8-27-2013

Multi-year Observations of Mid-latitude Middle Atmospheric Winds, Waves, and Temperature associated with SSW Events over Northern Utah

Chad Fish
Space Dynamics Laboratory, Utah State University

Vincent B. Wickwar
Utah State University

B. Thurairajah
Virginia Tech

Jan J. Sojka
Utah State University

F. T. Berkey
Utah State University

S. Bailey
Virginia Tech

Follow this and additional works at: https://digitalcommons.usu.edu/atmlidar_presentations

Part of the Atmospheric Sciences Commons, and the Physics Commons

Recommended Citation
Fish, Chad; Wickwar, Vincent B.; Thurairajah, B.; Sojka, Jan J.; Berkey, F. T.; Bailey, S.; Yuan, Titus; Taylor, Michael J.; Mitchell, N.; and Hocking, W., "Multi-year Observations of Mid-latitude Middle Atmospheric Winds, Waves, and Temperature associated with SSW Events over Northern Utah" (2013). International Association of Geomagnetism and Aeronomy, Presentations. Paper 8.
https://digitalcommons.usu.edu/atmlidar_presentations/8

This Presentation is brought to you for free and open access by the Green Beam (Rayleigh-Scatter LIDAR) at DigitalCommons@USU. It has been accepted for inclusion in Presentations by an authorized administrator of DigitalCommons@USU. For more information, please contact rebecca.nelson@usu.edu.
Multi-year Observations of Mid-latitude Middle Atmosphere Winds, Waves, and Temperature associated with SSW Events over Northern Utah

IAGA 2013, Paper 2.5-16

C. Fish¹,³, V. Wickwar², L. Sox², B. Thurairajah³, J. Sojka², F.T. Berkey⁴, S. Bailey³, T. Yuan², M. Taylor², N. Mitchell⁵, W. Hocking⁶

1. Space Dynamics Laboratory – Utah State University, US
2. Center for Atmospheric and Space Sciences – Utah State University, US
4. Utah State University, US
5. University of Bath - Centre for Space, Atmospheric & Oceanic Science, UK
6. University of Western Ontario – Atmospheric Dynamics Group, CA

Corresponding author: chad.fish@sdll.usu.edu
Instruments and Data Sets
Instrument Site Map

Limb Viewing, 625 km, 74.1° incl

[41.4° N, 111.5° W]

[41.9° N, 111.4° W]

TIMED SABER

ALO Rayleigh-scatter Lidar

BLO MWR

BLO MF IDI Radar
Database – Over 2 Decades of Observations

**Instrument** | **Recorded Observations**
--- | ---
IDI | 5 min, continuous
MWR | 60 min, continuous
RSL | Nightly averages, intermittent
SABER | ~ 2/day, continuous

SMLT = Stratosphere, Mesosphere, Lower Thermosphere

**Timeline**

- 1993
- 1998
- 2003
- 2008
- 2013

**ALO Rayleigh-scatter Lidar: SM Temp**

**BLO IDI: SMLT Winds, Waves**

**BLO MWR: MLT Winds, Waves, Temp**

**SABER: SMLT Temp, Pressure, Geopotential (Winds, Waves)**
Instrument Cross-Calibration/Comparison

BLO IDI/MWR: 2000-2001


RSL/SABER: 2002

From “Herron, J.P., Mesospheric Temperature Climatology Above Utah State University, Master’s Thesis, 2004”
Event Definition
Classification of SSW Events

Minor Northern Sudden Stratospheric Warming Event: midwinter polar temperatures increase by 25 K or more within a week at any stratospheric level [WMO 1978, item 9.4, 35–36]

Major Northern Sudden Stratospheric Warming Event: zonal-mean temperature increase is accompanied by a reversal of the net zonal-mean winds from westerly (eastward) to easterly (westward) north of 60 °N at 10 hPa (i.e., breakdown or major displacement of polar vortex)
Major Event Co-incident Data Sets

Table 1. Major Northern SSW events since 1999

<table>
<thead>
<tr>
<th>Date</th>
<th>Wind Shift (m/s)</th>
<th>Temperature Shift (°)</th>
<th>Measurement Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan – Mar 2001</td>
<td>50</td>
<td>35</td>
<td>IDI, RSL, MWR</td>
</tr>
<tr>
<td>Dec 2001 – Jan 2002</td>
<td>40</td>
<td>35</td>
<td>IDI, RSL</td>
</tr>
<tr>
<td>Jan - Feb 2003</td>
<td>40</td>
<td>25</td>
<td>IDI, RSL, SABER</td>
</tr>
<tr>
<td>Dec 2003 – Feb 2004</td>
<td>60</td>
<td>30</td>
<td>IDI, RSL, SABER</td>
</tr>
<tr>
<td>Dec 2005 – Feb 2006</td>
<td>70</td>
<td>40</td>
<td>SABER</td>
</tr>
<tr>
<td>Feb - Mar 2007</td>
<td>55</td>
<td>20-25</td>
<td>SABER</td>
</tr>
<tr>
<td>Feb 2008</td>
<td>65</td>
<td>25</td>
<td>SABER</td>
</tr>
<tr>
<td>Jan – Mar 2009</td>
<td>100</td>
<td>55</td>
<td>MWR, SABER</td>
</tr>
<tr>
<td>Jan – Mar 2010</td>
<td>60</td>
<td>35</td>
<td>MWR, SABER</td>
</tr>
<tr>
<td>Dec 2012 – Feb 2013</td>
<td>40</td>
<td>35</td>
<td>MWR, SABER</td>
</tr>
</tbody>
</table>

1At 60° N, 10 hPa, 2At 60-90° N, 10 hPa

See “The mid-latitude mesosphere’s response to sudden stratospheric warmings as determined from Rayleigh lidar temperatures, Sox, Leda; Wickwar, Vincent B.; Fish, Chad; Herron, Joshua P. ; paper 2.5-14 IAGA 2013” for pre-1999 events RSL observations
Climatology over Northern Utah
Tides and PWs

Planetary waves

Tides
SSW Events over Northern Utah
Minor event in early winter, followed by a major event in January/February 2001
Marked reversal in zonal and meridional mean winds over SMLT region at the onset of the major SSW event over Northern Utah. This is a typical feature in the major SSW events observations over Northern Utah. The winds reverse at higher altitudes and quickly descend into lower altitudes.

Strong reversal in vertical mean wind over SMLT region during formation of SSW is not a typical feature in the observations over Northern Utah. This is unique to this major SSW event.
Intense planetary wave activity is seen in the zonal and meridional components during the period of the SSW activity, followed by a relatively quiet planetary wave environment. At the onset of the SSW, the planetary wave structure (e.g., planetary wave modes) changes.
Temperatures

SSW Onset

Cooling in Mesosphere during formation and onset of SSW event, followed by warming in the Stratosphere and lower Mesosphere, then followed by cooling in the Mesosphere again

From “Sox et al; paper 2.5-14 IAGA 2013”
Winter 2002-2003

Major event in January 2003.
Intense planetary wave activity is seen in the zonal and meridional components during the period of the SSW activity, followed by a relatively quiet period. At the onset of the SSW, the planetary wave structure (modes) changes.
In addition to the strong change seen in the pattern of the derived zonal mean winds over the SMLT region at the time of the SSW onset, the derived EPD is distinctly negative (indicating planetary wave activity) during the SSW event.

This event initiated predominantly by planetary wave 1 activity, which is seen to be the strongest mode for this event. The major SSW events for the past decade are a result of primarily planetary wave 1 or 2 interactions (or a even mixture of both).
Cooling in Mesosphere during formation and onset of SSW event, followed by warming in the Stratosphere, then followed by cooling in the Mesosphere again.
Winter 2008-2009

“Model” major event in January/February 2009
Mean Winds and Waves

SSW Onset

MWR Mean Winds

BLO Mean Zonal Wind

SSW Onset

MWR Planetary Waves

BLO 91 km Zonal Spectral Analysis

Wind reversal

SABER Zonal Mean Winds

BLO Mean Meridional Wind

SSW Onset

BLO 91 km Meridional Spectral Analysis

SABER EPD

Divergence of EP Flux at 40N

Daynumber (1 = 1 January 2009)
Cooling in Mesosphere during formation and onset of SSW event, followed by warming in the Stratosphere, then followed by cooling in the Mesosphere again.
Winter 2012-2013

Major event this last winter; January/February 2013
Cooling in Mesosphere during formation and onset of SSW event, followed by warming in the Stratosphere, then followed by cooling in the Mesosphere again.
In Conclusion
Summary Table of Event Characteristics

Consistent pattern of wind reversal and reversal directions at all altitudes during SSW event onset.

<table>
<thead>
<tr>
<th>Date (Event)</th>
<th>PW Type</th>
<th>Formation Period</th>
<th>Onset Period</th>
<th>Low Therm</th>
<th>Post-Onset Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Strat (&lt; 50 km)</td>
<td>Meso (&lt; 90 km)</td>
<td>Strat (&lt; 50 km)</td>
<td>Meso (&lt; 90 km)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Temp</td>
<td>Wind</td>
<td>Temp</td>
<td>Wind</td>
</tr>
</tbody>
</table>

Consistent pattern of Mesospheric cooling prior to and following onset of SSW event.
Conclusions

The combination of BLO IDI and MWR, SABER, and ALO RSL observations provides an ongoing northern mid-latitude SMLT database for multi-decade and individual event studies.

Significant changes in wind, wave, and temperature patterns occur in the SMLT region at northern mid-latitudes during major SSW events (and minor events, although not reviewed in this presentation). They are distinct and repeatable from event to event.

Westward and southward winds dominate at all altitudes during the onset of a major SSW event. The change to westward zonal winds occurs in Mesosphere before changing in the Stratosphere (descending wind effect).

PW1/2 events precede onset of SSW events. The period of local PWs change (however no consistent frequency pattern (i.e., longer to shorter or shorter to longer)) after the buildup and at the onset of the SSW event.

The Mesosphere cools (10s of degrees) prior to and following onset of SSW events. The stratopause increases in altitude to 60-70 km during the onset period.

Still investigating the effects/impacts of major SSW events on Mesospheric and Lower Thermospheric vertical winds.

Also see “Sox et al; paper 2.5-14 IAGA 2013”
Future Considerations

The ALO RSL is being upgraded for future observations. A trial run occurred in summer 2012. See “Wickwar et al; paper 2.5-20 IAGA 2013”

The Na lidar developed at Colorado State University was re-located to USU in 2010 and will provide added wind, temperature, and Na density observations from Northern Utah. See “Yuan et al; JGR, D09114, 2012, doi:10.1029/2011JD017142”

An all-sky imager camera has been deployed at BLO a number of times since 2000. That data will be investigated jointly for gravity wave dynamics and activity during SSW events.

Multi-decadal ionosonde observations exist at BLO, allowing for joint studies of SSW event impacts and dynamics of the middle and upper atmosphere and ionosphere over Northern Utah. This work is currently underway.