Annual Report to
NOAA's Climate Variability and Predictability Program

Investigation of Surface Flux and Cloud/Precipitation Aspects of Air-Sea Interaction in the Tropical Eastern Atlantic

C. W. Fairall, D. Wolfe, L. Bariteau, S. Pezoa
NOAA Earth System Research Laboratory

Period covered by this report: Oct 1, 2005 - Sept 30, 2006
Project Manager: C. W. Fairall, Chief of Weather and Climate Physics Branch.
NOAA Earth System Research Laboratory Physical Sciences Division, 325 Broadway, Boulder, CO 80305
303-497-3253 Chris.Fairall@noaa.gov
Finance Contact: Jo Novosel, 303-497-6588 Jo.Novosel@noaa.gov
Lab Director: William D. Neff

7 January 2007

Investigation of Surface Flux and Cloud/Precipitation Aspects of Air-Sea Interaction in the Tropical Eastern Atlantic

Background

In this project we plan to analyze observations from a ship-based measurement program to obtain statistics on key surface, atmospheric boundary layer, cloud macrophysical and microphysical, and radiative properties relevant to NOAA's CLIVAR Atlantic Program. We plan to place a suite of instruments on NOAA ships deploying and servicing new buoys at 23W. The buoys are part of a joint NOAA AOML/PMEL project funded by NOAA's Office of Climate Observations (OCO).

The principal goal of the study is to examine the role of local air-sea interaction in the annual cycle of the Tropical Atlantic cold tongue and ITCZ complex. A second goal is to investigate modification of surface flux parameterizations in the presence of deep convection. The project will also provide comprehensive detail at a few points within a large array of *in situ* and satellite observations being used to investigate Tropical Atlantic variability.

The basic objectives of the measurements and analysis are to:

*Provide an assessment of the balance of surface fluxes and ABL structure in the TA equatorial cold tongue and ITZCZ complex.

*Advance development of bulk turbulent and radiative flux parameterizations either directly or by linking with LES and CRM research efforts.

*Advance understanding of the role of convective clouds, aerosols, and precipitation in cloud radiative forcing.

*Increase the utility of long time series buoy observations of air-sea fluxes through intercalibration, atmospheric profiles, cloud properties, and spatial context.

*Provide comprehensive information for operational weather forecast model evaluation/development and satellite calibration/validation and algorithm development

2006 Field Program

The PSD air-sea flux and cloud group conducted measurements of fluxes and near-surface bulk meteorology during the field program AMMA at 23 W Longitude from 5 S to 20 N Latitude (see instruments listed in Table 1). The ETL flux system was installed initially at Charleston, SC, in May 2006, shaken down and brought back into full operation in Puerto Rico in May, 2006. The observations were taken from May 22 to July 16 (see Figure 1).

The air-sea flux system consists of six components: (1) A fast turbulence system with ship motion corrections mounted on the jackstaff. The jackstaff sensors are: INUSA Sonic anemometer, LiCor LI-7500 fast CO_2/hygrometer, and a Systron-Donner motion-pak. (2) A mean T/RH sensor in an aspirator on the jackstaff. (3) Solar and IR radiometers (Eppley pyranometers and pyrgeometer) mounted on top of a seatainer on the 02 deck. (4) A near surface sea surface temperature sensor consisting of a floating thermistor deployed off port side with outrigger. (5) A Riegl laser rangefinder wave gauge mounted on the bow tower. (6) An optical rain gauge mounted on the bow tower. Slow mean data (T/RH, PIR/PSP, etc) are digitized on a Campbell 23x datalogger and transmitted via RS-232 as 1-minute averages. A central data acquisition computer logs all sources of data via RS-232 digital transmission:

1. Sonic Anemometer
2. Licor CO2/H2O
3. Slow means (Campbell 21x)
4. Laser wave sensor
5. not used
6. Systron-Donner Motion-Pak
7. Ship's SCS
8. ETL GPS

The 8 data sources are archived at full time resolution. At sea we run a set of programs each day for preliminary data analysis and quality control. As part of this process, we produce a quick-look ascii file that is a summary of fluxes and means. The data in this file come from three sources: The ETL sonic anemometer (acquired at 10 Hz), the ship's SCS system (acquired at 2 sec intervals), and the ETL mean measurement systems (sampled at 10 sec and averaged to 1 min). The sonic is 5 channels of data; the SCS file is 15 channels, and the ETL mean system is 42 channels. A series of programs are run that read these data files, decode them, and write daily text files at 1 min time resolution. A second set of programs reads the daily 1-min text files, time matches the three data sources, averages them to 5 or 30 minutes, computes fluxes, and writes new daily flux files.

Atmospheric aerosols were measured with a Particle Measurement Systems (PMS) Lasair-II aerosol spectrometer. The Lasair-II draws air through an intake and uses scatter of laser light from individual particles to determine the size. Particles are counted in six size bins: 0.1-0.2, 0.2-0.3, 0.3-0.5, 0.5-1, 1-5, and greater than 5.0 μm diameter. The ETL system was mounted in the seatainer on the 02 deck with the intake on the upwind side of the container. The system ran at 1.0 cfm (0.028 m3/min) sample volume flow rate with a count deconcentrator that reduces the counts a factor of 10 (to prevent coincidence errors). The time series of aerosol data from Leg I is shown in Fig. 2.

ETL/Flux and UM also operated six remote systems: a Vaisala CT-25K cloud base ceilometer, a 9.4 GHz vertically pointed Doppler cloud radar, a 915 MHz Doppler wind profiler, , a microwave radiometer systems and the Ronald H Brown's scanning Doppler C-band radar. The ceilometer is a vertically pointing lidar that determines the height of cloud bottoms from time-of-flight of the backscatter return from the cloud. The time resolution is 30 seconds and the vertical resolution is 15 m. The raw backscatter profile and cloud base height information deduced from the instrument's internal algorithm are stored in daily files.

ETL/Flux and UM used an integrated system in a seatainer that includes the 3-channel microwave radiometer (20.6-31.65-90.0 GHz Mark II unit). The UM 9.4-GHz radar antenna was mounted on the roof of the seatainer. The cloud radar systems can be used to deduce profiles of cloud droplet size, number concentration, liquid water concentration, etc. in stratus clouds. If drizzle (i.e., droplets of radius greater than about 50 μm) is present in significant amounts, then the microphysical properties of the drizzle can be obtained from the first three moments of the Doppler spectrum (see Fig. 3 for an example). One Radiometrics Inc. 'Mailbox' microwave radiometers was deployed, this unit is the same one that has been deployed on numerous TAO/PACS cruises. Measured microwave brightness temperatures are converted to estimates of column integrated vapor and liquid water using model-based retrieval algorithms.

The wind profiler is a Doppler radar that operates at 915 MHz, electronically stabilized. It has five beams, one that points vertically, two points to port side at 90˚ apart with a 45˚ offset from the bow, and two that points to starboard, these four beams have an elevation of 75˚each. The horizontal component of the wind speed and direction is calculated with these five vectorial beams for several kilometers up into the atmosphere. Each beam reflects off of clear air or air turbulence to determine the wind speed and direction at different levels.

Table 1. Instruments and measurements deployed by ESRL for the ship-based cloud/ABL AMMA-06 project.

Item	System	Measurement
1	Motion/navigation package	Motion correction for turbulence
2	Sonic anemometer/thermometer	Direct covariance turbulent fluxes
3	IR fast H_2O/CO_2 sensor	Direct covariance moisture/CO2 fluxes
4	Mean SST, air temperature/RH	Bulk turbulent fluxes
5	Pyranometer/Pyrgeometer	Downward solar and IR radiative flux
6	Ceilometer	Cloud-base height
7	0.92 Doppler radar profiler	Cloud-top height, ABL microturbulence
8	Rawinsonde	ABL wind, temperature, humidity prof.
9	23, 31 GHz :wave radiometer (ARM type - MAILBOX)	Integrated cloud liquid water Integrated total water vapor
10	Riegl Laser wave sensor	Ocean surface wave height/period
11	Lasair-II aerosol spectrometer	Aerosol size spectra
12	9.4 GHz Doppler cloud radar	Cloud microphysical properties
13	*Ronald H. Brown* C-band radar	Precipitation spatial structure

Data Processing

Preliminary processing of all systems was done in the field and a summary CD was distributed to the participants on the ship. An example for daily averaged surface flux components is shown in Fig. 4. A second round of processing (principally editing

and quality control) is done at ESRL; this has been completed for most instruments. Data files are posted on the ESRL archive:
ftp://ftp.etl.noaa.gov/et6/archive/AMMA/RHB
and will be made available to the AMMA database.

A considerable effort was devoted to intercomparisons activities associated with different research groups making observations on the cruise: ESRL, Ronald H. Brown, U. Miami, and Howard U. systems. Comparisons were done for solar and IR radiative fluxes, air temperature and humidity, and microwave radiometer retrievals of column water vapor. Several problems were found in some instruments (a few were corrected during the cruise).

Other Activities

Ludovic Bariteau presented preliminary results from the ESRL observations from the 2006 AMMA cruise on Ronald H. Brown at the AMMA SOP Debriefing and Process Studies Workshop held at Toulouse in November 2006 (see http://amma-international.org/meetings/thematicWorkshops/Nov2006/index.php). That presentation (*Shipboard Meteorological Measurements on the Ronald during AMMAv2.ppt*) is attached with this report.

Plans for FY2007

The principal activities planned for 2007 are analysis of the 2006 data and participation in the 2007 AMMA cruise to the same region. The analysis will focus on completed remaining processing and quality control tasks (processing of motion-corrected direct covariance turbulence fluxes will be completed soon) and the creation of an integrated data file combining many of the basic time series to simplify future analyses. Preliminary scientific issues will focus on flux, cloud, aerosol, and precipitation processes on the N-S cross sections at 23 W longitude. Another round of intercomparison activities is planned, including comparison of ESRL observations with buoy observations.

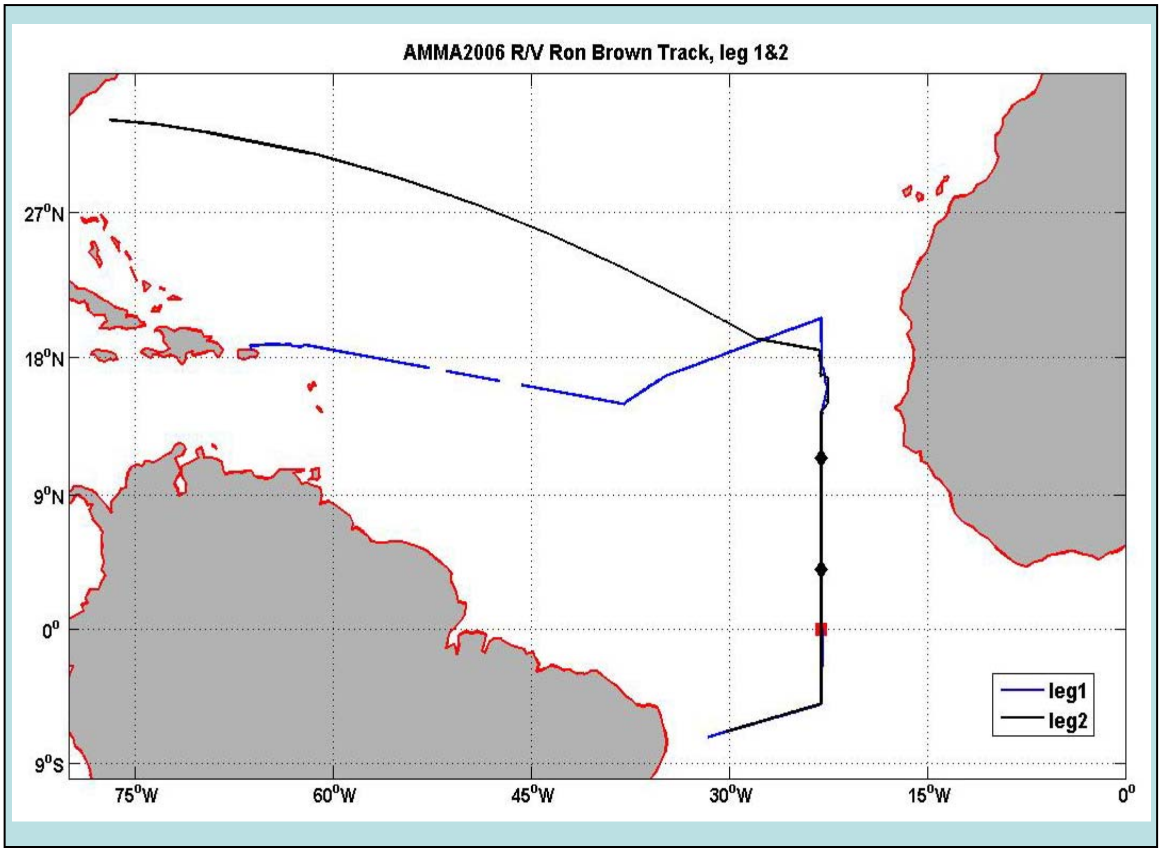

Figure 1. Map showing the ship track for ESRL measurements from R/V *Ronald H. Brown* during the AMMA 2006 field program.

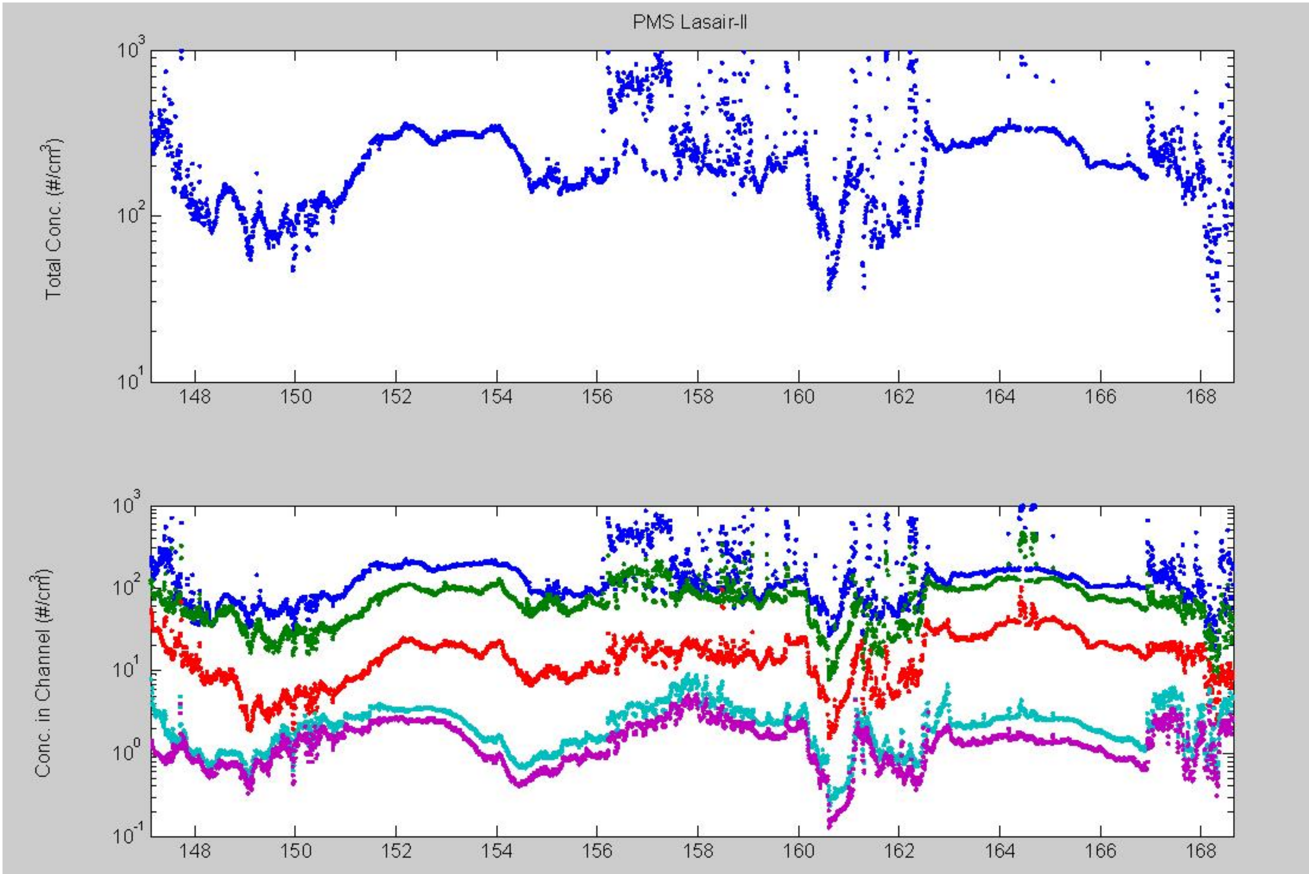

Figure 2. Aerosol concentrations from Lasair-II spectrometer for AMMA 2006 (leg1). Upper panel: total number concentration for aerosols larger than 0.1 micron diameter. Lower panel: aerosol concentrations for 0.1-0.2 (blue), 0.2-0.3 (green), 0.3-0.5 (red), 0.5-1.0 (cyan), and 1.0-5.0 (magenta). Spikes are caused by the ship's exhaust.

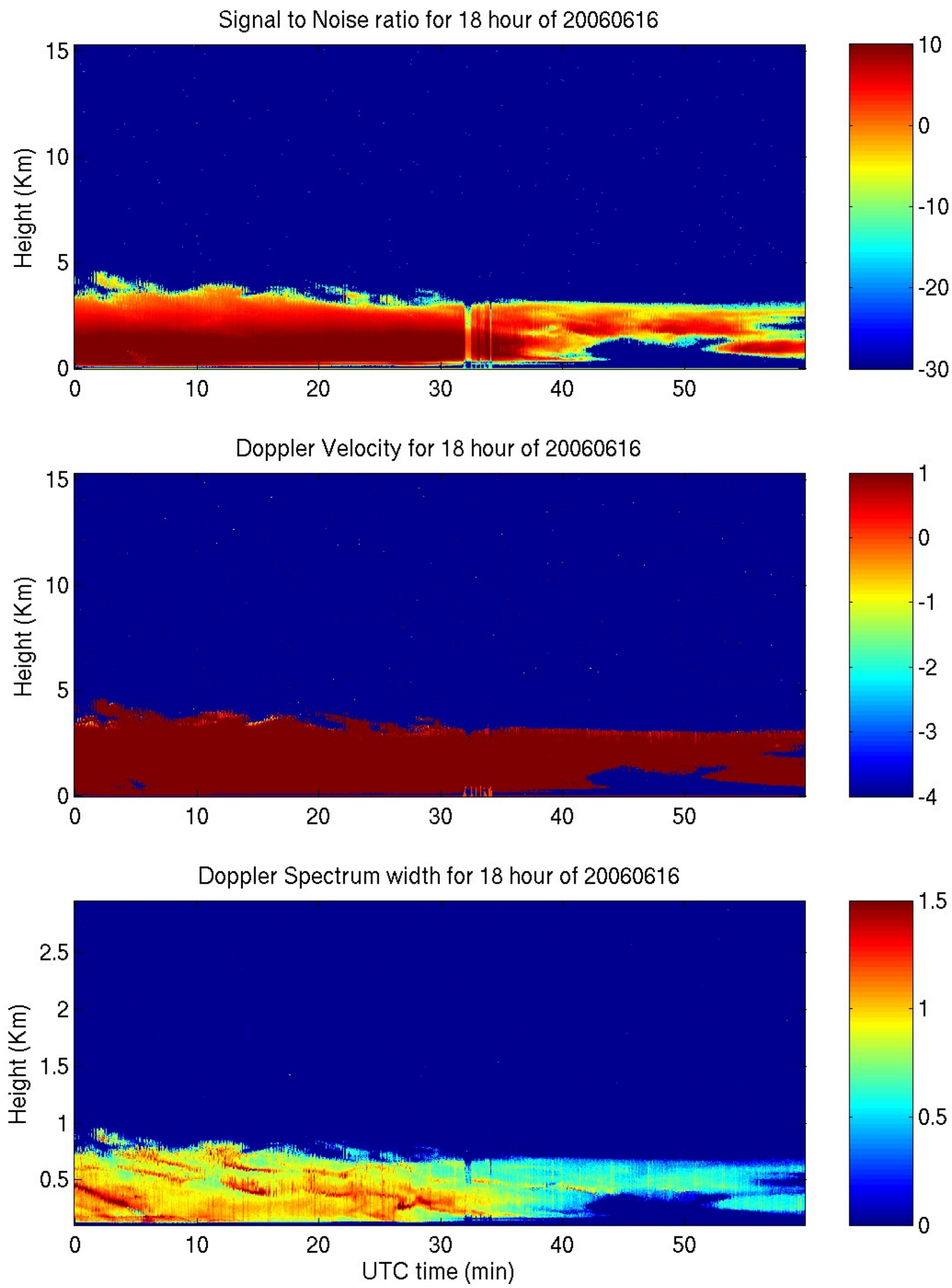

Figure 3. Time-height cross section data from 9.4 GHz cloud radar data for day 167 (June 16, 2006): upper panel, backscatter intensity; middle panel, mean Doppler vertical velocity; lower panel, Doppler width.

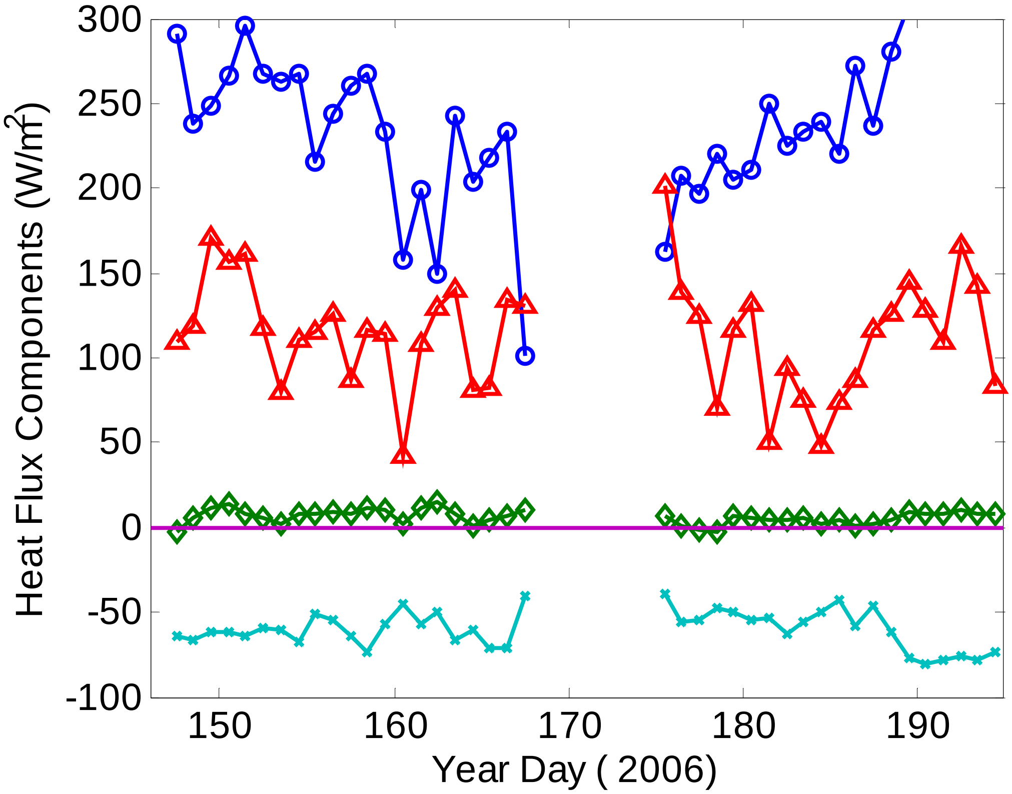

Figure 4. Time series of 24-hr average heat flux components: solar flux - circles; latent heat flux - triangles; sensible heat flux - diamonds; net IR flux x's.