Rayleigh lidar investigation of sudden stratospheric warming observed over Northern and Southern hemisphere stations

V. SIVAKUMAR[1,2], H. Bencherif[1], D.V.Acharyulu[1], A. Hauchecorne[3], D.N. Rao[4], S. Sharma[5] and P. B. Rao[6]

(1) Laboratoire de l'Atmosphère et des cyclones CNRS–UMR 8105, Université de La Réunion, Reunion Island, FRANCE.

(2) National Laser Centre, CSIR, Pretoria, SOUTH AFRICA.

(3) Service d'Aéronomie, CNRS, Paris, FRANCE.

(4) National Atmosphere Research Laboratory, P. B. No: 123, Tirupati – 517 502, INDIA.

(5) Physical Research Laboratory, Navarangapura, Ahmedabad – 380 009, INDIA.

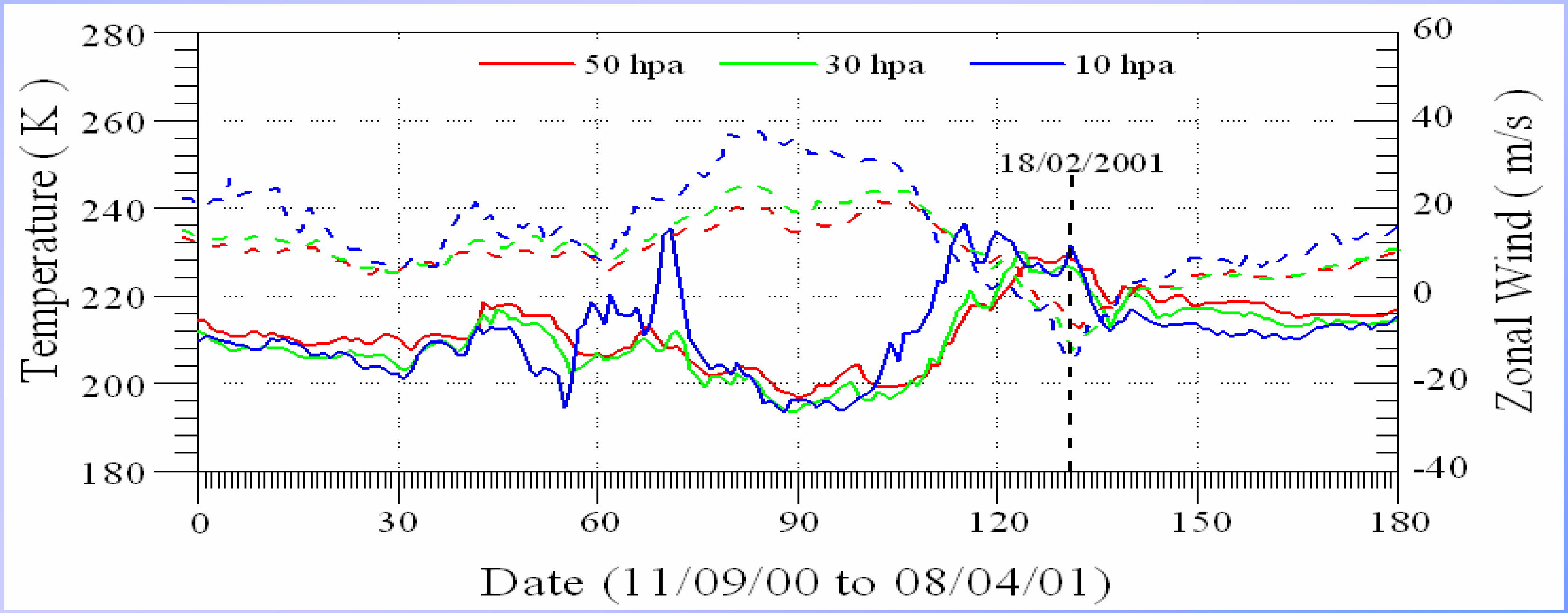
(6) National Remote Sensing Agency, Bala Nagar, Hyderabad-500 037, INDIA.

Plan of the presentation

- Definition of SSW
- Brief Introduction
- Classification of SSW
- Properties of SSW
- Objective of the study over tropical/sub-tropical and Mid-latitudes
- SSW event observed over a low-latitude station
- Results and Discussion of the low-latitude SSW event
- SSW event observed over a southern-sub tropical station
- Statistical characteristics of SSW observed over OHP (Mid-latitude)
- Summary of the result from OHP
- Summary of the presentation

Definition

During some winters, zonal-mean configuration is dramatically disrupted with polar stratospheric temperatures increasing rapidly with time, leading to a pole ward increase of zonal-mean temperature and, on occasion, a reversal of zonal-mean winds to an easterly direction exists. Such an event is called *Stratospheric Sudden Warming* (SSW).



Brief Introduction

First observation of the Stratospheric Sudden Warming (SSW) was made by *Scherhag* in 1952, using *radiosonde* measurements over Berlin.

***Schoeberl* (1978) provided a review on theory and observations of stratospheric warming using results reported from different places. The results were suggested that the warming is confined to the *Northern Hemisphere*, especially during *winter* over the *polar* region. Similarly, there is also some evidence of SSW occurrence in Southern Hemisphere and reported in many research papers.**

The cause for such warmings were attributed mainly due to *Planetary wave and /or Gravity wave* propagation.

There are many results reported for high latitude and very rarely for Mid and low latitudes.

Classification of SSW

The SSW have been classified as Major, Minor, Canadien and Final warmings ;

Major Warming

* strongest zonal mean temperature disturbances and increase in temperature over pole
* 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 and less interaction on the hemisphere
* no zonal mean wind reversal
* does not lead to a breakdown of the polar vortex

Canadian Warming

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

Final Warming

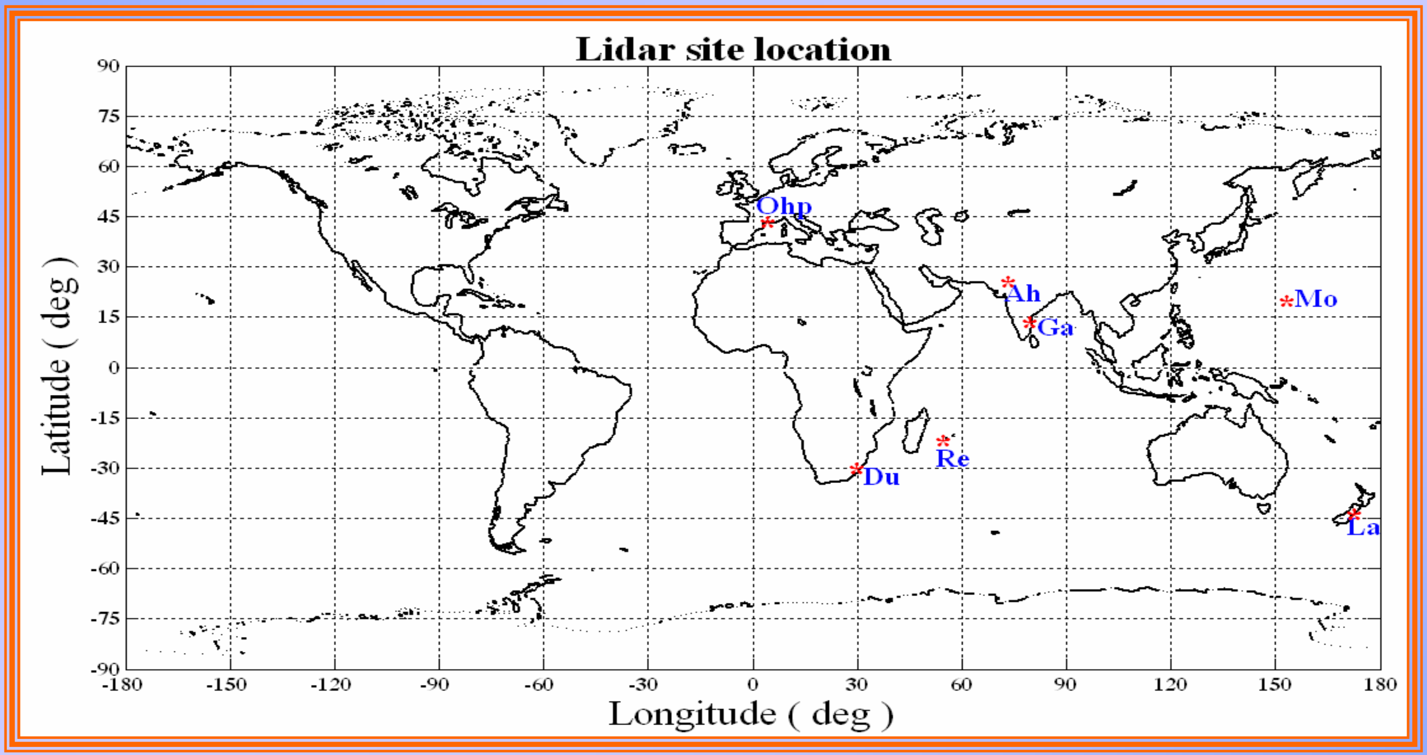
* occur in the end of winter(spring),
* markable transition in the stratosphere between westerly winds in winter and easterly winds in summer.
* lead to a breakdown of the cyclonic polar vortex.

Properties

- **SSW is a *large-scale dynamical event* to occur in the middle atmosphere.**
- **It is a *transient phenomenon***
- **It does not occur every year, but mostly it seems to occur in *winter hemispheres*.**
  - **Major warming may not occur every winter but mostly occur in every alternative winter**
  - **Minor warming occur every winter.**
- **It disturbs the stratospheric circulation, *strongly zonally asymmetric* before and during SSW.**
- **It may increase the temperature over poles into 40-60 K within a week.**
- **It also has a strong link with QBO phase (east/west).**

Objective of the study

We are interested to study and define the statistical charecteristics of SSW events observed at different latitudes using primarily ground based *LiDAR data* for both the Northern and Southern hemispheres. Later, we would like to do the same using *radiosonde* and also *satellite data*.



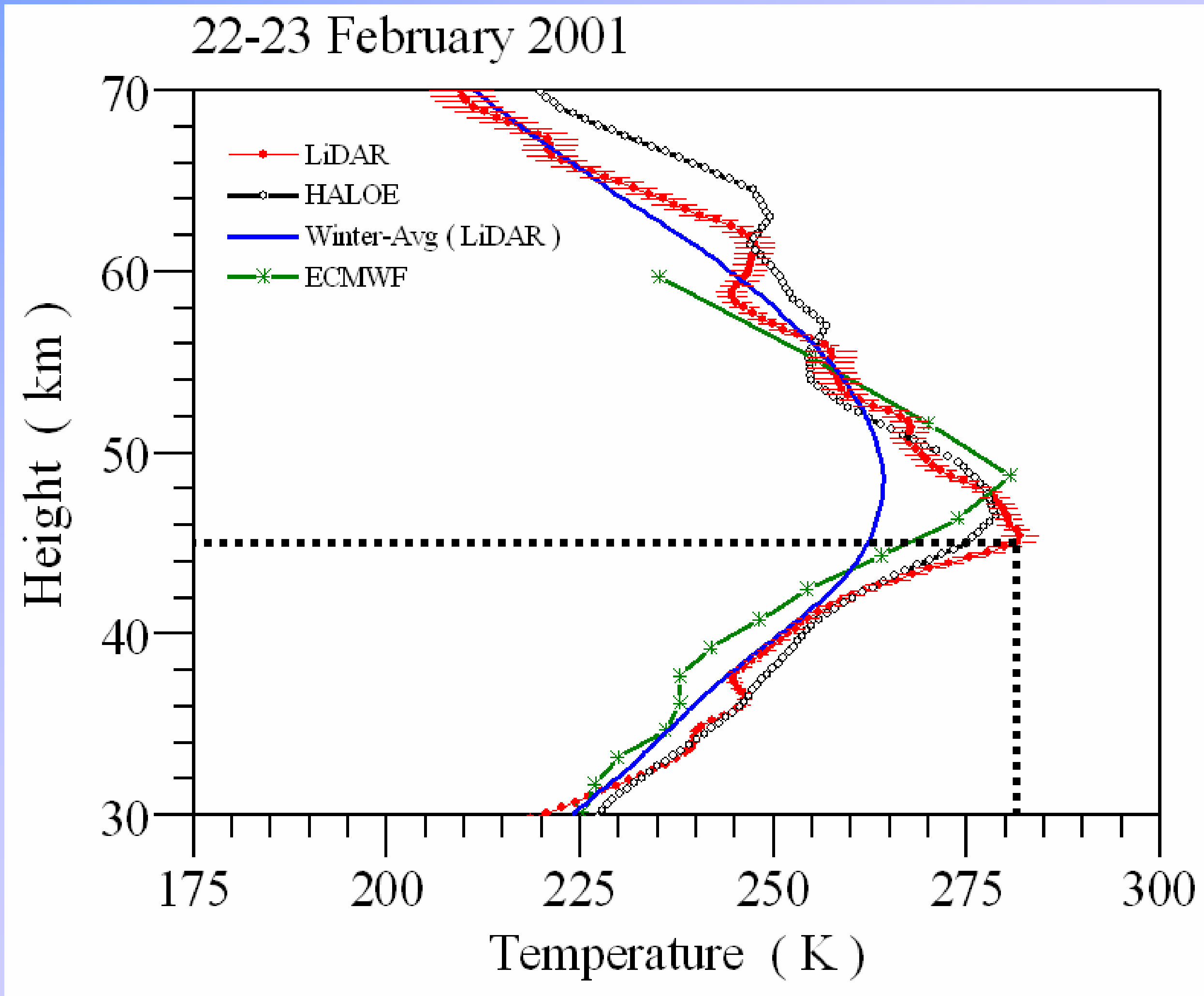
Northern Hemisphere:

Gadanki (13.5°N ; 79.2°E),
Mauna Loa (19.54°N ;155.58°E)
Mt Abu (24.41°N ; 72.50°E),
OHP (44°N ; 6°E)

Southern Hemisphere:

Reunion (21.8°S ; 55.5°E),
Durban (29.49°S ; 31.01°E),
Lauder (45.04°S ; 169.68°E)

Warming observed over a low-latitude station : Gadanki (13.5 N, 79.2 E)



Height profile of temperature obtained from Lidar and HALOE satellite data for the night of 22-23 February 2001. The figure is overlapped by the ECMWF data.

Data used :

Case study on 22-23 February 2001.

1. Rayleigh Lidar data :

Temperature profiles for the height range of 30-90 km with height and time resolutions of 300 m and 250 sec.

Time period of data : 2000-0200 LT.

2. HALOE satellite data :

The overpass (10.46°N; 73.31°E) HALOE satellite observation for the same day. The data corresponds to Net-ASCII (Version-19).

3. NCEP and ECMWF observations :

Data corresponds to 2.5°×2.5° grid from 1000 to 10 hPa and from 1013.25 to 0.20 hPa.

3. Results

Lidar and satellite observation

Warming is observed at ~ 46 km.

Observed temperature is ~ 283 K.

HALOE profiles are very close to the observed warming.

Magnitude of warming :

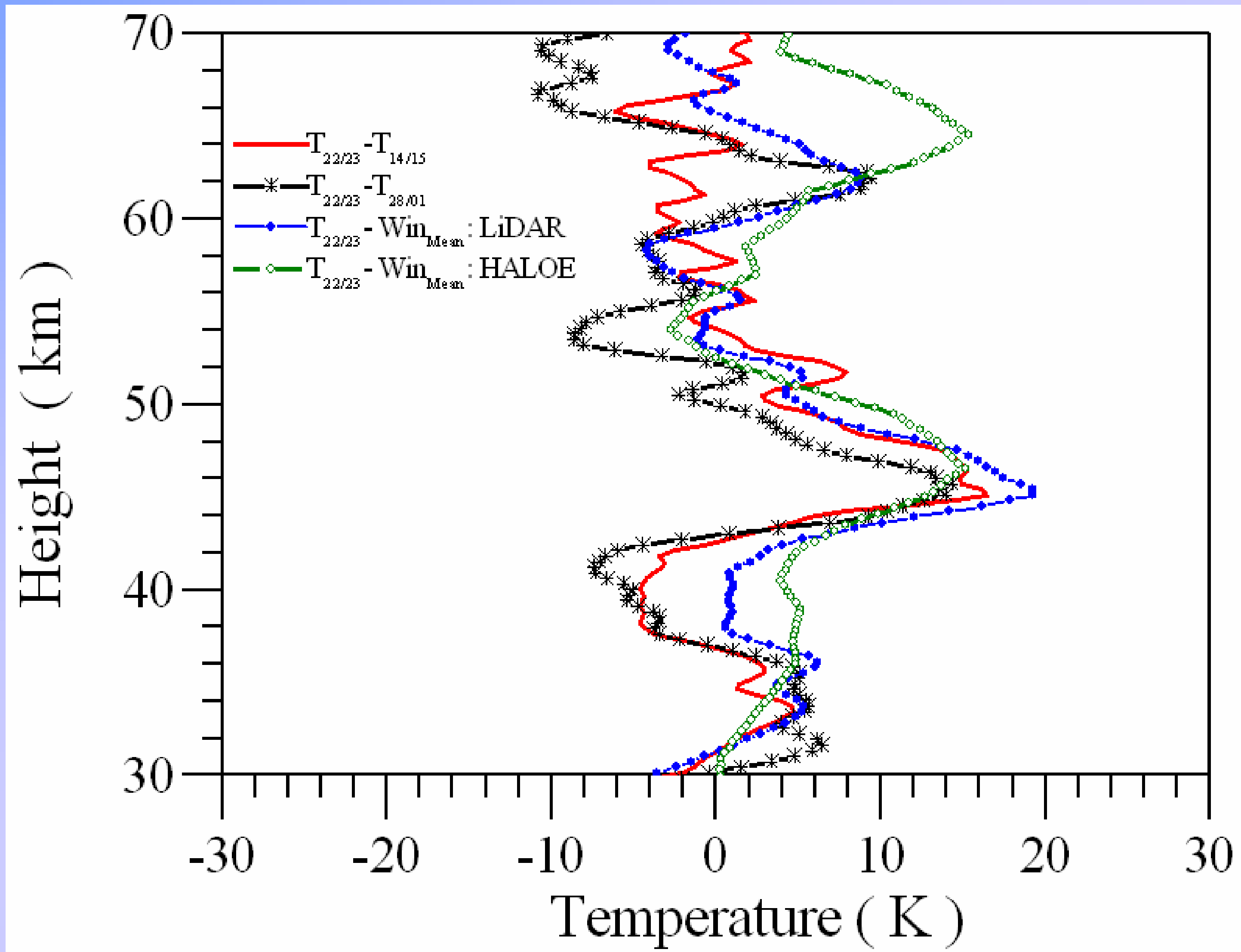
With respect to monthly mean ~ 18 K

Just a week before and after the event ~16 K

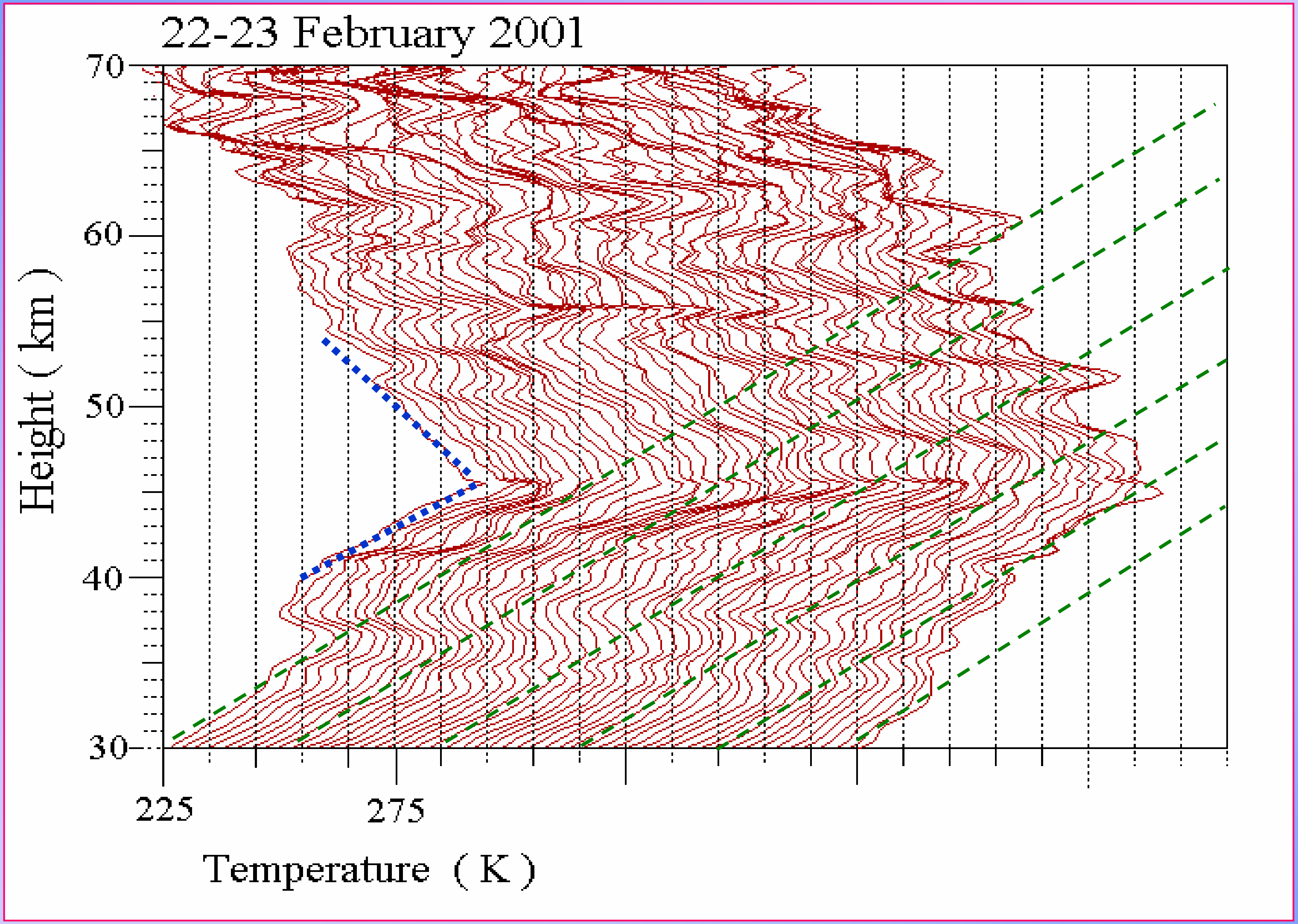
ECMWF data also depict the lidar observed warming with same order of magnitude.

The little discrepancy with height, is due to the differences in their height resolution.

Magnitude of warming

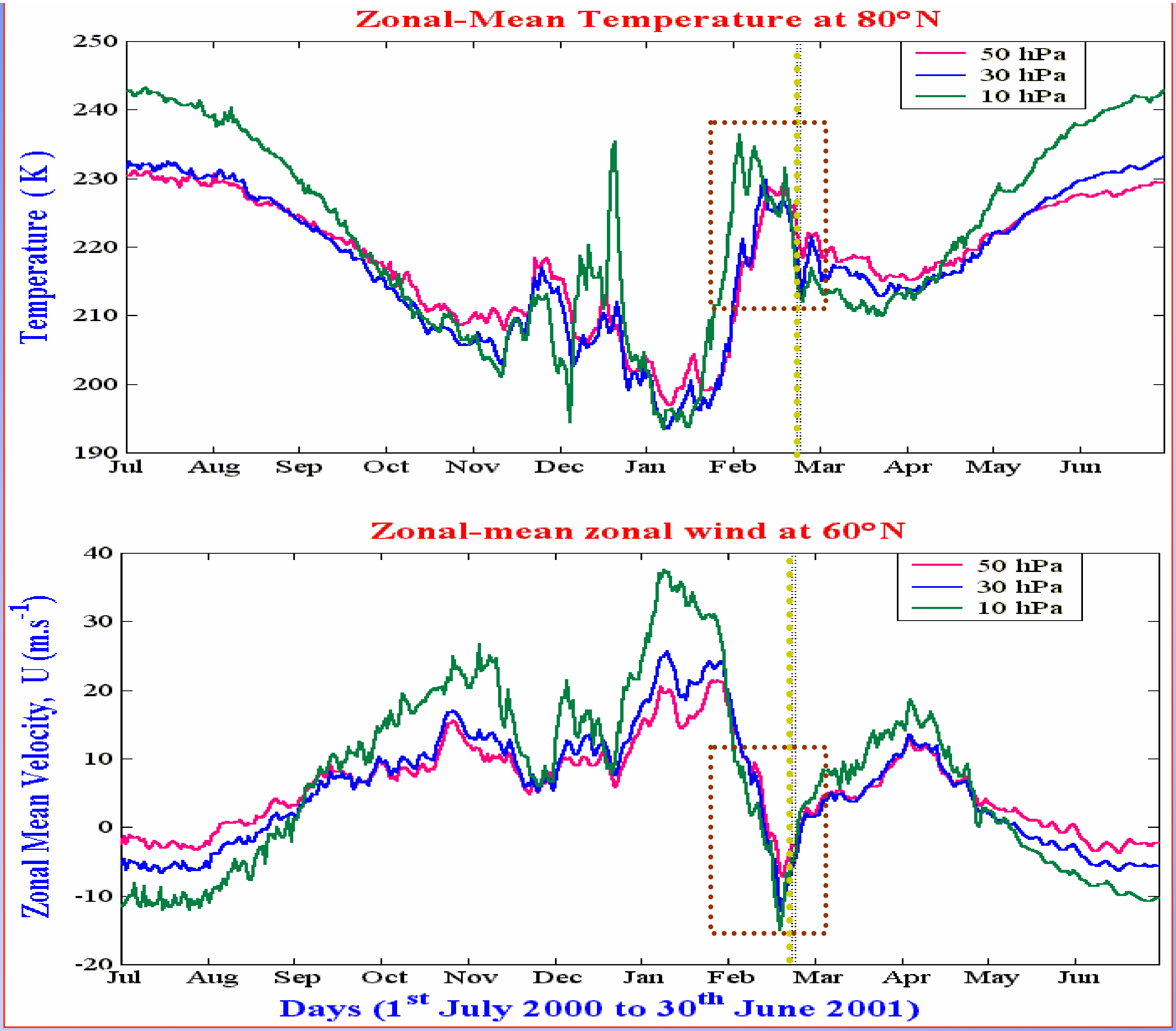


Role of GW

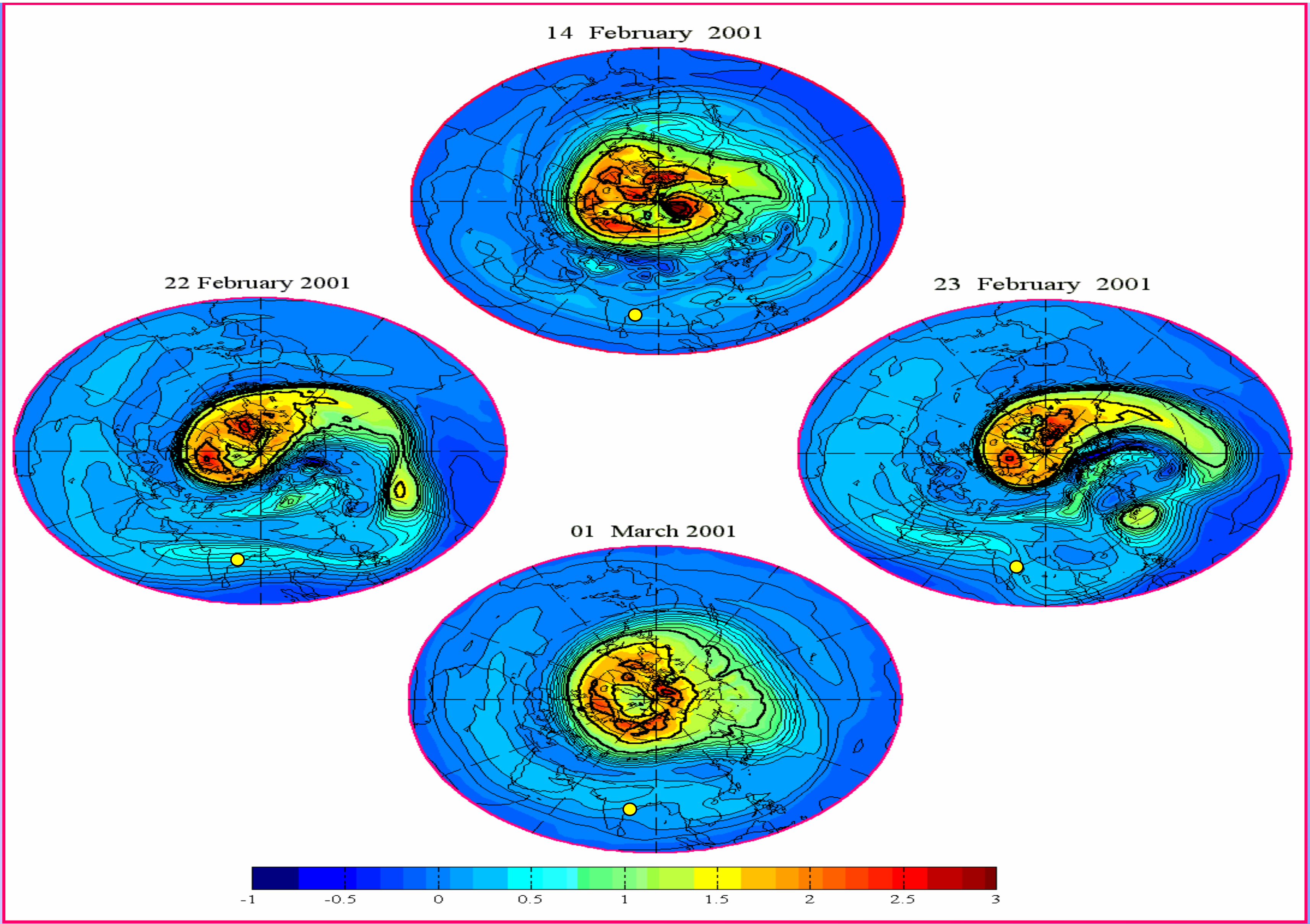


Time sequential plot of lidar measured temperature for the night of 22-23 February 2001, each profiles are off-set by 8 K.

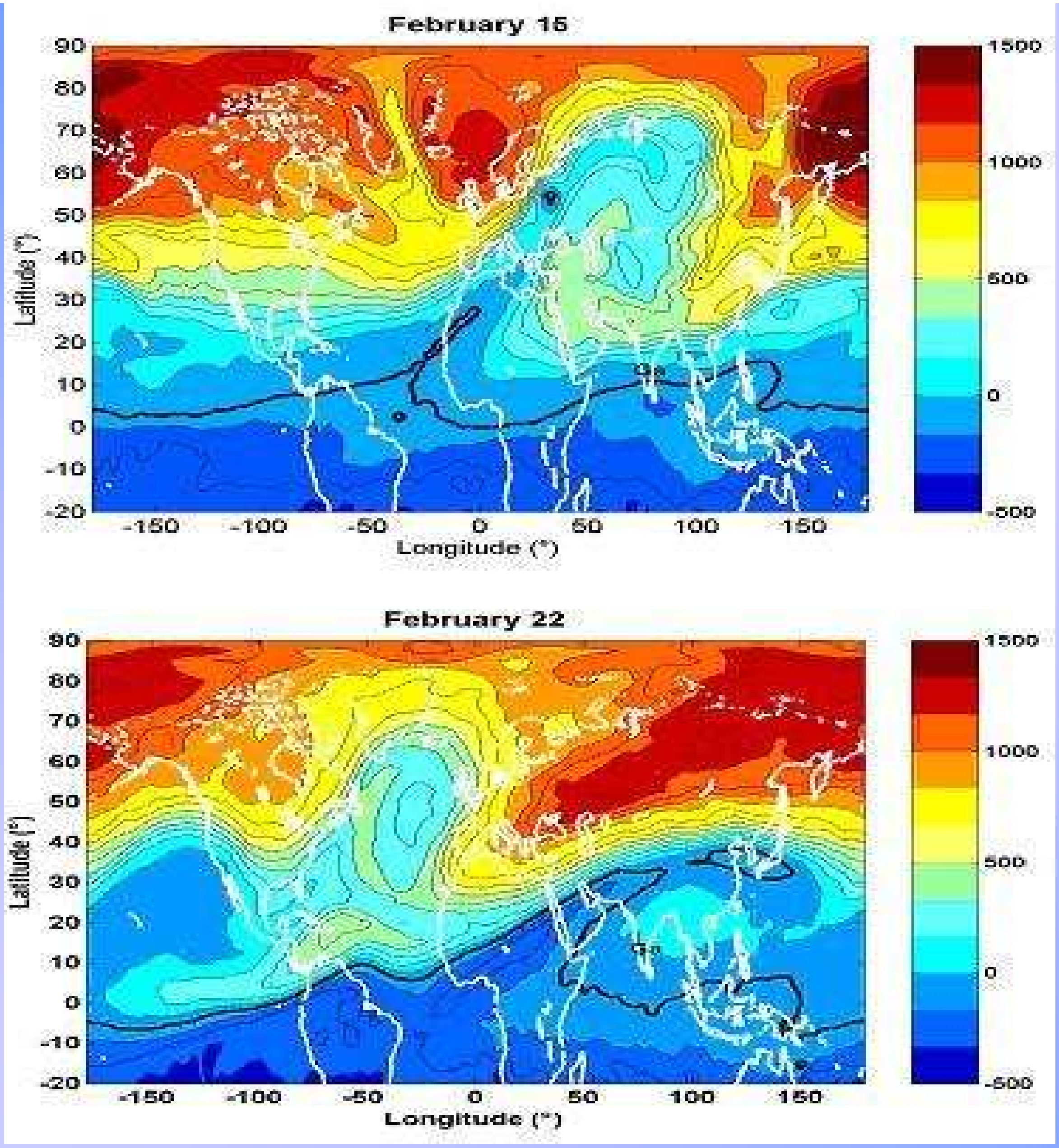
- **It provides a clear indication of a sharp changes in adiabatic lapse rate of ~7 K / km at above and below to the warming region.**
- **The magnitude of lapse rate is similar to that of mid-latitude observation and little lesser than that reported for high latitudes.**
- **This changes in the adiabatic lapse rate found be have great significances in producing warming and cooling effect at stratosphere and mesosphere.**
- **Few studies, too supported for the mesospheric cooling in connection to the stratospheric warming. The present observations show the mesospheric cooling of ~5-10 K in comparison with the normal days.**



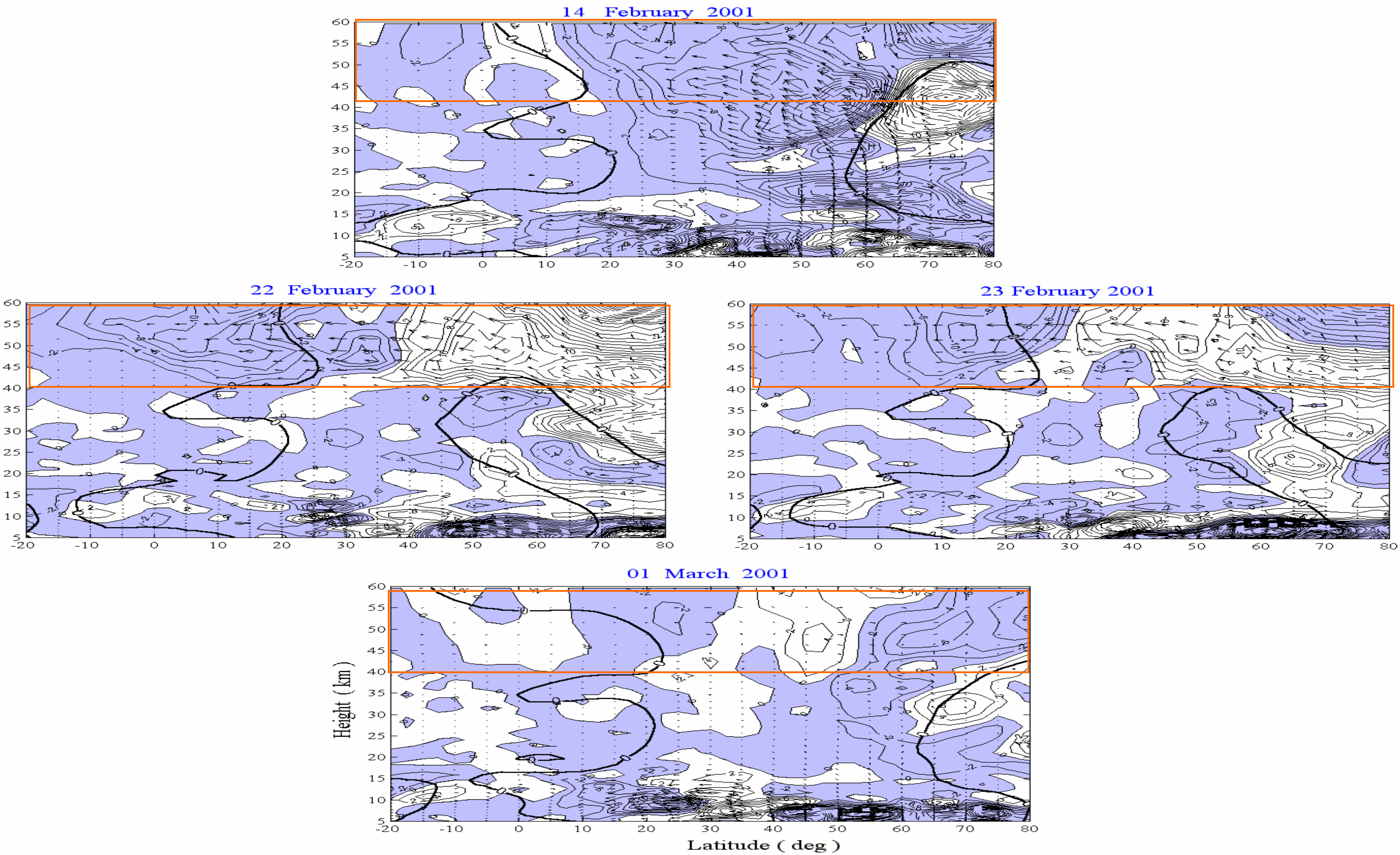
Variation of zonal-mean temperature at 80°N and zonal-mean zonal wind at 60°N from July 1, 2000 through June 30, 2001 at 3 different pressure levels in the stratosphere corresponds to 50, 30 and 10 hPa, derived from NCEP data. The dotted line indicates the day of event observed by the lidar.



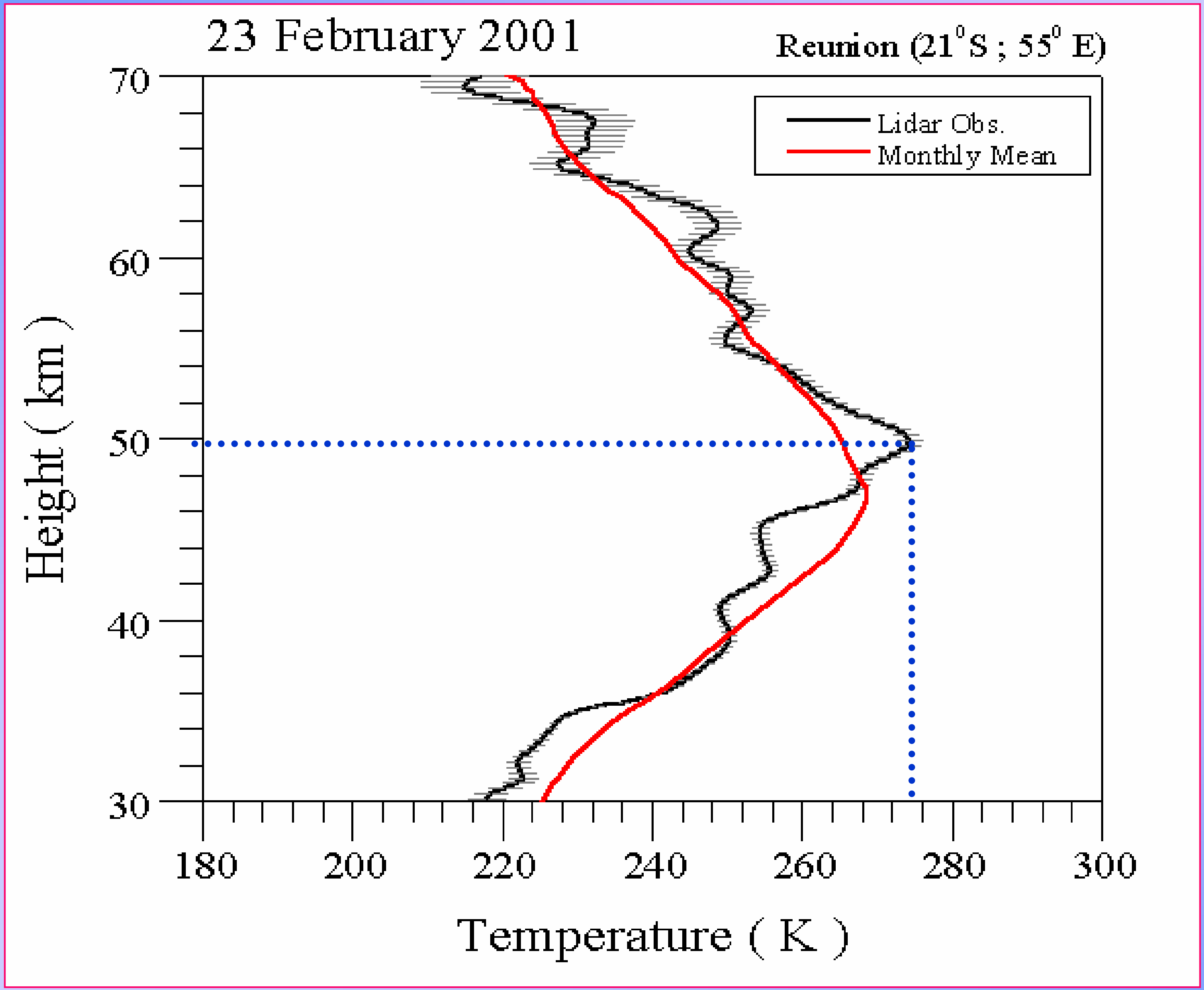
Evolution of Ertel's Potential Vorticity map at the 1900 K isentropic surface. The contour interval is $1x10^{-3}$ K kg^{-1} m^2 s^{-1} for PV < $10x10^{-3}$ K kg^{-1} m^2 s^{-1} solid lines); it is $5x10^{-3}$ K $kg^{-1}m^2s^{-1}$ for PV $\geq 10x10^{-3}$ K kg^{-1} m^2 s^{-1} (thick solid lines). 'Dot' indicates the location of the lidar station.



Evolution of Ertel's Potential Vorticity on the 1900-K isentropic surface for (a) Feb.15, and (b) Feb.22, 2001. The contour interval is 1x10^{-3} K.kg^{-1}.m^{2}.s^{-1} for PV<10x10^{-3} K.kg-1.m^{2}.s-1 (solid lines); it is 5x10^{-3}K.kg^{-1}.m^{2}.s^{-1} for PV ≥ 10x10^{-3}K.kg^{-1}.m^{2}.s^{-1} (thick solid lines). "Ga" indicates the location of the lidar station.



E-P flux cross-sections in the meridian plane. Contours represent values of the wave driving term D, the negative wave driving is shaded. The contour interval is 2 $ms^{-1}day^{-1}$, and dashed contours correspond to values more than 10 $ms^{-1}day^{-1}$ or less than -10 $ms^{-1}day^{-1}$. Thick contours represent zero zonal-wind lines.



Height profile of temperature as observed on 23 February 2001 for Reunion (21° S; 55° E)

Data used for OHP observation

1. Rayleigh LiDAR data:

A quasi-continuous LiDAR temperature data of 20 years (Jan 1982 to Dec 2001) over Observatory of Haute-Provence(OHP), south of France(44°N, 6°E) used.

Total Number of observations (20 years) : 2631 profiles

Total Number of observations in summer : 1394 profiles

Total Number of observations in winter : 1237 profiles

2. NCEP data:

Data corresponds to 2.5°×2.5° grid from 1000 hPa to 10 hPa. We use, Zonal mean temperature at 80 N and zonal mean wind at 60 N from NCEP data (to note the warming over poles). It is also used as a pre-cursor to define the Major and Minor warming with respect to the zonal mean wind reversal.

3. ECMWF data:

ECMWF ERA-40 reanalysis data corresponds to 2.5°×2.5° grid from 1000 hPa to 1 hPa. We use wind and temperature data to interpret the result, and for calculating E-P flux, Potential Vorticity one week before or after the event observed.

4. HALOE data:

Temperature measurements between 30 km to 80 km.

HALOE satellite observation overpass OHP site with ± 5 deg (latitude) and ± 10 deg (longitude) for the same day of the event noticed.

The data corresponds to Net-ASCII (Version-19).

Criteria followed

Criteria followed to classify SSW events observed over OHP as a Major and Minor warmings in terms of zonal mean :

Major warming:

- Warm temperatures observed 10 K and above the mean winter temperature observed over OHP *and*
- Wind reversal at 10 hPa observed over polar region few days before to the SSW event observed over OHP .

Minor warming:

- Warm temperatures observed 10K and above the mean winter temperature observed over OHP *and*
- No wind reversal at 10 hPa observed over polar region few days before to the SSW event observed over OHP.

Statistics of SSW events observed over OHP in 20 winters

Type of warming	Year of occurrence	Total No.of events in 20 winters
Major	*1982*(2),*1984*(2),*1985*(1),*1987*(2),*1988*(1),*2000*(1),*2001*(1)	10
Minor	*1982*(1),*1983*(3), *1984*(2),*1985*(2),*1986*(2),*1987*(2),*1988*(2), *1989*(1),*1990*(2), *1991*(2), *1992*(2), *1994*(1), *1995*(2), *1996*(1), *1997*(1),*1998*(1),*1999*(4),*2000*(1)	32
		42

Type of warming	Height of occurrence	Descent of stratopause	Magnitude of warm temperature
Major	38 km to 54 km	1 km to 7 km	12 K to 31 K
Minor	42 km to 53 km	1 km to 7 km	10 K to 34 K

	QBO Phase east	QBO Phase west	QBO Phase west/east
No. of Major SSWs	5	2	2
No. of Minor SSWs	16	12	2

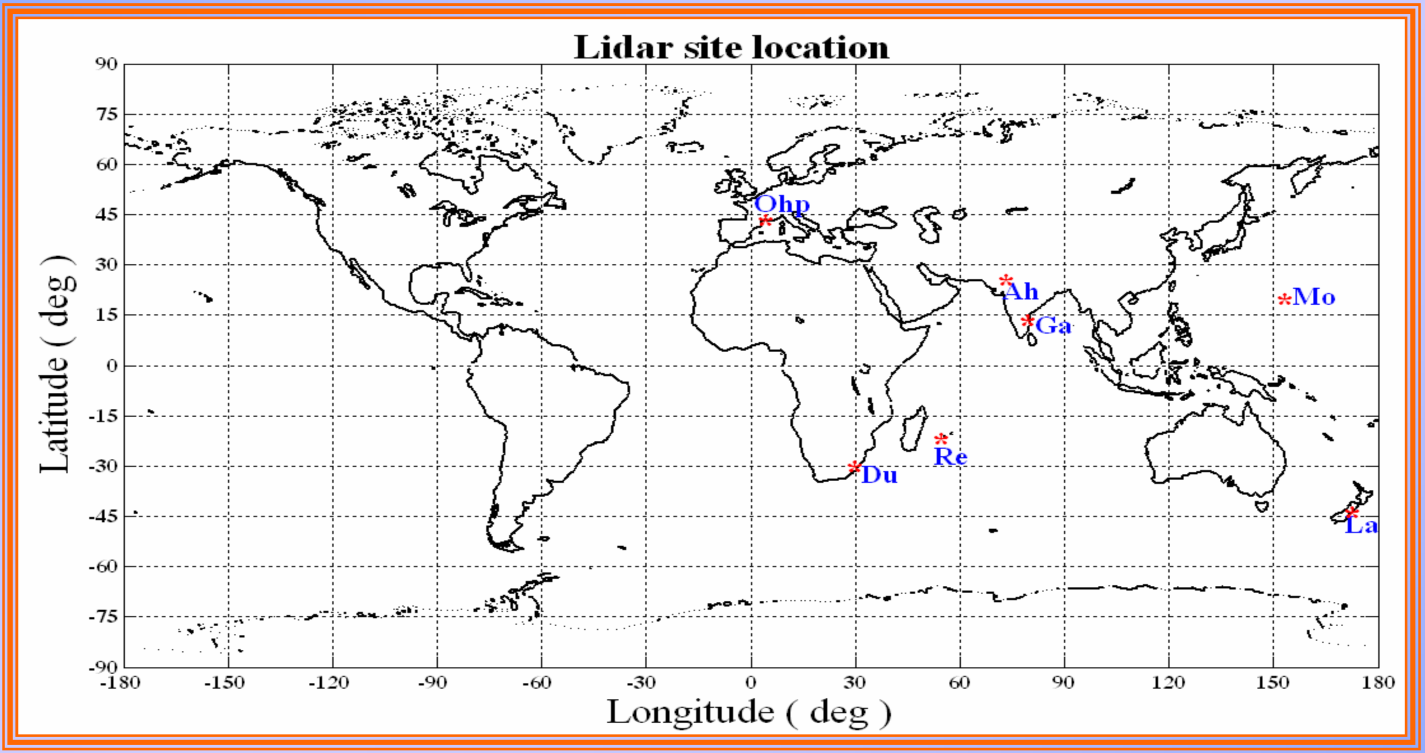
Summary of the result from OHP – SSW observation

- Our study shows that all SSW events occur by winter, i.e., between November and March. From 1237 daily winter profiles, 42 cases are detected as SSW over OHP. Most of them (76 %) have been classified as minor SSW and thus nearly a quarter of them (24 %) have been classified as major SSW.

- The observed major and minor SSWs are associated with descent of stratopause layer by 1 to 7 km. The height of occurrences of major SSW are distributed between 38 km and 54 km with magnitude in the 12-31 K temperature range, while the minor SSW appear at 42-53 km, closer to the usual stratopause layer and with a larger range of temperature magnitude (10-34 K).

Objective of the study

We are interested to study and define the statistical charecteristics of SSW events observed at different latitudes using primarily ground based *LiDAR data* for both the Northern and Southern hemispheres. Later, we would like to do the same using *radiosonde* and also *satellite data*.



Northern Hemisphere:

Gadanki (13.5°N ; 79.2°E),
Mauna Loa (19.54°N ;155.58°E)
Mt Abu (24.41°N ; 72.50°E),
OHP (44°N ; 6°E)

Southern Hemisphere:

Reunion (21.8°S ; 55.5°E),
Durban (29.49°S ; 31.01°E),
Lauder (45.04°S ; 169.68°E)

Summary of the presentation

- SSW event observed over a low-latitude is presented for the first time. It also evidenced that the importance of study over tropics/sub-tropical regions and mid-latitudes for better understanding the SSW event and their latitudinal extends.
- Using large amount of data sets (~ 20 years) from OHP (44 N), we have presented statistical characteristics of SSW observations.
- The existence of warming event over a southern-sub tropical station (Reunion, 21 S, 55 E) is also illustrated and further investigations are in progress.