Coupling the fire model with the atmosphere in the Community Earth System Model (CESM)

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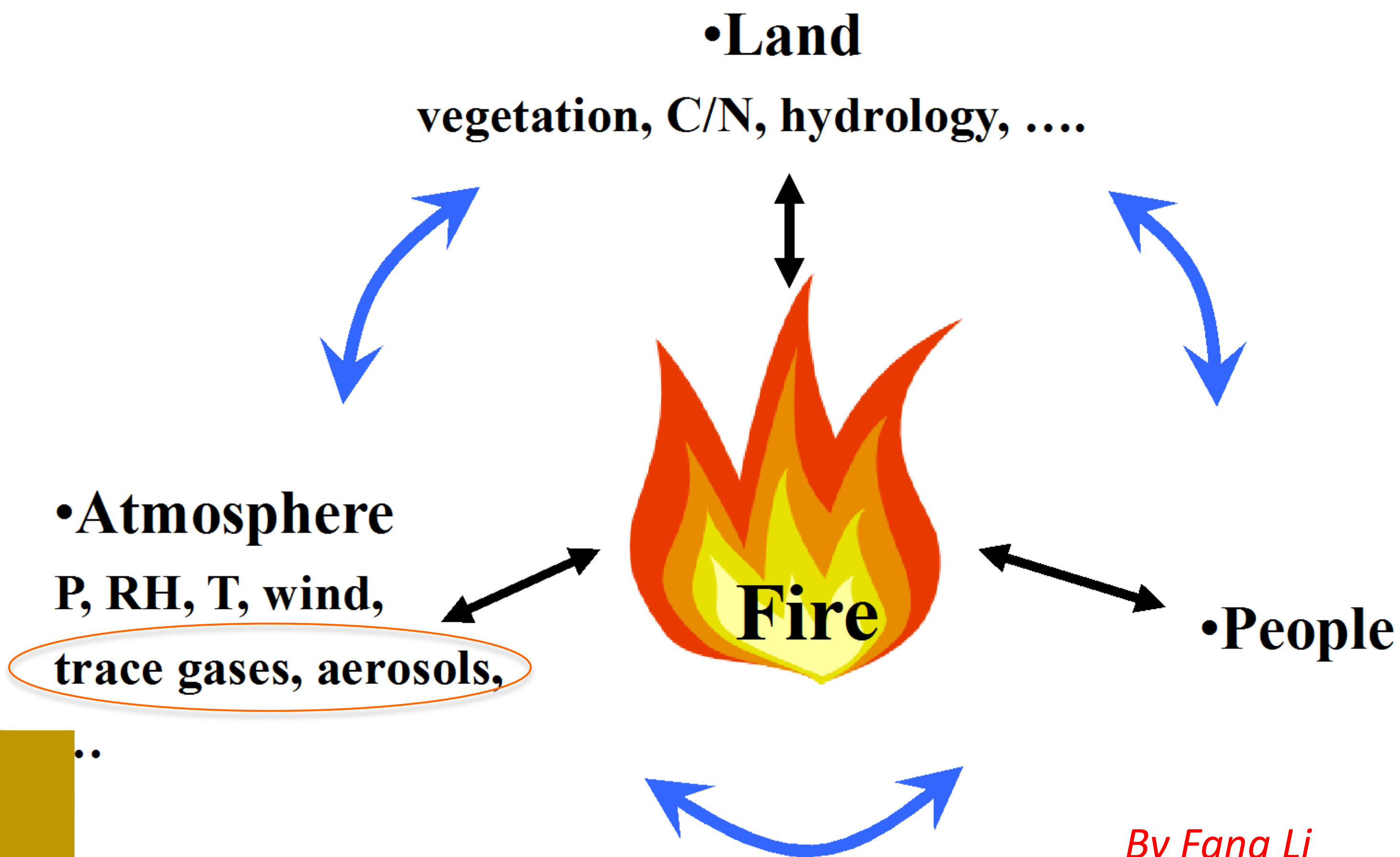
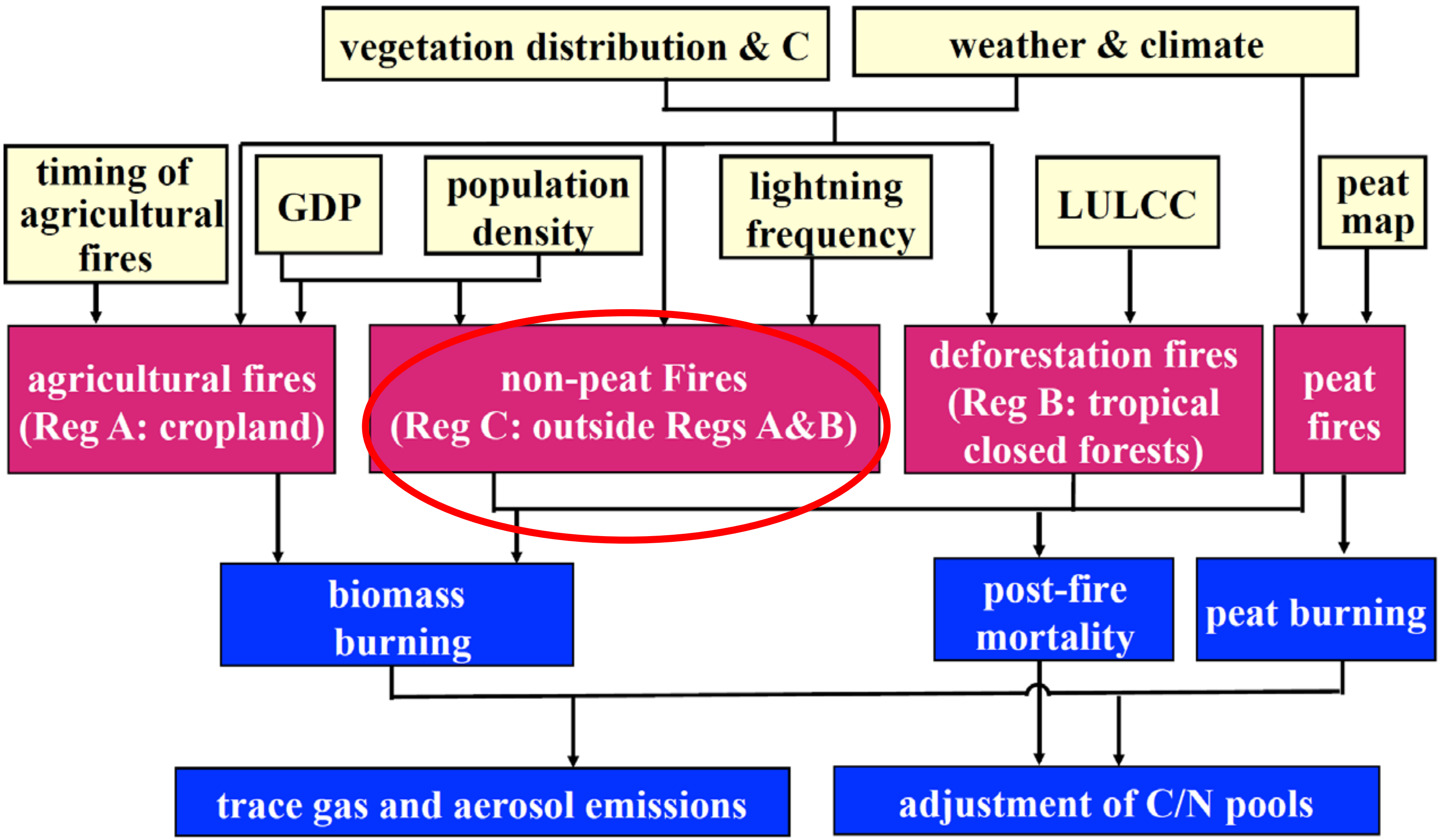


By Fang Li

Global Fire Scheme (CLM4.5 -> CLM5)



Li et al., 2013

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

1. Implementing a fire injection parameterization

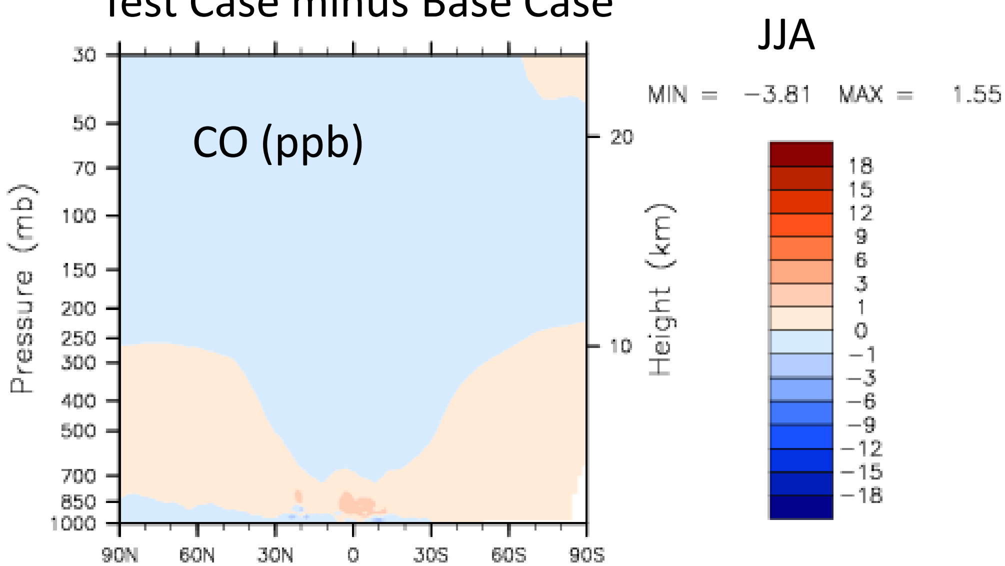
- Fire smoke injecting height parameterization developed by Maria Val Martin
  - based on new MISR stereo-derived plume heights and GFEDv4
  - Comprehensive scheme: dependent on PFT, season, and region
  - Simpler scheme: maximum altitude (ztop) dependent on PFT; Surface fire emissions from CLM evenly distributed between surface and ztop

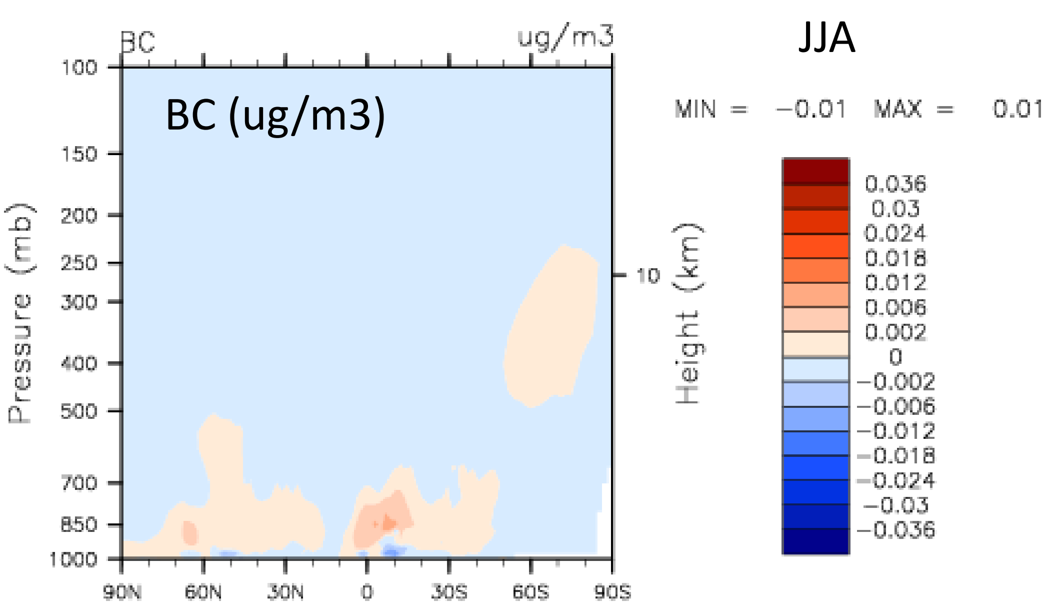
2. Evaluation of prognostic fire emissions based on CLM4.5 (work for CLM5.0 in progress)

- Fire emission total are calculated by default in the land model
- Coupling between land and atmosphere, as already done for biogenic emissions (MEGAN2.0)
- Important for climate simulations

Testing a new fire injection parameterization

Test Case minus Base Case





Fire emissions based on FINN

Base Case:

- Aerosol fire emissions are emitted in certain altitudes as external forcings
- Chemical gases are only emitted at the surface.

Test Case:

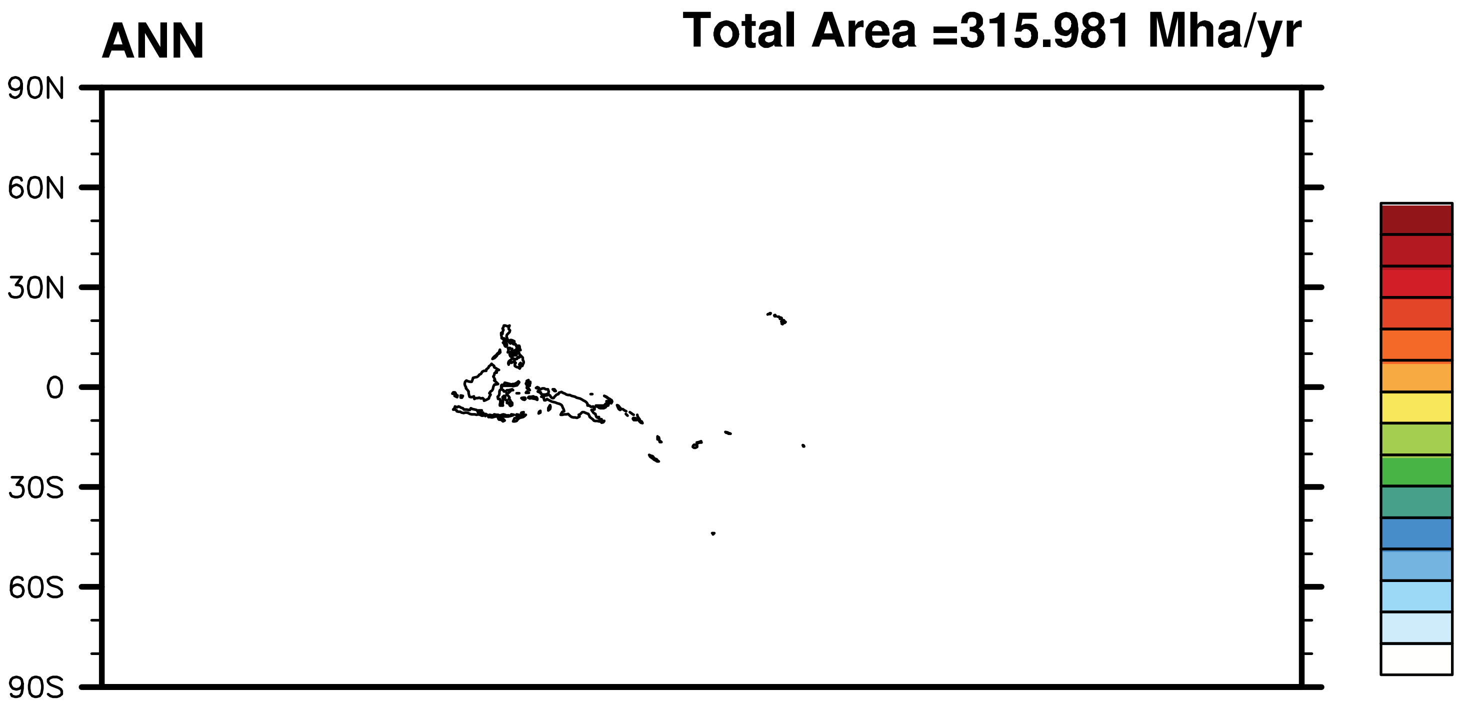
- Using fire smoke injecting height parameterization to distribute aerosols and tracers in the vertical.

-> vertical injection of tracers only impacts chemistry to a small amount, very similar distribution in aerosols

Coupling the fire model with the atmosphere

Model code: CAM5.4 (no CLUBB) CLM4.5

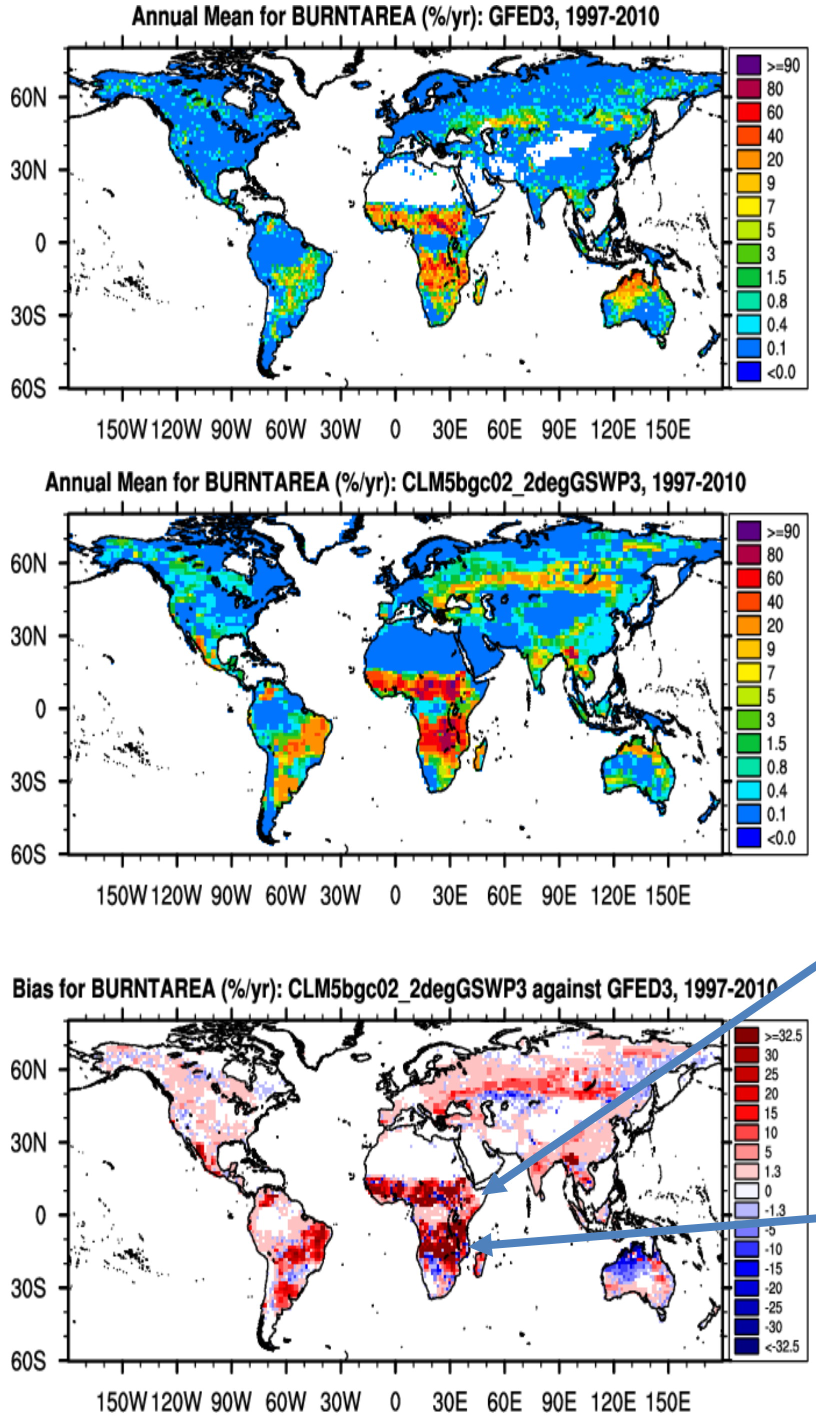
- Fire model produces area burned and amount of carbon released to the atmosphere
- Land calculates emission totals for each specie based on emission factors
  -> strong dependence on PFTs
- Emission totals for each component and grid box are passed from land to atmosphere
- Mapped to CAM-chem chemistry mechanism
- Vertical distribution of fire emissions

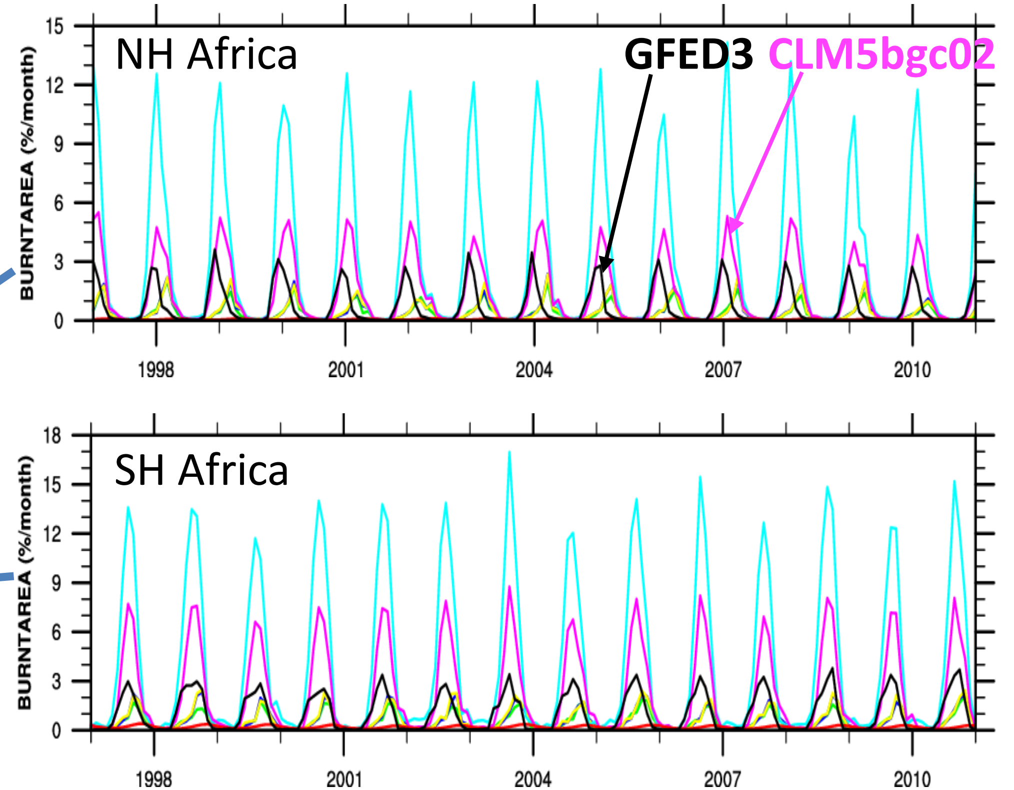


Burned Area from CLM5 (prelim. version) compared to GFED3

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

Model will be tuned for both CLM offline and online simulations.





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

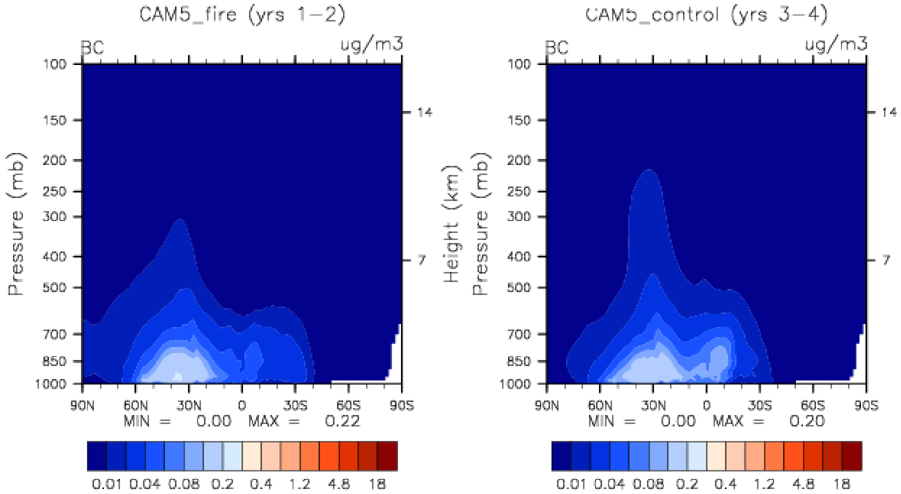
Model simulations:

- CAM5.4, CLM4.5, TS1 chemistry, F2005, MEGAN, 2deg, with and without prognostic fire emissions
- Land use and land cover change not used (8Mha/yr and ~0.4PgC/yr from tropical deforestation and degradation fires are missing)

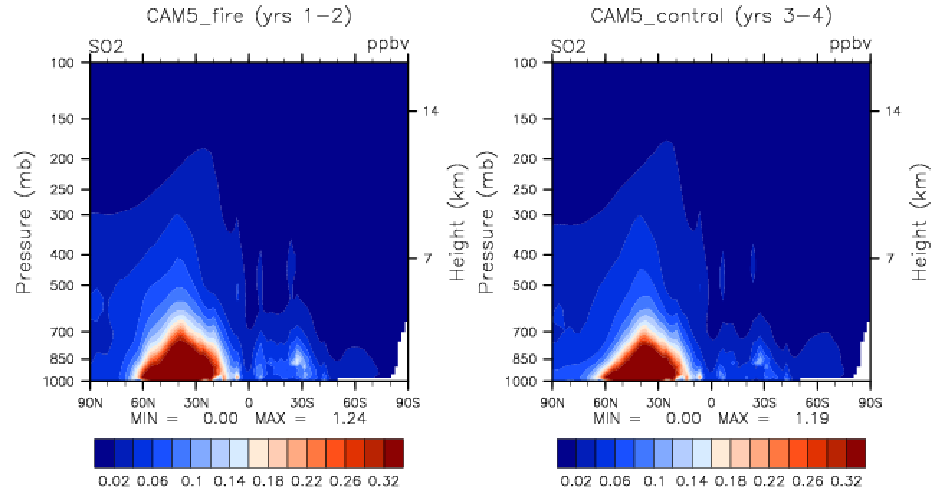
	CAMchem-fire	CAMchem-control
BC-BURDEN (TgC)	0.102	0.120
BC-EMIS-surface (TgC/yr)	5.268	5.268
BC-EMIS-Elev (TgC/yr)	1.767	2.145
BC-LIFETIME (days)	5.331	5.937
SO4-BURDEN (TgS)	0.418	0.365
SO4-EMIS (TgS/yr)	1.411	1.411
SO4-EMIS-surf (TgS/yr)	1.557	1.491
SO4-EMIS-Elev (TgS/yr)	0.145	0.080
SO4-TOTAL-PROD (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

Prognostic vs. prescribed fire emissions

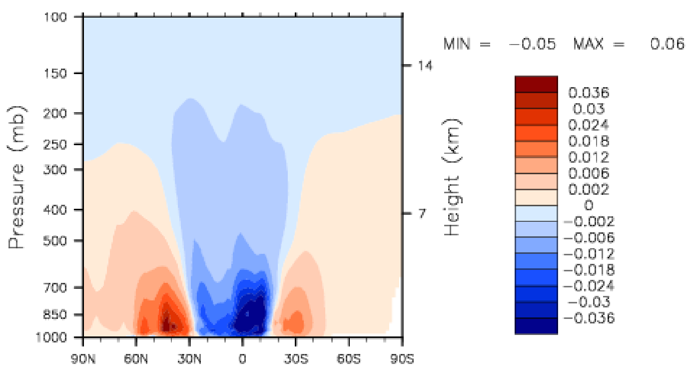
BC ug/m3



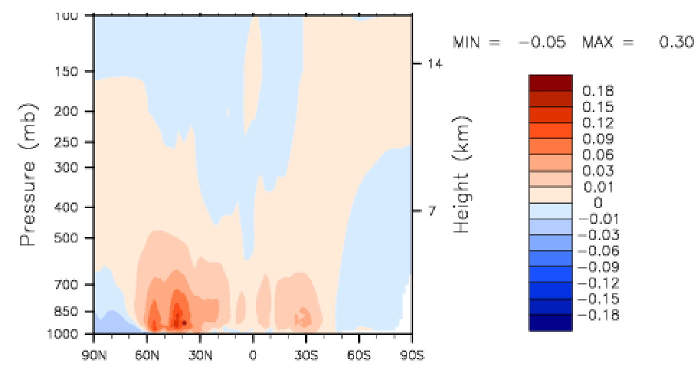
SO_2 ppb



CAM5 fire minus CAM5 control



CAM5 fire minus CAM5 control



- Reduction of BC in the tropics, increase in high latitudes
- Slight increase of SO_2 -> increase of SO_4 burden

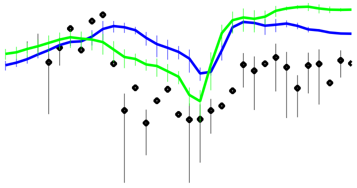
Prognostic Fires Prescribed Fires

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

March/April

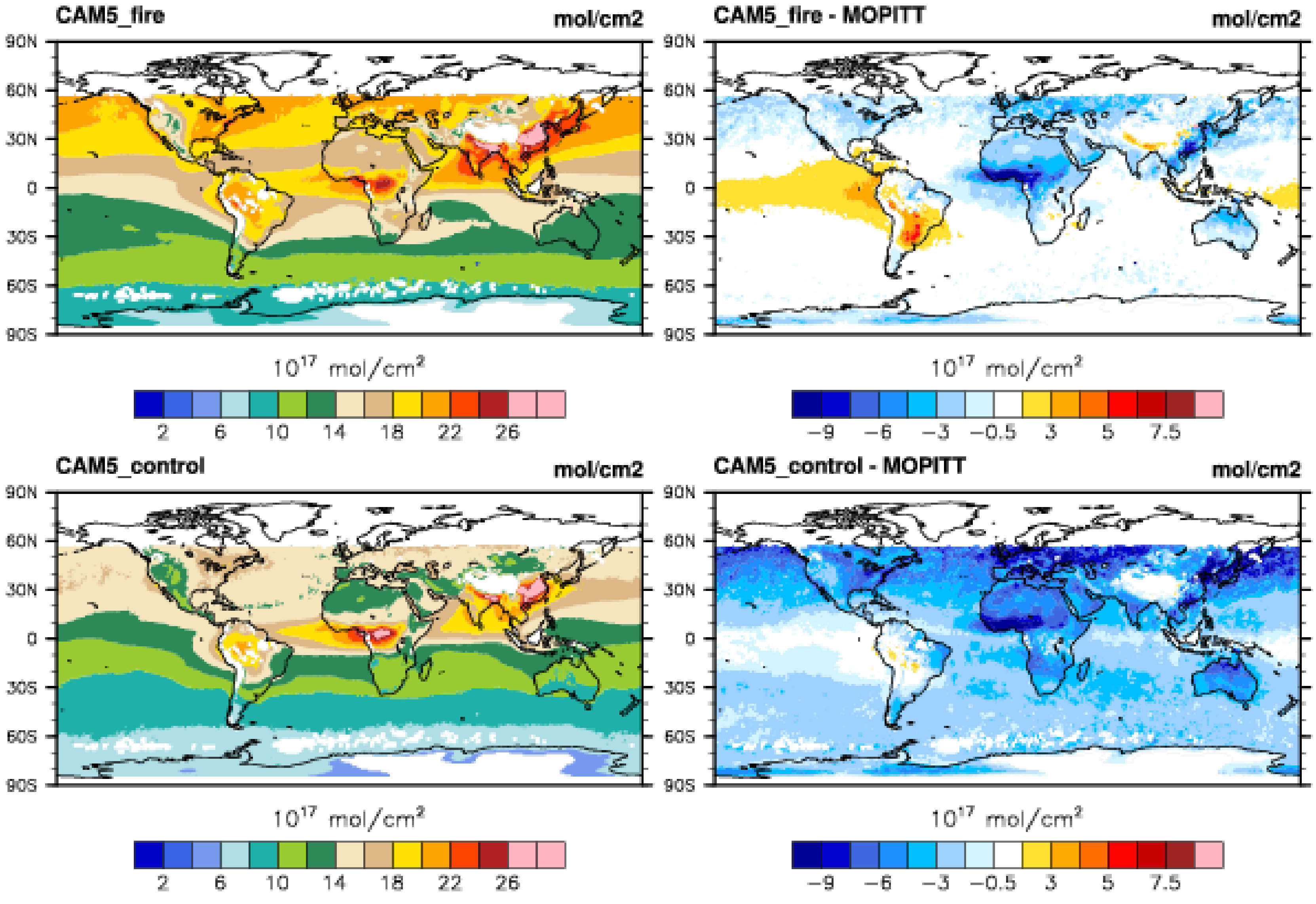
June/July

Aug./Sept.



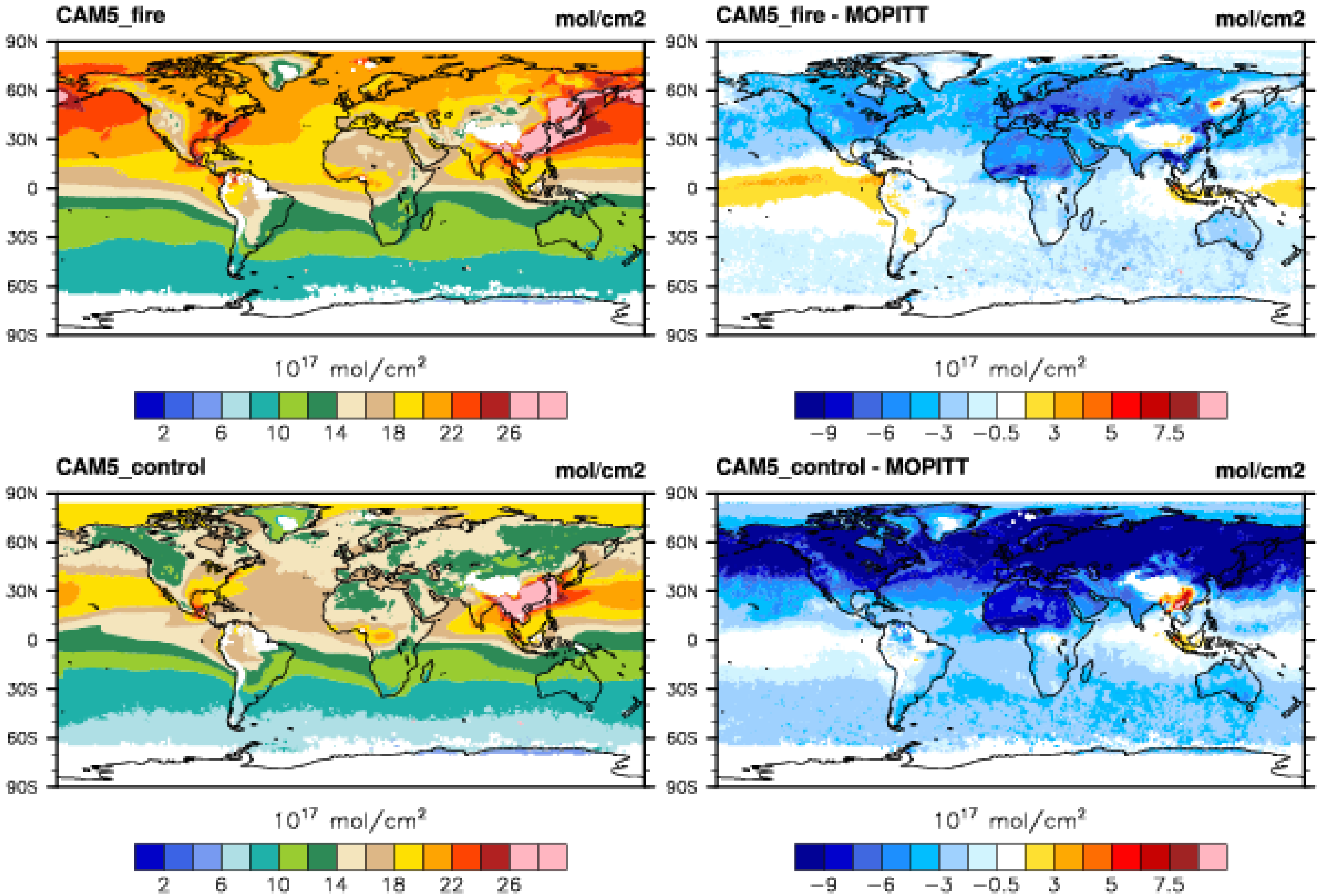
Comparison to MOPITT Satellite Data can help validate the fire model

December



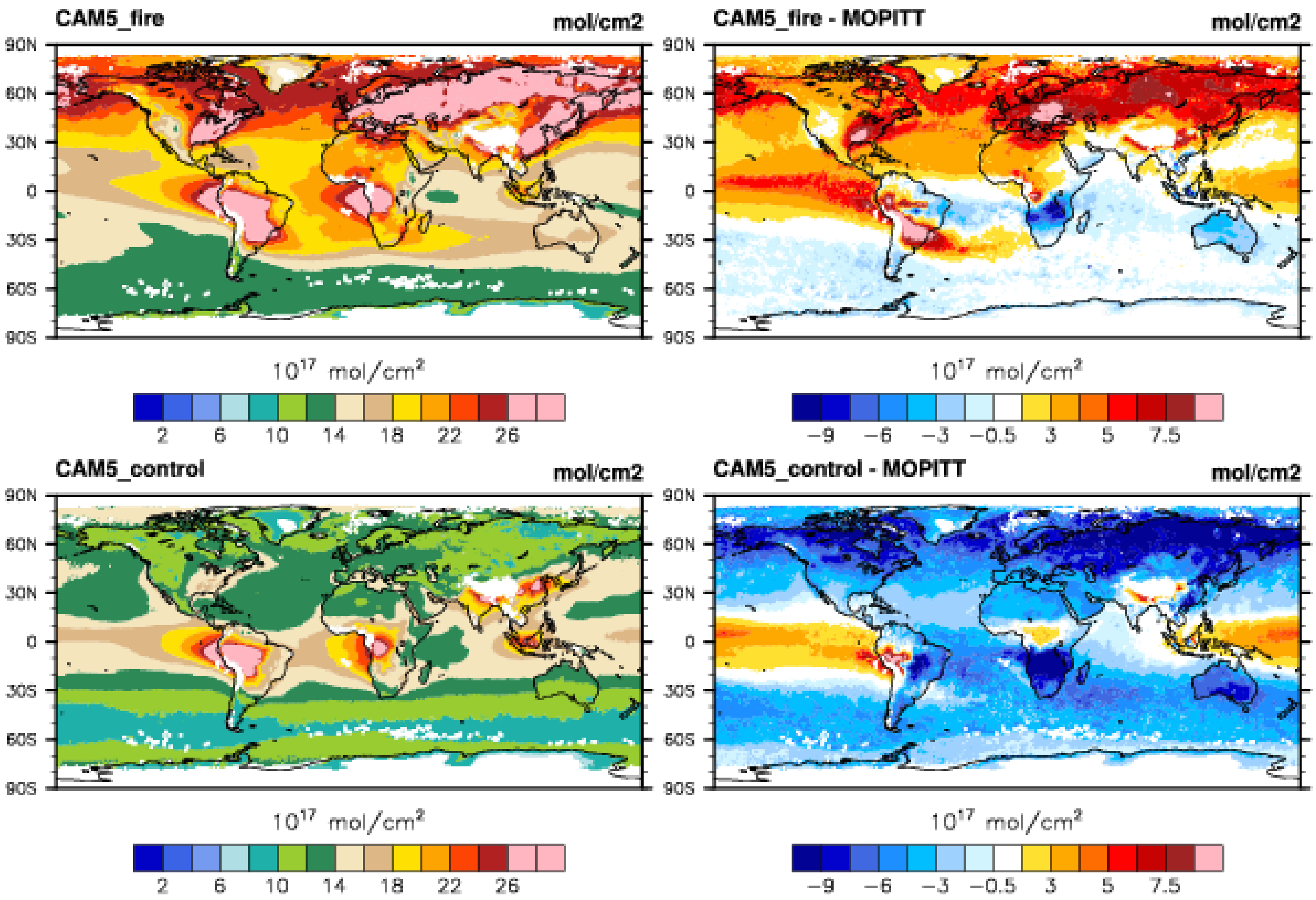
Comparison to MOPITT Satellite Data can help validate the fire model

April



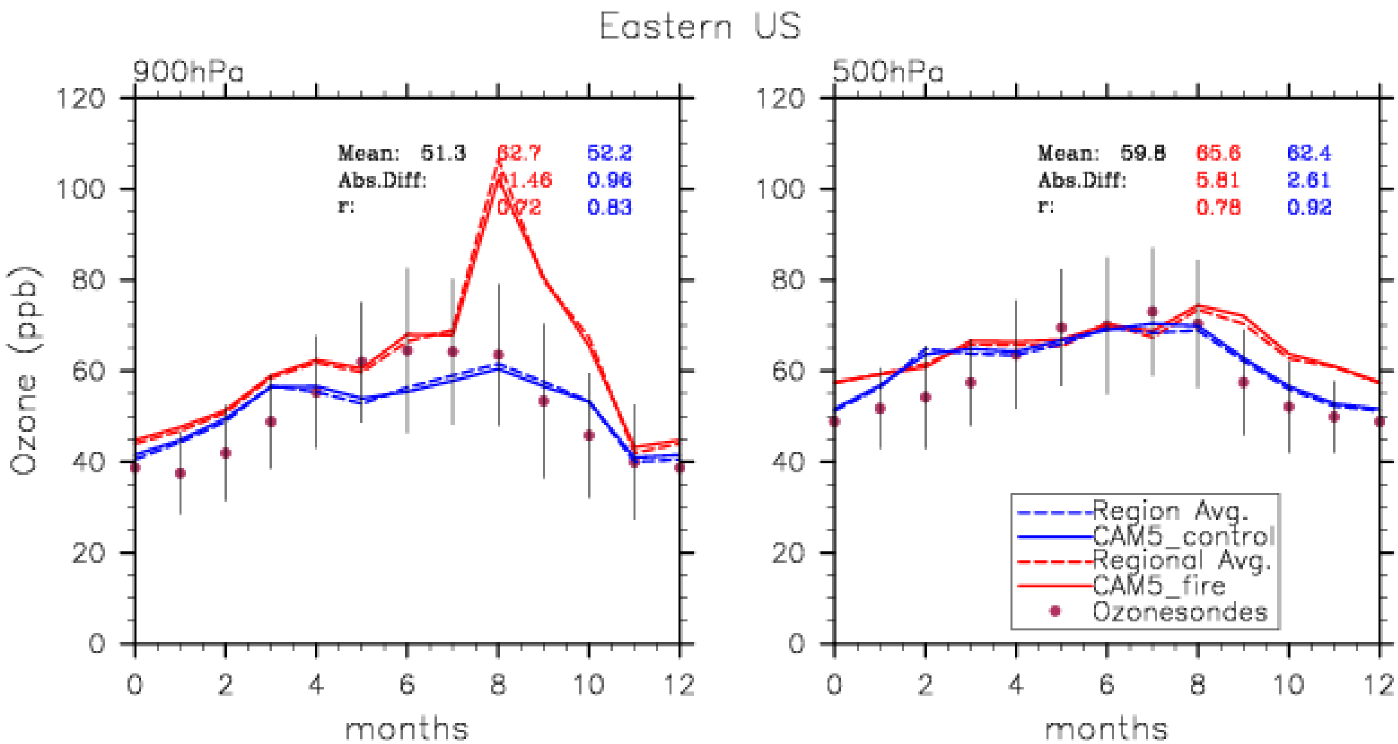
Comparison to MOPITT Satellite Data can help validate the fire model

September



Impact on ozone, seasonal differences

Comparison to ozonesonde observations

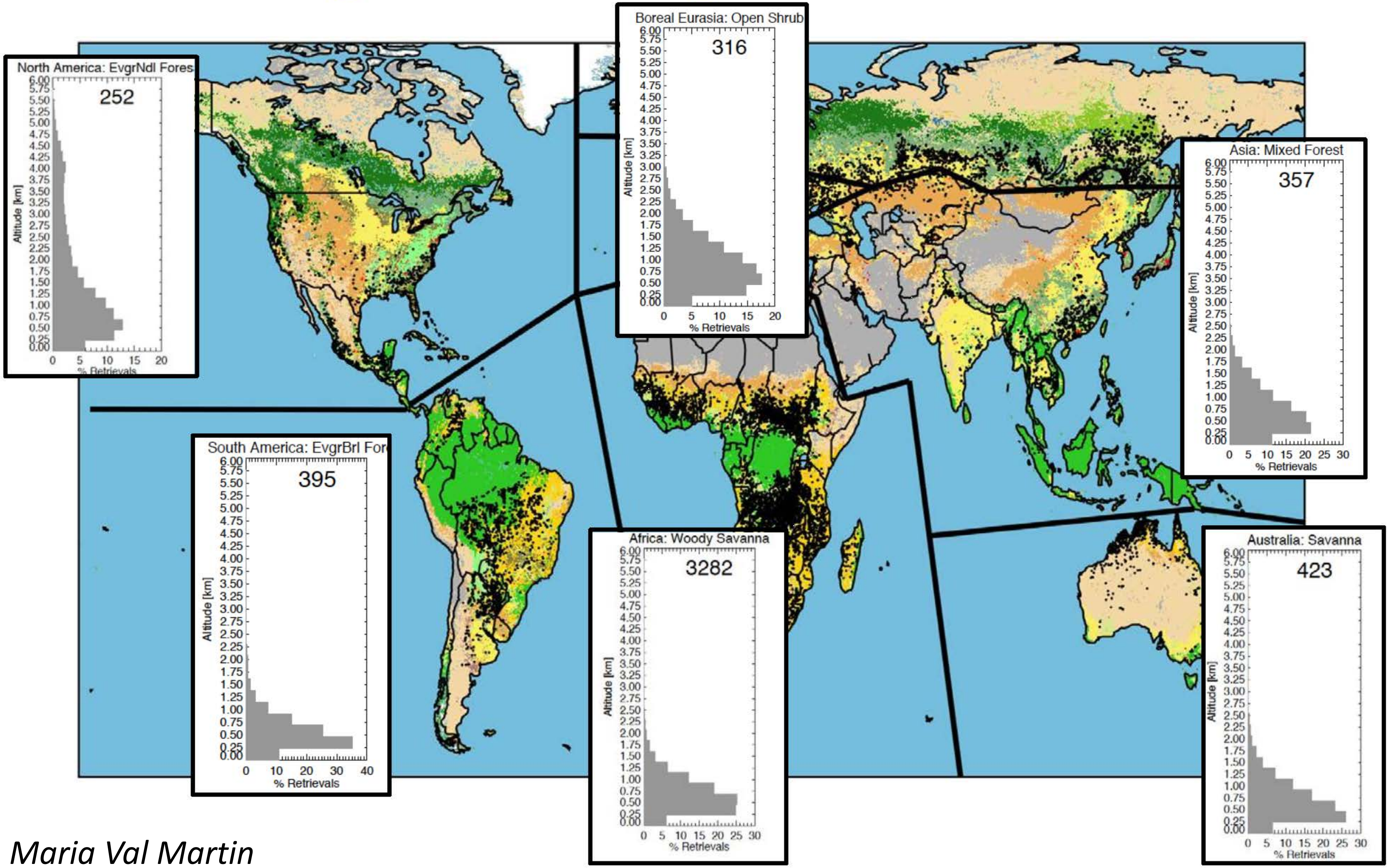


Very large emissions for some seasons and over certain regions can have significant impact on ozone. CAM-chem can help evaluate fire emissions in CLM.

Conclusion

- Coupling of fire emissions between land and atmosphere is working
- Injection height parameterization has been tested
- Fires in CLM4.5 coupled to the atmosphere produce reasonable representation of atmospheric aerosols
- Chemistry coupling can help reveal problems
- Improvement of seasonal fire emissions in CLM5, tuning will be applied

Examples"of"ver0cal"distribu0on"of"injec0on"" heights"across"regions"and"biomes"



Maria Val Martin

Global Fire Scheme (CLM4.5 -> CLM5)

Fuel combustibility (FC, $f_m = f_\theta f_{RH} f_T$)

(1) Change the dependence of FC on top 0.05m soil wetness (f_θ) to the dependence of fire on root zone soil wetness (f_β)

Function: reduce the overestimation of fires in Eurasian boreal forests

(2) Revise the dependence of fire on relative humidity (f_{RH})

From $f\,(RH_{real\text{-}time})$ to $f\,((1\text{-}a)RH_{real\text{-}time}+aRH_{30d})$

when fuel load is more than 2500 g C/m^2, the weight a (0 – 1) is higher with higher fuel load

Function: represent time-lag response of FC to weather/climate in regions with high fuel load

(3) Revise the dependence of fire on temperature (f_T)

Old: increasing function of T (-10 – 0°C)

Now: equal to 0 when T<0°C (the same with the Glob-FIRM)

Function: improve the simulation of fire seasonality in Boreal tundra

Updates by Fang Li