Status on a Multi-sensor Approach to Satellite-based Retrievals of Near-surface Humidity and Temperature

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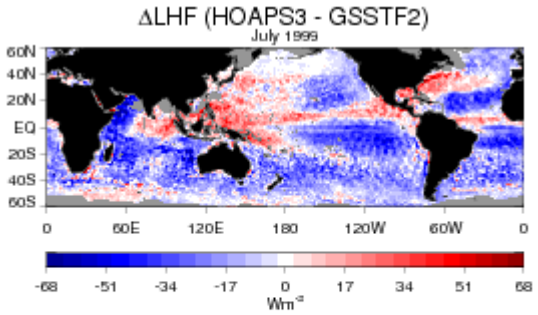
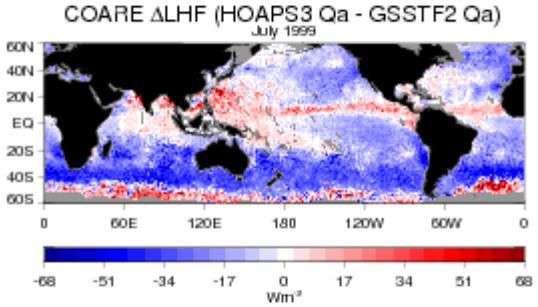
Accurate near-surface measurements of humidity and temperature are key components to retrieval of the turbulent heat fluxes.

- Bulk flux formulas require accurate inputs of SST, wind speed, Qa, and Ta (10 m height) to calculate surface turbulent fluxes.
- Improvements in accuracy of satellite SST and wind speed retrievals as outpaced retrieval improvements to Qa and Ta.
- Curry et al. [2004] indicated Qa and Ta are critical for success of achieving 10 Wm^{-2} accuracy.
- Satellite observations provide best option for global estimates of surface heat flux.

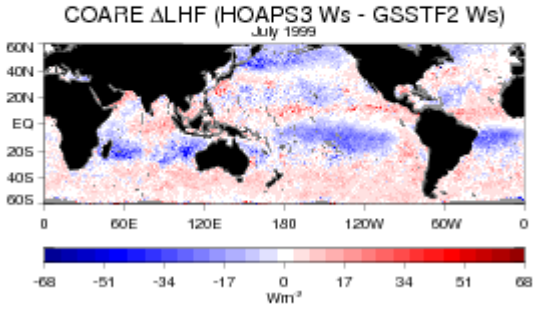
Example of LHF differences due to Qa differences



July 1999 monthly-mean difference in LHF between two satellite-derived products.



COARE-derived monthly mean difference using Qa from HOAPS3 and GSSTF2 and all other inputs fixed.

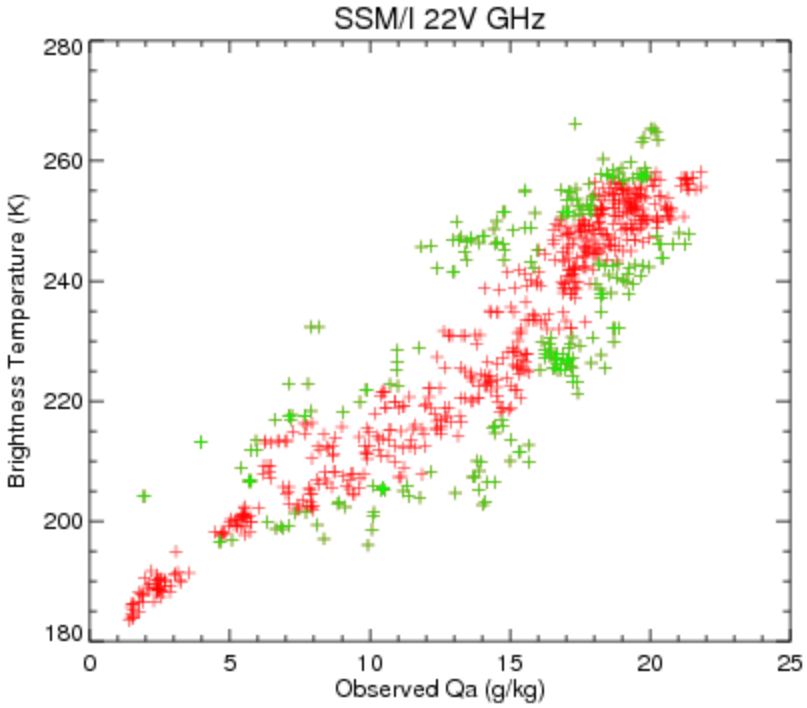


COARE-derived monthly mean difference using Ws from HOAPS and GSSTF2 and all other inputs fixed.

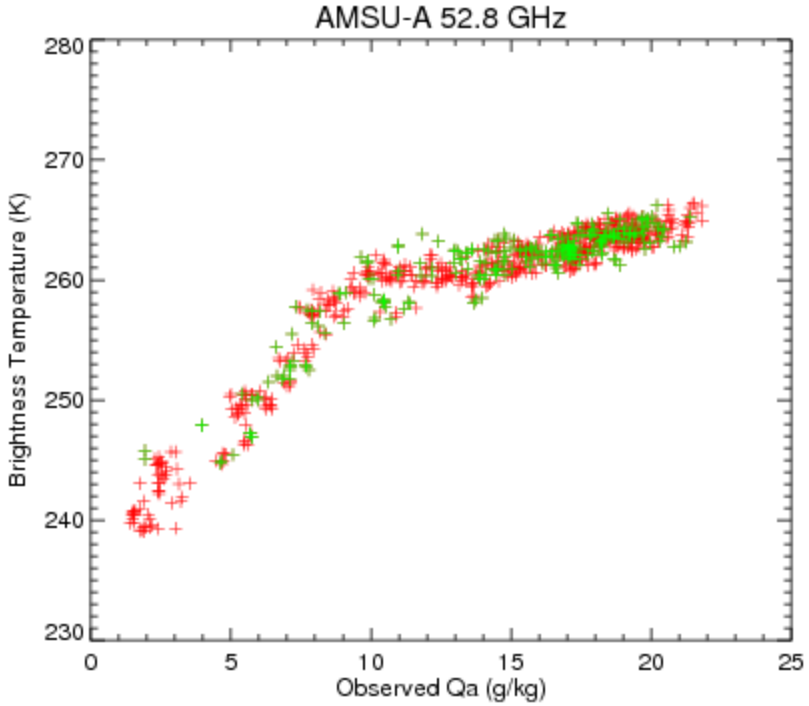
Satellite Qa Retrieval Background

- SSM/I (1987 – present) satellite observations traditionally used for Qa retrieval. Primarily utilize correlation between integrated water vapor and Qa. Most previous SSMI approaches used multi-linear regression.
- Jackson et al. (2006) improved accuracy of Qa retrievals using multi-sensor approach that used both SSM/I and NOAA-15 AMSU-A (1999-present) satellite data. Jackson et al. (2009) updated the training data set and corrected regional bias over the North Pacific and Atlantic during the summer.
- Lei Shi (NCDC) developed AMSU-A and AMSU-B neural network approach in 2008.
- Roberts et al. (2010) developed a neural network approach that uses both SSMI and SST observations.

Relationship of Satellite Radiance and Humidity

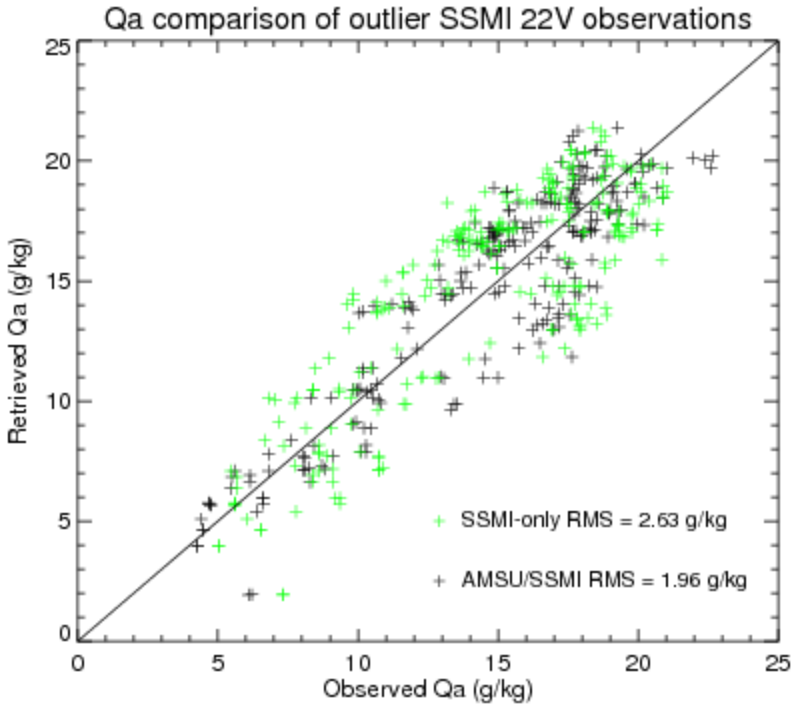


- Green points indicate satellite observations exceeding one standard deviation.
- Outliers mainly caused by deviation from standard water vapor profile.



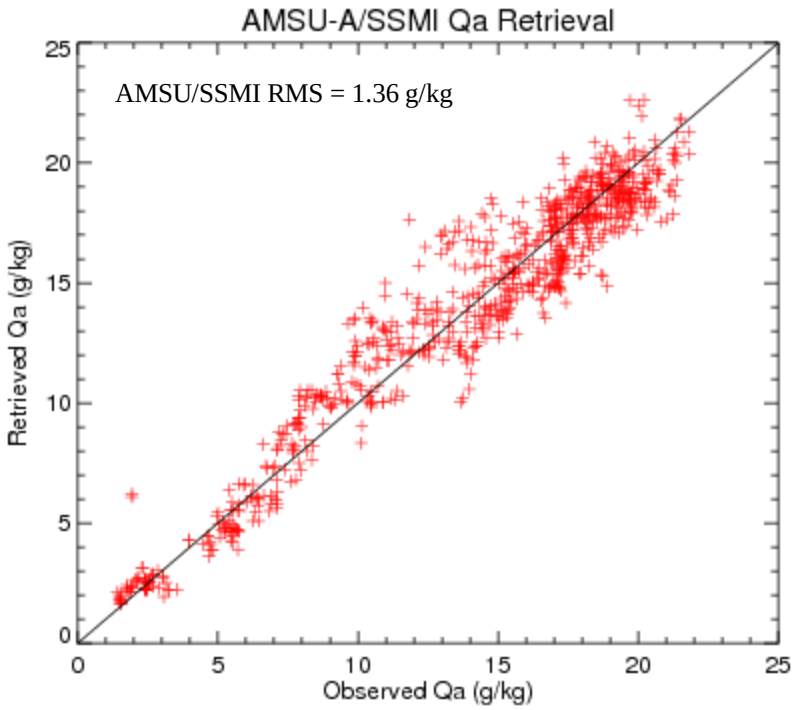
- Less scatter but non-linear due Clausius-Clapeyron relationship between temperature and humidity.

AMSU-A Impact on Qa Retrieval



SSMI-only Qa retrieval has RMS differences that are 0.6 g/kg larger than those derived using AMSU-A 52.8 GHz channel.

Jackson Qa Regressions Results

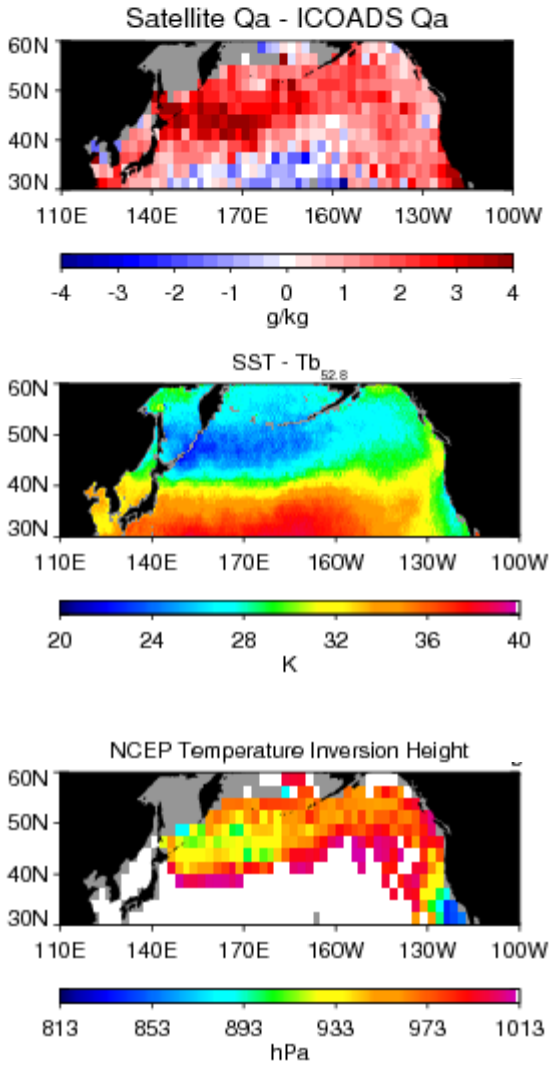


$$Qa = 1055.1 + 0.01828\, T^2_{52.8} - 8.79762\, T_{52.8} + 0.30281\, T_{19V} - 0.26577\, T_{37V} + 0.03018\, T_{22V}$$

- ~850 collocated ship observations from NOAA ESRL research vessels and satellite observations used to develop regression.
- Jackson et al. [2009] Qa retrieval uses quadratic term and more diverse set of in situ data than Jackson et al. [2006].
- Five channel SSM/I-only multi-regression retrieval has RMS = 1.74 g/kg.

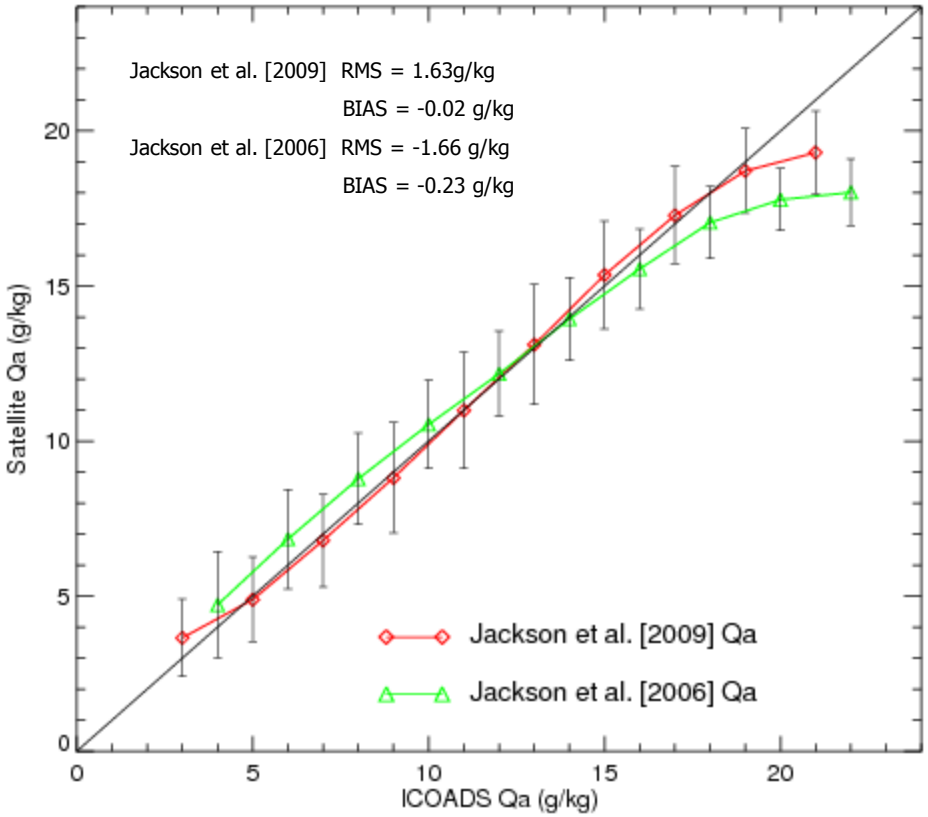
Stability Correction

July 1999



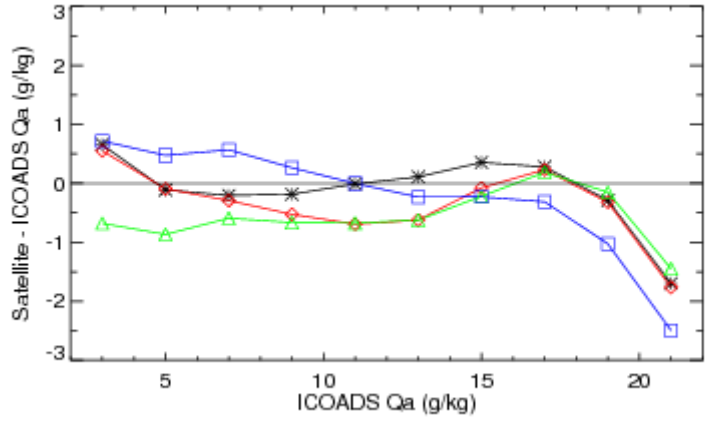
- North Pacific region shows a wet summer time Qa bias in the retrieval.
- NCEP Reanalysis data show temperature inversion regions correspond well with satellite Qa bias.
- Stability index defined as SST - AMSU 52.8 GHz channel also correspond well with Satellite Qa bias regions.
- Correct Qa wet bias using stability index and satellite – ICOADS Qa difference.

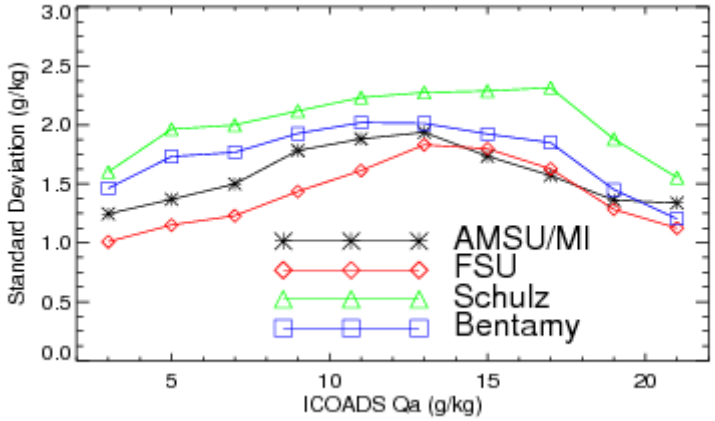
Satellite Qa Validation to ICOADS



- Used ICOADS IMMA v2.4 buoy and ship observations as independent validation.
- Updated satellite retrieval has less bias at high and low Qa.
- More in situ Qa data for middle and high Qa values improved retrieval.
- Quadratic 52.8 GHz term better represents non-linear relationship between lower tropospheric temperature and Qa.

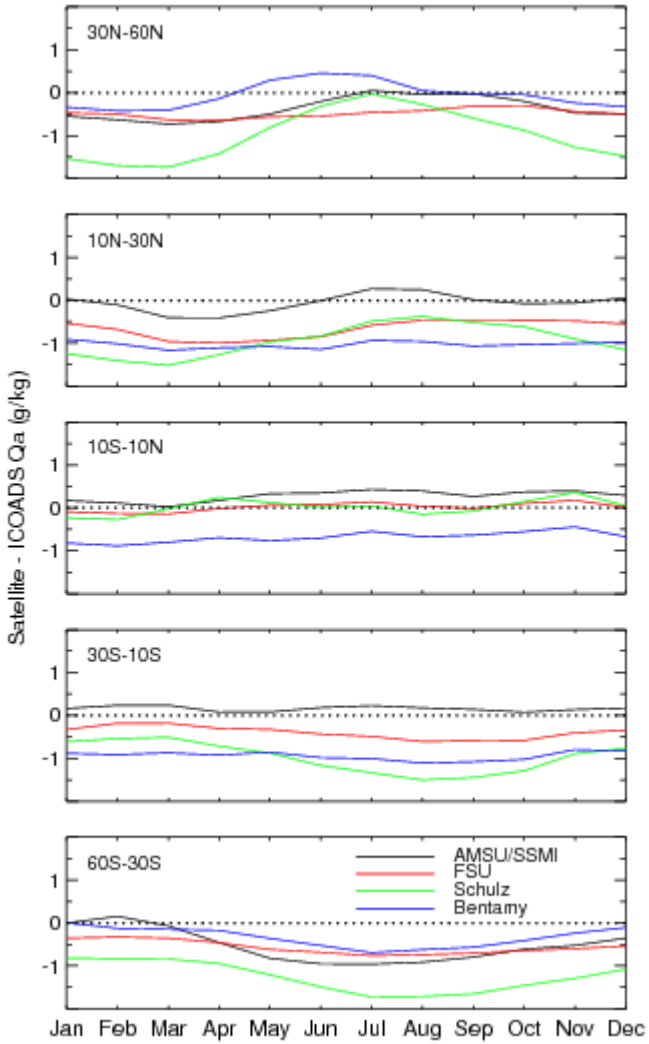
Satellite Qa Retrieval Comparison





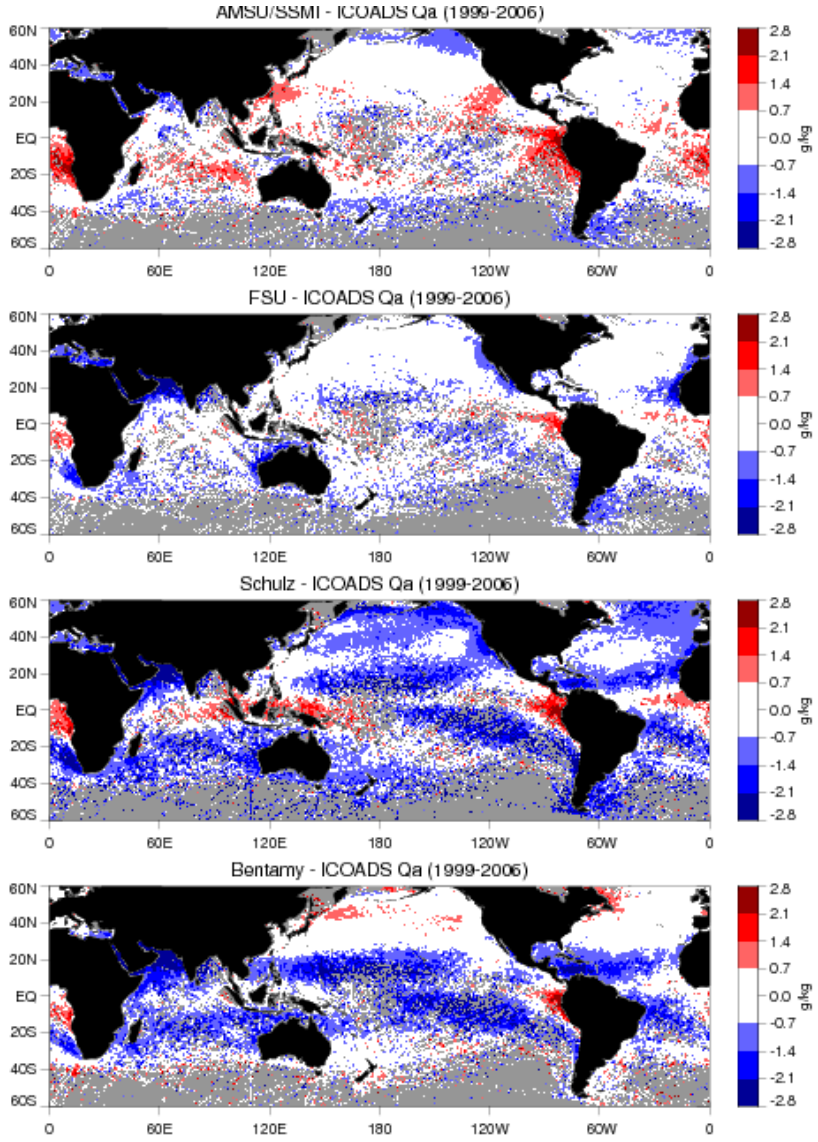
- Biases largest for Qa > 20 g/kg for all retrievals.
- Biases dependent on Qa.
- FSU Qa has lowest standard deviation and AMSU/MI shows least amount of bias relative to ICOADS.
- Schulz Qa is 1 g/kg less than ICOADS in most regions while Bentamy Qa shows bias with ICOADS at Qa > 15 g/kg.

Qa Satellite-ICOADS Seasonal Cycle



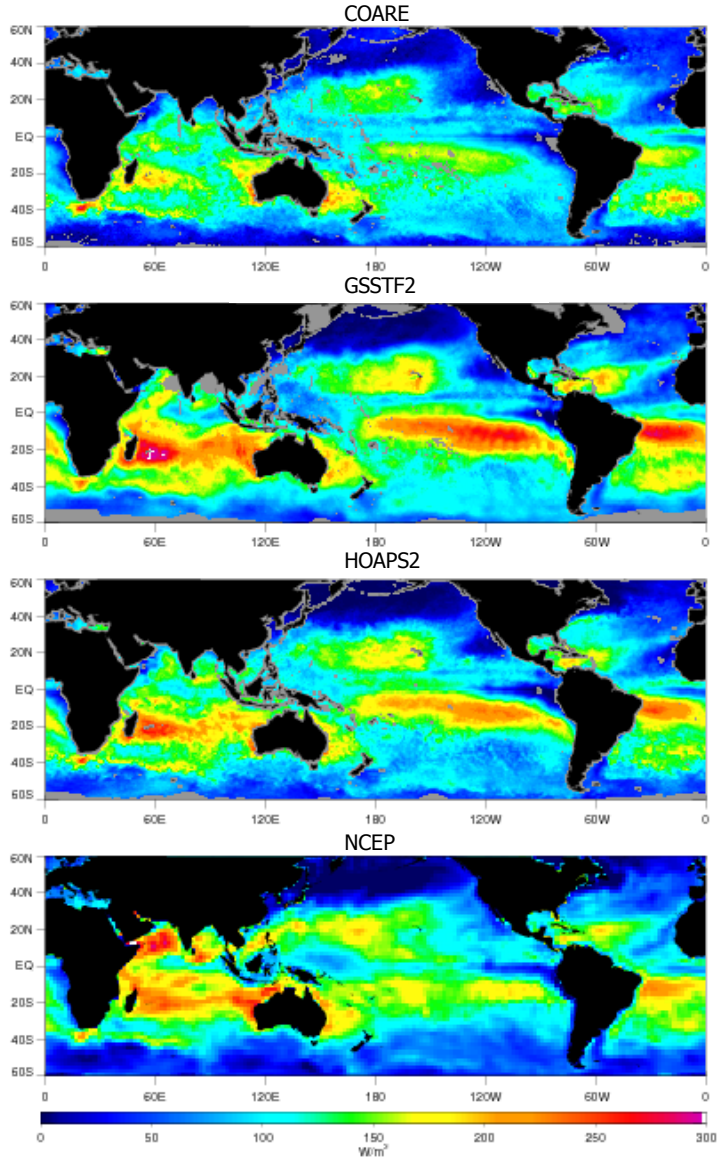
- Mid-latitude regions generally show the satellite retrievals to be drier than ICOADS.
- Subtropical regions have the AMSU/SSMI Qa in best agreement with ICOADS.
- Tropical region have ICOADS comparing best with FSU and Schulz.

Qa (1999-2006) map comparison



- All Qa retrievals have regional bias relative to ICOADS.
- AMSU/SSMI has regions more moist than ICOADS in Tropics.
- FSU shows least amount of bias in open ocean but exhibits a dry bias in western coastal regions.
- Schulz has more dry regions at all latitudes.
- Bentamy compares well with ICOADS in the mid-latitudes but drier than ICOADS in the tropical region.

Latent Heat Flux July 1999

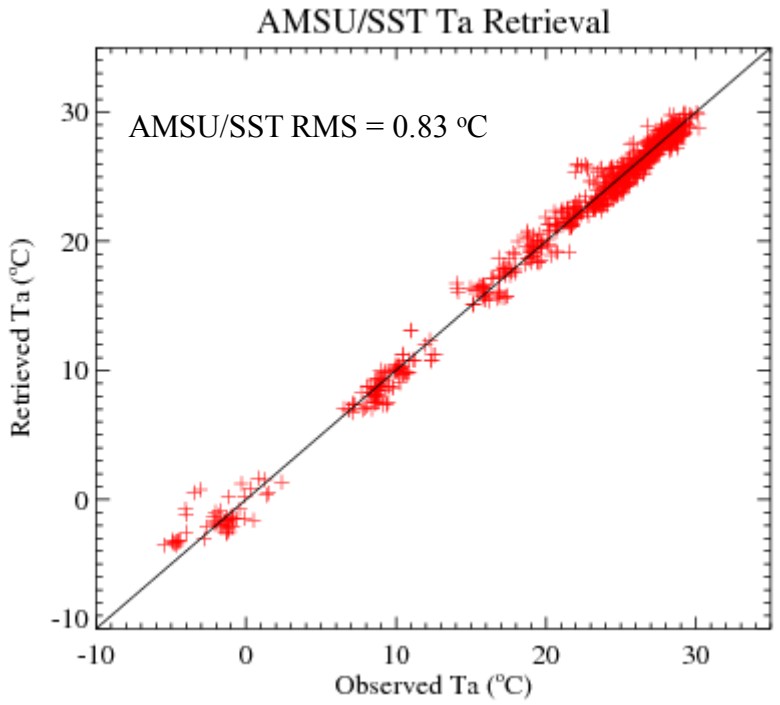


- COARE flux model using AMSU/SSMI Qa inputs indicates less latent heat flux in subtropical regions due to generally higher values of Qa.
- GSSTF2 and HOAPS2 use Qa retrievals that are drier in these regions and show significantly greater LHF.
- NCEP Reanalysis more like HOAPS2 and GSSTF2 in the Indian Ocean but has lower LHF in the Pacific subtropical region.

Satellite Ta Retrieval Background

- Satellite methods have generally not directly used satellite radiances but used satellite products such as Qa, SST, PW resulting in a retrieved Ta with high uncertainty or only regional application.
- Jackson et al. (2006) introduced a Ta retrieval using direct satellite observations from SSM/I and AMSU-A.
- Lei Shi (NCDC) has an AMSU-A and AMSU-B neural network method.
- Roberts et al. (2010) also uses direct satellite observations of SSM/I along with SST in a neural network approach.
- Most recent development combines AMSU-A and SST in a multi-linear regression retrieval.

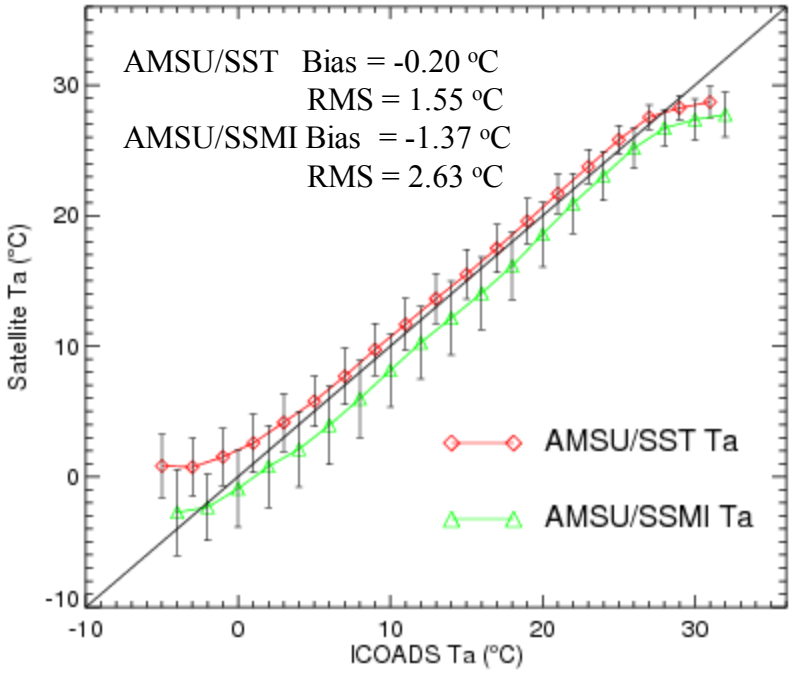
Jackson and Wick Ta Retrieval



$$Ta = -68.7550 + 0.805084\ SST + 0.408655\ T_{52.8} - 0.132514\ T_{53.6}$$

- Updated retrieval combines AMSU-A observations from 52.8 and 53.6 GHz channels with SST observations.
- Reynolds AVHRR daily averaged 0.25 degree SST used in regression.
- AMSU/SSMI Ta RMS = 1.80 °C. Reduction in retrieval Ta RMS differences of about 1 °C.

AMSU/SST Ta Validation Results

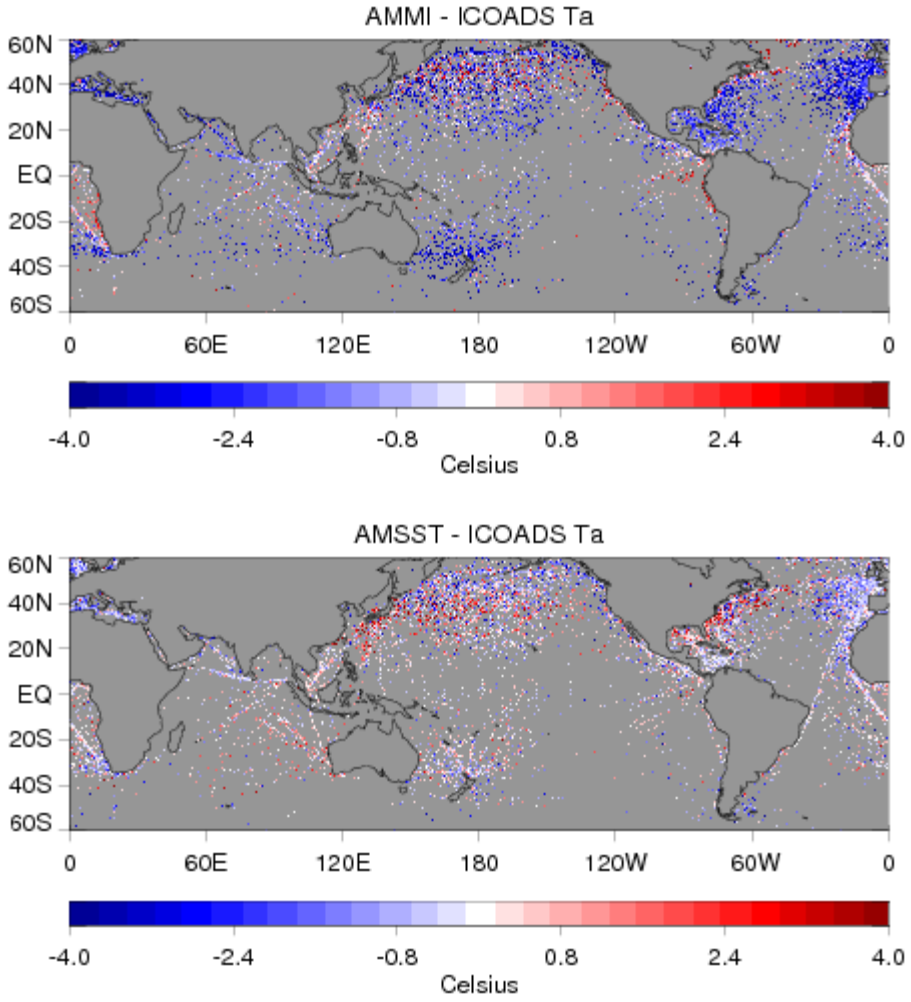


- ICOADS validation results shows updated retrieval is about 1 °C warmer than AMSU/SSMI retrieval and agrees better with ICOADS Ta observation.

- RMS errors are about 1 °C less with updated retrieval.

- New retrieval too warm when Ta < 0 °C

AMSU-A Ta algorithm comparison for 1999

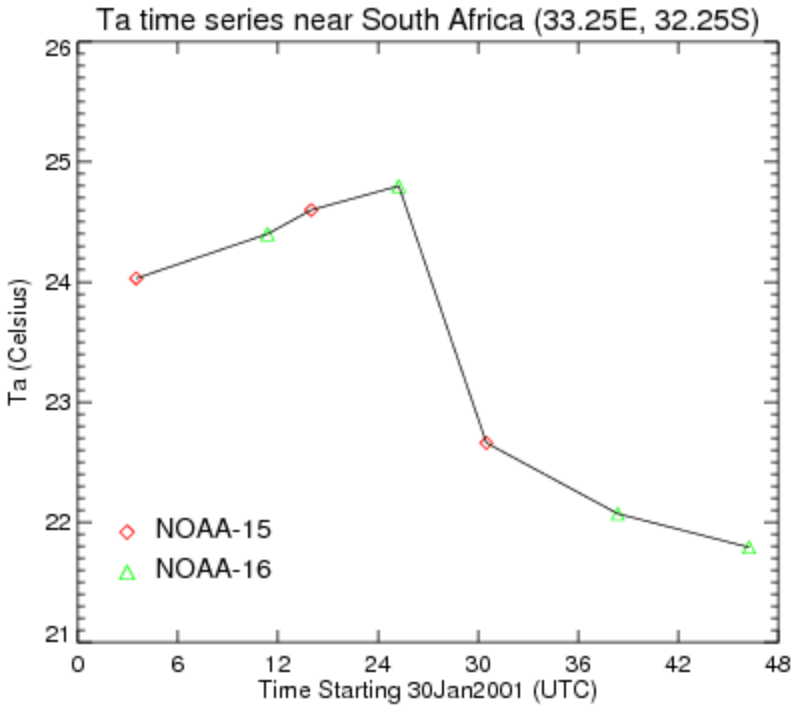


- The AMSU/SSMI Ta retrieval had notable cold bias in several regions in the Atlantic Ocean and Western Coast .

- AMSU/SST Ta retrieval removes most of the cold bias in the retrieval.

- AMSU/SST Ta has warm bias over the Gulf Stream and Kuroshio currents.

AMSU-A Diurnal Sampling

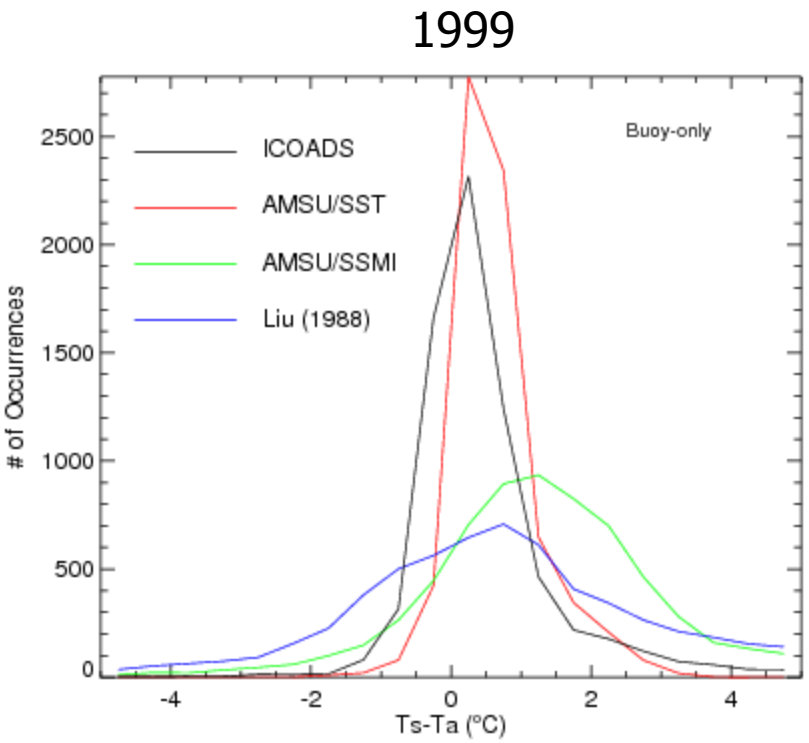


• Figure shows Ta changes over a 48 hour period using two different satellites. Two satellites typically provide 4 different time points per day.

• Currently, a suite of five satellites using AMSU could sample the diurnal cycle frequently even more frequently.

• AMSU satellites have greater diurnal coverage than SSMI. All SSMI satellites confined to ascending equatorial crossing between 17-21 LT.

Ts – Ta Relationship



- Reynolds daily mean SST used with satellite Ta observations.
- Distribution of Ts-Ta for buoy observations shows improvement from previous retrievals.
- Difficulty in accurately observing Ts-Ta < 0 °C.

Summary and Future Work

• Current multi-sensor Qa and Ta data sets span 10 years (1999-2008) with 0.5 degree spatial resolution and 3 hour time resolution. Plans are to extend this time series with current data.

• AMSU/SSMI Qa and AMSU/SST Ta datasets have relatively low bias and RMS error.

• AMSU-A is capable to providing frequent sampling of the diurnal cycle due to the several instruments in service and diverse local time observational sampling. This could allow for high temporal sampling from Ta retrieval.

• SSM/I era is coming to an end. Plan to extend the SSM/I with SSMIS data so Qa product can be extended.

• Plan to update retrievals using new AMSU-A limb correction, extend the retrieval domain from 60^{o} to 70^{o}, and apply Ta retrieval to all AMSU-A instruments.

• Improve the validation dataset by only using ship data with known instrument heights from the ICOADS and SAMOS databases. Height adjust all validation data to 10 m.