Recent CAM-chem Developments

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Joint Atmosphere-WACCM-Chemistry WG session

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CAM-chem status and development

- Scientifically validated release is available
  https://www2.cesm.ucar.edu/models/scientifically-supported
  - Includes updates for CCMI, MAM4, MEGAN corrections

- CESM1.5 development versions
  - not released, but available for developers
  - Expanded tropospheric chemistry ("TS1" - speciated aromatics, terpenes, updated isoprene oxidation, organic nitrates)
  - New SOA-VBS framework
  - Gas and aerosol emissions from CLM fire model, with vertical distribution applied in CAM
  - Ability to read 2 emissions files (different sectors, frequency) for a single compound

Additional Plans for CESM2 (for CMIP6)

Refine and evaluate SOA-VBS implementation (including differences for low and high NOx), updated chemistry reaction rates and yields, etc.

CAM-chem additions planned/proposed:

- FAST-J/CLOUD-J (or TUV)
- Nitrate aerosol in MAM

Test couplings of land, biogeochemistry and atmospheric chemistry

- **Including methane, biogenic VOCs, fire emissions**

Test and evaluate chemical and aerosol representation in CAM6/CLUBB at 1-degree (updates of the chemistry diagnostic tool needed)

Coupling the fire model with the atmosphere in the Community Earth System Model (CESM1.2)

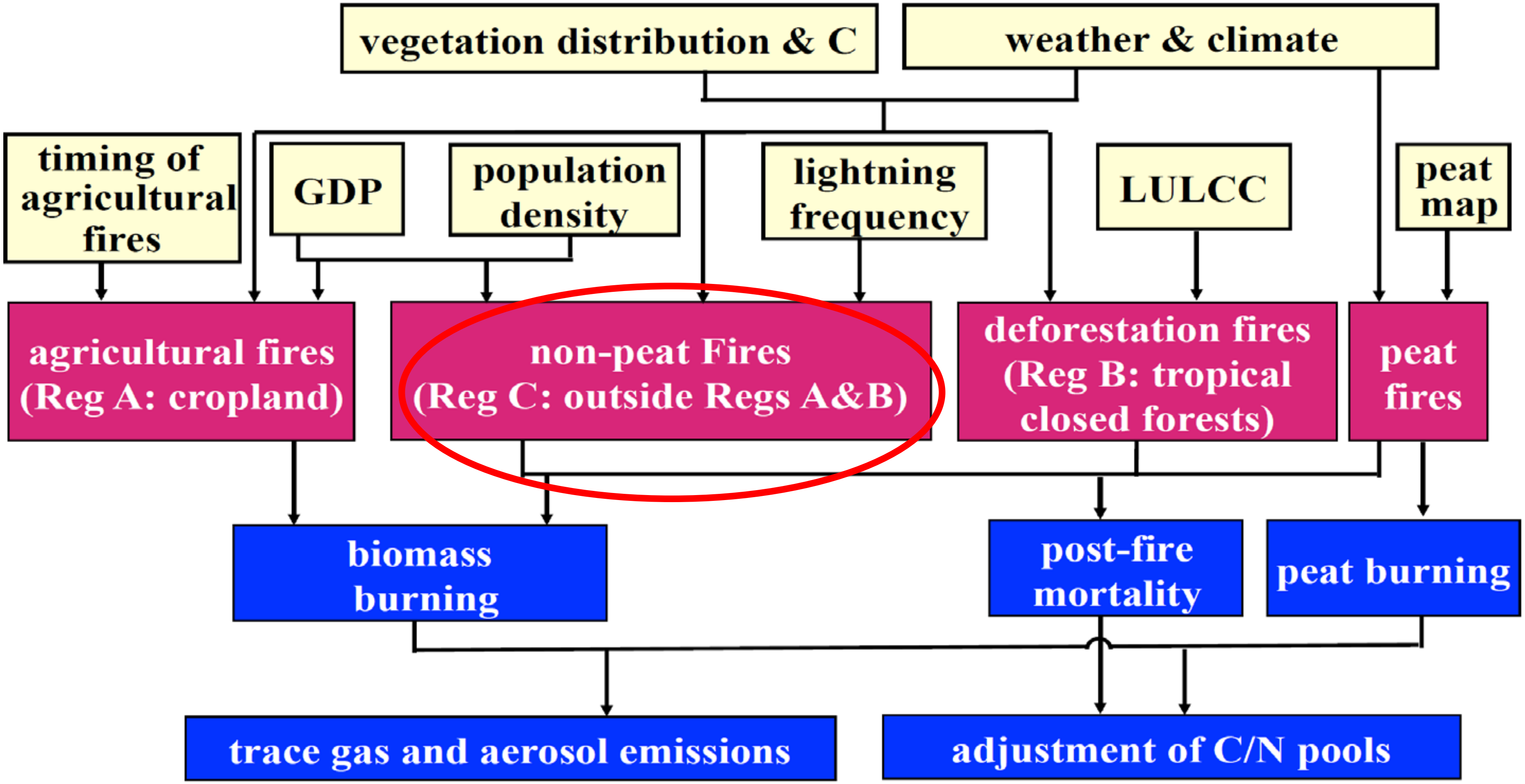
1. Implementing a fire injection parameterization

- Test injection height implementation

2. Evaluation of prognostic fire emissions based on CLM4.5 (work for CLM5.0 in progress)

- Test the impact of prognostic fires on aerosols and chemistry

Global Fire Scheme (CLM4.5 -> CLM5)



Li et al., 2013

Fire emissions CLM -> CAM-chem

CLM

Emissions for 52 compounds calculated based on PFT (emission factors from Akagi et al., ACP 2011, Wiedinmyer et al., GMD, 2011)

Mapped to CAM-chem chemistry mechanism and averaged to CAM grid

Maximum altitude (ztop) for vertical distribution of emissions weighted by PFT for each grid box

Emissions
Ztop
→

CAM

Surface fire emissions from CLM evenly distributed between surface and ztop

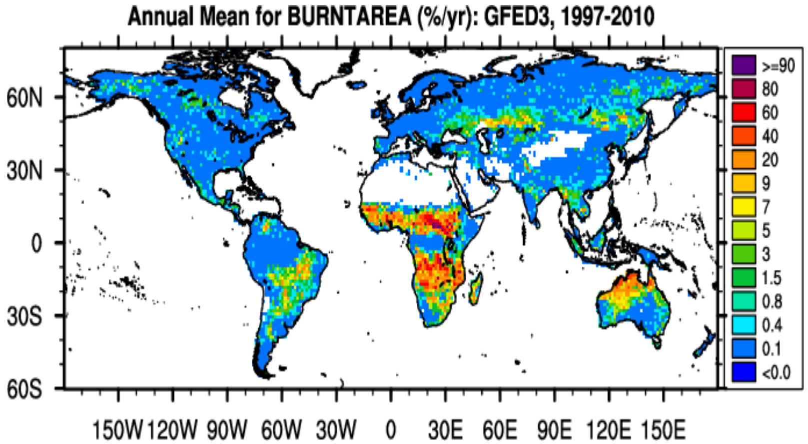
History fields:

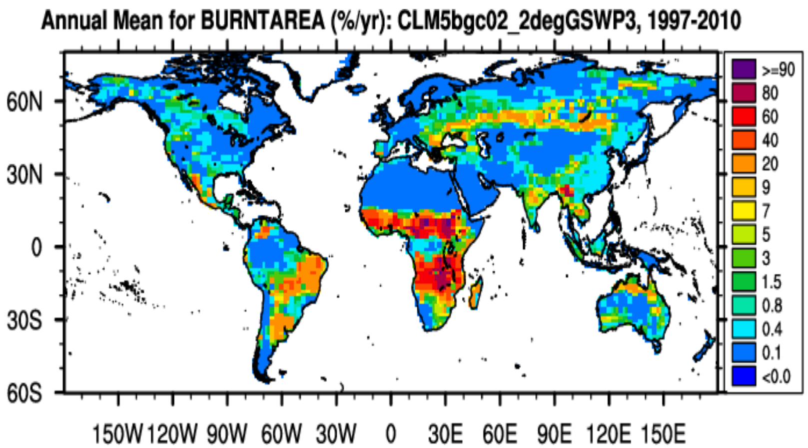
- FireSFLX: emissions from CLM
- FireFrc: vertically distributed emissions applied to chemical fields
- FireVFLX: integral of FireFrc (should match FireSFLX)

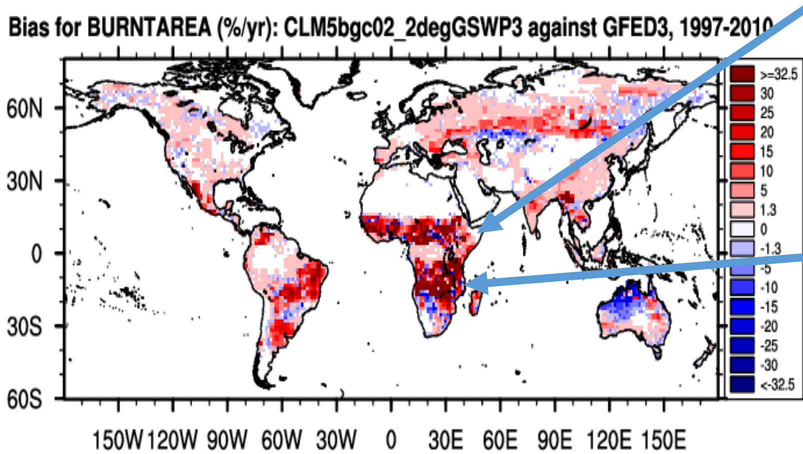
Maria Val Martin is developing a parameterization dependent on PFT, region and month, with non-uniform vertical distribution – still being tested.

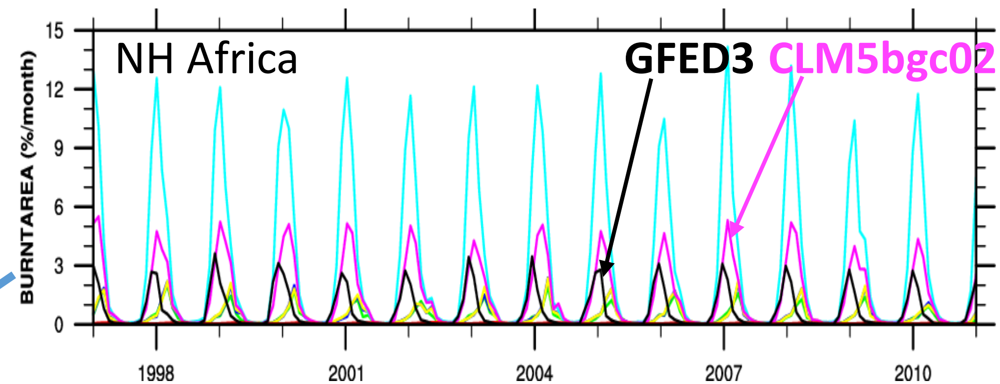
Burned Area from CLM5 (prelim.) compared to GFED3

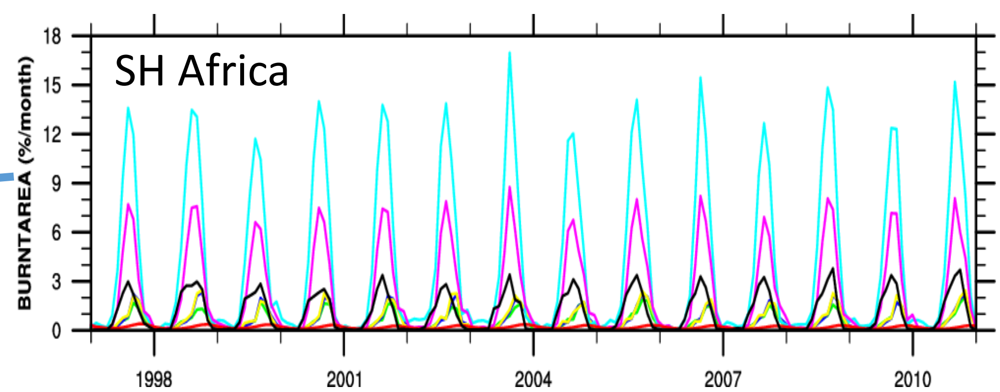
Tuning will be applied after final version of CLM5 is done, since parameterization of vegetation and carbon stocks may still change











Coupling the fire model with the atmosphere (CLM4.5)

Table 1: Budgets CAM5.4, CLM4.5 F2005

	CAMchem-fire	CAMchem-control
BC-BURDEN (TgC)	0.102	0.120
BC-EMIS-surface (TgC/yr)	5.268	5.268
BC-EMIS-Elev (TgC/yr)	1.767	2.145
BC-LIFETIME (days)	5.331	5.937
SO4-BURDEN (TgS)	0.418	0.365
SO4-EMIS (TgS/yr)	1.411	1.411
SO4-EMIS-surf (TgS/yr)	1.557	1.491
SO4-EMIS-Elev (TgS/yr)	0.145	0.080
SO4-TOTAL-PROD (TgS/yr)	37.124	32.608
SO4-LIFETIME (days)	3.916	3.861
CO-BURDEN (Tg)	354.7	275.4
CO-EMIS-surface (Tg/yr)	681.6	1050.9
CO-EMIS-Fire (Tg/yr)	760.1	0.0
CO-EMIS-toal (Tg/yr)	1441.7	1050.9
CO-CHEM-LOSS (Tg/yr)	2765.7	2230.0
CO-LIFETIME (yr)	46.8	45.1

- In general good representation of aerosol with prognostic fires
- Too large emissions of CO at this point -> impact on ozone in comparison to observations

-> Coupling to CAM-chem is a great way of evaluating the fires module

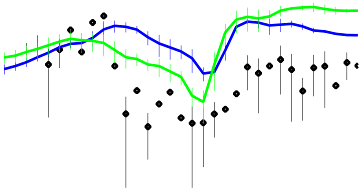
Prognostic Fires   Prescribed Fires

January   1-2km   4-5km   7-8km

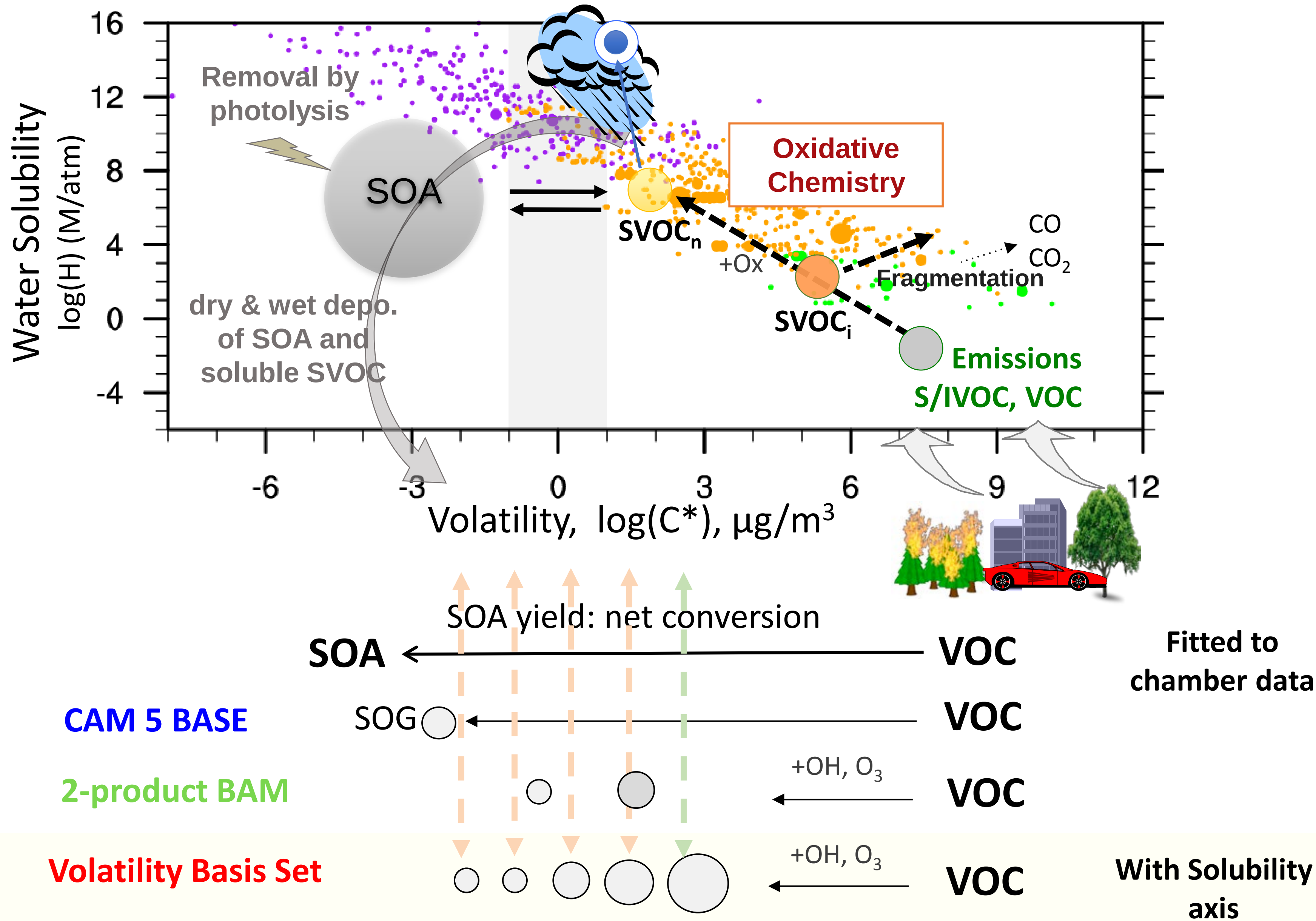
March/April

June/July

Aug./Sept.



Simplistic ways of treating the complex SOA lifecycle



Model configurations for SOA production and removal

- **CAM5 BASE run (Liu et al. 2012, GMD)**

  - SOG, oxygenated VOCs (gas), is not produced by oxidation, but directly emitted at the surface
  - Does not interact with VOC, is missing diurnal cycle
  - Amount of SOG is scaled arbitrarily by 50% (not here)
  - Additional semi-volatile and intermediate volatility precursors (S/IVOC) missing
  - SOA has no chemical loss through photolysis, what about aging?

1 species, 2 bins

Model configurations for SOA production and removal

Requires updated and full chemistry scheme

- **VBS-NY run (based on Hodzic et al. 2015, ACPD);** updated SOA algorithm uses volatility basis set (VBS), code modified from Shrivastava et al., 2015

-Updated chemical reactions and volatility bins from lab studies

-Addition of semi-volatile and intermediate volatility precursors (S/IVOC) from anthrop. and biomass burning sources (Jathar et al. 2014): $E_{SVOC} = 0.6\ E_{POA}$ and $E_{IVOC} = 0.2\ E_{NMVOC}$

- **VBS run:**

-Similar to VBS_NY with the addition of loss processes (photolysis)

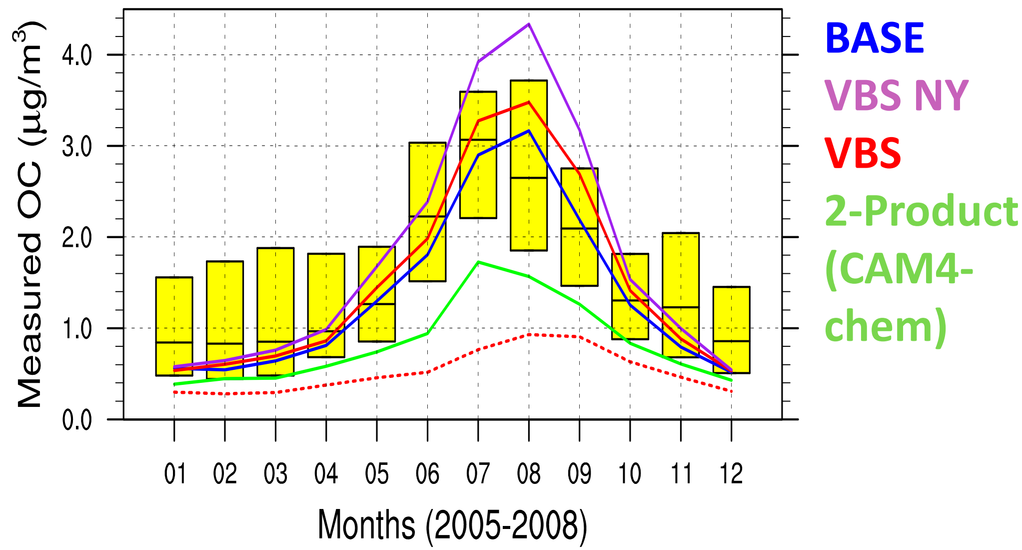
Additional 10 SOA species required (5 for each bin)

Additions 5 SOG species, 1 IVOC species

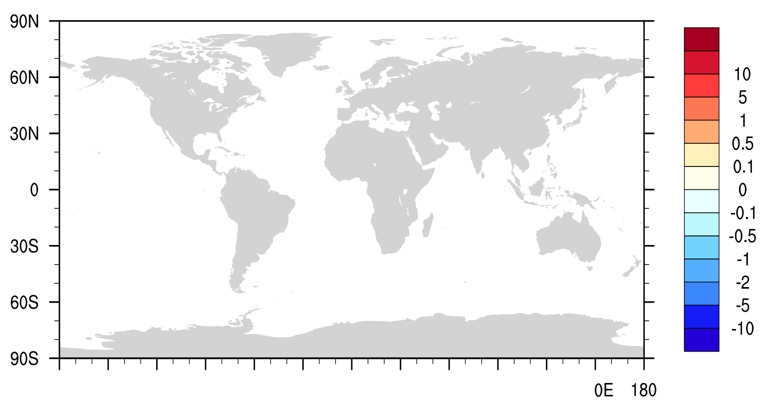
Results: Annual average SOA burden near the surface (up to 1.5km)

BASE SOA burden=0.24 Tg

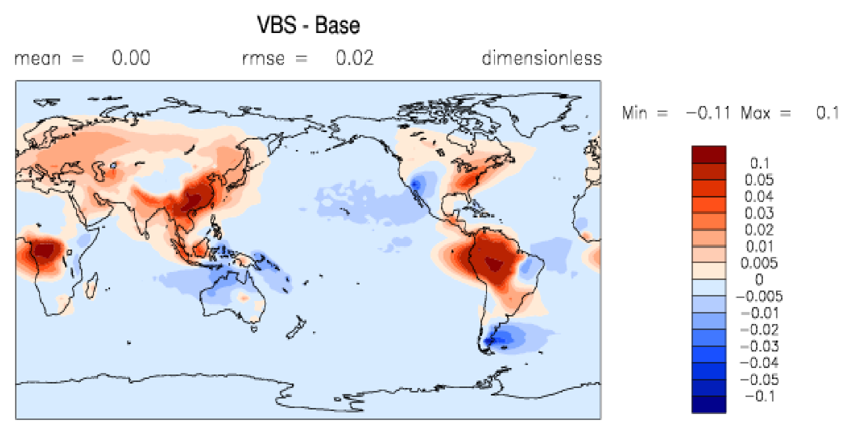
Model evaluation with the U.S. IMPROVE data



VBS - BASE



Large regional impact on AOD



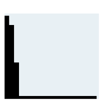
-> more production in source regions

Results: Zonal average of SOA (μg/kg)

BASE

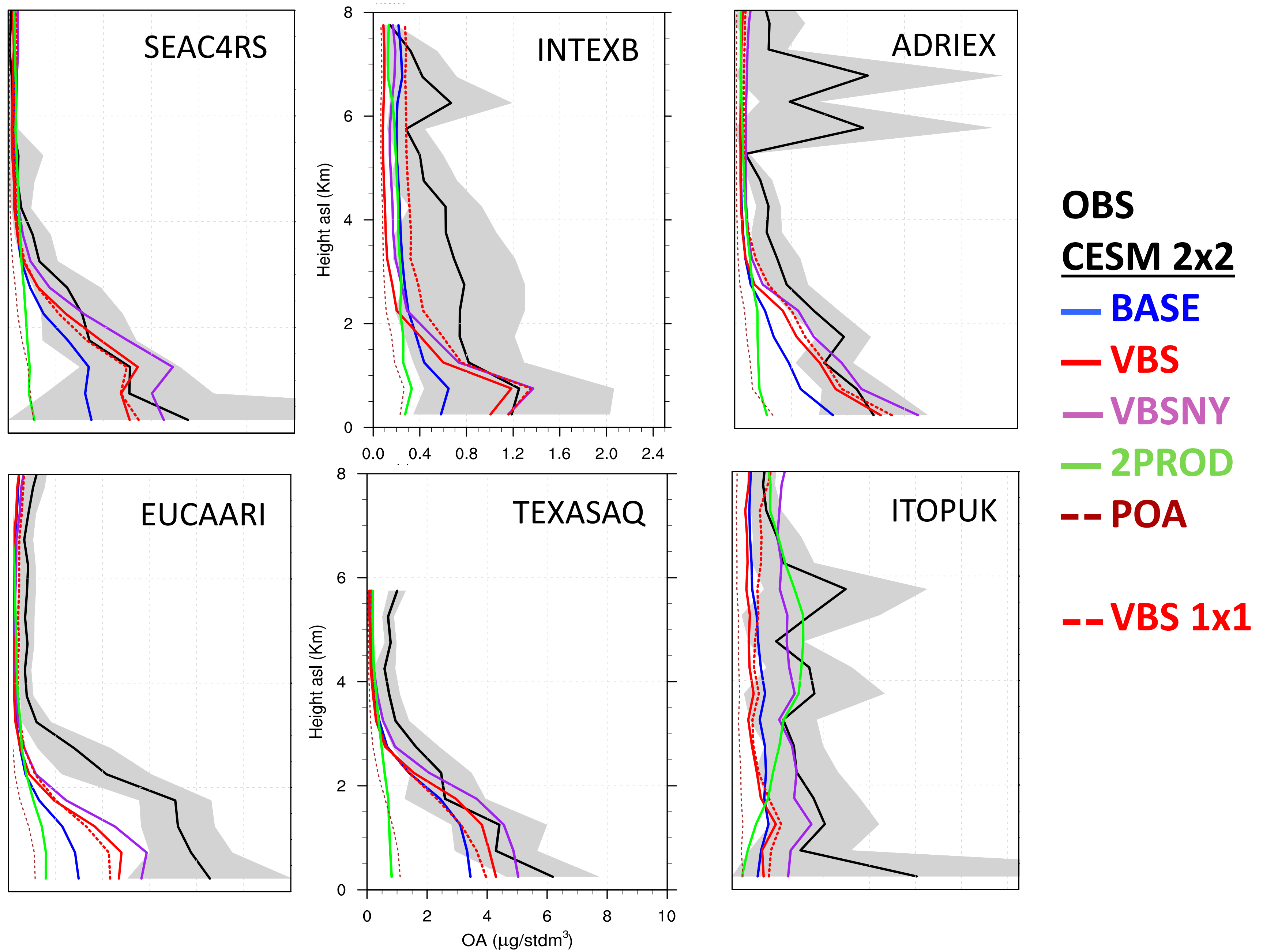
VBS

VBS - BASE



Difference in zonal distribution -> larger concentrations near source regions, lower concentrations in the upper troposphere

Comparisons with aircraft OA measurements



Summary and future work

Summary:

- We have added a flexible VBS framework into CAM5 that includes updated yields and photolysis removal rates based on recent lab. measurements, and explicit chemistry.
- Includes 3 categories to identify different sources (biomass burning, biogenic and fossil fuel)
  -> additional 30 SOA species
- Require full tropospheric chemistry
- Improve comparison to observations

Work towards the release:

- Compare diurnal cycle for different schemes, including clouds, precipitation, test climate impact (coupled model version)
- Simplify for climate simulations; only one SOA category
  -> reduce to 10 SOA species

Future work

- Test further updated chemistry and compare to field campaigns
- **Do a lot of new science with this !**