Recent Developments in CESM1_2_0

- **Summary of "Known Problems" in CAM4-Chem and CAM5-Chem**
- **Other developments**
- **Performance of CAM4 and CAM5, differences in CH_4 Lifetime**

Compsets: CESM1.2.0 CAM-Chem, grid:1.9x2.5	Model (phys)/ radiation/grid	Chemistry JPL 2010	Components / Meteorology
CAM4, static ocean:	CAM4, active		**Full ocn/ice, CLM4.0**
B_2000_TROP_MOZART (BMOZ)	**f19_g16**	trop_mozart	+MEGAN
B_2000_MOZSOA (BMOZSOA)		+soa chemistry	**data ocn/ice**
F_2000_TROP_MOZART (FMOZ)		trop_mozart, soa	+MEGAN
F_2000_MOZSOA (FMOZSOA)	**f19_f19**	trop_mozart, soa	+MEGAN
F2000_C4SSOA_L40 (FSOA)		trop/strat soa	+MEGAN
CAM4, specified dynamics:	CAM4, passive		**transient data ocn/ice,**
FGEOS_C4BAM_L40CN (FSDBAM)	**f19_f19**	trop_bam	**CLM4.0/CN, GEOS5**
FGEOS_C4MOZ_L40CN (FSDCHM)		trop_mozart	
CAM5, static ocean:	CAM5, active		**Full ocn/ice CLM4.0/**
B_2000_MOZMAM_CN (BMOZMAM)	**f19_g16**	trop_mozart,mam	**CN**
B_2000_STRATMAM3_CN (BSTRATMAM3)		trop/strat mam	
B_2000_STRATMAM7_CN		trop/strat mam7	
F_2000_MOZMAM_CN (FMOZMAM)		trop mam	**data ocn/ice,**
F_2000_STRATMAM3_CN	**f19_f19**	trop/strat mam	**CLM4.0_CN**
F_2000_STRATMAM7_CN		trop/strat mam7	
CAM4 superfast chemistry	CAM4, active	**super_fast_llnl**	**MEGAN VOC**
B_2000_CN_CHEM (B2000CNCHM)	**f19_g16**		**CLM4.0/CN**
B_1850_CN_CHEM (B1850CNCHM)			transient full ocn/ice
B_1850-2000_CN_CHEM (B20TRCNCHM)			
F_1850_CN_CHEM (F1850CNCHM)	**f19_f19**		static full ocn/ice

Known Problems in CESM1_2_0

- **CLM dry deposition**: Improvements of surface ozone in Western Europe and Eastern US due to improved deposition velocities (Maria's talk)
- T**ropospheric surface area density (SAD) calculations:** BC, and SOA* were not included in the surface area calculation (BMOZSOA, FMOZSOA, FSOA compset)
  -> results in smaller SAD, and a reduction of CH_4-lifetime
- **Compilation of AMWG climatology during run is not recommended!!!!**

Other Minor bug fixes

- **Possible double-counting SAD** between Tropopause (TP) and cloud top (if above TP) all CAM5-Chem compsets (minor impact)
- CAM5 (without chemistry): H_2SO_4 dry and wet deposition not included
- **dust_emis_fact adjustment:** FMOZMAM compset (dust_emis_fact = 0.21D0)
- **Corrections to dust emissions:** to use unmodified dust fluxes from the coupler each time step (only made a difference when going from step 0 to 1)
- **New soil erodebility files** for different resolutions
- **Corrections in aqueous chemistry** (setsox routine) for chemistry mechanisms with MAM3 aerosols that include NH3

Known Problems in CESM1_1_1

- **All MAM compsets**: tropospheric surface area calculation had a bug, too much surface area in the model (Feb 2013 working group meeting)
- **Dust tuning** was not applied to all compsets
- **MEGAN emissions factors**: CO emission factor had an error in the emission factor file going into CLM
- **Colette's SOA scheme**: units were not assigned correctly in the output

Other Developments

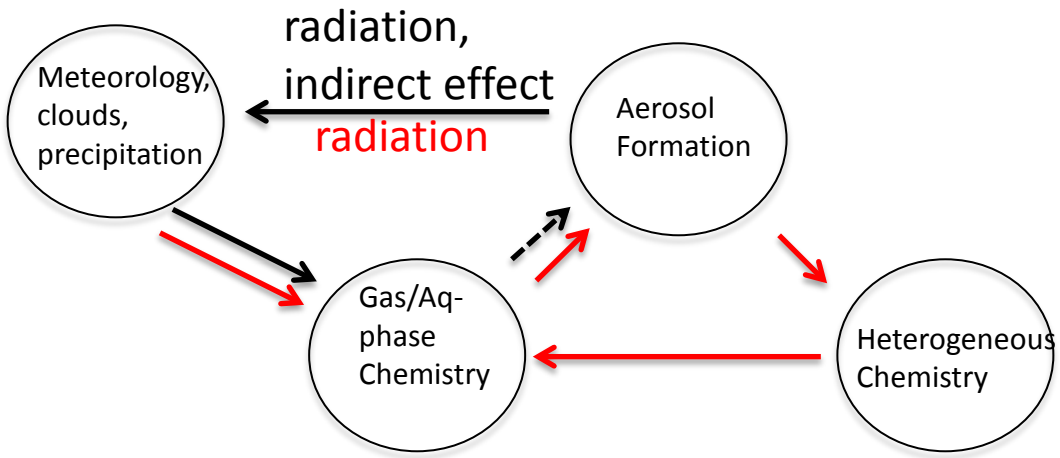
- **Chemistry-aerosol model interface:** Refactored to provide a more extendable framework. This will ease incorporation of other aerosol models. This eliminates numerous ifdefs that have been historically used to embed aerosol models within CAM-Chem.
- **MAM4** aerosol scheme ready to be implemented (Po-Lun)
- **CCMI tag** -> later today (Jean-Francois)
- **Chemistry and SOA development** (later today)

- **Developments on the preprocessor**: conversion to/from kpp
- **Different Resolutions:** 1deg with chemistry is running (RCP4.5, CCMI version)
- **Specified Dynamics:** half degree simulations are being tested

Meteorological Data (on /glade/p/cesm/chwg/metdata/)
Now routinely available.

GEOS5: 1.9x2.5, 2004-present (updated daily)
GEOS5: 0.9x1.25, 2012
MERRA: 1.9x2.5, 0.5x0.63, 1979-2013 (updated frequently)

The coupling between Chemistry and Aerosols in CESM -> CAM5-Chem



CAM5
CAM4-Chem

CAM5:

- Interactions between aerosols and clouds (indirect effect), modal scheme
- Limited interactions with gas-phase chemistry
- SO_4 formation (gas and aqu. phase), POM BC, SO_2 emissions, condensation to SOA

CAM4Chem:

- Gas-phase chemistry
- Limited interactions between aerosols and clouds, bulk scheme
- SOA formation, BC, SO_2/SO_4 emissions

-> CAM5Chem

- Interactive aerosols and chemistry
- SO4 formation

Still missing: SOA formation

CAM4/CAM5 with Chemistry

Setup:

- 1.9x2.5 horizontal resolution
- CESM1_2_0 (dry dep bug fix not included)
- trop/strat mechanism, improved SOA in CAM4-Chem
- Prescribed biogenic emissions (without MEGAN)
- Emissions: default for chemistry, aerosols

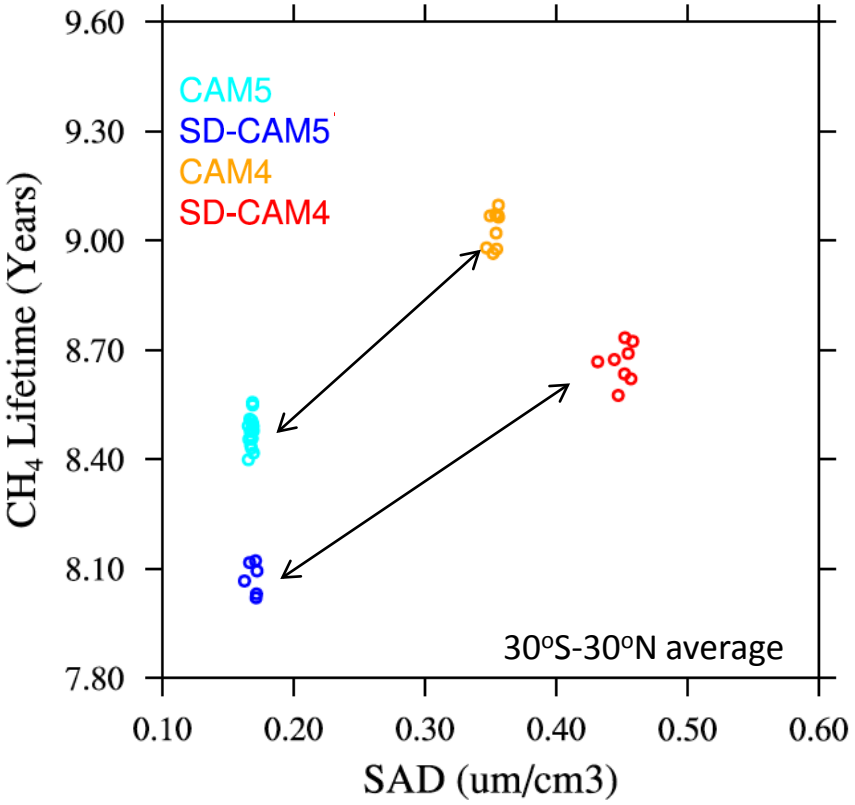
CAM4/CAM5 with Chemistry

Specifics	CAM4-Chem	SD CAM4-Chem	CAM5-Chem (MAM3)	SD CAM5-Chem
Meteorology	free-running	10% nudged	free-running	10% nudged
CH_4-Lifetime yr	8.989	8.537	8.442	8.045
CO-Lifetime yr	0.149	0.142	0.139	0.131
Lighting NOx	4.570	4.457	4.211	4.381
Optical Depth	0.100	0.098	0.098	0.105
SOA (TgS)	0.747	0.774	0.979	1.198
POM (TgC)	0.540	0.559	0.559	0.658
SO_4 (TgC)	0.495	0.518	0.384	0.413
BC (TgC)	0.113	0.114	0.078	0.091

Lifetime in CAM4/5 in general too low. Important impact on photo-chemistry.

Differences in Methane Lifetime

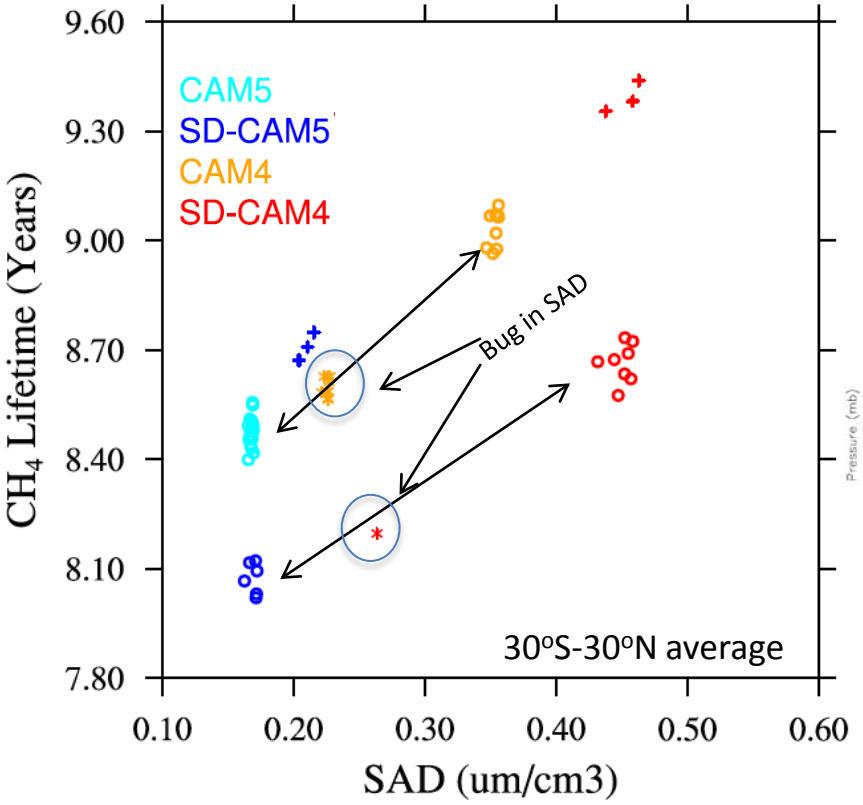
1. Differences in Surface Area Density

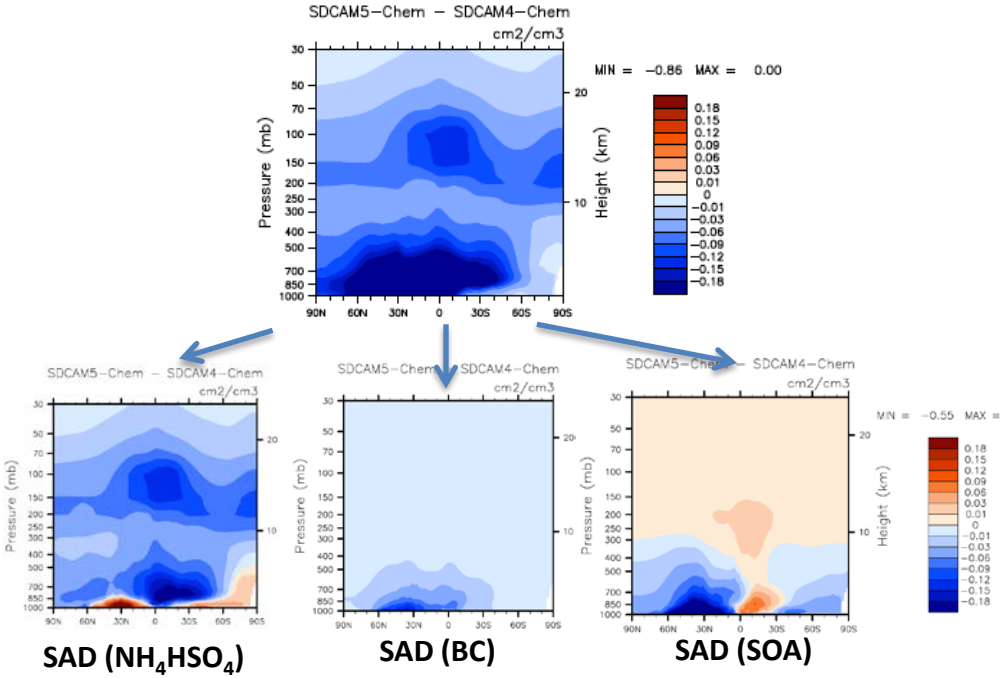


Same emissions, but large differences
in SAD and Methane Lifetime:

Differences in Methane Lifetime

1. Differences in Surface Area Density



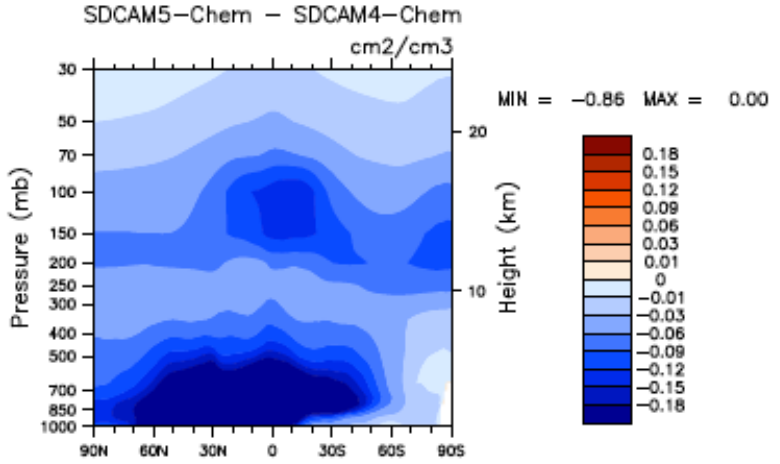


Same emissions, but large differences in SAD and Methane Lifetime:

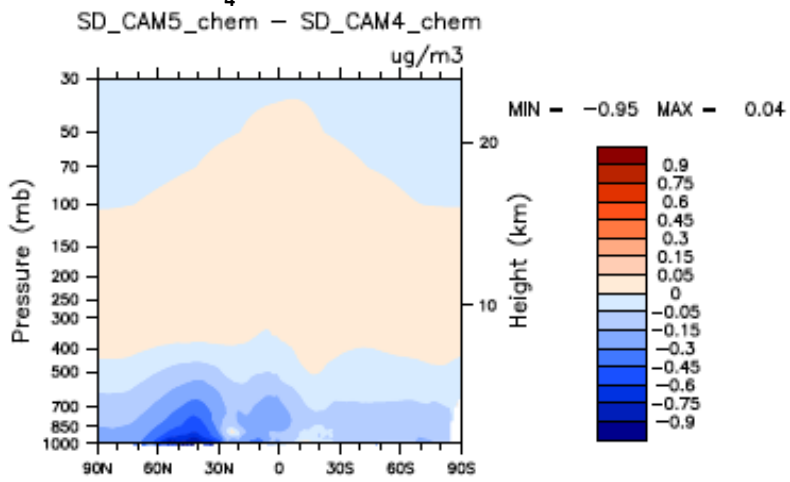
	SD CAM4-Chem	SD CAM5-Chem
SO4 Burden	0.518	0.413
Drydep	6.094	5.630
Wetdep	44.528	31.944
Chem-Prod	8.237	11.368
Aqu-Prod	42.471	24.097
BC (TgC)	0.114	0.091

Differences in Surface Area Density

SAD (NH_4HSO_4)

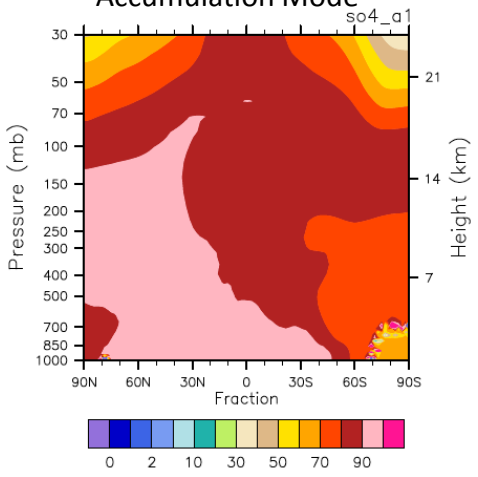


SO_4 mass

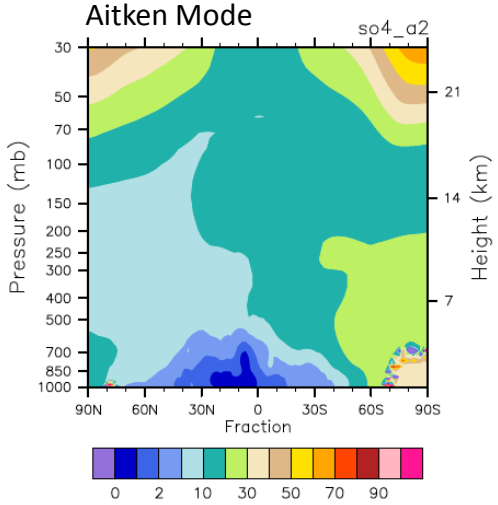


Fraction of different SO_4 modes in MAM3

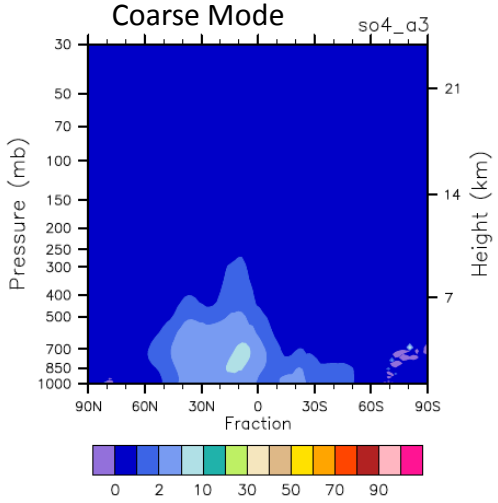
Accumulation Mode



Aitken Mode



Coarse Mode



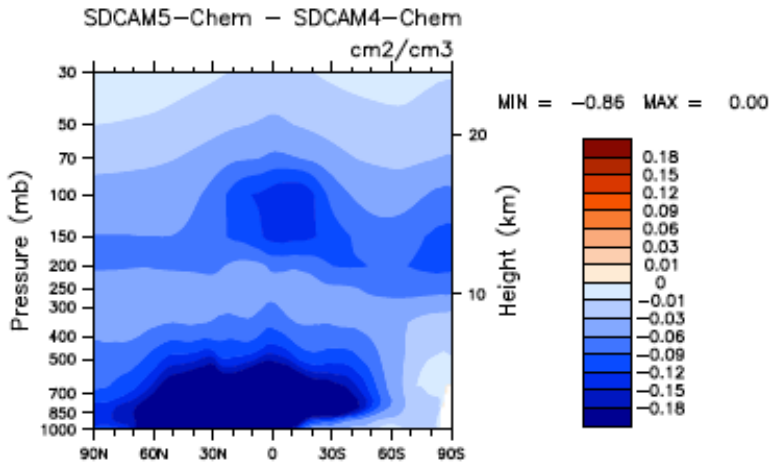
CAM5: most aerosols in accumulation mode (58-270nm)

CAM4: fixed mean radium 69.5nm

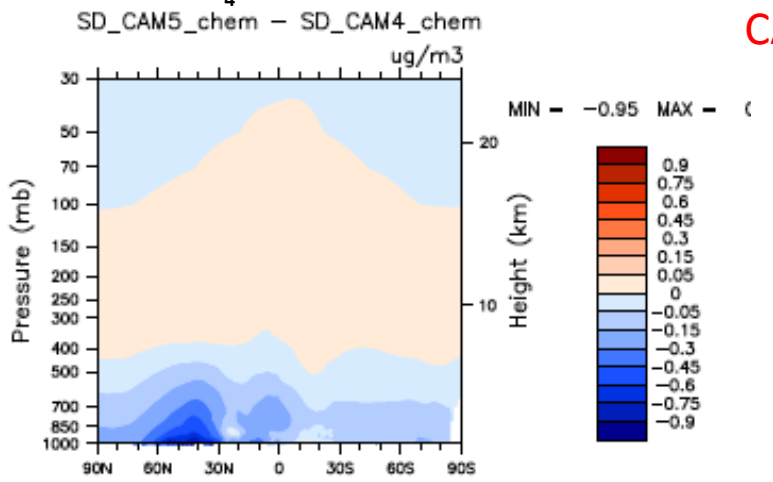
-> Same mass but different SAD

Differences in Surface Area Density

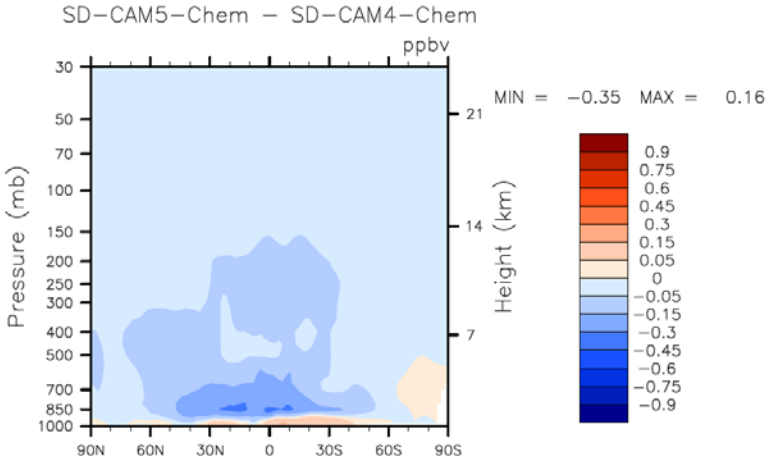
SAD (NH_4HSO_4)



SO_4 mass



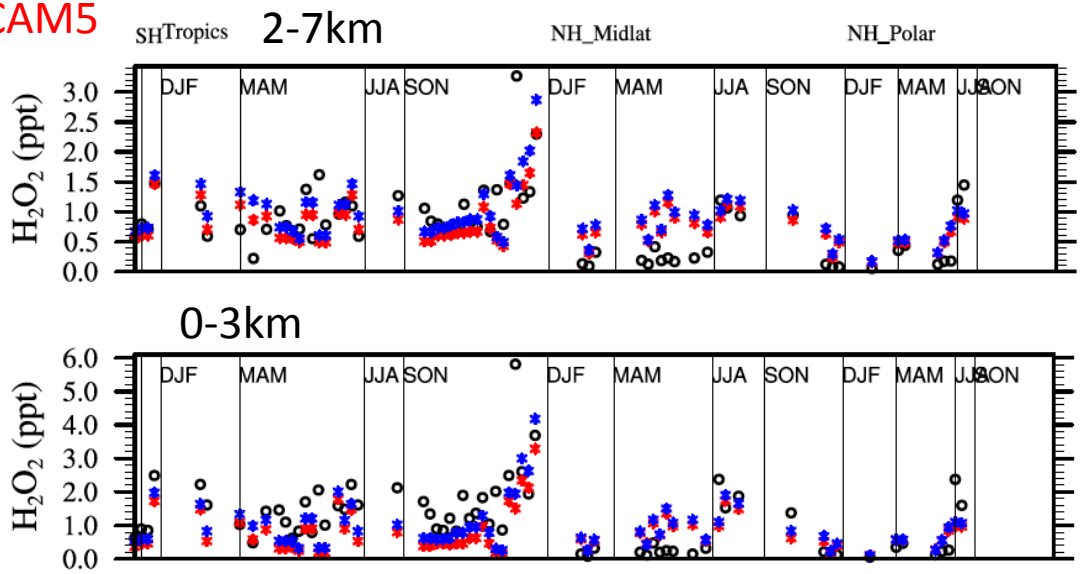
Differences in different H_2O_2



CAM4

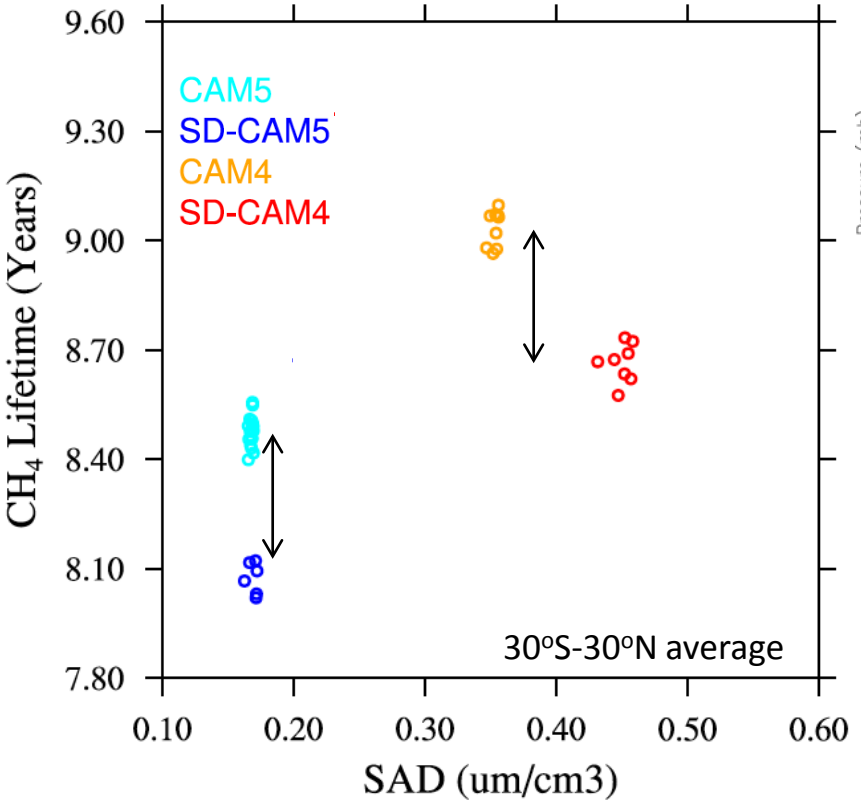
CAM5

Aircraft Observations



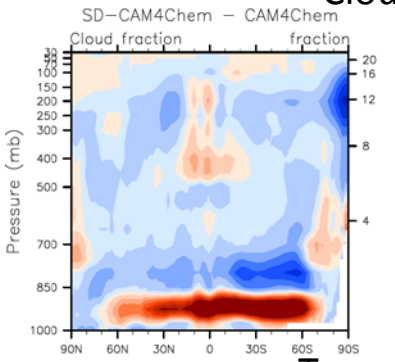
Differences in Methane Lifetime

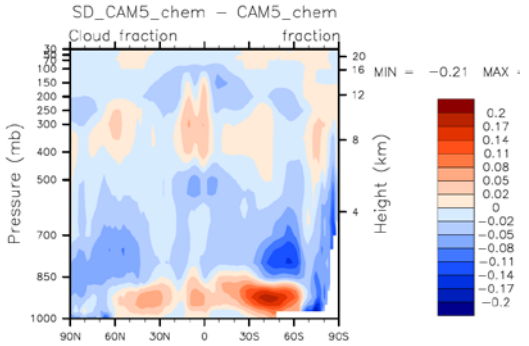
1. Differences in Surface Area Density



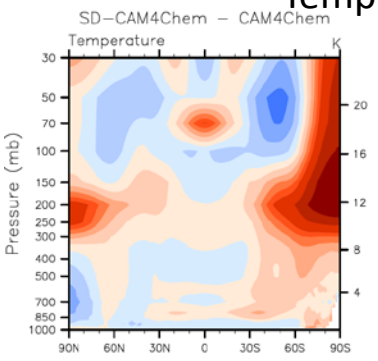
2. Differences in Meteorology

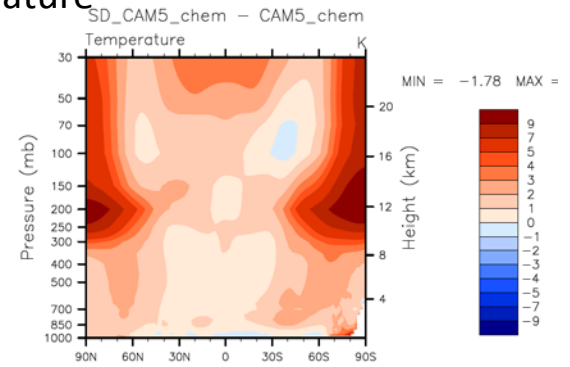
Cloud Fraction





Temperature

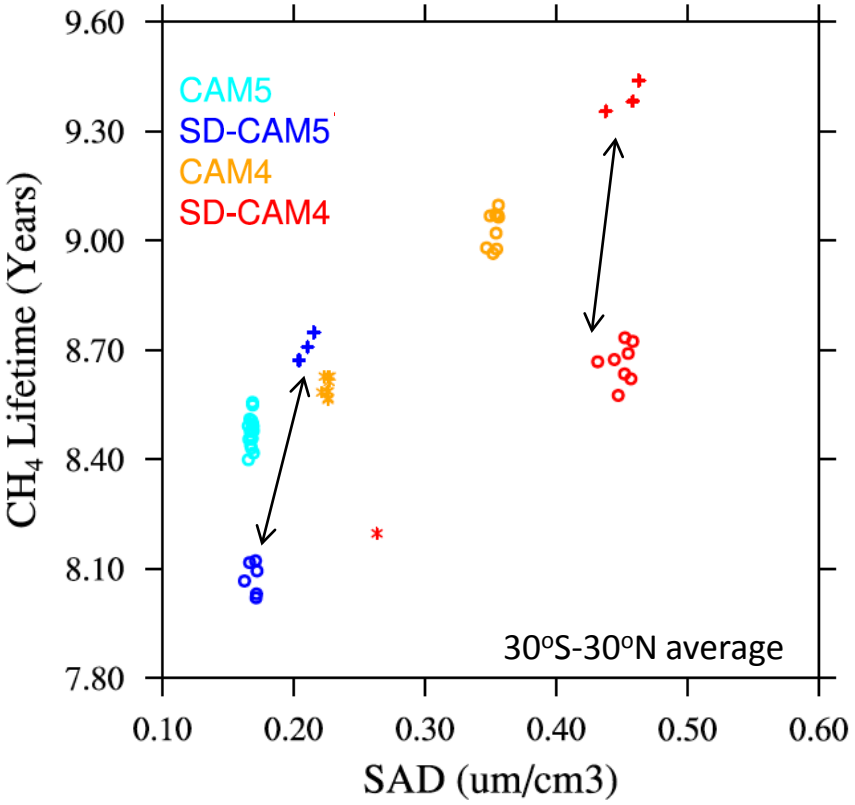


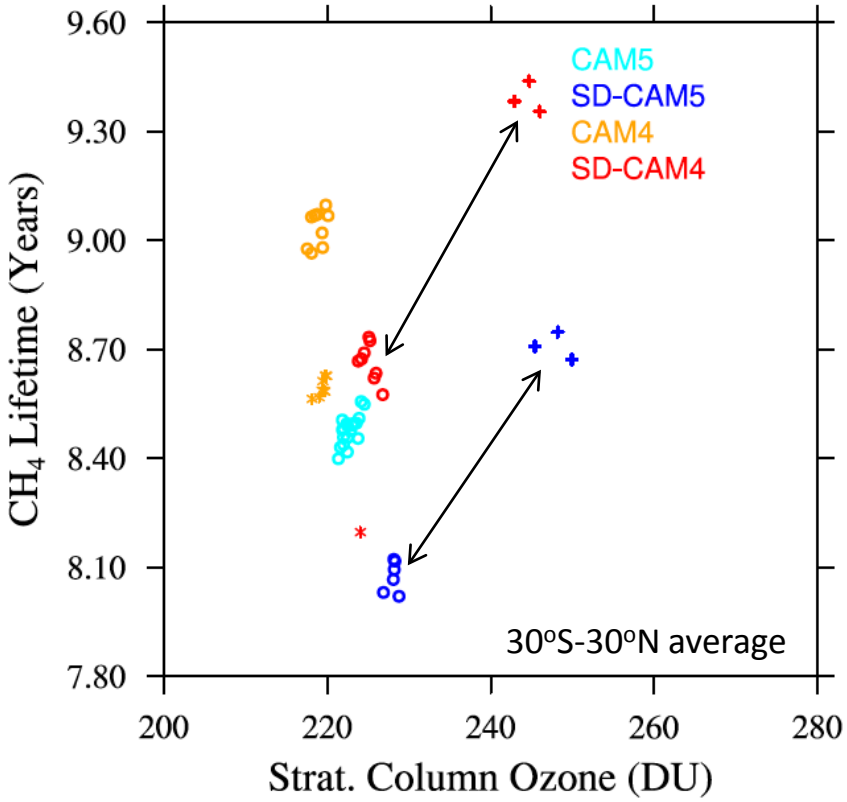


Differences in clouds and temperatures! Warmer temperatures speed up gas-phase chemistry and increase of OH, there decrease of methane lifetime

Differences in Methane Lifetime

3. Differences in Stratospheric Ozone Column



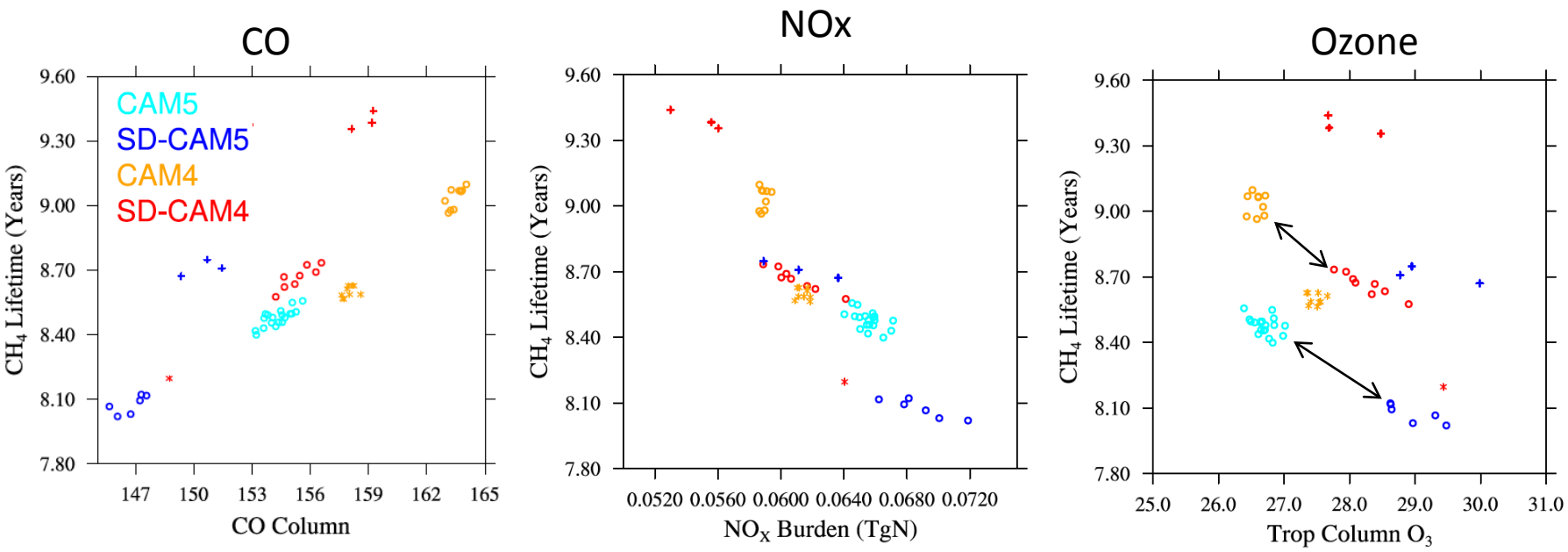


Too much column ozone in the stratosphere can be problematic!

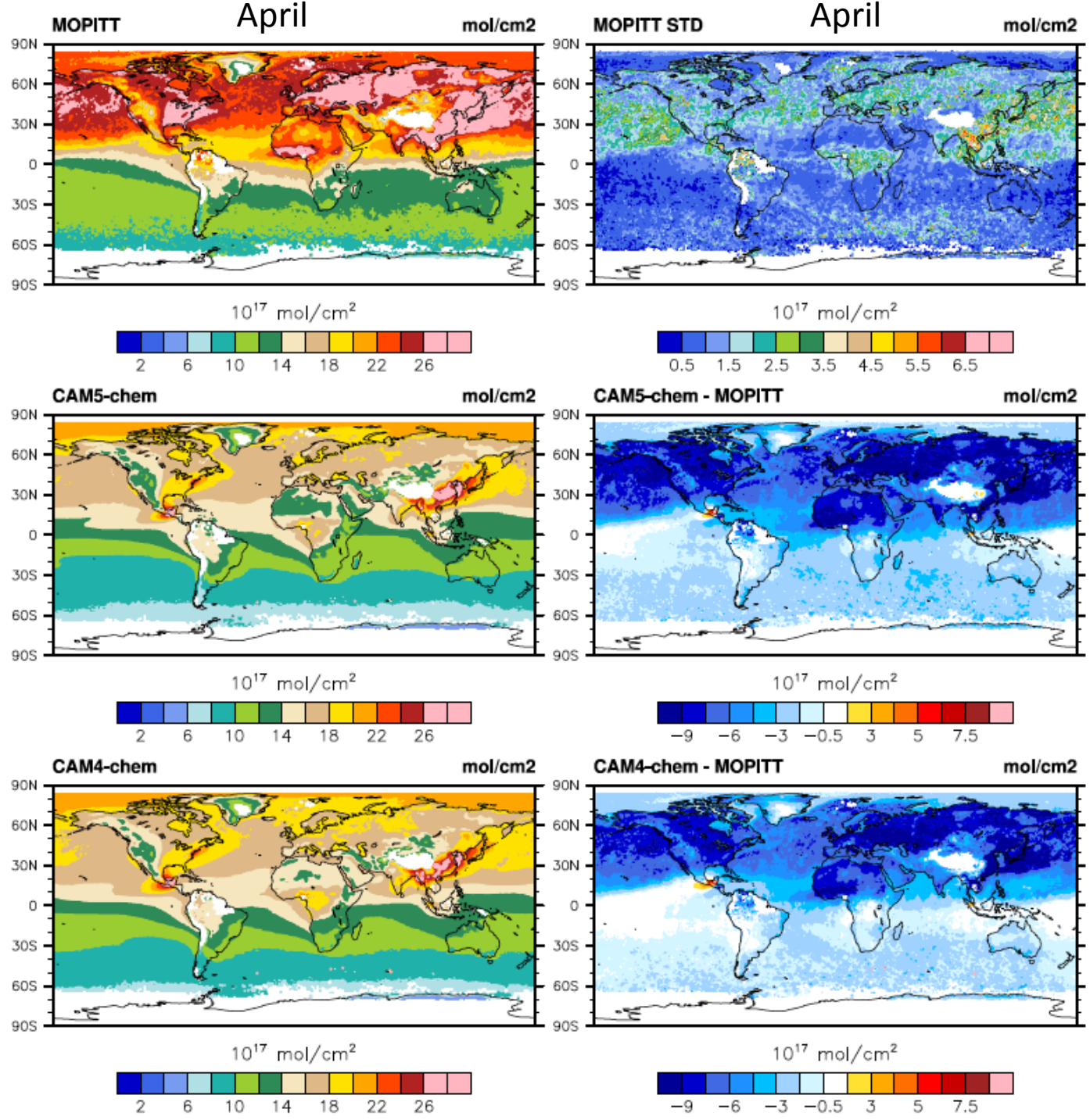
Differences in Methane Lifetime

1. Differences in Surface Area Density
2. Differences in Meteorology
3. Differences in Stratospheric Ozone Column

-> Correlation between CH_4-Lifetime and on NOx, CO, Ozone



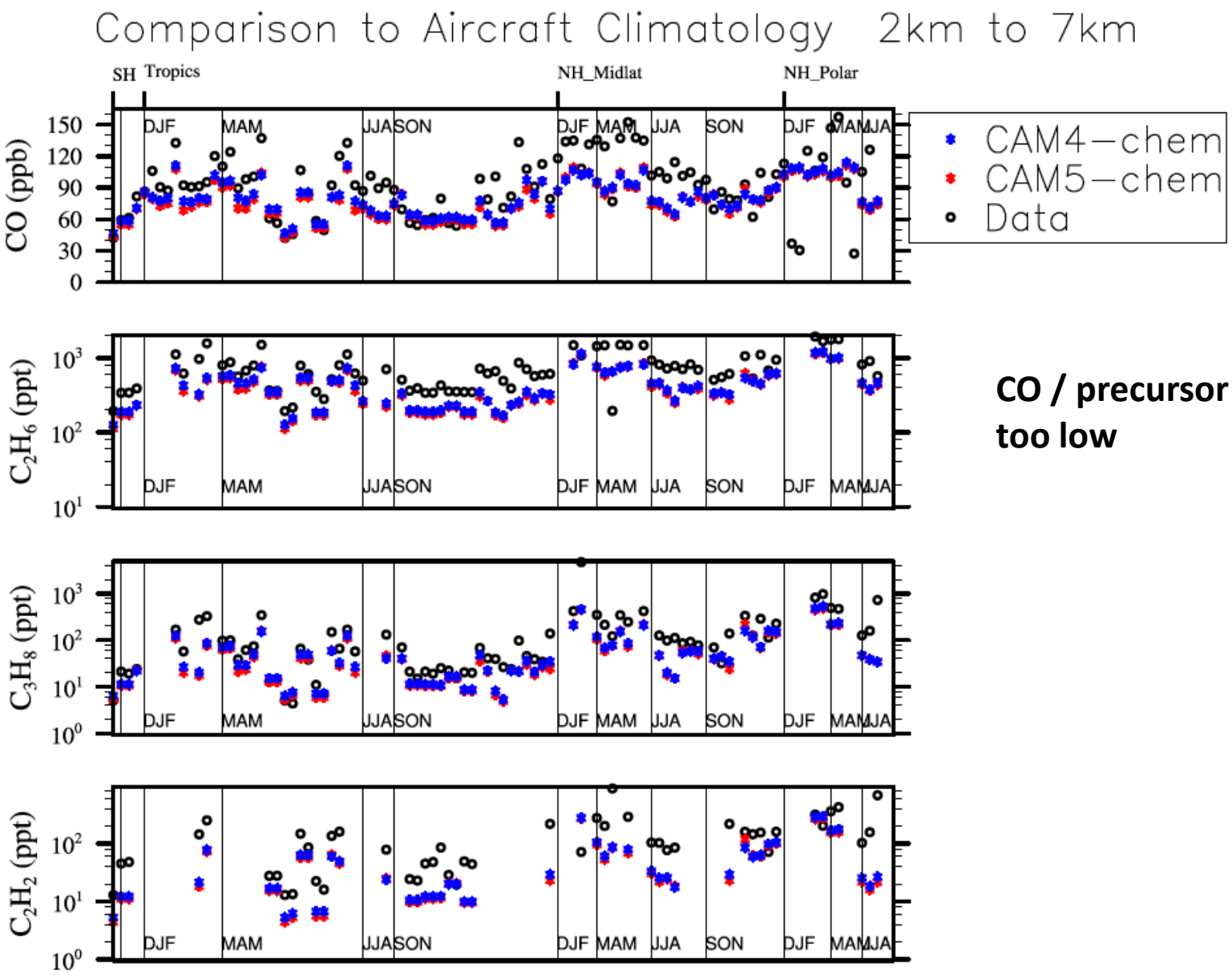
30°S-30°N average



Comparison to MOPITT climatology: April:

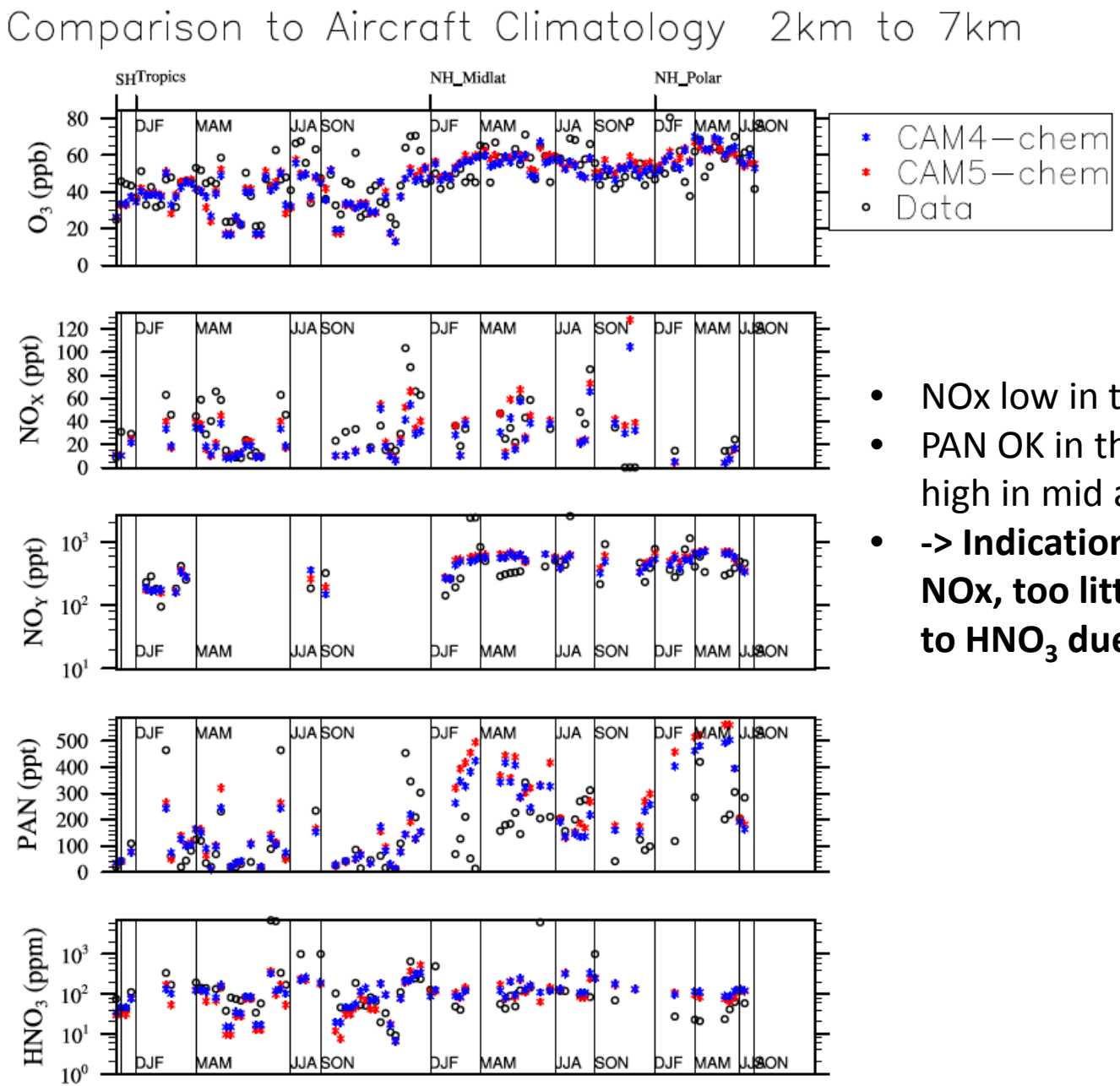
- CO Largely underestimated
- Improved presentation in CAM4-chem (longer lifetime)

Comparison to Aircraft Observations



CO / precursor emissions too low

Comparison to Observations



- NOx low in the Tropics
- PAN OK in the tropics, too high in mid and high latitudes
- **-> Indication of too much NOx, too little transformation to HNO_3 due to aerosols?**

Summary

Lifetime in different configuration of CESM with chemistry differs depending on

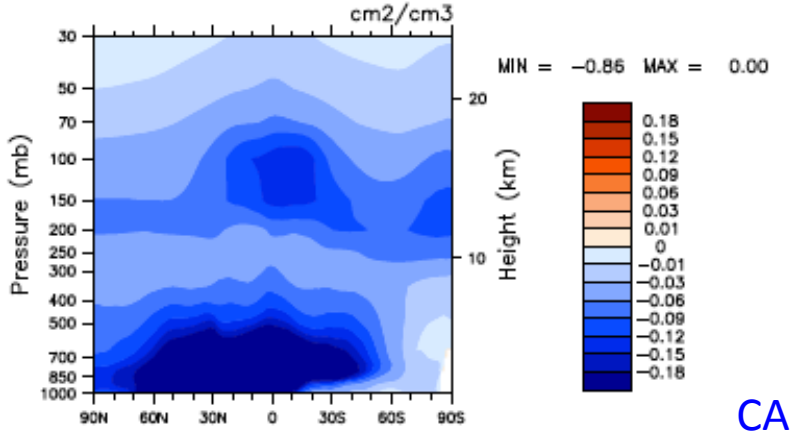
- Surface Area Density, Meteorology, Stratospheric Ozone

-> changes of CO and NOx due to changes in OH and heterogeneous reaction (NOx)

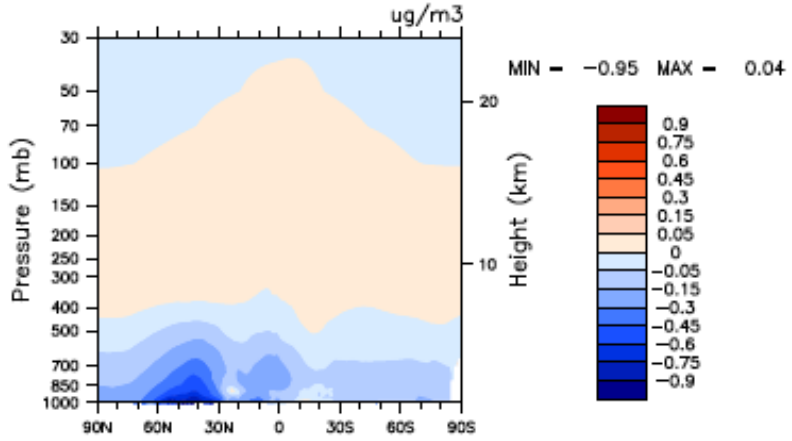
- CAM4-Chem has 0.5yr larger lifetime due to more SAD
- SD model simulations have 0.4 smaller lifetime (cold bias of free running models, differences in clouds)
- CO is underestimated in all models, too much OH, and probably due to emissions
- Overestimation of PAN in mid- and high latitudes, to few aerosol transformation of NOx to HNO_3? Too little deposition?

Differences in Surface Area Density

SAD (NH_4HSO_4)

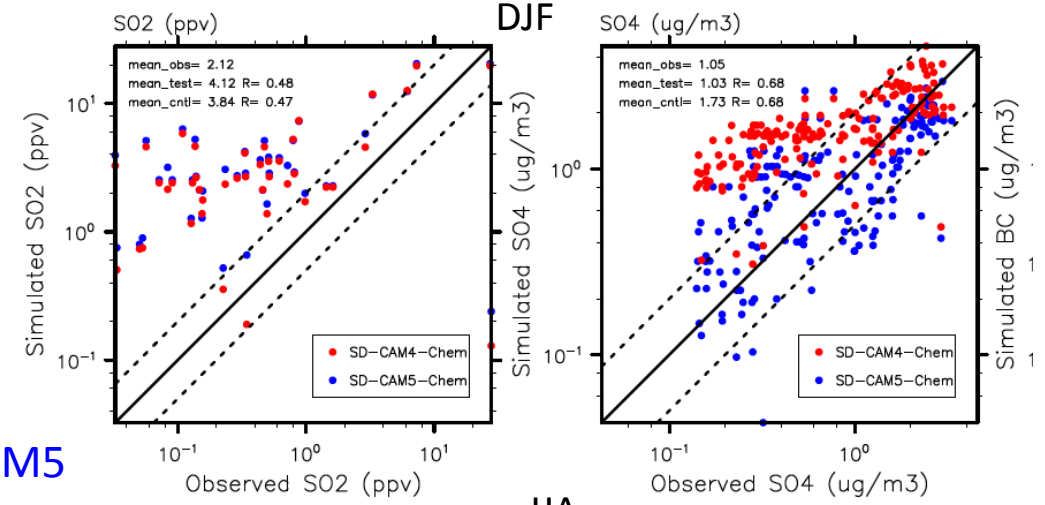


SO_4 mass



IMROVE Surface Data (rural regions)

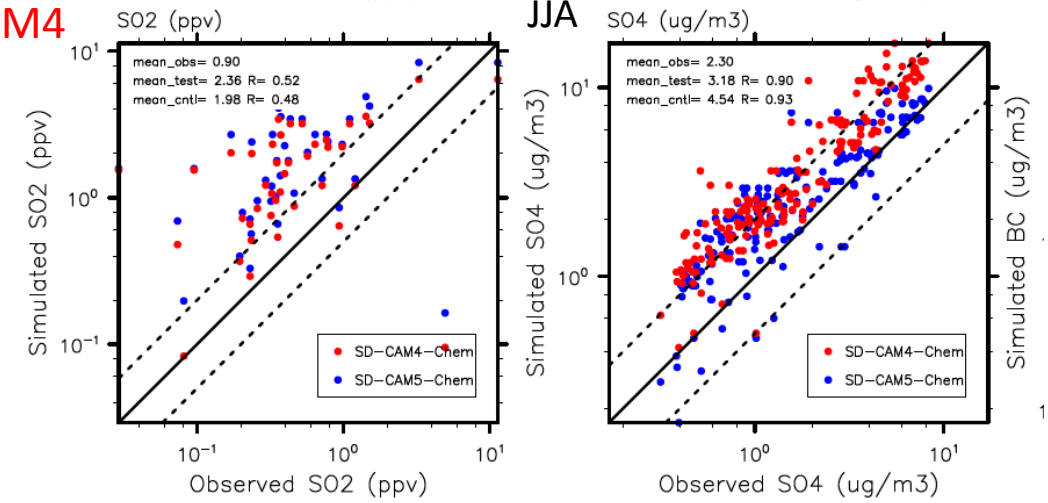
DJF

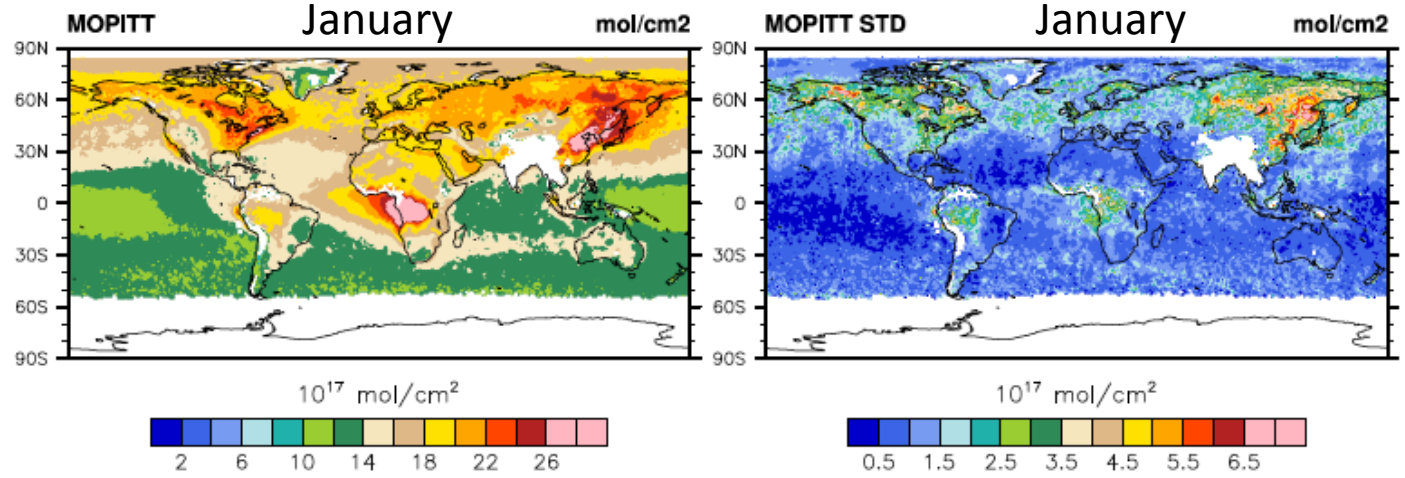


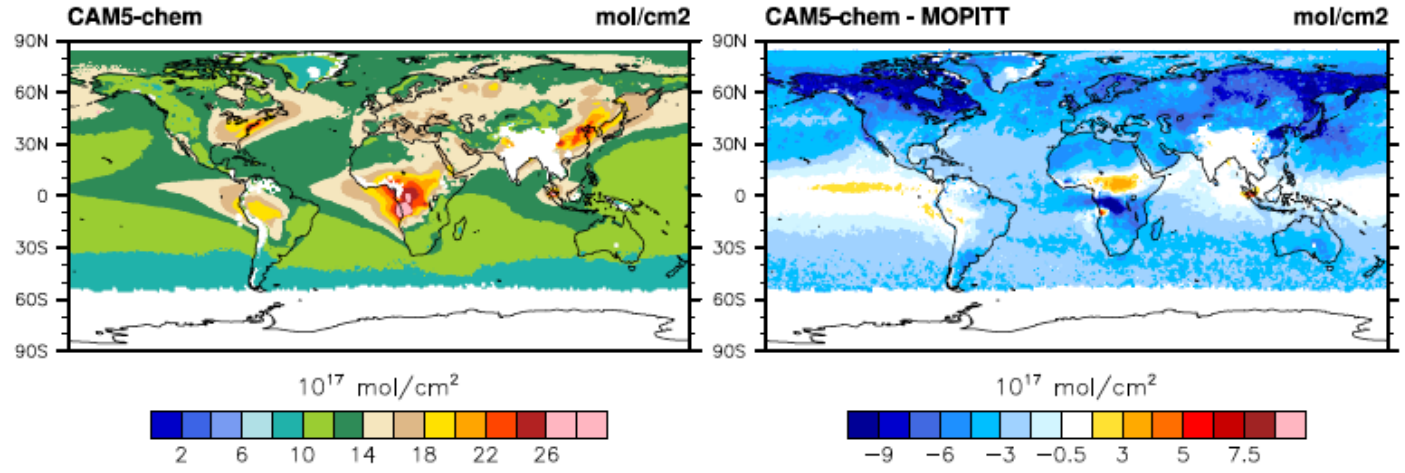
CAM5

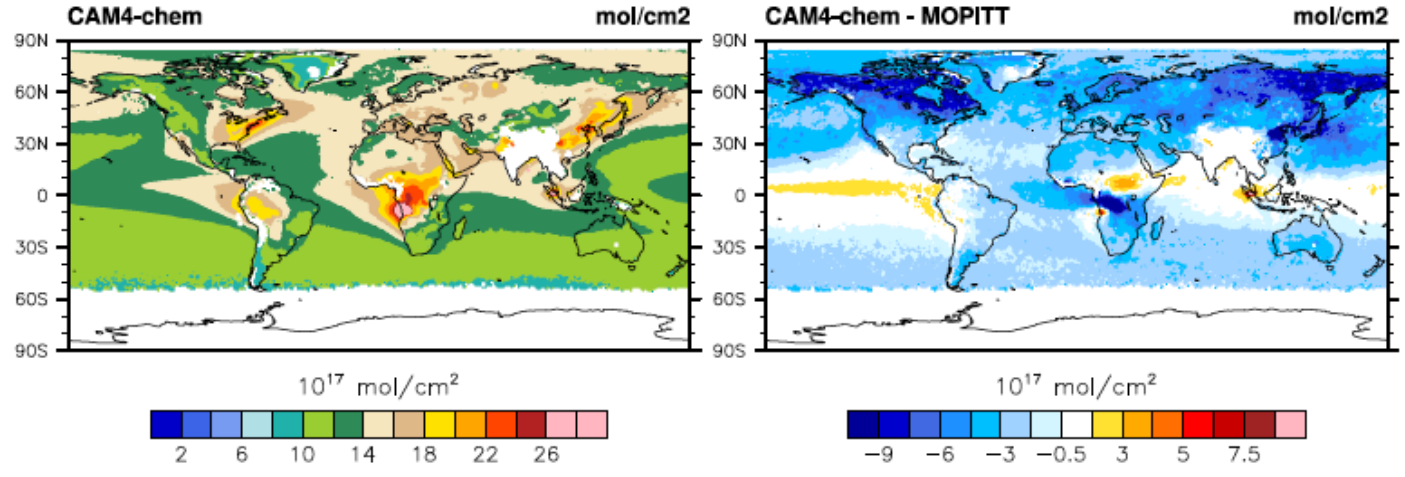
CAM4

JJA







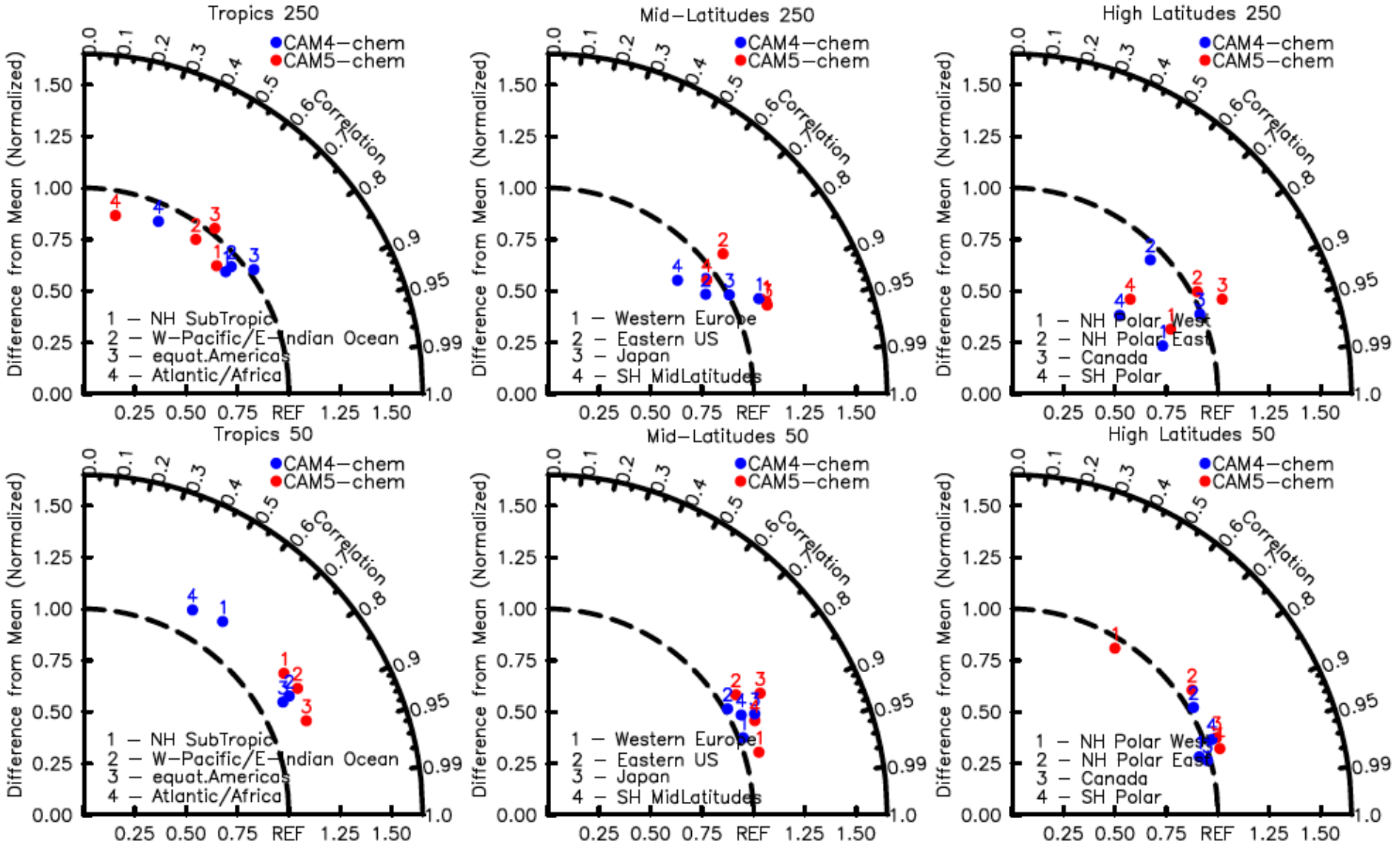


Comparison to MOPITT climatology: April:

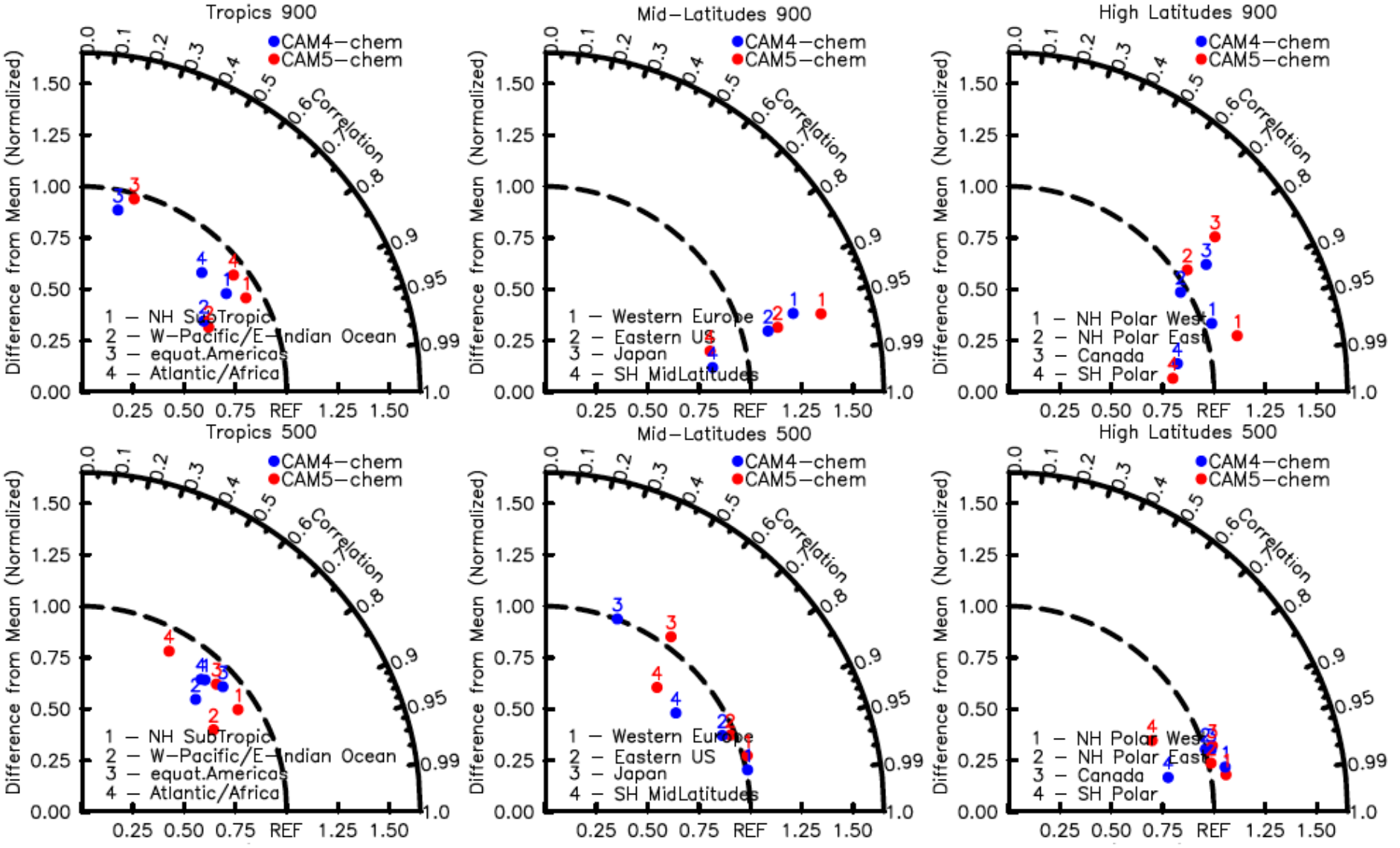
- CO Largely underestimated
- Improved presentation in CAM4-chem (longer lifetime)

Better agreement in other seasons

CAM4/CAM5 with Chemistry



CAM4/CAM5 with Chemistry



CAM5: adding interactive Chemistry

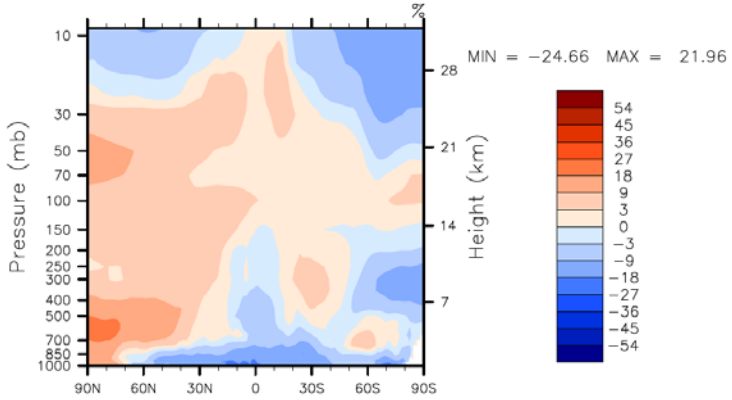
CAM5:

- Fixed gases: N_2, O_2, H_2O, O_3, OH, NO_3, HO_2 (prescribed with monthly mean values from CAM5Chem
- Chemically active: H_2O_2, H_2SO_4, SO_2, DMS, SOAG (Gas-phase chemistry, photolysis)
- Aerosol formation of SO_4: aq-phase, nucleation, from H_2SO_4

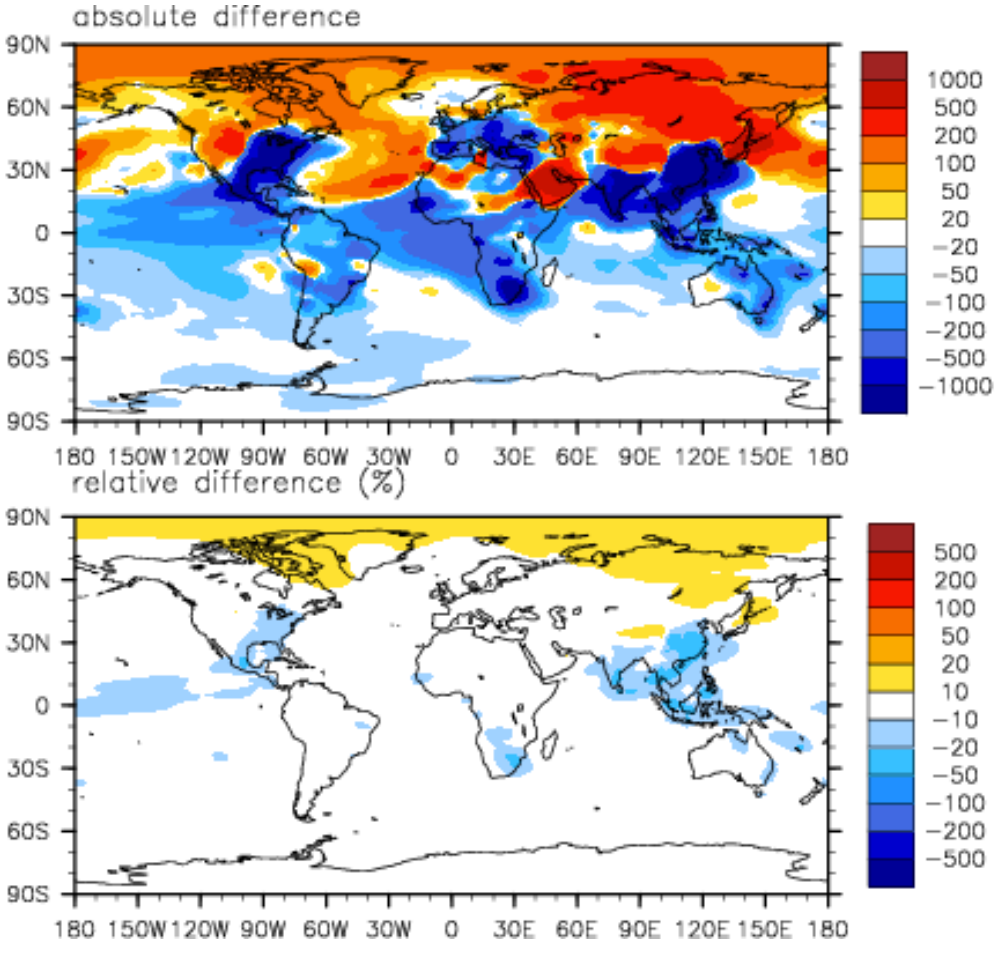
CAM5Chem

- Comprehensive chemistry mechanism (over 150 species)
- Coupling between tropospheric aerosols and heterogeneous reactions over tropospheric surface area density

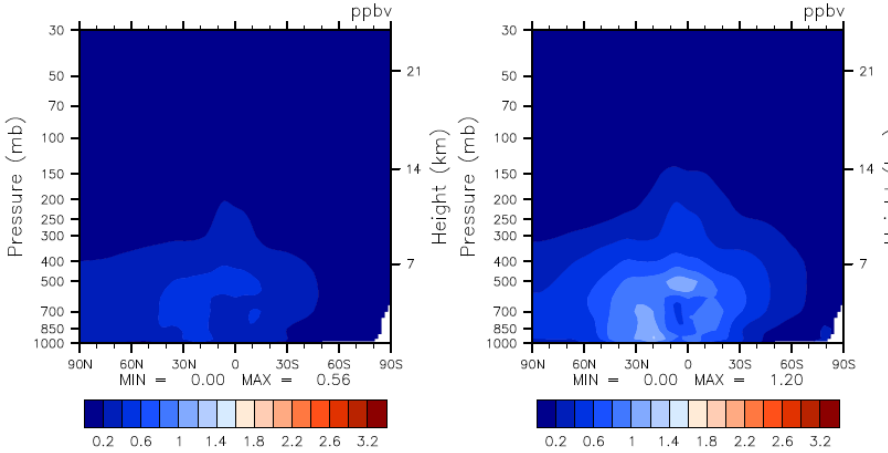
SO_4 relative difference (Climo-Chem)



Total Burden ANN SO4 Climo - Chem



H_2O_2 CAM5-Climo and CAM5-Chem



Climo compared to Chem, 20 years of simulation

- more SO_4 in high latitudes (more H_2SO_4 production in the gas-phase due to differences in OH (monthly avg. vs OH daily cycle)
- Less SO_4 in polluted areas (Less aq-phase, due to less H_2O_2)

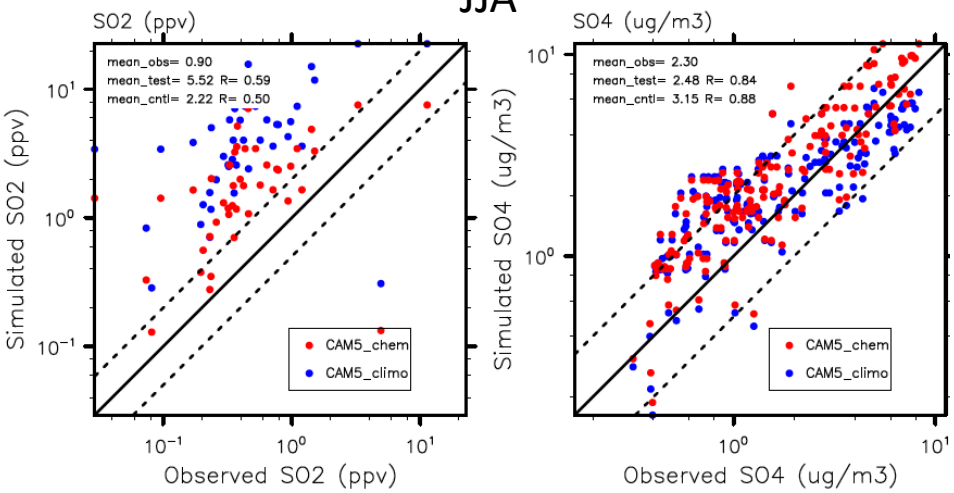
-> importance of interactive chemistry

Comparisons to Observations

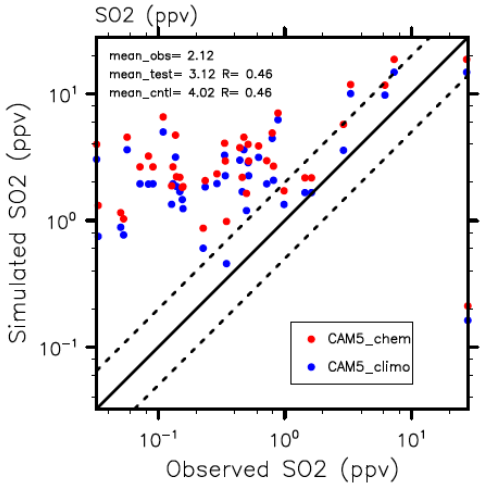
IMPROVE Surface Observations

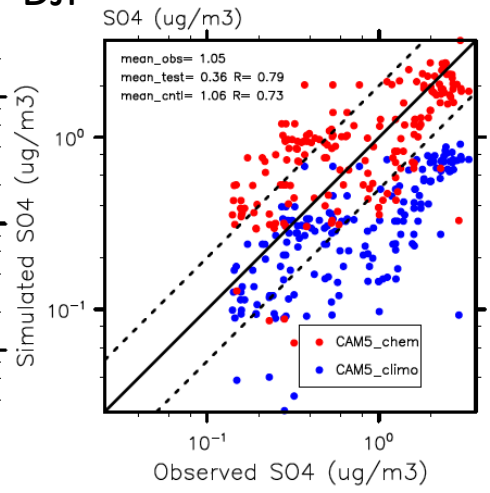
CAM5-Chem
CAM5-Climo

JJA

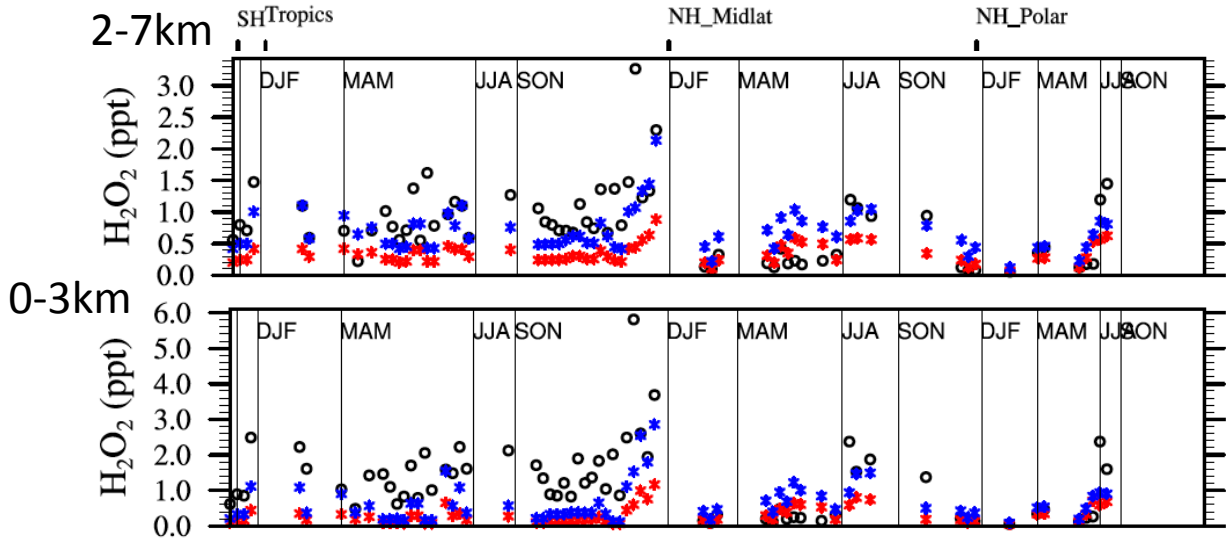


DJF

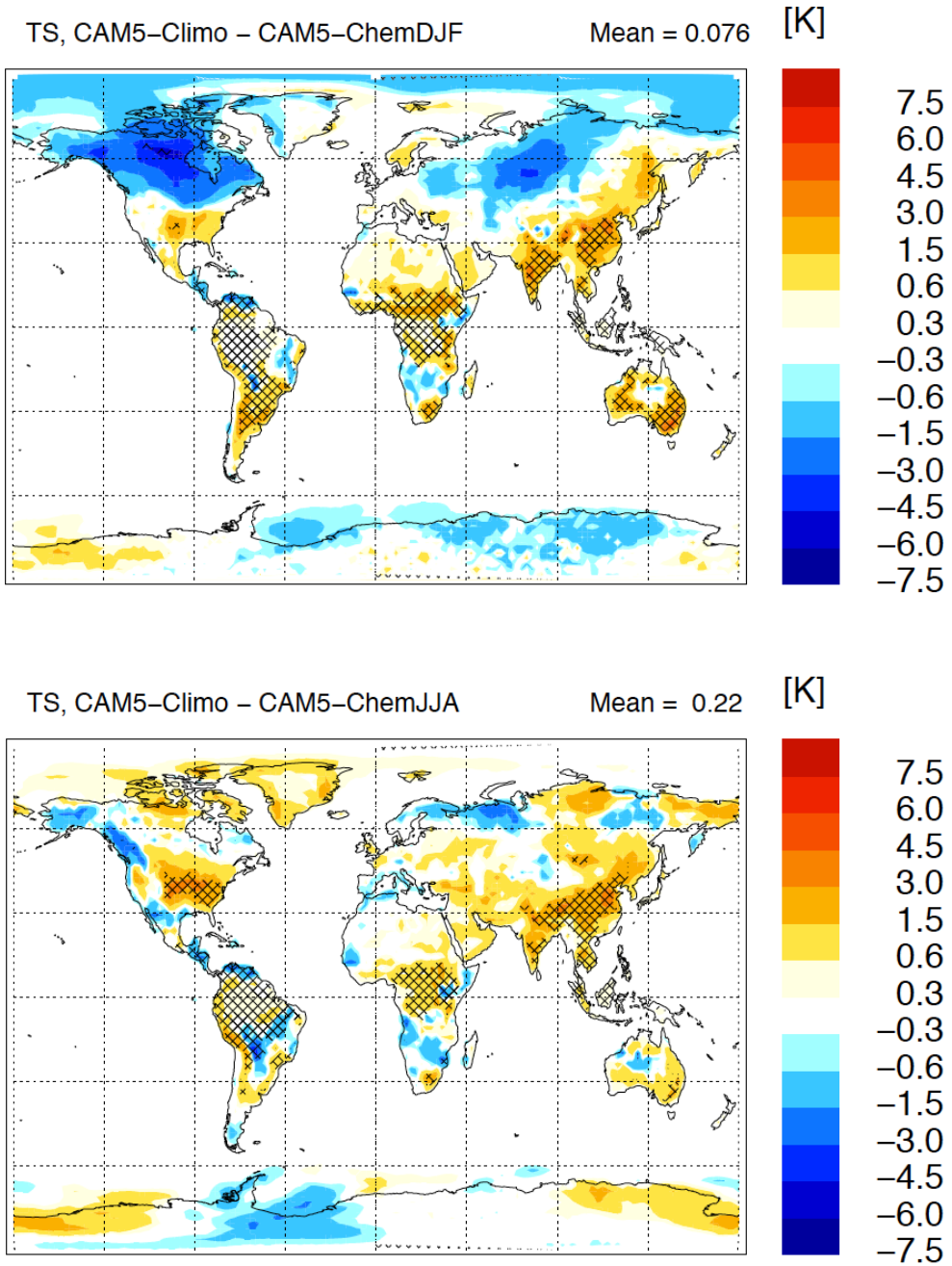




Aircraft Observations



CAM5-Climo
CAM5-Chem



Climatological minus Full-Chemistry Run:

- Surface temperature changes significant in highly polluted regions (-> changes in aerosols)
- US summer time warm bias
- Some changes in high latitudes

Hashed areas: significantly different on the 5% level based on the student t-test