



Improving Emission factors and Speciation Profiles of Wildfires Emission using recent observations

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+Now at LADCO

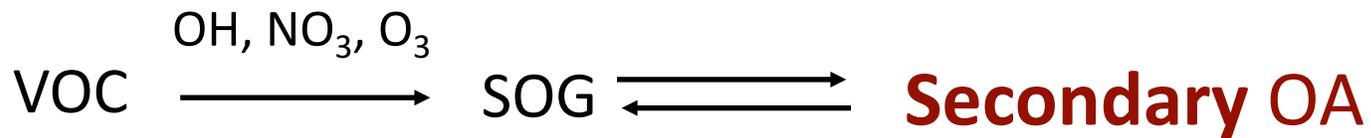
*Now at U.S. EPA

NW AIRQUEST meeting
June 13, 2018

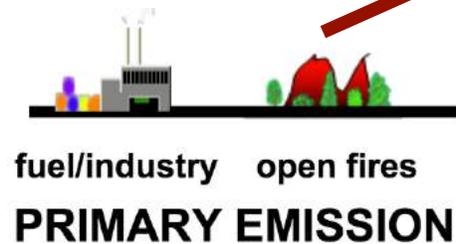


Particulate Matter (PM) from Fires

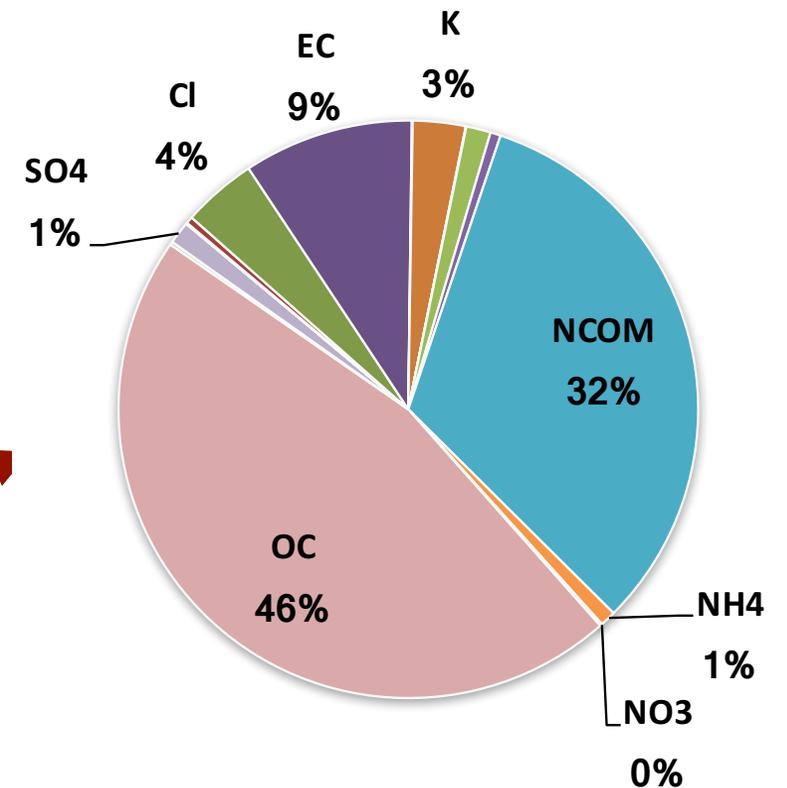
Organic Aerosols (OA)



**Primary OA
(OC + NCOM)**



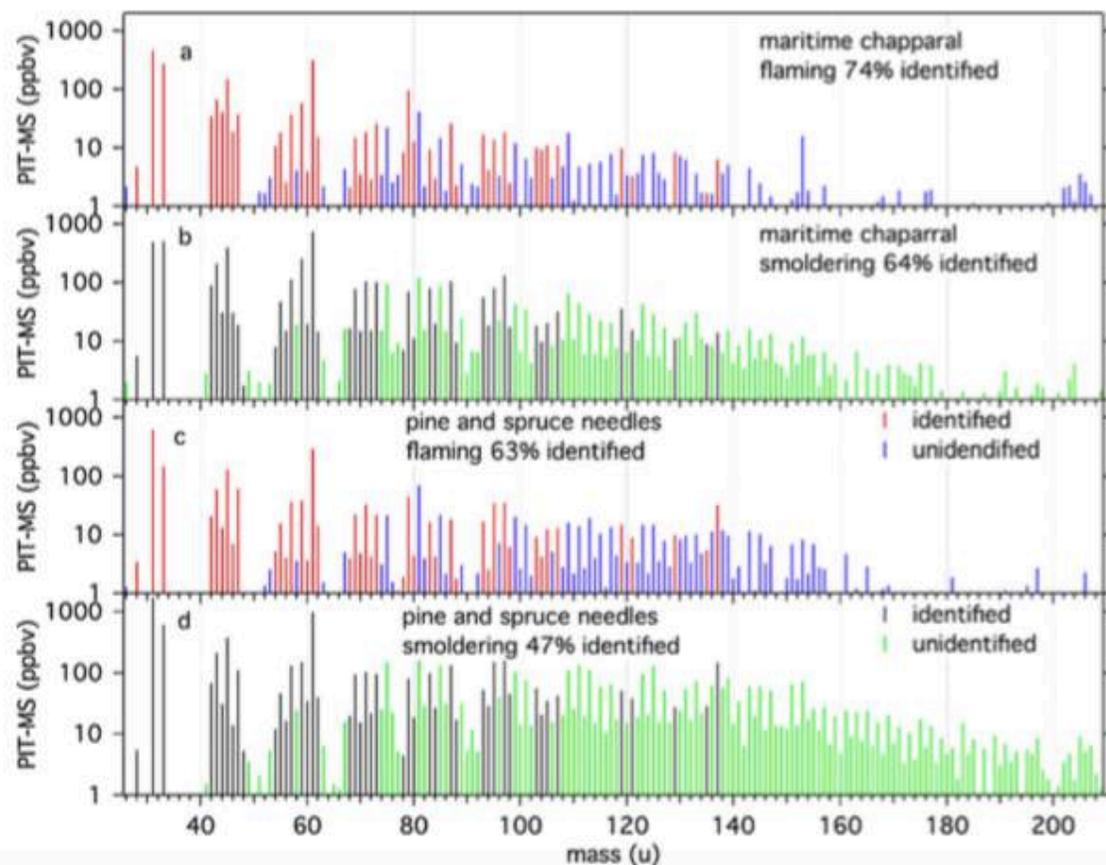
PM speciation for wildfire emissions





Uncertainty in SOA precursors from biomass burning emissions

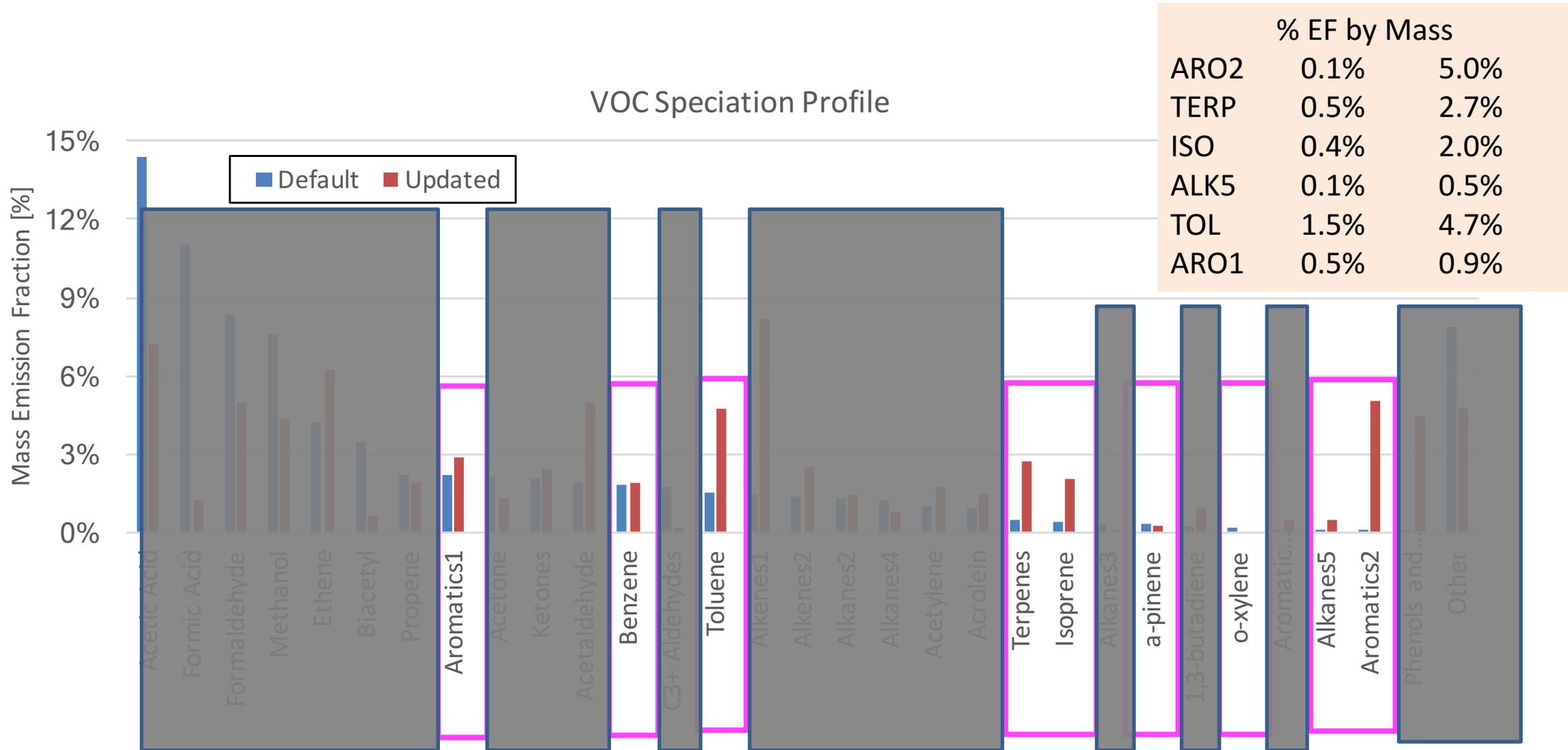
Unidentified species (blue or green)



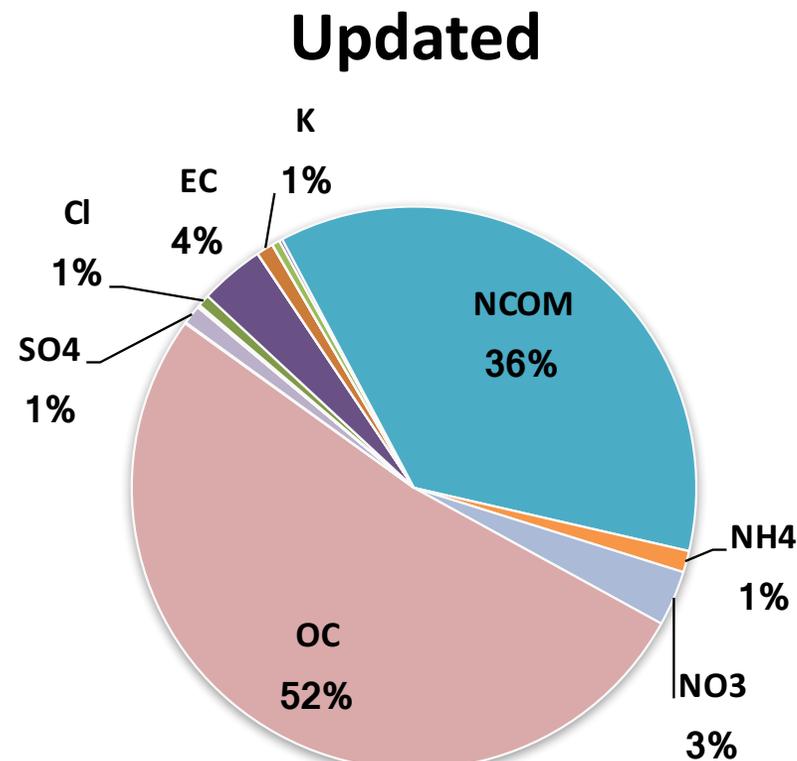
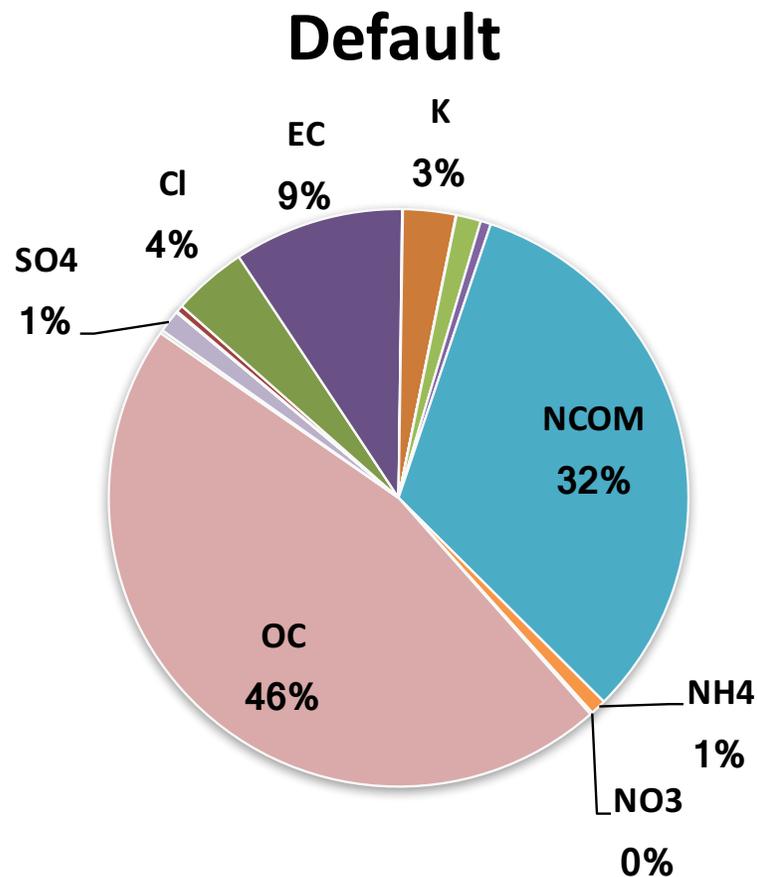
To improve the chemical speciation and emission factors of SOA precursors

- Use data from FLAME-4 (Fourth Fire Lab at Missoula Experiment) to calculate emissions factors and build an updated emissions inventory for 'boreal forest' land cover type

Updated VOC Speciation Profile in SAPRC07 based on FLAME-IV measurements



Updated PM2.5 Speciation Profile in SAPRC07 based on airborne measurements (BBOP and SEAC⁴RS)



Primary PM species:	Default	vs. Updated
Org Aerosol (OC +NCOM)	78%	88%↑
NO3	0%	3%↑
Elemental Carbon (EC)	9%	4%↓

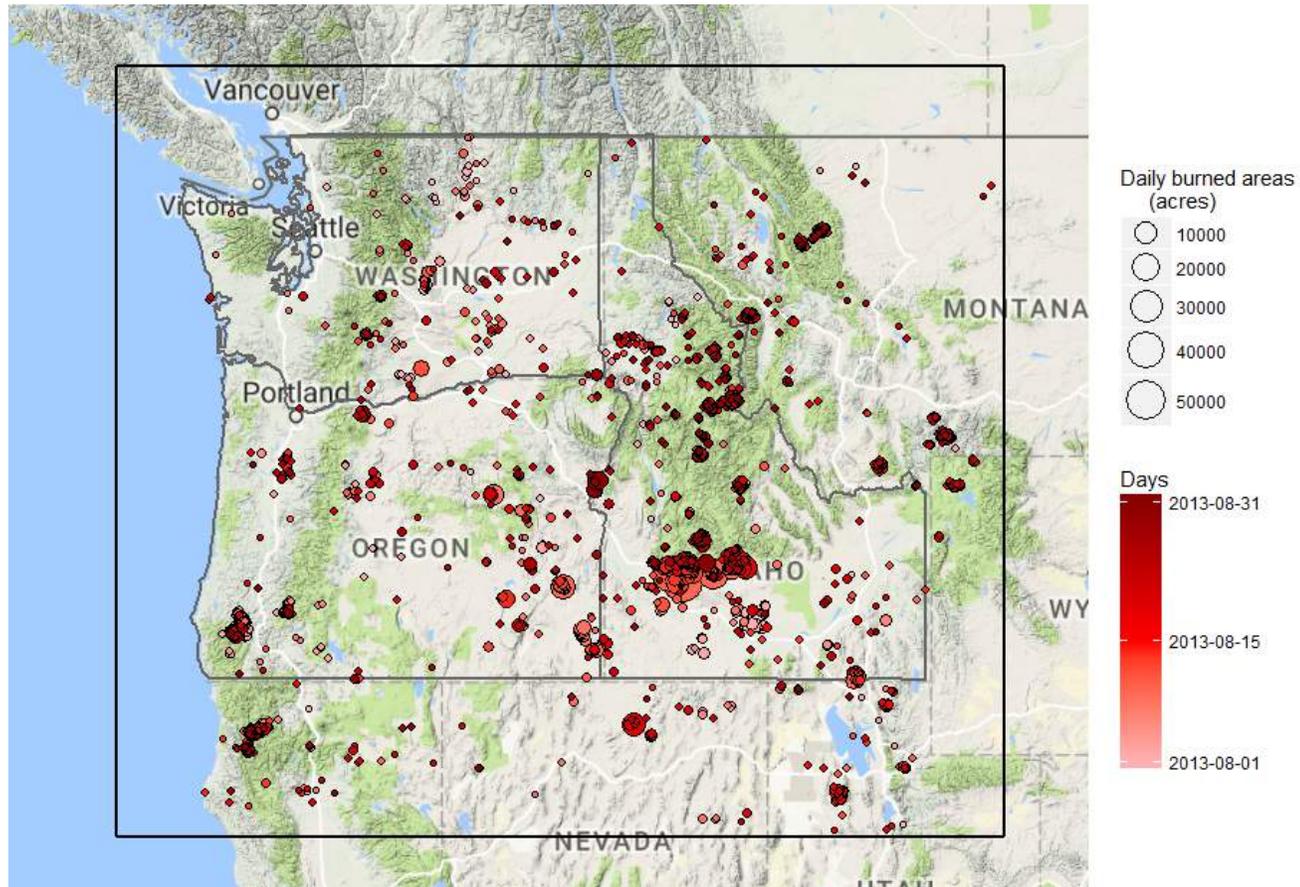


3-D Modeling

Tsengel
Nergui



Wildfire Activity Map, Aug 2013



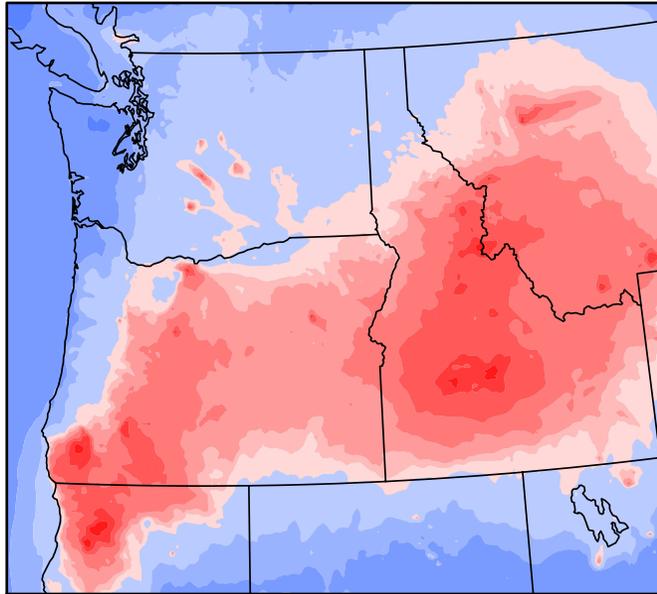
AIRPACT Modeling Framework

- WRF, MEGAN, BlueSky, SMOKE, and CMAQ
- 4 km x 4 km horizontal grids, with 37 layers
- **CMAQ version 5.2**

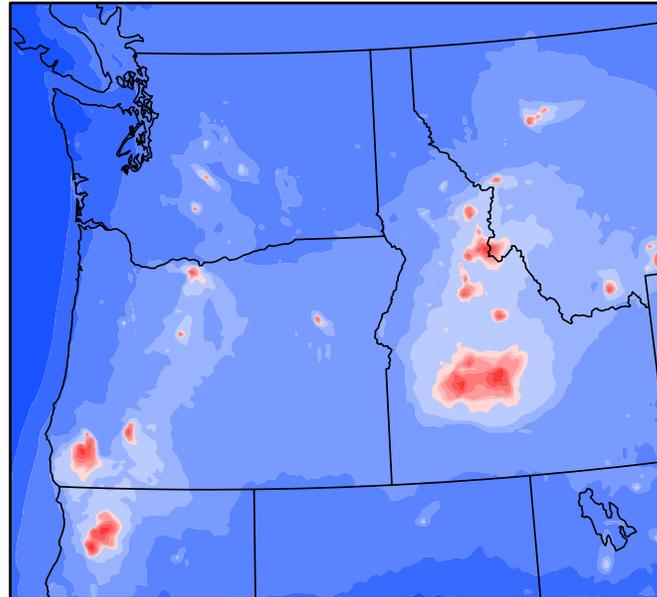
	Base run	Sensitivity run
Speciation	SMOKE default	Updated w/ obs
PM2.5 EFs	12 g/kg	12 g/kg x 2.23
VOCs EFs	32.4 g/kg	32.4 g/kg x 1.54

BASE run: Monthly PM_{2.5} and OA during Aug 2013

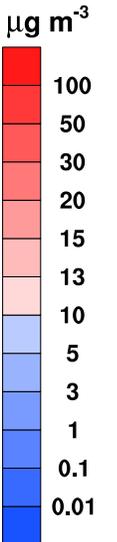
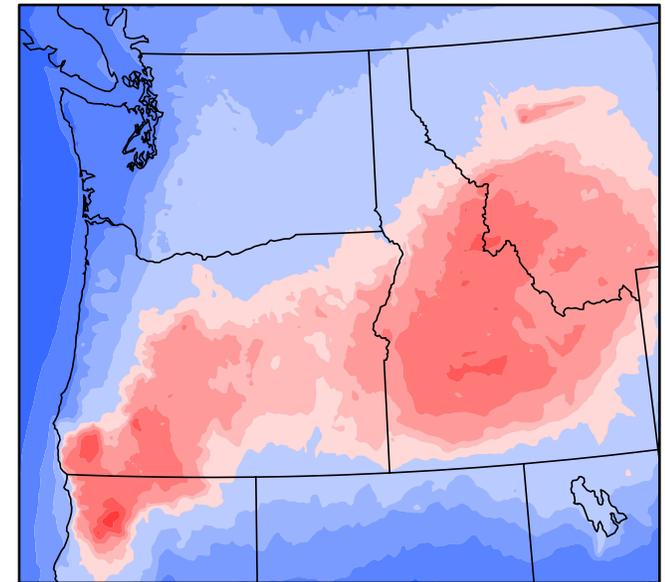
PM_{2.5}



POA

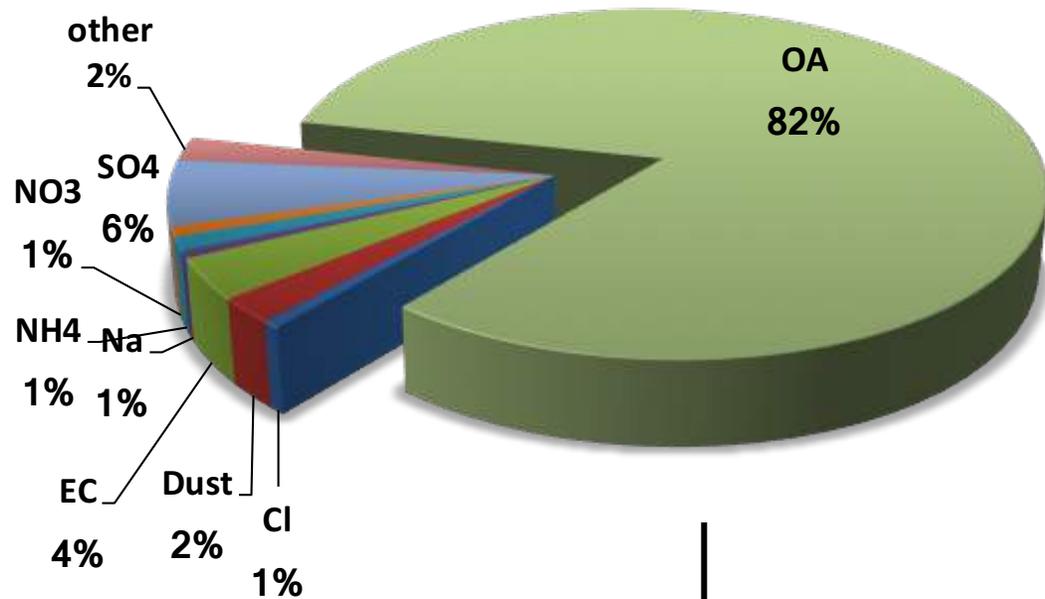


SOA

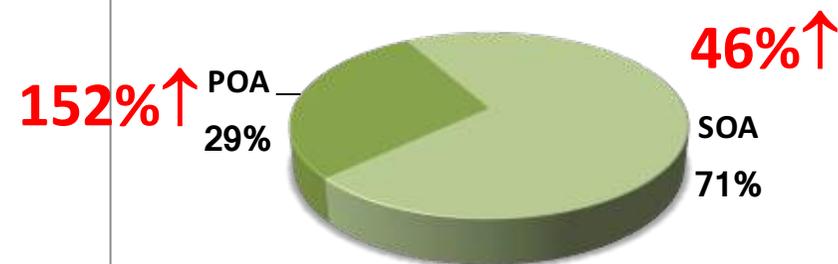
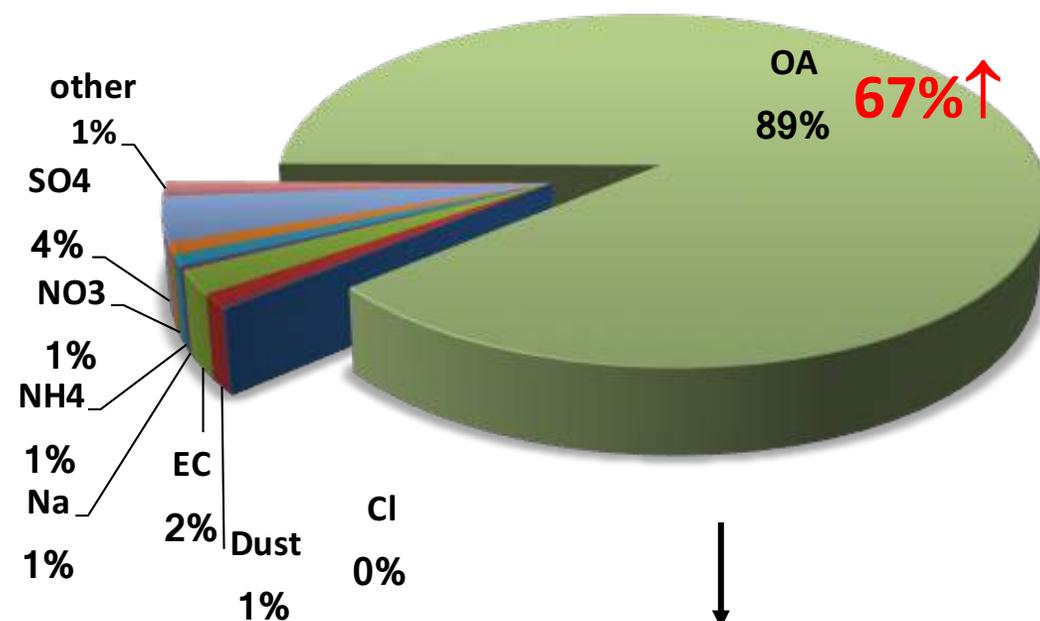


monthly PM_{2.5} compositions during Aug 2013

BASE: PM_{2.5} average (13.4 $\mu\text{g m}^{-3}$)



SENS.: PM_{2.5} average (20.8 $\mu\text{g m}^{-3}$) **55%↑**





(Preliminary) Model evaluation: August 2013

Kai Fan



- EPA AQS PM2.5 measurements
- Mt Bachelor Observatory OA measurements
 - Used Aerosol Mass Spectrometer
- Biomass Burning Observation Project (BBOP) aircraft field campaign
 - Evaluated CO only (for now).

“The U.S. Department of Energy’s Atmospheric Radiation Measurement (ARM) Climate Research Facility is deploying a G-1 research aircraft above wildfires in the U.S. Pacific Northwest region as part of the Biomass Burning Observation Project (BBOP).”

Instrumentation

For BBOP, the G-1 aircraft will be equipped with 35 instruments for measuring various atmospheric components, including nearly a dozen new instruments not previously used in airborne research. The instrument suite will measure the following:

- aerosol concentration and size distribution
- aerosol composition and gas chemistry
- aerosol optical properties, such as reflectance, scattering, and absorption
- energy (radiation) coming from the sun and Earth, and
- temperature, pressure, humidity, wind speed, and direction.



The ARM Aerial Facility maintains and operates the G-1 research aircraft, plus a large inventory of probes and sensors ideally suited for atmospheric research.

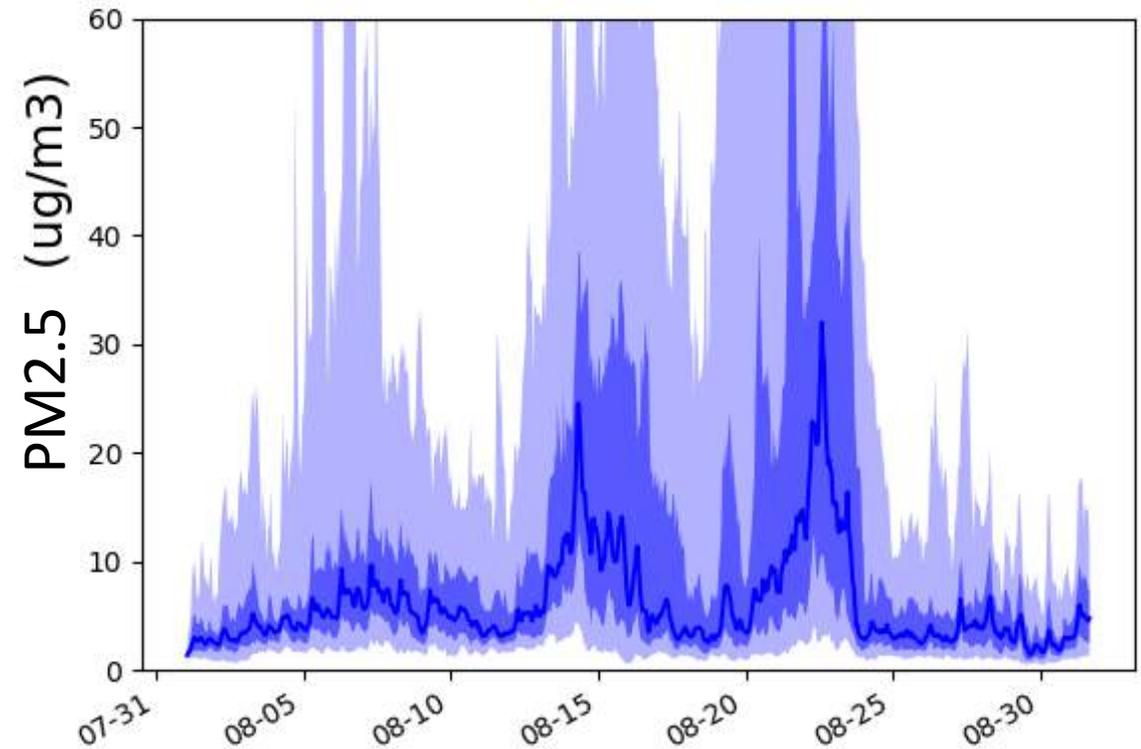
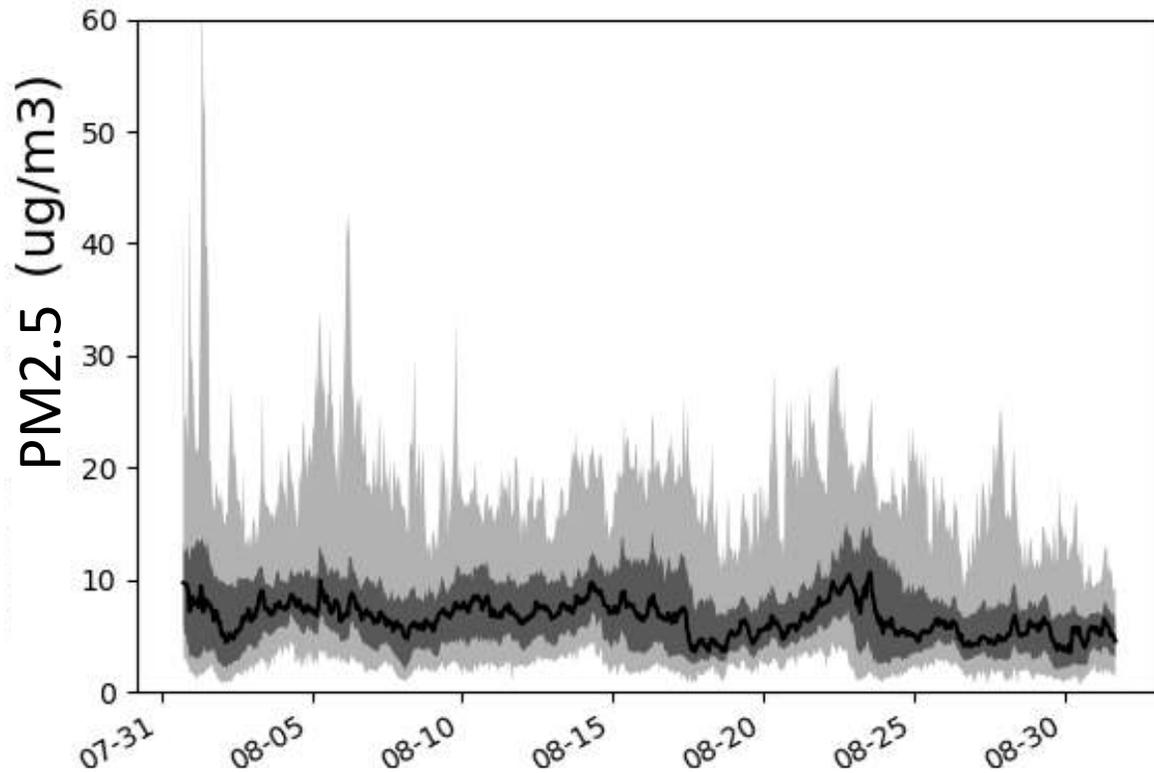


PM2.5 time-series over all AQS sites

AQS obs

Outer lines : 5%/95%
Inner lines: 25%/75%
Thick mid-line : median

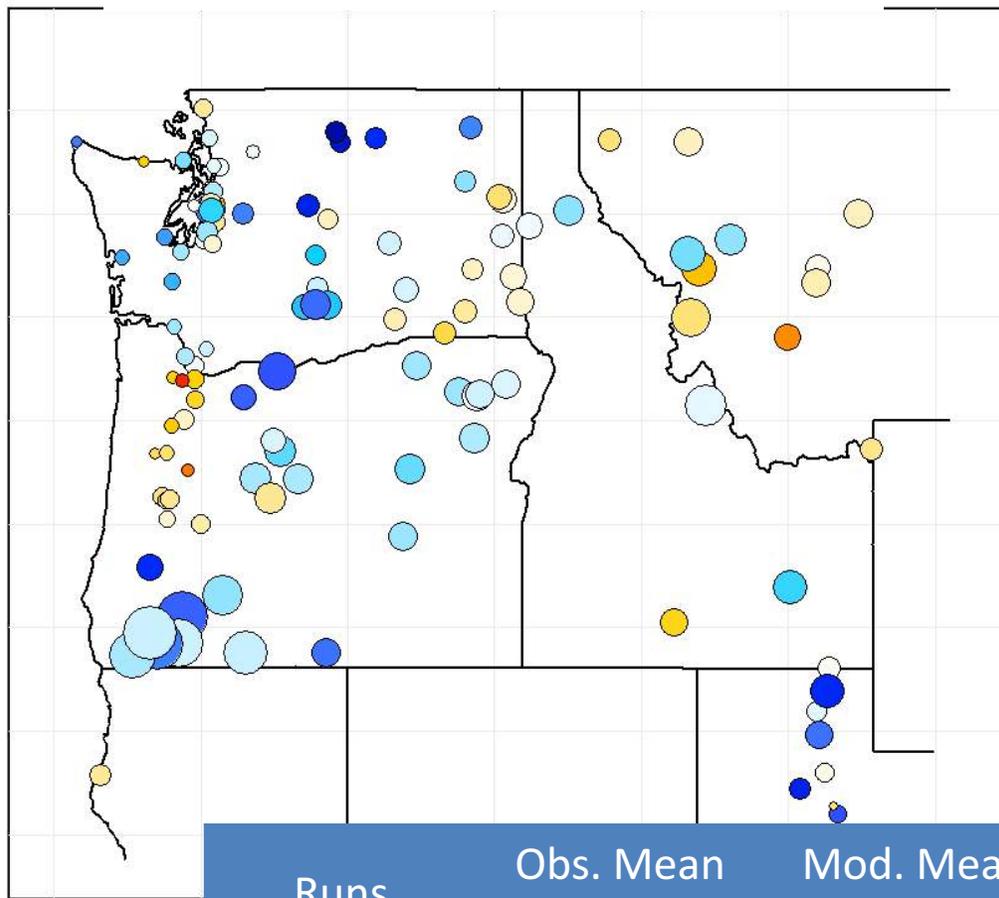
Model (BASE)



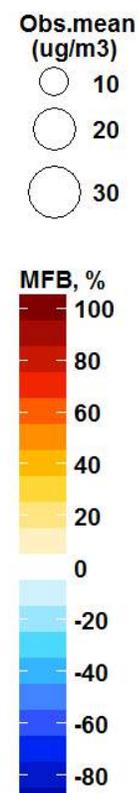
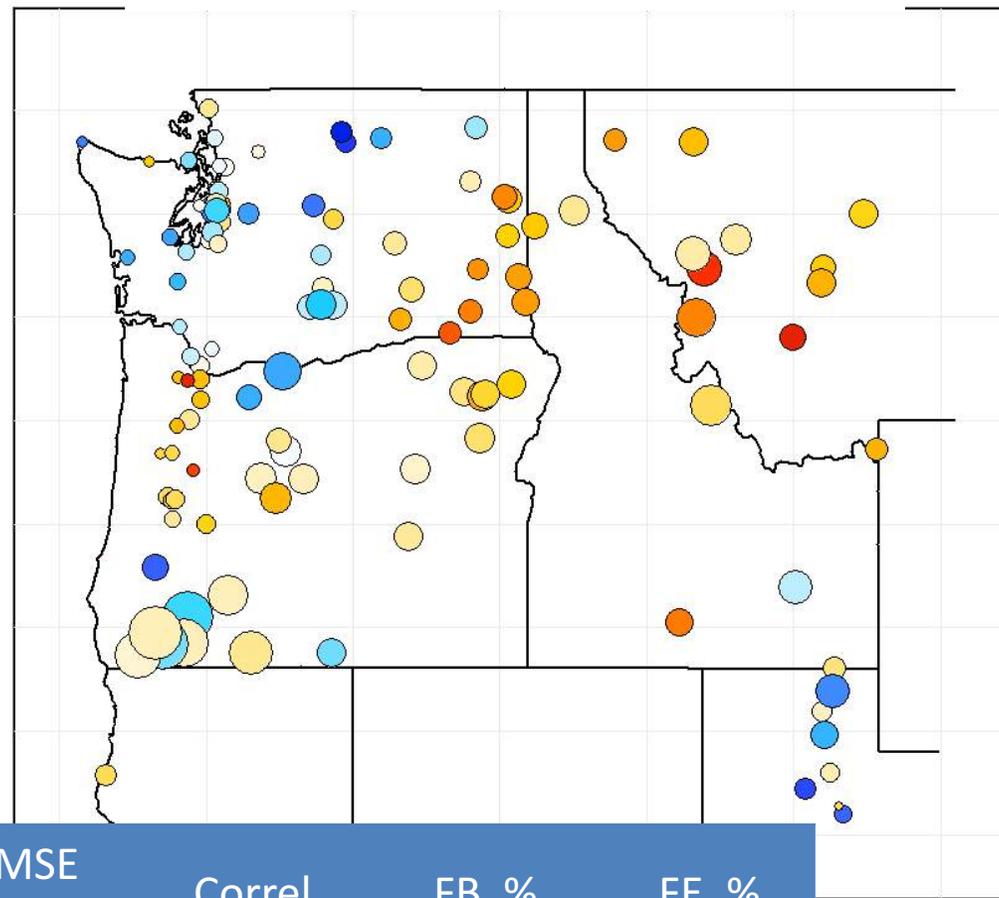


Fractional Biases for PM2.5 (AQS obs)

Base run



Sens run

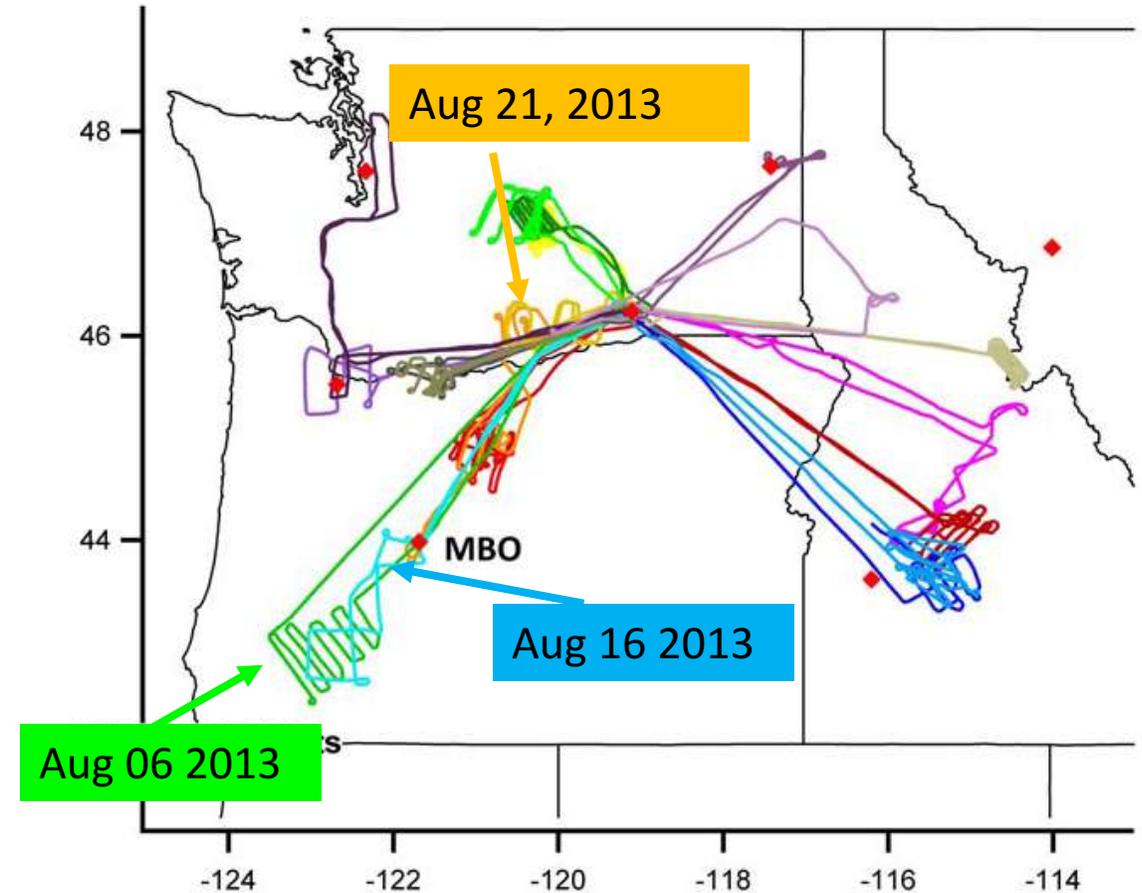
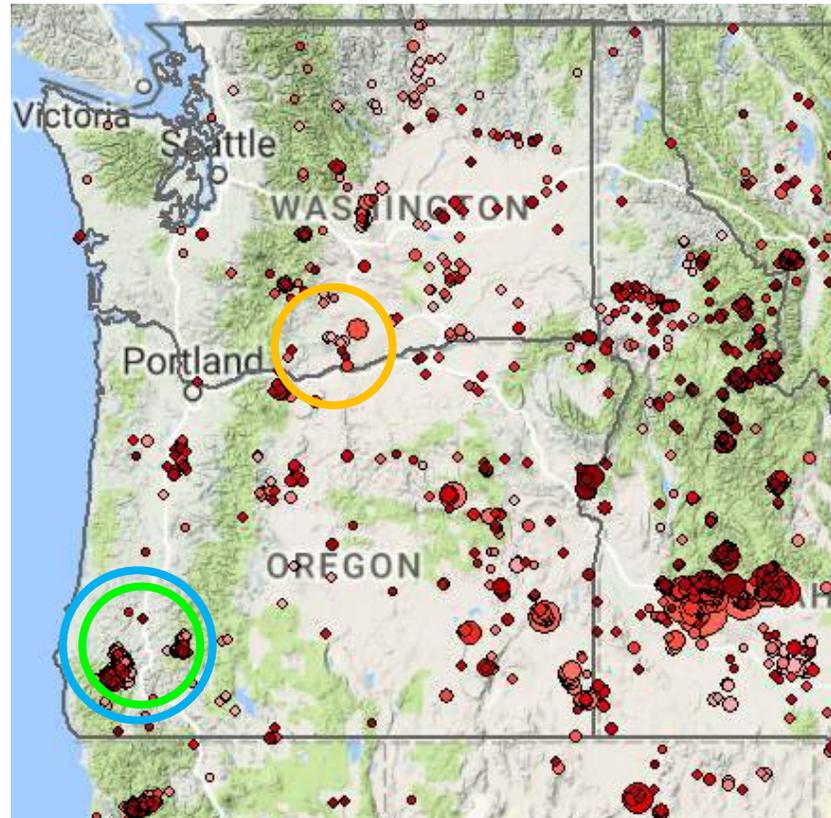


Runs	Obs. Mean [$\mu\text{g m}^{-3}$]	Mod. Mean [$\mu\text{g m}^{-3}$]	RMSE [$\mu\text{g m}^{-3}$]	Correl.	FB, %	FE, %
BASE	8.4	12.4	19.0	0.32	-8.2%	69.6%
SENS	8.4	18.0	28.9	0.32	9.4%	74.0%



BBOP: G-1 flight and Mt. Bachelor Observatory (MBO)

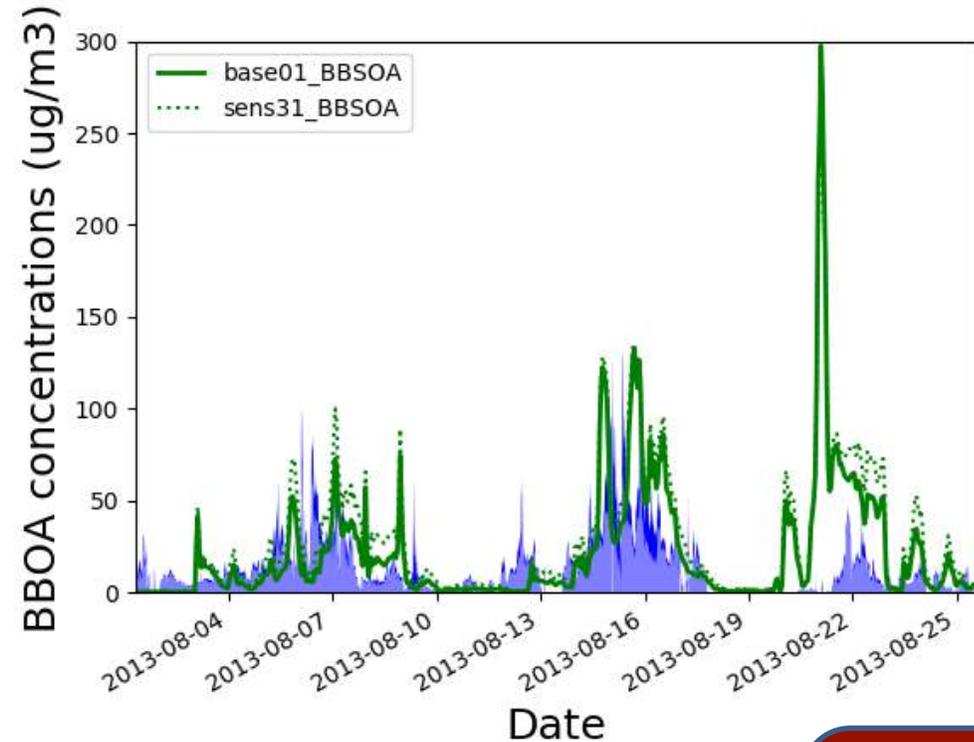
G-1 home base in Pasco, Washington,



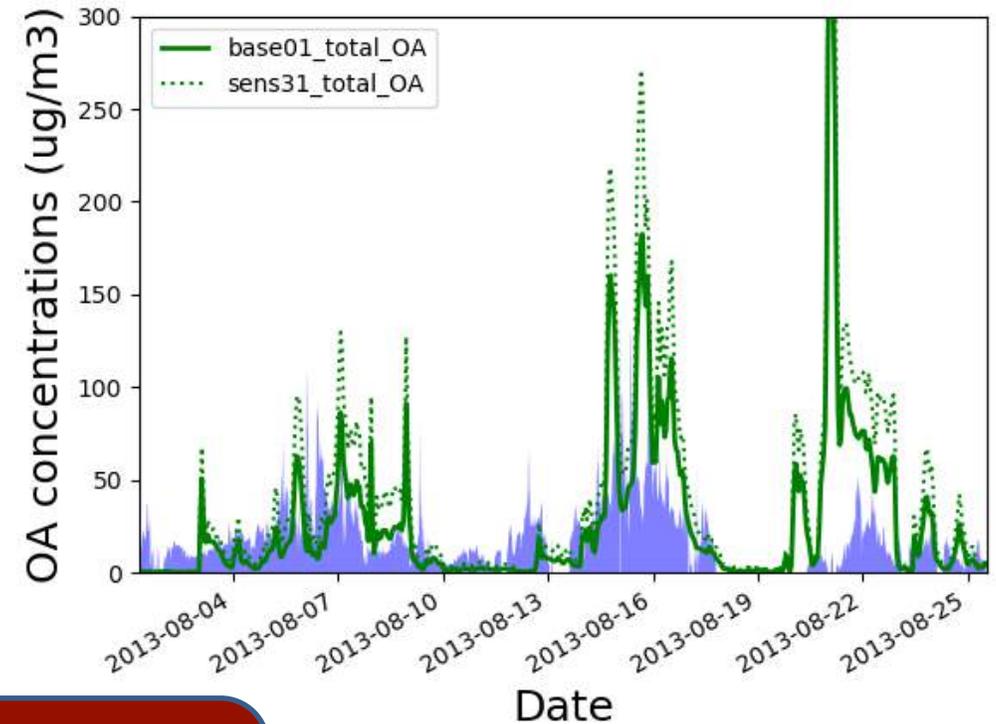


Organic Aerosols at MBO, OR

Biomass Burning OA (BBOA)



Total OA



Obs: $\text{BBOA/OA} = 0.75$
BASE run: $\text{BBOA/OA} = 0.80$
SENS run: $\text{BBOA/OA} = 0.69$



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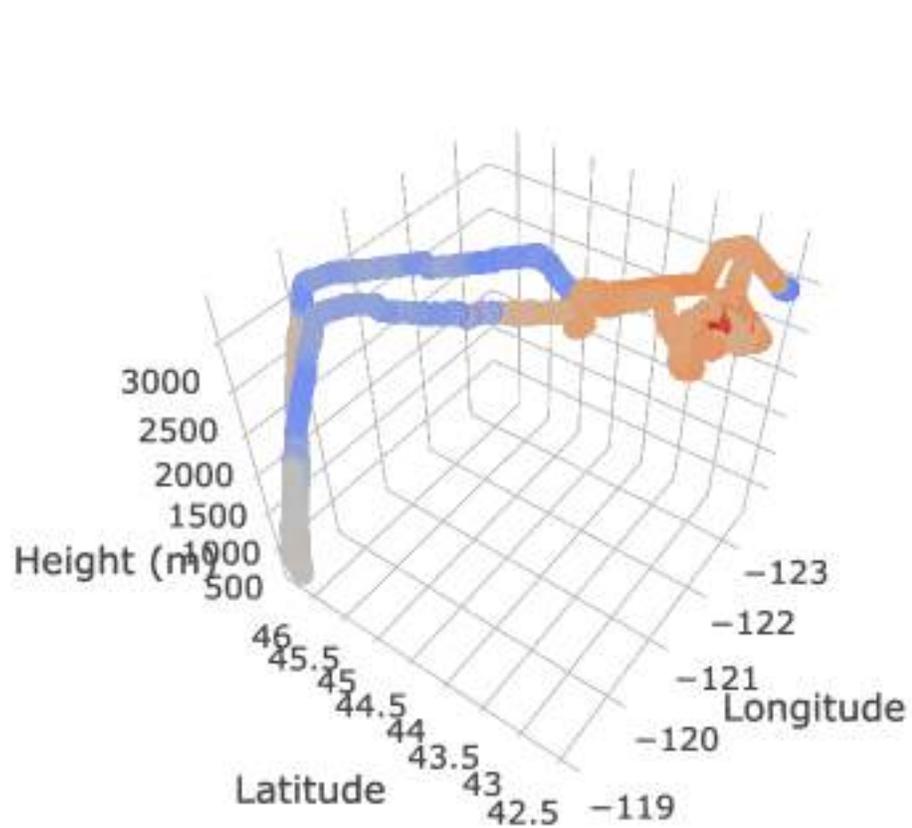
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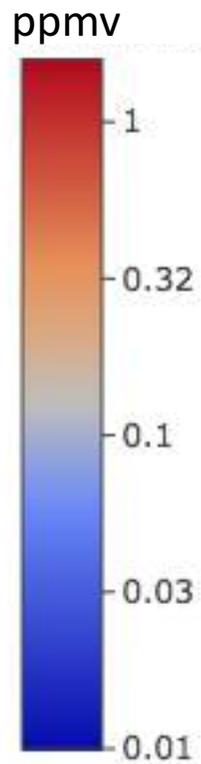
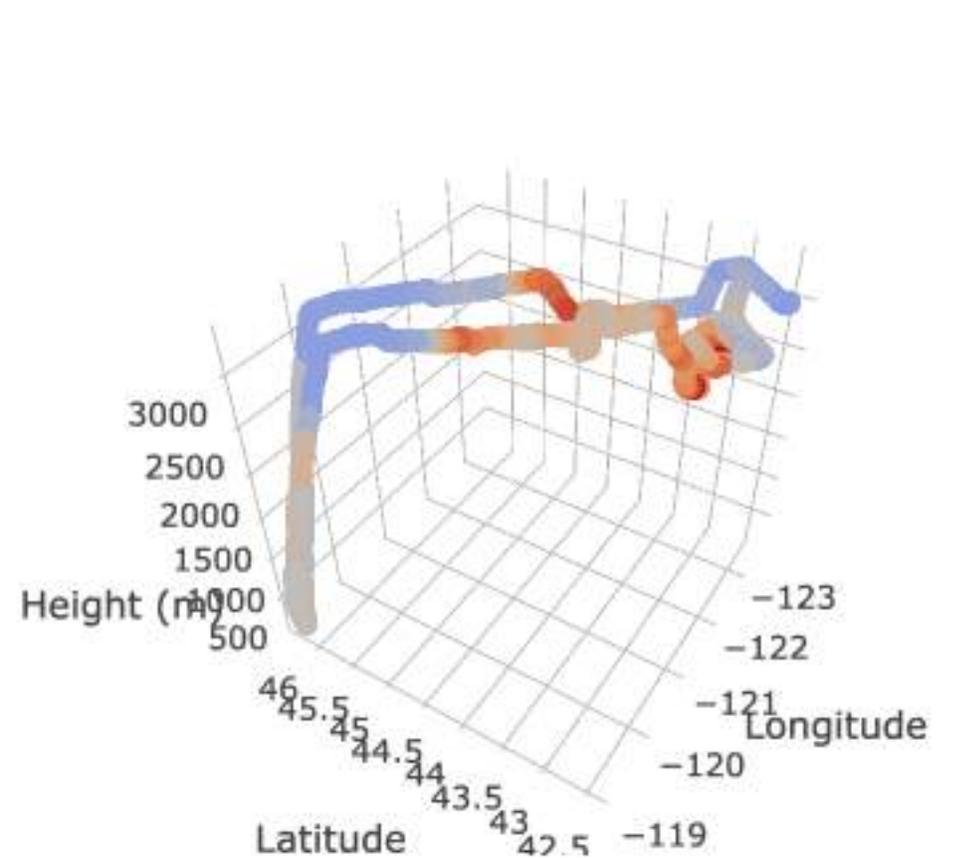


Flight-track CO: Aug 6, 2013

BBOP G-1 flight CO

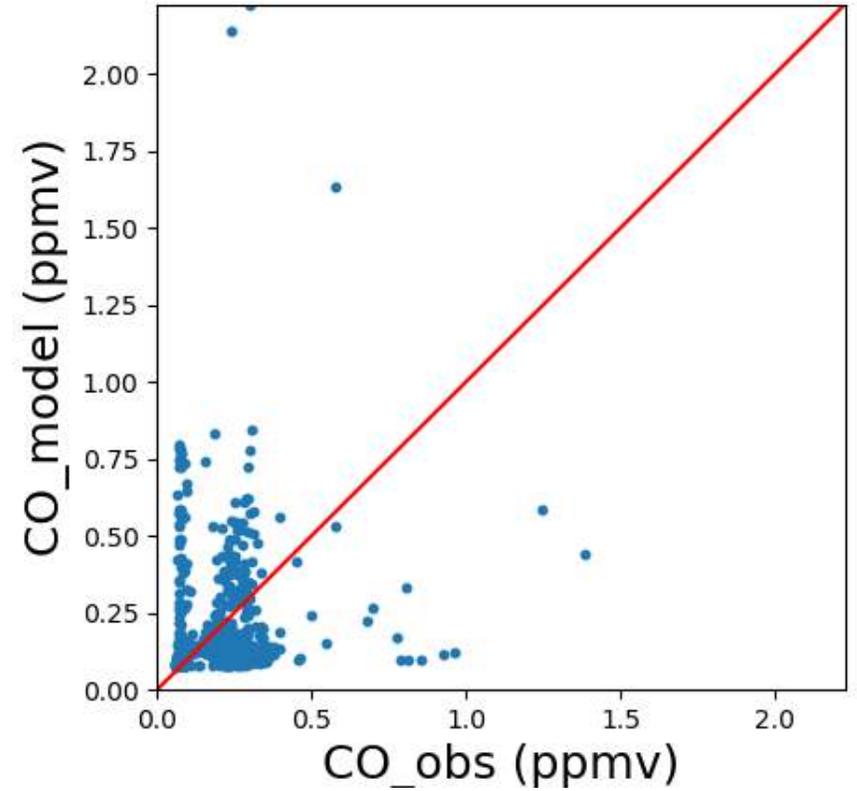
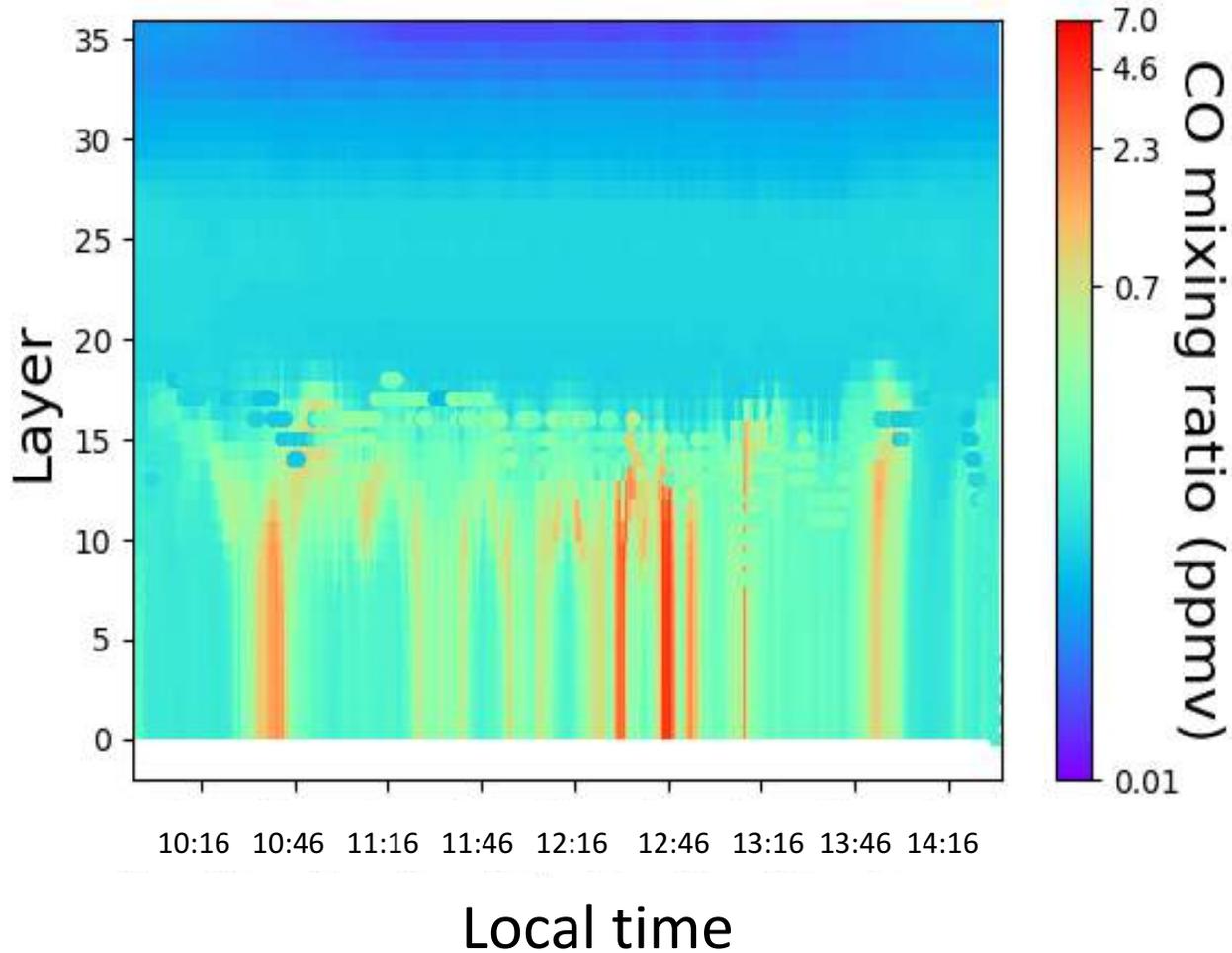


AIRPACT CO





CO along flight track: Aug 06, 2013

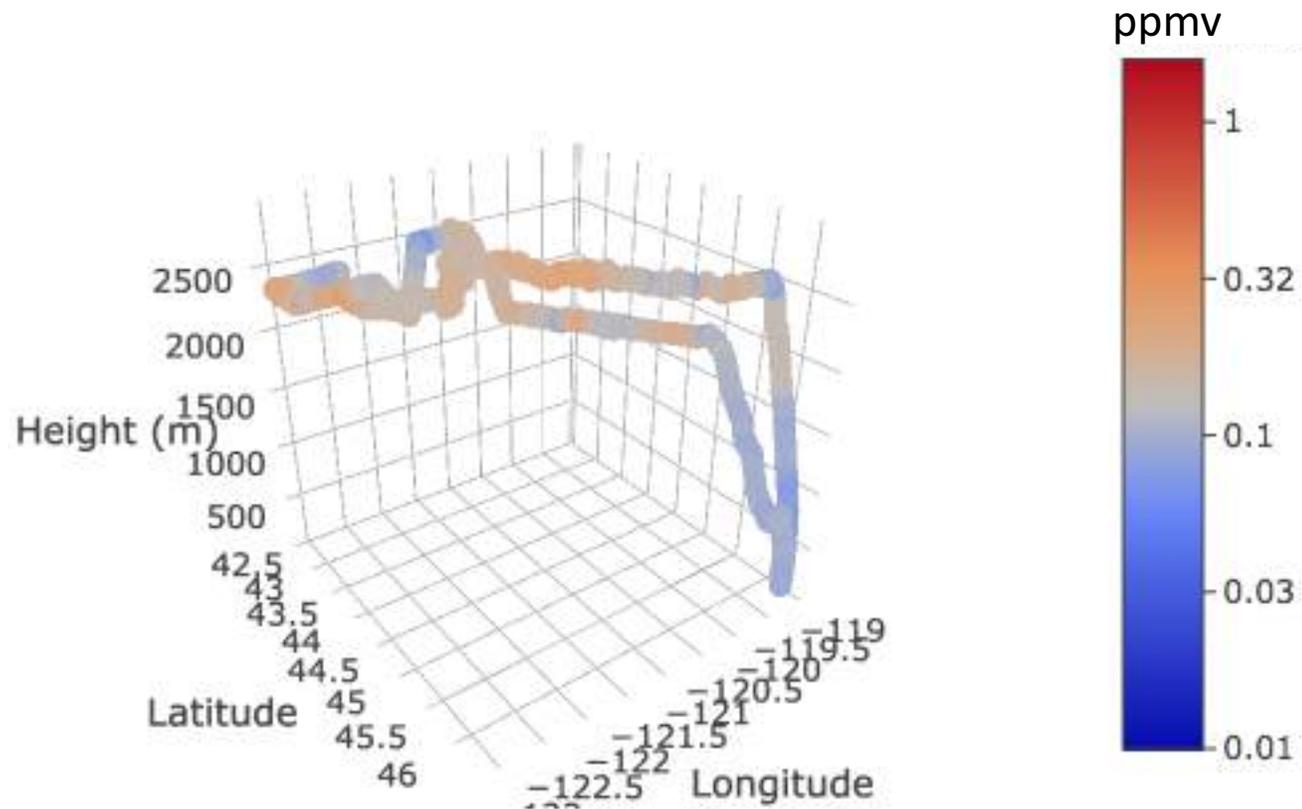


Runs	Obs. Mean [ppm]	Mod. Mean [ppm]	FB [%]	FE [%]
BASE	0.209	0.211	-6.8	54

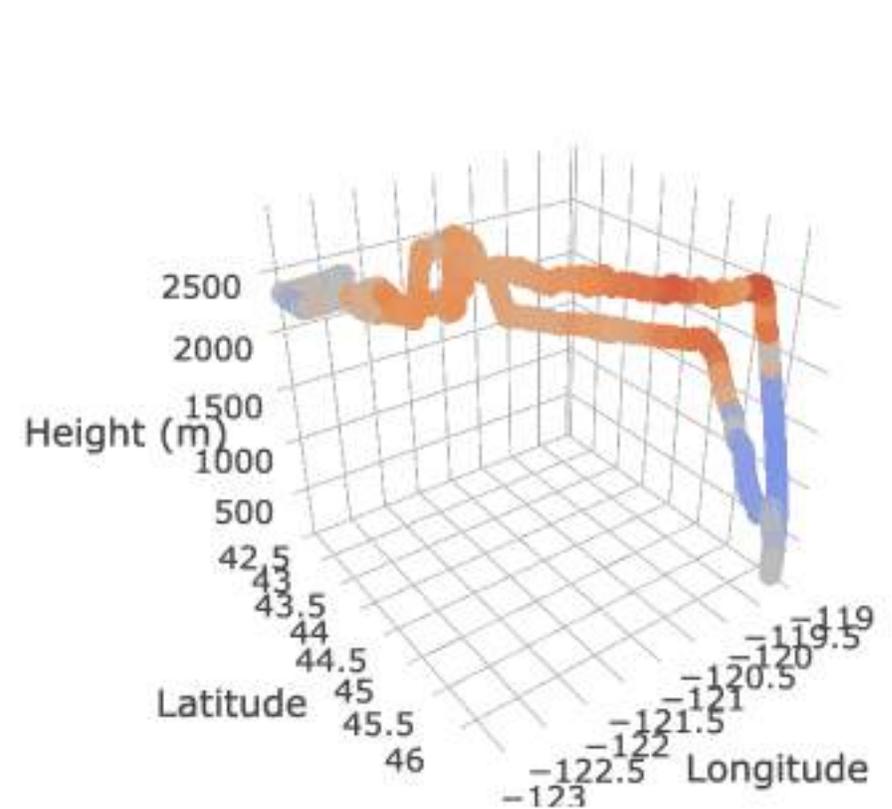


Flight-track CO: Aug 16, 2013

BBOP G-1 flight CO

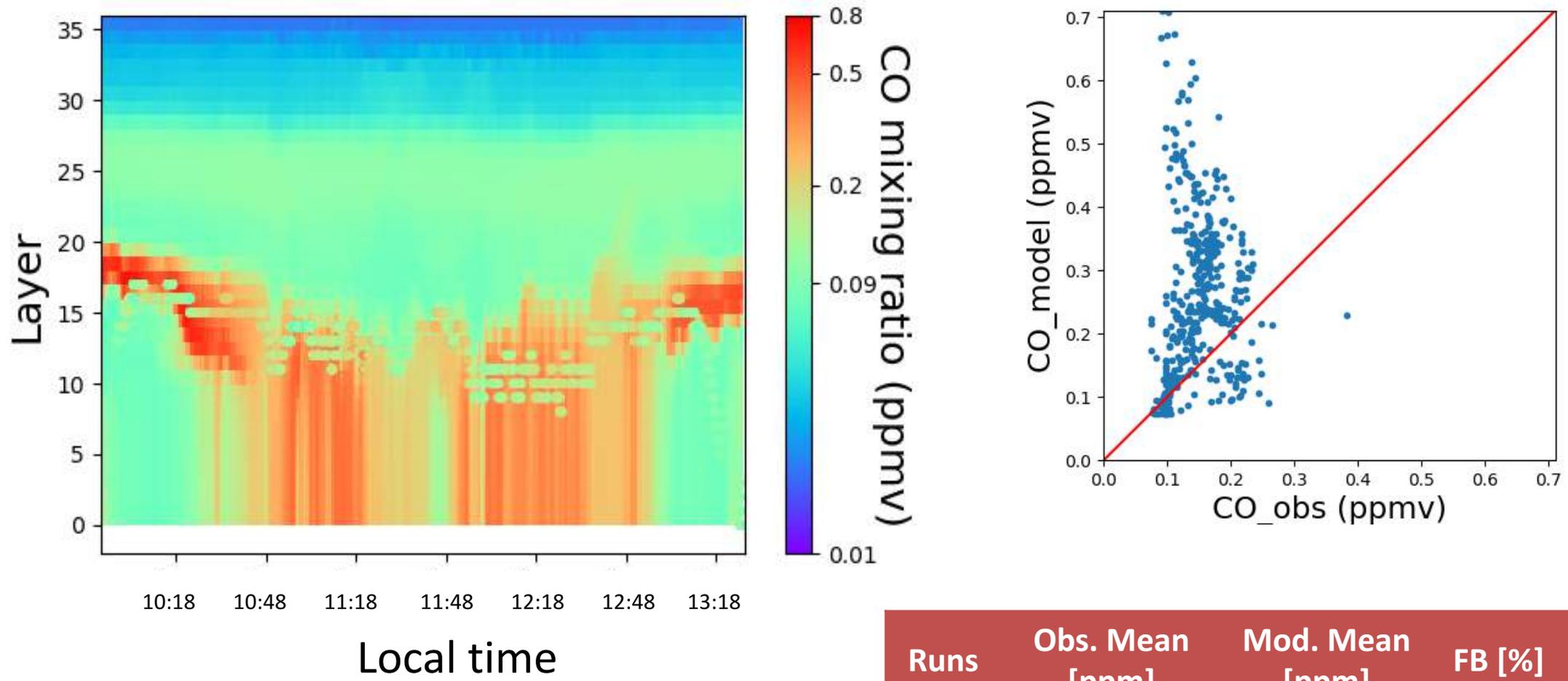


AIRPACT CO





CO along flight track: Aug 16, 2013

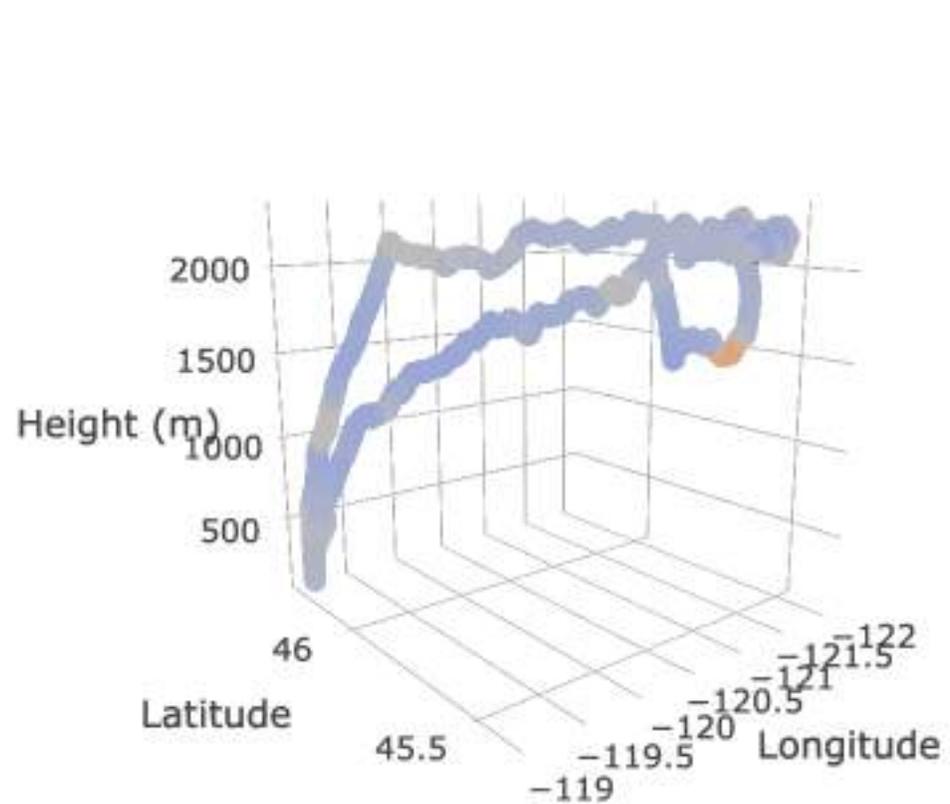


Runs	Obs. Mean [ppm]	Mod. Mean [ppm]	FB [%]	FE [%]
BASE	0.147	0.256	42	52

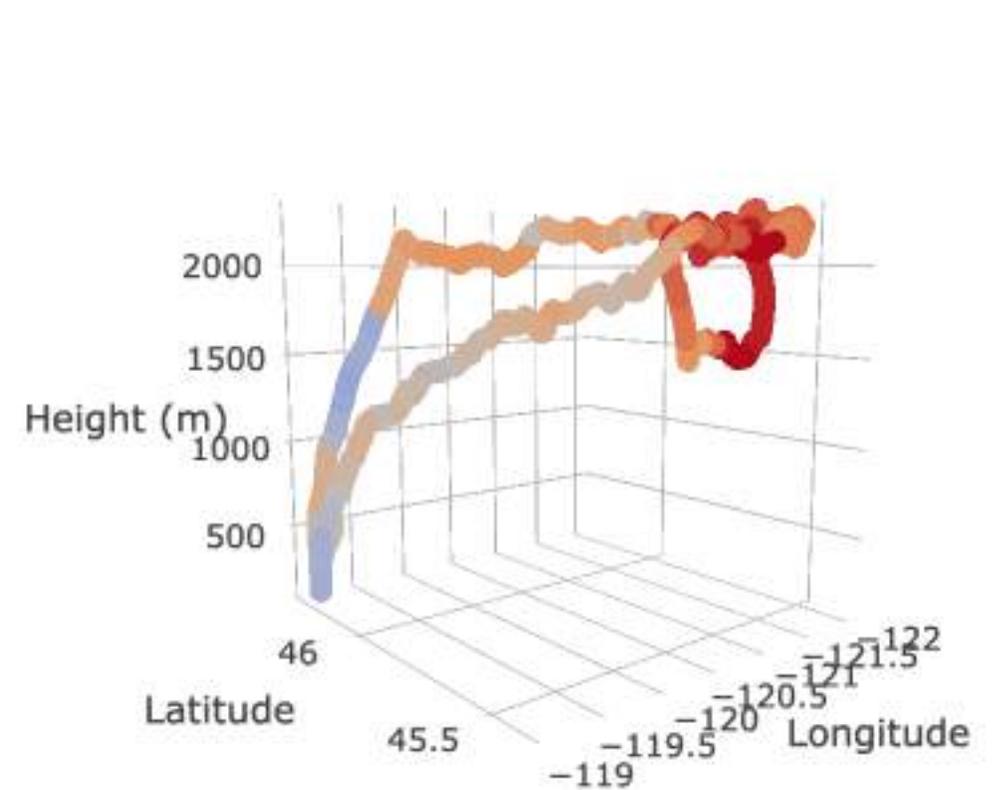


Flight-track CO: Aug 21, 2013

BBOP G-1 flight CO

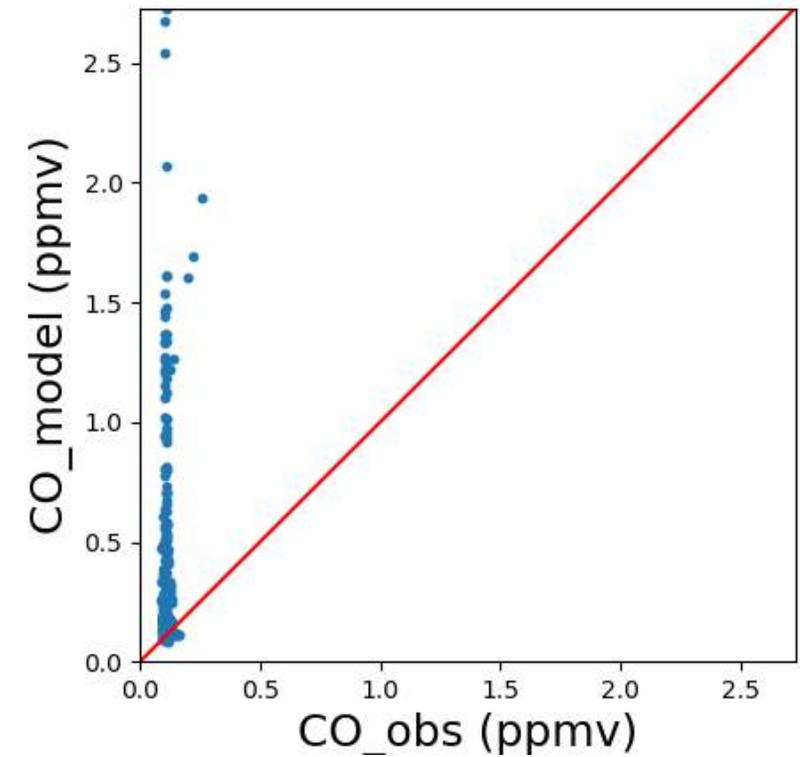
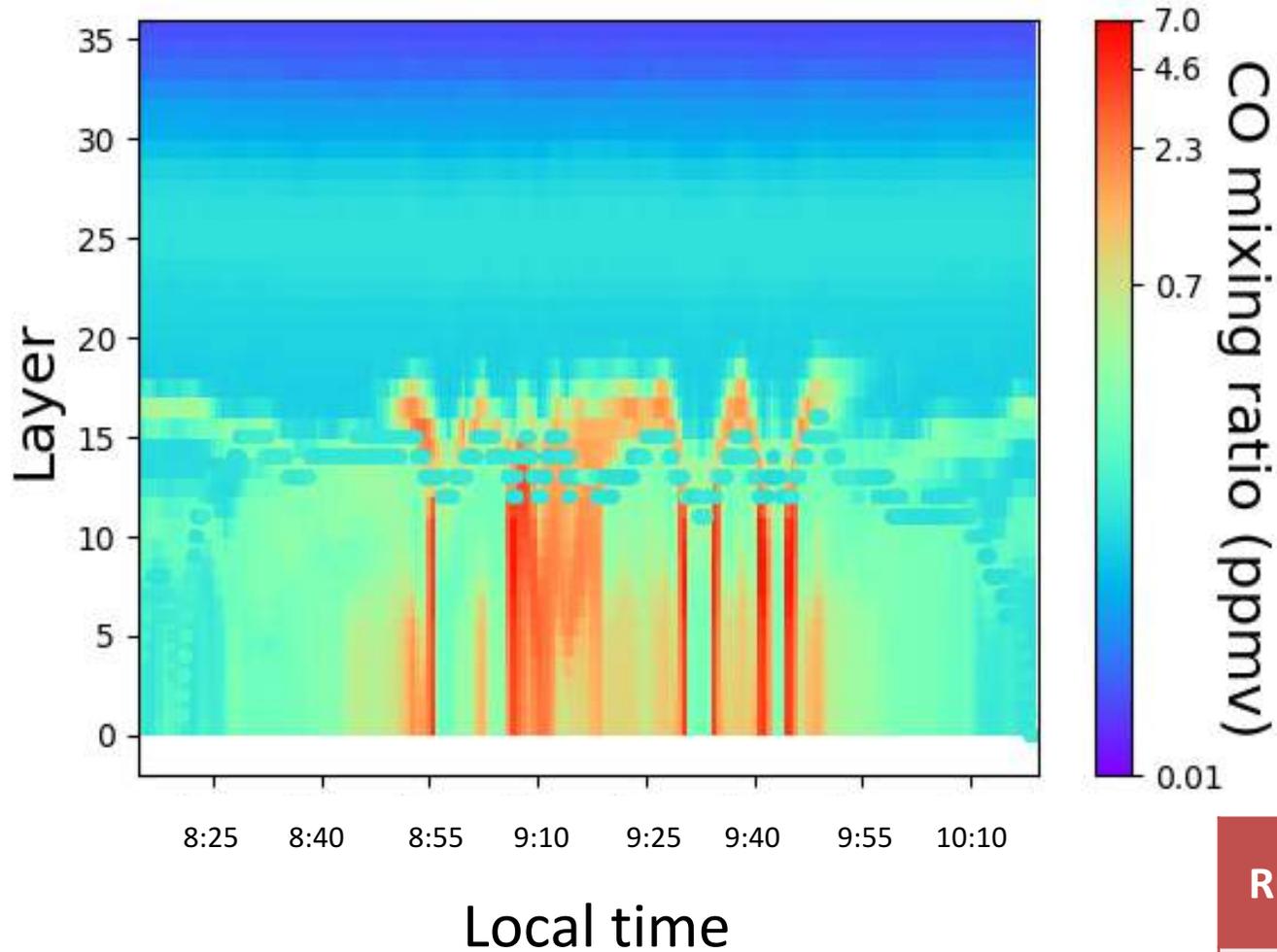


AIRPACT CO





CO along flight track: Aug 21, 2013



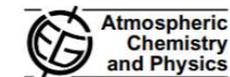
Runs	Obs. Mean [ppm]	Mod. Mean [ppm]	FB [%]	FE[%]
BASE	0.109	0.433	80	83



(Preliminary) Comparison to Val Martin et. al. 2010

Obtained from Wei Zhang from Idaho DEQ

Atmos. Chem. Phys., 10, 1491–1510, 2010
www.atmos-chem-phys.net/10/1491/2010/
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Smoke injection heights from fires in North America: analysis of 5 years of satellite observations

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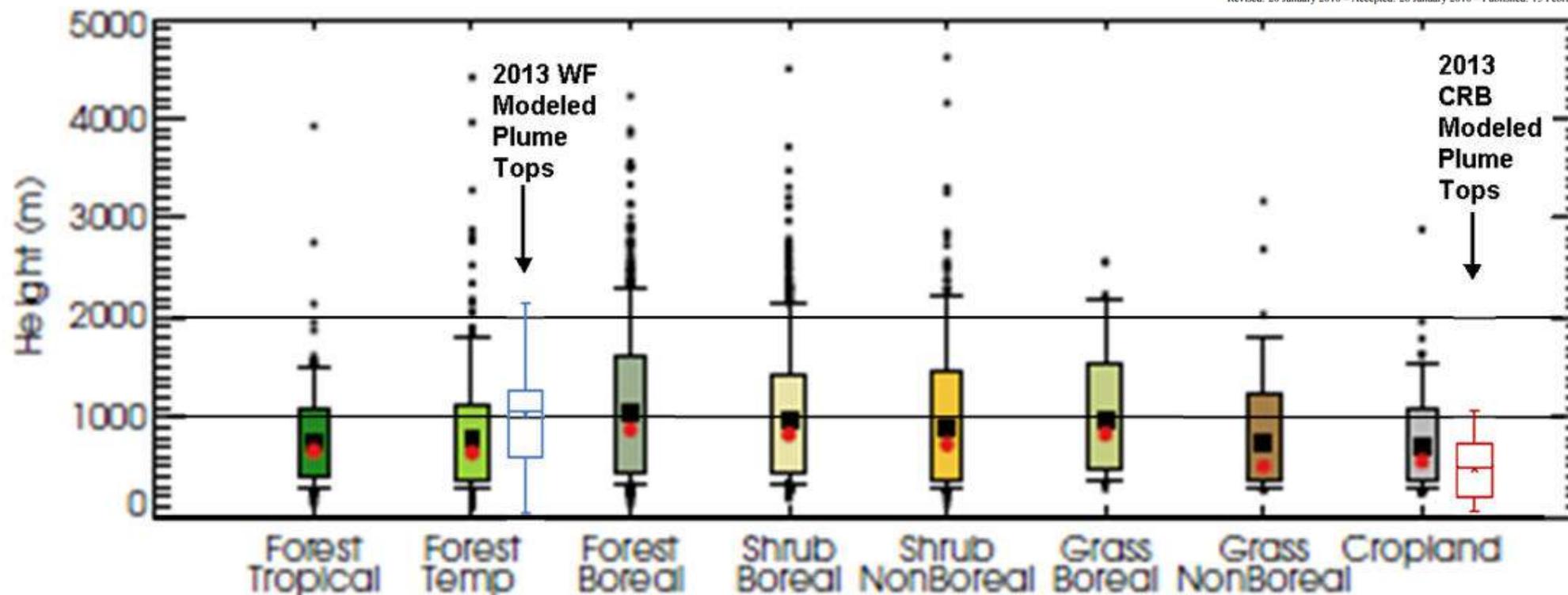
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Received: 14 August 2009 – Published in Atmos. Chem. Phys. Discuss.: 30 September 2009

Revised: 20 January 2010 – Accepted: 26 January 2010 – Published: 15 February 2010





Summary

- We have updated emission factors and lumped surrogate distributions for VOCs and PM_{2.5} for wildfire emissions, based on recent chamber and field measurements (FLAME-IV, BBOP/SEAC⁴RS).
- With updated emission factors and speciation profiles for PM_{2.5} and VOCs from wildfires, our simulations show the increase of POA (152%) and SOA (46%), total OA (67%), concentrations on average.
- Based on preliminary results from ground-based observation (AQS and MBO), it is unclear how much our updated wildfire emission treatments improve surface PM_{2.5} and OA predictions.
- Flight CO evaluations show that our model overpredicts CO mixing ratios in upper layers, possibly indicating too high wildfire plume rise, which is consistent with Wei Zhang's plume rise analysis.
- To improve wildfire smoke forecasts, we must have more comprehensive observation data including fire location/size/progression, fuel type, vertical profiles of pollutants and plume rise.



WRF-Chem: potential AIRPACT mirror system (preliminary results)

YUNHA LEE and Ana Carla Fernandez Valdes

Laboratory for Atmospheric Research (LAR)
Civil and Environmental Engineering
Washington State University

NW AIRQUEST meeting
June 13, 2018



Special Thanks to WA Ecology

With 15k support plus my matching startup funds, three computing nodes were purchased in a new WSU cluster called Kamiak.

Reasons to implement WRF-Chem:

- Mirror AIRPACT system to improve reliability
- Fundamentally different AQ modeling for 2 member ensemble forecast
- Larger domain to include more observations esp. field campaigns
- Coupled chemistry-meteorology forecasts (important for wildfire seasons)
- High-resolution air quality model (w/ Urban canopy model)
- Data Assimilation capability built-in in WRF-Chem



WRF-Chem setup

WRF v3.9.1. w/ MOZART-MOSAIC4bin

- Test run: Aug 1 to Aug 16 2017

Domain: Western US (followed the CANSAC forecast domain)

Resolution: 18 km

Emissions:

- MEGAN biogenic emissions
- FINN fire emissions
- NEI2011 anthropogenic emissions

Fast J Photolysis

Aerosol-Radiation interactions

Processes	Options
Microphysics	Morris 2-moment
Radiation physics	Rapid radiative transfer model (RRTM)
Surface layer physics	Monin-Obukhov (Janjic Eta) Similarity scheme
Land-surface Physics	Noah Land-Surface Model
PBL physics	Bougeault and Lacarrere (BouLac)
Cumulus parametrization	Grell 3D ensemble scheme
Urban canopy model	No UCM
Land use category	21
Diffusion	2 nd order diffusion, 2D Smagorinski

Fire INventory of NCAR (FINN) emissions

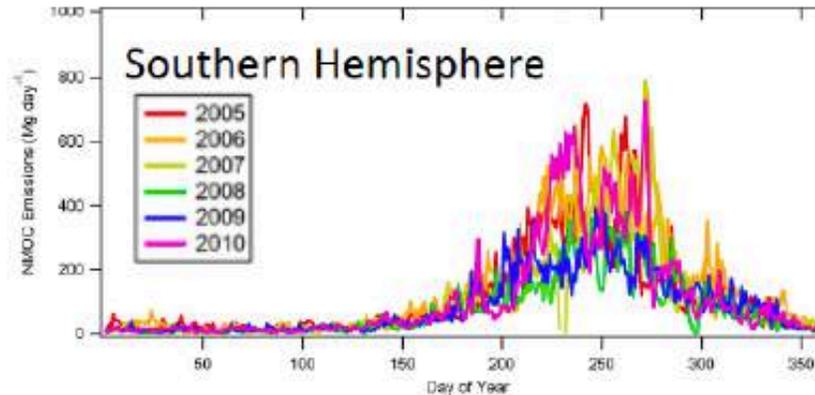
- FINN: Fire INventory from NCAR (Wiedinmyer et al., GMD, 2011)
- Daily, 1 km resolution, global estimates of the trace gas and particle emissions from open burning of biomass
- Uses satellite observations of active fires and land cover, together with emission factors and estimated fuel loadings

CO, NO_x,
VOCs, SO₂, PM



FINN combines:

- MODIS Fire Detections
- MODIS Vegetation Continuous Field and Land Cover Type
- Emission Factors: Akagi et al., ACP, 2011
- Speciation of VOC for MOZART-4, SAPRC-99, GEOS-Chem



Daily NMVOC Emissions
(from Wiedinmyer et al., 2011)

Visit near-real-time fire emissions:

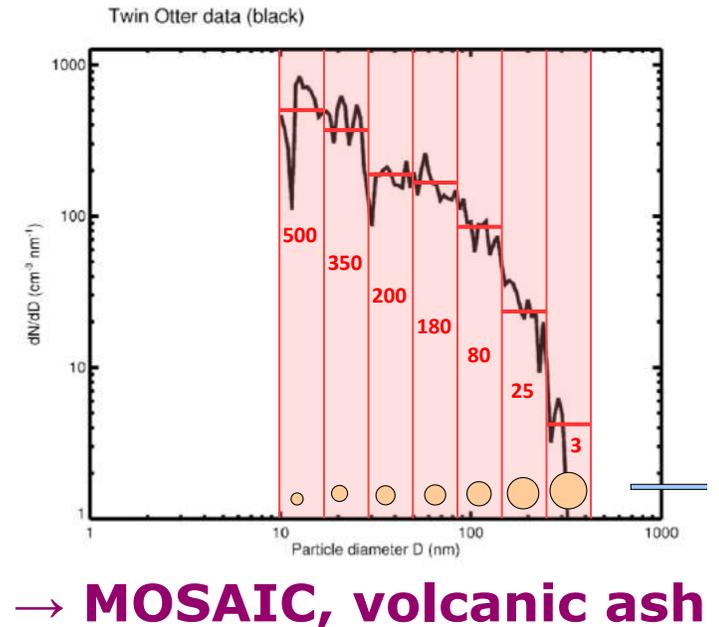
<https://www.acom.ucar.edu/acresp/forecast/fire-emissions.shtml>



MOSAIC aerosol module

Model for **S**imulating **A**erosol **I**nteractions and **C**hemistry (Zaveri et al., JGR, 2008)

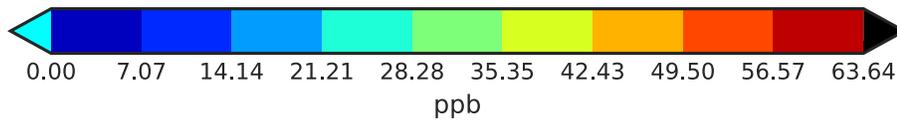
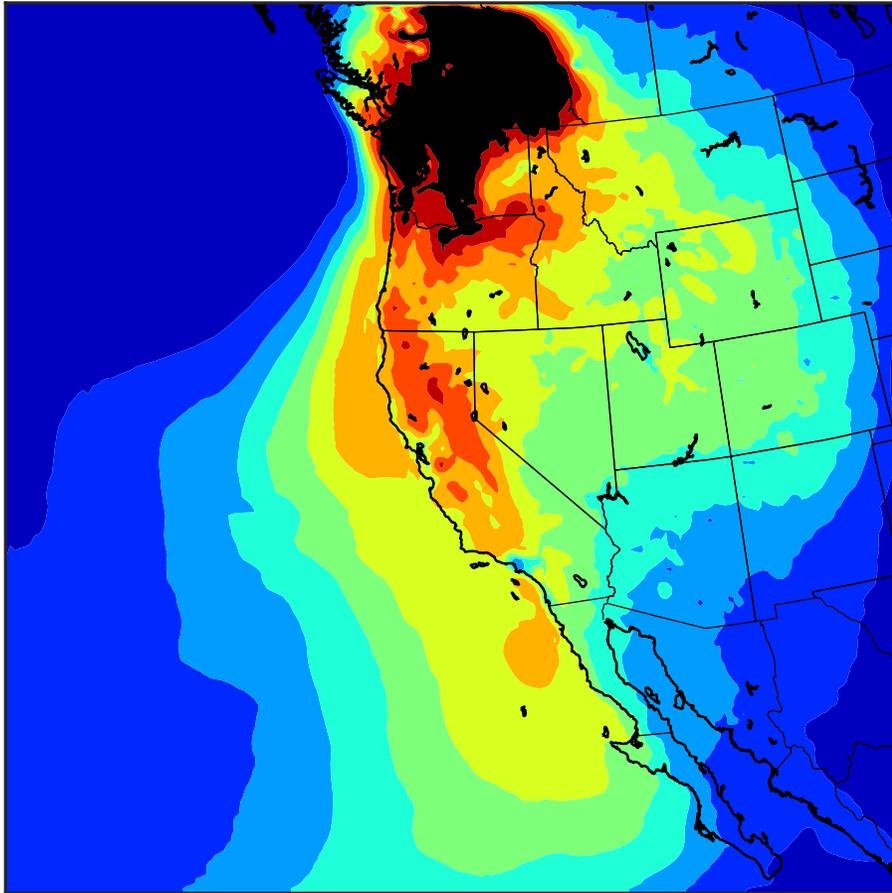
- Modern aerosol scheme in WRF/Chem
- 4 or 8 aerosol size sections (bins) 39 nm – 10 μm
- Interaction with radiation:
 - Direct aerosol effect
 - Effect on photolysis
- Interaction with clouds:
 - Aerosol number determines cloud drop number and size
 - Radiative response \rightarrow 1st indirect aerosol effect
 - Aqueous chemistry
 - Wet removal (scavenging)



Mean concentrations for Aug 1-16, 2017

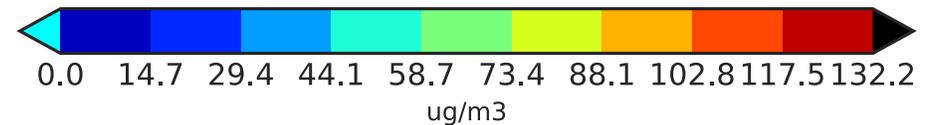
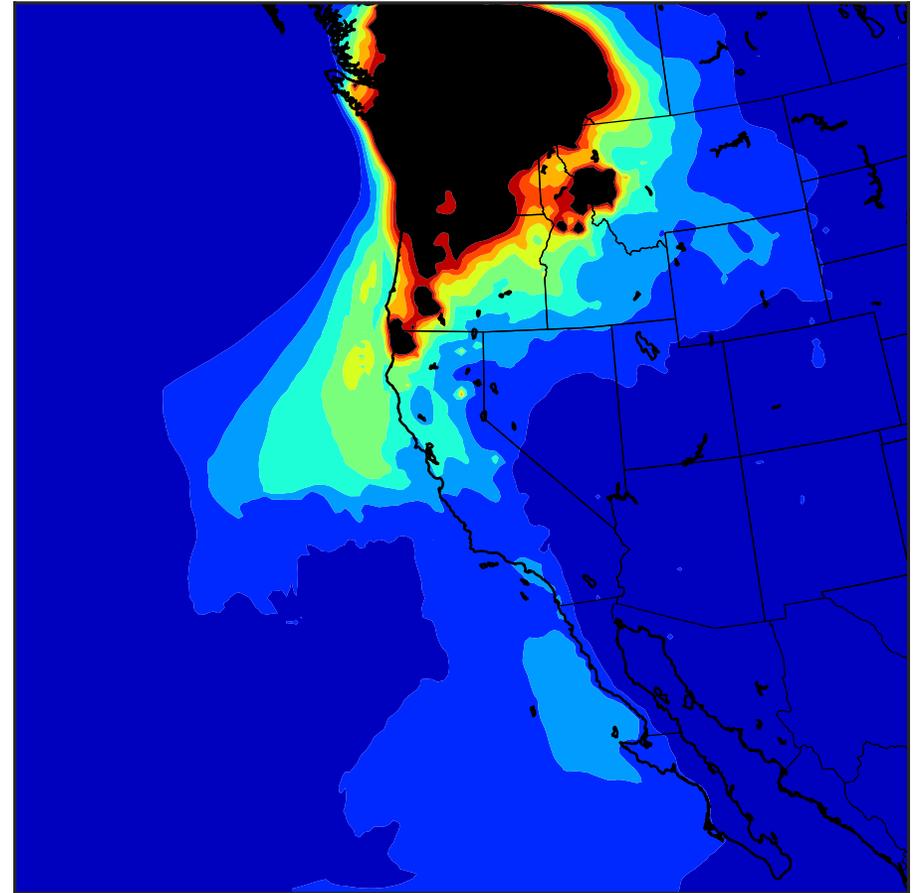
O₃

mean: 22.9 ppbv

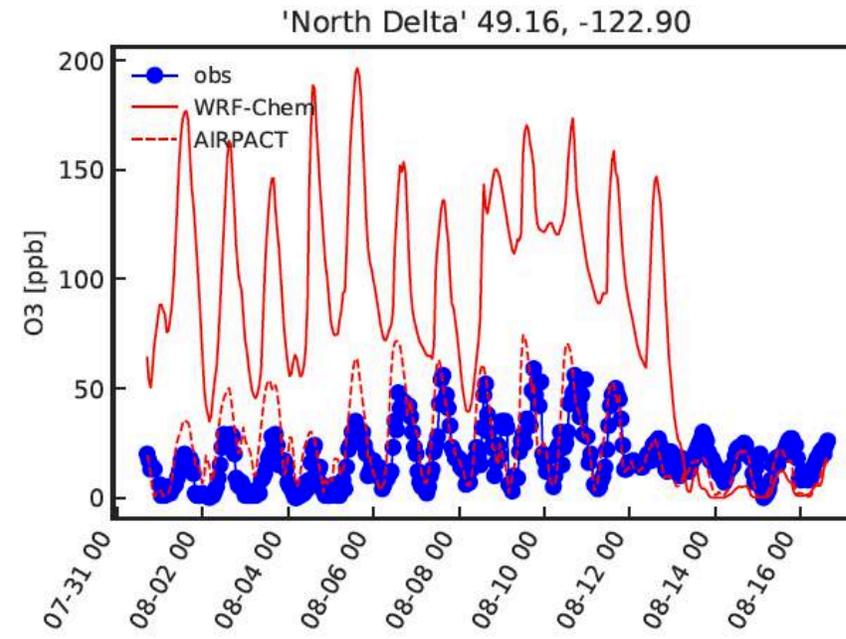
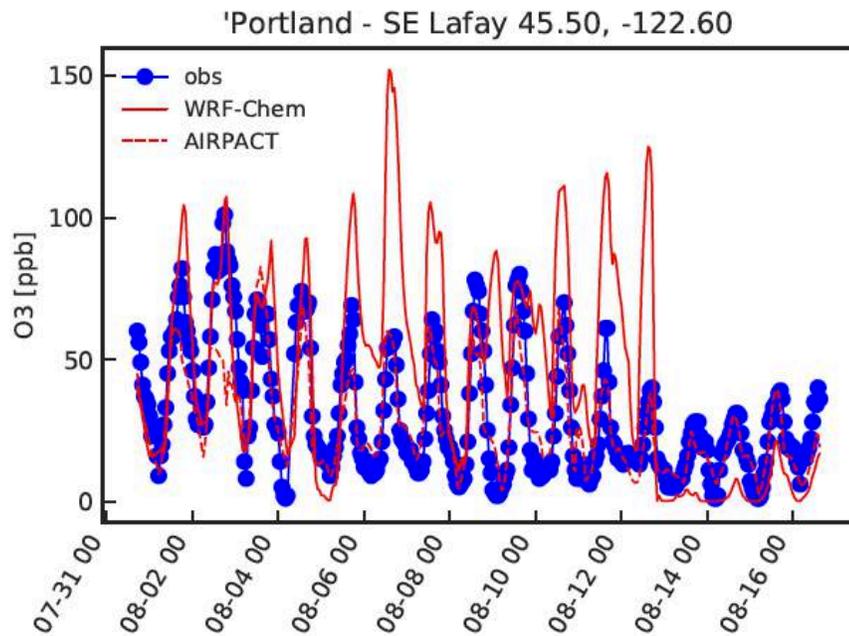
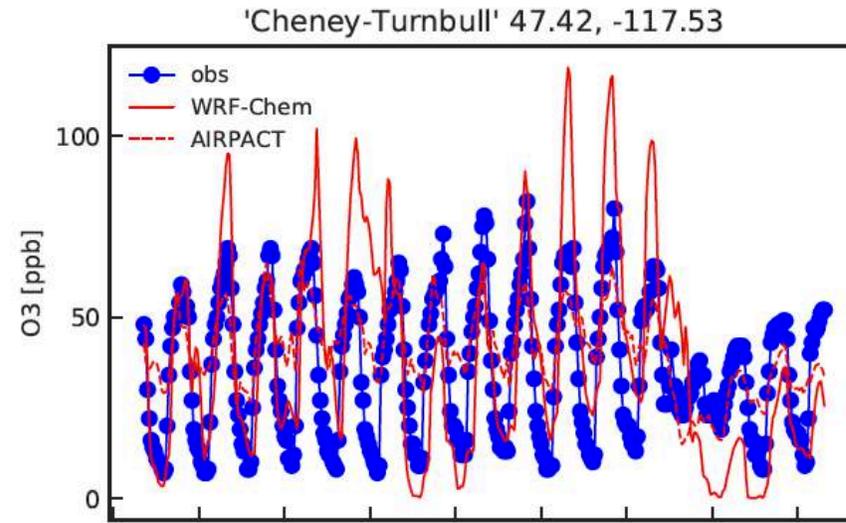
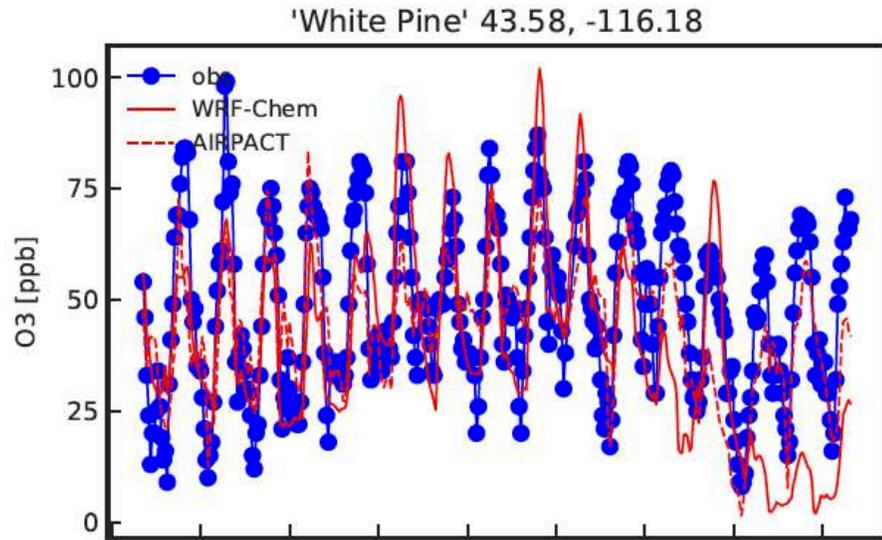


PM2.5

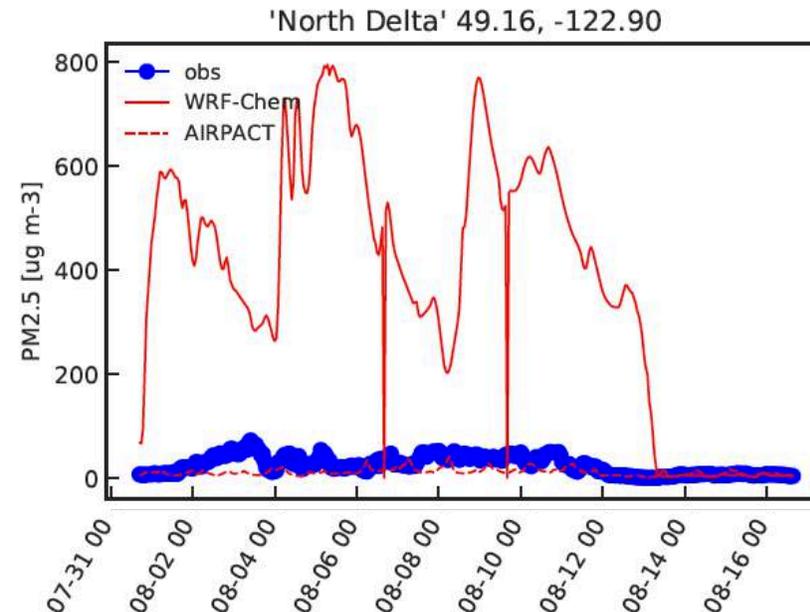
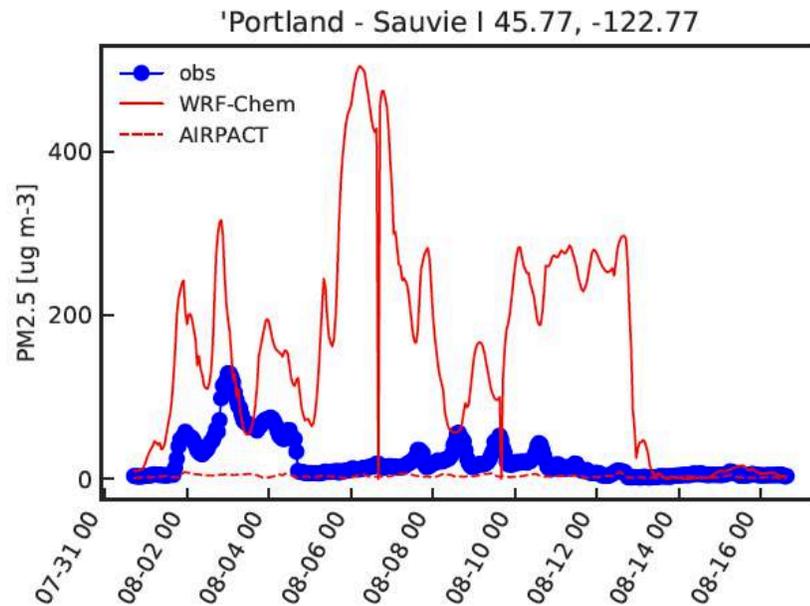
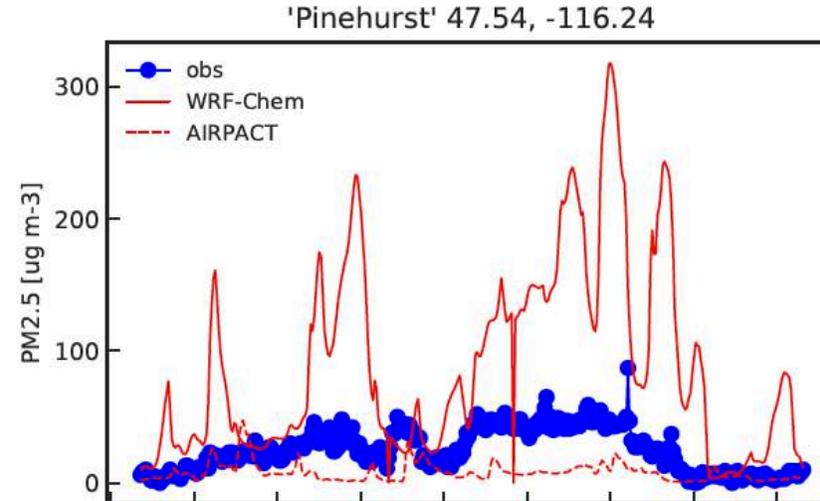
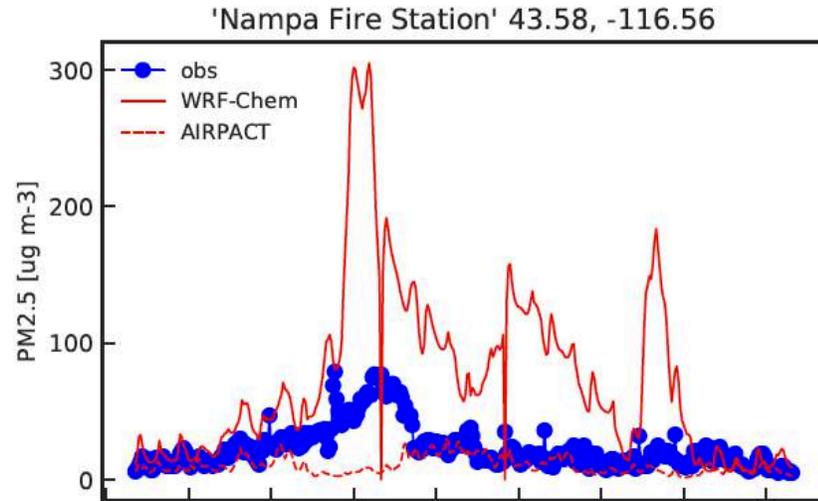
mean: 40.4 mg m⁻³



WRF-Chem vs AIRPACT-5: O₃ evaluation



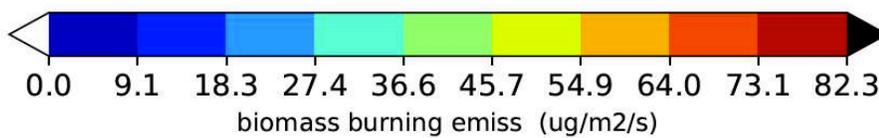
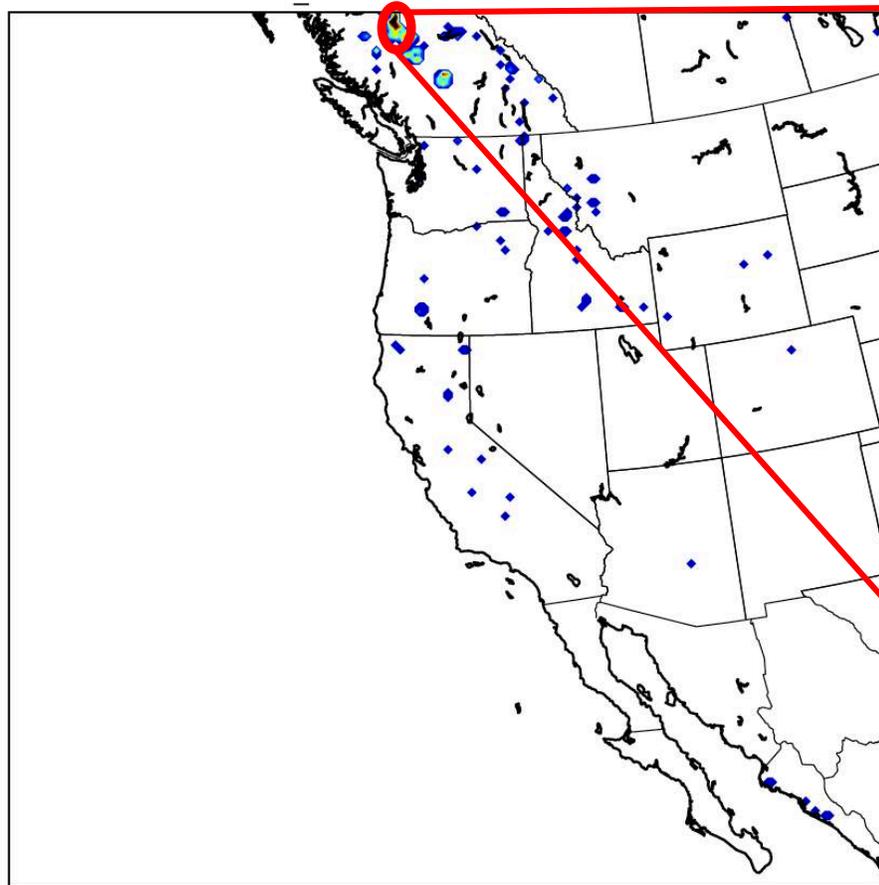
WRF-Chem vs AIRPACT-5: PM2.5 evaluation



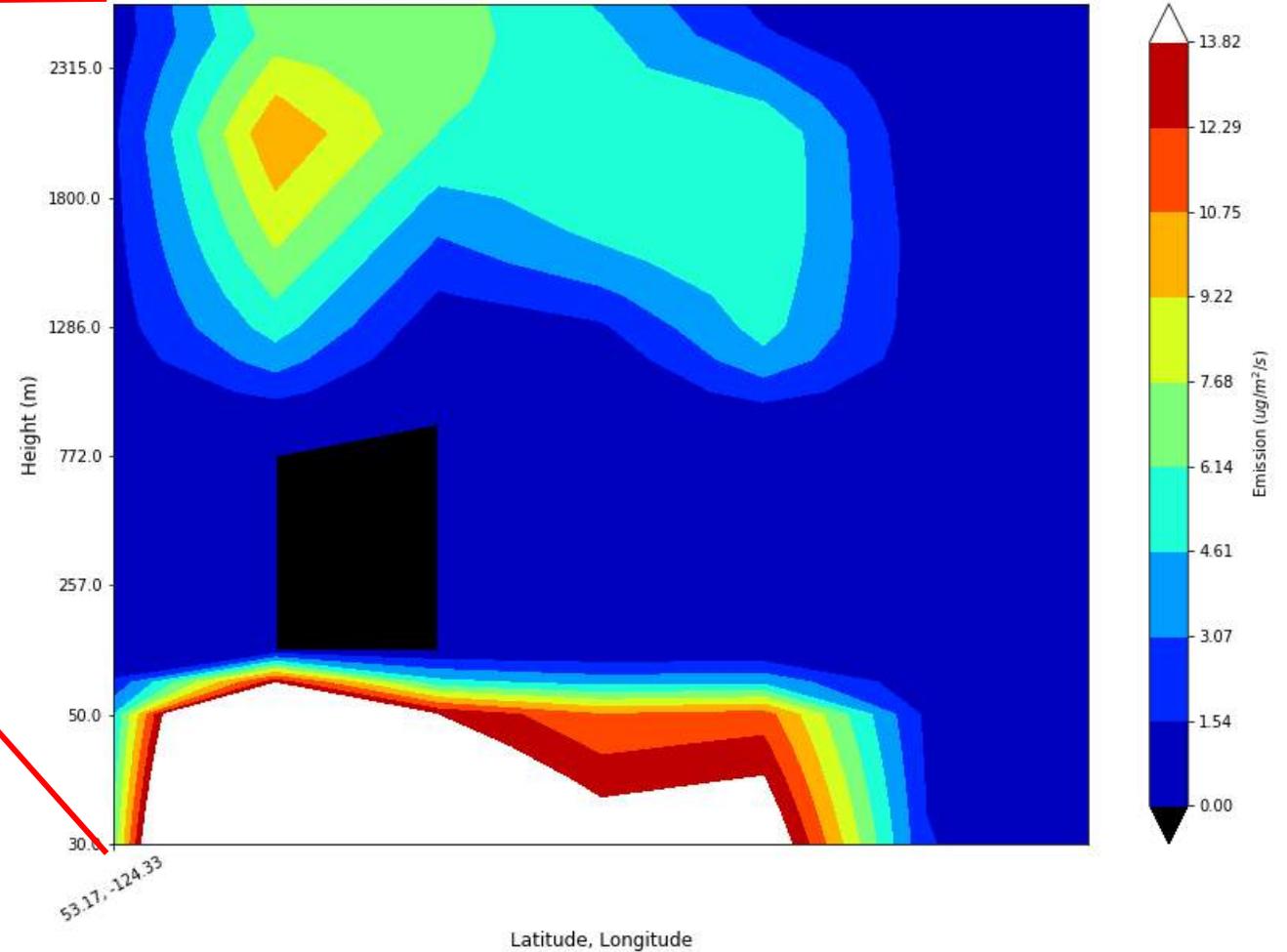


Problems in Fire Emissions

Fire emissions at 080517 UTC0



Daily Mean Vertical profile





Future works

- Investigate a vertical distribution of FINN fire emissions
- Implement BlueSky emissions (w/ a help from Susan O'Neill)
- Apply nesting domain to perform a high-resolution simulation
 - Use WRF-urban-Chem for urban areas
- Re-try UW's WRF domain and configuration
- Implement Data Assimilation to improve forecasting accuracy
 - Using surface air quality s and AOD data

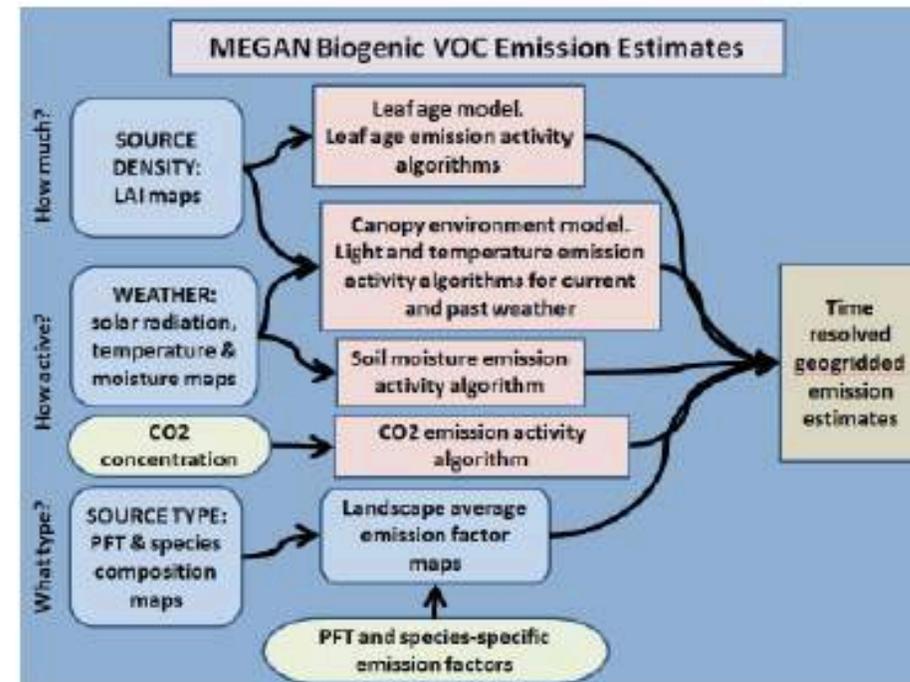


QUESTIONS?

MEGAN biogenic emission modeling

Model of Emissions of Gases and Aerosols from Nature

- Estimate emissions of VOCs, NO_x and CO from vegetation
- Driving variables include landcover, LAI, weather, and atmospheric chem composition
- Reference: *Guenther et al.*, GMD 2012 (for MEGAN v2.1)
- Note: as of current land cover used in MEGAN differs from that used within WRF-Chem
- Planned:
 - Update to latest MEGAN current version in WRF-Chem: 2.04
 - link to WRF-Chem land cover/CLM



from Guenther et al., 2012



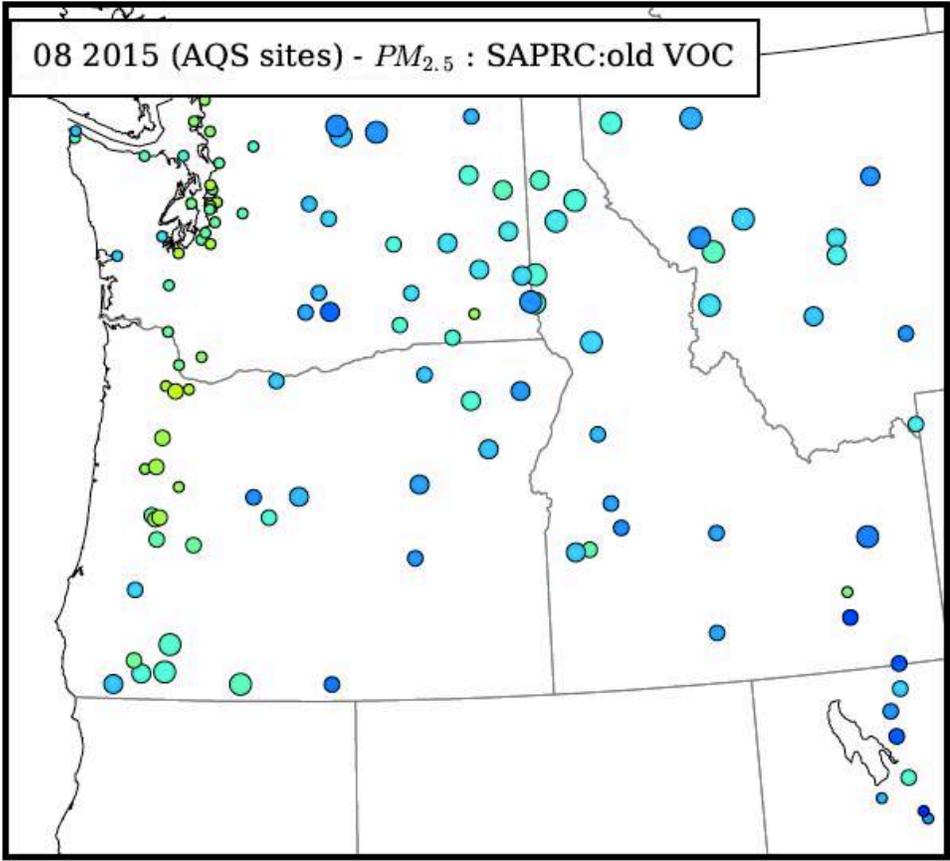
Why online?

- Offline modeling introduces errors for air quality applications
 - Error for offline modeling is increasing with increasing horizontal resolution
 - Power spectrum analysis can show the amount of information that is lost in offline runs
- 2-way feedback in-between chemistry and meteorology
 - Process studies relevant for global climate change
 - Ultimately it should lead to improved data assimilation (meteorology) and improved weather forecasts



Vertical Layer	Grid height [km]
1	0.0203
2	0.061
3	0.1056
4	0.1582
5	0.2156
6	0.2787
7	0.3528
8	0.4397
9	0.5426
10	0.6639
11	0.8064
12	0.9743
13	1.1721
14	1.4055
15	1.6802
16	2.0025
17	2.3795
18	2.8176
19	3.3246
20	3.9137
21	4.6025
22	5.4111
23	6.3502
24	7.3749
25	8.4156
26	9.4494
27	10.4721
28	11.4821
29	12.4822
30	13.4821
31	14.4821

AIRPACT-5 Fractional Bias PM_{2.5} August 2015



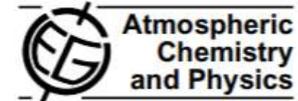


WRF-Chem

- Chemistry is online, completely embedded within WRF
- Consistent: all transport done by meteorological model
 - Same vertical and horizontal coordinates (no horizontal and vertical interpolation)
- Ideally suited to study feedbacks between chemistry and meteorology
- Ideally suited for air quality forecasting on regional to cloud resolving scales

Wildfire Plume Heights from Literature

Atmos. Chem. Phys., 10, 1491–1510, 2010
www.atmos-chem-phys.net/10/1491/2010/
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Smoke injection heights from fires in North America: analysis of 5 years of satellite observations

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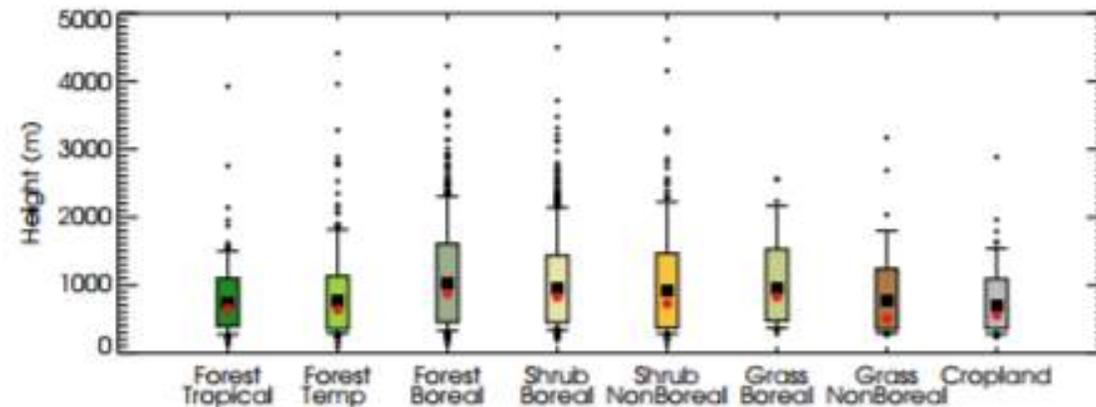


Fig. 6. Distribution of the median height above the terrain for smoke plumes in each biome (see Figure 3 for spatial distribution of the biomes). Bar plots indicate the distribution of the data. The medians (red circles) and the means (black squares) are shown along with the central 67% (color coded box) and the central 95% (thin black lines). Data that fall outside the bar plots are plotted with black circles.