14D.6 LOCAL VERSUS REMOTE CONTROLS OF EAST PACIFIC INTRASESONAL VARIABILITY

Adam V. Rydbeck* and Eric D. Maloney
Colorado State University, Fort Collins, Colorado

1. INTRODUCTION

1.1 *BACKGROUND*

The Madden-Julian oscillation (MJO) is the primary mode of tropical intraseasonal (30-90-day) variability that originates in the Indian Ocean and propagates slowly eastward at approximately 5 m/s west of the dateline. When the MJO moves east of the dateline, convection typically weakens, and the Kelvin-Rossby wave packet associated with the MJO decouples. After decoupling, MJO signals in zonal wind propagate rapidly eastward as a 30-35 m/s Kelvin wave (Zhang 2005) until it reaches the east Pacific where convective coupling reoccurs.

Intraseasonal variability in the east Pacific warm pool is often described as a local amplification of the eastward propagating MJO (Knutson and Weickmann 1987; Maloney and Kiehl 2002). However, many possibilities exist for the manner in which the east Pacific warm pool and tropical Eastern Hemisphere interact on intraseasonal timescales. The possible relationships between the aforementioned basins of intraseasonal variability can be divided into two categories. The first category is that of independence of the east Pacific warm pool intraseasonal variability from that of the tropical Eastern Hemisphere. This category suggests that the mechanisms and requirements for an intraseasonal oscillation in the east Pacific are entirely locally available, and the east Pacific may be phase locked to the Eastern Hemisphere via rapid Kelvin wave communication mechanisms. The second category suggests that the requirements and mechanisms for east Pacific intraseasonal variability are not entirely locally available, and remote controls from the Eastern Hemisphere are necessary to support significant intraseasonal variability in the east Pacific. These two categories of east Pacific intraseasonal variability are examined in two distinct models using mechanism denial tests.

1.2 *STUDY OUTLINE*

The study is organized as follows. Chapter two provides descriptions of both models used to analyze east Pacific intraseasonal variability and the methodology for evaluating the variability in both model, respectively. Chapter three details the results from the control and mechanism denial model runs. A summary and conclusions are presented in chapter four.

**Corresponding author address:* Adam V. Rydbeck, Dept. of Atmospheric Science, Colorado State University, 1371 Campus Delivery, Fort Collins, CO, 80523-1371; email: arydbeck@atmos.colostate.edu

2. DATA AND METHODOLOGY

To test the independence of east Pacific intraseasonal variability from that of the Eastern Hemisphere, the east Pacific must be isolated from outside tropical intraseasonal variability. The isolation of the east Pacific ensures that non-local intraseasonal signals are not influencing local intraseasonal variability. The first model used in this study is the International Pacific Research Center Regional Atmosphere Model (IRAM) that solves the hydrostatic primitive equations on an unstaggered horizontal 0.5° x 0.5° model grid that covers the domain from 25°S to 45°N and 150°W to 30°W. The model has 28 vertical levels with 11 below 800-hPa. The IRAM includes a physical package for convection, cloud, radiation, and turbulent mixing that is detailed in Wang et al. (2004). Except for the sea surface temperature taken from the NCEP/MMAB analysis, the initial and boundary conditions for the IRAM are from NCEP/NCAR reanalysis. A 12-year control simulation from 1997-2008 was run using the IRAM with no modifications. In order to isolate the east Pacific, a separate IRAM run, known as the filter run, uses a 30-90-day bandpass filter to remove intraseasonal signals from the initial and boundary conditions. By using the filtered initial and boundary conditions, the ability of the MJO to force the atmospheric model is removed.

The second model used in this study is the National Center for Atmospheric Research Community Atmosphere Model 3 (CAM). The standard deep convection parameterization in the CAM is substituted for the Relaxed Arakawa-Schubert (RAS) convection scheme of Moorthi and Suarez (1992). In the RAS convection scheme, both a minimum entrainment rate and convective rainfall re-evaporation into unsaturated air aid in more realistic intraseasonal variability (Tokiaka et al. 1988; Hannah and Maloney 2011). For all simulations using the CAM, the horizontal resolution is T85 (approximately 1.4° x 1.4°) and uses perpetual August 15th sea surface temperatures and insolation over a 10-year period. A control simulation was first run with no modifications to the CAM. To suppress eastward Kelvin wave propagation in the CAM, a sponge region is added to the central Pacific (20°S - 20°N, 175°W - 145°W). The sponge region extends through all vertical levels and uses a relaxation timescale of 1 day to effectively dampen Kelvin waves propagating across this region. The sponge region is applied to temperature, dry static energy, horizontal winds, specific humidity, and surface pressure. This scheme is known as the sponge run.

To analyze intraseasonal events in the east Pacific for both models, a lag composite technique is used. This method of indexing intraseasonal variability relies only on local intraseasonal variability in the east Pacific. The local index is constructed from the normalized first principal component (PC) of 30-90-day 850-hPa zonal wind and precipitation anomalies over the east Pacific region of 10°S - 25°N and 150°W - 70°W. Significant intraseasonal events are defined by the magnitude of the first PC. To qualify as a significant event, the PC value must be greater than 1.5 standard deviations from zero and a relative maximum with no other significant events occurring 20 days before or after it. Once significant events are determined, data is lagged at particular intervals from an event for certain 30-90-day variables and averaged to give a lag composite plot. This local method is not necessarily based on global MJO activity, but rather local intraseasonal variability.

3. RESULTS

3.1 *IRAM*

Figure 1 shows the positive and negative anomalous precipitation phases of an east Pacific intraseasonal event as a function of lag. The variables plotted are 30-90-day 850-hPa horizontal wind and precipitation anomalies. Similar to Figure 1, observations of the evolution of east Pacific intraseasonal events typically show positive precipitation anomalies east of 120°W associated with low-level westerly anomalies (Maloney and Esbensen 2007). Moreover, negative precipitation anomalies are associated with low-level easterly anomalies there. Unlike observations, the IRAM control composite event has a strong band of negative precipitation anomalies to the south of positive precipitation anomalies during the enhanced precipitation phases. In Figure 2, the same variables are shown at the same lags for the IRAM filter run. The IRAM filter run composite has similar but much weaker phases of easterly and westerly low-level wind anomalies for the particular lags. The precipitation anomalies at the respective lags are much noisier and weaker than the observational and the IRAM control composites. Moreover, an evaluation of the power spectrum of the low-level winds for the IRAM filter run reveal no significant power at intraseasonal timescales in the east Pacific warm pool at the 95% significance threshold. Only marginally significant power exists at approximately 35-40 day periods in the east Pacific warm pool precipitation for the IRAM filter run (not shown). The IRAM control run has significant power in both precipitation and low-level winds at characteristic 50-day periods in the east Pacific warm pool. The power spectrum for the IRAM control run agrees well with observations. From these results, the IRAM filter run does not support the ability of the east Pacific to produce significant and coherent intraseasonal variability in isolation from other intraseasonal signals, chiefly the MJO.

Because the observational boreal summer mean low-level flow is westerly in the east Pacific warm pool, anomalous westerlies constructively add to the mean wind, increasing the total wind. The increased total wind speed strengthens wind induced surface heat exchange mechanisms that can then help destabilize the east Pacific warm pool for convection. During periods of anomalous easterlies, the total wind speed is reduced promoting negative precipitation anomalies through the suppression of wind induced surface heat exchange

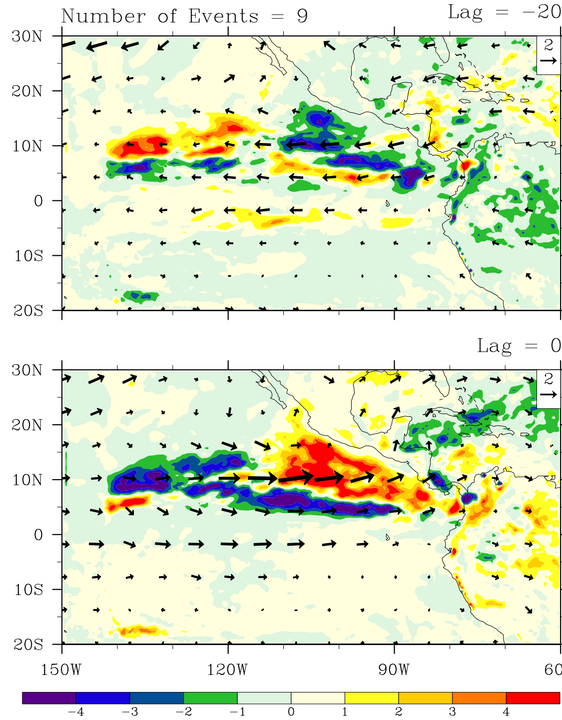

Figure 1. Lag composite plot of 30-90-day 850-hPa wind (vectors, m/s) and precipitation (color contours, mm/day) anomalies for lags -20 (top) and 0 (bottom) for the IRAM control run.

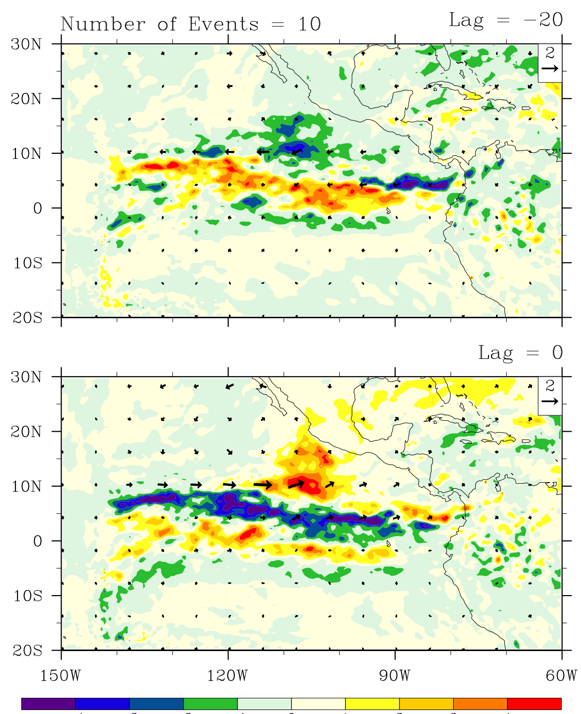

Figure 2. Lag composite plot of 30-90-day 850-hPa wind (vectors, m/s) and precipitation (color contours, mm/day) anomalies for lags -20 (top) and 0 (bottom) for the IRAM filter run.

mechanisms. Unlike observations, both IRAM model versions have easterly boreal summer mean low-level winds in the east Pacific warm pool. Because the mean low-level winds are from the opposite zonal direction than observations, low-level westerly anomalies in both IRAM model versions do not constructively add to the mean winds and do not enhance wind induced surface exchange mechanisms. Rather, they suppress them. The effects of the IRAM low-level mean wind bias are seen in composite plots of 30-90-day latent heat fluxes shown in Figure 3 for the IRAM filter run. The same effect can be seen in the IRAM control run (not shown). Negative (positive) 30-90-day latent heat fluxes occur during westerly (easterly) phases. This is opposite to observations and the CAM model also used in this study and represents a bias in the model. This bias may restrict the ability of the IRAM to produce independent modes of east Pacific intraseasonal variability.

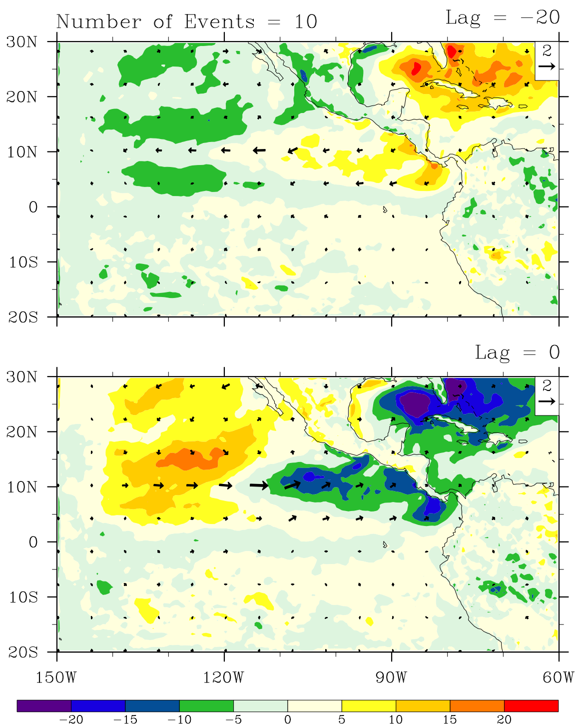

Figure 3. Lag composite plot of 30-90-day 850-hPa wind (vectors, m/s) and latent heat flux (color contours, W/m^2) anomalies for lags -20 (top) and 0 (bottom) for the IRAM filter run.

3.2 *CAM*

Lag composite plots of 30-90-day filtered 850-hPa zonal wind and precipitation anomalies for the CAM control and sponge runs are shown in figures 4 and 5, respectively. Unlike the IRAM model runs, the CAM model runs show remarkable similarity in both amplitudes and phase relationship between the low-level wind and precipitation anomalies that is of strong similarity to observations. In the CAM sponge run, lag-longitude correlation plots of equatorially averaged 30-90-day variables related to the MJO, such as 850-hPa zonal wind, 200-hPa zonal wind, and 400-hPa temperature, do not show coherent propagation across the Pacific Ocean in the CAM sponge region (not shown). This ensures the efficacy of the sponge region in isolating the east Pacific from Eastern Hemisphere communication via equatorial Kelvin waves. The inclusion of the sponge region does not prevent the east Pacific from producing independent intraseasonal variability. Although the east Pacific low-level wind does not contain significant power at the 95% threshold, precipitation does at characteristic 50-day timescales (not shown). Additionally, the first combined empirical orthogonal function of 30-90-day filtered 850-hPa zonal wind and precipitation anomalies for the CAM control run over the east Pacific warm pool (10°S - 25°N, 150°W - 70°W) is significant, according to the criteria of North et al. 1982, and explains 26% of the intraseasonal variance there. A similar analysis of the first empirical orthogonal function for the CAM sponge run is significant and captures analogous features of the CAM control run. Likewise the first empirical orthogonal function of the CAM sponge run explains 20% of the intraseasonal variability. The power spectrum, lag composite plots, and empirical orthogonal function analysis of the CAM model runs suggest that the east Pacific warm pool can be independent of Kelvin wave communication from the MJO.

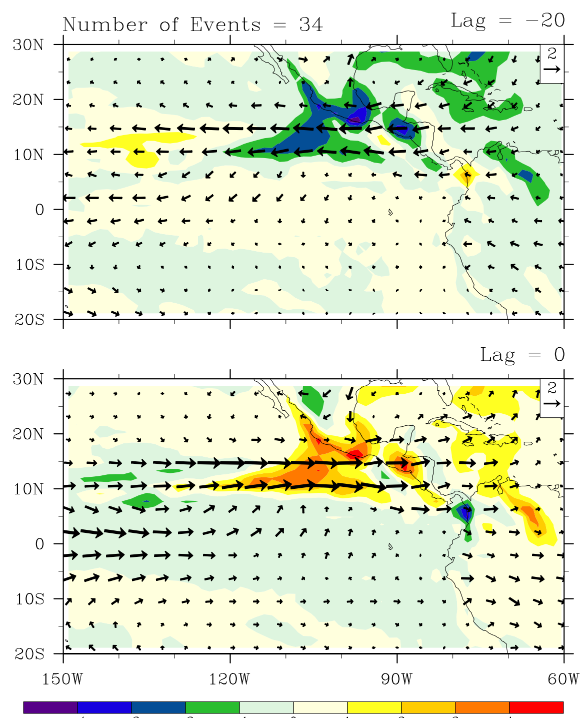

Figure 4. Lag composite plot of 30-90-day 850-hPa wind (vectors, m/s) and precipitation (color contours, mm/day) anomalies for lags -20 (top) and 0 (bottom) for the CAM control run.

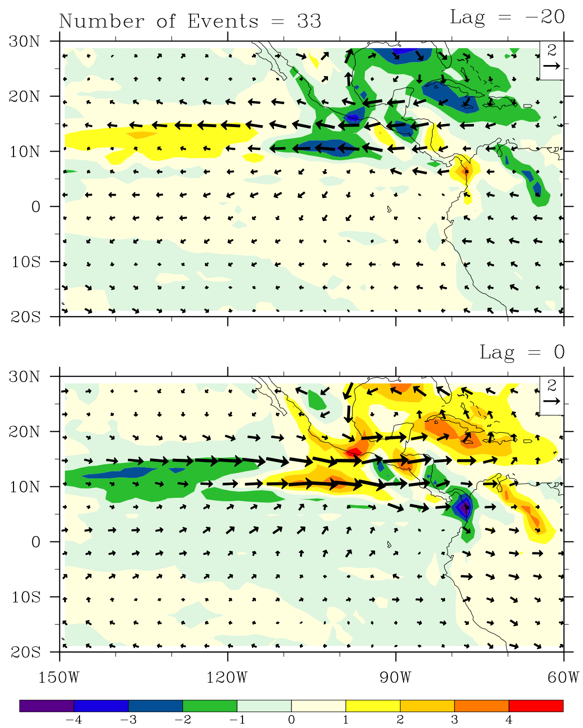

Figure 5. Lag composite plot of 30-90-day 850-hPa wind (vectors, m/s) and precipitation (color contours, mm/day) anomalies for lags -20 (top) and 0 (bottom) for the CAM sponge run.

4. CONCLUSION

To better understand the relationship between intraseasonal variability in the tropical Eastern Hemisphere and that in the east Pacific, models were used to isolate the east Pacific from outside intraseasonal variability. When 30-90-day variability was removed from the initial and boundary conditions of the IRAM, intraseasonal variability in the east Pacific was marginally significant in the precipitation field. Compared to observations and the control run, the lag composite plot of 30-90-day 850-hPa wind and precipitation anomalies in the IRAM filter run was much noisier and of weaker amplitude suggesting a strong dependence on the forcing from non-local intraseasonal signals. The lack of a local and independent intraseasonal mode of variability in the IRAM might be a result of the mean wind bias in the east Pacific warm pool. The presence of mean low-level easterlies instead of westerlies affects the magnitude of the total wind during anomalous intraseasonal easterly and westerly phases. The magnitude of the total wind is strongly linked to the magnitude of anomalous latent heat fluxes during these phases. As a result, the sign of the mean wind appears fundamental to wind induced surface heat exchange mechanisms that can help destabilize the atmosphere for an intraseasonal convective event.

The CAM supports the ability of the east Pacific to have independent intraseasonal oscillations in the absence of Kelvin wave communication from the MJO. This conclusion suggests that the requirements and mechanisms for intraseasonal variability are entirely locally available in the east Pacific. Moreover, local convective-circulation feedbacks appear important in the development and maintenance of east Pacific intraseasonal events as can be seen in the evolution of 30-90-day latent heat flux and surface convergence anomalies (not shown). Due to the strong correlation of intraseasonal variability in the east Pacific and Eastern Hemisphere seen in observations (Maloney et al. 2008), the east Pacific is perhaps paced by the Eastern Hemisphere. The east Pacific and Eastern Hemisphere could share resonant frequencies that are easily harmonized through rapid eastward Kelvin wave propagation, causing a phase locking. Future work includes correcting the climatological wind bias in the IRAM and performing moist static energy budgets to compare the development and maintenance of intraseasonal moist static energy anomalies in the east Pacific warm pool during events with and without communication from the MJO, respectively.

REFERENCES

Hannah, W. M. and E. D. Maloney, 2011: The role of moisture – convection feedbacks in simulating the Madden–Julian Oscillation. *J. Climate,* 24, 2754–2770.

Knutson, T. R. and K. M. Weickmann, 1987: 30-60 day atmospheric oscillations: Composite life cycles of convection and circulation anomalies. *Mon. Wea. Rev.,* 115, 1407-1436.

Maloney, E.D. and J. T. Kiehl, 2002: MJO-related SST variations over the tropical eastern Pacific during Northern Hemisphere summer. *J. Climate,* 15, 675-689.

———— and S. K. Esbensen, 2007: Satellite and buoy observations of intraseasonal variability in the tropical northeast Pacific. *Mon. Weather Rev.,* 135 , 3-19.

————, D. B. Chelton, and S. K. Esbensen, 2008: Subseasonal SST variability in the tropical eastern north Pacific during boreal summer. *J. Climate,* 21, 4149-4167.

Moorthi, S., and M. J. Suarez, 1992: Relaxed Arakawa–Schubert: A parameterization of moist convection for general circulation models. Mon. Weather Rev., 120, 978–1002.

Tokioka, T., K. Yamazaki, A. Kitoh, and T. Ose, 1988: The equatorial 30- 60 day oscillation and the Arakawa-Schubert penetrative cumulus parameterization. J. Meteor. Soc. Japan, 66, 883–901.

Wang, Y., S.-P. Xie, Xu, H. and B. Wang, 2004: Regional model simulations of marine boundary layer clouds over the Southeast Pacific off South America. Part I: Control experiment. *Mon. Weather Rev.,* 132, 274- 296.

Zhang, C.,2005: The Madden Julian Oscillation, *Reviews of Geophysics,* 43, RG2003.