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

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

IAGA 2013, Paper 2.5-16

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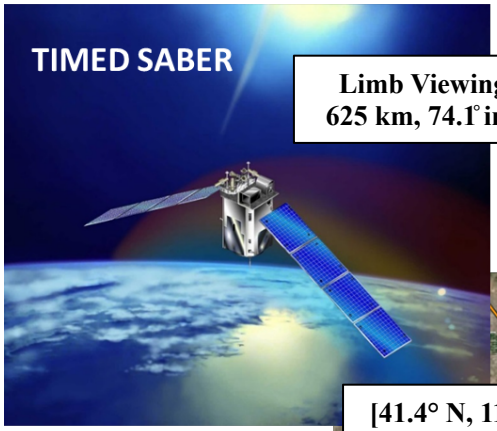
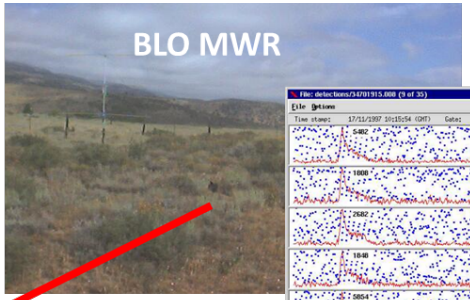
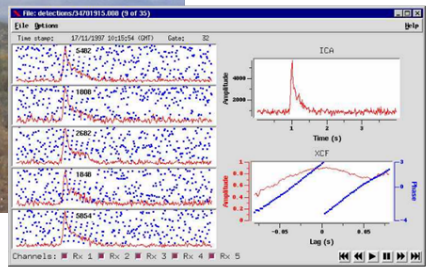
Instruments and Data Sets

Instrument Site Map



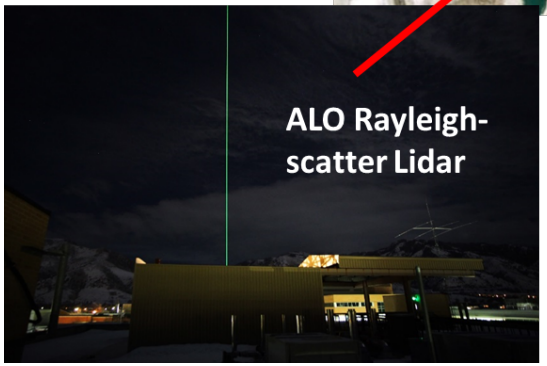
Limb Viewing,
625 km, 74.1° incl



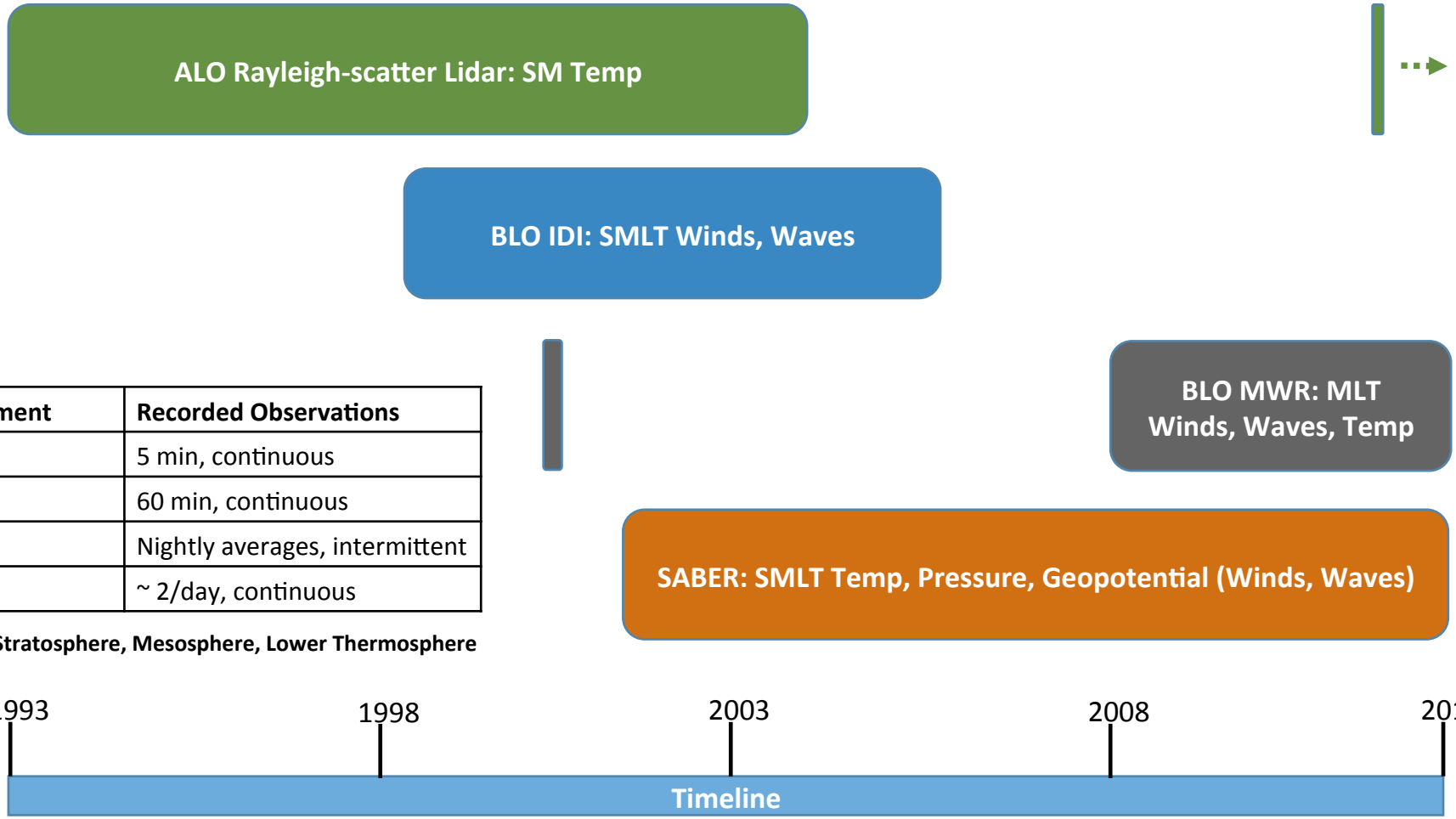


[41.9° N, 111.4° W]

[41.4° N, 111.5° W]



Database – Over 2 Decades of Observations

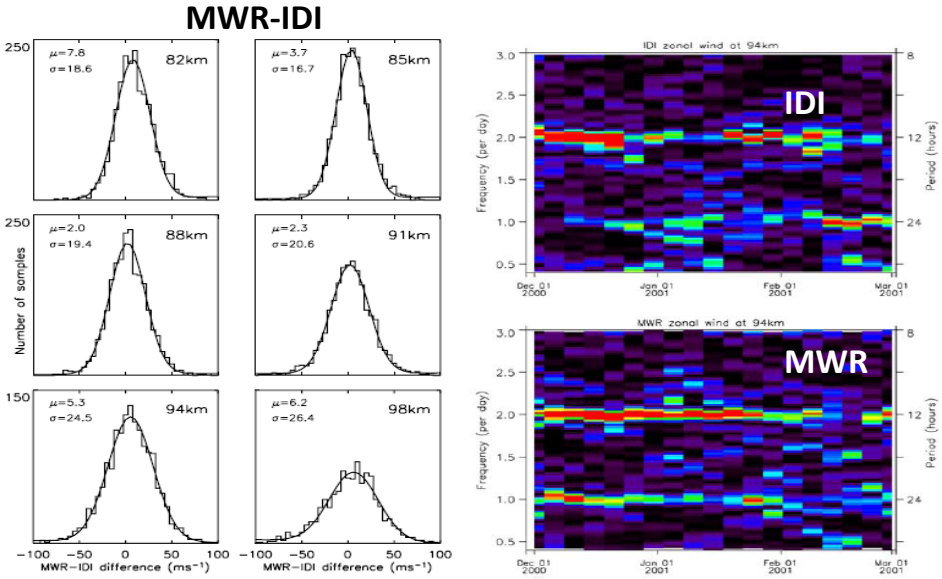


Instrument	Recorded Observations
IDI	5 min, continuous
MWR	60 min, continuous
RSL	Nightly averages, intermittent
SABER	~ 2/day, continuous

SMLT = Stratosphere, Mesosphere, Lower Thermosphere

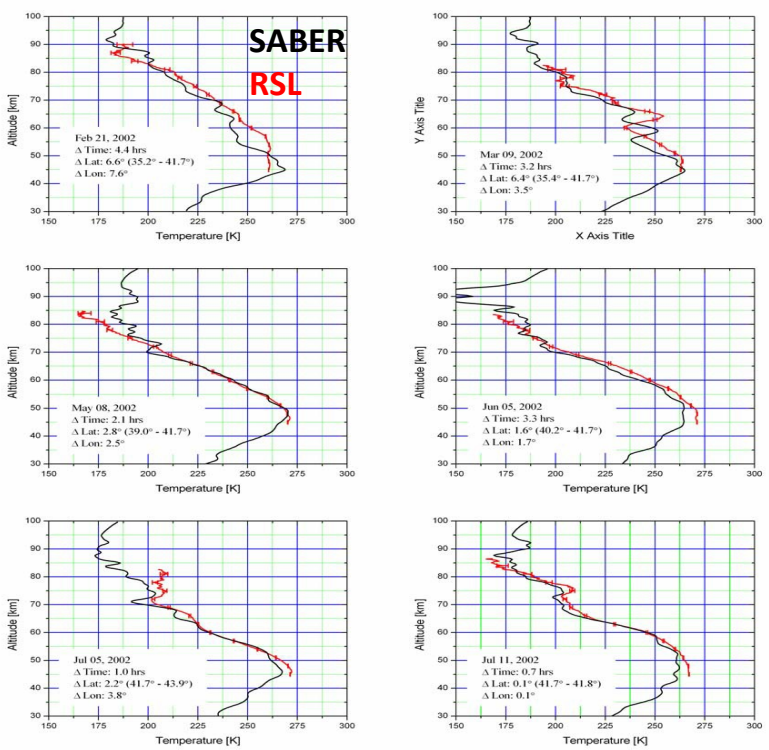
Instrument Cross-Calibration/Comparison

BLO IDI/MWR: 2000-2001



From "Jones, G. O. L., Berkey, F. T., Fish, C. S., Hocking, W. K., and Taylor, M. J., Validation of imaging Doppler interferometer"

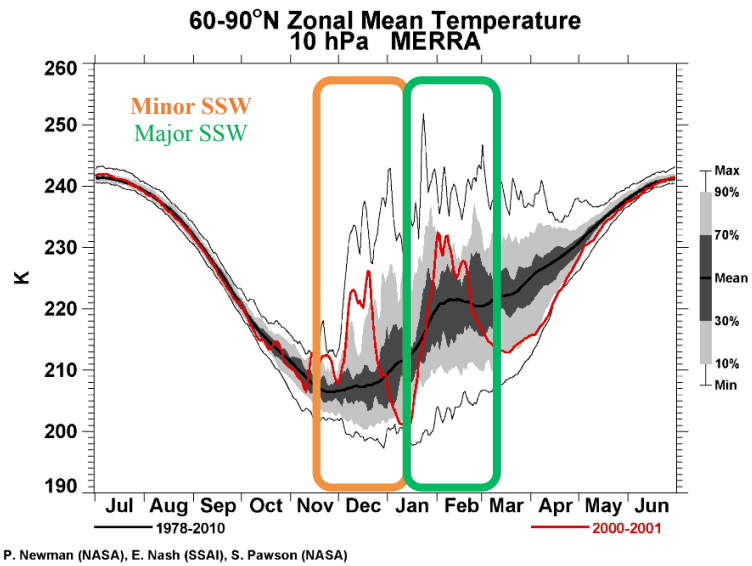
RSL/SABER: 2002

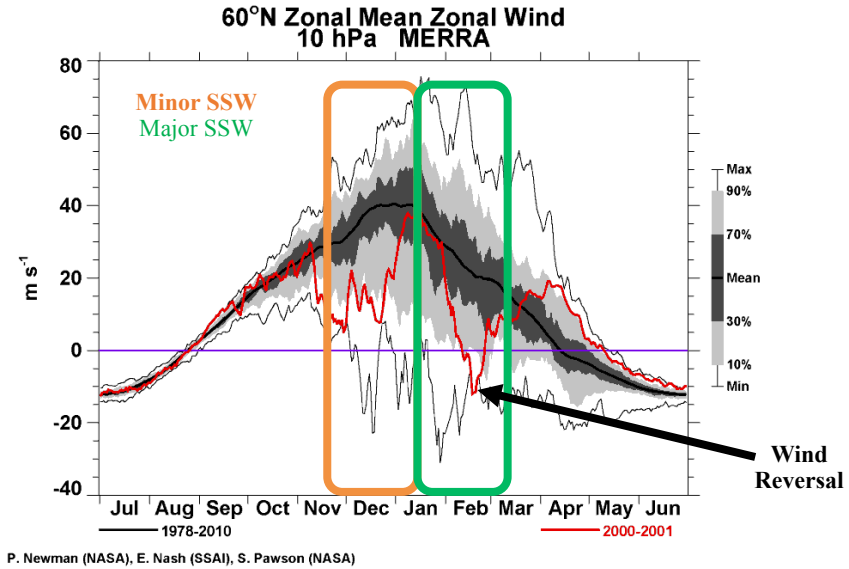


From "Herron, J.P., Mesospheric Temperature Climatology Above Utah State University, Master's Thesis, 2004"

Event Definition

Classification of SSW Events





Courtesy the NASA Modern-Era Retrospective Analysis for Research and Applications (MERRA) stratospheric meteorological database

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)

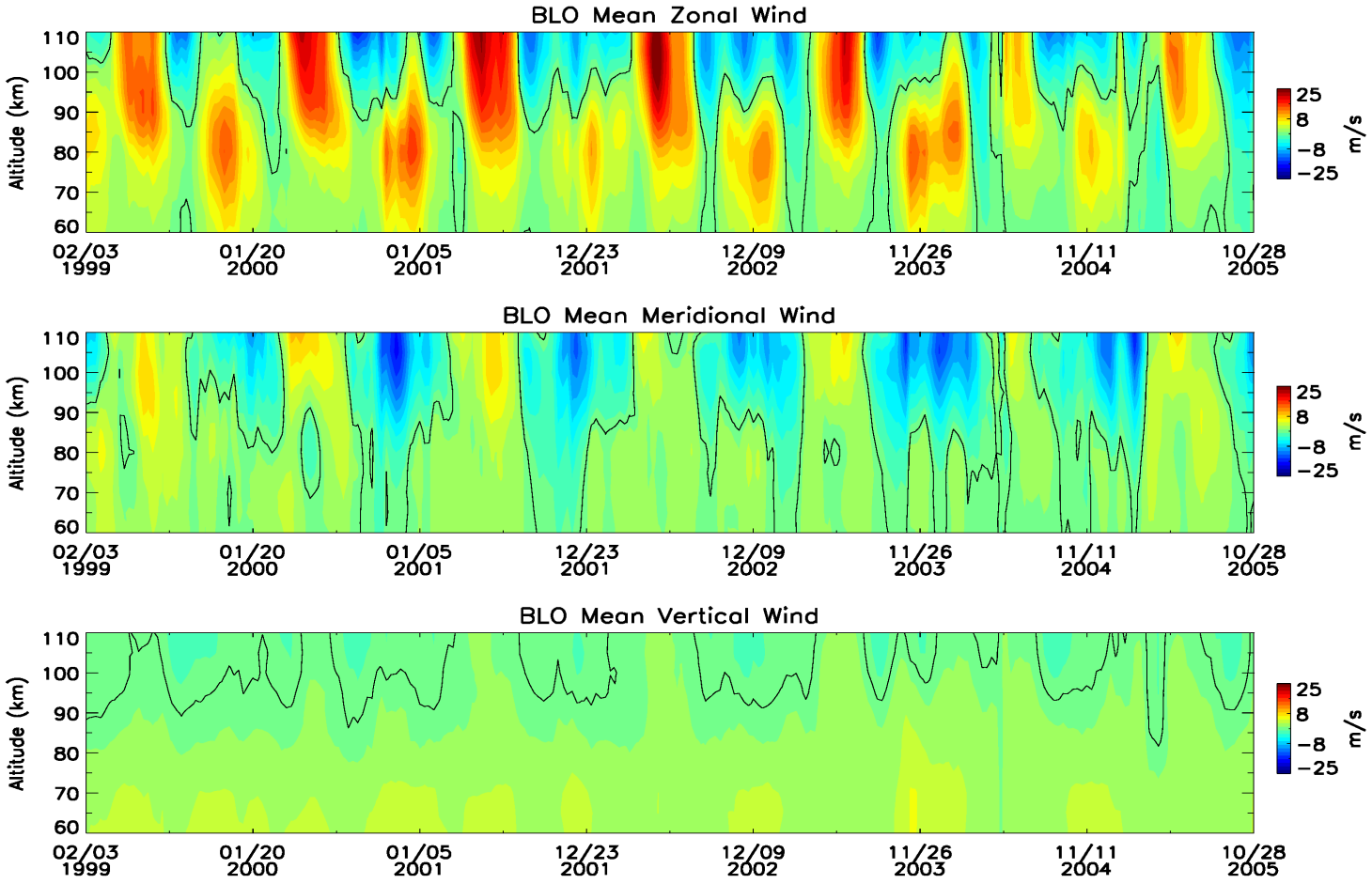
Major Event Co-incident Data Sets

Table 1. Major Northern SSW events since 1999			
Date	**[1]Wind Shift (m/s)**	**[2]Temperature Shift (°)**	**Measurement Sources**
Jan – Mar 2001	50	35	IDI, RSL, MWR
Dec 2001 – Jan 2002	40	35	IDI, RSL
Jan - Feb 2003	40	25	IDI, RSL, SABER
Dec 2003 – Feb 2004	60	30	IDI, RSL, SABER
Dec 2005 – Feb 2006	70	40	SABER
Feb - Mar 2007	55	20-25	SABER
Feb 2008	65	25	SABER
Jan – Mar 2009	100	55	MWR, SABER
Jan – Mar 2010	60	35	MWR, SABER
Dec 2012 – Feb 2013	40	35	MWR, SABER
[1]At 60° N, 10 hPa, [2]At 60-90° N, 10 hPa			

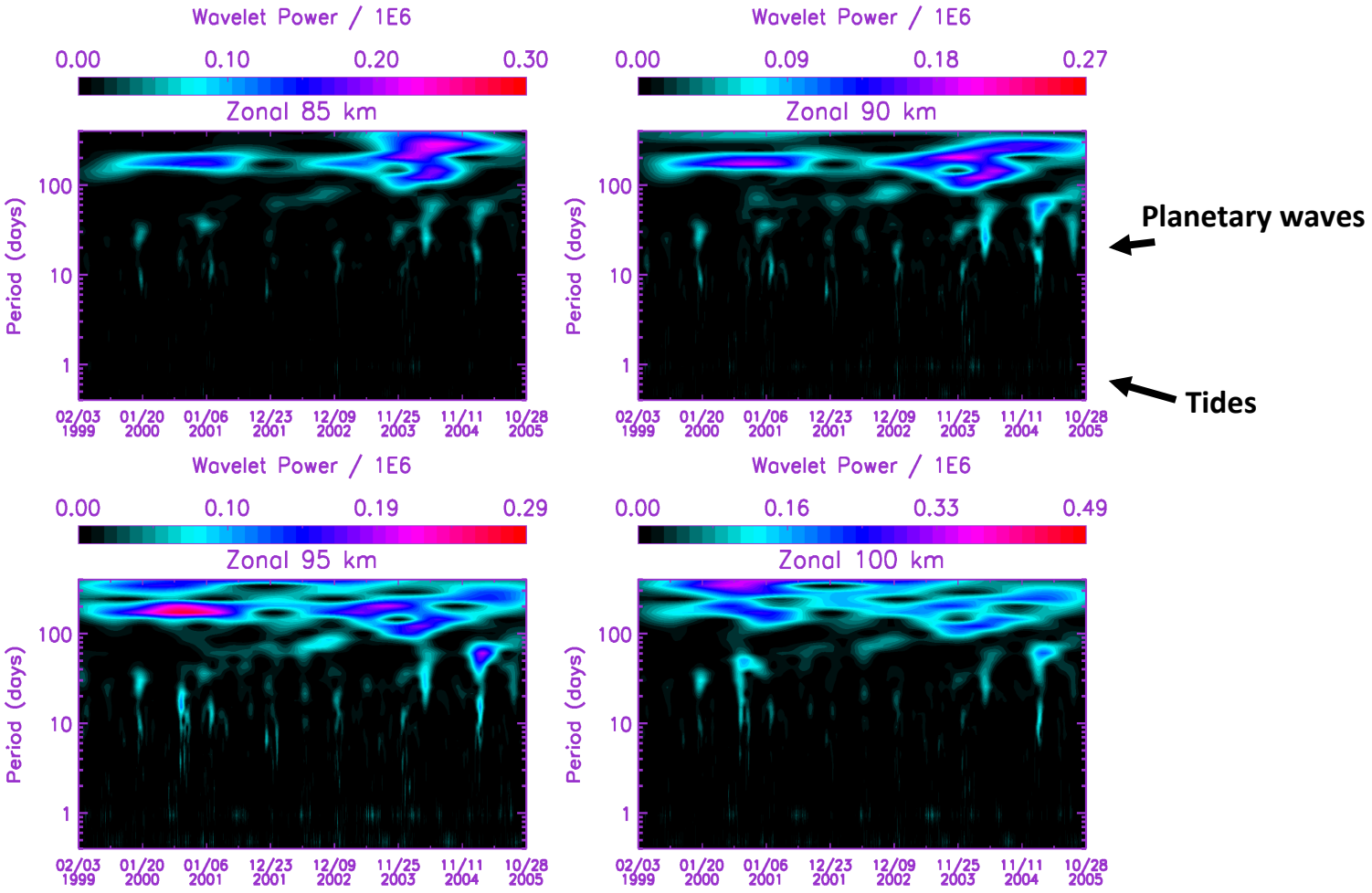
See "The mid-latitude mesosphere's response to sudden stratospheric warmings as determined from Rayleigh lidar temperatures, *Sox, Leda; Wickwar, Vincent B.; Fish, Chad; Herron, Joshua P. ; paper 2.5-14 IAGA 2013"* for pre-1999 events RSL observations

Climatology over Northern Utah

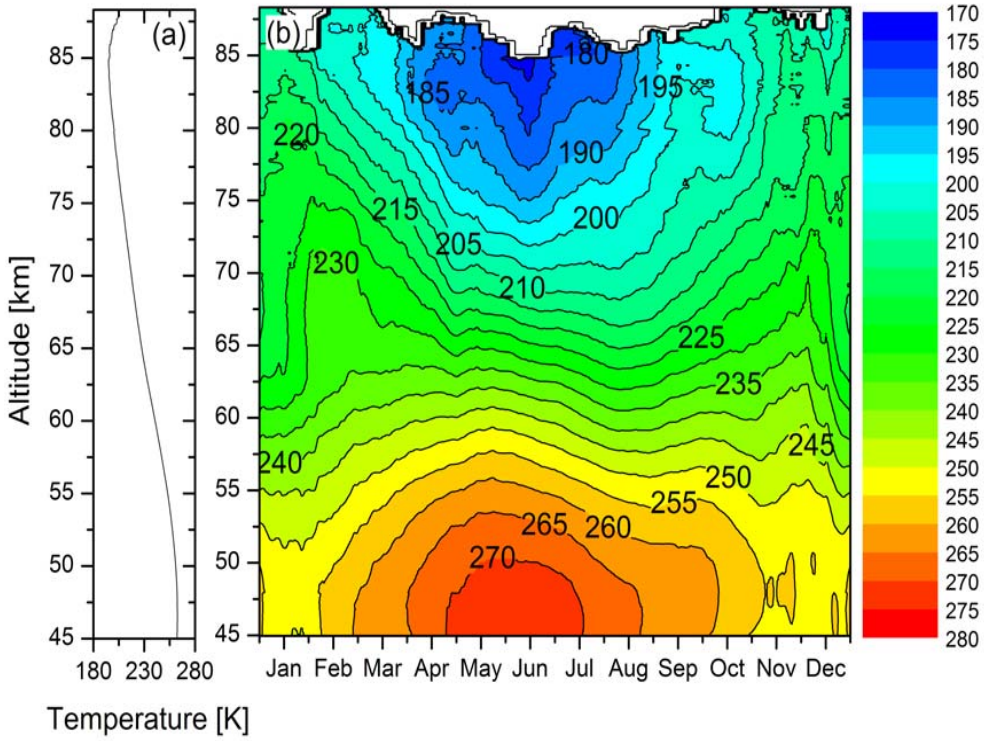
Mean Winds

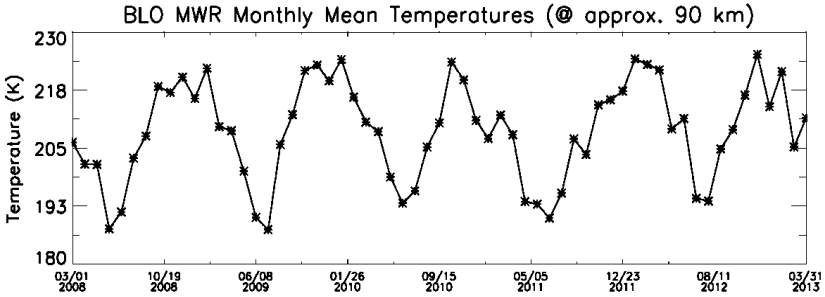

BLO Mean Zonal Wind
BLO Mean Meridional Wind
BLO Mean Vertical Wind
Altitude (km)
110
100
90
80
70
60
02/03 1999
01/20 2000
01/05 2001
12/23 2001
12/09 2002
11/26 2003
11/11 2004
10/28 2005
25
8
−8
−25
m/s

Tides and PWs



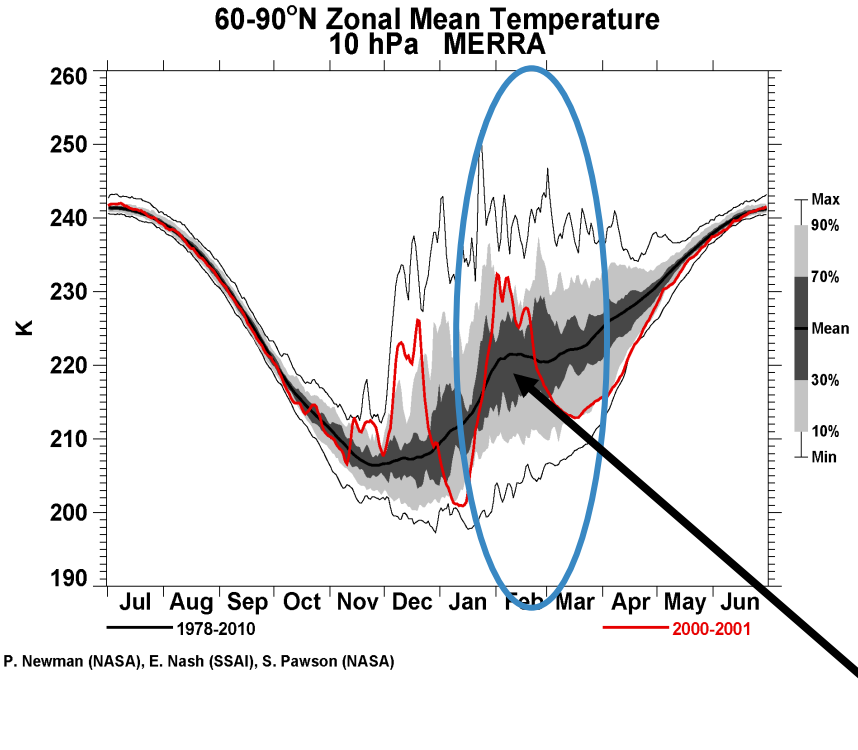
Temperature

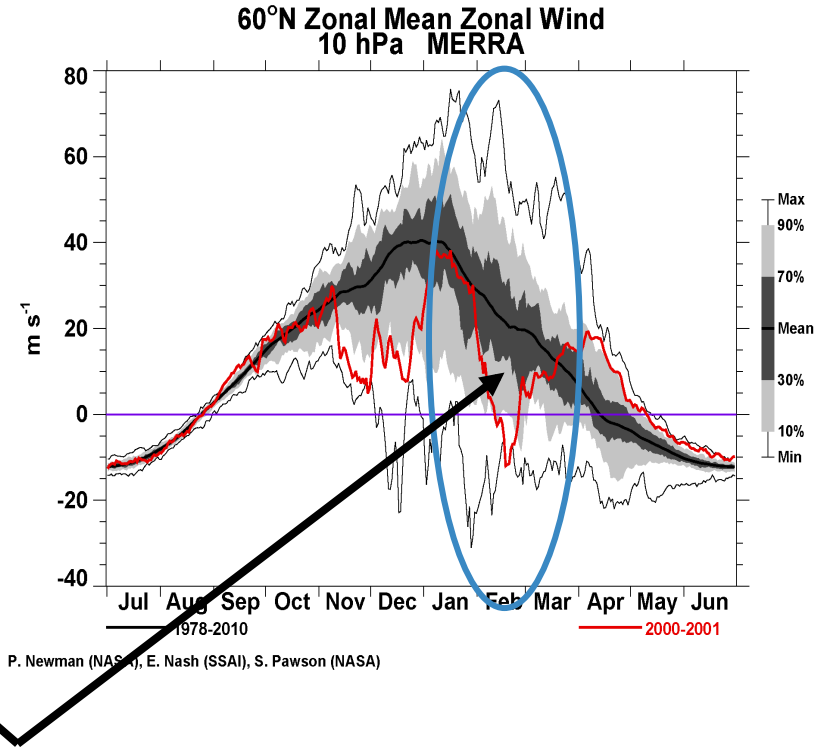




SSW Events over Northern Utah

Winter 2000-2001



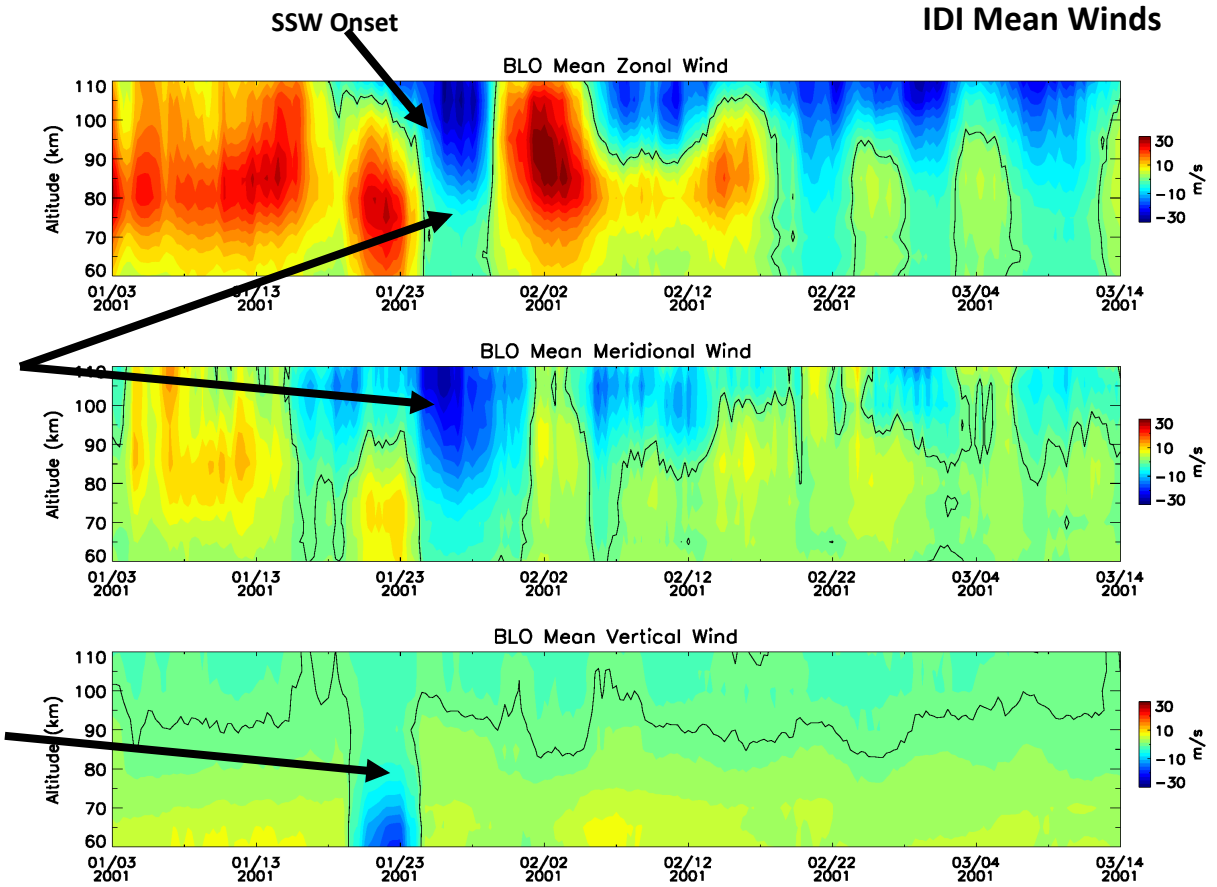


Minor event in early winter, followed by a major event in January/February 2001

Mean Winds

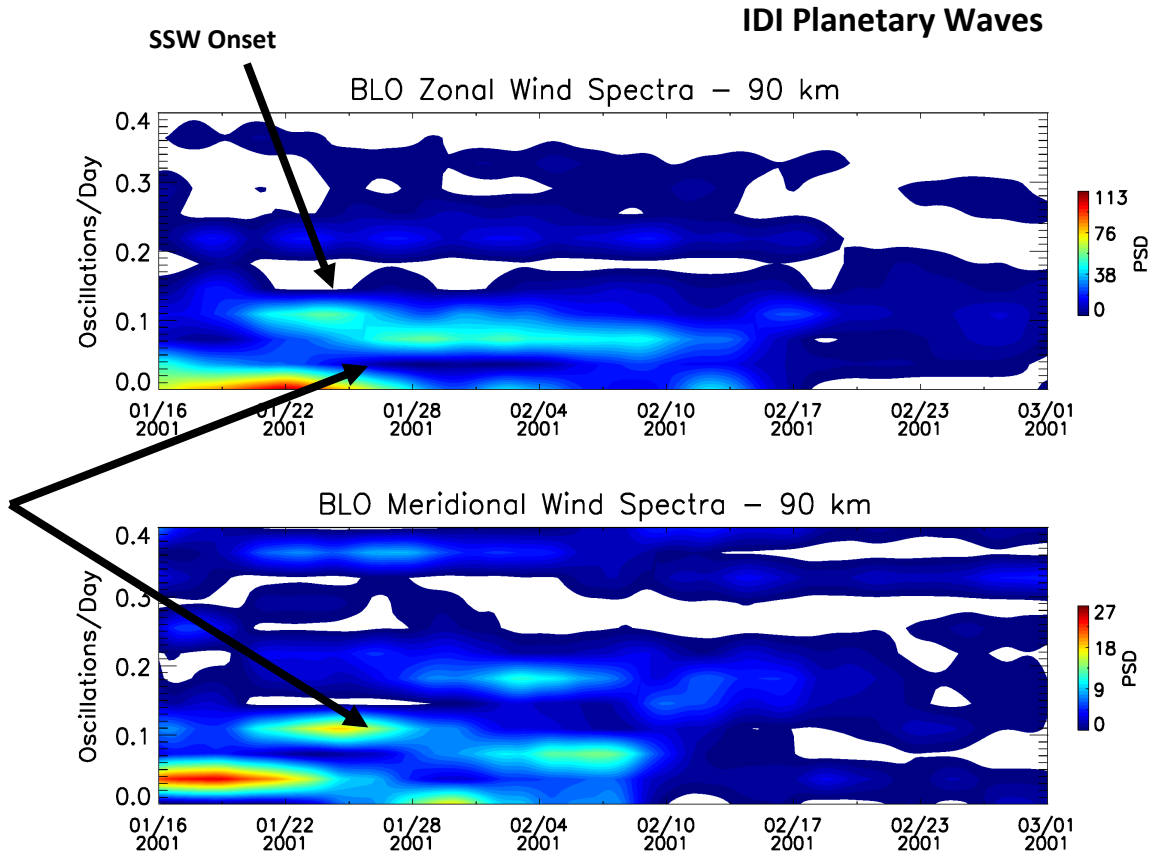
Marked reversal in zonal and meridional mean winds over SMLT region at the onset of the major SSW event over Northern Utah. This is a typical feature in the major SSW events observations over Northern Utah. The winds reverse at higher altitudes and quickly descend into lower altitudes.

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.



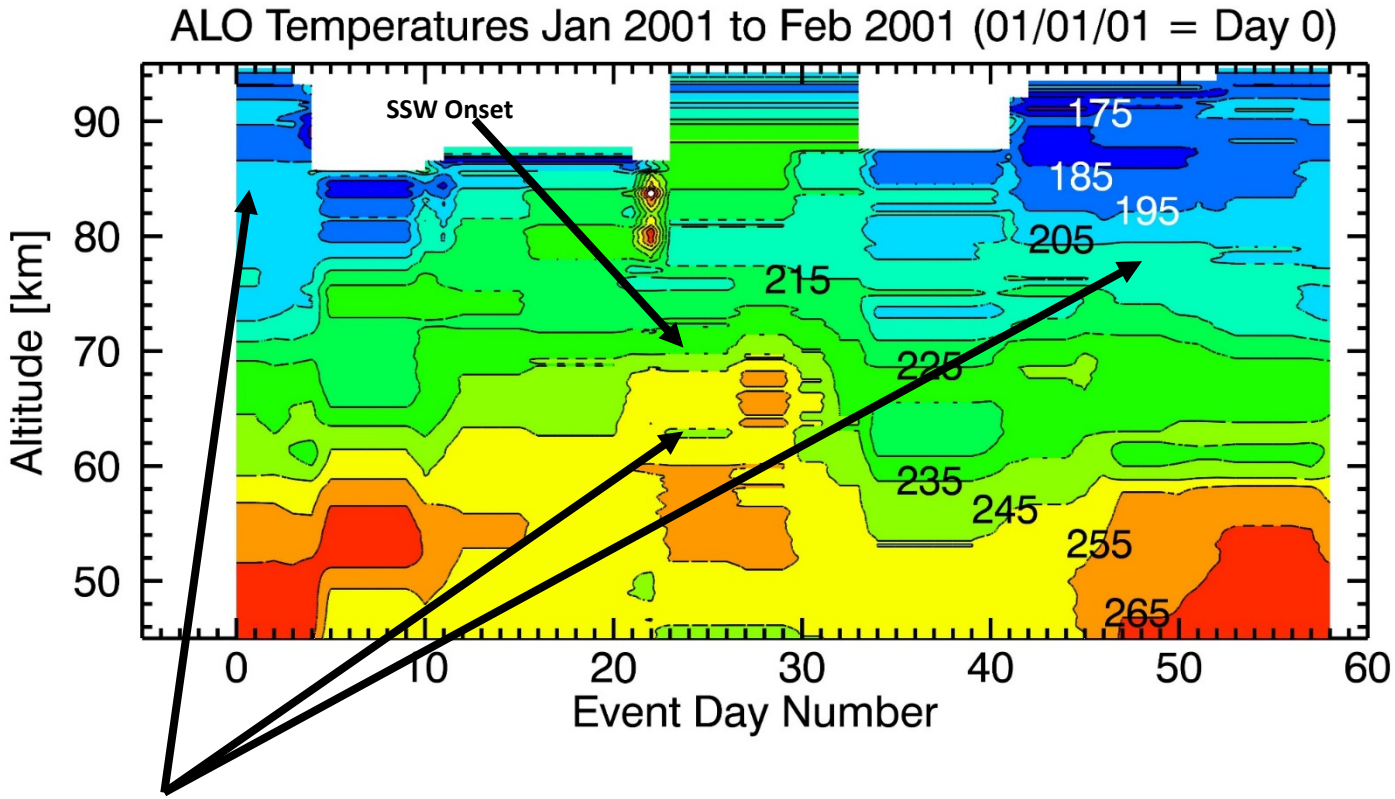
Waves

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

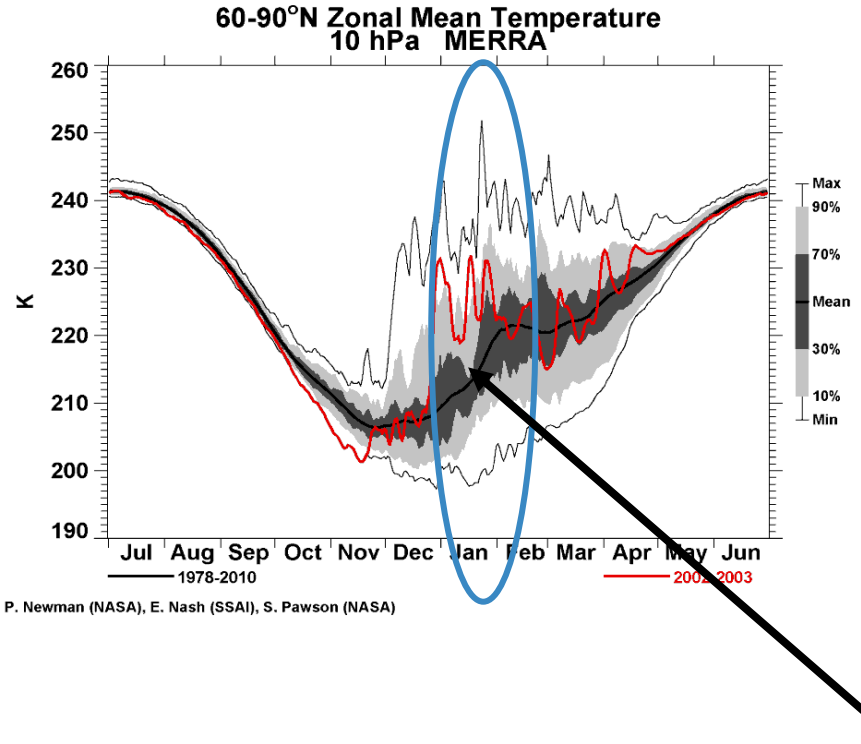
RSL Temperatures

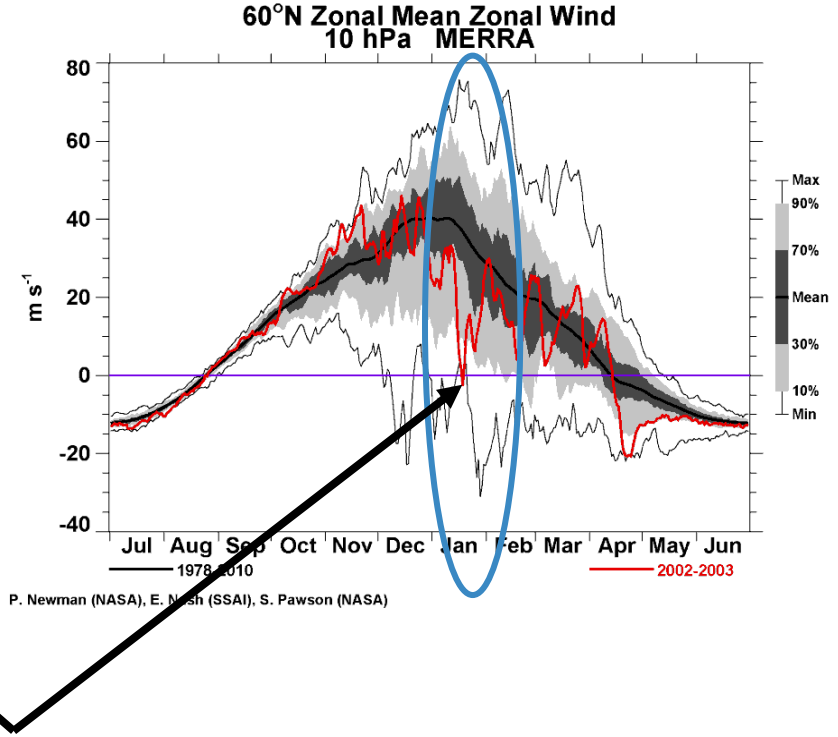


Cooling in Mesosphere during formation and onset of SSW event, followed by warming in the Stratosphere and lower Mesosphere, then followed by cooling in the Mesosphere again

From "*Sox et al; paper 2.5-14 IAGA 2013***"**

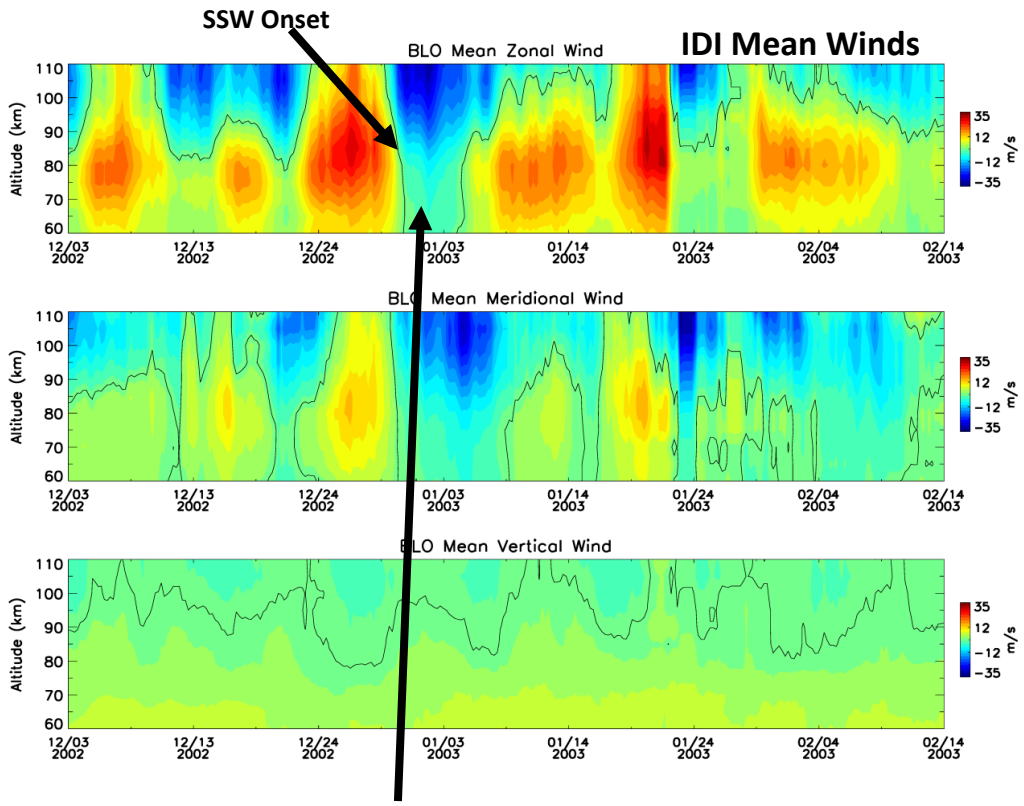
Winter 2002-2003



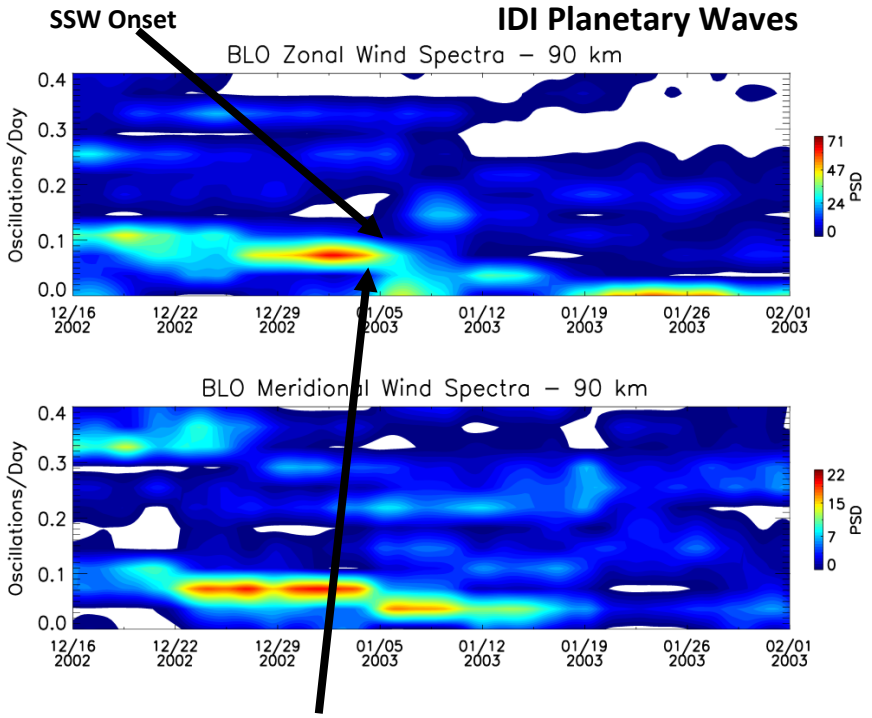


Major event in January 2003.

Mean Winds and Waves

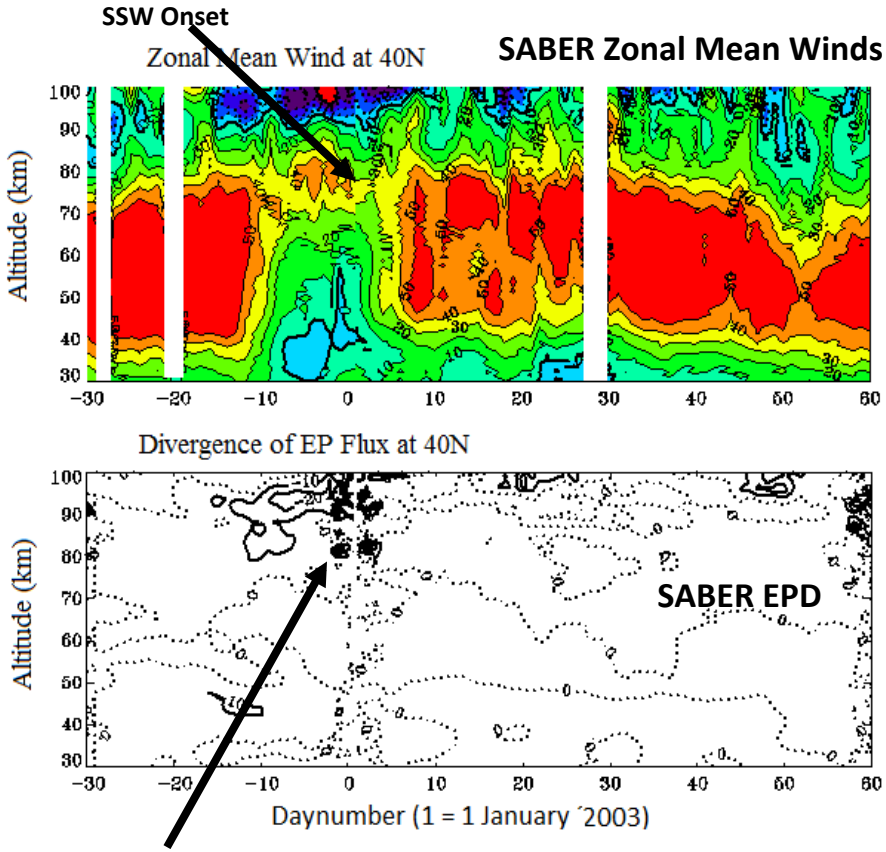


Reversal in zonal and meridional mean winds over SMLT region at the onset of the major SSW event.

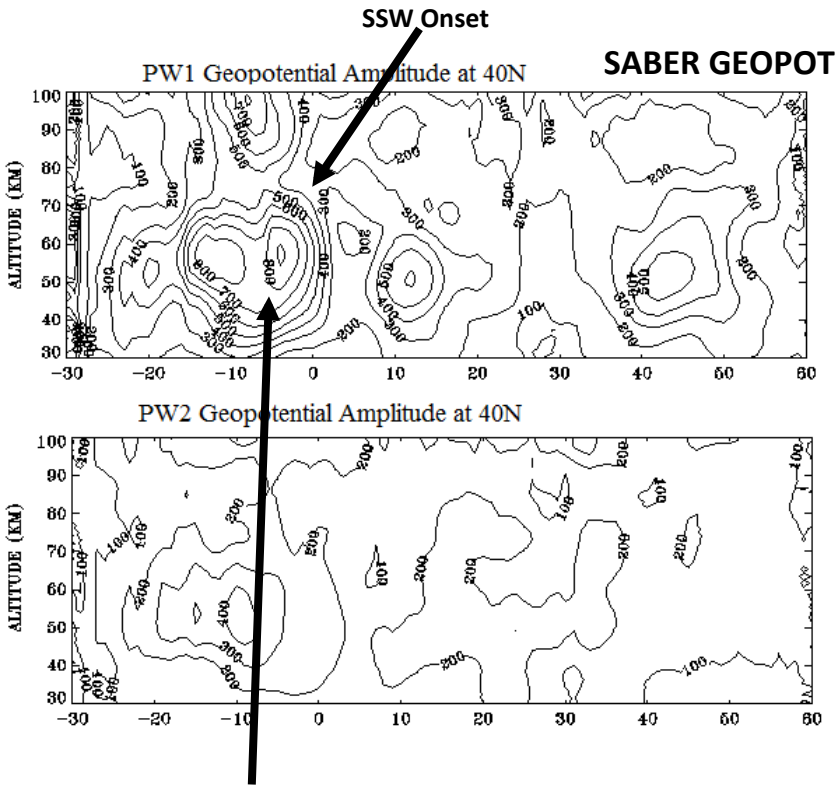


Intense planetary wave activity is seen in the zonal and meridional components during the period of the SSW activity, followed by a relatively quiet period. At the onset of the SSW, the planetary wave structure (modes) changes.

Mean Winds and Waves (cont)



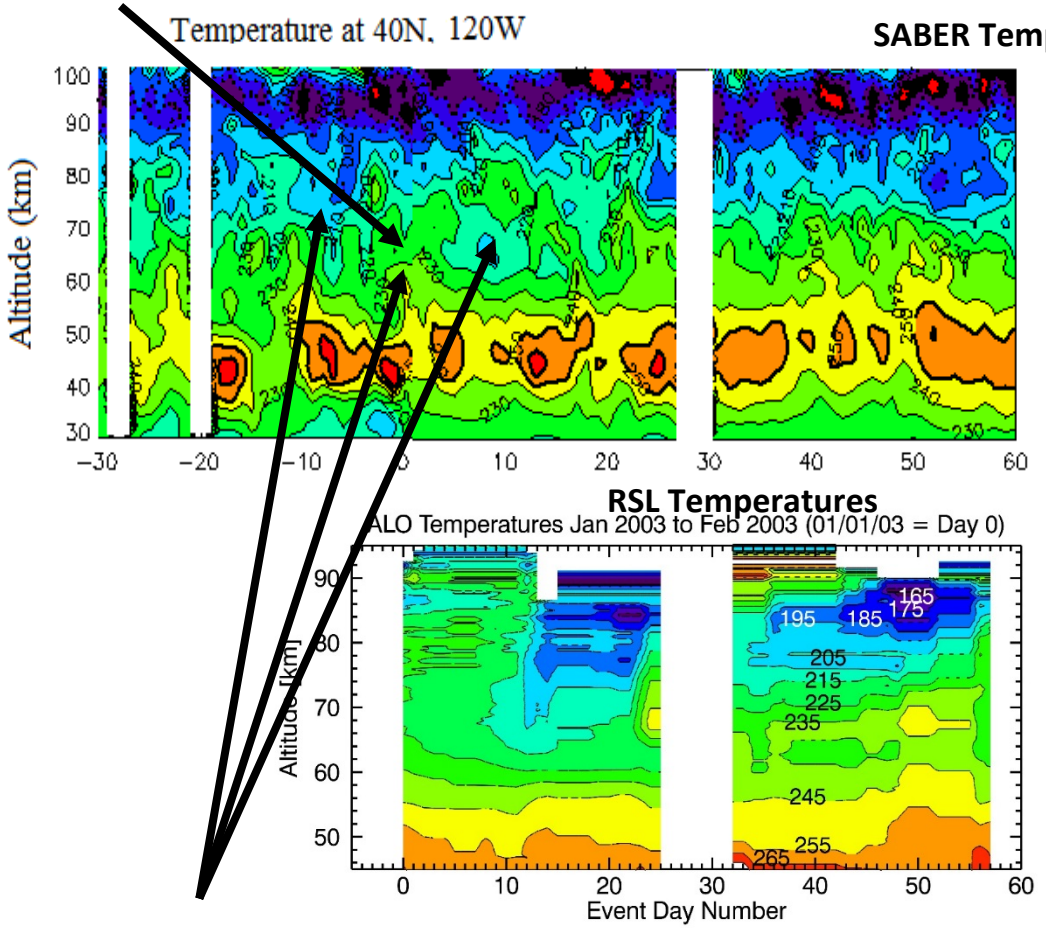
In addition to the strong change seen in the pattern of the derived zonal mean winds over the SMLT region at the time of the SSW onset, the derived EPD is distinctly negative (indicating planetary wave activity) during the SSW event.



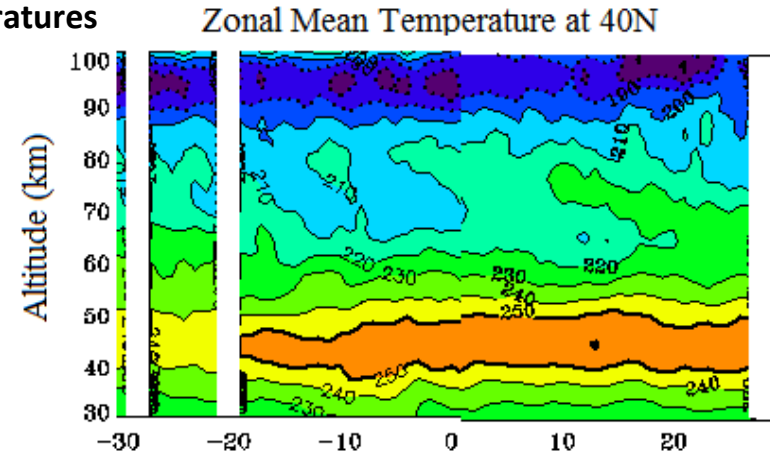
This event initiated predominantly by planetary wave 1 activity, which is seen to be the strongest mode for this event. The major SSW events for the past decade are a result of primarily planetary wave 1 or 2 interactions (or a even mixture of both).

Temperatures

SSW Onset



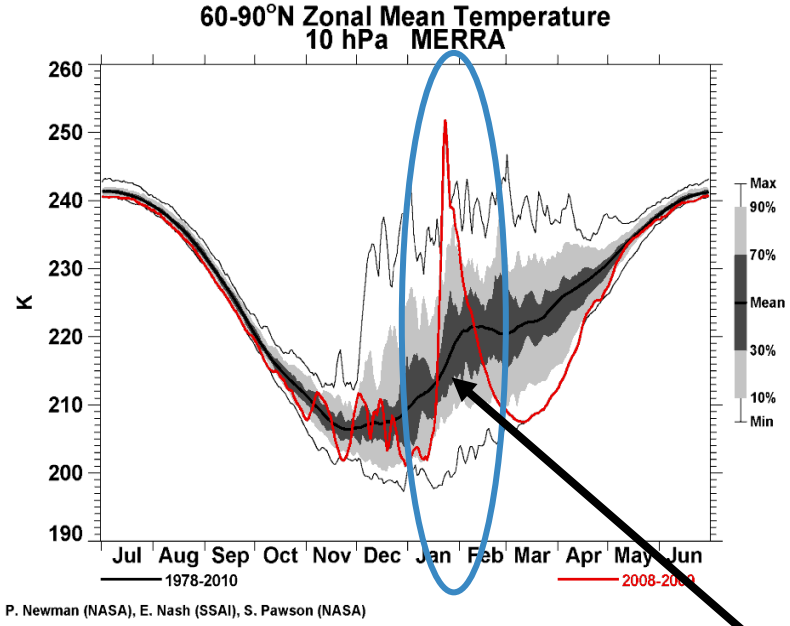
SABER Temperatures

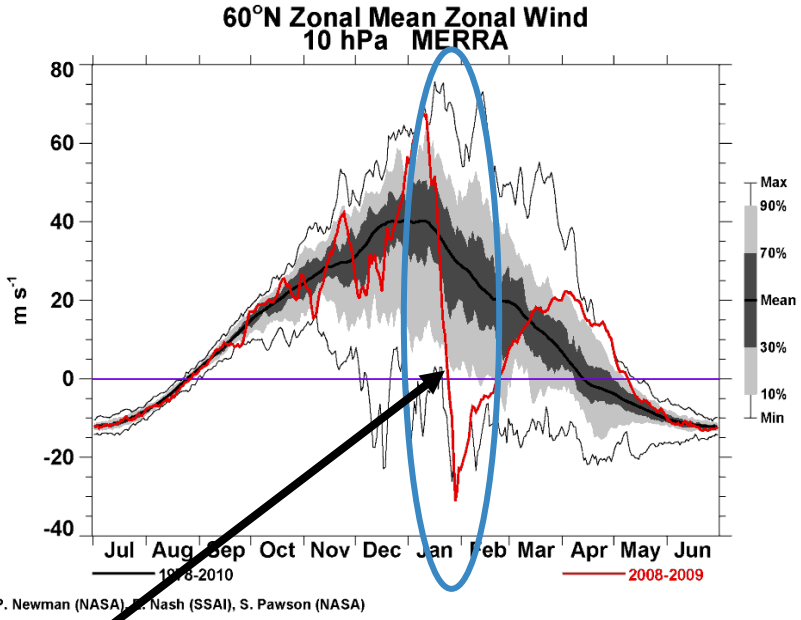


RSL Temperatures

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



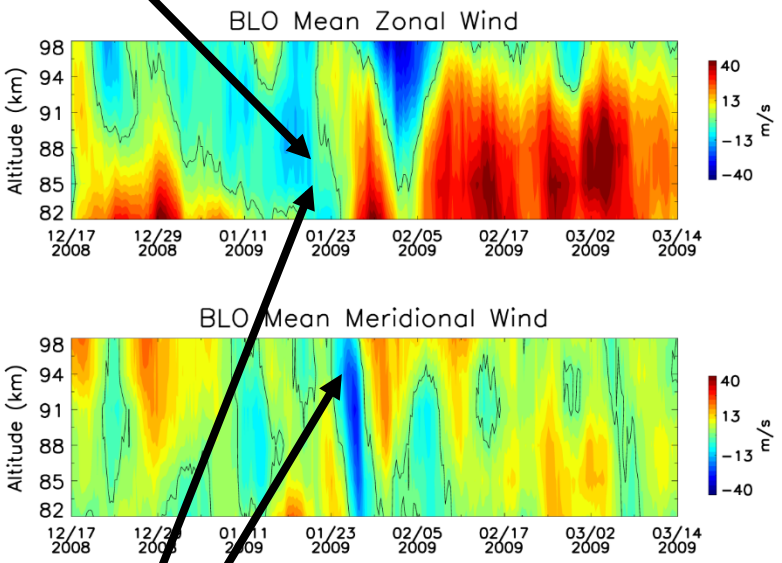


“Model” major event in January/February 2009

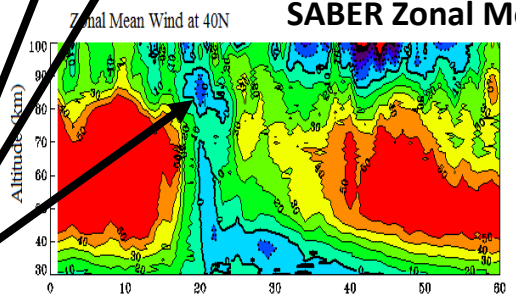
Mean Winds and Waves

SSW Onset

MWR Mean Winds



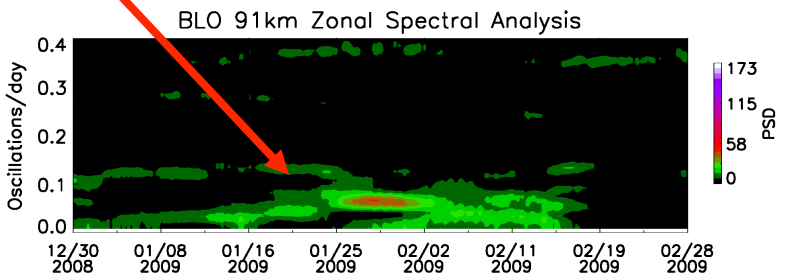
SABER Zonal Mean Winds

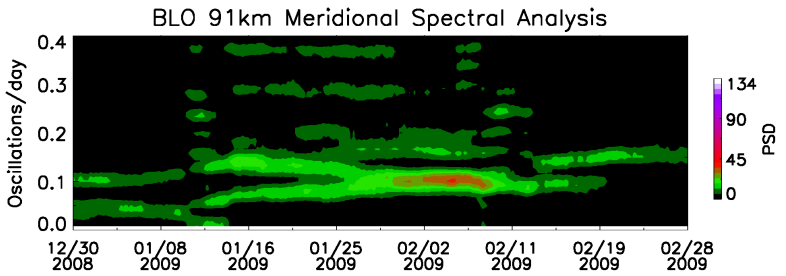


Wind reversal

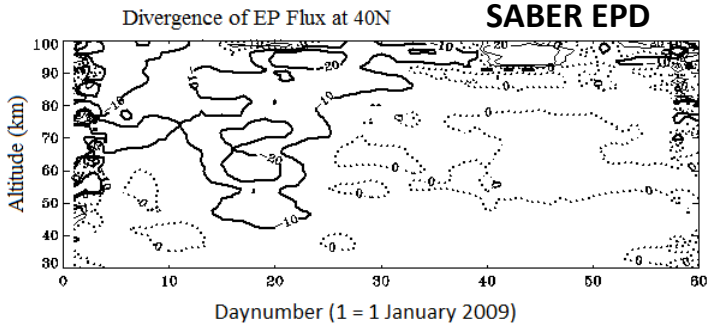
SSW Onset

MWR Planetary Waves



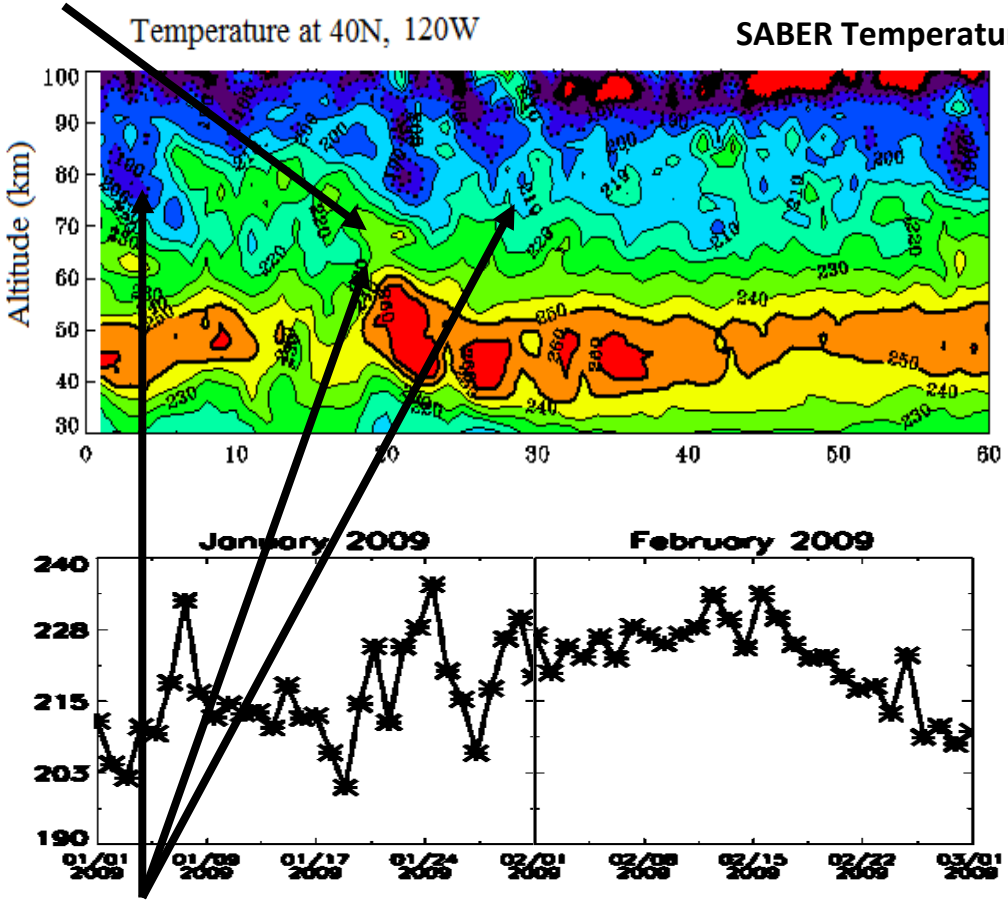


SABER EPD

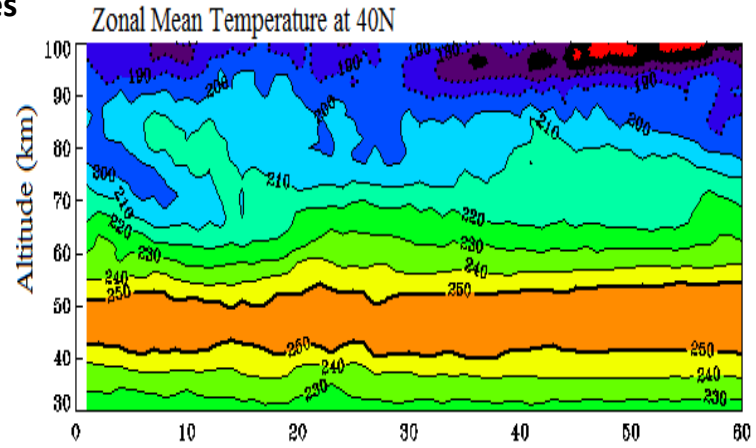


Temperatures

SSW Onset



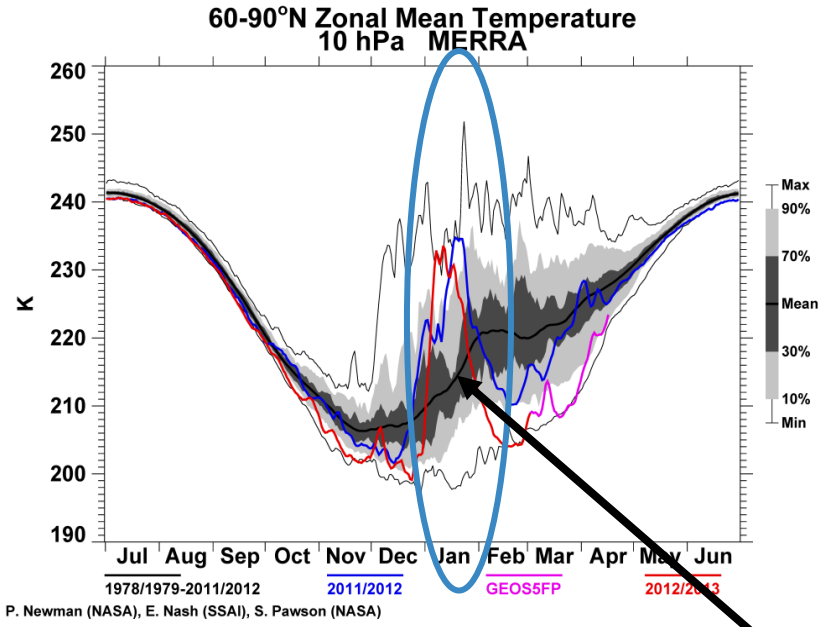
SABER Temperatures

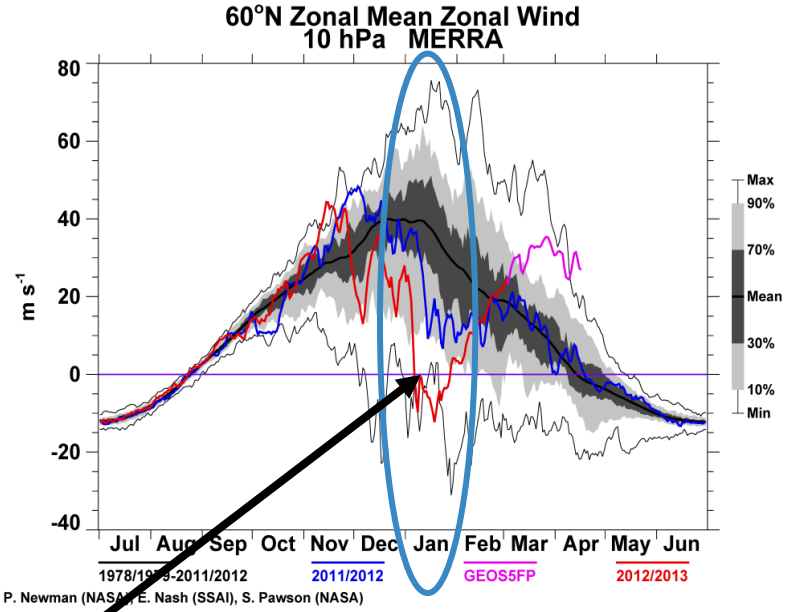


MWR Temperatures (~ 90 km)

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



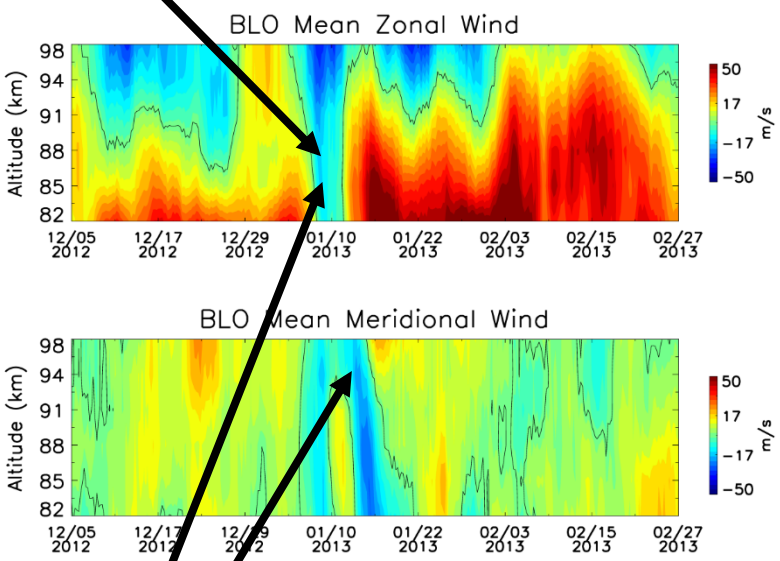


Major event this last winter; January/February 2013

Mean Winds and Waves

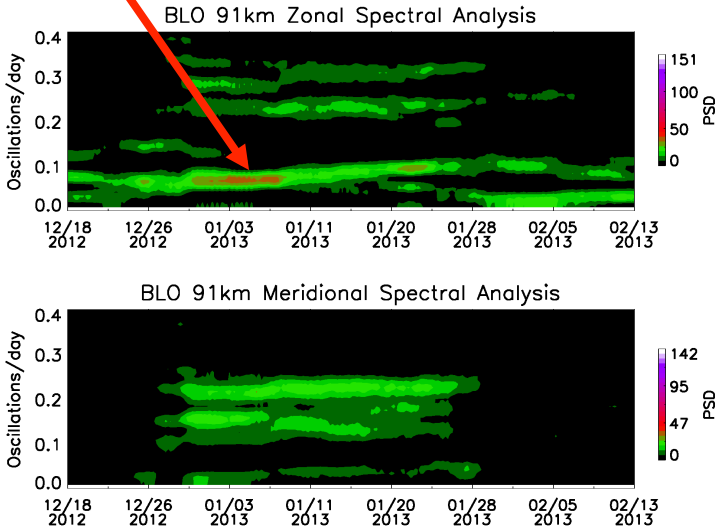
SSW Onset

MWR Mean Winds

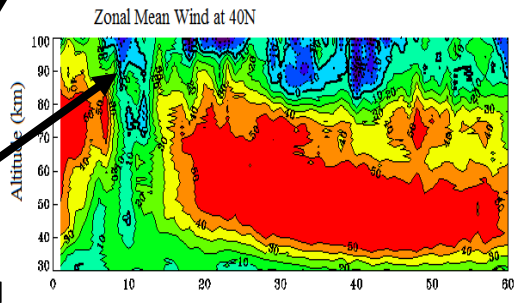


SSW Onset

MWR Planetary Waves

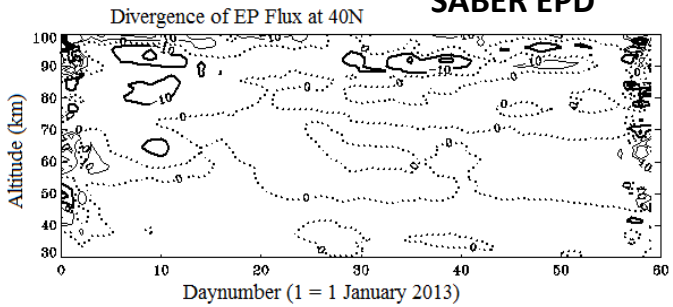


SABER Zonal Mean Winds



Wind reversal

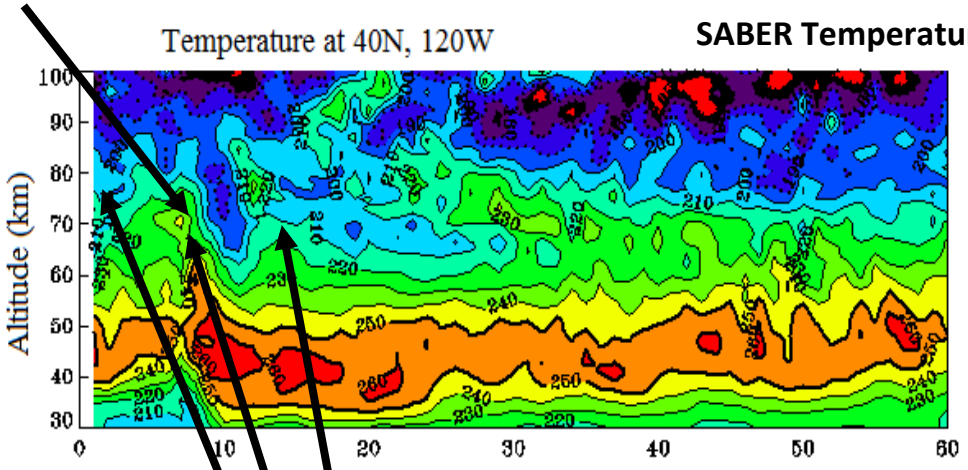
SABER EPD

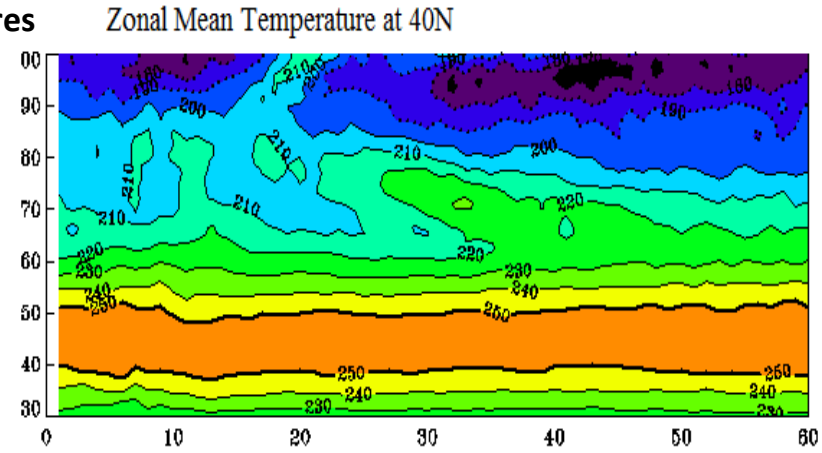


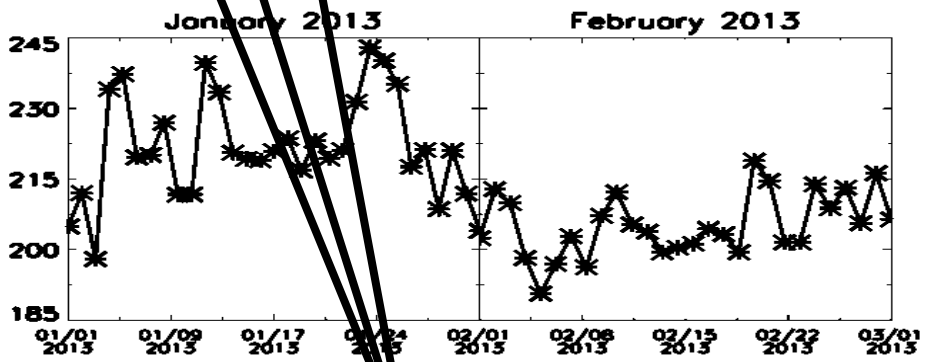
Temperatures

SSW Onset

SABER Temperatures







MWR Temperatures (~ 90 km)

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 3. Comparison of major SSW event dynamic

Date (Event)	PW Type	Formation Period						Onset Period						Post-Onset Period					
		Strat (< 50 km)		Meso (< 90 km)		Low Therm		Strat (< 50 km)		Meso (< 90 km)		Low Therm		Strat (< 50 km)		Meso (< 90 km)		Low Therm	
		Temp	Wind	Temp	Wind	Temp	Wind	Temp	Wind	Temp	Wind	Temp	Wind	Temp	Wind	Temp	Wind	Temp	Wind
Jan – Mar 2001	NA	265	NA	185	Z: E M: N V: U	NA	Z: E M: N V: D	255	NA	215	Z: W M: S V: D	NA	Z: W M: S V: D	265	NA	185	Z: E (Mix) M: N V: U	NA	Z: W M: S V: D
Dec 2001 – Jan 2002	NA	NA	NA	NA	Z: E M: N (Mix) V: U	NA	Z: W M: S (Mix) V: D	NA	NA	NA	Z: W M: S V: U	NA	Z: W M: S V: D	NA	NA	NA	Z: E M: N V: U	NA	Z: W M: S V: D
Jan – Feb 2003	PW1	260	Z: E	195	Z: E M: N V: U	180	Z: E (Mix) M: N (Mix) V: D	255	Z: W	225	Z: W M: S V: U	180	Z: W M: S V: D	260	Z: E	185	Z: E M: N (Mix) V: U	170	Z: W (Mix) M: S (Mix) V: D (Mix)
Dec 2003 – Feb 2004	PW1	260	Z: E	190	Z: E M: N (Mix) V: U	180	Z: W (Mix) M: S (Mix) V: D	250	Z: W	220	Z: W M: S V: U	170	Z: W M: S V: U (Mix)	260	Z: E	190	Z: E M: N (Mix) V: U	180	Z: W (Mix) M: S V: D (Mix)
Dec 2005 – Feb 2006	PW1	250	Z: E (Mix)	190	Z: E	180	Z: W (Mix)	260	Z: W	230	Z: W	160	Z: W	250	Z: E	200	Z: E	180	Z: W
Feb – Mar 2007	PW1/2	240	Z: E	190	Z: E	180	Z: W (Mix)	250	Z: W	220	Z: W	160	Z: W	250	Z: E	190	Z: E	160	Z: W
Jan – Feb 2008	PW1/2	240	Z: E	190	Z: E	170	Z: W	260	Z: W	210	Z: W	180	Z: W	250	Z: E	180	Z: E (Mix)	170	Z: E (Mix)
Jan – Mar 2009	PW1/2	250	Z: E	190	Z: E M: N (Mix)	180	Z: W M: N (Mix)	260	Z: W	220	Z: W M: S	180	Z: W M: S	250	Z: E	200	Z: E M: N	190	Z: W M: N (Mix)
Jan – Mar 2010	PW1/2	240	Z: E	190	Z: E M: N (Mix)	180	Z: W (Mix) M: N (Mix)	250	Z: W	220	Z: W M: S	180	Z: W M: S	260	Z: E	190	Z: E M: N	170	Z: W M: N (Mix)
Dec 2012 – Feb 2013	PW2	240	Z: E	200	Z: E M: N	180	Z: W (Mix) M: N (Mix)	260	Z: W	230	Z: W M: S	190	Z: W M: S	250	Z: E	190	Z: E M: N	180	Z: W M: N (Mix)

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.

Also see "*Sox et al; paper 2.5-14 IAGA 2013"*

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.

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.