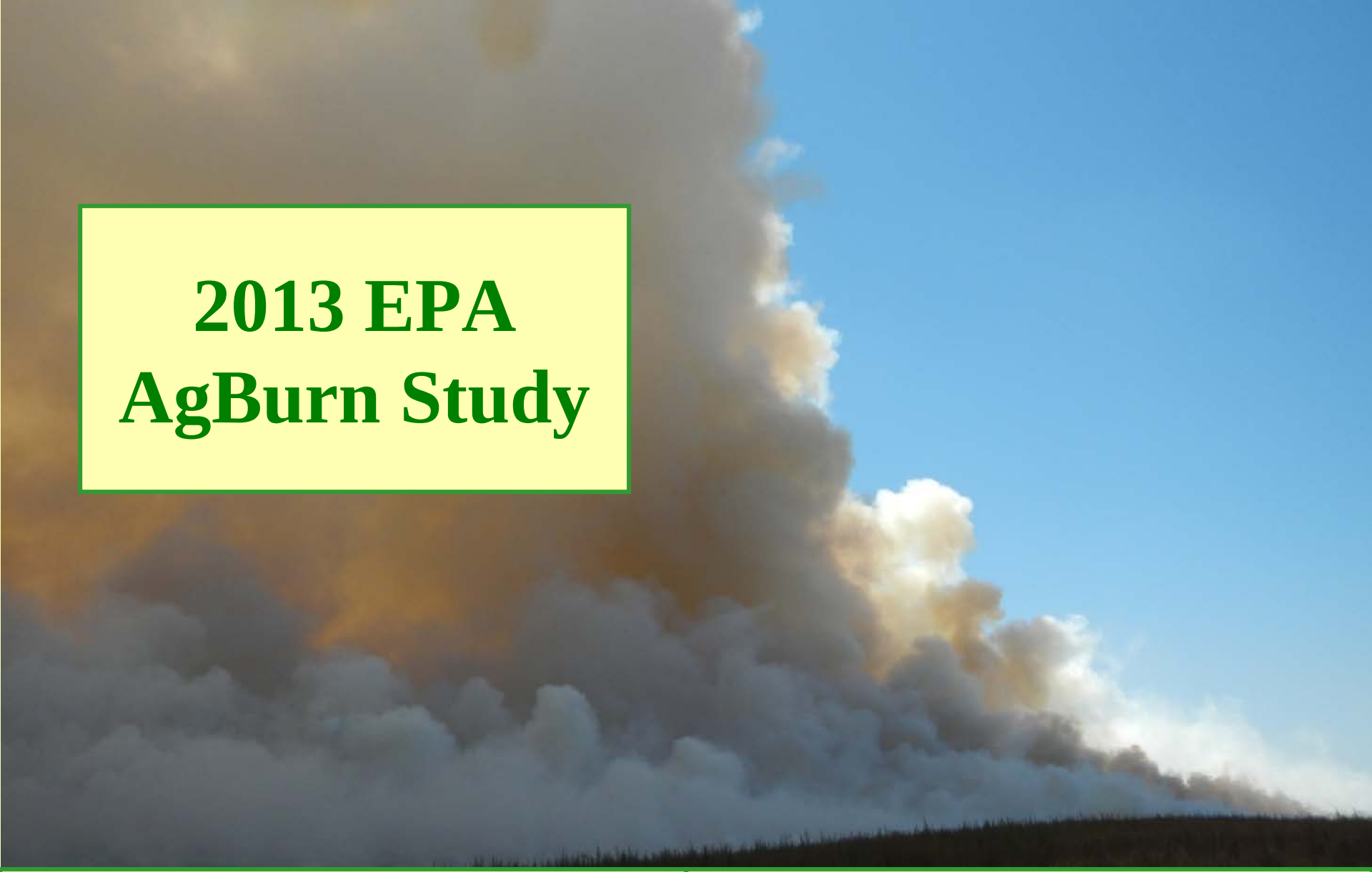


2013 EPA AgBurn Study

Robert Elleman
Environmental Protection Agency
Region 10, Seattle

Agricultural Burning Practices Task Force Meeting
February 10, 2016

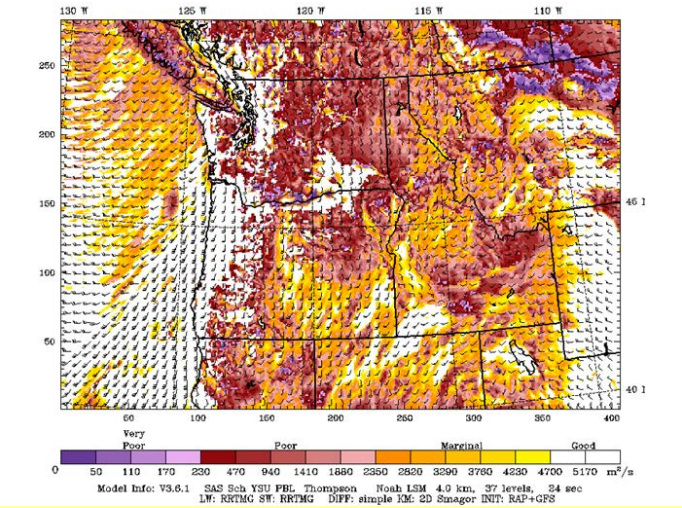
Northwest Regional Modeling Consortium (NRMC)

- **Collaborate on meteorological modeling and observations, primarily**

- **University of Washington (Cliff Mass) produces WRF weather forecasts and database of meteorological observations**

- **Members are State/Local/Tribal air quality agencies, National Weather Service, US Forest Service, Washington DNR, Seattle Public Utilities, WSDOT, etc.**

- **Current chair is Rob Elleman, EPA**



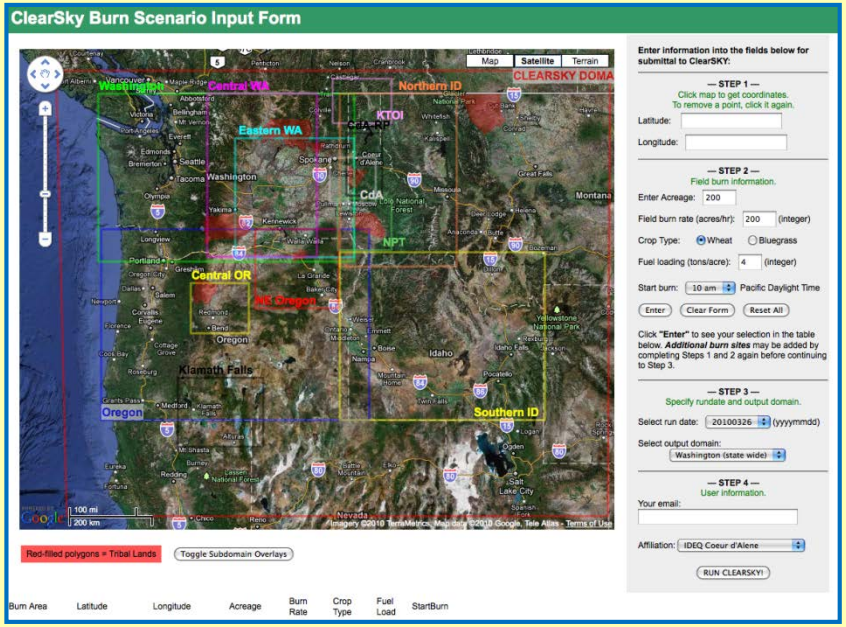
NW-AIRQUEST

- **Collaborate on air quality modeling, emission inventories, analyses, and topical technical issues**

- **Washington State University produces air quality forecasts and special projects.**

- **Primarily compromised by air quality agencies**

- **Current chair is Jeffrey Stocum, Oregon DEQ**



Build on Studies From Mid-2000s

AIR SCIENCES INC.

FINAL REPORT:

CEREAL-GRAIN RESIDUE
OPEN-FIELD BURNING
EMISSIONS STUDY

QUANTIFYING POST-HARVEST EMISSIONS FROM BLUEGRASS SEED PRODUCTION FIELD BURNING

MARCH 2004

GRASS SEED CROPPING SYSTEMS FOR A SUSTAINABLE AGRICULTURE

WASHINGTON STATE DEPARTMENT OF ECOLOGY

IDAHO DEPARTMENT OF ENVIRONMENTAL QUALITY

ENVIRONMENTAL PROTECTION AGENCY REGION 10

WASHINGTON TURFGRASS SEED COMMISSION

COEUR D'ALENE TRIBE

W. J. Johnston, Ph.D.
C. T. Golob, M.S.
Department of Crop and Soil Sciences
Washington State University
Pullman, WA 99164-6420

In collaboration with:

Air Sciences Inc.
Portland, OR

Missoula Fire Sciences Laboratory
Missoula, MT

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Atmospheric Environment 41 (2007) 6745–6761

ATMOSPHERIC ENVIRONMENT

www.elsevier.com/locate/atmosenv

Development of the ClearSky smoke dispersion forecast system for agricultural field burning in the Pacific Northwest

Rahul Jain[c], Joseph Vaughan[a], Kyle Heitkamp[d], Charleston Ramos[a], Candis Claiborn[a], Maarten Schreuder[b], Mark Schaaf[b], Brian Lamb[a,*]

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[b]*Air Sciences, Inc., 421 SW 6th Avenue, Suite 1400, Portland, OR 97204, USA*
[c]*Golder Associates, Calgary, BC, Canada*
[d]*Geomatrix, Inc., 19203 36th Avenue West, Suite 101, Lynnwood, WA 98036-5772, USA*

Received 19 December 2006; received in revised form 25 April 2007; accepted 25 April 2007

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Atmospheric Environment 40 (2006) 1007–1015

ATMOSPHERIC ENVIRONMENT

www.elsevier.com/locate/atmosenv

Particulate emissions from wheat and Kentucky bluegrass stubble burning in eastern Washington and northern Idaho

Ranil Dhammapala[a,*], Candis Claiborn[a], Jeff Corkill[b], Brian Gullett[c]

[a]*Department of Civil and Environmental Engineering, Washington State University, Pullman, WA 99164-2910, USA*
[b]*Department of Chemistry and Biochemistry, Eastern Washington University, Cheney, WA 99004-2431, USA*
[c]*U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Research Triangle Park NC 27711, USA*

Received 2 June 2005; received in revised form 9 November 2005; accepted 9 November 2005

Why Did We Do 2013 AgBurn

- **Reports of inconsistent model performance**
- **Studies from 2000s did not get field characteristics, emission factors, and plume dynamics all from the same burn**
  - **Not a negative statement about those studies, just a reflection of trade-offs and priorities**
- **More advanced measurement technologies**

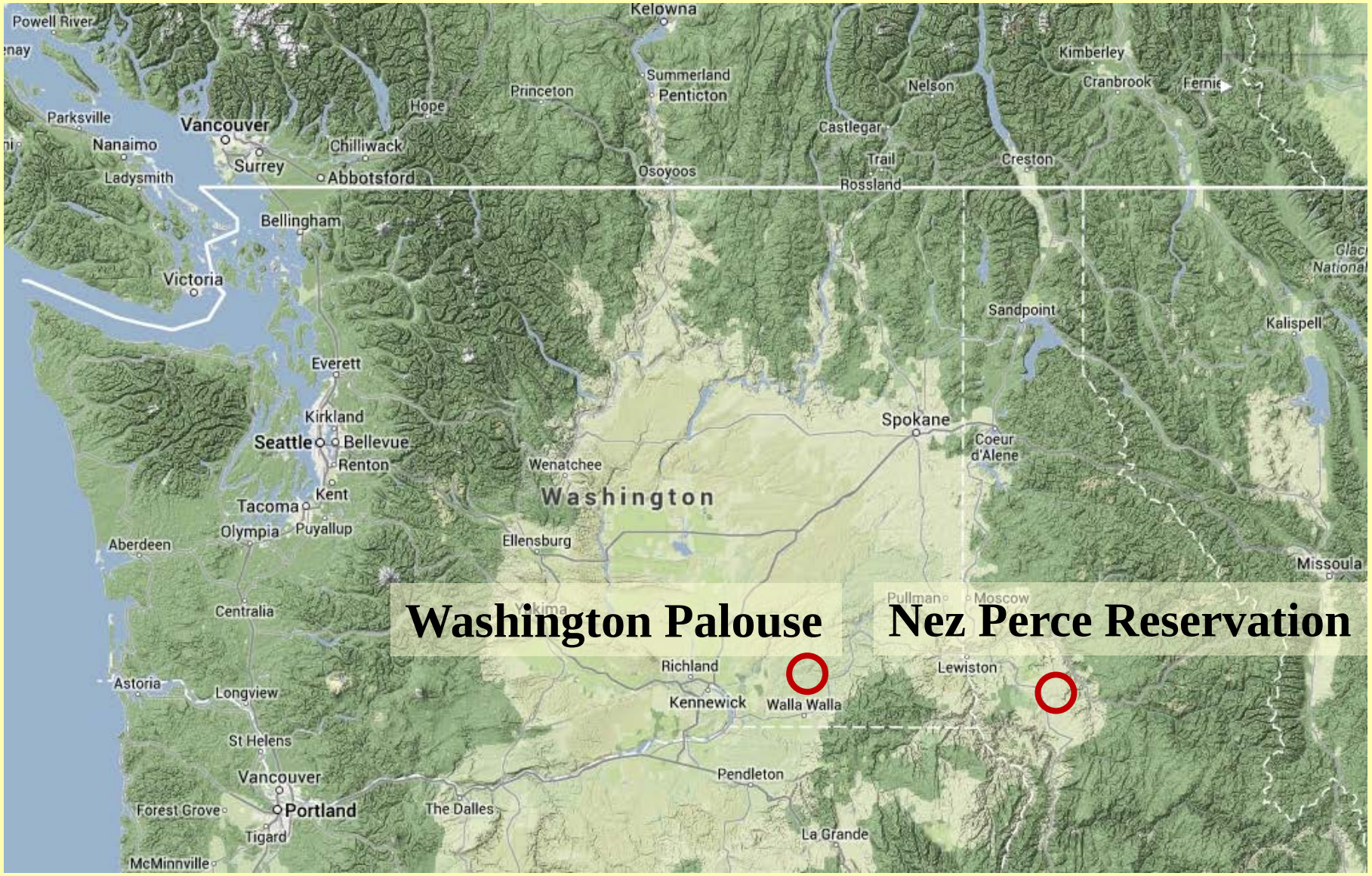
EPA Regionally Applied Research Effort (RARE)

- **RARE is an internal EPA program to match up lab scientists to regional issues of concern.**
- **A collaborator from mid-2000s is an EPA scientist and was interested in doing more ag burn work.**
- **We were able to round out the study because the smoke management community in PNW is unusually functional.**

Collaborators

- **EPA Office of Research and Development**
  - Brian Gullett, Amara Holder, Bill Mitchell, Rob Gribble, James Faircloth, Richard Snow, Chris Pressley
- **University of Dayton Research Institute**
  - Johanna Aurell
- **US Forest Service, Missoula Fire Sciences Lab**
  - Shawn Urbanski, Emily Lincoln, Steve Baker, Cyle Wold, Alex Petkov, Vladimir Kovalev, Wei Min Hao
- **US Forest Service, Pacific Wildland Fire Sciences Lab**
  - Susan O'Neill, Conamara Burke, Spus Wilder
- **EPA Region 10**
  - Chris Hall, Mike McGown, Keith Rose
- **Washington State University**
  - Joe Vaughan
- **National Weather Service, Spokane**
  - Ron Miller, Jon Fox, Todd Carter
- **Nez Perce Tribe and affiliated growers**
  - Julie Simpson, Andrea Boyer, Mary Fauci, Bryce Boyer
- **Washington Department of Ecology and affiliated growers**
  - Kary Peterson, Neil Hodgson, Paul Rossow, Ranil Dhammapala
- **USDA Agricultural Research Service**
  - Greg McCarty
- **University of Idaho**
  - Luigi Boschetti, Erik Boren, Wade Tinkham

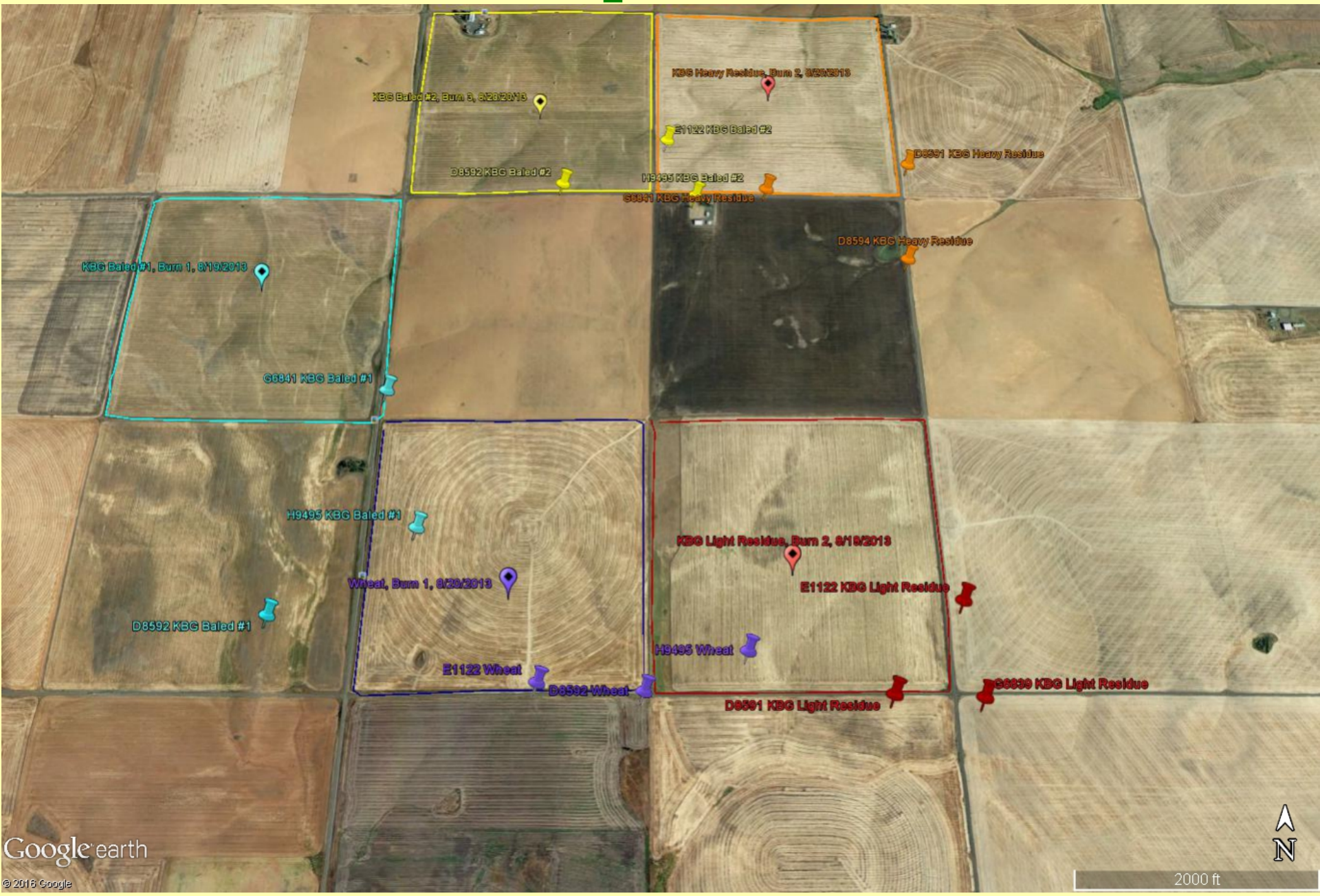
August 2013 Study, Two Locations



Nez Perce Reservation
Camas Prairie

- **Dryland rolling hills with square, generally 160 acre fields**
- **3000’ elevation and often mixing height of 3000-4000’ above ground**
- **Heavily influenced by local meteorology**
- **Sampled five fields 8/19-8/20**
  - **4 Kentucky Bluegrass**
  - **1 recently-harvested wheat field**

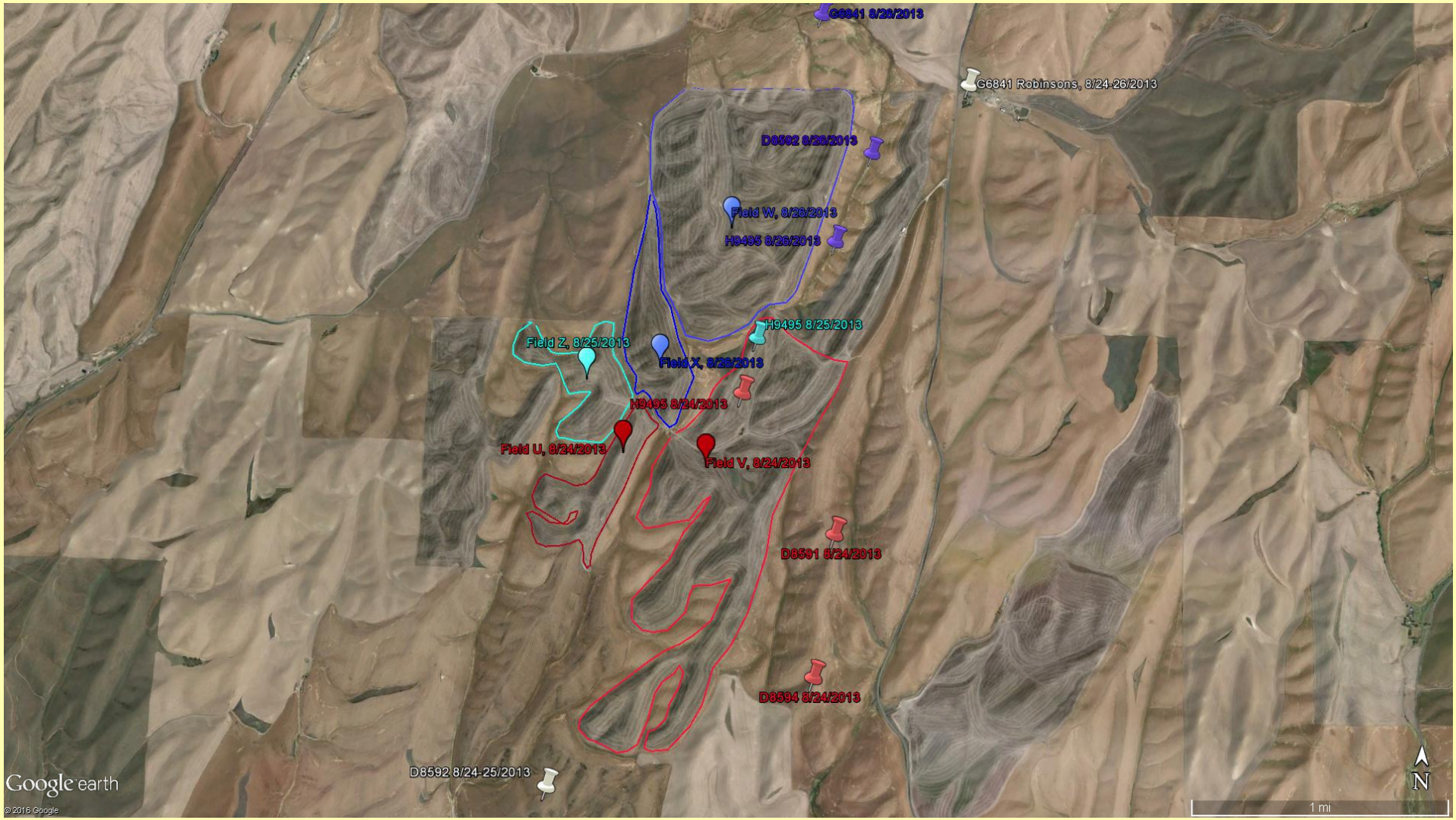
Nez Perce Fields, plus Ground EBAMs



Washington Palouse

- **Dryland, very hilly wheat fields of irregular shape and size (70 – 304 acres)**
- **1000’ elevation with mixing heights 4000-6000’ above ground**
- **Harvest in 2012, chem-fallowed then burned in 2013**
- **Very different ignition pattern than Nez Perce**
- **Sampled five fields on 8/24-26**

Walla Walla Fields, plus Ground EBAMs



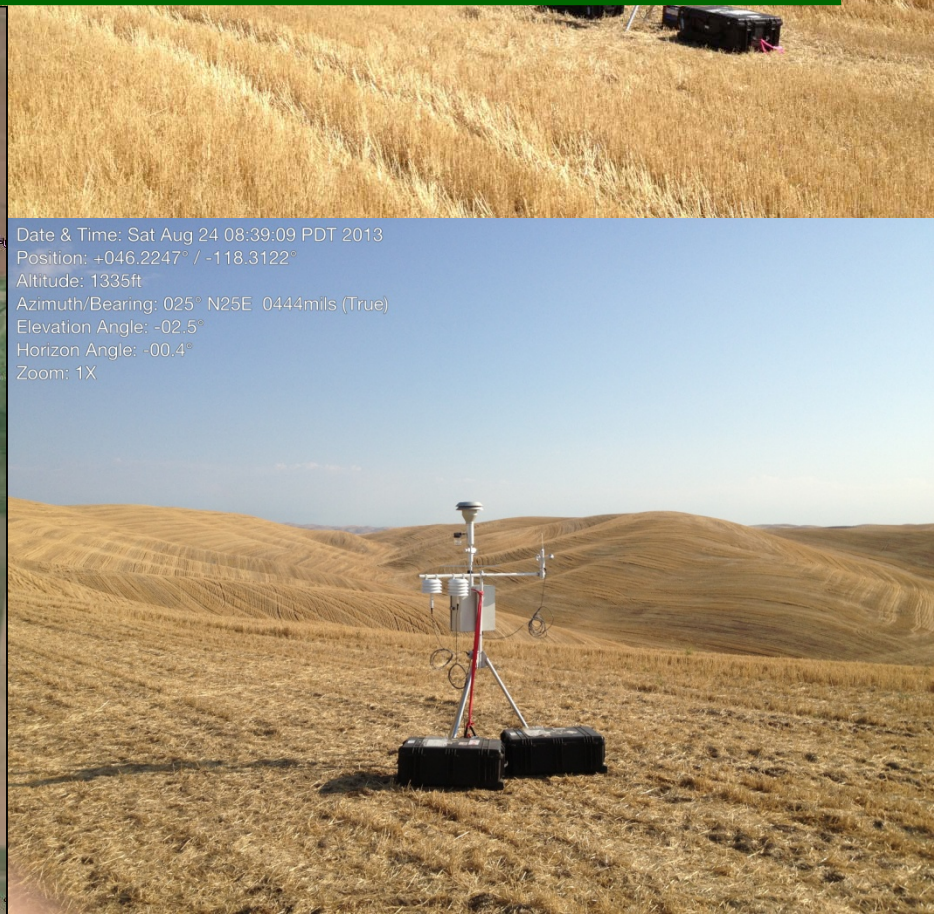
Fuel Measurements

Conamara Burke, USFS Pacific Wildland Fire Sciences Lab

Portable PM2.5 Network

Susan O'Neill, USFS Pacific Wildland Fire Sciences Lab

- **2 or 3 E-BAMs immediately downwind**
- **WSU nephelometer, Nez Perce/Ecology stations as background**



EPA-ORD Ground Samplers

- **Truck system** *Amara Holder, EPA-Office of Research and Development*
  - Photoacoustic soot spectrometer
  - Nephelometer
  - Single particle soot photometer
- **Sensor testing** *Bill Mitchell, EPA-Office of Research and Development*
  - "Sunset Labs model 6220" CO_2
  - “e2v model 5525” CO
  - "Shinyei" PM, > 1 µm
  - Thermistor, microchip MPC 9700
  - Relative Humidity, Honeywell sensor, H1H-Y010

EPA-ORD Instrumented Balloon

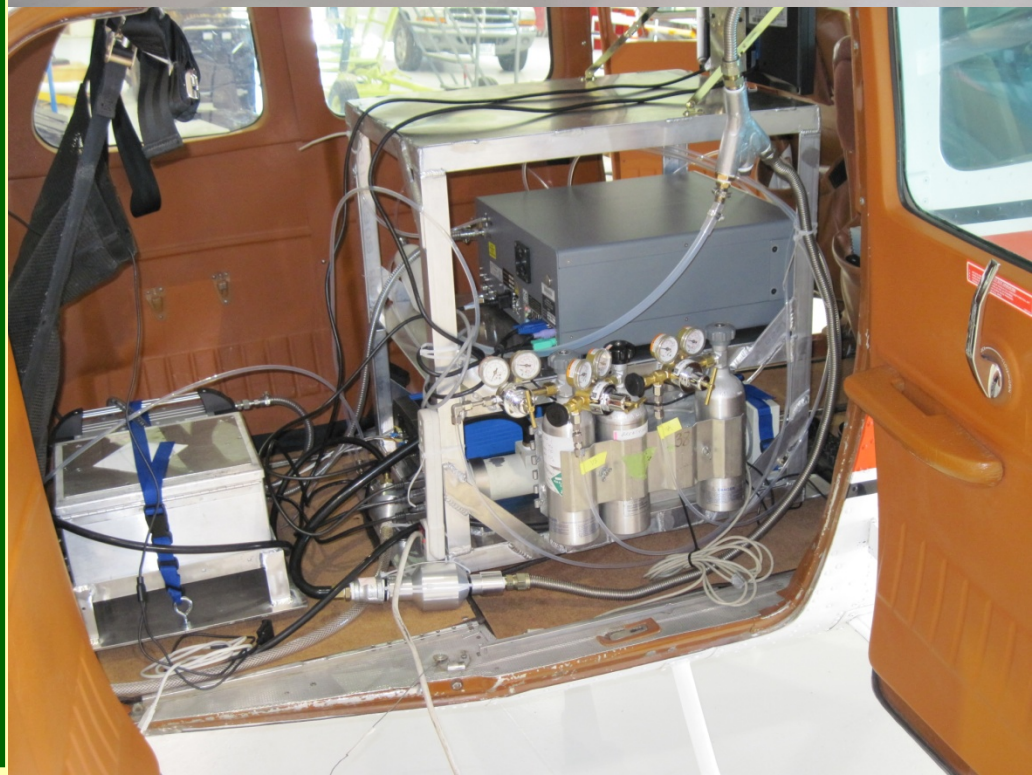
Brian Gullett, EPA Office of Research and Development

- CO_2
- CO
- temperature
- GPS
- 3D wind velocity
- black carbon
- $PM_{2.5}$
- batch sampling of
  - VOCs
  - SVOCs
  - PM_{10} and $PM_{2.5}$
  - Cl species
  - PM-borne metals
  - organic matter

US Forest Service Airplane

Shawn Urbanski, Missoula Fire Sciences Laboratory

- **Plume height and evolution of the plume downwind**
- **Instruments**
  - **Picarro gas analyzer: 2-second CO_2, CO, CH_4, and H_2O**
  - **Nephelometer: ~$PM_{2.5}$**
  - **Aethalometer: BC**



Lidar, Ceilometer, and Radiosondes

- **USFS Lidar**
  Wei Min Hao, USFS Missoula Fire Sciences Lab
  - Stationed 0.5-2 miles perpendicular to plume trail

- **Ceilometer**
  Joe Vaughan, Washington State University
  - Vaisala CL-31
  - Usually measuring background

- **Radiosondes**
  Rob Elleman, EPA
  - Temperature, RH, and Winds
  - Launched 30 minutes prior to burn

Variability in Plumes From Ignition Style

Measurement Results

Fuel Measurements

Conamara Burke, USFS Pacific Wildland Fire Sciences Lab

Biomass

Unit	Location	Fuel Type	Avg. (tons/acre)	Std Dev	Std Error
Grain	Nez Perce, ID	Grain	1.65	0.66	0.21
KBG LL	Nez Perce, ID	Kentucky Blue Grass Light Loading	1.61	0.46	0.15
KBG HL	Nez Perce, ID	Kentucky Blue Grass High Loading	2.87	1.24	0.39
KBG B	Nez Perce, ID	Kentucky Blue Grass Baled	1.16	0.27	0.09
Field V	Walla Walla, WA	Chem Fallow-- Winter Wheat	3.07	0.78	0.25
Field X	Walla Walla, WA	Chem Fallow-- Winter Wheat	3.39	0.80	0.25

STEM HEIGHTS, LITTER/THATCH DEPTHS

Unit	Location	Fuel Type	Avg. Stem Height (in)	Avg. litter depth (in)	Avg. thatch depth (in)
Grain	Nez Perce, ID	Grain	6.95	0.81	N/A
KBG LL	Nez Perce, ID	Kentucky Blue Grass Light Loading	5.58	N/A	0.53
KBG HL	Nez Perce, ID	Kentucky Blue Grass High Loading	4.10	N/A	0.85
KBG B	Nez Perce, ID	Kentucky Blue Grass Baled	5.00	N/A	N/A
Field V	Walla Walla, WA	Chem Fallow-- Winter Wheat	15.05	0.70	N/A
Field X	Walla Walla, WA	Chem Fallow-- Winter Wheat	16.45	0.85	N/A

Emission Factors

Preliminary Results from Aurell et al. (2015)

Burn No.	Date	Ignition Time	Location	Field ID	Fuel Type	Fuel Load (ton acre^{-1})	Moisture Content (%)	Size (acre)
1	8/19/2013	12:10?	Nez Perce, ID	KBG B1	Kentucky Bluegrass baled, light fuel load	1.16 (0.27)	32	163
2	8/19/2013	15:00?	Nez Perce, ID	KBG LL	Kentucky Bluegrass light loading	1.61 (0.46)	31	163
3	8/20/2013	11:40	Nez Perce, ID	Wheat	Wheat post-harvest stubble		11	163
4	8/20/2013	14:00	Nez Perce, ID	KBG HL	Kentucky Bluegrass high loading	2.87 (1.24)	21	163
5	8/20/2013	15:20	Nez Perce, ID	KBG B2	Kentucky Bluegrass baled		42	163
6	8/24/2013	09:45	Walla Walla, WA	V	Wheat – Chem Fallow	3.07 (0.78)	11	236
7	8/24/2013	12:15	Walla Walla, WA	U	Wheat – Chem Fallow		7	89
8	8/25/2013	10:50?	Walla Walla, WA	X	Wheat – Chem Fallow	3.39 (0.80)	8	66

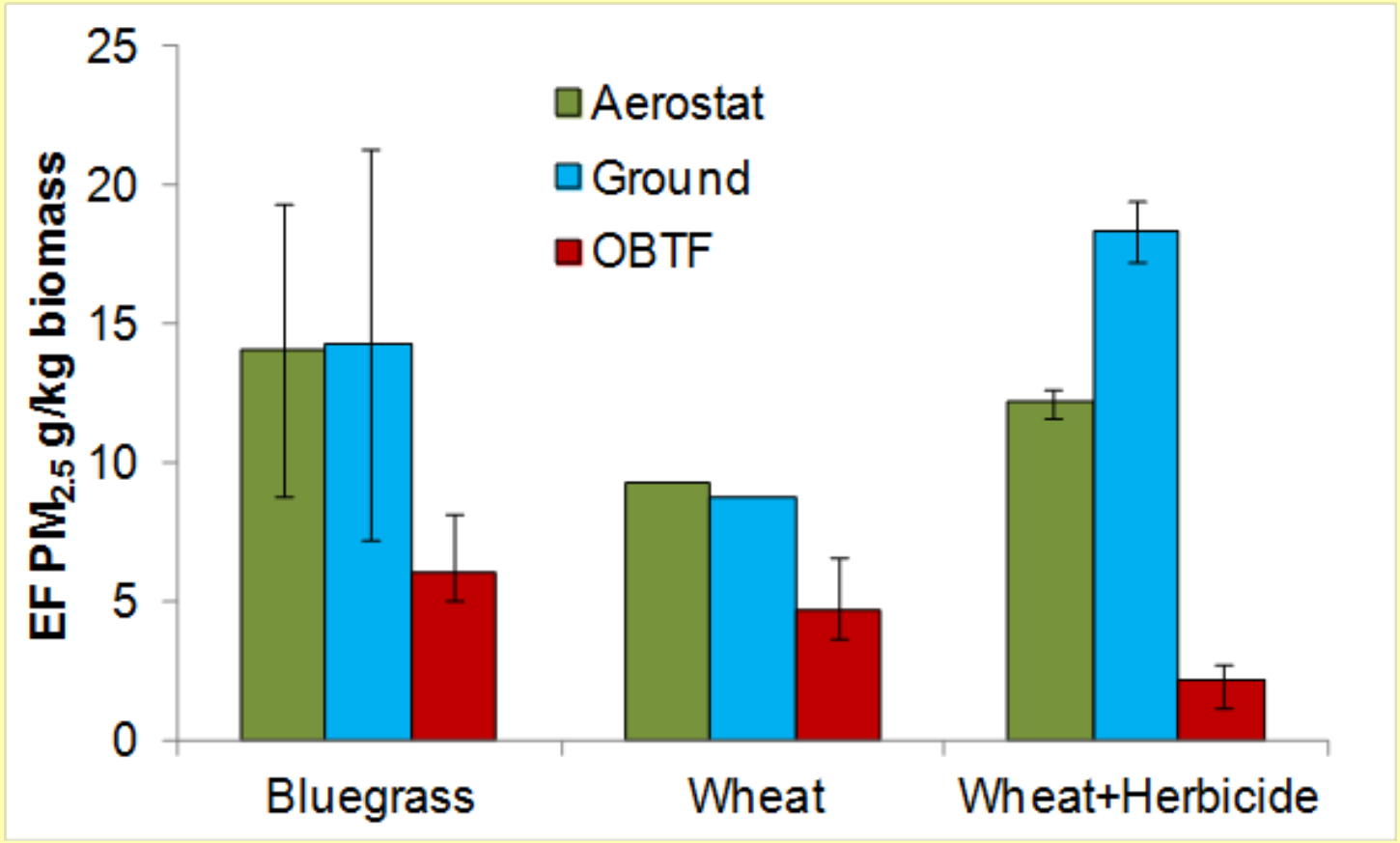
Table 8. Modified combustion efficiency and emission factors (g kg^{-1}) measured from Cessna-206.

Burn No.	Field ID	N[a]	Length[b] (km)	MCE	CO_2	CO	CH_4	$PM_{2.5}$[c]
1	KBG B1	7	12.6	0.952±0.007	1521±13	49.4±7.2	1.35±0.31	3.67±0.36
2	KBG LL	11	32.3	0.933±0.010	1483±23	68.1±10.0	2.36±0.33	12.4±2.98
3	Wheat	8	9.6	0.951±0.018	1511±32	49.9±17.7	1.45±0.61	3.48±1.41
4	KBG FL	12	29.1	0.926±0.015	1461±39	74.2±14.7	2.67±1.19	17.2±6.24
5	KBG B2	22	17.5	0.937±0.009	1501±17	64.7±8.7	1.98±0.33	7.44±1.53
6	V	15	28.3	0.965±0.005	1465±11	34.1±5.2	0.79±0.16	3.36±1.08
7[d]	U							
8	X	12	23.5	0.972±0.005	1478±11	27.0±5.2	0.63±0.16	2.60±1.00

[a]number of samples, [b]total flight sample length in km, [c]inferred $PM_{2.5}$ (see text), [d]Burn #7 was not sampled by the Cessna-206

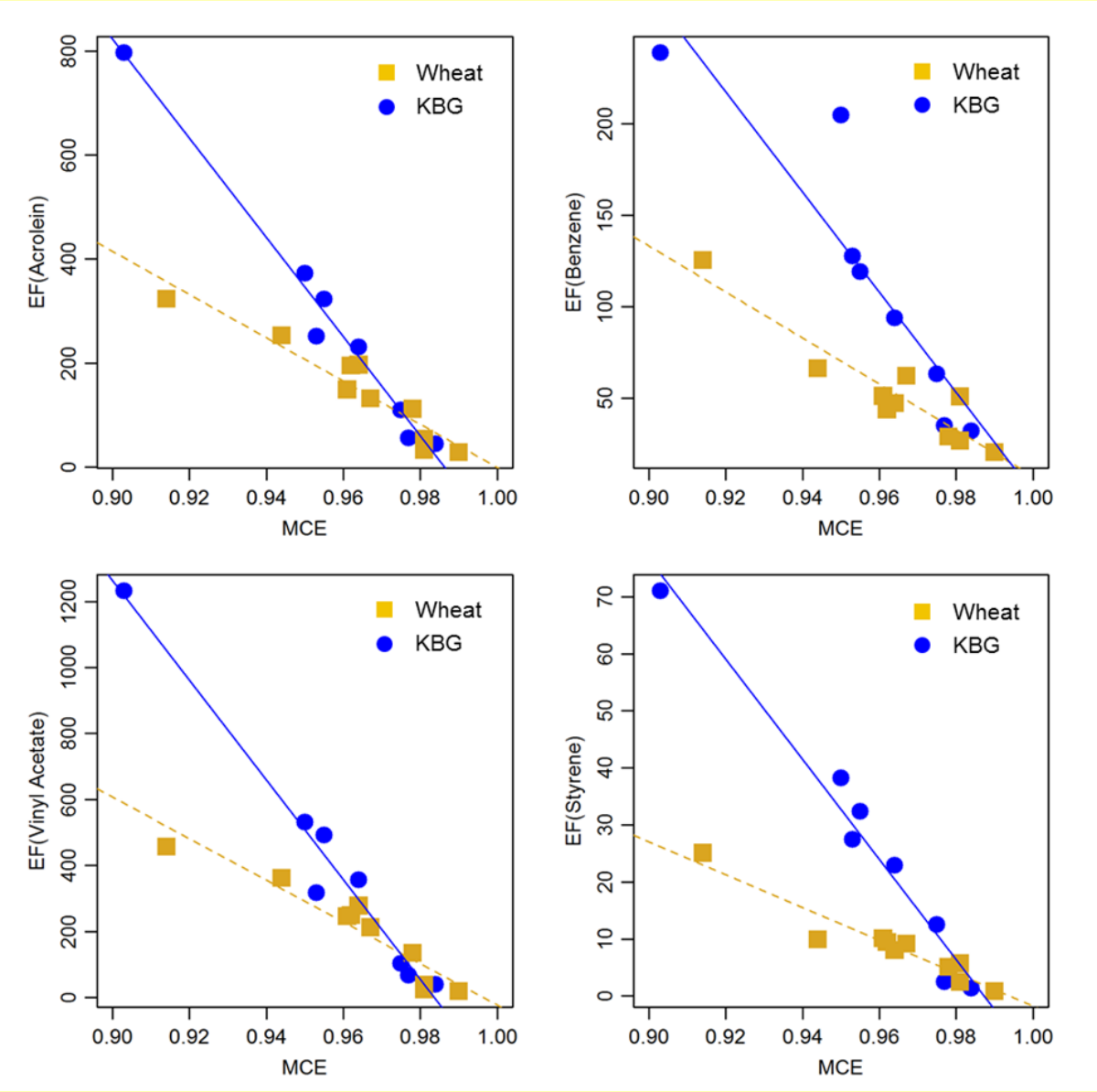
Emission Factors

Preliminary Results from Aurell et al. (2015)



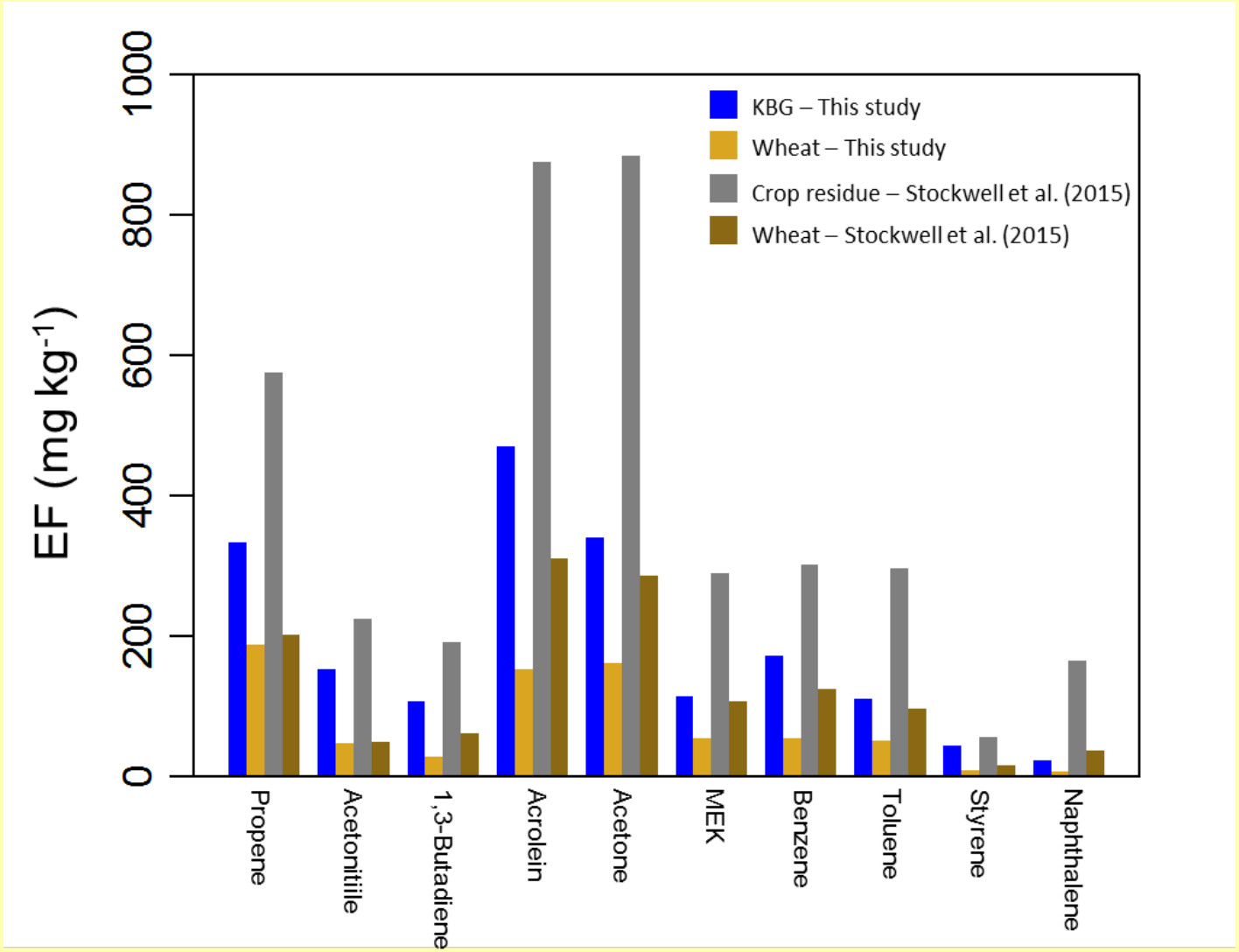
Emission Factors

Preliminary Results from Aurell et al. (2015)



Emission Factors

Preliminary Results from Aurell et al. (2015)



EPA AGU Poster, Dec. 2014

Black carbon and particulate matter optical properties from agricultural residue burning in the Pacific Northwest United States

Paper # A53B-3211

Amara Holder[1] Johanna Aurell[2], Susan O'Neill[3], Conamara Burke[3], Spus Wilder[3], Shawn Urbanski[3], Michael Hays[1], Brian Gullett[1], Robert Elleman[4]
[1]U.S. Environmental Protection Agency, Office of Research and Development
[2]University of Dayton Research Institute
[3]U.S. Forest Service
[4]U.S. Environmental Protection Agency, Region 10
Contact: holder.amara@epa.gov

Abstract

Open burning of agricultural residues is a common management practice that is used to quickly clear fields of post-harvest vegetation and to stimulate seed production in some grass species. Although cropland burning contributes only a minor fraction to the United States and Global burden of particulate matter (PM) and black carbon (BC) emissions, substantial impacts on local and regional air quality and visibility can occur during the burning season. Previous field measurements of agricultural burning emissions have shown large variations of PM emissions depending upon fuel species, field conditions, fuel loading, and harvest technique (Dhammapala et al. 2006), but there have been no corresponding measurements of the climate relevant properties of these emissions. The goal of this study was to assess black carbon emissions and aerosol optical properties from the burning of agricultural residues and determine representativeness of emissions from laboratory burns.

Methods

During the 2013 burning season in the Pacific Northwest United States, emissions were measured from burns carried out on cropland. Kentucky bluegrass residues (*Poa pratensis*), winter wheat stubble (*Triticum aestivum*), and chemically fallowed winter wheat stubble were burned in field.

Fields with different treatments (baled, low loading, high loading, chemically fallowed) were burned in an attempt to ascertain the importance of fuel loading on emissions.

Biomass was also collected in the field and brought to the lab and burned to determine the representativeness of laboratory simulations of crop burning.

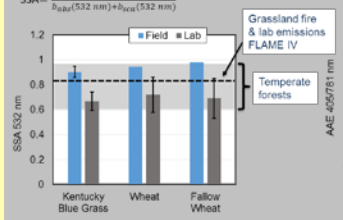
Measurement Approach	Measurement
Single particle soot photometer (SP2)	Refractory BC mass & size
Microaethalometer (AE-51)	Equivalent BC mass (filter based, optical)
Photo-acoustic soot spectrometer (PASS-3)	Aerosol absorption and scattering at 405, 532, and 781 nm
DustTrak (DRX 8533)	PM2.5 mass (real time)
Licor (NDIR)	CO_2
Teflon / Quartz Filters	PM2.5 mass/ EC mass (thermal-optical method, NIOSH 5040)

Optical Characteristics

The single scatter albedo (SSA) and absorption angstrom exponent (AAE) were calculated for each burn, averaged over the entire burn. SSAs were showed emissions that were dominated by scattering and within the large range of that observed for temperate forests (Reed et al. 2005), but were slightly higher than a grassland fire in Florida and lab measurements done as part of the FLAME IV experiment (Liu et al. 2014). AAEs showed strong spectral variation indicative of a large contribution from brown carbon. were similar to the grassland fire, but larger than prescribed fire emissions in the Southeastern US (Strand et al.).

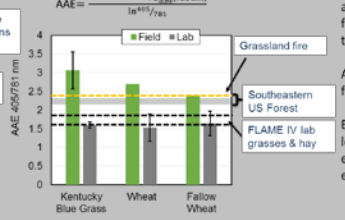
Single Scatter Albedo

$$SSA = \frac{b_{scat}(523\ nm)}{b_{abs}(532\ nm)+b_{scat}(532\ nm)}$$



Absorption Angstrom Exponent

$$AAE = \frac{\ln^{b_{abs}(405\ nm)}/_{b_{abs}(781\ nm)}}{\ln^{405}/_{781}}$$

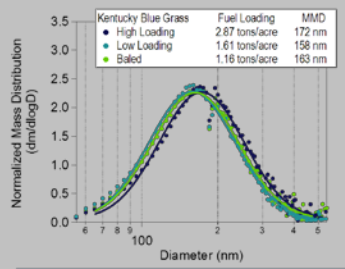


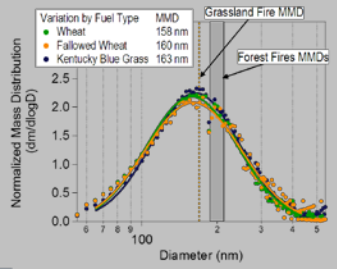
Field measurements of single scattering albedo had a positive linear correlation with fuel loading (r^2=0.7), regardless of species type.

Angstrom exponents varied by species and by field treatment, not by fuel loading.

Emissions from lab burns looked 'blacker', i.e. lower single scattering albedo and angstrom exponent than emissions in the field and exhibited no species dependent differences.

Refractory Black Carbon Size Distributions





Although black carbon emission factors varied by burn, the size distributions varied only slightly by fuel loading and fuel type.

Fuel (Field/Lab)	Mass Median Diameter (nm)	Geometric Standard Deviation
Wheat	158 / 172	1.52/1.50
Fallow Wheat	160 / 165	1.55/1.48
KBG	163 / 171	1.49/1.45

Mass median diameter (MMD) for all species were about the same as that measured for a grassland fire in Florida and somewhat smaller than emissions from forest fires.

The size distribution of emissions from lab fires was consistently smaller and slightly more narrow than those seen in the field.

Emission Factors

Field and lab Measurements of black carbon emissions (measured with the AE-51) were similar.

Additionally, PM emissions were much lower in the lab.

Therefore, the carbonaceous PM (TC) from lab burns was composed of a much larger fraction of elemental carbon (EC) than field emissions.

Fuel	Equivalent BC (g/kg)		EC/TC	
	Field	Lab	Field	Lab
Wheat	0.85	0.72	0.038	0.238
Fallow Wheat	0.50	0.39	0.020	0.141
Kentucky Blue Grass	0.49 – 0.84	1.11	0.038	0.139

Conclusions

- Emissions from open burning of agricultural residues are similar to those from wildland grass fires, and have properties that are distinctly different from emissions from fires on forested lands.
- Fuel loading had only a slight impact on single scattering albedo and black carbon size distribution.
- Simulated burns in the lab do not accurately capture the optical properties of open burning emissions, the cause of this disagreement is not known.

Acknowledgements

This work was funded by a collaboration between US EPA Region 10 and EPA Office of Research and Development. We would like to acknowledge Bill Mitchell, Chris Pressley, Richard Snow, James Faircloth from the US EPA, and Rob Gribble from Integrated System Solutions Inc. for assistance with field measurements, and Ron Williams from the US EPA for loaned aerosol measurement equipment.

References

Dhammapala et al. 2006 Atmos Environ **40** 1007-1015.
Liu et al. 2014 Geophys. Res. Lett. **41** 742-748.
Reed et al. 2005 Atmos Chem Phys **5** 799-825.
Strand et al. submitted to Int. J. of Wildland Fire

Modeling Results

ClearSky2 and ClearSky3 for RARE 2013

- **CS2 is 4-km system & CS3 is 1.333-km system**

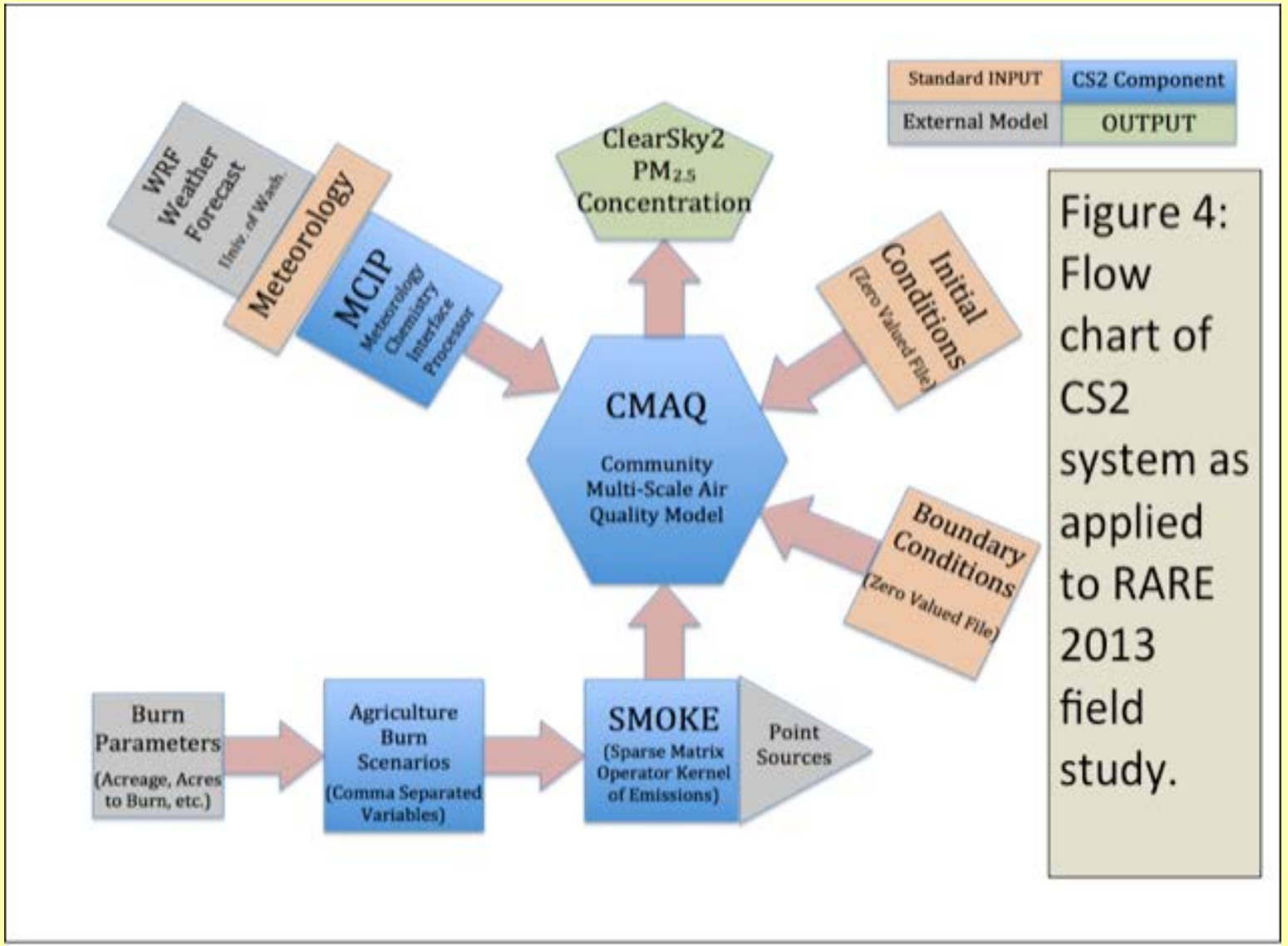
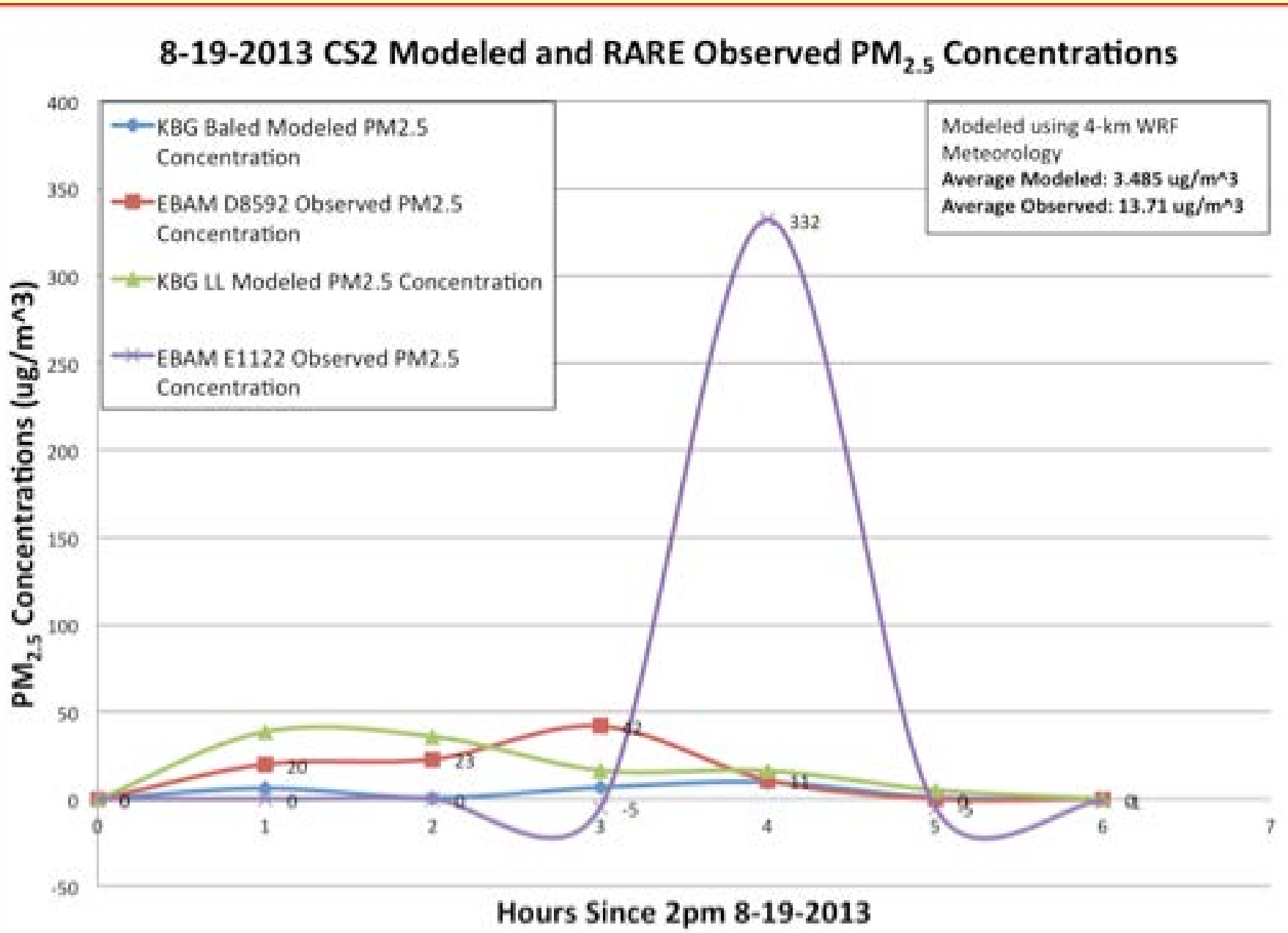
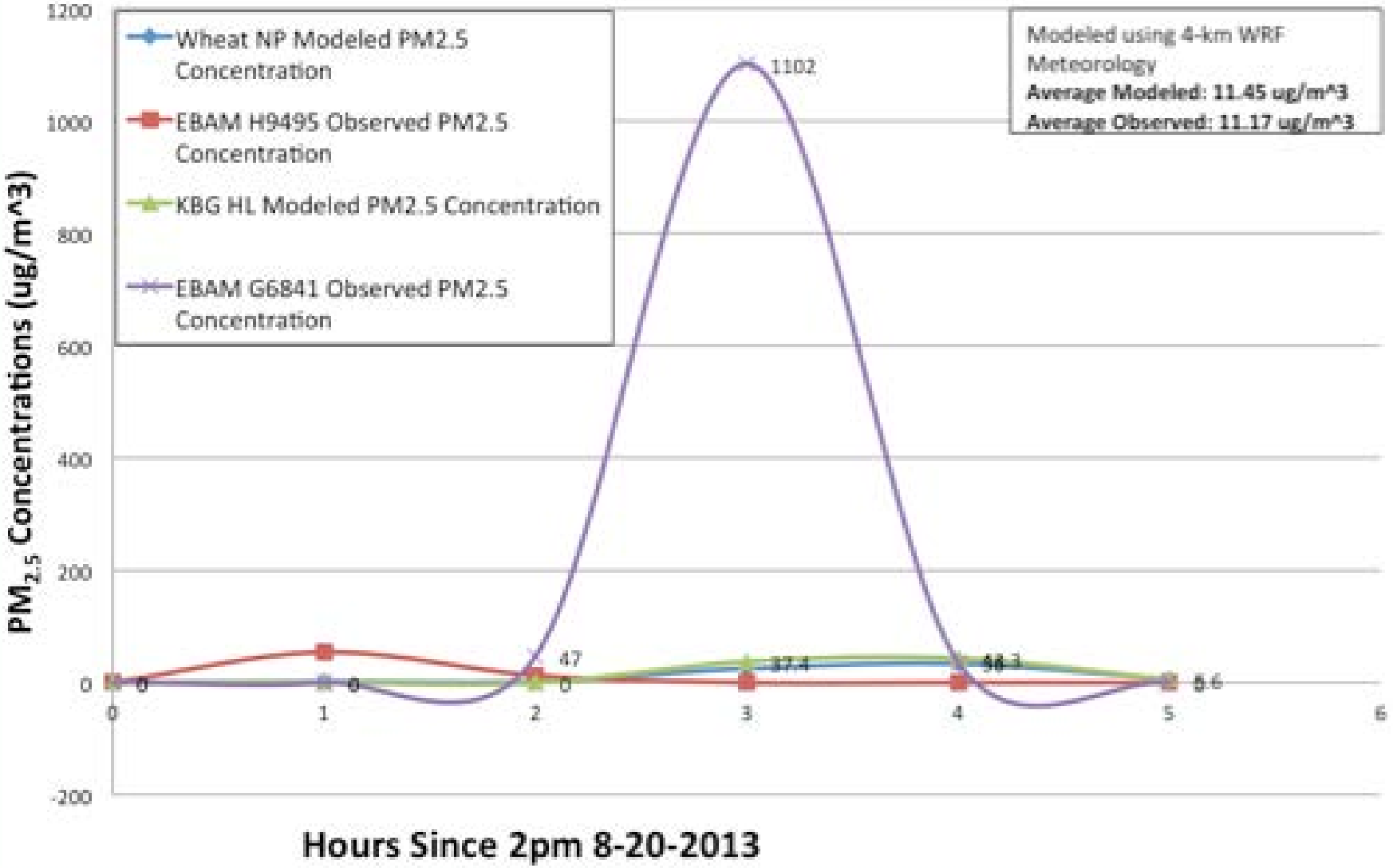


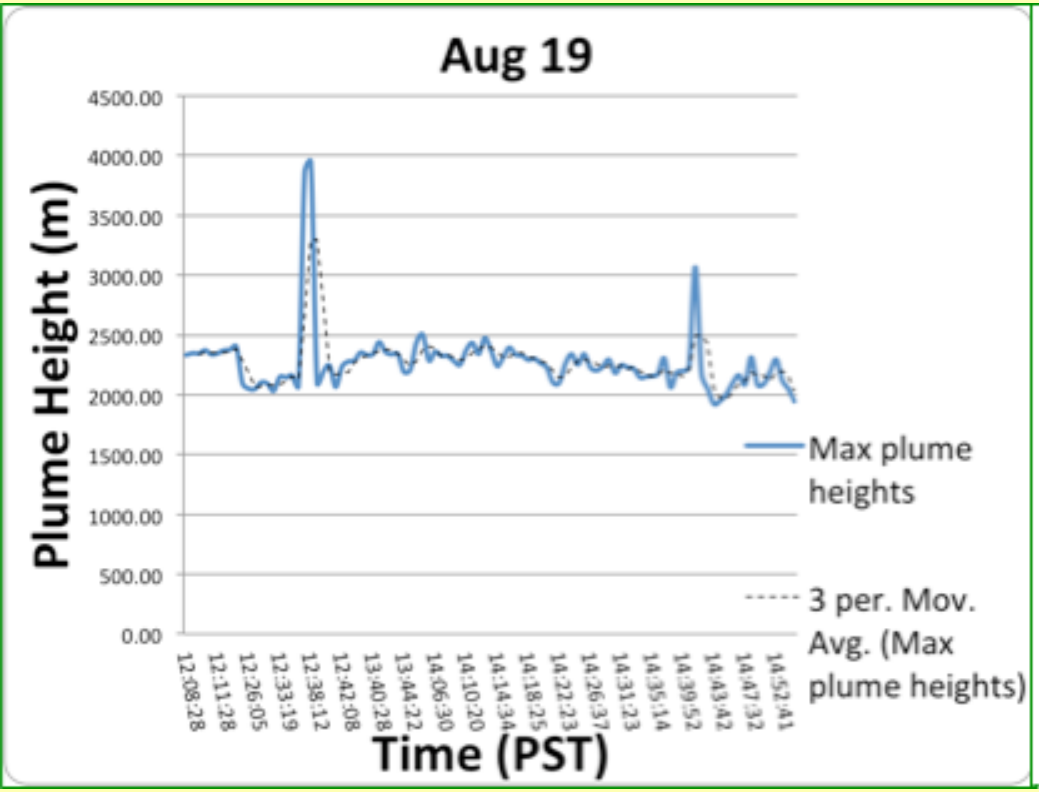
Figure 4: Flow chart of CS2 system as applied to RARE 2013 field study.

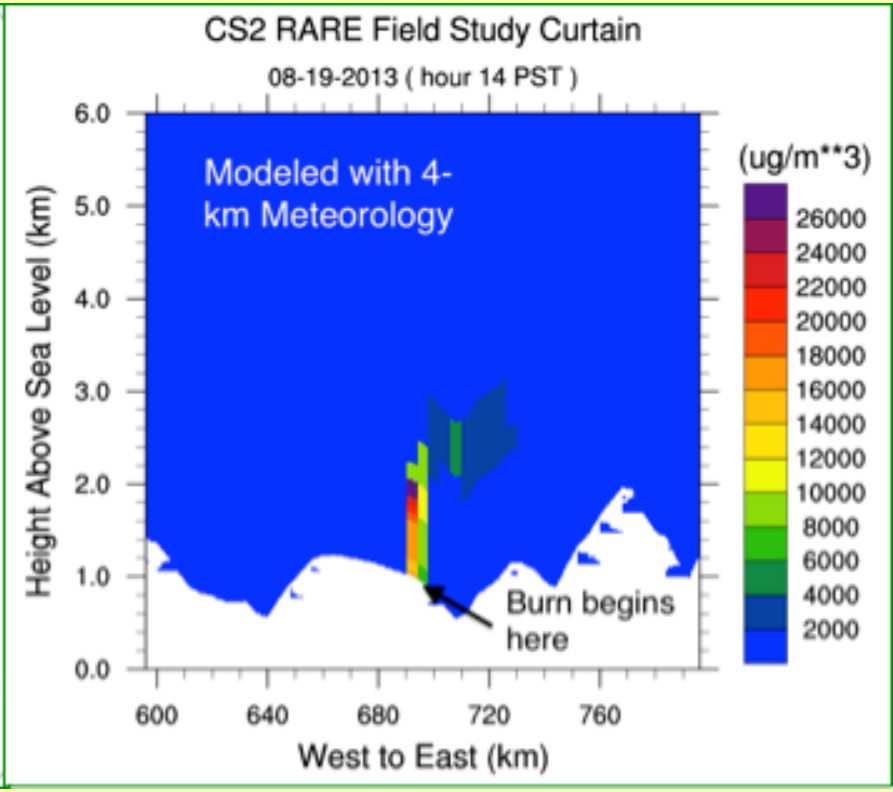

8-19-2013 CS2 Modeled and RARE Observed PM2.5 Concentrations
KBG Baled Modeled PM2.5 Concentration
EBAM D8592 Observed PM2.5 Concentration
KBG LL Modeled PM2.5 Concentration
EBAM E1122 Observed PM2.5 Concentration
Modeled using 4-km WRF Meteorology
Average Modeled: 3.485 ug/m^3
Average Observed: 13.71 ug/m^3
PM2.5 Concentrations (ug/m^3)
Hours Since 2pm 8-19-2013
400
350
300
250
200
150
100
50
0
-50
0
1
2
3
4
5
6
7
332
42
20
23
11
-5

8-20-2013 CS2 Modeled and RARE Observed $PM_{2.5}$ Concentrations

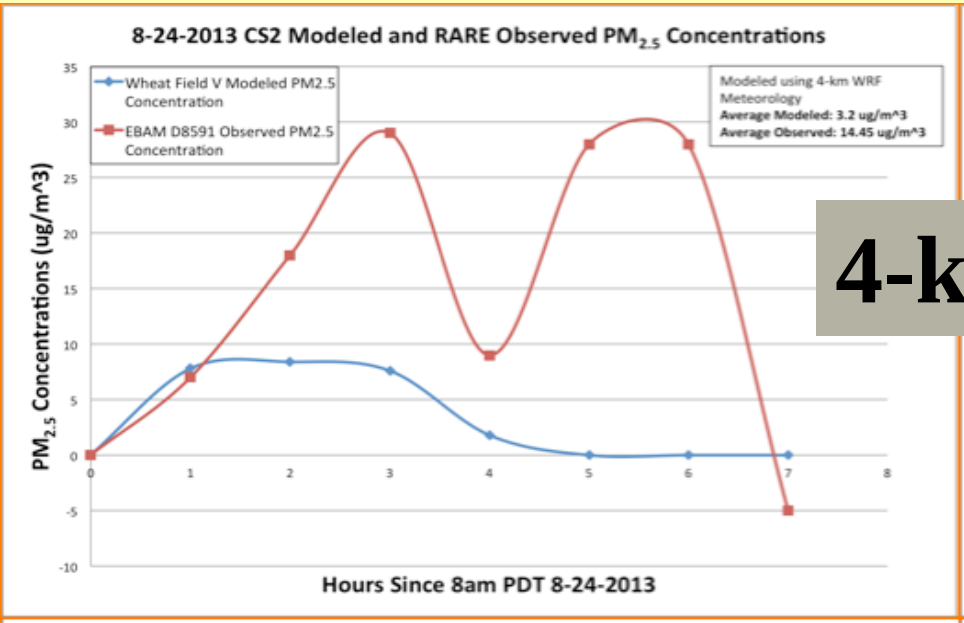


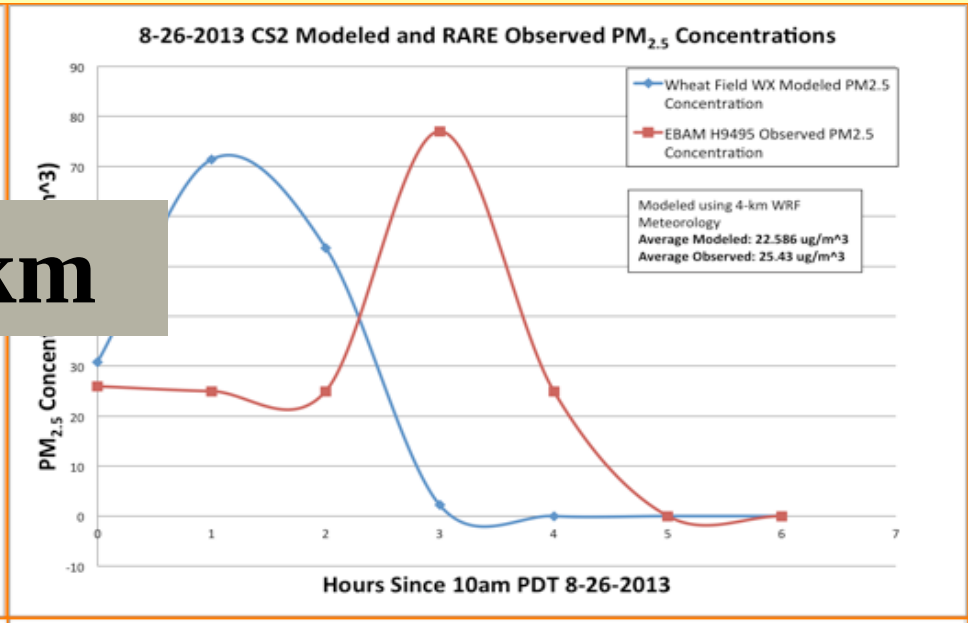
Plume Rise at Nezperce Burn of 08/19



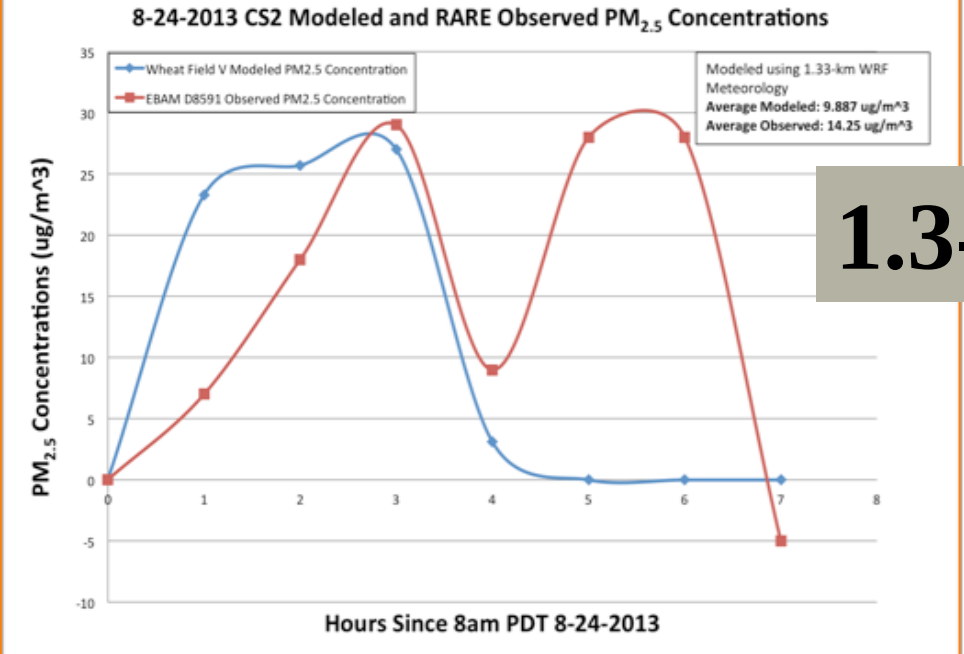


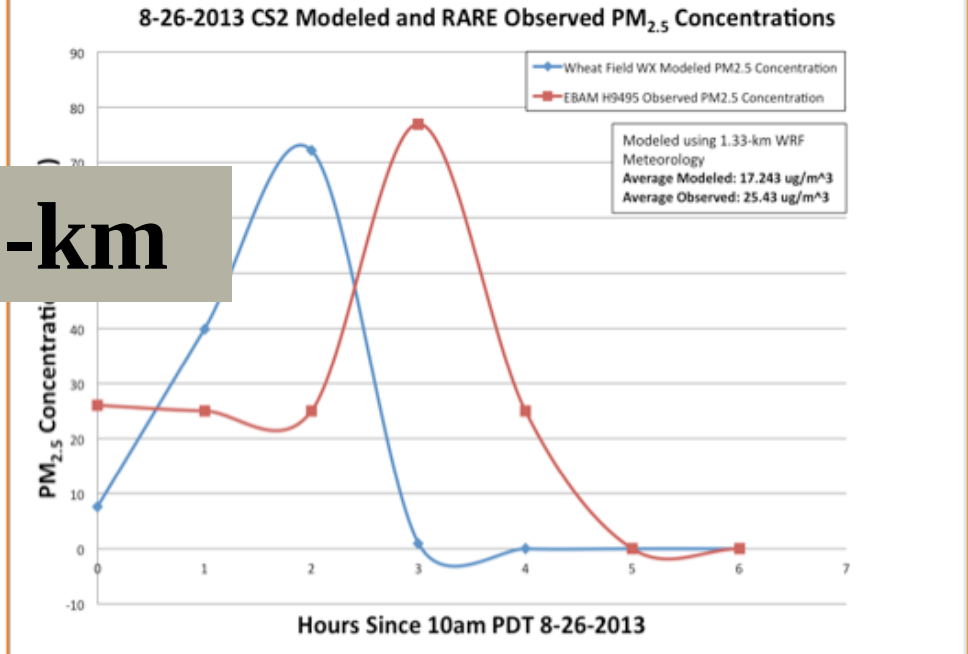
Walla Walla Burns:, 8/24 and 8/26





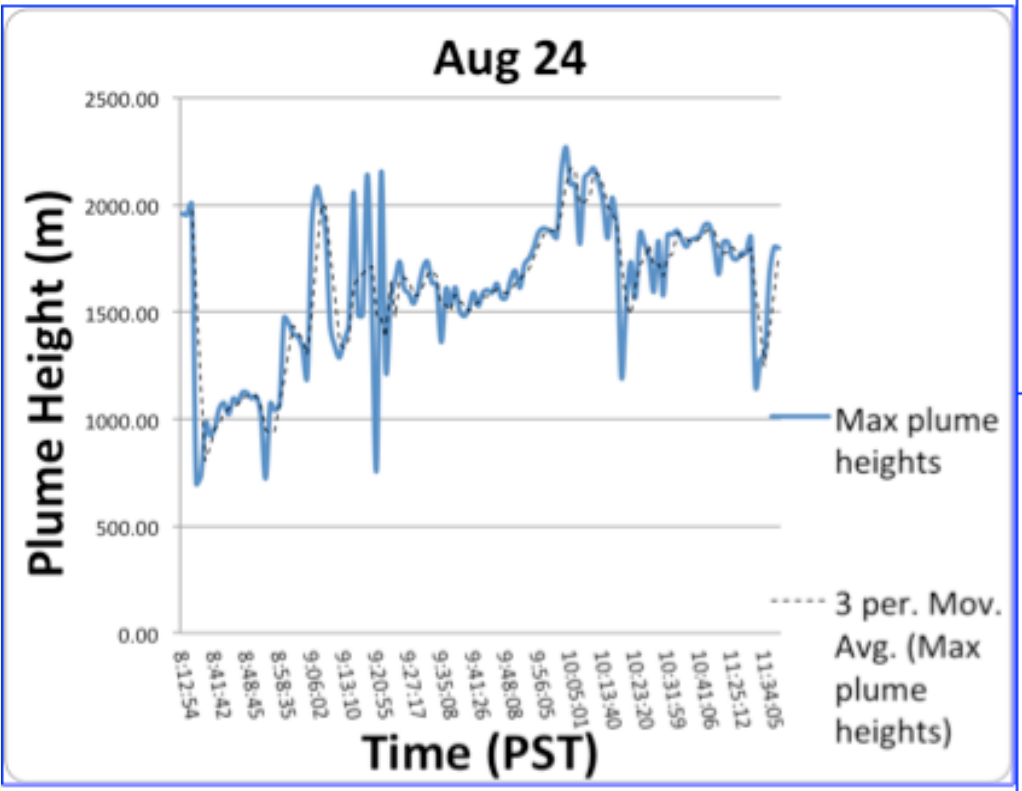
4-km

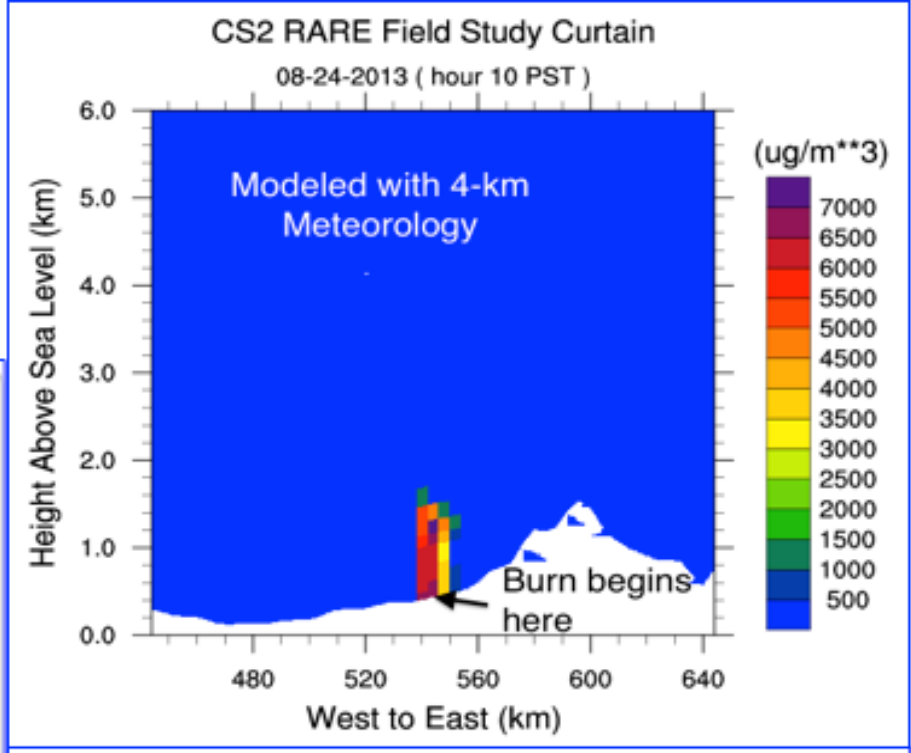


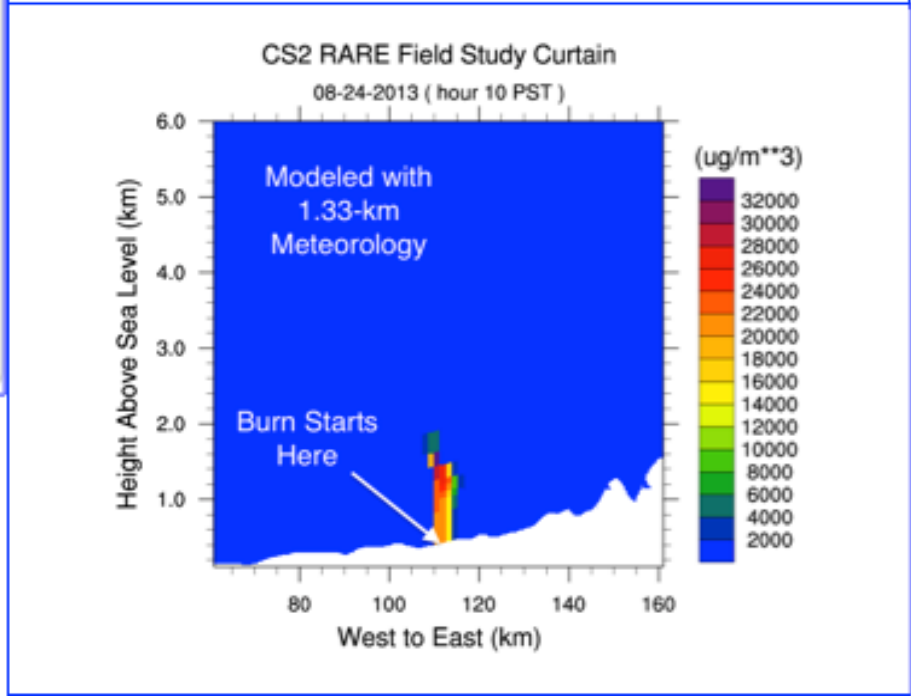


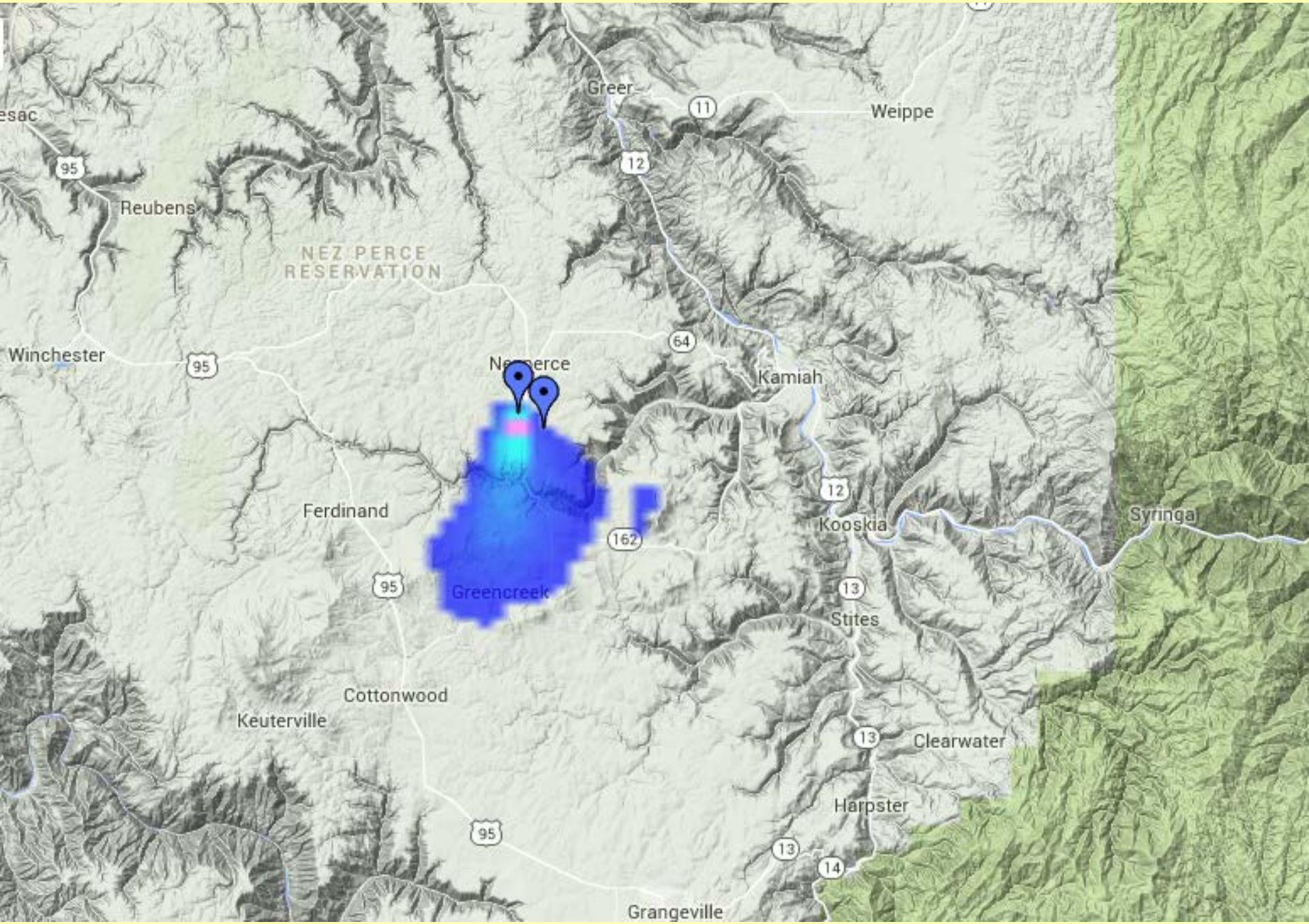
1.3-km

Plume Rise
08/24, Walla Walla





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Weippe
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12
95
Reubens
NEZ PERCE
RESERVATION
Winchester
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64
Kamiah
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Ferdinand
Kooskia
Syringa
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Greencreek
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Stites
Cottonwood
Keuterville
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Clearwater
Harpster
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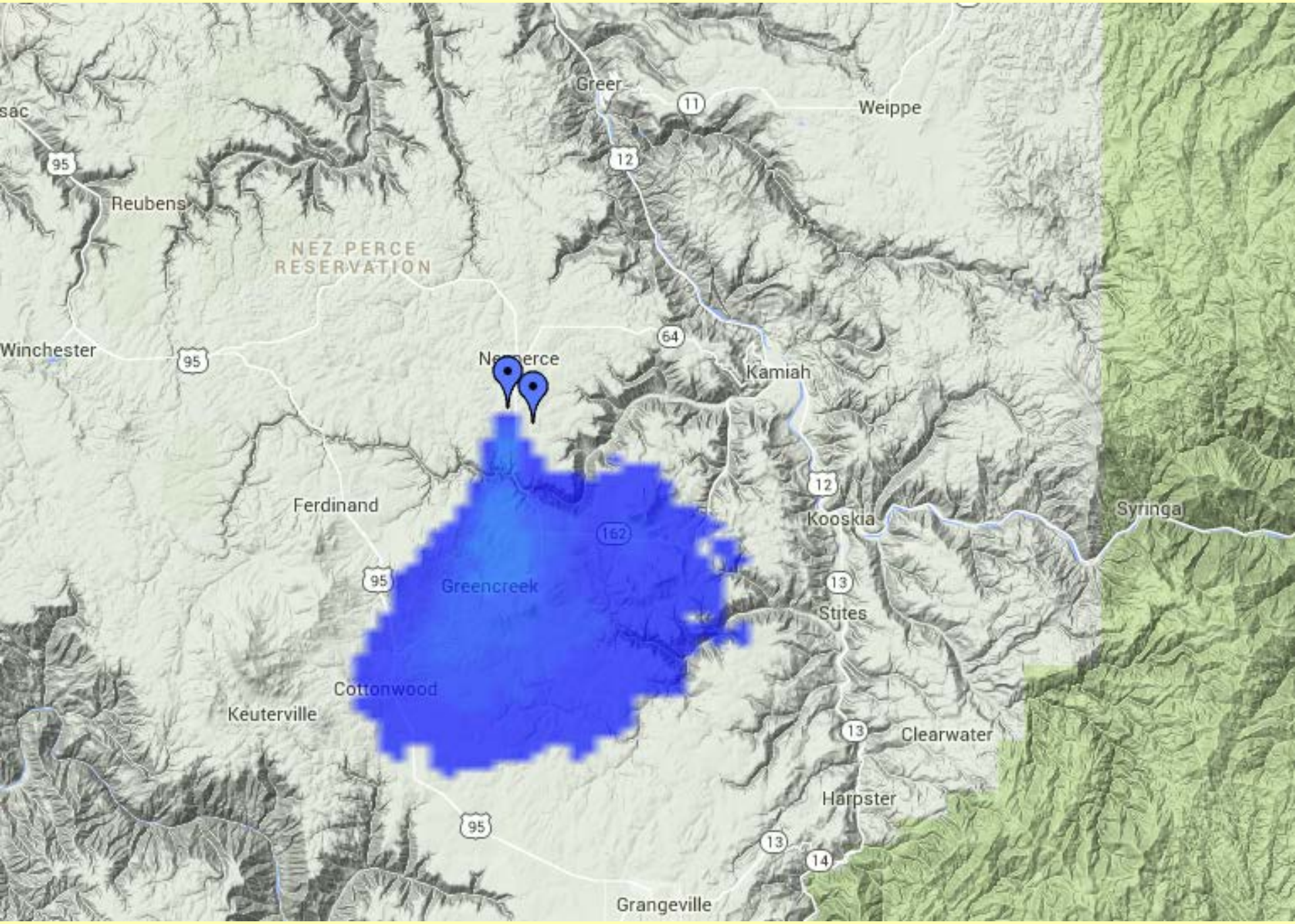
Grangeville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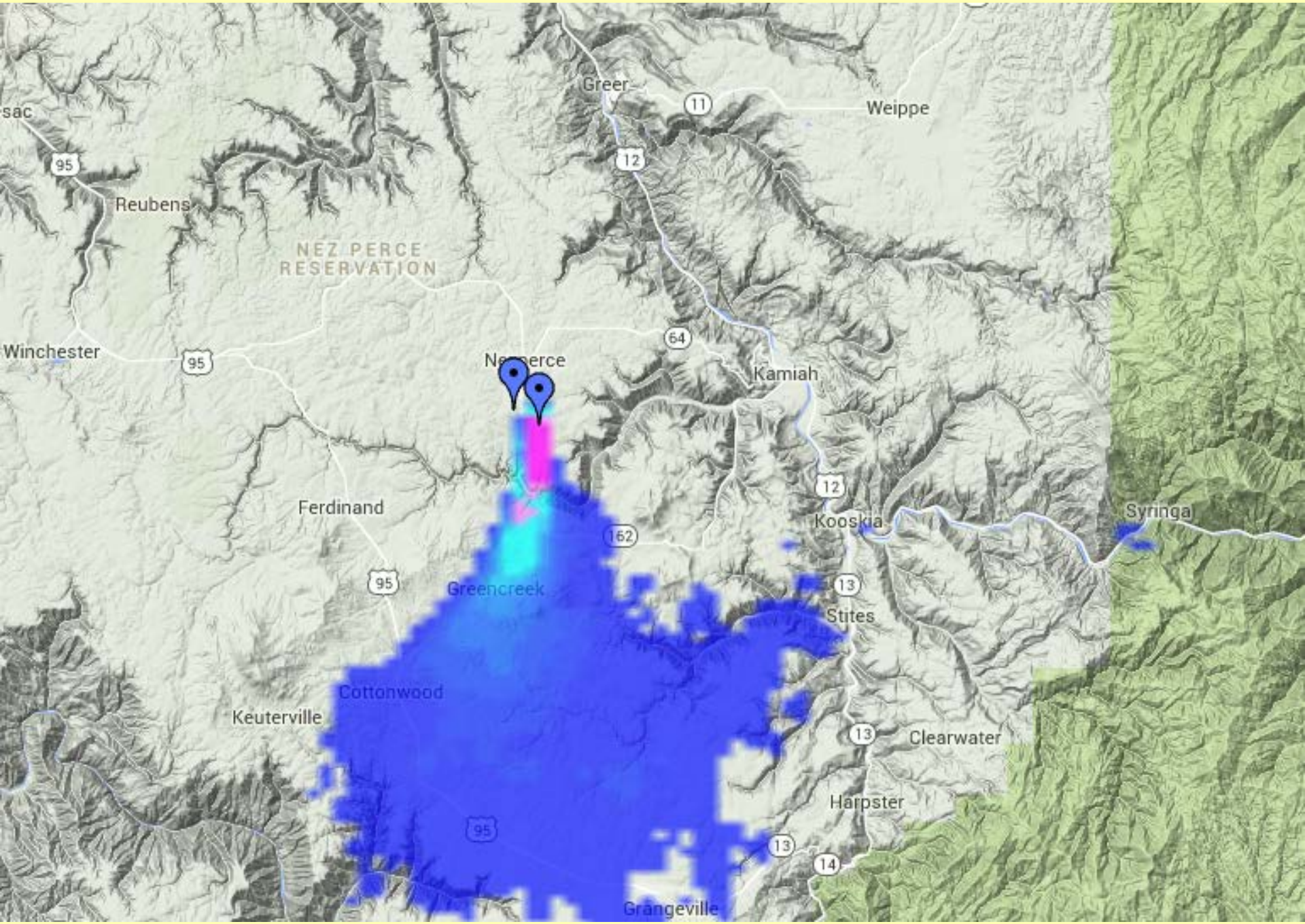
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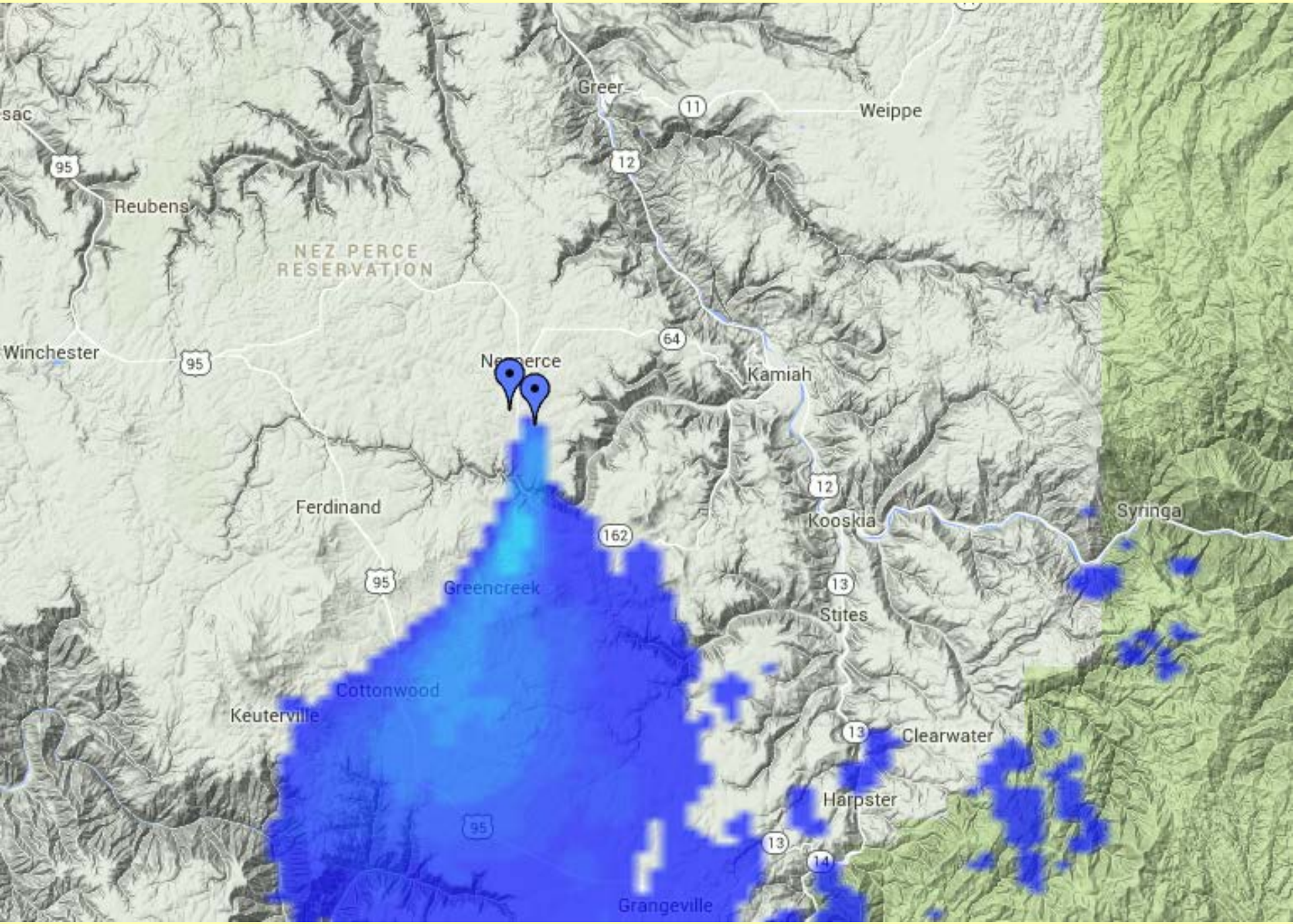
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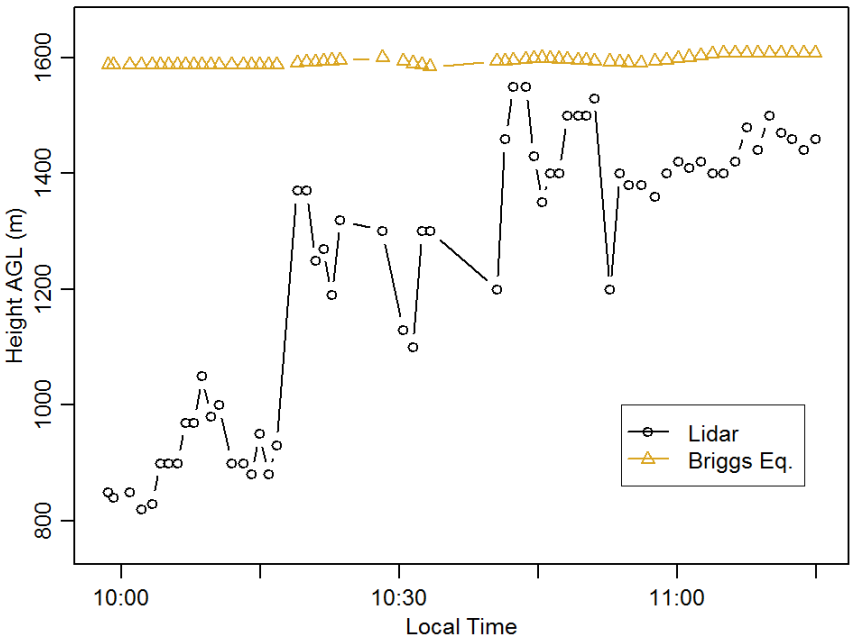
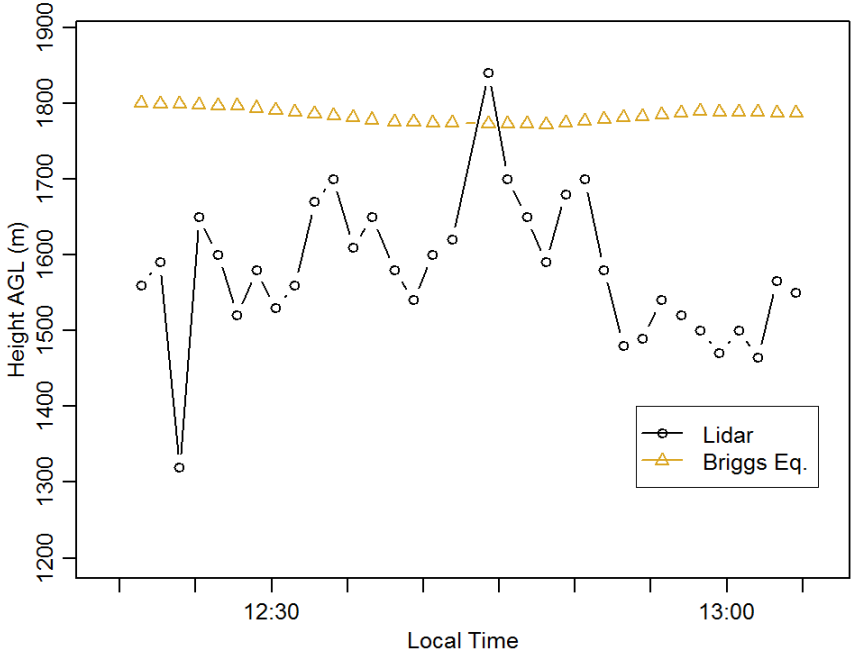
Plume Rise

Results from Shawn Urbanski, USFS-Missoula

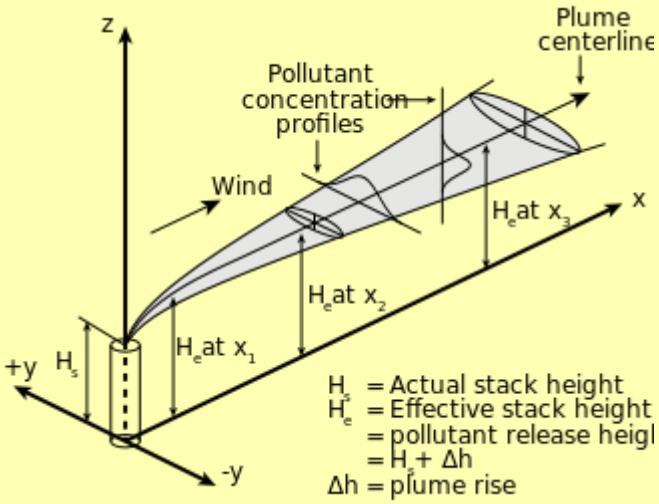


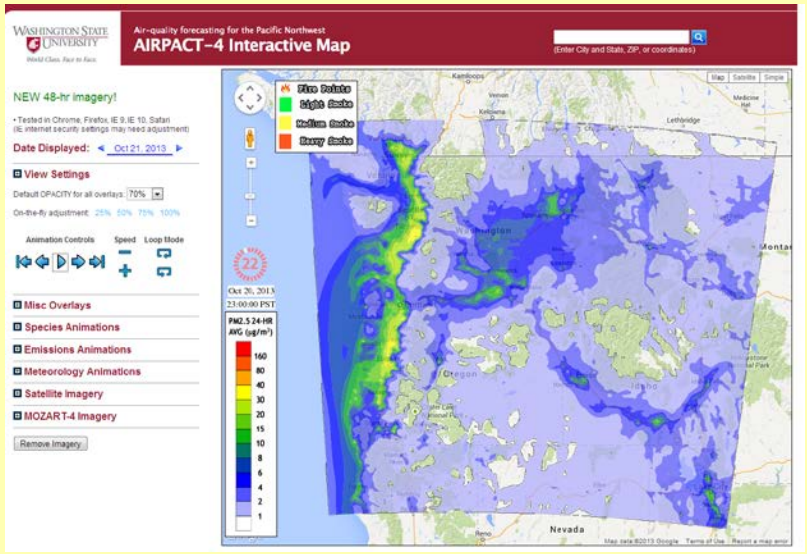


- **Simple Briggs plume rise predicts smoke lofts too high**
- **Useful comparison to more complex techniques**

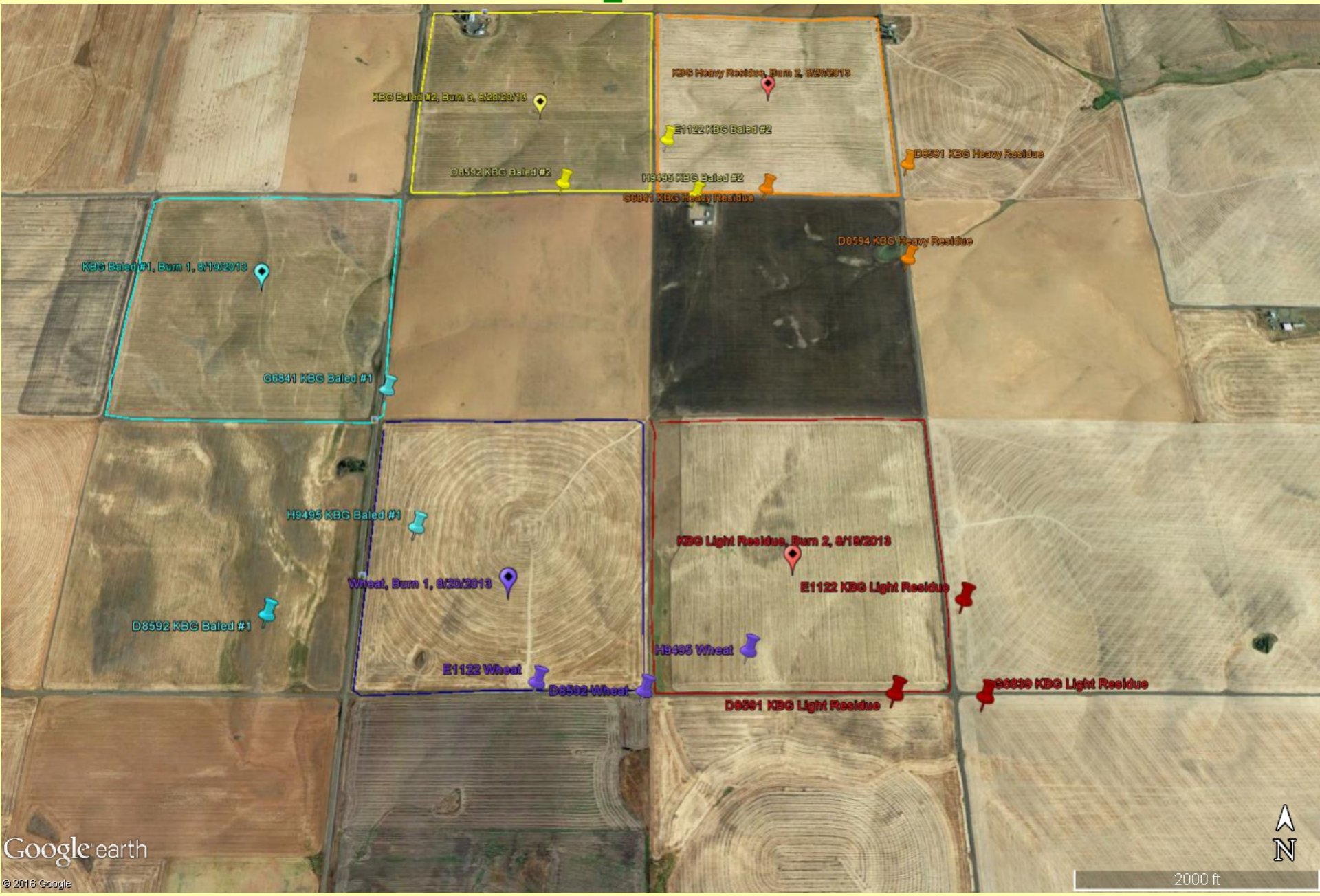
Next Steps

- **EPA-ORD will finish scientific journal article on measurements.**
- **Modelers are processing measurements and using them for model development and evaluation.**
  - **Washington State University**
  - **US Forest Service Research Station, Seattle**
  - **EPA, Research Triangle Park**



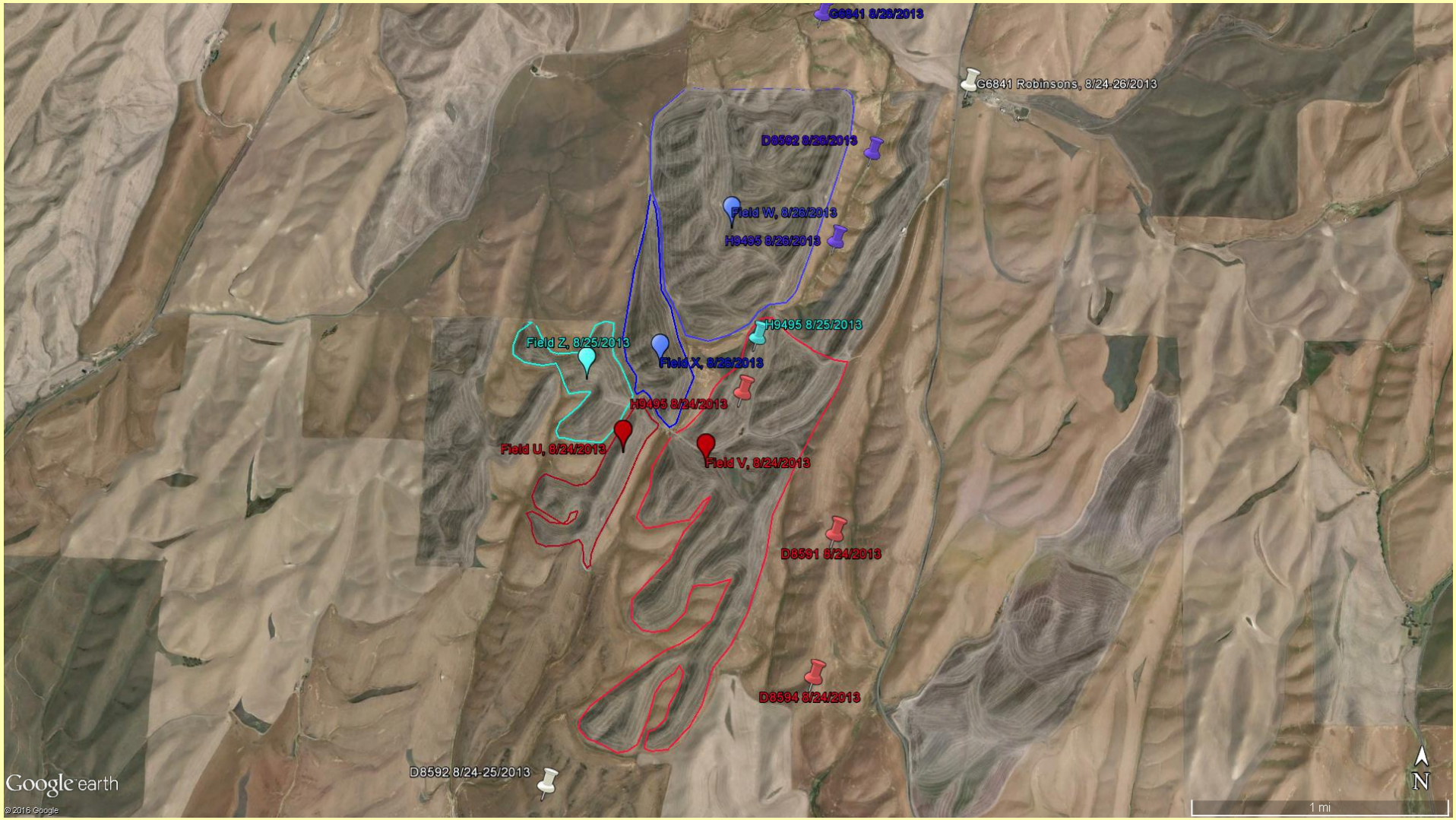


Nez Perce Fields, plus Ground EBAMs



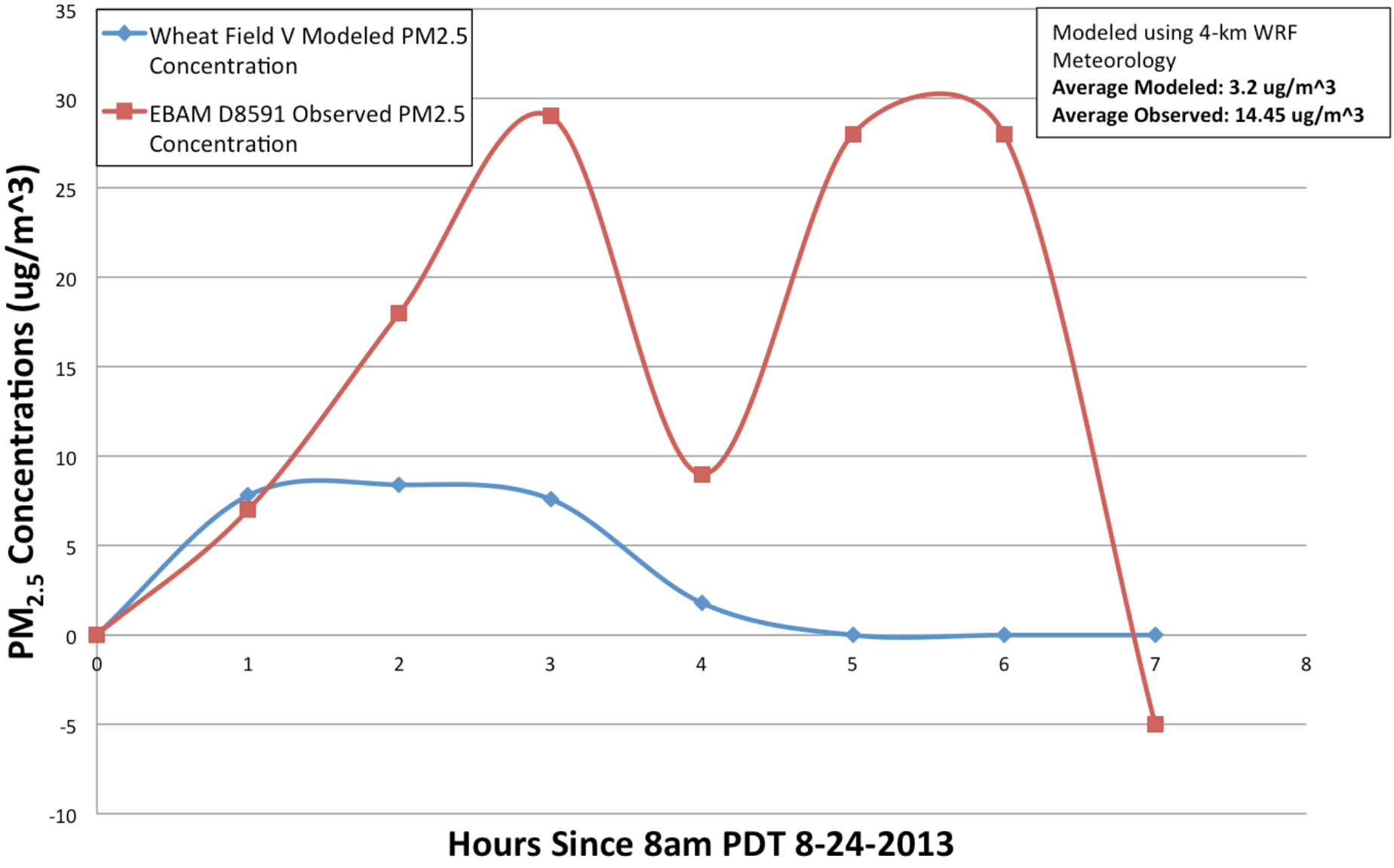
- **Nezperce, ID – 8/19/2013**
  - **KBG Baled – Kentucky Bluegrass Baled**
  - **KBG LL – Kentucky Bluegrass Light Loading**
- **Nezperce, ID – 8/20/2013**
  - **Wheat Stubble**
  - **KBG HL – Kentucky Bluegrass Heavy Loading**
- **Modeled only with 4-km WRF Meteorology**

Walla Walla Fields, plus Ground EBAMs

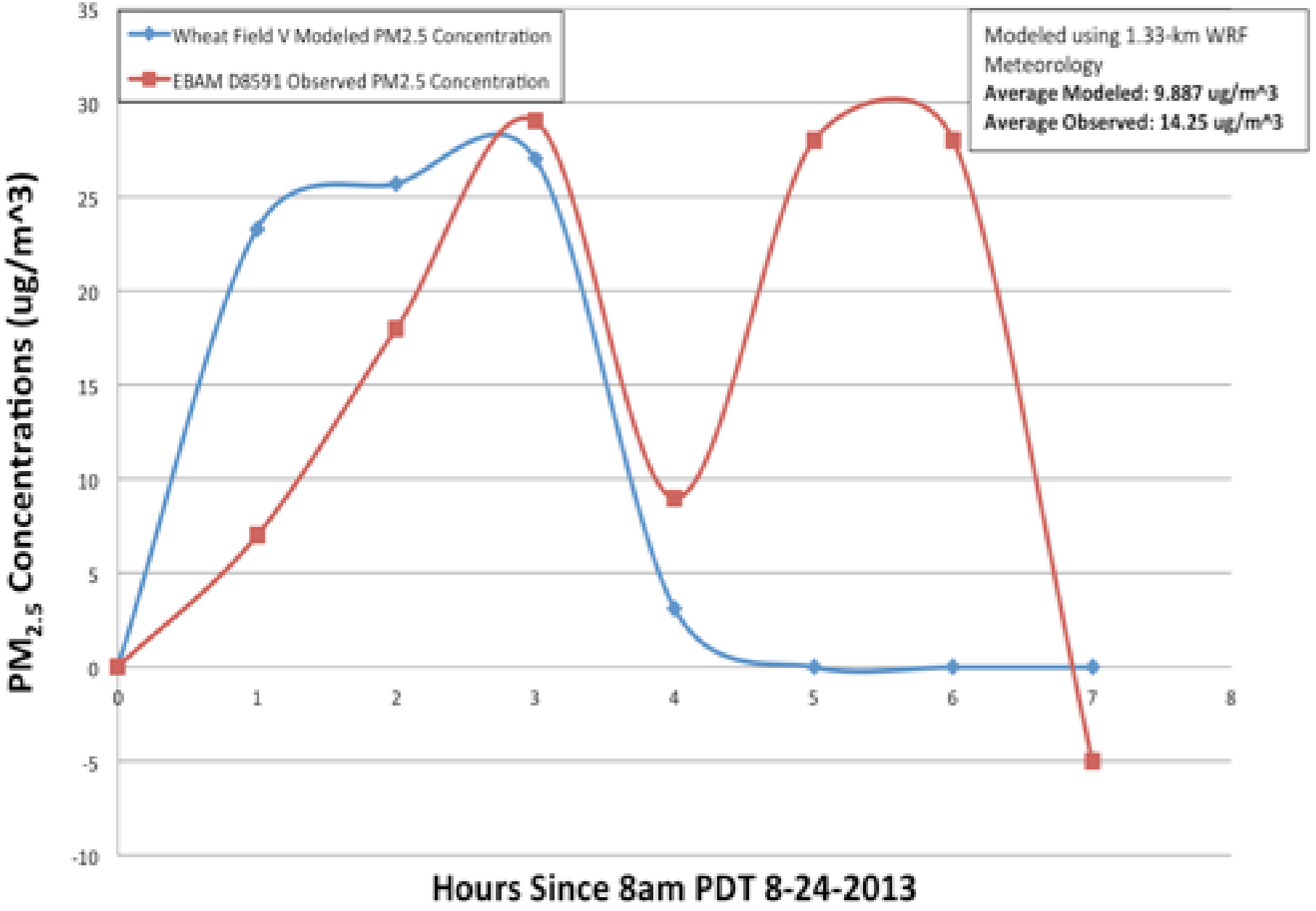


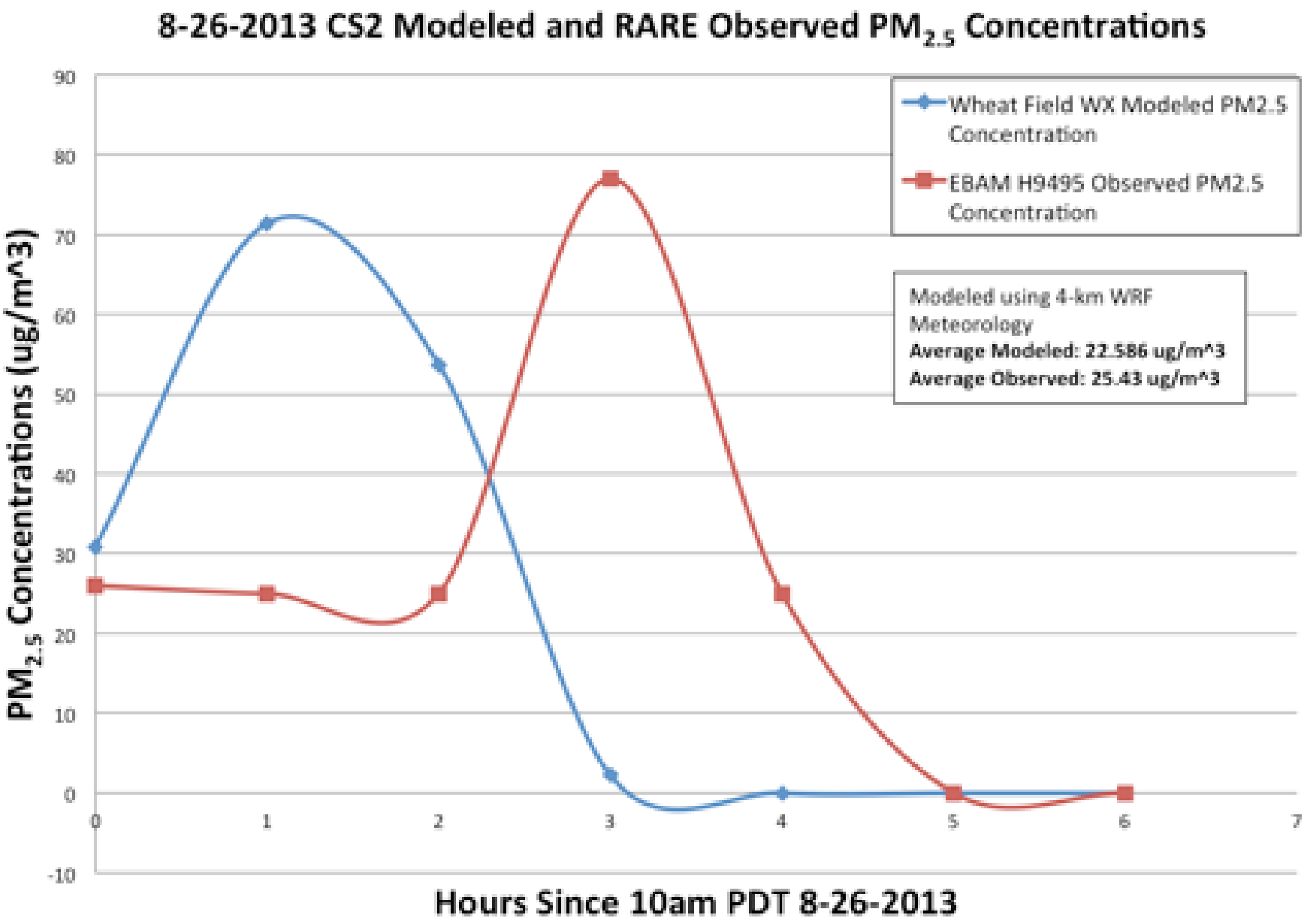
- **Walla Walla, WA – 8/24/2013,**
  - **Wheat Field V – Winter Wheat.**
- **Walla Walla, WA – 8/26/2013,**
  - **Wheat Field WX – Winter Wheat Fields W and X (burned together).**
- **Modeled with both 4-km and 1.333-km WRF Meteorology**

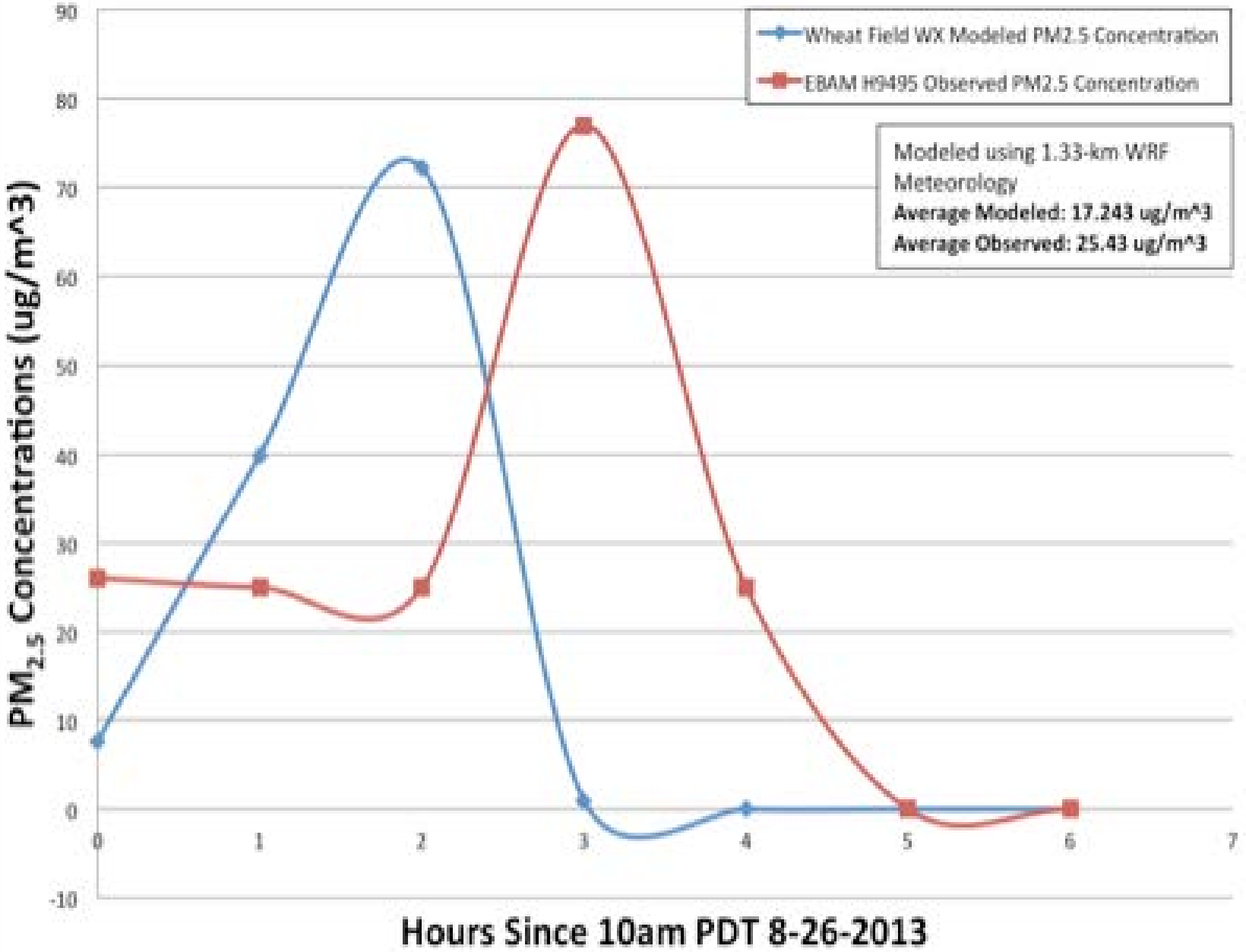
8-24-2013 CS2 Modeled and RARE Observed $PM_{2.5}$ Concentrations



8-24-2013 CS2 Modeled and RARE Observed $PM_{2.5}$ Concentrations




8-26-2013 CS2 Modeled and RARE Observed PM2.5 Concentrations
Wheat Field WX Modeled PM2.5 Concentration
EBAM H9495 Observed PM2.5 Concentration
Modeled using 4-km WRF Meteorology
Average Modeled: 22.586 ug/m^3
Average Observed: 25.43 ug/m^3
PM2.5 Concentrations (ug/m^3)
Hours Since 10am PDT 8-26-2013
90
80
70
60
50
40
30
20
10
0
-10
0
1
2
3
4
5
6
7


8-26-2013 CS2 Modeled and RARE Observed PM2.5 Concentrations
Wheat Field WX Modeled PM2.5 Concentration
EBAM H9495 Observed PM2.5 Concentration
Modeled using 1.33-km WRF Meteorology
Average Modeled: 17.243 ug/m^3
Average Observed: 25.43 ug/m^3
PM2.5 Concentrations (ug/m^3)
90
80
70
60
50
40
30
20
10
0
-10
0
1
2
3
4
5
6
7
Hours Since 10am PDT 8-26-2013