Applications of wildfire in CESM
As related to atmospheric composition and chemistry

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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
Other options in CESM

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

**Method 1**
- Burned area
- Biomass loading and fraction burned

GFED (CMIP6) FINN (active fire)

Fuel consumption \( \times \) Biomass loading and fraction burned

\( \text{(kg C burned)} \)

Biome-specific Emission Factors

\( \text{kg/kgC} \)

From field and lab studies (e.g. Akagi et al. 2011)

**Method 2**
- Fire radiative power (FRP)
- Biome-specific conversion factors

GFAS QFED

\( \text{Emissions} \)
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

Ranges based on emission factor uncertainty

Boreal North America

Tg CO emissions

Tg C from VOC emissions

CESM/CAM-chem simulations
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.

Fasullo et al., in review 2021

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

Cloud brightening across the Southern Hemisphere

Near-surface temperature (Jan 2021)
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.

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

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.
There is a fire model in the Land component. By default, fire emissions calculated from Land is not coupled to the Atmosphere.
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

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
- ......