



# AIRPACT-Fire: Improving Smoke Forecasts in the Pacific Northwest Using a Coupled WRF-CMAQ

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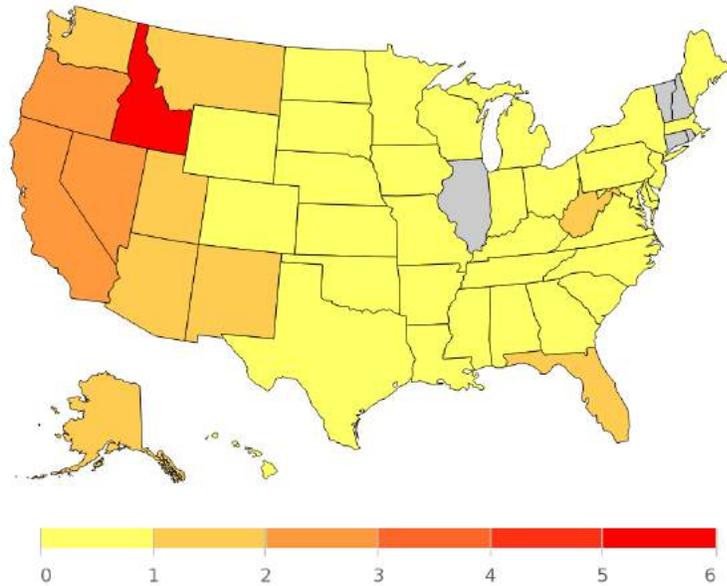
NW-AIRQUEST Annual Meeting, Seattle

June 12-14, 2018



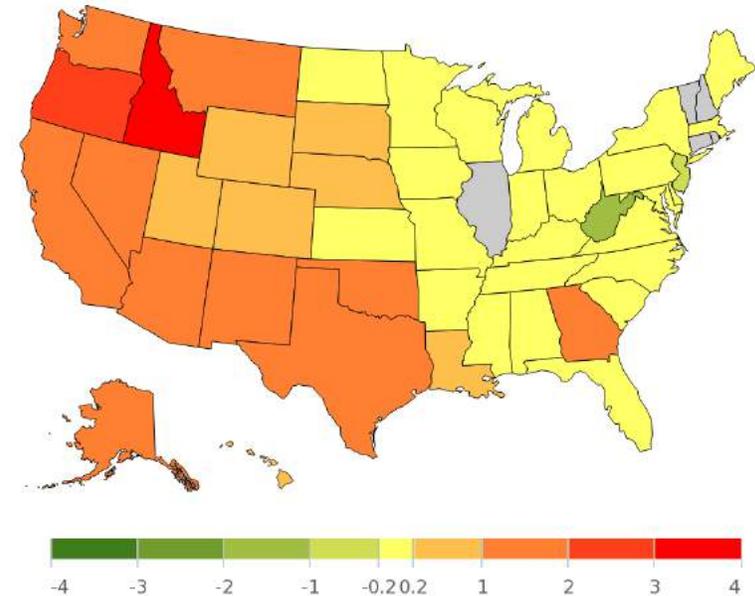
# Motivation

Average Annual Burned Acreage by State, 1984-2014



Acres per mile of land area

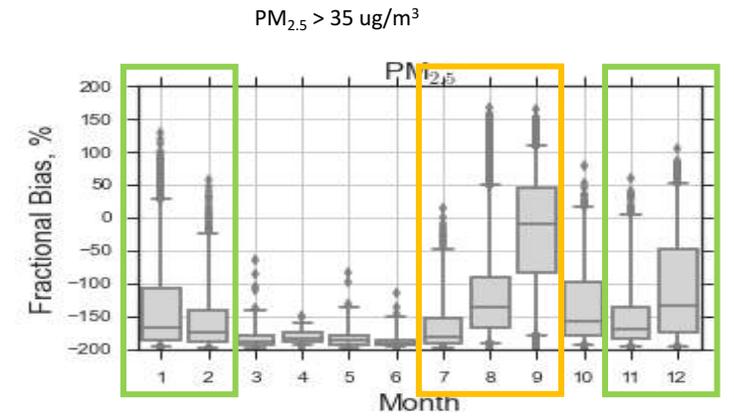
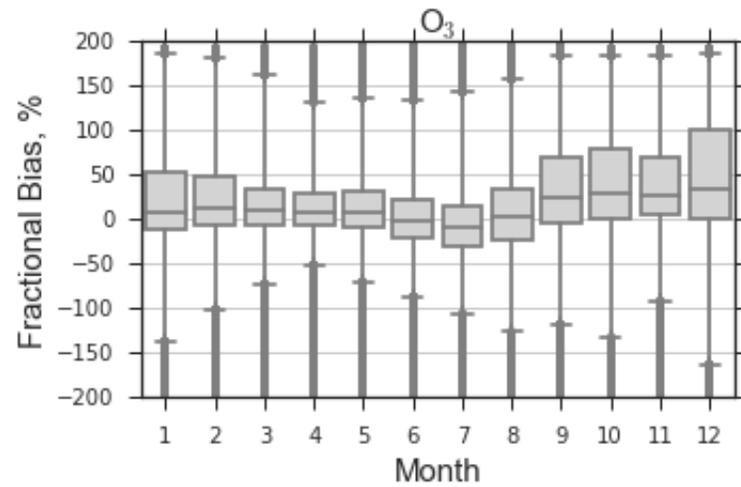
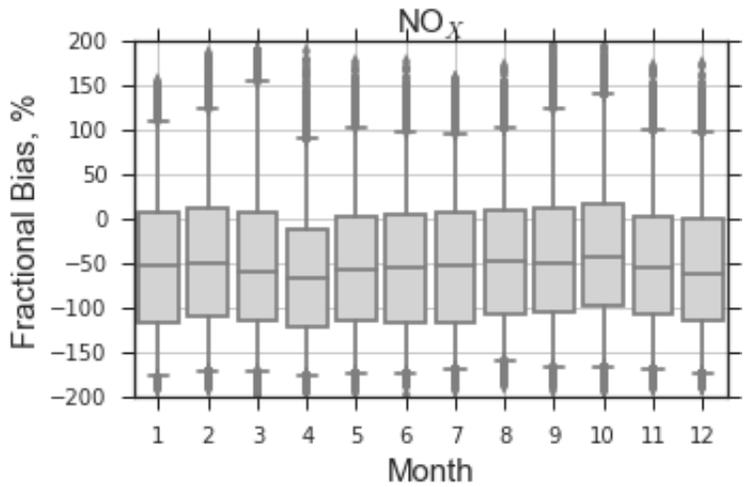
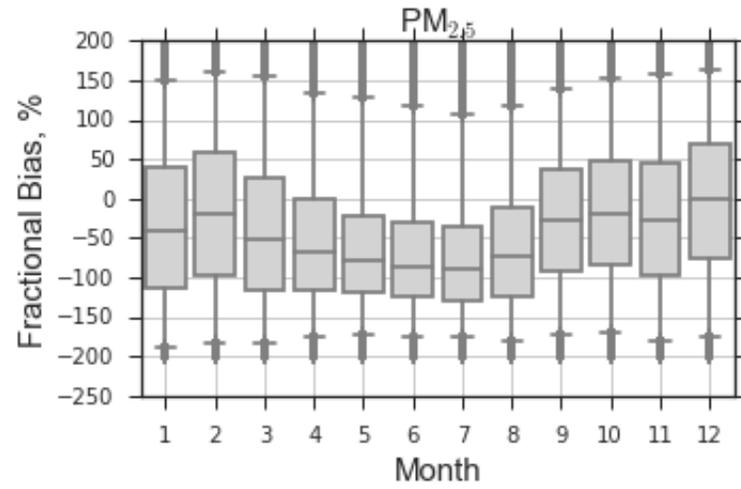
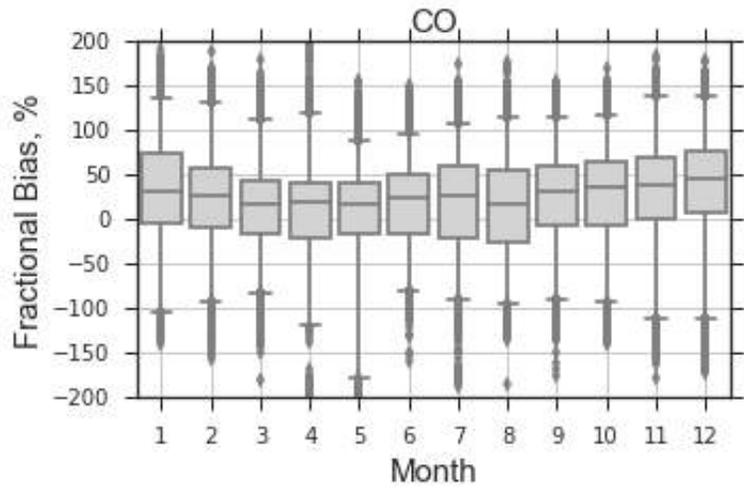
Change in Annual Burned Acreage by State Between 1984-1999 and 2000-2014



State	Average Annual Acreage Burned	Acres Burned in 2017
Idaho	5.42	686,262
Nevada	2.96	1,329,289
Oregon	2.89	714,520
California	2.64	1,266,224
Washington	1.78	404,223
Montana	1.42	1,366,498

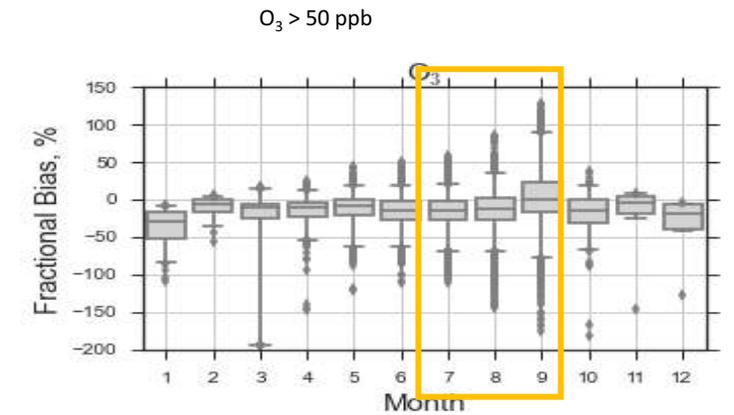
Figure source: <https://www.epa.gov/climate-indicators/climate-change-indicators-wildfires#>

# AIRPACT-5 Performance for 2017



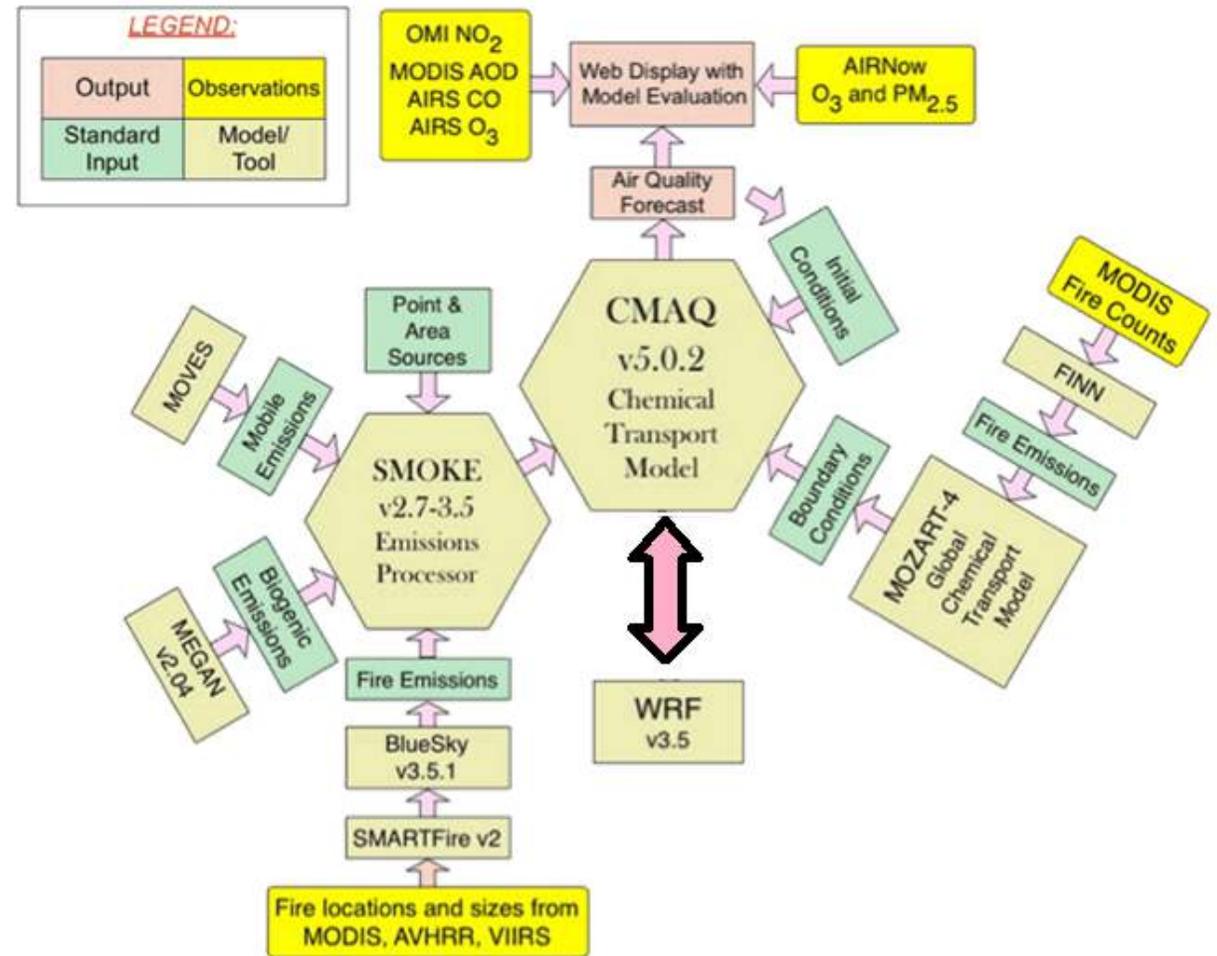
Residential wood combustion

Wildfires (inside/outside domain)



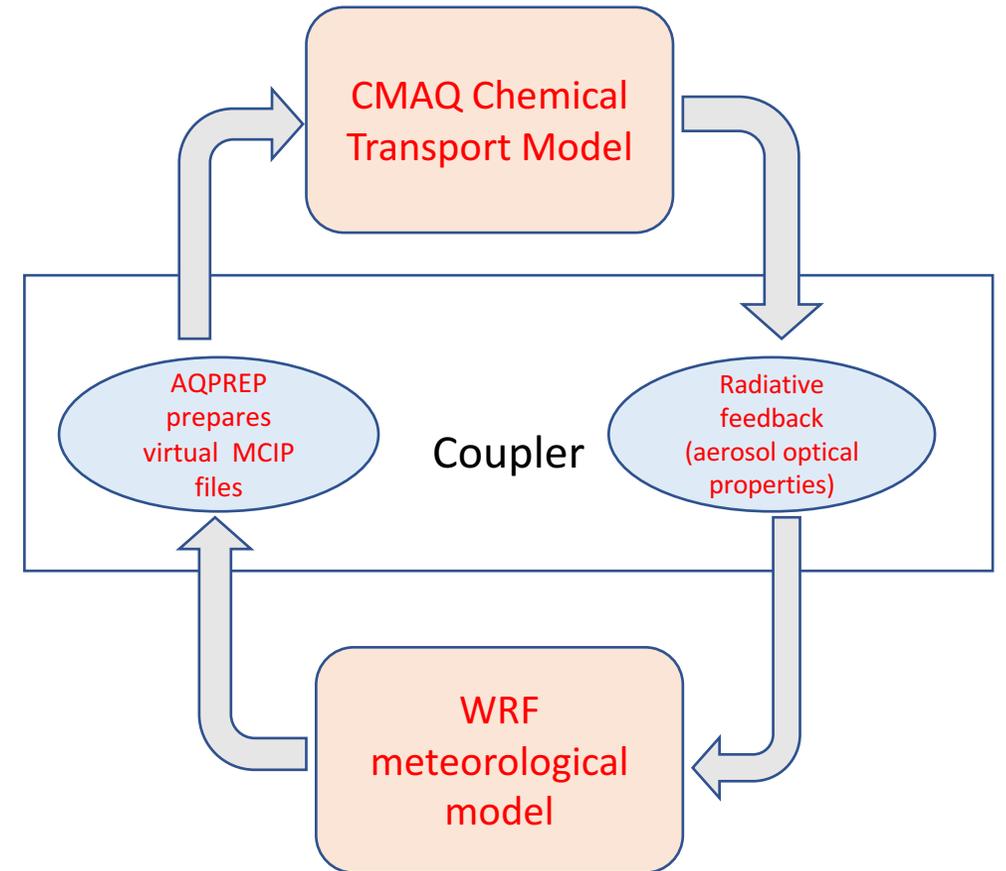
# Implementation of a Coupled WRF-CMAQ System

- WRF (version 3.8), CMAQ (version 5.2)
- Meteorology used is NOAA's High Resolution Rapid Refresh (HRRR) model, which as the name suggests, is frequently updated with observations
- Plume rise for point and fire sources in CMAQ using modified Brigg's plume rise algorithm
- Two different simulations:
  - Coupled WRF-CMAQ, with feedback
  - Coupled WRF-CMAQ, no feedback



# Implementation of a Coupled WRF-CMAQ System

- Coupling is through a coupler: exchange of information occurs at every 20<sup>th</sup> WRF time step
  - ~ every 5-6 minutes
- Only direct effects considered for the feedback
- Simulation period: Aug 29-Sept 10, 2017 (ongoing; current results only from 28-31 Aug)
- Coupled WRF-CMAQ also includes options for inline emissions (such as biogenics), but we use AIRPACT-5 emissions.
  - Also has a module for wind blown dust
- CB06 chemistry mechanism, AE6 aerosol module

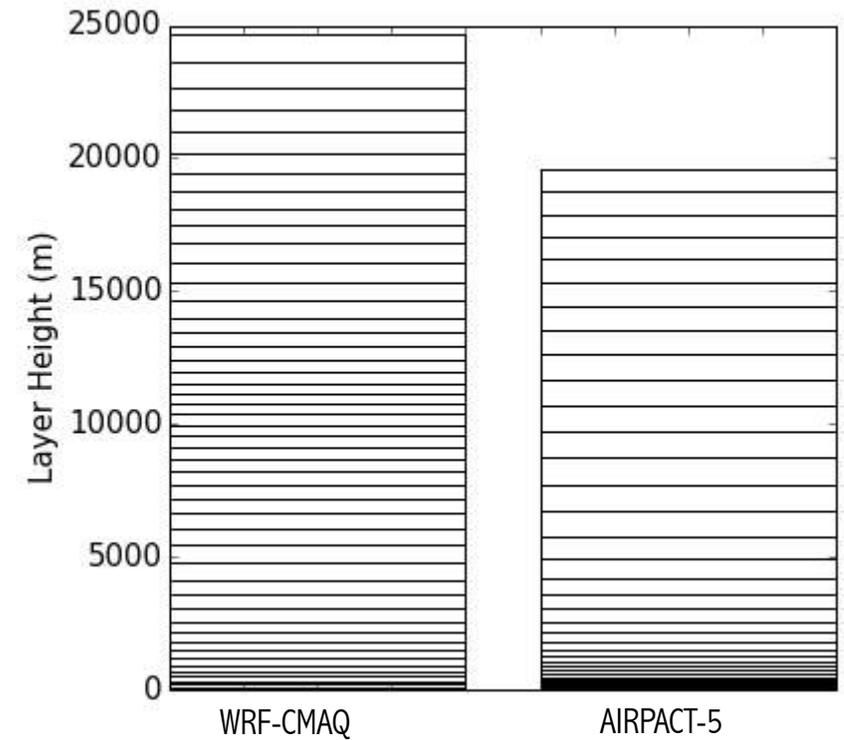


# Model configuration

## WRF configuration

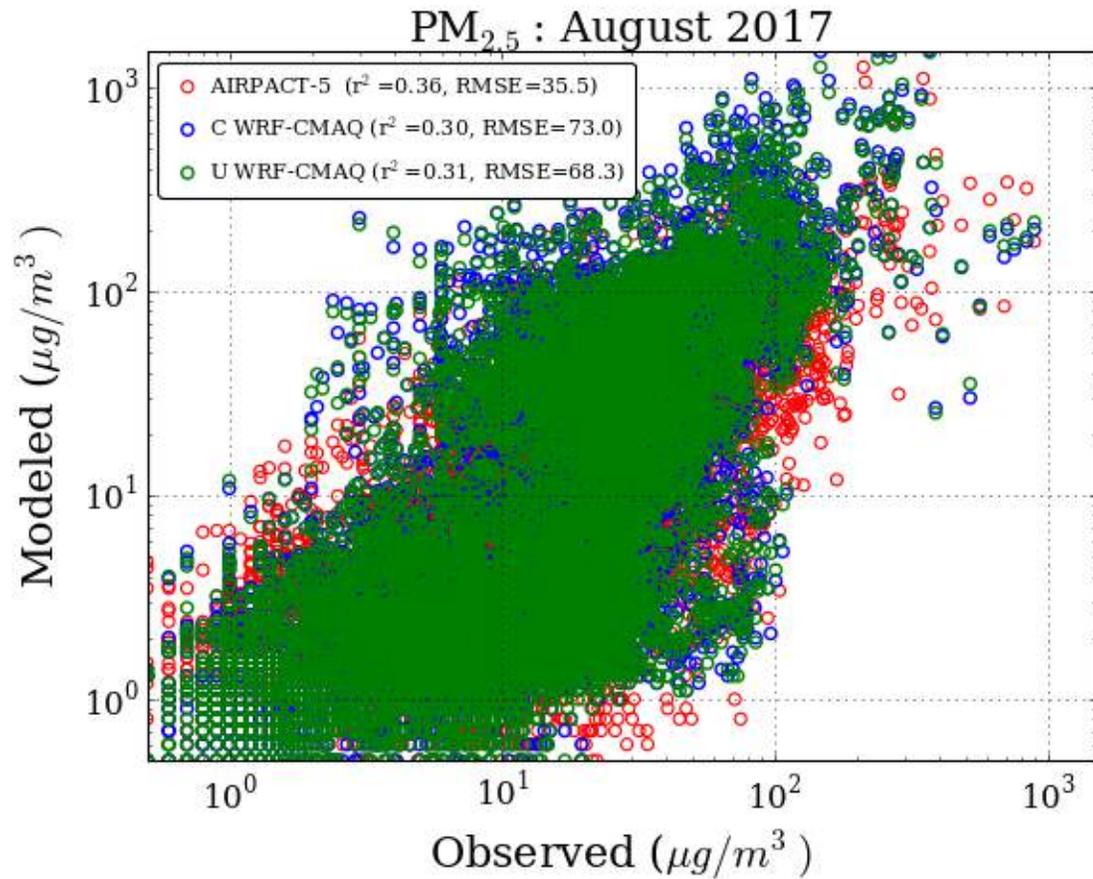
Field	Description
Domain	296(ew) x 292(sn) x 50(ver) 4000 m x 4000 m
Microphysics	Thomson microphysics scheme (aerosol aware)
Radiation physics	Rapid radiative transfer model (RRTMG)
Surface layer physics	MYNN
Land-surface Physics	RUC land-surface model
Boundary layer physics	MYNN 2.5 level TKE Nakanishi & Niino
Cumulus parametrization	No cumulus parametrization
Urban canopy model	No UCM
Land use category	21
Mosaic settings	Mosaic approach (only available for RUC LSM)

## CMAQ's Vertical Layer Structure



At row=100, column=100

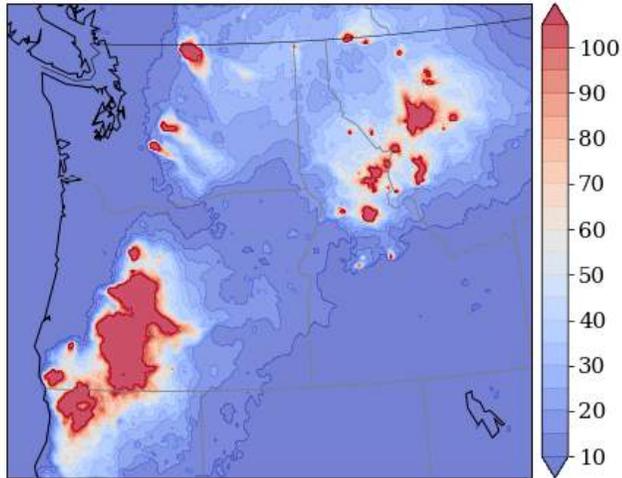
# Model Performance for PM<sub>2.5</sub> during the period



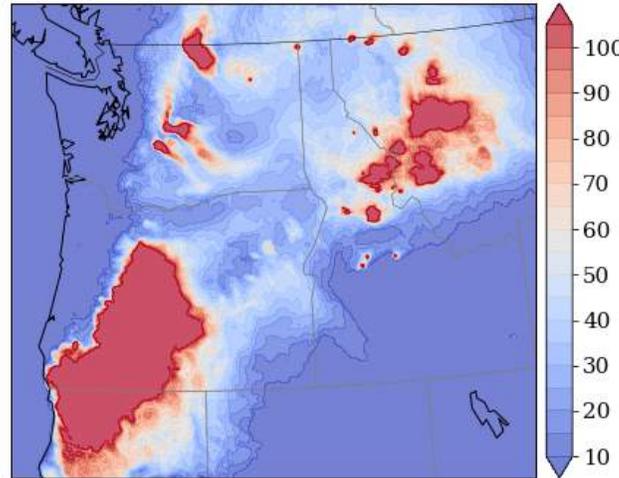
	Obs	AP5	C-WRF-CMAQ	U-WRF-CMAQ
Mean Modeled/observed	24.5	20.7	35.1	33.4
Mean bias		-3.76	10.4	8.9
Mean error		14.5	26.8	25.5
MFB		-29.4	-32.4	-34.9
MFE		69.6	90.0	90.0
#pairs	~9200			

# Model Performance at AirNow Monitors...

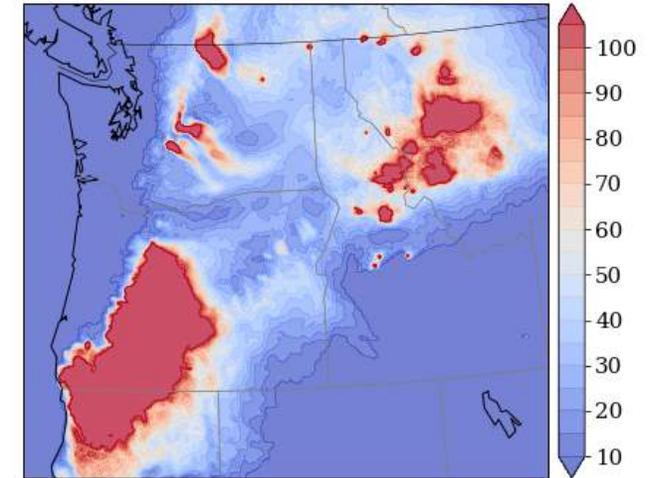
AIRPACT-5: Mean PM<sub>2.5</sub> (μg/m<sup>3</sup>)



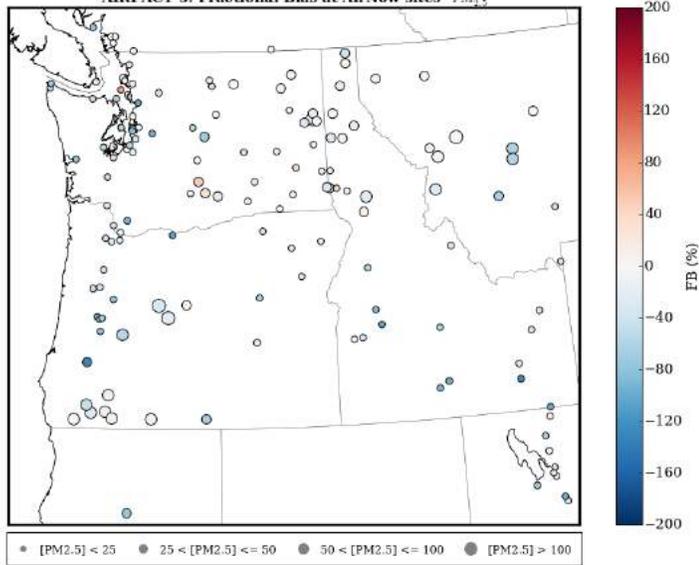
C WRF-CMAQ: Mean PM<sub>2.5</sub> (μg/m<sup>3</sup>)



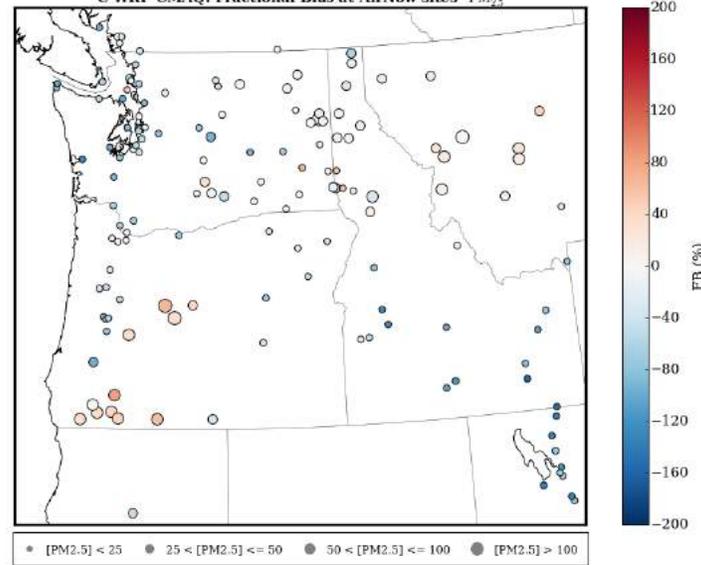
U WRF-CMAQ: Mean PM<sub>2.5</sub> (μg/m<sup>3</sup>)



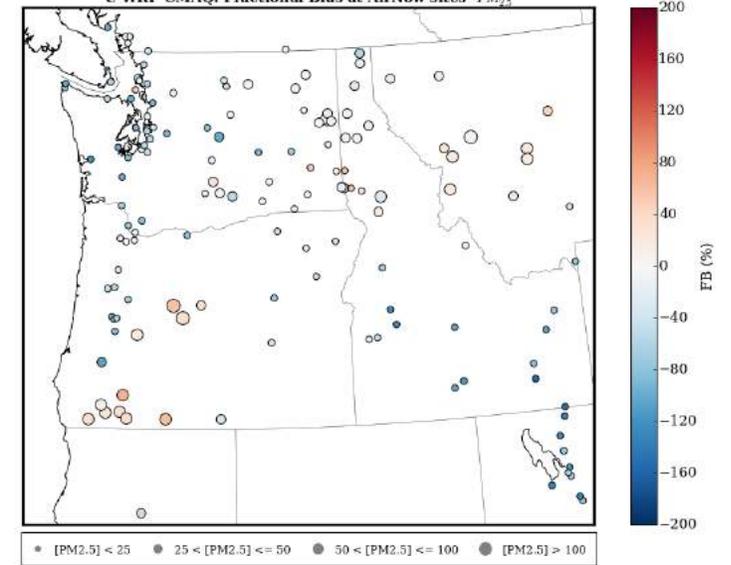
AIRPACT-5: Fractional Bias at AirNow sites- PM<sub>2.5</sub>



C WRF-CMAQ: Fractional Bias at AirNow sites- PM<sub>2.5</sub>

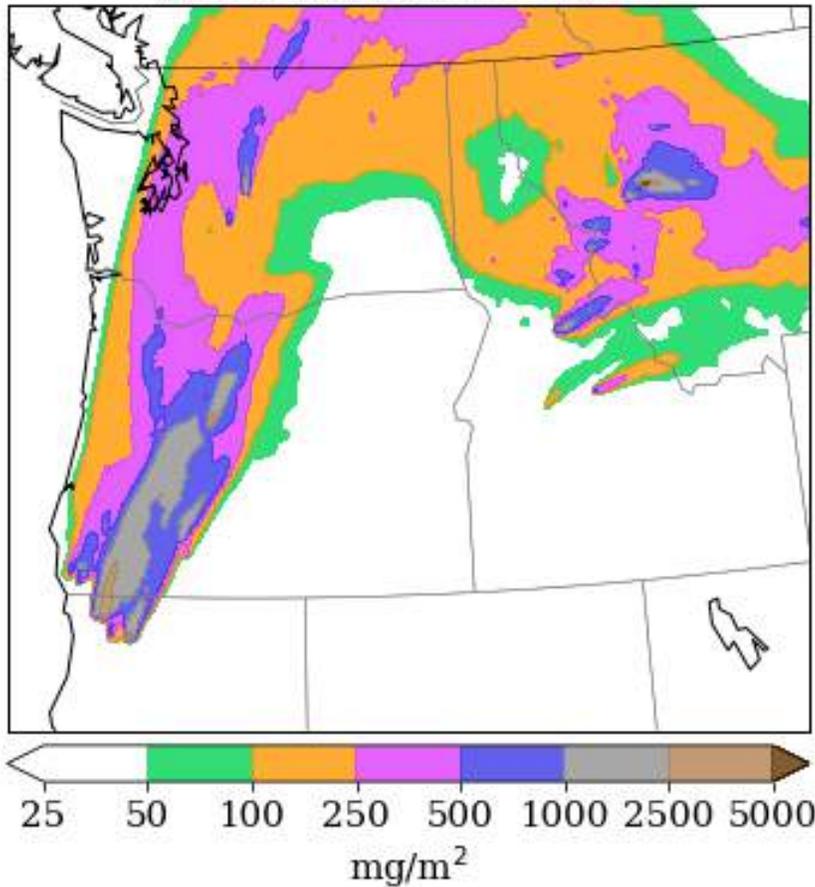


U WRF-CMAQ: Fractional Bias at AirNow sites- PM<sub>2.5</sub>

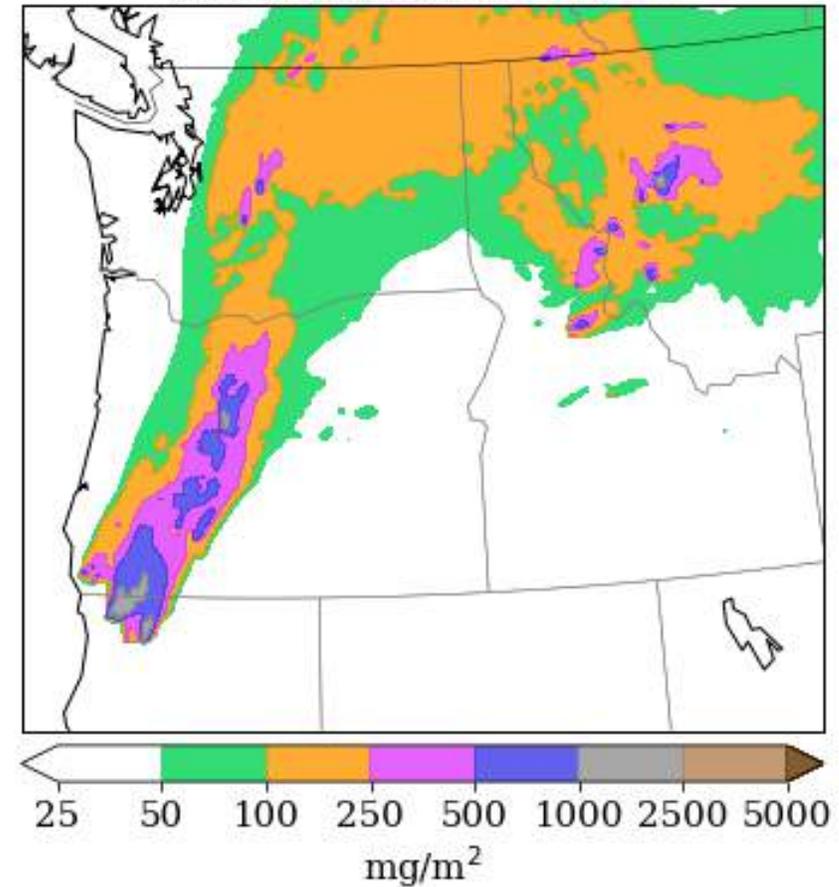


# Vertically Integrated Smoke

Coupled: Vertically Integrated Smoke on  
08-29-2017, 10PDT - 18PDT

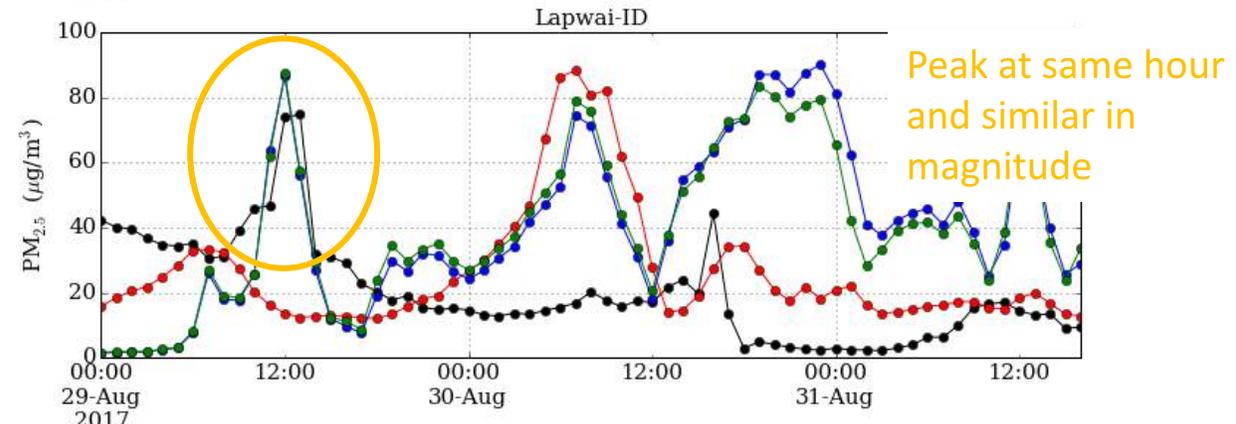
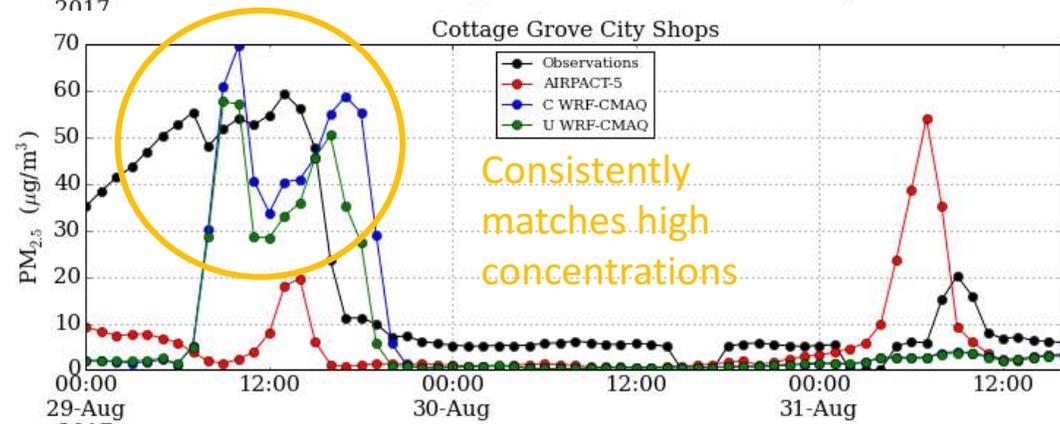
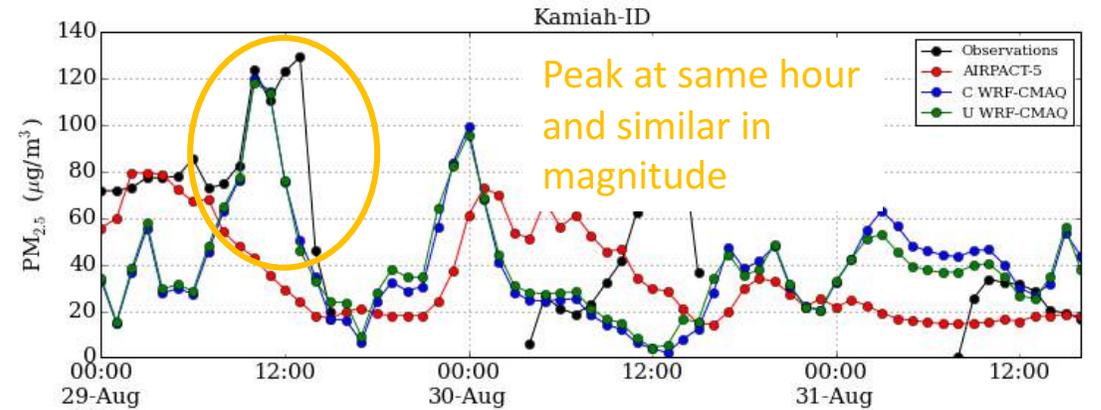
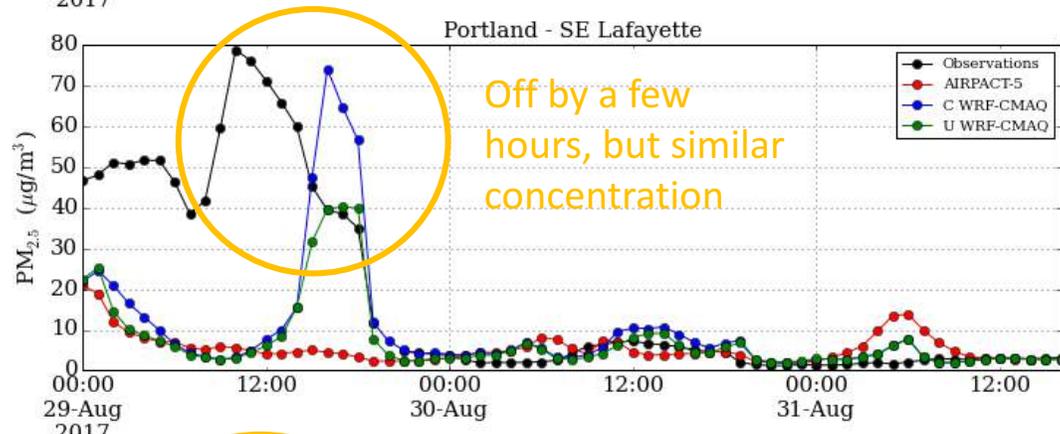
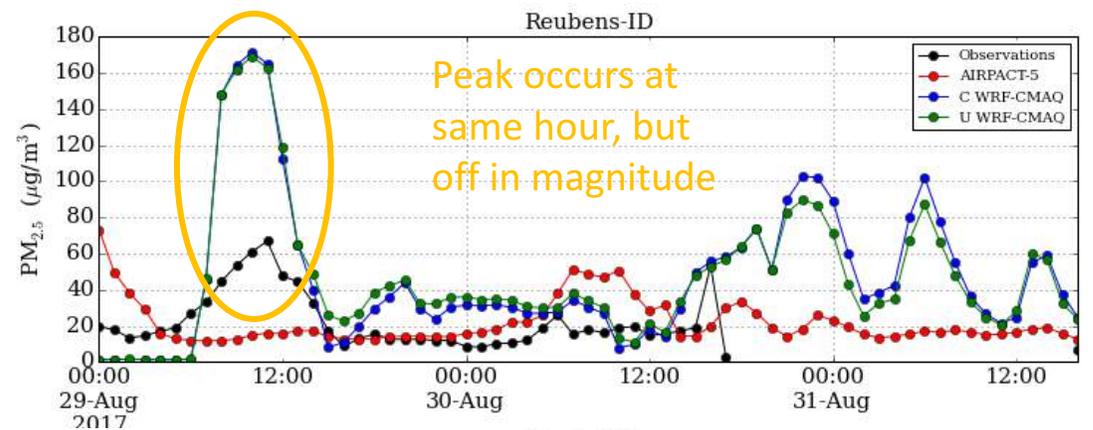
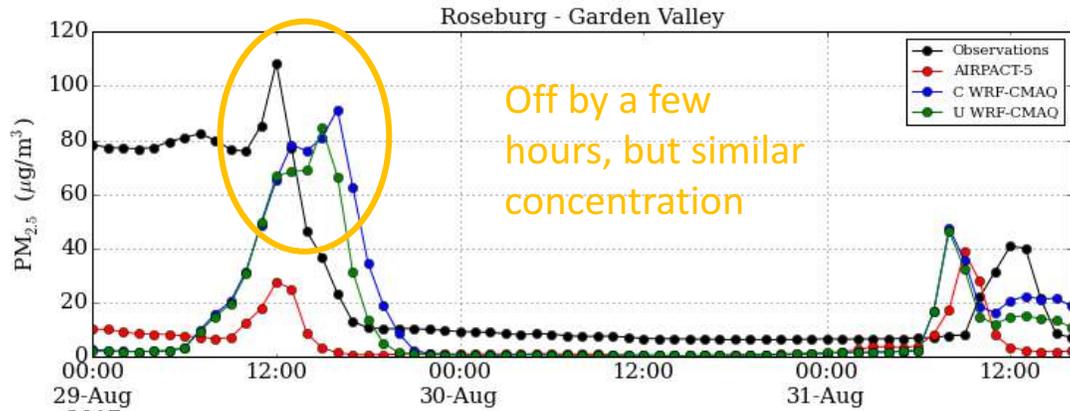


AP5: Vertically Integrated Smoke on  
08-29-2017, 10PDT - 18PDT

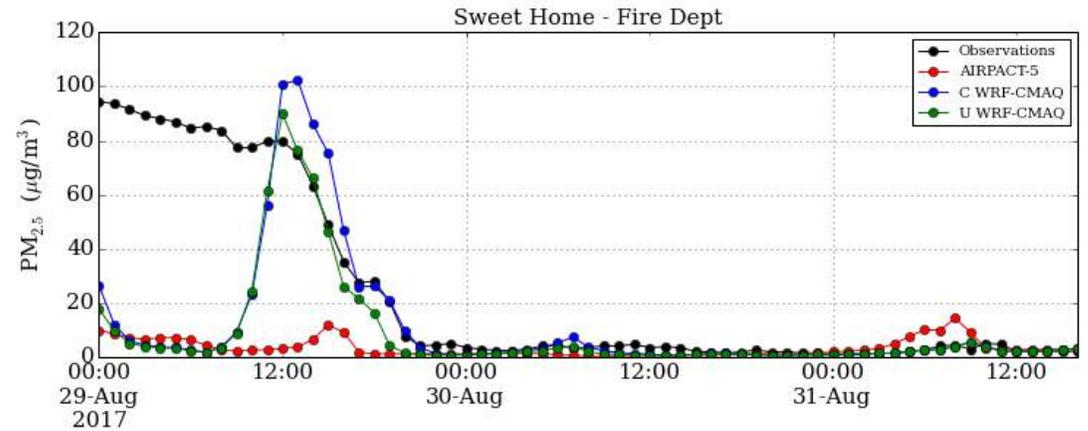
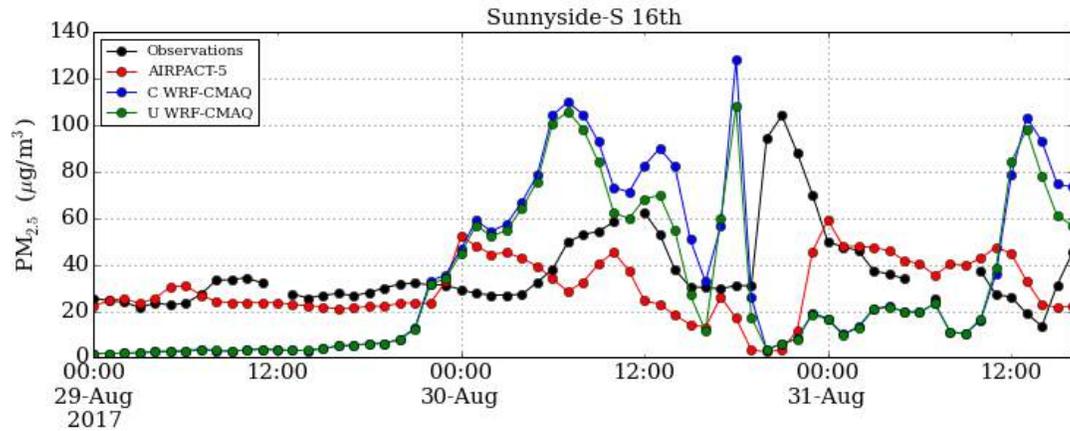
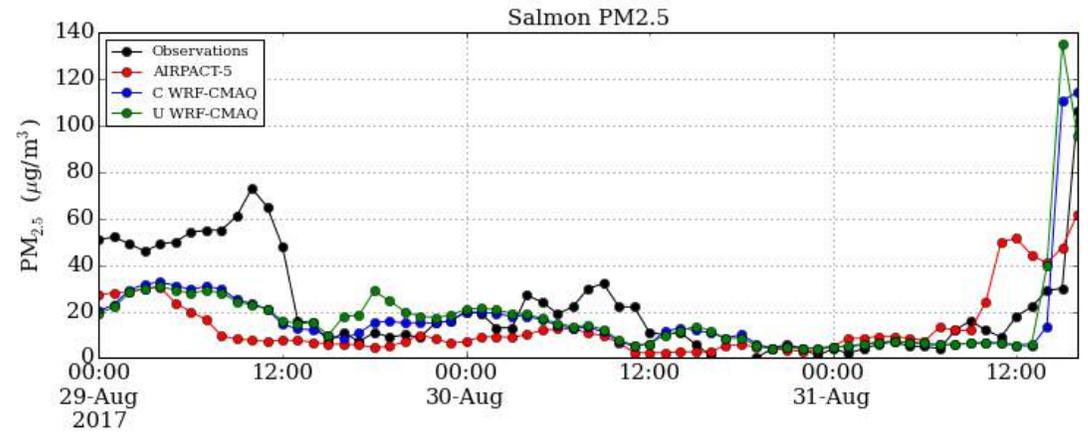
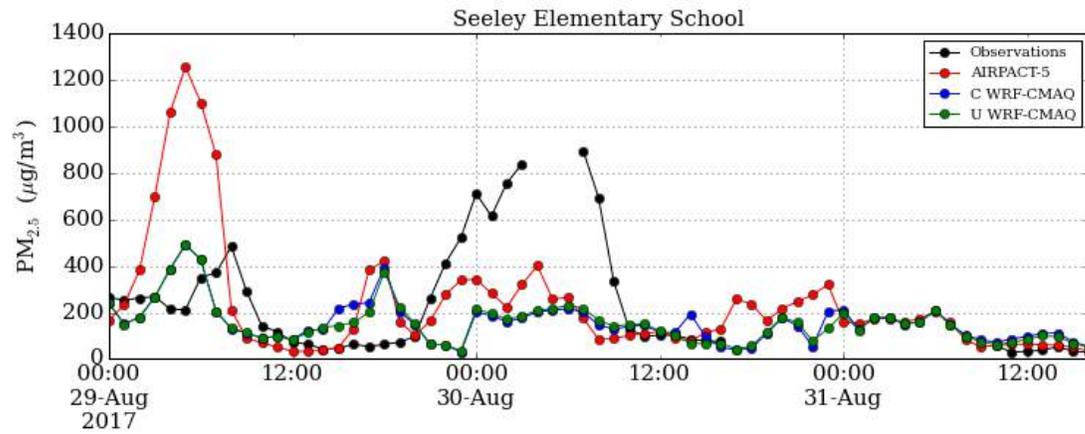


- Layer-by-layer integrated concentration field
- Looks like more smoke remains in the system for the coupled case compared to AIRPACT-5

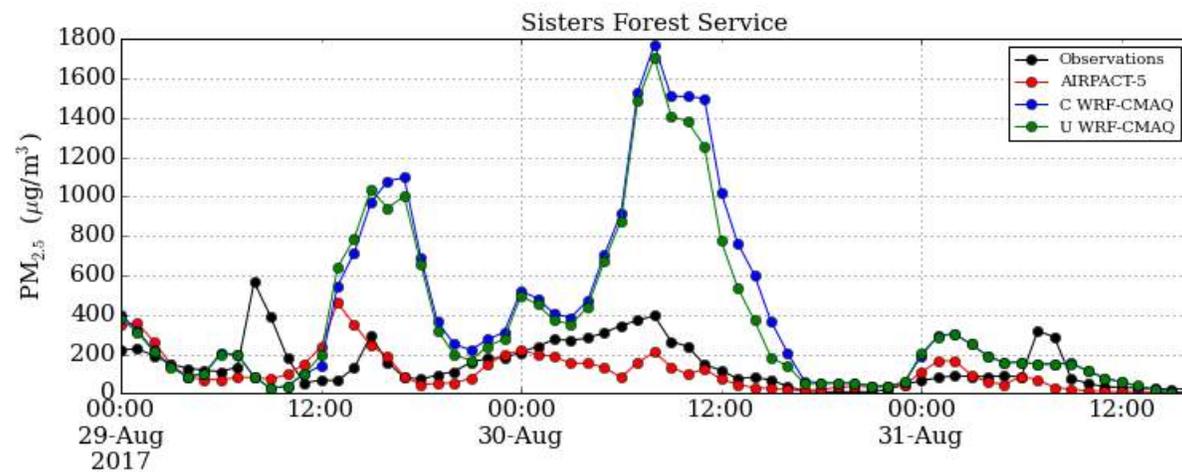
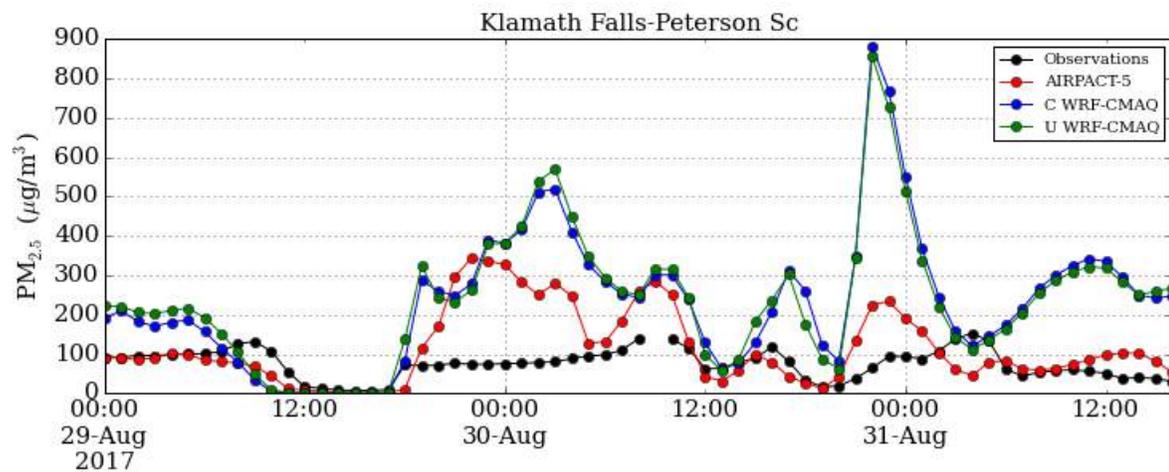
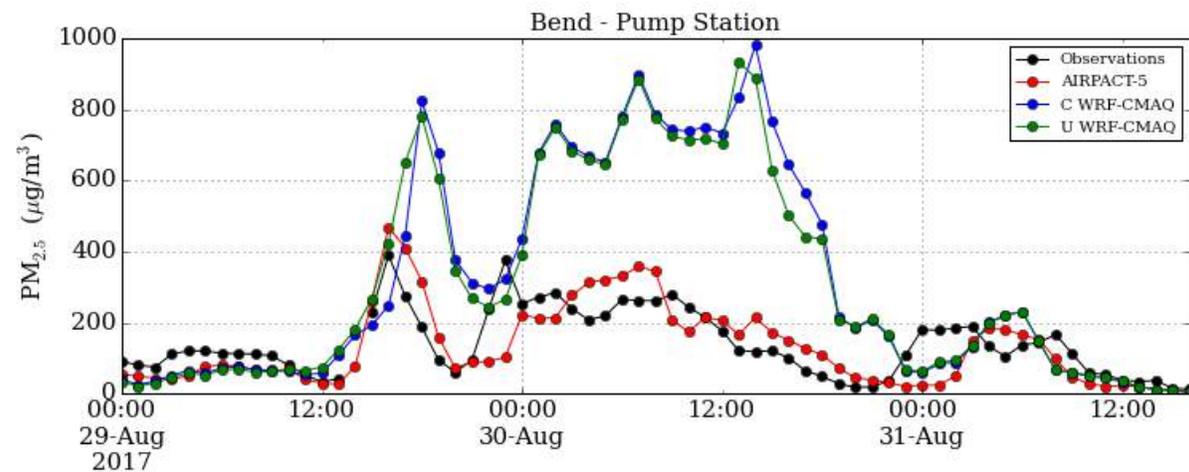
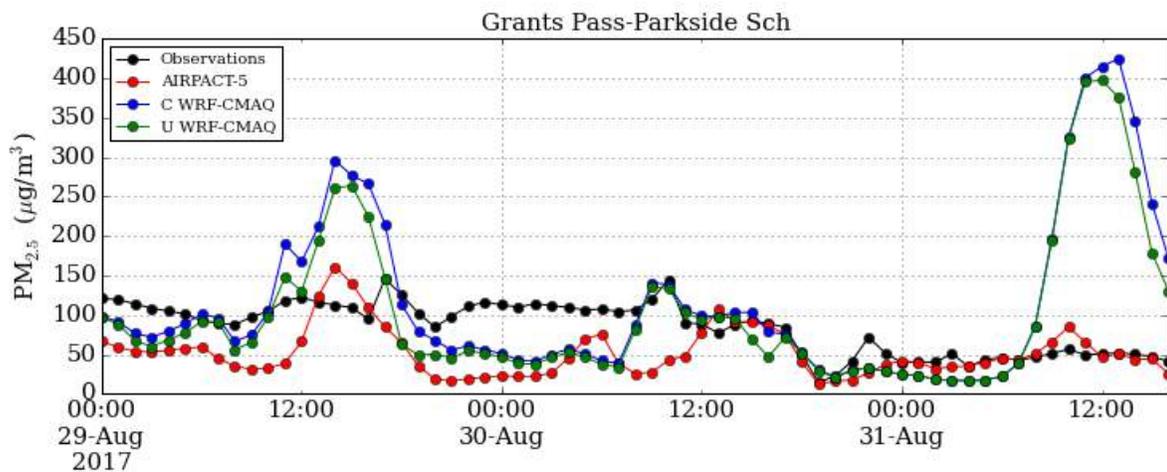
# Model Performance for PM<sub>2.5</sub> at selected sites



# Model Performance for PM<sub>2.5</sub> at selected sites...

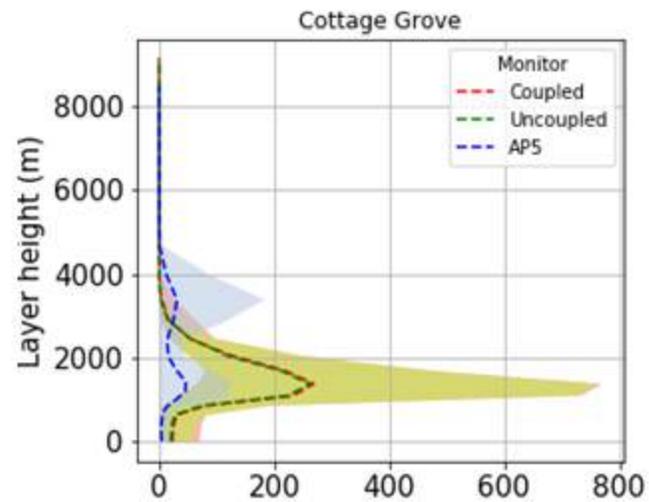
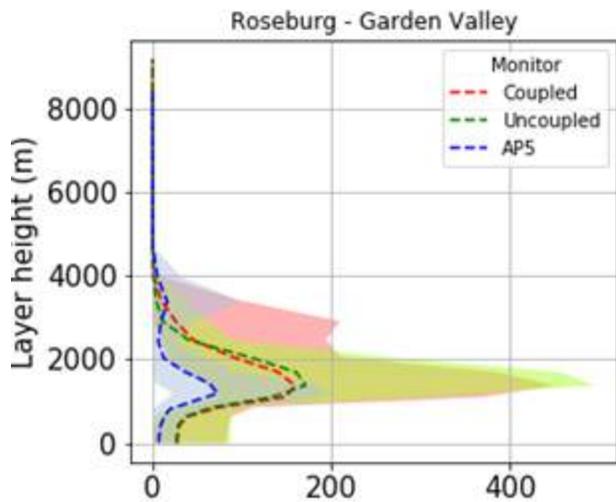
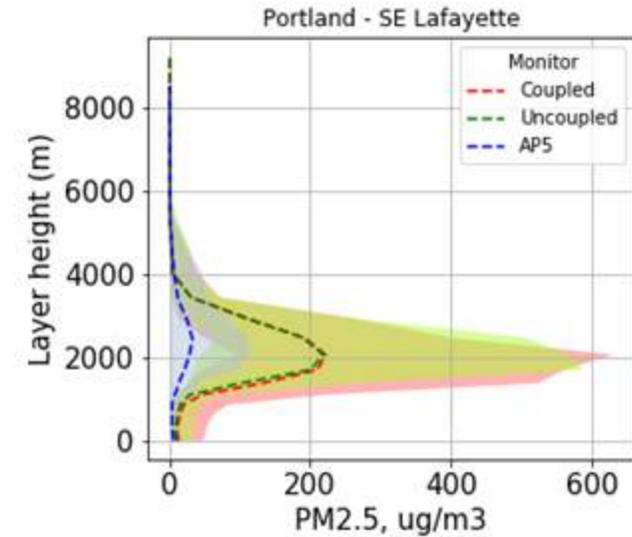
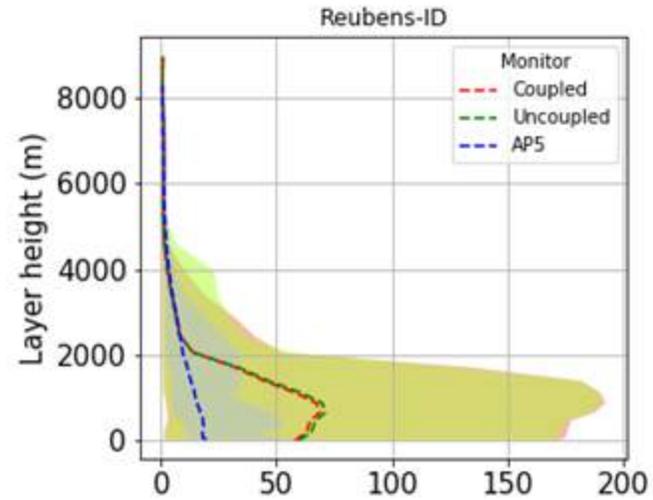
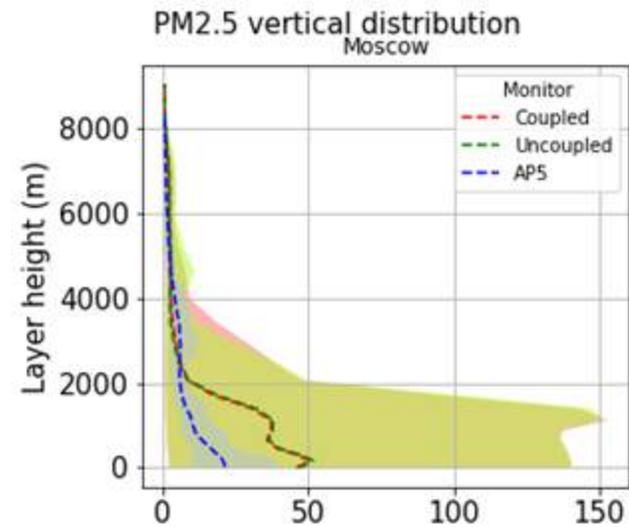


# Does HRRR / Coupled WRF-CMAQ Improve Model Performance?



Not always...Needs further investigation

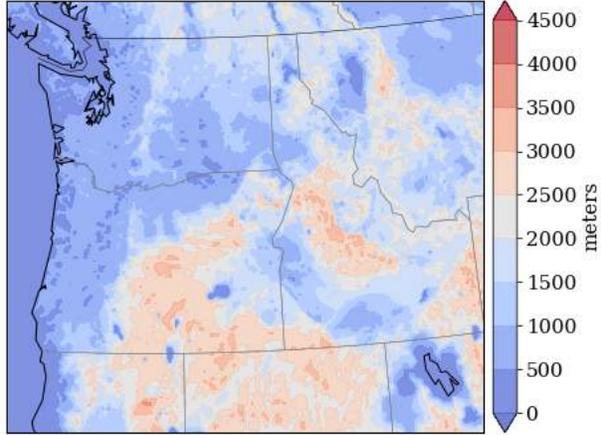
# Modeled PM<sub>2.5</sub> Vertical Distribution



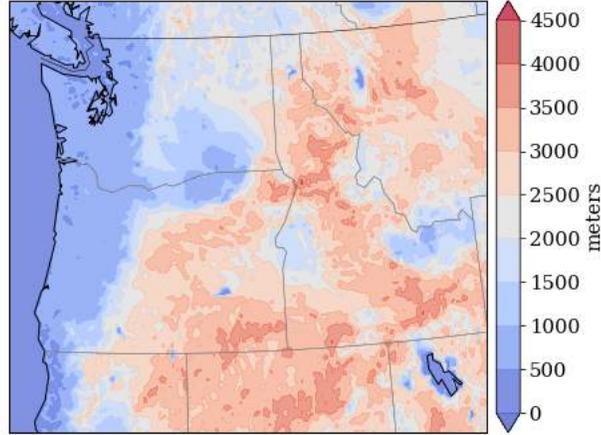
More PM aloft for  
WRF-CMAQ case compared to  
AIRPACT-5.

# Comparison of PBL Height

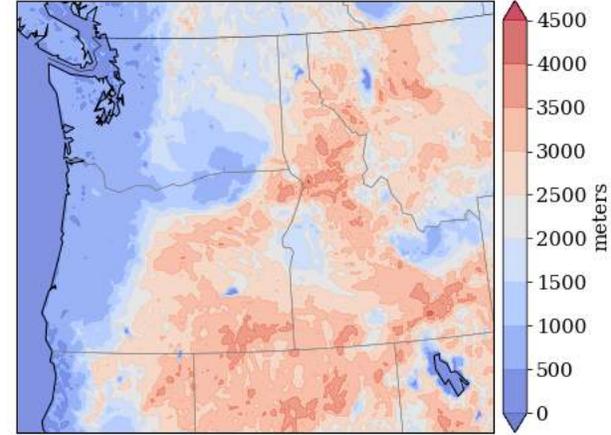
AIRPACT-5: mean PBL height between 10PDT-18PDT on 08/29/2017



C WRF-CMAQ: mean PBL height between 10PDT-18PDT on 08/29/2017

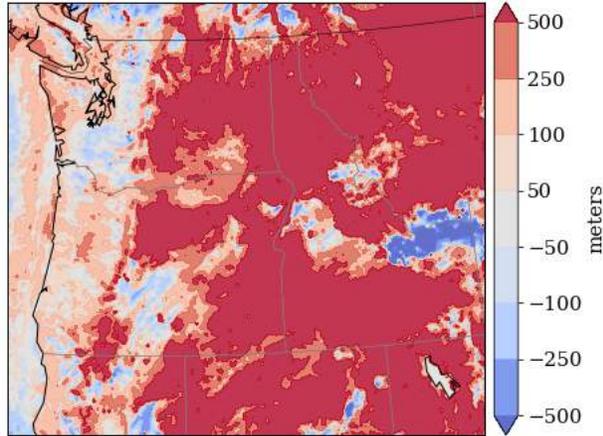


U WRF-CMAQ: mean PBL height between 10PDT-18PDT on 08/29/2017



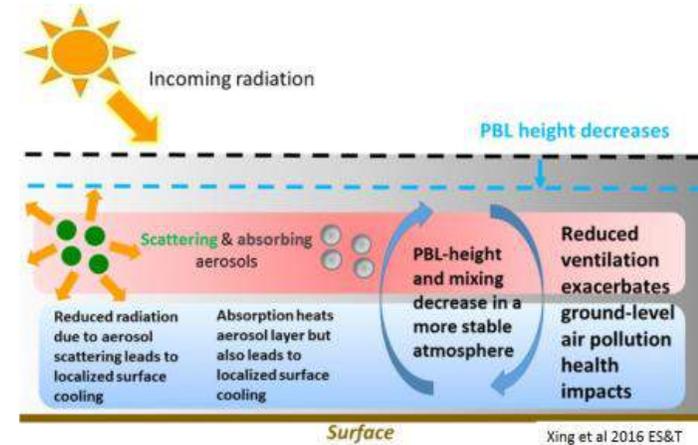
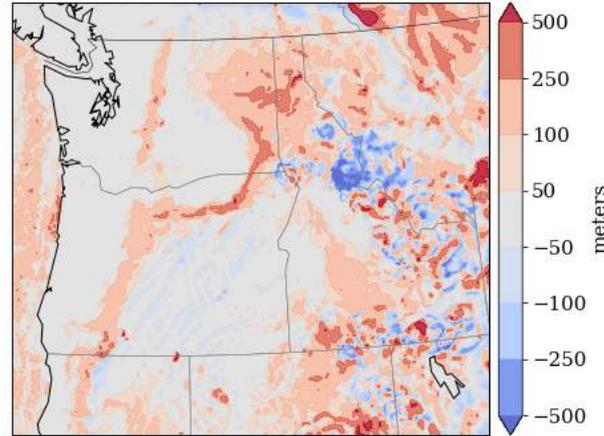
Difference

Coupled - AIRPACT-5: mean PBL height between 10PDT-18PDT on 08/29/2017

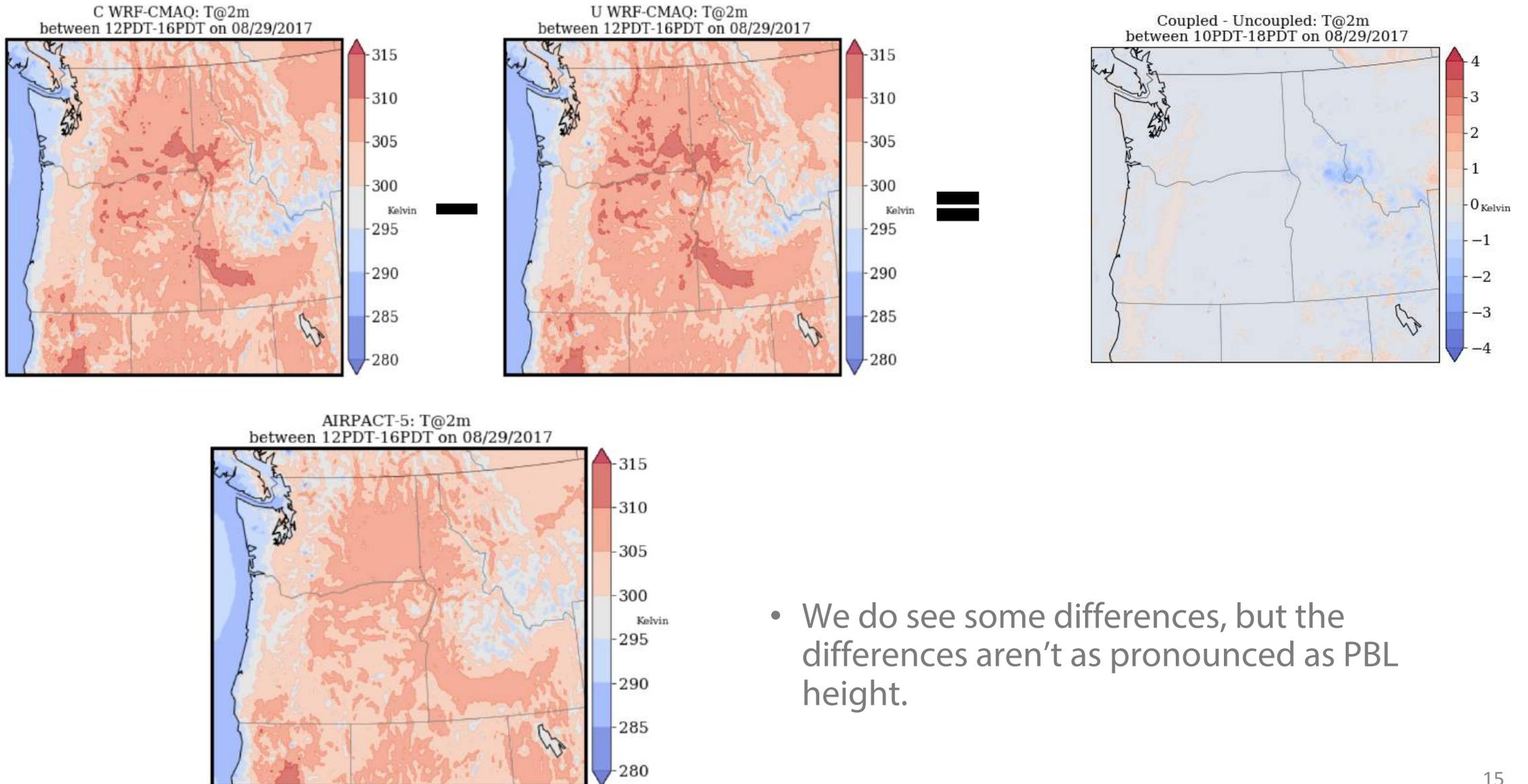


Difference

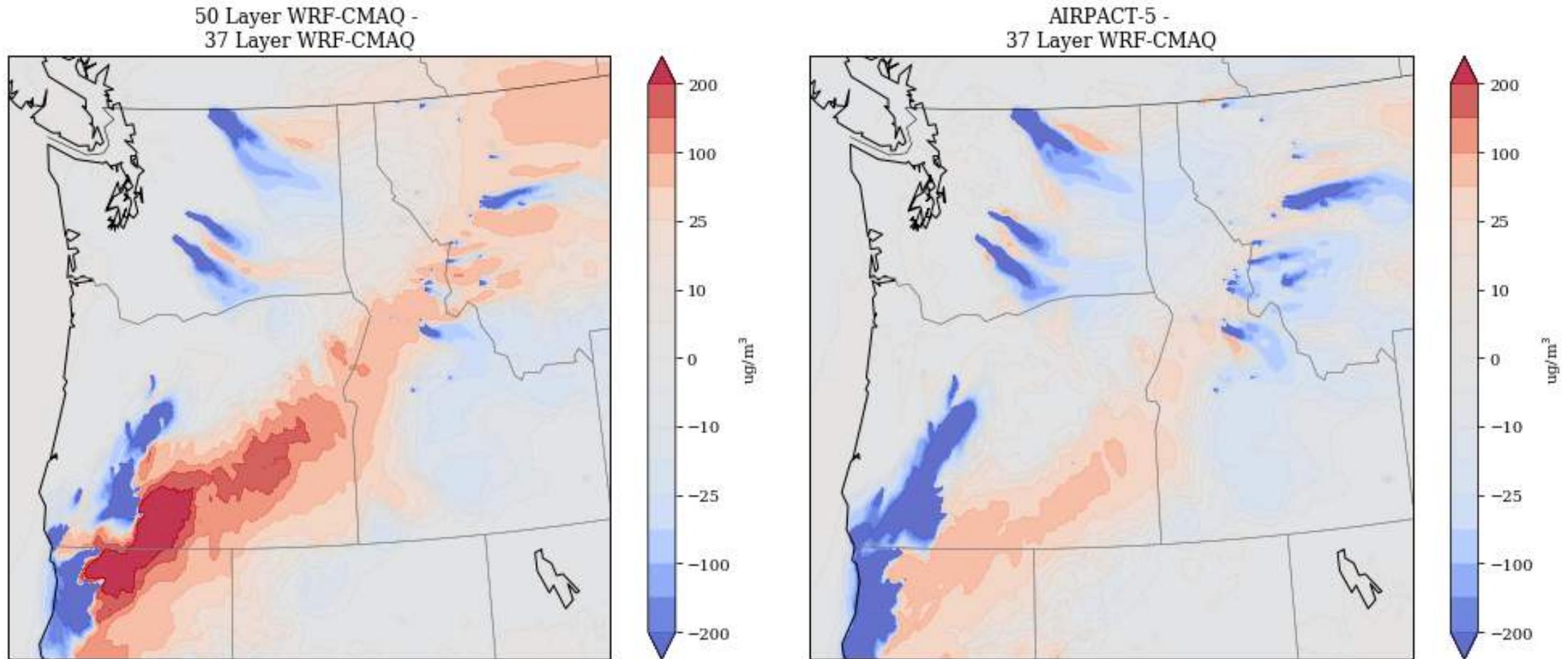
Coupled - Uncoupled: mean PBL height between 10PDT-18PDT on 08/29/2017



# What does Feedback Mean for Temperature?

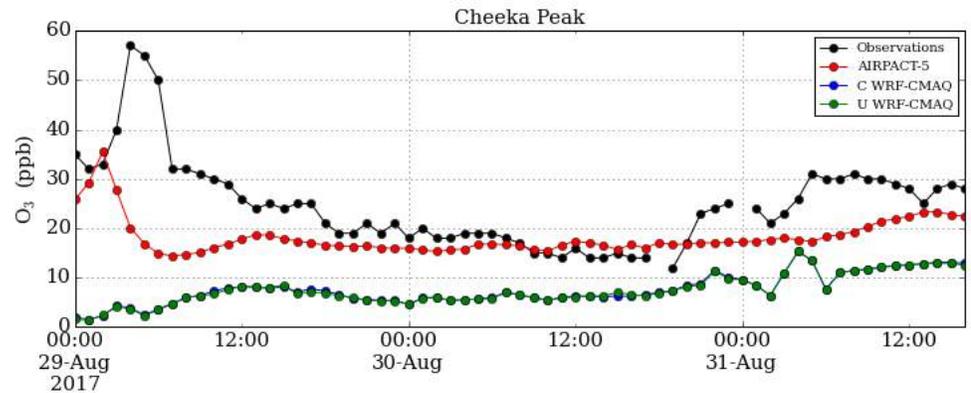
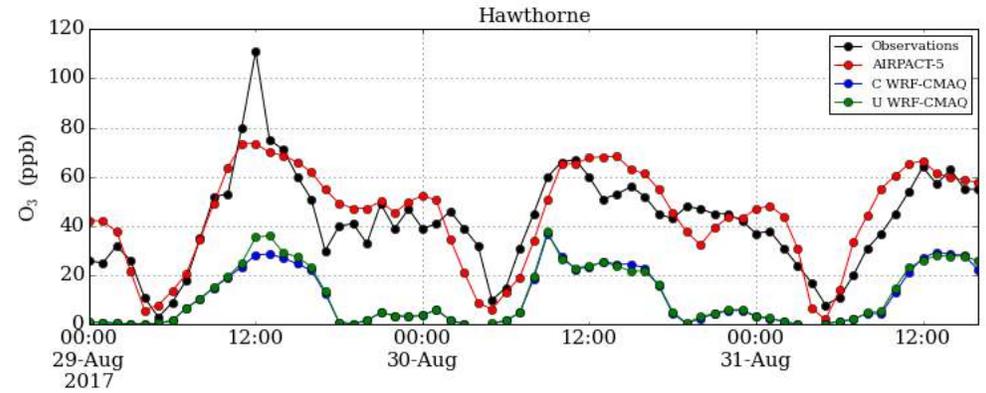
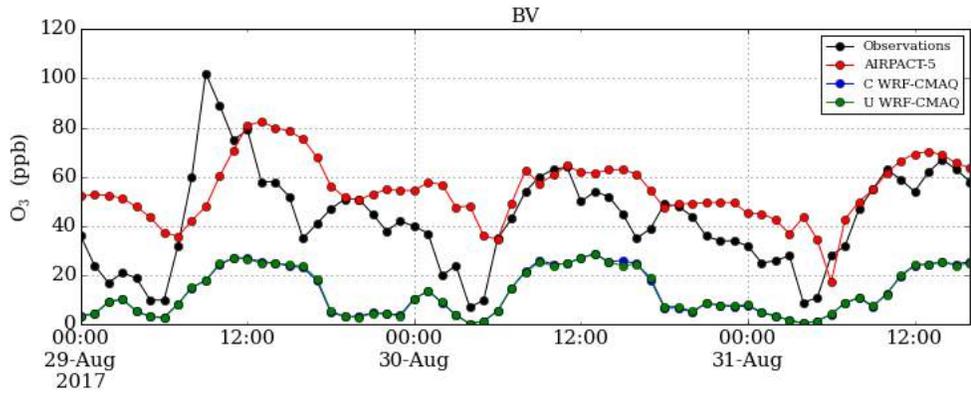
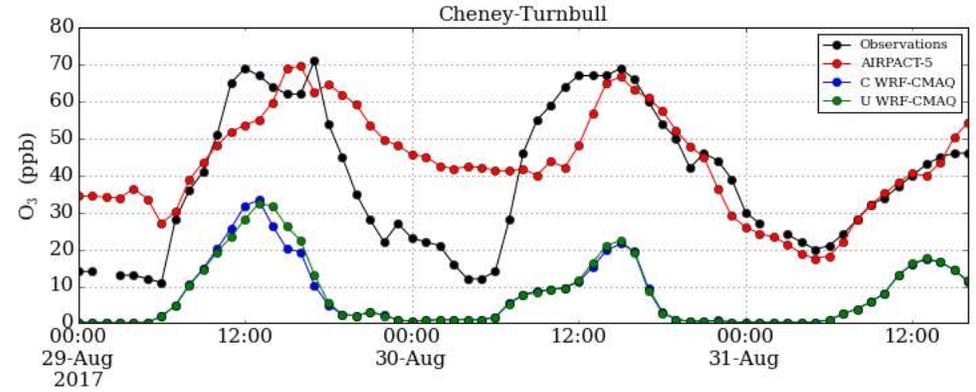
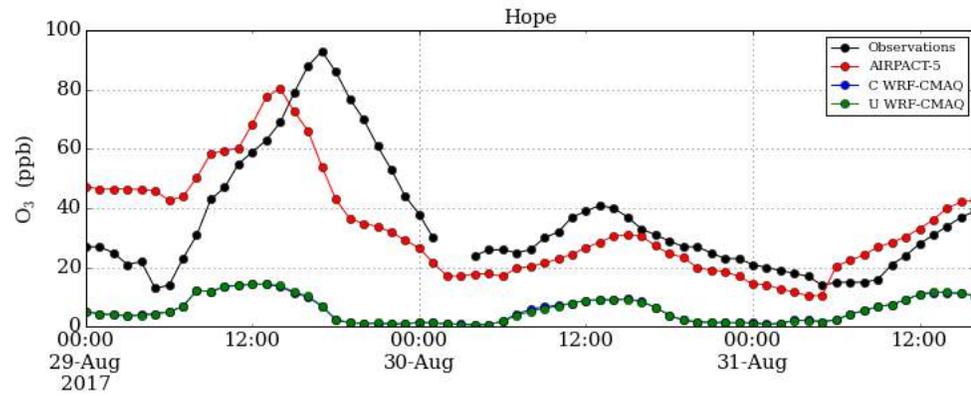


## Does vertical layer structure matter?



- Vertical resolution can make a big difference – investigate this?
- However, results are only based on 1 day of 37 layer WRF-CMAQ simulation and ICON is also a source of differences (37 layer WRF-CMAQ uses AIRPACT-5 ICON) 16

# Coupling effect on model performance for ozone



Both Coupled and uncoupled WRF-CMAQ O<sub>3</sub> is too low... suggesting something is missing

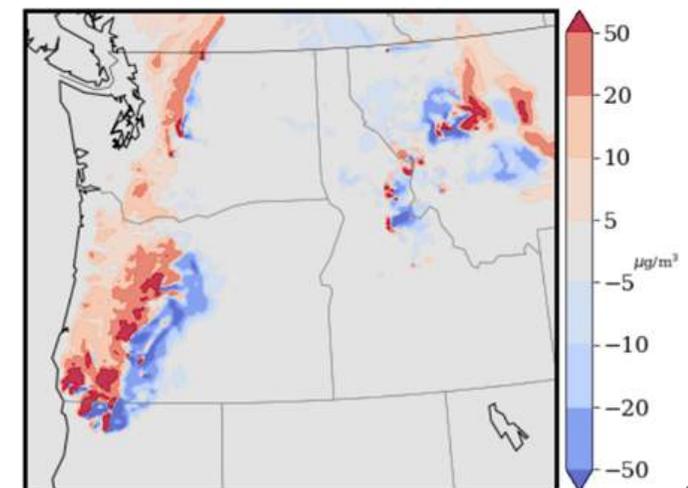
# Summary

- We have used HRRR meteorology for driving a coupled WRF-CMAQ
- AIRPACT-5 generally underpredicts at sites with large observed concentrations.
- While HRRR driven CMAQ results are promising at some sites, there are also large number of false alarms.
- It is hard to judge effect of feedback alone, when compared to AIRPACT-5, given we have implemented number of different changes ( HRRR meteorology, newer CMAQ version, feedback, inline plume rise).

## Future Work

- Extend the current simulations to include more intense wildfires from September 2017
- Analyzing impact on model performance for  $O_3$ ,  $NO_x$ , AOD, and plume rise
- Evaluating the effect of coupling in more detail on temperature, radiation, PBL height etc.
- Coupled model takes a long time to run. Ways to overcome this (simplified chemistry, no-chemistry etc.?)

Coupled - Uncoupled: Mean  $PM_{2.5}$  ( $\mu g/m^3$ )



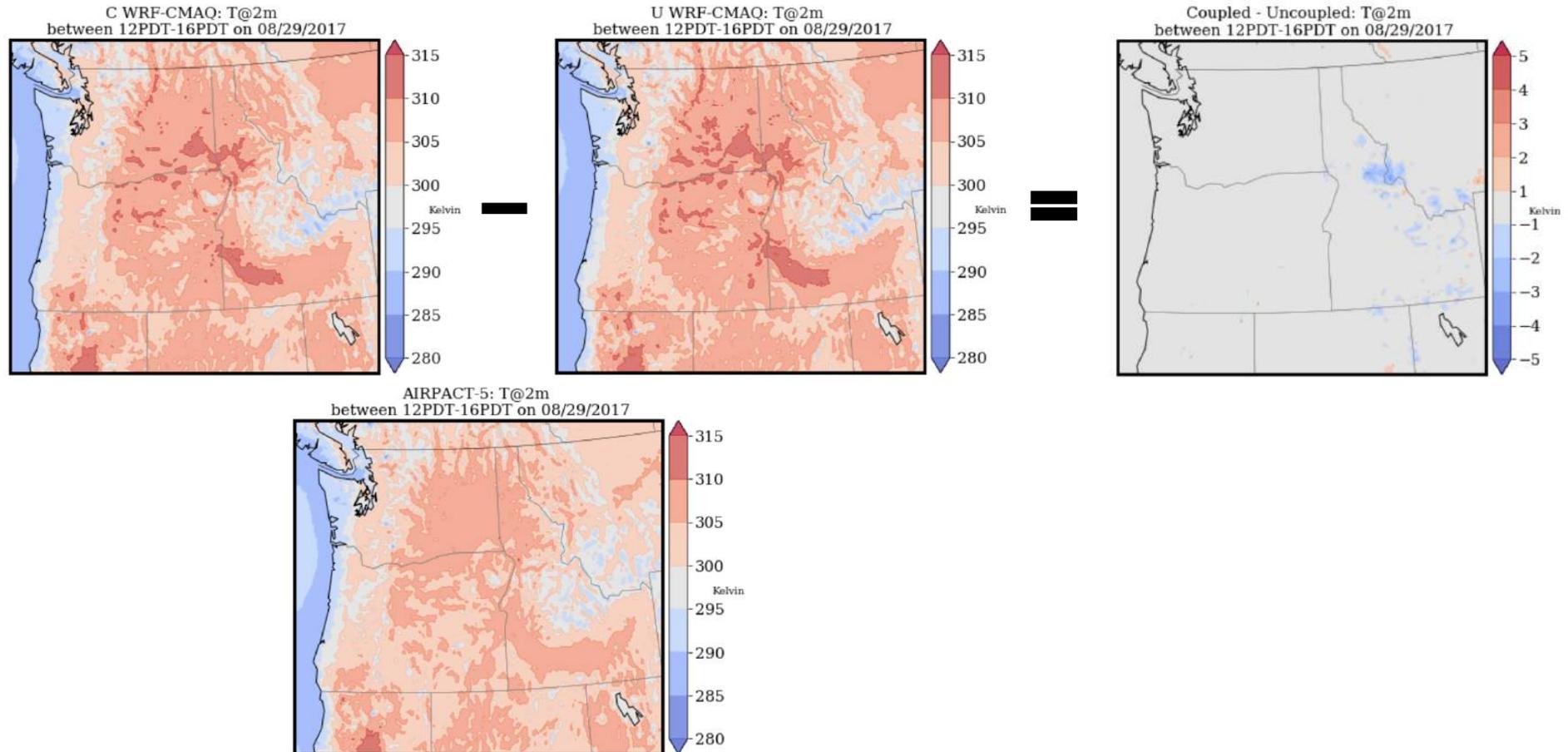
# Acknowledgement

- David Wong, National Exposure Research Laboratory  
US Environmental Protection Agency
- Eric James, CIRES UC Boulder / Earth Systems Research Laboratory, National Oceanic and Atmospheric Administration
- We thank the Joint Fire Science Program for funding AIRPACT-Fire project

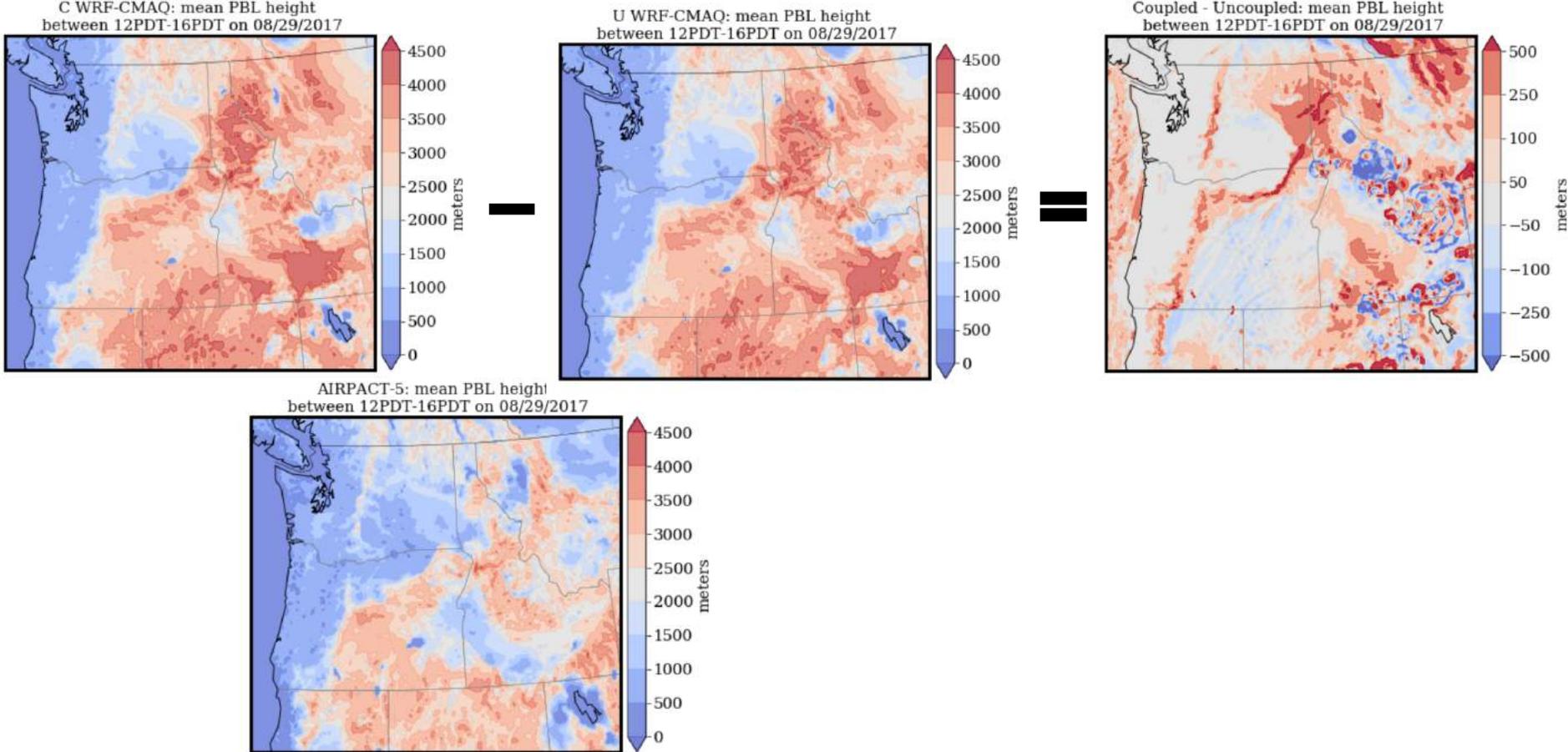


Questions??

# What does Feedback Mean for Temperature?



# How does feedback change PBL height?



Cloud Fraction on 08-29-2017, 10PDT - 18PDT

