Comparison of the 1997 and 2002 El Niño events - Model and Data Assimilation Results

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INTRODUCTION

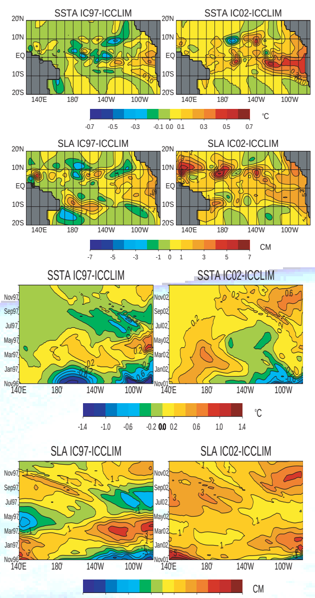
Time series of high quality ocean surface topography from TOPEX/Poseidon and Jason 1 allows a thorough comparison between two distinct El Niño events. The 1997-98 El Niño, the "event of the century", showed a strong zonal component of sea level variability along the equator, whereas the weaker 2002 event had a more meridional structure. In this study, observations of sea level and sea surface temperature (SST) are used along with data assimilation and ocean model experiments to isolate differences between initial states of the system, forcing, and the contribution of Kelvin and Rossby components to the development of the two events.

MODEL - The model is a reduced gravity, primitive equation, sigma coordinate model (Gent and Cane, 1989). The grid covers the Pacific tropical basin (124ºE-66ºW, 30ºS-30ºN), 1º longitude with stretched meridional resolution (to 0.33º at the equator), realistic coastline, and 20 layers in the vertical. It is forced with ECMWF wind stress, climatological solar radiation (ERBE), cloudiness (ISCPP) and rain (Oberhuber, 1988) . An embedded variable depth oceanic mixed layer (Chen et al., 1994) simulates oceanic vertical turbulent mixing. Surface fluxes are calculated by coupling the model to an advective atmospheric mixed layer (Seager et al., 1995).

DATA ASSIMILATION – The data assimilation technique is described in the poster "*Ensemble Reduced Order Kalman Filter for Data Assimilation*" presented by Ballabrera et al.

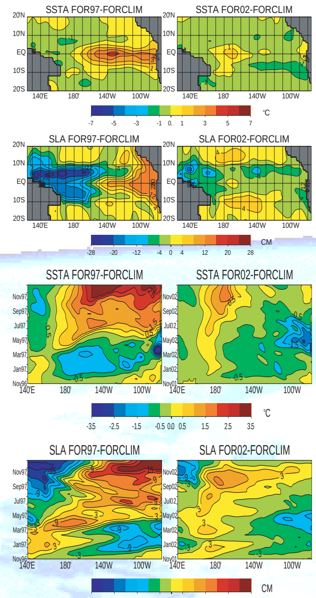
KELVIN/ROSSBY DECOMPOSITION – The technique of Delcroix et al. (1994) is used to separate TOPEX/Poseidon/Jason gridded sea level into the two components. The first 3 modes of the Rossby wave are retained.

ROLE OF INITIAL CONDITIONS



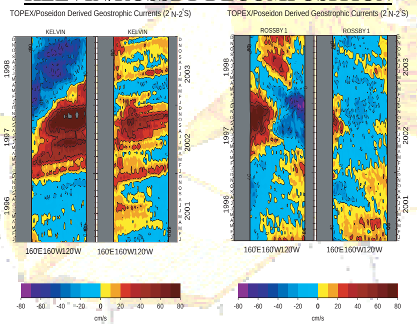
Different initial conditions (IC) for Nov96, Nov02 and Nov Clim are used to initiate model experiments for the two El Niño periods (Nov96-Dec97, Nov01-Dec02). By differencing two experiments with the same forcing but different ICs, the role of the ocean state at the start of the two events (Nov96 versus Nov01) can be examined. SST (top) and SL (2nd from top) are shown for Dec 1997 (left) and 2002 (right) after 14 month integrations. Longitude/time along the equator for SST (2nd from bottom) and SL (bottom) show that for both cases initial conditions alone induce a subsequent weak El Niño.

ROLE OF FORCING

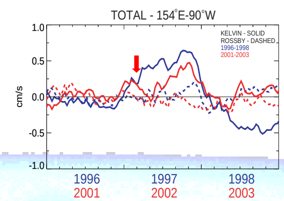


Plots of differences between two sets of experiments, 1997 – Clim (left) and 2002 – Clim forcing (right), with the same ICs isolate the role of forcing. These results show that for the 1997 event SST (top) and SL (2nd from top) are typical of the classical first mode El Niño patterns. However, the results of isolating the forcing for the 2002 event (right) show that the main SST anomaly is located in the central basin near the dateline. For sea level, the pattern shows a more meridional structure with negative values within 10° of the equator and positive anomaly poleward.

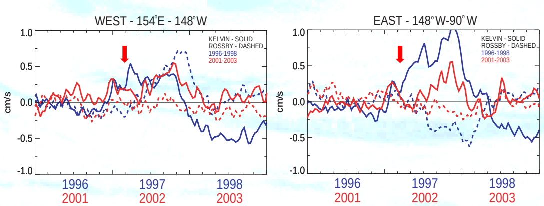
KELVIN/ROSSBY DECOMPOSITION



Another way to differentiate between the two events is to decompose the sea level signal from TOPEX/Poseidon/Jason gridded product into Kelvin and Rossby components. These results show that the two events are remarkably similar up until February of the El Niño year (1997, 2002). At that time the 1996-97 event intensified whereas the 2001-02 event weakened before returning in summer of 2002. The Rossby patterns for 1997 shows large amplitude while the 2002 signature is weak.

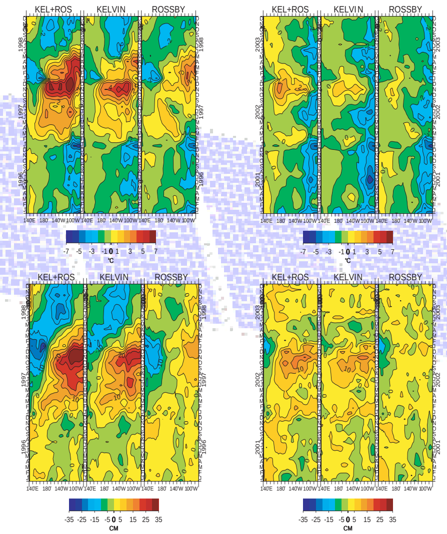


This plot shows the index over over all longitudes of the Kelvin (solid) and Rossby (dashed) currents for 1996-98 (blue) and 2001-2003 (red). Note how the two Kelvin curves diverge in February of the El Niño year (red arrow). Also note that the basin index Rossby wave values are much smaller than the Kelvin components (ie. 1997 east offsets west values).



In the western half of the basin (left) the Kelvin component for 1997 (solid blue) peaks in March 1997 then changes to upwelling by Nov 1997. The 2002 Kelvin wave (solid red) peaked in Nov 2002. The Rossby wave component for 2002 (dashed red) has little amplitude whereas the 1997 Rossby wave (dashed blue) shows strong downwelling peaking in Nov/Dec 1997 . For the East (right), the 2002 signal for both Kelvin and Rossby (red) looks very similar to the western half. However, the Kelvin and Rossby components for 1997 both show large values with the signs offsetting each other - Kelvin downwelling (blue solid), upwelling Rossby component (blue dashed) lagging the Kelvin and somewhat weaker in amplitude. These plots show that the 2002 El Niño was zonally consistent while the 1997 event had large differences between the east and western halves of the basin.

KELVIN/ROSSBY DATA ASSIMILATION



Assimilation of the Kelvin+Rossby, Kelvin, and Rossby components of the sea level signal is performed on a climatologically forced ocean model and shows the key role that the Rossby wave plays on the 1997 event. Longitude versus time plots of SL (bottom left) and SST (top left) for 1997 shows how assimilation of the Rossby component can contribute up to 1/3 of the El Niño signal. During the 2002 event the Rossby component showed no appreciable contribution to the warming

CONCLUSIONS

1) Forced ocean model results indicate that the state of the ocean for Nov96 and Nov01 leads to weak warm events. However, ICs alone do not provide enough information to simulate correct amplitude for 1997 and 2002 events.

2) Isolation of the impacts of the forcing shows distinct mechanisms for the two events - 1997 shows a large zonal slope whereas 2002 has a more meridional gradient.

3) The Kelvin wave signals for 1997 and 2002 are similar up until February of the El Niño year then the two events evolve very differently.

4) The Rossby component for the 1997 El Niño contributes to the strength, location and duration of the warming, whereas the 2002 Rossby component has little effect.

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