Evaluation of the satellite microwave multi-sensor retrieval of near-surface humidity and temperature using SAMOS observations and implications on satellite-derived heat and gas flux products.

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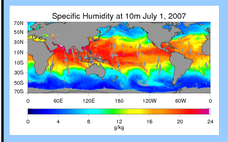
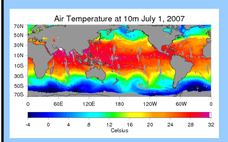
INTRODUCTION

The multi-sensor satellite retrieval of near-surface humidity (Qa) and temperature (Ta) was developed several years ago (Jackson et al. 2006, JGR). This retrieval optimally combines lower tropospheric AMSU-A temperature observations with the SSM/I microwave imager observations sensitive to total column water vapor. Previous updates to these retrievals include increasing the spatial resolution from 0.50 to 0.25 degrees, developing a unified limb correction for all AMSU-A satellites, and developing an adjustment to retrieval in regions where humidity and temperature are overestimated due to inversions in the temperature and water vapor profiles. Two new updates are presented here. The first update is introduces SSMIS microwave data into the retrievals. SSM/I observations effectively ended in 2009, so SSMIS data are needed to extend these products to the current day. The second update utilizes research vessel data from the Shipboard Automated Meteorological and Oceanographic System (SAMOS) Initiative to independently validate the satellite Ta and Qa retrievals and assess the Ts-Ta and Qs-Qa relationship of the satellite products with the ship observations. Impacts on the heat flux and CO_2 gas transfer retrievals generated using satellite-only inputs to the COARE and COAREG models is examined after corrections are made to the satellite Ta retrievals.

FLUX PRODUCT STATUS

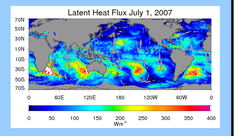


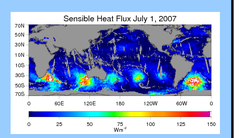


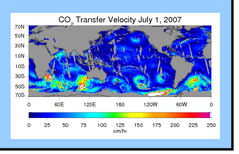
• Example of daily average flux products of 10 m specific humidity, air temperature, latent heat flux, sensible heat flux, and CO_2 transfer velocity.

• Heat flux and gas transfer products utilize COARE turbulent flux (Fairall et al. 1996, JGR) and COAREG gas transfer models (Fairall et al. 2000, Bound. Layer Met.; Jackson et al. 2012, JGR). Exclusively use satellite inputs such as Ta, Qa, Ts, U, R_l, and R_s to both models.

• 12 years (1999-2010) of satellite-derived flux products at 0.25 degree spatial resolution 3-hour time resolution. Plans are to have data available up to the current day. Web site (http://www.esrl.noaa.gov/psd/psd2/coastal/satres/realtime.html) provides near-realtime imagery of these products.

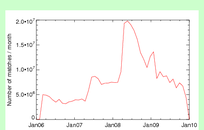


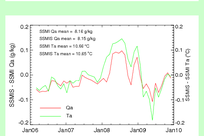




RETRIEVALS OF Ta AND Qa USING SSMIS

SSMIS is the successor of the SSM/I whose observations became available in March 2006. SSMIS channels are similar to SSM/I but adjustment of the SSMIS brightness temperatures was required to use these observations in the Ta and Qa satellite retrieval. SSMIS F16 and F17 observations were linearly mapped to be consistent with SSM/I F13 observations. Separating mappings were used for ascending and descending, and correction equations were based on one year of collocations.





• Qa retrievals were derived using SSM/I-only observations and SSMIS observations (combined with all available AMSU-A data) for a 4 year coincident period from 2006 to 2009.

• Top figure indicates the number of matched grid cells between the SSM/I-only and SSMIS-only Qa retrievals. Additional AMSU-A data from Metop-A provided more matches in 2007, and the addition of F17 SSMIS in early 2008 doubled the number of matches. Reduction of matches starting in late 2008 was due to the loss of F14 SSM/I in late 2008 and F15 SSM/I in early 2009. F13 SSM/I ended the SSM/I time series at the end of 2009.

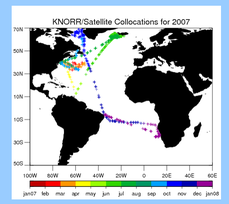
• Bottom figure indicates the difference in Qa between the matched data products. Differences between the satellite-derived products are shown to be less than 0.1 g/kg for Qa and 0.2°C for Ta. Small systematic differences are evident, particularly for Ta, when adding F17 SSMIS and removing F15 SSM/I observations but overall mean differences are small.

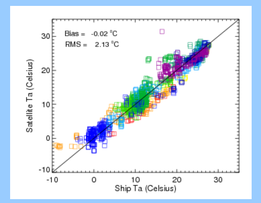
SATELLITE AND RESEARCH VESSEL COMPARISON

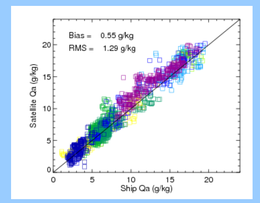
Evaluation of the satellite-derived Ta and Qa products has been conducted using research vessel data from the SAMOS Initiative (http://samos.coaps.fsu.edu/html/). This initiative provides accurate, high-quality marine meteorological and near-surface oceanographic observations from research vessels and select voluntary observing ships. Three research vessels were used in this study: Knorr, Atlantis, and Aurora Australis. The Knorr was used to evaluate and to adjust the satellite retrievals while the Atlantis and the Aurora Australis were used to validate the corrected satellite products.

Ship and satellite data were first collocated during 2007 between the Knorr and the satellite Ta and Qa products. Collocations used the satellite grid product (0.25º, 3-hourly) and one minute Knorr ship observations. Multiple ship observations were averaged for a given satellite grid cell. Satellite Ta and Qa products are defined at 10m. SAMOS Ta and Qa observations were adjusted to 10m height using the flux model described in Bourassa et al. 1999, JAS.

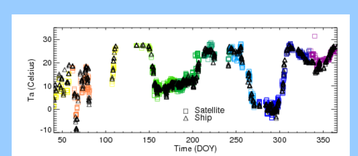
The map gives the collocations of the satellite product and Knorr observations for 2007. Color coding indicates the month of the collocation. A concentration of observations over the Gulf Stream and polar regions occur for this year, but tropical collocations also provide a good sampling of both dry and moist conditions for this year.

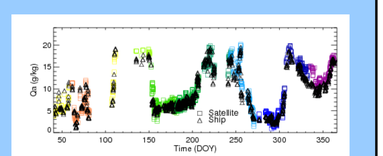






Scatter diagrams show the Ta and Qa relationships between ship and satellite observations. Ta shows an unbiased overall result; however, cold Ta observations from the ship over the Gulf Stream in March indicates the satellite retrieval failed to detect a shallow layer of cold air. The Qa relationship shows a wet bias for the satellite retrieval mainly due to the December observations in the subtropical south Atlantic. Subsidence in subtropical high regions can influence humidity and temperature profiles near the surface and bias the satellite retrieval to be too wet and warm. The time series plots also show good agreement between ship and satellite retrievals with the exceptions in March and December where Ta and Qa are overestimated by the satellite retrieval. The significant dynamic range of temperature and humidity observations over this one year period are captured well by the satellite retrievals.





SUMMARY

• 12 years (1999-2010) of Ta, Qa, sensible and latent heat flux, and CO_2 transfer velocity data have been generated and are available.
• SSMIS observations have been successfully implemented into the satellite Ta and Qa retrieval.
• SAMOS research vessel data shows good agreement with the original Ta and Qa retrieval. However, examination of the Ts-Ta and Qs-Qa relationship between ship and satellite indicated that satellite Ts-Ta needed adjustment.
• Adjustment of the satellite Ta retrieval resulted in less sensible heat flux in regions of high flux.
• CO_2 gas transfer velocity retrievals using the update Ta retrieval had small increases at high latitude locations.

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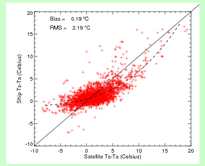
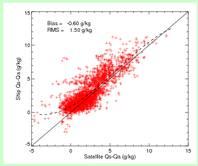
Ts-Ta AND Qs-Qa EVALUATION AND CORRECTION

The primary reason for retrieving Ta and Qa is for the computation of turbulent latent and sensible heat fluxes using bulk formulas. These formulas utilize the relationship Ts-Ta and Qs-Qa to determine gradients of temperature and humidity near the ocean surface. Ts indicates sea surface temperature from Reynolds et al. 2007, Jclim and Qs is specific humidity at the surface derived using Ts. Four years of matched satellite product data (2006-2009) and Knorr ship observations of Ts-Ta and Qs-Qa are given below.

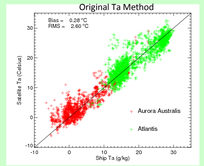


• Ts-Ta relationship between satellite and ship observations indicate overestimation of both negative and positive differences with satellite data. Best fit polynomial shown as dashed curve.

• Qs-Qa relationship is generally unbiased; however, satellite Qs-Qa indicates a few large negative values that are likely not physically reasonable.



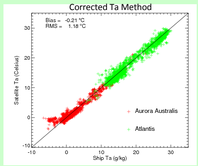
Application of the polynomial fit to the satellite Ta retrieval using the formula Ta_corrected = Ts – P(Ts-Ta) where P represents the polynomial fit shown by the curve above. The resulting updated satellite Ta retrieval was collocated with two independent SAMOS ships: the Atlantis and the Aurora Australis. The Atlantis primarily covered the coastal waters around North America while the Australis is an icebreaker used between Australia and Antarctica. Collocations occur for ~ 4 years of data (2006-2009) for the Atlantis and ~2 years of data for the Aurora Australis (2008-2009).



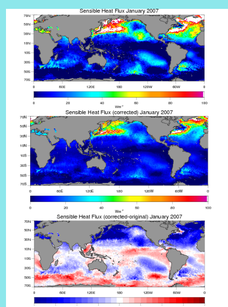
• Atlantis provides mainly warm Ta retrievals and the Aurora Australis the cold Ta observations. Bias and RMS similar to the Knorr results shown previously.

• Correction to the Ta satellite retrieval significantly reduces RMS differences between ship and satellite observations.

• Qa corrections (not shown) made insignificant improvements in the validation data.



HEAT FLUX IMPACTS



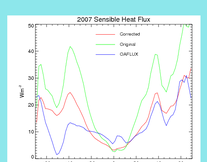
• Zonal mean changes in the satellite Ta retrieval reflect smaller overall SHF at most latitudes.

• Comparison of SHF using corrected Ta data with OAFLUX SHF (http://oaflux.whoi.edu/) shows good agreement in Northern Hemisphere but disagreement in Southern Hemisphere.

• January 2007 monthly mean global sensible heat fluxes (SHF) are shown for the original and the corrected satellite Ta retrieval. Largest fluxes occur over storm track regions of the Northern Hemisphere.

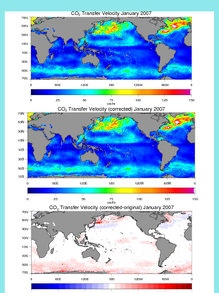
• Differences show a reduction of SHF in the storm track regions and enhancement of SHF in regions with low or negative flux.

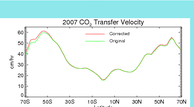
• SAMOS correction to the Ta retrieval had significant impact on global distribution of SHF.



GAS FLUX IMPACTS

Gas transfer velocity, k, is an essential parameter required to determine gas flux at the ocean surface given by equation $F = k\,\Delta(pCO_2)$. While most parameterizations of k are empirically related to only wind speed, COAREG models molecular and turbulent processes to determine k; therefore, Ta and sensible heat flux in this model impart buoyancy affects on gas transfer.





• January 2007 monthly mean gas transfer velocities show the highest values in the storm track regions where high wind speeds cause significant bubble-mediated exchange of gas.

• Difference map indicates sensitivity of Ta inputs in the COAREG model. CO_2 transfer velocity generally increased at high latitudes particularly near Japan and Newfoundland.

• Zonal averages indicate largest changes occur at high latitudes which ultimately results in greater gas flux.