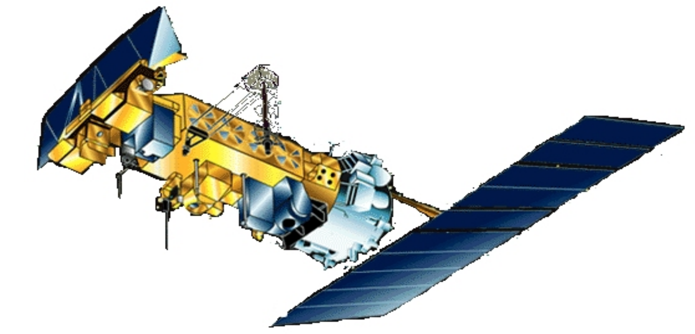
OS23E-04

Validation of the NESDIS operational Sea Surface Temperature products from AVHRR onboard NOAA 16-18



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Introduction

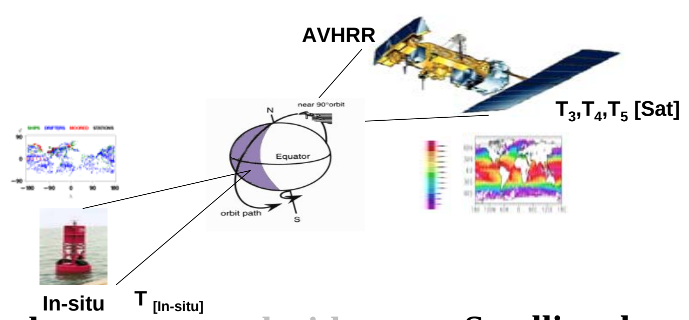
NOAA satellites provide repetitive daily global coverage of the Earth. For over two decades, the National Environmental Satellite, Data, and Information Service (NESDIS) has been generating Sea Surface Temperature (SST) products operationally from the Advanced Very High Resolution Radiometer (AVHRR). Global AVHRR SSTs are merged with *in-situ* SSTs and organized into monthly match-up files, which are used to calibrate SST algorithms (early in satellite mission); and then routinely validate SST products (for the lifetime of a platform). Climatological Bauer-Robinson (1985) SSTs, and many other ancillary data from both satellite and in-situ files, are also available on the match-up datasets.

Objective

Describe and document validation results of the heritage operational SST products from NOAA16-18 AVHRRs against *in situ* SST, and explore further improvements.

1. Generating match-up data

AVHRR brightness temperatures (T_3,T_4,T_5) are continuously merged with drifting and TOGA/TAO and PIRATA moored buoys within 25km/4h space-time window.



In-situ data merged with **Satellite data**

ID	Time	Lat/ Long	In-situ SST	Climate Temp

Time	Lat/ Long	T_{sfc}	T_3	T_4	T_5	Sat(θ)

2. Sea Surface Temperature Calculations

Coefficients of operational SST equations were obtained by regression analyses of the match-up data during the first 1-3 months of a sensor lifetime.

Day: Split-Window NLSST

$$T_{in\text{-}situ}=a_o + a_1 T_4 + a_2 T_{sfc} (T_4-T_5) + a_3 (T_4-T_5)(\sec\theta - 1)$$

	a_o	a_1	a_2	a_3
NOAA16	-247.389	0.911279	0.0808835	0.717441
NOAA17	-253.951	0.936047	0.0838670	0.920848
NOAA18	-253.308	0.934004	0.0724457	0.748044

Night: Triple-window MCSST

$$T_{in\text{-}situ}= a_o + a_1 T_4 + a_2 T_3 + a_3 T_5 + a_4 (T_3 - T_5) (\sec\theta - 1) + a_5 (\sec\theta - 1)$$

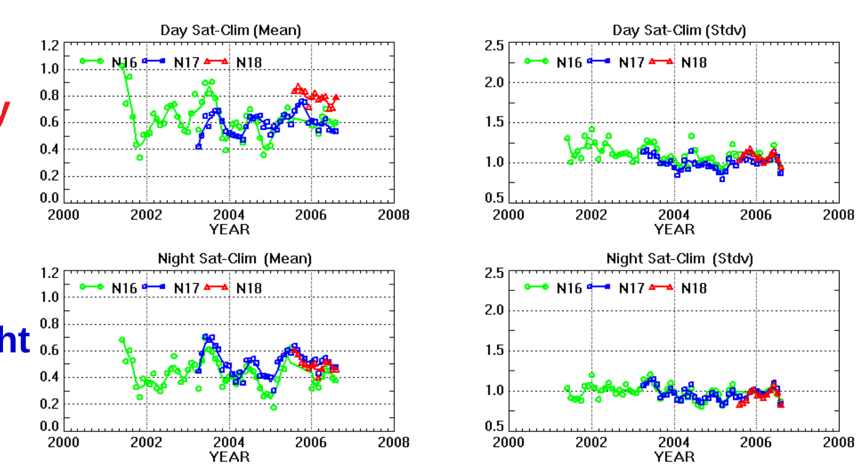
	a_o	a_1	a_2	a_3	a_4	a_5
NOAA16	-274.875	0.257489	1.25364	-0.502818	0.110607	1.12932
NOAA17	-275.456	0.573174	1.12933	-0.690623	0.0721864	1.66172
NOAA18	-274.686	0.467570	1.08556	-0.543265	0.137627	1.12622

3. Validation

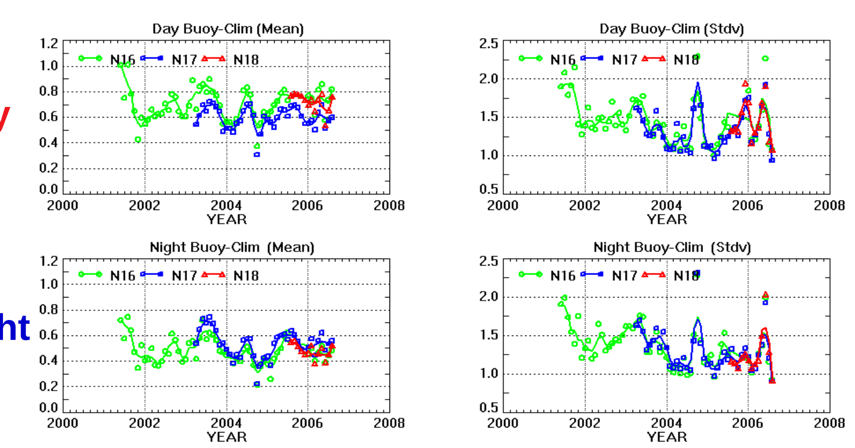
Independent match-up data are used to assess the accuracy of operational SST, by characterizing the global Bias and the Root Mean Squared Error (RMSE) of satellite SST minus *in-situ* SST, from 2001 till the present.

3.1 Initial Analyses of Match-Up Dataset

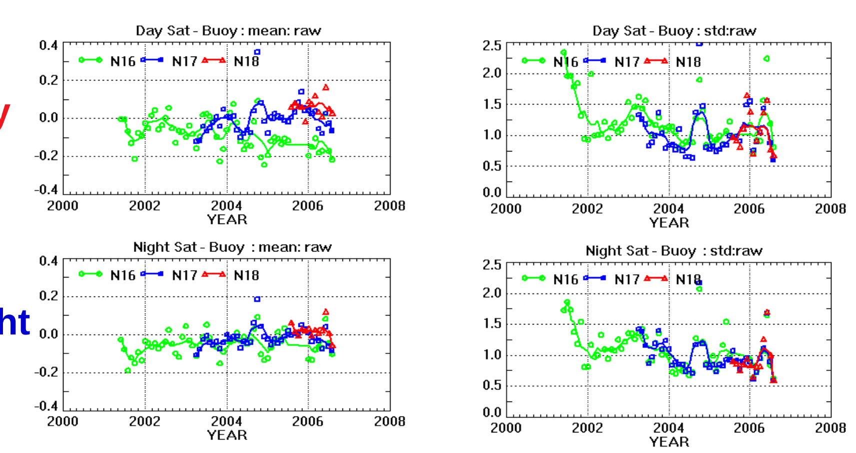
Satellite SST minus Bauer-Robinson climatological SST



***In-situ* SST minus Bauer-Robinson climatological SST**



Satellite SST minus *in-situ* SST



In situ SSTs are highly uncertain. As a result, RMS(Satellite – In-situ) may exceed RMS(Satellite – Climate) SST. Quality Control of in-situ SSTs is needed.

3.2 Outlier Removal: Extreme Outliers and Robustness

The common practice to remove outliers is to use ±4 sampling standard deviations (σ) around the sampling mean (e.g. Ostle and Malone 1988). However we found that the conventional central-σ in the match-up data set, are very sensitive to extreme outliers. This is because the ordinary central moment estimators require squaring and cubing the observations which causes them to give greater weight to the observations far from the mean resulting in substantial bias on the variance. The more outliers in the data, the larger the central-σ, and consequently, the less effective is the 4σ screening to remove outliers. On the contrary, L-moments (analogous to conventional central moments) are more robust to outliers (Hosking, 1990)

L-Moments

L-moments are linear combinations of Probability Weighted Moments (PWMs). The "L"in L-moments emphasizes the construction of L-moments from linear combinations of ordered statistics. L-moments have been defined for a probability distribution, but in practice must often be estimated from a finite sample. Estimation is based on a sample of size n arraigned in ascending order.

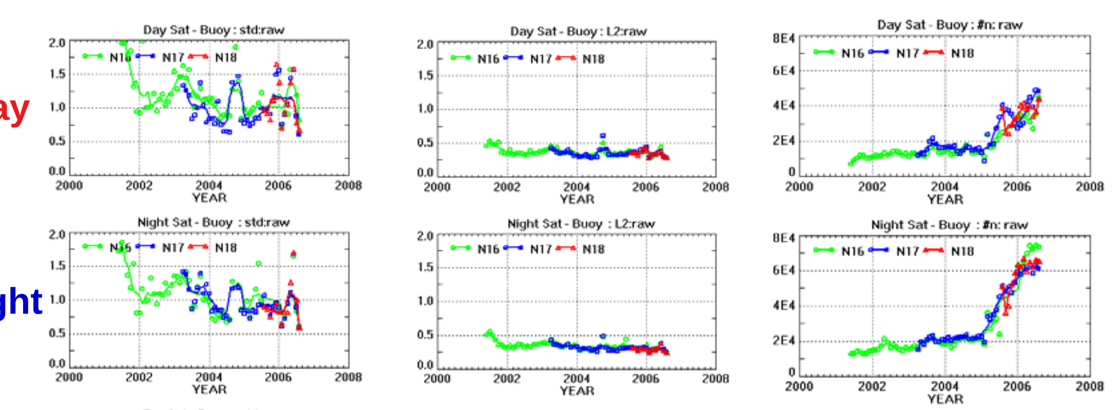
Let $x_{1:n} \le x_{2:n} \le \ldots < x_{n:n}$

$$b_r = \frac{1}{n}\sum_{j=r+1}^{n}\frac{(j-1)(j-2)\ldots(j-r)}{(n-1)(n-2)\ldots(n-r)}x_{j:n}$$

$L1=b_0$
$L2=2b_1-b_0$

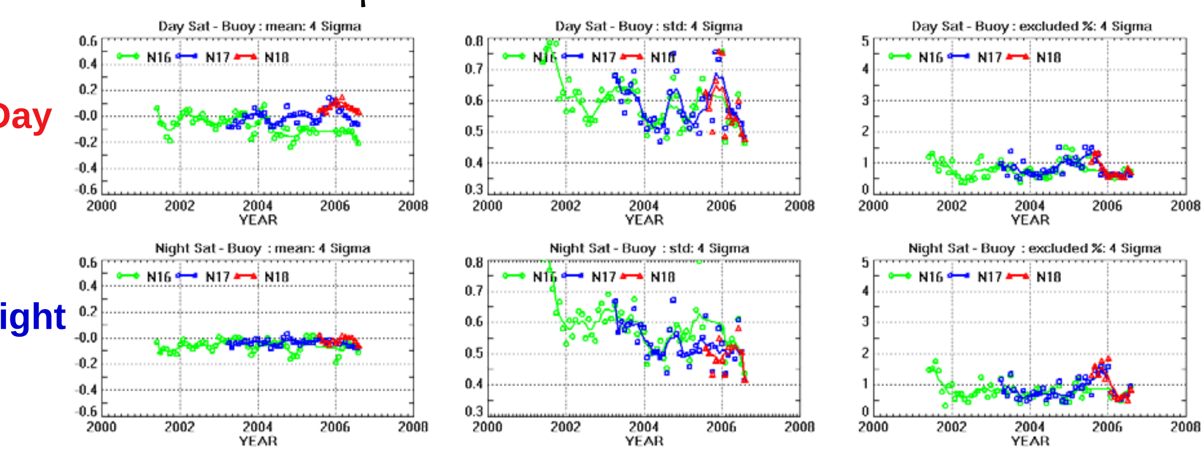
Statistical Parameter	Central moment	L-moment
Location (Mean)	μ	L1= μ
Scale (Stranded deviation)	σ	L2

Standard deviation prior to outlier removal in match-up



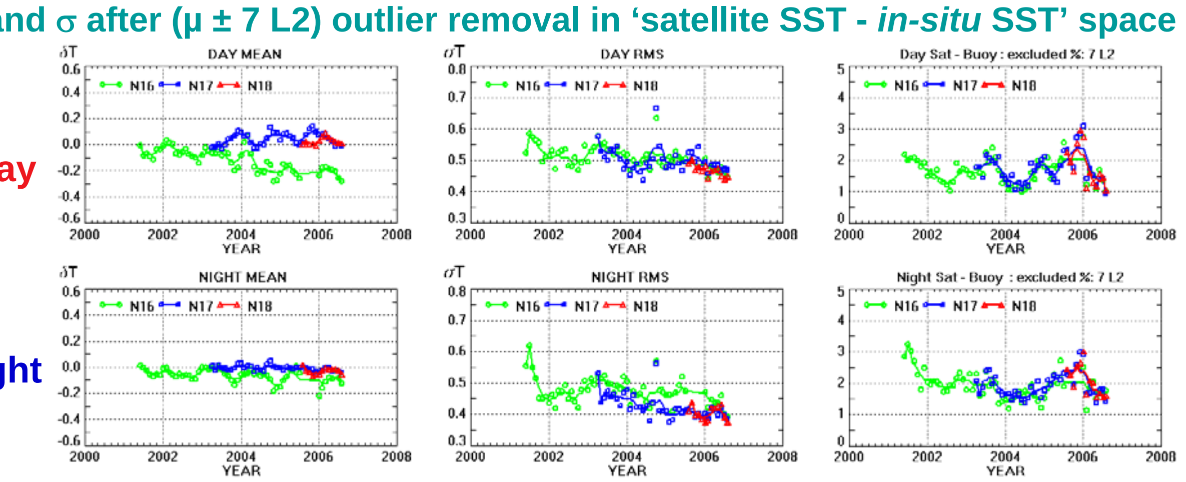
The central-σ is highly sensitive to outliers and therefore is progressively less effective to remove outliers as their relative proportion in the dataset increases. In contrast, the L-moment standard deviation (L2) is significantly less sensitive to presence of outliers, and is thus expected to be more effective for outlier removal. For a perfect Gaussian distribution without statistical extremes, 'σ = 1.77× L2' (Hosking, 1997), i.e., 'μ ± 4×σ' screening is approximately equivalent to 'μ ± 7×L2'.

μ and σ after (μ ± 4 σ) outlier removal in 'satellite SST – *in situ* SST' space



Validation Bias (μ) and RMSE (σ) after removing outliers using the central 4σ. This method removes from 0.5-1.5% outliers. Resulting RMSE's are from 0.4-0.8K. Time series are noisy.

μ and σ after (μ ± 7 L2) outlier removal in 'satellite SST - *in-situ* SST' space



Same as above but using the L-moments. This method removes from 1-3% outliers. The validation σ improves to 0.4-0.6K. Time series become more uniform.

Conclusion

The *in-situ* data are strongly contaminated by observational errors. Quality control is needed. Using L-statistics for screening outliers is more robust, compared to the conventional central moments due to the fact that the L-moments are less sensitive to outliers. The heritage SST Calibration and Validation at NESDIS are currently undergoing a careful re-evaluation and re-design.

Acknowledgement

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