Boreal Summer Intraseasonal Variability and Air-Sea Interaction in the Tropical Northeast Pacific

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1. Introduction and Background

The Madden-Julian oscillation (MJO) produces variations in low-level winds over the east Pacific warm pool that force variability in summertime precipitation, and an associated modulation of tropical cyclones. Recent studies have shown that these summertime MJO-related variations may be predictable up to 2-3 weeks in advance (e.g. Waliser et al. 1999). As shown below, one such event occurred during the EPIC2001 experiment, expressed in terms of 200 hPa velocity potential.

A more generalized lag-correlation analysis of NCEP reanalysis 30-90 day bandpass filtered zonal wind (7.5ºN-12.5ºN averaged) shows significant eastward propagation of MJO wind anomalies into the tropical eastern north Pacific during summertime. Spectral analysis indicates that a strong intraseasonal peak (~50 days) in the east Pacific warm pool occurs then (see below). The intraseasonal spectral peak in this region in precipitation and winds is as dominant as anywhere in the Tropics.

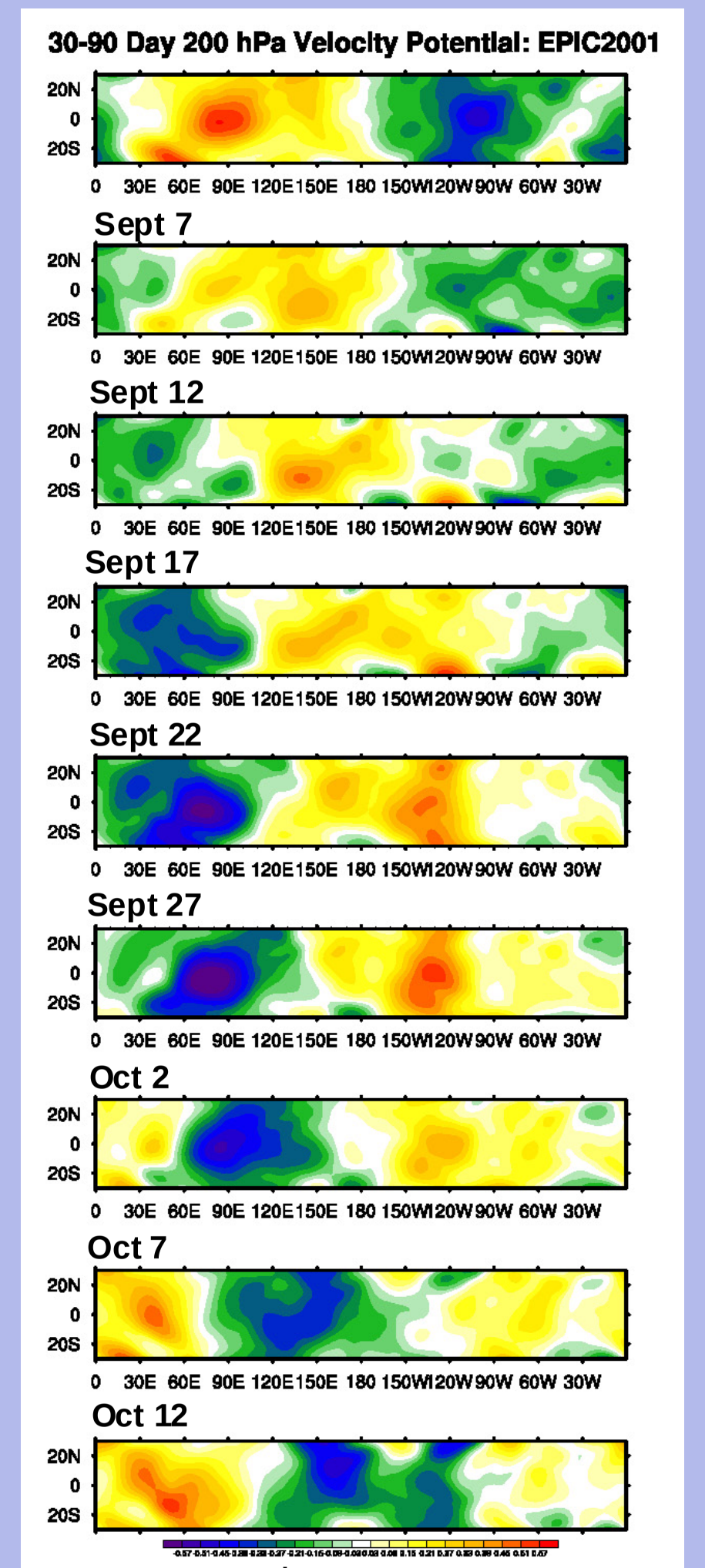
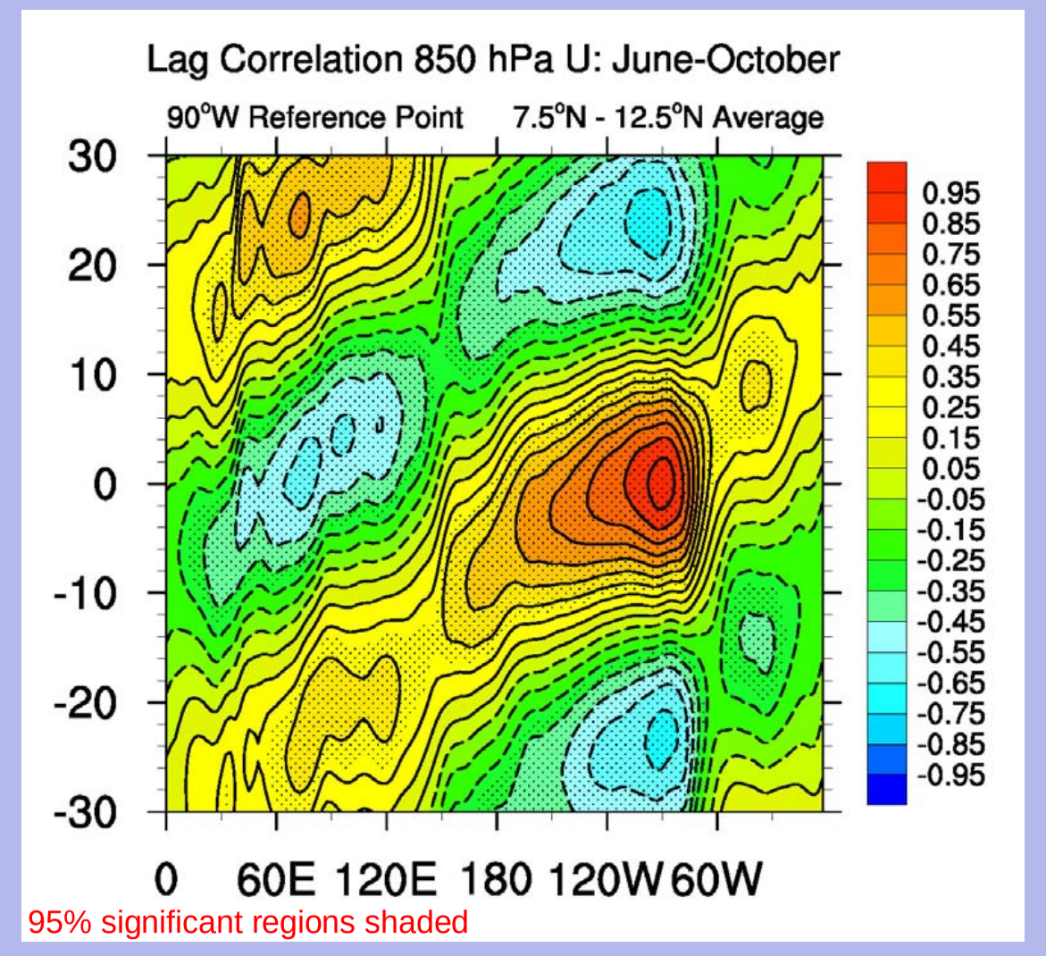
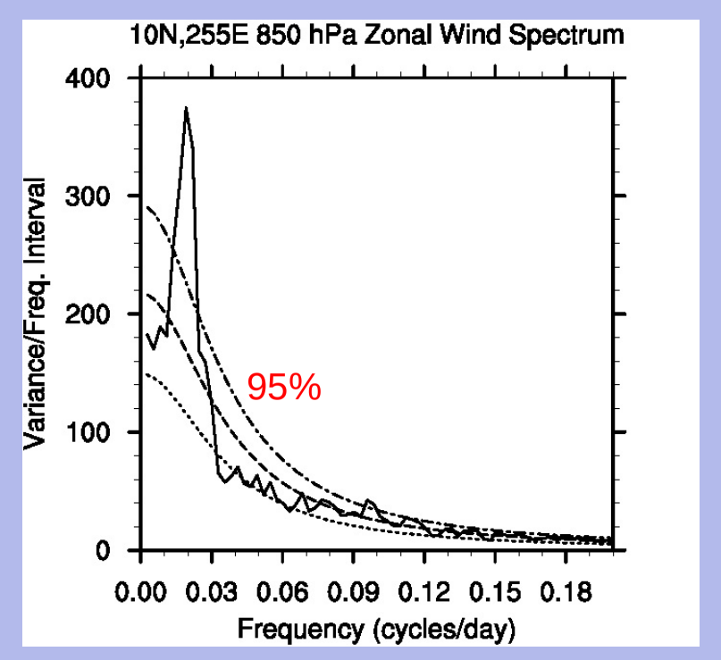


Figure 1.



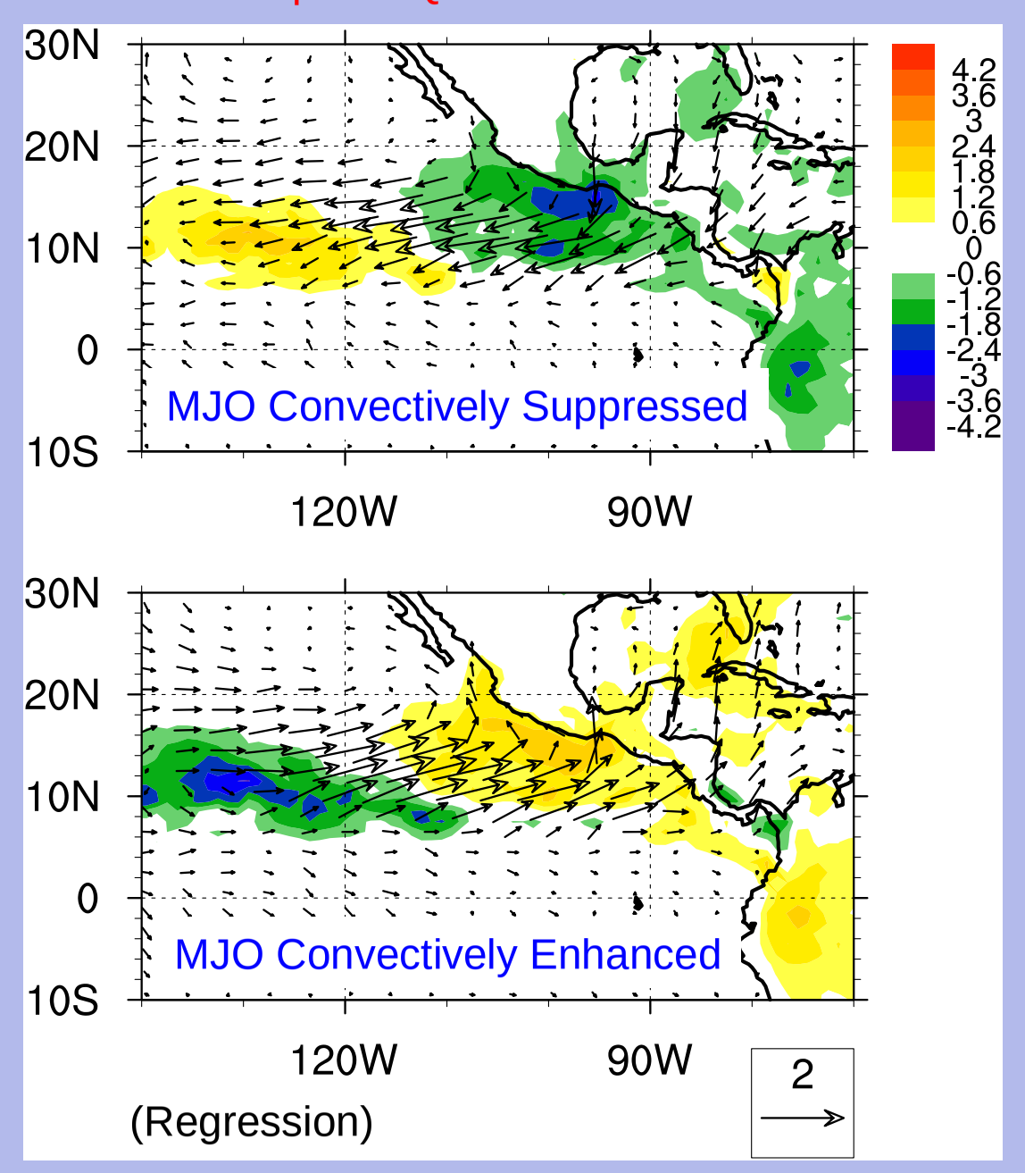


2. Analysis of the June-October MJO

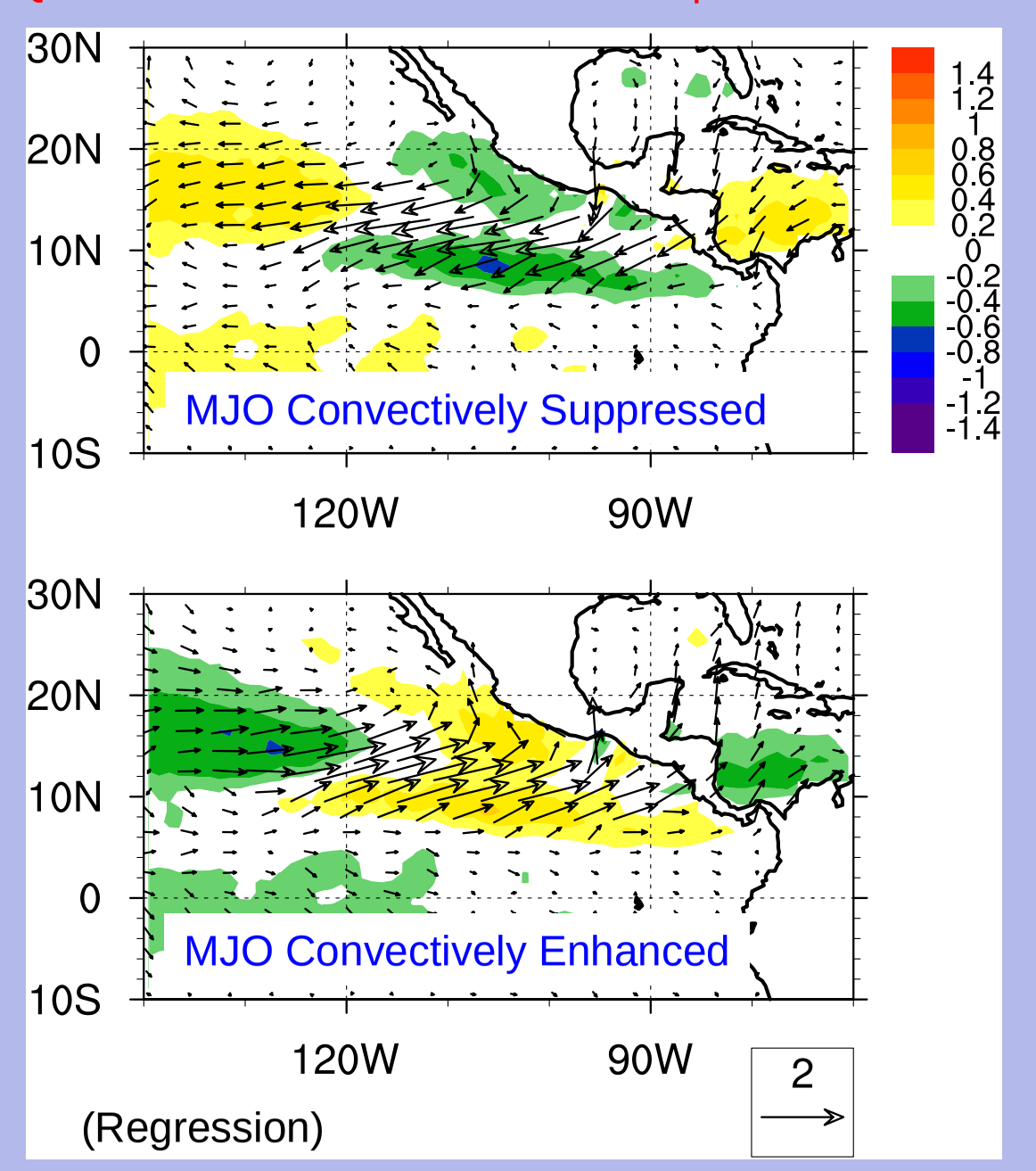
We conduct an analysis of the MJO in the east Pacific warm pool during June-October of 1998-2005 using satellite and buoy data. Enhanced TAO array measurements associated for EPIC2001 were available from 2000-2004.

Surface MJO westerly (easterly) anomalies are associated with an enhancement (suppression) of convection over the warm pool, and a suppression (enhancement) of convection to the east of 110ºW (see below left). Wind jets appear to be active during periods of MJO easterly anomalies (not shown).

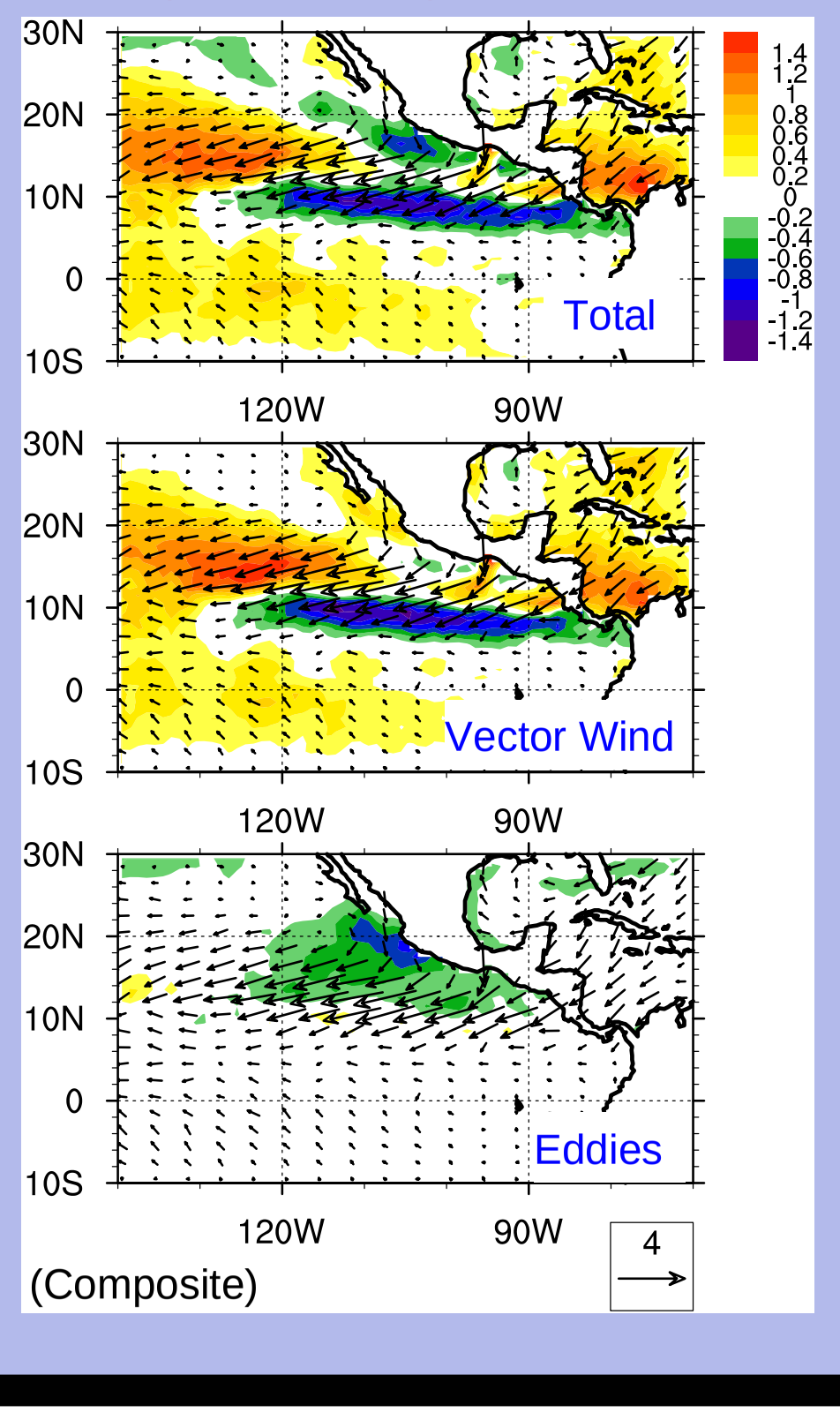
TRMM Precip and QuikSCAT Wind Anomalies



QuikSCAT Vector Wind and Wind Speed Anomalies



Convectively Suppressed Phase
Composite Wind Speed Anomalies

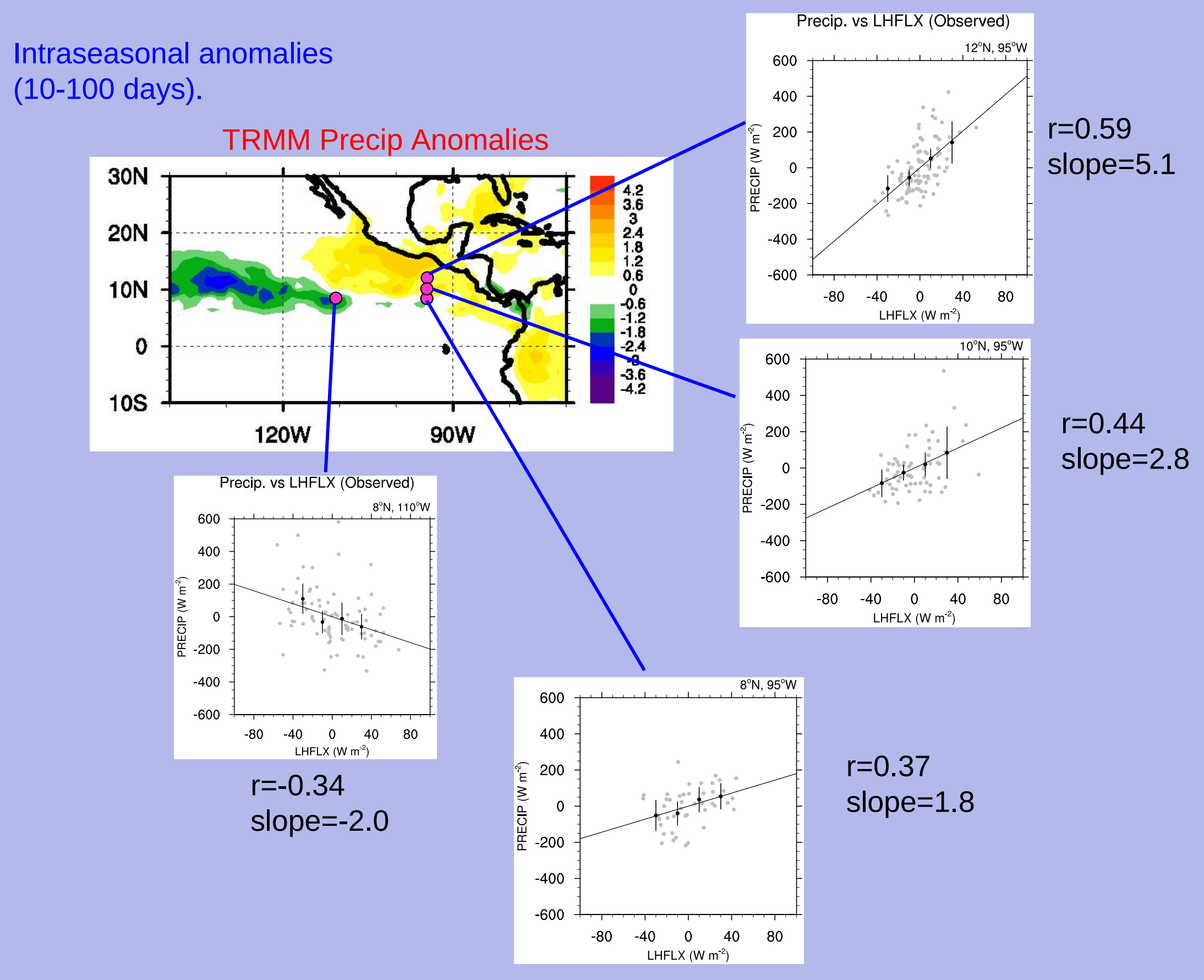


Wind speed over the warm pool is enhanced during periods of MJO westerly anomalies and enhanced precipitation, with suppression of wind speed during MJO easterly periods (see above).

Wind speed anomalies associated with the MJO appear to be caused both by intraseasonal vector wind anomalies added to the climatological southwesterly flow, and by variations in eddy activity, including easterly waves and tropical cyclones.

For example, the suppression of wind speed during MJO easterly periods appears to be about equally due to easterly anomalies added to the climatological southwesterly flow and suppression of eddy variance (see left).

Intraseasonal Precipitation vs. TAO Buoy Latent Heat Flux



The MJO-related variations in wind speed contribute to variations in latent heat flux during MJO events. In fact, latent heat flux anomalies are primarily wind-driven over this region.

An analysis from TAO buoys and TRMM indicates a significant coupling between latent heat flux and precipitation over the east Pacific warm pool (see left), suggesting that wind-evaporation feedback may help support MJO convection over the east Pacific warm pool during summertime.

Recent modeling work also suggests that wind-evaporation feedback supports MJO convection in this region (Maloney and Esbensen 2005), and is consistent with the more generalized view that wind-evaporation feedback supports MJO convection across the Tropics in regions of mean low-level westerly flow (e.g. Maloney and Sobel 2004).

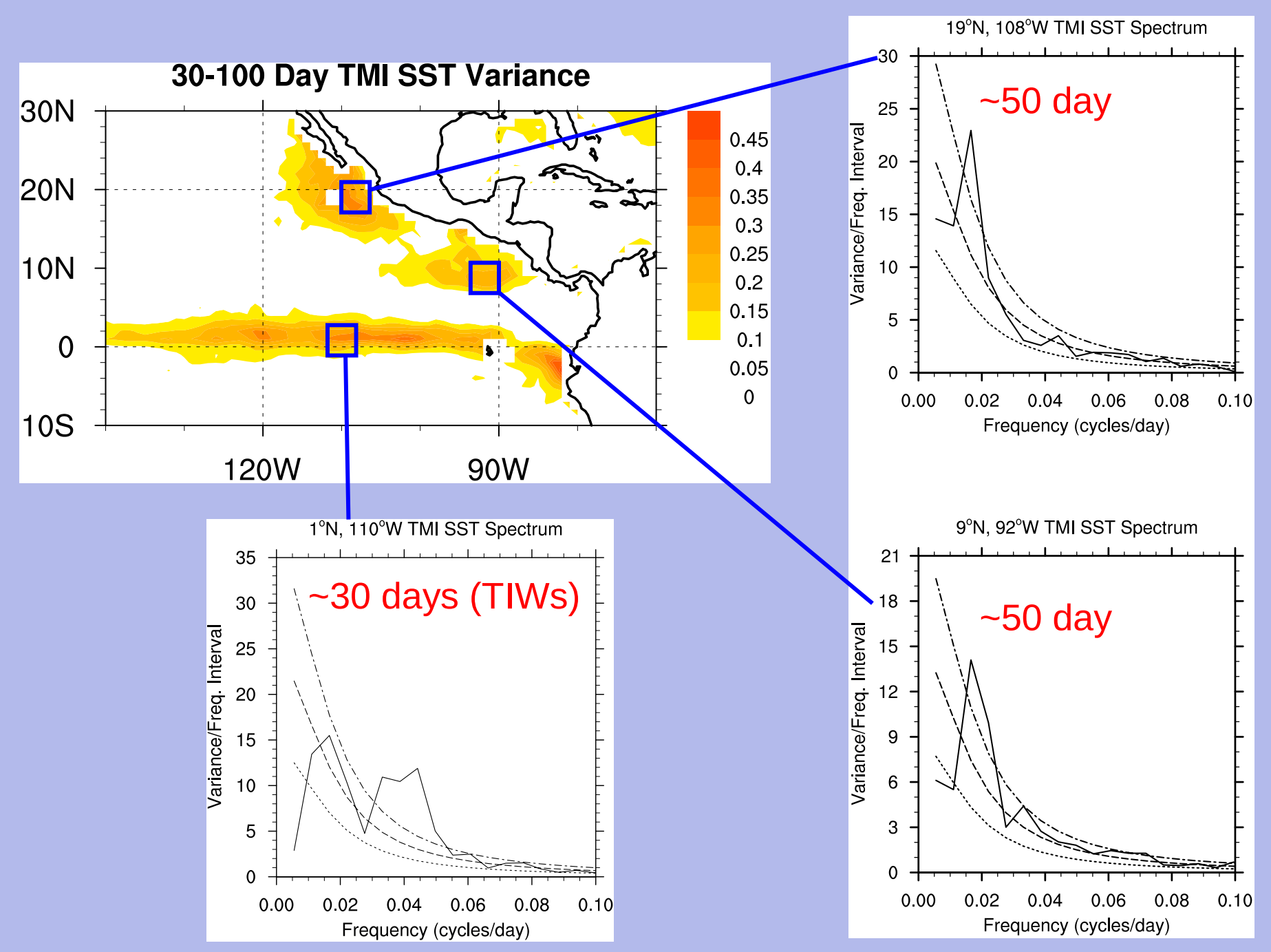
3. Analysis of Intraseasonal SST

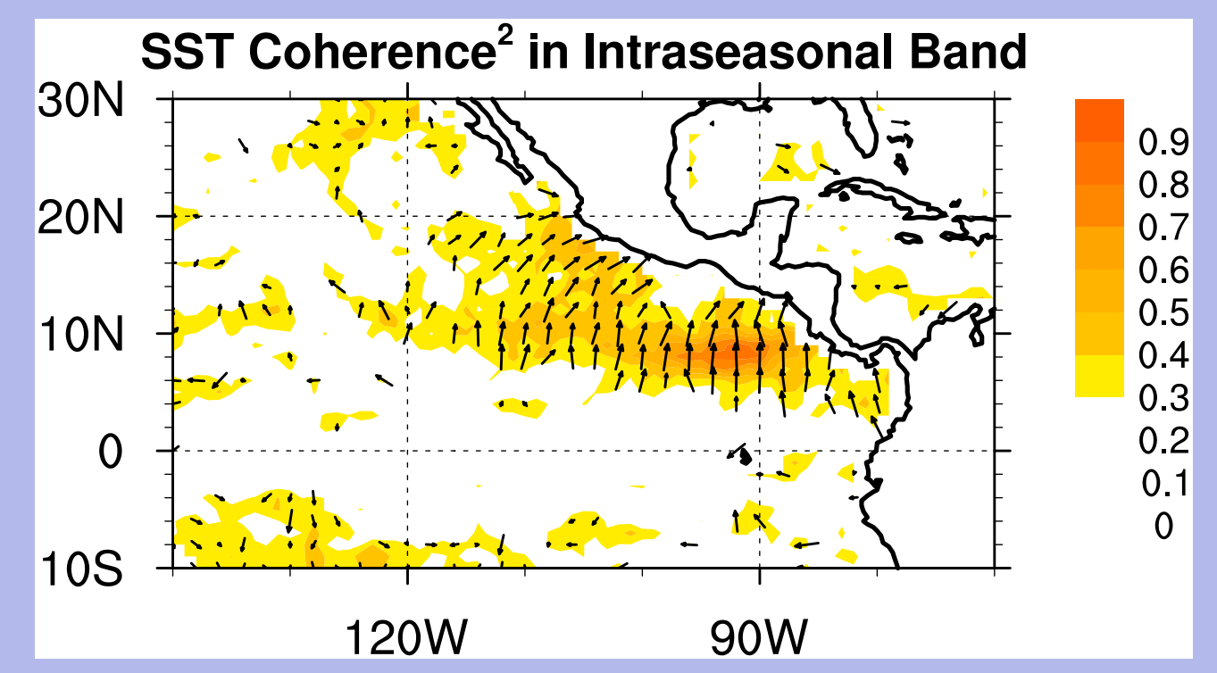
Intraseasonal SST variance during summertime maximizes over the east Pacific warm pool (see right), with another maximum in a band just to the north of the equator. The intraseasonal band (30-100 days) explains about 30% of the total SST variance (including interannual) over the east Pacific warm pool during summertime.

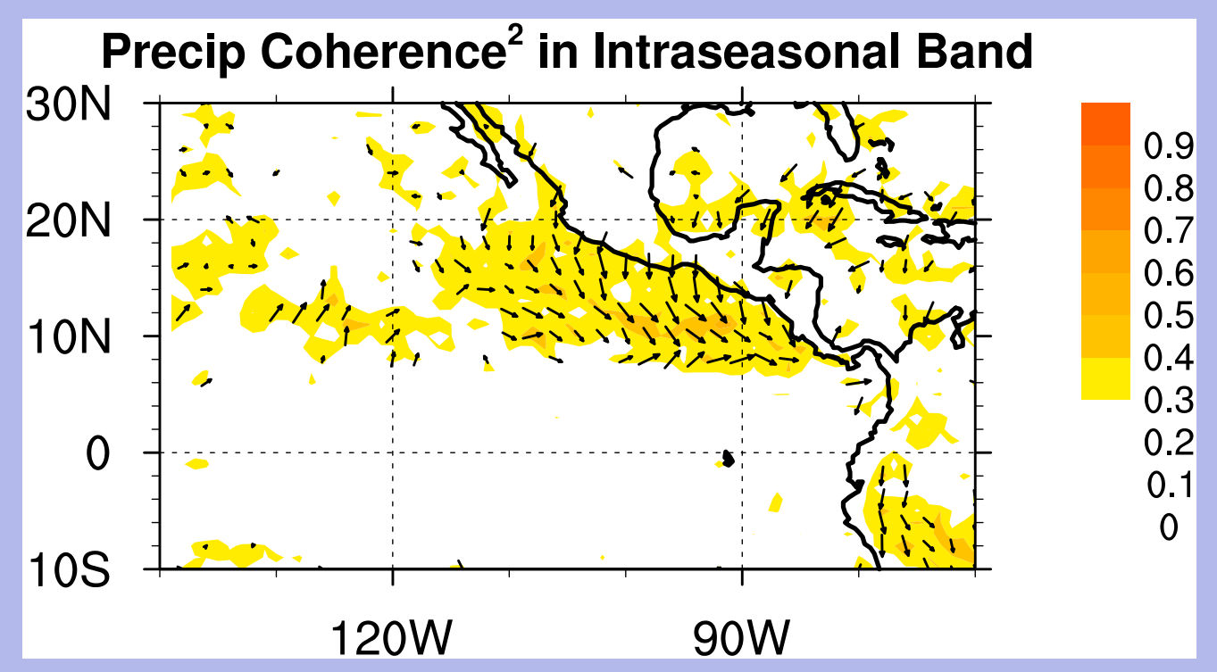
A spectral analysis using eight years of TMI SST data indicates a significant 50 day peak over the east Pacific warm pool during boreal summer. Only the climatological seasonal cycle was removed before the spectra were computed. As will be shown below, the MJO explains a large fraction of the intraseasonal SST variance in this region.

The equatorial variance maximum is likely associated with tropical instability waves, having a dominant period closer to 30 days than the 40-50 day periodicity associated with the MJO.

Analysis of June-October Intraseasonal SST





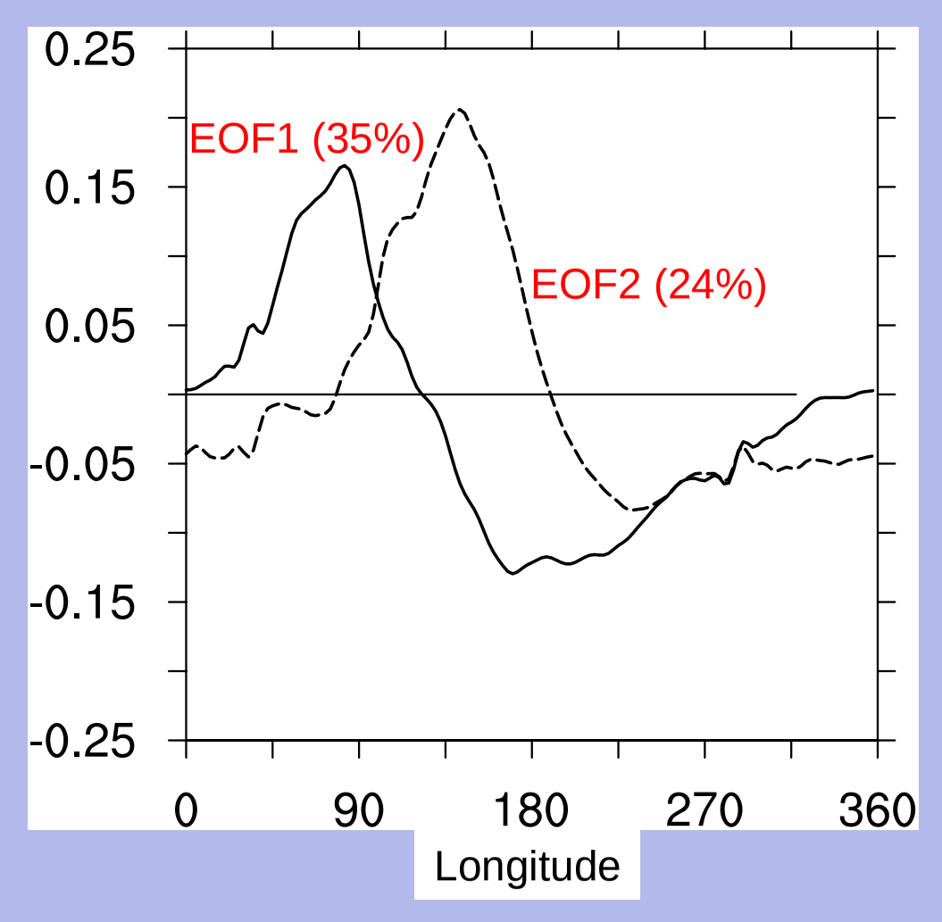


SSTs in the 30-90 day band are coherent across the east Pacific warm pool during summertime. Using a reference SST time series was at 9ºN, 92ºW, coherence squared is significant and exceeds 0.4 across much of the warm pool. While phase vectors broadly indicate an in-phase relationship for intraseasonal SSTs within the warm pool, SSTs north of 14ºN tend to lag those to the south by about 1/8 of a cycle (~5 days). Interestingly, no coherence occurs between warm pool and equatorial SST in the intraseasonal band, contradicting the results of Maloney and Kiehl (2002) who used Reynolds SST data.

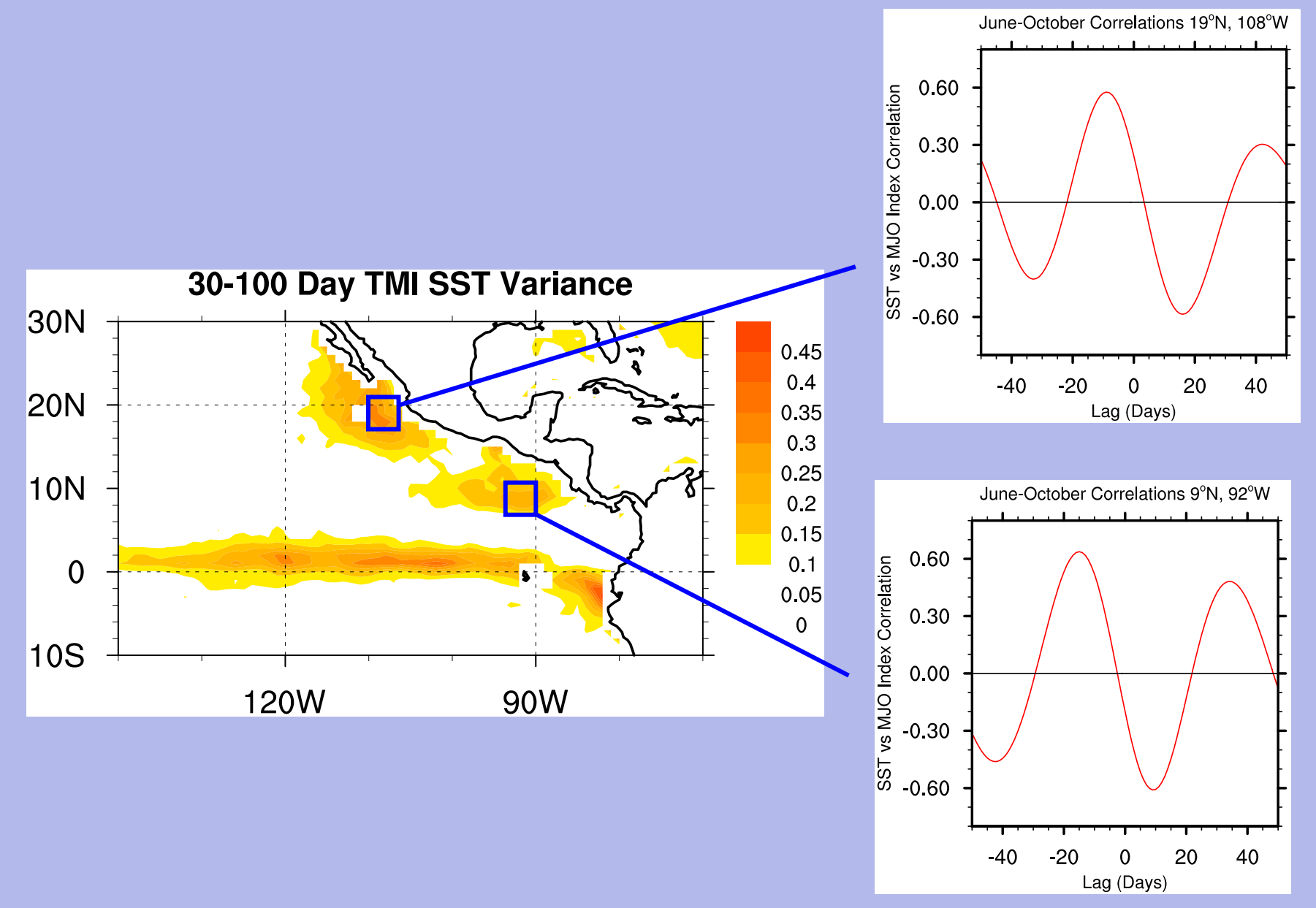
Coherence squared between SST and precipitation is also significant (0.3-0.4) in the intraseasonal band across the east Pacific warm pool, with precipitation lagging SST by a 1/4 phase (~10 days) when they are colocated spatially, although at increasing lags toward the north.

Intraseasonal SST variations in the east Pacific will be related to the MJO using the tropical equatorial MJO index of Maloney and Kiehl (2002). The leading EOFs of the 30-90 day equatorial averaged 850 hPa zonal wind represent a quadrature pair that defines the eastward propagating MJO (see right). Although peak variance for these EOFs occurs in the Eastern Hemisphere, substantial zonal wind variance also is captured in the east Pacific. The principal components of the leading EOFs are linearly combined to form an MJO index, as described in Maloney and Kiehl (2002).

Intraseasonal U850 Global EOFs
Used to Construct MJO Index

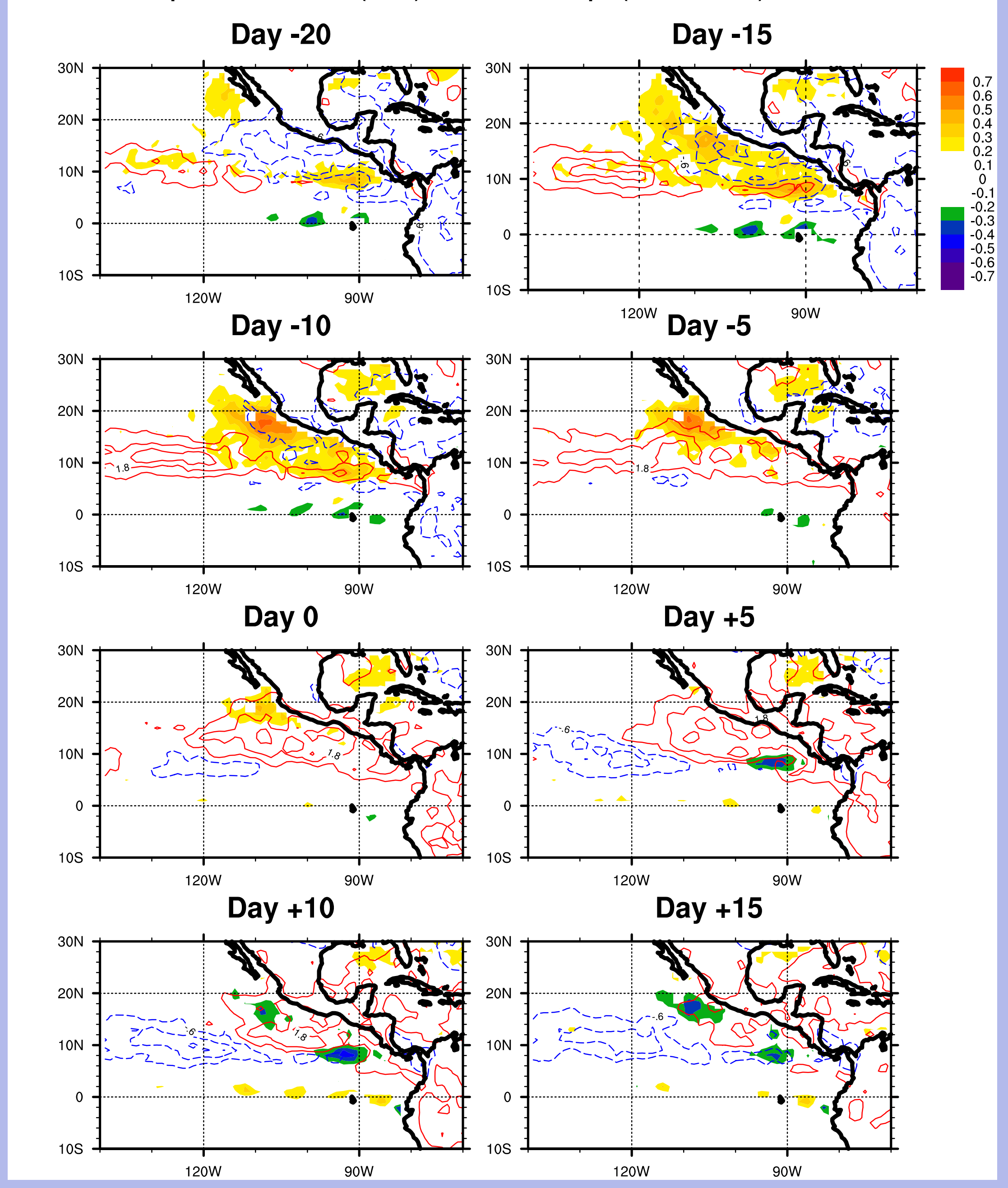


A lag correlation between the MJO index (multiplied by -1) and intraseasonal SST indicates that the MJO index explains about 40% of the intraseasonal SST variance in the east Pacific warm pool during June-October (see below). Thus, the MJO is an important factor in controlling east Pacific warm pool SST during summertime. SST leads the MJO index, the implications of which will become apparent below.



Significant MJO events are defined as maxima of the index exceeding 1σ, and a composite MJO event is created (as a function of lag in days) by averaging these significant events. Suppressed (enhanced) convection typically precedes positive (negative) SST anomalies by 5-10 days over the warm pool (see below). Peak to peak variations in SST can be as high as 1ºC over an MJO lifecycle. An asymmetry in the response is apparent, with warm SST anomalies that precede enhanced convection being stronger and more widespread than the corresponding cold anomalies after convection. This asymmetry is similar if events are defined using minima of the MJO index. Precipitation anomalies west of 110ºW are not associated with strong SST variations. Maloney and Kiehl (2002) used an atmospheric GCM coupled to a slab ocean to show that intraseasonal SST anomalies of even lesser magnitude than shown below are likely important for producing realistic MJO convective variability .

MJO Composite SST (Fill) and Precip (Contour) Anomalies



6. Conclusions

Satellite and buoy data show that the MJO is associated with strong precipitation and wind variations over the east Pacific warm pool during June-October that are supported by wind-induced latent heat flux variability. These latent heat flux anomalies are generated both by 1) vector mean winds adding constructively or destructively to the climatological wind field, and by 2) MJO-induced variations in easterly wave and tropical cyclone activity.

A significant 50-day intraseasonal spectral peak in SST occurs in the east Pacific warm pool during summertime, generated in large extent by the MJO. SSTs vary by up to 1ºC over the east Pacific warm pool during an MJO lifecycle. SST anomalies precede MJO precipitation anomalies by 5-10 days.

A full reference list can be found in Maloney and Esbensen (2006), in press in *Monthly Weather Review*.

We would like to thank the NOAA Climate Prediction Program for the Americas within the Climate Program Office (Grant# NA05OAR31006) for support of this research. The statements, findings, conclusions, and recommendations do not necessarily reflect the views of NOAA, or the Department of Commerce.