WRF-Chem evaluation during wildfire season over Western US and sensitivity results

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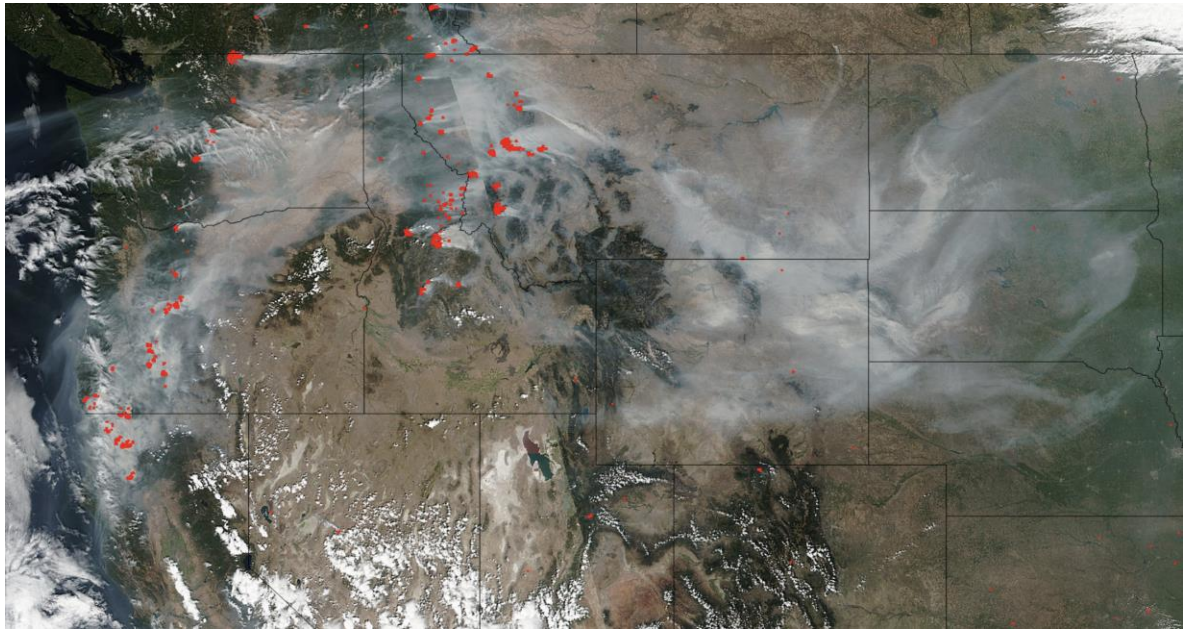
RECAP

Motivation

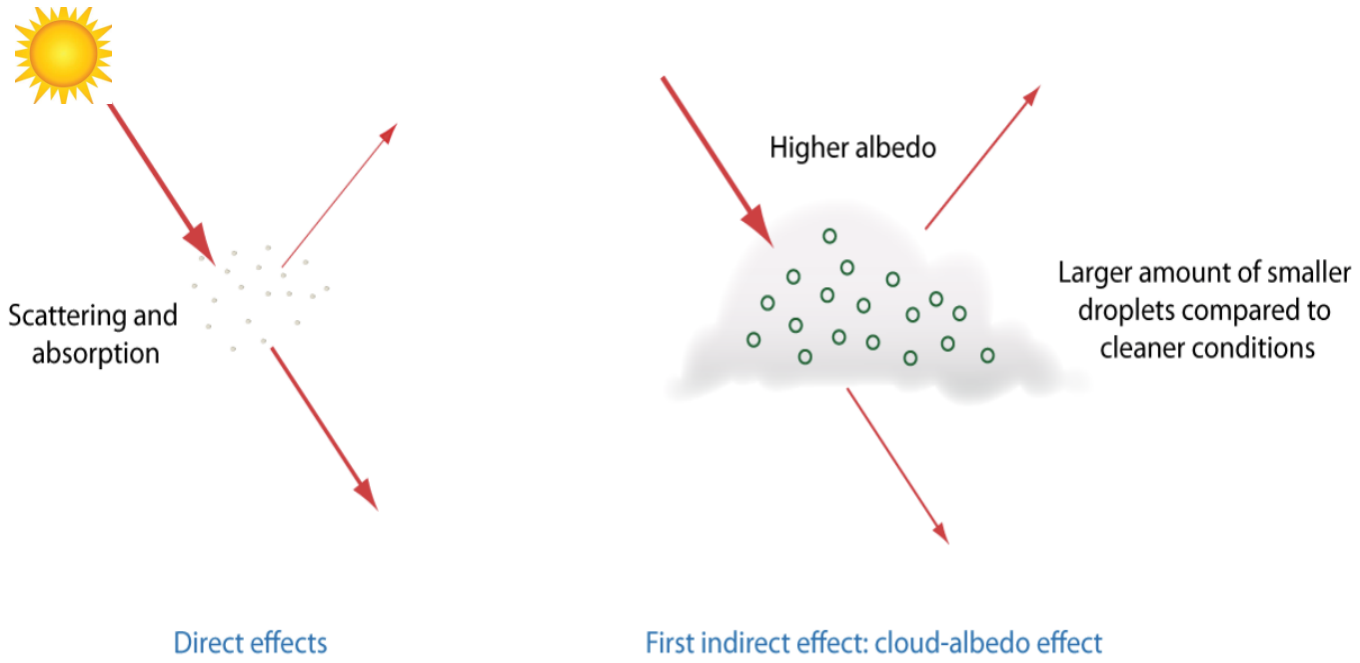
https://e360.yale.edu/assets/site/_1500x1500_fit_center-center_80/Washington-DNR-Chiwaukum-WildFires-2014-2015_WA-DNR_cropped.jpg



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

- Air quality over western US degrades severely due to wildfires
- Meteorology also affected due to aerosol-radiation and aerosol-cloud interactions
- **Wildfires expected to intensify in future (Spracklen et al., 2009)**

Study goals

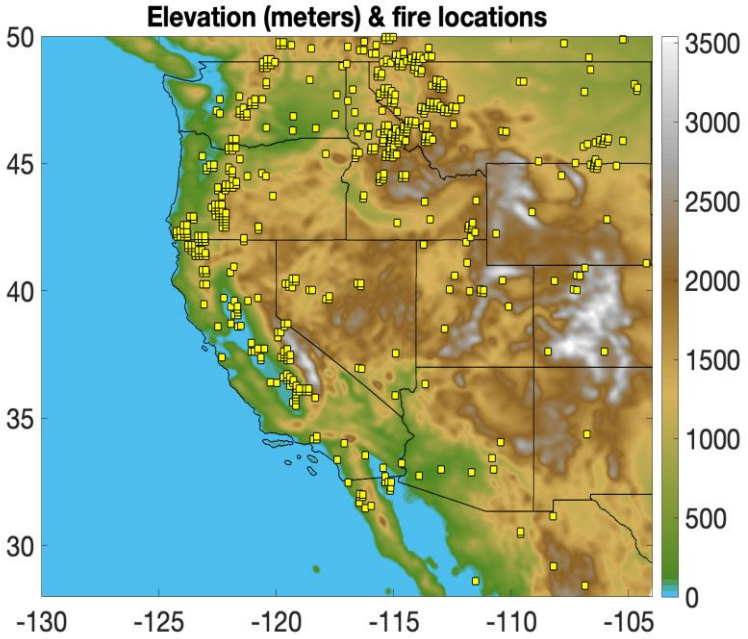


http://www.climate.be/textbook/images/image4x12.png

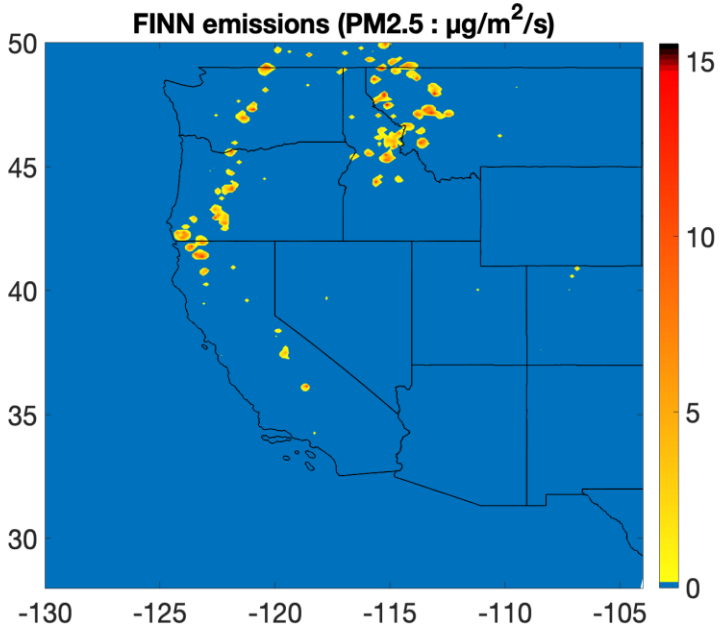
- **To study the impacts of wildfires on meteorology and atmospheric chemistry**
- WRF-Chem, an “online” meteorology-chemistry coupled model, suited?
- **Need to evaluate the model simulations against observations**

WRF-Chem simulations for September 2017

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



mean = 555 m



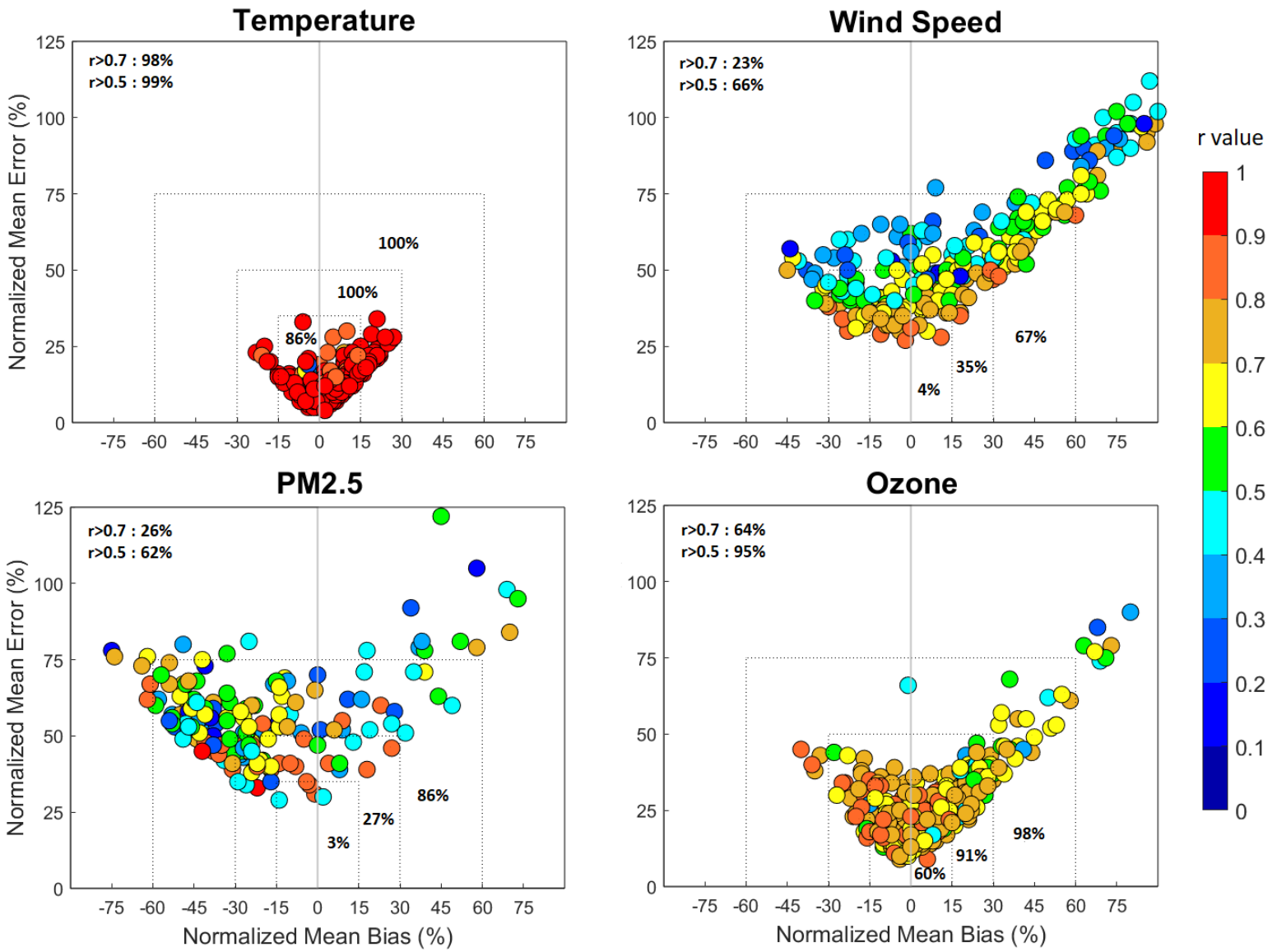
total = 188.1 kg/s

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-Freitas 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	NEI2014
Biogenic emissions	MEGAN

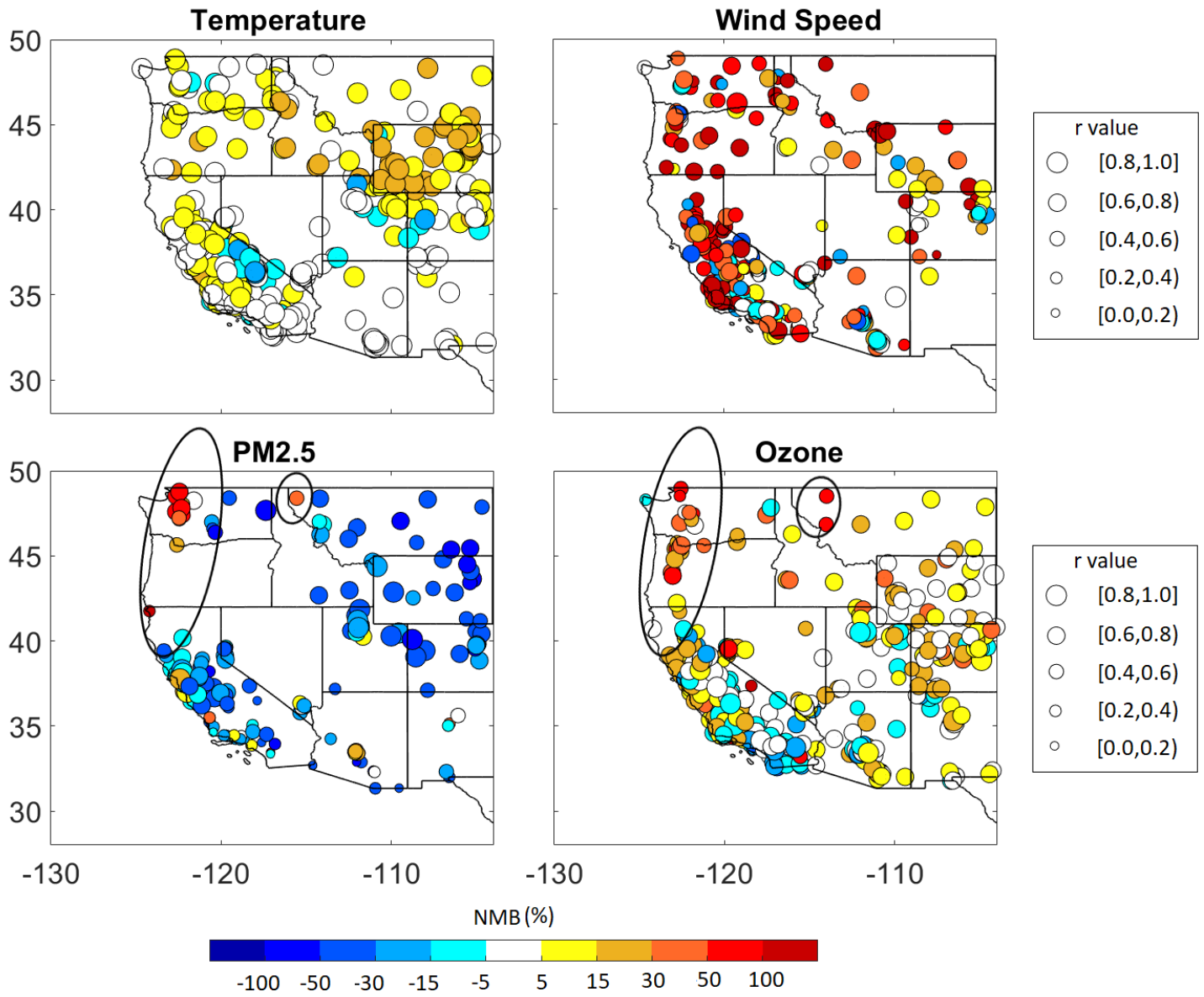
RESULTS:MODEL EVALUATION (Sept 1-30th, 2017)

Soccer plots



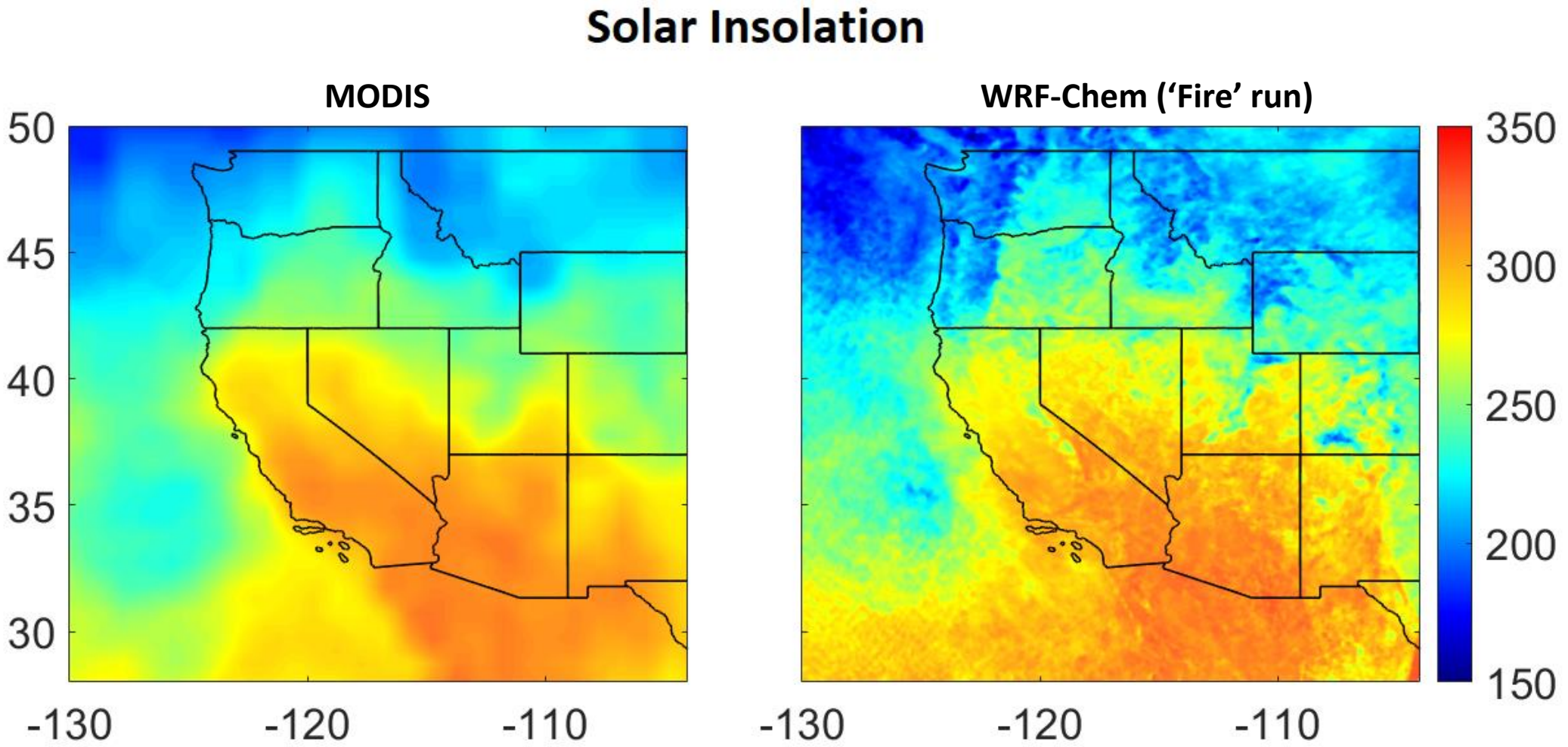
- **Good performance for temperature (2m)** with 98% locations having r>0.7 and 86% locations having |NMB (NME)| within 15% (35%)
- **Reasonable performance for wind speed (10m)** with 66% locations having r>0.5 and 67% locations having |NMB (NME)| within 60% (75%)
- **Moderate performance for PM2.5** with 62% locations having r>0.5 and 86% locations having |NMB (NME)| within 60% (75%)
- **Reasonably good performance for ozone** with 95% locations having r>0.5 and 98% locations having |NMB (NME)| within 60% (75%)

Spatial NMB (%) and r

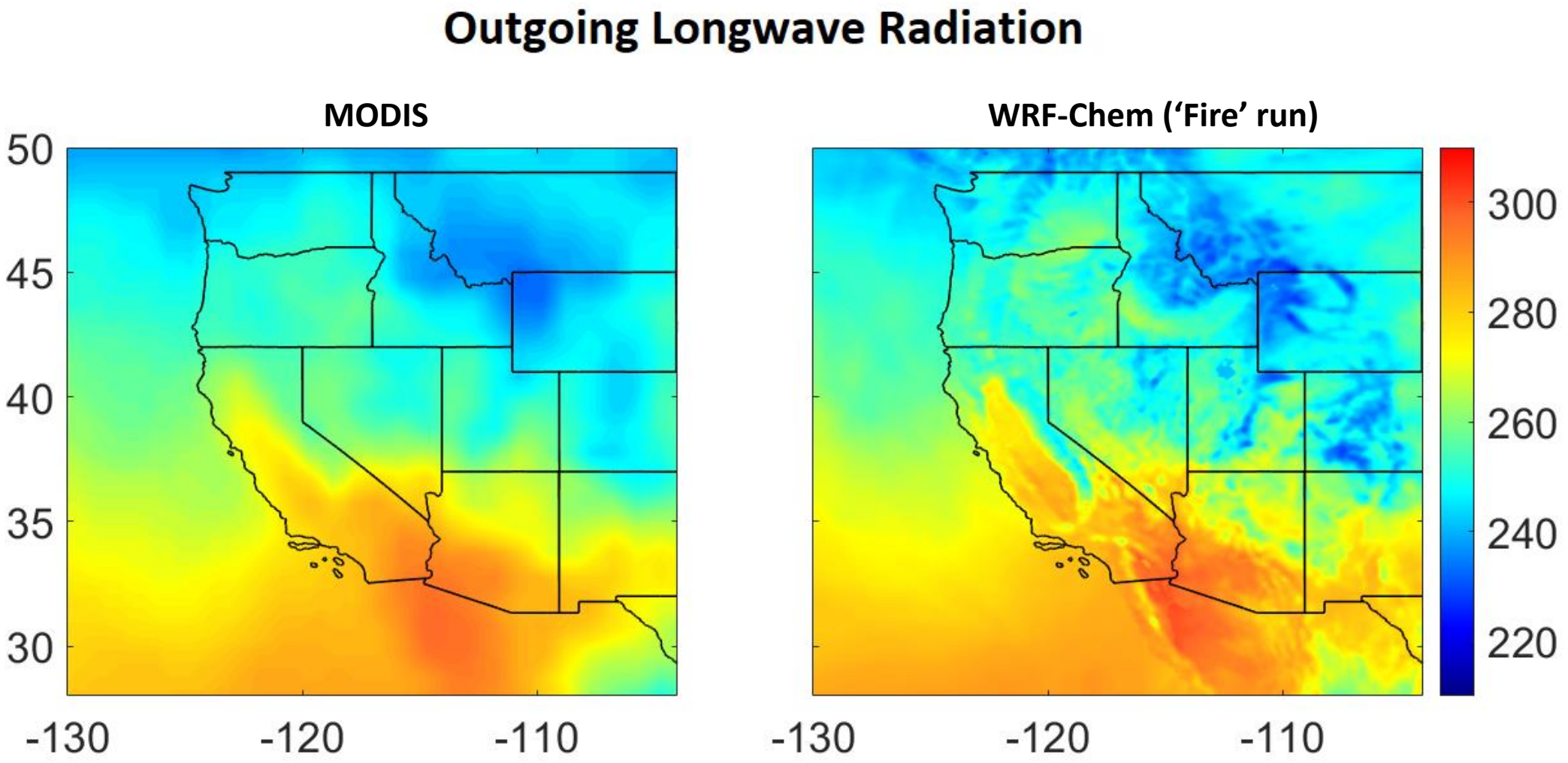


- Model resolution (12km) may not be able to adequately resolve topography; hence high biases for wind speeds
- Mean bias found to be mostly within ±3 m/s for wind speed
- Several stations where model underperforms for PM2.5 and Ozone are fire impacted locations
- At these locations mean bias is found to be within ±30 µg/m3 for PM2.5 and 15 ppbv for ozone

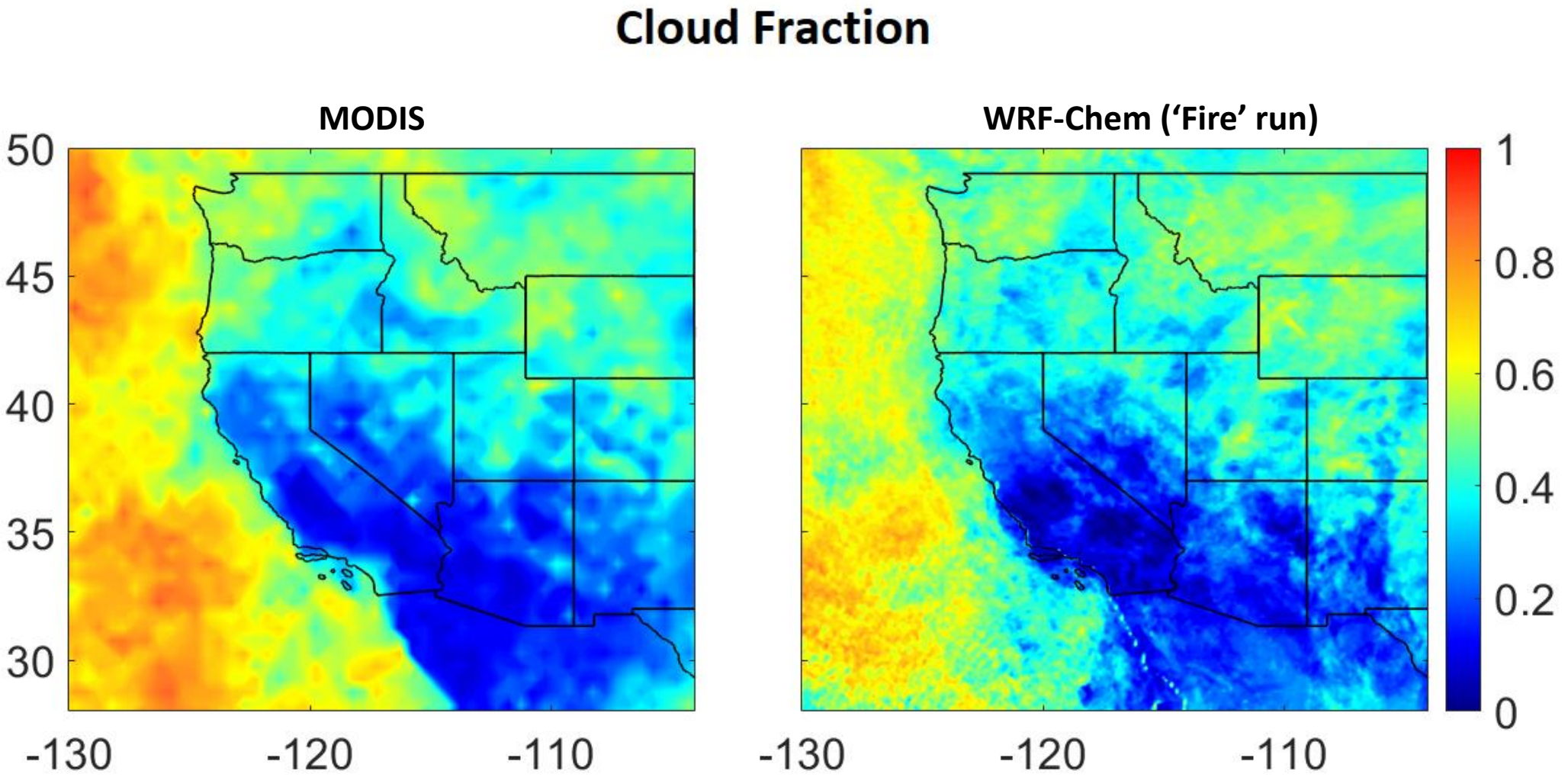
Satellite comparison



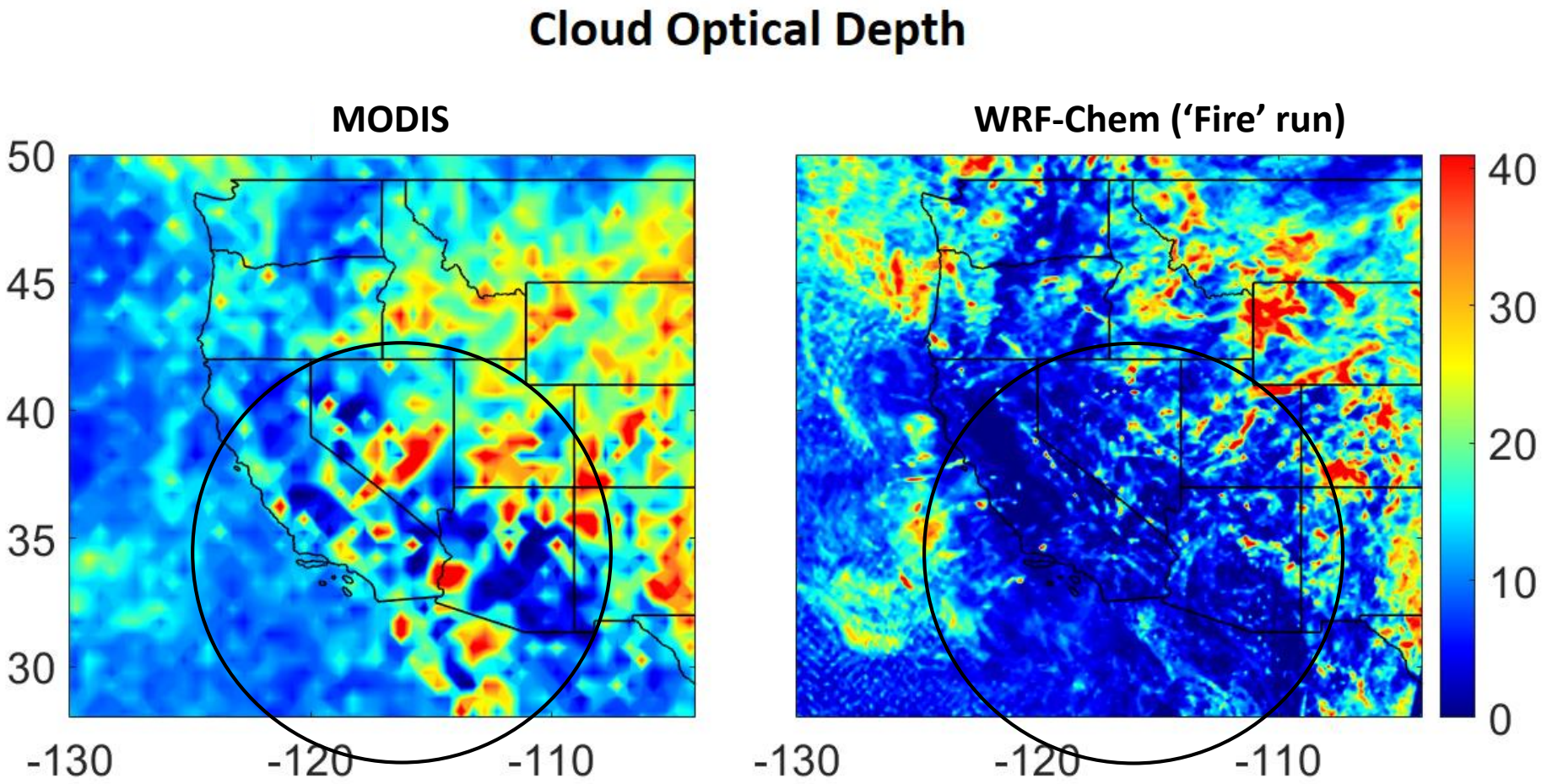
Satellite comparison



Satellite comparison



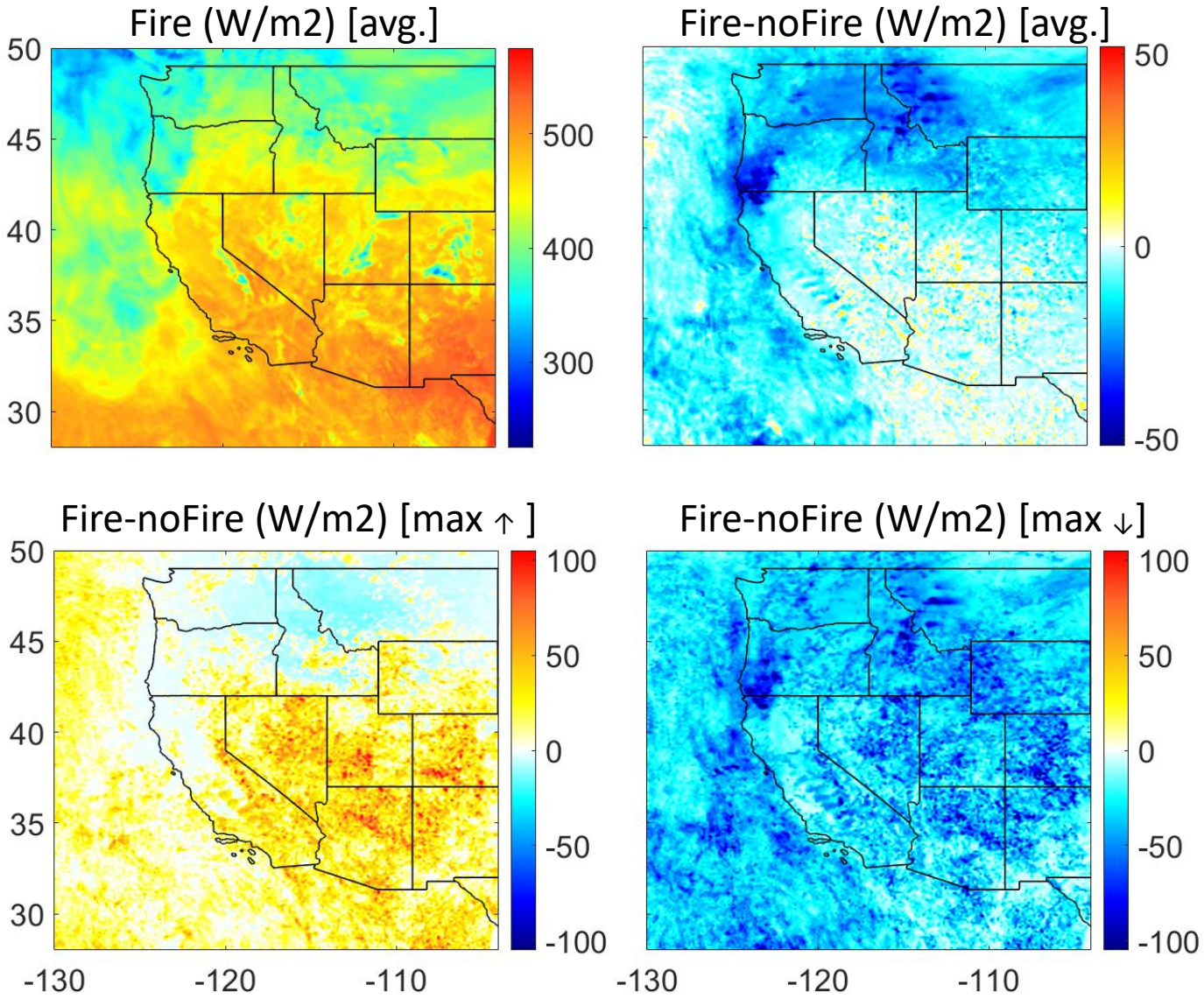
Satellite comparison



- **Lot of missing data in MODIS dataset for COD; so the provided figure may not be a good representative of monthly average COD**

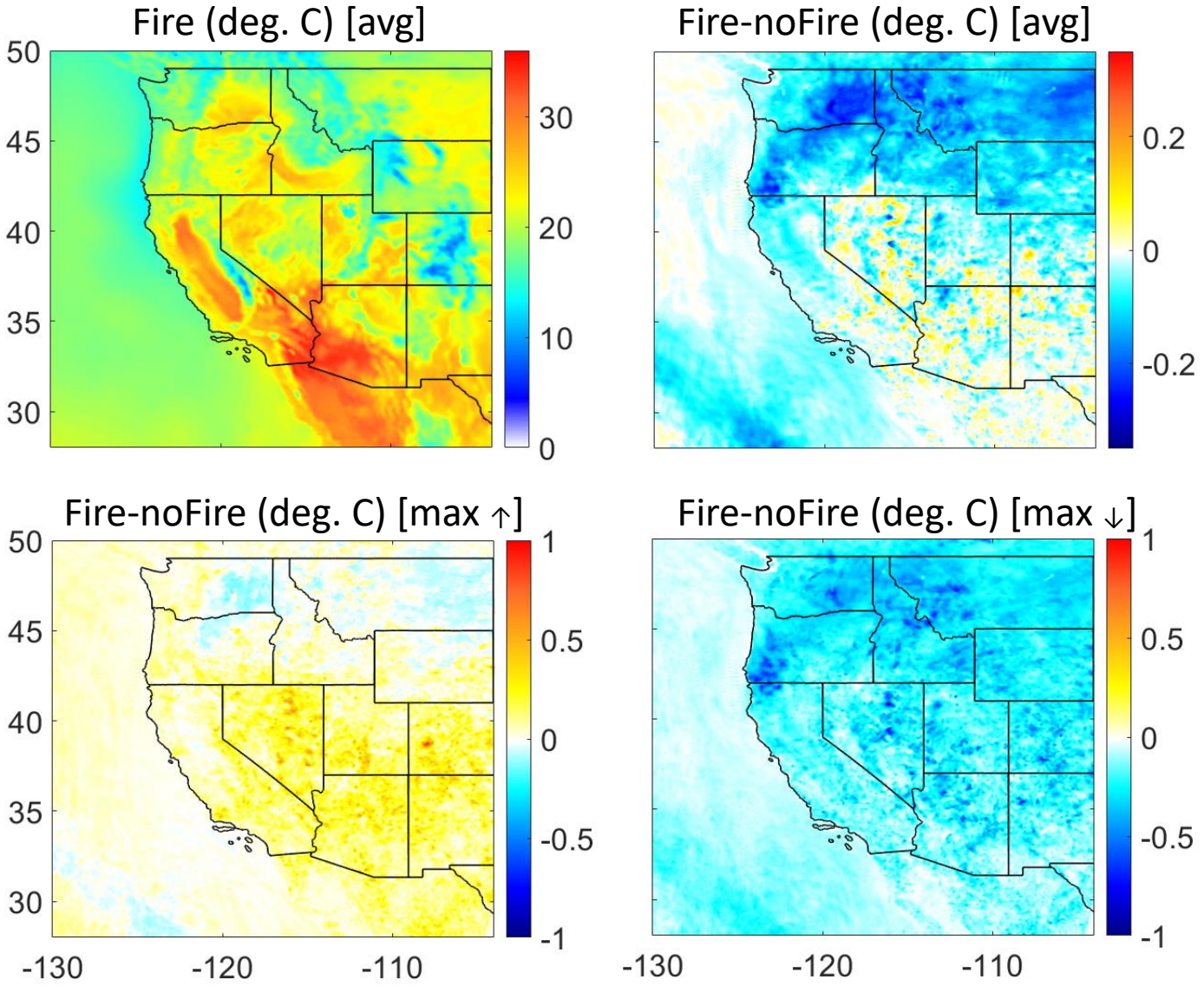
SENSITIVITY RESULTS (Sept 1-15th, 2017)

Solar Insolation



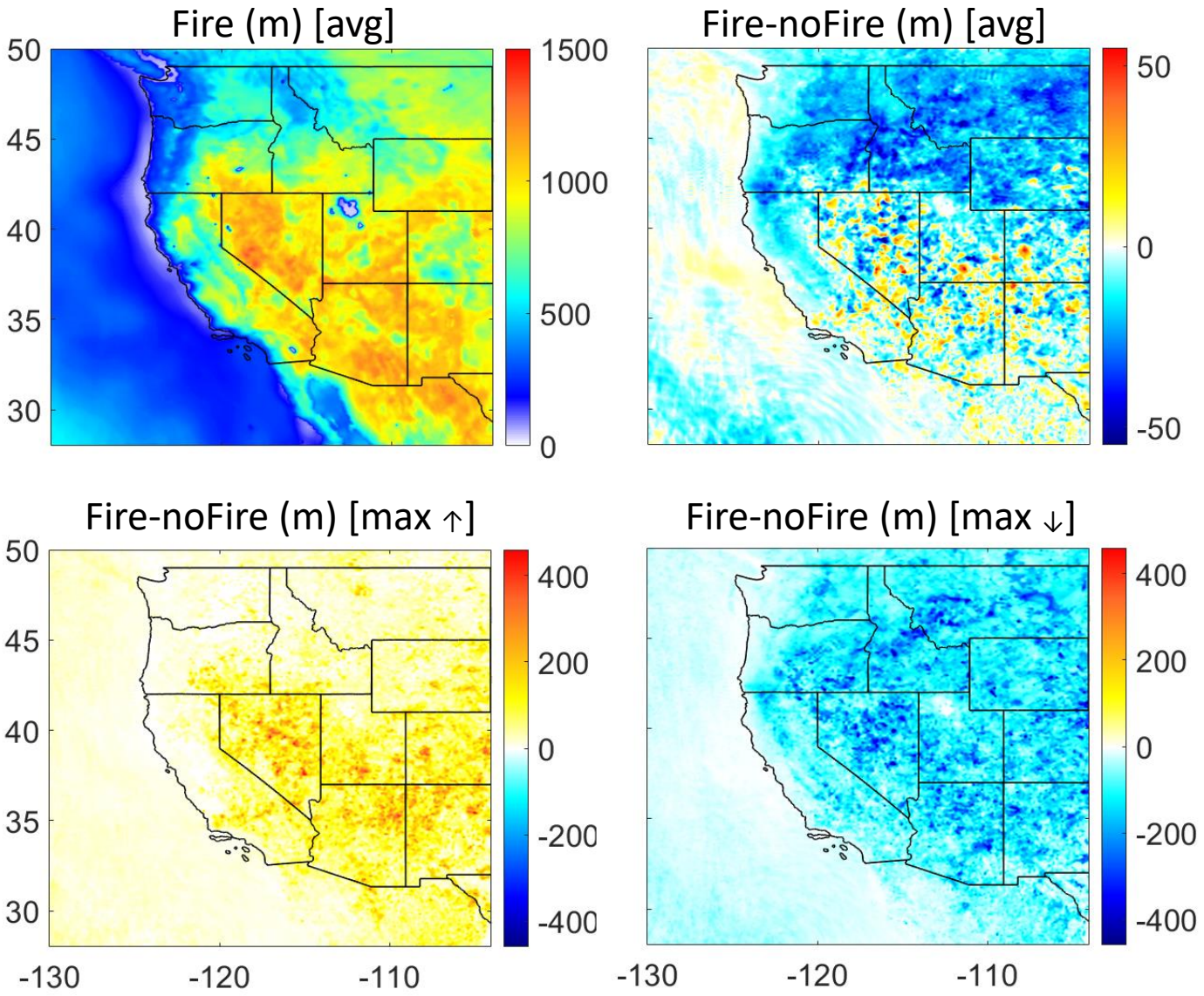
- **Solar insolation reduced by even more than 50 W/m2 in some locations in the north due to wildfires**
- **Reduction in solar insolation due to aerosol scattering and absorption**
- **Analysis of maximum enhancement (max ↑) occurring on diurnal scale in all model grids show enhanced insolation (>100 W/m2 in some areas) in the southern domain**
- **Analysis of maximum reduction (max ↓) occurring on diurnal scale in all model grids show reduced insolation by even more than 100 W/m2 in some regions**
- **Changes in southern domain due to change in cloud properties**

Temperature at 2 m



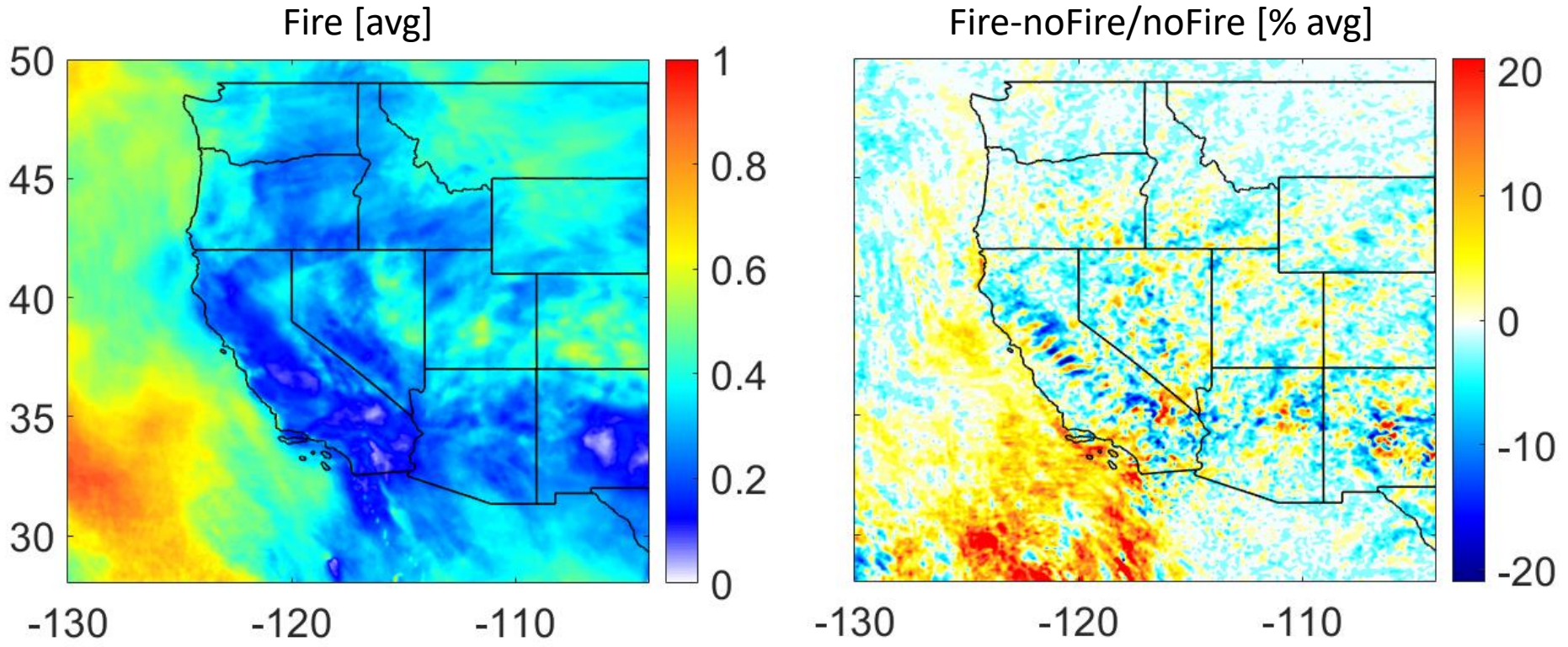
- **On average the temperature is reduced by upto 0.5 ^{o}C in some locations in the north due to wildfires**
- **Reduction in temperature due to reduction in downward shortwave radiation**
- **Analysis of maximum enhancement (max ↑) occurring on diurnal scale in all model grids show warming trend by upto 1 ^{o}C in the southern domain**
- **Analysis of maximum reduction (max ↓) occurring on diurnal scale in all model grids show cooling trend by upto 1 ^{o}C**
- **Changes in southern domain due to change in cloud properties**

PBLH



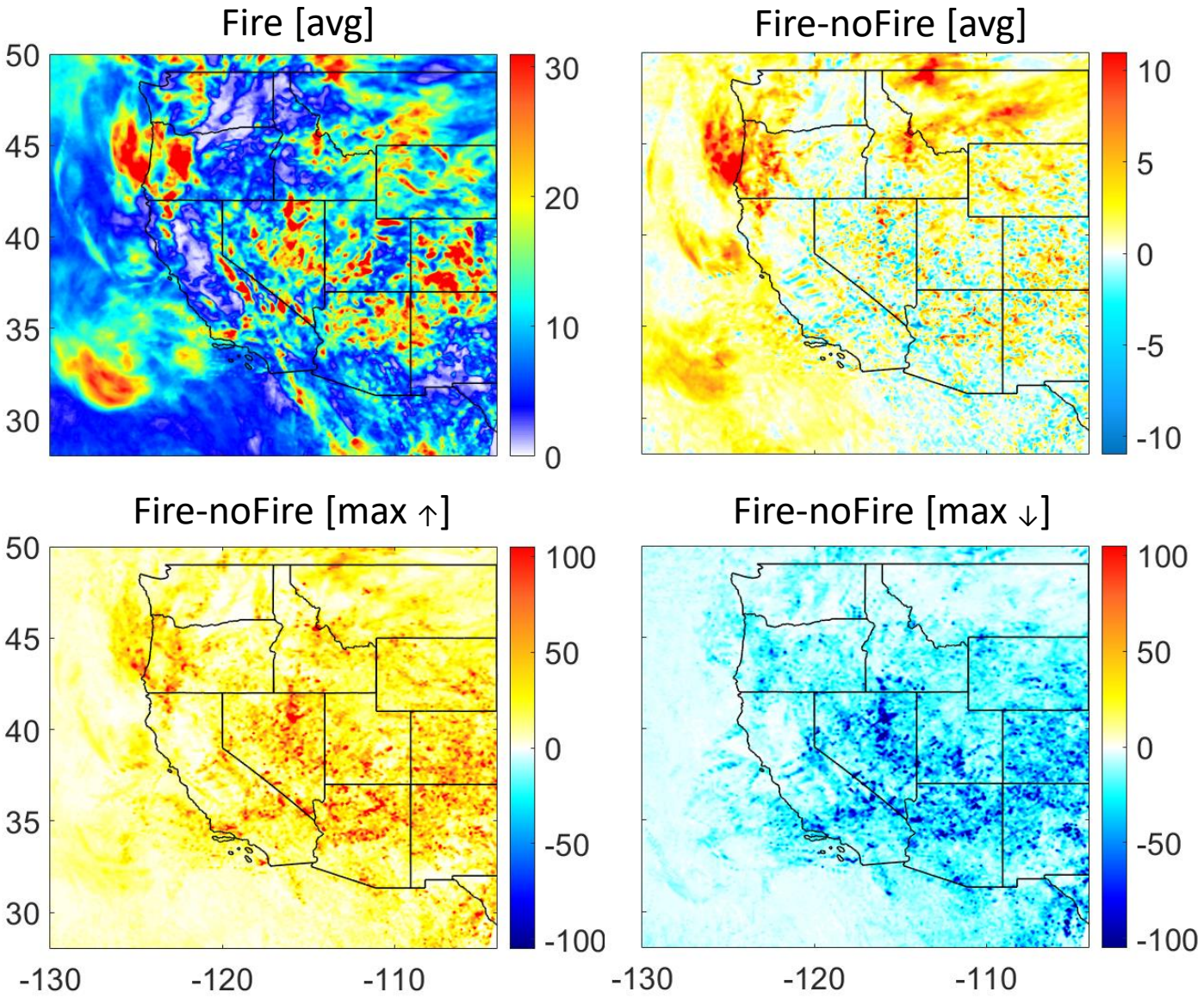
- **On average the PBLH is reduced by even more than 50m in some locations**
- **Reduction in PBLH due to reduced vertical mixing as a result of cooling near the surface**
- **Analysis of maximum enhancement (max ↑) occurring on diurnal scale in all model grids show increased PBLH by even more than 400m in the southern domain**
- **Analysis of maximum reduction (max ↓) occurring on diurnal scale in all model grids show reduced PBLH by even more than 400m in the southern domain**
- **Again changes in southern domain due to change in cloud properties**

Cloud Cover



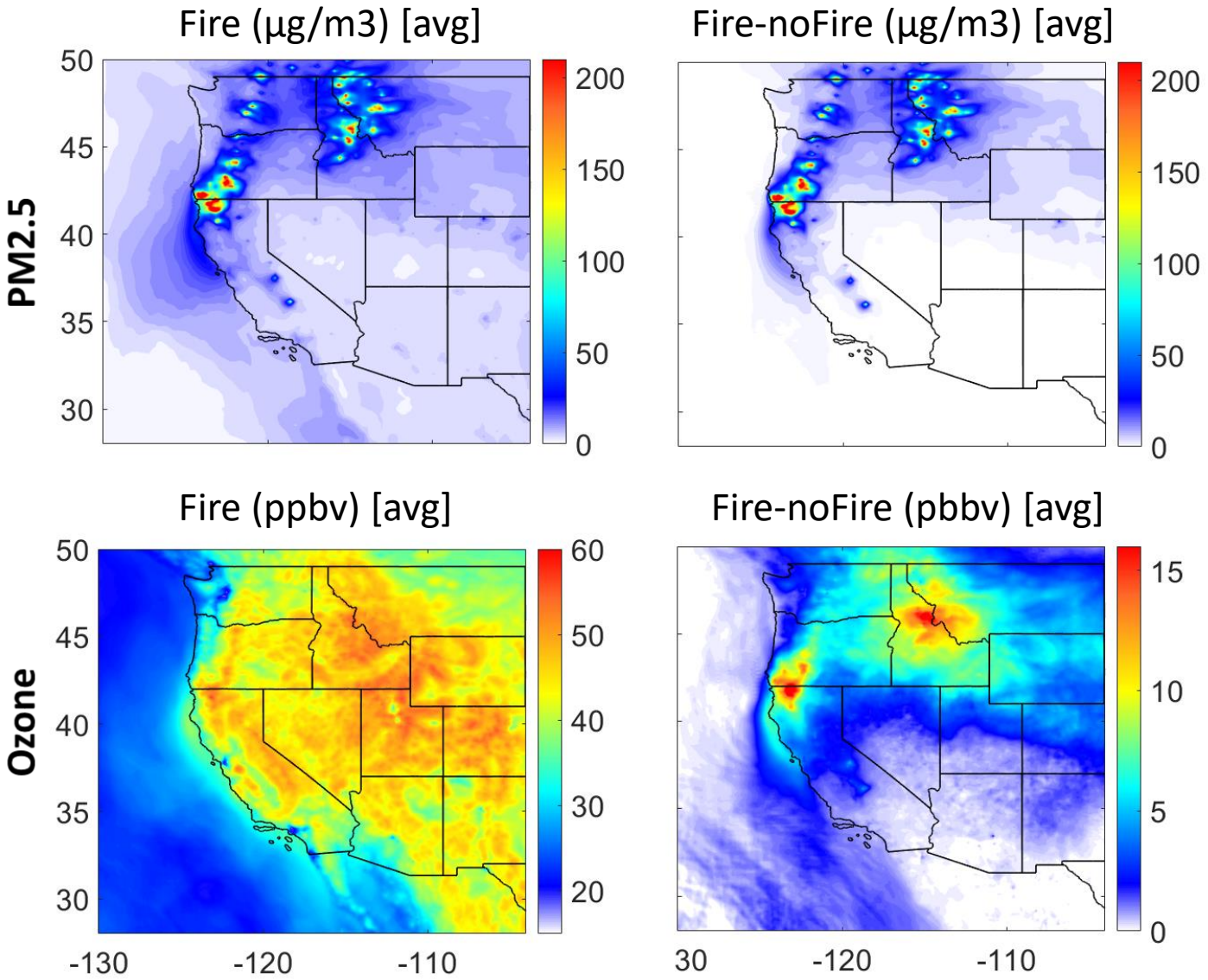
- **Average (temporal) cloud cover change by even more than 20% (mostly in southern parts of the domain)**

Cloud Optical Depth



- **On average the COD is enhanced by more than 10 units in locations close to wildfires**
- **Although there is no large change in cloud cover in these regions; the optical depth increases**
- **Analysis of maximum enhancement (max ↑) occurring on diurnal scale in all model grids show enhancements of even more than 100 units in several locations throughout the domain**
- **Analysis of maximum reduction (max ↓) occurring on diurnal scale in all model grids show reduction in COD by even more than 100 units**
- **High reductions mostly seen in southern domain**

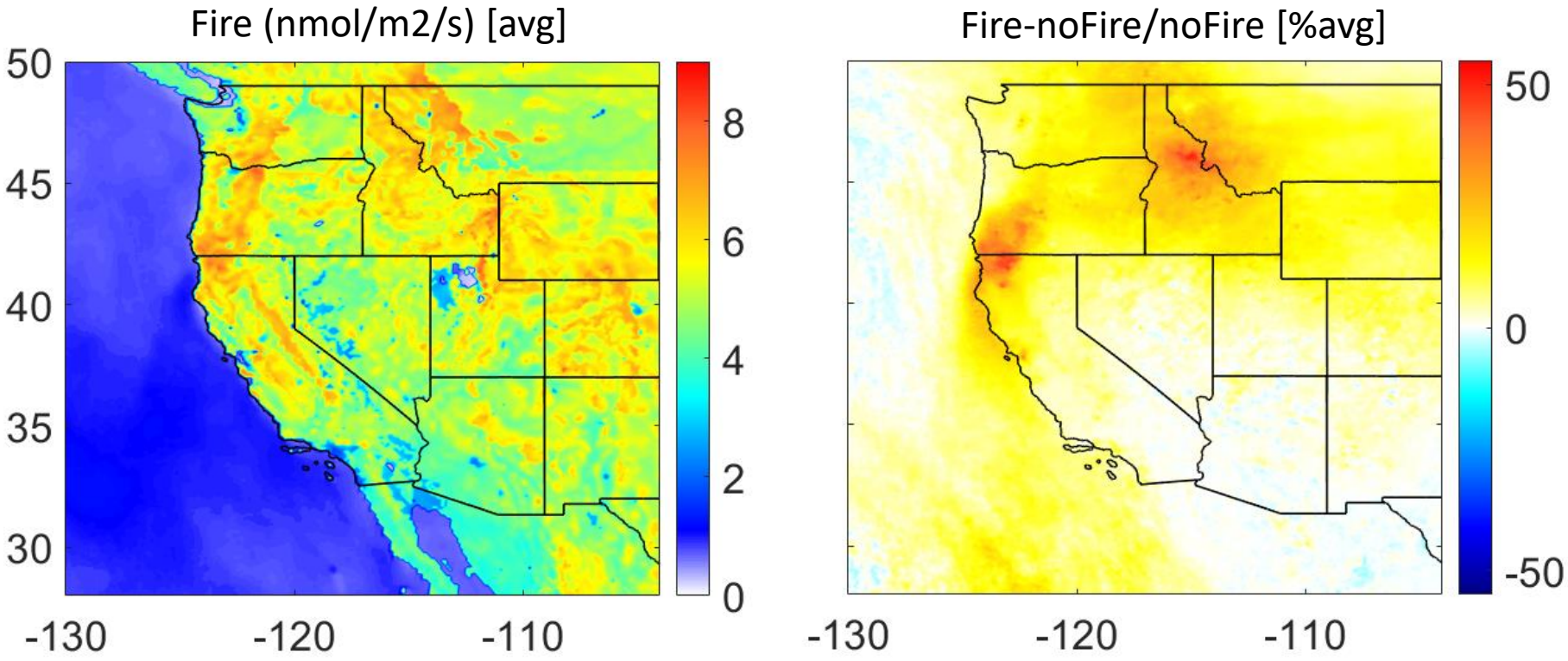
PM2.5 and Ozone



- **Large changes in PM2.5 (> 200 µg/m3) seen in areas close to wildfires**
- **Changes occur not just due to wildfires directly but also due to changes in meteorology; reduction in temperature and suppression of PBLH increases the surface PM2.5 concentration**

- **Ozone mixing ratios increased by even more than 15 ppbv in areas close to wildfires**
- **High levels of PM2.5 and ozone detrimental to human health; ozone is also known to impact vegetation**

Ozone dry deposition flux



- **Ozone dry deposition flux increase by even more than 50% thus modulating the buildup of ozone in the atmosphere**

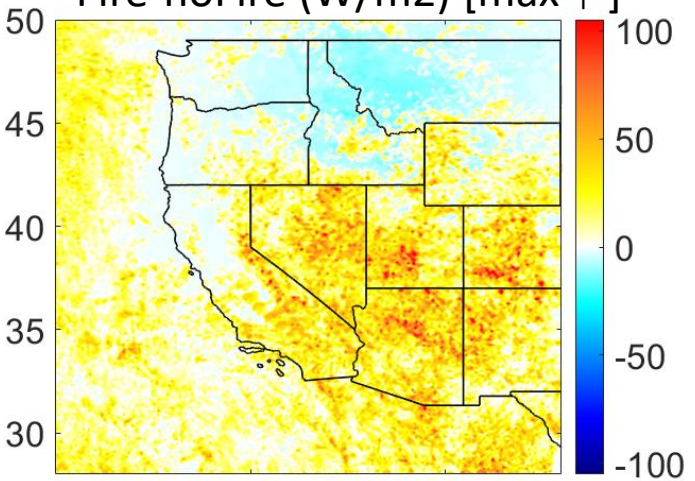
Summary and Conclusions

- Model performs reasonably well when evaluated against ground observations and satellite data
- Average (temporal) solar insolation reduces by even more than 50 W/m2 in some locations in the north due to aerosol scattering and absorption
- Average (temporal) surface temperature is reduced by up to 0.5 ^{o}C in some locations in the north due to reduction in downward shortwave radiation; PBLH reduced by more than 50m due to reduced vertical mixing
- Changes in solar insolation, surface temperature and PBLH in the southern domain due to change in cloud properties e.g. cloud cover (change by even more than 20% in some locations)
- COD is changed by more than 100 units on diurnal scale in several locations throughout the domain; on average changes more prominent in the wildfire impacted regions with enhancements more than 10 units
- Enhancements in surface PM2.5 and ozone occur not only due to wildfires emissions directly but also due to changes in meteorology; reduction in temperature and suppression of PBLH can increase surface pollutant levels
- Ozone dry deposition acts to modulate the buildup of ozone in the atmosphere; dry deposition flux increased by even more than 50% (temporal average) in locations close to wildfires
- **Wildfires impact the entire western US through changes in meteorology and air quality.**

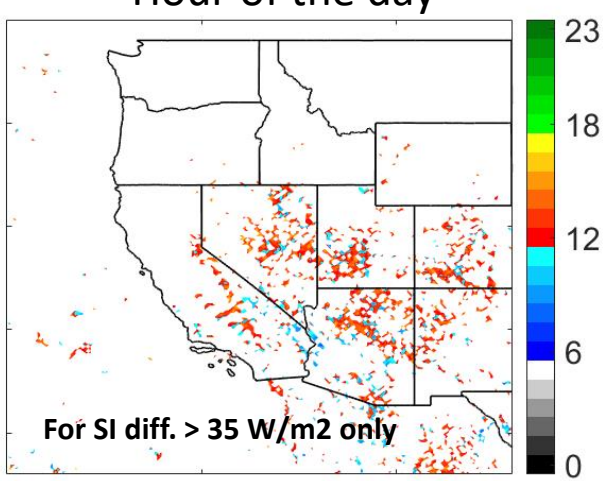
EXTRAS

Solar Insolation

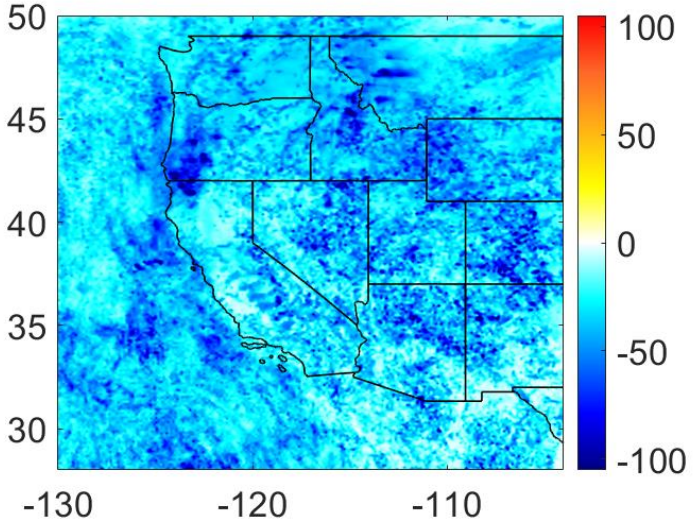
Fire-noFire (W/m2) [max ↑]



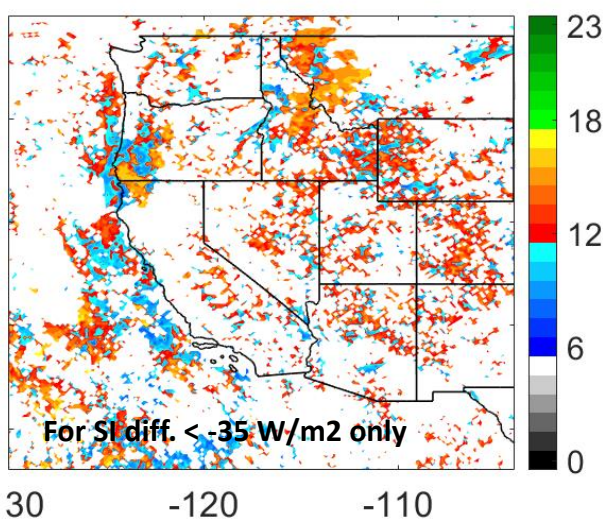
Hour of the day



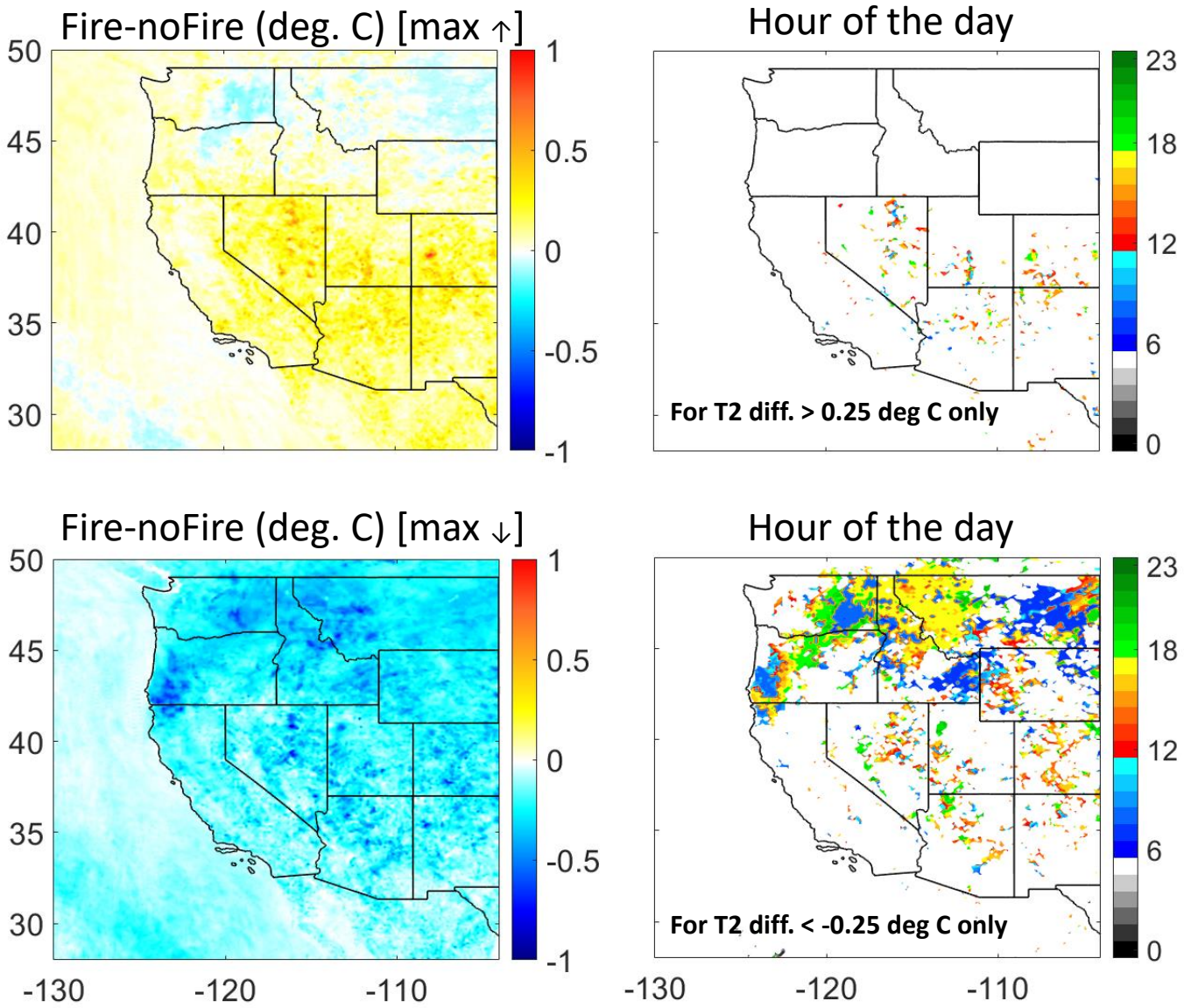
Fire-noFire (W/m2) [max ↓]



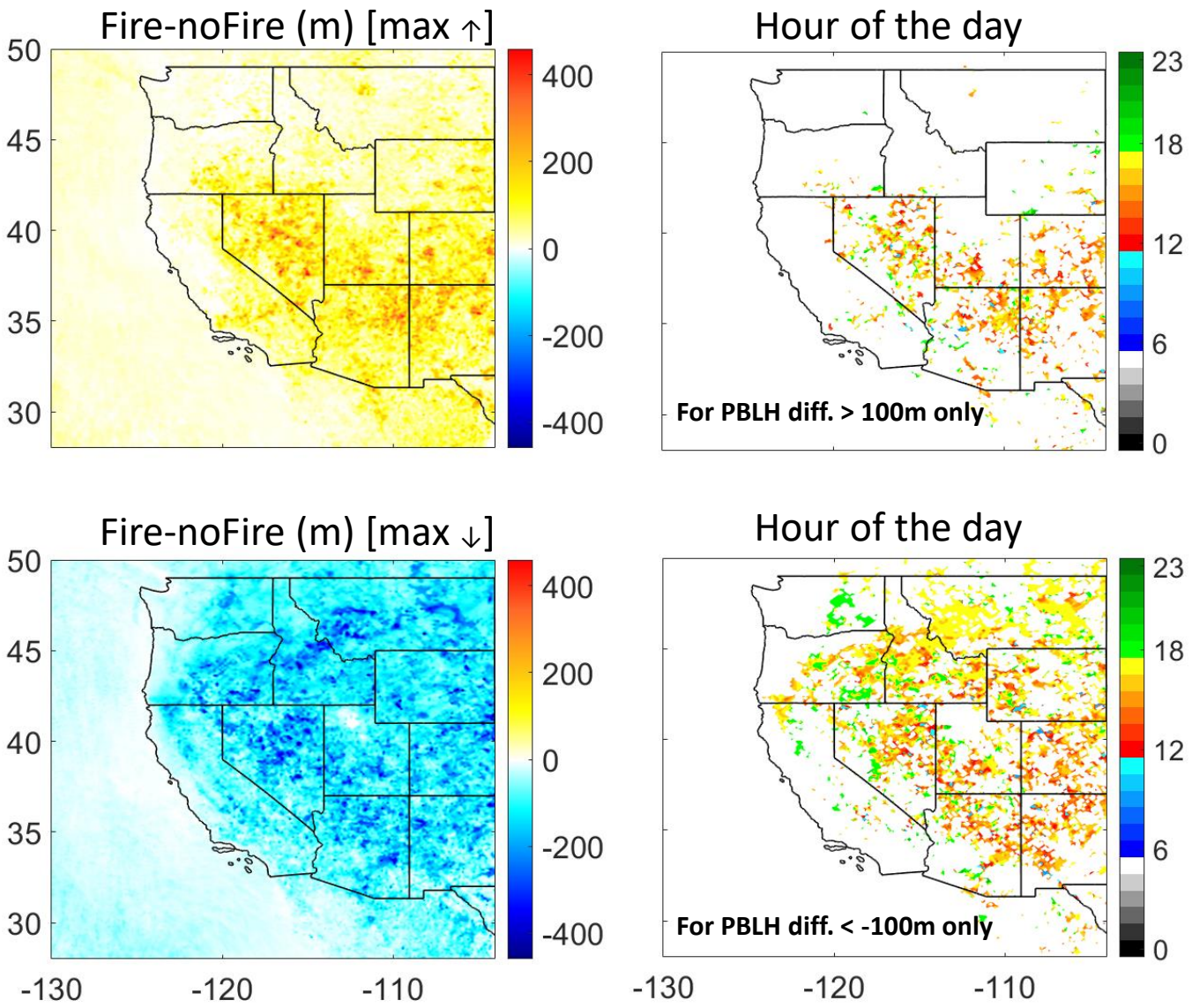
Hour of the day



Temperature at 2m

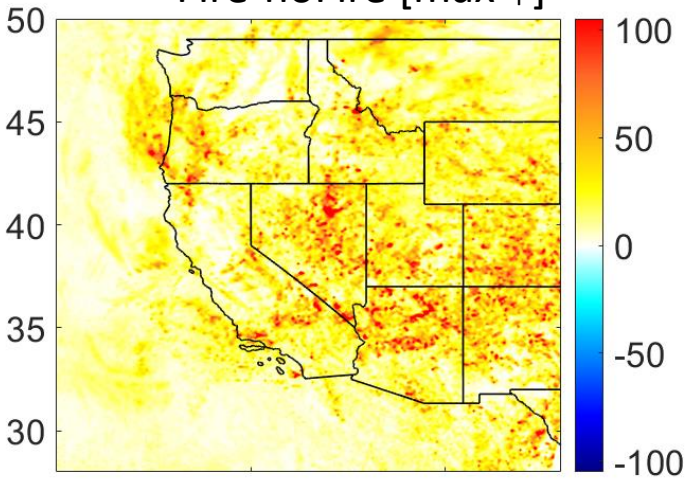


PBLH

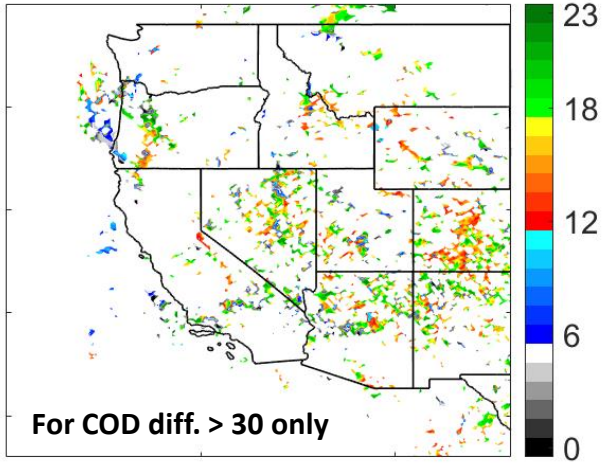

Fire-noFire (m) [max ↑]
50
45
40
35
30
400
200
0
-200
-400
Hour of the day
23
18
12
6
0
For PBLH diff. > 100m only
Fire-noFire (m) [max ↓]
50
45
40
35
30
400
200
0
-200
-400
-130
-120
-110
Hour of the day
23
18
12
6
0
For PBLH diff. < -100m only
-130
-120
-110

Cloud Optical Depth

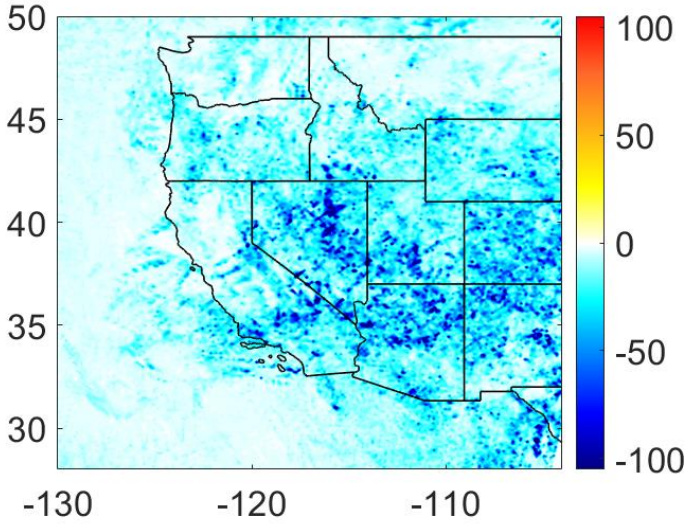
Fire-noFire [max ↑]



Hour of the day



Fire-noFire [max ↓]



Hour of the day