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# The Influence of Teleconnections on Synoptic-Scale Circulation Patterns Affecting Western Canadian Water Resources

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## 1. Introduction

Large-scale atmospheric circulation is linked to surface climate variables, such as temperature and precipitation. Indices of El Niño-Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Pacific North American (PNA) pattern have also been shown to influence surface climate (*i.e.* Beltaos and Prowse 2009; Shabbar *et al.* 2011). Although knowledge about atmosphere-surface links and teleconnection-surface links exist, less is known about how teleconnections influence characteristics of atmospheric circulation.

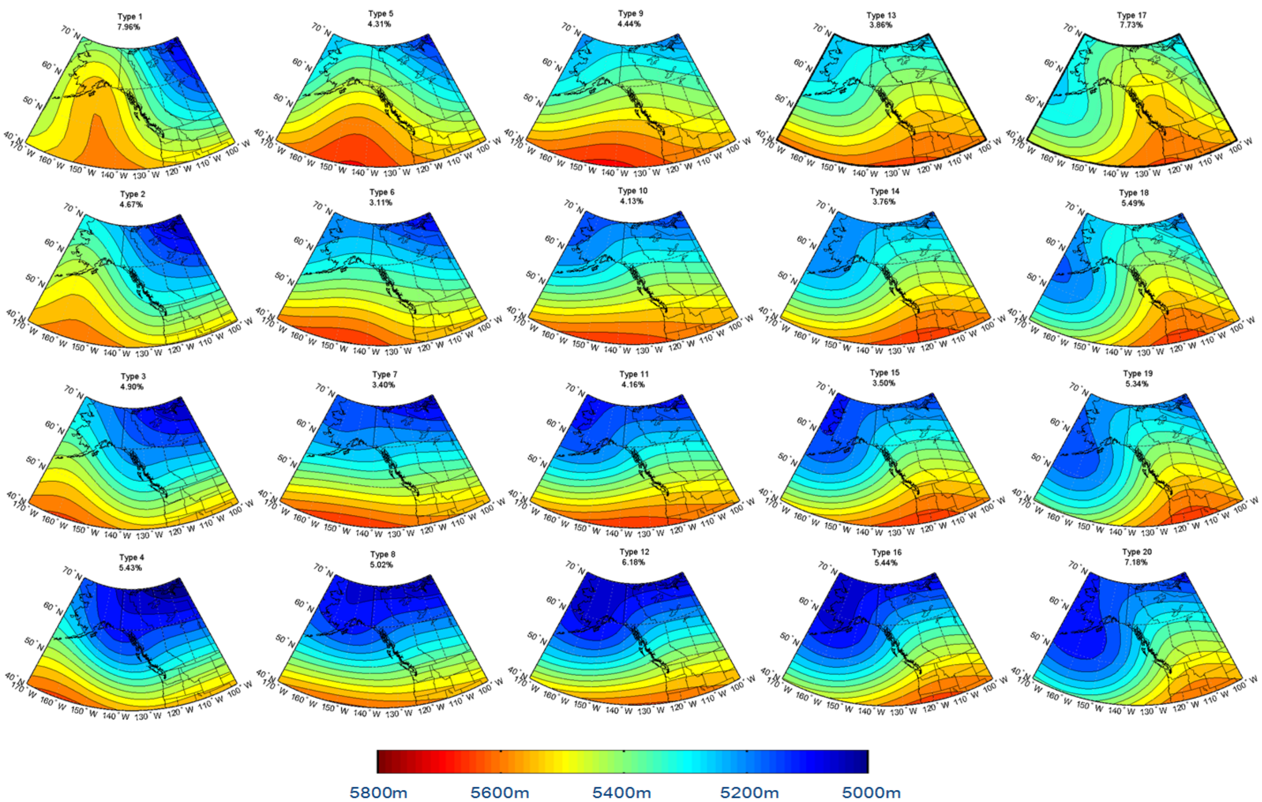


**Fig. 1** Synoptic classification using SOM. Daily patterns of 500 hPa gph for 1949-2011 snow accumulation season (Nov-Apr). The array of synoptic maps is used to assess surface climate variables across the entire study region.

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Winter snow accumulation supplies an important water storage component that is released during spring freshet and provides the largest contribution to annual streamflow on rivers originating on the leeward slopes of the Rocky Mountains. The Liard, Peace, and Athabasca Rivers are tributaries to the north-flowing Mackenzie River. The largest source of freshwater to the Arctic Ocean is river discharge, and most of the flow on the Mackenzie River originates well outside the arctic (Serreze *et al.* 2003). Magnitude of snowpack and timing of snowmelt has implications for river ice dynamics (Beltaos and Prowse 2009), Arctic sea ice formation (Lammers *et al.* 2001), and feedbacks to the global climate (Lewis *et al.* 2000). The east-flowing North Saskatchewan, Red Deer, Bow, and Oldman Rivers are tributaries to the Saskatchewan River. Water demand is highest during summer months as these rivers are heavily allocated for agricultural, municipal, and industrial use, as well as used for hydroelectricity generation. This region is subject to routine droughts and pluvials affecting seasonal water availability (Shabbar *et al.* 2011). Understanding flow on the Mackenzie and Saskatchewan Rivers requires knowledge of the headwater source region, specifically snow regimes of the Rocky Mountains and links to the controlling atmospheric conditions, including synoptic climatology. This research represents a brief synopsis of a larger study evaluating the atmospheric drivers of water availability on rivers originating on the leeward slopes of the Rocky Mountains in Canada, and will contribute to our understanding of the climatic redistribution of western Canadian water resources.

| | | | | |
|---|---|---|---|---|
| 71.6 | 40.5 | 44.7 | 37.9 | 70.2 |
| 39.7 | 22.1 | 30.4 | 28.0 | 45.5 |
| 36.8 | 22.8 | 26.2 | 24.7 | 42.2 |
| 56.7 | 40.0 | 45.7 | 45.0 | 66.7 |

**Fig. 2** Synoptic pattern persistence.

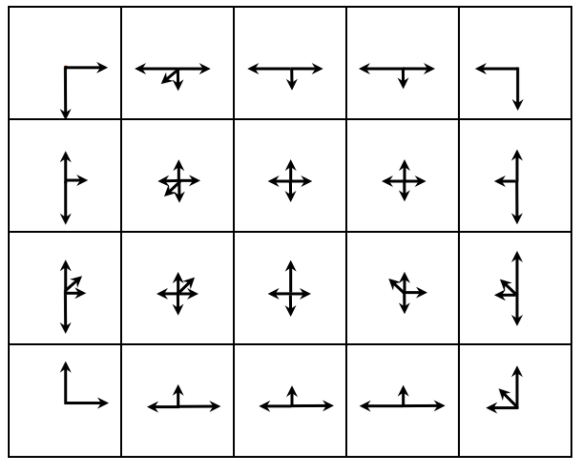

**Fig. 3** Synoptic pattern trajectory.

| | | | | |
|---|---|---|---|---|
| -0.69 | -0.42 | -0.01 | 0.24 | 0.57 |
| -0.84 | -0.33 | 0.05 | 0.39 | 0.75 |
| -0.78 | -0.24 | 0.20 | 0.49 | 0.76 |
| -0.76 | -0.18 | 0.21 | 0.55 | 0.77 |

**Fig. 4** Average PNA value corresponding to each synoptic type.

## 2. Data and methodology

To assess the characteristics of dominant synoptic circulation patterns as they relate to the spatial and temporal distribution of water availability, daily mid-tropospheric circulation patterns at 500 hPa geopotential height (gph) for 1949-2011 snow accumulation seasons (Nov-Apr) were classified using self-organizing maps (SOM), an iterative training process that uses competitive and cooperative learning to cluster and project data onto an organized output array (Kohonen 2001). This research used the batch algorithm SOM as it was determined to be faster and less subjective than the sequential algorithm (Kohonen 1999; Liu and Weisberg 2005; Jiang *et al.* 2011). Daily values of PNA, and monthly values of the Southern Oscillation Index (SOI) (representing ENSO), and PDO were used to calculate a 3-month (DJF) mean. The mean value was used to classify winters into positive or negative SOI, PDO, and PNA to evaluate changes in frequency.

## 3. Results

Daily synoptic circulation patterns were classified into 20 types (Figure 1). Persistence (Figure 2) represents the percentage of occurrences where the pattern is followed by the same pattern the following day. Trajectory (Figure 3) represents the preferential pattern shifts, which occurs primarily around the outer edge of the SOM array.

The average PNA value associated with each synoptic pattern was calculated (Figure 4), and indicates a clear pattern of strongly negative PNA in the far left column and strongly positive PNA in the far right column, a function of the organizational qualities of the SOM. Patterns 1-4 in the far left column of the SOM array were also determined to occur with a greater frequency during negative phases of PDO and positive phases of SOI, and patterns 17-20 in the far right column were found to occur with a greater frequency during positive phases of PDO and negative phases of SOI (Figure 5). Frequency differences for PDO, SOI, and PNA were assessed individually, with similar results. The strongest frequency relationships were found when isolating seasons that fit the criteria of coupled teleconnection phases, such as positive PDO, negative SOI, and positive PNA.

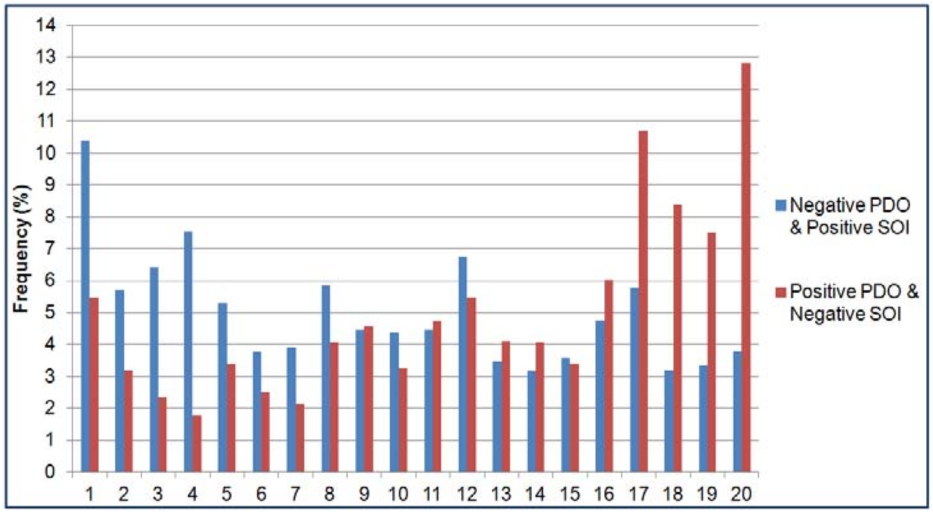


**Fig. 5** Frequency (%) of occurrence for each synoptic type during negative PDO coupled with positive SOI, and positive PDO coupled with negative SOI.

Synoptic types 1-4 are associated with higher precipitation and lower temperatures throughout the study region. A ridge of high pressure centred over the Pacific Ocean results in the advection of cold arctic air south across the Rocky Mountains. Synoptic types 17-20 are associated with lower precipitation and higher temperatures. These patterns are characteristic of high pressure over the continent and a strong Aleutian Low in the North Pacific Ocean.

## 4. Discussion and future work

Numerous studies have described the influence of teleconnections on surface climate; few have addressed the impacts of teleconnections on synoptic-scale circulation. Synoptic types 1-4 and 17-20 were determined to experience the greatest influence from teleconnection phases, as well as exerting the greatest influence on surface climate variables. During negative phases of PDO, positive phases of SOI, and negative phases of PNA, mid-tropospheric circulation is expected to favour high pressure ridging over the Pacific Ocean and result in higher precipitation and lower temperatures. During positive phases of PDO, negative phases of SOI and positive phases of PNA, mid-tropospheric circulation is expected to favour high pressure over the continent and a strong Aleutian Low over the North Pacific Ocean. These patterns of mid-tropospheric circulation result in lower precipitation and higher temperatures on the leeward slopes of the Rocky Mountains.

Future work includes statistical time series trend analysis of synoptic type frequency to determine significant increases or decreases over time. Further work to evaluate the spatial distribution of association with surface climate across the study area will be completed using a gridded dataset of daily values of precipitation and temperature at 10km resolution.

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