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Atmospheric Secular Mode and Its Possible Impact to Recent El Niño Teleconnection

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1. Atmospheric secular mode

Secular changes of the atmospheric circulation are usually illustrated with linear trend. Drawbacks of this linear approximation are obvious, for example, it can't catch decadal and inter-decadal variability. An attempt to resolve this issue is by using empirical orthogonal function (EOF) analysis. The outcome, however, is not quite promising, because the trend tends to be mixed with several other modes, among which is the ENSO teleconnection mode. The mixing of the trend with ENSO teleconnection may not be physically meaningful, since the Nino 3.4 SST index itself shows little long-term trend. Inspired by the successful separation of ENSO teleconnection mode from other modes in Peng *et al.* (2014), we developed a new method to retrieve atmospheric secular mode. The procedure is to remove ENSO teleconnection pattern linearly from the data (*e.g.* 200hPa height) first, and then apply EOF analysis to the residual. With this

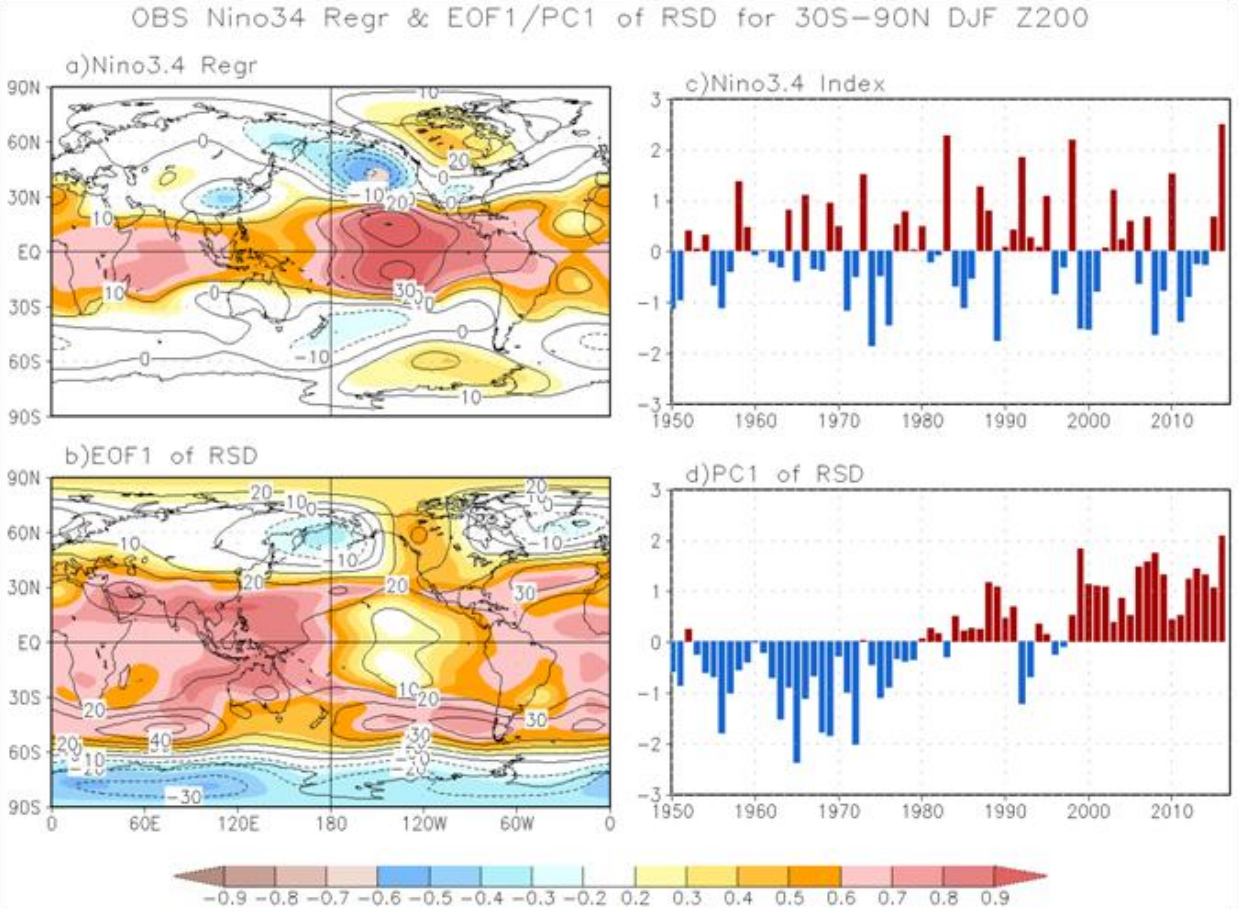

Fig. 1 ENSO teleconnection mode of DJF Z200 (upper) and the EOF1/PC1 of the DJF Z200 residual with ENSO mode linearly removed (lower). The spatial patterns are drawn with the regression (contours) and correlations (shadings) of the Z200 field to their corresponding time series (right panels).

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procedure, it is found that the first EOF mode can represent both long-term trend and inter-decadal variability. Further analysis indicates that the secular mode is related to the variation of sea surface temperatures (SSTs) in tropical Pacific warm pool and the Indian Ocean. This mode is potentially useful in climate diagnostics and short-term climate prediction.

Fig. 1 shows the ENSO teleconnection mode and the secular mode of DJF Z200. The ENSO teleconnection mode is well known, and a notable feature worth to be emphasized here is its biggest amplitude in the 2015/16 winter. For the secular mode, the spatial pattern exhibits mostly positive in the tropics, and wavy in extra-tropics. A notable feature in the northern hemisphere (NH) is a ridge centered over the west coast of North America. The time series is dominated by a warming trend, and superimposed to the trend is inter-decadal and inter-annual fluctuations. Note the magnitude of the time series at 2015/16 is the highest in the data period.

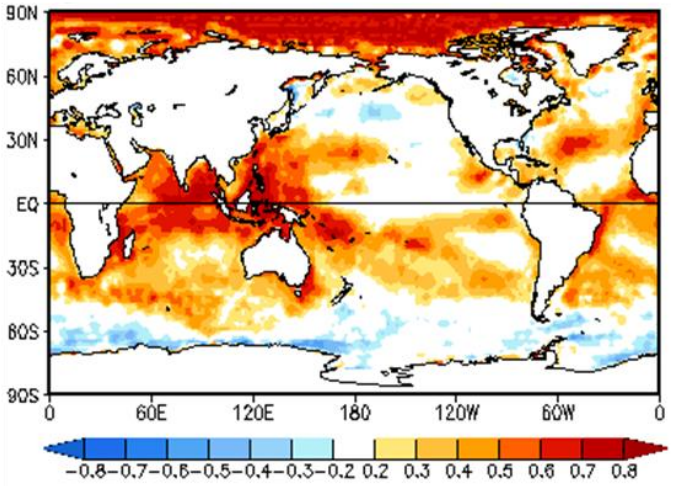

Fig. 2 Correlations of the PC1 of the DJF Z200 residual (Fig. 1a) to the DJF SSTs over 1949-2016 period.

Fig. 2 gives the correlations of SST to the time series of the secular mode. Obviously, the higher correlations are in the tropical Pacific warm pool and the Indian Ocean, suggesting the secular mode is likely forced by the air-sea interactions in those regions.

2. Possible impact on 2015/16 El Nino teleconnection

An immediate application of the secular mode is to interpret the abnormal El Nino teleconnection pattern in 2015/16 winter. It is well known that the 2015/16 El Nino is among the strongest in record, the North American climate in the winter, however, was quite different from the canonic patterns corresponding to strong El Nino. The significant different features include the precipitation deficit in southern California and

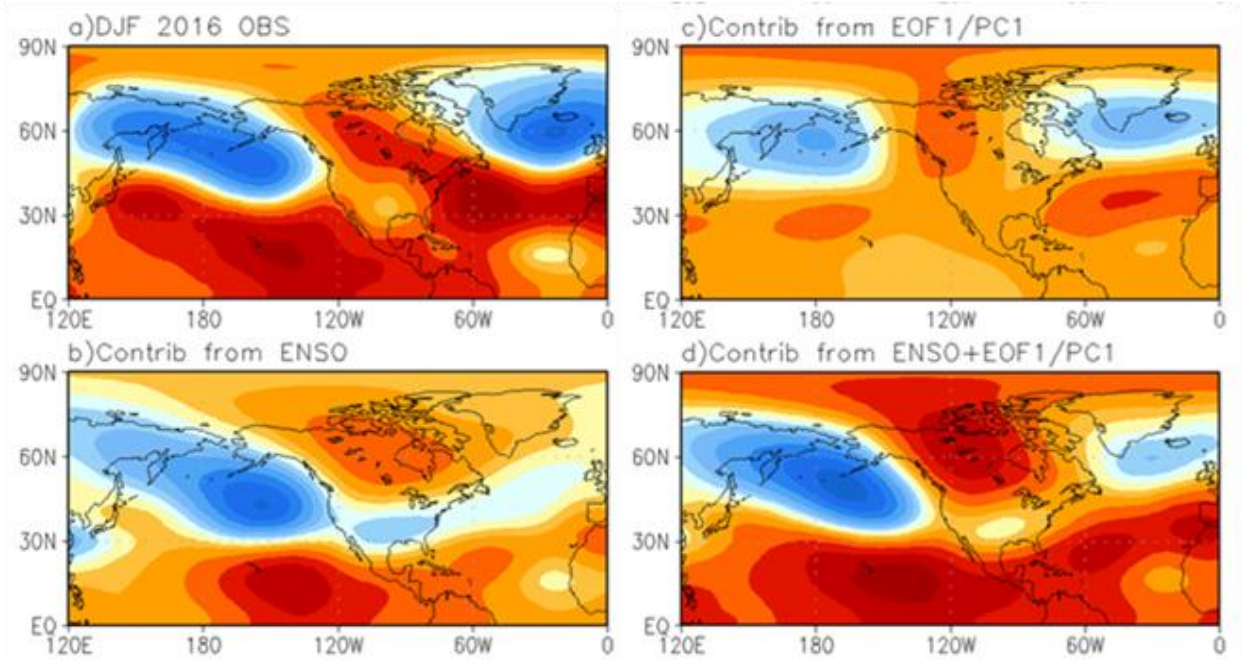

Fig. 3 DJF Z200 anomalies observed in 2015/16 (a), reconstructed with ENSO mode (b), with the secular mode (c) and with the both modes (d).

the moderate warming in the southern part of the United States, whereas in past strong El Nino winters, whole California had abundant rainfall and the southern states were mostly colder. In order to understand the unusual climate, we applied the analysis procedure describe above to the DJF 200hPa height (Z200) field since 1949. It is found that the secular mode, with its biggest amplitude ever since 1950, brought a strong ridge in the western coast of the continent, thus hindered storms to reach southern California. This mode also had contribution to the warming in the southern states for that winter.

Fig. 3 shows the Z200 anomalies observed in 2015/16 winter (panel a), and reconstructed with ENSO mode alone (panel b), with secular mode alone (panel c) and with the both modes (panel d). Panel b gives the canonic ENSO teleconnection pattern, where the low extending to west coast and southern states of US would bring excessive rainfall and lower temperature there. Panel c tells the impact of the secular mode, that is, building up a ridge over the west coast and pushing the jet northward over the ocean. As a result, the secular mode would cause less rainfall and warmer temperature in California and southern states, opposite to the ENSO effect. Panel d, being a combination of panel b and c, well resembles panel a, thus demonstrates that the secular mode is likely an important cause of the non-canonic El Nino teleconnection pattern in the winter.

References

Peng, P., A. Kumar, and B. Jha, 2014: Climate mean, variability and dominant patterns of the Northern Hemisphere wintertime mean atmospheric circulation in the NCEP CFSv2. *Clim. Dyn.*, **42**, 2783-2799.