E3SM-CARRM and its application to wildfire induced pyrocumulonimbus

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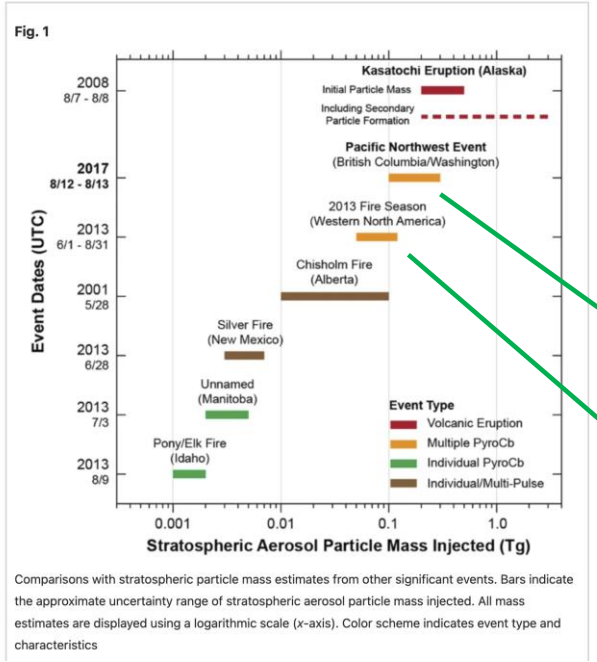
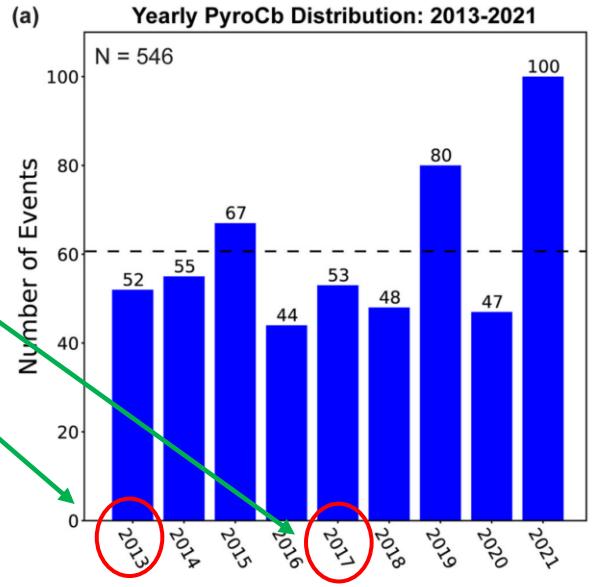
Work at LLNL was performed under the auspices of the U.S. DOE by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344.
Release Number: LLNL-PRES-867732

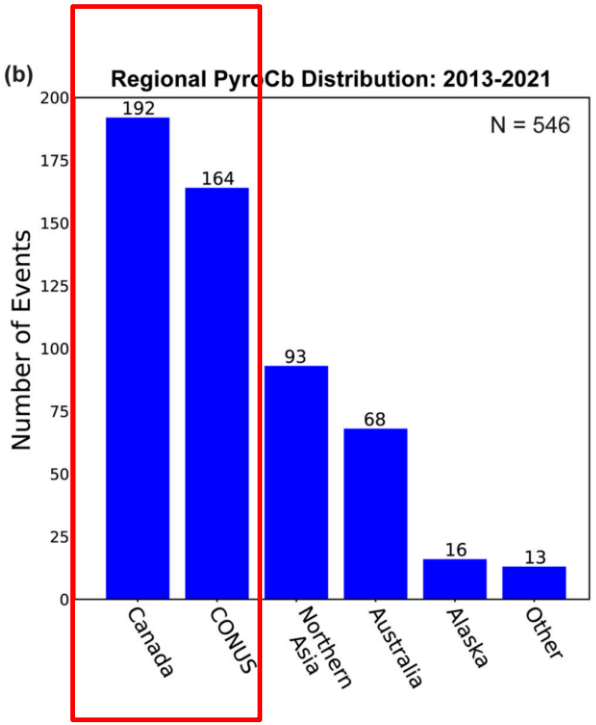
Extremes: pyrocumulonimbus (PyroCb) events



Peterson et al. 2018

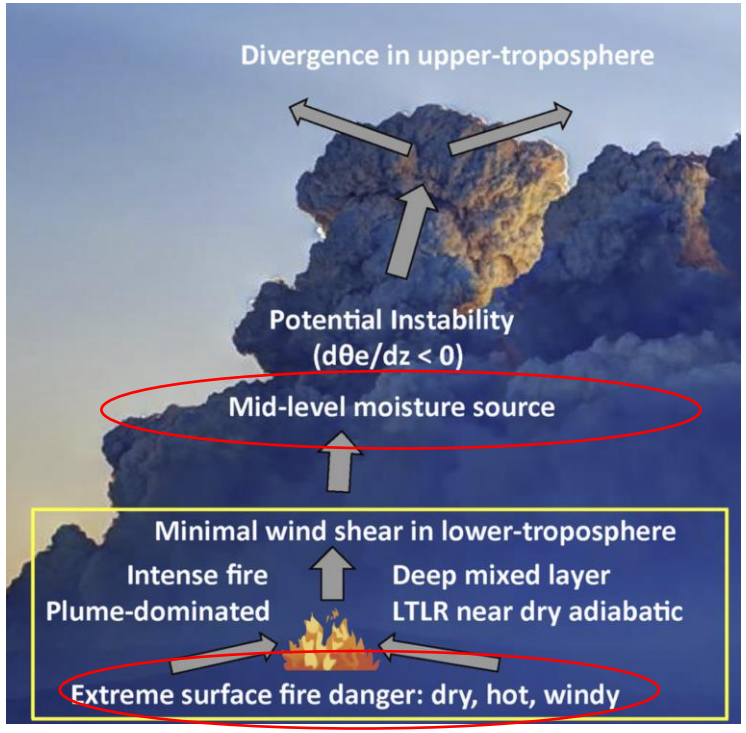


Fromm et al. 2022

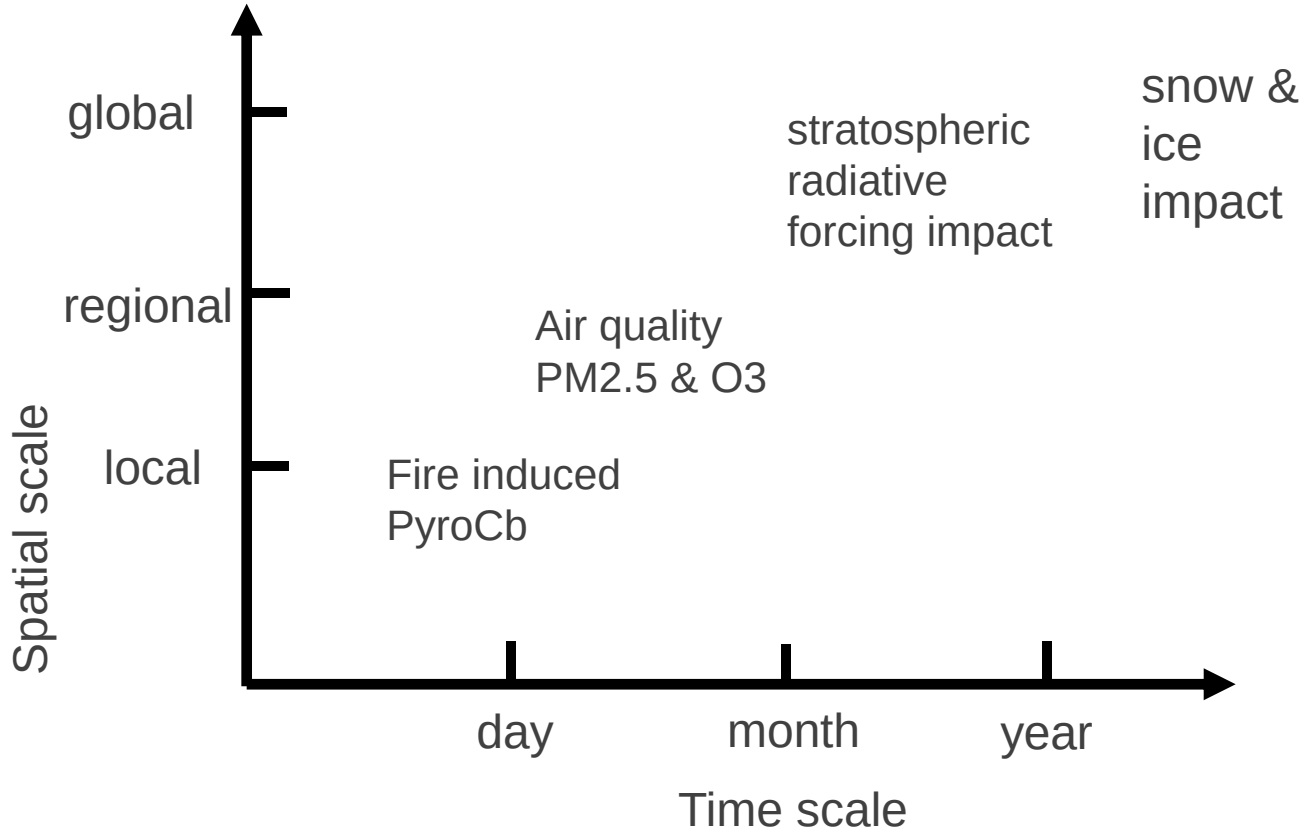


- Injected mass from Pacific Northwest Event is equivalent to a moderate volcanic eruption
- More PyroCb events are observed over Western North America (Peterson 2017).

The challenges to simulate PyroCb



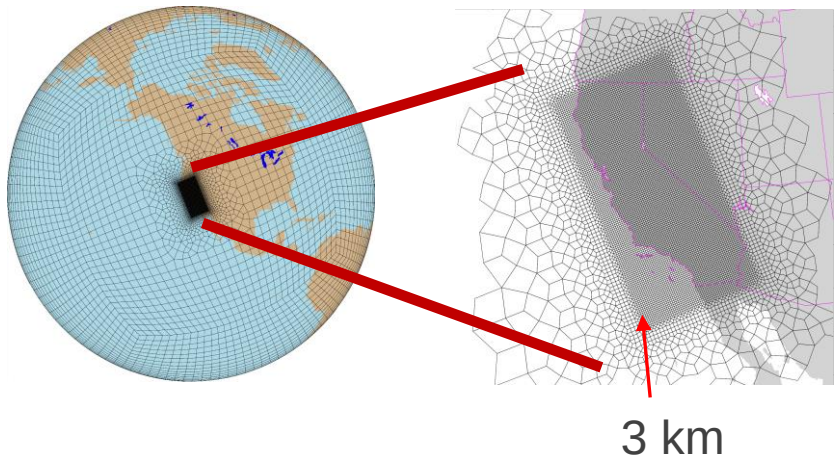
Peterson et al. 2017

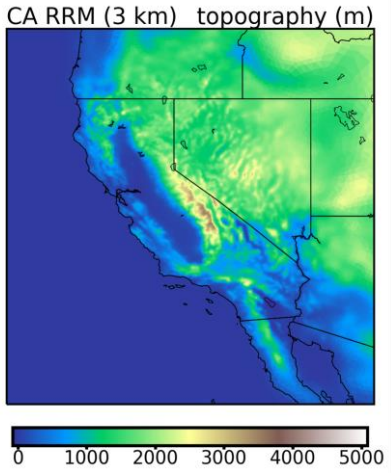


- The PyroCb is triggered by extreme wildfires and hard to be simulated by deep convection scheme.
- Regional Refined Model is better choice

Multiscale wildfire simulation framework: E3SM California Regionally Refined Model (E3SM-CARRM)

E3SM chemUCI MAM5 + CARRM + Wildfire enhancements

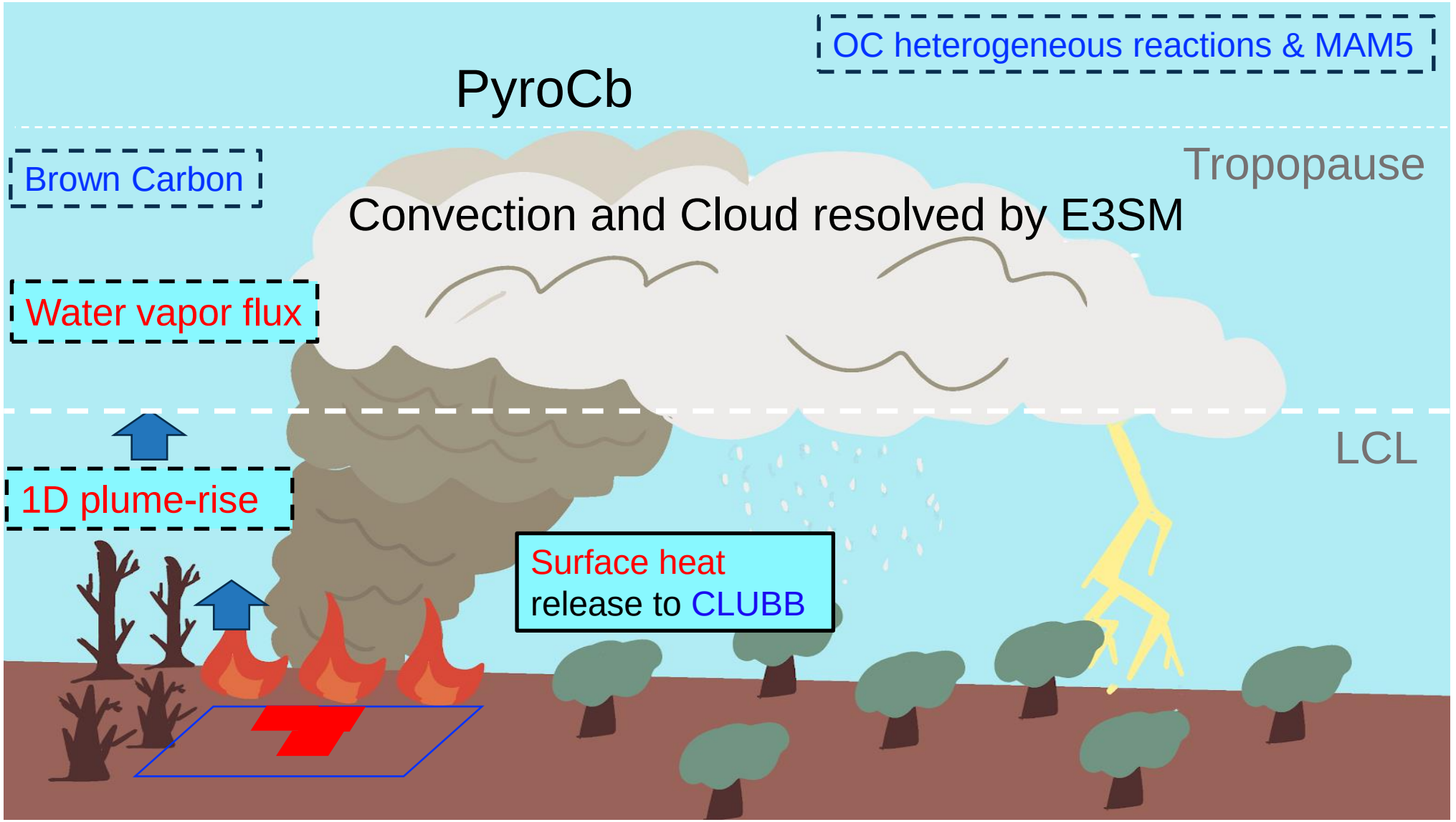




Topography

- chemUCI and MAM5 from V3 development
- 3-km mesh over California
- 100-km mesh globally
- Turned off deep convection scheme
- Free run over California
- Nudged simulation outside California

Wildfire enhancements

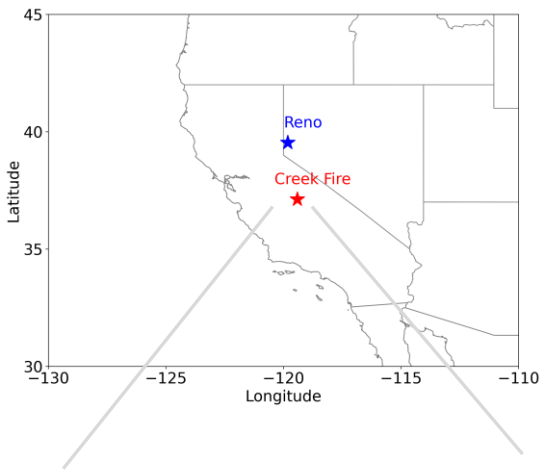


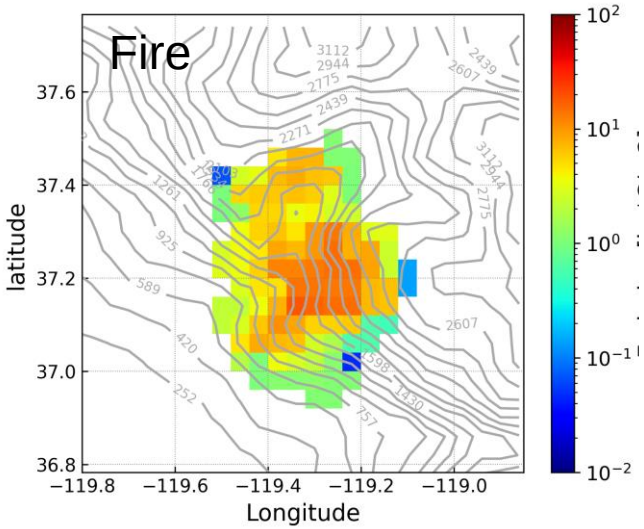
UCI fire data:
0.5 km
subgrid fire
information

E3SM-RRM
dycore
(*3 km*)
physics grid
(*5 km*)

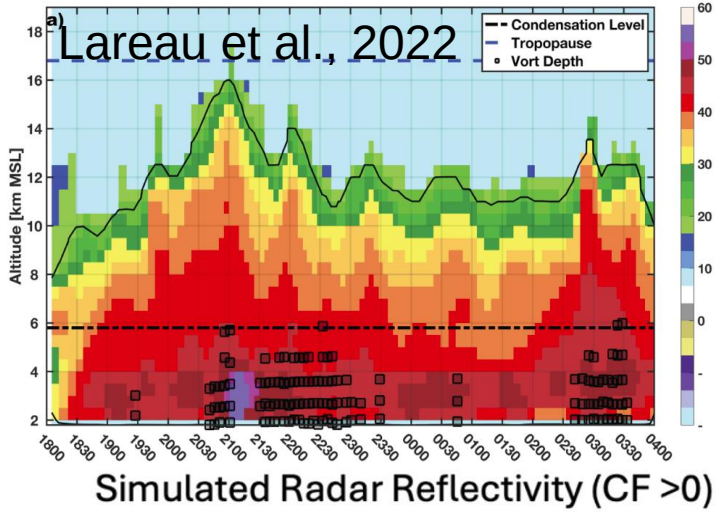
2020 Creek Fire case study

Creek Fire

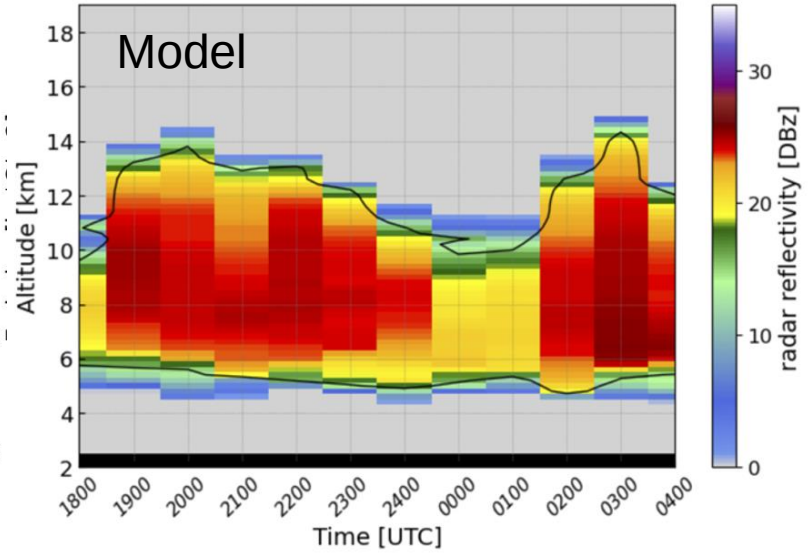




PyroCb comparison

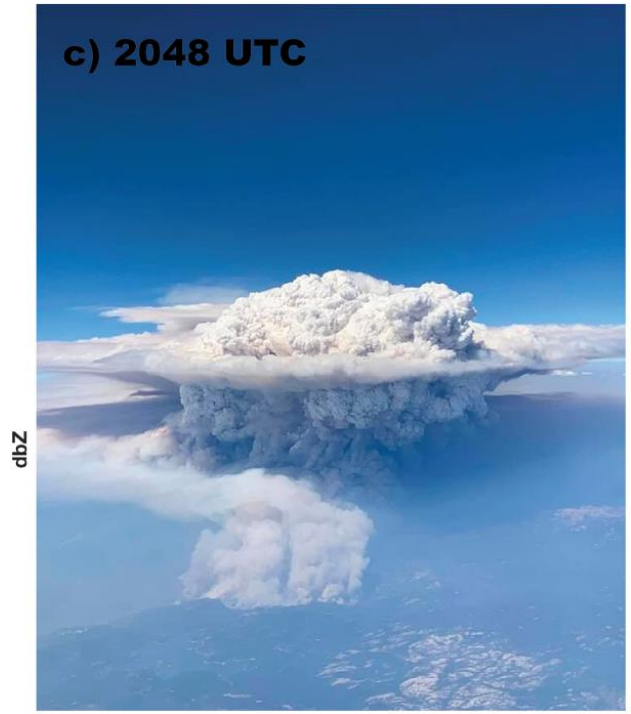


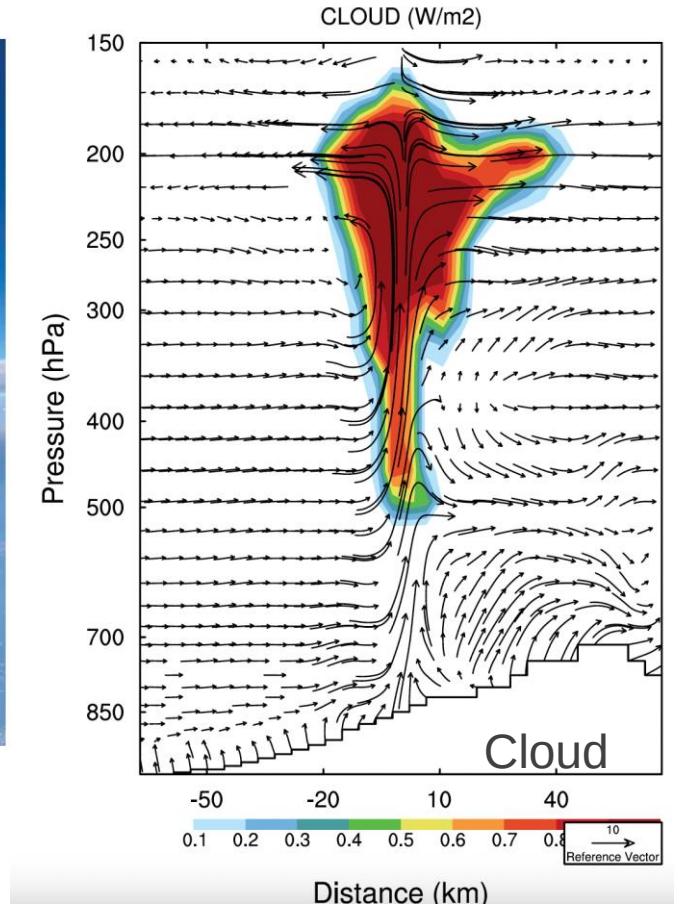
Radar observation

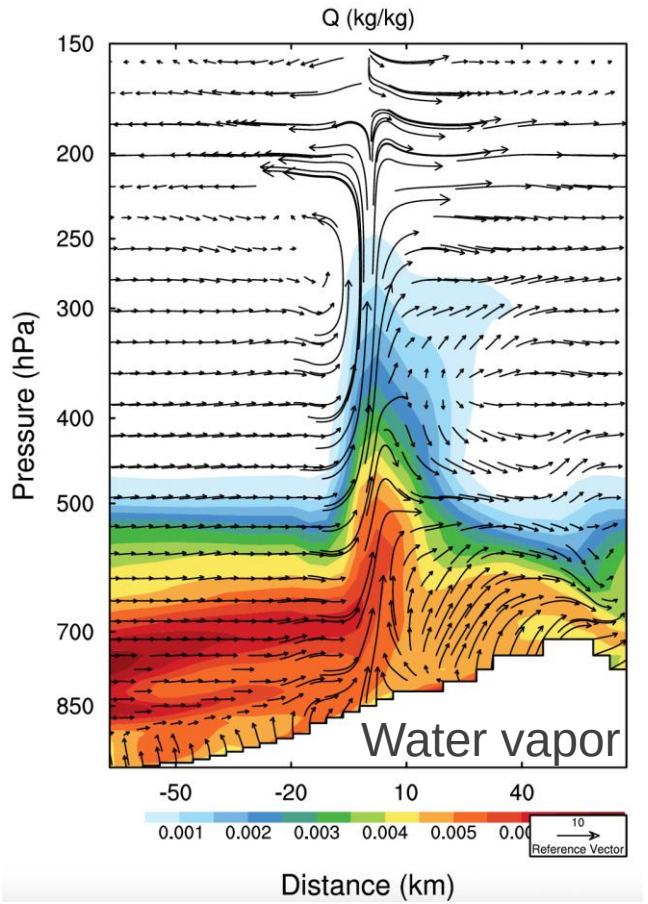


E3SM-CARRM

PyroCb vertical profile



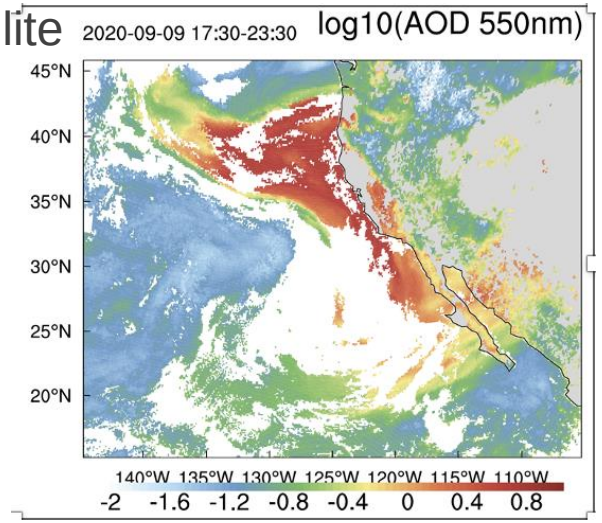


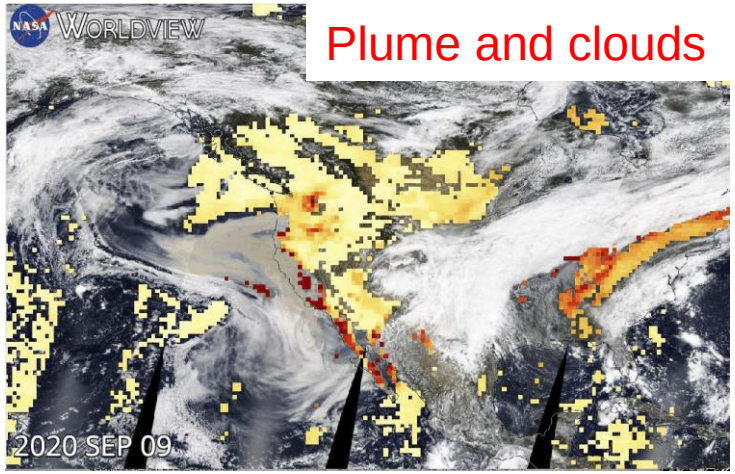


Convection from model dycore

The regional transport of aerosols

Satellite

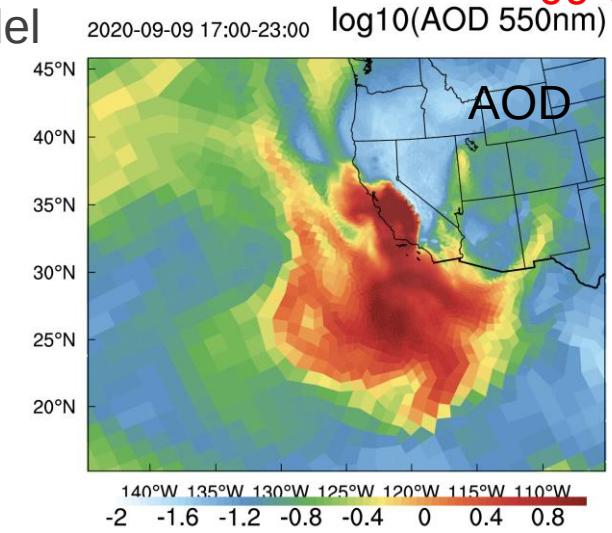


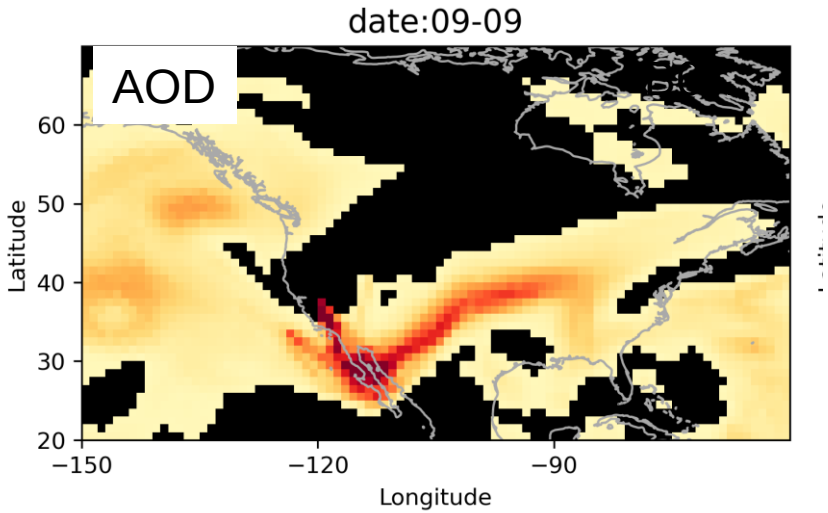


Plume and clouds

09-09-2020

Model





- E3SM-CARRM captures the regional transport of wildfire aerosols
- Computational efficiency: 0.12 SYPD on LC-dane with 10 cores (8.5 days to simulate one model year)

Our ongoing work:

- Analyze the dynamics of PyroCb and the role of aerosols.
- Assess the likelihood of PyroCb occurrence in specific incidents.
- Investigate secondary ignitions caused by PyroCb lightning.
- Estimate the impact on local air quality.
- Evaluate aerosol mass injections into the stratosphere from PyroCb events.
- Estimate the effects of wildfires on stratospheric chemistry and radiative forcing.

Future work

- Prepare long-term, high-resolution wildfire emission data.
- Use pyroCb observations (in-situ, AOD, SAOD, stratospheric balloon data, new satellite instruments) to constrain wildfire implementations.
- Conduct fire season E3SM-RRM simulations to estimate stratospheric injections from pyroCb.
- Apply RRM to regions beyond California if applicable.Utilize E3SM-RRM to generate wildfire aerosol properties for E3SM-LR historical simulations.

- What are the current and unique strengths and foundational capabilities of DOE for this topic?

The CARRM framework has been established and the fire package is in testing phase.

- What are the grand challenges in advancing the research on this topic?

Produce long-term wildfire data. Need various observational data to validate and constrain our model implementations. Computational resources are needed to conduct seasonal scale simulations.

- What role could other agencies play in facilitating our science?

NASA (FireSense, STRIVE) …