Interactions between meteorology and chemistry during wildfire season over Western US

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1. Introduction

- Air quality over western US deteriorates severely during wildfire season (June to October) when wildfires release mixture of air pollutants that is dispersed into the atmosphere and carried away to downwind areas.
- Meteorology can be also significantly affected by a large amount of air pollutants released from wildfires via aerosol-radiation and aerosol-cloud interactions.
- Wildfires are expected to intensify in future (Spracklen et al., 2009), possibly leading to frequent and worse pollution episodes.
- 3D air quality models like WRF-Chem can help to estimate the impacts of wildfires on meteorology and atmospheric chemistry.

2. WRF-Chem configuration

Base run description	
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 wave radiation	RRTMG
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
Biomass burning emissions	FINN v1
Anthropogenic emissions	NEI 2011
Biogenic emissions	MEGAN
Chemical boundary conditions	MOZART-4

- Model is run for September 2017 with 4 days 'spin up' time starting August 28 which is discarded for analysis. Two simulations are made.

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

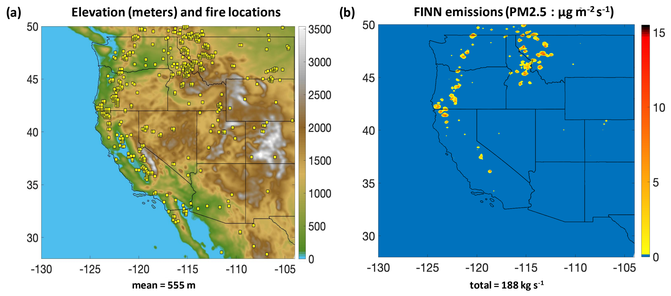

Figure 1. Terrain elevation and fire locations in **(a);** PM2.5 emissions from wildfires in **(b)** during first half of Sept 2017

Reference: Spracklen, D. V., Mickley, L. J., Logan, J. A., Hudman, R. C., Yevich, R., Flannigan, M. D., and Westerling, A. L.: Impacts of climate change from 2000 to 2050 on wildfire activity and carbonaceous aerosol concentrations in the western United States, J.Geophys. Res., 114, D20301, doi:10.1029/ 2008JD010966, 2009.

3. Time series at selected stations

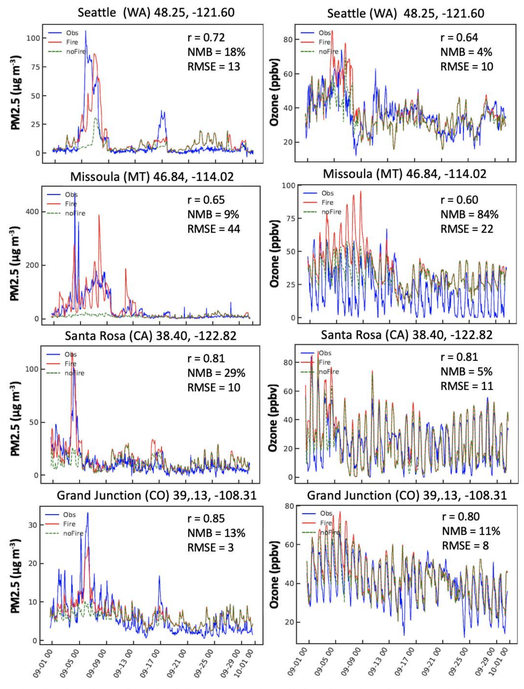

Figure 2. Time series for hourly surface PM2.5 concentrations (left column) and ozone mixing ratios (right column) at selected stations for Sept 2017 with observations in blue, 'Fire' run in red and 'noFire' run in dashed green. Correlation coefficient (r), normalized mean bias (NMB) and root mean square error (RMSE) values for 'Fire' run are given.

- Model predicts the temporal patterns well in both PM2.5 and O_3 with r values higher than 0.65 for PM2.5 and 0.6 for O_3. Model is able to capture peak PM2.5 concentrations qualitatively but shows underprediction especially at Missoula (MT), which is possibly quite close to a wildfire as seen from high PM2.5 levels (> 400 μg m^{-3}). Ozone is enhanced due to wildfires with much less degree than PM2.5 but tends to show overprediction even without wildfires at some stations.

4. Model evaluation: Correlation Coefficient (r) and NMB(%)

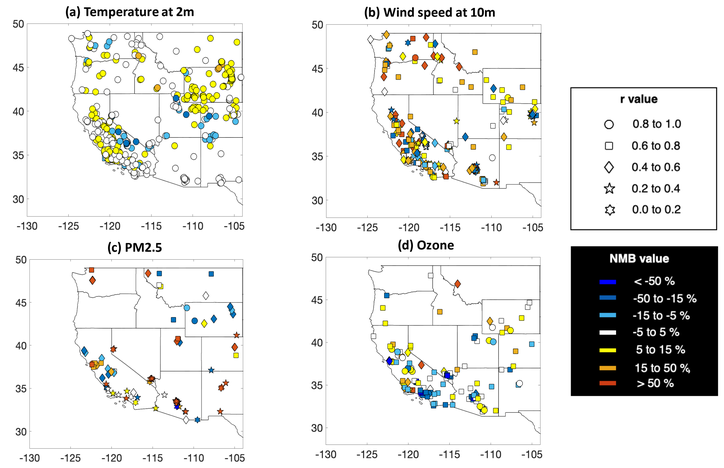

Figure 3. Model evaluation statistics (r and NMB values) for hourly **(a)** temperature at 2m; **(b)** wind speed at 10m; **(c)** PM2.5 concentrations; and **(d)** ozone mixing ratios at stations over western US for Sept 2017

- Model captured hourly variations in temperature well (r > 0.8 & |NMB| < 15%) at most stations.
- Wind speeds perform slightly worse than temperature (i.e., |NMB| > 15% at many stations), possibly due to unresolved topography at a 12 km grid resolution
- Model captured temporal patterns of PM2.5 better in the north (r > 0.4 mostly) than south (r < 0.4) , esp. over coastal areas in south-west where the model did not predict winds well.
- Ozone is predicted well in term of temporal patterns (r > 0.6 at most stations) but is biased high (|NMB| >15%) at some locations along the coast of California.

5. Sensitivity results and discussion

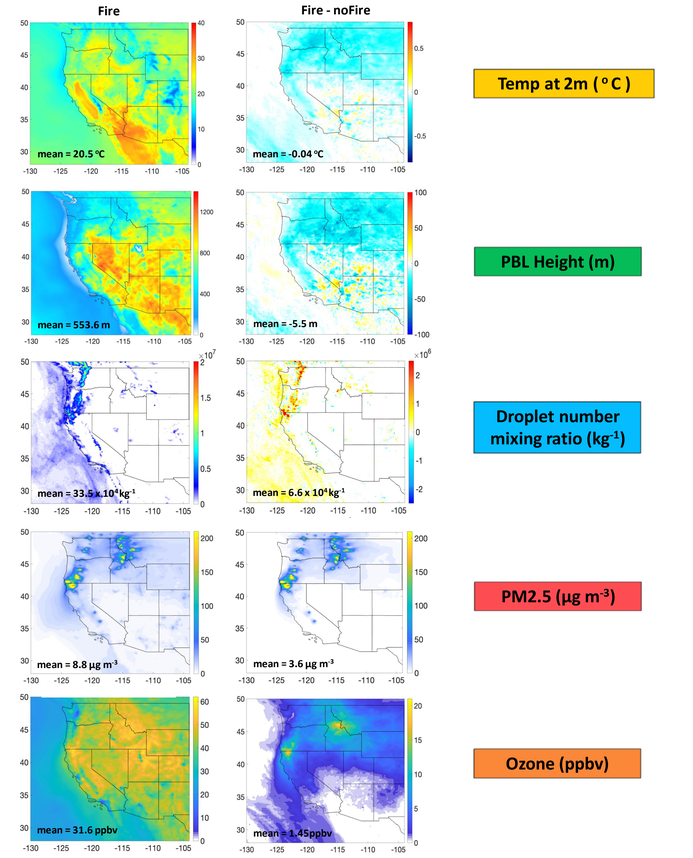

Figure 4. Sensitivity results for several meteorological and chemistry variables with corresponding base run (Fire) values in left column and difference between 'Fire' and 'noFire' run in the right column for first half of Sept 2017

- Wildfires result in reducing temperature at 2 m by -0.04 °C, on average, but up to -0.5 °C in some locations which is primarily attributed to reduction in downward shortwave radiation at surface due to feedback from aerosols released from wildfires .
- Boundary layer height (PBL height) also shows qualitatively similar reduction (-5.5 m on average but up to -50 m in some locations) possibly caused by reduced vertical mixing due to cooling near the surface.
- Droplet number mixing ratio increases (by about 25%) near surface especially in areas close to wildfires due to increased availability of cloud condensation nuclei (CCN).
- Wildfires increase surface PM2.5 concentration (averaged over time and domain) by about 3.6 μg m^{-3} (~70%) with much large changes (> 200 μg m^{-3}) observed in areas close to wildfires.
- Ozone mixing ratio (averaged over time and domain) is increased by 1.45 ppbv (~5%) but some locations show larger than 20 ppbv due to wildfires.

6. Summary and future work

- WRF-Chem performed reasonably well over western US for the wildfire period in Sept 2017.
- Surface air temperature is reduced down by 0.5 °C in some locations mainly via aerosol-radiation interaction associated with wildfires.
- Boundary layer height (PBL height) is reduced down by 50 m in some locations as cooling near the surface causes less vertical mixing.
- Droplet number mixing ratio is increased by 25% due to PM from wildfires.
- Wildfires increase surface PM2.5 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.
- We plan to investigate the role of feedback process with and without wildfires and also analyze the aerosol-radiation and aerosol-cloud interactions separately.