Observing System Research Studies

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1. PROJECT SUMMARY

This project supports the design, evaluation and development of the global ocean observing system for climate through a variety of research and leadership activities. These activities include data set preparation/dissemination, data analysis and modeling studies. The goal is to expand our knowledge of what we know and can rationalize, and what we cannot know or rationalize, from the observing system as deployed at present and from the historical data set that has been produced over past decades. It also supports the evolution of the observing system through evaluation of alternative observing strategies and evaluation of the differences between available ocean analysis products (taken as one measure of the uncertainty in the analysis products). A primary objective is identifying ocean and climate state indices that are of societal relevance, and understanding the limits on the accuracy of our estimates of these indices resulting from the observing system's limitations.

Finally it supports the goals of the Office of Climate Observations and NOAA's Climate Goal through the PI's activities as Chair of the OCO Climate Observing System Council, and of the Ocean Observations Panel for Climate (co-sponsored by the GOOS, GCOS and WCRP) and other national and international leadership activities involved with sustained ocean observing. The PI is also a member of the JCOMM Management Committee and works with its Program Areas to progress the development and delivery of global ocean services.

No data are collected through this project; the Ten Climate Monitoring Principles are not relevant to the activities undertaken.

Initial focus has been on SST variability since it is agreed to be the most important variable for climate impacts. Substantial work has been done also on subsurface ocean temperature conditions since these are important to future projections of climate and sea level changes. Work has been done with all of the variables of the global ocean observing system, and shall continue in FY09 as described below.

2. ACCOMPLISHMENTS

6 Papers are in print or have appeared in the literature since start of FY08.
3 Papers are currently in the review process.
3 research projects have made significant progress.

3. PUBLICATIONS

Carson, M. and D.E. Harrison, 2008: Is the upper ocean warming? Comparisons of 50-year trends from different analyses. *J. Climate*, 21(10), 2259–2268.

Carson, M. and D.E. Harrison, 2008: Upper Ocean Warming: Spatial patterns of Trends and interdecadal variability. NOAA Tech. Memorandum OAR-PMEL-138, NTIS: PB-2008107952, 31pp.

Chiodi, A.M. and D.E. Harrison, 2007: Mechanisms of summertime subtropical Southern Indian Ocean sea surface temperature variability: On the importance of humidity anomalies and the meridional advection of water vapor. *J. Climate*, 20(19), 4835–4852.

Chiodi, A.M. and D.E. Harrison, 2008: Hurricane Alley SST variability in 2005 and 2006. *J. Climate*, 21(18), 4710–4722.

Chiodi, A.M. and D.E.Harrison, 2008: Characterizing the interannual variability of the equatorial Pacific: an OLR Perspective. NOAA Tech. Memorandum OAR PMEL-140. NTIS:PB-2008112890, Seattle, WA 30pp.

Harrison, D.E. and A.M. Chiodi, 2009: Pre and post 1997/1998 westerly wind events and equatorial Pacific cold tongue warming. *J. Climate*, 22(3), 568–581.

4. SUBMITTED PAPERS

Carson, M. and D.E. Harrison, 2009: Regional Interdecadal Variability in bias-corrected Ocean Temperature Data. *J. Climate*, submitted.

Chiodi, A.M. and D.E. Harrison, 2009: An OLR-based index for North American seasonal climate anomalies. *J. Climate*.

Chiodi, A.M. and E.D. Harrison, 2009: Characterizing ENSO variability in the equatorial Pacific: An OLR perspective. *J. Climate*.

Larkin, N.K. and D.E. Harrison, 2009: The 1997–98 El Niño and the post-WWII composite event. *J. Climate*.

5. IN PROGRESS

Harrison, D.E., R.D. Romea, G. Vecchi, and A. Chiodi: Effects of surface forcing on the seasonal cycle of the eastern equatorial Pacific. Intended *J. Phys. Oceanogr*.

Chiodi, A.M., and D.E. Harrison: The annual range of Southern Hemisphere SST; Comparison with surface heating and possible reasons for the high-latitude fall off. Intended *J. Climate*.

6. BRIEF DESCRIPTION OF RESEARCH RESULTS

Ocean heat content is an ocean index that is straightforward to define and is relevant to assessment of climate variability and change. Its trends are of particular interest to society, as a test of global climate models and as a major component of sea level variability and rise. We have continued to probe the historical ocean data set and determine the extent to which accurate long term trend estimates of world ocean heat content can be made. Work completed early in FY08 showed that because so much of the world ocean has not been observed adequately to permit a meaningful trend estimate to be made, differences in the interpolation techniques used to produce a global "data set" have very substantial effects on the inferred global 50year trend. This questions the usefulness of recently published estimates of long term heat content trends. Recent work shows that expendable bathythermograph data introduce a decadally-varying temperature bias compared to other instruments in the historical data set that measure pressure and temperature concurrently. The effect of this bias on regional interdecadal temperature variability has been shown to be smaller that the remaining interdecadal temperature variability. This confirms that the regional ocean temperatures have undergone substantial changes over recent decades, and suggests that such changes are likely to continue to at least partially obscure longer-term subsurface trends in the near future. This work emphasizes the need for obtaining and maintaining global coverage of *in situ* observations in order to accurately determine long-term world ocean trends.

Indices for characterizing the ENSO-state of the planet are also important. As we have noted previously, the 'operational' El Niño index introduced by NOAA several years ago has many practical shortcomings and its use has led to confusion in many nations about what weather to expect. We continue to explore ENSO indices, and their strengths and weaknesses. In FY08 we showed that outgoing longwave radiation (OLR) information can be used to give rather unique perspective on recent El Niño behavior. This OLR perspective has a distinctly event-like character, not seen the indices most-commonly used describe the anomaly state of the tropical Pacific, such as Niño 3.4 region SSTA or the Southern Oscillation Index. This makes determination of "event-status" based on OLR less ambiguous than using other commonly used ENSO indices, which show a continuous interannual distribution of neutral-to-secondary-to-large anomalies. In OLR, the most commonly agreed upon warm-events stand out. OLR also offers a more dynamically-direct connection to the global seasonal weather anomalies caused by ENSO, which are of the more general societal concern that specific tropical Pacific conditions. Examination of NCEP/NCAR reanalysis atmospheric geopotential height anomalies confirms that significant and robust atmospheric circulation anomalies are driven over the North Pacific and North America in years distinguished by eastern central pacific OLR variability. Groups of years considered "El Niño" based on some other ENSO indices, but not particularly distinctive based on OLR behavior, do not show such anomalies. This work suggests that eastern central Pacific OLR information be used, both operationally and historically, to identify the El Niño events that are most likely to have substantial and predictable effects on N. American weather. Two papers on this work have been submitted for publication

It is important for the broader community to understand the anomaly patterns associated with any given ocean/climate index. Because ENSO is of such widespread societal interest, we updated the Harrison and Larkin (1986) global marine surface composite for El Niño events, based on the "conventional" El Niño classification list (which the OLR index also seems to identify). This paper, which was co-authored with Dr. Sim Larkin of the US Forest Service, has been submitted for publication, and is available for downloading to researchers and others.

Work was done to complete and bring to publication in respected journals some work ongoing from FY07. For example, we showed that the surface heat flux contribution of meridional advection of surface humidity can dominate interannual surface heat flux variability in subtropical Indian Ocean regions that are thought to affect southern Africa weather. This is contrary to previous suggestions that zonal wind speed effects on surface heat flux dominate in these regions. Results also show that surface heat flux dominates the effects of ocean heat flux convergence on interannual timescales in the subtropical regions of interest, contrary to some earlier hypotheses. The meridional-moisture-advection type of surface heat flux variability shown to be important in this case is caused by the Mascarene High in sea level pressure preferentially locating itself either near the coast of Madagascar or Western Australia. The case with the Mascarene High near Madagascar is conducive to the type of SST anomalies associated with increases in rainfall over southern Africa. This work makes the case that more must be learned about this type of basin scale atmospheric behavior in order to improve seasonal weather forecasting efforts in this region.

We also showed that it is possible to understand the differences in tropical North Atlantic SST anomalies in the 'hurricane alley' formation regions between 2005 (lots of hurricanes) and 2006 (few hurricanes) by considering differences in the large scale atmospheric circulation over the region, and the resulting changes in air-sea heat fluxes. It is not necessary to invoke changes in the atmospheric loading of aerosols off of West Africa to rationalize the observed SSTA patterns. It is necessary, however, to consider the effects of sub-seasonal atmospheric variability on the surface fluxes to accurately model the observed 2005 to 2006 SSTA difference. Results show low-wind, clear sky conditions associated with atmospheric anticyclones are conducive to forming shallow ocean-mixed-layers that warm rapidly; up to a degree per day, which is much more than expected from seasonal-climatology or monthly-mean conditions. Though strong cooling also occurs as the heat in these shallow surface layers are mixed to deeper depths, a substantial amount of this warming remains in the longer-term average and can be attributed to non-linear effects that warm the ocean more than would be expected from knowledge of monthly or seasonal mean conditions alone. This suggests that this sub-monthly atmospheric variability, or its effects, will have to be predicted to improve interannual SST predictions in these regions. This is somewhat of a break from traditional forecasting efforts in which seasonal mean conditions are predicted knowledge of the seasonal-mean base state. These papers show once again how important accurate knowledge of air-sea fluxes is for understanding (and predicting) SST anomalies of climate relevance; the observing system activities that serve to help us evaluate operational air-sea flux estimates are very important.

Trying to find indices that can help us forecast the onset, characteristics and strength of El Niño events is also of national interest. One obvious route is indices of equatorial Pacific surface zonal winds. To construct useful indices we must understand the space and time characteristics of winds in this region. We showed that there has been a change in the wind patterns associated with westerly wind events over the tropical Pacific since the major 1997-98 El Niño event, and that these seem sufficient to explain why we have been having more “Dateline El Niño” than “conventional El Niño” events since then. We used numerical ocean model experiments to obtain the latter conclusion. This work suggests a new index that takes into account the basin scale wind anomaly conditions present during a westerly wind event might be developed for tracking the likelihood of an El Niño appearing in any given year. Presentation of this work at national scientific conferences has been successful in generating considerable interest in the phenomena documented by this study among the research and forecasting/monitoring communities.

Progress has been made on a paper that determines the effects of the various components of surface forcing on the seasonal cycle in the eastern equatorial Pacific. Traditionally, much attention has been paid in the literature to the importance of the component of the seasonal cycle driven by meridional wind variability. Preliminary results show that zonal wind variability is at least as important and that accurate knowledge of both wind components and surface heat flux is necessary for ocean models to accurately resolve many aspects of the observed seasonal cycle. Progress has also been made on a paper that examines the reasons for the observed fall-off of seasonal range of surface SST with latitude. Preliminary results show that ocean mixed layer depth estimates available from the World Ocean Database 2005 can be used to reasonably predict the observed zonal mean SST seasonal range structure in the ice-free latitudes of the Southern Ocean. Using World Ocean Database 2001 data instead results in a much different answer at high latitude because this region of the world ocean was sampled considerably less during the pre-ARGO years. This shows the importance of the increased sampling provided by the ARGO program to our understanding of this fundamental feature of Earth’s climate.

7. OBSERVING SYSTEM MEETINGS/WORKSHOPS LED OR ATTENDED

4-6 Oct GCOS/IPCC Lessons-learned Syd
16-19 Oct GCOS SC Paris
31 Oct GOOS outreach Lon
29-30 Nov Autumn COSC
Jan 3 IOC on OceanObs/Info09
Jan 9-11 POGO9 Bermuda
Jan 28-Feb 1-3rd Reanalysis Wkshp Tokyo
March 13-14 GSOP-III Southampton UK
March 24-26 CWG Review Princeton NJ
April 7 pre-GSSC GOOS wkshp Paris
April 8-10 GSSC Paris
April 10-11 PICO Paris
April 8-12 El Niño Definition mtg. UHawaii
April 21-25 AOPC Geneva
May 5-9 WCRP Modeling Summit ECMWF
May 6-9 CLIMAR-III Gydnia Poland
May 19-23 Gijon ICES/PICES/IOC
Jun 2-4 IGST DC
June 9-13 OOPC 13 Buenos Aires
June30-4July GCOS Geneva
July 7-8 OSMC PMEL
Aug 26-28 PMEL Lab Review
Sept 3-5 DC OCO Annual Review