Dynamical and Chemical Variabilities in CESM3-WACCM7

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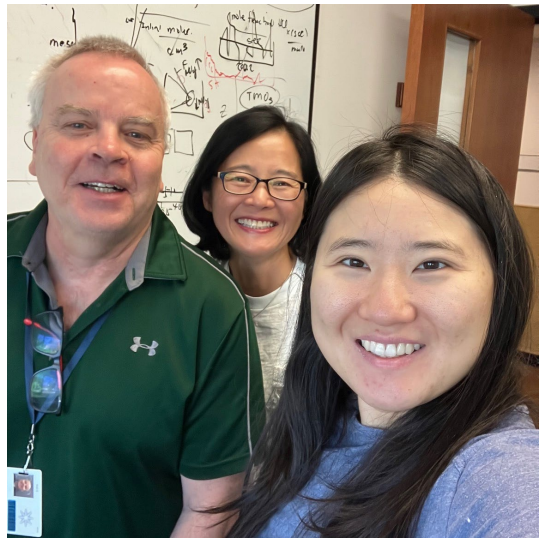
In this talk…

WACCM 7 *vs.* WACCM6

1. Quasi Biennial Oscillation (QBO)

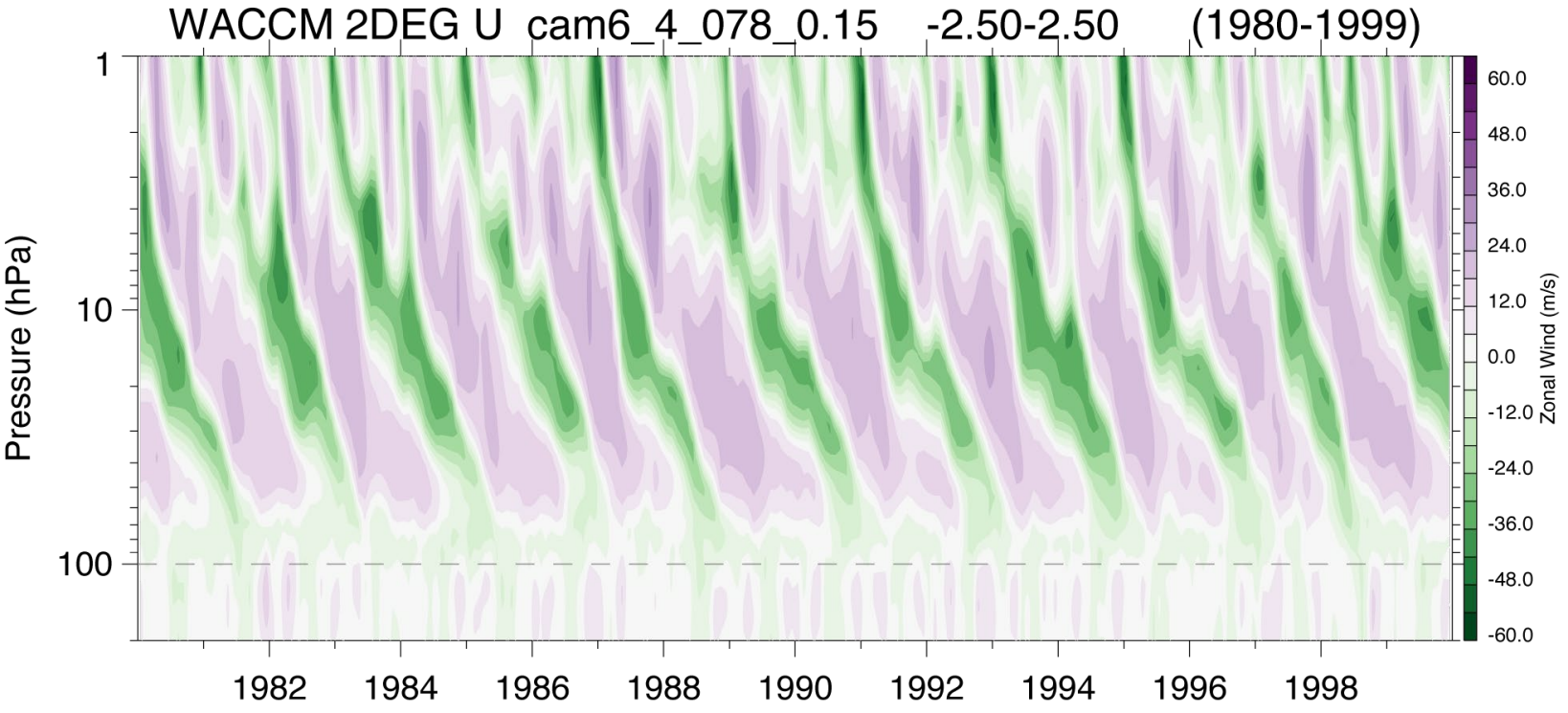
2. Water Vapor Tape Recorder

3. SH Polar Cap (60ºS-90ºS)
   Temperatures
   Total Column Ozone



QBO: WACCM6 -> WACCM7

Effect of HB diffusion (Holtslag and Beljaars, 1989)
Weakens the QBO amplitudes
Remove background and stable mixing (HB diffusion on Ri ≤ 0)



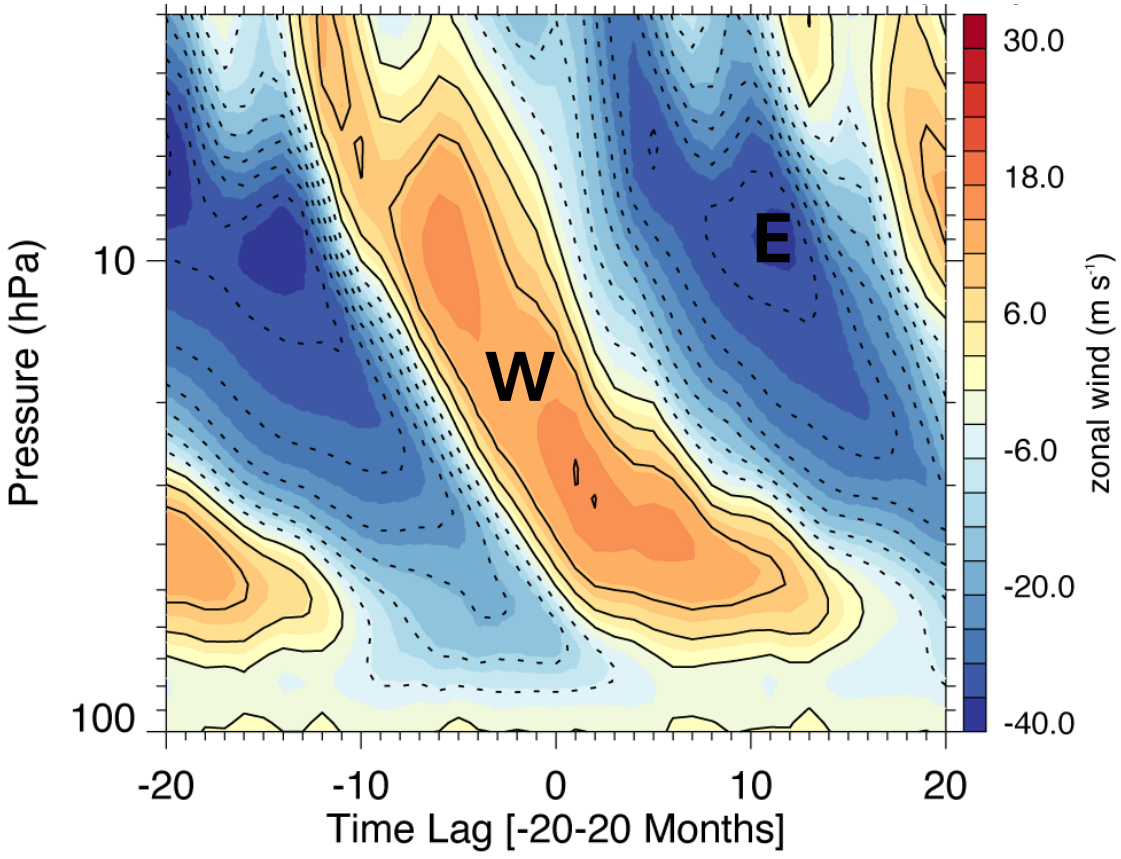
QBO in WACCM7 2 DEG

Reasonable amplitudes
Shorter period

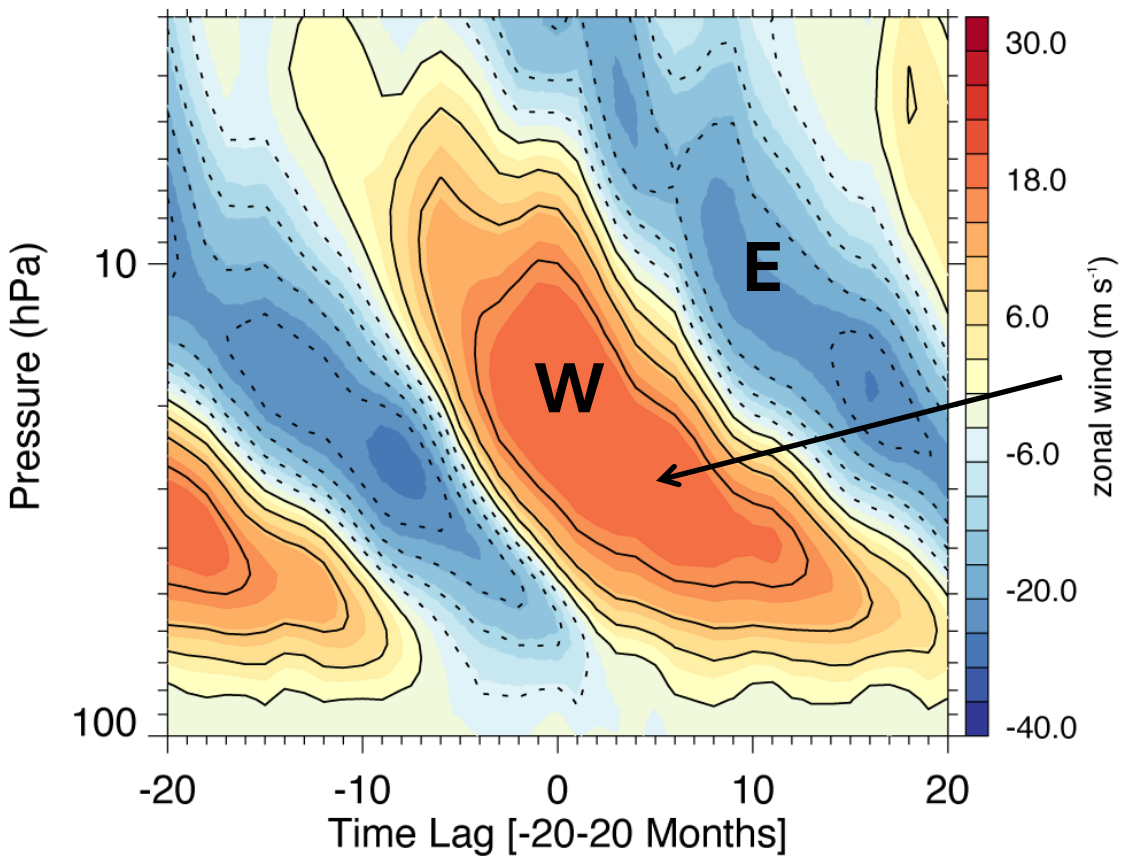
Tuning underway

QBO – Horizontal Resolution (1 or 2 DEG?)

WACCM 5.4 - 1DEG



WACCM 6 - 2DEG



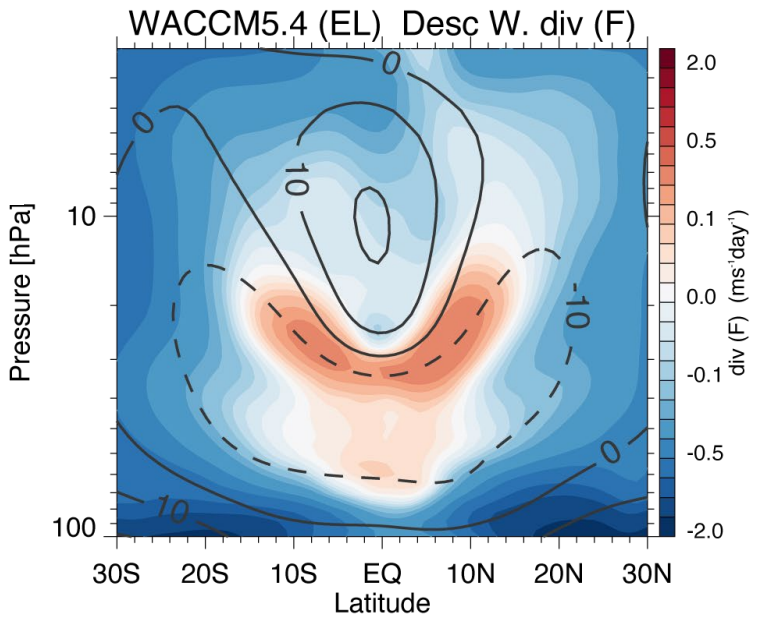
WACCM 2° - Stronger Westerly
Weaker Easterly

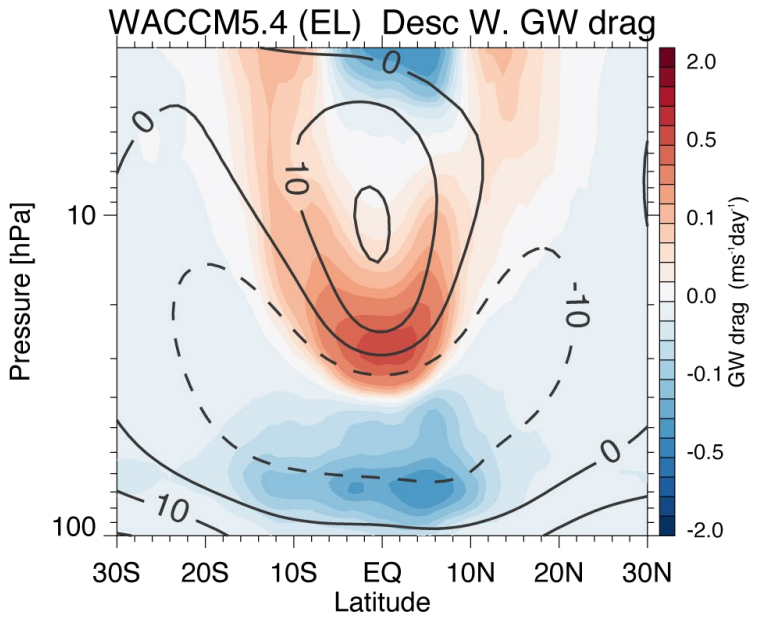
QBO composites (1980-1999, 45 hPa)

QBO – Horizontal Resolution (Waves)

WACCM 5.4
1DEG

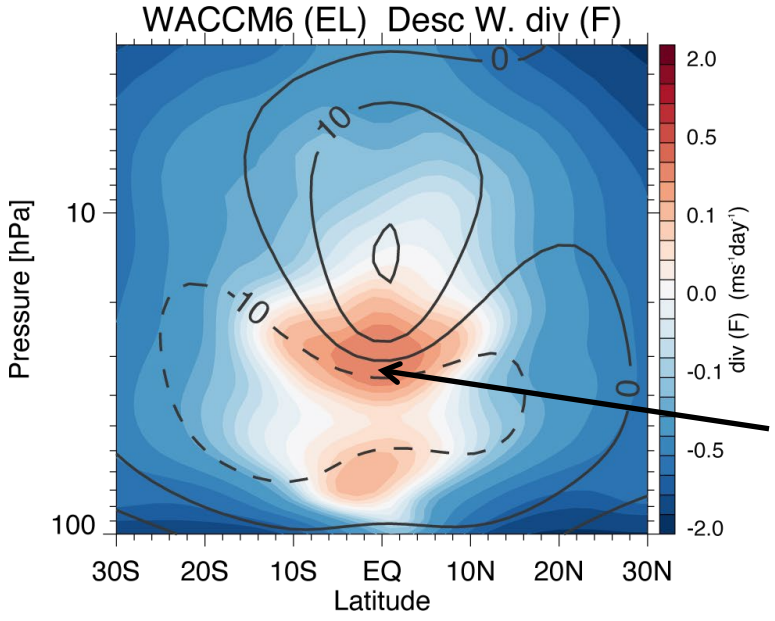
EP Flux Div.
(resolved waves)



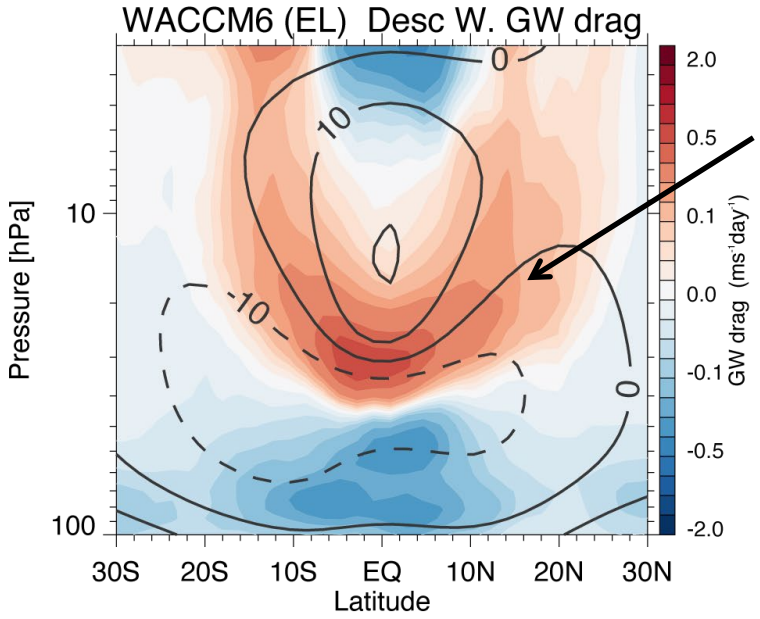


Gravity Wave
Drag
(parameterized
waves)

WACCM 6
2DEG

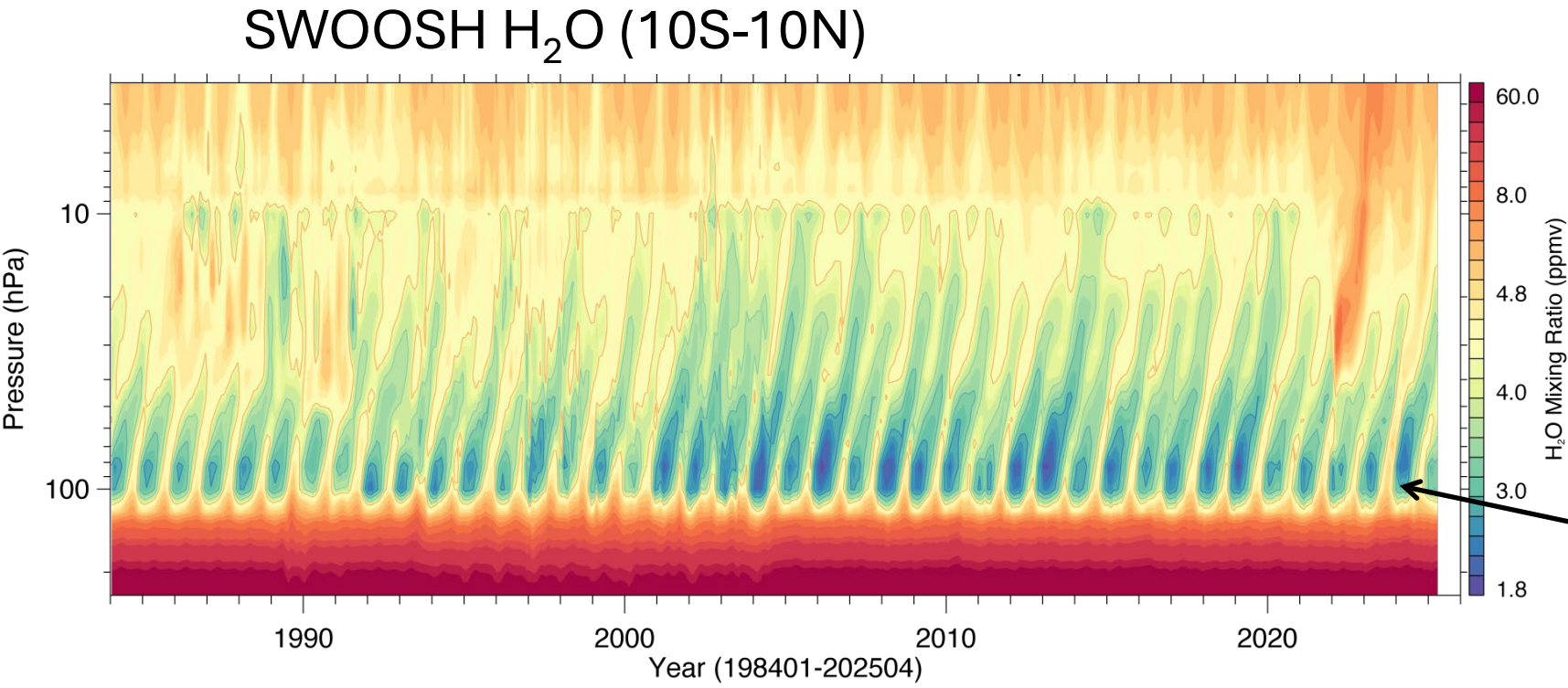


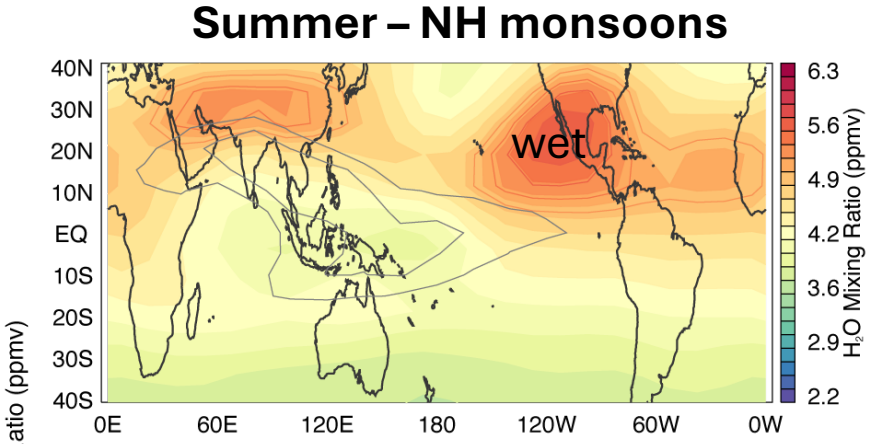
Max at the equator

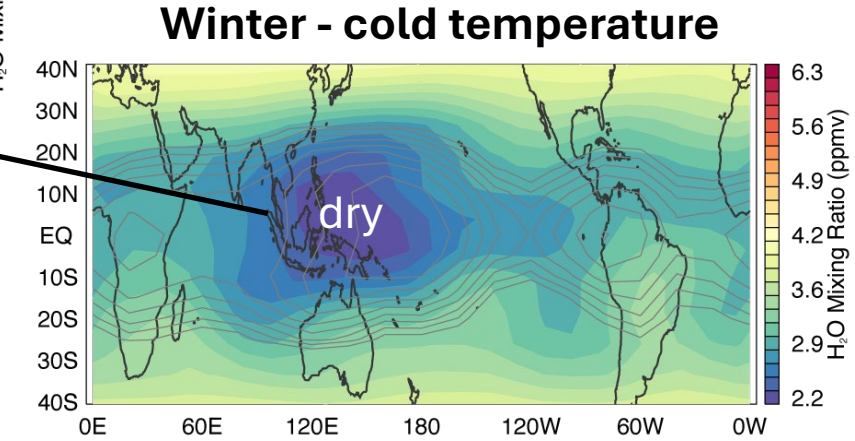


Larger contribution
from GW drag
(2 Deg)

H_2O Tape Recorder (Observations: SWOOSH & MLS)





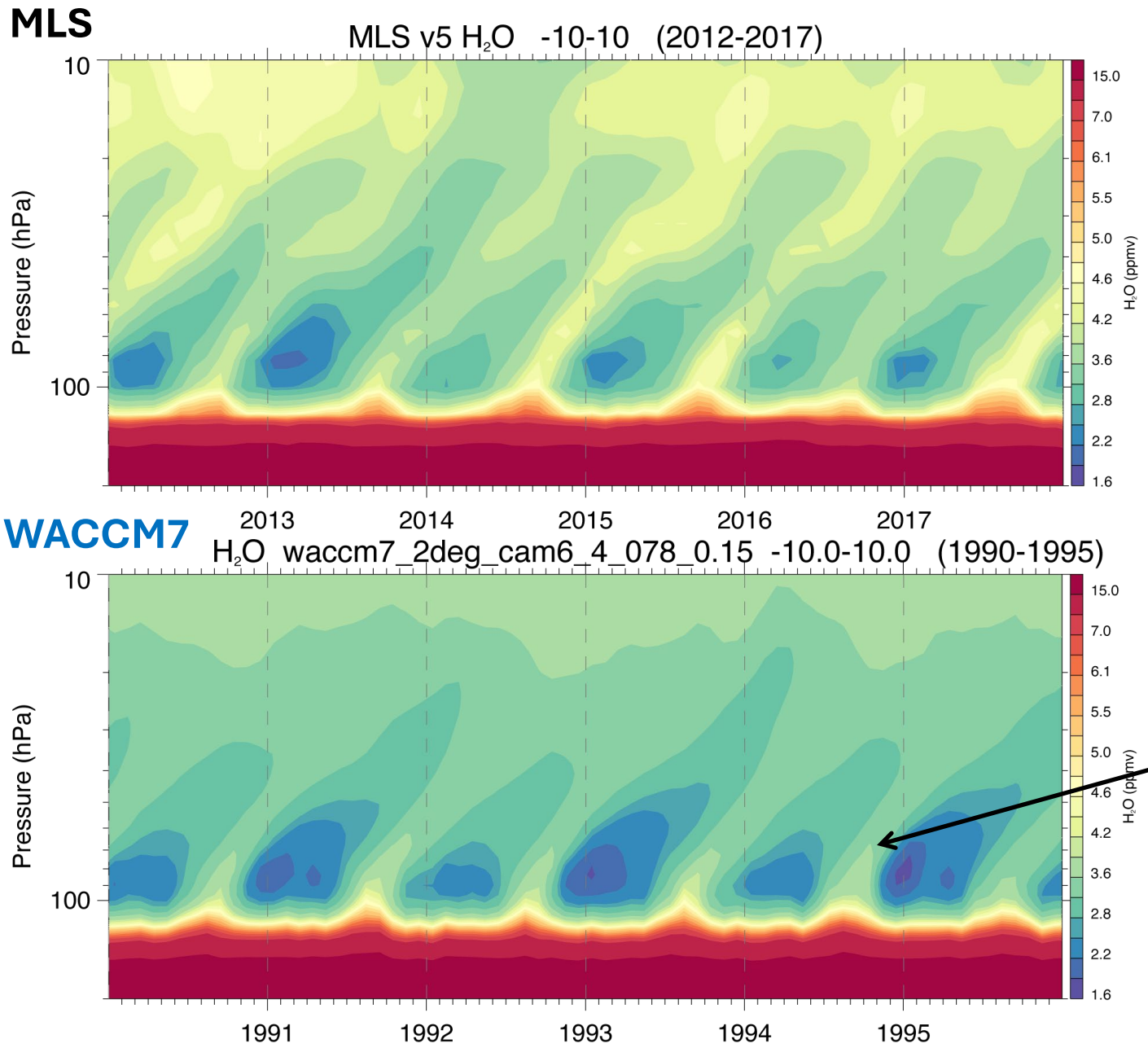


Large year to year variability in H_2O tape recorder

Wet phase – NH summer monsoons

Dry phase – Tropical cold point temperatures

H_2O Tape Recorder (MLS *vs*. WACCM7)



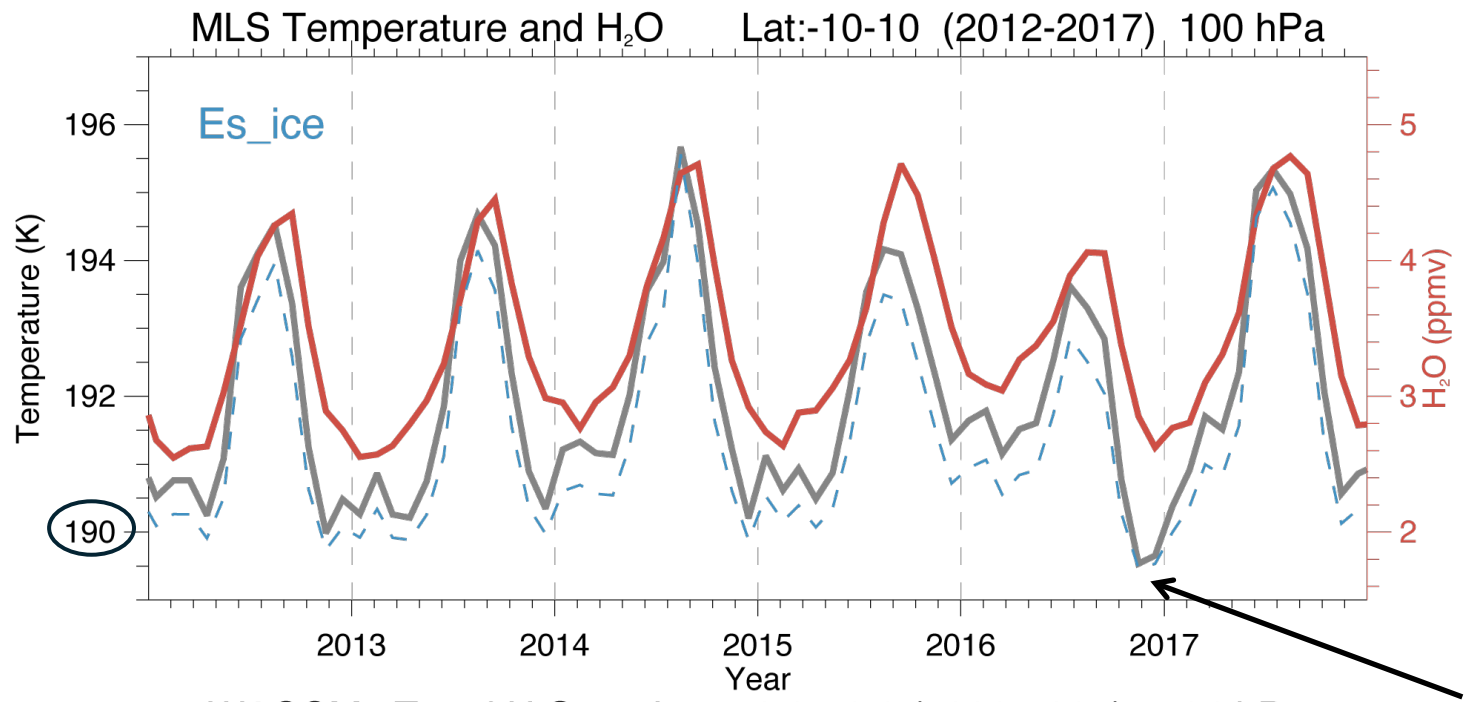
WACCM7 H_2O tape recorder

-entire stratosphere is drier than MLS

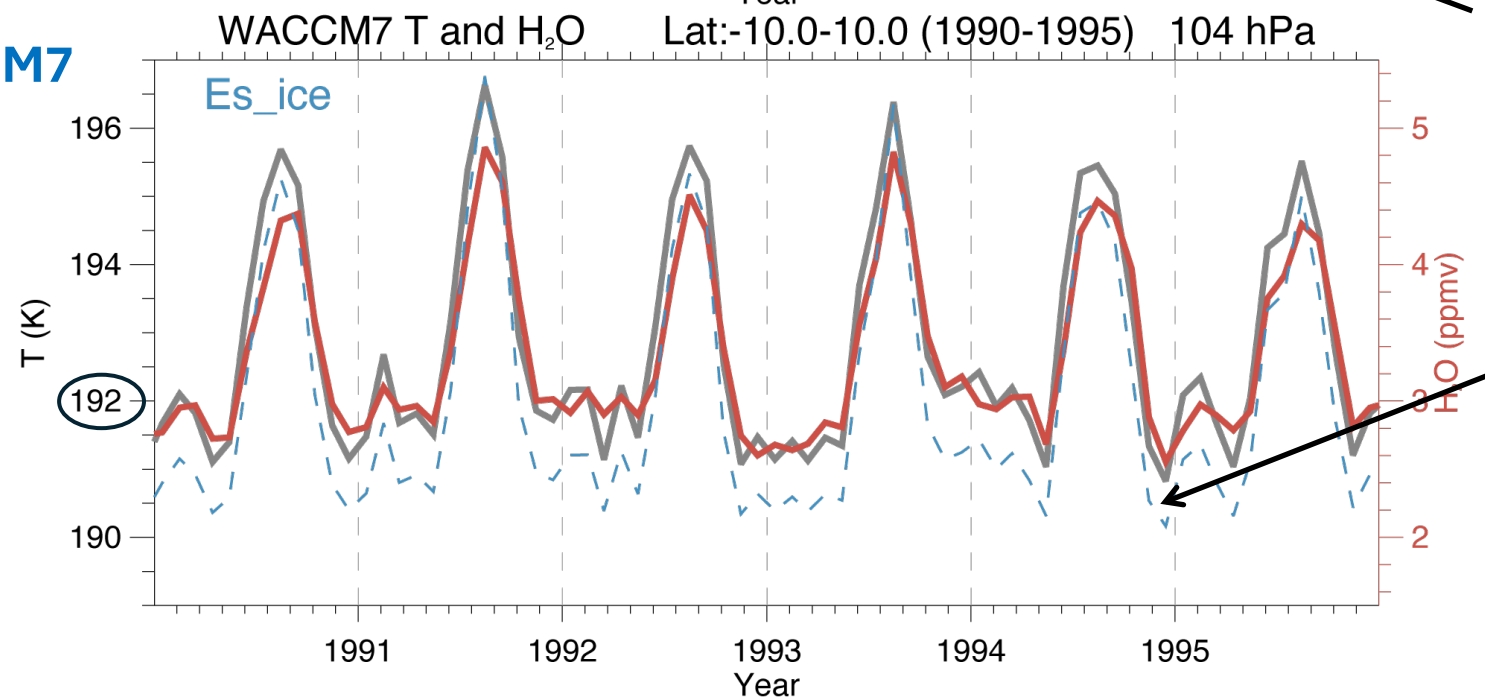
-both wet and dry phases < MLS

-wet phase does not propagate high enough (only up to ~70 hPa)

MLS



WACCM7



Dry phase

Is WACCM7 too cold ?

Temperatre at 100 hPa is warmer than MLS.

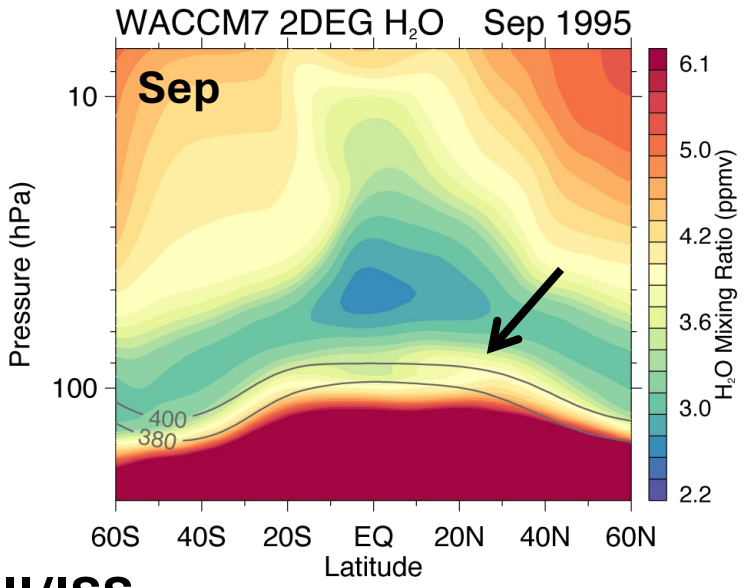
Clausius-Clapeyron Eq.

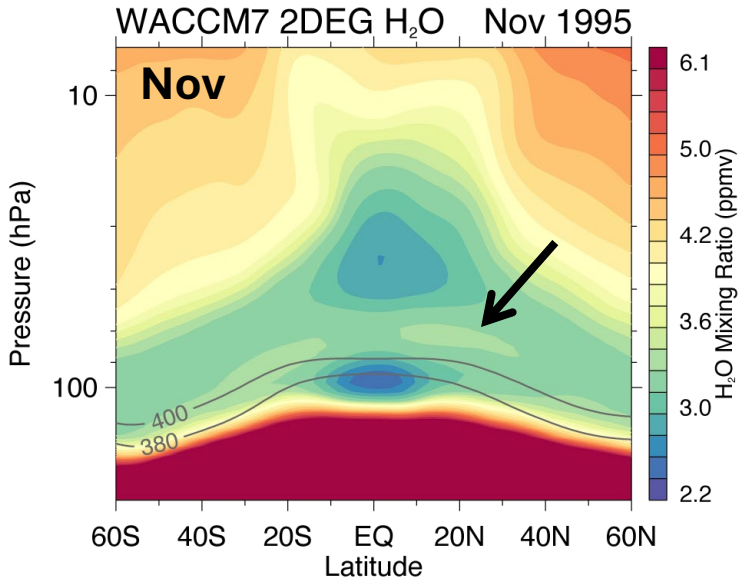
MLS (Nov 2016)
T – 189. 5K
Es_water – **5.56 ppmv**
Es_ice– 1.73 ppmv

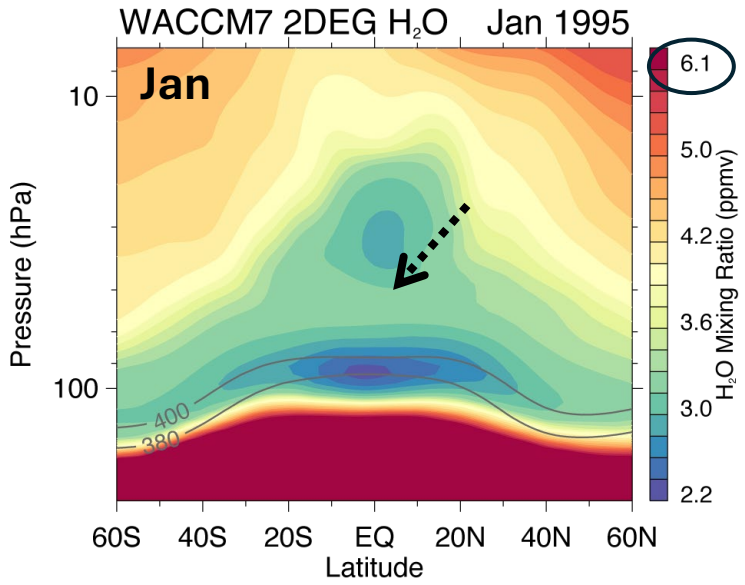
WACCM7 (Dec 1994)
T – 190.8 K
Es_water – **6.51 ppmv**
Es_ice – 2.08 ppmv

Evolution of wet phase

WACCM7

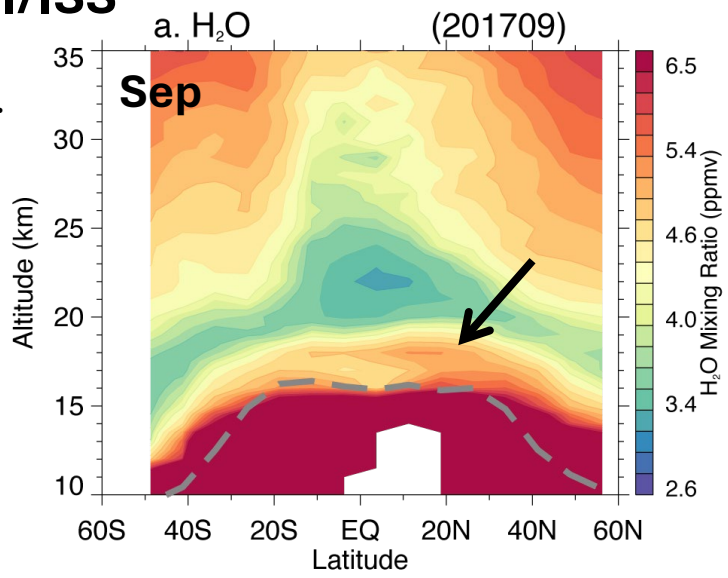


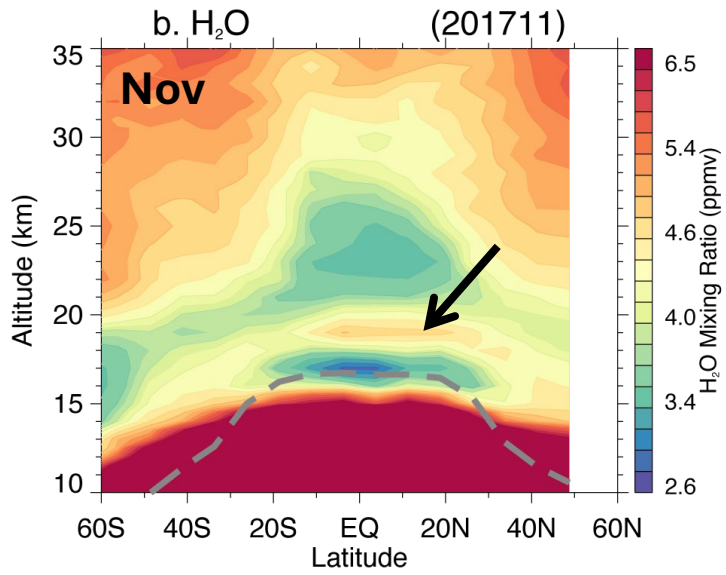


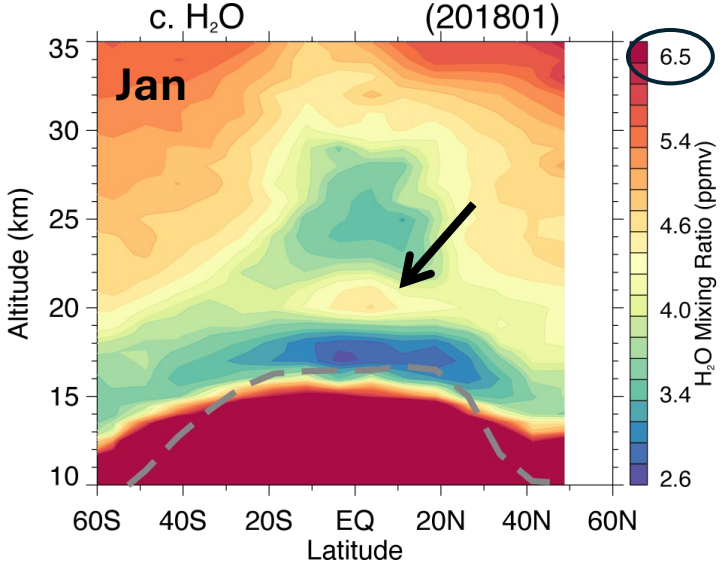


SAGE III/ISS

Park et al. (2021)



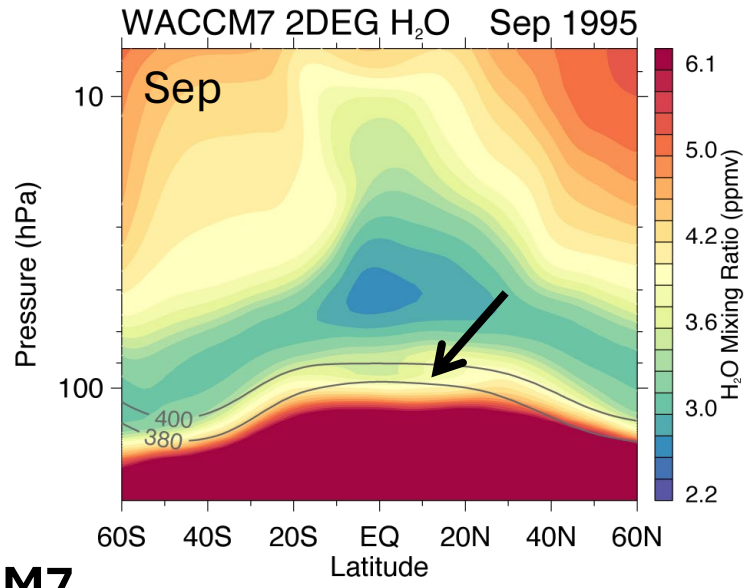


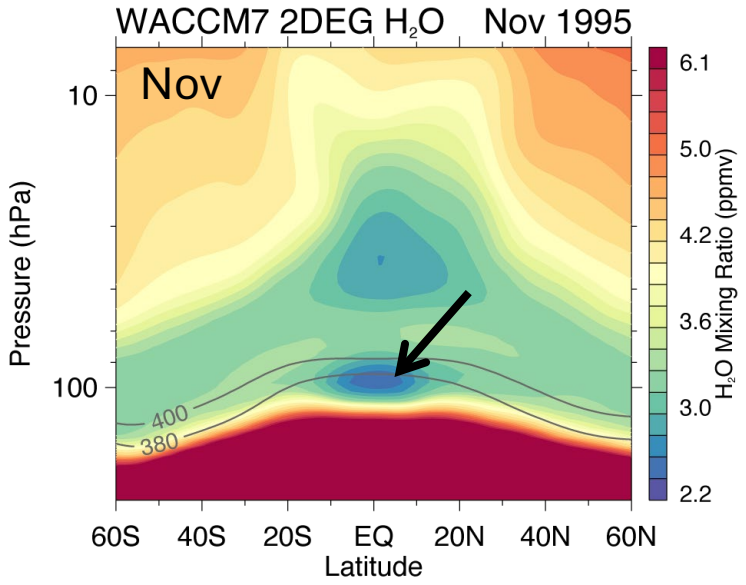


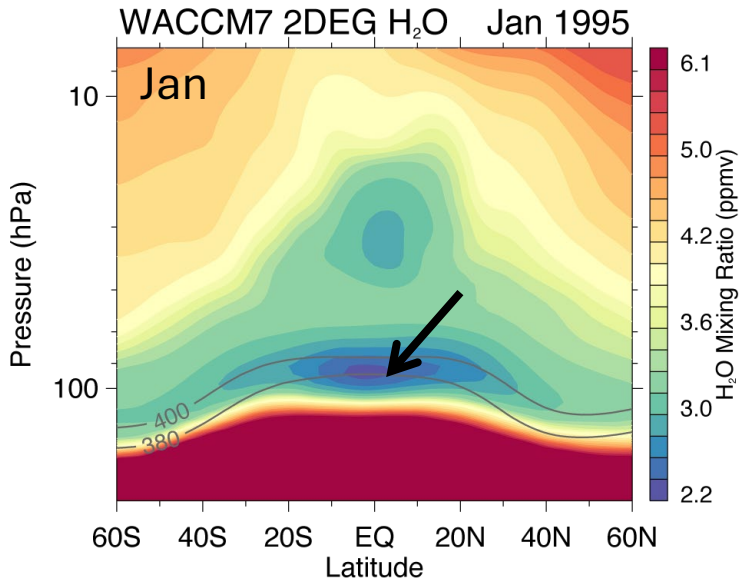
WACCM7 – Wet phase does not propagate high enough and much drier than SAGE III/ISS.

Evolution of wet phase

WACCM7

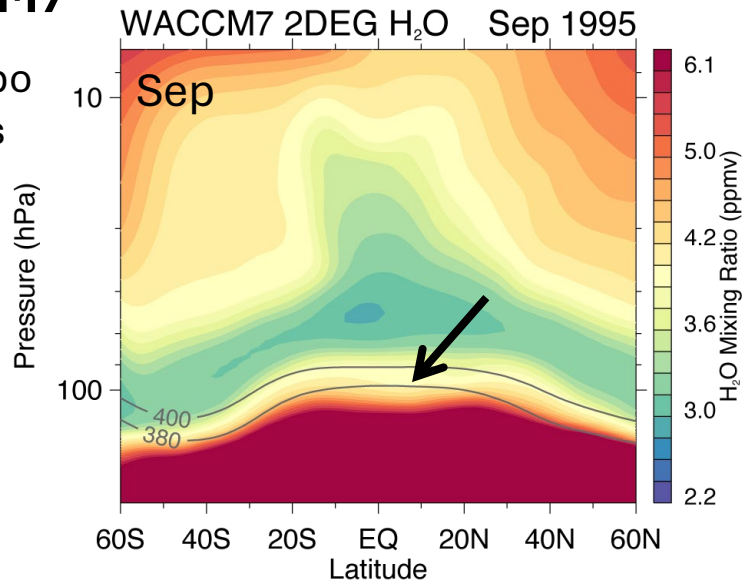


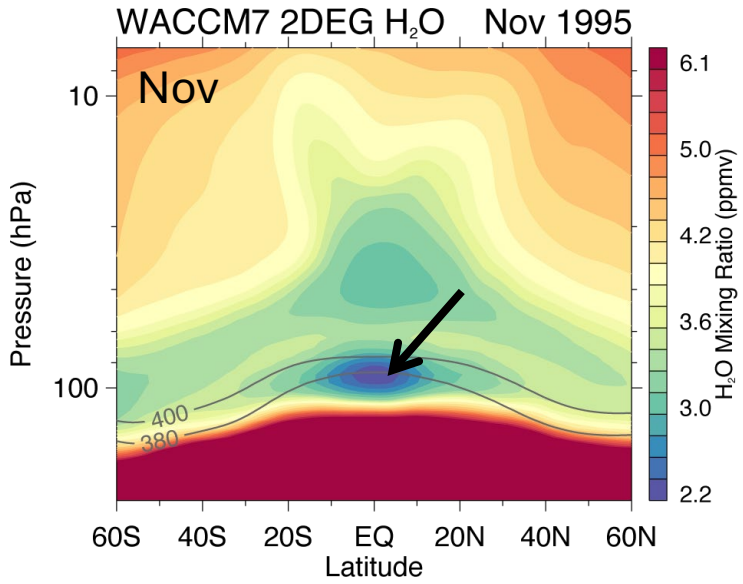


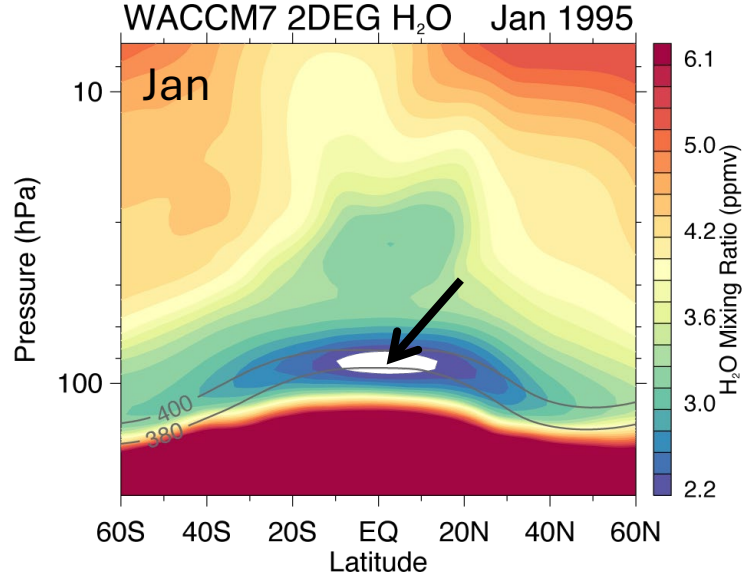


WACCM7

roughtopo
-beljaars

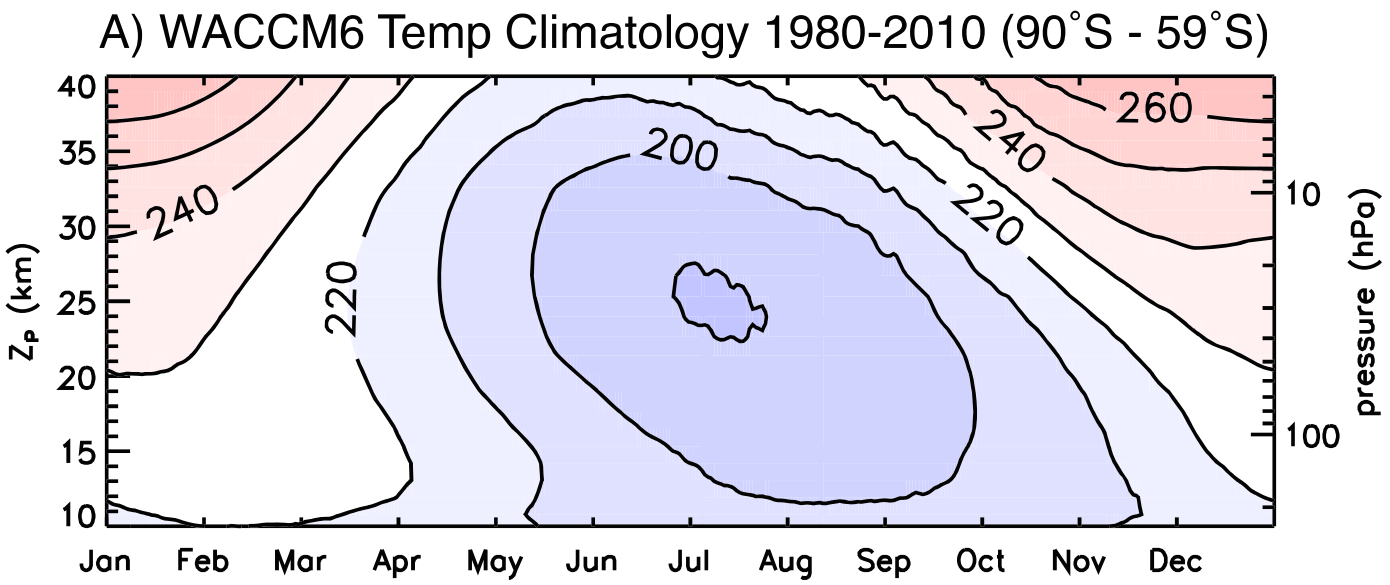






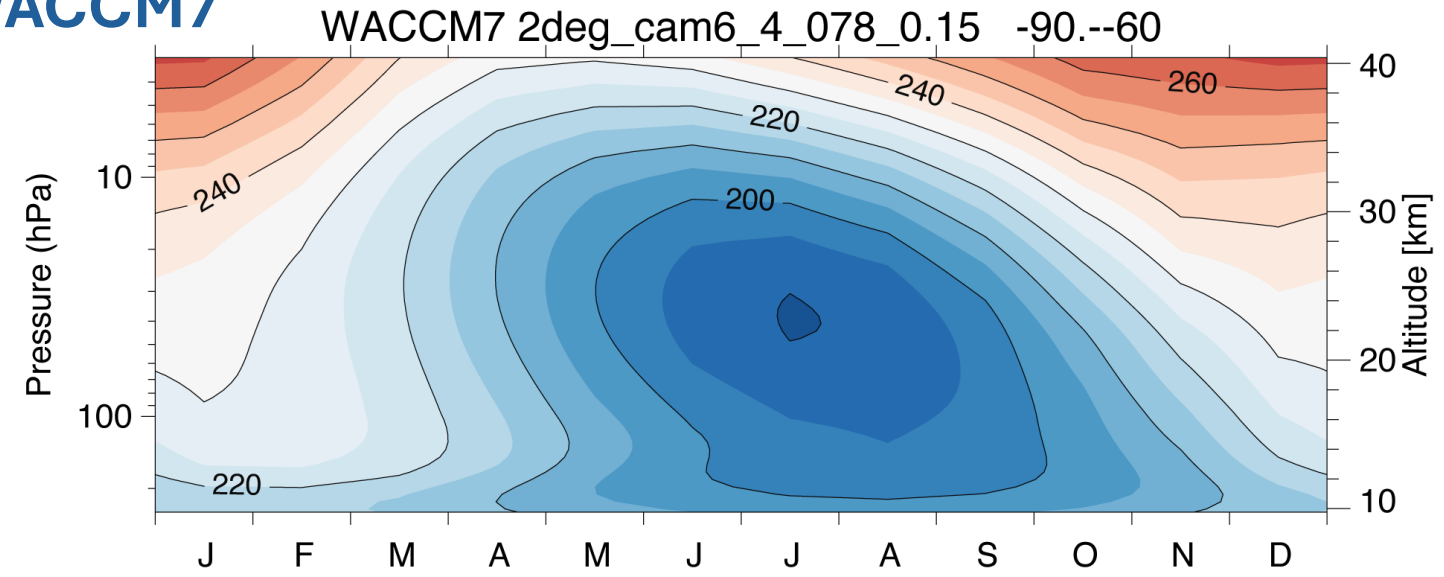
WACCM7: Roughtopo-beljaars makes H_2O even drier in the tropical lower stratosphere and slightly wetter above especially in NH winter.

WACCM6



Gettelman et al. (2019)

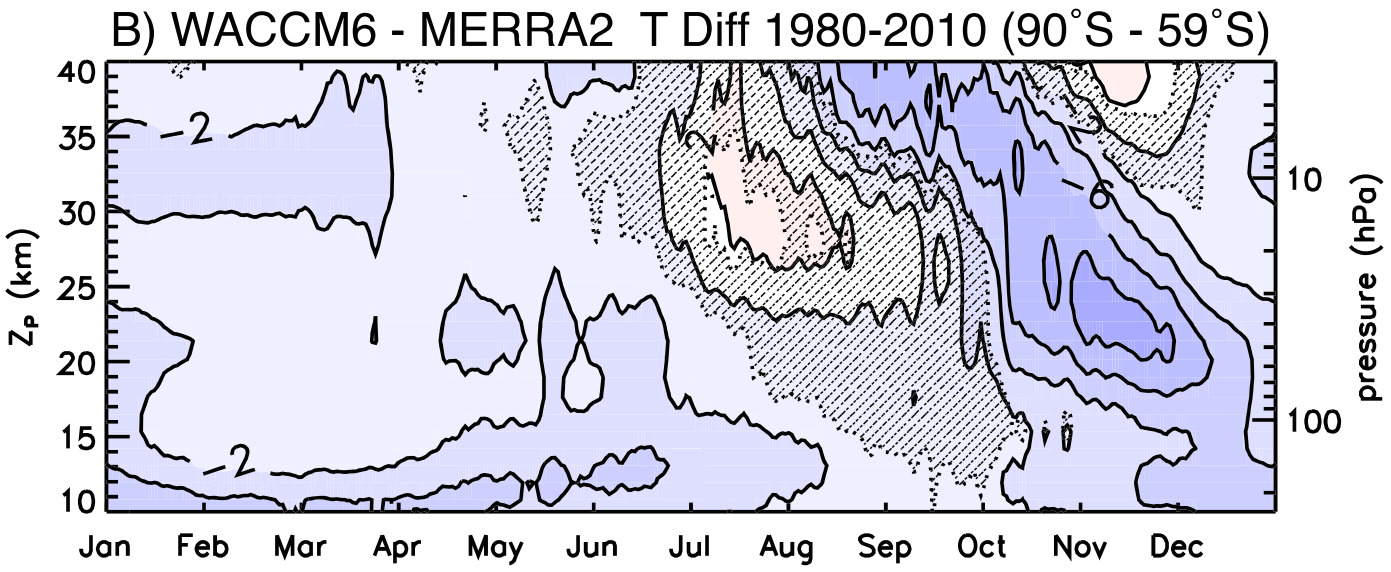
WACCM7



Polar Cap Temperatures (60ºS-90ºS)

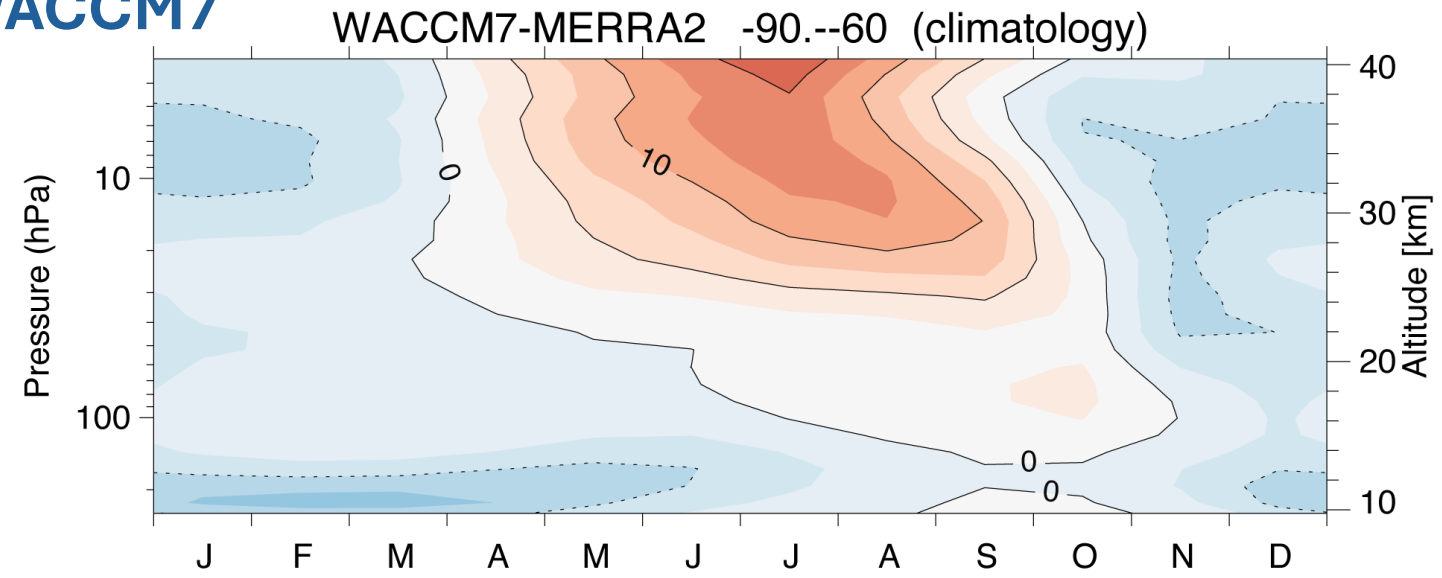
- Minimum T in July are similar (~190K) but located at lower altitude in WACCM7
- WACCM7 T lower in the lower stratosphere (Dec-Mar)

WACCM6



Gettelman et al. (2019)

WACCM7

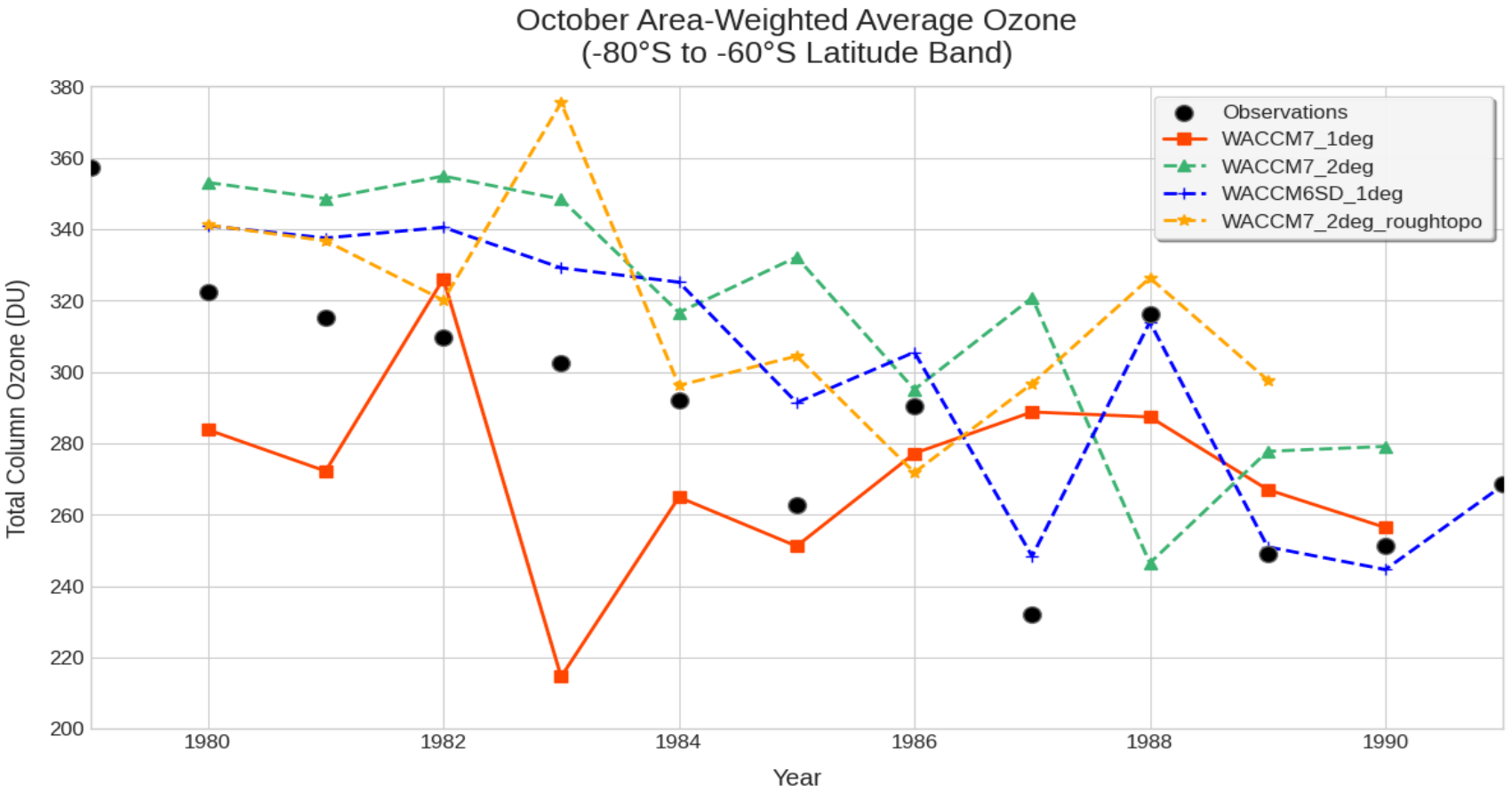


Polar Cap Temperatures (WACCM-MERRA2)

- SH winter (JJA) T biases propagate downward in spring
- Due to delayed breakdown of the SH polar vortex

- WACCM7 T bias much higher than WACCM6 above 25 km (Apr-Sep)

Total Column Ozone (WACCM6 *vs*. WACCM7)



SH Polar Region

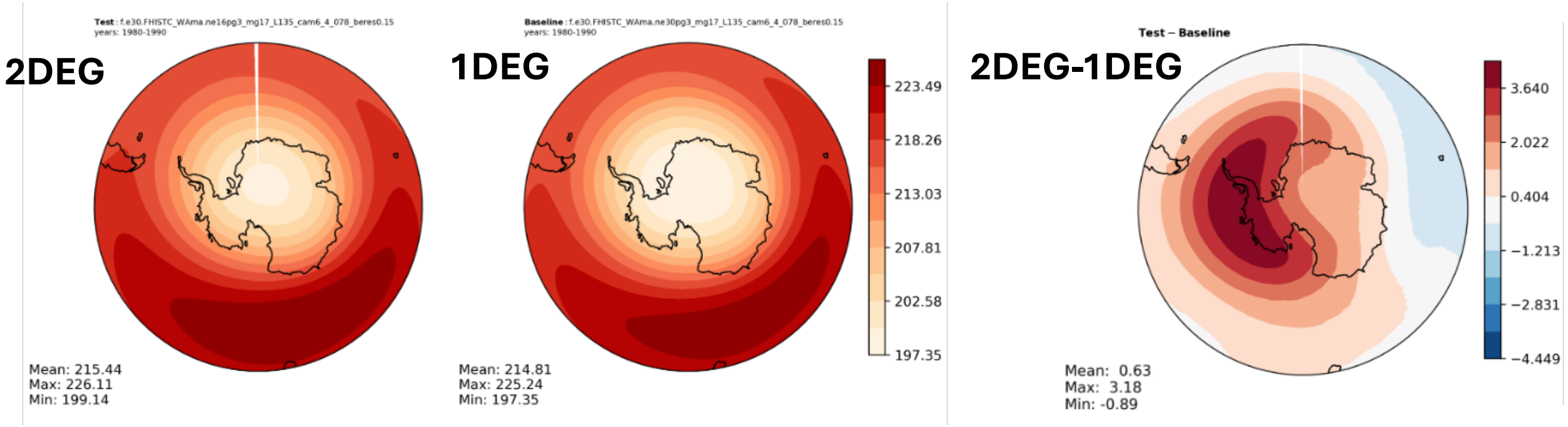
Cold temperatures (~ 78ºC)
Heterogeneous chemistry
Destroy ozone

Cold T –> Less Ozone

WACCM7 1DEG : Cold – Low Total Column ozone
WACCM6SD (MERRA2): Higher than observations
WACCM7 2DEG: Higher than WACCM6
Observations:SBUV-MOD

Figure from Jun Zhang

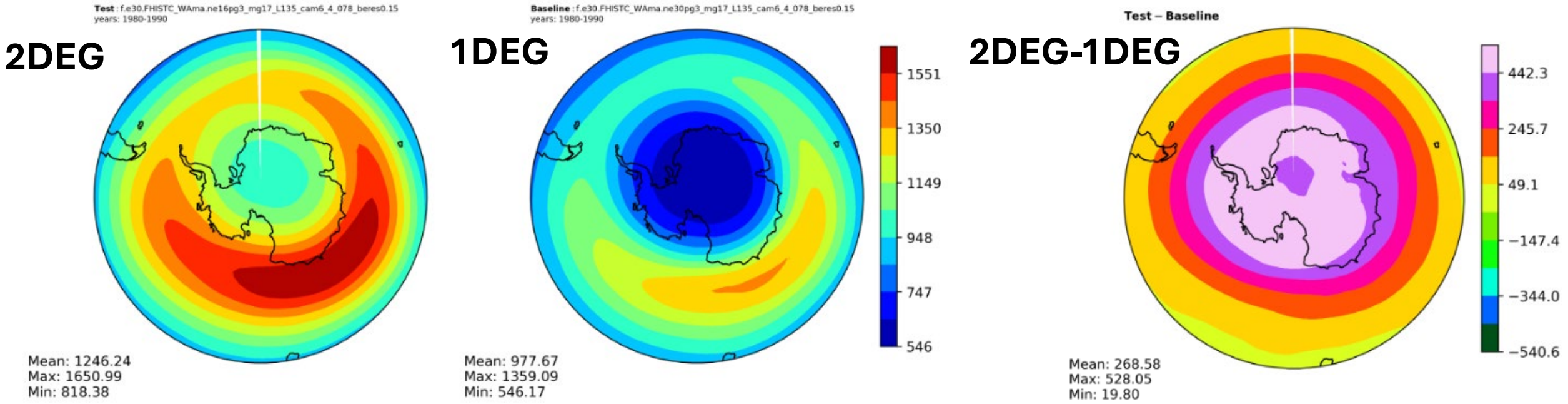
WACCM7 Temperature (100 hPa, Sep-Nov)



Temperature is warmer (2-3K) in WACCM7 2-deg simulation.

Figure from Jun Zhang

WACCM7 Ozone (100 hPa, Sep-Nov)



WACCM7 ozone is significantly lower in 1-deg than 2-deg simulation in the SH polar cap.

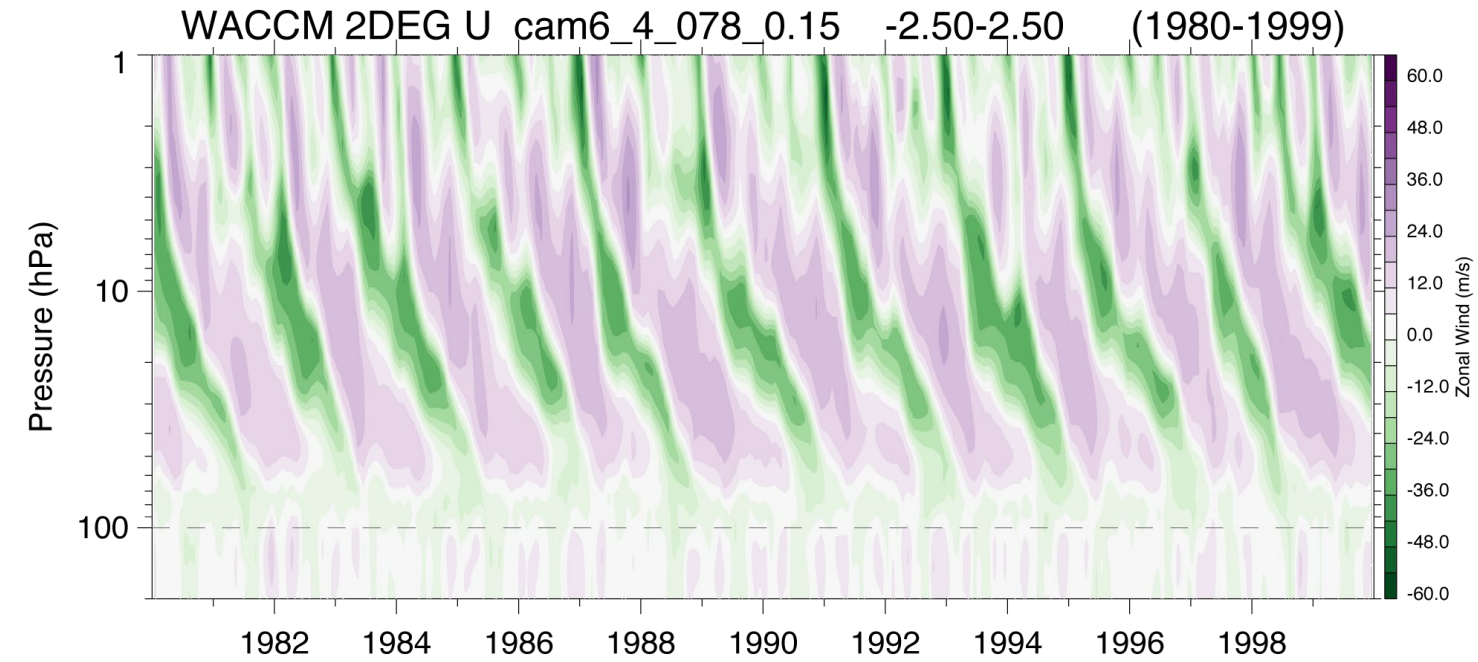
Figure from Jun Zhang

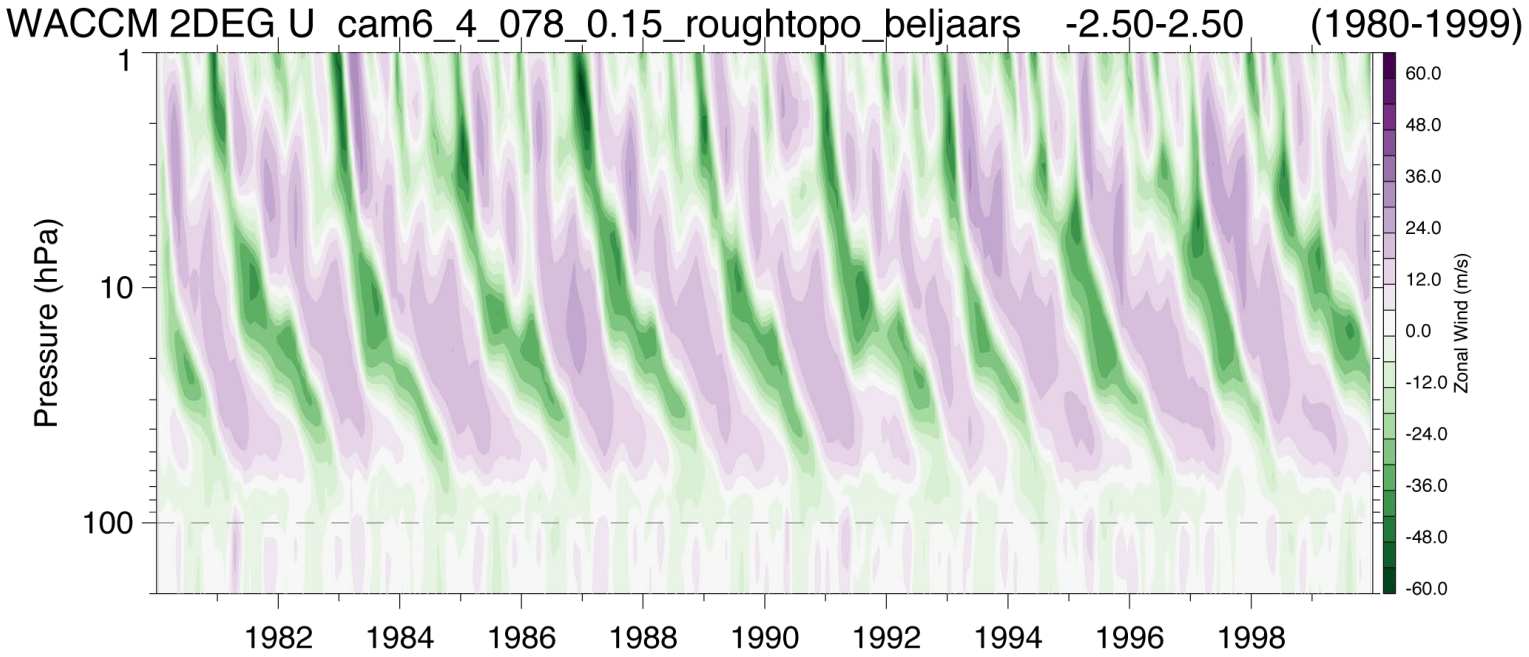
Summary

Understanding the differences between WACCM6 and WACCM7 is important in the current and future model development.

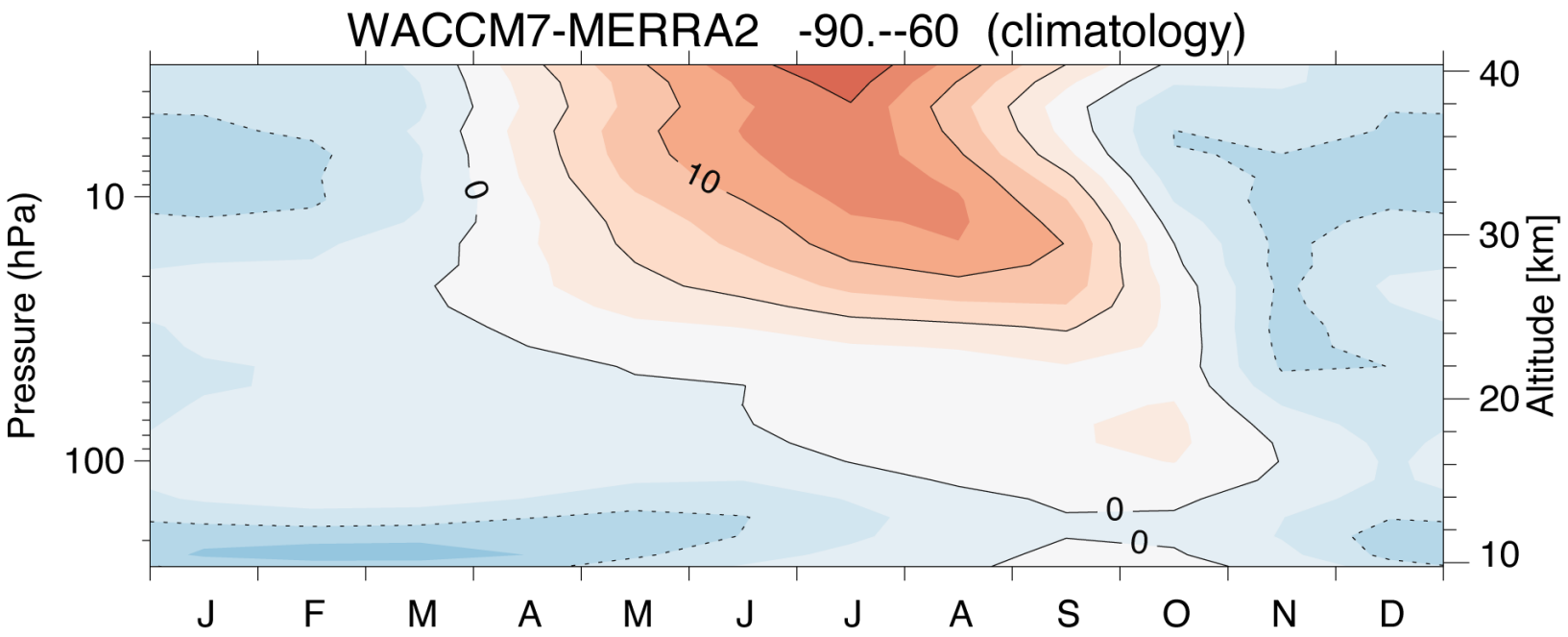
Tuning exercises are currently underway.

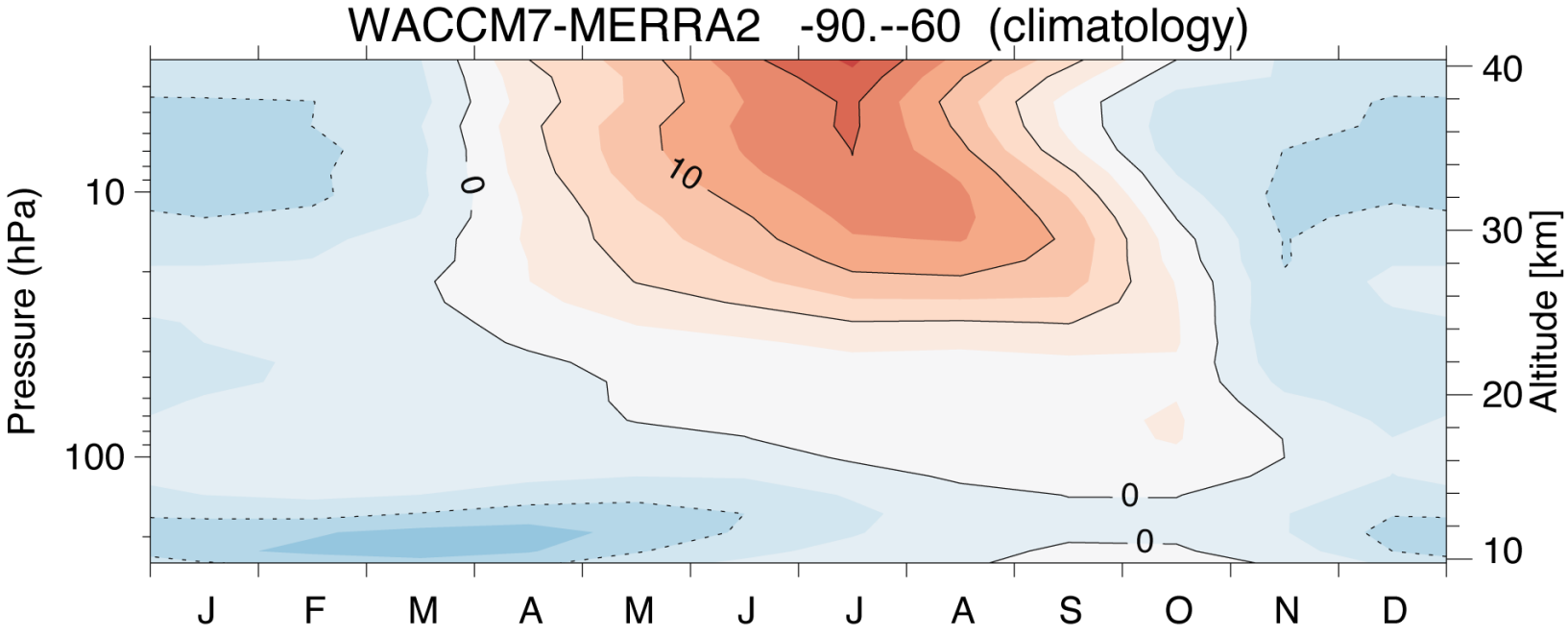
EXTRA SLIDES





Roughtopo Beljaars





Roughtopo Beljaars