ACSPO SST algorithm improvements

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Current SST algorithms in ACSPO: 1. Baseline SST (BSST)

- Two "global" regression equations for day and night
- Trained on global data sets of matchups (MDS)

Day: $T_S = a_0 + a_1 T_{11} + a_2 S_\theta T_{11} + a_3 \Delta T_{11\text{-}12} + a_4 \Delta T_{11\text{-}12} T_S^0 + a_5 \Delta T_{11\text{-}12} S_\theta + a_6 S_\theta$

Night: $T_S = b_0 + b_1 T_{3.7} + b_2 S_\theta T_{3.7} + b_3 \Delta T_{11\text{-}12} + b_4 S_\theta \Delta T_{11\text{-}12} + b_5 S_\theta$

T_λ	observed BTs, λ=3.7, 11 and 12 μm
T_S^0	first guess SST in ºC (L4 SST by Canadian Meteorological Centre-CMC)
Θ	satellite view zenith angle (VZA)
a and ***b***	regression coefficients (calculated from dataset of matchups – MDS)

$\Delta T_{\lambda1\text{-}\lambda2} = T_{\lambda1} - T_{\lambda2}$

$S_\theta = \sec(\Theta) - 1$

- For further information see *Petrenko et all, JGR, 2014*

- **BSST provides a tradeoff between precision of fitting in situ SST ("bulk") and sensitivity to "skin" SST**
- **Referred to as "sub-skin" rather than "skin" SST because:**

  - It is trained against *in situ* data

  -The sensitivity to "skin" SST is non-uniform and, in general, less than 1

Current SST algorithms in ACSPO:
2. Piecewise Regression (PWR) SST

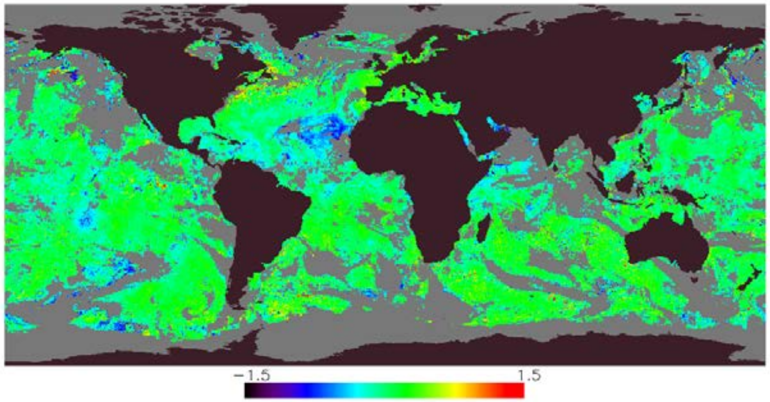
Produced with multiple regression equations for specific segments of the SST domain

- Segments are defined in the space of regressors rather than in the space of physical variables
- Segmentation parameter (Fisher distance) is derived from statistics of regressors within the global MDS:
- Regression coefficients are trained separately for each segment using the Least-Squares (LS) method
- PWR SST may be obtained from the ACSPO GDS2 files as BSST-SSES bias
- For further information see *Petrenko et al., JTECH, 2016*

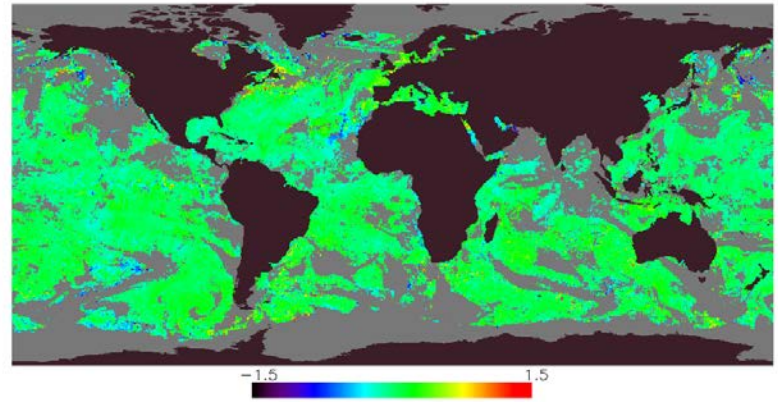
- **Precisely fits *in situ* SST, sensitivity to "skin" SST may be low**
- **May be soundly referred to as "bulk" SST**

Current SST algorithms in ACSPO:
Maps and global statistics of ACSPO SST – CMC (July 17 2016)

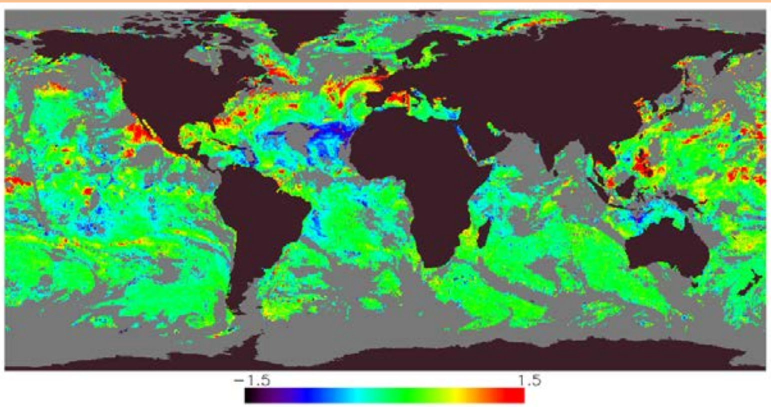
Night, BSST – CMC: Bias=0.07 K, SD=0.35 K



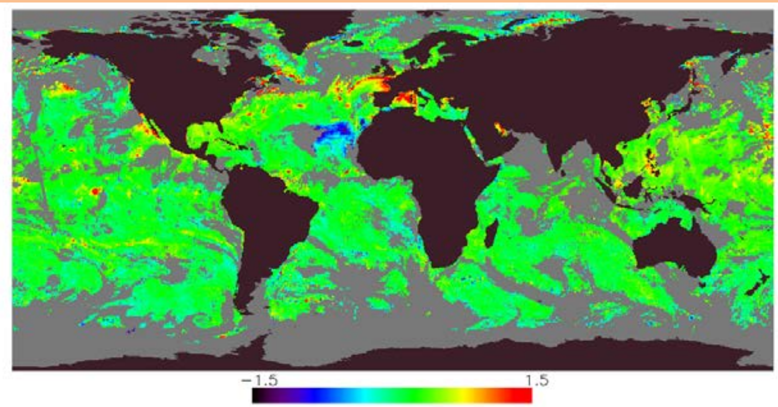
Night, PWR SST – CMC: Bias=0.05 K, SD=0.27 K



Day, BSST – CMC: Bias=0.27 K, SD=0.57 K



Day, PWR SST – CMC: Bias=0.27 K, SD=0.40 K



- **BSST provides reasonable global precision wrt L4 CMC,PWR SST further improves the precision**

- **Now that we have “bulk” SST, can “sub-skin” BSST be brought closer to “skin”?**
- **We cannot do it in full unless we get a reliable set of matchups with “skin” SST**
- **However we can adjust the sensitivity to “skin” SST (make it more uniform and closer to 1)**

Involving new VIIRS bands in SST retrieval

VIIRS Band	Wavelength (μm)	Current usage
M12	3.7	Night only
M13	4.05	Not used
M14	8.55	Not used
M15	10.76	Day, night
M16	12.01	Day, night

- **Currently, only the VIIRS bands, similar to AVHRR are used**
- **Two more VIIRS bands, 4.95 and 8.55 μm, also may be used for SST**

•This requires adding new regressors to the SST equations

Constructing "Extended" SST equation

In general, SST equation for N bands may include up to 3×N regressors:

$$T_S = a_0 + a_1 T_{\lambda 1} + \ldots + a_N T_{\lambda N} +$$

$$+ a_{N+1} T_{\lambda 1} S_\theta + \ldots + a_{2N} T_{\lambda N} S_\theta +$$

$$+ a_{2N+1} \Delta T_{\lambda 1 - \lambda 2} T_S^0 + \ldots + a_{3N-1} \Delta T_{\lambda 1 - \lambda N} T_S^0 + a_{3N} S_\theta$$

In the case of extended SST equation, the conventional **Least Squares (LS) method** may be suboptimal for coefficients calculation:

- The sensitivity of regression SST to "skin" SST may be low;
- The LS estimates of regression coefficients may be instable

A new approach to calculation of regression coefficients is required

Modified Method for Calculation of Regression Coefficients

- A constraint on mean sensitivity over the MDS is posed on the LS solution (**Constrained Least-Squares (CLS) method)**:

  mean sensitivity=1

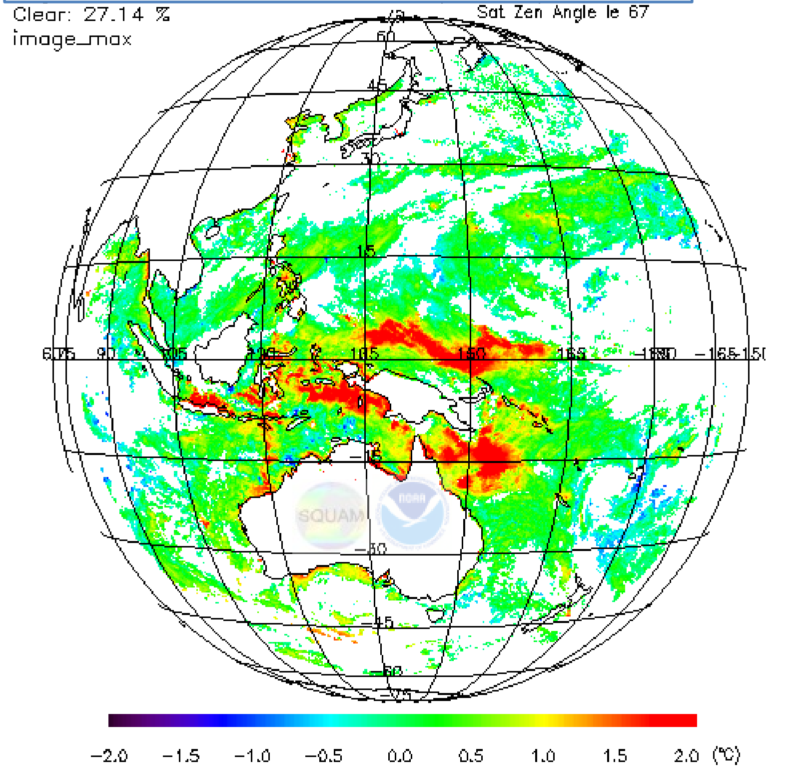
- Stability of coefficients is controlled by rejecting the least informative dimensions in the space of regressors (rather than by limiting the number of regressors).

- For further information, see *Petrenko et al., Proc. SPIE, 2016*

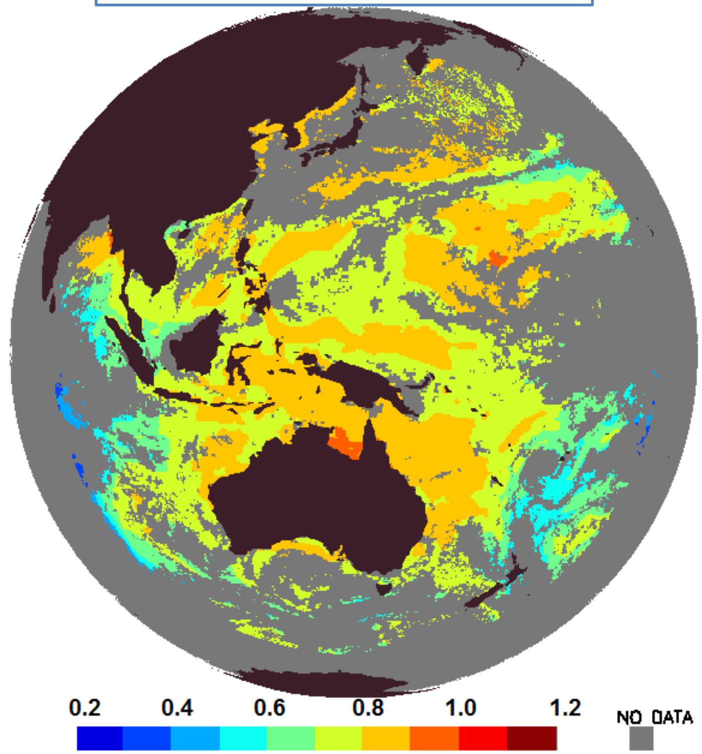
The resulting "extended" regression equation may include many regressors while producing stable SST estimates with predefined mean sensitivity

Initial Himawari-8 AHI BSST – CMC and sensitivity (8 January 2016, 5:00 UTC)

BSST-CMC: Bias=0.56 K, SD=0.65 K



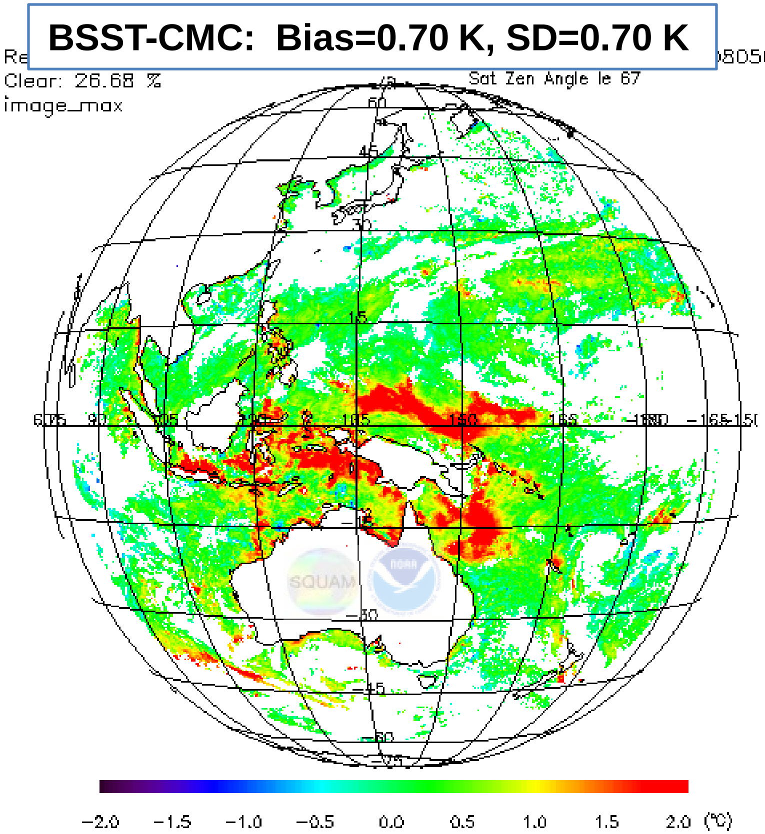
Sensitivity: Mean=0.76

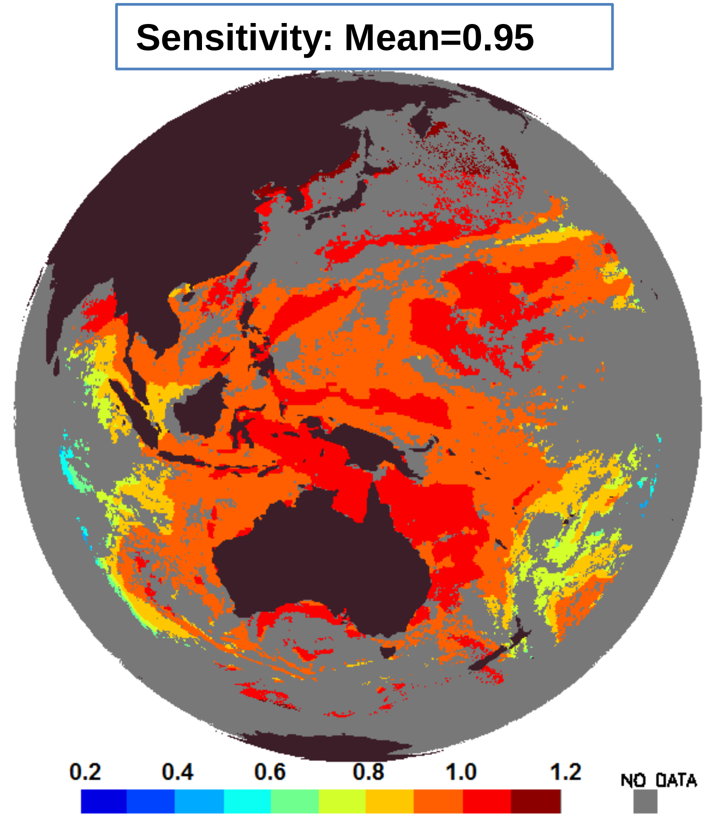


Initial coefficients calculated in June 2015 with the LS method using a limited (~1 month) MDS

- **AHI bands 8.6, 10.4, 11.2 and 12.3 µm are used**
- **BSST is retrieved for VZA < 67º**

Himawari-8 AHI BSST with CLS coefficients
(8 January 2016, 5:00 UTC)





The equation with CLS coefficients was implemented in May 2016 using ~ 1 year of matchups

- **The mean sensitivity increased from 0.76 to 0.95**
- **The diurnal warming effect in SST also increased**
- **However, the sensitivity remains spatially non-uniform**

Next step: Combining the PWR and the CLS Methods

- In ACSPO, PWR SST is produced using multiple regression equations for different segments of the SST domain. The coefficients are calculated with the LS method.
- This provides precise approximation of *in situ* SST but suppresses the sensitivity to "skin" SST.
- Now that we can control the mean sensitivity, we can recalculate the PWR coefficients with the CLS method.
- This approach was tested within the experimental version of ACSPO VIIRS

Global Daytime Statistics of the BSST Algorithms wrt in situ SST

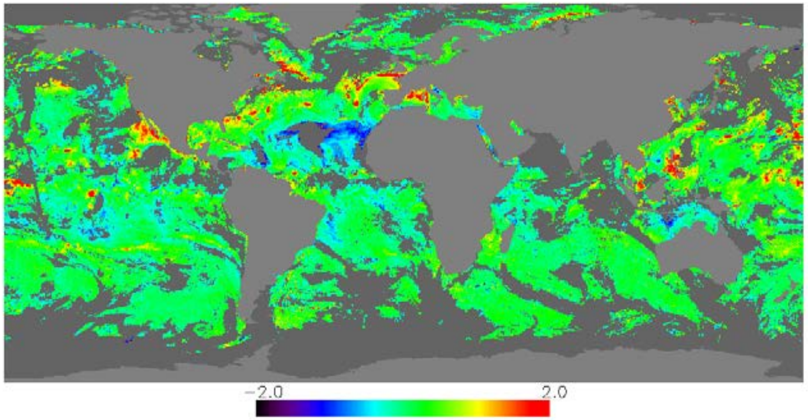
Statistics are derived from dataset of VIIRS matchups from May 2014 – June 2016

Algorithm	VIIRS Bands	SD, SST-in situ	Mean Sensitivity	SD sensitivity
1. Global + Least Squares (current)	11.2 and 12.3 μm	0.42	0.90	0.091
2. Global + Constrained Least Squares	8.6, 11.2 and 12.3 μm	0.47	1.00	0.091
3. PWR + Constrained Least Squares	8.6, 11.2 and 12.3 μm	0.39	1.00	0.043

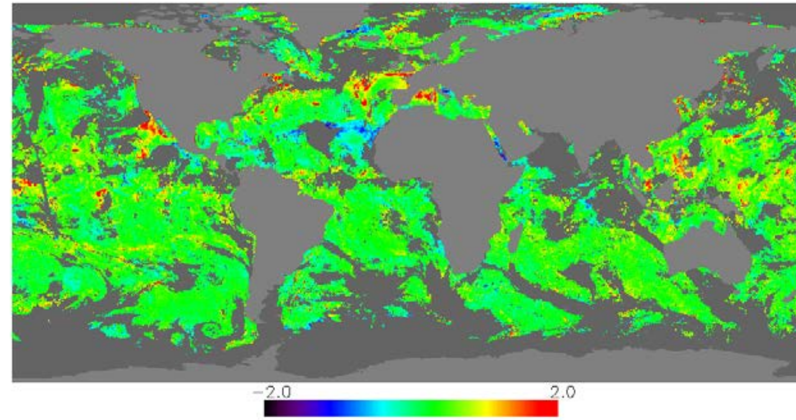
- •Since the largest effect was found for day, here we compare three daytime SST algorithms
- •The Global + LS (2 bands) algorithm provides usual SST precision and low mean sensitivity
- •The Global + CLS (3 bands) algorithm brings the mean sensitivity to 1, increases SD of fitting matchups
- •The PWR + CLS (3 bands) algorithm keeps the mean sensitivity =1, reduces SD of fitting matchups

Daytime maps of VIIRS BSST-CMC and Sensitivity with the Current and PWR+CLS algorithm (17 July 2016)

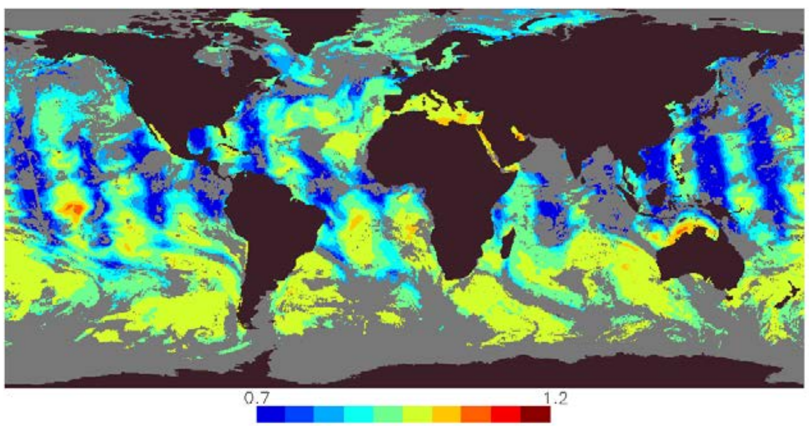
2-band BSST-CMC: Bias=0.27K, SD=0.57K



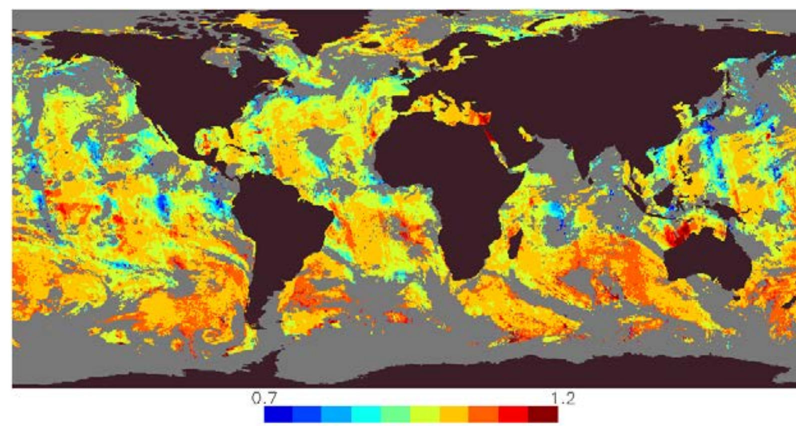
3-bands PWR/CLS SST-CMC: Bias=0.36K, SD=0.51K



2-band Sensitivity: Mean=0.90K, SD=0.09K



3-bands PWR/CLS Sensitivity: Mean=1.00, SD=0.05K



The 3-band PWR/CLS SST:

- **Increases daytime bias wrt CMC but reduces SD**
- **Optimizes mean sensitivity and improves its spatial uniformity**

Summary

- The current ACSPO Baseline SST may be brought closer to "skin" SST by
  - Using VIIRS bands 4.05 and 8.55 µm for SST retrieval along with the currently used bands 3.7, 11 and 12 µm
  - Bringing the mean sensitivity to the optimal value of 1 by using the Constrained Least-Squares method for coefficients calculation
  - Reducing spatial non-uniformity of sensitivity by Using the Piecewise Regression approach along with the CLS coefficients
- The "global" BSST algorithm with CLS coefficients has already been implemented for Himawari-8 AHI.
- Testing and implementation of the PWR algorithms with CLS coefficients is underway.

THANK YOU