SSES in ACSPO version 2.40

Performance analysis
and recommendations for assimilation in L4 SST

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Content

	Slide number
• The SSES objective	3
• The SSES concept	4
• Initial evaluation of SSES bias	5-11
• Example maps of SSES SD	12
• Summary	13
• Recommendations for the testing in L4	14

The SSES objective

- The baseline SST algorithm in ACSPO uses regression equations, one for day and one for night, each with a single global set of coefficients (i.e., the regression coefficients do not change in space and time).
- These regression equations are not equally accurate under all observational conditions. The errors in ACSPO SST depend on many variables, such as view zenith angle, water vapor content in the atmosphere, etc.
- The purposes of the ACSPO SSES are:

  1) to provide realistic estimates of SST bias and SD in the full range of observational conditions and at every pixel with valid SST in the ACSPO L2 product;

  2) to ultimately reduce SST errors with respect to *in situ* SST using the SSES bias

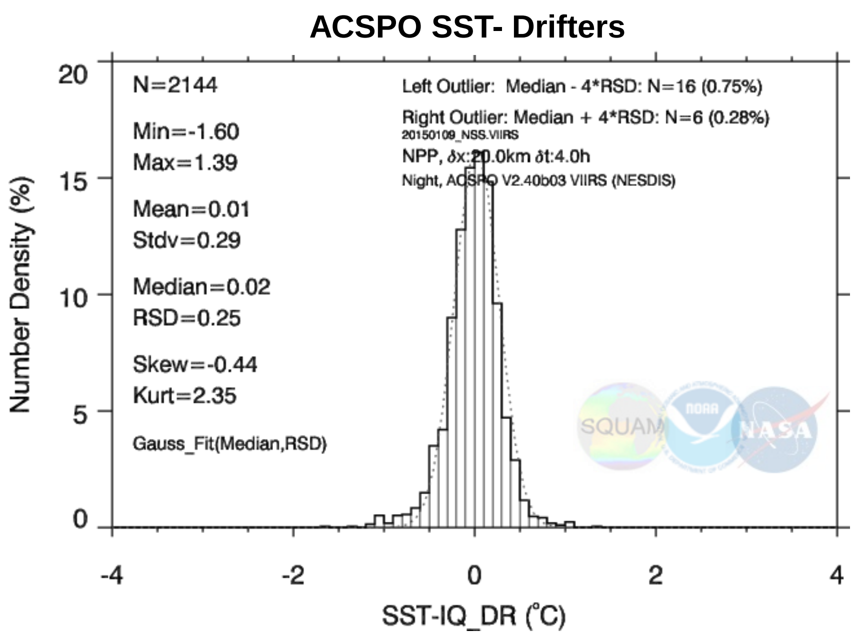
  3) to facilitate assimilation of ACSPO SST in L4 using the SSES SD (and bias).

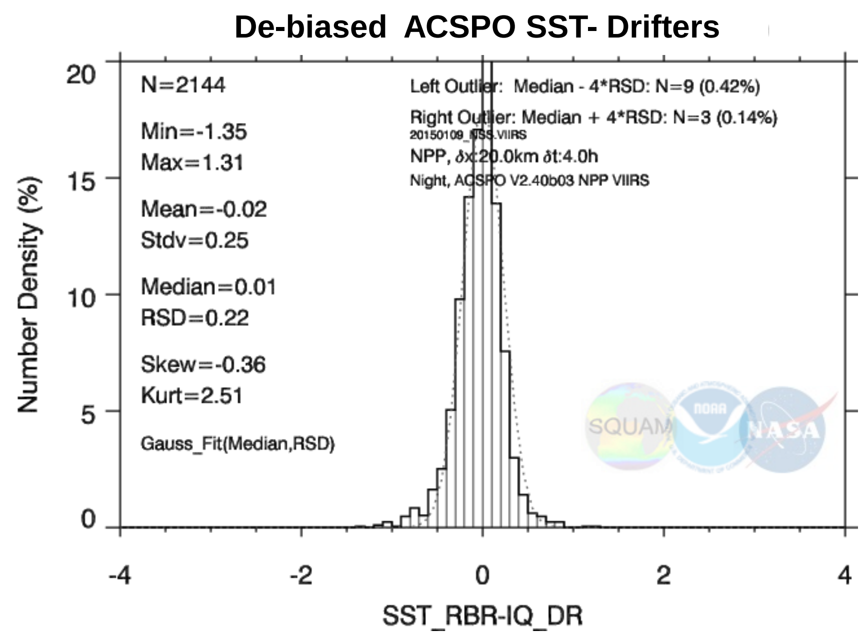
The ACSPO SSES concept

- SSES are analyzed as functions of regressors (terms of the SST equation) rather than physical variables (such as VZA, TPW etc.)
- SST pixels are subdivided into clusters, which are uniform in terms of (1) SD of regression SST minus *in situ* SST; and (2) observational conditions
- For each cluster, local regression coefficients and SSES SD are derived from the corresponding subsets of "VIIRS – in situ SST" matchups
- An auxiliary Piece-Wise Regression (PWR) SST is produced using "local" regression coefficients (i.e., specific for each cluster)
- For each pixel, SSES bias is estimated as ACSPO SST minus PWR SST
- Correction for the SSES biases (De-biased SST = ACSPO SST – SSES bias) thus transforms ACSPO SST back into PWR SST

- Slides 5-11 demonstrate the performance of the SSES bias correction by comparing ACSPO, De-biased, L4 (Canadian Met Center, CMC) and in situ SSTs
- The performance of SSES SD has not been evaluated yet. This can be done during assimilation of the ACSPO SST into L4 analyses (e.g., with weights dependent on SSES SD).

Nighttime histograms of ACSPO SST – *in situ* SST, (VIIRS, 9 Jan 2015)



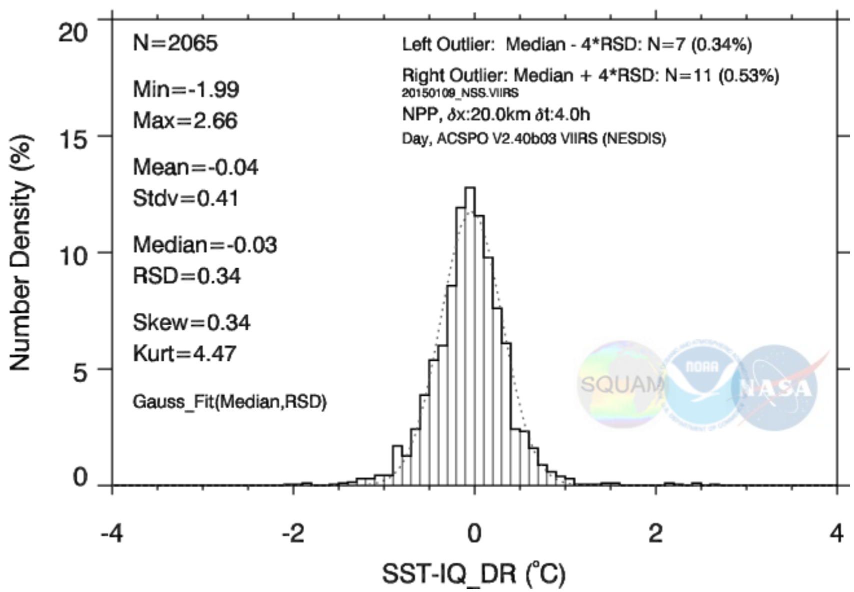


SSES bias correction reduces SD wrt drifters (in this case, from 0.29 K to 0.25 K)

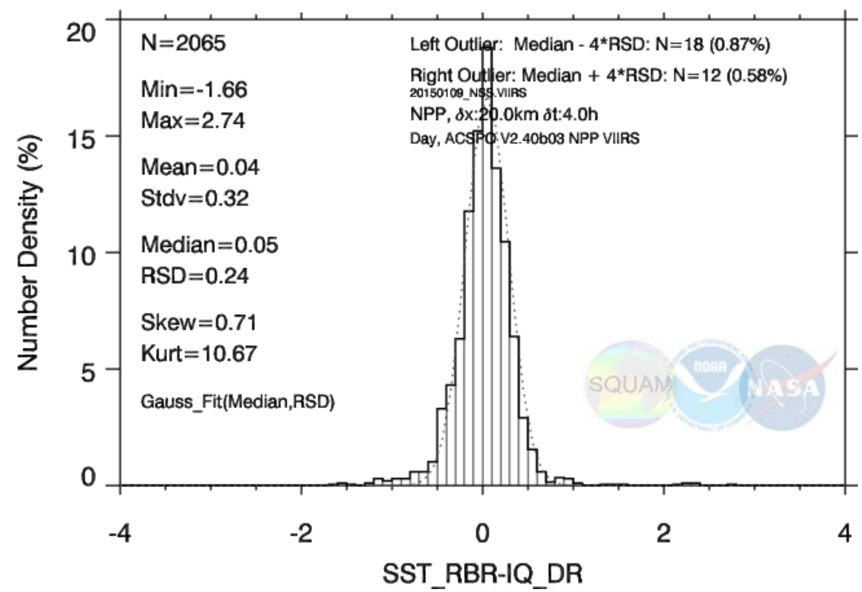
* Space-time match up criteria: ±10km, ±4hrs

Daytime histograms of ACSPO SST – *in situ* SST, (VIIRS, 9 Jan 2015)

ACSPO SST- Drifters



De-biased ACSPO SST- Drifters



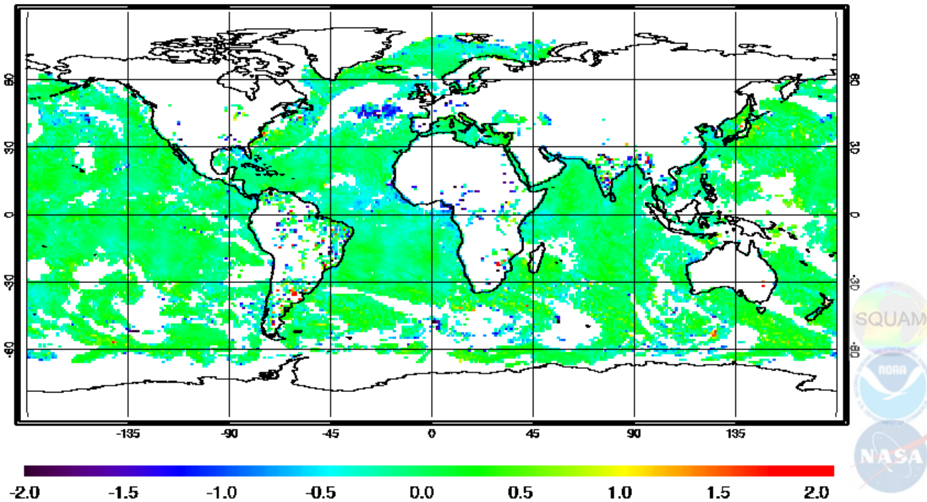
SSES bias correction reduces SD wrt drifters (in this case, from 0.41 K to 0.32 K)

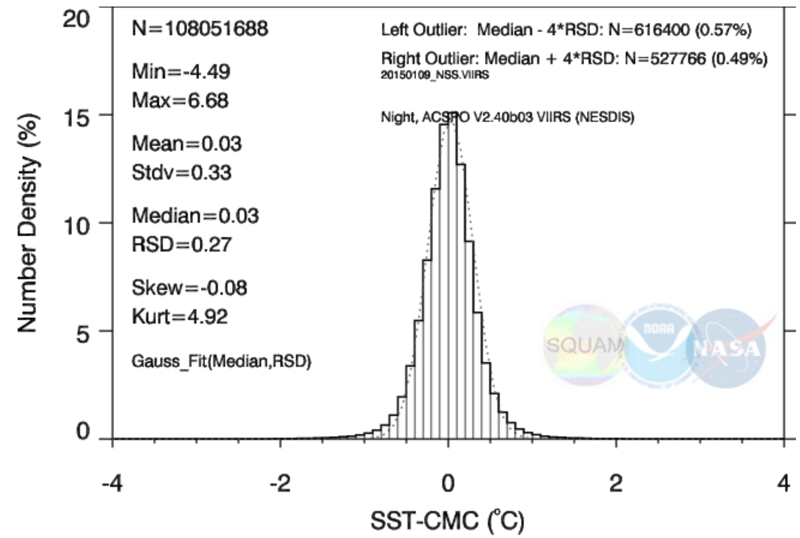
* Space-time match up criteria: ±10km, ±4hrs

The figures on slides 5-8 are produced with the experimental version of the NOAA SST Quality Monitor (SQUAM). For more results, please see http://www.star.nesdis.noaa.gov/sod/sst/squam/HR/index_exp.html#, where "Opr" represents operational SST and "RBR" is de-biased SST.

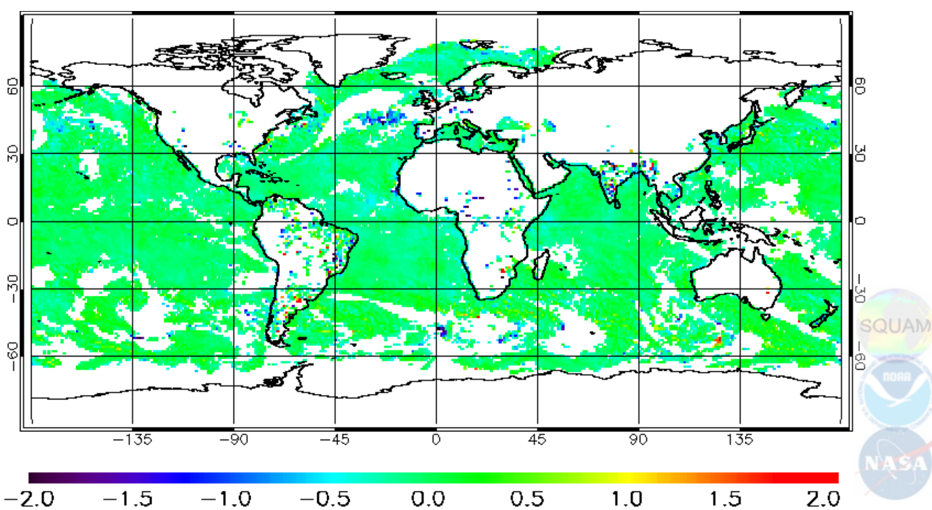
Nighttime maps & histograms of ACSPO SST - CMC, VIIRS, 9 Jan 2015

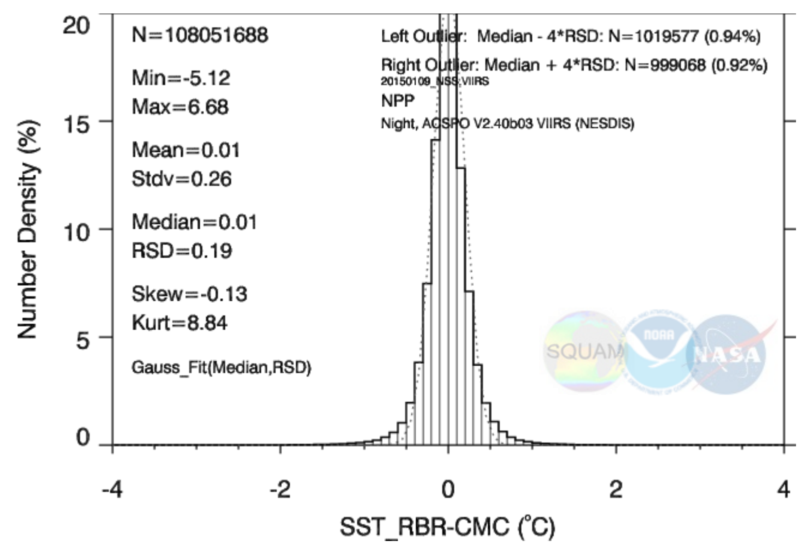
ACSPO SST - CMC





De-biased ACSPO SST - CMC

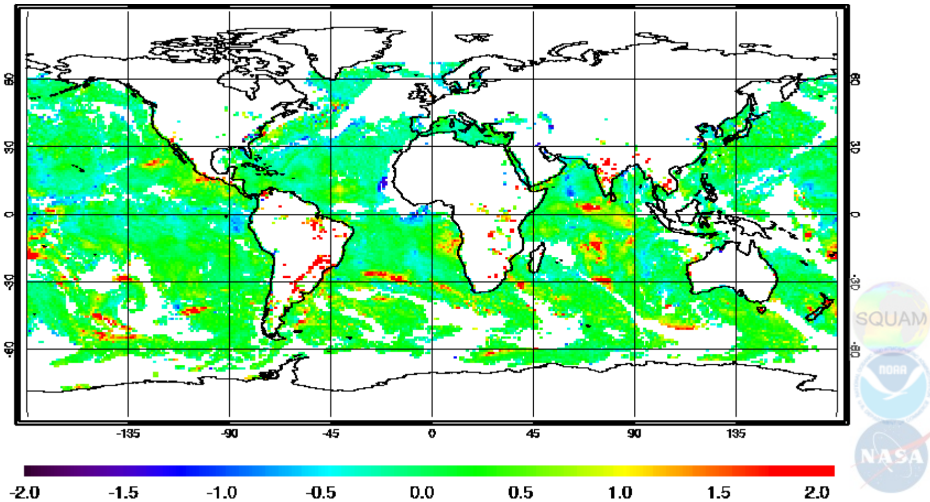


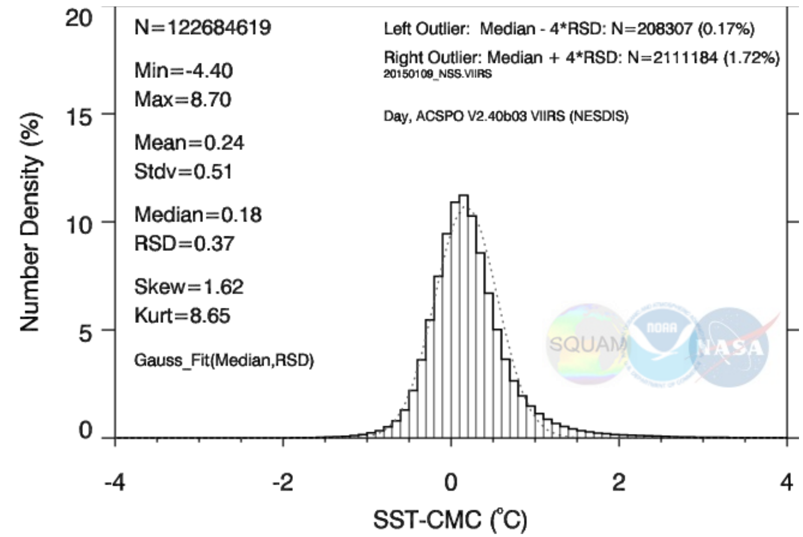


SSES bias correction improves consistency with CMC: Global SD reduces from 0.33 K to 0.26 K

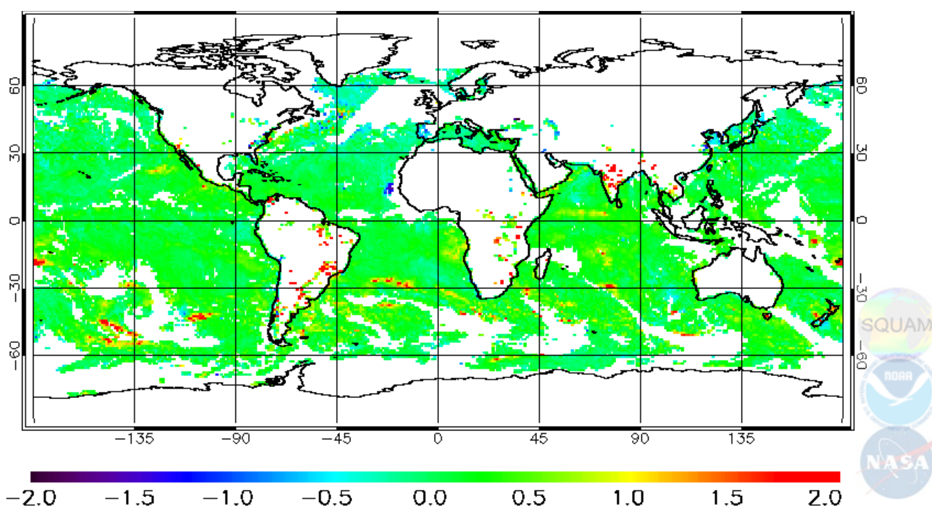
Daytime maps & histograms of ACSPO SST - CMC, VIIRS, 9 Jan 2015

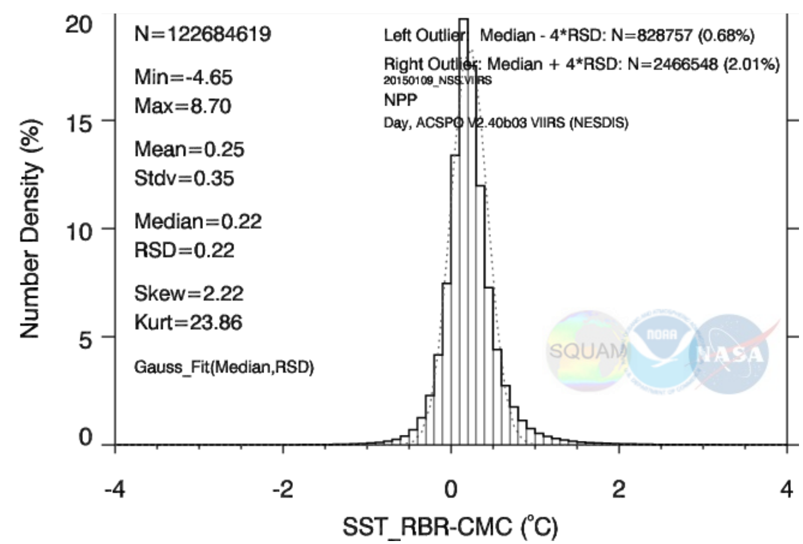
ACSPO SST - CMC





De-biased ACSPO SST - CMC



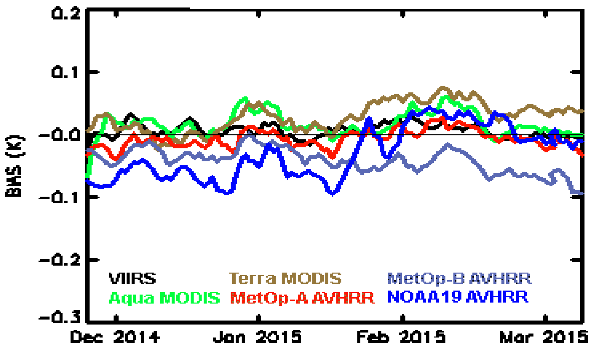


SSES bias correction improves consistency with CMC: global SD reduces from 0.51 K to 0.35 K

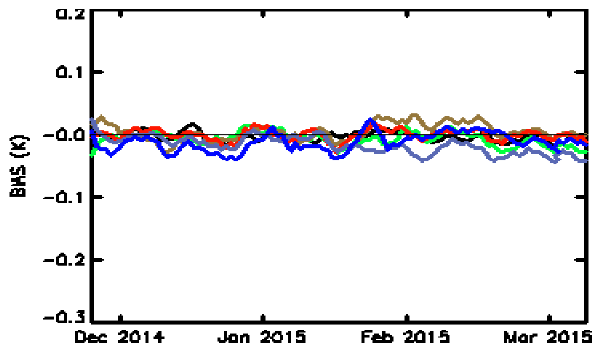
Time series of global nighttime daily mean and SD of SST – drifters, for 6 satellite sensors

- The sets of clear-sky matchups were collected for each sensor and used to calculate daily biases and SDs for all three SSTs
- Space-time match up criteria: ±10km, closest in time within ±2hrs (note reduced time window relative to previous results)
- Time series were smoothed with a ±3 days moving average filter

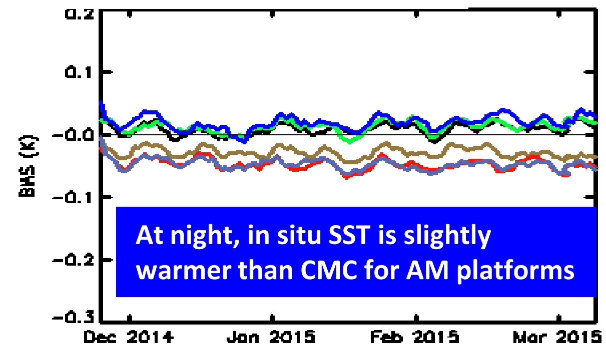
ACSPO SST – IN SITU



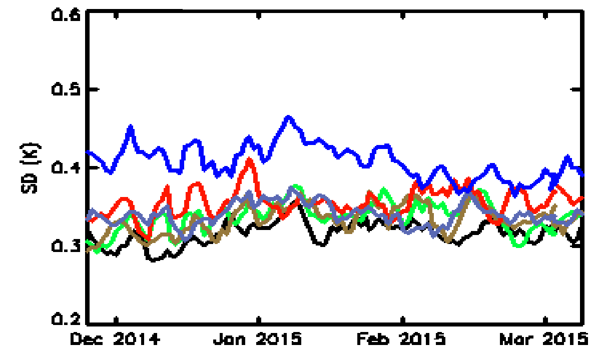
De-biased SST – IN SITU



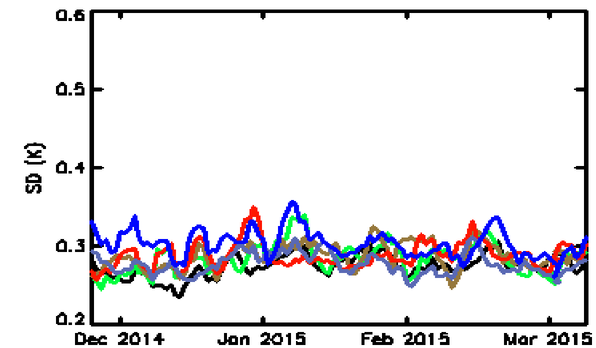
CMC – IN SITU



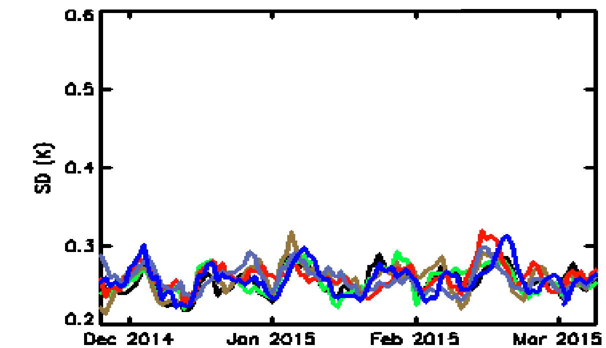
ACSPO SST – IN SITU



De-biased SST – IN SITU



CMC – IN SITU



Nighttime SSES bias correction:

- Reduces global "L2 – *in situ*" biases and SDs & Improves consistency between sensors
- Brings global SDs of "de-biased L2 – *in situ*" much closer to SDs for "CMC L4 – *in situ"*
- Global "de-biased L2 – *in situ*" biases are consistent between AM and PM platforms (because L2 is tied to in situ)
- Note that biases in "L4 – *in situ*" are subject to diurnal cycle in in situ SST (whereas L4 SST=const, daily average)

Time series of global daytime daily mean and SD of SST – drifters, for 6 satellite sensors

- The sets of clear-sky matchups were collected for each sensor and used to calculate daily biases and SDs for all three SSTs
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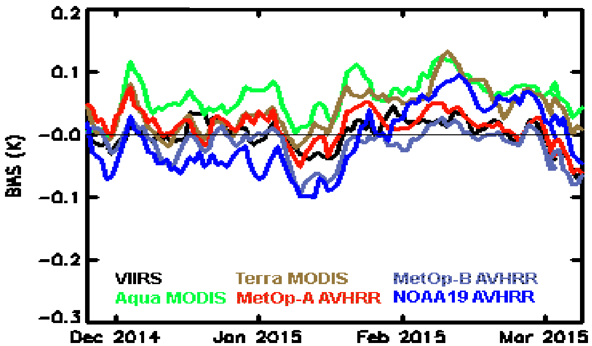
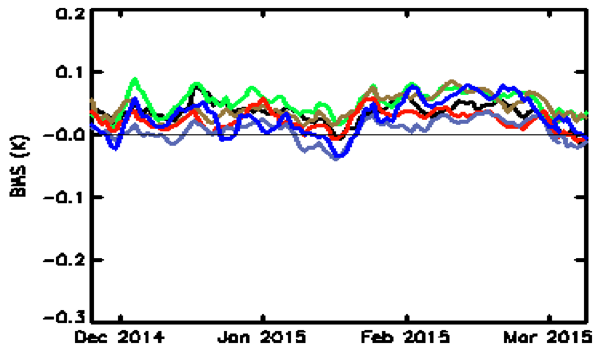
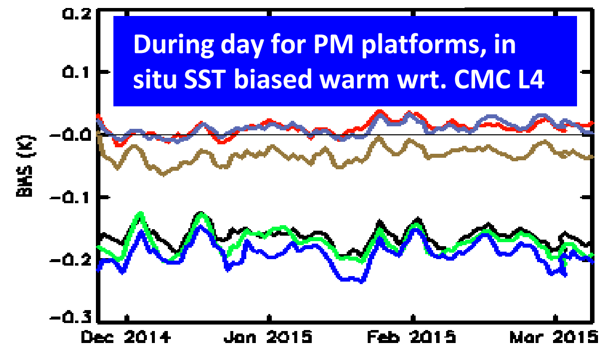
ACSPO SST – IN SITU



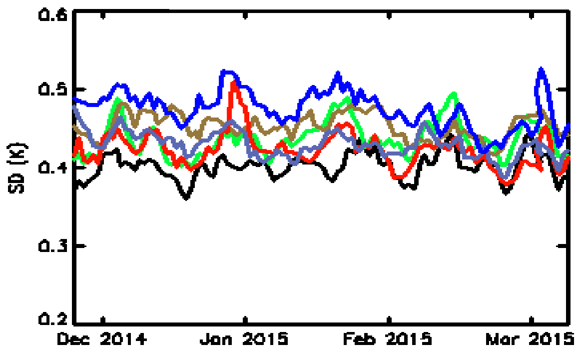
De-biased SST – IN SITU



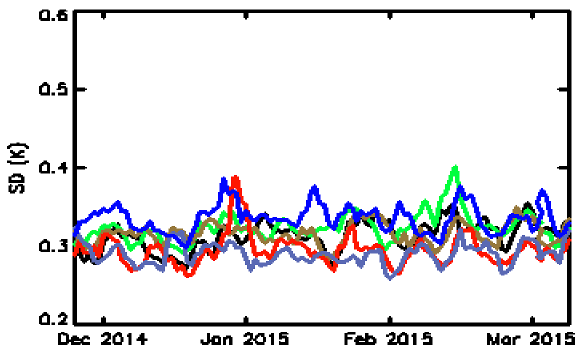
CMC – IN SITU



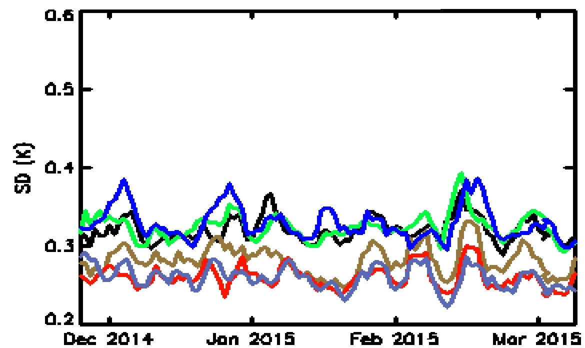
ACSPO SST – IN SITU



De-biased SST – IN SITU



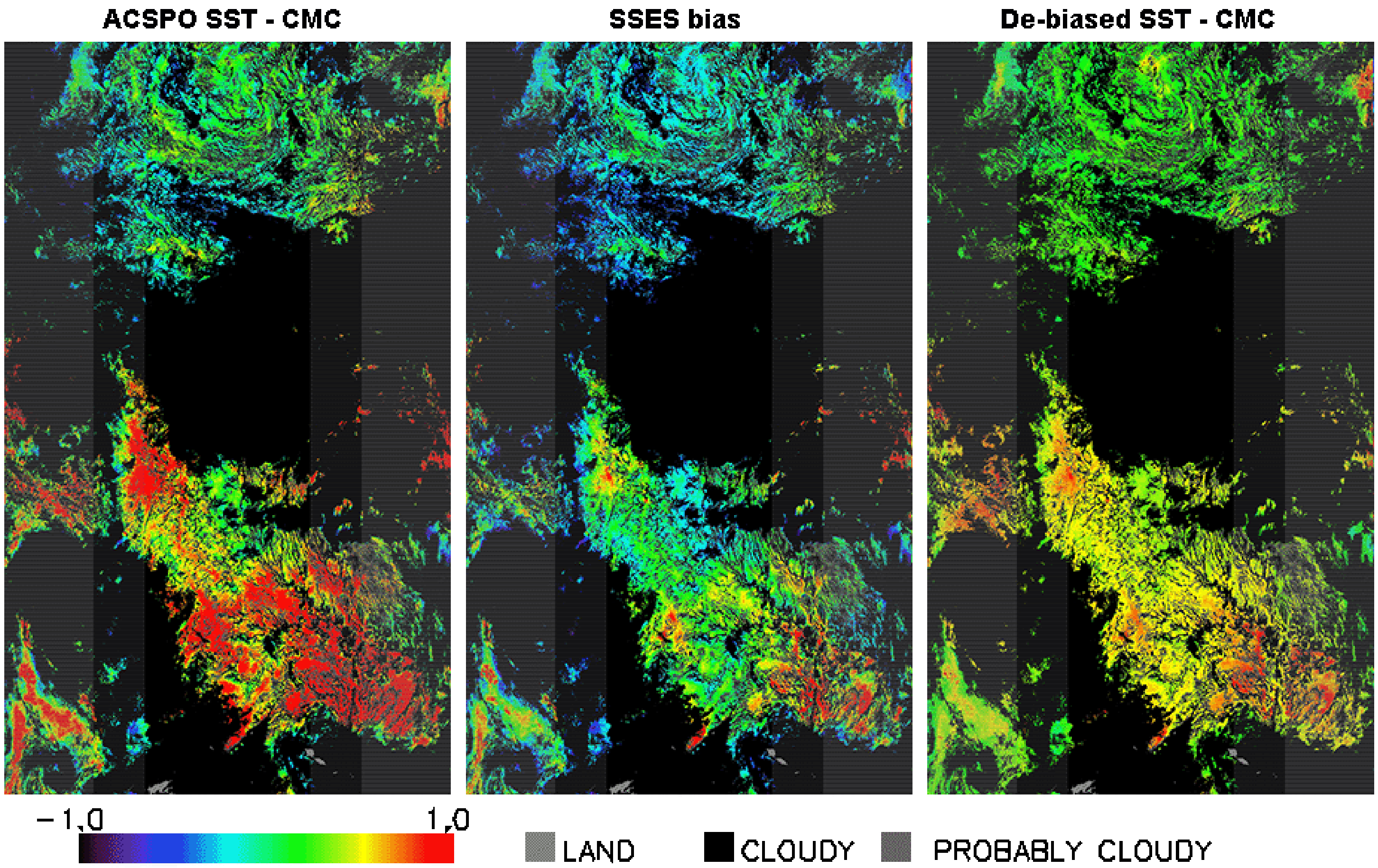
CMC – IN SITU

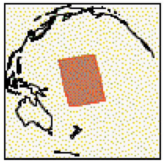


Daytime SSES bias correction:

- Reduces global "L2 – *in situ*" biases and SDs & Improves consistency between sensors
- Brings global SDs of "de-biased L2 – *in situ*" much closer to SDs for "CMC L4 – *in situ*"
- Global "de-biased L2 – *in situ*" biases are consistent between AM and PM platforms (because L2 is tied to in situ)
- Note that biases in "L4 – *in situ*" are subject to diurnal cycle in in situ SST (whereas L4 SST=const, daily average)

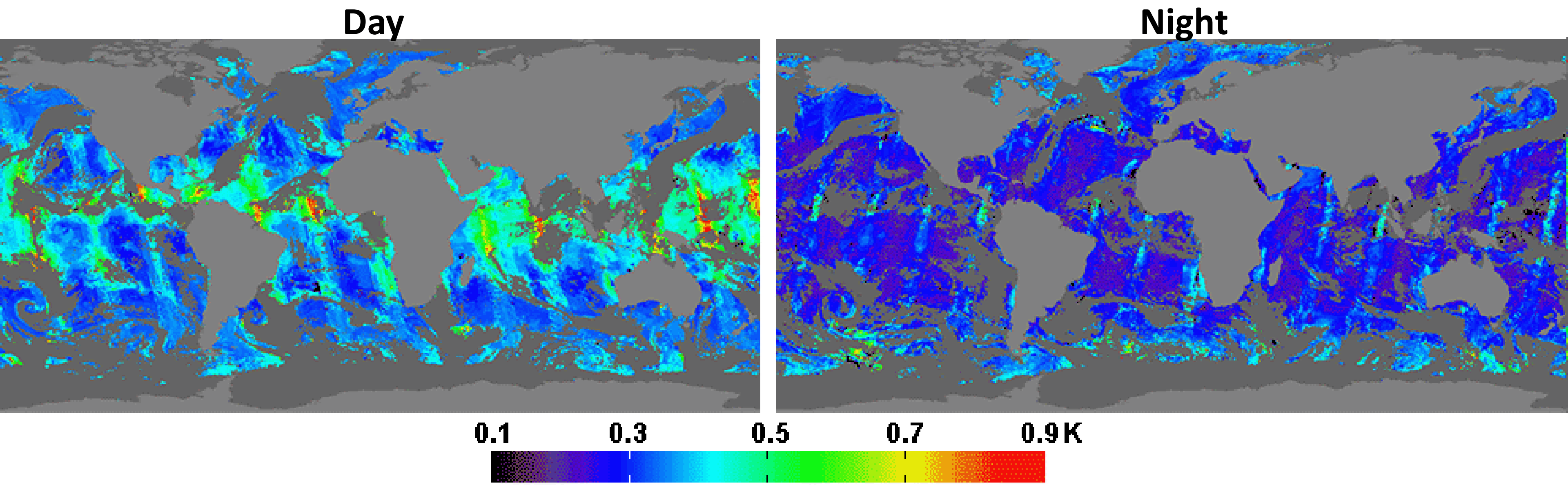
Instant image of ACSPO SST – CMC and de-biased SST – CMC (Equatorial Pacific, 19 December 2014, Day)





- Left image: residual cloud cause cold deviations of ACSPO SST from CMC, whereas diurnal surface warming causes warm deviations
- Middle image: SSES bias captures, to some degree, both types of anomalies
- Right image: de-biased ACSPO SST is less sensitive to both cloud leakages and diurnal surface warming

Daytime and nighttime maps of SSES SD (VIIRS, 4 November 2014)



- Geographical distributions of SSES SD are non-uniform, and significantly different between day and night
- Daytime SSES SD increases in the Tropics (high humidity), and at large view zenith angles
- Nighttime SSES SD is smaller than during the day, and also increases at large view zenith angles
- Note that both day and night SDs increase in the high latitudes, suggesting larger uncertainty in ACSPO SST (work is underway to improve)
- Accounting for non-uniformity of SSES SD may improve assimilation of the ACSPO SST into L4 products

Summary

- Correction for SSES biases on a pixel-by-pixel basis in ACSPO SST provides consistent and significant reduction in global biases and SDs with respect to (1) in situ SST and (2) L4 SST.

- Global SD of the “De-biased – in situ SST” is now comparable with the SDs for “L4 – in situ SST”

- Correction for SSES biases reduces the effects of cloud leakages, angular-dependent biases

- During the daytime, it additionally reduces the effect of diurnal warming

- These features of the De-biased SST make it a better proxy for bulk SST than the original ACSPO skin SST

- SSES bias correction improves consistency of all ACSPO products with in situ SST, which should facilitate their blending with in situ data. However, diurnal cycle in in situ data should be considered in the L4 analysis (diurnal-resolving L4?)

- If L4-specific bias correction is still needed/desired, it is expected to be simplified with the use of “de-biased SSTs”, which are now more uniform across retrievals conditions and various sensors

- It may be a better input for L4 SST products, due to reduced need in “bias correction” in satellite SST. Furthermore, the de-biased daytime ACSPO SST can be now used as input into L4 (and potentially for creating a “daytime L4 SST”). **This statement should be verified directly by L4 producers – see next slide.**

- **The performance of SSES SDs has not been evaluated yet. This can be done by assimilation of the ACSPO SST into L4 products (see next slide).**

Recommendations for testing in L4

- Assimilate nighttime De-biased SST into "foundation" L4 SST product(s)
  - Compare with assimilation of baseline ACSPO SST
  - Evaluate the effect of "L4 bias correction" (expected to be less critical for de-biased SST)
- Assimilate de-biased daytime ACSPO SST. Explore daytime (or diurnal-resolved) L4 SST
- Explore accounting for non-uniform SSES SD in assimilation of L2 SST into L4 products
  - Note that the current SSES SD in ACSPO characterizes the baseline ACSPO SST (rather than the De-biased SST). It is calculated as SD of "ACSPO – *In situ* SST" and, therefore, combines the errors of both ACSPO SST <u>and</u> *In situ* SST:

$$(\text{SSES SD})^2 = \text{SD}(\text{ACSPO SST})^2 + \text{SD}(\textit{In situ}\ \text{SST})^2$$

  - We suggest assimilating ACSPO SST and *In situ* SST into the L4 SST with corresponding weights:

ACSPO SST: $1/[\text{SSES SD}^2 - \text{SD}(\textit{In situ}\ \text{SST})^2]$ **_In situ_ SST:** $1/\text{SD}(\textit{In situ}\ \text{SST})^2$

  - Here, **SD(*In situ* SST)** is an estimate of SD of *in situ* measurements,

SD(In situ SST)≈0.25±0.02K (e.g. O'Carroll et al 2008; Xu and Ignatov 2010; Dash et al 2014)

- Due to the limitations of the GDS 2.0 format, the ACSPO v.2.40 does not provide SSES SD for De-biased SST. However, it can be added to the ACSPO output in the future ACSPO versions, by users' request.