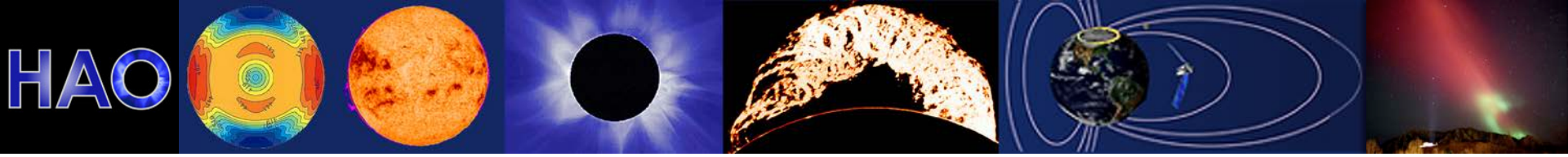

Long-Term changes in the thermosphere simulated by WACCM-X and TIME-GCM

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Motivation

- Long-term changes in the upper atmosphere have been simulated using upper GCMs with great success;
- Advantage of using a whole atmosphere GCM:
  - Lower and upper atmosphere are coupled dynamically, energetically, and chemically;
  - Some trace gases are chemically active below the thermosphere, require a GCM with a detailed chemical transport model;

TIME-GCM
(Thermosphere-Ionosphere-Electrodynamics General Circulation Model)

- 3D general circulation model (~35-600 km);
- Coordinate system: horizontal: rotating spherical geographical coordinates; vertical: pressure surface (hydrostatic equilibrium);
- Resolution: horizontal: 2.5°x 2.5°; vertical: 0.25 pressure scale height;
- 2-minute time step.

TIME-GCM Runs

- F10.7=F10.7a=70
- Kp=0.3
- Run #1: set CO_2 concentration at the 1996 level at the lower boundary (35 km), do a perpetual run for March equinox, run the model for 2 years for CO_2 to reach equilibrium at the mesopause region;
- Run #2: set CO_2 concentration at the 2008 level at the lower boundary (35 km), do a perpetual run for March equinox, run the model for 2 years for CO_2 to reach equilibrium at the mesopause region.

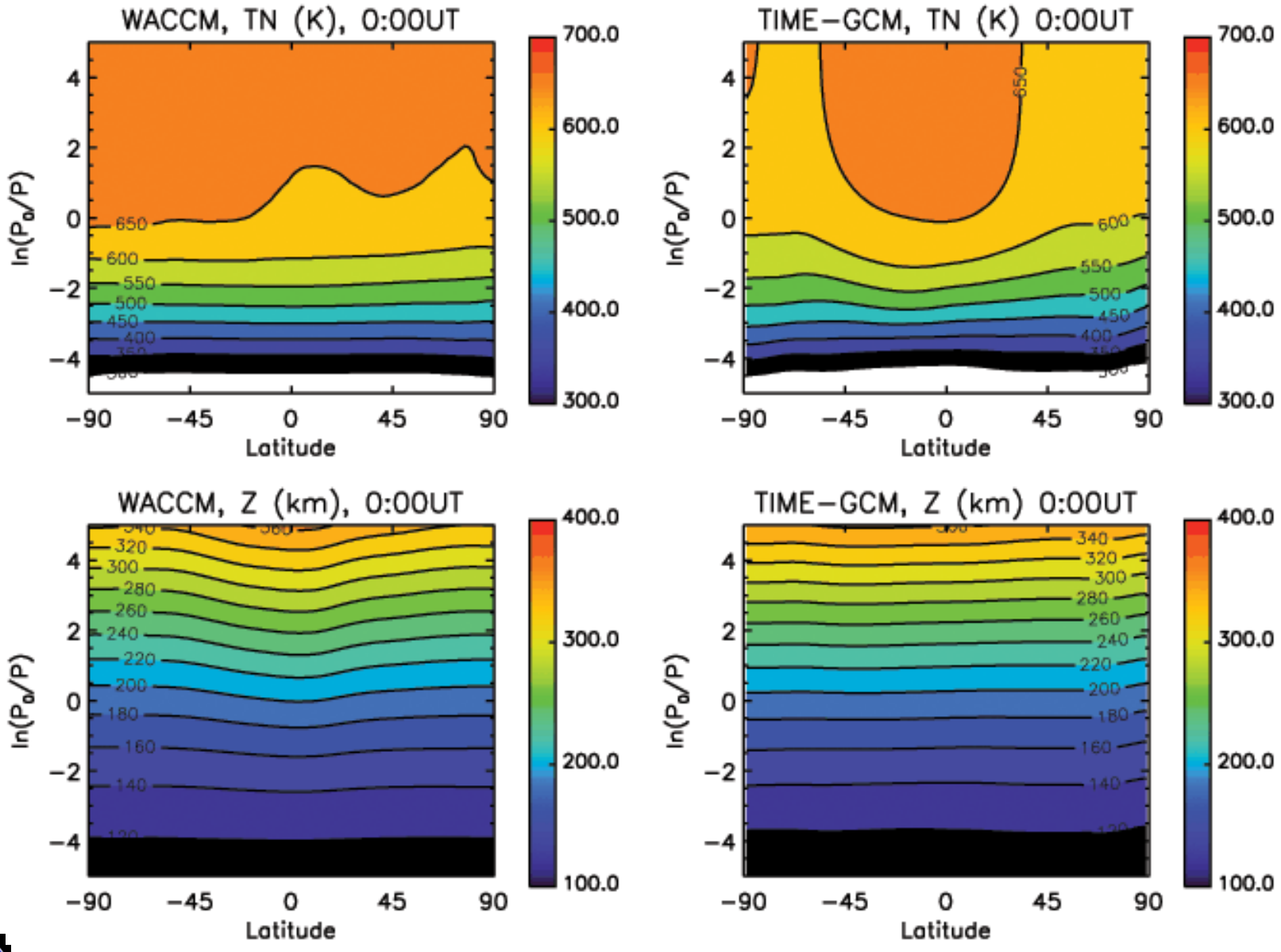
Calculate global mean for the last 10 days, and the 10-day mean.

WACCM-X Runs

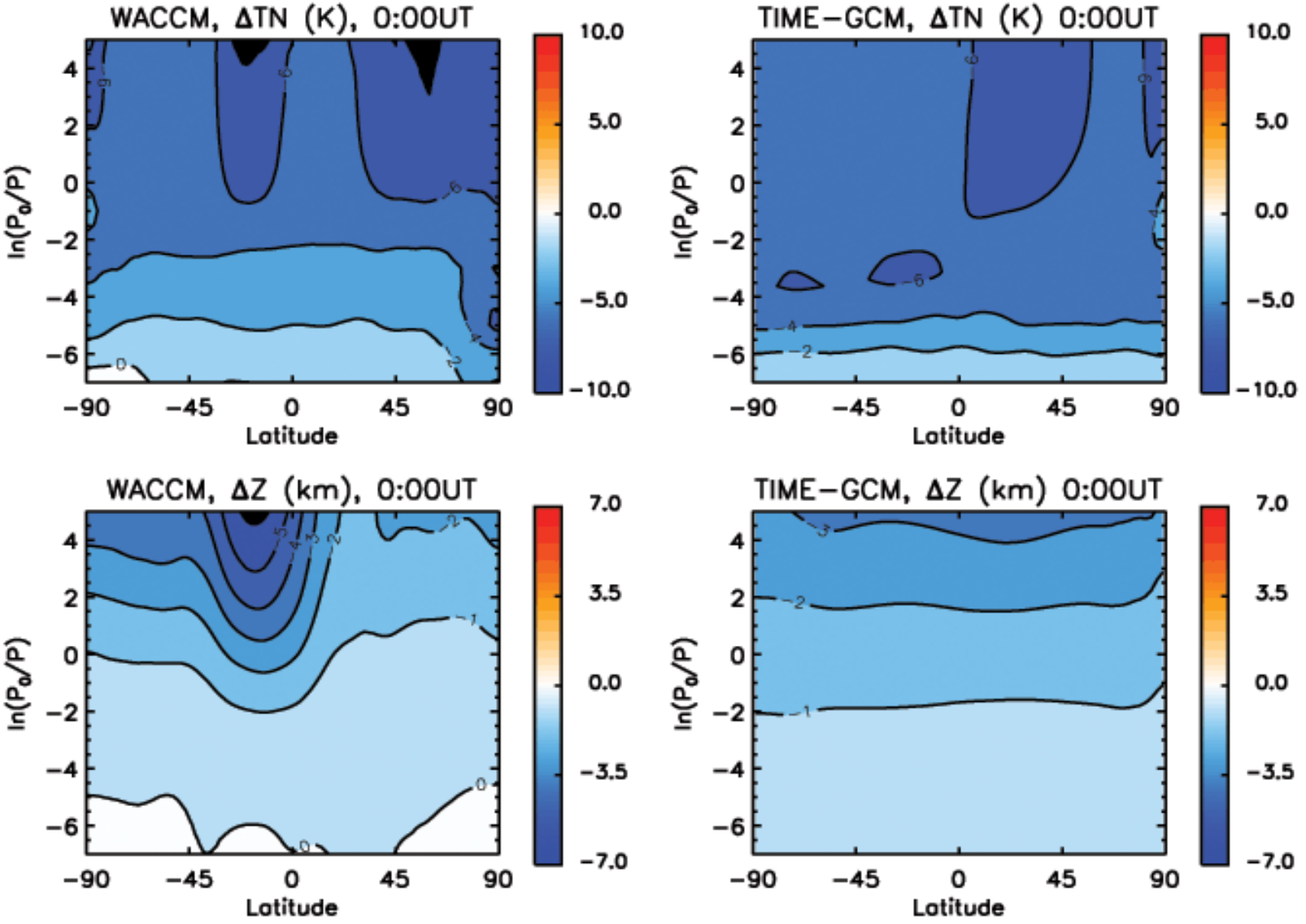
- WACCM-X (new version with ionosphere energetics)
  - $F_{10.7}=F_{10.7a}=70$
  - Kp=0.3
  - Run #1: use 01/01/1996 initial files for 10 instances, run the model for 3 months;
  - Run #2: use 01/01/2008 initial files for 10 instances, run the model for 3 months.

Calculate global mean for month of March, then ensemble mean.

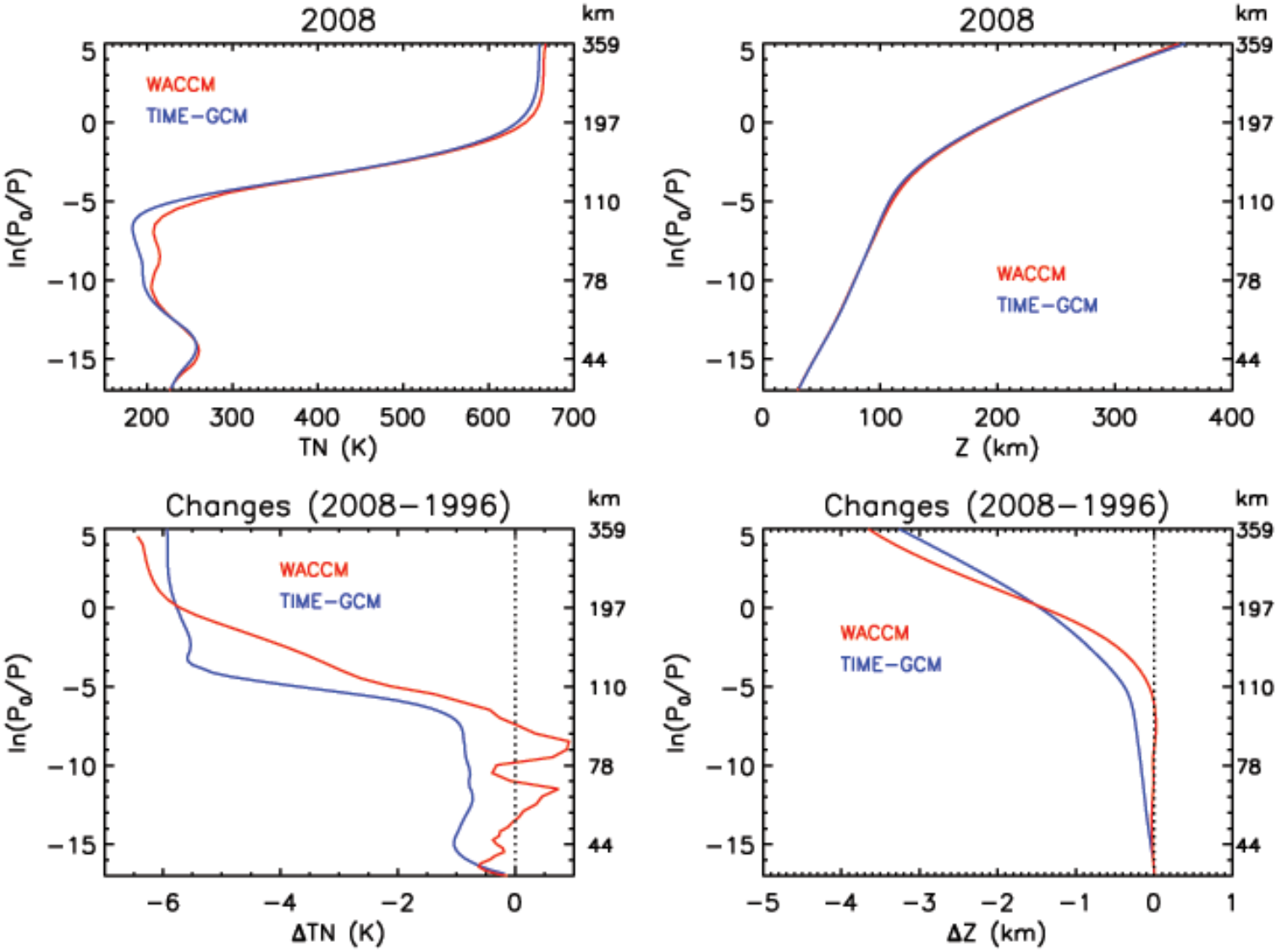
Temperature and Geopotential Height



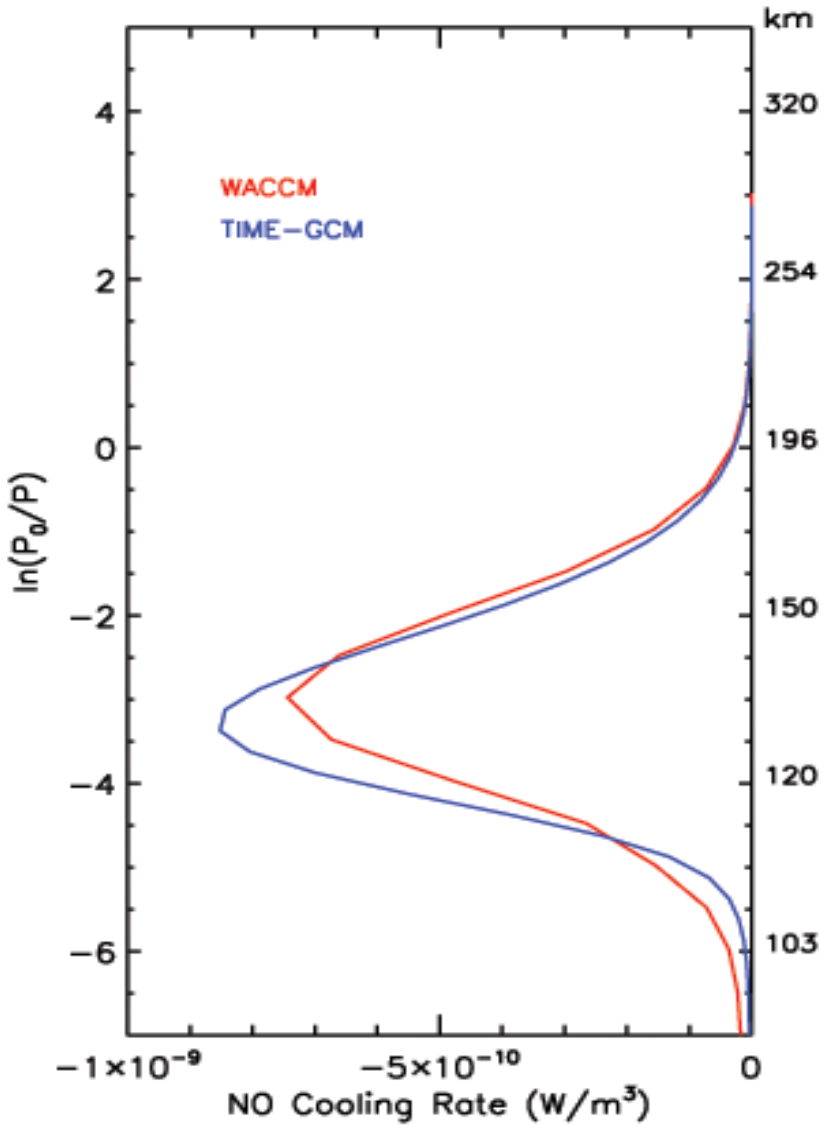
Changes of Temperature and Geopotential Height

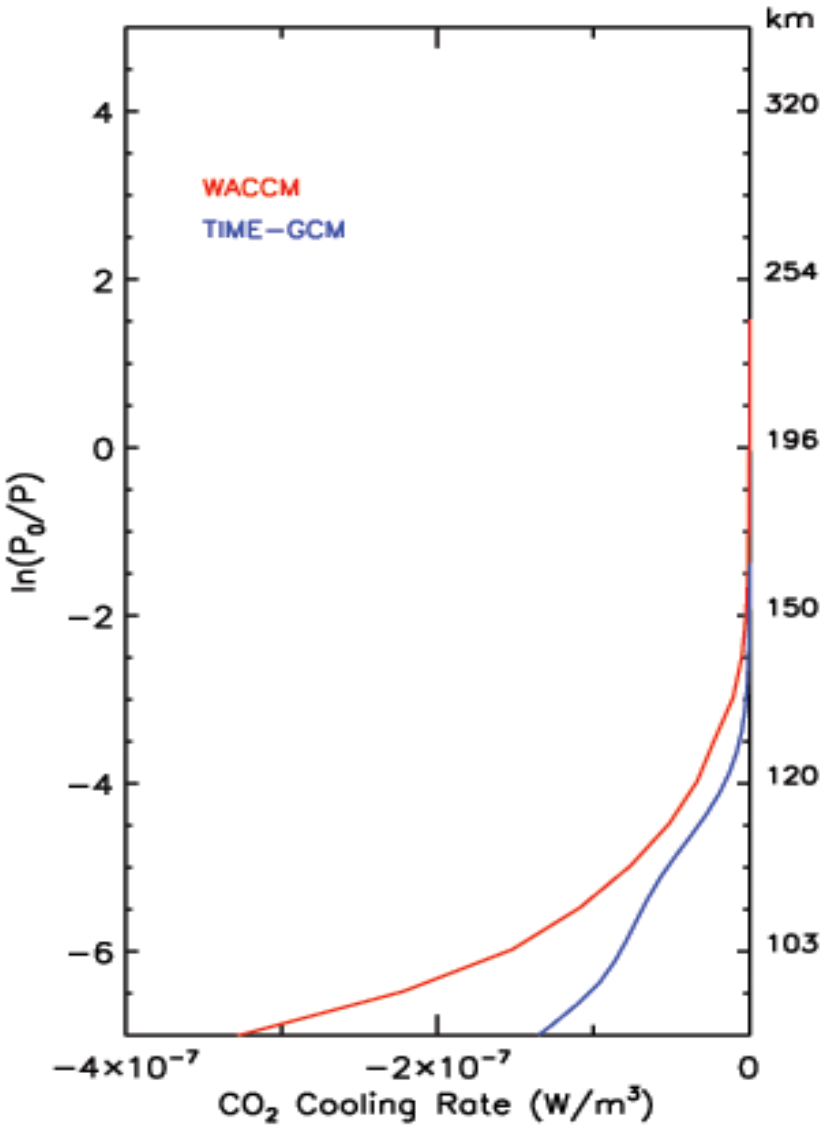


Global Mean Profiles of Temperature and Geopotential height, and their changes

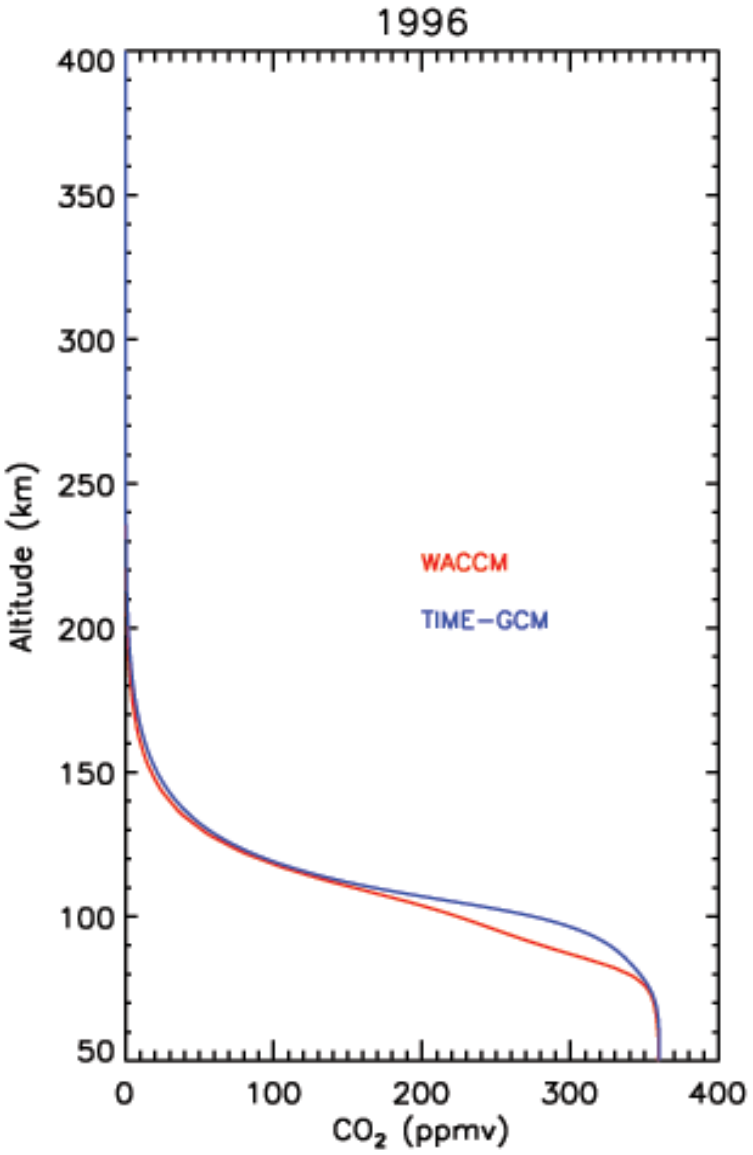


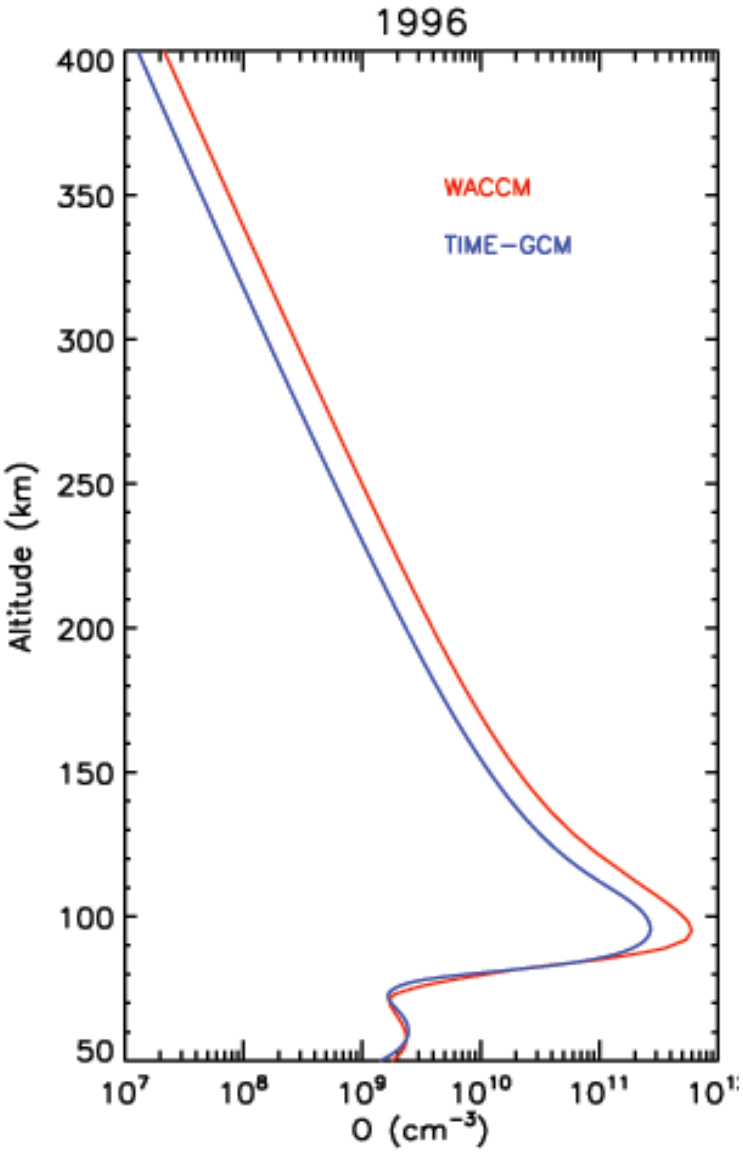
Global Mean Profiles of Infrared Cooling





Comparison of WACCM-X to TIME-GCM

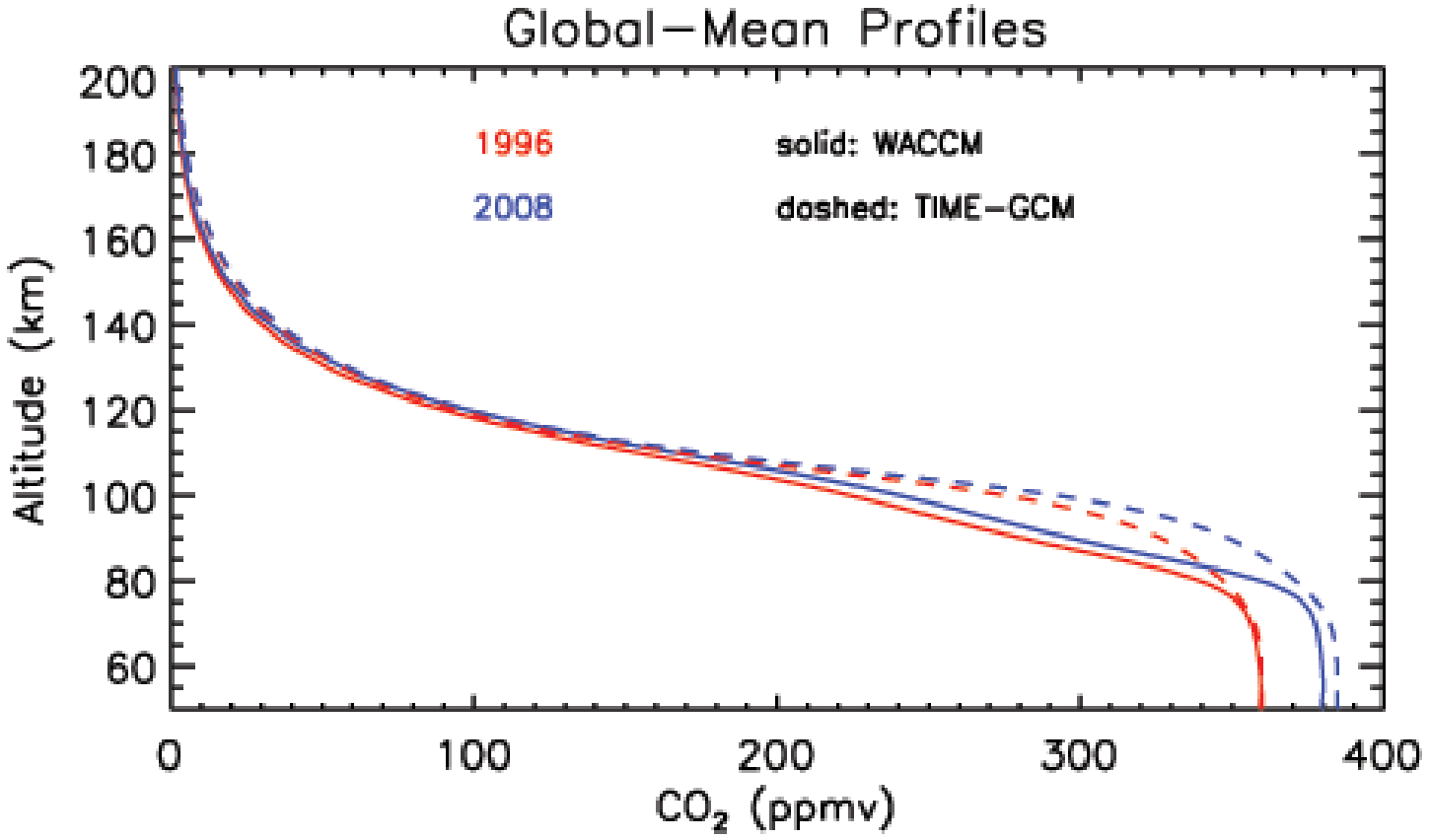




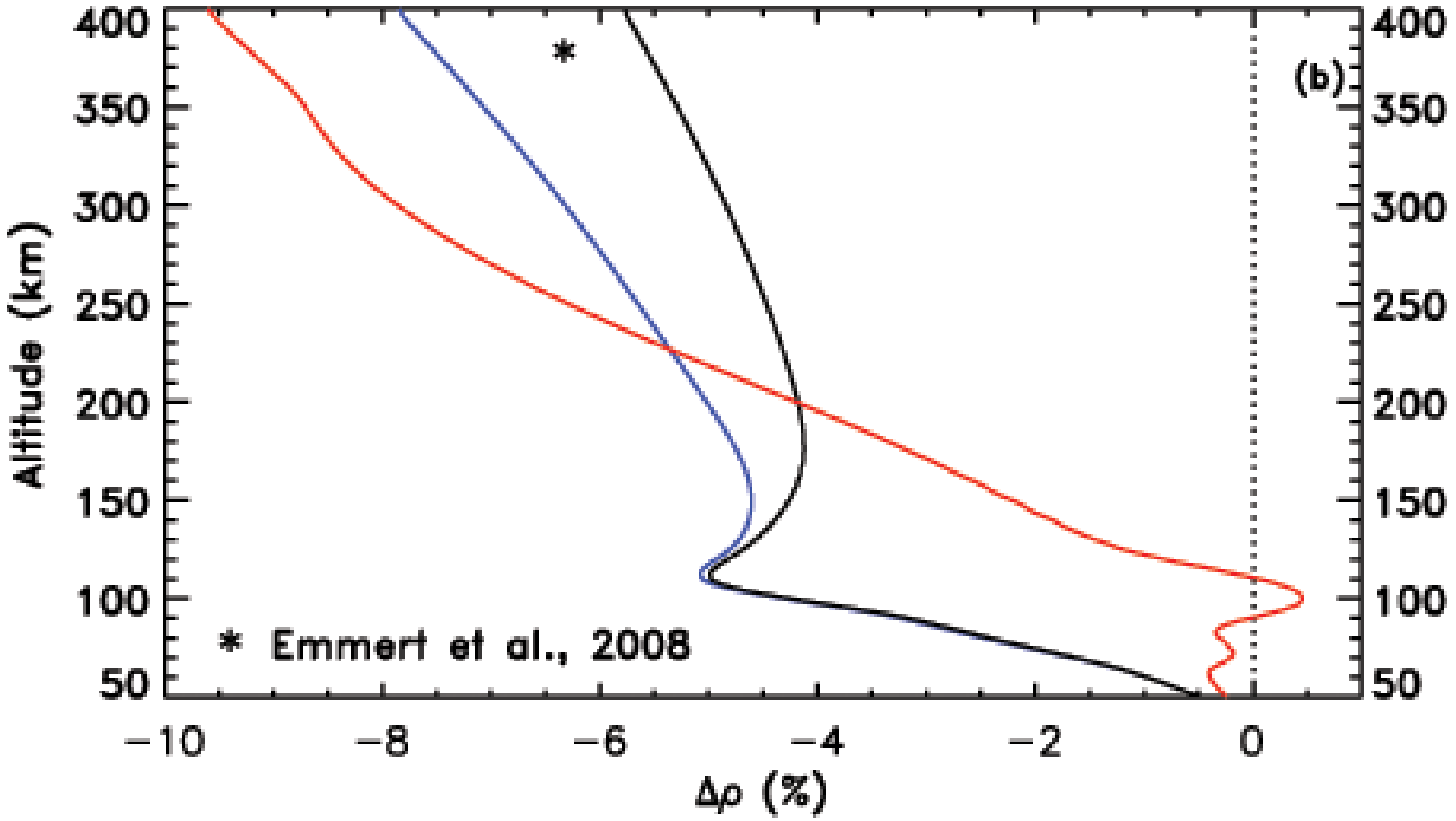
Summary

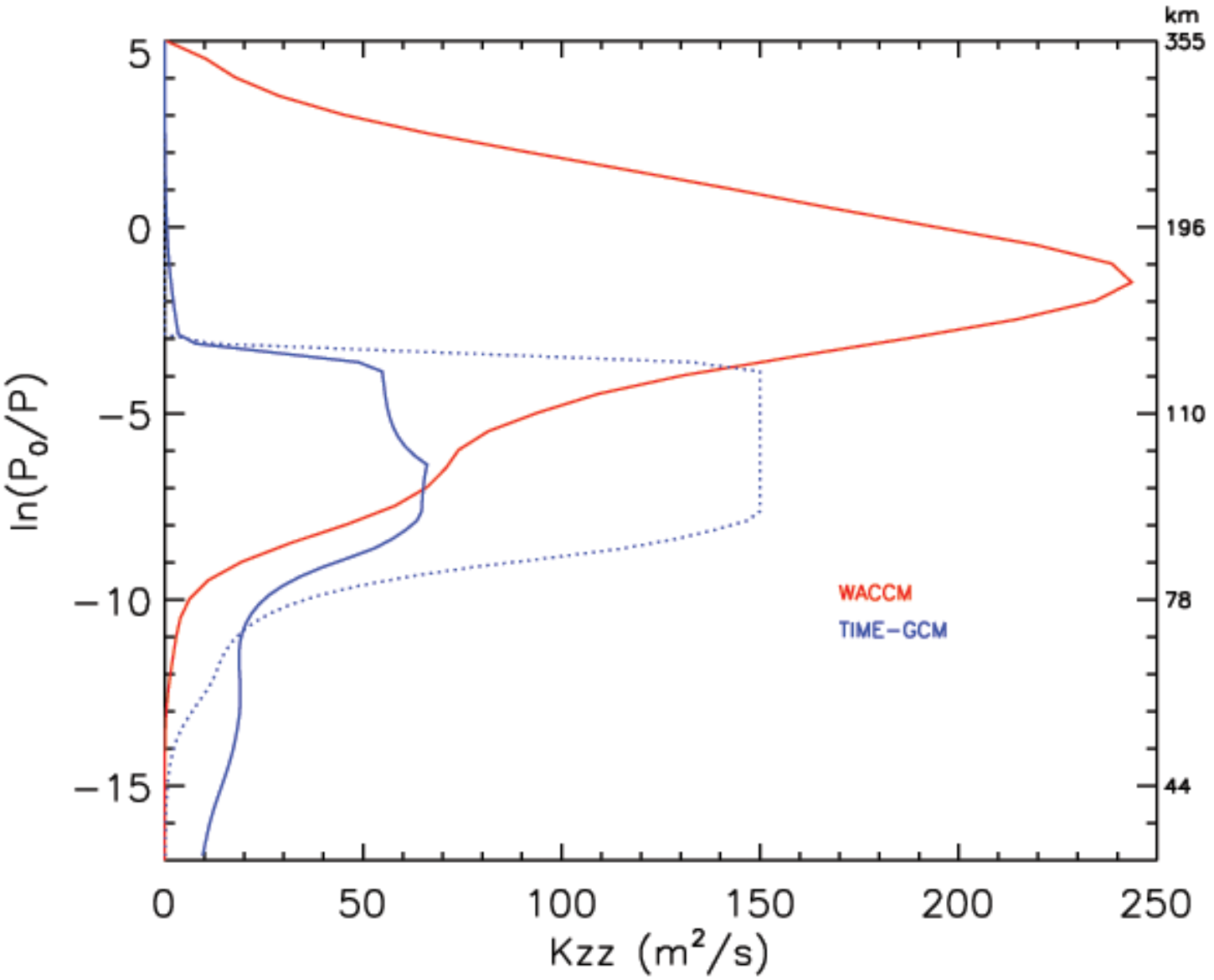
- This preliminary study shows that WACCM-X results are in qualitative agreement with TIME-GCM results;
- Long-term change simulated by WACCM-X is larger than that simulated by TIME-GCM due to much larger CO_2 cooling rate (about double);
- The larger CO_2 cooling rate in WACCM-X is due to the larger atomic oxygen density in WACCM-X (about double).

Comparison of WACCM-X to TIME-GCM

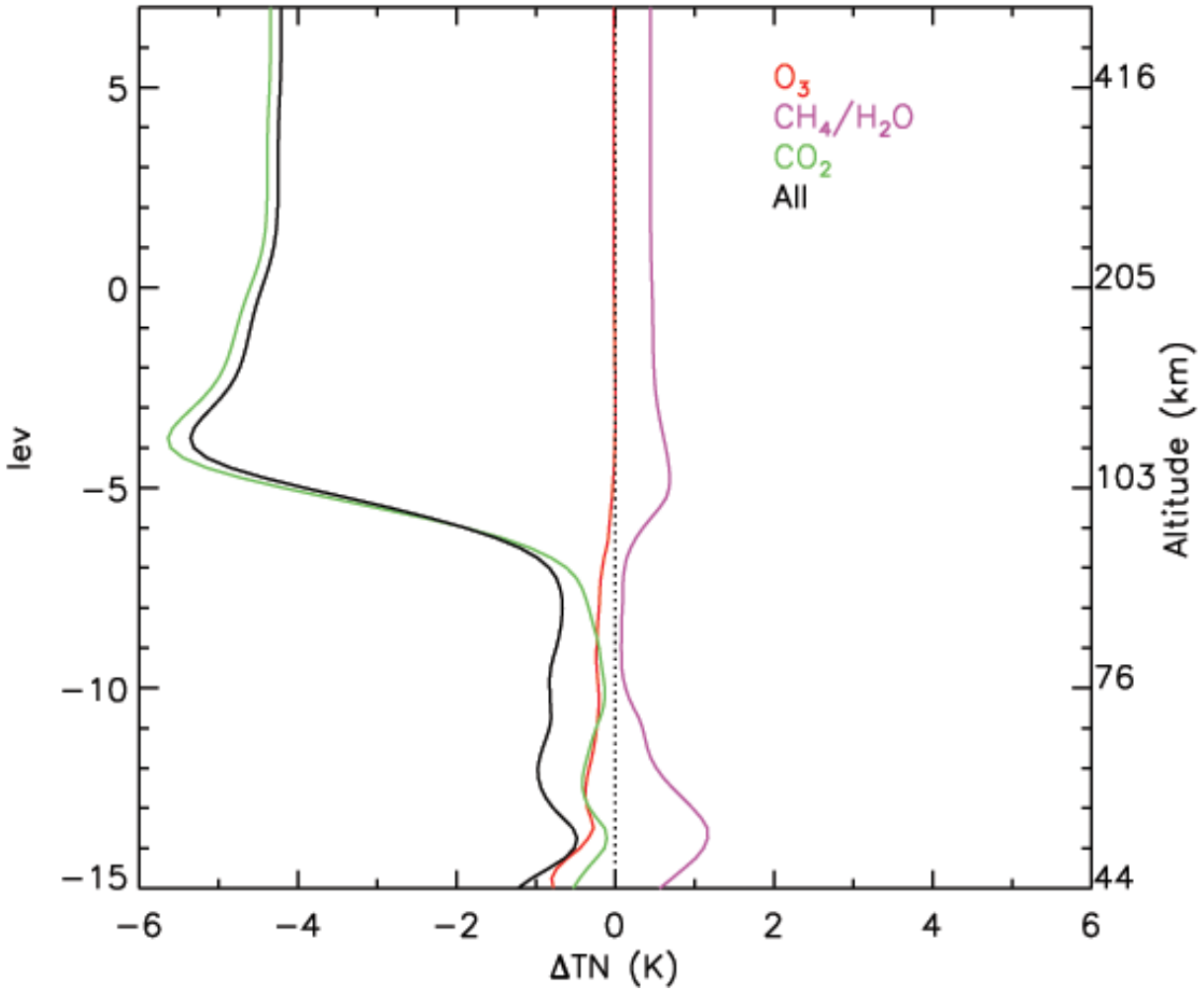


Comparison of WACCM-X to TIME-GCM

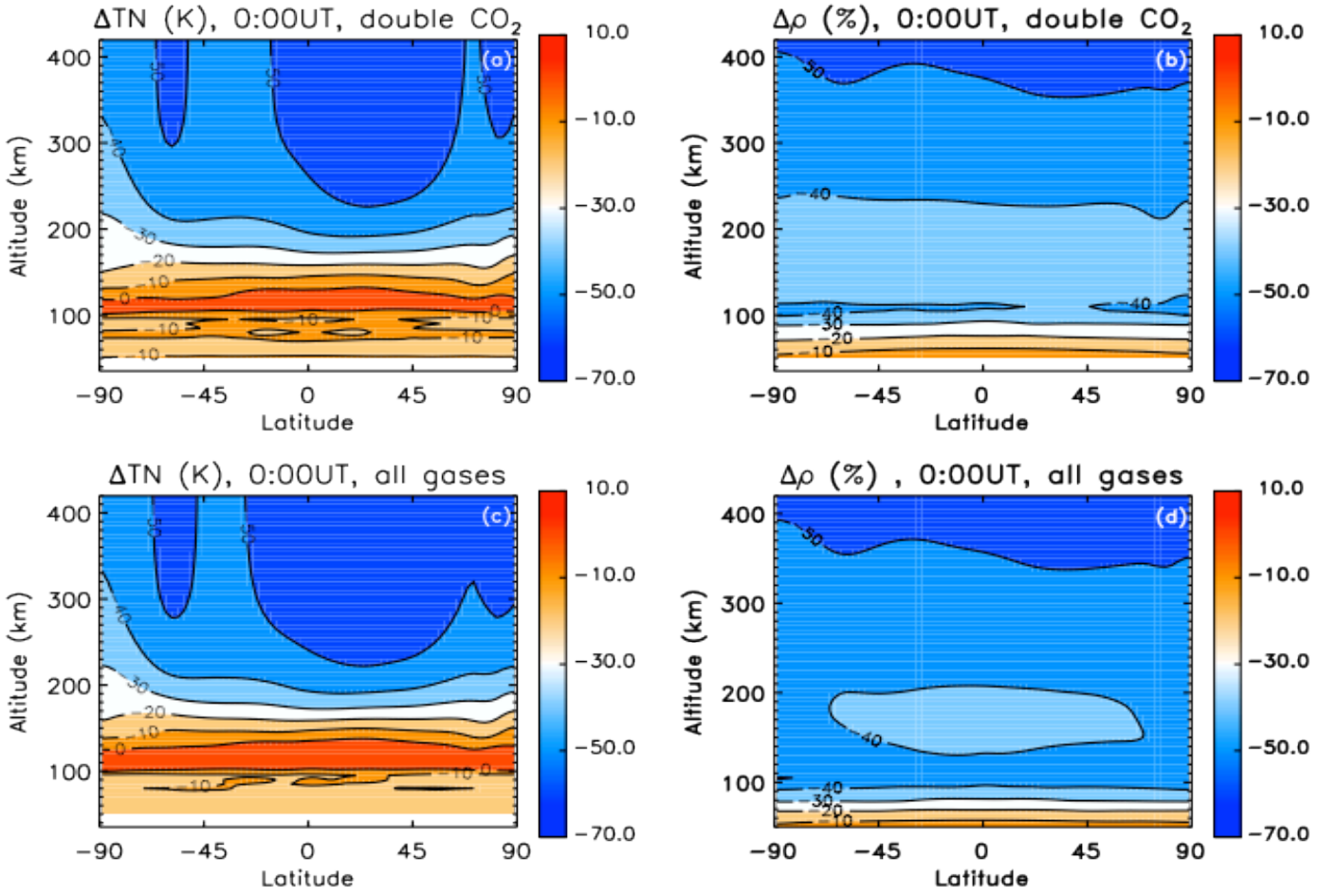



km
355
196
110
78
44
5
0
−5
−10
−15
ln(P₀/P)
0
50
100
150
200
250
Kzz (m²/s)
WACCM
TIME−GCM

Main Forcing: CO_2



Main Forcing: CO_2



Contribution by greenhouse gases: ~ -6%/decade

Global Mean Profiles of Temperature Changes