Current status and upcoming changes in ACSPO VIIRS SST

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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:

$$T_S = a_0(LST) + a_1 T_{11} + a_3(T_{11}-T_{8.6}) + a_4(T_{11}-T_{12}) + [a_5 + a_6 T_{11} + a_8(T_{11}-T_{8.6}) + a_9(T_{11}-T_{12})]S_\vartheta + [a_{11}(T_{11}-T_{8.6}) + a_{12}(T_{11}-T_{12})]T_S^0 + a_{13}V$$

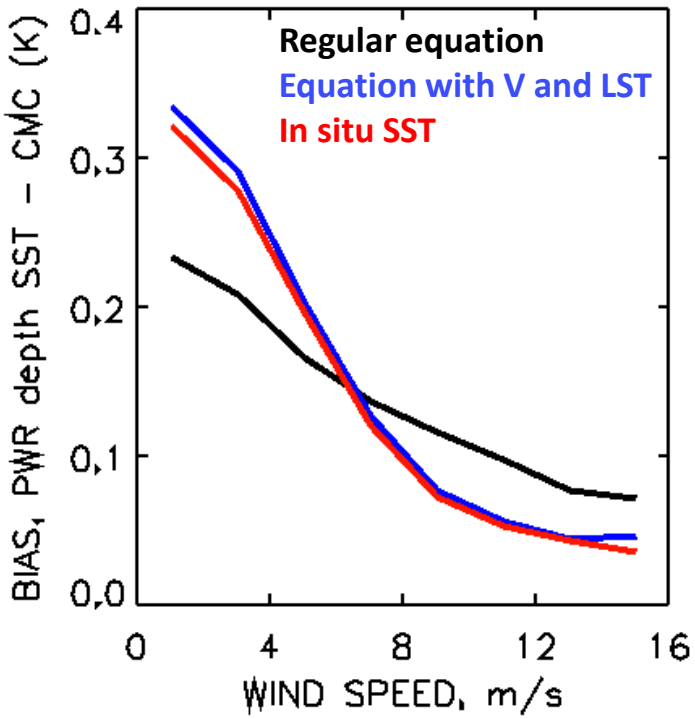
- LST is accounted for by correcting the offsets in the SST equations for every LST hour. During L2 processing, the offsets are interpolated to actual LST
- GFS Wind speed is added to the equation as an additional regressor

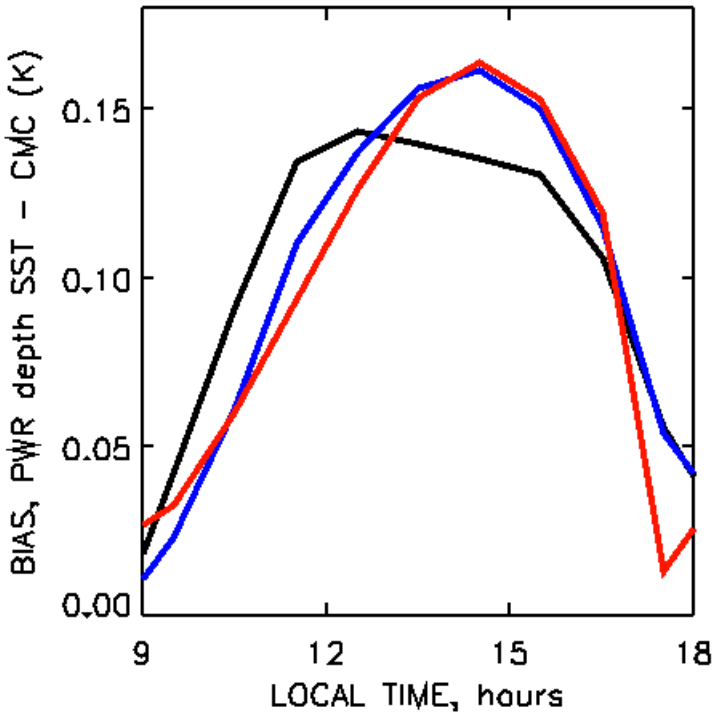
Expected improvement of daytime PWR SST precision wrt *in situ* SST due to accounting for *V* and LST

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

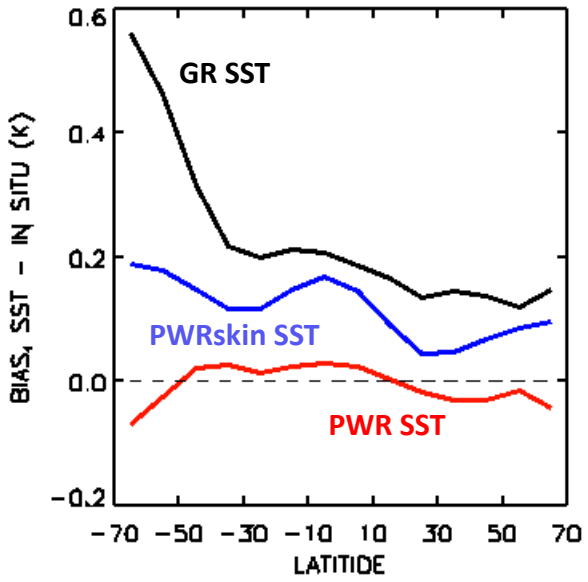
  "mean sensitivity =1"

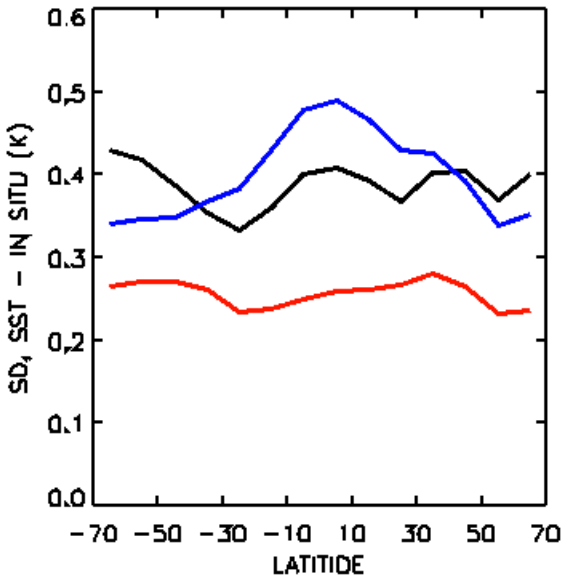
SD wrt in situ SST and sensitivity for GR SST and PWR skin SST

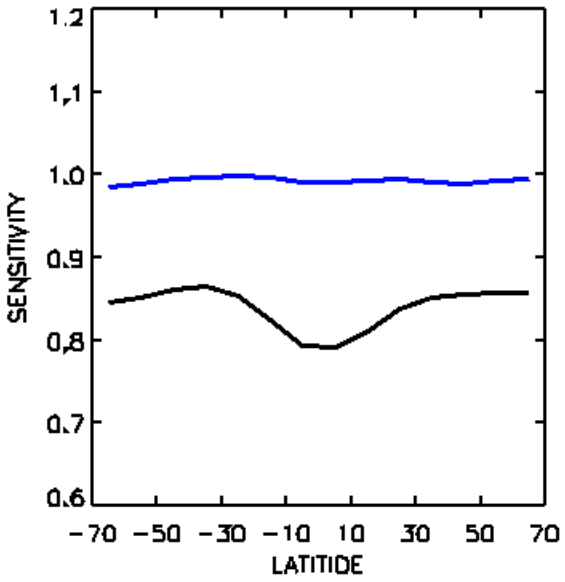
SST	Day		Night	
	SD wrt *in situ* SST	Sensitivity	SD wrt *in situ* SST	Sensitivity
GR SST	**0.37**	**0.85±0.08**	**0.33**	**0.90±0.04**
PWR skin	**0.38**	**1.00±0.05**	**0.31**	**1.00±0.03**

- 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



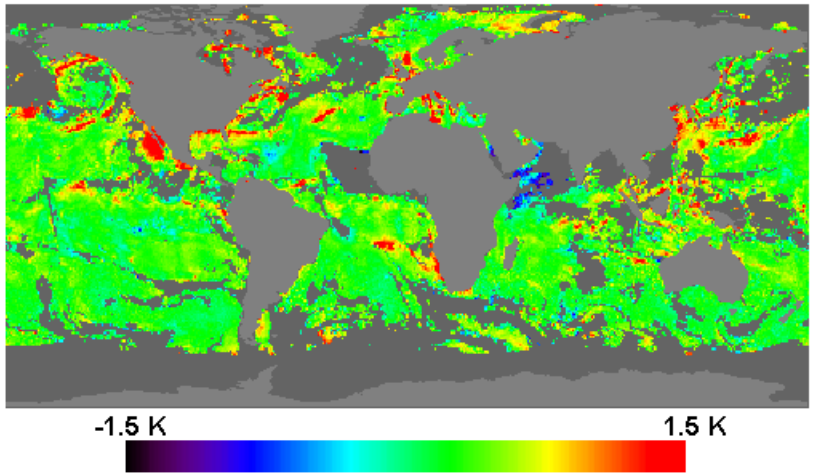




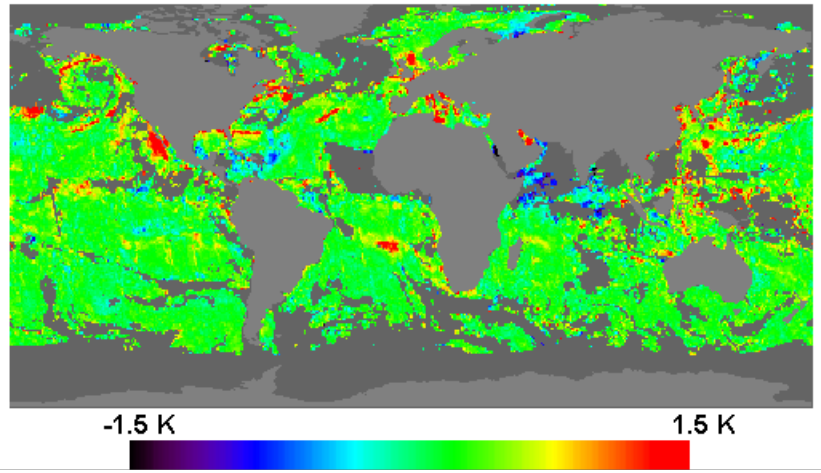
- GR SST produces large biases at high latitudes in the South
- PWRskin SST biases and SDs are maximum at low latitudes (expected)
- The biases and SDs for PWR are the smallest and the most uniform
- Sensitivity of GR SST is minimum at low latitudes, whereas the sensitivity of PWRskin SST is more uniform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

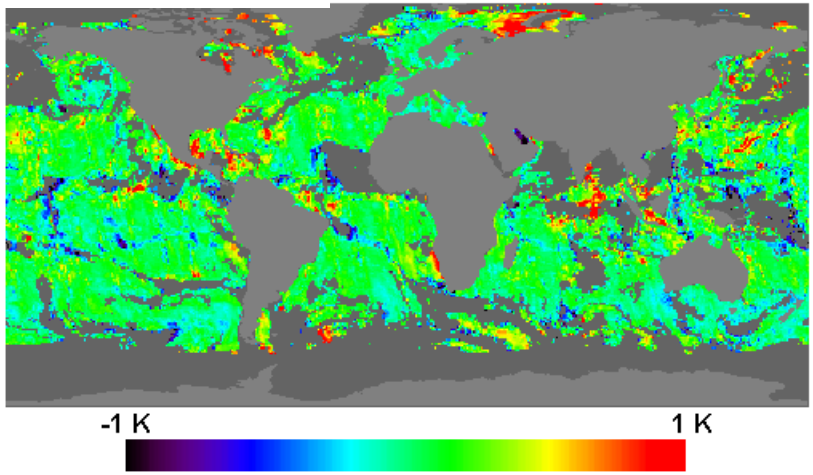


PWRS SST – CMC: Bias=0.32K, SD=0.50 K



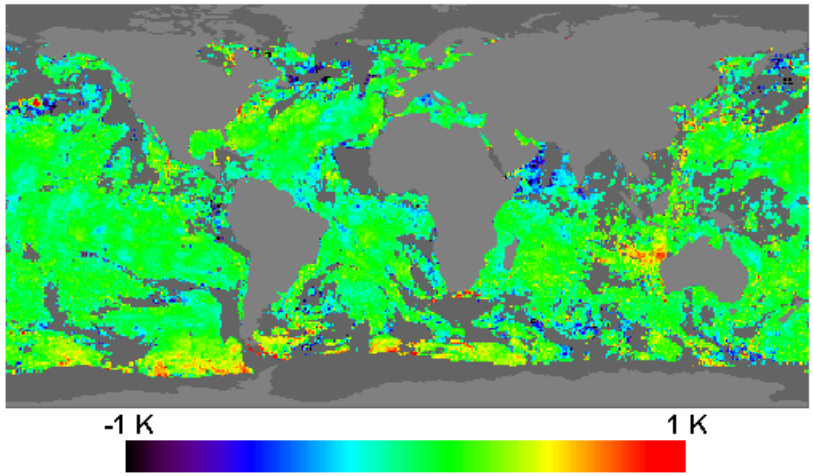
- PWRskin SST reduces warm biases in high latitudes

GR SST - PWRS SST

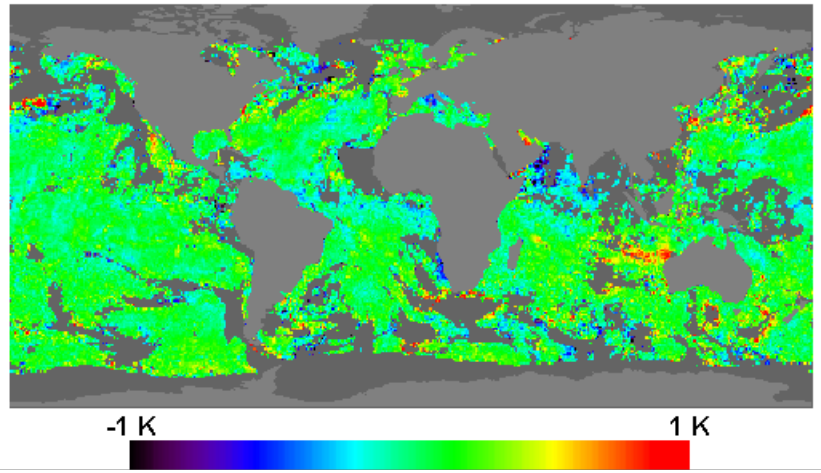


Nighttime maps of GR SST-CMC, PWR "skin" SST-CMC and GR SST-PWR "skin" SST (5 July 2017)

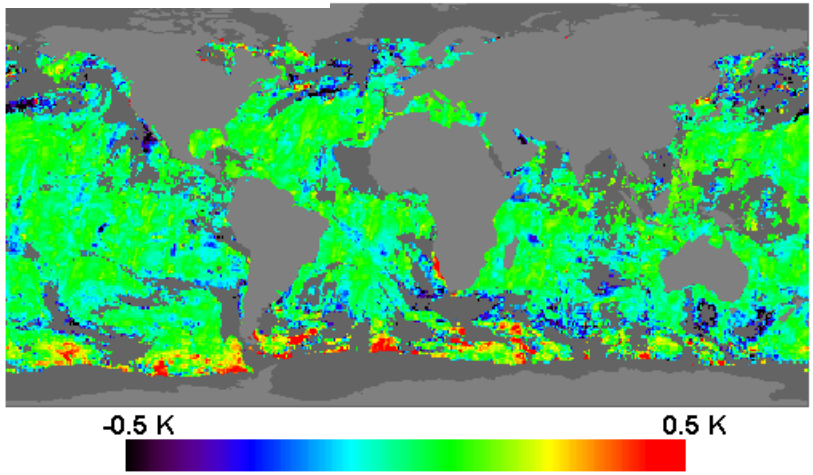
GR SST – CMC: Bias=0.11K, SD=0.32 K



PWRS SST – CMC: Bias=0.06K, SD=0.33 K



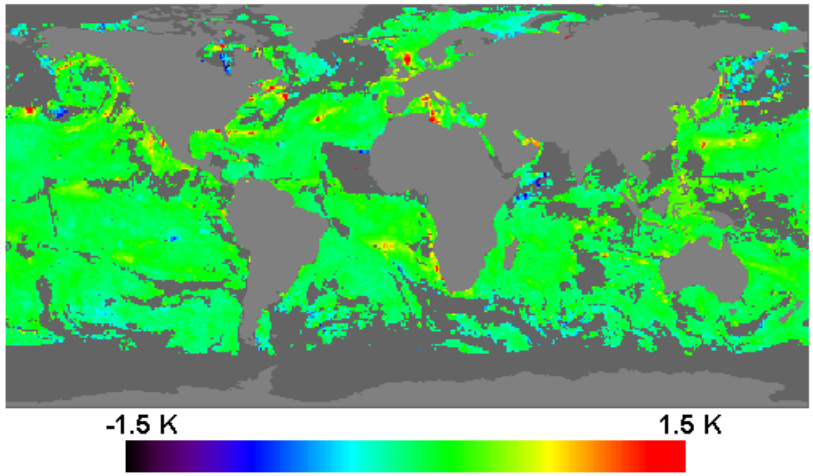
GR SST - PWRS SST



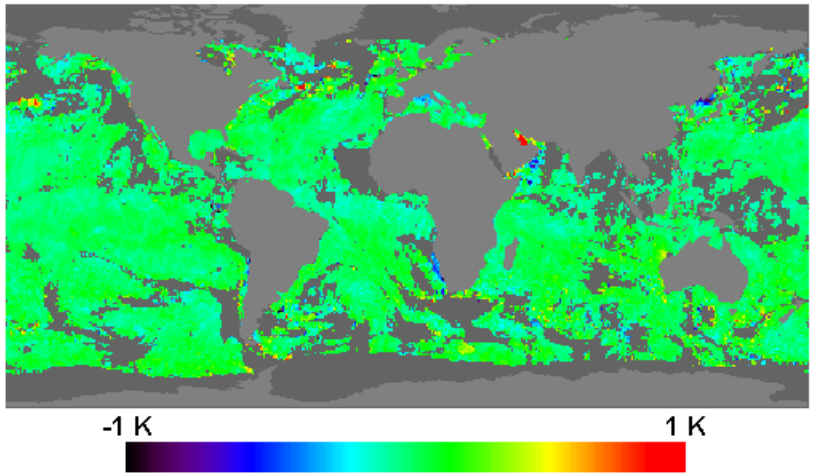
At night, the PWRskin SST reduces warm biases in high latitudes in the South

PWR SST minus CMC (5 July 2017)

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



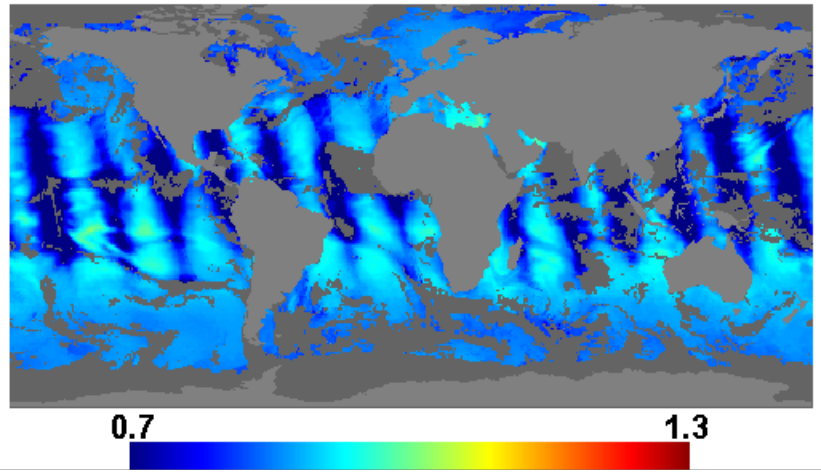
PWR SST – CMC, NIGHT: Bias=0.02K, SD=0.17 K



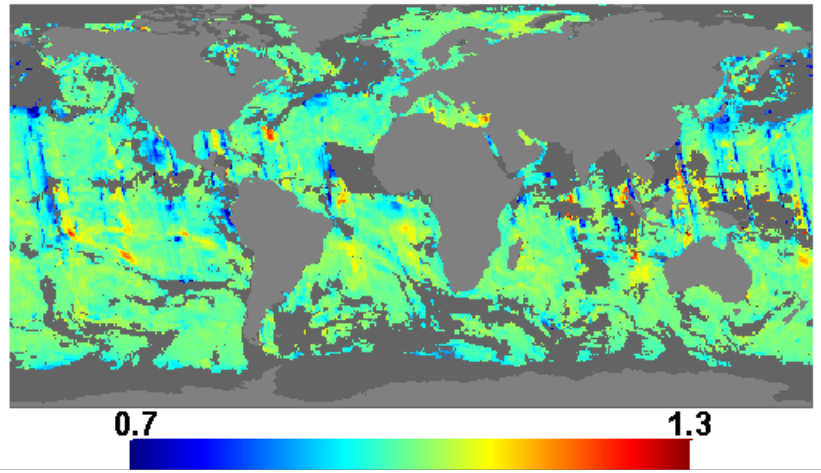
PWR SST is highly precise with respect to CMC

Sensitivities for GR SST and PWR skin SST

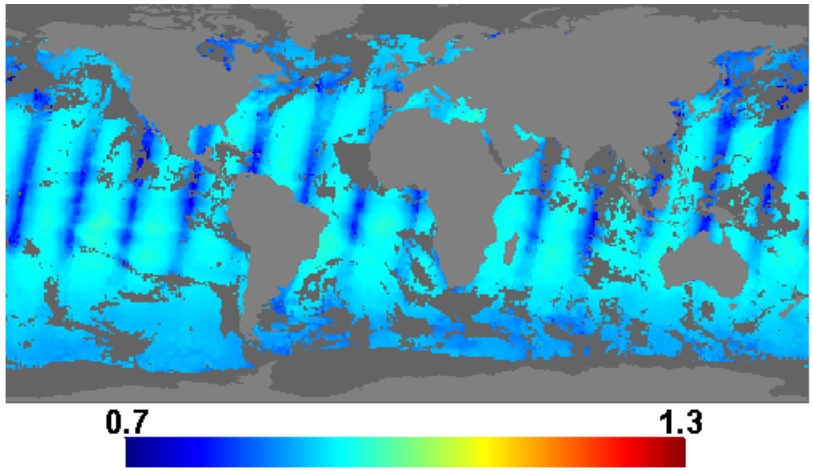
GR SST, DAY: mean=0.85, SD=0.08



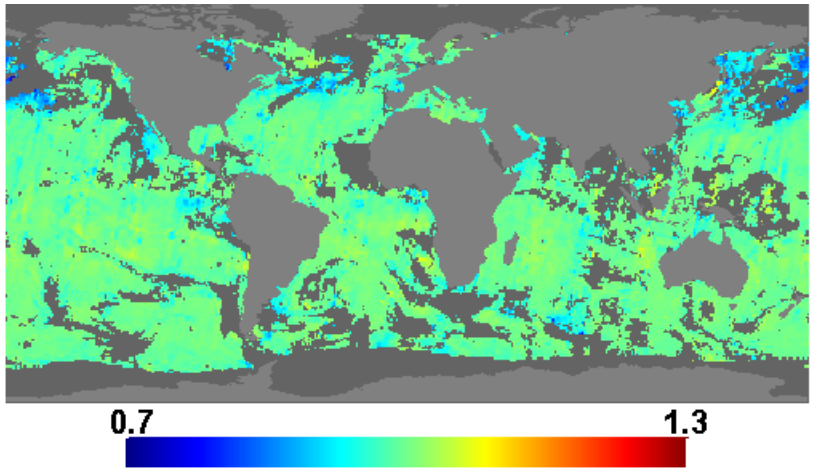
PWR skin SST, DAY: mean=0.99, SD=0.05



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



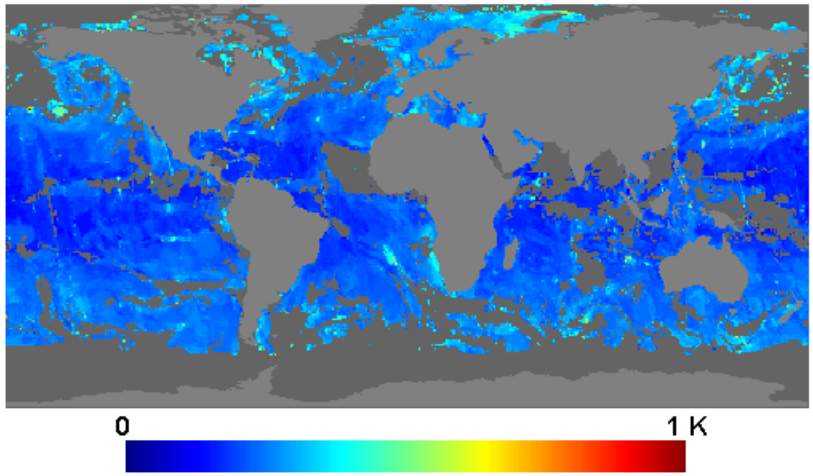
PWR SST, NIGHT: mean=0.99, SD=0.02



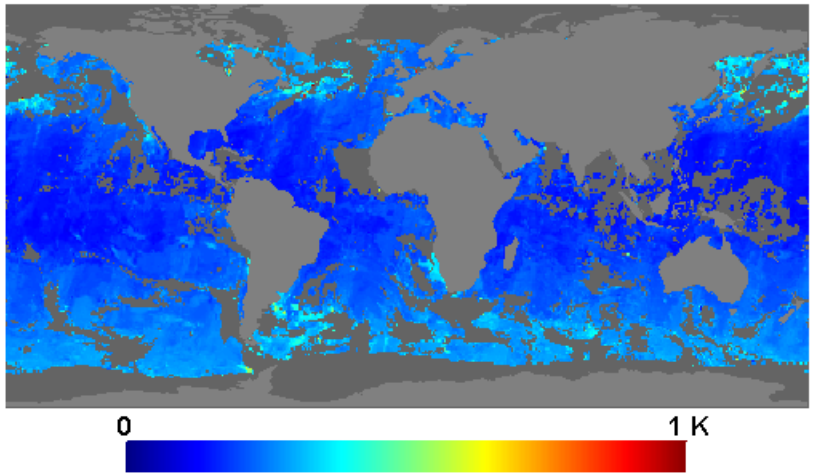
- Sensitivities for PWR skin SST are closer to 1 and more uniform

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