Response to Reviewer #2

We would like to thank the reviewer #2 for very thoughtful comments and suggestions. The manuscript is now revised following the reviewer's suggestions. Here, we briefly explain how we address each of the comment. The reviewer's comments are in italic font, and our replies are in normal font.

This paper examines the evolution of observed El Niño events over the period 1949-2013. A composite of SST anomalies for 21 events over 24 months of the ENSO cycle, i.e. year (0) and year (1), are constructed based on the Nino 3.4 SST anomalies that exceed 0.5°C. The unique aspect of the paper is that the EOFs are performed on anomalies averaged between 5°N-5°S over the 24 months of the ENSO cycle, i.e. the eigenvectors are in the longitude-time domain rather than longitude and latitude as is usually done and the points of the principal component (PC) give the amplitude of the full evolution for each of the 21 events. The authors find that there are two dominant EOFs of the inter-event evolution one that highlights the persistence of SST anomalies over Yr (1) in the eastern Pacific and a second EOF that shows a transition to La Niña conditions starting in boreal spring of Yr (1). The authors explore the atmosphere and ocean structures by regressing the depth of the 20 C isotherm, surface wind stress and precipitation (supplemental) on the two PCs.

While I think using this EOF method is a useful way to examine the evolution of warm ENSO events, I do have some minor concerns about the manuscript:

1) Introduction lines 58-59. The authors note that El Niño Modoki relies more on the zonal advection rather than thermocline (upwelling) feedback as it lies in the Central Pacific. While its likely that zonal advection of temperature anomalies is more important in the central than the east Pacific for ENSO variability, several studies have noted that Central Pacific ENSO appear to be more associated with surface flux variability as opposed to ocean dynamics, e.g. see

Yu., J.-Y., H.-Y. Kao and T. Lee, 2010: Subtropics-Related Interannual Sea Surface Temperature Variability in the Equatorial Central Pacific. Journal of Climate, 23, 2869-2884.

So this aspect of the energy budget should be mentioned as well.

Reply: We add the following sentence in the revised manuscript:
"Several studies have also noted that "El Niño Modoki" is more associated with surface heat flux variability as opposed to ocean dynamics [e.g., *Yu et al*., 2010]."

2) line 88-89. Provide reference for defining ENSO this way (or perhaps indicate this is the definition used at NCEP).

Reply: We mention that we are following the definition used at NCEP.

3) line 128. The authors indicate that the second EOF is not highly correlated with SSTAs in Nino 3.4 in DJF. As proof they state that "the correlation is ~0.5 which is not significant at the 99.9% level". However, this is a very, very high standard; for example a 95% significance level is used. Clearly a 0.5 correlation indicates that there is some relation between DJF Nino SSTs and EOF2, it's just weaker than the correlation with EOF 1.

Reply: This sentence is now revised to the following in the revised manuscript:
"This mode is also well correlated with the SSTAs in Niño 3.4 for DJF (0,+1), but not as strong as the correlation with the first mode (r = 0.49; significant at 95% level; not shown)."

4) In many places in the results sections (sections 3-6). The authors provide explanations for the results that are presented in the manuscript including, coupled Kelvin waves/slow SST mode, recharge-discharge paradigm, Rossby wave reflection paradigm, Sverdrup transport, off-equatorial Rossby waves, etc. However, it is often difficult to see these relationships from the figures shown in the text. Plots showing the Sverdrup transport or the off-equatorial waves are not presented (as acknowledged by the authors). Even for figures that are focused on the equator it can be difficult to determine the underlying dynamics. For example, in discussing Figure 3e (lines 192-196), which shows the composite mean (CM) + EOF2 the authors indicate that the thermocline in the east Pacific is anomalously deep in the boreal spring prior to an event and that this deepening is likely associated with the arrival of a downwelling Kelvin wave. However, the deepening in spring of yr (0) is mainly within 20° of the South American coast and if anything the local contours suggest a westward propagation of the anomalies *between 80°W and about 110°W. Thus, at least from this figure its unclear why this deepening is associated with a Kelvin wave and could well be due to local downwelling along the coast. In addition it's not clear that these anomalies are really crucial to the overall El Niño evolution.*

While I appreciate that the authors are trying to relate the results shown here to broader ENSO theory, I recommend that they:

a) either provide more detailed analyses (could be in the supplemental section) supporting the results relating to ENSO dynamics or save more of the speculation for the discussion section

Reply: We completely agree with the reviewer that detailed analysis related to ENSO dynamics is not properly presented in our original manuscript, and that some of the discussions related to ENSO dynamics are quite speculative. Therefore, following the reviewer's suggestion, we have removed all discussions about ENSO dynamics, involving coupled Kelvin waves, recharge-discharge paradigm, Rossby wave reflection paradigm, Sverdrup transport, and off-equatorial Rossby waves in the revised manuscript. In the revised manuscript, we only mention and discuss the slow SST mode because the fast ocean Kelvin waves, which travel with the speed of about 3m sec^{-1}, cannot be used to explain the slow eastward propagation of the air-sea coupled anomalies in Figure 2 and 4.

b) more carefully describe some of the findings - not all of the along equator results indicate eastward propagation associated with equatorial Kelvin waves

Reply: We have revised many sentences to provide more accurate description of our findings. For instance, in describing the early onset of El Niño (in section 5), we stated in the original manuscript that this is due to an early arrival of the downwelling equatorial Kelvin wave train in the EP. In the revised manuscript, we simply state that the early onset is linked to the thermocline in the EP being already deep in the boreal spring of the onset year.

c) sometimes the authors invoke the recharge-discharge mechanism and other times the delayed oscillator mechanism to explain certain features seen in Fig. 3 and S2. While these two aren't mutually exclusive, it seems that one should use a consistent set of arguments for the structure of the anomalies, i.e. Sverdrup transport (near the equator) and Rossby waves that *reflect off the western boundary as coastal and then equatorial Kelvin waves are two very different mechanisms for getting off-equatorial anomalies on to the equator (and neither of these mechanisms can be evaluated from the plots shown here)*

Reply: In the revised manuscript, we do not discuss either the recharge-discharge oscillator or the delayed oscillator.

d) the meaning of some of the terms, such as "slow SST mode", may not be know from people outside the ENSO community. So either a briefly explanation should be given with these type of terms when they are first presented, or they should either be dropped or replaced by non-field specific terminology.

Reply: In section 4 of revised manuscript, we briefly explain the slow SST mode:
"….. in accordance with the behavior of a slow "SST mode"- slowly propagating anomalies whose time scale is set by coupled air-sea interactions, rather than by fast ocean wave dynamics [*Neelin*, 1991; *Wang and Weisaberg*, 1969]."

5) It would be interesting to do a similar analysis but for La Niña events.

Reply: As sugegsted, we applied the same methodology to look at inter-La Niña variability. We used 22 La Niña events during the period of 1949-2013 to identify two leading modes of inter-La Niña variability. The two EOFs are now added in Figire S5, and briefly discussed in section 7. It appears that the first EOF mode of inter-La Niña variability describes a two-year La Niña transitioning to El Niño, and El Niño transitioning to a two-year La Niña. The first EOF mode, therefore, illustrates multi-year duration of La Niña (e.g. Okumura and Deser 2010; Okumura et al., 2011; Choi et al. 2013; DiNezio and Deser 2014). We plan to further investigate the leading modes of inter-La Niña variability in future studies.

Okumura, Y. M., and C. Deser (2010), Asymmetry in the duration of El Nino and La Nina. *J. Clim.*, 23, 5826–5843.

Okumura, Y. M., M. Ohba, C. Deser, and H. Ueda (2011), A proposed mechanism for the asymmetric duration of El Niño and La Niña. *J. Clim*, 24, 3822–3829.