Response to Reviewer #1

We would like to thank the reviewer #1 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 study aims at exploring the diversity in the spatio-temporal SST evolution amongst observed El Niño along the equatorial strip. Aside from a description of this diversity, the authors also discuss the mechanisms that could be responsible for it. Although the diversity of El Niño spatial patterns has been discussed extensively during the past ten years, there is only a handful of studies discussing the temporal diversity of El Niño evolution. I therefore believe that there is a very strong potential for the present study to represent a significant advance for the ENSO community and therefore to be published in GRL. However, two major concerns (rather easy to address I guess) prevent me to accept the present manuscript in its present form. I feel that the manuscript will strongly benefit from a more thorough discussion of previous published results as well as some analysis refinements. These two concerns are detailed below:

Major comment 1: EOF analysis. EOF are statistical tools that allow extracting the orthogonal basis functions that maximize the variance explained. As such, there are not supposed to extract physical modes of variability. As acknowledged by the authors (L240-244) and as evident on Figure 4, most El Niño events are often described as a mixture of EOF1 and EOF2. When looking at Figure 4, it appears to me that two spatio-temporal ENSO regimes can be identified: the regime of extreme El Niño events (1982-83 and 1997-98) which is approximately located along a diagonal axis PC1=PC2 and the regime of moderately warm events approximately oriented diagonally along the PC1=-PC2 axis. These rotated axes obey the directions preferred by the system, so these new axes may be more dynamical meaningful compared to the actual PC1 and PC2. While the first axis will represent the departure of extreme El Nino events compared to composite mean, the second axis (PC1=-PC2) will represent the late/early onset for moderate El Niño events compared to CM. Redoing Figure 3 along these rotated axis may provide a better description of the physical mechanisms involved in extreme El Nino events and late/early onset for moderate El Nino events. Such a procedure has been successfully applied by Takahashi et al. (2011) to describe non linearities in El Nino

evolution and reinterpret the canonical and Modoki El Niño. I think the authors should consider rewriting the paper based on rotated EOF axis along the preferential direction of ENSO system rather than discussing mechanisms based on EOF1 and EOF2 that are much more difficult to interpret physically. If the authors choose not to do so, they should strongly justify their choice. I don't think that orthogonality of the EOF patterns are required for the analysis to be meaningful.

Reply: We very much appreciate this thoughtful suggestion. As suggested, we present 90º-rotated EOFs in Figure 1, 3 and 4. As discussed in the revised manuscript (mainly in section 6), the first rotated EOF effectively describes the two extreme El Niños versus weak El Niños (e.g., 1958-1959 and 1977-1978 events). Similarly, the second rotated EOF reasonably well describes early-onset, early-terminating and transitioning El Niños (e.g., 1987-1988 event) versus late-onset, persistent and resurgent El Niños (e.g., 1968-1969 and 1986-1987 events). However, we still present and discuss the two original EOFs in the revised manuscript for two reasons. First, we think that is useful to characterize, for example, the two extreme El Niños as large amplitude and transitioning events. The two original EOFs are more effective in illustrating the two more or less independent (i.e., orthogonal) aspects of the two extreme El Niños. Second, it is logical to first describe the original EOFs before the rotated EOFs are presented.

Major comment 2: Discussion of previous results. Although the authors mention some papers discussing the variety of the temporal evolution of El Niño events, I feel that very relevant papers to the present study have not been considered (Takahashi et al. 2011, Dommenget et al. 2013, Lengaigne et al. 2006, McGregor et al. 2013). A discussion on the similarities/disagreements between these studies and the present one would also help the reader to better highlight the novelty of the present study.

Reply: The suggested articles are now cited and discussed in the revised manuscript. They are all listed in section 1. Additionally, Takahashi et al. [2011] is discussed in section 6 (on the issue of rotating the EOFs), Lengaigne et al. [2006] and McGregor et al. [2013] are discussed in section 5 (on the southward shift of the equatorial Pacific wind anomalies and the termination of El Niño), and Dommenget et al. [2013] is discussed in section 7 (on the El Niño-La Niña asymmetry in spatial and time evolution).

Few minor comments:
Abstract L2: "along the equator" should be added at the end of the first sentence to emphasize that this study focuses on equatorial spatio-temporal pattern.

Reply: “along the equator” is added to the sentence.

Section 1 - L62: From Figure 1, it seems to me that the El Niño peak occurs in NDJ or OND rather than in DJF.

Reply: It appears that the El Niño peak in Figure 1 is in November - January. For Niño 3 region, the peak is in November-December. For Nino3.4, the peak is in December-January. However, since SST anomalies in Nino3.4 during DJF (0,+1) have been more widely used to represent the amplitude of ENSO, we would like to use DJF instead of NDJ.

Section 1 - L65-66: The above references should be added to the list and further discussed in the discussion section.

Reply: The suggested articles are all listed in section 1 and discussed in section 5, 6 and 7.

Section 2 - L86-87: The authors should check the consistency of their wind patterns with NCEP1 and NCEP2 reanalysis to the wind pattern involved in the ENSO diversity are robust.

Reply: We used the NCEP-NCAR reanalysis to check the consistency of the wind patterns shown in Figure 2 and 4. As shown below, the wind anomalies derived from the NCEP-NCAR reanalysis are consistent with those derived form the 20CR, although the overall amplitude of the anomalies is relatively weak in those derived from the NCEP-NCAR reanalysis. Since the NCEP2 reanalysis is available only after 1979, we could not apply that reanalysis to our study, which covers 21 El Niño events between 1949 and 2013.

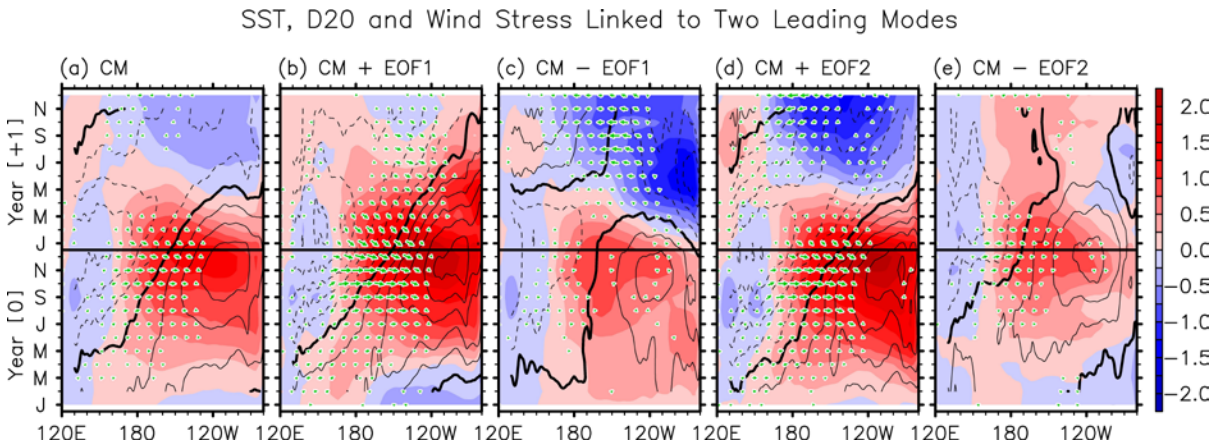

Figure R1: Same as Figure 2 except that the wind stress anomalies are derived from the NCEP-NCAR reanalysis [Kalnay et al., 1996].

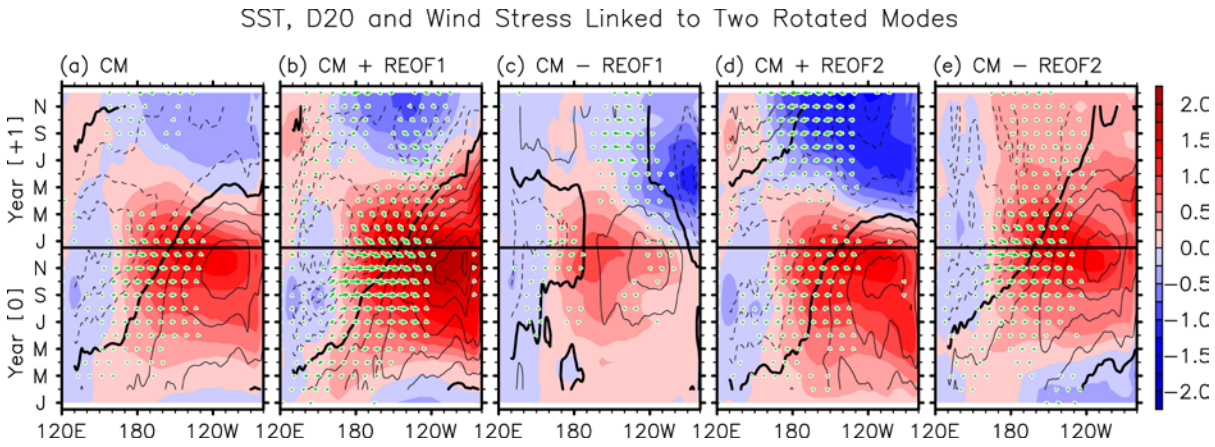

Figure R2: Same as Figure 4 except that the wind stress anomalies are derived from the NCEP-NCAR reanalysis [Kalnay et al., 1996].

Section 3 - L111-114: Mention the % of variance explained by the third EOF mode to justify the fact of not discussing it.

Reply: The third EOF explains only 9.6% of the total variance. This is now mentioned in the revised manuscript.

Takahashi, K., Montecinos, A., Goubanova, K., & Dewitte, B. (2011). ENSO regimes: Reinterpreting the canonical and Modoki El Niño. Geophysical Research Letters, 38(10).

Dommenget, D., Bayr, T., & Frauen, C. (2013). Analysis of the non-linearity in the pattern and time evolution of El Niño southern oscillation. Climate dynamics, 40(11-12), 2825-2847.

Lengaigne, M., Boulanger, J. P., Menkes, C., & Spencer, H. (2006). Influence of the seasonal

cycle on the termination of El Niño events in a coupled general circulation model. Journal of climate, 19(9), 1850-1868.

McGregor, S., Ramesh, N., Spence, P., England, M. H., McPhaden, M. J., & Santoso, A. (2013). Meridional movement of wind anomalies during ENSO events and their role in event termination. Geophysical Research Letters, 40(4), 749-754.