Observed and Modeled Air-Sea Flux in the Northwest Tropical Atlantic

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Introduction

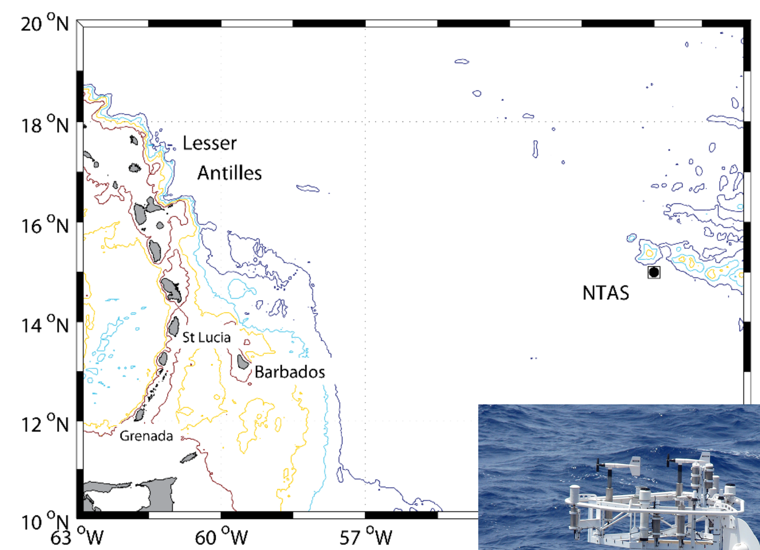
A surface mooring site, called the Northwest Tropical Atlantic Station (NTAS) has been maintained with NOAA support since 2001. Surface meteorological variables observed on the NTAS buoy are withheld from models and made available as independent reference data to explore air-sea interaction processes, validate remote sensing products, anchor hybrid air-sea flux fields, and investigate model performance.

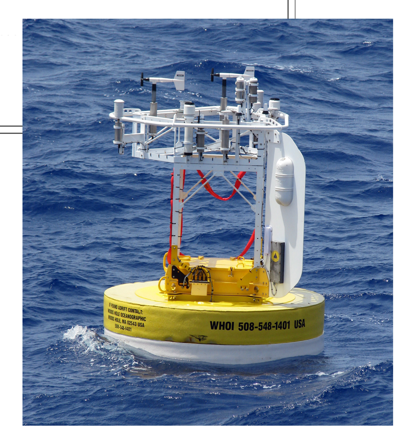
The NTAS site is located at 51°W, 15°N, roughly 1,000 km east of the lesser Antilles, in the North Atlantic trade wind regime.

The NTAS buoy is outfitted with ASIMET meteorological instrumentation (Hosom et al. 1995), measuring ten variables that enable fluxes of momentum, heat and moisture to be computed.

Moorings are replaced annually. Calibration, intercomparison, and characterization of errors (e.g. island heat effect, flow distortion) improve measurement accuracy.

Heat flux component errors are 2-4 W/m^2, while the error in net heat flux is about 8 W/m^2 (Colbo and Weller (2009) and Bigorre et al. (2013).

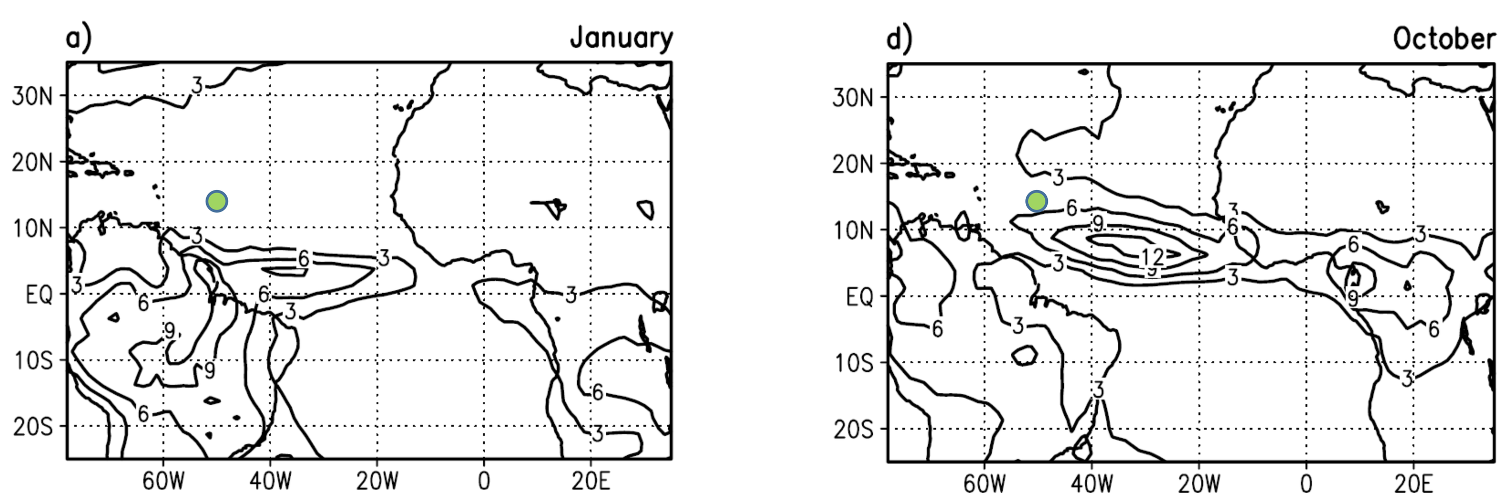




Influence of the ITCZ

Trade winds from the Northern and Southern hemispheres converge at the Intertropical Convergence Zone (ITCZ), which can be identified as an east-west precipitation band migrating seasonally north and south. The ITCZ has a mean location near 6 N in the Atlantic. Cloud cover associated with the ITCZ influences the regional radiative forcing.

The seasonal cycle is the dominant signal in heat flux at the NTAS site, but there are notable impacts from the northernmost excursion of the ITCZ in the fall (Sep-Nov): Wind speeds drop, precipitation peaks, and a distinct "shoulder" is seen in longwave radiation.



Contours of precipitation rate (mm/d) in the topical Atlantic for (left) January and (right) October. These are 17-year monthly composites from blended satellite and rain gauge products (Chiang et al., 2002). The NTAS site is indicated by the green dot.

Data Availability

Time series data of surface meteorology for individual deployments are available from
http://uop.whoi.edu/currentprojects/NTAS/ntasarchive.html

Concatenated, multi-year time series of meteorological data and fluxes are available from
http://uop.whoi.edu/ReferenceDataSets/ntasreference.html

Methods

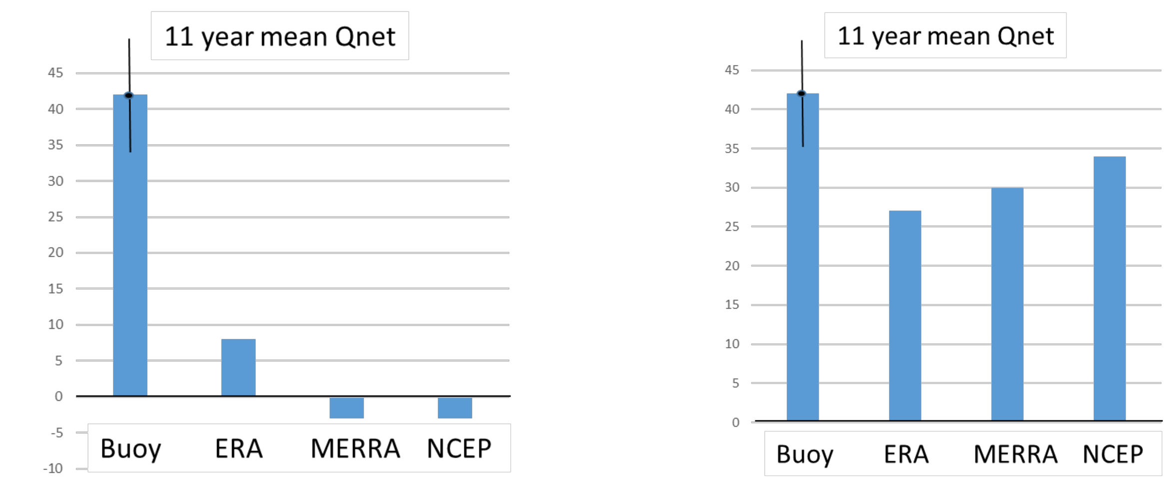
The buoy meteorological measurements are a contiguous 11 year data set at 1 minute intervals from mooring deployments between April 2001 and March 2012. For comparison to models, the buoy data were averaged to daily values and adjusted to standard heights. Air-Sea fluxes were estimated using the COARE 3.0 bulk algorithm (Fairall 1996; 2003), which takes into account air stability.

The buoy fluxes were used to describe the seasonal cycle, to identify the presence of the ITCZ, and to diagnose the strengths and weaknesses of three reanalysis model products:

- ERA-Interim (European Center for Medium-Range Weather Forecasts),
- MERRA-2 (National Aeronautics and Space Administration).
- NCEP-2 (National Centers for Environmental Predictions)

Results – Buoy flux vs. models

Comparing the native fluxes (as received in the reanalysis models) to the buoy fluxes showed significant differences (larger than the buoy errors) in several flux components. The eleven-year mean buoy Qnet showed an ocean heat gain of 42 W/m^2, while NCEP and MERRA showed heat loss of a few W/m^2. Applying the COARE algorithm to the surface meteorological variables from the models brought the turbulent flux components closer to the buoy values and reduced the Qnet discrepancies to about 10 W/m^2.



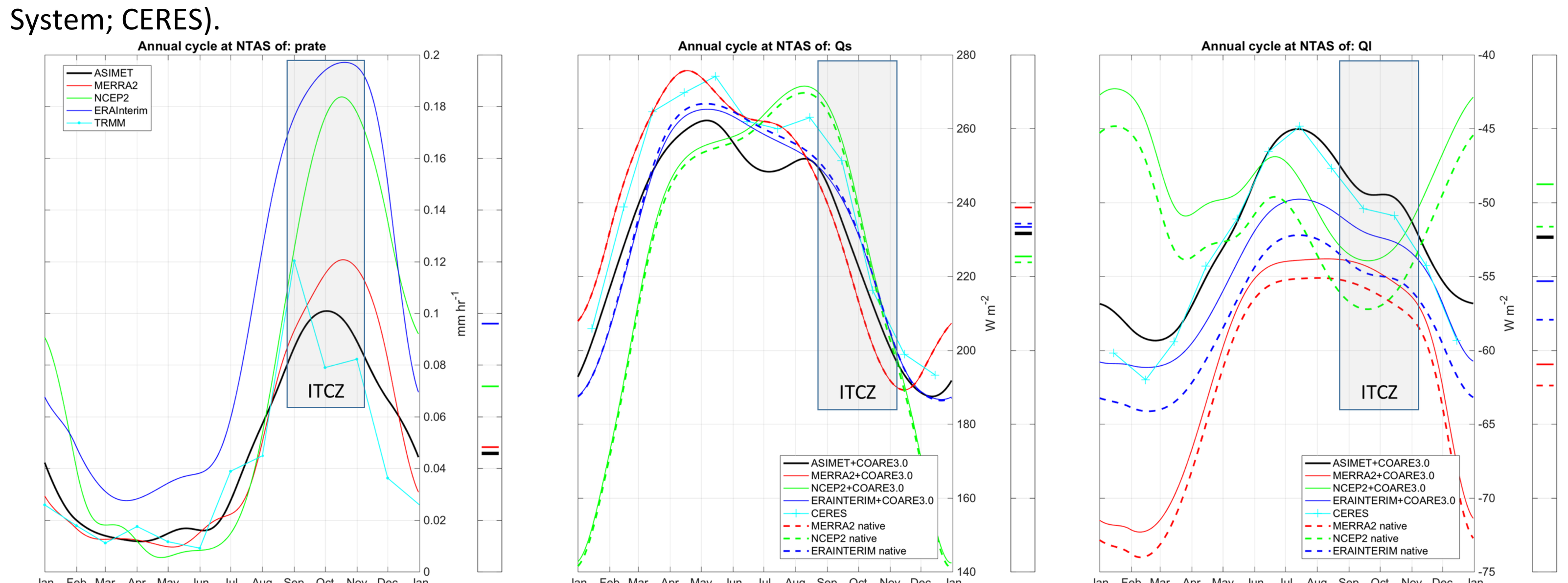
Eleven-year average net heat flux from the NTAS buoy compared to (left) the native fluxes from the models and (right) fluxes computed using the COARE algorithm and surface meteorological variables from the models. Error bars of +/- 8 W/m^2 are shown for the buoy flux.

The majority of the discrepancy in net heat flux after applying the COARE algorithm was found in the radiative fluxes.

- Shortwave radiation (SWR): ERA in good agreement with buoy; MERRA overestimates ocean heat gain; NCEP underestimates ocean heat gain, especially in winter.
- Longwave radiation (LWR): ERA in good agreement with buoy; MERRA shows a persistent low bias; NCEP is a poor match to the observed annual cycle.

The annual cycle of precipitation was reproduced reasonably well by all three reanalysis products, although with notable differences in amplitude, especially near ITCZ . ERA and NCEP are high compared to the buoy while MERRA is similar.

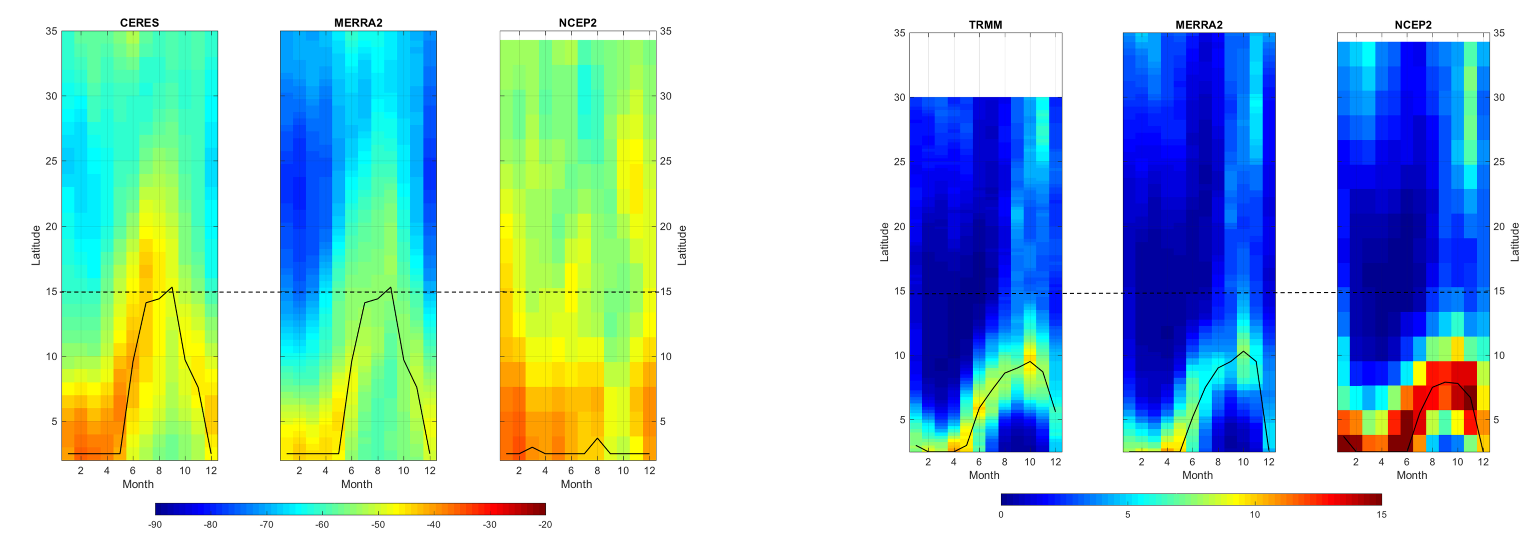
There is a good agreement between buoy measurements and satellite remote sensing products for precipitation (Tropical Rainfall Measurement Mission; TRMM), shortwave and longwave radiation (Clouds and Earth's Radiant Energy System; CERES).



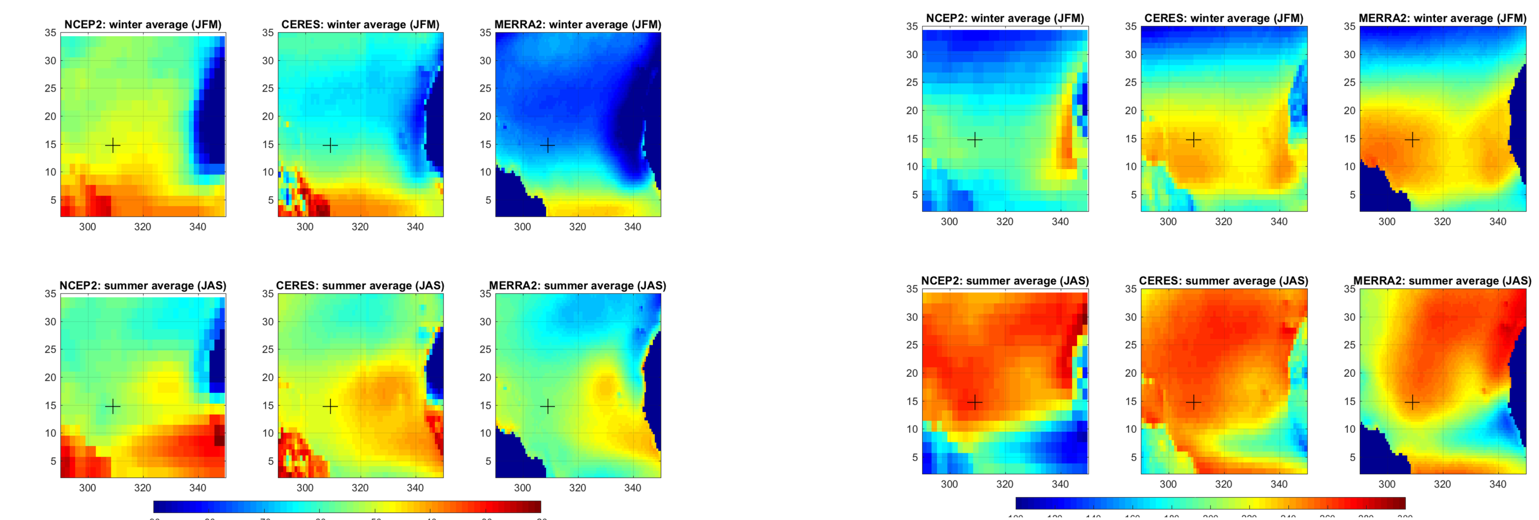
Eleven-year mean annual cycle of (left) precipitation, (middle) shortwave radiation, (right) longwave radiation at the NTAS site from the buoy compared to three reanalysis models. Remote sensing observations from (left) TRMM (middle and right) CERES are also shown. The time period influenced by the ITCZ is shaded.

Results – Satellite flux vs. models

Satellite remote sensing (e.g. CERES) and model products allowed regional patterns of the annual cycle to be examined: MERRA shows a pattern of LWR variability comparable to that of CERES, although with a notable low bias.
NCEP radiation patterns are different in outer tropics in winter (similar to discrepancy with NTAS buoy), and near Equator in summer.
Precipitation is well represented in models, although it is enhanced near South America in NCEP .



Hovmoller diagrams for: net longwave radiation (W/m^2, left), precipitation rate (mm/d, right) showing the annual cycle vs. latitude for eleven-year means. Solid lines indicate the maximum value for each month. A dashed line is shown at the latitude of the NTAS mooring. Based on longitudinal averages from 51W to 44W.



Maps of net longwave (left) and shortwave (right) radiation (W/m^2), for winter and summer, using data from 2001 to 2012.

Conclusions

- Native fluxes from ERA, NCEP and MERRA showed large differences in individual flux components and net heat flux (Qnet) relative to the buoy.
- Using a common bulk flux algorithm brought the turbulent flux components closer to the buoy values and reduced the Qnet discrepancies to about 10 W/m^2.
- Radiative fluxes from the reanalysis products were inconsistent in reproducing the observed annual cycle. ERA performed well, MERRA had persistent biases, and NCEP showed large discrepancies.
- A regional assessment comparing remote sensing products to the models indicated that seasonal variability in cloud cover (as diagnosed from longwave radiation) is not well reproduced in some of the models, leading to the radiative flux discrepancies.
- Precipitation showed relatively good agreement among observations, models and remote sensing products. Thus, to the extent that radiation differences were due to clouds, precipitating clouds did not appear to be the main culprit.

Acknowledgment

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CINAR Cooperative Institute for the North Atlantic Region

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