Observing System Research Studies

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1. Project Summary

The Observing System Research Studies group performs data and modeling studies to identify climatically significant ocean-atmosphere interaction patterns, identify indices that usefully characterize their amplitudes and study their linkages to US and global weather anomalies, with the goals of improving our awareness and understanding of present climate conditions and the effectiveness of the global observing system for climate. We seek to identify useful climate indices/indicators of the state of the climate system, together with estimates of their uncertainty, that help society understand, forecast and project seasonal and longer term weather and climate anomalies. Often this involves estimating the uncertainty in our present ability to make statements of scientific and societal relevance with the historical ocean and climate data sets. We provide guidance about the specific activities required of the global climate observing system to meet its goals as well as work to help understand developing user needs.

We also work within the NOAA, US, international and intergovernmental ocean and climate organizations, with particular focus on the Global Climate Observing System program, the Joint Commission on Oceanography and Marine Meterorology and the CLIVAR program, to develop and advance agreed international plans for the climate observing system, standards for making the observations and for sharing data among all interested parties, and for internationally coordinated activities to exploit the data collected, for the good of all nations.

This project does not collect any observations, but does make ocean and climate information available via the State of the Ocean website at PMEL, and collaboration with the Observing System Monitoring Center project led by Steve Hankin.

2. Scientific and Observing System Accomplishments

The PI continued to serve as Co-Editor of the Proceedings of the Ocean Observations 2009 Symposium and the production work for the DVD and Volumes 1, 2a and 2b was substantially completed.

Following the successful publication of work from previous years, which we shall not discuss here (see FY10 Progress Report) in order to save space, we have focused considerable effort on different aspects of subseasonal to interannual variability phenomena, because this is the dominant timescale of anomalies from the seasonal cycle that affect society. Most of our climate forecasting skill derives from associations with the ENSO phenomenon, so that understanding better how to identify and make use of these associations is very important. So also is understanding better the factors that enhance forecast skill. ENSO also has major impacts on the rate at which carbon dioxide concentration changes in the atmosphere and we have found some previously unreported asymmetries in the global carbon system response to El Nino and La Nina periods, which will be important for the development of global carbon cycle models and projections. We have contributed to outreach about climate variability and trends to the global oceanic fishery management community, emphasizing with examples the extent to which interannual to decadal variability will, in most places, dominate long term trends for the next couple of decades. These contributions are described in more detail below. Please see also the figures included in the accompanying Power Point slides.

For example we have re-examined the roles that various types of subseasonal wind events play in the initiation, and hence predictability, of warm-ENSO (El Nino) events. Specifically, we have analyzed the historical records of sea surface temperature anomaly in the equatorial tropical Pacific for the changes that follow Westerly Wind Events, and times in which the Madden Julian Oscillation is active. The Westerly Wind Events (WWEs) we consider are characterized by average zonal wind anomalies of about 7 m/s over 7 or so days that occur in the western and central equatorial Pacific, whereas the Madden Julian Oscillation (MJO) is characterized by oscillatory wind anomalies, with an easterly and westerly phase, at lower amplitudes, but longer (30-90 day range) periods. Because both classes of intra-seasonal wind event have expression in the equatorial Pacific, where wind stress anomalies are known to be an effective means of driving equatorial waveguide warming, there has been much confusion about the relationship between WWEs, the MJO and waveguide warming in the tropical Pacific. Our results show that understanding the sources and predictability of tropical Pacific Westerly Wind Events remains essential to improving predictions of the onset of El Nino events. Westerly Wind Event effects and frequency is unaffected by the state of the Madden Julian Oscillation. This work has been presented at international conferences and is described in the submitted manuscript entitled Subseasonal atmospheric variability and El Nino waveguide warming; observed effects of the MJO and Westerly Wind Events, by A.M. Chiodi and D.E. Harrison. See attached Power Point slide for more information.

Group work has also identified characteristics of the tropical Pacific anomaly (i.e. ENSO) state that are better indicators of oncoming US seasonal weather anomaly impacts of El Nino than the commonly used ENSO-indices. This work has shown that, since 1979 when outgoing longwave

radiation observations became available, most of the useful US seasonal weather impact of El Niño events is associated with the few events identified by the Chiodi and Harrison (2010) OLR El Niño index. These events produce composite seasonal regional weather anomalies that are 95% statistically significant and robust, in the sense that they are associated with almost all events. This work also shows that there are very few statistically significant seasonal weather anomalies, even at the 80% confidence level, associated with the non-OLR El Niño events. A major enhancement of statistical seasonal forecasting skill over the contiguous US states appears possible by incorporating these results. It is essential to respect that not all events commonly labeled as El Niño events lead to statistically useful US seasonal forecast skill. This work shows that digging through our historical climate records can still produce valuable results, and has been presented at national scientific conferences and will be described in the manuscript entitled, An OLR-El Nino index for effects on US seasonal weather anomalies, by A.M. Chiodi and D.E. Harrison. See attached Power Point slides.

After the seasonal cycle, the largest variability in atmospheric CO_2 concentration occurs on interannual time scales and most of this is associated with ENSO. We have looked in detail at the connection between the ENSO extremes, La Nina and El Nino, and the global planetary carbon cycle. Specifically, we have separately examined the characteristics of interannual atmospheric CO_2 concentration variability connected with La Nina and El Nino events and found substantial and previously unreported asymmetries between the anomalous season-to-season changes in concentration that occur during them. The La Nina composites yield statistically significant anomalies, but with smaller amplitude and shorter duration than the El Nino composites, implying that the uptake anomalies that occur during La Nina events are substantial, but not as strong or long-lasting as the efflux anomalies that occur during El Nino events. Composites also show that the concentration-change anomalies peak near the end of the calendar year and are robust (limited event to event variability) for both La Nina and El Nino events (1991-92 being the conspicuous exception), but processes not connected with La Nina appear to cause uptake anomalies (years with low atmospheric CO_2 growth) that are as large or larger than those that occur during La Nina years. On the other hand, all of the years with the largest (top 20%) concentration increase anomalies (notwithstanding anthropogenic emission trends) in the past 50 years have been El Nino years. These asymmetries between the large-scale effects of La Nina and El Nino events on the carbon cycle will be missed by studies that combine these extremes into a single mode of variability. This work means that future efforts to better understand the processes by which these events control the planetary carbon cycle should consider La Nina events separately from El Nino events. The composites described in detail by this study also will provide useful benchmarks for testing for the successful inclusion of biogeochemical processes in Earth System Models, an ongoing focus of the next round of International Panel on Climate Change modeling efforts. This work has been presented at national conferences and is described in the manuscript (soon to be submitted) entitled, The interannual variability of atmospheric carbon dioxide concentration and its response to La Nina and El Nino events, by A.M. Chiodi and D.E. Harrison. See attached Power Point slides for more information.

Because ENSO is such a big factor in the global carbon system, we anticipated that oceanic changes might be a significant factor in the long term trend in the fraction of CO2 emissions that remain in the atmosphere. This led us to examine further the prospects for identifying long-term

trends in the global planetary carbon cycle system and ENSO behavior using the available historical records. Our results did not come out as we'd expected (see below).

An important role of the ocean plus land carbon-cycle systems in the times since the industrial revolution has been to absorb much of the carbon dioxide (CO2) that has been emitted by human activity. Whether there has been a change in recent decades in the rate at which anthropogenically produced CO2 emitted to the atmosphere is absorbed by natural land and ocean processes is important to climate policy and is critical information for efforts to predict future atmospheric CO2 concentration. Some studies have suggested that the fraction of emitted CO2 that remains in the atmosphere (Airborne Fraction/AF) will increase as CO2 is accumulated on land and in the ocean, but there is disagreement on whether any change has been observed. Our work shows that uncertainties in the rate of emissions from land use changes (e.g. deforestation) means that Airborne Fraction trend cannot be determined reliably at present. The null hypothesis should remain that there is no trend. It will be at least decades before the most recently published trend will become statistically significant compared to the natural interannual variability in the system, and even then, we will not be able to trust it unless our knowledge of the time history of land use change emissions is somehow greatly improved. This work has been presented at the WCRP conference, and will shortly appear in the refereed literature. (see manuscript: Determining CO2 Airborne Fraction Trends with Uncertain Land Use Change Emission Records, by A.M. Chiodi and D.E. Harrison.)

Harrison and Carson, in preparation for a keynote presentation at the Climate Change and Oceanic Fisheries workshop at Rarotonga (to be held in Oct 2011), prepared a survey of recent results on oceanic trends and variability as well as some new results on variability and trends in the Cook Islands region of the tropical South Pacific ocean. This work emphases that the smaller the space scale of interest, the more likely interannual to decadal variability are to dominate oceanic conditions of relevance to fisheries management. Too often, because of relatively short fisheries time series observations, managers have assumed that recent trends can be associated with climate change and can be projected to continue. We show that when longer records are available this is generally an unwise assumption. This work will be written up and submitted for publication in the special volume to result from the workshop.

The task of identifying which aspects of climate are undergoing very long term trends has received increased attention in recent times. Historical records of marine climate have and will continue to be key to this task, but because observing long term trends was not a goal of most of our observing activities until recently, it is challenging to find appropriate high quality observational records for this task. We used a high quality, century-length (135yr) record, that of sea level pressure at Darwin, Australia, which is a very good proxy for the state of ENSO, to illustrate some of the issues faced in such trend studies, and identify some of the qualities required from a historical record to yield reliable trend estimates. We find that the distribution of multi-decadal trends includes nearly equal numbers of positive and negative trends, and many of these misleadingly pass common tests of statistical significance. This is not a useful length of record for estimating long term trends for this quantity. Over the full record, there is no statistically significant trend at the 95% level. For ENSO, given only a single multi-decadal record, one would be very unlikely to be able to estimate the long term trend. This work was presented at the MARCDAT-III meeting.

We also have partnered with colleagues to better characterize a class of summertime rainfall events in Oregon and Washington that affects wildland fire management.

In partnership with the US Forest Service, the co-investigator has also performed work to characterize the regional atmospheric conditions associated with the summertime heavy precipitation events that occur along the forested slopes of the Columbia River Basin in eastern Washington and Oregon. Results have identified categories of rainfall events that are more or less likely to be accompanied by lightning and more or less likely to occur at the higher/lower elevations, depending on the direction of their anomalous flow over the defining Columbia Basin Region. Although the more intense wintertime storms of this region have received more attentions, a moderate rain event in the early summer serves to postpone the start of the wildland fire season; such a rain event in late summer/early fall can effectively end that threat. This work is partly intended to aid wildland fire management efforts. See manuscript: Summertime Rainfall Events in Eastern Oregon and Washington, by N. A. Bond, A.M. Chiodi, N.K. Larkin and J. Barbour.

2.1. Outreach and Education

The PI served as Co-Editor of the three Volumes of Proceedings of the Ocean Observations 2009 Conference in Venice, Italy. All formal review and revision of Community White Papers and Plenary Papers was completed and the final production work on the papers, for the Symposium DVD (to be released by ESA) and for the hardcopy volumes (Vol 1- Plenary papers, Vol 2a and 2b – Community White Papers) was initiated. The Co-Editors anticipate the DVDs and hard copies will be distributed early in FY12.

The PI continued to serve as the Chair of the NOAA/OAR/CPO/COD Climate Observing System Council and as a steering committee member on the Global Climate Observing System steering committee. He continues also as member of the Commission of Climatology Expert Team on Climate Change Detection and Indices; as a member of the National Weather Service Climate Test Bed Science Advisory; and as a member of the CLIVAR task team on ocean climate indices. He is also Senior Fellow of the Joint Institute for the study of the Atmosphere and Ocean (NOAA/UW), Senior Fellow of the Joint Institute for Marine and Atmospheric Research (NOAA/U Hawaii) and External Fellow of the Joint Institute for Marine Observations (NOAA/UCSD and others)

We presented our work in numerous national, international and intergovernmental fora during FY11. These include:

Estimating long term trends in ENSO variability, A.M. Chiodi and D.E. Harrison, Third International Workshop on Advances in the Use of Historical Marine Climate Data (MARCDAT-III) 2-6 May 2011, Frascati, Italy [Talk]

An OLR-based El Nino Index for effects on U.S. seasonal weather anomalies, A.M. Chiodi and D.E. Harrison, The Open Science Conference of the World Climate Research Program, in Denver, CO, USA, 24-28 October 2011 [Poster]

Determining airborne fraction trend with uncertain land use emission estimates, A.M. Chiodi and D.E. Harrison, The Open Science Conference of the World Climate Research Program, in Denver, CO, USA, 24-28 October 2011 [Poster]

Subseasonal Variability and El Nino waveguide warming; observed effects of the MJO and Westerly Wind Events, A.M. Chiodi and D.E. Harrison, The Open Science Conference of the World Climate Research Program, in Denver, CO, USA, 24-28 October 2011 [Poster]

Seasonally averaged U.S. atmospheric circulation, temperature and precipitation anomalies, The OLR-El Nino perspective. A.M. Chiodi and D.E. Harrison, 2011 Fall American Geophysical Union Meeting, San Francisco, CA, USA, 5-9 December 2011. [Poster]

The interannual variability of atmospheric CO2 concentration and its response to La Nina and El Nino events, A.M. Chiodi and D.E. Harrison, 2011 Fall American Geophysical Union Meeting, San Francisco, CA, USA, 5-9 December 2011. [Talk]

3. Publications and Reports

3.1. Publications by Principal Investigators

Kamenkovich, I., W. Cheng, C. Schmid, and D.E. Harrison, 2011: Effects of eddies on an ocean observing system with profiling floats: Idealized simulations of the Argo array. *J. Geophys. Res.*, 116, C06003, doi: 10.1029/2010JC006910.

Chiodi, A. M., and D.E. Harrison, 2012: Determining CO_2 airborne fraction trends with uncertain land use change emission records. *International Journal of Climate Change: Impacts and Responses*, **3**, [In press]

Bond, N.A., A.M. Chiodi, N.K. Larkin, and J. Barbour, 2012: Summertime rainfall events in eastern Oregon and Washington. *J. Hydrometeor.* [In review]

Chiodi, A.M. and D.E. Harrison, 2012: The interannual variability of atmospheric CO2 concentration and its response to La Nina and El Nino events. [In revision]

Chiodi, A.M. and D.E. Harrison, 2012: Subseasonal atmospheric variability and El Nino waveguide warming; observed effects of the MJO and Westerly Wind Events. *J. Climate*, [submitted]

Chiodi, A.M. and D.E. Harrison, 2012: An OLR-El Nino index for effects on US seasonal weather anomalies. [In preparation]

D.E. Harrison and A.M. Chiodi, 2012: Estimating trends in ENSO with Darwin SLP. [In preparation]

Ocean Obs. 09 Conference Proceedings

Drinkwater, M.R., H. Bonekamp, P. Bontempi, B. Chapron, C. Donlon, J.-L. Fellous, P. DiGiacomo, D.E. Harrison, P.-Y. LeTraon, and S. Wilson, 2010: Status and outlook for the space component of an integrated ocean observing system. In *Proceedings of the "OceanObs'09: Sustained Ocean Observations and Information for Society" Conference (Vol. 1)*, Venice, Italy, 21–25 September 2009, Hall, J., D.E. Harrison, and D. Stammer, Eds., ESA Publication WPP-306, doi: 10.5270/OceanObs09.pp.17.

Lee, T., D. Stammer, T. Awaji, M. Balmaseda, D. Behringer, J. Carton, N. Ferry, A. Fischer, I. Fukumori, B. Giese, K. Haines, E. Harrison, P. Heimbach, M. Kamachi, C. Keppenne, A. Köhl, S. Masina, D. Menemenlis, R. Ponte, E. Remy, M. Rienecker, A. Rosati, J. Schroeter, D. Smith, A. Weaver, C. Wunsch, and Y. Xue, 2010: Ocean state estimation for climate research. In *Proceedings of the "OceanObs'09: Sustained Ocean Observations and Information for Society" Conference (Vol. 2)*, Venice, Italy, 21–25 September 2009, Hall, J., D.E. Harrison, and D. Stammer, Eds., ESA Publication WPP-306, doi: 10.5270/OceanObs09.cwp.55.

Palmer, M.D., J. Antonov, P. Barker, N. Bindoff, T. Boyer, M. Carson, C.M. Domingues, S. Gille, P. Gleckler, S. Good, V. Gouretski, S. Guinehut, K. Haines, D.E. Harrison, M. Ishii, G.C. Johnson, S. Levitus, M.S. Lozier, J.M. Lyman, A. Meijers, K. von Schuckmann, D. Smith, S. Wijffels, and J. Willis, 2010: Future observations for monitoring global ocean heat content. In *Proceedings of the "OceanObs'09: Sustained Ocean Observations and Information for Society" Conference (Vol. 2)*, Venice, Italy, 21–25 September 2009, Hall, J., D.E. Harrison, and D. Stammer, Eds., ESA Publication WPP-306, doi: 10.5270/OceanObs09.cwp.68.

Rienecker, M.M., T. Awaji, M. Balmaseda, B. Barnier, D. Behringer, M. Bell, M. Bourassa, P. Brasseur, J. Carton, J. Cummings, L.-A. Breivik, E. Dombrowsky, C. Fairall, N. Ferry, G. Forget, H. Freeland, S.M. Griffies, K. Haines, D.E. Harrison, P. Heimbach, M. Kamachi, E. Kent, T. Lee, P.-Y. Le Traon, M. McPhaden, M.J. Martin, P. Oke, M.D. Palmer, E. Remy, T. Rosati, A. Schiller, D.M. Smith, D. Snowden, D. Stammer, K.E. Trenberth, and Y. Xue, 2010: Synthesis and assimilation systems—Essential adjuncts to the Global Ocean Observing System. In *Proceedings of the "OceanObs'09: Sustained Ocean Observations and Information for Society" Conference (Vol. 1)*, Venice, Italy, 21–25 September 2009, Hall, J., D.E. Harrison, and D. Stammer, Eds., ESA Publication WPP-306, doi: 10.5270/OceanObs09.pp.31.

Stammer, D., A. Köhl, T. Awaji, M. Balmaseda, D. Behringer, J. Carton, N. Ferry, A. Fischer, I. Fukumori, B. Giese, K. Haines, E. Harrison, P. Heimbach, M. Kamachi, C. Keppenne, T. Lee, S. Masina, D. Menemenlis, R. Ponte, E. Remy, M. Rienecker, A. Rosati, J. Schröter, D. Smith, A. Weaver, C. Wunsch, and Y. Xue, 2010: Ocean information provided through ensemble ocean syntheses. In *Proceedings of the "OceanObs'09: Sustained Ocean Observations and Information for Society" Conference (Vol. 2)*, Venice, Italy, 21–25 September 2009, Hall, J., D.E. Harrison, and D. Stammer, Eds., ESA Publication WPP-306, doi: 10.5270/OceanObs09.cwp.85.

3.2. Other Relevant Publications

The following publications cite or make use of the work of this project.

Boschat, Ghyslaine. Interannual relationships between Indian Summer Monsoon and Indo-Pacific coupled modes of variability during recent decades. CLIMATE DYNAMICS, SEP 2011.

Terray, Pascal. Southern Hemisphere extra-tropical forcing: a new paradigm for El Nino-Southern Oscillation. CLIMATE DYNAMICS, JUN 2011.

Morioka, Yushi. Climate variability in the southern Indian Ocean as revealed by self-organizing maps. CLIMATE DYNAMICS, NOV 2010.

Rong, Xinyao. Upscale feedback of high-frequency winds to ENSO. QUARTERLY JOURNAL OF THE ROYAL METEOROLOGICAL SOCIETY, APR 2011.

Singh, Awnesh. Contrasting the flavors of El Nino-Southern Oscillation using sea surface salinity observations. JOURNAL OF GEOPHYSICAL RESEARCH-OCEANS, JUN 23 2011.

Singh, Awnesh. Estimating the effects of ENSO upon the observed freshening trends of the western tropical Pacific Ocean. GEOPHYSICAL RESEARCH LETTERS, NOV 8 2011.

Yin, Jianjun. Different magnitudes of projected subsurface ocean warming around Greenland and Antarctica. NATURE GEOSCIENCE, AUG 2011.

Montecinos, Aldo. Non-ENSO interannual rainfall variability in central Chile during austral winter. THEORETICAL AND APPLIED CLIMATOLOGY, DEC 2011.

Boucharel, J. ENSO nonlinearity in a warming climate. CLIMATE DYNAMICS, NOV 2011.

Khider, D. Assessing El Nino Southern Oscillation variability during the past millennium. PALEOCEANOGRAPHY, SEP 15 2011.

Shinoda, Toshiaki. Anomalous tropical ocean circulation associated with La Nina Modoki. JOURNAL OF GEOPHYSICAL RESEARCH-OCEANS, DEC 2 2011.

Moore, G. W. K. Global Warming, El Nino, and High-Impact Storms at Extreme Altitude: Historical Trends and Consequences for Mountaineers. JOURNAL OF APPLIED METEOROLOGY AND CLIMATOLOGY, NOV 2011.

Boucharel, J. ENSO nonlinearity in a warming climate. CLIMATE DYNAMICS, NOV 2011.

Kug, Jong-Seong. A possible mechanism for El Nino-like warming in response to the future greenhouse warming. INTERNATIONAL JOURNAL OF CLIMATOLOGY, AUG 2011.

Ohba, Masamichi. Simulation of Asymmetric ENSO Transition in WCRP CMIP3 Multimodel Experiments. JOURNAL OF CLIMATE, NOV 15 2010.

Lengaigne, Matthieu. Contrasting the termination of moderate and extreme El Nio events in coupled general circulation models. CLIMATE DYNAMICS, AUG 2010.

Jayakumar, A. Processes controlling the surface temperature signature of the Madden-Julian Oscillation in the thermocline ridge of the Indian Ocean. CLIMATE DYNAMICS, DEC 2011.

Klingaman, Nicholas P. The Impact of Finer-Resolution Air-Sea Coupling on the Intraseasonal Oscillation of the Indian Monsoon. JOURNAL OF CLIMATE, MAY 15 2011.

Halkides, Daria. Mechanisms controlling seasonal mixed layer temperature and salinity in the Southwestern Tropical Indian Ocean. DYNAMICS OF ATMOSPHERES AND OCEANS, APR 2011