

AIRPACT-Fire for enhanced communication of human health risk with improved wildfire smoke modeling

Serena Chung, Joe Vaughan, Brian Lamb

Laboratory for Atmospheric Research, Washington State University

Farren Herron-Thorpe, Matthew Kadlec

Washington State Department of Ecology

Adam Kochanski

Department of Atmospheric Sciences, University of Utah

Susan O'Neill, Narasimhan (Sim) Larkin

USDA Forest Service, Pacific Northwest Research Station

September 3, 2015

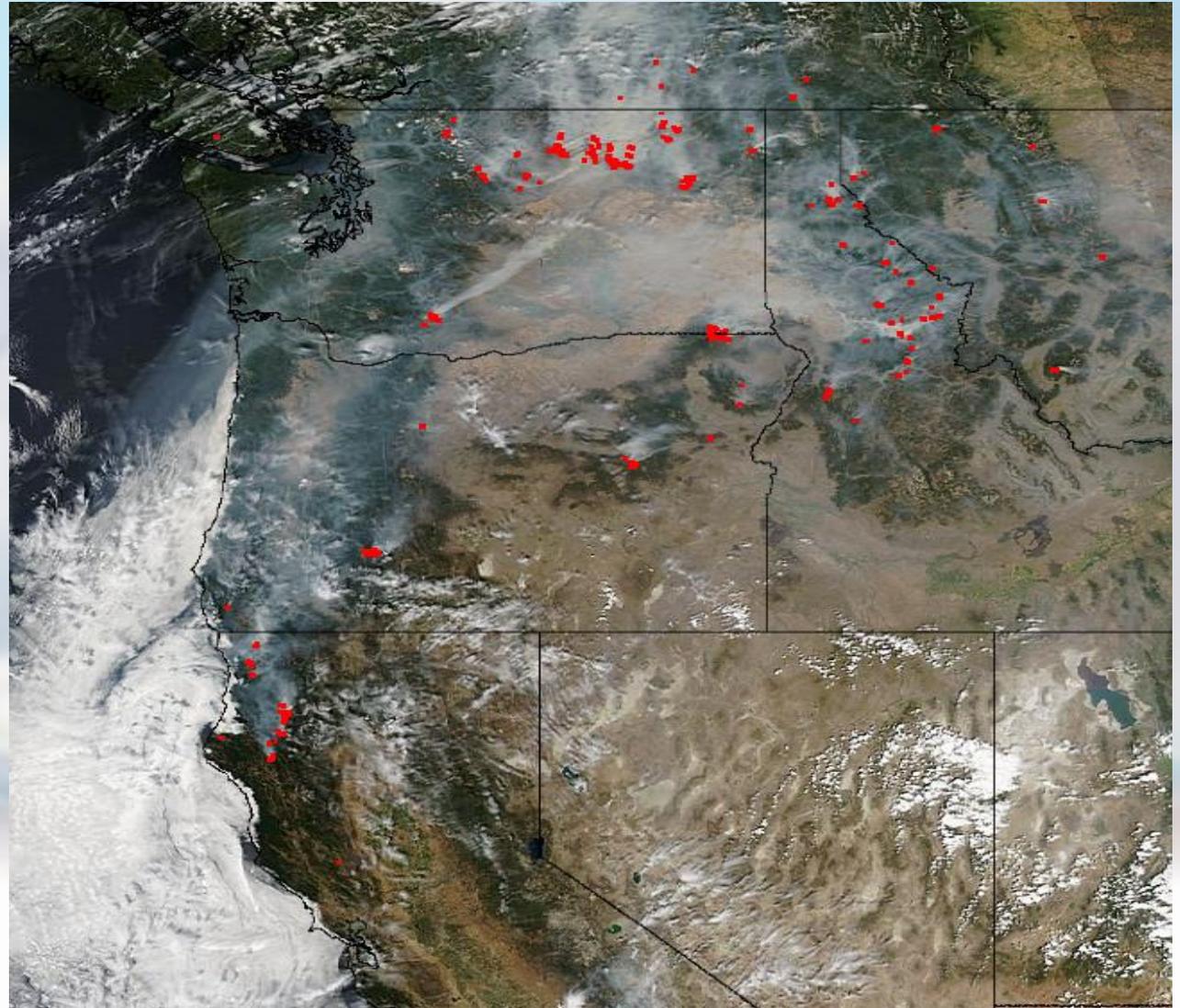


Presentation Overview:

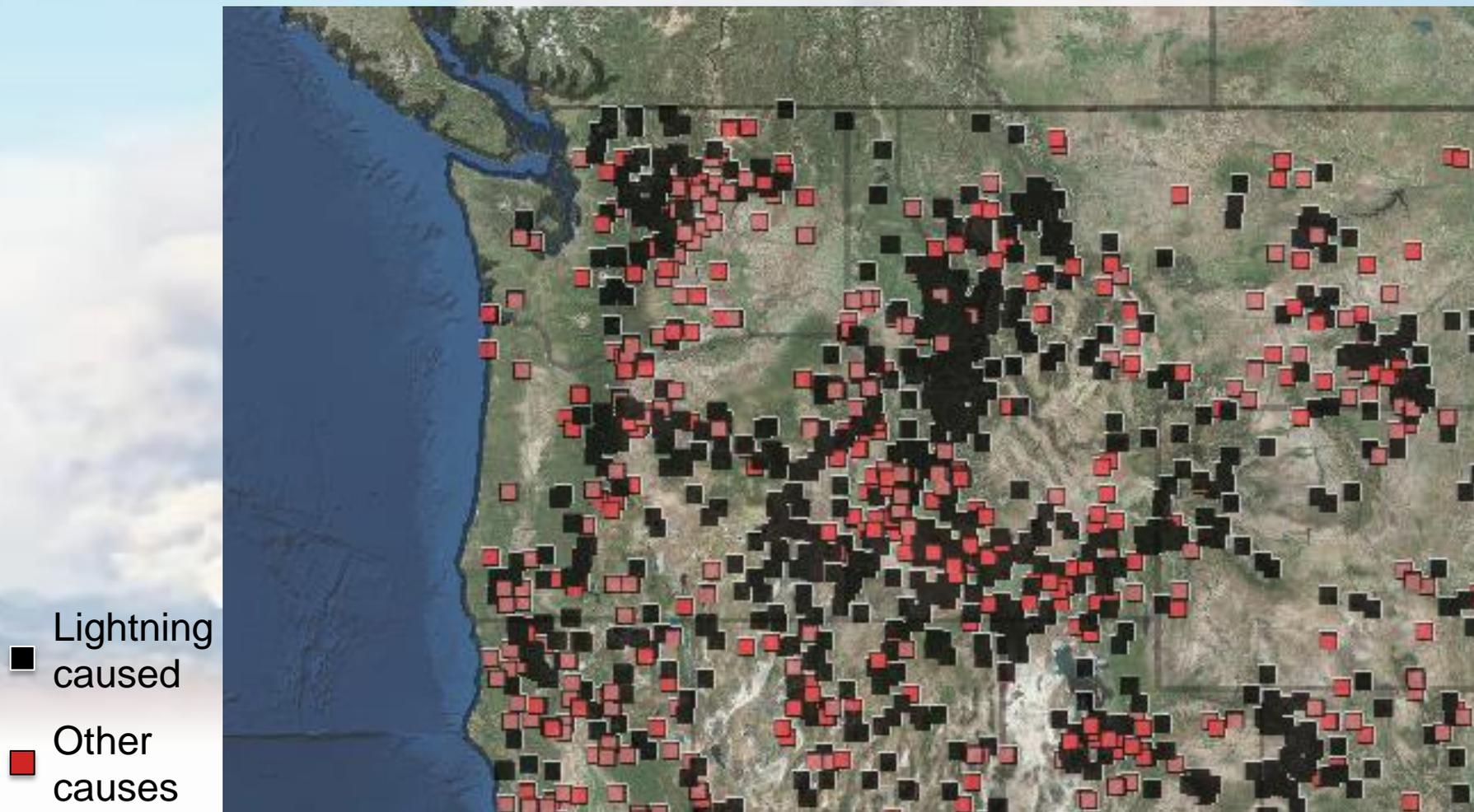
- ❖ Fires in the Pacific Northwest (PNW)
- ❖ Overview of the AIRPACT Forecast System for the PNW
 - ❖ Fire Emissions Framework
 - ❖ Model Evaluation
- ❖ Planned upgrade
 - ❖ WRF-SFIRE
- ❖ Summary

Current Ongoing Wildfire Season

MODIS Image
August 23, 2015



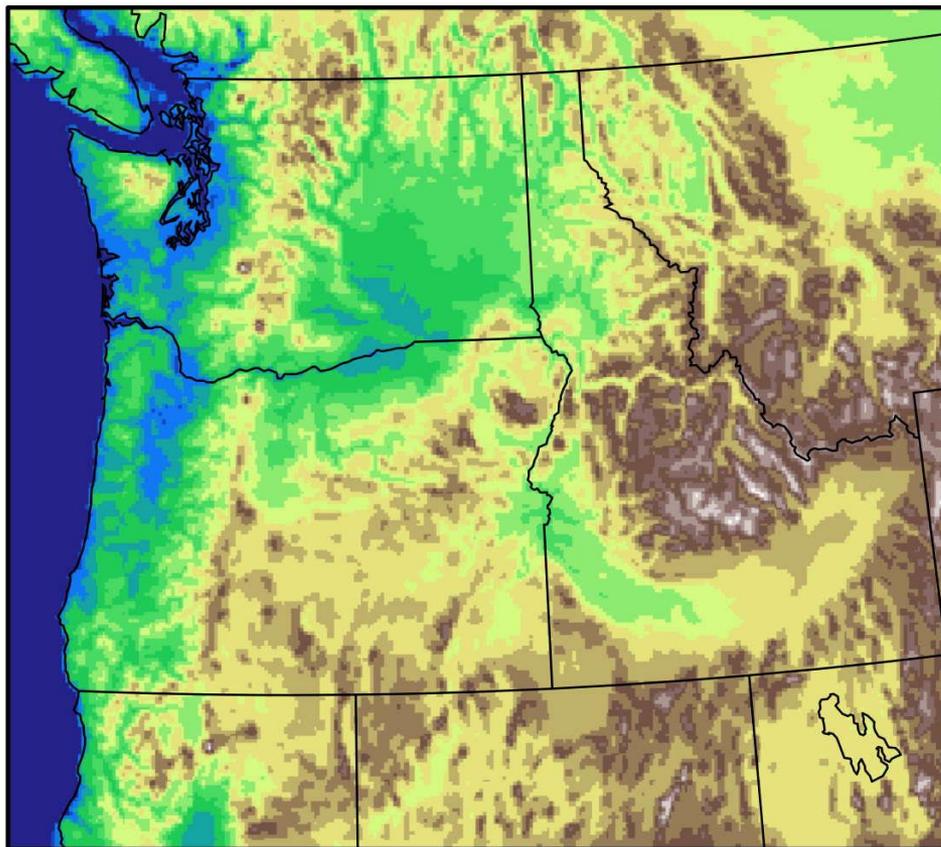
Wildland Fires in the Pacific Northwest during 2012-2014



From GEOMAC: <http://www.geomac.gov/viewer/viewer.shtml>

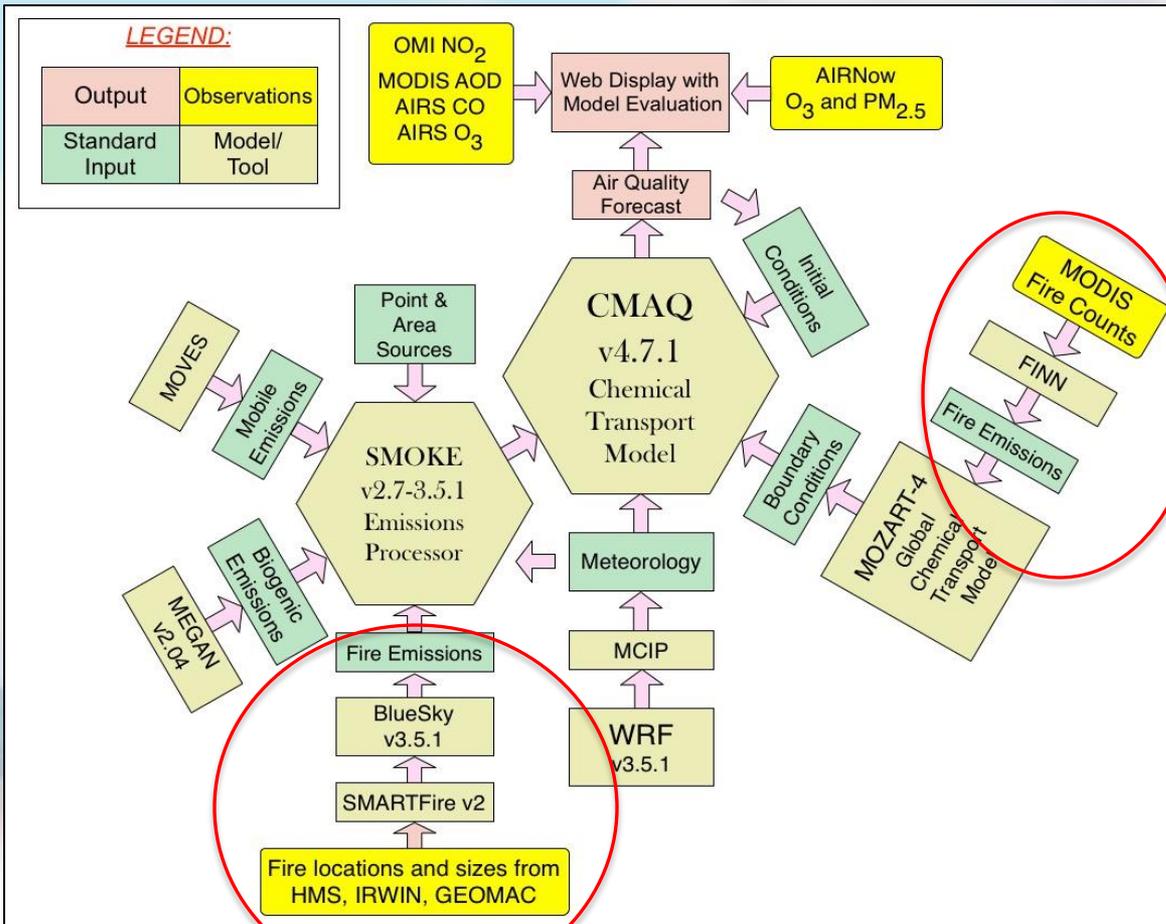
AIRPACT Regional Air Quality Forecasting System:

Model Terrain on 4-km CMAQ grid



- ❖ Pacific Northwest domain
- ❖ Operational since 2001
- ❖ ~7 years of online archive
- ❖ AIRPACT-4
 - 48-hour forecasts posted to the web daily by ~5 am Pacific Time
 - 4-km x 4-km grid cells (285 columns x 258 rows)

AIRPACT-4 Modeling Framework



❖ WRF-ARW v3.5.1

- Daily forecasts from Univ. of Washington

❖ CMAQ v4.7.1

- SAPRC99 gas-phase mechanism
- AERO5 aerosol module

❖ MOZART-4

- Daily forecasts for chemical boundary conditions

Components of AIRPACT-4

Fire Emissions Framework:

- ❖ Within CMAQ domain:
 - *SMARTFIRE2* for fire activity (locations and sizes)
 - *BlueSky 3.5.1* for emission and heat flux
 - Emissions for Canada are obtained from the *BlueSky Canada* system: <http://firesmoke.ca/data/emissions/sf2>
 - *SMOKE* for plume-rise speciation of VOC and $PM_{2.5}$
- ❖ Chemical Boundary Conditions
 - *MOZART-4* (Emmons et al., 2010) includes fire emissions from *FINN* (Wiedinmyer et al. 2011), which is based on *MODIS Rapid Response* fire counts

SMARTFIRE2:

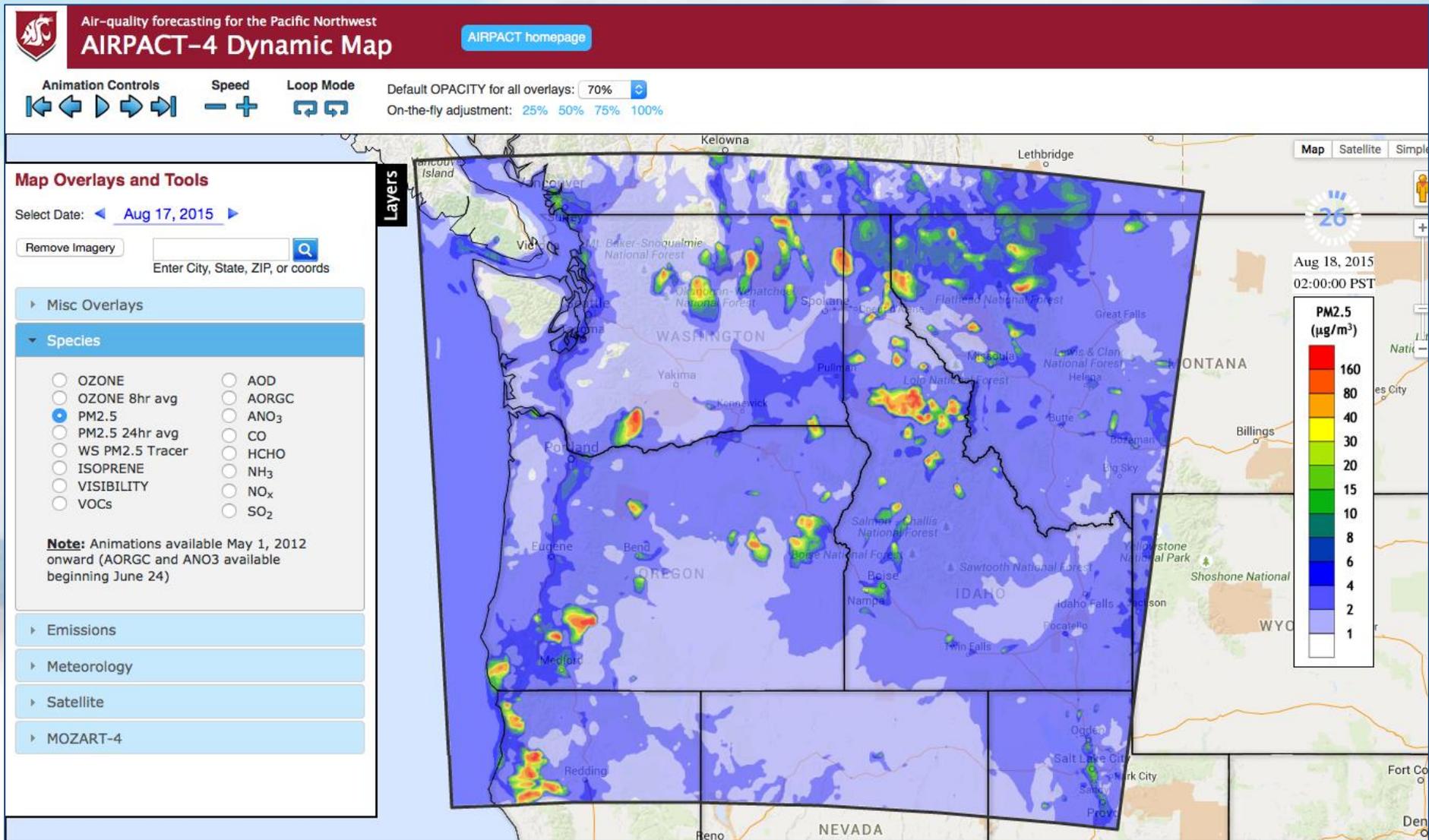
- ❖ Reconciles data streams:
 - *NOAA's Hazard Mapping System (HMS)*
 - *(Infrared fires perimeter from GEOMAC)*
 - *(Incident Command Information from IRWIN)*
- ❖ Provides fire locations and sizes (areas)
 - *Fire sizes scaled by number of HMS detects*
- ❖ Due to timing, forecast system is using fire locations and sizes from “yesterday”
- ❖ Reference: Larkin and Raffuse, 2012

Fire Emission Modeling:

- ❖ BlueSky v3.5.1 options selected:
 - *FCCSv2 fuels map (Prichard et al. 2011)*
 - *CONSUMEv3 for combustion completeness (Prichard et al. 2006)*
 - *FEPS for emissions (Anderson et al 2004)*
 - *BlueSky options not used: plume rise, dispersion, time rate*
- ❖ BlueSky Output
 - *Daily emissions of CO, NO_x, NH₃, VOC, PM_{2.5}*
 - *Daily heat flux*
- ❖ SMOKE v3.5.1
 - *Speciates NO_x, VOC, PM_{2.5}*
 - *Temporal profile for time rate*
 - *Converts heat flux to buoyant flux to calculate plume rise using Brigg's algorithm*

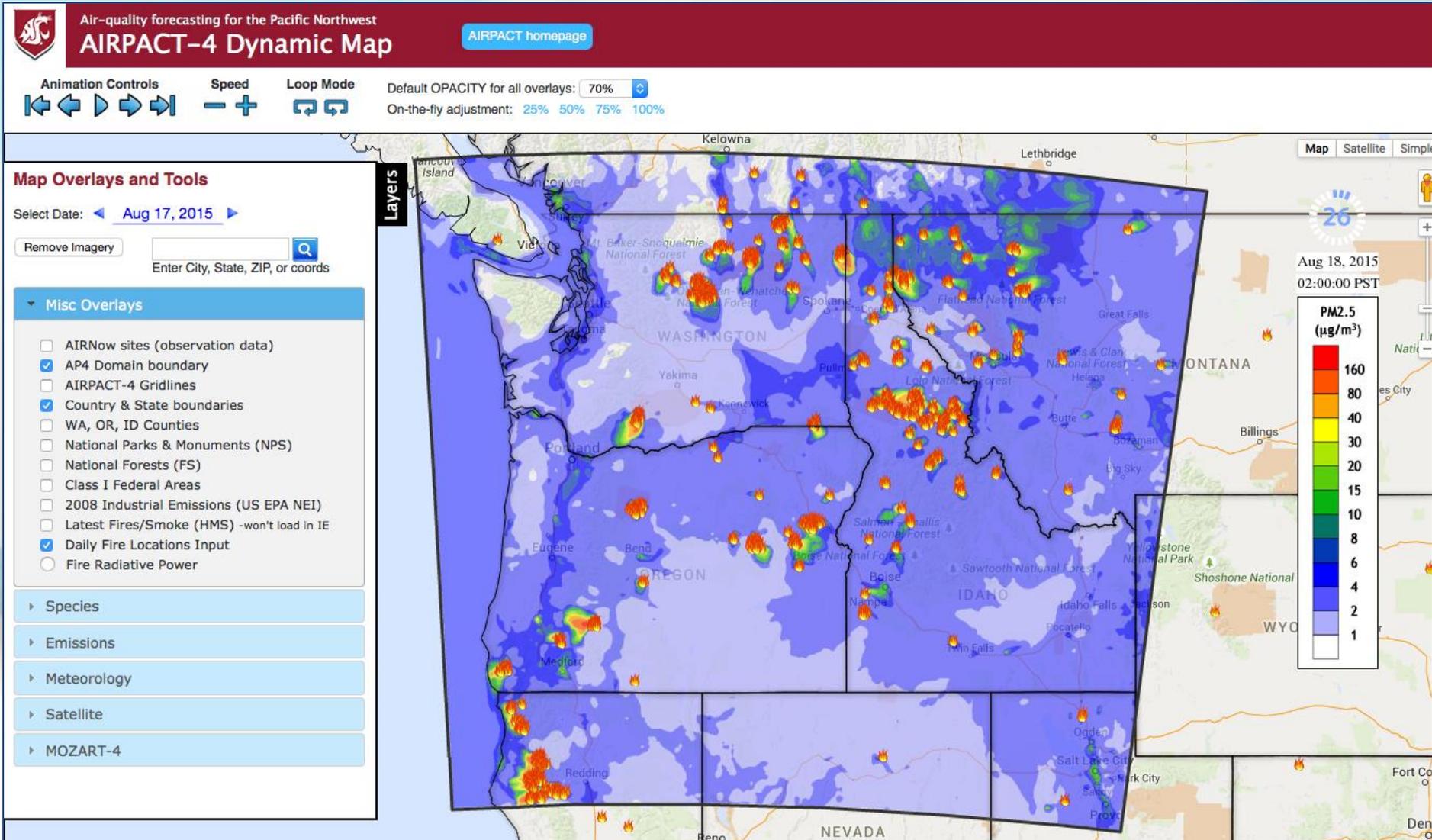
Online output – Hourly Concentrations

(<http://lar.wsu.edu/airpact>)



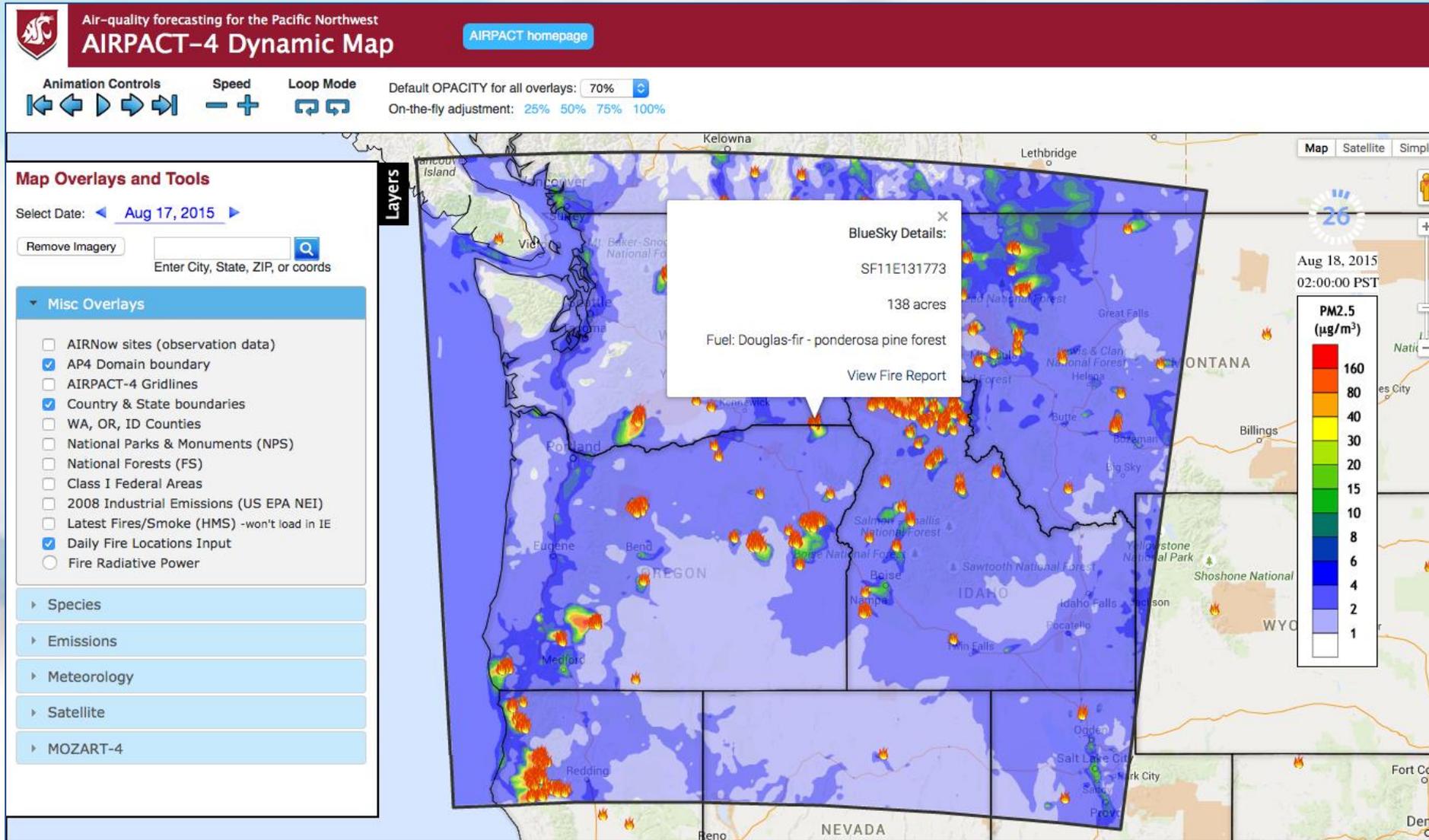
Online output – Daily Fire Locations

(<http://lar.wsu.edu/airpact>)



Online output – Individual Fire Information

(<http://lar.wsu.edu/airpact>)



SMARTFIRE2 Information

(<http://128.208.123.111/smartfire/events/5554c709-3134-4fb8-a7ad-6d2f823082a5/>)

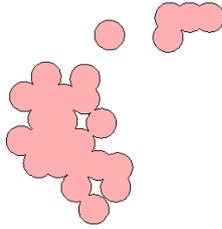


admin data **events** streams

[Home](#) • [Events](#) • [realtime](#) • [Unnamed fire in Columbia County, Washington](#)

Unnamed fire in Columbia County, Washington

Location	Columbia County, Washington
Total Area	1,978 acres
First detected	Friday, Aug 14, 2015
Most recently detected	Monday, Aug 17, 2015
Detection confidence	70%
Containment	Unknown
Fire Type	WF



Attributes

CNTRY: USA
CNTRY_FIPS: US
CNTY: Columbia
CNTY_FIPS: 013
date_created: 2015-08-15
DateTime: 2015-08-14T21:20:00.000Z
display_name: Unnamed fire in Columbia County, Washington
EcoSys: 22
FIPS: 53013
FIPS_FULL: US53013
FIPS_representative_fraction: 100%
fire_type: WF
Lat: 46.112
Lon: -117.676
Method of Detect: MODIS
probability: 0.7
Satellite: MODIS AQUA
STATE: Washington
STATE_FIPS: 53
Time: 2120
unique_id: 5554c709-3134-4fb8-a7ad-6d2f823082a5
YearDay: 2015226

Detected As

Name	Source	Area	Start Date	End Date
Unknown Fire	HMS	1,978 acres	Friday, Aug 14, 2015	Monday, Aug 17, 2015

History

Date	Area (acres)
2015-08-13	660 acres
2015-08-14	542 acres
2015-08-15	710 acres
2015-08-16	66 acres



Version 2.0.44633.W388

Near-Real Time Evaluation

(<http://lar.wsu.edu/airpact>)

AIR-quality forecasting for the Pacific Northwest
AIRPACT-4 Dynamic Map [AIRPACT homepage](#)

Animation Controls: Speed: Loop Mode: Default OPACITY for all overlays: 70% On-the-fly adjustment: 25% 50% 75% 100%

Map Overlays and Tools

Select Date: Aug 5, 2015

Enter City, State, ZIP, or coords

Misc Overlays

- AIRNow sites (observation data)
- AP4 Domain boundary
- AIRPACT-4 Gridlines
- Country & State boundaries
- WA, OR, ID Counties
- National Parks & Monuments (NPS)
- National Forests (FS)
- Class I Federal Areas
- 2008 Industrial Emissions (US EPA NEI)
- Latest Fires/Smoke (HMS) -won't load in IE
- Daily Fire Locations Input
- Fire Radiative Power

Species
Emissions
Meteorology
Satellite
MOZART-4

2015 AIRPACT-4 vs AIRNow Performance

To open in a new tab, click [here](#).

Station
Kennewick-S Clodfelt

Date range
2015-07-28 to 2015-08-06

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

OZONE for Kennewick-S Clodfelt

OZONE 8-HR AVG (ppb)

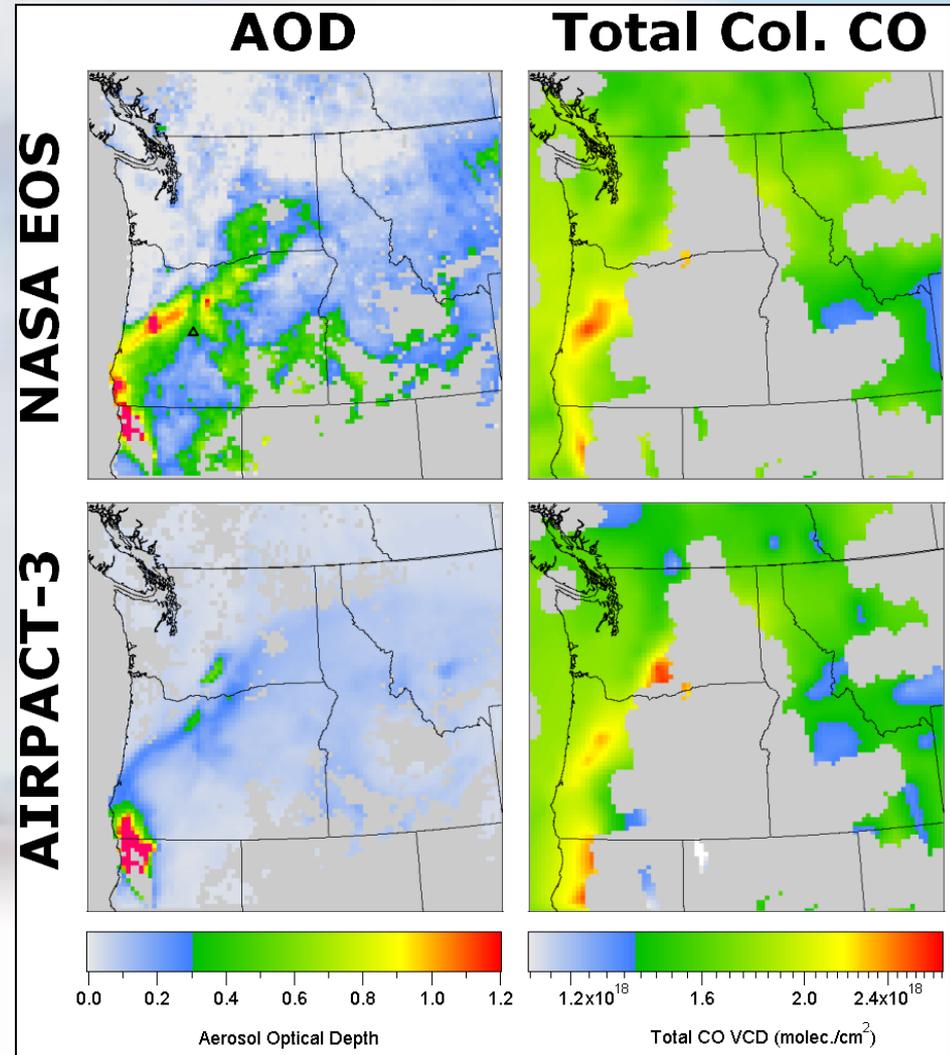
- 100
- 90
- 80
- 75
- 70
- 65
- 60
- 55
- 50
- 40
- 30
- 25
- 20
- 15
- 10
- 5
- 1

AIRPACT-3 Performance

(reanalysis, 12-km, BlueSky 3.1, CMAQ 4.6)

July 20, 2008 (~2 pm PDT)

- ❖ AIRPACT-3 forecasts of $PM_{2.5}$ downwind (+100 km) of fires are generally too low, in contrast to CO
 - Uncertainty in primary PM emission
 - Low VOC emissions
 - Low SOA
 - VOC speciation
 - Missing semi- and intermediate-volatile VOC in emission

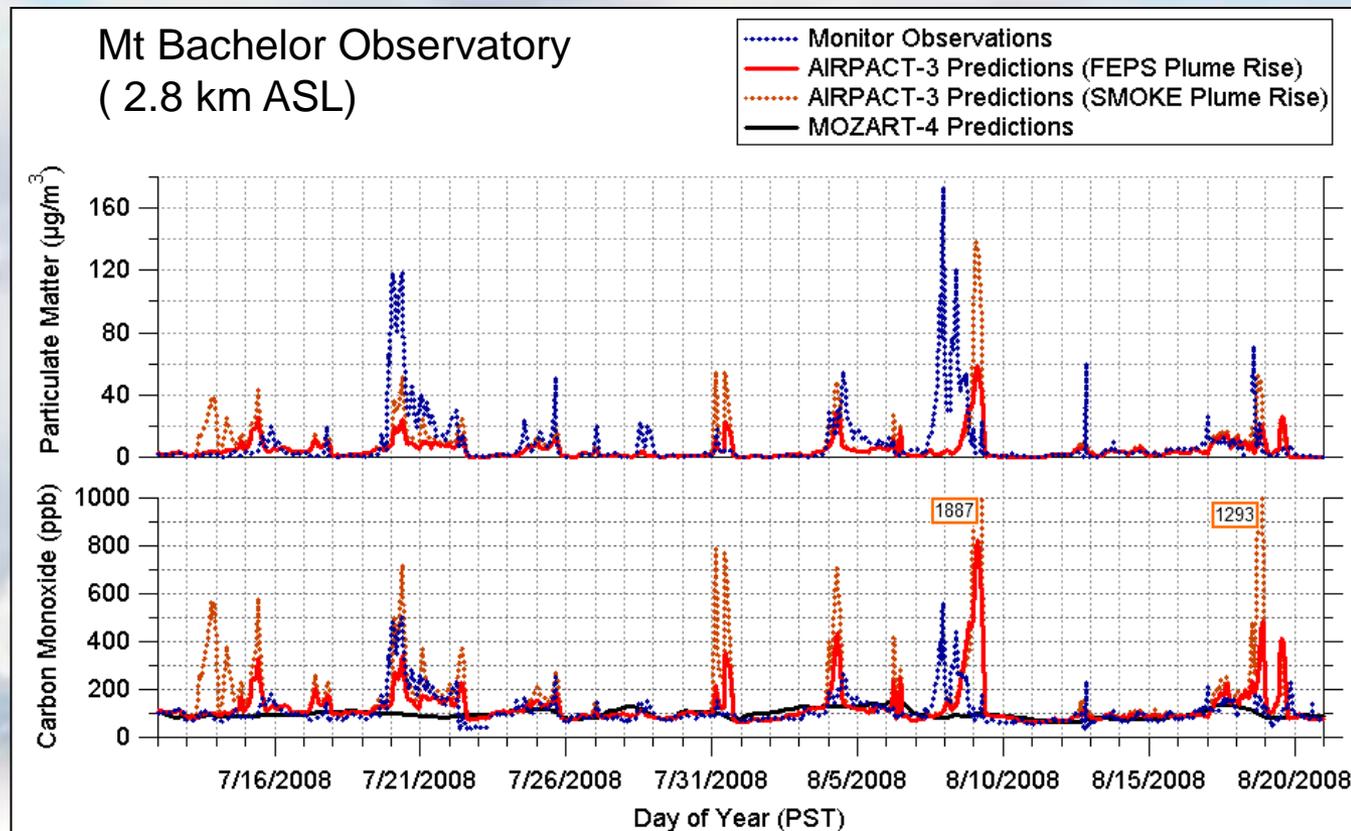


Herron-Thorpe et al. 2014

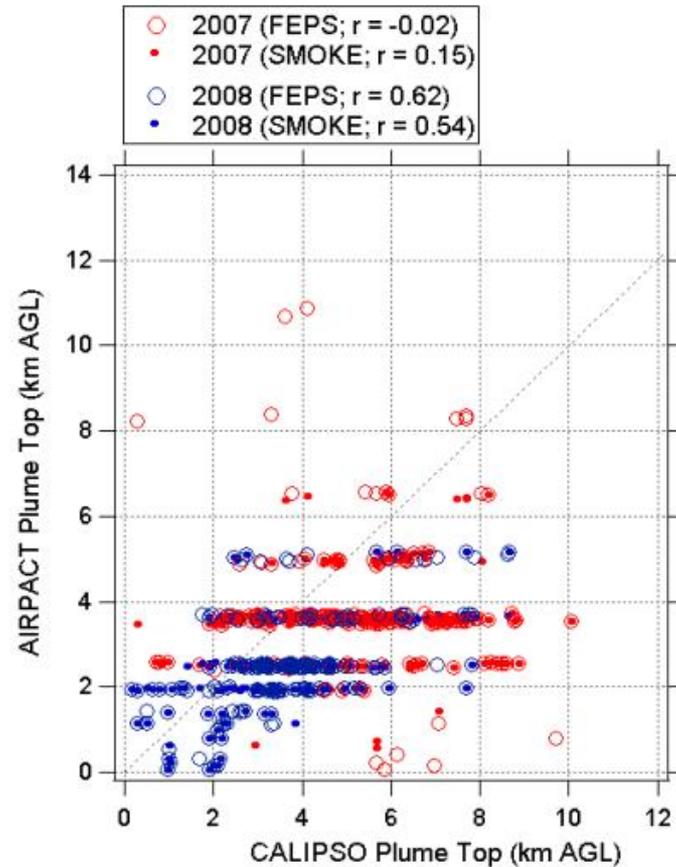
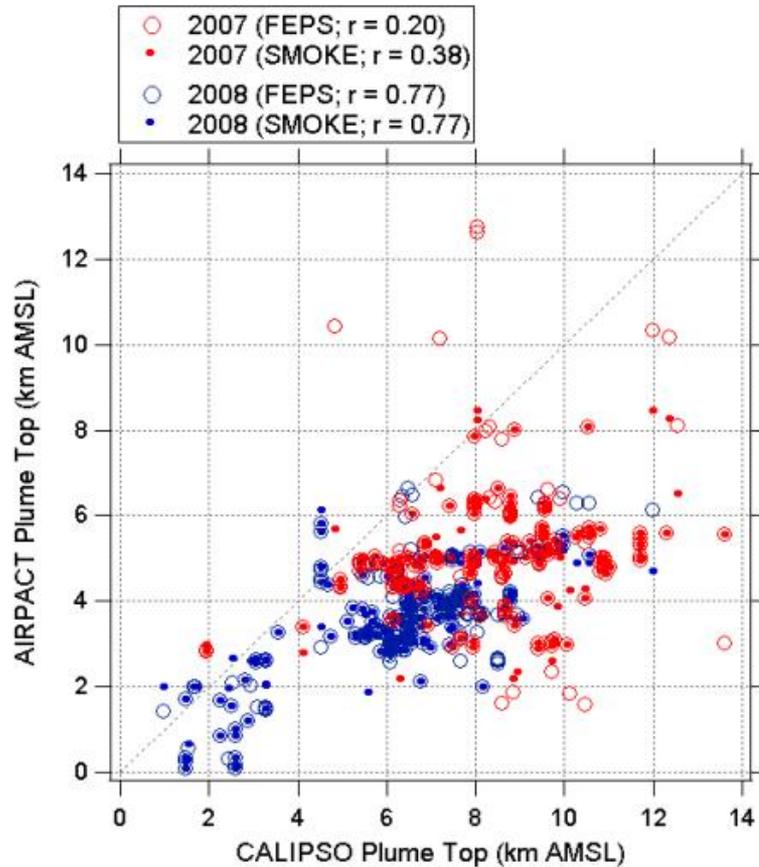
Comparison of Plume Rise methods

(AIRPACT-3 reanalysis 12-km, BlueSky 3.1, CMAQ 4.6)

- ❖ Model under-predicts $PM_{2.5}$ when CO performs well
- ❖ Treatment of plume rise makes a big difference



Comparison of Plume Rise methods (AIRPACT-3 reanalysis: 12-km, BlueSky 3.1, CMAQ 4.6)



Some Weaknesses in the Current Framework:

Real plume rise



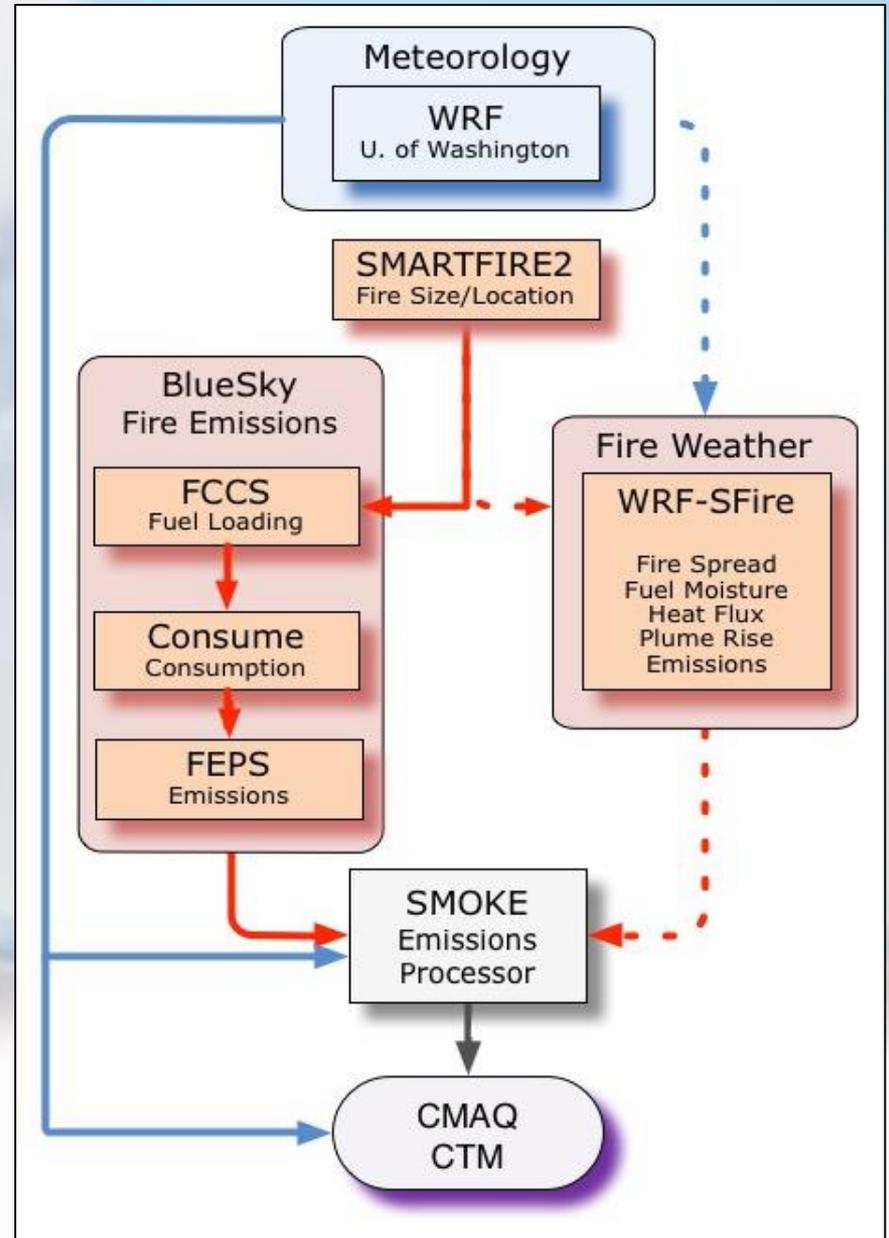
Modeled
plume rise



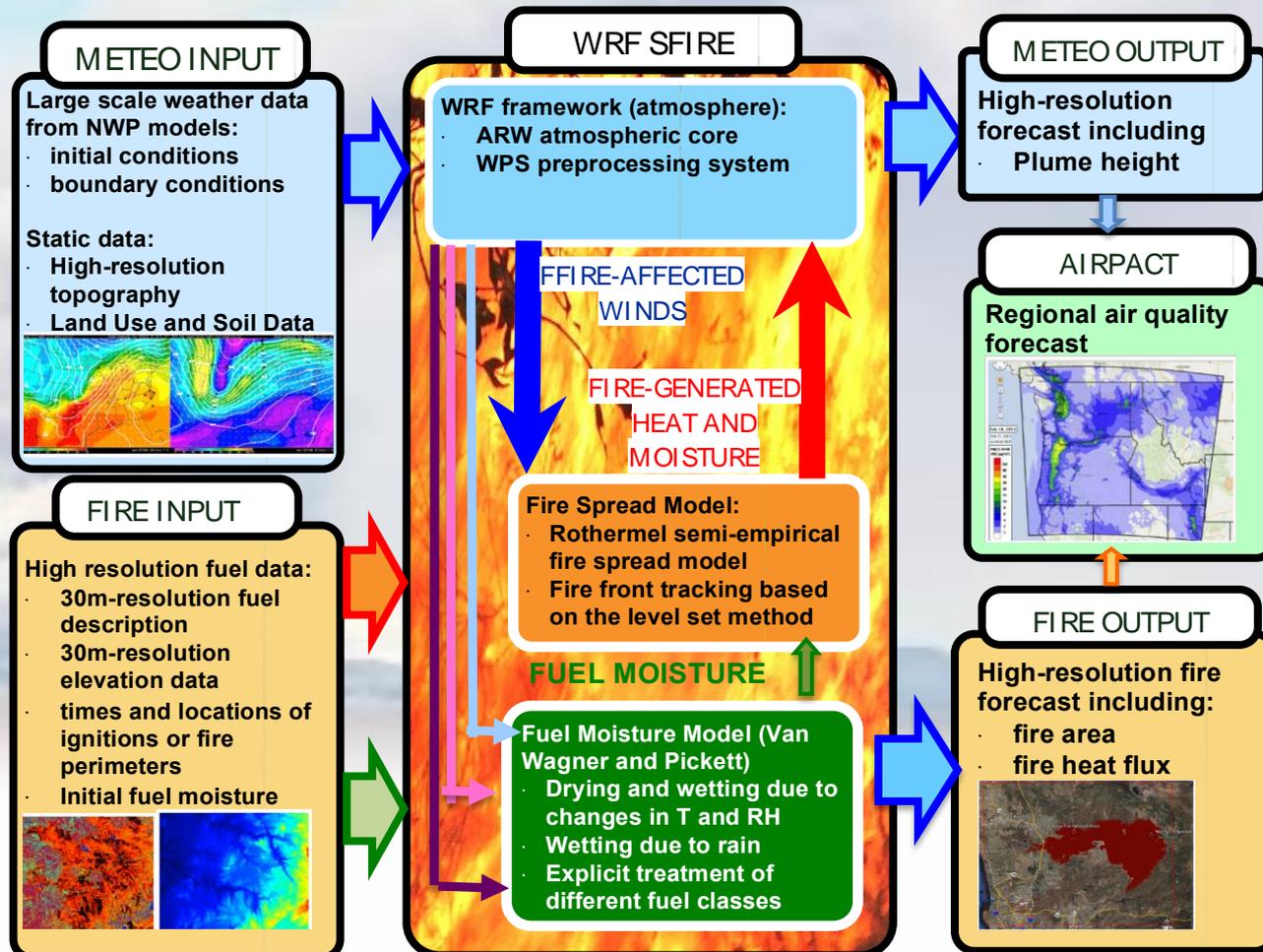
- ❖ Persistence Assumption:
 - *Tomorrow's area burned will be the same as that from yesterday's or two days ago*
- ❖ Fixed diurnal profile
- ❖ Plume rise
 - *Based on algorithm for power plants*
- ❖ Constant fuel moisture of "dry"

New Framework with WRF-SFIRE:

- ❖ WRF-SFIRE is a two-way coupled atmosphere and fire model (Mandel et al. 2011)
 - *WRF-ARW for meteorology*
 - *Rothermel (1972) semi-empirical fire spread model – fire spread depends on wind speed and terrain slope*
 - *Heat and moisture released by the fire feedback to atmosphere dynamics*

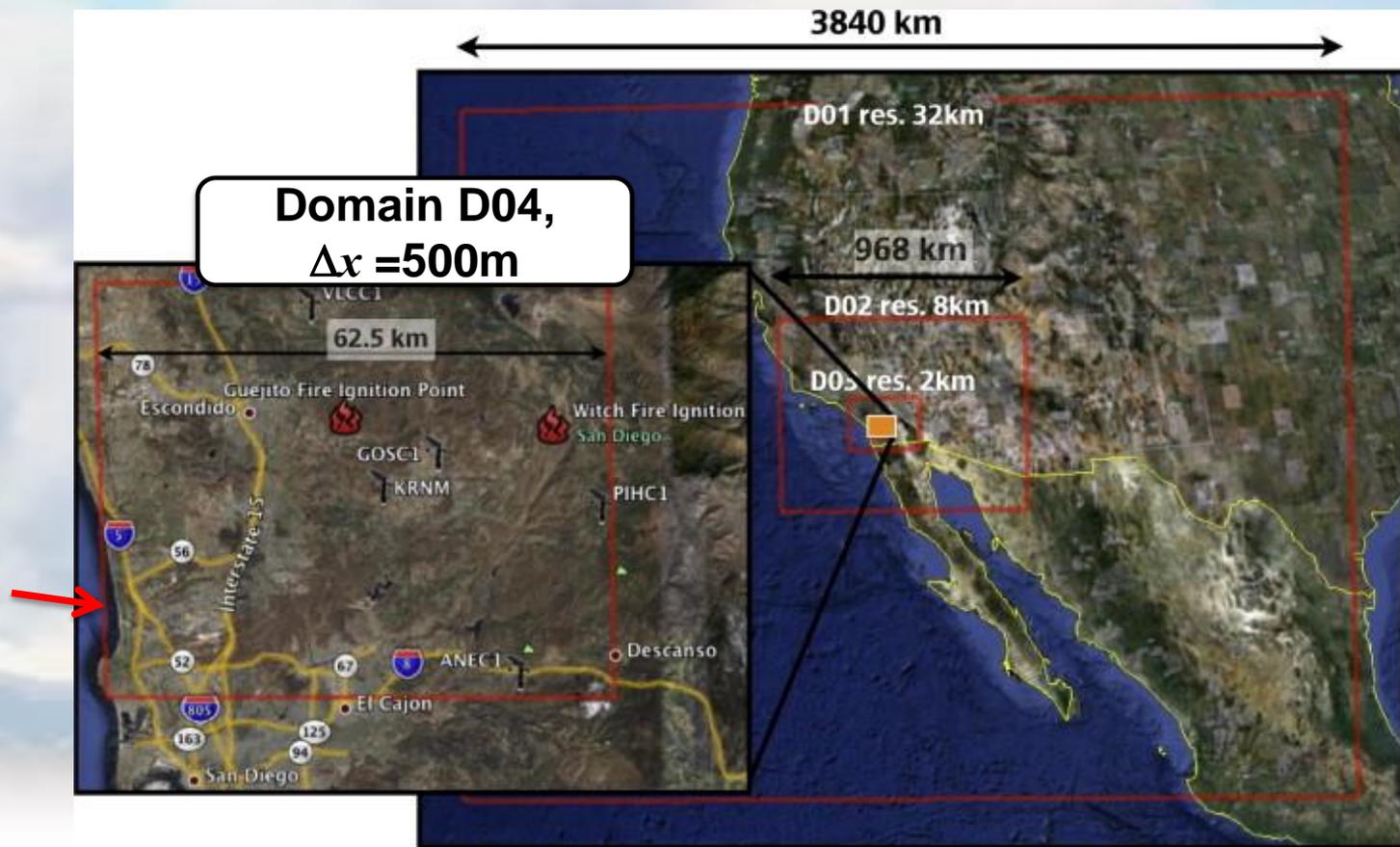


WRF-SFIRE: coupled atmosphere-fire model



WRF-SFIRE Reanalysis Case Study: 2007 Witch Fire

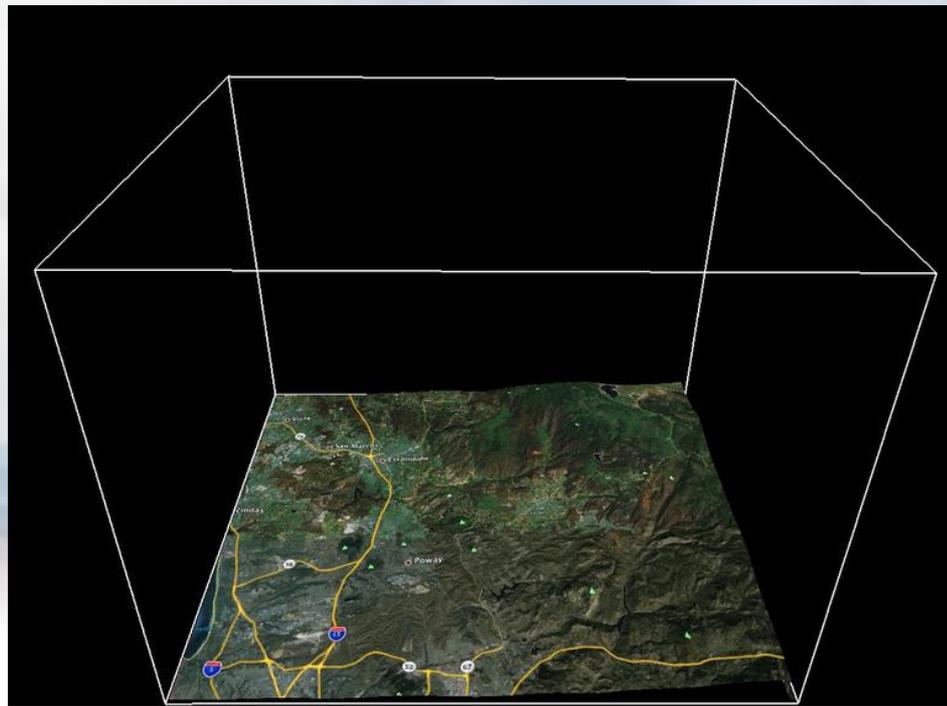
3125 x 2625
($\Delta x = 20 \text{ m}$)
fire mesh at
within the
smallest
WRF Domain



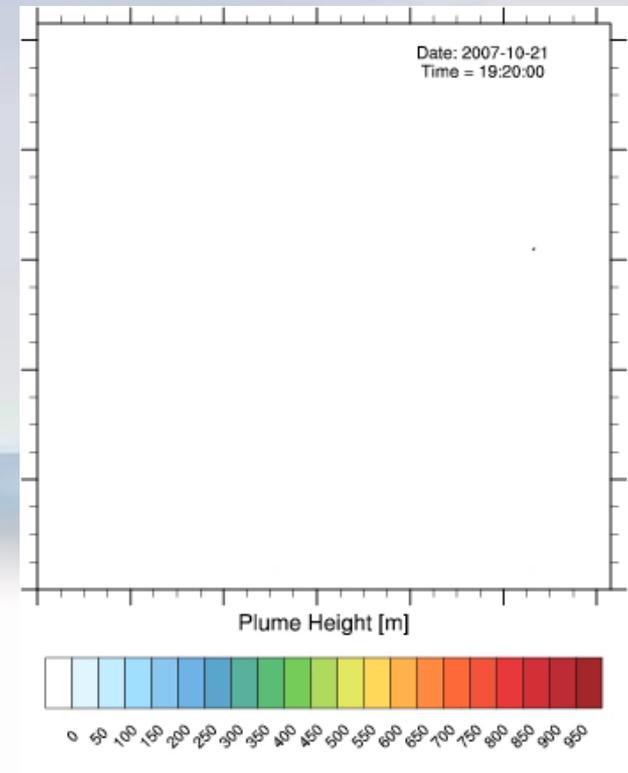
Kochanski et al. 2013

WRF-SFIRE Case Study: 2007 Witch Fire

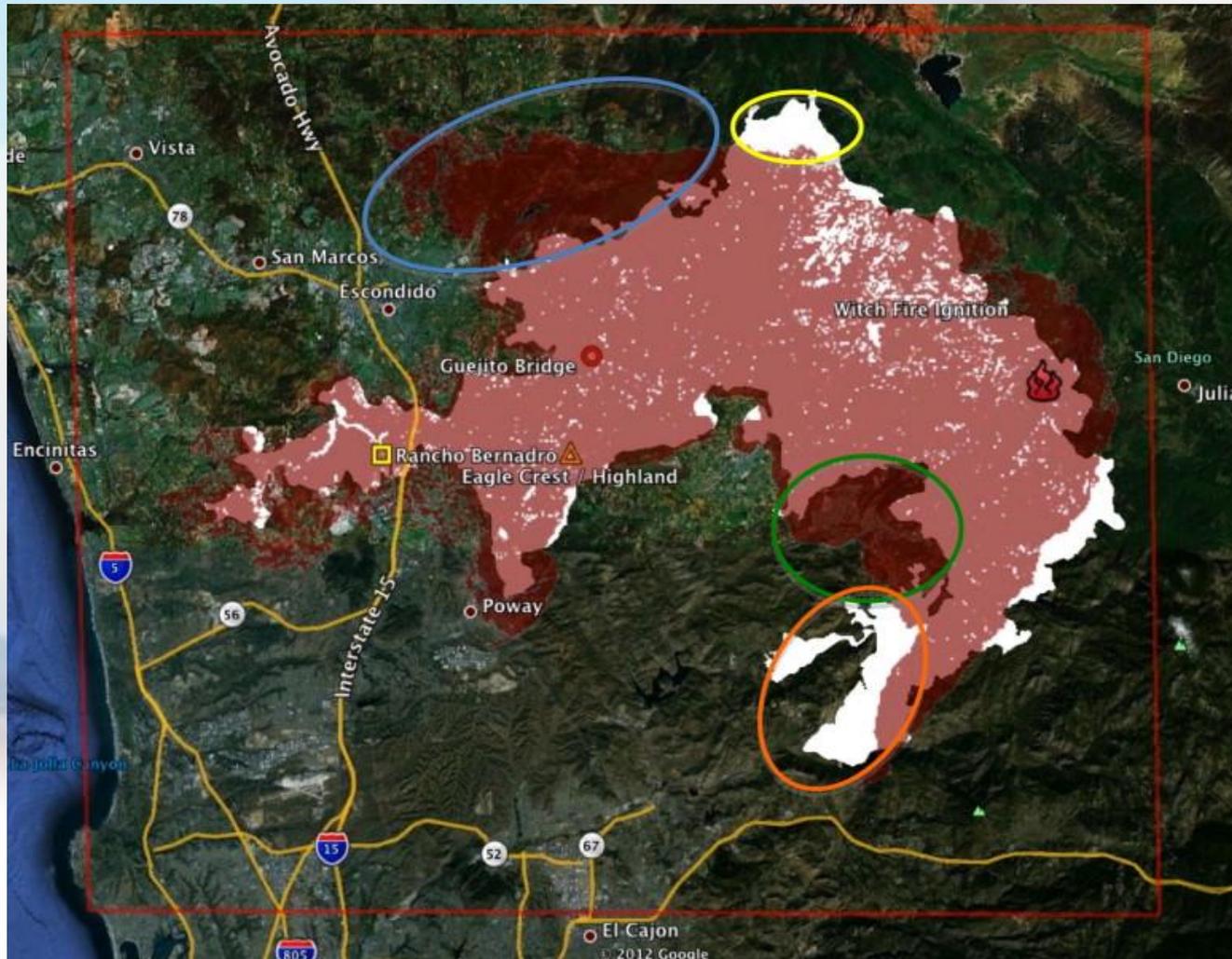
- The plume rise is resolved by the dynamics based on the amount of the fire-generated heat and meteorological conditions
- Emissions are computed based on FINN
- Smoke may be represented as a passive tracer (fast), or as chemical fluxes integrated with WRF-Chem (slow)



← 62.5 km →



WRF-SFIRE Case Study: 2007 Witch Fire



Observed (white)
vs. simulated (red)
fire perimeter at 17
PDT on October 23
2007 (60 hours into
simulation)

Kochanski et al. 2013

Summary

- ❖ AIRPACT is a widely used tool for federal, state and local agencies in the PNW in managing air quality concerns
- ❖ In retrospective mode (when fire activity is more certain), AIRPACT generally models smoke location well but $PM_{2.5}$ concentrations are under-predicted due a combination of primary emissions being too low and not enough SOA.
- ❖ Future work includes:
 - ❖ Use WRF-SFIRE for dynamic fire area and plume rise
 - ❖ Update emission factors and speciation for VOC
 - ❖ Update SOA chemistry mechanism

Acknowledgements:

❖ NW-AIRQUEST:

EPA Region 10, Washington Department of Ecology; Washington Department of Natural Resources; Washington Local Air Agencies (Benton County Clean Air Agency, Northwest Regional Clean Air Agency, Olympic Regional Clean Air Agency, Puget Sound Clean Air Agency, Southwest Clean Air Agency, Spokane Regional Clean Air Agency, Yakima Regional Clean Air Agency; Idaho Department of Environmental Quality; Oregon Department of Environmental Quality; Lane Regional Air Protection Agency; Nez Perce Tribe; University of Washington; Washington State University; Environment Canada; BC Ministry of Environment; National Park Service, Pacific West Region; USDA Forest Service, Pacific Northwest Research Station

❖ NASA

❖ NSF

❖ NIST

❖ Joint Fire Science Program

WRF-SFIRE Case Study: 2007 Witch Fire

b) 10.22.2007 02:45 local time



c) 10.22.2007 05:00 local time



d) 10.22.2007 08:00 local time



f) 10.22.2007 20:00 local time



g) 10.23.2007 00:15 Local time



h) 10.23.2007 15:00 local time

