Annual Progress Report to NOAA's Climate Observations Program

High Resolution Climate Data From Research and Volunteer Observing Ships

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PROJECT SUMMARY

This project involves the measurement of direct high-resolution air-sea fluxes on one to two cruises per year and the development of a roving standard flux measuring system to be deployed on a series of NOAA and UNOLS research vessels to promote the improvement of climate-quality data from those platforms. An adjunct task is maintenance and operation of the C-band scanning Doppler radar and the stabilized wind profiling radar on the NOAA ship *Ronald H. Brown*. Because buoys and most ships and satellites rely on bulk methods to estimate fluxes, another aspect of this project is the use of direct measurements to improve the NOAA/COARE bulk flux algorithm. Originally one cruise was the annual TAO buoy tending cruise to 95 and 110 W on the *Ronald Brown*, but that has been discontinued in favor of an annual cruise to the equatorial Atlantic Ocean with Dr. Bob Molinari (AOML) as part of the African Multidisciplinary Monsoon Analyses (AMMA) and Saharan Dust studies. The second cruise, which also occurs in the fall, is the annual excursion to turn around the Stratus climate buoy at 20 S 85 W. A full suite of direct, inertial-dissipation, and bulk turbulent fluxes are measured along with IR and solar radiative fluxes, precipitation, and associated bulk meteorological properties. This effort represents a partial transition of research from the OGP CLIVAR PACS program to operations under the Climate Observations Program (COP).

The project development is the result of a recent NOAA-sponsored workshop on high-resolution marine measurements (Smith et al., 2003, *Report and Recommendations from the Workshop on High-Resolution Marine Meteorology*, COAPS Report 03-01, Florida State University, pp38) which identified three important issues with the planned NOAA air-sea observation system: 1) the need for a data quality assurance program to firmly establish that the observations meet the accuracy requirements, 2) the need for observations at high time resolution (about 1 minute), 3) and the need to more efficiently utilize research vessels, including realizing their potential for the highest quality data and their potential to provide more direct and comprehensive observations. For seasonal time scales, the net air-sea flux (sum of 5 flux components) must be constrained within 10 Wm^{-2}. Buoys and VOS systems are required to operate virtually unattended for months, so considerations of practical issues (e.g., power availability, instrument ruggedness, or safe access) are balanced against inherent sensor accuracy and optimal sensor placement. As discussed above, an important function of the in situ measurements is to provide validation data to improve NWP and satellite flux fields. Here, high time resolution and more direct observations are invaluable for interpreting surface flux measurements and diagnosing the source of disagreements; such information can be provided by suitably equipped research vessels (R/V). Thus, the accuracy of buoy and VOS observations must be improved and supplemented with high-quality, high time resolution measurements from the US R/V fleet (which is presently underutilized). The necessity for both high time resolution and high accuracy places extreme demands on measurements because some sources of error (such as the effect of ship flow distortion on wind speed) tend to average out over a large sample. To accomplish this task will require a careful intercomparison program to provide traceability of buoy, VOS, and RV accuracy to a set of standards.

This project directly addresses the need for accurate measures of air-sea exchange (Sections 5.2 to 5.4, *Program Plan for Building a Sustained Ocean Observing System for Climate*. The project is a joint effort by ESRL and Dr. Robert Weller of the Woods Hole Oceanographic Institution (WHOI). NOAA COP funds the ESRL component and Dr. Weller is

seeking NSF fund for the WHOI component. The ESRL Air-Sea Interaction Group website can be found at: http://www.etl.noaa.gov/et6/air-sea/. ESRL also cooperates with Dr. Andy Jessup (APL University of Washington) on radiative sea surface temperature measurements, Dr. Frank Bradley (CSIRO, Canberra Australia) on precipitation, Drs. M. Cronin and N. Bond (PMEL) on buoy-ship intercomparisons and climate variability analysis, and Dr. Mike Reynolds (DOE BNL) on radiative fluxes. A new website is under construction for this project (High Resolution Climate Observations http://www.esrl.noaa.gov/psd/psd3/air-sea/oceanobs/). An associated website (http://www.esrl.noaa.gov/psd/psd3/wgsf/) contains a handbook on best practices for flux measurements plus a database of high-resolution flux data. This work will be closely monitored by the new WCRP Working Group on Surface Fluxes (WGSF) which is chaired by C. Fairall. This will give the project high visibility in the CLIVAR, GEWEX, and SOLAS programs. This project will be managed in cooperation with JCOMM (and other) panels as per instructions of Mike Johnson.

FY2007 ACCOMPLISHMENTS

For the *Ronald Brown* C-band and wind profiler radar project, routine maintenance was performed on the wind profiler at Charleston, SC, after the NOAA 2007 PNE/AMMA in May and June 2007.

ESRL completed two research cruises as planned: the Bob Molinari buoy deployment cruise in the Atlantic in the summer of 2007 (this is the *PNE/AMMA-Saharan Dust* cruise) on board the R/V *Ronald H. Brown* and the joint ESRL/WHOI cruise to the climate reference buoy (25 S 80 W), also on board the *Brown* in October 2006. The preliminary processed data can be found at ftp://ftp.etl.noaa.gov/et6/cruises .

A synthesis of the main results of the previous five years of strategic observations was produced in the form of three scientific publications (two appeared in print in 2006 and one is was accepted in 2007). The third paper (Fairall et al., 2007) dealt with the analysis of radiative cloud forcing based on the four years of ESRL ship-based observations. Here the emphasis was on the linkage cloud forcing to cloud properties such as fractional coverage and liquid water path. This paper showed that the three observational data sets (ESRL ship data, TAO buoy data, and ISCCP satellite estimates) agreed much more closely than NWP estimates, which have considerable problems with the representation of clouds. A second paper (Ghate et al., 2007) based on combining annual observations from the ESRL cruises to the WHOI buoy and radiative flux data from the buoy was submitted. A technique to derive stratocumulus cloud fraction using the WHOI observations was developed and applied to the buoy observations to give a five-year climatology (for 2001-2006). The results were compared with the satellite derived monthly cloud fraction and the ceilometer derived zenith cloud fraction (available during the maintenance cruises). The initial results and analysis show that the technique can be effectively applied to the longer datasets and the continuous observation from the WORS. Seasonal, inter-seasonal and average diurnal variations in cloud cover are obtained for five years of observations. The buoy-derived cloud fractions were compared with ISSCP satellite-derived low-cloud and total cloud fractions. The satellite gets total cloud well, but is completely wrong on the partitioning between cloud heights.

Considerable progress was also made on developing the portable flux standard and implementing ship and buoy intercomparisons for quality assurance. Production of the roving

flux standard is essentially complete. We upgraded one of the existing ESRL flux systems to create the portable standard (i.e., rather than build an entire new system from scratch). The upgrade features three parts: 1) convert from a network cabled sensors to wireless transmission and 2) improve the radiative flux and navigational measurements, 3) streamline the data acquisition and display processes. The first step is to simplify the shipping, installation, and tear down process so that it is cheaper and more practical to operate on a series of ships. The second step is necessary to close some accuracy shortcomings, balance the sources of error between radiative and turbulent fluxes, and take advantage of recent developments in GPS technology.
*Wireless hardware was acquired in FY2005. Field tests were done on several cruises. Alternative wireless hardware was tested in 2007 and a number of problems (data dropouts) were solved.
*A market survey of pitch/roll compensation systems for the radiative flux measurements was conducted and a suitable system could not be located for a reasonable cost. A system was designed in-house at ESRL and components were ordered in FY2005. The system was built in 2006 and laboratory motion tests were conducted. The system was field tested in on the October 2007 WHOI/stratocumulus cruise and it was a complete success.
*The portable standard will be deployed in spring of 2008.

The PI of this project has been chair the WCRP Working Group on Surface Fluxes (WGSF) since 2003. He also serves on the International Geophysical Union International Climate Dynamics and Meteorology Working Group A (Boundary Layers and Air-Sea Interaction). In 2004 he was invited to join the SOLAS Focus 2 (air-sea flux physics) Working Group to develop the Surface Ocean-Lower Atmosphere Study (SOLAS) International Implementation Plan and has been named to the US SOLAS Advisory Group.

PUBLICATIONS (FY 2007)

Fairall, C. W., J. E. Hare, Ludovic Bariteau, A. Grachev, and R. J. Hill, 2006: Coastal effects on turbulent bulk transfer coefficients and ozone deposition velocity in ICARTT. *J. Geophys.* **111**, D23S20, doi:1029/2006JD007597.

Wolfe, D. E., C.W. Fairall, D.C. Welsh, M. Ratterree, A.W. Brewer, J.M. Intrieri, C.J. Senff, B.J. McCarty, S. Tucker, D.C. Law, A.B. White, and D.E. White, 2007: Shipboard multi-sensor merged wind profilers from NEAQS 2004: Radar wind profiler, high-resolution Doppler lidar, GPS rawinsonde, *J. Geophys. Res.*, **112**, D10S15, doi:10.1029/2006JD007344.

Fairall, C. W., J. E. Hare, T. Uttal, D. Hazen, Meghan Cronin, Nicholas A. Bond, and Dana Veron, 2007: A seven-cruise sample of clouds, radiation, and surface forcing in the Equatorial Eastern Pacific. *J. Clim.*, to appear.

Kara, Birol, Alan J. Wallcraft, E. Joseph Metzger, Harley E. Hurlburt, and C. W. Fairall , 2007: Wind stress drag coefficient over the global ocean. *J. Clim.*, accepted.

Ghate, Virendra P., Bruce A. Albrecht, Christopher W. Fairall and Robert A. Weller, 2007: Climatology of marine stratocumulus cloud fraction in the South-East Pacific using

surface longwave radiative flux observations. *J. Clim.*, submitted.

CONFERENCES (FY 2007)

28h Session of the Joint Scientific Committee for the WCP, World Climate Research Program, Zanzibar, Tanzania, 26-30 March, 2007 Presentation: The WCRP Working Group on Surface Fluxes. [http://www.wmo.ch/pages/prog/wcrp/pdf/Doc%205.5%20WGSF%2015.02.pdf]

Office of Climate Observation 4th Annual System Review, NOAA, Silver Spring MD, 5-7 June 2007. Poster presented: *The SURFA Project: Reconciling in situ and Operational NWP Surface Fluxes*.

Attached Publications

These papers are available as .pdf files from

ftp://ftp.etl.noaa.gov/user/cfairall/oceanobs/pubs/fy07/

Fairall, C. W., J. E. Hare, Ludovic Bariteau, A. Grachev, and R. J. Hill, 2006: Coastal effects on turbulent bulk transfer coefficients and ozone deposition velocity in ICARTT. *J. Geophys.* **111**, D23S20, doi:1029/2006JD007597 .

Wolfe, D. E., C.W. Fairall, D.C. Welsh, M. Ratterree, A.W. Brewer, J.M. Intrieri, C.J. Senff, B.J. McCarty, S. Tucker, D.C. Law, A.B. White, and D.E. White, 2007: Shipboard multi-sensor merged wind profilers from NEAQS 2004: Radar wind profiler, high-resolution Doppler lidar, GPS rawinsonde, *J. Geophys. Res.*, **112**, D10S15, doi:10.1029/2006JD007344.

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