Chemistry-Climate Working Group

Overview of what's new in Chemistry/Aerosol

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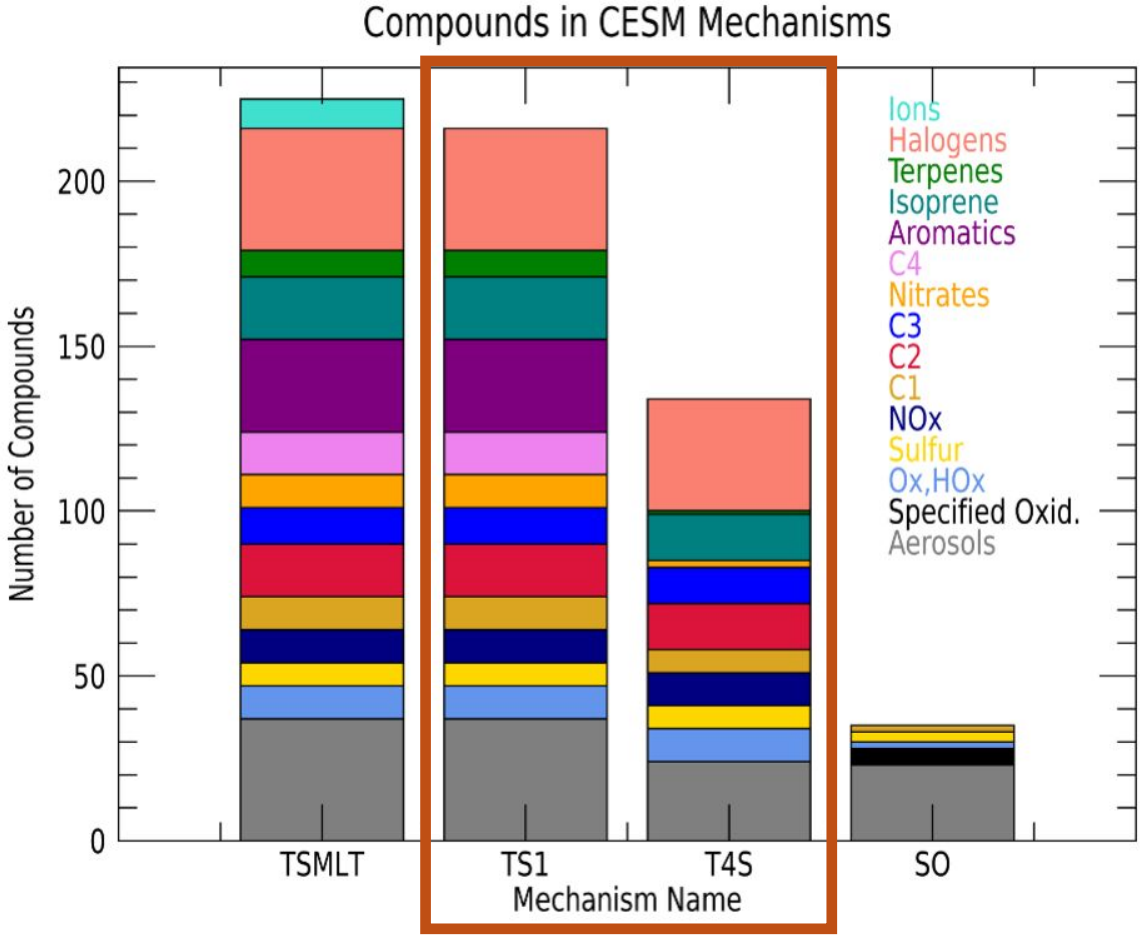
MOZART Chemistry Options in CESM3



Name	Description	# tracers	# reactions
T1MA (TSMLT)	T1 with stratosphere, mesosphere, lower thermosphere chemistry	234	583
T1S (TS1)	T1 with comprehensive stratospheric chemistry and full sulfur chemistry	231	528
T4S	T4 with comprehensive stratospheric chemistry, no odd F, C>3 hydrocarbons simplified	141	364
SO	Specified Oxidants, with GHGs	31	12

produced by Louisa Emmons

CESM Configurations with Chemistry

WACCM

TSMLT->T1MA
234 tracers

Middle Atmosphere (MA)
100 tracers

Specified chemistry -> Prescribed Oxidants
31 tracers

Provides Upper Boundary Conditions

oxidants, ozone, strat. aerosol

Air Quality Chemistry

T1S: 231 tracers
T3S: 278 tracers
T5S (halogen chemistry): 277 tracers

MOSAIC/CARMA

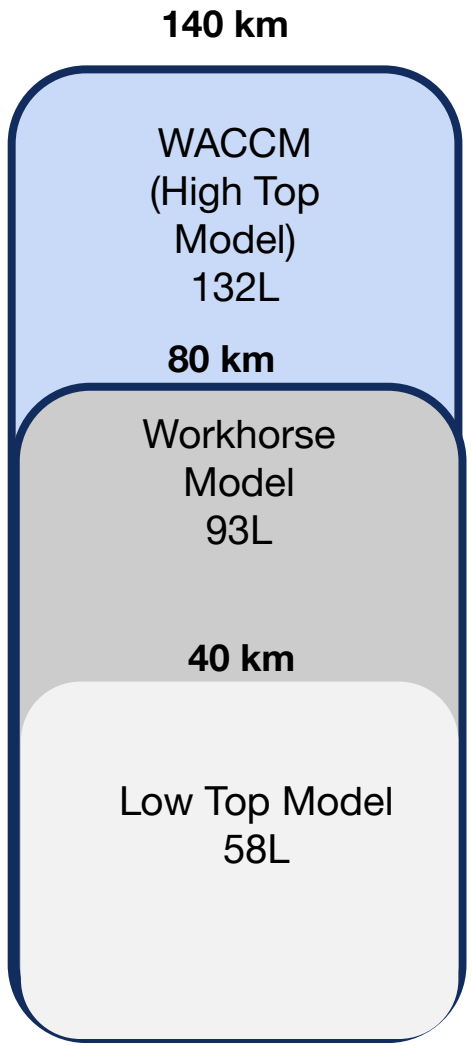
Trop4 / Strat Chemistry

T4S: 141 tracers
30% cheaper than TS1

As TS1 but cheaper tropospheric chemistry for climate

Specified Oxidant Chemistry

31 tracers
prescribed ozone, oxidants, aerosol
interactive GHGs and tropospheric aerosol



Fully coupled simulations with chemistry are required for GHG chemistry runs

Chemistry-Climate Production Experiments for CMIP7

Mid-top model configuration with T4S chemistry with MAM5 aerosol scheme

- Comprehensive interactive tropospheric (T4) and stratospheric (S) chemistry for long climate simulations
- Interactive aerosols in troposphere and stratosphere (including volcanoes)
- Production of oxidants, aerosol, nitrogen deposition fields for prescribed oxidant chemistry
- Required for AerChemMIP and GeoMIP contribution for CMIP7 and other MIPS (CCMI, HTAP)

Mid-top model configuration with T1S and Short-Lived Halogen chemistry (Tier 2)

- Improved chemistry and halogen representation for improved air quality and climate purposes. **Impact on tropospheric oxidants and GHGs.**
- AerChemMIP and GeoMIP contributions
- Baseline for more detailed chemistry climate studies

Chemistry-Climate Production Experiments for CMIP7

Included in standard CMIP7 simulations

- T4S climate chemistry, includes interactive aerosol and oxidants
- MAM5 aerosol scheme, independent stratospheric aerosol mode
- New dust emissions based on Leung et al., 2024
- Online DMS emissions based on Online Air-Sea Interface for Soluble Species (OASIS)

Not Included in initial CMIP7 (potentially in later simulations / VSL halogen runs)

- New Photolysis scheme (TUV-x) (-> Tier 2 simulations)
- Short-Lived Halogen emissions and chemistry (-> Tier 2 simulations)
- Updated Soil NOx emissions (-> Tier 2 simulations)
- Marine Organic Aerosol Emissions
- MEGAN3 biogenic emissions
- CARMA aerosol / cloud (including nitrate implementation)
- HEMCO emissions (processing emissions online)

Status and Next Steps for CMIP 7 (in progress)

In Progress:

- Production of T4S MT HIST simulations (fixed SSTs) 1980-2015 (CMIP6 emissions)
- Production and testing of new CMIP7 volcanic forcing files, surface emissions, and other forcings (-> currently using WACCM 2deg), see Ben Gaubert's talk
- Production of new forcing files from the T4S MT HIST simulation, to be integrated in the MT Specified Oxidant simulations

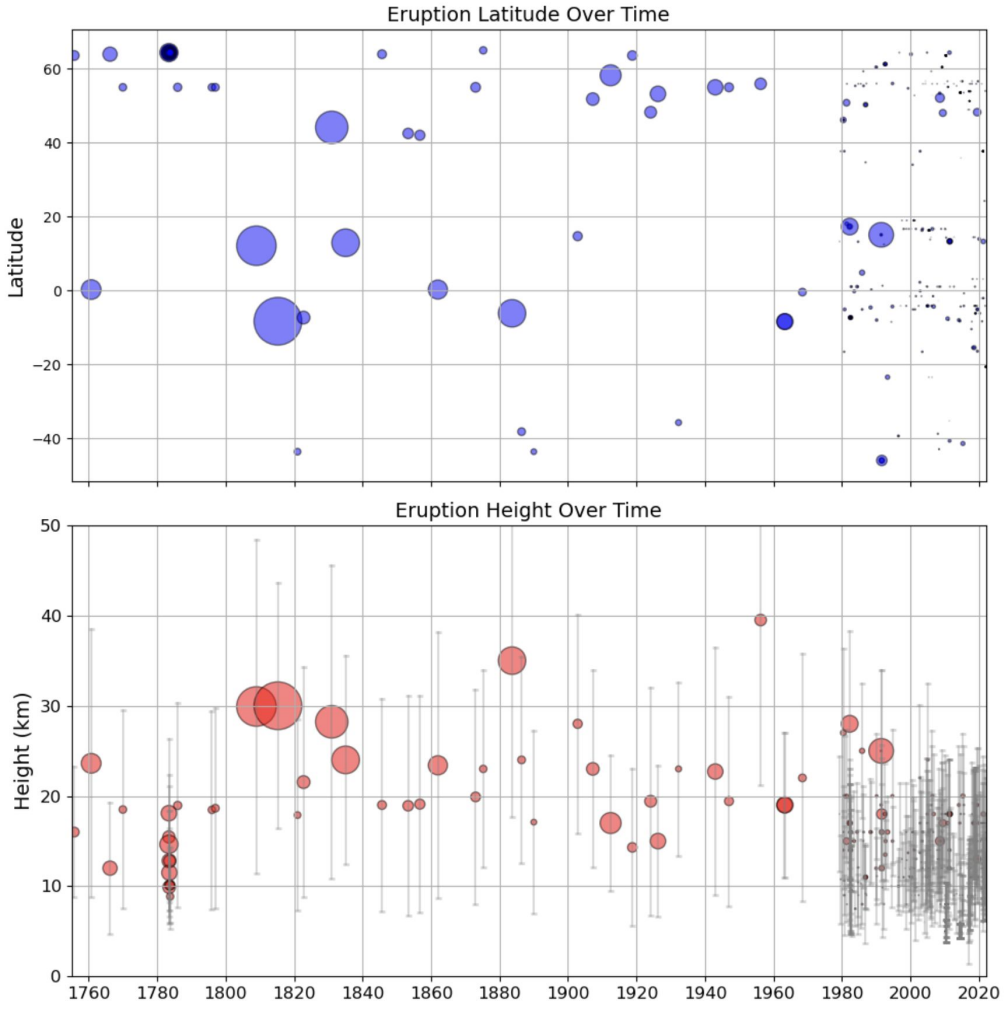
Next Steps:

- Run a 1850 MT T4S simulation to produce forcing files for the next set of 1850 runs

-> as soon as the new tag is available

- Test historical simulations
- Prepare for Tier 2 simulations

Volcanic SO2 emissions Data Set to be finalized for CMIP7

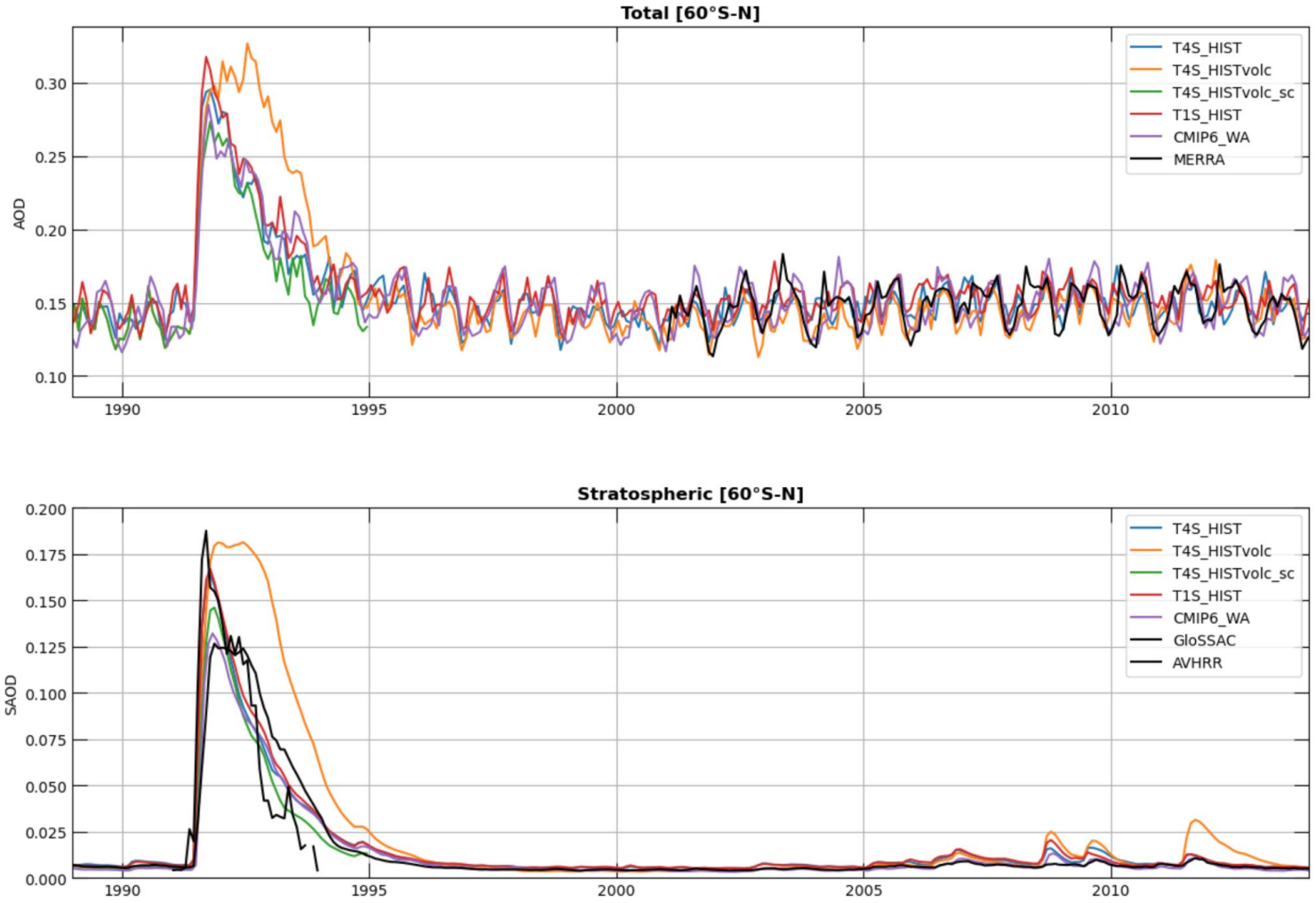


Key differences between the VolcanEESM database and the CMIP6plus dataset include:

- **Injection height variability**: CMIP6plus exhibits greater variability in injection heights, while pre-satellite eruptions (before ~1970) are generally modeled with injections around 17–18 km altitude.
- **Eruption locations**: Some adjustments have been made to the locations of eruptions in CMIP6plus.
- **Inclusion of missing eruptions**: CMIP6plus includes eruptions that were missing from earlier versions of the dataset.
- **Satellite era improvements**: More eruptions are included in the post-1970 satellite era in CMIP6plus.
- **Plans to include more eruptions throughout the dataset**

T4S MT Performance: AOD and Volcanic Forcing

Stratospheric Aerosol optical depth at 550 nm



T4S MT HIST

T1S MT HIST

T4S MT HIST new CMI7 volc

T4S MT HIST new CMI7 volc scaled (1989-1994)

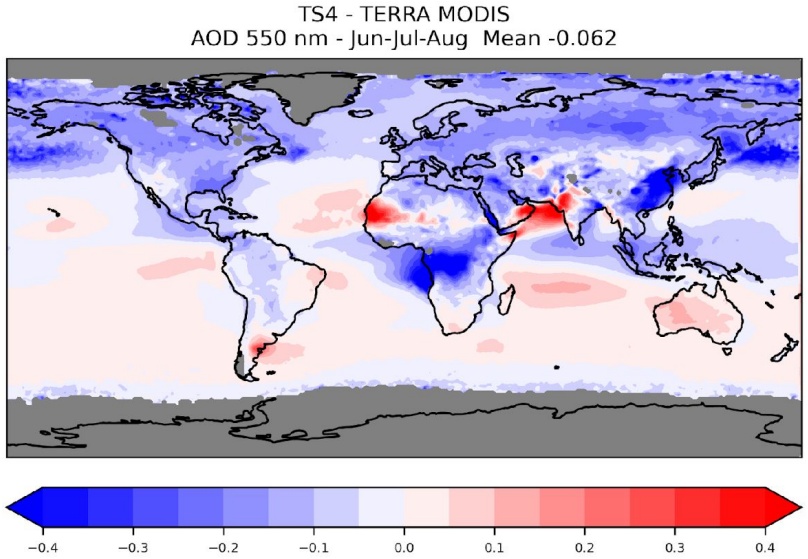
CMIP6 WACCM

MERRA2 / GloSSAC and AVHRR

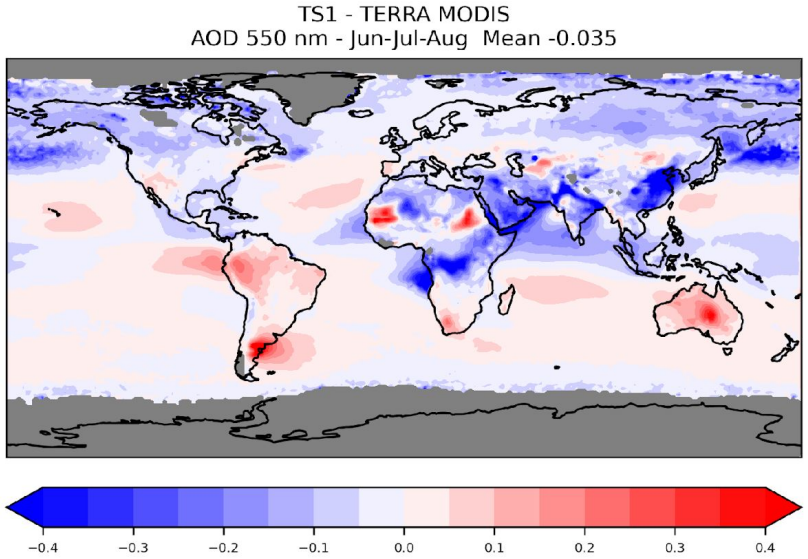
T4S MT Performance: Using new Dust Emissions

Aerosol Optical Depth: Model minus MODIS Data

New Dust and Changes in Land



Old Dust and Land

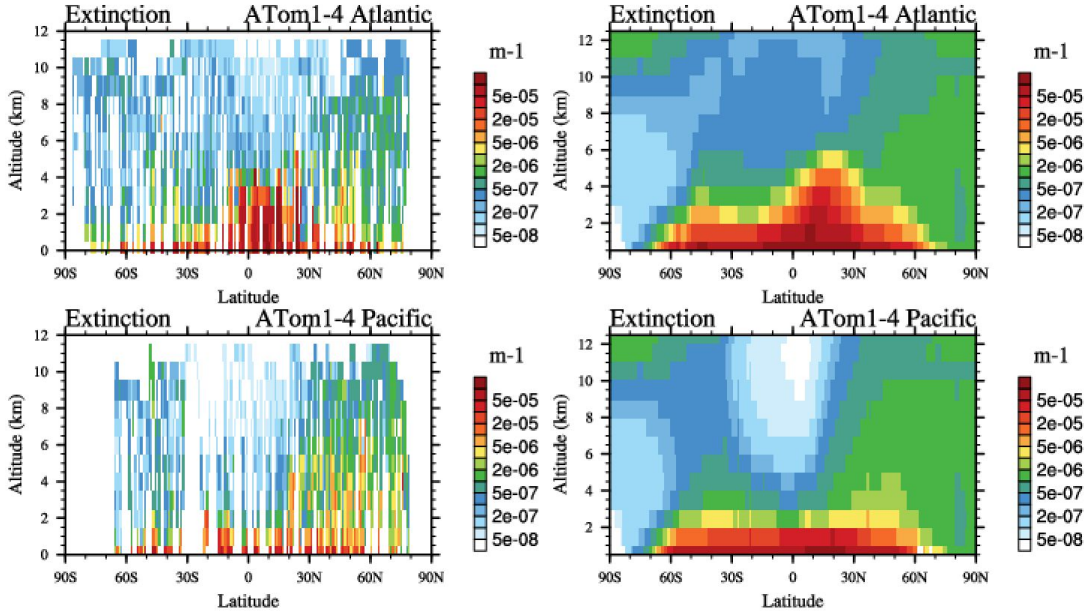


- Significant improvement in AOD over the SH (Australia, South America)
- Currently potential issues with biogenic emissions from the land for SOA formation. This may cause some underestimation of AOD over land (Central Africa, Eastern China, etc.)

T4S MT performance: Comparisons to Aircraft Data

Extinction

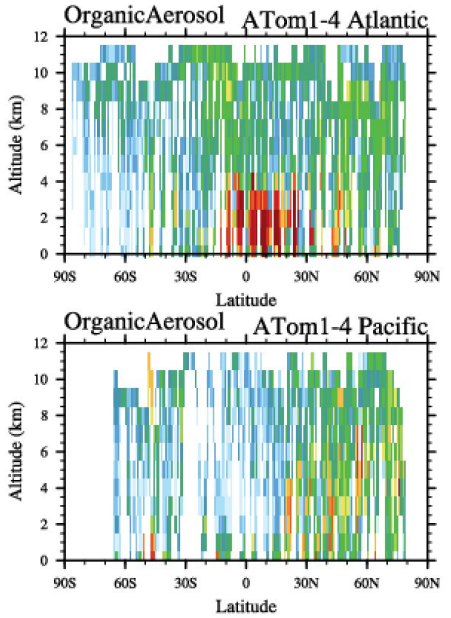
ATom data



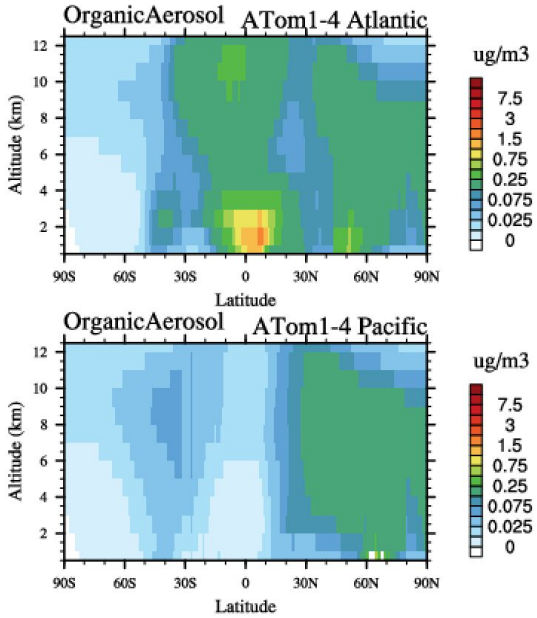
T4S MT new dust

Organic Aerosol

ATom data

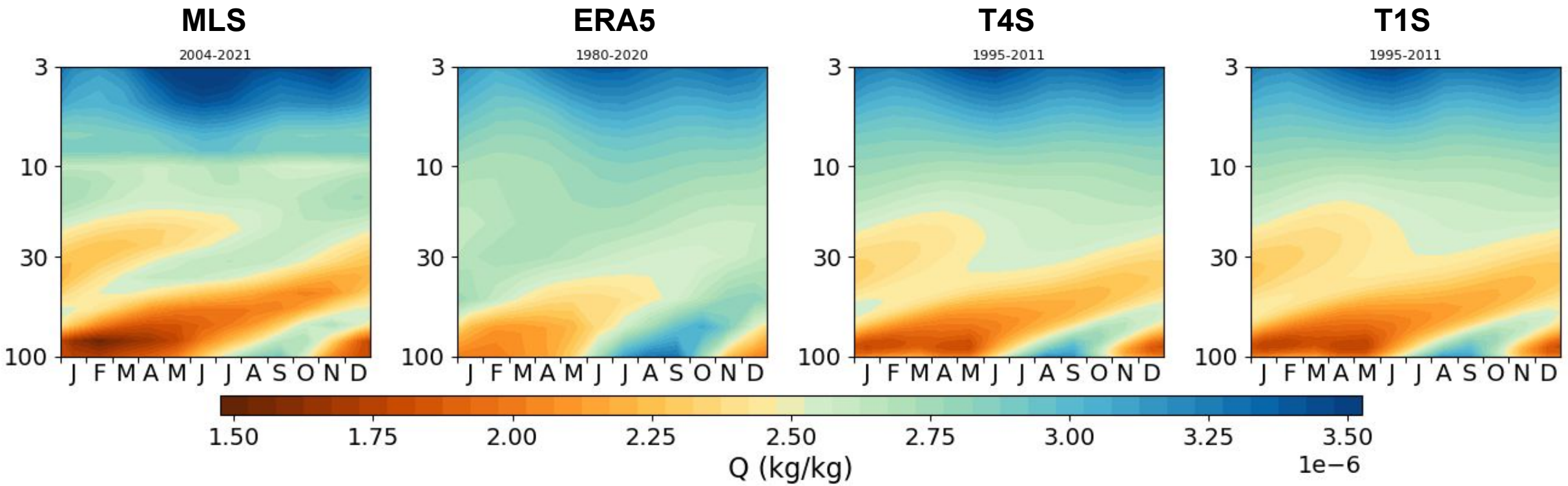


T4S MT new dust



- Extinction is reasonable, some underestimation over the Pacific mid-to high latitudes
- Underestimation of Organic Aerosol (possible due to reduced biogenetic precursor emissions)

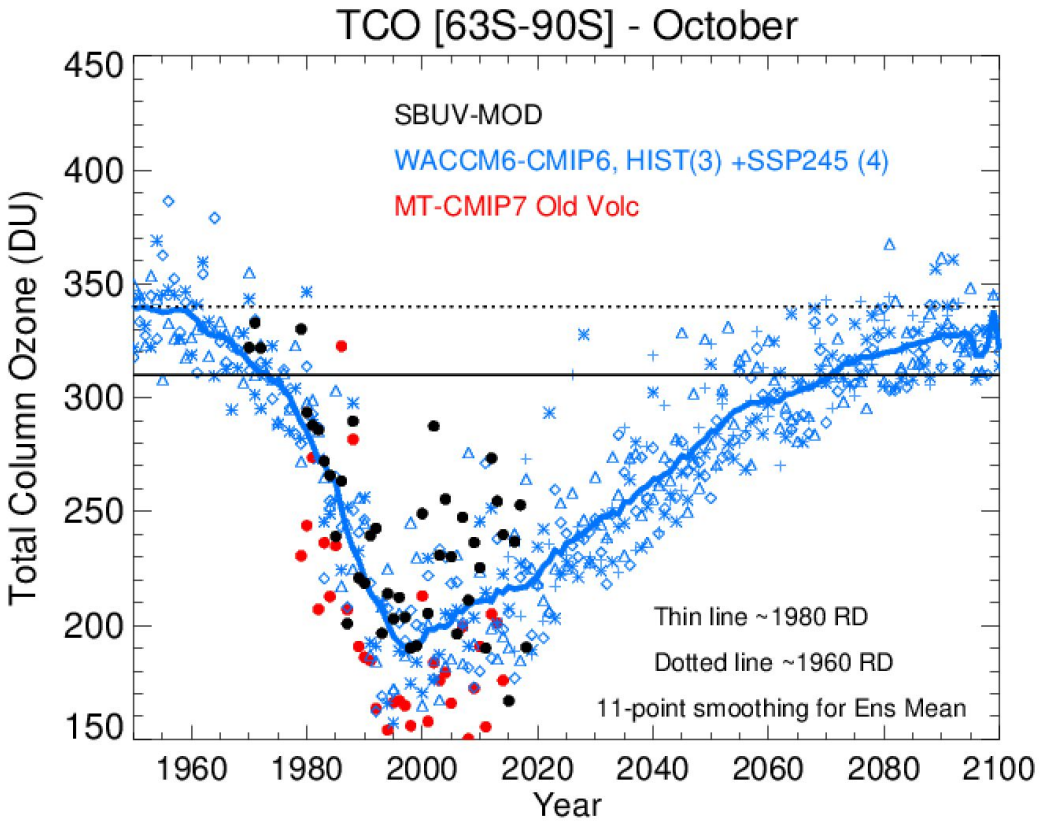
T4S MT performance: Tape Recorder

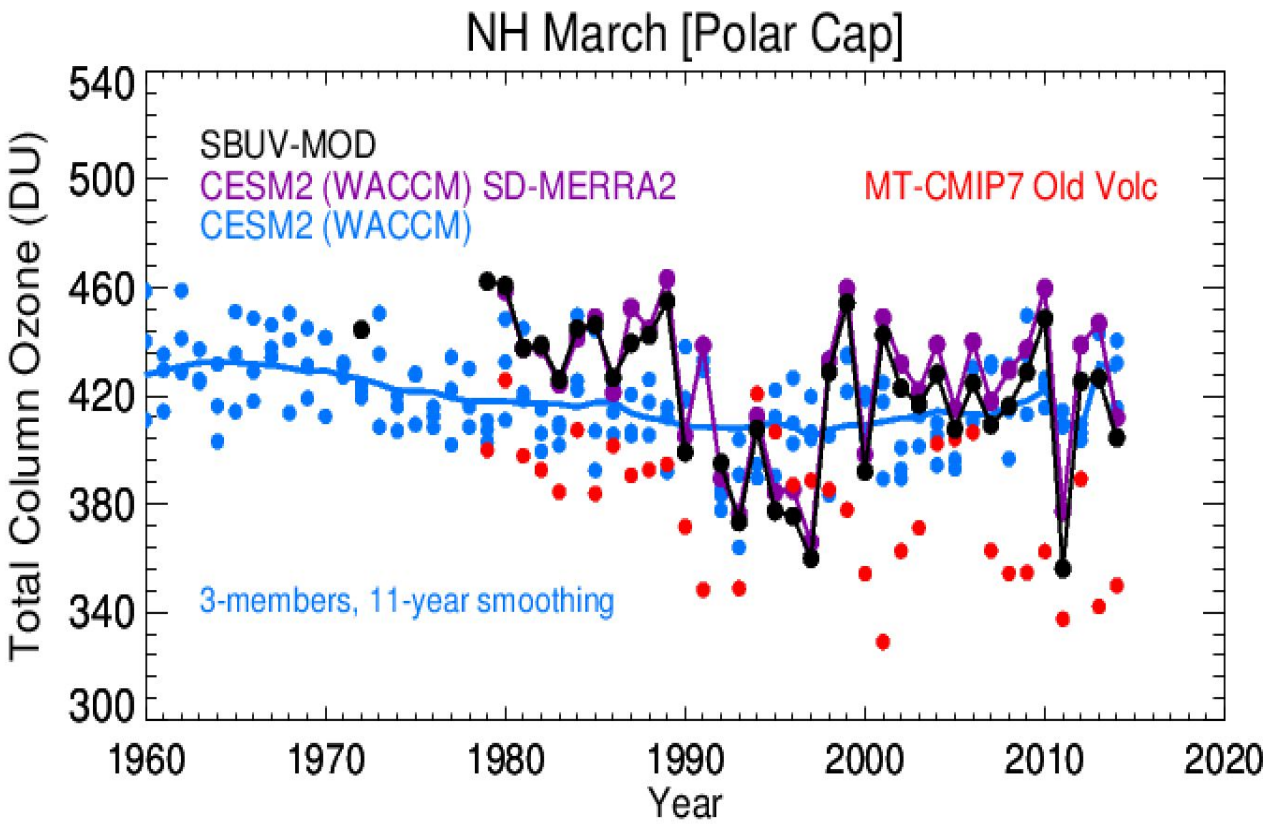


Climatology of zonal mean seasonal cycle water vapor in the tropical band

- Tape Recorder minimum and maximum look reasonable
- Peak in April/May is not realistic

T4S MT performance: Total Column Ozone

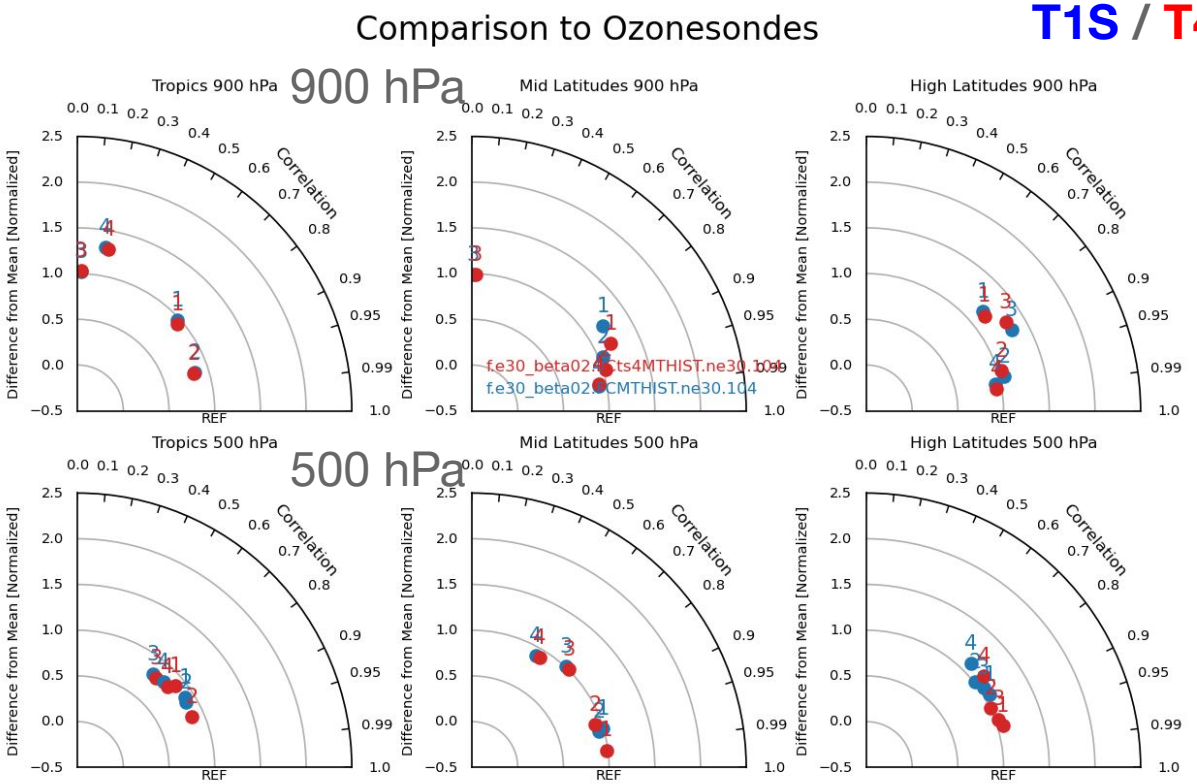


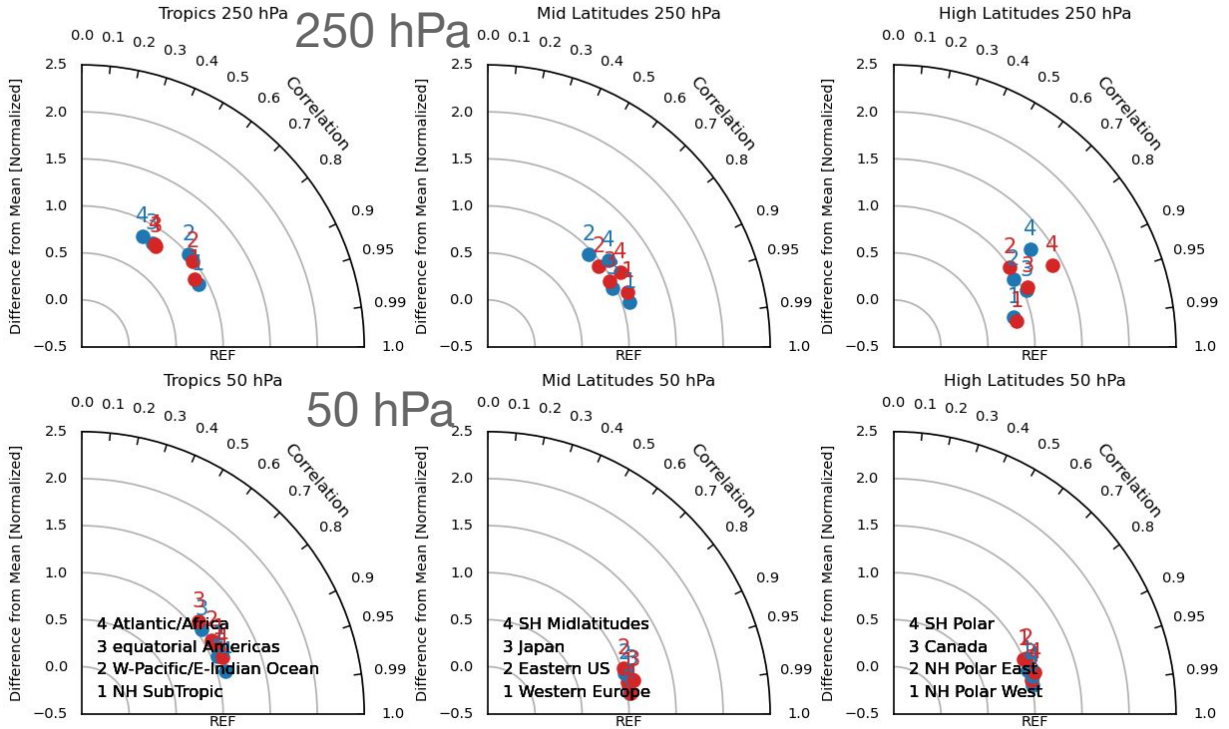


produced by Doug Kinnison

- Total Column Ozone Evolution for SH October looks reasonable
- Values are too low, especially for NH March. Need to check temperatures, winds, SSW.

T4S vs T1S MT performance: Comparisons to Ozone Sondes





- Reasonable performance of ozone compared to ozonesonde observations
- T4S is very similar to T1S performance

Highlights of other CAMchem Development

Improve knowledge of Short Lived Halogens (SLH) on the atmospheric oxidation capacity

Halogen influence on Oxidation Capacity:

(clean environments)

$X + O_3 \rightarrow XO + O_2$

$O_3 + h\nu \rightarrow O^1D + O_2$

$O^1D + H_2O \rightarrow 2\ OH$

(polluted environments)

$Cl + VOCs \rightarrow RO_2 + HCl$

$RO_2 + NO \rightarrow NO_2 + RO$

$RO + O_2 \rightarrow HO_2 + Products$

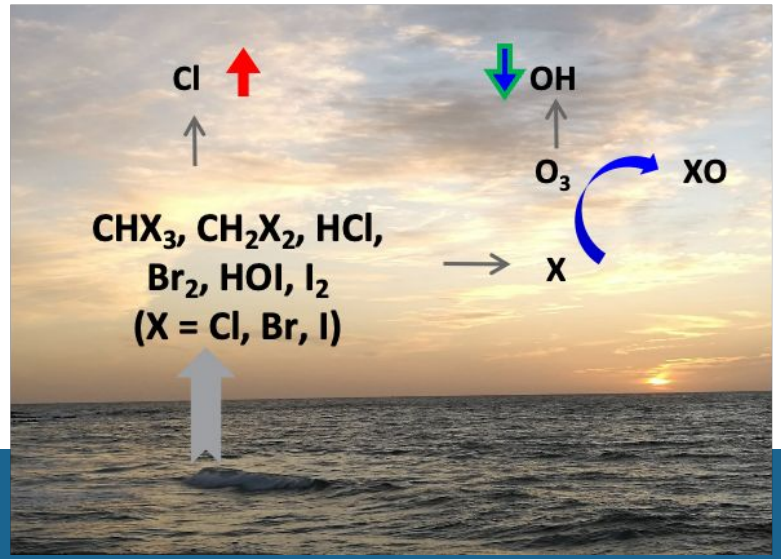
$HO_2 + NO \rightarrow NO_2 + OH$

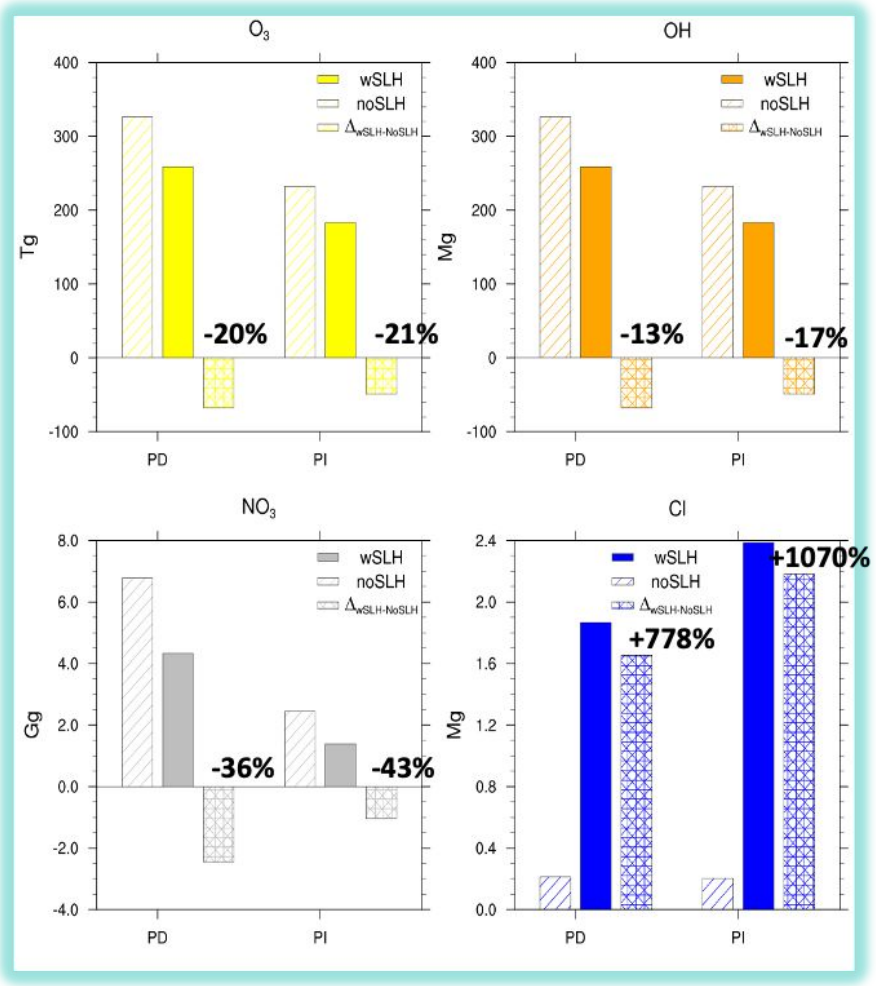
$XO + HO_2 \rightarrow HOX$

$HOX + h\nu \rightarrow X + OH$

SLH indirectly decrease OH

SLH Halogens indirectly increase OH

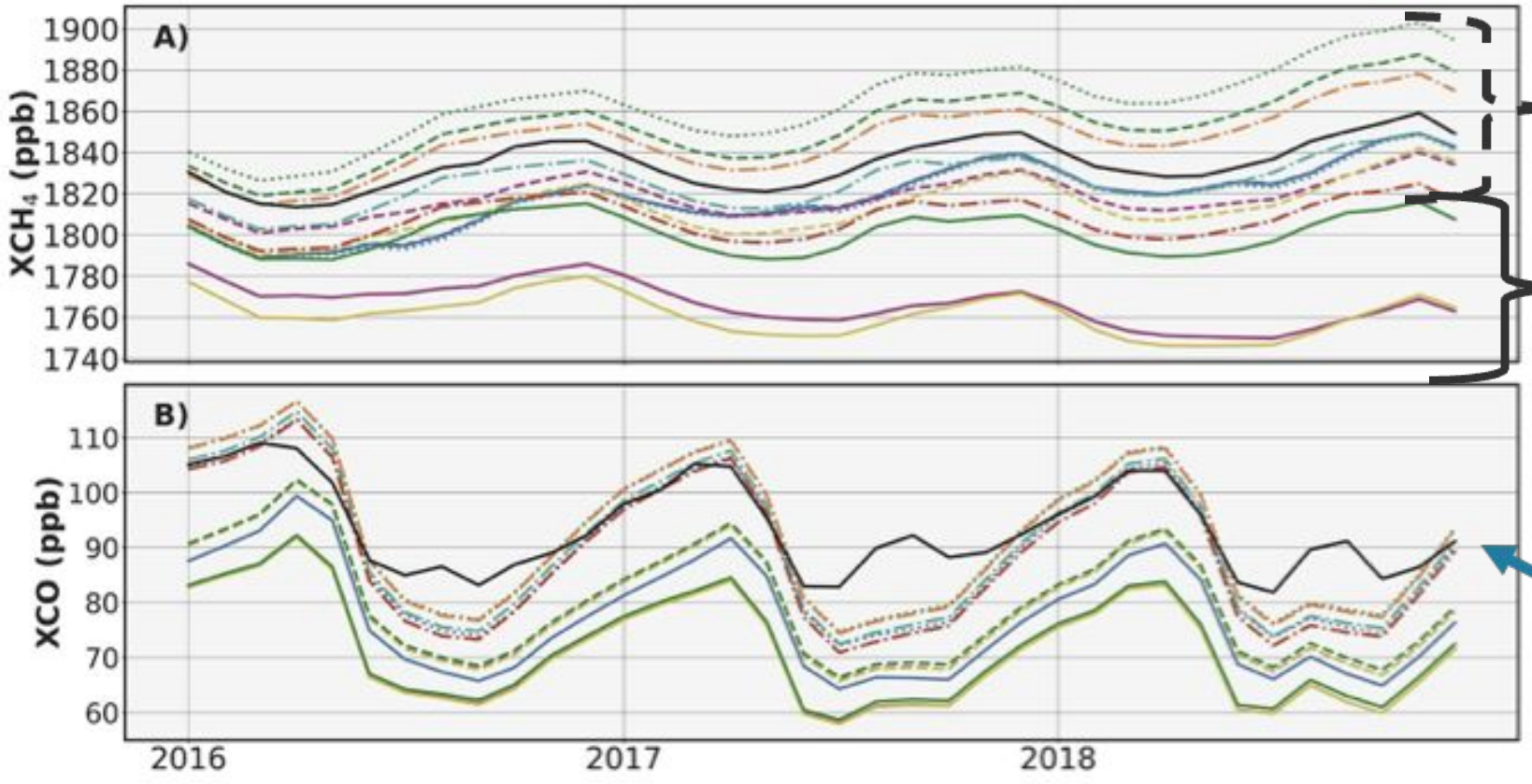




- Implications for main oxidants (OH, O_3, NO_3, Cl)

Importance of Short Lived Halogen Chemistry with Interactive Methane

Comparison of CESM2.2 with GOSAT CH_4 and MOPITT CO (2016-2018 monthly means)



SLH chemistry (dashed lines)
-> realistic methane concentrations

Default T1S chemistry
-> unrealistic methane concentrations (when using emission driven methane)

SLH chemistry with posterior CO emissions

work by Ben Gaubert

- Updated halogen representation in CESM2.2 Improves OH, CO and CH_4:
- Net OH reduction with most profound impact over the ocean
- Result in an increase in CO and CH_4 due to a longer lifetime with respect to OH

MUSICA
Multiscale Infrastructure for Chemistry and Aerosols

MUSICA: configurations of CESM

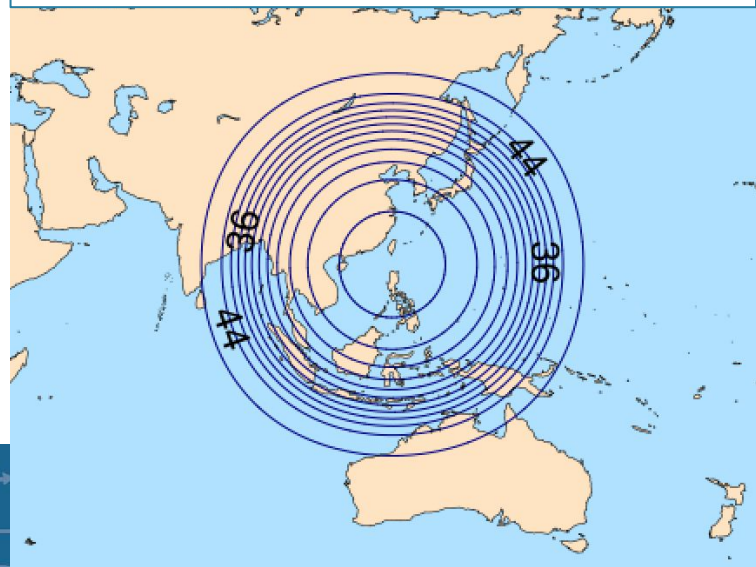
MUSICAv0: Regionally refined grids in CAM-chem (Spectral Element)

- Australia (Rebecca Buchholz)
- Michigan (Noribeth Mariscal, Wayne State Univ.)
- Simultaneous N.America, Europe, Asia refined regions (Louisa Emmons)
- numerous studies with CONUS grid (Alma Hodzic, Ben Gaubert, …)
- Dynamical downscaling work (Kwesi Quagraine)

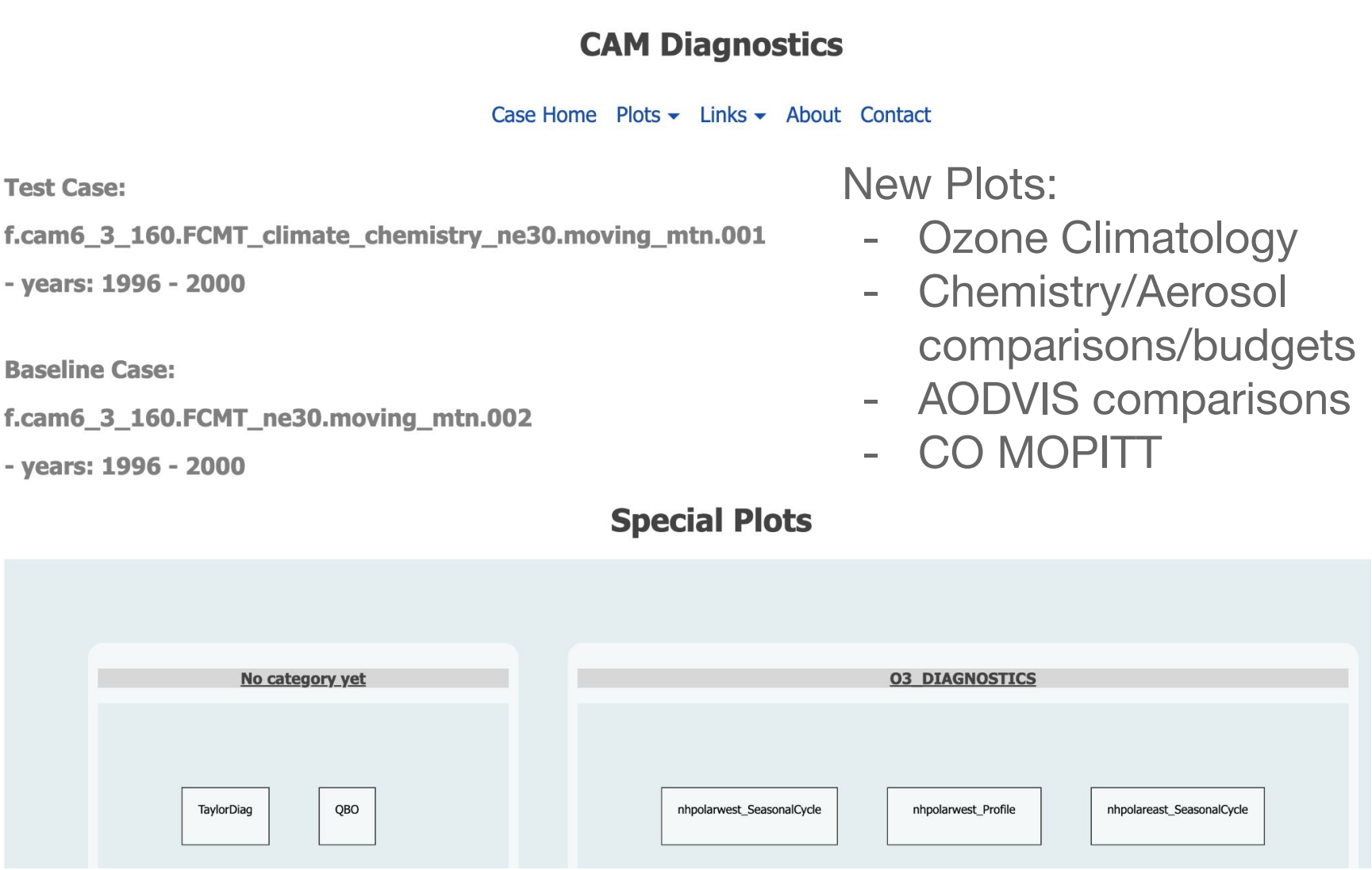
MUSICAv1:

- CAM-chem with MPAS dynamical core, allowing refined grid down to 1-km resolution
- Currently testing grid with 3 km refined region, 60 km globally
- Centered over Asian Summer Monsoon (ACCLIP analysis; Ren Smith, Mary Barth)
- over Philippines-Taiwan (ASIA-AQ analysis; Wenfu Tang)

MPAS 60->3 km grid for ASIA-AQ



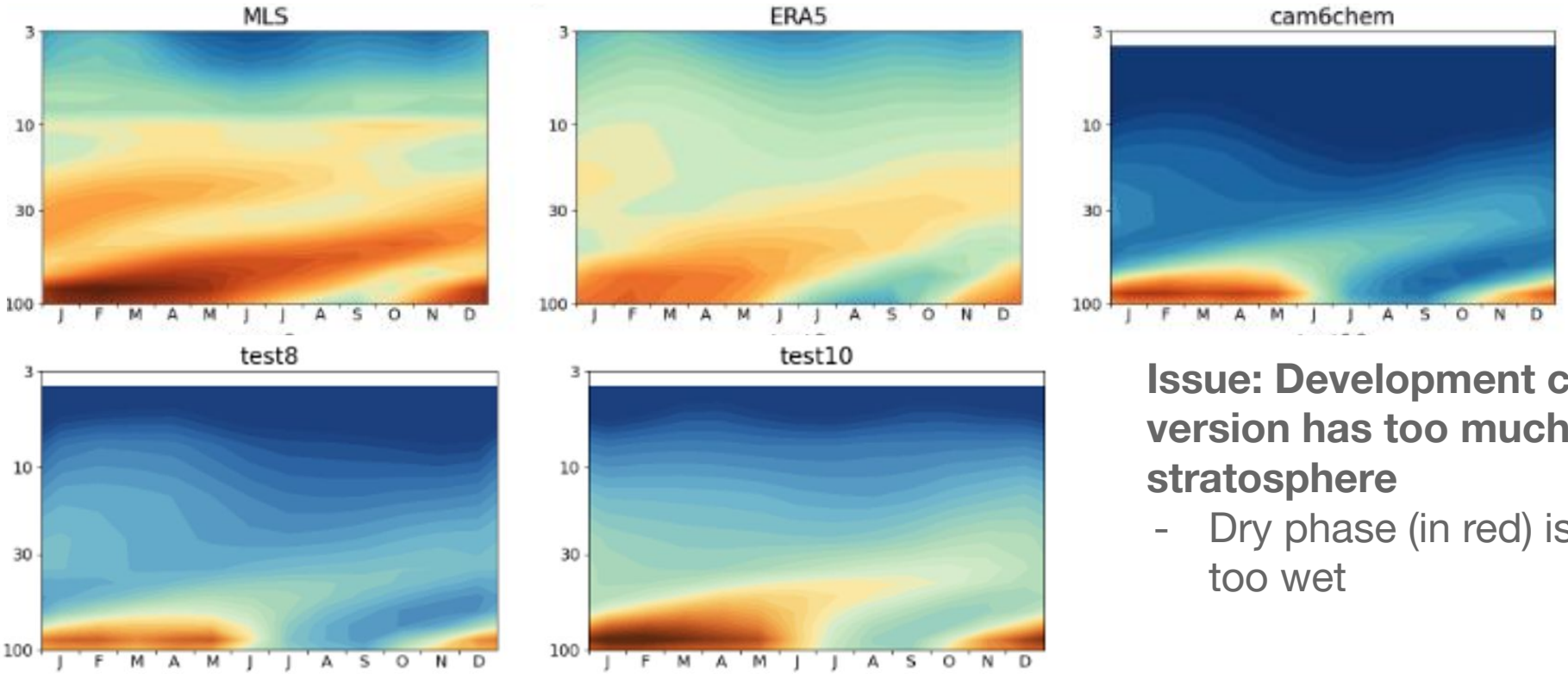
New ADF Chemistry Options in Development



New Plots:

- Ozone Climatology
- Chemistry/Aerosol comparisons/budgets
- AODVIS comparisons
- CO MOPITT

CAM6-Physics Water Vapor Tests (Development Version)



Issue: Development cam6 physic's default version has too much water vapor in the stratosphere

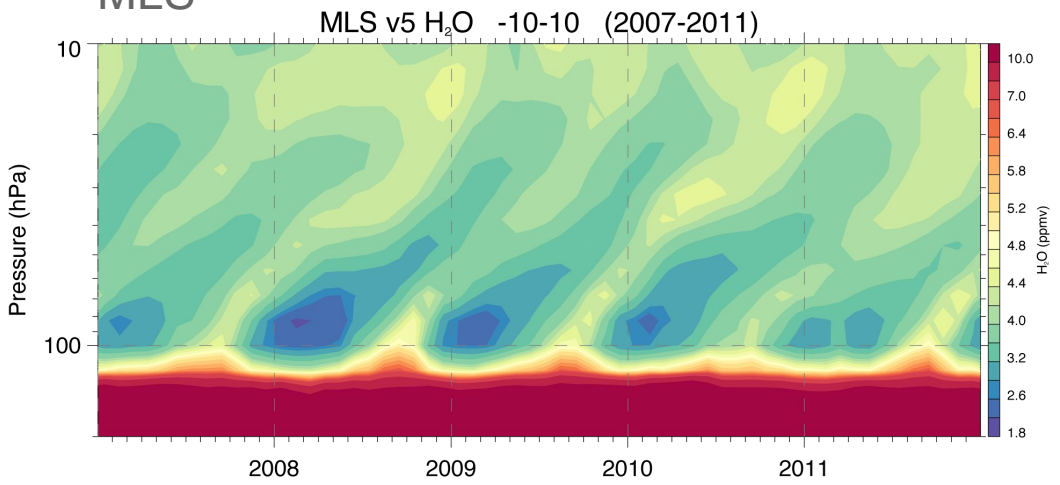
- Dry phase (in red) is about right, wet phase is too wet

2 tests H_2O tests helped to dehydrate the stratosphere

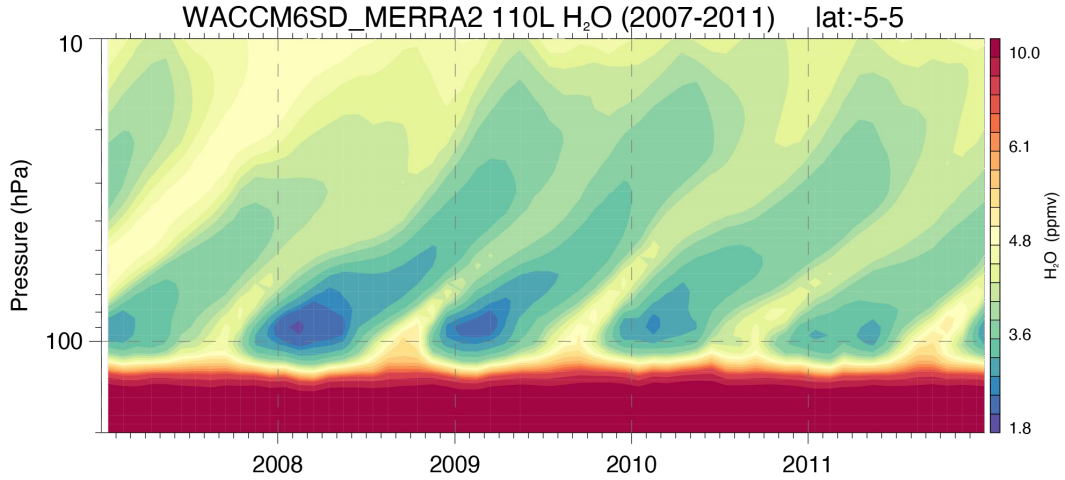
- Increase of ice formation in the stratosphere -> change stratospheric ice formation from 100%RH to 80%RH -> faster ice formation
- Increase of fall velocity of small slow ice -> faster removal of ice

CAM6-Physics Water Vapor Tests

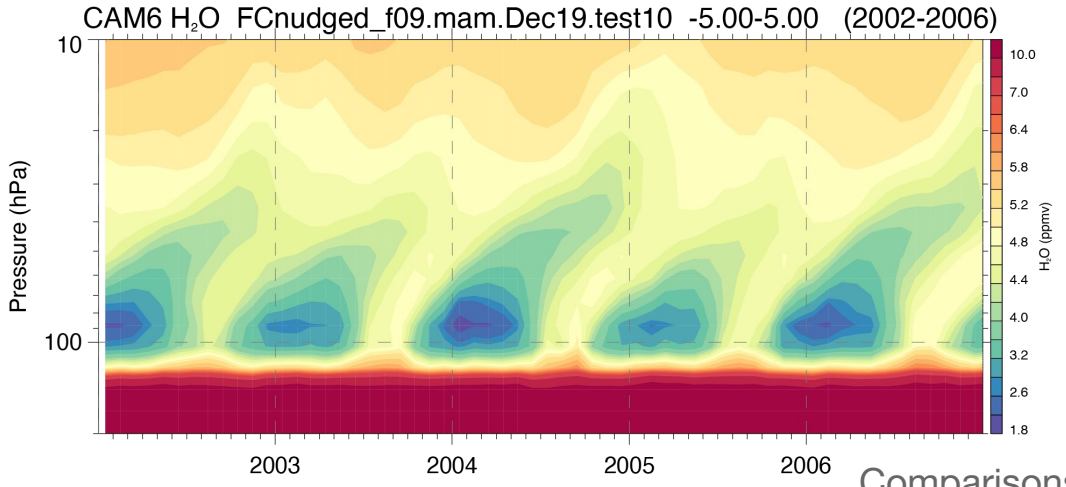
MLS



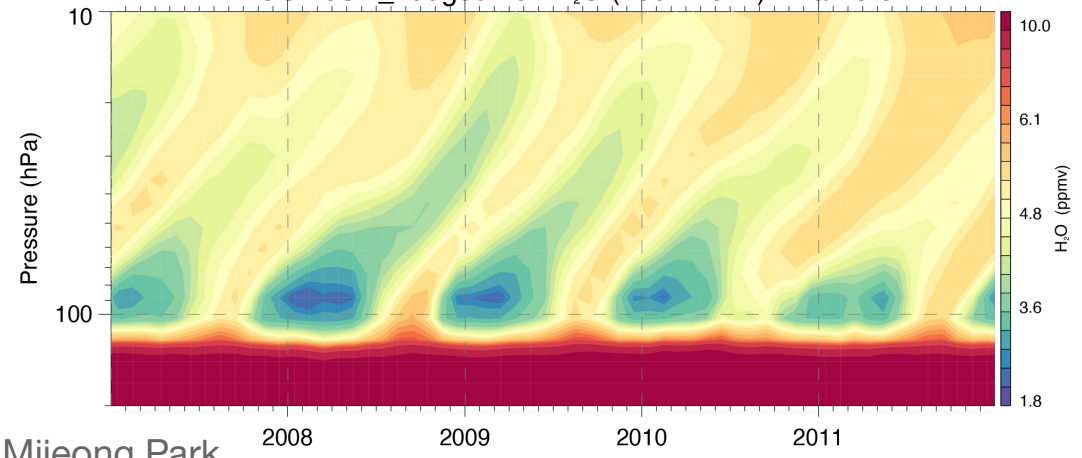
CESM2.2 WACCM6 110L model



CESM3 cam6-physics CAMchem 32L model



CESM2.2 WACCM6 70L model



Comparisons by Mijeong Park