DIGITAL CIRCUMPOLAR VORTEX AREA INDEX CALCULATIONS FOR THE NORTHERN AND SOUTHERN HEMISPHERES

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Abstract

By calculating the area encompassed from the pole to the 5640-m contour at the 500-mb constant pressure level, the temporal ebb and flow of the cool air pool can be observed. Mean monthly, by year, circumpolar vortex area indexes have been calculated for the Northern and Southern Hemispheres and are presented for the period 1948-2002. Recent digital advances have enabled these calculations to be automated and to provide greater precision than past analytical and manual measurements. While a discernible contractual (warming) pattern is evident in the Northern Hemisphere beginning late in the 1960s, the pattern of contraction (warming) is observable in the Southern Hemisphere from 1948 through the present.

1. Introduction

The circumpolar vortex can be defined as a persistent cold, low-pressure center around which the midlatitude westerly winds circulate. If considered a representation of the pole (singularity) to equator temperature gradient, the vortex area increases in size into the winter season and correspondingly decreases in size in the summer.

The area of the cool air pool at defined upper levels of the atmosphere has been studied for decades. Using planimeter and manual methods of measurement, Angell and Korshover (1977a, b; 1978a, b) conducted pioneering work at the 300-mb level in the 1970s. The change in circumpolar vortex area served as a proxy for the change in mean hemispheric tropospheric temperature. Peterlin (1981) calculated 500-mb circumpolar area index values by summing 36 meridian lengths at 10-degree intervals from the pole to the 5640-m contour on the NOAA/National Weather Service (NWS), National Meteorological Center (NMC; now part of the National Centers for Environmental Prediction (NCEP)), 500-mb constant pressure, hemispheric analysis chart in weekly increments, and suggested use of the circumpolar vortex area index as a tool for forecasting surface temperature. Peterlin et al. (1987) suggested gross regional implications could be inferred and a series of mean charts over the climatological year were presented as decadal normals.

Working with different best representative geopotential heights, Frauenfeld and Davis (2000) suggested the circumpolar vortex area might offer some information about climate change, that is, warming or cooling over time. But, the correlation analysis they performed on the entire Northern Hemisphere (NH) 500-mb circumpolar vortex did not produce any relationships, lending support to their notion that vortex responses to El Niño/Southern Oscillation (ENSO) are regional. This study selects a single geopotential height for all periods and for both hemispheres.

The purpose of this paper is to present the first results of an automated circumpolar vortex area index computed over the 1948-2002 period for both the Southern and Northern Hemisphere, to briefly discuss observable trends, and acknowledge additional research potential. While this paper considers only the 500-mb constant pressure level, additional pressure levels are available for more complex consideration and will be presented in the future, for both hemispheres.

2. Data Sources and Methods

Datasets used in this study are from the NOAA/NWS National Centers for Environmental Prediction and National Center for Atmospheric Research (NCEP-NCAR) reanalysis project. The reanalysis includes spatial gridding of the original irregularly spaced dataset into a global grid with a 2.5-degree spacing in both latitude and longitude. Details of the reanalysis project are described in Kalnay et al. (1996). A nearly complete set of the historical grids is available via the NOAA-CIRES Climate Diagnostics Center (CDC) Web site (www.cdc.noaa.gov).

The daily averaged geopotential height grids were downloaded for all available pressure levels for each year, 1948-2002, the period of record for this study. The geopotential height grid data for a user chosen pressure level and date are contoured onto a polar stereographic view of the Northern or Southern Hemisphere. An arbitrary date

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Table 1. Comparison of selected 30-year normals of monthly mean index values for the Northern Hemisphere.

	1950-1979	1960-1989	1970-1999	1980-2002
Jan	156.04	154.76	153.38	150.01
Apr	126.89	126.30	125.38	124.92
Jul	51.46	50.60	48.23	45.32
Oct	99.87	99.51	98.69	98.14

Table 2. Comparison of selected 30-year normals of monthly mean index values for the Southern Hemisphere.

	1950-1979	1960-1989	1970-1999	1980-2002
Jan	114.60	113.78	112.34	111.28
Apr	122.36	120.34	118.82	117.36
Jul	153.78	152.86	150.18	150.79
Oct	141.34	140.01	139.37	139.09

range and time step can be specified by the user. The 5640-m contour at the 500-mb constant pressure level was selected as the target contour, the geographical boundary for which the circumpolar vortex index was calculated. The 5640-m contour was selected after trial and error based on measurability about the vortex during the summer season when the vortex shrinks considerably.

Making use of the NCEP-NCAR reanalysis project dataset and modern computer processing, the calculation of the circumpolar vortex index was computed via a series of 144 adjacent spherical triangles superimposed on the hemispheric plot. One vortex of all triangles meets at the pole, each forming an angle 2.5 degrees wide at this vertex. Two sides of each triangle extend on longitude lines from this pole vertex to the remaining two vertices which both lie on the target contour line. The third side of each triangle is formed by a very short segment of the target contour itself. When all 144 triangles are in place, the exact and total area enclosed by the target contour is completed; the area of each triangle is computed in units of spherical degrees. The derivation of this method is described in detail by Miller (1994). The summed area of all 144 triangles is our circumpolar vortex index. Since each hemisphere has a total area of 360 spherical degrees, the ratio of our circumpolar vortex index to 360 yields the fraction of the hemisphere under the influence of the circumpolar vortex.

There is some room for inaccuracy in computation should an isoline fold or regress across longitudinal lines of a cutoff low or be embedded on the equator side of the isoheight (contour) selected to define the vortex area. We have purposely tried to minimize this potential for inaccuracy.

The circumpolar vortex area can be computed daily, weekly, monthly, seasonally and annually. This study deals exclusively with 500-mb monthly index values calculated on day 15 of each month (1948-2002). The circumpolar area index on the 15th serves as a representative sample for each month, which can be studied and compared to all months in the 55-year series. Monthly mean values were computed. A larger area represents more significant cooling; a smaller area represents warming. As the Northern Hemisphere area expands, the Southern Hemisphere area contracts. The range of expansion/contraction in the Southern Hemisphere is approximately one half that of the Northern Hemisphere.

Climatological normals can be defined in several ways. Thirty-year averages (1950-1979, 1960-1989, 1970-1999, and a partial 1980-2002) of index values were calculated for "normal" comparison. Table 1 reflects the pattern in the Northern Hemisphere, contraction in July and expansion in January. Each succeeding 30-year mean (normal) is warmer, although with only 23 years in the final base period, the warmest, 1980-2002, is useful only as an illustration of an ongoing trend. In the Southern Hemisphere (Table 2), the normal values also reflect a continuous, consistent, ongoing contractual phase of the vortex.

To compute an annual mean monthly circumpolar area index, the 12 midmonth index values were simply summed and an average value computed and presented as representative of the year. Looking at the Northern Hemispheric annual circumpolar area index plot (Fig. 1), the period 1948-1963 suggests an expansive pattern that reverses in 1964 and becomes contractive. While visual warming occurs over the length of the period, momentum appears in pulses, specifically 1963-64, 1984-85, and 1997-98. Figure 2, a graphical representation of the Southern Hemispheric annual plot, depicts a consistent and definitive contractive pattern with little interruption. There are few periods of sharp year-to-year variability, 1985-1987 being an exception, although without trend reversal.

3. Use of the Area Index as a Forecasting Tool

Circumpolar vortex studies can provide useful information to the operational forecaster, generally at the synoptic or macro scales. At an annual level, the size of the vortex can provide a reasoned approach to recognizing the pattern and pathway of global change. While no one has suggested global temperatures have been constant over long periods of time, global change is now charged with political and societal context that begs for a scientific underpinning. This paper's annual representation suggests some variability in warming in the northern hemisphere where most studies have been completed, but suggests a consistent, progressive and continuing warming in the Southern Hemisphere.

Weekly circumpolar vortex area index values over a period as short as 6 to 12 weeks can offer a regression set that when forced forward as a forecast can provide monthly mean trend values for temperature that are representative of persistence. If vortex values are broken into regional components, the regional component along the North American Pacific coast can offer some insight into the placement of the polar jet boundary and the large-scale movement of warming or cooling trends about the Southern and Central Plains.

This paper considers vortex measurements mainly at the annual level, although some monthly mean values are used to support the global pattern. Work at the seasonal, monthly, and weekly hemispheric and regional level is ongoing.

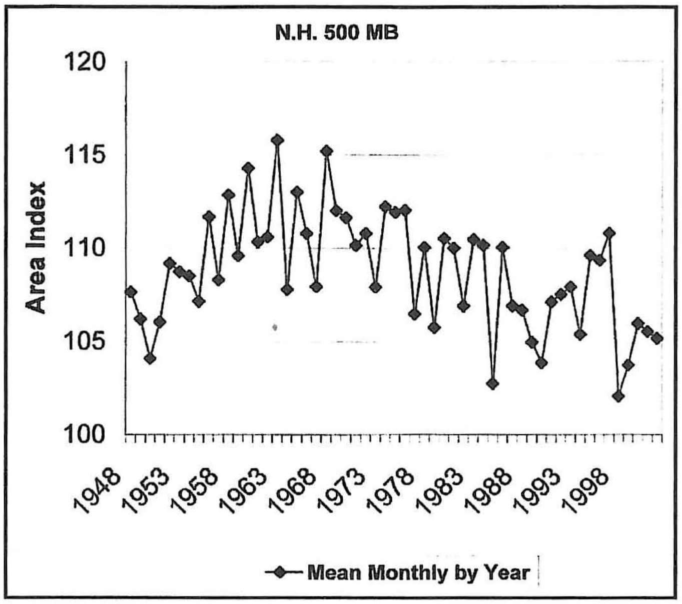

Fig. 1. Graph of Northern Hemisphere yearly mean vortex area index values, 1948-2002.

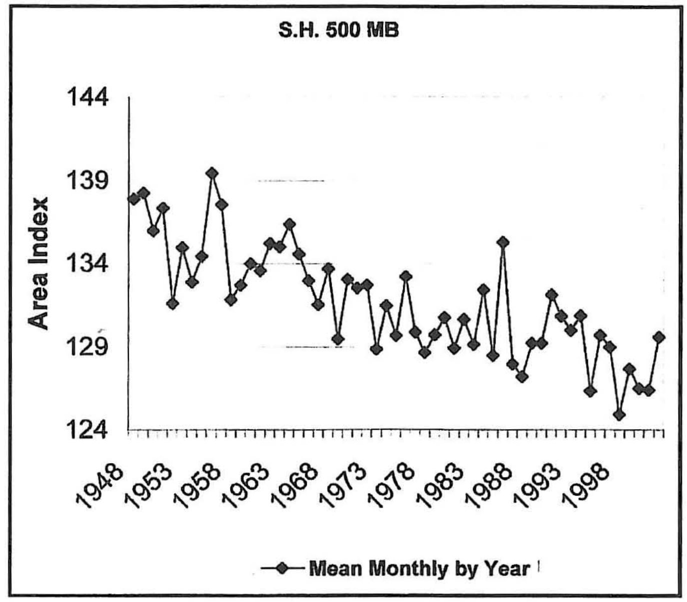

Fig. 2. Graph of Southern Hemisphere yearly mean vortex area index values, 1948-2002.

4. Summary and Conclusion

The annual mean Northern Hemispheric circumpolar vortex area index for the period 1948-2002 depicts early cooling from 1948 to 1963. A period of extreme volatility occurs from 1963 to 1968, after which, a discernable pattern of warming is established and persists. The interval 1997-1998 suggests a period of extreme volatility that accelerates the contractual pattern. The 1976-1977 data is not nearly as extreme as 1963-1964, 1984-1986 or 1997-1998. While not suggesting a cause, whatever the forcing mechanism, the depicted warming arising from the volatility of the 1960's is consistently evident after 1968.

The yearly Southern Hemispheric circumpolar vortex area index for the period 1948-2002 is more consistent and less volatile year to year than the Northern Hemisphere, although the periods 1951-1952, 1957-1958, and 1986-1987 seem to warrant in-depth analysis. However, the Southern Hemispheric circumpolar area index presentation consistently and continuously displays a warming trend, 1948-2002.

The authors found no evidence of a relationship to El Niño variability, although that is more a consequence of the smoothing procedure used in calculating the mean monthly area index by calendar year than anything else. Episodic events that occur over a period less than a full year and those that occur across calendar years could be effectively masked. When the index is calculated and presented by month or by week, there may be a greater likelihood of presenting a relationship with other indices, specifically, ENSO, the Pacific Decadal Oscillation, the North Atlantic Oscillation or the Arctic Oscillation.

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Authors

Albert Peterlin formed ERREx, Inc., in 2000 when he retired as Chief Meteorologist of the United States Department of Agriculture (USDA). Prior to joining USDA, he worked in the NOAA National Weather Service including duty as a line forecaster, agricultural meteorologist, warning preparedness hydrologist, and in NWS Modernization activities including involvement with the WSR-88D program and as the Deputy Program Manager for AWIPS.

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