

Climate change in the mesosphere from 1850 to 2100 in CESM-WACCM

Daniel R. Marsh

National Center for Atmospheric Research, Boulder, USA



NCAR is sponsored by the National Science Foundation





CESM-WACCM features

- Model top at ~140 km (66 levels)
- Horizontal (lat x lon) resolution: 1.9° x 2.5°
- Fully-interactive chemistry
- **Coupled to 1° resolution 'deep' ocean model (POP2)**
- Nudged Quasi-Biennial Oscillation (QBO)
- Forced with daily varying spectral irradiance rather than annual mean TSI
- Thermospheric processes - aurora, ion chemistry, molecular diffusion
- Parameterization for gravity waves from convection and fronts
- SSW frequency of 4.5 / decade



NCAR

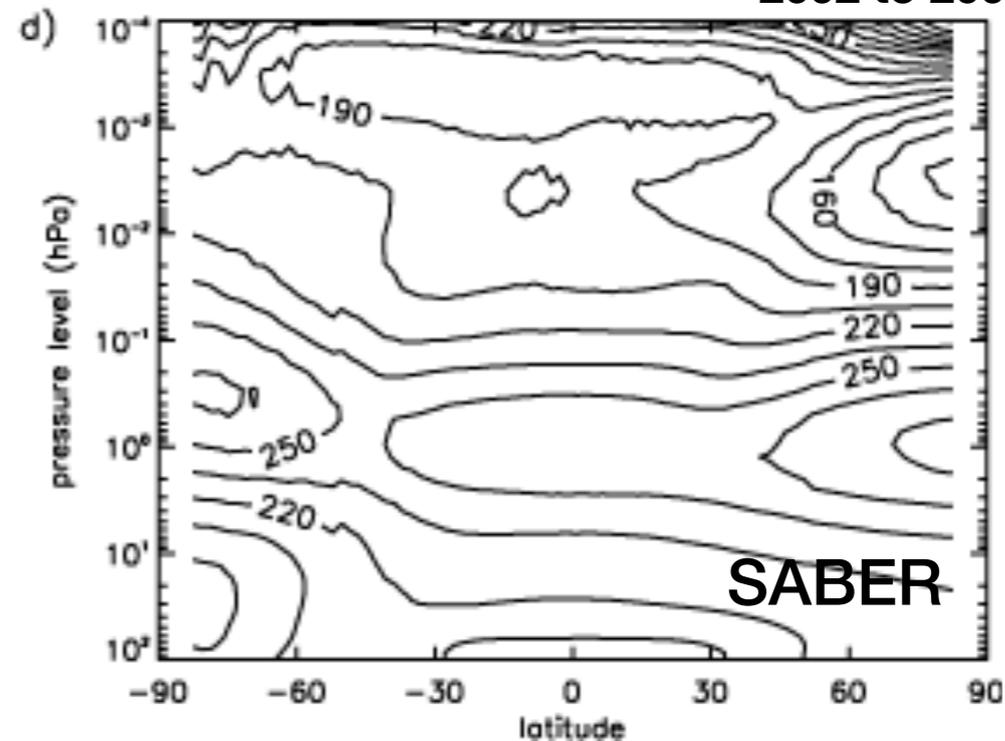
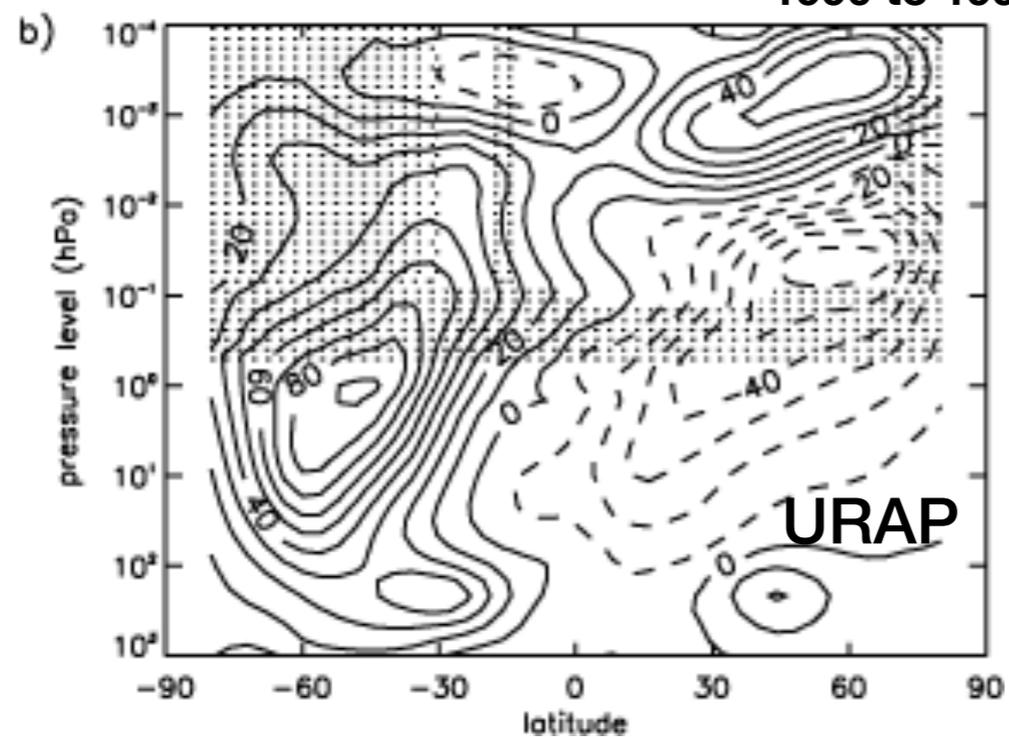
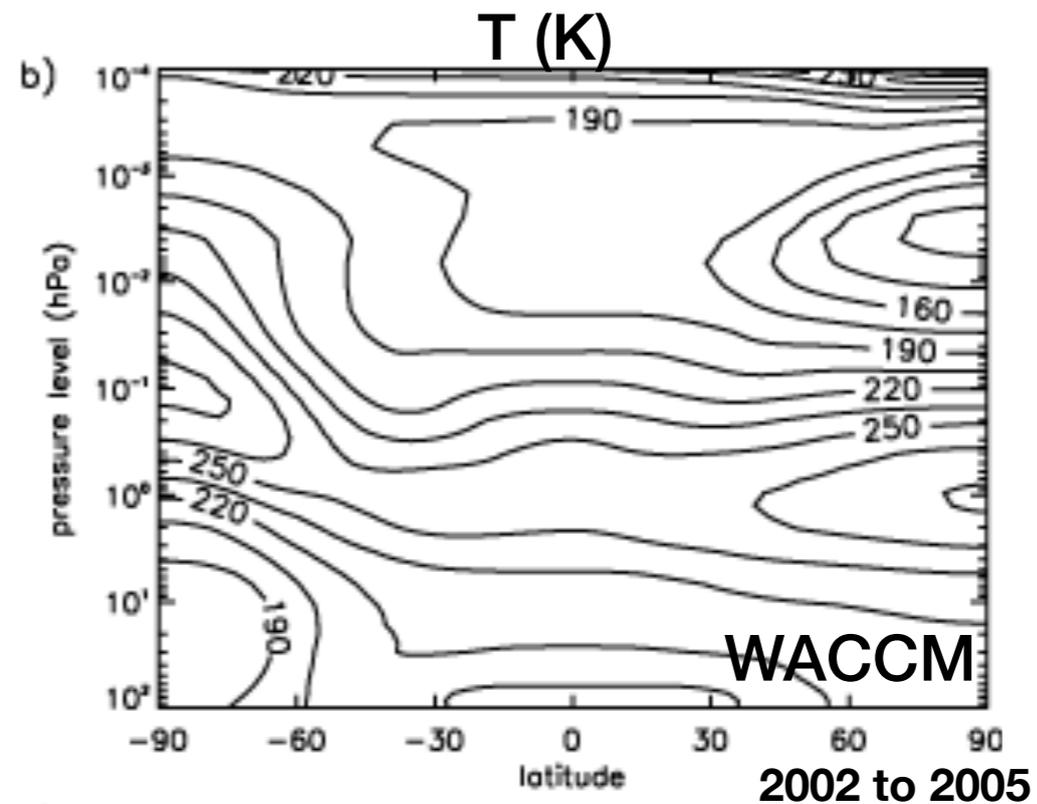
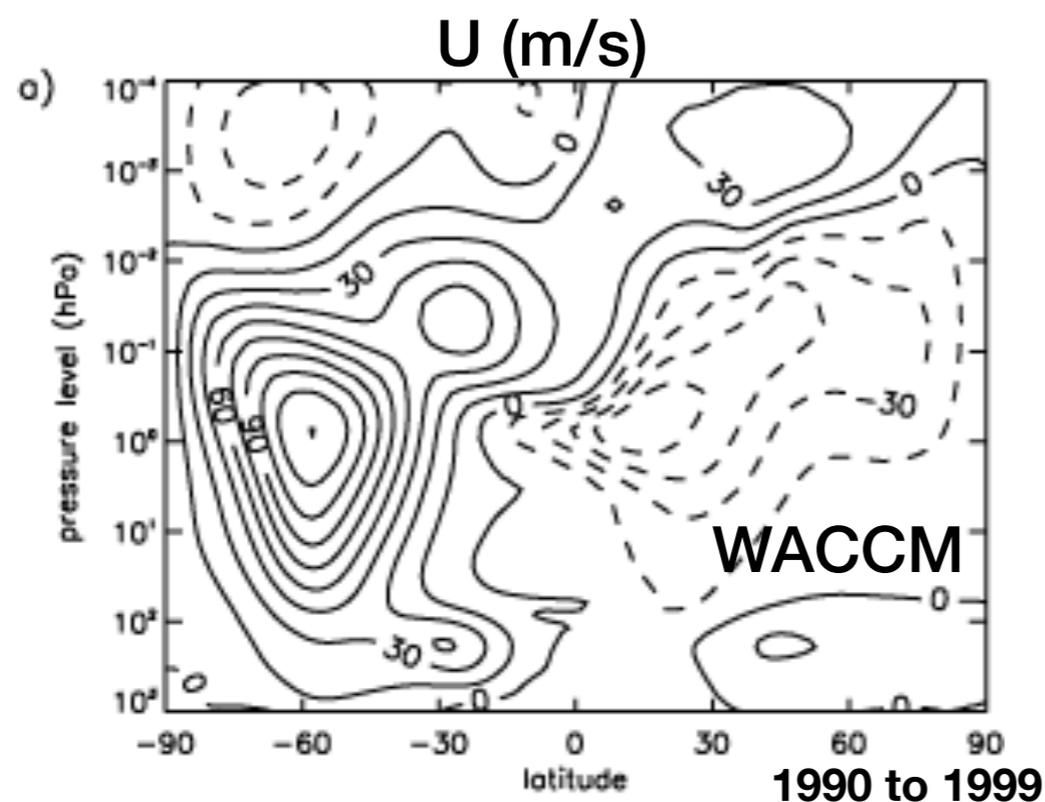


WACCM

Whole Atmosphere
Community Climate Model



Present day July zonal wind and temperature



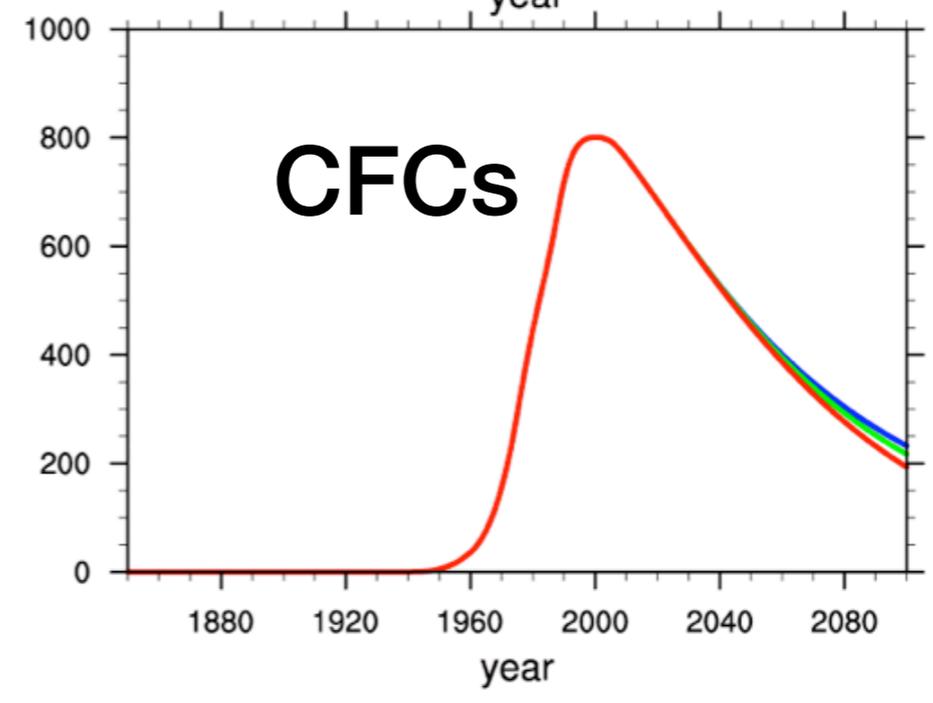
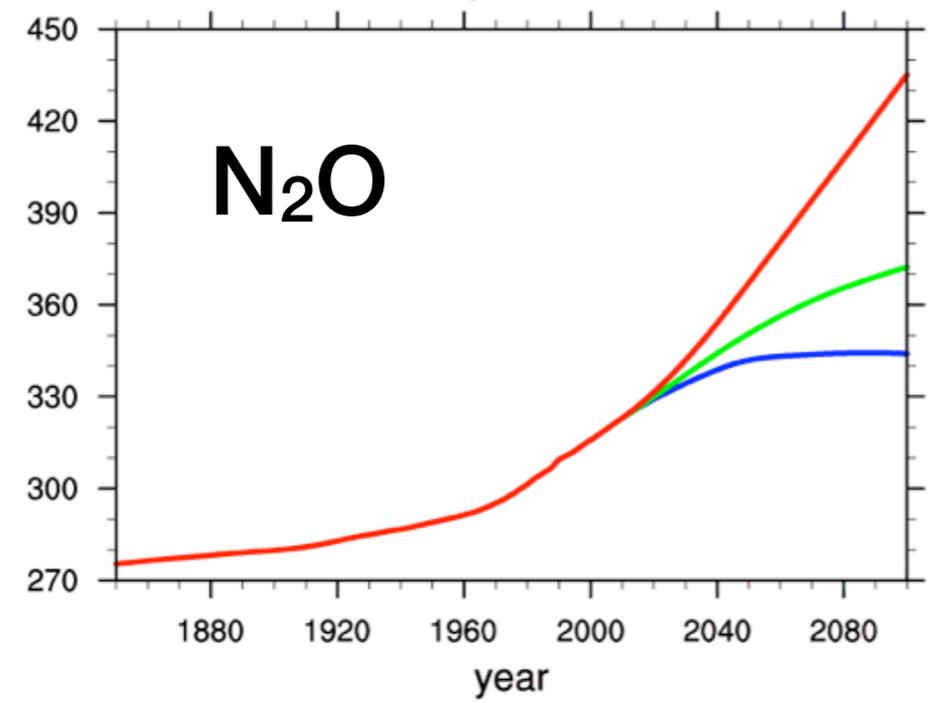
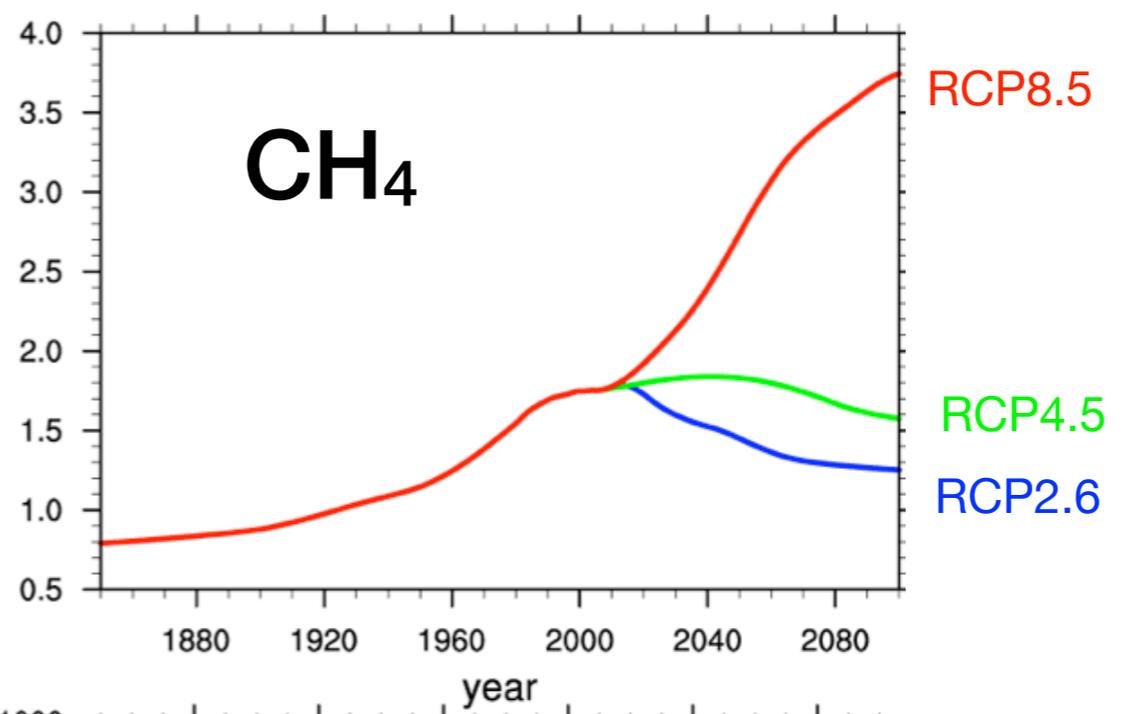
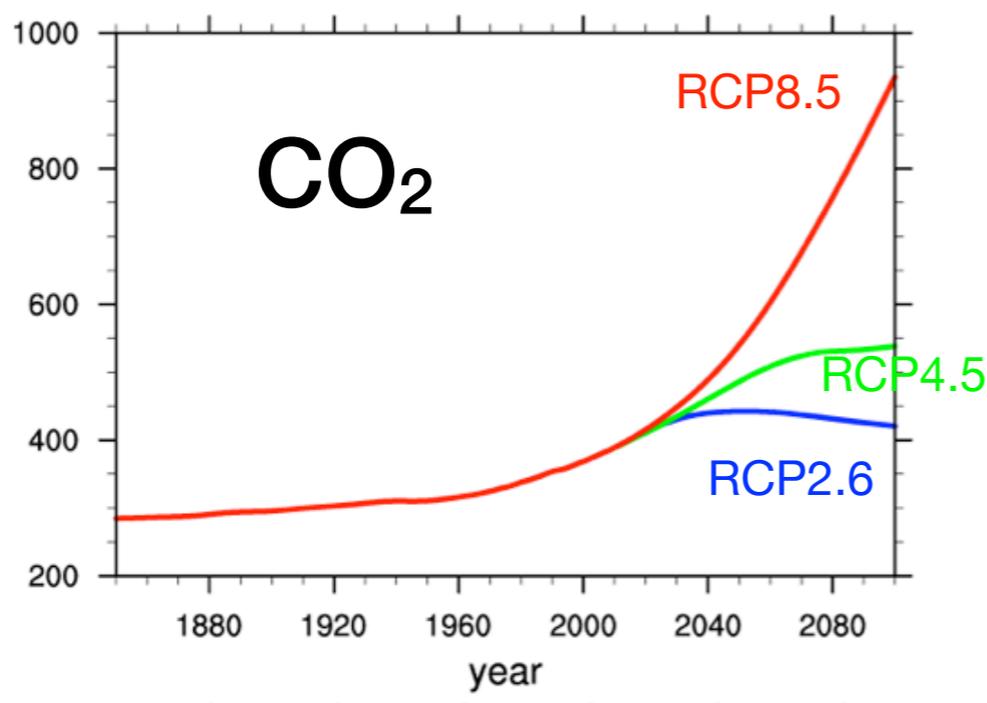


Coupled simulations for IPCC CMIP5

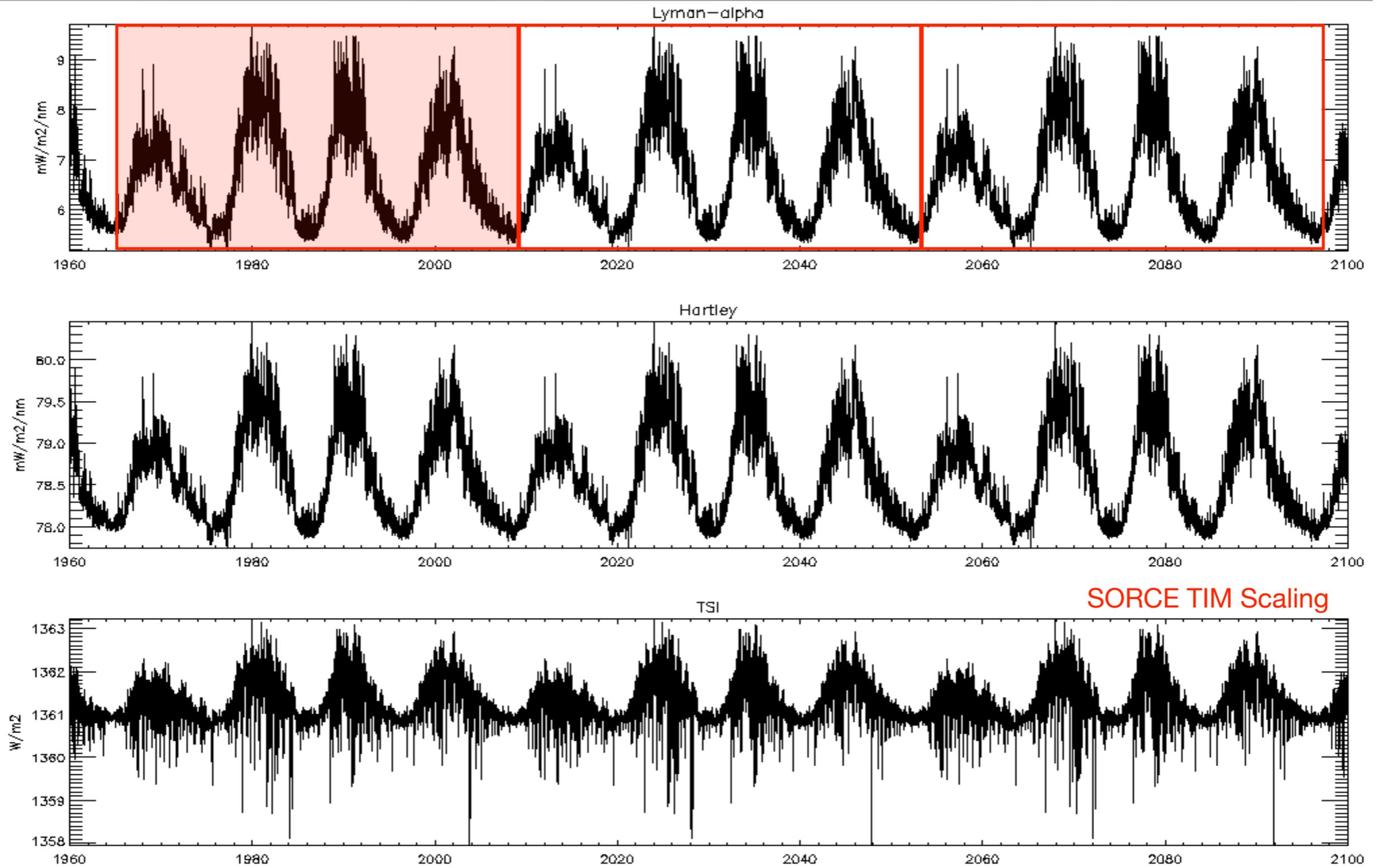
- Pre-industrial 'timeslice' control - perpetual 1850 conditions
- Transient simulations:
 - Ensemble of 1955-2005 simulations with observed forcing: GHG/ODS, solar daily spectral irradiance, volcanic sulphate heating. Here look at mean of 1985-2005.
 - 2005-2100 under Representative Concentration Projections (RCPs): RCP2.6, 4.5, 8.5 are radiative forcing (W/m^2) in 2100. Here look at mean of 2080-2099 and RCP2.6 & RCP8.5.

Transient boundary concentrations (ppmv)

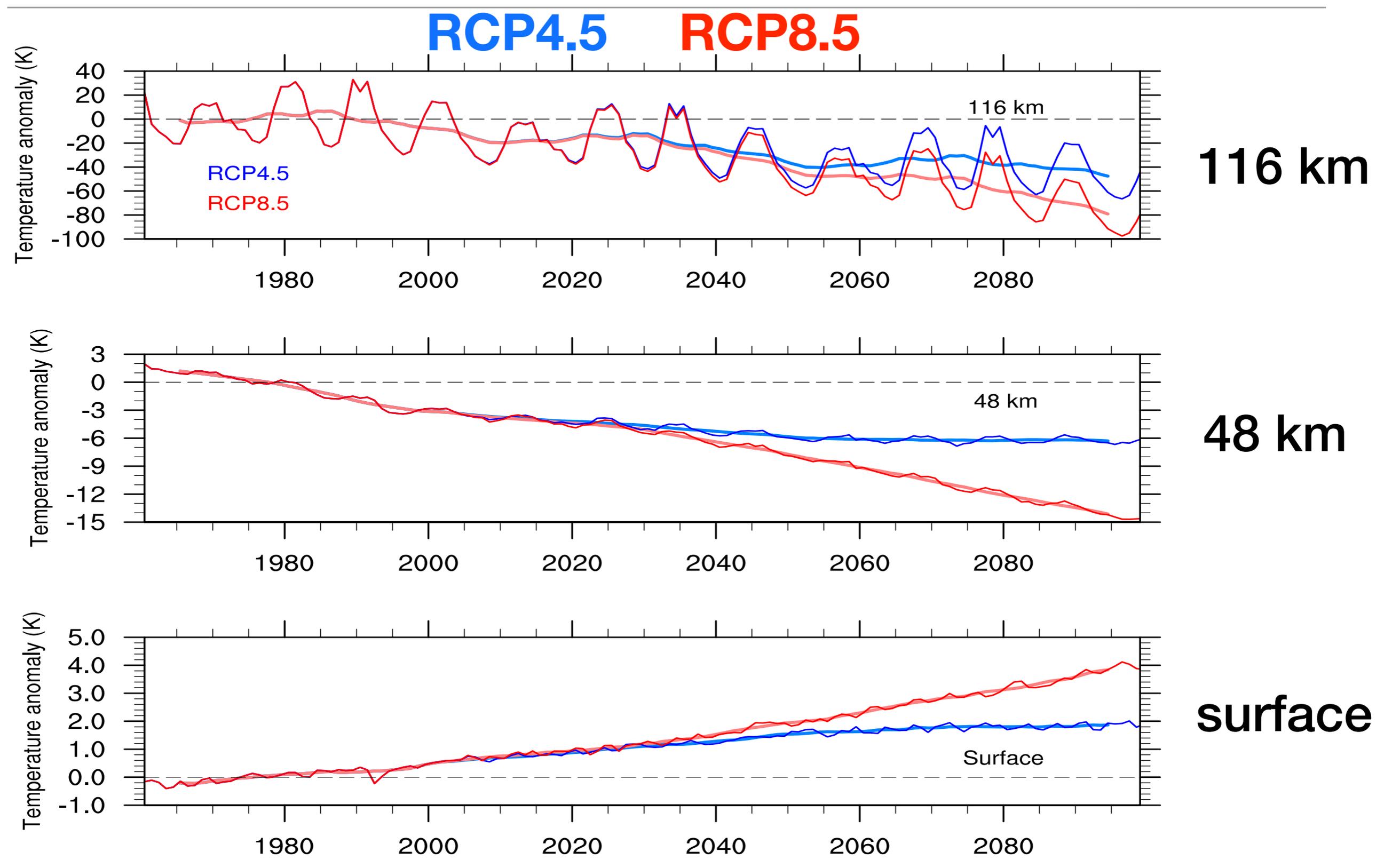
Representative Concentration Projections (RCPs)
2.6, 4.5, 8.5 are radiative forcing (W/m^2) in 2100.



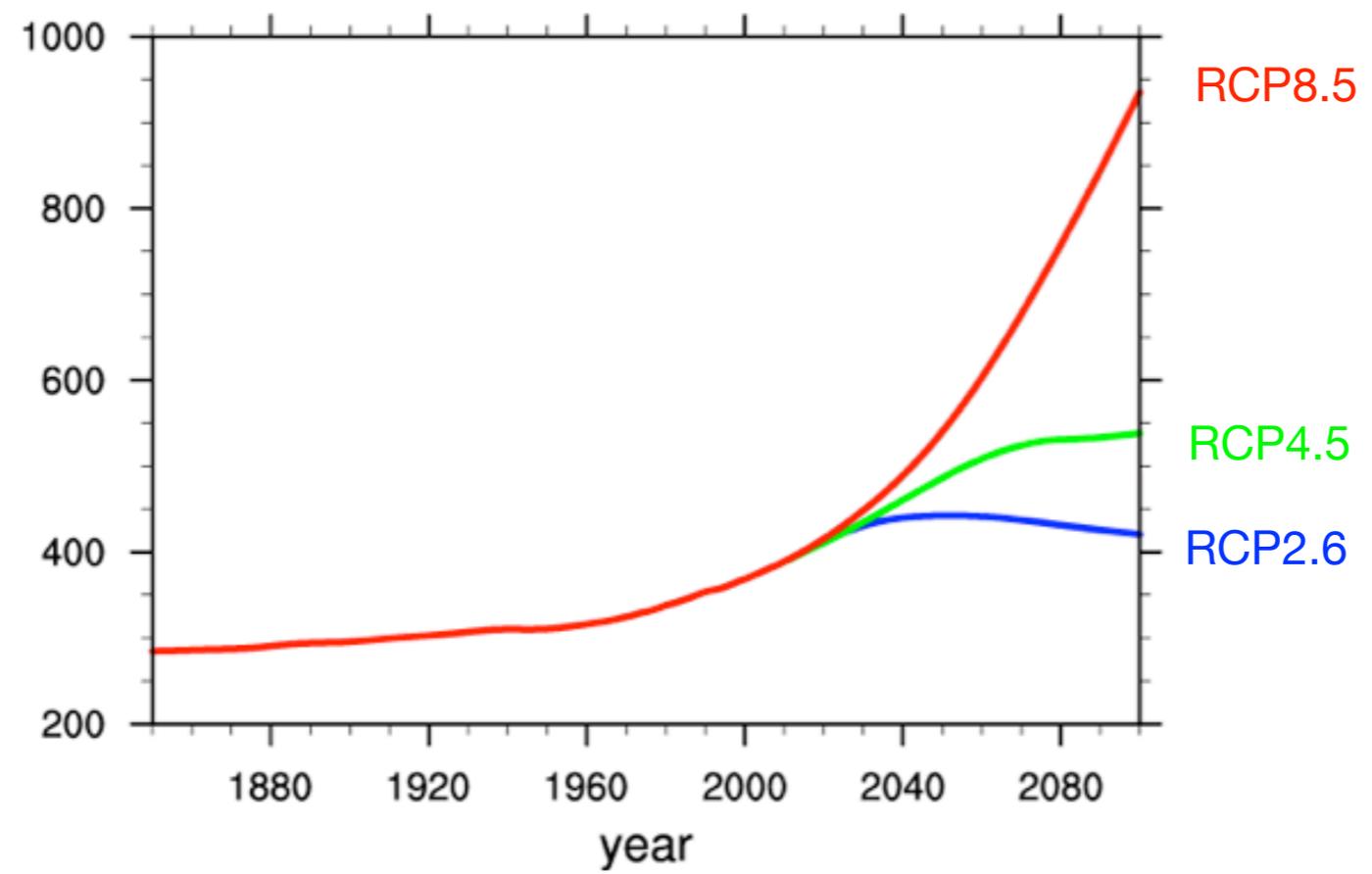
Solar forcing (repeating 44-year period from 1965-2008)



Global mean temperature anomalies relative to 1961-1990



Carbon Dioxide





NCAR

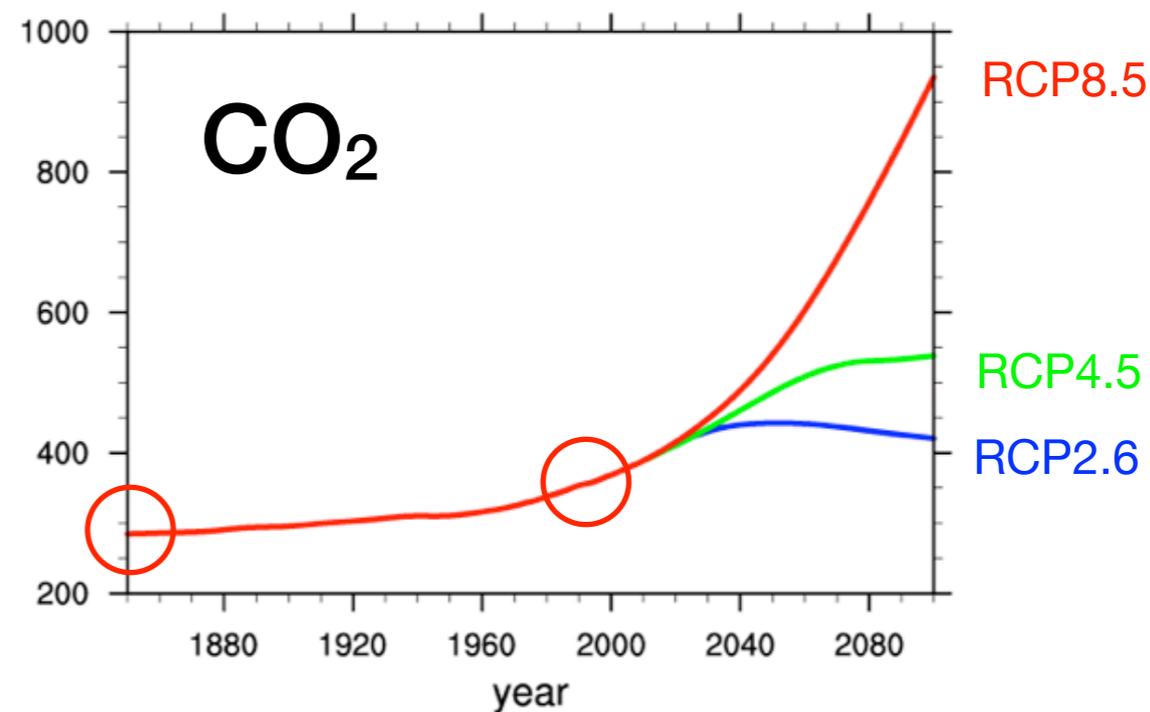
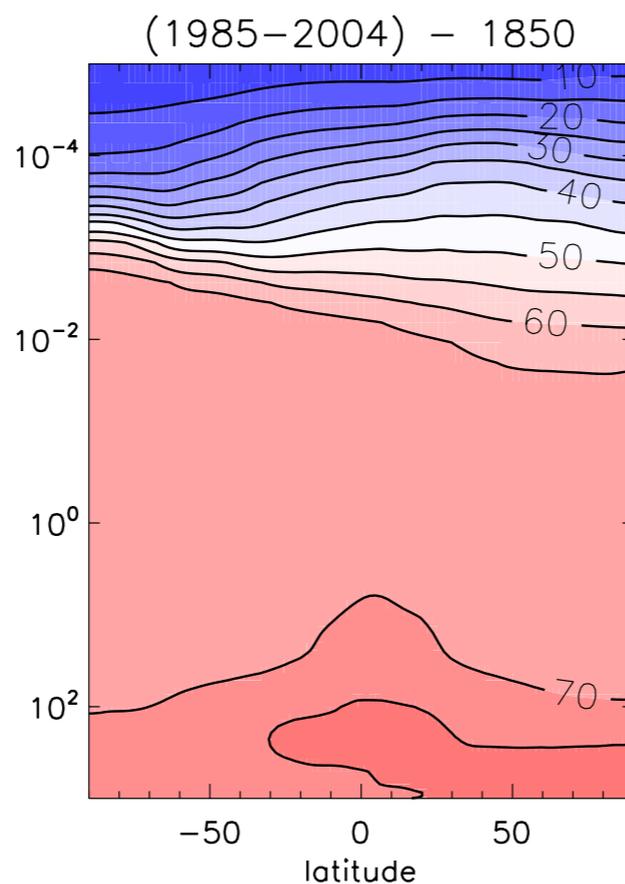
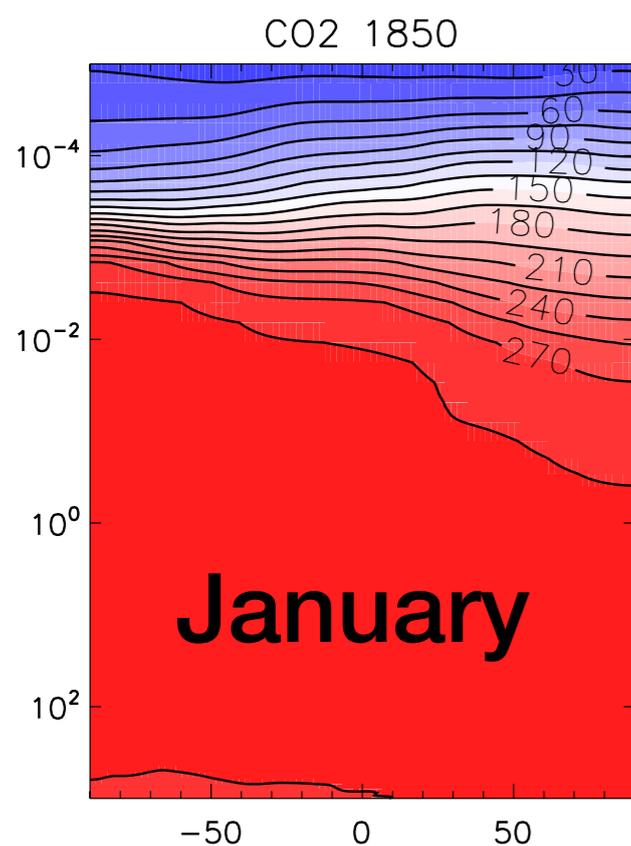


WACCM

Whole Atmosphere
Community Climate Model



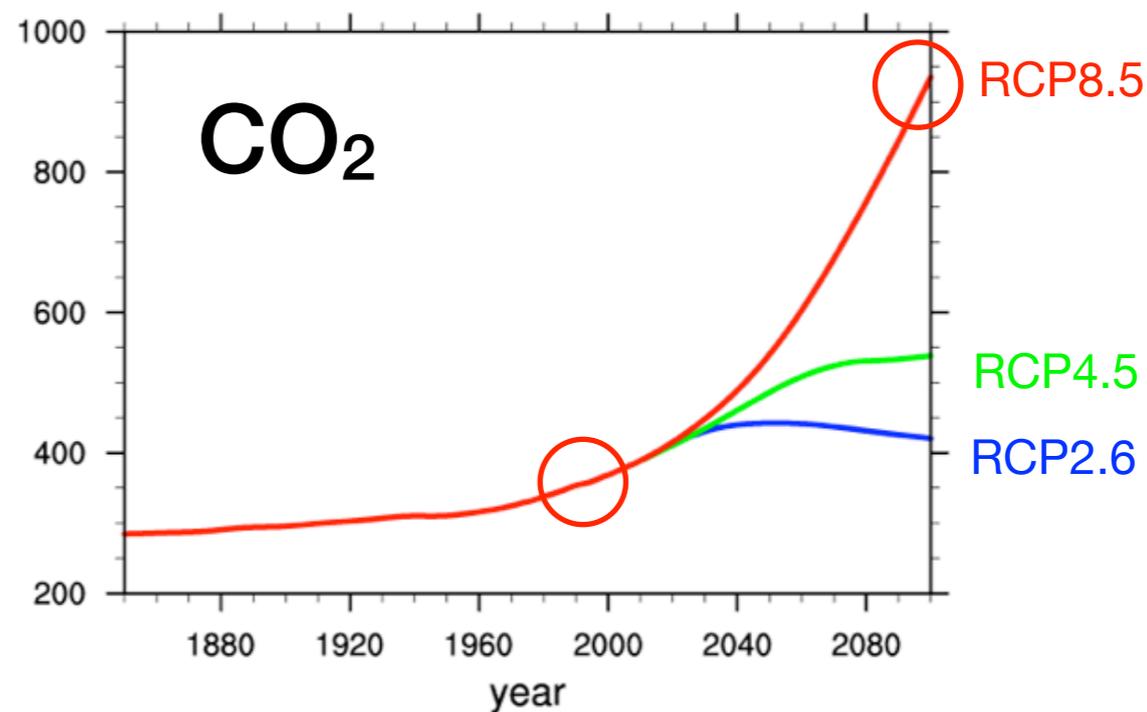
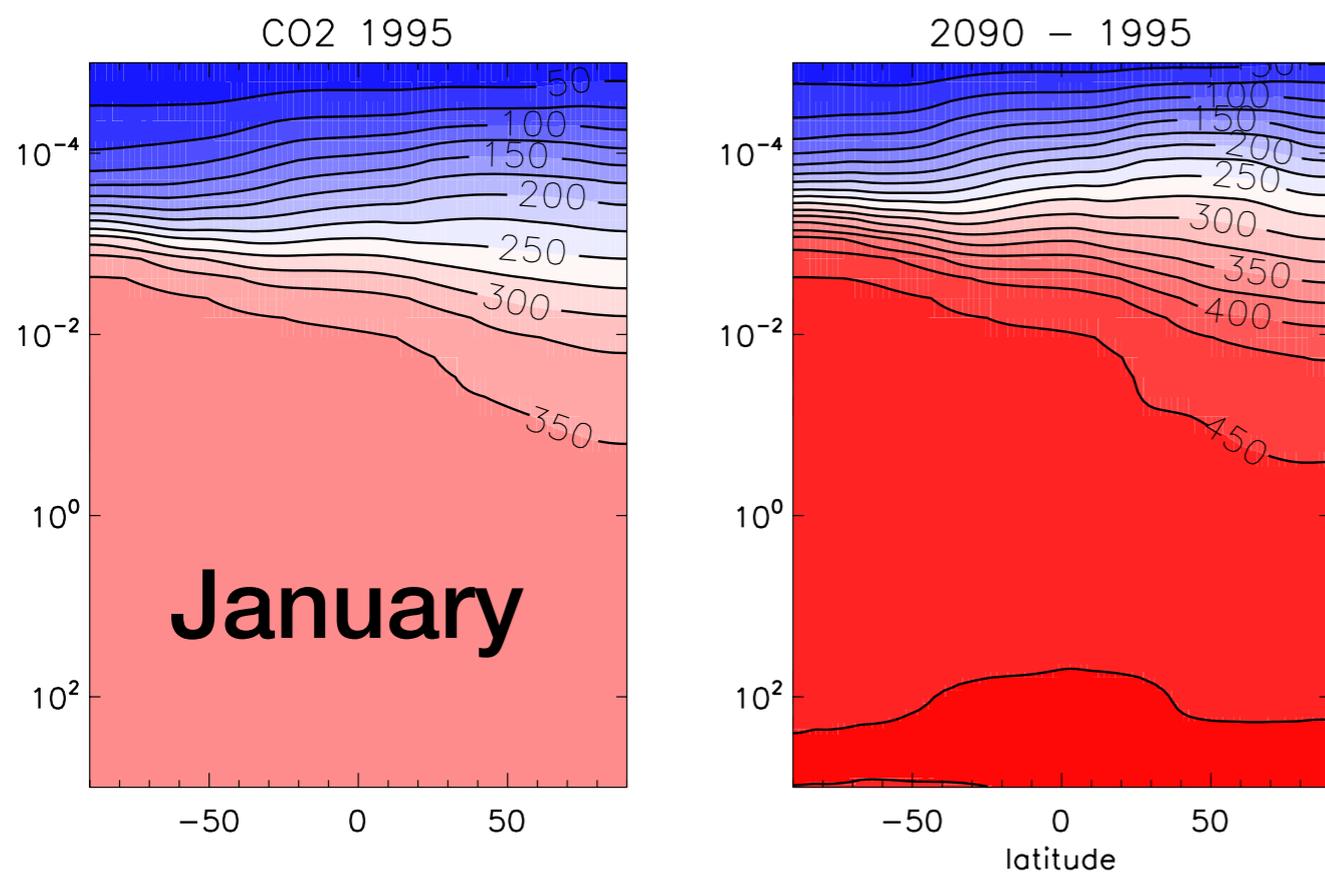
Carbon Dioxide 1850 to present



Increase of >60 ppmv up to mesopause

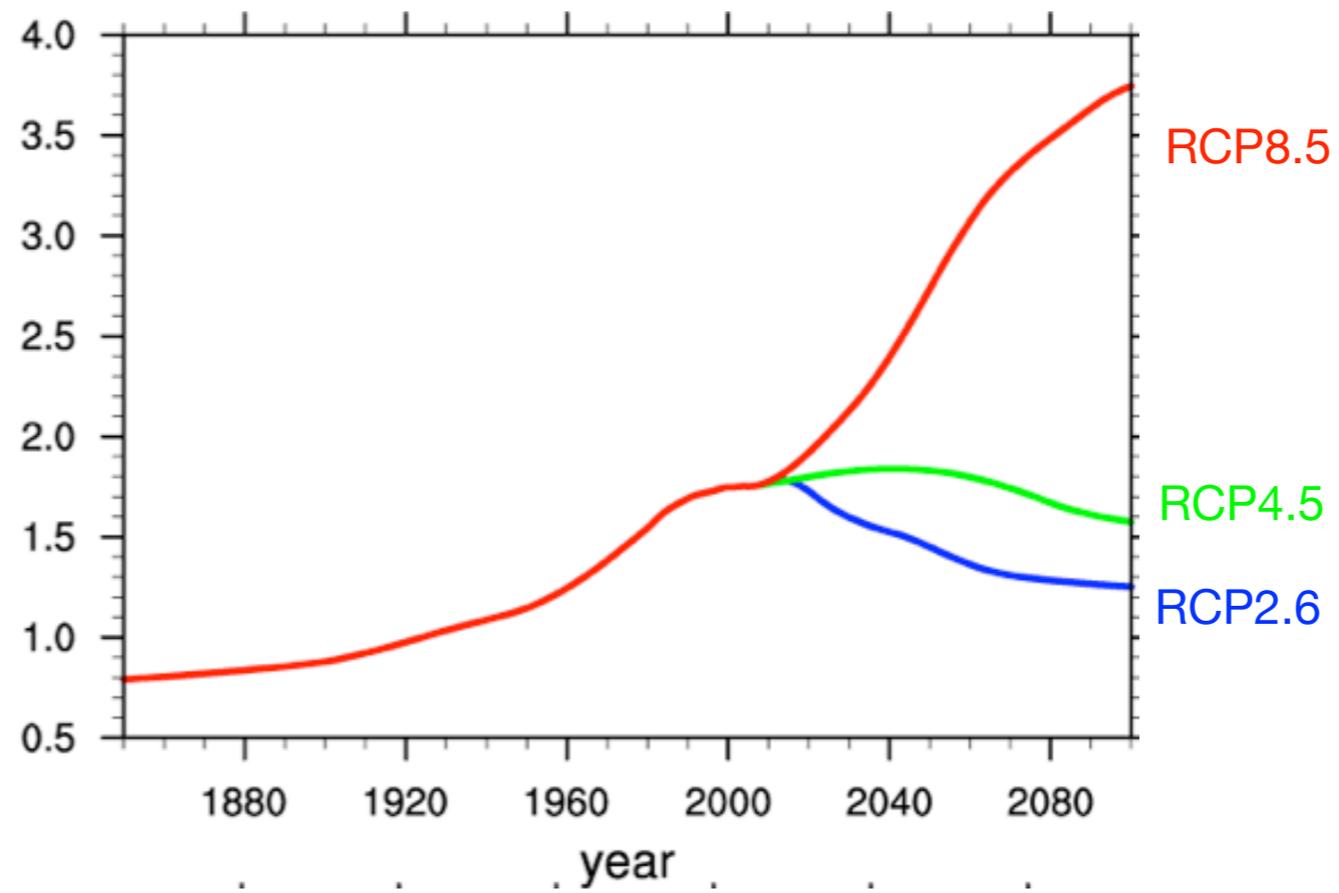


Carbon Dioxide present to 2100 (RCP8.5)



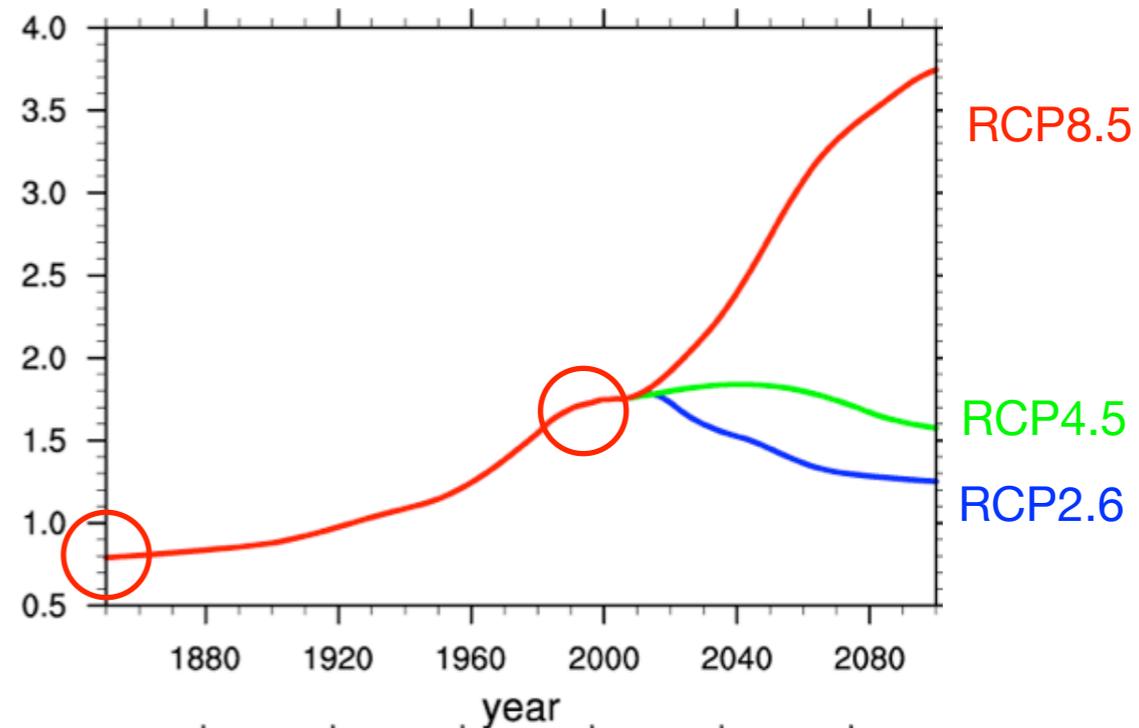
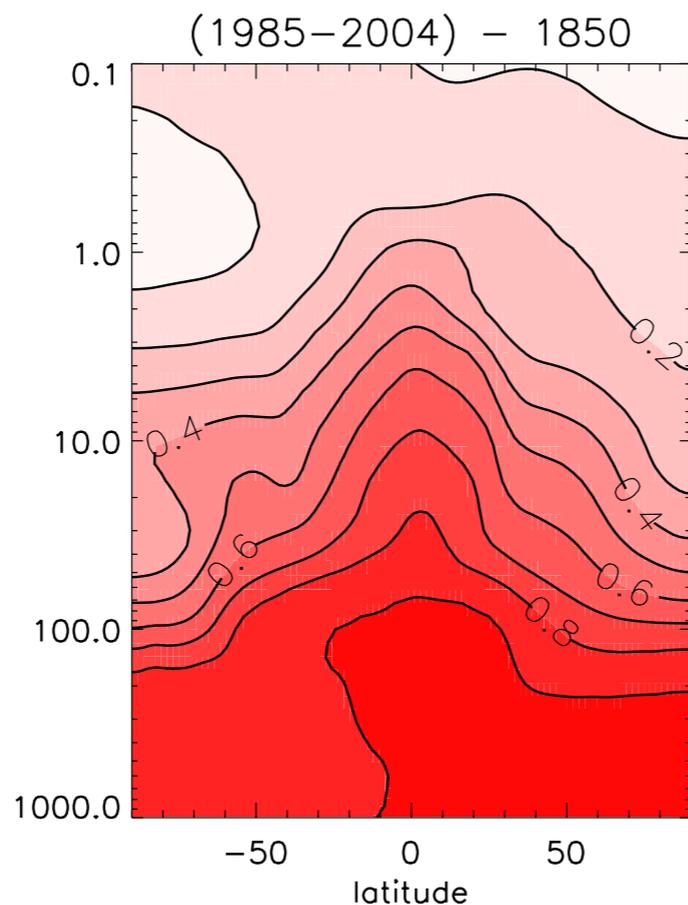
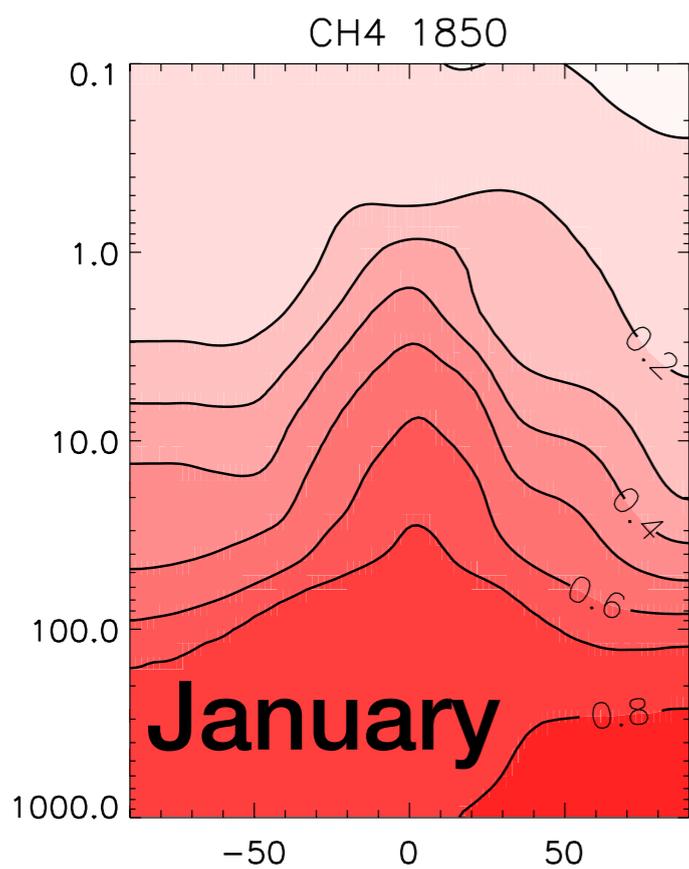
Increase of >400 ppmv up to mesopause

Methane





Methane 1850 to present



Approximate doubling in the troposphere



NCAR

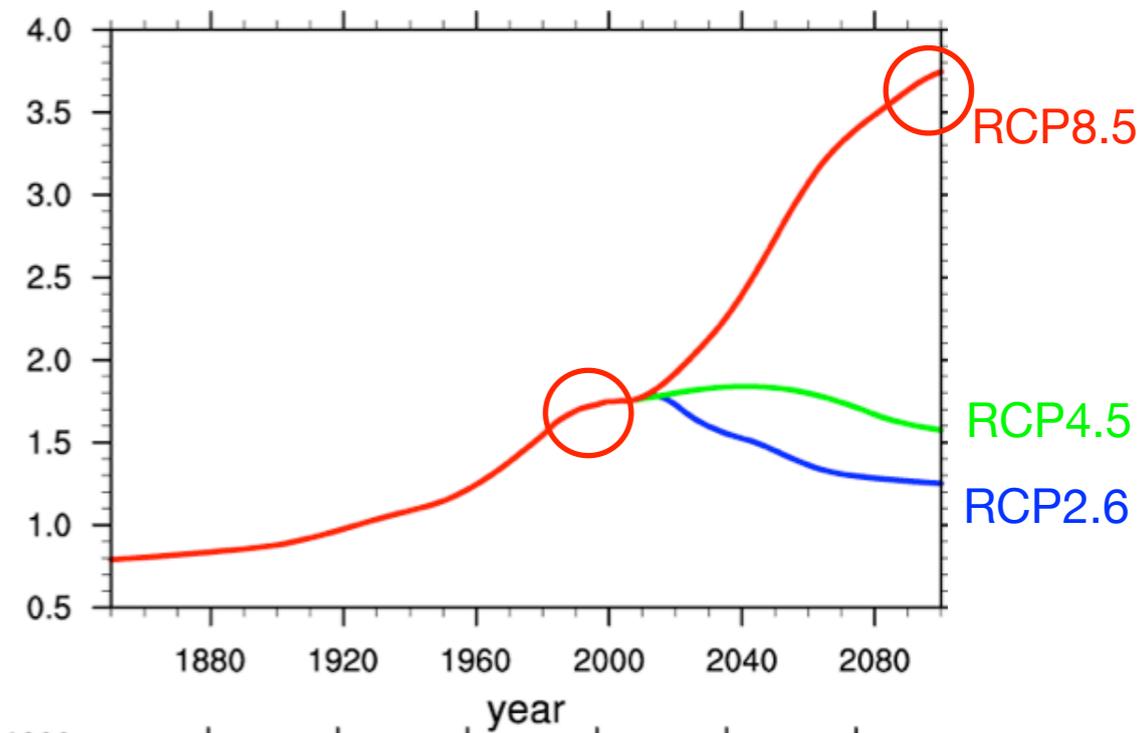
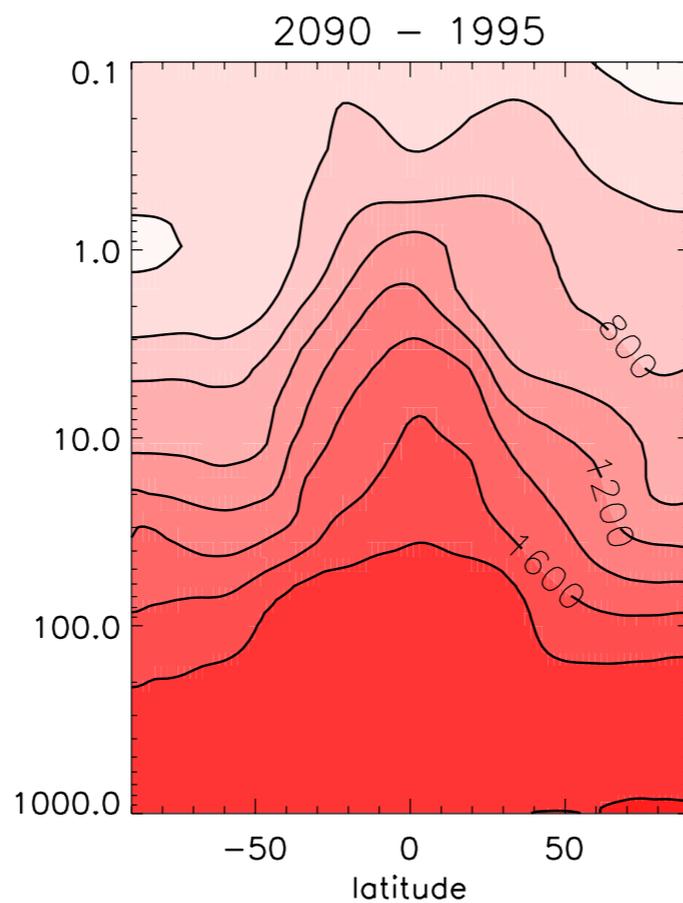
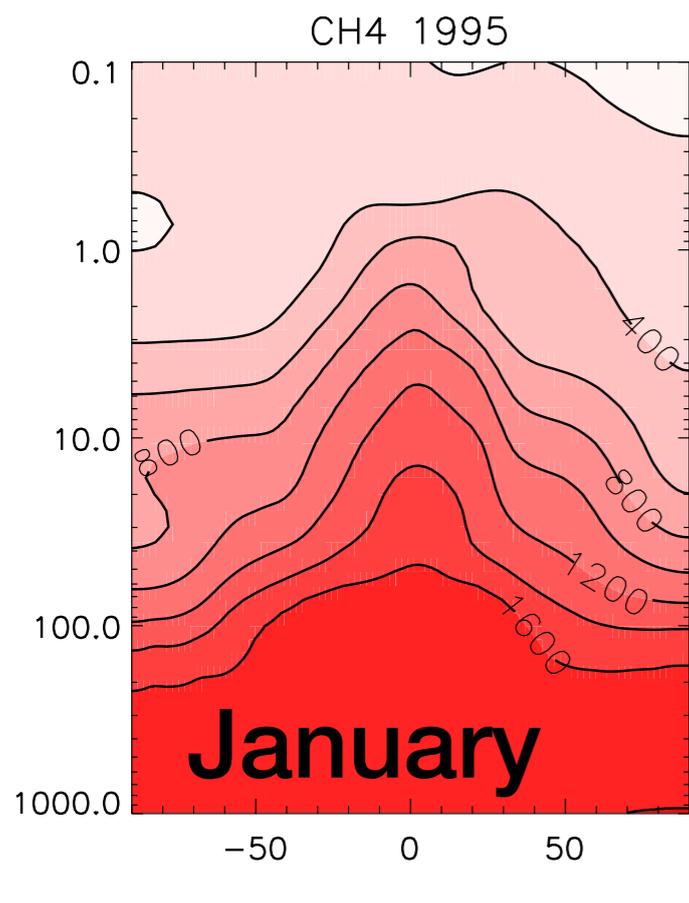


WACCM

Whole Atmosphere
Community Climate Model



Methane present to 2100 (RCP8.5)



Additional doubling by 2100



NCAR

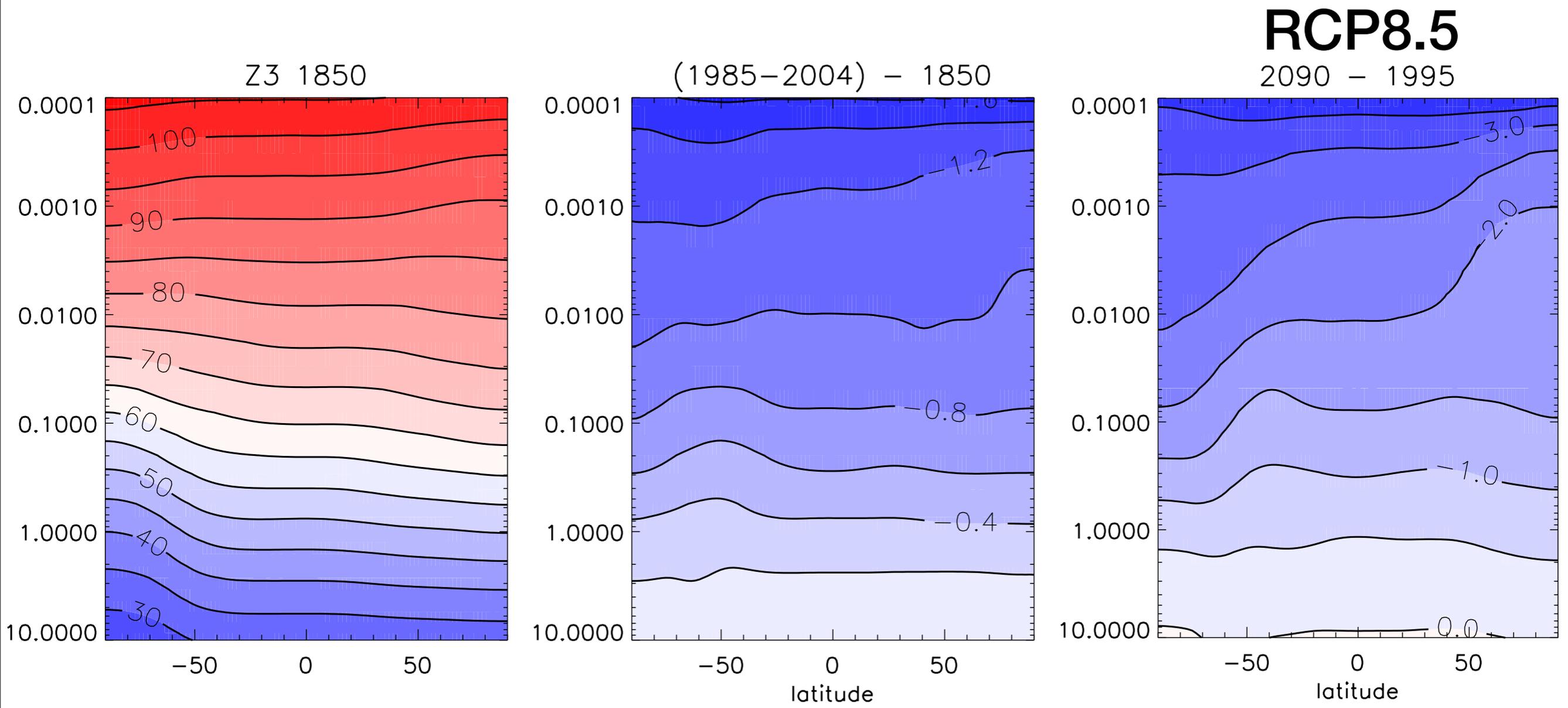


WACCM

Whole Atmosphere
Community Climate Model



Geopotential height (km) trends in July

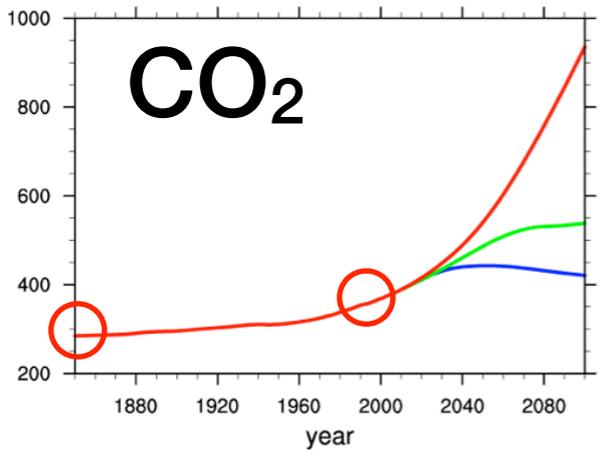


At PMC heights the atmosphere has shrunk >1 km and could shrink >2 km by 2100 under RCP8.5

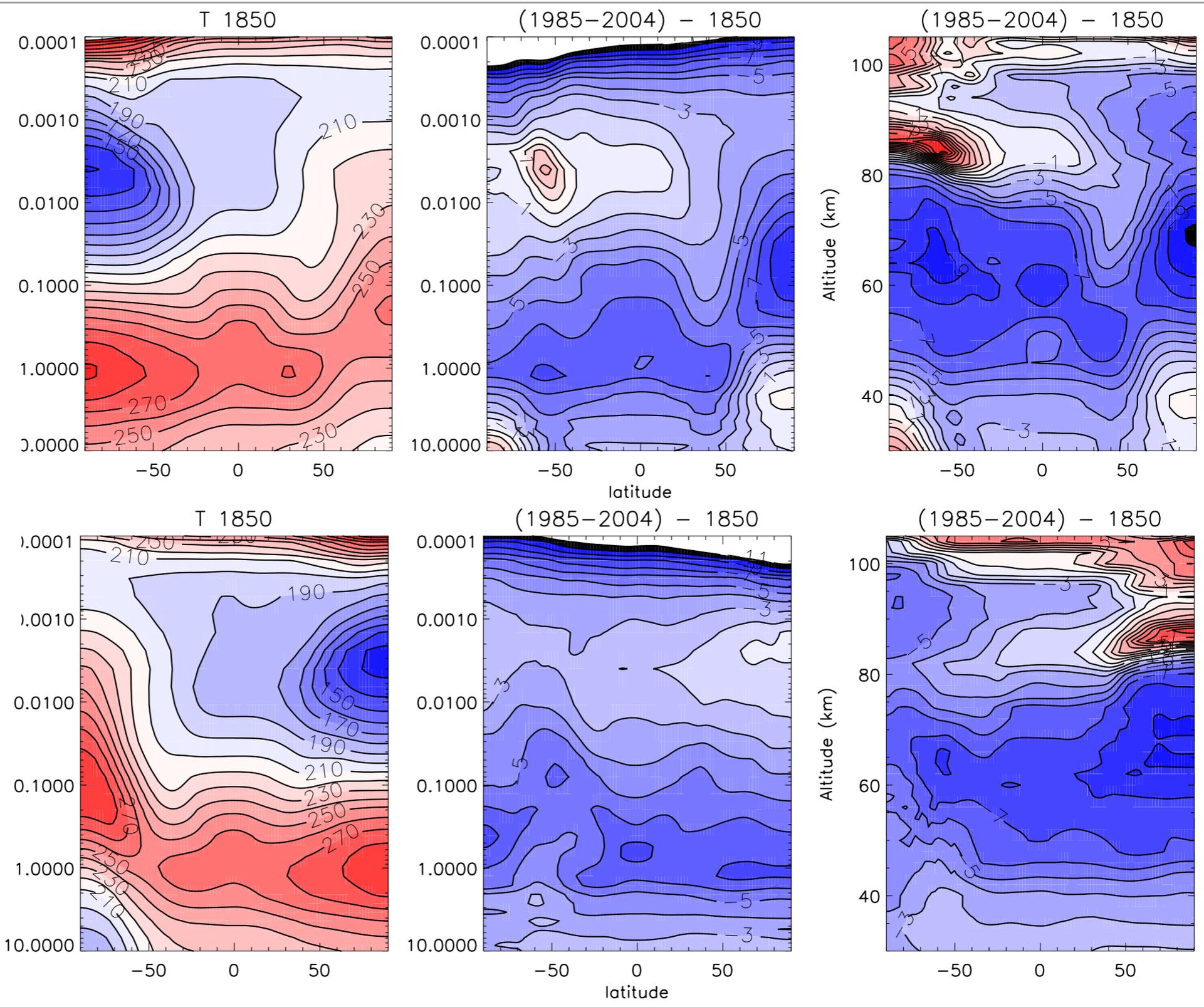
Calculated changes depend on coordinate system used.

Temperature 1850 to present

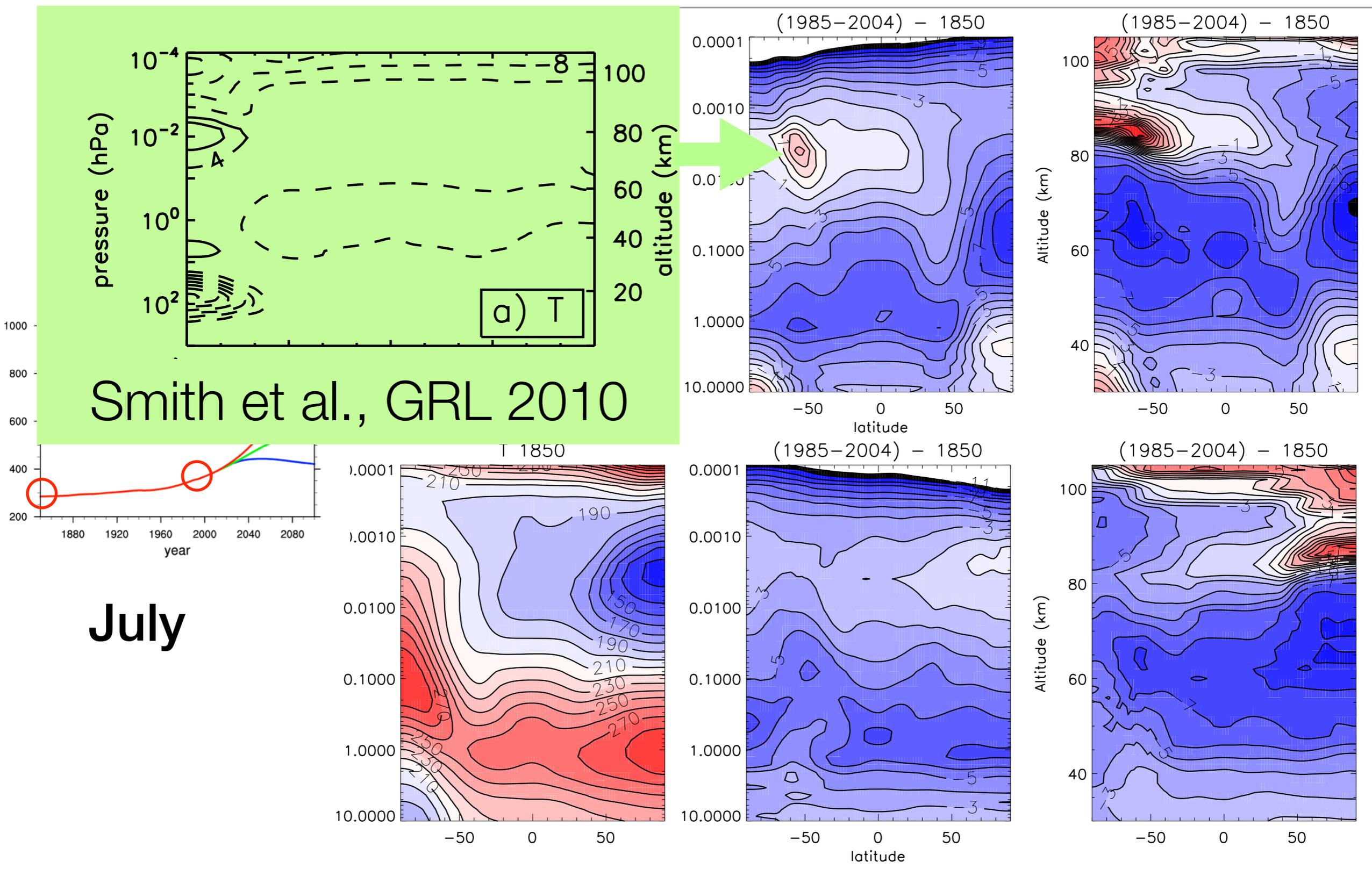
January



July



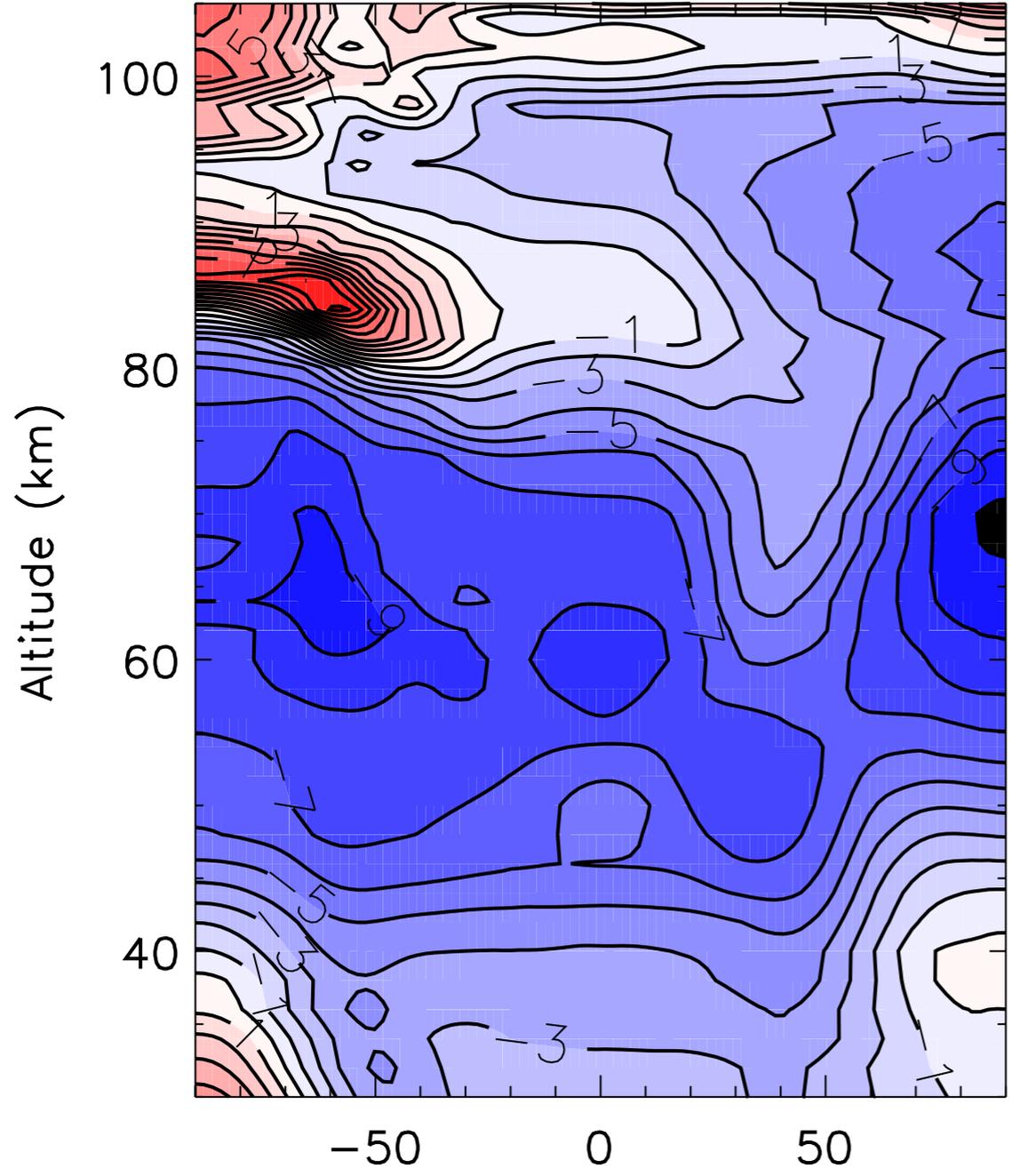
Temperature 1850 to present



Temperature 1850 to present

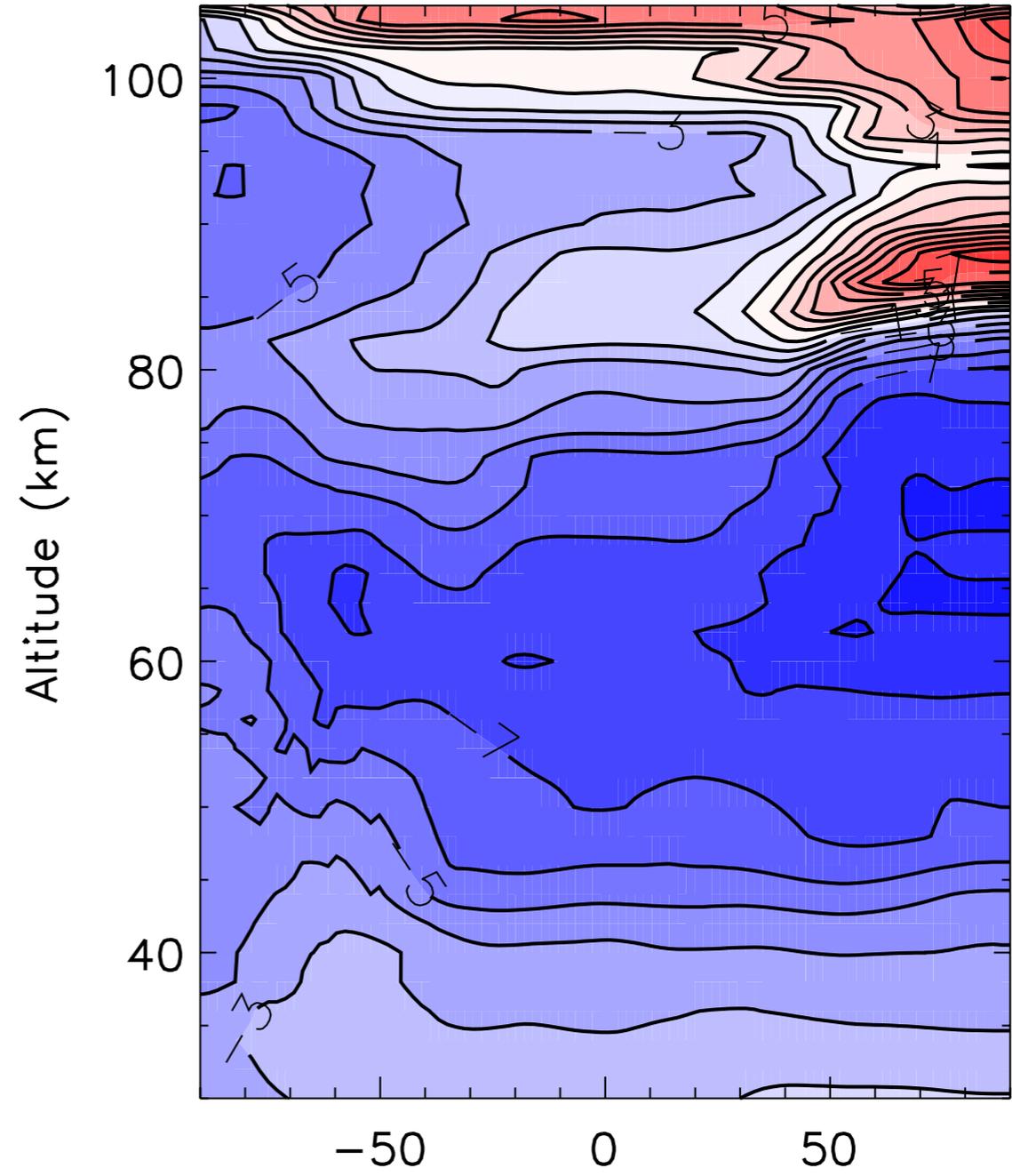
January

(1985-2004) - 1850



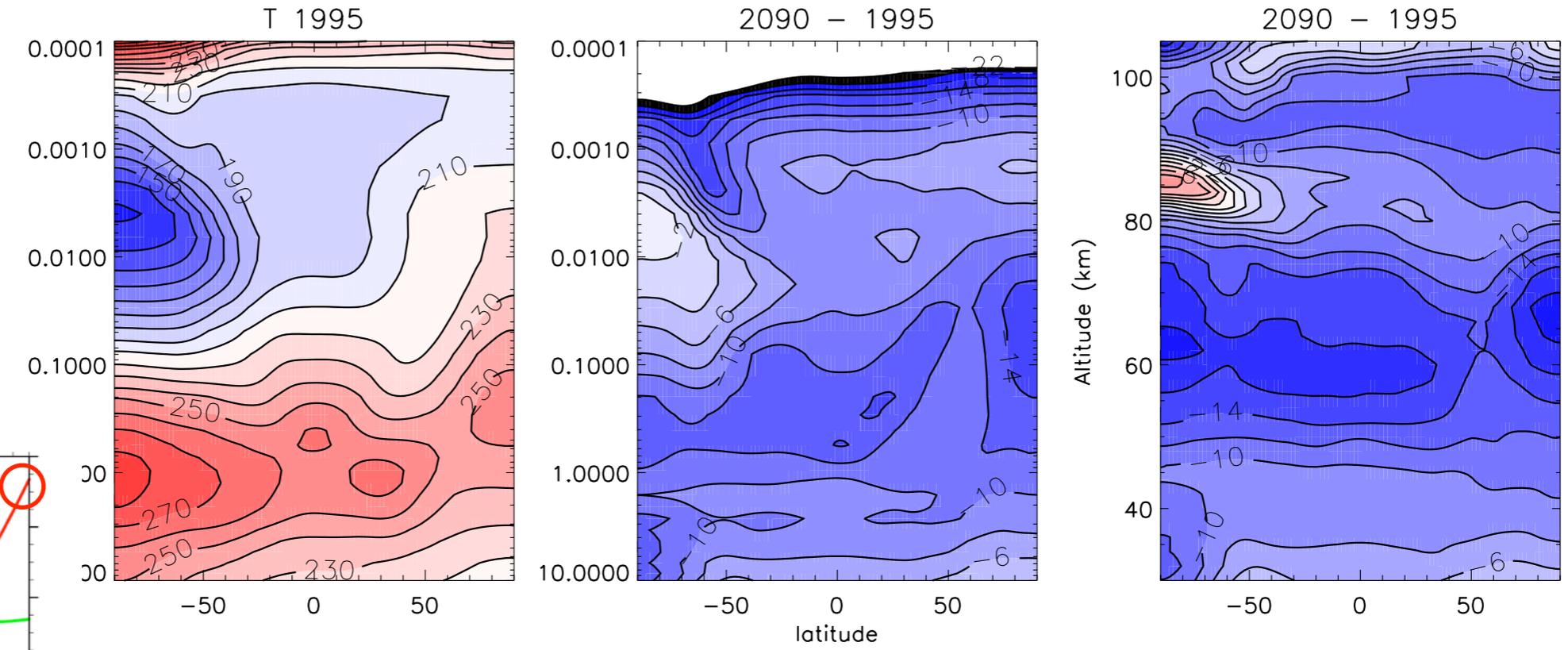
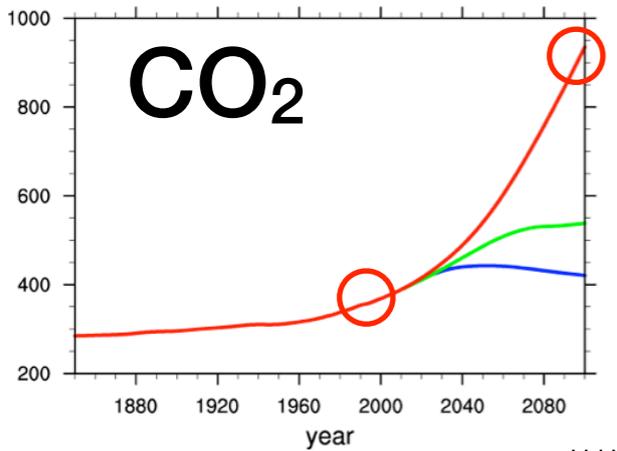
July

(1985-2004) - 1850

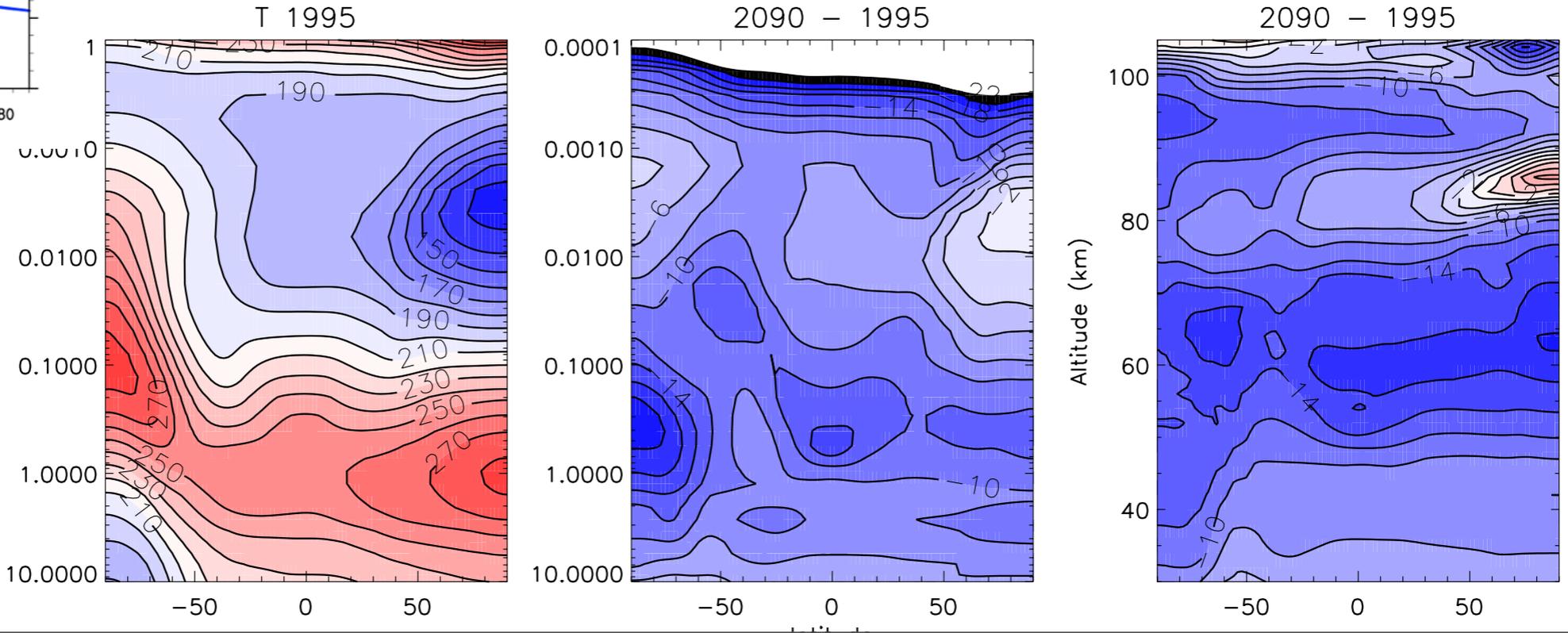


Temperature present to 2100 (RCP8.5)

January



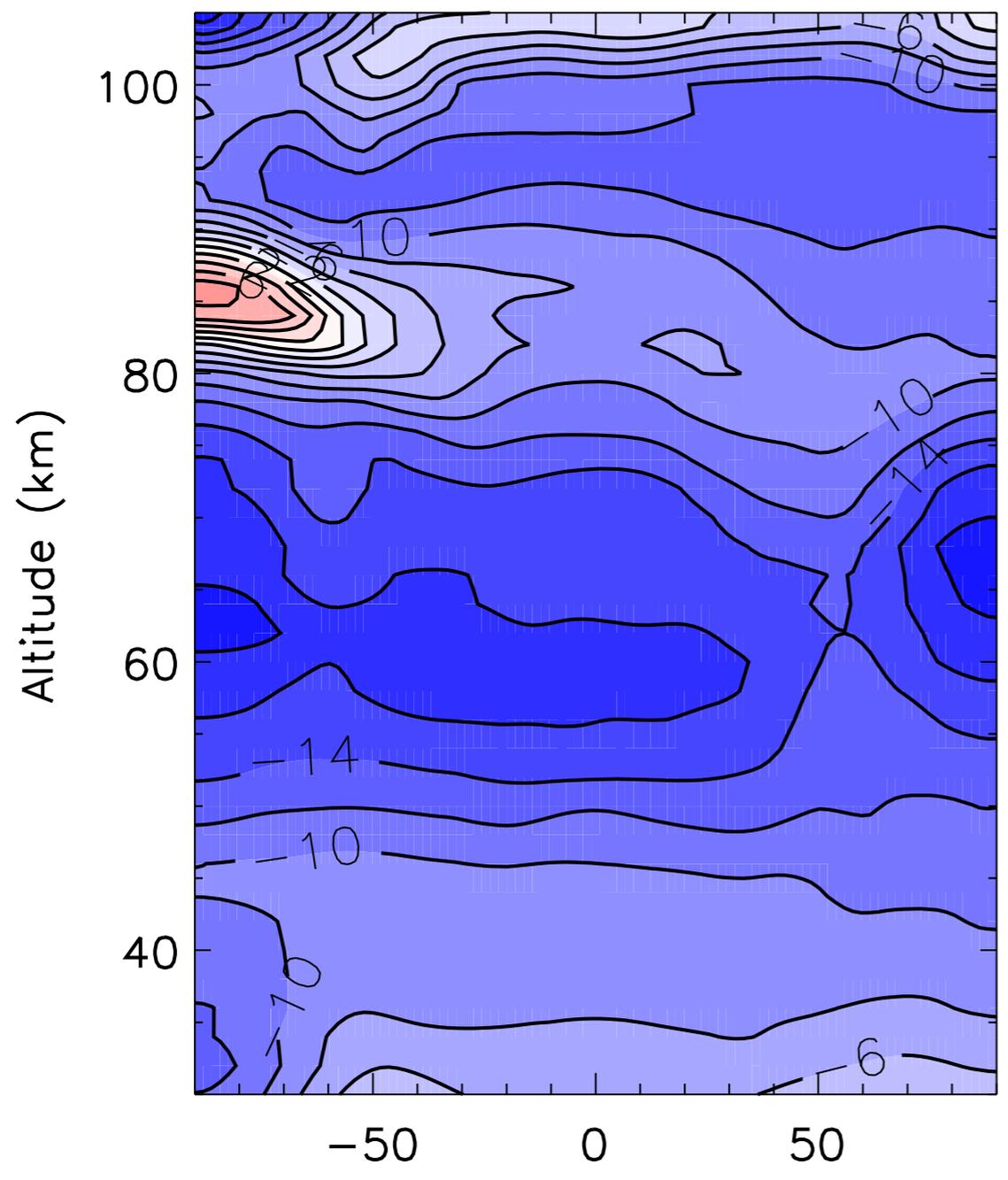
July



Temperature present to 2100 (RCP8.5)

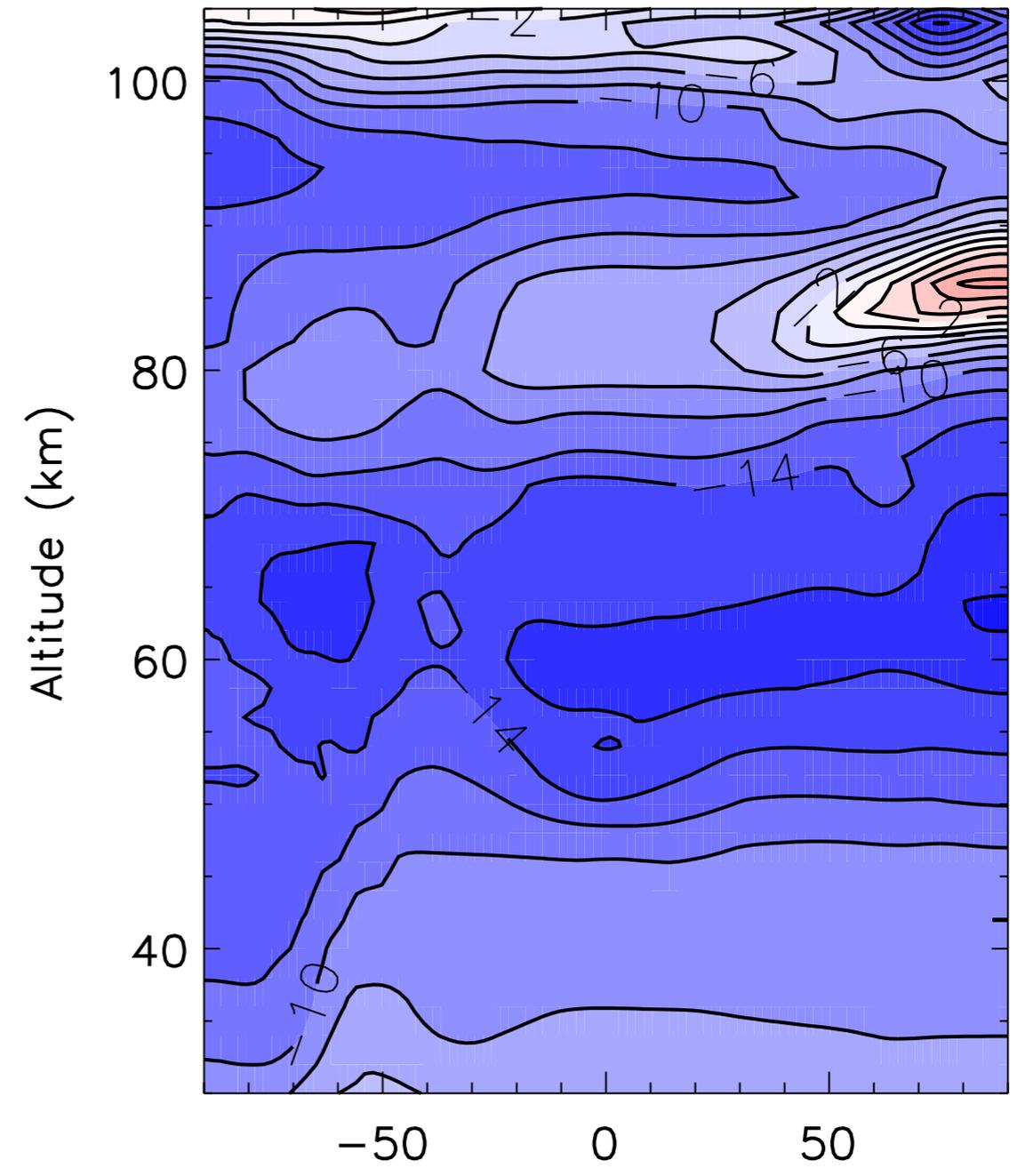
January

2090 - 1995



July

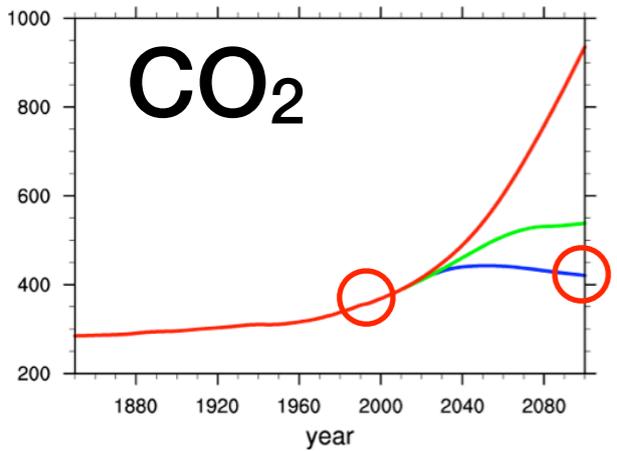
2090 - 1995



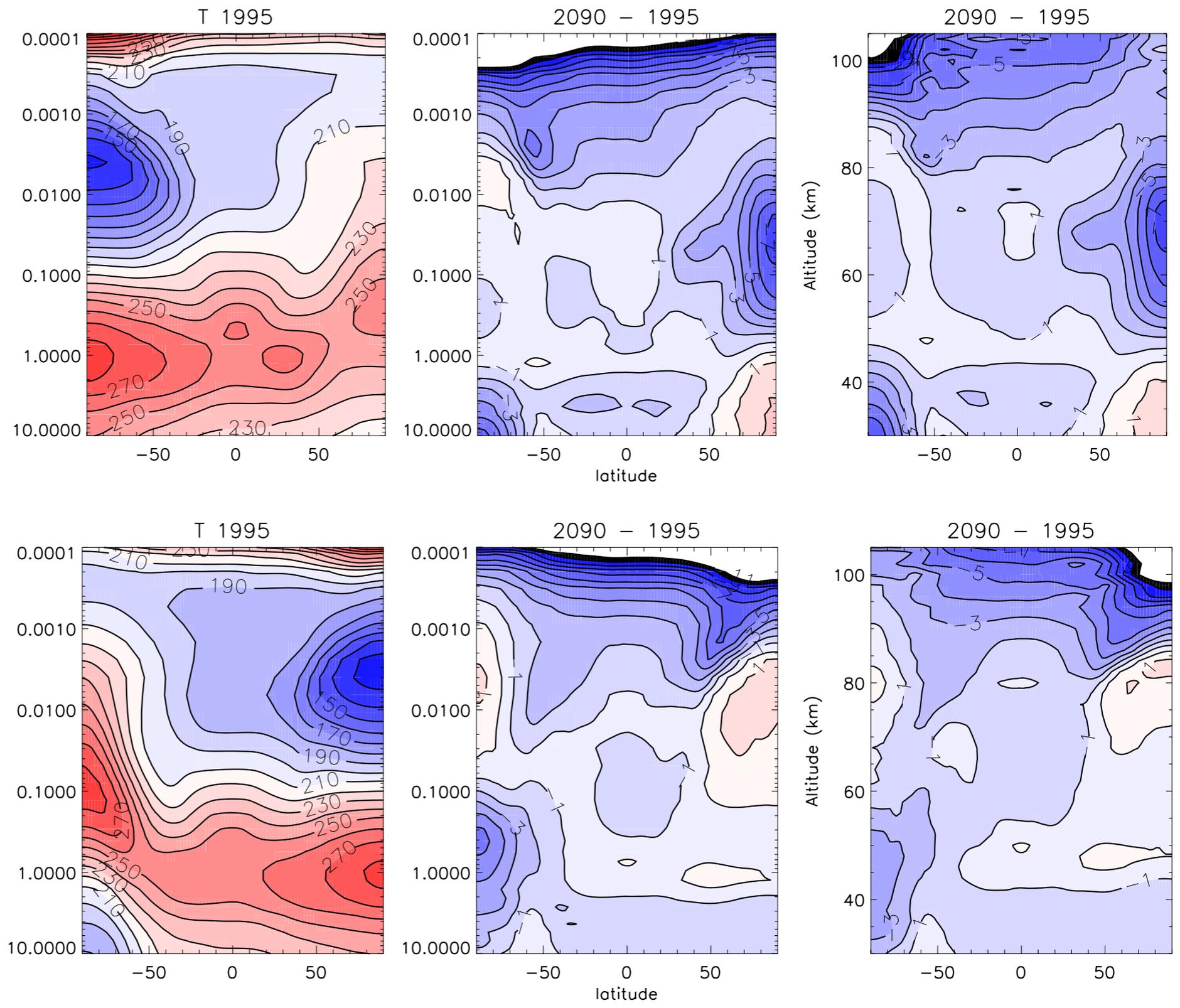


Temperature present to 2100 (RCP2.6)

January



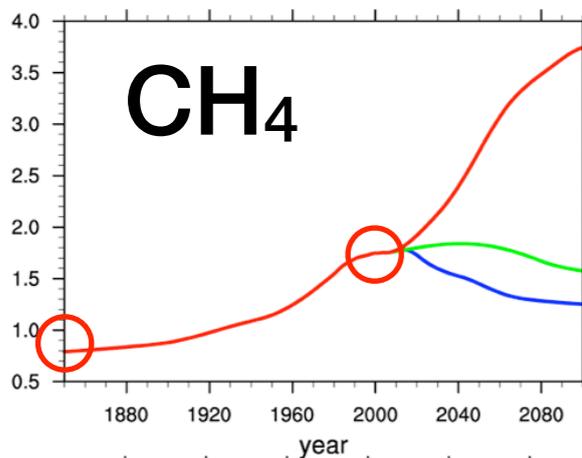
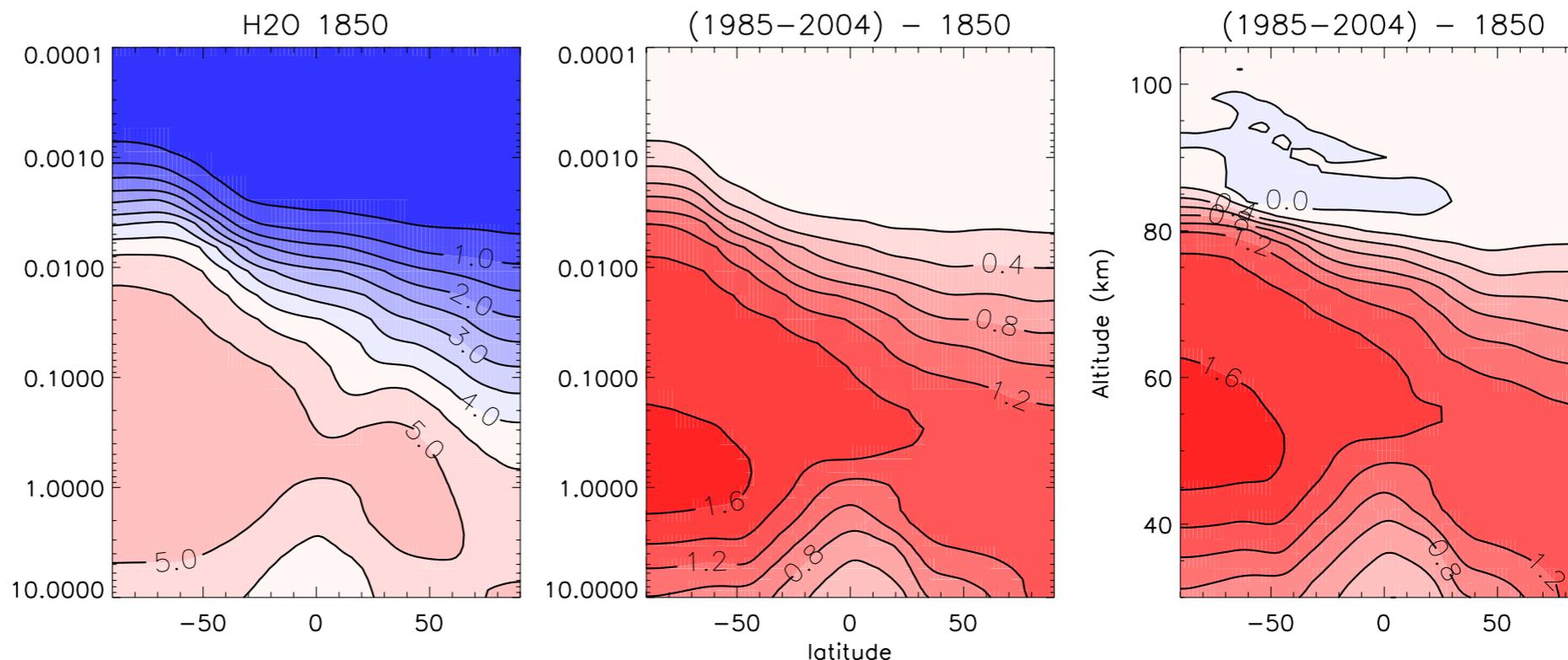
July



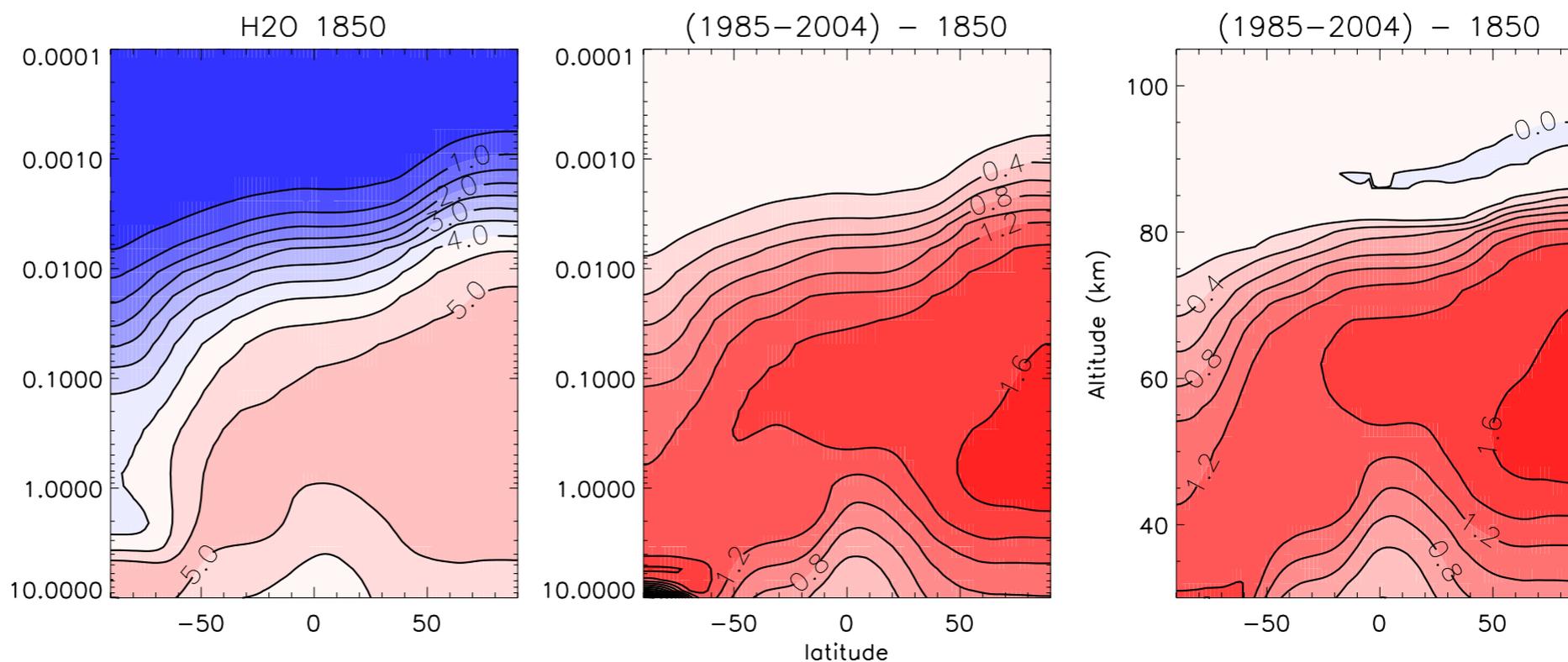


Water vapor 1850 to present

January



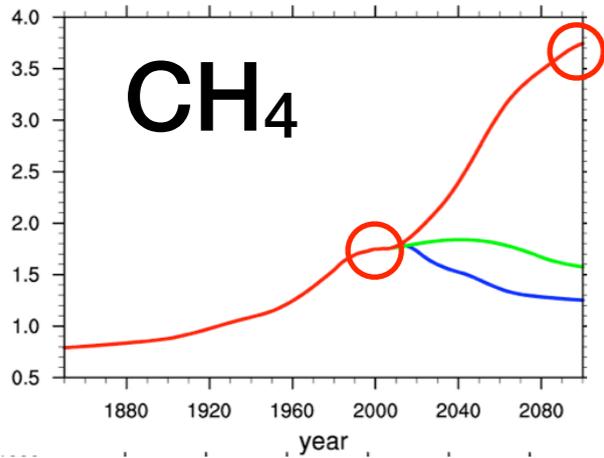
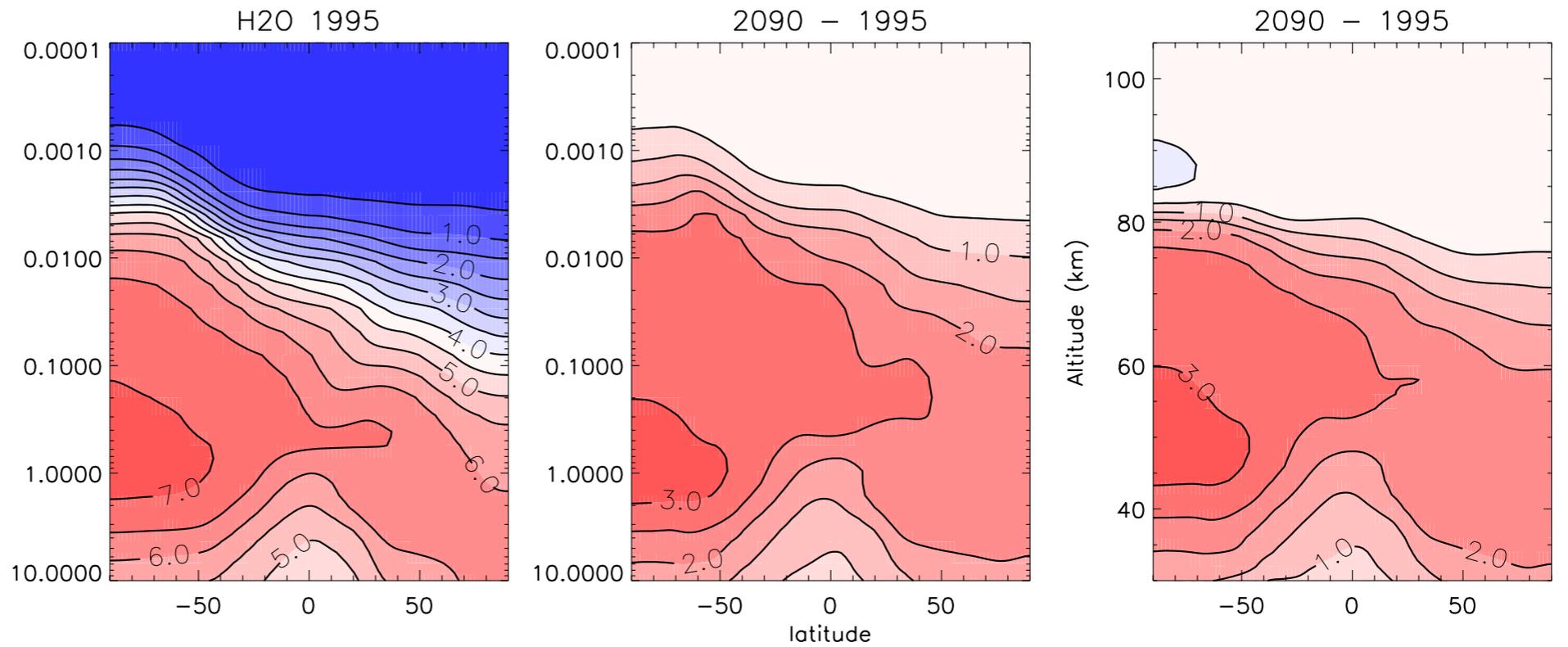
July



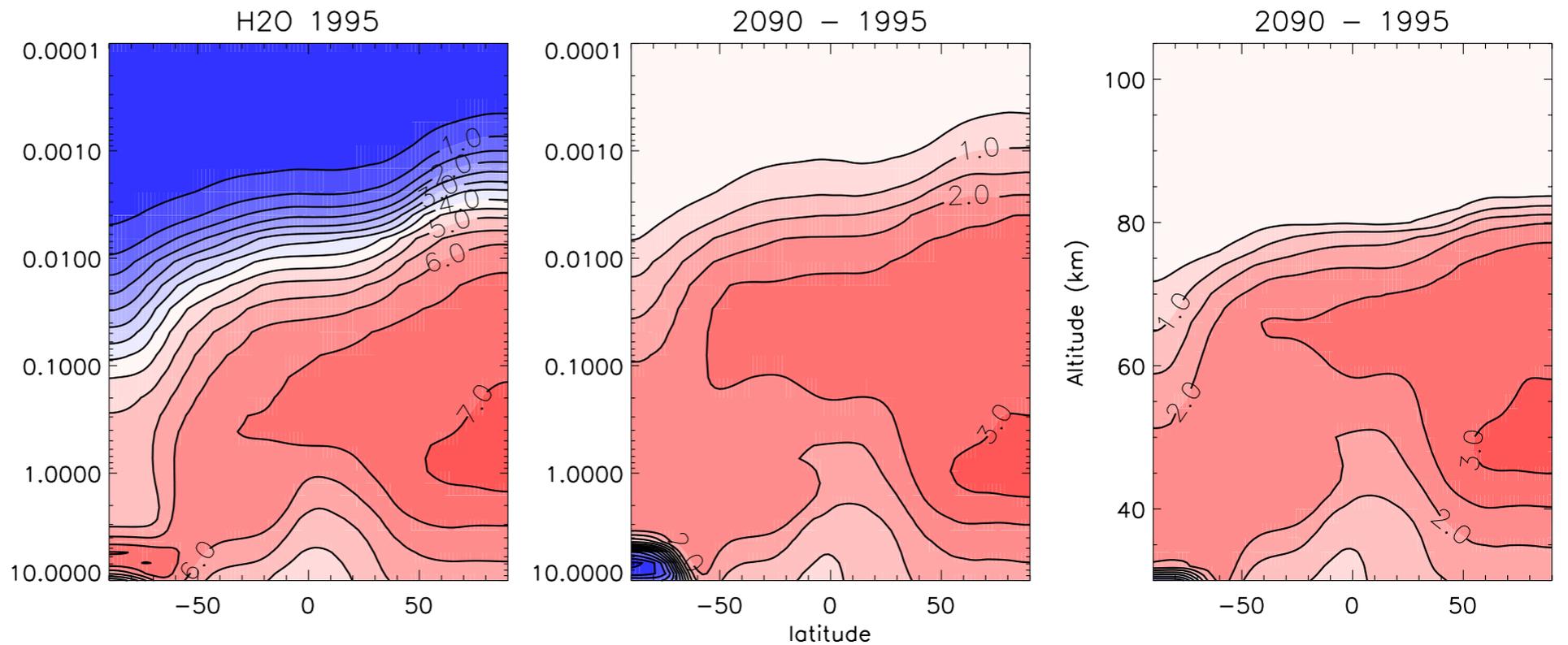


Water vapor present to 2100 (RCP8.5)

January



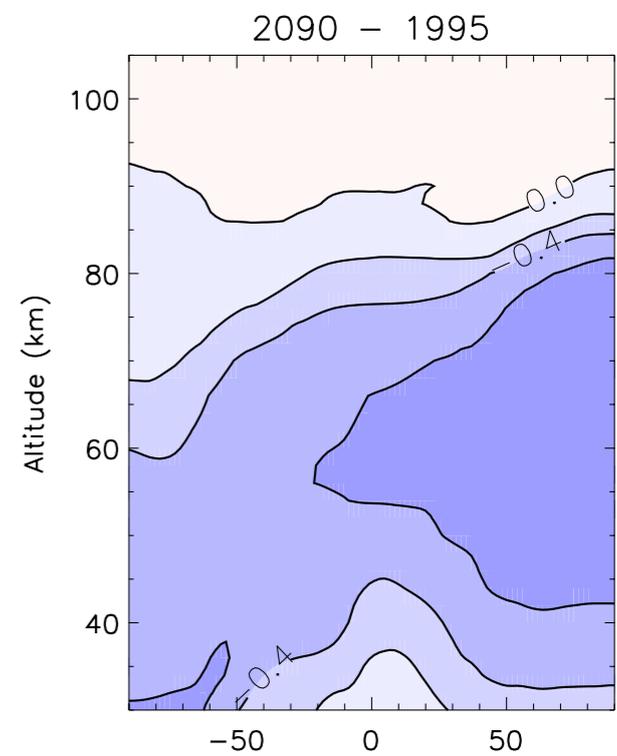
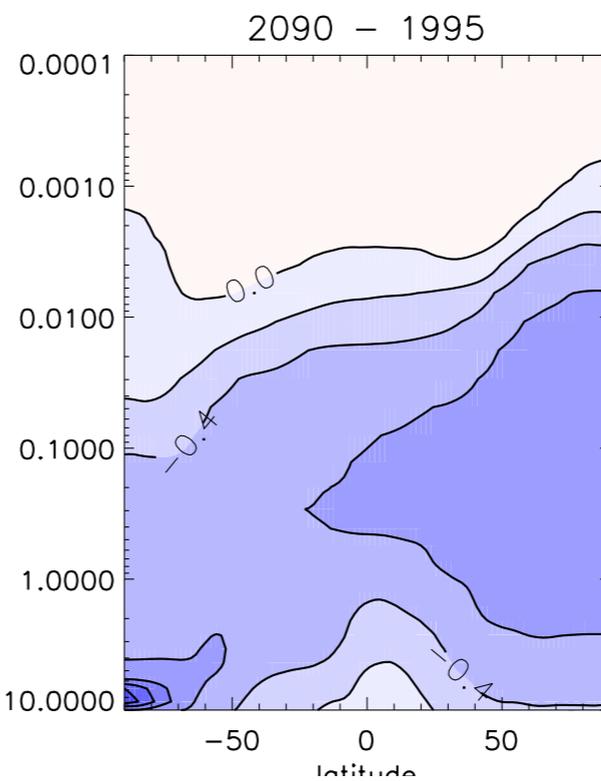
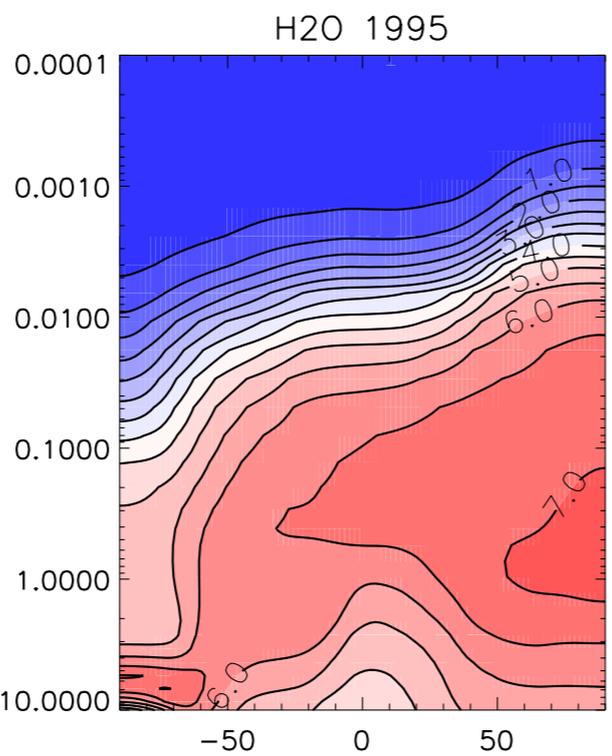
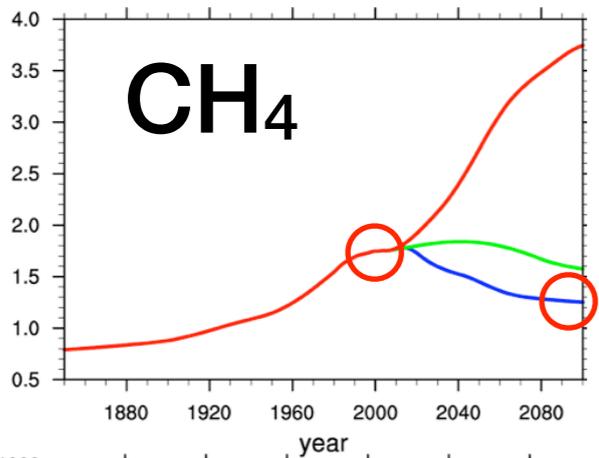
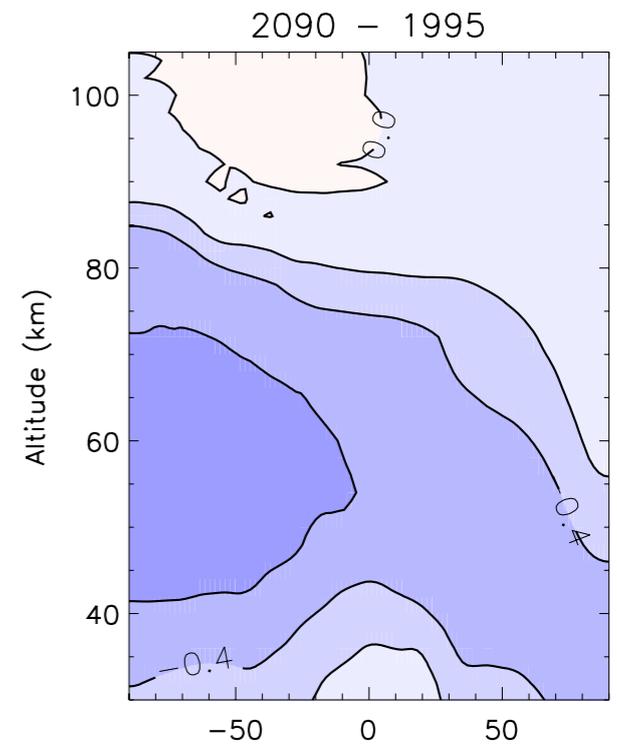
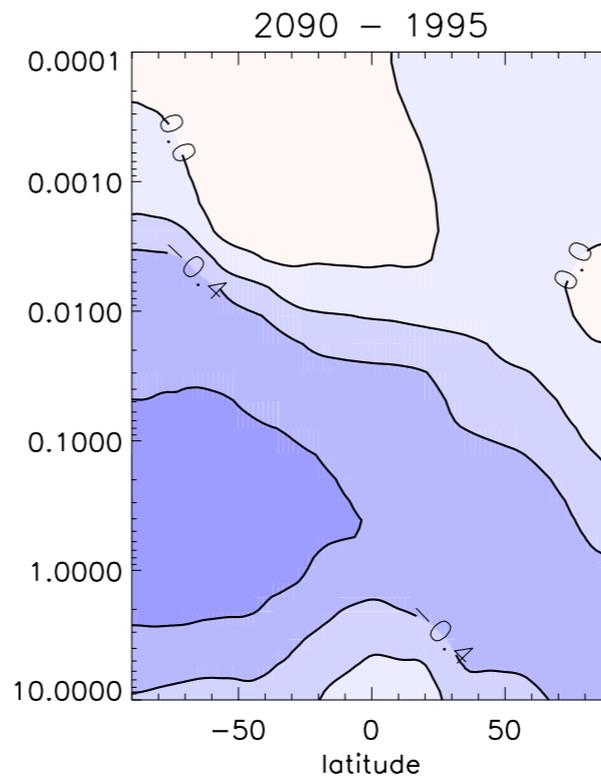
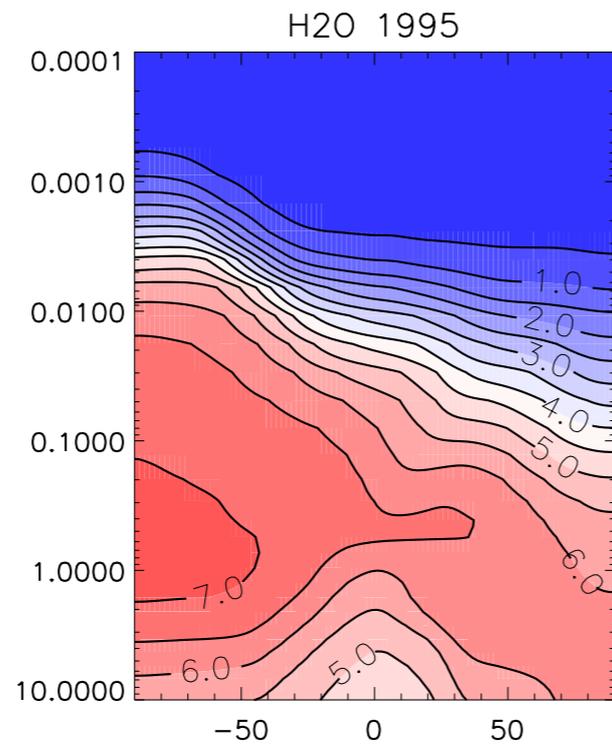
July





Water vapor present to 2100 (RCP2.6)

January

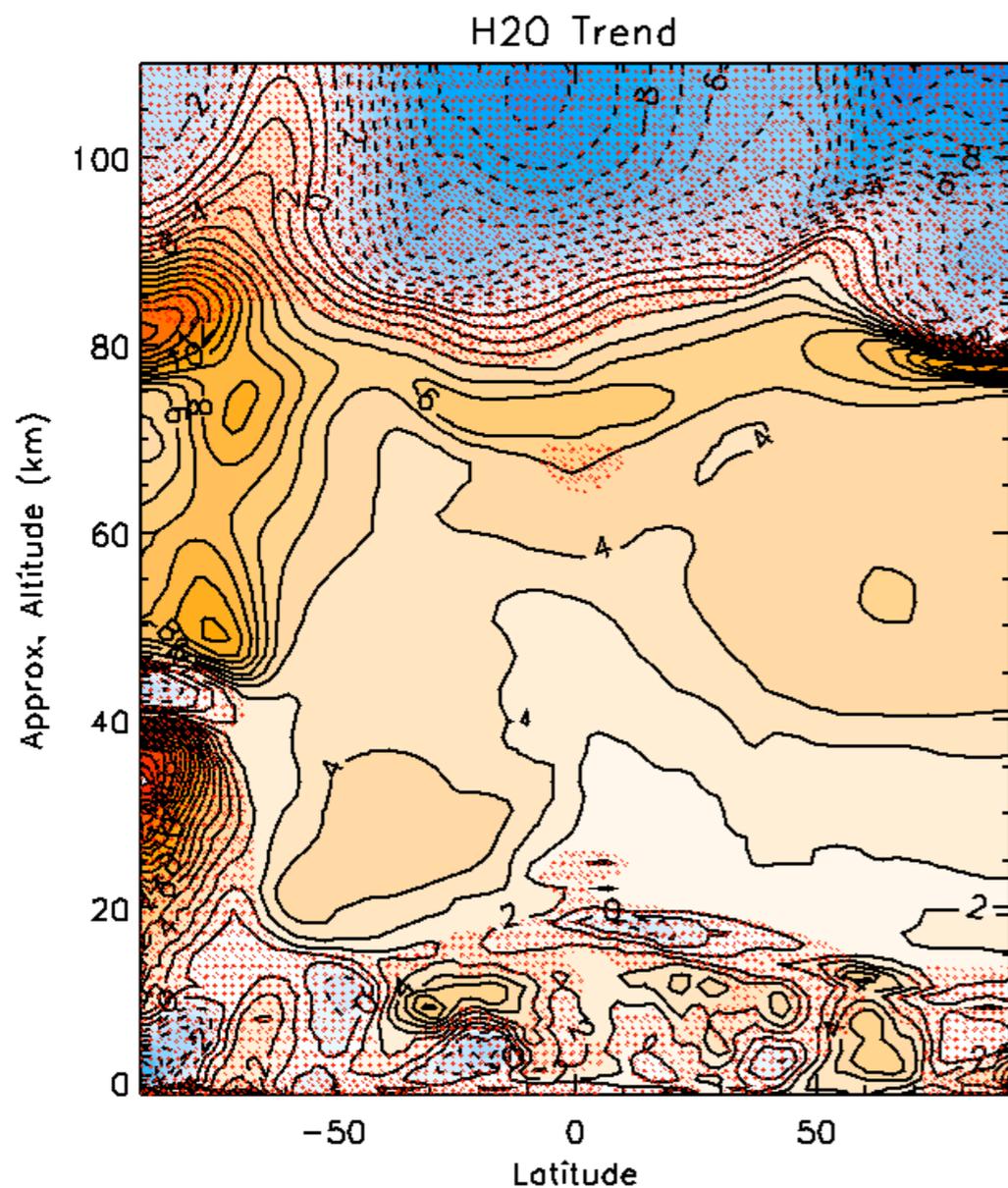


July



Important caveat

July water vapor (%/decade) with WACCM -PMC



Any trend in PMC will modify background atmosphere. e.g. an increase in clouds leads to more water below peak

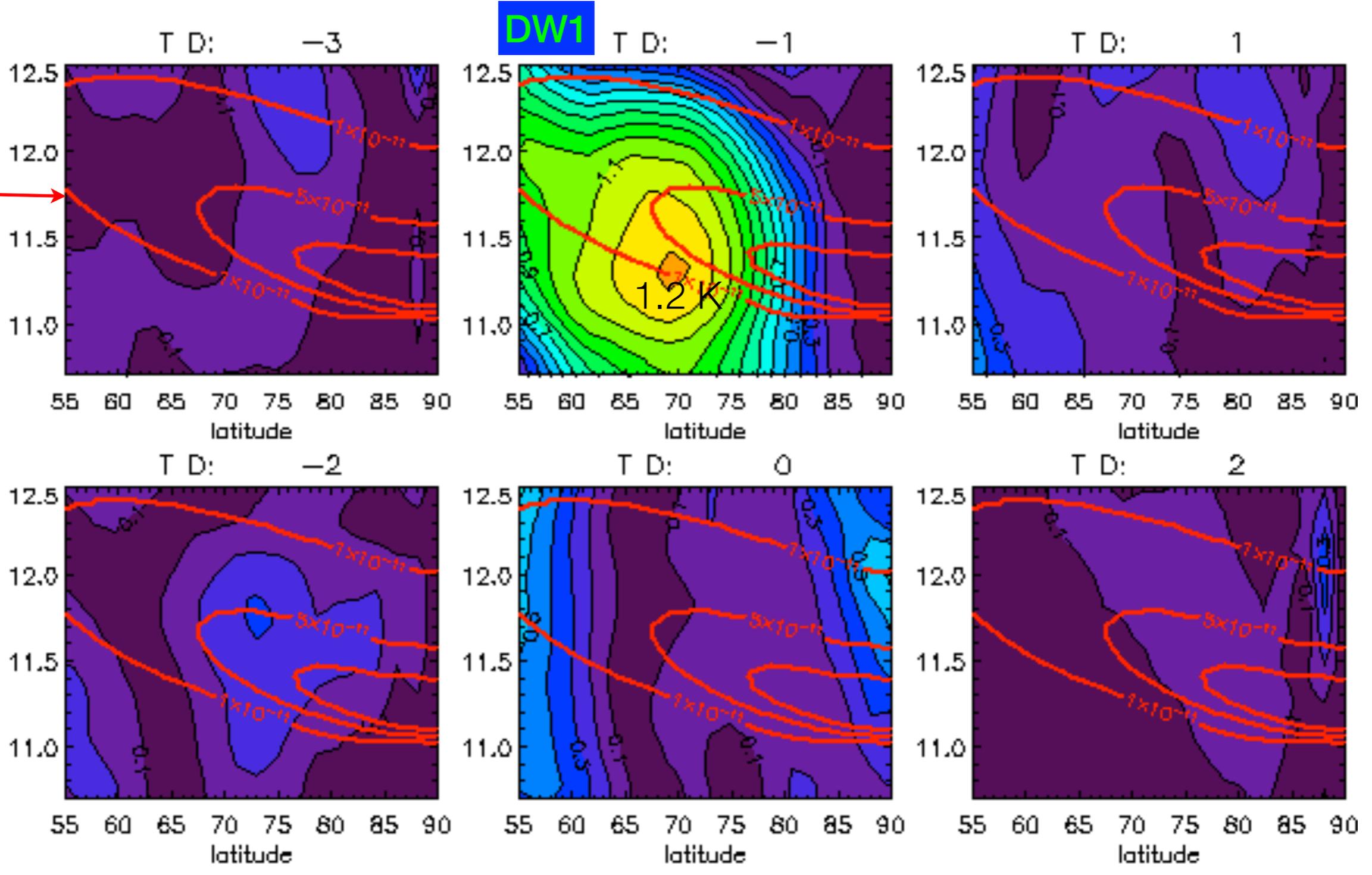


Tides and trends



Northern Hemisphere Diurnal Temperature Tides

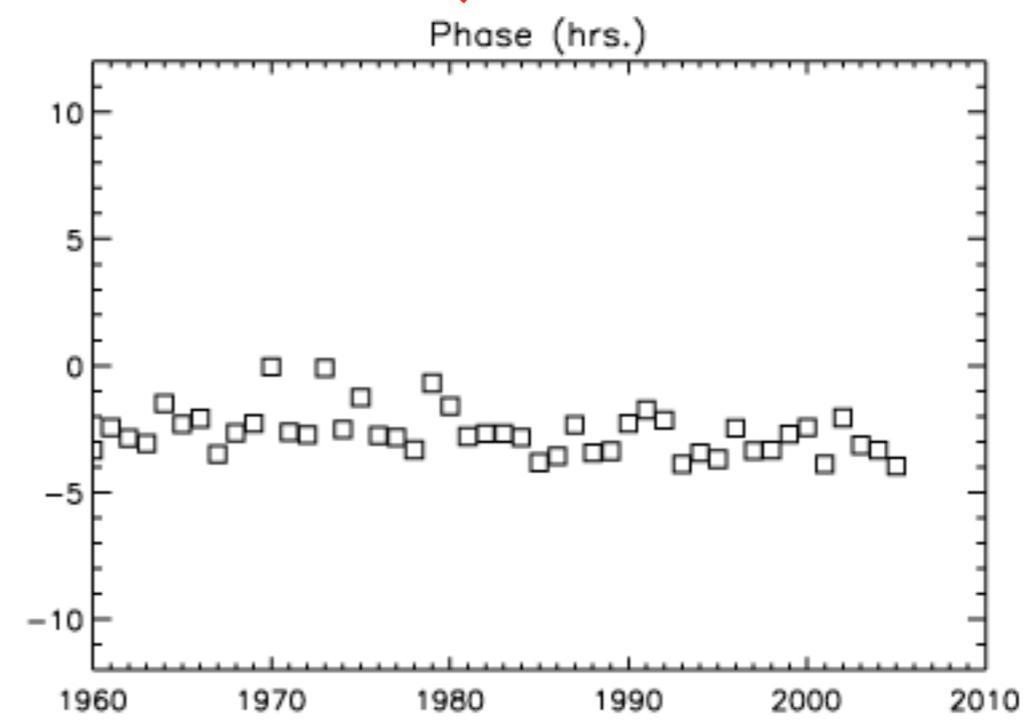
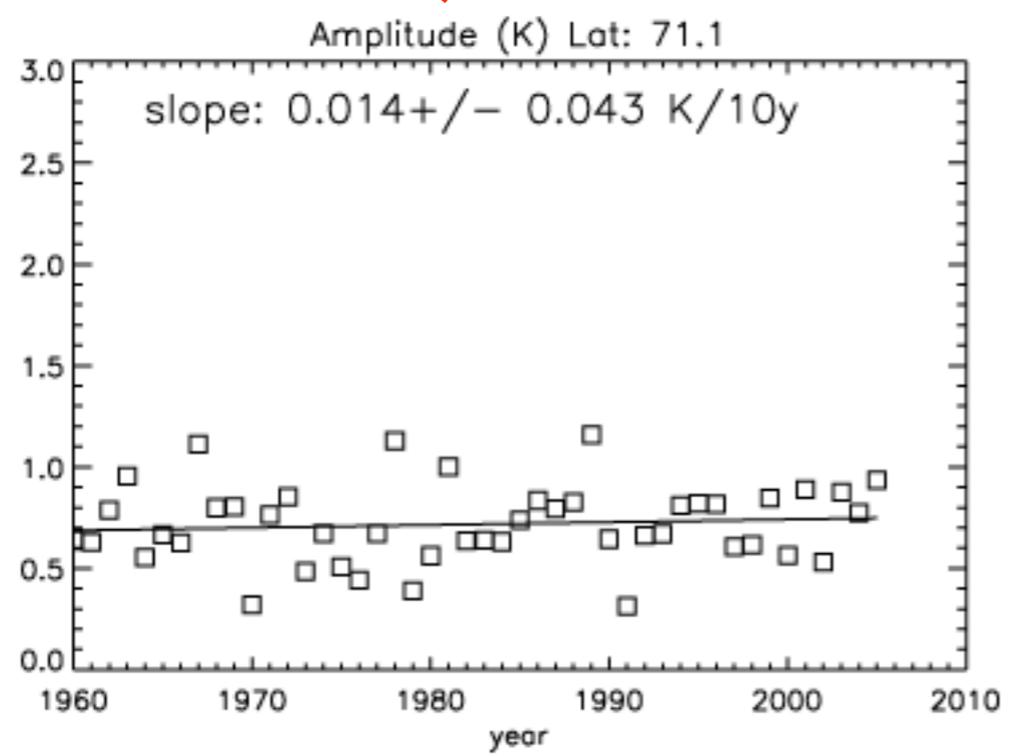
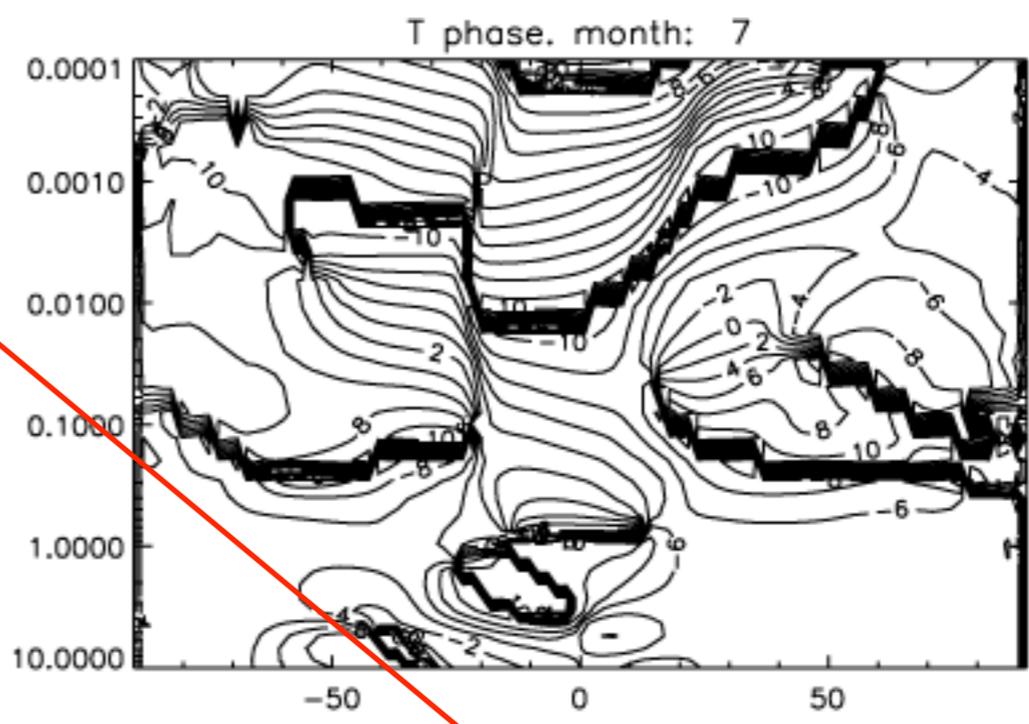
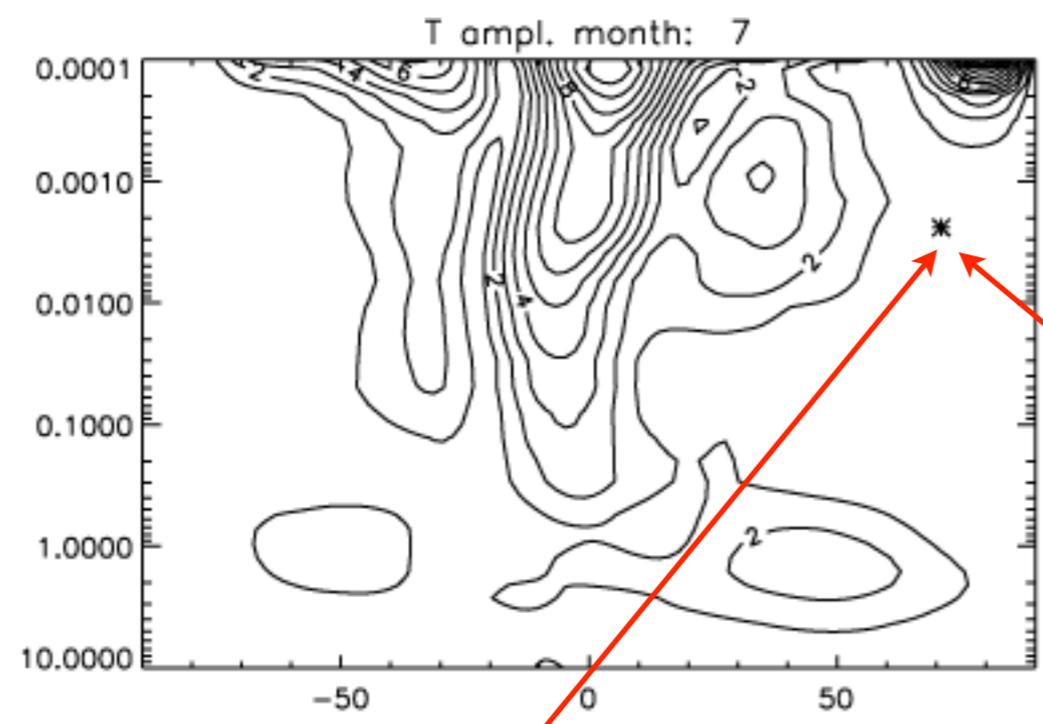
PMC
ICE
MASS



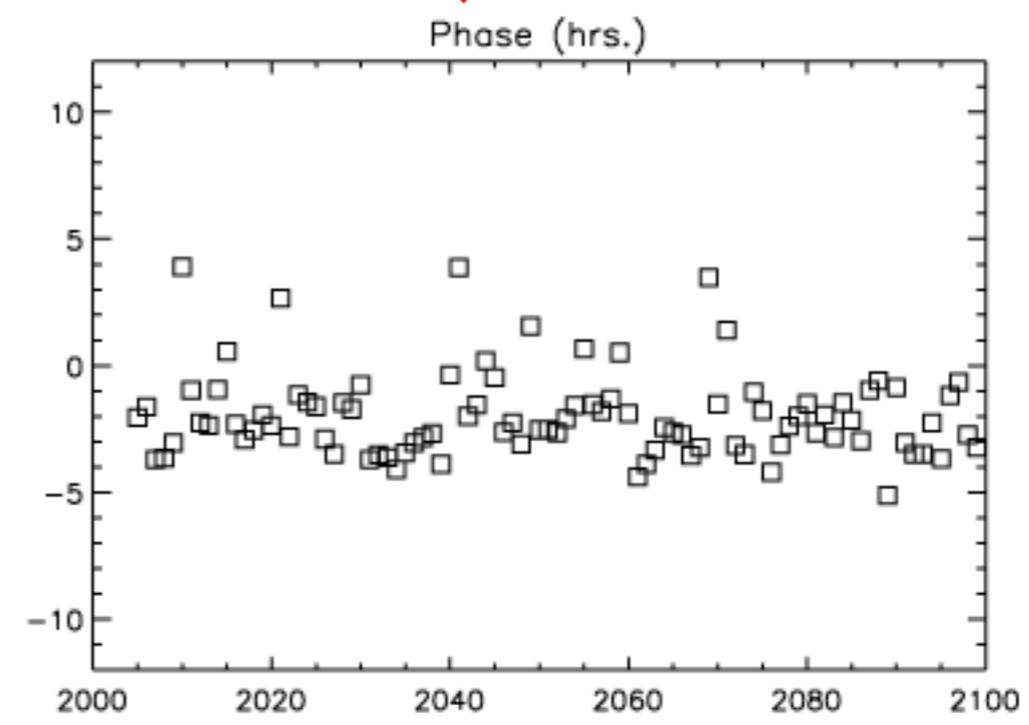
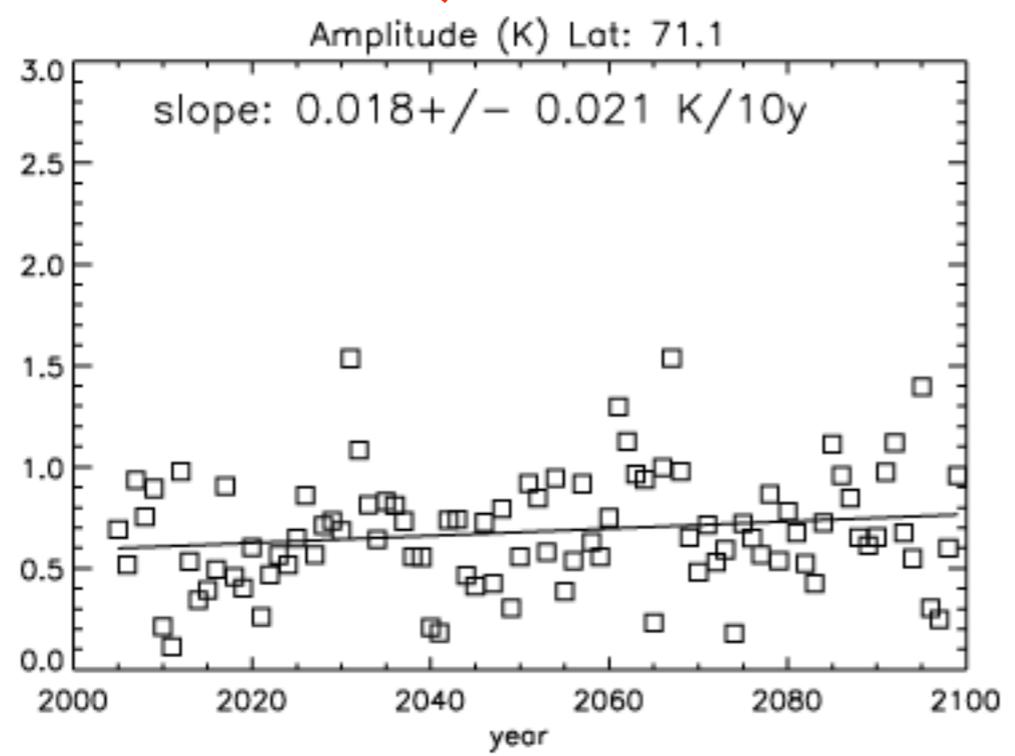
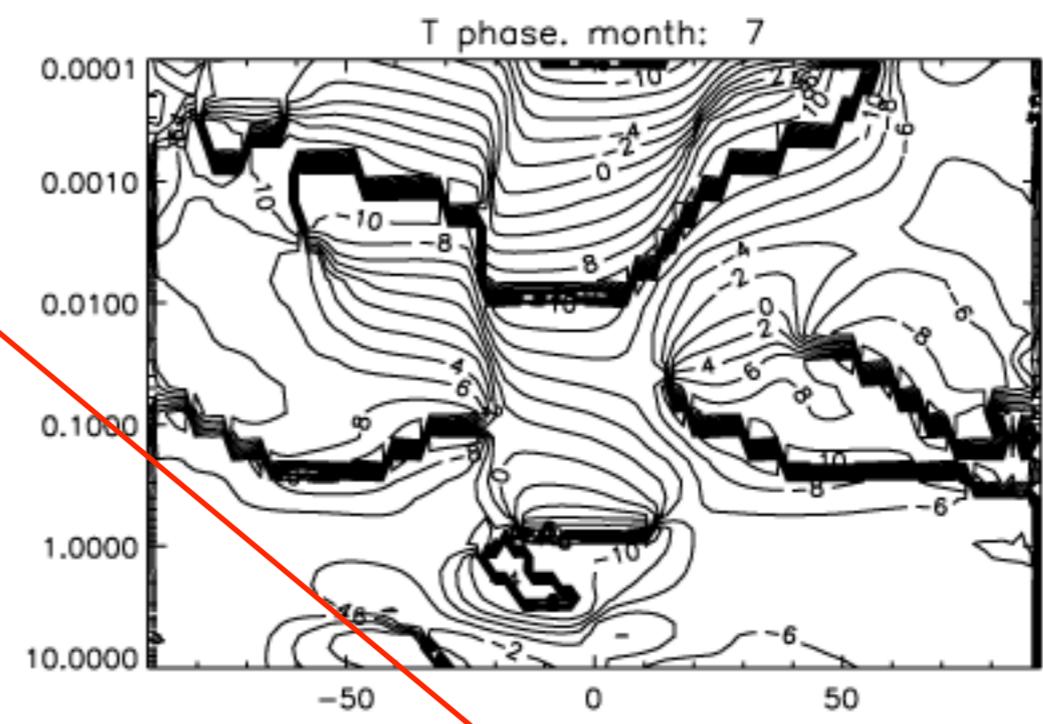
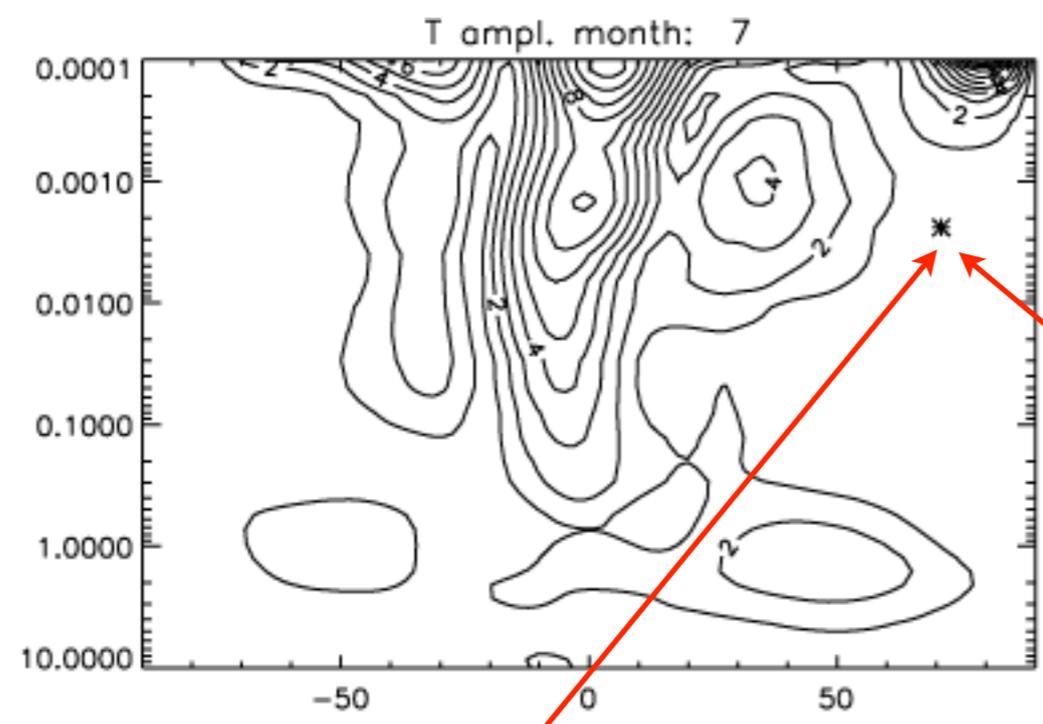
10 to 30 DFS

MOCA-9 presentation

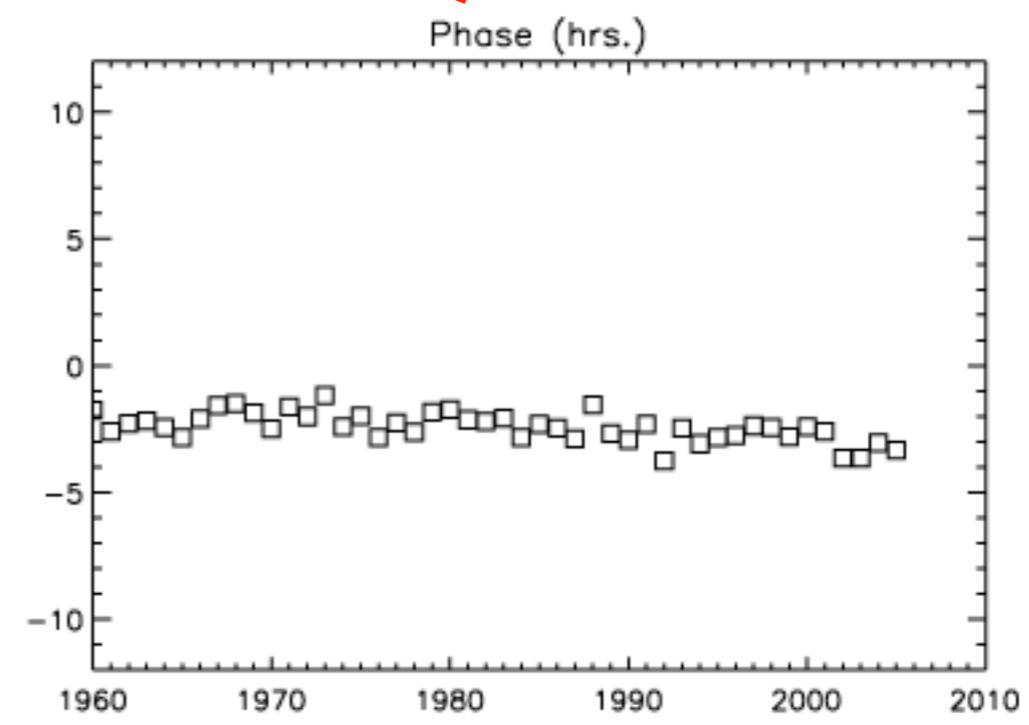
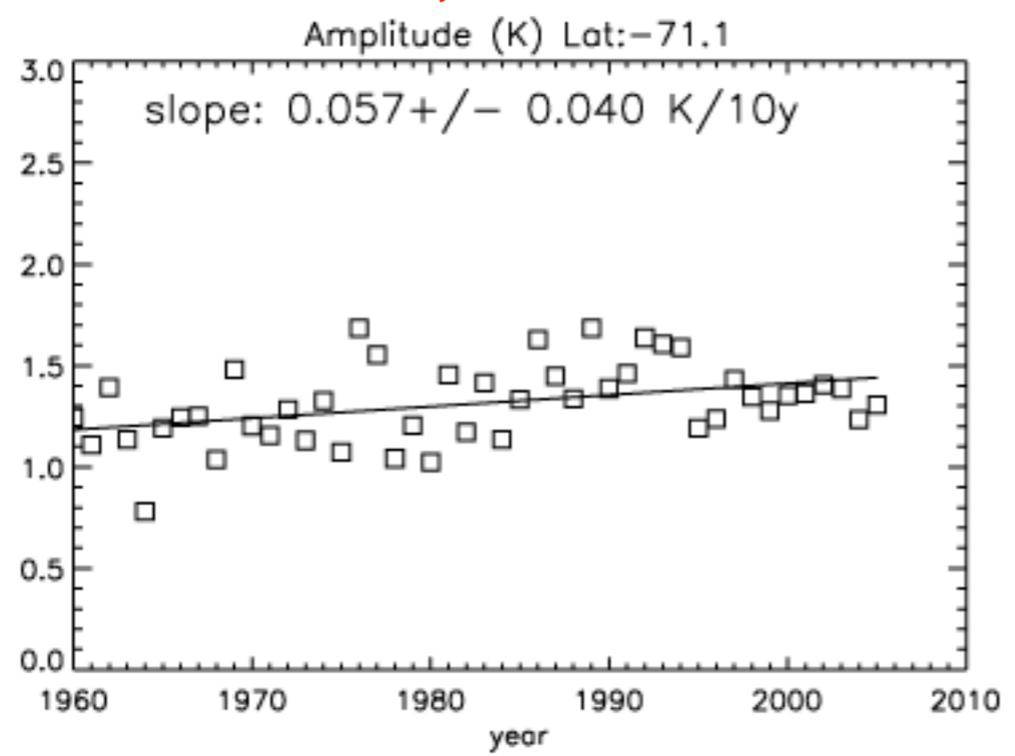
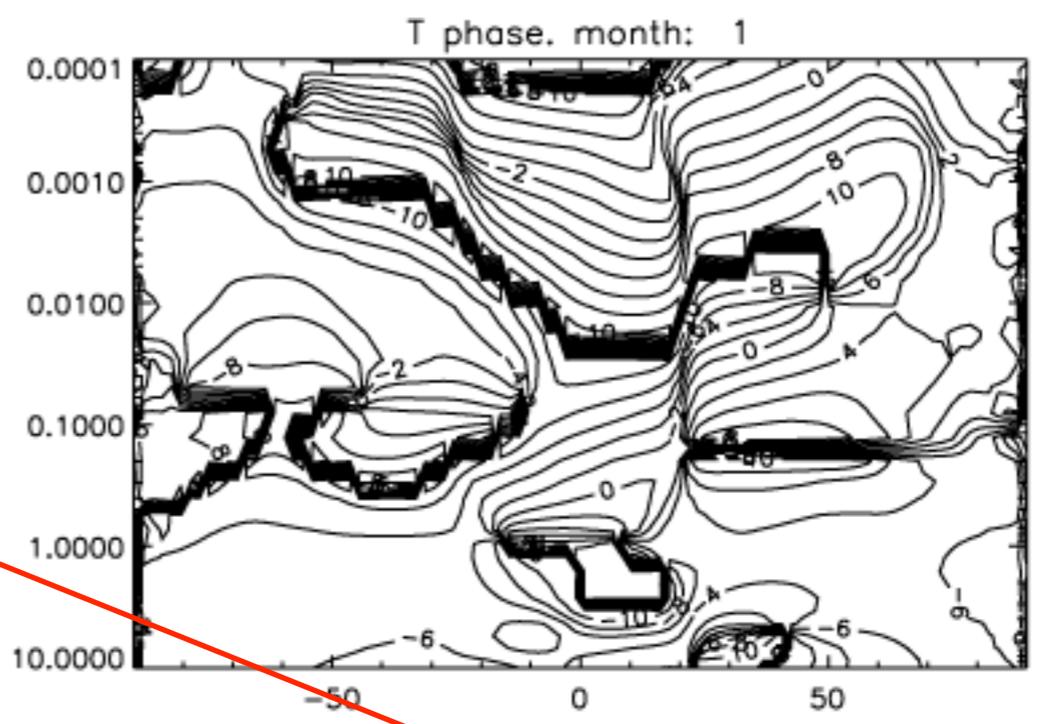
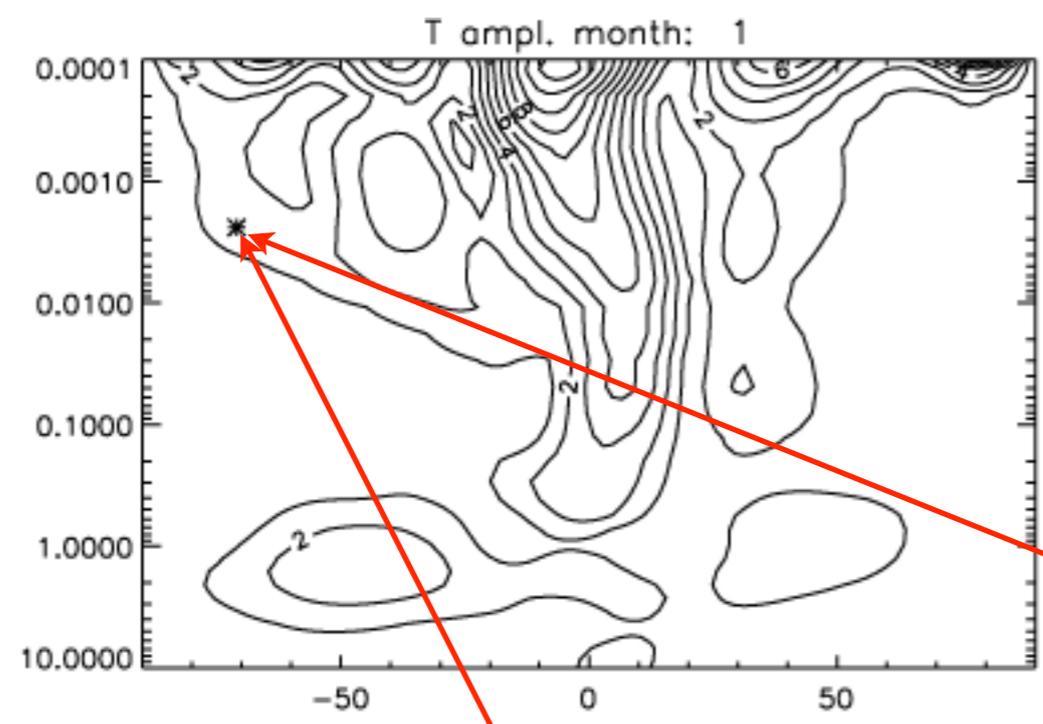
DW1 July 1960-2005



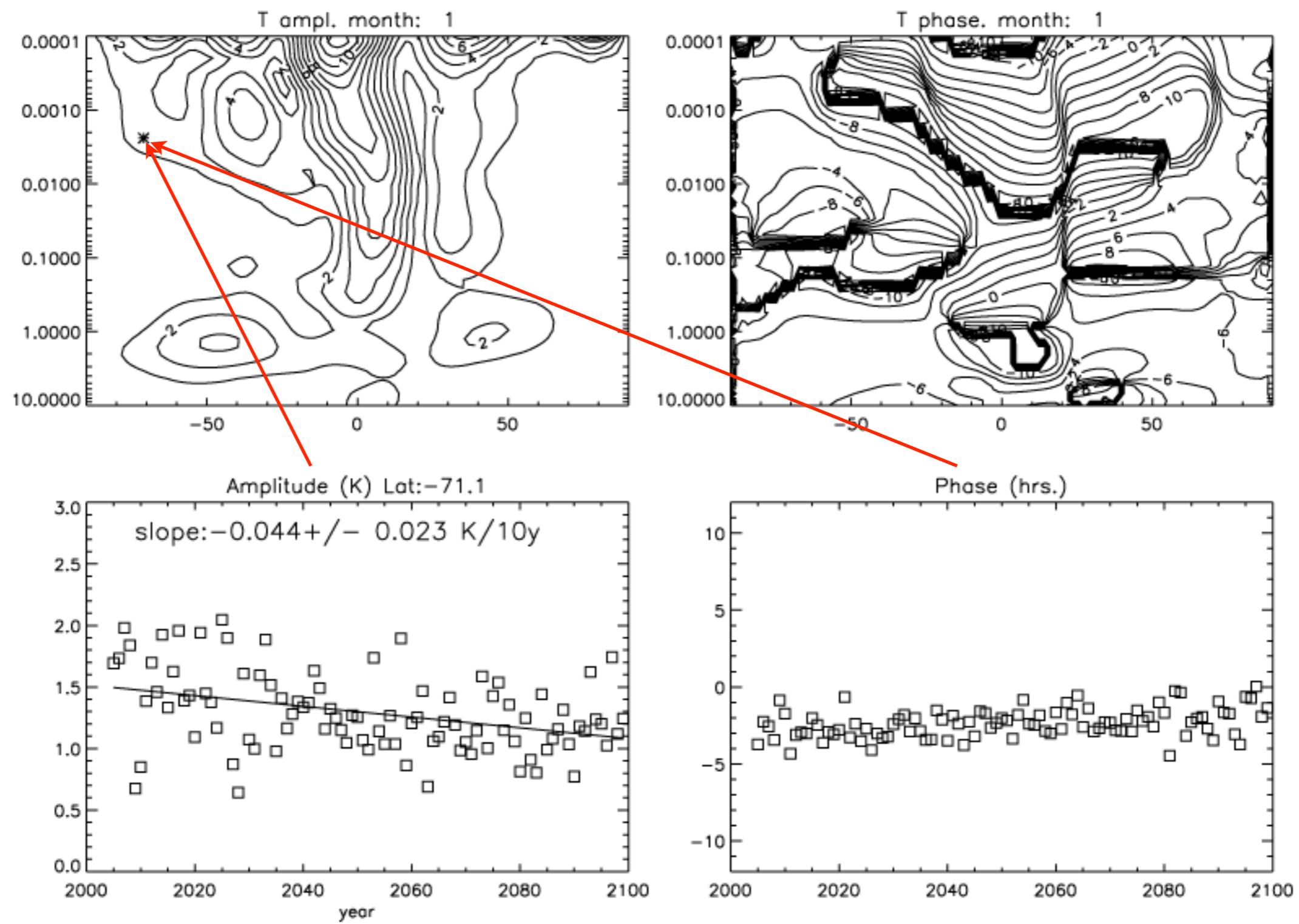
DW1 July 2005-2100



DW1 Jan 1960-2005



DW1 Jan 2005-2100





NCAR

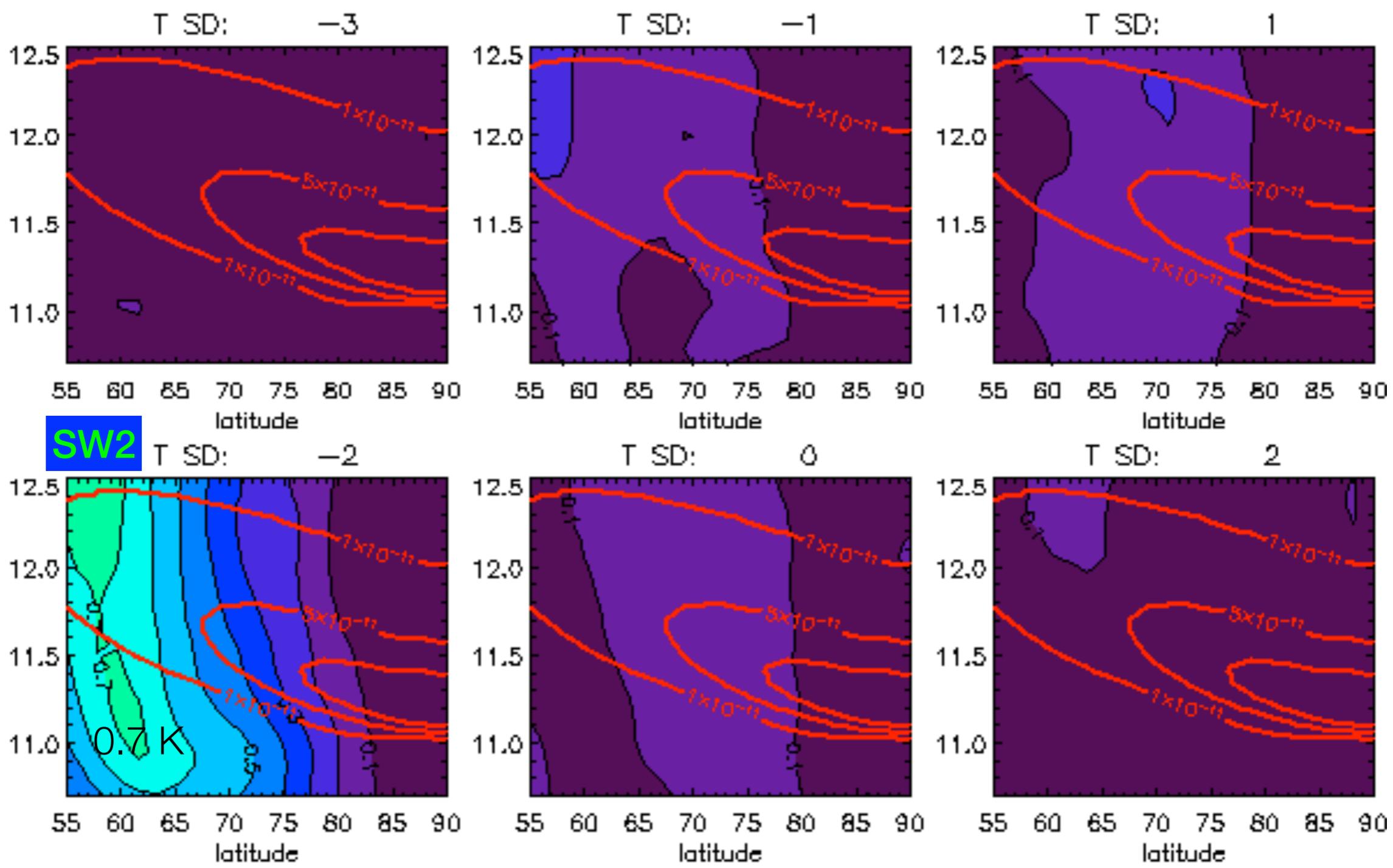


WACCM

Whole Atmosphere
Community Climate Model

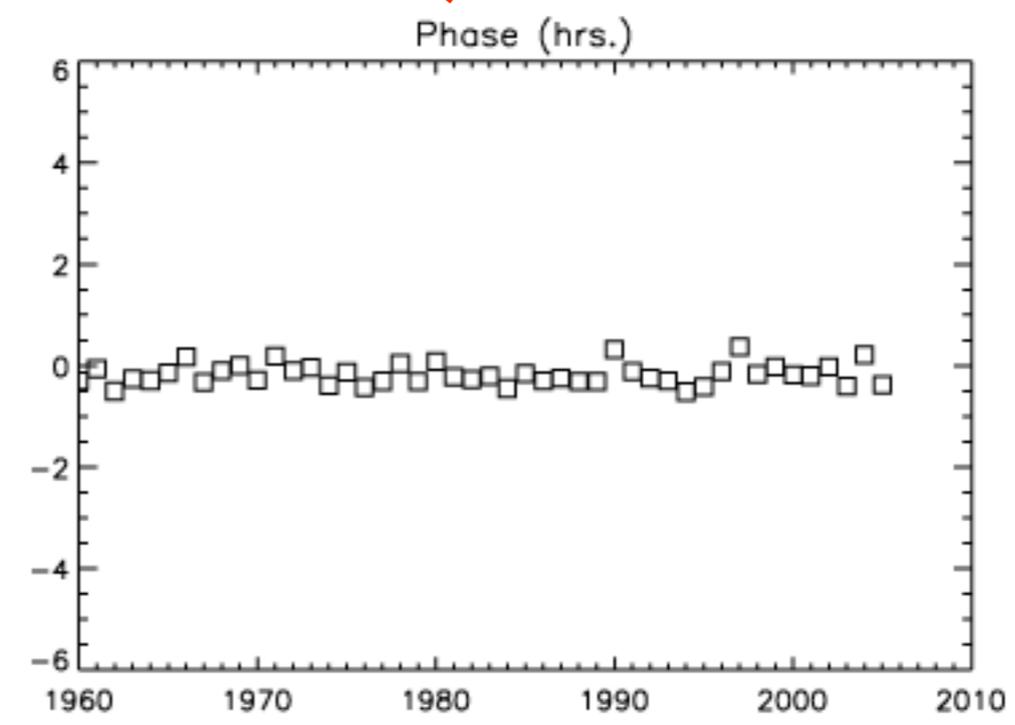
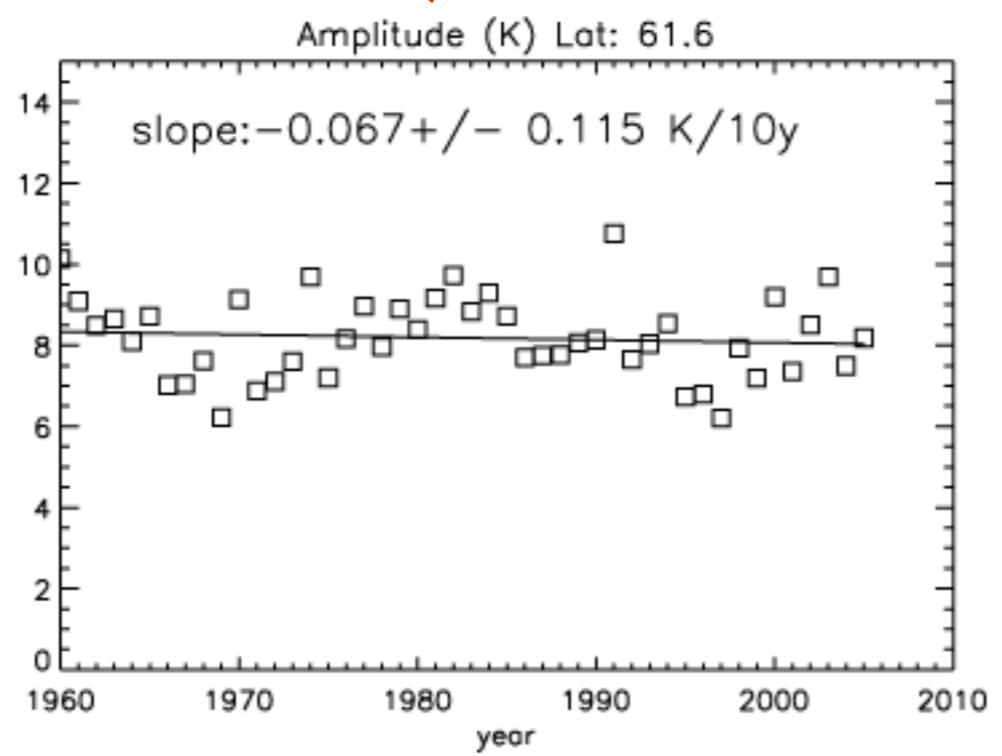
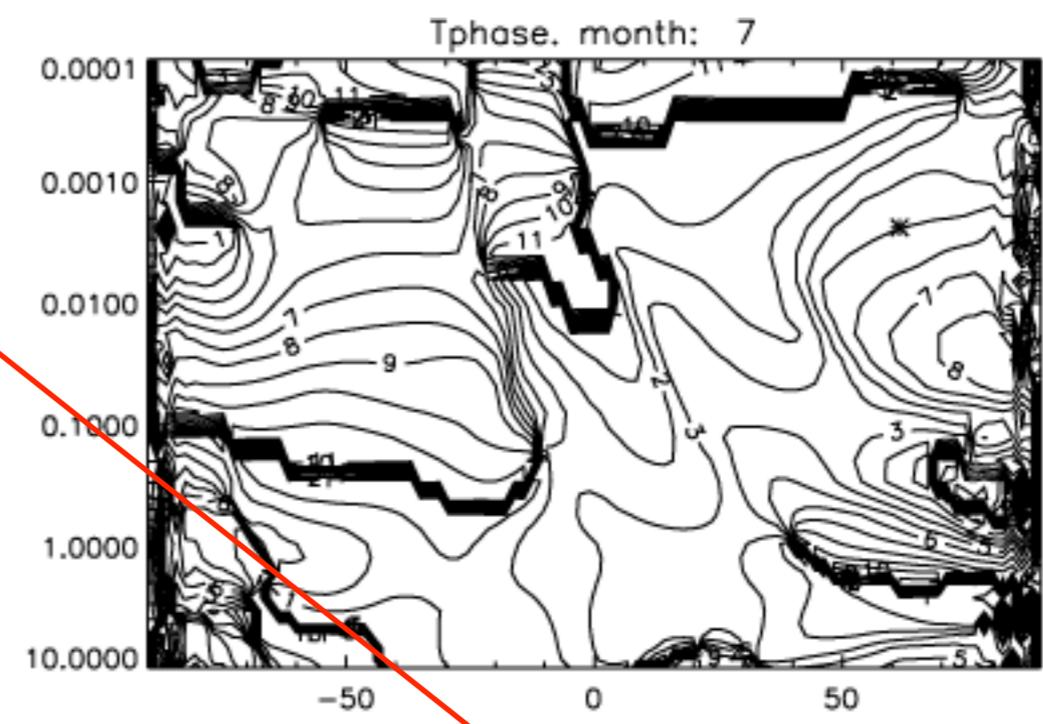
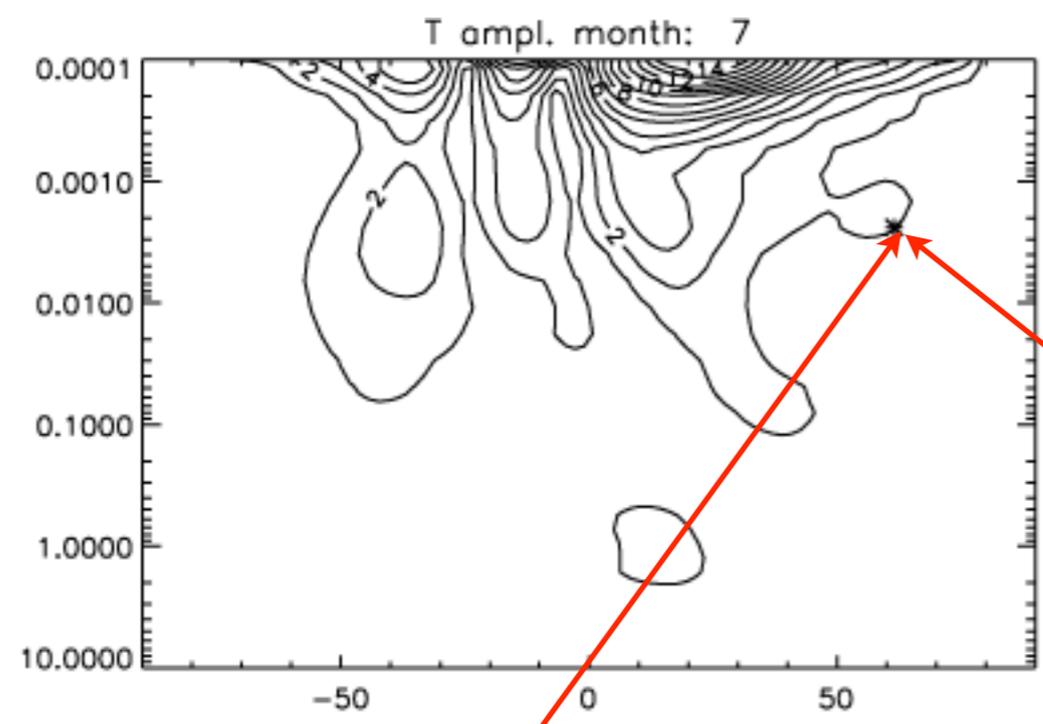


Northern Hemisphere Semi-diurnal Temperature Tides

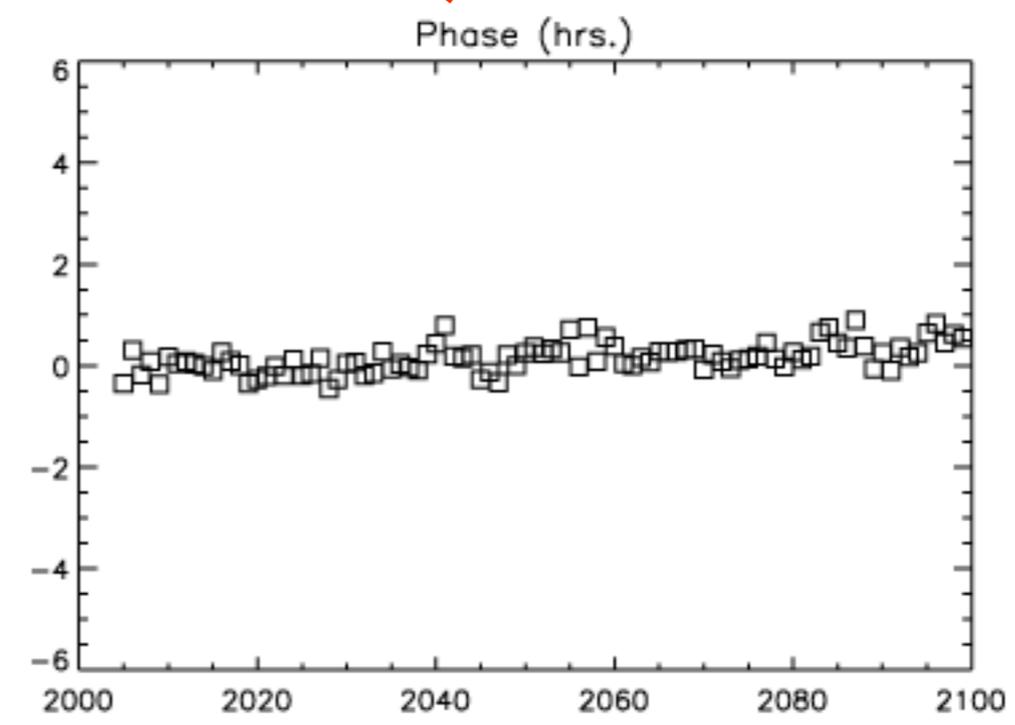
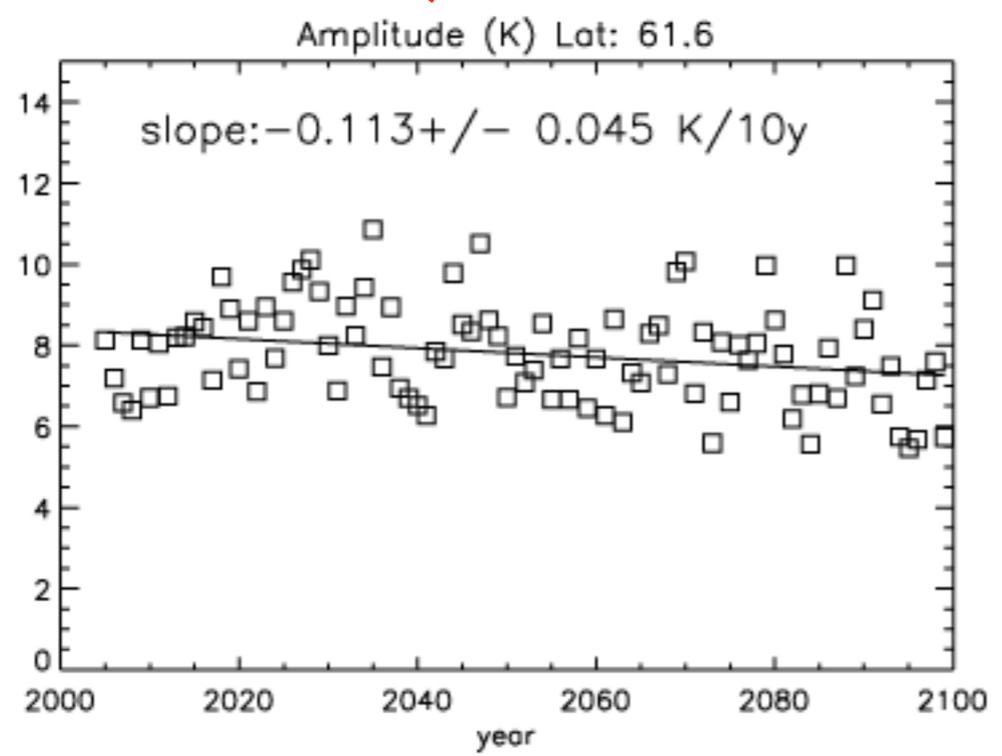
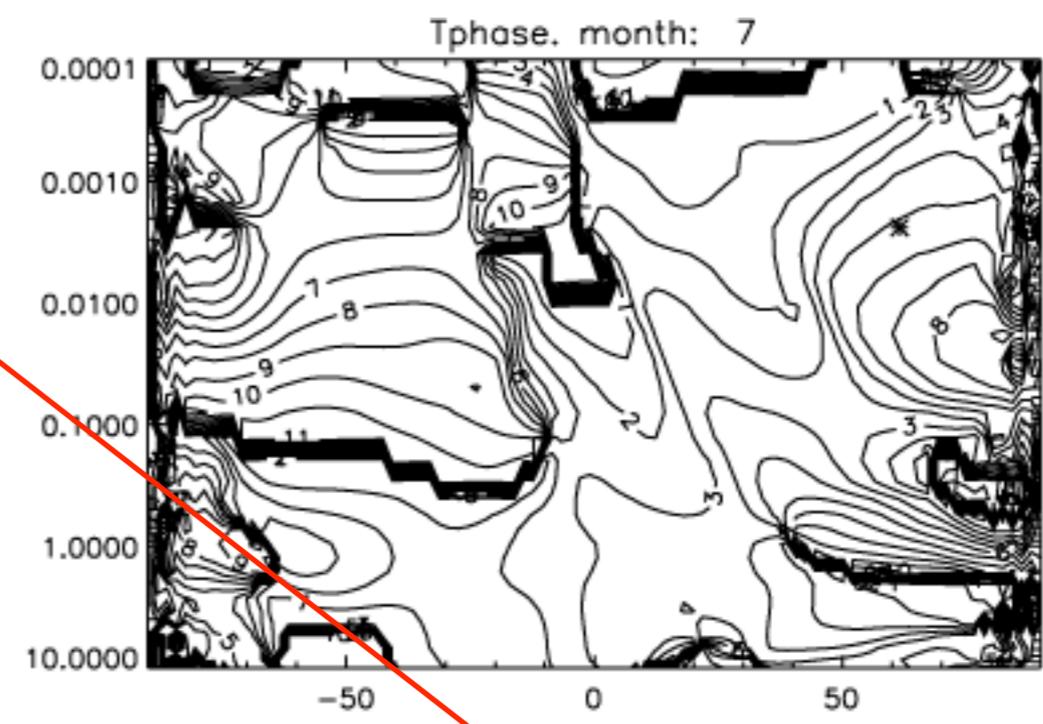
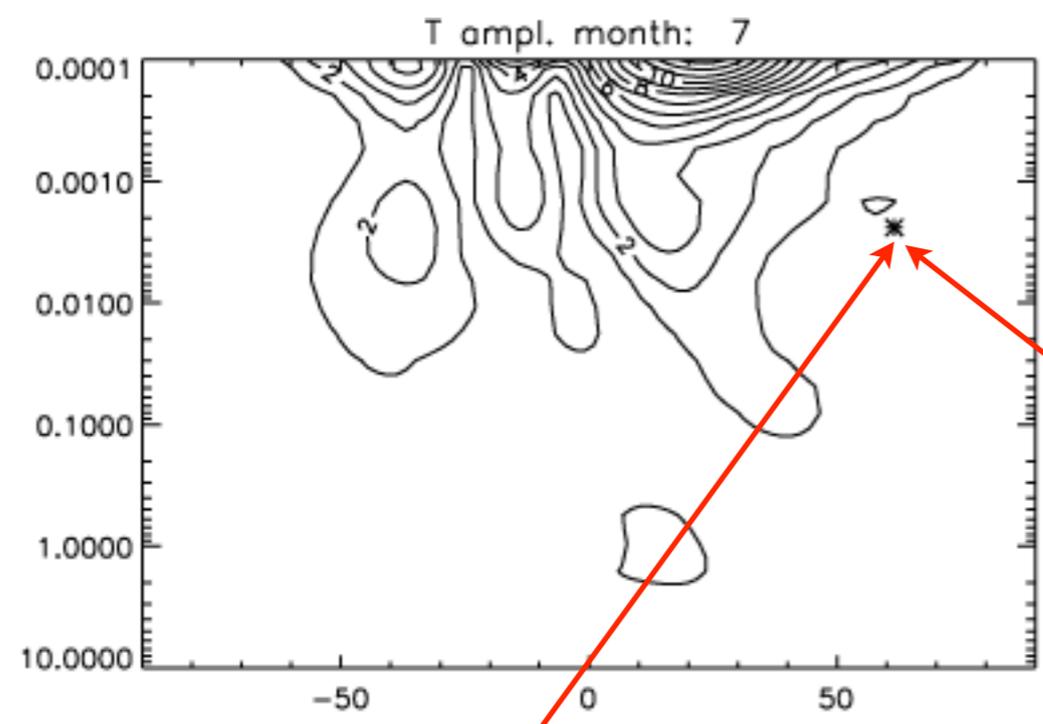


MOCA-9 presentation

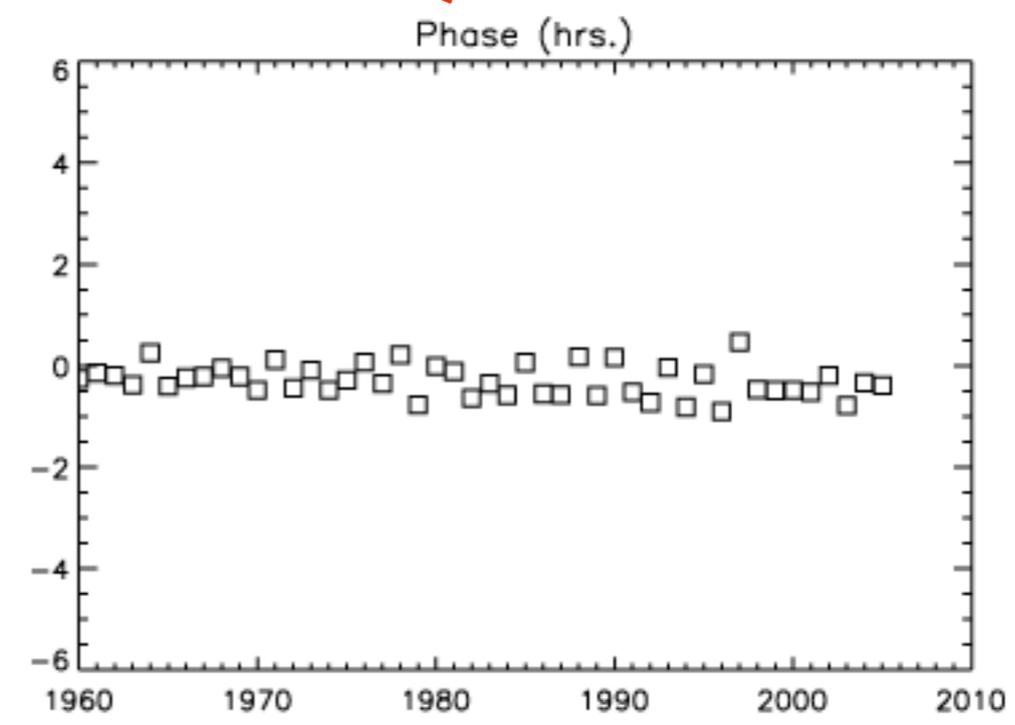
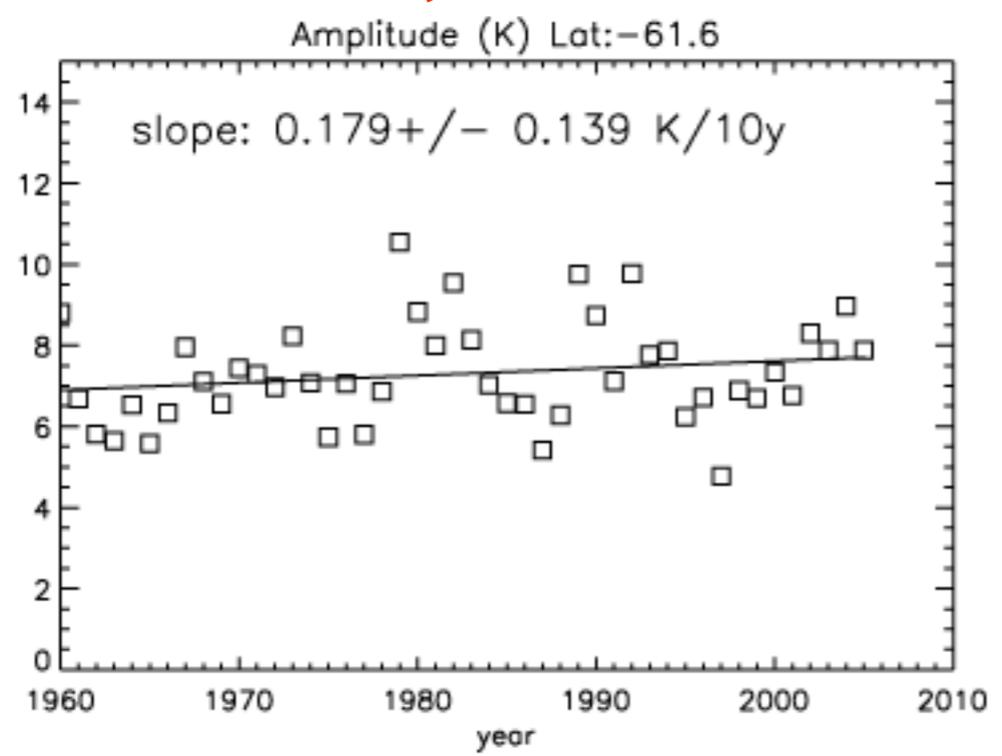
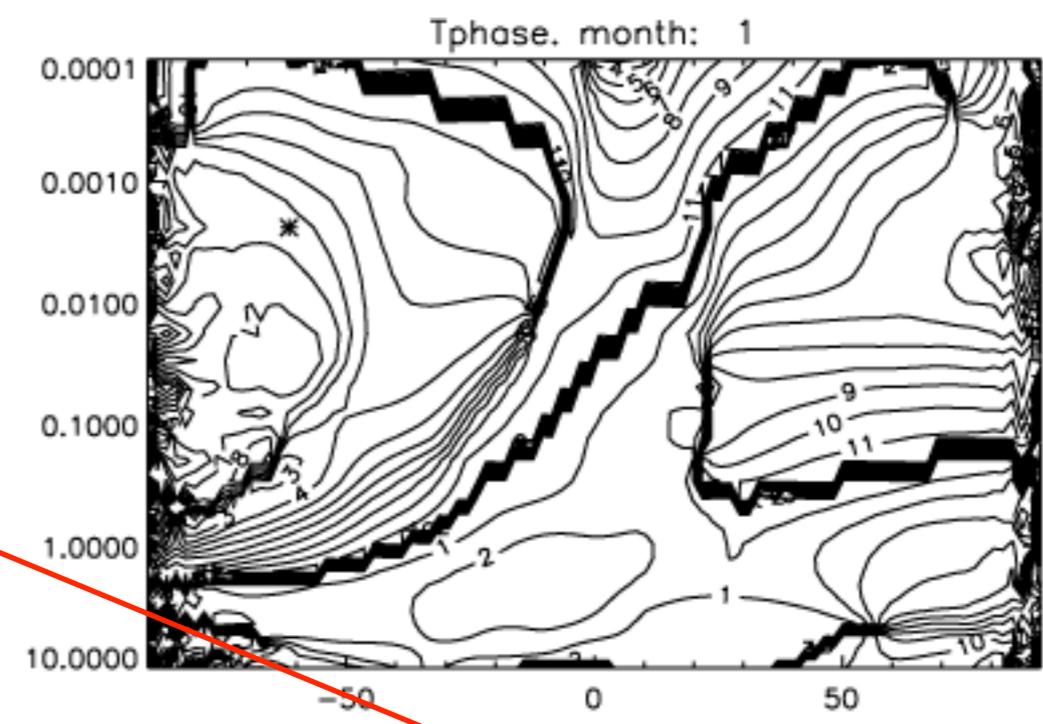
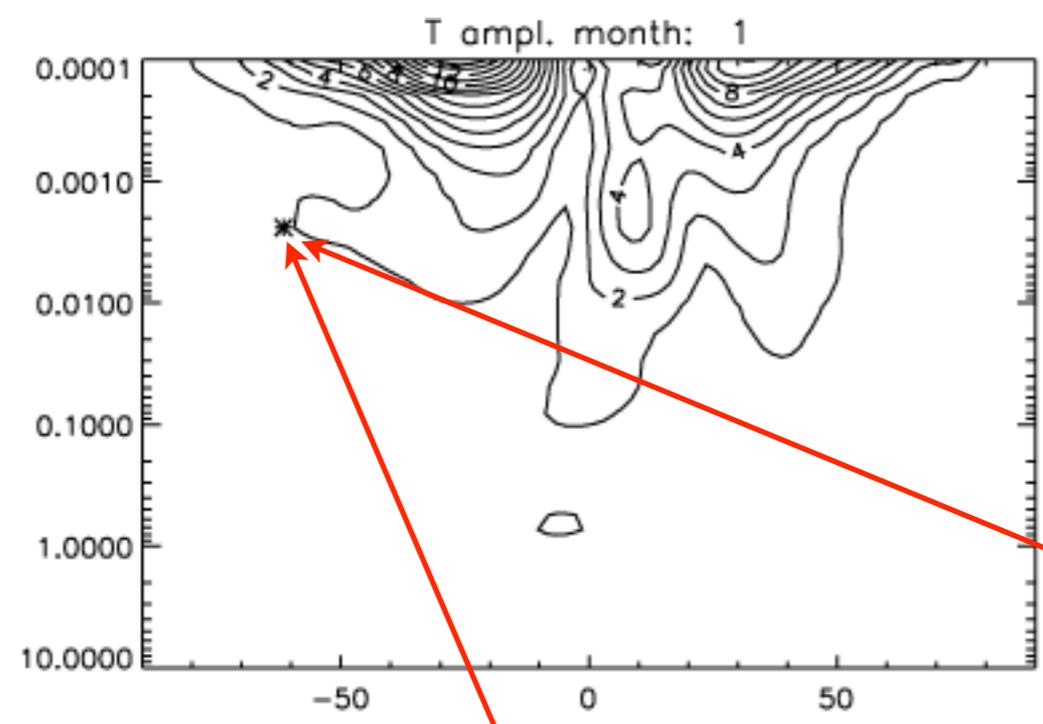
SW2 July 1960-2005



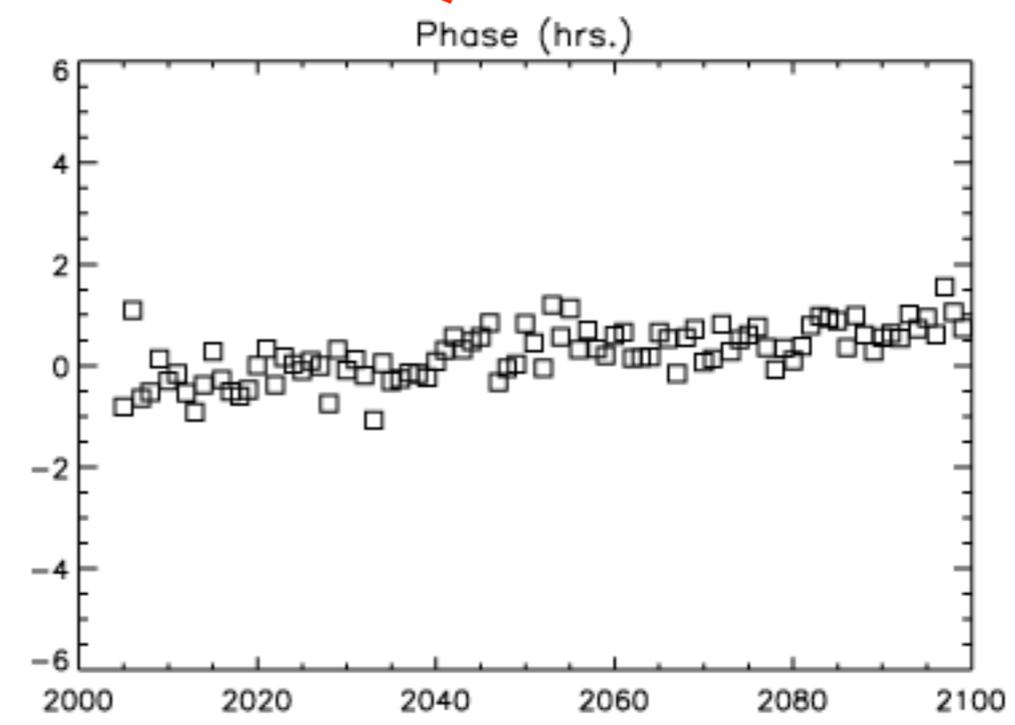
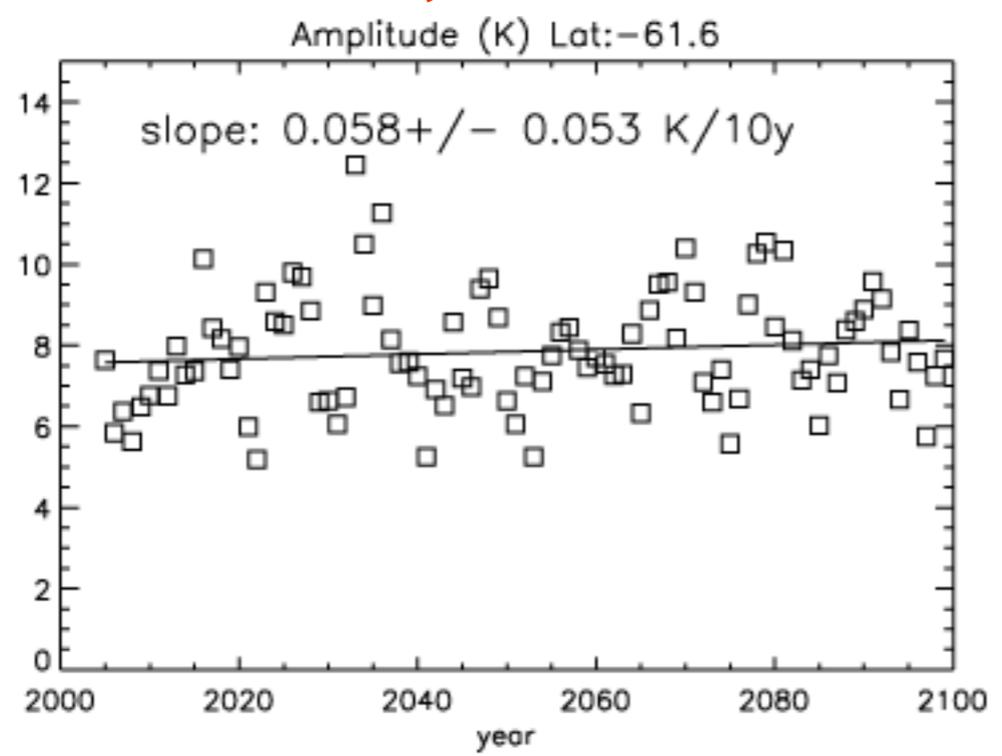
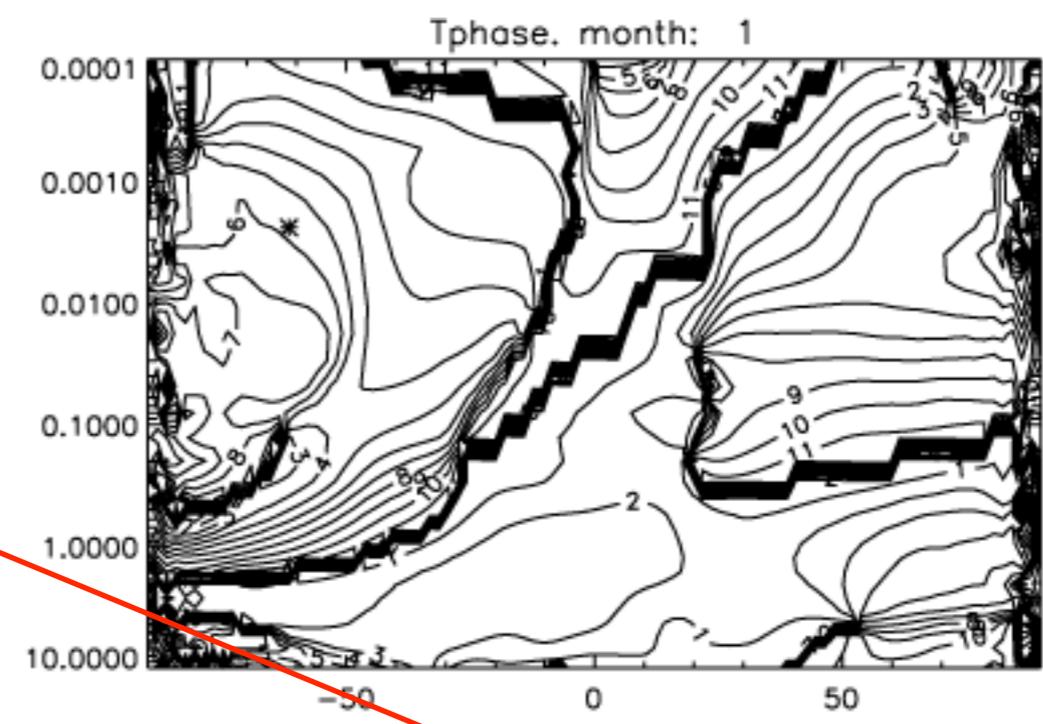
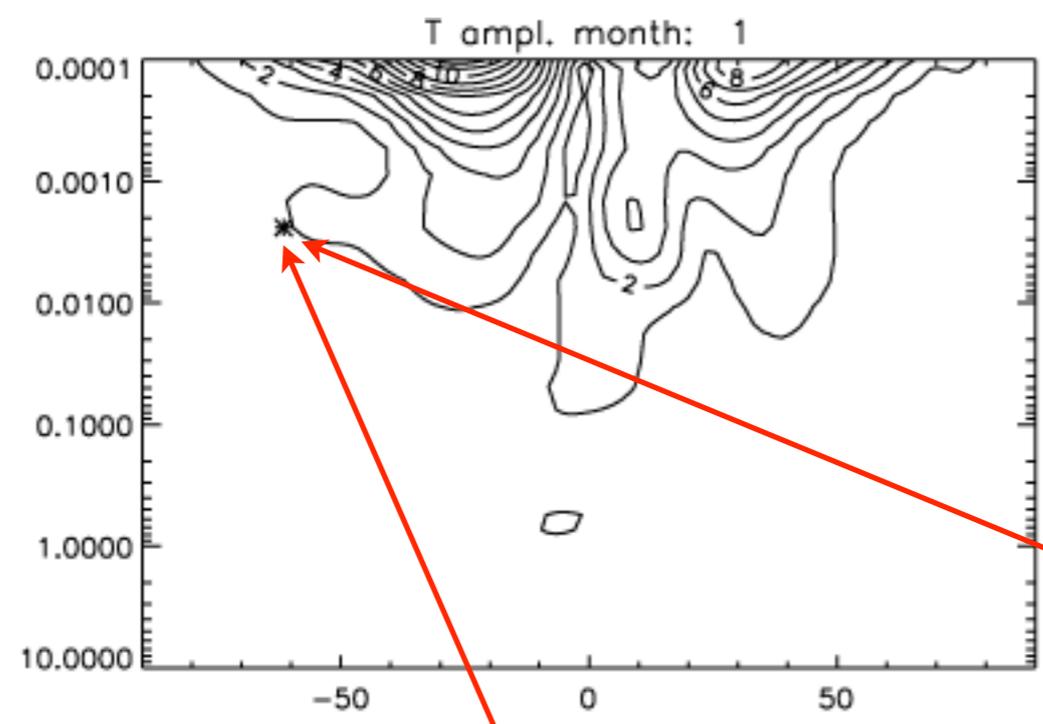
SW2 July 2005-2100



SW2 Jan 1960-2005



SW2 Jan 2005-2100





Summary

- Past and future integrations completed for IPCC CMIP5 using CESM-WACCM (only high-top coupled model to include interactive chemistry and thermosphere).
- Mesospheric CO₂ has increased 60 ppmv from 1850 to present and could increase more than 400 ppmv under one RCP. This has/will lead to cooling throughout the MLT when viewed at constant pressure surfaces.
- Methane has doubled and could double again. Water vapor could increase 1-2 ppmv by 2100.
- Still, at PMC heights there is a temperature trend zero line, *when viewed at constant altitude*, no matter the scenario (past and future)!
- Migrating tides have statistically significant trends in the SH, likely related to changes in stratospheric ozone.

Acknowledgements

- @NCAR - Mike Mills, Natalia Calvo, Doug Kinnison, Francis Vitt, Rolando Garcia, Jean-Francois Lamarque, Andrew Conley, CESM Working group co-chairs and liaisons ...
- External collaborators - Lorenzo Polvani, Marilyn Raphael, Fabrizio Sassi
- CSEG, particularly Mariana Vertenstein and Chris Fischer
- Substantial computing resources were provided by the Climate Simulation Laboratory at NCAR's Computational and Information Systems Laboratory
- CESM project is supported by the National Science Foundation and the Office of Science (Bio. & Env. Res.) of the U.S. Department of Energy
- see www.cesm.ucar.edu/working_groups/WACCM

Thank you



NCAR is sponsored by the National Science Foundation

