Meteorology and chemistry interactions during wildfire season over Western US

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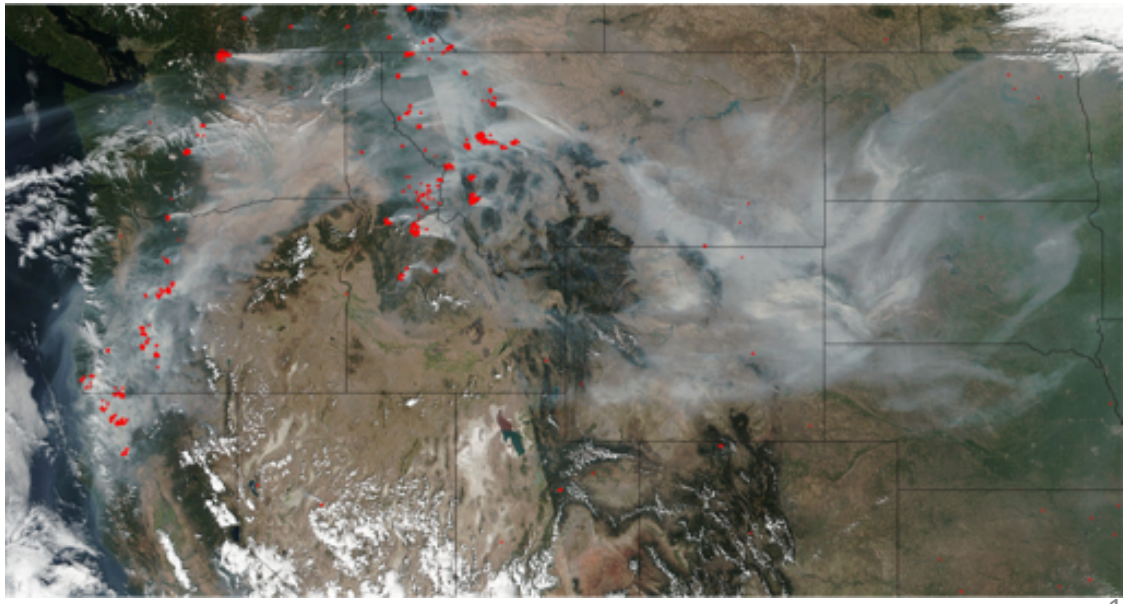
Motivation

https://e360.yale.edu/assets/site/_1500x1500_fit_center-center_80/Washington-DNR-Chiwaukum-WildFires-2014-2015_WA-DNR_cropped.jpg

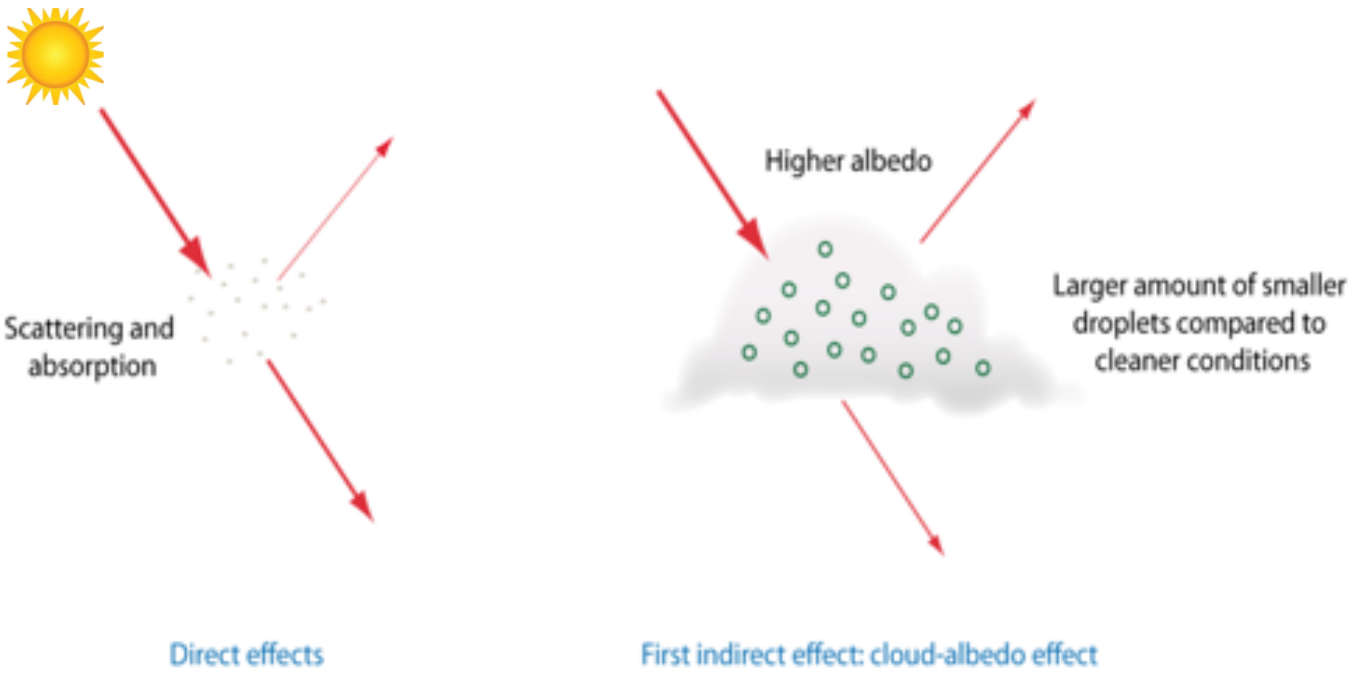
- Air quality over western US degrades severely due to wildfires
- Meteorology also affected due to aerosol-radiation and aerosol-cloud interactions



https://www.nasa.gov/sites/default/files/thumbnails/image/unitedstates.a2017246.2112.1500m.jpg

- Wildfires expected to intensify in future (Spracklen et al., 2009)

Study goals



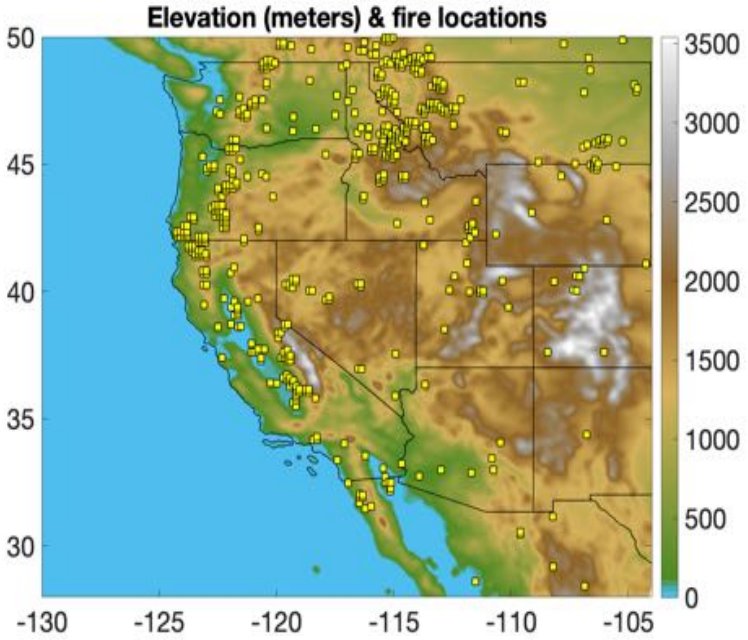
http://www.climate.be/textbook/images/image4x12.png

- **Study the impacts of wildfires on meteorology and atmospheric chemistry**

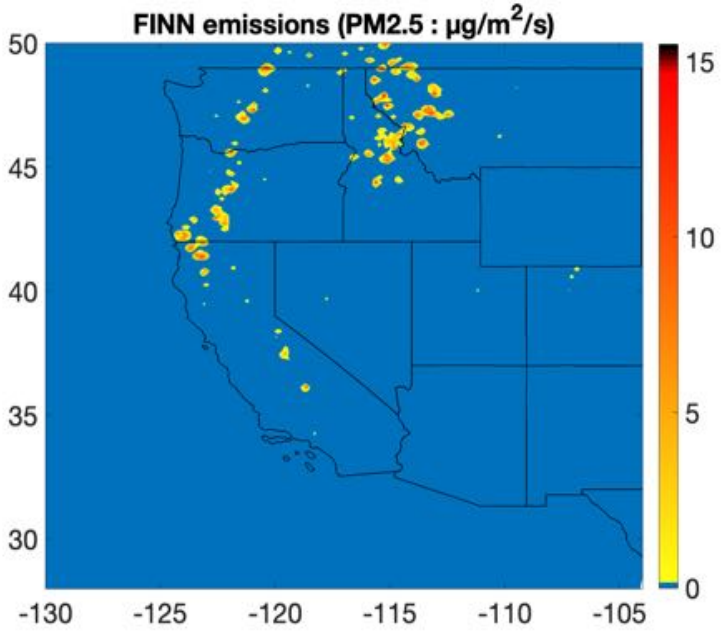
- WRF-Chem, an "online" meteorology-chemistry coupled model, suited?
- **Evaluate the model simulations against observations**

WRF-Chem simulations for September 2017

Scenarios	Key details
Fire	Includes wildfires emissions and aerosol feedbacks
noFire	Includes aerosol feedbacks but no wildfires emissions



mean = 555 m

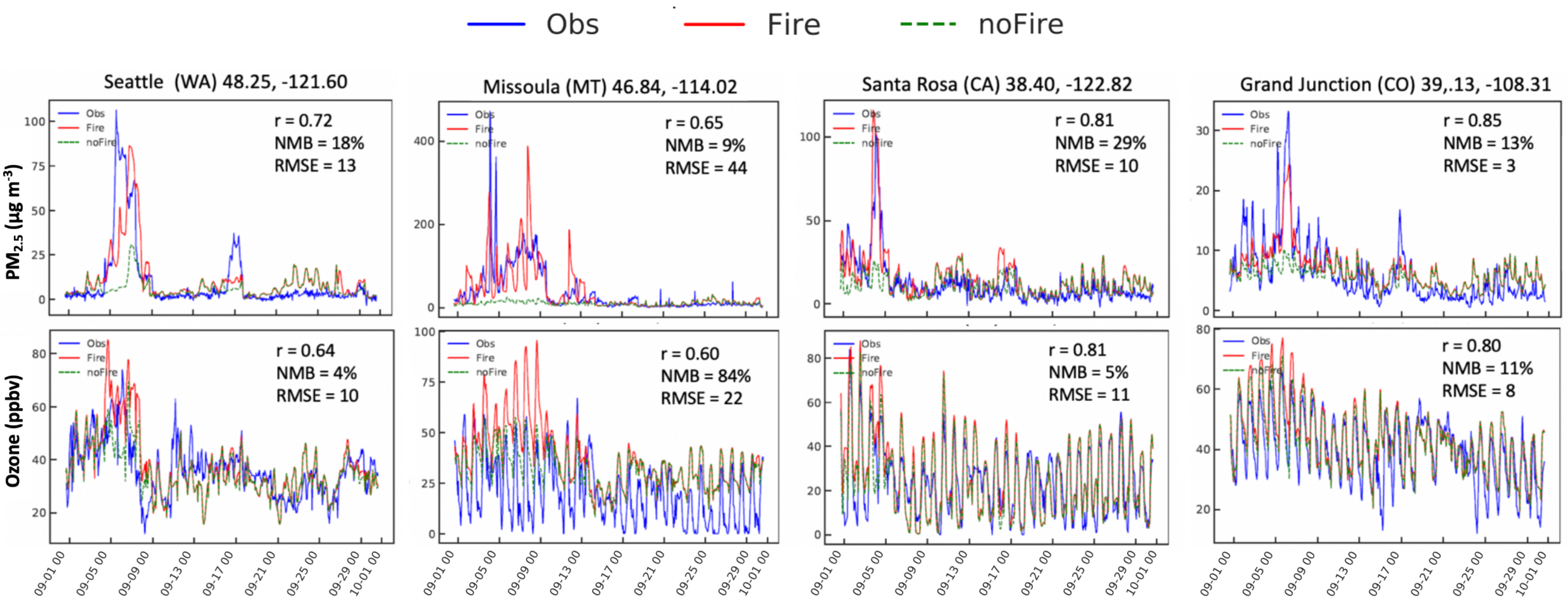


total = 188.1 kg/s

WRF-Chem configuration for “Fire” run

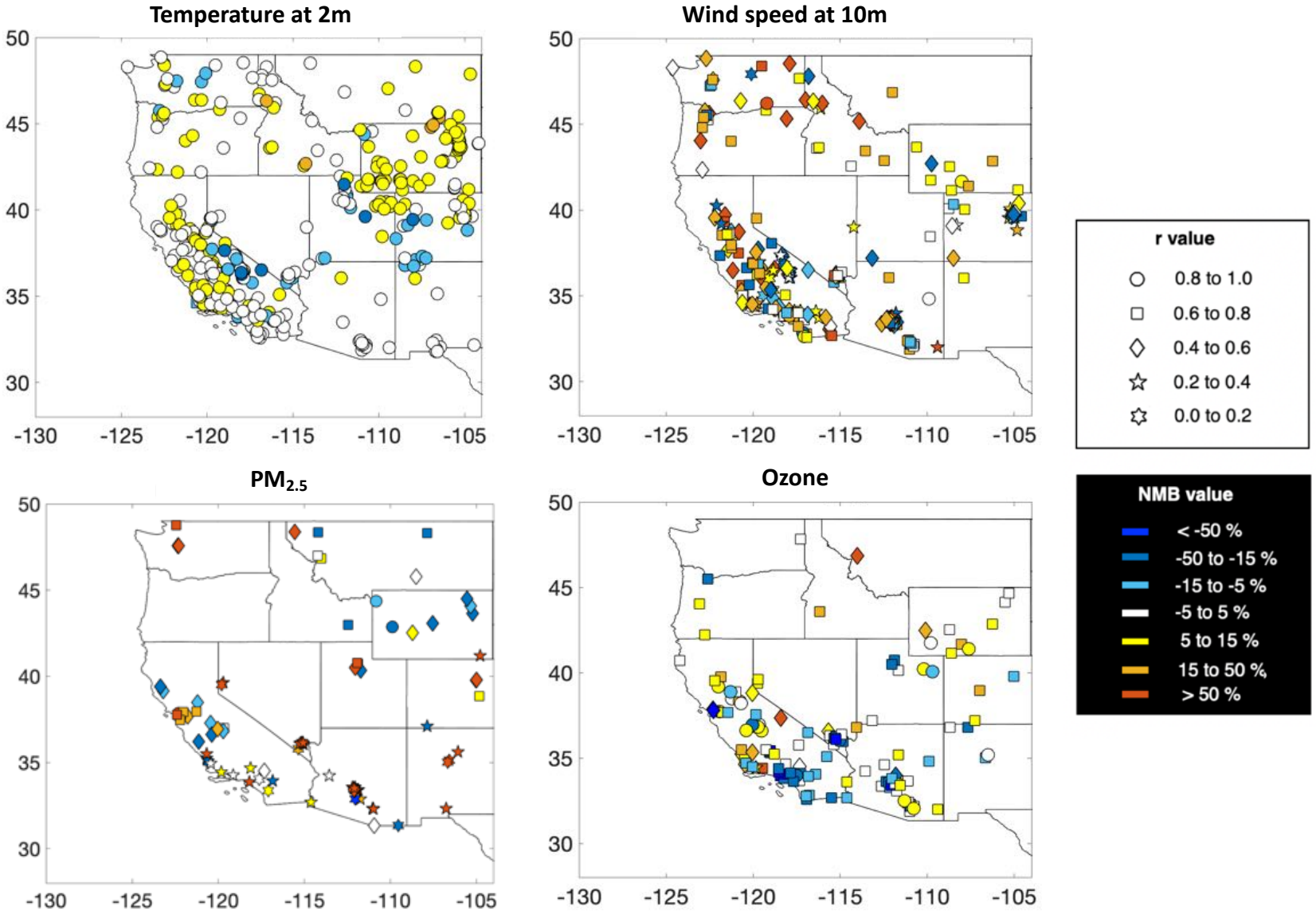
Model version	WRF-Chem 3.9.1
Resolution	12km (horizontal); 32 vertical levels
Cloud microphysics	Morrison 2-moment scheme
Boundary layer	Bougeault and Lacarrere (BouLac) PBL
Long and short wave radiation	RRTMG
Cumulus parameterization	Grell 3D Ensemble scheme
Urban surface physics	Multi-layer, BEP scheme
Gas phase chemistry	MOZART
Aerosol module	MOSAIC-4 bin
Chemical boundary conditions	MOZART-4
Biomass burning emissions	FINN v1
Anthropogenic emissions	NEI 2011
Biogenic emissions	MEGAN

Surface $PM_{2.5}$ and O_3



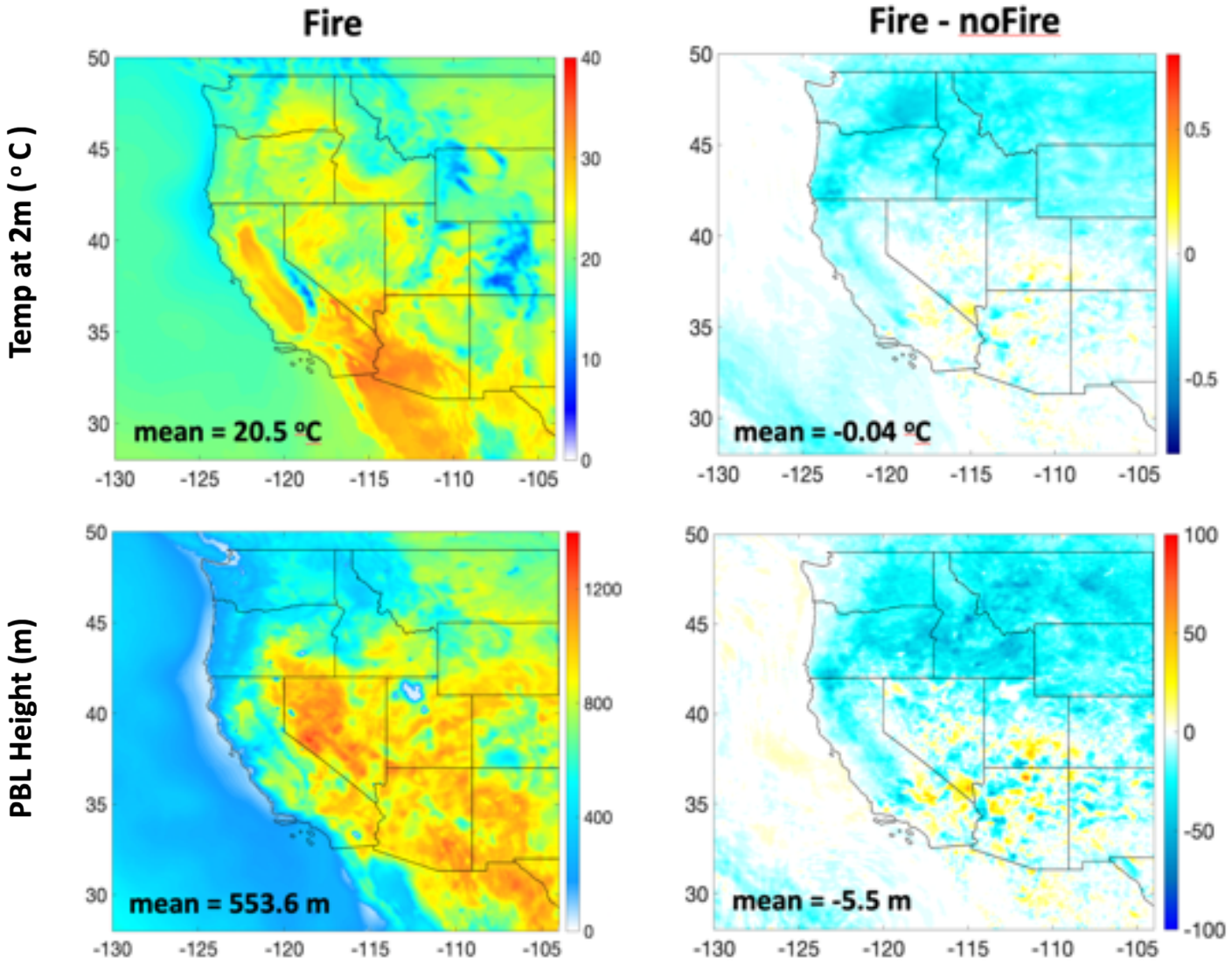
- **Model captures peak $PM_{2.5}$ concentrations qualitatively** but shows underprediction
- **Ozone reproduced well** but overestimated even without wildfires at some stations (e.g. Missoula)

Correlation Coeff. (r) and NMB(%)



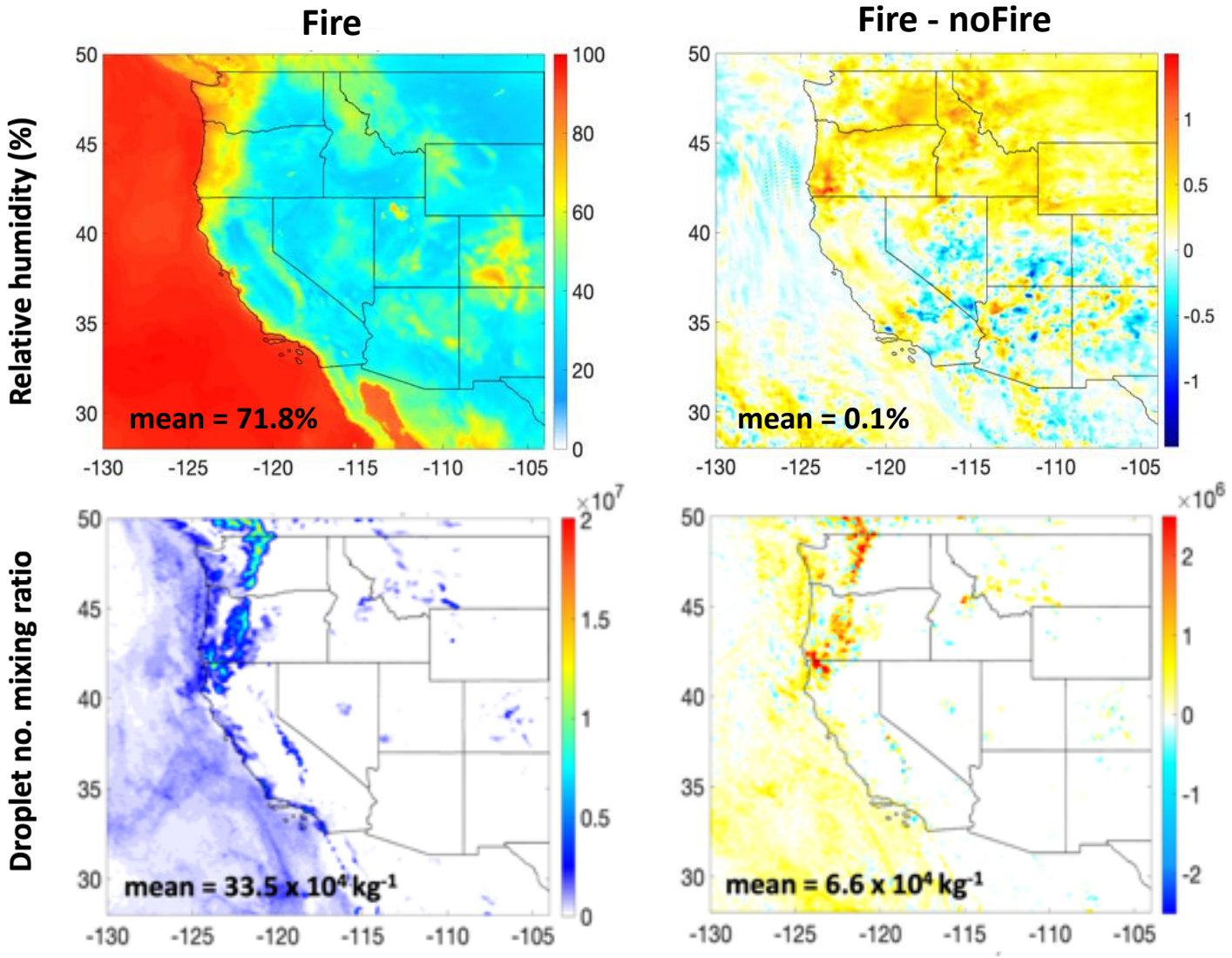
- r > 0.8 & |NMB| < 15% for temp at 2 m at most sites
- moderate performance for wind speed (r > 0.4 mostly)
- better performance in the north than south for PM2.5 (r > 0.4)
- r > 0.6 for ozone at most sites

Impact on Temp at 2 m and PBL height



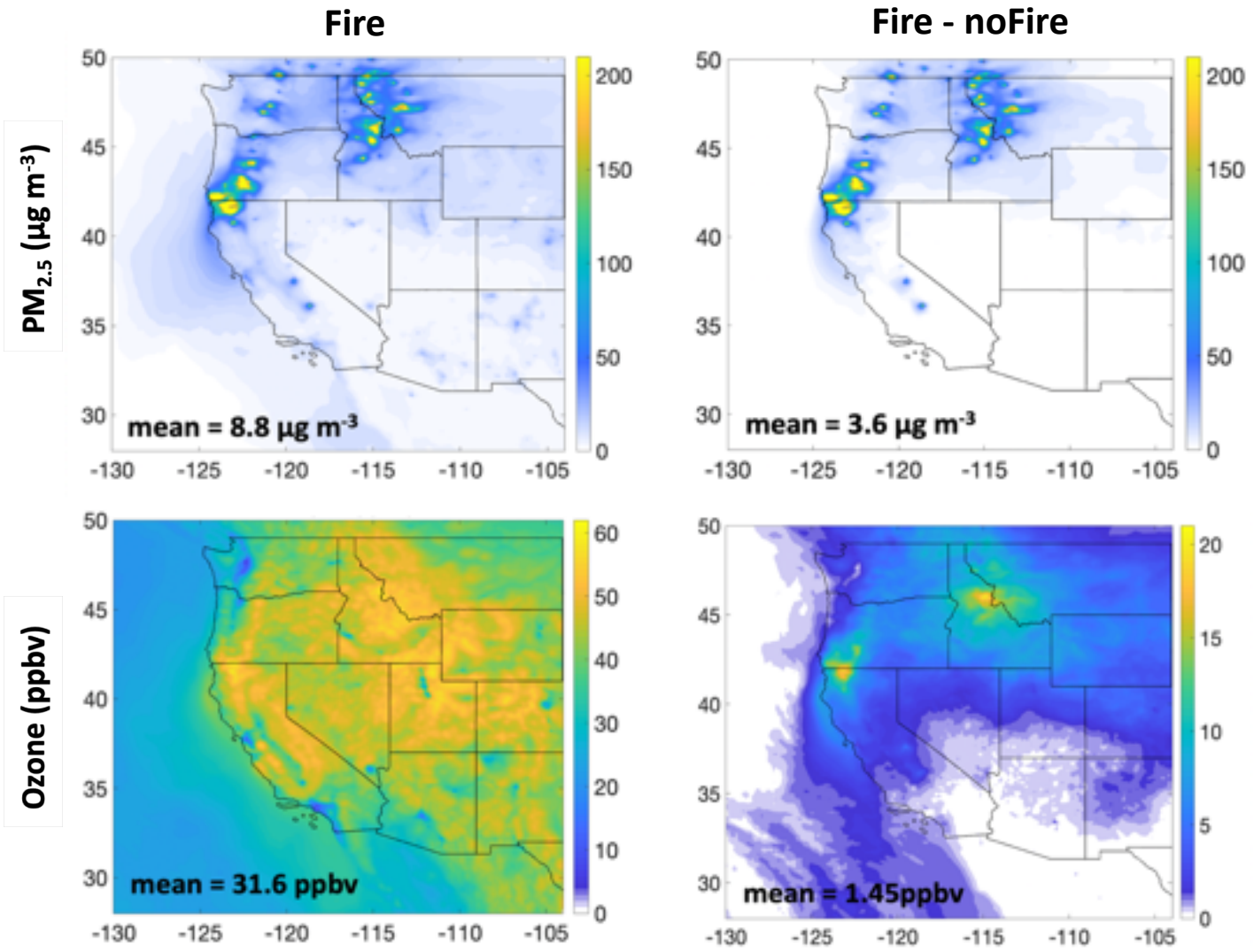
- 2m temperature reduced by 0.5 °C in some locations in north
  - Due to reduction in downward shortwave radiation
- Boundary layer height (PBL height) reduced by down to 50 m
  - Due to reduced vertical mixing as a result of cooling near the surface

Impact on RH and cloud droplet numbers



- Relative humidity (RH) near surface changed by more than 1%
  - RH increases in the north due to decrease in surface temp. & PBLH
- Droplet no. mixing ratio increased (by about 25%) near surface
  - due to higher availability of cloud condensation nuclei (CCN)

Impact on $PM_{2.5}$ and Ozone

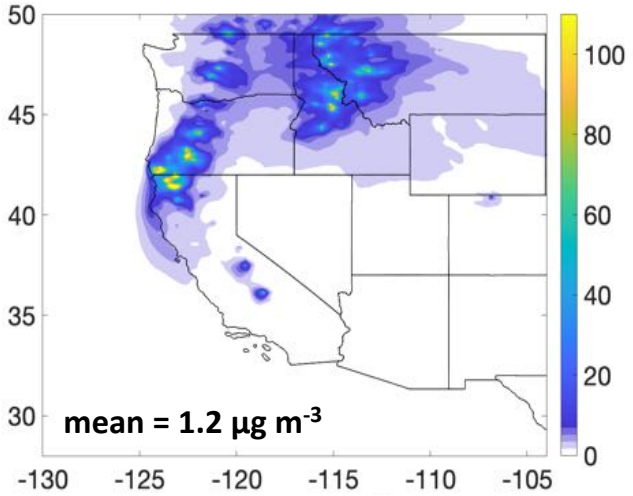


- Increase in surface $PM_{2.5}$ conc. by about 3.6 µg m^{-3} (~70%)
- Large changes (> 200 µg m^{-3}) observed in areas close to wildfires
- Ozone mixing ratio increased by 1.45 ppbv (~5%)
- Large changes (> 20 ppbv) seen in some areas directly affected by wildfires

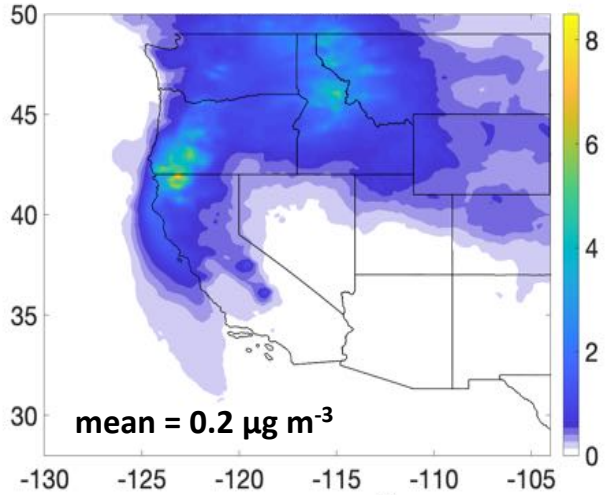
Impact on $PM_{2.5}$ composition

Fire - noFire

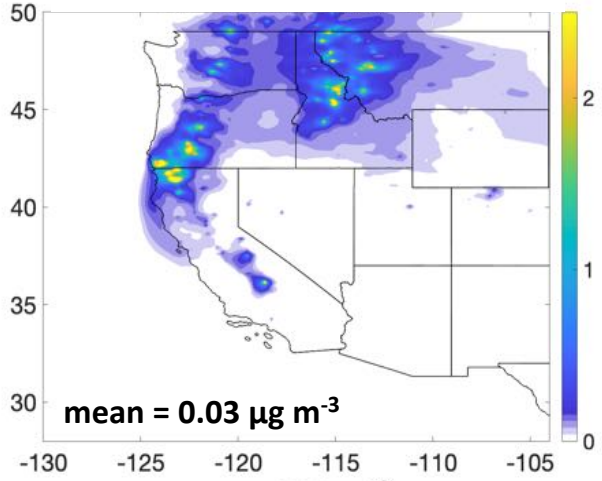
Primary Org. aerosol (µg m^{-3})



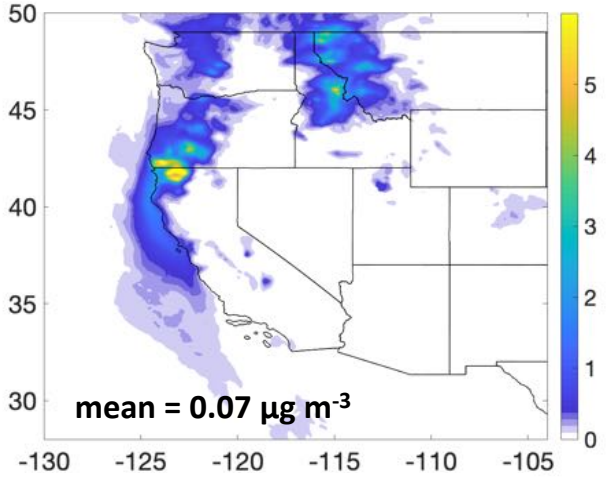
Secondary Org. aerosol (µg m^{-3})



Black carbon (µg m^{-3})



Nitrate (µg m^{-3})



- 77% increase in POA concentration
- POA is the major PM2.5 component esp. in areas close to wildfires
- SOA production enhanced by 38%
- 27% and 23% increase in BC and nitrate concentrations respectively

Summary and future works

- **WRF-Chem performed reasonably well over western US during Sept 2017**
- Surface air temperature reduced by 0.5 ^{o}C in some locations mainly via aerosol-radiation interaction associated with wildfires
- Boundary layer height (PBL height) reduced by 50 m in some locations
- Wildfires increase surface $PM_{2.5}$ concentration and ozone mixing ratio (averaged over time and domain) by about 70% and 5%, respectively, with a large increase in areas close to wildfires.
- **Evaluate PM composition against observations**
- **Plan to investigate the role of aerosol feedbacks associated with wildfires**