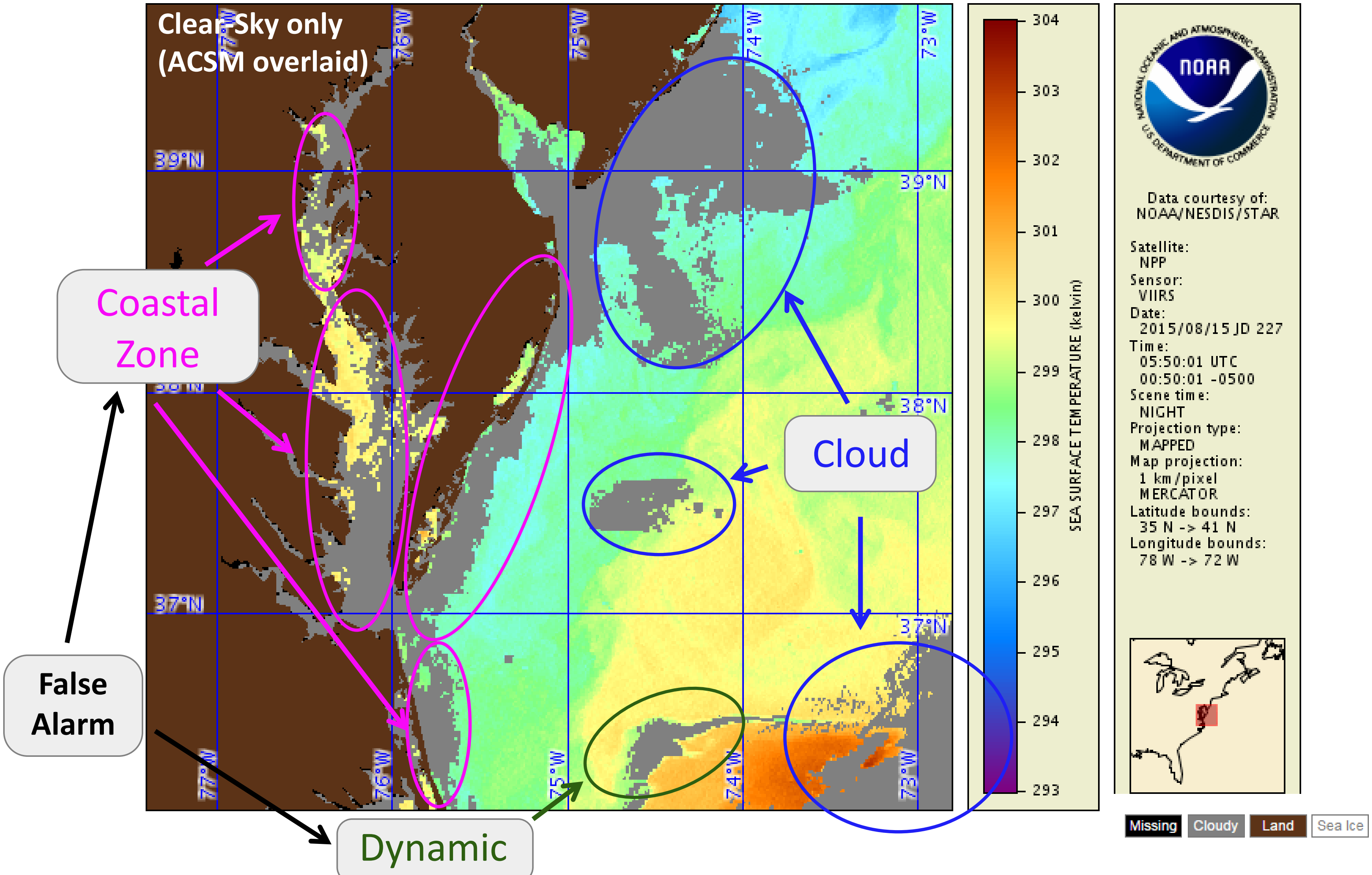
Identify areas of improvement

ACSPO Clear-Sky Mask Overly Conservative In Coastal / Dynamic areas

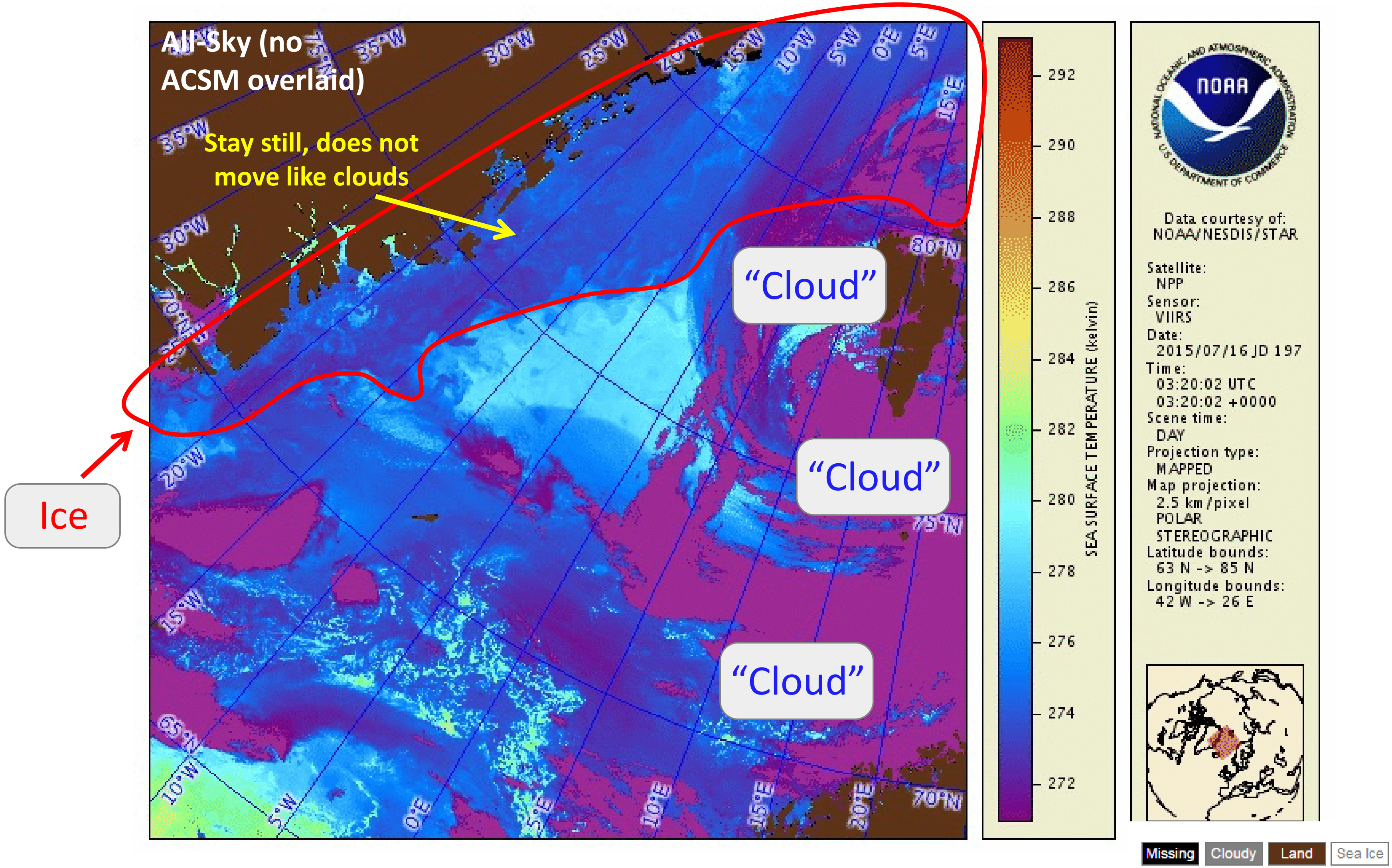


ACSPO Clear-Sky Mask Overly Conservative In Coastal / Dynamic areas

✓ The cold regions (coastal and dynamic areas) may be identified as “cloud” by the ACSM



Current ACSPO ice mask Comes from 0.1º CMC L4
May not be fully accurate and sufficiently hi-res



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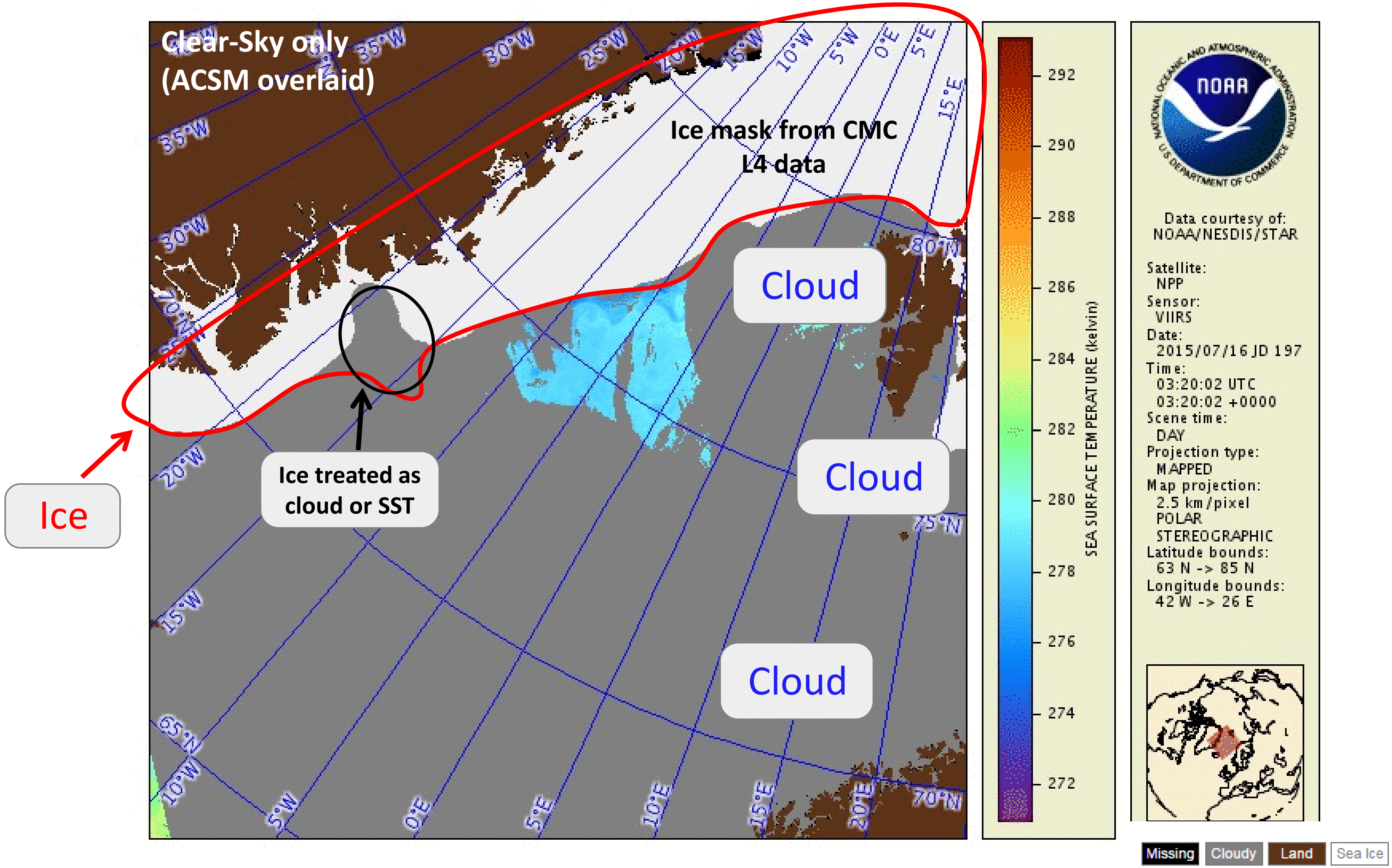
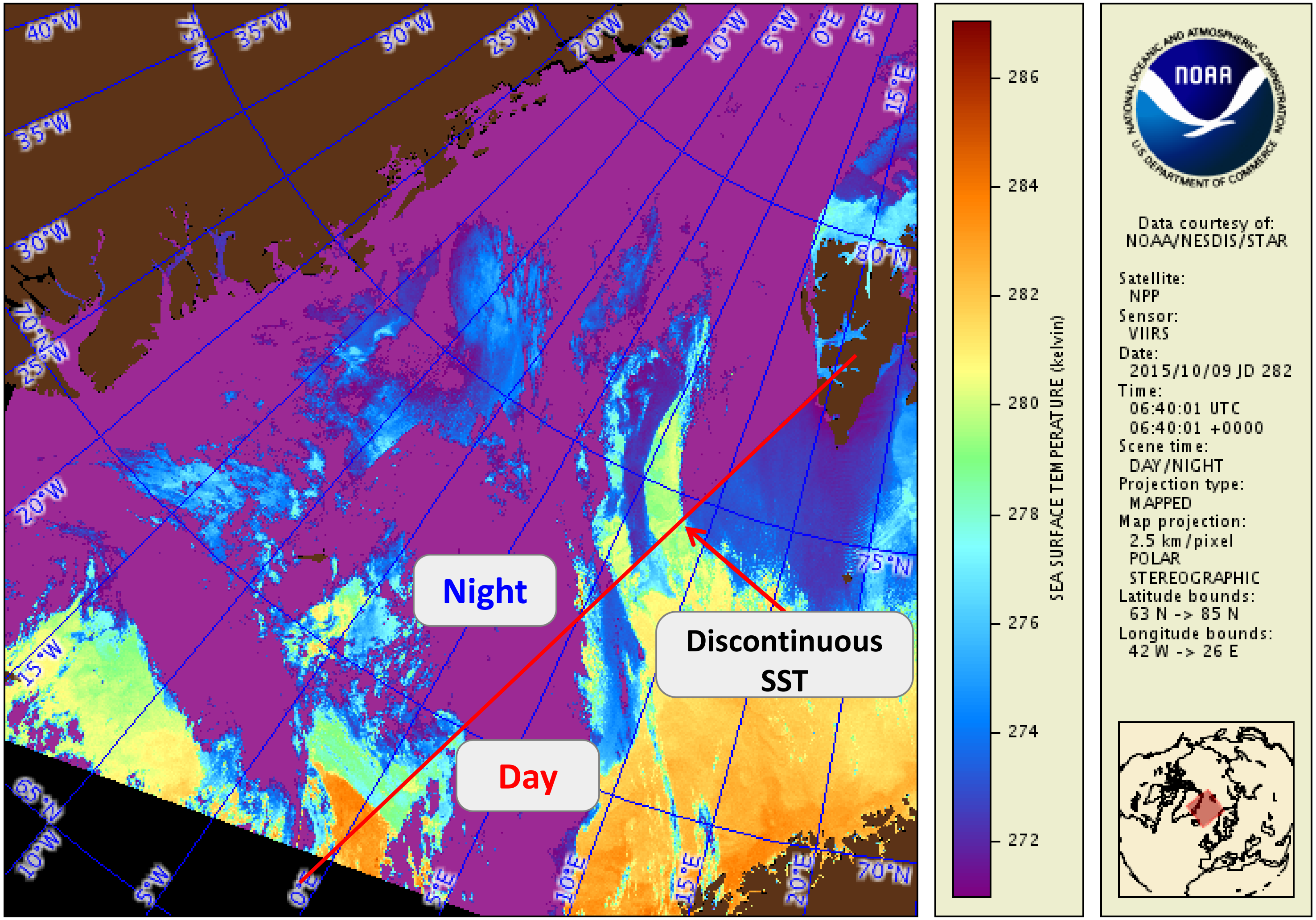


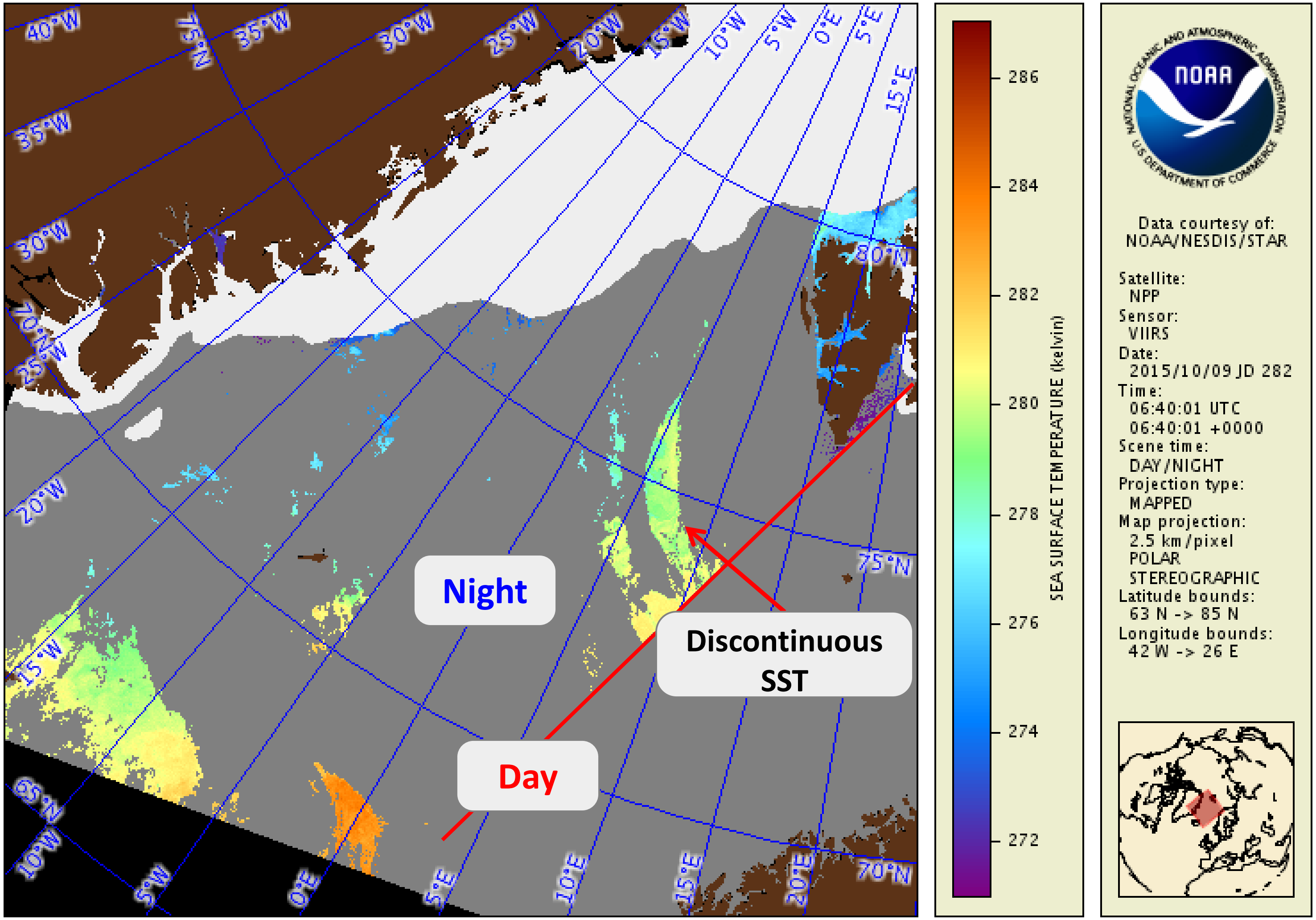
Sea ice and cold water may be identified as "cloud" by the ACSM

Example #3: Discontinuity problem in day/night transition zone



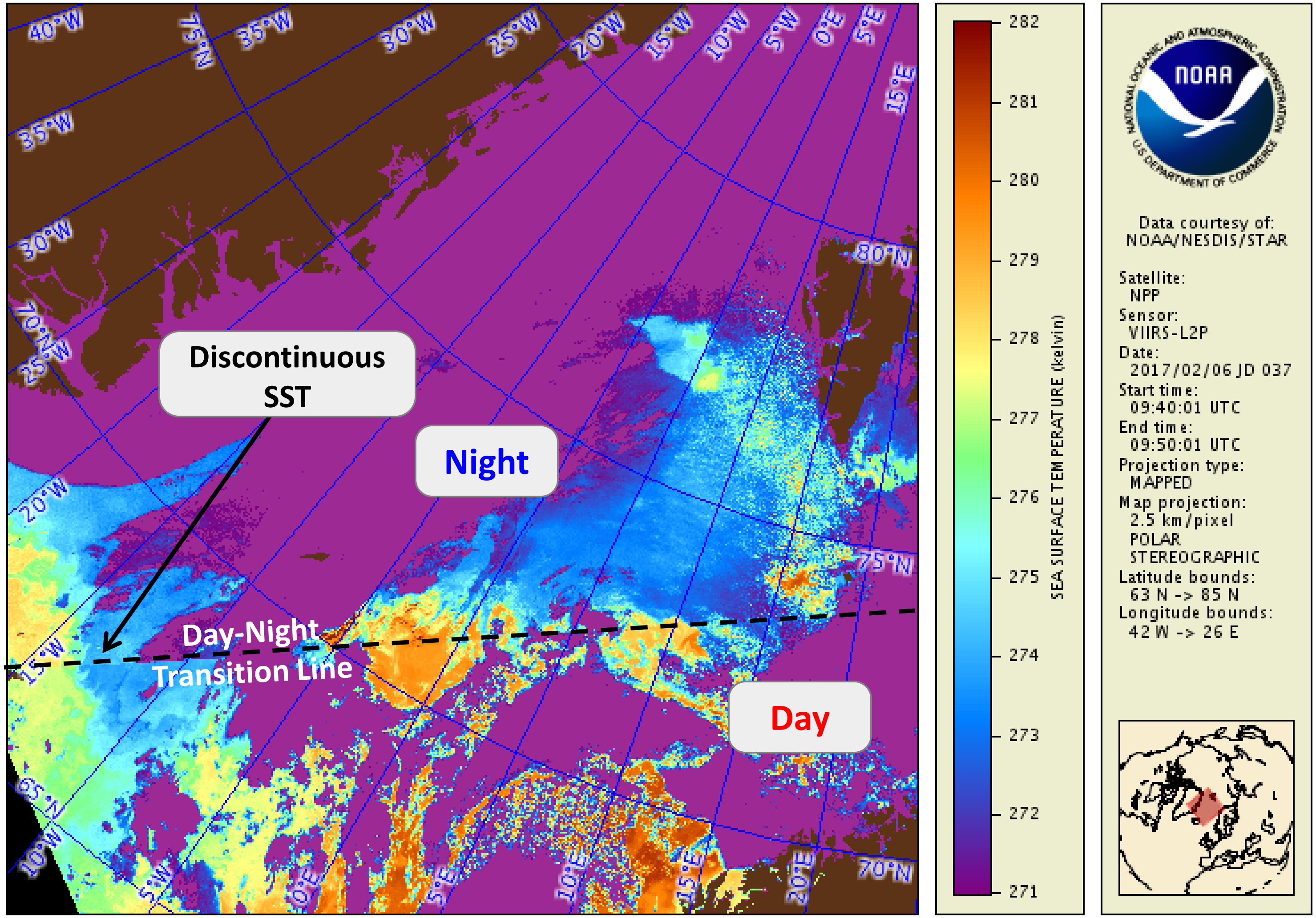
SST algorithm is different in daytime and nighttime, which causes discontinuity

Example #3: Discontinuity problem in day/night transition zone



Use of gross filter **RGCT** instead of ratio filter **RRCT** causes cloud mask discontinuity

Example #3: Discontinuity problem in day/night transition zone



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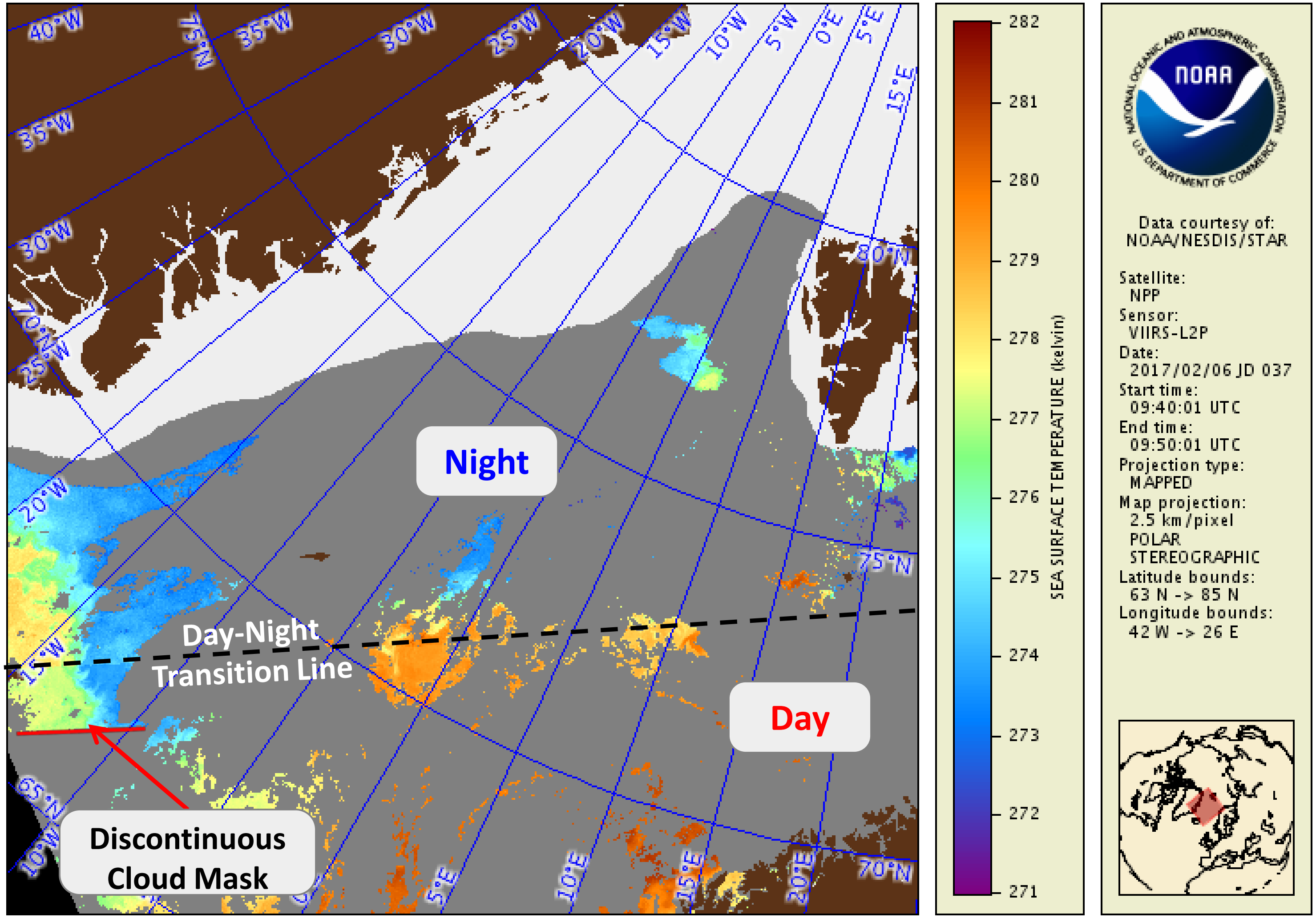


The use of gross filter **RGCT** instead of ratio filter **RRCT** may cause cloud mask discontinuity

Conclusion

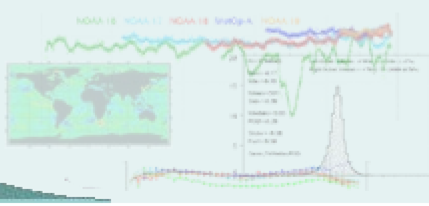
Potential improvements of ACSPO using ARMS

- The current “in-pixel” ACSPO Clear-Sky Mask may be overly conservative in coastal, dynamic , and hi-lat areas – work on pattern recognition improvements is underway (Irina’s talk)
- The current ice mask used in ACSPO comes from 0.1º CMC L4 and has room for improvement – have not looked into that yet
- Discontinuity in both SST and mask seen in day/night “twilight” zone in earlier versions of ACSPO – improved in recent ACSPO
- ARMS is a first step towards data fusion
  - ✓ Data of different overpasses from the same platform cane “collated” to generate an L3C
  - ✓ Data from multiple platforms can be “super-collated” to generate an L3S

Potential improvements in ARMS

- SSES effectively reduce global consistency of satellite SST with in situ SST. We plan to add SSES “on-off” button in ARMS, to see its effect on local imagery
- Improve web speed efficiency
- Listen to users what else might be needed

SST Quality Monitor Version 2 (SQUAM2)

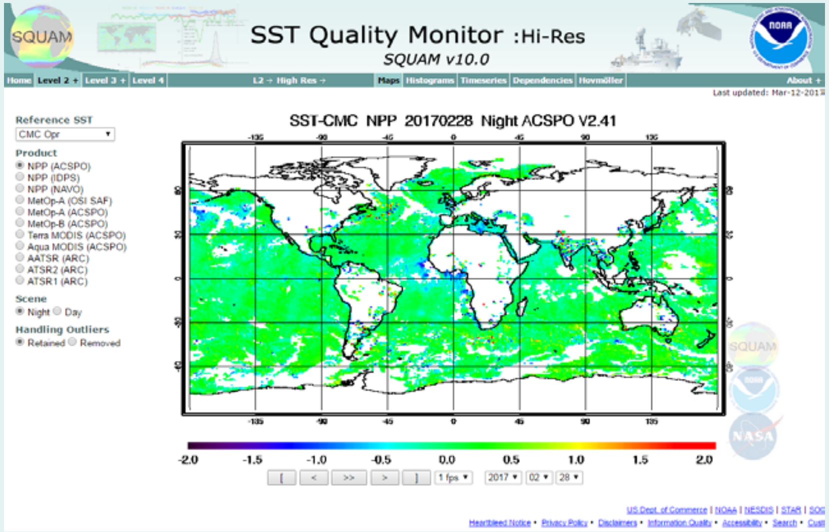


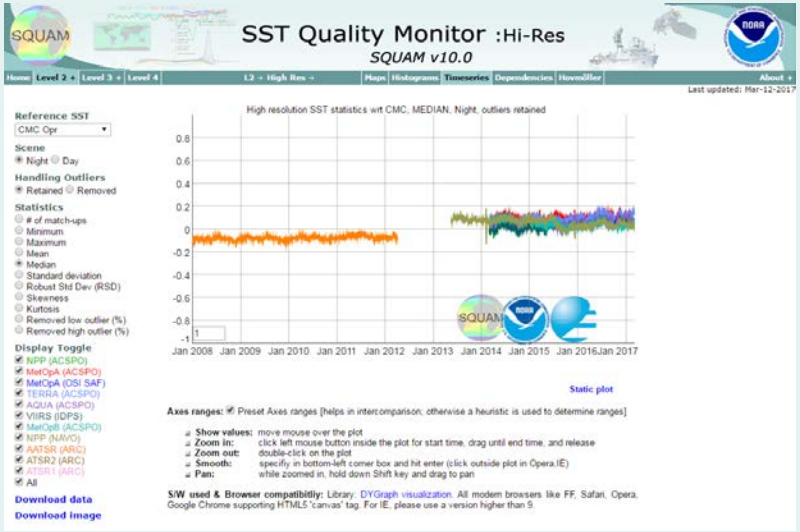
Kai He[1,2], Xinjia Zhou[1,3], Sasha Ignatov[1],
Maxim Kramar[1,2], Pransanjit Dash[4]

1. NOAA STAR; 2. GST, Inc.; 3. CIRA CSU; 4. EUMETSAT

SQUAM Background

- Development started in 2007 at NOAA. V1.0 released in 2009
- Today, SQUAM is a GHRSST resource for near real-time monitoring and validation of major global SST products produced by SST community
- Plots: Maps, histograms, time series, dependencies, Hovmöller diagrams
- Data monitored: community L2, L3, and L4 SSTs
- Web interface & interactive plotting





Methodology

- SQUAM analyzes **bias** of product SST *w.r.t.* reference SST

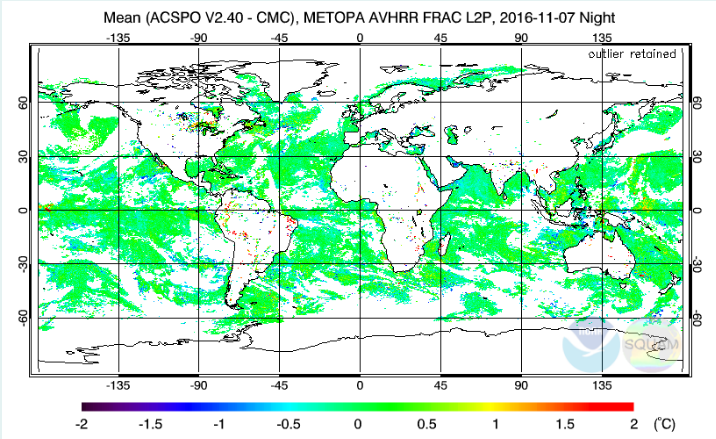
$$\Delta T = T_{product} - T_{ref}$$

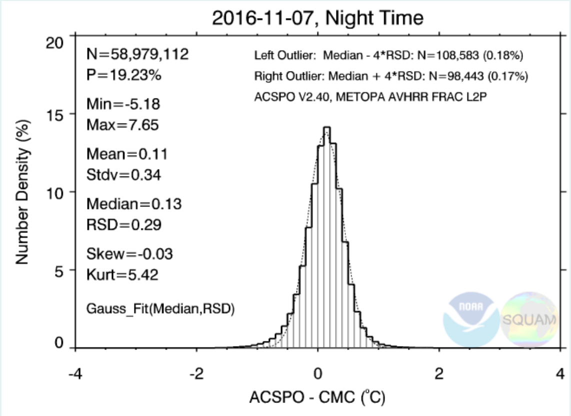
- Customarily, *in situ* SSTs are the natural choice of T_{ref} for SST validation. However, the global distribution is sparse and non-uniform in both space and time
- SQUAM supplements *in situ* validation with analyses against global L4 SSTs as reference
  - Higher coverage
  - Quality more uniform in space and time than *in situ* due to QC and bias adjustment in L4 production
  - Multiple L4 references, allowing sensitivity assessment to T_{ref} field
- The underlying assumption is that global distribution of ΔT is close to Gaussian
  - May be contaminated by outliers caused by sensor malfunction, suboptimal algorithm, cloud leakage, etc.
  - Statistical metrics of Gaussian can be used to monitor stability of SSTs and quality control them

Methodology

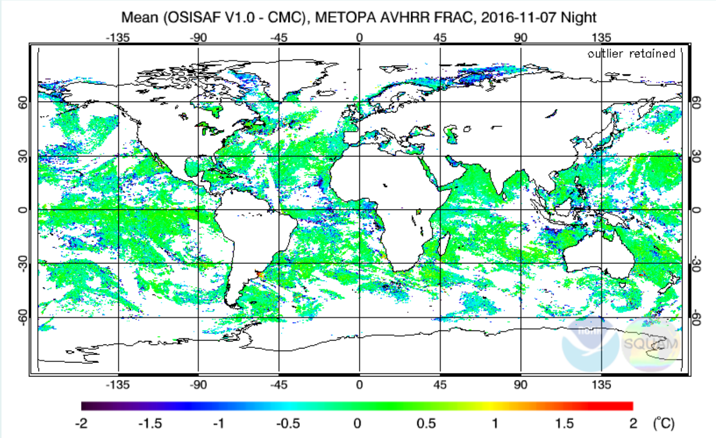
- *ΔT* should be small, centered at zero, and have a near-Gaussian distribution
- Left tail may be indicative of residual cloud and/or aerosol contamination

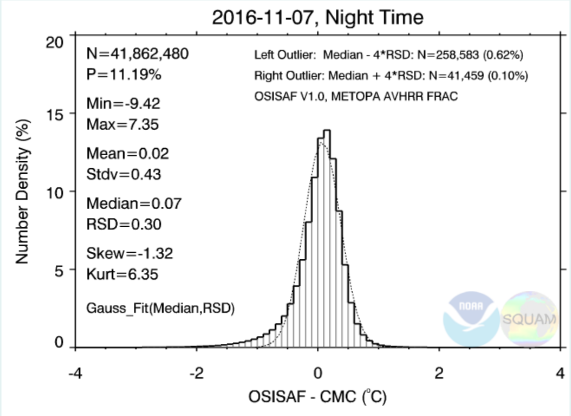
ACSPO





OSI-SAF

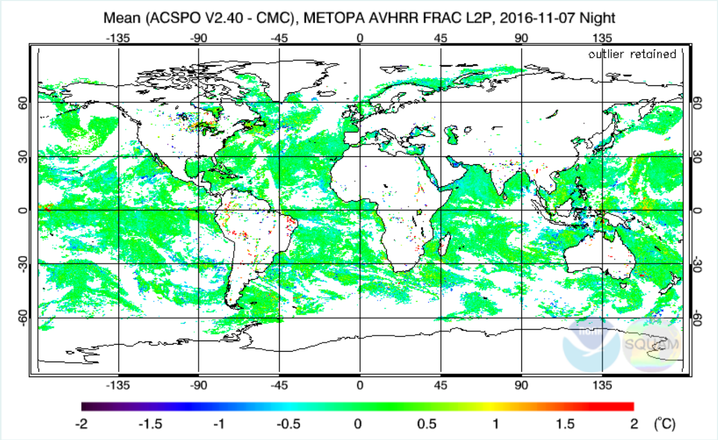


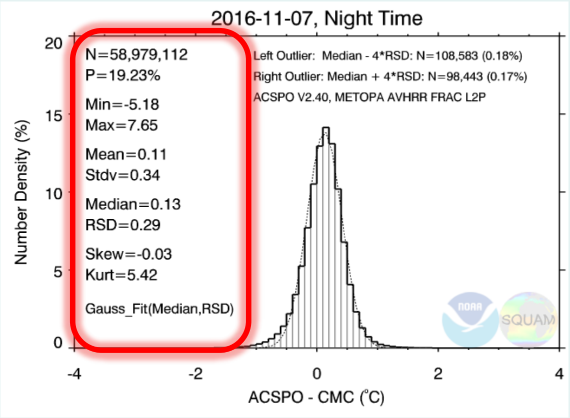


Methodology

- Maps & Histograms vs. L4 provide a global “snapshot” for daily diagnostics

ACSPO





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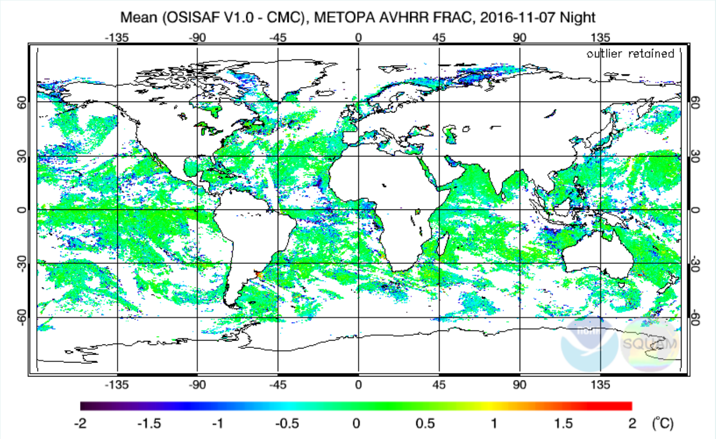
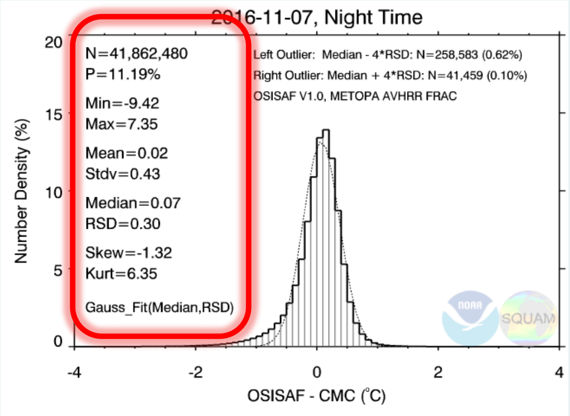
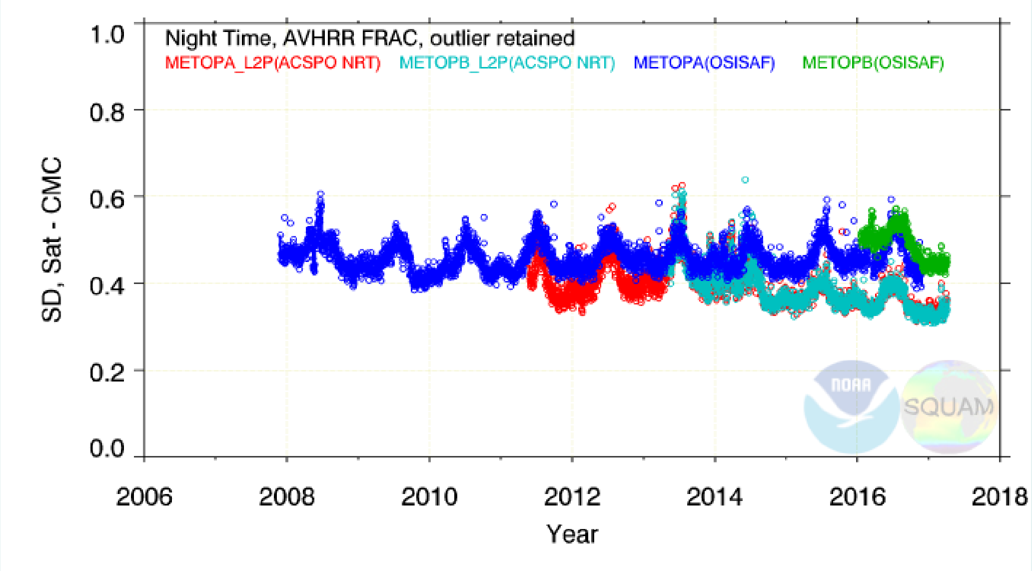
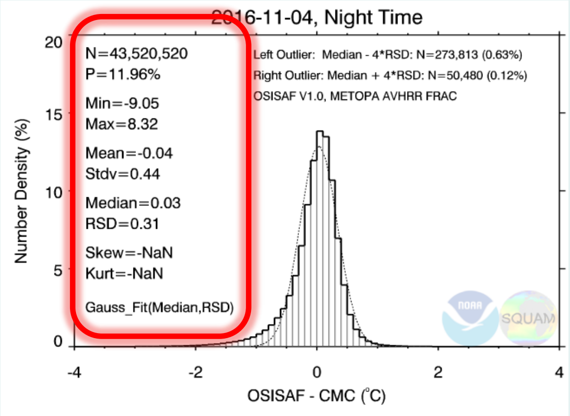




Methodology

- Maps & Histograms vs. L4 provide a global "snapshot" for daily diagnostics
- Time series of statistics of *ΔT* are generated to monitor stability and cross-platform consistency



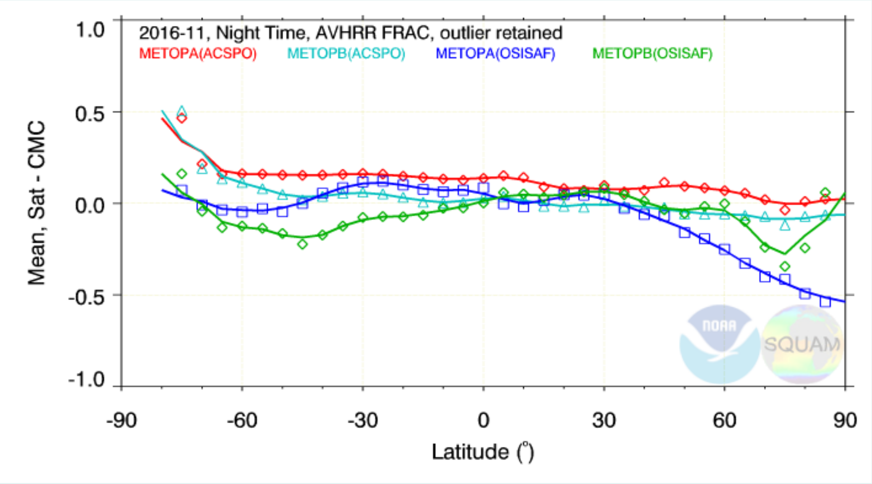


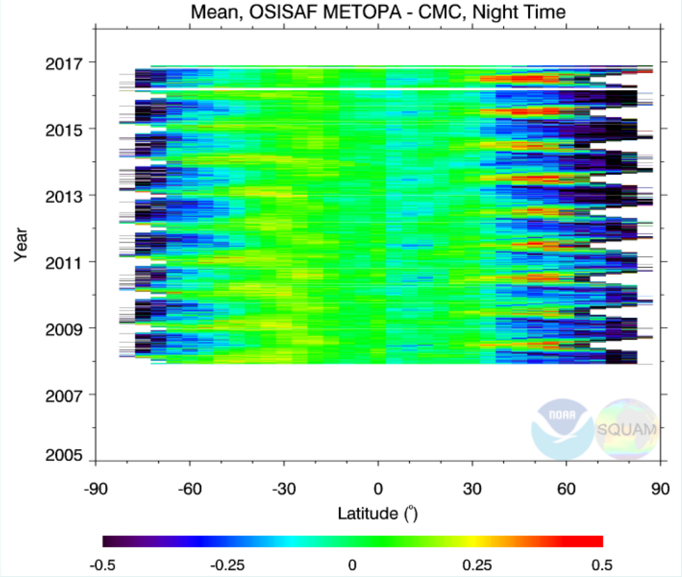
Methodology

- Maps & Histograms vs. L4 provide a global "snapshot" for daily diagnostics
- Time series of statistics of *ΔT* are generated to monitor stability and cross-platform consistency
- Dependencies & Hovmöller plots help to identify and understand outliers & instabilities

Latitude dependence

Mean - Latitude





Motivation for Redesign

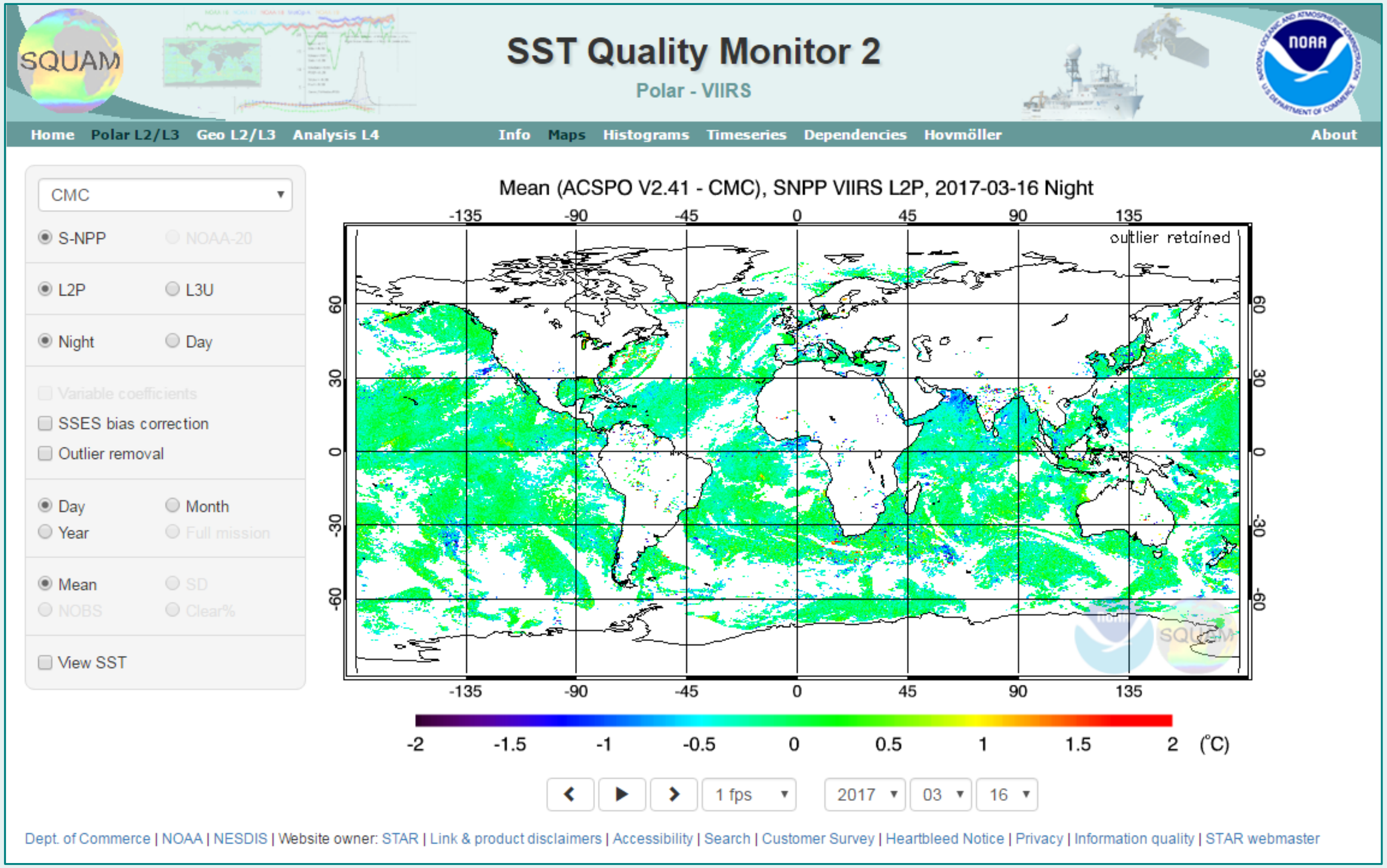
- Challenging data volumes and demand of computing resources
  - New gen polar: VIIRS onboard SNPP and future J1 – J4; AVHRR FRAC onboard Metops; MODIS onboard Terra and Aqua
  - New gen geo: ABI onboard G16 and future GOES-S/T/U, AHI onboard Himawari-8/9
  - Reanalyses (RAN): AVHRR GAC and VIIRS, future FRAC, MODIS, etc.
- Need for adding new functionalities
  - SSES bias correction
  - Variable regression coefficients (for ACSPO RAN SSTs)
  - SQUAM processing improvements: time aggregation, match-up, etc
- Need for updating the 8-year-old web interface
  - Room for improvement with new web tech (graphic, interactivity, speed, etc.)

Facing the need for reorganization and redesign

- Development of SQUAM2 started in 2016

SQUAM 2: A Snapshot

www.star.nesdis.noaa.gov/sod/sst/squam2/ (Current URL)



SQUAM 2: Organization

	Polar L2/L3	Geo L2/L3	Analysis L4
High Resolution	**S-NPP VIIRS** ACSPO L2P ACSPO L3U **AVHRR FRAC** ACSPO L2P OSISAF L2P	**Himawari-8 AHI** ACSPO L2P **GOES-16 ABI** ACSPO L2P	MUR (JPL)
Low Resolution	**AVHRR GAC** ACSPO		CMC (Environment Canada) OSTIA (Met Office) GMPE (Met Office) Reynolds (NOAA) GAMSSA (Bureau)

SQUAM 2 Polar

- VIIRS, AVHRR FRAC, AVHRR GAC
- Reference SST:
  - L4: CMC, OSTIA, Reynolds
  - *In situ* (iQuam v2): drifters + tropical moorings, ARGO floats
- ACSPO L2P & L3U
  - Currently a mix of RAN and NRT data (seamless records)
  - RAN: 01 Mar 2012 -- 05 Dec 2015
  - NRT: 06 Dec 2015 – present
- Day & Night
- **SSES bias correction**
- Outlier removal (currently defined as >±4RSD)
- Time aggregation: day, month, year, full mission (future)
- Maps & histograms
  - View SST (in addition to *ΔT)*
- Time series
  - Stats include: NOBS, clear ratio, min/max, mean/median, sd/rsd, skew/kurt, low/high outlier ratio
- Dependencies plots & Hovmöller diagrams
  - Sat view angle, solar zen angle, lat/lon, SST, SST- air temperature, wind speed, total precipitable water, glint angle, scattering angle

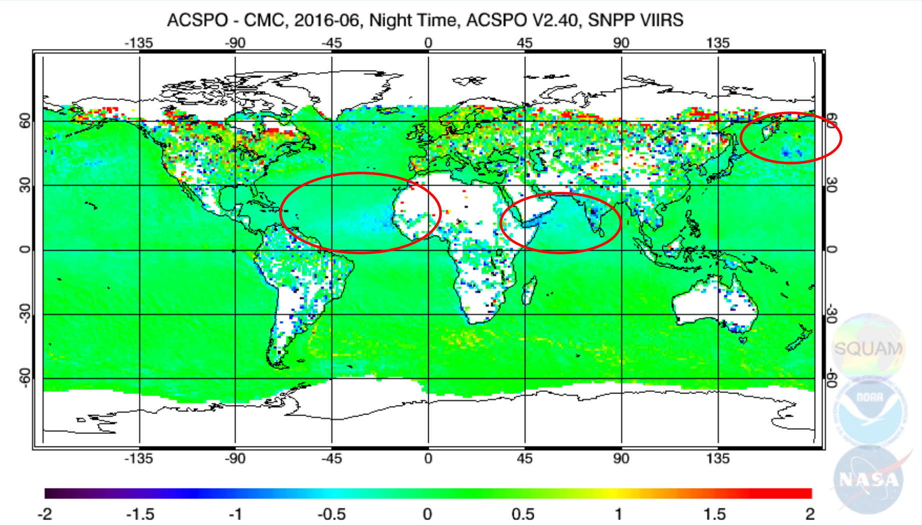
SQUAM 2 Polar

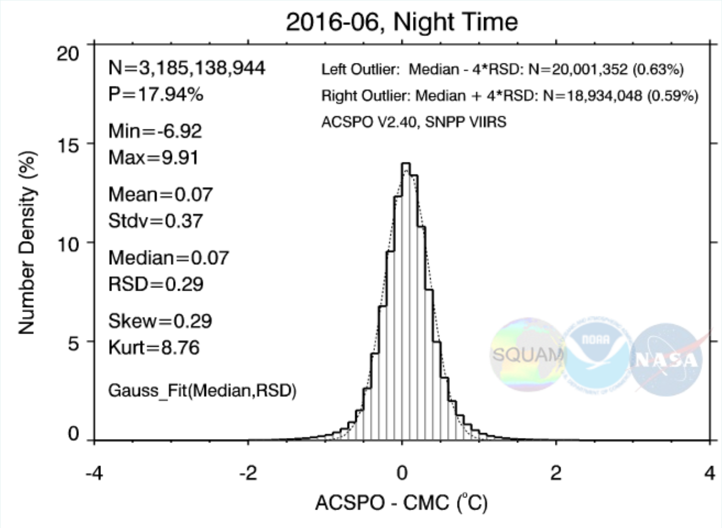
Example: SSES bias

- Using maps & histograms to show SSES bias correction on aerosol effect (link)
  - VIIRS L2P, ACSPO – CMC L4
  - Jul 2016, monthly aggregated, nighttime
- Cold bias in typical areas affected by aerosols
  - Tropical eastern Atlantic, Indian ocean, north-west Pacific

BEFORE applying SSES bias correction

S-NPP VIIRS, 2016-06, Bias=0.07K SD=0.37K



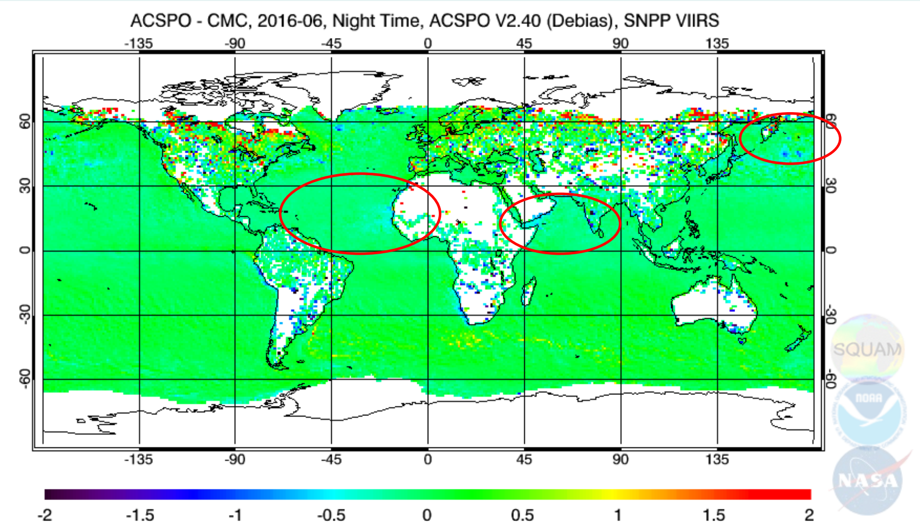


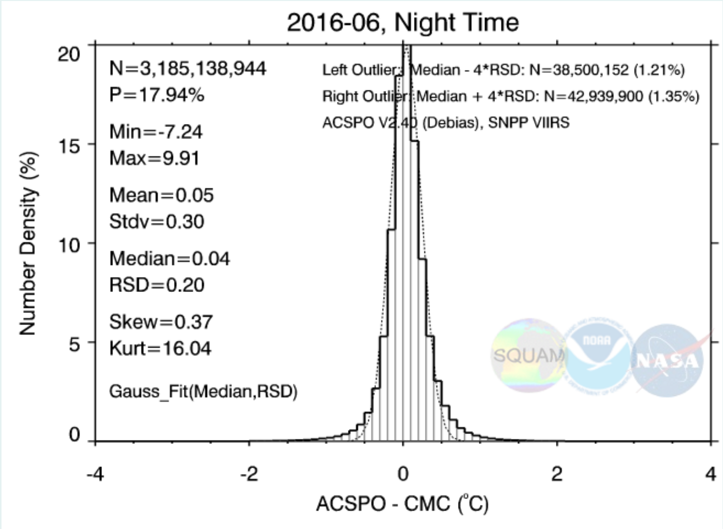
SQUAM 2 Polar
Example: SSES bias

- Using maps & histograms to show SSES bias correction on aerosol effect (link)
  - VIIRS L2P, ACSPO – CMC L4
  - Jul 2016, monthly aggregated, nighttime
- Cold bias in typical areas affected by aerosols
  - Tropical eastern Atlantic, Indian ocean, north-west Pacific

AFTER applying SSES bias correction

S-NPP VIIRS, 2016-06, Bias=0.05K SD=0.30K





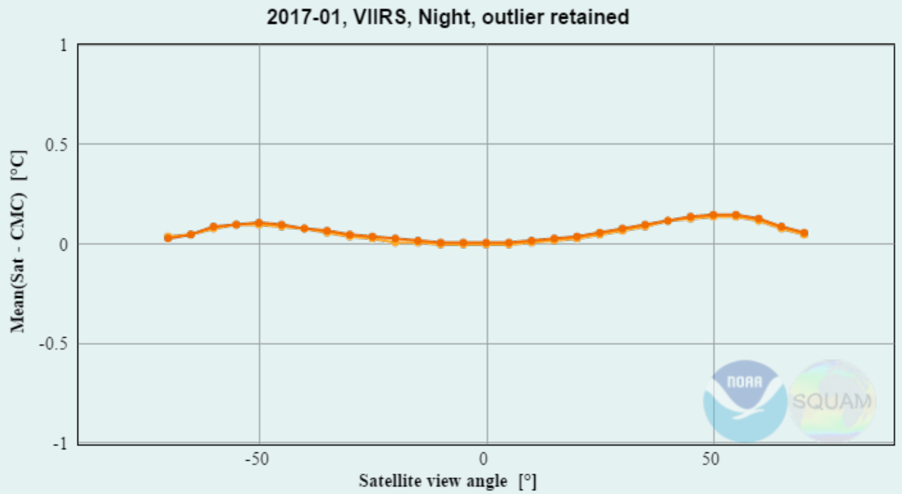
SQUAM 2 Polar

Example: SSES bias

- Using dependency plots and Hovmöller diagrams to show how SSES mitigates biases related to dependence variables (link)
  - VIIRS, ACSPO – CMC L4
  - Dependence variable: satellite view angle

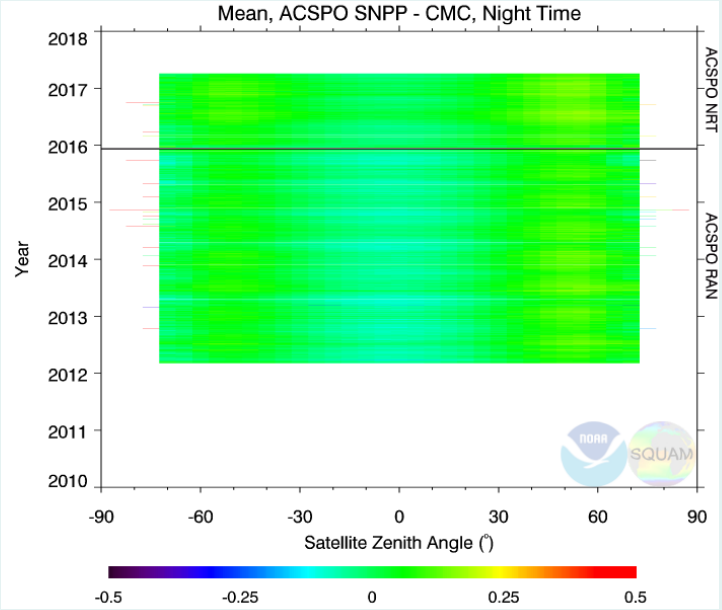
BEFORE applying SSES bias correction

Dependency – 2017-01, monthly, night



– SNPP L2p – SNPP L3U

Hovmoller – SNPP L2P, daily, night



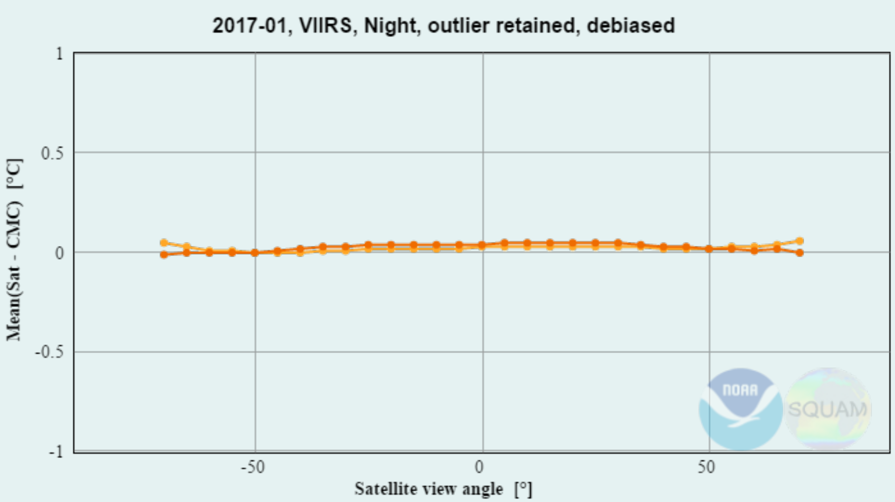
SQUAM 2 Polar

Example: SSES bias

- Using dependency plots and Hovmöller diagrams to show how SSES mitigates biases related to dependence variables (link)
  - VIIRS, ACSPO – CMC L4
  - Dependence variable: satellite view angle

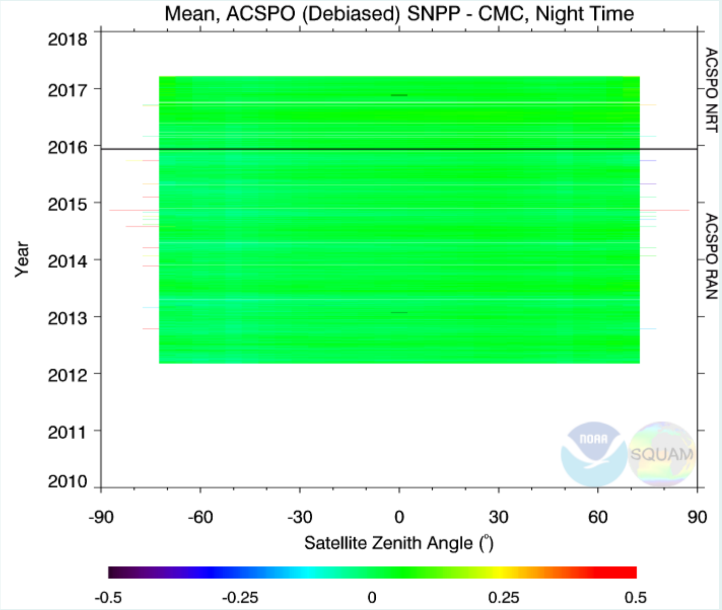
AFTER applying SSES bias correction

Dependency – 2017-01, monthly, night



– SNPP L2p – SNPP L3U

Hovmoller – SNPP L2P, daily, night



SQUAM 2 Polar

- VIIRS, AVHRR FRAC, AVHRR GAC
- ACSPO RAN
- PM & AM families (seamless records for each; two platforms at a time)

NOAA-16	PM	30 Aug 2002 – 06 Jun 2005
NOAA-18	PM	07 Jun 2005 – 21 Feb 2009
NOAA-19	PM	22 Feb 2009 – present
NOAA-17	Mid-AM	30 Aug 2002 – 22 Nov 2006
Metop-A	Mid-AM	23 Nov 2006 -- present

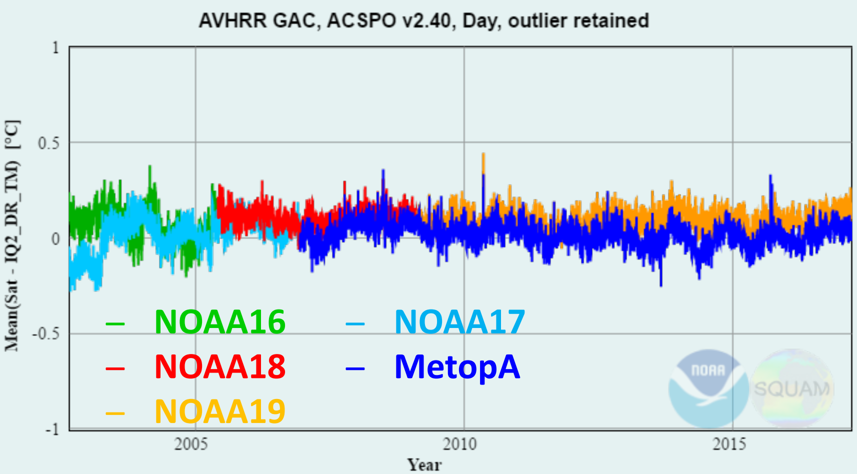
- Variable regression coefficients
  - Ex: time series of mean bias against *in situ*.
- Time series of double difference
  - Daytime – nighttime, satellite – AM ref satellite, satellite – PM ref satellite

SQUAM 2 Polar

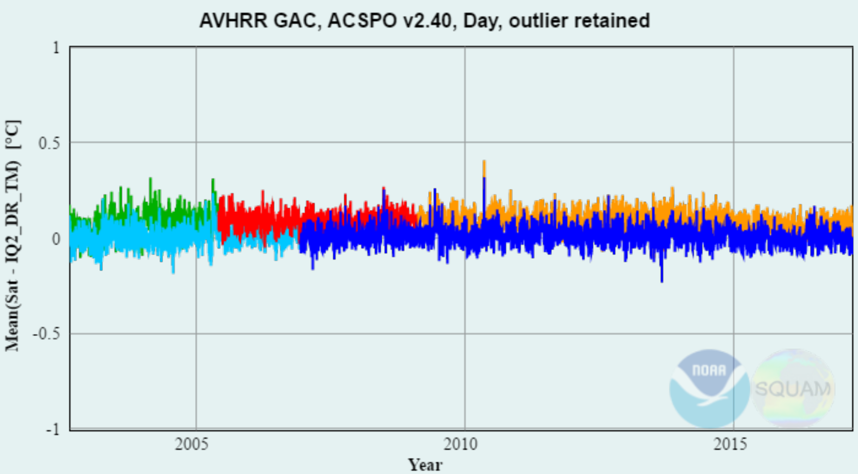
Example: variable coefficients

- AVHRR GAC SSTs are unstable due to brightness temperature (BT) artifacts, which are caused by suboptimal calibration, drifting orbits, etc.
- Without a "stable version" of BT, variable regression coefficients are employed in ACSPO RAN
- Variable regression coefficients are dynamically derived using a 90-day moving window
- fixed coefficients vs. variable coefficients in GAC RAN time series (link)
  - Validated against drifters + tropical moorings
  - Mean, day time
- Greatly suppress the variations, especially in NOAA16 & NOAA17

Fixed coefficients



Variable coefficients



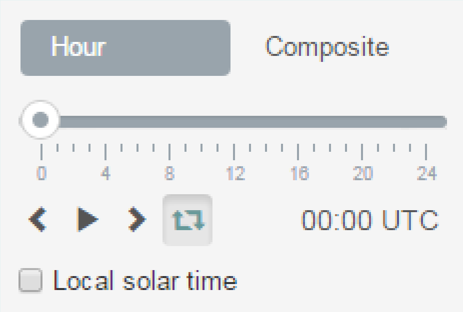
SQUAM 2: Geo

- Hamawari-8 AHI, GOES-16 ABI (upcoming)
- Reference SST:
  - L4: CMC, OSTIA
  - *In situ* (iQuam v2): drifters + tropical moorings, ARGO floats
- ACSPO L2P
  - 14 Apr 2015 – present
- SSES bias correction, outlier removal, time aggregation
- Hour & local solar time, and composite
  - Hour: specify hour of day (HOD) in both UTC and local solar time (LST)
  - Composite: daytime/nighttime, button to compare to VIIRS
- Maps & Histograms
  - Satellite view (default) and equiangular projection
- Time series
  - View all hours or by individual hour (in both UTC and LST)
- Dependencies & Hovmöller
  - Local hour dependency

SQUAM 2: Geo

Hourly analysis

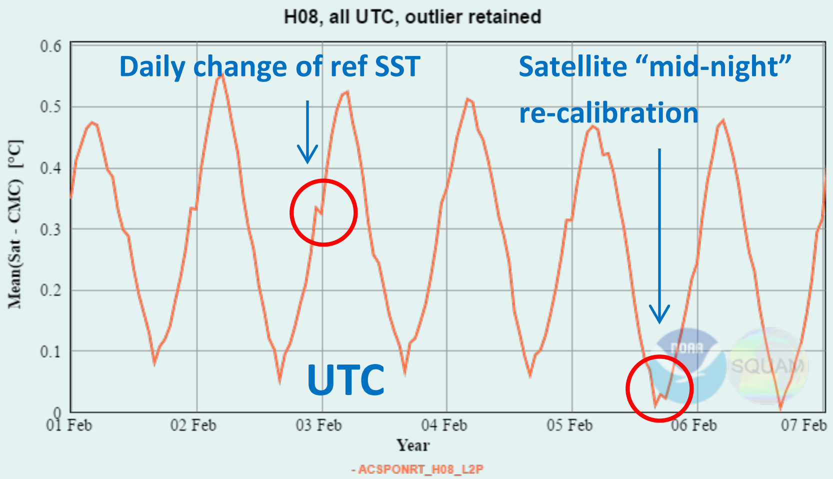
- Hourly analysis in SQUAM Geo
  - H08 AHI temporal frequency: every 10 min (GOES-16 ABI: 5 or 15min)
  - SQUAM picks 1st full disk image in a 1-hour interval
  - Compatible with time aggregation (month, etc.)
- UTC based (default)
  - For monitoring sensor performance
- Local solar time based
  - For scientific analysis, since physics are based on local time, such as diurnal cycle effect.
  - LST results are computed by splitting full disk images based on LST hour and regrouping.
- Interactive control
  - Hour slider
  - Navigation bar
  - Toggle between “looping” and “rolling”
    - Pressed (looping): constrained to 24 hrs UTC/LST
    - Unpressed (rolling): allow crossing onto the adjacent day/month

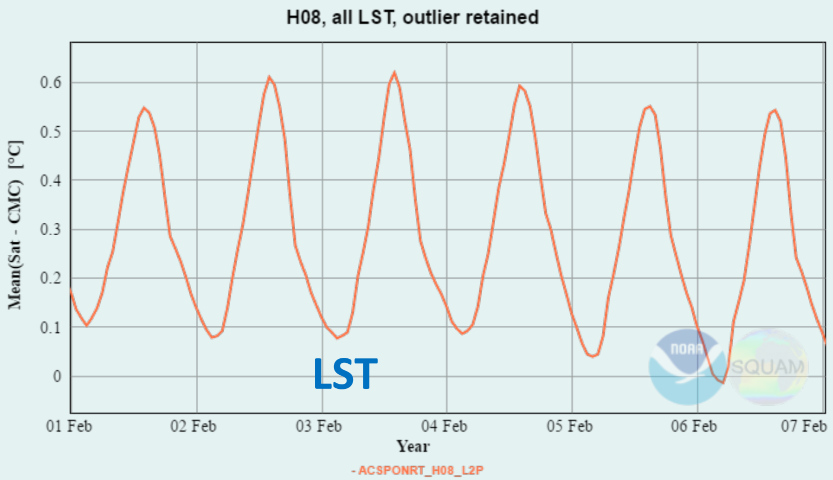


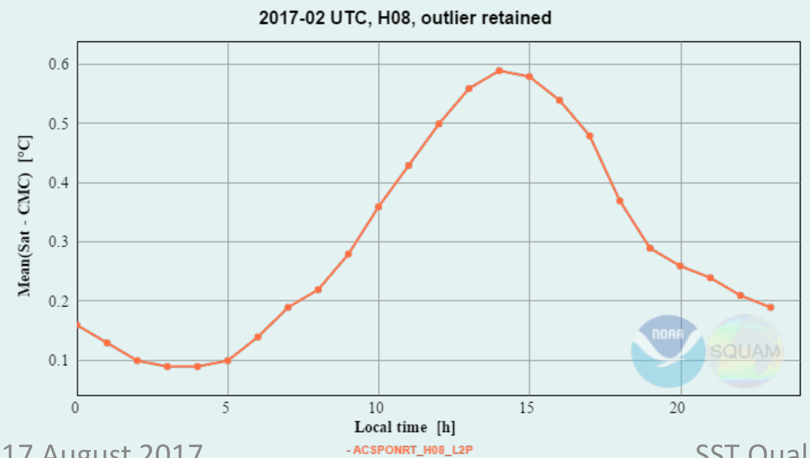
SQUAM 2: Geo

Example: diurnal cycles

- In SQUAM time series (link)
  - Mean bias, H08 against CMC
  - Local solar time
  - 01 Feb – 07 Feb, 2017
- Also in SQUAM dependency plots with time aggregation (link)
  - Dependence variable: local time
  - Feb 2017, monthly aggr.
- min ~ 0.1K @03:00 LST, max ~ 0.6K @14:00 LST

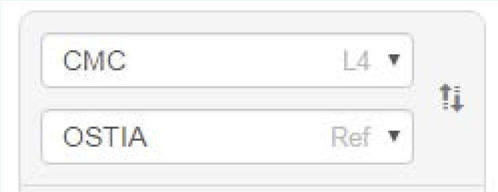






SQUAM 2: Analysis (L4)

- L4 SSTs: CMC, OSTIA, GMPE, Reynolds, GAMSSA, MUR
- *in situ* reference in addition to L4: drifters + tropical moorings, ARGO floats
- Interactive controls
  - L4 box & Ref box
  - Not simply interchangeable: L4 SST is mapped to the grids of the Ref SST
  - Swap if selecting identical ones, or clicking "swap" button

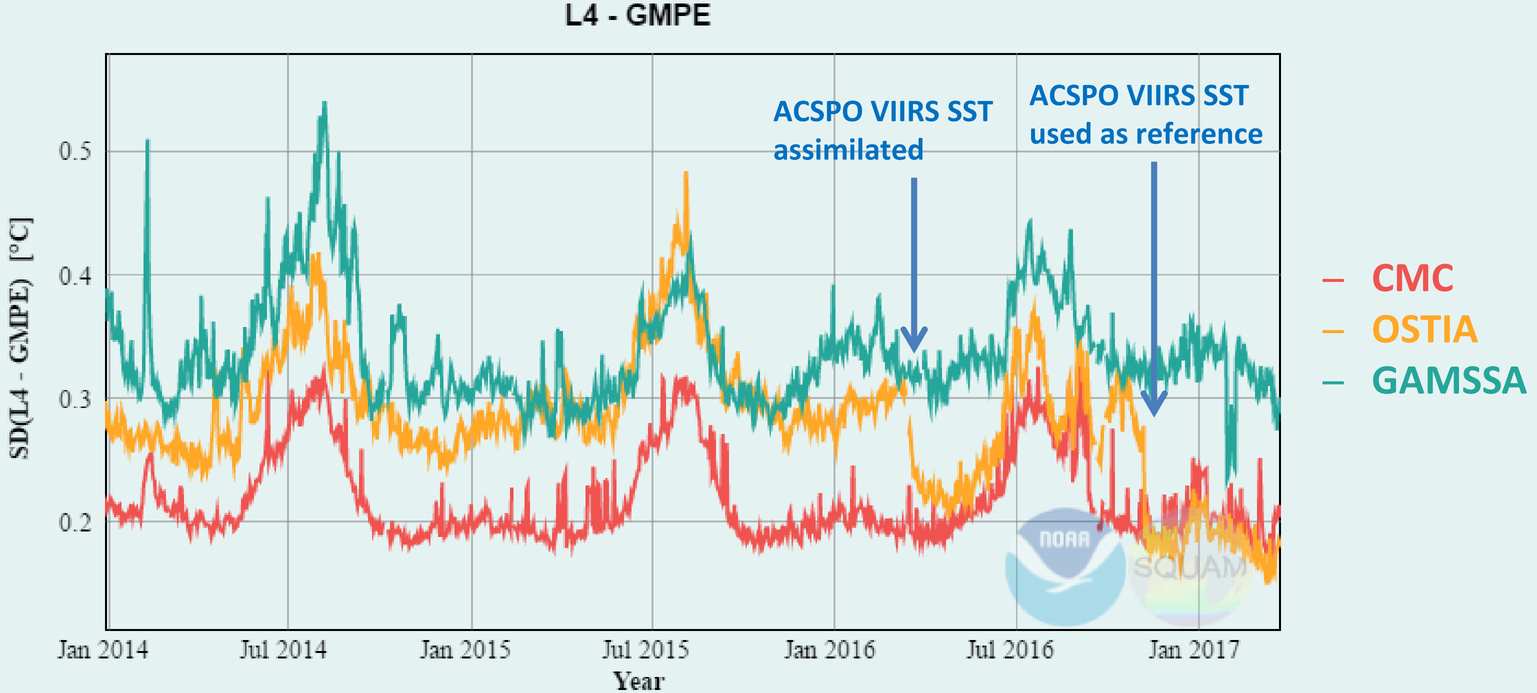


- Time aggregation
- Maps & histograms
  - Ice and/or land mask in "view SST" mode
- Time series
- Dependencies & Hovmöller
  - Dependence variables: latitude, SST

SQUAM 2 L4

Example: OSTIA

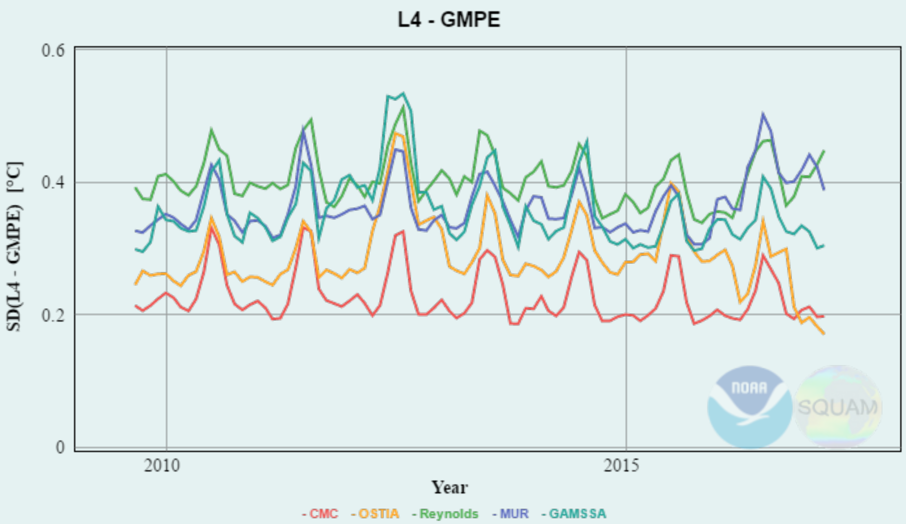
- OSTIA had made two changes in 2016 (link)
  - Mar 2016, SD(OSTIA – GMPE) decreased from ~0.3K to ~0.23K (OSTIA started to assimilate ACSPO VIIRS SST)
  - Nov 2016, SD dropped from ~0.27K to ~0.20K (OSTIA started using ACSPO VIIRS as reference)
  - OSTIA SD is now comparable with CMC, which has been assimilating ACSPO VIIRS SST since May 2014
- GAMSSA SD remained pretty much at the same level as the “pre-ACSPO” OSTIA
- This case study gives an idea of potential room for improvement in GAMSSA

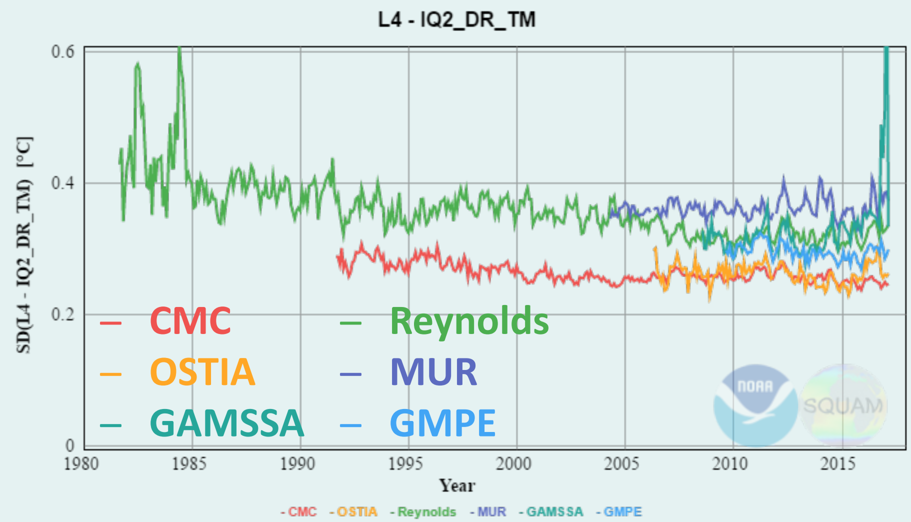


SQUAM 2 L4

Example: against *in situ*

- The results of “L4 – GMPE” and “L4 – in situ” are not fully consistent
- This is because *in situ* data have been assimilated in all L4 analyses (except GMPE), more aggressively in some L4s than in the others
- CMC (and more recently, OSTIA too) are on the lower envelope of points against both GMPE and in situ, suggesting overall better performance





SQUAM 2
Web functionality

- Web-based features

Permalink	URL stores all tab and button selections, easy for bookmarking and sharing
Session caching	Polar, Geo, and Analysis memorize their tab & button selections independently
Interactive plots	Available in time series and dependencies, powered by DYGraph JS library. Both image and data are export-able.

- interactive plot cheat sheets

Zoom in	Hold your click and drag
Reset zoom	Double click or check “Axis range: preset”
Pan	Hold Shift key and drag
Show values	Hover on the data point
Smooth	Enter *n* in the left corner box for *n*-point mean filtering
Toggle dataset visibility	Check/un-check “Display toggles” boxes
Download	Press button for data download or image export

SQUAM 2

Summary

- SQUAM has been upgraded and redesigned to
  - Meet challenging demands of data volume and computing resource due to new platforms and products
  - Stay more centric to NOAA ACSPO products
  - Support new techniques (SSES, variable coefficients, etc)
  - Improve processing algorithms and efficiency
  - Enhance web interface and functionality
- We are committed to support SQUAM2 for our community users and partners. Ongoing development and improvements are based on user needs and feedback
  - Opinions on the current contents, functionality, features?
  - Suggestions of wanted features? Feedback is appreciated & improvements will be made
- We plan to release SQUAM2 in place of heritage SQUAM by the GHRSST Meeting in June 2017

Thank you!

NOAA in situ SST Quality Monitor Version 2 (*i*Quam2)

Current url: www.star.nesdis.noaa.gov/sod/sst/iquam/v2

Xinjia Zhou[1,2], Alexander Ignatov[1], Feng Xu[1,3,4], Kai He[1,3]

[1]NOAA STAR; [2]CSU CIRA; [3]GST Inc.; [4]Fudan University, China

Motivation and Objective

- NOAA is responsible for wide range of polar and geostationary satellite SST products (including swath – L2, gridded – L3) and blended/analysis L4 SSTs.
- High-quality, unified *in situ* standard is needed for consistent Cal/Val
  - Covers full satellite era 1981 – pr
  - Includes all available normal-quality and high-quality *in situ* SSTs suitable for satellite Cal/Val (drifters, moorings, ARGO floats, ships)
  - Uniformly processes all *in situ* data using state-of-the-art QC, consistent with wider oceanographic, meteorological, and climate communities such as Met Office, NOAA NCEP, ICOADS. Preserve all heritage QFs for user's option.
  - Provides data in community consensus, user friendly format, via web interface with minimal latency, to support NRT Cal/Val applications
  - Reprocesses data periodically, to support long-term satellite consistent/climate data records (CDRs)

Motivation and Objective

- **In 2008, conducted inventory of available *in situ* SSTs for the use in Cal/Val**
  - ICOADS r2.40 (Sep 1981 – Jul 2007; not available in NRT; suboptimal QC for satellite Cal/Val)
  - FNMOC (Sep 1998 – pr; available in NRT; suboptimal QC for satellite Cal/Val)
  - NCEP GTS (Jan 1991 – pr; available in NRT; no QC)
  - Documented in: *Xu, Ignatov, 2010: Evaluation of in situ SSTs for use in Cal/Val, JGR, 115, C09022.*

- **In 2009, launched *in situ* SST Quality Monitor version 1 (*i*Quam1)**
  www.star.nesdis.noaa.gov/sod/sst/iquam/ (google "iquam")
  - Uses NCEP GTS data as feed (1991-pr)
  - Included drifters, tropical and coastal moorings, ships
  - State of the art UK MO Bayesian QC
  - Documented in: *Xu, Ignatov, 2014: In situ SST Quality Monitor (iQuam), JTECH, 31, 164.*

Today, *i*Quam has become a GHRSST community resource which is widely used nationally and internationally, to support Cal/Val and data assimilation for various blended and satellite SST products

*i*Quam users (we are aware of)

- NOAA STAR/OSPO – JPSS, GOES-R, Himawari, AVHRR (SQUAM, USA)
- JPL MUR (US) – M. Chin
- U. Miami MODIS, VIIRS Teams (US) – K. Kilpatrick, L. Williams
- Felyx (France/UK) – J.-F. Piolle
- CMS (France) – A. Marsouin
- JAXA (Japan) – Y. Kurihara, M. Kachi
- Ocean University (China) – L. Guan
- CMA (China) – S. Wang
- SOA (China) – Q. Tu
- NOAA geo-polar blended team (USA) – P. Koner, J. Mittaz, A. Harris, E. Maturi
- NOAA NCEI/Silver Spring (USA) – K. Saha
- NOAA NCEI/Asheville (USA) – V. Banzon
- EUMETSAT (Germany) – P. Dash, A. O'Carroll
- NASA GMAO (USA) – Ricardo Todling, Santha Akella, Guillaume Vernieres
- ABoM (Australia) – Irina Sakova, Helen Beggs

…

Enhancements in *i*Quam2

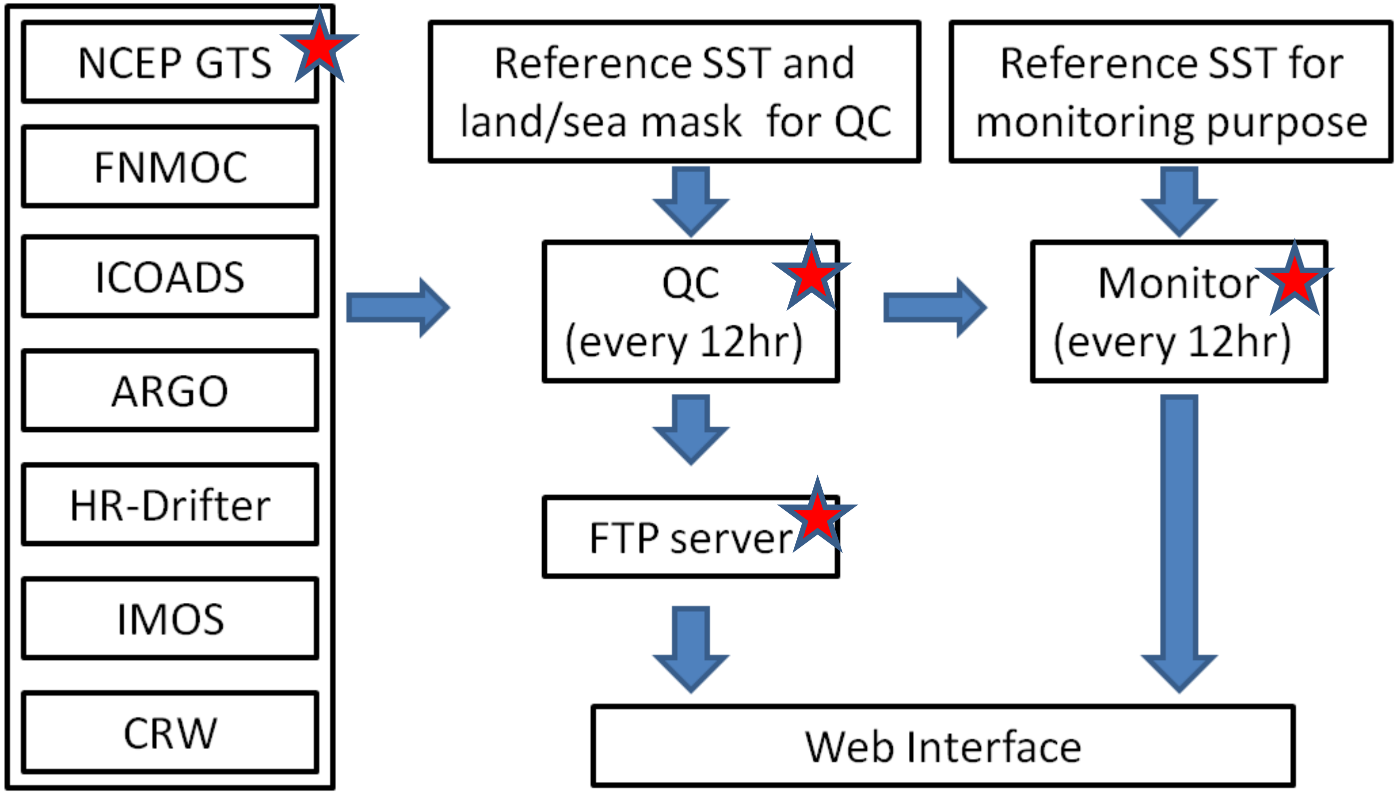
As *i*Quam user community grows, it requested several enhancements

- Extend time series to full satellite era (Sep 1981 – on)
- Improve QC, by adding
  - the 2nd reference SST (CMC)
  - performance history check (*i*Quam check similar to the UKMO/CMS "black lists")
  - CMS black list; and individual QFs from data producers (ICOADS, ARGO, IMOS)
- Improve web interface
  - Redesign web engine (from flash player to High Charts)
  - Add daily (hourly) statistics
  - Enhance graphics (interactive display, and print/save functions)
- Add new *in situ* data
  - ARGO Floats (in NRT and post-processing modes)
  - High-Resolution Drifters
  - IMOS Ships
  - Coral Reef Watch buoys
- Change output data files to NetCDF4. (Maximally reconcile with GHRSST GDS2 satellite L2/L3 format).

Functionality and Data Flow

The *i*Quam is a web-based near-real time system. It performs 4 major functions

- Ingests various *in situ* SSTs
- Performs a uniform Quality Control (QC)
- Monitors QCed *in situ* SSTs online
- Serves reformatted *in situ* SST data with quality flags appended



Quality Control in *i*Quam

Category	Check	Type of error handled	Physical basis
Preprocessing	Duplicate Removal	Duplicates arise from multiple transmission or data set merging	Identical space/time/ID
Plausibility	Geo-location checks	Unreasonable Geolocation	Range of single fields & Relationships among them
Internal consistency	Tracking	Points falling out of track	Travel speed exceeds limit
	Spike check	Discontinuities in SST time series along track	SST gradient exceeds limit
External consistency	Reference Check	Measurements deviating far away from reference	Bayesian approach (Ref. SST: daily OI SST v2 and CMC 0.2)
Mutual consistency	Cross-platform Check	Mutual verification with nearby measurements ("buddies check")	Bayesian approach based on space/time correlation of SST field
Performance consistency	Performance history check	Bad performance of single platform ID	Outlier rate exceeds limit (50%) in single platform
Heritage quality flags	All the heritage QFs are preserved in iQuam2 output files, including ICOADS, ARGO Floats, HR-Drifters, IMOS Ship and CMS blacklist.		

Quality level

iQuam2 quality level definition:

string quality_level:flag_meanings = "invalid not_used not_used low_quality acceptable_quality best_quality" ;
string quality_level:flag_values = "0b, 1b, 2b, 3b, 4b, 5b" ;

quality_level = 5 :

- ✓ Geo-location check pass
- ✓ Duplicate check pass
- ✓ Platform ID check pass
- ✓ Tracking check pass
- ✓ Spike check pass
- ✓ Performance history check pass
- ✓ Reference check probability < 0.5
- ✓ Cross-platform check probability < 0.1

quality_level = 4 :

- ✓ Geo-location check pass
- ✓ Duplicate check pass
- ✓ Platform ID check pass
- ✓ Tracking check pass
- ✓ Spike check pass
- ✓ Performance history check pass
- ✓ Cross-platform check probability < 0.5

Or

- ✓ Geo-location check pass
- ✓ Duplicate check pass
- \- Platform ID check fail
- \- Tracking check fail
- ✓ Spike check pass
- ✓ Performance history check pass
- ✓ Reference check probability < 0.5
- ✓ Cross-platform check probability < 0.1

quality_level = 3 :

- ✓ Fails to meet the criteria of ql = 5 or ql = 4

quality_level = 0 :

- ✓ Both references are unavailable

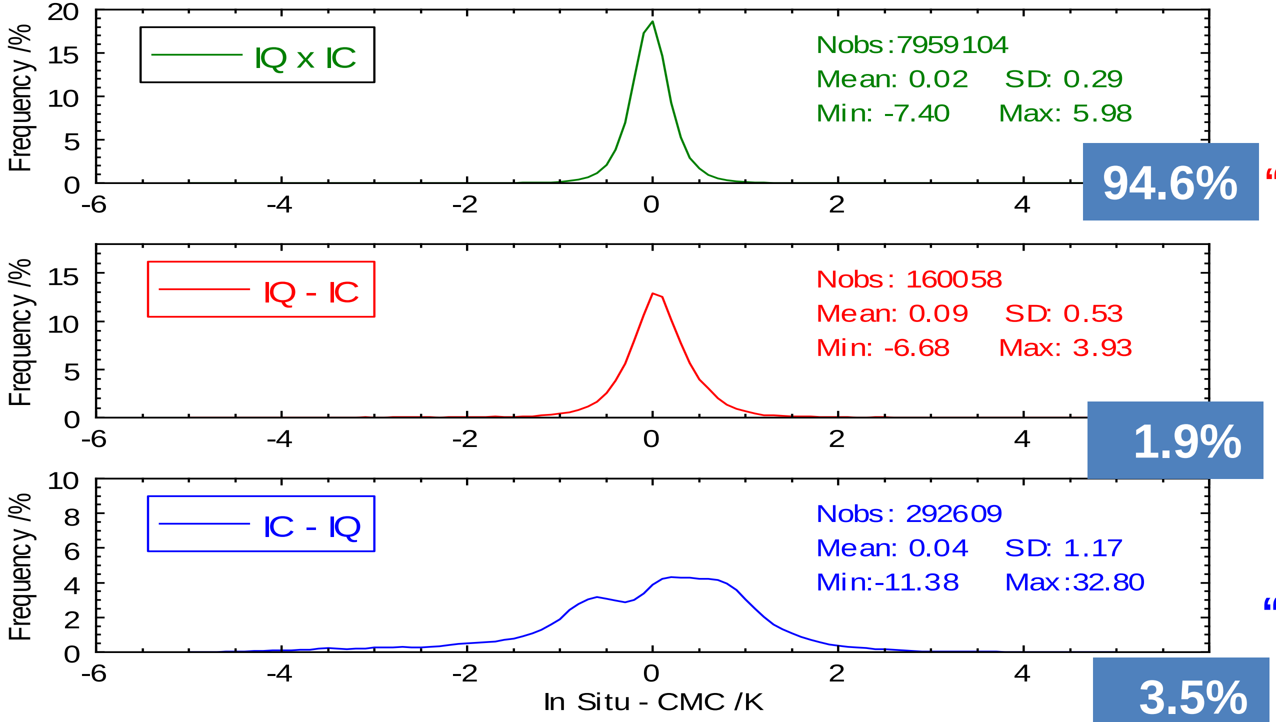
% of Data by Quality Levels
Example for Feb 2017

	Total Num	% of QL = 5	% of QL = 4	% of QL = 3
Argo floats	12,469	92.8	2.1	5.1
Drifters	607,840	91.6	2.4	6.0
HR-Drifters	156,951	74.7	1.8	23.5
Tropical Moorings	25,942	95.7	2.1	2.2
Coastal Moorings	235,223	79.3	2.7	18.0
CRW Moorings	15,340	95.1	2.0	2.9
Ships	80,745	66.9	4.3	28.8
IMOS Ships	63,849	65.8	0.6	33.6

Based on our observation, QL = 0 is not exist

Drifters QC
*i*Quam vs. ICOADS

Jan 2006 – Dec 2006



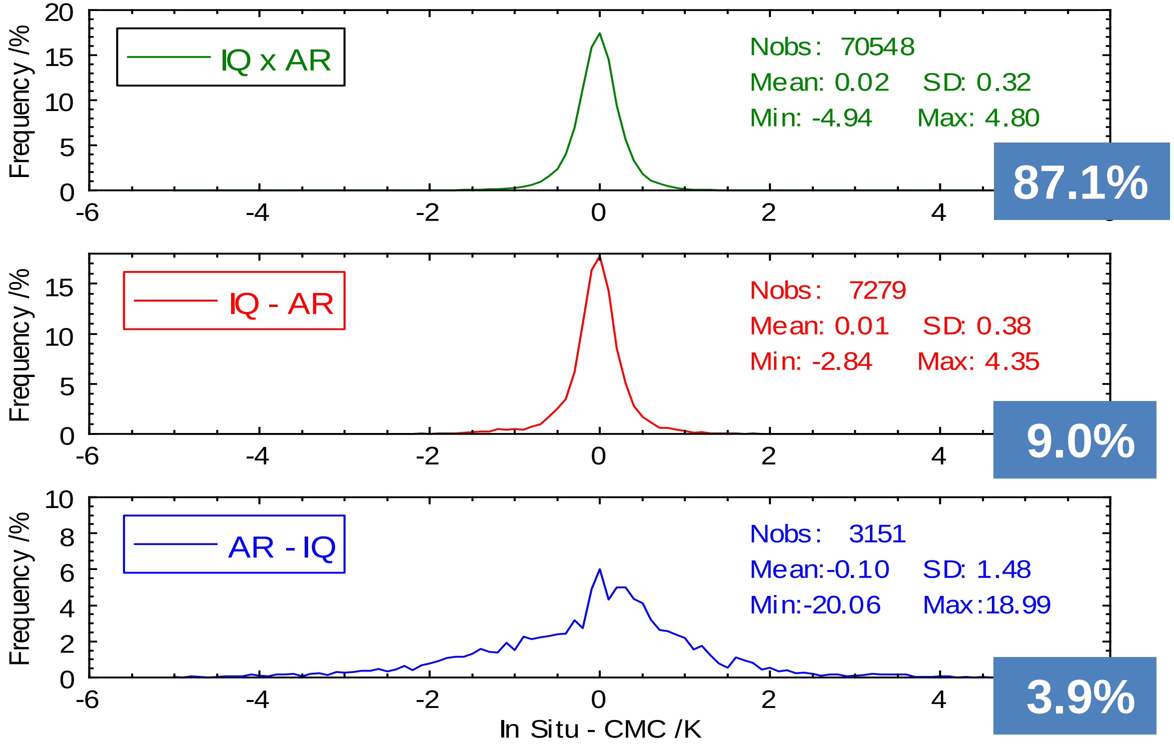
Data passing both QCs show a Gaussian distribution with Bias~0.02K and SD~0.29K

"iQuam leakages" (data pass iQuam QC but fail IC) are close to Gaussian shape but with degraded statistics. Suggests that this portion of data is noisier but still normal.

"IC leakages" (data pass IC QC but fail iQuam QC) significantly deviate from normal distribution with SD exceeding 1K.

ARGO floats QC
*i*Quam vs. Heritage

Jan 2006 – Dec 2006



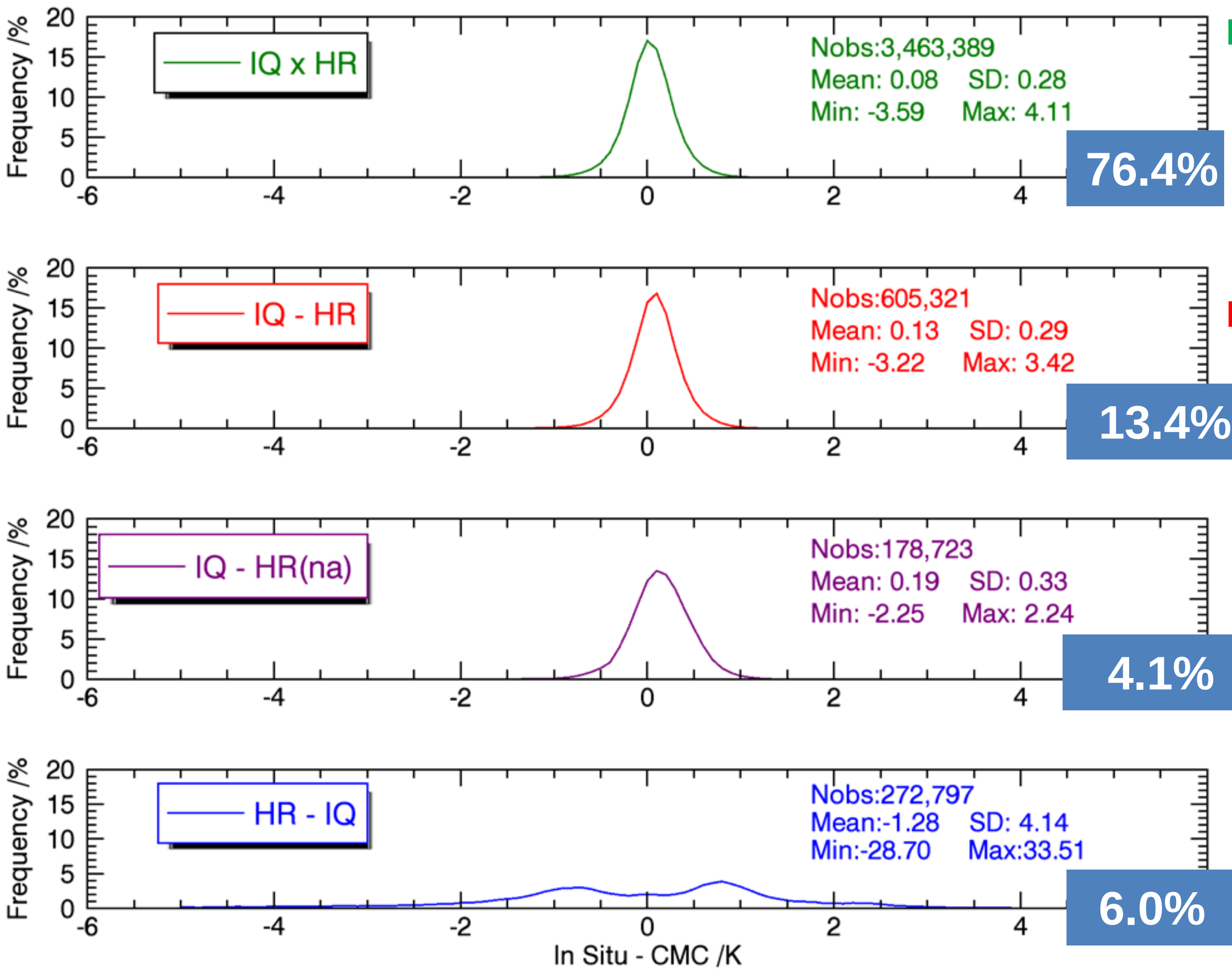
Data passing both QCs show a Gaussian distribution with Bias~0.02K and SD~0.32K

"iQuam leakages" (data pass iQuam QC but fail AG) are comparable with IQ x AG. This suggests that these data are normal but with little bit higher noise.

"AG leakages" (data pass AG QC but fail iQuam QC) deviate from normal distribution and SD over 1.4K.

HR-Drifter QC
*i*Quam vs. Heritage

Jan 2012 – Mar 2015



Data passing both QCs show a narrow Gaussian distribution with Bias~0.08K and SD~0.28K

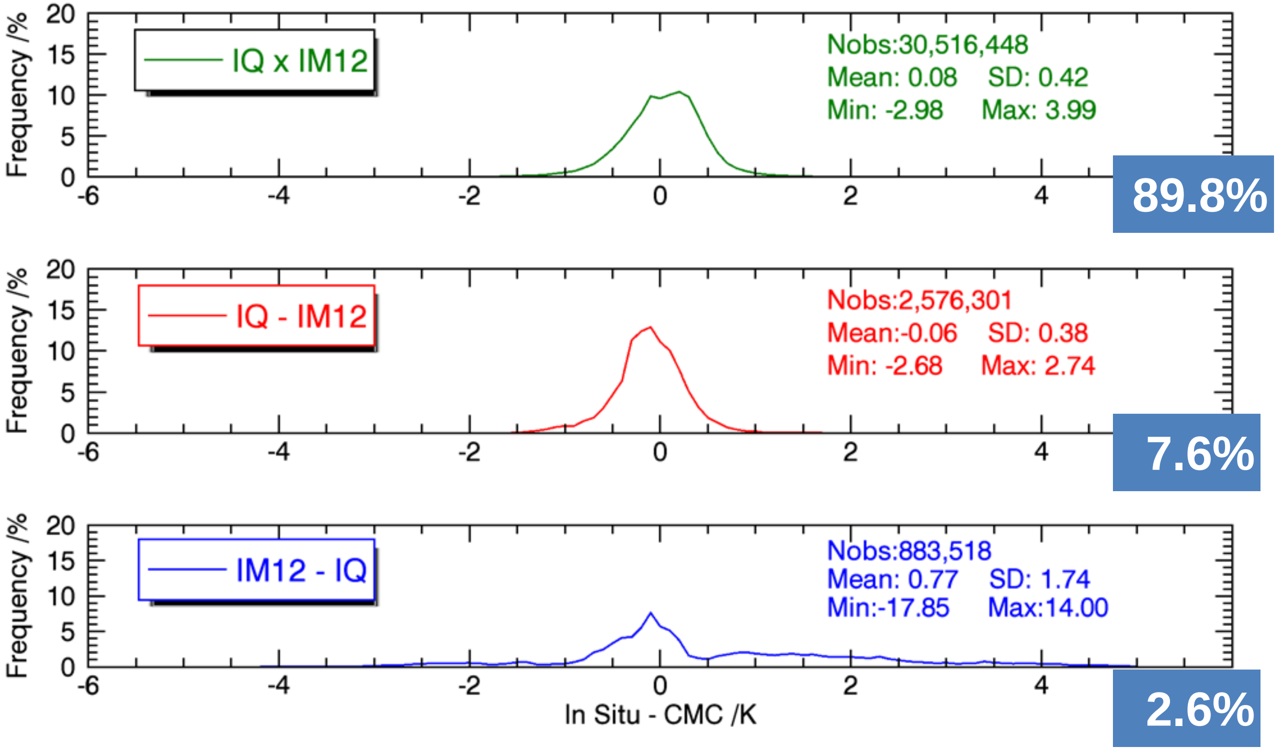
IQ 'leakage' has comparable stats with IQxHR, suggesting that HR QC is overly conservative

HR(na) stats are slightly degraded, likely due to regional biases

HR 'leakages' (data pass HR QC but fail iQuam) are significantly degraded

IMOS IM12 Ships QC
*i*Quam vs. Heritage

Aug 2012 – Dec 2014



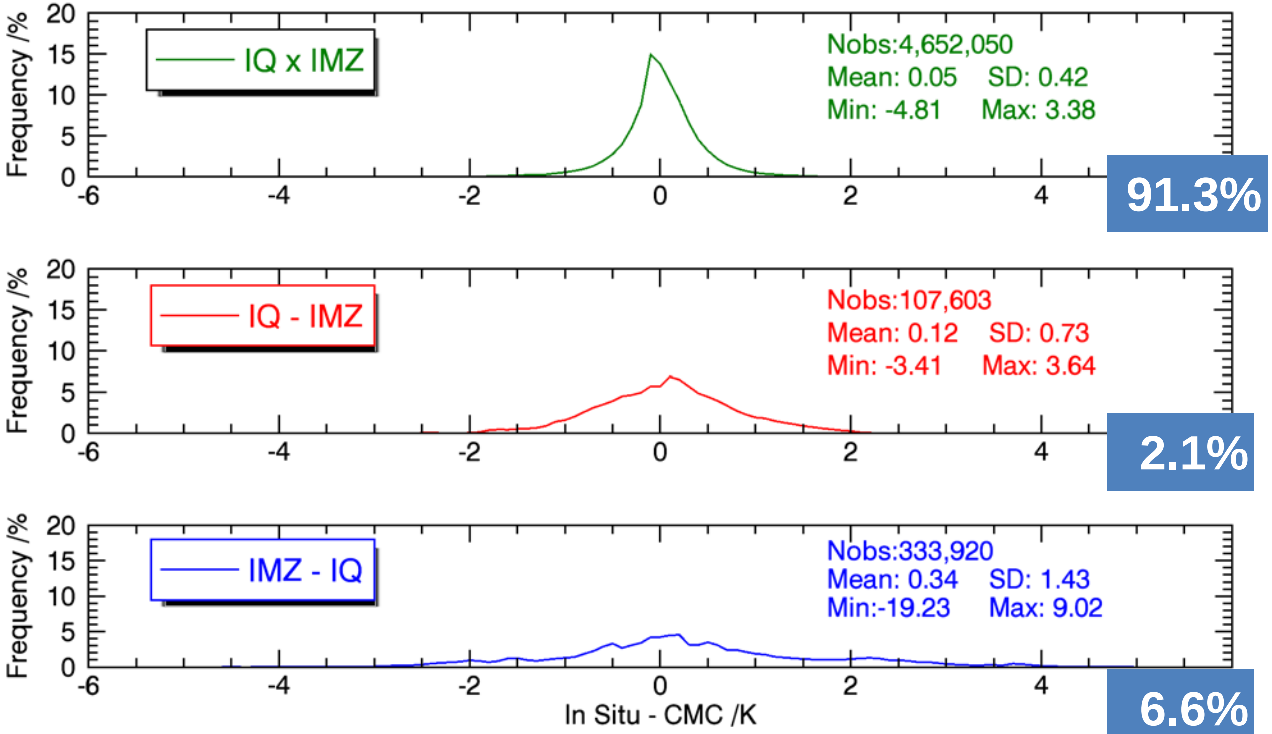
Data passing both QCs show a Gaussian distribution with Bias~0.08K and SD~0.42K

"iQuam leakages" (data pass iQuam QC but fail IM12) are comparable with IQ x IM12. This suggests that the IM12 QC is overly conservative. It removes 7.6% of data.

"IM12 leakages" (data pass IM12 QC but fail iQuam QC) are significantly degraded. This suggests that iQuam QC is instrumental, for ~2.6% of data

IMOS IMZ Ships QC
*i*Quam vs. Heritage

Aug 2012 – Dec 2014



Data passing both QCs show a narrow Gaussian distribution with Bias~0.05K and SD~0.41K

Stats for "iQuam leakages" (data pass iQuam QC but fail IMZ) are degraded. Suggests that IMZ QC contain valid and independent info that iQuam2 doesn't have. (~2% of the data)

"IMZ leakages" (data pass IMZ QC but fail iQuam QC) are significantly degraded. Suggests that iQuam QC is instrumental to improve the quality of IMOS data (~6% of the data)

What *i*Quam QFs/QLs should I use?

1. Using iQuam QL=5 is recommended. This is what we monitor in the *i*Quam web page and use for NOAA Cal/Val
2. All heritage QFs are also reported in iQuam. Our "confusion matrix" analyses suggest that they do not add much to the iQuam QFs. (The only heritage QF which was found unique, the IMOS IMZ, is included in the iQuam2 QL=5)
3. All individual iQuam QFs are also reported in data files. Advanced users are welcome to build their own QLs

Monitor Interface (1)

NOAA NESDIS STAR

in situ SST quality monitor v2.0

NOAA / NESDIS / STAR

Monitor Data About

www.star.nesdis.noaa.gov/sod/sst/iquam/v2

- Maps
- Statistics
- Time Series
- Platforms

2017 ▾ 03 ▾ 26 ▾

Show hour 0

Month Day

Ref SST used in QC

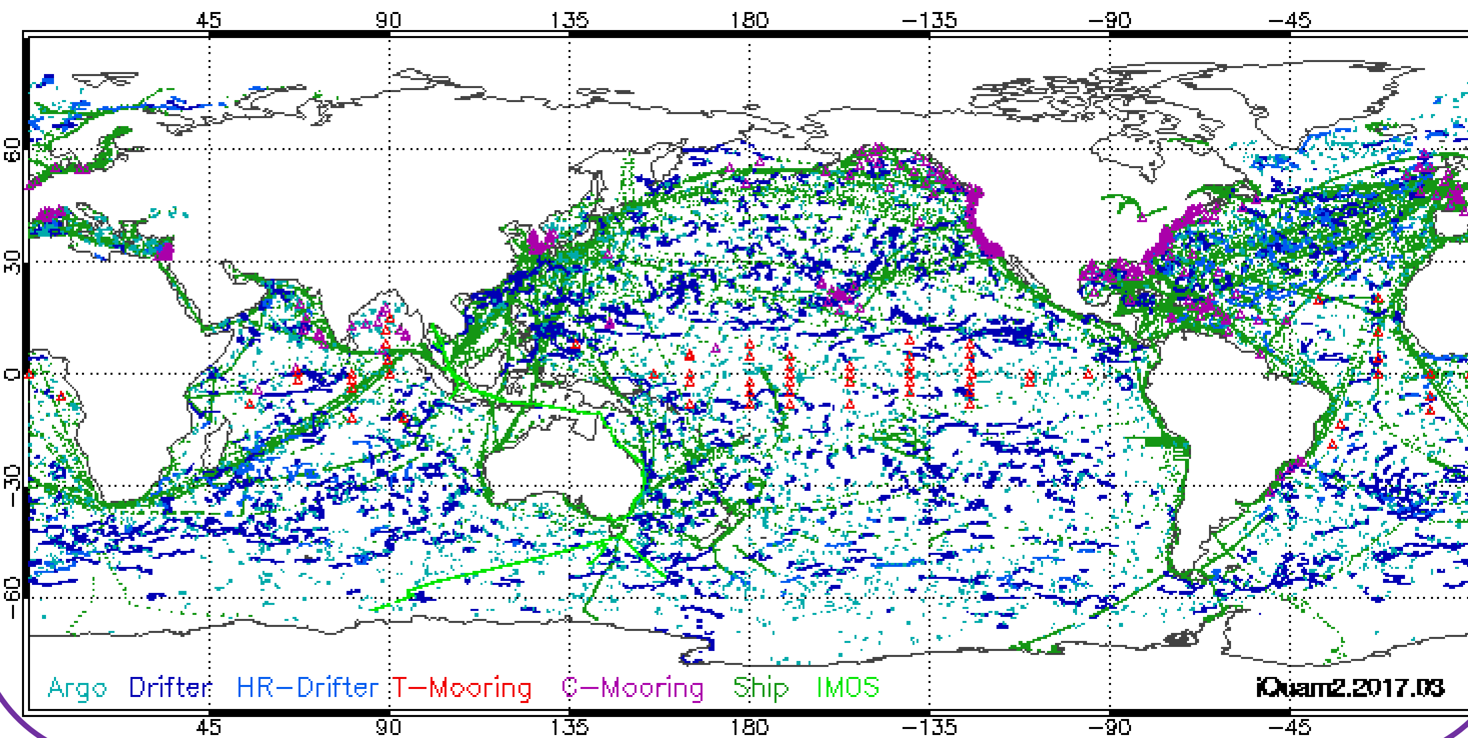
Reyn CMC

QCed Outlier

- Argo - Argo Floats
- Drifter - Conventional drifters
- HR-Drifter - High-Resolution Drifters
- T-Mooring - Tropical Moorings
- C-Mooring - Coastal Moorings
- CRW - Coral Reef Watch Buoys
- Ship - Conventional ships
- IMOS - IMOS Ships

Symbol = one observation.

All Platforms | Argo | Drifter | HR-Drifter | T-Mooring | C-Mooring | CRW | Ship | IMOS



Monitor Interface (2)

iQUAM

- Maps
- Statistics
- Time Series
- Platforms

2017 ▼ 03 ▼ 26 ▼

◉ Month ○ Day

Ref SST used in QC
☑ Reyn ☐ CMC

Ref SST used in Monitoring
○ Reyn ◉ CMC

N_Obs - number of obs;
N_QC - number of obs passed QC;
DR,GL,TS,SG,RS,XP,PH,XQ - nobs detected by each check:

- AL - All checks combined.
- DR - Duplicate Removal
- GL - Geo-Location
- TS - Travel-Speed (aka. Tracking)
- SG - SST-Gradient (aka. Spike)
- RS - Ref SST (aka. background); 1 - Reynolds, 2 - CMC
- XP - Cross-Platform (aka. buddy). Performed on top of RS. 1- Reynolds, 2 - CMC
- PH - Performance History (aka. iQuam blacklist)
- XQ - External QC (from input data)

Statistics are calculated over (In situ - Ref SST).
In situ: obs that passed iQuam QC
Ref1 = Reynolds; Ref2 = CMC

Note: N_Mtchp - number of (in situ - Ref) match ups. (Smaller than N_QC due to missing Ref SST in some points.)

For more information, see About.

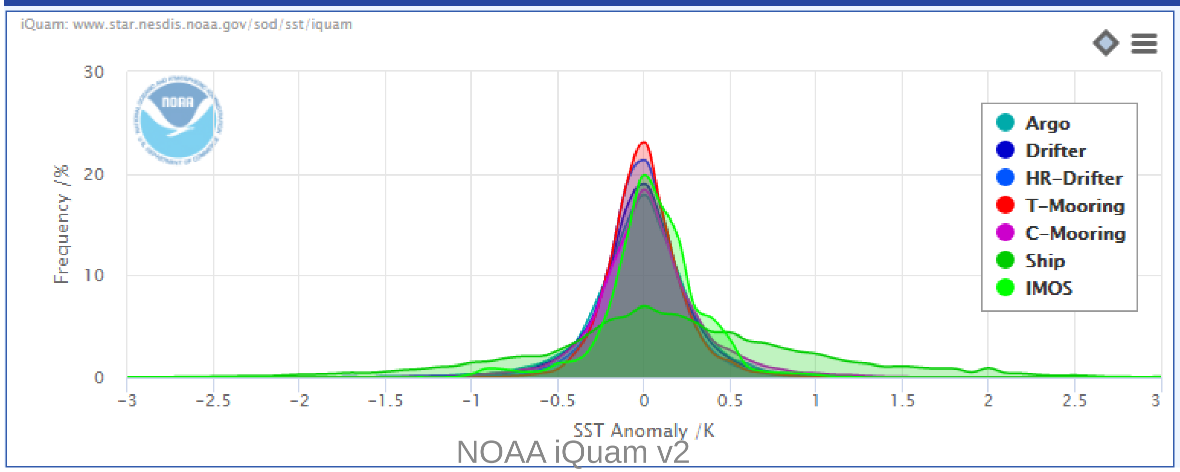
QC Statistics - NOBS | QC Statistics - Percent

Platform	N_ID	N_Obs	N_QC	AL	DR	GL	TS	SG	RS	XP	PH	XQ
Argo	3,771	9,495	8,914	581	0	0	0	0	392	373	0	208
Drifter	1,578	602,147	555,279	46,868	1,377	8,817	119	787	32,155	32,155	3,613	0
HR-Drifter	266	125,642	96,410	29,232	0	18,949	41	87	9,934	9,934	221	96,410
T-Mooring	62	23,132	22,016	1,116	89	1	2	4	902	853	167	0
C-Mooring	294	215,950	201,111	14,839	0	1	7,123	321	7,101	7,056	338	0
Ship	1,658	101,912	80,212	21,700	23	352	358	232	18,837	18,951	1,784	0
IMOS	4	40,988	40,638	350	0	0	0	0	63	79	0	271

In situ - Ref SST Statistics

Platform	N_Mtchp	MEAN	MED	SD	RSD	MIN	MAX	SKEW	KURT
Argo	8,914	0.04	0.04	0.33	0.24	-6.77	2.79	-1.16	25.42
Drifter	543,534	0.03	0.04	0.33	0.21	-5.22	3.89	-2.27	23.31
HR-Drifter	96,410	0.04	0.04	0.26	0.19	-3.87	3.80	-0.86	14.28
T-Mooring	21,566	0.05	0.04	0.22	0.18	-1.35	1.71	0.39	3.02
C-Mooring	196,685	0.07	0.06	0.34	0.24	-3.27	2.72	-0.11	7.03
Ship	78,187	0.21	0.17	0.85	0.67	-4.78	6.20	0.07	1.25
IMOS	40,638	0.10	0.10	0.29	0.21	-2.70	1.54	-0.43	2.85

Histograms (Normalized at NOBS) | Histograms (Normalized at MAX)



Monitor Interface (3)

iQUAM

- Maps
- Statistics
- Time Series
- Platforms

Monthly Daily

Ref SST Used in QC
Reyn CMC Both

Ref SST Used in Monitoring
Reyn CMC

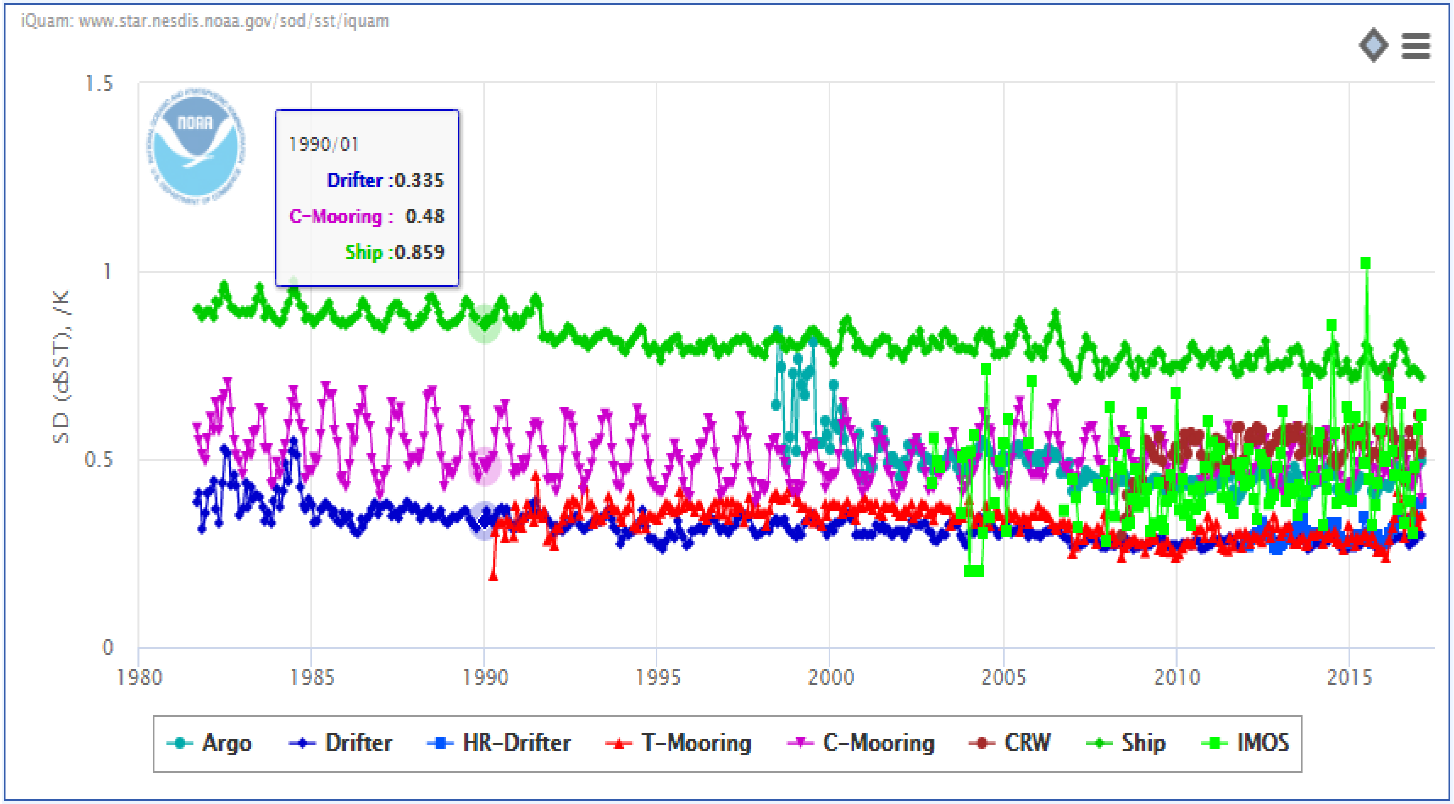
N_ID - number of platforms/IDs;
N_Obs - number of obs passed QC;
Mean,Median,SD,RSD,Max,Min - statistics of dSST (In situ - Ref).

QC statistics by check:

- *DR - Duplicate Removal*
- *GL - Geo-Location Check*
- *TS - Travel-Speed (aka. Tracking)*
- *SG - SST-Gradient (aka. Spike)*
- *RS - Reference SST (aka. background); 1-Reynolds, 2-CMC*
- *XP - Cross-Platform (aka. buddy). Performed on top of RS. 1-Reynolds, 2-CMC*
- *PH - Performance History (aka. iQuam blacklist)*
- *XQ - External QC (from input data)*
- *AL - All checks combined.*

N_ID | N_ID_norm | N_Obs | N_Obs_norm | Mean | Median | SD | RSD | Min | Max

Argo QC | Drifter QC | HR-Drifter QC | T-Mooring QC | C-Mooring QC | CRW QC | Ship QC | IMOS QC



Monitor Interface (4)

iQUAM

Monitor | Data | About

- Maps
- Statistics
- Time Series
- Platforms

2017 ▾ 03 ▾

<< < > >>

Monthly Daily

Ref SST Used in QC
Reyn CMC Both

Ref SST Used in Monitoring
Reyn CMC

NOBS - number of obs;
N_QC - nobs of passed QC;
Err% - rate of obs denied by QC;
N_Mp - nobs of passed QC match-ups;
Mean,SD,Max,Min - statistics calculated over (In situ - Reference) SST.
In situ: obs that passed iQuam QC
Ref: Reynolds or CMC

DR,GL,TS,SG,RS,XP,PH,XQ - nobs detected by each check

- *AL - All checks combined.*
- *DR - Duplicate Removal*
- *GL - Geo-Location*
- *TS - Travel-Speed (aka. Tracking)*
- *SG - SST-Gradient (aka. Spike)*
- *RS - Reference SST (aka. background); 1-Reynolds, 2-CMC*
- *XP - Cross-Platform (aka. buddy). Performed on top of RS. 1-Reynolds, 2-CMC*
- *PH - Performance History (aka. iQuam blacklist)*
- *XQ - External QC (from input data)*

Lat,Lon - starting location of in-situ

Tips:
Click column header to sort.
Click ID to show individual ID monitor window.

Argo | Drifter | HR-Drifter | T-Mooring | C-Mooring | Ship | IMOS

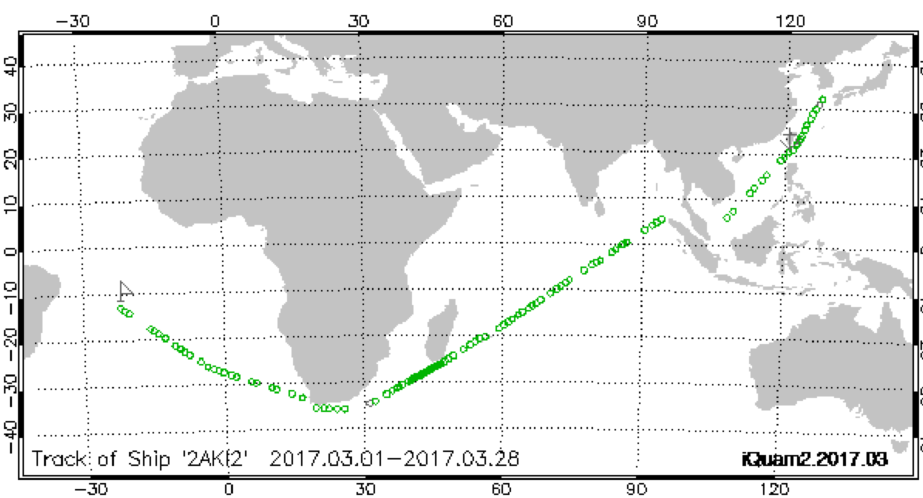
Showing 1 to 29 of 1,403 entries

Search:

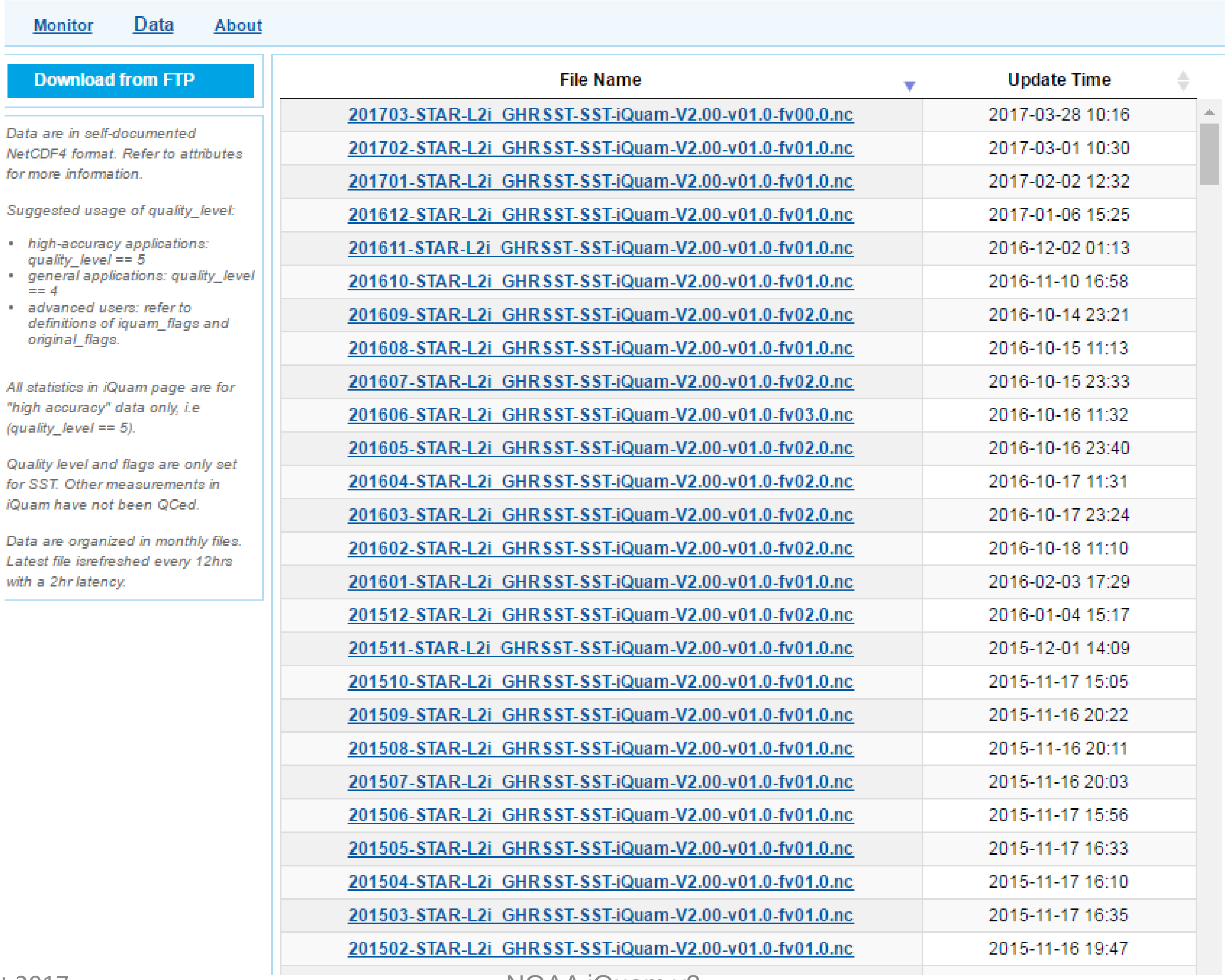
ID	NOBS	N_QC	Err%	N_Mp	Mean	SD	Min	Max	AL	DR	GL	TS	SG	RS	XP	PH	XQ	Lat	Lon
2AJU5	7	4	42.9	4	-0.20	0.63	-0.69	0.73	3	0	0	0	0	2	3	0	0	-18.6	153.4
2AKI2	120	117	2.5	115	0.59	0.51	-2.14	1.76	3	0	0	0	0	3	3	0	0	-12.9	-22.1
2AKI3	17	17	0.0	15	0.50	0.31	-0.17	0.81	0	0	0	0	0	0	0	0	0	4.4	80.0
2AKI4	6	6	0.0	6	0.67	0.43	0.35	1.46	0	0	0	0	0	0	0	0	0	3.2	122.6
2ARS4	13	13	0.0	13	0.38	0.46	-0.10	1.13	0	0	0	0	0	0	0	0	0	57.1	2.2
2BOK5	7	1	85.7	1	1.58		1.58	1.58	6	0	0	0	0	6	6	0	0	52.9	-166.3
2BUH7	2	2	0.0	2	-0.47	0.91	-1.12	0.17	0	0	0	0	0	0	0	0	0	50.8	-133.0
2CWB2	84	68	19.1	51	-0.25	0.80	-2.10	1.51	16	0	1	0	2	13	13	0	0	29.1	-93.7
2DTQ2	6	4	33.3	4	-0.04	0.68	-0.59	0.92	2	0	0	1	0	1	1	0	0	49.2	178.6
2FGX5	56	46	17.9	45	0.41	0.66	-1.05	2.15	10	0	0	0	0	8	8	2	0	26.8	-17.2
2FRE8	18	17																	
2GNG3	36	34																	
2GYL6	17	17																	
2HCH5	11	10																	
2HDG2	34	32																	
2HDG3	2	2																	
2HFZ6	32	28																	
2HFZ7	45	44																	
2HHG5	58	56																	
2ICH7	23	0																	
2ICH8	19	5																	
2ICH9	36	36																	
2ICI2	40	40																	
2ICI3	55	46																	
2ICI4	25	16																	
2ICI5	45	43																	
2ICI6	3	3																	
2ICI9	112	111																	

Platform '2AKI2'

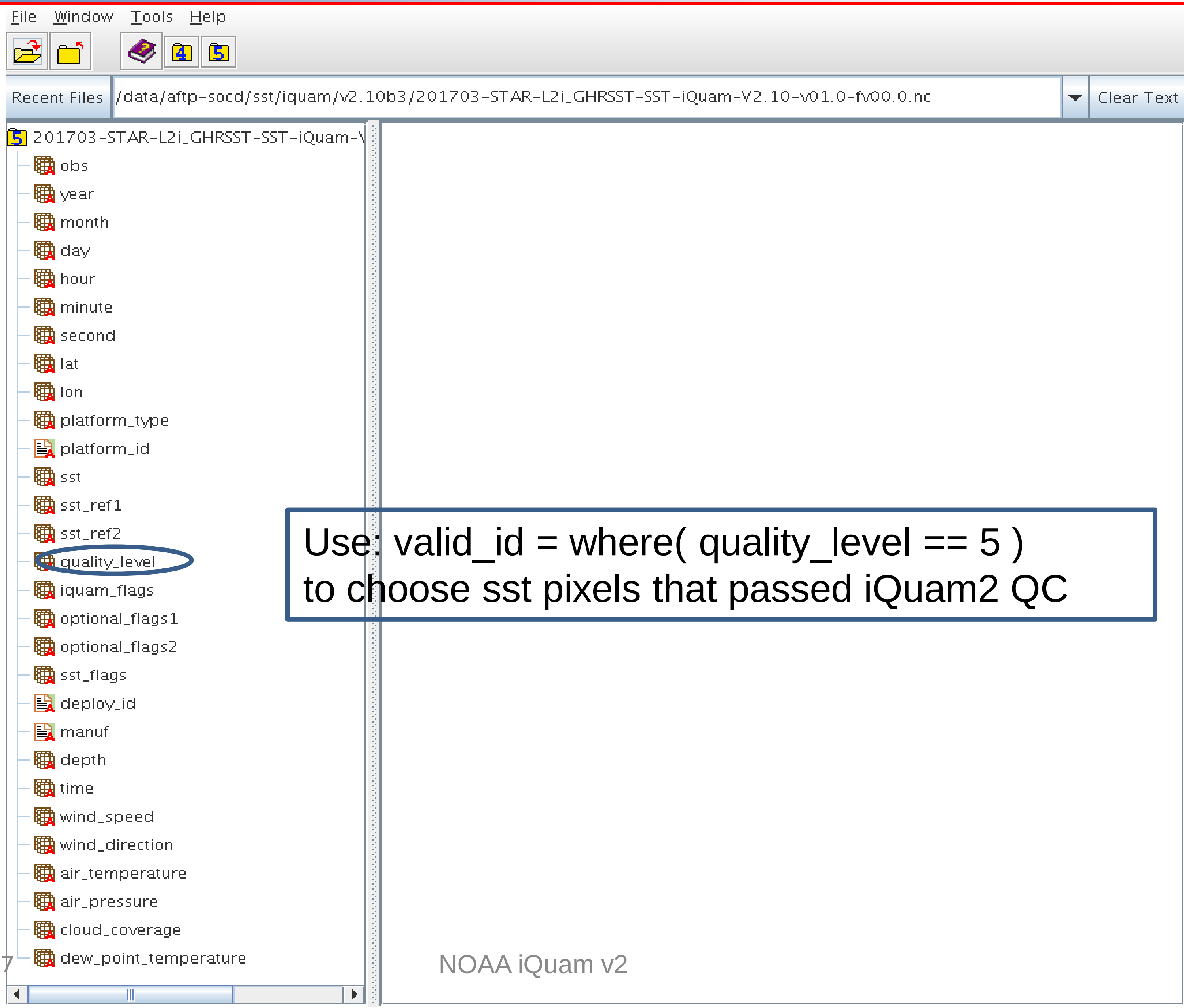
Track map for the month | SST anomaly for the month | Performance in history



FTP Interface



File format (opened in hdfview)



Use: valid_id = where(quality_level == 5)
to choose sst pixels that passed iQuam2 QC

Help Page

Monitor Data About

- System Overview
- FAQ & Contacts
- Version Update
- References
- Links
- Acknowledgement

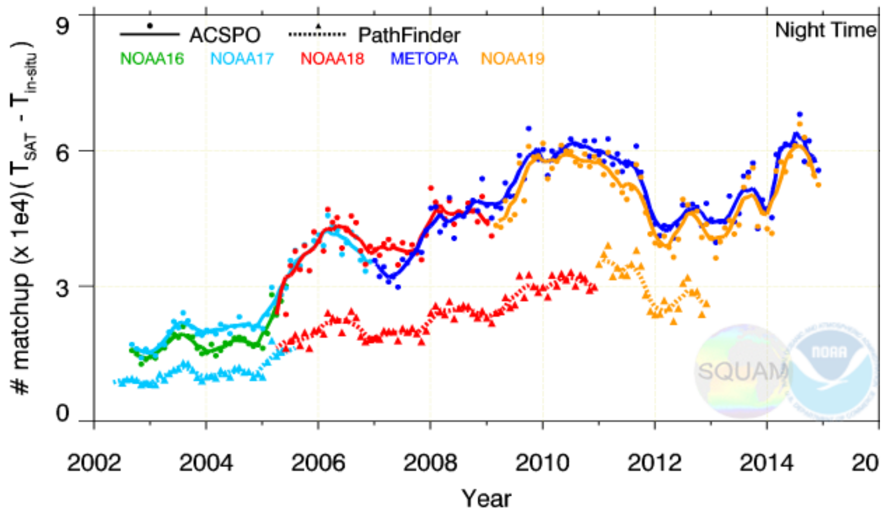
Journal Papers

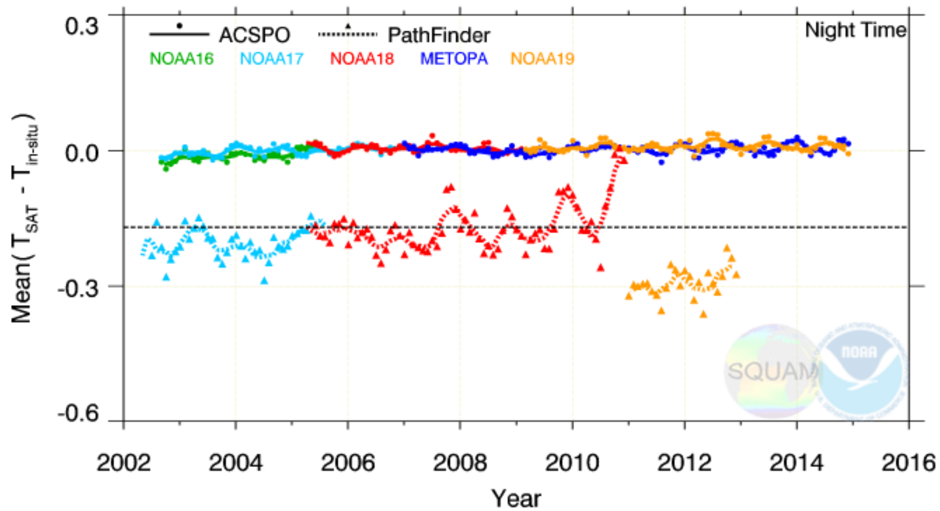
- Xu, F. and A. Ignatov, 2014: *in situ* SST quality monitor (*i*Quam), JTECH. link
- Xu, F. and A. Ignatov, 2010: Evaluation of *in situ* SSTs for use in the calibration and validation of satellite retrievals, JGR. link

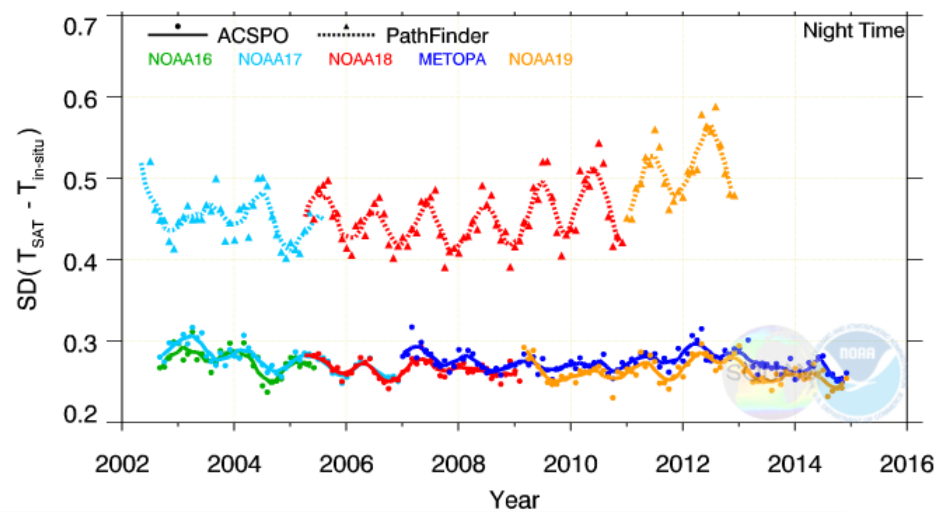
Conference Presentations

- Ignatov, A., F. Xu, and X. Zhou, 2014: In situ SST Quality Monitor (*i*Quam), CLIMAR4 Workshop, Asheville, NC, June 2014.link
- Ignatov, A. and Xu, F., 2013: *in situ* SST quality monitor: from *i*Quam1 to *i*Quam2, 14th GHRSST meeting, Woods Hole, MA, July 2013. download
- Xu, F. and A. Ignatov, 2010: Implementation and evaluation of quality control for *in situ* SST for use in satellite Cal/Val, 2010 AGU Ocean Sciences Meeting, Portland, OR, Feb 2010. download

Val of AVHRR GAC RAN1 Against Drifters + Tropical Moorings



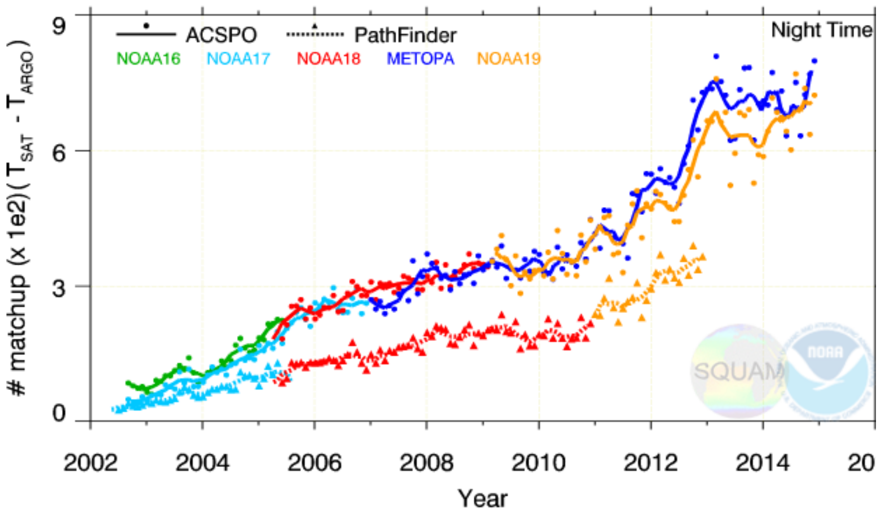


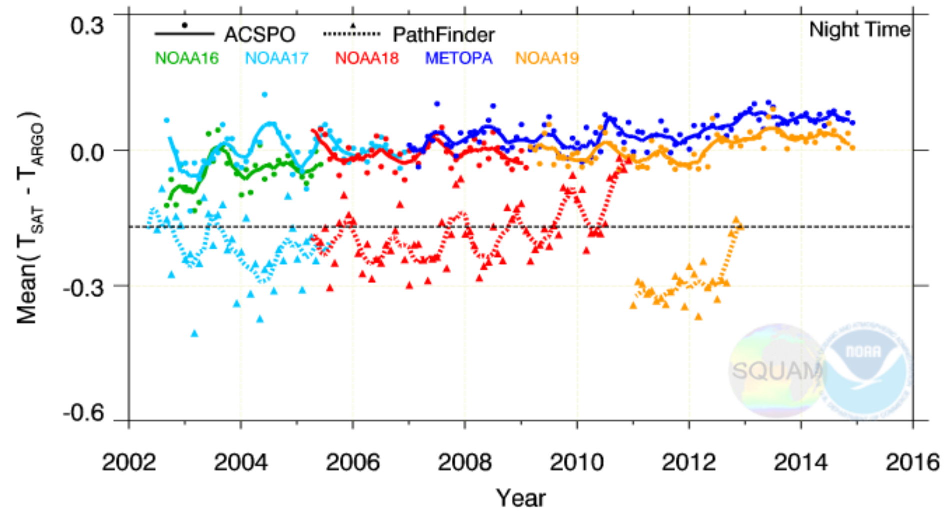


Ignatov, et al., AVHRR GAC SST Reanalysis Version 1 (RAN1), Remote Sensing, 2016

Fig. 1: Drifter and Tropical mooring matchup with Satellite SST, **sample number** (left), **mean bias** (right upper) and **standard deviation** (right lower)

Val of AVHRR GAC RAN1 Against Argo Floats





See more plots on squam2/polar at:
www.star.nesdis.noaa.gov/socd/sst/squam2/polar/avhrrgac/

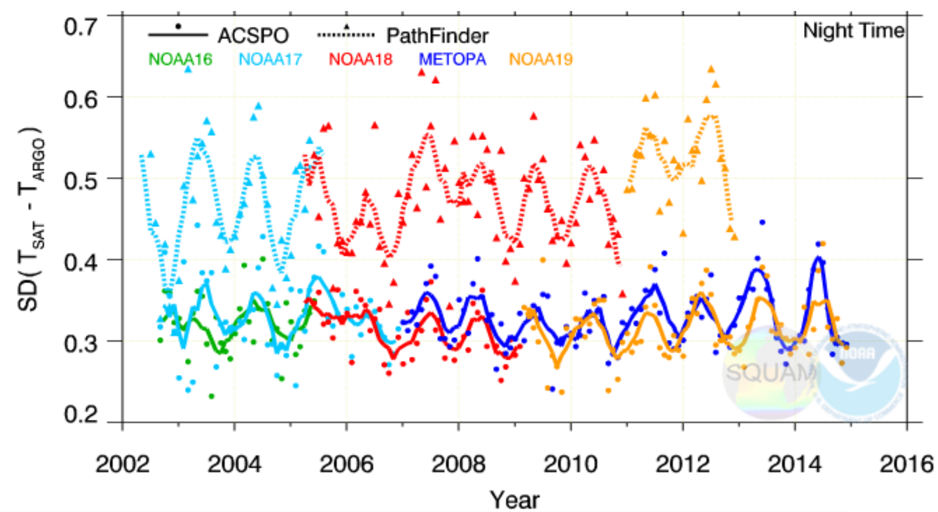
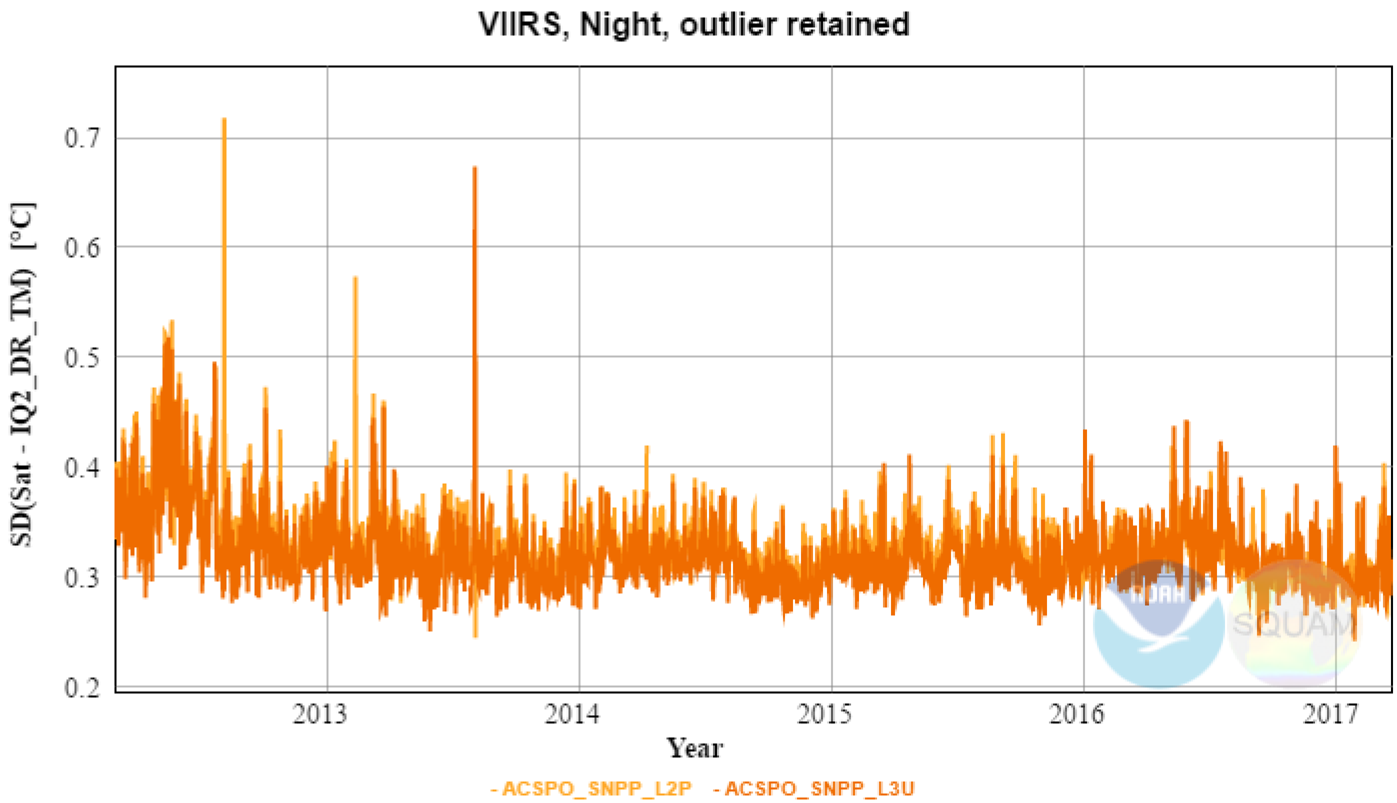


Fig. 2: Argo floats matchup with Satellite SST, **sample number** (left), **mean bias** (right upper) and **standard deviation** (right lower)

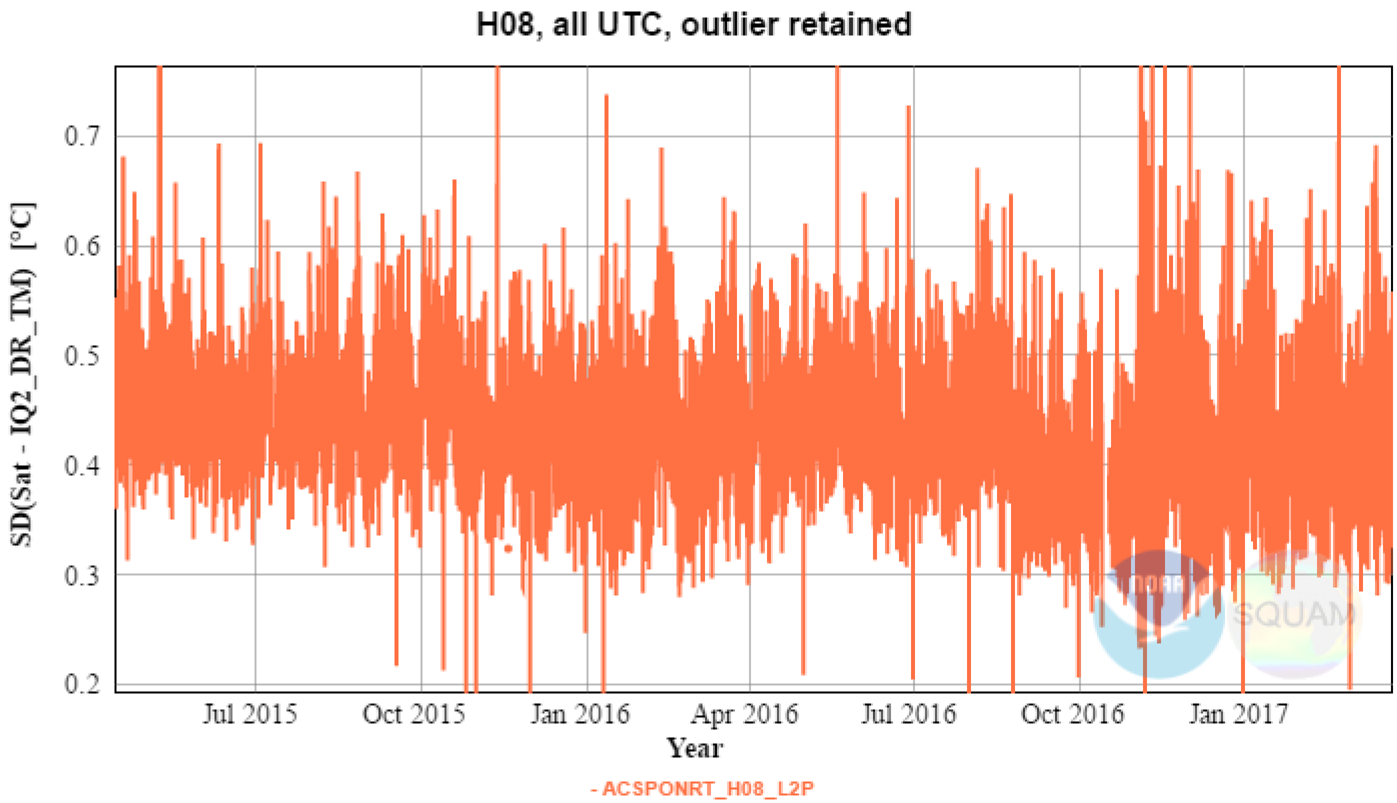
Standard Deviation of VIIRS SST Against Drifters + Tropical Moorings

iQUAM



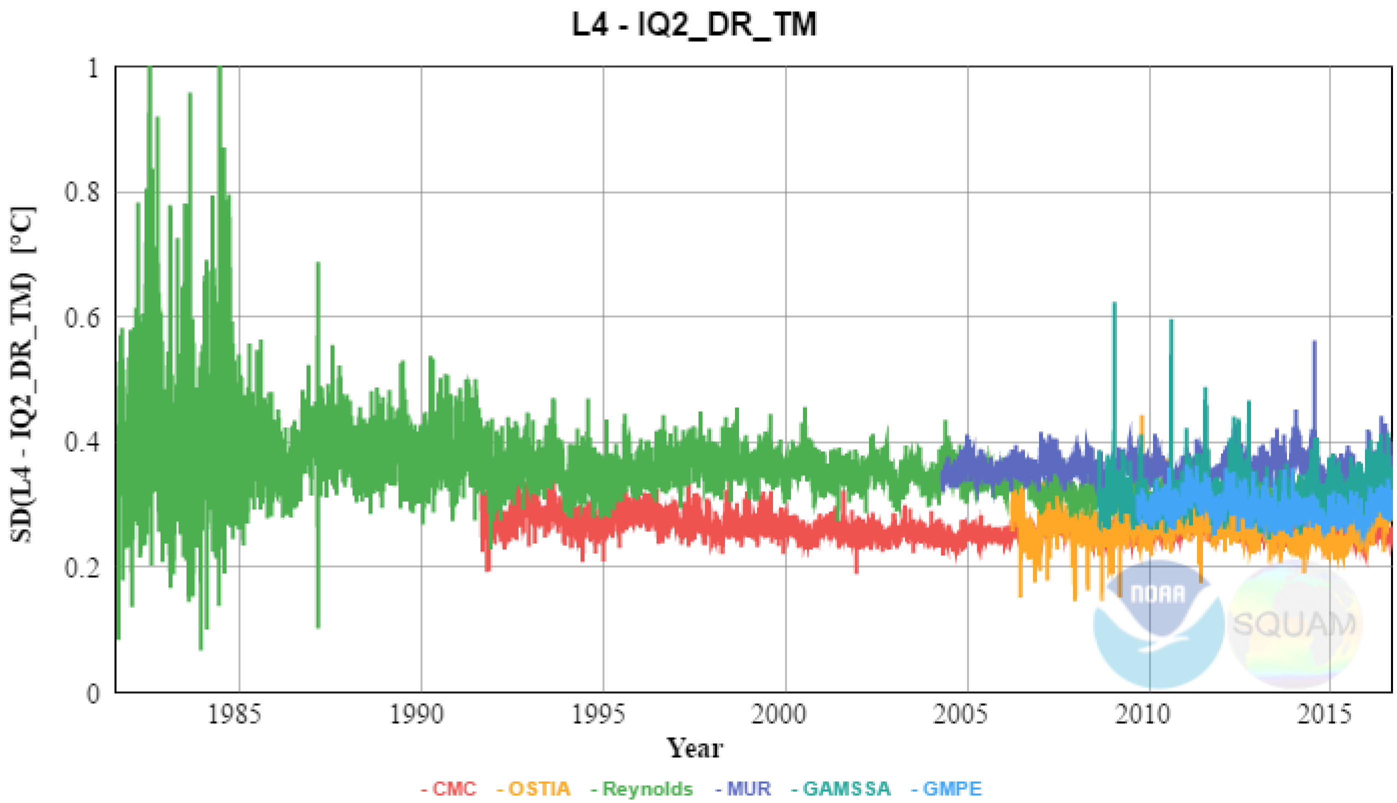
See more plots on squam2/polar at: www.star.nesdis.noaa.gov/socd/sst/squam2/polar/viirs/

Comparison with GEO



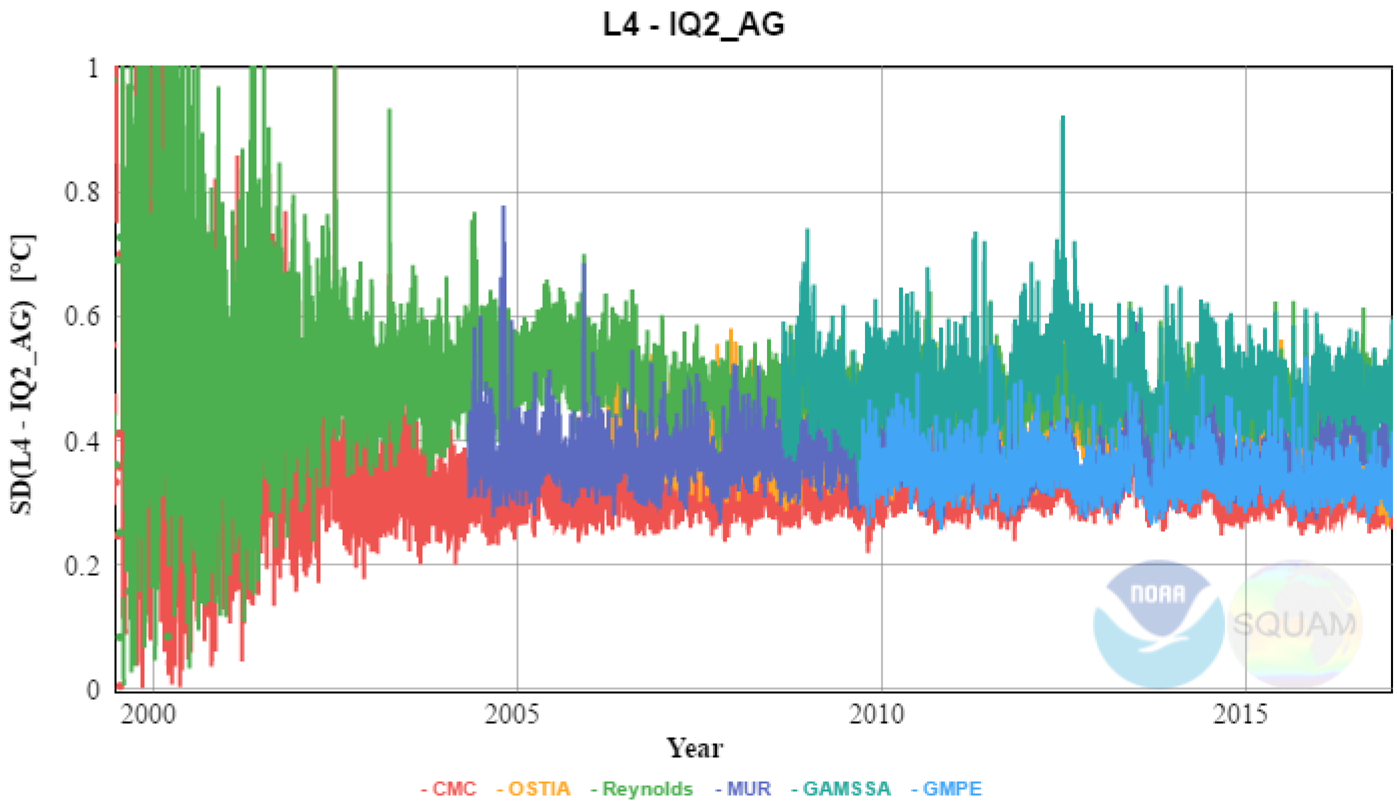
See more plots on squam2/geo at: www.star.nesdis.noaa.gov/socd/sst/squam2/geo/ahi_abi/

Comparison with L4 (1)



See more plots on squam2/analysis at: www.star.nesdis.noaa.gov/socd/sst/squam2/analysis/l4

Comparison with L4 (2)



See more plots on squam2/analysis at: www.star.nesdis.noaa.gov/socd/sst/squam2/analysis/l4

Conclusion and Future Work

Summary of enhancements in iQuam2

- ✓ Longer time series cover full satellite era (Sep 1981 – on)
- ✓ Improved QC
- ✓ Improved web interface
- ✓ Add more *in situ* data
- ✓ Change output data files to NetCDF4

Ongoing work

1. Collect users' feedback and implement iQuam2. Retire iQuam1
2. Archive w/GHRSST (PO.DAAC/NCEI). Document in literature
3. Transition to *i*Quam2 in all NOAA Cal/Val applications including SQUAM
4. Work towards *i*Quam3
    a) Add more *in-situ* data types from SAMOS Ships, Ocean Profilers et al.
    b) Test 3-way error analysis, to determine errors in individual *in situ* data and append sses
    c) Include ship radiometers?

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  - J.-F. Piolle, D. Poulter (IFREMER/Felyx),
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  - M. Chin (JPL).


Thank you!
Questions? Comments?