An anomalously cold 2013-14 North American Winter: the role of the North Pacific Oscillation/West Pacific Pattern

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39th Climate Diagnostics and Prediction Workshop
October 2014

Motivation

- Winter 2013-14 (defined here as DJF) was exceptionally cold across large swaths of North America.
- The affects of extreme regional climate are well-appreciated; it is known that energy prices in winter are closely related to weather and climate extremes.
- This past winter prompted hypotheses on the cause of extreme regional winters in an otherwise warming global climate (e.g. Palmer, 2014)
  - Specifically, how the two might be related!

Motivation

- What follows here is, in part, a cautionary tale: extreme North American seasonal climate need not be directly caused by anomalous patterns of tropical convection.

- First, we ought to assess climate anomalies in the context of known patterns of variability.

Background on the NPO/WP

- The North Pacific Oscillation (NPO) is the north-south dipole in winter sea-level pressure over the North Pacific, first identified back in 1924 by Gilbert Walker.
- This is considered the Pacific basin analog of the North Atlantic Oscillation, in terms surface pressure centers of action and the latitudinal displacement of storm tracks.
- The West Pacific (WP) pattern was identified by Wallace and Gutzler (1981) from mid-tropospheric teleconnection analysis.
- These have been shown to be essentially the same variability, the NPO being the sea-level pressure reflection of the WP geopotential height pattern.

Objectives and Methods

- The objective of this analysis is quantitative attribution of the 2013-14 winter circulation anomalies over North America.
- Leading teleconnection patterns are identified by rotated EOF analysis of wintertime 200-hPa height, in which the leading eight modes are subject to varimax rotation. Monthly data for the Northern Hemisphere from 1979-2014 is used.
- The NPO/WP emerges as the third-leading pattern, explaining ~11% of the monthly variance.

Methods

- 200-hPa height, 850-hPa temperature, and precipitation are reconstructed to assess the contribution of the NPO/WP and other variability patterns to the observed anomalies.
- Multiplication of each spatial pattern with its principal component (PC) value for the target month, and summing the various EOF contributions yields the reconstructed signal.
- This is facilitated by the fact that the PCs are orthogonal.

Methods of Assessing Subseasonal Variability

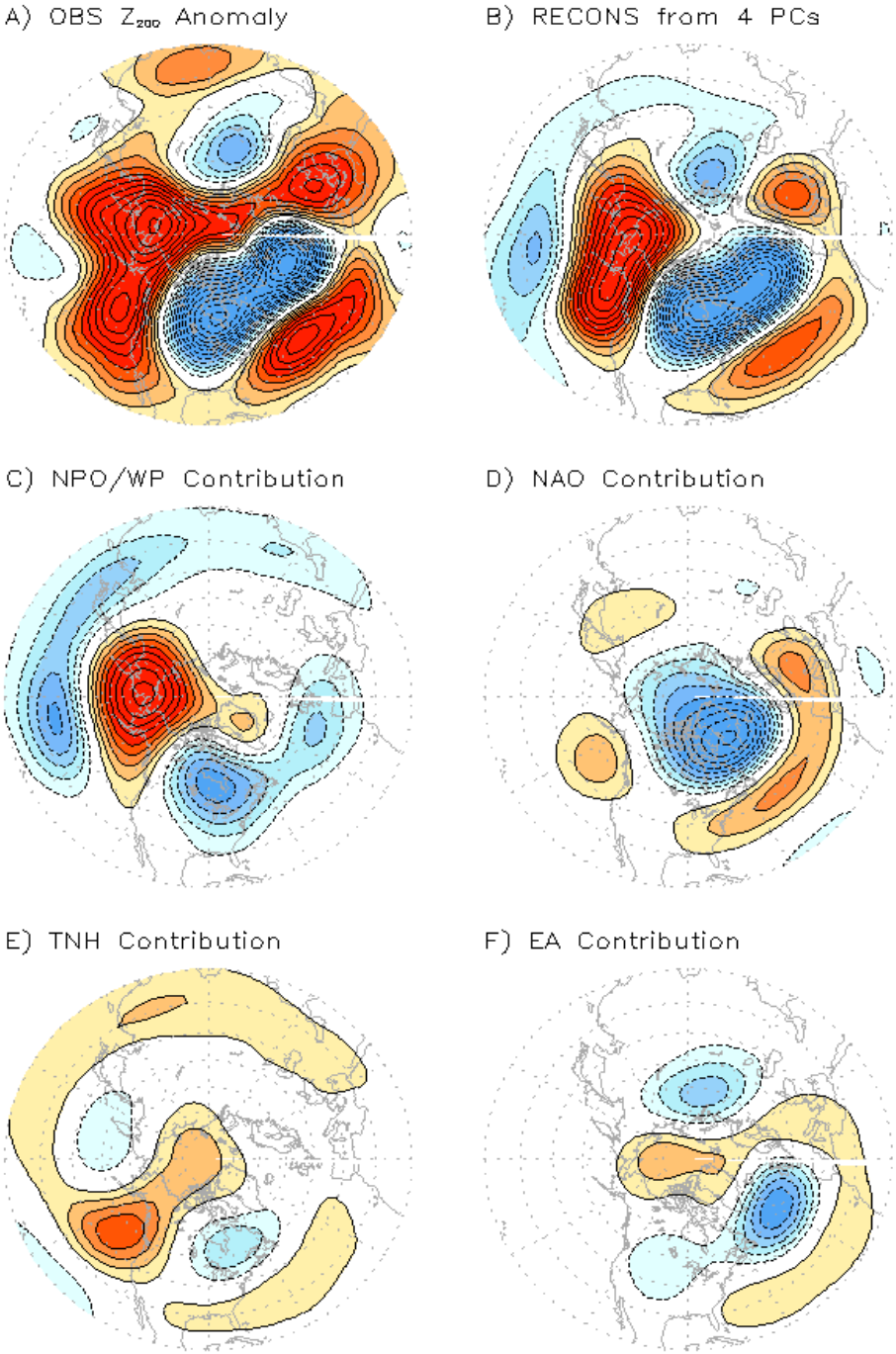
- Some attention is given to subseasonal variability in this analysis.
- Following Baxter and Nigam (2013), an extended, rotated EOF analysis is conducted on pentad data to yield subseasonal patterns of spatiotemporal variability.
- Streamfunction is the preferred variable here, since it identifies the MJO's extratropical response, precluding its aliasing onto the internal extratropical patterns.
- The 120-day running mean anomaly is removed from the data prior to analysis, to filter out interannual variability.
- The NPO/WP subseasonal pattern emerges as the fourth-leading mode of variability.

- The total observed z200 anomaly is shown in panel (A), while the reconstruction from four leading PCs is shown in (B); all are contoured at 15m intervals.

- Panels (C)-(F) show the individual contribution from the four patterns with the most anomalous PC values for the winter in question.

- Note that the NPO/WP contribution is most similar to the observed pattern over North America.

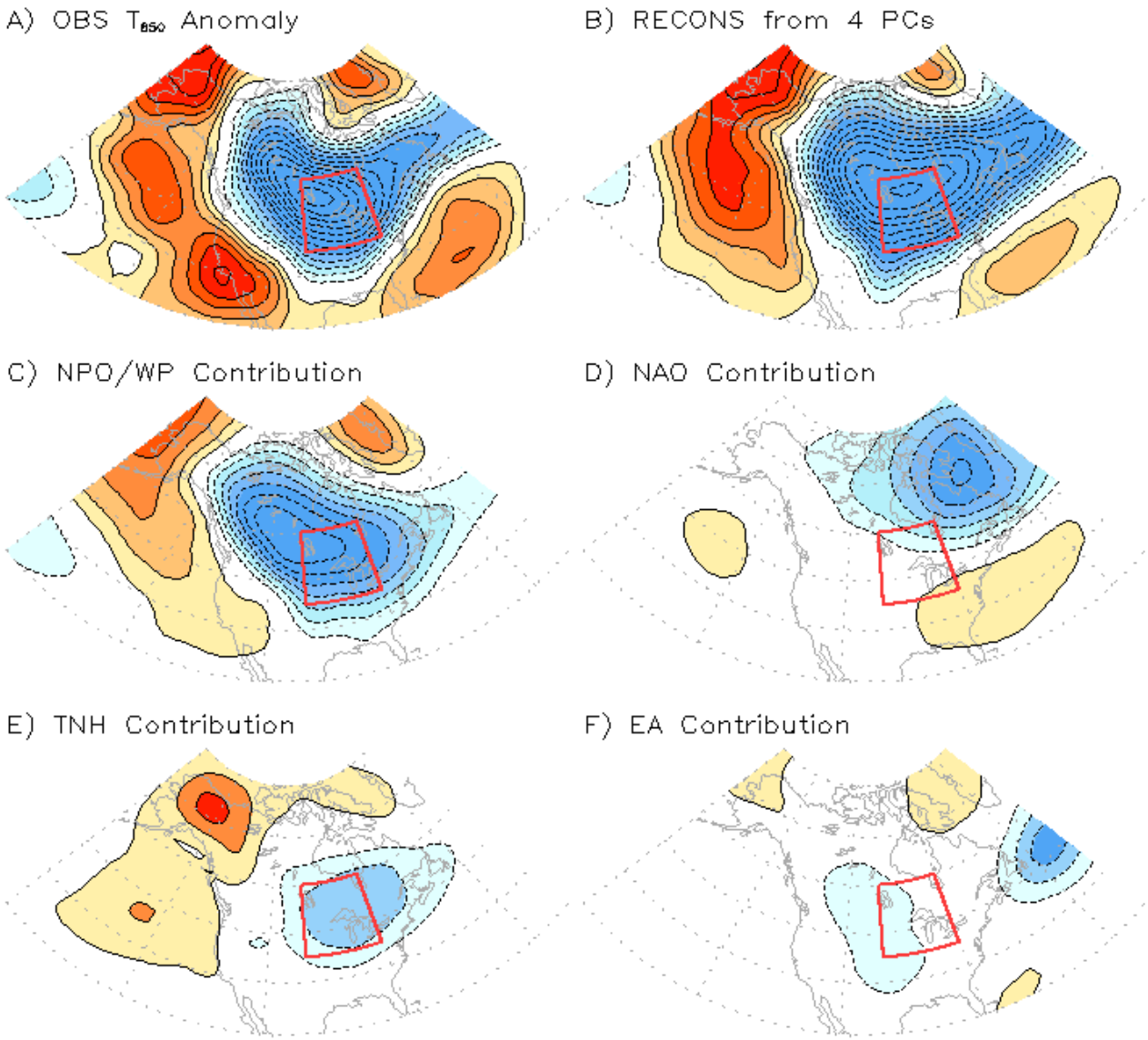
- There is a weaker contribution from the Tropical-Northern Hemisphere pattern (TNH)

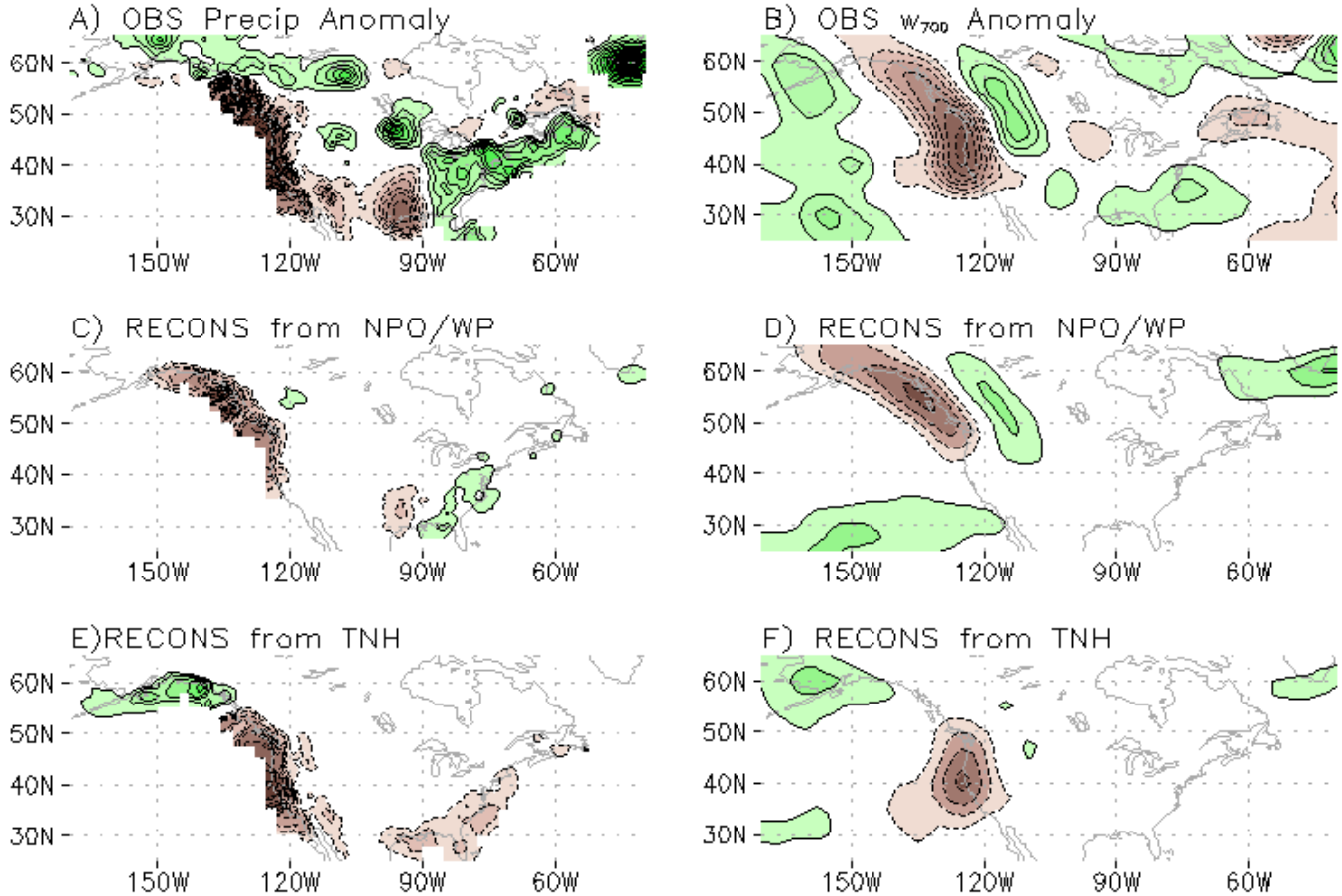


- Same format as the previous figure, except for 850-hPa temperature over North America; contour interval here is 0.5 K.

- Observed anomalies as low as -7 K are centered southwest of Hudson Bay, more than half of which can be attributed directly to the NPO/WP, followed distantly by the TNH pattern.

- The red box outlined marks a region whose area-averaged T_{850} anomalies are used in time series analysis. This was chosen due to its proximity to the core of the cold anomaly and populated areas in the east-central part of the continent.





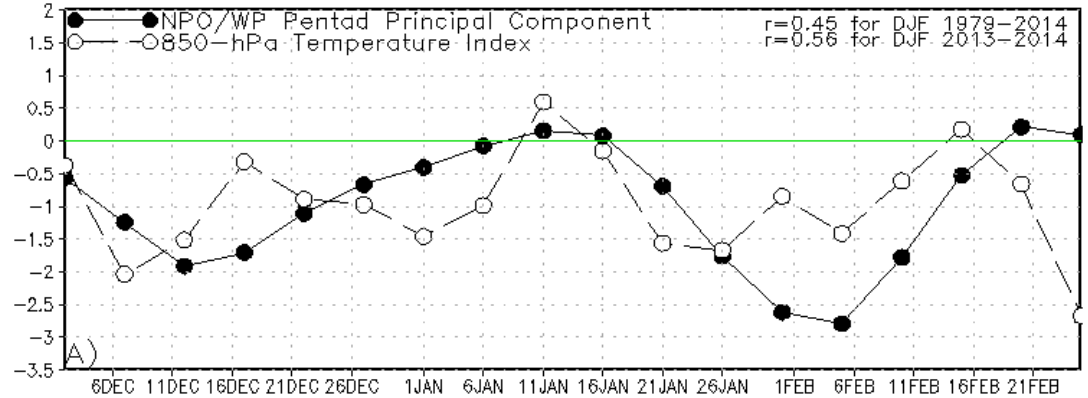
- This figure shows reconstructions of precipitation (C and E), and 700-hPa vertical velocity (D and F), at intervals of 0.25 mm/day and 1 cm/s, respectively, for the just the NPO/WP and TNH

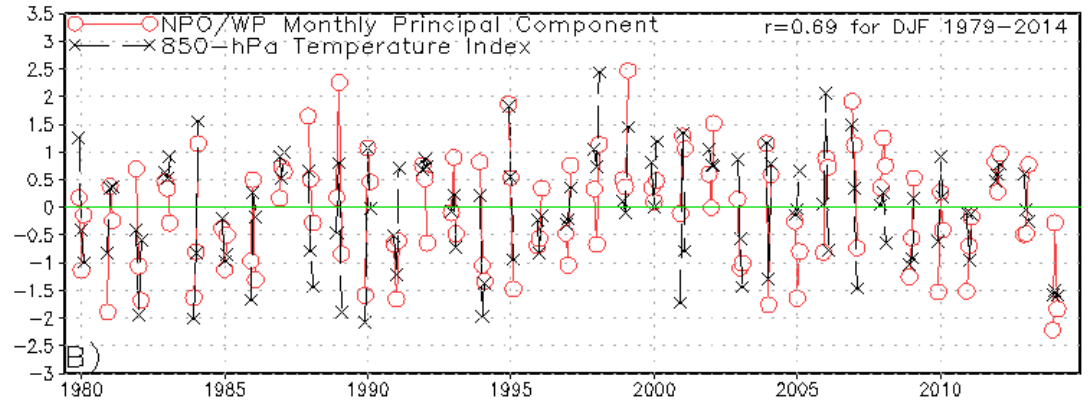
- Note the importance of the two patterns over the West Coast. The TNH seems most important for California precipitation anomalies.

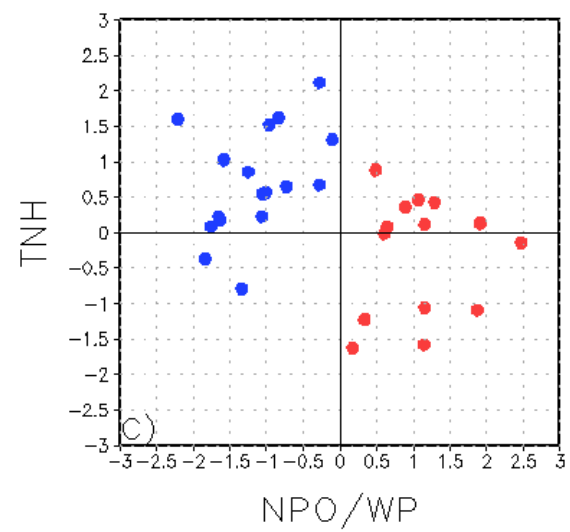
- Panel (A) shows the subseasonal variability of the NPO/WP principal component along with the T_{850} index for the box outlined in Figure 2 (40-55N, 95-80W). On pentad time scales, a correlation of 0.45 over the whole period is impressive, though the correlation was slightly higher over just the past winter (~0.56).

- Panel (B) shows the monthly time series for that shown in (A). December 2013 and February 2014 were among the lowest PC values in the analysis. Note the relationship between the NPO/WP and the temperature index during other well-known cold periods, such as Jan-Feb 1994, Dec 1989, and Dec 1983. The correlation over the entire period is 0.69.

- Panel (C) shows a scatter plot where blue (red) marks indicate a T_{850} index more than one standard deviation below (above) normal. The x- and y- axes are the normalized NPO/WP and TNH PC values.

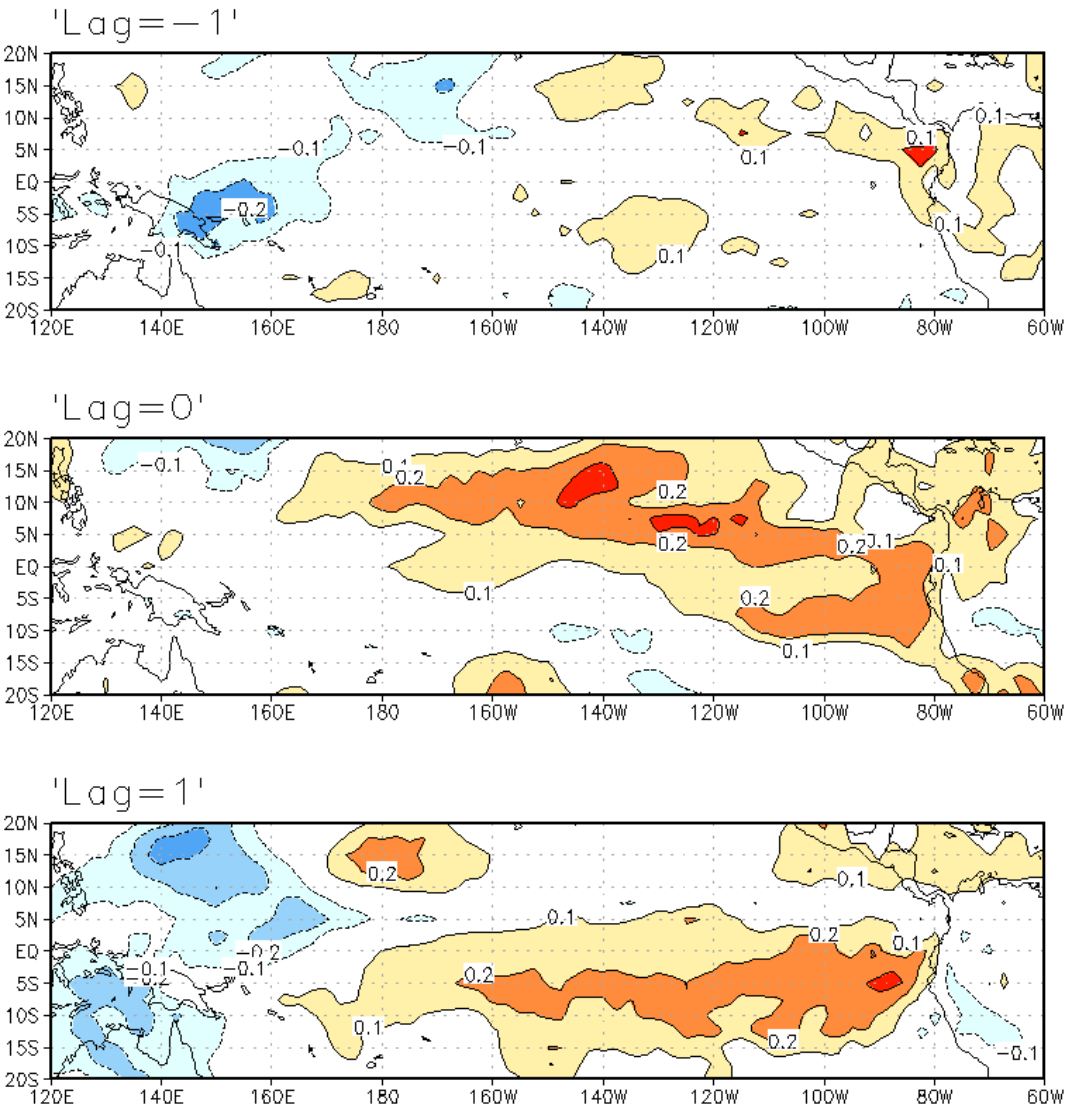




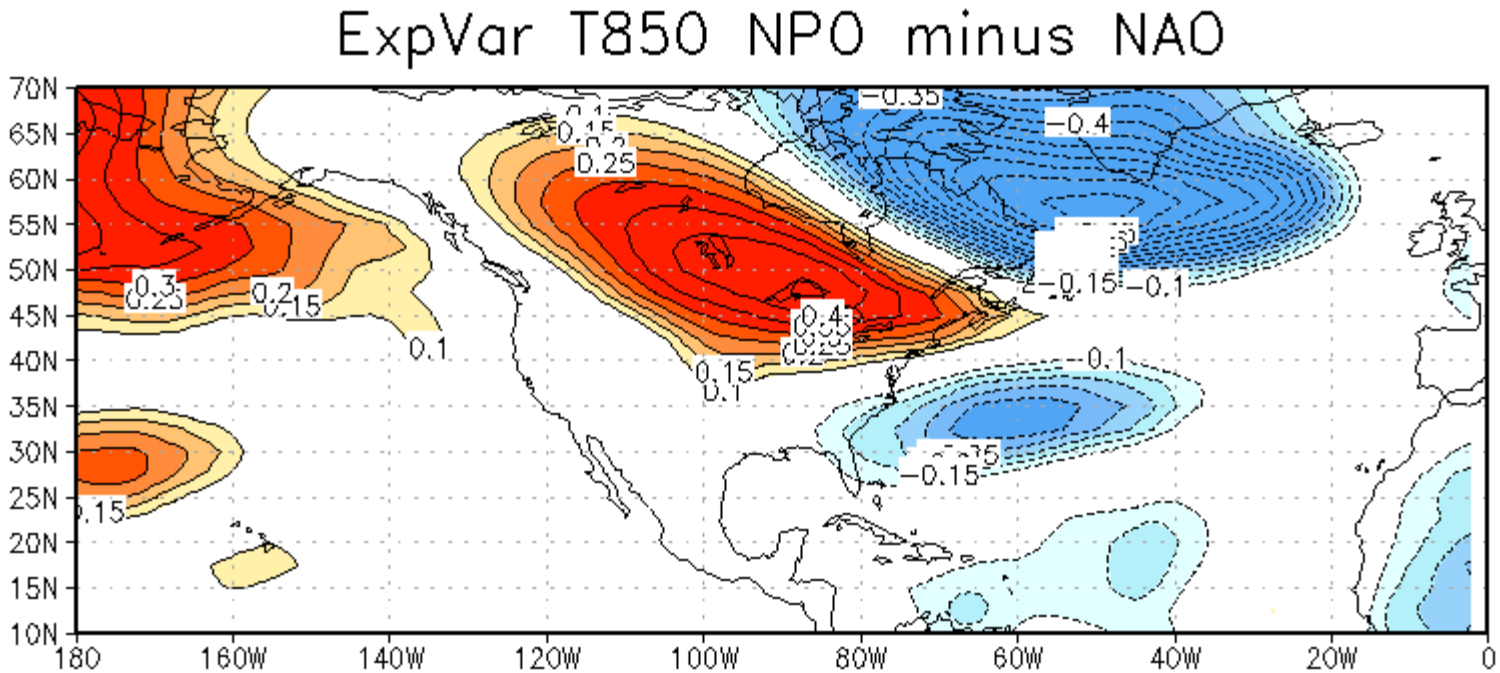


NPO/WP Related to Tropical Convection

- Here, the lead/lag correlation between the monthly NPO/WP PC and OLR anomalies are shown at 0.1 intervals.
- Negative lag corresponds to OLR leading the NPO/WP.
- Correlations are unimpressive, suggesting any link between the WP/NPO and tropical convection is tenuous at best. Correlations with velocity potential are equally unimpressive.
- In fact, one could hypothesize that extratropical wave breaking contributes to convective anomalies in the eastern and central Pacific.



NPO/WP vs. NAO Over North America



- This figure shows the difference in T_{850} explained variance between the NPO/WP and the NAO. Positive values indicate a larger role for the NPO/WP.

- The NPO/WP explains more T_{850} variance over the north-central and northeastern CONUS, while the NAO is more important over the Southeast U.S. and Europe (latter not shown).

Conclusions

- The NPO/WP was the leading pattern of variability contributing to the anomalously cold 2013–14 winter over North America, explaining more than half of the observed T_{850} anomaly.
- There is little evidence to support a causal link between anomalous tropical convection and the NPO/WP, suggesting that the Tropics cannot be implicated as the primary cause of the observed temperature anomalies.
- A concerted research effort is warranted to understand the seasonal predictability, if any, of the WP/NPO.