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Temperatures in the Mid-Latitude Mesosphere During Sudden Stratospheric Warmings as Determined from Rayleigh Lidar Data

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**Introduction**

Sudden Stratospheric Warming (SSW) events are major disturbances in the polar region of the stratosphere that cause major changes in stratospheric temperature and circulation. SSWs are characterized by a temperature increase of ten degrees Kelvin, averaged over 60°-90° latitude, and a weakening of the polar vortex that persists for the order of a week at the 10 hPa level (roughly 32 km) [Lubitzke and Naojak, 2001]. The polar vortices are cyclones centered on both of the Earth’s poles that are present from the mid-crustosphere to the lower stratosphere. Eastward zonal winds define the strong polar vortices in the winter. Increased planetary wave (PW) activity in the polar stratosphere is the deposition of the PW’s westward momentum in the polar vortex. This weakens, and in the case of major SSWs, can reverse the zonal wind direction to westward. The reversal of the stratospheric jet allows more eastward propagating gravity waves (GWs) to travel up into the mesosphere, where in normal winter conditions, westward propagating GWs dominate [Liu and Roble, 2002]. The atypical wintertime GW filtering and the planetary enhancing westward GWs induces an equatorward circulation in the mesosphere, which leads to the cooling of the upper mesosphere. While these mesospheric coolings have been observed in the polar regions for several decades [Lubitzke, 1972], they have only recently been observed at mid-latitudes [Yuan et al., 2012].

**Instrumentation and Data Analysis**

The original Rayleigh lidar at the Atmospheric Lidar Observatory (ALO) on Utah State University’s campus in Logan, UT, measured relative densities that were then reduced using the Chavin-Haugeherme method [Hancechere and Chavin, 1996] to give absolute temperatures. For the purpose of this study, averages were calculated for a whole night with a spatial resolution of 3 km. The calculated 11-year temperature climatology [Herron, 2007] was used.

Major SSW events were defined using the NCEP-NASA MERRA 60°-90° latitude, 10 hPa level winds, both at 10 hPa. Examples of the MERRA temperatures and zonal winds can be seen in Figure 1. The vertical blue lines denote the January 2003 major warming.

**Results**

During a SSW event, the polar stratosphere switches from typical winter conditions to summer conditions for the order of a week. At approximately the same time, the mesosphere undergoes a similar transformation. The winter (January-February) and summer (June-July) ALO climatologies are shown in Figure 3a and 3b, respectively. In Figure 3c, an example of temperature data during SSW events in January and February 2001 are shown. The blue vertical line denotes the peak of a minor SSW, and the red line denotes the peak of a major SSW. One can see that the mesospheric temperatures in Figure 3c more closely resemble the summer climatologies for the winter climatological temperatures. December-February 2001 temperatures from the SABER instrument aboard the TIMED satellite for 40°N, 120°W (Figure 3d) are also shown to agree well with Rayleigh lidar temperatures.

Mesospheric temperatures for the January 2001 major SSW event are shown in Figure 4, where the red line again denotes the peak of the SSW. The black curves are nightly averages and the green curves are the climatological temperatures for the corresponding day of the climatological year. One can see that the mesospheric coolings begin about six days prior to the peak of the SSW on January 14, 2003 and seem to dissipate after the SSW peak. These coolings are centered at about 80 km, the largest magnitude of cooling for the event was -10 K and happened on January 18, 2003 about two days prior to the peak of the SSW.

To gain a better understanding of the time evolution of the mesospheric coolings at mid-latitudes, temperature difference plots were created. Of the 6 major SSW events examined in this study, 5 of the mesospheric coolings seemed to follow the same time evolution pattern. The temperature differences were calculated by subtracting the climatological night’s temperatures from the nightly averages. This way, coolings are represented by negative temperature differences and warmings are represented by positive values. Temperature difference values of -1.5 K are taken to be the noise level in these plots. Day zero is the peak day of the corresponding SSW event, negative values are prior to the event, and positive values are after the peak of the event. In Figure 5, a time evolution pattern emerges from the plots that includes a cooling, between 70-80 km that precedes day zero, that then intensifies and moves up in altitude near day zero and dissipates and lowers in altitude after day zero.

**Conclusions and Future Work**

In this study, we have shown that the mesospheric coolings associated with sudden stratospheric warmings extend down to mid-latitudes for almost every major SSW event between 1993-2004. The occurrence of these mesospheric coolings prior to the peak of the SSW event was also observed. Finally, a pattern in the time evolution of the mesospheric coolings was illustrated using temperature differences.

To further this work, additional event periods, which correspond to the other types of SSWs (minor, final) can be examined. Additionally, future zonal wind and temperature measurements from nearby meteor winds lidar and Na lidars can be combined with the Rayleigh lidar temperatures to provide a more comprehensive description of the middle latitude mesosphere during sudden stratospheric warmings.

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**References**


