CHAPTER 4

STATE OF THE SCIENCE

This final chapter contains selected abstracts and a bibliography of FY 2003 publications from scientific journals treating the global observation of ocean heat, carbon, fresh water, and sea level change. A select number of abstracts of particularly relevant scientific papers are presented first, chosen by the principal investigators (PI) of the science projects funded by NOAA's Office of Climate Observation. Website urls follow the bibliographic reference if the publication and expanded abstract can be found online.

4.1 Selected Abstracts

Bourassa, M. A., D. M. Legler, J. J. O'Brien, and S. R. Smith, SeaWinds validation with research vessels, *Journal of Geophysical Research, 108(C2),* doi:10.1029/2001JC001028, 2003. http://www.coaps.fsu.edu/~bourassa/publications.shtml (6th from top of page)

ABSTRACT

The accuracy of vector winds from the SeaWinds scatterometer on the QuikSCAT satellite is assessed, for rain-free conditions, through comparison with observations from research vessels. Several factors that contribute to uncertainty in scatterometer winds are isolated and examined as functions of wind speed. The independent sources of uncertainty considered herein are ambiguity selection, wind speed, wind direction (for correctly selected ambiguities), variability associated with spatial separation between scatterometer and ship observations, and random errors in the ship observations. Rain-related errors, which are functions of wind speed and rain rate (hence varying on an event to event basis), are not examined. Ambiguity selection refers to the selection of a unique scatterometer wind direction from multiple likely solutions. For SeaWinds on QuikSCAT, in rain free conditions, ambiguity selection is found to be near perfect for surface wind speed (w) > 8 ms^{-1}; however, ambiguity selection errors cause the directional uncertainty to exceed 20° for w < ~5 ms^{-1}. Improved statistical methods that account for the spatial variability in the winds and uncertainty in the ship data are applied to determine uncertainties in speed and direction separately for correctly selected ambiguities. These uncertainties (averaged over the full comparison set) are found to be 0.45 ms^{-1} and 5° for the QSCAT-1 model function and 0.3 ms^{-1} and 3° for the Ku-2000 model function.

The QuikSCAT winds are examined as vectors through two new approaches. The first is a method for determining vector correlations that considers uncertainty in the comparison data set. The second approach is a wind speed dependent model for the uncertainty in the magnitude of vector errors. For the QSCAT-1 (Ku-2000) model function, this approach shows ambiguity selection dominates uncertainty for 2.5 < w < 5.5 ms^{-1} (0.6 < w < 5.5 ms^{-1}), uncertainty in wind speed dominates for w < 2.5 ms^{-1} and 5.5 < w < 7.5 ms^{-1} (w < 0.6 ms^{-1} and 5.5 < w < 18 ms^{-1}), and uncertainty in wind direction (for correctly selected ambiguities) dominates for w > 7.5 ms^{-1} (w > 18 ms^{-1}). This approach also shows that spatial variability in the wind direction, related to inexact spatial co-location, is likely to dominate rms differences between scatterometer wind vectors and in-situ comparison measurements for w > 4.5 ms^{-1}. Similar problems will exist with many validation efforts. The techniques used herein are applicable to any validation effort with uncertainty in the comparison data set or with inexact co-location. Application of these techniques leads to more accurate estimates of observational uncertainty.

Bretherton, C. S., T. Uttal, C. W. Fairall, S. E. Yuter, R. A. Weller, D. Baumgardner, K. Comstock, and R. Wood, The EPIC 2001 Stratocumulus Study, *Bulletin of the American Meteorological Society*, to appear, 2003. http://www.ofps.ucar.edu/epic/publications/publication_refs.html (2nd from top of page)

ABSTRACT

Overlaying the cool southeast Pacific Ocean is the most persistent subtropical stratocumulus cloud deck in the world. It produces a profound affect on tropical climate by shading the underlying ocean and by radiatively cooling and stirring up turbulence in the atmosphere. In October 2001, the East Pacific Investigation of Climate undertook an exploratory cruise from the Galapagos Islands to Chile. The cruise gathered an unprecedented dataset integrating radiosonde, surface, cloud remote sensing, aerosol, and ocean measurements. Scientific objectives included measuring the vertical structure of the ABL in this region, understanding what physical processes are determining the stratocumulus cloud albedo, and understanding the fluxes of heat and water that couple the atmosphere and the ocean in this region.

An unexpectedly well-mixed stratocumulus-capped boundary layer capped by a strong inversion was encountered throughout. A strong diurnal cycle was observed, with thicker clouds and substantial drizzle (mainly evaporating above the sea surface) during the late night and early morning. This was driven in part by local diabatic processes but was reinforced by a surprisingly pronounced diurnal cycle of vertical motion. The vertical motion appears to be an inertia-gravity wave driven by daytime heating over South America that propagates over 1000 km offshore. Much more nocturnal drizzle and pronounced mesoscale cellularity were observed in 'clean' conditions when cloud droplet concentrations and aerosol concentrations were low. Entrainment of dry, warm air is inferred to be the primary regulator of cloud thickness in this region, but drizzle also appears to have a large indirect impact by inhibiting and changing the spatial organization of turbulence.

Brunke, M. A., C. W. Fairall, X. Zeng, L. Eymard, and J. A. Curry, Which bulk aerodynamic algorithms are least problematic in computing ocean surface turbulent fluxes?, *Journal of Climate*, *16*, 619-635, 2003. http://ams.allenpress.com/amsonline/?request=get-abstract&issn=1520-0442&volume=016&issue=04&page=0619 (abstract only)

ABSTRACT

Bulk aerodynamic algorithms are needed to compute ocean surface turbulent fluxes in weather forecasting and climate models and in the development of global surface flux datasets. Twelve such algorithms are evaluated and ranked using direct turbulent flux measurements determined from covariance and inertial-dissipation methods from 12 ship cruises over the tropical and midlatitude oceans (from about 5°S to 60°N). The four least problematic of these 12 algorithms based upon the overall ranking for this data include the Coupled Ocean–Atmosphere Response Experiment (COARE) version 3.0 and The University of Arizona (UA) schemes as well as those used at the European Centre for Medium-Range Weather Forecasts (ECMWF) and the National Aeronautics and Space Administration (NASA) Data Assimilation Office for version 1 of the Goddard Earth Observing System reanalysis (GEOS-1). Furthermore, the four most problematic of these algorithms are also identified along with possible explanations. The overall ranking is not substantially affected by the use of the average of covariance and inertial-dissipation flux measurements or by taking into consideration measurement uncertainties. The differences between computed and observed fluxes are further evaluated as a function of near-surface wind speed and sea surface temperature to understand the rankings. Finally, several unresolved issues in terms of measurement and algorithm uncertainties are raised.

Colbo, K. and R. Weller, Mooring observations from the eastern subtropical Pacific, *EOS Transactions AGU*, *84(52),* Ocean Sciences Meeting Supplement, Abstract, S31E-10, 2003. http://www.agu.org/cgi-bin/SFgate/SFgate?&listenv=table&multiple=1&range=1&directget=1&application=os04&database=%2Fdata%2Fepubs%2Fwais%2Findexes%2Fos04%2Fos04&maxhits=200&=%22OS31E-10%22 (abstract only)

ABSTRACT

As part of the East Pacific Investigation of Climate (EPIC), a buoy was moored at 20°S, 85°W in October 2000. The buoy has now returned three years of both surface meteorology and upper ocean density and velocity. Aside from providing a unique data set from this poorly sampled portion of the oceans, the data sets also allow us to investigate some specific processes of importance to all of the oceanic eastern boundary regions. Westward propagating Rossby waves are known to be generated by sea surface height anomalies, due to Coastally Trapped Waves traveling poleward along the South American coast. The open ocean signature of interannual scale disturbances has been seen in TOPEX data, but the signature of the interseasonal waves has not been as well studied. Our data provides a clear data set from which to study these higher frequency Rossby waves. The mooring is also located in a region of high evaporation and almost no precipitation leading to a mixed layer that is strongly destabilized by salinity. The resulting gradients at the thermocline are strongly susceptible to salt fingering. This salt fingering provides a mechanism to inject salt onto the equatorward traveling salinity minima, and hence alter Mode water properties.

Cosca, C. E., R. A. Feely, J. Boutin, J. Etcheto, M. J. McPhaden, F. P. Chavez, and P. G. Strutton, Seasonal and interannual CO_2 fluxes for the Central and Eastern Equatorial Pacific Ocean as determined from fCO_2-SST relationships, *Journal of Geophysical Research*, *108(C8),* 3278*,* doi: 10.1029/2000JC000677, 2003. http://www.agu.org/journals/jc/jc0308/2000JC000677/2000JC000677.pdf (PDF)

ABSTRACT

In order to determine high-resolution variations of CO_2 distributions in the equatorial Pacific, we have developed seasonal and interannual fCO_2-SST relationships from shipboard data. The data were gathered onboard NOAA ships from 1992 through 2001. The cruises during the 10-year period included 89 transects of the equatorial Pacific between 95°W and 165°E, and spanned two El Niño events (1992–1994 and 1997–1998). Data were collected during the equatorial warm season (January–June) and cool season (July–December) as well as during all phases of the ENSO cycle, making it possible to examine the interannual and seasonal variability of the fCO_2-SST relationship. There is a significant difference between the regression lines for El Niño versus non-El Niño data sets. During both non-El Niño and El Niño periods we observed seasonal differences in the fCO_2-temperature relationship. With respect to the non-El Niño period, the seasonal regression lines have lower root mean square (rms) deviations than the composite non-El Niño regression line, and the slopes are significantly different at the 95% confidence level. The slope for the cool season is less negative than the slope for the warm season, suggesting higher biological productivity occurs during the latter half of the year. The derived fCO_2-SST relationships have been combined with satellite-based temperature data to provide a composite time-space map of fCO_2 in the central and eastern equatorial Pacific and corresponding fluxes for the period between 1985 and 2001. The mean flux for the 16-year record is 0.3 ± 0.1 PgC yr^{-1} for an area that covers approximately half of the Pacific equatorial belt.

Keywords: CO_2 flux, equatorial Pacific oceanography, fCO_2-SST relationships, CO_2 modeling, seasonal CO_2 flux, interannual CO_2 flux

Cronin, M. F., N. Bond, C. Fairall, J. Hare, M. J. McPhaden, and R. A. Weller, Enhanced oceanic and atmospheric monitoring for the eastern Pacific, *EOS Transactions AGU, 83(19)*, 205, 210-211, 2002. http://www.pmel.noaa.gov/~cronin/EPIC/cron2442.pdf (PDF)

ABSTRACT

The Eastern Pacific Investigation of Climate Processes (EPIC) is a five-year experiment to improve the understanding of the intertropical convergence zone (ITCZ), its interaction with the cool water that upwells along the equator in the eastern Pacific, and the physics of the stratus cloud deck that forms over the cool waters off South America. EPIC fieldwork began in 1999 and involves short-term process studies, embedded within longer-term enhanced monitoring built on the El Niño Southern Oscillation (ENSO) observing system. At this writing, we are halfway through the enhanced monitoring portion of the experiment and have just completed the two-month process study EPIC2001. In this report, we review the status of the EPIC program and present some preliminary scientific results from the enhanced monitoring data set.

Fairall, C. W., E. F. Bradley, J. E. Hare, A. A. Grachev, and J. B. Edson, Bulk parameterization of air-sea fluxes: Updates and verification for the COARE algorithm, *Journal of Climate*, *16*, 571-591, 2003. http://ams.allenpress.com/amsonline/?request=get-document&issn=1520-0442&volume=016&issue=04&page=0571

ABSTRACT

In 1996, version 2.5 of the Coupled Ocean–Atmosphere Response Experiment (COARE) bulk algorithm was published, and it has become one of the most frequently used algorithms in the air–sea interaction community. This paper describes steps taken to improve the algorithm in several ways. The number of iterations to solve for stability has been shortened from 20 to 3, and adjustments have been made to the basic profile stability functions. The scalar transfer coefficients have been redefined in terms of the mixing ratio, which is the fundamentally conserved quantity, rather than the measured water vapor mass concentration. Both the velocity and scalar roughness lengths have been changed. For the velocity roughness, the original fixed value of the Charnock parameter has been replaced by one that increases with wind speeds of between 10 and 18 m s^{-1}. The scalar roughness length parameterization has been simplified to fit both an early set of NOAA/Environmental Technology Laboratory (ETL) experiments and the Humidity Exchange Over the Sea (HEXOS) program. These changes slightly increase the fluxes for wind speeds exceeding 10 m s^{-1}. For interested users, two simple parameterizations of the surface gravity wave influence on fluxes have been added (but not evaluated).

This new version of the algorithm (COARE 3.0) was based on published results and 2777 1-h covariance flux measurements in the ETL inventory. To test it, 4439 new values from field experiments between 1997 and 1999 were added, which now dominate the database, especially in the wind speed regime beyond 10 m s^{-1}, where the number of observations increased from 67 to about 800. After applying various quality controls, the database was used to evaluate the algorithm in several ways. For an overall mean, the algorithm agrees with the data to within a few percent for stress and latent heat flux. The agreement is also excellent when the bulk and directly measured fluxes are averaged in bins of 10-m neutral wind speed. For a more stringent test, the average 10-m neutral transfer coefficients were computed for stress and moisture in wind speed bins, using different averaging schemes with fairly similar results. The average (mean and median) model results agreed with the measurements to within about 5% for moisture from 0 to

20 m s^{-1}. For stress, the covariance measurements were about 10% higher than the model at wind speeds over 15 m s^{-1}, while inertial-dissipation measurements agreed closely at all wind speeds. The values for stress are between 8% (for inertial dissipation) and 18% (for covariance) higher at 20 m s^{-1} than two other classic results. Twenty years ago, bulk flux schemes were considered to be uncertain by about 30%; the authors find COARE 3.0 to be accurate within 5% for wind speeds of 0–10 m s^{-1} and 10% for wind speeds of between 10 and 20 m s^{-1}.

Feely, R. A., C. L. Sabine, K. Lee, F. J. Millero, M. F. Lamb, D. Greeley, J. L. Bullister, R. M. Key, T. - H. Peng, A. Kozyr, T. Ono, and C. S. Wong, In situ calcium carbonate dissolution in the Pacific Ocean, *Global Biogeochemical Cycles, 16(4)*, 1144, doi: 10.1029/2002GB001866, 2002.
http://www.agu.org/pubs/crossref/2002/2002GB001866.shtml (abstract only)

ABSTRACT

Over the past several years researchers have been working to synthesize the WOCE/JGOFS global CO_2 survey data to better understand carbon cycling processes in the oceans. The Pacific Ocean data set has over 35,000 sample locations with at least two carbon parameters, oxygen, nutrients, CFC tracers, and hydrographic parameters. In this paper we estimate the in situ $CaCO_3$ dissolution rates in the Pacific Ocean water column. Calcium carbonate dissolution rates ranging from 0.01–1.1 μmol kg^{-1} yr^{-1} are observed in intermediate and deepwater beginning near the aragonite saturation horizon. In the North Pacific Intermediate Water between 400 and 800 m, $CaCO_3$ dissolution rates are more than 7 times faster than observed in middle and deep water depths (average = 0.051 μmol kg^{-1} yr^{-1}). The total amount of $CaCO_3$ that is dissolved within the Pacific is determined by integrating excess alkalinity throughout the water column. The total inventory of $CaCO_3$ added by particle dissolution in the Pacific Ocean, north of 40°S, is 157 Pg C. This amounts to an average dissolution rate of approximately 0.31 Pg C yr^{-1}. This estimate is approximately 74% of the export production of $CaCO_3$ estimated for the Pacific Ocean. These estimates should be considered to be upper limits for in situ carbonate dissolution in the Pacific Ocean, since a portion of the alkalinity increase results from inputs from sediments.
Keywords: $CaCO_3$ dissolution, anthropogenic CO_2, Pacific Ocean, aragonite saturation, calcite saturation, carbonate lysocline

Foltz, G. R., S. A. Grodsky, J. A. Carton, and M. J. McPhaden, Seasonal mixed layer salt budget of the tropical Atlantic Ocean, *Journal of Geophysical Research*, *108(C5),* 3146, doi:10.1029/2002JC001584, 2003.
http://www.atmos.umd.edu/~senya/HTML/pirata_salt/abstract.html (abstract only)

ABSTRACT

This paper addresses the atmospheric and oceanic causes of the seasonal cycle of mixed layer salinity in the tropical Atlantic based on direct observations and model data. Data sets include up to five years (September 1997 - December 2002) of measurements from moored buoys of the Pilot Research Array in the Tropical Atlantic (PIRATA), near-surface drifting buoys, and a numerical ocean model reanalysis. We analyze the mixed layer salt balance at nine PIRATA mooring locations and find that the seasonal cycles of evaporation, precipitation, entrainment, and mean horizontal salt advection all contribute to seasonal mixed layer salinity variability in the northwest (4°N - 15°N along 38°W). The balance is similarly complex along the equator. Here precipitation decreases eastward (between 35°W and 10°W), while freshening from zonal

advection increases eastward. Horizontal eddy advection provides an important source of freshening along the equator during boreal summer and fall, when tropical instability waves are present. Meridional advection, combined with entrainment and vertical turbulent diffusion (we suspect), opposes the freshening effects of precipitation, mean zonal advection, and eddy advection, resulting in a weak seasonal cycle of mixed layer salinity. The balance in the southeast (6°S - 10°S along 10°W) includes significant contributions from mean horizontal advection. Here our estimates are highly uncertain due to a lack of knowledge of horizontal salinity transport.

Freitag, H. P., M. J. McPhaden, C. Meinig, and P. Plimpton, Mooring motion bias of point Doppler current meter measurements, In: *Proceedings of the IEEE Seventh Working Conference on Current Measurement Technology*, San Diego, CA, 13-15 March 2003, IEEE, Piscataway, NJ, 155-160, 2003.
http://www.pmel.noaa.gov/tao/proj_over/frei2539_v5.pdf (PDF)

ABSTRACT

Upper-ocean current measurements have been made for more than 20 years from taut-line surface moorings deployed in the equatorial Pacific by NOAA's Pacific Marine Environmental Laboratory (PMEL). Until 1998 the moorings were instrumented with mechanical current meters (MCMs, either Vector Averaging Current Meters (VACM) or Vector Measuring Current Meters (VMCM)). Comparison with nearby subsurface 150 kHz Acoustic Doppler Current Profilers (ADCP) indicated that differences between the two measurement systems were generally small (i.e., mean differences of 5 cm s^{-1} or less). By the early-1990's, maintenance of the aging MCMs (designed in the 1960s and 1970s) was difficult, time consuming and expensive. Early tests of the Sontek Argonaut-MD current meters by PMEL indicated that it was a good candidate for replacement of the MCMs. Subsequent comparisons between Argonaut-MD data and nearby ADCPs revealed significant bias between the two, with the Argonaut-MD reporting lower horizontal current speed. Further investigation, including the analysis of high-frequency output from the Argonaut-MD compass/tilt-sensor (Precision Navigation model TCM2), found that the source of the bias was the inability of the compass/tilt sensor to function properly in response to extreme lateral and rotational accelerations experienced by the instruments in high current speed regimes. A solution to this problem was to reduce the acceleration of the current meters by attaching vanes to each instrument. Since PMEL introduced this modification, differences between Argonaut-MD and ADCP data are comparable to those found previously between MCM and ADCP.

Garzoli, S. L., and J. Servain, CLIVAR workshop on tropical Atlantic variability, *Geophysical Research Letters, 30(5),* 8001, doi:10.1029/2002GL016823, 2003.
http://www.agu.org/journals/gl/gl0305/2002GL016823/2002GL016823.pdf (PDF)

INTRODUCTION (partial)

Climate variability in the tropical Atlantic region and the land that surrounds it represents a difficult problem in terms of large-scale circulation and ocean-atmosphere-land interactions, with important economic and social impacts (CLIVAR Initial Implementation Plan, June 1998). During recent decades a large multi-decadal swing in the Atlantic climate has been observed and it is believed to be caused by interactions between the Atlantic Ocean and the overlaying atmosphere. These climate swings are directly or indirectly related to the tropical Atlantic region where surface temperature variability and the associated changes in winds, sea level pressure, intertropical convergence zone (ITCZ), and the Hadley circulation occur on interannual to

decadal time scales. These covariant fluctuations are collectively called Tropical Atlantic Variability (TAV).

Gibson, B. A., S. E. Postawko, J. Ensworth, M. L. Morrissey, J. Wurman, and S. Ellis, Introducing high-tech and low-tech geoscience-related technology to disadvantaged schools in the Tropical Pacific, *Journal of Geoscience Education*, *51*, 2003. http://www.nagt.org/Mar03/March03-06.html (abstract only)

ABSTRACT

The Schools of the Pacific Rainfall Climate Experiment (SPaRCE) is a cooperative educational and research project that involves elementary, middle, and high schools, trade schools, colleges, and meteorological services from various Pacific Islands, atolls, and the U.S. The educational materials that the program provides to Pacific area schools involve mostly the use of non-technical, simple equipment and experiments. This is due to the cost of materials and postage, and the fact that most schools are isolated, lack funds, or do not have reliable electricity. The material sent to participants includes plastic direct-read rain gauges, workbooks, and videos that discuss tropical Pacific related weather phenomenon. Recently, the SPaRCE program was able to deploy automated weather stations to a limited number of participants. In addition, the SPaRCE program had also supplied four Pacific-area schools with Micro-Tops devices, a hand-held radiometer which measures total column ozone. The SPaRCE program hopes to continue providing the participating educators with more opportunities to use technology in their geoscience curriculum.

Gilson, J. and D. Roemmich, Mean and temporal variability in Kuroshio geostrophic transport south of Taiwan (1993-2001), *Journal of Oceanography, 58*, 183-195, 2002. http://www.terrapub.co.jp/journals/JO/abstract/5801/58010183.html (abstract only)

ABSTRACT

Observations of the Kuroshio south of Taiwan have been carried out on a quarterly basis since late 1992 as part of the basin-wide High Resolution expendable bathythermograph/expendable conductivity-temperature-depth (XBT/XCTD) network. Mean geostrophic transport in the Kuroshio, 0-800 m, from 34 cruises is 22.0 Sv ± 1.5, consistent with previous results from moorings and geostrophic calculations in the upstream Kuroshio region. The mean core of the current has speed about 90 cm s^{-1} and is located close to Taiwan. At this location the Kuroshio appears to be confined mainly to the upper 700 m, and there is no evident tight recirculation of the current. Eddy variability is substantial, and large eddies can be seen propagating westward for thousands of kilometers in TOPEX/Poseidon altimetric data, impinging on the current and altering its structure and transport. The annual range in transport is about 8 Sv ± 6, with maximum in summer. Interannual variability is about 12 Sv ± 6, with transport maxima in 1995 and 2000 and a minimum in 1997-1998. Interannual variability in the upstream Kuroshio may be uncorrelated with that in the downstream region south of Japan, where the transport is much greater. Our quarterly sampling aliases high frequency variability of the current, and an improved boundary-current observation program would include more frequent transects and occasional deeper measurements.

Gloor, M., N. Gruber, J. L. Sarmiento, C. L. Sabine, R. A. Feely, and C. Rödenbeck, A first estimate of present and preindustrial air-sea CO_2 flux patterns based on ocean interior carbon measurements and models, *Geophysical Research Letters, 30(1),* 1010, doi: 10.1029/2002GL015594, 2003.
http://www.agu.org/journals/gl/gl0301/2002GL015594/2002GL015594.pdf (PDF)

ABSTRACT

The exchange of CO_2 across the air-sea interface is a main determinant of the distribution of atmospheric CO_2 from which major conclusions about the carbon cycle are drawn, yet our knowledge of atmosphere-ocean fluxes still has major gaps. A new analysis based on recent ocean dissolved inorganic carbon data and on models permits us to separately estimate the pre-industrial and present air-sea CO_2 flux distributions without requiring knowledge of the gas exchange coefficient. We find a smaller carbon sink at mid to high latitudes of the southern hemisphere than previous data based estimates and a shift of ocean uptake to lower latitude regions compared to estimates and simulations. The total uptake of anthropogenic CO_2 for 1990 is 1.8 (±0.4) Pg C yr^{-1}. Our ocean-based results support the interpretation of the latitudinal distribution of atmospheric CO_2 data as evidence for a large northern hemisphere land carbon sink.

Goni, G., and M. Baringer, Surface currents in the tropical Atlantic across high density XBT line AX08, *Geophysical Research Letters, 29 (24),* 2002.
http://www.agu.org/journals/gl/gl0224/2002GL015873/2002GL015873.pdf (PDF)

ABSTRACT

Three temperature sections that cross the tropical Atlantic obtained from high density XBT transects are used to identify the major surface currents and to compute their water mass transports. The dynamic heights are computed using XBT temperature profiles with salinity derived from historical T-S relationships. The values of dynamic height estimated from altimeter data used in conjunction with climatological dynamic height fields are within 3 cm of the XBT-derived values. The error in XBT-derived dynamic height introduced by using historical T-S relationships instead of actual salinity values are estimated to be of the order of 1.5 cm. Dynamic height estimates using the actual salinity values underestimate those obtained using historical T-S relationships. The structure exhibited in the dynamic height and altimeter-derived sea height fields do not reveal all the upper ocean currents, making these temperature sections presented here critical for computing transports and identifying currents in this region.

Goni, G. and P. Rizzoli (editors), *Interhemispheric Water Exchange in the Atlantic Ocean*, Elsevier Oceanographic Series, Vol. 68, 2003.
http://www.elsevier.com/wps/find/bookdescription.cws_home/699546/description#description (BOOK)

DESCRIPTION

Recent results from modeling and observational studies demonstrate that the tropical Atlantic is a critical region for processes that maintain the meridional overturning circulation, such as cross-equatorial exchanges, and for sea surface temperature variability that impacts on climate variability of the coupled tropical ocean/atmosphere system.

The theme of this book is the inter-hemispheric and inter-gyre exchanges of heat, salt and fresh water, while its goal is to improve the knowledge of the tropical Atlantic dynamics and how it affects the global ocean. A clear understanding of the dynamics of processes that affect the flow

of mass and heat between the southern and the northern hemispheres in the upper few hundred meters in the tropical Atlantic and of those associated to the ocean circulation or to surface signals, from decadal, inter-annual to mesoscale periods, becomes necessary to better evaluate their contribution to the interhemispheric mass exchange. These processes are believed to be largely responsible in driving the sea surface temperature, which in turn, is a critical parameter to investigate ocean-atmospheric interactions. Output produced by regional models is also used to complement the observations and to provide additional information on their spatial and temporal variability. The subtropical cells, by bringing water masses subducted in the subtropics to the equator, and zonal currents investigated here contribute to the interhemispheric water exchange.

Special attention is also given to the warm and salty anticyclonic rings shed by the North Brazil Current, which are now known to have a much broader impact, not only on interhemispheric water mass transfer, but also on the environment of remote regions. Observations from different sources are blended together, are used to validate model outputs and are also assimilated into models to obtain a more complete and accurate picture of the oceanic circulation and of its time evolution.

Grebremichael, M, W. F. Krajewski, M. Morrissey, D. Langerud, G. J. Huffman, R. Adler, Error uncertainty analysis of GPCP monthly rainfall products: A data based simulation study, *Journal of Applied Meteorology*, *42*, 1837-1848, 2003.
http://ams.allenpress.com/pdfserv/i1520-0450-042-12-1837.pdf (PDF)

ABSTRACT

This paper focuses on estimating the error uncertainty of the monthly 2.5° x 2.5° rainfall products of the Global Precipitation Climatology Project (GPCP) using rain gauge observations. Two kinds of GPCP products are evaluated: the satellite-only (MS) product, and the satellite–gauge (SG) merged product. The error variance separation (EVS) method has been proposed previously as a means of estimating the error uncertainty of the GPCP products. In this paper, the accuracy of the EVS results is examined for a variety of gauge densities. Three validation sites—two in North Dakota and one in Thailand—all with a large number of rain gauges, were selected. The very high density of the selected sites justifies the assumption that the errors are negligible if all gauges are used. Monte Carlo simulation studies were performed to evaluate sampling uncertainty for selected rain gauge network densities. Results are presented in terms of EVS error uncertainty normalized by the true error uncertainty. These results show that the accuracy of the EVS error uncertainty estimates for the SG product differs from that of the MS product. The key factors that affect the errors of the EVS results, such as the gauge density, the gauge network, and the sample size, have been identified and their influence has been quantified. One major finding of this study is that 8–10 gauges, at the 2.5° scale, are required as a minimum to get good error uncertainty estimates for the SG products from the EVS method. For eight or more gauges, the normalized error uncertainty is about 0.86 ± 0.10 (North Dakota: box 1) and 0.95 ± 0.10 (North Dakota: box 2). Results show that, despite its error, the EVS method performs better than the root-mean-square error (rmse) approach that ignores the rain gauge sampling error. For the MS products, both the EVS method and the rmse approach give negligible bias. As expected, results show that the SG products give better rainfall estimates than the MS products, according to most of the criteria used.

Lamb, M. F., C. L. Sabine, R. A. Feely, R. Wanninkhof, R. M. Key, G. C. Johnson, F. J. Millero, K. Lee, T. – H. Peng, A. Kozyr, J. L. Bullister, D. Greeley, R. H. Byrne, D. W. Chipman, A. G. Dickson, C. Goyet, P. R. Guenther, M. Ishii, K. M. Johnson, C. D. keeling, T. Ono, K. Shitashima, B. Tilbrook, T. Takahashi, D. W. R. Wallace, Y. W. Watanabe, C. Winn and C. S. Wong, Consistency and synthesis of Pacific Ocean CO_2 survey data, *Deep-Sea Research II*, *49 (1-3)*, 21-58, 2002. http://jelly.pmel.noaa.gov/admin/scripts/Publications.asp?ABSTRACT_REQUEST=2201 (abstract only)

ABSTRACT

Between 1991 and 1999, carbon measurements were made on twenty-five WOCE/JGOFS/OACES cruises in the Pacific Ocean. Investigators from 15 different laboratories and four countries analyzed at least two of the four measurable ocean carbon parameters (DIC, TAlk, fCO_2, and pH) on almost all cruises. The goal of this work is to assess the quality of the Pacific carbon survey data and to make recommendations for generating a unified data set that is consistent between cruises. Several different lines of evidence were used to examine the consistency, including comparison of calibration techniques, results from certified reference material analyses, precision of at-sea replicate analyses, agreement between shipboard analyses and replicate shore based analyses, comparison of deep water values at locations where two or more cruises overlapped or crossed, consistency with other hydrographic parameters, and internal consistency with multiple carbon parameter measurements. With the adjustments proposed here, the data can be combined to generate a Pacific Ocean data set, with over 36,000 unique sample locations analyzed for at least two carbon parameters in most cases. The best data coverage was for DIC, which has an estimated overall accuracy of ~3 µmol kg^{-1}. TAlk, the second most common carbon parameter analyzed, had an estimated overall accuracy of ~5 µmol kg^{-1}. To obtain additional details on this study, including detailed crossover plots and information on the availability of the compiled, adjusted data set, visit the Global Data Analysis Project web site at: http://cdiac.esd.ornl.gov/oceans/glodap.

McNeil, B. I., R. J. Matear, R. M. Key, J. L. Bullister and J. L. Sarmiento, Anthropogenic CO_2 uptake by the ocean based on the global chlorofluorocarbon dataset, *Science, 299*, 235-239, 2003. http://www.sciencemag.org/cgi/content/full/299/5604/235

ABSTRACT

We estimated the oceanic inventory of anthropogenic carbon dioxide (CO_2) from 1980 to 1999 using a technique based on the global chlorofluorocarbon data set. Our analysis suggests that the ocean stored 14.8 petagrams of anthropogenic carbon from mid-1980 to mid-1989 and 17.9 petagrams of carbon from mid-1990 to mid-1999, indicating an ocean wide net uptake of 1.6 and 2.0 +/- 0.4 petagrams of carbon per year, respectively. Our results provide an upper limit on the solubility-driven anthropogenic CO_2 flux into the ocean, and they suggest that most ocean general circulation models are overestimating oceanic anthropogenic CO_2 uptake over the past two decades.

McPhaden, M. J., Tropical Pacific Ocean heat content variations and ENSO persistence barriers, *Geophysical Research Letters, 30(9),* 1480, doi:10.1029/2003GL016872, 2003. http://www.agu.org/pubs/crossref/2003/2003GL016872.shtml

ABSTRACT

Data from the tropical Pacific Ocean for the period 1980–2002 are used to examine the persistence of sea surface temperature (SST) and upper ocean heat content variations in relation to El Niño and the Southern Oscillation (ENSO). The present study demonstrates that, unlike for SST, there is no spring persistence barrier when considering upper ocean heat content. Conversely, there is a persistence barrier for heat content in boreal winter related to a seasonal reduction in variance. These results are consistent with ENSO forecast model studies indicating that accurate initialization of upper ocean heat content often reduces the prominence of the spring prediction barrier for SST. They also suggest that initialization of upper ocean heat content variations may lead to seasonally varying enhancements of forecast skill, with the most pronounced enhancements for forecasts starting early and late in the development of ENSO events.

Niiler, P. P., N. A. Maximenko, and J. C. McWilliams, Dynamically balanced absolute sea level of the global ocean derived from near-surface velocity observations, *Geophysical Research Letters, 30(22*): 2164-2167, 2003. http://www.agu.org/pubs/crossref/2003/2003GL018628.shtml

ABSTRACT

The 1992–2002 time-mean absolute sea level distribution of the global ocean is computed for the first time from observations of near-surface velocity. For this computation, we use the near-surface horizontal momentum balance. The velocity observed by drifters is used to compute the Coriolis force and the force due to acceleration of water parcels. The anomaly of horizontal pressure gradient is derived from satellite altimetry and corrects the temporal bias in drifter data distribution. NCEP reanalysis winds are used to compute the force due to Ekman currents. The mean sea level gradient force, which closes the momentum balance, is integrated for mean sea level. We find that our computation agrees, within uncertainties, with the sea level computed from the geostrophic, hydrostatic momentum balance using historical mean density, except in the Antarctic Circumpolar Current. A consistent horizontally and vertically dynamically balanced, near-surface, global pressure field has now been derived from observations.

O'Brien, K., K. McHugh, G. Vecchi, E. Harrison, S. Hankin, and A. Manke, The Observing System Monitoring Center: A Tool for Evaluation of the Global Ocean Observing System, *Proceedings of the 20th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, 2004 AMS Annual Meeting, Seattle, WA, 12–15 January 2004, paper P1.35, 2004. http://ams.confex.com/ams/84Annual/techprogram/paper_73535.htm (PDF)

INTRODUCTION

In order to properly understand climate variability, the development, evaluation and maintenance of a sustained global observing system is required. As the Intergovernmental Panel on Climate Change (IPCC 2001) states, “Concern has been expressed about the present condition of the observational networks.” Kevin Trenberth adds, “To advance the understanding of climate change and its forcings, it will be necessary to have a comprehensive global observing system reliably producing high-quality data and products.” (Trenberth 2002). The Observing System

Monitoring Center (OSMC) is being constructed in order to assess the effectiveness of the current global ocean observing system as well as to aid in the planning and evaluation of new observing system components. Currently, the observing system for climatic data consists of a variety of sensors measuring a multeity of physical variables from numerous platforms. Ensuring the effectiveness of the observing system requires software and data systems to keep track of the performance of the different sensors in near-real time. The near-real time data access is critical to promptly overcome any shortcomings of the observing system. The goal of the OSMC is to fill the clear need for near-real time overseeing of the global ocean climate observing system. The OSMC will be an information gathering, decision support and display system and will also display current historical status of globally distributed data collection systems. In addition, the OSMC will provide the data visualization tools necessary to identify the coverage of any given collection of platforms and parameters.

Petersen, W. A., R. Cifelli, D. J. Bocippio, S. A. Rutledge, and C. W. Fairall, Convection and easterly wave structure observed in the Eastern Pacific warm-pool during EPIC-2001, *Journal of the Atmospheric Sciences*, *60*, 1754-1773, 2003.
http://olympic.atmos.colostate.edu/epic/epic_pdf/petersen_2003.pdf (PDF)

ABSTRACT

During September–October 2001, the East Pacific Investigation of Climate Processes in the Coupled Ocean–Atmosphere System (EPIC-2001) intertropical convergence zone (ITCZ) field campaign focused on studies of deep convection in the warm-pool region of the eastern Pacific. This study combines C-band Doppler radar, sounding, and surface heat flux data collected aboard the R/V *Ronald H. Brown* during EPIC to describe the kinematic and thermodynamic states of the ITCZ environment, together with tendencies in convective structure, lightning, rainfall, and surface heat fluxes as a function of 3–5-day easterly wave phase.

Three easterly waves were observed at the location of the R/V *Brown* during EPIC-2001. Wind and thermodynamic data reveal that the wave trough axes exhibited positively correlated *u* and y winds, a slight westward phase tilt with height, and relatively strong (weak) northeasterly tropospheric shear following the trough (ridge) axis. Temperature and humidity perturbations exhibited mid- to upper-level cooling (warming) and drying (moistening) in the northerly (trough and southerly) phase. At low levels, warming (cooling) and moistening (drying) occurred in the northerly (southerly) phase.

Composited radar, sounding, lightning, and surface heat flux observations suggest the following systematic behavior as a function of wave phase: zero to one-quarter wavelength ahead of (behind) the wave trough in northerly (southerly) flow, larger (smaller) convective available potential energy (CAPE), lower (higher) convective inhibition (CIN), weaker (stronger) tropospheric shear, larger (smaller) convective rain fractions, higher (lower) conditional mean rain rates, higher (lower) lightning flash densities, and more (less) robust convective vertical structure occurred. Latent and sensible heat fluxes reached a minimum in the northerly phase and then increased through the trough, reaching a peak during the ridge phase (leading the peak in CAPE). Larger areas of light convective and stratiform rain and slightly larger (10%) area-averaged rain rates occurred in the vicinity of, and just behind, the trough axes in southerly and ridge flow. Importantly, the transition in convective structure observed across the trough axes when considered with the relatively small change in area mean rain rates suggests the presence of a transition in the vertical structure of diabatic heating across the easterly waves examined. The inferred transition in heating structure is supported by radar-diagnosed divergence profiles that exhibit convective (stratiform) characteristics ahead of (behind) the trough.

Rudnick, D. L. and R. E. Davis, Red noise and regime shifts, *Deep-Sea Research I*, *50(6)*, 691-699, 2003.

ABSTRACT

The analysis of interdecadal physical and biological variability is made challenging by the relative shortness of available time series. It has been suggested that rapid temporal changes of the most energetic empirical orthogonal function of North Pacific sea surface temperature (sometimes called the Pacific Decadal Oscillation or PDO) represents a ''regime shift'' between states with otherwise stable statistics. Using random independent time series generated to have the same frequency content as the PDO, we show that a composite analysis of climatic records recently used to identify regime shifts is likely to find them in Gaussian, red noise with stationary statistics. Detection of a shift by this procedure is not evidence of nonlinear processes leading to bi-stable behavior or any other meaningful regime shift.
Keywords: Climatic changes; Statistical analysis; Regime shifts; Pacific Decadal Oscillation

Sabine, C.L., and M. Hood, Ocean carbon scientists organize to achieve better coordination, cooperation, *Eos, Transactions AGU, 84(23)*, 218–220, 2003.
http://www.globalcarbonproject.org/PRODUCTS/Sabine&Hood.2003.pdf (PDF)

INTRODUCTION

Studies of the global carbon cycle and climate change necessarily involve investigations across regional and political boundaries. Recognizing the need to develop an international research framework, various working groups of programs such as the International Geosphere-Biosphere Programme (IGBP) have developed research strategies for global carbon cycle studies.

Based on recommendations from these programs, several nations are now moving ahead with plans for large-scale ocean carbon observations. Many of these national and regional studies are similar in focus, and have been designed to complement studies in other countries. However, there is an immediate need for global-scale coordination of these carbon observations and research efforts. There is also an urgent need to critically assess the overall network of planned observations to ensure that the results, when combined, will meet the requirements of the research community.

As part of a new pilot project, the Global Carbon Project (GCP) and the Ocean CO_2 Panel have joined forces to coordinate ongoing, large-scale ocean carbon observations over the next decade. This project coordination draws upon the long-term experience of the Ocean CO_2 Panel parent organizations; the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC). It also draws on the carbon focus, and ties to the scientific community of the GCP parent organizations; the IGBP, the International Human Dimensions Programme (IHDP), and the World Climate Research Programme (WCRP). The International Ocean Carbon Coordination Project (IOCCP) has been organized to:

- gather information about ongoing and planned ocean carbon research and observation activities;
- identify gaps and duplications in ocean carbon observations;
- produce recommendations that optimize resources for international ocean carbon research and the potential scientific benefits of a coordinated observation strategy; and
- promote the integration of ocean carbon research with appropriate atmospheric and terrestrial carbon activities.

Only through a coordinated ocean sampling effort and improved basic scientific understanding of the ocean carbon cycle will the overall goal of skillful predictions of future atmospheric CO_2 be attained.

Sabine, C. L., R. A. Feely, R. M. Key, J. L. Bullister, F. J. Millero, K. Lee, T. - H. Peng, B. Tilbrook, T. Ono, and C. S. Wong, Distribution of anthropogenic CO_2 in the Pacific Ocean, *Global Biogeochemical Cycles, 16(4),* 1083, doi: 10.1029/2001GB001639, 2002. http://www.agu.org/pubs/crossref/2002/2001GB001639.shtml (abstract only)

ABSTRACT

This work presents an estimate of anthropogenic CO_2 in the Pacific Ocean based on measurements from the WOCE/JGOFS/OACES global CO_2 survey. These estimates used a modified version of the ΔC^* technique. Modifications include a revised preformed alkalinity term, a correction for denitrification, and an evaluation of the disequilibrium terms using an optimum multiparameter analysis. The total anthropogenic CO_2 inventory over an area from 120°E to 70°W and 70°S to 65°N (excluding the South China Sea, the Yellow Sea, the Japan/East Sea, and the Sea of Okhotsk) was 44.5 ± 5 Pg C in 1994. Approximately 28 Pg C was located in the Southern Hemisphere and 16.5 Pg C was located north of the equator. The deepest penetration of anthropogenic CO_2 is found at about 50°S. The shallowest penetration is found just north of the equator. Very shallow anthropogenic CO_2 penetration is also generally observed in the high-latitude Southern Ocean. One exception to this is found in the far southwestern Pacific where there is evidence of anthropogenic CO_2 in the northward moving bottom waters. In the North Pacific a strong zonal gradient is observed in the anthropogenic CO_2 penetration depth with the deepest penetration in the western Pacific. The Pacific has the largest total inventory in all of the southern latitudes despite the fact that it generally has the lowest average inventory when normalized to a unit area. The lack of deep and bottom water formation in the North Pacific means that the North Pacific inventories are smaller than the North Atlantic.
Keywords: Pacific Ocean, anthropogenic CO_2, carbon cycle, total CO_2, ΔC^*, optimum multiparameter analysis

Snowden, D. P. and R. L. Molinari, Subtropical cells in the Atlantic Ocean: An observational summary, *Elsevier Oceanography Series, 68*, 2003.
http://www.aoml.noaa.gov/general/pubs/publist1.html (abstract only)

ABSTRACT

In this paper, we survey the observational literature pertaining to the shallow meridional overturning circulation cells connecting the subduction regions of the subtropical North and South Atlantic Ocean with the upwelling regions on and near the equator. These subtropical cells (STCs) exist in both hemispheres, but they are not symmetric about the equator. The southern hemisphere STC has a structure consistent with the cannonical feature (*i.e.,* subduction in the southern hemisphere subtropics, transport of the subducted water to the Equatorial Undercurrent, upwelling on the equator, and return of the upwelled water to the subtropics). However, there is no clear evidence to indicate that water subducted in the northern hemisphere subtropics reaches the equator. Rather, pathways of water subducted in the subtropical North Atlantic have been observed to the North Equatorial Countercurrent. Upwelling regions for these northern hemisphere water masses are not yet defined. Characteristics of the STCs which must be more fully explored (*e.g*., temporal variability, transports, mixing) in order to understand their impacts on the regional climate variability of the tropical Atlantic Ocean are identified.

Sun, B., L. Yu, and R. A. Weller, Comparisons of surface meteorology and turbulent heat fluxes over the Atlantic: NWP model analyses versus moored buoy observations, *Journal of Climate*, *16*, 679-695, 2003.
http://ams.allenpress.com/pdfserv/i1520-0442-016-04-0679.pdf (PDF)

ABSTRACT

Surface meteorological variables and turbulent heat fluxes in the National Centers for Environmental Prediction–National Center for Atmospheric Research reanalyses 1 and 2 (NCEP1 and NCEP2) and the analysis from the operational system of the European Centre for Medium-Range Weather Forecasts (ECMWF) are compared with high-quality moored buoy observations in regions of the Atlantic including the eastern North Atlantic, the coastal regions of the western North Atlantic, and the Tropics. The buoy latent and sensible heat fluxes are determined from buoy measurements using the recently improved Tropical Ocean Global Atmosphere Coupled Ocean–Atmosphere Response Experiment (TOGA COARE) flux algorithm.

The time mean oceanic heat loss from the model analyses is systematically overestimated in all the regions. The overestimation in latent heat loss ranges from about 14 W m^{-2} (13%) in the eastern subtropical North Atlantic to about 29 W m^{-2} (30%) in the Tropics to about 30 W m^{-2} (49%) in the midlatitude coastal areas, where the overestimation in sensible heat flux reaches about 20 W m^{-2} (60%). Depending upon the region and the NWP model, these systematic overestimations are either reduced, or change to underestimations, or remain unchanged when the TOGA COARE flux algorithm is used to recalculate the fluxes. The bias in surface meteorological variables, one of the major factors related to the biases in the revised NWP heat fluxes, varies with region and NWP analysis. Generally the temperature and humidity biases in the coastal regions are much larger than other regions. In the extratropical regions, NCEP1 and NCEP2 generally show a wet bias, which is mainly responsible for the underestimation in the revised NWP latent heat loss. In the Tropics a dry bias is found in the NWP analyses, particularly in ECMWF and NCEP2, which contributes to the overestimation in the revised NWP latent heat loss. Compared to NCEP1, NCEP2 shows less cold bias in 2-m air temperature and thus less biased sensible heat flux; NCEP2 also shows less humid bias in 2-m humidity in the extratropical regions but more dry bias in 2-m humidity in the Tropics, either of which leads to a more biased latent heat flux in NCEP2.

Despite the significant biases in the NWP surface fields and the poor representation of short-time sea surface temperature variability, the NWP models are able to represent the dominant short-time variability in other basic variables and thus the variability in heat fluxes in the wintertime coastal regions of the western North Atlantic (on timescales of 3–4 days and 1 week) and the northern and southern subtropical regions (on a timescale of about 2 weeks), but ECMWF and particularly the NCEP analyses do not represent well the 2–3-week variability in the tropical Atlantic.

Takahashi, T., S. C. Sutherland, R. A. Feely, and C. E. Cosca, Decadal variation of surface water pCO_2 in the Western and Central Equatorial Pacific, *Science*, *302*, 852-856, 2003. http://clickit.go2net.com/search?pos=4&ppos=0&plnks=0&uplnks=20&cat=web&cid=239171&site=srch&area=srch.noncomm.google&shape=textlink&cp=info.dogpl&cluster-click=0&pd=0&coll=1&query=takahashi+decadal+variation+of+surface+water+pco2+in+the+western+and+central+equatorial+pacific&qq=ee_IY!60DpnrXIWhvGymmem70_NrZUR4qrMS2MLDMWVPTem)!2CrQogoR+M_P (PDF)

ABSTRACT

The equatorial Pacific Ocean is one of the most important yet highly variable oceanic source areas for atmospheric carbon dioxide (CO_2). Here, we used the partial pressure of CO_2 (PCO_2), measured in surface waters from 1979 through early 2001, to examine the effect on the equatorial Pacific CO_2 chemistry of the Pacific Decadal Oscillation phase shift, which occurred around 1988 to 1992. During the decade before the shift, the surface water PCO_2 (corrected for temperature changes and atmospheric CO_2 uptake) in the central and western equatorial Pacific decreased at a mean rate of about –20 μatm per decade, whereas after the shift, it increased at

about +15 µatm per decade. These changes altered the CO_2 sink and source flux of the equatorial Pacific significantly.

Vallée, C., R. A. Weller, P. R. Bouchard, W. M. Ostrom, J. Lord, J. Gobat, M. Pritchard, T. Westberry, J. Hare, T. Uttal, S. Yuter, D. Rivas, D. Baumgardner, B. McCarty, J. Shannahoff, M.A. Walsh, F. Bahr, Long-Term Evolution of the Coupled Boundary Layers (STRATUS) Mooring Recovery and Deployment Cruise Report, NOAA Research Vessel *R H Brown*, Cruise RB-01-08, 9 October – 25 October 2001, *Technical Report*, WHOI-2002-02, UOP-2002-01, 2002.
http://uop.whoi.edu/stratus/images/Stratus2Cruise.pdf (PDF)

ABSTRACT

This report documents the work done on cruise RB-01-08 of the NOAA R/V *Ron Brown*. This was Leg 2 of R/V *Ron Brown's* participation in Eastern Pacific Investigation of Climate (EPIC) 2001, a study of air-sea interaction, the atmosphere, and the upper ocean in the eastern tropical Pacific. The science party included groups from the Woods Hole Oceanographic Institution (WHOI), NOAA Environmental Technology Laboratory (ETL), the University of Washington (UW), the University of California, Santa Barbara (UCSB), and the University Nacional Autonoma de Mexico (UNAM). The work done by these groups is summarized in this report. In addition, the routine underway data collected while aboard R/V *Ron Brown* is also summarized here.

Willis, J., D. Roemmich and B. Cornuelle, Combining altimetric height with broadscale profile data to estimate steric height, heat storage, subsurface temperature and SST variability, *Journal of Geophysical Research, 108(C9)*, 3292-3303, doi:10.1029/2002JC001755, 2003.
http://www.agu.org/journals/jc/jc0309/2002JC001755/2002JC001755.pdf (PDF)

ABSTRACT

A new technique is demonstrated for combining altimetric height (AH) and seasurface temperature (SST) with in situ data to produce improved estimates of 0/800 m steric height (SH), heat content, and temperature variability. The technique uses a linear regression onto AH to construct an initial guess for the subsurface quantity. This guess is then corrected toward the in situ data creating an estimate with substantially less error than could be achieved using either data set alone. Inclusion of the SST data further improves the estimates and illustrates how the procedure can be generalized to allow inclusion of additional data sets. The technique is demonstrated over a region in the southwestern Pacific enclosing the Tasman Sea. Nine-year time series of heat storage and temperature variability, averaged over 4° latitude and longitude and 1 year in time, are calculated. The estimates have RMS errors of approximately 4.6 W/m^2 in heat storage, 0.10ºC in subsurface temperature and 0.11ºC in surface temperature, and fractional errors of 20, 28, and 18%, respectively, relative to the total variance overall spatial and temporal scales considered. These represent significant improvements over previous estimates of these quantities. All the time series show strong interannual variability including the El Nino event of 1997. Application of these techniques on a global scale could provide new insight into the variability of the general circulation and heat budget of the upper ocean.

4.2 Bibliography of Science Articles and Reports Published by OCO-funded Scientists During FY 2003

A bibliography of all science publications published during FY 2003 is found below. Articles are separated into published articles and articles in press, books and book chapters, submitted articles, articles in preparation, reports and memos, proceedings, abstracts, encyclopedia entries, newsletters, and brochures and pamphlets.

Legend for projects affiliated with publications
A key is provided to show the affiliation between each published article and the science projects shown below (PI = Principal Investigator; co-PI = co-Principal Investigator; PM = Project Manager; PL = Project Leader).

A. Western Boundary Time Series in the Atlantic Ocean (PMs: Baringer, Johns, Meinen, Garzoli, Flosadottir)
B. ENSO Observing System (PM / PI: Cook / Molinari)
C. High Resolution XBT/XCTD (HRX) Transects (PI / PL: Kennel / Davis)
D. Drifter Observations (PI / PL: Kennel / Niiler)
E. Underwater Gliders for Monitoring Ocean Climate (PI / PL: Kennel / Davis)
F. Lagrangian Salinity Profiling: Evaluation of Sensor Performance (PI / PL: Kennel / Schmitt)
G. Development of an Underway CTD (PI / PL: Kennel / Rudnick)
H. Data Assimilation (PI / PLs: Kennel / Cornuelle, Stammer, Miller)
I. High Resolution Climate Data from Research and Volunteer Observing Ships (PM: Fairall)
J. Global Repeat Hydrographic/CO_2/Tracer Surveys in Support of CLIVAR and Global Carbon Cycle Objectives (PIs: Feely, Wanninkhof)
K. Document Ocean Carbon Sources and Sinks: Initial Steps Towards a Global Surface Water pCO_2 Observing System Underway CO_2 Measurements on the NOAA ships Ka'imimoana and Ron Brown and RVIB Palmer and Explorer of the Seas (PMs / co-PIs: Feely, Wanninkhof / Sabine, G. Johnson, Baringer, Bullister, Mordy, Zhang)
L. Tropical and Sub-tropical Atlantic Surface Drifters Array (PM: Garzoli)
M. Implementation of High Density XBT Lines in the Atlantic Ocean (PMs: Garzoli, Goni, Baringer, Molinari)
N. TAO Array and PIRATA (PI: McPhaden)
O. Global Sea Level Center: In-Situ Sea Level, The University of Hawaii Sea Level Center (PM: Merrifield)
P. Program Support through the Assimilation, Analysis and Dissemination of Global Raingauge Data (PI / co-PIs: Morrissey / Postawko, Greene)
Q. The "Global Drifter Program" (PI: Niiler)
R. Climate Variability in Ocean Surface Turbulent Fluxes (PI / co-PIs: O'Brien / Bourassa, Smith)
S. Quality-Evaluated Meteorological Data from Research Vessels (PI / co-PIs: O'Brien / Bourassa, Smith)
T. *In situ* and Satellite Sea Surface Temperature (SST) Analyses (PM: Reynolds)
U. Ocean Reference Stations and Northwest Tropical Atlantic Station for Flux Measurement (NTAS) (PMs: Weller, Plueddemann)
V. Implementation of One High Density XBT Line with TSG and IMET Instrumentation in the Tropical Atlantic (Atlantic VOS) (PIs: Weller, Hosom)

Published Articles and Articles in Press

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Beron-Veron, F. and M. Olascoaga, Spectral, formal, and nonlinear stability in a layered quasigeostrophic with application to the Atlantic North Equatorial Current, *Interhemispheric Water Exchange in the Atlantic Ocean*, *Elsevier Oceanographic Series*, *68*, Elsevier Science, 2003. (M)

Bishop, J. K. B., R. E. Davis and J. T. Sherman, Robotic observations of dust storm enhancement of carbon biomass in the North Pacific, *Science*, *298*, 817-821, 2002. (E)

Bourassa, M. A., D. M. Legler, J. J. O'Brien, and S. R. Smith, SeaWinds validation with research vessels, *Journal of Geophysical Research, 108(C2),* doi:10.1029/2001JC001028, 2003. (S)

Bretherton, C. S., T. Uttal, C. W. Fairall, S. E. Yuter, R. A. Weller, D. Baumgardner, K. Comstock, and R. Wood, The EPIC 2001 Stratocumulus Study, *Bulletin of the American Meteorological Society*, to appear, 2003. (I)

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Diaz, H., C. Folland, Y. Manabe, D. Parker, R. Reynolds and S. Woodruff, Workshop on advances in the use of historical marine climate data, *WMO Bulletin*, *51*, 377-380, 2002. (T)

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