# Pixel-to-Pixel Variability of AVHRR and MODIS L2 SST Fields

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## Introduction

The object of this work was to determine the local precision, which we refer to as the pixel-to-pixel (P2P) sigma, of L2 SST fields obtained from AVHRR and MODIS instruments carried on US satellites. The P2P sigma is what determines the accuracy of small scale SST gradients. Most measures of the accuracy of SST fields are based on matchups, generally separated significantly in space and/or time thus including contributions from non-cloud atmospheric contamination (Fig. 1). The P2P sigma is based on small spatial and temporal separations and is substantially smaller in value than the sigma generally quoted for these sensors. Determination of P2P sigmas for AVHRR were based on Pathfinder SST fields of the Sargasso Sea using a spectral approach and, for MODIS Aqua, were based on global 1 km SST fields using a variogram approach. The two approaches were shown to produce similar results in Wu et al. (2017) for sigmas in excess of 0.1 K.

## Results

The AVHRR fields were analyzed separately in the along-scan and along-track directions for regions >90% cloud free thus eliminating P2P variability associated with misclassifield pixels. MODIS data were analyzed in 1° x 1° squares for regions at least 80% cloud free with the P2P sigmas averaged for each square. Fig. 2 shows the AVHRR and MODIS P2P sigmas. For each of the AVHRRs the value represents a mean over the lifetime of the instrument while for MODIS Aqua it represents an average for 2002-2012. P2P sigma for all sensors showed little change over the periods observed. The lower panel of Fig. 3 shows the geographic distribution of the MODIS P2P sigmas – corresponding to the yellow square in Fig.1 – and the upper panel shows the MODIS sigma determined from a 3-way comparison with in situ and AMSR-E SSTs – a measure of the contribution of non-cloud atmospheric contamination to the variability of MODIS SSTs, green square (excluding misclassification errors).

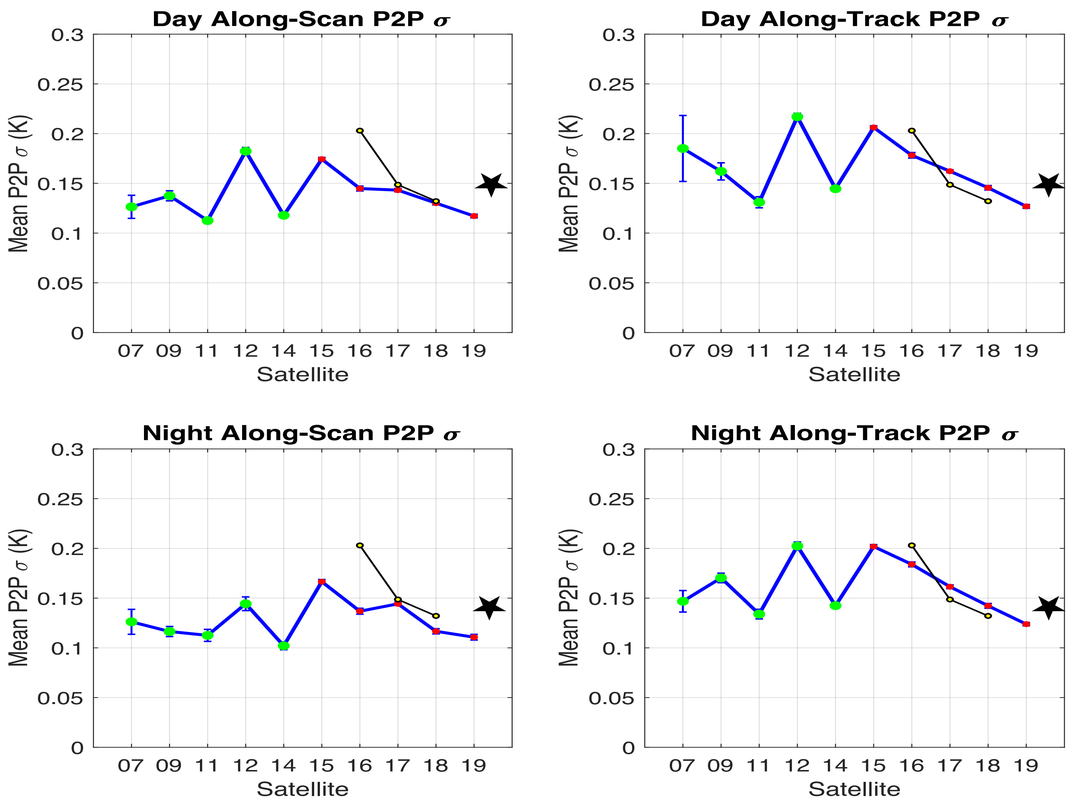


**Fig. 2.** P2P $\sigma$ versus satellite. Green circles: for AVHRR/2. Red circles: for AVHRR/3. Black stars for MODIS Aqua (no error estimates yet). Error bars are the standard error of the mean. Black line with yellow data values are estimated p2p $\sigma$ based on NE$\Delta$T values.

## Discussion – Decreasing the P2P sigma without increasing the overall sigma

Both Pathfinder and MODIS SSTs are based on the NLSST retrieval algorithm, which near nadir is:

$$SST_{sat} = a + bT_{11} + c(T_{11} - T_{12})SST_{guess} + d(T_{11} - T_{12})(\sec\theta - 1)$$

The $c(T_{11} - T_{12})SST_{guess}$ term corrects for atmospheric water vapor hence it varies on atmospheric spatial scales, which are generally large compared to the pixel separation for AVHRR and MODIS. Assuming that brightness temperature NE$\Delta Ts, \delta T_{11}$ & $\delta T_{12}$, are independent, the retrieval variance near nadir is:

$$\delta SST_{sat}^2 = b^2\,\delta {T_{11}}^2 + \gamma^2\,(\delta T_{11}^2 + \delta T_{12}^2) \quad \text{with} \quad \gamma = c\,SST_{guess}$$

Since $\gamma$ is generally > b and $\delta T_{11} \approx \delta T_{12}$ the water vapor term contributes at least twice as much to the P2P variance as the $bT_{11}$ term, which, in turn, means that the P2P sigma of the NOAA AVHRR and NASA MODIS products could be substantially reduced by averaging this term over an order 10x10 pixel region, as is done by CMS and the Plymouth remote sensing group, without a significant, if any, increase in the sigma when compared with in situ values. Sounds like a win-win (as they say in Washington) to us!

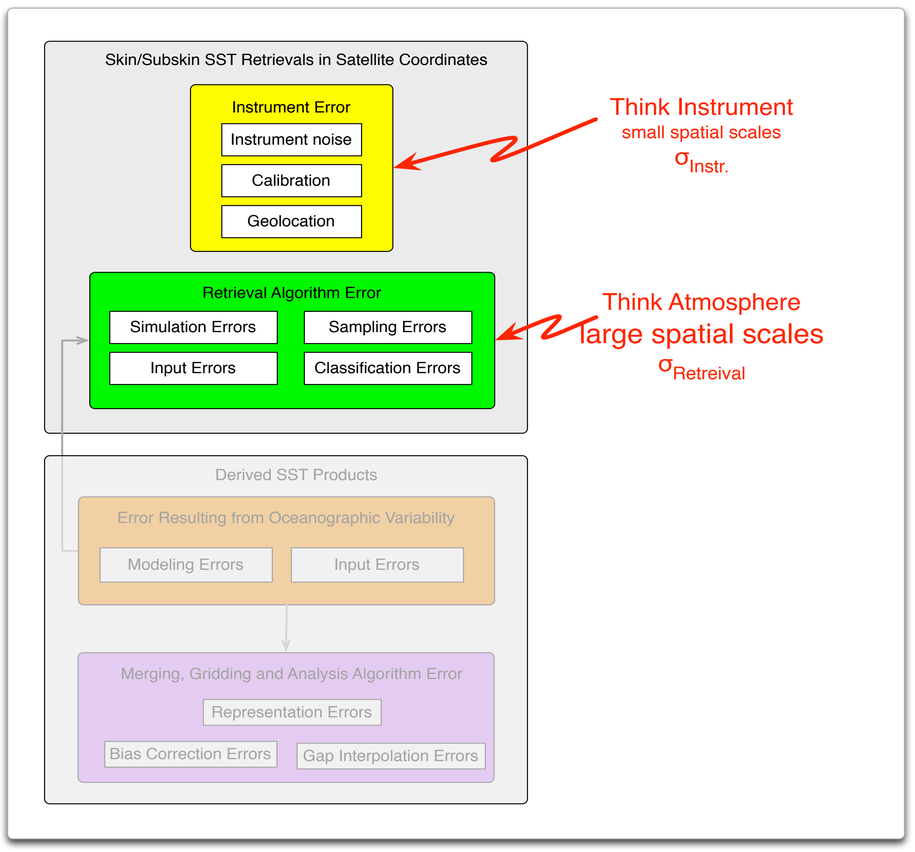


**Fig. 1.** SST error budget conceived by the NASA/NOAA SST Science Team

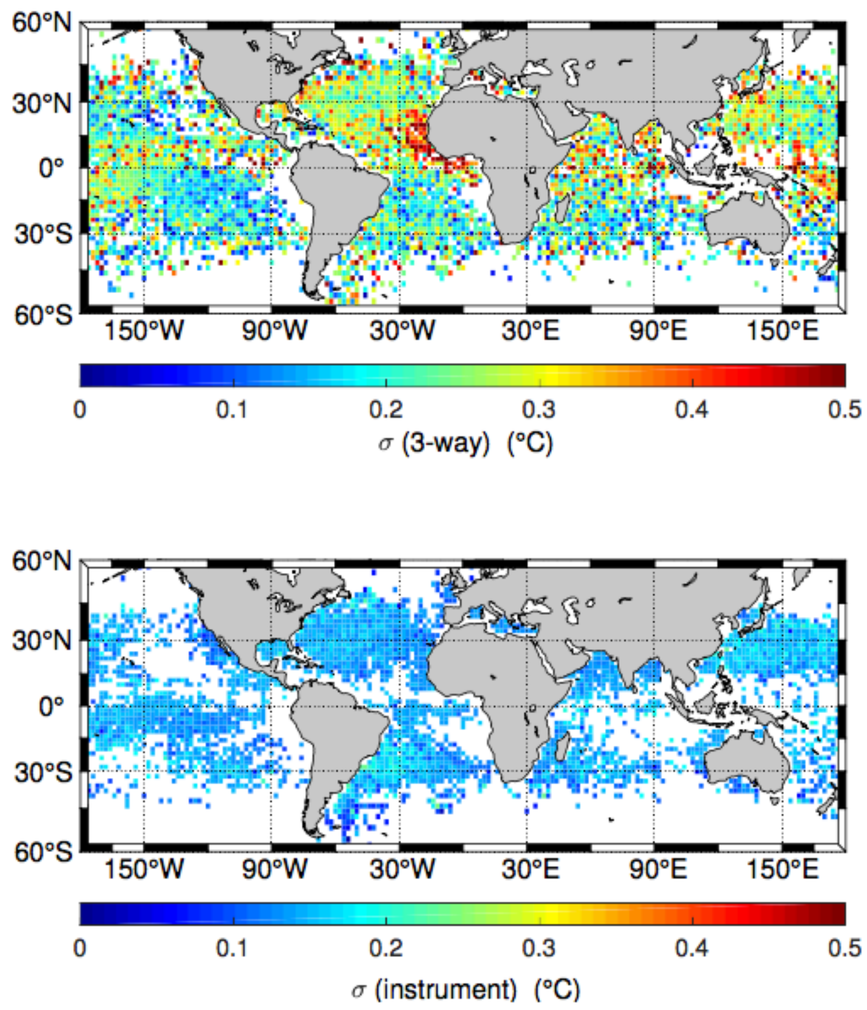


**Fig. 3.** Upper panel: MODIS SST sigma from 3-way comparison. Lower panel: MODIS P2P sigma.

## Conclusions

P2P sigma for AVHRR and MODIS

- ~ 0.15 K.
- Is slightly greater during daytime than nighttime.
- Is stable over time for all instruments.
- Is substantially smaller than the sigmas generally quoted for these sensors, which are order 0.3 to 0.5 K.
- Could be reduced substantially (more than a factor of two) by averaging the water vapor term in the retrieval algorithm over a region that is relatively large compared with the pixel spacing. This would result in a substantial reduction in the error of the SST gradient determined from these datasets.

## References

Wu, F., Peter Cornillon, Guan, L. and Kilpatrick, K. (2019). Pixel-to-Pixel Uncertainty in NOAA AVHRR SST Fields from 1982 to 2015. Remote Sensing, 5295–11
Wu, F., Cornillon, Peter, Boussidi, B. and Guan, L. (2017). Determining the Pixel-to-Pixel Uncertainty in Satellite-Derived SST Fields. Remote Sensing 9

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