Applications of wildfire in CESM

As related to atmospheric composition and chemistry

Rebecca Buchholz
Project Scientist, NCAR/ACOM
Wenfu Tang
Postdoctoral Fellow, NCAR/ACOM

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NCAR
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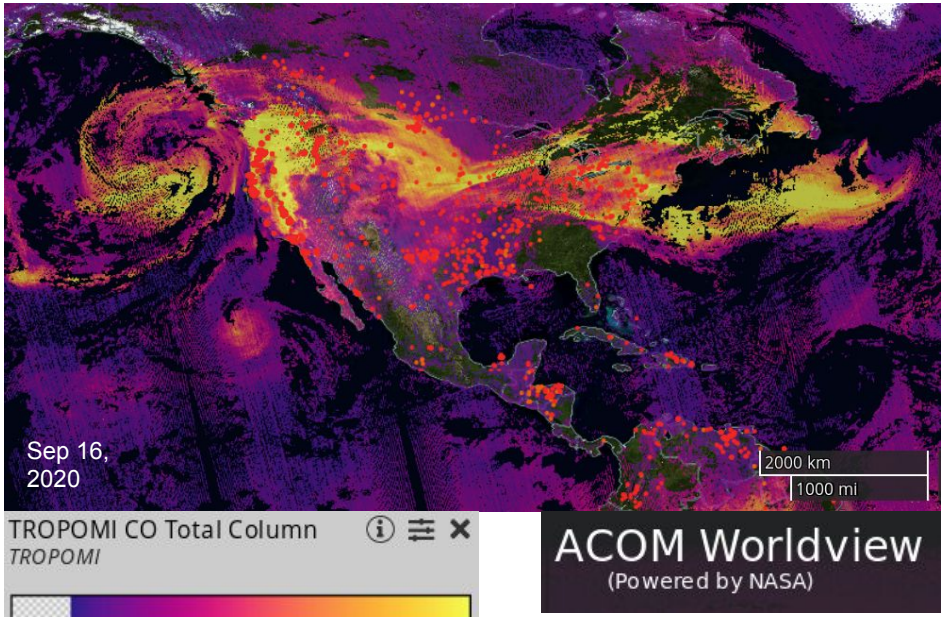
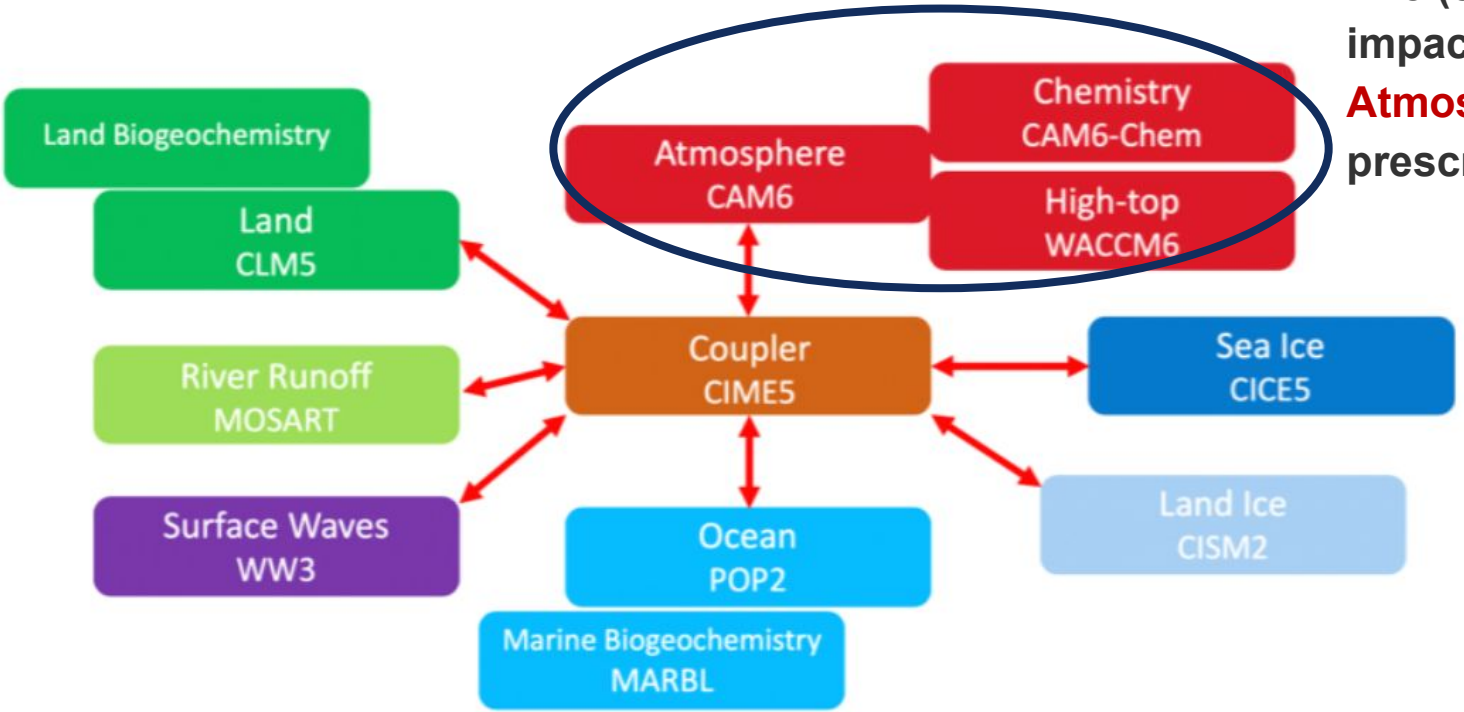
Wildfires and atmospheric chemistry

- Trace gases and aerosols emitted from fires degrade air quality (lead to ozone, PM2.5)
- Impacts occur close to fire, as well as transported far downwind
- Fire emissions change weather properties (clouds, precipitation)
- Two-way climate feedback
- Many possible ways to use fire emissions in modeling studies with CESM2



1.40e+18mol/cm²>=4.01e+18 mol/cm²

Other options in CESM

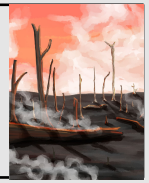


Fire (emissions) impacts in the Atmosphere --- using prescribed emissions.

Creating wildfire emissions (offline)

Method 1

Burned area
x
Biomass loading and fraction burned



GFED (CMIP6) FINN (active fire)

Fuel consumption
(kg C burned)

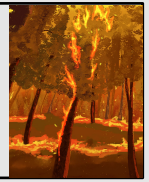
x

Biome-specific
Emission Factors
kg/kgC
From field and lab studies (e.g. Akagi et al. 2011)

→ Emissions

Method 2

Fire radiative power (FRP)
x
Biome-specific conversion factors

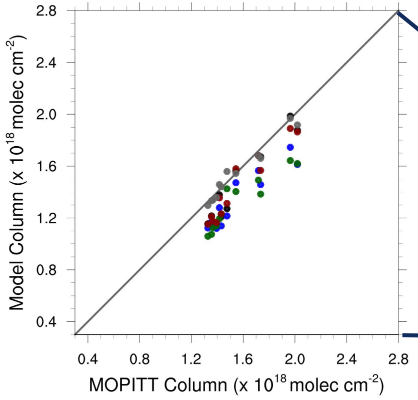


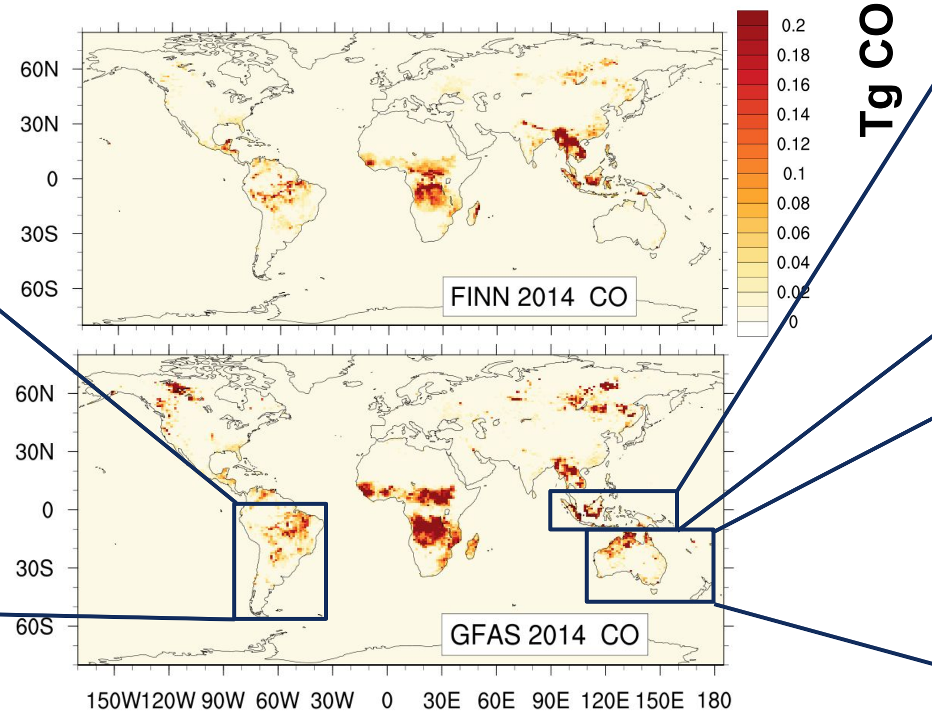
GFAS QFED

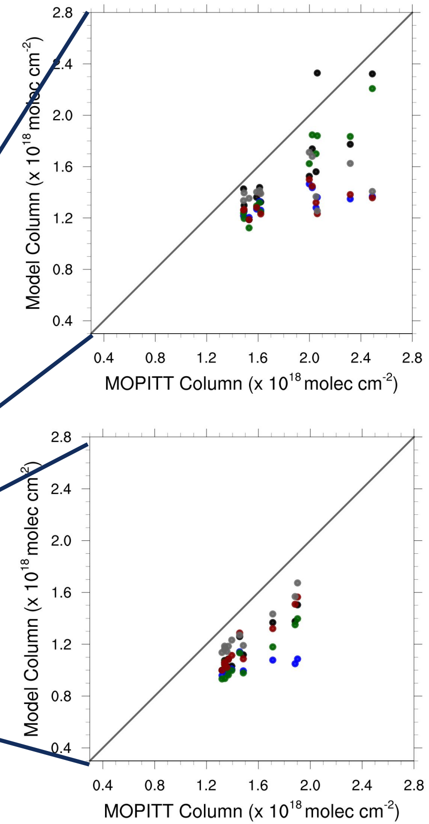
Variability between different inventories

In different regions, different inventories perform the best

CMIP6 v1.2
FINN v1.5
GFAS v1.2
QFED v2.5
QFED v2.5 (all)

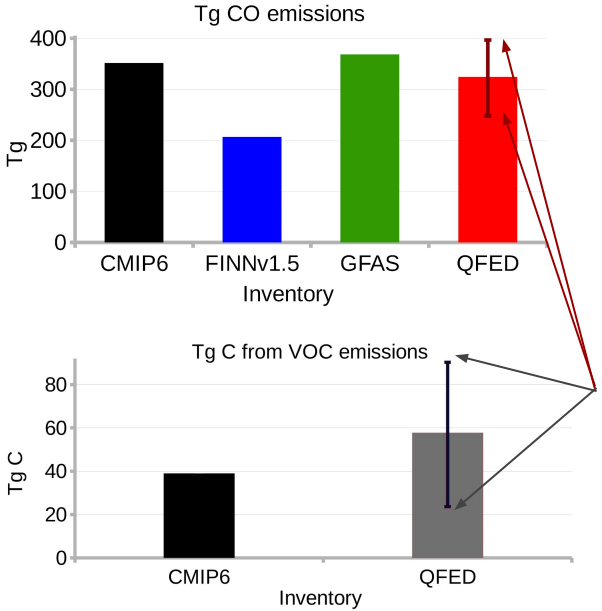






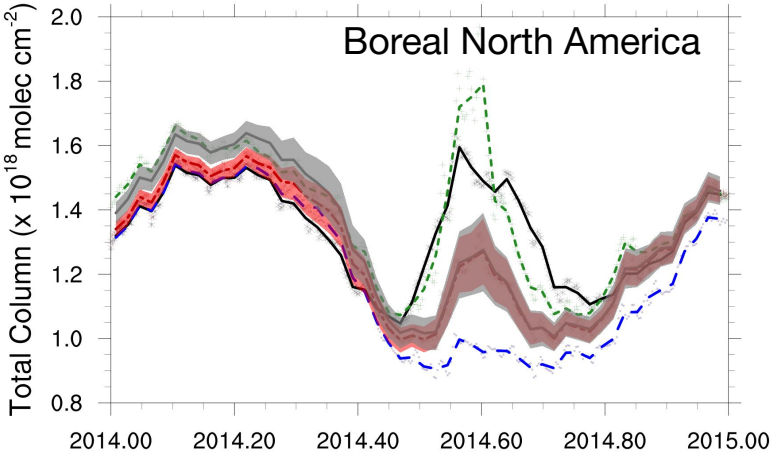
Uncertainties

- Land cover - aggregation of biomes, misidentification, estimation of fuel consumption
- Fire detection - missing small fires, overpass times, cloud interference
- Emission factors - aggregation of biomes, instrument uncertainty



CESM/CAM-chem simulations

Ranges based on emission factor uncertainty

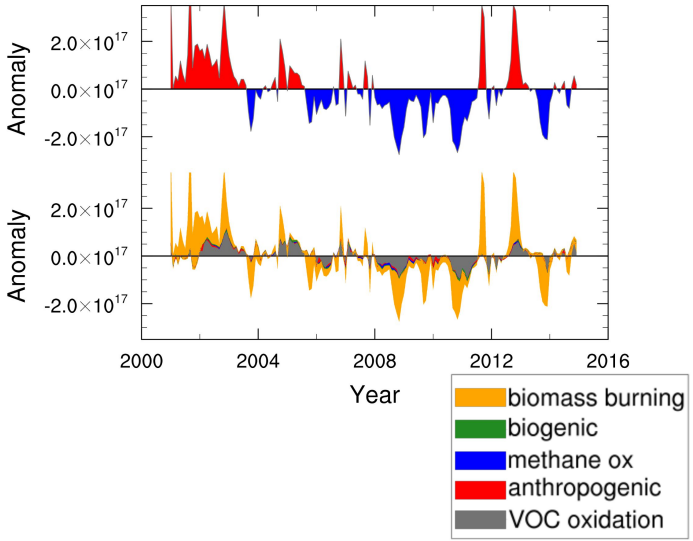


Tracking wildfire impact on air quality

Use the model to track and trace composition impacts

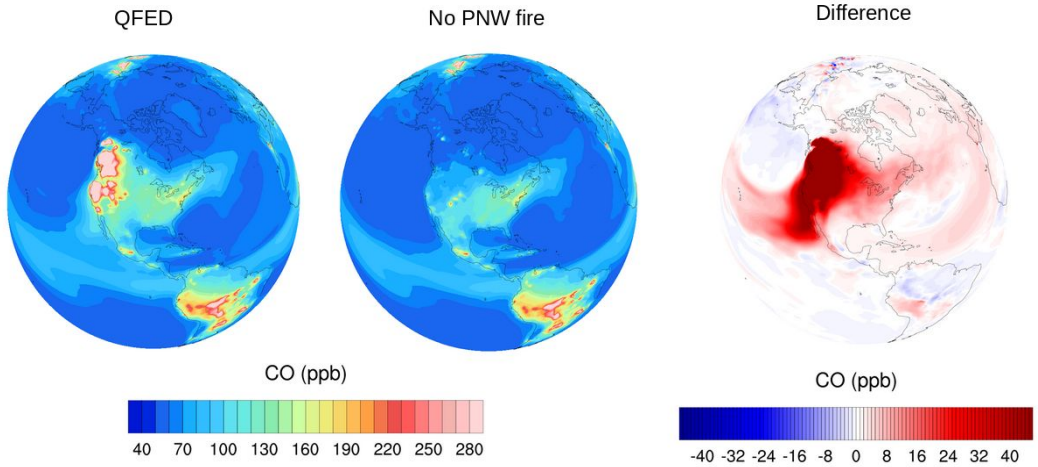
Tagged tracer studies: No change in chemistry

Australasia CO anomaly sources



Sensitivity studies: Chemical feedback

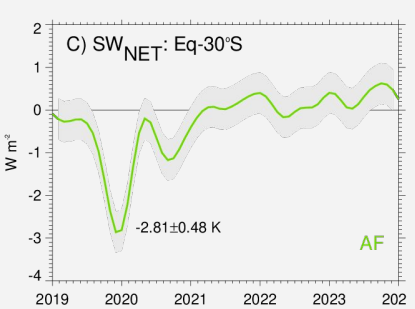
North American fire impacts



Buchholz et al., in review, 2021

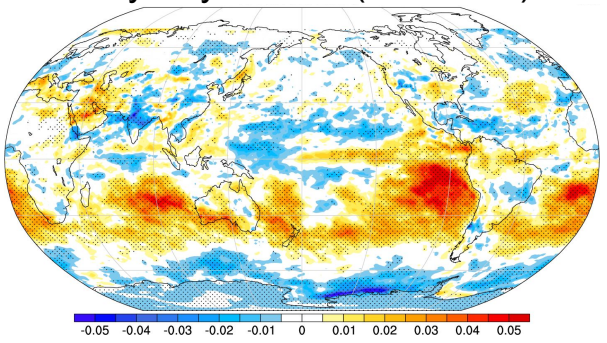
Climate feedback from the Australian 2019/2020 wildfire season

- SSP2-4.5 fire compared to GFED Australian fire emissions
- Robust climate response, on par with a major volcanic eruption, mainly due to aerosol-cloud interactions.
- Interhemispheric radiative imbalance anomaly is greater than at any time during the entire span of the CESM2 LE.

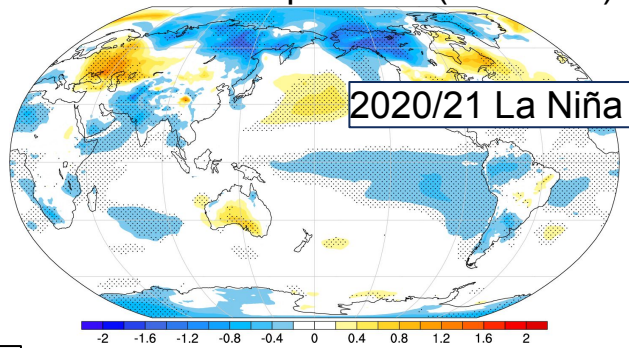


Large all-sky effects (>2 W m^{-2})

Cloudy Sky Albedo (Jan 2020)



Near-surface temperature (Jan 2021)



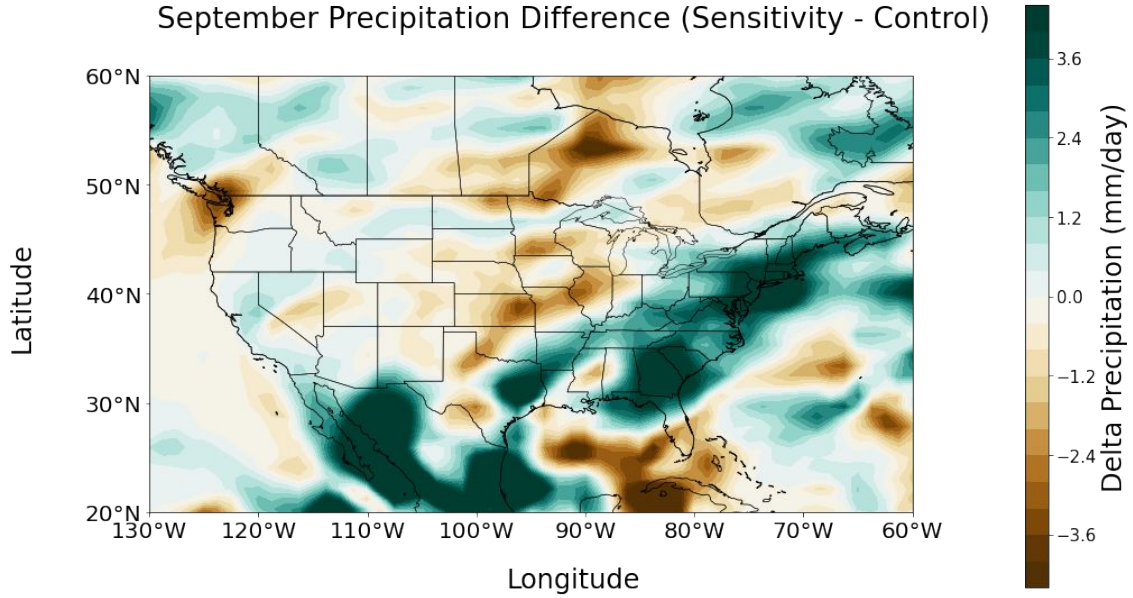
2020/21 La Niña response

Cloud brightening across the Southern Hemisphere

Fasullo et al., in review 2021

Pacific Northwest Wildfire (PNW) Emissions Impact on Precipitation

Control run: using FINNv2.2 fire emissions
Sensitivity run: fire emissions over PNW turned off



In September, the Northeast, Mid-Atlantic, and Southeast US regions experienced a significant precipitation decrease when PNW wildfire emissions are turned off.

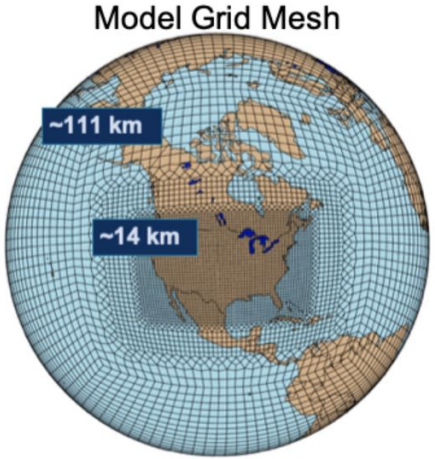
Wildfire emitted aerosol and trace gases can affect precipitation through cloud microphysics, such as cloud fraction, and atmospheric dynamics, such as 250mb Jet Stream.

Work done by Peizhi Hao (CU Boulder), summer intern

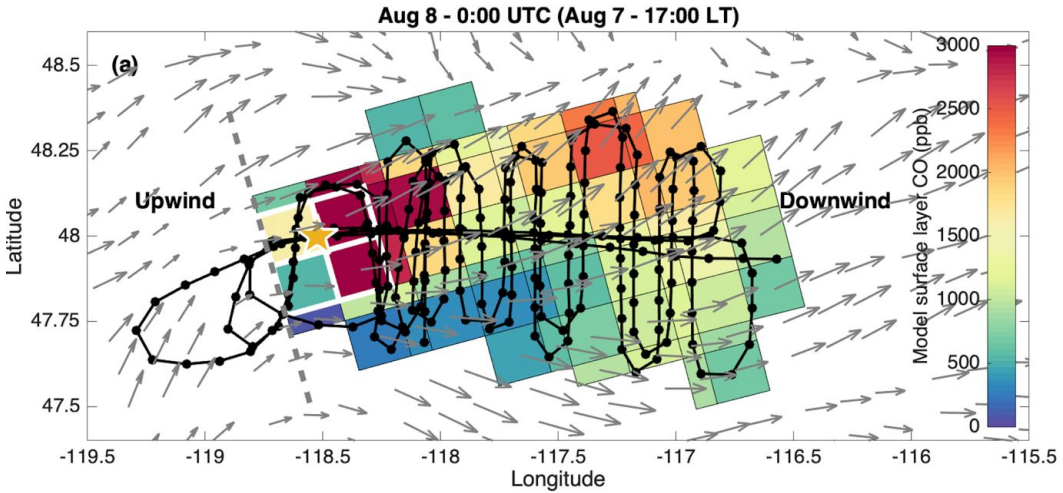
Fires in MUSICA-V0

MUSICA-V0: CAM-CHEM-SE-RR

the Multi-Scale Infrastructure for Chemistry and Aerosols (MUSICA) Version 0 is a regionally refined version of the CAM-chem global chemistry climate model.



Williams Flats Fire (Aug 7th 2019 at WA)

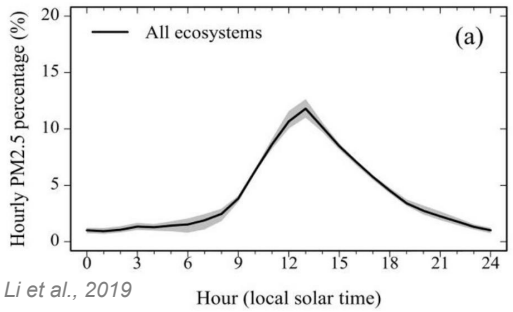


The model grid is fine enough to directly compare to airborne measurements, allowing evaluation of emissions, transport, and chemistry in the model.

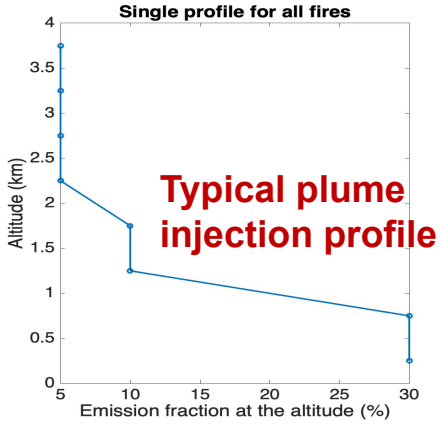
This resolution is also fine enough to study fire impacts on air quality.

Impact of fire diurnal cycle and plume rise in the model

Typical diurnal cycle of fire:

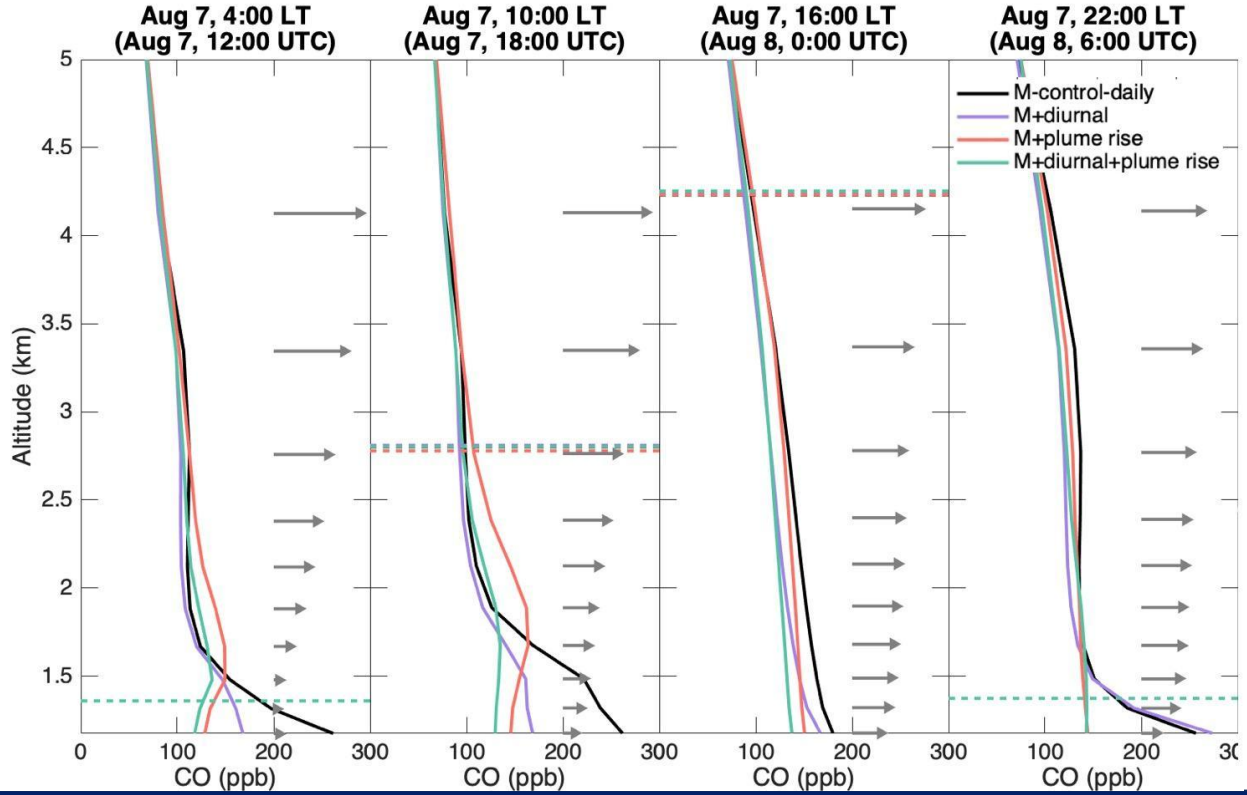


Li et al., 2019

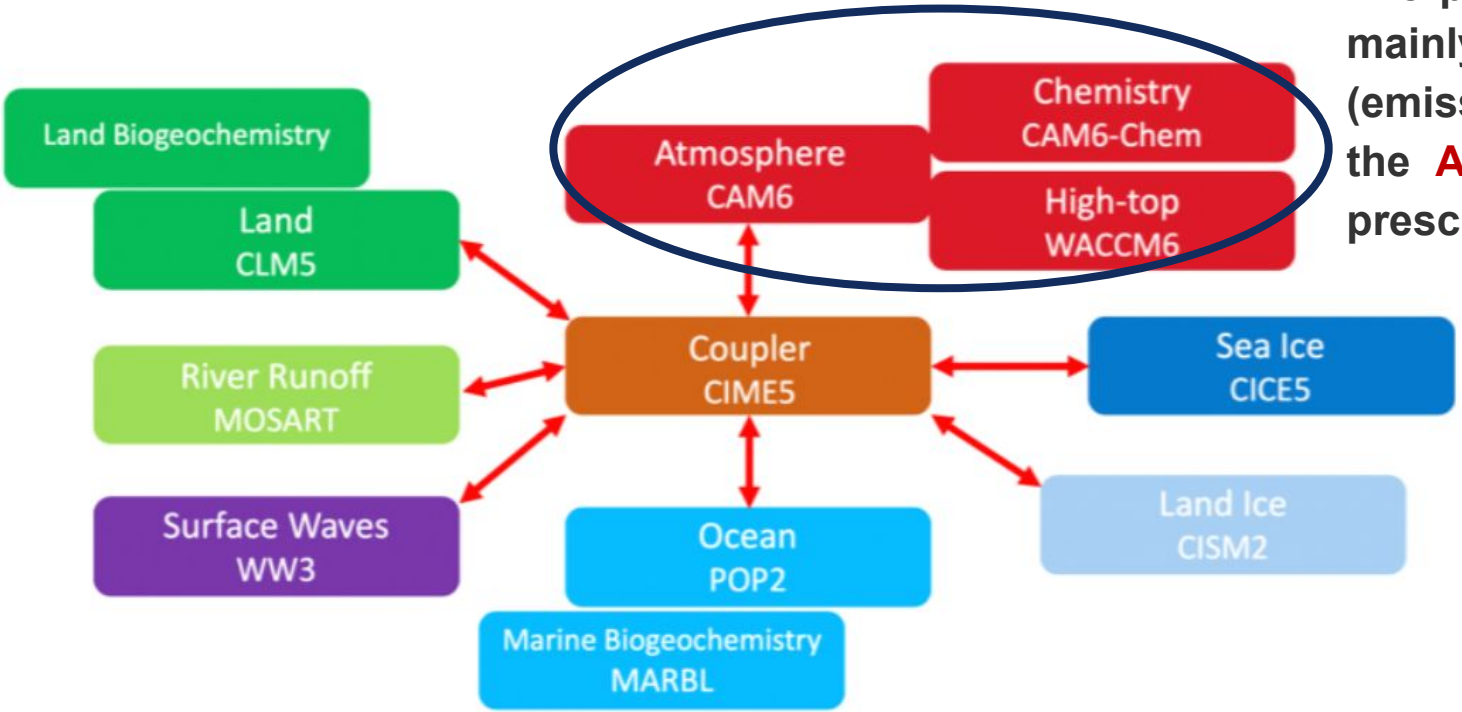


Typical plume injection profile:

Williams Flats Fire (Aug 7th 2019 at WA)



Other options in CESM

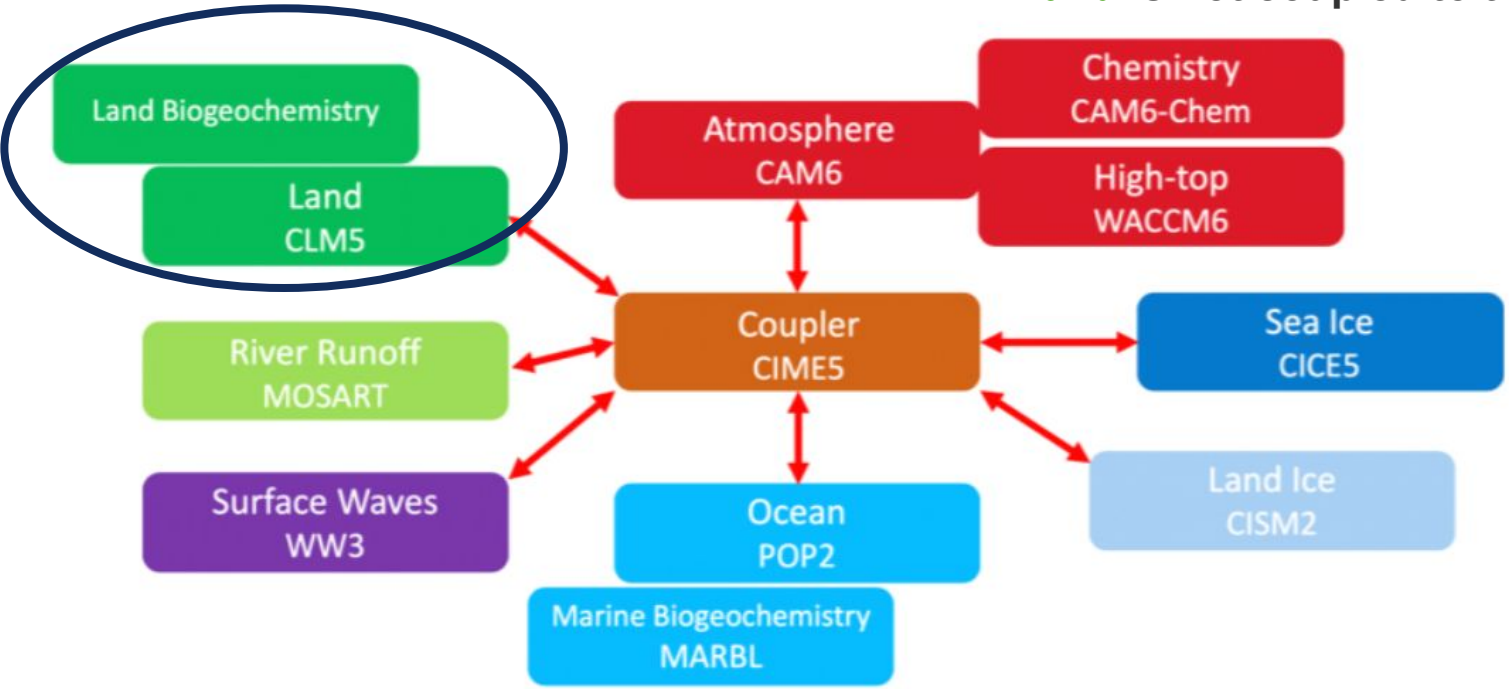


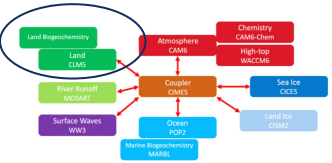
The previous examples mainly focus on the fire (emissions) impacts in the Atmosphere using prescribed emissions.

Other options in CESM

There is a fire model in the Land component.

By default, fire emissions calculated from Land is not coupled to the Atmosphere.





Fire model in Land

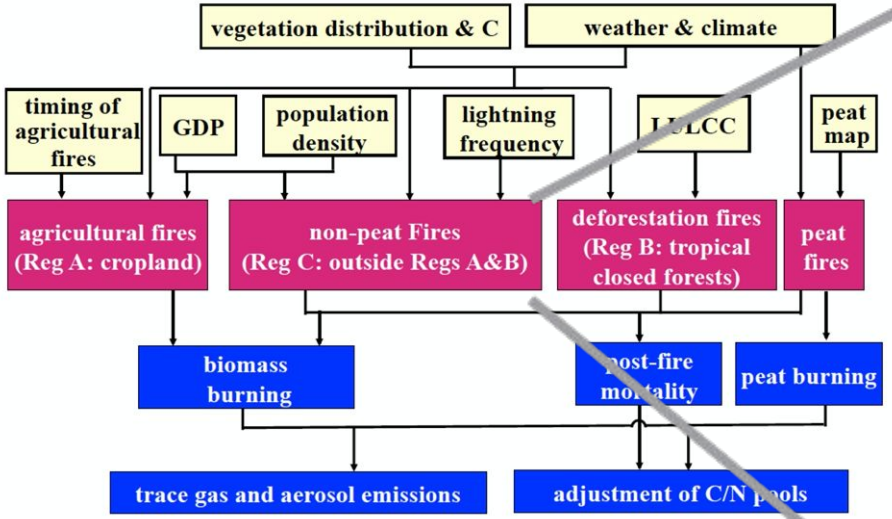


Fig. 2. Structure of new fire parameterization. Fire scheme described in Li et al. (2012a, b) is used in Region C with modifications by mainly adding the economic influence in the fire occurrence component and the socioeconomic influence in the fire spread component.

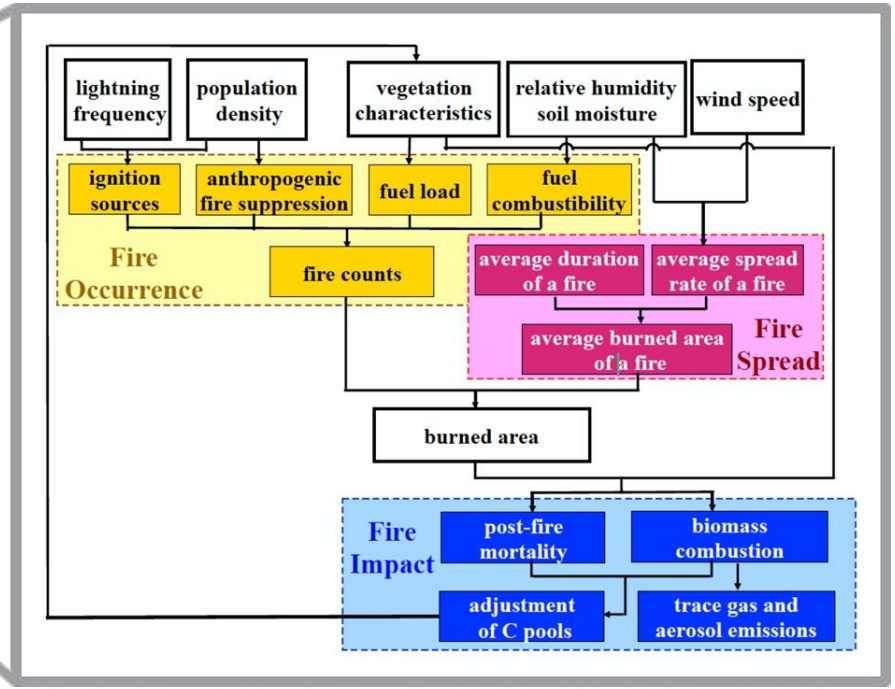


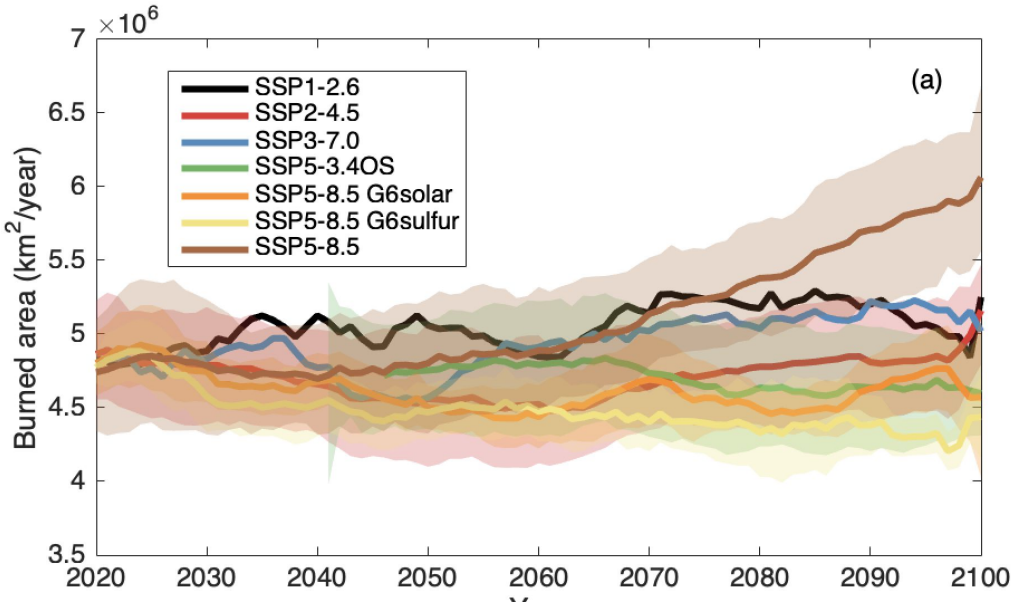
Fig. 1. Fire parameterization of Li et al. (2012a, b). It contains three components: fire occurrence, fire spread, and fire impact.

Li et al., 2012, 2013

Future projections of fires under Different Scenarios

1. **SSP1-2.6:** sustainable development
2. **SSP2-4.5:** middle-of-the-road development
3. **SSP3-7.0:** substantial land use changes
4. **SSP5-8.5:** unmitigated baseline scenario
5. **SSP5-3.4OS:** overshoot scenario
6. **G6Sulfur:** geoengineering-stratospheric sulfate aerosols
7. **G6Solar:** geoengineering-solar irradiance reduction

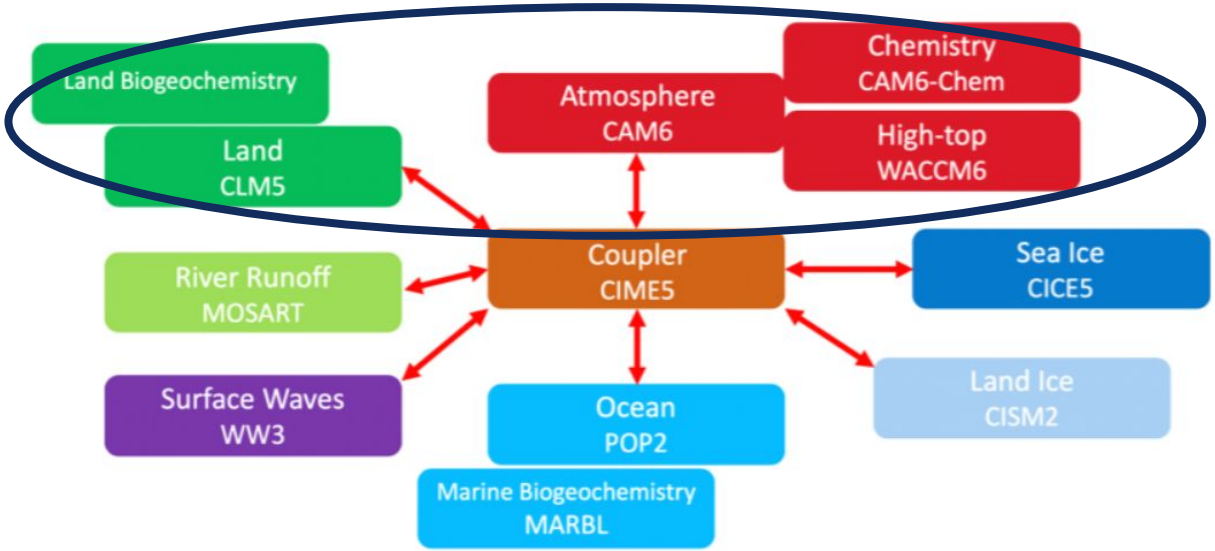
Burned area



The global total wildfire burned area is projected to decrease under the geoengineering and overshoot scenarios, and increase under the other scenarios.

Other options in CESM and Future work

Attempts to couple fire emissions calculated from Land to the Atmosphere (in progress).



- Future fires
- Geoengineering impacts on fires
- HONO chemistry
- Reactive nitrogen and aerosols
- Forecasting fires and fire impacts
- Data Assimilation
- Air quality and health
- ……

buchholz@ucar.edu, wenfut@ucar.edu