Subseasonal atmospheric variability and El Niño waveguide warming

Observed effects of the Madden-Julian Oscillation and Westerly Wind Events

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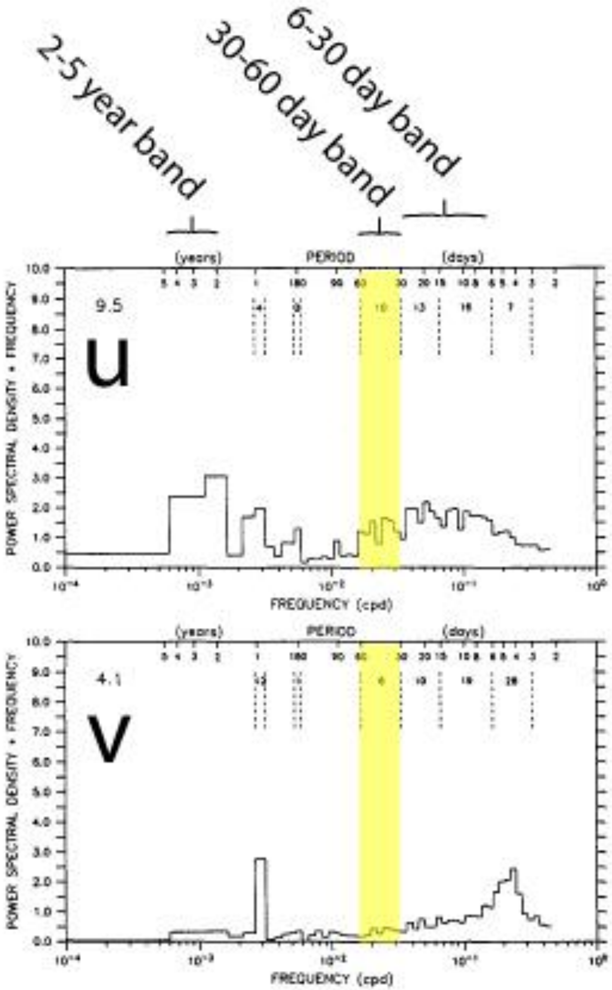
Introduction



Energy preserving (density x frequency) spectra at 1N, 173E (Tarawa, Is.) from Harrison and Luther (J. Climate, 1990)

• Western Tropical Pacific wind variability is characterized by substantial sub-seasonal as well as interannual variance (the 30-60 day band is a substantial component, but not the whole story).

•We are interested in sub-seasonal processes that initiate or influence El Nino events.

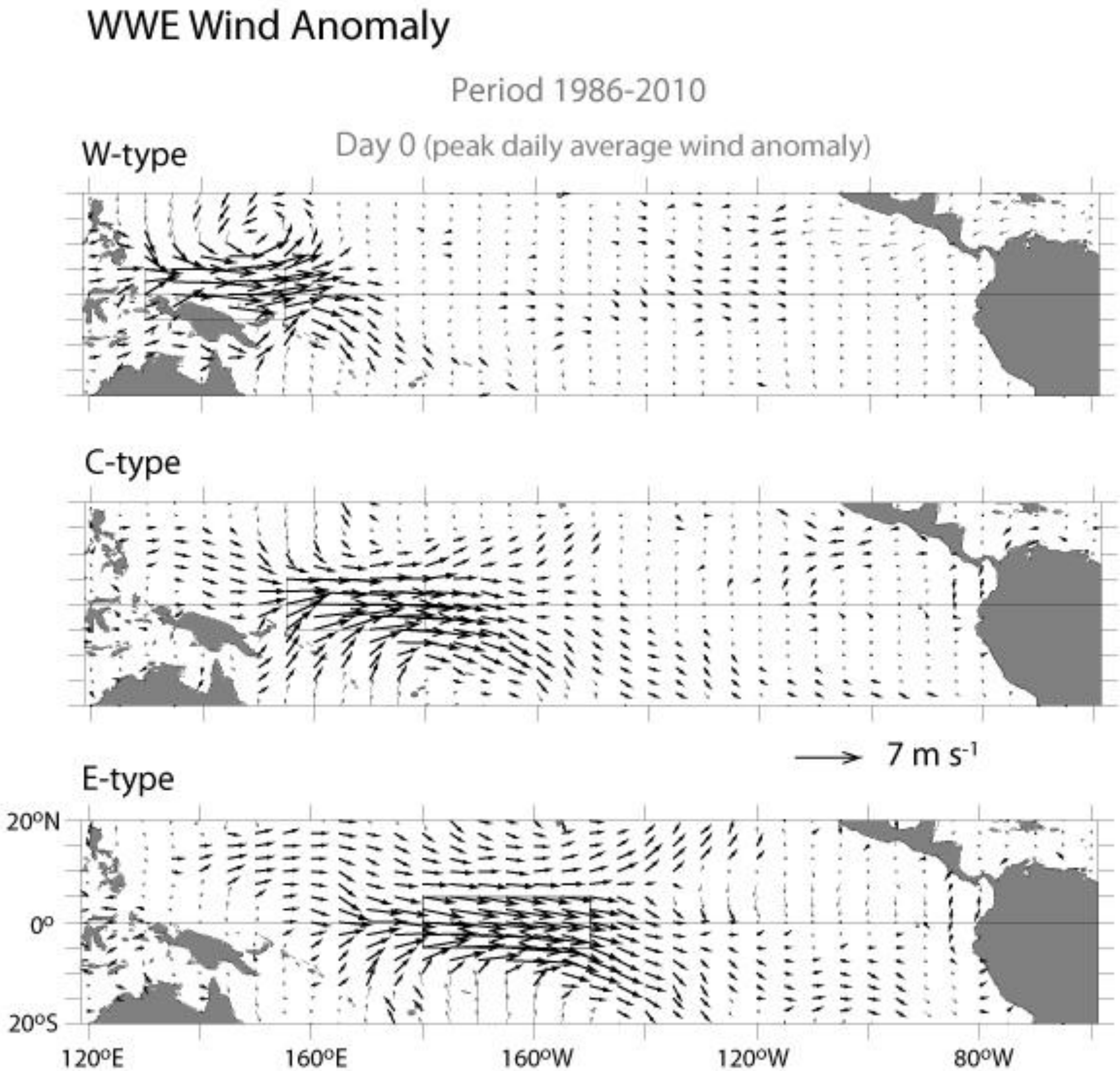
•WWEs, characterized by ~7m/s wind anomalies over ~7days, have been shown to precede. waveguide warming of a few tenths of a degree C.

•The MJO (atmospheric phenomenon characterized by coherent 30-90 day variance and eastward translation) has been hypothesized to influence ENSO through effects on WWEs, as well as have a more direct influence on El Nino event initiation through its expression on surface winds in the tropical Pacific.

•Clarity is needed on the relationships between the MJO and WWEs and their effects on tropical Pacific waveguide warming

Outline

- WWE and MJO definitions
- Compare composite waveguide SST anomaly changes following the MJO and following WWEs (all, co-occurring, single)
- Co-occurrence statistics
- Conclusions



•WWEs defined based on an objective scheme (Vecchi and Harrison, 1997) which defines "W", "C" and "E" type events based on three equatorial regions.

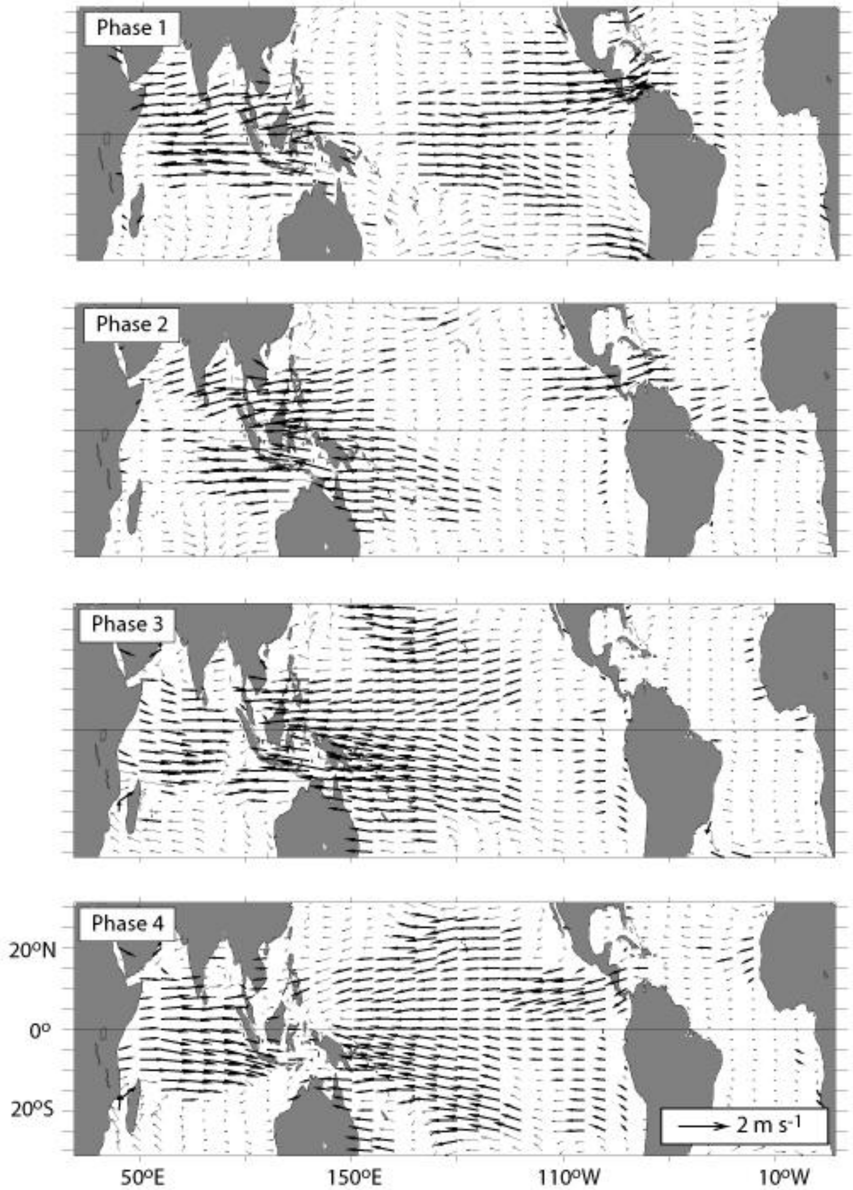
•WWE = any interval of 3 or more consecutive days for which WWE-region average zonal wind anomaly exceeds 2 m/s.

• "Day 0" is the event-day with maximum zonal wind anomaly

•Statistically significant anomalies are seen ~7 days before/after Day 0 in a composite sense

Wind data from ECMWF 12-hr forecasts

MJO-active composite wind anomalies (phases 1-4 of 8)

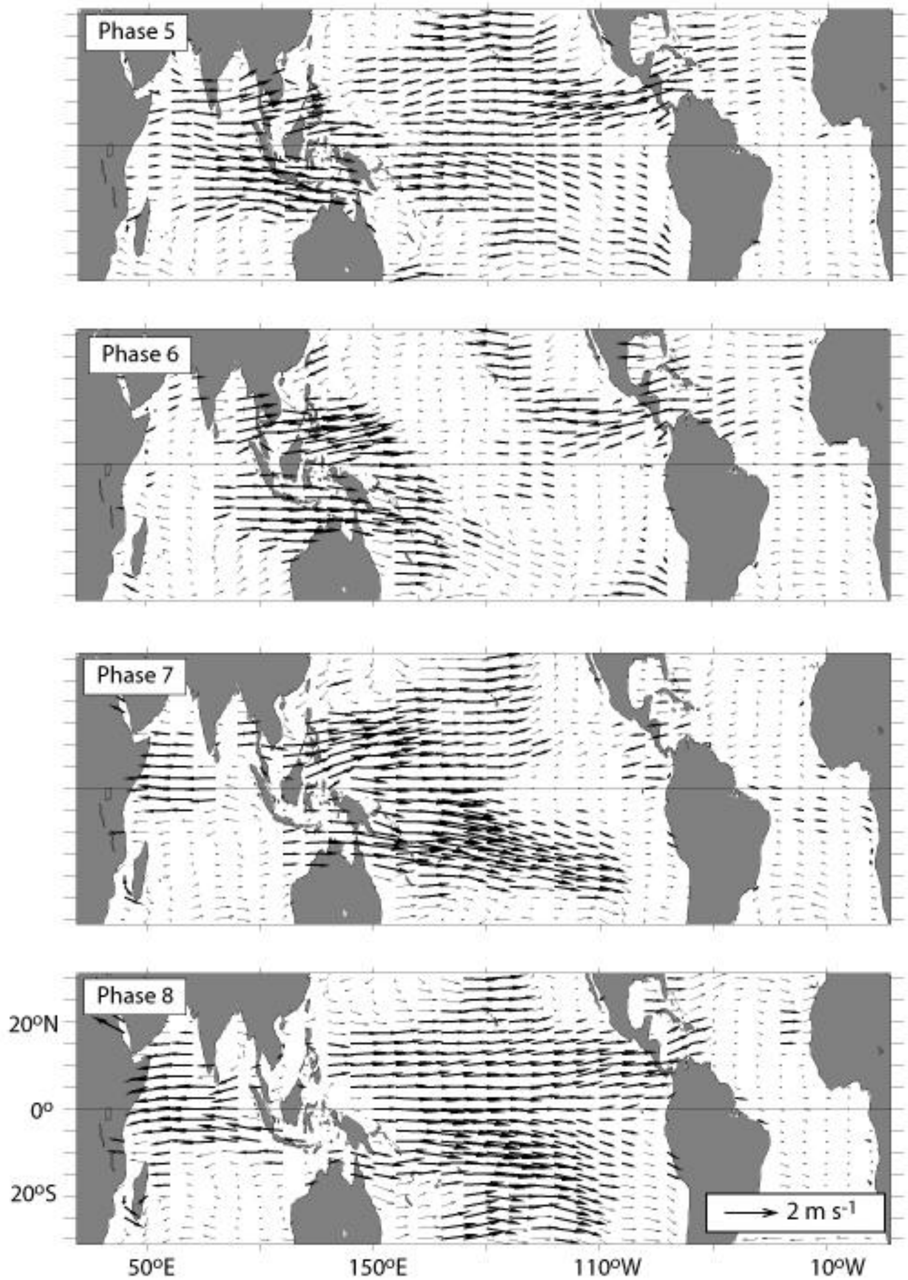


• MJO-state determined by the now commonly used Wheeler and Hendon (2004) daily index (based on a pair of EOFS of combined equatorial 850-hPa zonal wind, 200-hPa zonal wind and OLR).

•8 MJO phases, active (amplitude > 1) and inactive (amplitude < 1) state

•We look at "MJO-events": periods 1986-2010 when the index amplitude remains > 1 for at least 20 days.

•Event composites show significant tropical Pacific surface wind anomalies, both easterlies and westerlies, are associated with the active-phases of the MJO.



MJO-active composite wind anomalies (phases 5-8 of 8)

Statistical significance at the 95% level is obtained in the tropical Pacific at zonal amplitudes of ~1.5-2 m/s.

Our main focus is on ENSO-neutral conditions (|NINO3| < 0.75C) because we are interested processes capable of initiating a transition to warm-ENSO (El Nino) state

In ENSO-neutral conditions, our methods identify:

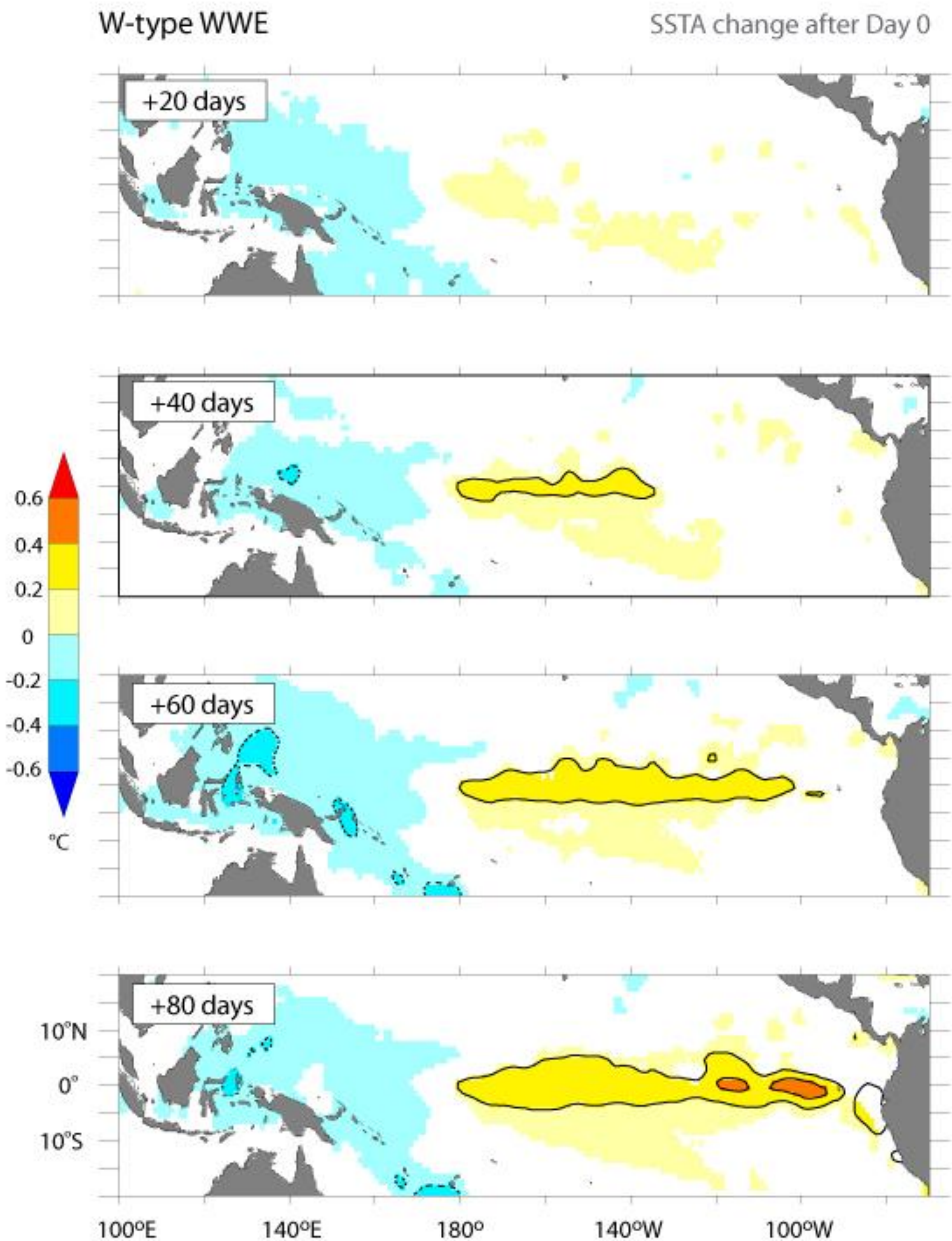
• 62 MJO events, the vast majority of which (58) reach their surface westerly phase (phase 6, 7 or 8).

and

• 98 W-type WWEs, 105 C-type WWEs and 52 E-type WWEs

Of these 58 MJO events, 41 have WWEs embedded in them and 17 do not.

To examine MJO and WWE effects on SSTA, we compiled the observed SSTA changes following each type of event in the 1986-2010 period (starting from event-day minus 20 in the WWE case, and 20 days before the MJO-event first reaches its westerly phase in that case).

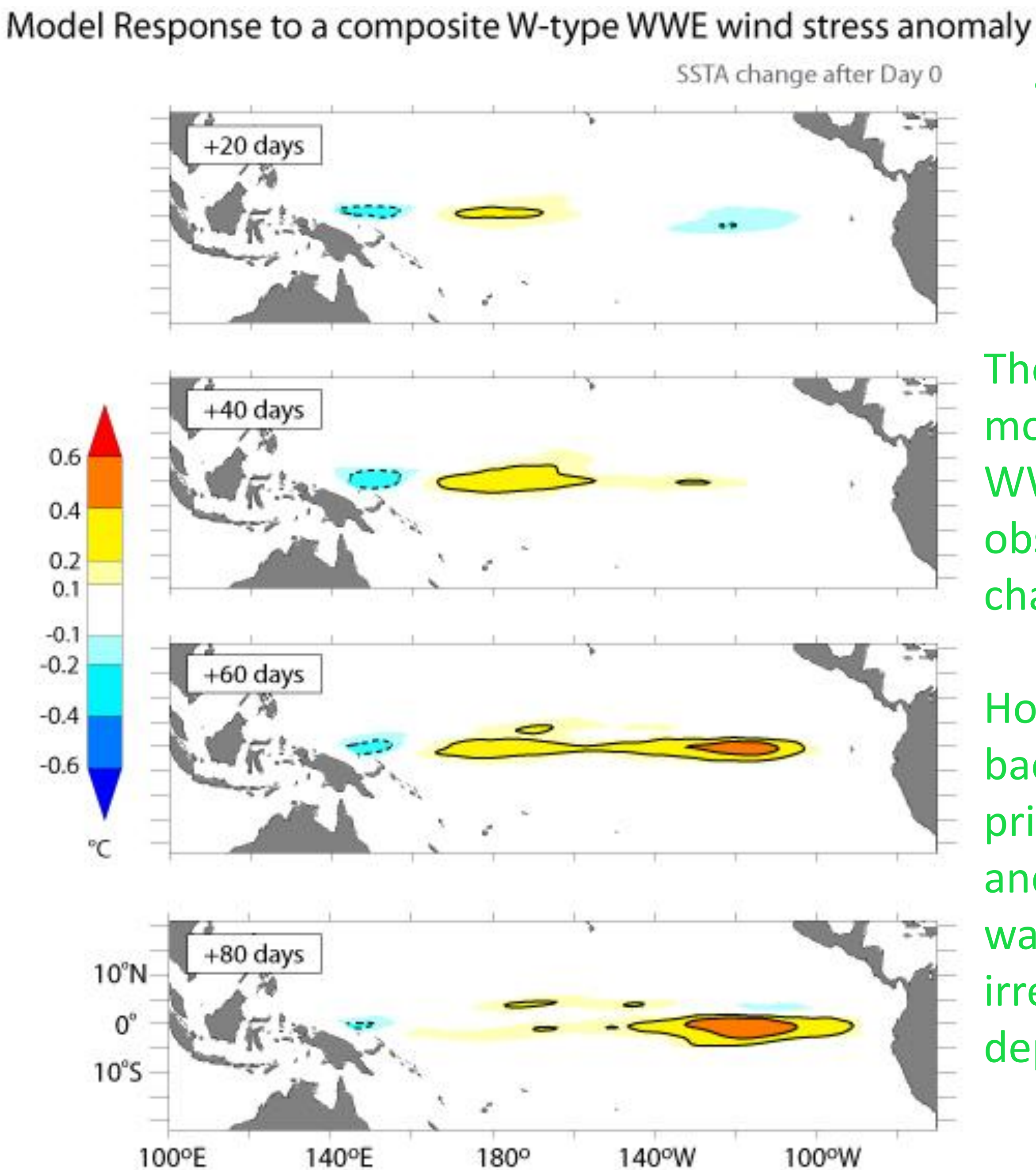


ENSO-neutral conditions, period 1986-2010, shading where statistically significant at 95%

The WWE case:

Statistically significant and coherent warming occurs in the central and eastern equatorial Pacific following each type of equatorially centered WWE (W, C and E). The warming persists, on average, well into day +80.

Significant warming occurs regardless of whether or not the MJO contains a WWE.

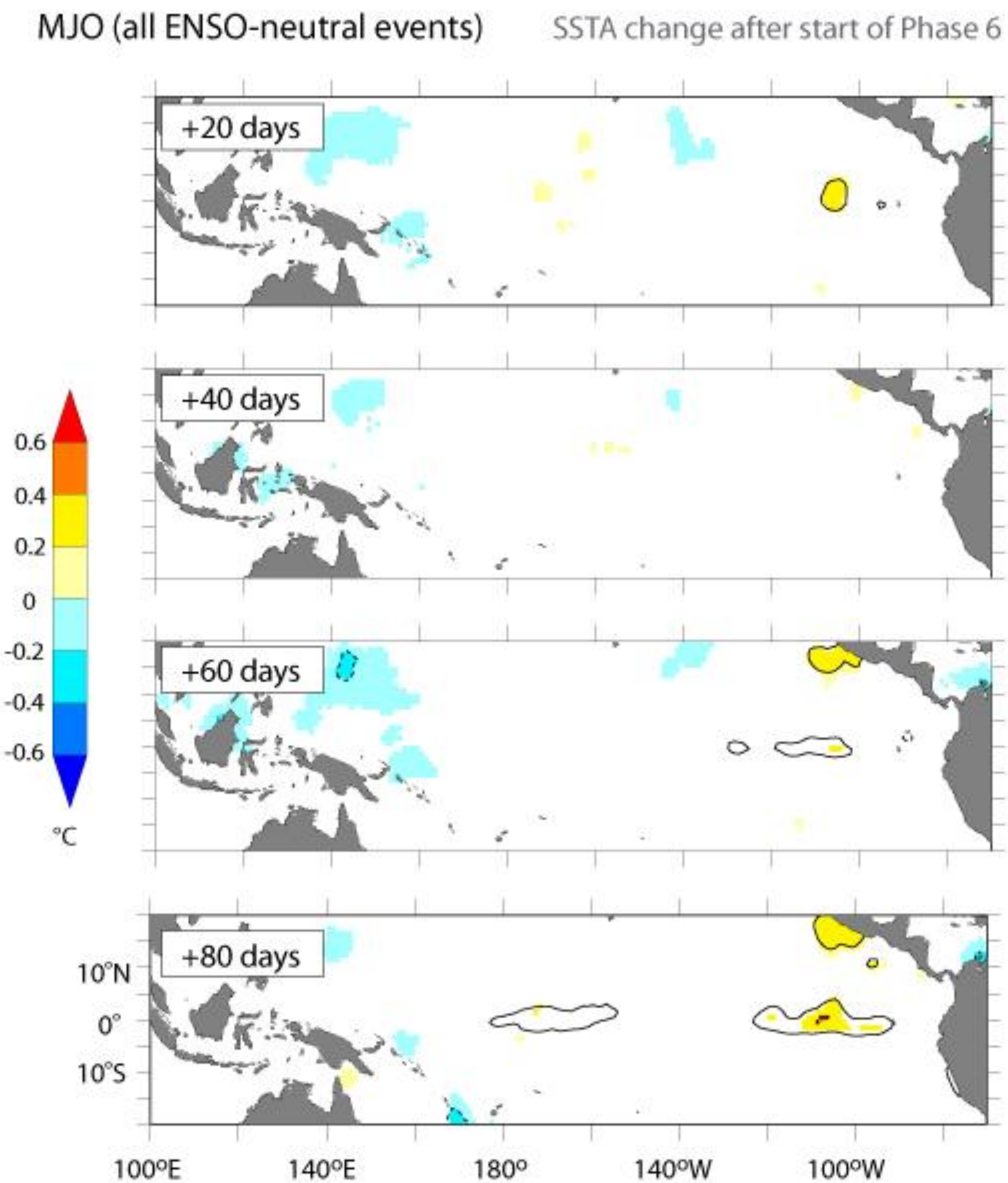


The WWE case: model results

The SST warming seen in ocean models following an applied WWE closely resembles the observed composite SSTA change.

Horizontal advection of the background SST gradient is a primary warming mechanism and central Pacific waveguide warming occurs largely irrespective of mixed layer depth behavior.

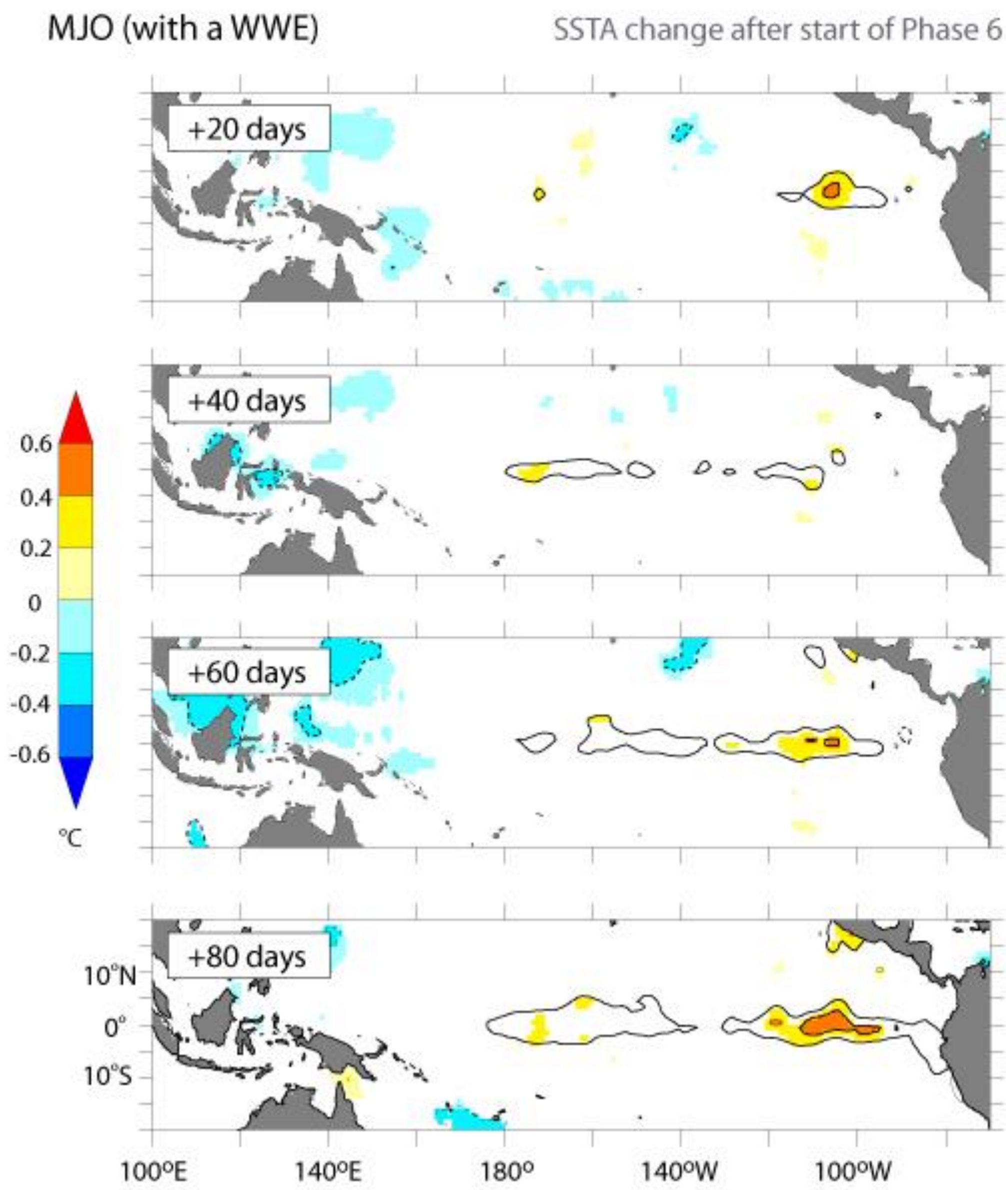
The all-MJO case: **with and without WWEs**



The +20 and +40 day composites show little persistent change within the oceanic equatorial waveguide

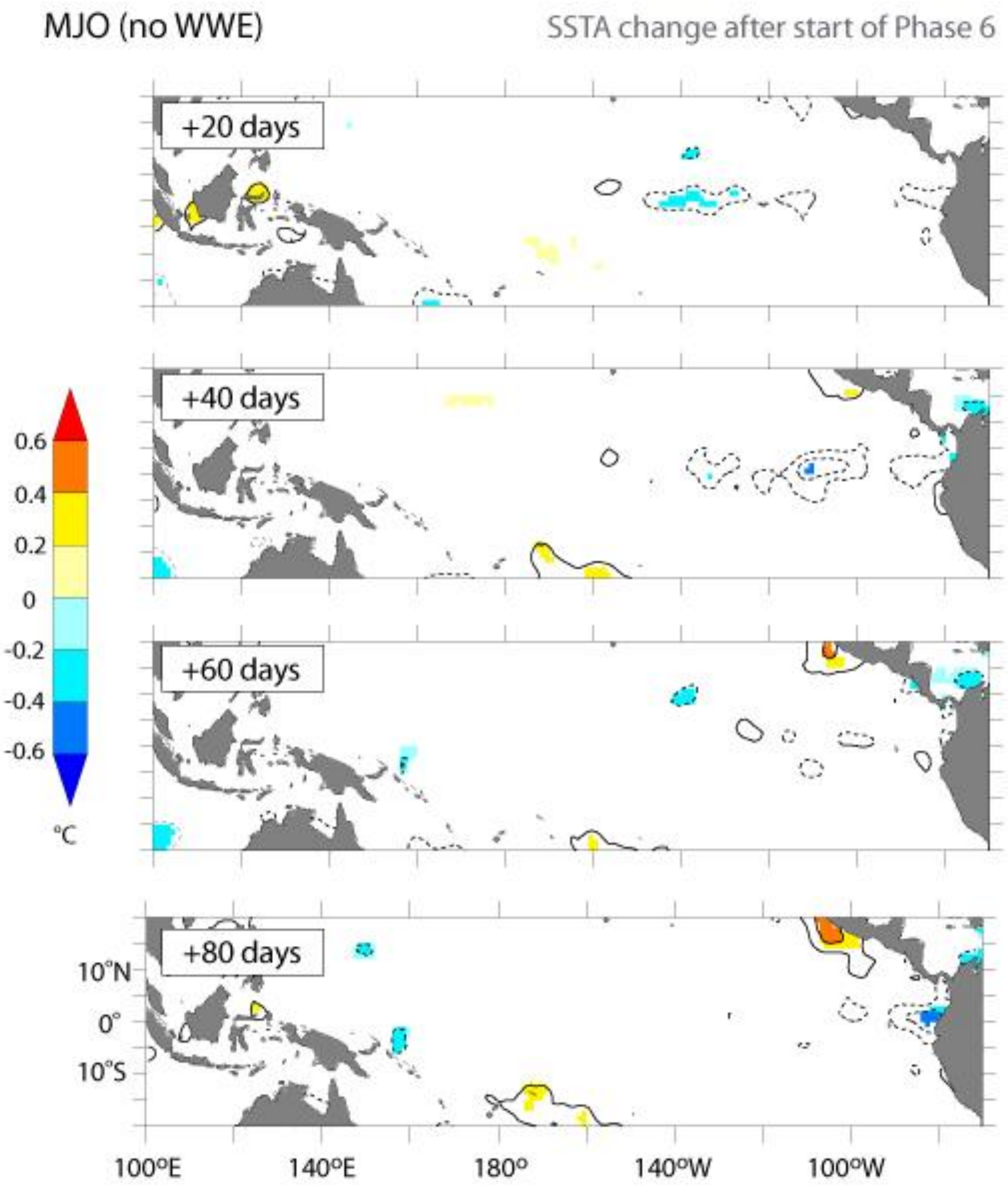
By day +60, warming of a few tenths °C is seen in the eastern tropical Pacific that intensifies to a statistically significant anomaly (peak amplitude > 0.4C) by day +80.

The MJO **with WWEs** case



Larger and more statistically significant warming amplitudes are seen in the case where a WWE occurs during the MJO event. The warming patterns seen are consistent with previously discussed effects of westerlies in the western tropical Pacific.

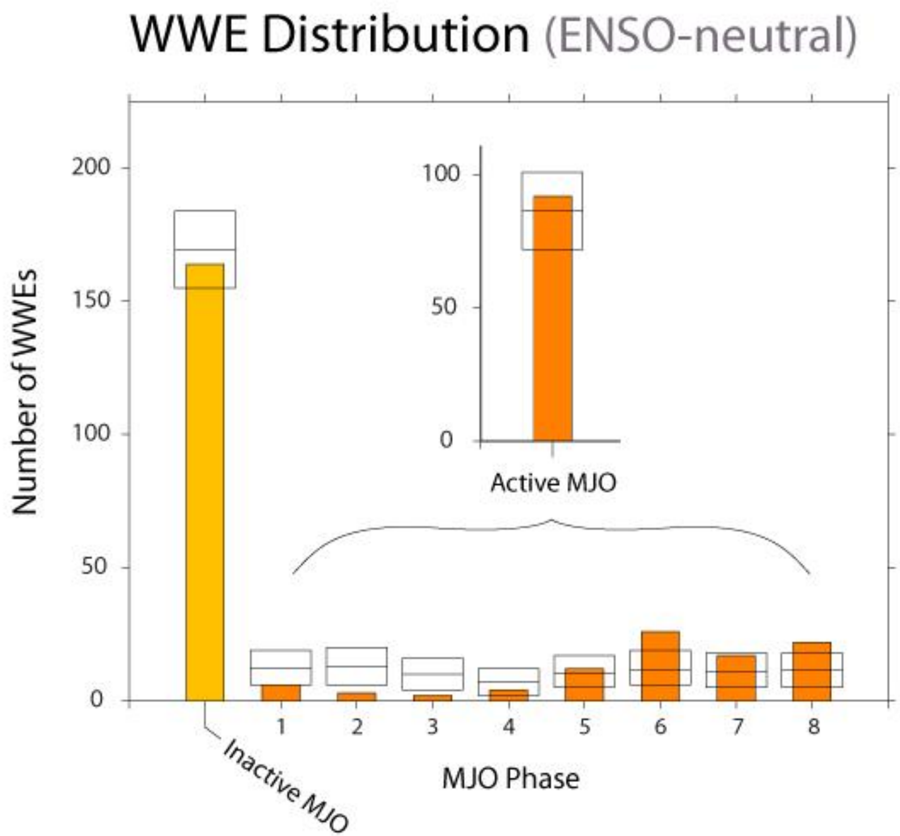
The MJO **without WWEs** case



No such warming occurs if WWEs are absent.

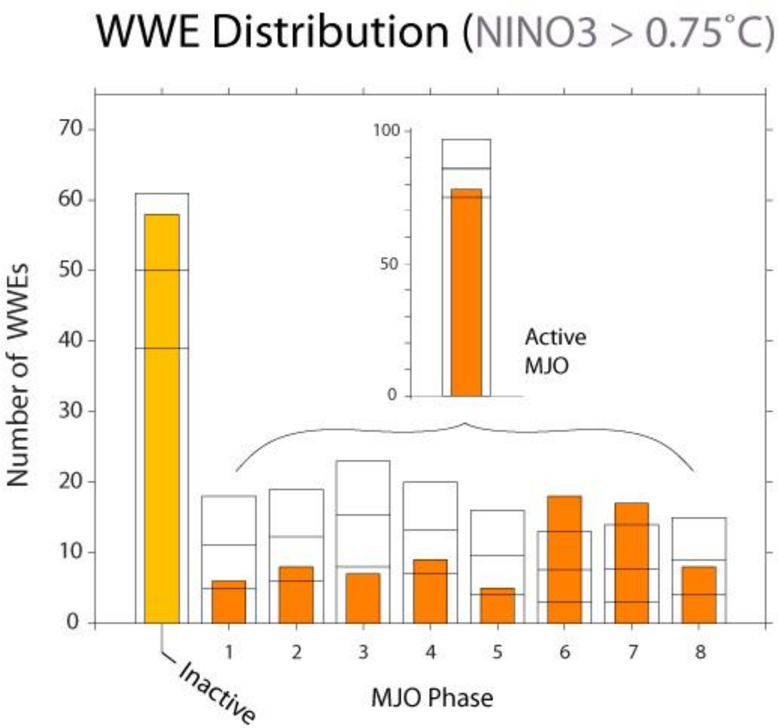
WWEs, not the MJO, are key to cold-tongue warming.

But is WWE frequency influenced by MJO-state?



We find that the null hypothesis that there is no connection between MJO-state (active/inactive) and the chances of WWE occurrence holds; **The MJO does not influence WWE frequency.** However, when they co-occur, the WWE tends to occur in a MJO phase with surface westerlies in the tropical Pacific.

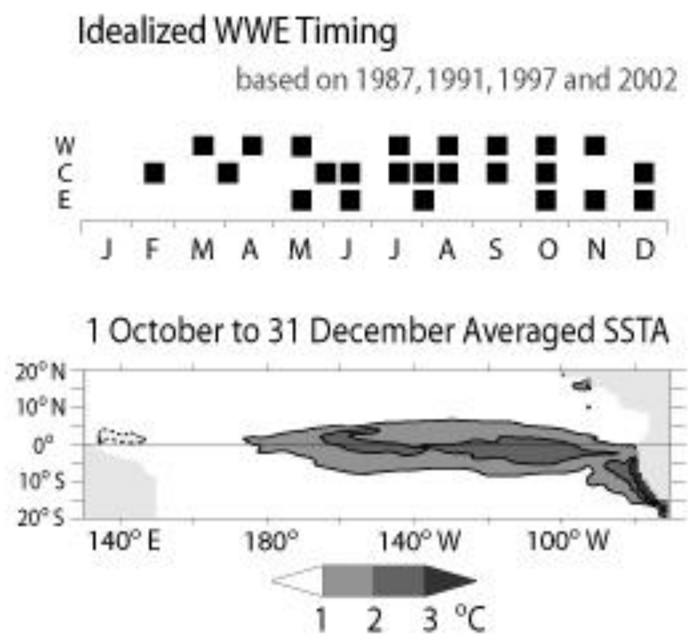
Results based on Monte Carlo examination of the 1986-2010 record. ENSO-neutral case shown here.



The relationship remains statistically insignificant in warm-ENSO conditions, and also if just the strongest (e.g. top 5%, top 10% based on maximum daily amplitude) MJO events are considered.

Thus, even in extremes (ENSO-state, MJO-amplitude) the chances of seeing a WWE are not affected by the MJO (contrary to some claims).

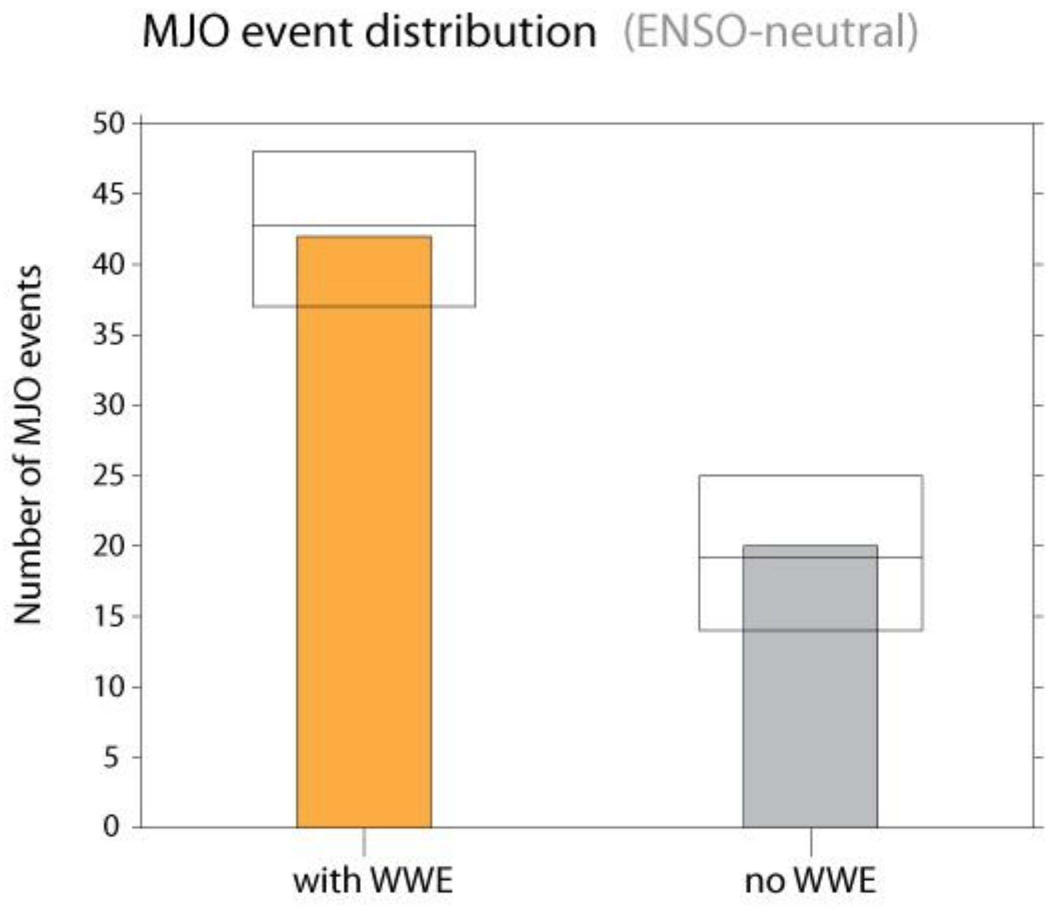
However, we find that WWE frequency increases from ~1.3 per month (256 WWEs in 5784 days) in ENSO-neutral, to ~2.4 per month (136 WWEs in 1744 days) in warm-ENSO conditions. Model results suggest that this is enough to drive an El Nino event.



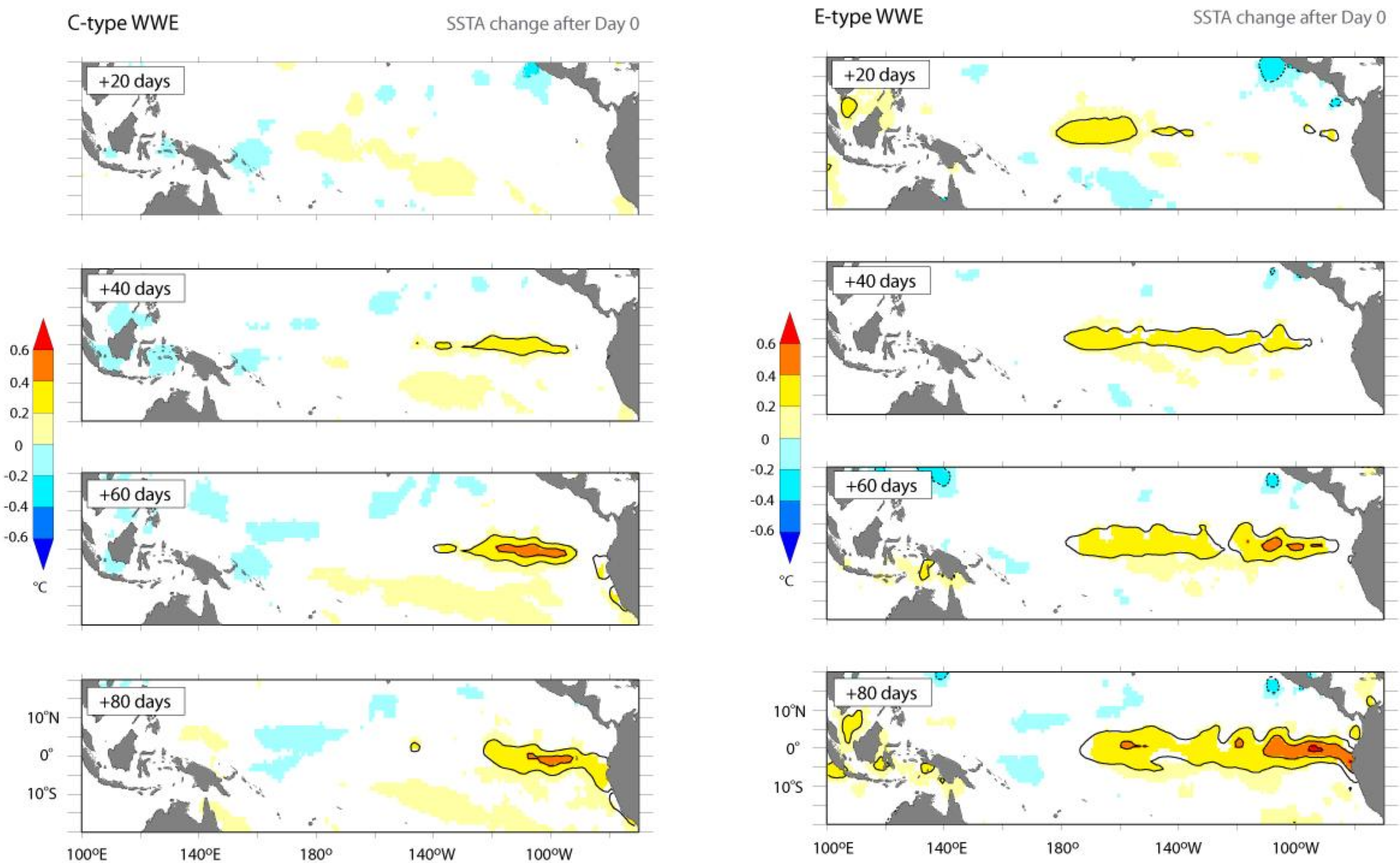
From Harrison and Chiodi (2009, J. Climate)

Conclusions

- Waveguide warming, upwards of a few tenths of a degree is seen, in an average sense, following W- C- and E-type WWEs that occur during ENSO-neutral conditions. Warming amounts are similar for WWEs that are and are not embedded in an MJO.
- There is waveguide warming for the MJO+WWE events in similar amounts as following WWEs that are not embedded in an MJO, and there is very little statistically significant waveguide warming following the MJOs that do not contain an embedded WWE.
- Improving understanding of the processes and predictability of Westerly Wind Events will benefit our understanding of ENSO.
- This confirms findings of Vecchi (2000) with a near doubling of period.
- Though characterized by short timescales, waveguide dynamics and increased WWE frequency in warm-ENSO conditions mean that WWEs strongly influence interannual SST variability in the equatorial Pacific waveguide region.

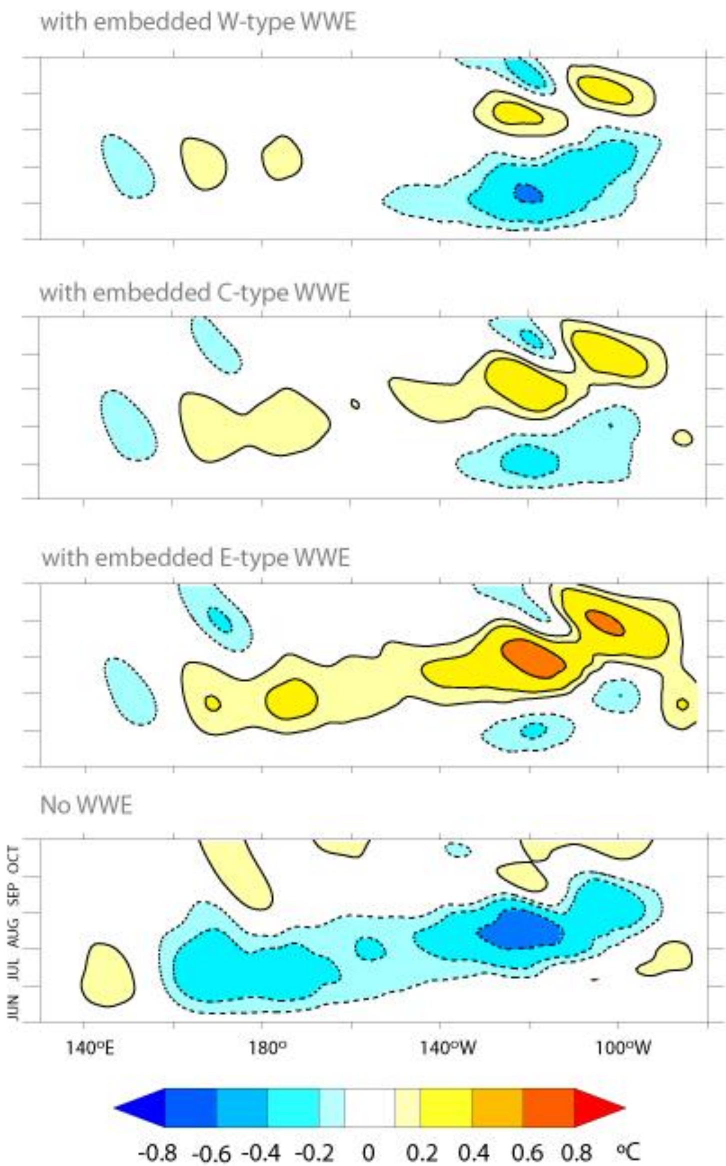


The converse holds as well.

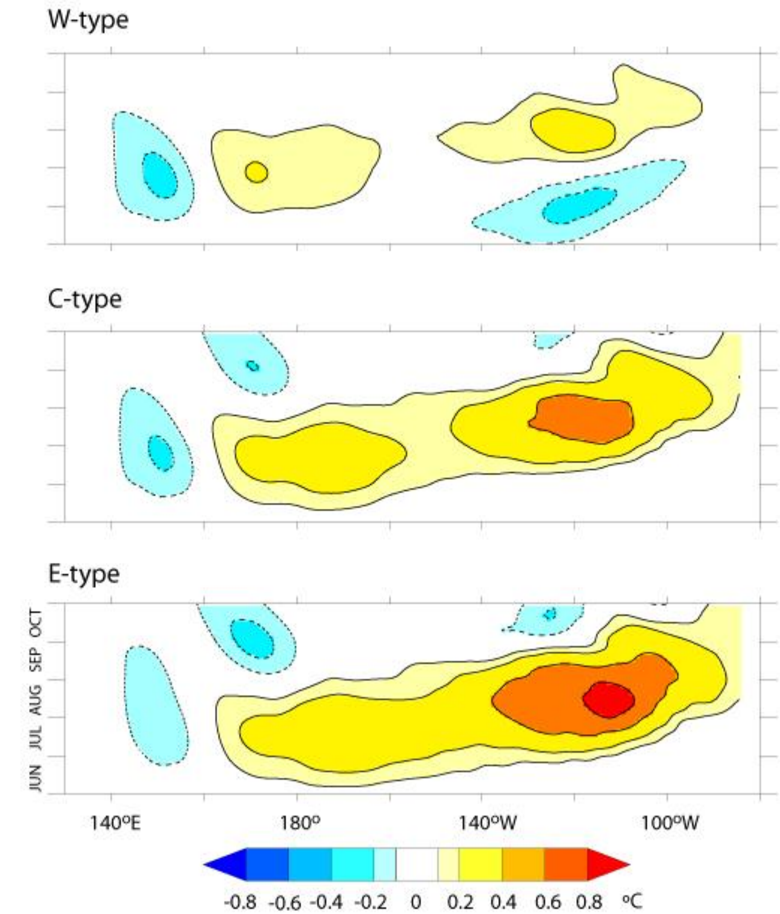


C-type WWE
SSTA change after Day 0
+20 days
+40 days
+60 days
+80 days
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
°C
10°N
0°
10°S
100°E
140°E
180°
140°W
100°W
E-type WWE
SSTA change after Day 0
+20 days
+40 days
+60 days
+80 days

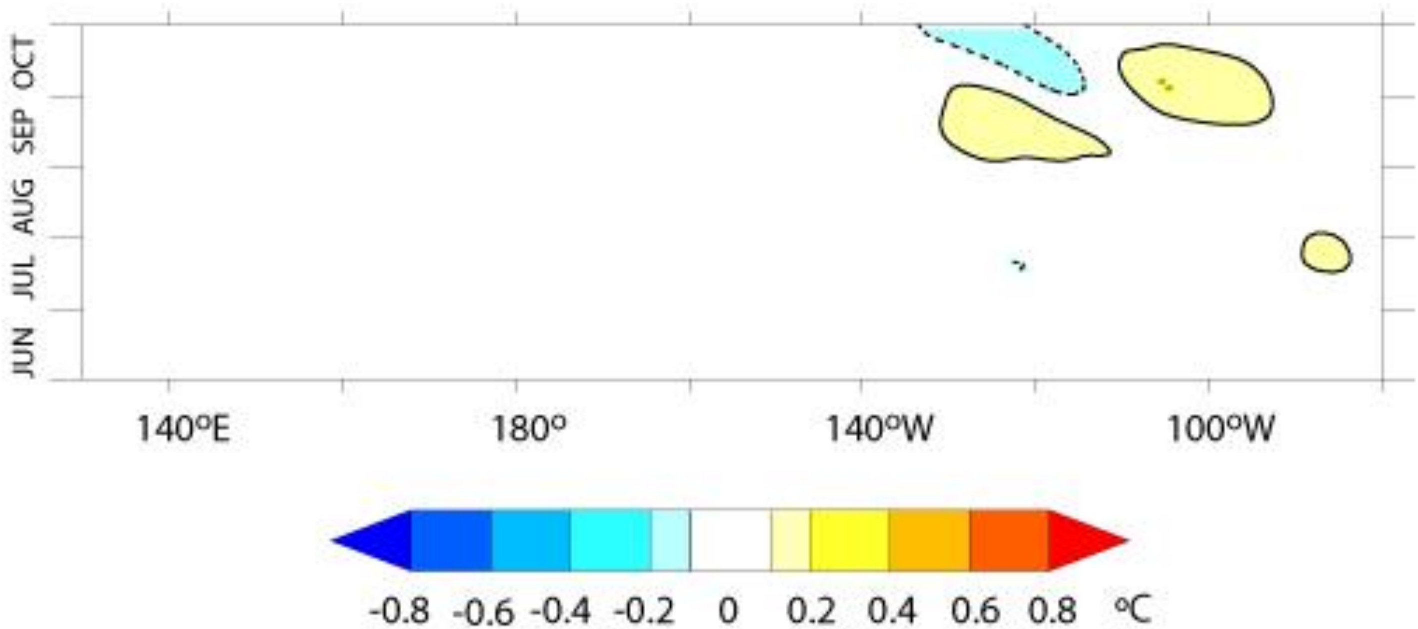
Model Response to composite MJO-wind stress anomaly

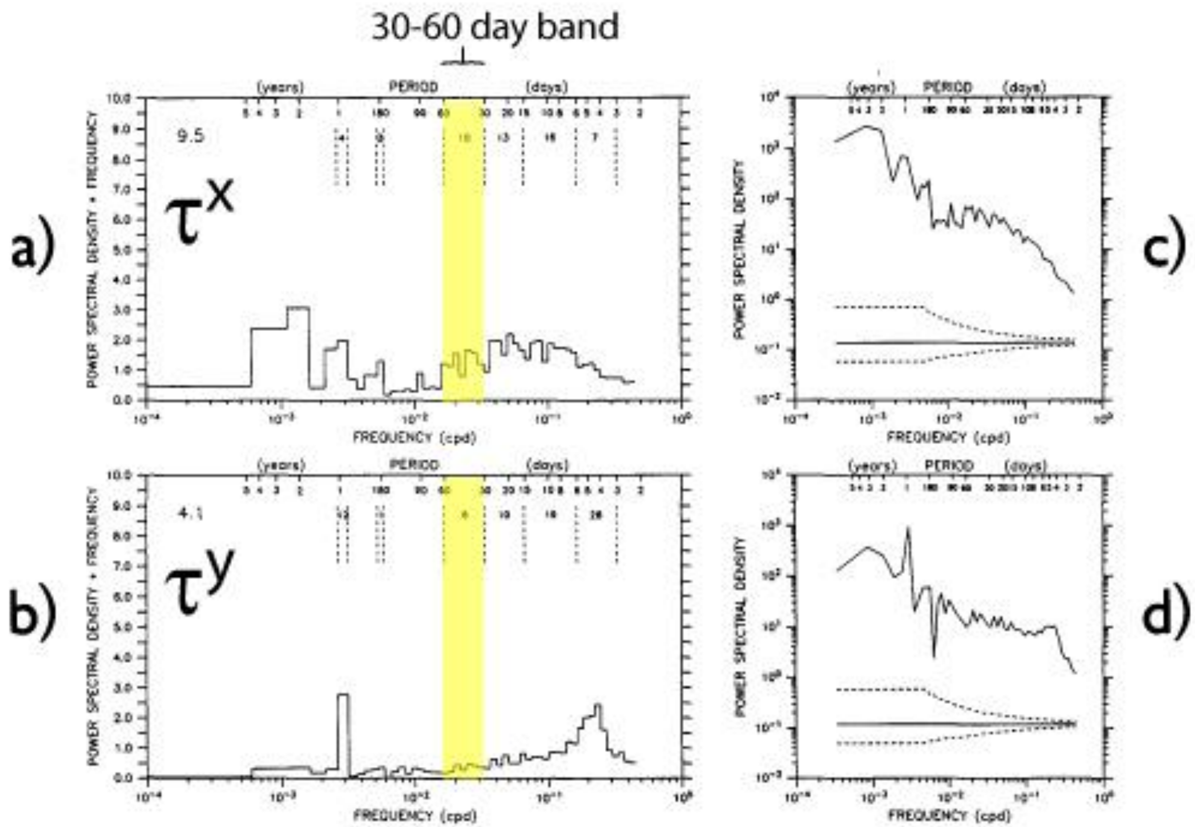


Model Response to composite WWE wind stress anomaly



Model Response to composite MJO-wind stress anomaly

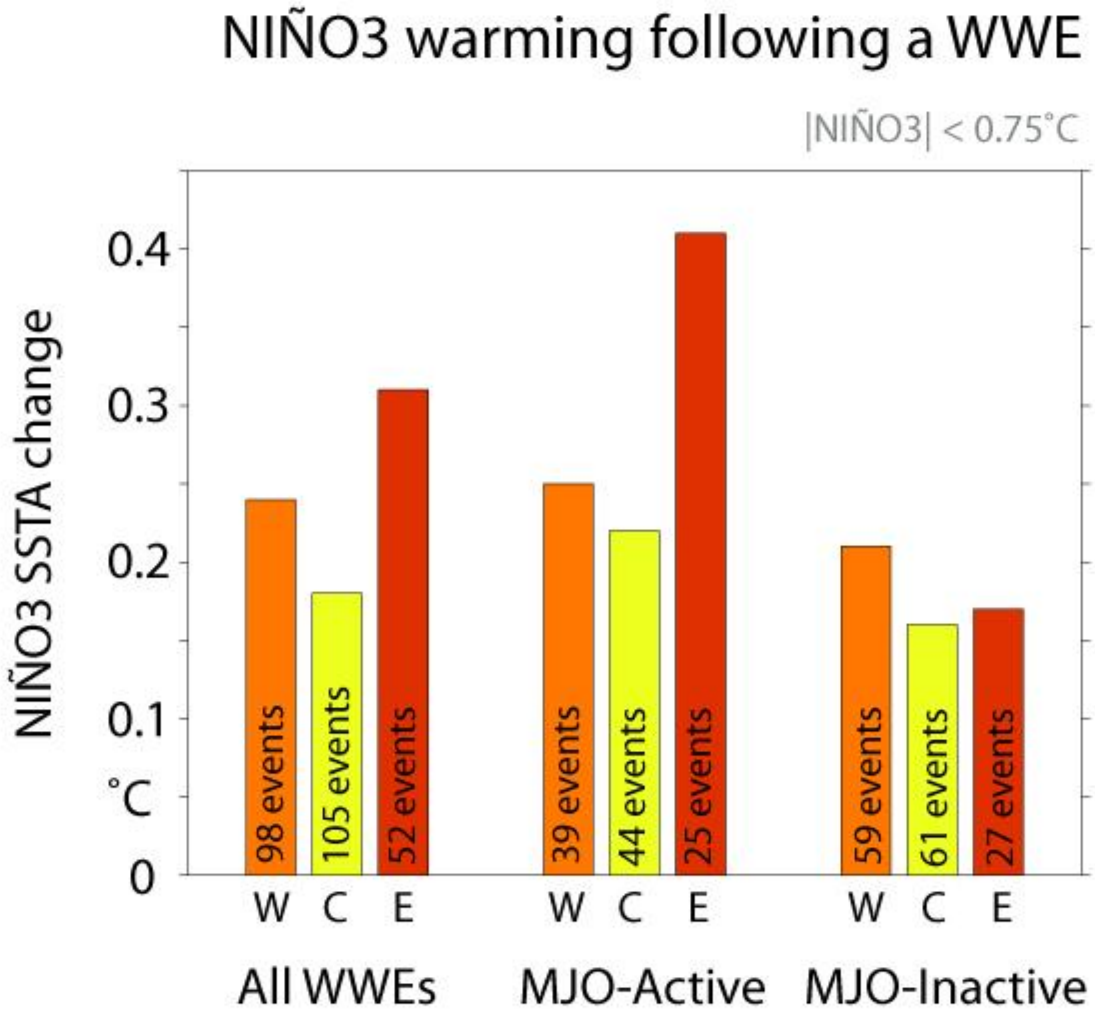




TARAWA

FIG. 7. Frequency power spectra of zonal and meridional wind at Tarawa (1°N, 173°E), in energy preserving (a), (b) and log–log (c), (d) plots. Confidence intervals of 95% are indicated on the log–log plots. Total variance is indicated in the upper left of (a) and (b).

From Harrison and Luther (J. Climate, 1990)



NIÑO3 warming following a WWE
|NIÑO3| < 0.75˚C
NIÑO3 SSTA change
˚C
0
0.1
0.2
0.3
0.4
98 events
105 events
52 events
39 events
44 events
25 events
59 events
61 events
27 events
W
C
E
W
C
E
W
C
E
All WWEs
MJO-Active
MJO-Inactive