Chemistry-Climate Working Group

Overview of what's new in Chemistry/Aerosol

Simone Tilmes - NCAR/ACOM Chemistry-Climate co-chair
Rafael Fernandez – CONICET, UNCUYO, Chemistry-Climate co-chair
Rebecca Buchholz, Shawn Honomichl - NCAR/ACOM Chemistry-Climate Liaison
Francis Vitt – NCAR/ACOM Software Engineer

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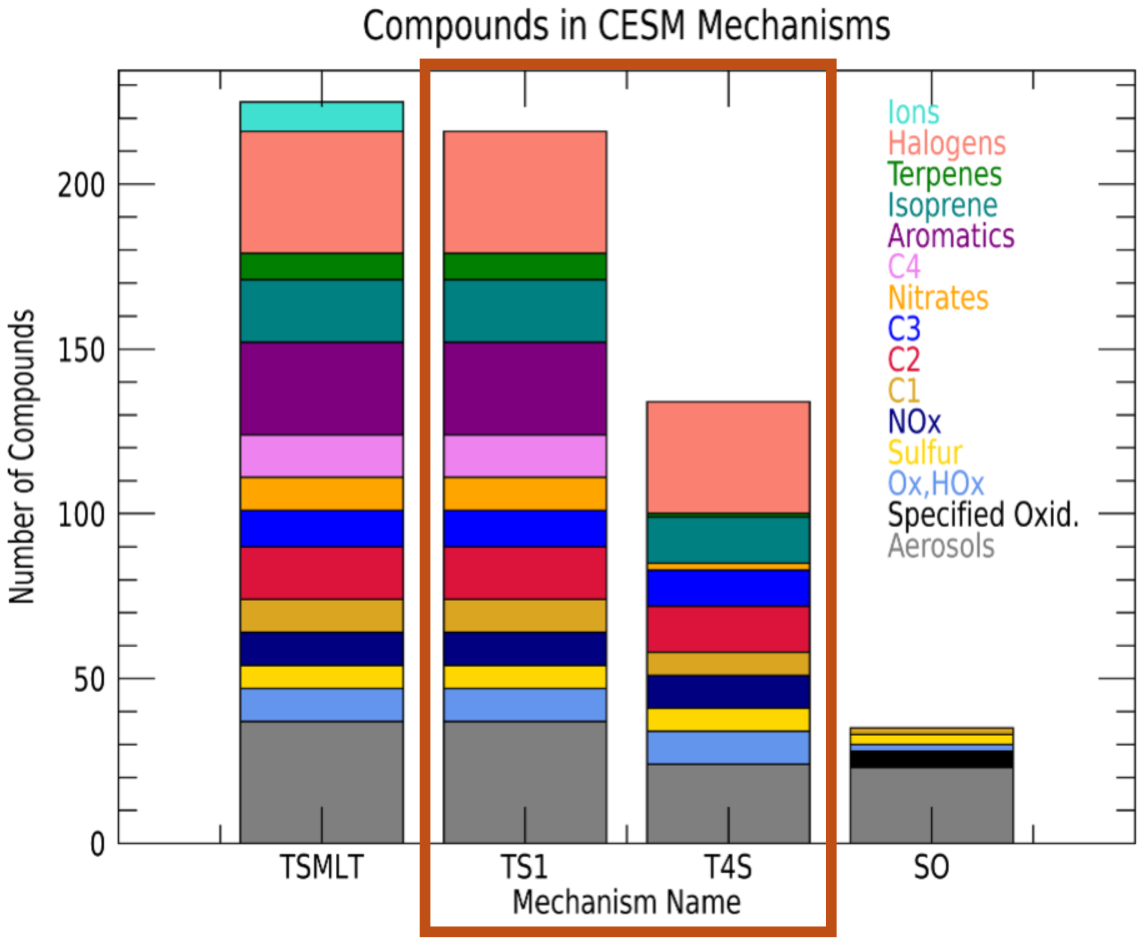
MOZART Chemistry Options in CESM3



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

Air Quality Chemistry

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

MOSAIC/ CARMA

oxidants, ozone, strat. aerosol

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

140 km

WACCM (High Top Model)
132L

80 km

Workhorse Model
93L

40 km

Low Top Model
58L

Fully coupled simulations with chemistry are required for GHG chemistry runs

Configuration for CESM3 Chemistry-Climate Production Experiments

To be Included in standard CESM3 configuration

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

Development priorities: potentially in later production simulations

- New Photolysis scheme (TUV-x) (-> Tier 2 simulations) (Doug Kinnison, Jun Zhang)
- Short-Lived Halogen emissions and chemistry and interactive methane (-> Tier 2 simulations) (Rafa Fernandez, Ben Gaubert, Behrooz, Doug)

- Updated Soil NOx emissions (-> Tier 2 simulations) (Maria Val Martin)
- Marine Organic Aerosol Emissions
- MEGAN3 biogenic emissions
- MAM4 and CARMA aerosol updates (Danny Leung, Ilaria Quaglia, Simone)
- HEMCO emissions (processing emissions online)

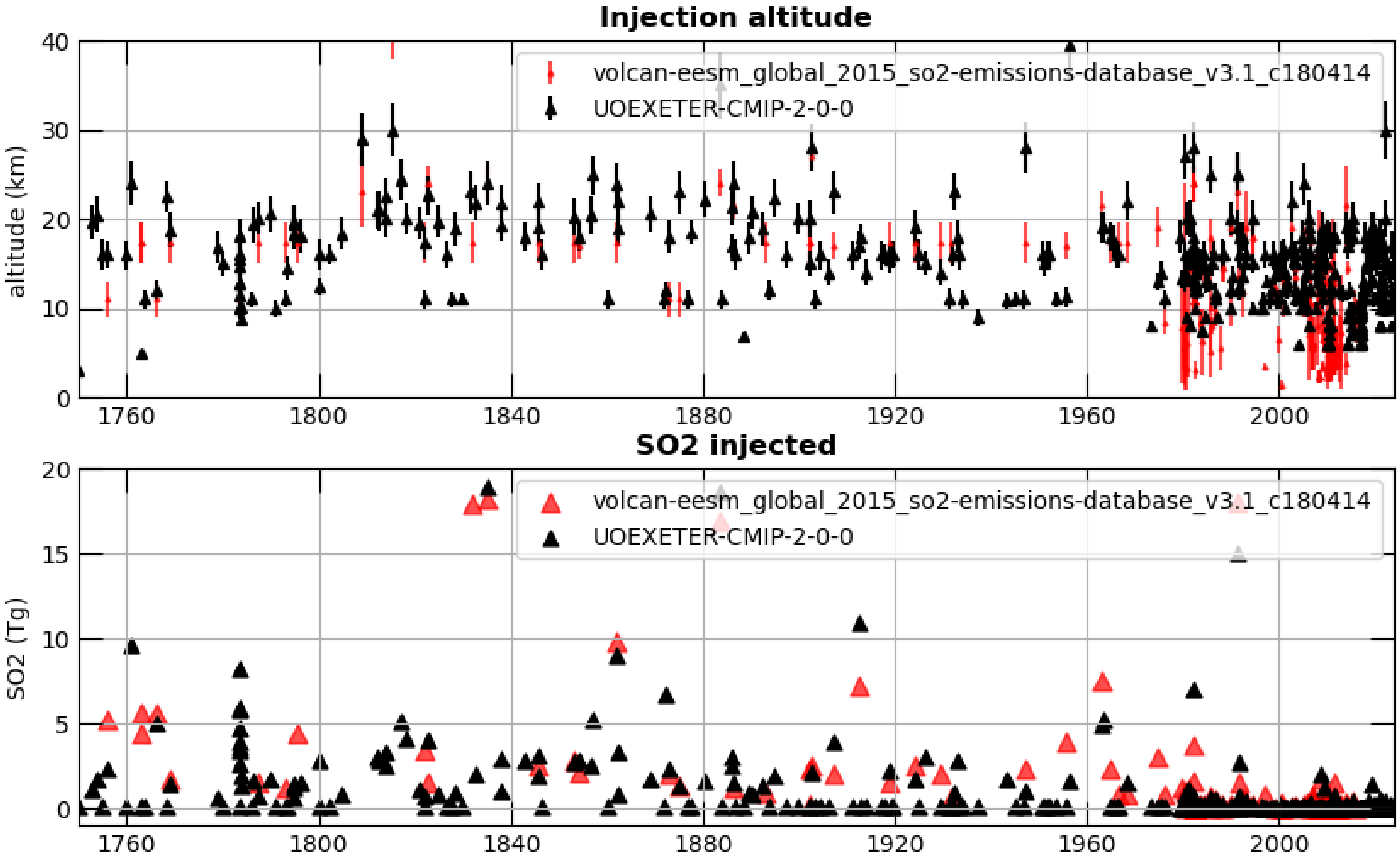
Status and Next Steps for CESM3 development

In Progress:

- Production of T4S MT HIST simulations (fixed SSTs) 1980-2015 (CMIP6 emissions)
  - ➔ identification of issues in the biogenic emissions and bug in the coupler -> fixed
  - ➔ New simulations with updated dynamics to be tested

- Testing of the CESM3 cam6-physics configuration (Shawn's talk)
- *Production and testing of new CMIP7 volcanic forcing files, surface emissions, and other forcings (-> currently using WACCM6 2deg)*

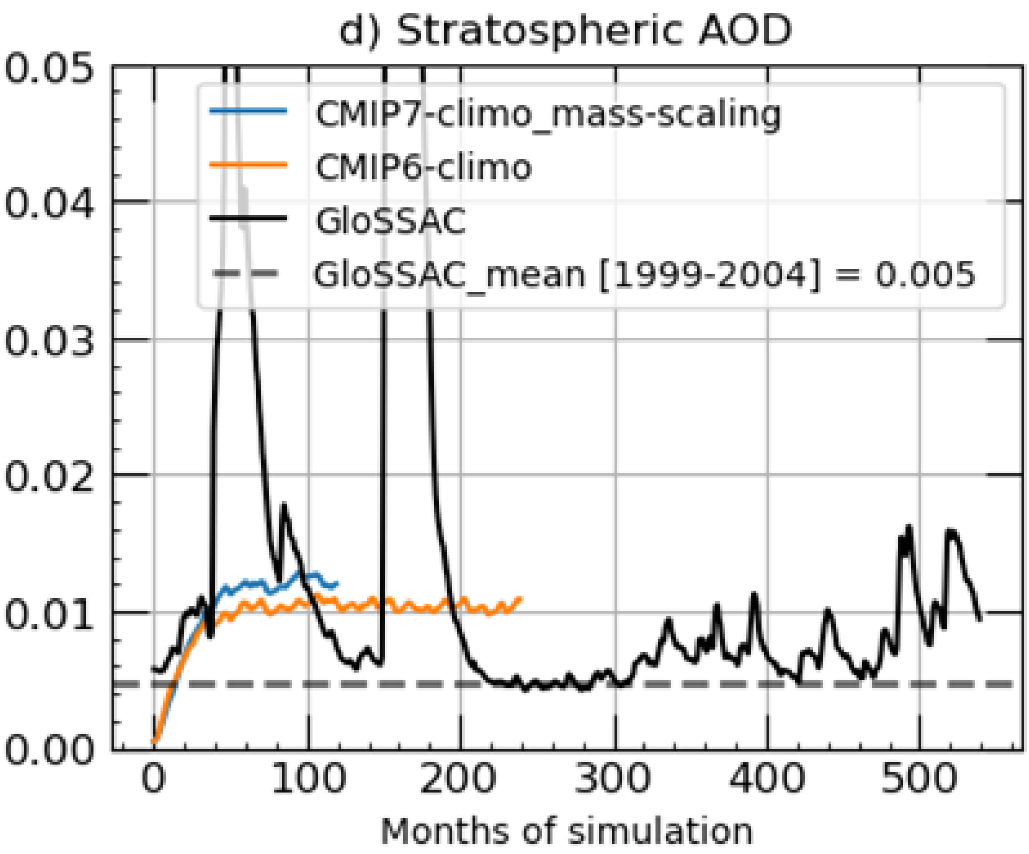
CMIP7 forcings: Volcanic SO_2 emissions Data Set finalized for CESM3



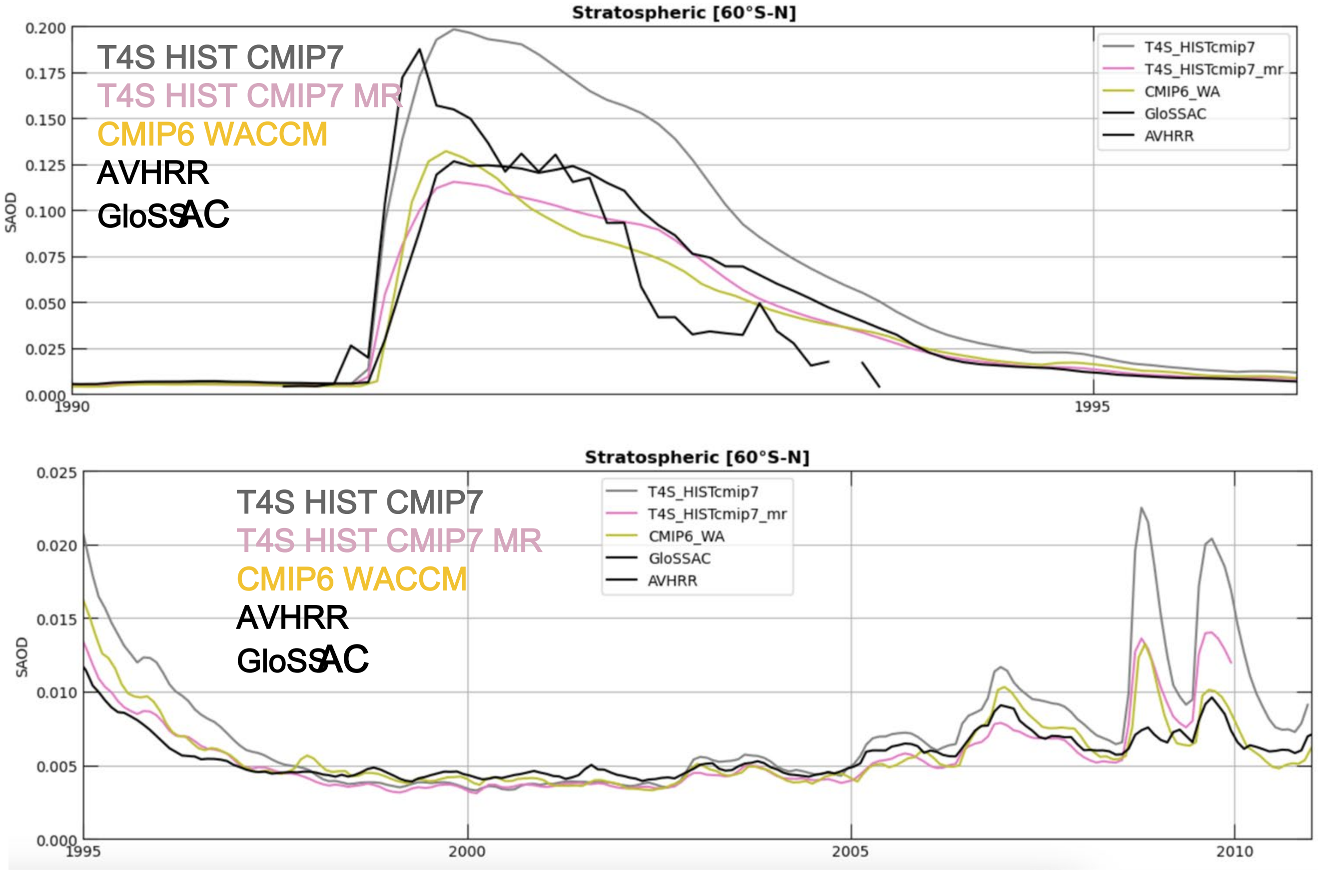
Key differences between the VolcanEESM database and the CMIP6plus dataset include:

- Injection height variability
- Inclusion of missing eruptions
- Satellite era improvements
- New small emissions before 1970

CMIP7 forcings: Volcanic SO_2 emissions Data Set finalized for CESM3



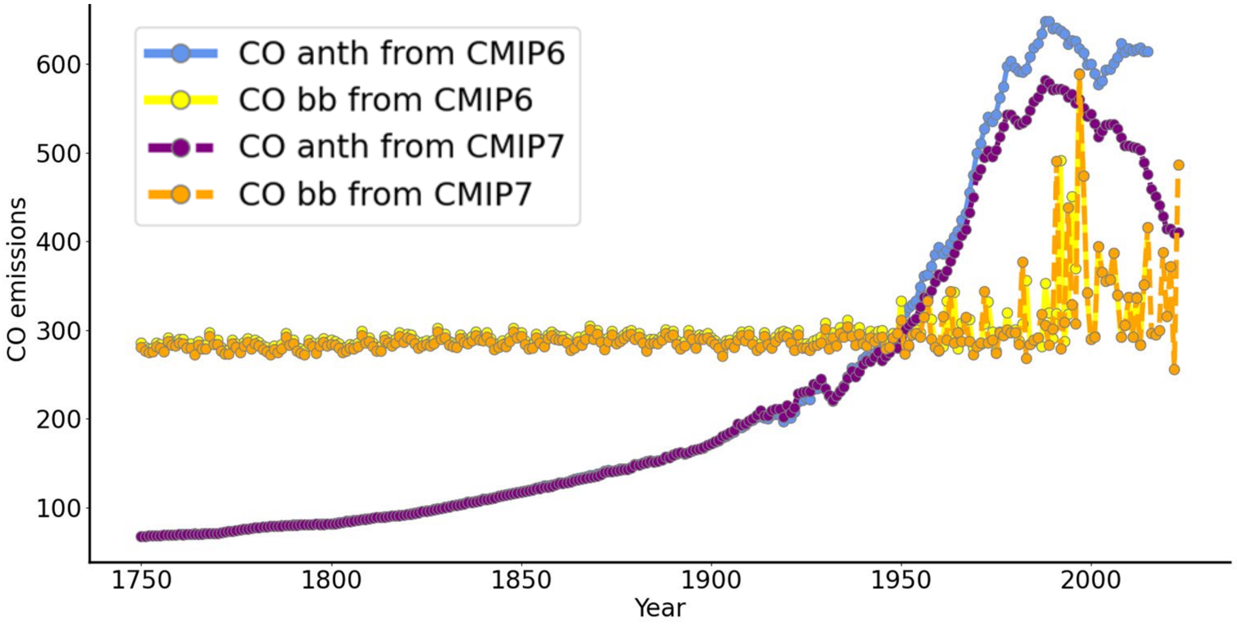
Stratospheric AOD



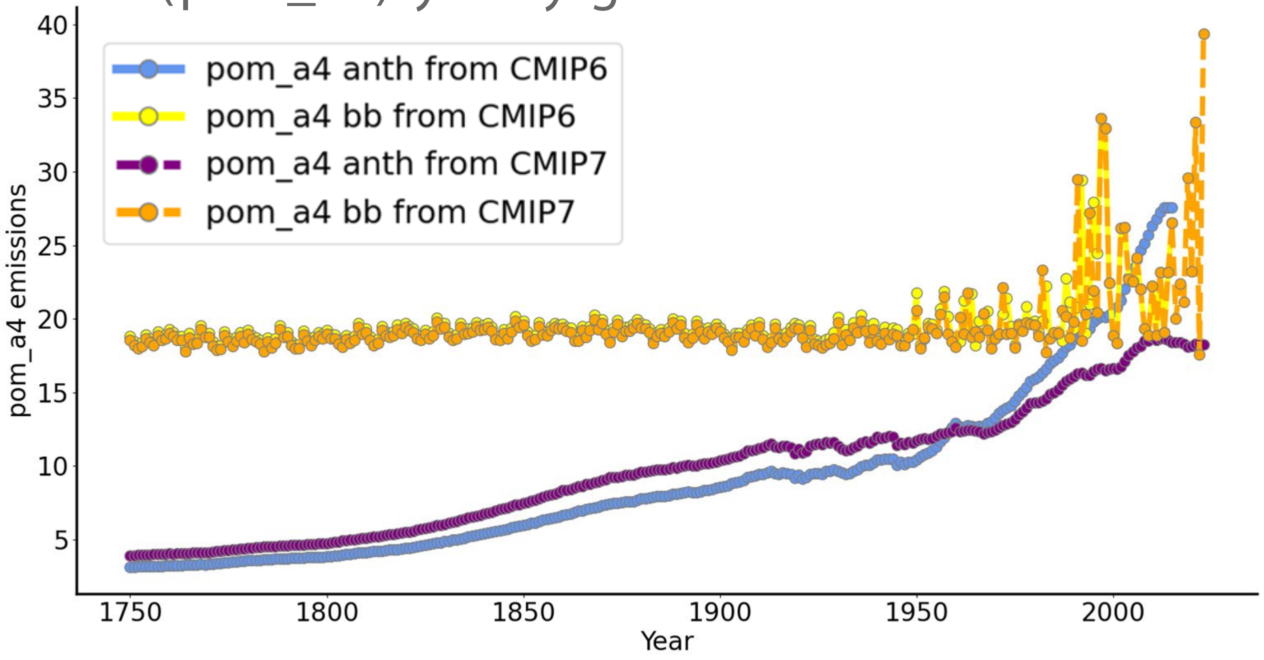
CMIP7 forcings: anthropogenic and biomass burning emissions

https://wcrp-cmip.org/cmip7-task-teams/forcings/

Gas example: Carbon monoxide (CO) yearly global sum emissions



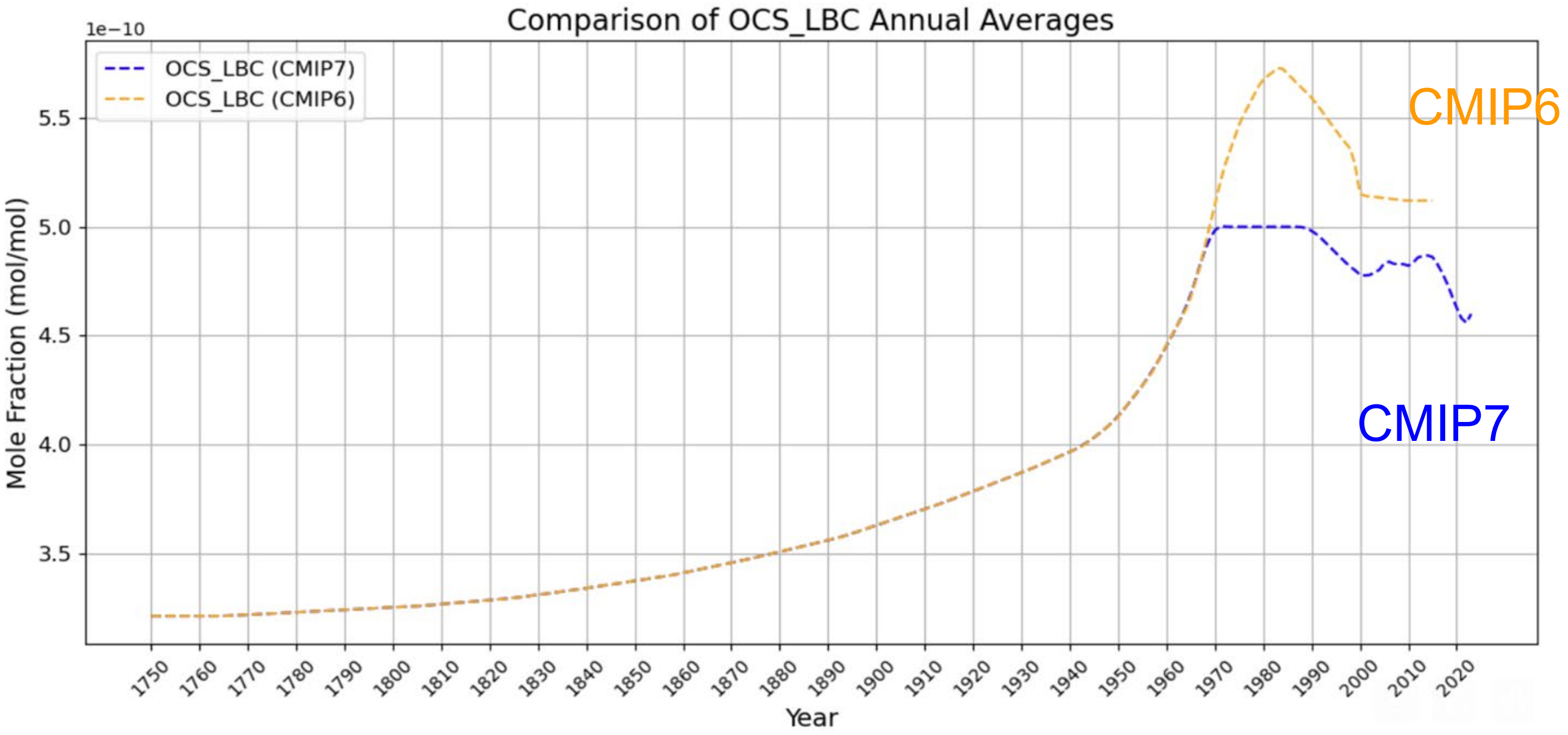
Aerosol example: Primary organic matter (pom_a4) yearly global sum emissions



- CMIP7 anthropogenic emissions are lower than CMIP6, post about year 2000
- Fire emissions are consistent between CMIP6 and CMIP7

CMIP7 forcings: Lower Boundary Conditions (GHG forcings)

There are 43 greenhouse gas concentrations and species included in CMIP7, with the majority remaining consistent with those used in CMIP6. However, a few have undergone significant updates, such as OCS (carbonyl sulfide).



New ADF Chemistry Options in Development

CAM Diagnostics

Case Home | Plots | Links | About | Contact

Test Case:

f.cam6_3_160.FCMT_climate_chemistry_ne30.moving_mtn.001

- years: 1996 - 2000

Baseline Case:

f.cam6_3_160.FCMT_ne30.moving_mtn.002

- years: 1996 - 2000

New Plots:

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

Special Plots

No category yet

TaylorDiag | QBO

O3_DIAGNOSTICS

nhpolarwest_SeasonalCycle | nhpolarwest_Profile | nhpolareast_SeasonalCycle

Log-P

Q_logp	U_logp	T_logp
RELHUM_logp	O3_logp	CH4_logp
CO_logp	N2O_logp	NO_logp
NO2_logp	NOX_logp	SO2_logp
BIGALK_logp	C2H4_logp	C2H5O2_logp
C2H5OH_logp	C2H5OOH_logp	C2H6_logp
C3H6_logp	C3H7O2_logp	C3H7OOH_logp

MELODIES MONET

A modular framework to compare model results and observations of atmospheric chemistry

MELODIES: Model EvaLuation using Observations, DIagnostics and Experiments Software
MONET: Model and ObservatioN Evaluation Toolkit

EarthCube

https://github.com/NCAR/MELODIES-MONET

Version 1 almost released

Matches model results to time and location of observations

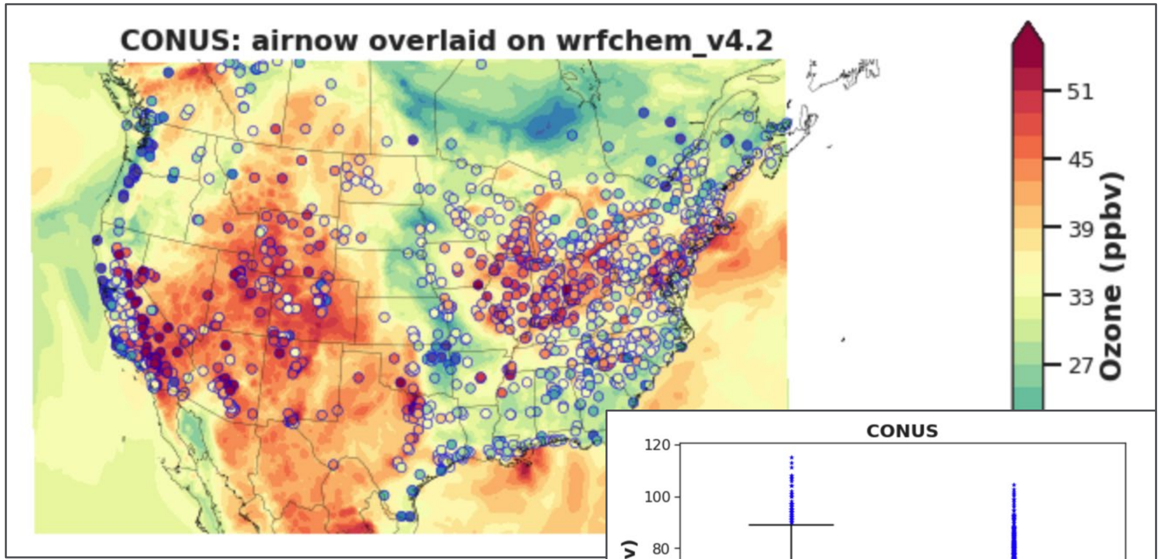
ADF provides climatological evaluation

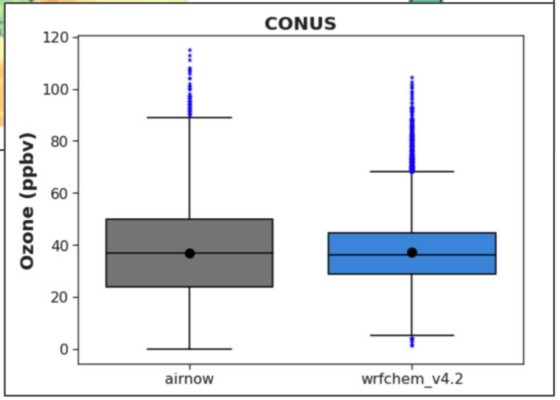
Current observations:

- EPA AirNow
- Aeronet
- Aircraft (ICARTT files)
- Satellites: MODIS AOD, MOPITT CO, TROPOMI NO2, OMPS

In progress:

- Pandora
- GEMS





https://www2.acom.ucar.edu/events/melodies-tutorial-2024

CCWG Participation in MIPs (current and future)

Recent and ongoing work (CESM2 simulations):

- CCMI-2 Simulations using WACCM6 (Doug Kinnison and Simone Tilmes)
- Hunga Tonga Assessment (APARC): using WACCM6 with MAM4 and CARMA (workshop ongoing right now at the ML)
- GeoMIP comparisons (Walker's talk in the WACCM session)
- ISAMIP (Interactive Stratospheric Aerosol Model Intercomparison)
- HTAP Simulations using CESM2.2 CAM-Chem (Louisa Emmons and Rebecca Buchholz)
- VSL-MIP using WACCM6 (Rafa Fernandez, Doug Kinnison and others)

Future plans (CMIP7-ready version):

- CMIP7 DECK (if decided on) (MT model with TS4 chemistry)
- GeoMIP Fast track (MT model with TS4 chemistry)
- AerChemMIP (potentially using updated chemistry with VSL halogens and interactive methane emissions (TS1)
- …

Task Force on Hemispheric Transport of Air Pollution (HTAP)

UNECE
Convention on Long-range Transboundary Air Pollution

HTAP organized under UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP)

- Mandate to **quantify the long -range (hemispheric to global) influence of remote sources of air pollution** (including methane) in the UNECE region
- Current legislation is not sufficient to meet the long-term clean air objectives of CLRTAP

New round of multi-model experiments (HTAP3-**OPNS** Ozone, PM, Nitrogen and Sulphur Deposition) to address:

- Relative contributions of intra-regional and extra-**regional sources** to air pollution
- Contributions under **future** emission scenarios and under future climate change
- Impacts of ground-level **ozone**, especially damage to vegetation; effects of **methane** on ground-level ozone; effects of **wildfires** on long-range air pollution; total atmospheric **deposition**
- **Free-running future simulations** with chemistry-climate models

Will start running as soon as emissions are finalized

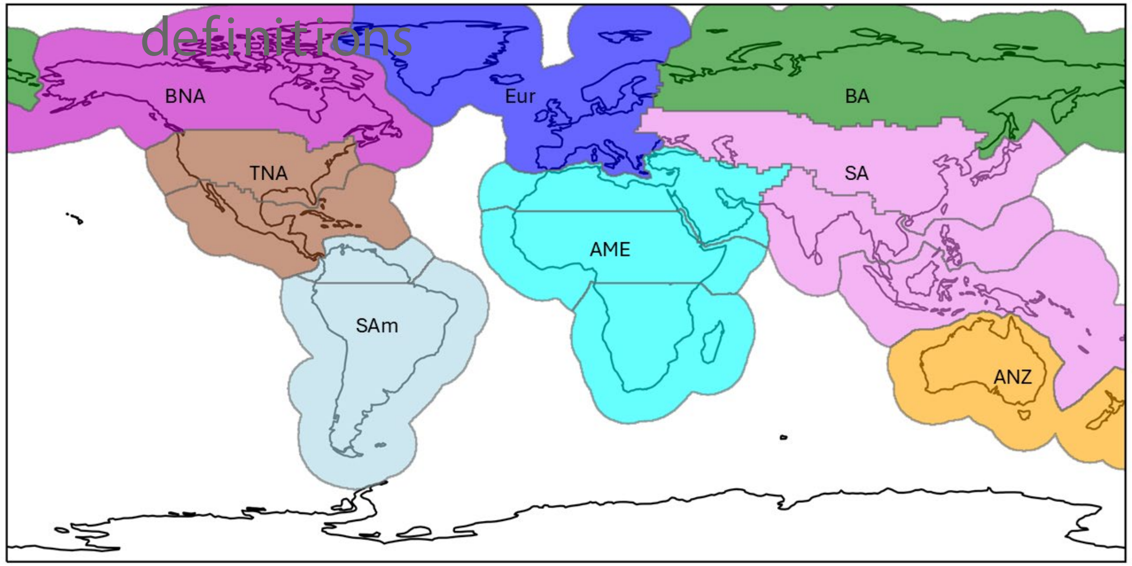
Please contact Louisa Emmons (emmons@ucar.edu)
if you want to contribute to CAM-chem simulations for this

Task Force on Hemispheric Transport of Air Pollution (HTAP)

UNECE
Convention on Long-range Transboundary Air Pollution

Multi-model experiments (HTAP3-**Fires**) will address:

Regional perturbation definitions



Base simulations 2003-2020 (priority):
- Historical Baseline
- Zero Fires

Sensitivity Simulations
(optional, prioritized, 2015-2019 if need shorter time):
- Agriculture versus wildfire
- Regional perturbations
- Future Fires (D. Hamilton provided dataset)

Other Simulations (optional, lower priority): Connect with AMAP SLCF, Case studies of events (e.g. Australia 2019/2020), Inventory intercomparison, Interactive fires, Data assimilation

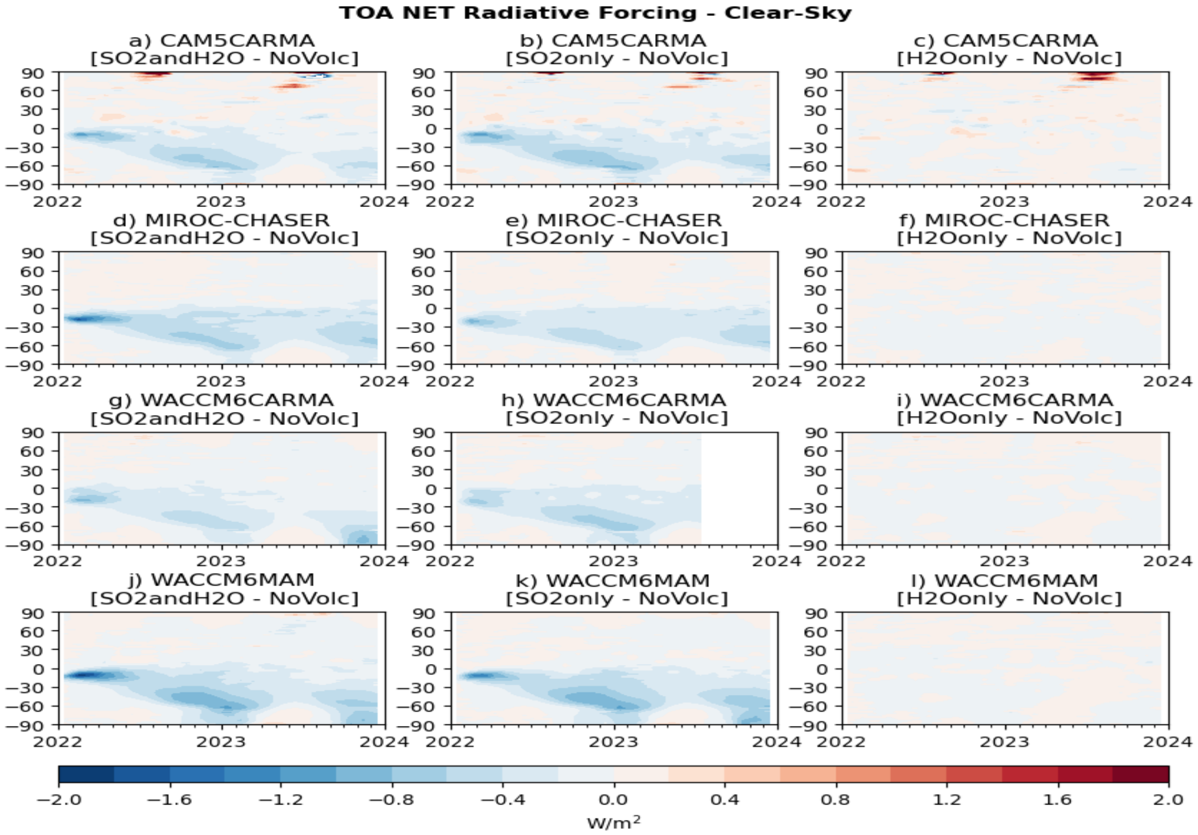
Will start running as soon as emissions are finalized. Fire emissions will be: GFAS4HTAPv1.2.1 (beta available)

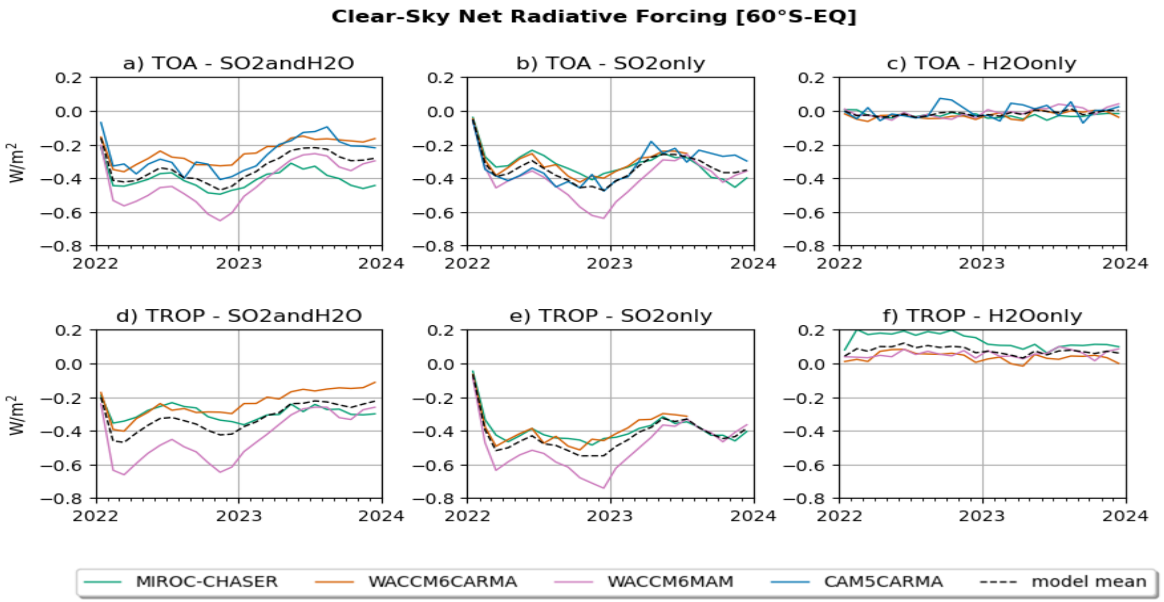
Please contact Rebecca Buchholz (buchholz@ucar.edu)
if you want to contribute to CAM-chem simulations for this

Other CAMchem Development

Evaluating the impacts of the Hunga eruption on radiative forcing: Insights from Multi -Model Analysis

Results from the Exp2a of **Zhu et al. (2024): Hunga Tonga-Hunga Ha'apai Volcano Impact Model Observation Comparison (HTHH-MOC) Project: Experiment Protocol and Model Descriptions**





Hunga Tonga eruption had a significant impact on Radiative Forcing in the Southern Hemisphere in 2023,2024

- RF SO2 and H2O ≃ -0.3 ± 0.1
- RF H2O only = +0.08 ± 0.04 at TROP (negligible at other levels)

Ilaria Quaglia

Quaglia et al., paper draft to be submitted (estimated end of July 2025)

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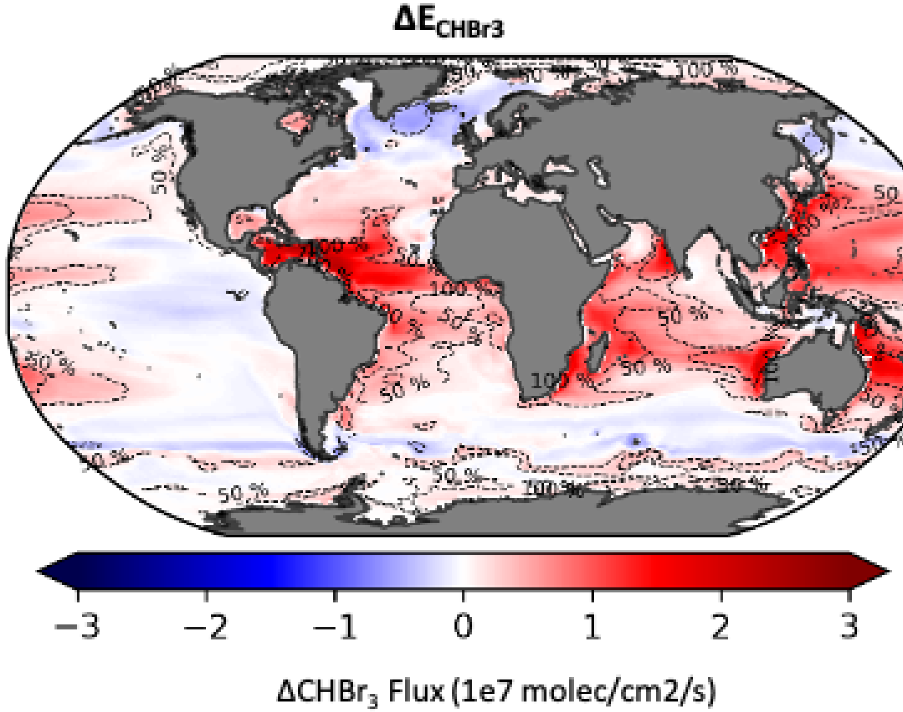
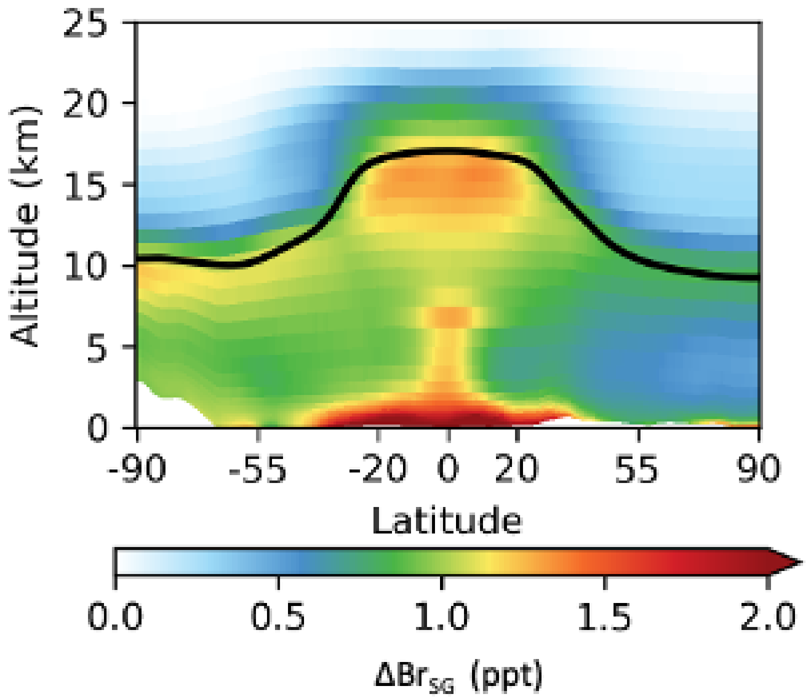
CESM2 OASISS module for short lived halogens (SLH chemistry

Impact of climate change scenarios on future oceanic emissions

- Emissions of oceanic bromocarbons (for example, $CHBr_3$ below) could increase by up to 40% by the end of the century, due to climate change.



- Changes in emissions results in 20-50% increase in the UTLS bromine (from source gases). This is significant for the ozone layer implications.



- **New 1-deg oceanic concentration and emissions files of $CHBr_3$ and CH_2Br_2 are ready to use in CESM simulations** (Roozitalab, et al., 2025 – will be submitted to JGR-Atmospheres soon!)

Behrooz Roozitalab

*SLH chemistry developed by Rafa Fernandez and Alfonso Saiz Lopez team (Talk on Tuesday in CCWG) Contact: behroozr@ucar.edu

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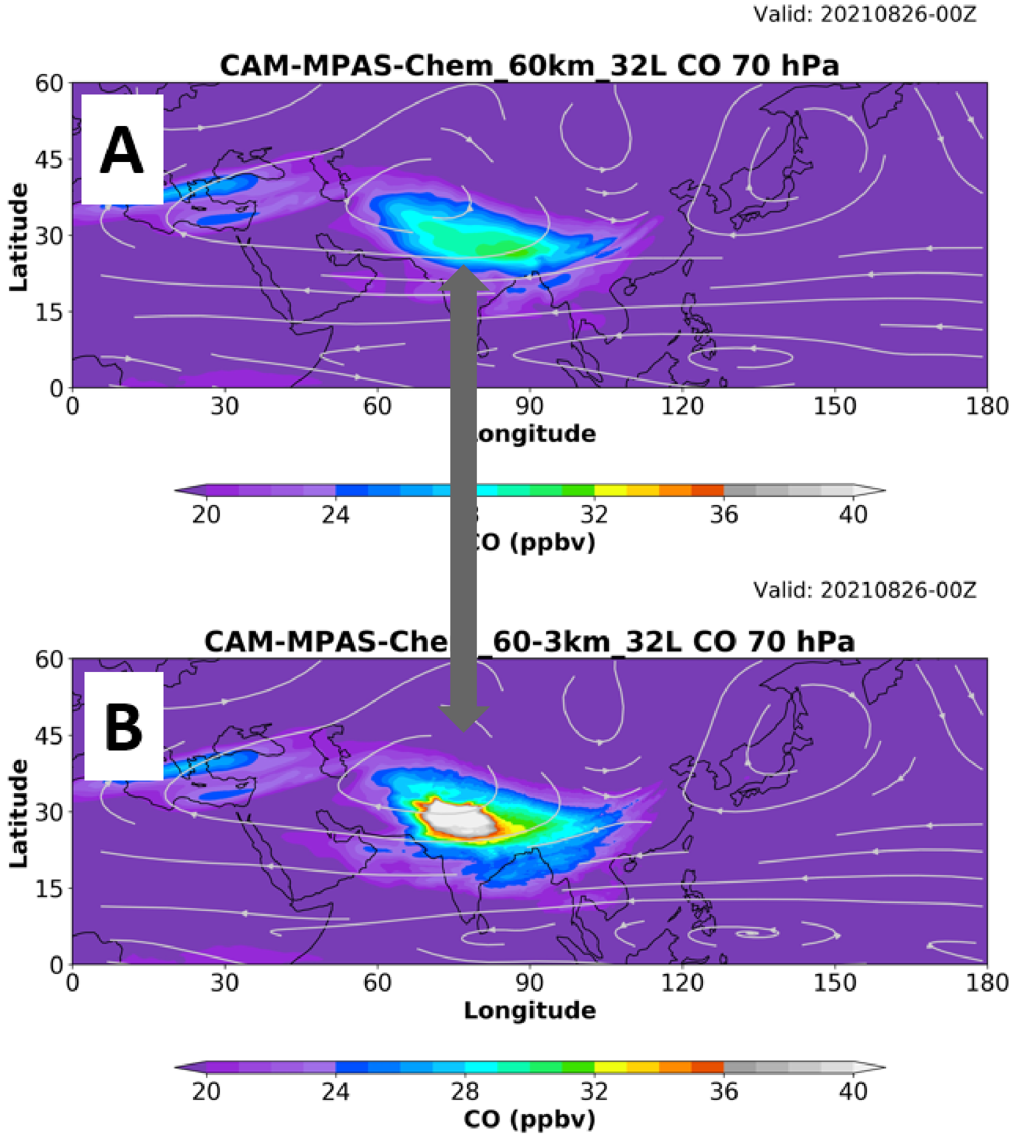
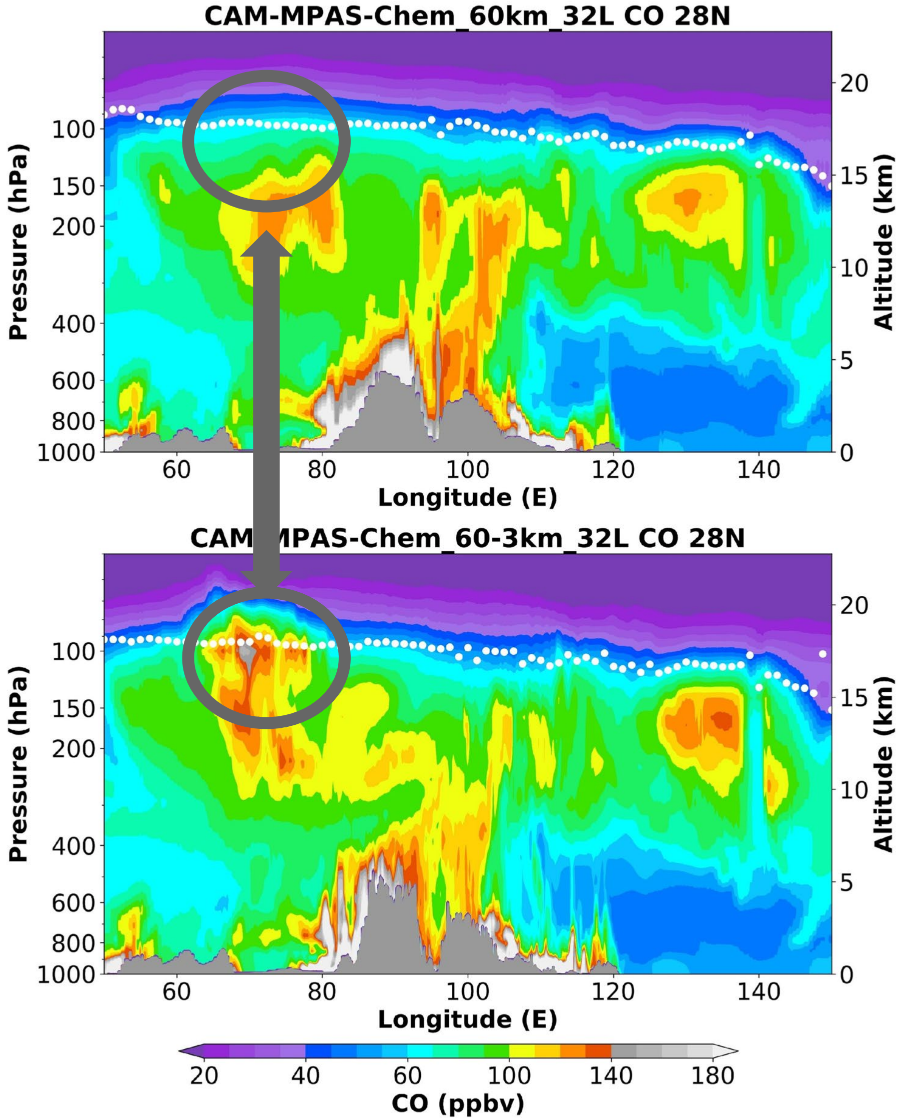
Regional grid refinement increases transport to the UT/LS

60km uniform

60-3km refined





Ren Smith

Mary Barth