



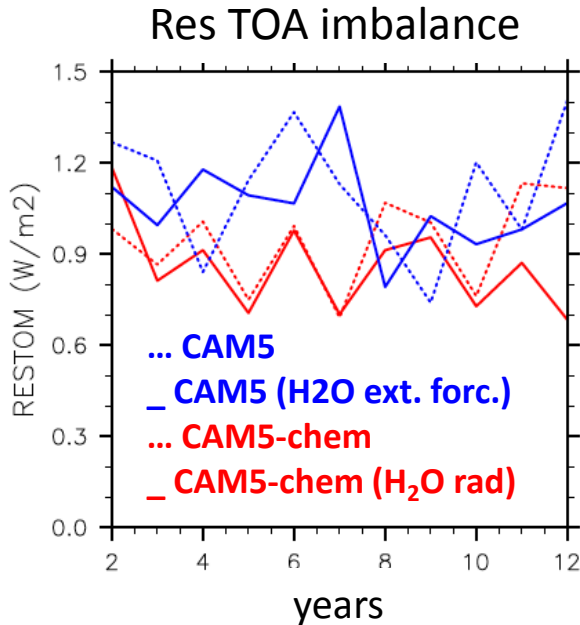
Understanding the importance of chemistry representation in CESM1-CAM5

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CAM-chem team*

- Radiative impact of different chemistry descriptions
- Improved aerosols formation using hourly input data set for chemistry in CAM5
- Importance for climate



Comparison between CAM5 and CAM5-chem



**Solid lines: most similar setup
between CAM5 and CAM5-chem
-> larger imbalance in CAM5**

**Model Setup CESM 1.2.2, F2000 case,
CLM4.0, bgc -cn**

CAM5

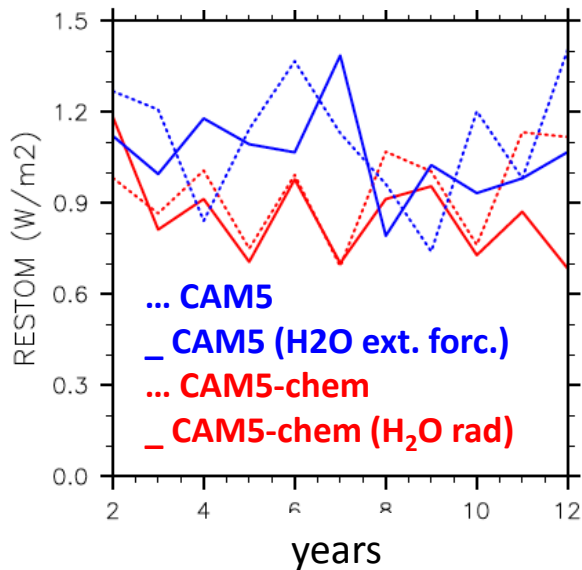
- Simple chemistry (see later)
- Wet and dry deposition of H_2O_2 , H_2SO_4 , SO_2 (Neu scheme for wet deposition)
- Monthly fields: HO_2 , NO_3 , O_3 , OH
- Added H_2O external forcing for methane oxidation (solid)

CAM5-chem

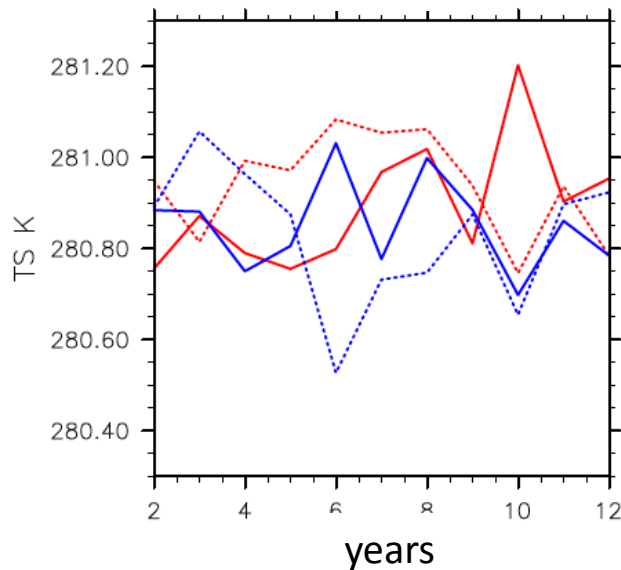
- Comprehensive tropospheric and strat. chemistry (145 chem./aer. species)
- Only H_2O radiatively active (solid)
- Wet and dry deposition (Neu scheme for wet)
- Used to derive input fields for CAM5

Comparison between CAM5 and CAM5-chem

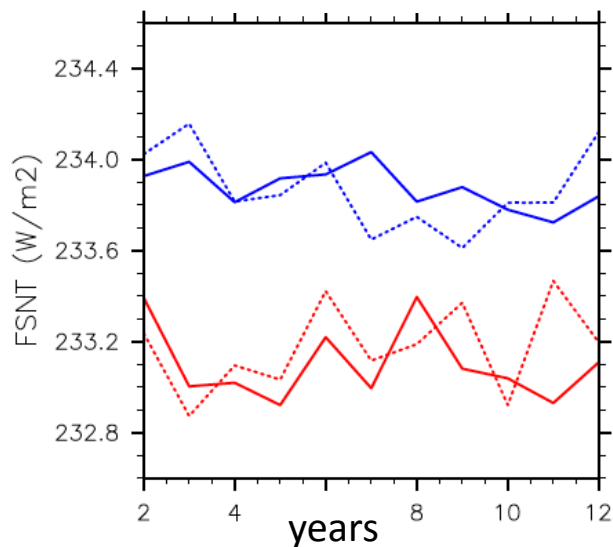
Res TOA imbalance



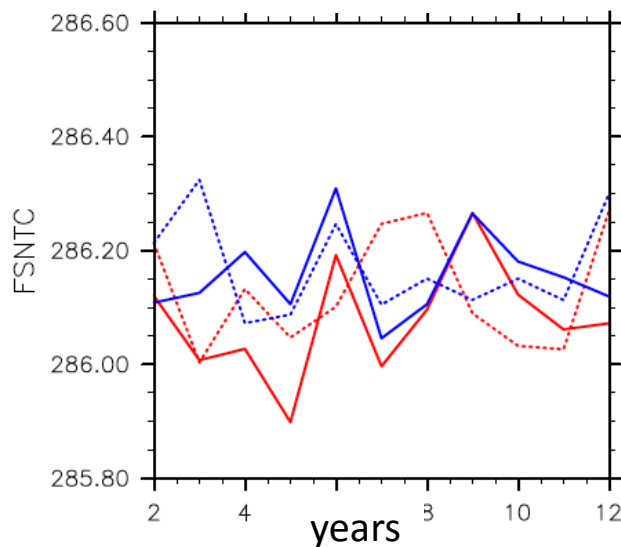
TS Land



FSNT (net SW TOA)



FSNTC (clear sky)



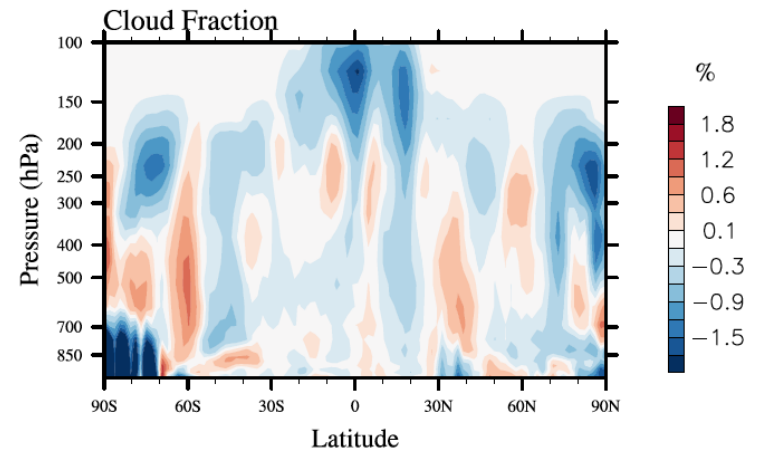
- Short-wave net forcing for clear sky about the same.
- Less outgoing net short-wave radiation in CAM5 compared to CAM5-chem

-> smaller SW cloud forcing without chemistry

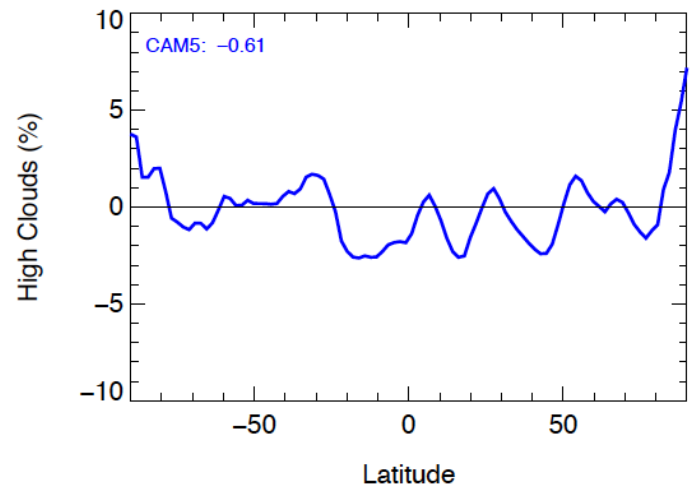
Comparison between CAM5 and CAM5-chem

	CAM5	CAM5-chem
RESTOM	1.05 +/- 0.1	0.82 (0.90)
FSNT	233.9 +/- 0.2	233.1
FSNTC	286.2 +/- 0.1	286.1
SWCF	-52.3	-53.0
CLDHGH	38.2	38.5
CLDMED	27.2	27.4
CLDLOW	44.2	44.2
SO ₄ (TgS)	0.448	0.477
SO ₄ gase-phase Prod (TgS/yr)	13.33	12.69
SO ₄ aqu-phase Prod (TgS/yr)	27,.83	31.16

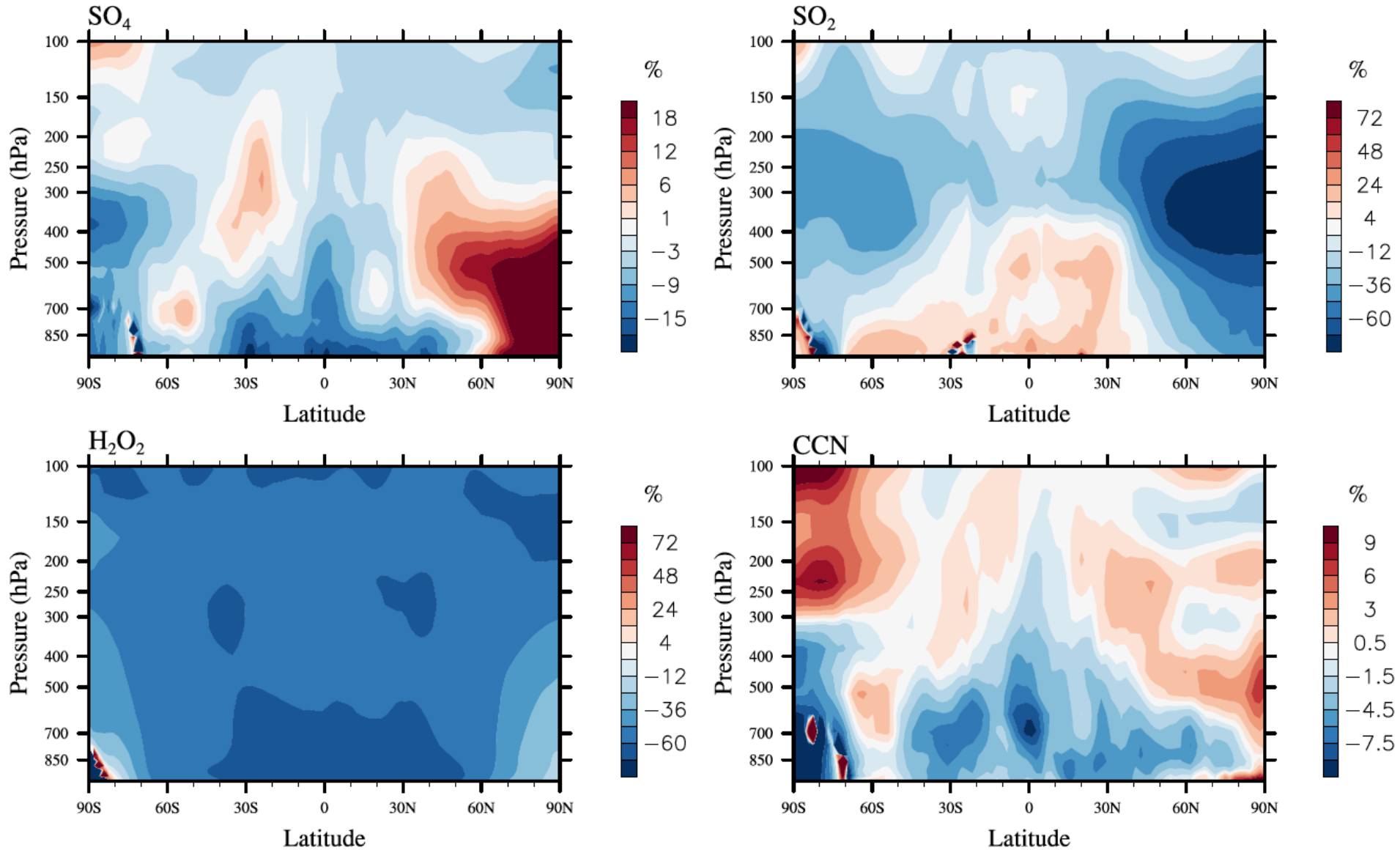
Differences in cloud Fraction:



relative difference of high cloud frac.



Comparison between CAM5 and CAM5-chem



Where do these differences come from? How can they be improved?

Differences between CAM5 and CAM5-chem

CAM5:

Fixed: (N₂, O₂, H₂O,) O₃, OH, NO₃, HO₂
(prescribed with monthly mean values)

Chemically active: H₂O₂, H₂SO₄, SO₂, DMS, SOAG

Chemistry: photolysis of H₂O₂, DMS,

[usr_HO2_HO2] HO₂ + HO₂ -> H₂O₂
H₂O₂ + OH -> H₂O + HO₂

[usr_SO2_OH] SO₂ + OH -> H₂SO₄
DMS + OH -> SO₂

Aerosol formation of SO₄:

Chemically: from SO₂ -> H₂SO₄

aq-phase (H₂O₂, O₃), nucleation, from H₂SO₄

Added H₂SO₄ deposition (was missing in CESM1_2_0)

CAM5-Chem:

Comprehensive tropospheric and stratospheric chemistry

Photolysis, DMS,

[OH_OH_M] OH + OH + M -> H₂O₂ + M

[OH_H2O2] H₂O₂ + OH -> H₂O + HO₂

[usr_HO2_HO2] HO₂ + HO₂ -> H₂O₂ + O₂

[H2O2_O] H₂O₂ + O -> OH + HO₂

[CL_H2O2] CL + H₂O₂ -> HCL + HO₂

[usr_HO2_aer] HO₂ -> 0.5*H₂O₂ (not in CAM5)

[usr_SO2_OH] SO₂ + OH -> H₂SO₄

DMS + OH -> SO₂

-> much more comprehensive description of chemistry (including H₂O₂ and Ozone)

-> impact on SO₄ formation

CAM5-hourly: prescribed hourly fixed fields derived using 5 year averages.

CAM5-hourly-het: adding heterogeneous production of H₂O₂

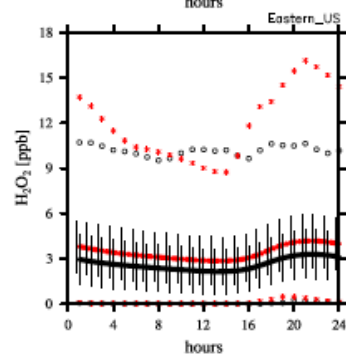
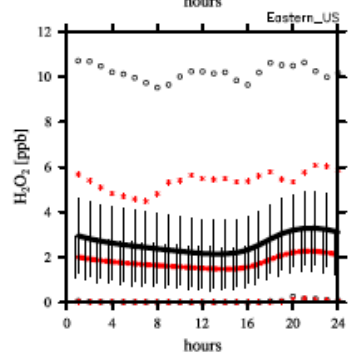
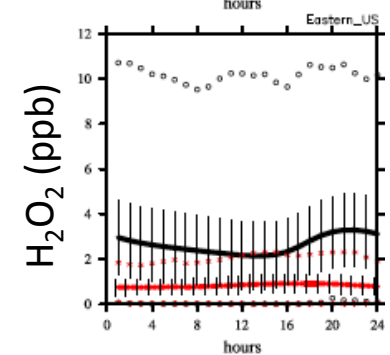
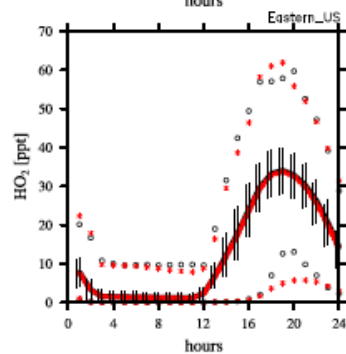
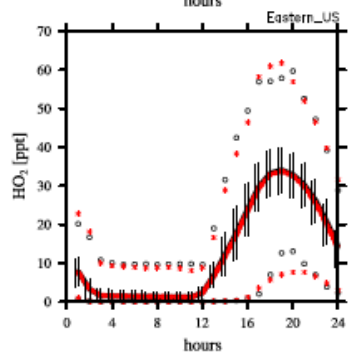
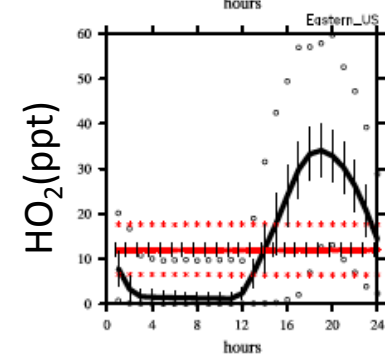
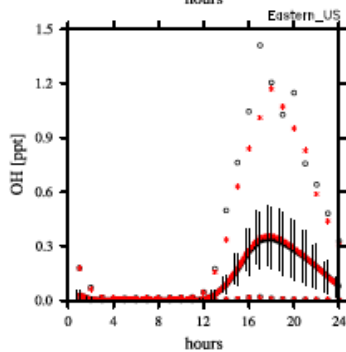
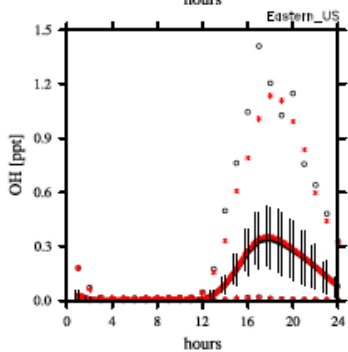
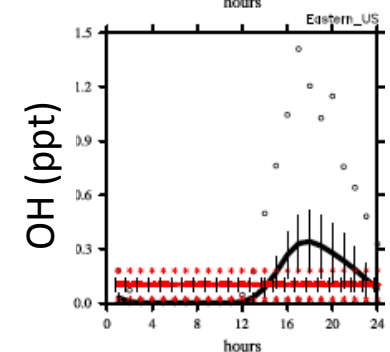
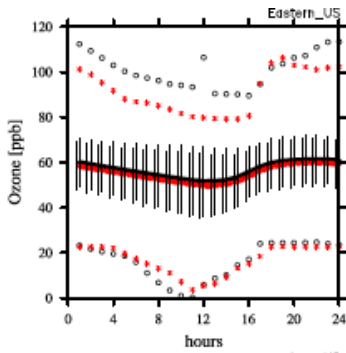
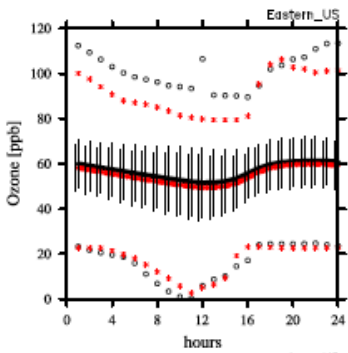
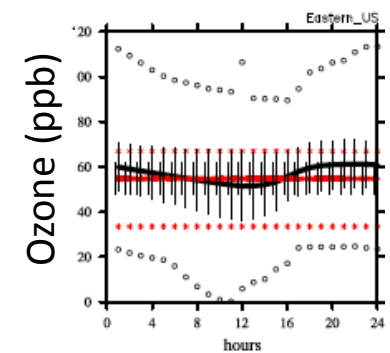
CAM5**CAM5-hourly****CAM5-hourly-het**

Diurnal Cycle Over Eastern US CAM-chem vs. CAM5

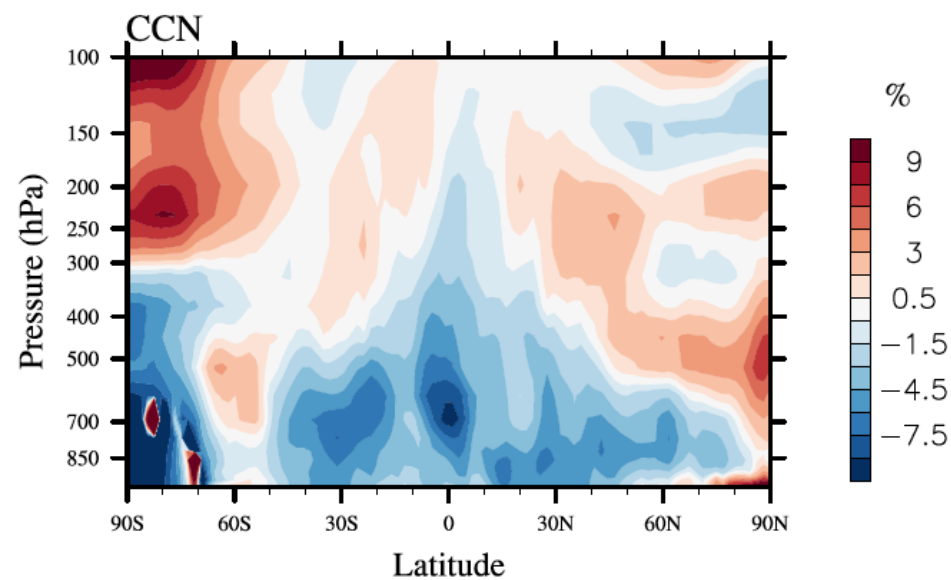
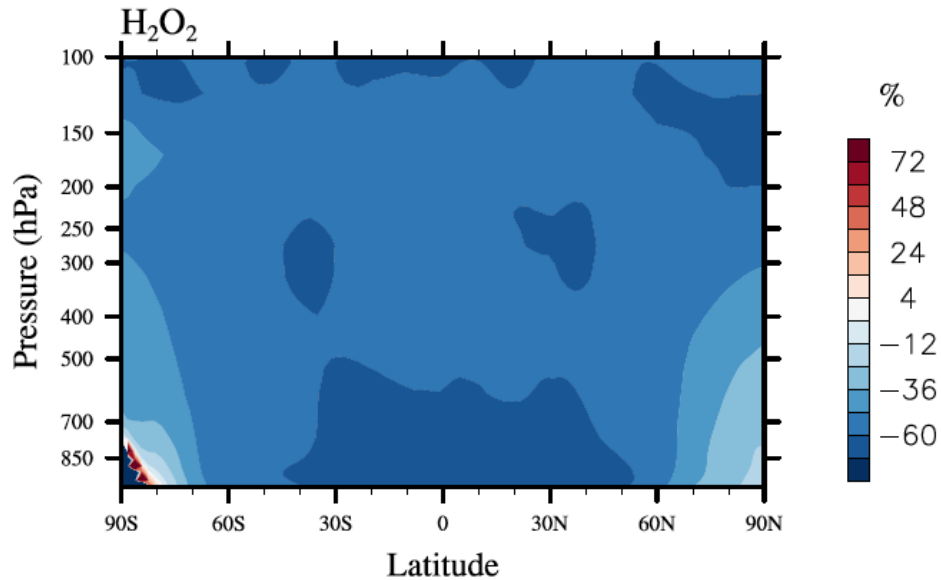
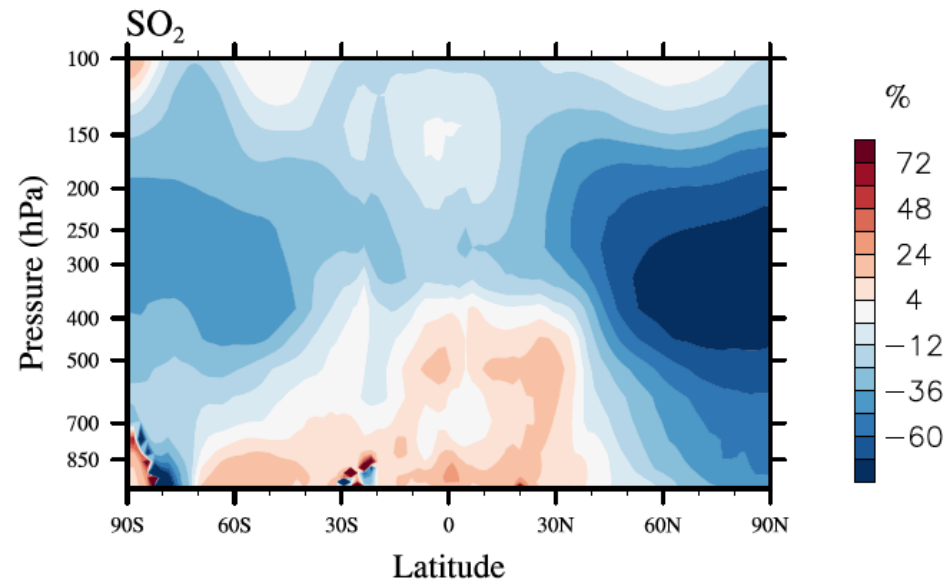
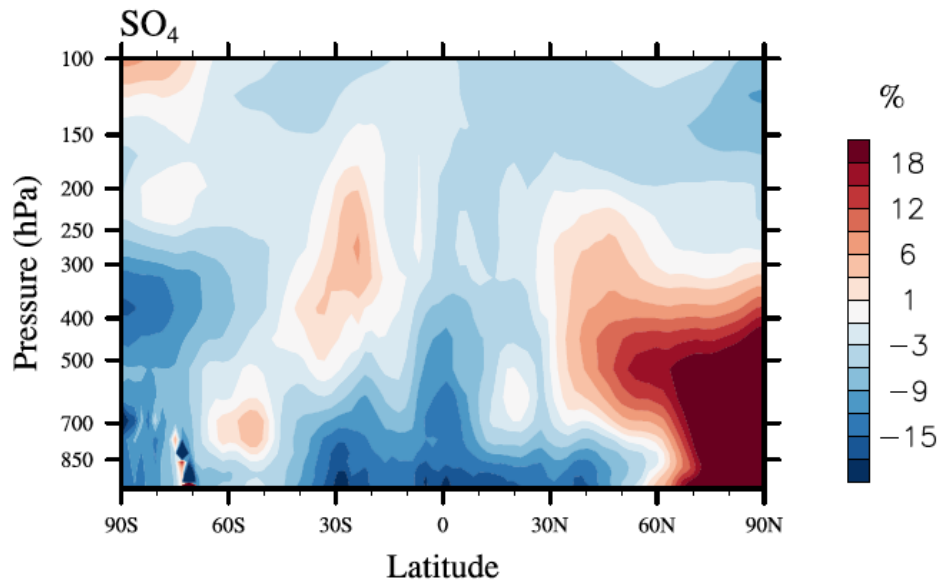
Monthly mean OH and HO₂
does produce too little H₂O₂
-> changes in formation of SO₄
-> impact on direct and indirect effect

- Use of hourly input file for O₃, OH, HO₃ and NO₃ (not shown) improves H₂O₂
- Additional OH+OH->H₂O₂ on aerosols, results in slightly too much H₂O₂ (not further discussed)

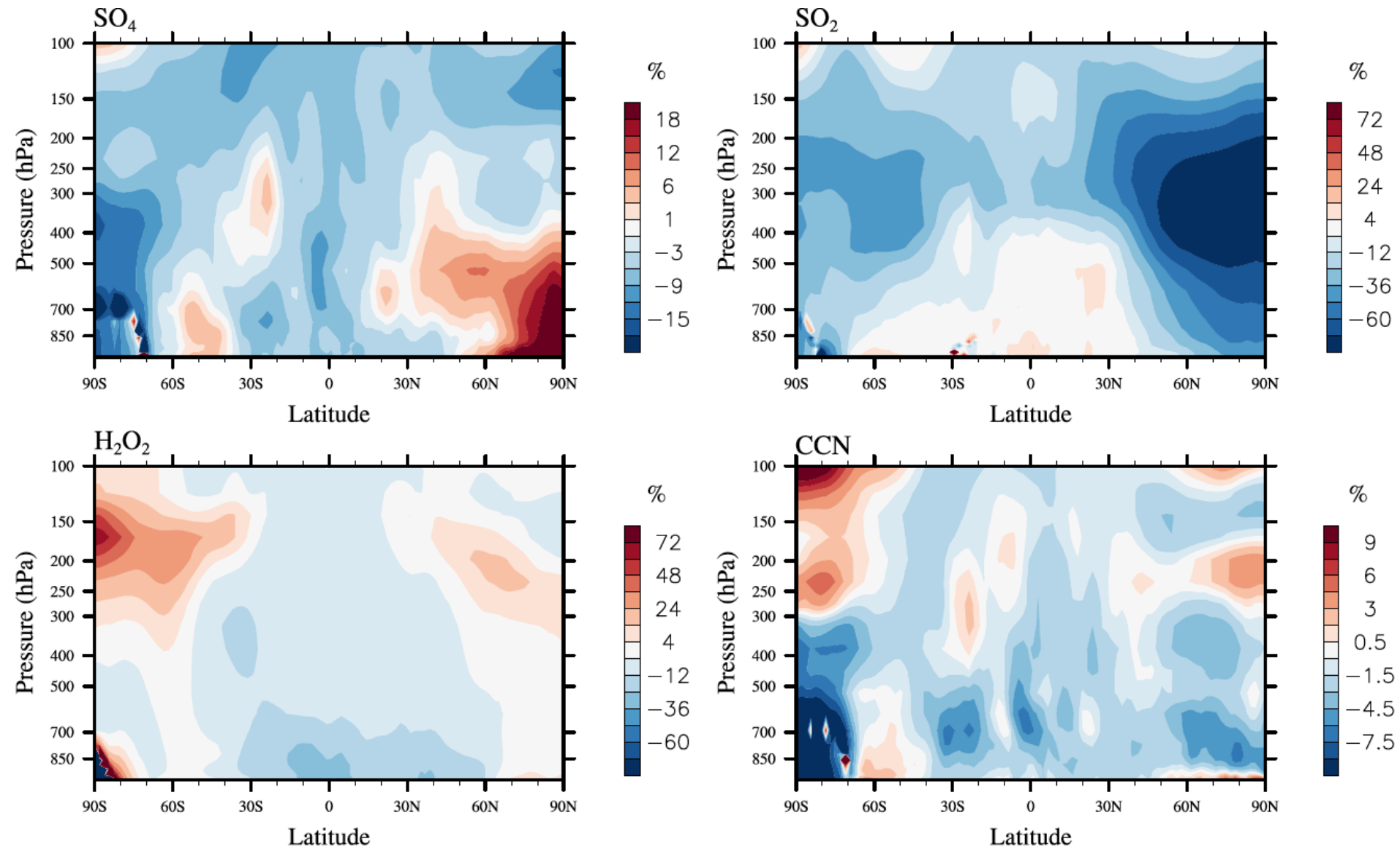
About 30% more processing time required for hourly input.



Comparison between CAM5 and CAM5-chem



Comparison between CAM5-hourly and CAM5-chem



CAM5 - CAM5-chem

CAM5-hourly – CAM5-chem

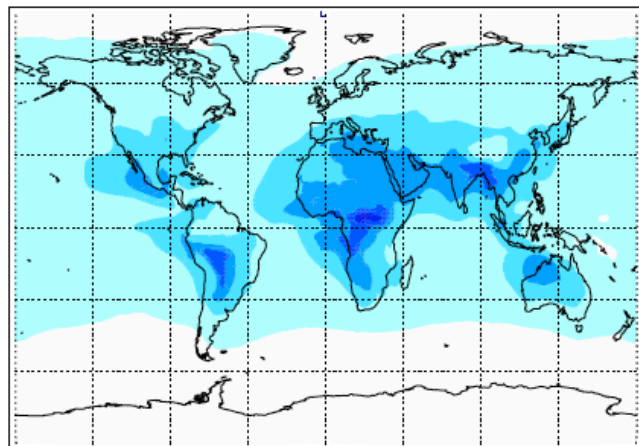
Boundary Layer

H₂O₂

H2O2, CAM5 – CAM5chem ANN

Mean = -0.58

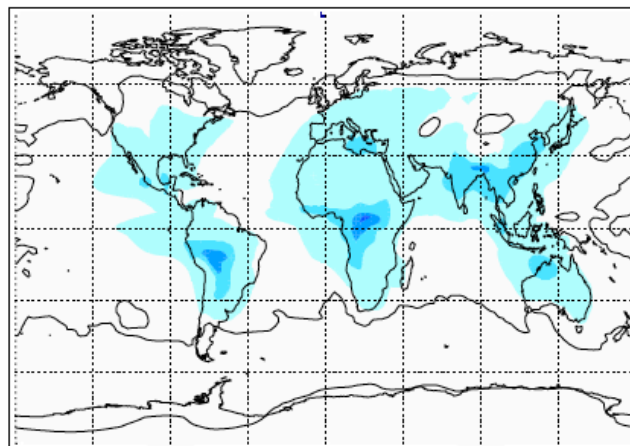
[ppb]



H2O2, CAM5-hourly – CAM5chem ANN

Mean = -0.17

[ppb]

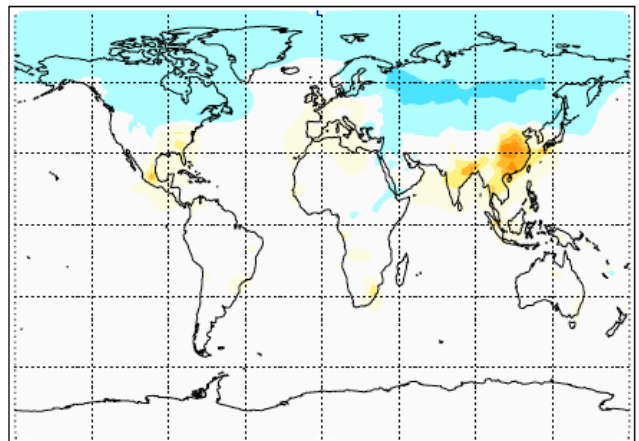


SO₂

SO2, CAM5 – CAM5chem ANN

Mean = 0.0056

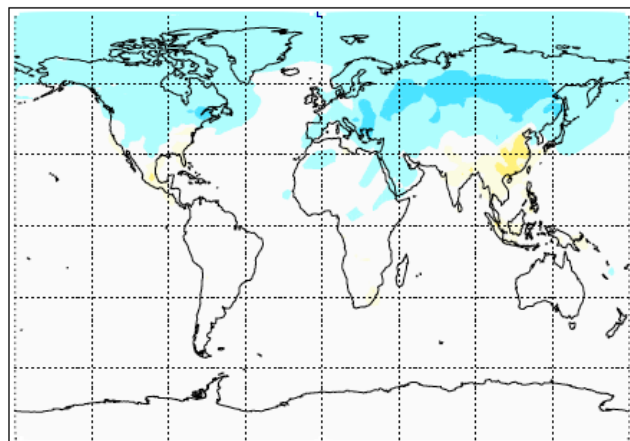
[ppt]



SO2, CAM5-hourly – CAM5chem ANN

Mean = -0.020

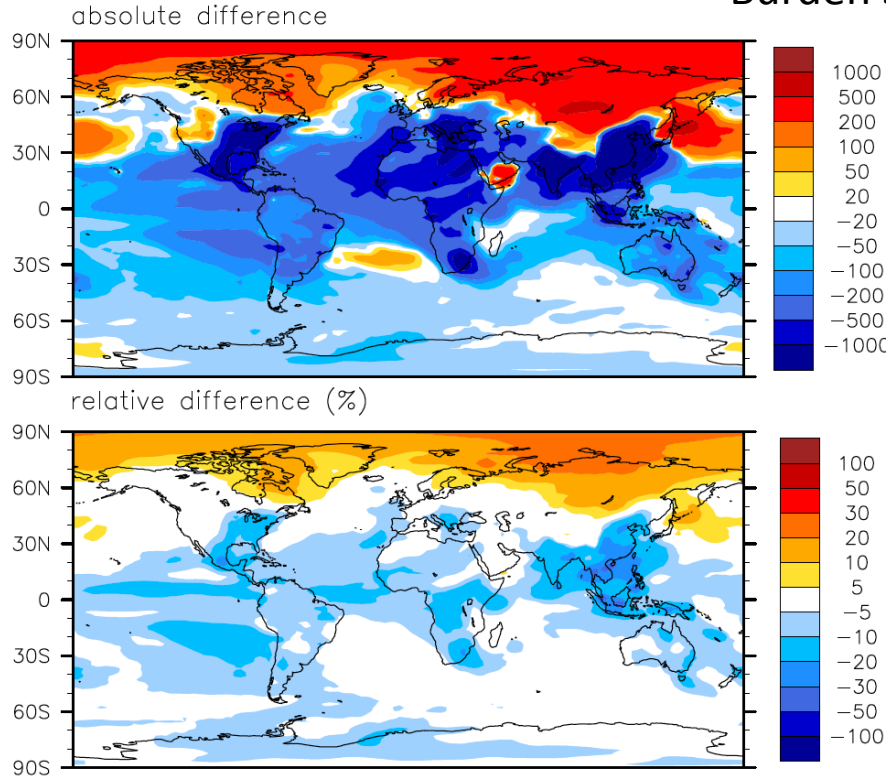
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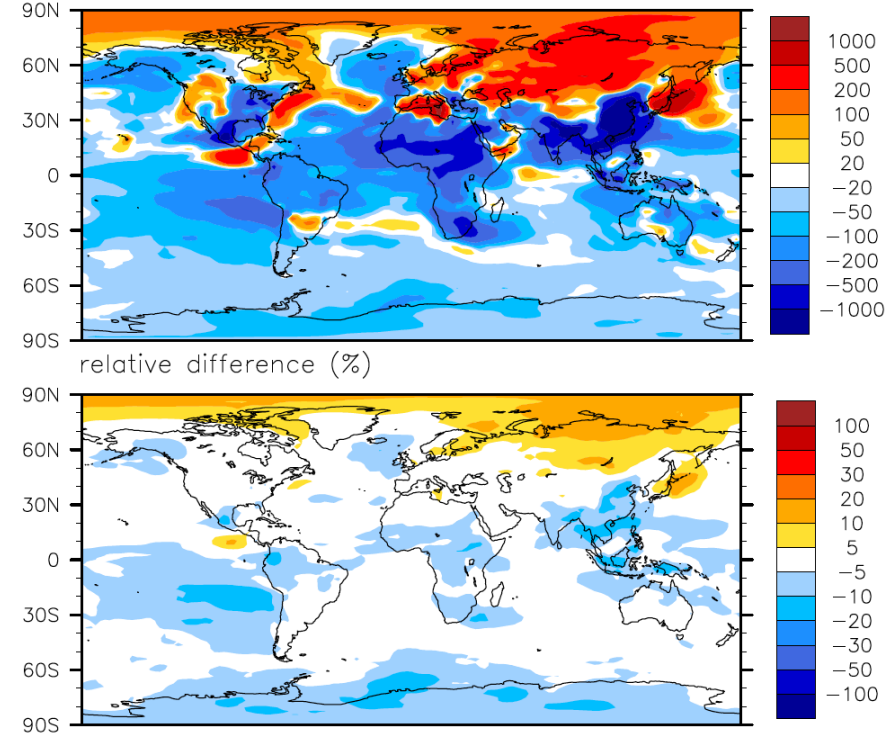
CAM5 - CAM5-chem

CAM5-hourly – CAM5-chem

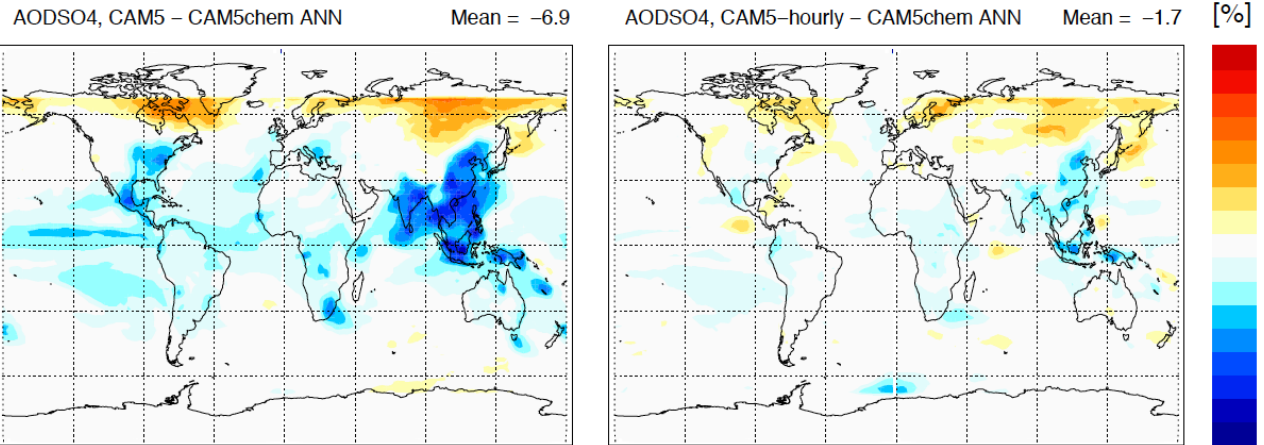
Burden SO_4



absolute difference



AOD SO_4



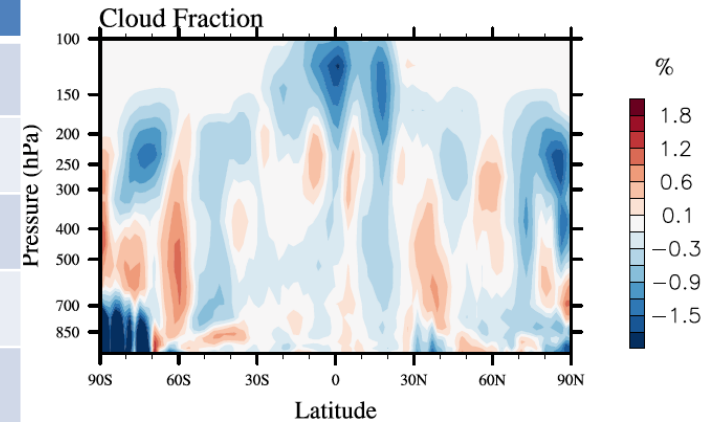
Hourly prescribed fields:

Improvement of aerosol burden and AOD for SO_4 especially in polluted areas

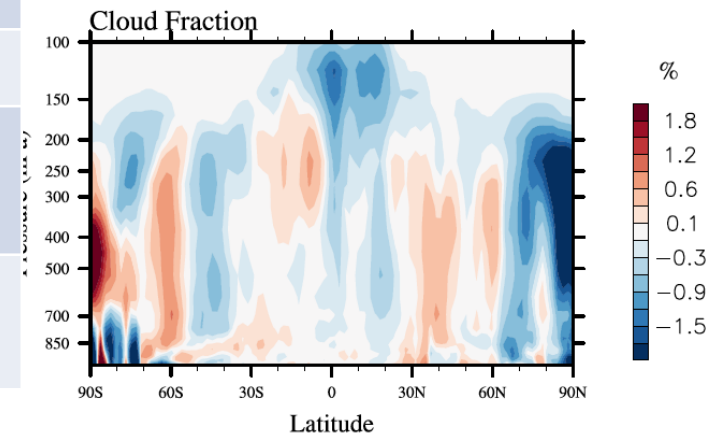
-> large regional impact

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CAM5 - CAM5-chem

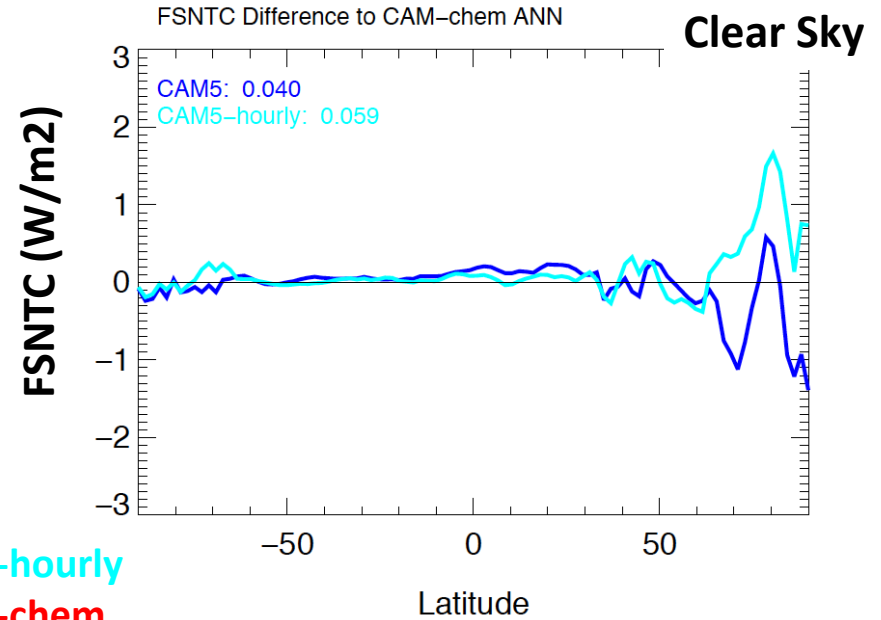
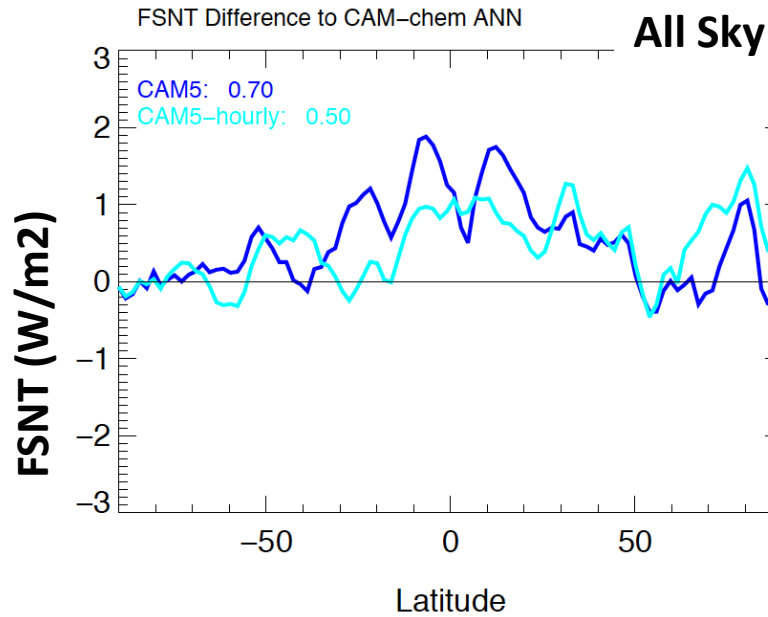


CAM5-hourly - CAM5-chem

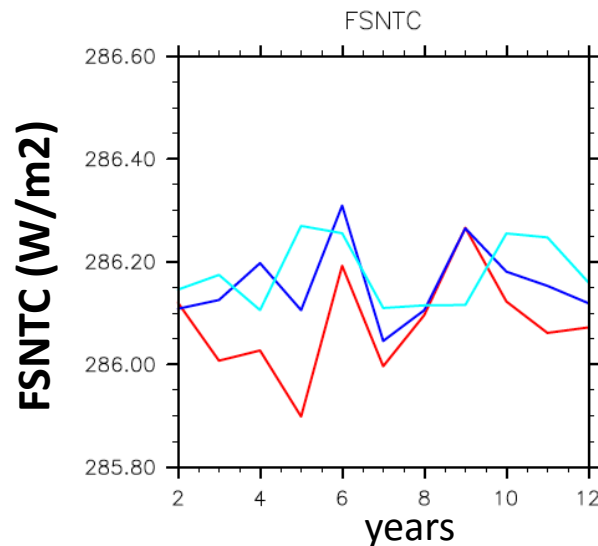
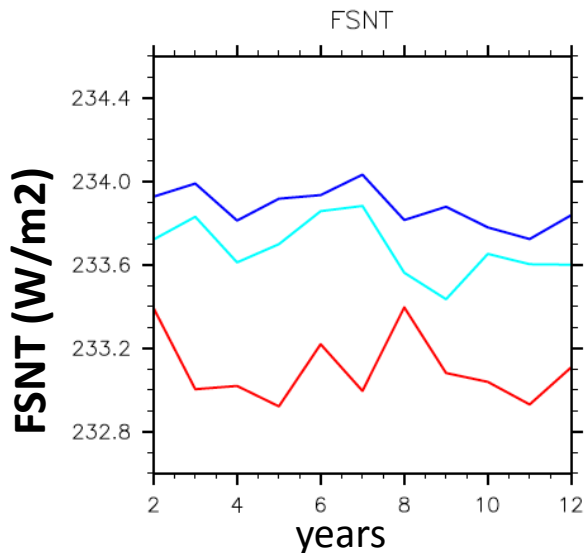


Impact on net SW radiation at top of the atmosphere

Difference to CAM5-chem



CAM5
CAM5-hourly
CAM5-chem



Hourly prescribed fields:
Only small impact on clouds and radiation
-> **interactive chemistry and aerosol processes cannot be reproduced**

Summary

Slightly larger TOA imbalance in CAM5 without full chemistry

- Mainly due to differences in the cloud forcing
- Slightly smaller CCN, Temp., H₂O without full chemistry
- Reduced SO₄ burden in mid- and low latitudes, overestimation in high latitude

Impact of hourly prescribed fields (30% more expensive)

- Improved representation of SO₄ formation
- Large regional impact in polluted areas
- Only small improvement of clouds and radiation

Interactive chemistry and aerosol processes cannot be reproduced with simple chemistry in CAM5

- > Potentially larger impact in a coupled simulations
- > Test prescribed aerosol distribution?

Question: Is there a better simplified chemistry for CAM5?