SOUTHERN HEMISPHERE TELECONNECTION PATTERNS AND THEIR RELATION TO AUSTRALIAN HYDROCLIMATIC VARIATION: POTENTIAL PRECIPITATION AND STREAMFLOW LONG-RANGE FORECASTING.

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Abstract

An exploratory analysis of the relationship between Southern Hemisphere's (SH) atmospheric/oceanic variables and streamflow and precipitation variation in Australia is presented. A 2.5^{o}x2.5^{o} gridded data of 700mb geopotential heights (Z_{700}) for the SH, obtained from the US National Center for Environmental Prediction and the National Center for Atmospheric Research, (NCEP-NCAR reanalysis), were used to characterize the atmosphere. A rotated principal component analysis of the data identified the principal modes of variability. The trends observed in the Annular and Tropical Influence modes from 1948 to 2000 suggest increased pressures in mid-latitudes and lower pressures in the tropics. The causes behind these trends are unknown and require more research. It is expected that our study will show significant links between circulation and oceanic patterns and hydroclimatic variation in Australia. The final objective of this ongoing study is to provide a basis for long-range precipitation and streamflow forecasts throughout Australia.

Key Words: Australia, Geopotential Height, circulation, streamflow, precipitation, PCA, forecast

Introduction

The objective of this exploratory analysis is to relate geopotential heights teleconnection patterns obtained from rotated principal components analysis (RPCA) and hydroclimatic variation in Australia. This exploratory analysis is part of an ongoing effort to improve the skill of long-range streamflow and precipitation forecasting in Australia using remote atmosphere-oceanic climatic information from global and hemispheric circulation patterns and their relation to El Niño-Southern Oscillation (ENSO).

Previous studies of teleconnections in the southern hemisphere (SH) used point correlation analysis to determine interconnection between far-away regions (Mo and White, 1985; Kousky and Bell, 1992). Recently, data transformations based on eigen analysis such as RPCA have been more frequently used to determine teleconnection patterns (Kidson, 1991; 1999; Barnston and Livezey, 1987; Thompson and Wallace, 2000a; 2000b, Mechoso et al., 1991). Barnston and Livezey (1987) discuss the differences between both types of analysis. We decided to use RPCA, because this type of analysis produces orthogonal principal components, a useful characteristic for their use in statistical and probabilistic prediction models.

The relationship between these teleconnection patterns and surface climatological variables has been well documented (Kutzback, 1967; Kidson, 1997; 1999; Sinclair et al., 1997). For the SH in particular, Kidson (1997; 1999) presented studies relating synoptic patterns in New Zealand and their relation to weather regimes and surface variables.

Monthly geopotential height data used in this study were obtained from the US National Center for Environmental Prediction and the National Center for Atmospheric Research, (NCEP-NCAR Reanalysis) from 1948 to 2000. It is known that some locations of the SH observation stations used to compose the gridded data set were incorrectly entered in the data set (Kidson, 1999). A preliminary assessment by NCAR/NCEP suggested that the error only affects the results of the reanalysis south of about 40-60S, and there it only doubles the intrinsic uncertainty of the analysis, and that the differences decrease rapidly as the timescale increases from synoptic to

monthly and the spatial scale increases (Kidson, 1999). The Second NCEP/NCAR Reanalysis data will provide data from 1979 to the present. However, it is highly improbable that the Second Reanalysis will contain data from 1948 to 1978 (NCEP/NCAR Second Reanalysis webmaster, personal communication). For our purposes, the largest data set at monthly time-scales will be used because it provides the largest range of variability available. Future work will compare the PCA results from both data sets.

It is expected that the results obtained here will be an improvement on our previous hydroclimatology research for Australia (Piechota and Dracup, 1996; 1999; Piechota et al., 1998; 2001; Chiew et al., 1998).

Methods

The 700mb geopotential data from the NCEP/NCAR reanalysis were re-scaled by the square-root of cosine of latitude (Thompson and Wallace 2000a) to assign equal weight to equal areas. Monthly principal components were computed from a rotated principal component analysis (RPCA), based on the covariance matrix of the 1948-2000 monthly geopotential height data. Varimax rotation (Richman, 1986) was applied to the eigen-vectors. We regressed the resulted principal components with the original raw data to display the loadings as heterogeneous correlation maps. Other levels (e.g. 300mb, 500mb and 850mb) were also computed for comparison purposes. Additionally, versions of the components for each month (Barnston and Livezey, 1987) were obtained from individual RPCA.

Results

The heterogeneous correlation maps between the first six monthly PCs and the original NCEP-NCAR data are shown on Figure 1. The domain of the analysis is the entire SH. The entire hemisphere data was analyzed, expecting that the tropical influence would be kept in an independent component orthogonal to the rest of the components. As it can be seen from Figure 1, the tropical influence on the data is indeed contained in the sixth component.

The Annular Mode is slightly different than the version by Thompson and Wallace (2000a; 2000b) who used unrotated PCA. The unrotated Annular Mode by Thompson and Wallace (2000a; 2000b) has characteristics similar to our first and second modes. By rotating the components the

patterns are separated into individual components making them more regionalized. A discussion of the advantage of rotating PCs can be found in Richman (1986) and O'Lenic and Livezey (1988). Also, the first rotated PC of seasonal stream-functions computed from 300mb NCEP/NCAR data by Kidson (1999) resembles our Annular Mode. However, our dominant mode is not the Annular Mode, but the Antarctic Oscillation. Analyses at other levels (Table 1) show that the Antarctic Oscillation is really the dominant mode of geopotential height variations at levels equal or below 500mb.
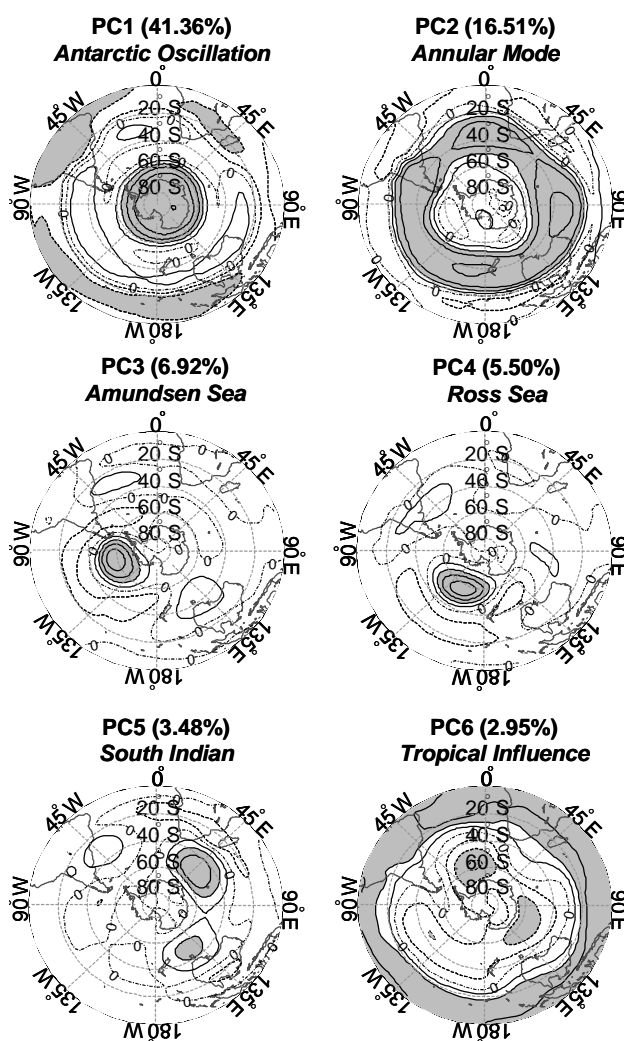

Figure 1. Heterogeneous correlation maps between monthly 700mb geopotential heights gridded data and the PC scores from the first six rotated principal components extracted from the raw data from 1948 to 2000. Contours every 0.2, negative contours are dashed, zero contour is labeled. Shading was used for correlations having absolute magnitudes higher or equal to 0.4.

A RPCA by Mo (2000) in the SH using seasonal mean 500mb geopotential heights extracted from the NCEP/NCAR data from 1949 to 1998 compares well with some of our monthly analysis. In general Mo's first mode pattern resembles a combination of our first two modes; Mo's second mode is comparable with our Admunsen Sea mode; and Mo's third mode is similar to our Ross Sea mode.

Table 1. Variance explained by rotated principal component analyses on NCEP-NCAR geopotential height data at different levels. AO: Antarctic Oscillation; AM: Annular Mode; AS: Admunsen Sea; RS: Ross Sea; SI: South Indian; and TI: Tropical Influence.

	Pressure level (mb)			
	300	**500**	**700**	**850**
AO	8.86	56.52	41.36	29.68
AM	70.47	13.69	16.51	17.93
AS	0.98	1.75	6.92	3.32
RS	2.49	4.85	5.5	3.79
SI	0.87	1.07	3.48	1.77
TI	3.09	3.88	2.95	0.99

Versions of the components for all months (Barnston and Livezey, 1987) were calculated from separate analysis taking each month one at a time (not shown here). A new component, which was a combination of the Annular Mode and the Antarctic Oscillation, resulted from this individual analysis (Table 2). Thus, the differentiation between these two modes is only seen in the monthly components.
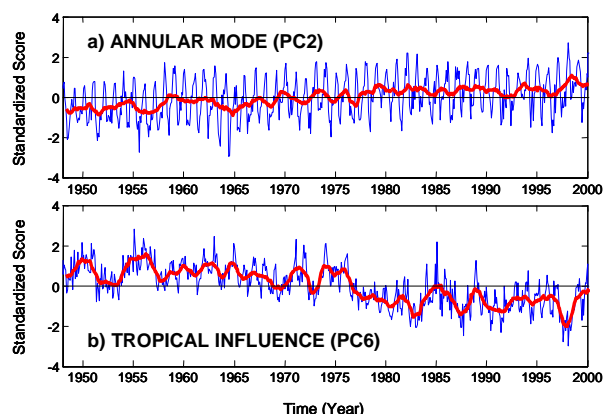

Figure 2. Standardized scores of the first (Annular Mode) and sixth (Tropical Influence) rotated monthly principal components representing 700mb geopotential height variation in the southern hemisphere. The thicker line represents the 24-months running average of the data.

An interesting feature that was observed from the components is the upward trend in the Annular

Mode coupled with a strong downward trend in the Tropical Influence mode, suggesting increased transport from the tropics to mid-latitudes (Figure 2).

Although these trends may be related to similar observations in the increase of global cloud cover (Norris, 1999), the lower confidence on the NCEP-NCAR data makes it difficult to estimate the certainty of these results (Thompson and Wallace, 2000b). Surface and meteorological data may provide more insights about these trends and their origin.

Table 2. RPCA position of the versions of the monthly components at each month. The first position corresponds to the highest variance captured by a separate RPCA using the data from each month separately. AO: Antarctic Oscillation; AM: Annular Mode; AS: Admunsen Sea; RS: Ross Sea; SI: South Indian; and TI: Tropical Influence.

	RPCA mode					
	AO	**AM**	**AS**	**RS**	**SI**	**TI**
Jan	1		3	3	9	2
Feb	1		9	2	7	3
Mar	1		3	2	10	4
Apr	1		3	2	9	4
May	1	*Combined with Antarctic Oscillation*	2	3	6	4
Jun	2		4	1	5	6
Jul	1		4	2	10	5
Aug	1		6	3	9	5
Sep	1		5	2	10	3
Oct	1		2	2	10	5
Nov	1		3	3	10	5
Dec	1		2	3	5	4

Discussion and Future Work

This study represent the first phase in the evaluation of using geopotential height data for the prediction of hydrometeorological variations in Australia. The results showed that extensive regions around the SH are teleconnected with climatic variations of remote regions.

The study also showed that the Antarctic Oscillation may play an important role of climatic variation on the SH. At levels below 500mb the Antarctic Oscillation is the main mode of variability of the geopotential height data from NCEP-NCAR, being more important than the Annular Mode.

The trends observed in the Annular and Tropical Influence modes suggest increased pressures in mid-latitudes and lower pressure in the tropics.

The causes behind these trends are unknown and require more research.

Future work will verify these results with the Second Reanalysis data, will use oceanic information, and relate the results from this study to hydroclimatic variables in Australia. The changes in circulation patterns associated with ENSO will also be investigated. The final results from this research will be the improvement on the skill of long-range hydrologic forecasting models in Australia using atmospheric/oceanic variables.

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