Whole Atmosphere Working Group Overview and Developments

CESM Joint AMWG, CCWG, ESPWG, CVCWG, and WAWG Winter WG Meeting

Martina Bramberger (ACOM), Mijeong Park (ACOM), Nick Pedatella (HAO), Daniele Visioni (Cornell), and WACCM/WACCM-X Developers

NCAR

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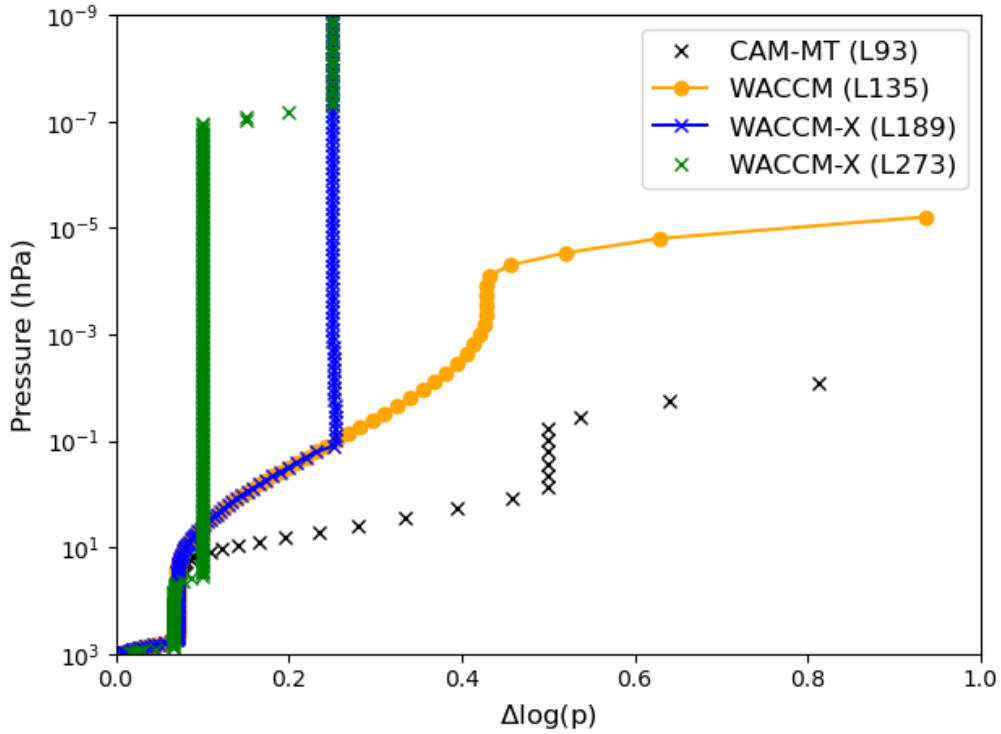
WACCM & WACCM-X for CESM3

	Dyn. Core	Resolution	# levels	Chemistry	Physics
WACCM6	FV	1°, 2°	70 (110)	TSMLT, MA	CAM6
WACCM7	SE	ne30, ne16	135	t1ma, t4ma	CAM7
WACCM-X 2.1	FV	1°, 2°	130	TSMLT, MA, IT chemistry	CAM6
WACCM-X v?	SE	ne30, ne16 (ne120)	189 (273)	t1ma, t4ma IT chemistry	CAM7



Priority development objectives:

- Good QBO at both 1° and 2° resolutions
- Seasonal cycle of winds/temperatures in the stratosphere-mesosphere and the impact on chemistry
- Thermosphere extension of SE dycore, ionosphere-thermosphere climatology

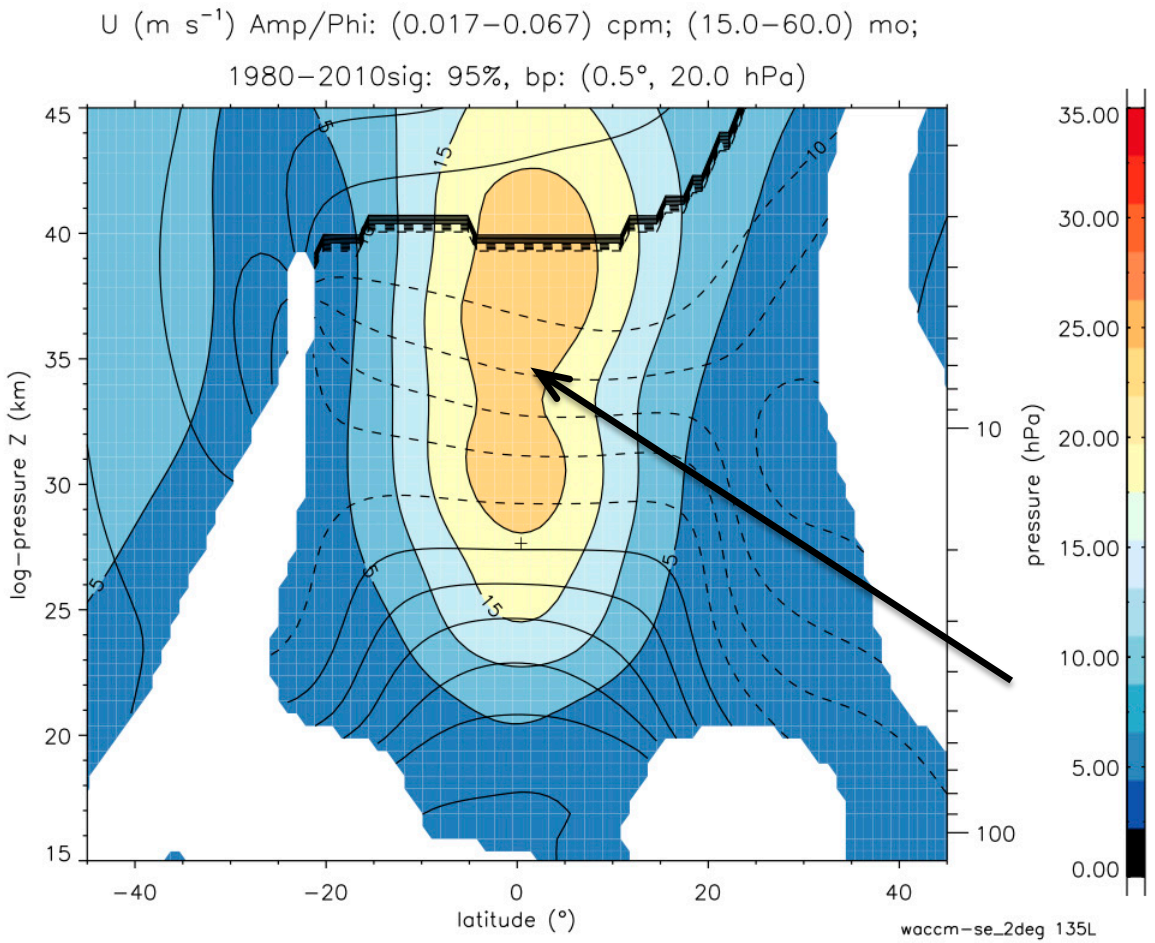
WAWG Recent Developments and Updates

- **WACCM**
  - **Tuning the QBO**
  - Tested updated chemical mechanisms (T1MA, T4MA)
  - Stability for WACCM7 with ne30 resolution
  - **Baseline simulations as benchmark for evaluation and future tuning**

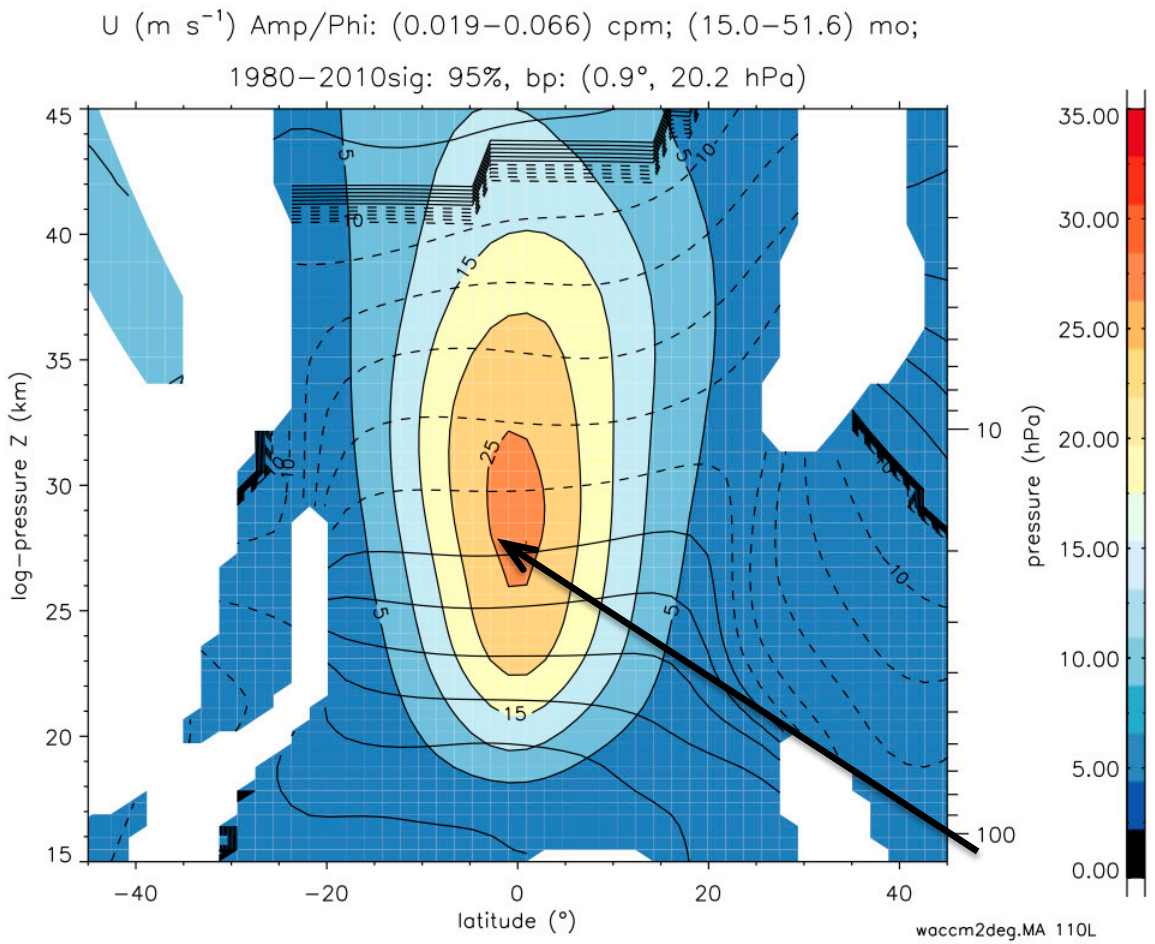
- **WACCM-X**
  - Extension of SE dycore into the thermosphere
  - **Updated chemistry in the mesosphere and thermosphere**
  - **High-resolution capability, including nudging to reanalyses**

QBO structures in 2º WACCM (SE vs. FV) as of Summer 2023

WACCM-SE-2DEG 135L

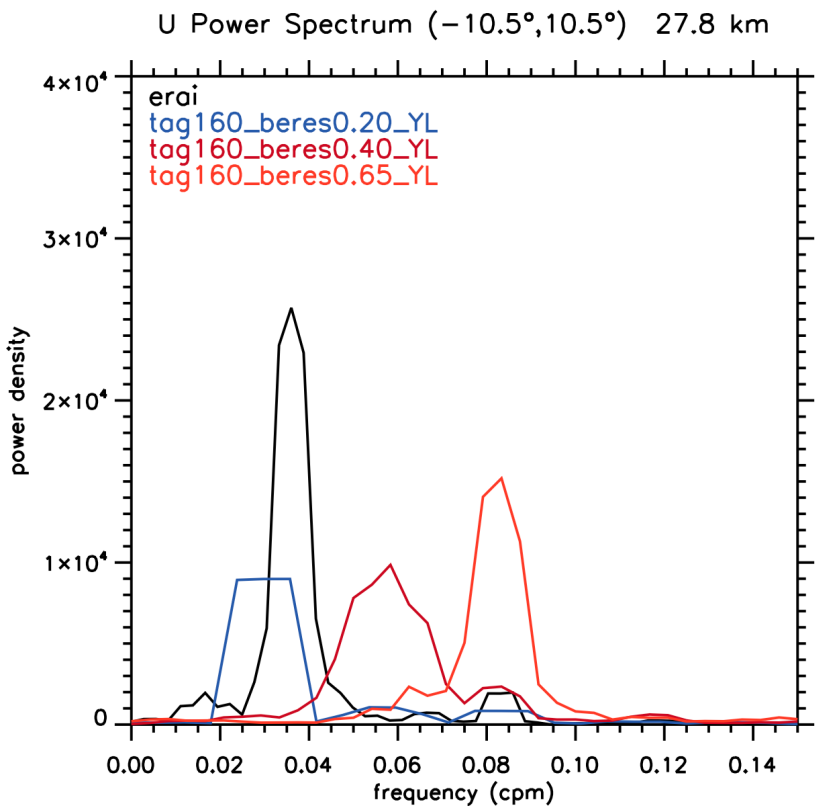


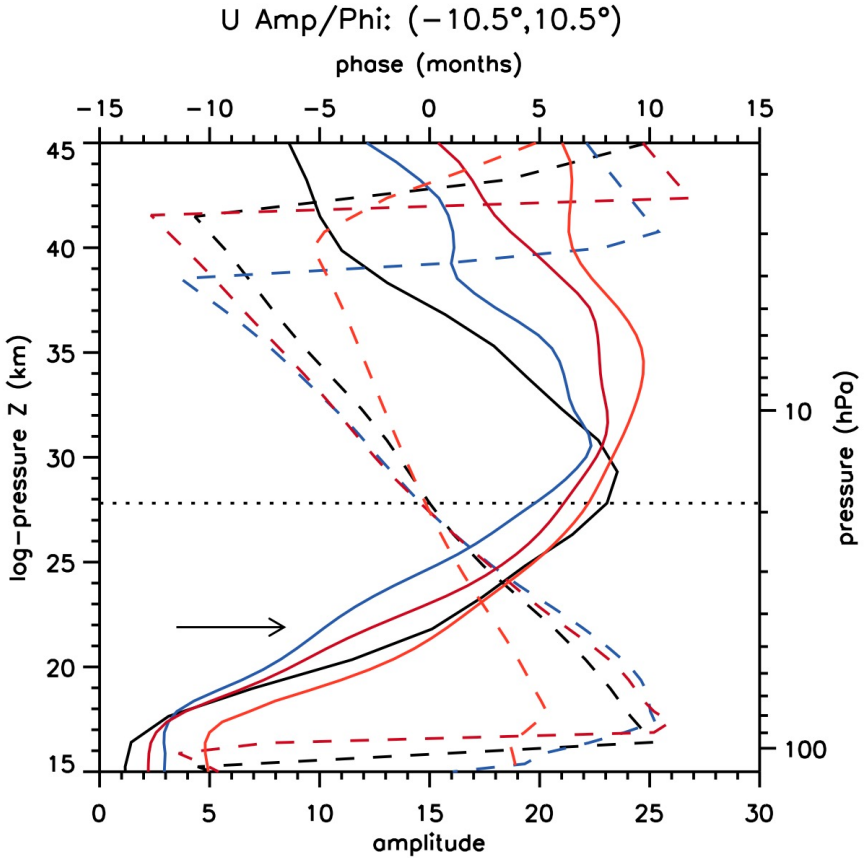
WACCM-FV-2DEG 110L

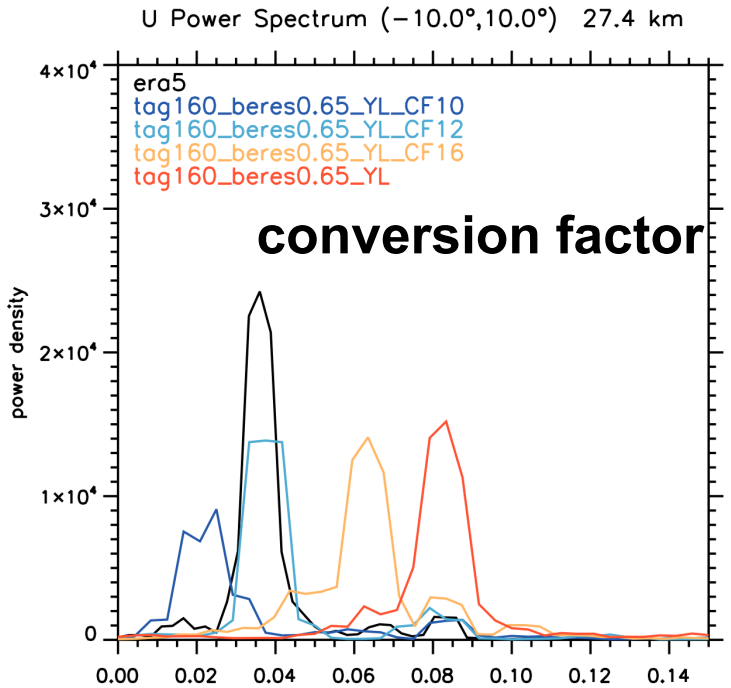


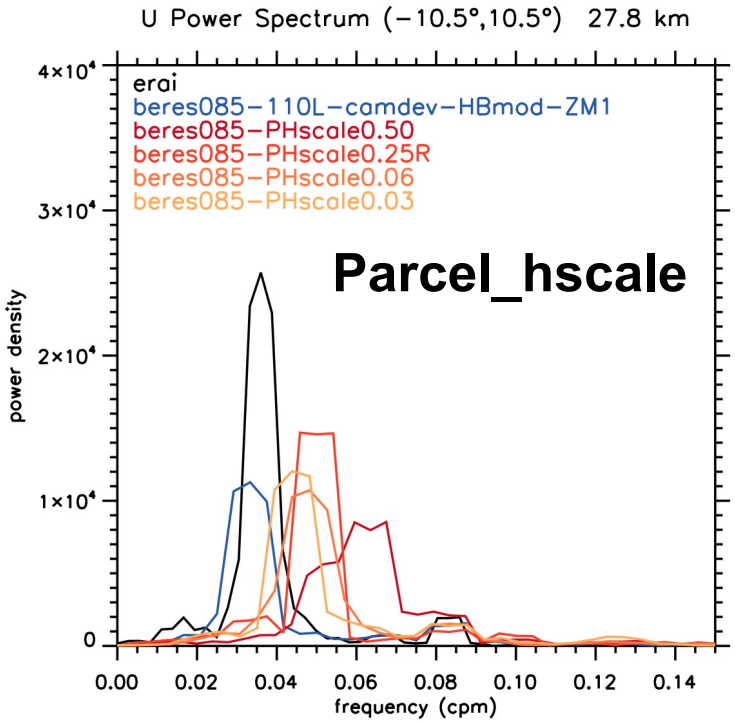
The QBO in WACCM7 has much weaker amplitudes and the maximum was at 35-40 km

Tuning, Tuning, and more Tuning…









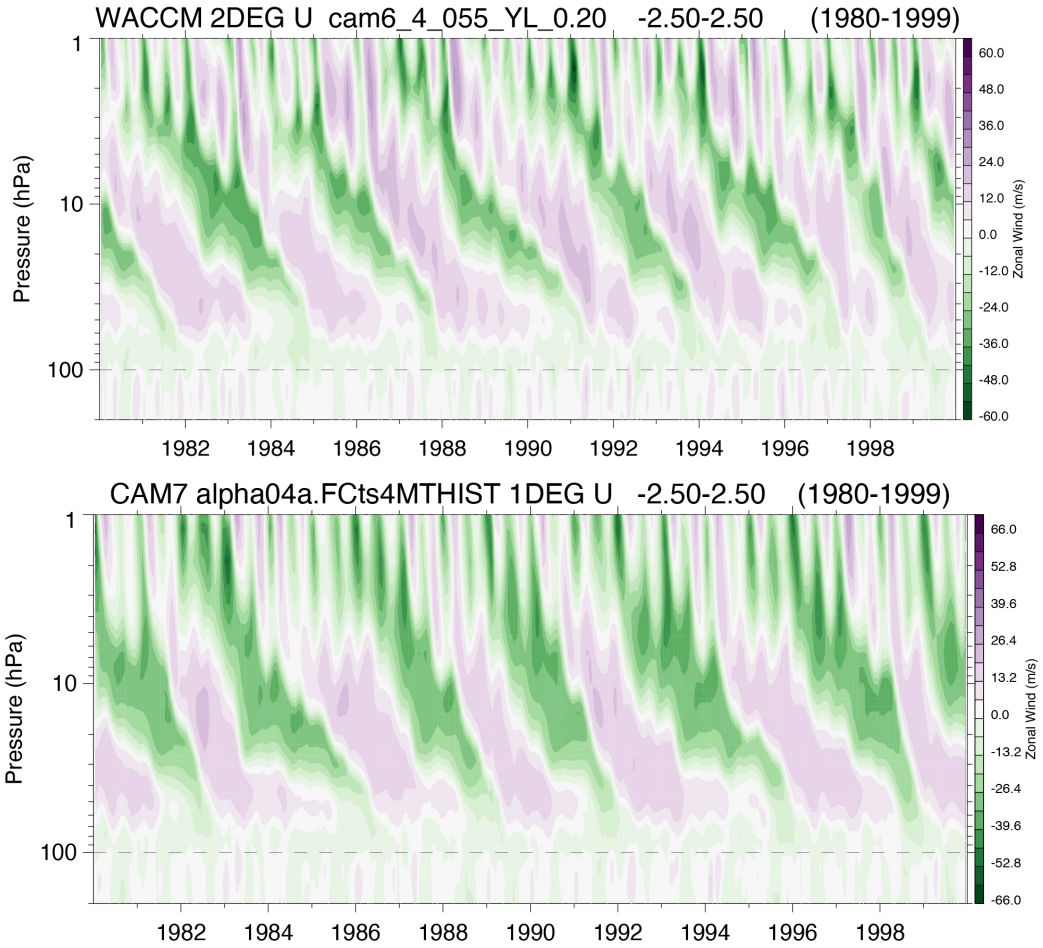
effgw_beres_dp (0.2 -- > 0.65)

-decrease periods

-increase amplitudes (more at higher altitudes)

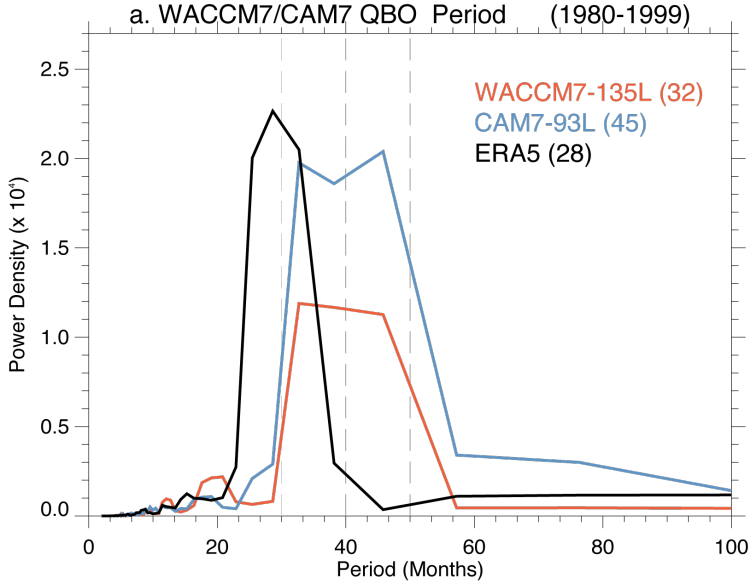
More details: Thursday 8:50-9:10, “Tuning the QBO in CESM3-WACCM7”, Mijeong Park

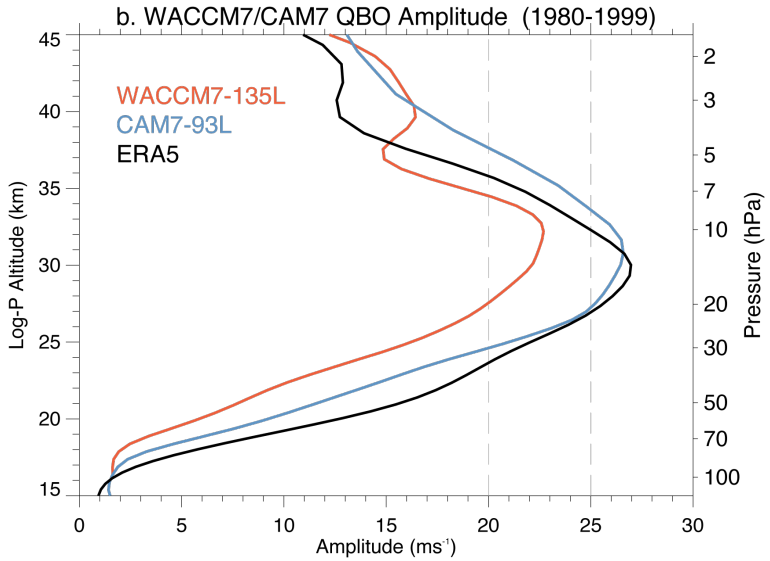
QBO in WACCM7 & CAM7 (recent)



WACCM7 2 DEG (cam6_4_055)

CAM7 MT 1 DEG (alpha04)

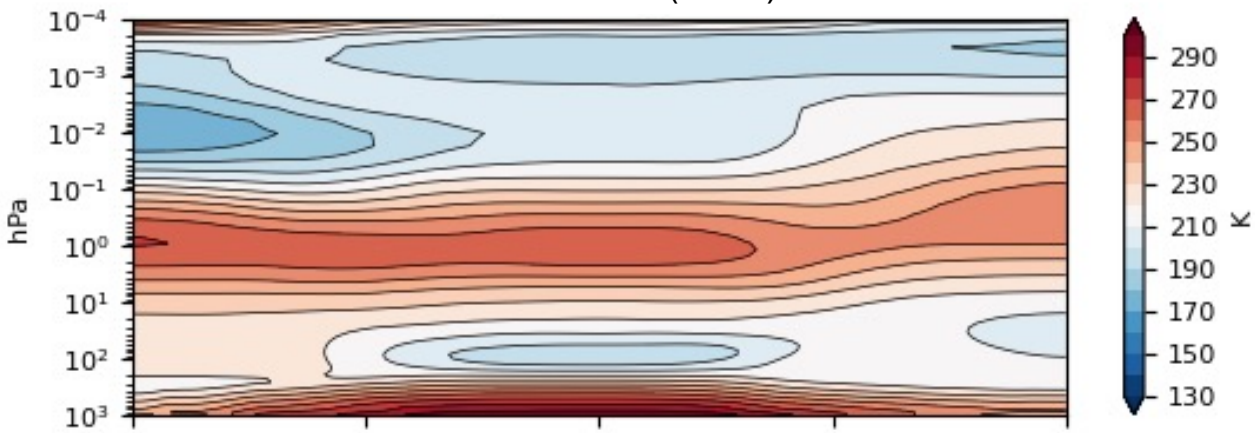




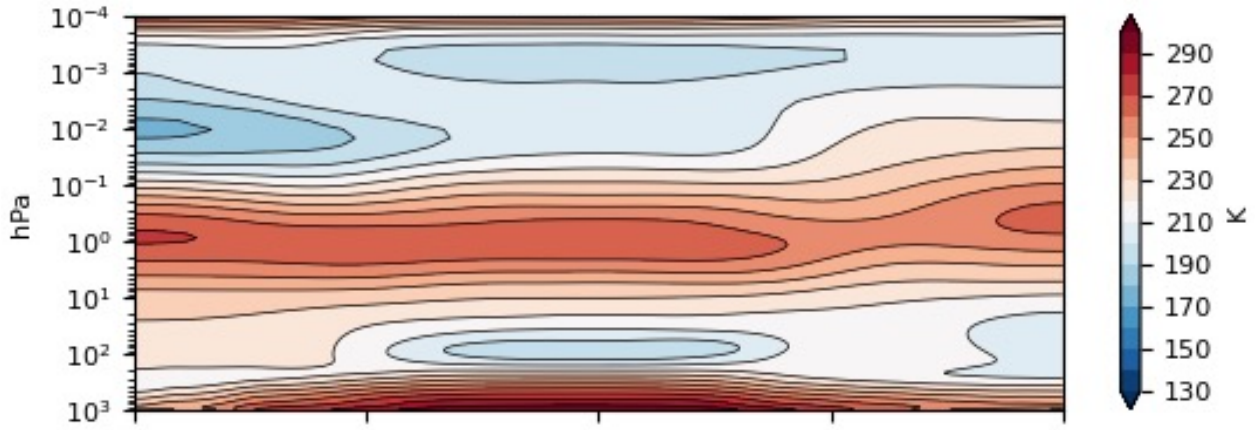
CAM7 MT – Stronger amplitude and much slower QBO.
WACCM7 – Increase effgw_beres_dp should lead to stronger amplitude & faster QBO (we have room for tuning).

Temperature climatology (DJF) in WACCM7 is similar to WACCM6

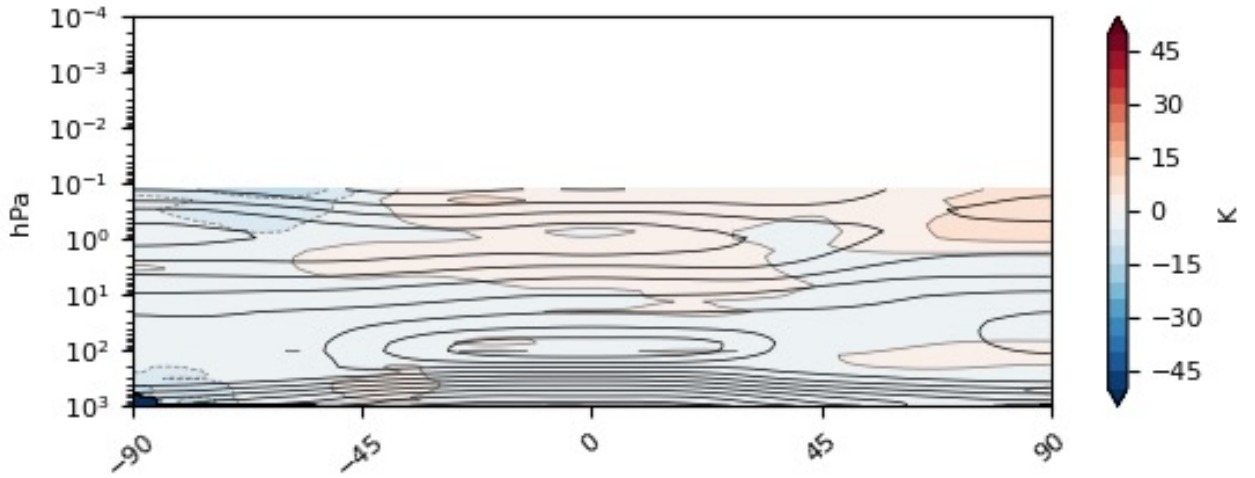
DJF WACCM6 (AMIP)



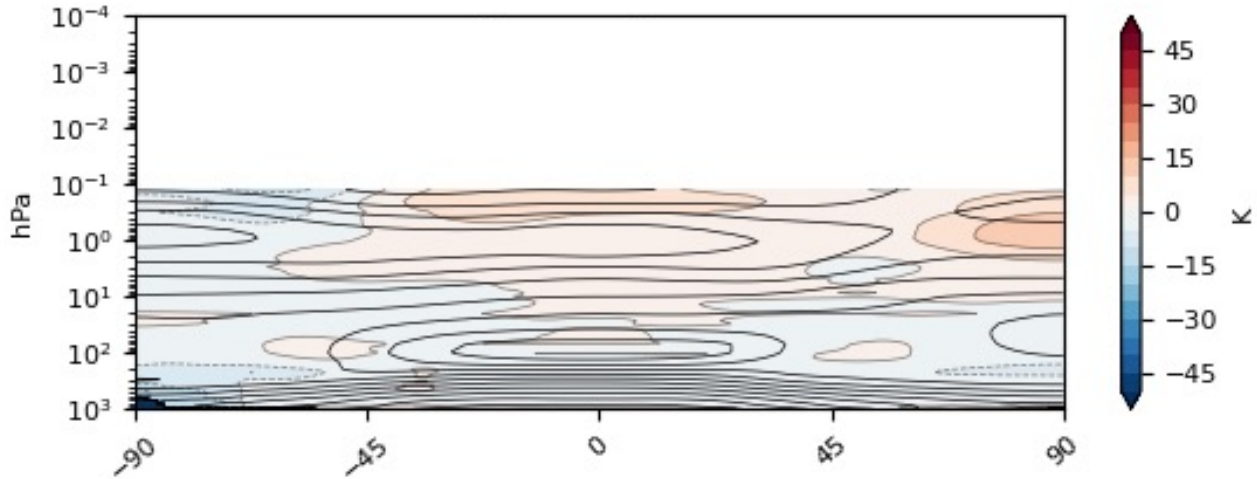
DJF WACCM7



WACCM6-MERRA2

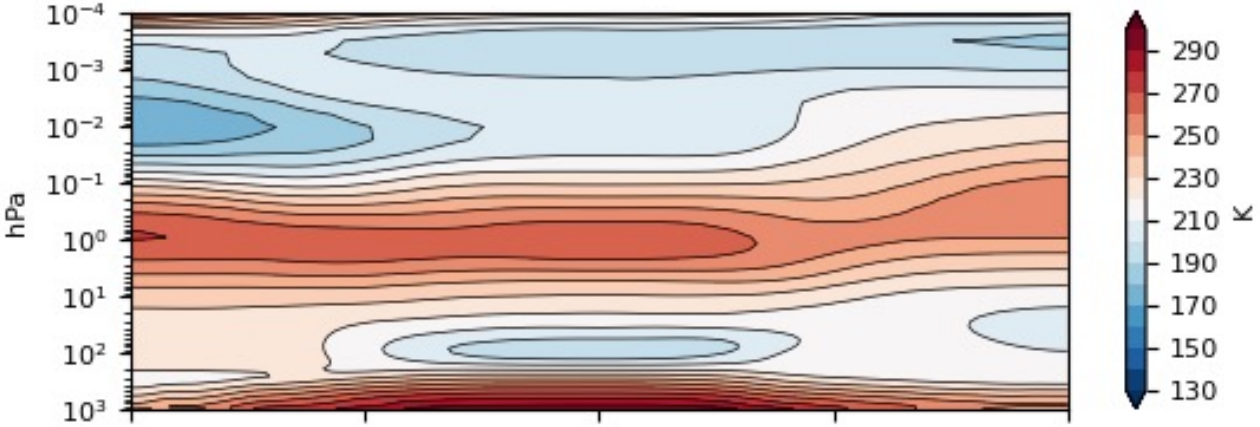


WACCM7-MERRA2

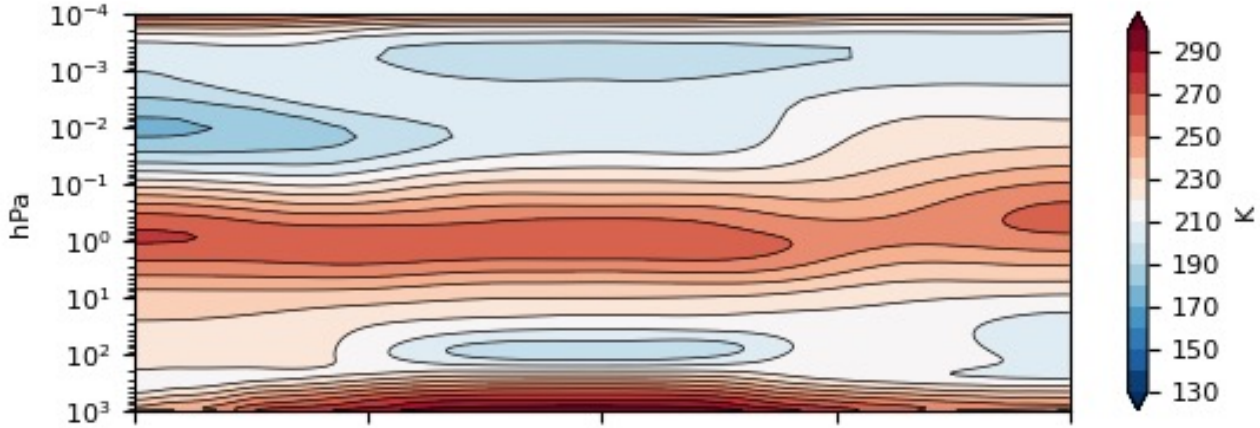


Temperature climatology (DJF) in WACCM7 is similar to WACCM6

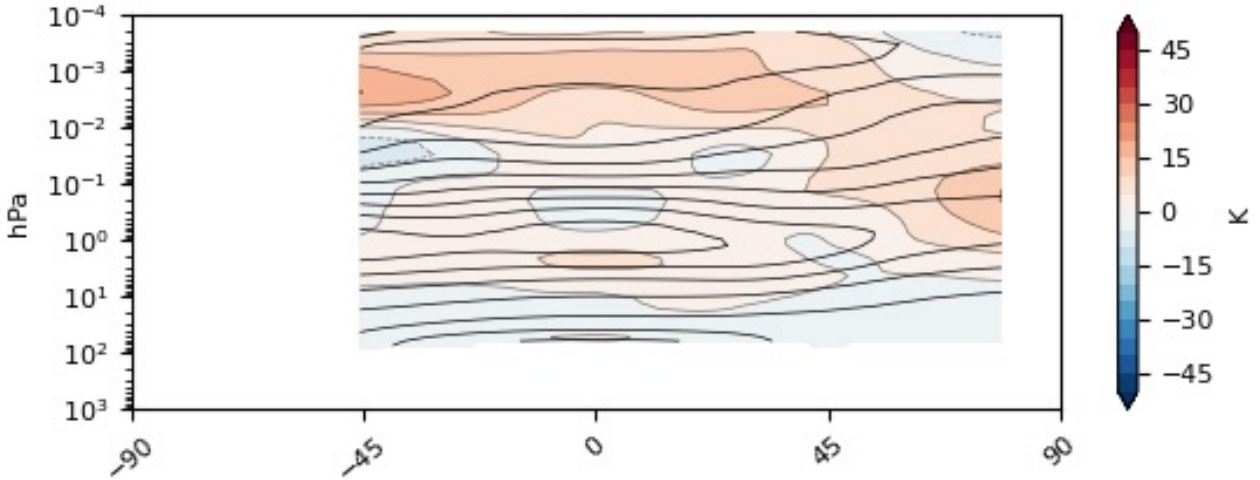
DJF WACCM6 (AMIP)



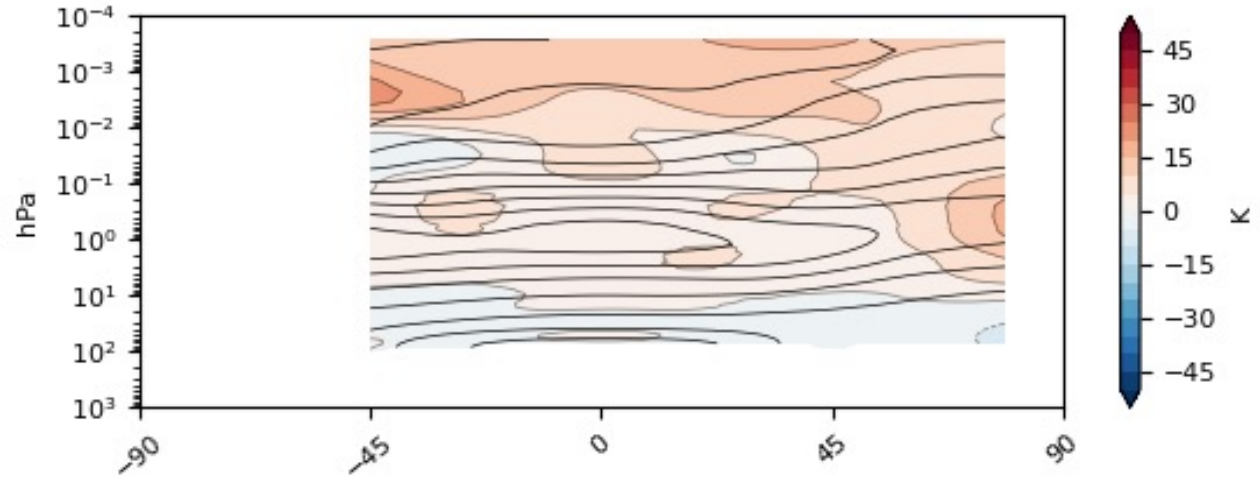
DJF WACCM7



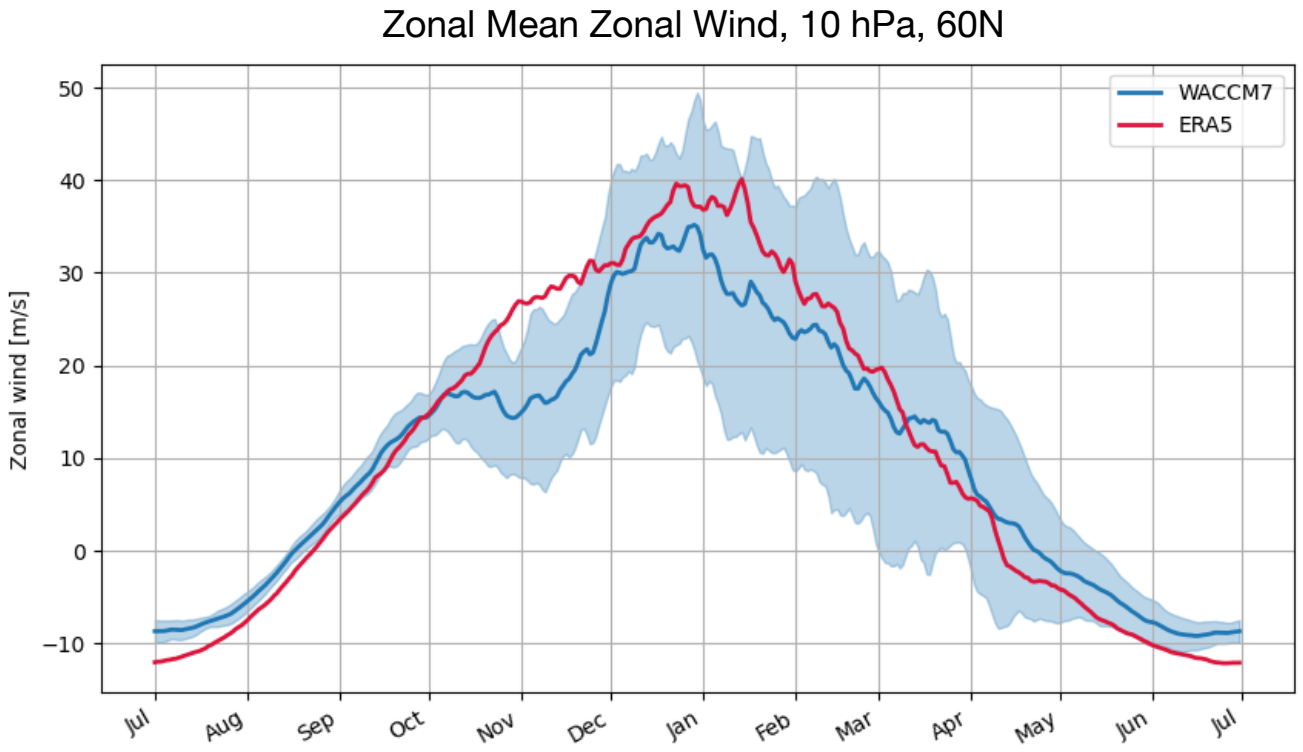
WACCM6-SABER

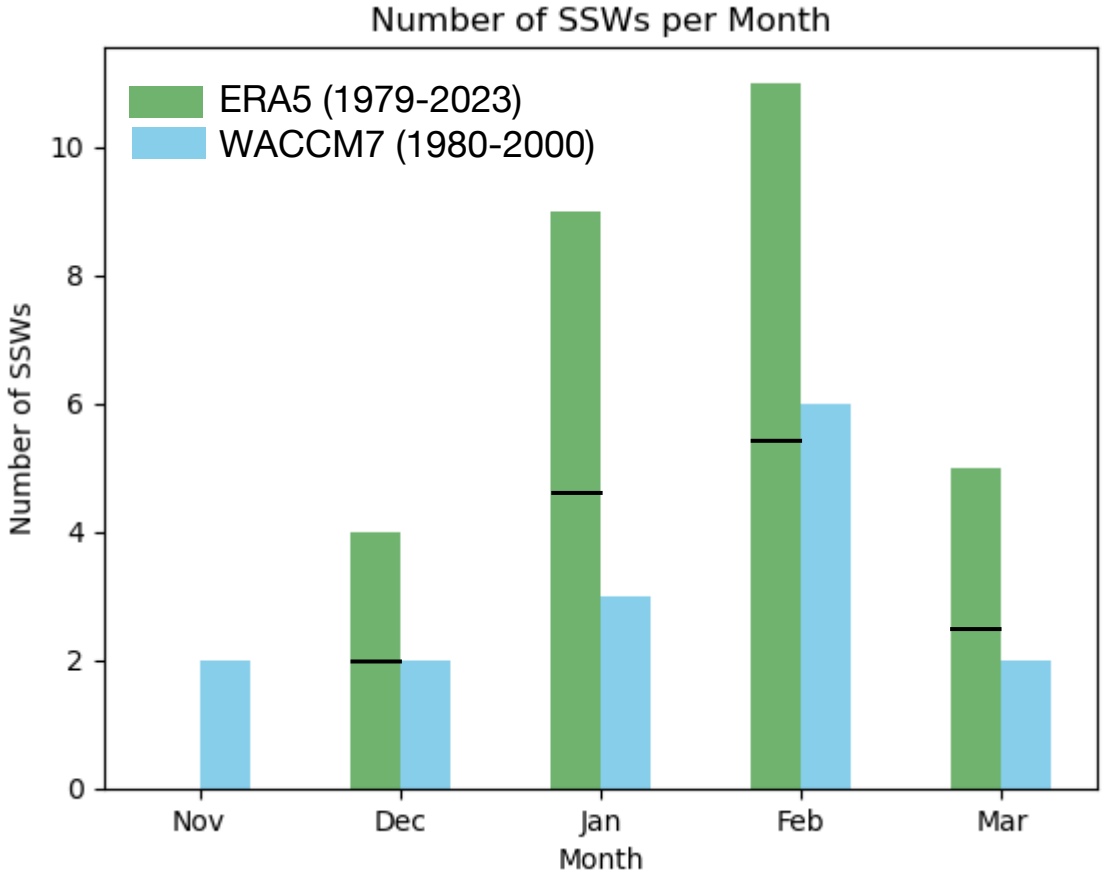


WACCM7-SABER



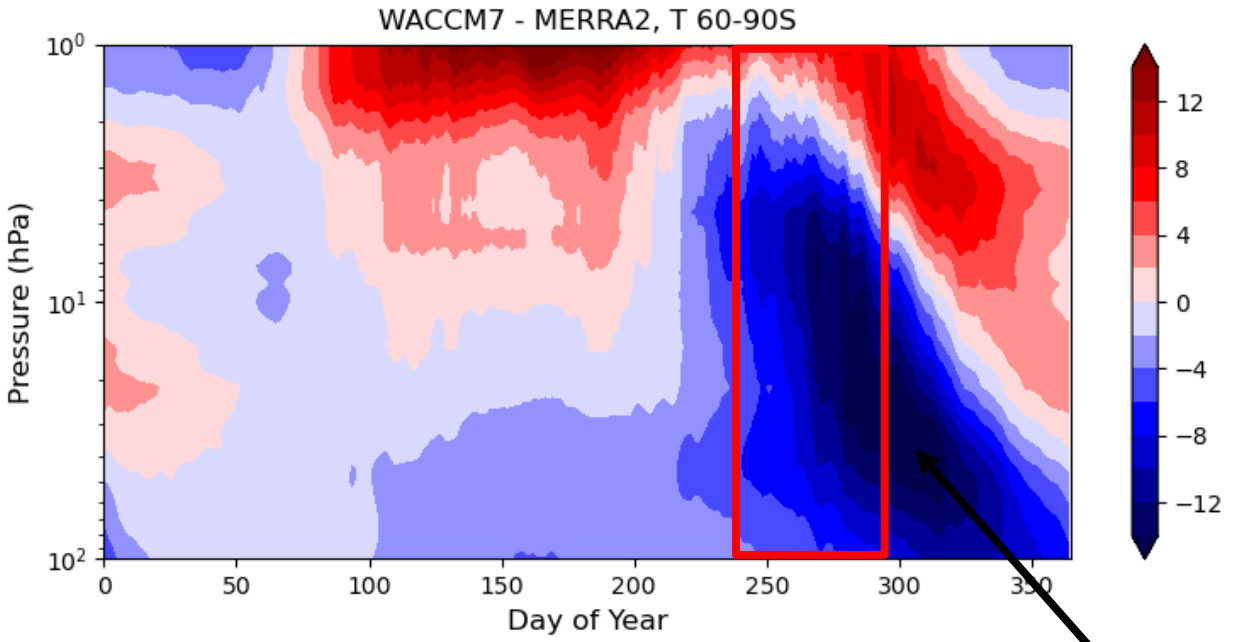
Northern Hemisphere stratosphere winds show good agreement with ERA5 and distribution of SSWs is reasonable

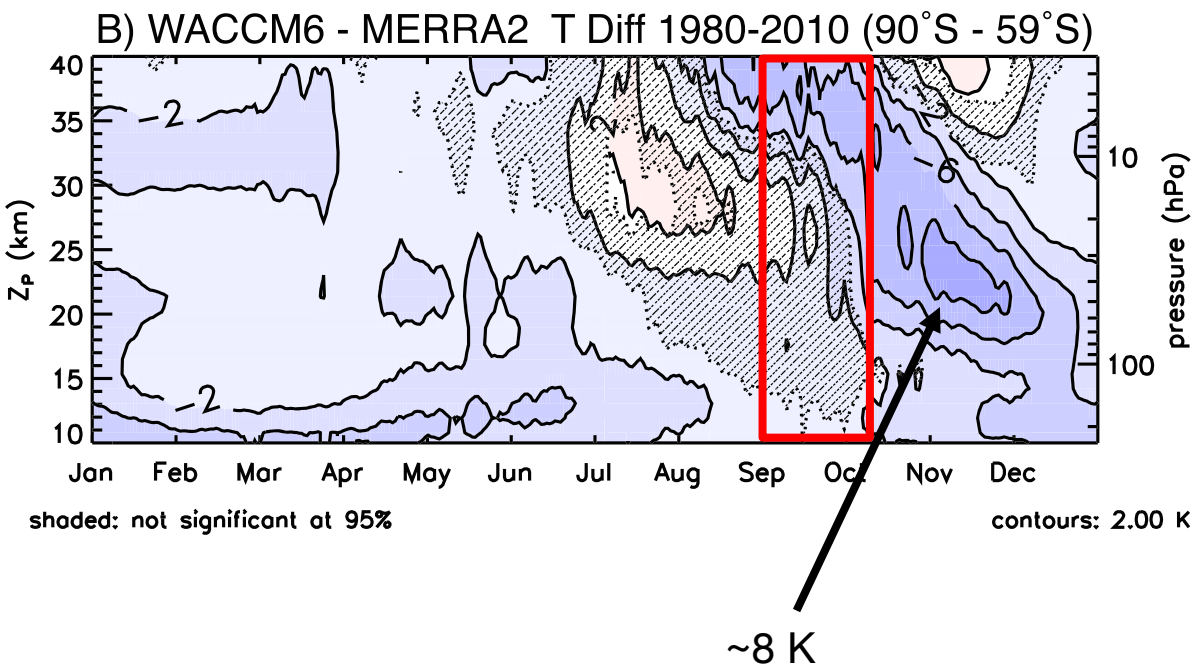




- Occurrence of November SSWs also occurred in CESM2-WACCM6
- Need extended runs to reliably determine the SSW statistics

Southern Hemisphere polar stratosphere has a large temperature bias that considerably exceeds the bias in WACCM6





Earlier negative temperature bias in WACCM7 will impact ozone in September-October

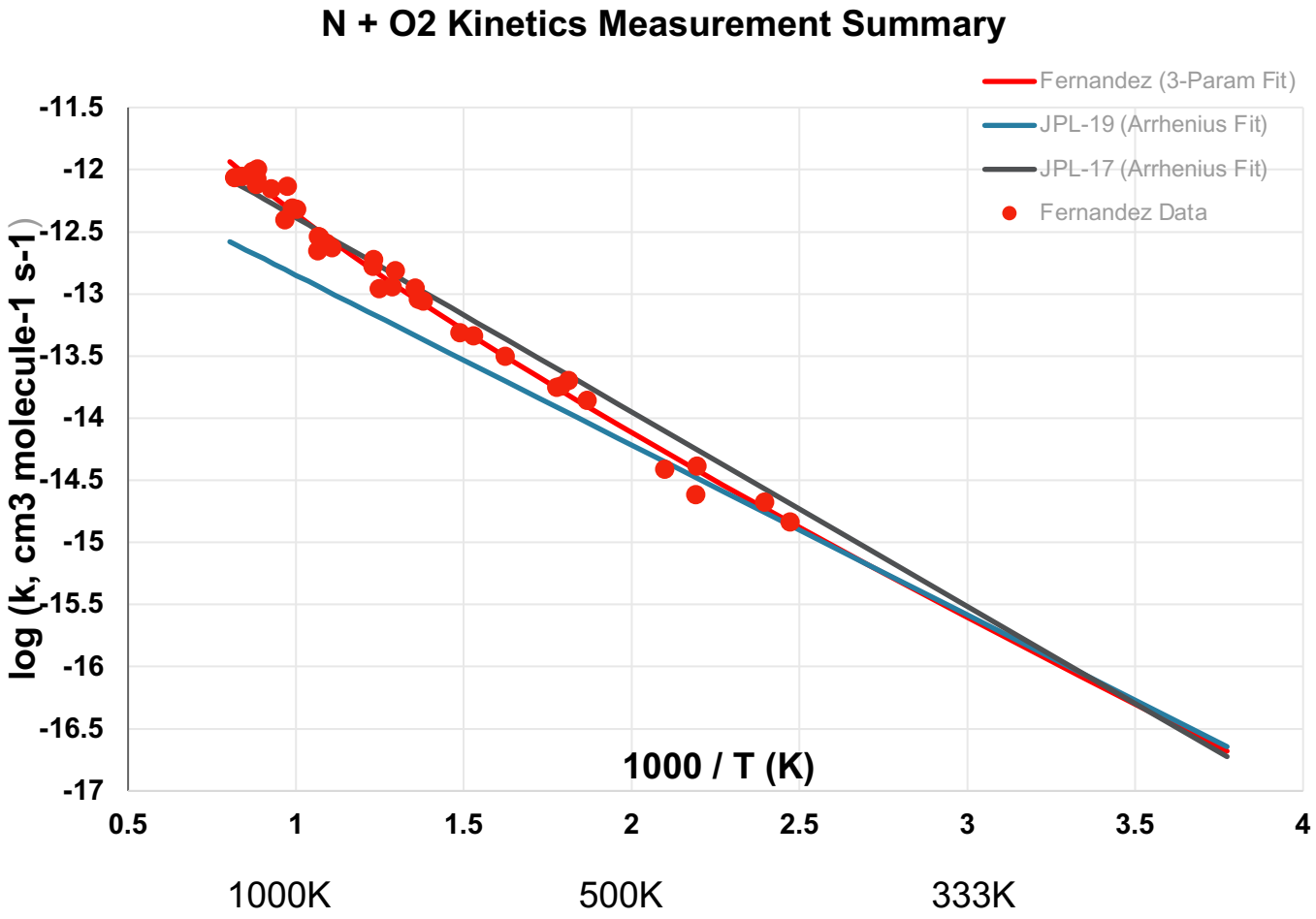
(Gettelman et al., 2019)

Chemistry Updates for the Mesosphere and Thermosphere

	Reaction	Original Rate Constant (A, Ea/R)	Updated	Comment
Updated rates	$N(^4S) + O_2$ -> $NO + O$	JPL-19 3.3e-12, 3150	3-parameter fit, Next slide	Fernandez et al., 1998
	$N(^2D) + O_2$ -> $NO + O(^1D)$	5e-12	K=6.2e-12 (T/300.)	Duff et al., 2003
	$N(^2D) + NO$ -> $N_2 + O(^1D)$	NA	K = 7.3e-11	Roble, 1995
New reactions	$N(^2D)$ -> $N(^4S) + hv$	NA	K = 1.06e-5	Roble, 1995
	$N(^2D) + e$ -> $N(^4S) + e +$ 2.38 eV	NA	K = 3.6e-10_r8 * $(Te/300.0\_r8)^{1/2}$	Roble, 1995

Credit: Doug Kinnison, Jun Zhang (ACOM)

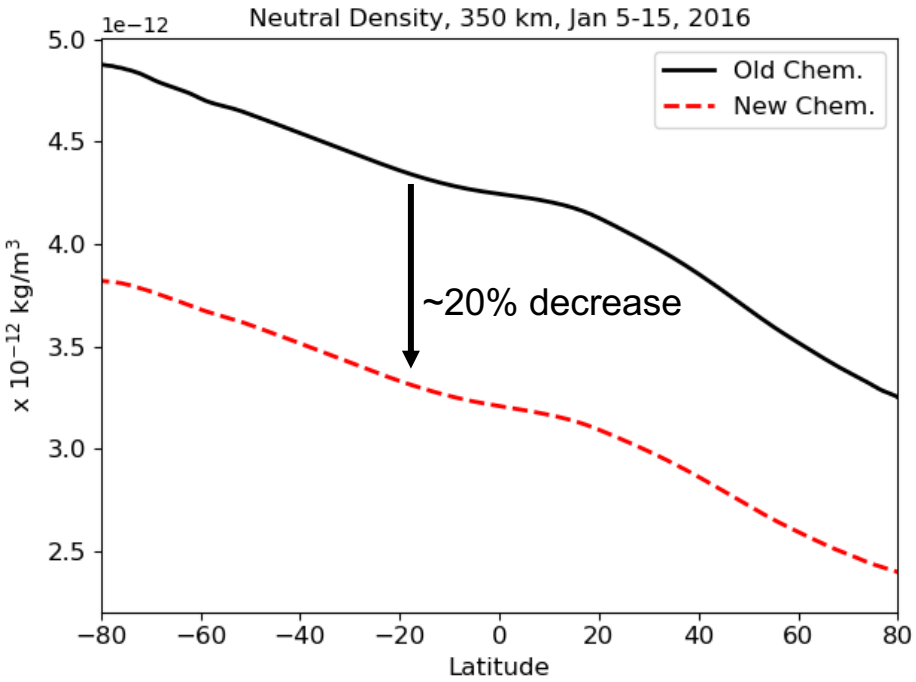
Updated N + O_2 Reaction Rate

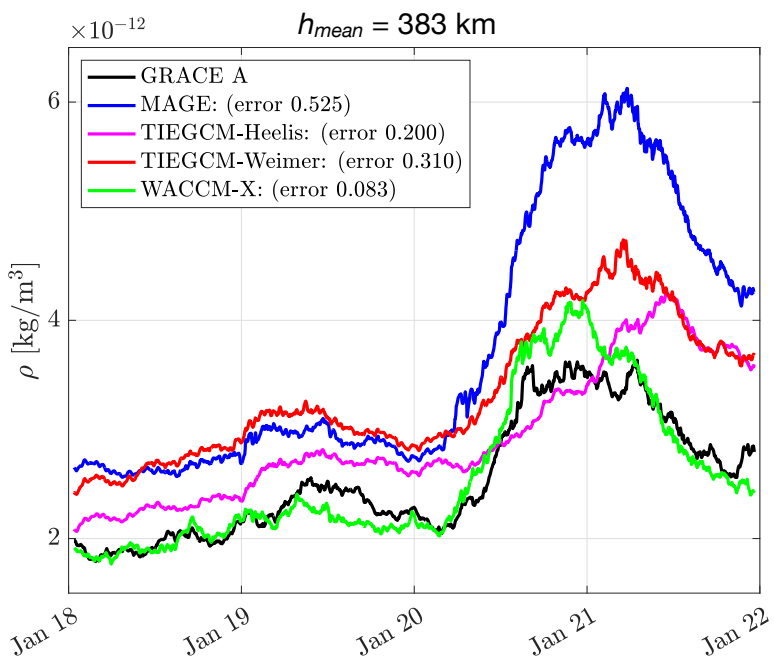


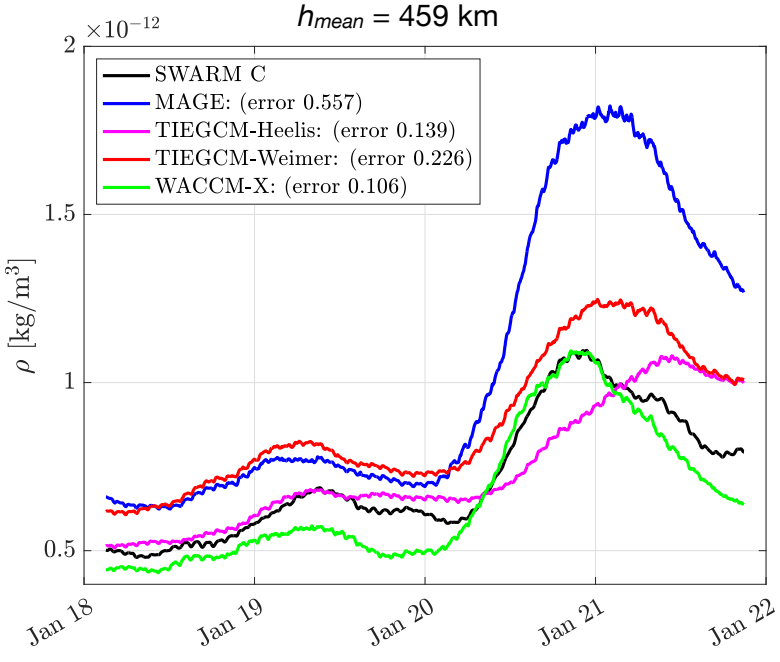
- Decrease in reaction rate from JPL-17 (CESM2) to JPL-19 leads to less NO production at high temperatures
- NO cools the thermosphere, so less NO leads to larger temperatures and neutral densities

Credit: Doug Kinnison, Jun Zhang (ACOM)

WACCM-X simulated neutral densities with updated reaction rates show good agreement with observations







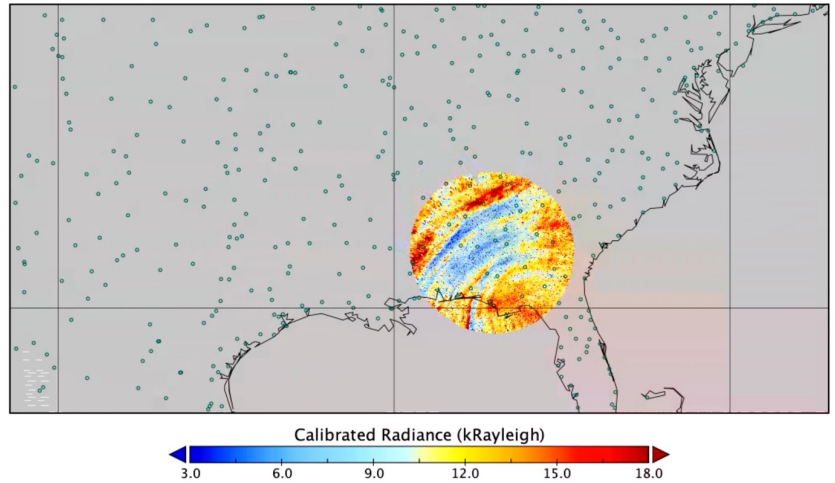
Credit: Jordi Vila Perez (HAO)

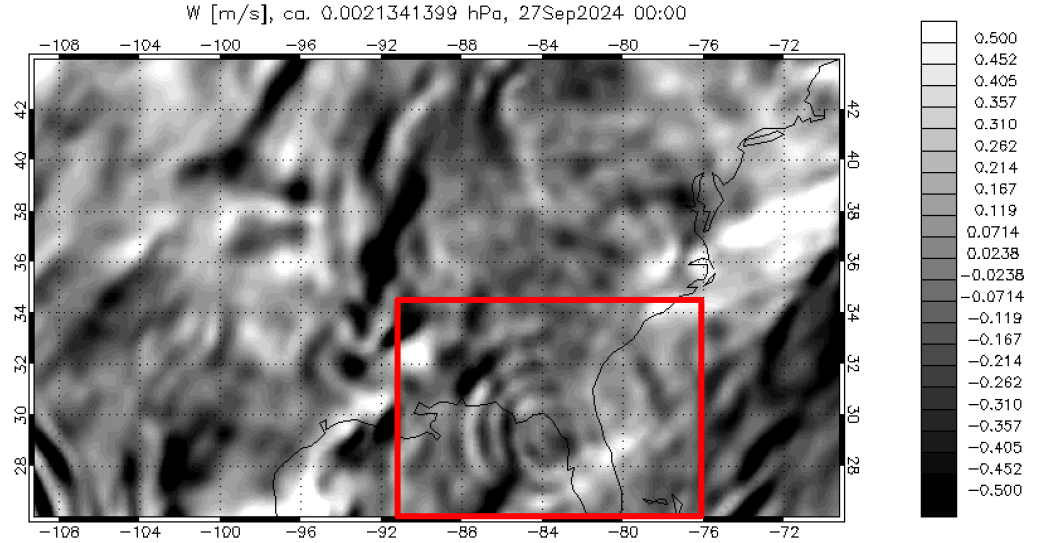
Implementation of meteorological constraint for high-resolution (ne120, ~0.25°) WACCM-X

- Recently implemented physics-side nudging for high-resolution WACCM-X simulations
- Enables simulations of the day-to-day variability of small-scale waves, and their impacts, on the middle and upper atmosphere
- Capability enables new scientific studies and is used to support current and future satellite missions
- More details: Thursday 9:50-10:10 “Meteorologically constrained high-resolution WACCM-X simulations” Nick Pedatella

Gravity Waves from Hurricane Helene

NASA AWE Observation 02:49 UT, Sept 27 2024 (~87 km)

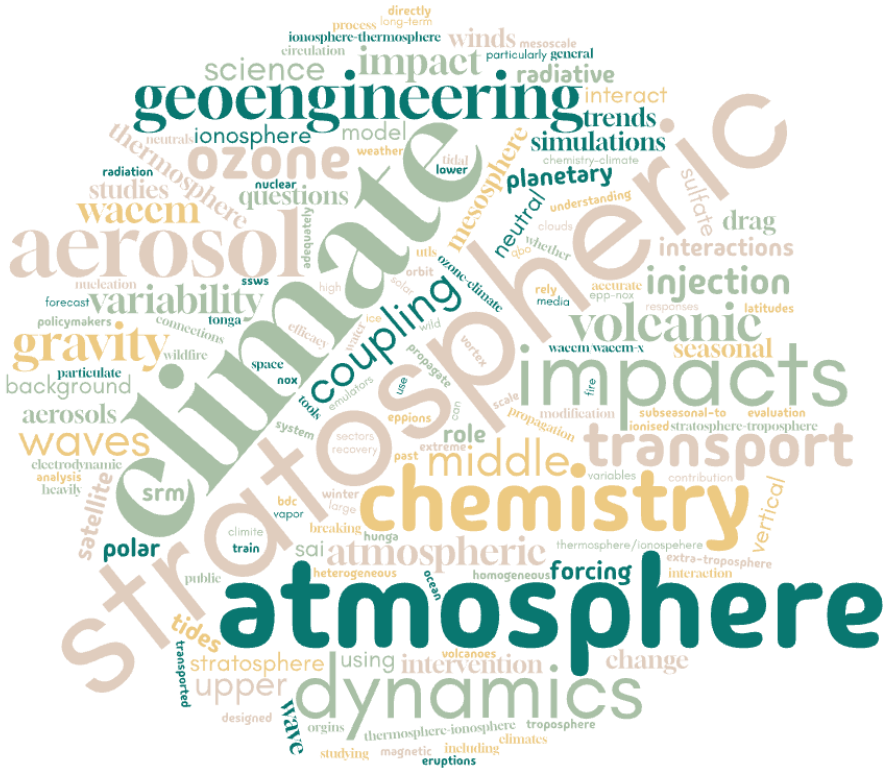




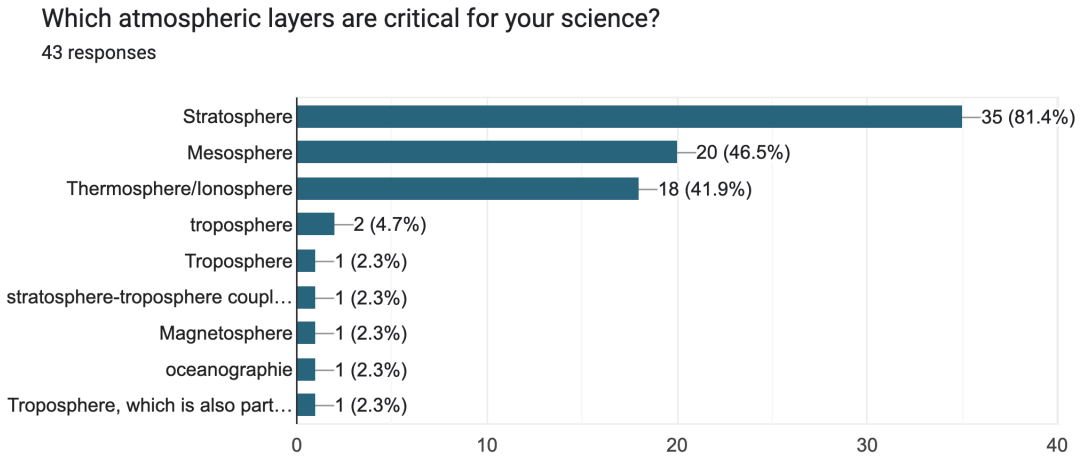
Credit: Hanli Liu (HAO), Jiarong Zhang (USU)

WACCM(-X) Community Survey

What science questions are you using WACCM/WACCM-X for?



- January 2025 WACCM(-X) community survey received 43 responses
- Wide range of science use cases that span the whole atmosphere (surface to ionosphere/thermosphere)
- Usage of CAM-MT vs. WACCM for stratosphere science needs to be clarified
- More details Thursday 10:10-10:30 (Martina Bramberger)



Summary and Remaining Development Tasks

- Tuning of the QBO remains a challenge in WACCM7.
- Need to address the large cold bias in the SH stratosphere. Hope is that this is fixed by the updated gravity wave parameterization.
- Model throughput and cost remain an issue for ne30 (1°) due to occasional instabilities and the need to run with a large nsplit.
- Benchmark year long WACCM-X simulations for evaluation of ionosphere-thermosphere.