Observing Systems Research Studies: Climate Phenomena and Impacts

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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 and indices that usefully characterize their amplitudes and their linkages to US and global weather anomalies, with the goals of improving our awareness and understanding of present climate conditions, the effectiveness of the global observing system for climate and helping society understand, forecast and project seasonal and longer term weather and climate anomalies. 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. 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 also work within the NOAA, US, international and intergovernmental ocean and climate organizations, with particular focus on the Global Climate Observing System program, the Global Ocean Observing System, the Joint WMO/IOC Commission on Oceanography and Marine Meteorology 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 NOAA's Pacific Marine Environmental Laboratory (http://stateoftheocean.osmc.noaa.gov/), and collaboration with the Observing System Monitoring Center project now lead by Kevin O'Brien and Eugene Burger.

2. Scientific and Observing System Accomplishments

a) Reliably projecting future atmospheric CO_2 levels requires models capable of predicting global carbon cycle variability. Development of such Earth System Models is ongoing but in need of more useful benchmarks. Group work has led to improved benchmarks in the form of improved knowledge of the effects that El Nino and La Nina events have on year-to-year changes in global atmospheric CO_2 concentration. It has long been known that there is a connection between El Nino and La Nina events and extremes in the rate of change of atmospheric CO_2. Due to group work, it is now understood that the effects of strong La Nina events are about 50% weaker than those of strong El Nino events, and act over different seasons, with statistically significant La Nina effects being seen from September Year 0 to May Year 1, and El Nino effects from December Year 0 to August Year 1. Also, weaker La Nina events do not have statistically significant effects, whereas the weaker El Nino events have effects comparable to the larger El Nino events. Results from this work have been published in the Chiodi and Harrison 2014a journal article.

b) Subseasonal wind variability across the equatorial Pacific Ocean is widely understood to be an important precursor to the development of El Nino events, but until now there has been confusion in the literature as to which classes of subseasonal wind events are and are not important to the onset and development of El Nino events. Group work has compared the inter-relationships between two classes of wind events, namely Westerly Wind Events and the Madden-Julian Oscillation (MJO), and the observed changes in sea surface temperature along the Pacific's oceanic waveguide. The results of this study are clear. Westerly Wind Events drive waveguide warming and help initiate El Nino events regardless of the state of the MJO. MJO events drive waveguide warming only if they contain Westerly Wind Events embedded in them. Further, the chance of seeing a Westerly Wind Event remains the same whether or not an MJO event occurs. It is the Westerly Wind Events that are important to the initiation and growth of El Nino events, not the MJO. Better understanding the processes that cause Westerly Wind Events and their predictability remains an avenue for better understanding these aspects of ENSO. This work has resulted in the Chiodi, Harrison and Vecchi 2014 paper listed below.

c) Previous group work has shown that following the large El Nino event of 1997-98, Westerly Wind Events have, in a composite average sense, an adjacent easterly wind element in the cold tongue that effectively cancels out much of the eastern cold tongue warming that would otherwise be driven by the westerly wind anomaly element of the event. We also previously showed that a series of Westerly Wind Events that include such an easterly element results in a Central Pacific El Nino, whereas Westerly Wind Events without cold-tongue easterlies drive Eastern Pacific El Nino events (Harrison and Chiodi, Journal of Climate, 2009).

Easterly wind events, which we refer to as Easterly Wind Surges, can occur independently of Westerly Wind Events and are frequently an aspect of waveguide wind variability. Although they are much less visible in terms of wind speed than Westerly

Wind Events, the Easterly Wind Surges act on top of the already easterly trade winds to produce wind stress anomaly amplitudes that are comparable to the stress anomalies of westerly wind events. Group research has documented the occurrence statistics of Easterly Wind Surges as well as their spatial scales and amplitudes. Our results show them to increase in frequency as the tropical Pacific anomaly state transitions into its cool-SSTA (La Nina) phase. Model experiment and observational analysis also show that it is just as easy for an Easterly Wind Surge to cool the central to eastern Pacific oceanic waveguide by a few tenths of a degree C over the course of two to three months, as is it for Westerly Wind Events to warm it. EWSs are as important to the onset of La Nina event cold tongue cooling as are WWEs to the onset of El Nino cold tongue warming.

In the course of this work, we found that the numerical weather model reanalysis wind stress estimates that we used to identify EWSs were biased relative to the TAO buoy winds. Only after the reanalysis winds were matched to TAO were we able to accurately reproduce the observed SSTA variations in the forced ocean model experiments. This underscores how important the TAO buoy measurements are to our ability to diagnose the observed equatorial Pacific SSTA changes through our knowledge of the winds. Model experiments with an ocean general circulation model also show that the easterly wind stresses associated with a series of Easterly Wind Surges, such as typically occur during a La Nina year, can drive a full amplitude La Nina event. Future studies that result in a better understanding of the processes that cause Easterly Wind Surges will improve our understanding of the processes that drive La Nina. This work will appear as the Chiodi and Harrison 2014b paper, currently in press at the Journal of Climate.

d) Some of our previous work has shown that outgoing longwave radiation conditions indicative of clear skies in the western equatorial Pacific (the equatorial region typically associated with maximum deep atmospheric convection) are a useful precursor to La Nina-type seasonal weather anomalies over the US, and many other affected regions around the world. Recent work has led to the understanding that Easterly Wind Surges are connected to these conditions, meaning that in addition to altering the tropical atmospheric heating patterns, these “clear sky” conditions are also associated with wind events that cool the waveguide over the coming 2-3 months. Together, these results challenge the majority view by suggesting that El Nino and La Nina development relies more on synoptic scale variability than has previously been realized. A paper describing the connection between this synoptic scale OLR behavior and global seasonal precipitation anomalies is in review at the Journal of Climate. Understanding better the connections between waveguide SSTA, atmospheric circulation and OLR anomalies will be essential for improved seasonal ENSO weather forecast skill.

e) We have continued to contribute to outreach about climate variability and trends to the global oceanic fishery management community. We have shown that because the El Nino-Southern Oscillation (ENSO) greatly affects several Pacific fisheries and the magnitude of ENSO variability is so strong that it will likely dominate environmental conditions in the tropical Pacific in the next few decades, compared to the ‘climate change’ projections from most coupled earth system models, fishery management

decisions will have to be made in a context of very substantial uncertainty about upcoming environmental conditions (Harrison and Chiodi, 2014).

f) Recent work has shown that diagnosis of ENSO SSTA development is feasible with accurate knowledge of winds across the Pacific waveguide, but high quality wind observations from the TAO/Triton buoy array are needed to do this successfully. Specifically, we have shown that since the TAO buoy array has been fully deployed (beginning ~1986), spring to fall integrals of wind stress over the Pacific ocean waveguide are highly correlated (r~0.9) with end of year Nino3.4 SSTA, but there are 30 year trends in the Interim European Centre for Medium Range Forecasting reanalysis wind stress estimates (generally considered to be among the best reanalyses) that are inconsistent with the TAO buoy data. The diagnosis of observed SSTA suffers importantly if the reanalysis data is not first corrected with the TAO observations. Even though TAO observations have been assimilated into atmospheric reanalysis products, it's important to use the TAO data independently to improve the usefulness of the reanalyses to understanding ENSO development.

g) These results basically show that zonal winds along the equatorial Pacific are the dominant driver of end of year ENSO conditions and that, in our present observing system configuration, the TAO buoys are key to making useful estimates of the zonal winds (along with many other variables). These results, along with some closely associated ocean general circulation model hindcasts of equatorial Pacific SSTA in individual El Nino years were well received at the recent 39th NOAA Climate Diagnostic and Prediction Workshop, in St. Louis, and have motivated us to study further the relationship between ENSO SSTA development and zonal winds along the equatorial Pacific, as well as and the importance that high quality wind observations have in our ability to better understand these relationships.

h) DEH was a co-organizer of the TPOS 2020 workshop, lead author on one TPOS White Paper (Harrison et al, 2014, see below), and co-author on another (Cronin et al, 2014, see below).

i) DEH was a co-organizer of the GODAE OceanView Symposium.

j) We have begun work to understand better the wind changes that are associated with the termination of La Nina events and, hopefully, to understand better why La Nina events often follow one another while El Nino events almost always happen one at a time.

k) We also continue to search for useful ocean indices that can help with prediction skill or societal impact skill.

3. Outreach and Education

a) Our group partners with the group formerly led by Steve Hankin, and presently under the direction of Eugene Burger, to provide the State of the Ocean Climate website (http://stateoftheocean.osmc.noaa.gov), which gives an at-a-glance view of the amplitudes of ocean climate indices, along with estimates of their uncertainty that can be linked to major patterns of climate variability.

b) Group outreach efforts have included publication of results in the peer reviewed literature and presentations at various national and international scientific conferences and workshops (such as are listed below) to inform various scientific communities about the relevant aspects of group research results.

c) The co-P.I. has made the following presentations at national and international scientific conferences;

An OLR perspective on La Nina and El Nino seasonal weather impacts over North America, A.M. Chiodi and D.E. Harrison, NOAA's 38th Climate Diagnostics and Prediction Workshop, 21-24 October 2013, College Park, MD.

An OLR perspective on ENSO impacts on seasonal weather anomalies, A.M. Chiodi and D.E. Harrison, European Geosciences Union General Assembly, 27 April – 2 May 2014, Vienna, Austria.

Subseasonal atmospheric variability and El Nino waveguide warming; observed effects of the Madden-Julian Oscillation and Westerly Wind Events, A. M. Chiodi, D.E. Harrison and G.A. Vecchi, 2014 Ocean Sciences Meeting, 23-28 February 2014, Honolulu, Hawaii.

d) DEH participated in numerous NOAA, national and international activities in his roles as Global Climate Observing System Steering Committee member, member of the international Expert Team on Climate Change Detection and Indices, member of the international Commission on Agriculture Fisheries and Climate Change task team, and as technical expert in a number of other activities. In addition to intersessional work, he participated in the following:

Oct 21-24, 2013 Global Climate Observing System Steering Committee, Offenbach
Dec 16-18 Climate Obs Division Strategic Plan, DC
Jan 24, 2014 NCEP, Climate Program Office Stakeholder mtg DC
Jan 27-30 San Diego, Tropical Pacific OS Review. La Jolla
Mar 10-11 GCOS Terrestrial Observations Panel for Climate JRC, Ispra,
Apr 7-11 GCOS Atmospheric Observations Panel for Climate, JRC Ispra
May 13-15, Arctic Prediction Wkshp, Boulder
June 11-12, Future Ocean Science Advisory Board, Kiel
July 22-24 GCOS Ocean Observations Panel for Climate, Barcelona

Sept 9-11 PMEL Laboratory Science Review
Sept 22-23 UW Ocean Faculty Retreat
Sept 30-3Oct GCOS SC, Geneva

4. Publications and Reports

4.1. Publications by Principal Investigators

Published

Chiodi, A.M., and D.E. Harrison (2014a): Comment on Qian et al. 2008: La Niña and El Niño composites of atmospheric CO_2 change. Tellus B, 66, 20428, doi: 10.3402/tellusb.v66.20428

Chiodi, A.M., D.E. Harrison, and G.A. Vecchi (2014): Subseasonal atmospheric variability and El Niño waveguide warming: Observed effects of the Madden-Julian Oscillation and Westerly Wind Events. J. Climate, 27(10), doi: 10.1175/JCLI-D-13-00547.1, 3619–3642.

In press

Chiodi, A.M., and D.E. Harrison (2014b): Equatorial Pacific easterly wind surges and the onset of La Niña events. J. Climate, doi: 10.1175/JCLI-D-14-00227.1.

Harrison, D.E., and A.M. Chiodi (2014): Multi-decadal variability and trends in the El Niño-Southern Oscillation and tropical Pacific fisheries implications. Deep-Sea Res. II, doi: 10.1016/j.dsr2.2013.12.020.

Proceedings:

Cronin, M.F., M. Bourassa, C.A Clayson, J. Edson, C. Fairall, R.A. Feely, D.E. Harrison, S. Josey, M. Kubota, B. Praveen Kumar, K. Kutsuwada, B. Large, J.T. Mathis, M.J. McPhaden, L. O'Neill, R. Pinker, K. Takahashi, H. Tomita, R.A. Weller, L. Yu, and C. Zhang (2014): TPOS White Paper #11: Wind stress and air-sea fluxes observations: status, implementation and gaps. In Proceedings of the Tropical Pacific Observing System 2020 Workshop, A Future Sustained Tropical Pacific Ocean Observing System for Research and Forecasting, La Jolla, CA, 27–30 January 2014.

Harrison, D. E., N. Bond, L. Goddard, R. Martinez and T. Yamagata. Some societal impacts of ENSO (2014). TPOS White Paper #2. In Proceedings of the Tropical Pacific Observing System 2020 Workshop, A Future Sustained Tropical Pacific Ocean Observing System for Research and Forecasting, La Jolla, CA, 27–30 January 2014.

4.2. Other Relevant Publications

This section includes a partial list of peer-reviewed papers that have appeared in print within the last year, been authored by scientists outside of our group, and cite recent work by the project P.I, or co-P.I. The first two publications in this list are attached, for reference.

Capotondi, A., and Coauthors, 2014: Understanding ENSO diversity, Bull. Amer. Met. Soc., In press, doi:10.1175/BAMS-D-13-00117.1

Kennedy, J.J., 2014: A review of uncertainty in in situ measurements and data sets of sea surface temperature, Reviews of Geophysics, **52**, 1-32.

Abe, H., and Coauthors, 2014: Oceanic Rossby waves induced by the meridional shift of the ITCZ in association with ENSO events, *J. Oceanogr.*, **70,** 165-174.

Banholzer, S., and S. Donner, 2014: The influence of different El Nino types on global average temperature, *Geophys. Res. Lett.*, **41**, 2093-2099.

Banse, K., S., and Coauthors, 2014: Oxygen minimum zone of the open Arabian Sea: variability of oxygen and nitrate from daily to decadal timescales. Biogeosciences, **11**, 2237-2261.
Ham, Y.-G. and J.-S. Kug, 2014, ENSO phase-locking to the boreal winter in CMIP3 and CMIP5, *Clim, Dyn*., **43**, 305-318.

Cai, W., and Coauthors, 2014: Increasing frequency of extreme El Nino events due to greenhouse warming, *Nature Climate Change*, **4**, 111-116.

Choi, K.-Y., G.A. Vecchi and A.T. Wittenberg, 2013: ENSO Transition, Duration, and Amplitude Asymetries: Role of the Nonlinear Wind Stress Coupling in a Conceptual Model, *J. Climate*, **26,** 9462-9476.

Di Lorenzo, E. and Coauthors, 2013: Synthesis of Pacific Ocean Climate and Ecosystem Dynamics, *Oceanogr.*, **26**, 68-81.

Donders, T.H., and Coauthors, 2013: ENSO signature in botanical proxy time series extends terrestrial El Nino record into the (sub)tropics, *Geophys, Res. Lett.*, **40**, 5776-5781.

Dong, Lu, T. Zhou, and B. Wu, 2014: Indian Ocean warming during 1958-2004 simulated by a climate system model and its mechanism, *Clim. Dyn*., **42**, 203-217.

Ha, Y., and Coauthors, 2013: Different Pacific Ocean Warming Decaying Types and Northwest Pacific Tropical Cyclone Activity, *J. Climate*, **26**, 8979-8994.

Hoell, A. and C. Funk, 2013: The ENSO-Related West Pacific Sea Surface Temperature Gradient, *J. Climate,* **26**, 9545-9562.

Karnauskas, K.B., 2013: Can we distinguish canonical El Nino from Modoki? *Geophys. Res. Lett.*, **40**, 5246-5251.

Kim, W., and W. Cai, 2014: The importance of the eastward zonal current for generating extreme El Nino. *Clim. Dyn*, **42**, 3005-3014.

Liu, C., X. Ren, X. Yang, 2014: Mean flow-storm track relationship and Rossby wave breaking in two types of El Nino, *Adv. Atmos. Sci.*, **31**, 197-210.

Luebbecke, J.F., and M.J. McPhaden, 2014: Assessing the Twenty-First Century Shift in ENSO Variability in Terms of the Bjerknes Stability Index, *J. Climate,* **27**, 2577-2587.

Miyasaka, T., and Coauthors, 2014: Multidecadal modulations of the low-frequency climate variability in the wintertime North Pacific since 1950, *Geophys. Res. Lett.*, **41**, 2948-2955.

Morioka, Y., and Coauthors, 2014: Role of Tropical SST Variability on the Formation of Subtropical Dipoles. *J. Climate*, **27**, 4486-4507.

Murphy, B.F., S.B. Power, and S. McGree,, 2014: The Varied Impacts of El Nino-Southern Oscillation on Pacific Island Climates, *J. Climate*, **27**, 4015-4036.

Philippon, N., and Coauthors, 2014: Timing and Patterns of the ENSO Signal in Africa over the Last 30 Years: Insights from Normalized Difference Vegetation Index Data, *J. Climate,* **27**, 2509-2532.

Radebach, A., and Coauthors, 2013: Disentangling different types of El Nino episodes by evolving climate network analysis, *Physical Review,* **88**(5).

Romanov, Y., N.A. Romanova and P. Romanov, 2014: Changing effect of El Nino on Antarctic iceberg distribution: From canonical El Nino to El Nino Modoki, *J. Geophys. Res.-Oceans,* **119**, 595-614.

Salas, M. A., M.E.H. Cerda, J. V. Cruz, E.A. Romero, and C.T.L. Barrie, 2014: THE INFLUENCE OF STRONG EL NINO PHASES ON THE RAINFALL OVER THE YUCATAN PENINSULA, MEXICO. *Analele stiintifice ale Universitatii" Alexandru Ioan Cuza" din Iasi-seria Geografie*, ***60***(1), 15-28.

Sheffield, J., and Coauthors, 2013: North American Climate in CMIP5 Experiments, Part II: Evaluation Simulations of Intraseasonal to Decadal Variability, *J. Climate,* **23**, 9247-9290.

Son, C.-Y., and Coauthors, 2014: Characteristics of tropical cyclone-induced precipitation over the Korean River basins according to three evolution patterns of the Central-Pacific El Nino, *Stochastic Environmental Research and Risk Assessment*, **28**, 1147-1156.

Sooraj. K. P., and Coauthors, 2013: Recent drought events over the central Indian region: Pacific Ocean origin and insights from moisture budgets, *Int. J. Climatol.*, **33**, 2781-2798.

Stein, K., and Coauthors, 2014: ENSO Seasonal Synchronization Theory, *J. Climate*, **27**, 5285-5310.

Sutton, A.J, and Coauthors, 2014: Natural variability and anthropogenic change in equatorial Pacific surface ocean pCO2 and pH, *Global Biogeochem. Cyc.*, **28,** 131-145.

Vihma, T., 2014: Effects of Arctic Sea Ice Decline on Weather and Climate: A Review. *Surveys in Geophysics*, **35**, 1175-1214.

Vimont, D.J., M.A. Alexander, and M. Newman, 2014: Optimal growth of Central and East Pacific ENSO events, *Geophys. Res. Lett*., **41**, 4027-4034

Widlansky, M.J., and Coauthors, 2014: An Interhemispheric Tropical Sea Level Seesaw due to El Nino Taimasa, *J. Climate*, **27**, 1070-1081.

Wilks. D. S., 2014: Probabilistic canonical correlations analysis forecasts, with application to tropical Pacific sea-surface temperatures, *Int. J. Climatology*, **34**, 1405-1413.

Wittenberg, A. T. and Coauthors, 2014: ENSO Modulation: Is it Decadally Predictable?, *J. Climate*, **27**, 2667-2681.

Yamagami, Y., and T. Tozuka, 2014: Interdecadal changes of the Indian Ocean subtropical dipole mode. *Climate Dynamics*, 1-10.

Yang, C., B. Ren, G. Li, and J. Zheng, 2014: Change of the wintertime SSTA variability over the West Pacific after the mid-1980s: Effect of the increasing El Niño Modoki. *J. Geophys. Res.: Atmos*. , ***119*(**9), 5204-5225.

Yang, S. and X. Jiang, 2014: Prediction of Eastern and Central Pacific ENSO Events and Their Impacts on East Asian Climate by the NCEP Climate Forecast System, *J. Climate*, **27**, 4451-4472.

Yuan, C. and Coauthors, 2014: Predictability of the subtropical dipole modes in a coupled ocean-atmosphere model, **42**, 1291-1308.

Zhang, W., F.-F. Jin, and A. Turner, 2014: Increasing autumn drought over southern China associated with ENSO regime shift, *Geopys. Res. Lett*., **431**, 4020-4026.

Zhang, T. and D.-Z. Sun, 2014: ENSO Asymmetry in CMIP5 Models, *J. Climate*, **27,** 4070-4093.

Zhang, T., J. Perlwitz and M.P. Hoerling, 2014: What is responsible for the strong observed asymmetry in teleconnections between El Nino and La Nina? *Geophys. Res. Lett.*, **41**, 1019-1025.

Zheng, Y., R. Zhang, and M.A. Bourassa, 2014: Impact of East Asian Winter and Australian Summer Monsoons on the Enhanced Surface Westerlies over the Western Tropical Pacific Ocean Preceding the El Nino Onset, *J. Climate*, **27**, 1928-1944.

Zou, Y., and Coauthors, 2014: CMIP5 model simulation of the impacts of the two types of El Nino on the US winter temperature, *J. Geophys, Res.-Atmos.*, **119**, 3076-3092.

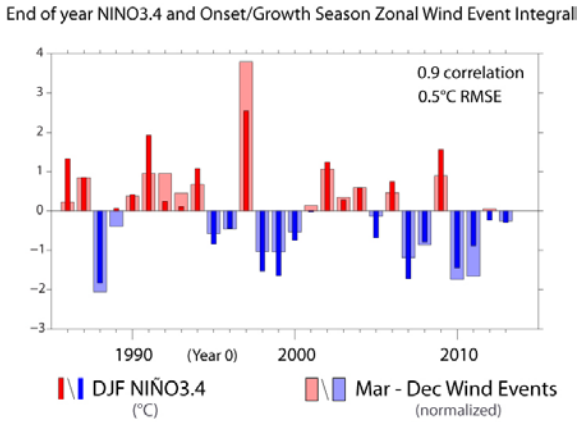
5. Slides

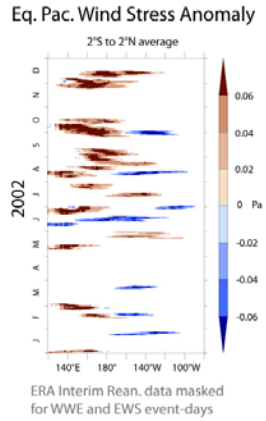
(The three following slides have also been attached as Power Point slides)

1.

End of calendar year ENSO SSTA can be diagnosed from accurate knowledge of that year's subseasonal wind variability

Example year: to get the integral value we count up red (westerly) minus blue (easterly) shaded regions





ERA Reanalysis wind stress, matched to TAO, is used for westerly/easterly wind event identification

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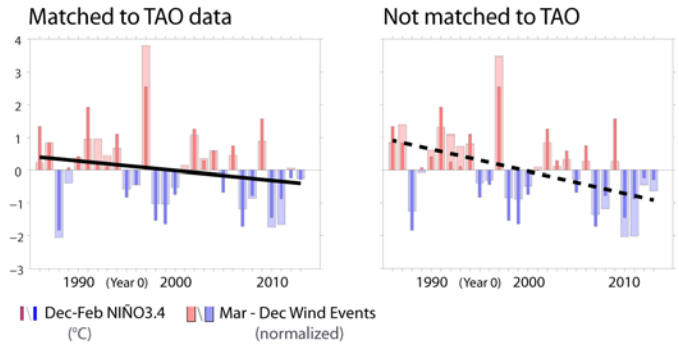
2.

We need TAO to be able to do this successfully!

We use ERA-Interim reanalysis data to identify the subseasonal westerly/easterly wind events, but the reanalysis data has a trend in the Eq. Pacific over recent decades that is inconsistent with (twice as large) as what is seen in the TAO measurements.

Results with 30-yr trend:



The reanalysis data first needs to be matched to TAO to produce the good results (left panel). If the raw reanalysis data is used, a misleading trend appears in the wind event integral result (right panel).

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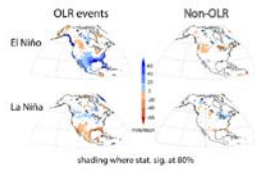
3.

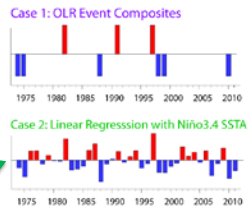
Wintertime (DJF) Global Precipitation Hindcasts: OLR vs SST



We've shown previously that the familiar ENSO seasonal weather anomalies are only strongly associated with the subset of EN & LN events identified by OLR. What are some forecast implications of this?

Case 1: We apply OLR composite precipitation only in the 3 (6) El Nino (La Nina) years identified by OLR by the beginning of December Year 0. *Otherwise, the hindcast anomaly = 0.*

Case 2: We specify DJF precip. anomaly via linear regression with SON-average NINO3.4 SSTA.



Then we examine anomaly correlation coefficients between observed & hindcast precip. This is done globally (60°S to 60°N). **The correlation is computed over all years**, not just those identified by OLR.

RESULTS:

OLR-approach: 27% of land reaches correlation significant at 95%

Linear-Niño34: 16% of land reaches correlation significant at 95%

OLR perspective leads to better hindcast correlation in most locations, even though anomaly is only specified in OLR years!

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