NCAR
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Overview:
Chemistry Aerosol Working Group

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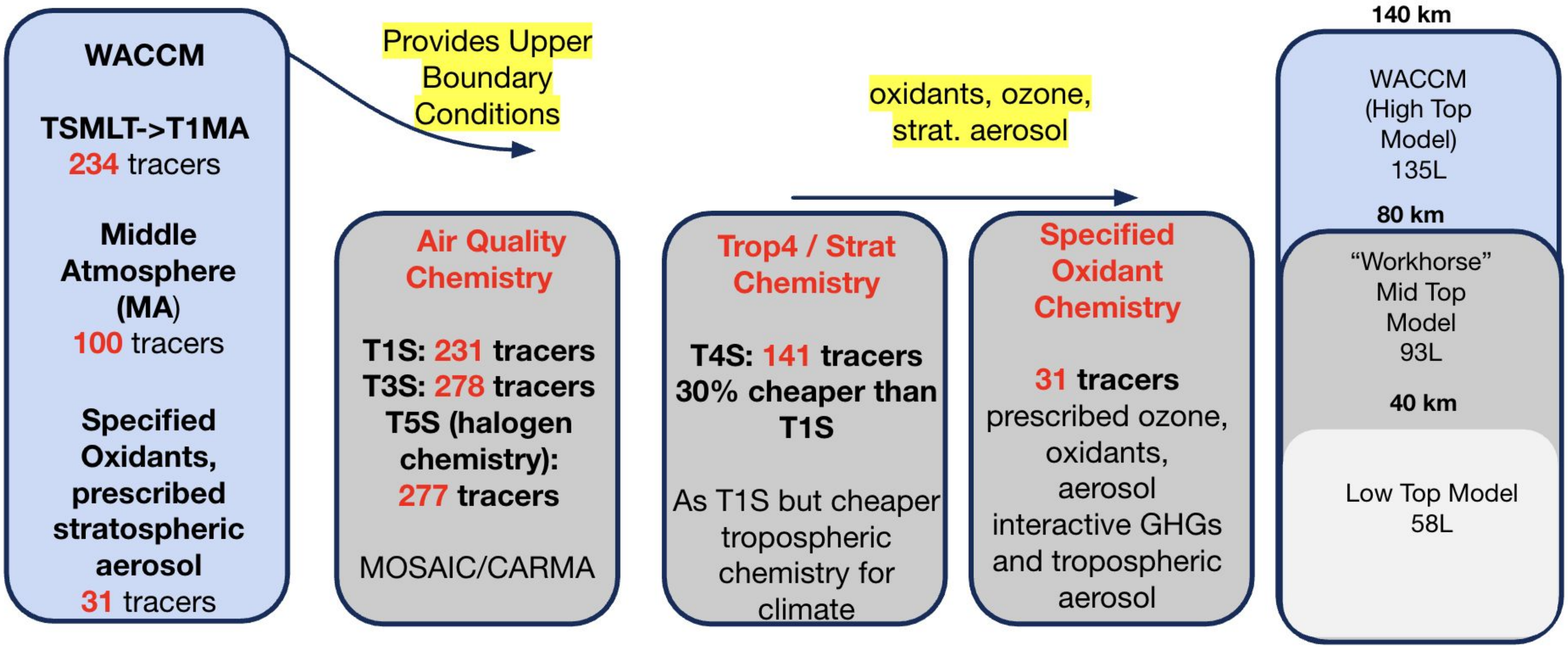
CESM Configurations with Chemistry



CESM3/CMIP7 Workhorse Model, Fast Track

Chemistry

- T4S MT L93, includes interactive aerosol and oxidants
- Specified Oxidants (SO) simple chemistry with updated SOA

Aerosols

- MAM5 aerosol scheme, and bug fixes
- New dust emissions based on Leung et al., 2024
- Online DMS, and other ocean emissions based on Online Air-Sea Interface for Soluble Species (OASISS) -> more sulfate
- Bug fixes: wet removal, aqueous-phase chemistry

Emissions

- CMIP7 forcings: Lower boundary conditions, emissions, volcanic emissions

Main Priorities going forward

Improvements of OH, methane lifetime, and ozone

- T5S MT L93 Short-Lived Halogen emissions and chemistry (Tier 2)
- Interactive methane emissions (Tier 2)
- New Photolysis scheme (TUV-x) (Tier 2)

Improved aerosol/chemistry interactions

- Capabilities to run CARMA in CESM3/CAM7 Physics
- Heterogeneous uptake on sea salt and dust
- Nitrate aerosols, Marine Organic Aerosol Emissions

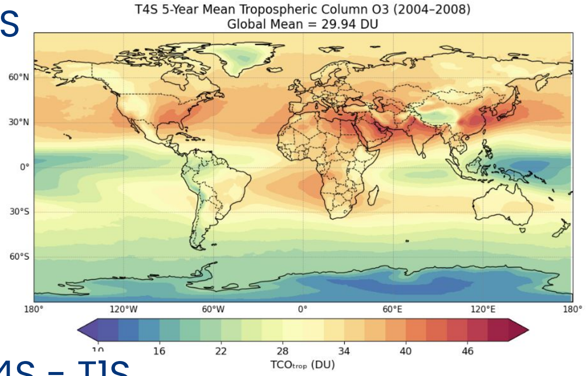
Improved land-atmosphere, ocean-atmosphere coupling

- Land-atmosphere coupling: Interactive fire emissions, soil NOx, MEGAN3 biogenic emissions
- Ocean-atmosphere coupling: additional online ocean emissions

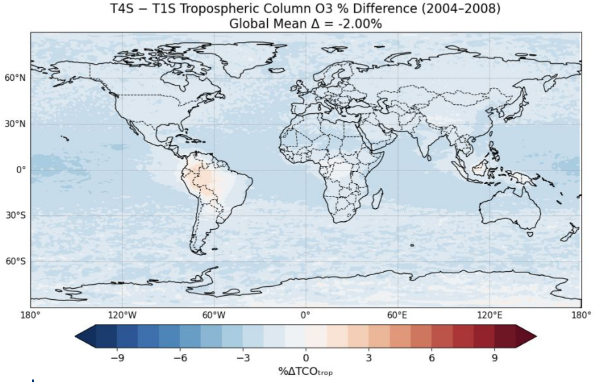
T4S vs T1S Climate vs Air Quality Chemistry

Tropospheric Column Ozone

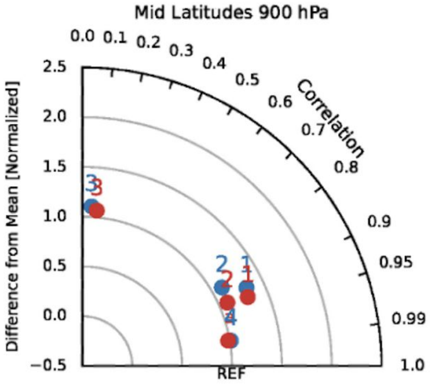
T4S



T4S - T1S



Ozonesonde comparison

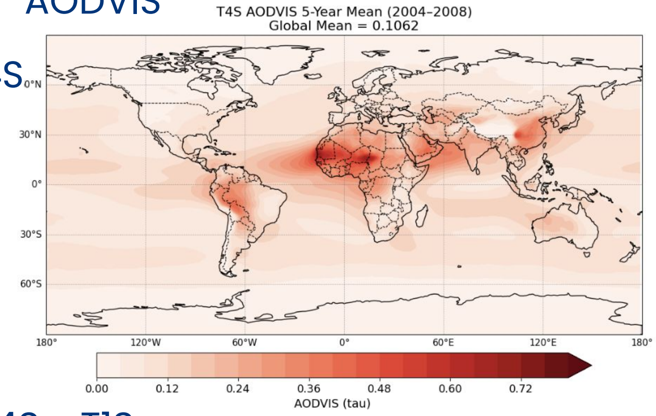


Small differences in Tropospheric Ozone. Some differences in AOD (cam6-physics)

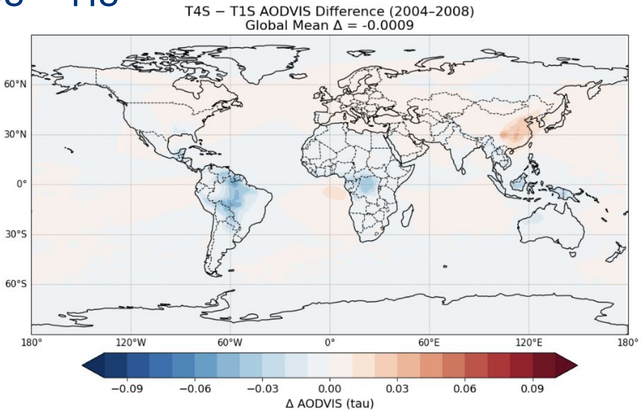
Zhang et al., 2026 submitted

AODVIS

T4S



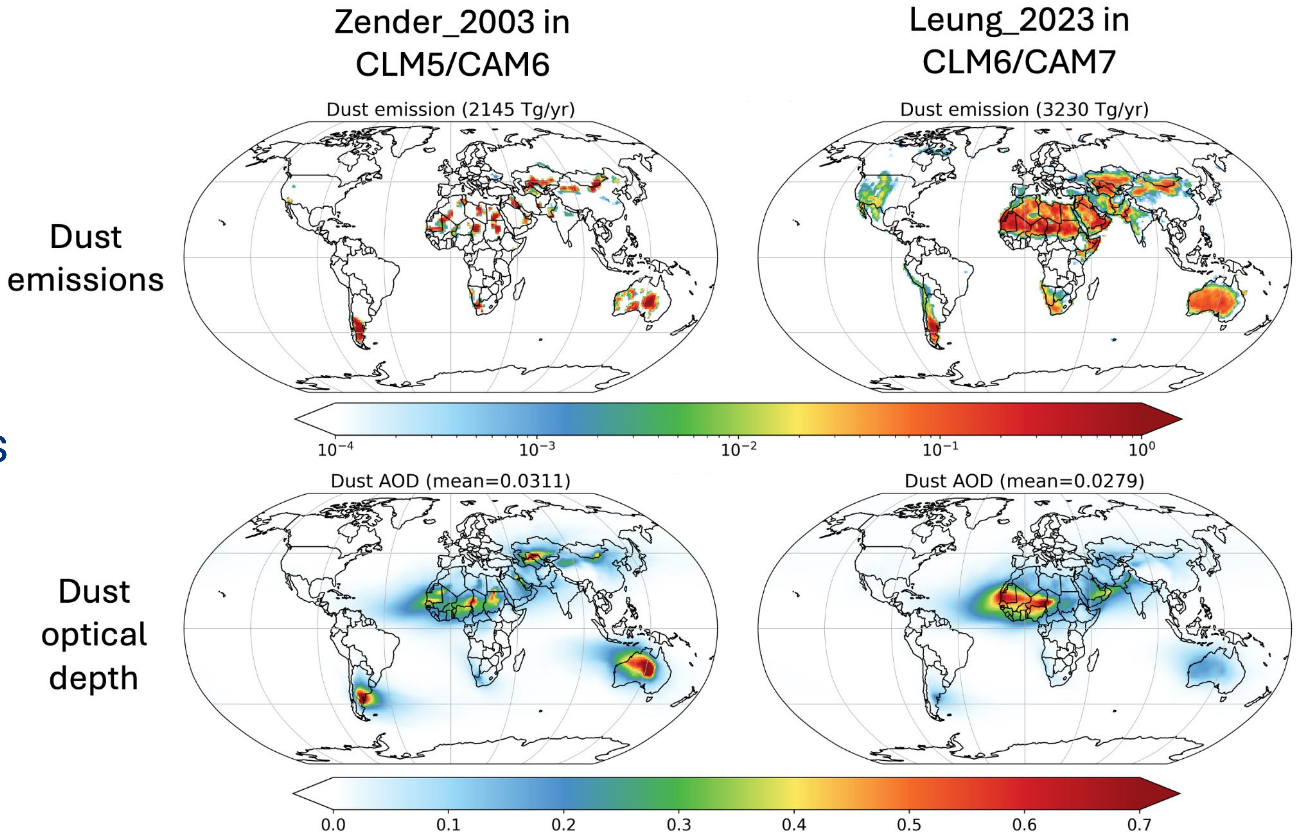
T4S - T1S



Updated Dust Tuning

CESM3 uses Leung et al. (2023) dust emissions

- Zender 2003 dust emissions are spatially discontinuous across the globe
- Leung 2023 simulates spatially continuous dust
- Dust optical depth reasonably peaks in the Sahara

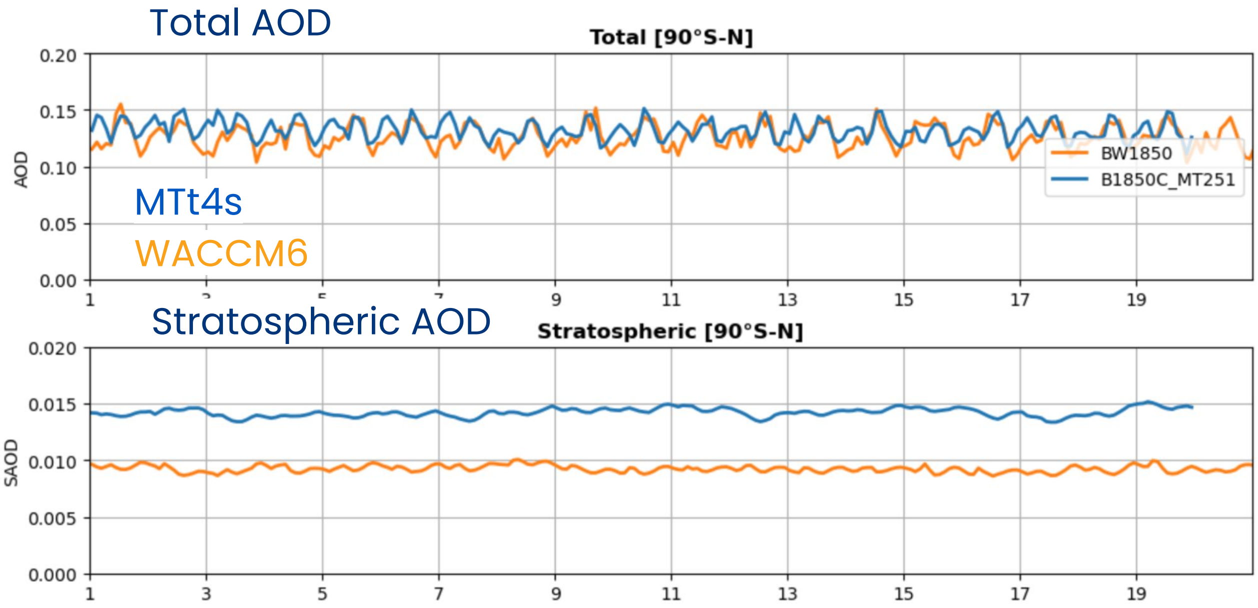


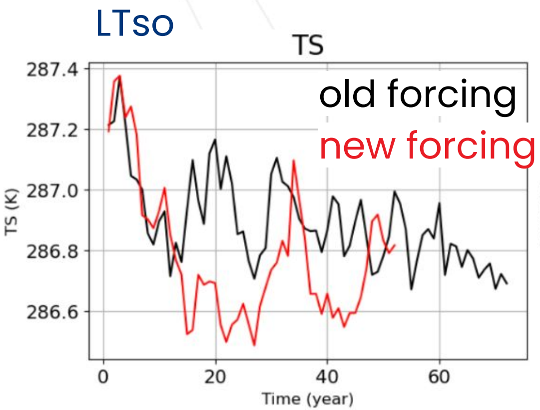
Figures: Danny Leung

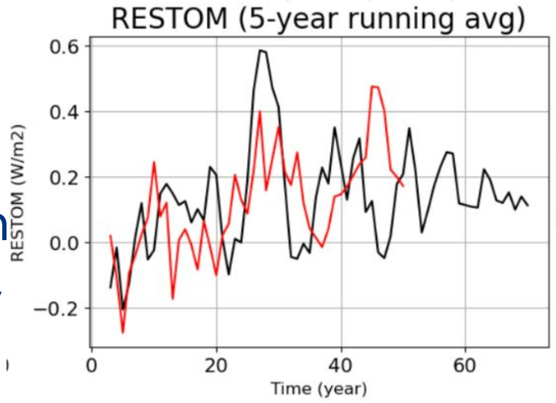
Status: MTt4s test simulations

- BC1850 MTt4s 20 year test run -> forcings for LTso simulations
- FC1975-2020 MTt4s comparisons to WACCM6
- FC2016-2020 MTt4s nudged / comparisons to ATOM

BC1850 MTt4s: Produces Aerosol/Ozone/Oxidants







Stratospheric AOD is significantly larger in MTt4s then in WACCM6 (PI control), with little impact on LTso RESTOM, similar forcing in the Ltso experiment.

 | *see talk by Ilaria Quaglia on Tuesday*

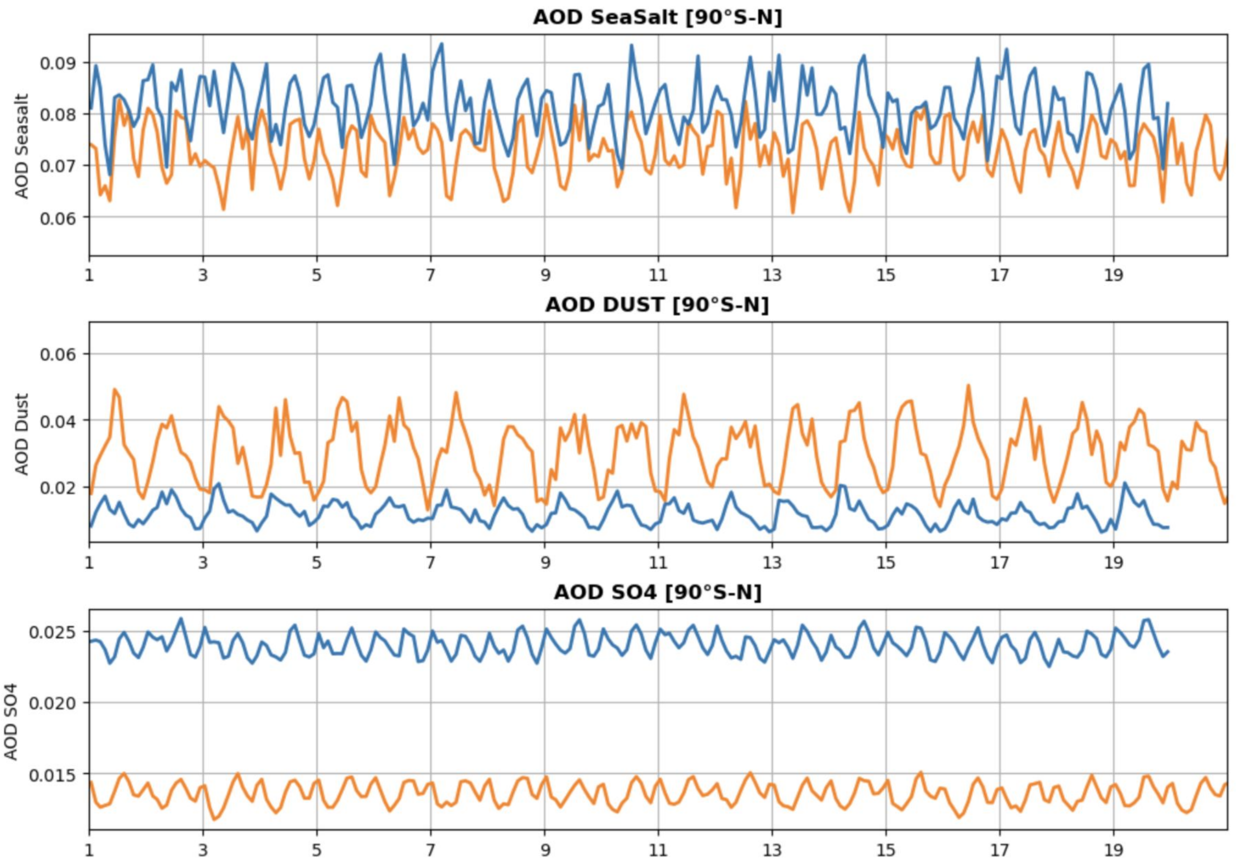
BC1850 MTt4s: Produces Aerosol/Ozone/Oxidants

PI Control

AOD
Sea
Salt

AOD
Dust

AOD
SO4

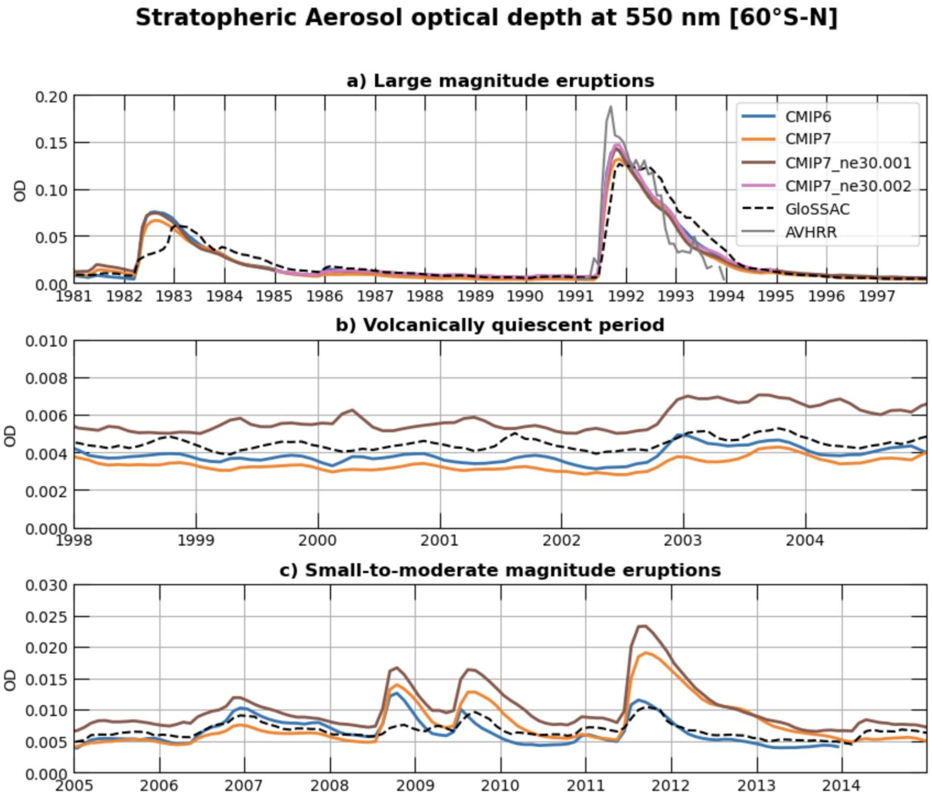


MTt4s
WACCM6

MTt4s FHIST 1975-2020

Stratospheric AOD

MTt4s
WACCM6-CMIP
WACCM6-CMIP
GloSSAC
AVHRR



New CMIP7 volcanic emissions database, with reduced altitude injections for large volcanoes and mass scaling

- Good AOD (and aerosol) representation of large magnitude volcanoes
- Slight overestimation in background aerosols compared to GLoSSAC
- Overestimation of some of the small to moderate magnitude eruptions
- In general better representation than WACCM6

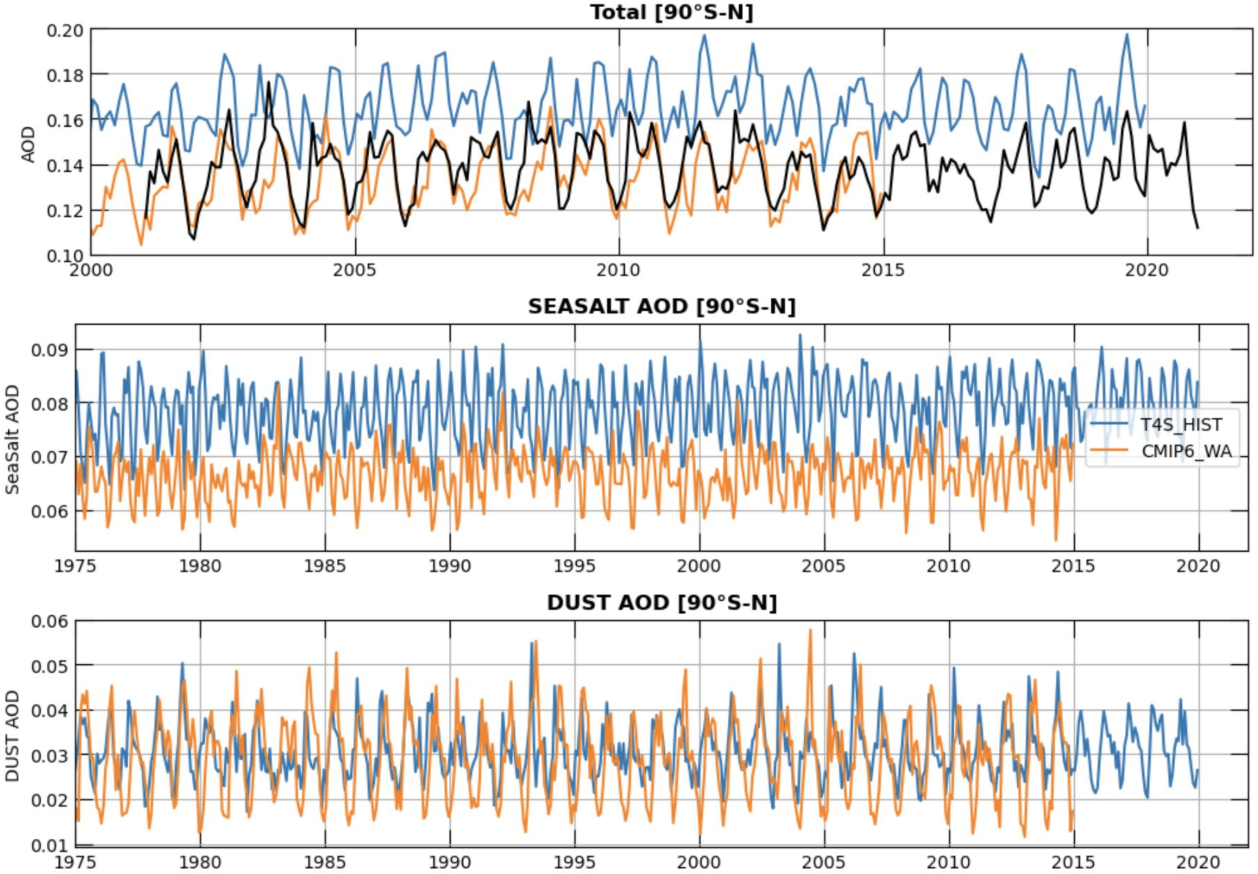
see talk by Ilaria Quaglia on Tuesday

MTt4s FHIST 1975-2020

AODVIS

AOD Sea Salt

AOD Dust



MTt4s

WACCM6

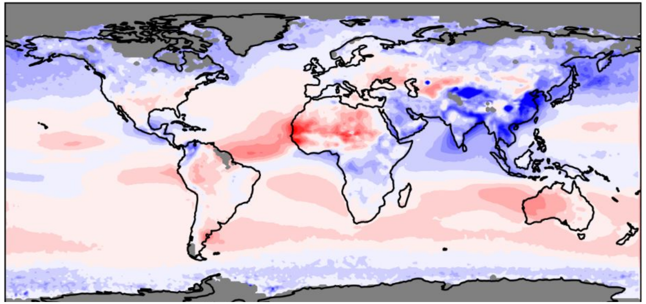
MERRA2

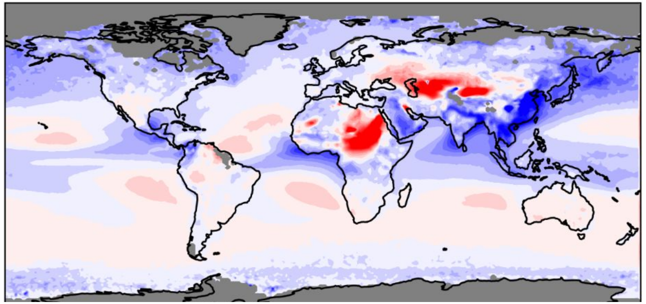
MTt4s 1975-2020: AODVIS compared to MODIS Obs.

MTt4s

WACCM6

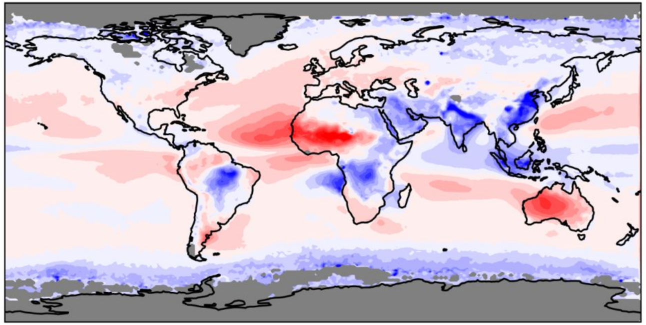
Mar-Apr-May
Mean:-0.018

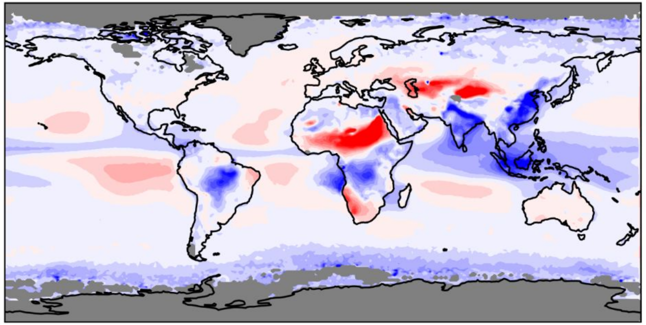




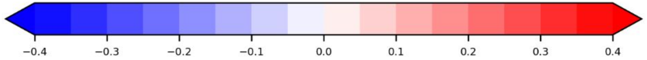
Mean:-0.044

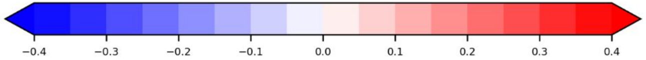
Sep-Oct-Nov
Mean:-0.009





Mean:-0.032





MTt4s 2016–2018 nudged : Comparisons to ATom

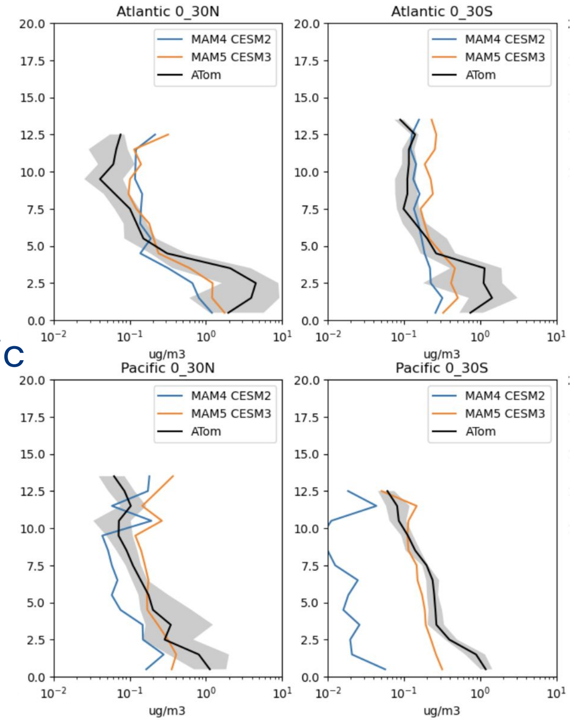
Sulfate

Atlantic

0-30N

0-30S

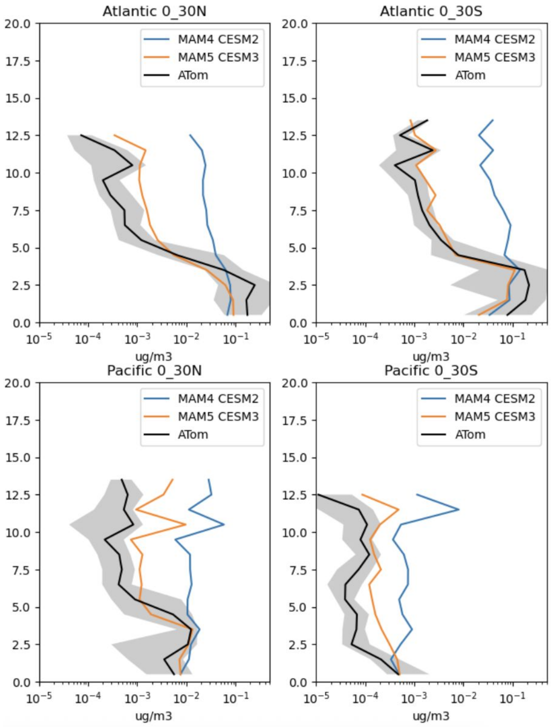
Pacific



Black Carbon

0-30N

0-30S



MTt4s

CAM6

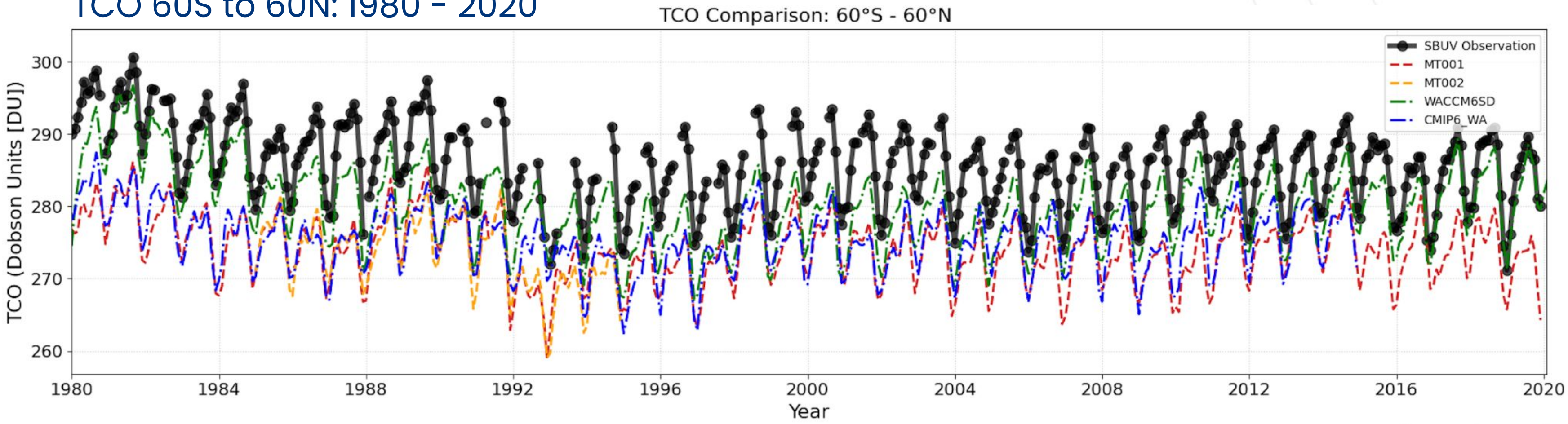
ATom

Comparisons to ATom Aircraft observations:

- Improvements in Sulfate (Tropical and Southern Ocean) due to new DMS emission
- Improvements in Black Carbon and other variables (updated convective wet removal)

MTt4s 1975-2020: Chemistry

TCO 60S to 60N: 1980 - 2020



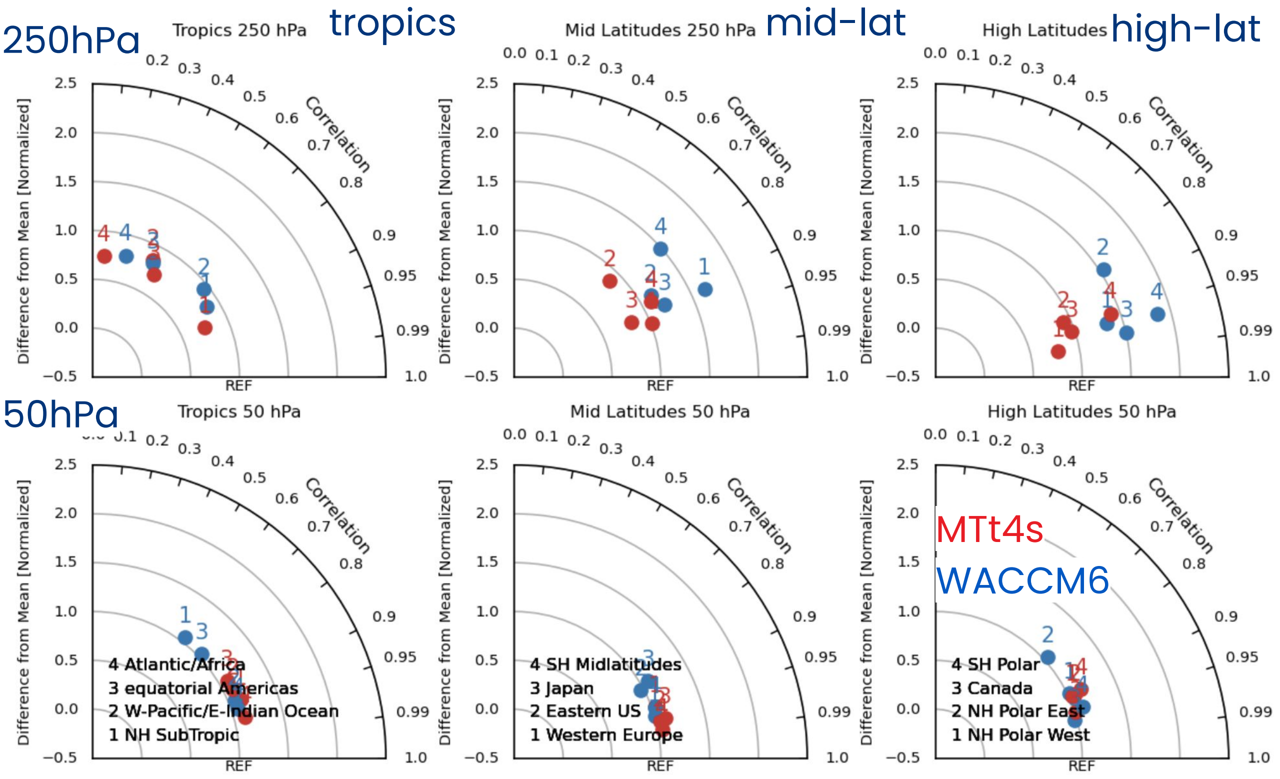
MTt4s 1
MTt4s 2
WACCM6
WACCM6 SD
SBUV Obs.

Total Column Ozone 1980-2020 compared to SBUV Observations

- Ozone around 5-10DU lower than observations, as in WACCM6
- somewhat stronger reduction in 1992 (after Mt Pinatubo)
- Note: Jun's talk shows increased TCO by 5-10 DU with interactive TUV-x (check out talk on Wednesday)

 | Figures: Jun Zhang

MTt4s 1975-2020: Chemistry

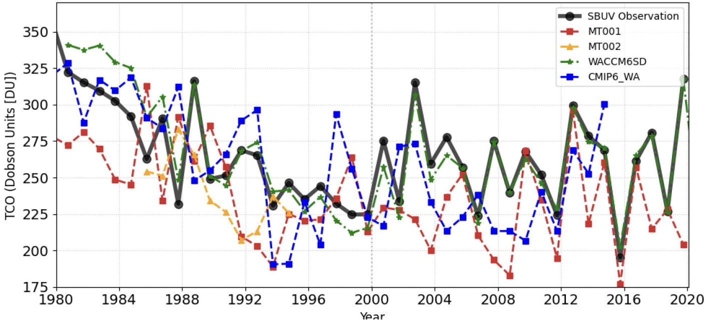


Ozonesonde comparisons

- significant improvement around 250hPa -> better resolved vertical layers
- somewhat reduced tropospheric ozone (update in lighting NOx, currently <3TgN/yr)
- methane lifetime improved

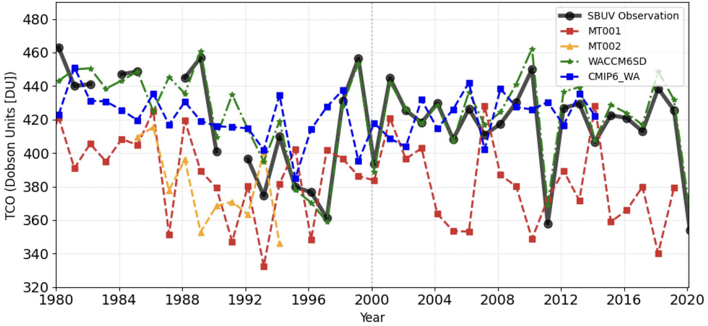
MTt4s 1975-2020: Polar Ozone

TCO 60-80S October: 1980 - 2020



TCO SH:
too much ozone depletion similar to WACCM6

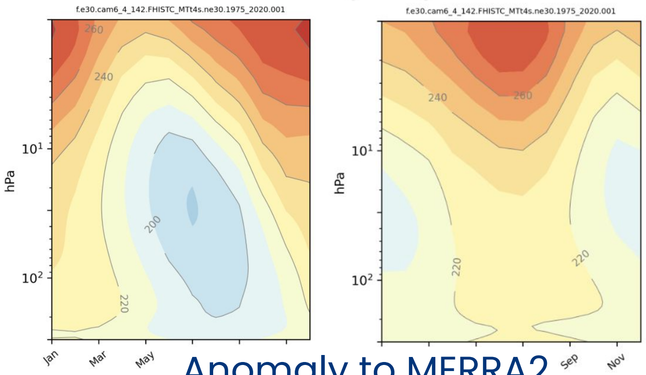
TCO 60-80N March: 1980 - 2020



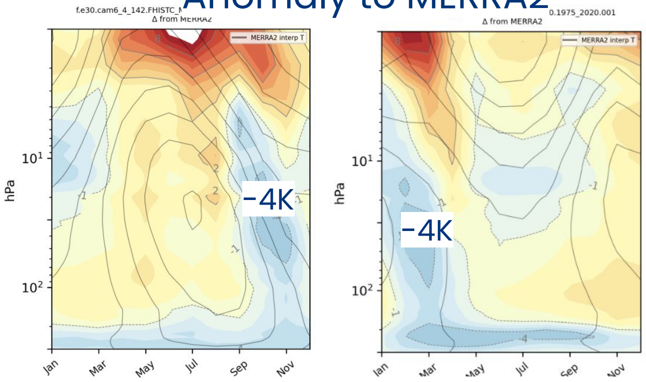
TCO NH:
too much ozone depleting

Polar Vortex tuning ongoing

60-90 SH Temperature 60-90NH



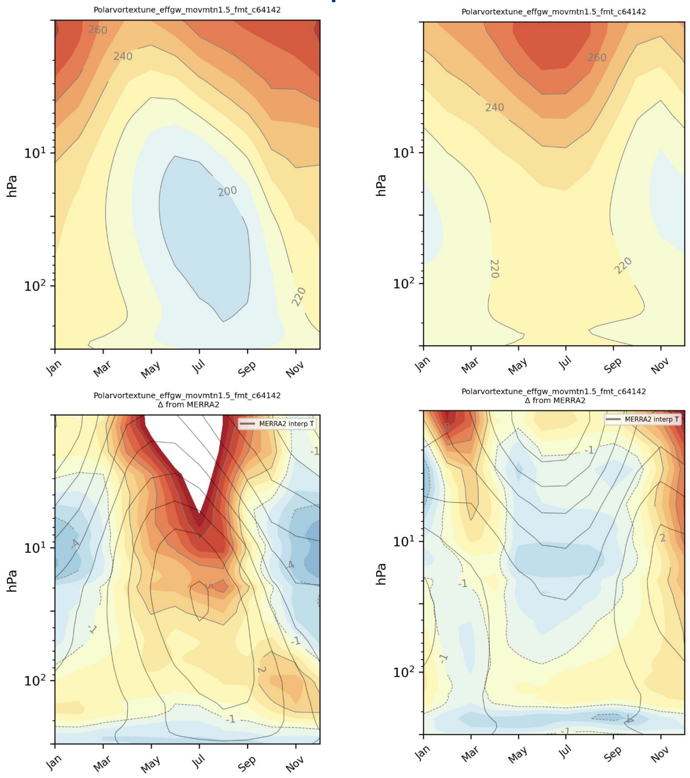
Anomaly to MERRA2



| Figures: Jun Zhang, ADF Shawn Honomichl

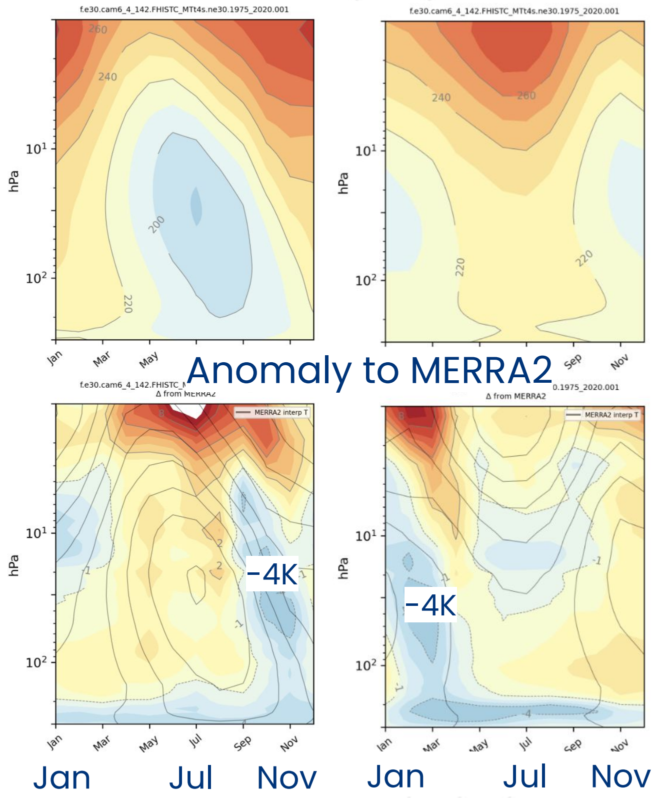
New Polar vortex tuning runs from Martina

60-90 SH Temperature 60-90NH



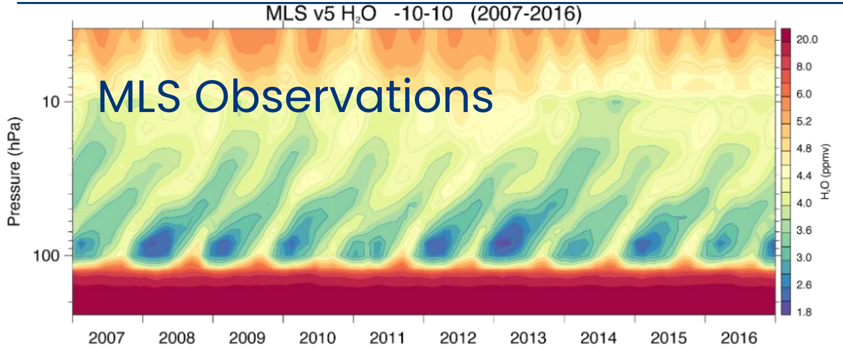
- SH polar vortex now too warm
- Stronger high bias in upper part
- NH polar vortex looks better

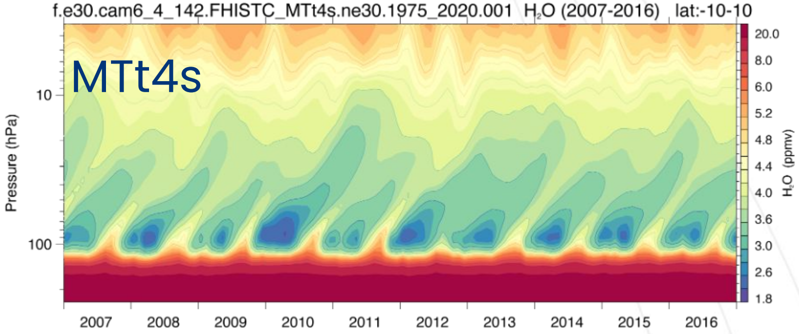
60-90 SH Temperature 60-90NH

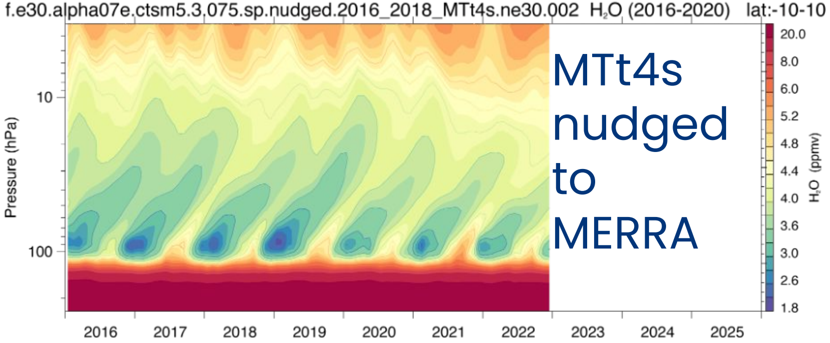


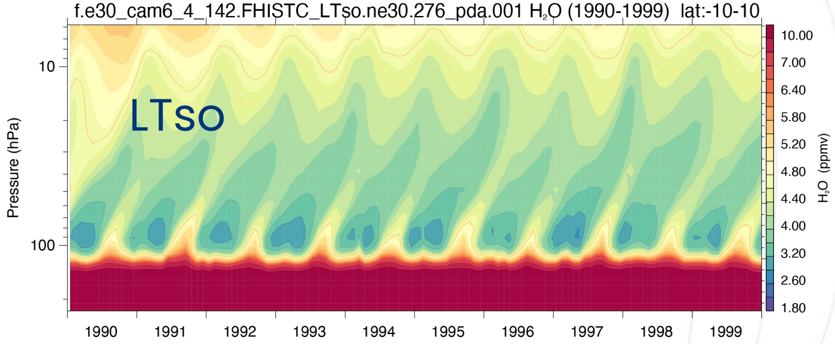
 | Figures: ADF Shawn Honomichl

Status: MTt4s 1975-2020: Tape Recorder









- MTt4s shows overall agreement with observations (MLS)
- Wet phase is slightly drier than MLS, double peak still persists
- MTt4s shows significant improvement over LTso

Summary and Conclusions

Improvements between MTt4s compared to WACCM6

- Improved stratospheric Aerosol Representation -> new CMIP7 emissions
- Improved tropospheric Aerosol Representation, e.g., wet removal
- Sea-salt is used for tuning -> somewhat high
- Dust dependent on land surface: differences between B- and F- cases
- Sulfate improvements -> new DMS scheme (more work required)
- Chemistry
  - Improvements in ozone in the UTLS (higher vertical resolution)
  - Improved methane lifetime
- Tape recorder looks reasonable (much better than in WACCM6)

To-do before we can start the PI-Control spin-up

- Integrate upper stratospheric heating rates (pull request in progress)
- Polar vortex tuning
- Tuning of lightning NOx