# RECENT DEVELOPMENTS IN TELECONNECTION INDICES AND THEIR APPLICATION IN LONG-RANGE FORECASTING

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## 1. INTRODUCTION

The use of teleconnection indices in long-range weather forecasting has garnered an enormous amount of attention over the last ten years or so, largely in response to improved understanding of ENSO-related processes. Indeed, teleconnection indices based on oceanographic and atmospheric aspects of ENSO have a very high profile in the long-range forecasting literature, as well as the products produced by agencies involved with the forecasting process, including the Canadian Institute for Climate Studies (CICS) and the Climate Prediction Centre (CPC). Of course, there is good reason for so much attention to be directed towards ENSO, for it is associated with much of the observed climate variability, including that of the midlatitudes. In describing their ENSO-based prediction methodology, CICS (2001) notes that about 30 to 40% of midlatitude seasonal climate variability can be predicted, and that the remaining variability is due to "other not-well-researched forcing phenomenon and a remaining large part is due to the chaotic nature of the atmosphere". We here report our preliminary investigation of the potential of two of the aforementioned not-well-researched forcing phenomona to be utilized in long-range forecasting schemes. In particular, we calculate correlations of the Arctic Oscillation (AO) and Pacific Decadal Oscillation (PDO) indices with seasonal temperature and precipitation conditions at select Canadian prairie climate stations. These two teleconnections were selected because they have, rather quickly over the last few years, obtained a substantial amount of attention in the climatological literature, not to mention the media. We provide only very general introductions to the nature of these oscillations, but provide references for the interested reader.

## 2. ARCTIC OSCILLATION

The Arctic Oscillation (AO) arrived on the teleconnection scene only within the last two years, or so, when Thompson and Wallace (e.g., 1998, 2000) and Thompson *et al.* (2000) used the term to describe the leading Empirical Orthogonal Function of winter SLP anomalies poleward of 20°N. Interestingly, these authors suggest that the AO is essentially identical to the more familiar North Atlantic Oscillation (NAO), or, perhaps more correctly, that the NAO is simply a regional component of the larger-scale, hemispheric AO. In any case, the claims of Thompson and Wallace and their followers are somewhat controversial, and are being evaluated and re-evaluated by many others (see Kerr, 1999; Deser, 2000).

The AO essentially describes how atmospheric pressure rises and falls in a seesaw fashion, causing winds to oscillate in strength. The positive phase of the AO occurs when Arctic pressure is lower than normal and there is an accompanying rise in pressure around 55°N. The positive phase of the AO tends to be associated with a stronger polar vortex, and strengthened northerly winds; also, storm systems that develop over the oceans take a more northerly course than normal. In addition, the positive phase is linked to increased precipitation over Northern Europe and Alaska and decreased precipitation in Spain and California. Eurasia is warmer than normal due to strong winds moving the moderating influence of oceans onto the continents. In North America, conditions tend to be colder than normal in eastern Canada, and warmer than normal in the central region.

The negative phase of the AO occurs when Arctic pressure is higher than normal and pressure in the mid-latitudes is lower than normal. Opposite conditions to those described above are produced by the negative phase of the AO.

## 3. PACIFIC DECADAL OSCILLATION

The PDO is an El Niño-like teleconnection pattern, based on anomalous sea-surface temperature conditions in the Pacific. The term “Pacific Decadal Oscillation” was coined by Hare in 1996, in association with his research into connections between Alaska salmon production cycles and Pacific climate (Mantua *et al.* 1997). As indicated by its name, the PDO is much more persistent than ENSO. Mantua *et al.* (1997) found that major climatic regime shifts occurred in the North Pacific in 1925, 1947, and 1977. These interdecadal shifts were found to be linked to significant changes in sea-surface temperatures (SSTs), air temperature, pressure, and the biota throughout the Northern Hemisphere. The authors also noted that ENSO and the PDO were clearly related to one another both spatially and temporally, although this is still a matter of some debate.

The positive (warm) phase of the PDO is characterized by cooler than normal SSTs in the North Pacific, and warmer than normal SSTs in the central and eastern tropical Pacific, and along the west coast of North America. In the negative (cool) phase, the North Pacific is warmer than normal, and the central and eastern tropical Pacific, and coastal waters of western North America, are anomalously cool.

During the winter, the warm phase of the PDO is associated with warmer than normal temperatures over Alaska and western Canada, and cooler than normal temperatures over the southeastern United States. The warm phase is also associated with above normal precipitation along the west coast, in northern Mexico, and in south Florida, but precipitation is below normal over much of the interior of North America.

During the summer, the warm phase of the PDO is associated with above normal temperatures along the west coast of North America and in south Florida; the central part of North America experiences below normal temperatures. Above normal precipitation occurs over most of the interior of North America.

The cold phase produces conditions opposite to those described for the warm phase.

## 4. METHODS

Twelve stations with long, relatively continuous records were selected for analysis (Figure 1). Major cities were excluded to minimize any urban bias in the climate record. Daily precipitation totals and daily maximum and minimum temperatures were extracted for 1900-1999, and aggregated to produce monthly and seasonal precipitation totals and average maximum, minimum, and mean temperatures. The monthly and seasonal AO and PDO teleconnection indices for the same period were also aggregated into monthly and seasonal averages. The AO data were obtained from Thompson (2001); the PDO data were obtained from Franzin (2001)

The influence of the AO and PDO on the climate of the prairies was evaluated with a series of stepwise multiple regression models. Specifically, the teleconnection indices were used as predictors of winter (Dec-Jan-Feb), spring (Mar-Apr-May), summer (Jun-Jul-Aug), and fall (Sep-Oct-Nov) temperature (maximum, minimum and mean) and total precipitation. A model was generated for each of the four climate variables for each of the four seasons, resulting in a total of 16 models for each station. Both simultaneous and lagged variables for the PDO and AO were entered as candidate regressors into the model. For example, for any given season the candidate regressor variables included the monthly values for the current season, an aggregate variable representing the whole season, and monthly and seasonal values for up to one year prior to the season in question. Using standard procedure as a guide, the variable selection criteria used in the construction of the stepwise models were as follows: probability of $F \leq 0.05$ for entry, and probability of $F \geq 0.1$ for removal.

## 5. RESULTS

Summaries of the model results are presented in Figures 2, 3, and 4. The correlation, r, between the AO and PDO indices and temperature (maximum, minimum, and mean) during the winter (DJF) averaged 0.5 for all 12 stations. There is little variation in the magnitude of the correlation between the 12 stations. Two teleconnection indices were used in each of the three temperature models: the February PDO and the Dec-Jan-Feb AO.

In spring (MAM) the correlation between the AO and PDO variables and temperature averages 0.4. PDO indices were used most often in the models; the February PDO was selected as statistically significant by the stepwise procedures for 25% of the stations. The May AO was selected for approximately 20% of the station models.

The average correlation between temperature and the AO and PDO during the summer (JJA) is only 0.35. At four stations no variables were found to meet the selection criteria; the average correlation only includes those for which a model was produced.

In the fall (SON) the average correlation between temperature and the AO and PDO is only 0.31, but this is based on models from only three of the stations. More than 62% of the variables selected for the fall models were PDO values.

Thus, it appears clear that the AO and PDO have much stronger and more consistent patterns of correlation with temperature in the Canadian prairies during winter. The strength and spatial coherence of these relationships decreases through spring and summer, and is at a minimum in fall.

The average correlation between the AO and PDO and winter precipitation is 0.38. However, there is a substantial amount of variability in the strength of the relationship between the 12 stations. The maximum correlation is 0.68 for Birtle, Manitoba, and the minimum is 0.23 for Prince Albert, Saskatchewan. PDO indices were selected for model inclusion most frequently; at least one of the January PDO, the February PDO, or the DJF PDO was selected for every station.

The average correlation for spring precipitation is 0.25; only five of the 12 stations produced models. PDO indices were again the most selected variables.

For the summer, the correlation between the teleconnection indices and precipitation is 0.29; models were produced for only seven stations. The most frequently selected variables were associated with the AO.

The average correlation for fall precipitation models is 0.30. Neither the PDO nor the AO were favored as model variables for fall precipitation.

## 6. CONCLUSION

The purpose of this study was to explore, in a very cursory fashion, the ability of the AO and PDO teleconnection indices to 'explain' variation in seasonal temperature and precipitation conditions in the southern Canadian prairires. More accurately, the study investigated whether or not the AO and PDO are correlated with these seasonal weather variations. With the assistance of a series of stepwise multiple regressions, the AO and the PDO have both been shown to be somewhat correlated with seasonal temperature and precipitation variations at the 12 stations selected for analysis. The correlations are strongest in the winter, for both temperature and precipitation. The correlations with temperature decrease throughout the spring and summer, reaching a minimum in fall. The correlations with precipitation are generally weaker than those with temperature, and weakest in spring.

In all seasons but the summer, PDO indices were selected by the stepwise regression procedure more often than the AO indices. That is, the AO appears to be a better predictor of variations in temperature and precipitation during the summer. In any case, the AO and PDO are both important modes of low frequency climate variability on the Canadian prairies, during all seasons. Consequently, these two teleconnections should be considered for inclusion in stochastic seasonal forecasting models for the Canadian prairies. Of course, the development of these models should involve more rigorous analyses of the correlations than those presented here. In particular, the development of the models must include a process of validation, and regional variations of the correlations should be assessed. Indeed, it is suspected that there are important variations in the teleconnection-climate relationships across the prairies.

## 7. REFERENCES

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FIGURE 1. Location of selected climate stations

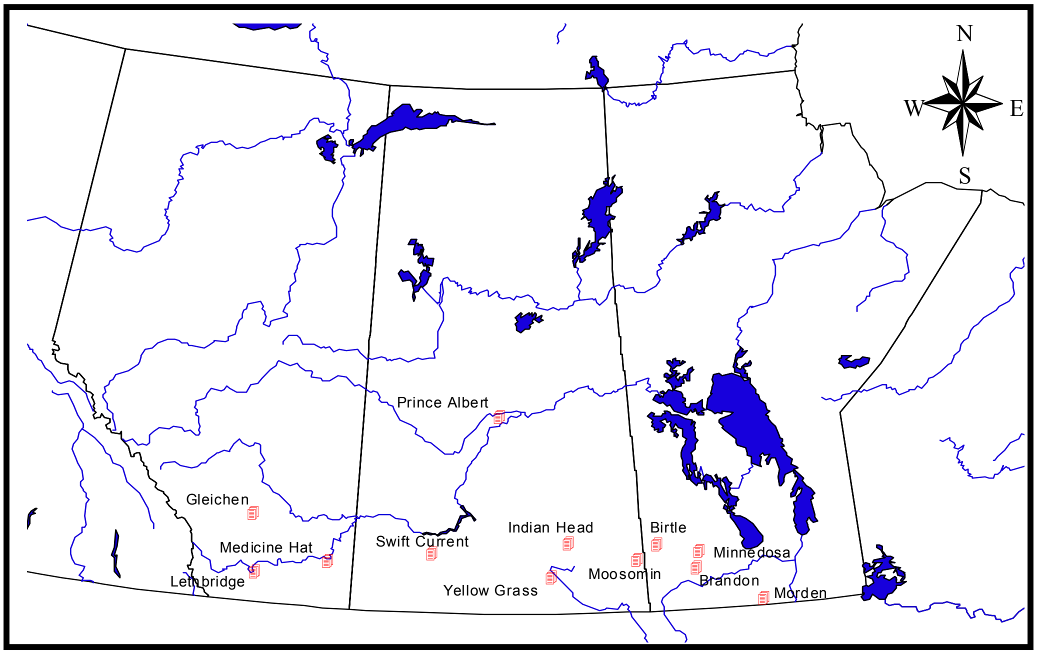

FIGURE 2. Evolution of Mean Correlations between AO and PDO Teleconnections and Seasonal Climate

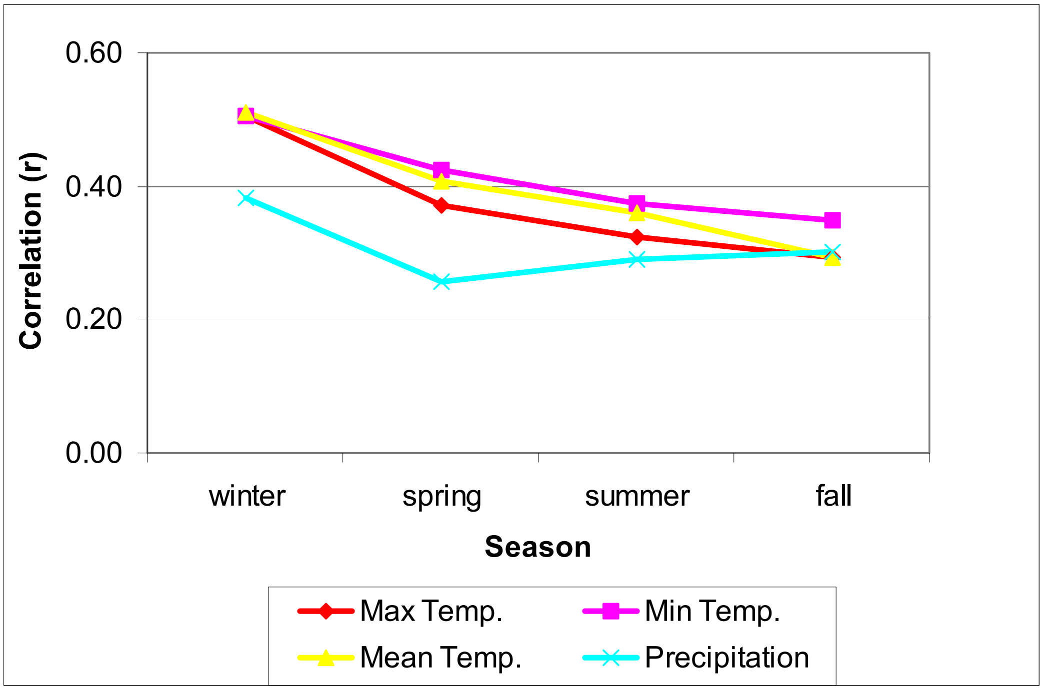

FIGURE 3. Seasonal Evolution of Variable Selection: PDO and AO vs. Temperature

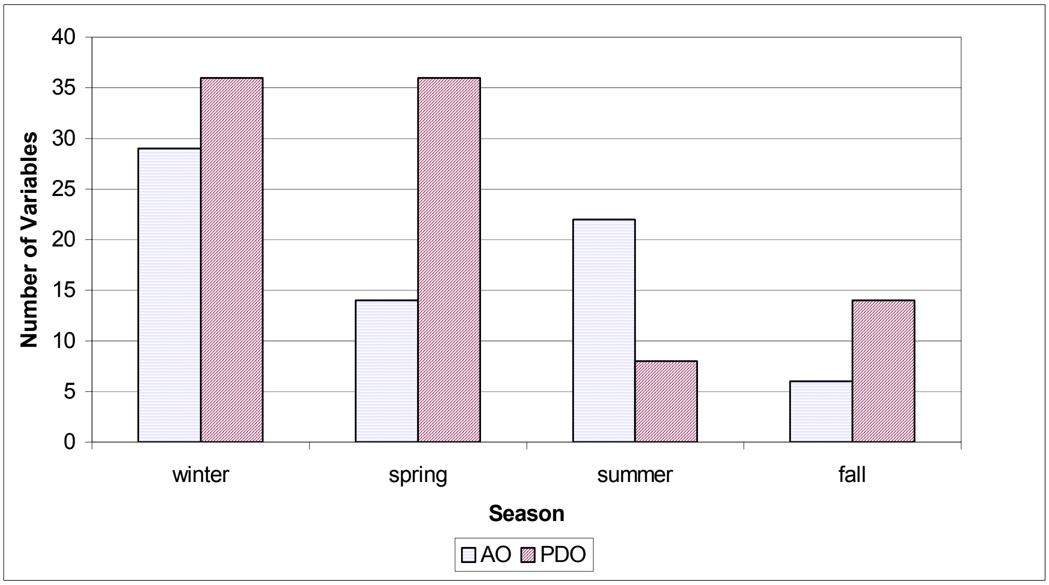

FIGURE 4. Seasonal Evolution of Variable Selection: PDO and AO vs. Precipitation