9-10-2013

Rayleigh Lidar Observations of the Mid-Latitude Mesosphere During Stratospheric Warming Events and a New Rayleigh-Mie-Raman Lidar at USU

Leda Sox
Utah State University

Vincent B. Wickwar
Utah State University

Chad Fish
Space Dynamics Laboratory, Utah State Univeristy

Joshua P. Herron
Utah State University

Matthew T. Emerick
Utah State University

Rayleigh Lidar Observations of the Mid-Latitude Mesosphere During Stratospheric Warming Events and a New Rayleigh-Mie-Raman Lidar at USU

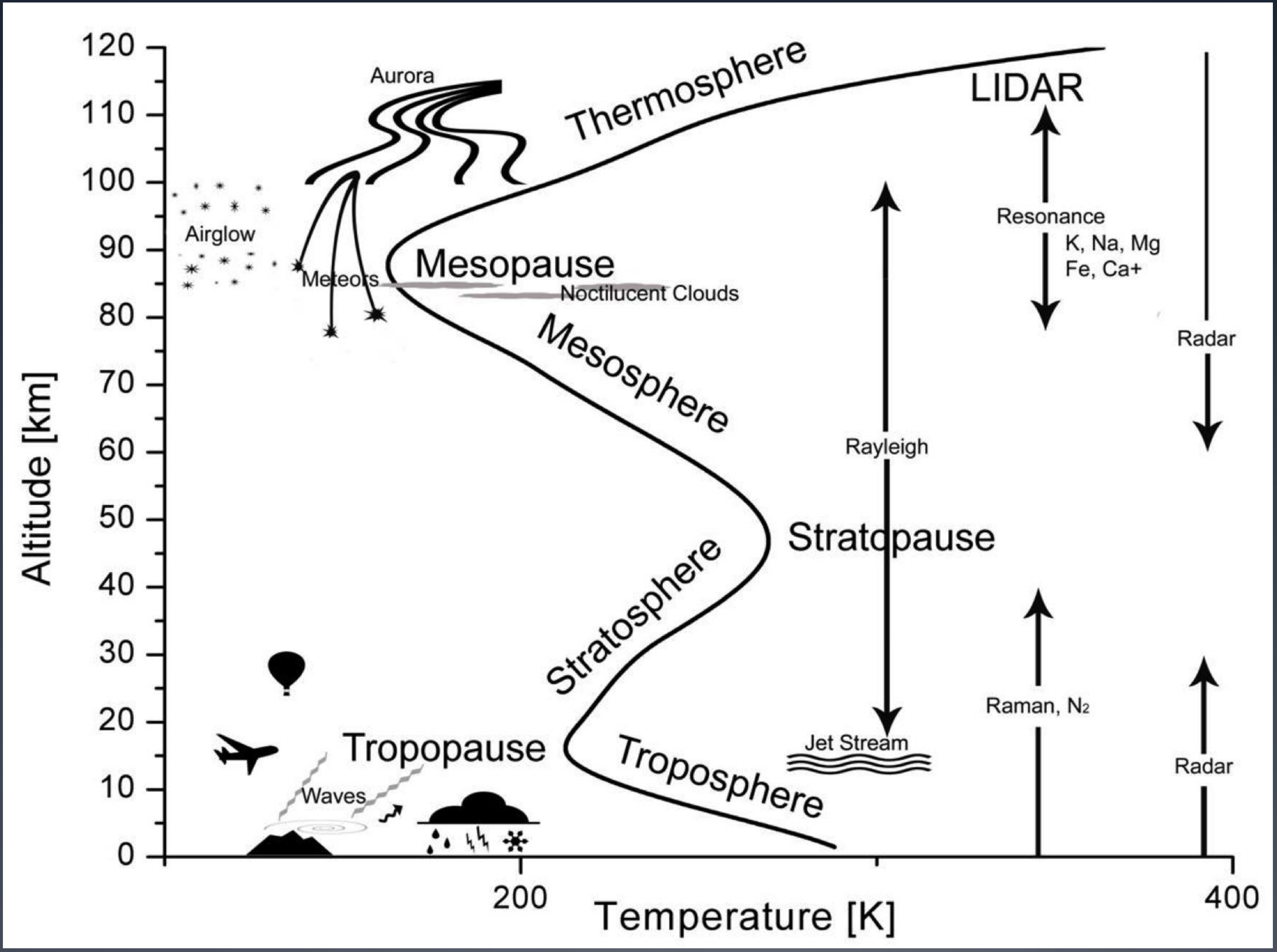
Leda Sox[1], Vincent B. Wickwar[1],Chad Fish[2],
Joshua P. Herron[2] and Matthew T. Emerick[1]

[1]Center for Atmospheric & Space Sciences
and Physics Department, Utah State University
[2]Space Dynamics Lab, Utah State University

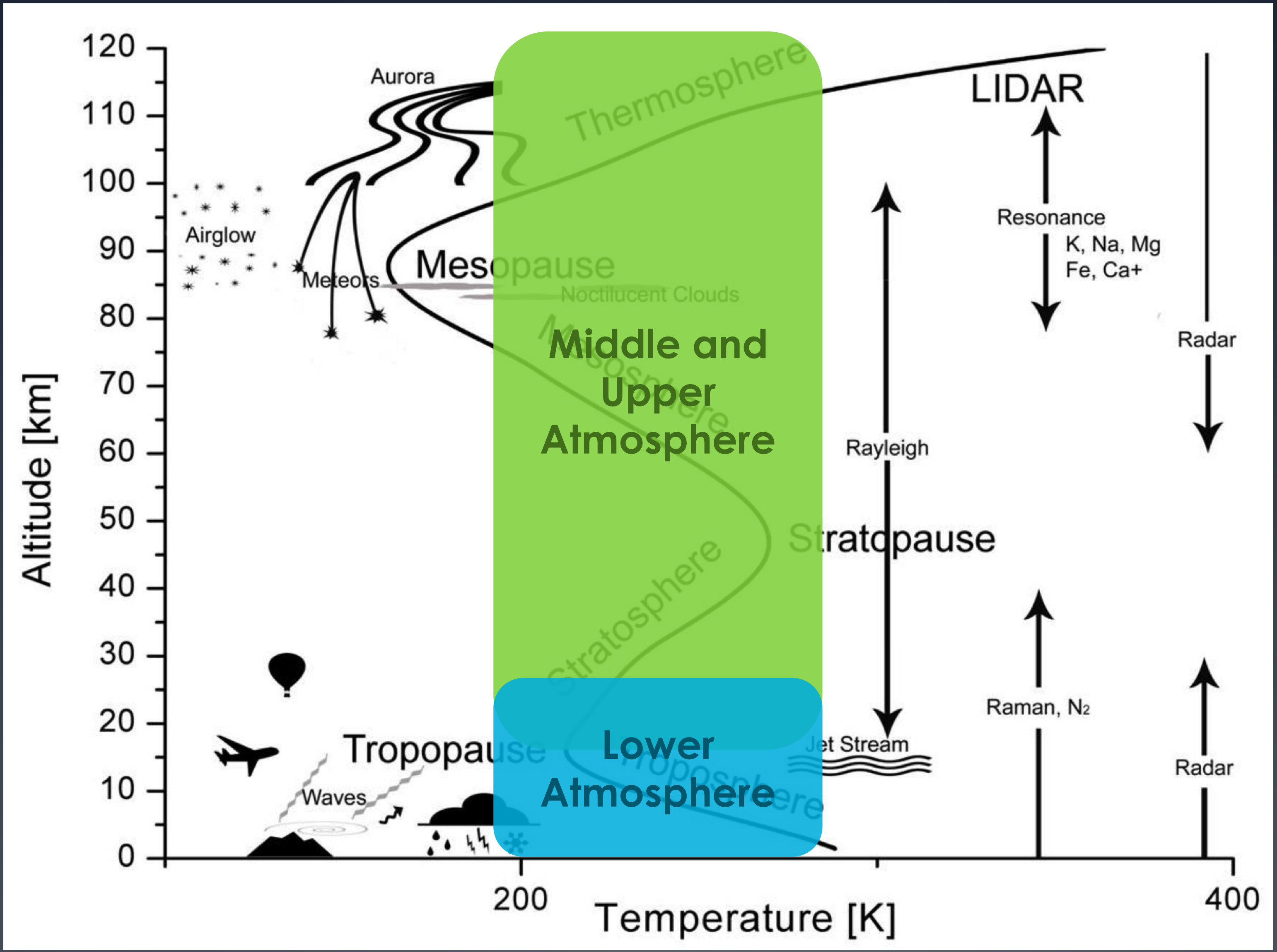
USU Physics Colloquium
September 10, 2013

ALO Atmospheric Lidar Observatory

The Atmosphere



The Atmosphere



Aeronomy Professors at USU

Bela Fejer

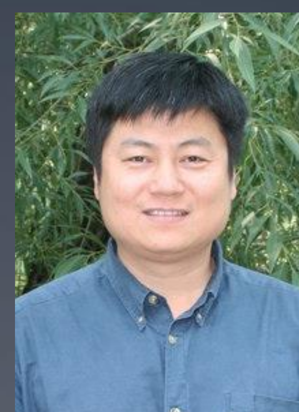
Ludger Scherliess

Robert Schunk

Jan Sojka

Michael Taylor

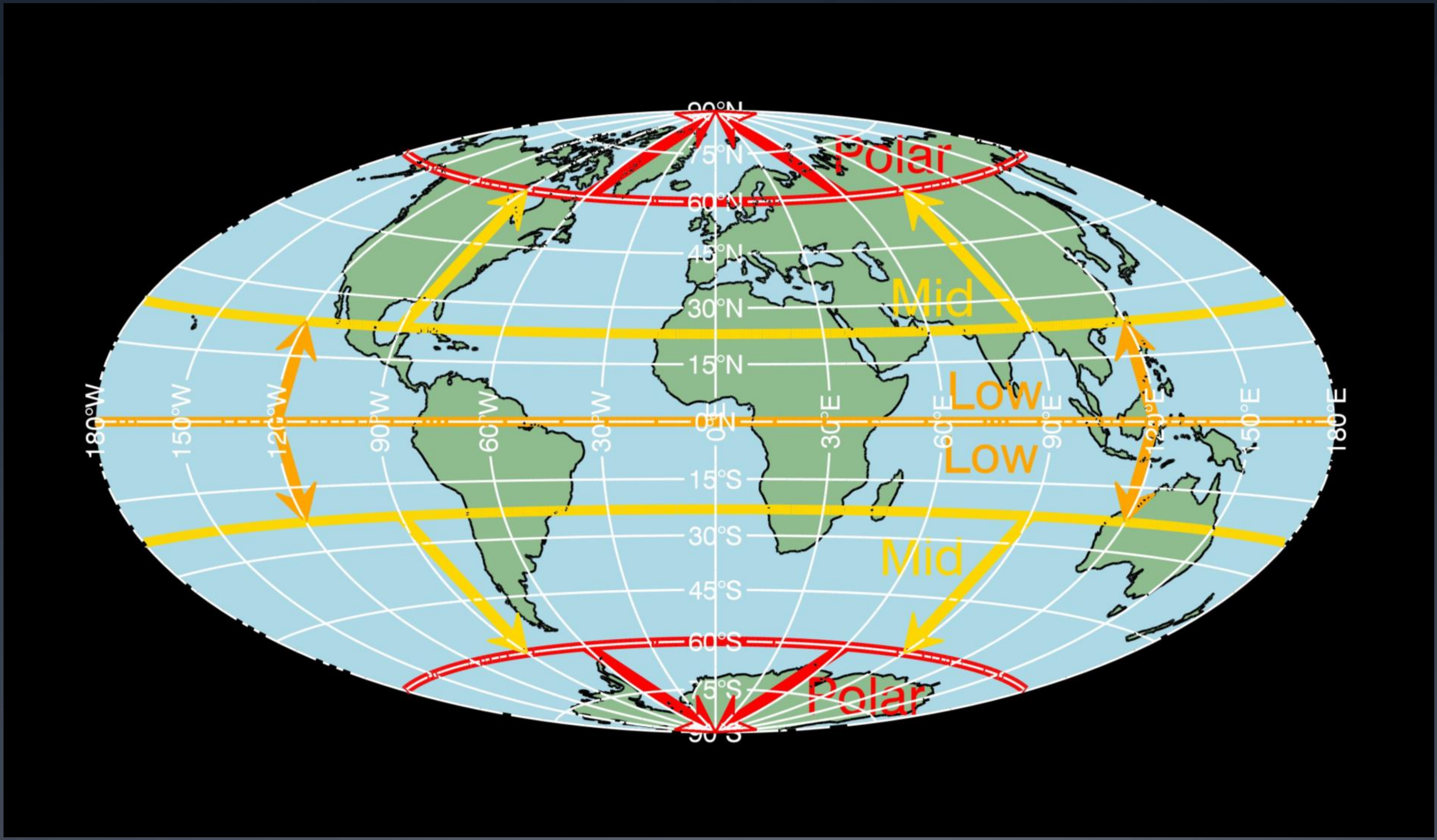
Vincent Wickwar



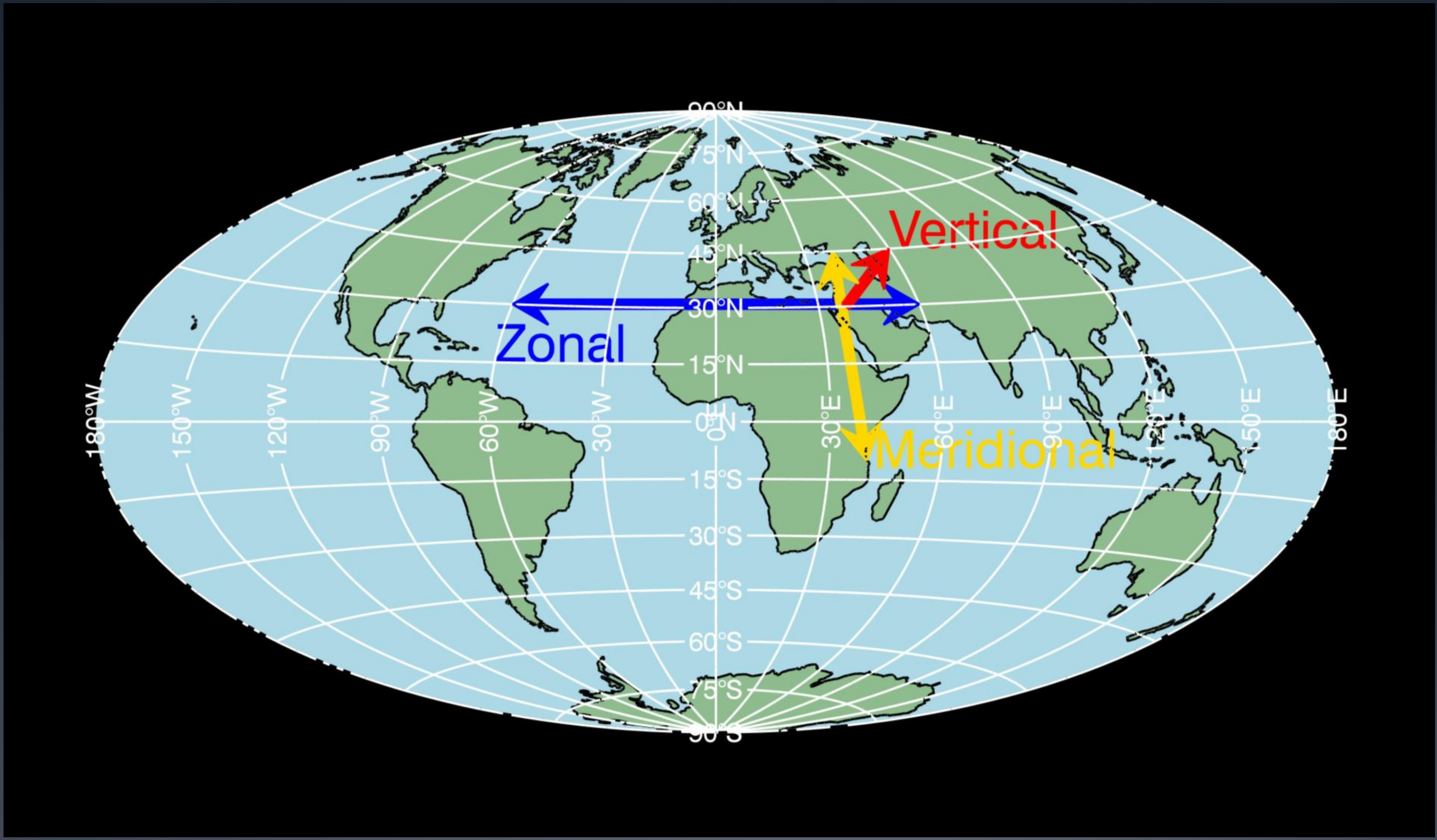
Tao (Titus) Yuan

Lie Zhu

Global Aeronomy Terms-Regions



Global Aeronomy Terms-Directions



The Polar Vortex

http://eesc.columbia.edu/courses/v1003/lectures/ozone/

Eastward

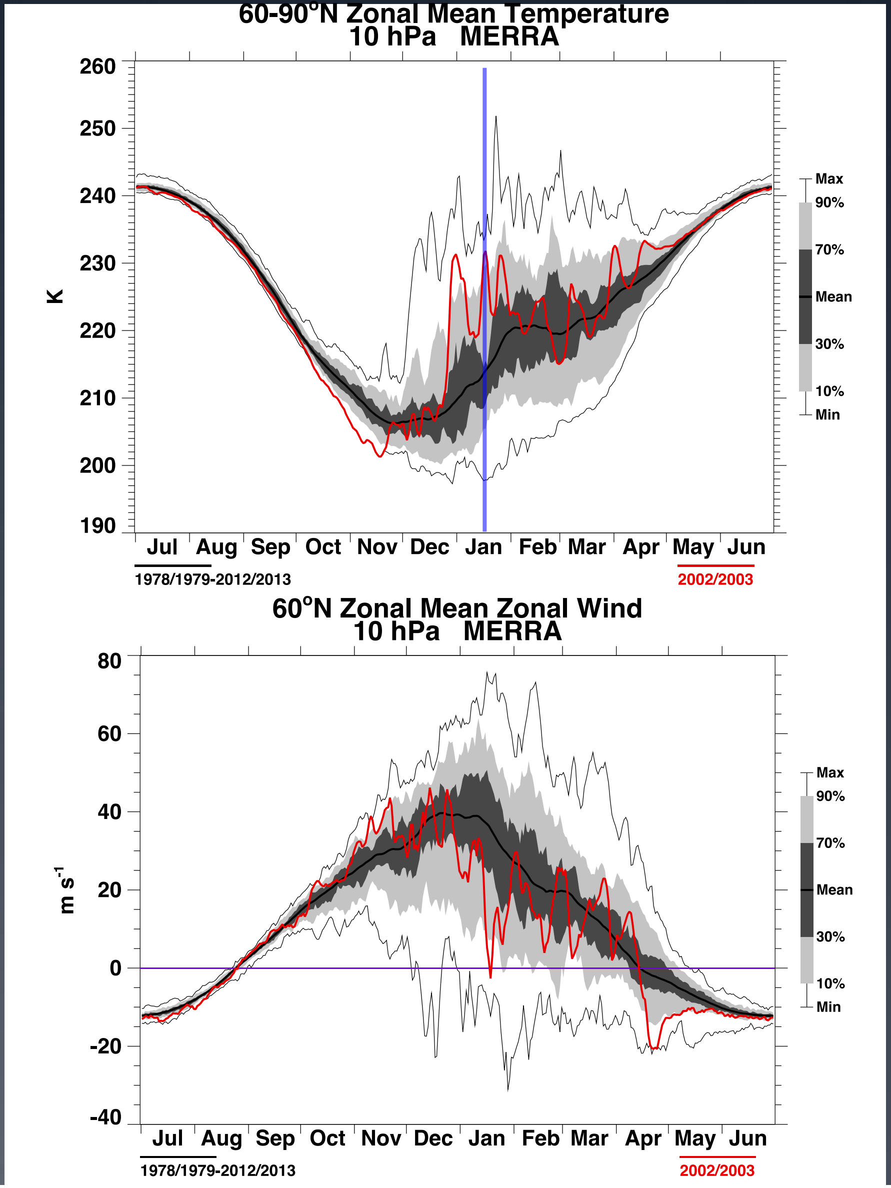
Winter

Westward

Summer

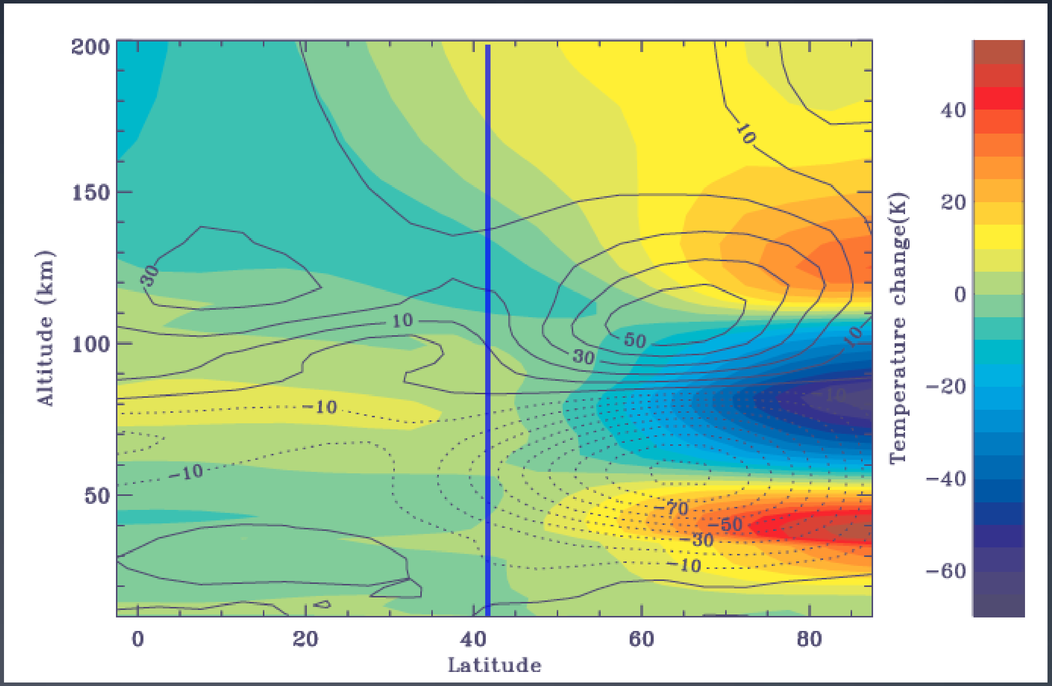
Sudden Stratospheric Warmings

- Caused by wintertime increase in planetary waves (periods ≥ 2 days), which results in a slowing or even reversal of the polar vortex
- Minor SSW: temperature increase (60°-90°N; 10 hPa≈32 km)
- Major SSW: temperature increase (60°-90°N; 10 hPa) + mean zonal wind reversal (60°N; 10 hPa)
- Nearly all of the major SSWs have occurred in the Northern Hemisphere



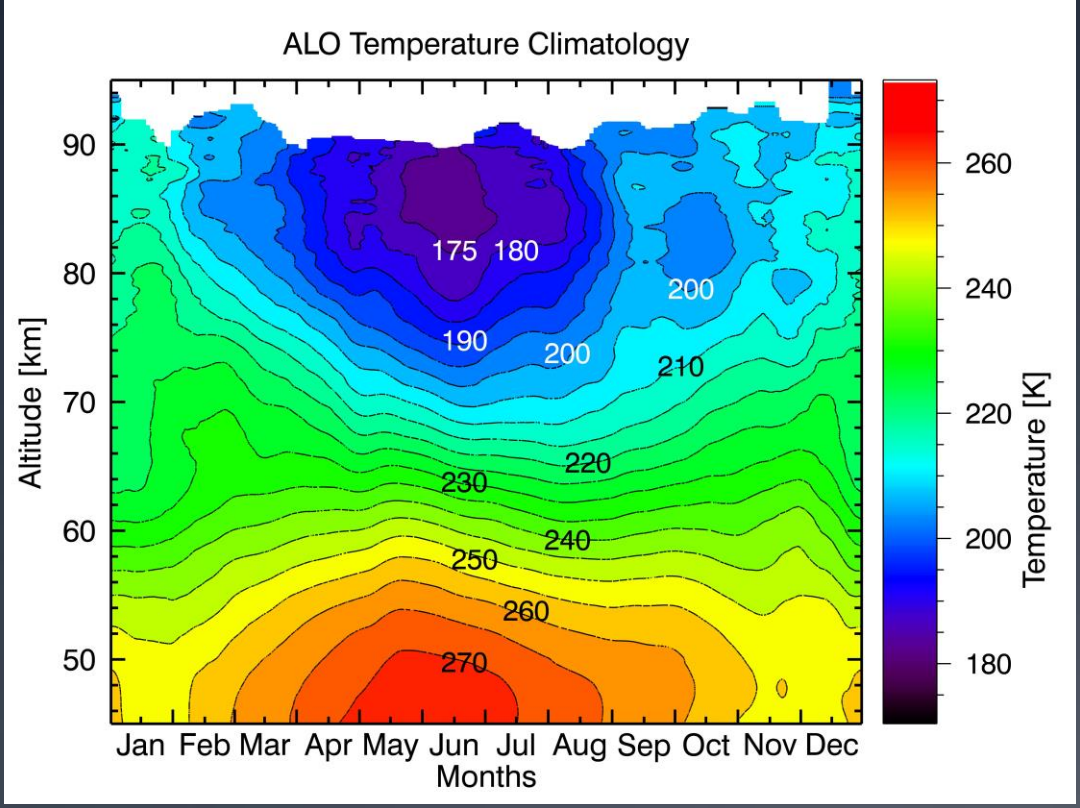
Previous SSW Studies

* Whiteway and Carswell (1994), Von Zahn, et al. (1998), Walterscheid, et al. (2000), and Liu and Roble (2002) report coolings in the upper mesosphere (~60-80 km), warmings in the lower meosphere (around 50 km) at high latitudes
* Virtually NO change in temperature at mid latitudes (Liu and Roble, 2002)
* Yuan et al. (2012), reported coolings of ~20 K from 80-90 km at mid-latitudes



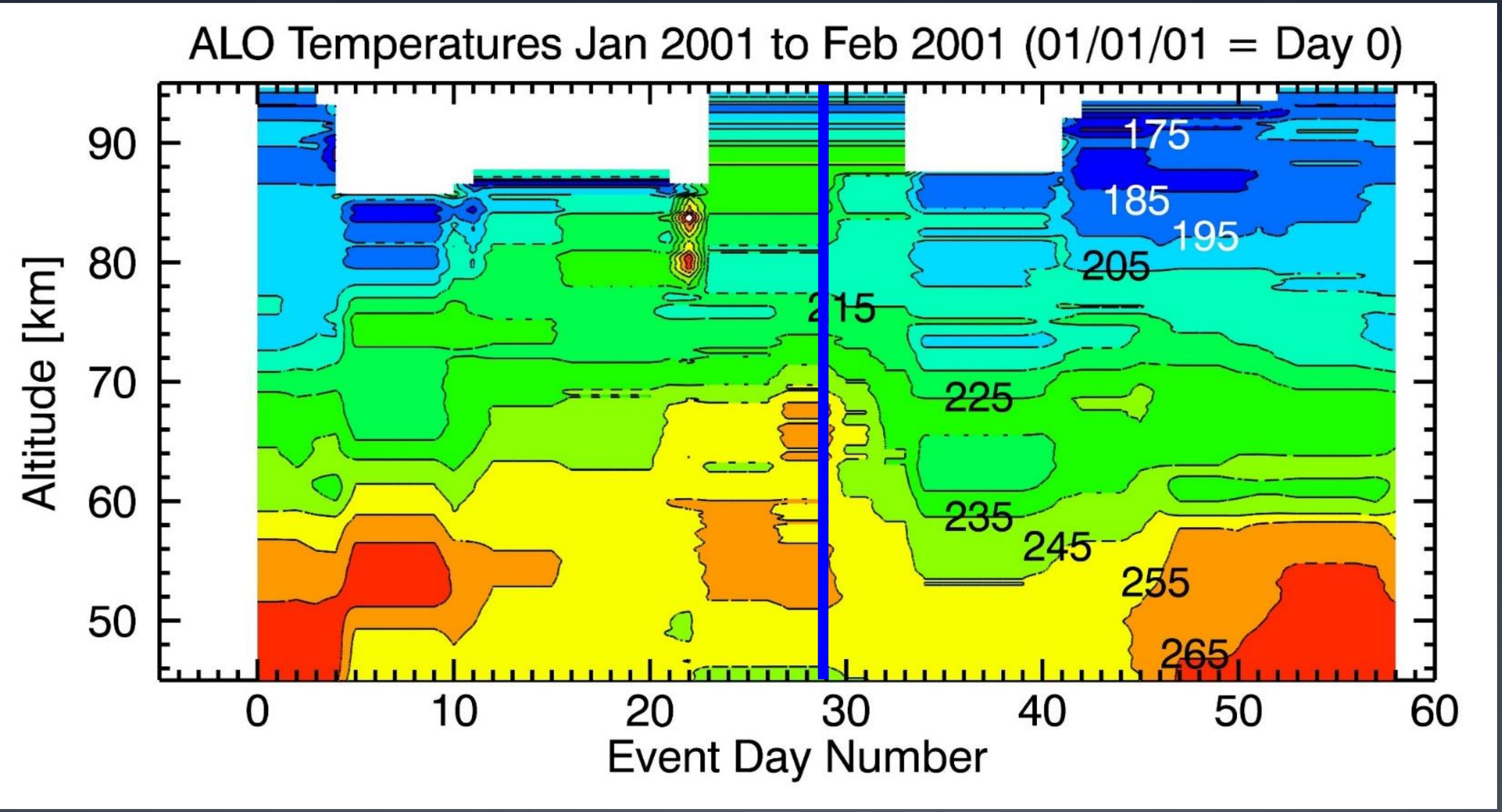
(Liu and Roble, 2002)

ALO Rayleigh Lidar 1993-2004

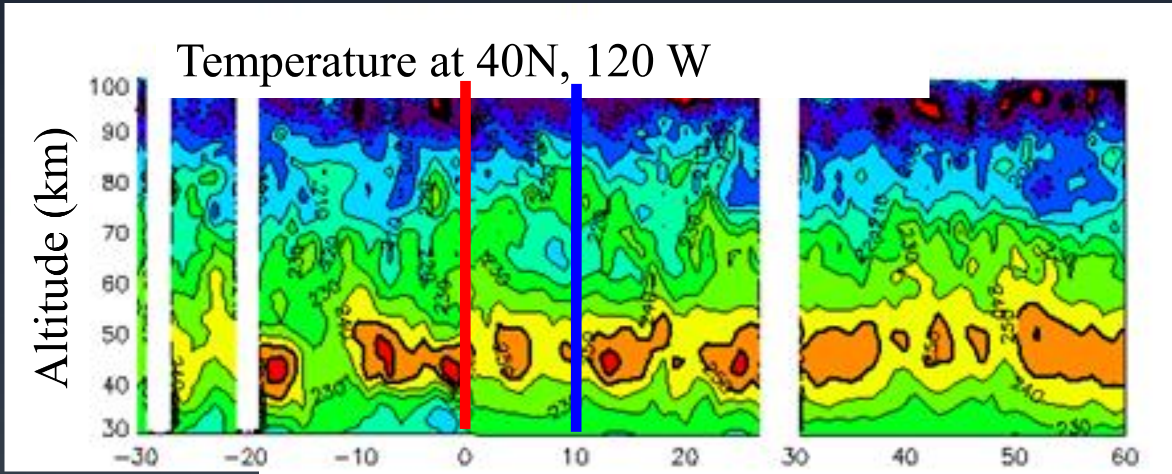


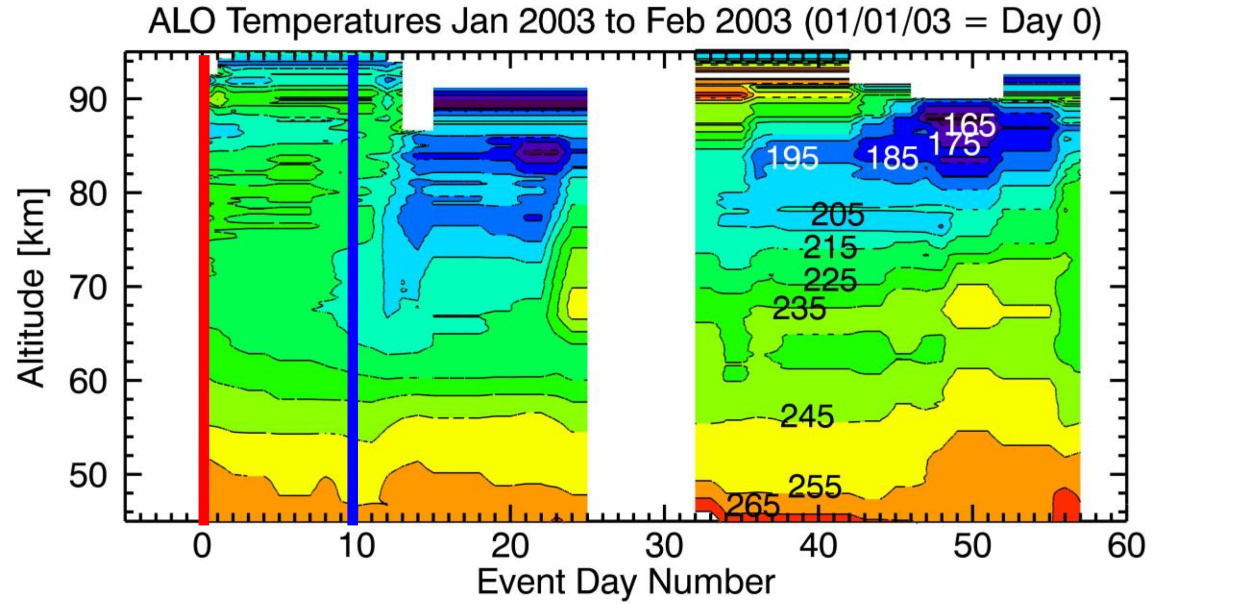
- Located at the Atmospheric Lidar Observatory (ALO; 42°N, 112° W)
- 45-90 km attitude range
- 5000 hours of temperature data taken over 11 years in climatology (*Herron, 2007*)
- Climatological composite year averaged 31 days across and 11 years deep

Mid-Latitude Mesospheric Temperatures - 1 of 2



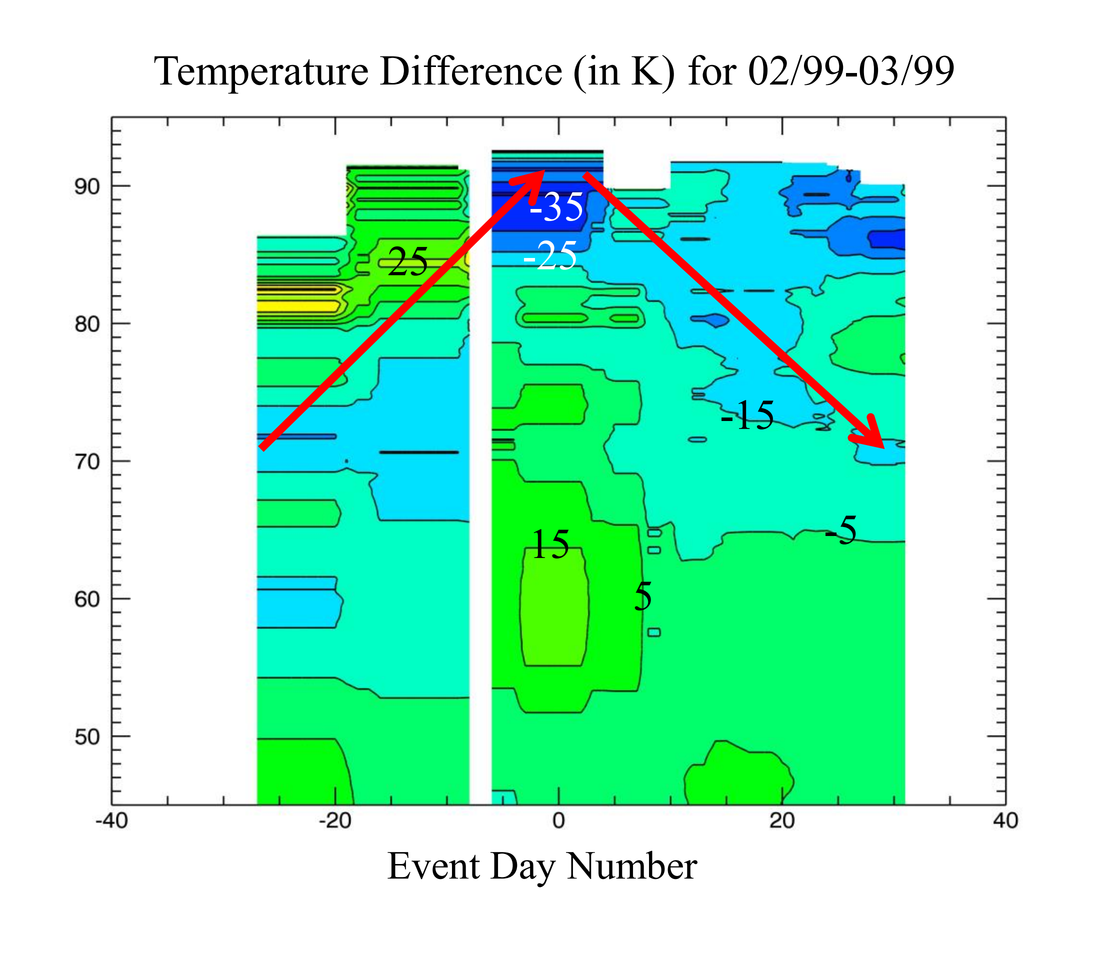
Mid-Latitude Mesospheric Temperatures – 2 of 2



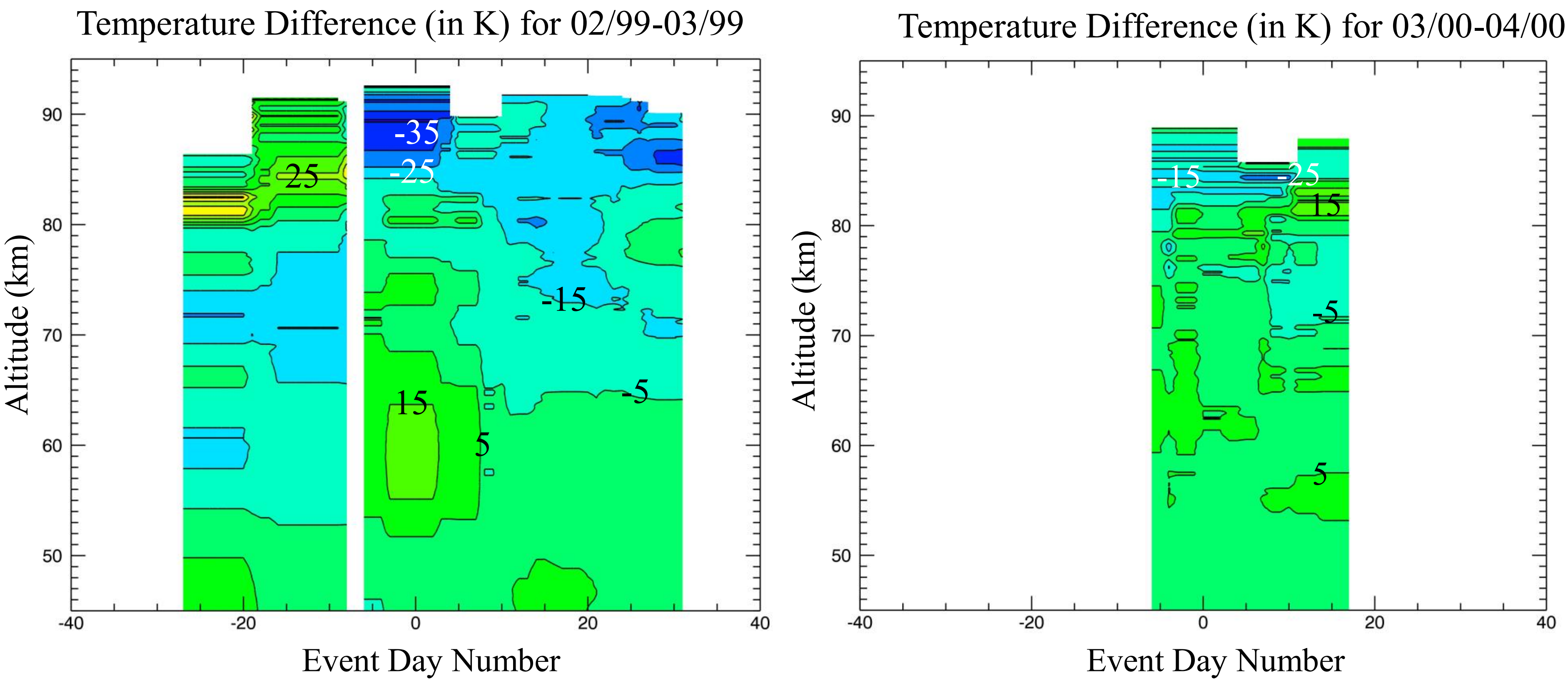


Results

* Coolings and warmings defined by the difference between nightly averaged temperatures and climatological temperatures for that day of the year
* Coolings between -15 and -45 K
* Coolings start at about 70-80 km before peak day, rise to 80-90 km during peak and lower again to 70-90 km afterward
* Warmings between 15 and 25 K
* Warmings stationed in lower mesosphere from 50-70 km

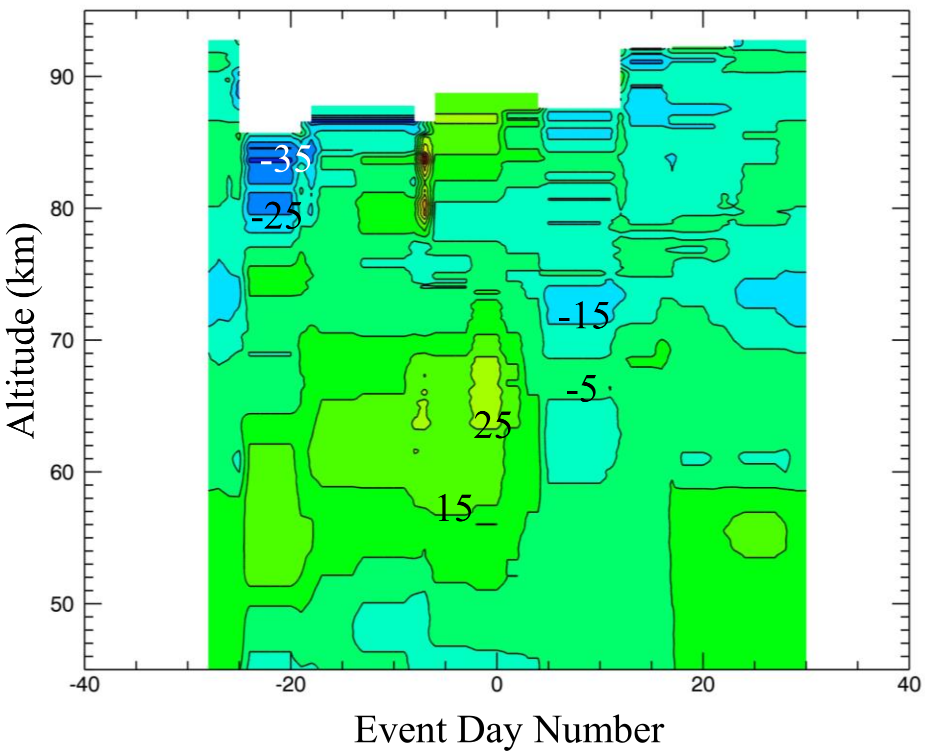


Results-1 of 3

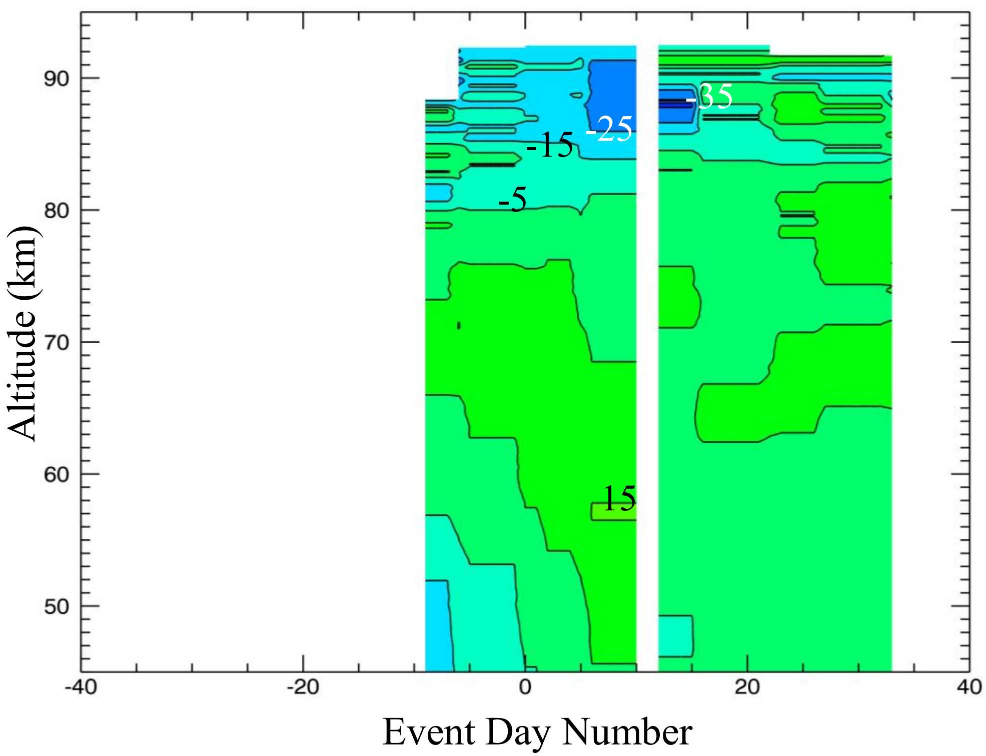


Results-2 of 3

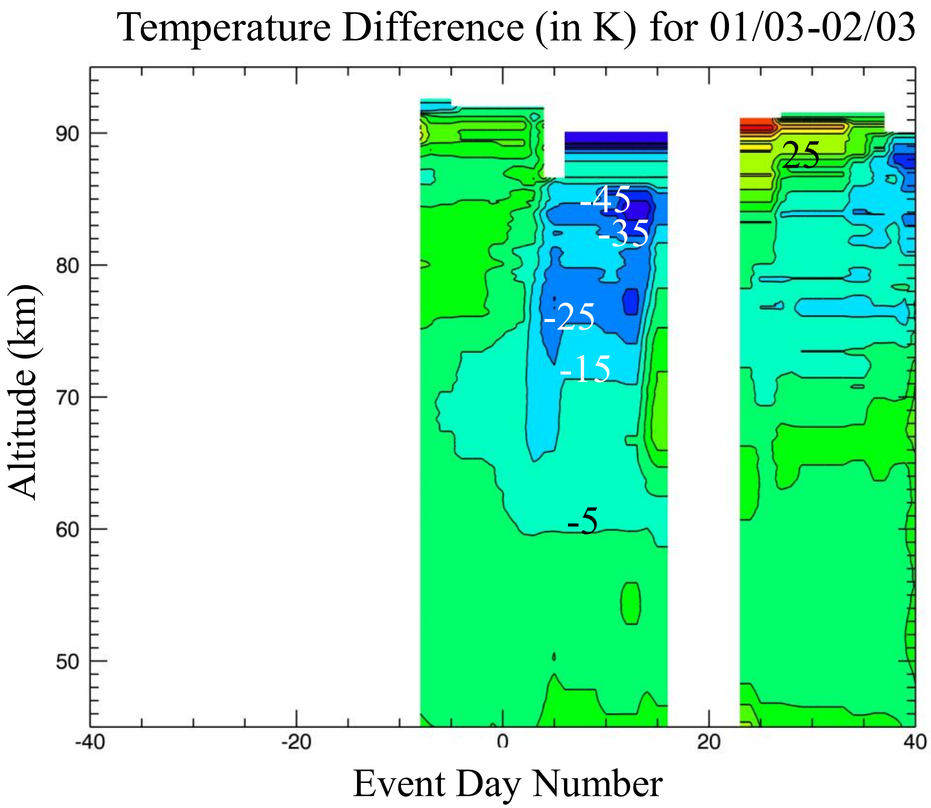
Temperature Difference (in K) for 01/01-02/01

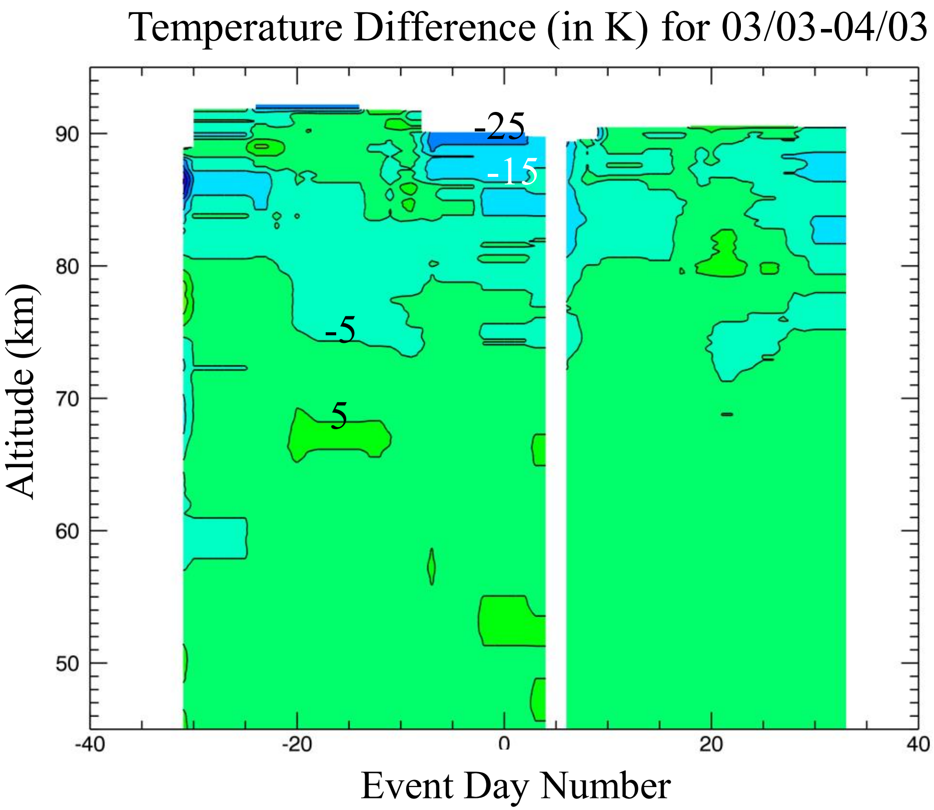


Temperature Difference (in K) for 02/02-03/02



Results-3 of 3

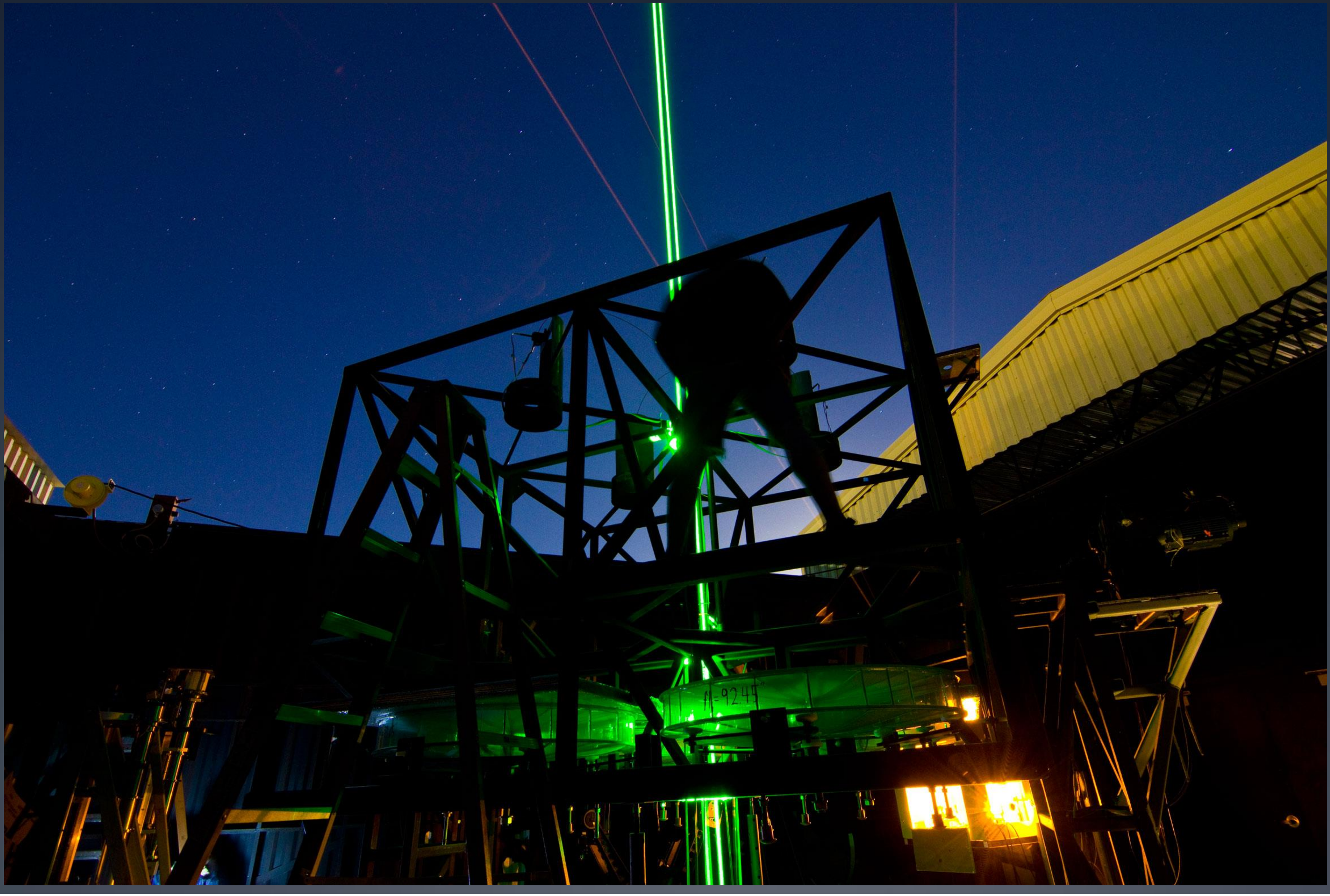




Conclusions

* A general cooling pattern was found in the upper mesosphere using mid-latitude rayleigh lidar data acquired during six major, Northern Hemisphere SSWs
* The coolings had magnitudes of 15-45 K.
* The temporal evolution of this phenomena showed coolings at altitudes of 70-90 km that then rise to 80-90 km while becoming colder near the peak of the SSW and finally descend back to 70-90 km while lessening in strength as the SSW descends from its peak.
* Similar coolings were shown at high latitudes previously, whereas these coolings happened at mid-latitude
* Similar cooling magnitudes and altitudes to previous mid-latitude study

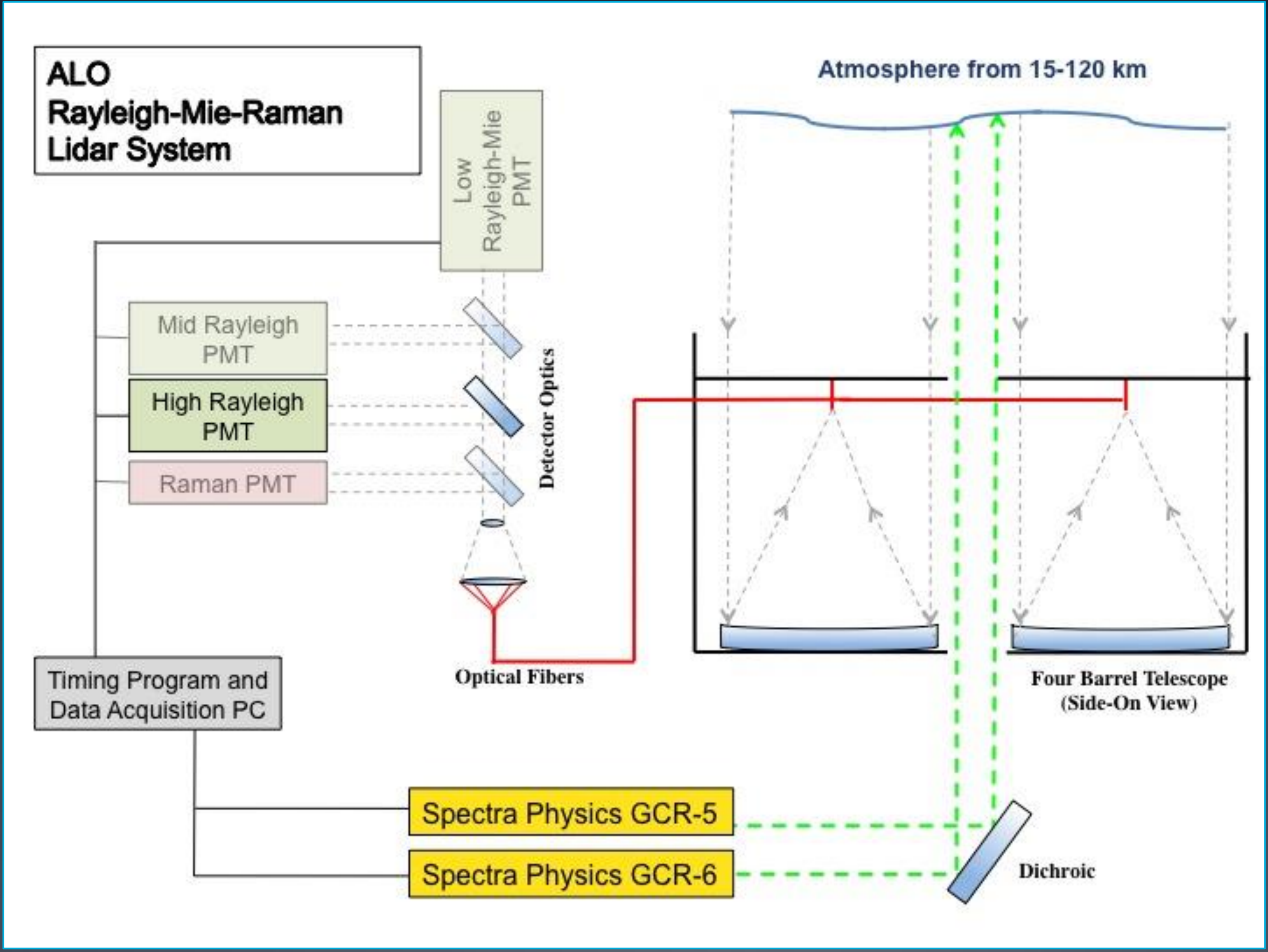
New Rayleigh-Mie-Raman Scatter Lidar



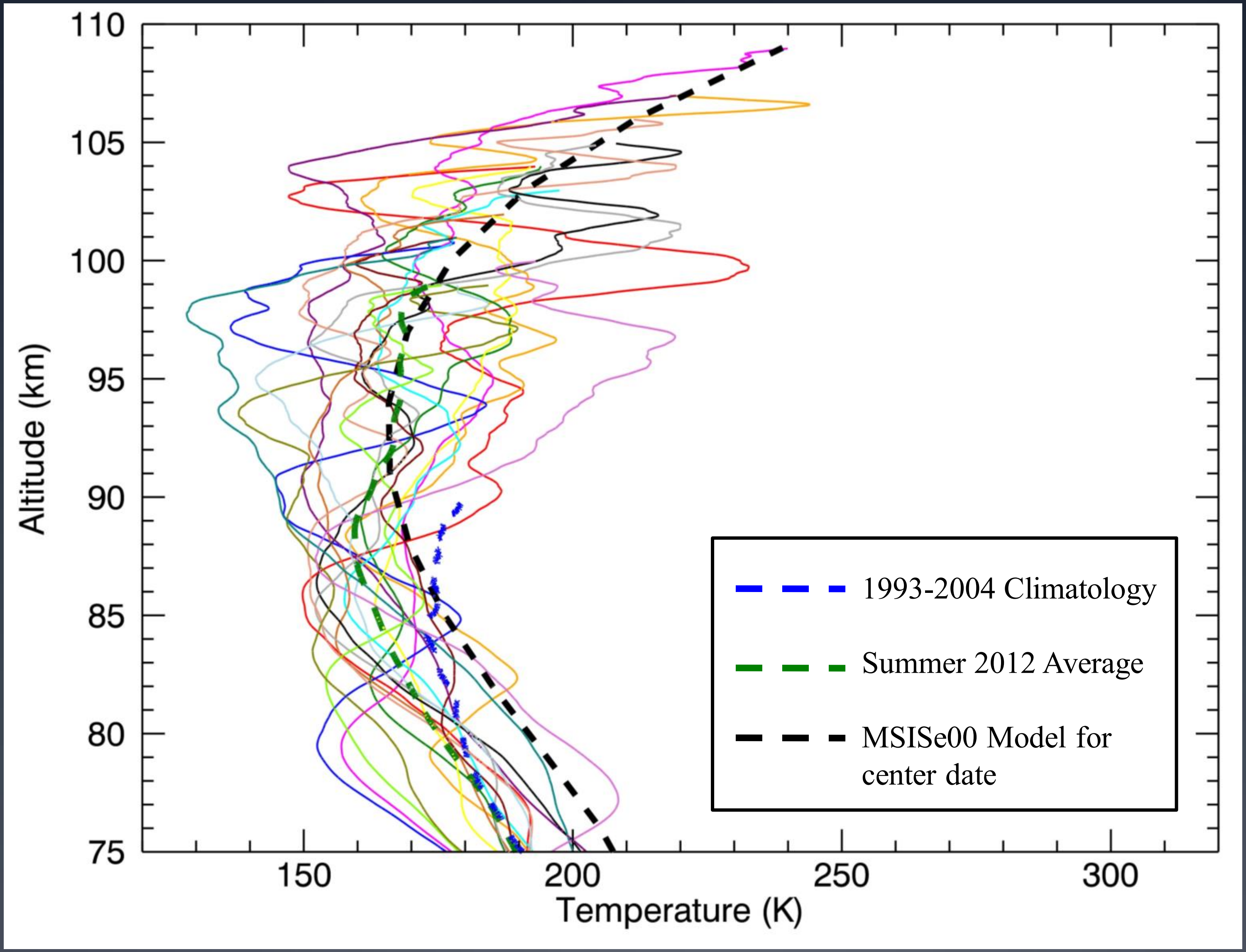
System Upgrades

* Original ALO Rayleigh lidar system
  - Laser power ~21 W at 532 nm & 0.15 m^2 collecting area—PAP ≈ 3.1 Wm^2
  - Good data from 45 to ~90 km for 1993 – 2004
* New ALO Rayleigh-Mie-Raman lidar system
  - laser power 42 W at 532 nm, ~4.9 m^2 collecting area—PAP ≈ 206 Wm^2
  - Data altitude range from 15 to 120 km
  - This dynamic range will be achieved by using 4 PMT detector channels: 2 Rayleigh scatter channels, 1 Rayleigh-Mie scatter channel and 1 Raman scatter channel

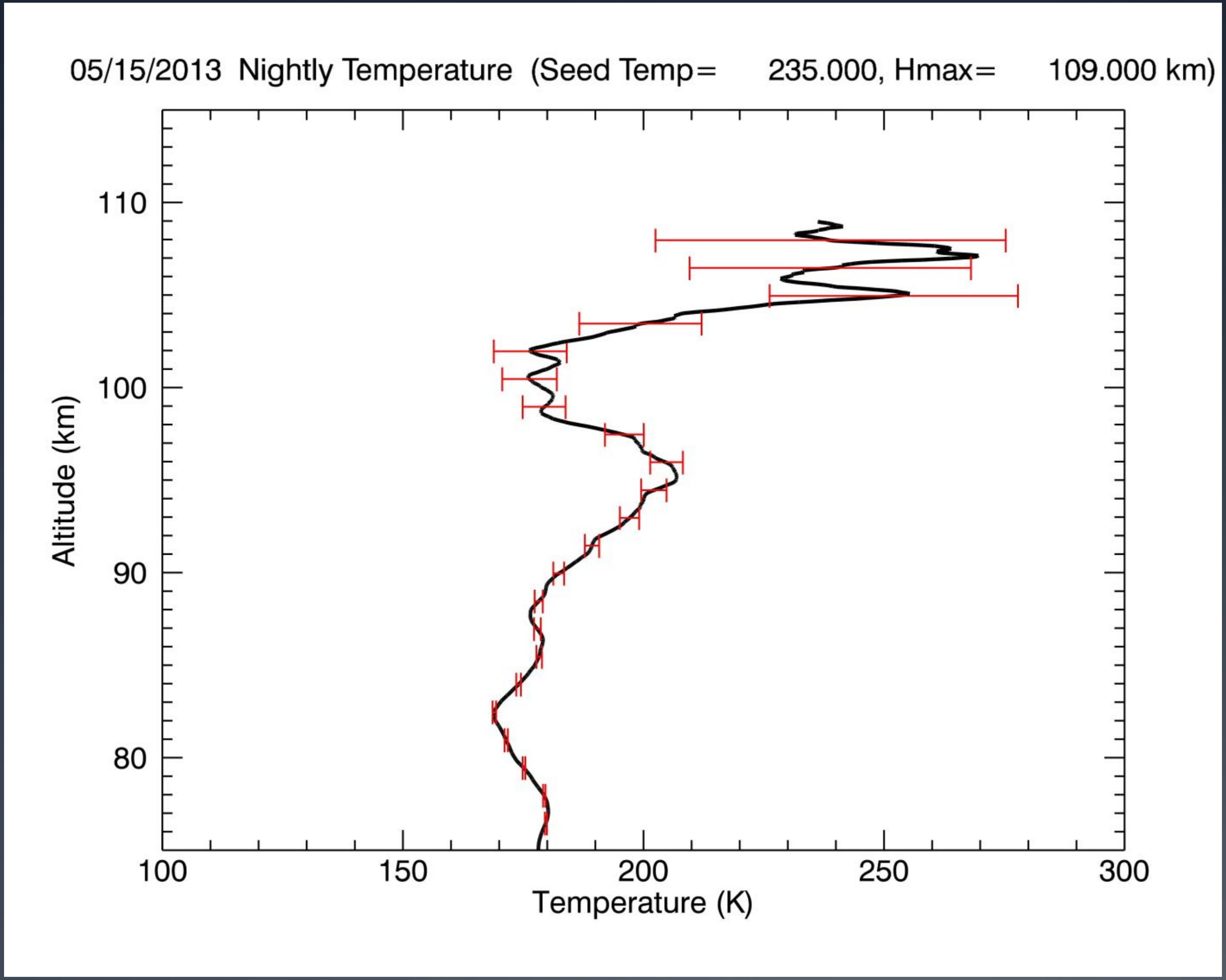
System Upgrades



June-July 2012 Campaign

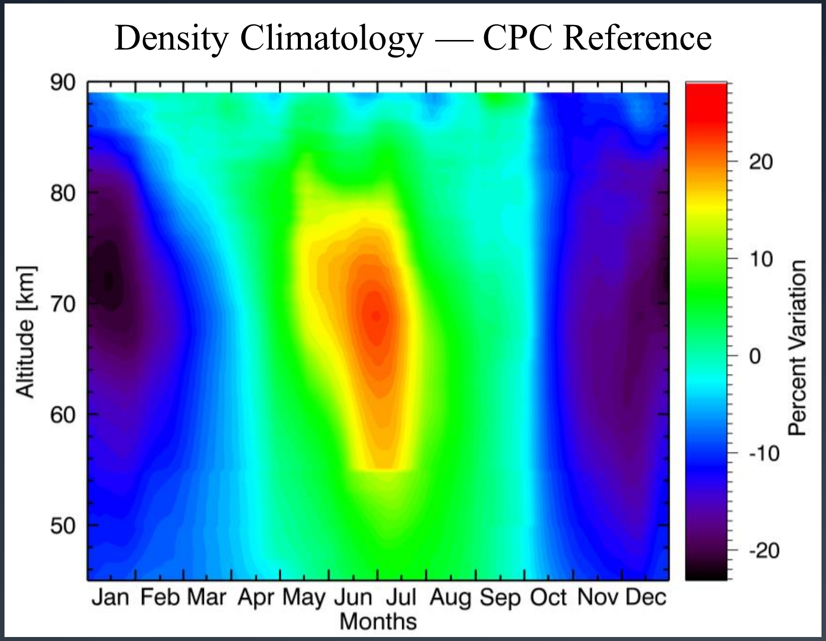


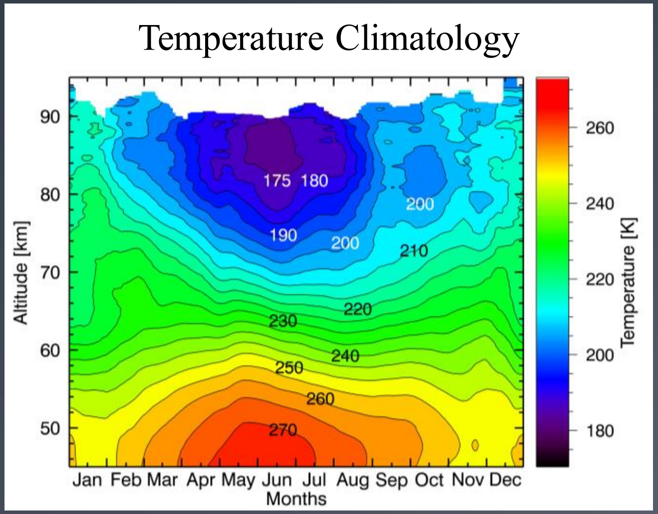
Temp Profile from May 2013



2 hours of data

Scientific Applications





* Temperature Climatology
* Noctilucent Clouds
* Thin Aerosol Layers
* Mesospheric Inversion Layers
* Characterization of Mesopsheric Gravity Waves
* Upward Propagation of Gravity Waves-Growth and Energy Loss
* Climatological Trends in Temperatures from 11 Years of Data
* Solar Cycle Effects on Temperatures
* Sudden Stratospheric Warmings

What's Next for the RMR Lidar

- Installing all of the detector optics and hardware
- Implementing new data reduction methods to increase altitude range higher (*Khanna 2012*)
- Making continuous observations!
- Preparing the telescope cage for rotating and scanning functionality

Thomas Amely

Interested in Working with Us?

Vincent Wickwar, PI

vincent.wickwar@gmail.com

Leda Sox, Grad Student

leda.sox@gmail.com

Website: www.usurayleighlidar.com

Thomas Amely

References

* Whiteway, J. A., Carswell, A. I., Rayleigh Lidar Observations of Thermal Structure and Gravity Wave Activity in the High Arctic during a Stratospheric Warming, *J. Atmos. Sci.*, Vol. 51, No. 21, Pages 3122-3136, 1994.

* Von Zahn, U., Fielder, J., Naujokat, B., Langematz, U., Kruger, K., A note on record-high temperatures at the northern polar stratopause in winter 1997/1998, , *Geophys. Res. Lett.*, Vol. 25, No. 22, Pages 4169-4172, 1998.

* Walterscheid, R. L., Sivjee, G. G., Roble, R. G., Mesospheric and Lower Thermospheric Manifestations of a Stratospheric Warming Event Over Eureka, Canada (80°N), *Geophys. Res. Lett.*, Vol. 27, No. 8, Pages 2897-2900, 2000.

* Liu, H.-L., and R. G. Roble, A study of a self-generated stratospheric sudden warming and its mesospheric–lower thermospheric impacts using the coupled TIME-GCM/CCM3, *J. Geophys. Res.*, 107(D23), 4695, doi:10.1029/2001JD001533, 2002.

* Yuan, T., B. Thurairajah, C.-Y. She, A. Chandran, R. L. Collins, and D. A. Krueger (2012), Wind and temperature response of midlatitude mesopause region to the 2009 Sudden Stratospheric Warming, J. Geophys. Res., 117, D09114, doi:10.1029/2011JD017142, 2012.

* Khanna, J., Bandoro, J., Sica, R. J., McElroy, C. T., New technique for retrieval of atmospheric temperature profiles from Rayleigh-scatter lidar measurements using nonlinear inversion. *Appl. Opt., 51*, *7945-7952*, 2012.