Reprocessing the 20-year satellite record of SST

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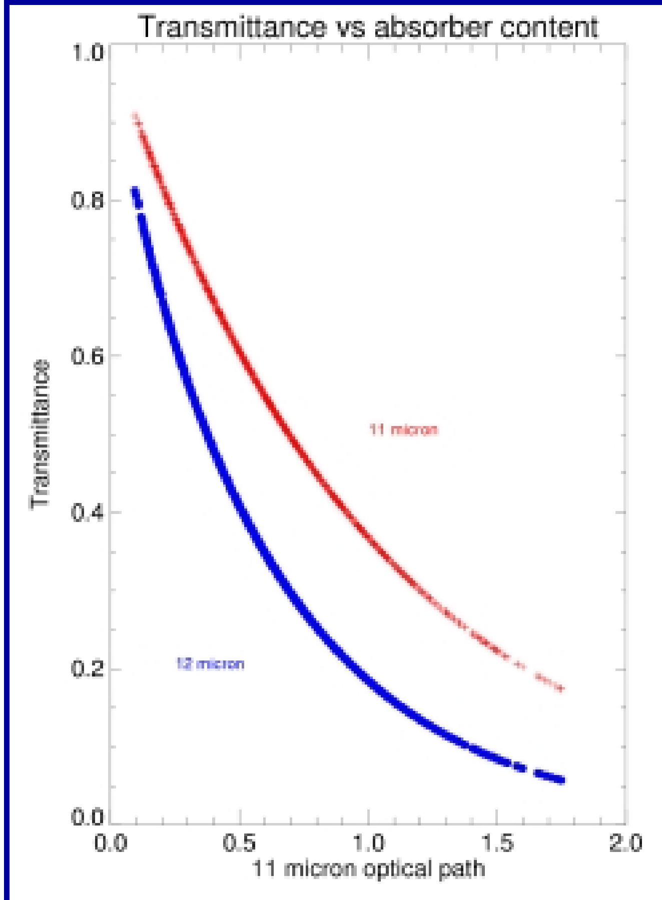
Satellite data – pros and cons

Main advantages of satellite data:

- *Frequent and regular global coverage (cloud cover permitting for IR)*
- *'Single' source of data*
- *Many observations*

Challenges

- *Not a direct measure. A retrieval process is required*
- *Single source + many observations means that data must be accurate, or risk swamping the conventional record with erroneous values*
- *Lack of other sources in remote regions to cross-compare*



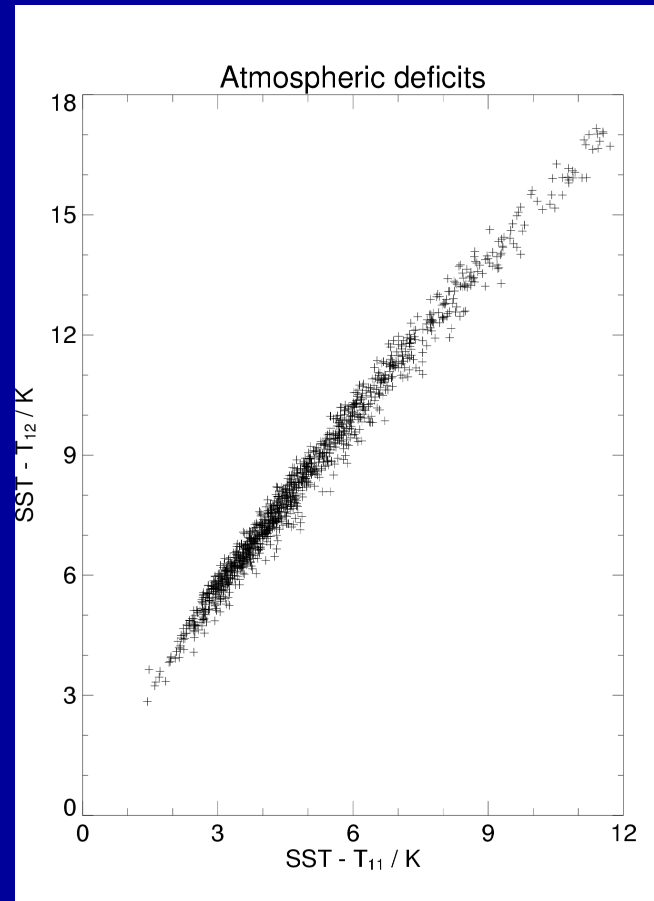
Early theory required

$$\mathrm{SST} - T_i = k_i \boldsymbol{F}(\mathrm{atm})$$

This allowed

$$SST = \frac{k_2 \boldsymbol{T}_1 - k_1 \boldsymbol{T}_2}{(k_2 - k_1)}$$

And hence the “split-window” equation, mystique about channel differences, etc.



Only need to assume $\mathrm{SST} - T_i \propto \mathrm{SST} - T_j$ to get $\mathrm{SST} = a_0 + \Sigma a_i T_i$

Some refinements to account for non-linearity, scan angle:

$$\mathrm{SST} = a_0 + a_1 T_{11} + a_2 T_{12} + \mathrm{SST}_{bg} a_3 (T_{11} - T_{12}) + \mathrm{SZA} a_4 (T_{11} - T_{12})$$

Reprocessing of historical data

- Unless we have one of these…
- …we must reprocess old data to the standard required for climate monitoring
  - *Primarily* **AVHRR (1981 –)***, an instrument originally designed for cloud*
  - *Also* **ATSR (1991 –)** *and* **GOES (1994 –)**
  - **TMI (1997 –)***,* **MODIS (1998 –)** *and* **AMSR (2002)**

Expected SST trend is ~0.2 K/decade

Hence requirement is that <u>observing system</u> must be <u>stable to <0.1 K/decade</u>

Obtaining an optimal result requires:

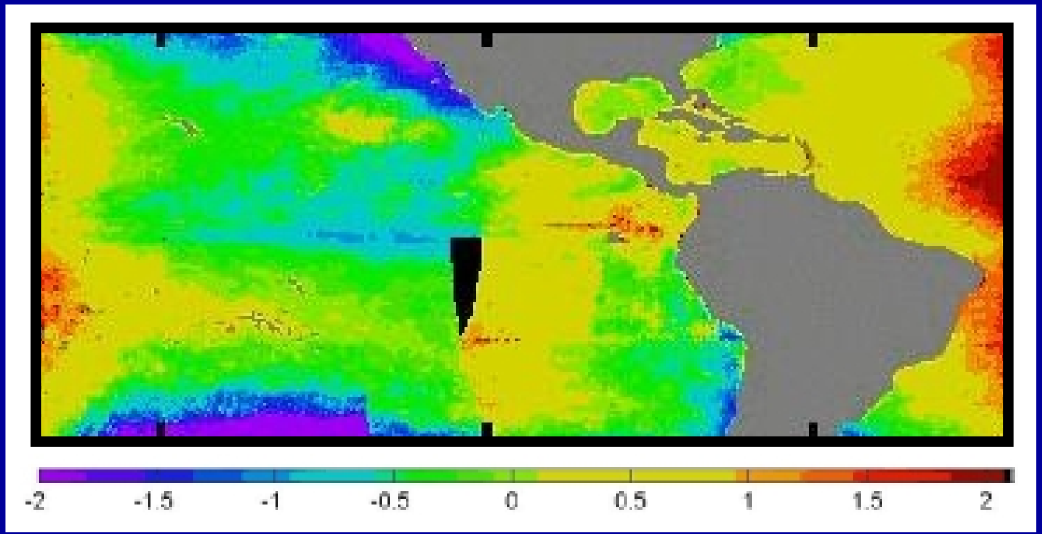
- Reliable error characterization
  - *Retrieval errors display varying spatial and temporal characteristics*
  - *Background field displays substantial geographic variation*
- Elimination of sources of retrieval bias and artificial secular trends
- Compensation for surface effects, particularly those related to the diurnal cycle. Sun-synchronous orbits will alias & orbit drift causes problems

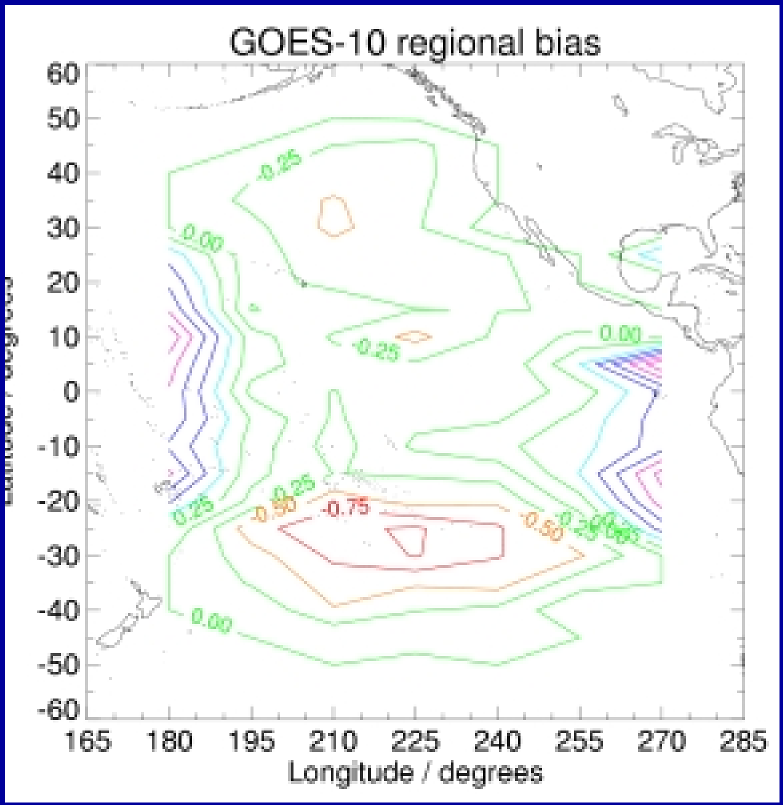
Radiative transfer-based retrievals

- The chief advantage of radiative transfer (RT) is that it allows specification of the retrieval algorithm *without bias towards the data-rich regions*
- The *in situ* data can then act as a *random independent sampling* of the retrieval conditions
- If the observed errors agree with the modeled ones, then high confidence can be placed on the modeled errors in data-sparse regions

Spatial pattern of TMI – GOES differences

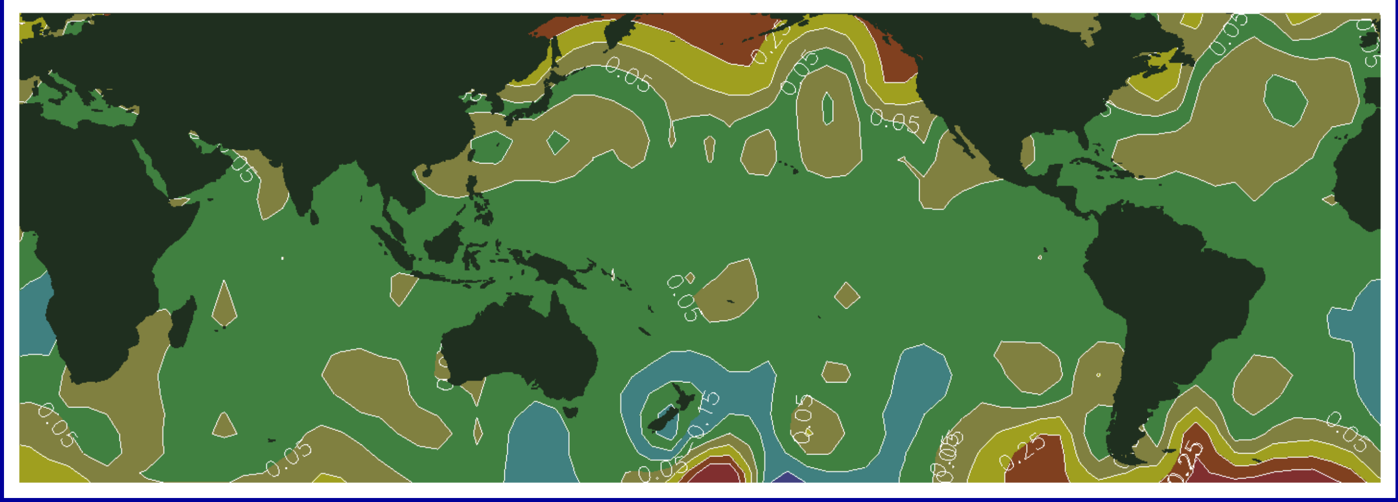
Fixed viewing geometry of GOES emphasizes that single “global” linear retrieval equation is regionally sub-optimal





Bias pattern for GOES-W similar to that predicted by radiative transfer

Impact of restricted training data



Radiative transfer - challenges

Modeling must be accurate

- *Spectroscopy (mainly continuum), emissivity*
- *Representative input data (atmospheric profiles)*
- *Noise characteristics of real data*
- *Filter functions*

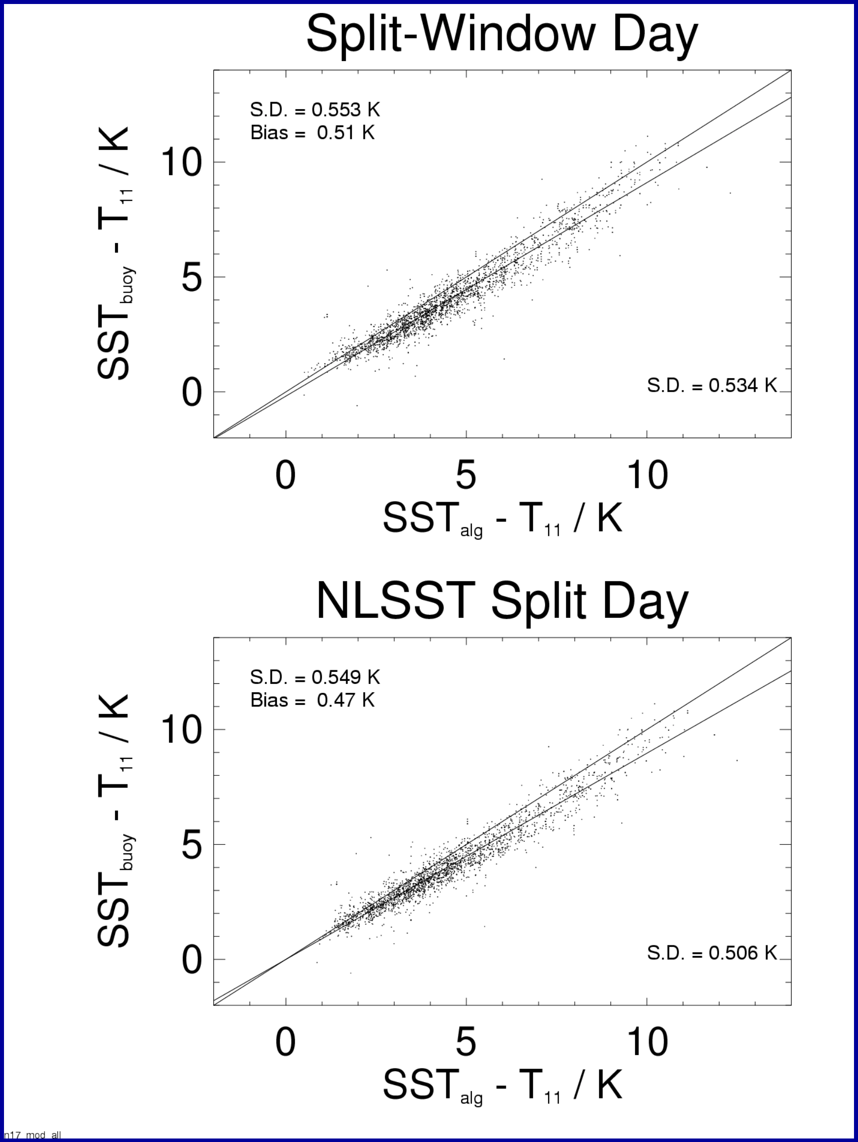
Sensor calibration must be accurate

Cloud masking, aerosols

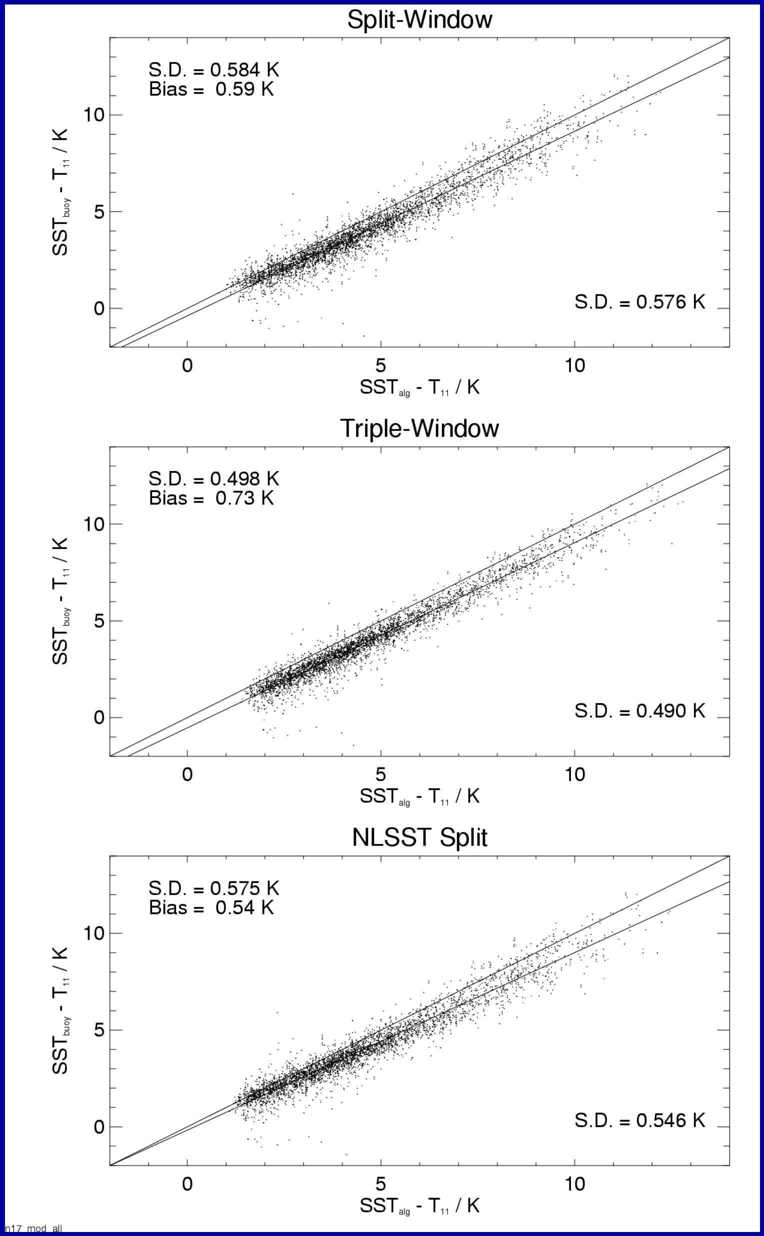
Surface effects (skin vs. bulk)

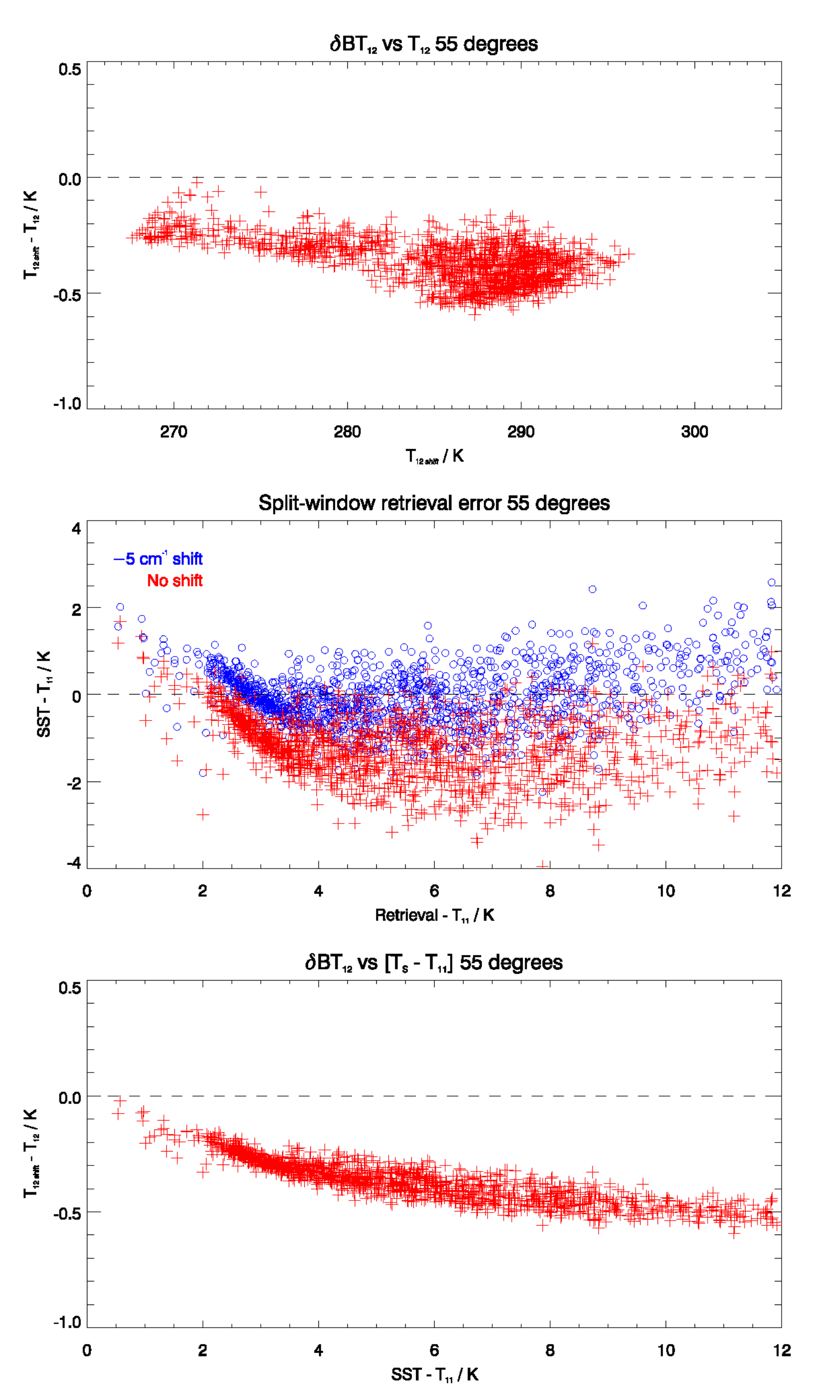
- *Also relevant for empirical retrieval methods*

Modtran NOAA-17 RT retrieval against *in situ*



Night





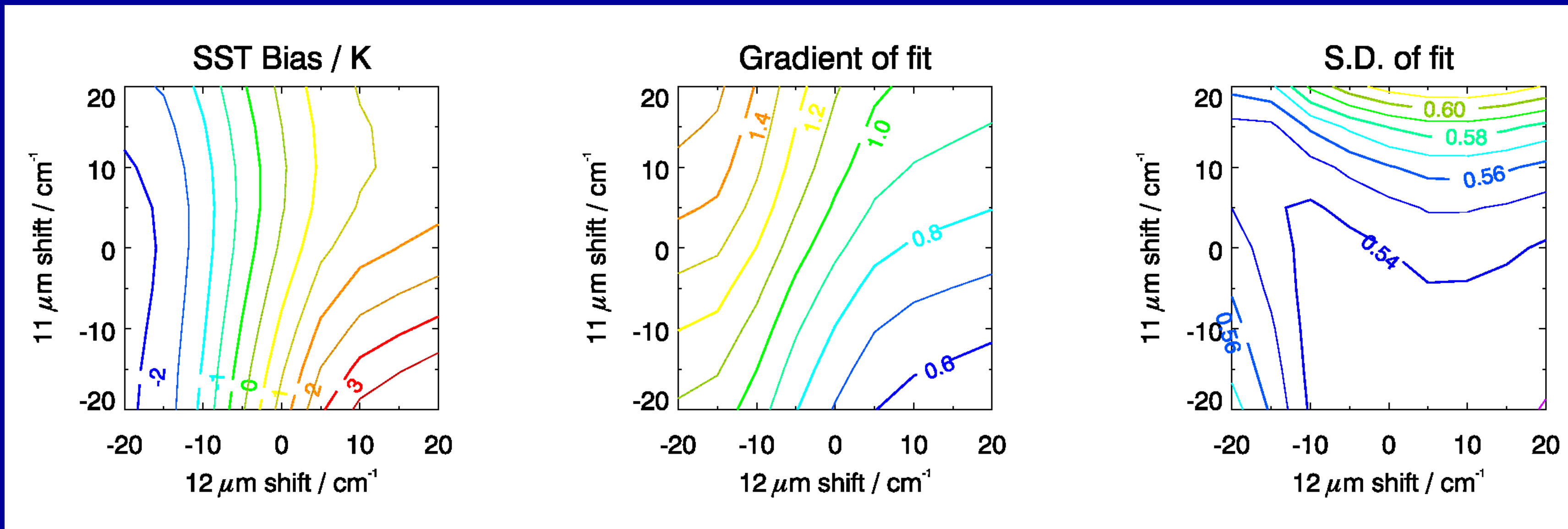
Impact of spectral response error on RT modelling

Impact is greater at high water vapour loadings

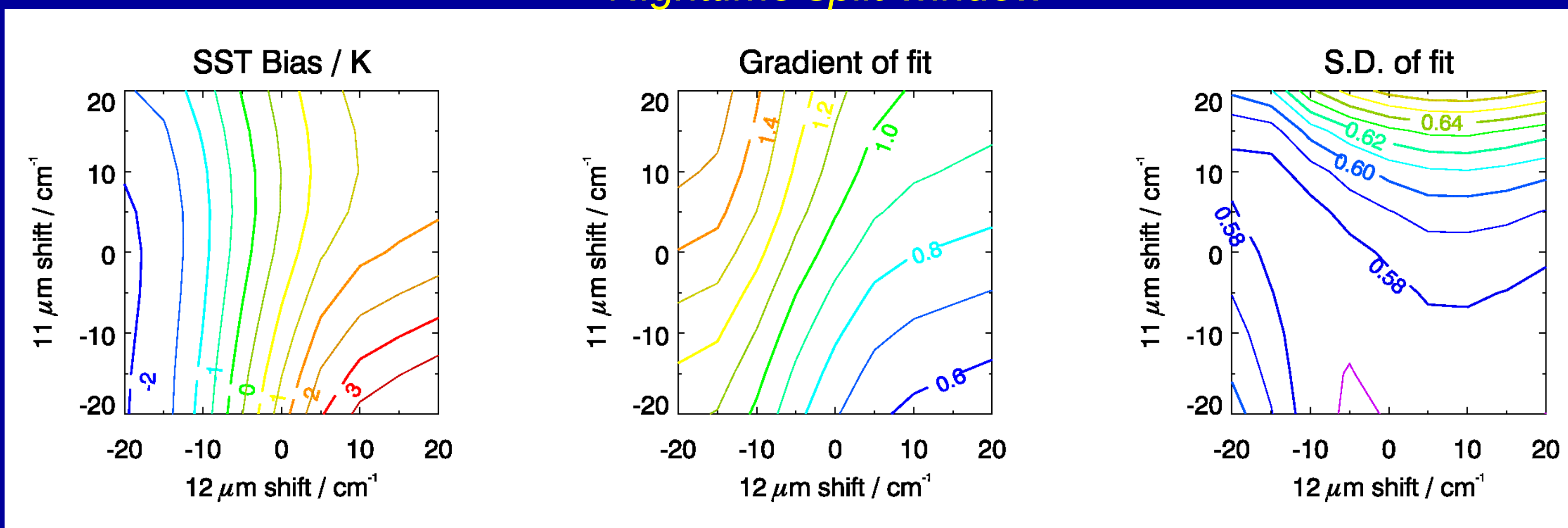
Impact is greater at higher scan angles

Results of perturbing NOAA-17 11 & 12 µm spectral response functions

Daytime split-window



Nighttime split-window



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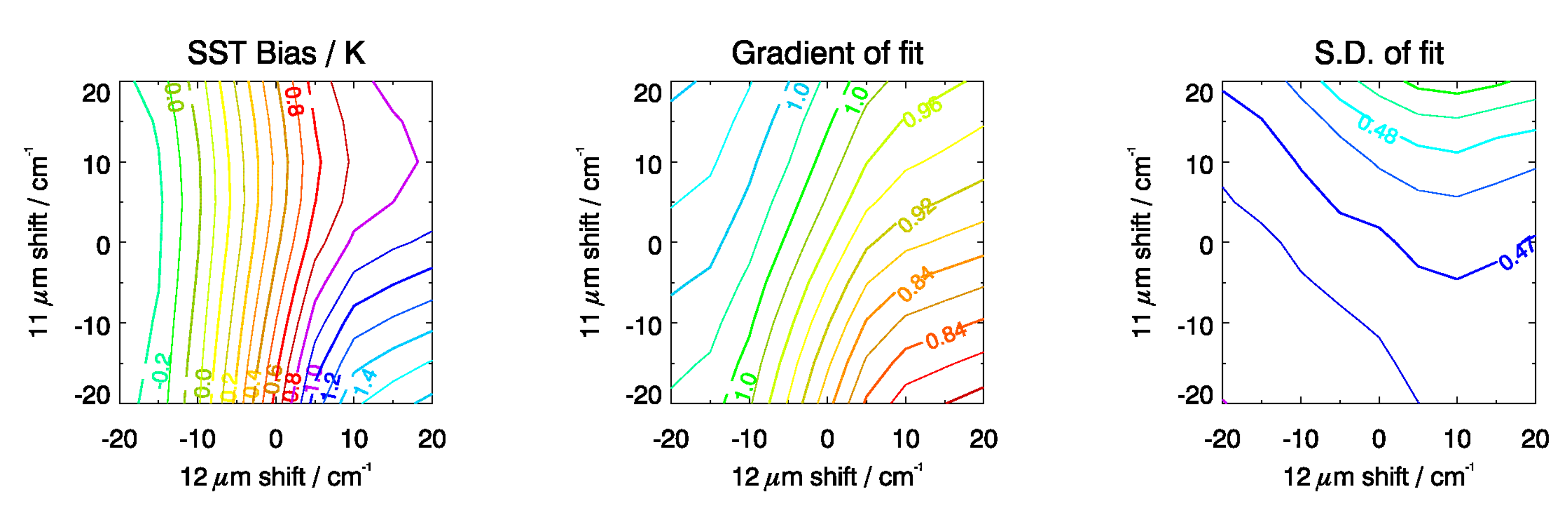
Results of perturbing NOAA-17 11 & 12 µm spectral response functions cont'd

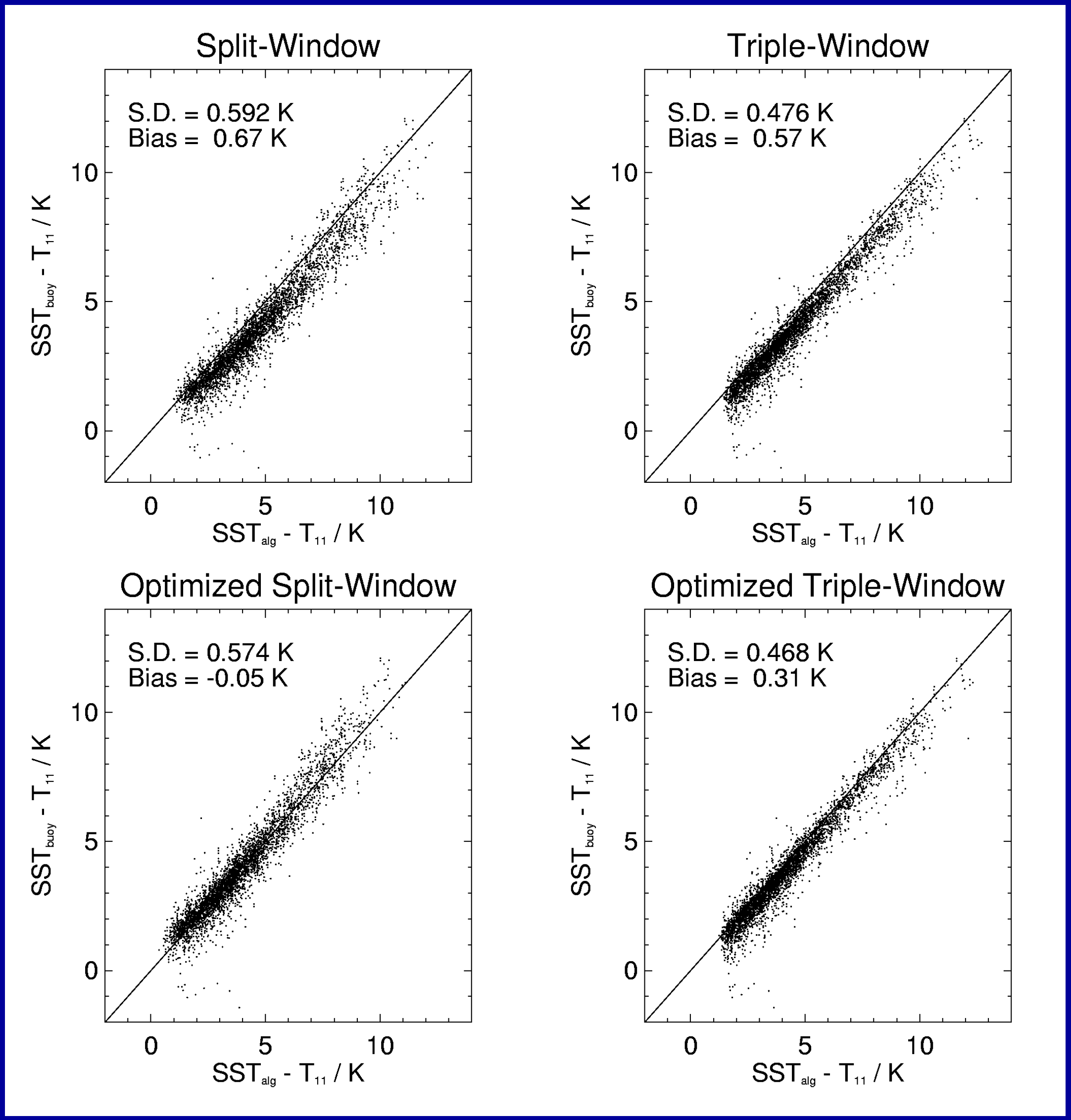
Nighttime triple window



Combination with a 3rd channel (3.7 µm) does not produce fully consistent results

Contours are much finer than for split-window retrievals – remaining discrepancies may be explained by residual instrument calibration errors

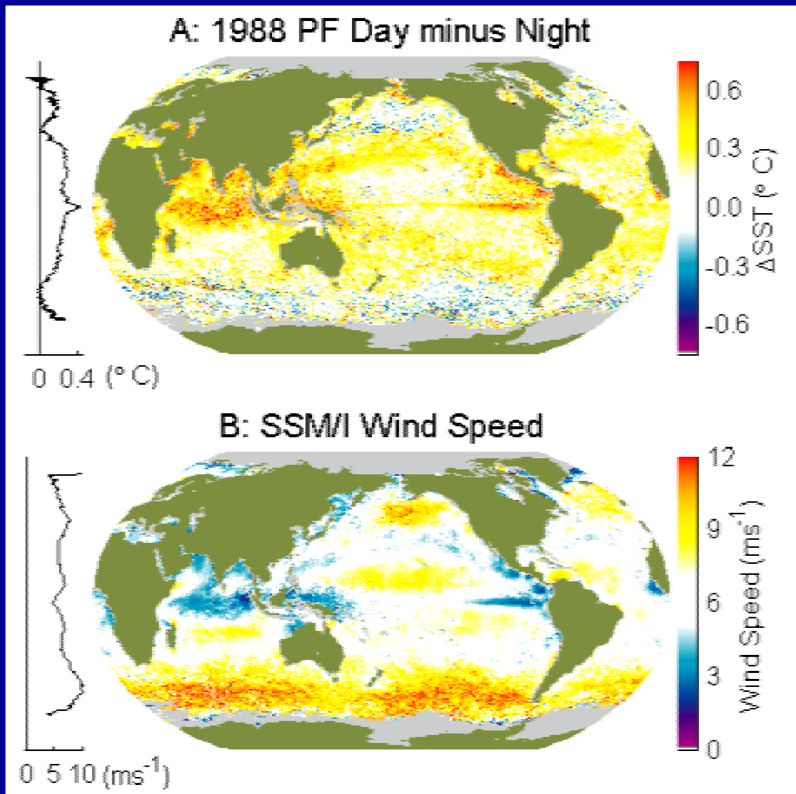
Impact of adjusted spectral response

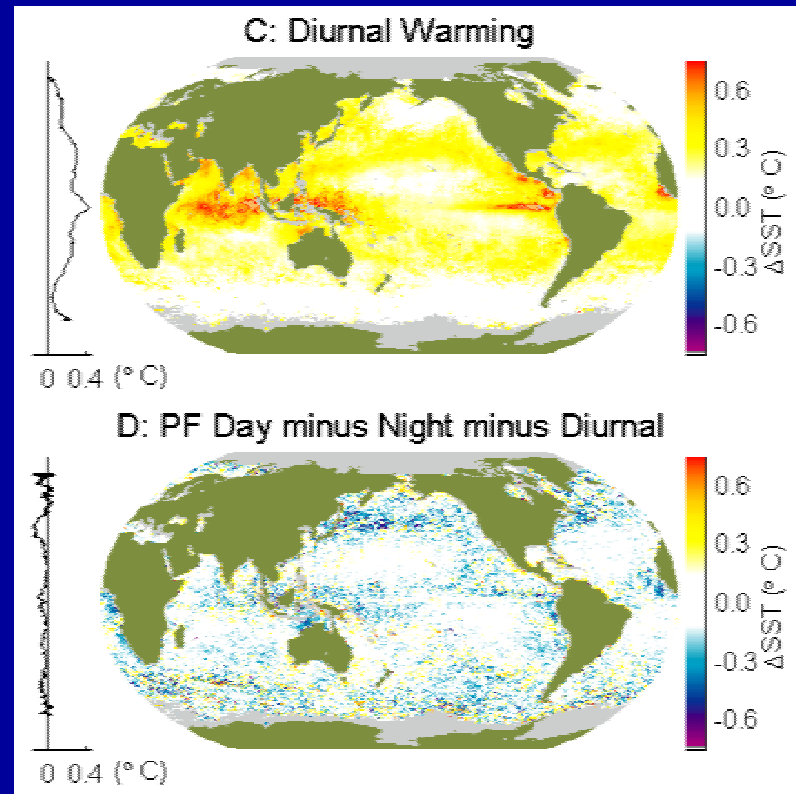


In practice, split-window retrieval will be replace by more sophisticated retrieval method

Triple-window uses adjusted filters as determined by analysis of 11 and 12 µm data

Empirical correction for diurnal warming



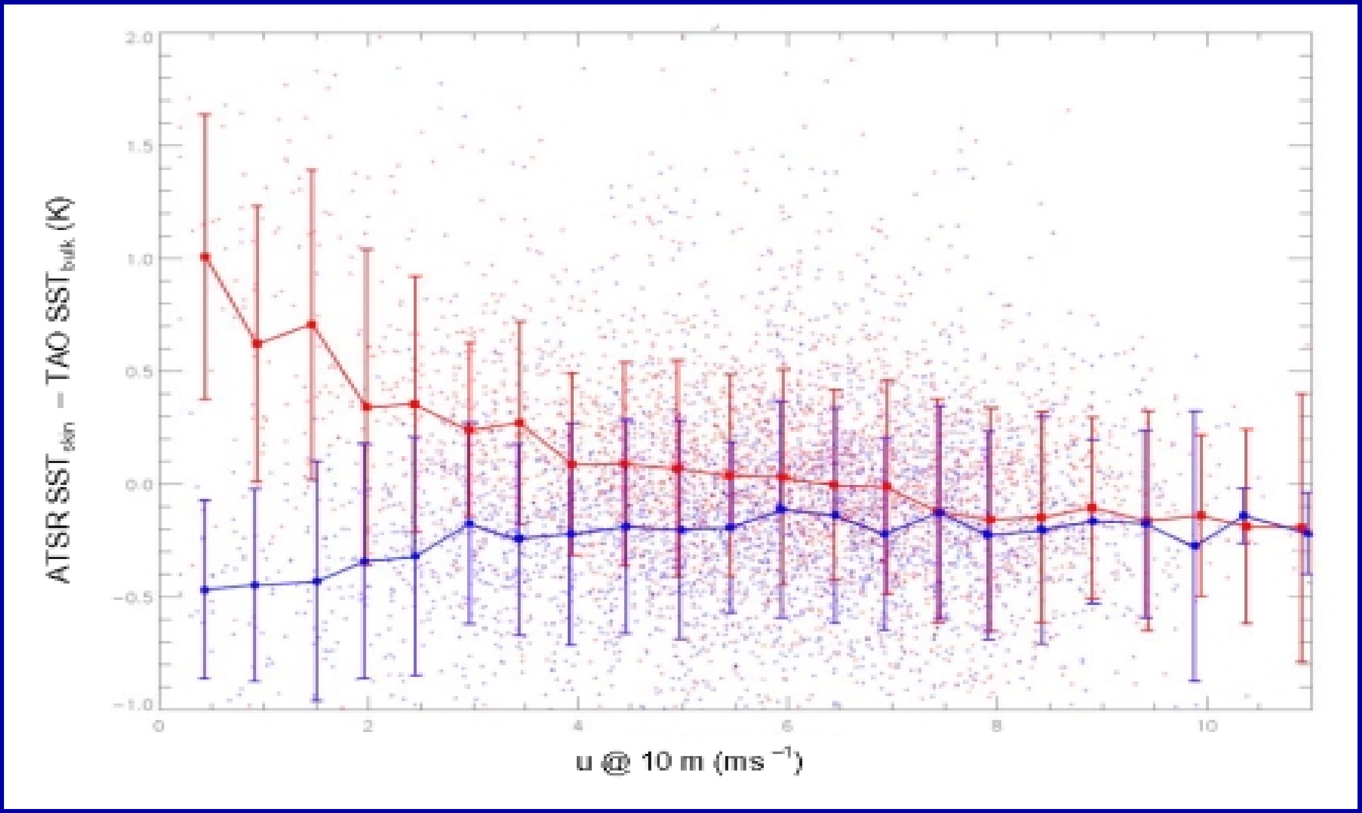


Day – night differences vary geographically. Global bias is 0.22 K

Global bias is slightly negative (-0.05 K) after correction

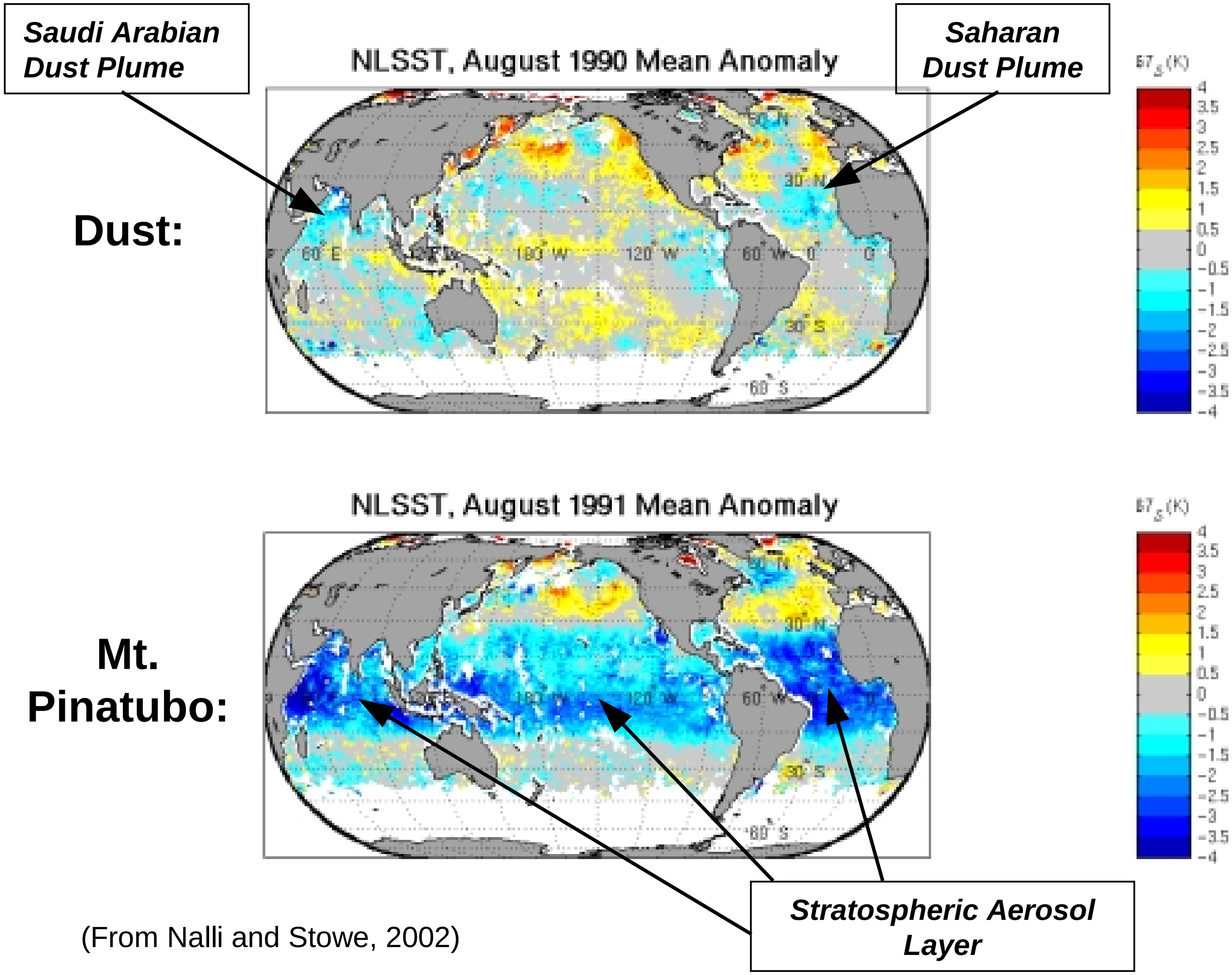
Not the final answer, but a step in the right direction

Magnitude of skin effect



- ATSR skin temperatures compared with TAO bulk SSTs show typical cool skin at night (asymptotes to approx. –0.15 degK)
- Daytime adds effect of diurnal thermocline

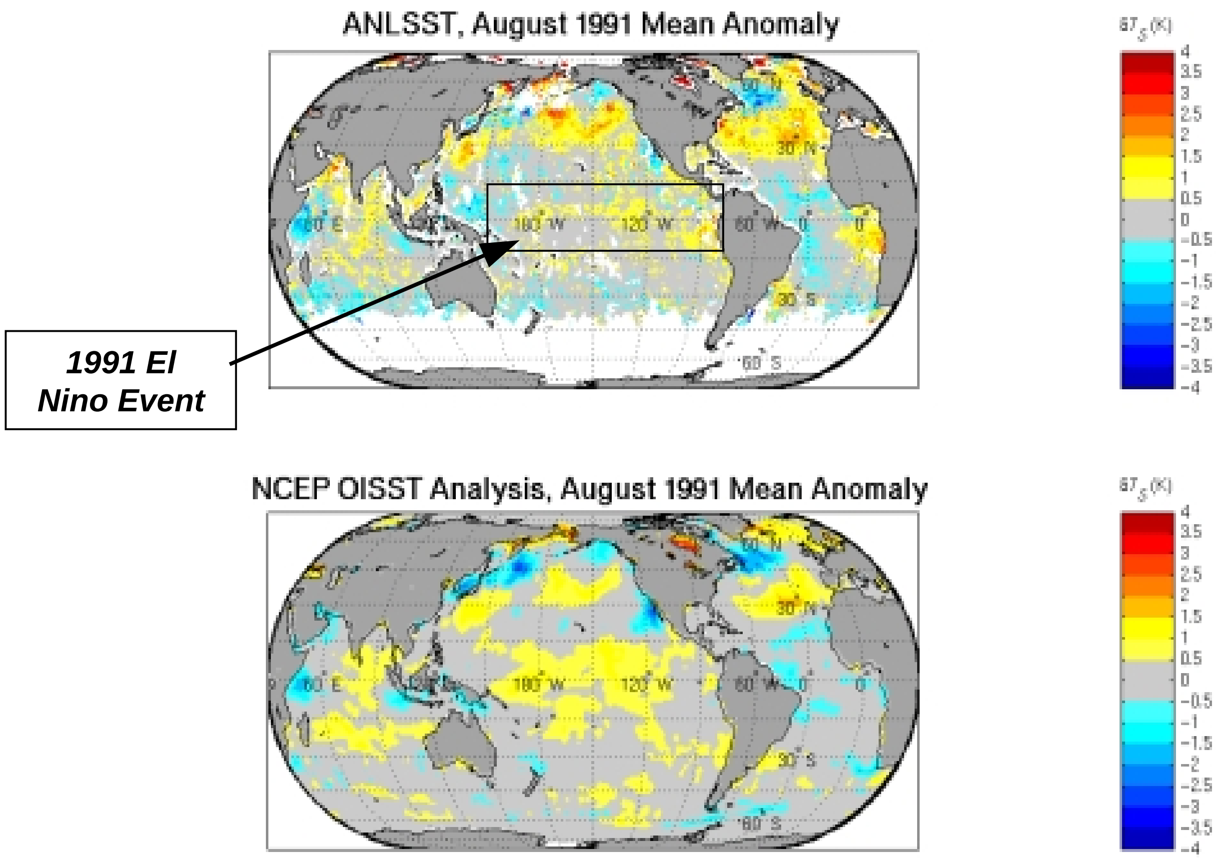
Uncorrected NLSST



(From Nalli and Stowe, 2002)

Aerosol-Corrected NLSST (ANLSST)

Correction for Mt. Pinatubo 1991

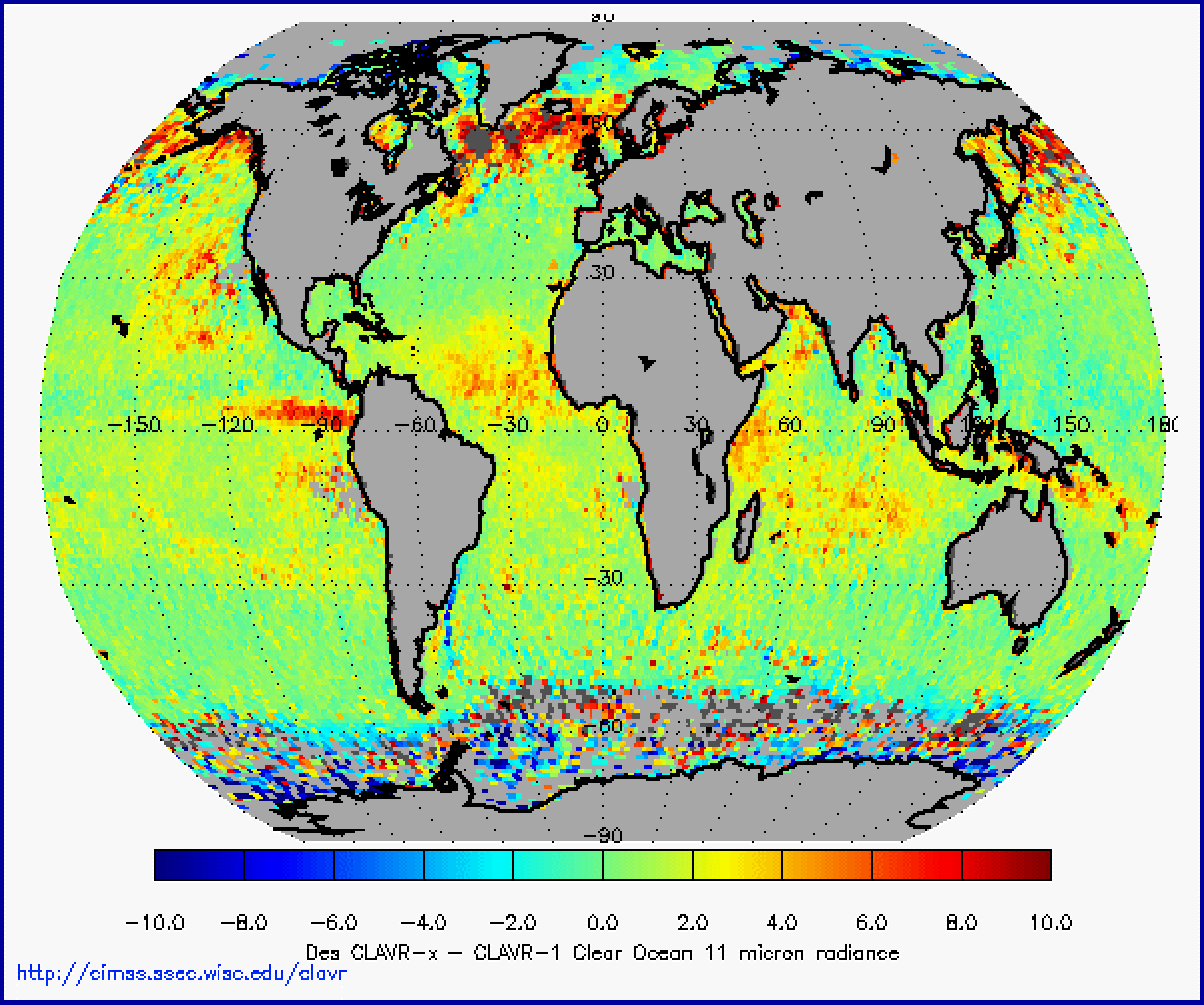


(From Nalli and Stowe, 2002)

AVHRR Reprocessing Project

AVHRR Reprocessing Project – cont'd

NOAA-11 clear-sky radiance difference

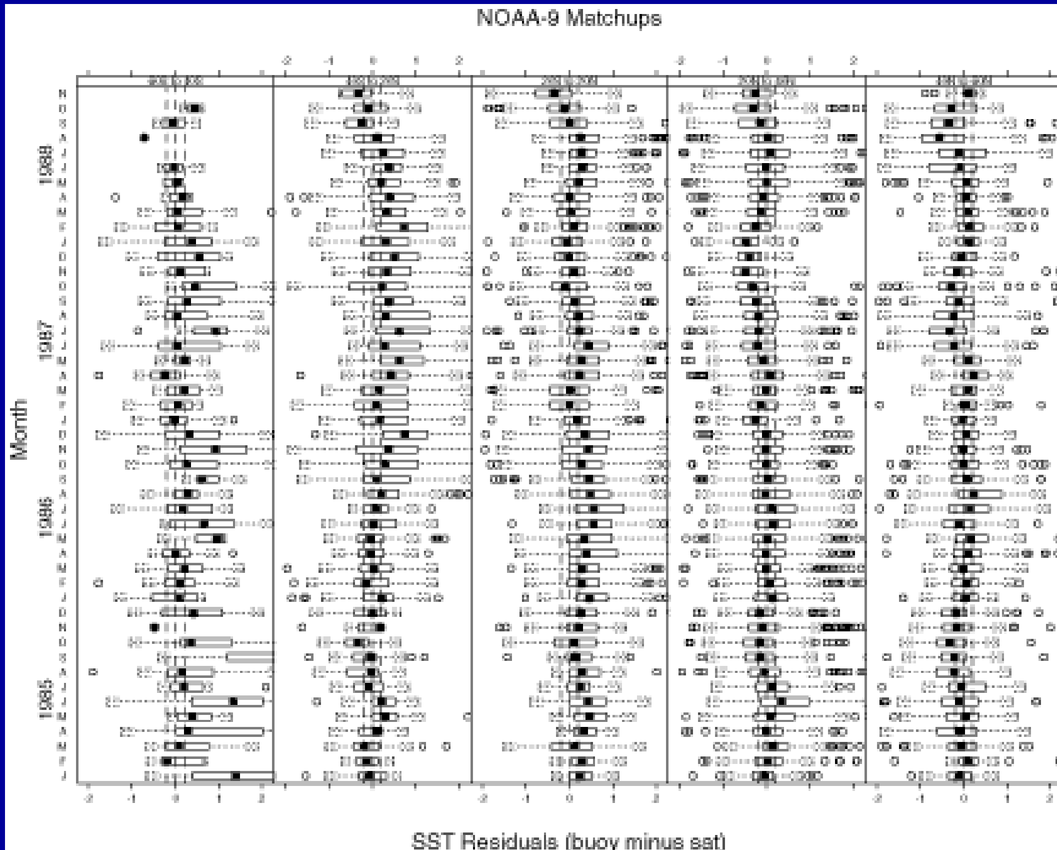


Summary

An optimal climate SST product requires:

- Careful instrument characterization “after-the-fact”
- A common retrieval framework, with known error characteristics (temporally and geographically varying)
- Modeling of surface effects (accurate fluxes preferable)
- Analysis methods to take account of characteristics of input data (e.g. non-gaussian errors) and increment covariance structure

Quality of *in situ* based SST



AVHRR Pathfinder SSTs are derived using 5-month rolling regression against *in situ*

Not done prior to 1985, quality of results displays regional and temporal characteristics