Study on the impact of sudden stratosphere warming in the upper mesosphere-lower thermosphere regions using satellite and HF radar measurements

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Brief introduction

Neutral atmosphere (including the MLT) and ionosphere are linked by energy and momentum transfer.

Thus, this whole region forms a coupled system in which influences that originates at one height or in one region can have profound influence elsewhere in the system.

Present paper objectives:

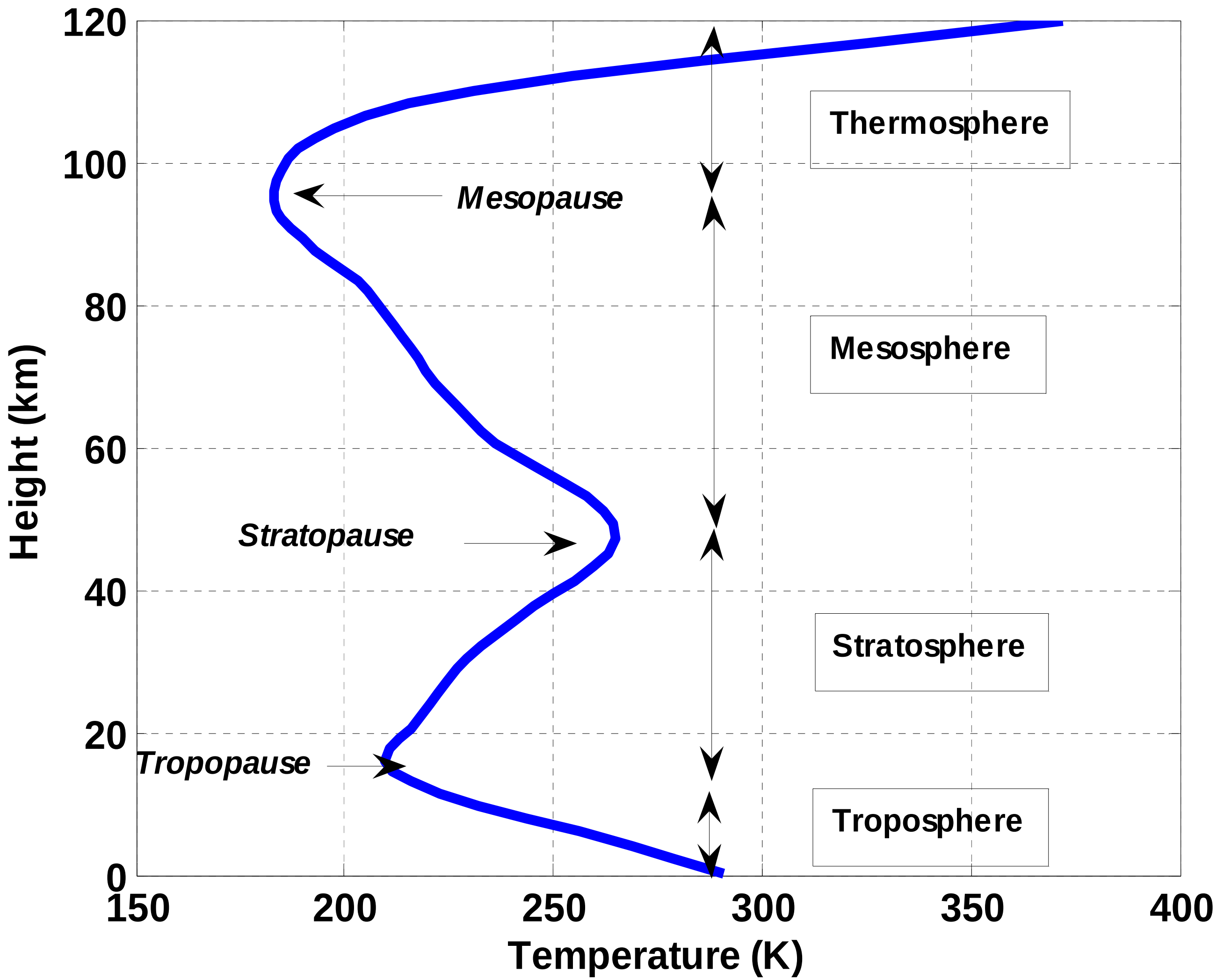
- Use the September 2002 SH SSW to study the coupling between the MLT and the region below (In the SH)

- Use middle atmospheric parameters such as;

-**Temperature**
- **Wind (e.g. mean wind, zonal mean zonal wind)**
- **Waves in the atmosphere**

1. Planetary waves (2 to 30 days period)
2. Tides (non-migrating and migrating tides)
   - Diurnal tides (24 hour period)
   - Semidiurnal tides (12 hour period)
3. Gravity waves (several minutes to hours)

Structure of the Atmosphere



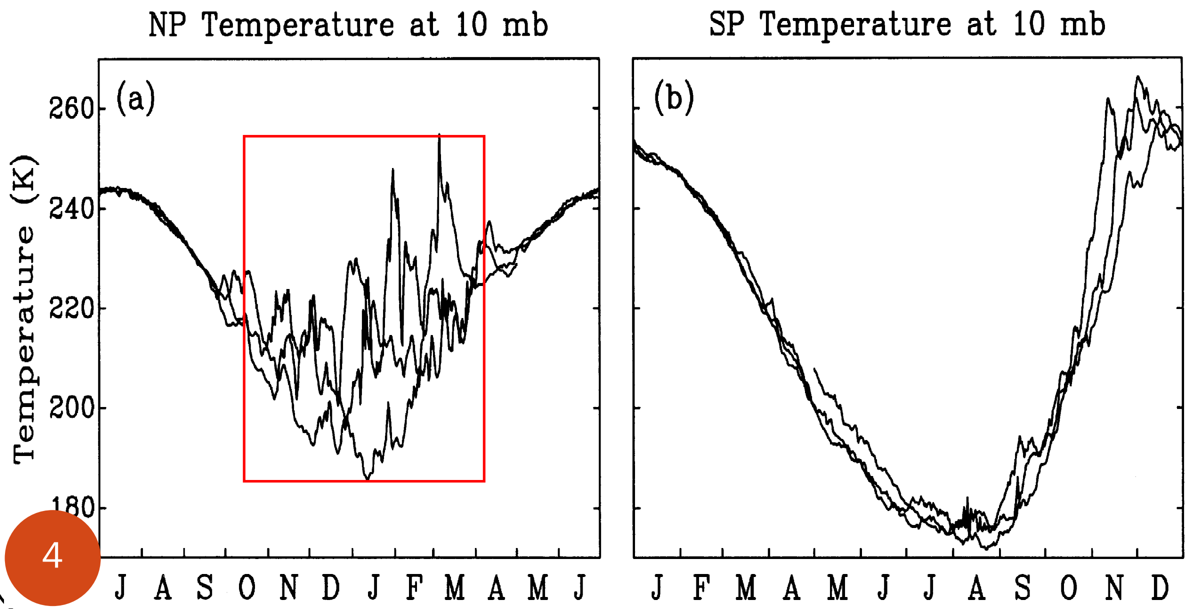
Stratospheric Warming

The first observations of sudden stratospheric warming (SSW) was made by Richard Scherhang in 1952, using radiosonde measurements over Berlin, Germany.

This event is initiated by the propagation of planetary wave disturbances from the troposphere into the stratosphere and the MLT [Matsuno, (1971)]

Planetary waves interact strongly with the pre-existing mean zonal flow in the region above the troposphere

Planetary waves have westward phase speeds (relative to the local wind) and thus carry westward angular momentum; the resulting westward forcing leads to a deceleration of the wintertime polar Stratospheric jet stream and a warming of the pole below the forcing region, which accounts for the sudden warming phenomenon



Example of SW from Canadian Middle Atmosphere Model (CMAM)

Adapted from Shepherd et al., [2000]

Classification of SSW

Major Warming :

- strongest zonal mean temperature disturbances,
- zonal mean wind reversal
  (at 10hpa usual westerly winds are replaced by easterlies as far south as 60°N),
- lead to a breakdown of the cyclonic polar vortex

Minor Warming :

- weaker zonal mean temperature perturbations,
- no zonal mean wind reversal
- does not lead to a breakdown of the polar vortex

Canadien Warming :

- often occur in early winter over Canada,
- the polar vortex does not breakdown but strongly distorts and displace
  - from the pole.

Final Warming :

- occur in the end of winter,
- mark the trasition in the stratosphere between westerly wind in winter and
  -easterly winds in summer.
- lead to a breakdown of the cyclonic polar vortex.

Data used

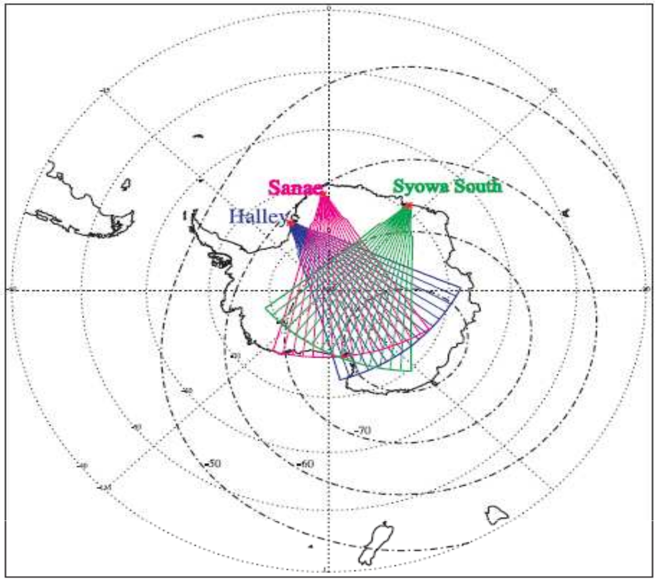
❖ SuperDARN radar (SANAE, [Antarctica 71.68 deg. S and 2.85 deg. W])

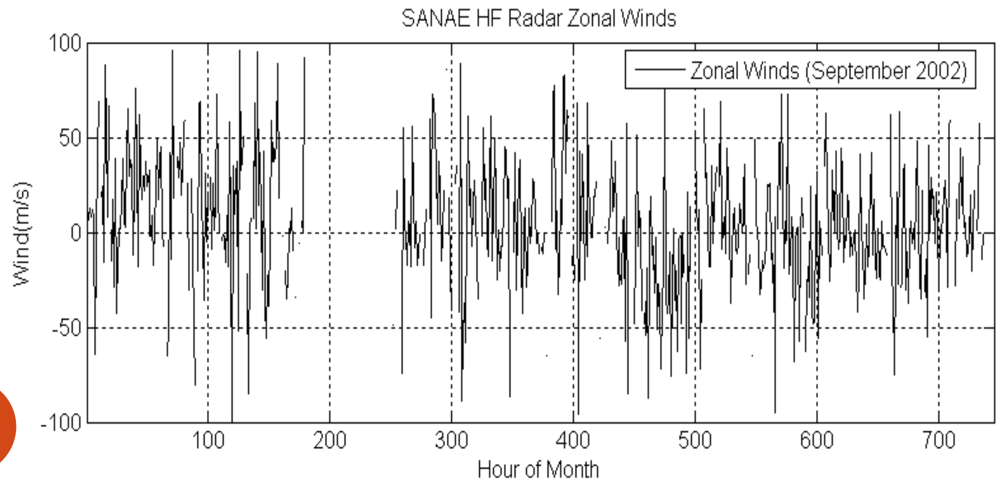
❑ A t each SuperDARN site, there is a 16-antenna main array connected to a phasing matrix which permits the single beam to be swept through 16 successive positions in increments of 3.25°, giving an azimuth extent of ~52°

❑ The meteor trail echoes occur predominantly in and below the lower *E* region (~95 km) [Hussey et al.,2000], thus acquisition of the winds in meteor region is accomplished by using data from the first several range gates of the radar

❑ The backscatter at this distance is primarily due to meteors, and thus a nominal height of 90-95 km is assumed

❑ Hourly wind averages are computed for each beam direction giving a line of-sight wind velocity





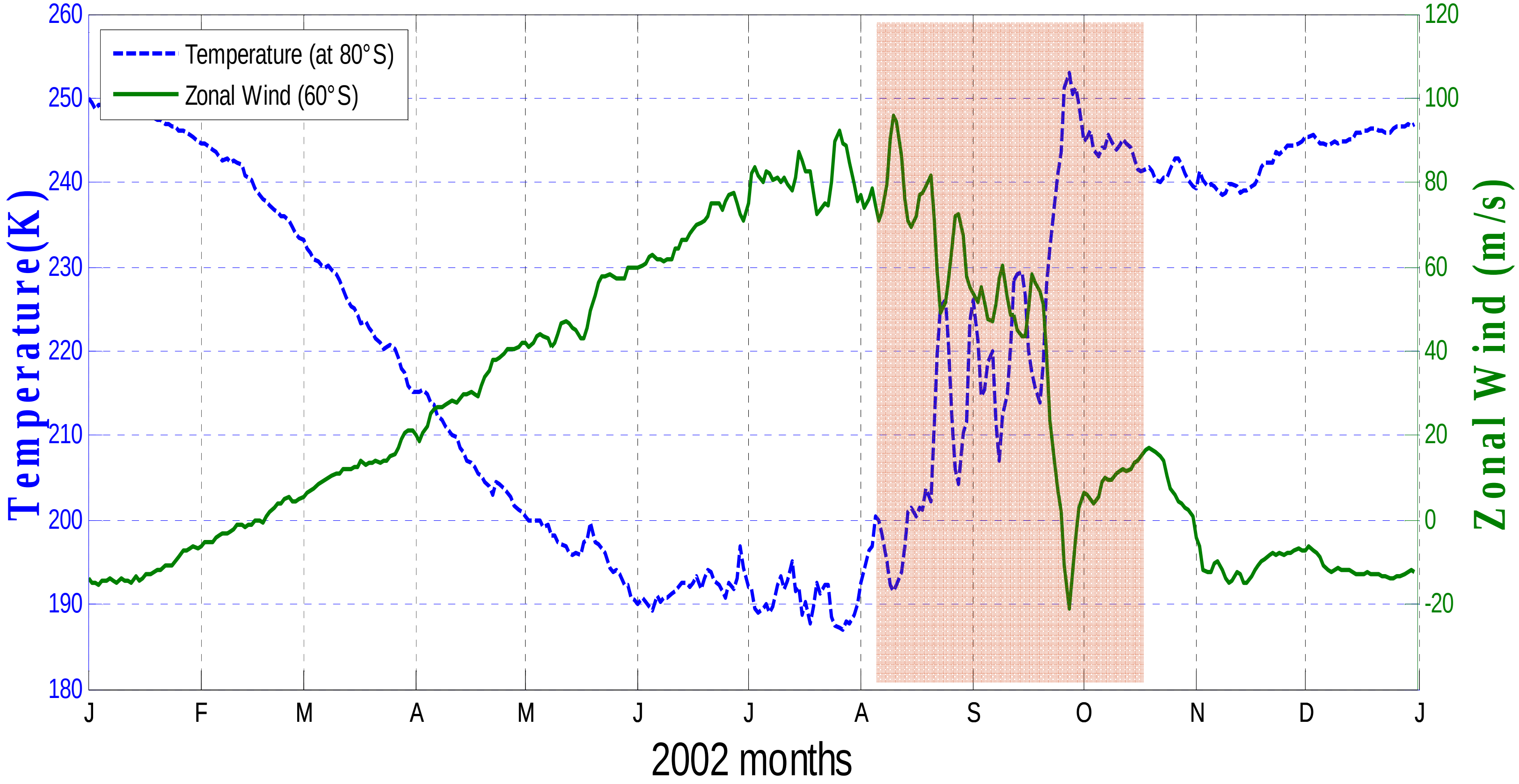
❖ NCEP data

- ❑ Data corresponds to 2.5°×2.5° grid from 1000 hPa to 10 hPa, zonal mean temperature at 80 S and zonal mean wind at 60 S, we use NCEP data to note the warming over poles

❖ SABER Satellite

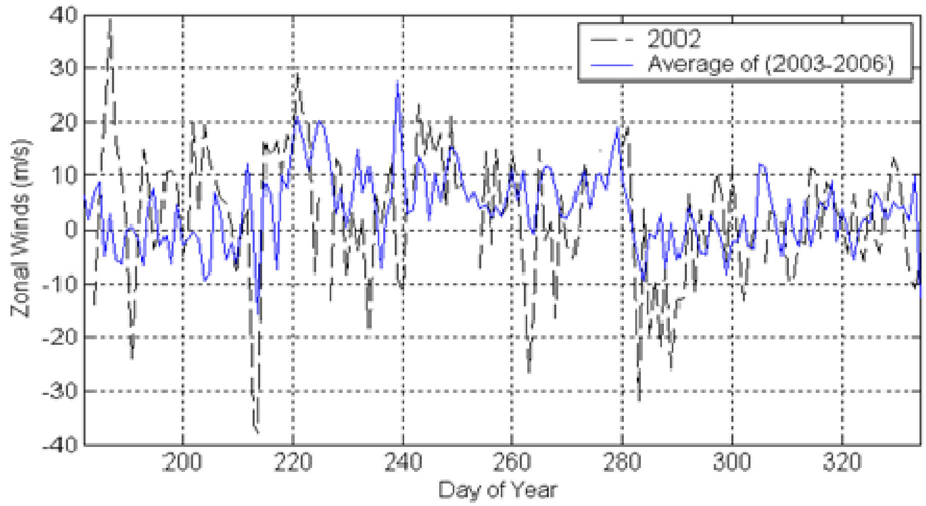
- ❑ Vertical temperature profiles are derived from the version 1.07 of SABER level 2A data (downloaded from the web site *http:/saber.gats-inc.com*)
- ❑ The TIMED satellite was launched on 7 December 2001 into a 625 km orbit of 74.1° inclination
- ❑ SABER instrument began taking measurements in late January 2002
- ❑ By step-scanning the atmosphere limb, SABER measures height profiles of temperature and selected chemical species in the 10-180 km altitude range, with a horizontal resolution along track of 400 km

The SSW at 10 hPa (~32 km)

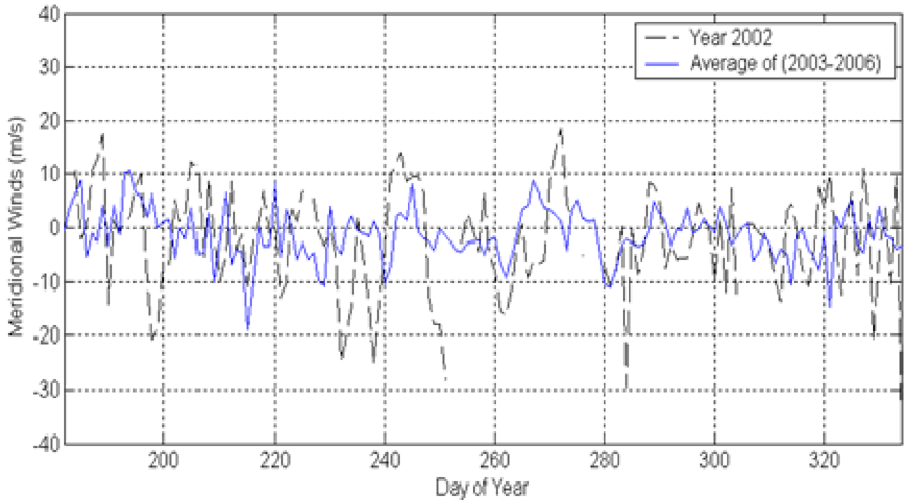


Zonal and Meridional wind

- **Zonal winds component**
  - Many brief periods of easterly winds
  - indicates the presence of high amplitudes of planetary waves

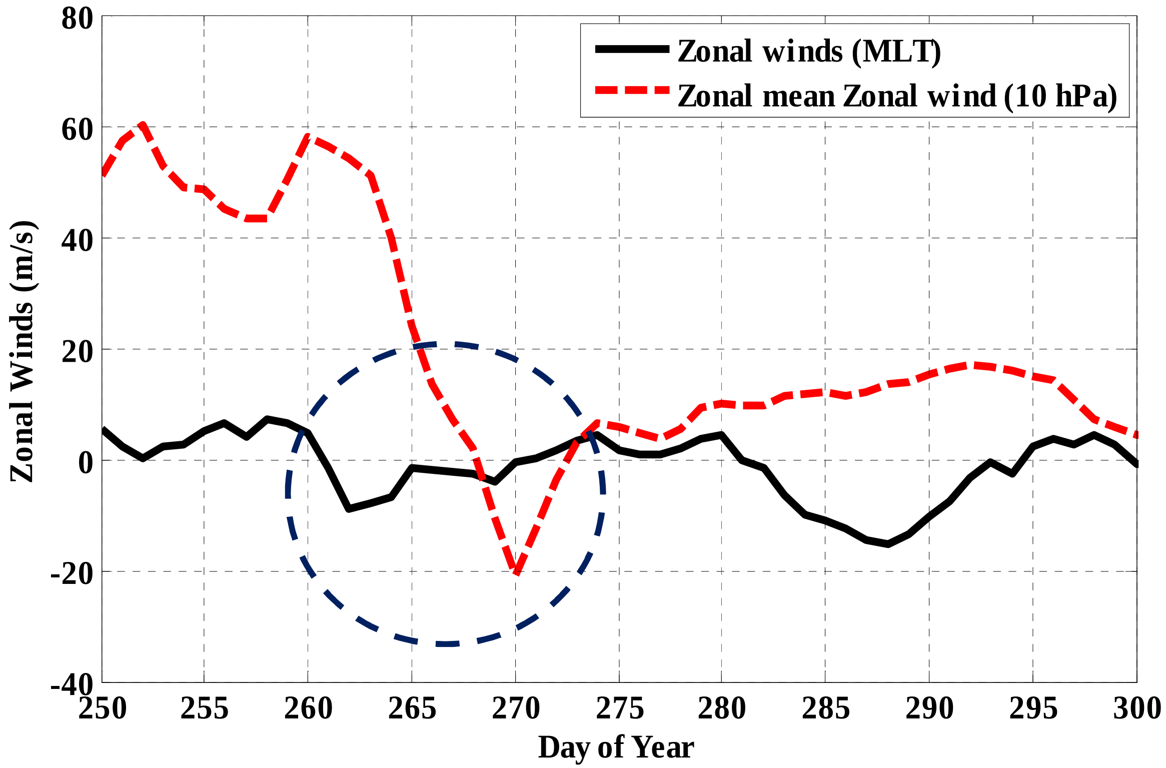


- **Meridional winds component**
  - enhancement due to major SSW

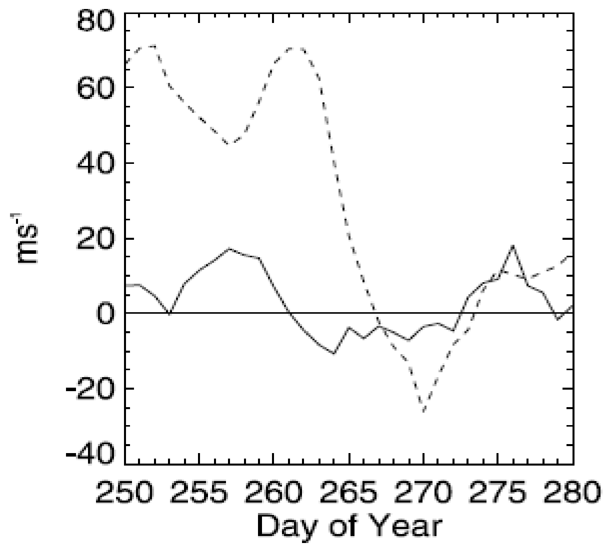


Stratosphere and MLT zonal wind reversal

- The red dashed line represents the time evolution of zonal wind at 10 hPa (~32 km) derived from the NCEP at 60°S
- Solid black line represents zonal wind observations from SANAE HF radar (averaged over 4-day data window sliding by 1-day interval at ~94 km height)



- MLT wind reversal started on day 261 (18 Sept), ~7 days before the reversal at the stratosphere.



Adapted from Andrews et al, [2004]

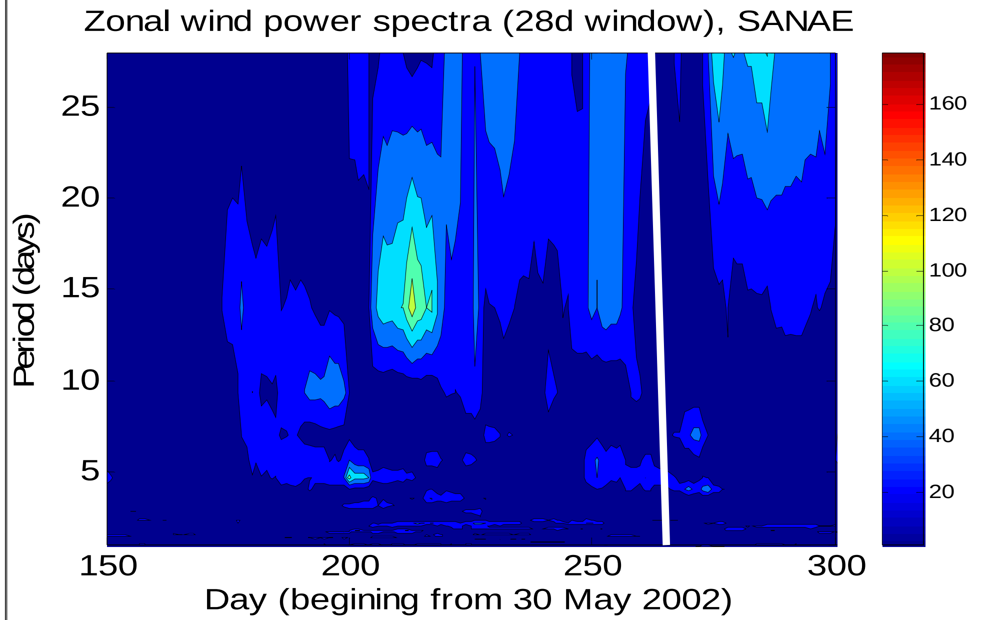
Spectral characteristics

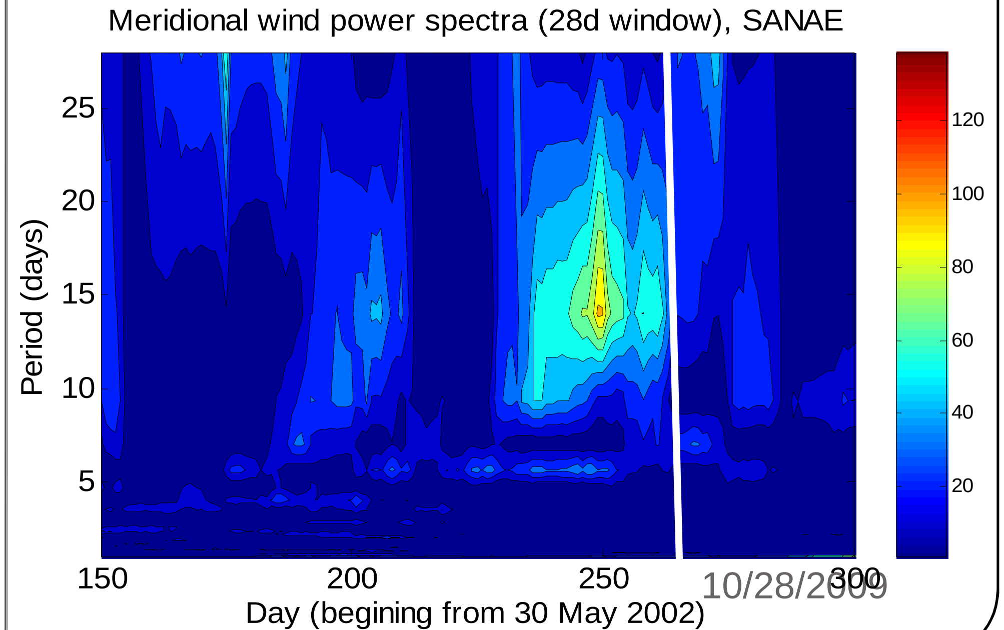
Dynamic Fourier spectra using a 28-day data window that is shifted forward by 1-day at a time

The deduced power for a given data window was attributed to a central day given by day 14 of that particular 28-day interval

Zonal wind power spectra is characterised by dominant peaks near to periods of 5-day, 10-day and 14- to 16-day waves in the mid-winter

The spectrum for the meridional wind component which is shown in figure 5(b) also shows the presence of a 14- to 16-day wave around 7 September (250th of Julian days)

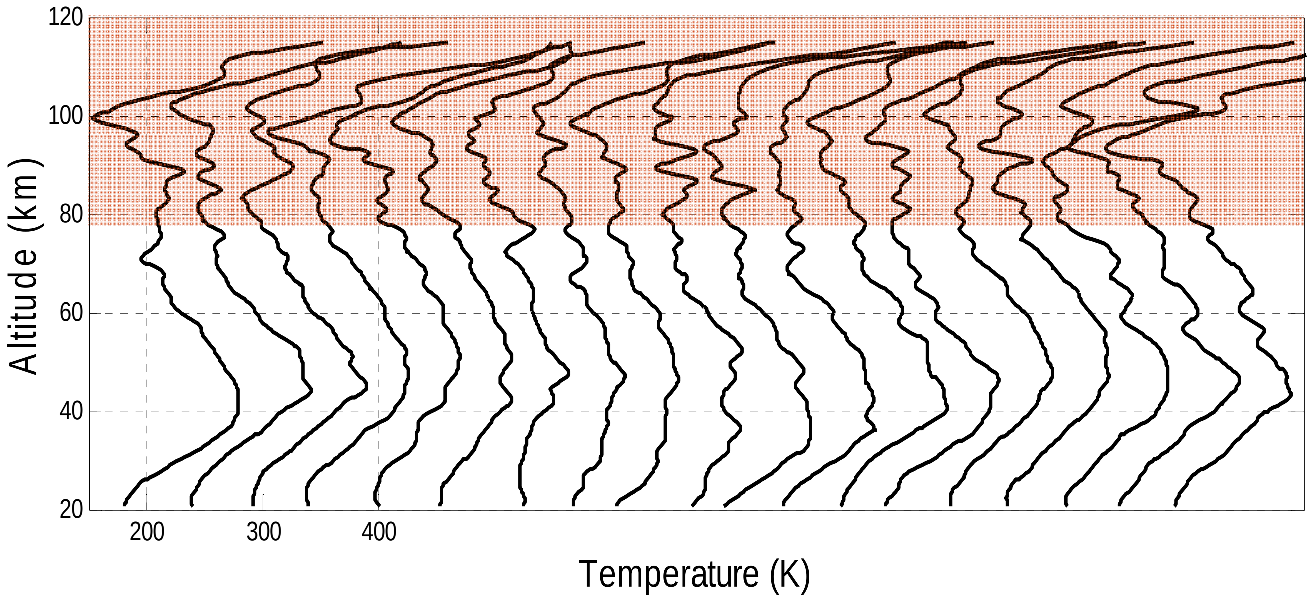




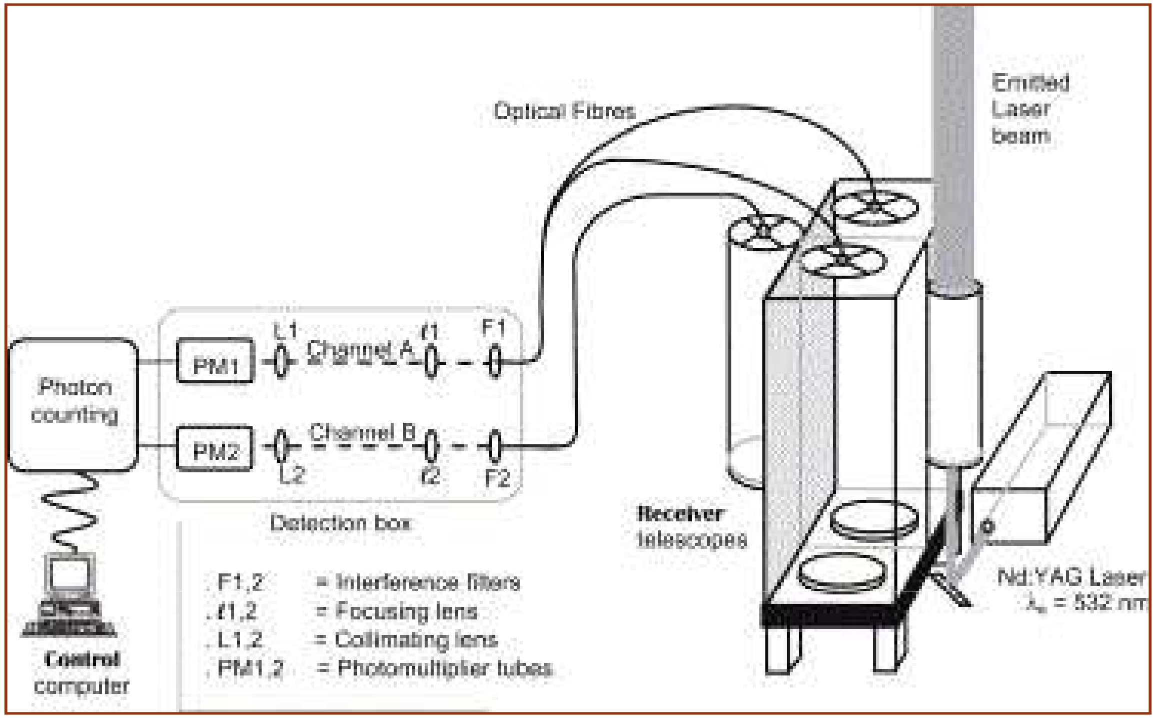
Vertical temperature profiles from SABER satellite

SABER obtain profiles from 52°S to 83°N during its north-looking mode for 60 days, switches to an analogous south-looking mode and then repeats that sequence for the subsequent months [Remsberg et al., 2003].

The profiles are for successive days from 1 to 19 September 2002 (244 - 262 day) and closest as the satellite overpasses over the SANAE site



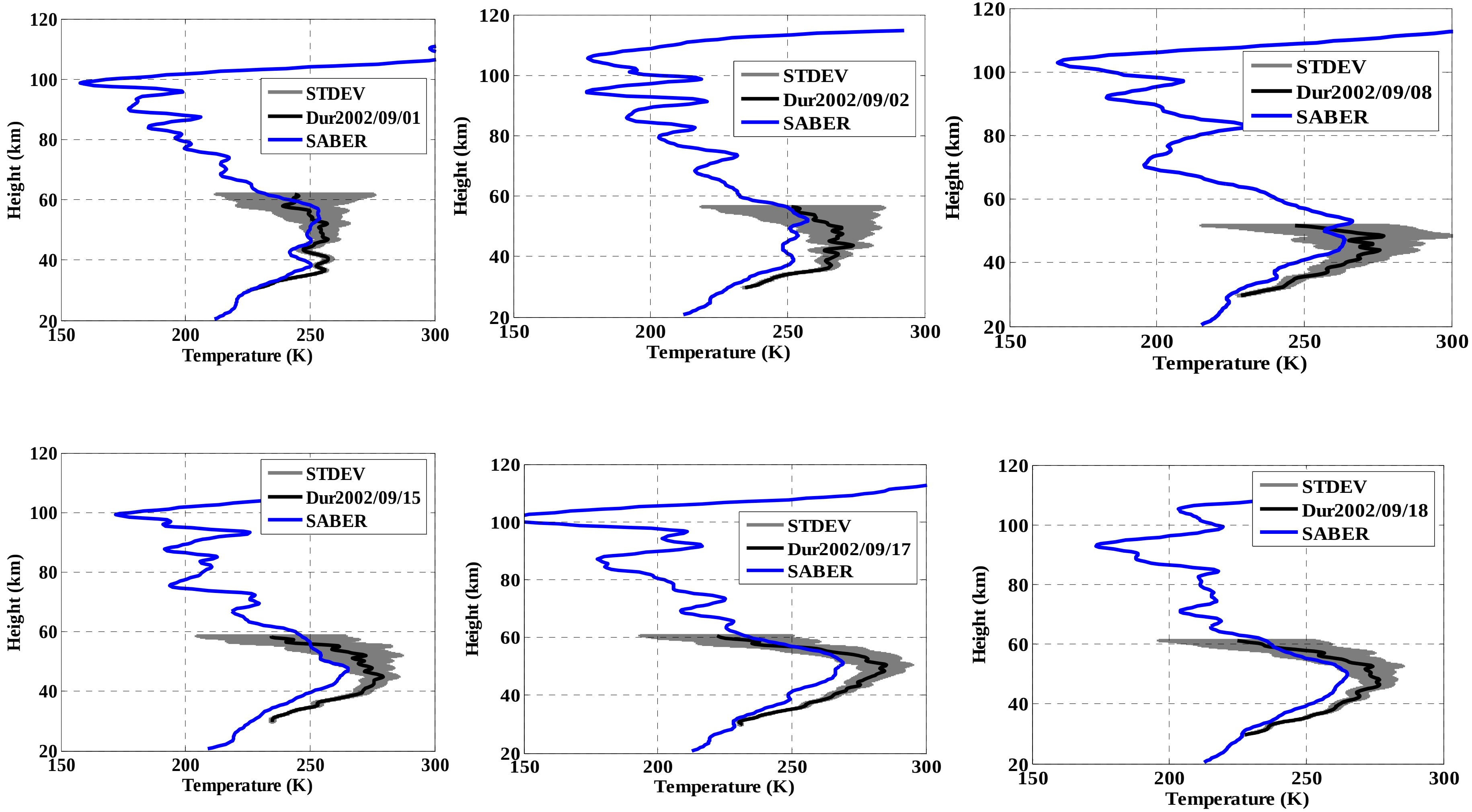
Rayleigh-Mie LiDAR [UKZN, Durban]



Transmitters		Receivers
Spectra physics GCR-150	Spectra physics GCR-3	Newtonian telescopes
Emitted wavelength: $\lambda_e = 532$ nm	Emitted wavelength: $\lambda_e = 532$ nm	Channel A: 2 parabolic mirrors
Repetition rate: 10 Hz	Repetition rate: 30 Hz	Diameter of each mirror: 445 mm
Energy per pulse: 300 mJ	Energy per pulse: 500 mJ	Focal length: 2000 mm
Pulse width: 6–7 ns	Pulse width: 5–7 ns	Channel B: 1 parabolic mirror
Beam divergence (FWHM): 0.50 mrad	Beam divergence (FWHM): 0.50 mrad	Diameter: 200 mm
		Focal length: 1000 mm

$$P(R,\lambda) = P_0 \frac{c\tau}{2} A\eta \frac{O(R)}{R^2} \beta(R,\lambda) \exp\left[-2\int_0^R \alpha(r,\lambda)\mathrm{d}r\right]$$

Vertical temperature profiles (SABER vs. Durban LiDAR)



Conclusion

HF radar data set from SANAE base in Antarctica was used to examine the dynamical structure of the MLT region during the unprecedented major SSW occurred in late September 2002.

Identified the SSW using NCEP reanalyses data using Labitzke et al., [2000] criterion

We have shown that the mean zonal wind (from SANAE HF radar) throughout 2002 winter at ~94 km showed enhancement due to a series of large planetary waves amplification in the stratosphere.

Identified 5-day, 10-day and 14- to 16-day waves during the 2002 austral winter.

Downwards propagation of circulation disturbance in the middle atmosphere.

MLT showed cooling and temperature inversions few days before the SSW occurrence.

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Acknowledgements

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