JP1.13

Towards Continuous Error Characterization of Sea Surface Temperature in the Advanced Clear-Sky Processor for Oceans (ACSPO)

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Motivation

The new SST product, the Advanced Clear-Sky Processor for Oceans (ACSPO) is recently developed and put into operation at NOAA/NESDIS. Customarily, accuracy and precision of SST are characterized by one global mean bias and one standard deviation (stdv). The GHRSST has become increasingly interested in supplying error estimates in each individual pixel, the so called Single-Sensor Error Statistics (SSES) (Donlon et al, 2007). SSES is critically important for blending different SST products, and also useful for SST developers to evaluate the performance of their SST product, identify potential areas for improvement, and guide its future optimization. For SST users, the SSES can provide comprehensive quality information about the SST product and facilitate decisions on the domains of data suitable for their particular applications.

Prior Work and Our Objective

Currently, the SSESs are routinely provided by different SST producers to the GHRSST and used for global analyses such as OSTIA (Stark et al., 2007). However, there have been few publications on the specifics of how the error characterization of satellite SSTs have been performed, e.g.

- Minnett and Evans (2006) – SSES Hypercube, LUT, wrt. *in situ*
- Castro et al. (2008) – LUT, wrt. *in situ*
- Vazquez-Cuervo et al. (2004) – Aerosol/Cloud, MPFSST vs ASST2

Our objective is to incorporate the SSES in the future version of ACSPO and generate ACSPO products in L2P format. This study reports our intermediate progress towards this goal.

Data

AVHRR SST (T_S):

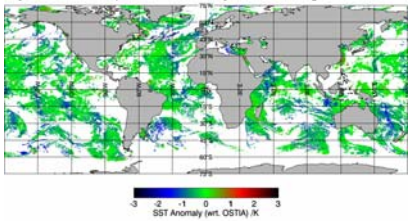
- NOAA-17, 18 and MetOp-A
- ACSPO v1.0 (clear-sky mask based on CRTM simulation)
- Nighttime triple-window MCSST

Reference SST (T_R): Global analysis SSTs instead of *in situ*, to analyze in full retrieval domain, and to increase statistics

- daily 0.25° Reynolds OI v2. (AVHRR only) (Reynolds et al, 2007)
- daily 0.05° OSTIA (Stark et al., 2007)

SST Residual: $\Delta T = T_S - T_R$

Fig.1 SST anomaly wrt. OSTIA (nighttime MetOp-A 2008-9-17)



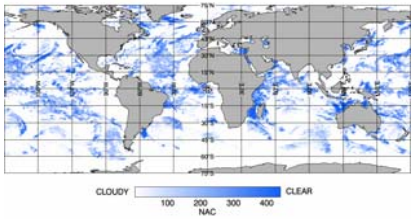
Problem Formulation

Multi-dimensional retrieval space:

$$\vec{\alpha} = [N, \theta, W, V, T_s, T_a, \tau]$$

N: number of ambient clear-sky ocean pixel (NAC) (counted in 12-pix proximity); θ: view zenith angle; W: column water vapor; V: surface wind speed; τ: aerosol optical depth; Ts: SST; Ta: air temperature…

Fig.2 Global map of NAC corresponding to fig.1



Basic assumption: the SST residual, in some statistical sense, continuously depends on the retrieval conditions (retrieval space)

$$\Delta T \sim N(b, \sigma) \qquad b = f(\vec{\alpha}), \quad \sigma = g(\vec{\alpha}) \qquad \vec{\alpha} = [\alpha_i] \qquad \alpha_i = N, \theta, W, \ldots$$

Objective: estimation of the dependence of mean bias (b) and stdv (σ) on the retrieval space, i.e. the continuous functions $f(\cdot)$ and $g(\cdot)$

Methodology:

1. Bin along each axis, Estimate bias and stdv within each bin as

$$\hat{b} = \sum_n \Delta\hat{T} \Big/ n, \qquad \hat{\sigma} = \sum_n (\Delta\hat{T} - \hat{b})^2 \Big/ (n-1)$$

2. Select the form of analytical function

$$\hat{b} = f_\beta(\vec{\alpha}) + \varepsilon$$

3. Curve fitting / Optimization

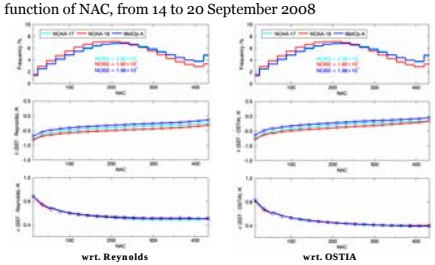
$$\vec{\beta}^* = \arg\min_{\vec{\beta}} \sum_m \left| \hat{b} - f_\beta(\vec{\alpha}) \right|^2$$

Curve fitting Algorithm: Iterative reweighting least square method (Holland and Welsch, 1977), with bi-square weights (DuMouchel and O'Brien, 1989)

$$w_i = \begin{cases} \left(1 - d_i^2 / D^2\right)^2 & d_i < D \\ 0 & else \end{cases}, \qquad D = 6 \times \mathrm{Median}(d_i)$$

Characterization of Bias vs. NAC

Fig.3 Histograms of NAC, and bias/stdv of SST anomalies as a function of NAC, from 14 to 20 September 2008



Select fit-function for $b=f(N)$

$$b \equiv f_N(N) = a_0 + a_1 \exp(-a_2 N)$$

Here parameter a_0 is the asymptotic limit for a mean bias over clear-sky ocean (i.e., when NAC is approaching infinity); a_1 is the amplitude of the mean bias caused by the NAC; a_2 is the decay rate.

Fig.4 Fitting bias vs. NAC dependencies shown in fig.3

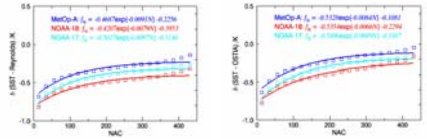
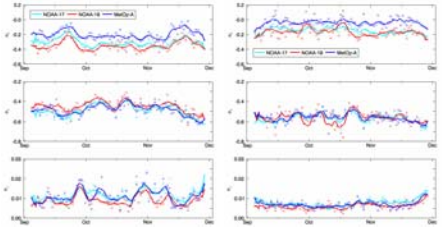


Fig.5 Three-month time series of fitted parameters



- a_0 shows ACSPO is biased low (0.1-0.4K) wrt. Reynolds, (0.0-0.3K) wrt. OSTIA; a_1 is fairly stable for both refs.; a_2 appears smaller and more stable wrt. OSTIA.

Bias correction vs. NAC

Fig.6 Time series of first four statistical moments before and after correction of bias vs. NAC (corresponding to MetOp-A of fig.5) (coefficients derived from previous day are used in correction)

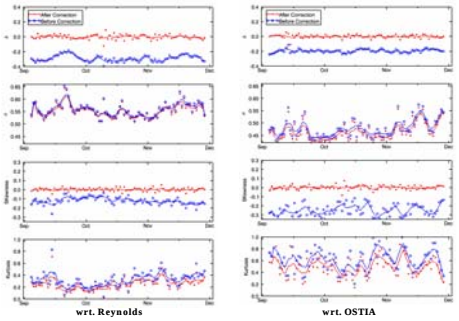
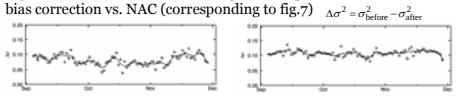


Fig.7 Time series of root-mean-squared improvement in stdv after bias correction vs. NAC (corresponding to fig.7) $\Delta\sigma^2 = \sigma^2_{before} - \sigma^2_{after}$



-global bias/skewness approach zero
-stdv improved by ~0.1K

Discussion

Advantages of continuous error characterization

- simple and easy to document and reuse
- more stable (less sensitive to noise), limited number of degrees of freedom, but sufficient to describe the intrinsic factors affecting the SST error.

Future works

- take into account more factors
- analyze stdv dependences
- extend to daytime data
- apply to the brightness temperatures M-O residuals

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Acknowledgement: This work was supported by the GOES-R AWG funded by the GOES-R Program Office. Dr. Xu acknowledges the CIRA post-doc fellowship. We thank our colleagues John Sapper (OSDPD), Prasanjit Dash (STAR/CIRA), Boris Petrenko (STAR/IMSG), Nikolay Shabanov (STAR/IMSG), Yury Kihai (STAR/PSGS), and Denise Frey for helpful discussions. The views, opinions, and findings contained in this report are those of the authors and should not be construed as an official NOAA or US Government position, policy, or decision.

89th AMS Annual Meeting, Phoenix, AZ 11-15 Jan 2009