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

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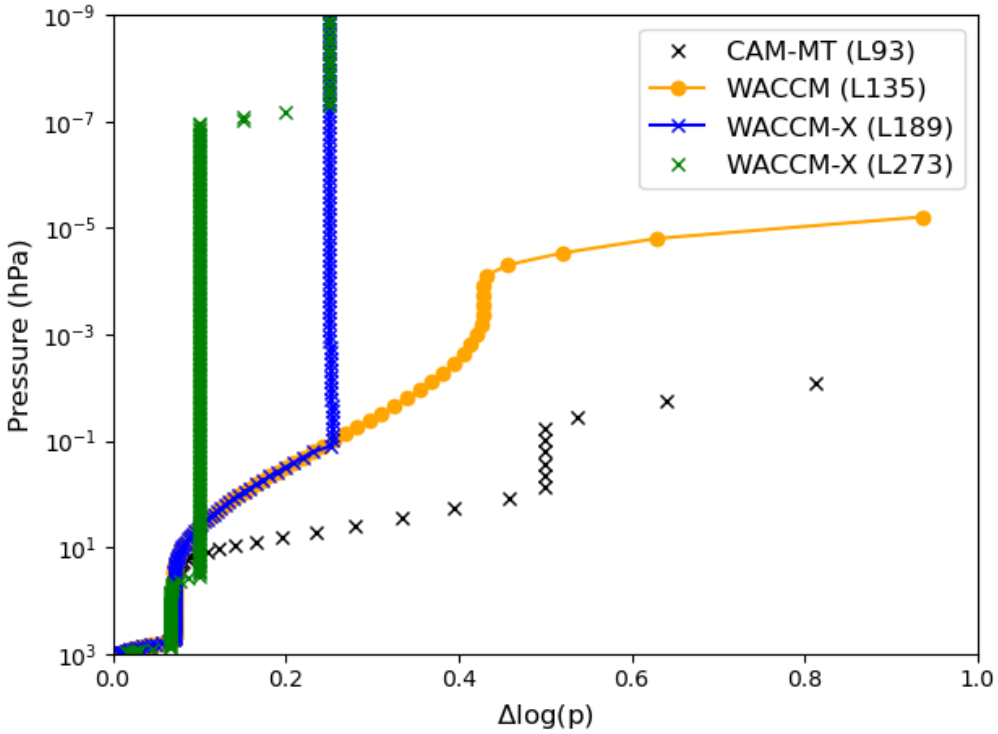
WACCM & WACCM -X for CESM3

	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



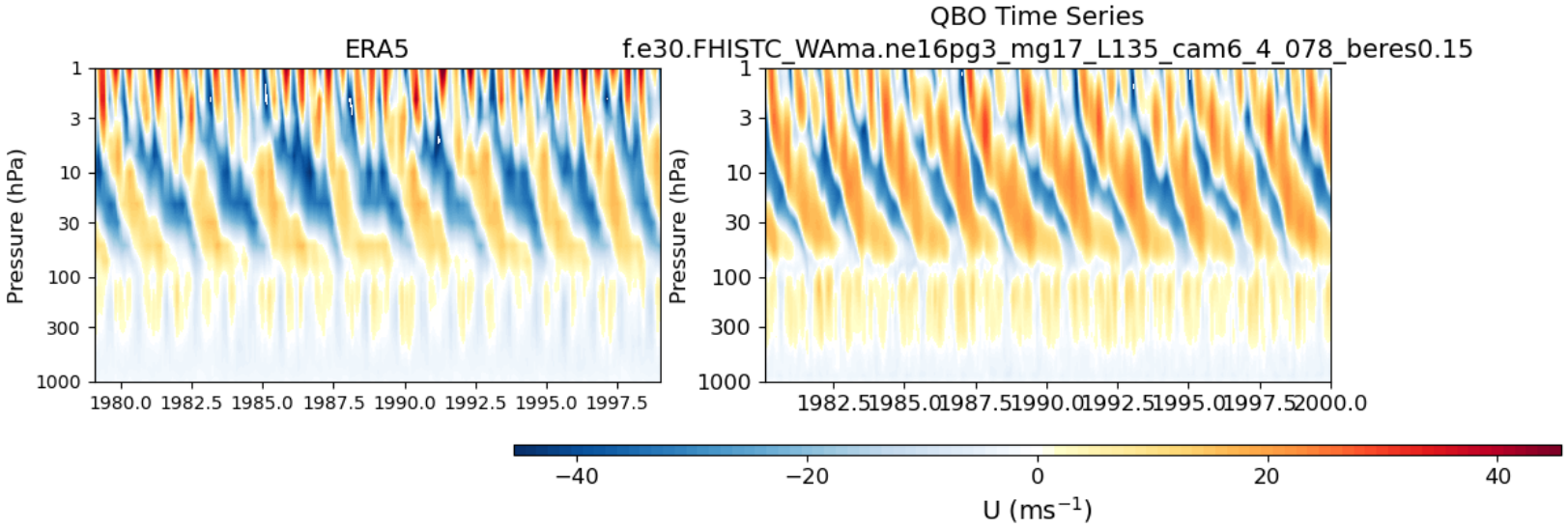
Priority development objectives:

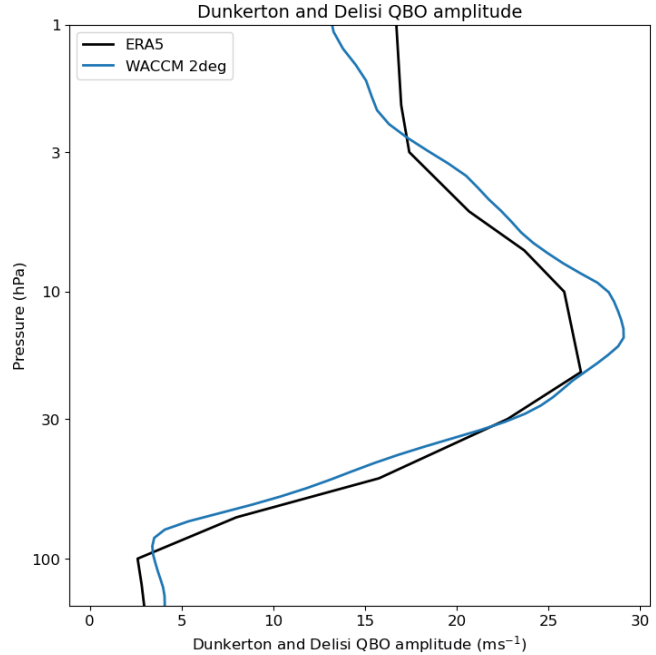
- Good QBO at both 1° and 2° resolutions
- Seasonal cycle of winds/temperatures in the stratosphere-mesosphere and the impact on chemistry
- Thermosphere extension of SE dycore, ionosphere-thermosphere climatology

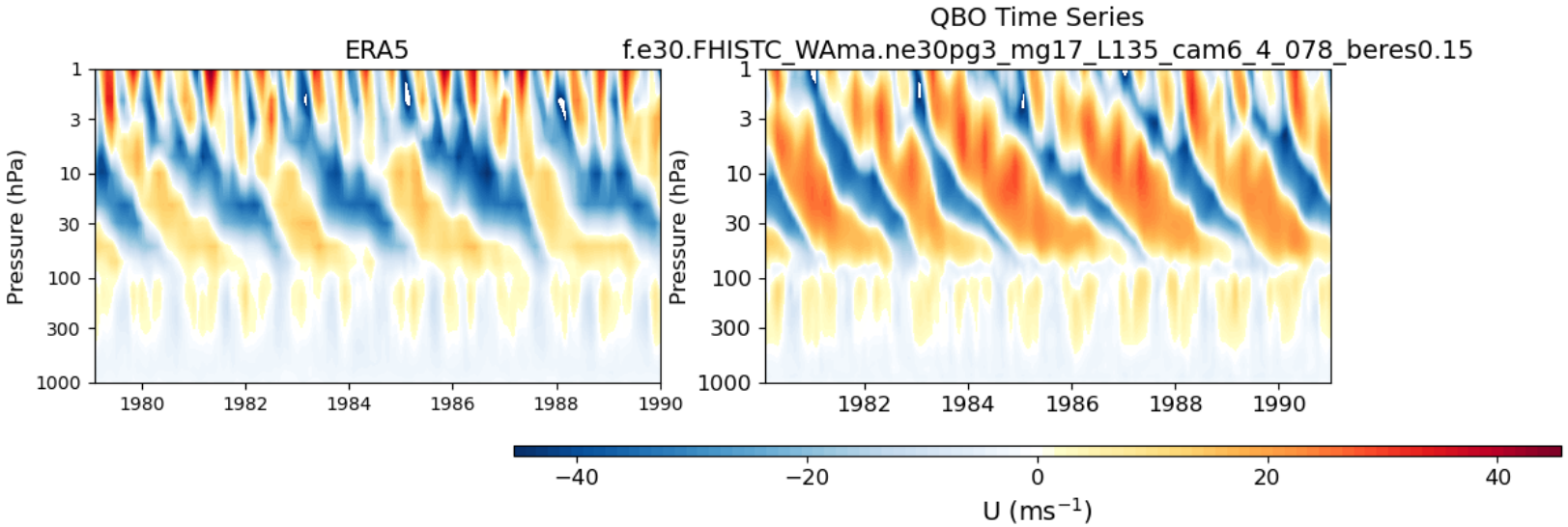
WACCM7 / WACCM7 -X Status for CESM3

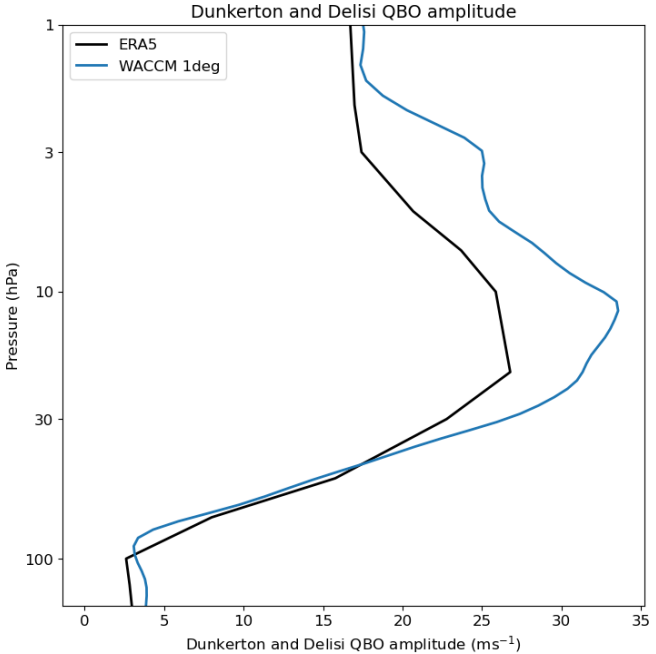
- QBO tuning is progressing, with QBO looking reasonable though not perfect
- Stratosphere, mesosphere, and lower thermosphere dynamics and seasonal cycle have been evaluated. No major issues, but still some room for improvement.
- Updated nitrogen chemistry in lower thermosphere which improves thermosphere temperature and neutral density in WACCM-X
- Updating Shapiro filter in WACCM-X for SE dycore
- Gravity wave parameterization tuning for high-resolution (NE120) WACCM-X
- ADF now supports more WACCM-focused results
- Known issues/biases: robust calculation of TEM diagnostics for SE dycore, water vapor tape recorder in WACCM

Results from base -runs - QBO



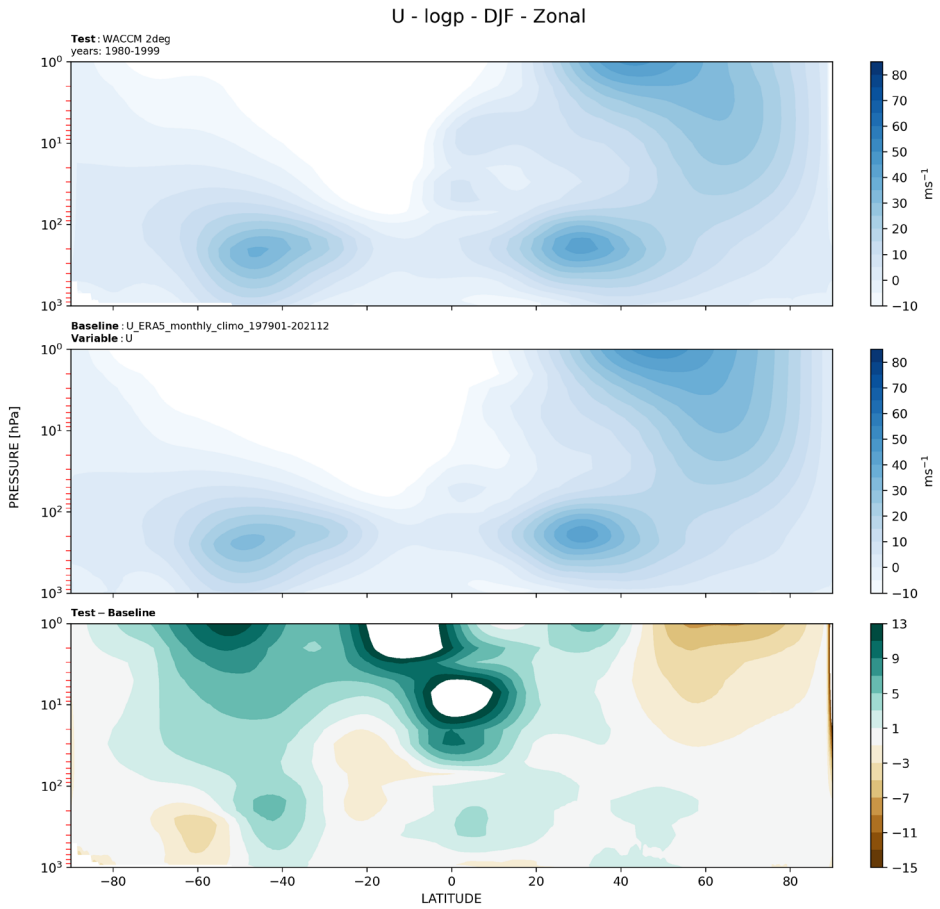




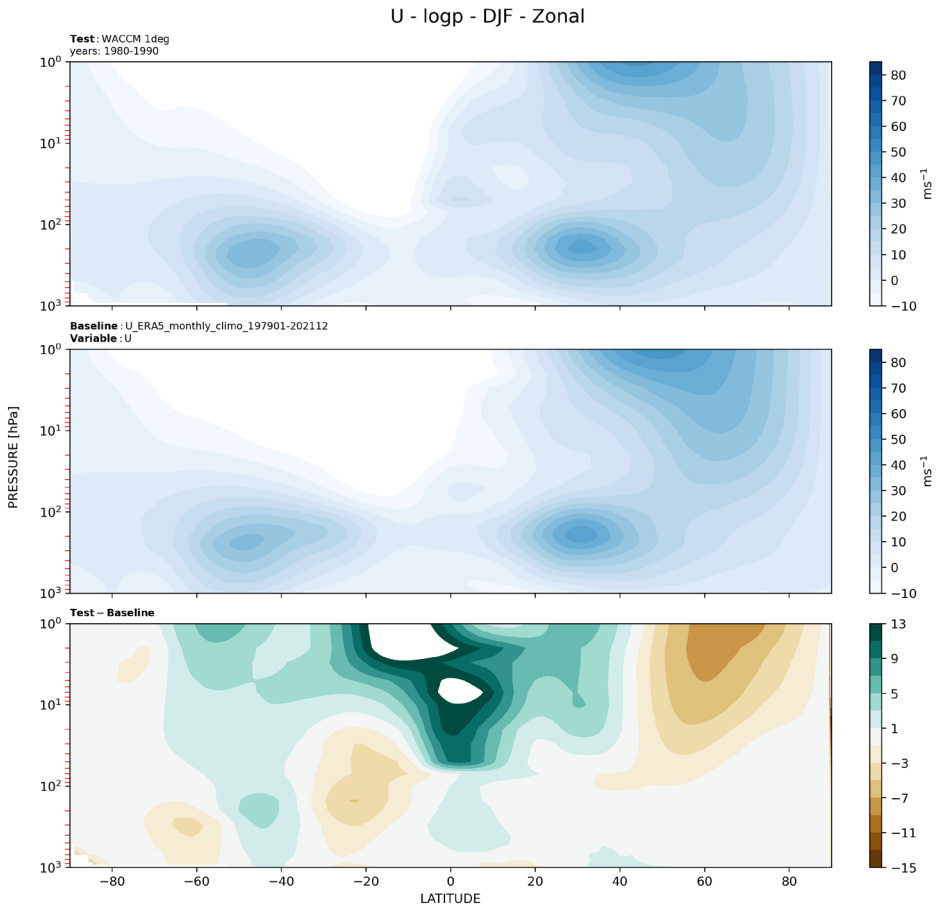


Results from base -runs – Polar Vortex (DJF)

2 deg

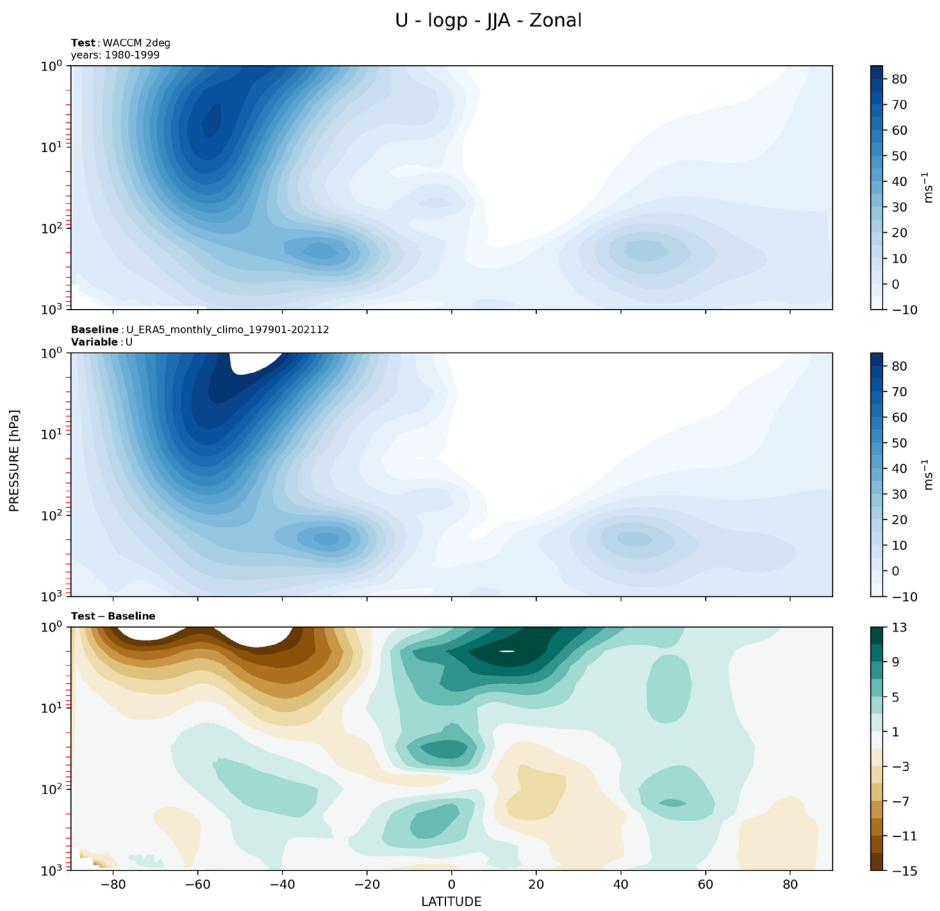


1 deg

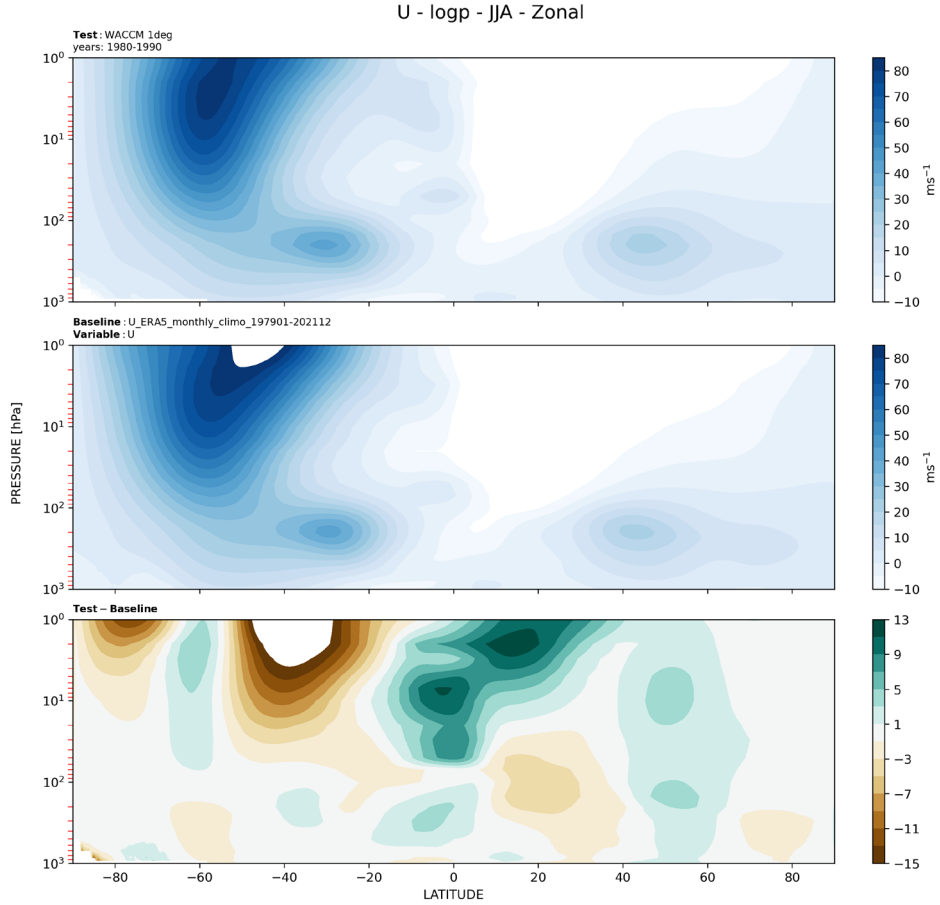


Results from base -runs - Polar Vortex (JJA)

2 deg

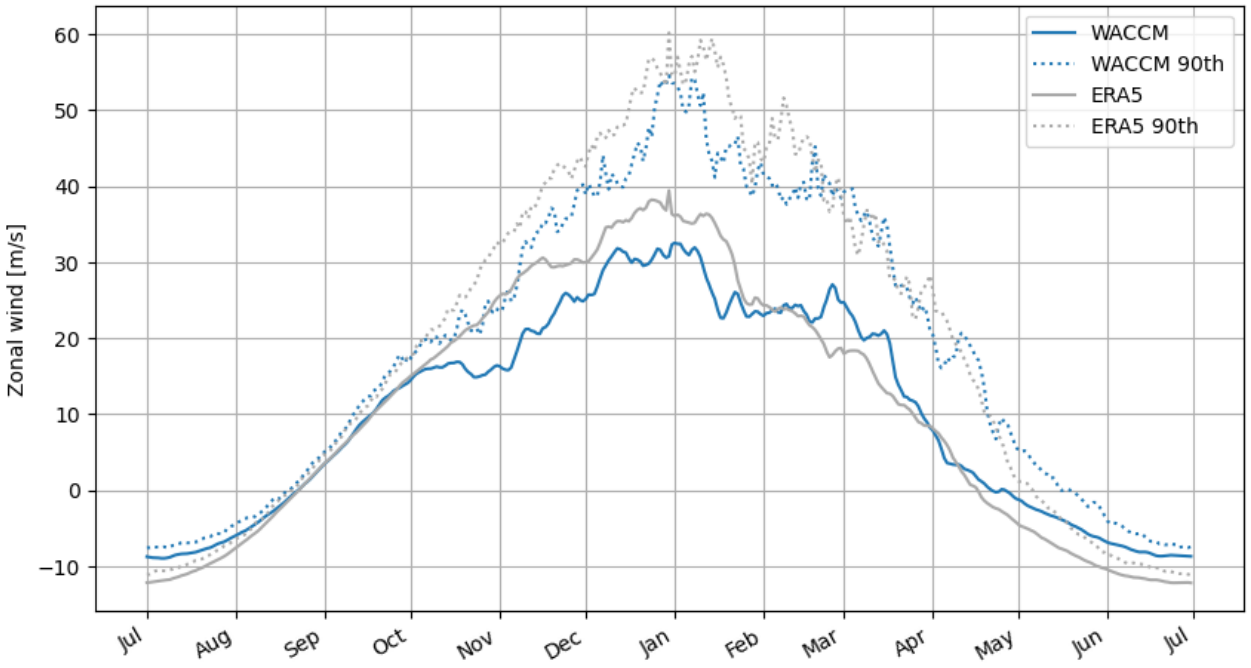


1 deg

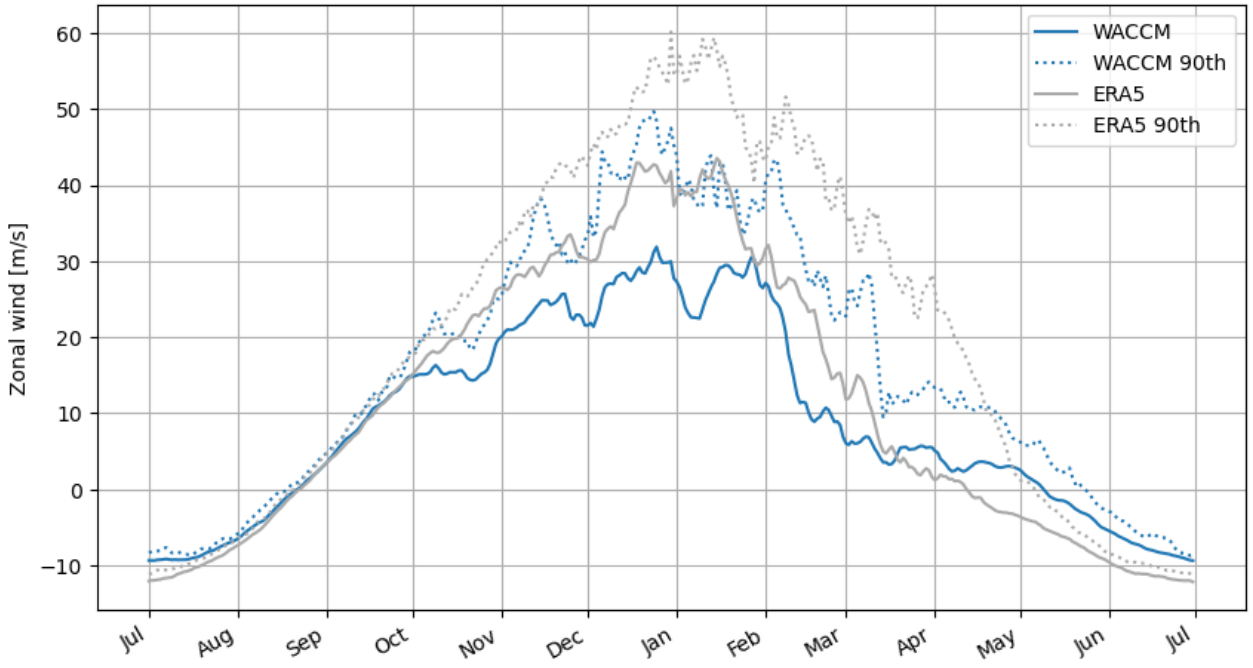


Results from base -runs - Seasonal Cycle (NH)

2 deg

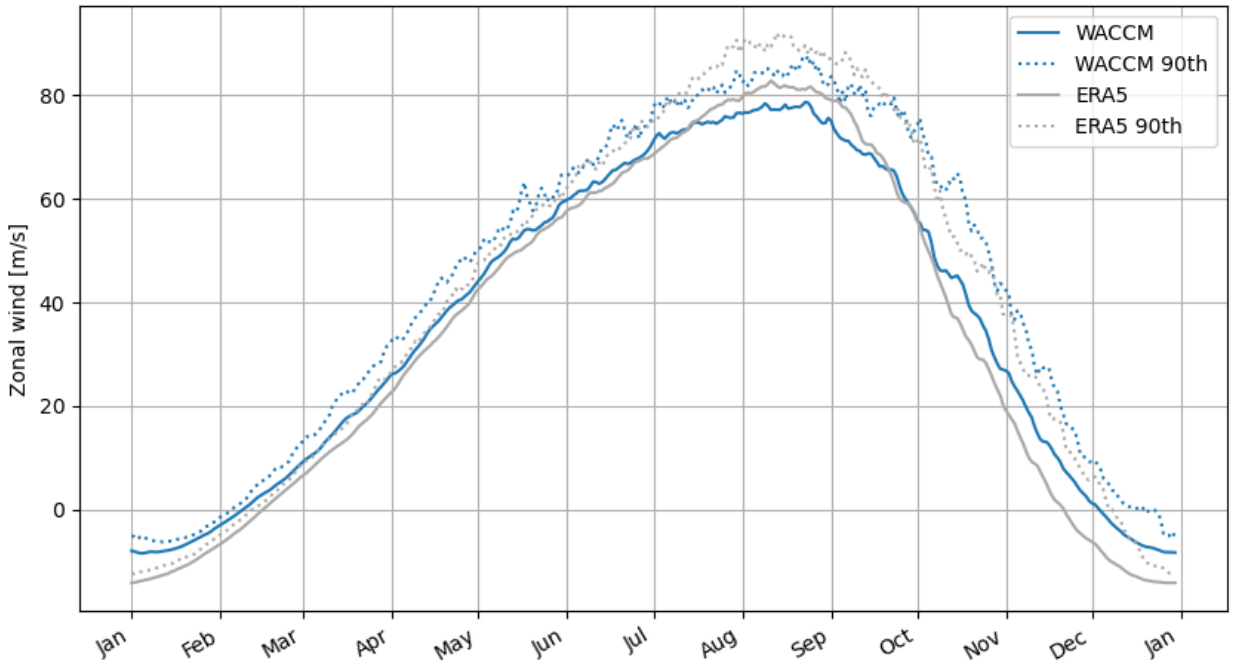


1 deg

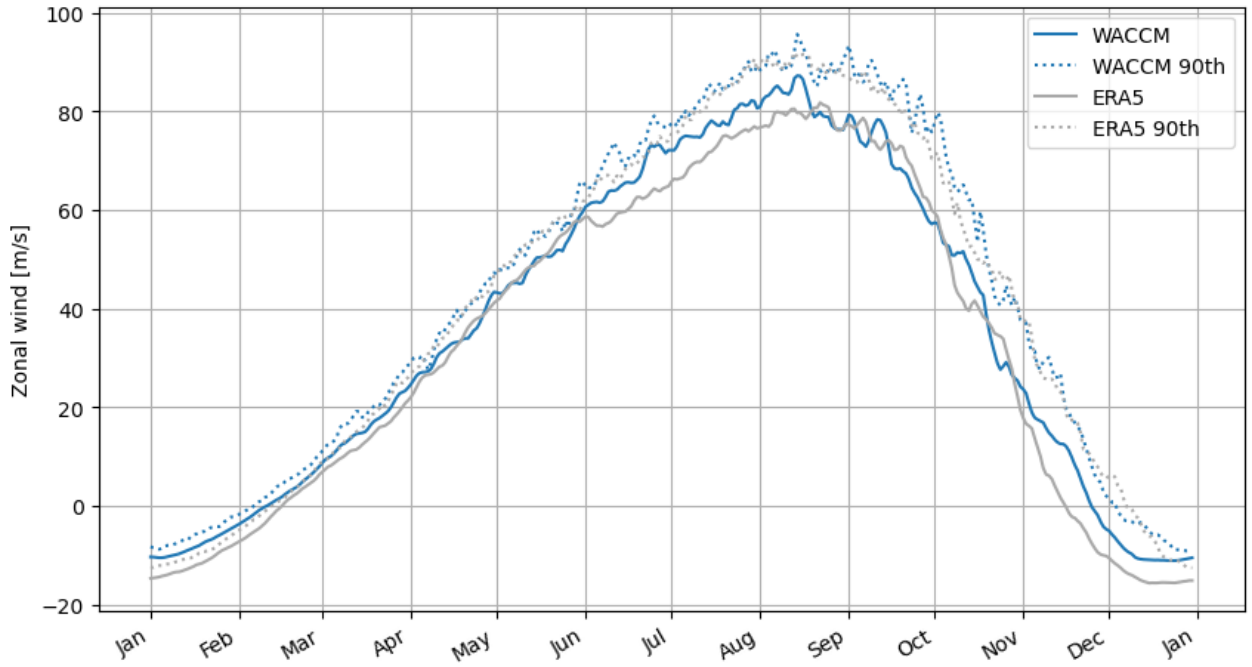


Results from base -runs – Seasonal Cycle (SH)

2 deg



1 deg



Current/Future WAWG Development Plans

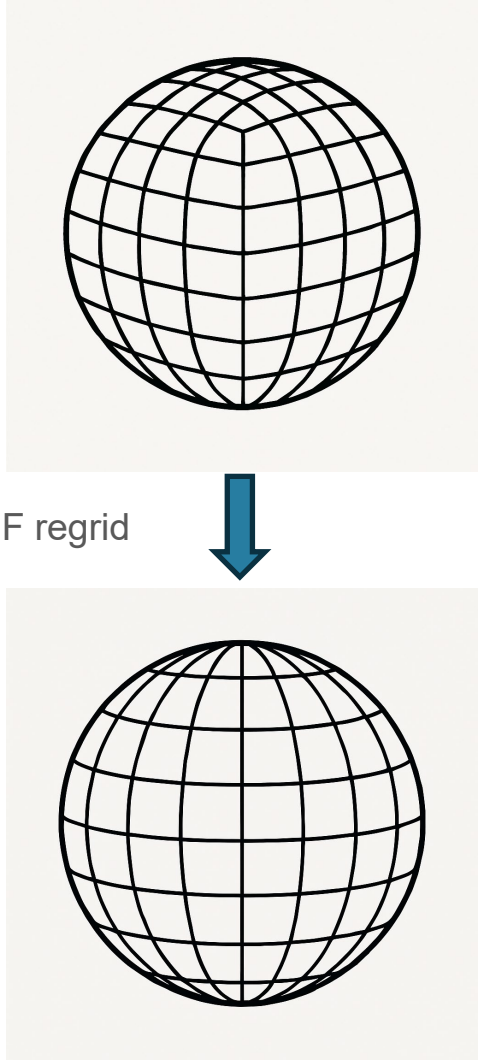
- WACCM
  - New method to calculate zonal means for TEM fluxes
  - In-line photolysis with TUV -x
  - WACCM – MPAS development

- WACCM-X
  - Two-way coupling with GAMERA magnetosphere model
  - Improved ionosphere dynamo and transport
  - Scale aware gravity wave parameterization & thermosphere GW parameterization
  - Interface with JEDI for space weather data assimilation

- Reducing model cost through ML applications
  - Potential venues include ML troposphere, ML aerosol microphysics

Alternative Zonal Means and TEM diagnostics

- Use ESMF library to remap dynamical quantities from unstructured physics grid to a distributed regular longitude-latitude grid
- Straight forward to compute zonal-means and TEM diagnostics on the regular longitude-latitude grid
- Inline parallel ESMF-regridding capabilities are efficient
- Adds only 1-2% to overall cost of WACCM
- Working on understanding potential noise issues at high latitudes



Francis V.
Justin R.

In-line Photolysis

- Photolysis was previously calculated by first using a lookup table (LUT)
- Using this approach photolysis rates did not include the direct effects on actinic flux from aerosol scattering and absorption.
- Now in-line calculation of the actinic flux.
- uses in-line Tropospheric ultraviolet-extended (TUV-x) allows the actual aerosol profiles in the column to be included in the calculation.
- For the aerosols, the optical properties (aerosol optical depth, single-scattering albedo, and asymmetry factor) calculated for the coarser band structure used by the radiative transfer code have been interpolated onto the wavelength grid used by TUV-x.

E.g., after Pinatubo eruption, the sulfate aerosols layer in the stratosphere can affect the photolysis rates in the atmosphere.

Jun Z.

WACCM – MPAS implementation

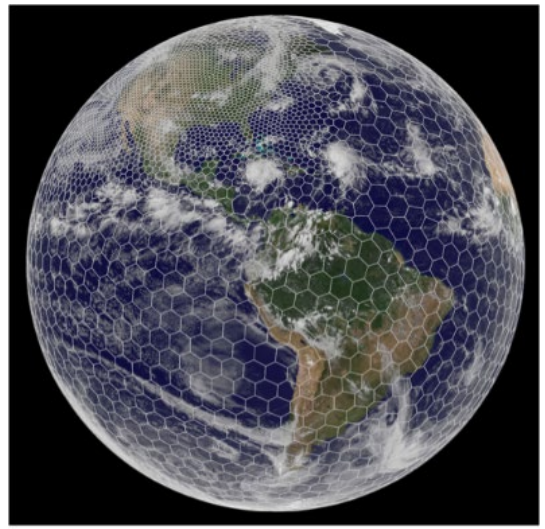
Previous development

- Stable WACCM/MPAS specified chemistry configuration for 120 km horizontal mesh with 70 vertical levels.
- Development of WACCM with the non-hydrostatic MPAS-A dynamical core S Kamali, HL Liu, W Skamarock, J Klemp, F Vitt… - Journal of Advances in Modeling Earth Systems, 2024

Currently under development

- Stable configuration for 120 km horizontal mesh with 135 vertical levels for WACCM/MPAS with full chemistry with the goal of studying QBO.
- Constant pressure upper boundary development in MPAS standalone underway that requires more testing before bringing the changes into CESM. This is being developed specifically for geospace applications.
- Regional refinement to 3 km over CONUS (SIMA S2S^2)

MPAS
Model for Prediction Across Scales



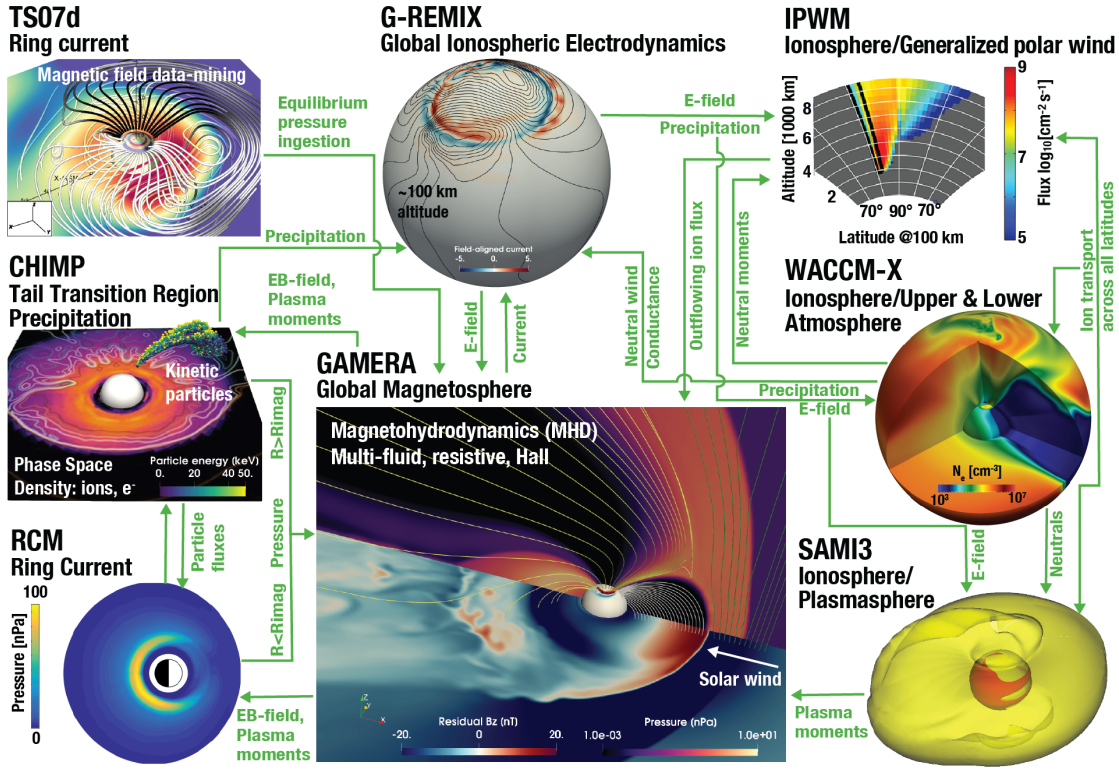
Soudeh Kamali

NSF NCAR Operated by UCAR

WACCM-X/GAMERA: Towards a whole geospace model

- Forcing from the magnetosphere at high-latitudes is one of the largest uncertainties in simulating the upper atmosphere response to geomagnetic storms
- Empirical models fail to reliably capture the high-latitude forcing
- NASA Center for Geospace Storms (CGS) and HAO have recently completed ***two-way coupling*** between WACCM-X and the GAMERA magnetosphere model, paving the way for a whole geospace model

Model Framework for CGS MAGE



MAGE: Multiscale Atmosphere-Geospace Environment Model

Summary and Remaining Development Tasks

- Stratosphere, mesosphere, and lower thermosphere dynamics and seasonal cycle have been evaluated in baseline runs
- In-line photolysiscalculation with TUV-x
- WACCM goes MPAS
- WACCM-X is heading towards wholegeospace model

Development Tasks:

- TEM calculation
- Low-frequency tropical GW parameterization
- WACCM with CAM7 93l vertical grid
- Explore ML options for tuning and replacing troposphere
- In-line photolysis calculation