REDESIGNED SSES IN THE ADVANCED CLEAR-SKY PROCESSOR FOR OCEANS

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Objectives

- **The SSES algorithm in ACSPO v.2.40 was redesigned, with the specific objective to improve assimilation of ACSPO L2/L3U products in the "foundation" L4 analyses.**

- **The new SSES is expected to satisfy the following requirements**

  1. **Applying SSES biases to ACSPO SST should minimize the need for bias correction during the L4 analyses *(tested by improving the consistency with in situ* and L4 SST)**

  2. **SSES SDs should characterize the precision of ACSPO SST under variable conditions. This should allow optimal weighting of ACSPO SSTs with other data in the L4 analyses *(not tested yet)***

- **This presentation evaluates the performance of the new SSES bias correction against *in situ* and L4 SST.**

Baseline regression SST in ACSPO (BSST)

The ACSPO adopts regression SST equations by OSI-SAF (*Lavanant et al., 2012*)

Day: $T_S = a_0 + (a_1 + a_2 S_\vartheta) T_{11} + [a_3 + a_4 T_S^0 + a_5 S_\vartheta] (T_{11} - T_{12}) + a_6 S_\vartheta$

Night: $T_S = b_0 + (b_1 + b_2 S_\vartheta) T_{3.7} + (b_3 + b_4 S_\vartheta) (T_{11} - T_{12}) + b_5 S_\vartheta$

$T_{11}, T_{12}, T_{3.7}$	observed BTs in bands 11, 12 and 3.7 µm
$S_\vartheta = 1/\cos(\vartheta)$	ϑ is VZA
T_S^0	first guess SST (in °C)
a’s and ***b***’s	regression coefficients trained on global datasets of matchups (MDS)

- **These equations are used globally, each with a single set of coefficients**
- **Retrieval errors essentially vary across the global SST domain**
- **SSES should be estimated independently for separate segments of the SST domain uniform in terms of retrieval errors**
- **The question is: How to define the “segments with uniform errors”?**

The segmentation concept

- **<u>Customarily,</u> SST retrieval errors are parameterized with certain physical variables (such as TPW, VZA, latitude, wind speed, aerosol, etc) (**e.g., *Castro et al., 2008; Minnett, 2014; Petrenko et al., 2014)*
- **This approach was initially used in ACSPO (Petrenko and Ignatov, 2014)**
- **However, it remains unclear if it is possible to account for all essential physical effects (e.g., underscreened clouds)**

- **<u>In the redesigned ACSPO v2.40</u>:**
  - ✓ **SSES are analyzed in the space of regressors (terms of the SST equation, excluding the offset). This way, the effects of all physical variables are aggregated into a limited number of arguments.**
  - ✓ **The segmentation parameter is derived from the statistics of regressors within the training dataset of matchups (MDS); as a result, it is directly linked to the SD of retrieval error**

Segmentation parameter

- The segmentation parameter is introduced as Fisher distance in the space of regressors:

$$\rho=[(\mathbf{R} - \langle\mathbf{R}\rangle)^T D^{-1}(\mathbf{R} - \langle\mathbf{R}\rangle)]^{0.5},$$

R	is a vector of regressors
$\langle\mathbf{R}\rangle$	is a mean **R** over the MDS
D	is a covariance matrix of **R** within the MDS

- SD of the retrieval error is a monotonic function of ρ
- The dependencies of the retrieval errors on ρ are different along different directions in the space of regressors. To account for such anisotropy:
  - An orthogonal basis is introduced in the space of regressors, with the origin at $\langle\mathbf{R}\rangle$
  - Segmentation is performed independently in each orthant of this basis

Implementation of SSES in ACSPO v.2.40

Generation of LUT:

- The segmentation criteria are derived from the global MDS
- The global MDS is subdivided into subsets of matchups belonging to specific segments
- For each segment, SSES SDs and local regression coefficients are calculated and stored in the LUT

L2 processing:

- The SST pixels are ascribed to segments (using regressors' values)
- Corresponding SSES SDs and local coefficients are obtained from LUT
- An auxiliary product - **Piecewise Regression (PWR) SST -** is produced with local coefficients
- **SSES biases are** calculated as **differences between the Baseline SSTs and PWR SSTs**

Correction of SSES biases transforms BSST back into PWR SST;
PWR SST = De-biased ACSPO SST

The precision of fitting *in situ* SST with Baseline and De-biased SST

(Dependent) MDS from 15 May 2013 – 8 Aug 2014

SST	Statistics	S-NPP VIIRS	Aqua MODIS	NOAA19 AVHRR	MetOp-A AVHRR	MetOp-B AVHRR	Terra MODIS
		Day, afternoon sensors			Day, morning sensors		
Baseline	Bias	0	0	0	0	0	0
	SD	0.41	0.45	0.50	0.43	0.44	0.46
De-biased	Bias	0	0	0	0	0	0
	SD	0.31	0.33	0.34	0.31	0.30	0.32

		Night, afternoon sensors			Night, morning sensors		
Baseline	Bias	0	0	0	0	0	0
	SD	0.33	0.35	0.46	0.38	0.36	0.35
De-biased	Bias	0	0	0	0	0	0
	SD	0.25	0.26	0.29	0.27	0.26	0.26

Applying SSES biases reduces daytime SDs from 0.41-0.50 K to 0.30-0.34 K and nighttime SDs from 0.33-0.46 K to 0.25-0.29 K

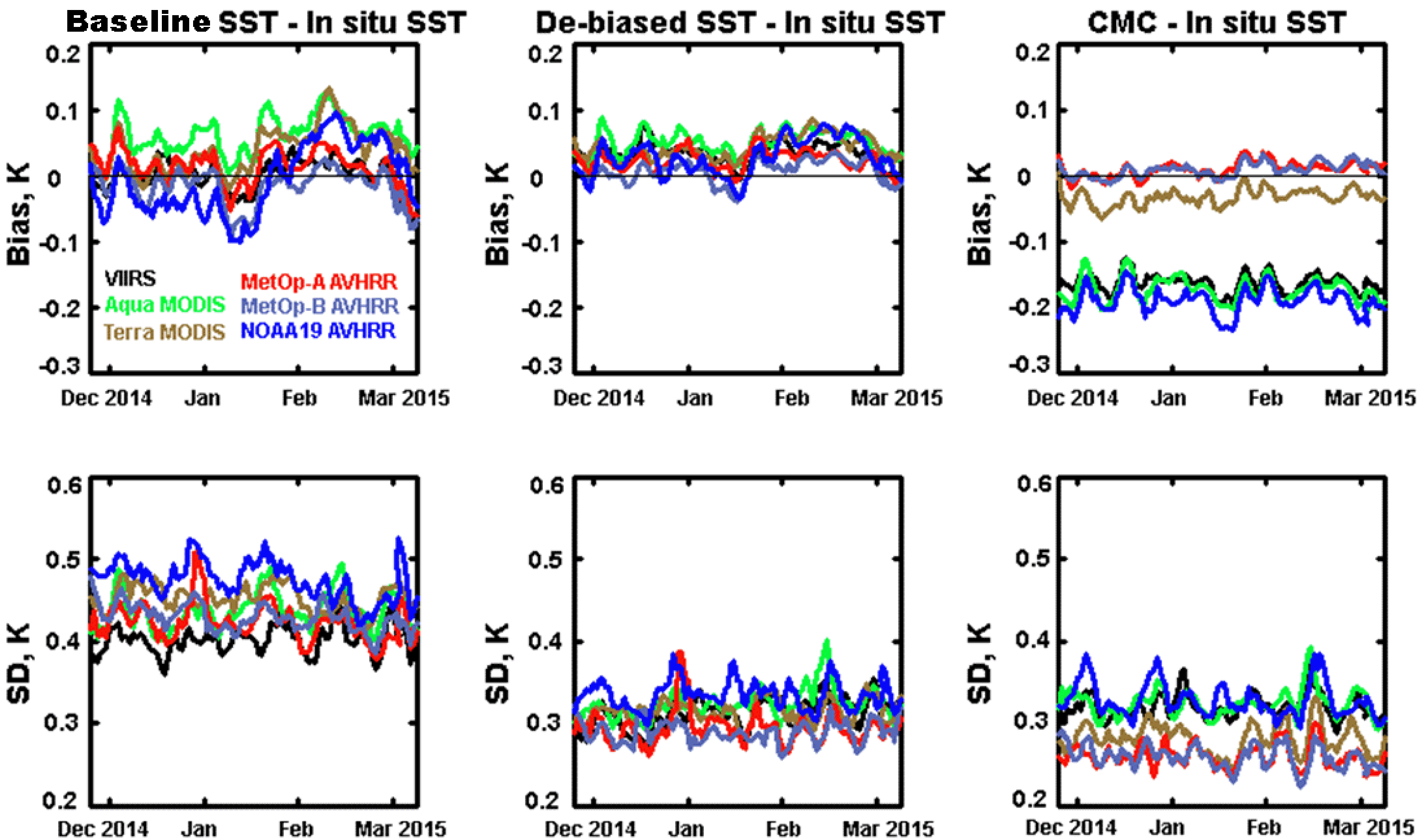
The statistics of fitting *in situ* SST with De-biased SST and CMC

- (Dependent) MDS from 15 May 2013 – 8 Aug 2014
- CMC is Canadian Met Center L4 SST

SST	Statistics	S-NPP VIIRS	Aqua MODIS	NOAA19 AVHRR	MetOp-A AVHRR	MetOp-B AVHRR	Terra MODIS
		Day, afternoon sensors			Day, morning sensors		
De-biased	Bias	0	0	0	0	0	0
	SD	0.31	0.33	0.34	0.31	0.30	0.32
CMC	Bias	-0.19	-0.20	-0.21	-0.01	-0.01	-0.06
	SD	0.34	0.34	0.35	0.30	0.30	0.31
		Night, afternoon sensors			Night, morning sensors		
De-biased	Bias	0	0	0	0	0	0
	SD	0.25	0.26	0.29	0.27	0.26	0.26
CMC	Bias	0.01	0.02	0.02	-0.07	-0.07	-0.04
	SD	0.27	0.28	0.29	0.31	0.29	0.29

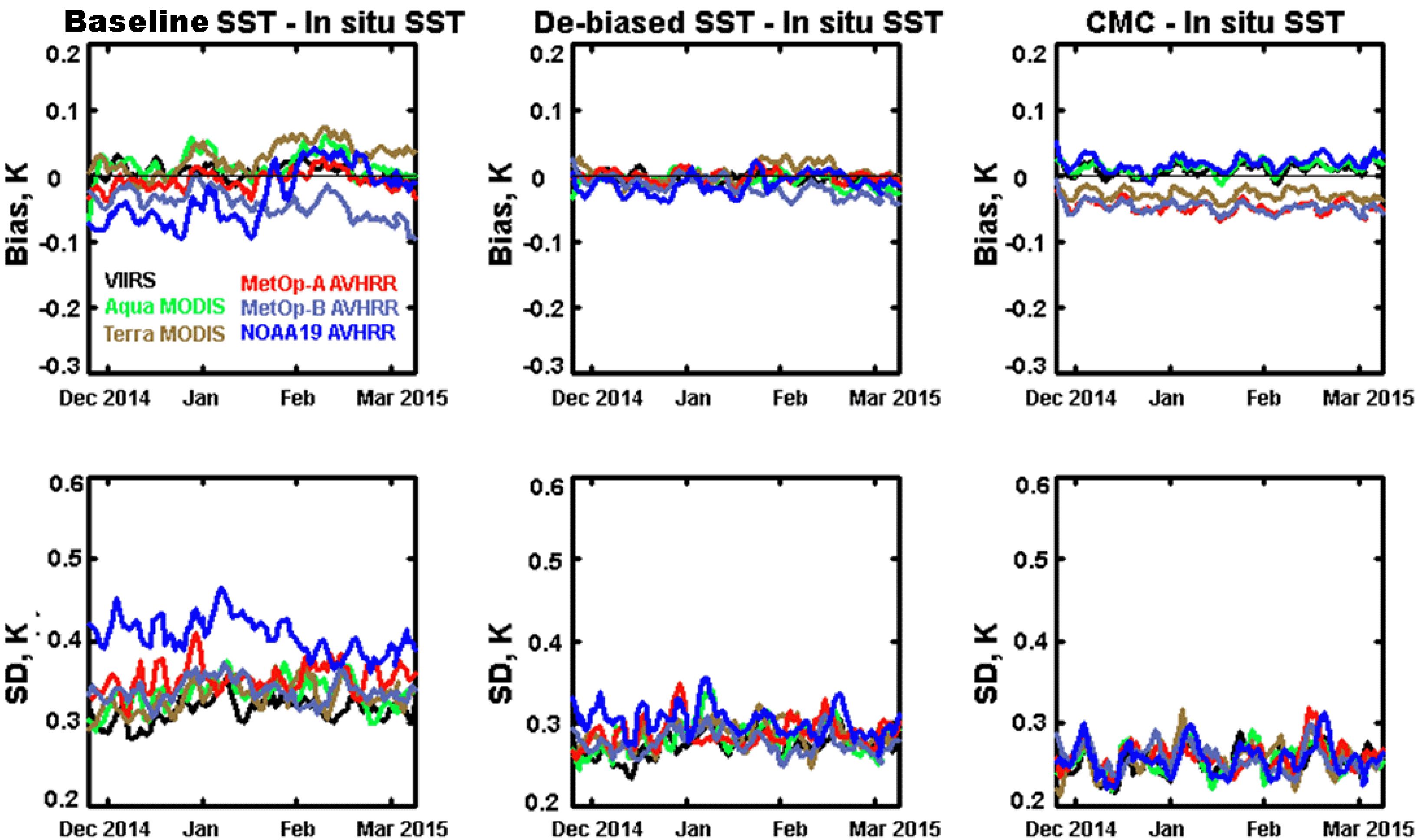
- **SDs for De-biased SST are close to CMC SST**
- **CMC SST is biased cold wrt daytime matchups for afternoon platforms (S-NPP, Aqua, NOAA19) and wrt nighttime matchups for the morning platforms (Terra, MetOp-A, MetOp-B)**
- **The De-biased ACSPO SST does not have such biases**

Time series of daily daytime Bias and SD wrt *in situ* SST, 24 November 2014 – 10 March 2015 (independent MDS)



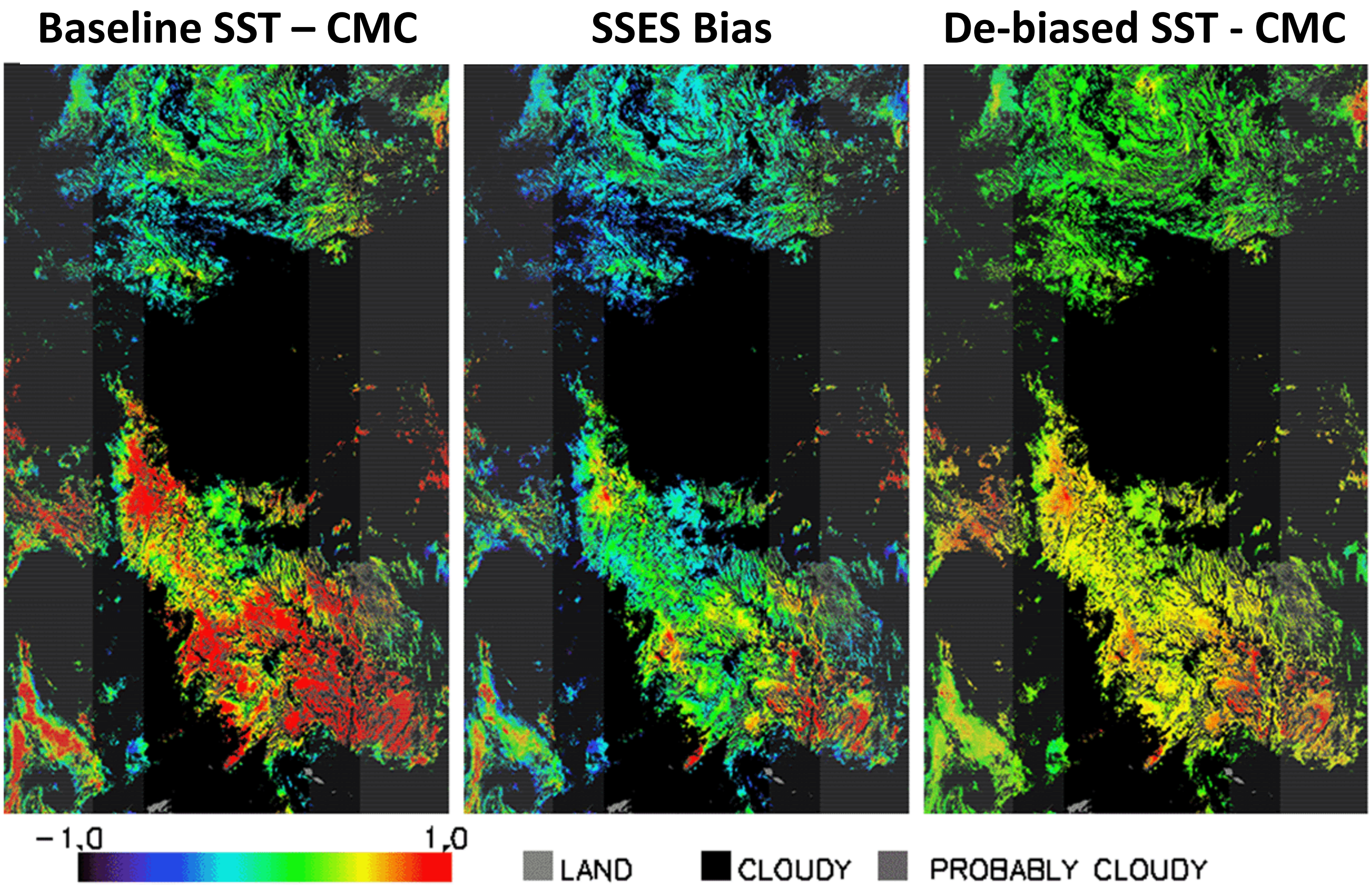
- **De-biased ACSPO SST:**
  - -improves cross-platform consistency of biases and reduces SDs to the CMC level
  - -unlike CMC, does not produce daytime biases for the afternoon platforms

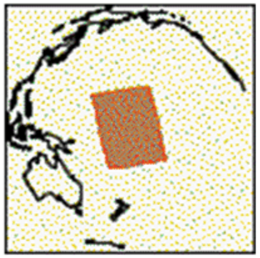
Time series of daily nighttime Bias and SD wrt *in situ* SST, 24 November 2014 – 10 March 2015 (independent MDS)



- **De-biased ACSPO SST:**
  - **-improves cross-platform consistency of biases and reduces SDs to the CMC level**
  - **-unlike CMC, does not produce nighttime biases for the morning platforms**

The effect of the daytime SSES bias correction (VIIRS, 19 December 2014)

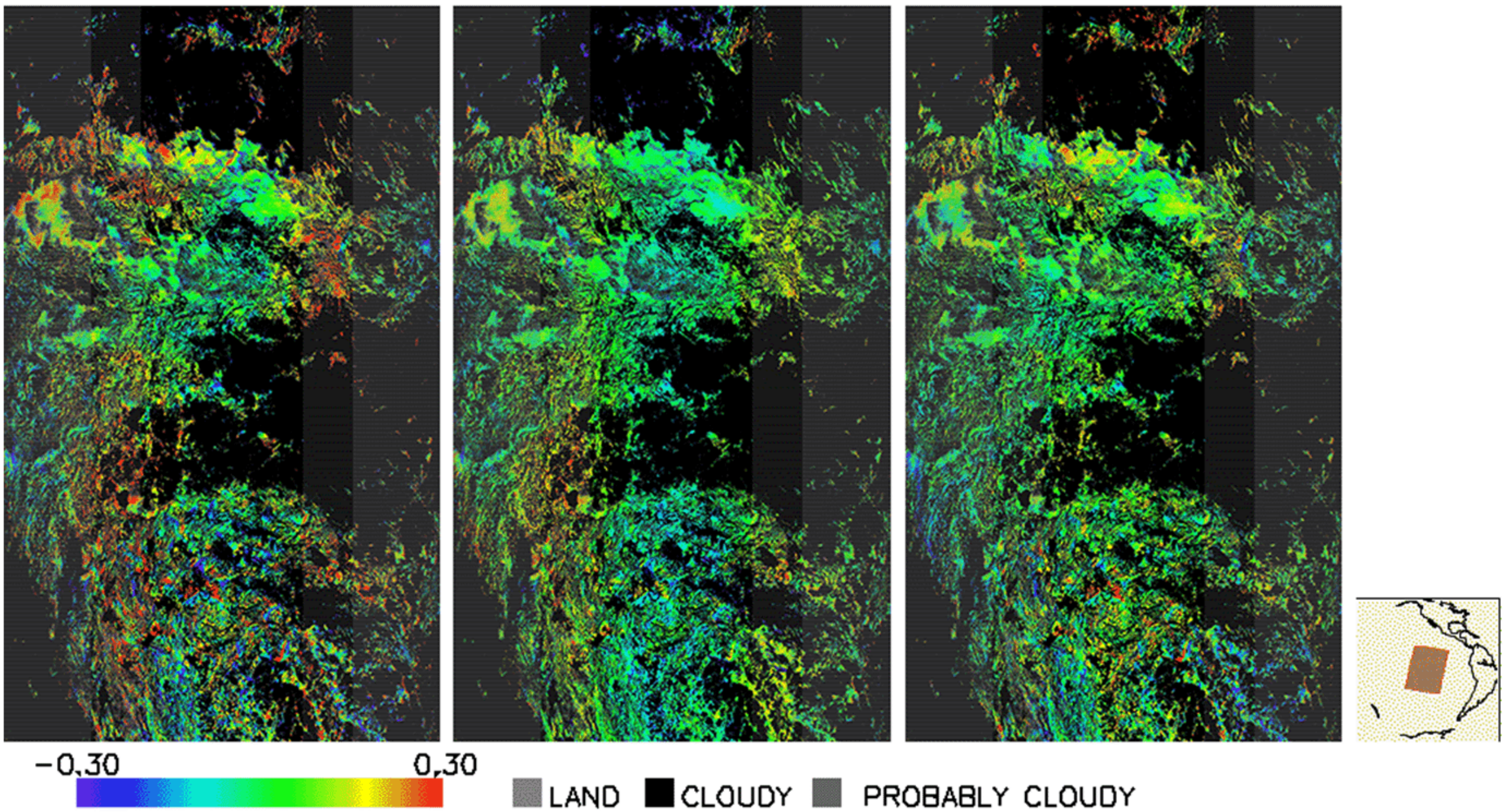




Correction of SSES biases reduces the effects of cloud leakages and diurnal warming

The effect of the nighttime SSES bias correction (VIIRS, 19 December 2014)

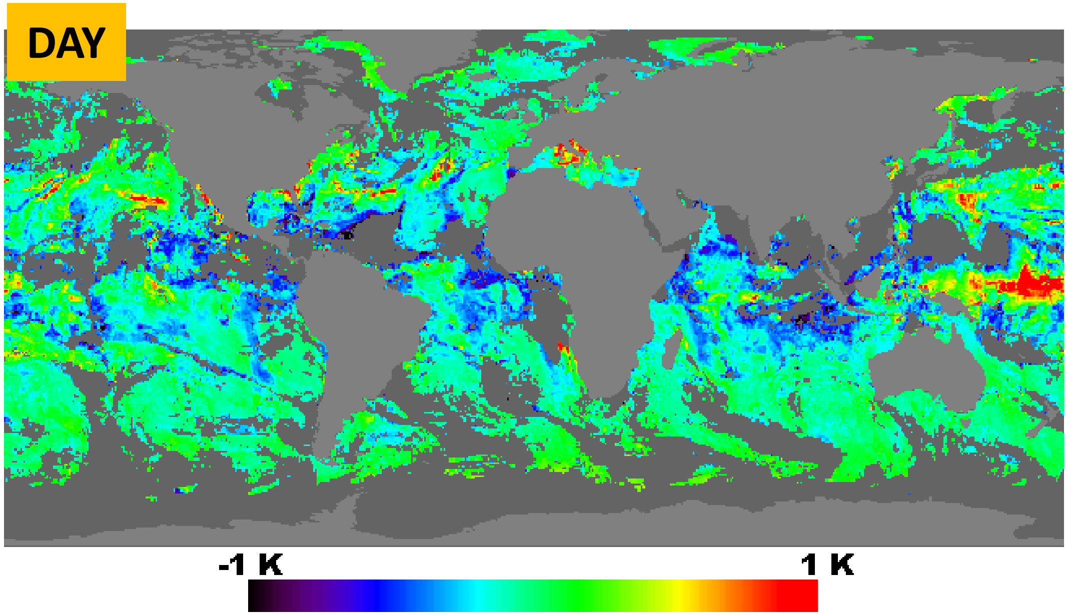
Baseline SST – CMC | **SSES Bias** | **De-biased SST - CMC**



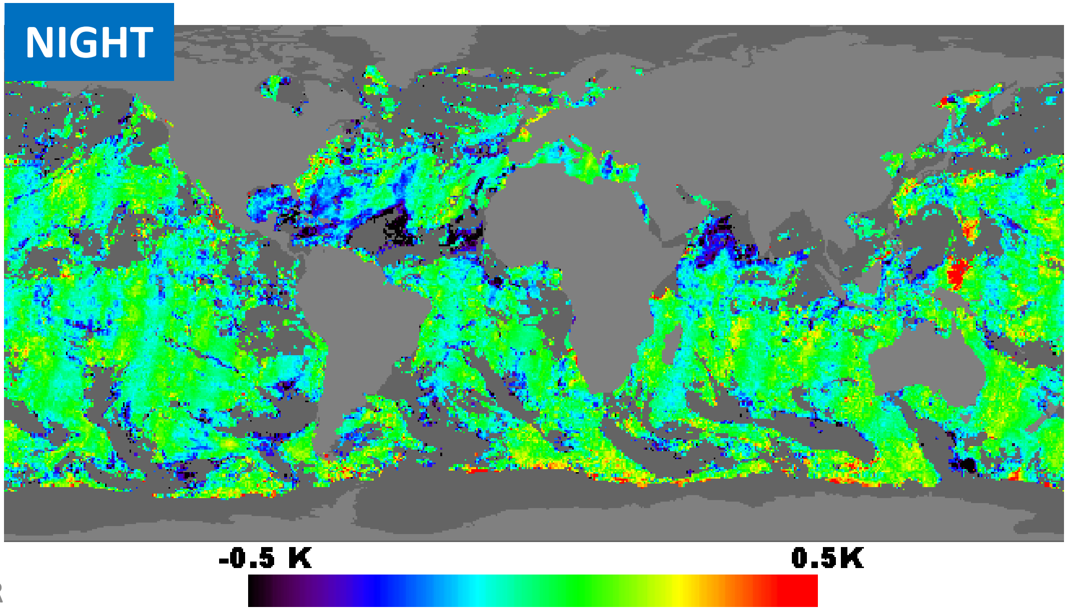
Correction of SSES biases reduces the effects of VZA and cloud leakages

SSES Biases (VIIRS, 7 July 2015)

- Daytime SSES biases respond to diurnal surface warming, residual cloud, and VZA

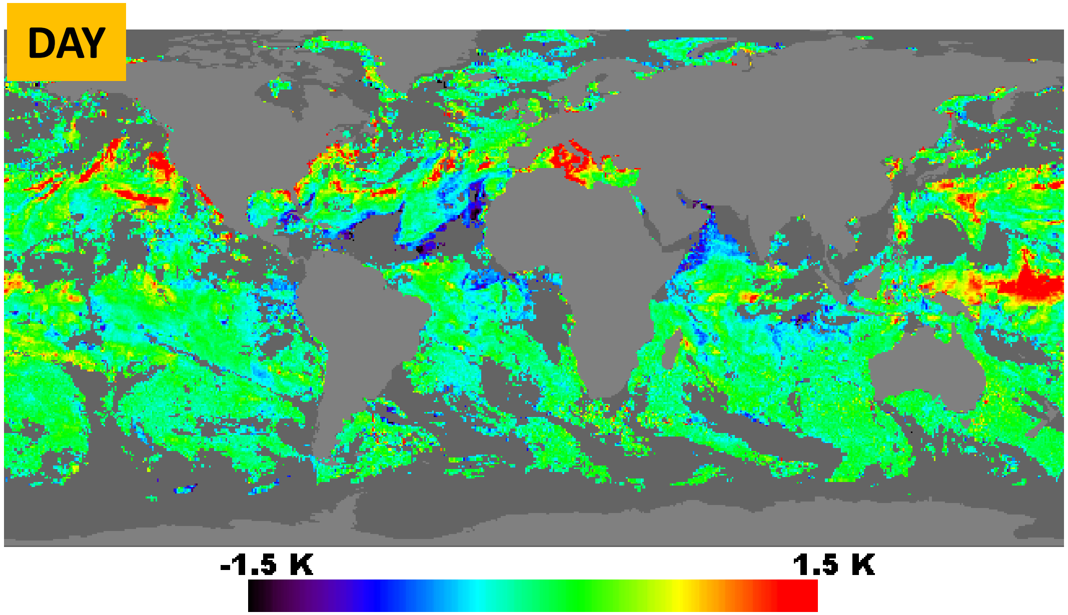


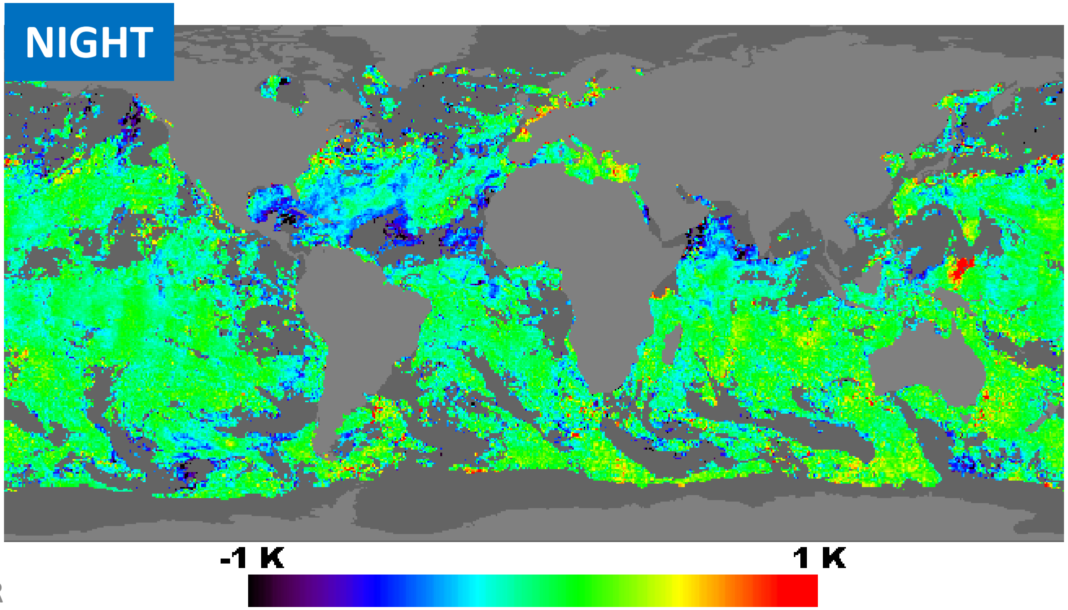
- Nighttime SSES biases mostly reflect the dependence on VZA and cloud leakages



Only the pixels with Quality Level=5 are used in ACSPO

Baseline SST – CMC SST (VIIRS, 7 July 2015)



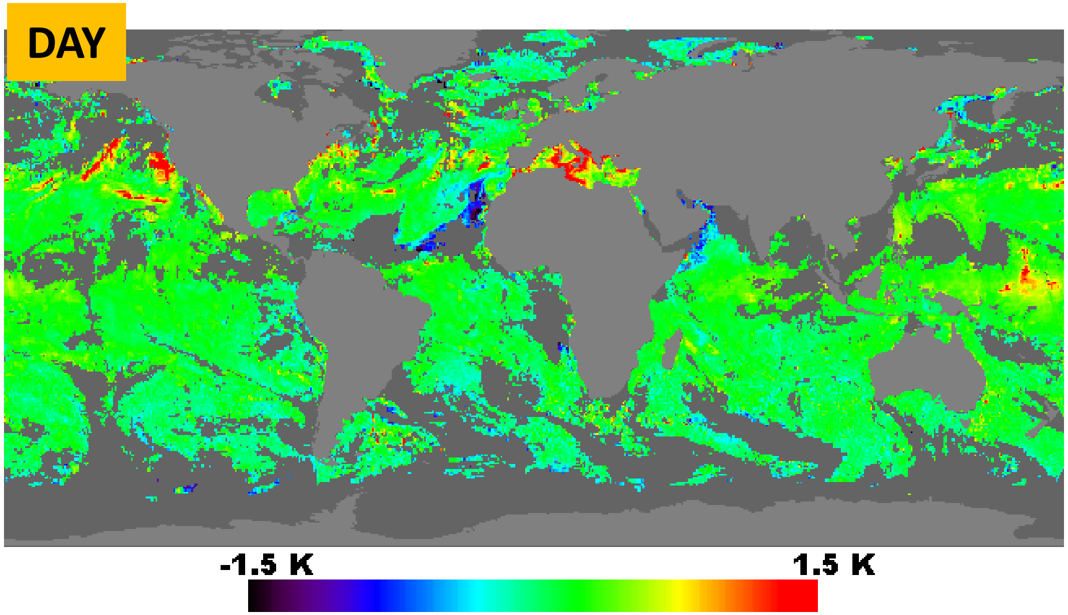


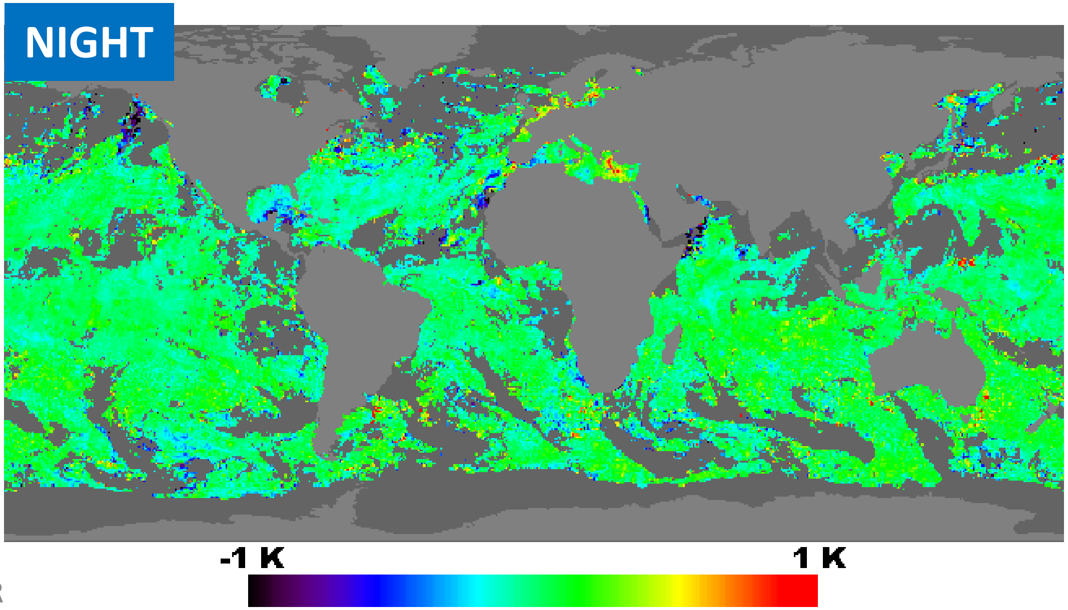
Deviations of Baseline SST from CMC are consistent with SSES biases

De-biased SST – CMC SST (VIIRS, 7 July 2015)

The statistics of ACSPO SSTs wrt CMC

SST	Bias	SD
Day		
Baseline	0.24 K	0.60 K
De-biased	0.24 K	0.42 K
Night		
Baseline	0.04 K	0.37 K
De-biased	0.24 K	0.30 K



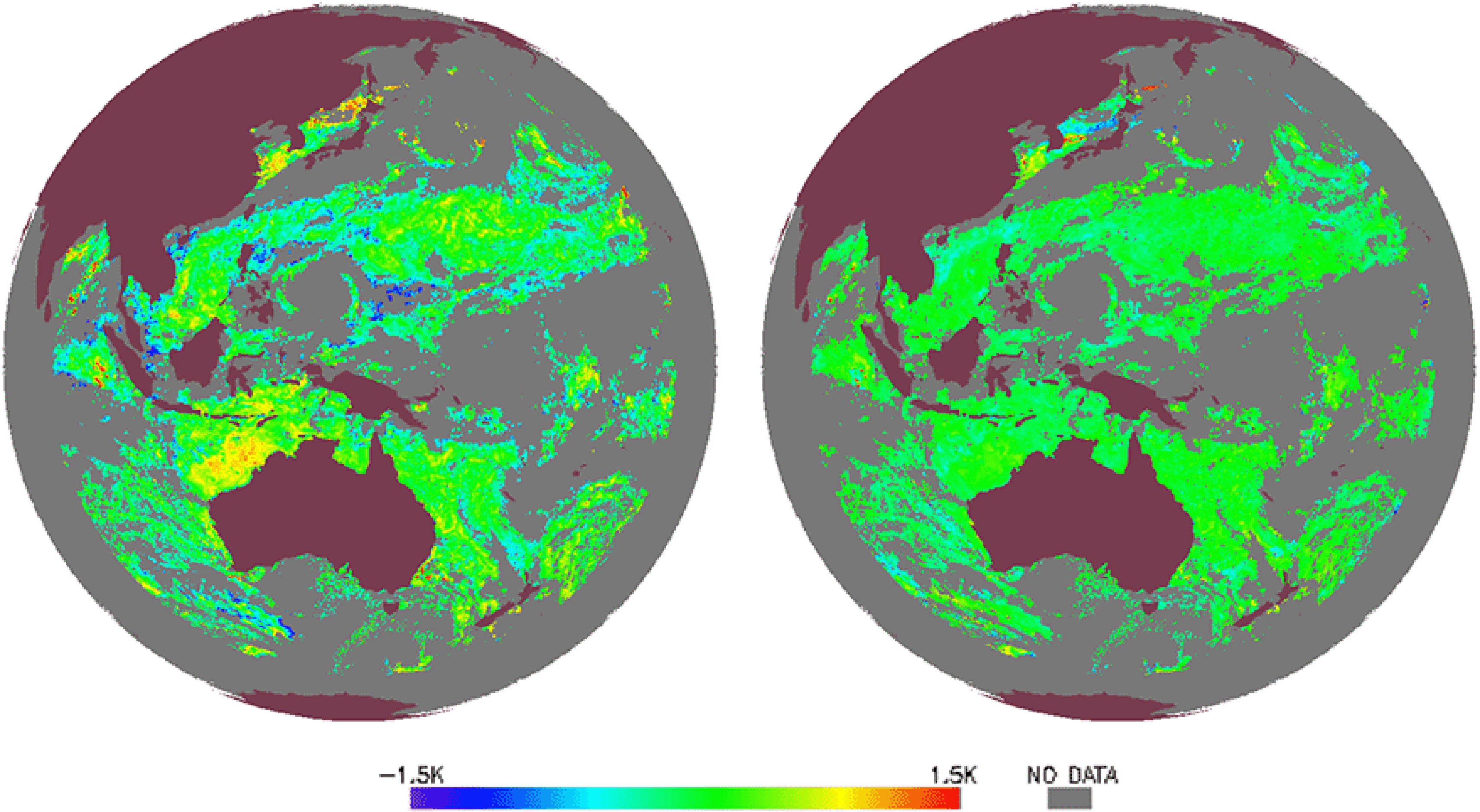


Bias correction improves consistency with CMC

SST from HIMAWARI-8 (launched on 7 October 2014)
(Images for 6 May 2015, 23:20 – 23:30 am)

Baseline SST-CMC: Bias=0.16 K, SD=0.44 K

De-biased SST-CMC: Bias=0.06 K, SD=0.22 K



The statistics are estimated for VZA < 67^o

Comparison of the approaches to coefficients' stratification

The following algorithms are compared here:
ACSPO: Lavanant et al., 2012, Petrenko et al., 2014; Pathfinder: Kilpatrick et al., 2015; LATBAND: Minnett and Evans, 2009

Source	Algorithm	SD wrt *in situ* SST
Petrenko et al., JGR, 2014	Previous ACSPO*, *global coefficients*	0.47 K
	Pathfinder*, *coefficients depend on* T_{11}- T_{12} *(proxy of TPW)*	0.45 K
	LATBAND*, *coefficients depend on latitude*	0.45 K
	Current ACSPO**, *global coefficients*	0.42 K
This study	Current ACSPO**, *global coefficients*	0.41 K
	ACSPO PWR SST**, *coefficients depend on regressors*	0.31 K

* The "classic" NLSST equation *(Walton et al., 1998)*:

$$T_S = a_0 + a_1 T_{11} + a_3 T_S^0 (T_{11} - T_{12}) + a_3 S_\vartheta (T_{11} - T_{12})$$

** The current ACSPO equation (proposed by the OSI-SAF):

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

Stratification of coefficients in the space of regressors is more efficient way of fitting in situ SST than stratifications in terms of physical variables

Summary

- **The ACSPO v.2.40 offers two SST products:**
  - Baseline ACSPO SST: Sufficiently accurate wrt *in situ* SST & sensitive to SST_{skin}
  - The De-biased ACSPO SST is substantially more precise wrt *in situ* SST (closer to SST_{depth})
- **Currently, the De-biased ACSPO SST is not reported as a separate layer in the ACSPO output. It can be obtained as "Baseline SST minus SSES bias"**
- **The De-biased ACSPO SST brings SDs wrt *in situ* SST close to SDs for CMC L4 but does not produce significant sensor-dependent biases typical for CMC.**
- **This suggests the De-biased ACSPO SST can be used for the following applications:**
  - It may simplify the bias correction in the existing "foundation" L4 analyses
  - Daytime de-biased ACSPO SSTs can be assimilated in L4 analyses, in addition to nighttime SSTs
  - It may be used for specific daytime L4 analyses
- **The ultimate test for the ACSPO SSES will be using it in the L4 analyses. <u>Feedback from the L4 producers is strongly appreciated</u>**

Thank you

Backup slides

Problems and Limitations

1. **Some segments (i.e. observational conditions) are represented with small number of matchups. This makes the SSES for such segments unreliable.**
   - ✓ *Currently, the segment is not used if it includes less than 10 matchups; in this case, SSES bias =0 and SSES SD = NaN.*

   The problem will be mitigated by further accumulation of matchups and optimization of the segmentation algorithm

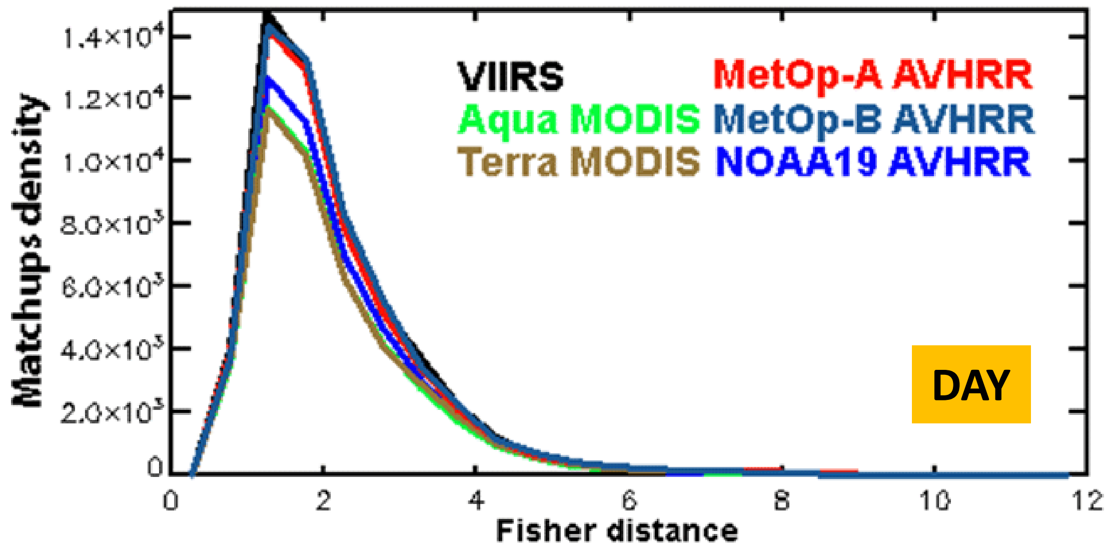
2. **No seamless connection of de- biased SSTs at the segment's boundaries in ACSPO v. 2.40. Overall, the SST images look smooth, although sometimes the discontinuities in PWR SST may occur**

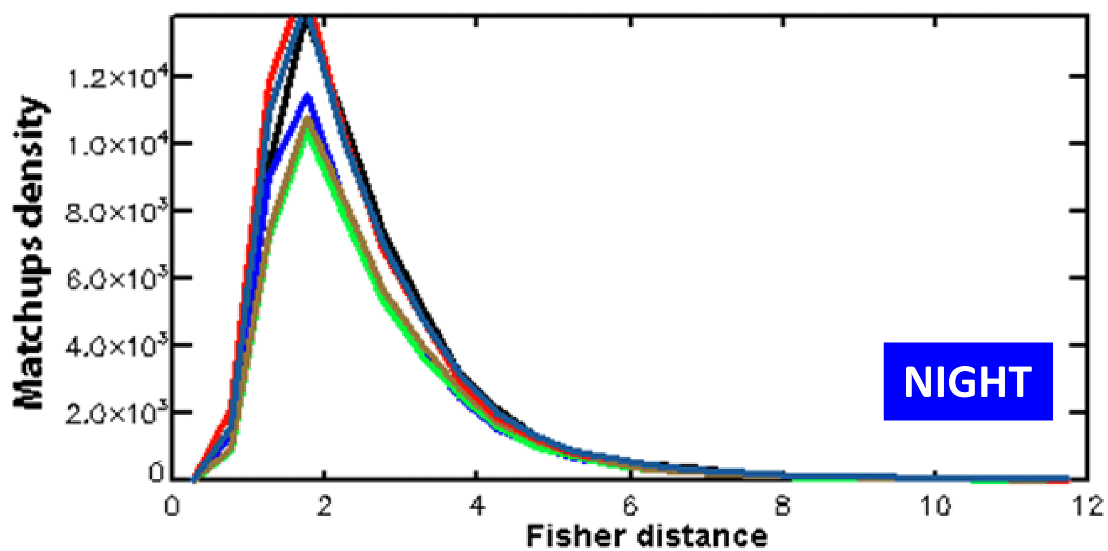
   In the next version of ACSPO, spatial smoothing of the local regression coefficients will be implemented.

Densities of matchups as functions of Fisher distance,

MDS for all sensors were collected from 15 May 2013 – 8 August 2914

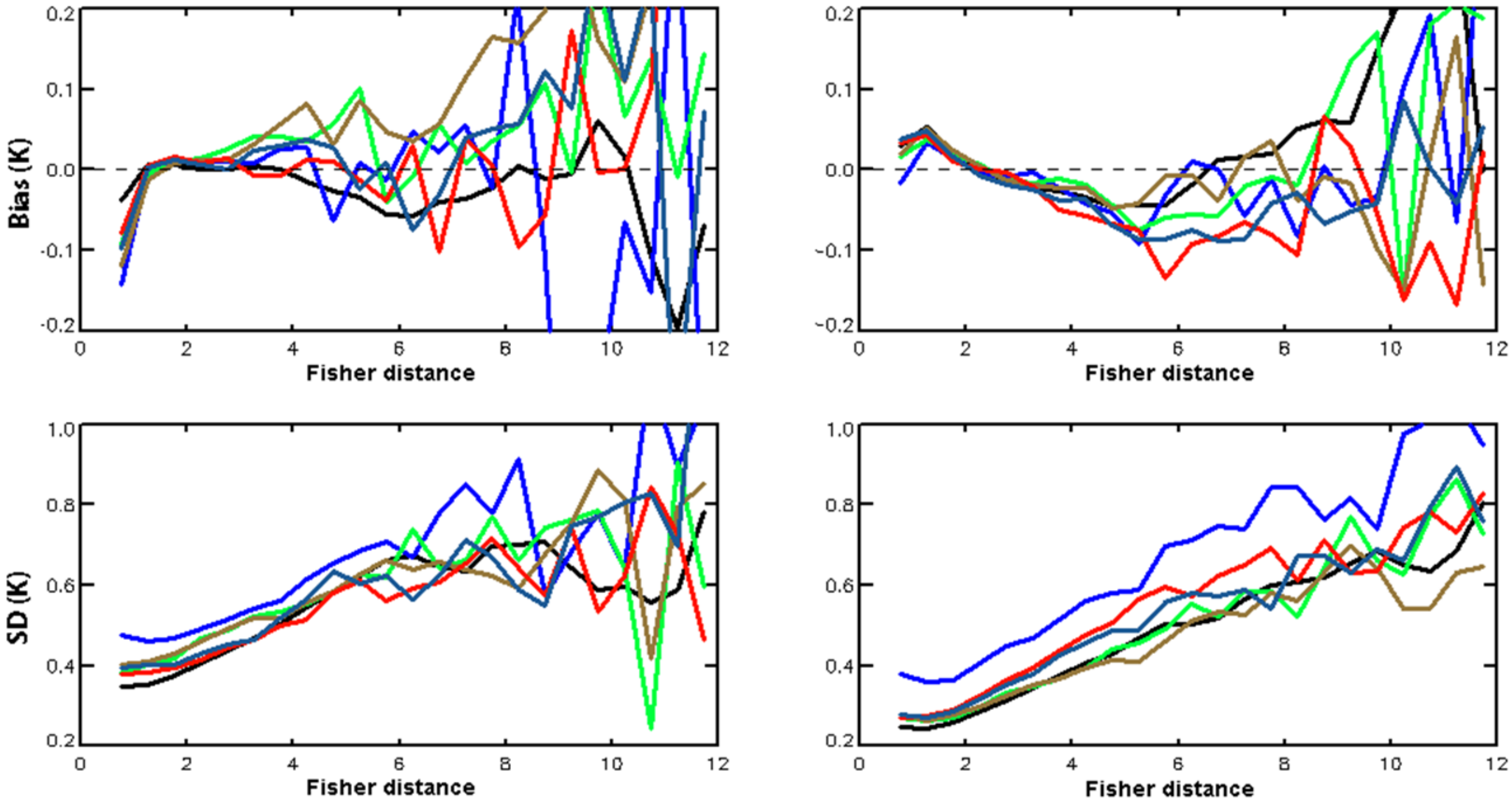
- **Matchups are distributed similarly for all sensors;**
- **The range of ρ is limited (this simplifies the segmentation)**
- **Most part of matchups are within the interval ~1< ρ < ~6**





Bias and SD of BSST as functions of Fisher distance

MDS for all sensors were collected from 15 May 2013 – 8 August 2914



- **Biases and SDs are most stable and consistent within the interval ~1< ρ < ~6**
- **SDs quasi-monotonically increase with ρ**