Whole Atmosphere Working Group Overview and Developments

CESM Workshop

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Primary WAWG Developments and Updates (June 2023 – present)

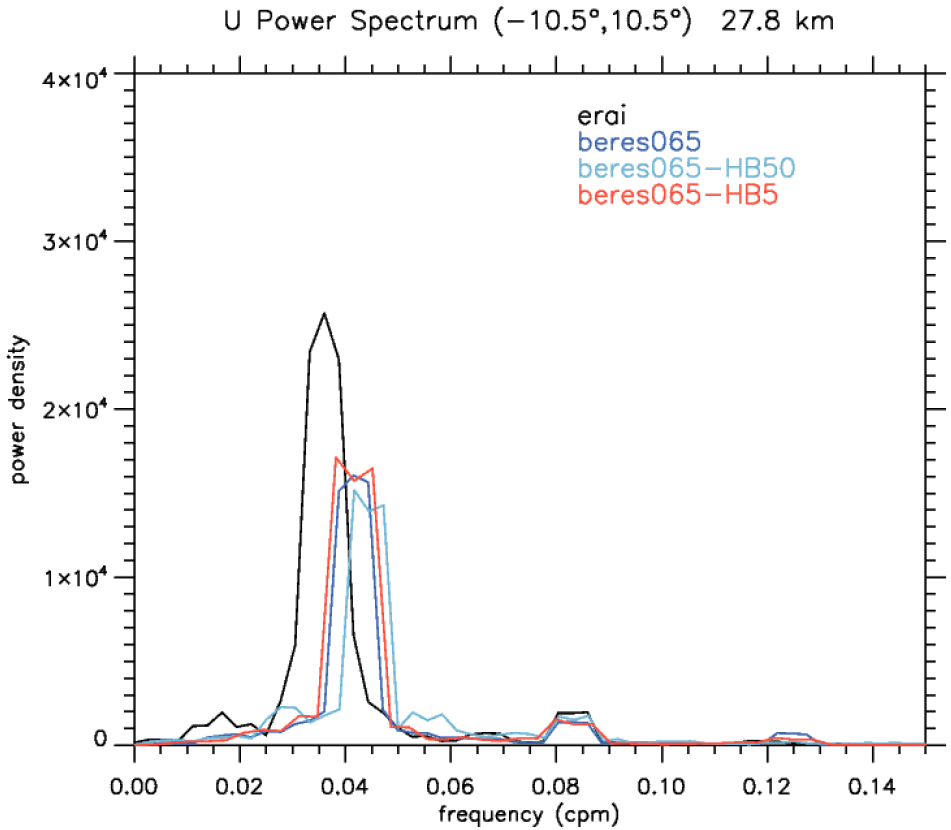
- WACCM
  - Transitioned development to cam_dev physics and cam6_3_132 tag
  - Addressed issues with model stability
    - HB diffusion with modification to act only on unstable T profiles
    - Updates to SE dycore for stability
    - Significantly improved model throughput
  - Baseline simulations as benchmark for evaluation and future tuning
  - Initial implementation of TUV-x in WACCM (Doug Kinnison winter WG meeting presentation)
  - QBO tuning in WACCM with 2° SE dycore

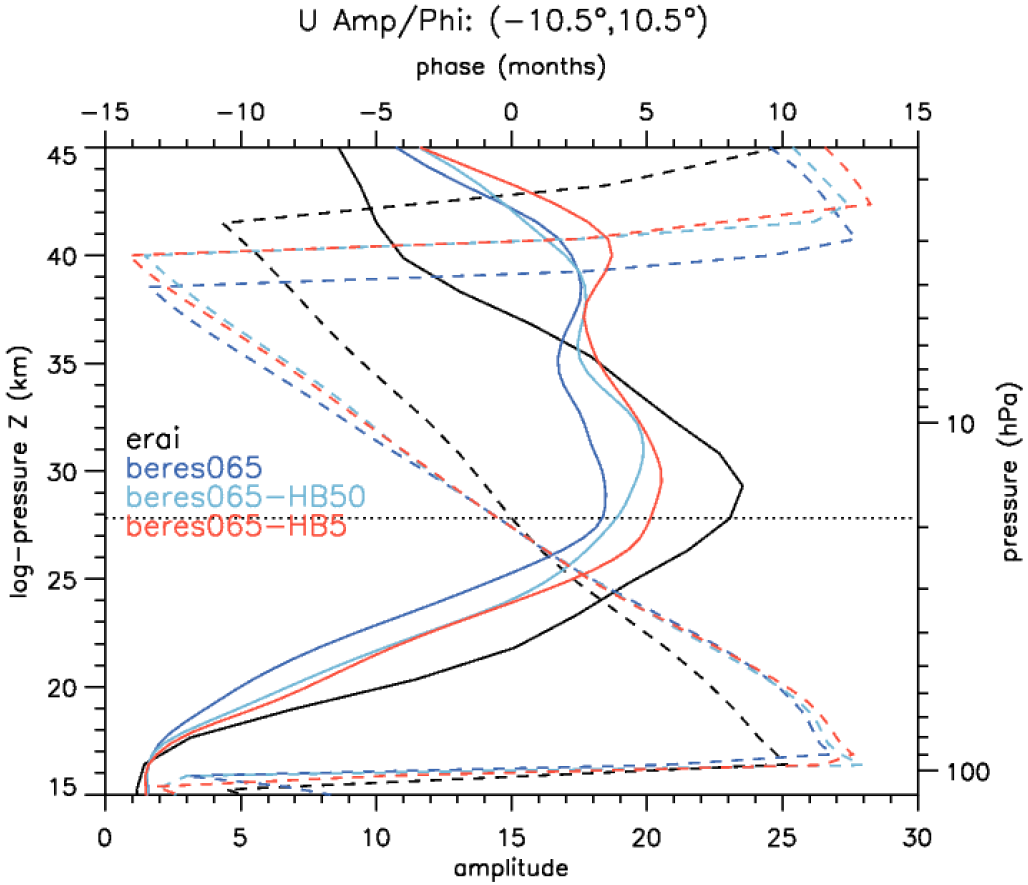
- WACCM-X
  - Preliminary tests with NE16/L189 and cam6_3_132
  - Updates to $N+O_2$ chemistry
  - Nudging high-resolution simulations

QBO Tuning for WACCM7

- Aim is to have a good QBO in WACCM7 at both 1° and 2° resolutions.
- Have not been able to get a good QBO after transitioning to cam_dev physics and adding HB diffusion.
- Development focus for the past months is on understanding why the QBO has degraded and trying to obtain a good QBO.
- Consider the effects of: HB diffusion, conversion factor, and cam_dev physics
- All results from Mijeong, Sasha, and Rolando

Effects of HB Diffusion





Introduction of HB diffusion (for model stability) degrades the QBO

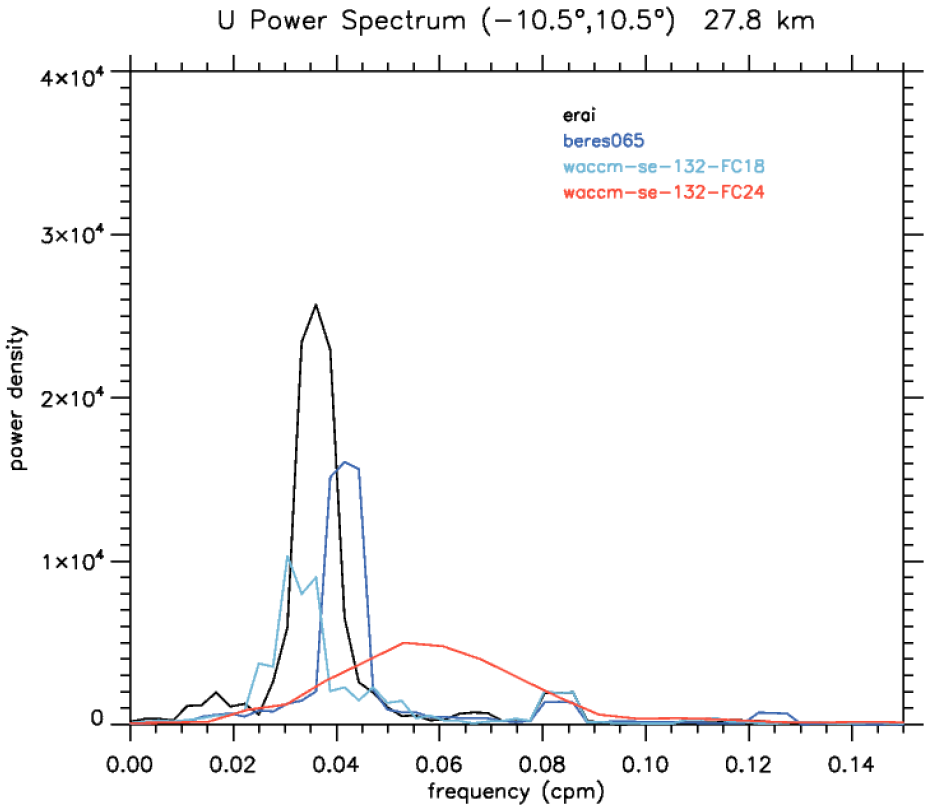
HB diffusion with Ri number trigger does not degrade the QBO (not shown)

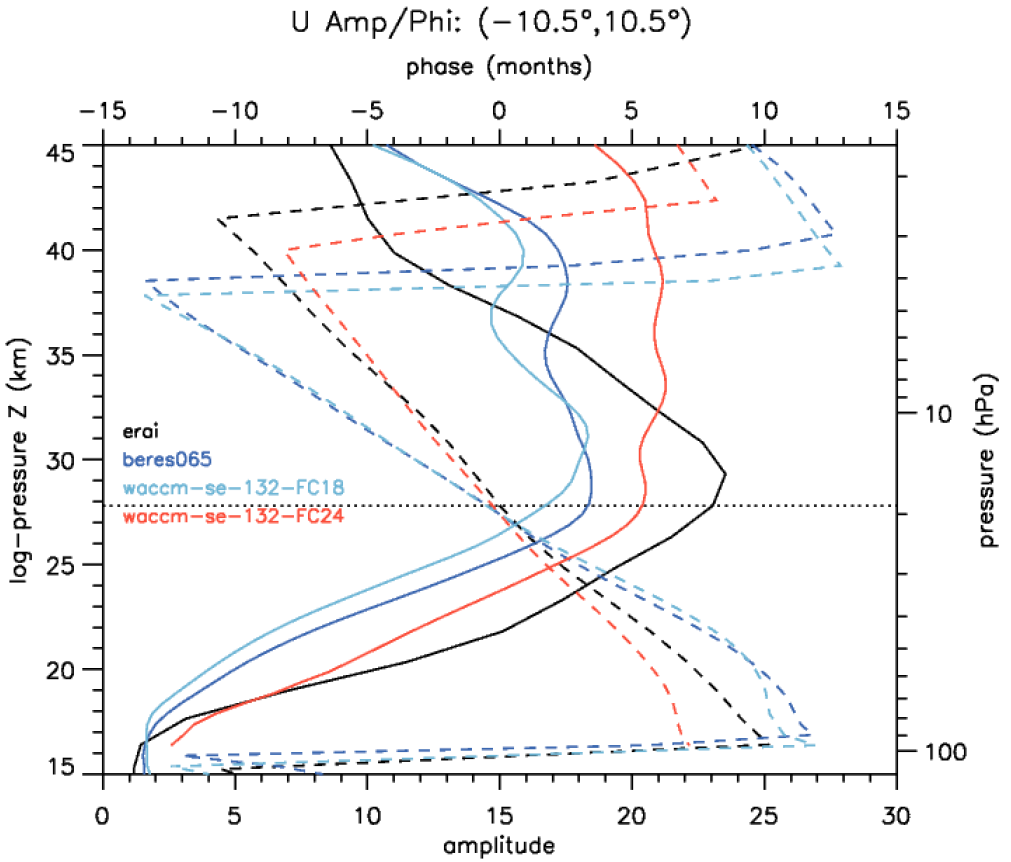
beres065 – baseline simulation

beres065-HB50 – no HB below ~3 hPa

beres065-HB5 – no HB below model level 5

Effects of Conversion Factor (CF)



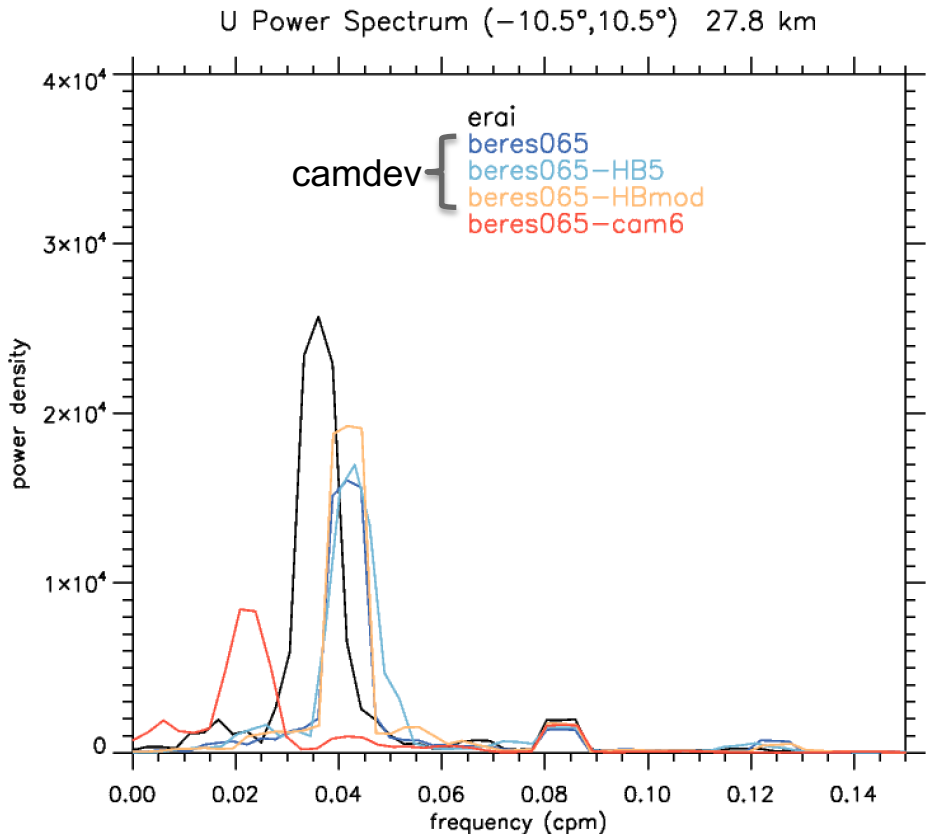


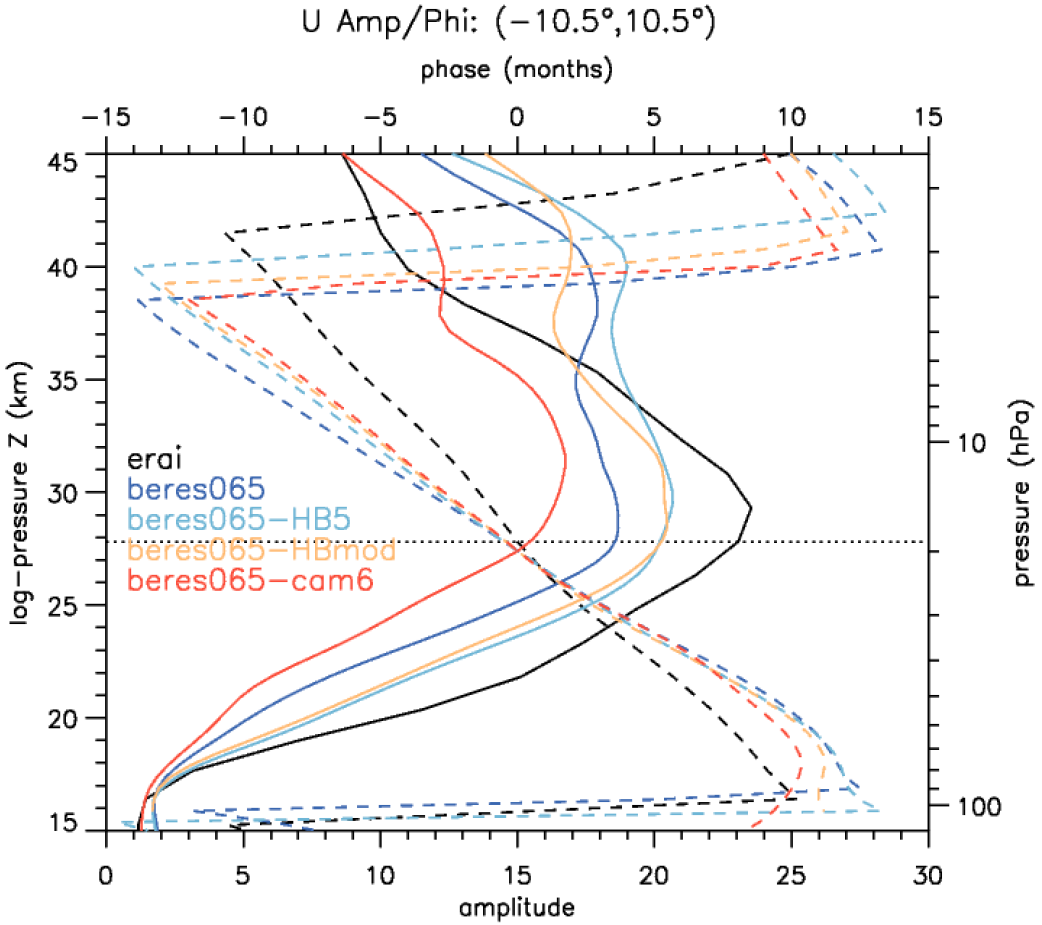
beres065 – baseline simulation
FC18 – conversion factor of 18
FC24 – conversion factor of 24

Changing the conversion factor can be used for QBO tuning

Conversion factor alone will not address the QBO deficiencies

Effects of cam_dev Physics





beres065 – baseline simulation
beres065-HB5 – no HB below level 5
beres065-HBmod – HB only when unstable
beres065-cam6 – CAM6 physics (w/ HB)

Implementation of cam_dev physics significantly impacts the QBO

Longer period and weaker amplitude QBO in CAM6 physics could potentially be tuned with changes to CF and/or effgw_beres

QBO Summary and Path Forward

- Inclusion of HB diffusion and cam_dev physics has significantly impacted the QBO.
- Effect of HB diffusion can be mitigated if it is applied based on a Richardson number trigger. This allows the use of HB diffusion to be applied throughout the domain to control dynamical instabilities.
- Reason for the degradation when implementing cam_dev physics remains unknown.
- Given that the QBO with cam_dev physics has been untunable, we need to understand what changed between CAM6 and cam_dev physics that adversely impacted the QBO.

Updated $N+O_2$ Reaction Rate for WACCM-X

- Updated the $N+O_2 \rightarrow NO+O$ reaction rate
- NO is a radiative cooler for the thermosphere so change in NO density can significantly influence the thermosphere temperature
- JPL-17 reaction rate used for CESM2
- Updated JPL-19 reaction rates are based on fitting to low temperatures
- Implemented a new three-parameter fit based on the available observations

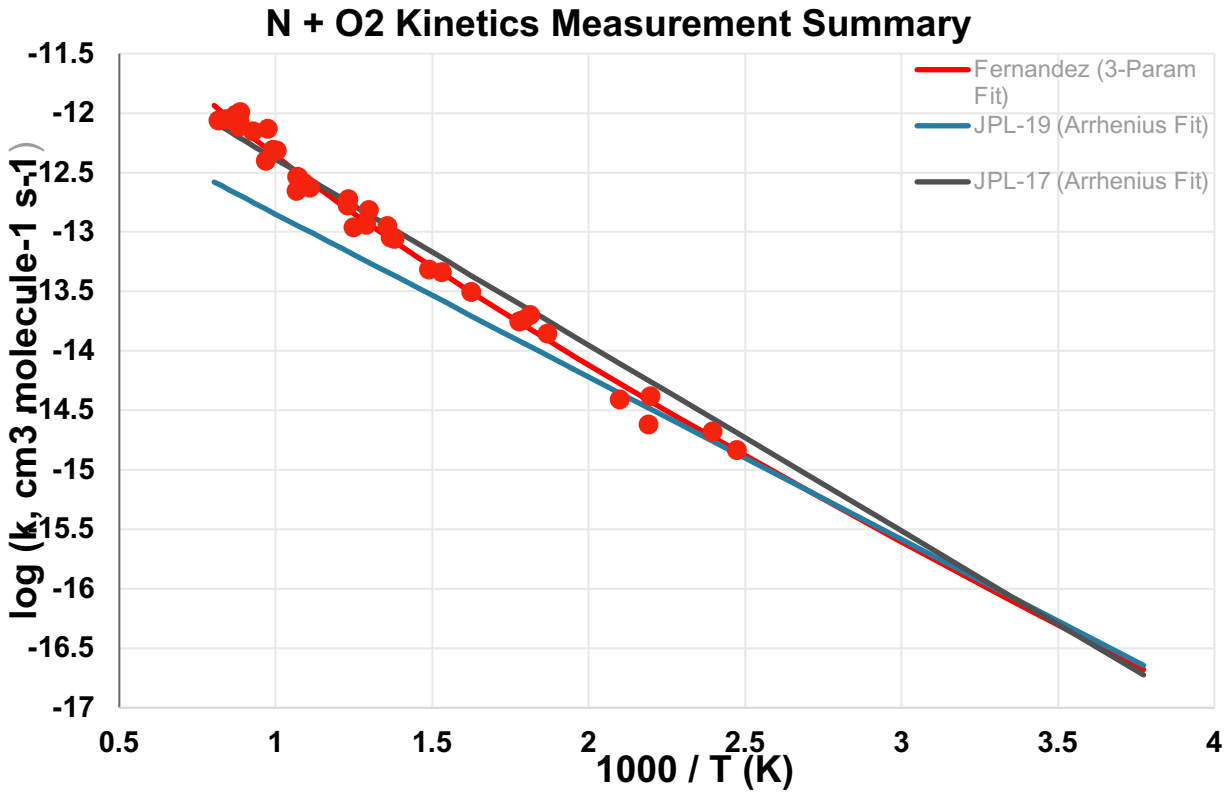
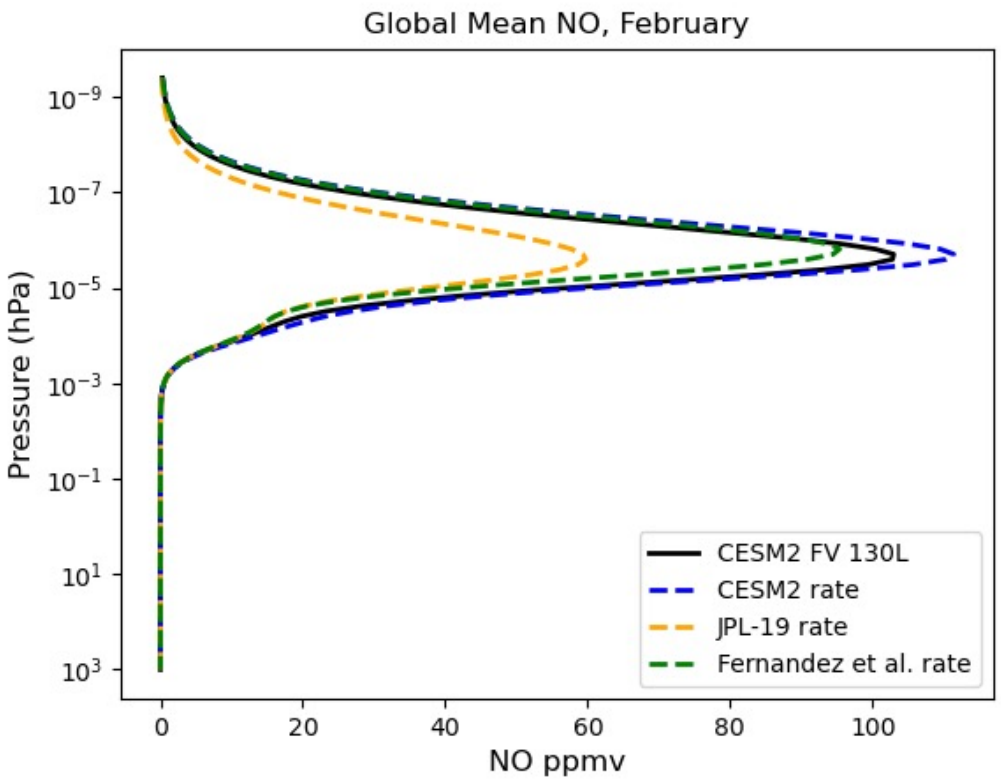
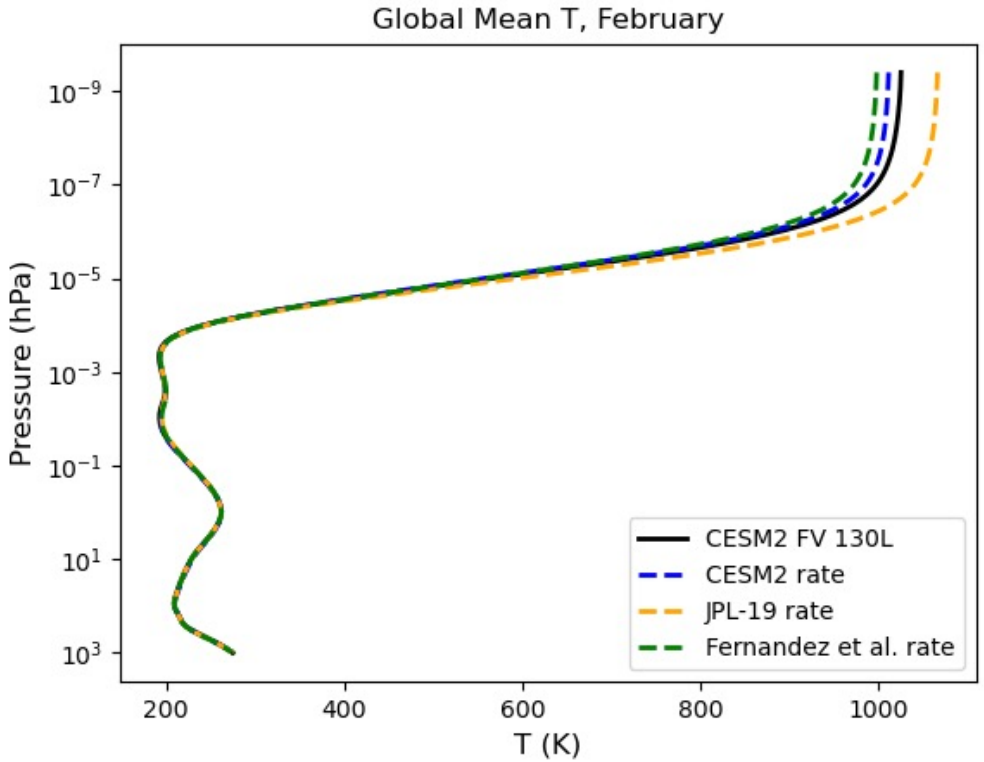


Figure courtesy John Orlando

WACCM-X Simulations for Solar Medium Conditions



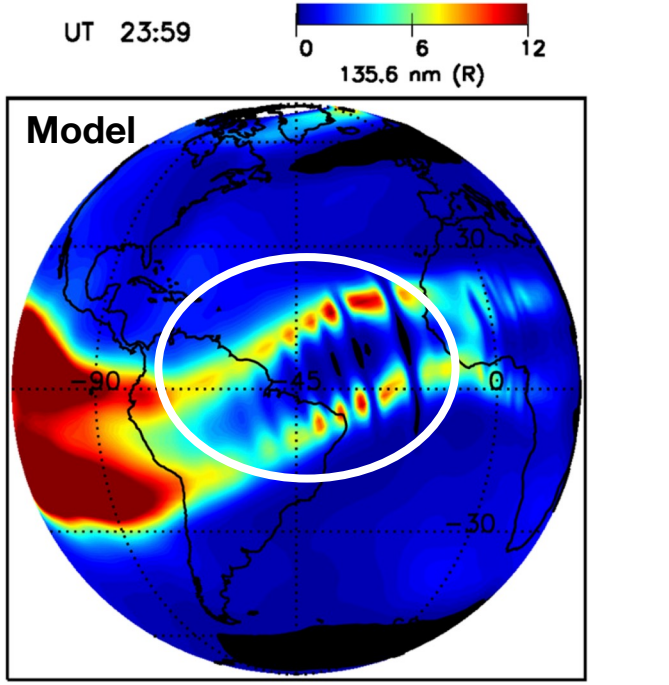


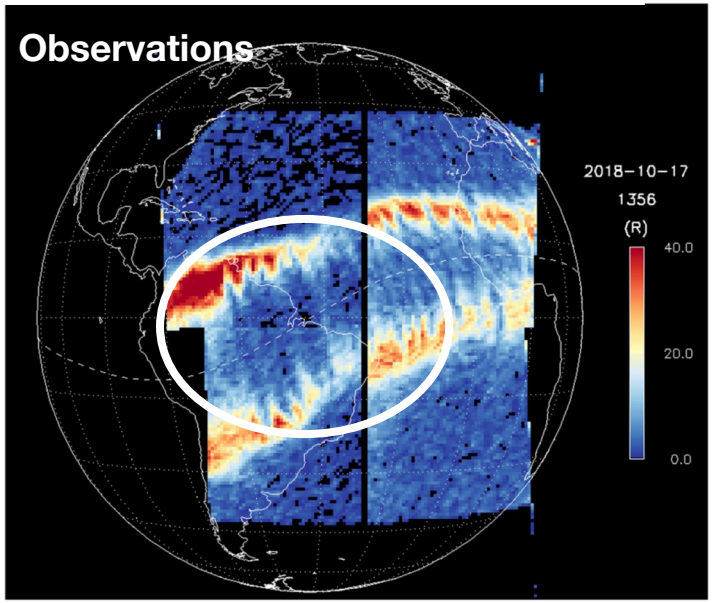
Results show the sensitivity of the thermosphere temperature to NO densities.

Will compare WACCM-X NO to newly available observations to understand if this is a potential source of the current thermosphere density and temperature bias in the model.

Nudging High-Resolution (NE120) WACCM-X Simulations

- For simulating the wave variability during real events, we need to develop the nudging capability for high-resolution model simulations.
- This is an important capability if we want to model the day-to-day space weather driven by gravity waves.
- Nudging high-resolution SE-dycore requires care to capture the large-scale variability without damping the smaller scale waves.

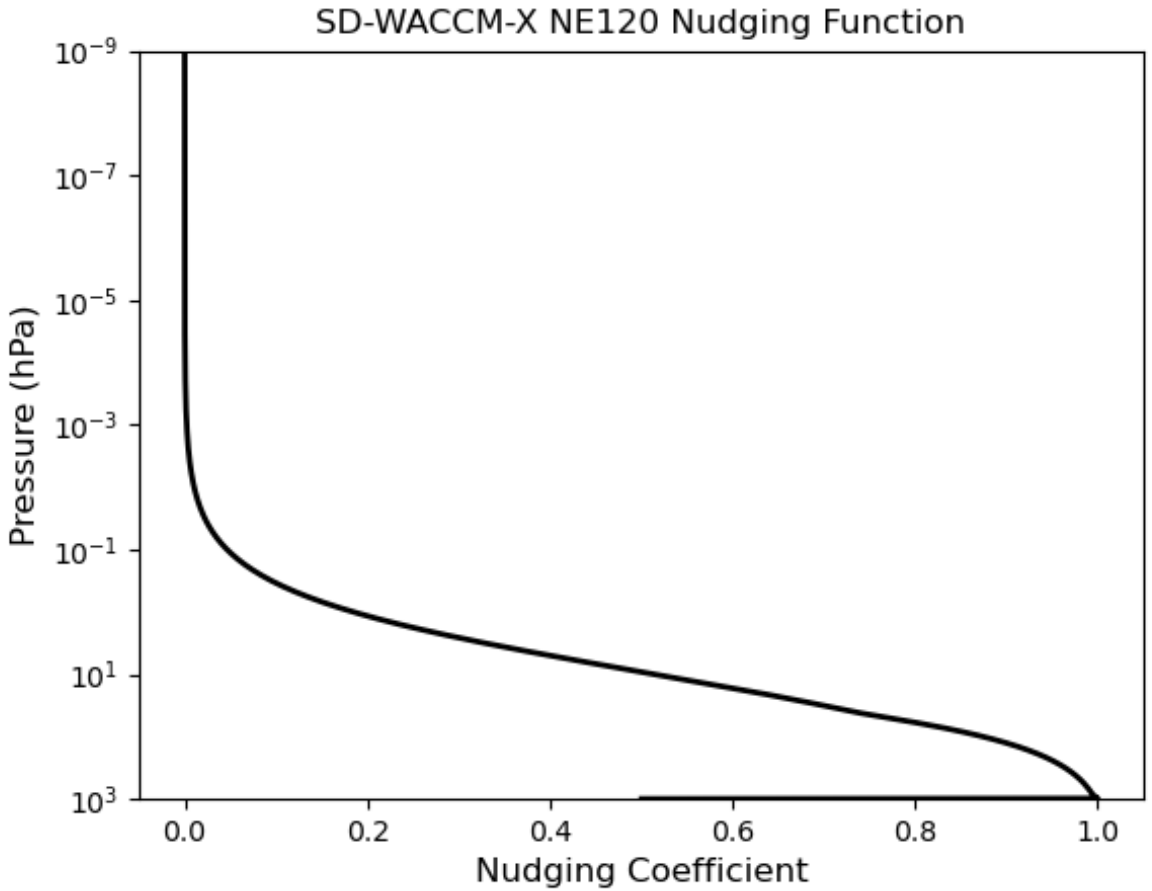




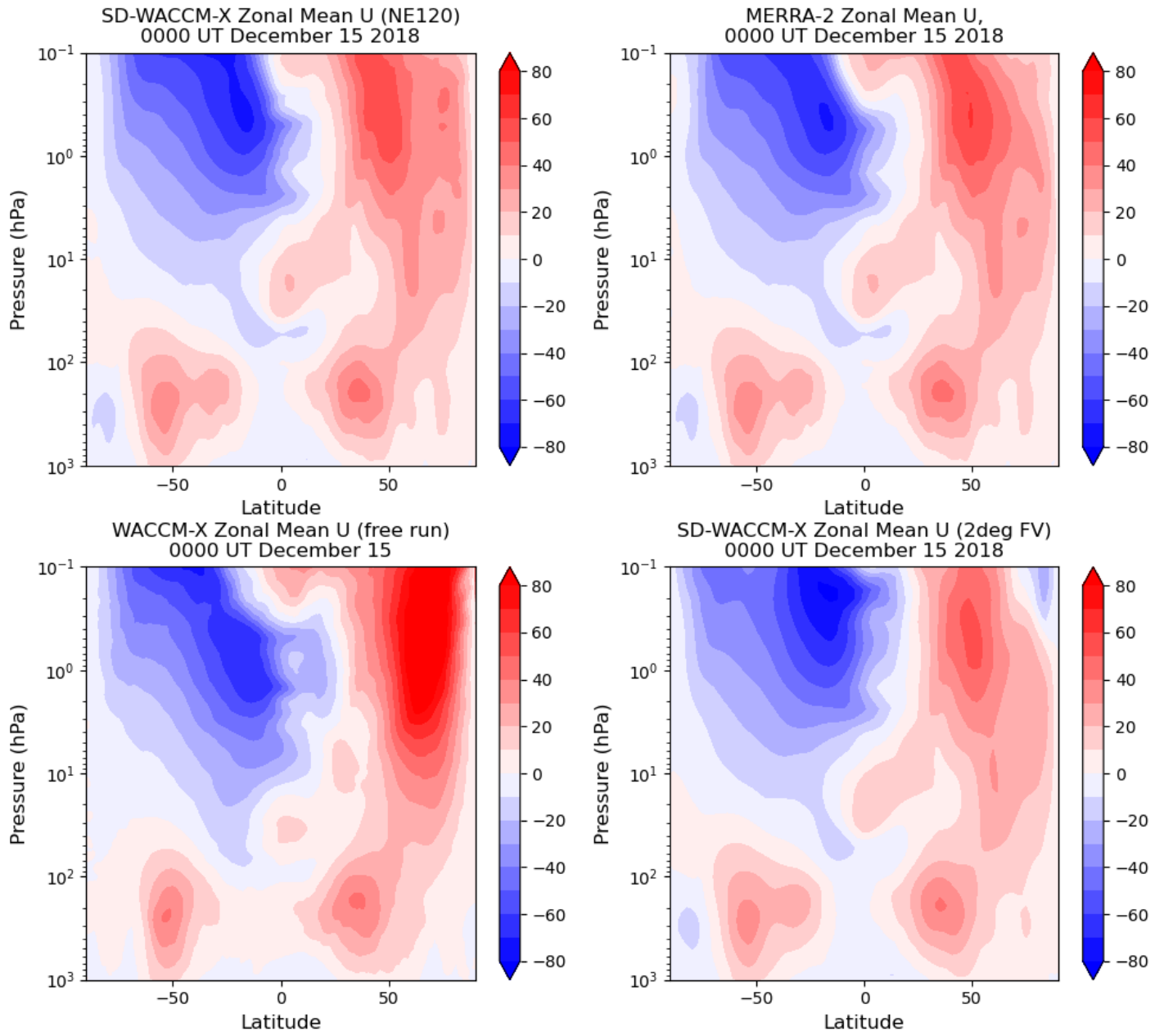
(Huba and Liu, 2020)

Nudging High-Resolution (NE120) WACCM-X Simulations

- Use the physics based nudging approach
- Vertical profile shape includes a significant ramp-down in the stratosphere
- Nudging factor is set to 0.3 which results in a relatively weak nudging



Nudged NE120 simulations are in good agreement with MERRA-2 and 2-degree FV simulations.



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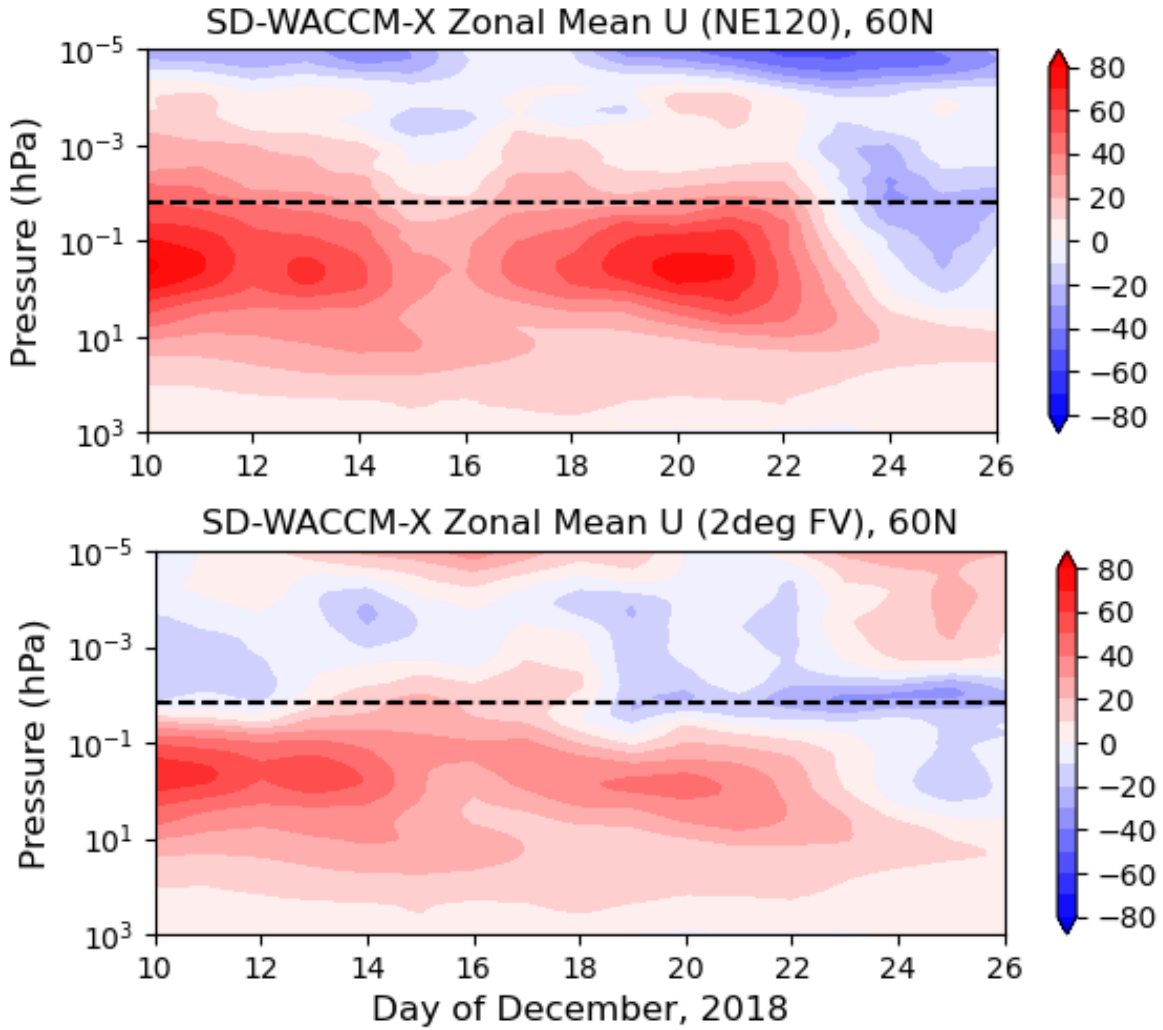
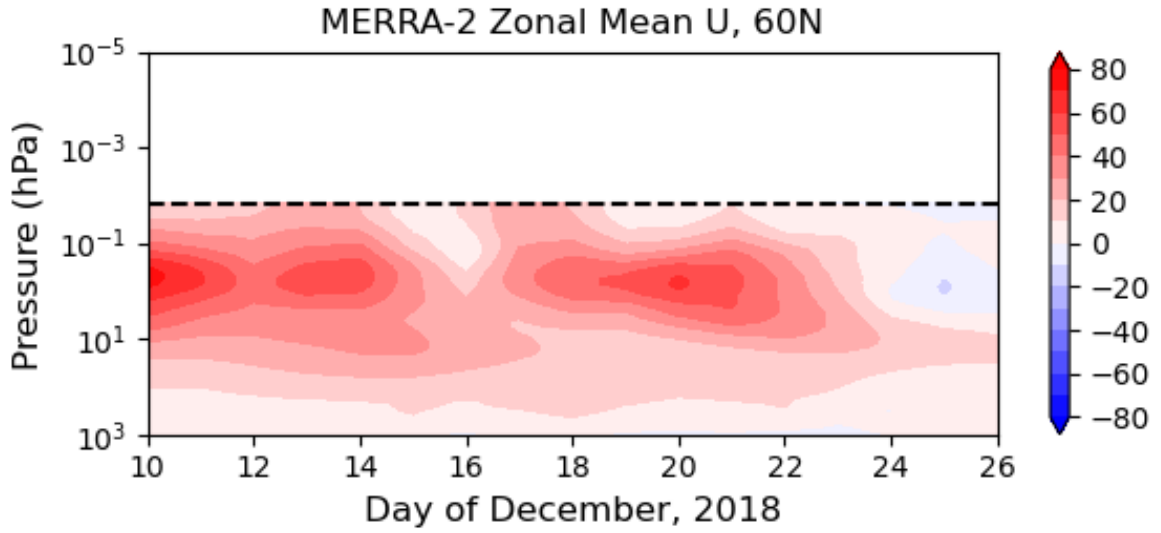
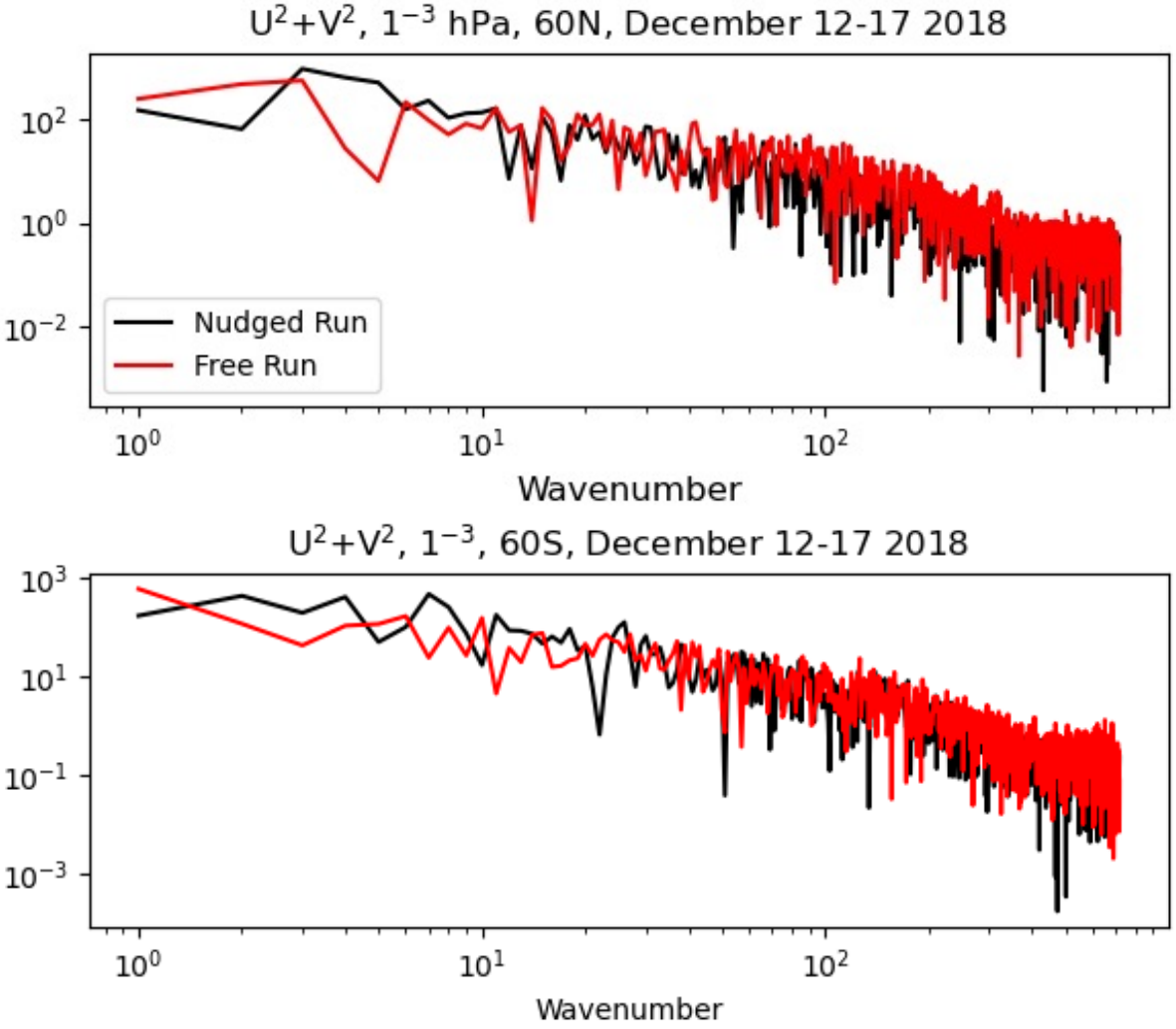
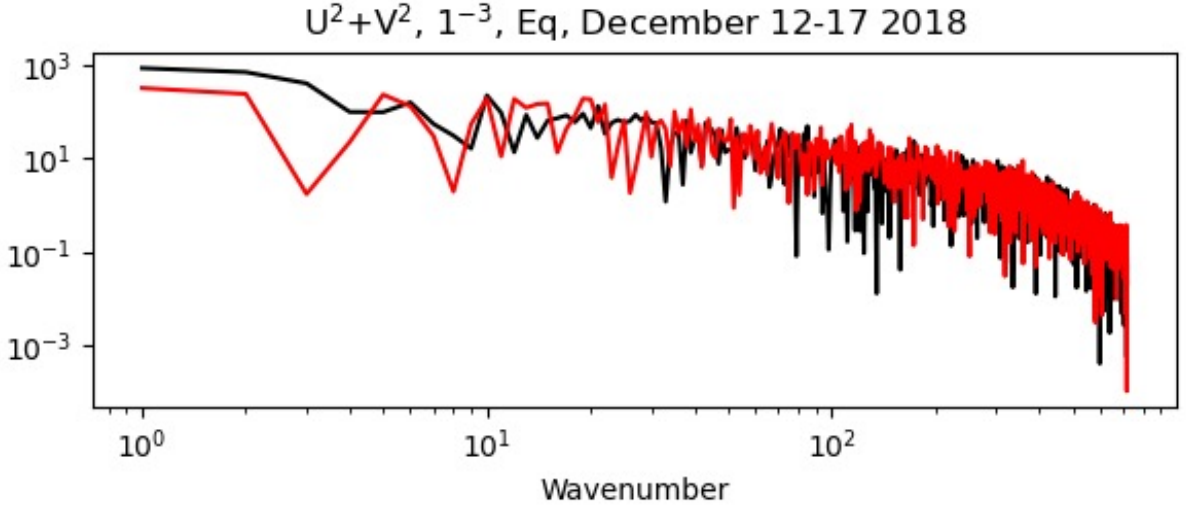




Comparison of the power spectra with and without nudging demonstrates that the nudging has not adversely impacted the wave spectrum





Near-term Development Focus for WACCM7/WACCMX7

- Continue focus on tuning of the QBO and understanding why cam_dev physics has significantly impacted the QBO.
- Evaluate long-term WACCM7 simulations with regards to the following metrics:
  - SSW frequency and distribution
  - MLT temperature and winds
  - Seasonal cycle of stratosphere ozone in SH polar regions (status: significant cold pole bias)
  - Water vapor tape recorder (status: slightly wrong seasonality)
  - Stratosphere aerosol optical depth for both climatology and volcanic response
  - Further discussion from Daniele Visioni at 2:30 PM
- Continue implementation of TUV-x in CESM.
- Continue development of MPAS-WACCM(-X)
- Evaluate NO in WACCM-X against TIMED/SABER observations.
- Longer WACCM-X simulations with 189L and updated $N+O_2$ to evaluate model climatology.