GHRSST-XVIII Science Team Meeting
5 – 9 June 2017, Quingdao, China

Retrieval of diurnal cycles in "depth" and "skin" SSTs from the new generation ABI/AHI geostationary sensors with ACSPO

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

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

Objectives

- Processing data of the geostationary Himawari-8 AHI and GOES-16 ABI at NOAA with the ACSPO system has shown the capability of monitoring the diurnal cycle (DC) in SST
- However, it was recognized that quantitative estimation of DC shapes and magnitudes requires further optimization of SST algorithms
- In particular, substantial difference in the DCs in SSTskin and SSTdepth calls for more specific targeting the retrievals at each of the two SSTs
- Two existing ACSPO products, the Global Regression (GR) SST and the Piecewise Regression (PWR) SST, already can be viewed as certain approximations of SSTskin and SSTdepth.
- The presentation discusses possible improvements to the ACSPO AHI/ABI products in terms of DC monitoring

Current ACSPO SST equation for AHI/ABI

AHI/ABI bands used for SST:

Band	11	13	14	15
Wavelength (µm)	8.6	10.4	11.2	12.3

$$T_S = a_0 + a_1 T_{11} + a_2(T_{11}-T_8) + a_3(T_{11}-T_{10}) + a_4(T_{11}-T_{12}) +$$
$$+[a_5 + a_6 T_{11} + a_7(T_{11}-T_8) + a_8(T_{11}-T_{10}) + a_9(T_{11}-T_{12})]S_\vartheta +$$
$$+ [a_{10}(T_{11}-T_8) + a_{11}(T_{11}-T_{10}) + a_{12}(T_{11}-T_{12})]T_S^0$$

$T_8, T_{10}, T_{11}, T_{12}$	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

Using the same equation for day and night minimizes DC discontinuities

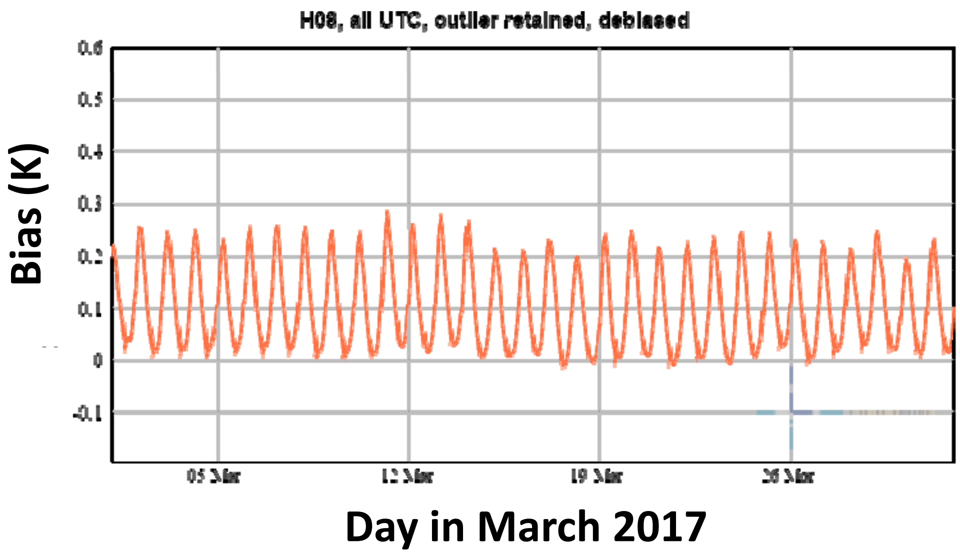
ABI/AHI SST products in the current ACSPO

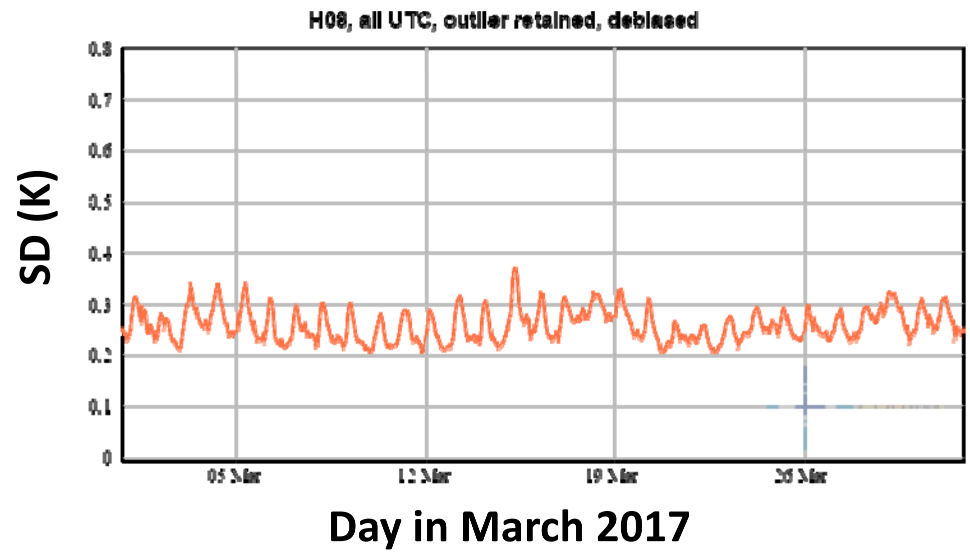
Algorithm	Global Regression (GR) SST	Piecewise Regression (PWR) SST
Representation in ACSPO GDS2 file	"sea_surface_temperature"	"sea_surface_temperature" -"SSES_bias"
Stratification of coefficients	Single set of coefficients	Uses multiple sets of coefficients for separate segments of the SST domain, defined in the space of regressors (*Petrenko et al., GHRSST-XVI; JTECH, 2016)*
Training of coefficients	Fitting *in situ* SST under the constraint "mean sensitivity* =0.95"	Best (unconstrained) fitting *in situ* SST
Precision wrt *in situ* SST	~0.4 K	~0.25 K
Sensitivity to SSTskin	~0.7-1.1	Not controlled
Approximation of:	**SSTskin**	**SSTdepth**

*The definition of sensitivity by *Merchant et al. (GRL, 2009)* is used

Improving SSTdepth estimates

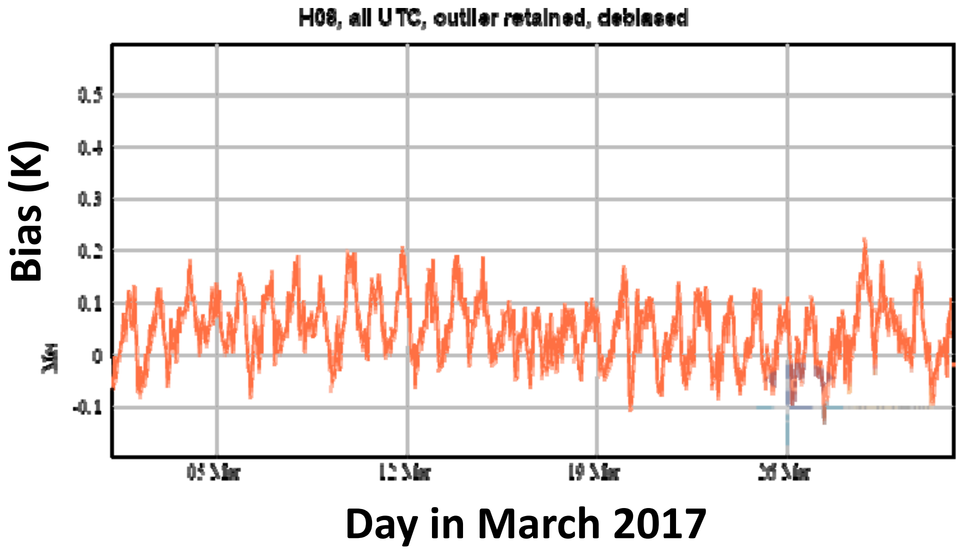
Bias and SD of AHI PWR SST wrt CMC (March 2017)

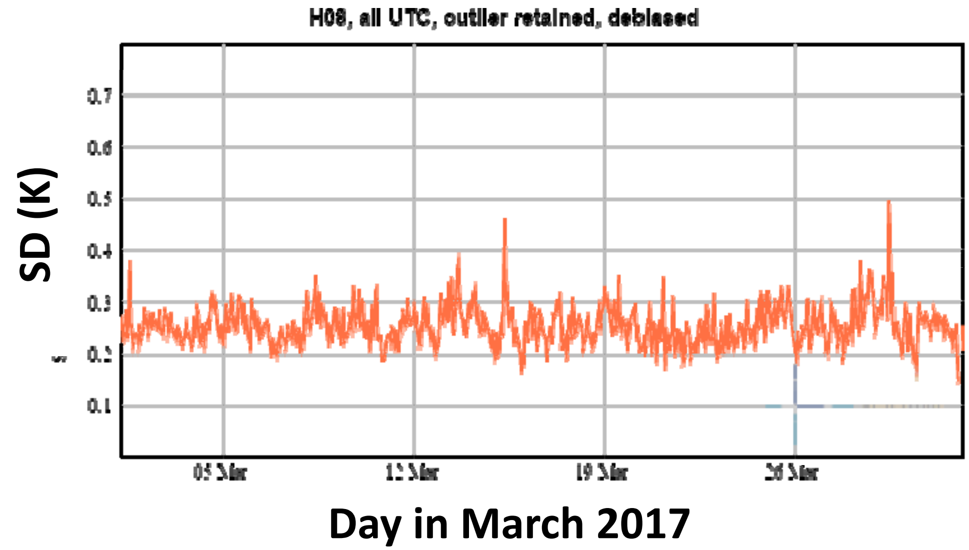




- The DC magnitude ≈0.25 K
- SD wrt CMC ≈0.2-0.3 K

Bias and SD of AHI PWR SST wrt *in situ* SST (March 2017)





- PWR SST fits *in situ* SST with SD≈0.25 K
- The residual DC magnitude wrt *in situ* SST (~0.15 K)
- The reason for inaccurate reproduction of DC in SSTdepth is that observed BTs respond to SSTskin, which is in general biased wrt SSTdepth.

Piecewise Regression "depth" SST (PWRdepth SST)

- The reproduction of DC in SSTdepth may be improved by accounting for SSTskin/SSTdepth bias
- The SSTskin/SSTdepth bias is driven by many variables and, among them, by **wind speed (*V*)** and **Local Solar Time (LST)**, which are available during L2 processing.
- These two variables are introduced into the equation for modified **PWRdepth SST**:

$$T_S = a_0(LST) + a_1T_{11} + a_2(T_{11}-T_8) + a_3(T_{11}-T_{10}) + a_4(T_{11}-T_{12}) +$$
$$+ [a_5 + a_6T_{11} + a_7(T_{11}-T_8) + a_8(T_{11}-T_{10}) + a_9(T_{11}-T_{12})]S_\vartheta +$$
$$+ [a_{10}(T_{11}-T_8) + a_{11}(T_{11}-T_{10}) + a_{12}(T_{11}-T_{12})]T_S^0 + a_{13}V$$

- GFS Wind speed is added to the equation as a regressor
- 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.

SDs of PWR and PWRdepth SSTs wrt *in situ SST* and CMC

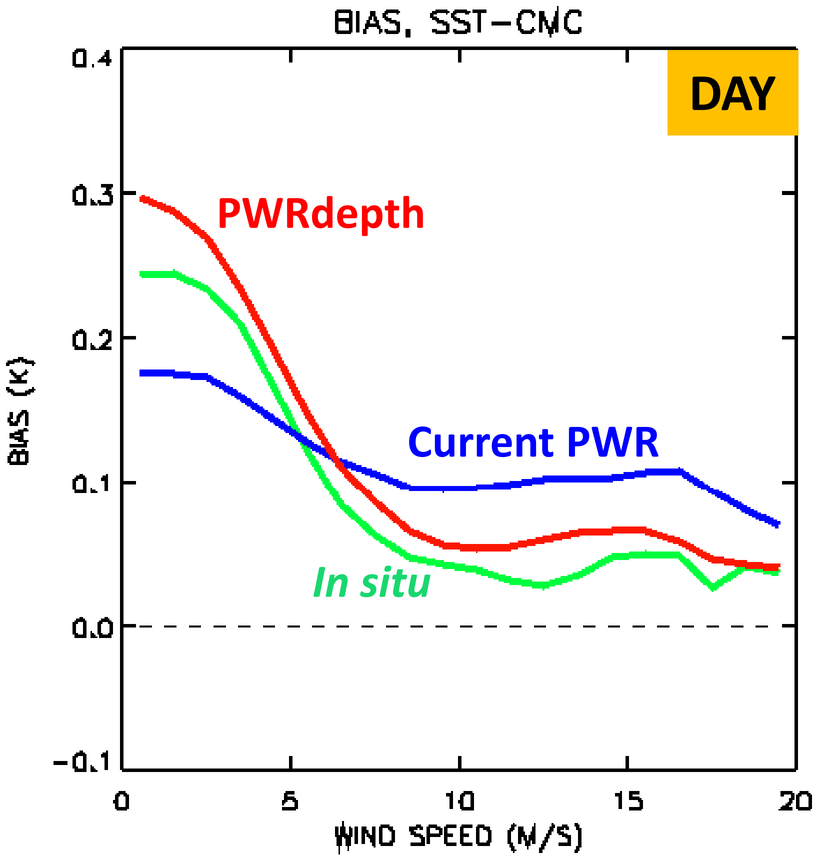
Reference	PWR SST (current)	PWRdepth SST	*In situ* SST
	Training MDS: January – December 2016		
In situ SST	0.25 K	0.23 K	0
CMC	0.17 K	0.19 K	0.28 K
	Validation MDS: January-April 2017		
In situ	0.26 K	0.25 K	0
CMC	0.17 K	0.20 K	0.27 K

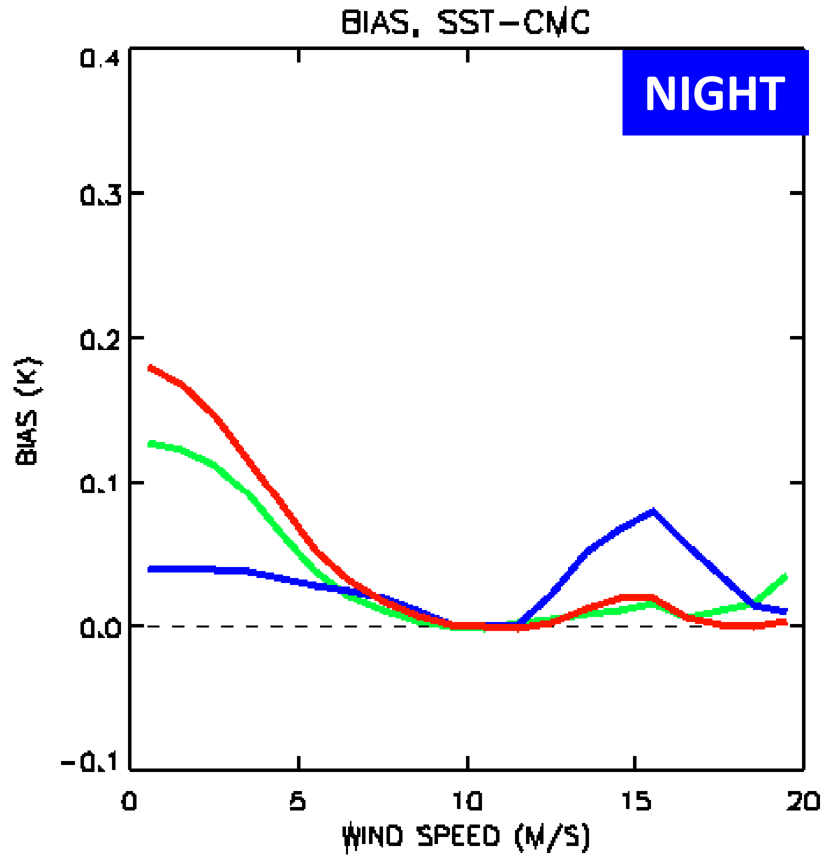
Accounting for wind speed and LST:

- ✓ Reduces SD wrt *in situ* SST
- ✓ Increases SD wrt CMC, brings it closer to the SD of *in situ* SST-CMC

PWR SSTs - CMC as functions of wind speed

Validation MDS: January – April 2017

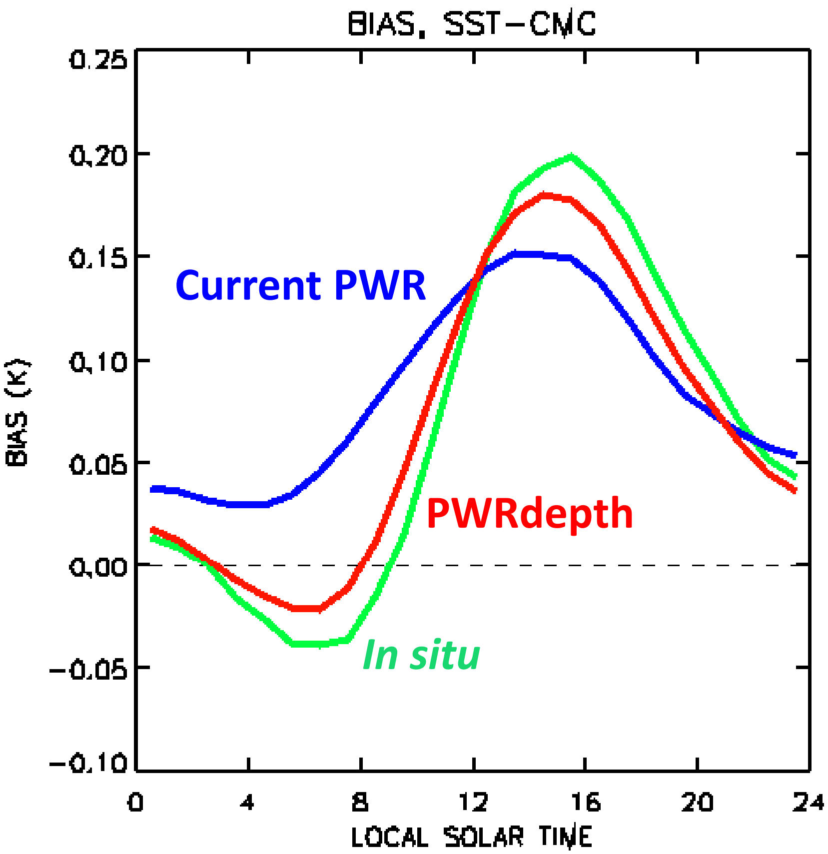




PWRdepth SST makes the dependencies more consistent with *in situ* SST

PWR SSTs - CMC as functions of Local Solar Time

Validation MDS, January – April 2017



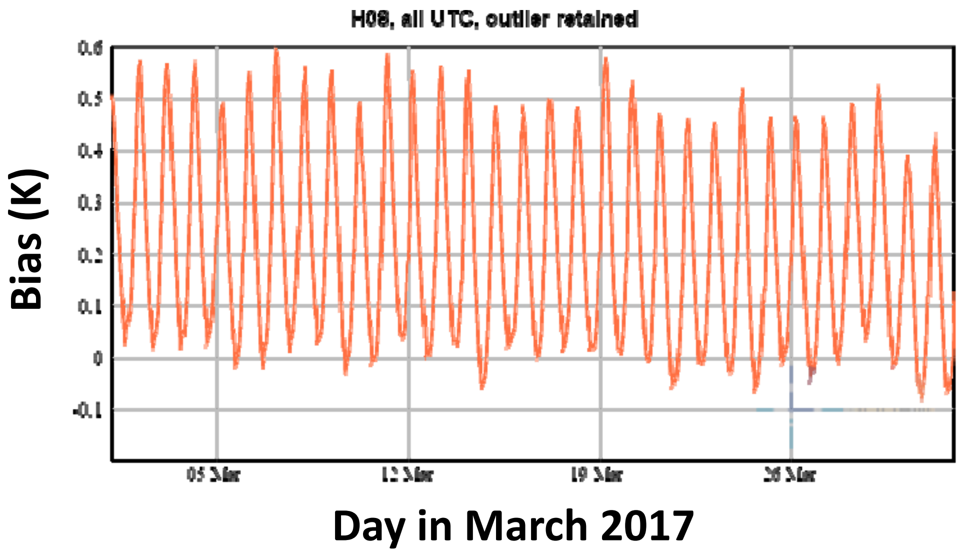
Statistics	*In situ* SST	Current PWR SST	PWRdepth SST
DC magnitude wrt CMC	0.24 K	0.14 K	0.21 K
DC magnitude wrt *in situ* SST	0	0.15 K	0.04 K
LST of minimum	6:30	3:30	5:30
LST of maximum	15:30	13:30	15:30

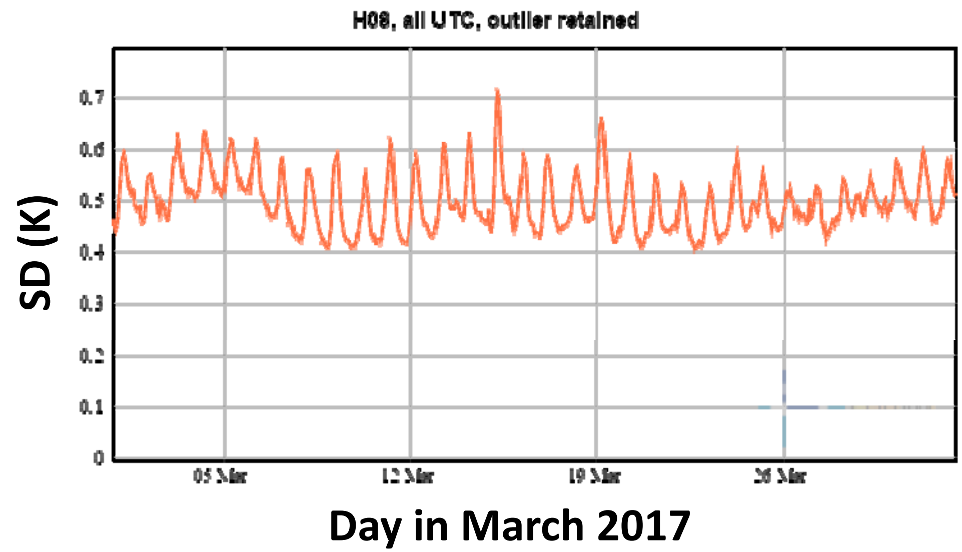
PWRdepth SST:

- ✓ Increases the DC magnitude, brings it closer to *in situ* SST
- ✓ Significantly reduces DC magnitude wrt *in situ* SST
- ✓ Shifts the times of DC maximum and minimum closer to *in situ* SST

Improving SSTskin estimates

Bias and SD of Global Regression SST wrt CMC (AHI, March 2017)





- GR SST shows diurnal signal with magnitude ≈ 0.5 K and SD ≈ 0.4-0.6 K

- The lack of "ground truth" for SSTskin precludes validation of estimated DC magnitude
- It is assumed, however, that the estimates of DC are affected by variable biases and sensitivity, typical for global regression algorithms

The Piecewise Regression “skin” SST (PWRskin SST)

- The **Piecewise Regression (skin) SST (PWRskin SST)** algorithm is aimed at :
  - ✓ Reducing variability of SST biases and sensitivity compared with GR SST;
  - ✓ Bringing sensitivity closer to 1
- The **PWRskin 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”

Statistics of AHI GR and PWRskin SSTs wrt *in situ* SST

All the statistics are for matchups with V>6 m/s

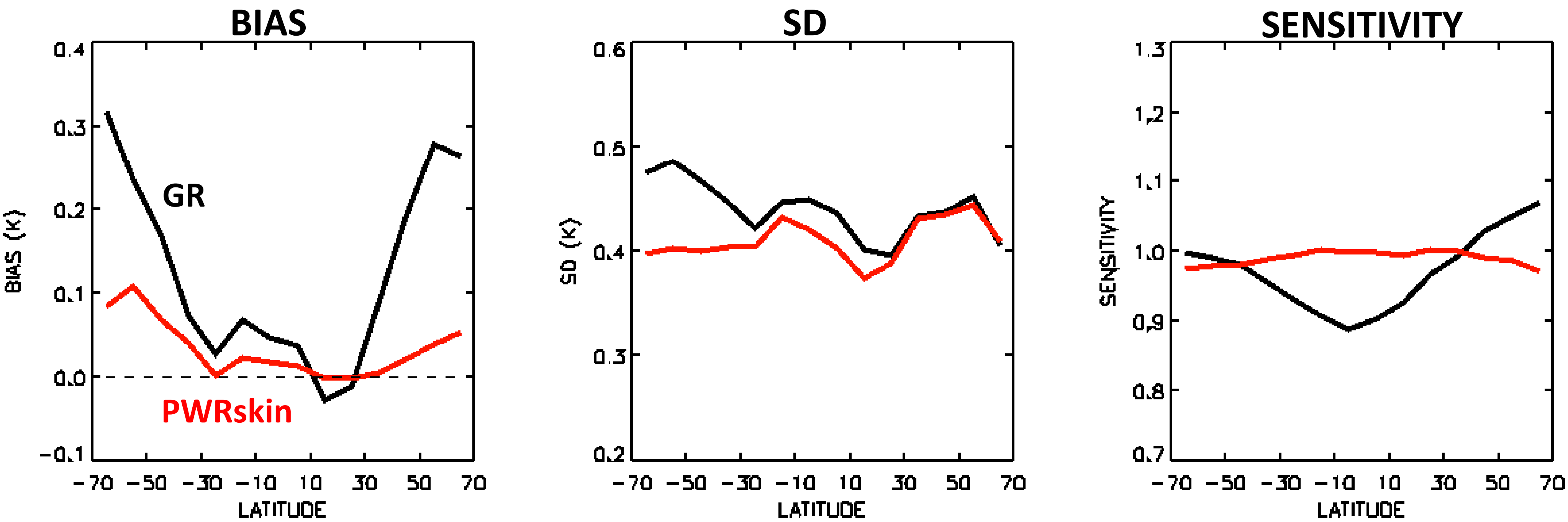
Algorithm	SD	Mean sensitivity	SD of sensitivity
Training MDS: January-December 2016			
GR SST	0.48 K	0.95	0.10
PWRskin SST	0.39 K	1.00	0.06
Validation MDS, January-April 2017			
GR SST	0.44 K	0.94	0.10
PWRskin SST	0.40 K	1.00	0.06

PWRskin vs. GR SST:

- ✓ SDs are smaller (suggests more uniform regional biases)
- ✓ Mean sensitivities are closer to optimal
- ✓ SDs of sensitivities are smaller (sensitivity is less variable)

Bias, SD wrt *in situ* SST and sensitivity of GR and PWRskin SSTs as functions of latitude

Validation MDS (January-April 2017, *V*>6 m/s)



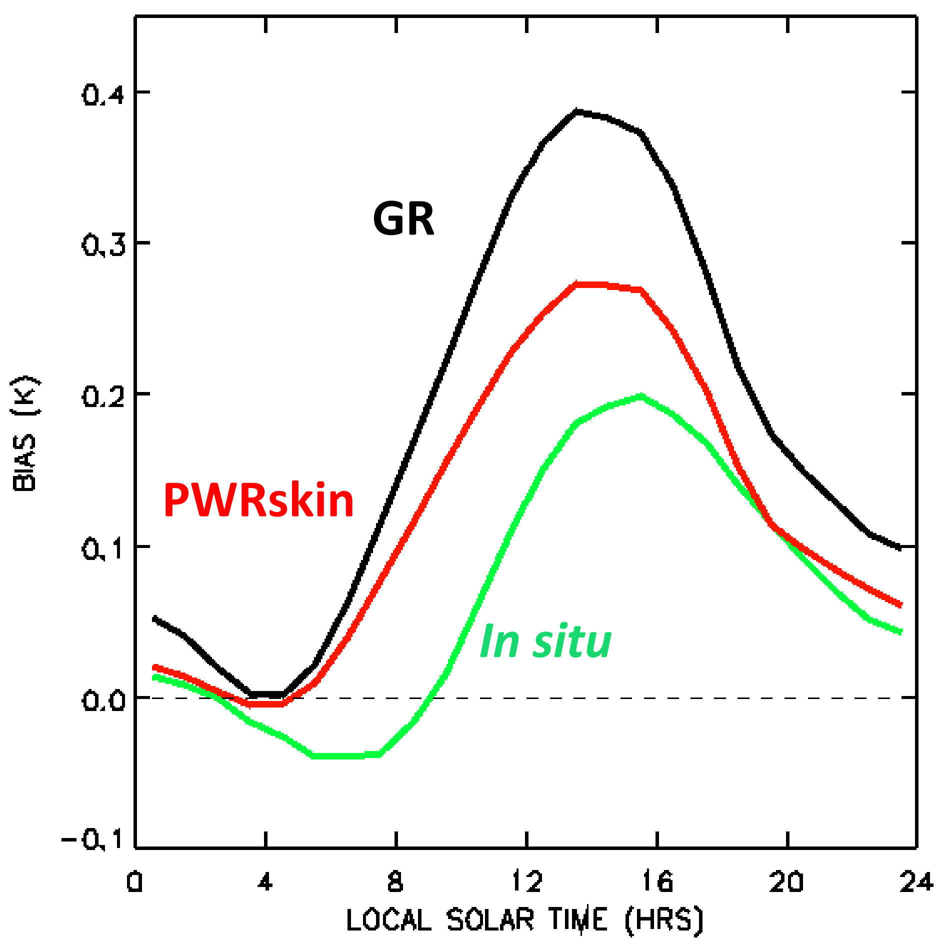
- GR SST biases and sensitivity are non-uniform, increasing from low to high latitudes
- PWRskin SST biases are more uniform, SD is smaller, sensitivity is less variable and closer to optimal

Biases in GR and PWRskin SSTs wrt CMC as functions of local solar time

Validation MDS: January-April 2017, all winds

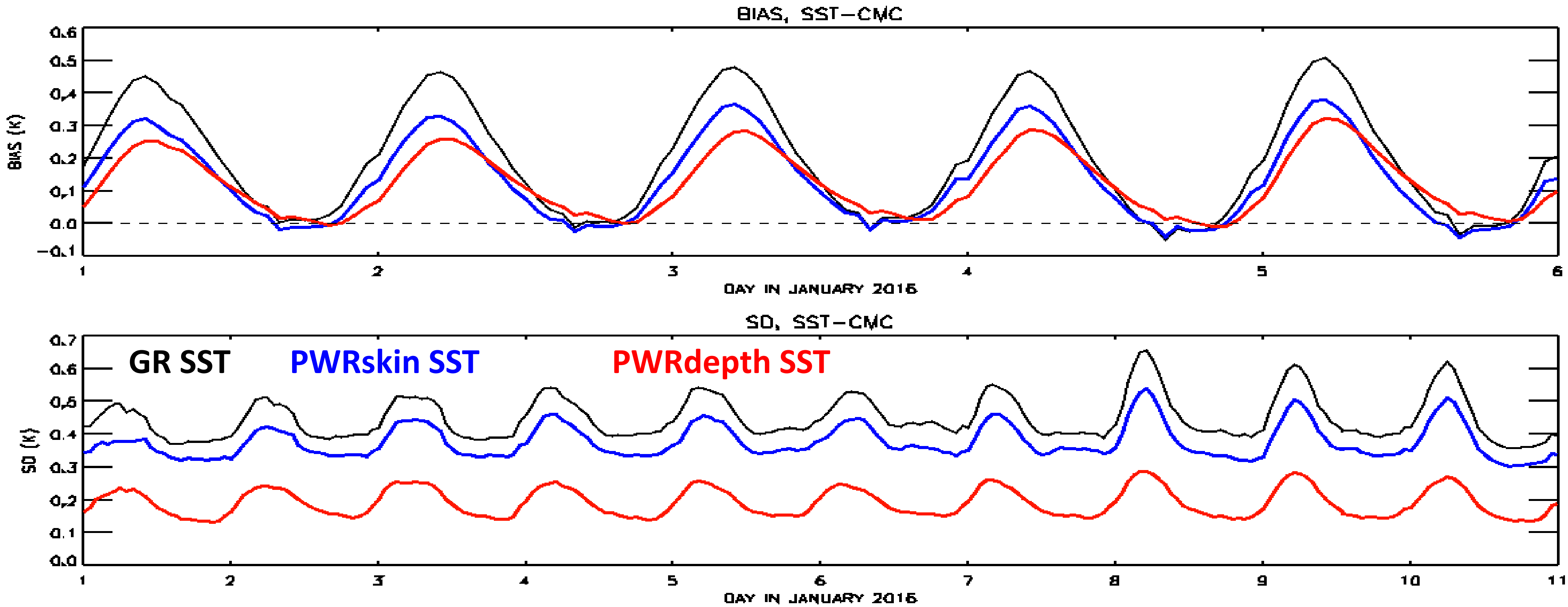
Statistics	*In situ* SST	GR SST	PWRskin SST
DC magnitude	0.24 K	0.45 K	0.28 K
LST of minimum	6:30	3:30	3:30
LST of maximum	15:30	13:30	13:30

- DC minima and maxima in both GR and PWRskin SSTs occur earlier than in *in situ* SST
- **The DC magnitude in PWRskin SST significantly reduces, due to more uniform biases and sensitivity**



Examples of GR, PWRskin and PWRdepth SSTs with the experimental ACSPO version

Time series of bias and SD wrt CMC in experimental ACSPO version (AHI, 1-6 January 2016)

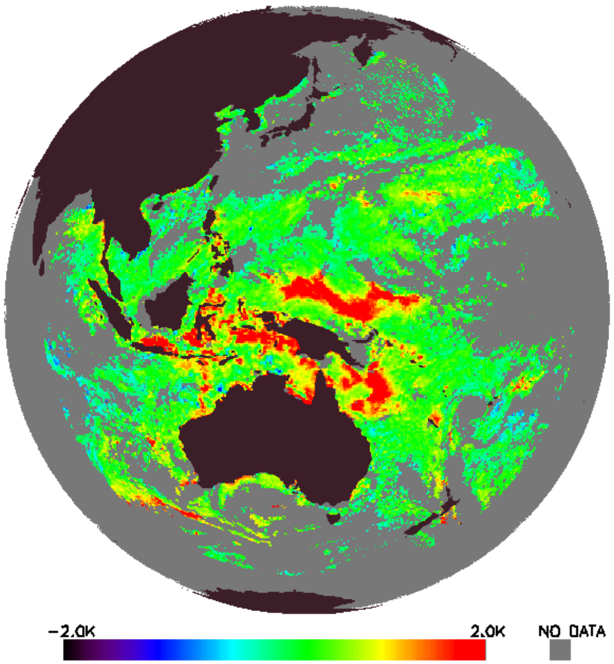


Parameter	GR	PWRskin	PWRdepth
DC magnitude	0.5 K	0.35 K	0.25 K
SD wrt CMC	0.45 K	0.4 K	0.2 K

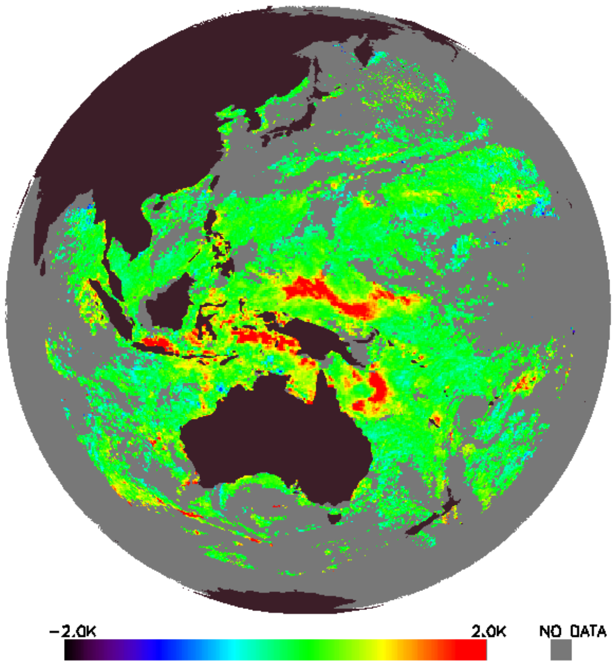
- DC magnitude and SD wrt CMC reduce from GR to PWRdepth SST
- Maxima and minima of DC in PWRdepth SST happen later than in PWRskin and GR

GR, PWRskin and PWRdepth SSTs minus CMC
(AHI, 01-08-2016, 5:00 UTC, Day)

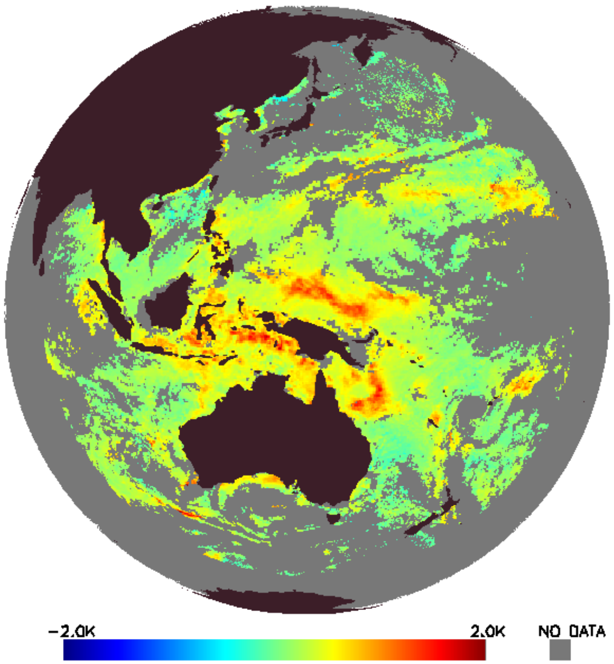
GR SST-CMC:
Bias=0.66 K, SD=0.66 K



PWRskin SST-CMC:
Bias=0.50 K, SD=0.54 K



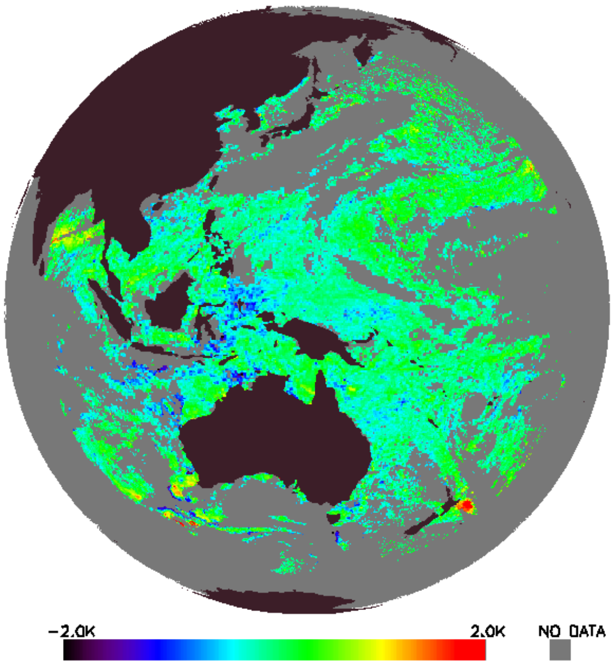
PWRdepth SST-CMC:
Bias=0.39 K, SD=0.29 K



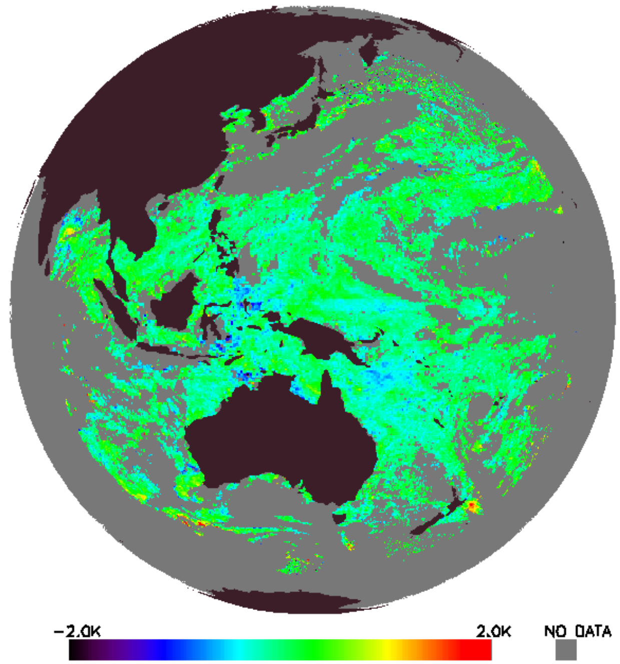
- PWRskin SST reduces the diurnal signal and SD, compared with GR SST
- PWRdepth SST further the diurnal signal and SD wrt CMC

GR, PWRskin and PWRdepth SSTs minus CMC
(AHI, 01-08-2016, 18:00 UTC, Night)

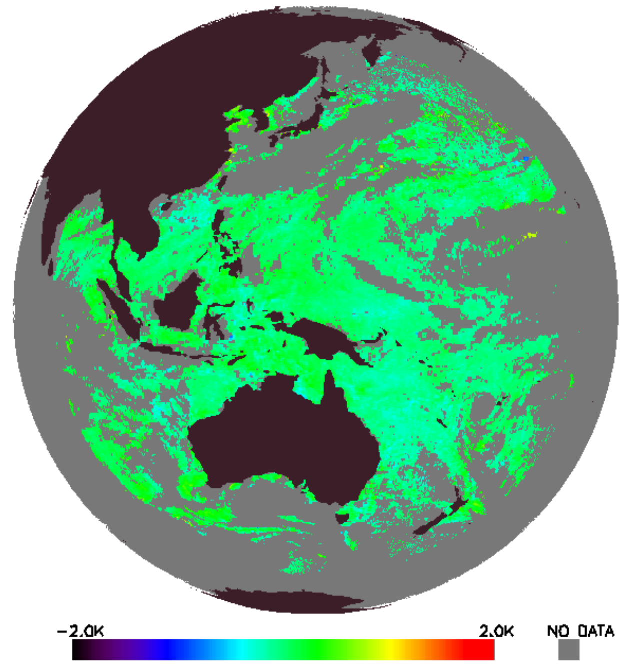
GR SST-CMC:
Bias=-0.03 K, SD=0.41 K



PWRskin SST-CMC:
Bias=-0.03 K, SD=0.33 K



PWRdepth SST-CMC:
Bias=-0.01 K, SD=0.15 K

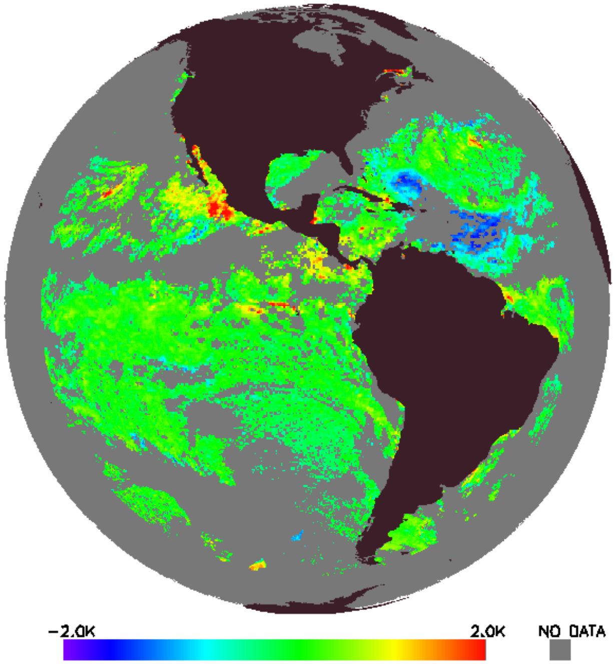


- PWRskin SST reduces cloud leakages and SD, compared with GR SST
- PWRdepth SST further SD wrt CMC

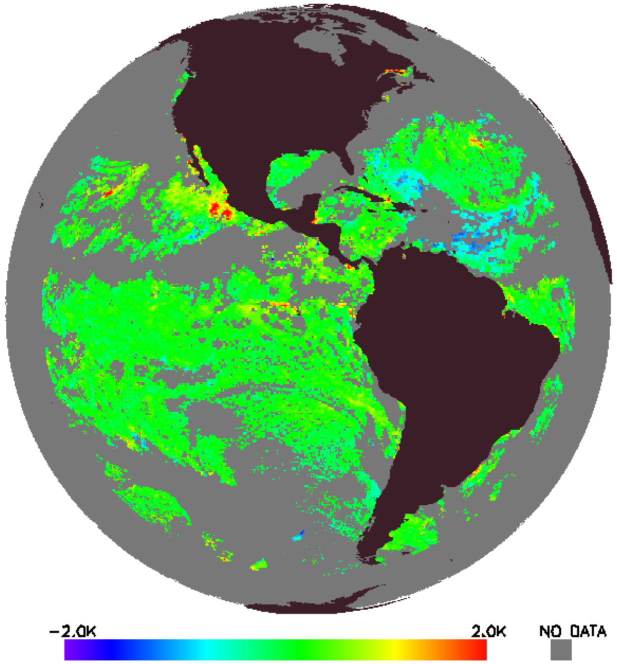
GR, PWRskin and PWRdepth SSTs minus CMC
(G-16 ABI, 05-24-2017, 20:00 UTC, Day)

The G16-ABI images are preliminary and non-operational

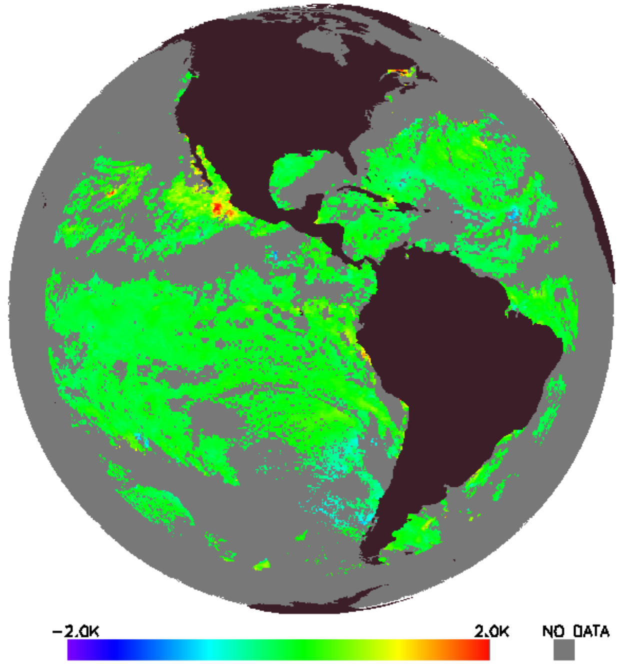
GR SST-CMC:
Bias=0.31 K, SD=0.54 K



PWRskin SST-CMC:
Bias=0.24 K, SD=0.43 K



PWRdepth SST-CMC:
Bias=0.19 K, SD=0.26 K

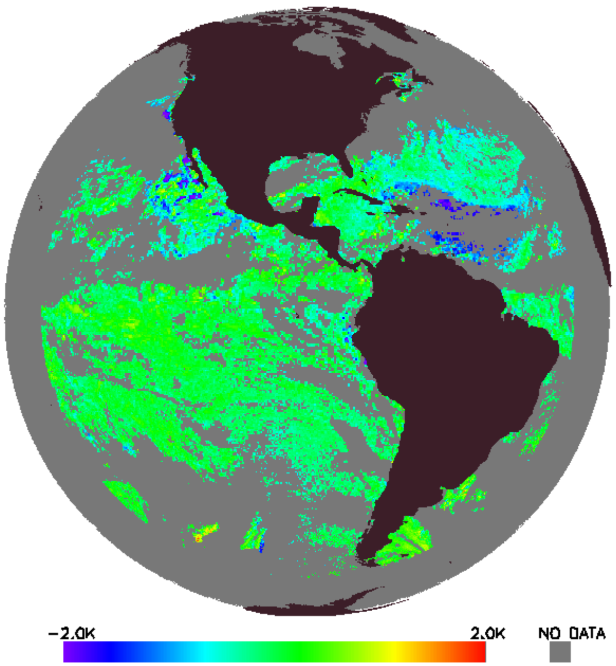


- PWRskin SST reduces the diurnal signal and SD compared with GR SST
- PWRskin SST also reduces cold SST anomaly over the Atlantic ocean
- PWRdepth SST further reduces deviations from CMC

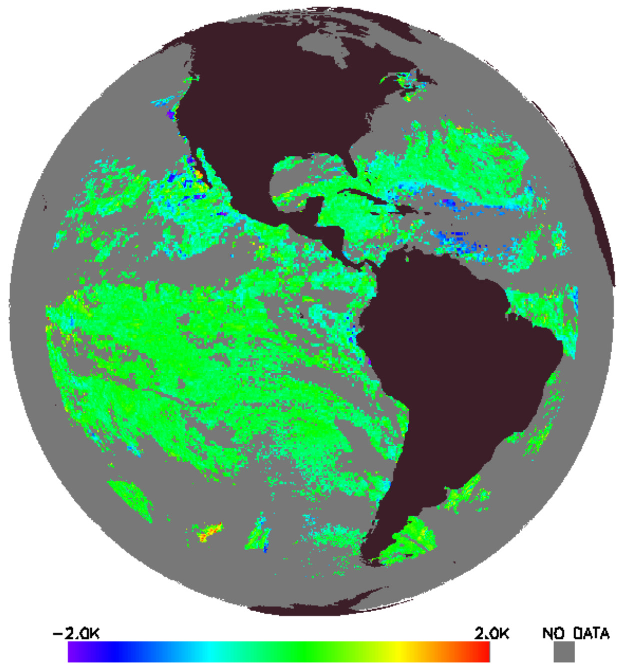
GR, PWRskin and PWRdepth SSTs minus CMC (G-16 ABI, 05-24-2017, 20:00 UTC, Day)

The G16-ABI images are preliminary and non-operational

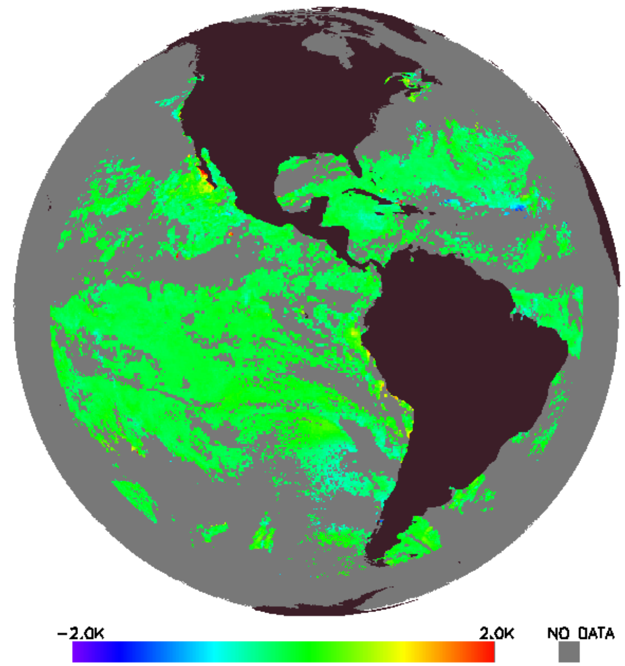
GR SST:
Bias=-0.06 K, SD=0.50 K



PWRskin SST:
Bias=-0.03 K, SD=0.42 K



PWRdepth SST:
Bias=0.05 K, SD=0.21 K



- PWRskin SST reduces SD compared with GR SST
- PWRskin SST also reduces cold SST anomaly over the Atlantic ocean
- PWRdepth SST further reduces deviations from CMC

Summary and future work

- Two Piecewise Regression algorithms have been developed to improve the reproduction of diurnal signals in “skin” and “depth” SST
- The **Piecewise Regression “depth” SST**:
  - ✓ Accounts for the dependencies of SSTskin/SSTdepth bias from wind speed and local solar time
  - ✓ Improves the reproduction of DC in *in situ* SST (including the magnitude and the times of maxima and minima).
- The **Piecewise Regression “skin” SST**:
  - ✓ Minimizes regional biases and variations in sensitivity, typical for Global Regression SST
  - ✓ Is expected to improve the reproduction of DC in SSTskin
- Large difference between DC magnitudes in GR and PWRskin SSTs illustrates the importance of controlling variations in SST biases and sensitivity for monitoring the DC in SSTskin
- The future developments will be focused at:
  - ✓ Extensive testing, validation and further enhancement of the “skin” and “depth” SST products,
  - ✓ Finding new sources of ground truth for SSTskin and new ways of SSTskin validation
  - ✓ After testing, these new algorithms may be implemented in one of the future versions of ACSPO

Thank you