Wintertime North Pacific Teleconnection Patterns

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Abstract

Atmospheric low-frequency anomalies, also known as teleconnection patterns, are most energetic in the Northern Hemisphere during the winter season. These teleconnections have a far-reaching impact on weather and climate that spans the Northern Hemisphere. In this study, the teleconnections of the wintertime North Pacific are examined from the continuum perspective with self-organizing map (SOM) analysis. Using daily ERA-Interim reanalysis data for the 1979-2011 period, we found that most of the North Pacific teleconnections can be grouped into several Pacific/North America (PNA)-like, Western Pacific (WP)-like, and East Pacific (EP)-like SOM patterns. Each of the SOM patterns has an e-folding time scale of 7 to 10 days.The WP-like SOM patterns undergo a decline in their frequency from early to late winter, and vice versa for the EP-like SOM patterns, corresponding to an eastward seasonal shift of the North Pacific teleconnections. It is shown that the interannual variability of the PNA, WP, and EP can be interpreted as arising from interannual changes in the frequency of the corresponding SOM patterns. The seasonal shift and interdecadal trend of these teleconnections are found to be associated with corresponding changes in sea ice and precipitation.

Motivation

Using EOF analysis of daily 250-hPa zonal wind, Athanasiadis et al.(2010) found that the EOF1 is closely related to the Pacific/North America (PNA) pattern, the EOF2 undergoes a seasonal shift: the Western Pacific (WP) pattern during early winter (November and December; ND) and the Eastern Pacific (EP) pattern in late winter (February and March; FM), which has received very little attention before.

1. Is the seasonal shift physically realistic in the atmosphere?
2. What's the insight of the North Pacific variability to the climate?

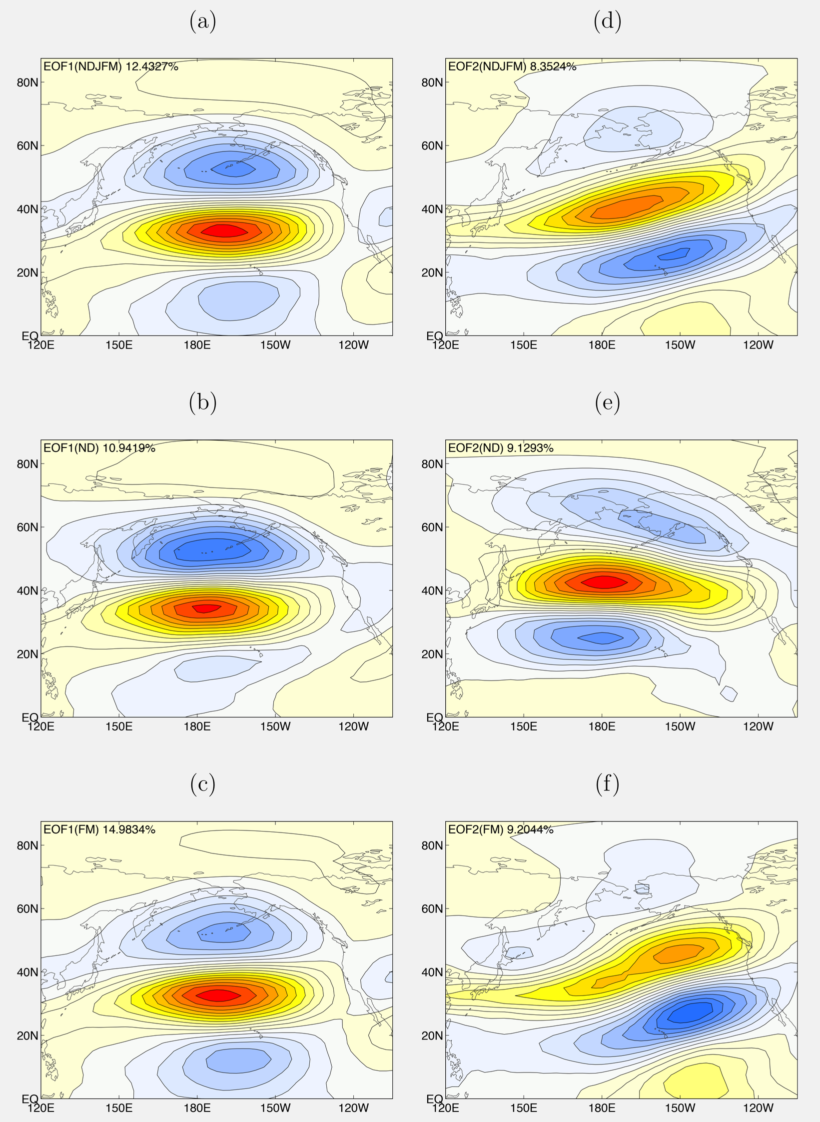

Fig. 1: (Left) EOF1 spatial pattern for (a) the entire winter (Nov - Mar), (b) early winter (ND) and (c) late winter (FM). (Right) The same as the left column except for EOF2. Warm colors denote positive values and cold colors negative values. Contour interval is 0.01.

Self-Organizing Map (SOM)

SOM analysis is a neural network algorithm, that uses an unsupervised iterative training procedure to analyze large amounts of data. We use SOM analysis to examine North Pacific teleconnections from a continuum perspective (Johnson et al. 2008). SOM analysis has two primary advantages over EOF analysis: (1) The SOM patterns more closely resemble the daily fields than do the EOF patterns; (2) Each day is associated with a particular SOM pattern, i.e. , the SOM pattern with the smallest Euclidean distance with the daily field. This enables one to assign an occurrence frequency for each SOM pattern.

Results

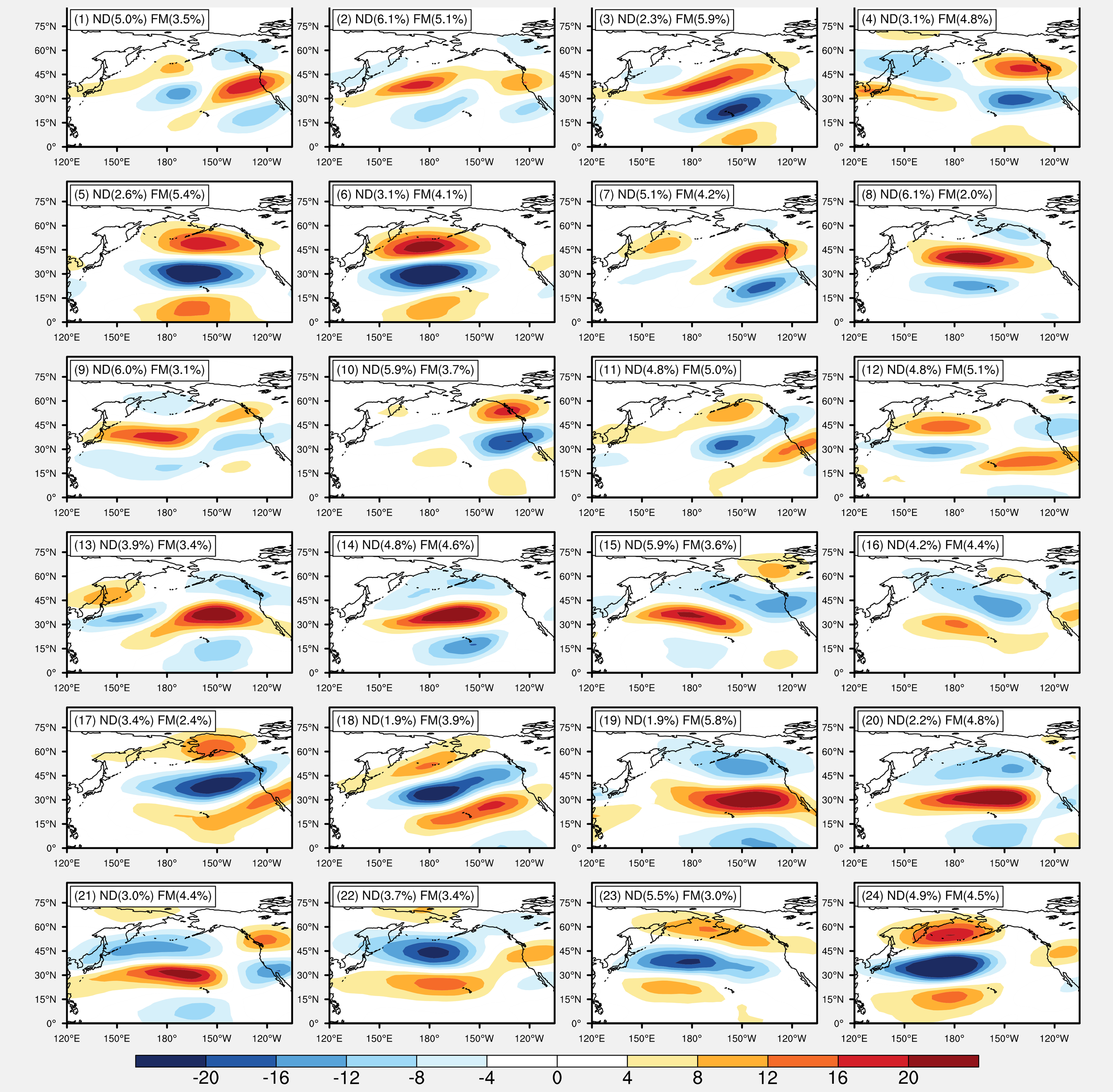

Fig. 2: SOM patterns of the anomalous 250-hPa zonal wind for NDJFM. Percentages on the top left of each map describe the occurrence frequency in early winter (ND) and late winter (FM).

In general, the WP-like patterns undergo a seasonal decline in their frequencies, while the EP-like patterns show an increase in their frequencies (Table 3). There are also seasonal changes in the PNA pattern: A stronger southern (northern) center is detected in late (early) winter.

Teleconnections	Related SOM patterns, their porlarity and frequency										Timescale
PNA	SOMs	5	6	11	14	15	19	20	21	24	10 (11)
	Polarity	-	-	-	+	+	+	+	+	-	
	Frq-ND	2.6%	3.1%	4.8%	4.8%	5.9%	1.9%	2.2%	3.0%	4.9%	
	Frq-FM	5.4%	4.1%	5.0%	4.6%	3.6%	5.8%	4.8%	4.4%	4.5%	
WP	SOMs	8	17	22	23						8 (9)
	Polarity	+	-	-	-						
	Frq-ND	6.1%	3.4%	3.7%	5.5%						
	Frq-FM	2.0%	2.4%	3.4%	3.0%						
EP	SOMs	3	4	9	18						7 (7)
	Polarity	+	+	+	-						
	Frq-ND	2.3%	3.1%	6.0%	1.9%						
	Frq-FM	5.9%	4.8%	3.1%	3.9%						

Table 1. The PNA-, WP-, and EP-like SOMs, their polarity and occurring frequency in early and late winter.The last column shows the average *e*-folding time scale for each SOM (Unit: days). Values in parentheses are the *e*-folding time scale obtained from the EOF time series.

The correlations between the seasonal mean SOM frequency and PC time series are 0.93, 0.86, and 0.78 for the PNA, WP and EP patterns, respectively. The PNA underwent a significant downward trend, WP and EP didn't show a significant trend.

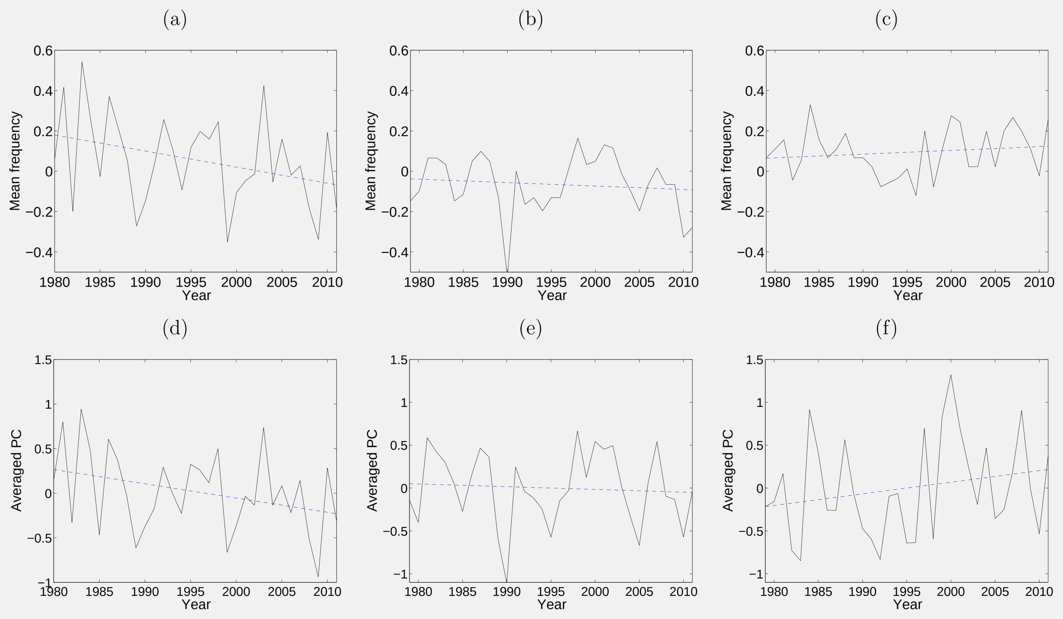

Fig. 3: Group-averaged winter-mean occurrence frequencies for the (a) PNA-like SOMs, (b) WP-like SOMs, and (c) EP-like SOMs. Principal component for the (d) winter mean EOF1-NDJFM, (e) early-winter mean EOF2-ND, (f) late-winter mean EOF2-FM.

Results

WP SOMs are mostly closely related to an increase in sea ice over the Arctic Ocean, Bering Sea, and Sea of Okhotsk and the EP SOMs to a decrease in sea ice over the Sea of Okhotsk, and Hudson Bay.PNA SOMs are weakly related to sea ice. Both wind-driven sea-ice motion and freezing and/or melting of sea ice due to horizontal temperature advection contribute in part to these sea ice changes.

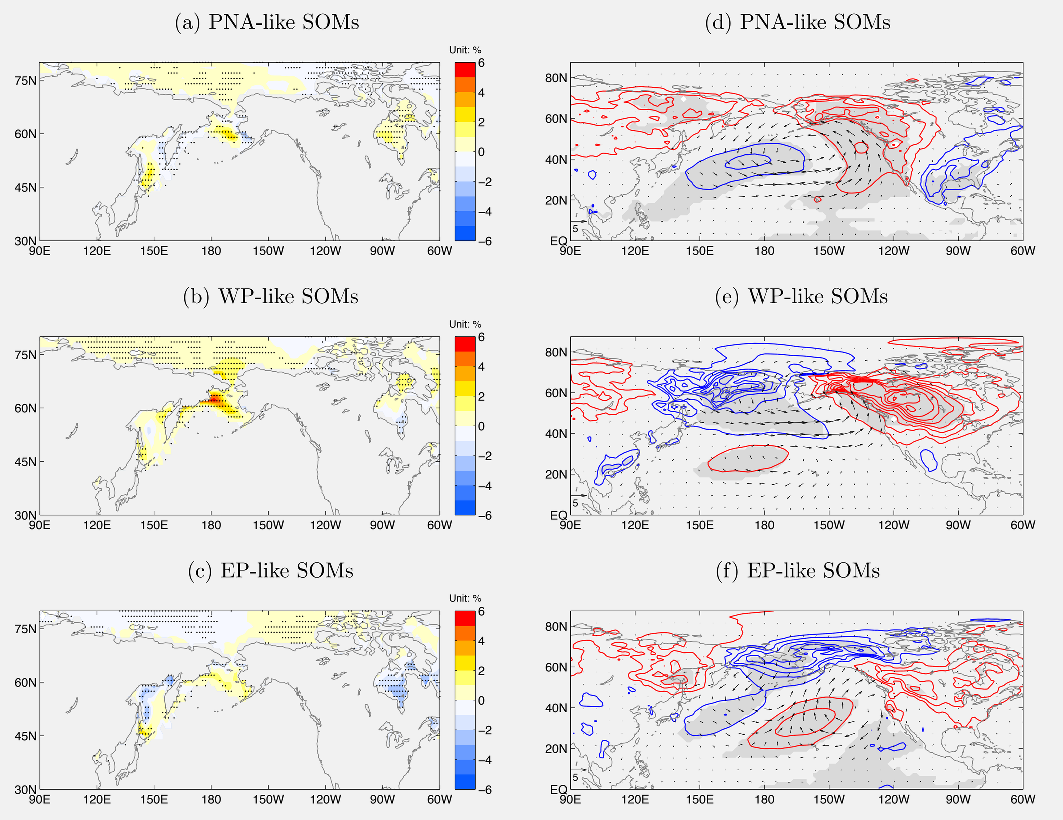

Fig. 4: (Left) Group-composite anomalous sea-ice cover based on PNA-like(top), WP-like (middle), and EP-like (bottom) SOMs.(Right) As left column except for the 10-meter wind vector (arrows) and 2-meter temperature (contours).

The PNA is related to zonal precipitation shifts over northeastern Pacific. The seasonal shift from WP-like to EP-like patterns during the winter may account for a northeastward seasonal shift in North Pacific precipitation and a northward seasonal shift along the west coast of North America.

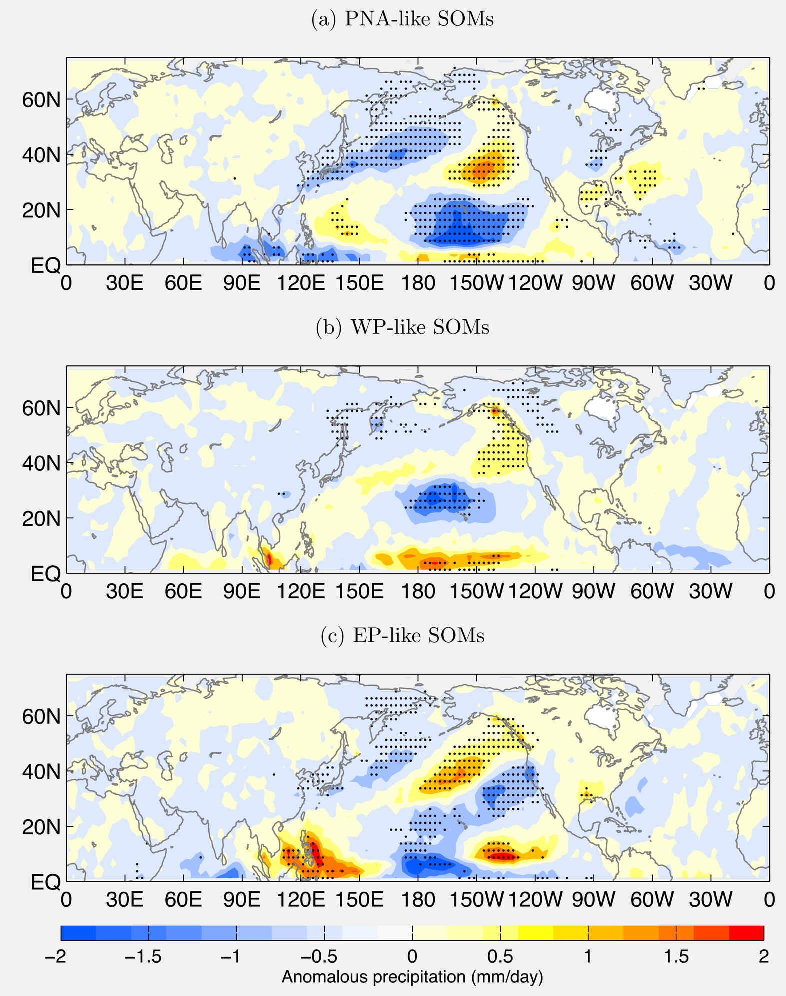

Fig. 5: Group-composite anomalous precipitation based on (a) PNA-like SOMs; (b) WP-like SOMs; (c) EP-like SOMs.

Conclusion

In conclusion, using SOM analysis, we have examined the dominant North Pacific teleconnection patterns from the continuum perspective. This has enabled us to more accurately determine the spatial structure of the teleconnection patterns than with previous methods, and has helped us to learn new features of the seasonal variation of the teleconnection patterns.Furthermore, because our findings show that interannual variability of the dominant North Pacific teleconnections can be interpreted as arising from the interannual variability in the frequency of the corresponding SOM patterns, a SOM approach may also shed light onto the processes that drive climate variability.

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