Assessment of regional air quality and health impacts from the NARA aviation biofuel supply chain

Vikram Ravi, Brian Lamb

Washington State University

Cody Sifford, Francesca Pierobon, Indroneil Ganguly

University of Washington

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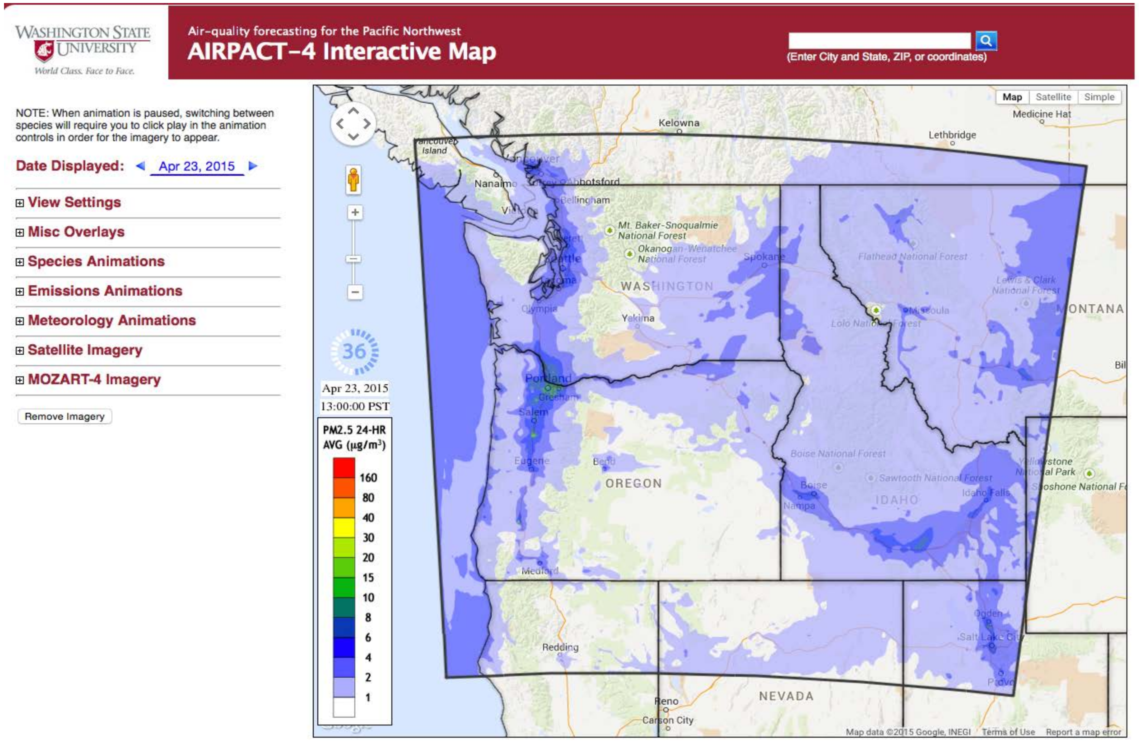
Motivation and objective

- There are a wide range of air quality issues that affect the Pacific Northwest:
  - Summertime ozone
  - Wintertime stagnation and elevated $PM_{2.5}$ concentrations
  - Smoke from prescribed and wild fires
  - Regional haze associated with a wide range of pollutant sources
  - Air Toxics
- **Objective** - for a NARA like supply chain and biorefinery, what will be the impacts on various criteria pollutants and other impacts such as on regional haze and human health?

We will follow two different cases for our work – prescribed fire approach and slash pile approach

AIRPACT air quality forecasting system



www.lar.wsu.edu/airpact

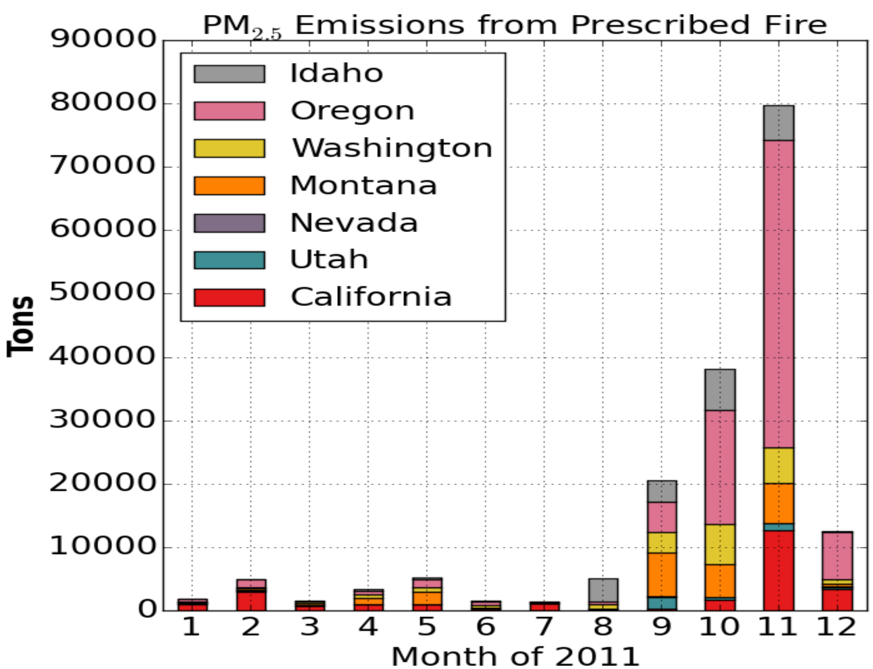
- First regional forecast system in the US, May, 2001
- Explicit and dynamic treatment of all anthropogenic and natural emissions, including wildfires
- Daily 48-hr forecasts
- Hourly concentration maps of ozone, PM and other pollutants

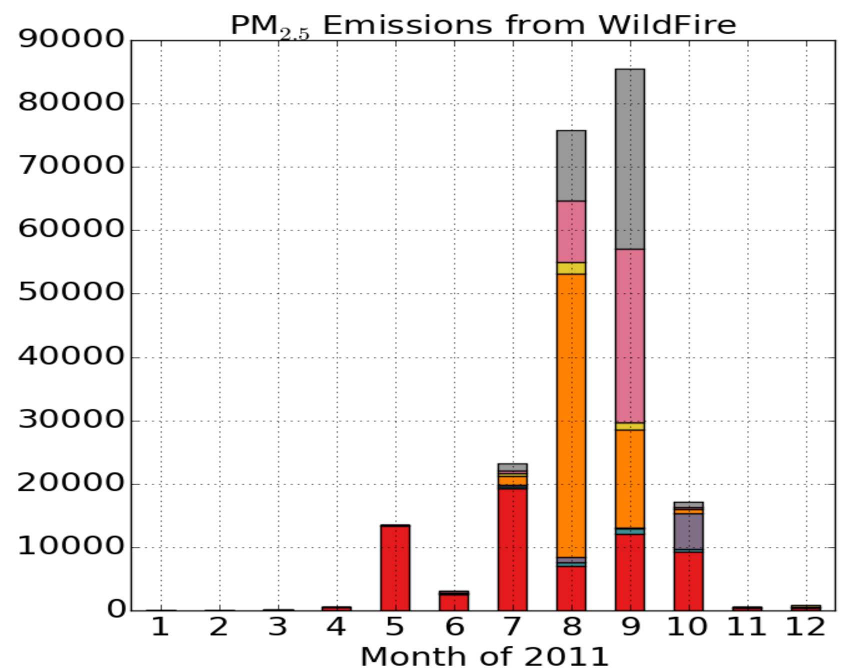
Northwest International Air Quality Environmental Science and Technology (**NW AIRQUEST**) Consortium

- a consortium of clean air agencies and institutions
- seeks to develop, maintain, and enhance a sound scientific basis for air quality management decision-making in the Pacific Western Region of North America

Methodology for the study

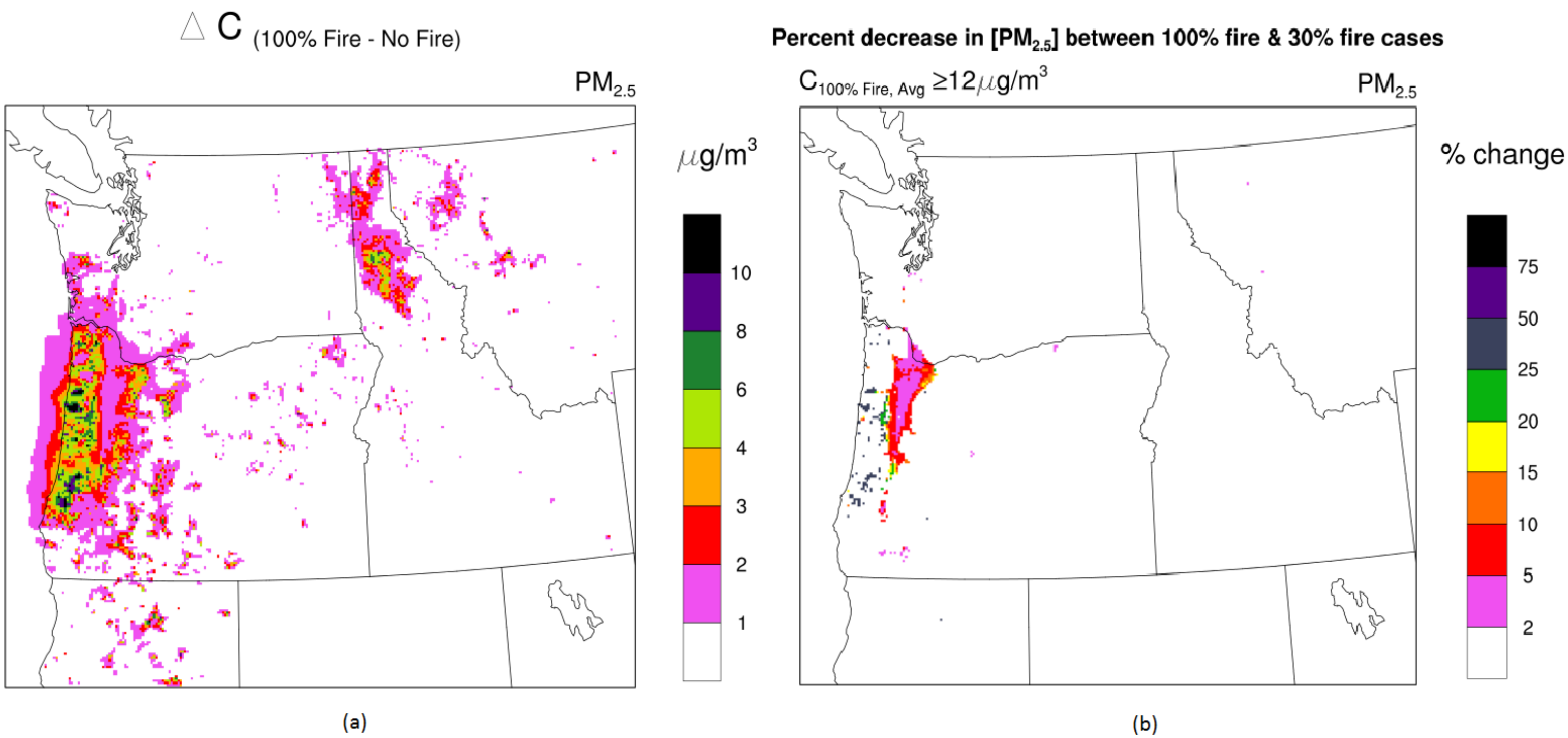
- Prescribed fire emissions for the model domain were extracted from the National Fire Emission Inventory (NFEI) 2011 available from the US EPA.





- Model simulations for October –November, 2011 for three different emission scenarios:
  - o **100% Fire (with fire) Case:** includes all the fire emissions as per NFEI 2011
  - o **30% Fire Case:** includes all the fire sources as per NFEI 2011, but all fire emissions uniformly reduced by 70%
  - o **No Fire Case:** none of the fires from NFEI 2011 were included

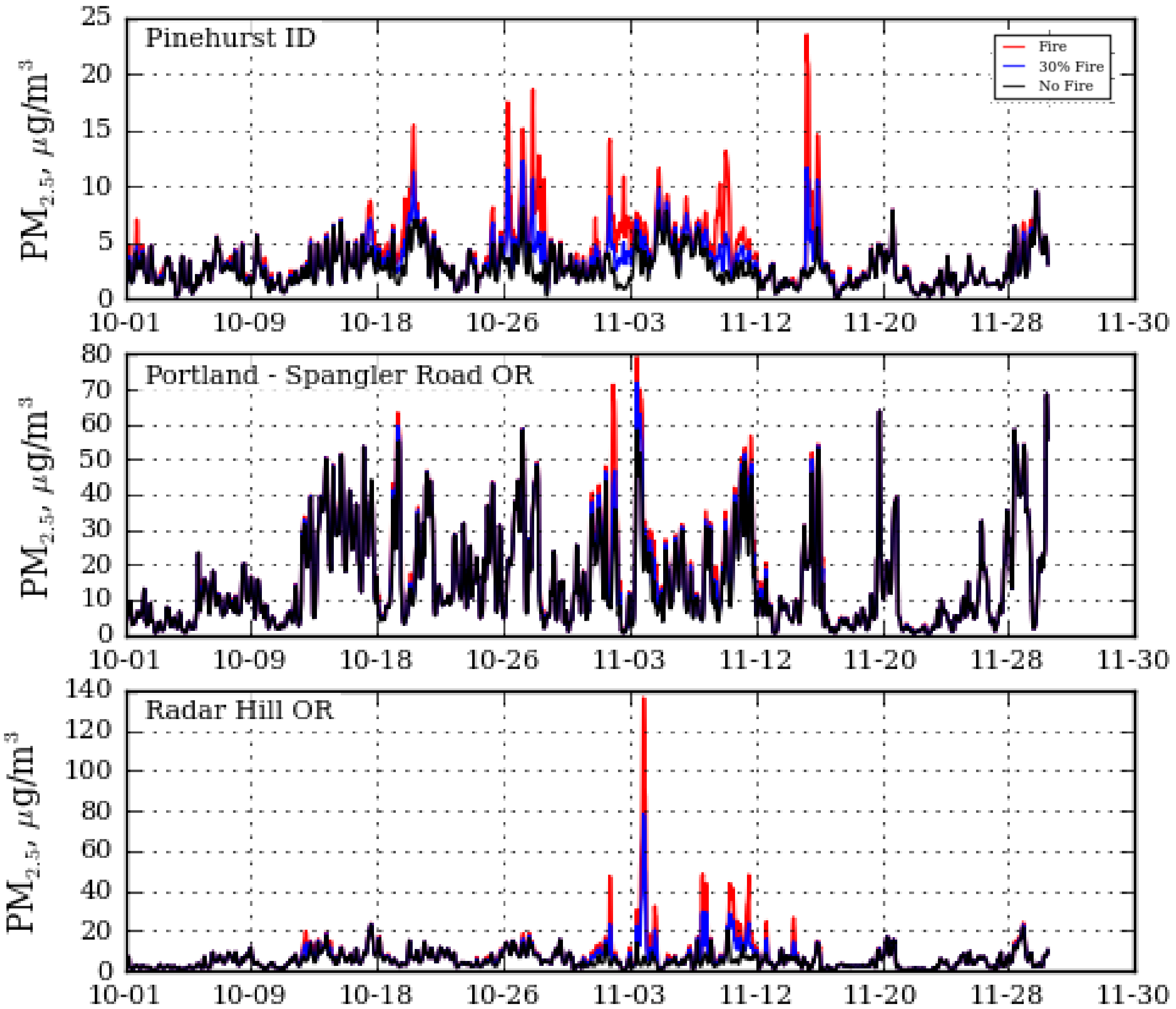
Impact of emission reduction by 70%



- 70% emission reduction scenario reduces $PM_{2.5}$ concentration by 50% -75% for some areas
- Emission reduction impact is maximum for Oregon (where most fires occur)
- Cells where 2 month average concentration for 100% fire case is > 12μg/m^3 only are considered.

Impacts at the local scale

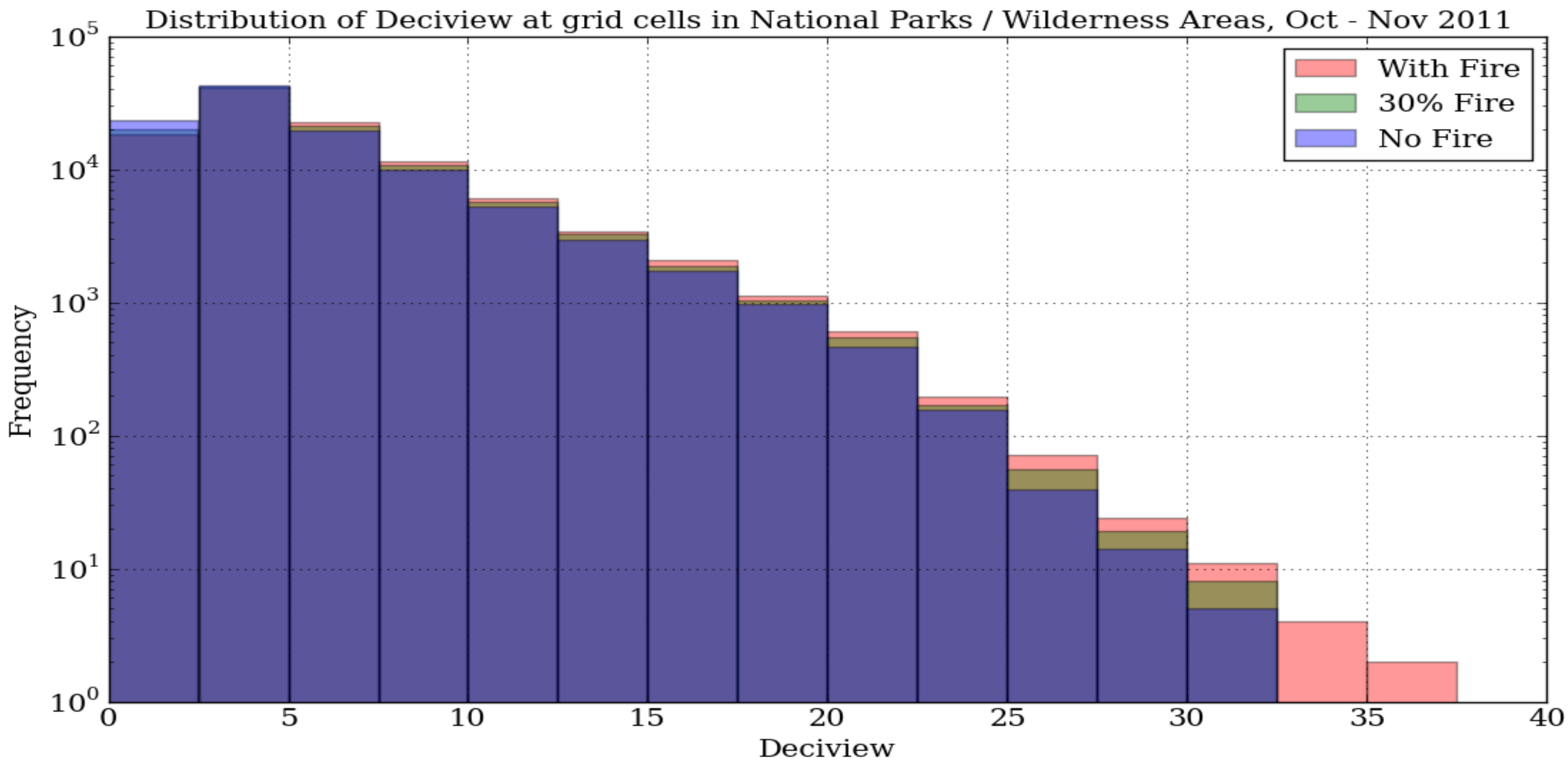
- Modeled simulations indicate elevated $PM_{2.5}$ concentrations at several locations
- Hourly concentrations increases of 40 - 140 µg/m³ seen at some locations which either adds to the already high concentrations or pollutes pristine environments
- Small – large contributions at some non-attainment areas such as Oakridge (OR) and Pinehurst (ID)



Visibility benefits

- Regional haze rule (1999) requires to improve visibility in protected environments to pre-industrial era by 2064
- *"Improving visibility during haziest days while not impairing during the cleanest days"*
- We looked at the visibility benefits of reducing fire emissions for
  - annual average basis,
  - haziest 20% days and
  - cleanest 20% days
- No changes were seen for the cleanest 20% days since most clean days were during January – June
- On an annual averaged basis, only few sites show visibility impairment due to all prescribed fires, and the benefits aren't significant
- During the haziest 20% days, a number of protected class I areas show visibility impairment due to prescribed fires and also visibility benefits for these sites for the 30% fire case

Impact on visibility in class I areas

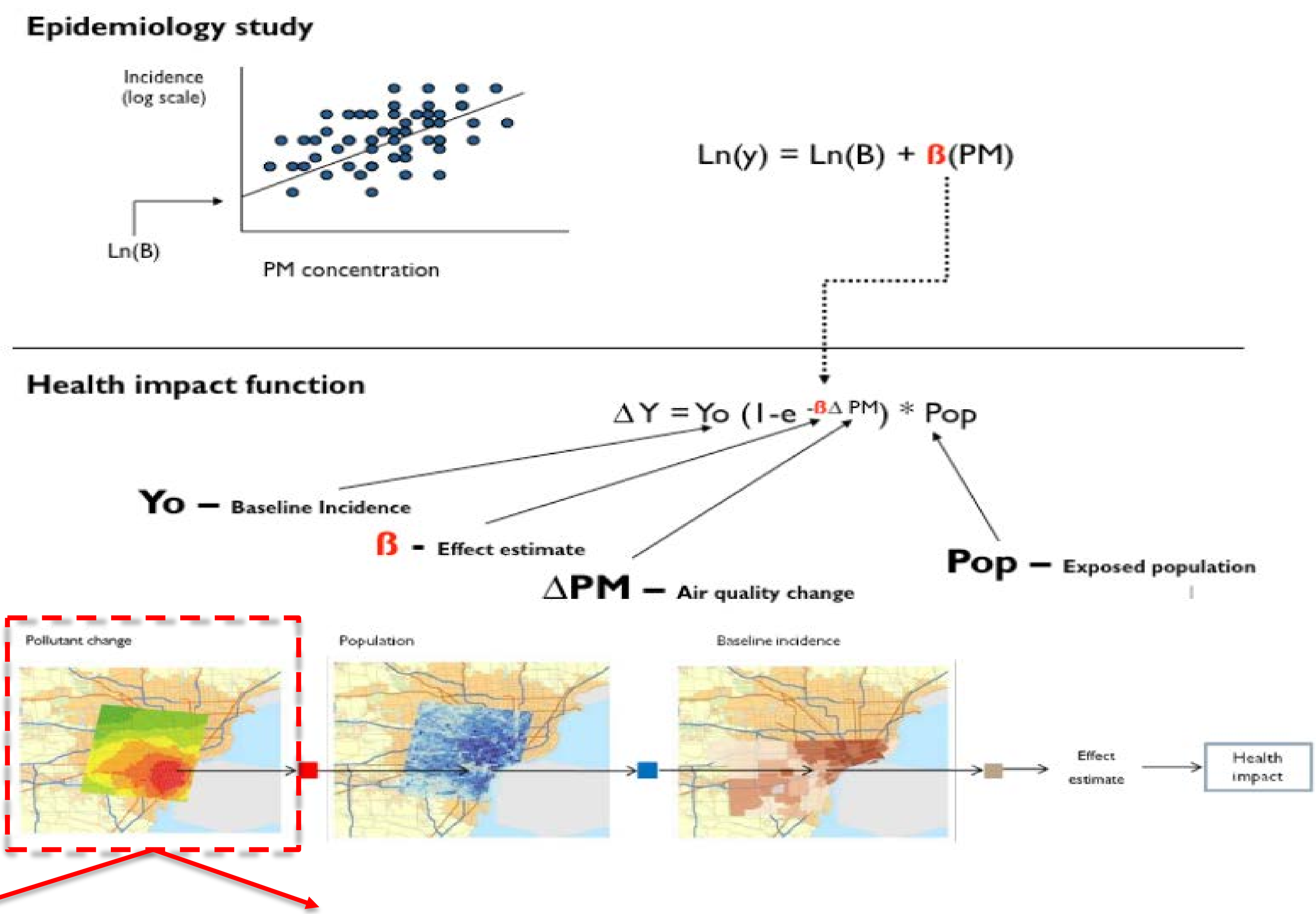


- At higher deciviews we see visibility improvements for a number of cells
- Overall distribution shifts to left, indicating improved visibility

Visibility benefits for the 20% haziest days at selected sites

Site Name	Observed recalculated	Modeled		$(DV)_{Fire}$ – $(DV)_{No\text{-}Fire}$	$(DV)_{Fire}$ – $(DV)_{30\%\ Fire}$
	$(DV)_{recal}$	$(DV)_{Fire}$	$(DV)_{No\text{-}Fire}$		
Trinity	12.54	9.38	8.89	0.49	0.19
Monture	11.83	9.31	8.98	0.33	0.14
Cabinet Mountains	11.41	8.77	8.53	0.24	0.11
Mt. Hood	13.18	10.99	10.42	0.57	0.24
Kalmiopsis	11.93	8.97	8.63	0.35	0.14
Crater Lake	10.62	8.55	8.31	0.24	0.09
Three Sisters Wilderness	13.88	11.48	11.10	0.39	0.17
Wishram	17.76	15.99	15.67	0.32	0.13

Estimating health benefits due to fire reduction using BenMAP



CASE 1
100% fire – no fire

CASE 2
100% fire – 30% fire

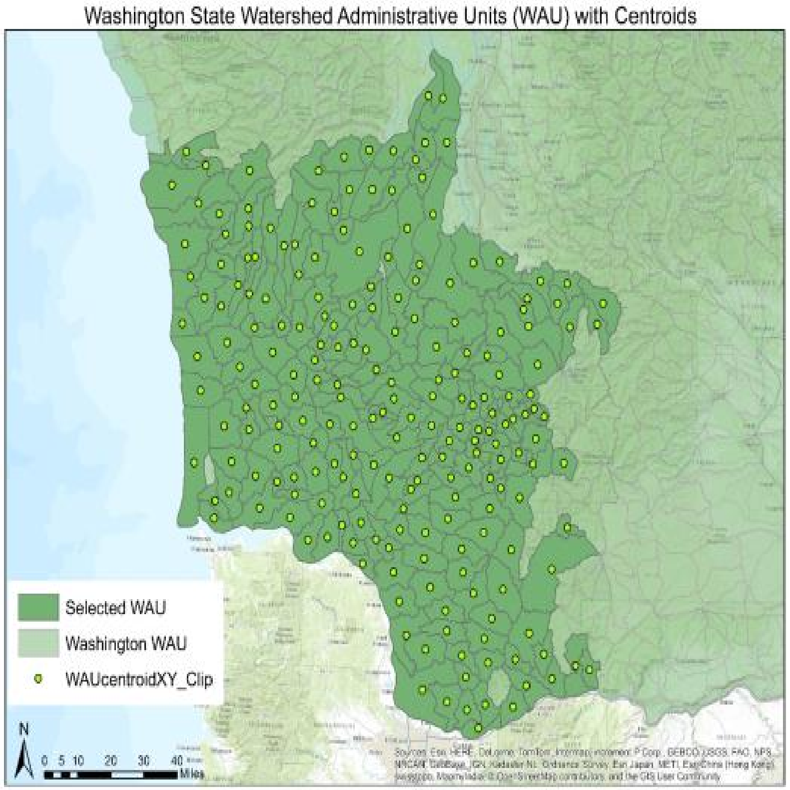
(fig source: BenMAP CE user guide)

Health impact estimates for various health endpoints

$PM_{2.5}$ health endpoint	Age range	Impact estimate (95% C.I.) $\Delta y = y_{100\%\ Fire} - y_{No\ Fire}$	Impact estimate (95% C.I.) $\Delta y = y_{100\%\ Fire} - y_{30\%\ Fire}$
MORTALITY			
All-cause mortality (Pope et al.)	30-99	70 (19-121)	32 (9-55)
All-cause mortality (Krewski et. al.)	30-99	70 (47-93)	32 (22-42)
All-cause mortality (Laden et. al.)	25-99	179 (80-278)	82 (37-127)
OTHER HEALTH IMPACTS			
Acute Myocardial Infarction	0-99	6 (3-9)	3 (1-4)
Chronic Bronchitis	27-99	47 (1-93)	22 (1-43)
Upper Respiratory Symptoms	9-11	1800 (330-3251)	828 (151-1501)
Emergency Room Visits Asthma	0-99	32 (9-54)	15 (4-25)
Hospital Admissions all Cardiovascular (less myocardial infarcations)	65-99	6 (4-8)	3 (2-4)
Hospital Admissions All respiratory	65-99	12 (7-18)	6 (3-8)
Minor restricted activity days	18-64	52476 (43090 - 61750)	24620 (20136-29073)
Work loss days	18-64	8939 (7600-10269)	4159 (3528-4788)

Methodology for slash pile approach

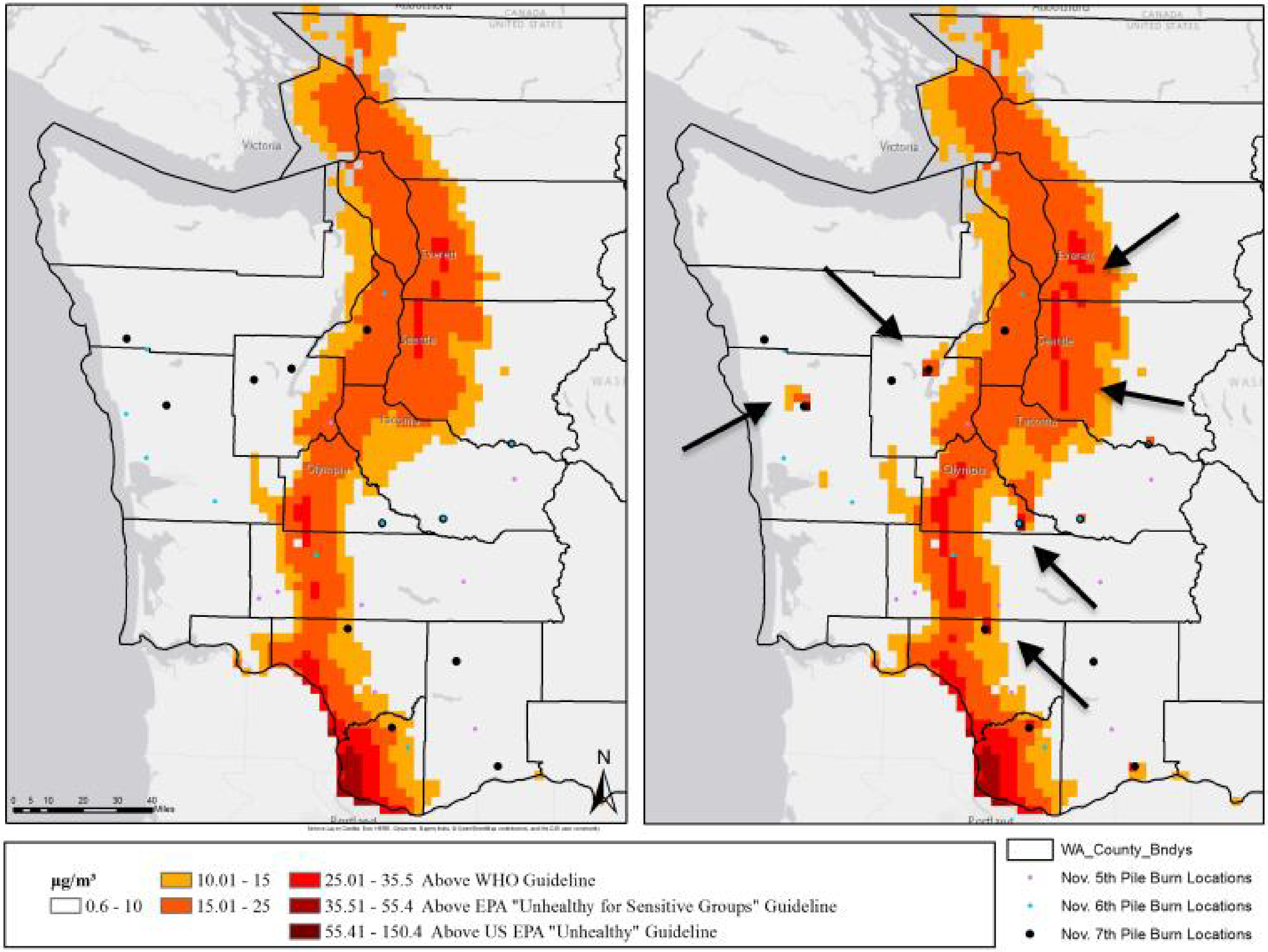
- **Piles modeling**, including sizes, shapes and distributions ~ 800,000 tons of biomass based on the results of the burned in 29 days;
- **Calculation of slash pile emissions** from burning biomass piles through Bluesky Playground online tool;
- **Evaluation of pollutants concentrations in air**, based on AIRPACT chemical transport and atmospheric interactions;
- **Calculation of the potential human intake and impacted populations** and comparison of the concentrations with the EPA and WHO air quality standards.



Air quality impacts based on slash pile burns

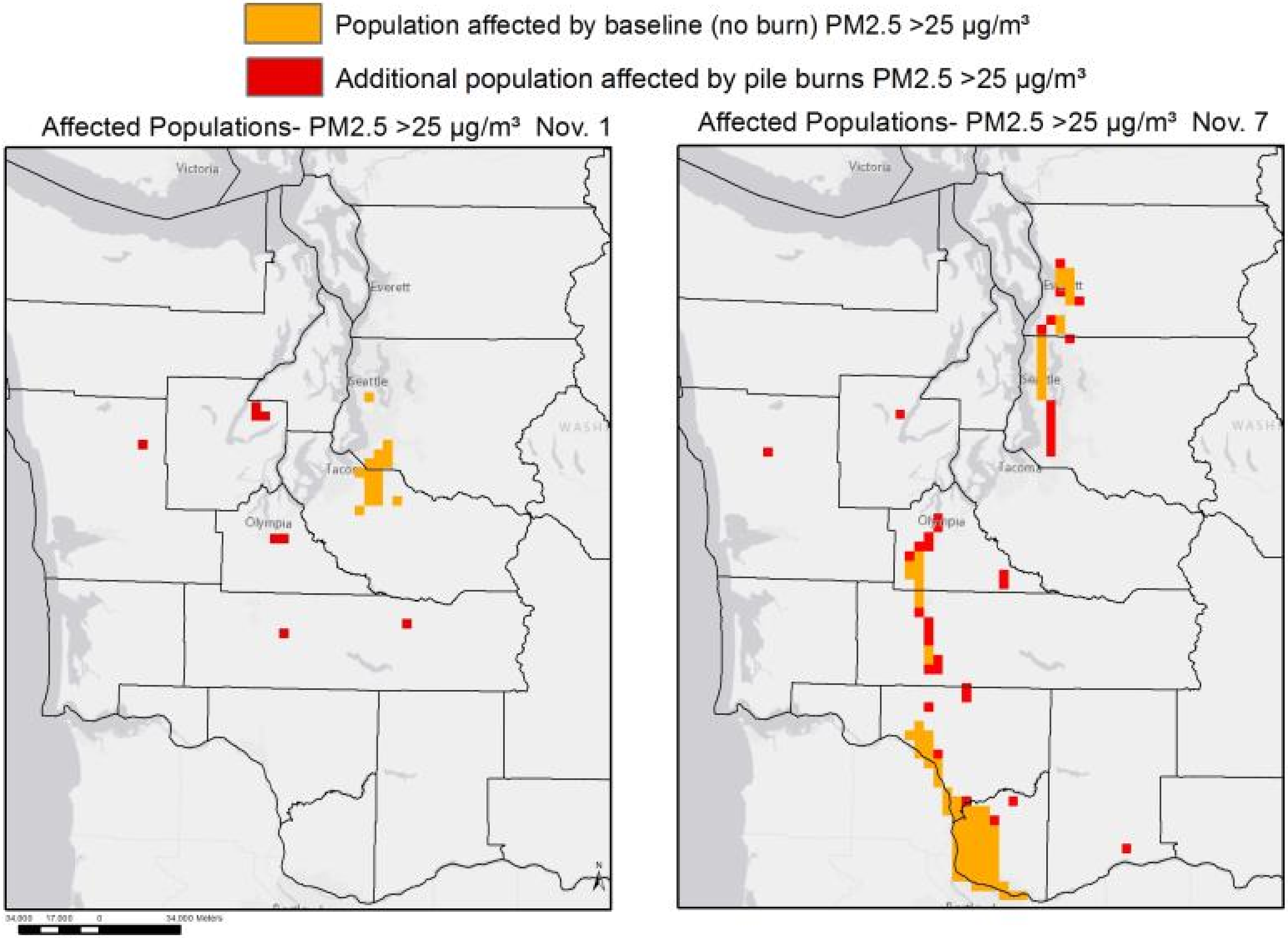
Baseline PM2.5 Concentrations
(November 7th Western Washington)

Baseline + Pile PM2.5 Concentrations
(November 7th Western Washington)



Additional exposure due to slash pile burns

Affected Populations- PM2.5 >25 μg/m³



Conclusion

- Prescribed fire based analysis:
  - We see significant improvement in air quality specifically for the western part of the domain where we also see maximum emissions
  - Visibility improvements are seen for the worst 20% days at several class I areas, while no significant impact is seen on annual basis
  - Prescribed fires alone are expected to cause health impacts across an array of endpoints. 70% reduction in prescribed fire emission will benefit by reducing mortality, and morbidity by 50-60% for most of the endpoints considered here.
- Slash pile based analysis:
  - Results show an increase in poor air quality in the direct vicinity of the pile burns mainly caused by $PM_{2.5}$ and $PM_{10;}$
  - Particulate matter can travel great distances away from the pile burns, reaching densely populated areas such as Seattle and Tacoma, in addition to impacting smaller communities;
  - Particulate matter concentrations with the added pile burns exceeded several air quality standards over the burn period, some concentrations reaching EPA "very unhealthy" air quality status.

Air quality regulations

- The revised AQI breakpoints are outlined in the table below:

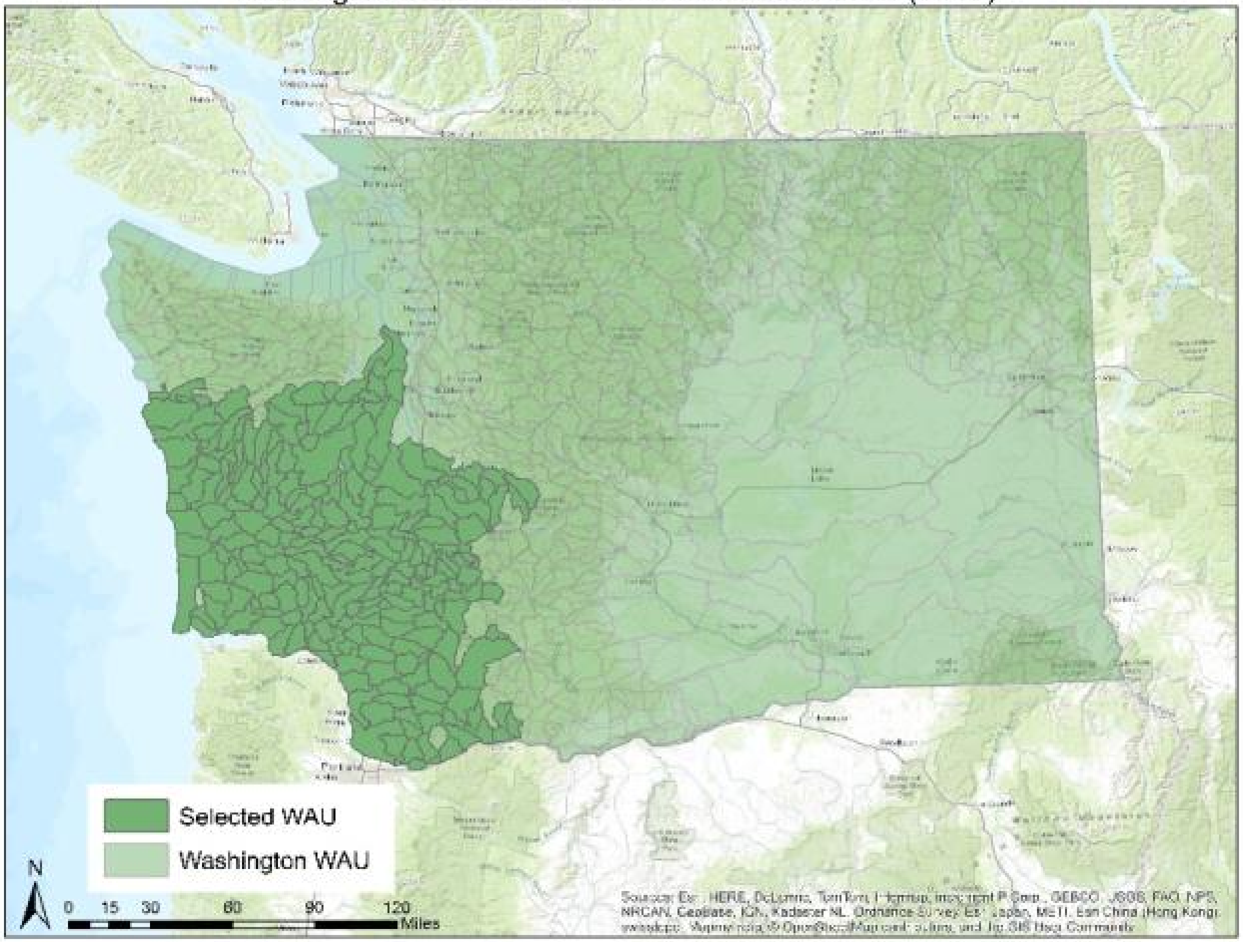
AQI Category	Index Values	Previous Breakpoints (1999 AQI) (µg/m³, 24-hour average)	Revised Breakpoints (µg/m³, 24-hour average)
Good	0 - 50	0.0 - 15.0	0.0 – 12.0
Moderate	51 - 100	>15.0 - 40	12.1 – 35.4
Unhealthy for Sensitive Groups	101 – 150	>40 – 65	35.5 – 55.4
Unhealthy	151 – 200	> 65 – 150	55.5 – 150.4
Very Unhealthy	201 – 300	> 150 – 250	150.5 – 250.4
Hazardous	301 – 400	> 250 – 350	250.5 – 350.4
	401 – 500	> 350 – 500	350.5 – 500

Revisions to the air quality index (EPA 2012)

Methodology Biomass Supply Calculation

- Biomass supply from 3 timbersheds in SW Washington where numerous facilities can be used in the scenario
- Comprised of 11 counties
- The project area includes 214 Watershed Administrative Units (WAU)

Washington State Watershed Administrative Units (WAU)



Air quality and health impacts based on slash pile burns

Days when the total (baseline + prescribed burn) ambient 24 hours $PM_{2.5}$ average is greater than:

25 microgram/cubic meter (WHO guideline)
Exceeded **28 out of 29 days**

35.5 microgram/cubic meter (US EPA guideline "Unhealthy for Sensitive Groups")
Exceeded **23 out of 29 days**

55.5 microgram/cubic meter (US EPA guideline "Unhealthy")
Exceeded **13 out of 29 days**

150.5 microgram/cubic meter (US EPA guideline "**Very Unhealthy**")
Exceeded **2 out of 29 days**

250.5 microgram/cubic meter (US EPA guideline - **Hazardous**)
Exceeded **1 out of 29 days**

Model performance evaluation

	AQS		IMPROVE		
Metric	No Fire	with Fire	No Fire	with Fire	
# obs-model pairs	6453	6453	545	545	
Mean Observed	8.41	8.41	2.79	2.79	
Mean Modeled	7.51	8.03	2.06	2.46	
MB	-0.90	-0.38	-0.72	-0.32	
ME	5.16	5.17	1.54	1.40	
MFB	-19.70	-13.54	-17.50	-4.69	
MFE	60.88	58.63	58.80	52.27	
MNB	7.04	13.04	inf	inf	
MNE	61.83	62.72	inf	inf	
RMSE	7.71	7.77	2.79	2.44	

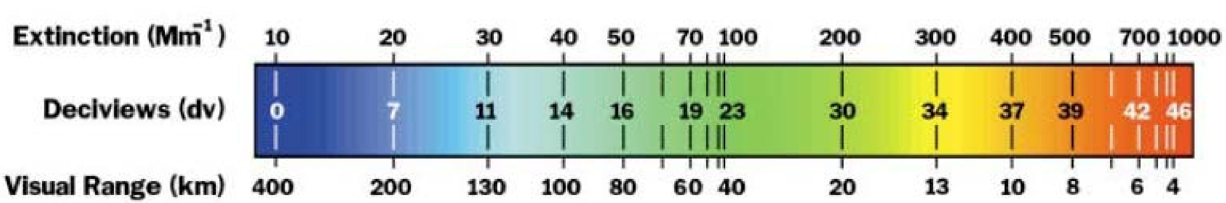


Figure 2: Comparison of extinction coefficient, deciviews and visual range (Malm, 1999)