Evaluation of Chemistry & Aerosols in WACCM & CAM-chem

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CESM2 Chemistry Scheme

- T1 tropospheric chemistry in TS1 (CAM-chem) and TSMLT1 (WACCM)
- MAM4 aerosols
- SOA-VBS framework
- Prognostic volcanoes
- Atmospheric nitrogen deposited to land model (NDEP, NHDEP)
- CAM-chem and WACCM compsets (1850, HIST, SD, …)

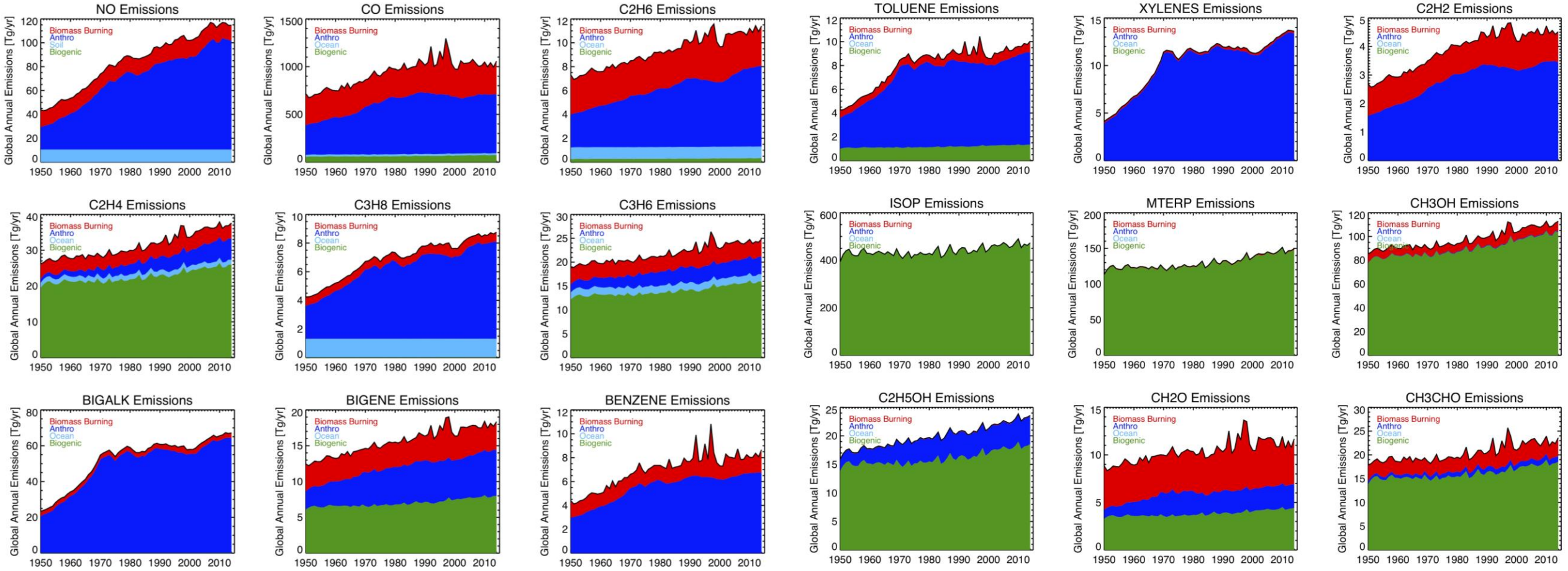
Publications

- CESM2 chemistry (MOZART-T1, TSMLT1) (Emmons et al., in prep. for JAMES)
- VBS-SOA (Tilmes et al., in prep. for JAMES)

CESM2 simulations shown here

- CAM-chem with Specified Dynamics (SD):
  - Nudged to MERRA2 meteorology (2001-2016)
  - Emissions from CMIP6-anthro, QFED biomass burning
- CAM-chem-AMIP (CESM2.0) (F-case, Observed SSTs)
- WACCM-SD (Nudged to MERRA2 meteorology, 1970-2015)
- WACCM-AMIP (F-case, Observed SSTs)
- WACCM-HIST (B-case: fully coupled)
  - 0.9x1.25 resolution
  - CMIP6 Emissions for anthro and biomass burning

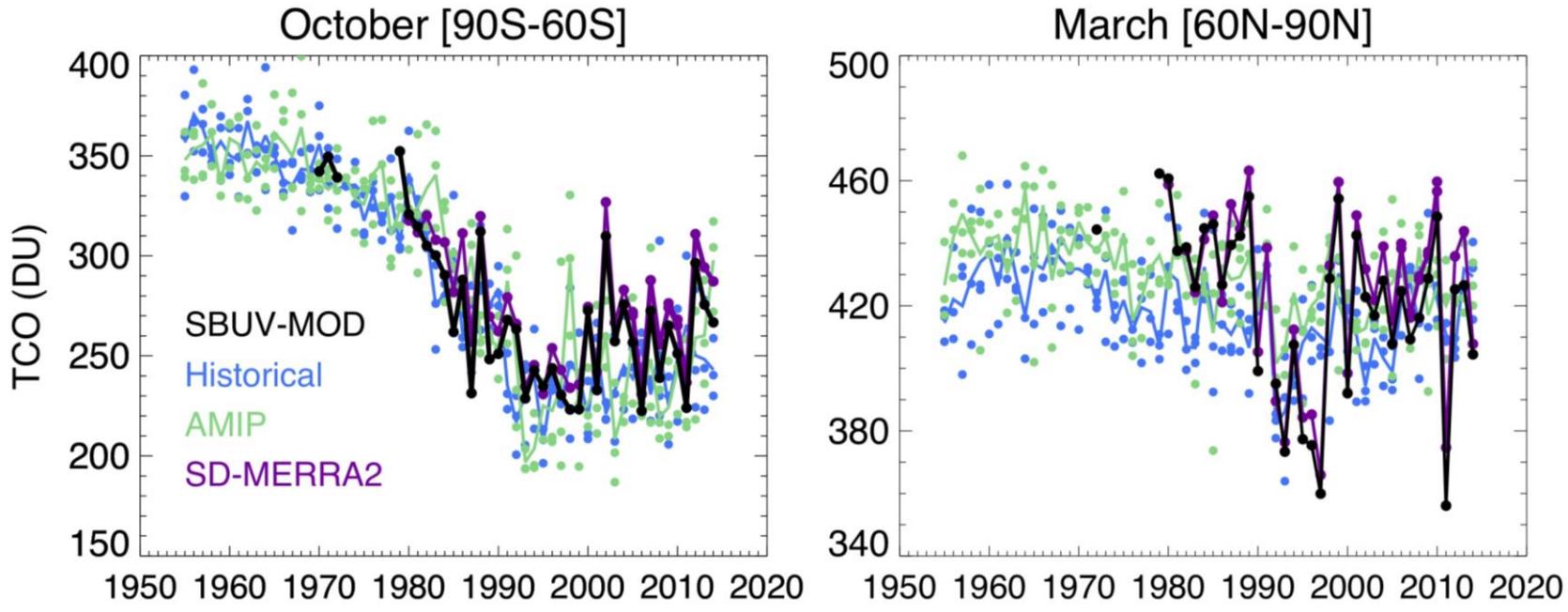
CMIP6 Emissions

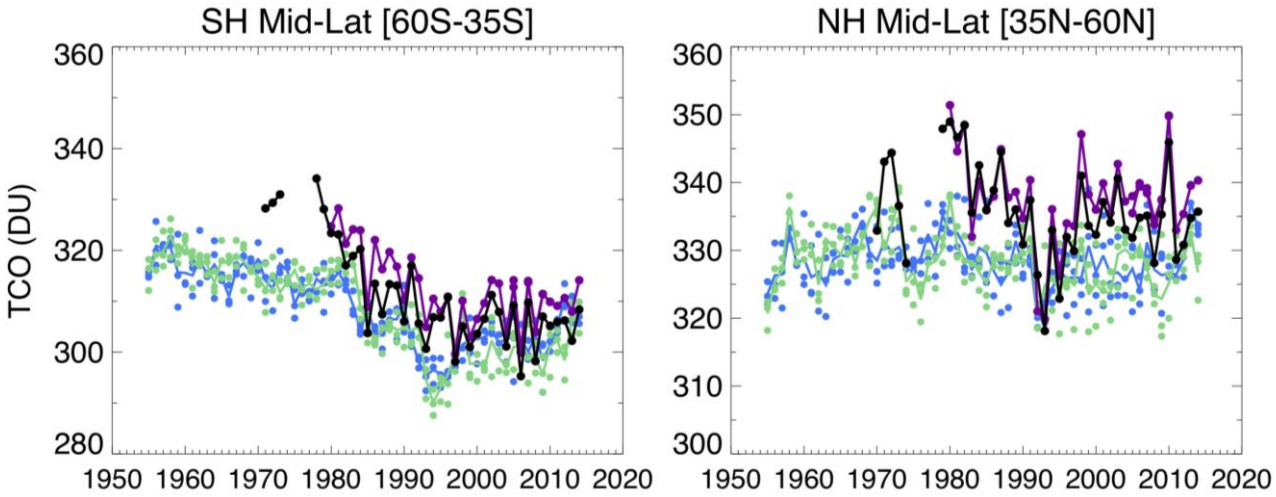


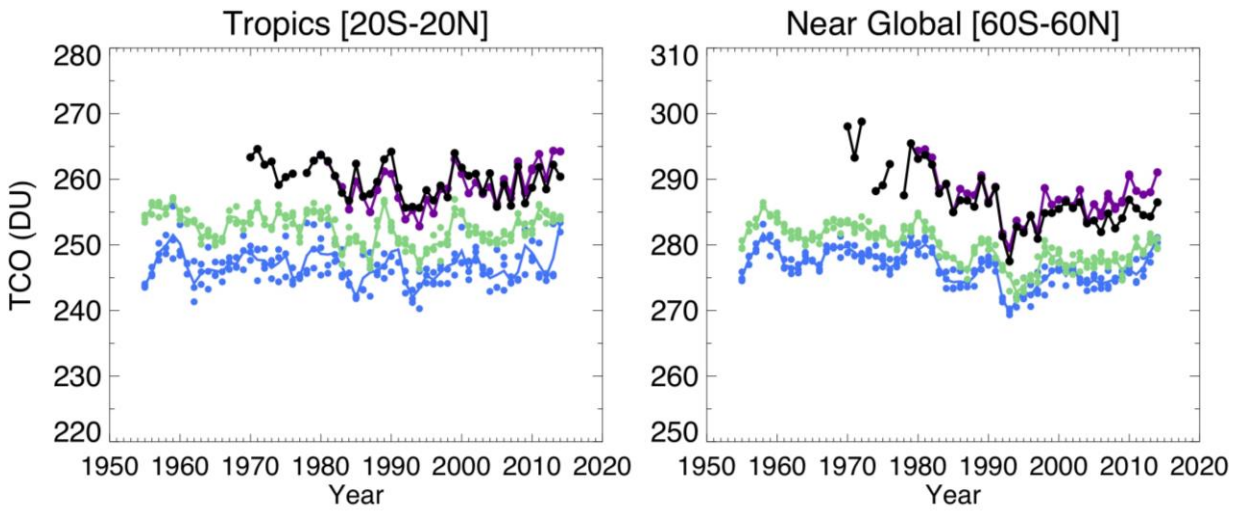
Biomass Burning
Anthro
Ocean
Biogenic

Anthro and Biomass burning – specified by CMIP6
Ocean CO&HCs, Soil NO – POET inventory (same as CCMI)
Biogenic – calculated online with MEGANv2.1 in CLM

Total Column Ozone
WACCM



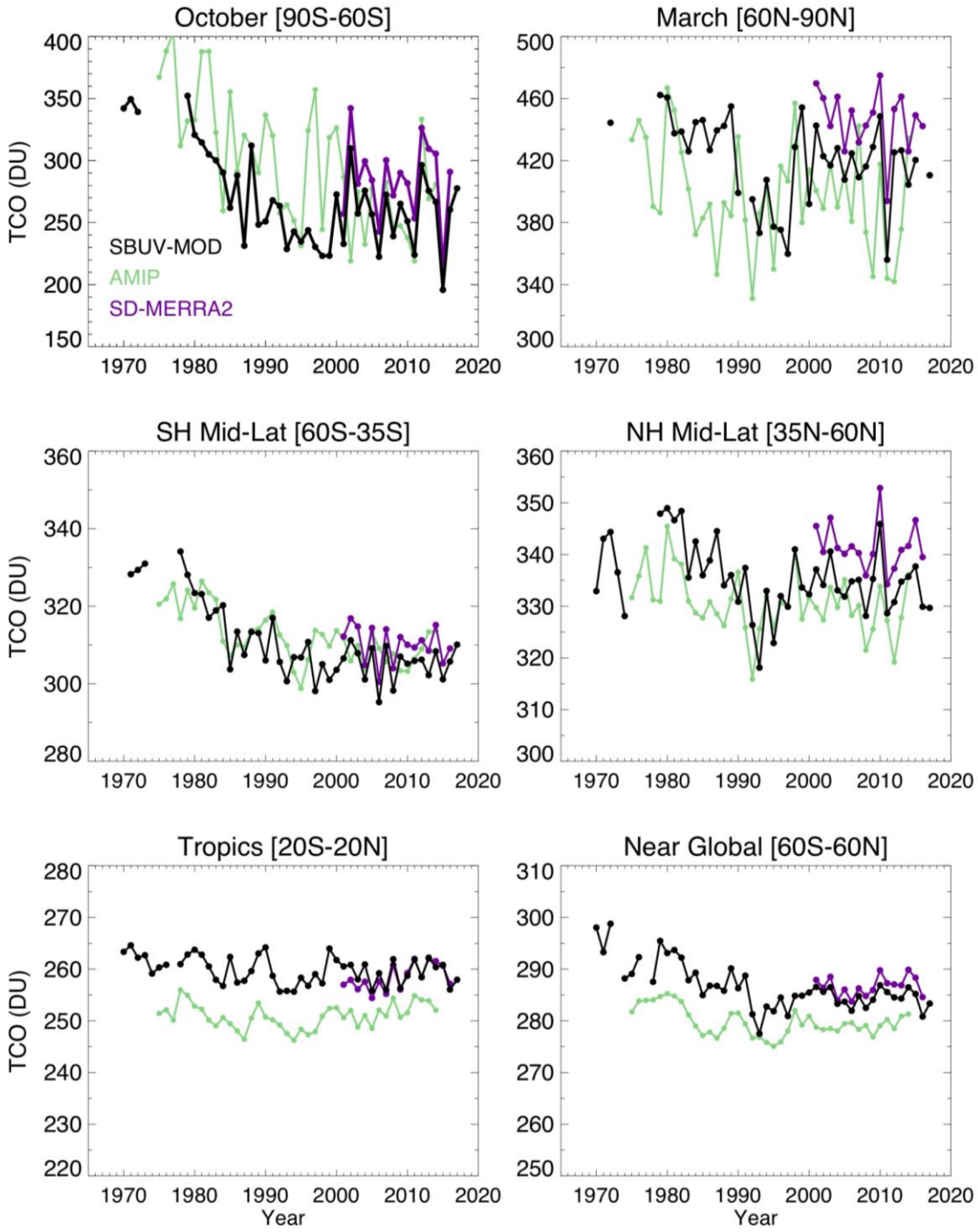




Total Column Ozone CAM-chem

AMIP: F-case CAM-chem (CESM2.0)

SD-MERRA2: CAM-chem-SD (CESM2.1)

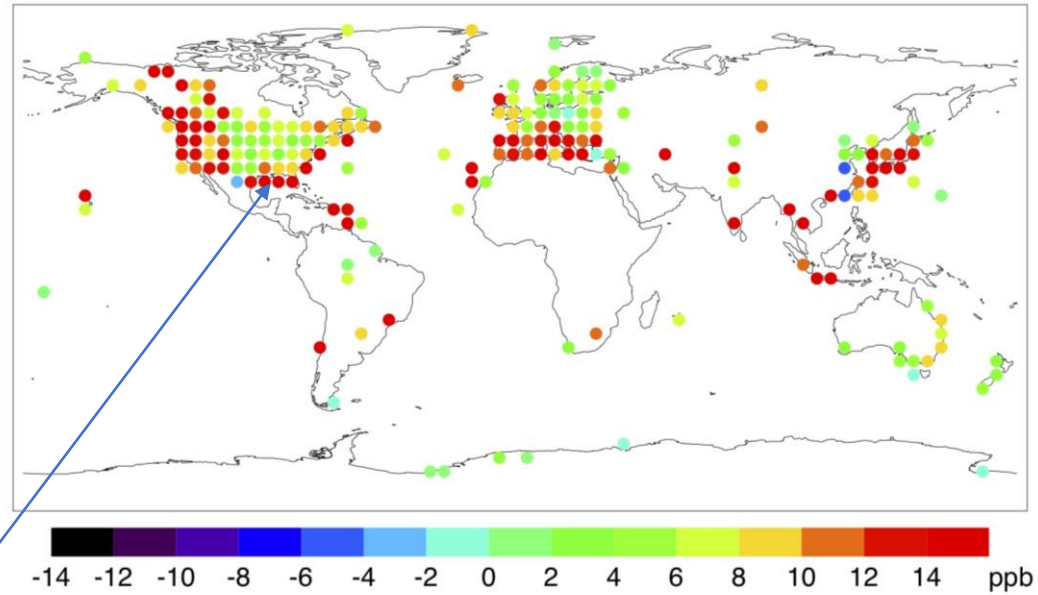


CESM2 CAM-chem – Evaluation of tropospheric chemistry: O_3

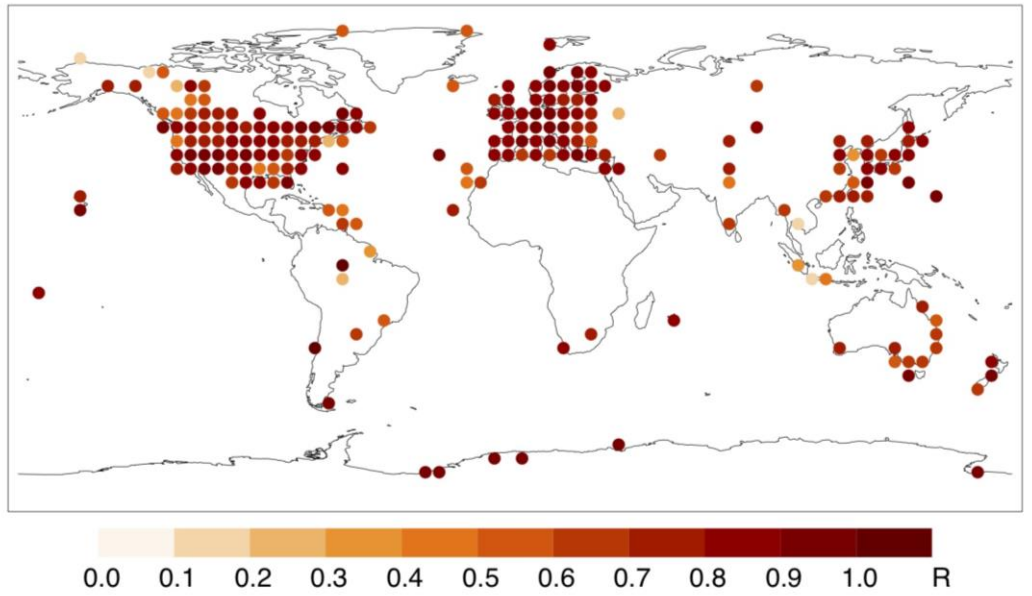
Surface ozone is evaluated with the Tropospheric Ozone Assessment Report (TOAR) Surface Ozone database [Schultz et al., Elementa, 2017]

- CAM-chem surface ozone matches observations well in many regions, but is high in more polluted regions
- High correlation coefficient in most locations

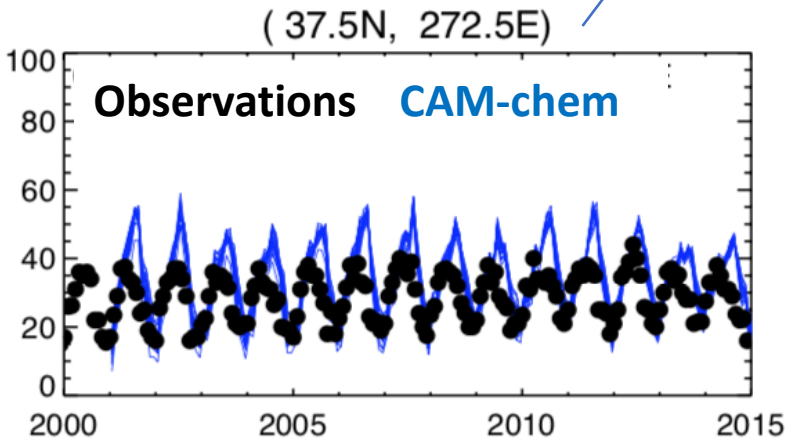
Median Bias (CAM-chem - TOAR) O3 [ppb]
2001-2014



Correlation coefficient (CAM-chem vs TOAR)

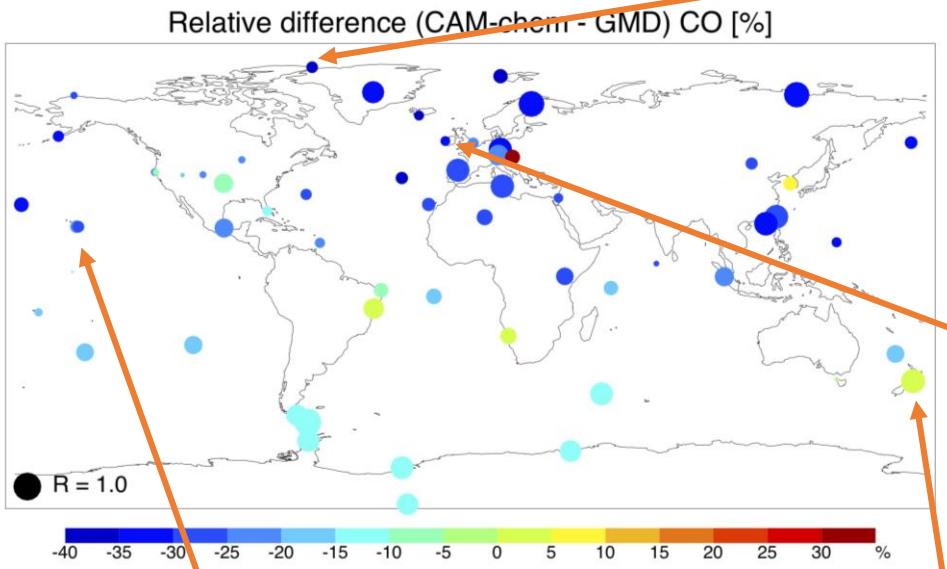


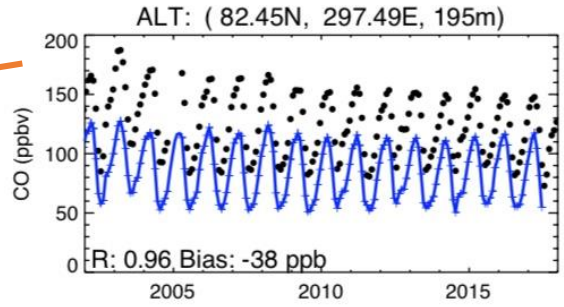
Time series for Alabama shows model ozone is high in summer, but matches in winter

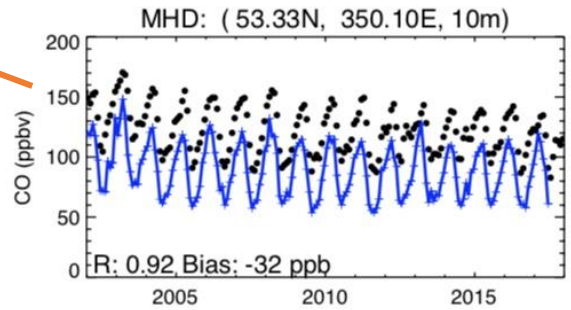


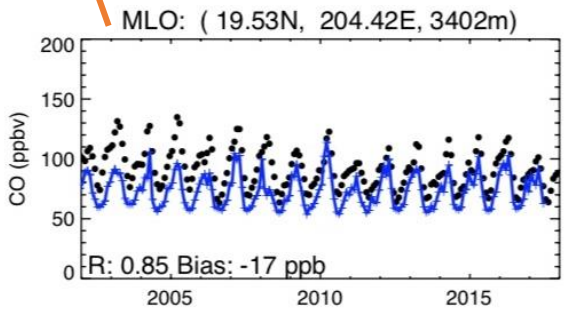
Evaluation of Surface CO

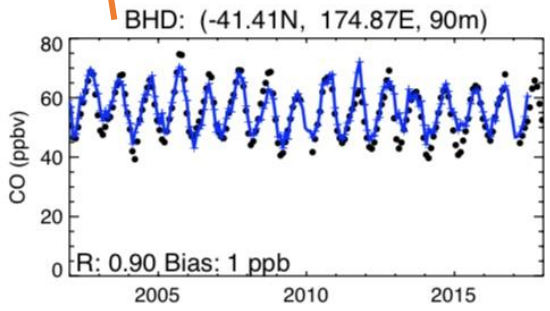
CAM-chem-SD monthly mean CO compared to **NOAA/GMD CO** from flask samples

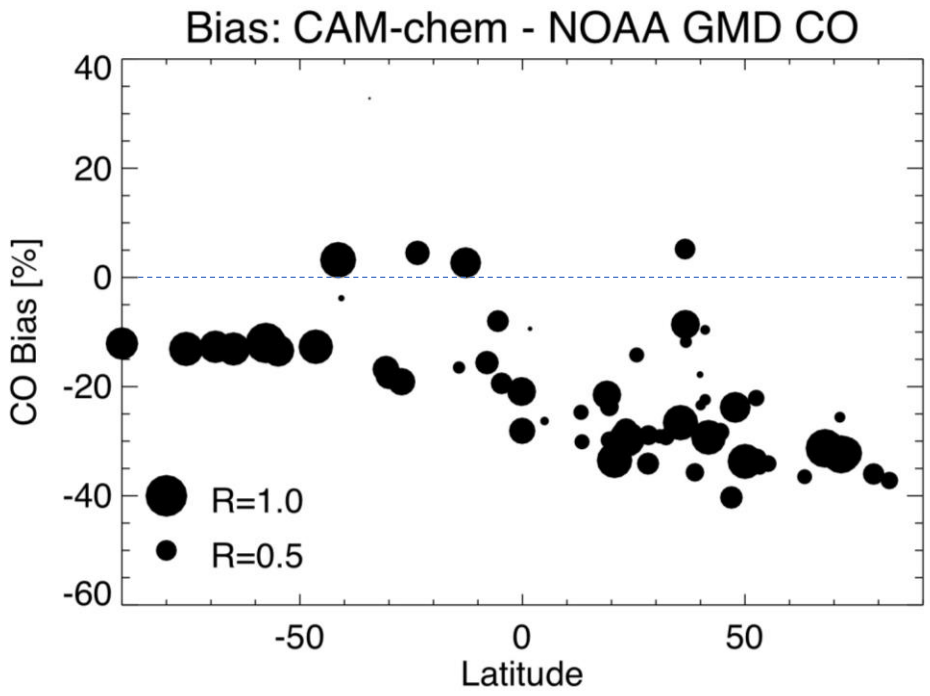












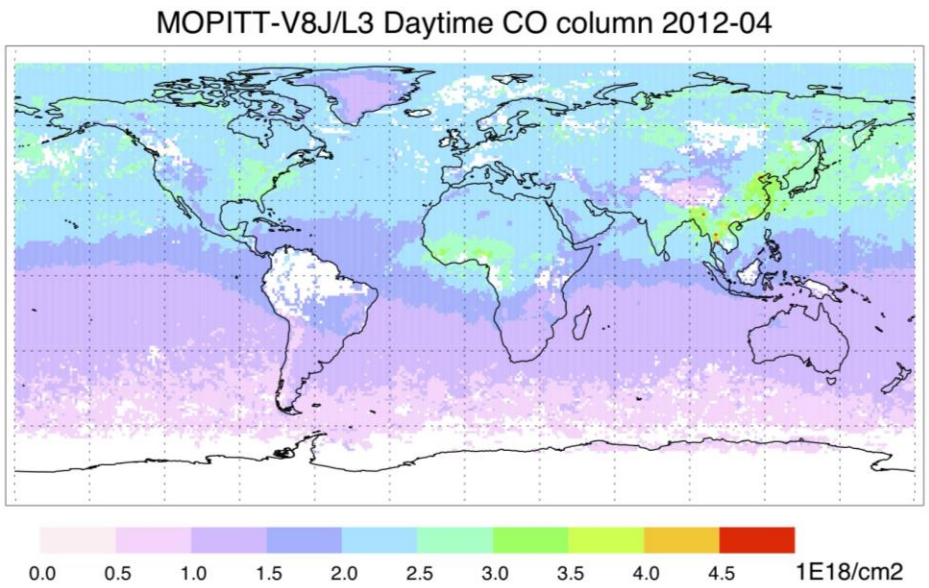
Generally good seasonal correlation

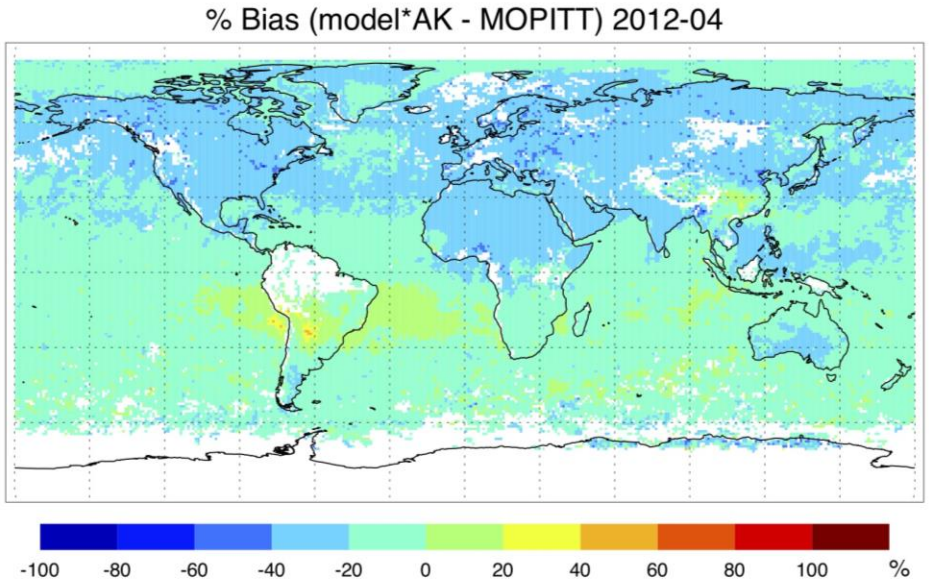
NH low bias ~40ppb (30%)

15% low bias at high southern latitudes

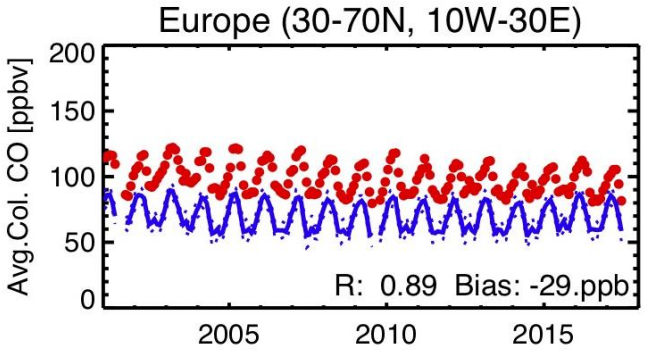
→ Emissions too low

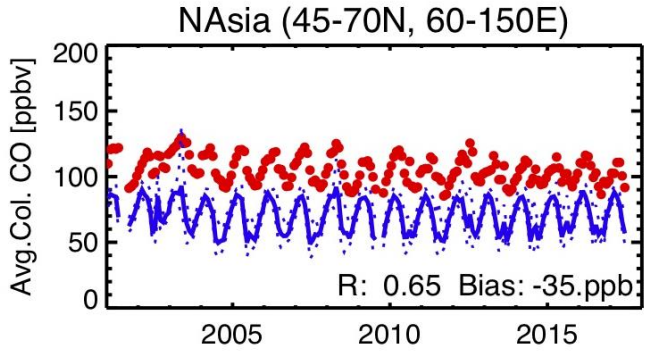
Evaluation of Tropospheric CO

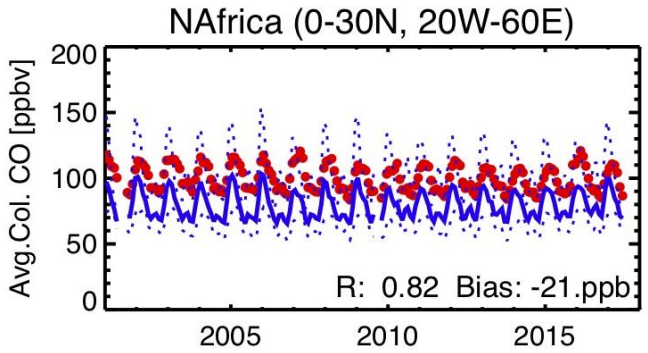


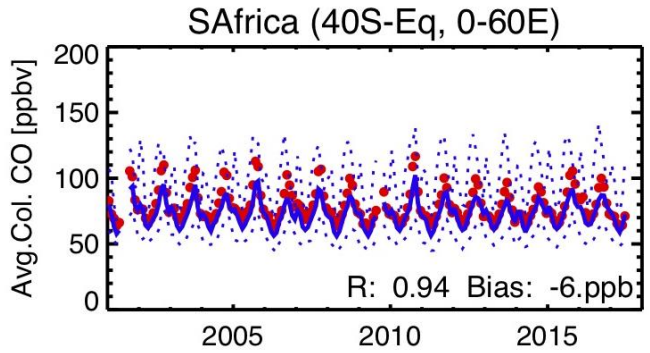


MOPITT CO column retrievals (V8 Joint TIR/NIR), converted to average mixing ratio, compared to **CAM-chem-SD** tropospheric column (surface to 50 hPa) – monthly means



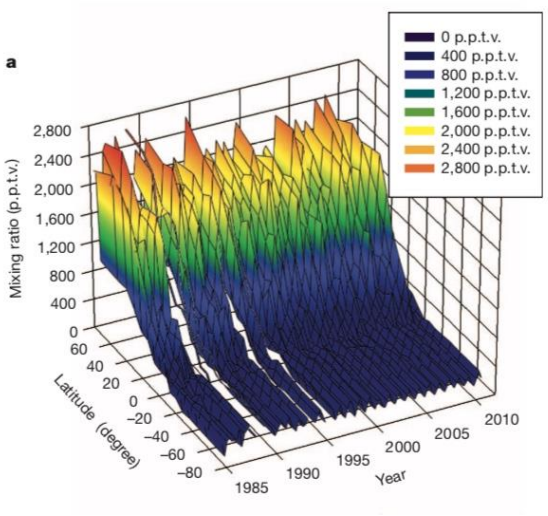






Model is low (~30 ppb) in NH
SH, dominated by fires, agrees well

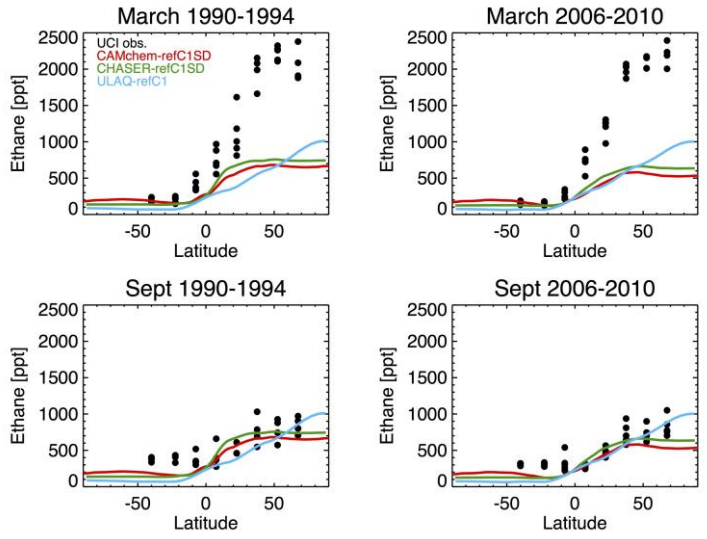
Evaluation of Surface Ethane (C_2H_6)



Ethane emitted in oil & gas extraction and other industry

Lifetime of a couple months

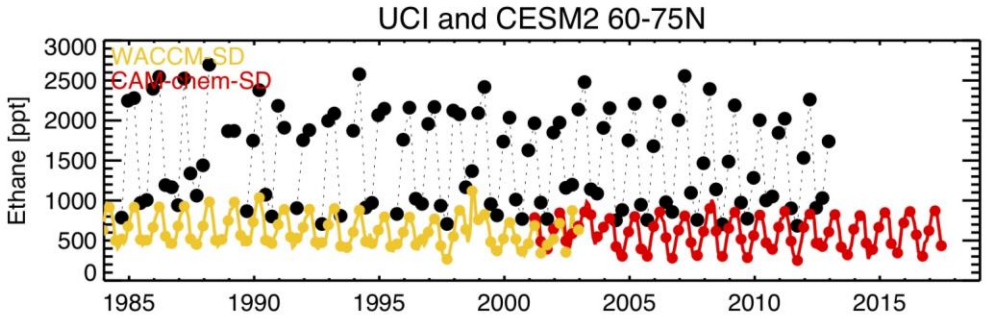
Ethane measured from New Zealand to Alaska since 1984 to present (Simpson, Nature, 2012).

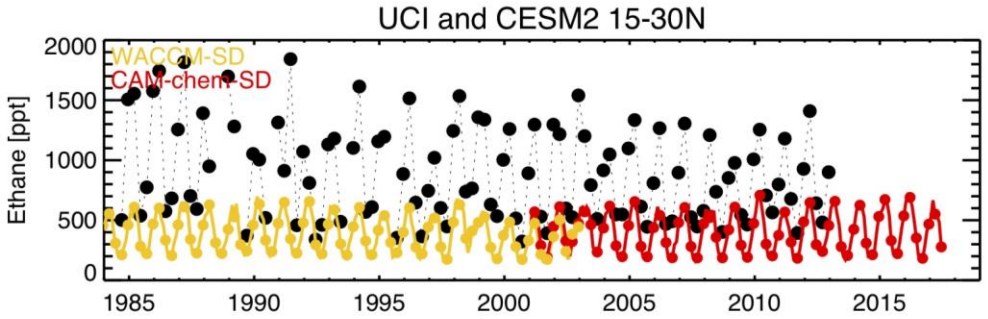


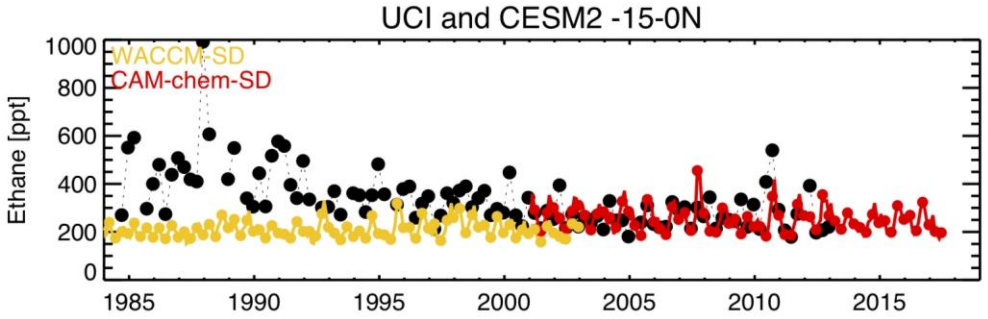
CCMI models greatly underestimated C2H6 in NH

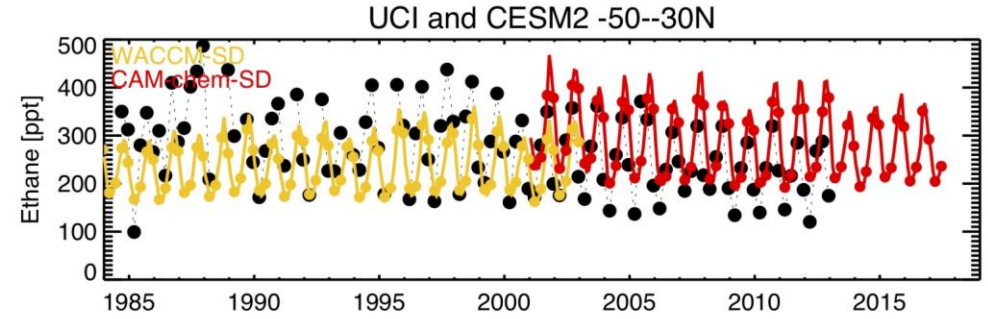
→ too low emissions

CESM2 with CMIP6 emissions still greatly underestimates ethane in NH









UC-Irvine Global Survey data available at:
http://cdiac.ornl.gov/trends/otheratg/blake/blake.html

Comparisons to CCMI evaluations

For CCMI, CAM4-chem (CESM1.1) run with CCMI emissions:

- REFC1 – specified SSTs
- REFC2 – fully coupled
- REFC1SD – specified dynamics

Evaluated with observations from:

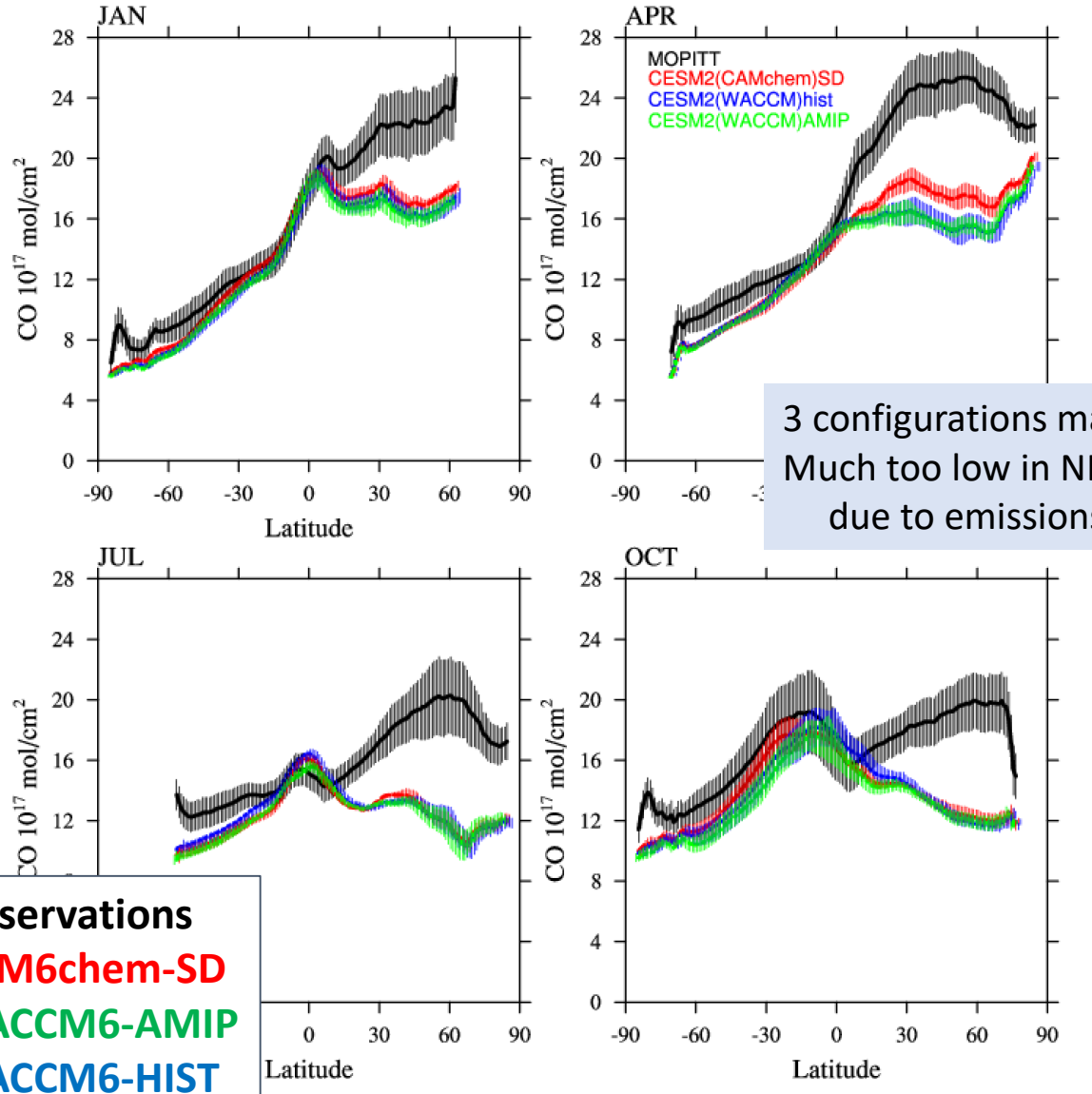
- MOPITT CO climatology
- MLS/OMI ozone climatology for tropospheric and stratospheric columns
- Ozonesonde climatology

CCMI results from *Tilmes et al. [GMD, 2016]*

CESM2 results to be in *Emmons et al. [in prep.]*

CESM2 Evaluation of CO Column compared to CCMI

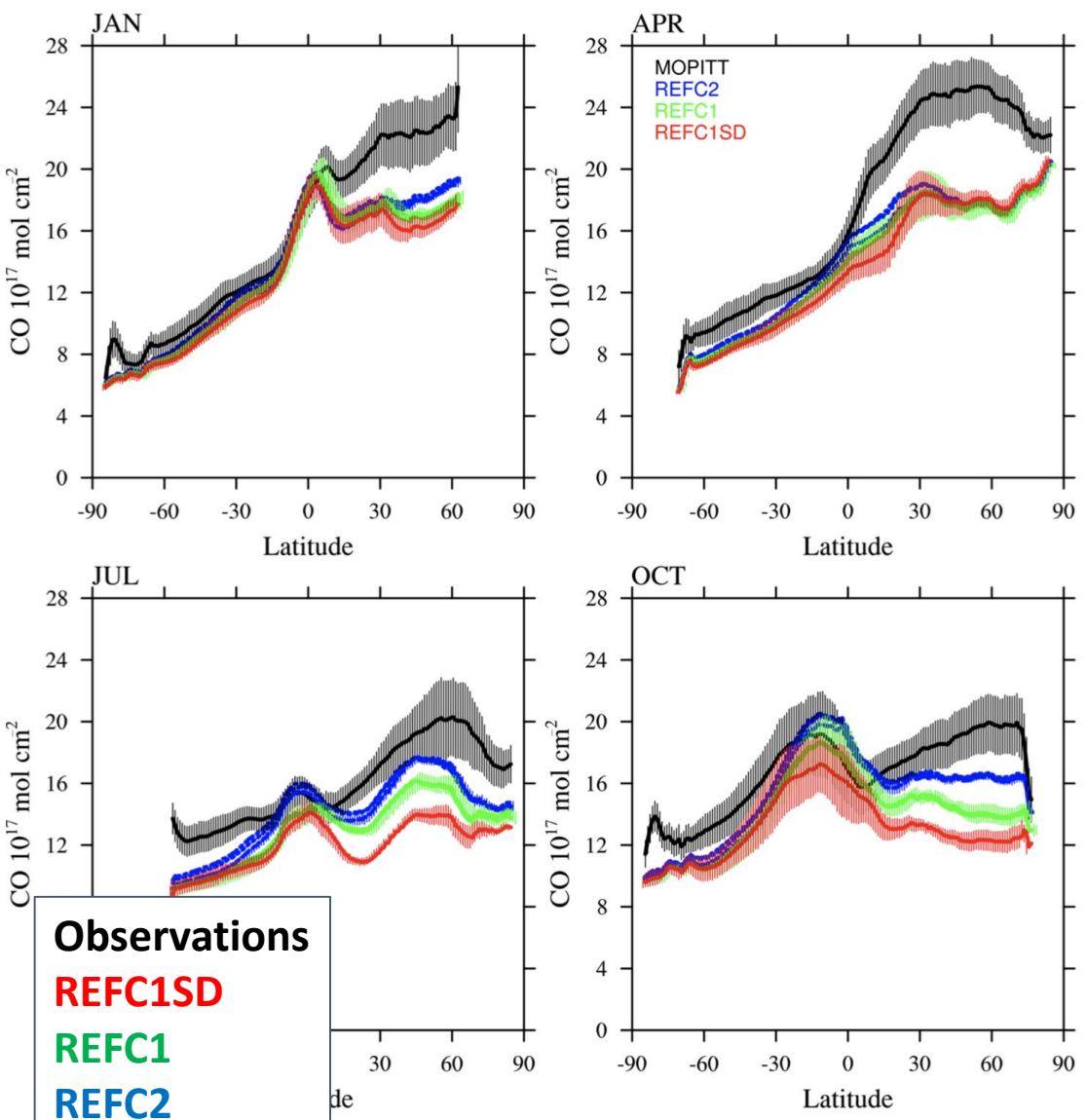
Tropospheric CO Column CESM2 (CAMchem/WACCM)



3 configurations match
Much too low in NH
due to emissions

Observations
CAM6chem-SD
WACCM6-AMIP
WACCM6-HIST

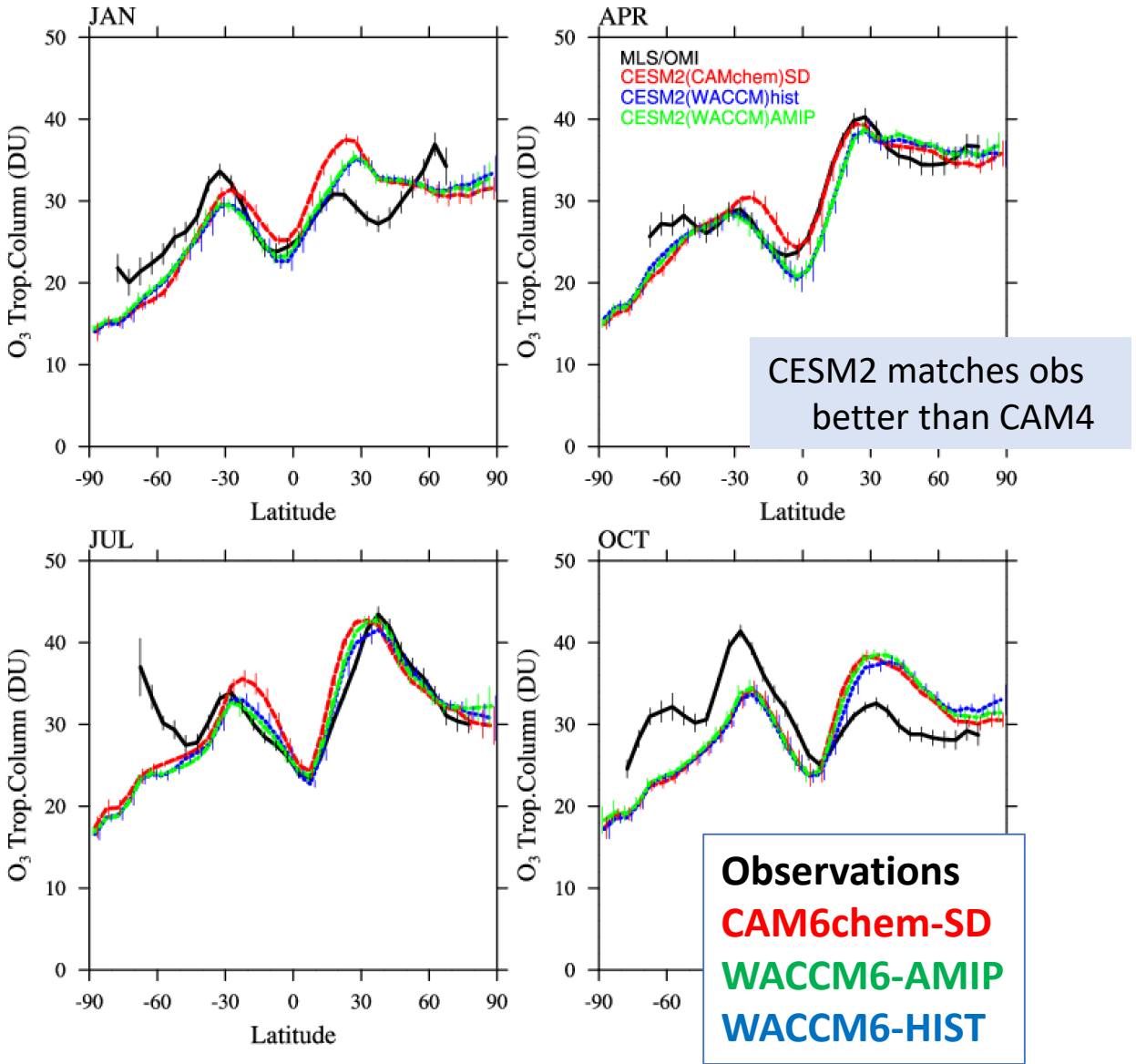
Tropospheric CO Column CCMI (CAM4chem)



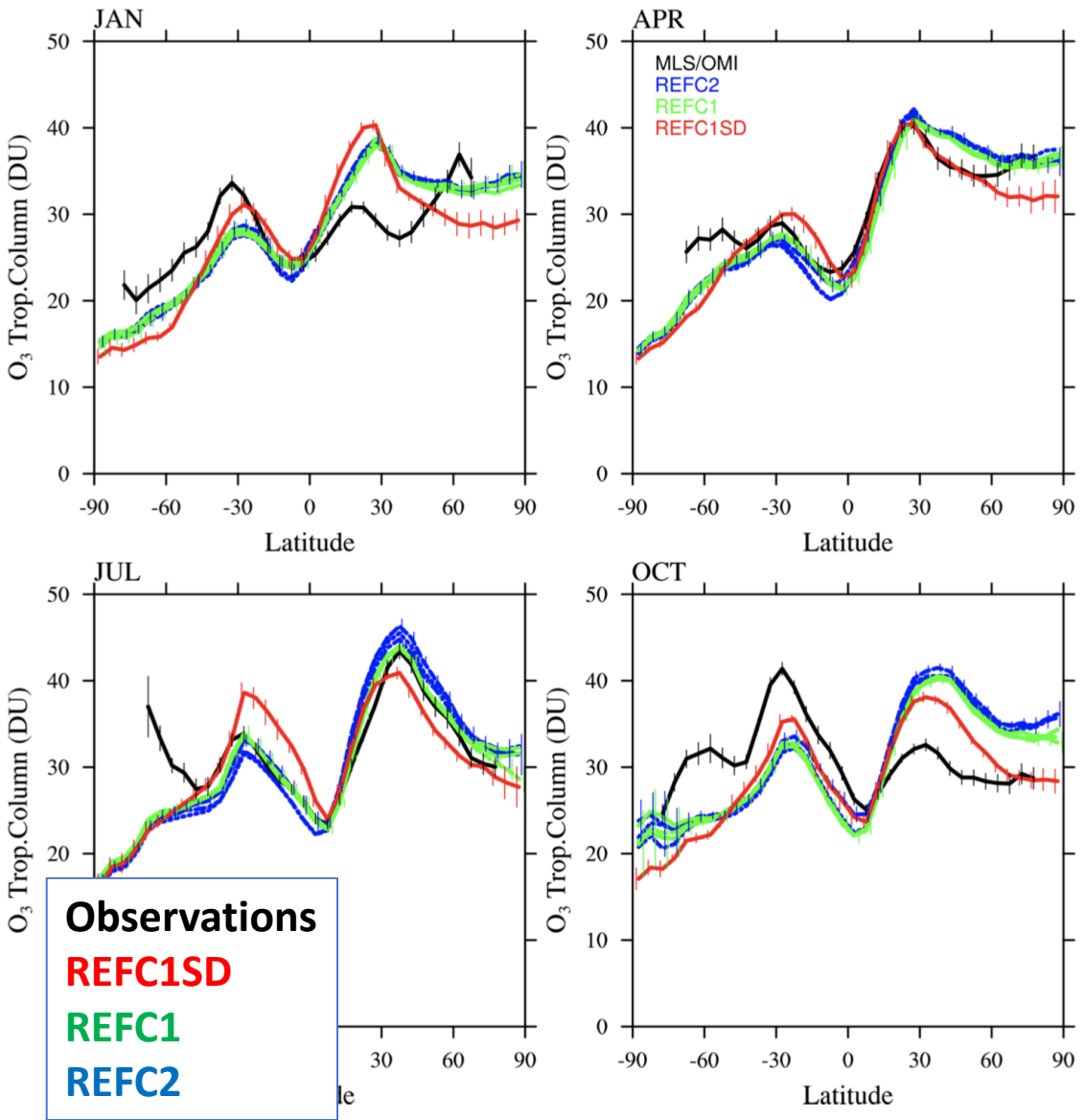
Observations
REFC1SD
REFC1
REFC2

CESM2 Evaluation of Tropospheric Ozone Column compared to CCMI

Tropospheric Ozone Column CESM2 (CAMchem/WACCM)

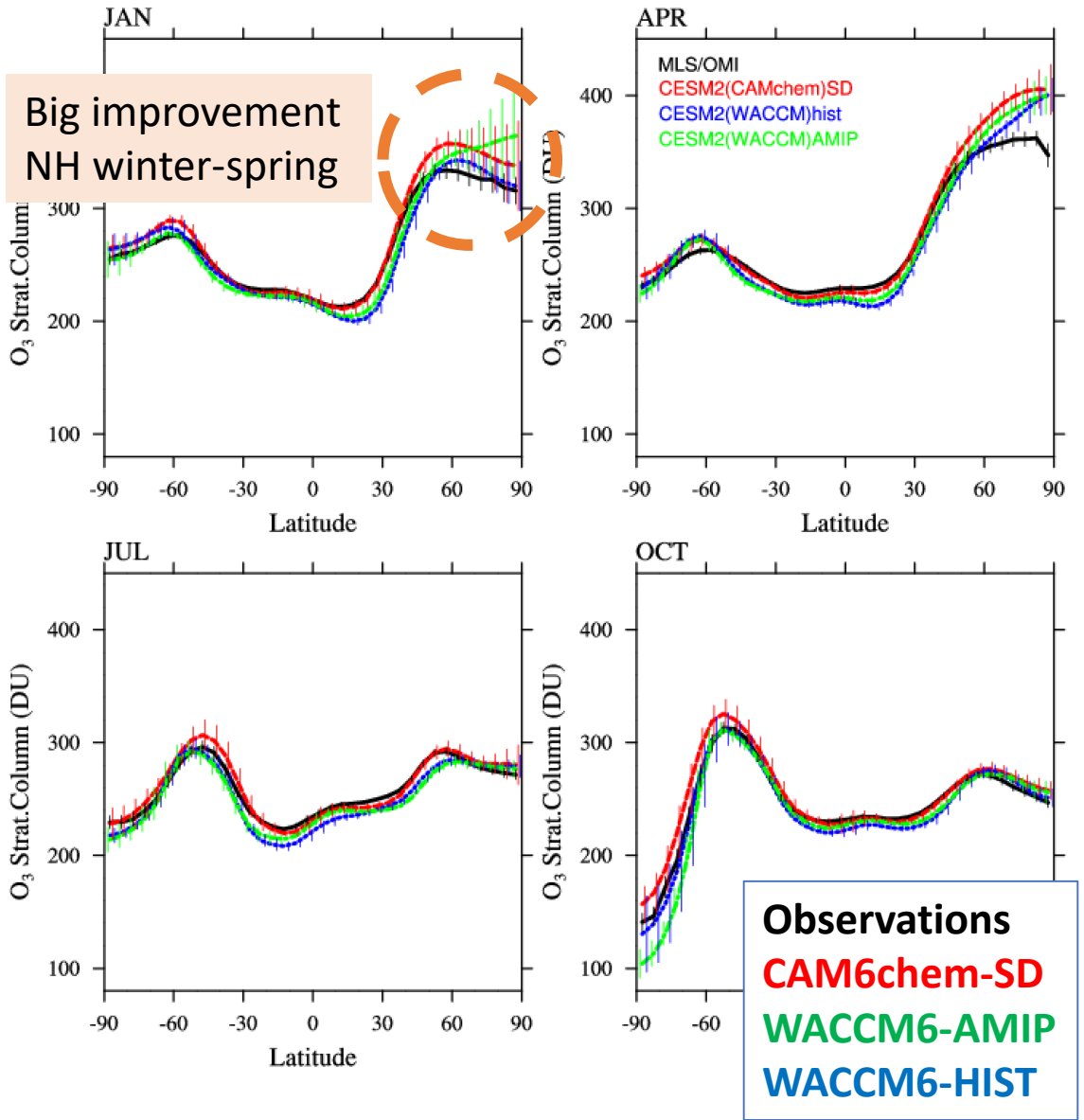


Tropospheric Ozone Column CCMI (CAM4chem)

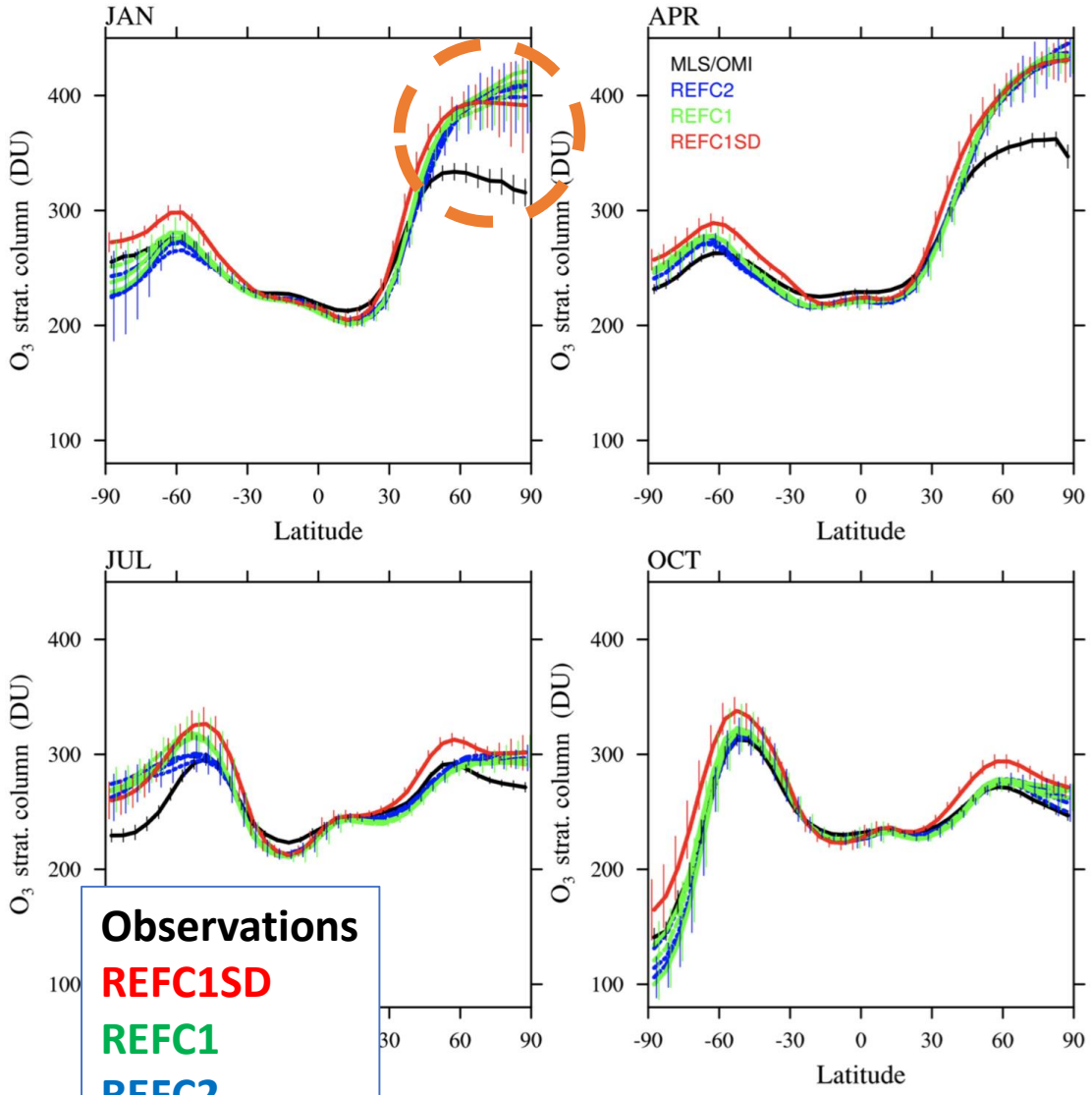


CESM2 Evaluation of Stratospheric Ozone Column compared to CCMI

Stratospheric Ozone Column CESM2 (CAMchem/WACCM)

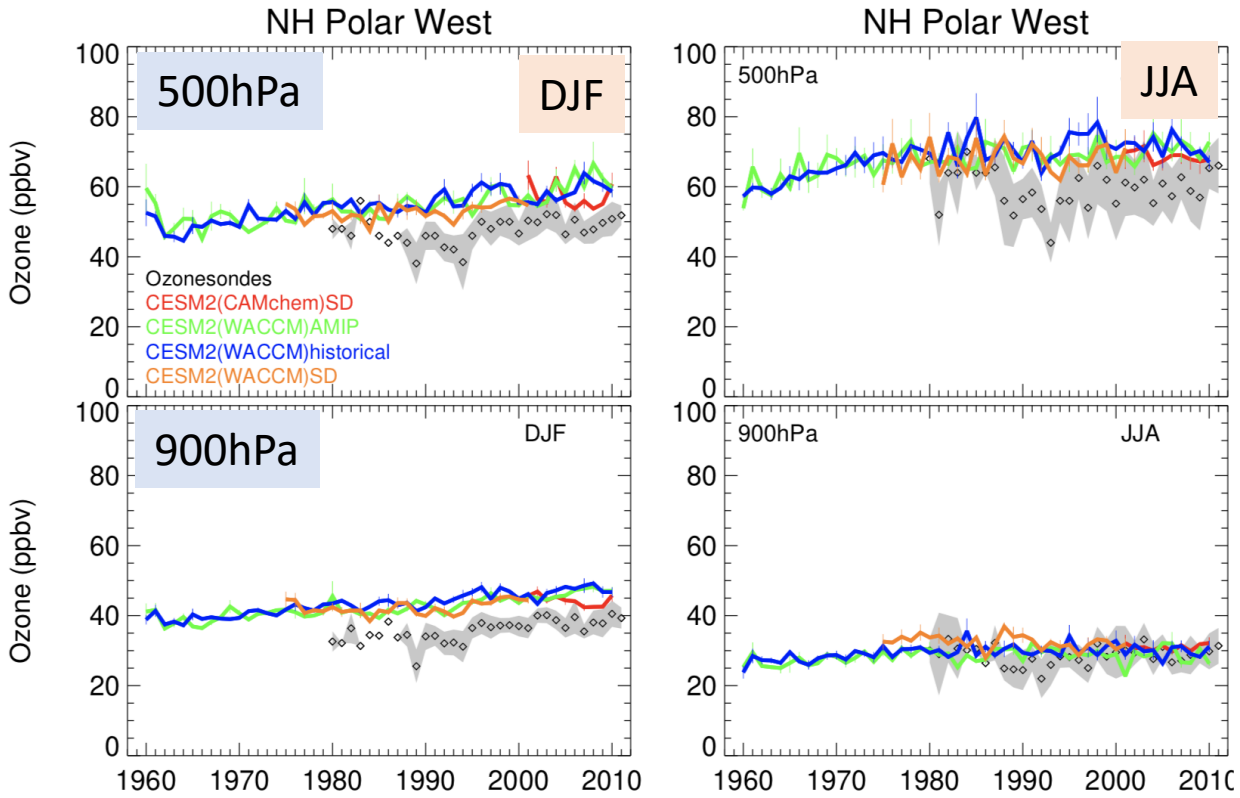


Stratospheric Ozone Column CCMI (CAM4chem)



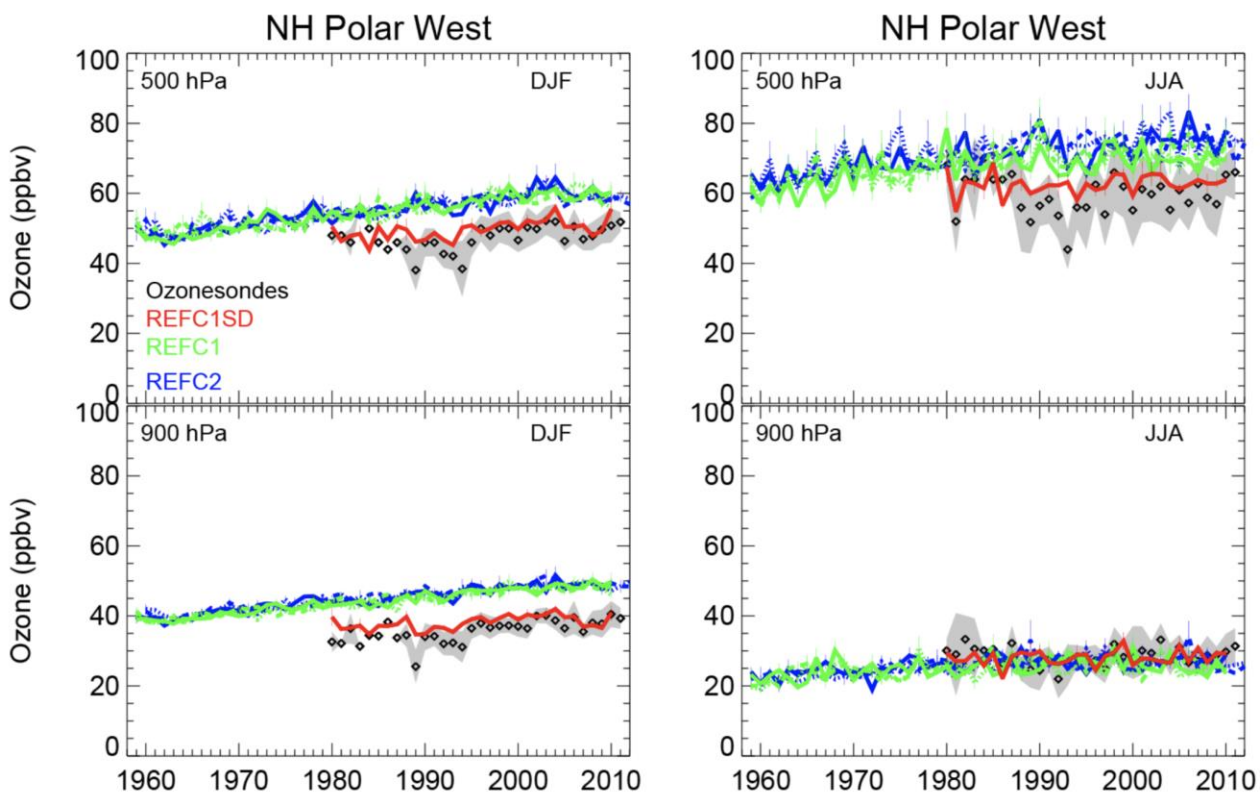
CESM2 Evaluation of Tropospheric Ozone timeseries

CESM2 (CAMchem/WACCM)



Observations
CAM6chem-SD
WACCM6-AMIP
WACCM6-HIST
WACCM6-SD

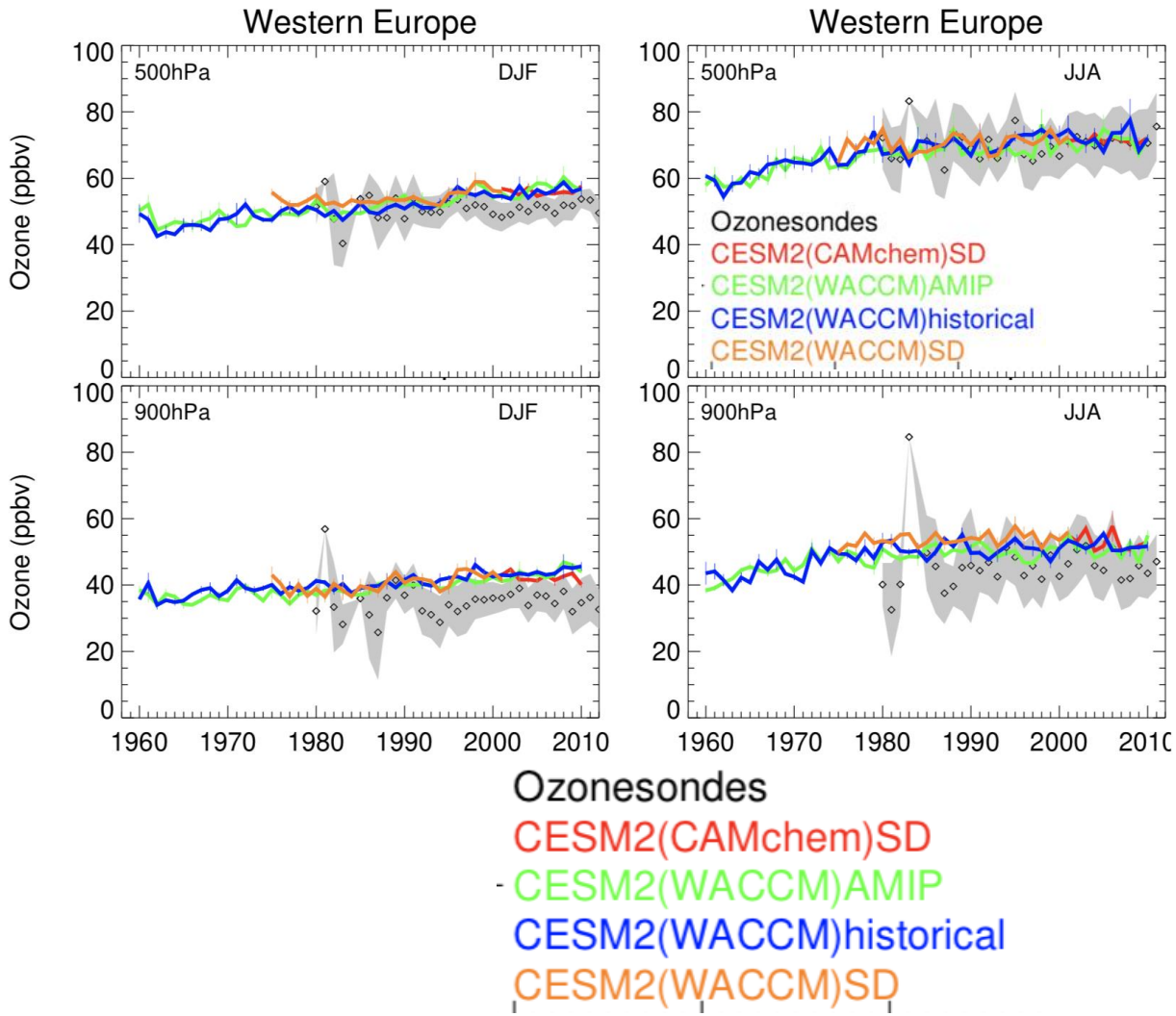
CCMI (CAM4chem)



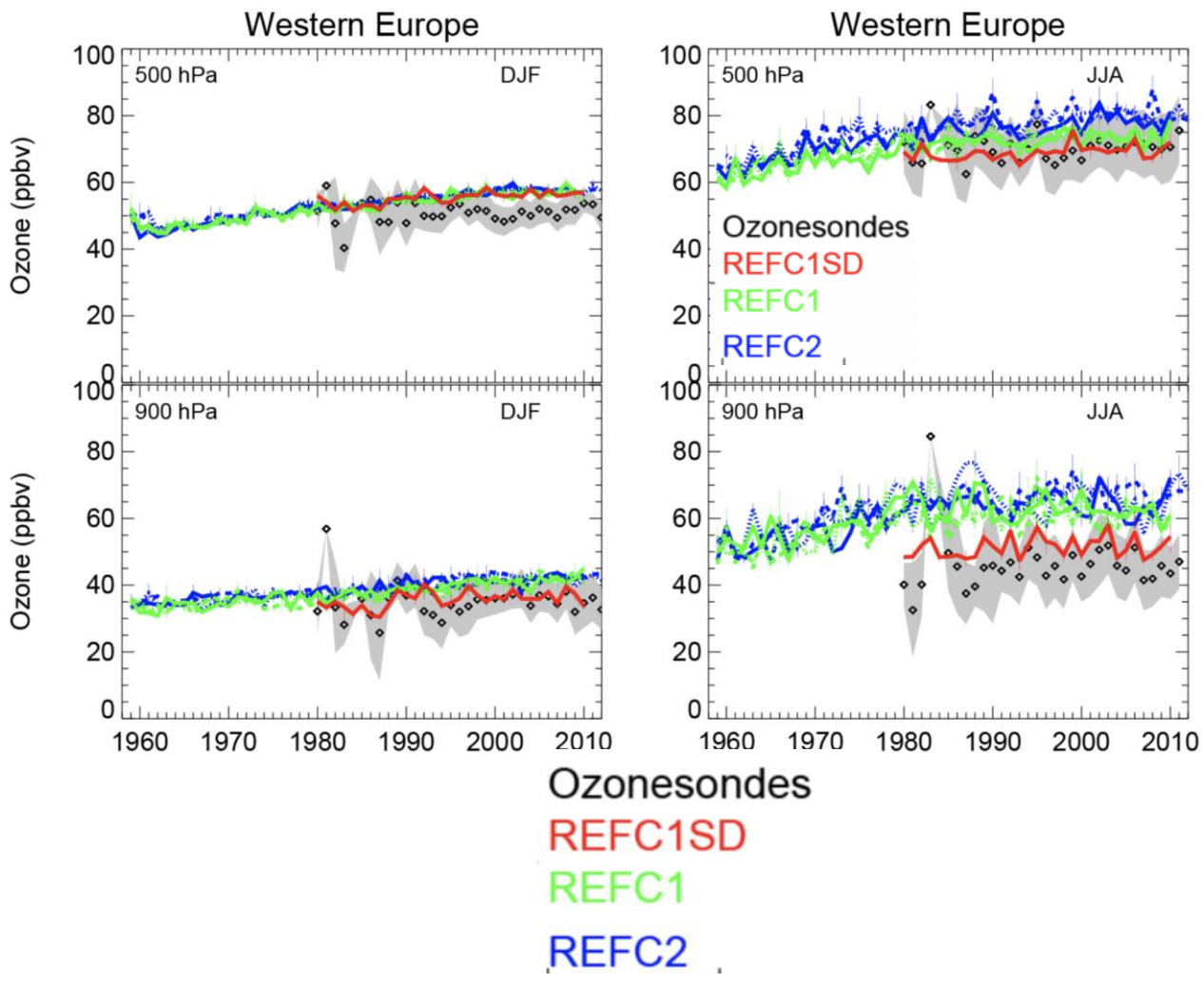
Observations
REFC1SD
REFC1
REFC2

CESM2 Evaluation of Tropospheric Ozone timeseries

CESM2 (CAMchem/WACCM)

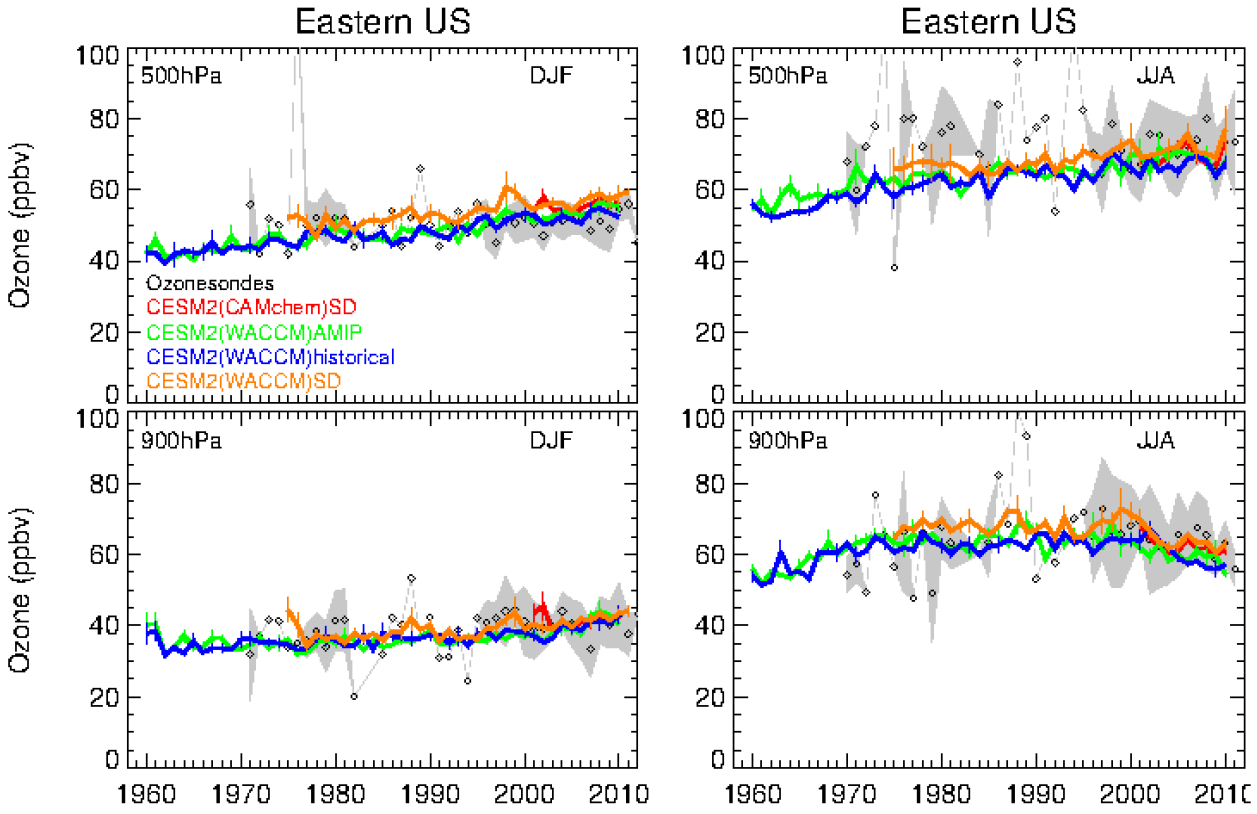


CCMI (CAM4chem)

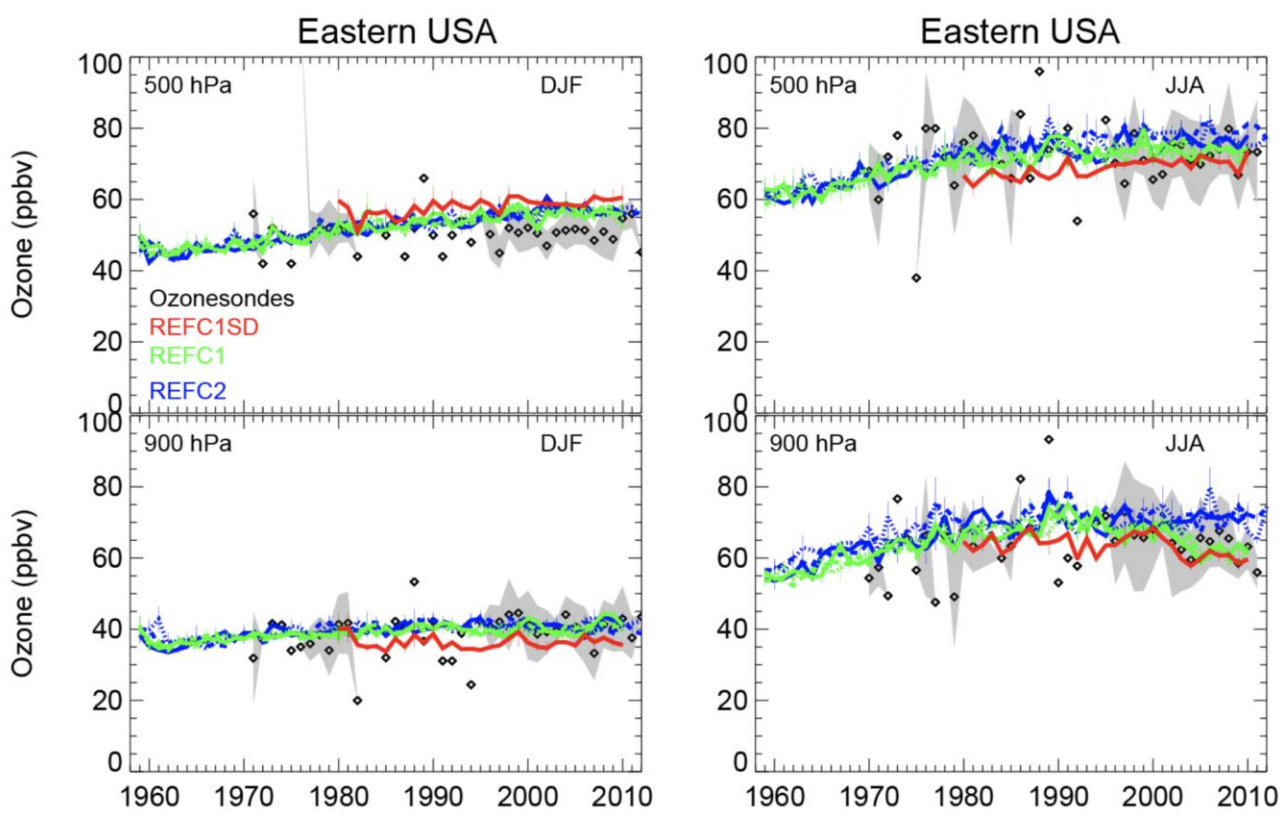


CESM2 Evaluation of Tropospheric Ozone timeseries

CESM2 (CAMchem/WACCM)



CCMI (CAM4chem)

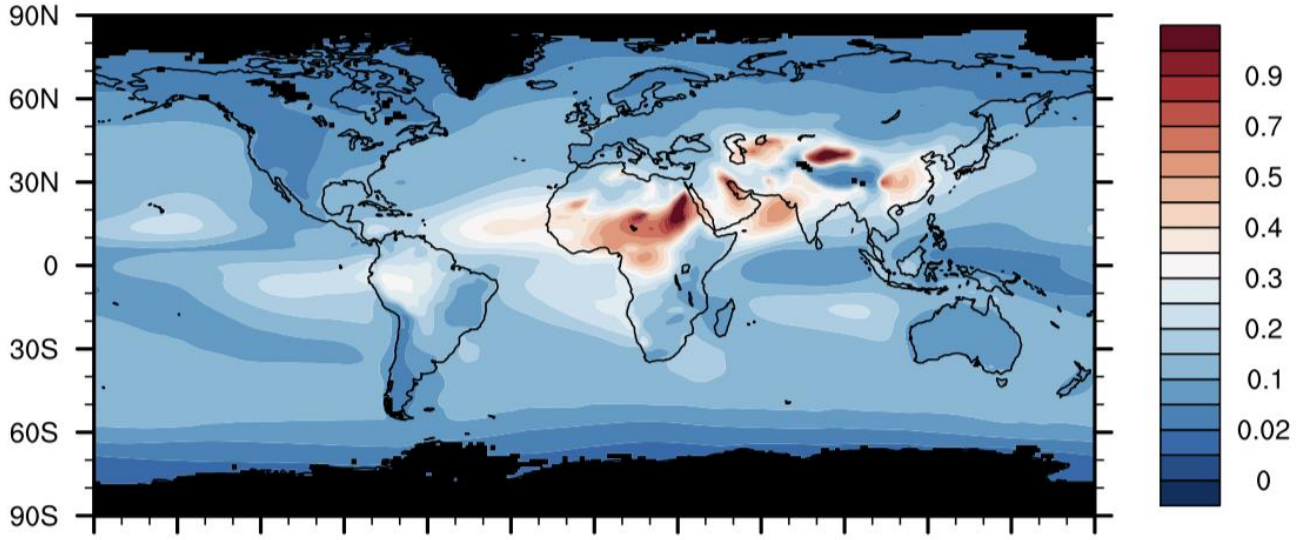


Ozonesondes
CESM2(CAMchem)SD
CESM2(WACCM)AMIP
CESM2(WACCM)historical
CESM2(WACCM)SD

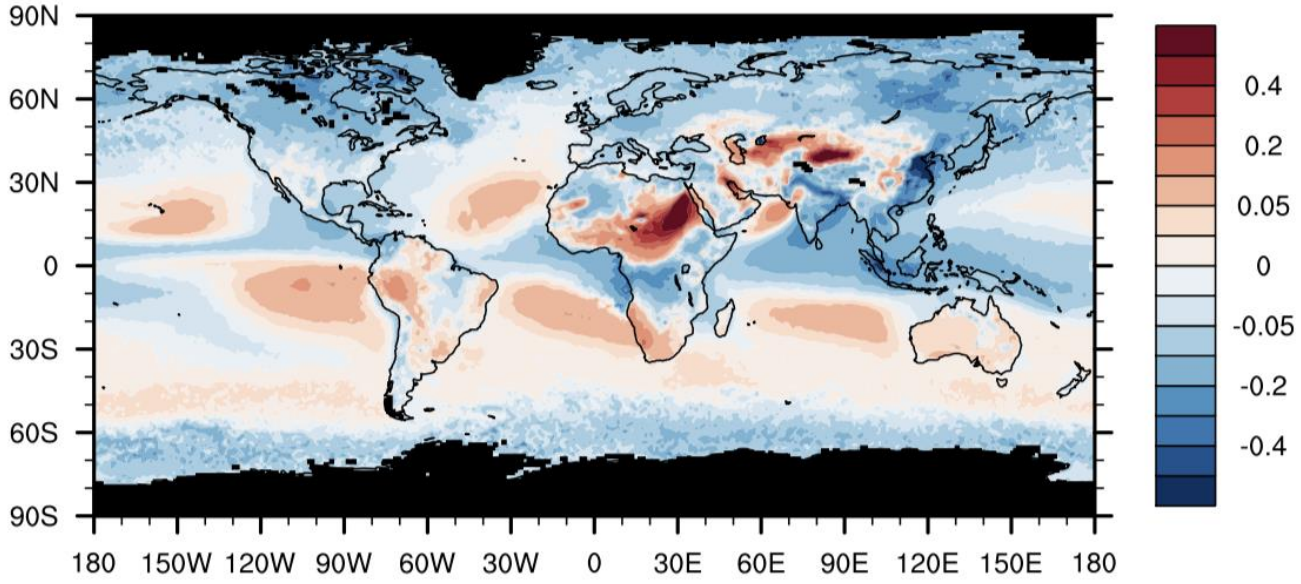
Ozonesondes
REFC1SD
REFC1
REFC2

Aerosol Optical Depth, comparisons with satellite observations (Aqua / Terra)

WACCM (AMIP) AOD (2002-2014)



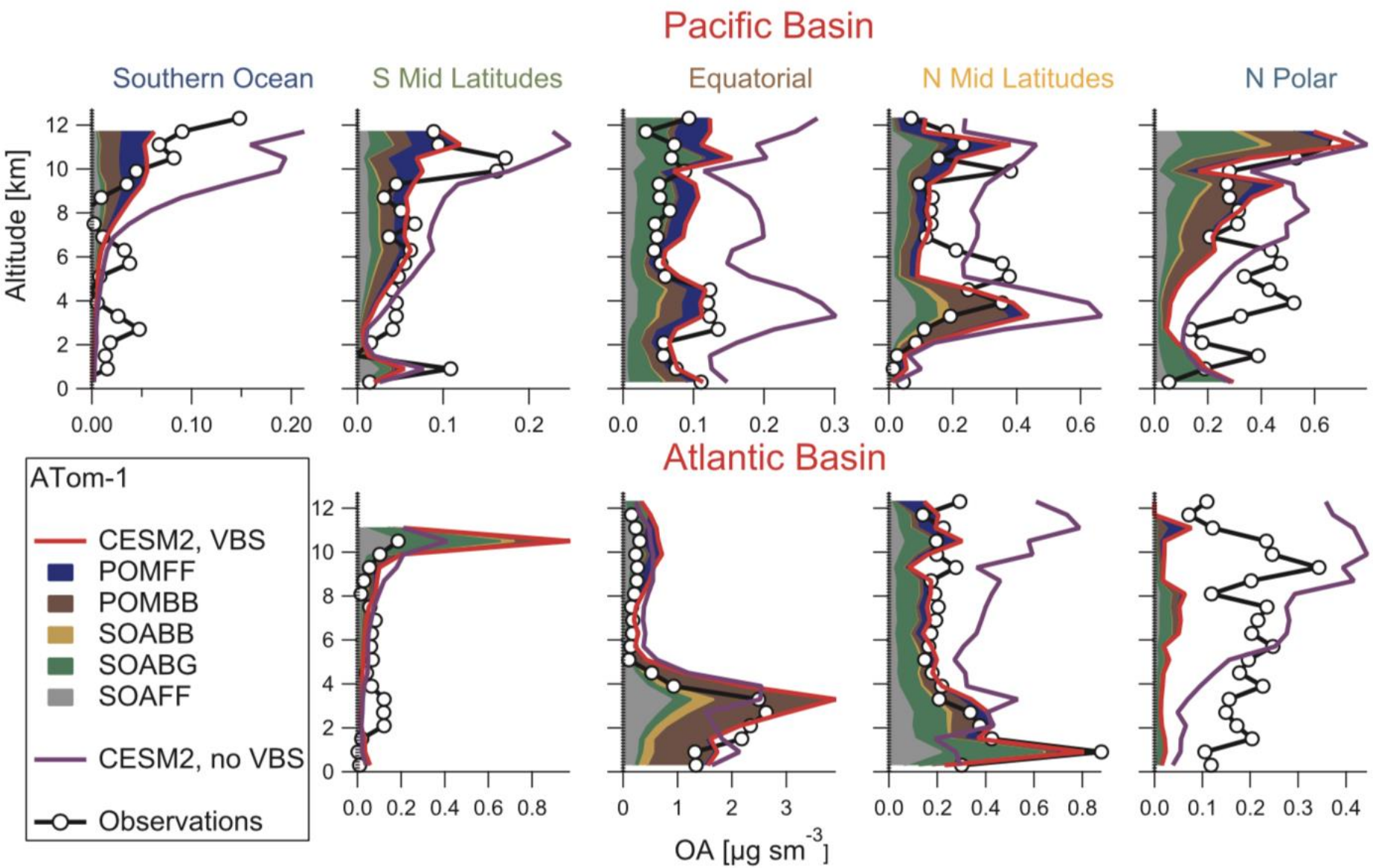
WACCM (AMIP) minus Aqua/Terra



Differences in AOD between WACCM and satellite observations:

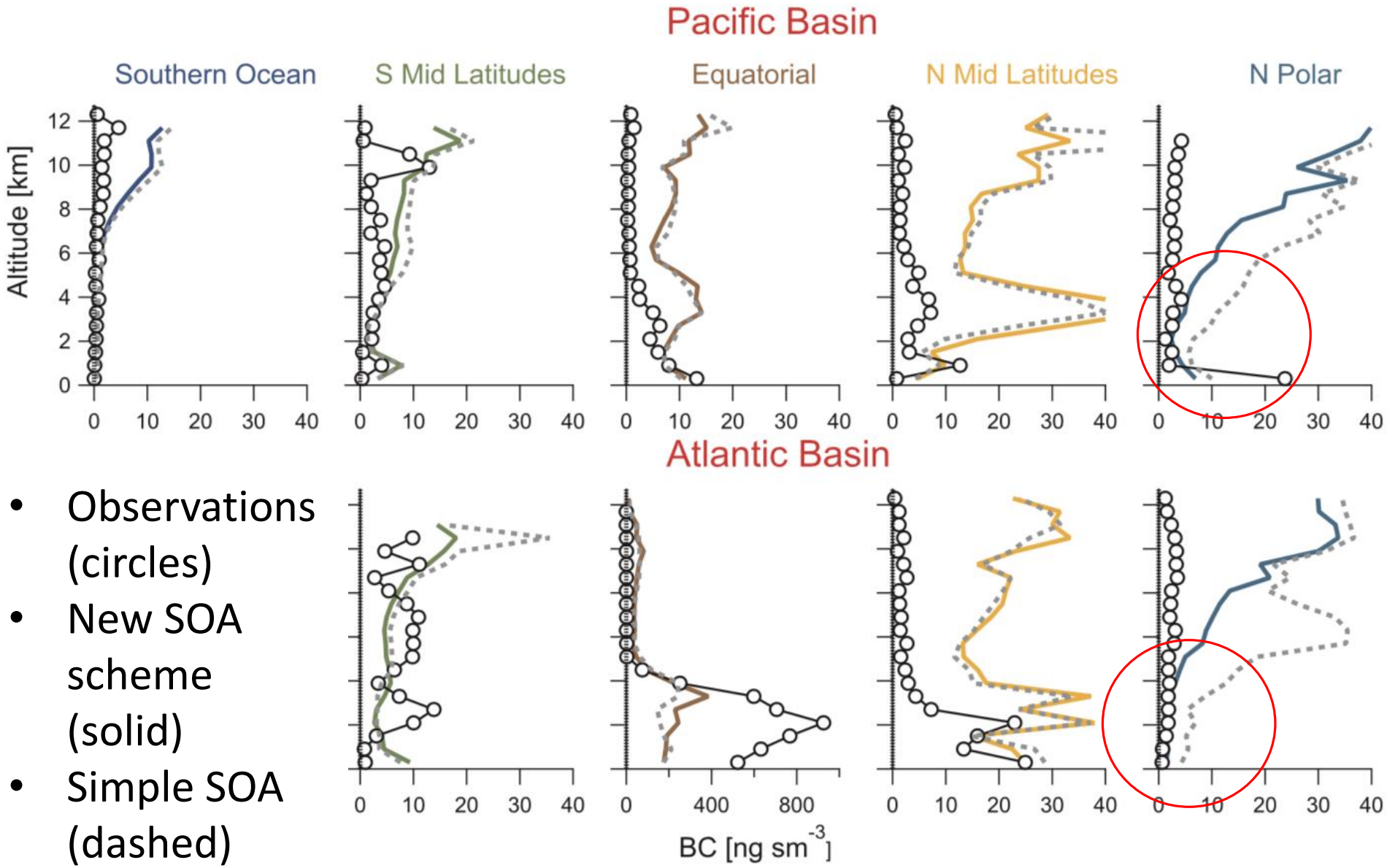
- Sub-tropics and Southern Ocean -> too much sea-salt in the model
- Overestimation over Central Africa and over desert regions -> differences in dust
- Underestimation of AOD over South-East Asia: potential underestimation of anthropogenic emissions

CESM2 Evaluation of Secondary Organic Aerosols with Aircraft Observations



- Improved representation of SOA with new parameterization (VBS approach)
- Source contribution between POM and SOA indicates too high POM/SOA ratio, needs improvement

WACCM Black Carbon compared to aircraft obs.



- Observations (circles)
- New SOA scheme (solid)
- Simple SOA (dashed)

New SOA scheme

- BC and POM too high
- Improved POM and BC in NH high latitudes < 6km
- Potential impact on clouds over the Arctic

(see Pengfei's and Simone's talk)

Summary

- WACCM-SD matches observed column ozone
- CMIP6 emissions of CO and HCs are too low, which will impact tropospheric ozone
- A number of factors probably drive model high bias of surface ozone
- CESM2 simulations with various configurations (B, F, SD cases) are much more consistent than in CCMI

Any suggestions of further evaluation to include in chemistry description paper are welcome