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Atmospheric Lidar Observatory (ALO) Ten-Year Mesospheric Temperature Climatology

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Abstract

The Rayleigh-scatter lidar at the Atmospheric Lidar Observatory (ALO) on the Utah State University (USU) (41.7°N, 111.8°W) campus has been in operation since 1993. The temperature database now contains over ten years of Rayleigh-scatter temperatures. A multi-year temperature climatology has been calculated from these observations along with the RMS and interannual variability. These temperatures and the climatology are currently being used in a number of mesospheric studies, including mesospheric inversion layers, tides, planetary waves, cyclical variations, trends, longitudinal comparisons, and validation studies.

Instrument

The Rayleigh-scatter lidar, Figure 1, primarily consists of a pulsed Nd:YAG laser generating 18 watts at 532 nm, a 44 cm diameter telescope, a mechanical chopper, and a gated photomultiplier tube.

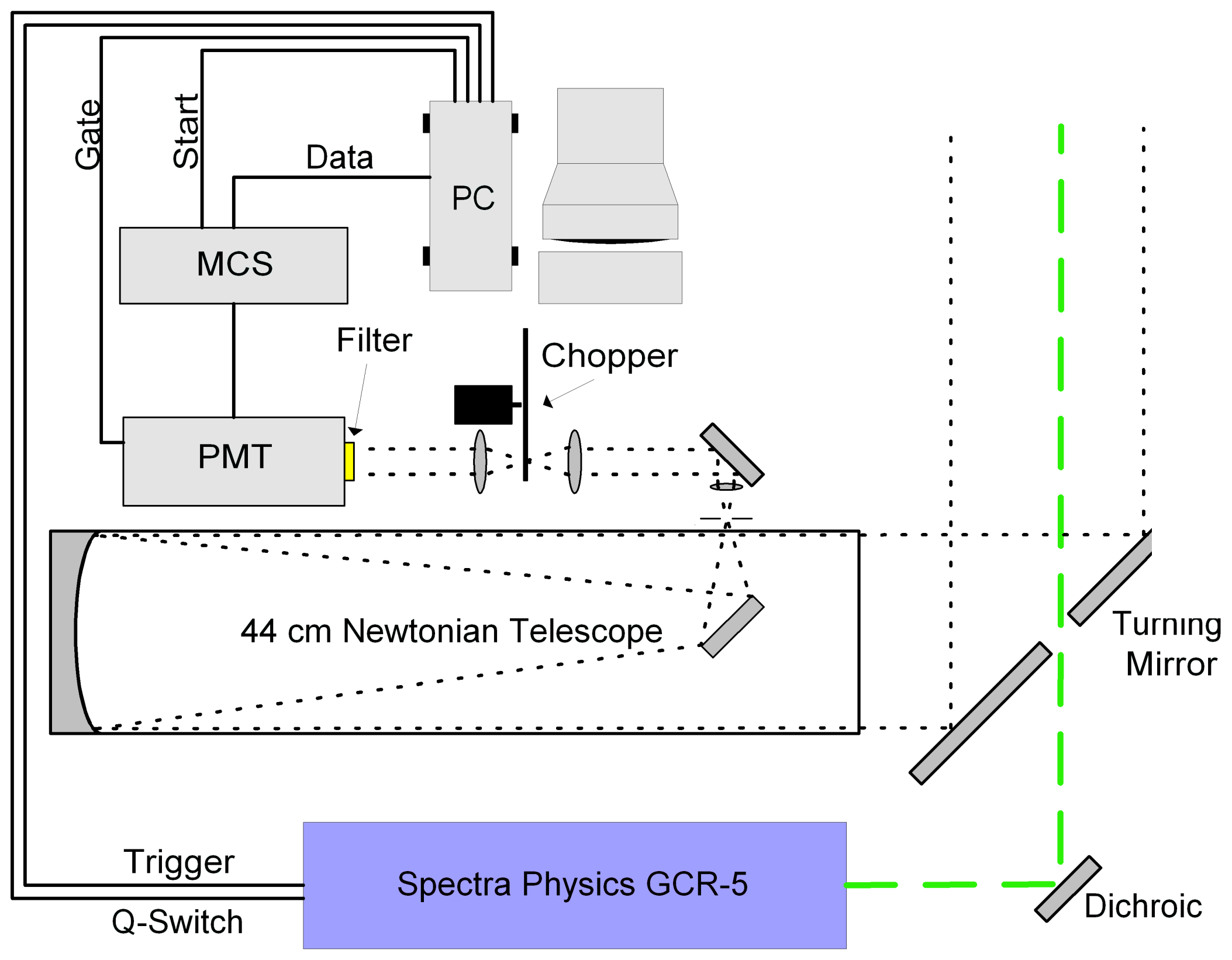

Figure 1, Lidar schematic

The lidar produces profiles of relative density from the Rayleigh-scatter returns. The returns are integrated in time for 2 minutes (3600 pulses) and 37.5 m (250 ns) in altitude.

Temperature Climatology

The relative density profiles from the lidar are averaged over hourly, nightly, monthly and multi-year monthly periods and the temperatures then calculated. One method to calculate a multi-year monthly temperature is to use a running 31 day window, Figure 2. By averaging the relative densities, the range of the temperature profiles is increased to above 90 km. The data reduction technique is described in *Herron* [2004].

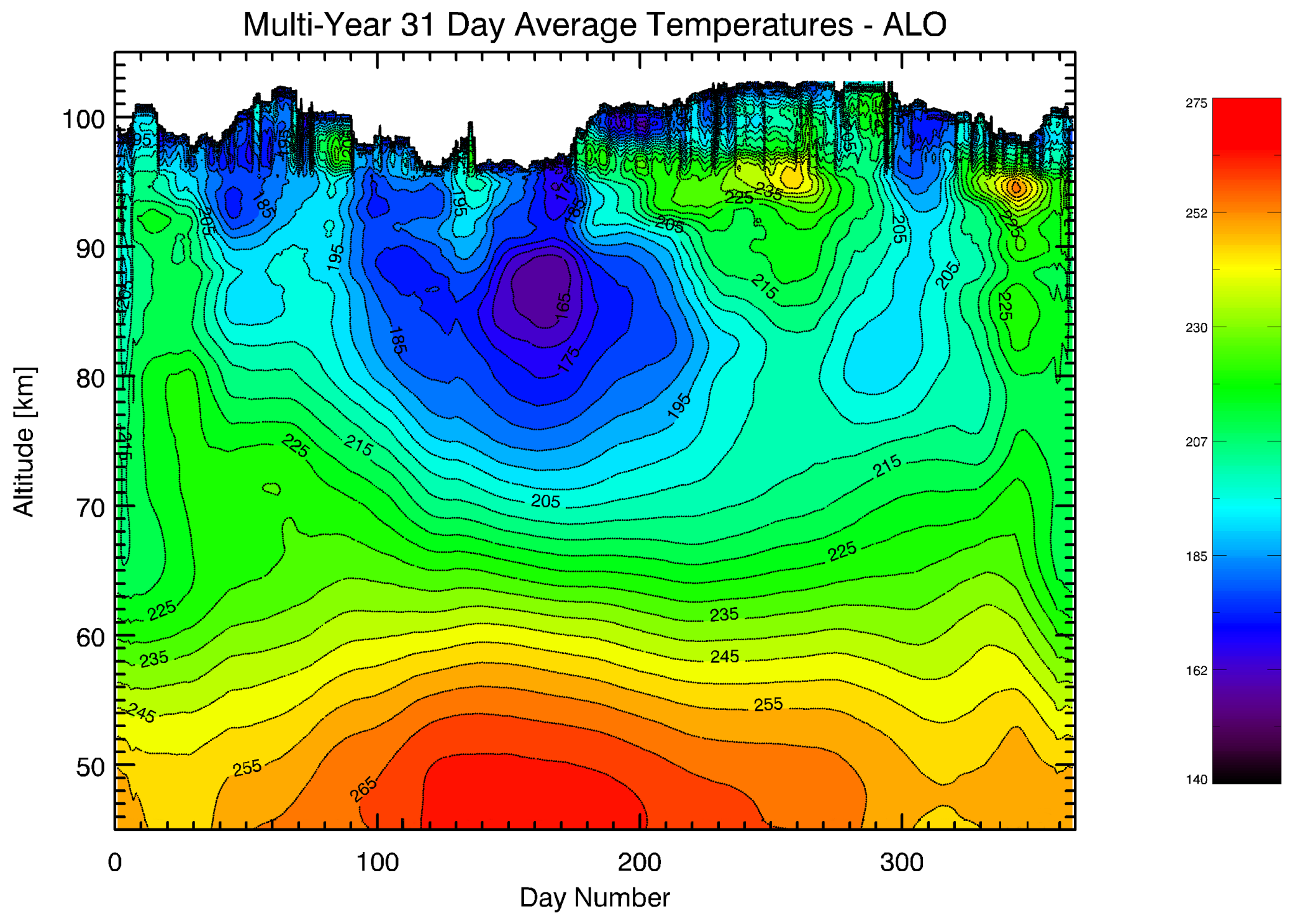

Figure 2, Temperature plot based on multi-year 31-day averages. For the temperature calculations the relative densities were averaged over 3 km. A boxcar average was applied for 1.5 km and 15 days to the temperature profiles for the contour plot.

The temperatures are shown from the start of their integration, where the first 10 km are influenced by the starting temperature taken from the CSU climatology [*She et al.,* 2000]. The temperature climatology from the lidar shows the hot stratopause and the cool mesopause during the summer months. The maximum stratopause temperature occurs ~35 days earlier than the minimum mesopause temperature. The mesopause increases in altitude during the winter months beyond the range of the lidar. Likewise, it is difficult to determine the peak of the stratopause during the winter because it may drop below 45 km.

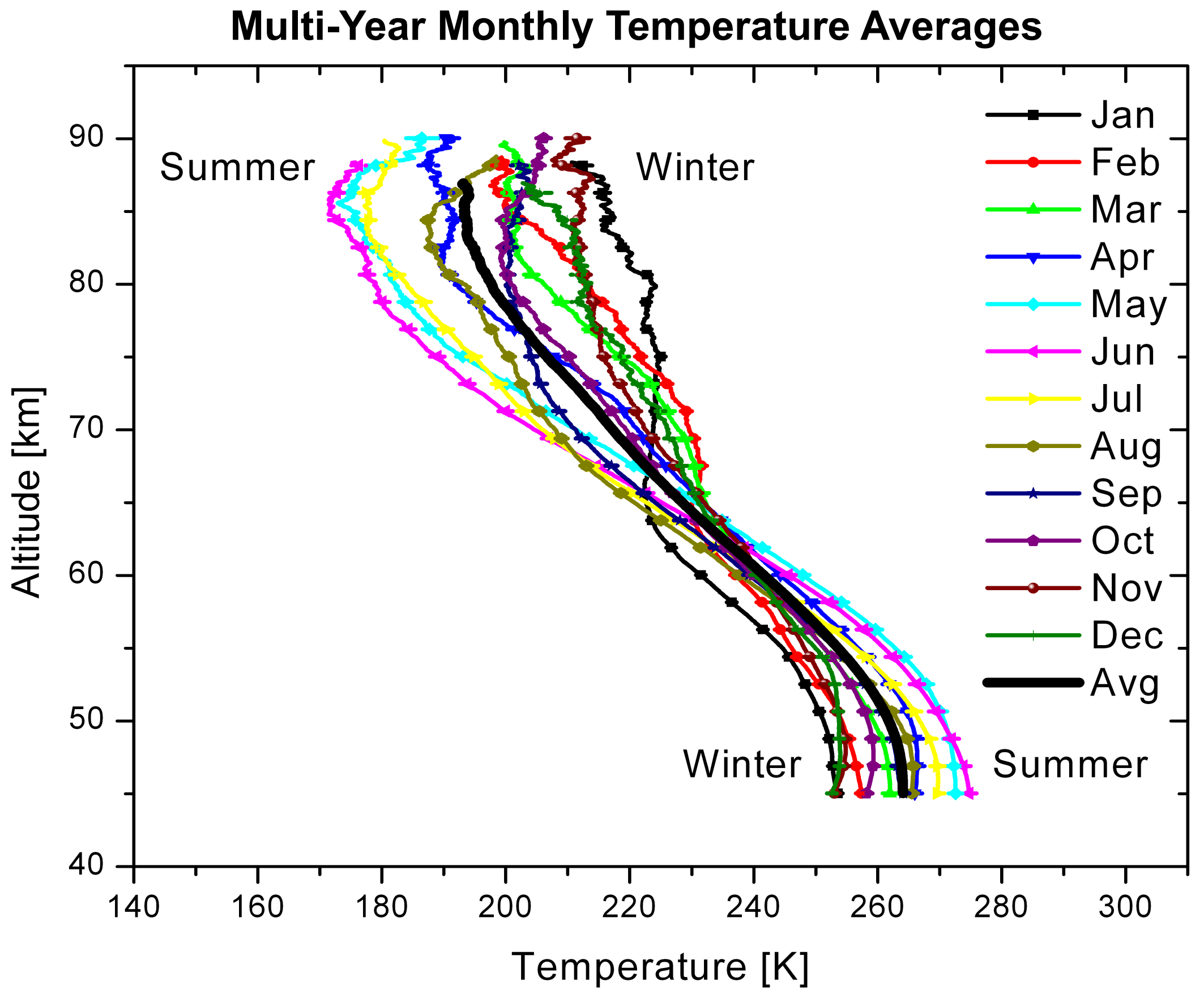

Figure 3, Individual monthly temperature means. The error bars are the standard deviation of the mean for each month.

Another view of the climatology is given in Figure 3, It clearly shows the relation between radiative control and dynamical control. Below 65 km the temperature structure of the mesopause is linked to the radiative input and we get warmer temperatures during the summer and cooler temperatures during the winter. Above 65 km the temperatures are cooler in the summer than the winter. This is due to the meridional circulation of the atmosphere which is controlled by wave dynamics.

Inversion layers in the mesosphere have been seen with lidar systems for some time now. They are typically defined as regions of zero or positive lapse rate. The ALO lidar consistently has inversion layers during the months from November to February which can be seen between 60 and 80 km as increased temperatures in Figure 3 and as heating in Figure 4. These inversion layers are also seen at other times of the year and the statistics on these are given in another poster.

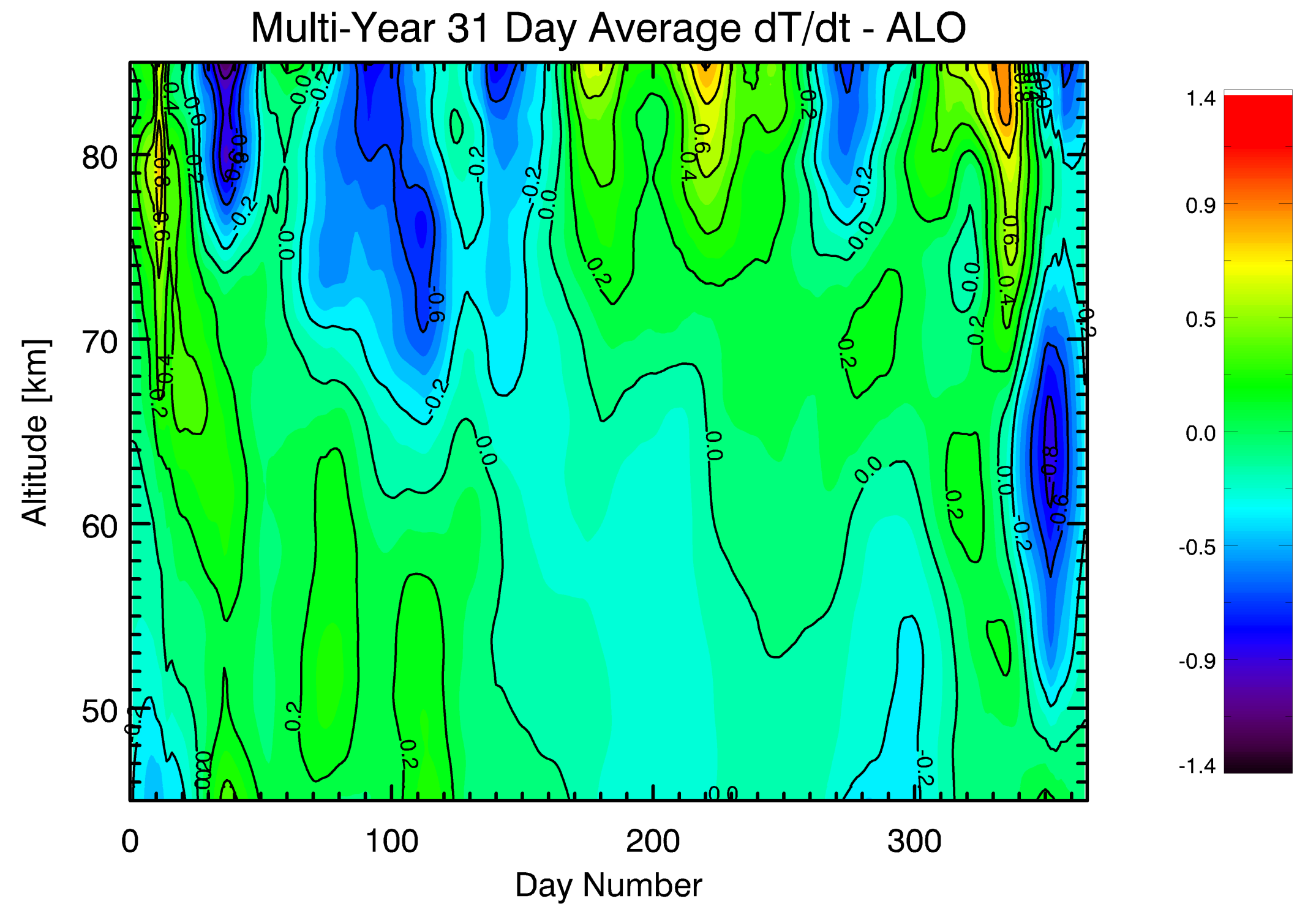

Figure 4, Derivative of the 31-day average temperatures given in Figure 2 the resulting heating/cooling rates are given as degrees K per day [K/dy]

The spring equinox shows a period of enhanced cooling followed by a short period of warming. The fall equinox shows a more extensive period of enhanced warming followed by a period of cooling. The equinox transition periods have been seen with other instruments, but not over the extended altitude range possible with the lidar.

Temperature Variability

Heavy averaging of the lidar returns enables the development of smooth temperature profiles suitable for showing the evolution of the temperatures, but it averages out much of the night-to-night geophysical variability. Figures 5 and 6 show the individual nightly temperature profiles measured with the lidar from January and July.

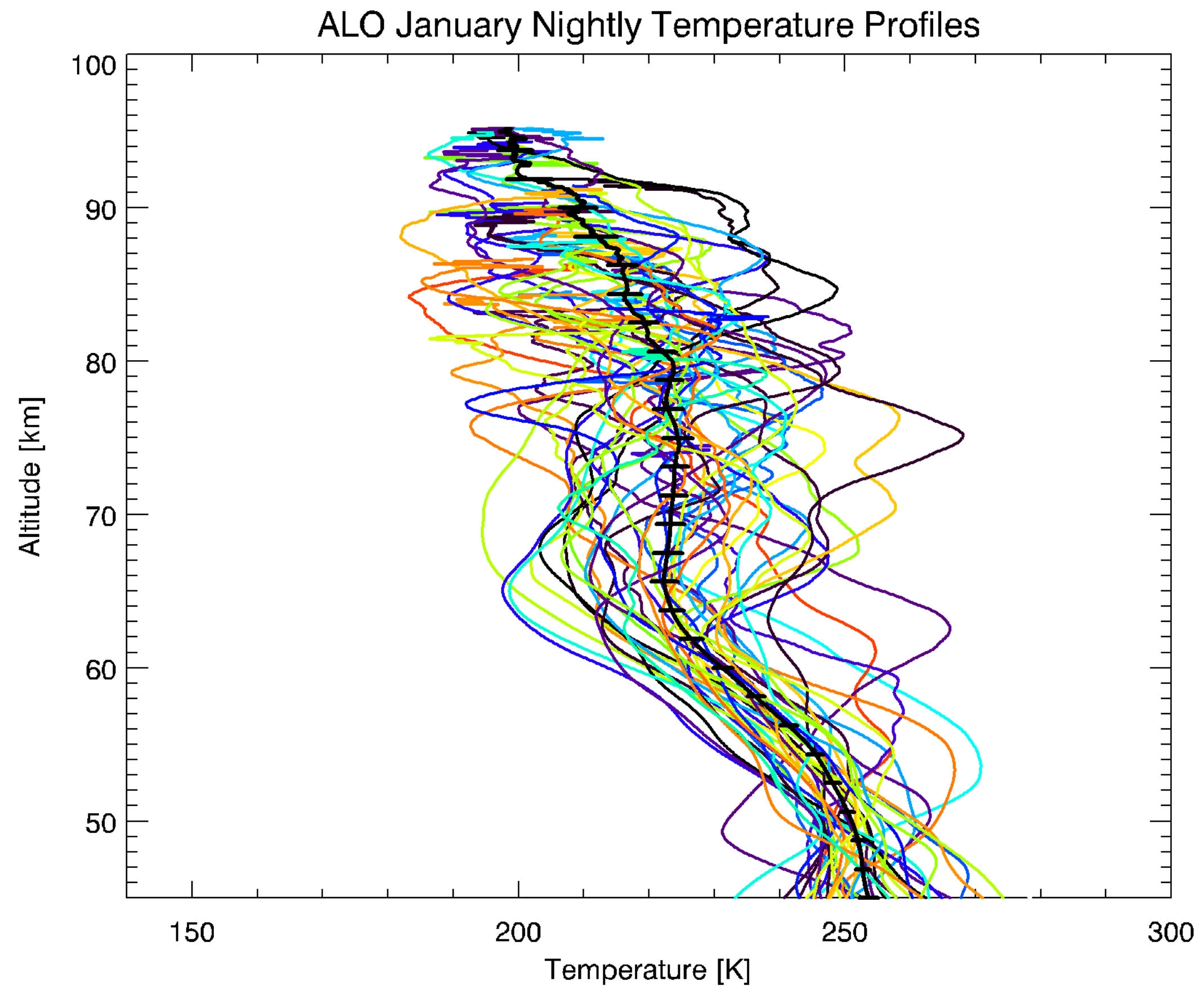

Figure 5, Nightly temperature profiles for January. The monthly mean with its error bar indicating the standard deviation of the mean is given in black.

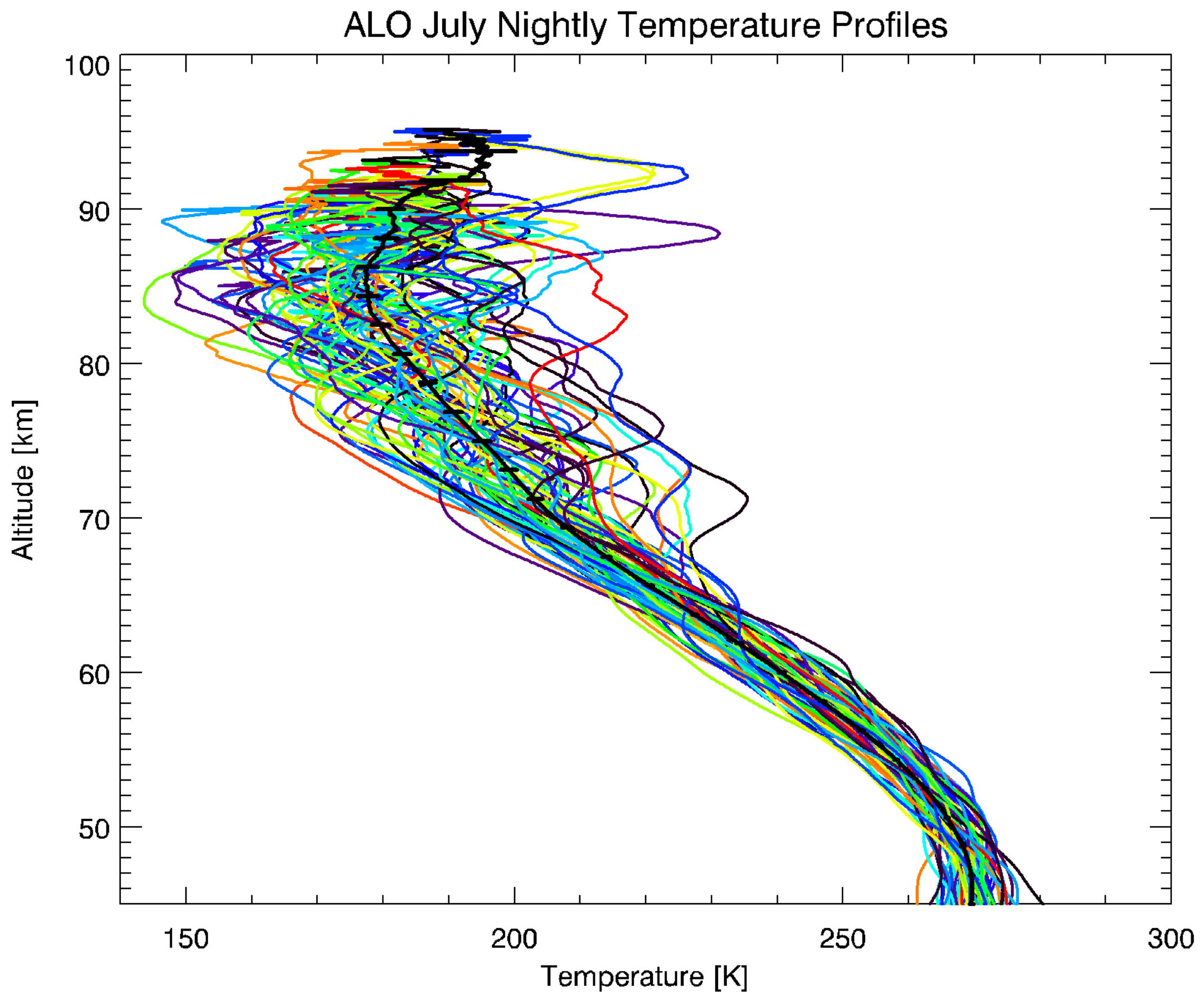

Figure 6, Nightly temperature profiles for July. The monthly mean with its error bars indicating the standard deviation of the mean is given in black.

The nightly temperatures in Figures 5 and 6 have a 1.5 km boxcar average applied to remove the small-scale fluctuations. These nightly temperature profiles can vary more than 50 K during a given month. These large temperature fluctuations are driven by dynamics in the atmosphere in the form of gravity waves, tides and planetary waves. An analysis of these waves has been carried out by *Nelson* [2004] and is presented in another poster. There is a marked difference in the behavior of the waves during the two months shown. During January there is considerable wave activity over the entire altitude range of the lidar. Whereas, in July the temperatures increase dramatically above 65 km. This is another demonstration of the importance of dynamics at mid-latitudes during both the winter and summer months.

To better understand the transition between the winter and summer condition, the RMS variation of the nightly temperature profiles is shown in, Figure 7.

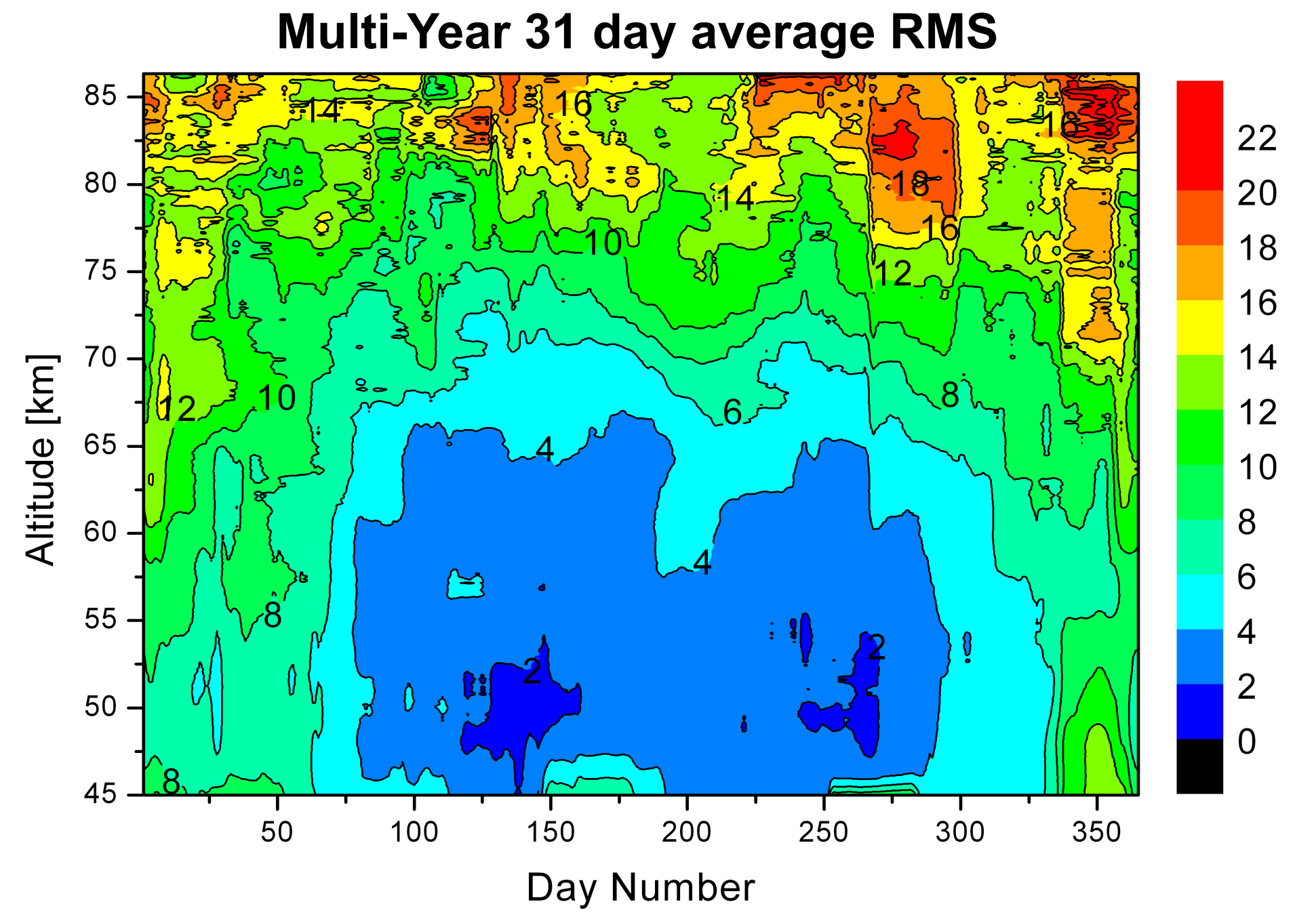

Figure 7, RMS variation in degrees K calculated from the nightly temperature profiles.

The RMS variation is calculated from the nightly temperature profiles using the same 31 day window as the temperature contour plot of Figure 2. It shows the variability on scales of 2 to 31 days. The greatest variations in the temperature profiles are from the winter months. However at higher altitudes there is a constant high level of variability for the entire year. This is consistent with wave activity being very important in controlling this region.

Conclusion

With more than 10 years of data, a detailed temperature climatology has been developed for mid latitudes above the Rocky Mountain chain. It shows the great importance of dynamical control even at mid latitudes. It provides information on the two-level mesopause, on the equinox transition periods, and on the wave structure. Now that these temperatures are available, they are being used for a range of studies, some of which are being shown in other posters. (For more information, see www.usu.edu/alo.)

Acknowledgements

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