The exceptional Arctic winter 2005/06

An example to investigate polar processes using different assimilations systems

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(7) Freie Universität Berlin

Outline

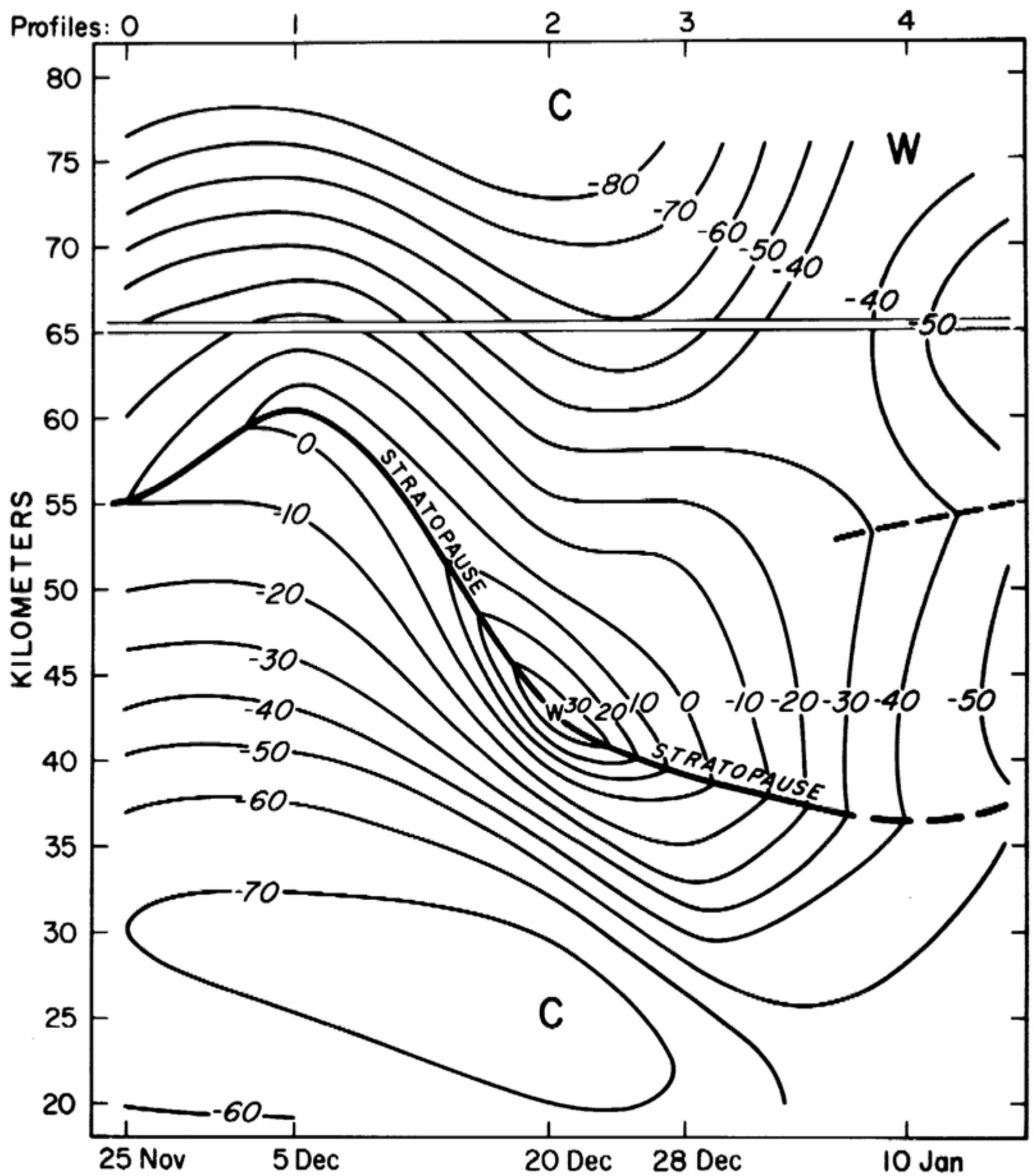
1. The NH winter 2005-06:

    a) Dynamical evolution
    b) Data intercomparison

2. Interannual variability during NH winters

3. Temperature oscillations

Motivation

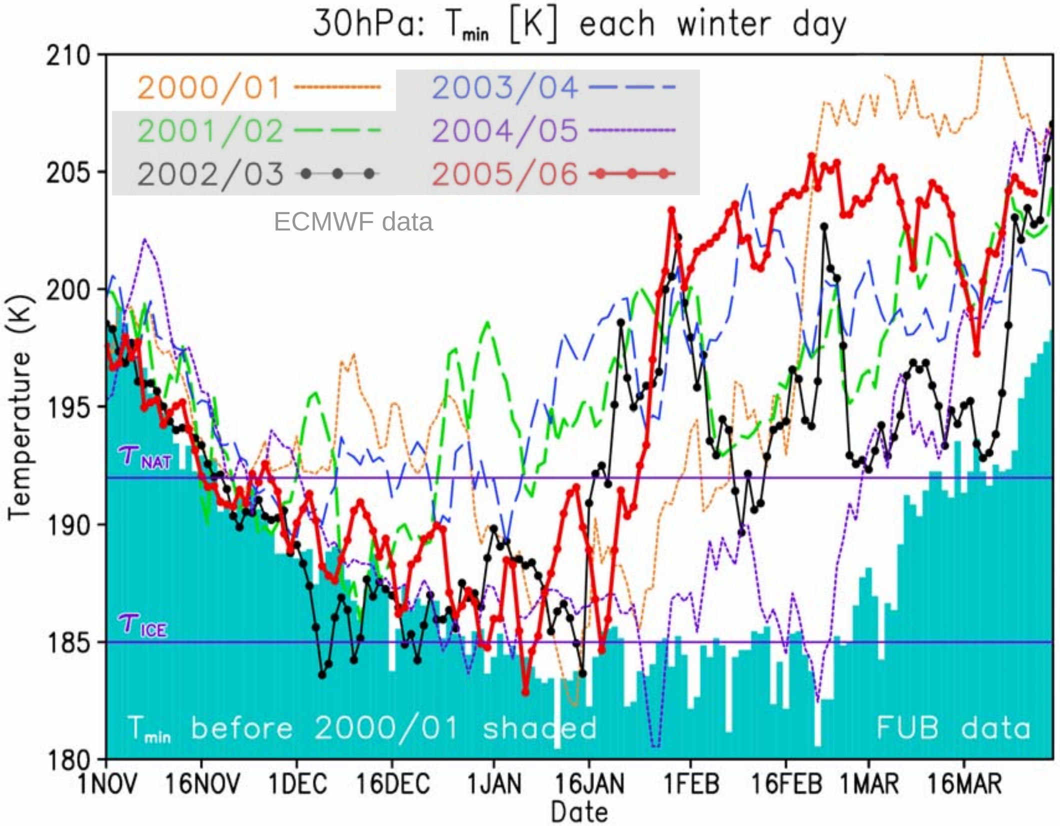


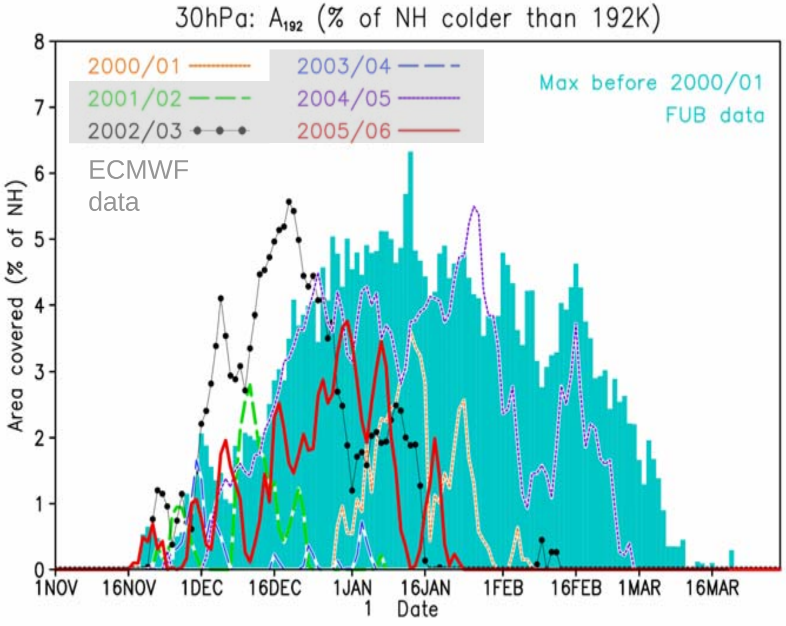
Schematic distribution of temperature at 57°N, 07°W during the development of a Major Midwinter Warming (Labitzke 1972, *JAS*)

Characteristics of the winter 2005/06

- Canadian Warming at the end of November
- Cold early winter (Dec-mid Jan)
- 11th January: strong stratopause warming, strongest since measurements ?
- 21. January: major midwinter warming with the longest period of easterly winds at 10hPa, 60°N since 1957
- Late winter cooling in the upper stratosphere
- Late final warming on 7th May 2006

1a. T_{Min} and A_{TNat}





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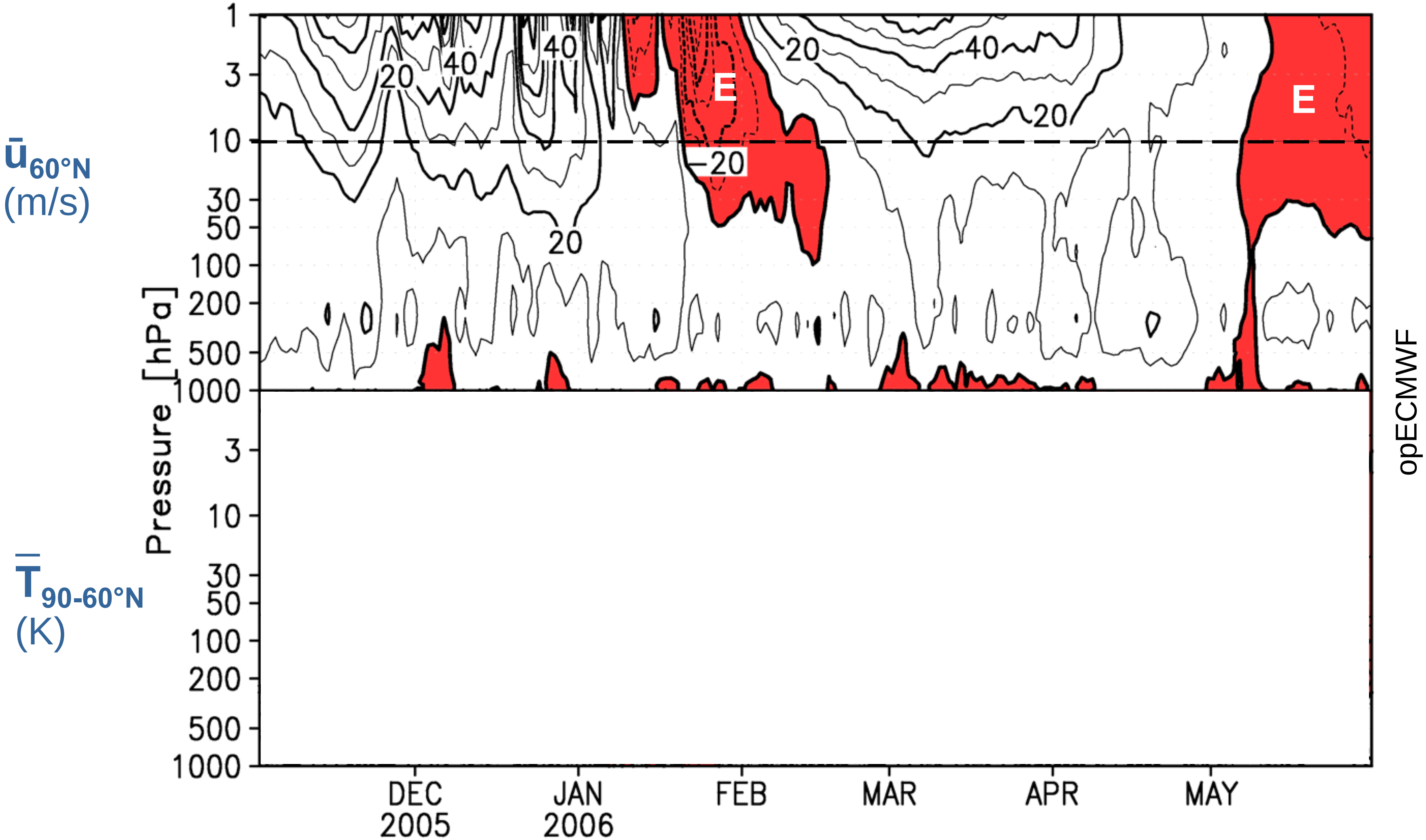
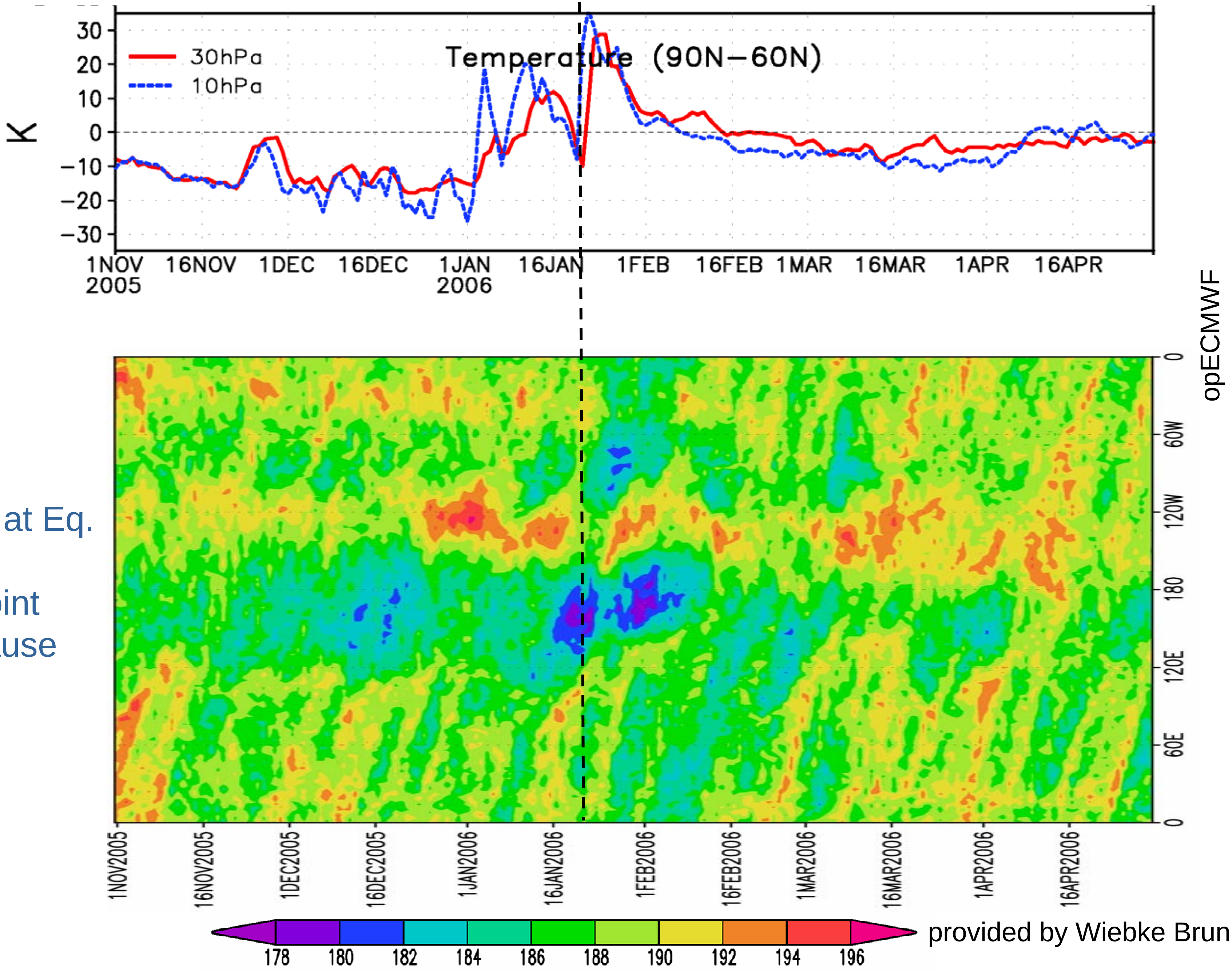
1a. Dynamical evolution



Very long persistent easterly winds during mid-winter at 10 hPa, 60°N; longest period since regular measurements started (end of 1950)! Excellent example for ST coupling

⇒ Major Warming end of January impacts the $NAO/AO_{1000hPa}$ in March!

1a.



T_{Min} [K] at Eq.

Cold point tropopause

provided by Wiebke Brunn

1b. Data intercomparison:
The NH winter 2005/06

Meteorological analyses used

GEOS-4 (Goddard Earth Observation System Version 4.03):

- 55 levels, surface-0.01 hPa; 1.0°x1.25° resolution

op ECMWF (operational European Centre for Medium-Range Weather Forecasts):

- 4D-Var; spectral model; interpolated from T106 to 2.5°x2.5° in examples shown here
- New: T799/L91; 1000–0.01 hPa (top at ~80km); operational since 1. February 2006;
- Old: T512/L60; 1000-0.1hPa (top at ~60km); before 1. February 2006;

MetO (UK Met Office):

- since 13 March 2006 change to operational NWP model, 1000-0.1 hPa, 0.375x0.5625 grid
- October 1991 – 12 March 2006, 3D-Var, 1000-0.1 hPa; 2.5x3.75 grid

NCEP/CPC (US National Centers for Environmental Prediction/Climate Prediction Center):

- Objective Analysis in stratosphere, joined to GDAS assimilation at 100 hPa (10 hPa after April 2001)
- 1000-0.4 hPa; 65x65 polar stereographic hemispheric grids
- Interpolated to 2.5x5.0 for examples shown here
- "Balanced" winds [e.g., *Randel*, 1987, JAS, 44, 3097–3120] from geopotential heights

NCEP/REA (NCEP/National Center for Atmospheric Research Reanalysis):

- 3D-Var system; T62
- 1000-10 hPa; 2.5x2.5 grid

ERA-40 Reanalysis (ECMWF Reanalysis)

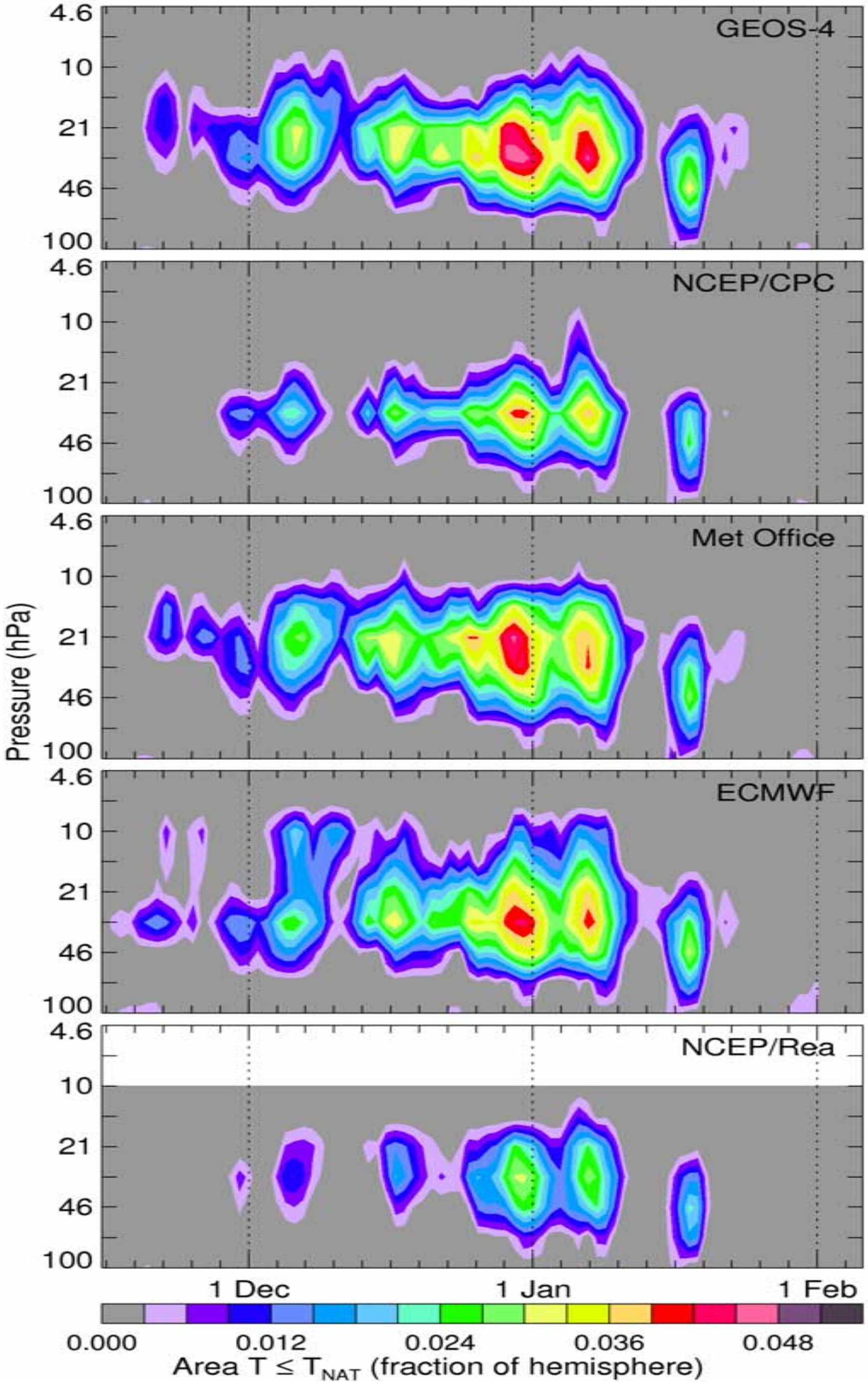
- (3D-Var, T159); interpolated from T106 to 2.5x2.5
- July 1957- August 2002

FUB (Freie Universität Berlin):

- *Subjective analyses of radiosondes, 100-10 hPa, 5x5, NH, July 1957-June 2001*

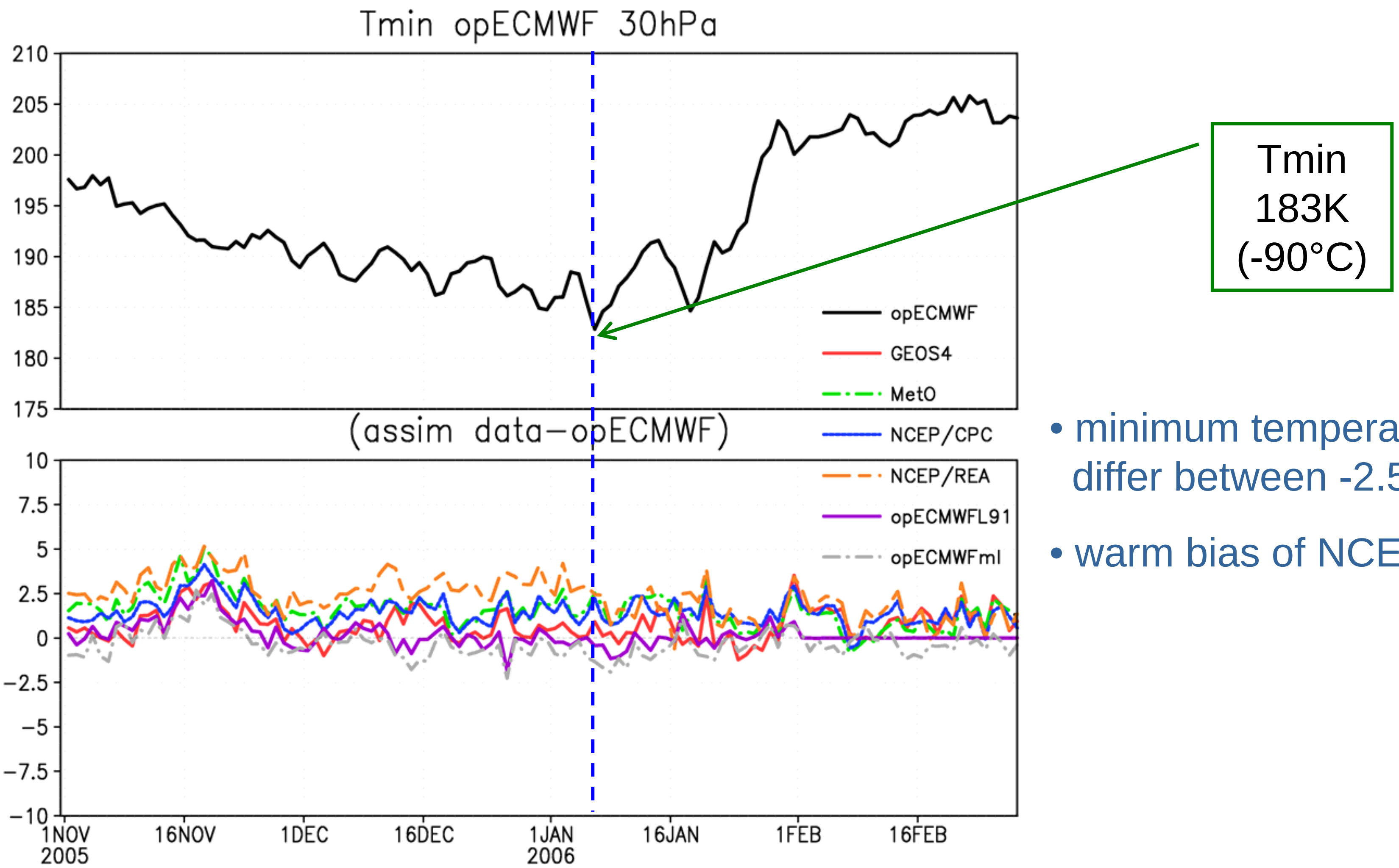
Manney et al [JGR 2003, MWR 2005] summarize main characteristics of these datasets

1b. T_{Nat}



- Only T_{NAT} areas from November 2005 until January 2006
- Note: T_{NAT} fraction area is smaller than in other years

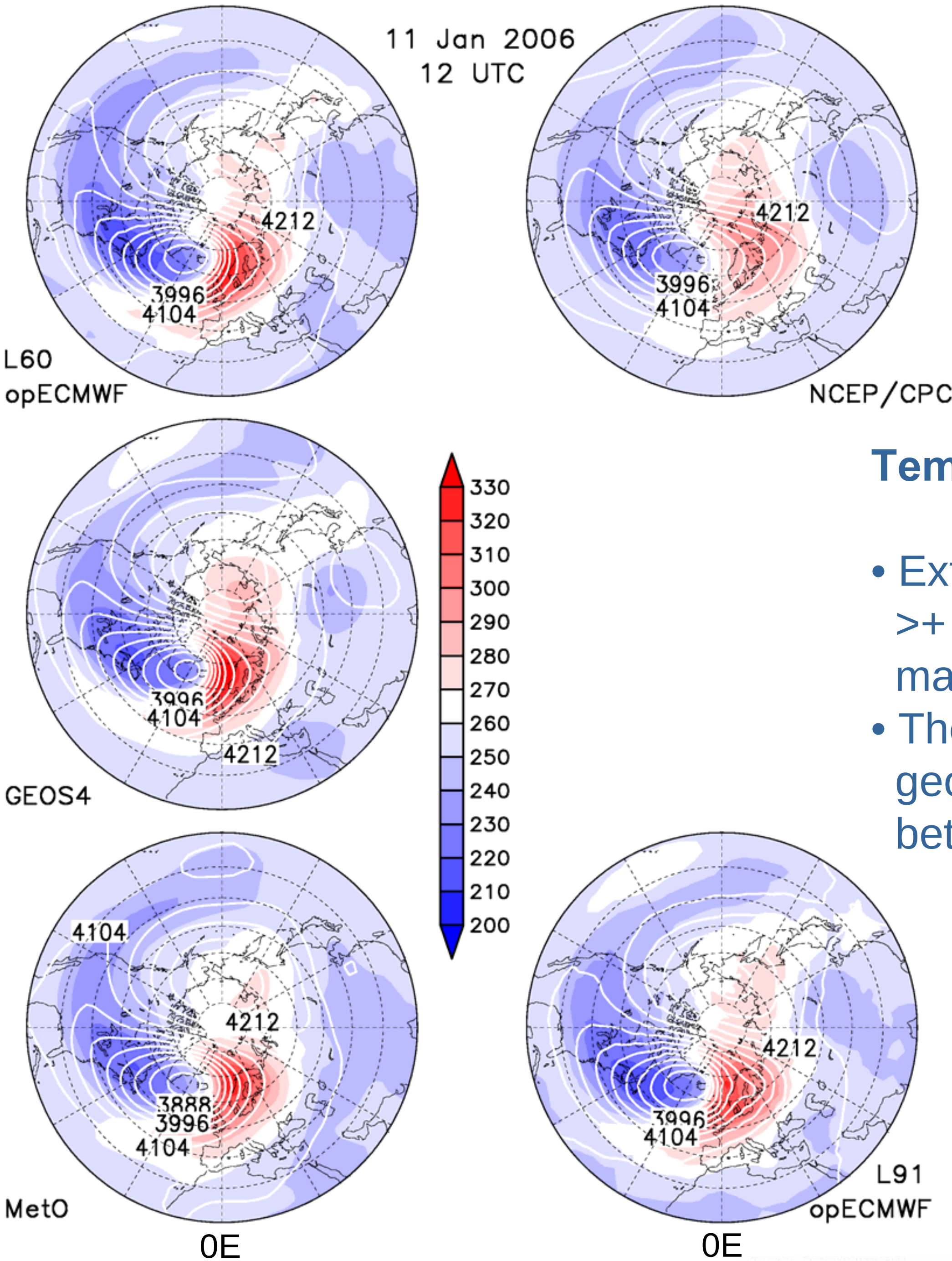
1b. T_{Min} at 30 hPa



- minimum temperatures differ between -2.5 and 5K
- warm bias of NCEP/REA

opECMWF GEOS4 MetO NCP/CPC NCEP/REA opECMWF L91 opECMWFml

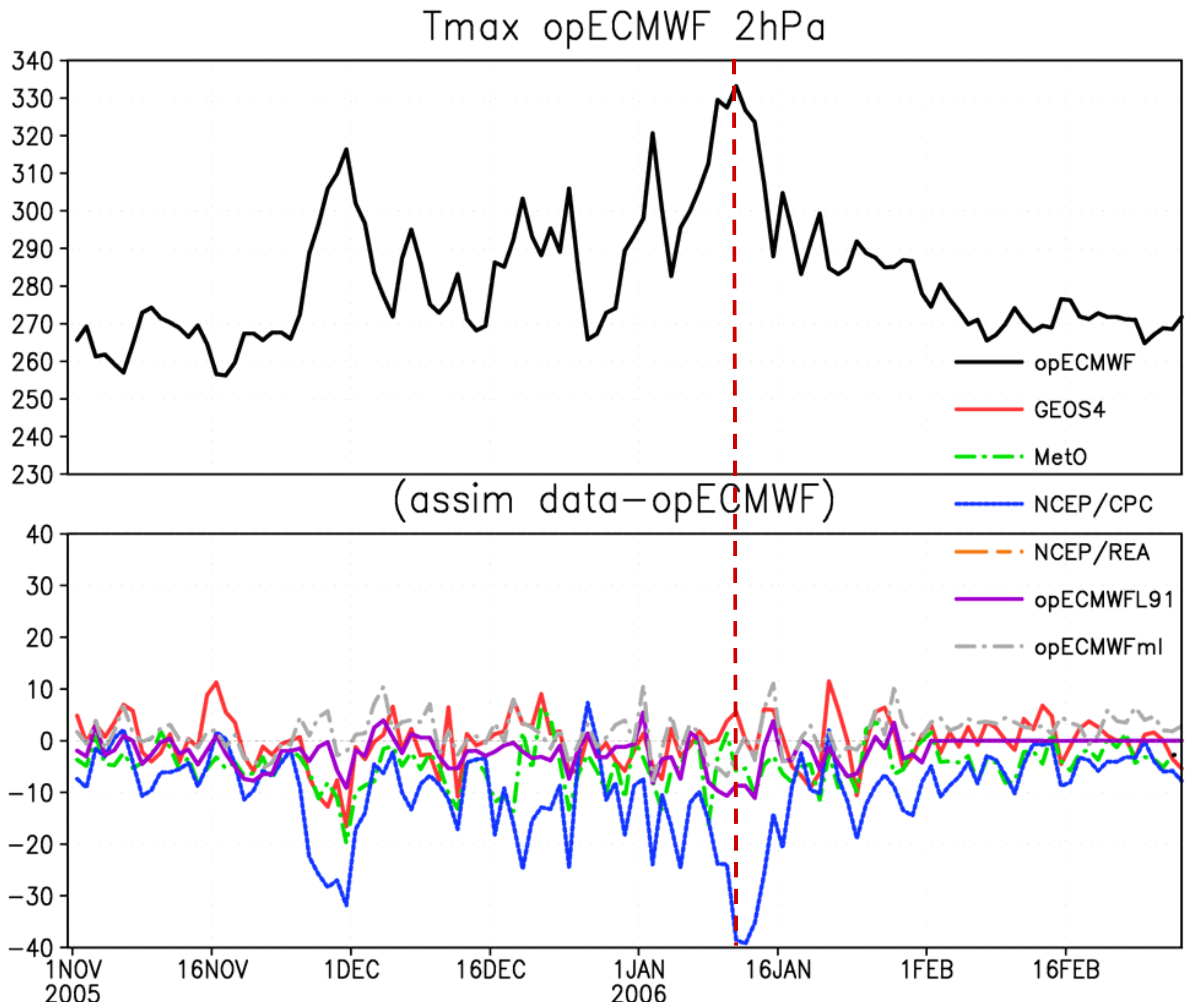
1b. synoptic on 11 January 2006



Temp and g. Height: 20°-90°N, 2 hPa

- Extreme strong stratopause warming >+ 60°C, exceeding so far observed maxima > real?
- The extremes of temperature and geopotential height vary substantially between the different data sets

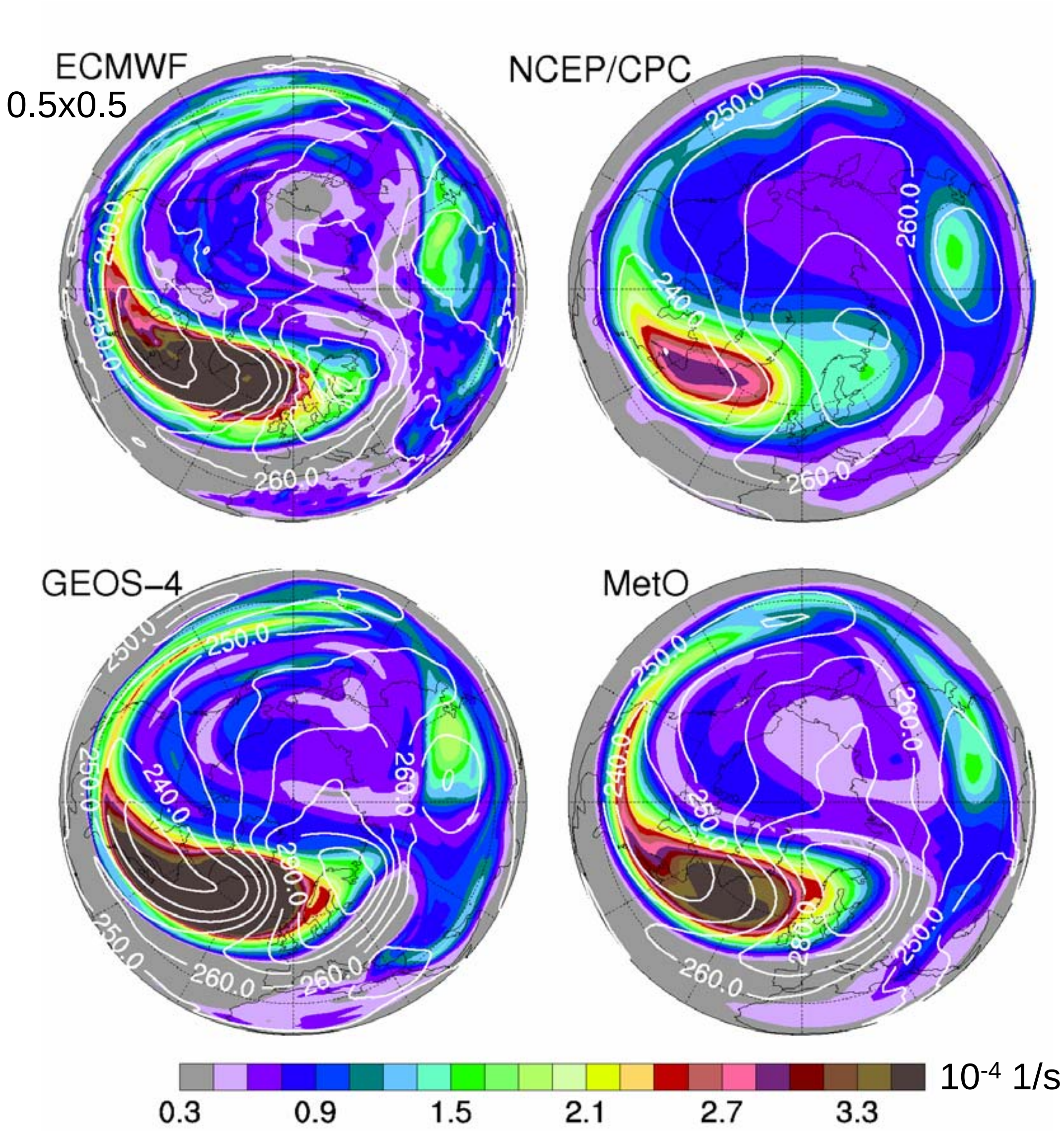
1b. T_{Max} at 2 hPa



- extreme temperatures differ between 12K and <-40K
- GEOS4 simulates the highest T_{Max}
- opECMWF L91 model is 10K less warmer than L60
- NCEP/CPC underestimates strength of the stratopause warming by a factor of 3-4.

opECMWF GEOS4 MetO NCP/CPC NCEP/REA opECMWF L91 opECMWFml

1b. synoptic on 11 January 2006



sPV + Temp (K), 1500K

- **ECMWF:** higher horizontal resolution shows a better definition of vortex and tropical intrusion filaments

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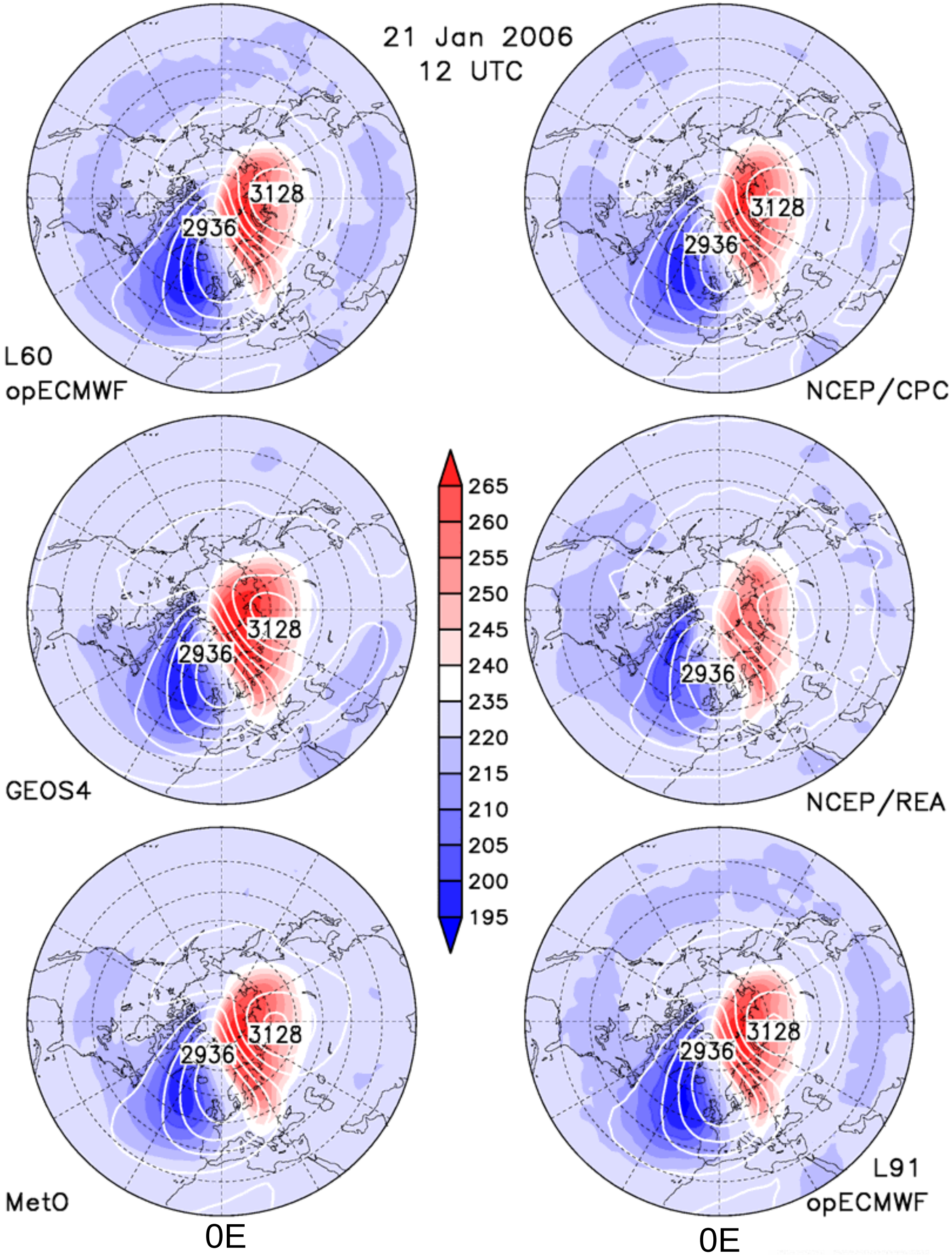
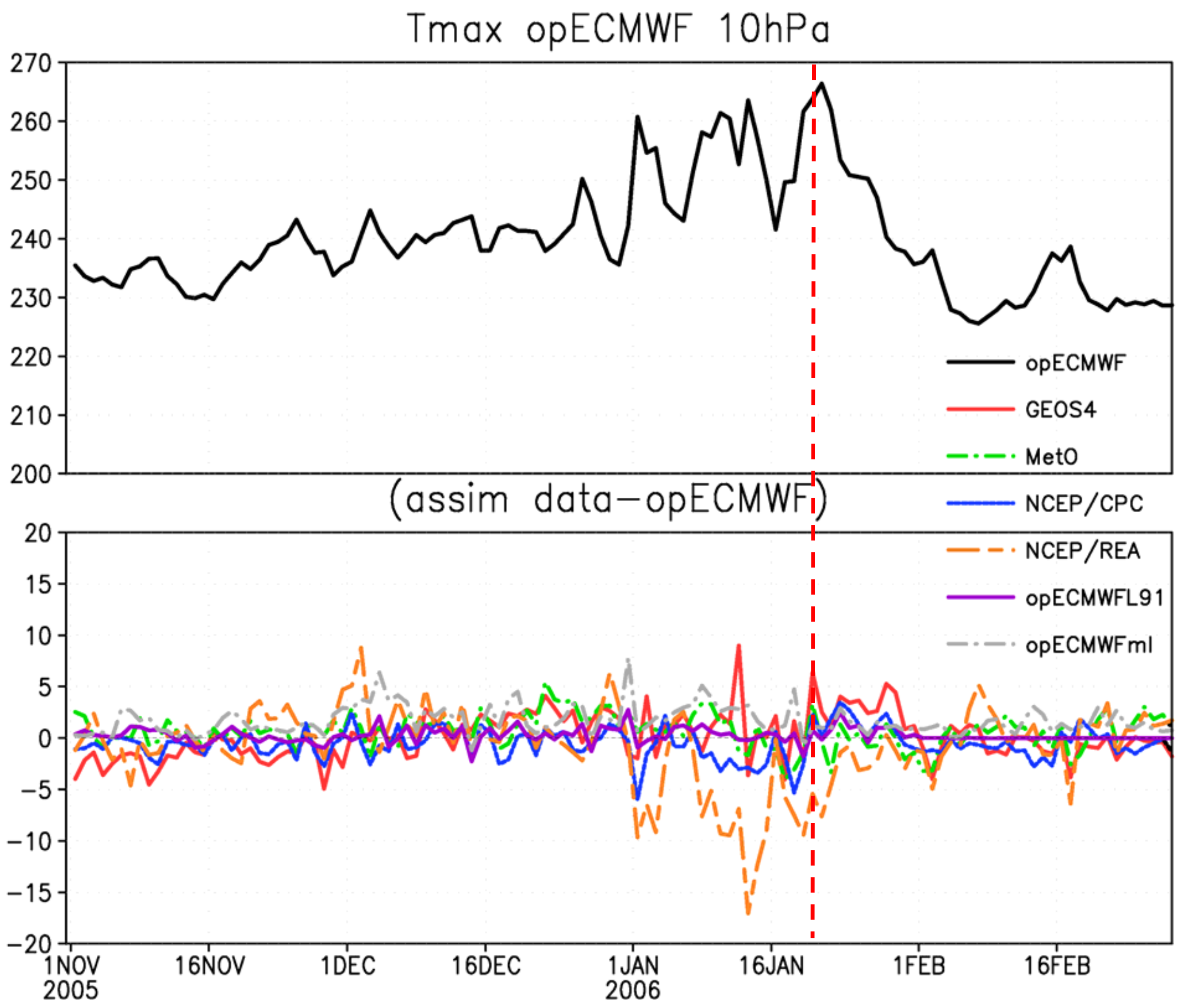


1b. synoptic on 21 January 2006

Temp(K) g.Height (dam),10 hPa

- Major Warming criterion fulfilled
- Wave 1 warming
- good overall presentation in the different data analyses

1b. T_{Max} at 10 hPa

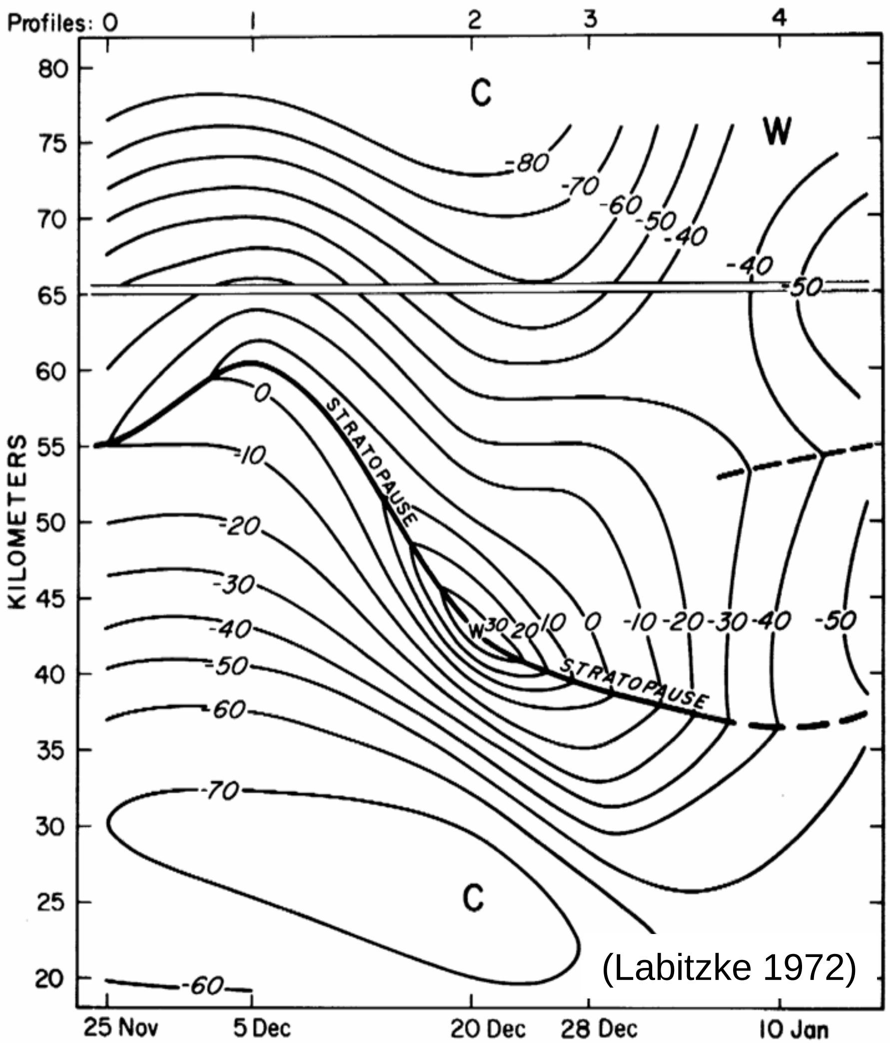


- Extreme temperatures differ between +10K and -18K
- cold bias of NCEP/REA

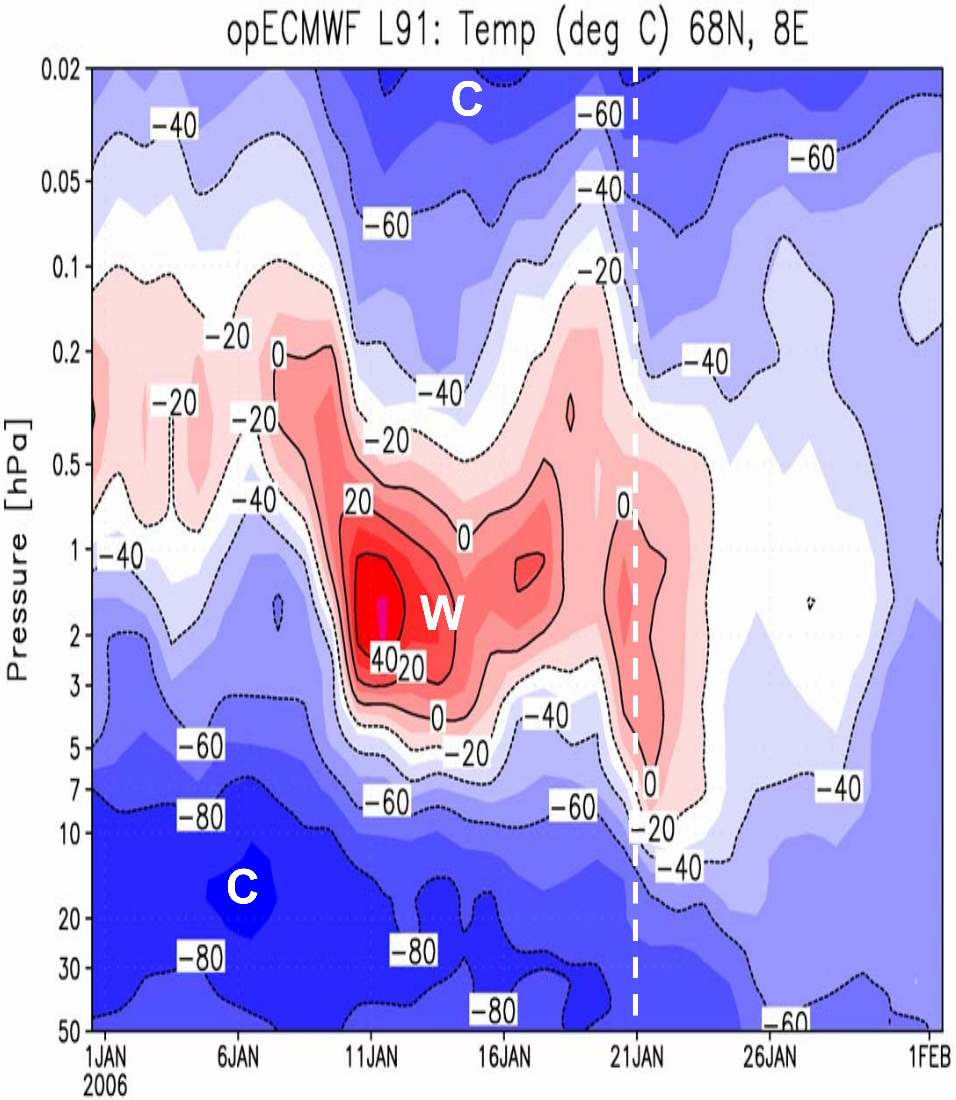
opECMWF GEOS4 MetO NCP/CPC NCEP/REA opECMWF L91 opECMWFml

Stratopause and Major Midwinter Warming

schematic distribution

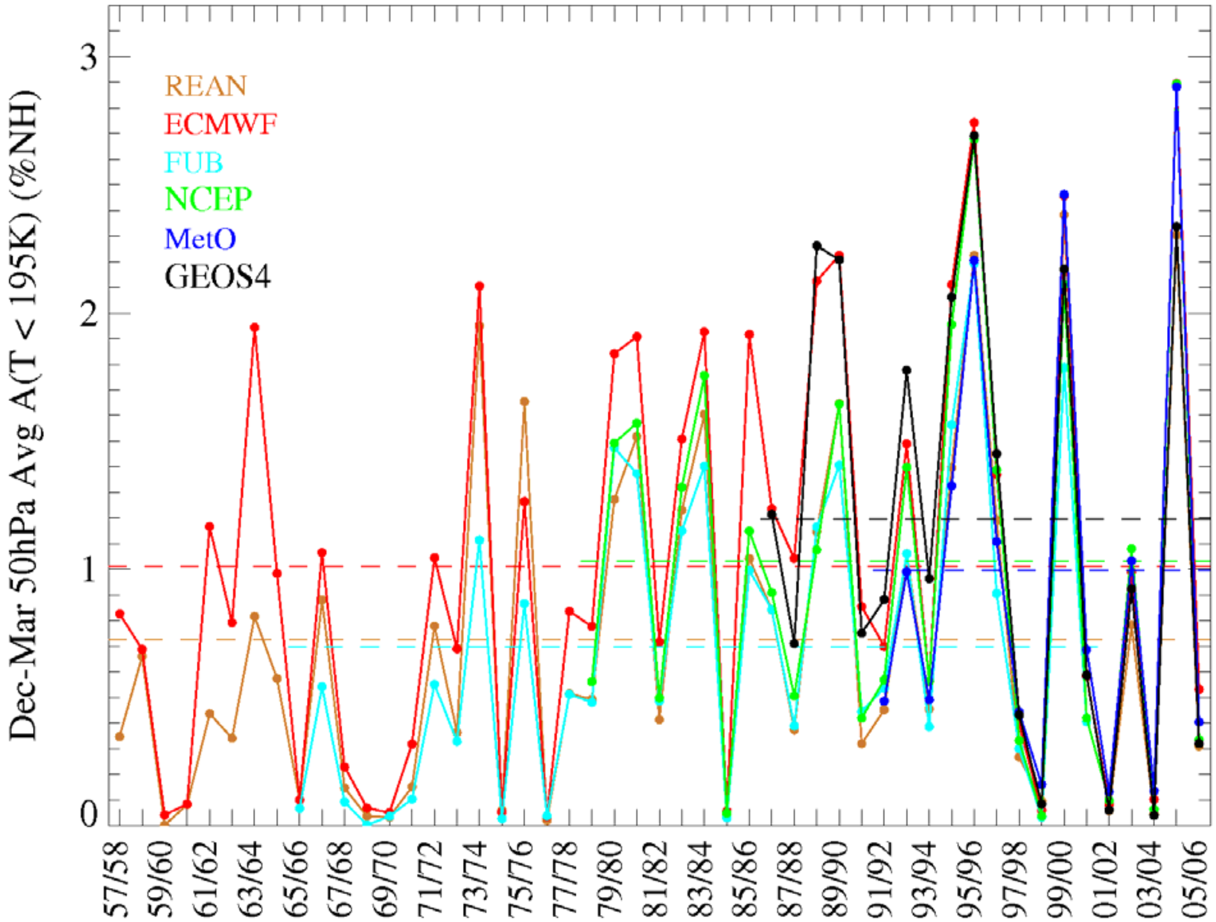


(Labitzke 1972)



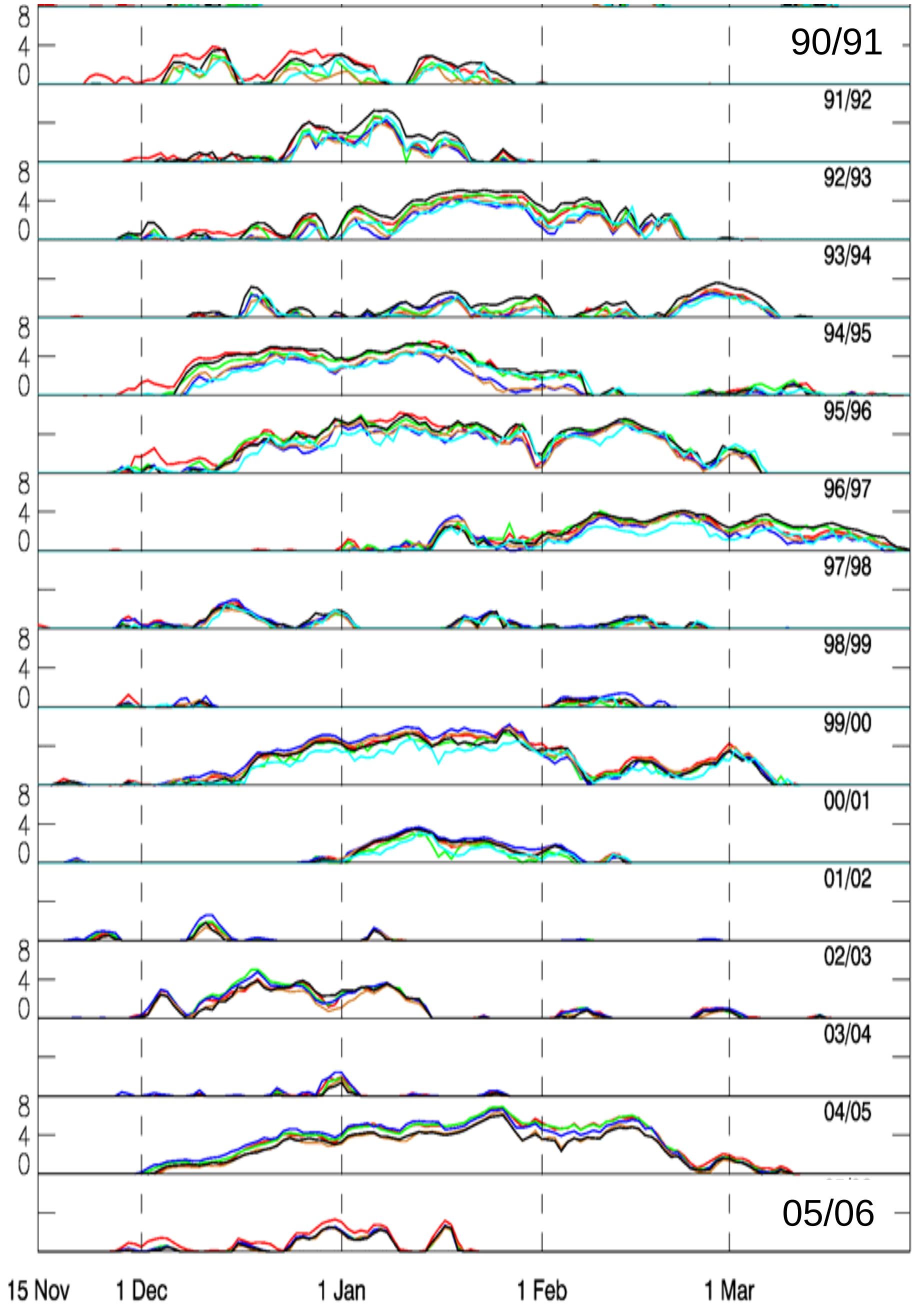
2. Interannual variability during NH winters

2. T ≤ 195K at 50 hPa



Manney et al., 2005 updated

ERA40/opECMWF NCP/CPC MetO NCEP/REA GEOS4 FUB

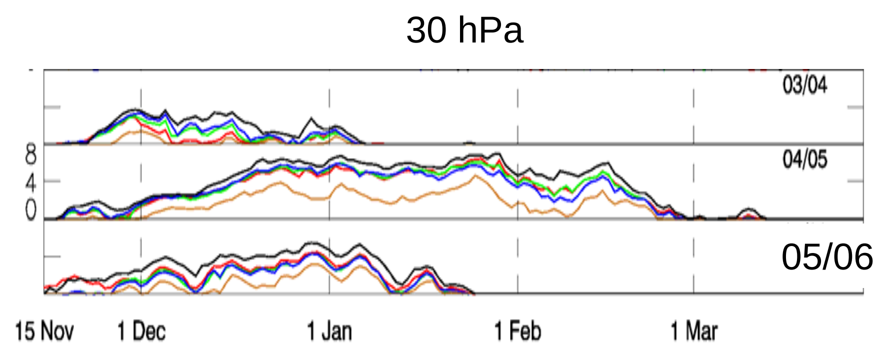


Area with $T \leq T_{NAT}$ (% NH) at 50 hPa, from 1990/91 to 2005/2006

NCEP/CPC and NCEP/REA very similar, with ERA-40 and GEOS4 giving larger areas in earlier years

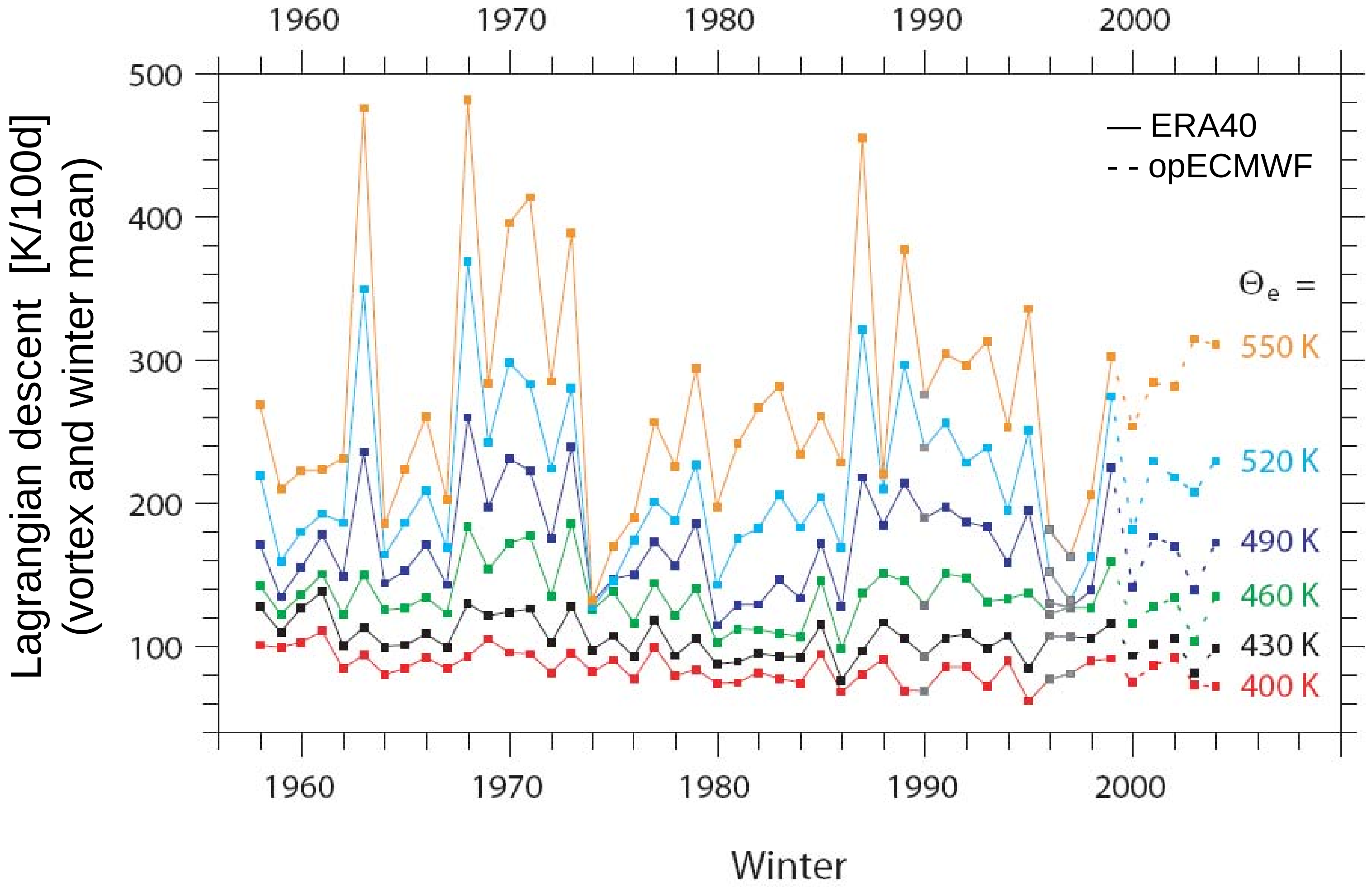
All analyses quite similar in last five years, but opECMWF has a slightly bigger area in the winter 2005/06

Differences at 50 hPa in general more pronounced in cold years, whereas at 30 hPa differences increase in general



ERA40/opECMWF NCP/CPC MetO NCEP/REA GEOS4 FUB

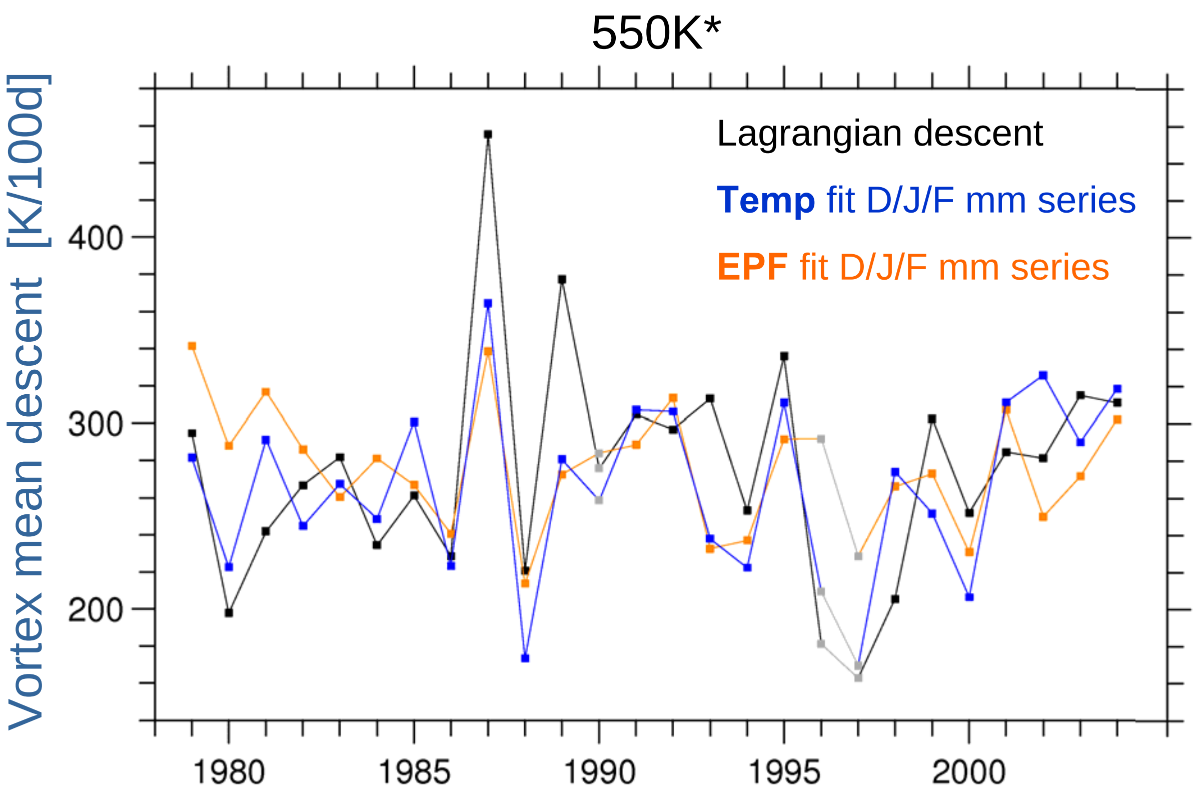
2. Descent in polar vortex for NH winters 1957/58-2003/04

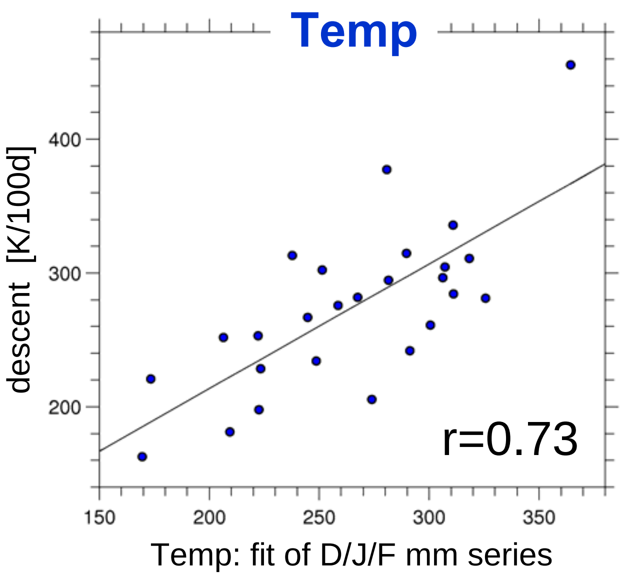


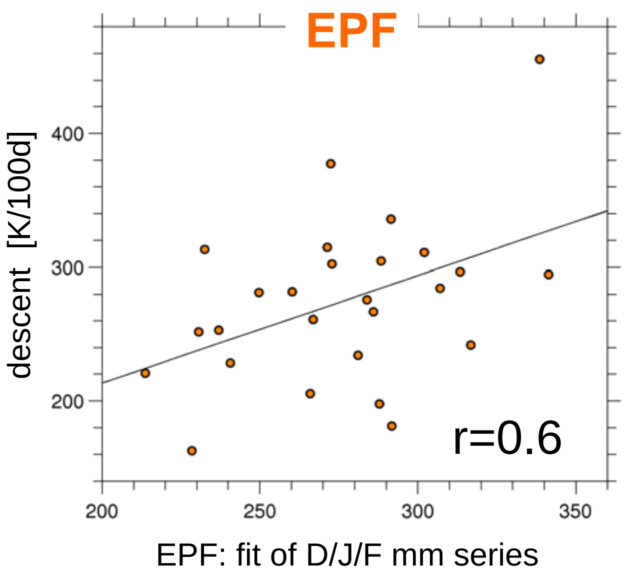
Susann Tegtmeier (2006)

2. Descent in polar vortex for NH winters

correlated with







(*Backward trajectories started on 10. March, 550K for 100days.)

Susann Tegtmeier (2006)

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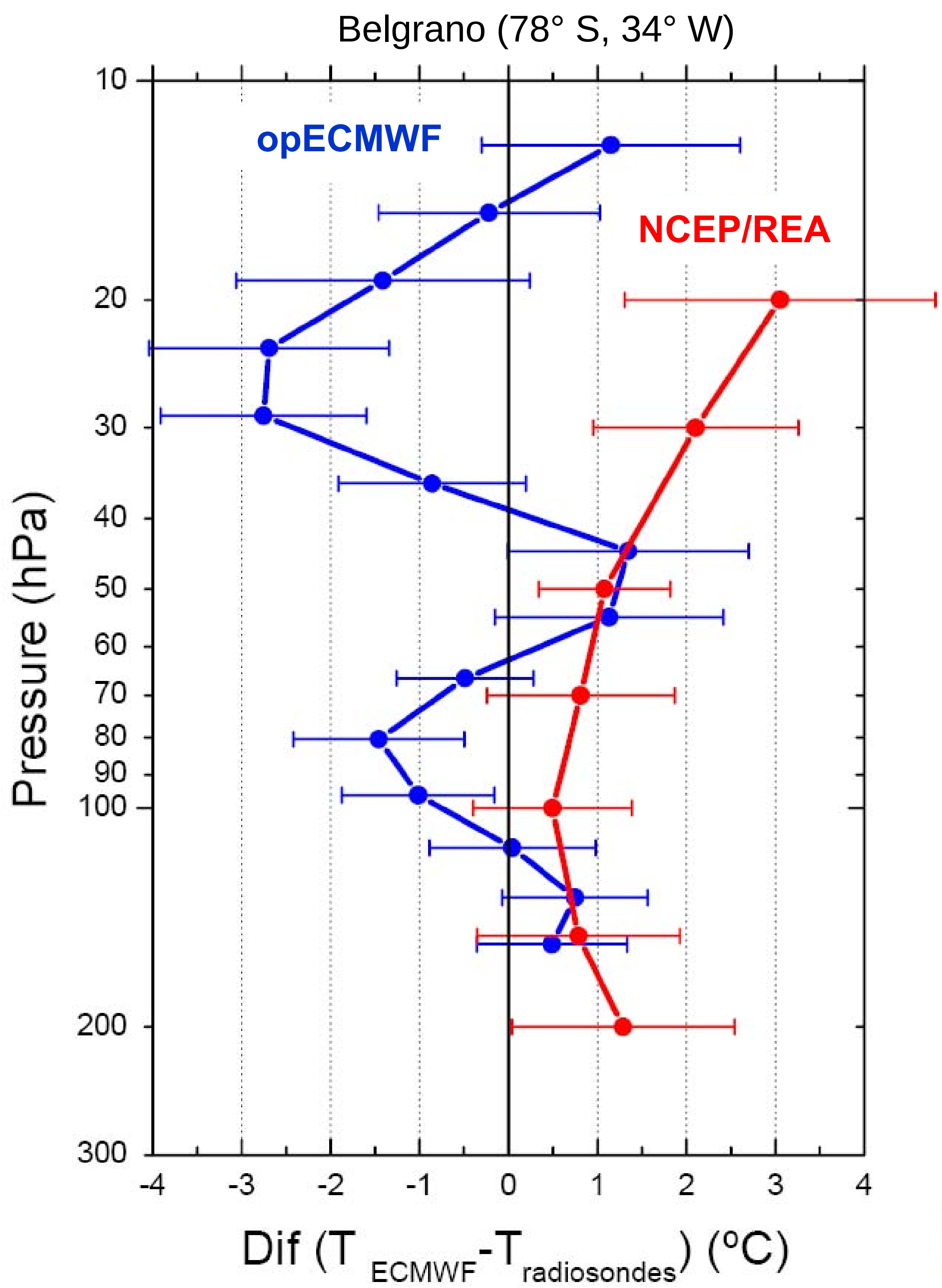
3. Temperature oscillations in ERA40 and opECMWF



3. Temp difference between analyses and radiosonde:

SH 2003

- displays a vertical structure of Dif T in opECMWF
- at 375 K (80 hPa) and 510 K (30 hPa) opECMWF underestimates the temperature; around 450 K (50 hPa), it is slightly overestimated.

Parrondo et al., *ACPD* 2006

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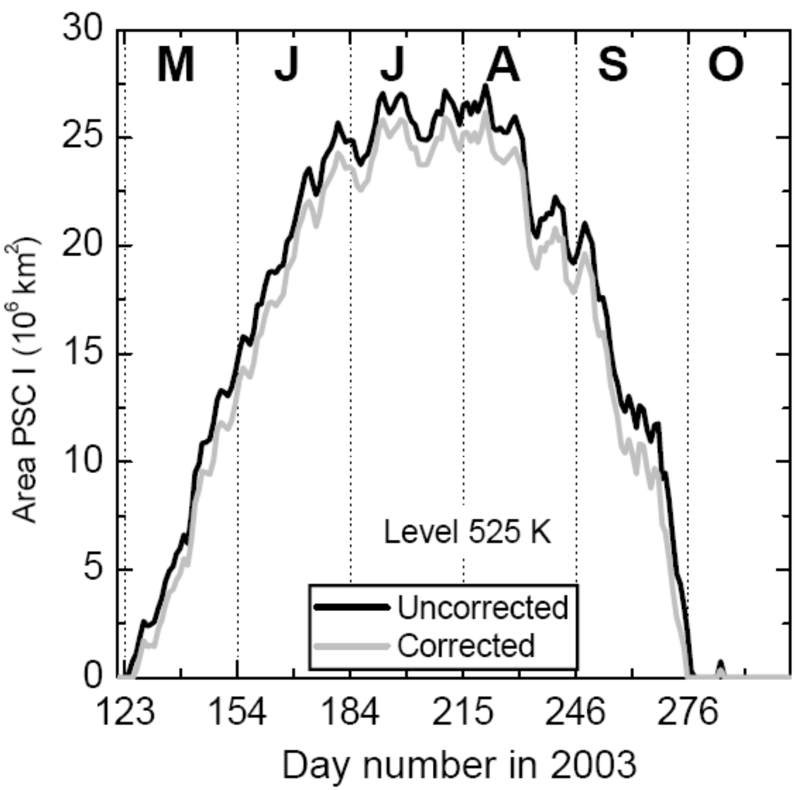
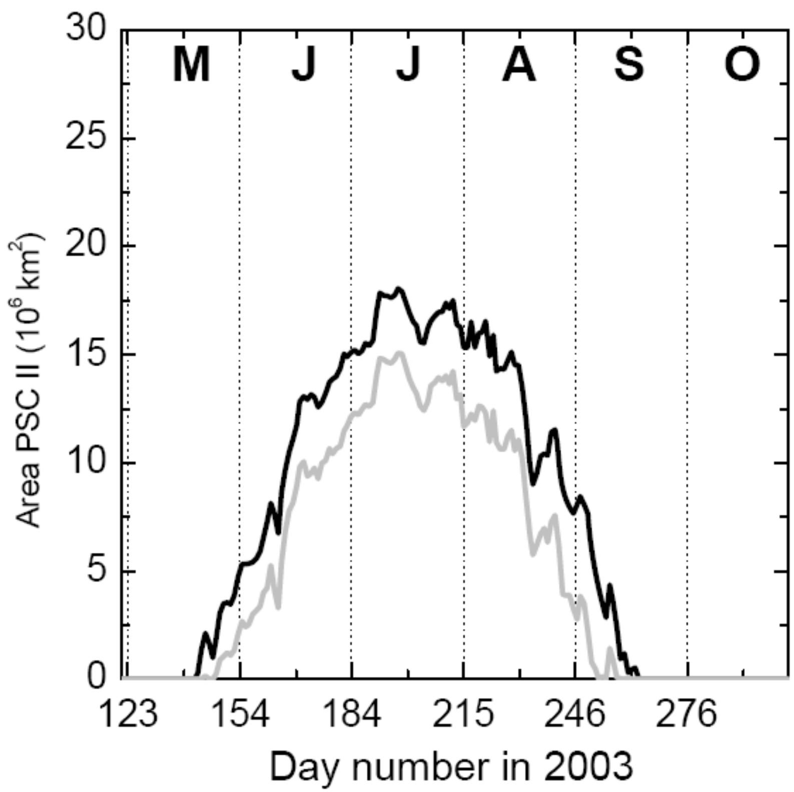
3. Sensitivity of PSC Area on temperature oscillation: SH 2003



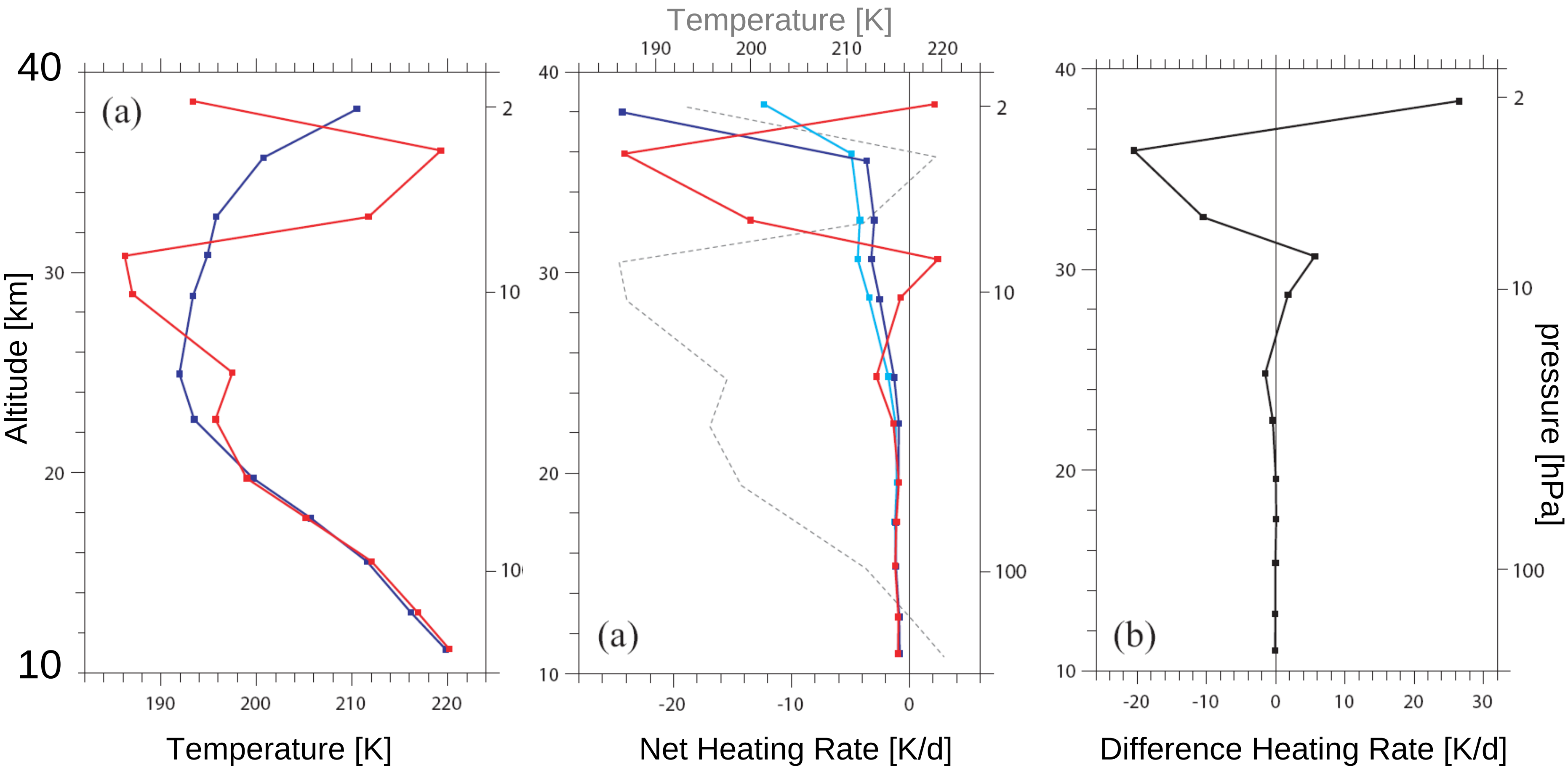


Parrondo et al., *ACPD* 2006

opECMWF temperature

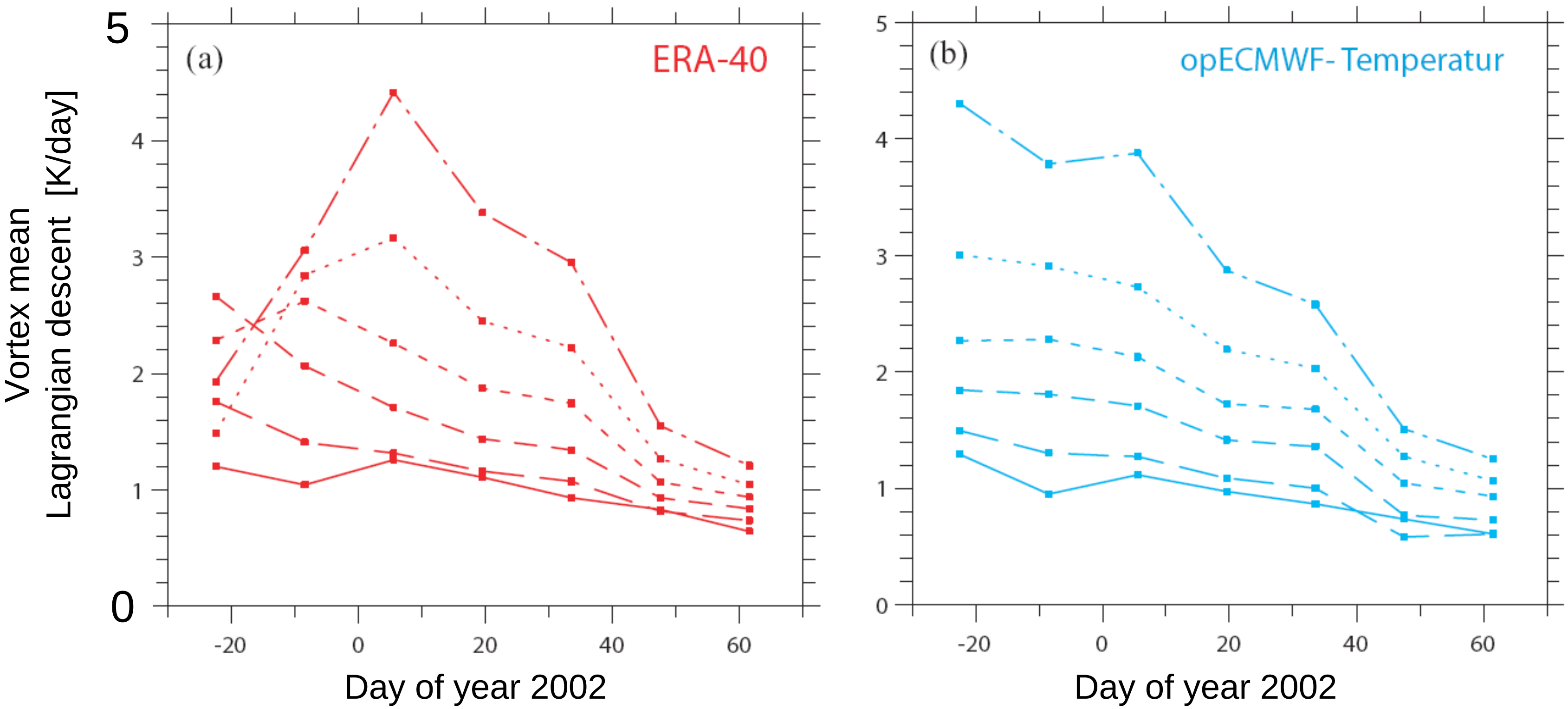
corrected by radiosondes

3. Sensitivity of heating rates on temperature oscillations: 16. Dec 2001



ERA40 **opECMWF**

3. Sensitivity of diabatic descent on temperature oscillations: NH winter 2001/02



Summary – Outlook

- The Arctic winter 2005/06 had a cold early winter period, a disturbed warm midwinter period connected with a typical upper late winter cooling and a late final warming $\Rightarrow$ Good example to compare different assimilations.

- In general: The differences between the data assimilation increase with increasing height and during more dynamically active situations. An extreme strong stratopause warming occurred on 11 January 2006. If the extreme strength is realistic or not still has to be clarified (further studies are needed) e.g. with new satellite instruments.

- Note again: For many purposes NCEP/REA and ERA40 stratospheric analysis should better not be used (e.g. Manney et al 2003 and 2005; Uppala et al 2005)!

- Temperature oscillations are having an impact on the heating rates, diabatic descent and on PSC area.

- The upper stratosphere is an interesting new region for data intercomparison as new satellite measurements are available now and data assimilations centres are increasing their model lid to include even mesospheric levels (GEOS4, opECMWF L91, MetO upcoming).

Diagnostics to access

- T_{Min}
- T_{Nat}, T_{ice}
- synoptic maps
- T_{Max}
- stratopause
- break-up date, break-down date

opECMWF L60, opECMWF L91, MetO, NCEP/REA, NCEP/CPC, GEOS-4, GEOS-5, (ERA40, FUB), and others…

The End

3. The NH winter 2005/06

Temperature difference at 80°N, 10°E