Antarctic Warming Events in Winter Observed by Automatic Weather Stations: An Analysis of Extreme Temperature Increases

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1. Abstract

The surface temperature trend of the austral winter over the Antarctic has been shown to be relatively flat and described as coreless (van Loon 1967). There have, however, been deviations for a month from this flat temperature trend, shown in the second harmonic of the mean temperatures (Wendler and Kodama 1993). One cause for these increases in temperature may be brief but rapid increases in surface temperature. Observations from the University of Wisconsin-Madison (UW) Automatic Weather Station (AWS) network (Lazzara et al. 2012) have shown dramatic and rapid increases in temperature in austral winter. An investigation of these events was conducted for all UW AWS in the years 2002 through 2017. These warming events in winter (WEW), for the purposes of this study, are defined as increases in temperature observed at a UW AWS of 30^{o} Celsius or greater in 5 days or less, with a decrease in temperature during that period of no more than 10^{o} Celsius. This study divided Antarctica into seven sectors. If more than one WEW occurred in a sector simultaneously, these WEW were counted as a regional warming event in winter (RWEW). The Ross Ice Shelf was shown to have the largest number of WEW and RWEW, followed by Marie Byrd Land/Ellsworth Land in West Antarctica. Four sectors of the continent were chosen to investigate the synoptic setup of RWEW. By investigating three RWEW, it was found that the typical setup included a 3-wave pattern in 500 hectoPascal (hPa) geopotential heights in the Southern Ocean with strong meridional flow in the region of the warming events. Connections between RWEW and climate indices affecting Antarctic circumpolar atmospheric circulation are also investigated.

2. Results

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In the years 2002-2017, 405 WEW were observed in the UW-Madison AWS network (Fig. 1).

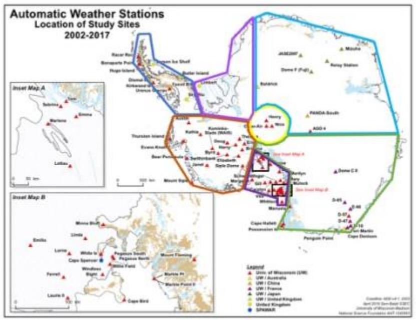

Figure 1: Map of all AWS used in this study, and the seven sectors (Peninsula, Southwest, South, Southeast, Northeast, Northwest, South Pole).

A total of 194 RWEW were observed during this period. The South Sector experienced the most WEW (238) and RWEW (75) and had the highest rate of RWEW per year (4.69). The Southwest Sector had the second most WEW (84) and RWEW (53) as well as the second highest rate of RWEW per year (3.31).

Twelve RWEW were investigated further in terms of synoptic-setup and mean 500 hPa geopotential heights, with three events studied in each of four sectors (South, Southwest, Northeast, Southeast) (Fig. 1). The 500 hPa level was chosen to allow comparison between the atmospheric setup during case studies to various climate indices, e.g. SAM, Zonal Wave 3, Planetary Wave Index (Raphael 2004; Irving and Simmonds 2015).

In the South, Northeast, and Southeast sectors, the mean 500 hPa geopotential heights indicated a 3-wave pattern during RWEW (Fig. 2).

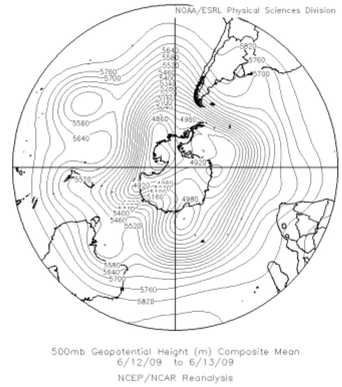

Figure 2: Mean 500 hPa geopotential heights during an RWEW in the Southeast sector, 12-13 June 2009.

The Southwest sector did not have as clear-cut a regime in the 500 hPa geopotential height field.

3. Conclusion

The 3-wave pattern in the mean 500 hPa geopotential height field has been known to influence meridional transport of moisture and energy (van Loon and Jenne 1972; Hobbs and Raphael 2010), and it is a common deviation from the typically annular distribution of geopotential heights in the southern latitudes (Fogt et al. 2012).

The reasoning for the South sector, namely the Ross Ice Shelf (RIS), being preferential to RWEW appears to be the placement of the Amundsen-Bellingshausen Sea Low (ABSL) influencing meridional warm air advection, topography, and the synoptic influences on regional wind regimes. The ABSL, when positioned properly, advects warm, moist air poleward and over the RIS and Marie Byrd Land. The relatively low elevation of the region (compared to East Antarctica) allows for more advection over the RIS. With the cyclonic circulation of the nearby ABSL, the Ross Air Stream is enhanced over the RIS, leading to higher wind speeds and greater mixing out of the inversion. These factors enhance the propensity for RWEW in the South sector.

While climate indices were investigated in terms of their correlation to RWEW, few clear-cut patterns emerged. One fairly consistent pattern was shown with the Planetary Wave Index (PWI), where in the month or two leading up to an RWEW, it increased in magnitude to near its maximum for the year. More investigation is needed to determine stronger relationships between climate indices and the occurrence of RWEW.

4. Acknowledgments

The authors appreciate the support of the Division of Polar Programs at the National Science Foundation under grant numbers ANT-1245663 and ANT-1543305 and the high-performance computing support from Yellowstone (ark:/85065/d7wd3xhc) provided by the National Center for Atmospheric Research's Computational and Information Systems Laboratory, sponsored by the National Science Foundation.

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