Comparing present-day methane lifetime estimates within CAM4-chem and CAM5-chem configurations

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Description and evaluation of tropospheric chemistry and aerosols in the Community Earth System Model (CESM1.2)

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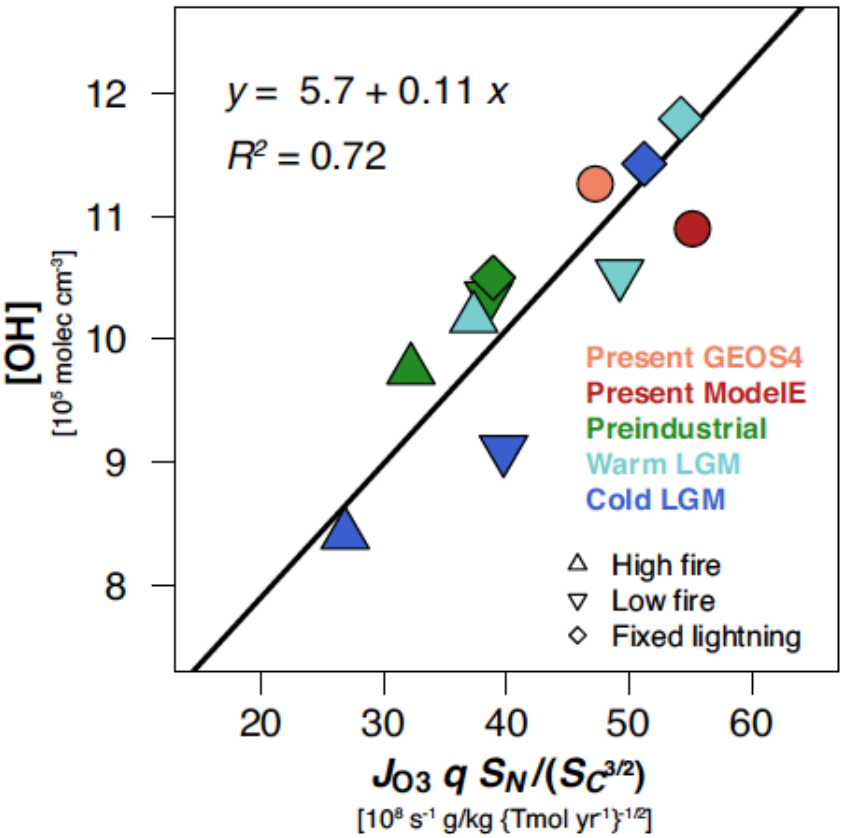
Question: What controls Methane Lifetime in CESM?

Naik et al., 2013

ACCMIP Models

τ_{CH_4} (years)		
1850	1980	2000
9.3	8.8	8.4
9.1	10.1	10.0
8.7	9.7	9.4
8.9	9.6	9.1
8.6	9.7	9.6
8.9	9.7	9.4
11.9	11.4	10.6
10.4	9.8	9.2
11.6	12.1	11.6
10.1	10.7	10.5
*	*	8.7
8.2	7.5	7.1
10.7	9.9	9.2
9.7	9.6	9.1
9.8	*	9.9
15.0	14.7	14.0
10.1 ± 1.7	10.2 ± 1.7	9.7 ± 1.5
17.3	16.4	15.6
Obs. estimates		$10.2^{+0.9}_{-0.7}$, 11.2 ± 1.3

Murray et al., 2014 using GEOS-Chem



Experiments

CESM1.2.2, F2000 fixed SSTs, same emissions, about similar global lightning NOx burden, same chemistry (trop/strat. Chemistry)

- CAM5-chem vs CAM4-chem: 20 years free running
- Specified Dynamics SD-CAM5-chem, SD CAM4-chem (year 2000 emissions) Meteorology from 2000-2010.
- CAM5-MAM4-chem
- Sensitivity experiments to investigate changes in methane lifetime

Differences between CAM4 and CAM5

CAM5-chem vs. CAM4-chem:

- Modal vs. bulk aerosol model
- Differences in treatment of cloud, convection, turbulent mixing
- 26L vs 30 horiz. Levels (56L for Specified Dynamics)

-> different aerosol burden and Surface Area Density (SAD)

-**> influences heterogeneous and aqueous reaction in particular HOx, and NOx**

-> differences in chemistry

Global Budgets

CESM 1.2.2	CAM4-Chem	SD CAM4-Chem	CAM5-Chem	SD CAM5-Chem
Sim. Years	20 years	2000–2009	20 years	2000–2009
Meteorology	CAM4	MERRA (10 %)	CAM5	MERRA (10 %)
Aerosol	BAM	BAM	MAM3	MAM3
Vert. Res.	26L	56L	30L	56L
CH_4 Burden (Tg)	4153	4074	4103	4064
CH_4 Lifet. (yr)	8.82	8.35	8.31	7.83
CO Burden (Tg)	308	299	289	283
CO Lifet. (yr)	0.135	0.128	0.134	0.120
O_3 Burden (Tg)	310	309	310	313
O_3 Lifet. (days)	24	24	22	24
O_3 Net. chem.[a] ($Tg\,yr^{-1}$)	515	474	530	480
O_3 STE ($Tg\,yr^{-1}$)	344	357	390	362
LNO_x ($Tg\,N\,yr^{-1}$)	4.3	4.3	4.6	4.3

Methane Lifetime:

Free Running CAM4-chem: 8.82 yrs

½ yr

Specified Dynamics: CAM4-chem: 8.35 yrs

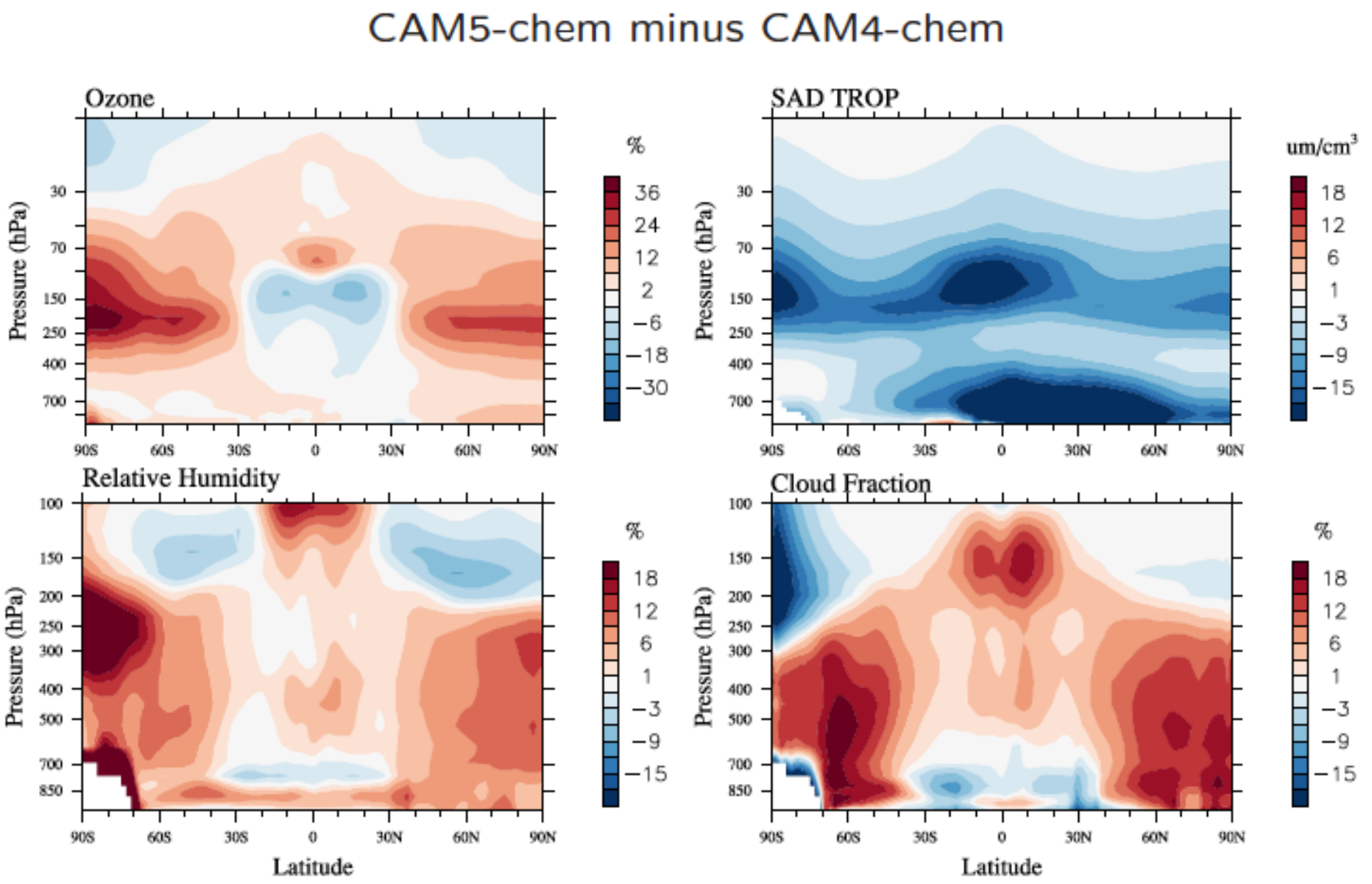
½ yr

½ yr

Free Running CAM5-chem: 8.31 yrs

Specified Dynamics: CAM5-chem: 7.83 yrs

What are the drivers for differences in CH_4-Lifetime in CESM?



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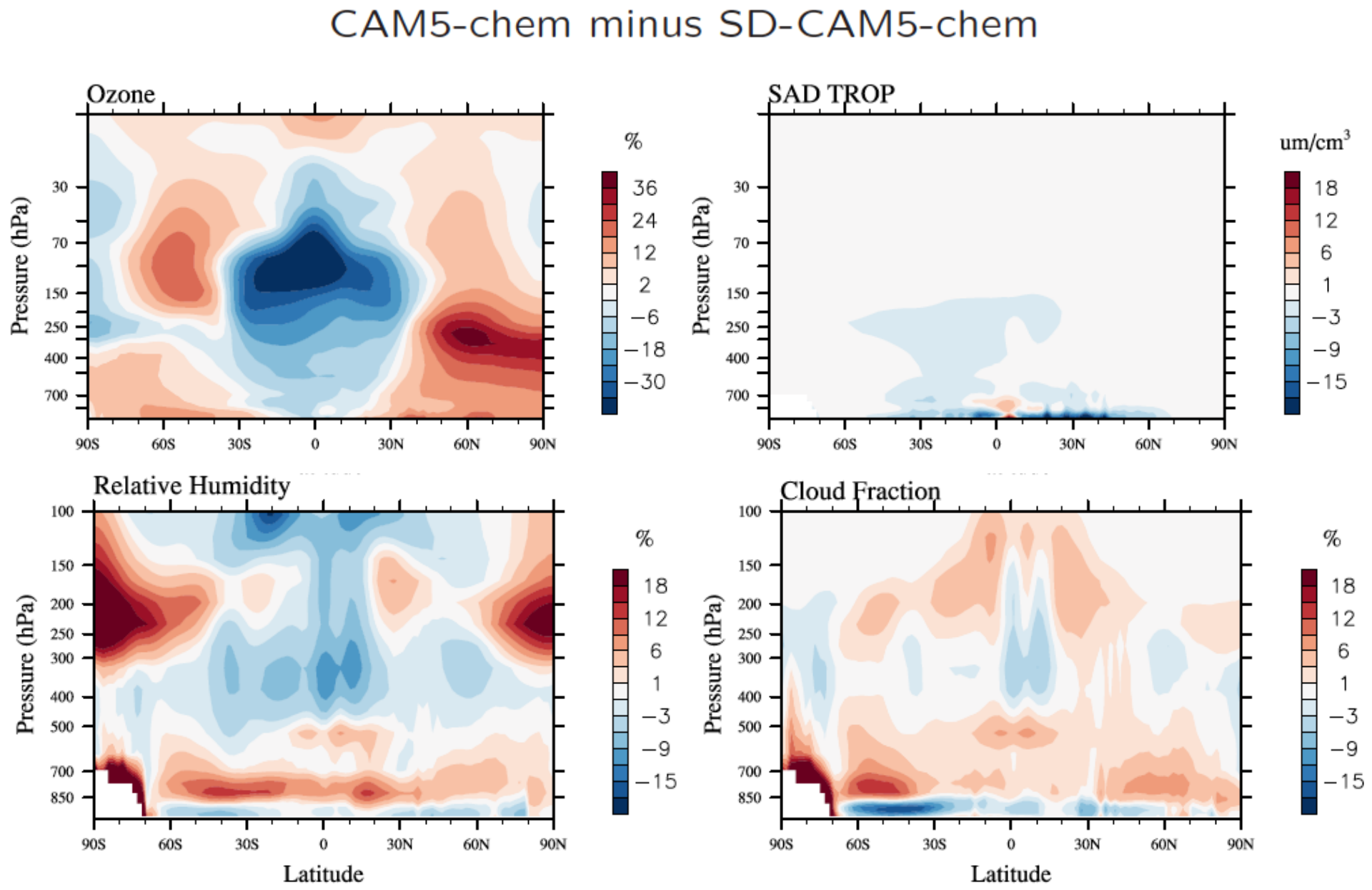
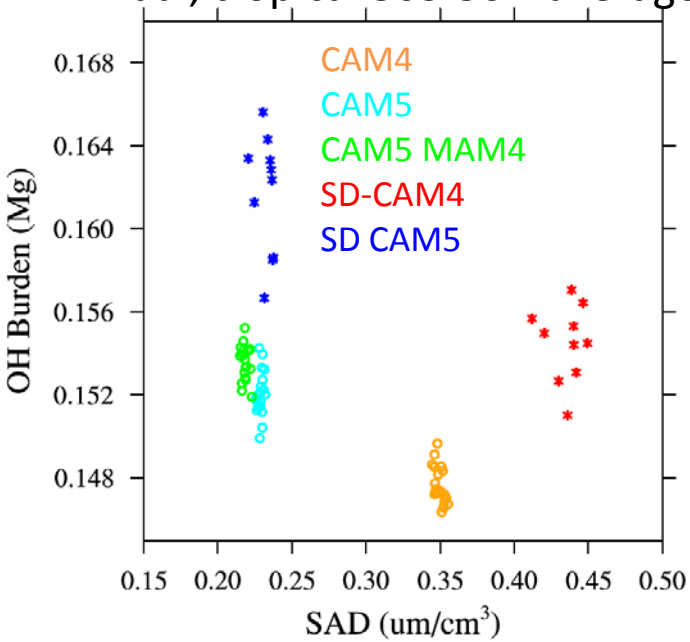
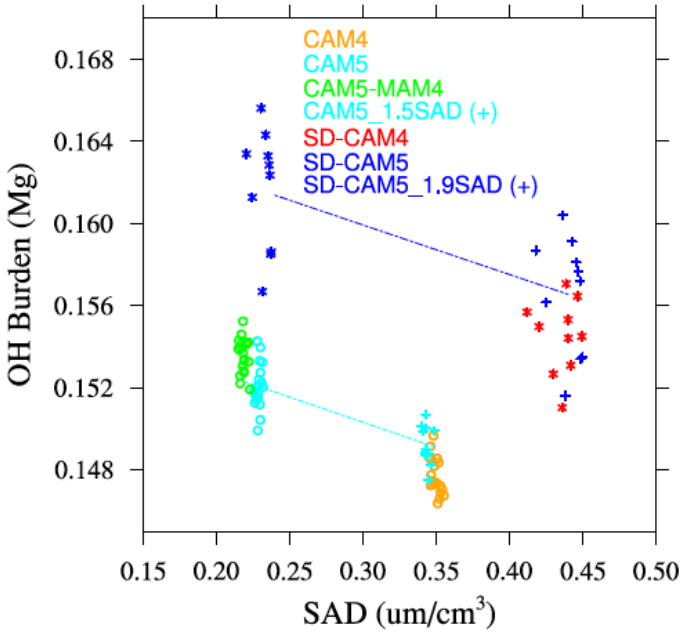


Correlations between OH burden and other variables

Annual, tropical 30S-30N averages:





Correlation between OH and Trop. Surface Area Density:

- Increased het. reactions lead to increased uptake of HOx -> increased H_2O_2 -> **reduction of OH**

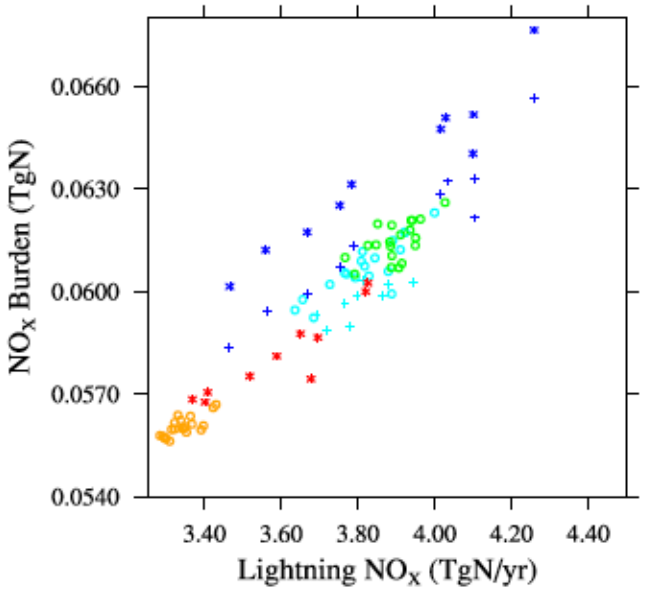
-> changes in aerosol formation

- Increased uptake of N_2O_2 -> reduced NOx

-> change in ozone

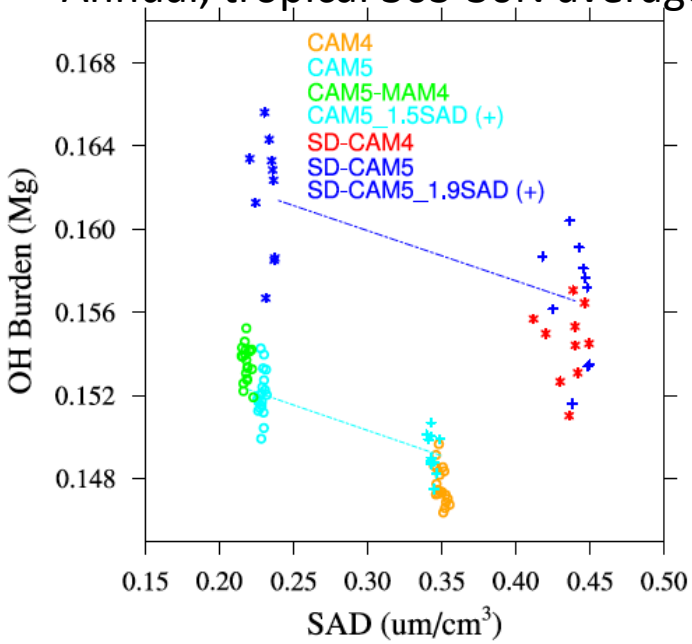
Sensitivity Experiments, adjusted SAD to CAM4-chem:

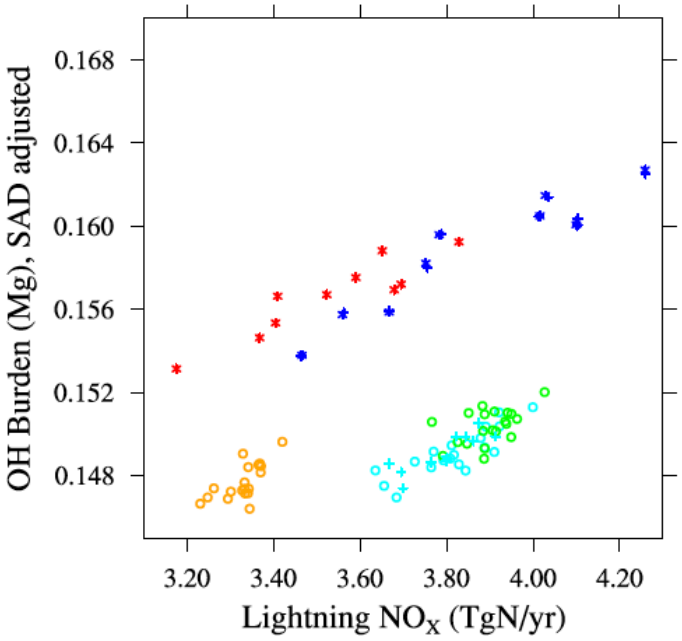
- CAM5-chem 1.5*SAD
- SD-CAM5-chem * 1.9SAD



Correlations between OH burden (adjusted to SAD)

Annual, tropical 30S-30N averages:





Differences in SAD important driver for CH_4-lifetime differences

-> leads to approximately half a year differences between CAM4 and CAM5

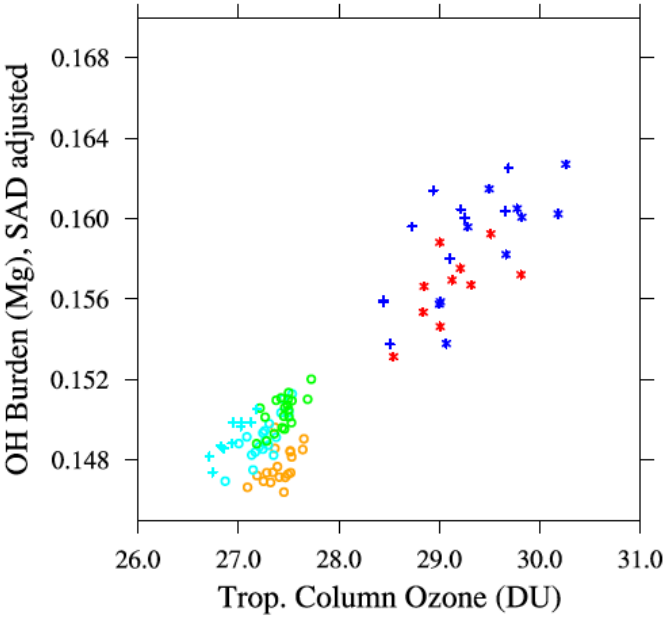
OH is adjusted to SAD = 0.35 um/cm³ and correlated to other variables

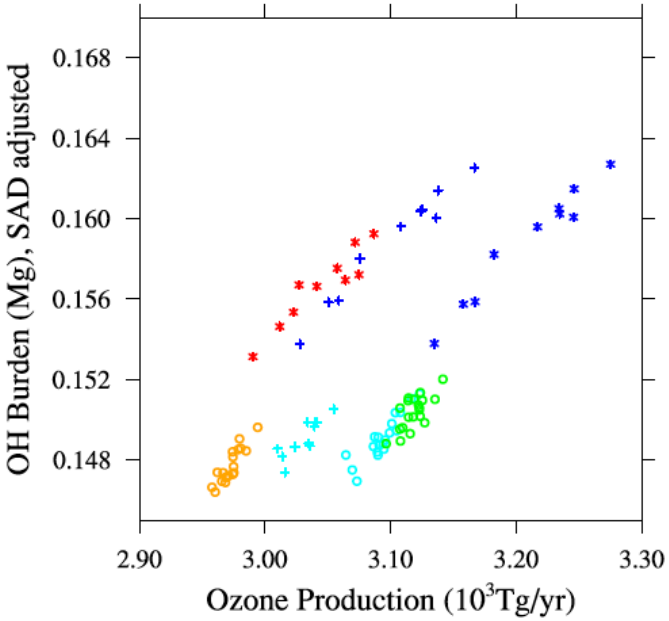
- correlation to lightning NOx (LNOx)

-> Difference of LNOx explains half the differences between free running and specified dynamics simulations.

Correlations between OH burden (adjusted to SAD)

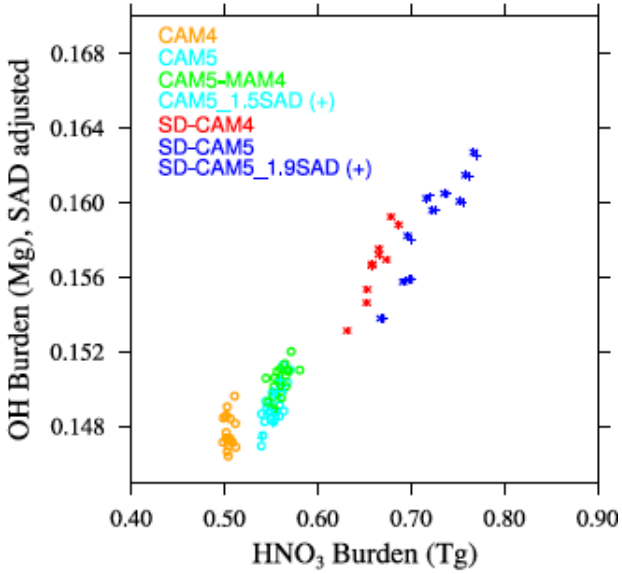
Annual, tropical 30S-30N averages:





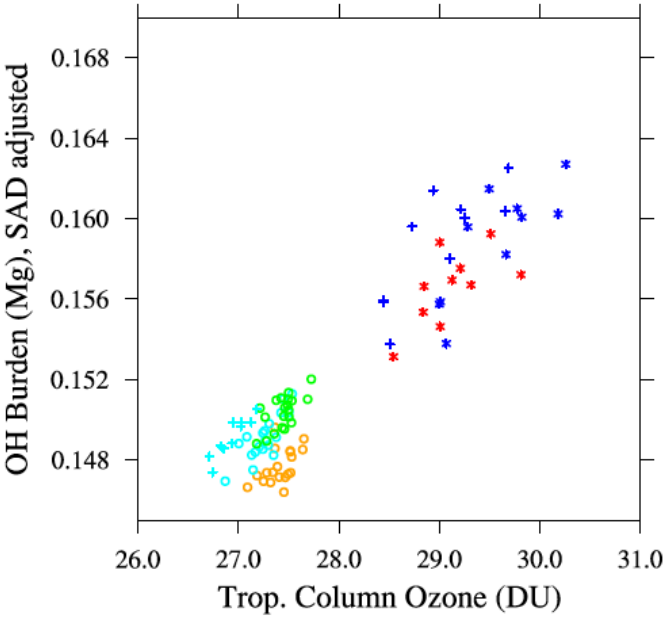
OH is adjusted to SAD = 0.35 um/cm^3 and correlated to other variables

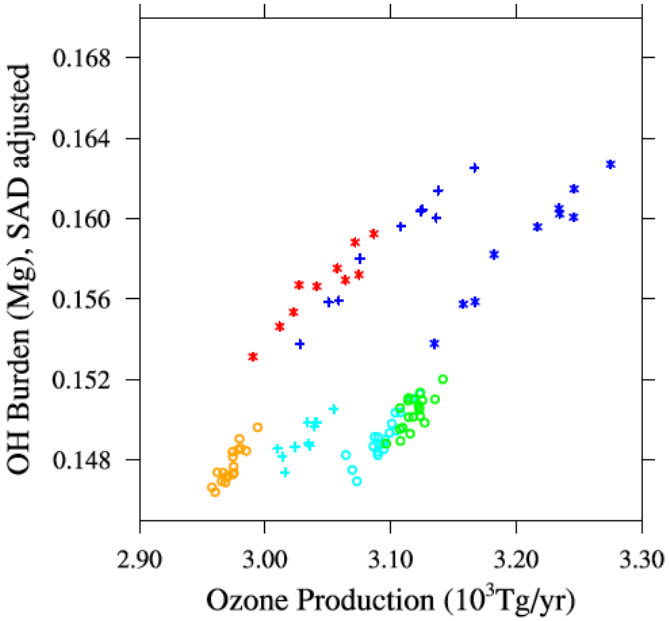
- Correlation to tropospheric column ozone
- Caused not only by differences in ozone production, but likely also by differences in strat/trop exchange, more ozone -> more OH



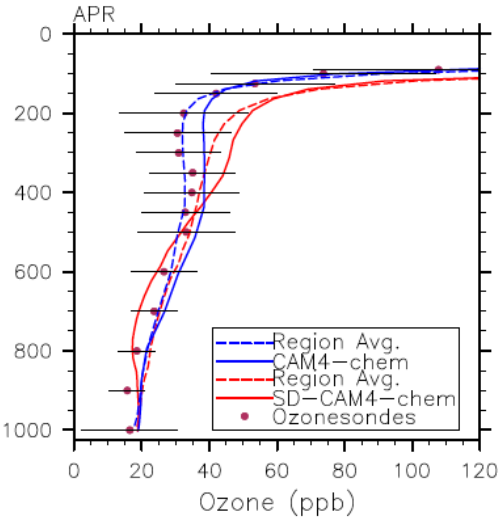
Correlations between OH burden (adjusted to SAD)

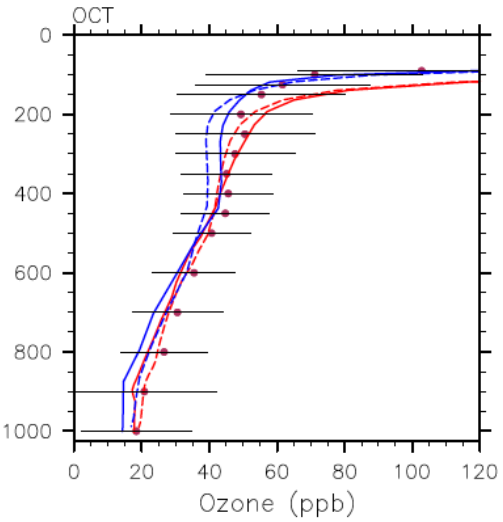
Annual, tropical 30S-30N averages:





Constrain with Ozonesonde observations





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- Correlation to tropospheric column ozone
- Caused not only by differences in ozone production, but likely also by differences in strat/trop exchange, more ozone -> more OH

Summary

Important drivers for methane lifetime differences in CESM:

- **Differences in tropospheric surface area density**

-> explain approximately half a year difference between CAM4 and CAM5

- **Differences in lightning NOx (LNOx)**

-> explain about half the difference in CH_4-lifetime between free running and specified dynamics simulations

- **Differences in tropospheric column ozone**

-> explain other half of the differences between free running and SD simulations,
likely caused by differences in trop/strat exchange