

Forecasting Wildfire Smoke PM_{2.5} using the AIRPACT5 Air-Quality Forecasting System: recent experience, emerging approaches and a near-term application.



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Refinery and Chemical Industry Emissions Symposium

November 7, 2019

UC Davis Conference Center

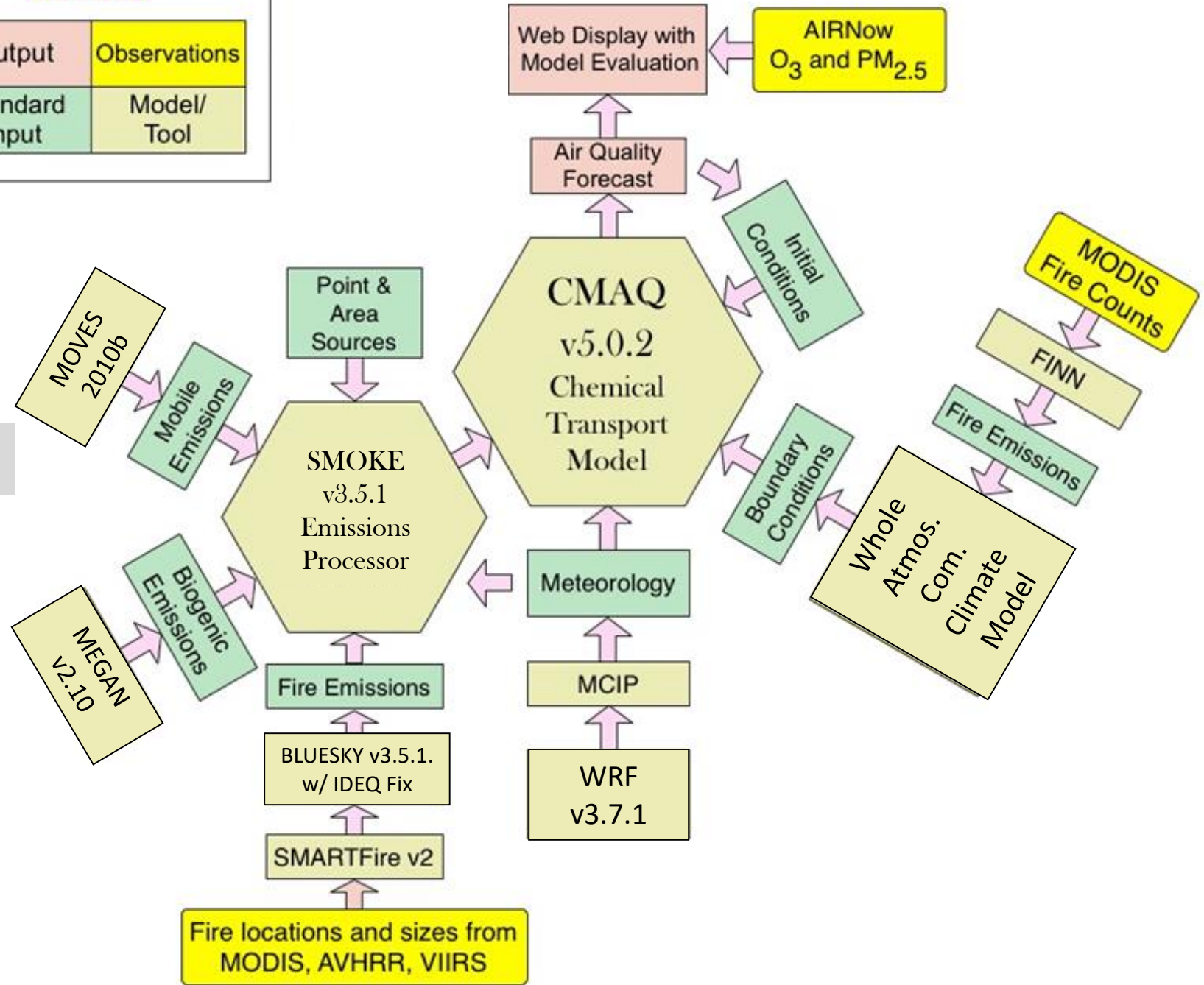
Air-quality Indicator Reporting for Public Access and Community Tracking: AIRPACT

- Forecasting AQ in WA state since 2001
- AIRPACT5 forecasts highly resolved AQ:
 - Nightly run forecasts the next two days (48 hours)
 - Spatial scale of 4-km grid covers WA, ID, & OR.
 - Criteria pollutants: PM2.5, O3, CO, NO2, SO2, & related precursors and products
- Supported by NW-AIRQUEST consortium: EPA, WA Ecology, OR DEQ, ID DEQ, Local & Tribal agencies, Env. CAN.

LEGEND:

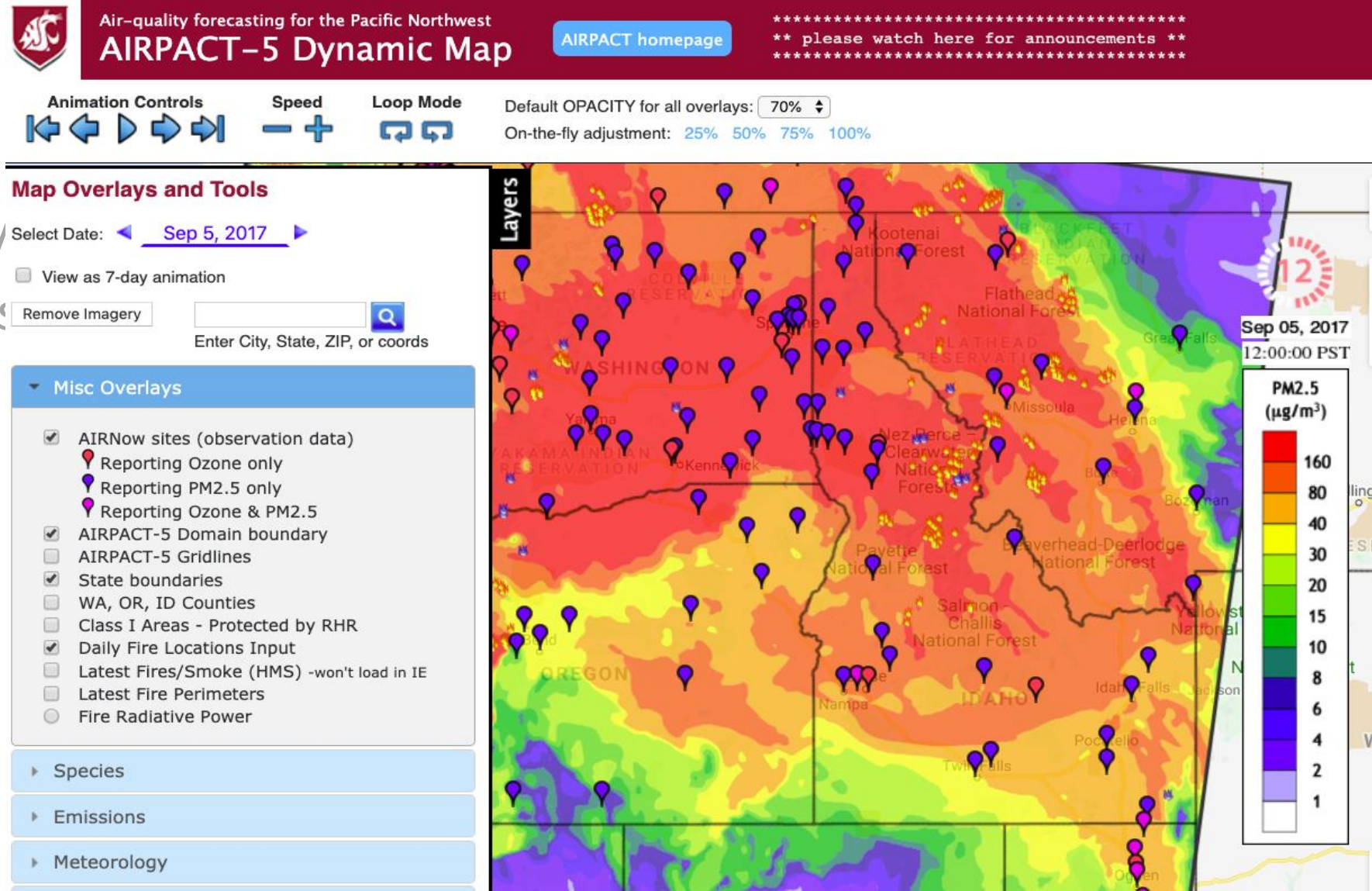
Output	Observations
Standard Input	Model/ Tool

It is complicated....



Tour of AIRPACT5 at: <http://lar.wsu.edu/airpact/>

- Forecasts (Imagery)
- Monitoring Sites
- Performance Charts
- Boundary Conditions
- Curtain Plots



Tour of AIRP

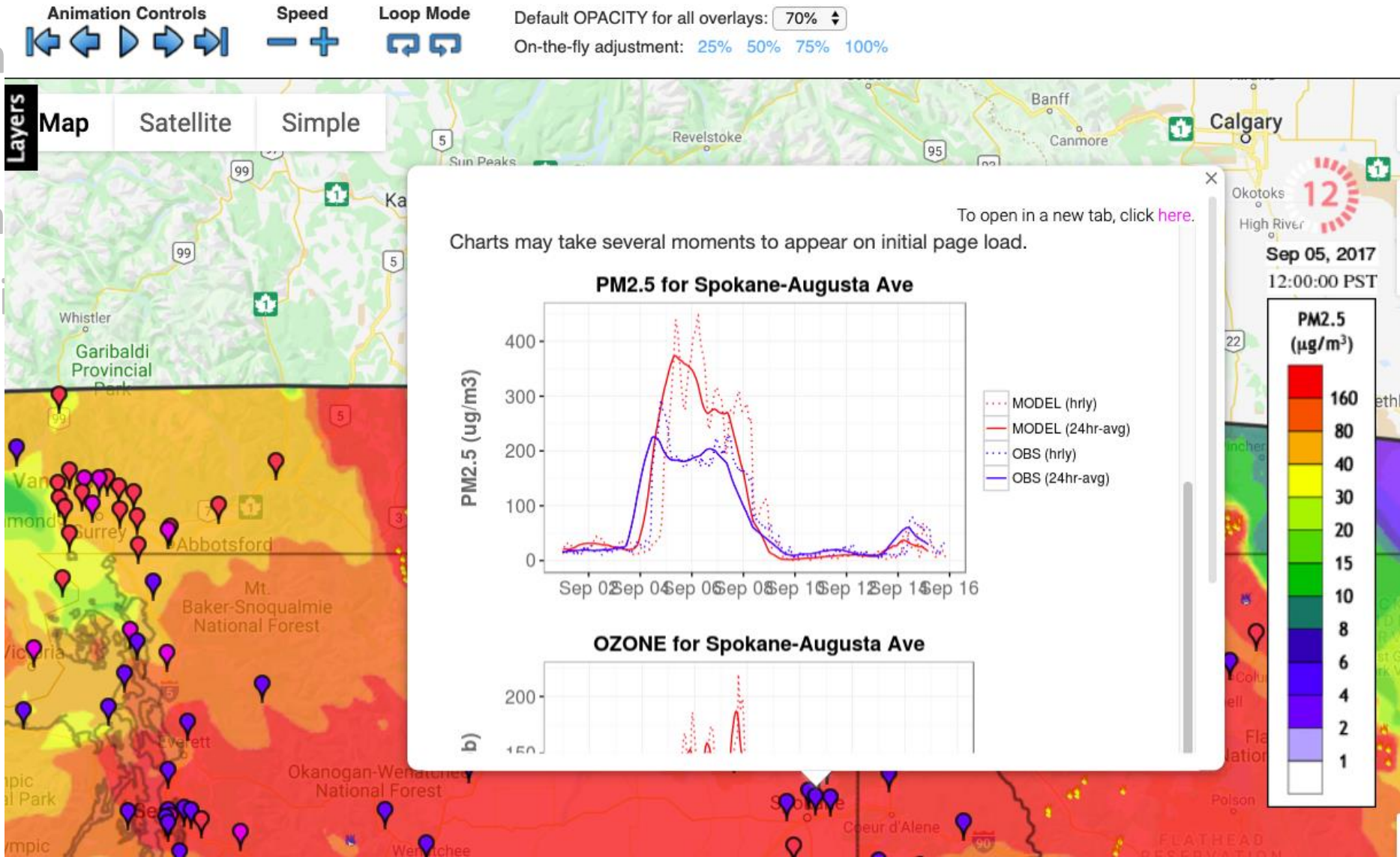


Air-quality forecasting for the Pacific Northwest
AIRPACT-5 Dynamic Map

[AIRPACT homepage](#)

** please watch here for announcements **

- Forecasts (see Im
- Monitoring Sites
- Performance Cha
- Boundary Condit
- Curtain Plots



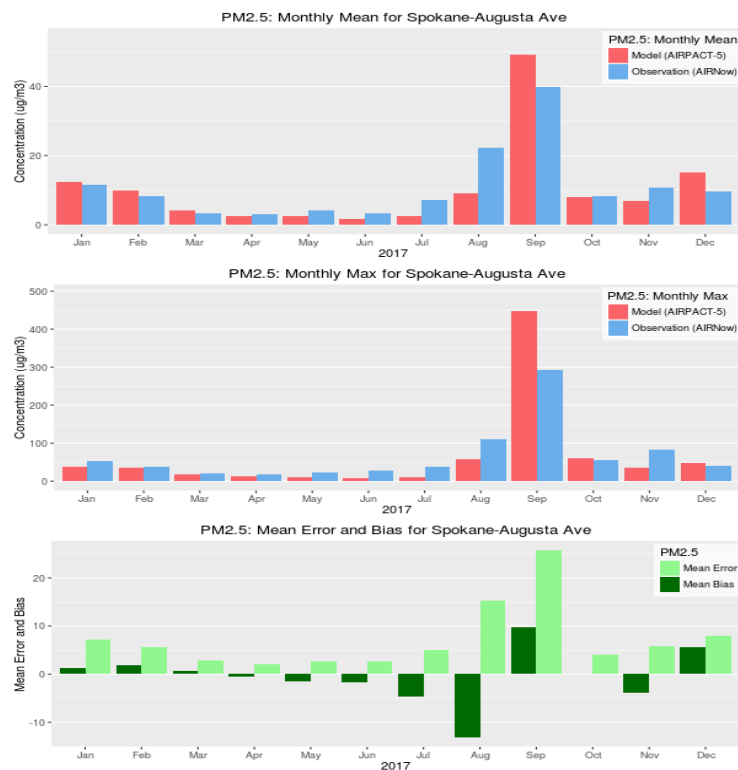
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2017 AIRPACT-5 vs AIRNow Performance

[2017 Monthly Statistics](#) [AIRPACT Home](#)

Charts may take several moments to appear on initial page load.



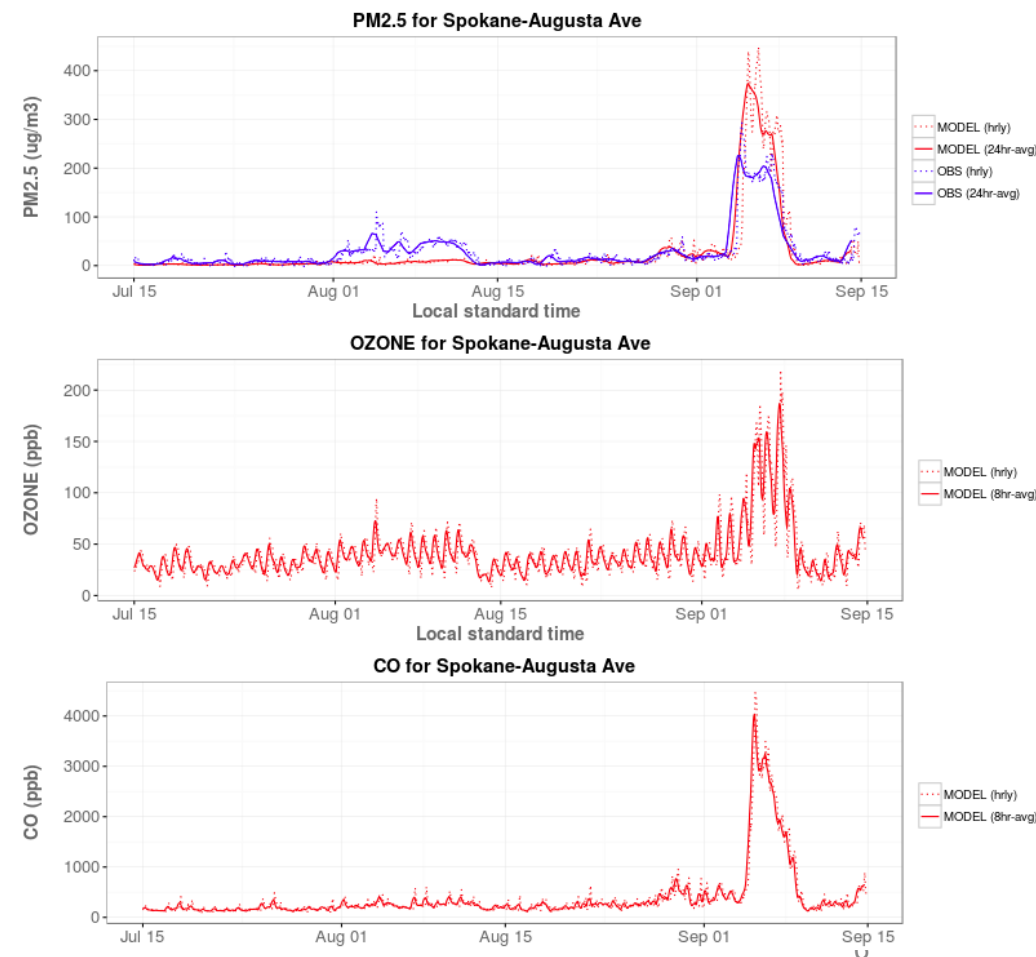
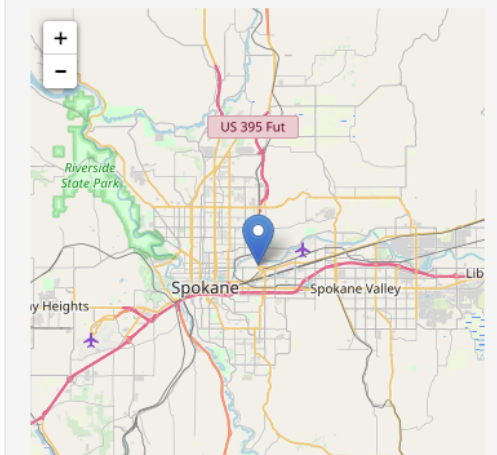
Select Parameter
 O3 PM2.5 CO NOx

Select State or Province
WA

Select Site Name
Spokane-Augusta Ave

Enter date range
2017-07-15 to 2017-09-14

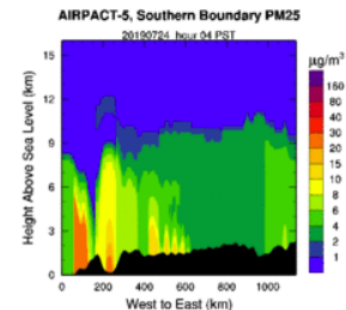
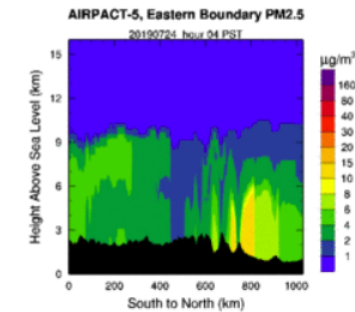
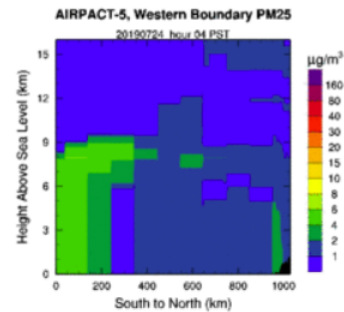
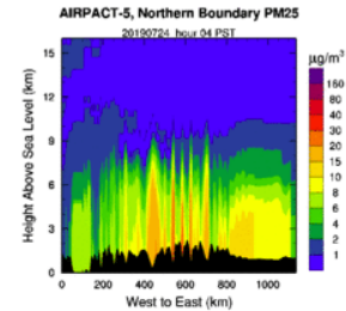
[Download Data](#)



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- Monitoring Sites
- Performance Charts/Stats
- **Boundary Conditions**
- Curtain Plots

10 timestep animation, every 6 hours

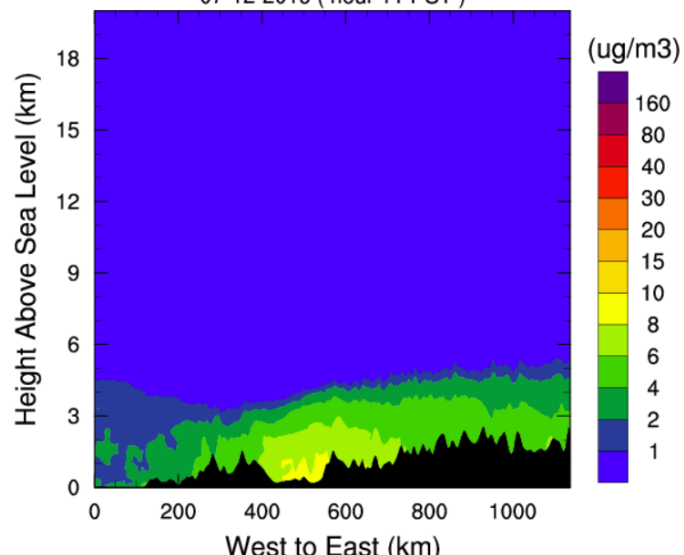


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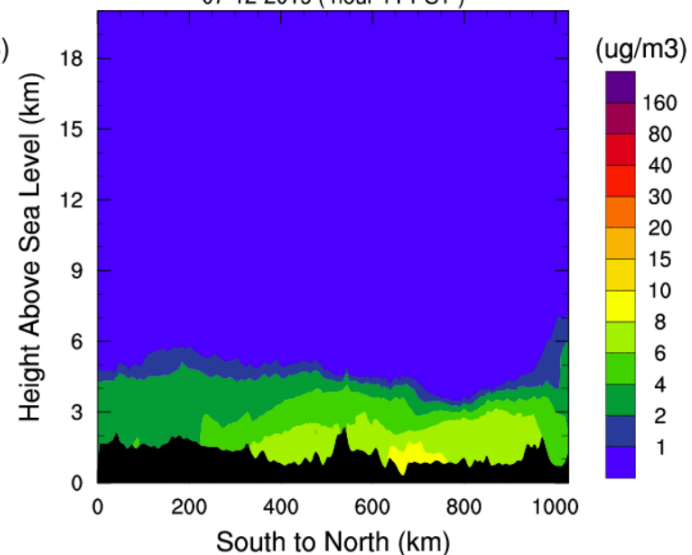
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PM2.5 West-to-East Curtain Plot for Row 156
07-12-2019 (hour 11 PST)



PM2.5 South-to-North Curtain Plot for Col 159
07-12-2019 (hour 11 PST)



AIRPACT-5 Emissions

Too
Long! Don't
Read!

Anthropogenic emissions based on the 2011 NEI

- Updates to major point sources (2014)
- Reductions in Residential Wood Combustion (Urban Areas)
- 2014 MOVES and NONROAD
 - MOVES static lookup tables:
 - increases processing speed
 - speeds forecast completion
 - but is year-specific.
- Area Fugitive Dust only used on 'dry-side', east of the Cascades

Fire emissions - modified BlueSky approach

- Rx Fire, Ag Fire, and WF from NEI *are not used*.

Biogenic emissions - MEGAN 2.1

- Parallel mode (increases speed)
- MODIS Land Cover & Land Use

Canada Emissions from 2010



AIRPACT Anthropogenic Emissions Update

Too
Long! Don't
Read!

EPA 2014 NEI v2 used as basis for AIRPACT-6 Emissions Inventory

- Updates to Point Sources by states (2017)
- MOVES and NONROAD projected to 2019
 - Large reductions in vehicle CO/NO_x/VOCs and Road Dust
 - Large reductions in ship SO₂ in SECA

Transition from SMOKE v3.5.1 to SMOKE v4.5 in progress

- Requires (as distributed) Intel nodes
- Fixed width format no longer used for inputs or profiles
- New version of SMOKE-MOVES (includes hotelling and new SCCs)
- Continuing to use CB-05 speciation; CB-06 not supported yet in current forecasting implementation of SMOKE-MOVES (i.e. in static lookup tables)

AIRPACT-5 Fire Emissions (Modified BlueSky)

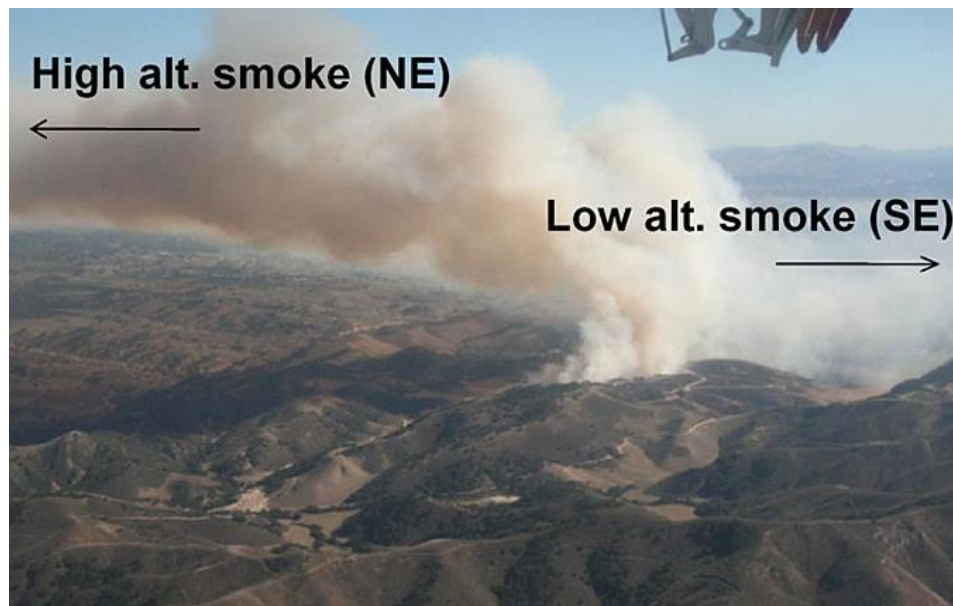
- SMARTFIRE-2 is queried at 10 pm PDT for USA fire locations and sizes
 - NOAA HMS fire-detects and Infrared fire perimeters from GEOMAC
 - “Spin-up” (24-hrs) look back and “persistence” assumption used for
 - Fire locations detected 1-2 days prior to the forecast date.
 - All fire acreages divided by 3 to correct for HMS double counting.
 - Rx fire assumed if October – June, and treated as pile burn.
 - Rx Fires not fuel specific (assumes ~100 tons fuel burned per HMS detect)
 - Avoids very large over-estimates in cold months

- FCCS fuels map from BlueSky 3.5.1 is queried
 - Fire emissions and heat flux looked up from BlueSky sensitivity analysis
 - Emissions scale linearly
 - Heat flux scales non-linearly
 - Allows fire emissions to be processed in less than 5 minutes, even when there are 1000s of fire locations

- Canadian fire emissions come directly from BlueSky Canada
 - BlueSky Canada does not assume large acreage per HMS detect, so no Rx fire replacement or size adjustment is needed.

AIRPACT-5 Fire Plume Rise

- Original BlueSky approach specified Plume Top, Plume Bottom, and Smoldering Fraction based on Briggs (no PBL considered)
 - Used until 2014
- Improved SMOKE approach used WRF Planetary Boundary Layer height (meters a.g.l) to constrain plume rise
 - Used until 2018
- Note: SMARTFIRE aggregates HMS hot-spots locations, which directly impacts BlueSky heat and plume rise calculation.
 - Plume rise is modeled individually for each aggregate location.
 - Total heat release is used rather than heat/area. **This is too much!**



AIRPACT-5 Fire Plume Rise Update

New Modified Plume Rise Approach developed by Wei Zhang (IDEQ) addresses plume rise problems in the SMOKE approach:

1. Smoldering fraction is too low:

Change implements new smoldering fraction by plume class based on the literature (WRAP/ DEASCO3)

- SMOKE calculates smoldering fraction using area burned.
 - New “virtual fire area” provided to SMOKE

2. Plume rise was too high for large fires:

Change assumes multiple fronts for big fires and reduces the heat flux which drives plume rise

- SMOKE calculates plume rise as a function of heat
 - New lower “virtual heat” provided to SMOKE

Artificial Intelligence / Machine Learning for improved forecasts:

Random Forest and Multiple Linear Regression Daily Max 8-hr Ozone. (Fan, Dhammapala, & Lee)

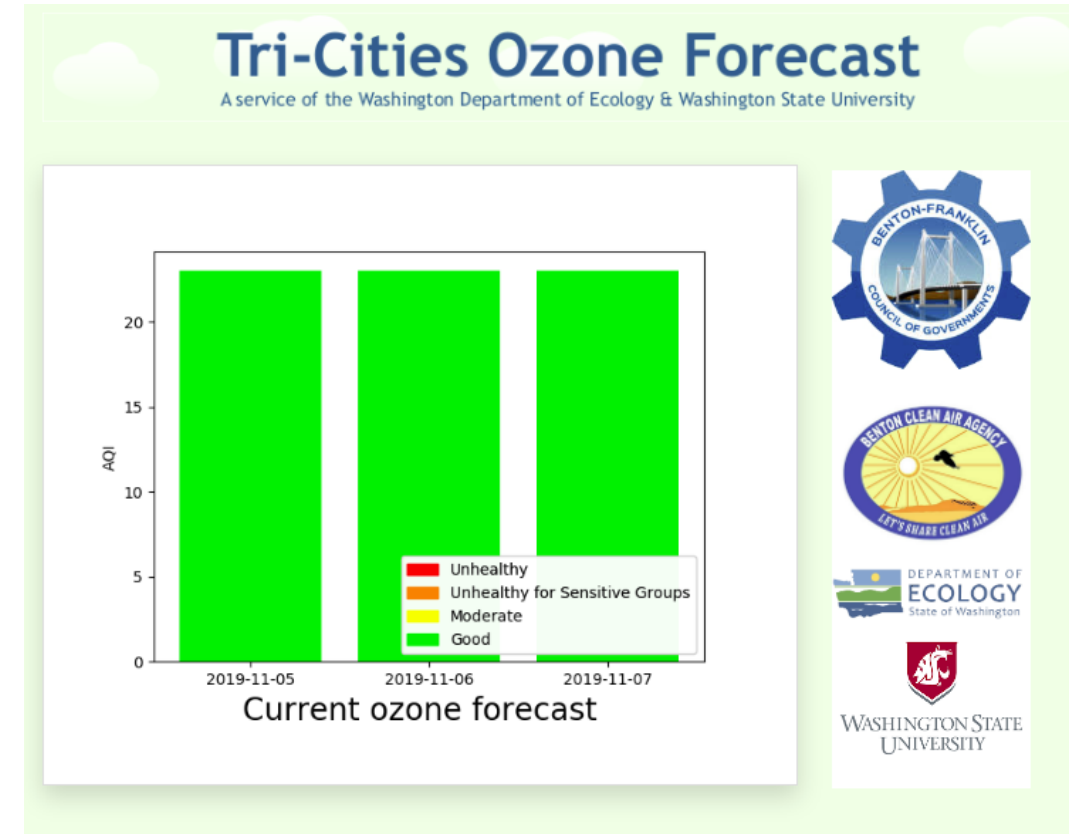
- Predicts high ozone events at Kennewick, WA.
- Models used:
 - multiple linear regression,
 - generalized additive model, and
 - random forest model

WRF met in Kennewick (PBL, P, Temp, U, V, RH) + month + weekday + hour + previous day 8-hr avg. O₃

Multiple Linear Regression (MLR)

Generalized Additive Model (GAM)

Random Forest Model (RF)

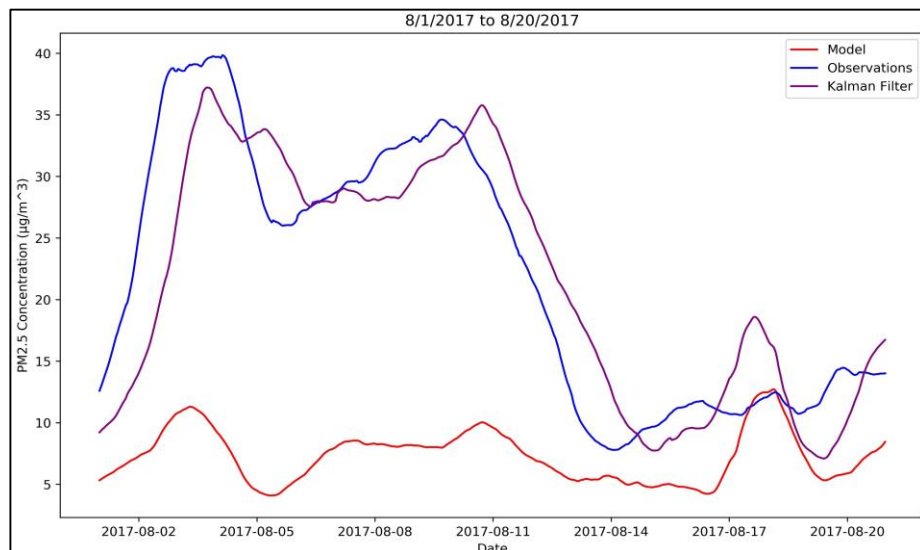


Tri-Cities Ozone Forecast is now featured on the AIRPACT5 Home Page!

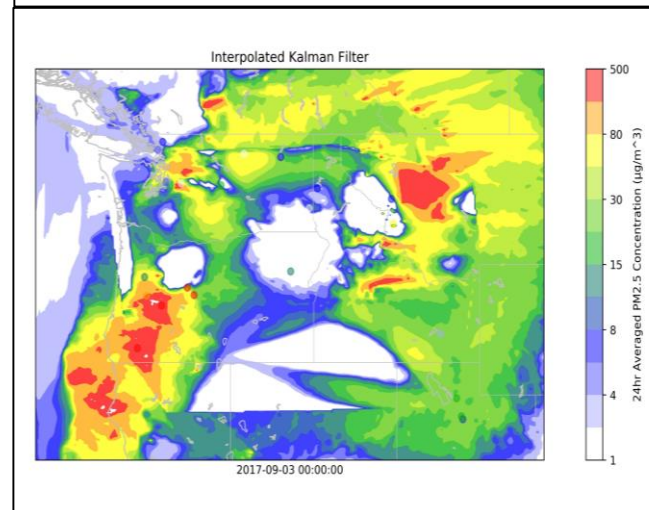
Artificial Intelligence / Machine Learning for improved forecasts:

Kalman Filter Bias Correction for 24-hr (average) PM2.5 forecast, in development.

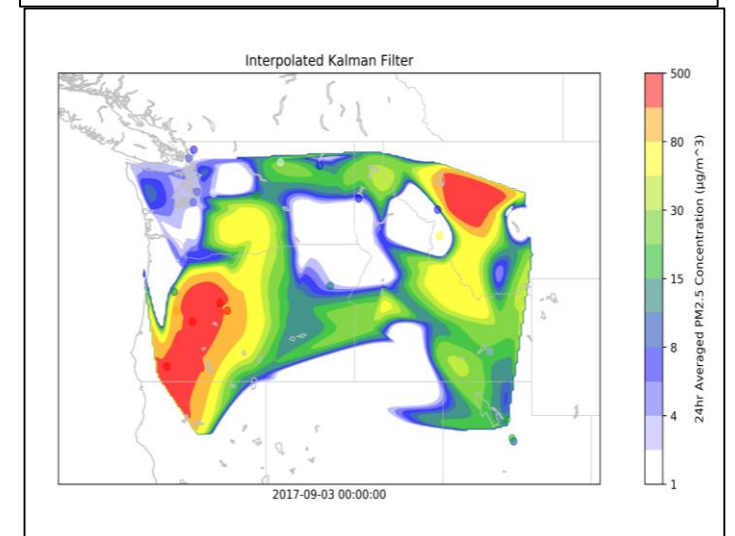
- Compute Kalman Filter Bias at each monitoring site for 24-hr PM2.5 using preceding four days, and Apply Correction:
 - Grid-applied method:
 - Interpolate the Bias over grid w/ cubic-spline and correct gridded forecast.
 - Site-applied method:
 - Apply Bias as correction to forecast at monitor grid-cell, and interpolate w/ cubic-spline.



Grid-Applied for 20170903.



Site-Applied for 20170903.



CENSE: CARDIOPULMONARY EVENTS FROM SMOKE ESTIMATOR

- CRFs: Concentration Response Functions for 7 conditions (asthma, COPD, Myocardial Infarction, etc.) from WA ECY Matt Kadlec.'s review of biomass burning smoke $PM_{2.5}$ epidemiological literature.
- Relative Risk [excess %]: $RR = F(\text{cardiopulmonary cond.}, \text{age}, 24\text{-hr } PM_{2.5})$
- Relative Risk map = $F(\text{AP5 bias-corrected } PM_{2.5} \text{ forecast map}, RR(\dots))$
- Smart Phone App & website to serve Relative Risk forecast for users by: latitude/longitude, smart phone location, or user's zipcode.
- Covered under HIPPA?
- Funding:
 - Joint Fire Science Program,
 - Amazon Catalyst-WSU,
 - AI for Earth Microsoft Azure Compute Grant.
- In progress...



Thank you!

Questions?