Tracing the Inter-hemispheric Coupling during Northern Polar Summer Periods of 2002-2010 using TIMED/SABER Measurements

by

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2009 EGU General Assembly
Vienna, Austria
April 03-08, 2011

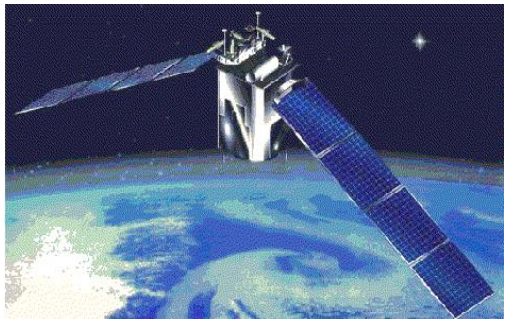
Motivation for the study

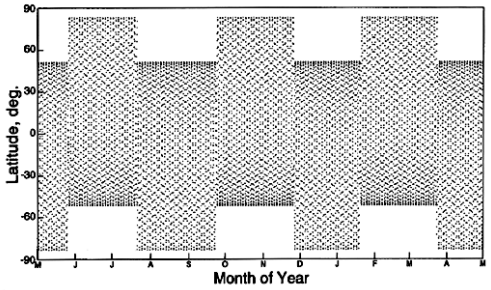
- Polar summer mesopause in 2002 was unusually warm.
- During this summer the stratospheric warming in the Southern hemisphere was also higher than usual.
- Becker et al., 2004: extreme stratospheric planetary wave activity leads to decrease of PMCs in Northern Hemisphere.
- Karlsson et al., 2007: correlation between PMC radii and winter stratospheric temperatures. Planetary wave activity in winter hemisphere affects the interhemispheric flow.
- Espy et al., 2011: correlation of extra heating with QBO.
- This work: extending the analysis to 2002-2010 using SABER data

The SABER Instrument Aboard the TIMED Satellite

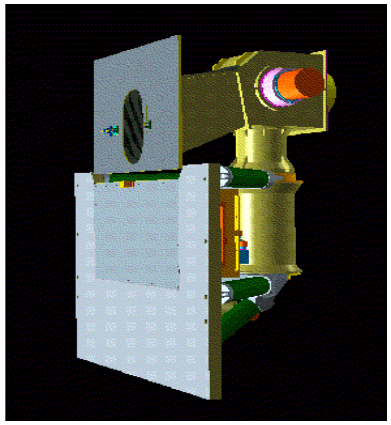
TIMED: Thermosphere, Ionosphere, Mesosphere Energetics & Dynamics
74.1° inclined 625 km orbit;
Latitudinal coverage: 83° S–52° N / 53° S–82° N
Data available since 25 January 2002

SABER: Sounding of the Atmosphere Using Broadband Emission Radiometry

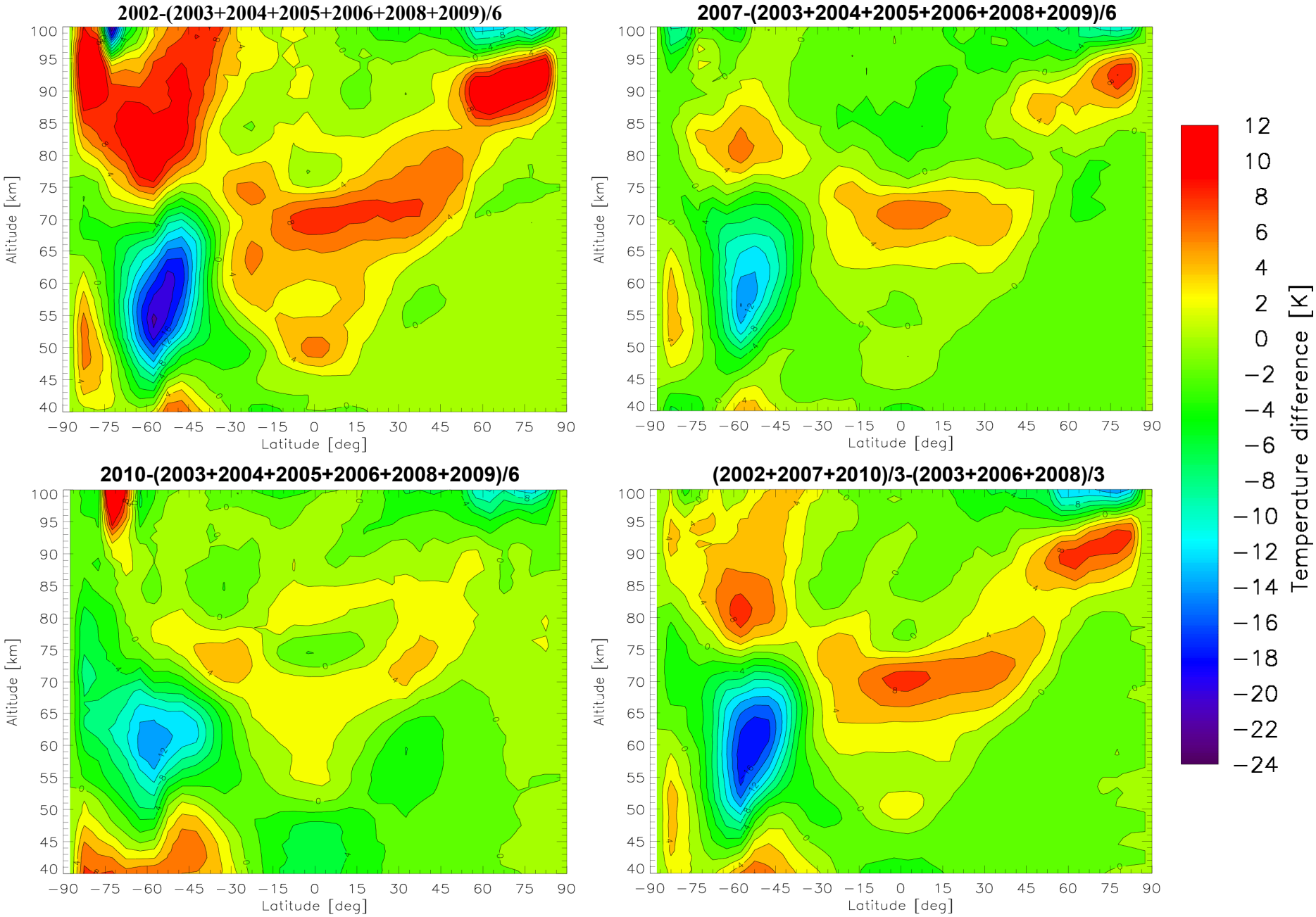




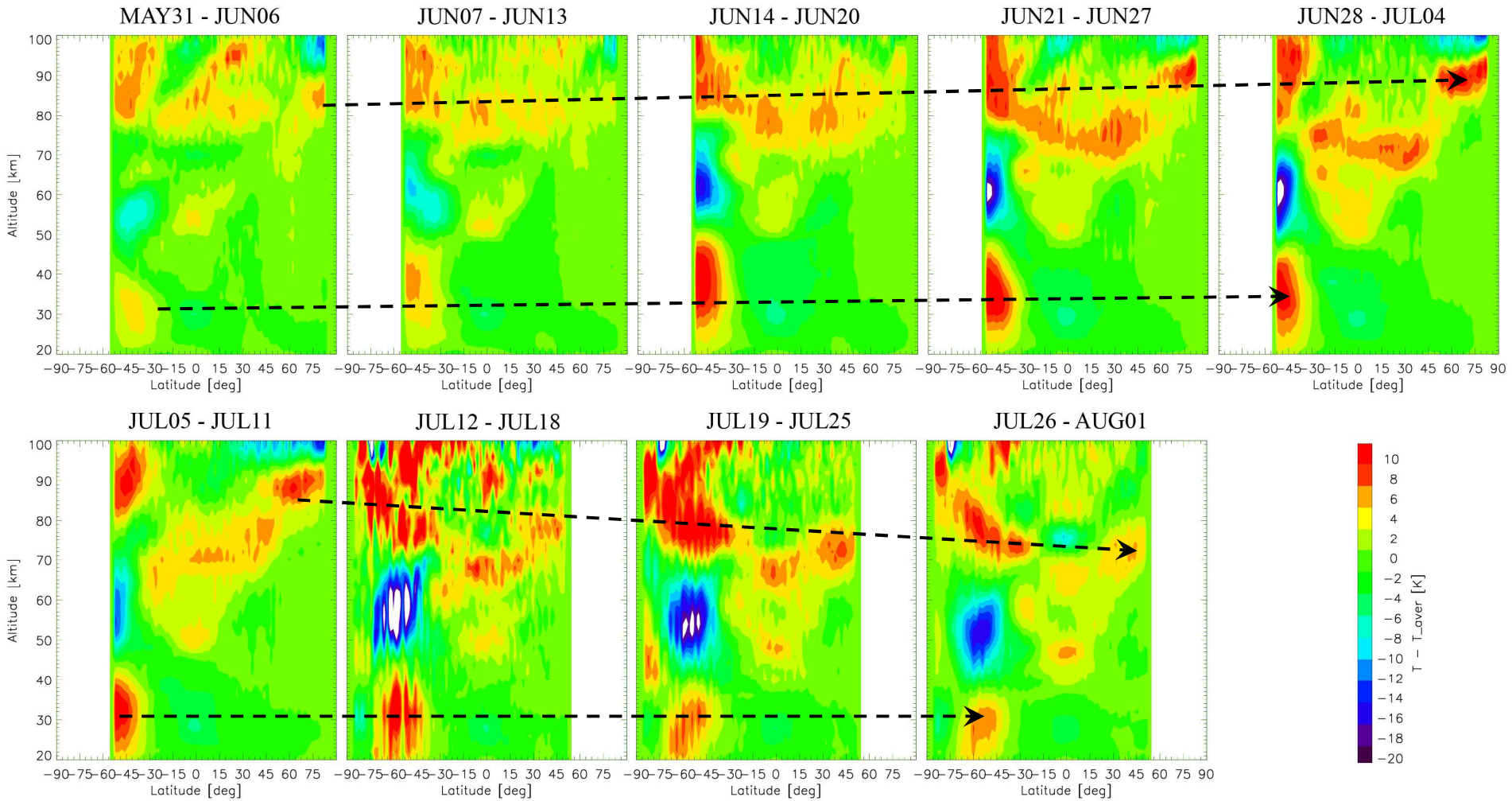
- Limb scanning infrared radiometer (~10–100 km, ~2 km footprint)
- 10 broadband channels (1.27–17 μm)
- Products: kinetic temperature, pressure, CO_2, O_3, H_2O, NO, O_2, OH, O, H



Temperature anomalies in 2002-2010



$T - T_{ave}$ (K) sequence: June-July, 2002



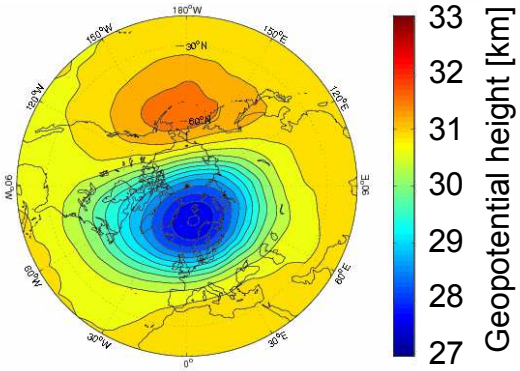
Note the features along the dashed lines that exist from the beginning of the season.

Sudden Stratospheric Warmings

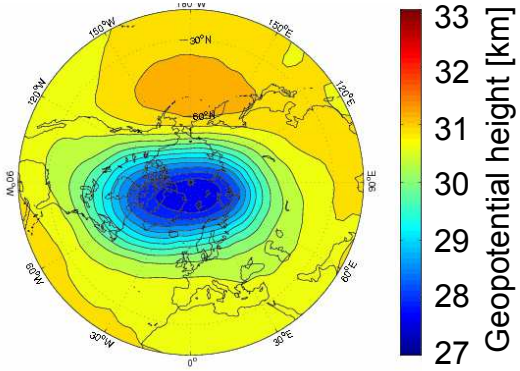
- Polar vortex breakdown causes SSW and leads to changes in geopotential heights (right).
- Tracing these signatures in h_{geopot} enables one to identify the strength and time of SSW event.
- Was 2002 SSW in Southern Hemisphere different compared to other years?
- Were there any other years that demonstrated the same behavior in h_{geopot}?

See the next slide for Δh_{geopot}(10hPa) plots where $\Delta h_{geopot} = h_{MAX} - h_{MIN}$

Geopotential height
at 10hPa on 19-Jan-1958

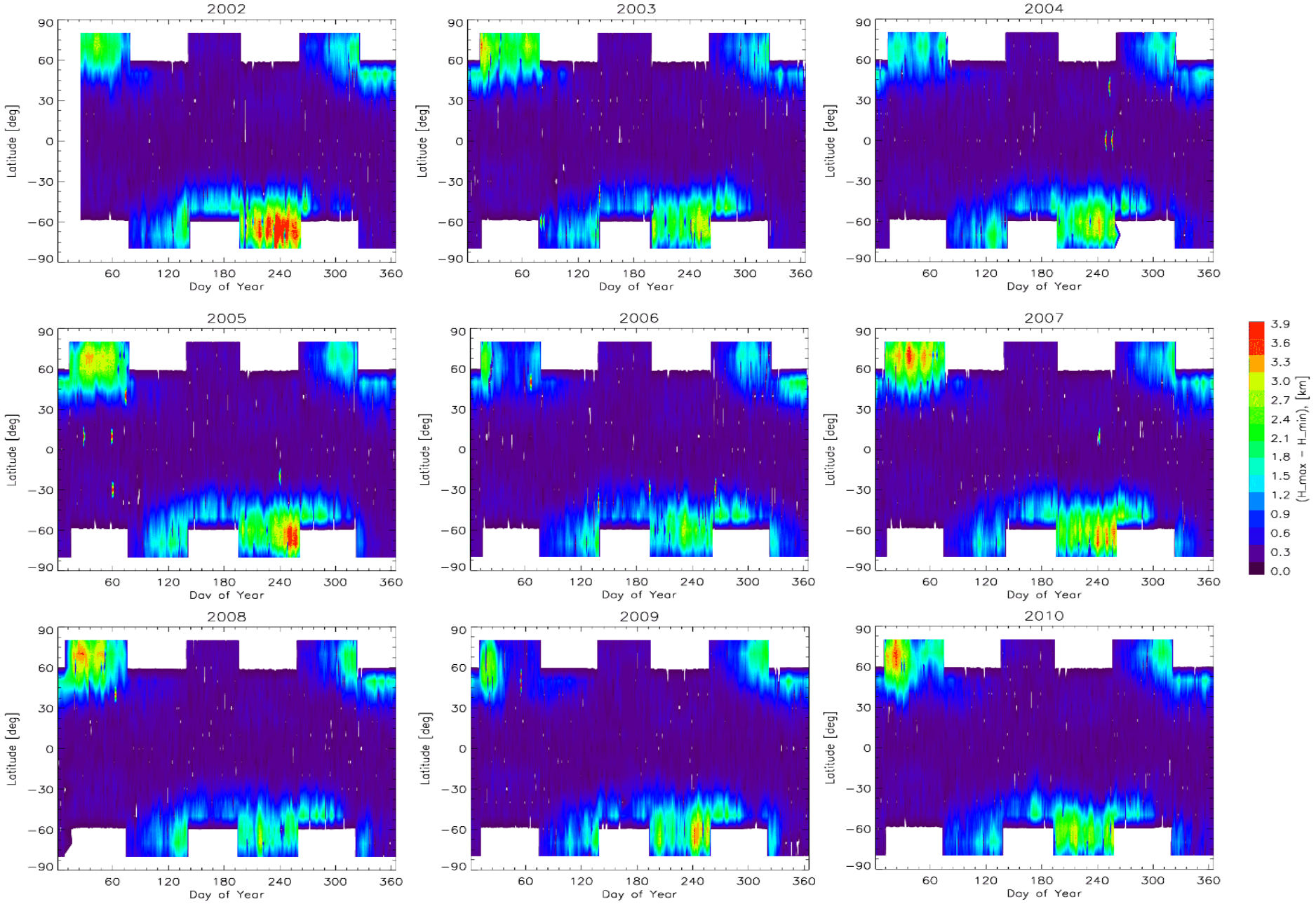


Geopotential height
at 10hPa on 04-Jan-1973



The Sudden Stratospheric Warming Website:
http://www.appmath.columbia.edu/ssws/

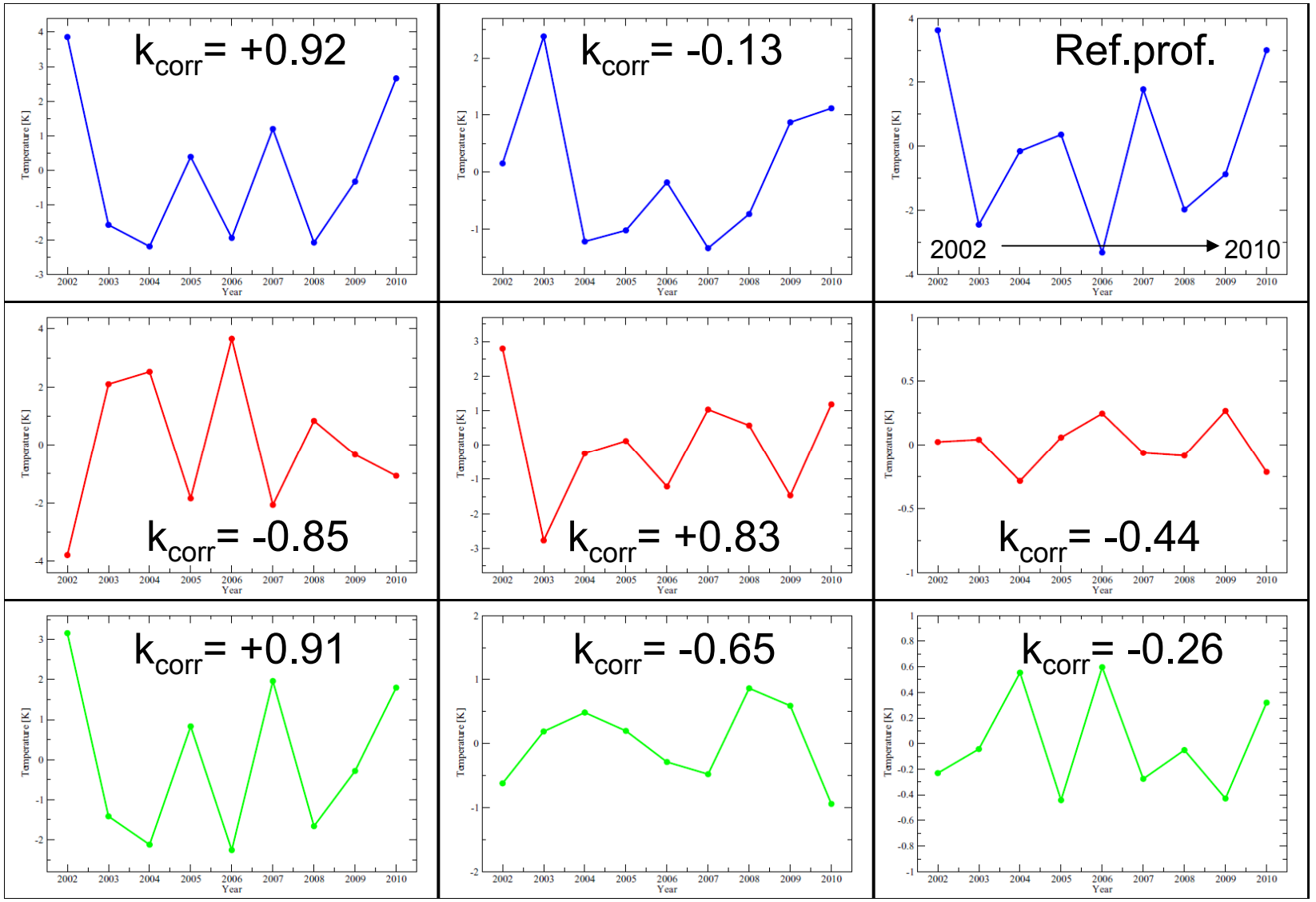
Δh_{geopot}(10hPa) in 2002-2010



Studying the Δh_{geopot}(10hPa) plots

- The behavior of Δh_{geopot} is similar for all winter periods in both hemispheres in 2002-2010.
- The maximum value of Δh_{geopot} is 3.6-3.9 km and was reached in SH 2002, SH 2005, NH 2007, SH 2007, NH 2008, 2010.
- The longest period of large Δh_{geopot} was in SH 2002 and began **after** DOY=200.
- At the same time the strongest warming in the polar summer mesosphere in 2002 corresponds to DOY=160-195 that happened **well before** the enhanced SSW activity in the Southern Hemisphere has started.
- Both the stratospheric warming in winter hemisphere and polar mesospheric warming in days 145-200 are not associated with a polar vortex breakup. After DOY=200 the breakup just added heating to the stratosphere.

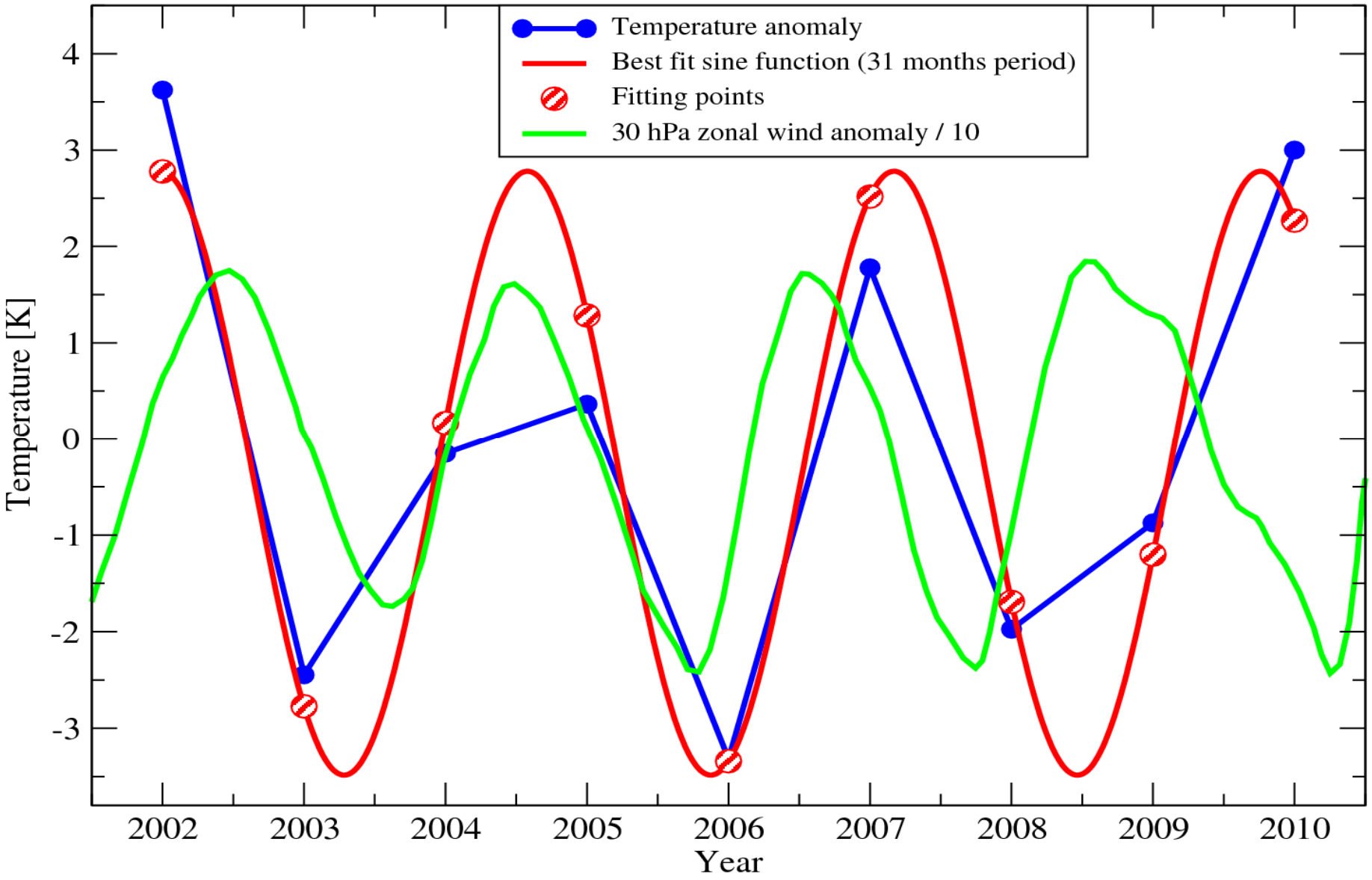
Correlations of T_{mesop}, $T_{stratop}$, and T_{trop} for DOY 182-212



Fitting the polar summer mesosphere temperature anomaly

k_{corr}=0.97 for 31 months oscillation ≠ QBO (24.5 months) !

Wind anomaly source: http://www.cpc.ncep.noaa.gov

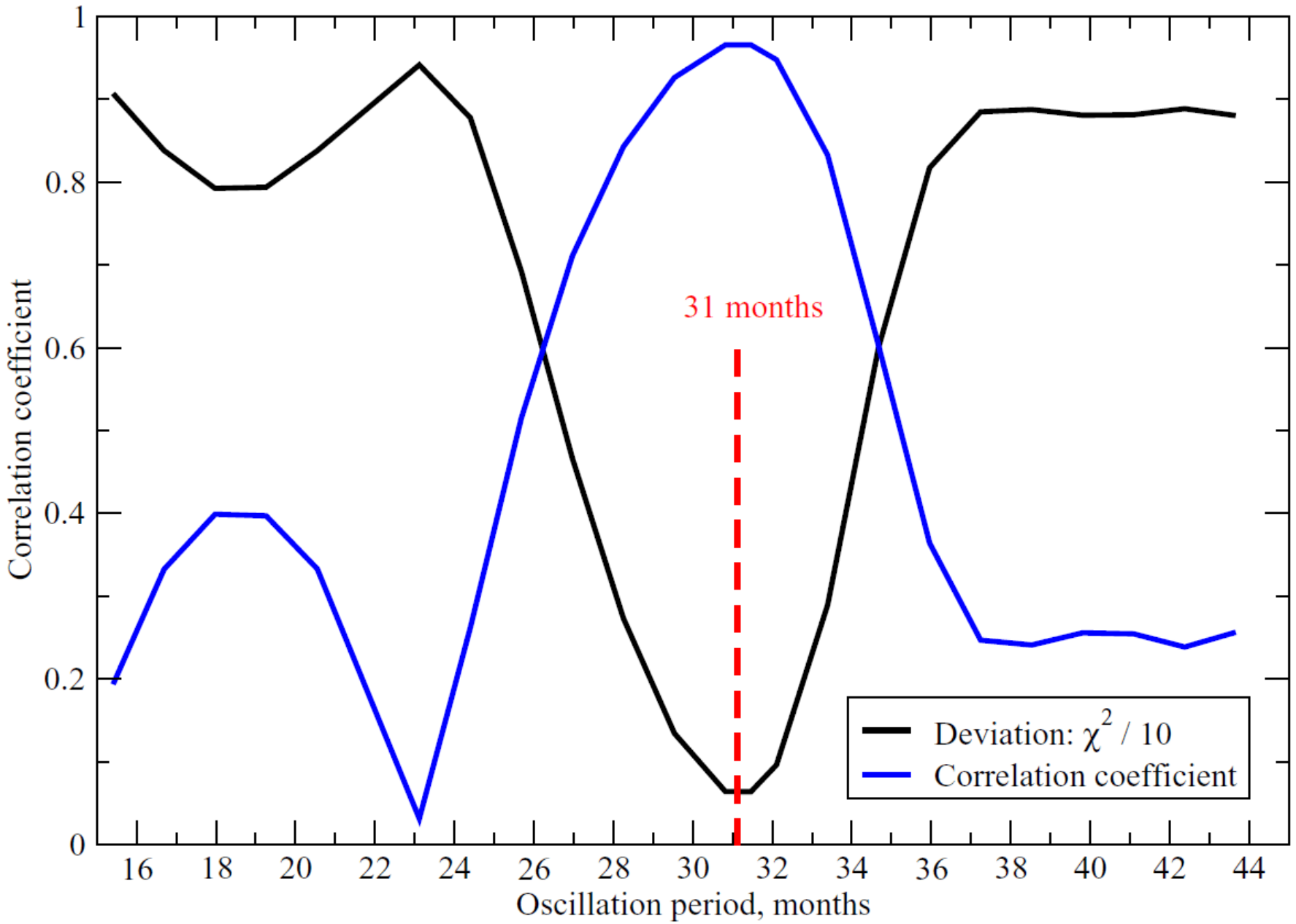


Conclusions

- SABER pressure/temperature dataset for 2002-2010 was analyzed.
- Temperature anomalies similar to that of summer 2002 were observed for summers of 2007 and 2010.
- Sudden stratospheric warming in SH did not precede the mesospheric warming in NH: the whole structure developed simultaneously.
- NH mesopause temperature correlates with SH tropopause, SH mesopause, and tropical stratopause temperatures and anticorrelates with SH stratopause temperatures that is in agreement with Karlsson et al., 2007.
- Temperature anomaly has a period of 31 months that is not matching current QBO period of 24.5 months.
- Explanation requires either varying time lag or admixing another oscillation.

Additional slides

Oscillation period for temperature anomaly in NH mesopause



Energy transfer by planetary waves

Geostrophic relationships:

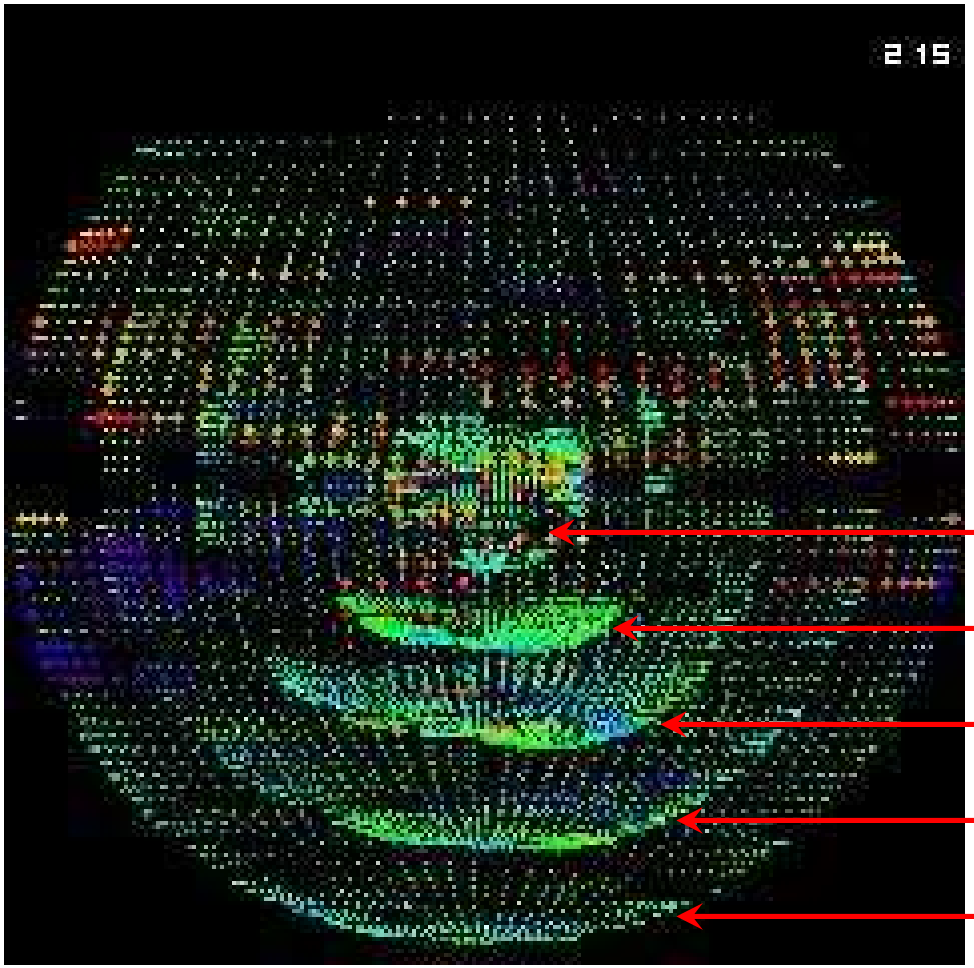
$$f \times v = d\Phi / dx \qquad f \times u = d\Phi / dy$$

where $f = 2\ \Omega \sin \phi$ *is the Coriolis parameter;* Ω *is angular speed of Earth,* ϕ *is latitude;* $\Phi = g \times \zeta$, *g is free fall acceleration,* ζ *is geopotential height; v and u are S-N and E-W wind components; x and y correspond to S-N and E-W directions, respectively.*

Correspondingly, $v = g / f \times d\zeta / dx$

Knowing ***v*** *and* ***T*** *and their variations* ***v'*** *and* ***T'*** *over certain period enables one to build* ***v'T'*** *distributions that show the* ***heat transfer by planetary waves****.*

Heat transfer by planetary waves in 2002



DOY counter

Color coding

S-N transfer

Zero transfer

N-S transfer

100 hPa level

10 hPa level

1 hPa level

0.1 hPa level

0.01 hPa level

The major “heat wave” in S-N direction in 2002 corresponds to DOY=236 at 10 hPa level. No significant flows had been observed before this day.

Northern Summer Mesopause Temperatures and PMC Occurrence Frequency