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

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

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USU Physics Colloquium
September 10, 2013
The Atmosphere

Middle and Upper Atmosphere

Lower Atmosphere

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Rayleigh Lidar Observations of SSWs and New RMR Lidar at USU
Sept 10, 2013
Aeronomy Professors at USU

Bela Fejer  
Ludger Scherliess  
Robert Schunk  
Jan Sojka

Michael Taylor  
Vincent Wickwar  
Tao (Titus) Yuan  
Lie Zhu
Global Aeronomy Terms-Directions

Vertical

Zonal

Meridional
The Polar Vortex

Winter → Eastward

Westward ← Summer

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

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Sept 10, 2013
Sudden Stratospheric Warmings

- Caused by wintertime increase in planetary waves (periods $\geq 2$ 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


- 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
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

ALO Temperatures Jan 2001 to Feb 2001 (01/01/01 = Day 0)

Altitude [km]

Event Day Number

50 60 70 80 90

0 10 20 30 40 50 60

175 185 195 205 215 225 235 245 255 265
Mid-Latitude Mesospheric Temperatures – 2 of 2

Temperature at 40N, 120 W

ALO Temperatures Jan 2003 to Feb 2003 (01/01/03 = Day 0)
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
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Results - 2 of 3

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

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

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Results-3 of 3

Temperature Difference (in K) for 01/03-02/03

Temperature Difference (in K) for 03/03-04/03

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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

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System Upgrades

* Original ALO Rayleigh lidar system
  - Laser power ~21 W at 532 nm & 0.15 m² collecting area—PAP ≈ 3.1 Wm²
  - 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 m² collecting area—PAP ≈ 206 Wm²
  - 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

ALO Rayleigh-Mie-Raman Lidar System

Mid Rayleigh PMT

High Rayleigh PMT

Raman PMT

Timing Program and Data Acquisition PC

Optical Fibers

Atmosphere from 15-120 km

Four Barrel Telescope (Side-On View)

Spectra Physics GCR-5

Spectra Physics GCR-6

Dichroic
June-July 2012 Campaign

1993-2004 Climatology

Summer 2012 Average

MSISE00 Model for center date
Temp Profile from May 2013

05/15/2013 Nightly Temperature (Seed Temp = 235.000, Hmax = 109.000 km)

2 hours of data
Scientific Applications

- Temperature Climatology
- Noctilucent Clouds
- Thin Aerosol Layers
- Mesospheric Inversion Layers
- Characterization of Mesospheric 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
Interested in Working with Us?

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References


