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Midlatitude Mesospheric Temperature Anomalies During Major SSW Events as Observed with Rayleigh-Scatter Lidar

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SSWs and USU Rayleigh Lidar Temperatures from 1993-2004
In this initial study of the mesosphere's response to SSWs above Logan, UT, we will focus on periods when there were major SSW events during the Utah State University Rayleigh-Scatter Lidar's (RLS) original operational range from 1993 to 2004 [Table 1].

A major SSW is characterized by both a stratospheric temperature increase averaged over the latitudes 60° north and poleward, and a complete reversal of the zonal-mean circulation to westward at 60° north [as seen in NASA's Modern-Era Retrospective Analysis for Research and Applications reanalysis dataset [NASA MERRA]]. This creates a complete change in the circulation, or a breakdown, of the polar vortex [Labitzke and Naujokat, 2000]. Two major SSSWs, at northern latitudes, can be seen in Figures 1 (a) and (b).

The original RLS system ran at a midlatitude site (41.7° N, 111.8° W), on the campus of Utah State University from 1993-2004. The RLS measured relative densities that were then used in the Chan-Hauchoene method [Hauchoene and Chanin, 1980], which uses hydrostatic equilibrium and the ideal gas law to give absolute temperatures. The initial temperature values for the downward integration came from the CSU climatology [She et al., 2000].

Figures 1 (a) and (c) depict a winter period in the RLS data that includes a major SSW period in November 1998, then two consecutive major SSSWs in December 1998 and February 1999 and ends with a post-SSW period in March 1999. One may note warmer regions in the lower mesosphere and colder regions in the upper mesosphere before and after the peak dates of the two SSSWs.

Midlatitude Mesospheric Temperatures during Major SSWs

The RLS observations made during seven SSW events show a temperature range (~160-280 K), from high to low altitudes, more characteristic of the summer climatology [Fig 2 (a)] than the expected winter climatological temperature range (~180-265 K). This temperature reversal from winter to summer conditions most often starts at the peak date and continues for several weeks [Figs 3 (a-g)].

In order to better define coolings and warmings during an SSW event, as compared to the RLS climatological temperature difference plots [Figs 4(a-g)], were created by subtracting the climatological night's temperatures [Fig 2 (a)] from the individual night's averaged temperatures [Fig 3]. The upper mesospheric coolings, that are typically located from 70-95 km, and the lower mesospheric warmings, from 45-70 km, are roughly one order of magnitude higher than those predicted in Liu and Roble, [2002] for midlatitudes. They are more comparable to the coolings and warmings that have been found in the polar mesosphere [Labitzke, 1972] and range from less than ~50 K (coolings) to more than ~50 K (warmings).

Conclusions and Future Work

Conclusions from this study about the midlatitude mesosphere include:

- A dense temperature dataset acquired by the USU Rayleigh lidar has overlapped significantly with nearly all of major SSW event from 1993-2004, giving a better understanding of the midlatitude mesosphere's behavior during these events.
- The whole mesosphere tends to switch from the climatological temperature range of winter to that of summer from the time of the stratospheric zonal wind reversal at 60 N.
- The mesospheric temperature anomalies, coolings in the upper mesosphere and warmings in the lower mesosphere, are roughly the same magnitude at midlatitudes as they are in the polar regions.

This work will be furthered by examining the climatological aspects of these midlatitude temperature anomalies and by pushing the observational range into the lower thermosphere, in future observations, through a series of upgrades to the USU Rayleigh lidar that are currently underway.