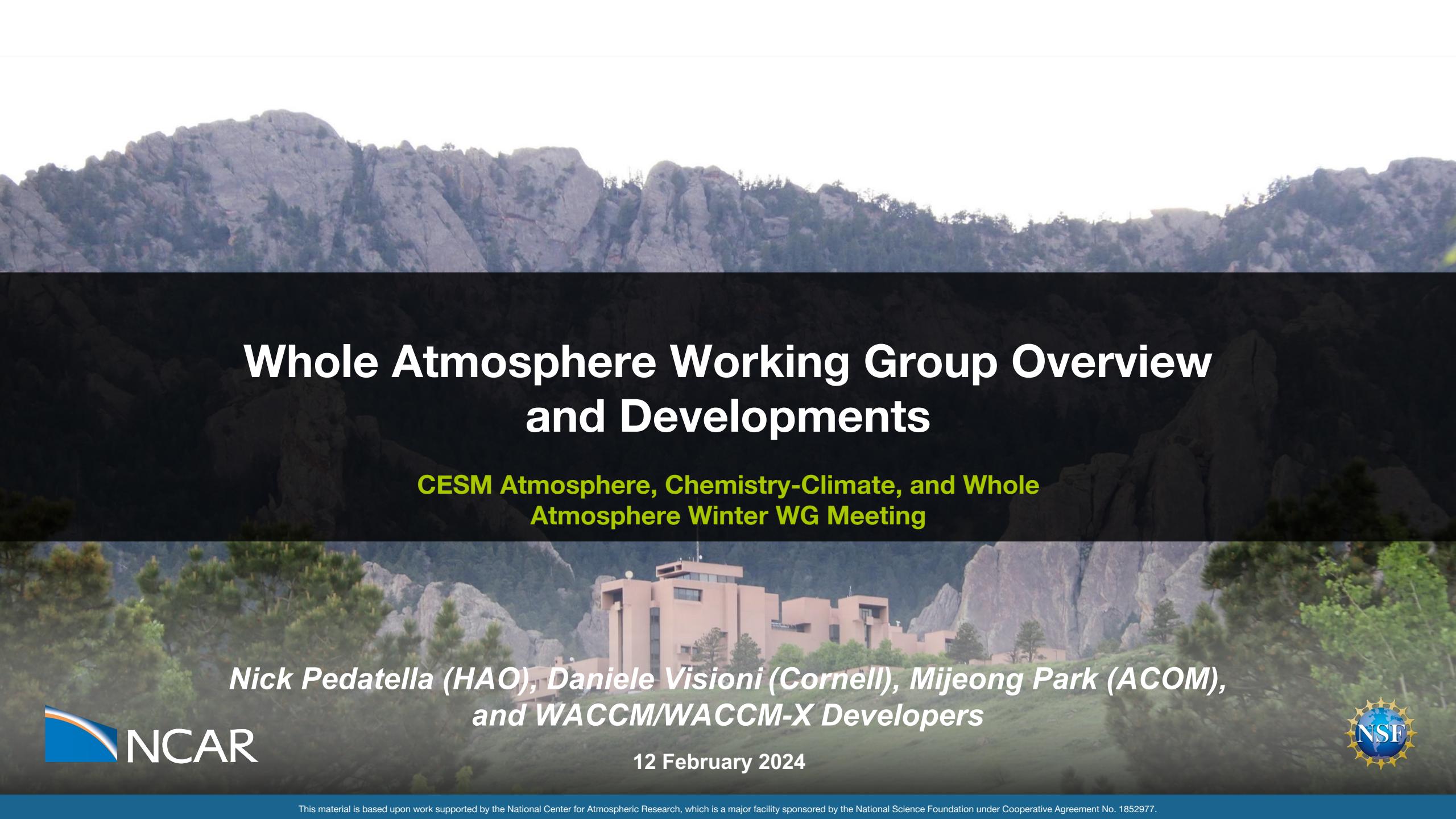


Whole Atmosphere Working Group Overview and Developments

CESM Atmosphere, Chemistry-Climate, and Whole Atmosphere Winter WG Meeting

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

12 February 2024

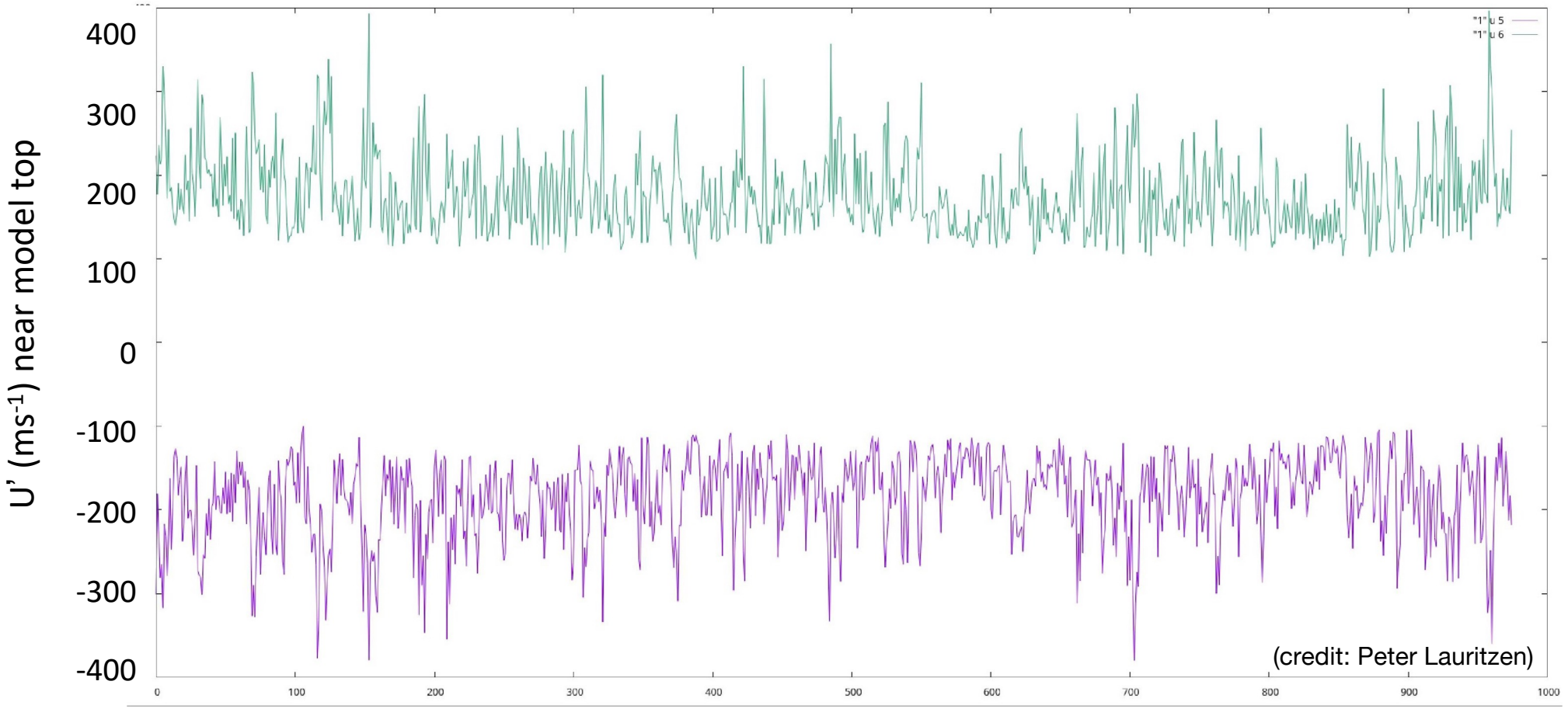
This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

Primary WAWG Developments and Updates

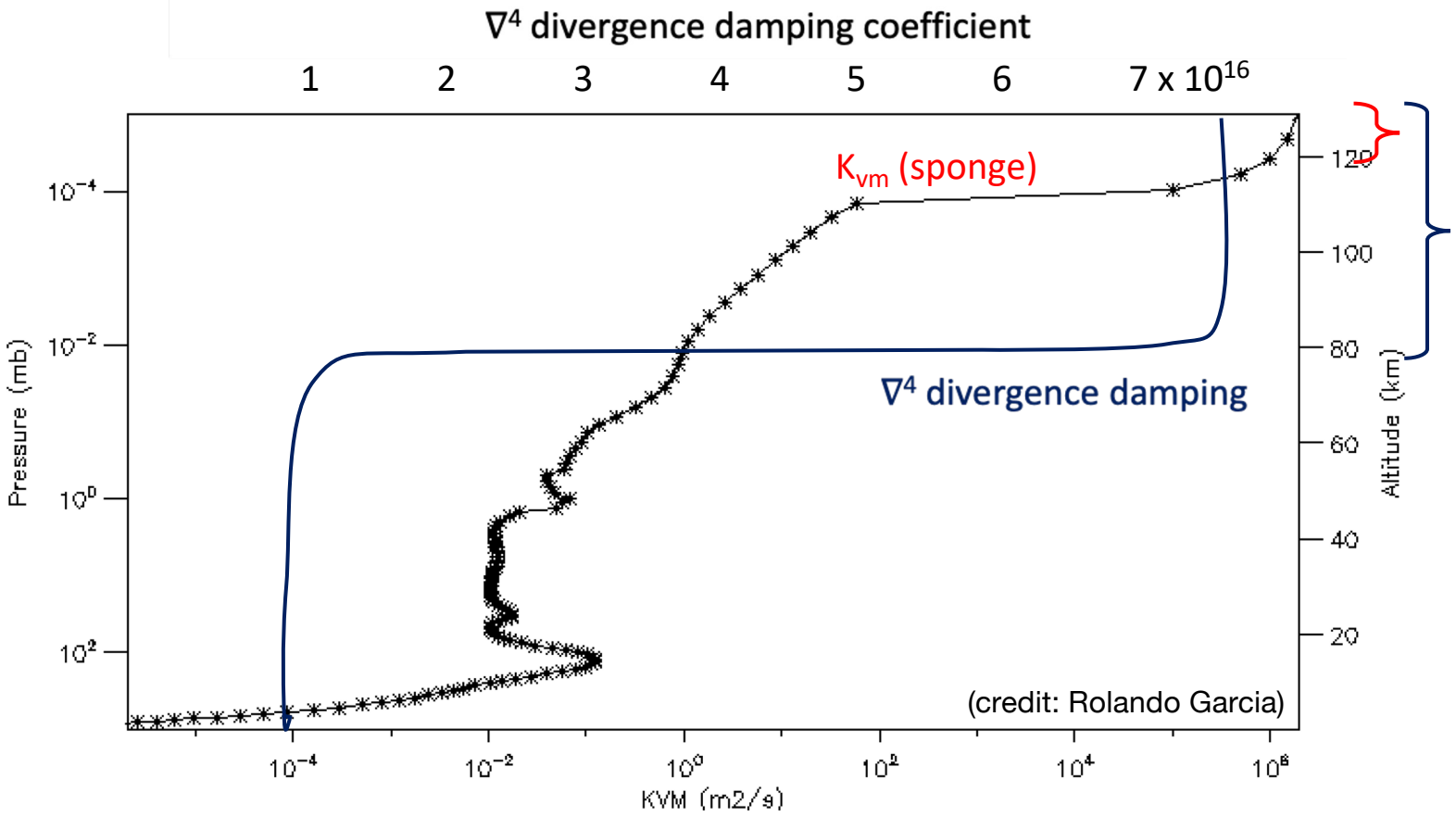
- WACCM
  - Transitioned development to cam_dev physics and cam6_3_132 tag
  - Addressed issues with model stability
    - HB diffusion
    - Updates to SE dycore for stability (Peter Lauritzen)
    - Significantly improved model throughput
  - Baseline simulations as benchmark for evaluation and future tuning
  - Inline photolysis and heating using TUV-x (Doug Kinnison)

- WACCM-X
  - Extension of SE dycore into the thermosphere (Hanli Liu)
  - Preliminary tests with NE16/L189 and cam6_3_132
  - Long term historical and projection simulations of space climate

Instabilities in SE-WACCM required short timestep, leading to high model cost and slow throughput



SE-WACCM instabilities addressed by adjustments to the sponge layer and divergence damping



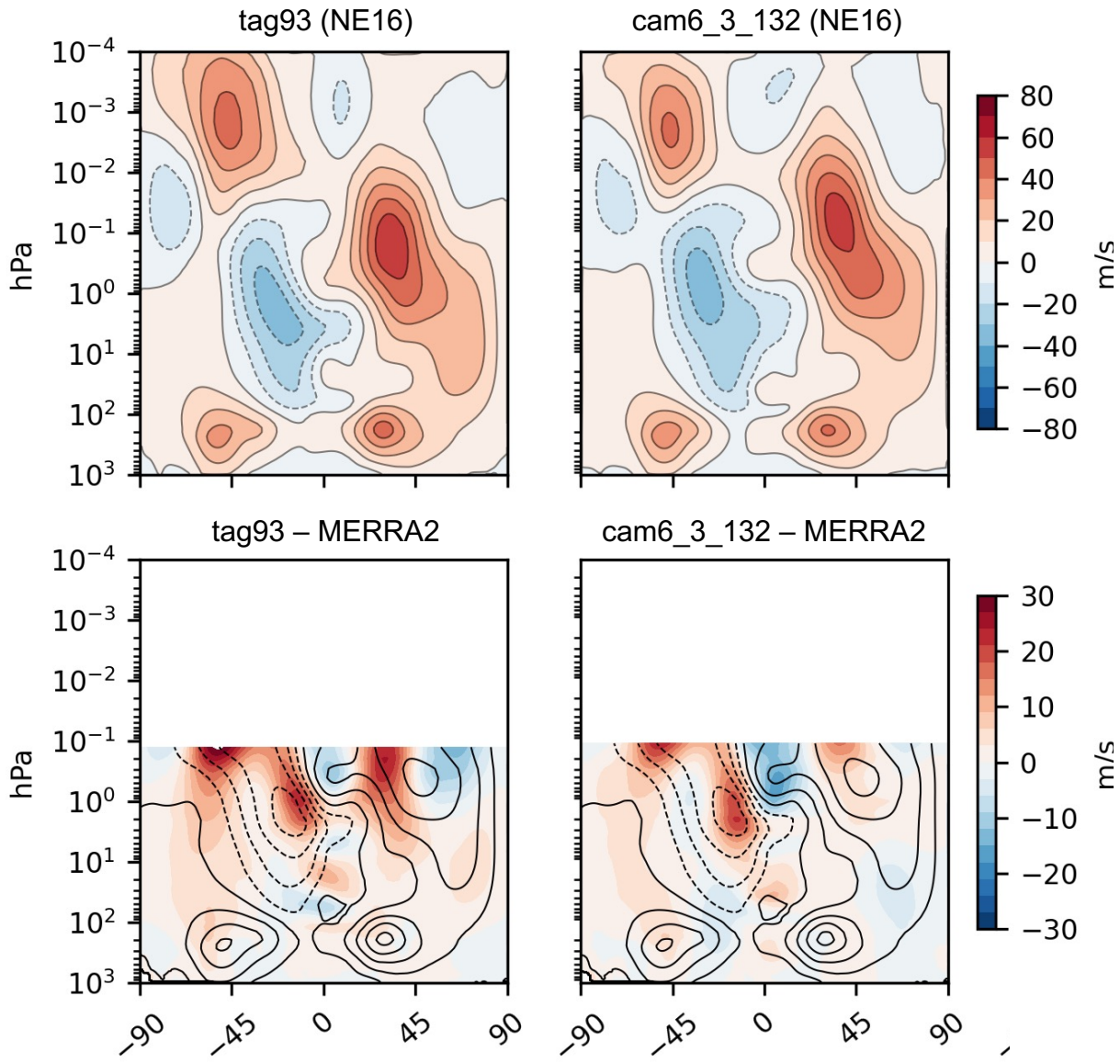
Enhanced damping in sponge layer

Deeper ∇4 divergence damping

SE-WACCM Model Cost and Performance

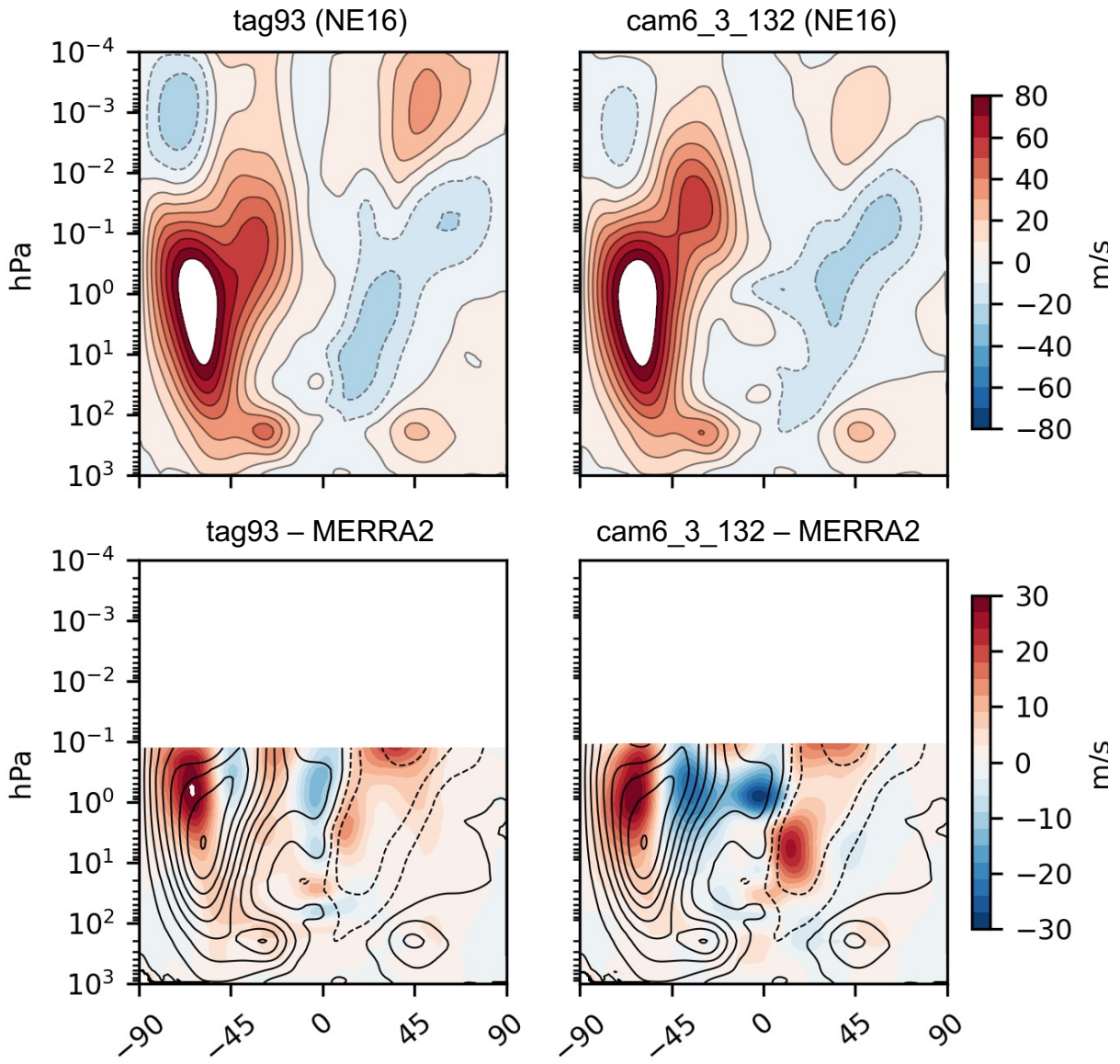
- 2 degree:
  - Model Cost: ~4,500 pe-hours/simulated year running on ~1500 processors
  - Model Throughput: ~8 simulated_years/day
- 1 degree:
  - Model Cost: (~25,000) pe-hours/simulated year running on ~5400 processors
  - Model Throughput: ~5 simulated_years/day
- Above results are F-cases with reduced (MA) chemistry
- Without addressing model stability the cost increases by ~2x and the throughput is significantly worse (~1yr/day at 1°)

Zonal Mean Zonal Winds (DJF)
2° SE-WACCM



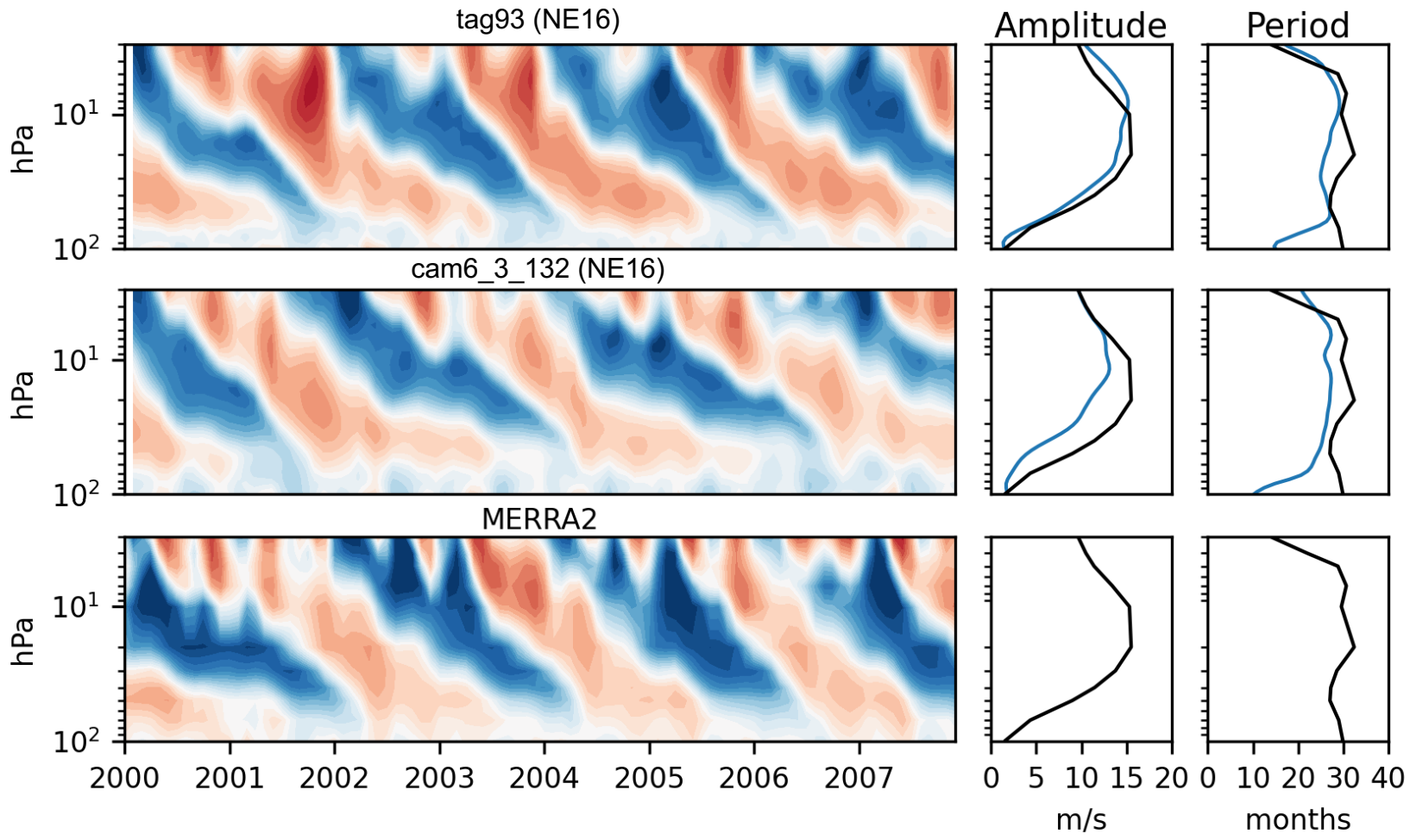
tag93: “best” tuned version from Nick Davis

Zonal Mean Zonal Winds (JJA)
2° SE-WACCM



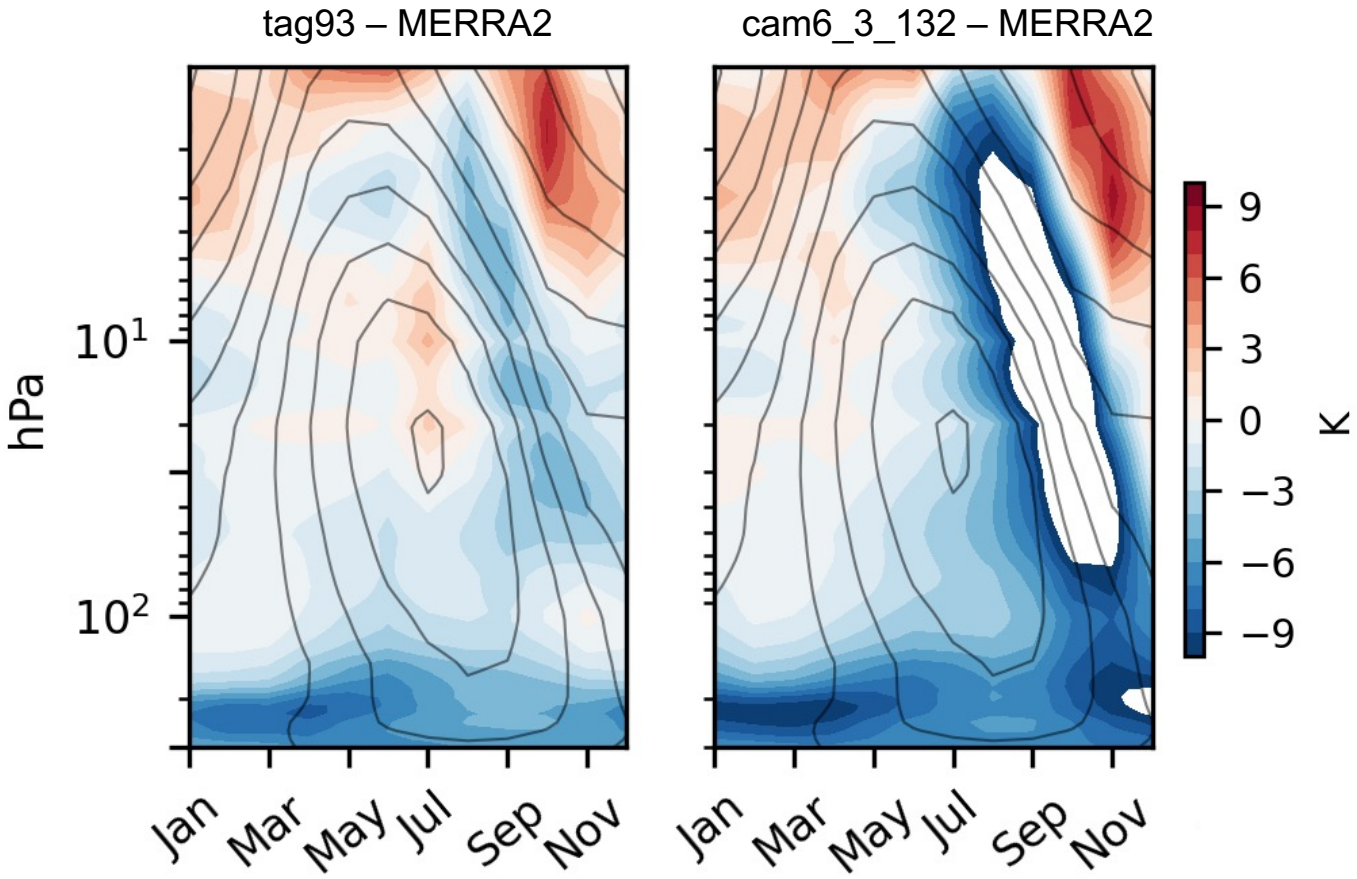
tag93: “best” tuned version from Nick Davis

QBO Comparison (2° SE-WACCM)



Southern Hemisphere polar cap temperatures

2° SE-WACCM

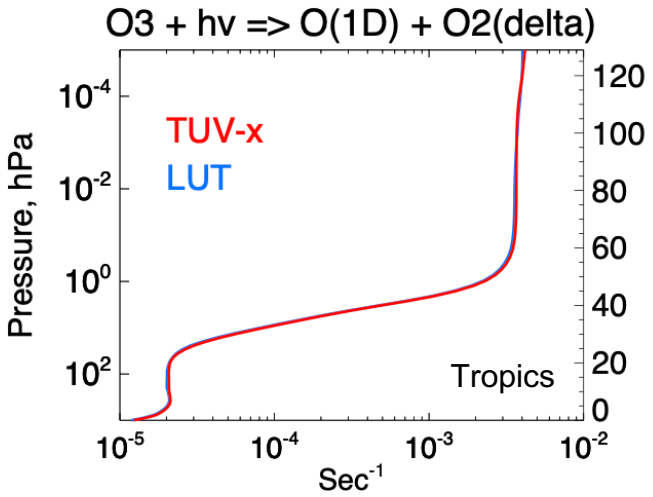


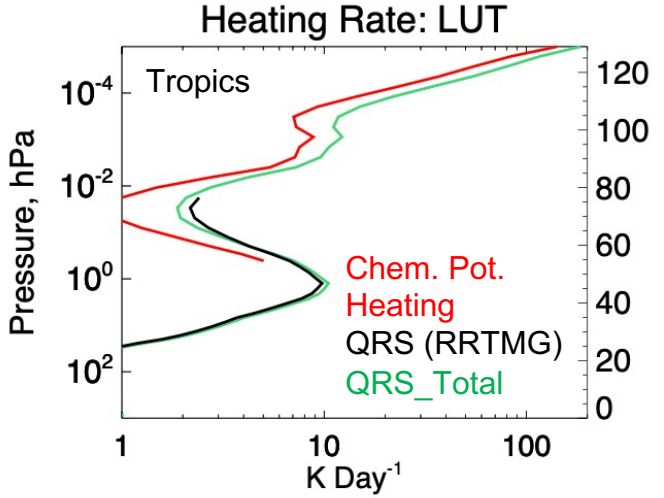
Large cold bias in WACCM simulations with cam6_3_132

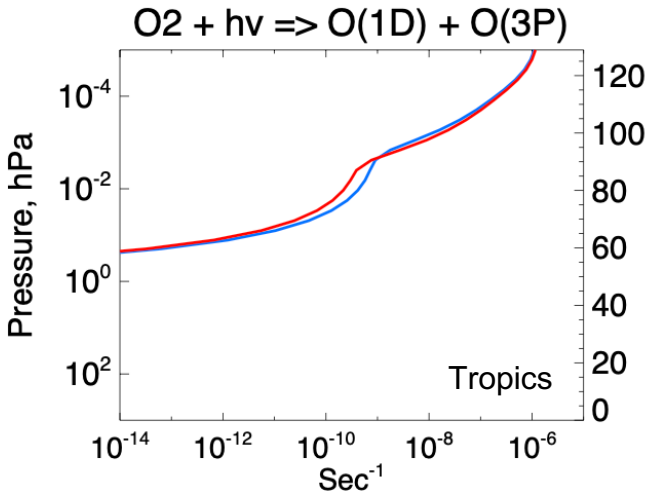
black contours denote MERRA2 zonal-mean U

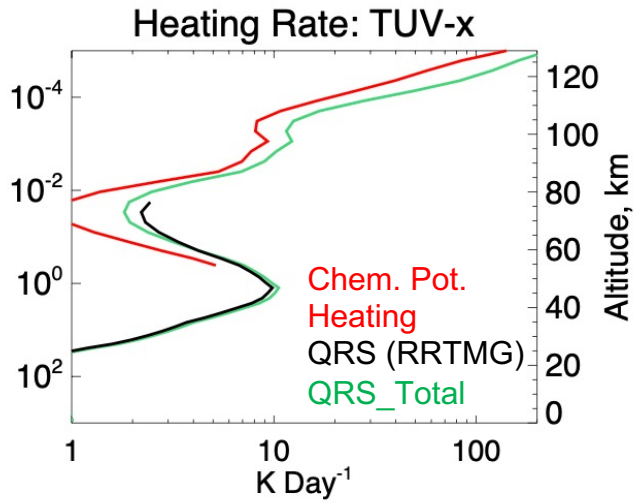
Inline Photolysis and Heating using TUV-x

- TUV-x is running in a version of CESM2 WACCM6 with TSMLT1 chemistry.
- TUV-x can include both clouds and aerosols in the radiative transfer. This is big improvement over the current LUT approach.
- Initial comparisons of photolysis rates are consistent with the LUT approach (right).
- The inline TUV-x photolysis heating and chemical potential heating is also consistent with the LUT approach (right).
- Next steps are to add a realistic representation of cloud overlap.
- More details from Doug Kinnison (Tuesday AM)





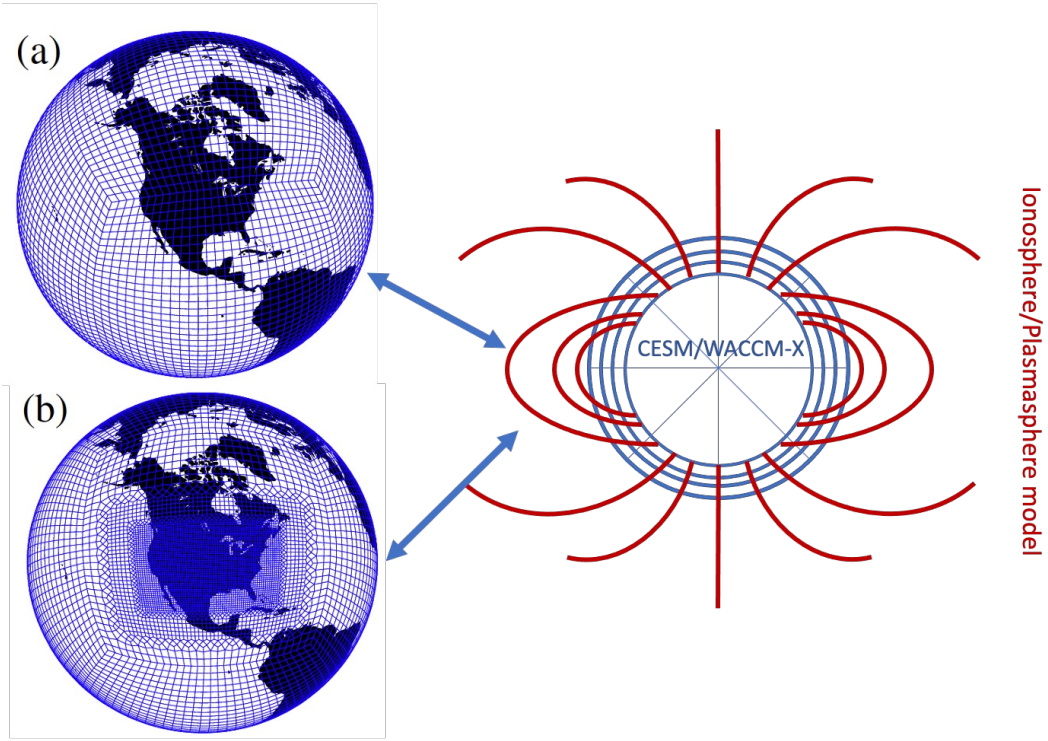




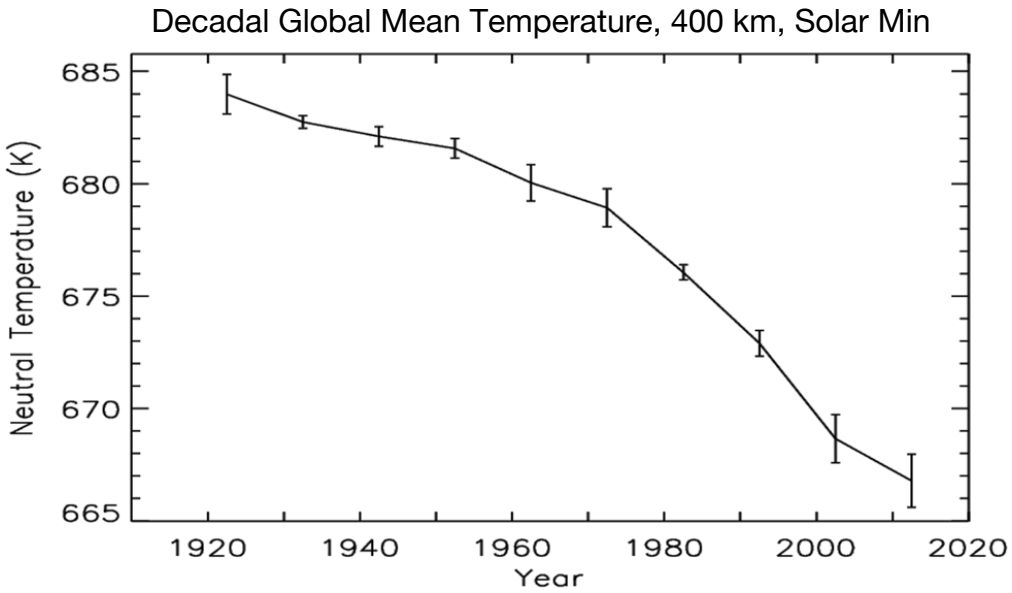
QRS_Total = QRS+QCP+QRS_EUV+QRS_CO2NIR+QRS_AUR+QTHERMAL

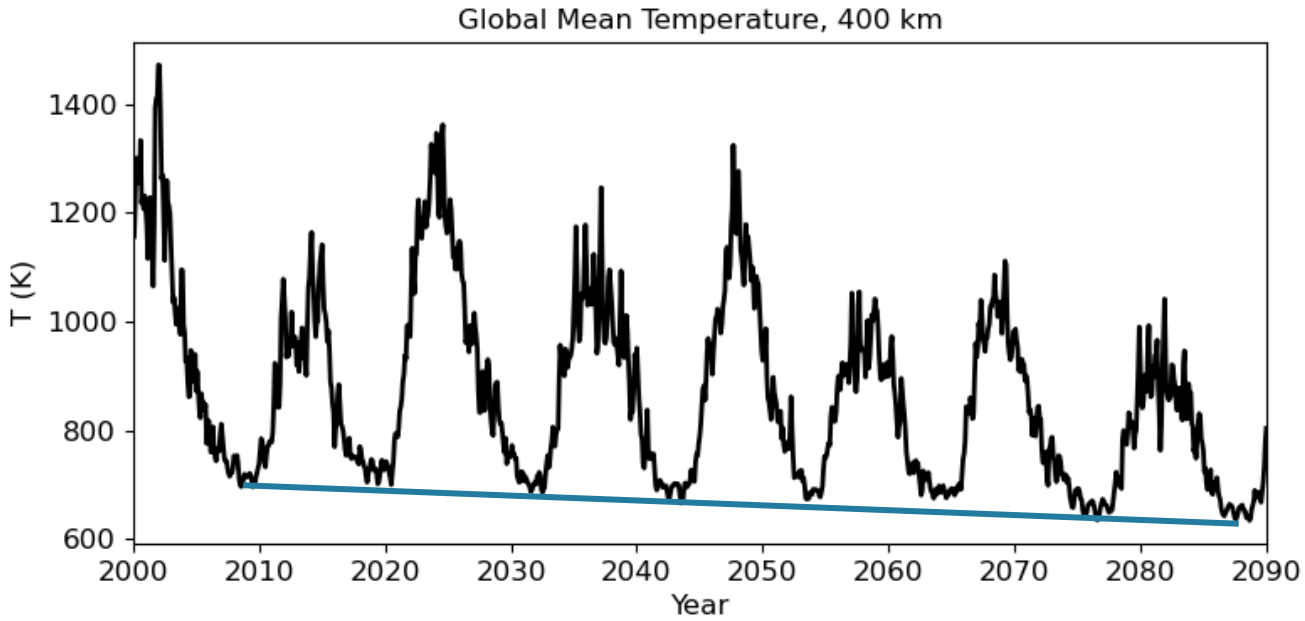
WACCM-X Developments

- SE dynamical core extended into the thermosphere
  - Species dependent dynamical core
  - Molecular viscosity/diffusion in horizontal direction
  - Regridding between physics mesh and geomagnetic grid
  - More details from Hanli Liu (Tuesday AM)
- Configurations
  - NE16/L130 (CAM6 physics)
  - NE16/L189 (CAM development physics)
  - NE60/L130
  - NE120/L273
- Long-term simulations for historical (1920-2010) and future space climate (2000-2090)



WACCM-X Historical and Future Space Climate Simulations



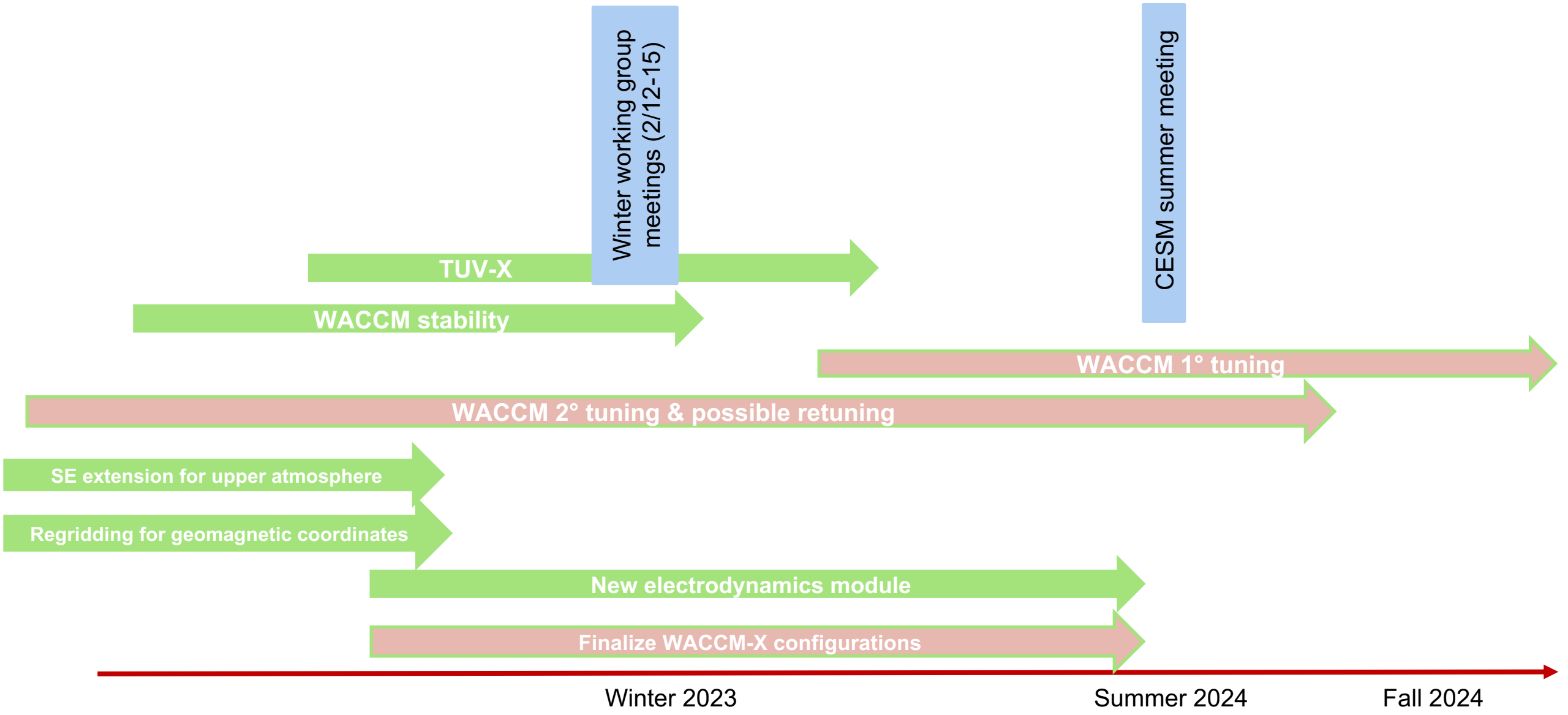


Physics time step in WACCM-X (5 min) requires adjustment to CLUBB/microphysics
- Parameters tuned based on 10 year CAM/WACCM runs by Adam Herrington

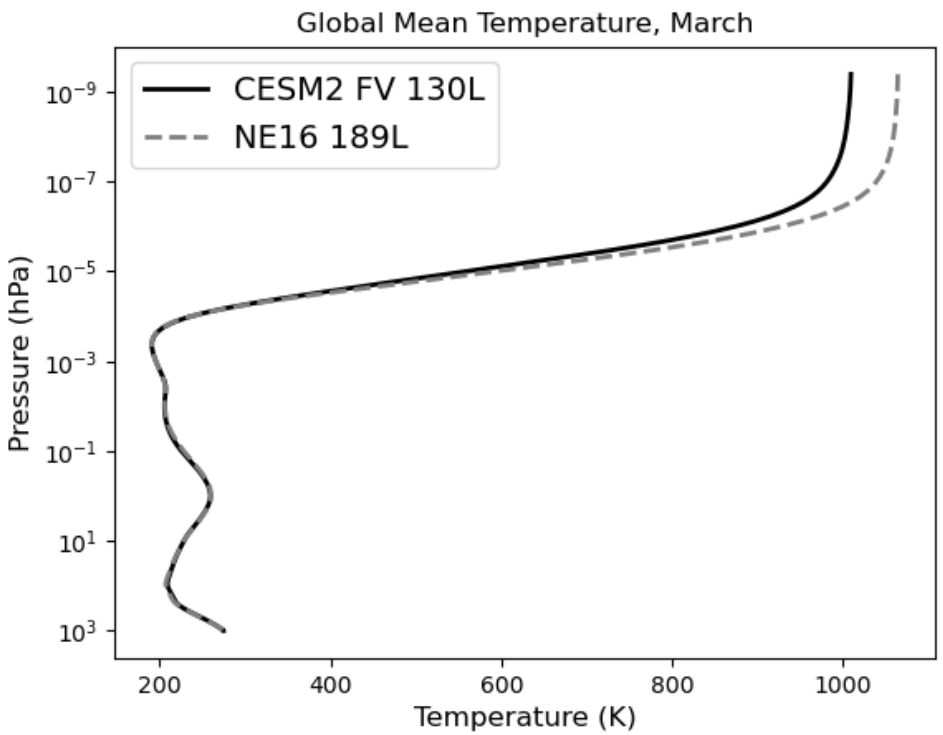
Surface warming in coupled runs is still larger than expected

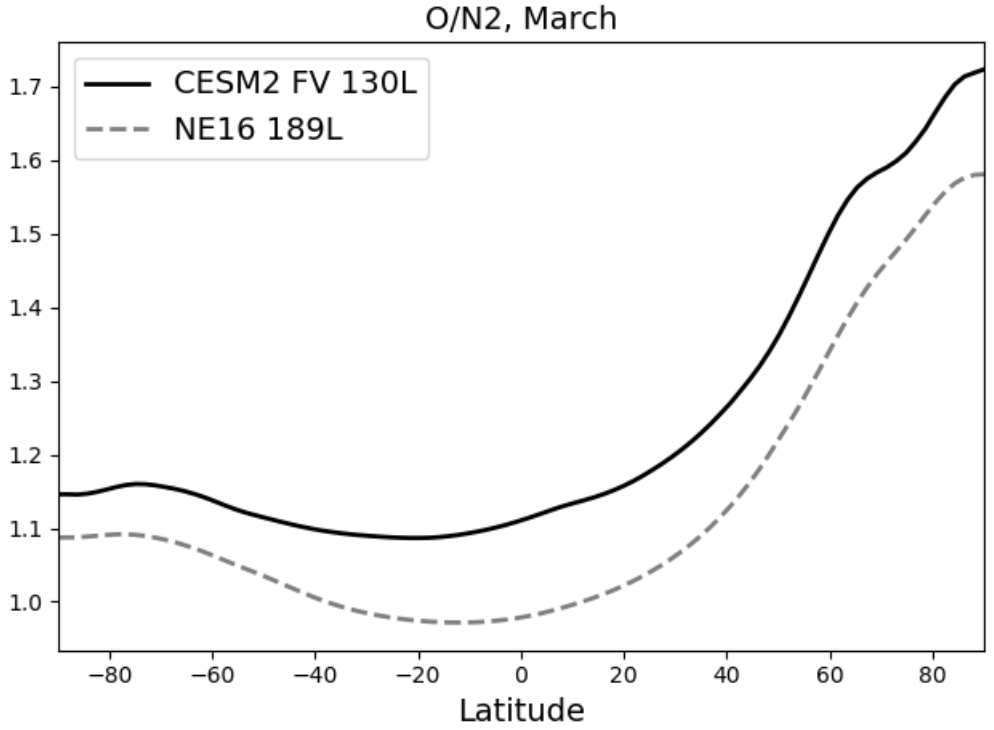
(McInerney et al., 2024)

WAWG Timeline



Results for WACCM-X NE16/L189 and CAM development physics





Thermosphere temperature is increased and composition (O/N2) decreased in NE16/L189

Model Cost: FV (~22,000 pe-hr/yr; 0.56 sim yr/day) , SE (~46,000 pe-hr/yr; 0.25 sim yr/day)

RESTOM and Annual Mean/Global Mean Ts