Annual Report to
NOAA's Climate Observations Program

High Resolution Climate Data From Research and Volunteer Observing Ships

Period covered by this report: Oct 1, 2003 - Sept 30, 2005

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26 September 2005

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 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 ETL and Dr. Robert Weller of the 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 can be found at: 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 this 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.

FY2005 PROGRESS

For the *Ronald Brown* C-band and wind profiler radar project, hardware upgrades and routine maintenance was performed on the wind profiler at Woods Hole Oceanographic Institution prior to the NOAA Stratus 2005 cruise planned for October 2005. While the ship was in WHOI Engineer John Novak RadTech Inc. installed the transmitter following its repair. Novak was joined by two engineers from SIGMET, Inc. Dan Wolfe and this group spent two days upgrading the C-band radar software and solving several software/hardware problems with the motion compensation for the pedestal. The software licenses and maintenance were also continued with SIGMET. The C-band radar and wind profiler are also to be operated during the Bob Molinari buoy deployment cruise in the Atlantic in the summer of 2006 (this is the *AMMA/Saharan Dust* cruise).

ETL completed two research cruises as planned: the annual TAO tender cruise to 95 and 110 W longitude in the equatorial Pacific on board the R/V *Ronald H. Brown* and the joint ETL/WHOI cruise to the climate reference buoy (25 S 80 W), also on board the *Brown*. Two related research highlights will be described here. One of the goals of this project is promoting the accuracy of buoy-based climate reference observations. ETL ship measurements from previous deployments have been used to evaluate TAO buoy and the WHOI Stratus buoy. A very detailed comparison has been done with 9 ETL cruises to the EPIC enhanced TAO buoys in the East Pacific and the buoys were found to meet the WCRP standard of 10 W/m2 for 1 week averages of net heat flux (described in *Accuracy of buoy-derived and NWP surface heat fluxes in the Tropical Pacific*, Cronin et al., submitted to JGR). A paper on ship-buoy comparisons for the WHOI flux reference site has also been submitted. The second research highlight is a pilot evaluation of research vessel near-surface meteorology and bulk flux estimation data quality. This also was based on the 9 TAO cruises and 3 cruises to the WHOI Stratus location. Three ships were examined: NOAA ships *Ronald H. Brown* and *Ka'imi Moana* and the UNOLS ship *Roger Revelle*. The results are summarized below:

*Comparison of ETL sensors across entire R/V pool suggests no significant bias in ETL data.
* Basic *sensors* on R/V's within or close to required accuracy
* Some problems with sensor placement (e.g., RHB 1999-2003)
* Some problems with early ship-ETL intercomparions (KAI and RHB) indicate poorly performing sensors often not replaced immediately.
*Better monitoring or redundancy is required for R/V's to meet climate goals

Considerable progress was also made on developing the portable flux standard and implementing ship and buoy intercomparisons for quality assurance. Dr. Frank Bradley of CSIRO Canberra Australia visited ETL for a month in the summer of 2005 to work on the flux measurement handbook. Considerable progress was made and a draft was circulated among coauthors. The first review draft will be substantially complete by November 2005. It is planned to circulate a second draft in time for feedback at the SAMOS meeting in Boulder in April 2006. A website for the project has been begun (http://www.etl.noaa.gov/programs/oceanobs/)

Production of the roving flux standard is well underway. We plan to upgrade one of the existing ETL flux systems to create the portable standard (i.e., rather than build an entire new system from scratch). The upgrade will feature two parts: 1) convert from a network cabled sensors to wireless transmission and 2) improve the radiative flux and navigational measurements. 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. A field test was conducted in Boulder in June and a prototype system was installed on the *Brown* at WHOI. We will do the fall Stratus cruise with the prototype system. Following evaluation of the results, the wireless components will be engineered for the portable system.

*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 inhouse at ETL and components were ordered. The system will be built in 2006.

*In January 2005 the ETL flux system was installed and operated on the UNOLS R/V *Seward Johnson* to participate in the RICO field program. This gave us an opportunity to evaluate two commercial full 6-compenent navigation systems (PosMV and JAVAD) by comparing their motion outputs with the ETL system. Both systems compared well with the ETL system and would be suitable for the portable standard.

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). 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

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, 2004: The EPIC 2001 Stratocumulus Study. *Bull. Am. Met. Soc*., **85**, 967-977.

Hare, J. E., C. W. Fairall, W. R. McGillis, B. Ward, and R. Wanninkhof, 2004: Evaluation of the NOAA/COARE air-sea gas transfer parameterization using GasEx data. *J. Geophys. Res*., **109** (C8): Art. No. C08S.

Curry, J. A., and 18 coauthors, 2004: SEAFLUX. *Bull. Am. Met. Soc.*, **85**, 409-424

Zeng, X., M. A. Brunke, M. Zhou, C. W. Fairall, N. A. Bond, and D. H. Lenschow, 2004: Marine atmospheric boundary layer height over the Eastern Pacific: Data analysis and model evaluation. *J. Clim*., **17**, 4159-4170.

Raymond, D. J., S. K. Esbensen, M. Gregg, C. S. Bretherton, L. K. Shay, and T. Uttal, 2004: EPIC2001 and the coupled ocean-atmosphere system of the tropical East Pacific. *Bull. Am. Met. Soc*., 85, 1341-1354.

Pyatt, Hollis, B. A. Albrecht, C. W Fairall, Nick Bond, and P. Minnis, 2005: Evolution of marine atmospheric boundary layer structure across the Cold Tongue ITCZ Complex. *J. Clim*., **18**, 737-753.

Kollias, Pavlos, C. W. Fairall, P. Zuidema, J. Tomlinson, and G. A. Wick, 2004: Observations of marine stratocumulus in SE Pacific during the PACS 2003 Cruise. *Geophys. Res. Lett*., **31**, Art. No. L22110.

Huebert, B., B. Blomquist, J. E. Hare, C. W. Fairall, T. Bates, and J. Johnson, 2004: Measurements of the sea-air DMS flux and transfer velocity using eddy correlation. *Geophys. Res. Lett.*, **31** (23): Art. No. L23113.

Hare, J. E., C. W. Fairall, T. Uttal, D. Hazen, Meghan Cronin, Nicholas A. Bond, and Dana Veron, 2005: A seven-cruise sample of clouds, radiation, and surface forcing in the Equatorial Eastern Pacific. NOAA Tech Memo, 91pp.

Wick, Gary A., J. Carter Ohlmann, Christopher W. Fairall, and Andrew T. Jessup, 2005: Improved oceanic cool-skin corrections using a refined solar penetration model. *J. Phys. Oceanogr.*, to appear.

Cronin, M. F., N. Bond, C. W. Fairall, and R. A. Weller, 2005: Surface cloud forcing in the Eastern Tropical Pacific. *J. Clim.*, to appear.

Zhou, Mingyyu, Xubin Zeng, Michael Brunke, Zhanhai Zhang, and C. W. Fairall, 2005: Study on macro- and microphysical properties of stratus and stratocumulus over the Eastern Pacific. J. Appl. Meteorol., submitted.

Cronin, M., C. W. Fairall, and M. J. McPhaden, 2005: Accuracy of buoy-derived and NWP surface heat fluxes in the Tropical Pacific. *J. Geophys. Res.*, submitted.

CONFERENCES

25th Session of the Joint Scientific Committee for the WCP, World Climate Research Program, Moscow, Russia, 1-6 March, 2004. Presentation: The WCRP Working Group on Surface Fluxes.

Seventh Annual Meeting of the WCRP/CLIVAR VAMOS Panel, NOAA-OGP, Guyaquil, Ecuador, 22-25, March, 2004.

Office of Climate Observation Annual System Review, NOAA, Silver Spring MD, 13-15 April 2004. Poster presented: Cloud forcing of the surface energy budget of the ITCZ/Cold Tongue complex in the tropical Eastern Pacific.

Second Workshop on High-Resolution Marine Meteorology, NOAA, Silver Spring, MD, 15-16 April, 2004. Paper presented: High-Resolution Climate Data from Research and Volunteer Observing Ships: A Strategic Intercalibration and Quality Assurance Program
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Focus 2 Working Group for the International SOLAS Implementation Plan, Surface Ocean-Lower Atmosphere Study, IGBP, Montreal, Canada, 17-19 May, 2004.

First International CLIVAR Scientific Conference, WCRP, 21-25 June, 2004. Posters given: 1) Cloud forcing of the surface energy budget of the ITCZ/Cold Tongue complex in the tropical Eastern Pacific, 2) Investigation of air-sea interaction and cloud processes in the EPIC stratocumulus region.

Eigth Annual Meeting of the WCRP/CLIVAR VAMOS Panel, NOAA-OGP, Mexico City, Mexico, 9-11, March, 2005.

Office of Climate Observation 3rd Annual System Review, NOAA, Silver Spring MD, 25-27 April 2005. Poster presented: Evaluation of the Accuracy of *in situ* Sources of Surface Flux Observations for Model Validation: Buoys and Research Vessels in the Eastern Pacific.

FY2006 PLANS

The major effort in FY06 will be execution of the two cruises (AMMA/Saharan Dust and WHOI climate buoy cruises), continued work on the *Ronald Brown* C-band radar, and continued development of the portable flux standard. Approximately 40 days of air-sea flux data will be obtained on the AMMA cruise and about 20 days of data on the WHOI cruise (Stratus2005).

The AMMA cruise is being done as a transition of the project from 6 years of East Pacific TAO cruises to begin gather data in the Atlantic. We have submitted a small proposal to the CLIVAR Atlantic Program (Jim Todd) for additional funding for cloud and precipitation data analysis. The Stratus2005 cruise will be our fourth cruise to 25 S 85 W at the WHOI flux reference site.

A second component will be continued engineering, testing, and construction of the roving flux standard. Our plan is to build and deploy the pitch/roll compensation system for the downward solar and IR flux systems. We will also deploy standard (uncompensated) units to allow us to assess the accuracy gains of stabilization. A wireless transmission-based flux system will be constructed in FY06 but the first deployment is not scheduled yet. We are considering deploying it on the *Ronald Brown* in the fall of 2006 so it can be tested side-by-side with the older system.

Construction will continue on the High Resolution Climate Observations website. The first task will be completing the handbook for flux observations and creating an online version. We also plan to update our ship data base so that all cruises through 2005 are publicly available. Joint analysis projects with WHOI and PMEL will continue.

For the Ronald Brown radar systems project, the installation of the two new computers, software upgrades, and recent maintenance on the pedestal and motion measuring system puts us in an excellent position for ongoing radar observations. Laser leveling of the antenna motion stabilization (INU) will be performed in the next shipyard period (presently unscheduled). The Sigmet software licenses and maintenance will also need to be continued (this is k$9 per year). In the near future we may need to install a completely new version of the software at significant expense. We are pursuing separate funds to do this.

In 2006 we plan to begin work on a permanent flux system installation for the *Ronald H. Brown*. We have had discussions with the ship on engineering, cabling, and computer space for the system. Funds have been obtained from the NOAA Carbon Cycle program to include routine measurements of CO2 fluxes.

Outreach efforts during the reporting period center on educational contacts through the University of Colorado CIRES 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. This project has been dubbed ‘Ocean Interactions’ and can be found at: http://cires.colorado.edu/~k12/interactions/. The fall 2005 WHOI climate buoy cruise will have one NOAA Teacher-at-Sea on board.

FY2006 BUDGET

The total ETL request to COP for this project is k$360 in FY2006. 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	186
Capital equipment	100
Travel	22
Shipping	15
Supplies	10
Sondes	15
Misc	12

The breakdown of this budget is as follows: operations - 70%, data management - 10%, R&D - 20%. The program supports 0.66 federal FTE and 0.66 non Federal FTE; 0.30 Fed FTE are devoted to the project but not funded by it.

ADD TASKS

None

APPENDIX

Attached Publications

These papers are available as .pdf files from

ftp://ftp.etl.noaa.gov/user/cfairall/oceanobs/pubs/fy05/

Zeng, X., M. A. Brunke, M. Zhou, C. W. Fairall, N. A. Bond, and D. H. Lenschow, 2004: Marine atmospheric boundary layer height over the Eastern Pacific: Data analysis and model evaluation. *J. Clim*., **17**, 4159-4170.

Pyatt, Hollis, B. A. Albrecht, C. W Fairall, Nick Bond, and P. Minnis, 2005: Evolution of marine atmospheric boundary layer structure across the Cold Tongue ITCZ Complex. *J. Clim.*, **18**, 737-753.

Kollias, Pavlos, C. W. Fairall, P. Zuidema, J. Tomlinson, and G. A. Wick, 2004: Observations of marine stratocumulus in SE Pacific during the PACS 2003 Cruise. *Geophys. Res. Lett*., **31**, Art. No. L22110.

Huebert, B., B. Blomquist, J. E. Hare, C. W. Fairall, T. Bates, and J. Johnson, 2004: Measurements of the sea-air DMS flux and transfer velocity using eddy correlation. *Geophys. Res. Lett.*, **31** (23): Art. No. L23113.