The solar cycle effect in the MLT region
–
Simulations with HAMMONIA

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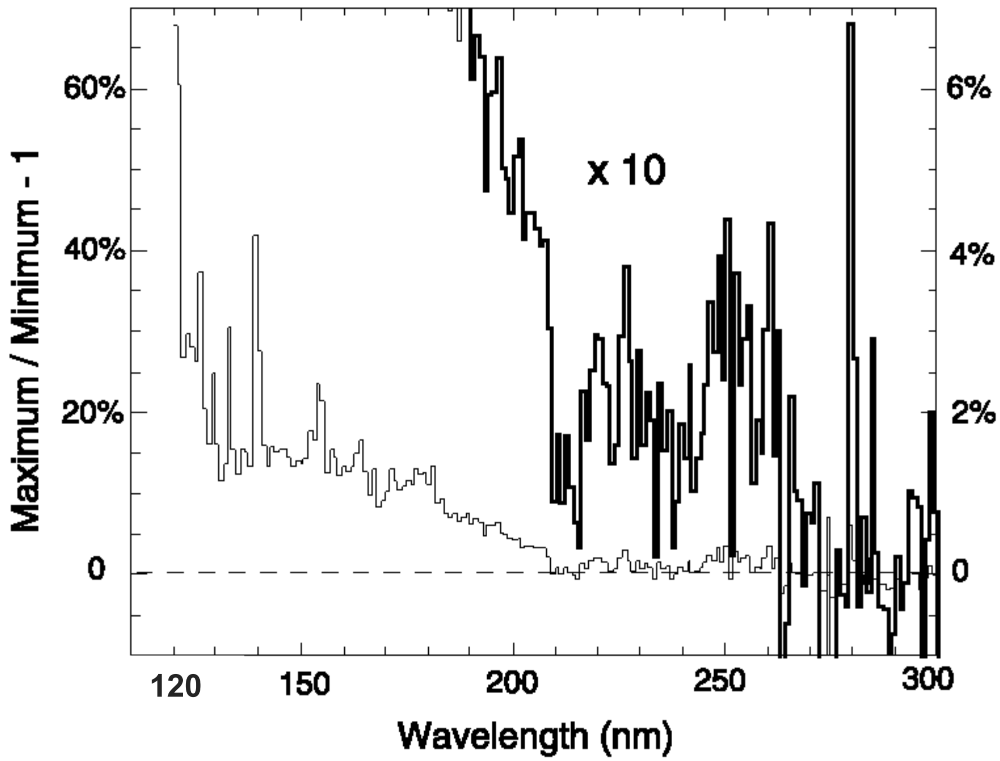
Variability of solar UV irradiance as given by UARS / SOLSTICE (Maximum: 1992, Minimum: 1996)



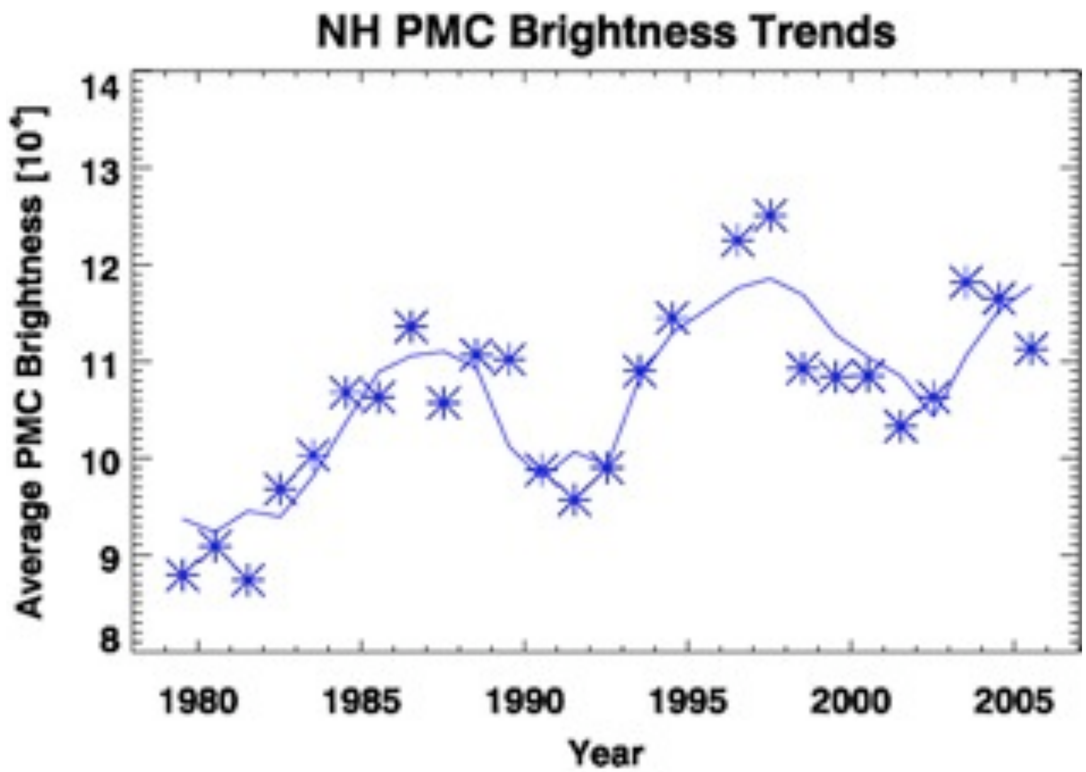
(Rottmann, Space Sc. Rev., 2000)

Content

- Observations of solar cycle signals in the MLT
- HAMMONIA – model description
- Solar cycle (and other) signals in simulations of the recent past (1960-2006)
    - What is the simulated response of the MLT to different forcing types (natural vs. anthropogenic)?
    - How representative are short observational time series?
    - Where does the signal in the MLT originate (local radiative vs. remote dynamic)?
- Summary / Conclusions

Solar Cycle in Polar Mesospheric Clouds (aka NLCs)

(source: Wikipedia)



(DeLand et al., JGR, 2007)

Solar cycle effect on temperature simulation vs. observations

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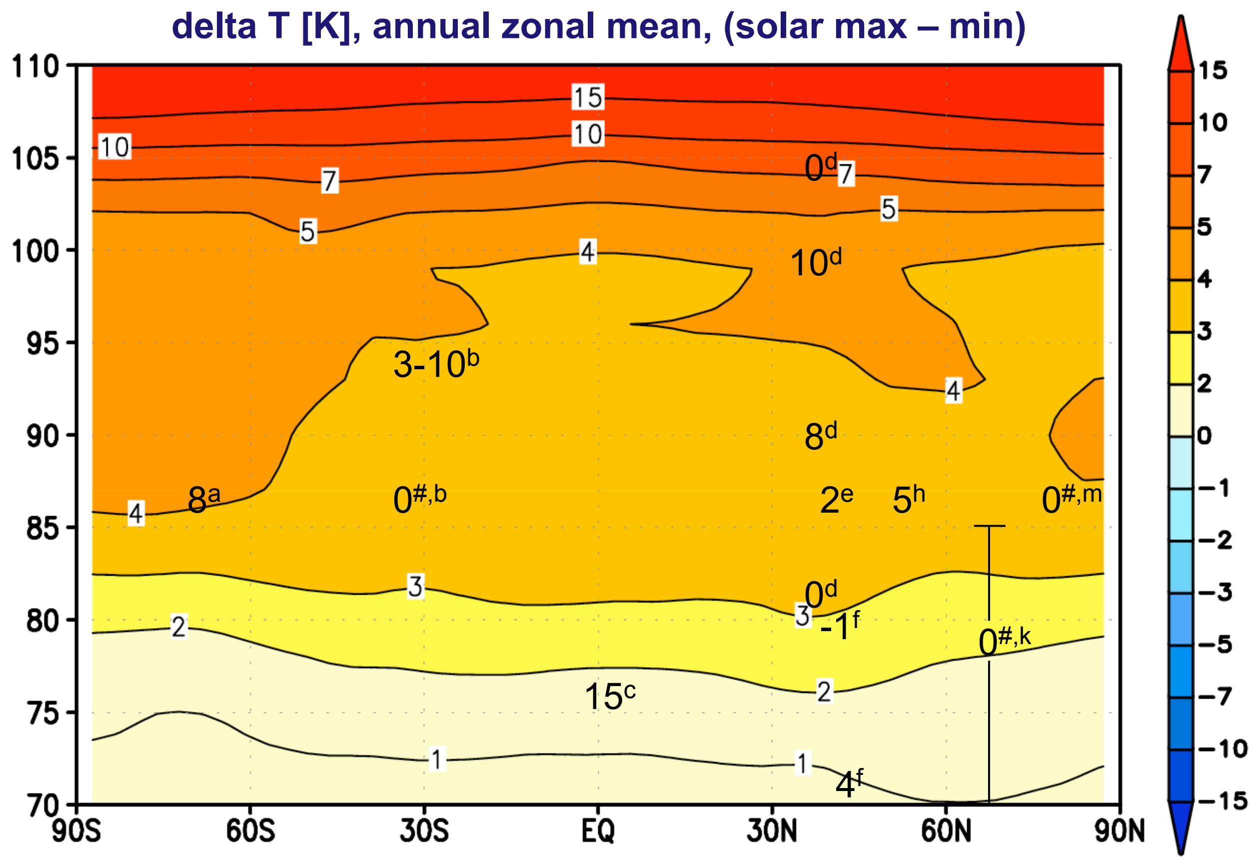

a: French, PhD thesis, 2002, OH
b: Reisin & Scheer, Ph. Ch. Earth, 2002, OH, O2
c: Mohanakumar, Ann. Geo., 1995, rockets
d: She & Krueger, Adv Sp. Res., 2003, lidar
e: Lowe, workshop paper, 2002, OH
f: Keckhut et al., JGR, 1995, lidar
g: Semenov, Ph. Ch. Earth, 2000, OH
h: Offerman et al., Adv. Space Res., 2003, OH
j: Espy & Stegmann, Ph. Ch. Earth, 2002, OH
k: Luebken, GRL, 2000, rockets
m: Sigernes et al., JGR, 2003, OH

#: zero or at least no significant trend

Numbers: observations as reviewed by Beig et al., Rev. Geophys., 2003;
Color shading: simulated by HAMMONIA, Schmidt et al., 2006

Temperatures observed by TIMED/SABER

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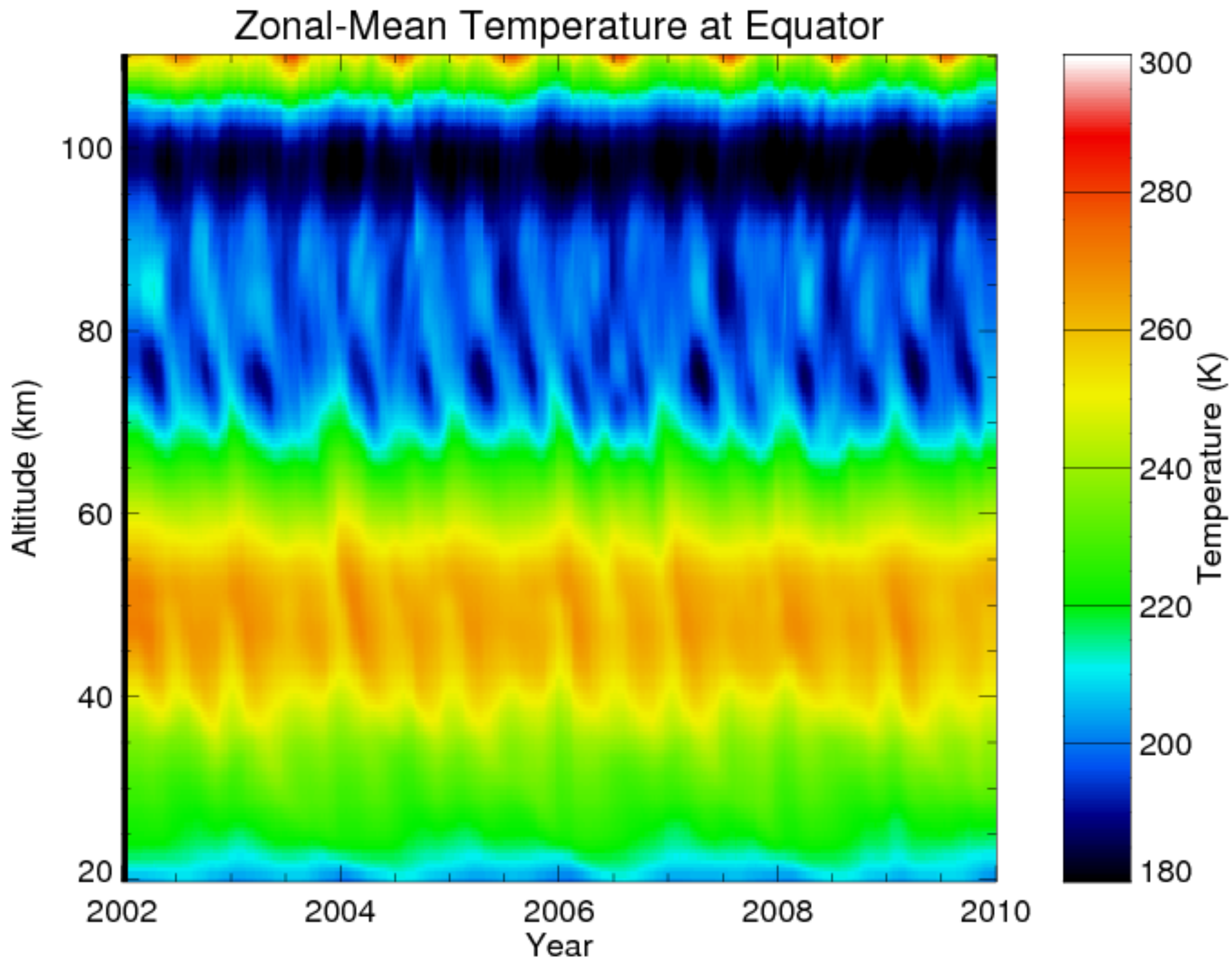
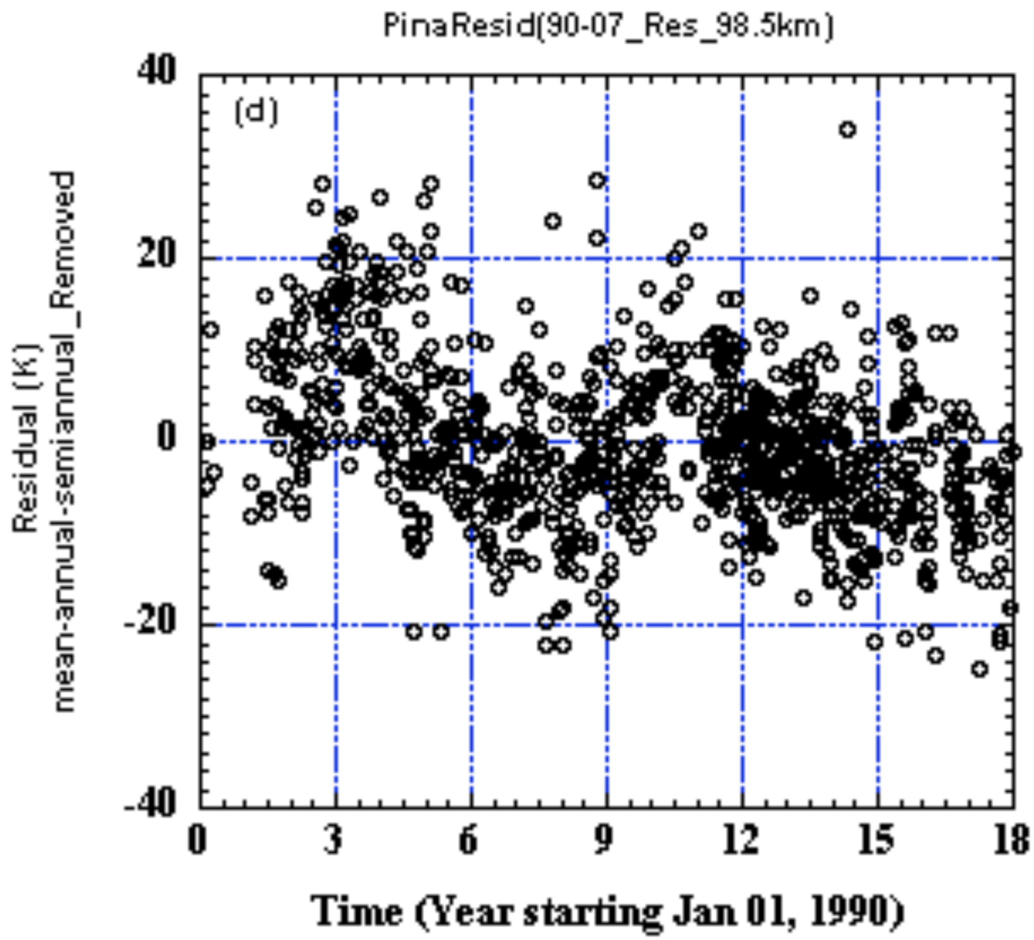


(Figure courtesy from Sam Yee, APL/JHU)

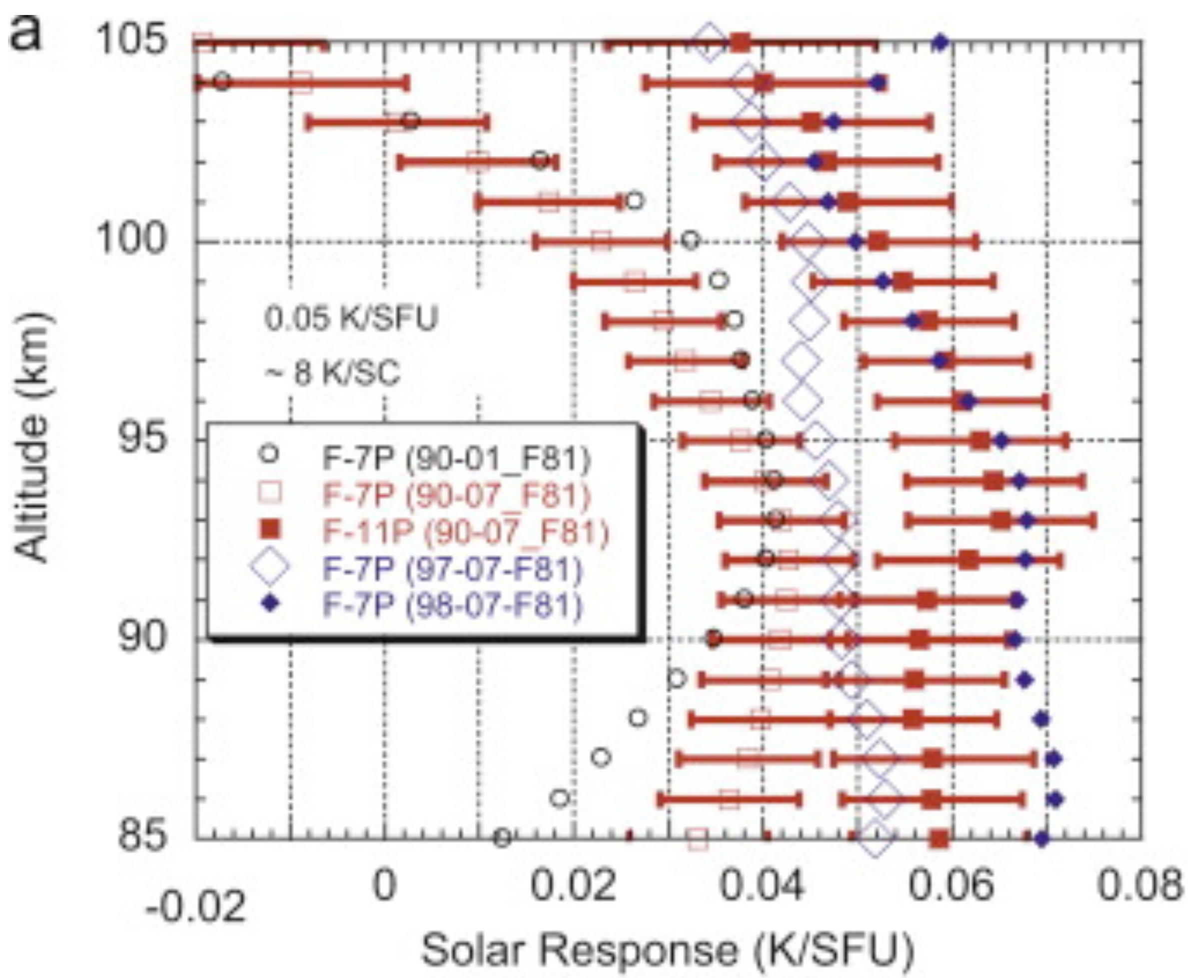
Temperature anomalies (deseasonalized) above Fort Collins,CO (41N)

98.5 km



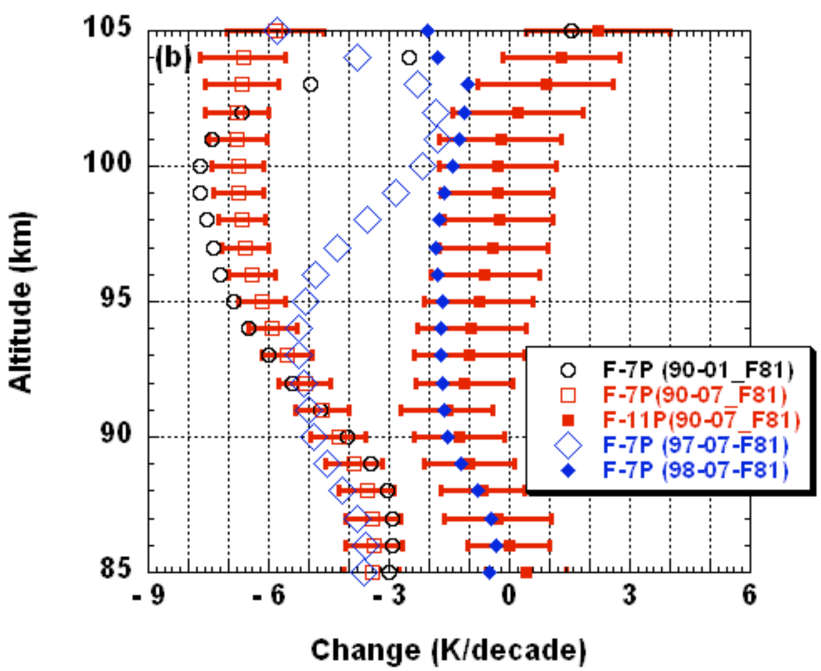
(She et al., JASTP, 2009)

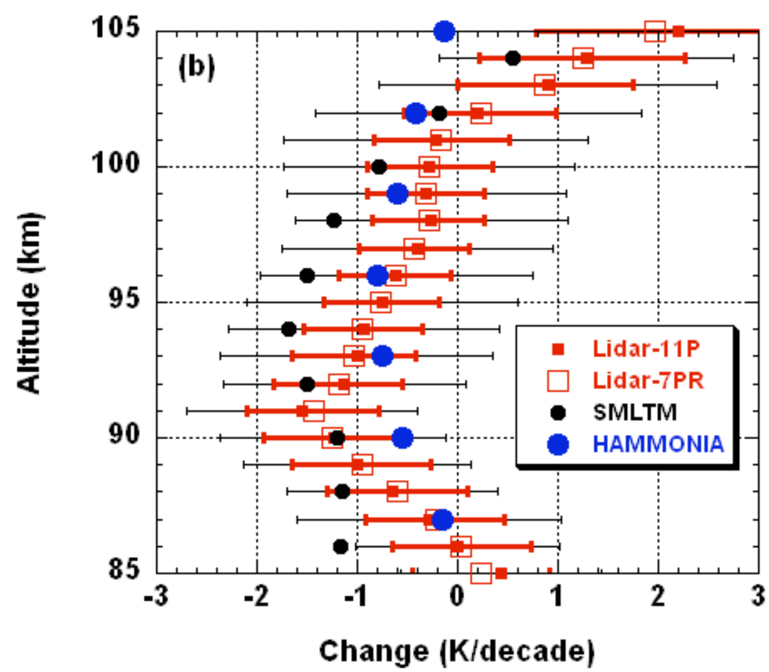
The solar signal
above Fort Collins,CO (41N)



(She et al., JASTP, 2009)

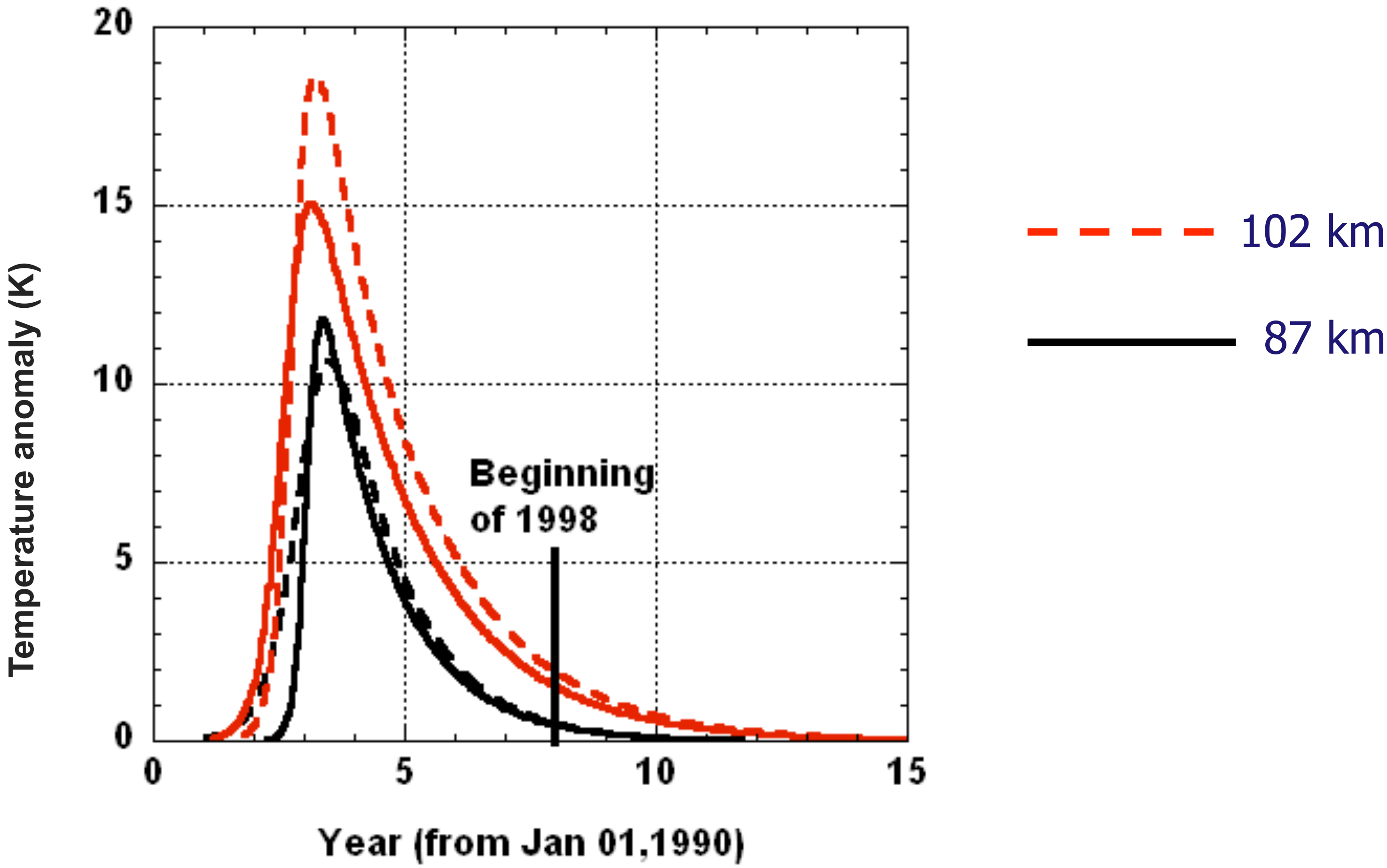
Temperature trends
above Fort Collins,CO (41N)





(She et al., JASTP, 2009)

Pinatubo temperature signal above Fort Collins,CO (41N)



(She et al., JASTP, 2009)

HAMMONIA

Hamburg Model of the
Neutral and Ionized Atmosphere

HAMMONIA – Hamburg Model of the Neutral and Ionized Atmosphere

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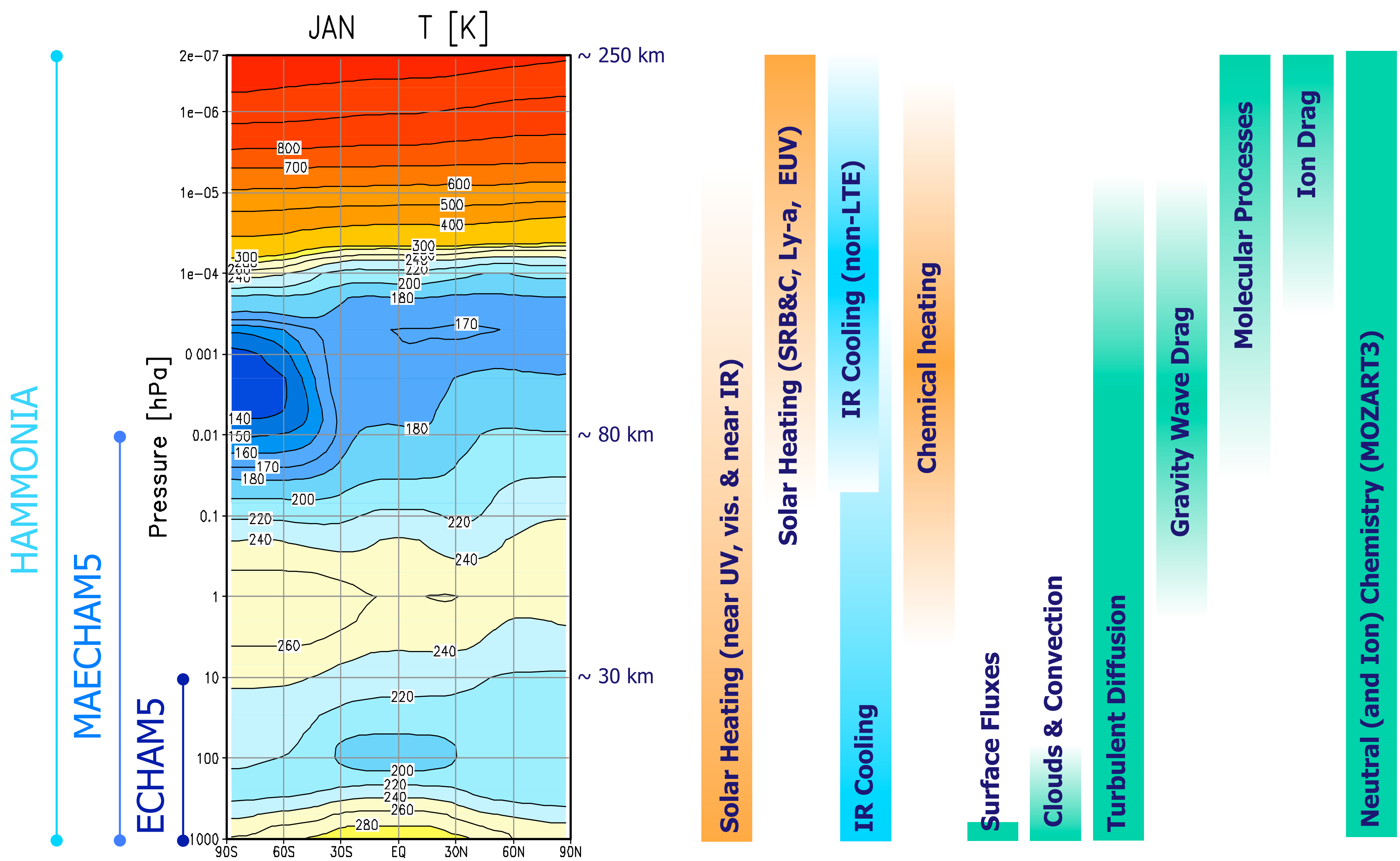
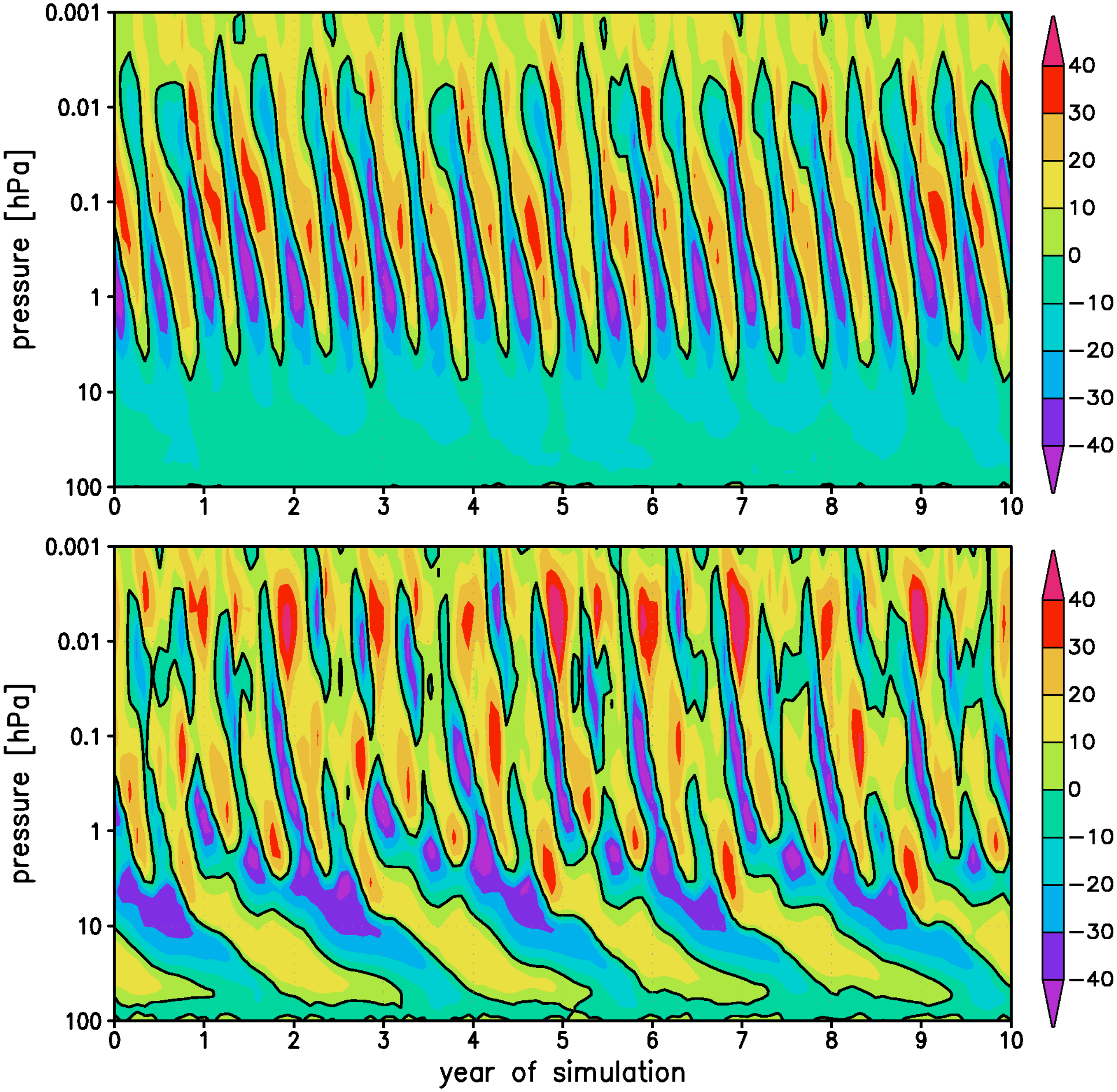


Simulations performed at T31 with 119 vertical layers

Equatorial zonal wind (m/s)
in model versions of different vertical resolution



67 layers
strat. resolution:
~ 2000 m

119 layers
strat. resolution:
~ 800 m

(Pena-Ortiz, Schmidt, et al., submitted to JGR)

Characteristics of CCMVAL Ref1b

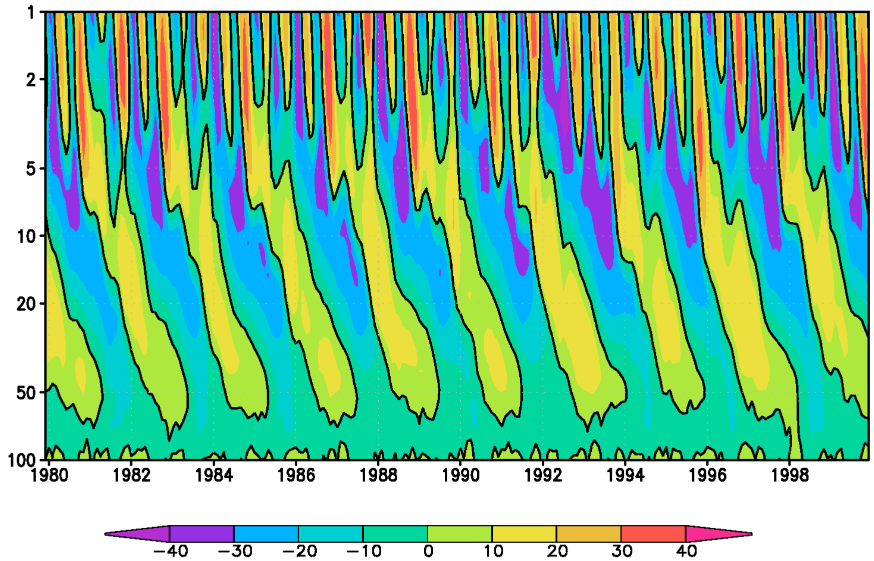
CCMVAL Ref1b experiment

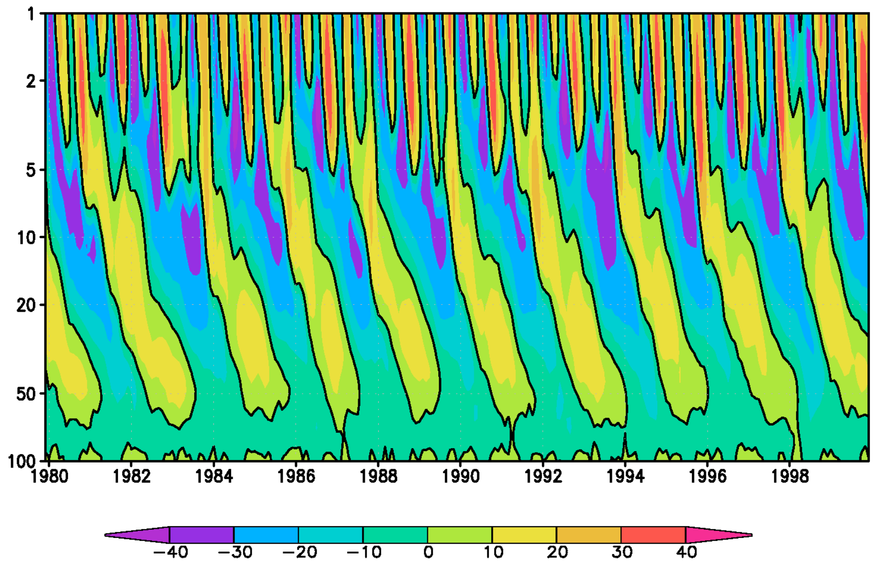
- Simulation of the recent past (1960-2006)
- Observed SSTs
- Chemical lower boundary: observed GHG concentrations, observed CFCs, further trace gases from RETRO simulation
- Observed / reconstructed solar radiation
- Prescribed heating/cooling from volcanic aerosol
- Internally generated (or nudged) QBO

Description of CCMVAL2 simulations:
Eyring et al., SPARC Newsletter, 2008

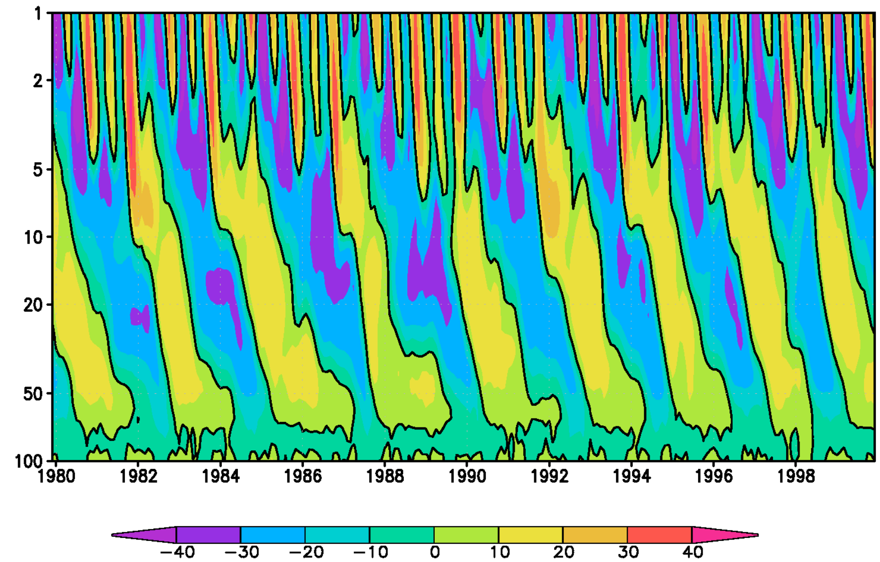
SPARC / CCMVAL report published in April 2010:
http://www.atmosp.physics.utoronto.ca/SPARC/CCMVAL_FINAL/index.php

2 simulations with internally generated QBO





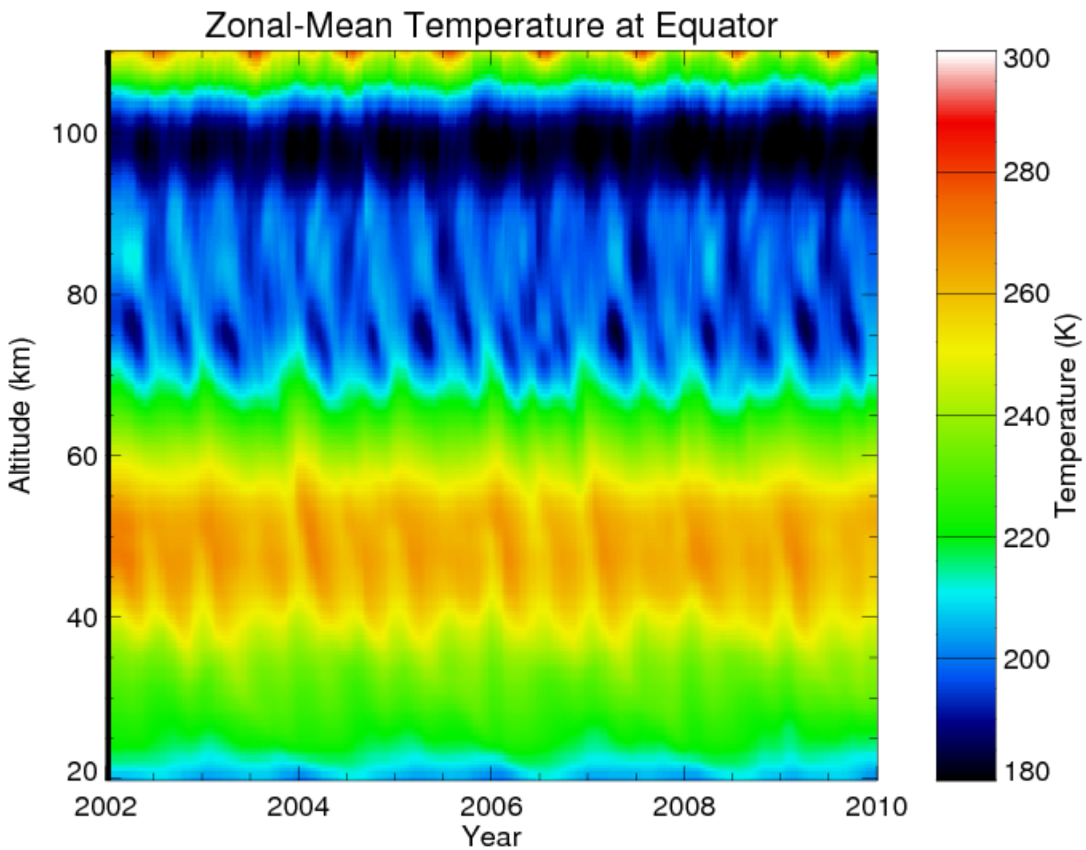
1 simulations with “nudged” QBO



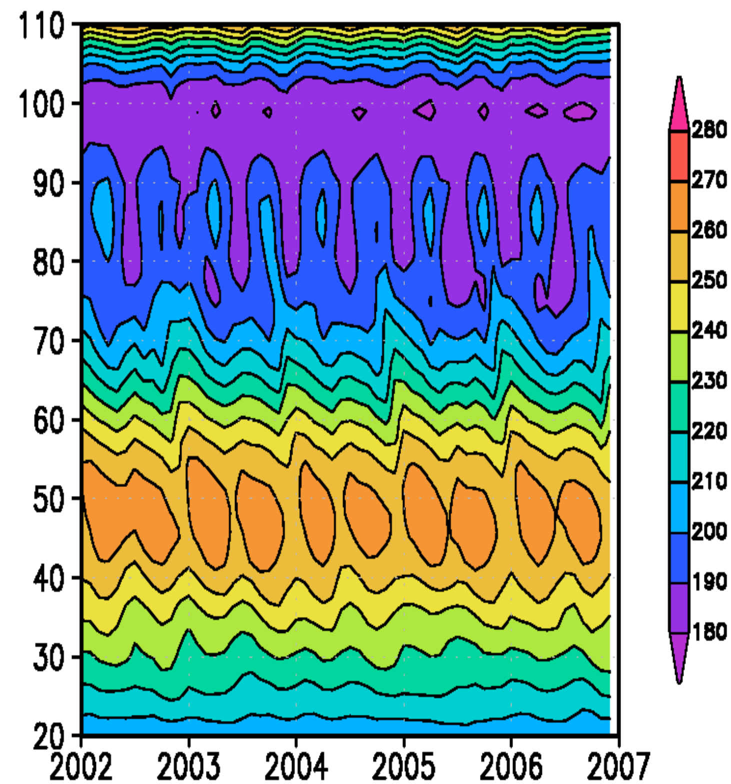
Solar cycle QBO interactions:
Labitzke, GRL, 1987;
Labitzke and van Loon, 1988;
…
Schmidt et al., JGR, 2010

T(K), SABER vs. HAMMONIA

SABER



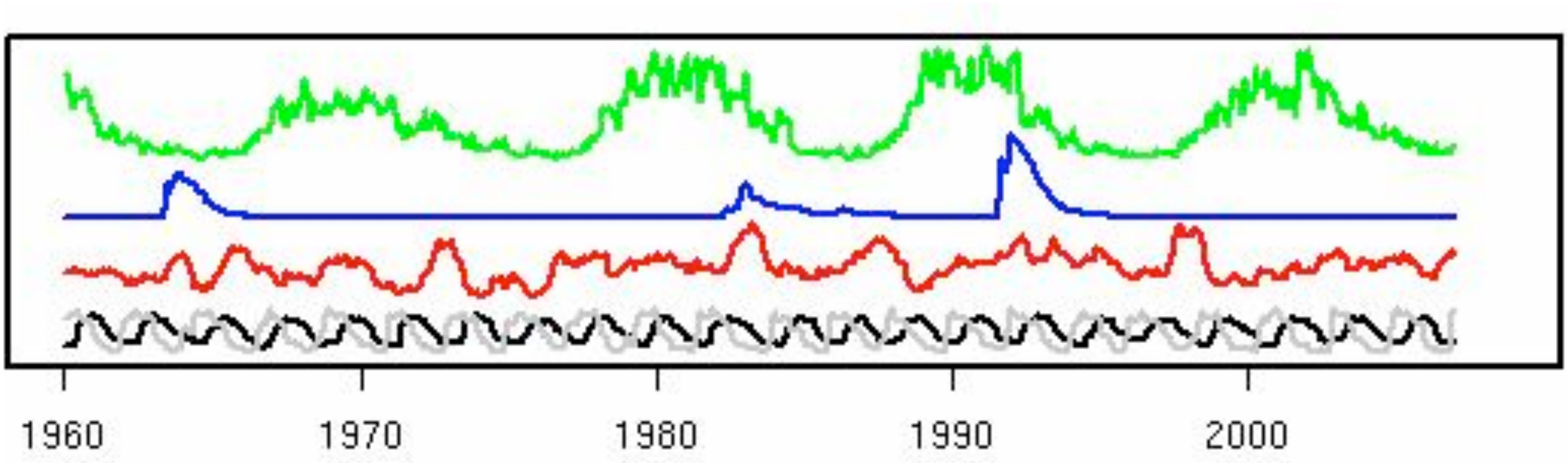
HAMMONIA



(Figure courtesy from Sam Yee, APL/JHU)

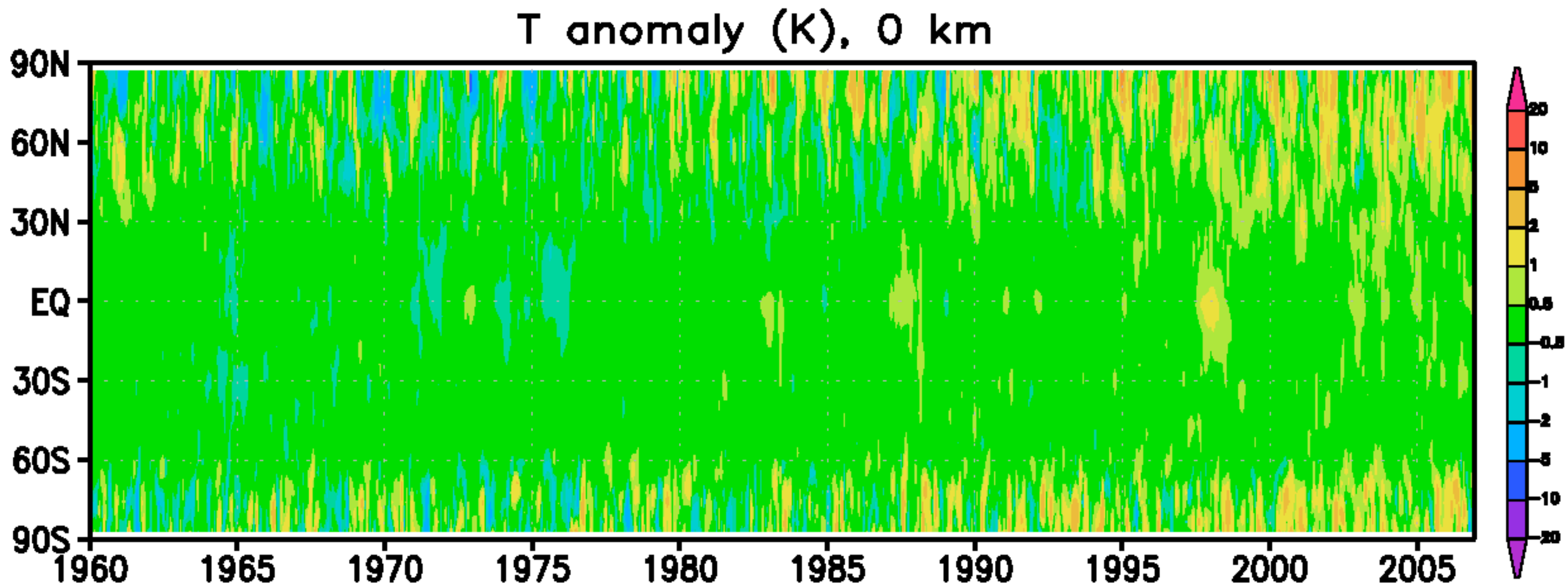
Multiple linear regression

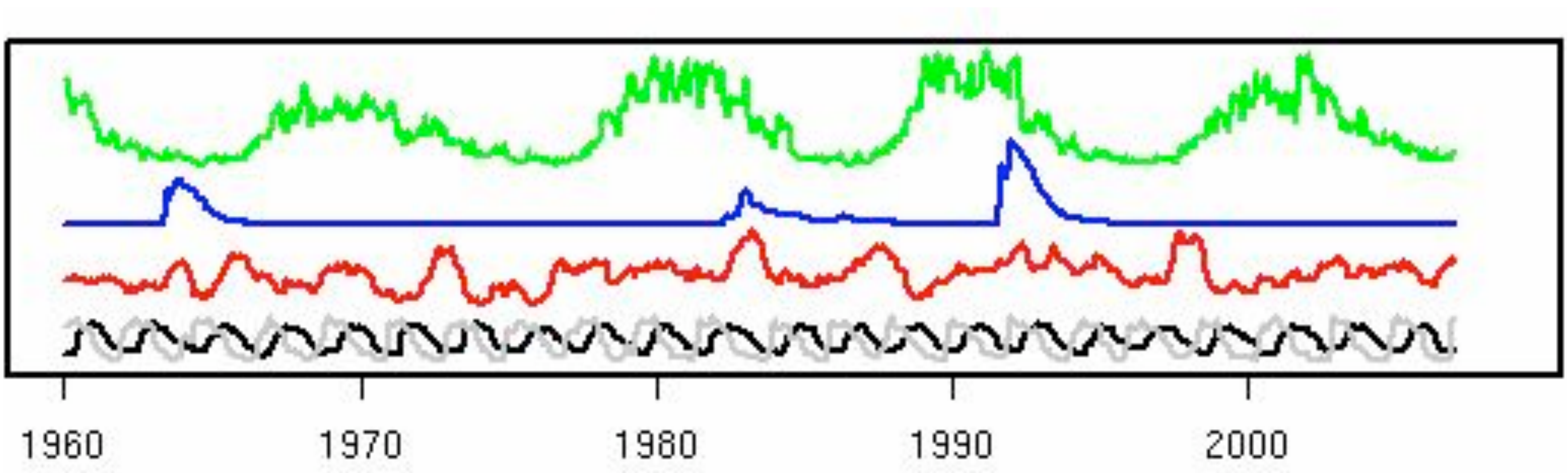
$$T_{anom}(t) = c_{trend}*t + c_{solar}*F107(t) + c_{volc}*SAD(t) + c_{enso}*MEI(t) + c_{qbo28}*u28(t) + c_{qbo10}*u10(t)$$



F10.7 index stratospheric aerosol SAD MEI ENSO index QBO (28 hPa) QBO (10 hPa)

Temperature anomalies from CCMVAL Ref1b experiment





Temperature anomalies from CCMVAL Ref1b experiment

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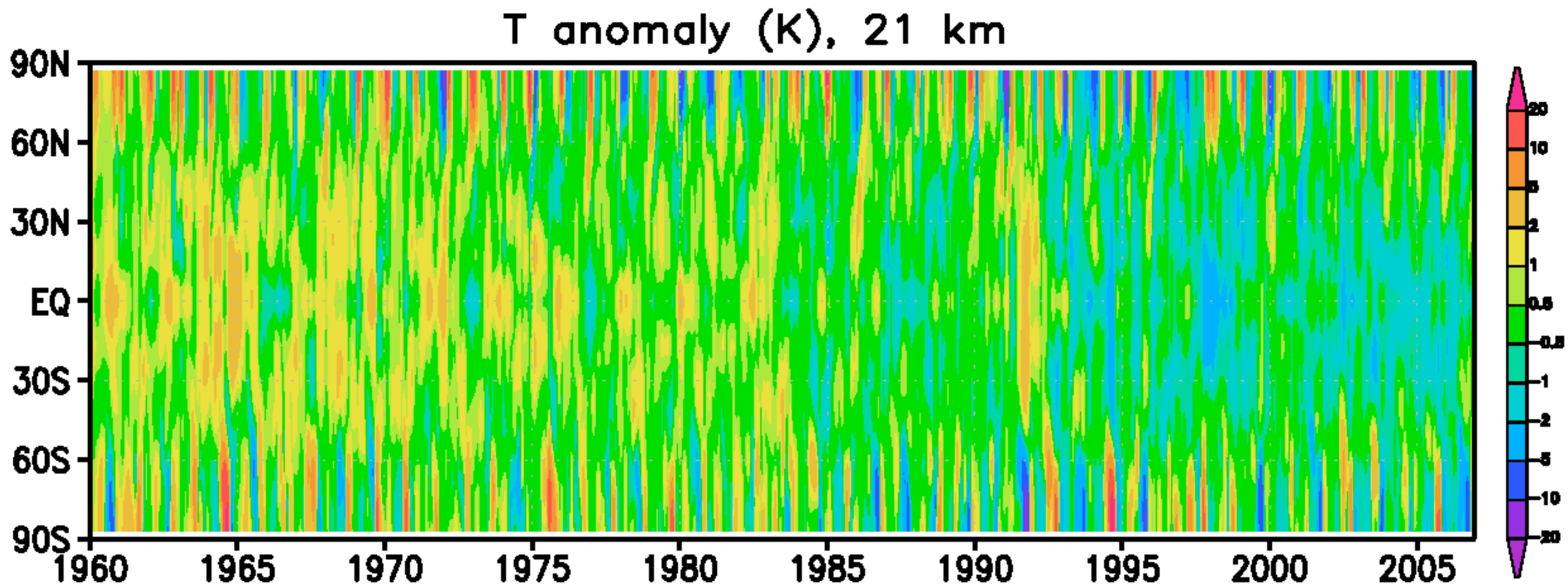
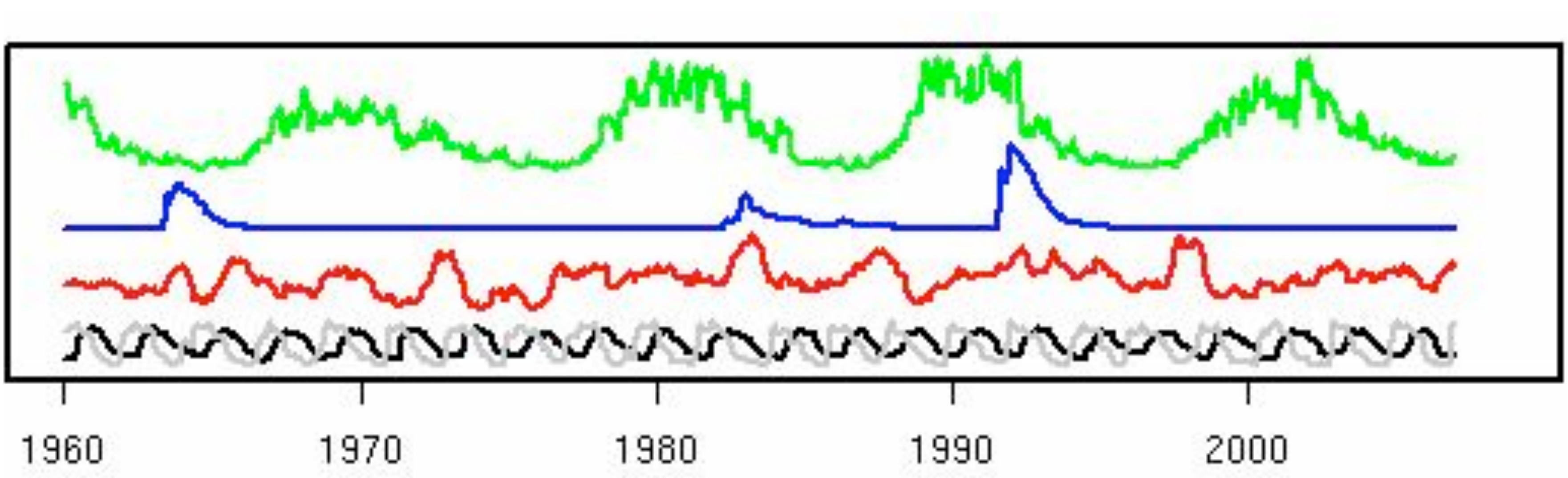
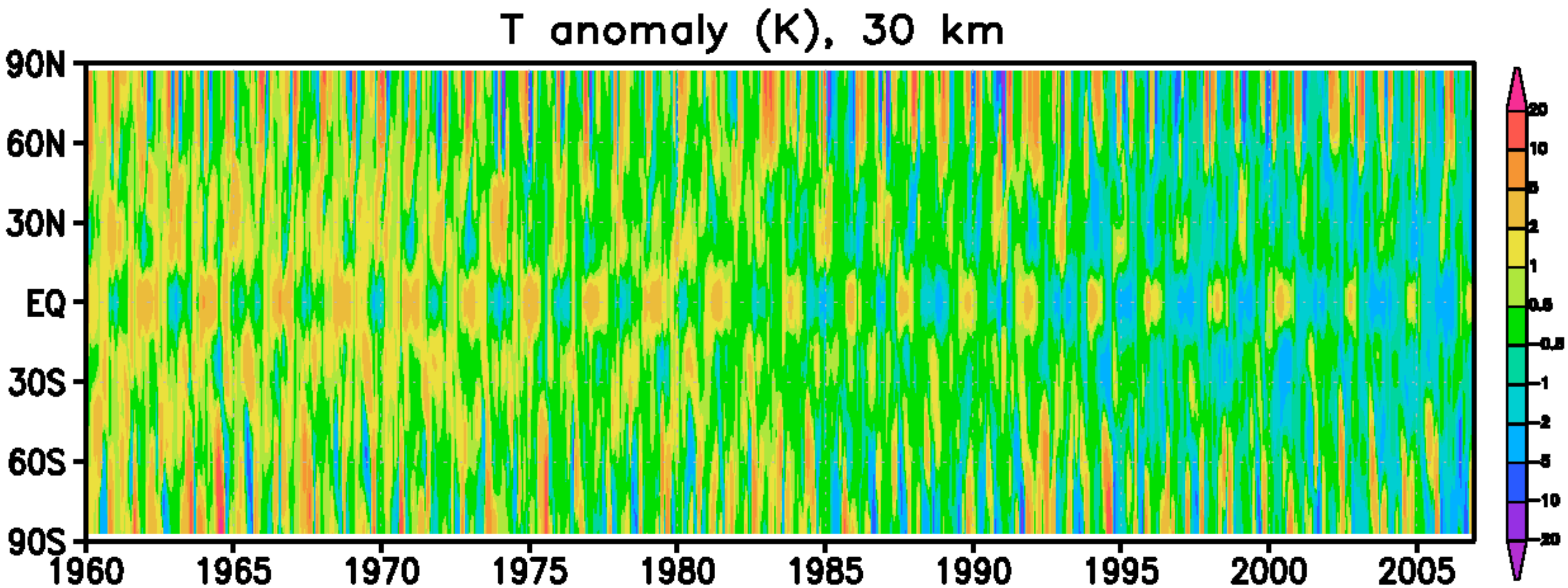
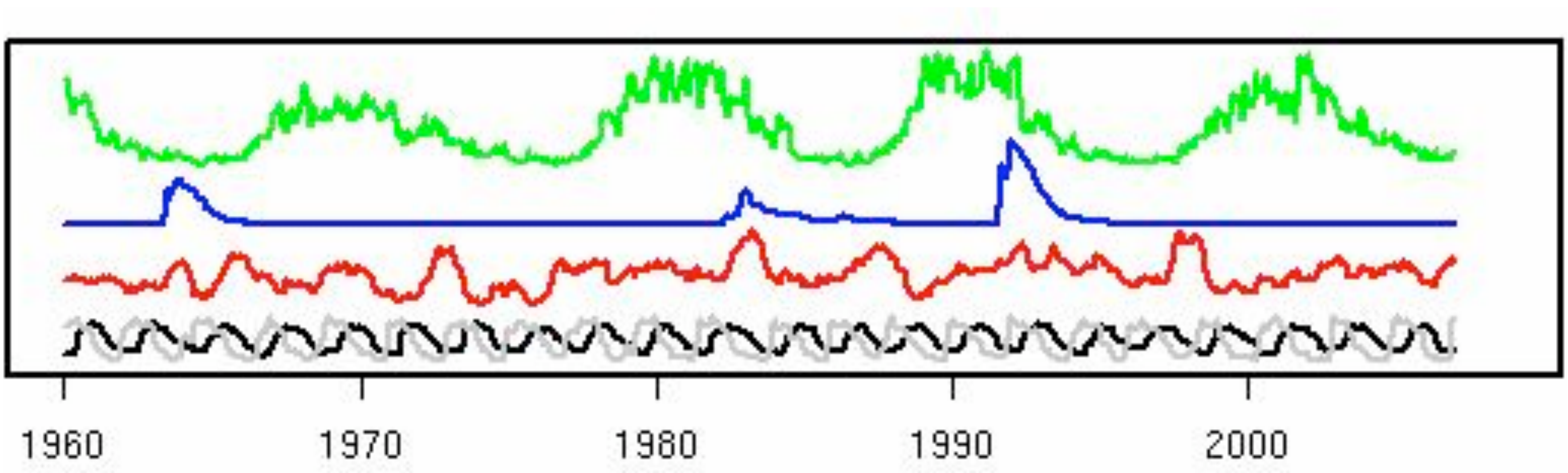


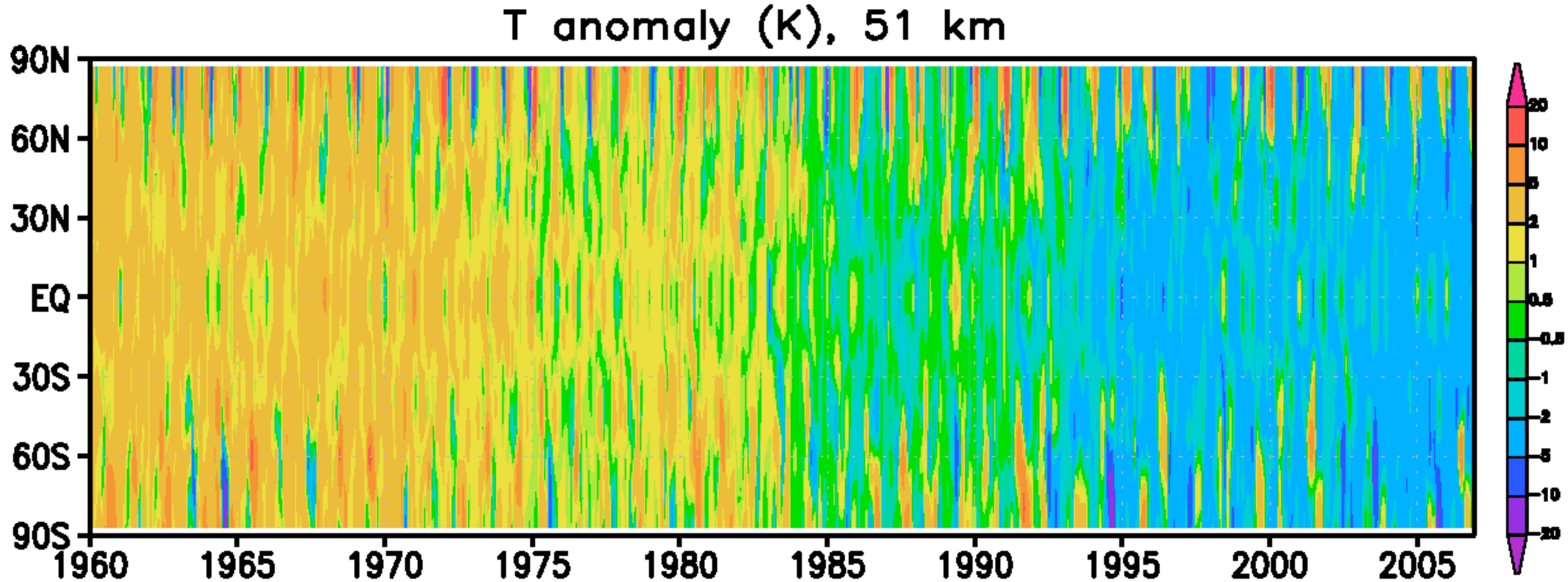


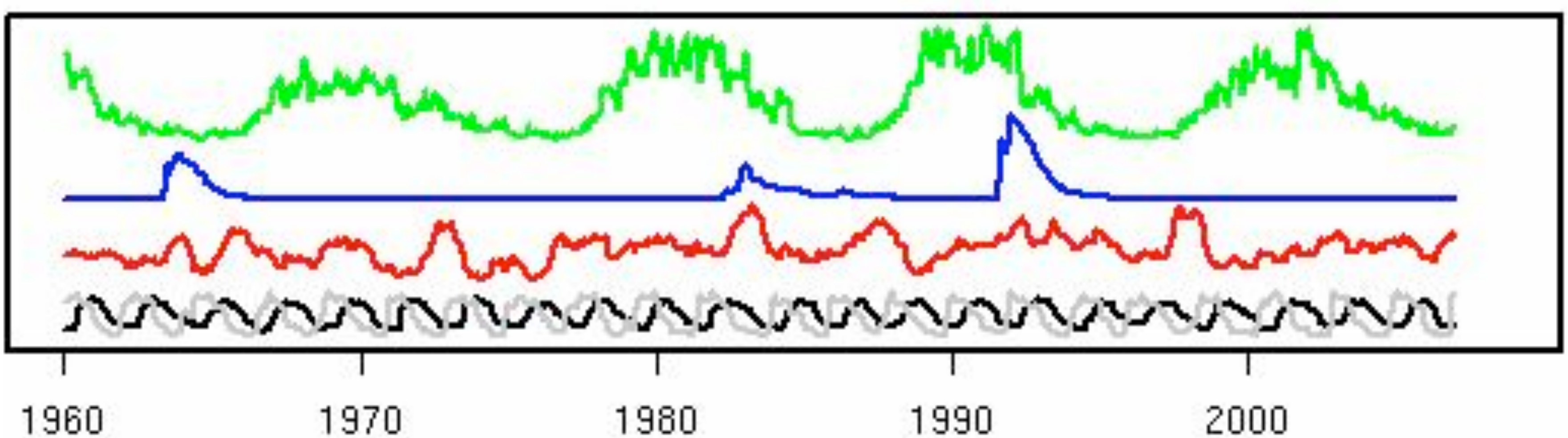
Temperature anomalies from CCMVAL Ref1b experiment





Temperature anomalies from CCMVAL Ref1b experiment





Temperature anomalies from CCMVAL Ref1b experiment

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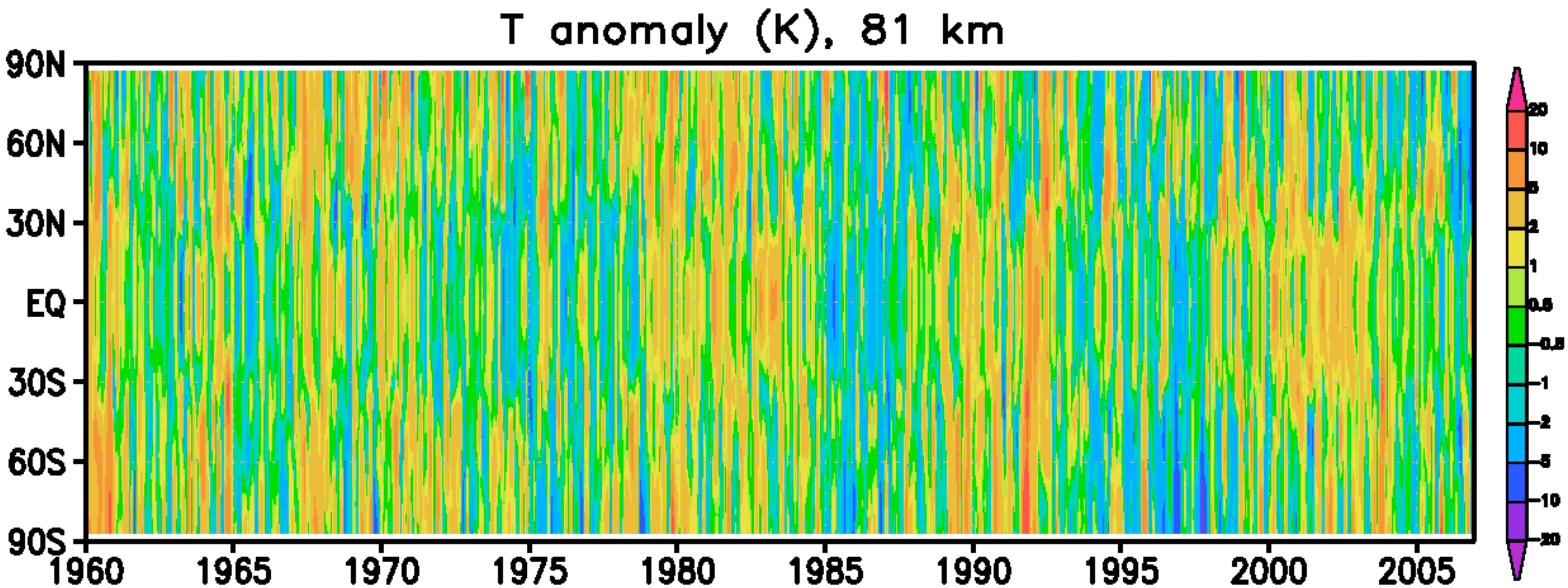

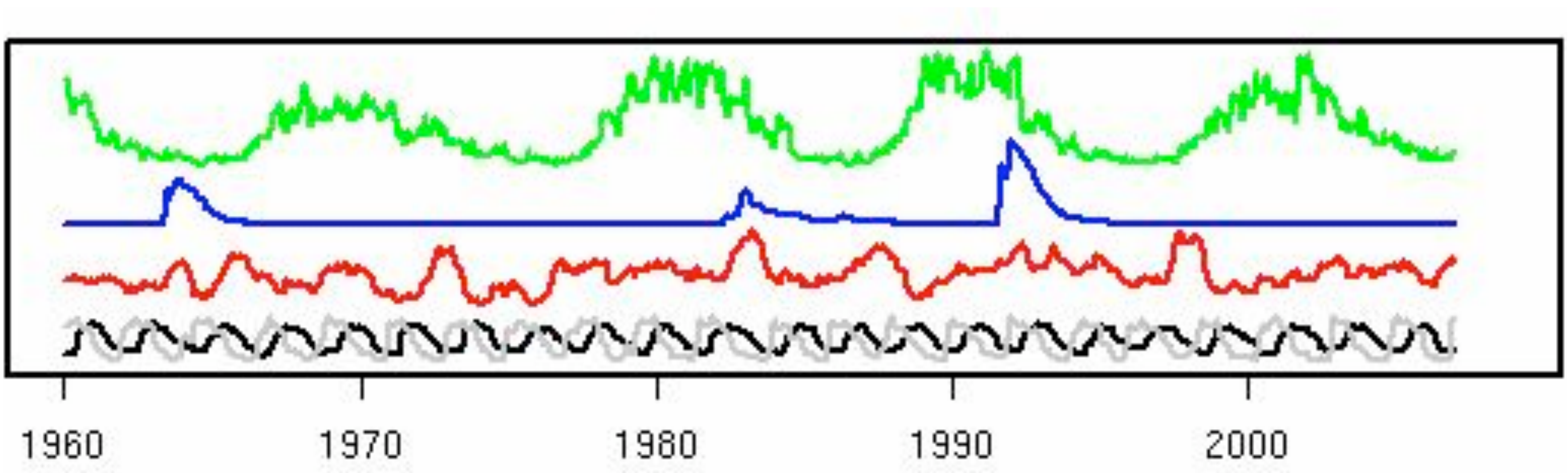

Temperature anomalies from CCMVAL Ref1b experiment

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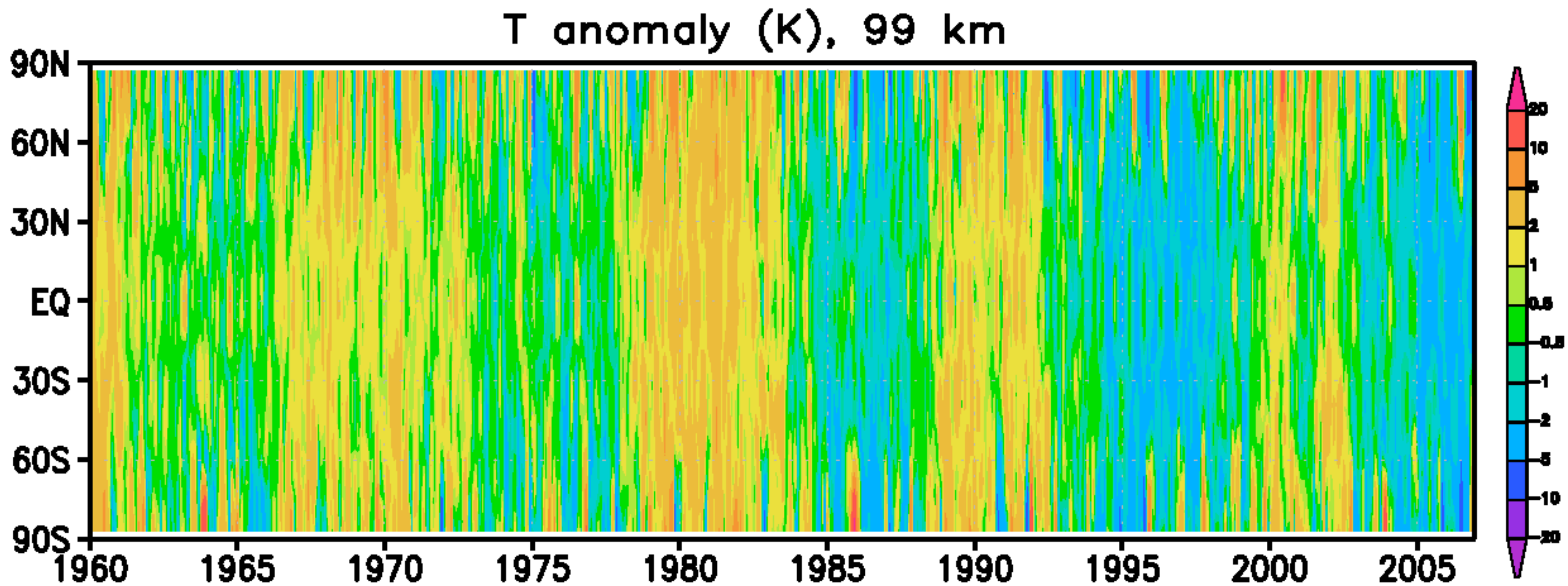

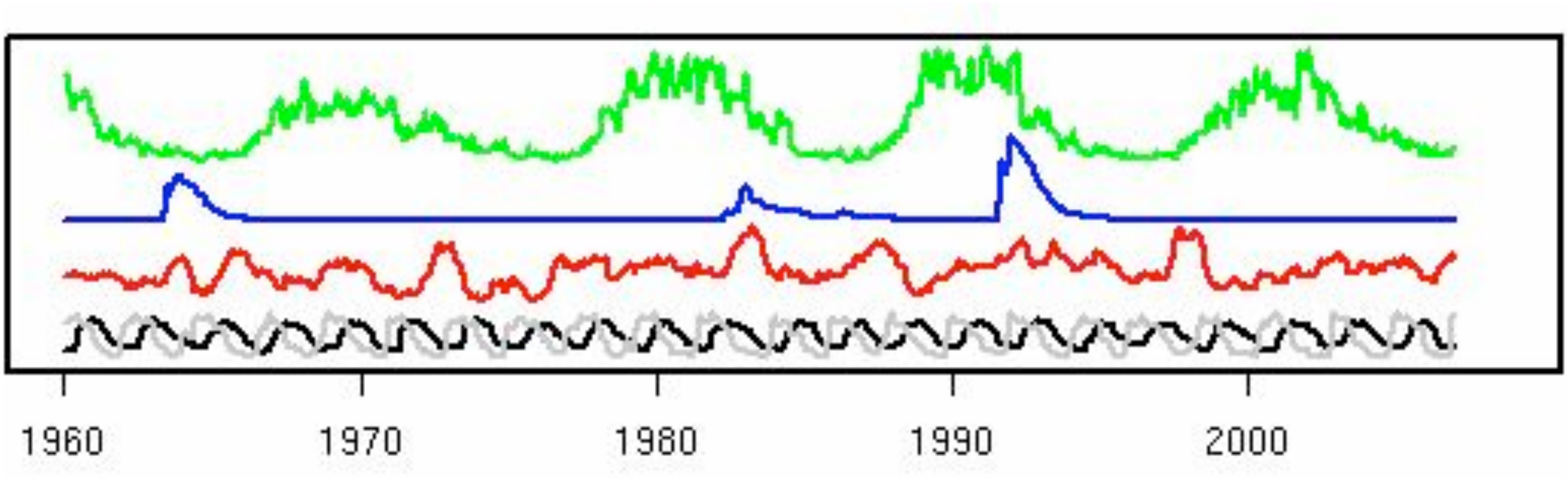

Δ T (solar variability), annual mean, 1960-2006

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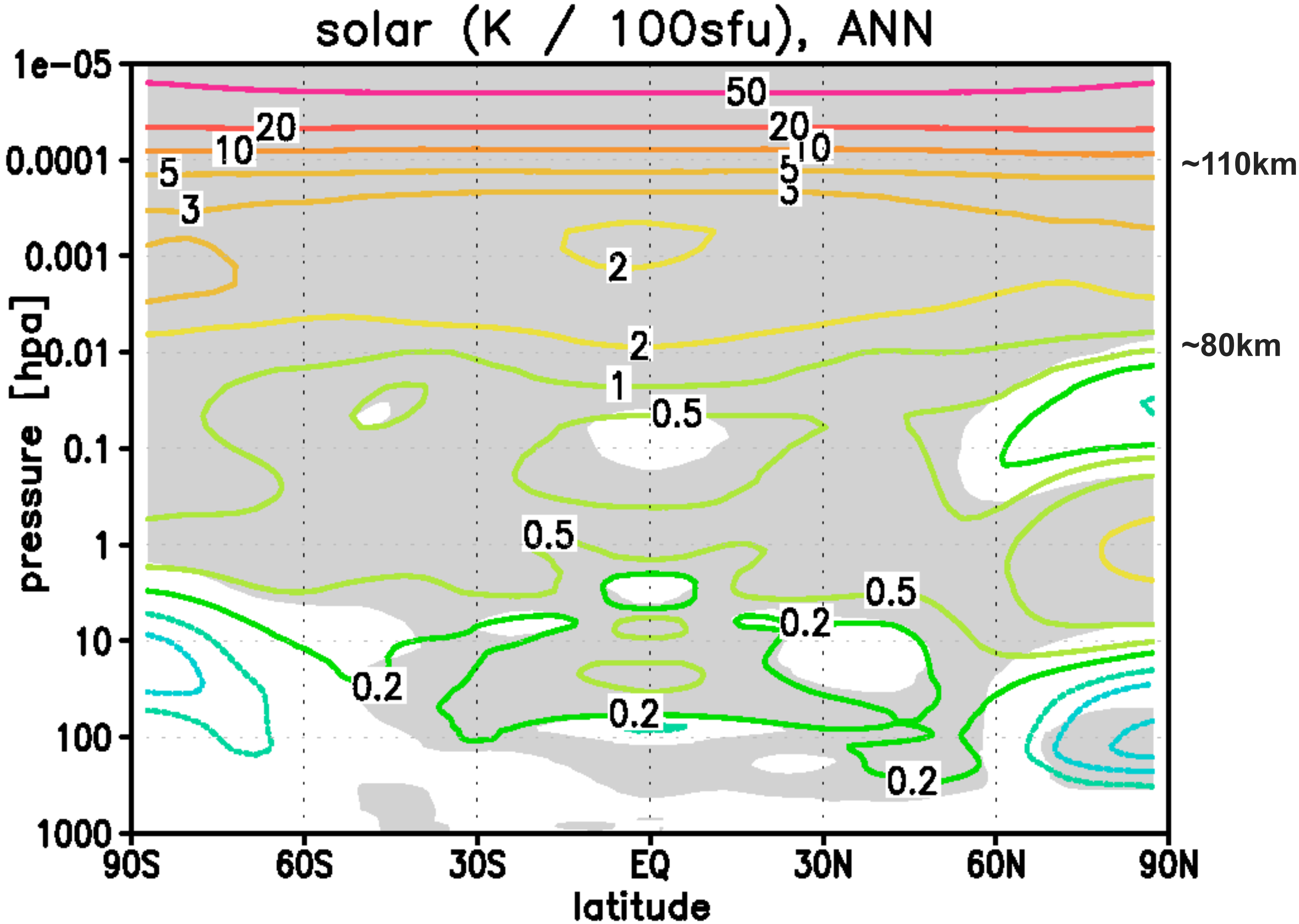
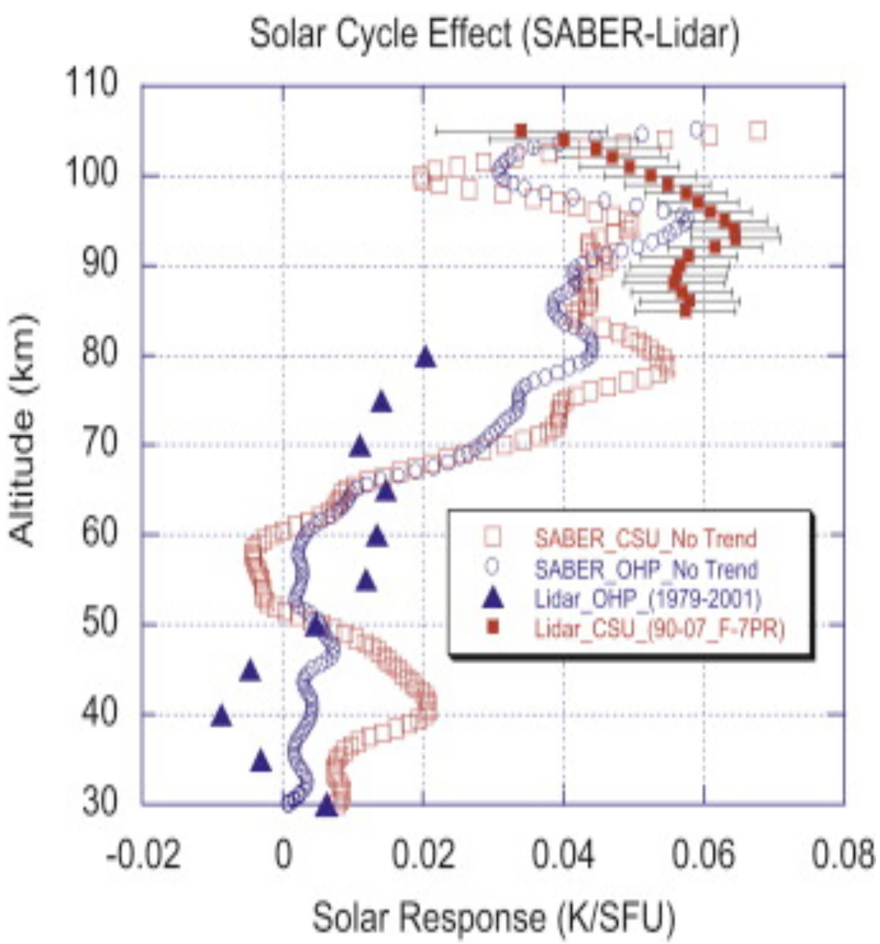
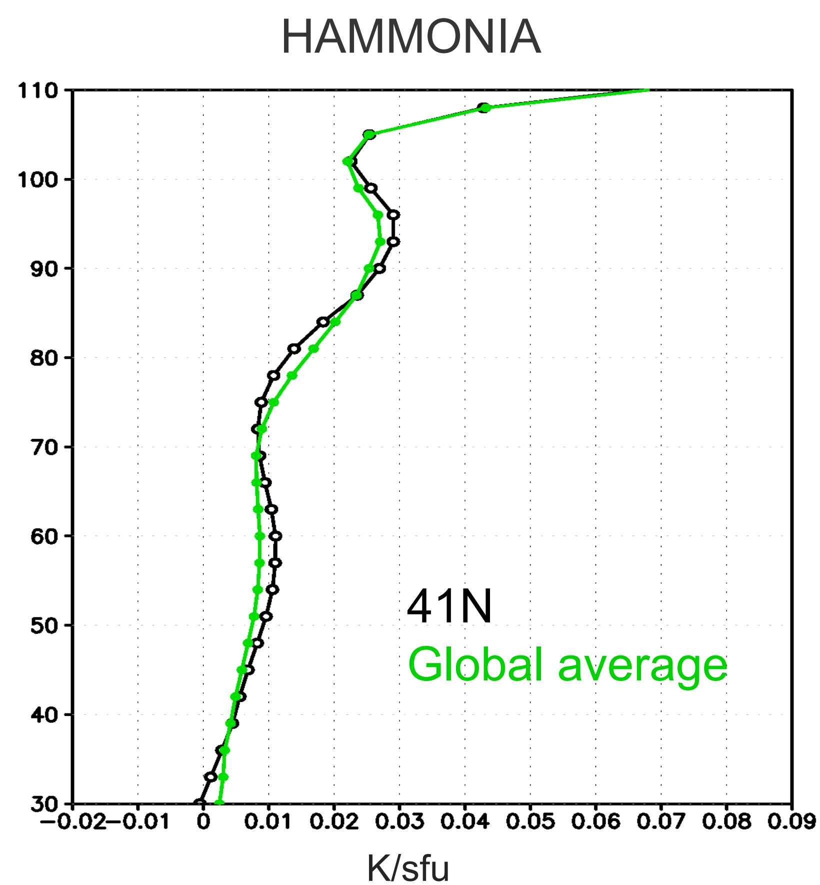


The solar signal
above Fort Collins,CO (41N)

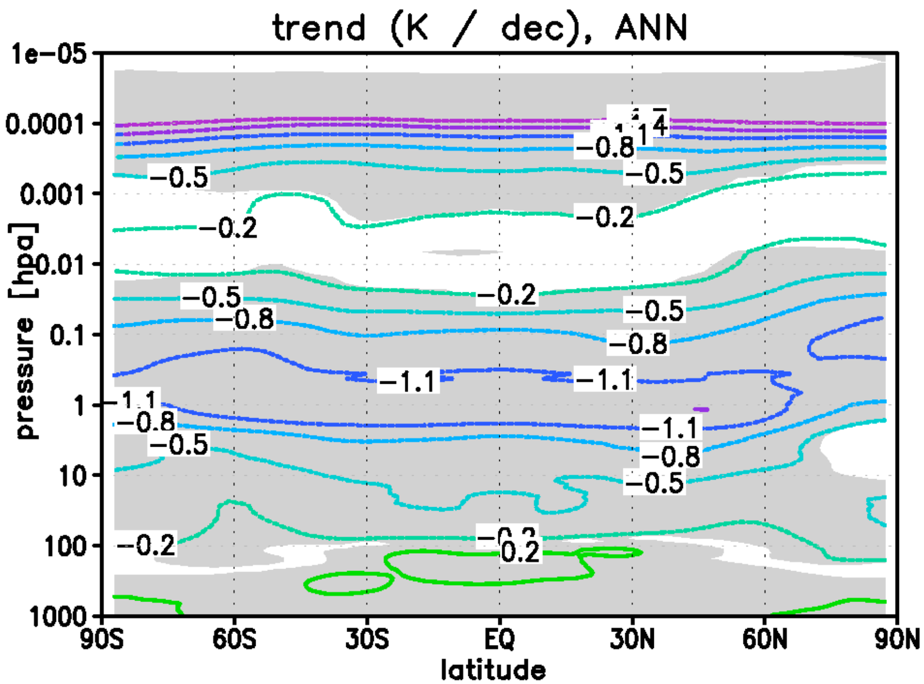




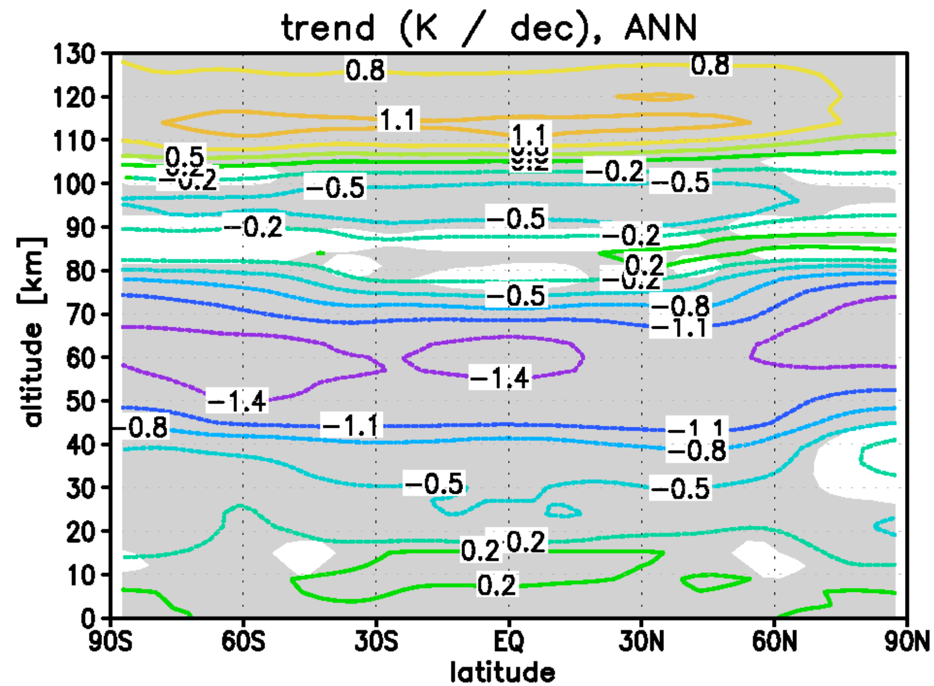
(She et al., JASTP, 2009)

Δ T (trend), annual mean,
pressure vs. Altitude coordinates

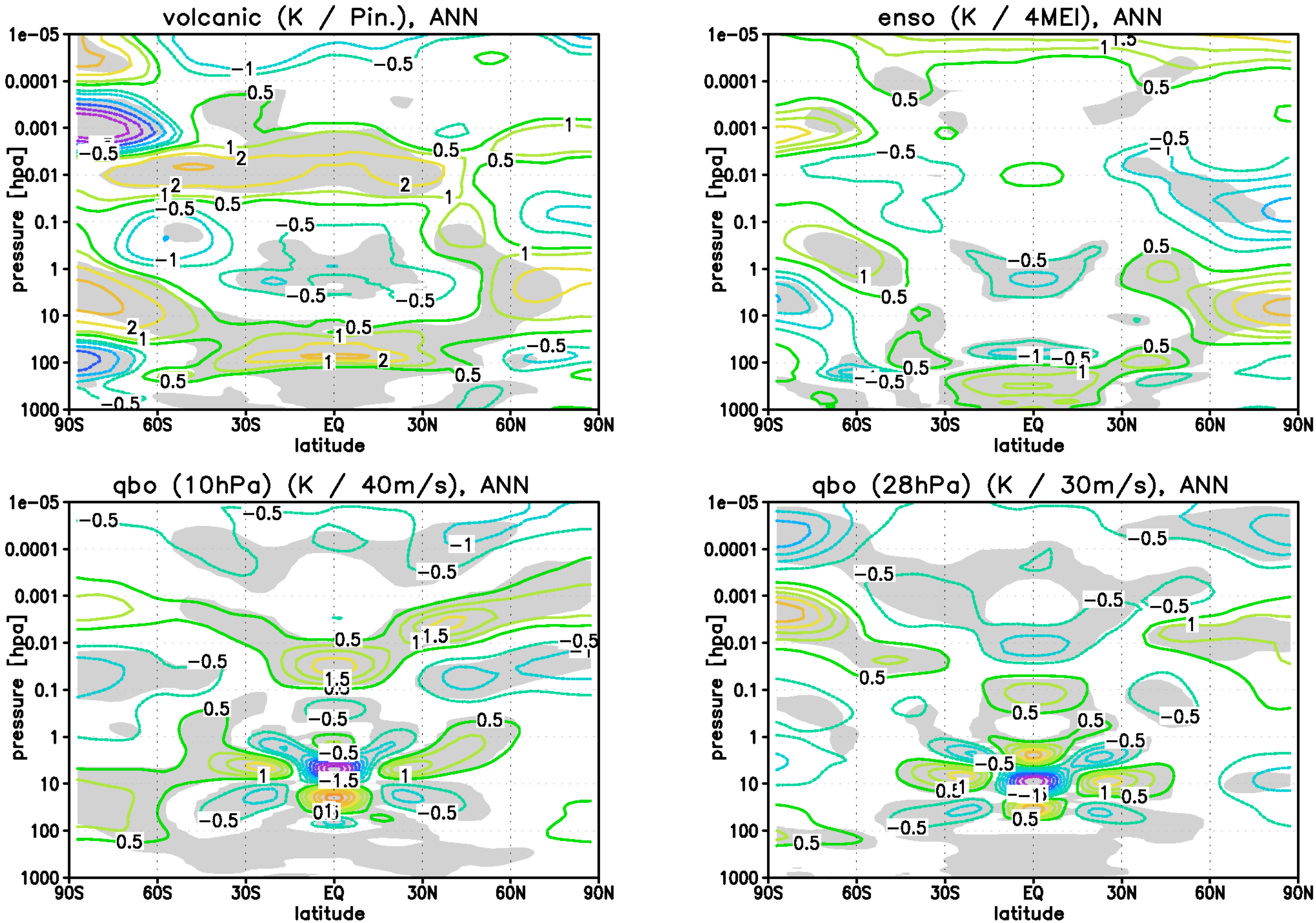
pressure



altitude



Δ T, annual mean



Δ T (solar variability), annual mean

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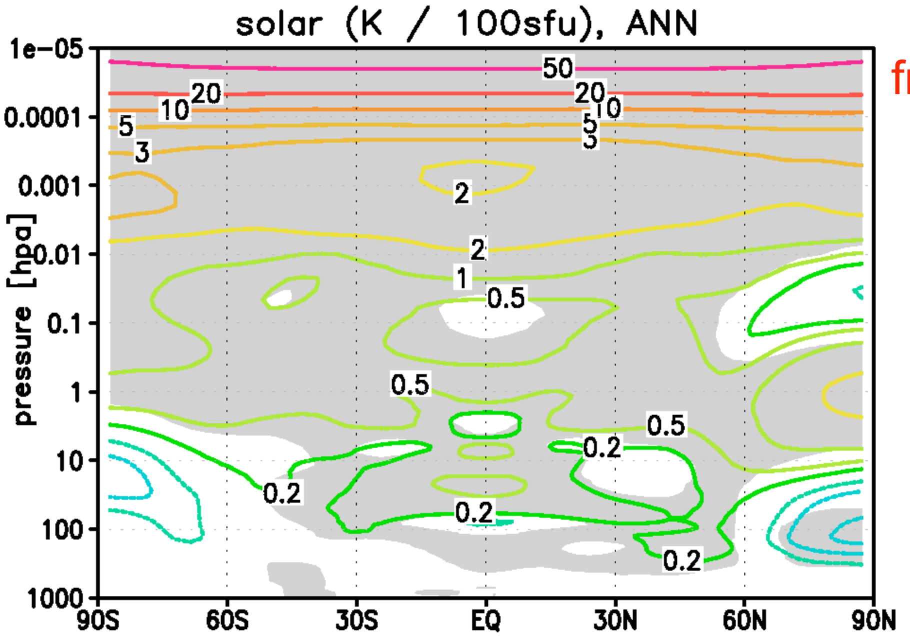
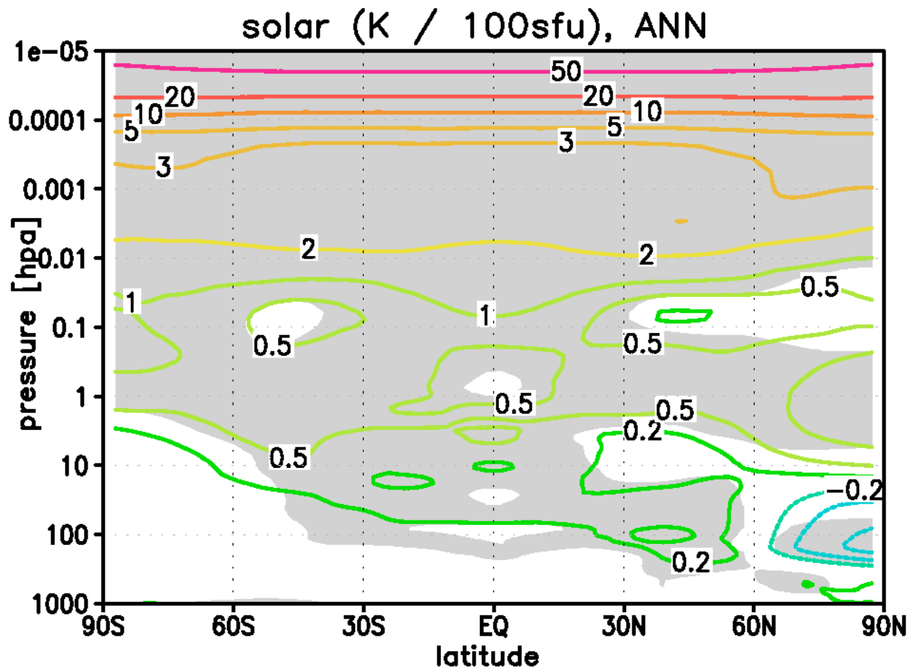
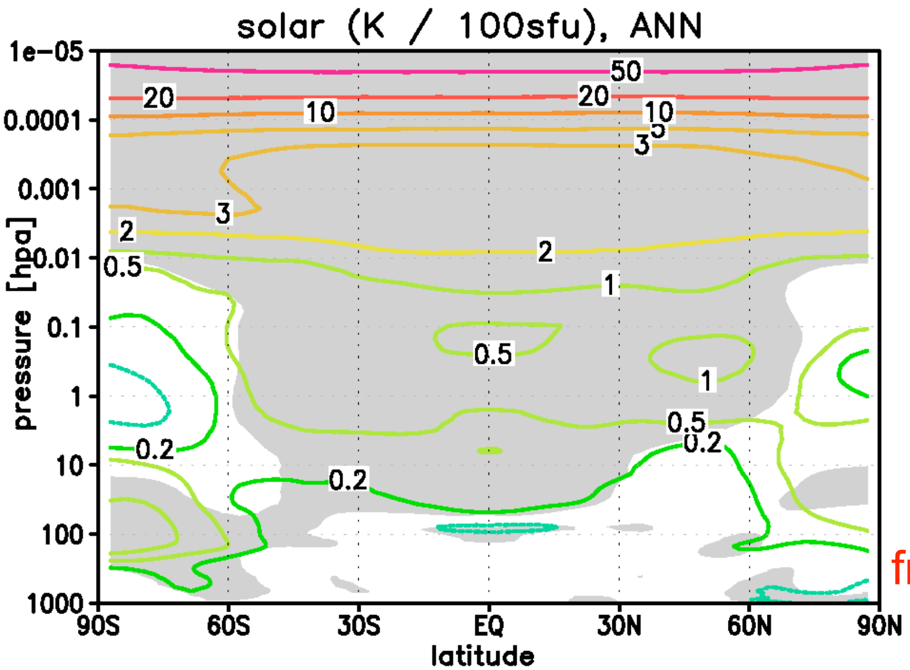


free QBO

nudged QBO





free QBO

Δ T (solar variability), January

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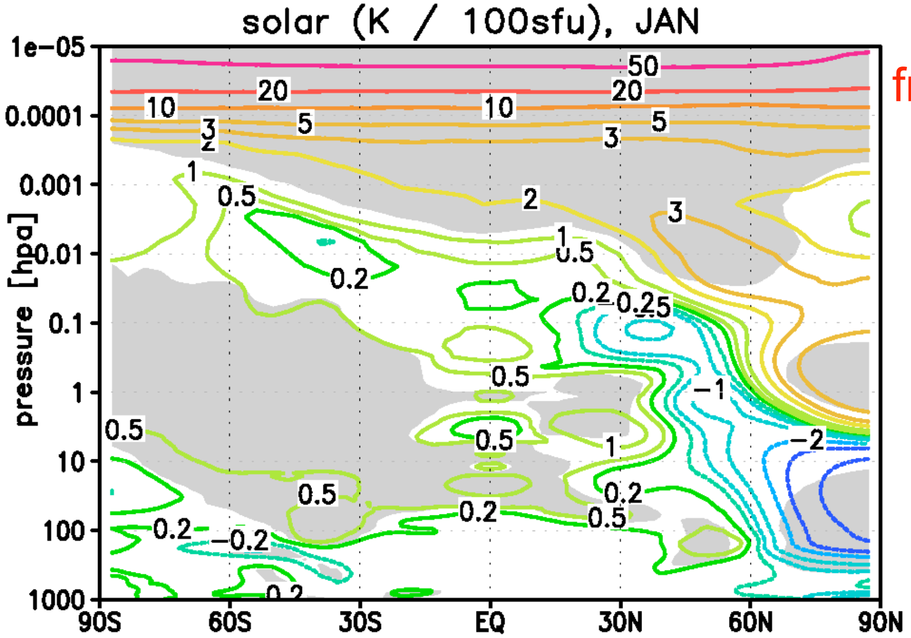
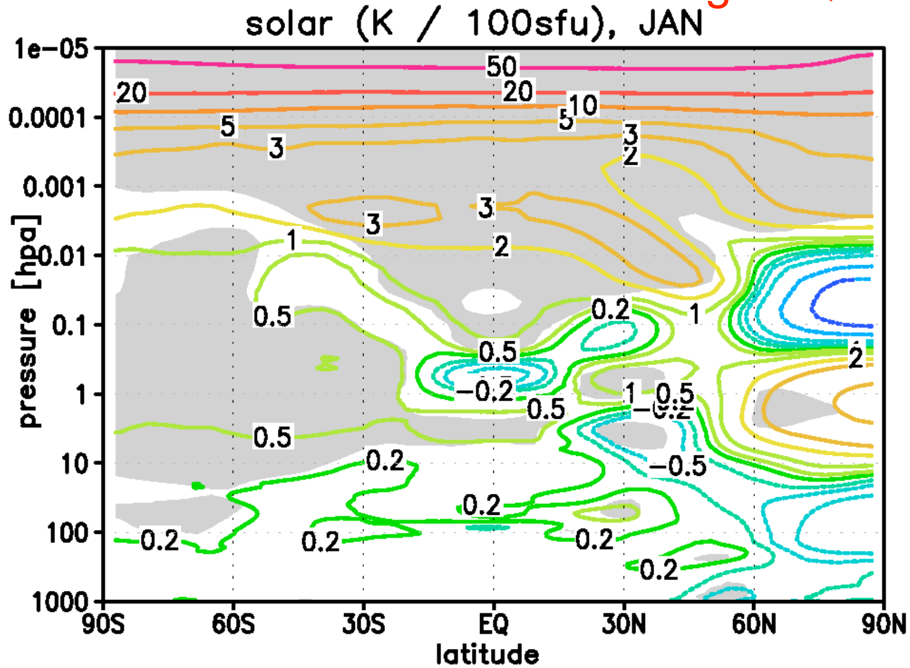
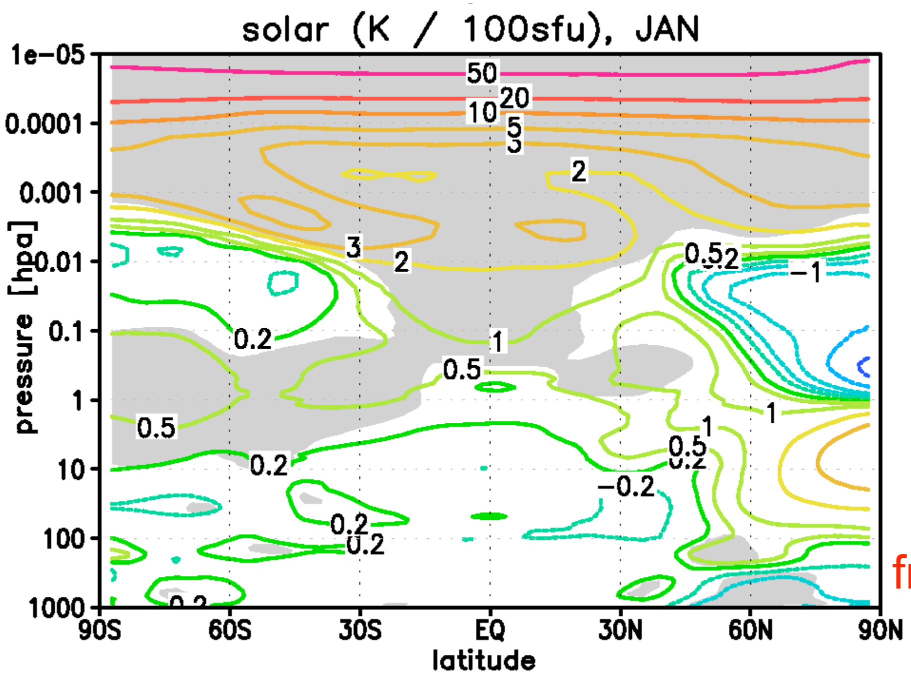


free QBO

nudged QBO





free QBO

T(K), January, ERA interim vs. HAMMONIA

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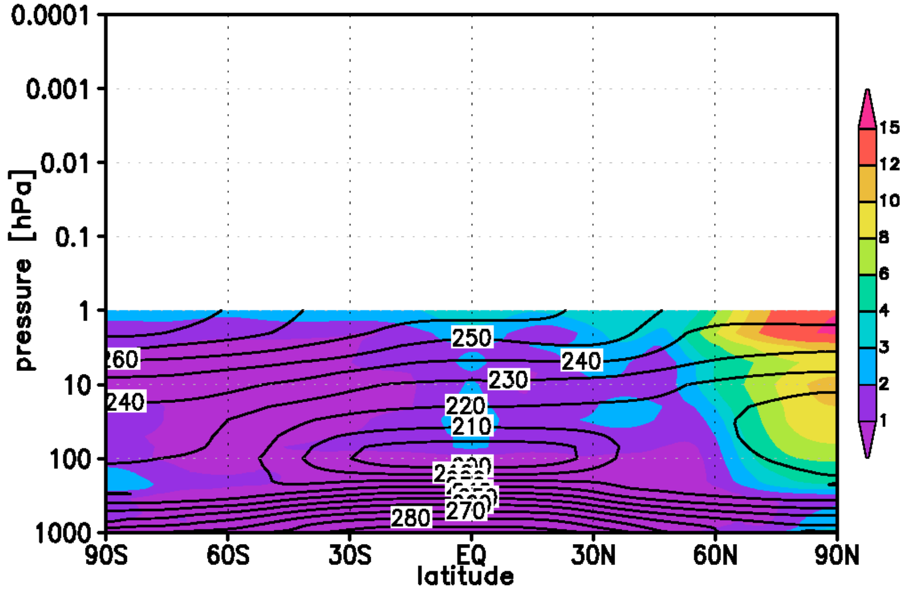
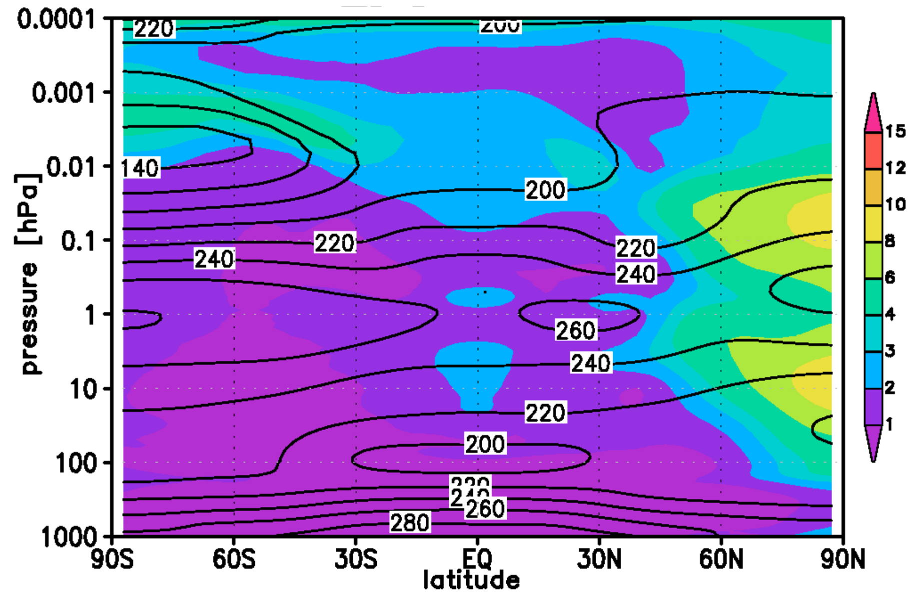
ERA, T(K), January



HAMMONIA, T(K), January



Isolines: average temperature 1989-2006
Shading: standard deviation 1989-2006

NB: Simulated variability in the MLT may be underestimated because of missing variability from geomagnetic and solar particles.

Solar signal in different solar cycles and experiments at 0N and 80N

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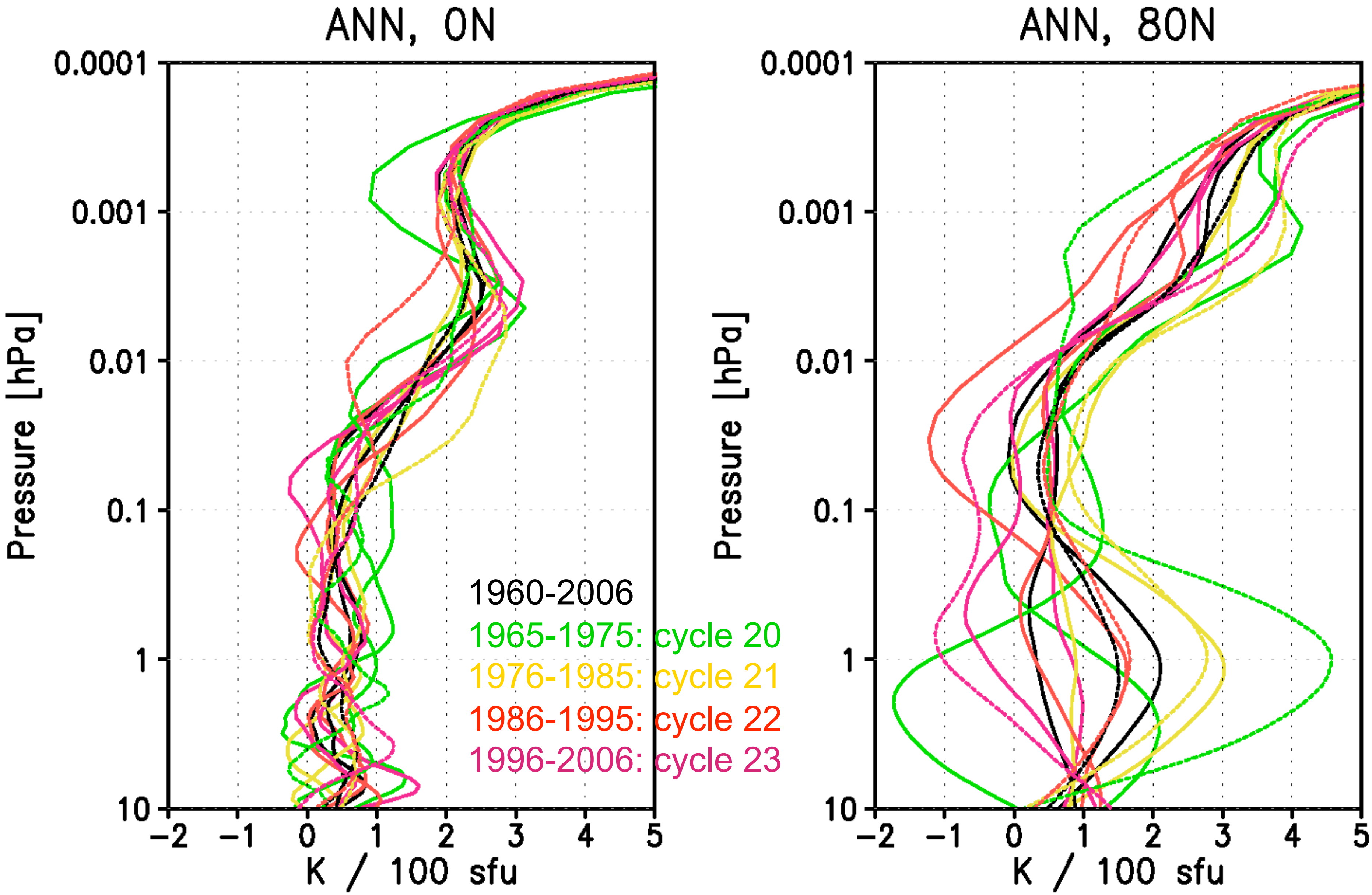
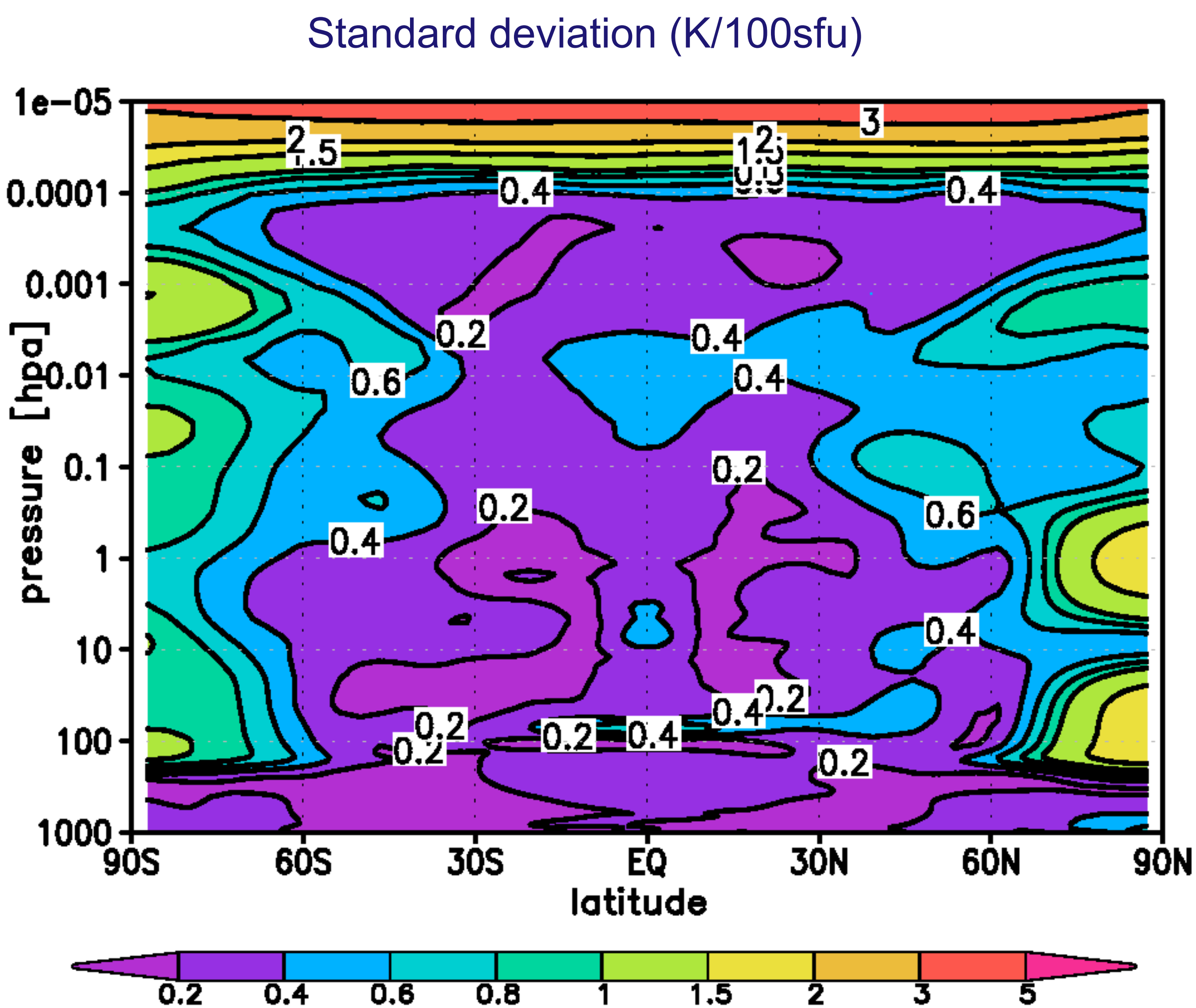
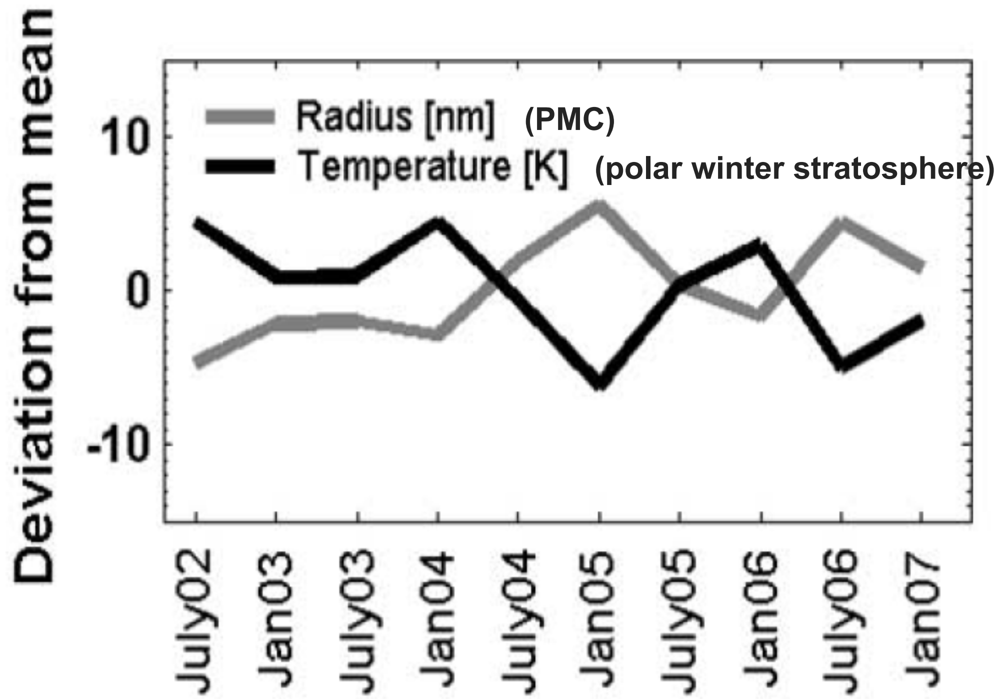


Standard deviation in estimated solar signals from 12 simulated solar cycles



Polar winter stratosphere and polar summer mesopause region are dynamically linked. (e.g. Becker and Schmitz, 2003; Becker et al., 2004; Becker and Fritts, 2006; Schmidt et al., 2006; Karlsson et al., 2007, 2009)



(Karlsson et al., GRL, 2007)

Interhemispheric temperature correlations, CMAM vs. HAMMONIA

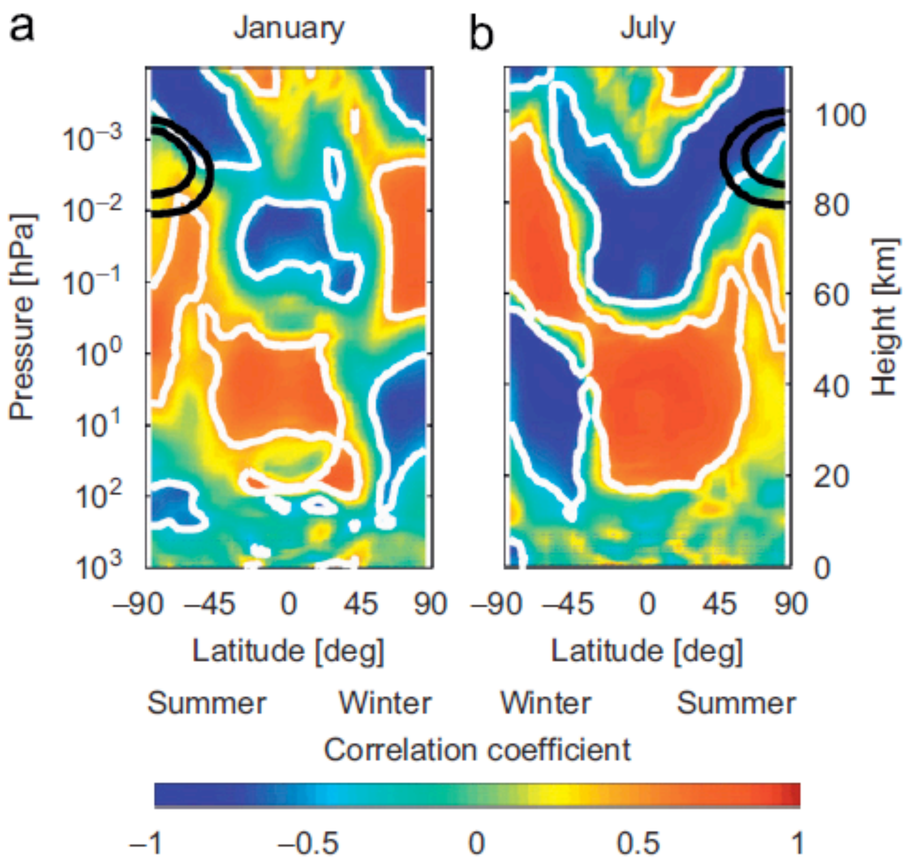
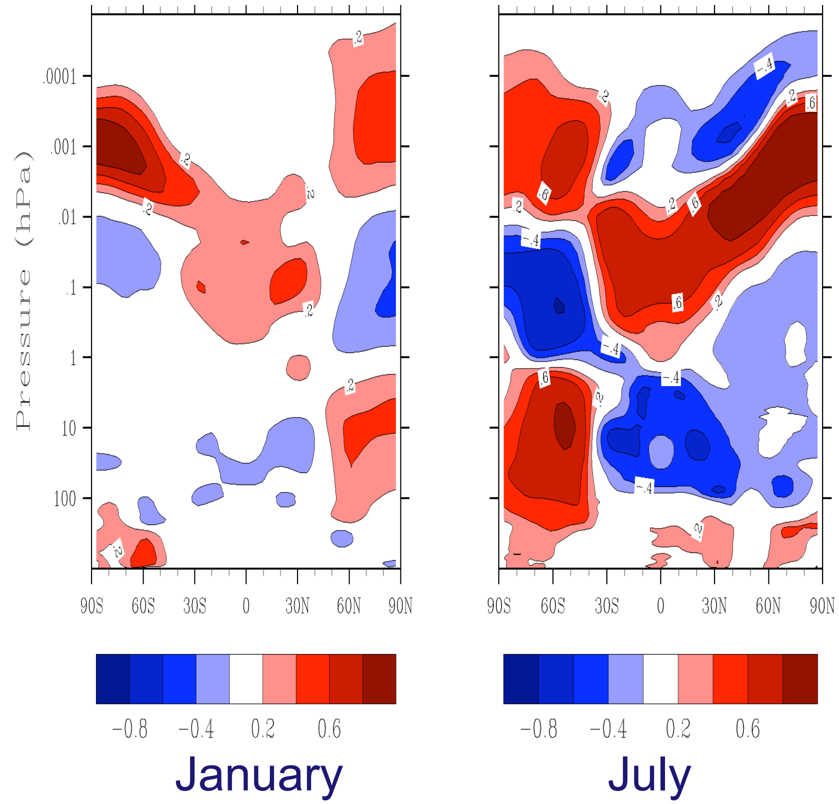


Fig. 1. Correlation between the CMAM monthly and zonal mean temperature anomaly in the summer mesopause region (from 0.3×10^{-2} to 0.3×10^{-4} hPa and latitudes poleward of 50°) and the monthly and zonal mean temperature anomalies in the rest of the atmosphere for (a) January and (b) July. For consistency with the observations shown in Fig. 2(b), the temperature anomalies in the summer mesopause region have been multiplied by -1 before computing the correlation. White lines denote the 95% significance level. The black lines show the climatological 130 and 150 K temperature contours, which indicate the location of the polar summer mesopause. Approximate altitude (based on log-pressure with a scale height of 7 km) is indicated. Note that the model domain extends much higher than the vertical range of the plots.



(Karlsson et al., JASTP, 2009)

Simulated correlation
NH winter stratosphere - SH summer mesopause

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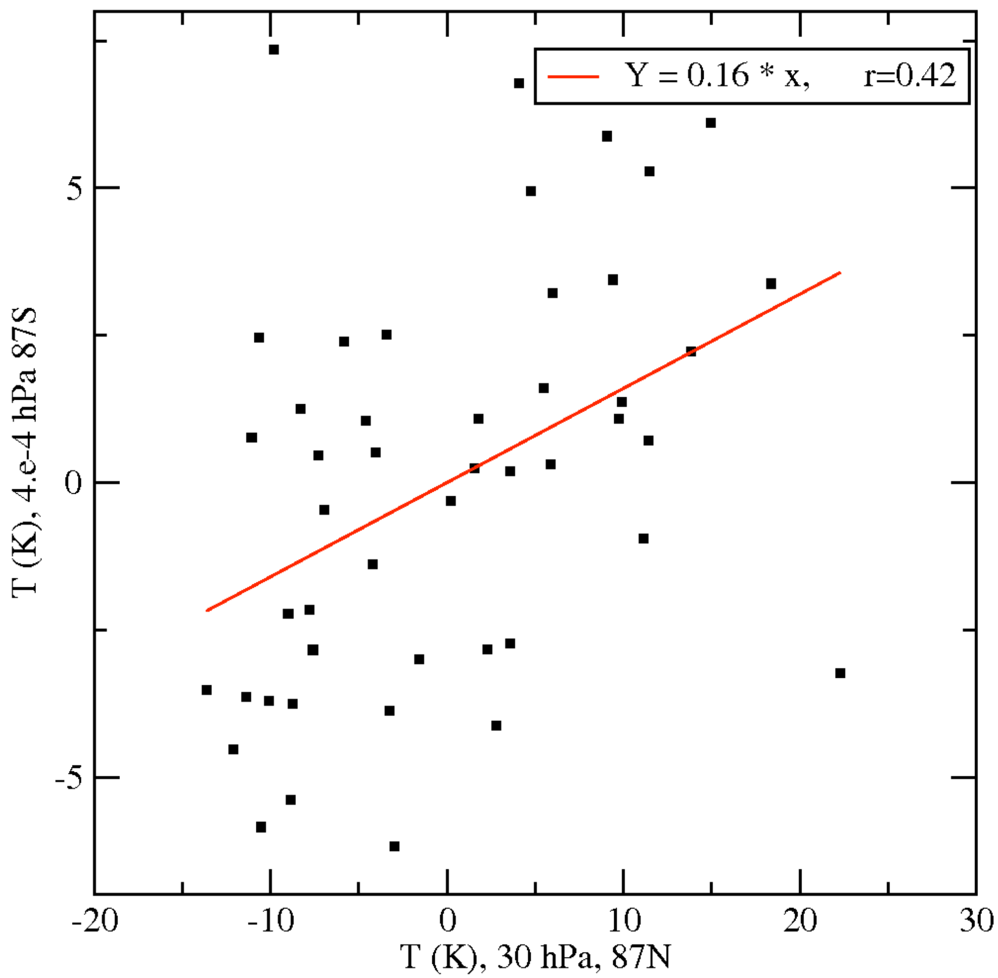
January



Simulated correlation
SH winter stratosphere - NH summer mesopause

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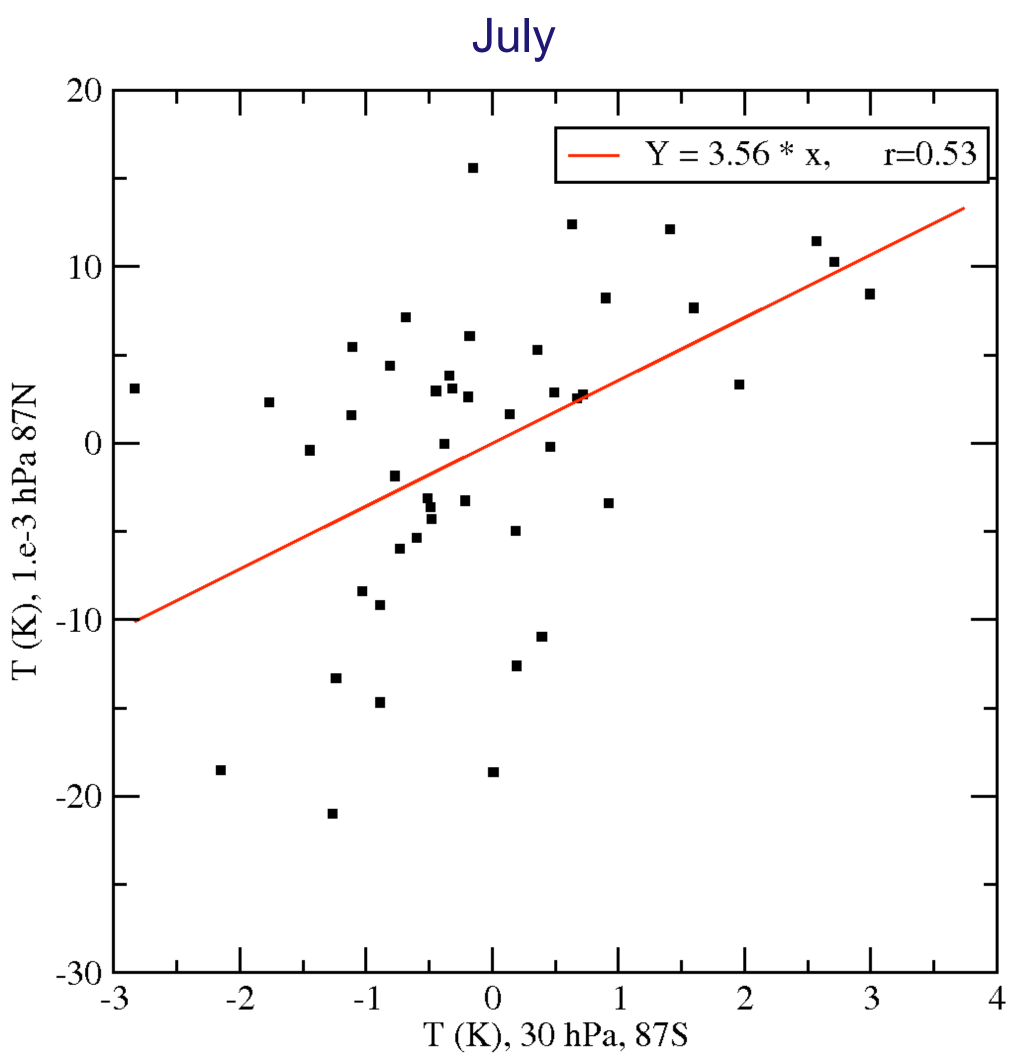

Summary / Considerations

- Mesopause responses simulated by HAMMONIA:
  - Solar forcing :~3K/100sfu
  - Trend: insignificant at the mesopause; up to -1.5K/decade in the lower mesosphere)
  - ENSO, QBO, volcanoes have locally significant effects
- Available time series are often too short for an unambiguous attribution of observed signals. (How strong is the volcanic influence in the mesopause region?)
- However, in the low to mid-latitude MLT, global observations over one solar cycle should provide a good estimation of the solar UV influence.
- The MLT high latitudes are strongly influenced by the variability of the stratosphere.
- Other types of solar input have a temperature effect on the MLT: 27-day variability (Gruzdev et al., ACP, 2009); EPP

Acknowledgments

• Heinz-Juergen Punge (now at LSCE/CEA)
• DFG (CAWSES SPP)
• DKRZ (German Climate Computing Center)

Thank you!