Examining the Impacts of an Interactive Fire Plume-Rise Model in E3SM on Aerosol Radiative Effects

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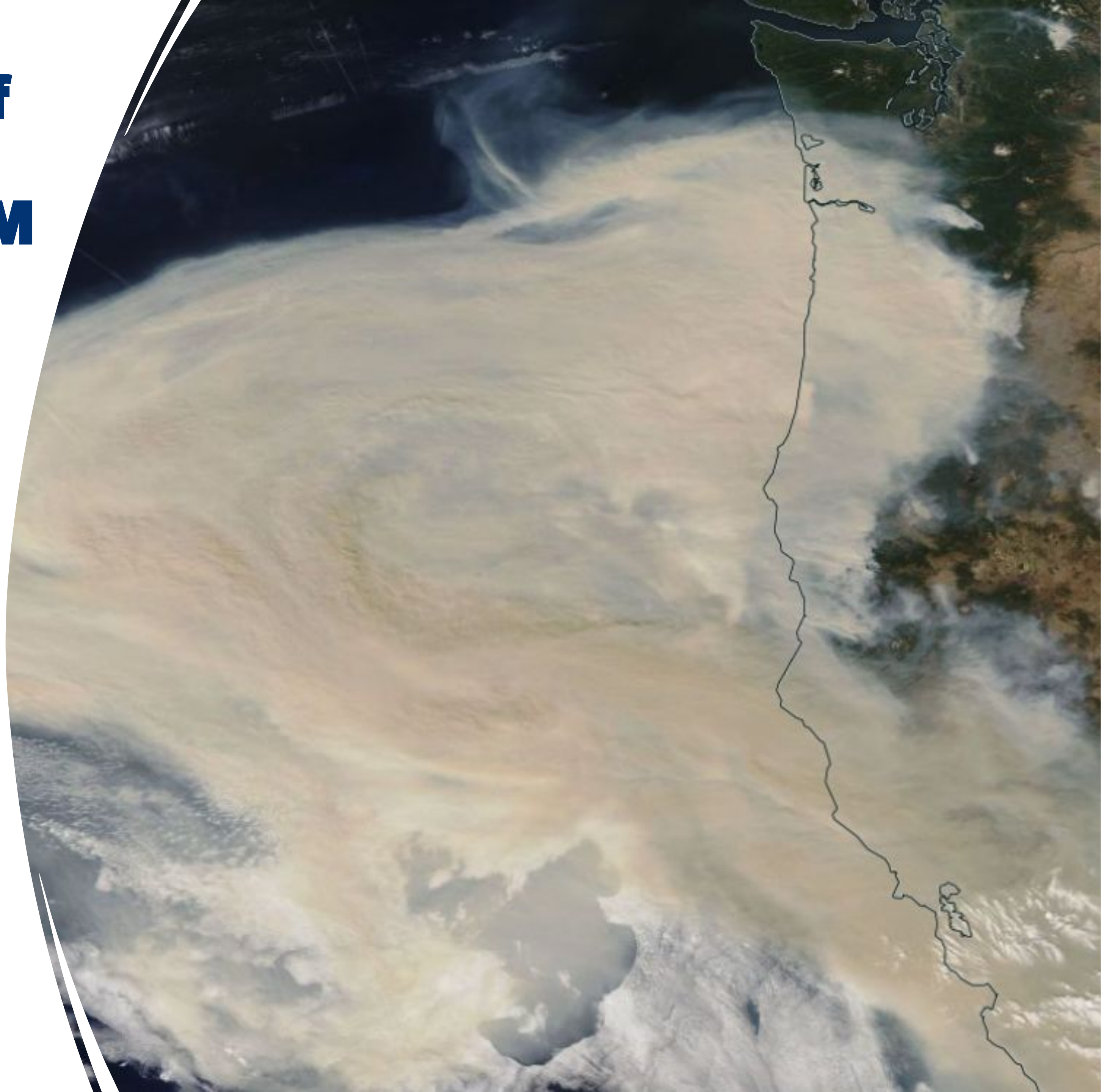
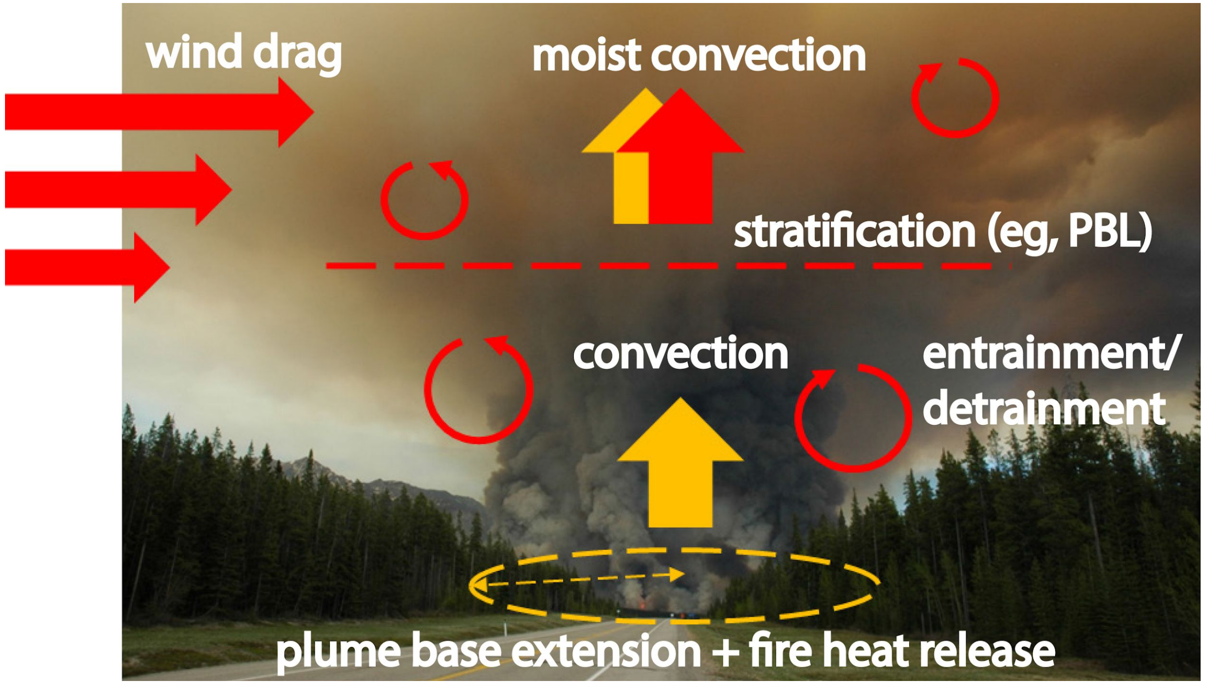


Motivation – Background

- Biomass burning aerosols (BBA)
- Injection heights of BBA
- More extreme fires in the future.

Motivation – 1D plume-rise model

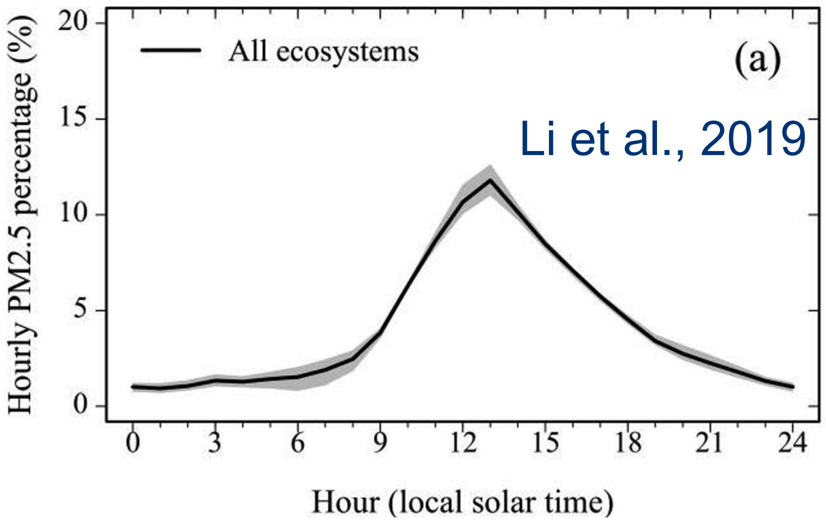
- Prescribed injection heights in GCMs
- 1D plume-rise model by Freitas et al., 2007
  - Host models (WRF-Chem, DOE E3SM, CESM, etc.)
  - 6 equations of ω, T, and cloud hydrometeors.
  - Inputs: fire size and fire heat flux, and ambient conditions (T, ϱ, ω, U, V, qv)



Paugam et al., 2016

Methodology

- Fire properties (Val Martin et al., 2012)
  - Heat flux: Fire radiative power (FRP)×10
  - Fire size: Scaled-FRP
- Different fire intensity
  - Based on FRP
  - Small-medium-big-extreme four bins
- Strong diurnal cycle
  - Fire diurnal cycle in Li et al. (2019)



Methodology – Model configuration

- E3SMv1 with ne30 grid (~1°)
- 2018: QFED daily fire emissions + MODIS FRP retrievals
- Four cases with different vertical profiles and fire diurnal cycles
- The same BBA emission files used in all cases, including BC and POM

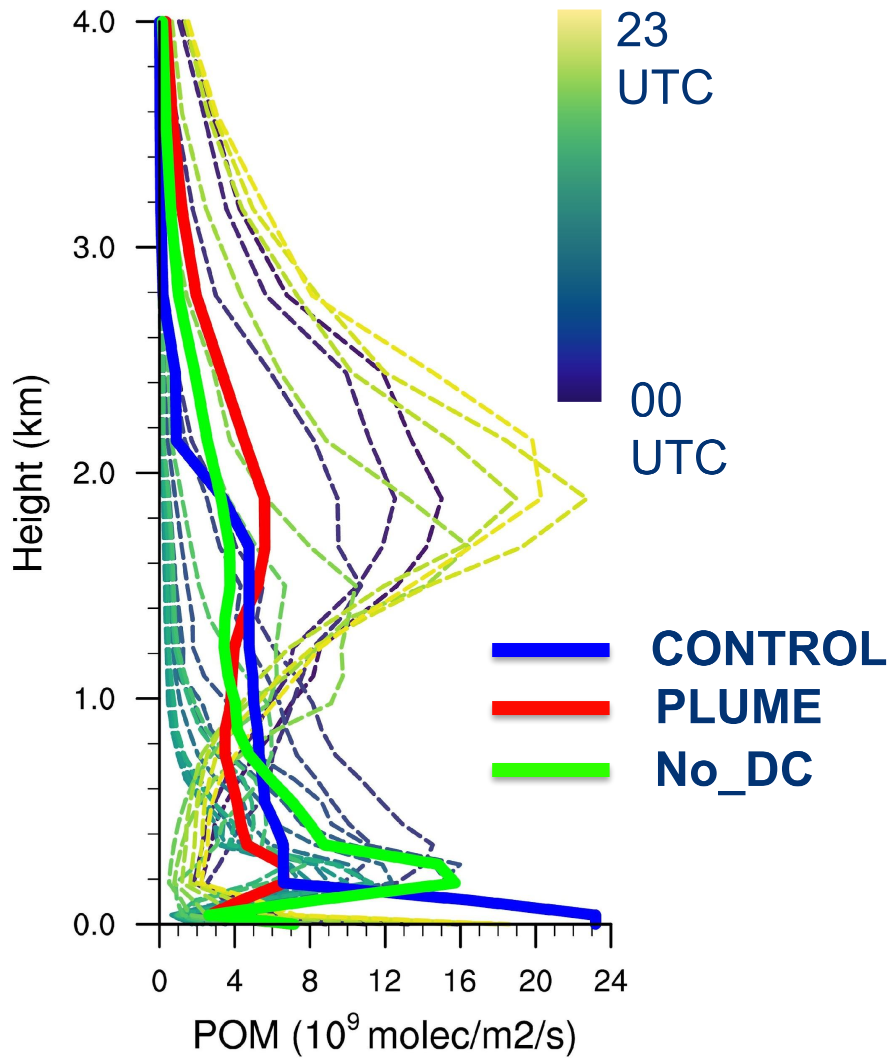
Case	Vertical Profiles	Fire diurnal cycle
CONTROL	Default	Constant
PLUME	Plume-rise	Yes
No_DC	Plume-rise	Constant
SURFACE	Surface	Constant

Vertical profiles of BBA emissions

Vertical profiles BBA emissions in North America during August

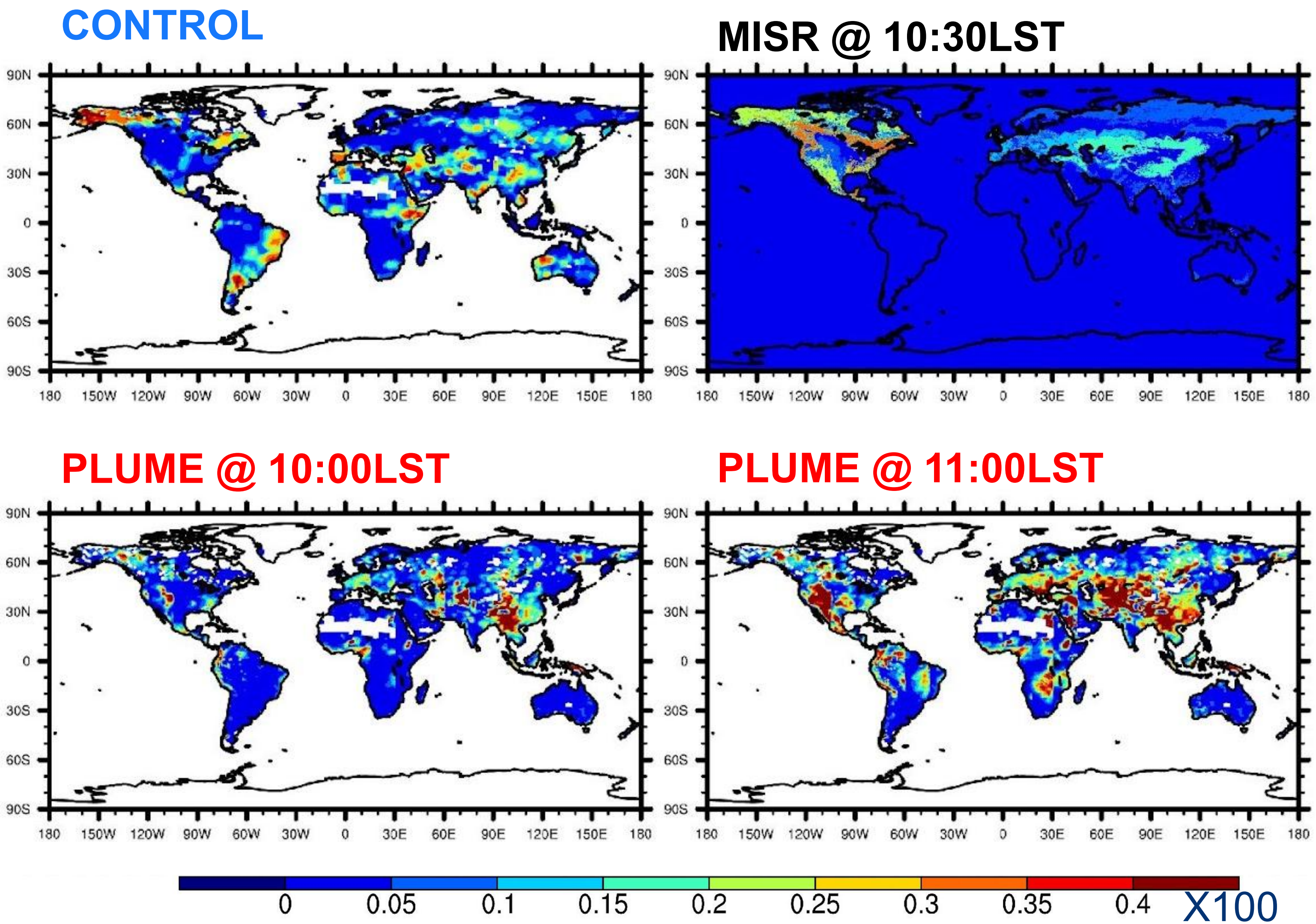
- Diurnal cycle in dash lines:
  - Strong diurnal cycle
  - Below 1km during local night
  - Peaking at 2km during afternoon.

- Monthly averaged in solid lines:
  - More BBA above 2 km due to plume-rise model + fire diurnal cycle assumption



Injection height: model vs. MISR

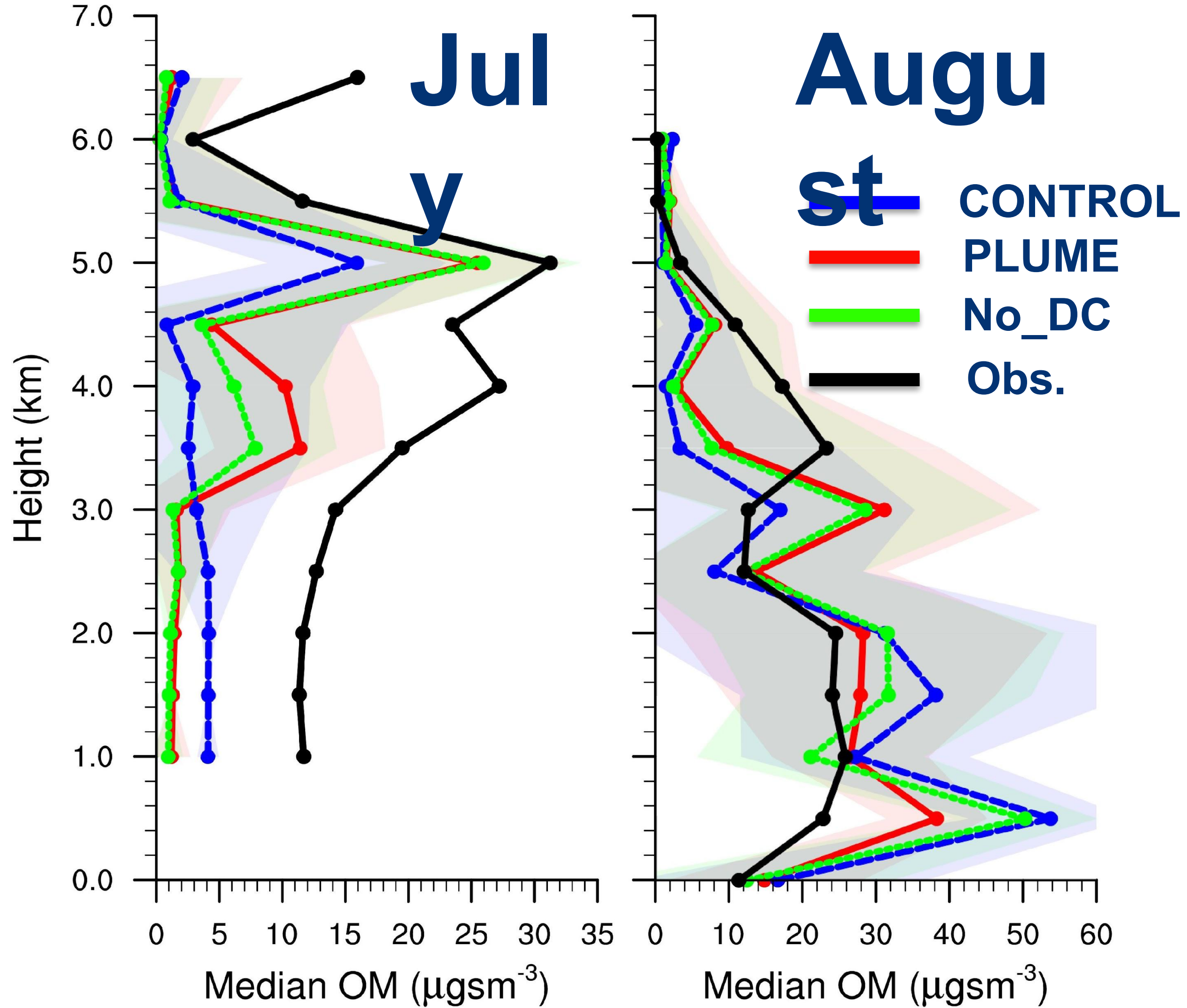
Percentage of BBA injected higher than 2km in JJA



- MISR plume product (2008~2010; Val Martin et al., 2018)
- CONTROL
  - Underestimates in N. America
  - Overestimates in Alaska and S. America
- PLUME:
  - from 10LST to 11LST
  - Overestimates in C. Asia and S.E. Asia

Vertical profiles of BBA

Vertical profiles of median BBA mass mixing ratio vs. NOAA WE-CAN

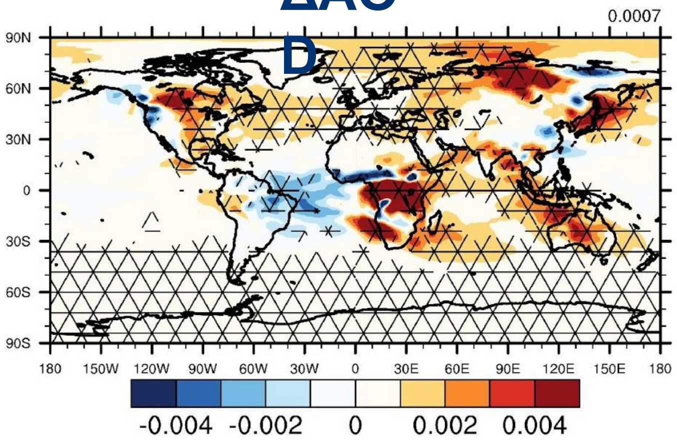


- Hourly outputs sampled along the flight track
- PLUME
  - Reasonably captures both peaks at 5 km and 4km in July
  - Reduces bias under 2km in August
- CONTROL
  - Predicts too many BBAs below 2km

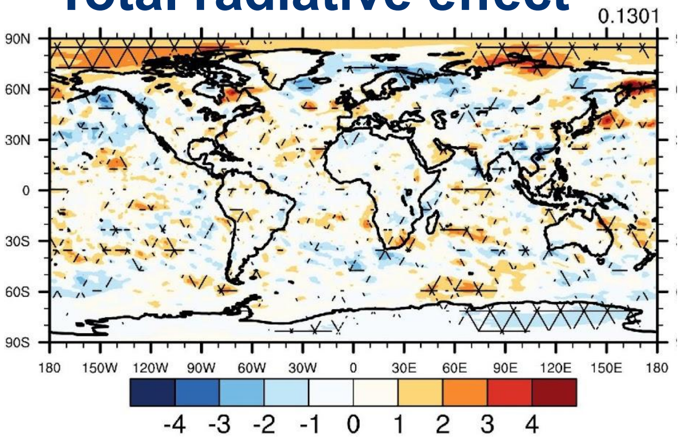
BC+POM AOD and radiative effects

PLUME – CONTROL

ΔAOD

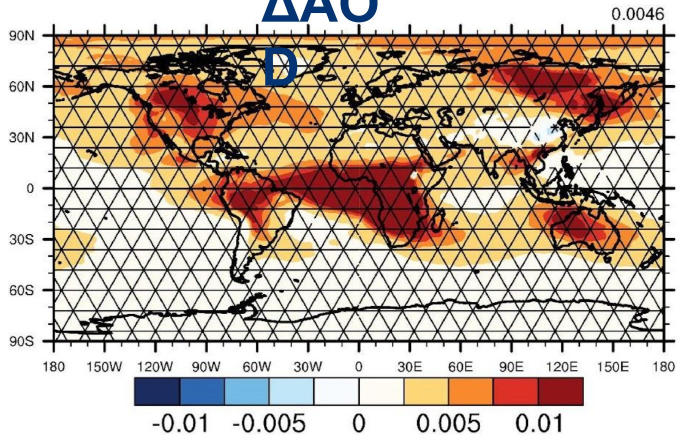


Total radiative effect

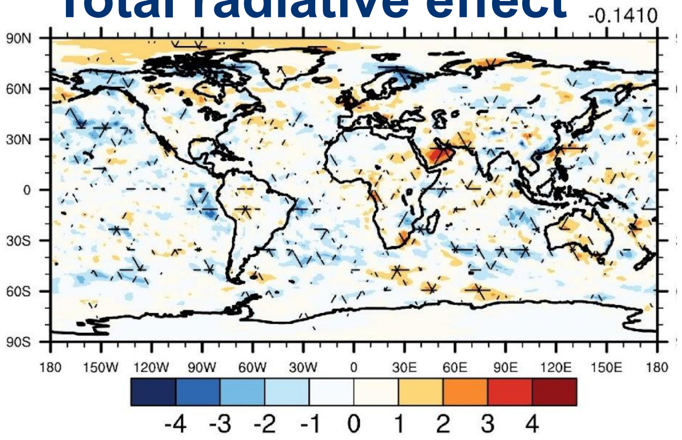


PLUME – SURFACE

ΔAOD



Total radiative effect



- PLUME vs. CONTROL
  - Slightly higher AOD_{BC+POM}
  - Dipole features
  - Warming effect (0.13 Wm^{-2}): surface albedo effect + semi-direct effect
- PLUME vs. SURFACE
  - Significantly higher AOD_{BC+POM}
  - Cooling effect (-0.14Wm^{-2}): strong indirect effect (CDNC increase)

Summary

1. In this study, we incorporate an interactively fire plume-rise model in the DOE Energy Exascale Earth System Model (E3SM).

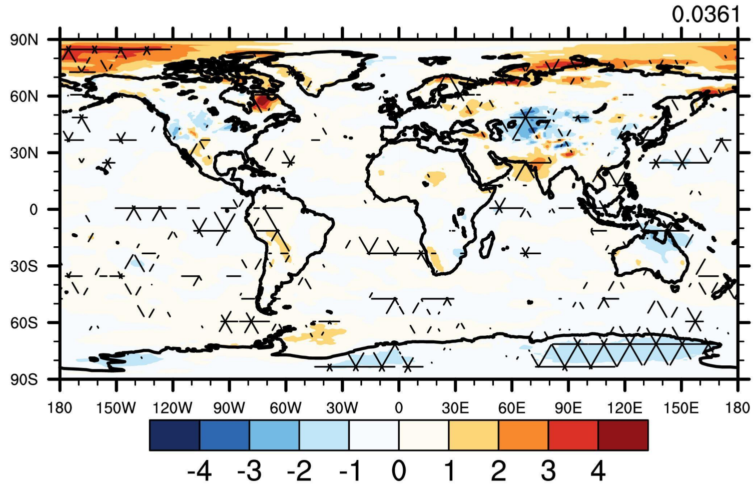
2. E3SM with the plume-rise model outperforms the default model compared to the NOAA WE-CAN in-situ observation.

3. The inclusion of the plume-rise model cause strong warming effect (0.13 Wm^{-2}). The radiative effect is sensitive to the Injection height in a non-linear manner.

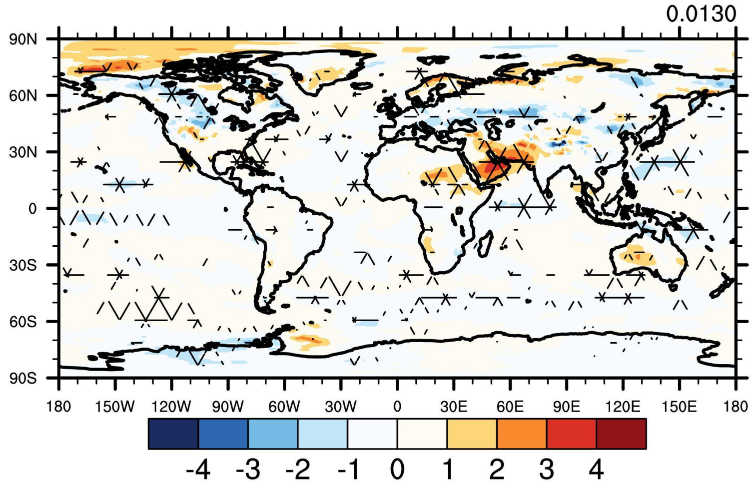
Email you questions to zlu@tamu.edu

Additional slides: residual effect

PLUME - CONTRL

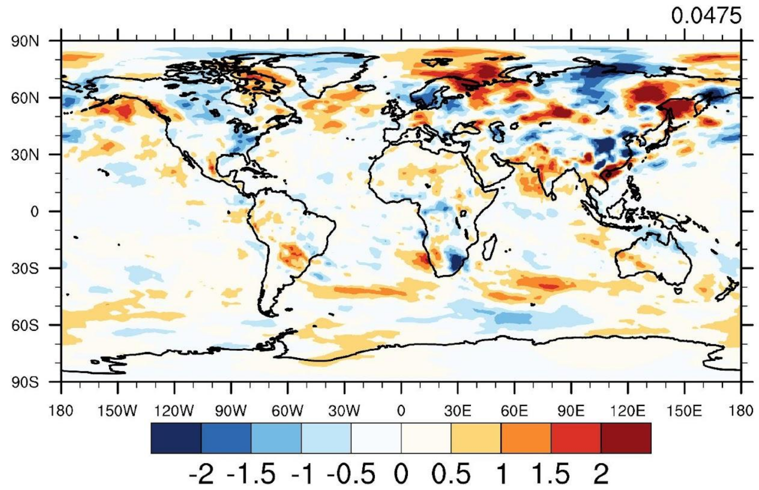


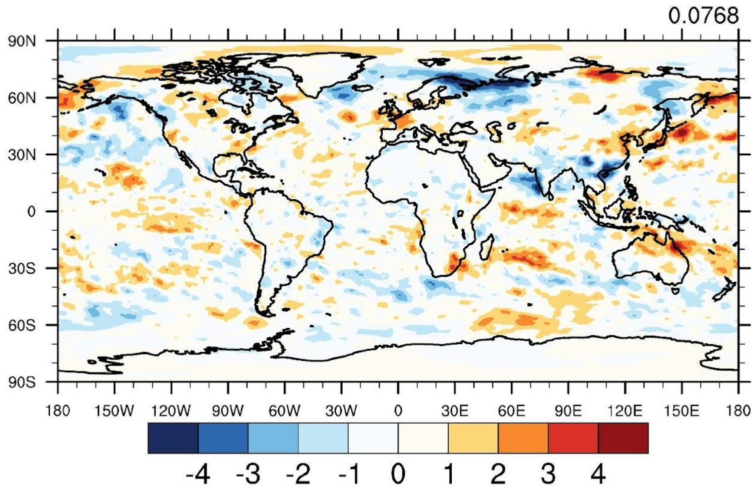
PLUME - Surface



Additional slides: CDNC

PLUME - CONTROL





PLUME - SURFACE