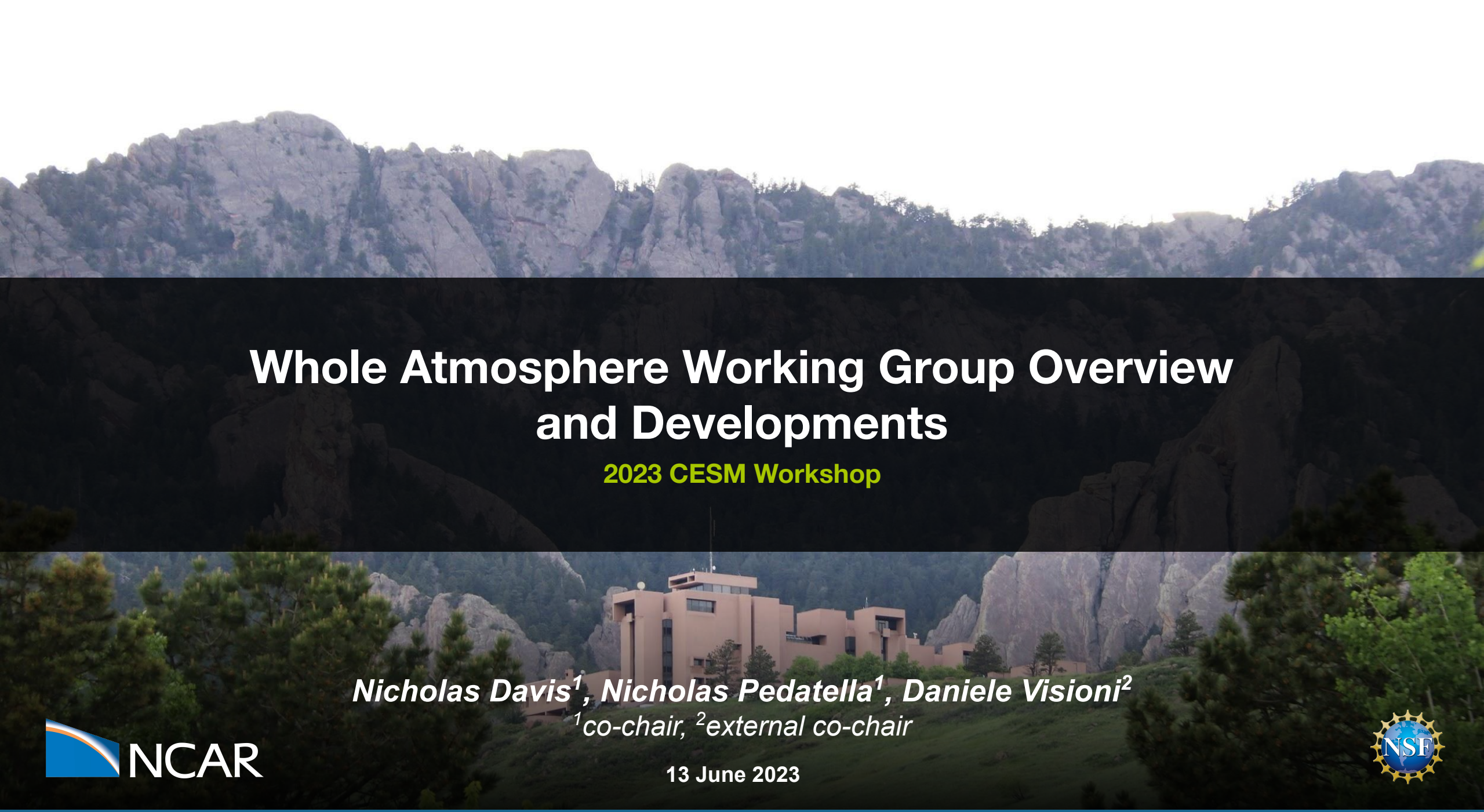

Whole Atmosphere Working Group Overview and Developments

2023 CESM Workshop

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[1]co-chair, [2]external co-chair

13 June 2023

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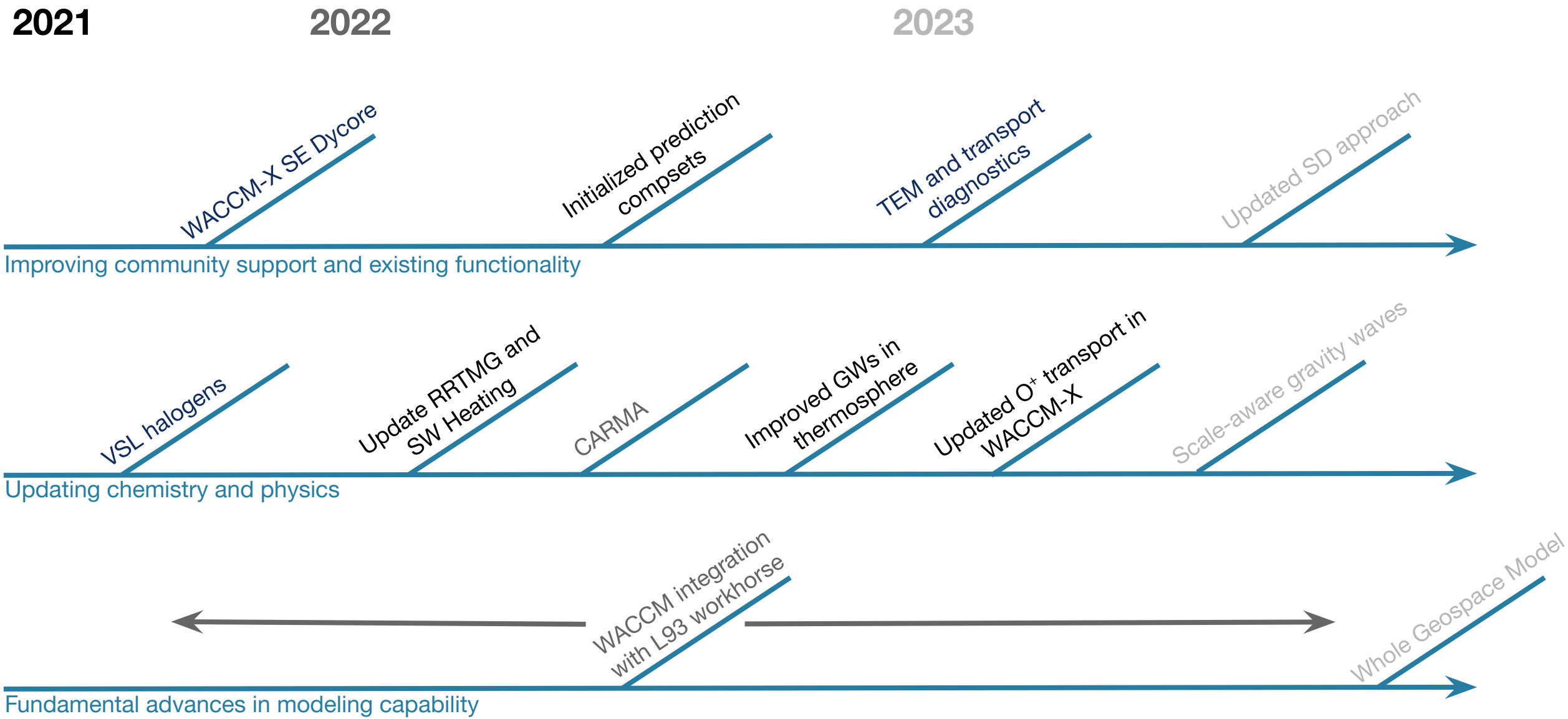
Nominal WAWG Development Timeline (circa 2020-2021)

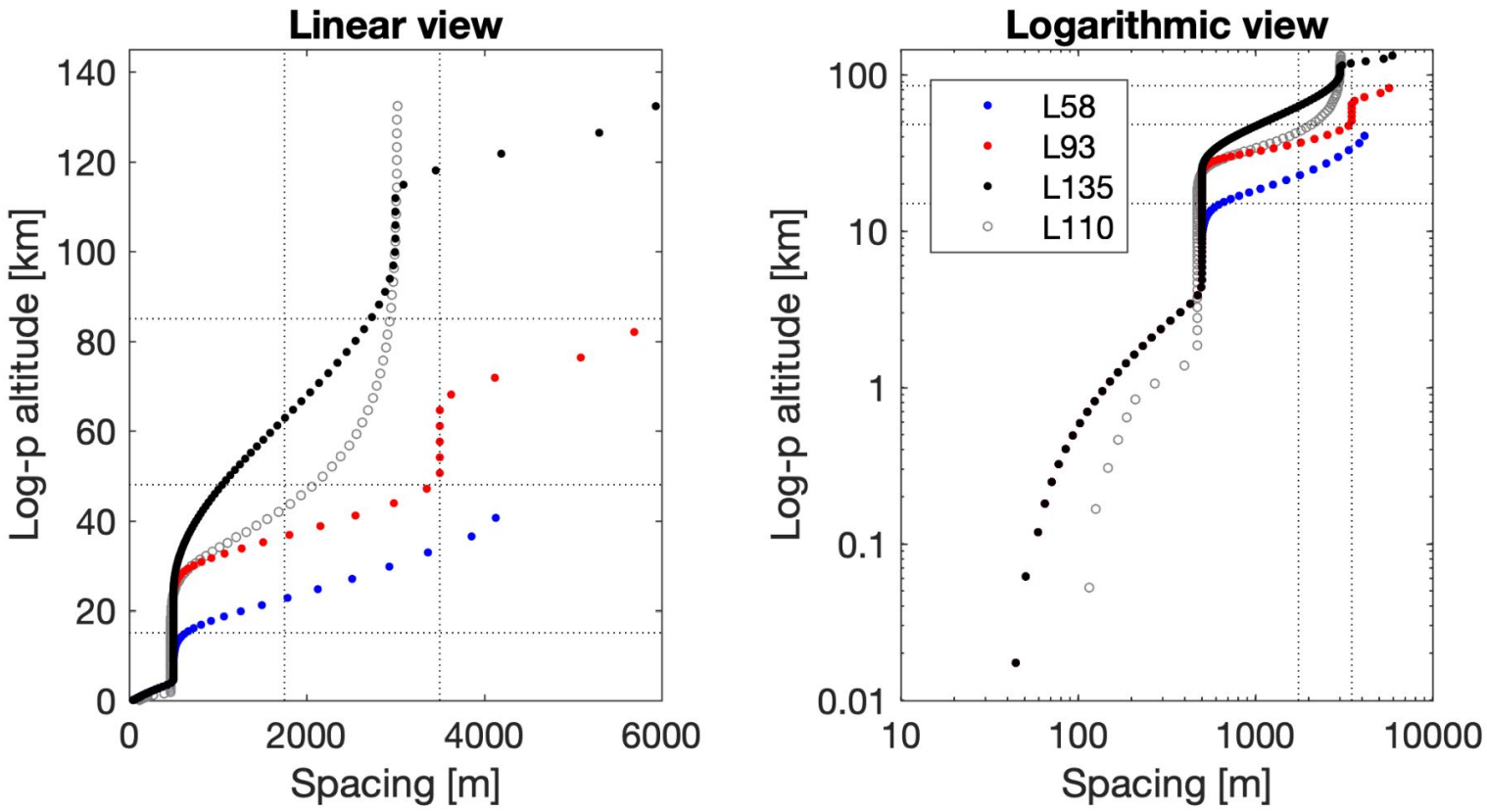


WAWG Developments and Accomplishments

- Developments and accomplishments
  - Stable spectral element (SE) dycore configuration at ne16 (~2 deg) and L135 with middle atmosphere (MA) chemistry
  - CARMA
  - Initial configuration and testing of L189 WACCM-X with SE dycore at ne16
  - Preliminary WACCM-X/GAMERA coupling (Hanli)
  - Continued use for solar intervention studies (Daniele, Ewa, Matthew)
  - New ad-hoc tool used to CMORize CCMI-2022, also being used for QBOi
- Development priorities
  - Evaluation and tuning of L135 WACCM and L189 WACCM-X using the SE dycore
  - MPAS vertical extension
  - WACCM-X/GAMERA
  - Lightweight WACCM-X
  - Regional refinement

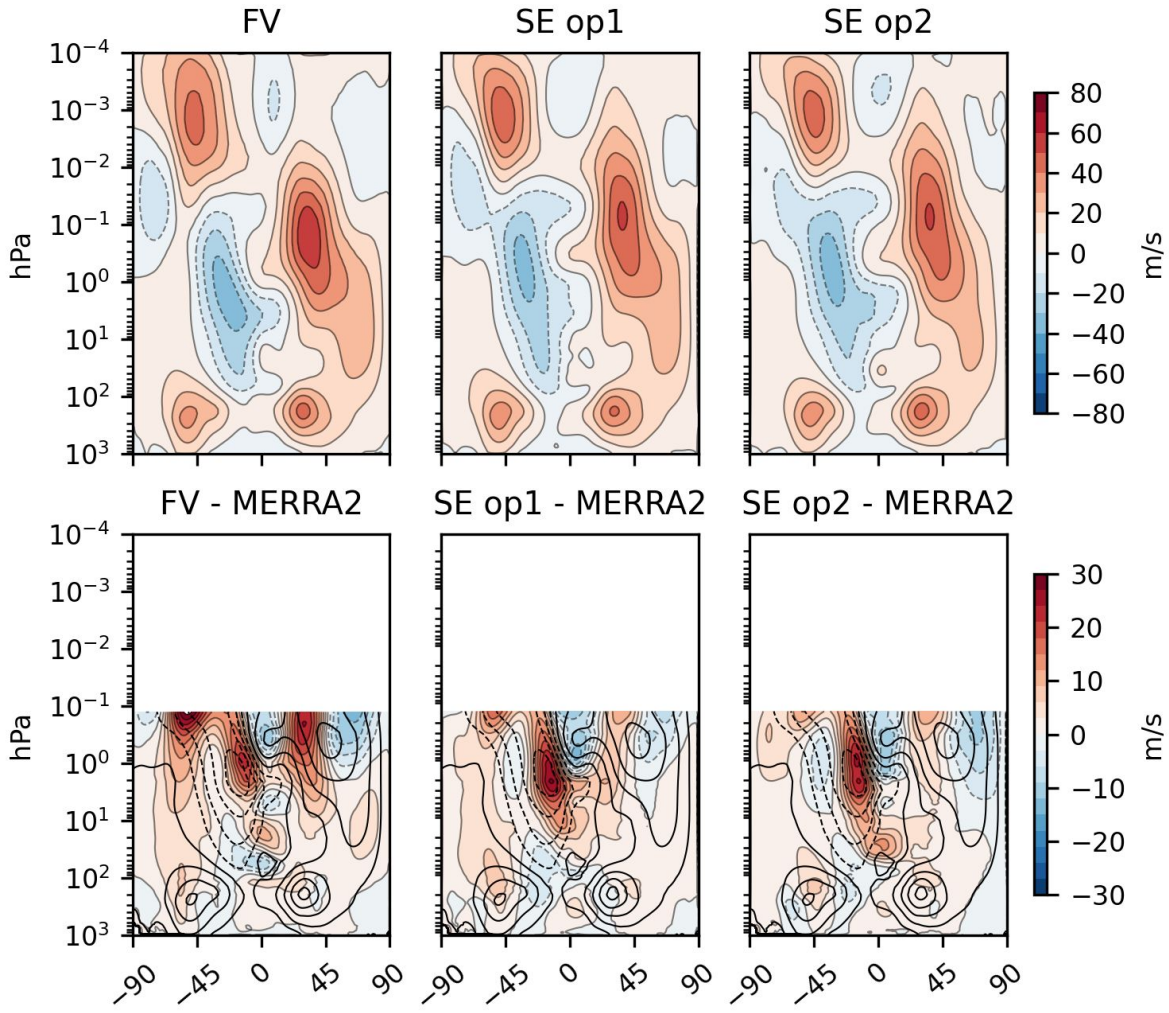
WACCM7, integrating with the CAM workhorse model

- L135 shares L93 workhorse grid from surface to ~25 km
- More gentle fall off of grid spacing through upper stratosphere and mesosphere than L110
- Sponge layer spacing, HB diffusion for stability
- ne16 (~2 deg) tuning is finishing up, moving to ne30 (~1 deg)
- ne16 with MA chemistry: 7k core hours/sim year



Current workhorse vertical grids and their spacing. Vertical dotted lines indicate ¼ and ½ of a 7km scale height, while horizontal dotted lines indicated approximately the tropopause, stratopause, and mesopause.

WACCM7 tuning - reduced polar vortex, mesopause biases

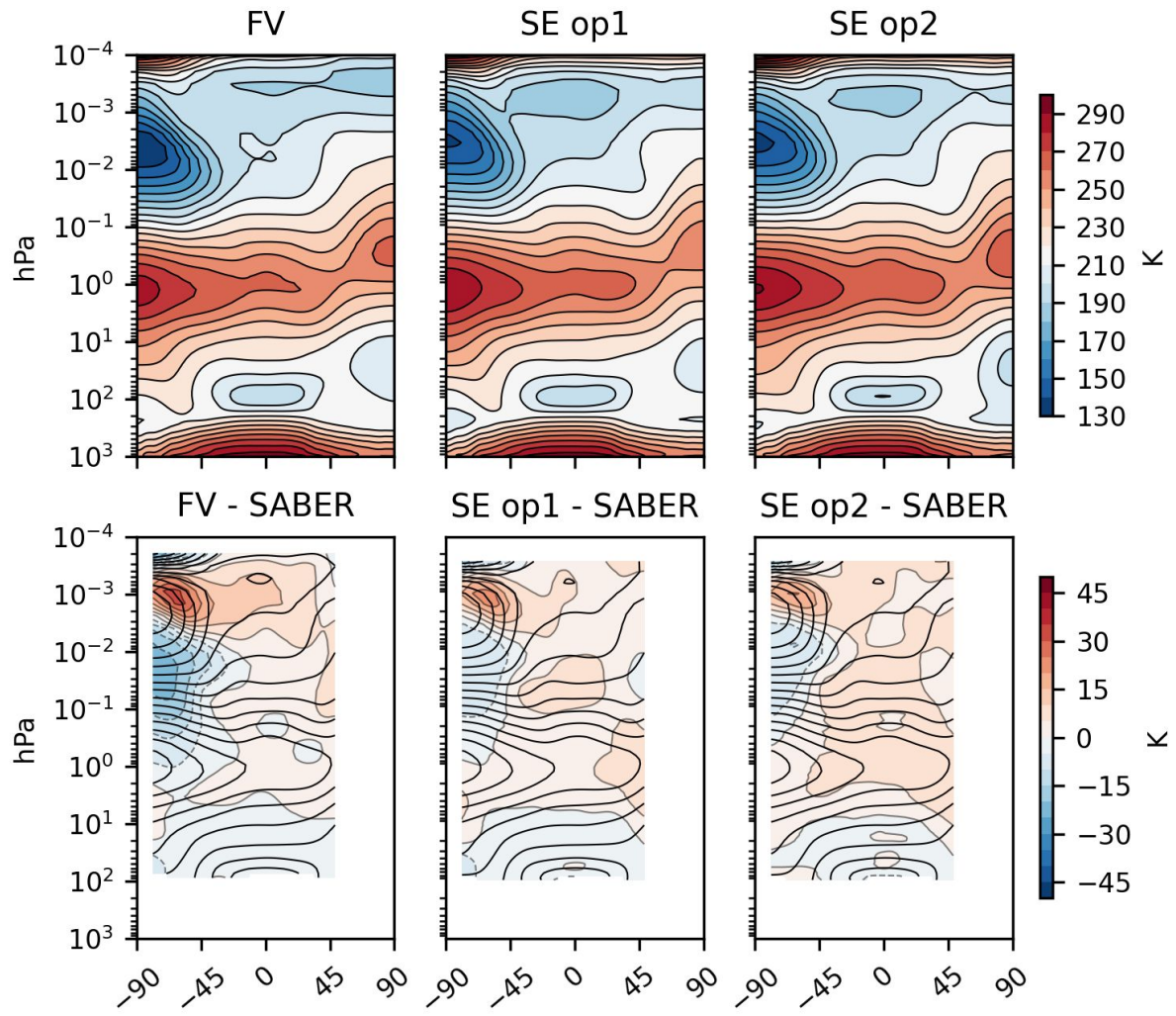


- Current best configuration of WACCM7 SE (“SE op1”) has reduced NH vortex biases and reduced SH easterly biases
- Second-best configuration of WACCM7 SE has similar NH cold vortex bias, but otherwise reduced biases throughout the stratosphere

Comparison of zonal mean zonal wind in DJF from WACCM6 FV and two current WACCM7 SE configurations with MERRA2.

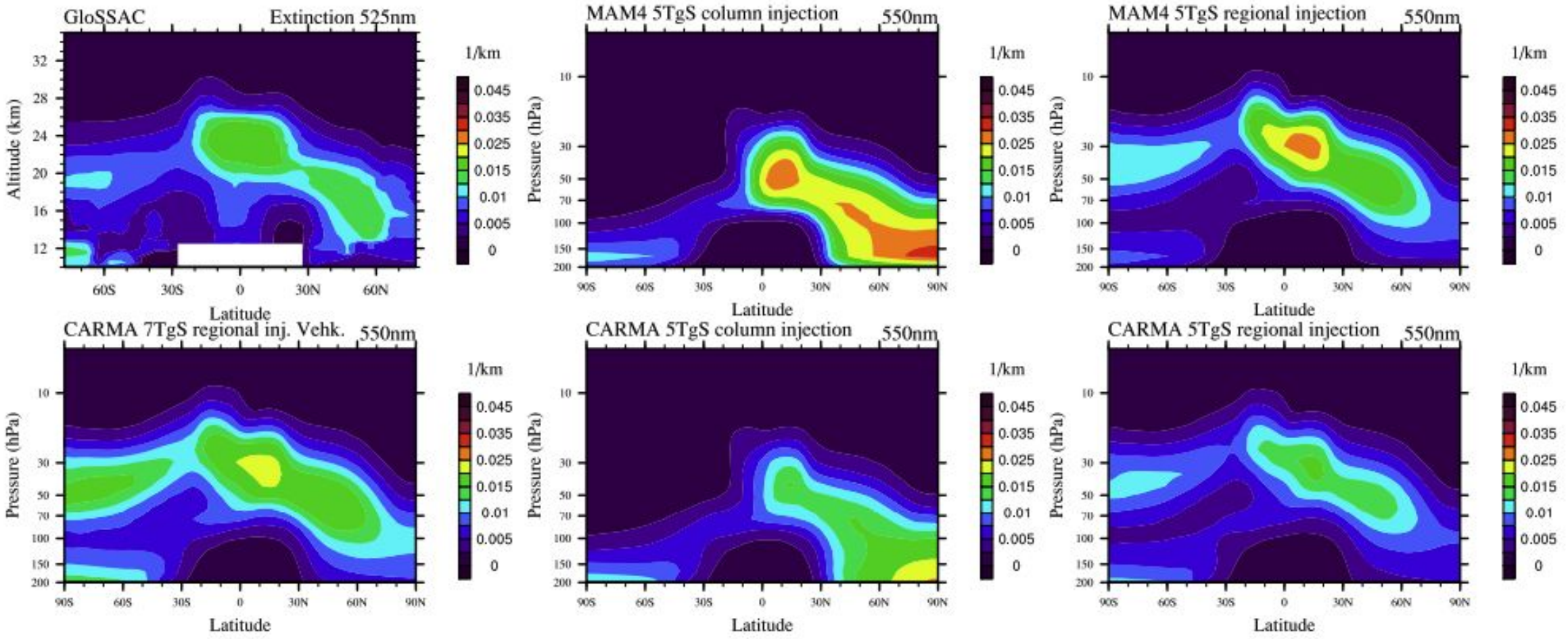
WACCM7 tuning - reduced polar vortex, mesopause biases

- Current best WACCM7 SE configurations have a slightly warmer mesopause than WACCM6 FV (order 4K)
  - But lower biases overall
- New tuning knob: frontal gravity wave spectrum half-width
  - More direct control on mesopause



Comparison of zonal mean temperature in December from WACCM6 FV and two current WACCM7 SE configurations with SABER.

Updates to the microphysical aerosol scheme in WACCM

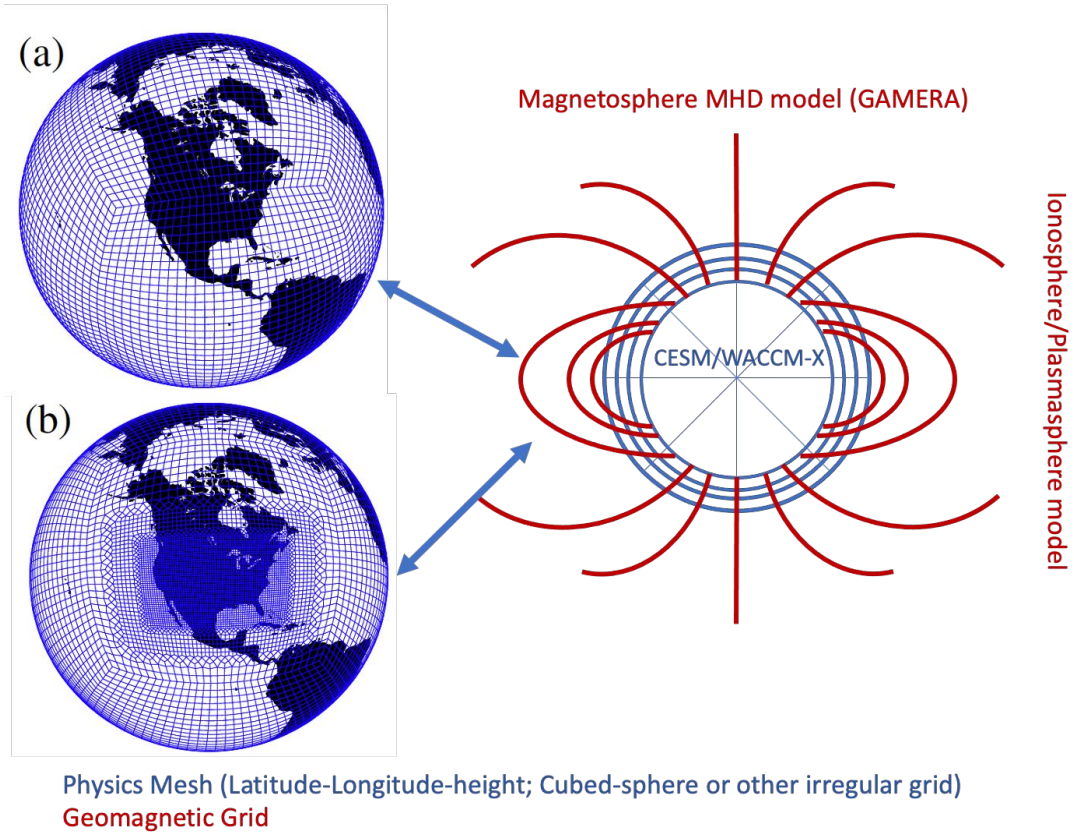


Zonal average aerosol extinction (550 nm for the model and 525 nm for GLoSSAC), GlosSAC climatology (top left) and different model simulations using WACCM-MA

Credit: Simone Tilmes

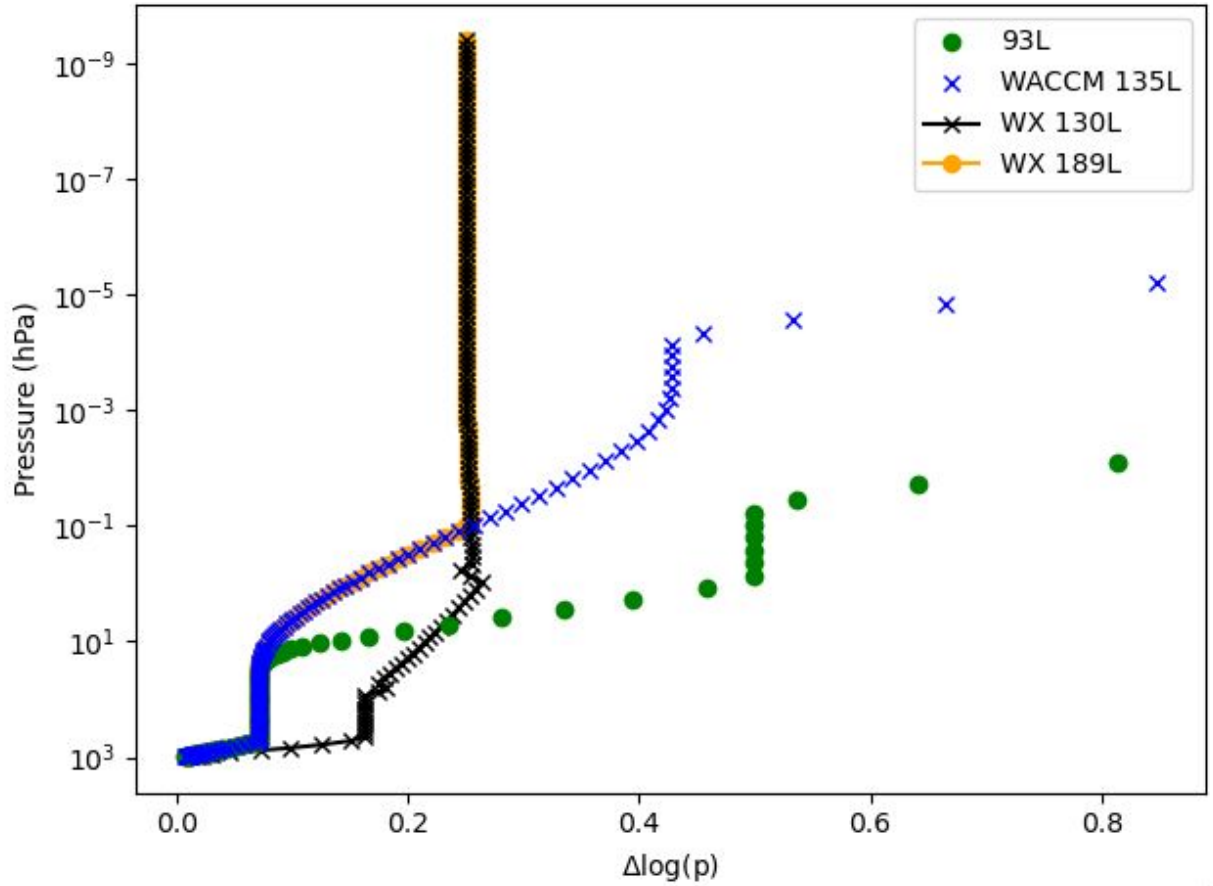
WACCM-X SE Development

- Neutral dynamics and physics
  - WACCM-X species dependent SE dynamical core with CSLAM transport
  - Molecular viscosity/diffusion in horizontal direction
- Regridding between physics mesh and geomagnetic grid
  - Interactive ionospheric dynamo, transport, and energetics.
- Configurations:
  - NE120 (~0.25°) horizontal, 0.1 scale height vertical
  - NE16 (~2°) horizontal, 0.25 scale height vertical
- Developed as part of SIMA initiative

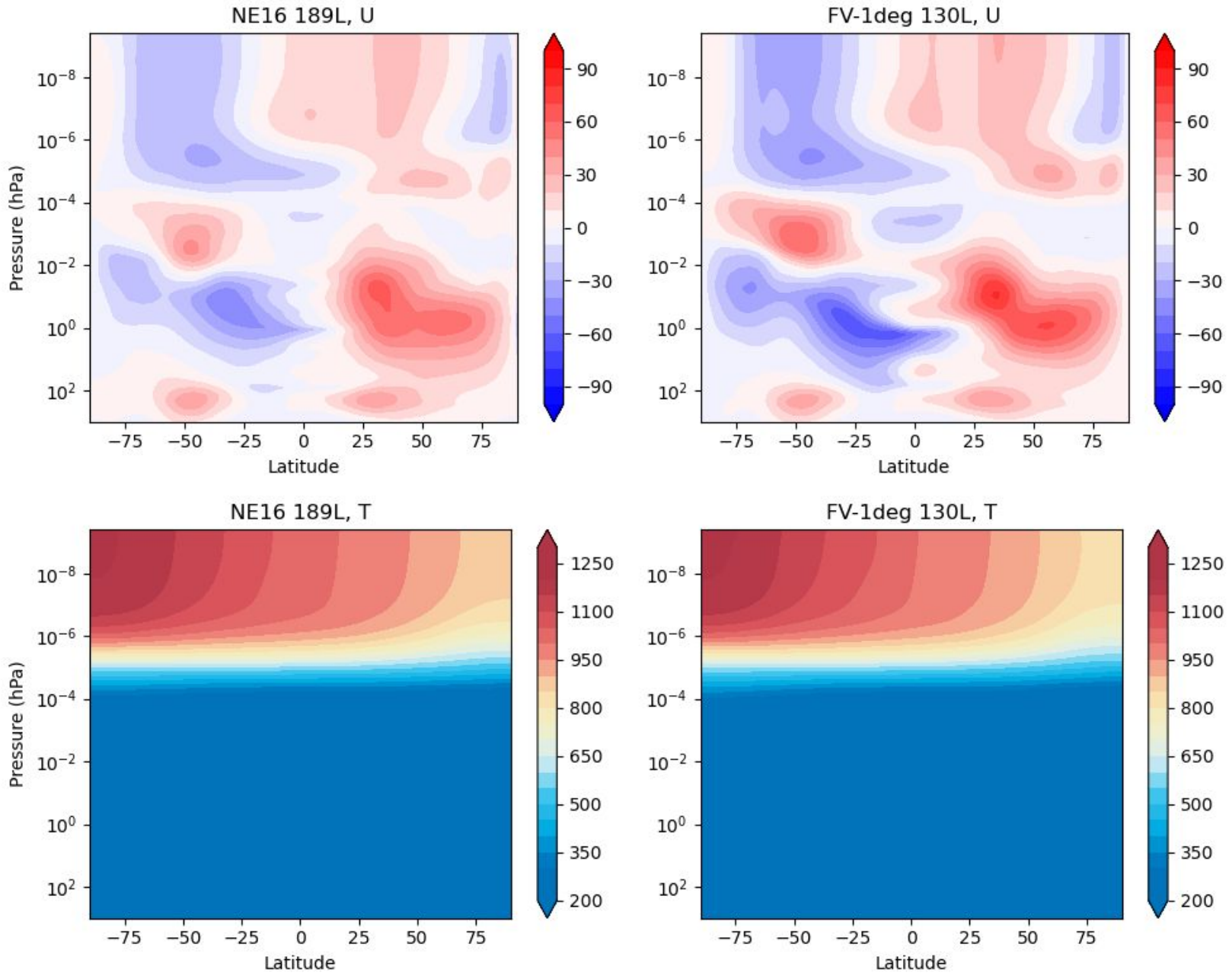


L189 WACCM-X7 Development

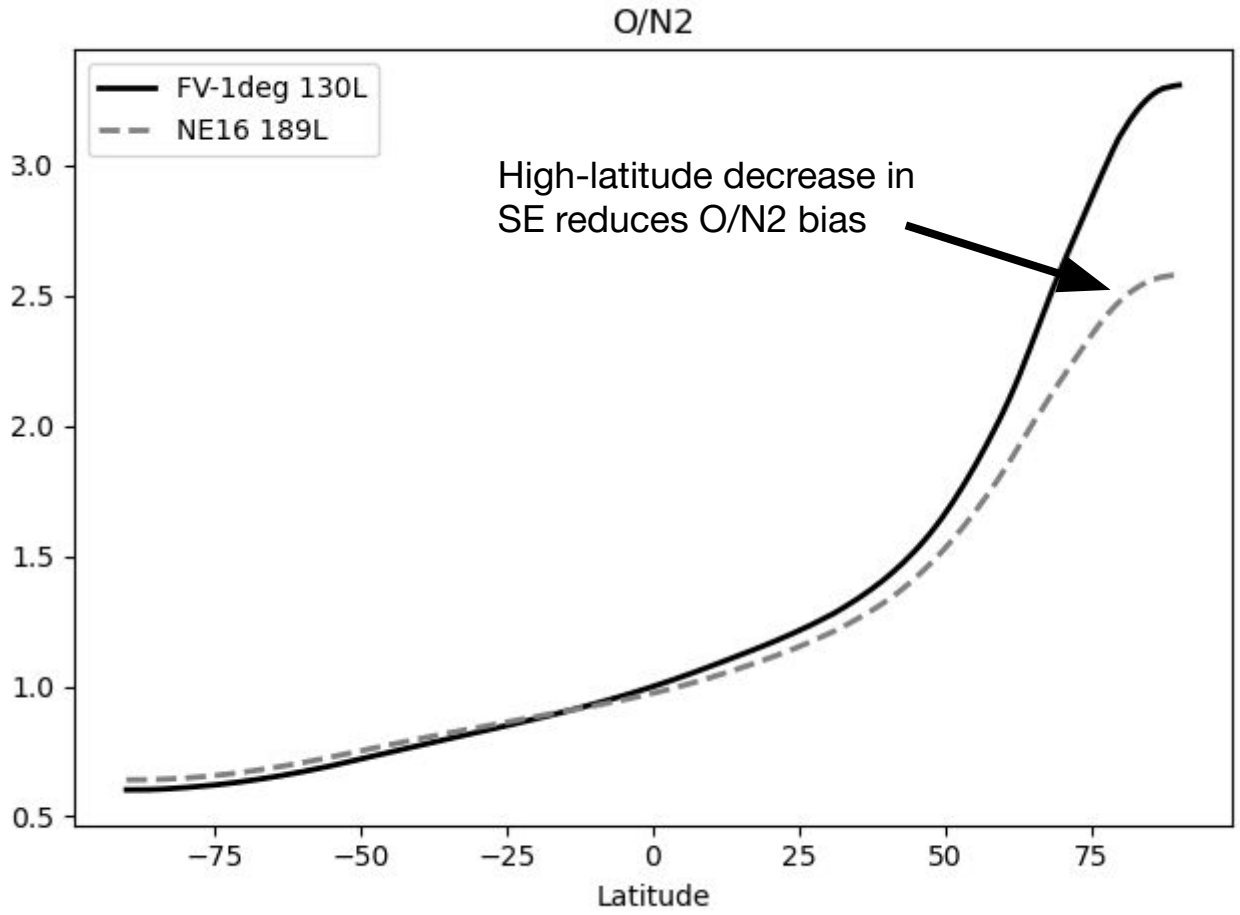
- WACCM-X L189 vertical grid follows the CAM7/WACCM7 grid up to ~10^{-1} hPa
- Tested with CAM development version and WACCM GW parameters (r003)
- Nominal 1 degree (ne16) simulations for January solar medium conditions

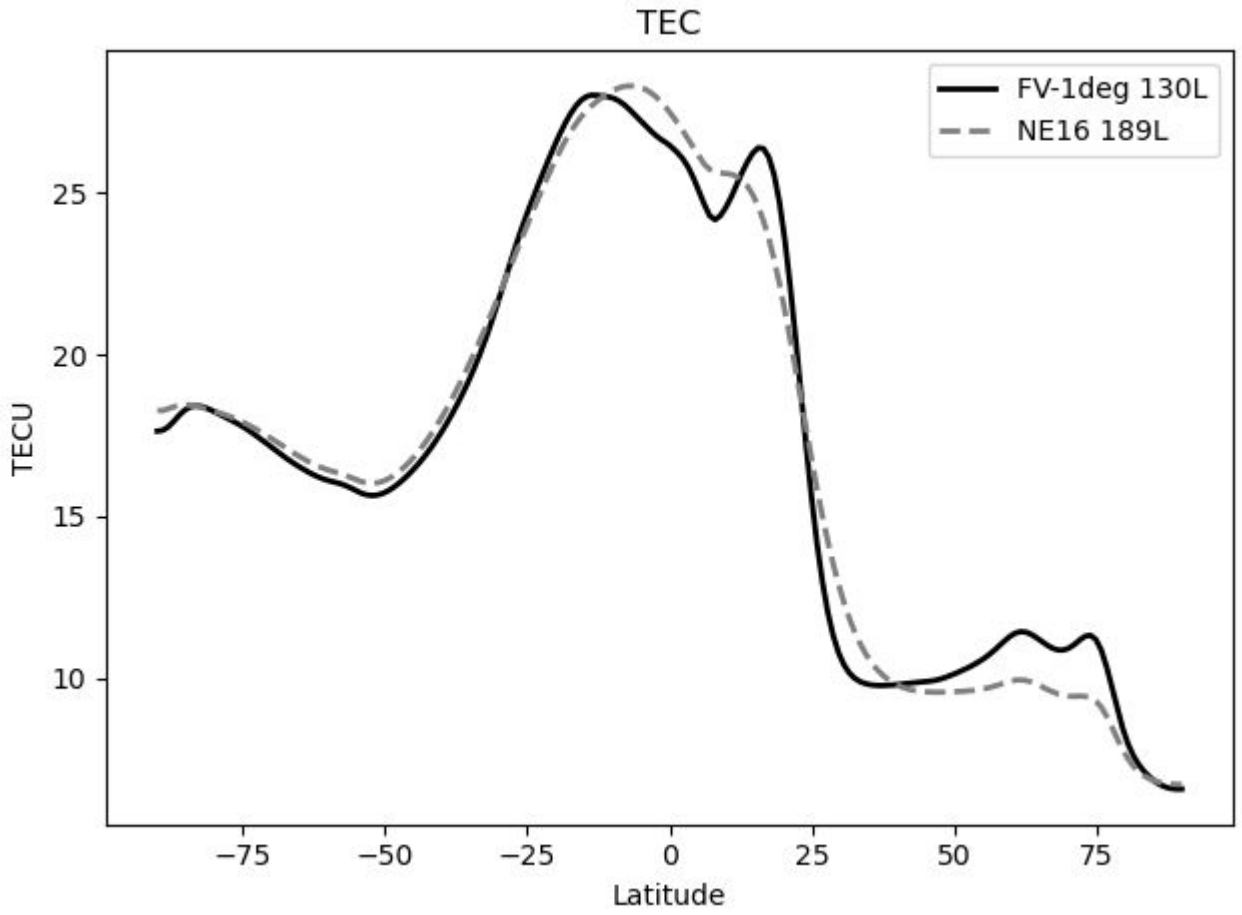


Winds in temperatures in ~1° SE and FV are in general agreement

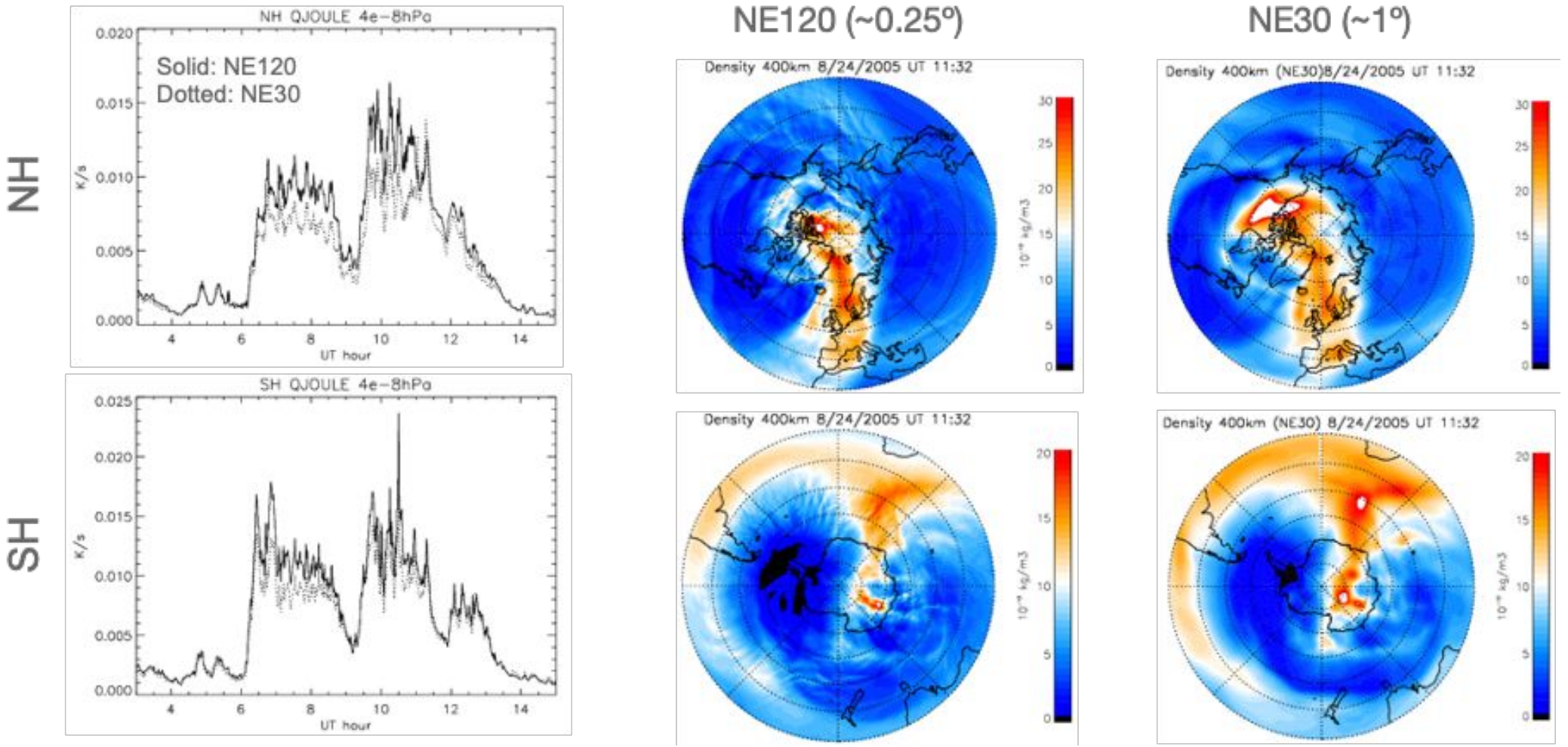


SE and FV dynamical cores have generally similar thermosphere composition and electron density





Towards a Whole Geospace Model: WACCM-X/GAMERA



Joule heating (left) and thermosphere density (right) in WACCM-X driven by GAMERA (Grid-Agnostic MHD for Extended Research Applications) high-latitude forcing

Summary

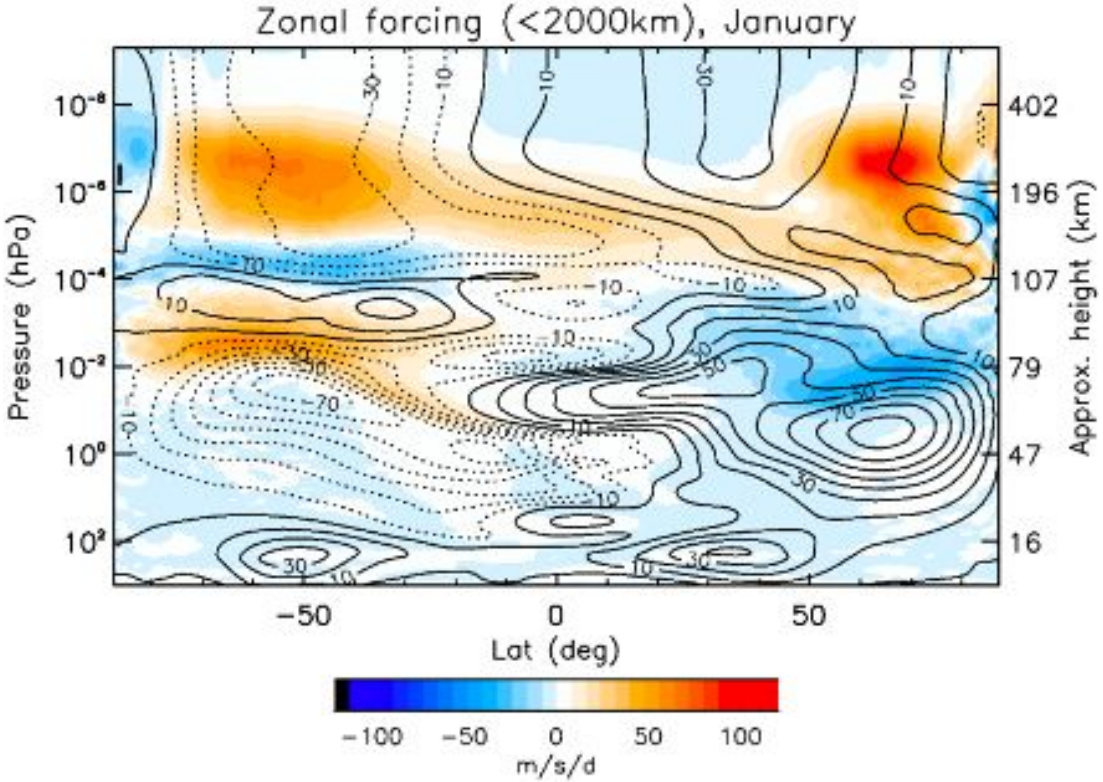
- WACCM SE with interactive chemistry is now stable and being tuned
  - Sponge layer spacing
  - HB diffusion
  - Currently focused on polar vortex, mesopause, QBO bias reduction
  - Starting multi-decadal simulations to assess sudden warming frequency, variability

- WACCM-X SE
  - Initial assessment of WACCM-X SE simulations at L189
  - Considering development of lightweight WACCM-X for thermosphere-ionosphere focused studies that may not require detailed representation of troposphere-stratosphere
  - Toward a whole geospace model: coupling with GAMERA coupling

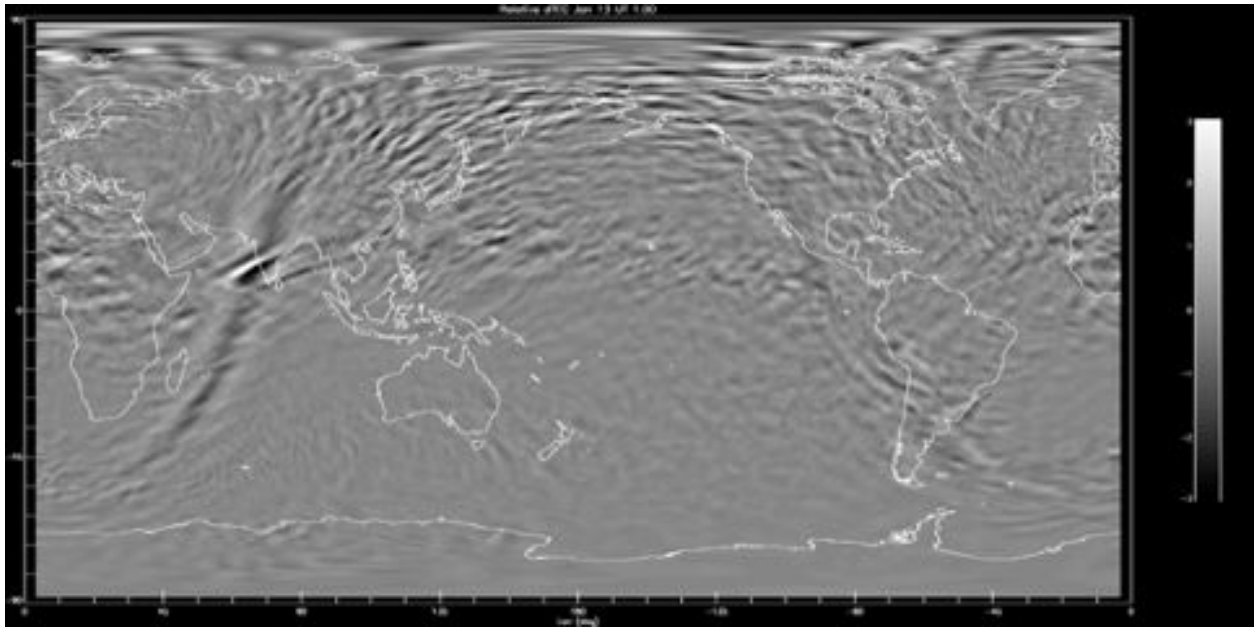
- Parallel development of simplified/low-cost and cutting edge/high-cost model configurations
- WAWG session will highlight key science applications, including climate intervention, stratospheric ozone, and whole atmosphere/geospace coupling

High Resolution WACCM-X SE

- Better representation of gravity wave forcing in high-resolution WACCM-X improves dynamics and thermosphere composition
- Resolves small-scale perturbations in thermosphere and ionosphere, such as those that occur during the Hunga-Tonga eruption

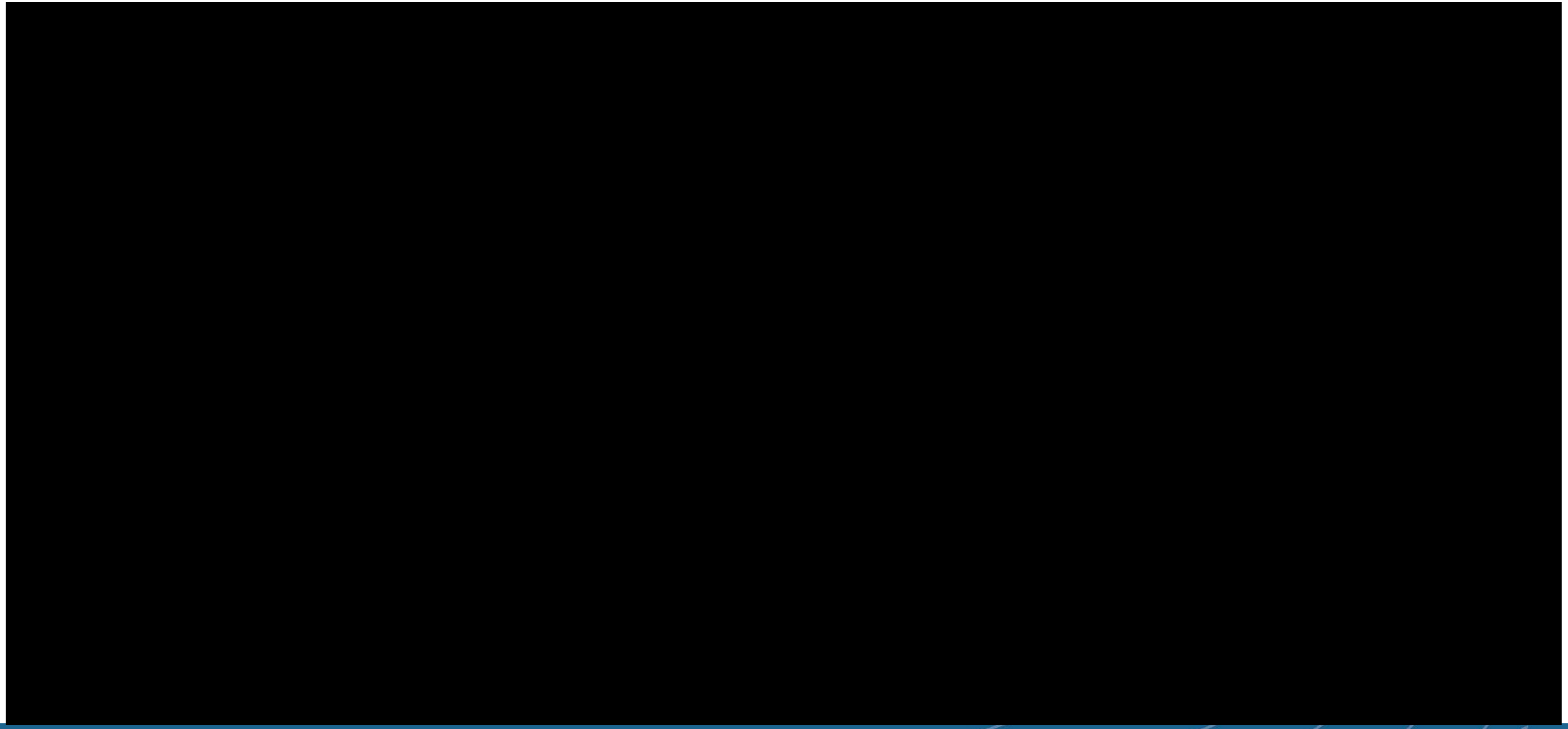


Perturbations in Total Electron Content (periods < 2 h)

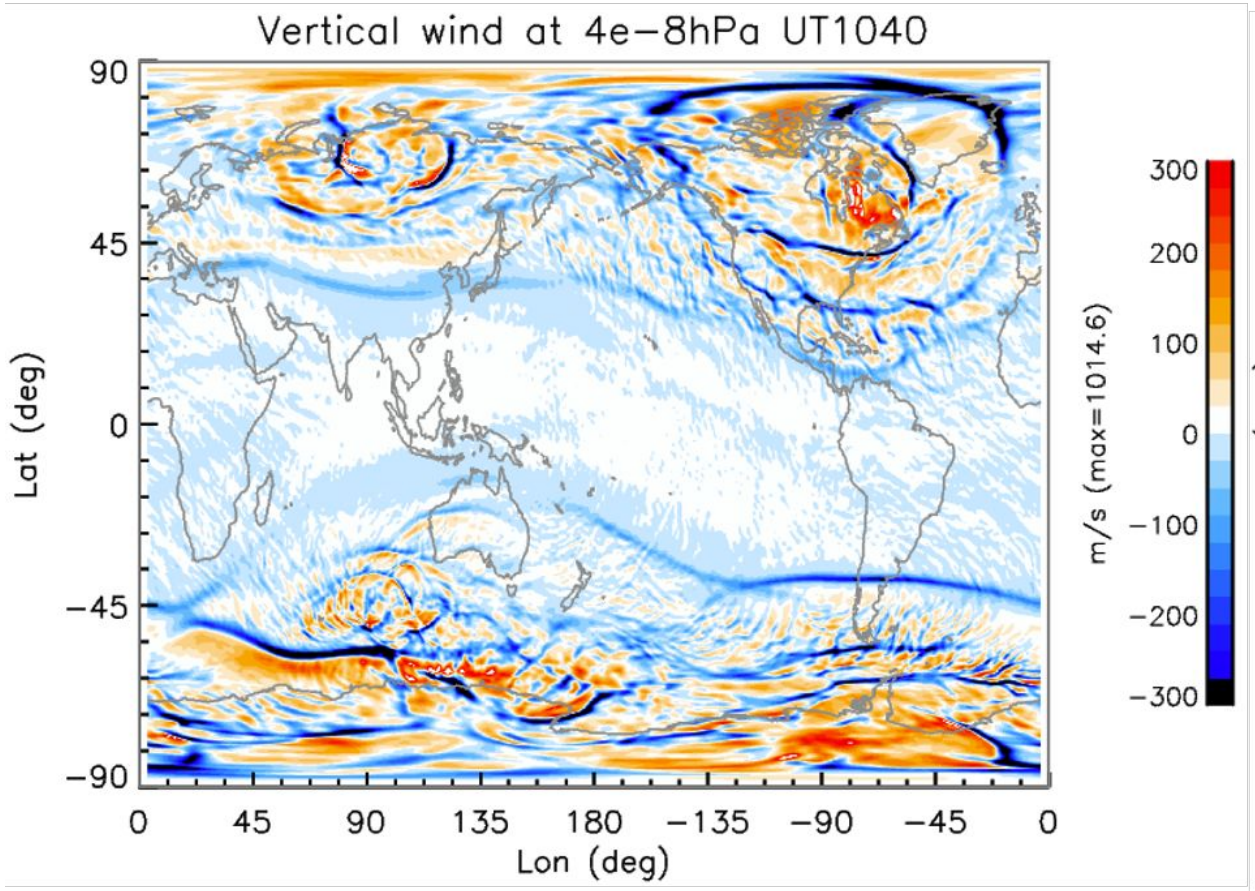


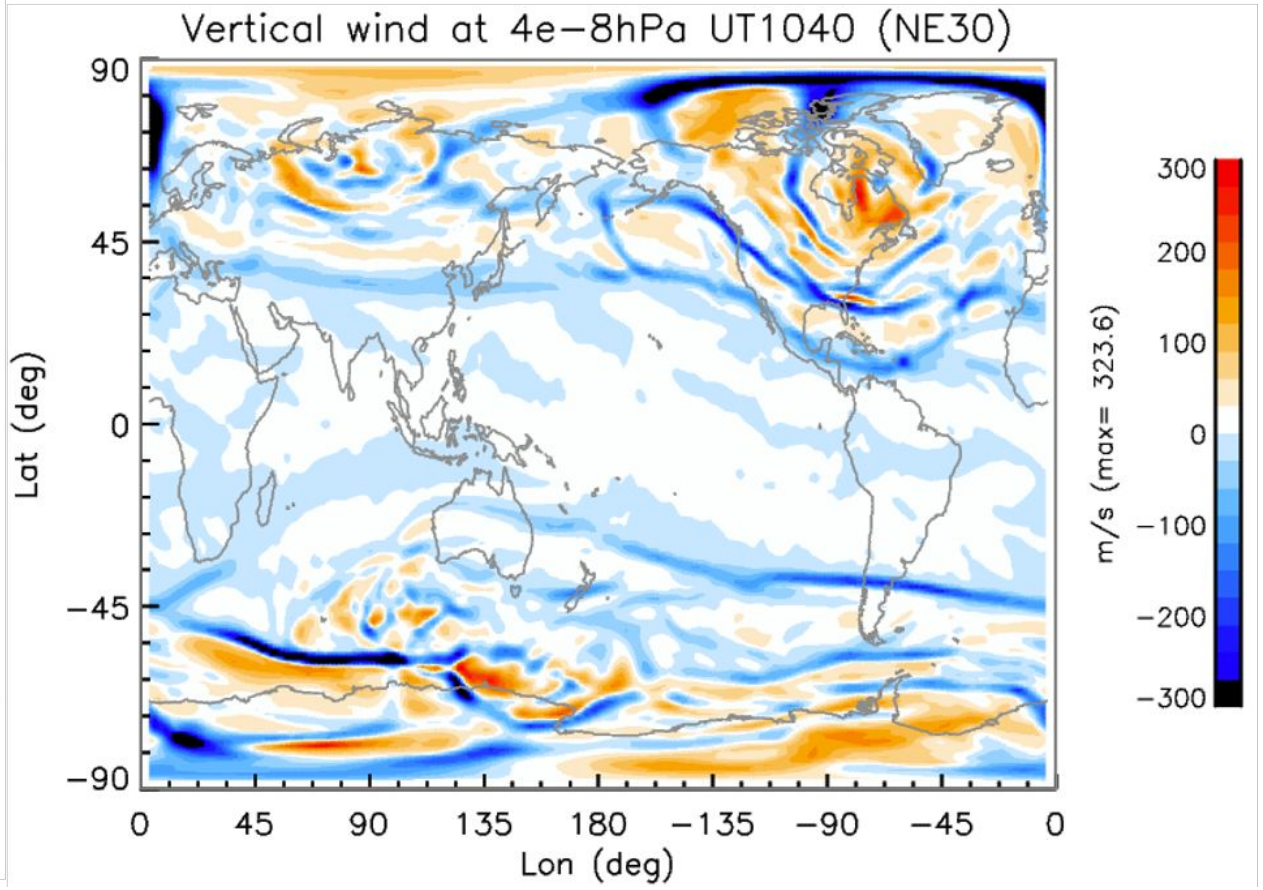
Credit: Hanli Liu

WACCM-X simulations of surface pressure (bottom) and total electron content (top) following Hunga-Tonga eruption



Towards a Whole Geospace Model: WACCM-X/GAMERA



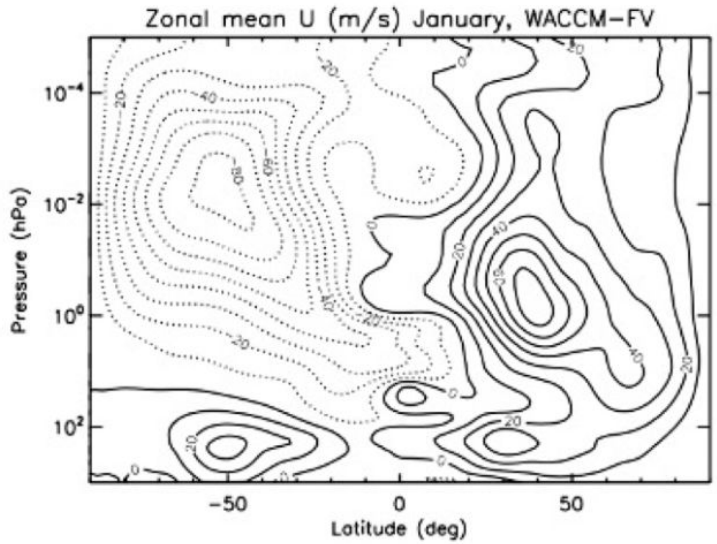


Thermosphere vertical winds in WACCM-X driven by GAMERA (Grid-Agnostic MHD for Extended Research Applications) high-latitude forcing at high and low resolutions

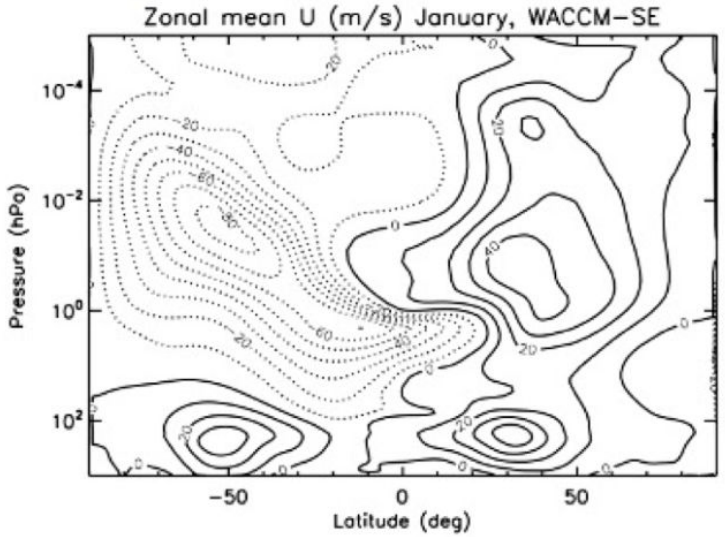
Upper Atmosphere Extension of MPAS

- MPAS-A was extended to higher altitudes (supported by SIMA)
- Provides non-hydrostatic capabilities to WACCM
- The mean zonal wind and temperature climatology from SC-WACCM/MPAS-A was validated against results from SC-WACCM using FV and SE dynamical cores.
- More details presented in Chemistry/Whole Atm. WG session on Wednesday

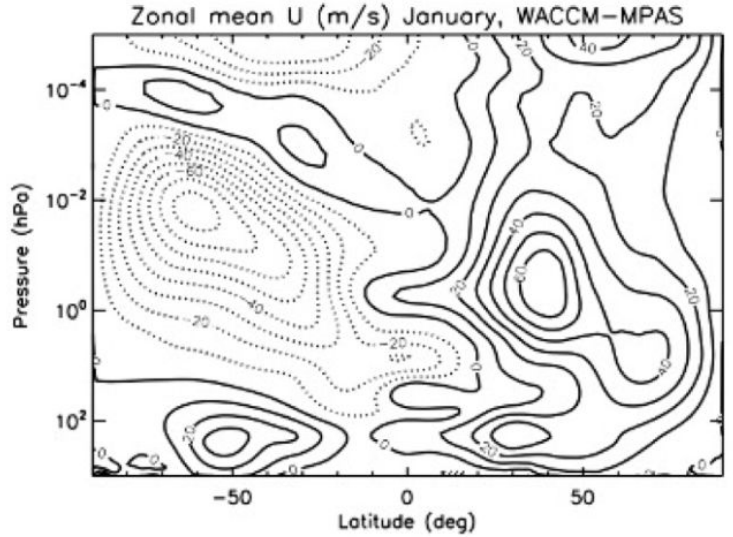
Finite Volume (FV)



Spectral Element (SE)



MPAS-A



Credit: Soudeh Kamali