Annual 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 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. One cruise is the annual TAO buoy tending cruise to 95 and 110 W on the *Ronald Brown*, which occurs every Fall. The other cruise is the annual cruise to turn around the Climate Buoy at 20 S 85 W, also in the fall. 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 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 to a data quality assurance program to firmly establish that the observations meet the accuracy requirements, 2) a need for observations at high time resolution (about 1 minute), 3) a need to more efficiently utilize research vessels including realizing their potential for the highest quality data and their potential to provide more direct and more comprehensive observations. For seasonal time scales the net air-sea flux (sum of 5 flux components) needs to be constrained within 10 Wm^{-2} . Buoys and VOS systems must operate virtually unattended for months, so considerations of practical issues (e.g., power availability, 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 can be invaluable for interpreting surface flux measurements and diagnosing the source of disagreements; such information can be provided by suitably equipped RV's. Thus, the accuracy of buoy and VOS observations must be improved and supplemented with high-quality, high time resolution measurements from the US Research Vessel 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 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 ETL and the Dr. Robert Weller, Woods Hole Oceanographic Institution (WHOI). NOAA COP funds the ETL component and Dr. Weller is seeking NSF fund for the WHOI component. The ETL air-sea interaction group website is http://www.etl.noaa.gov/et6/air-sea/. ETL 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 ths project (High Resolution Climate Observations). The website is planned to contain 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.

FY2003 PROGRESS

The air-sea flux part of this project has been transitioned from the CLIVAR/PACS program to Climate Observations Program, so COP did not fund any observations in FY03. The TAO tender cruise was conducted in the fall of 2002. A complete 8-cruise PACS data base is now available at ftp://ftp.etl.noaa.gov/et7/users/cfairall/EPIC/epicmonitor/combined_files. These data include air-sea fluxes, cloud properties, wind profiles, and rawinsondes. The data are publically open to all and are shared explicitly with joint investigators (see above). The data are also used in scientific collaboration by Dr. Z. Xeng (U. Arizona), C. Bretherton (U. Washington), B. Albrecht (U. Miami), and B. Stevens (UCLA). The cruises are done in piggyback mode, so there is no impact on ship time requests. Approximately k$65 was spend ordering new sensors (aerosol spectrometer, two laser wave gauges, and a fast humidity sensor) for future field programs. Additional high quality mean humidity/temperature sensors and computers were ordered on ETL base funds. Considerable effort was devoted to planning and preparations for the two upcoming fall cruises. Installation of the equipment on the ships and execution of the cruises will occur in FY04.

For the *Ronald Brown* C-band and wind profiler radar project, training sessions for scientists and engineers were done on the ship, in Boulder, and at Sigmet, Inc. This expanded the number of people who are trained to operate this radar system. Routine maintenance was done on the radar in Charleston. This included replacing wiring, calibrations and leveling of the C-band radar. New Linux computers were configured to replace the two radar computers on the ship. The software licenses and maintenance were also continued with Sigmet, Inc.

Two research accomplishments are highlighted here. The latest version of the NOAA/COARE bulk flux algorithm was published (Fairall et al., 2003). This algorithm is the most accurate and widely used method to compute air-sea fluxes and is the basis of most air-sea fluxes computed from buoys. This algorithm was cited 281 times in the scientific literature in the calendar year 2003. It also contains the most accurate representation of CO2 fluxes presently available, which also impacts the second objective of the COP sustained ocean observing system (Document ocean carbon sources and sinks). A second highlight is the use of the 8-cruise database to examine efficacy of the parameterization of planetary boundary layer (PBL) height in the current version of the NCAR Community Climate Model (CCSM2). The analysis showed that the present implementation in CCSM2 gave poor correlation (r^2=0.06) with measured PBL heights but that if the model vertical resolution was doubled the correlation increased significantly (r^2=0.78). This is a major demonstration of how marine observations can be used to improve climate models.

The PI of this project has been appointed to chair the WCRP Working Group on Surface Fluxes. He also serves on the International Geophysical Union International Climate Dynamics and Meteorology Working Group A (Boundary Layers and Air-Sea Interaction),

PUBLICATIONS

Petersen, Walter A., R. Cifelli, D. J. Bocippio, S. A. Rutledge, and C. W. Fairall, 2003: Convection and easterly wave structure observed in the Eastern Pacific warm-pool during EPIC-2001. *J. Atmos. Sci.*, **60**, 1754-1773.

Fairall, C. W., E. F. Bradley, J. E. Hare, A. A. Grachev, and J. B. Edson, 2003: Bulk parameterization of air-sea fluxes: Updates and verification for the COARE algorithm. *J. Clim.*, **16**, 571-591.

Brunke, M. A., C W. Fairall, and X. Zeng, 2003: Which bulk aerodynamic algorithms are least problematic in computing ocean surface turbulent fluxes? *J. Clim.*, **16**, 619-635.

Grachev, A. A., C. W. Fairall, J. E. Hare, and J. B. Edson, 2003: Wind stress vector over ocean waves. *J. Phys. Oceanography*, **33**, 2408-2429.

Bretherton, C. S., T. Uttal, C. W. Fairall, S. E. Yuter, R. A. Weller, D. Baumgardner, K. Comstock, and R. Wood, 2003: The EPIC 2001 Stratocumulus Study. *Bull. Am. Met. Soc*., to appear.

Hare, J. E., C. W. Fairall, W. R. McGillis, B. Ward, and R. Wanninkhof, 2003: Evaluation of the NOAA/COARE air-sea gas transfer parameterization using GasEx data. *J. Geophys. Res*., to appear.

Curry, J. A., and 18 coauthors, 2003: SEAFLUX. *Bull. Am. Met. Soc.*, to appear.

Zeng, X., M. A. Brunke, M. Zhou, C. W. Fairall, N. A. Bond, and D. H. Lenschow, 2003: Marine atmospheric boundary layer height over the Eastern Pacific: Data analysis and model evaluation. *J. Clim*., submitted.

Raymond, D. J., S. K. Esbensen, M. Gregg, C. S. Bretherton, L. K. Shay, and T. Uttal, 2003: EPIC2001 and the coupled ocean-atmosphere system of the tropical East Pacific. Bull. Am. Met. Soc., submitted.

CONFERENCES

NOAA 27th Annual Climate Diagnostics and Prediction Workshop, NOAA-OGP, Fairfax, VA, 21-25 October, 2002.
Twelve Conference on Interactions of the Sea and Atmosphere, AMS, Long Beach CA, 10-14 February, 2003. Papers presented: 1) Bulk parameterization of air-aea fluxes: Updates and verification of the COARE algorithm (Invited). 2) The air-sea moisture transfer coefficient for

wind speeds from 0 to 20 m/s.

Workshop on High-Resolution Marine Meteorology, NOAA, Florida State University, Tallahassee, FL, 3-5 March, 2003. Paper presented: Shipboard monitoring of stratocumulus cloud properties in the PACS region.

Sixth Annual Meeting of the WCRP/CLIVAR VAMOS Panel, NOAA-OGP,, Miami, FL,23-27 April, 2003.

NOAA Intra-Seasonal to Interannual Prediction Program Workshop, NOAA-OGP, Silver Spring, MD, 12-13 August, 2003.

FY2004 PLANS

The major effort in FY04 will be execution of the TAO and WHOI climate buoy cruises plus continued work on the *Ronald Brown* C-band radar. Approximately 40 days of air-sea flux data will be obtained on the TAO cruise and about 15 days of data on the WHOI cruise. A second component will be planning for construction (beginning in FY2005) of the roving flux standard. Ship time will be in piggyback mode. The new sensors acquired in FY2003 (with the exception of the laser wave gauges, which did not arrive in time) will be deployed for the first time. Besides collecting the high resolution flux data, we will be doing pilot study evaluation of a UNOLS ship (R/V *Revelle*) IMET system as part of our plans to upgrade research vessel climate data. The *Revelle* is the ship for the WHOI buoy cruise and the present ETL seagoing flux system will provide the roving standard. Construction will begin on the High Resolution Climate Observations website. The first task will be compiling material for the online handbook for flux observations.

For the Ronald Brown radar systems project, installation of the two new computers needs to be done while the ship is in port. Laser leveling of the antenna motion stabilization (INU) should be done in port also. It has been suggested that this should be done every few years. Routine maintenance, such as calibrations, will need to be done to have the system functional for upcoming experiments. The Sigmet software licenses and maintenance will also need to be continued (this is k$9 per year).

Outreach efforts this project center on educational contacts through the University of Colorado Outreach program and the NOAA Teacher-at-Sea program. For the TAO cruise a link has been set up for twice-weekly exchanges with 10 middle school classes around the US. The WHOI climate buoy cruise will have two Teachers-at-Sea on board.

FY2004 BUDGET

The total ETL request to COP for this project is k$190 in FY2004. This is augmented by k$25 in PI salary and about 50 k$ in other ETL base contributions (salary, travel, etc). The COP budget breakdown is as follows

Salaries, including overhead	117
Capital equipment	0

Travel	22
Shipping	19
Supplies	8
Sondes	12.5
Misc	11.5

The breakdown of this budget is as follows: operations - 70%, data management - 10%, R&D - 20%. The program supports 0.15 federal FTE and 0.72 non Federal FTE; 0.20 Fed FTE are devoted to the project but not funded by it.

ADD TASKS

Note that this project budget is planned to increase to k$360 in FY2005. This increase reflects adding the additional task of constructing the roving flux standard.

.**APPENDIX**

Additional Publications using ETL data

Webster, P. J., C. W. Fairall, P. W. Hacker, R. Lukas, E. F. Bradley, and S. Godfrey, 2002: The Joint Air-Sea Monsoon Interaction Experiment (JASMINE) Pilot study. *Bull. Am. Met. Soc.*, **83**, 1603-1630..

Comstock, K. K., R. Wood, S. E. Yuter, and C. S. Bretherton, 2004: Reflectivity and rain rate in and below drizzling stratocumulus. Quart. J. Roy. Met. Soc., submitted.

Attached Publications

Petersen, Walter A., R. Cifelli, D. J. Bocippio, S. A. Rutledge, and C. W. Fairall, 2003: Convection and easterly wave structure observed in the Eastern Pacific warm-pool during EPIC-2001. *J. Atmos. Sci.*, **60**, 1754-1773.

Fairall, C. W., E. F. Bradley, J. E. Hare, A. A. Grachev, and J. B. Edson, 2003: Bulk parameterization of air-sea fluxes: Updates and verification for the COARE algorithm. *J. Clim.*, **16**, 571-591.

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