Pre- and Post-1997/1998 Westerly Wind Events and Equatorial Pacific Cold Tongue Warming

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Abstract

The large El Niño-Southern Oscillation (ENSO) event of 1997/1998 marked a change in the character of sea surface temperature anomaly (SSTA) behavior in the equatorial Pacific cold tongue region and its relationship to Westerly Wind Events (WWEs.) Observational statistics compiled during and prior to the large El Niño event of 1997/1998 link WWEs to substantial (up to 3°C) warming in the eastern Pacific cold tongue region. Since 1998, however, relatively little WWE-related cold tongue warming has been observed and warm equatorial Pacific SST anomalies (SSTAs) have tended to be trapped near the dateline, rather than extending to the American coast as in a classical warm-ENSO composite. Here, the relationship between WWEs and cold-tongue warming is revisited using *in situ* and operational forecast winds and *in situ* and satellite-based SST. Significant differences are found in the basin scale zonal wind anomalies associated with WWEs that occurred before and after 1997/1998. Although the post-1997/1998 composite WWE westerly anomalies are very similar to their predecessors within the defining WWE regions, conditions east of the WWE regions are different; there are enhanced equatorial easterlies in the post-1997/1998 cases. General ocean circulation model experiments are conducted to explore the extent to which the observed changes in the character of post-1997/1998 WWEs can explain the recent behavior of cold tongue SSTAs. It is found that the wind differences can account for the changes in the average cold tongue warming associated with pre- and post- 1997/1998 WWEs.

Composite SSTA change following a WWE

Previously presented techniques (Vecchi and Harrison 2000; VH00) identify three types of WWEs who's defining regions span the equator (named **W**, **C** and **E**.) Averaged over the 1986-98 period, cold tongue warming of up to 1°C is known to follow individual WWEs of these types (see Fig. 1 left-side panels and VH00.) This study documents and investigates the fact that little to none of this type of cold tongue warming is seen in the post-1997/98 results (Fig. 1 right-side panels.)

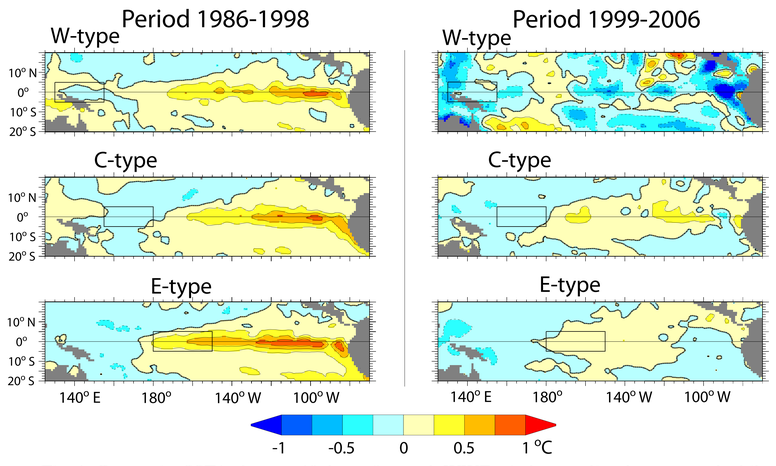

Fig. 1. Composite SSTA changes 60 days after peak WWE wind anomalies that occurred while equatorial Pacific SST conditions were near normal. Black boxes indicate the respective WWE regions. Data from NOAA OISST.

Period differences in WWE wind anomalies

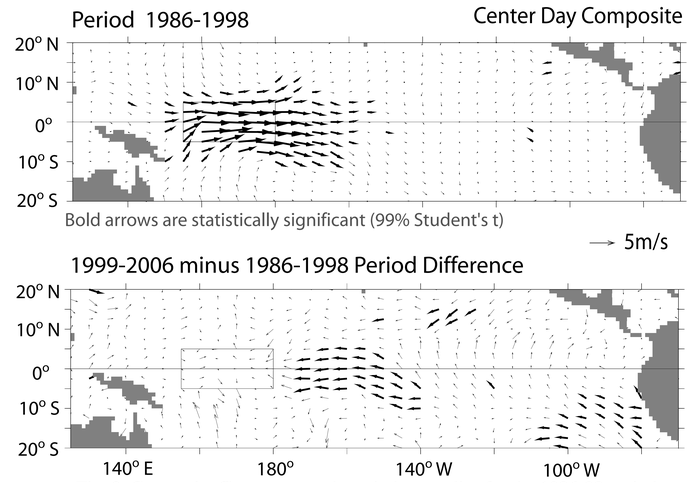

Fig. 2. Composite **C**-type center day wind anomalies for the 1986-98 period (upper panel) and the difference between thee 1999-2006 and 1986-98 period composites. Wind data from ECMWF 12-hourly 10-m winds.

WWE wind anomalies have large amplitudes (average zonal 10-m wind anomaly 6-7 m s^{-1} with peaks upwards of 15 m s^{-1},) large zonal scales (1400-2500 km) and short duration (typically 6 days; see Vecchi and Harrison 1997.) Average composite wind anomaly for **C**-type events during the 1986-98 period clearly shows large (order 10 m s^{-1},) statistically significant peak zonal wind anomalies centered in the **C**-region (Fig. 2 upper panel.) Outside of this region there is little significant anomaly. The period difference (Fig. 2 lower panel) shows relatively little change in the defined region, indicating that the average near-dateline easterlies, to the east of the C-region, were at increased strength during the WWEs that occurred in the 1999-2006 period.

Time-longitude plots of the **C**-type composite show that the increases in central Pacific easterlies in the 1999-2006 period occurred mainly during times of WWEs (not shown.) Qualitatively similar results, showing nearly contemporaneous, pulsed increases in easterlies, east of the defined regions, were obtained for **W**-type and **E**-type events, but are not shown here for brevity.

Ocean Model Results

General circulation ocean model results for single WWEs show surface warming of several tenths °C west of the dateline following each of the three types of pre-1997/98 WWEs (C-type results shown in Fig. 3, left panel.) This is consistent with previous modeling studies that looked at the effects of single-WWEs (Giese and Harrison 1991.) In the post-1997/98 case, although there is still considerable warming west of the dateline, the ocean response is dramatically different in the cold tongue region (Fig. 3, right panel.)

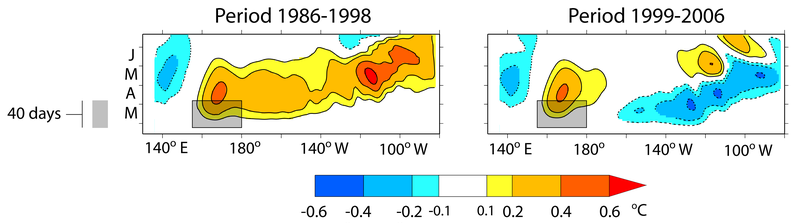

Fig. 3. Time-lon plots of 2°S to 2°N averaged model SSTAs from single **C**-type WWE. Wind anomaly applied everywhere west of 120°W

To examine the effects of multiple WWEs, a second set of experiments was performed in which several WWEs of each type were applied over the course of a model year, in a manner consistent with the type-dependent average frequency of events during four recent years with anomalous warmth in the cold tongue region. Pre-1997/98 results show > 1°C warm anomalies along much of the cold tongue region in Oct-Nov-Dec (Fig. 4, left panel,) consistent with previous observations of mature phase warm-ENSO events. Post-1997/98 results show mainly cooling in the cold tongue region (Fig. 4, right panel.)

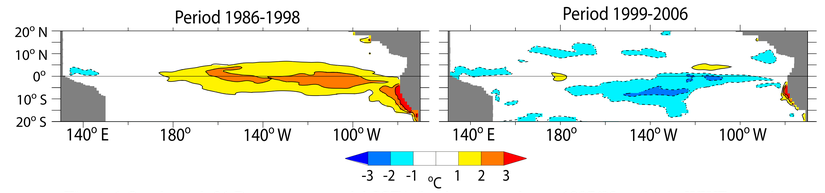

Fig. 4. 1 Oct through 31 Dec average model SSTA for the pre- and post-1997/98 multiple-WWE experiments. Timing of the applied WWEs is the same in each case (24 total, C-type is most common with 10 events.)

Conclusions

We have examined the average characteristics of recent westerly wind events and the equatorial Pacific SST changes following them by compositing them over the period since the major 1997/98 El Niño event. The composite WWE wind anomaly patterns are very similar to their predecessors over their defining regions. There are, however, statistically significant easterly anomalies east of the event-definition regions in this later period.

Composite SST changes following recent-period composite WWEs are shown to be substantially different than those following the previous period-composite. Whereas significant cold tongue warming was characteristic of the 90-days following previous period WWEs, on average, there has been little cold tongue warming following recent-period composite WWEs. Overall, warm SSTAs have been much more confined to the central equatorial Pacific since 1998 than during the 1986-1998 period.

A series of forced ocean model experiments shows that recently observed average patterns of SSTA have been broadly consistent with forcing by recent period average WWEs, just as earlier-period average SSTA patterns were consistent with forcing by earlier-period average WWEs.

Weak "dateline"-type El Niño behavior (see Larkin and Harrison 2005) has been unusually common in the recent period. This is consistent with WWE forcing being a primary mechanism of warm-ENSO SST evolution in the recent period, just as it was in the previous-period. Whether WWEs are the main mechanism for recent El Niño events will require additional study.