TES SST Measurements through Two Years of Operations

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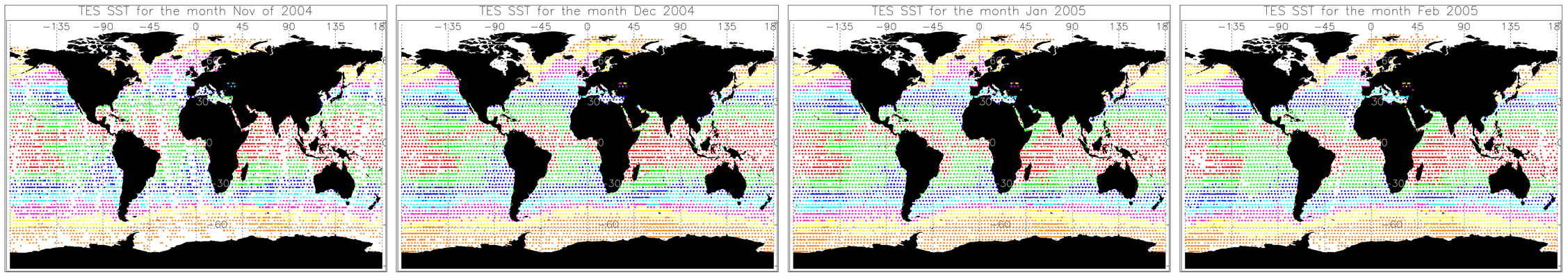
Abstract

The Tropospheric Emission Spectrometer (TES) launched July 15, 2004 on the EOS Aura spacecraft has acquired sea surface temperatures as part of nadir observations over the ocean. Sea surface temperature (SST) is of interest both as part of the standard products being archived at the Atmospheric Sciences Data Center Distributed Active Archive Center (http://eosweb.larc.nasa.gov/PRODOCS/tes/table_tes.html) and as a stringent test of retrieval methodology. Small SST errors demonstrate overall self-consistency and accuracy of TES radiometric calibration, forward model calculations and inversion algorithms. SSTs obtained over the two years of operations are examined to assess the skill of the TES retrieval relative to effective cloud optical depth and SST degrees of freedom of signal.

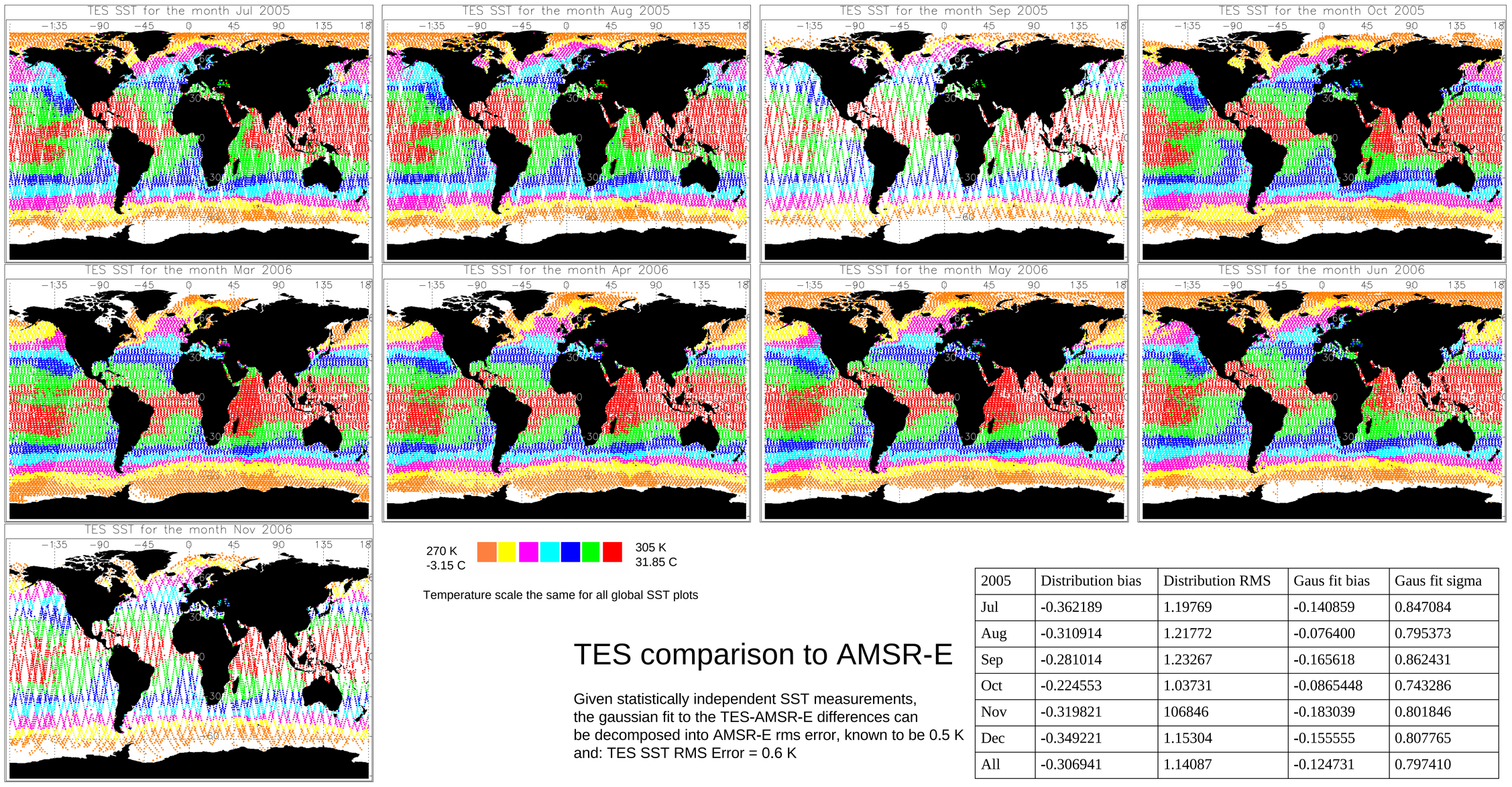


Motivation to look at TES SST:

SST is a stringent test of TES calibration and retrieval algorithms. Over the two years of operation TES has undergone multiple de-icing procedures and an increase in the operating temperature of the optical bench to improve signal to noise. SST analysis can help determine the effects of these procedures. It can also provide a sensitive test for cloud retrieval biases. SST is a global quantity that is actively measured by multiple methods: buoys, ships, remote sensing instruments – AIRS, AMSR-E, MODIS, GOES, etc., and there are many validated products – Reynolds Optimally Interpolated SST, real-time global (RTG) SST, etc.

TES Global Surveys

From Nov 2004 through May 2005, TES acquired up to 1152 nadir target scenes (2 scans averaged) in 16 orbits every other day; from May 2005 through Dec 2005, TES acquired up to 3456 unaveraged nadir target scenes in 16 orbits every other day. From Jan 2006 on, TES has acquired up to 3408 nadir target scenes. Sea surface temperature was retrieved along with temperature, water vapor, and ozone profiles. Microwindows covering frequencies from 990 cm^{-1} to 1380 cm^{-1} were used . Scans had a resolution of 0.1 cm^{-1}. The TES footprint is 5 km by 8 km. Target scenes are evenly spaced along track,



Temperature scale the same for all global SST plots

TES comparison to AMSR-E

Given statistically independent SST measurements, the gaussian fit to the TES-AMSR-E differences can be decomposed into AMSR-E rms error, known to be 0.5 K and: TES SST RMS Error = 0.6 K

2005	Distribution bias	Distribution RMS	Gaus fit bias	Gaus fit sigma
Jul	-0.362189	1.19769	-0.140859	0.847084
Aug	-0.310914	1.21772	-0.076400	0.795373
Sep	-0.281014	1.23267	-0.165618	0.862431
Oct	-0.224553	1.03731	-0.0865448	0.743286
Nov	-0.319821	106846	-0.183039	0.801846
Dec	-0.349221	1.15304	-0.155555	0.807765
All	-0.306941	1.14087	-0.124731	0.797410

Conclusion: TES SST is about 0.13 K cooler than AMSR-E. TES variance wrt AMSR-E is about 0.8 K implying TES RMS Error ~0.6 K. SST selection by either effective cloud optical depth or degrees of freedom of signal for SST results in distributions vs. AMSR-E or ROI that are closer to normal (random error) statistics, showing that a large number of outliers are due to systematic effects and that cloud optical depth is definitely the single largest such effect. The TES cloud algorithm is effective in modeling this interference. TES errors both before optical bench warm-up with two-scan averaged retrievals and after with single scan retrievals show TES achieving results comparable to other orbiting sensors. TES SST is a product that therefore can be used with well understood errors and bias. TES SST is likely the best SST product to use in conjunction with other TES products given its accuracy and matched spatial and temporal co-location.

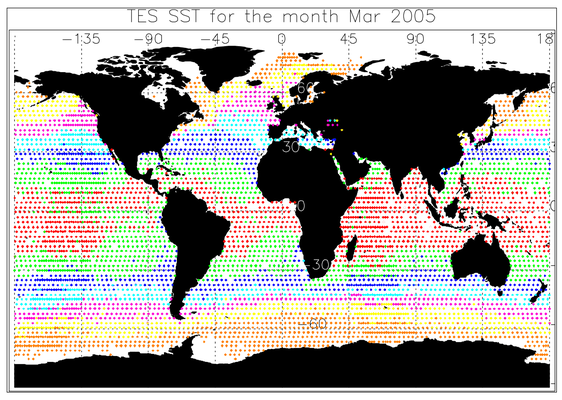
This work has been performed for NASA under contract to the California Institute of Technology and the Jet Propulsion Laboratory.

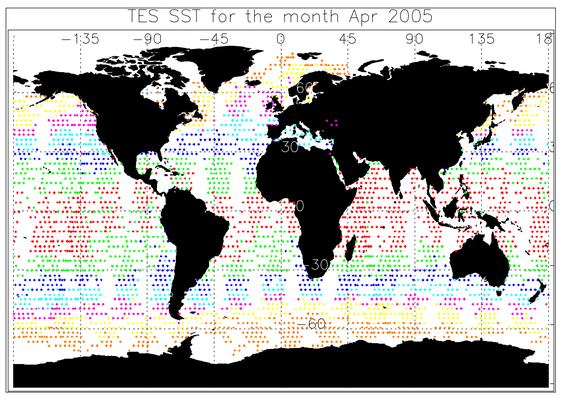
TES SST Measurements through Two Years of Operations (cont.'d)

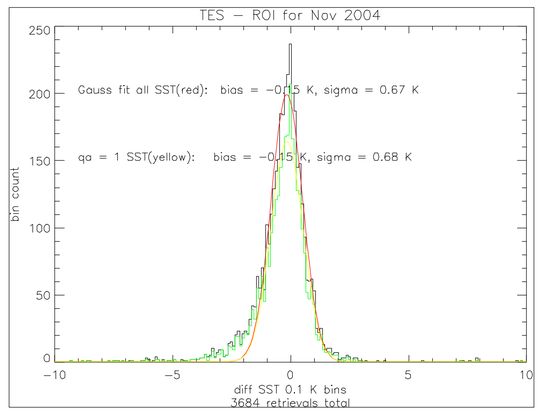
TES has been producing data for a little over two years. Although TES nominally performs a global survey every other day, there have been some gaps in data. A major gap was in the spring of 2005 after the instrument went into safe mode. A response team determined that the event was most likely caused by a high energy cosmic ray and the instrument was put back into normal operations. Other gaps have been caused by focal plane de-icing and an optical bench warm-up. The optical bench warm-up successfully increased signal significantly, particularly important for methane and other trace gases with smaller signal.

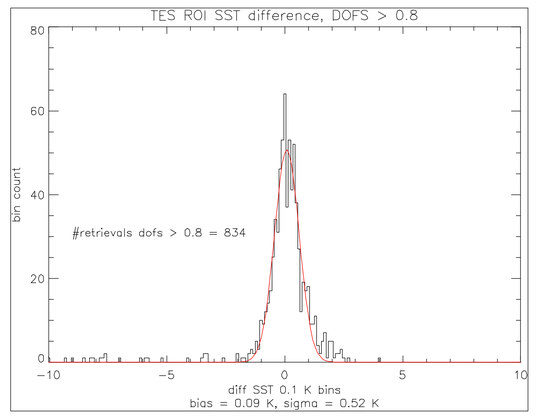
The SST time series represented here by monthly plots contains over 140,000 SST measurements made over this time frame.

The two histograms below, are for Nov 04 and are representative of the two-scan averaged global surveys done in the initial operation of TES. These SST differences are between Reynolds Optimally Interpolated SST rather than AMSR-E, although the statistics are very similar. The plot above shows a small negative bias, similar but slightly smaller than the single scan retrievals. The 1 sigma width of the gaussian fit is also slightly smaller, in part due to two competing effects – greater signal after optical bench warm-up per scan and going to single nadir scans in the global surveys. The green histogram is based on selecting SSTs from retrievals with an 'overall good quality' flag set. The yellow gaussian is the best fit to that data. The second plot is based on selecting SSTs with degrees of freedom of signal greater than 0.8 (max is 1.0) rather than selecting for small effective cloud optical depths. In this case it can be seen that the negative outliers have almost completely been removed, resulting in a slight positive bias. The 1 sigma width is also smaller at ~0.5 K. Further work on the relative merits of selecting high quality SSTs based on effective optical depth or DOFS will be done.



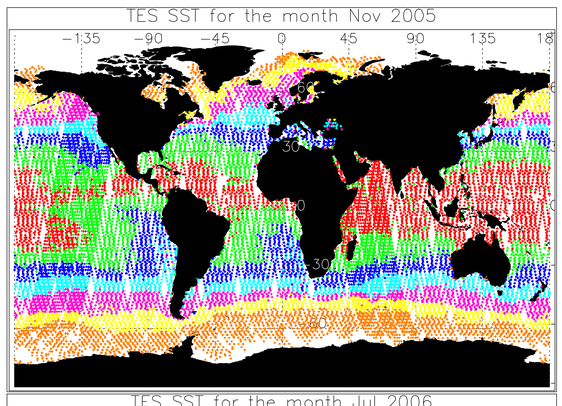


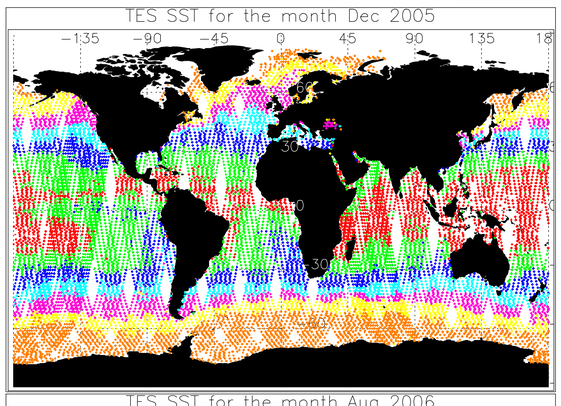


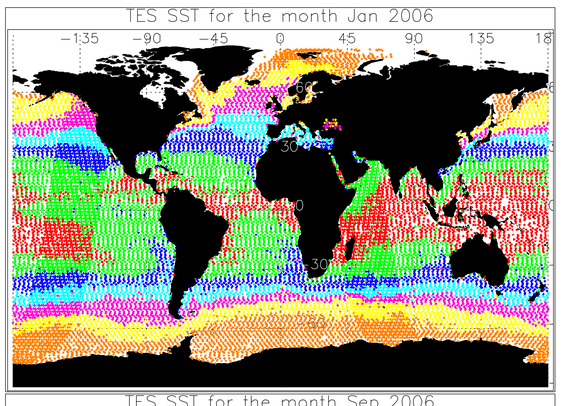


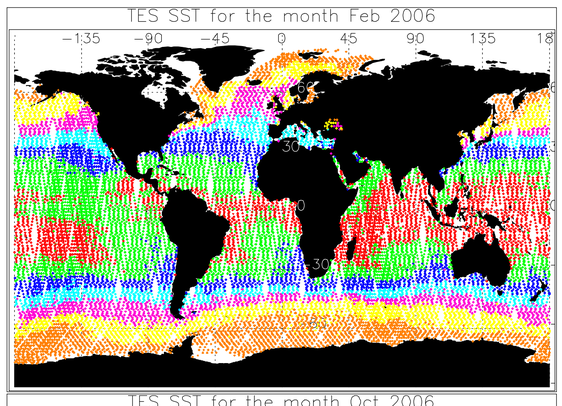
Above: global surveys with nominally 1152 two-nadir scans per retrieval,
Below: global surveys with 3456/3152 single nadir scans per retrieval

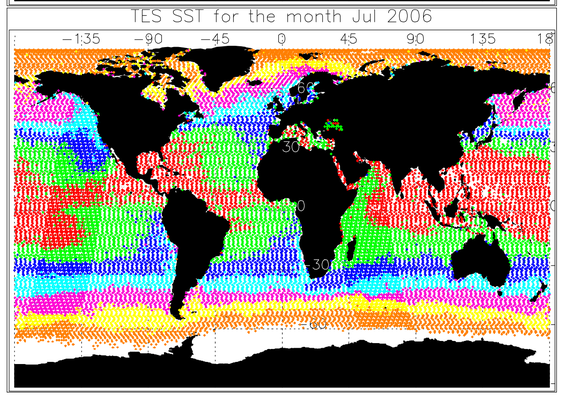
Temperature scale the same for all global SST plots
270 K
-3.15 C
305 K
31.85 C

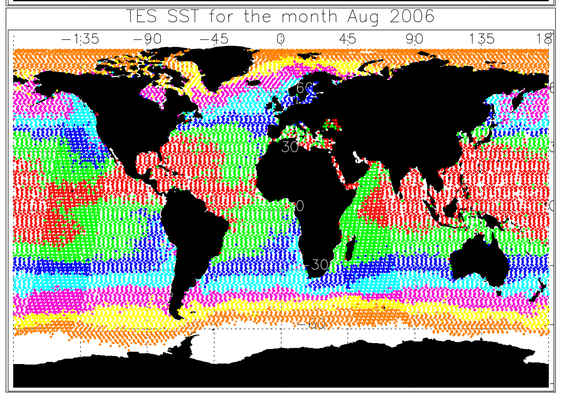


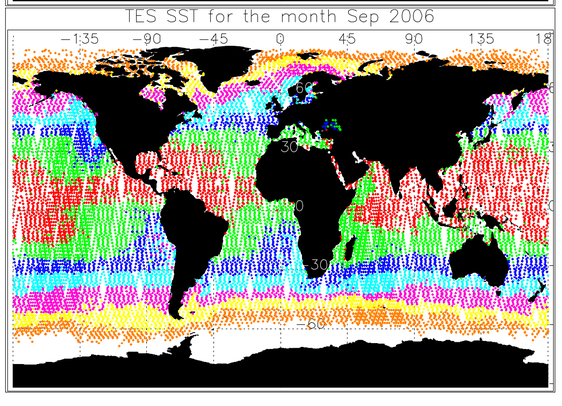


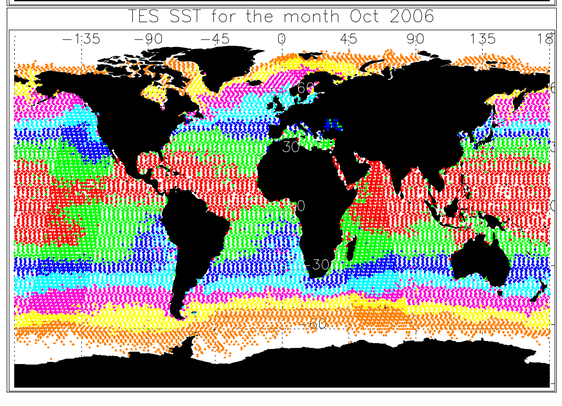


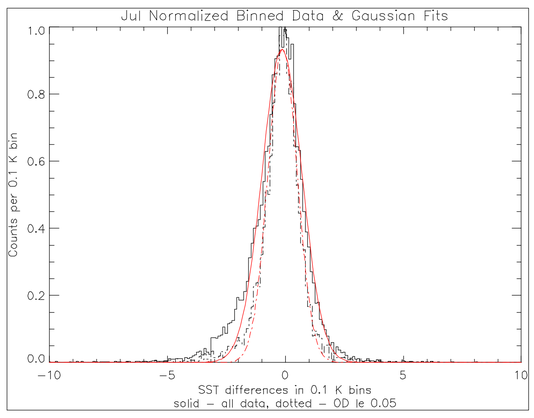


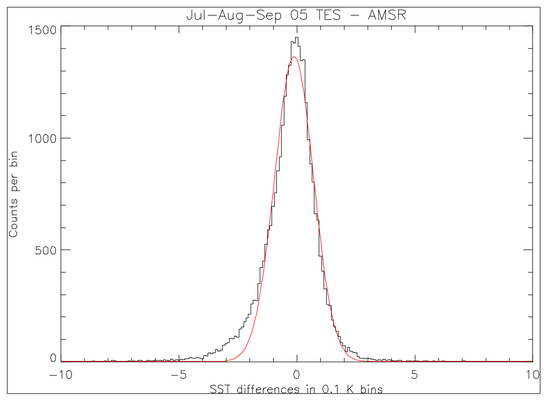


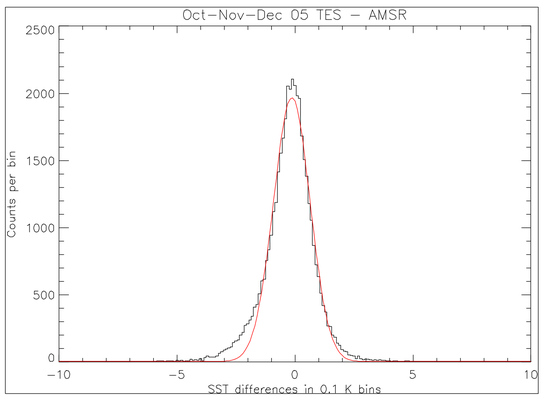


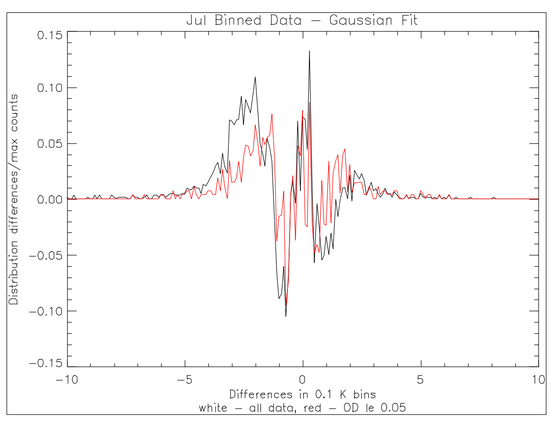












TES and AMSR-E SST difference histograms (above, black) and the gaussian fits to the histograms (red) show the relative variation of TES and AMSR-E SSTs. AMSR-E has an RMS error reported between 0.5 K and 0.6 K. If the TES and AMSR-E errors are both completely random wrt each other then TES RMS error (using average sigma from gaussian fitted distribution) is between 0.53 K and 0.63 K. The July normalized histograms and gaussians to the left and above show how preferentially selecting TES SSTs with low retrieved effective optical depth (less than 0.05 in this case) produces a more nearly normal distribution. The plot to the left shows the normalized differences of the two cases. The low effective optical depth (red) case shows a sharp reduction of the cold outliers between 0 and -5 K wrt all SSTs and the overall distribution is clearly more symmetric although cold outliers still number slightly more than warm outliers. The peaks of the gaussians match well with the peaks of the binned distributions and justify taking the biases of the distributions as being the offset of the gaussians from 0, rather than the average over the entire distribution. In other words we define the bias as the offset of the peaks rather than the average difference which is more affected by outliers.