Effects of plume rise on long-range transport of wildfire aerosols and Arctic clouds using the Multi-Scale Infrastructure for Chemistry and Aerosols (MUSICAv0) model

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Background

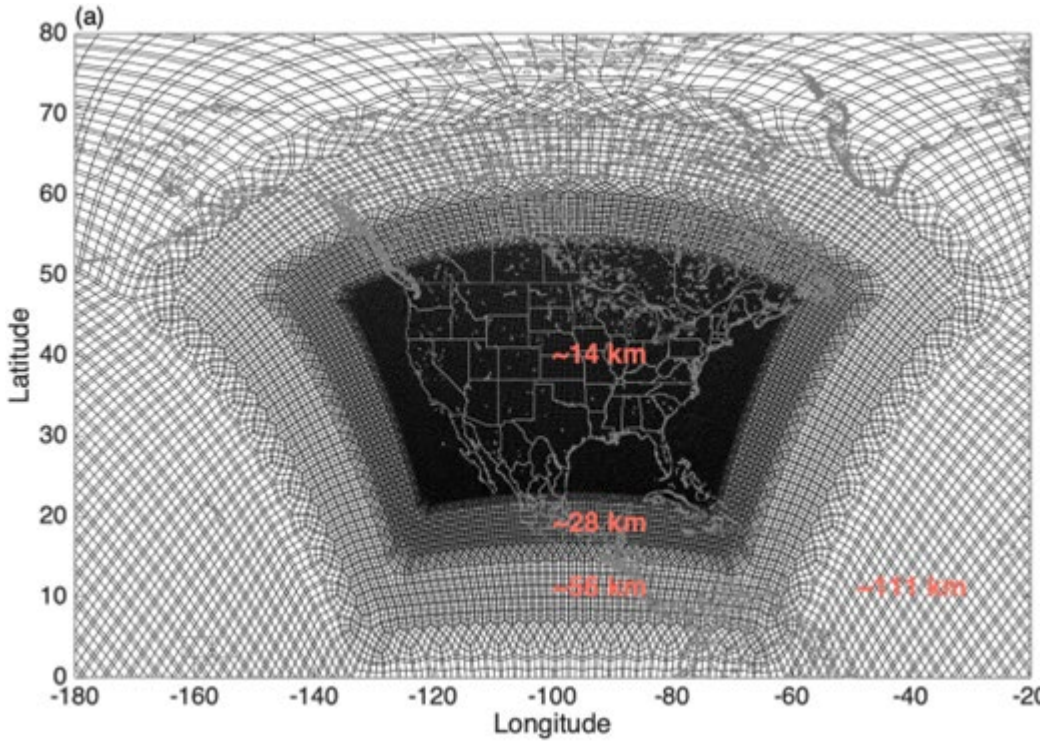
- Wildfires emit gases, aerosols, and water vapor near the surface or at higher altitudes.
- The injection height affect the transport and lifetime of aerosols.
- Wildfire aerosols reduce sea ice loss in the Arctic. (Blanchard-Wrigglesworth et al., 2025).
- Few global climate models calculate the vertical profiles of biomass burning aerosols emissions (Lu et al., 2023).

PNNL

This study incorporates a plume-rise model in the NCAR Community Earth System Model version 2 (CESM2) and investigates its effects on long-range transport of wildfire aerosols and Arctic clouds

Method

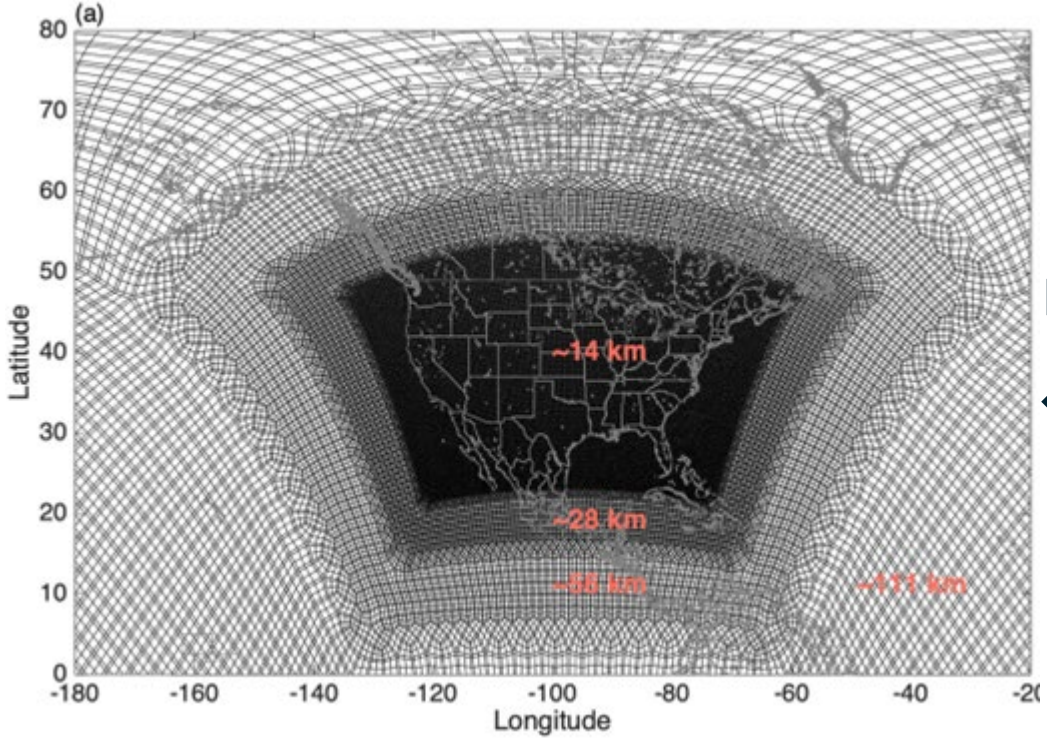
- The Multi-Scale Infrastructure for Chemistry and Aerosols (MUSICAv0), a configuration of CAM6-chem in CESM 2.2



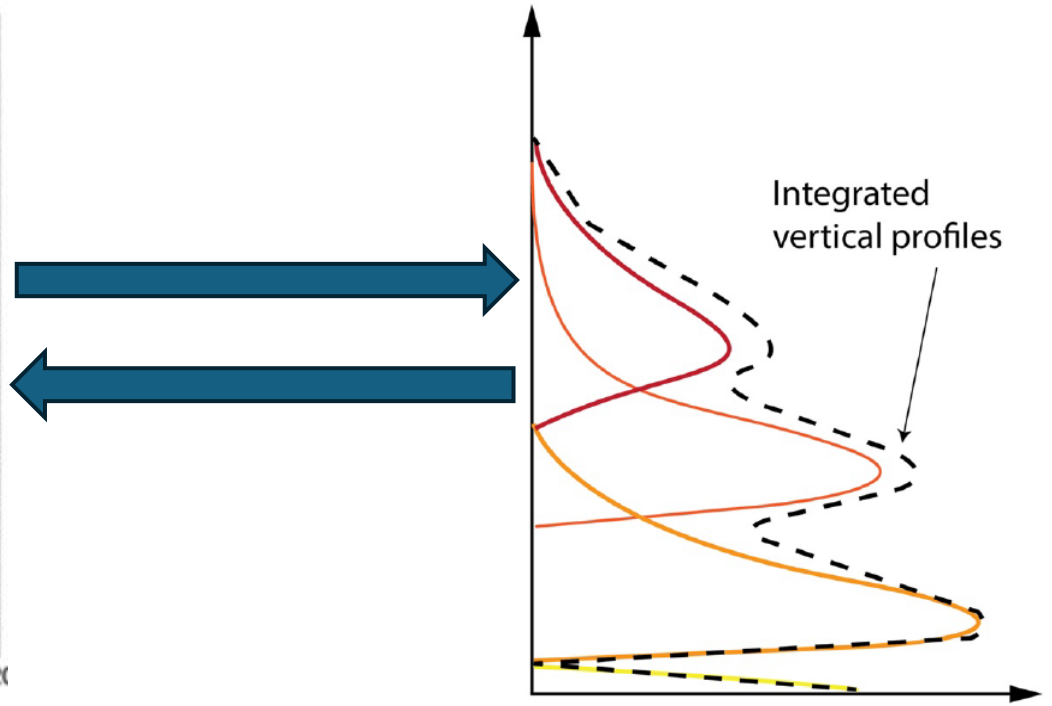
Tang et al., 2019

Method

- The Multi-Scale Infrastructure for Chemistry and Aerosols (MUSICAv0), a configuration of CAM6-chem in CESM 2.2
- The plume-rise model (Freitas et al., 2007; Lu et al., 2023)



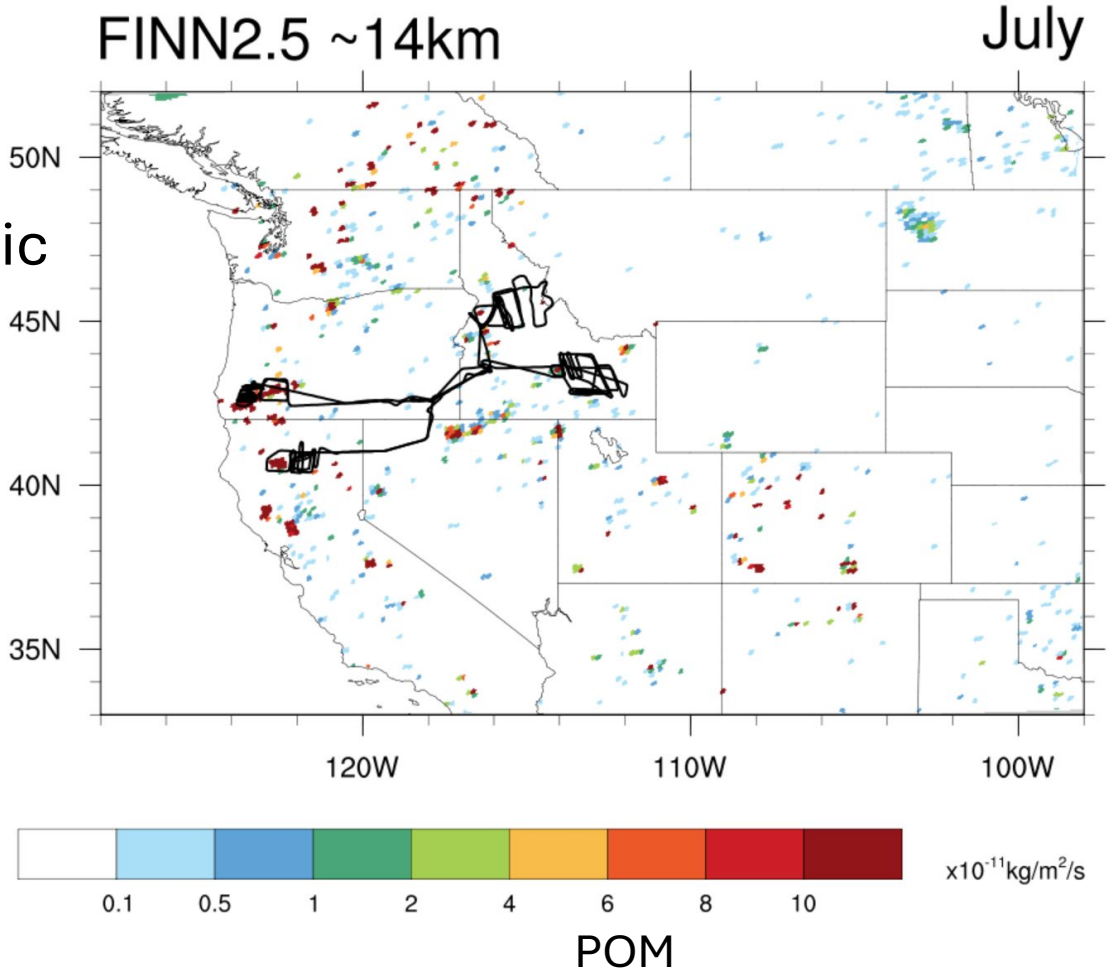
Tang et al., 2019



Lu et al., 2023

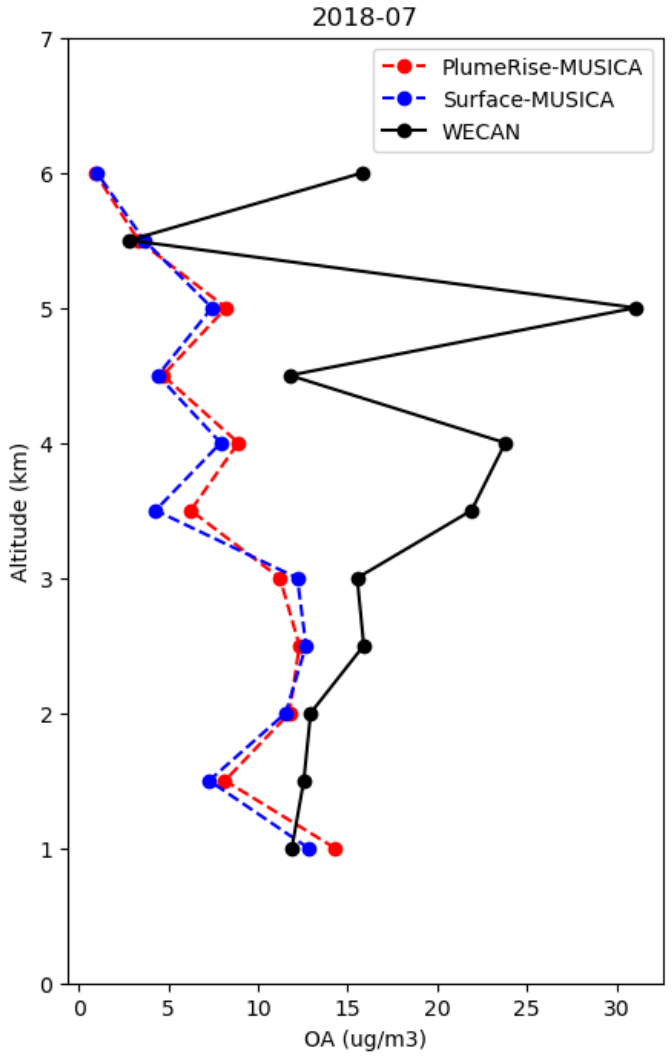
Biomass Burning Emissions

- Inventory: **Fire INventory from NCAR (FINN)**
- Species: Black Carbon (BC), Particulate Organic Matter (POM), CO, SO2, NOx
- Period: July-August 2018
- Flight measurement: Western Wildfire Experiment for Cloud Chemistry, Aerosol Absorption, and Nitrogen (**WE-CAN**)

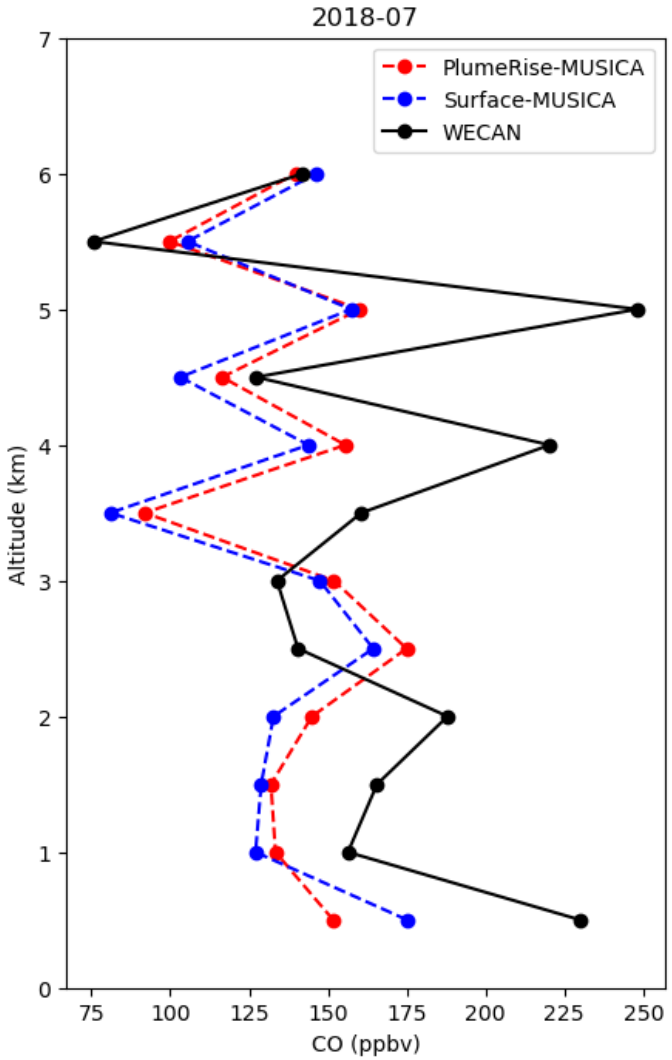


Median profiles of organic aerosol and CO

Organic Aerosol



CO

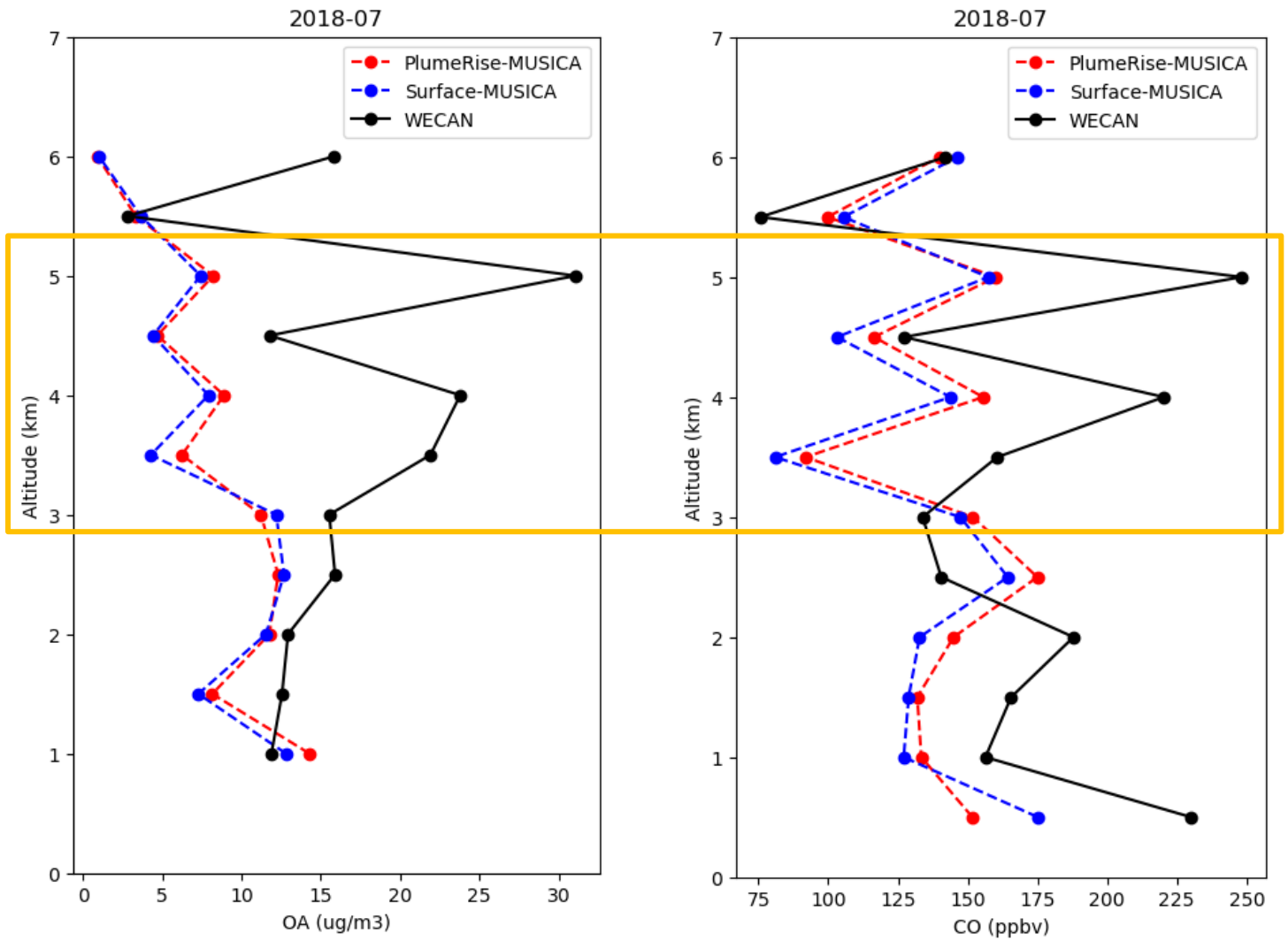


Median profiles of organic aerosol and CO

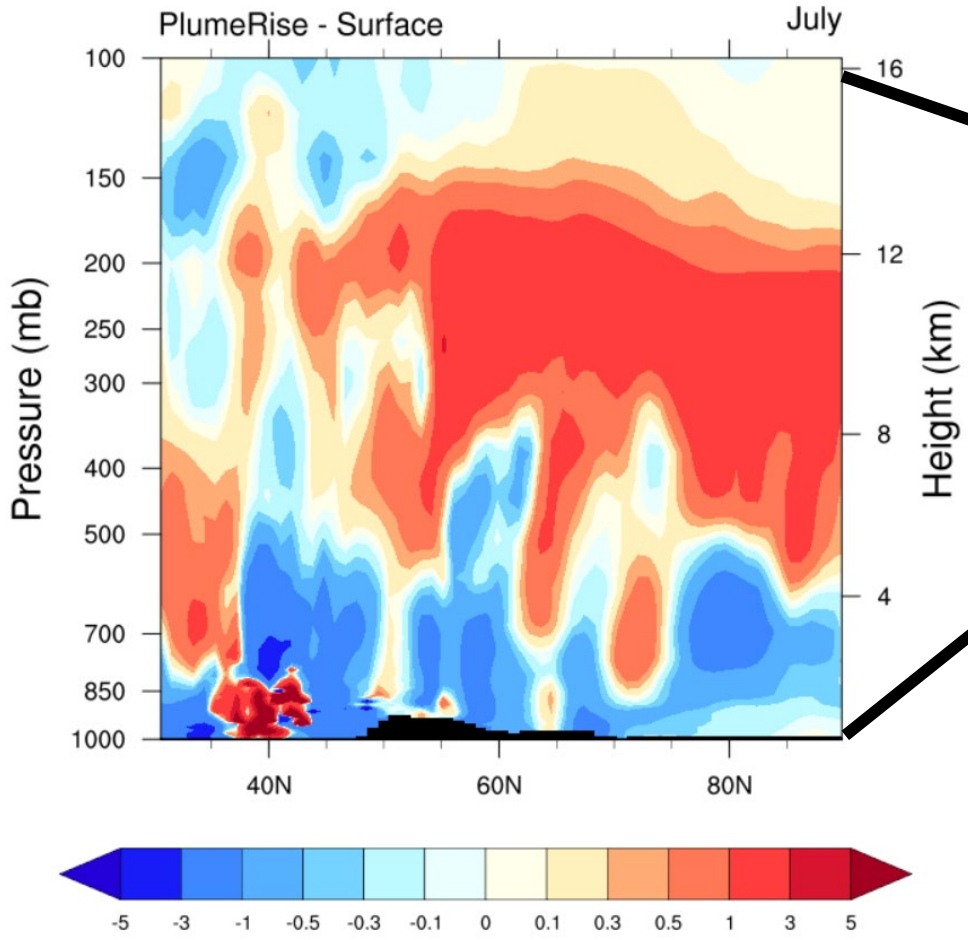
Organic Aerosol

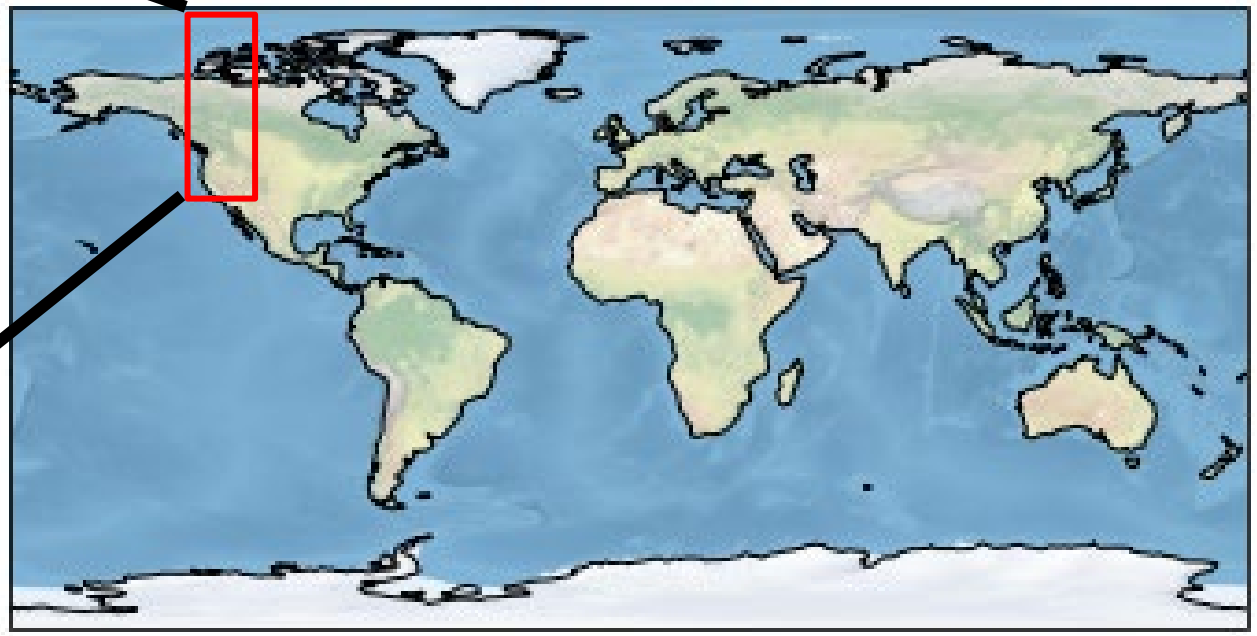
CO

3-5km

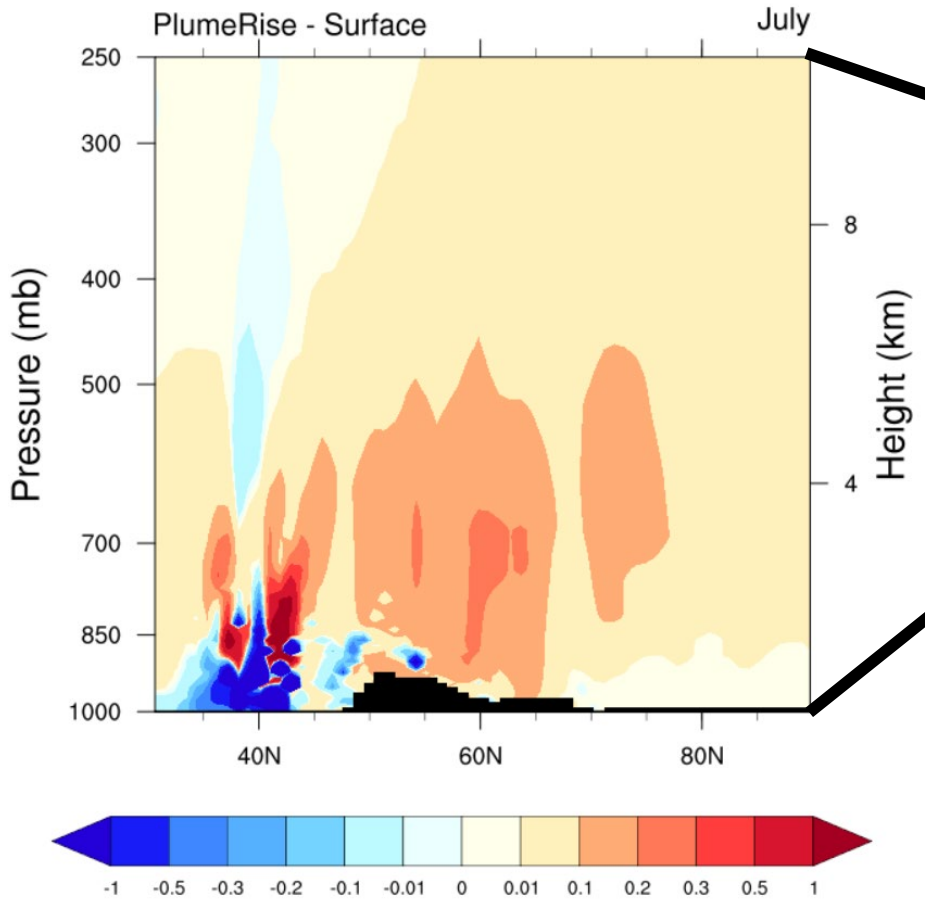


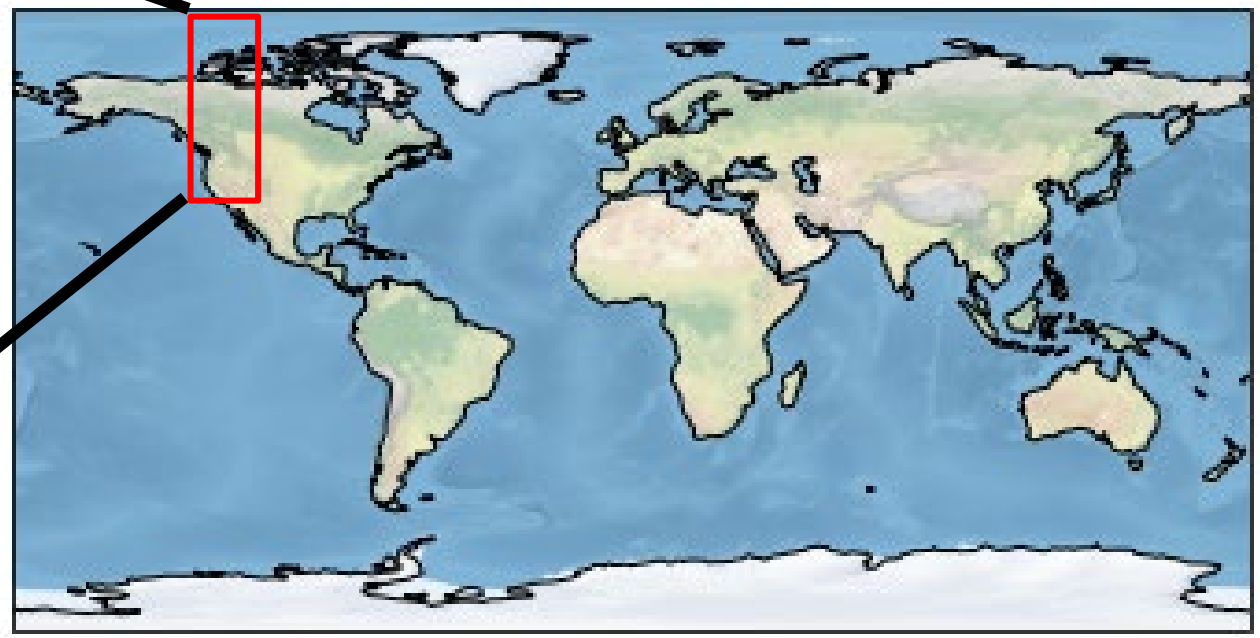
Changes in vertical distributions of CO over the Western North America



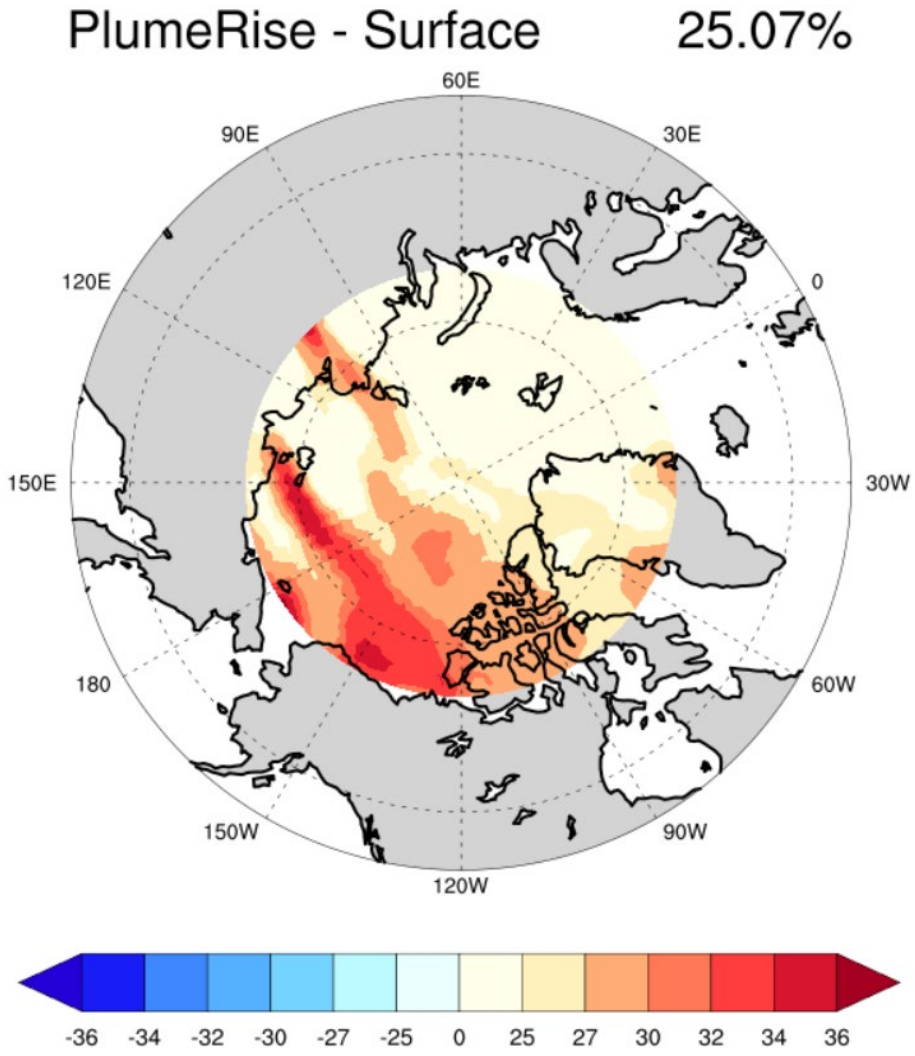


Changes in vertical distributions of POM over the Western North America



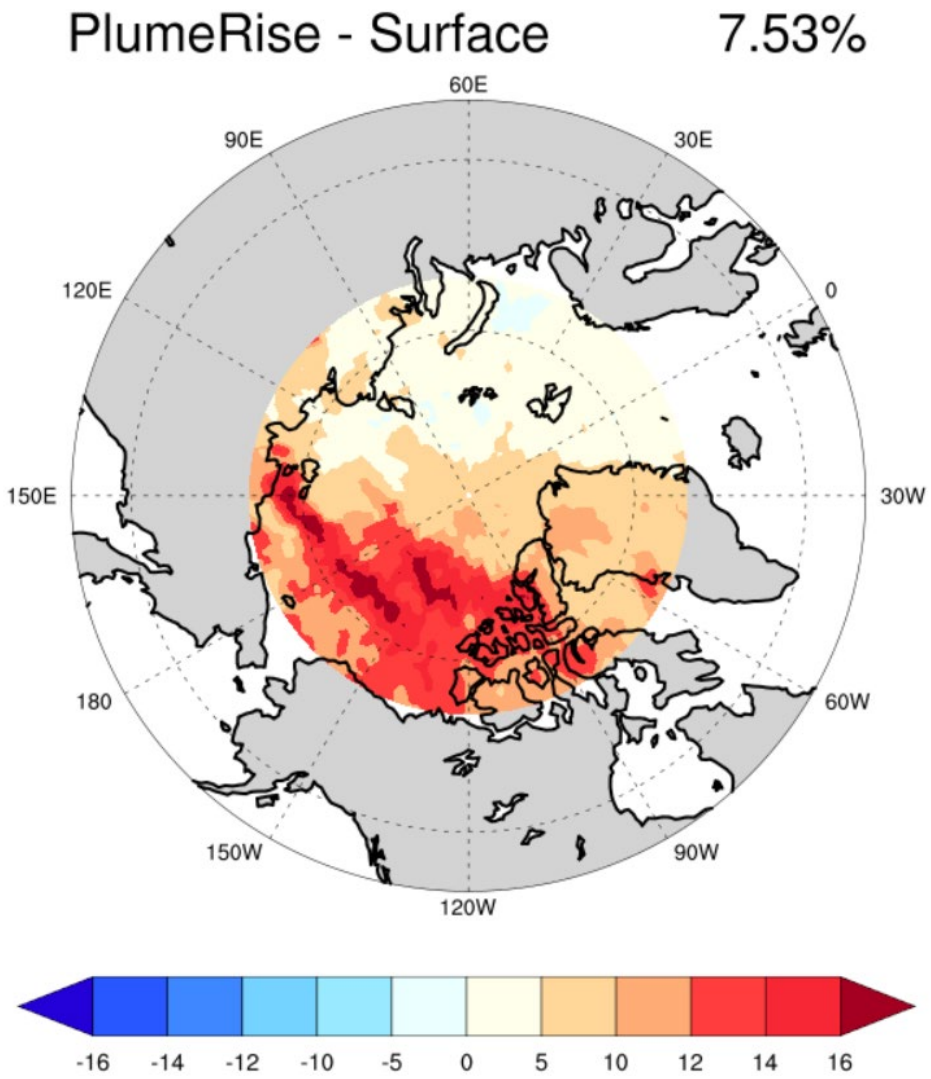


Enhanced transport of POM to the Arctic



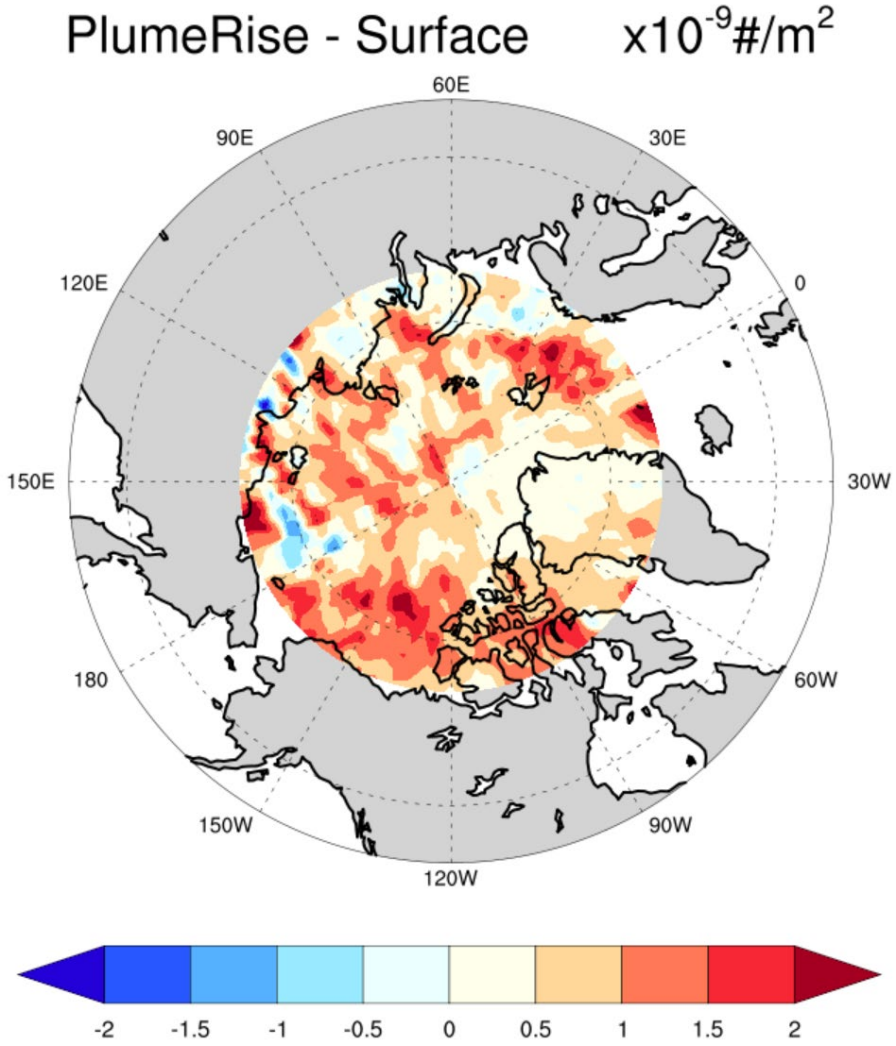
POM burden increases by ~25% in the Arctic (70-90N)

Increased Aerosol Optical Depth in the Arctic



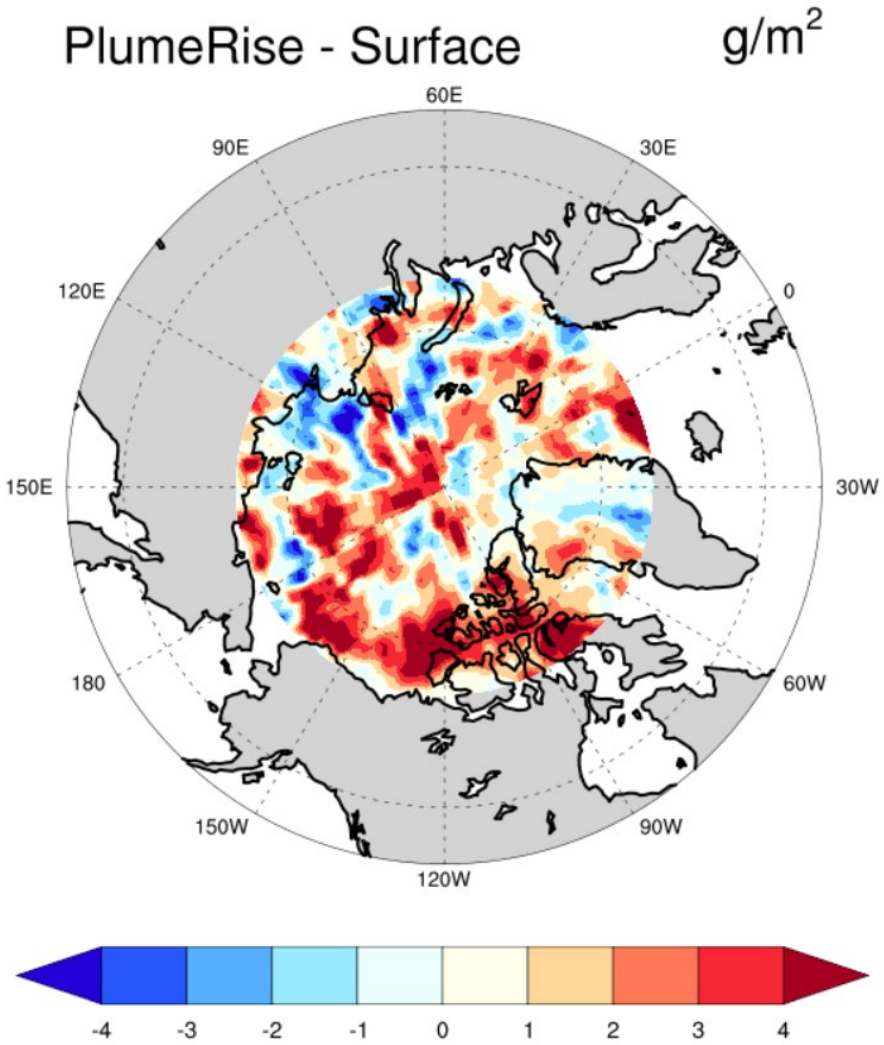
Aerosol optical depth increases by ~15% in the downstream from the boreal wildfires

Response of Cloud Droplet Number Concentrations to increased aerosol transport in the Arctic



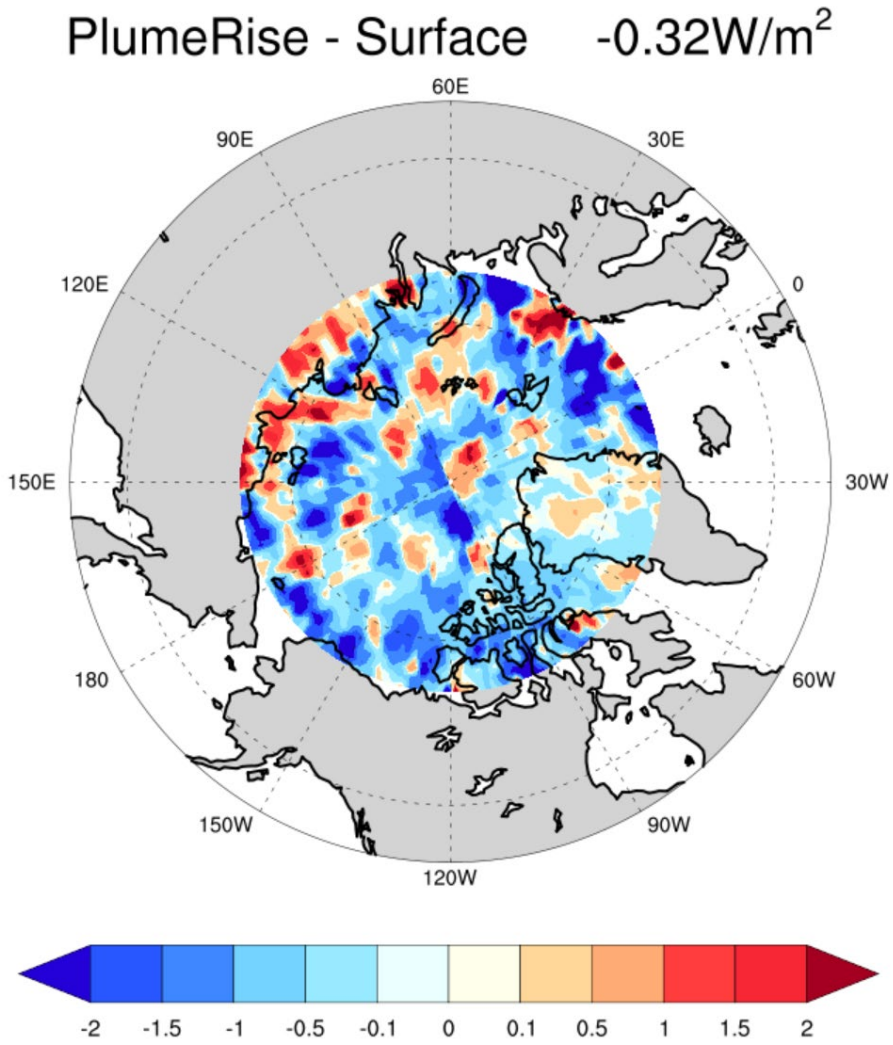
CDNC increases by 5.2% in the Arctic (70-90N)

Response of Liquid Water Path to increased aerosol transport in the Arctic

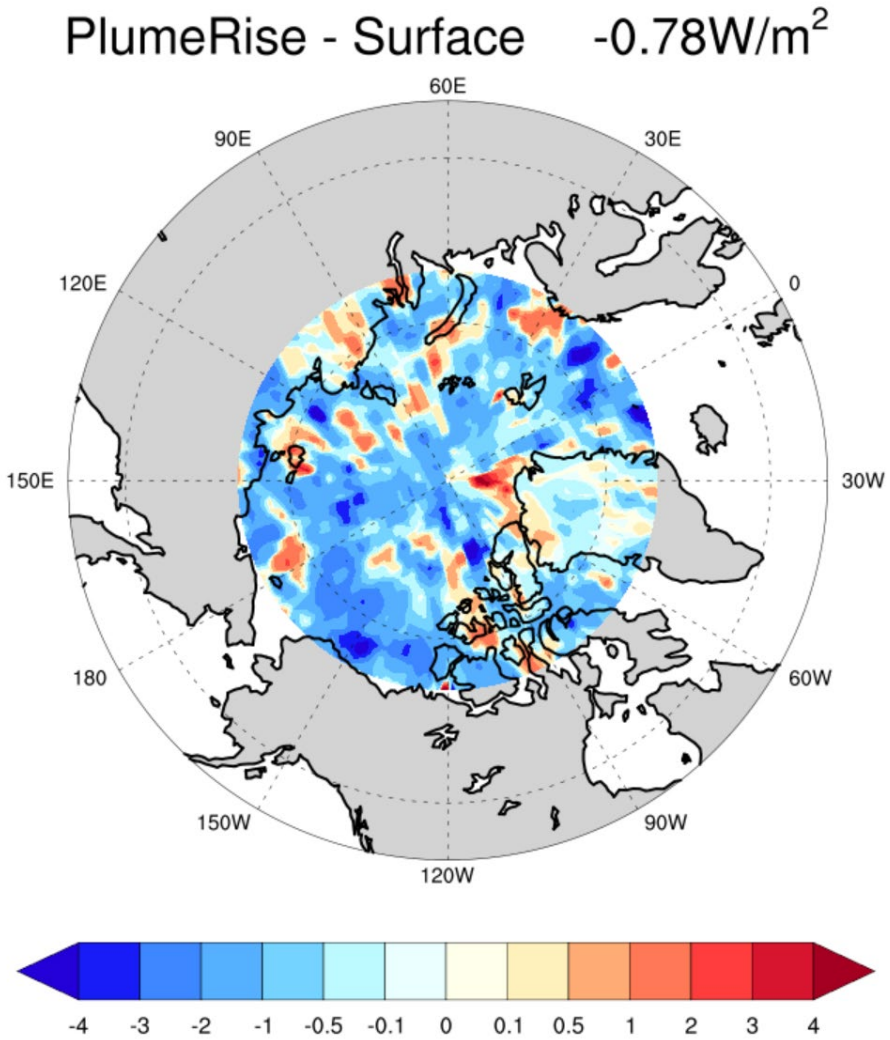


Liquid water path increases by 1.1% in the Arctic (70-90N)

Response of Shortwave Cloud Forcing to increased aerosol in the Arctic



Response of Surface Radiative Flux to increased aerosol in the Arctic



Summary

- Plume rise model (Freitas et al., 2007) is included in variable-resolution CESM2.2 to interactively calculate the vertical distribution of biomass burning aerosols/gases emissions.

- In July 2018, compared to simulations with BBA emissions at surface, plume rise enhances the transport of POM/BC to the Arctic where the POM/BC concentrations increases by ~25%.

- In the Arctic, cloud droplet number concentrations increase by 5%, and shortwave cloud forcing decreases by –0.32 W/m^2. The snow-darkening effect will be further examined in the future.

Thanks