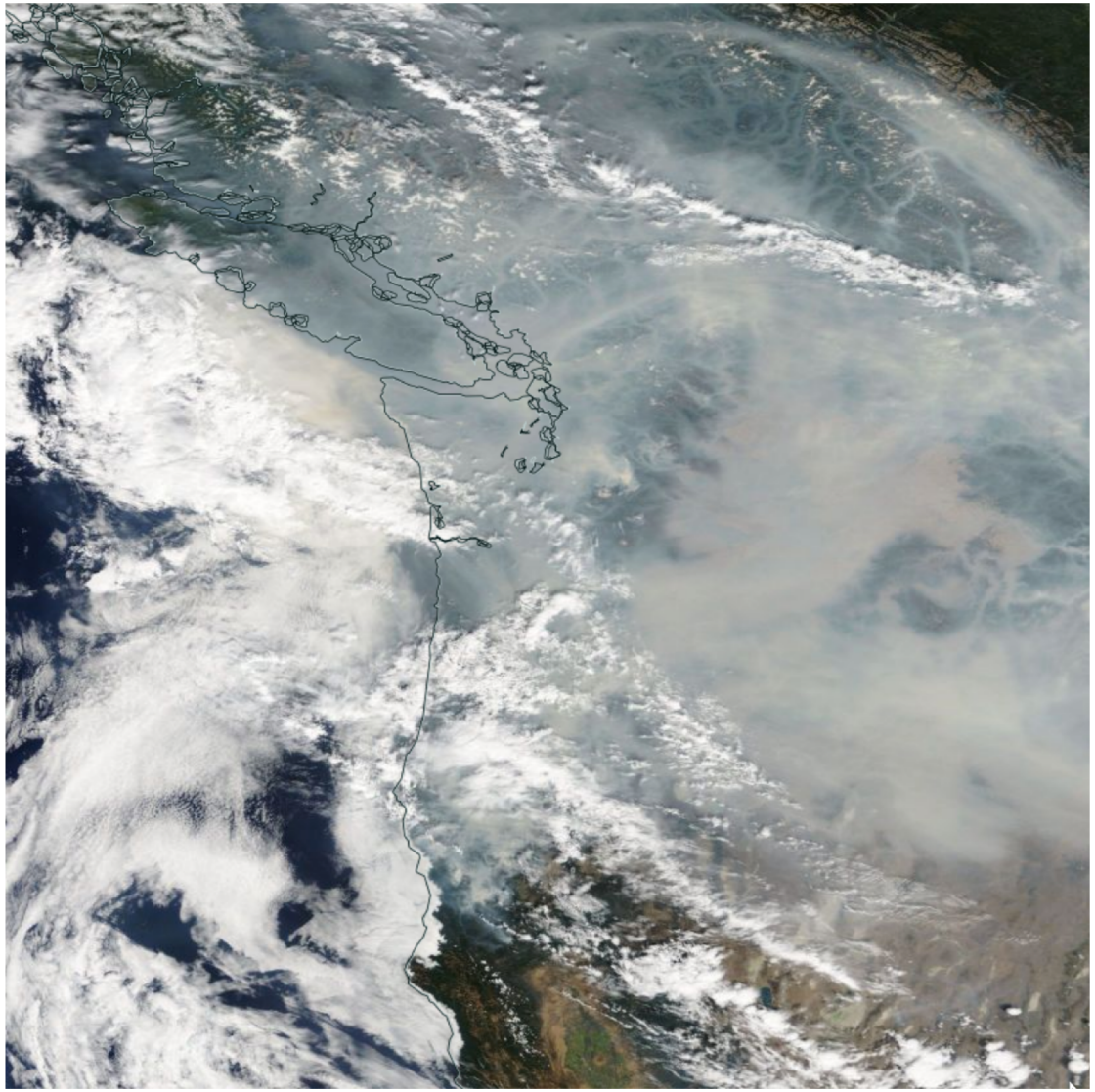
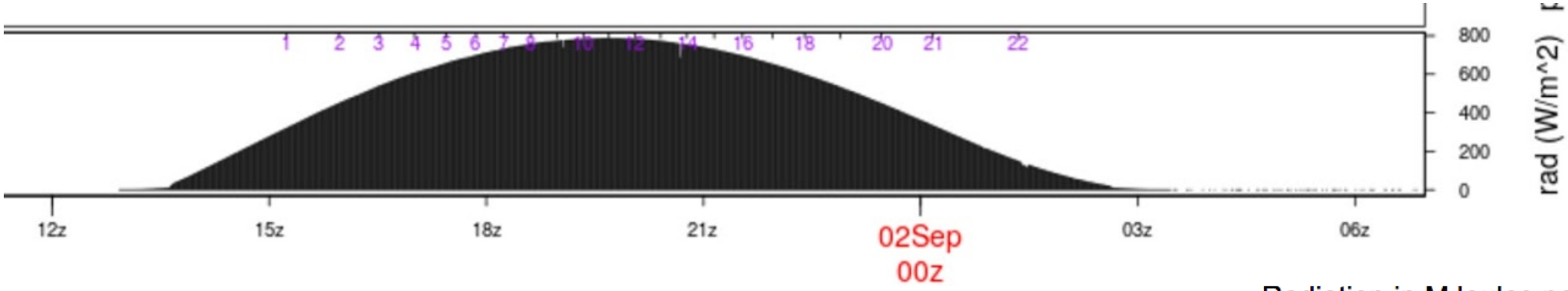
Wildfire Smoke and UW WRF

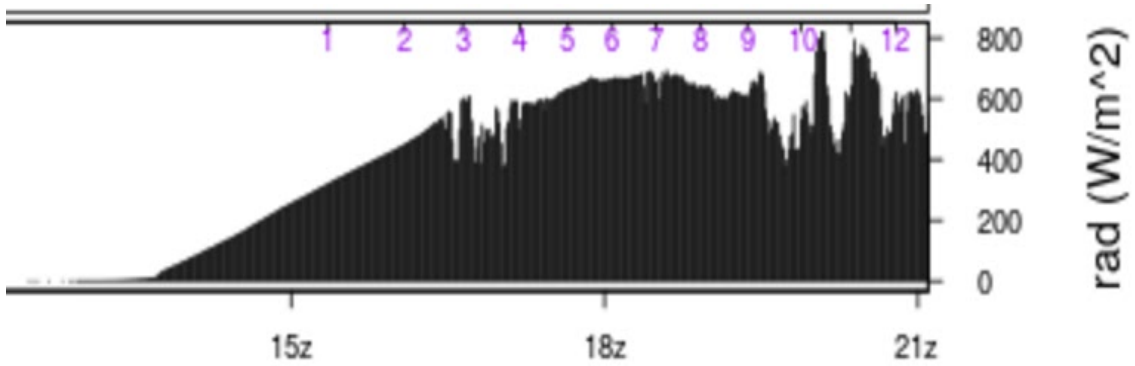
Cliff Mass and David Ovens
University of Washington
WRF Workshop June 2018

During the summer of 2017, dense veils of wildfire smoke covered the western U.S. for weeks



The impacts on solar radiation were profound (e.g., 25-35% drop in solar flux at surface in Seattle)

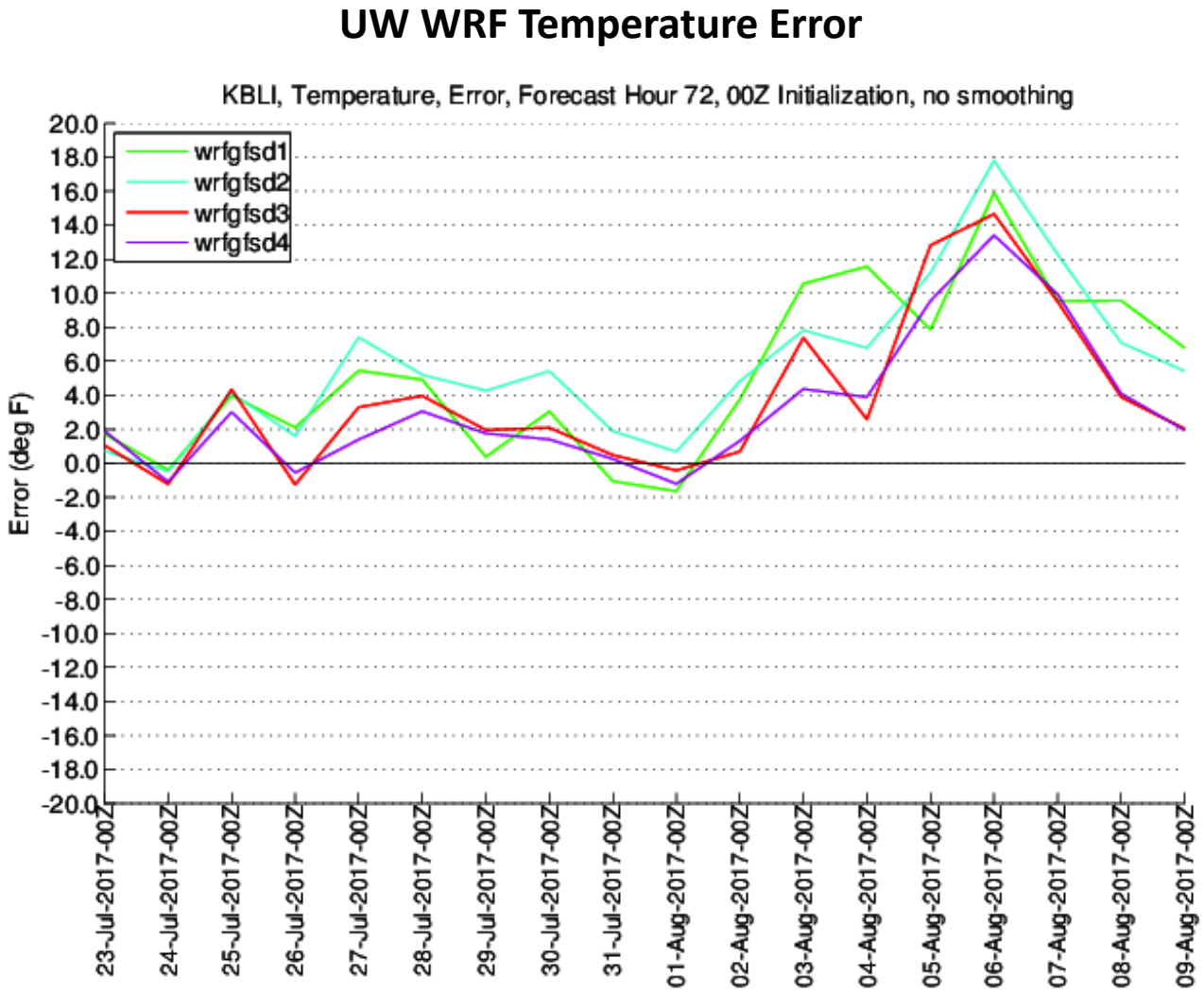




Radiation in MJoules per m2

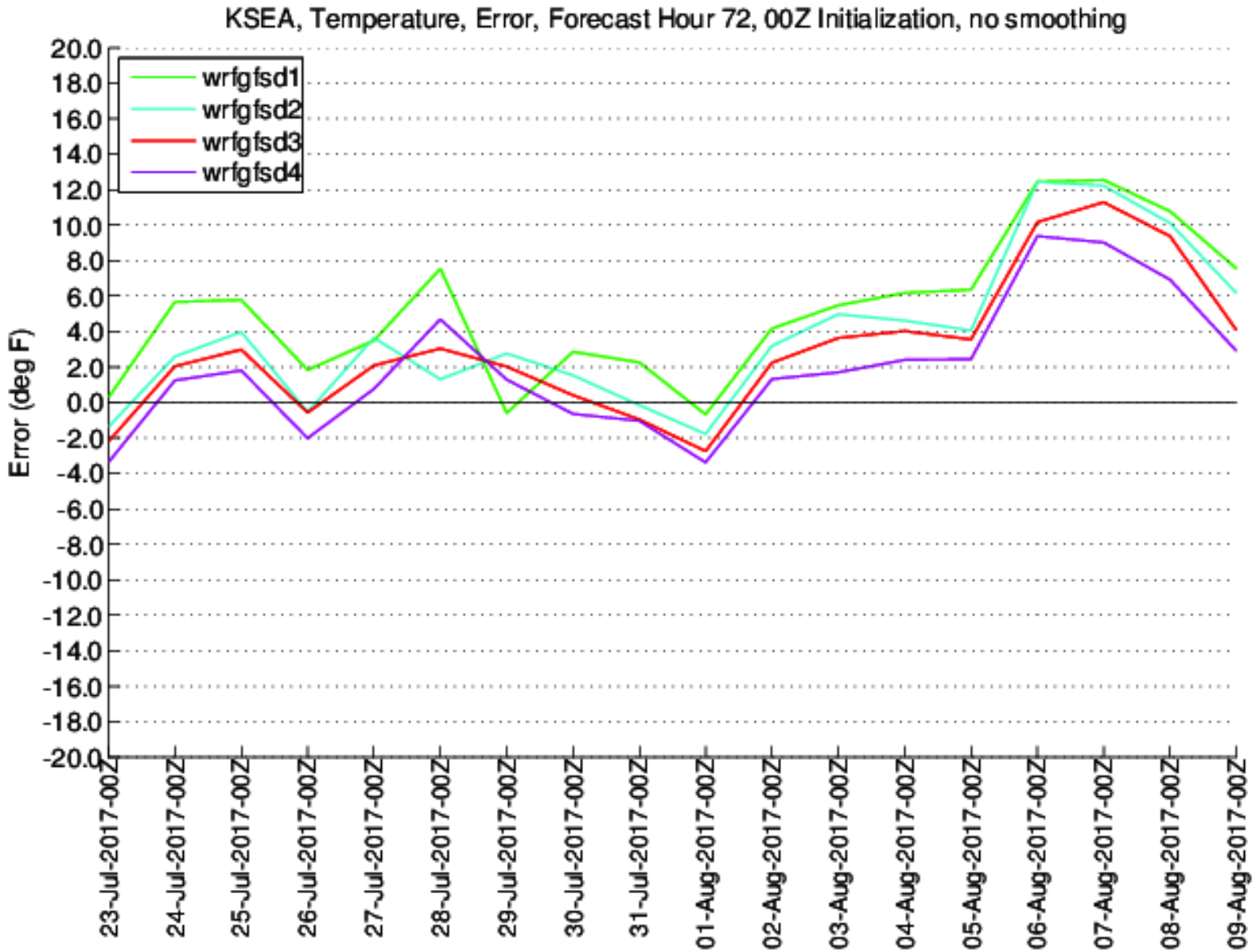
7/31	26.80
8/1	25.37
8/2	23.22
8/3	22.55
8/4	23.33
8/5	19.19
8/6	19.14
8/7	21.09
9/8	22.62

The result was substantial cooling (as high as 15F) that was not captured by the UW Operational WRF System

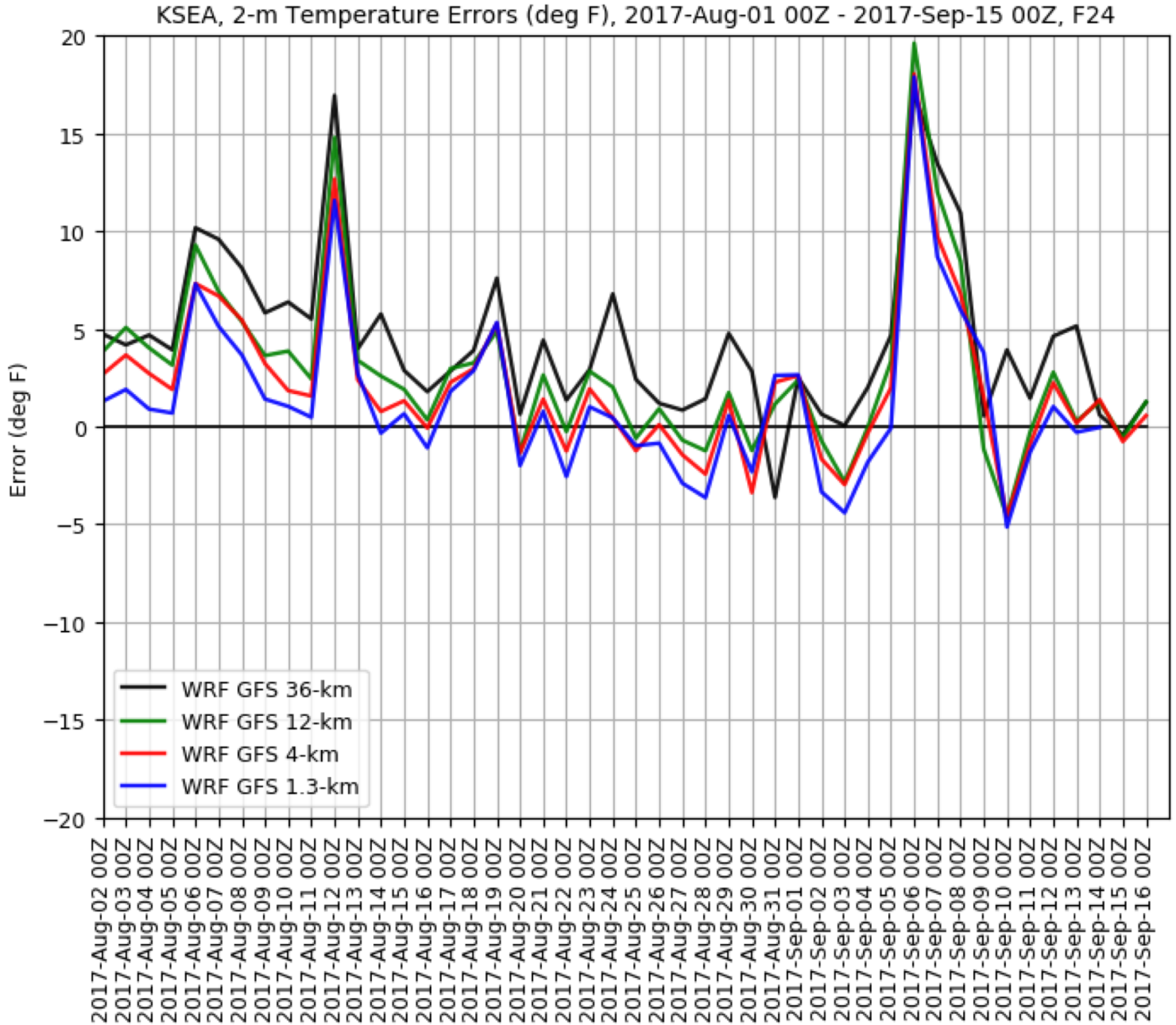


Bellingham, WA

Seattle


KSEA, Temperature, Error, Forecast Hour 72, 00Z Initialization, no smoothing
wrfgfsd1
wrfgfsd2
wrfgfsd3
wrfgfsd4
Error (deg F)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
-18.0
-20.0
23-Jul-2017-00Z
24-Jul-2017-00Z
25-Jul-2017-00Z
26-Jul-2017-00Z
27-Jul-2017-00Z
28-Jul-2017-00Z
29-Jul-2017-00Z
30-Jul-2017-00Z
31-Jul-2017-00Z
01-Aug-2017-00Z
02-Aug-2017-00Z
03-Aug-2017-00Z
04-Aug-2017-00Z
05-Aug-2017-00Z
06-Aug-2017-00Z
07-Aug-2017-00Z
08-Aug-2017-00Z
09-Aug-2017-00Z

Seattle August 2-Sept 16



UW WRF users were complaining!

- Large temperature errors where smoke was dense
- Messing up boundary layer depth forecasts.

So I promised to get smoke impacts into the operational WRF model

- In this talk I will describe our approach
- Would be very interested in any suggestions of better ways to do it.
- This month, we will initiate our Beta version in preparation for the wildfire/smoke season.

But how?

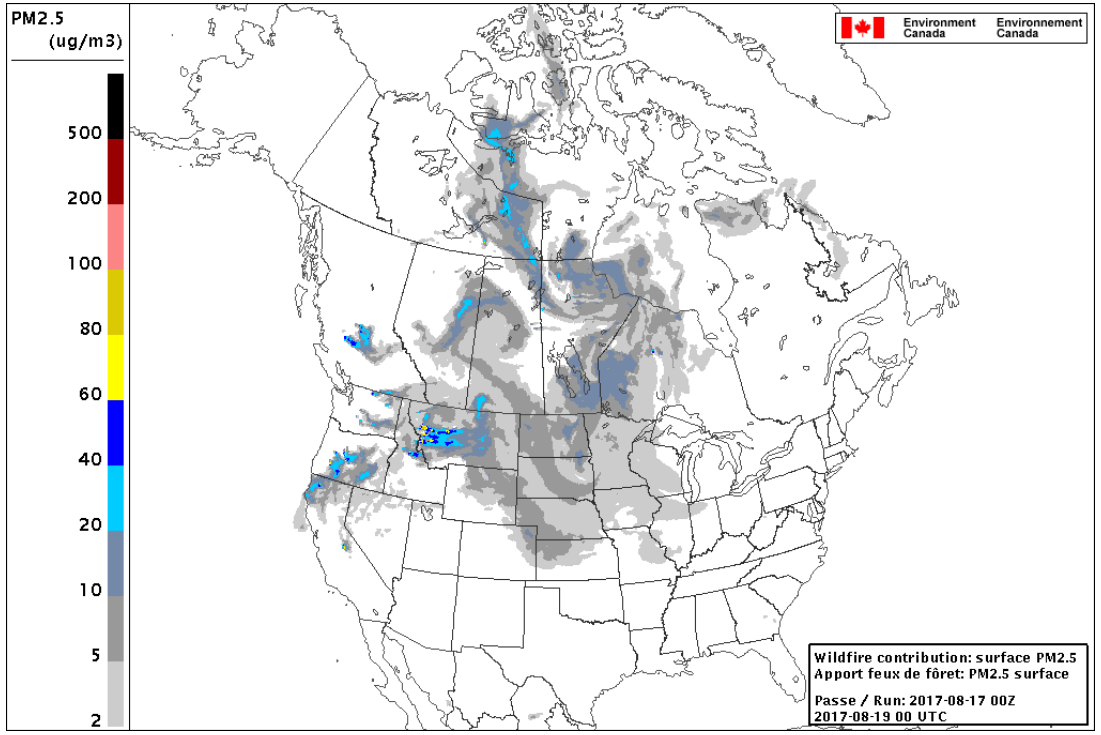
- **Didn’t want to run WRF-CHEM**
- **Didn’t want to bother getting fire inventory and doing emissions modeling.**
- **In the first cut, wanted to avoid explicit modeling of the 3D nature of the smoke, just deal with the reduction of solar radiation to the surface.**

A simple approach

- Secure a 2D field of smoke-related aerosol optical depth at initialization and forecast times.
- Plug it into the RRTMG radiation scheme in WRF.
- Thus, add smoke into our model with little overhead.
- Go home and get a class of wine.

BUT DOES THIS WORK?

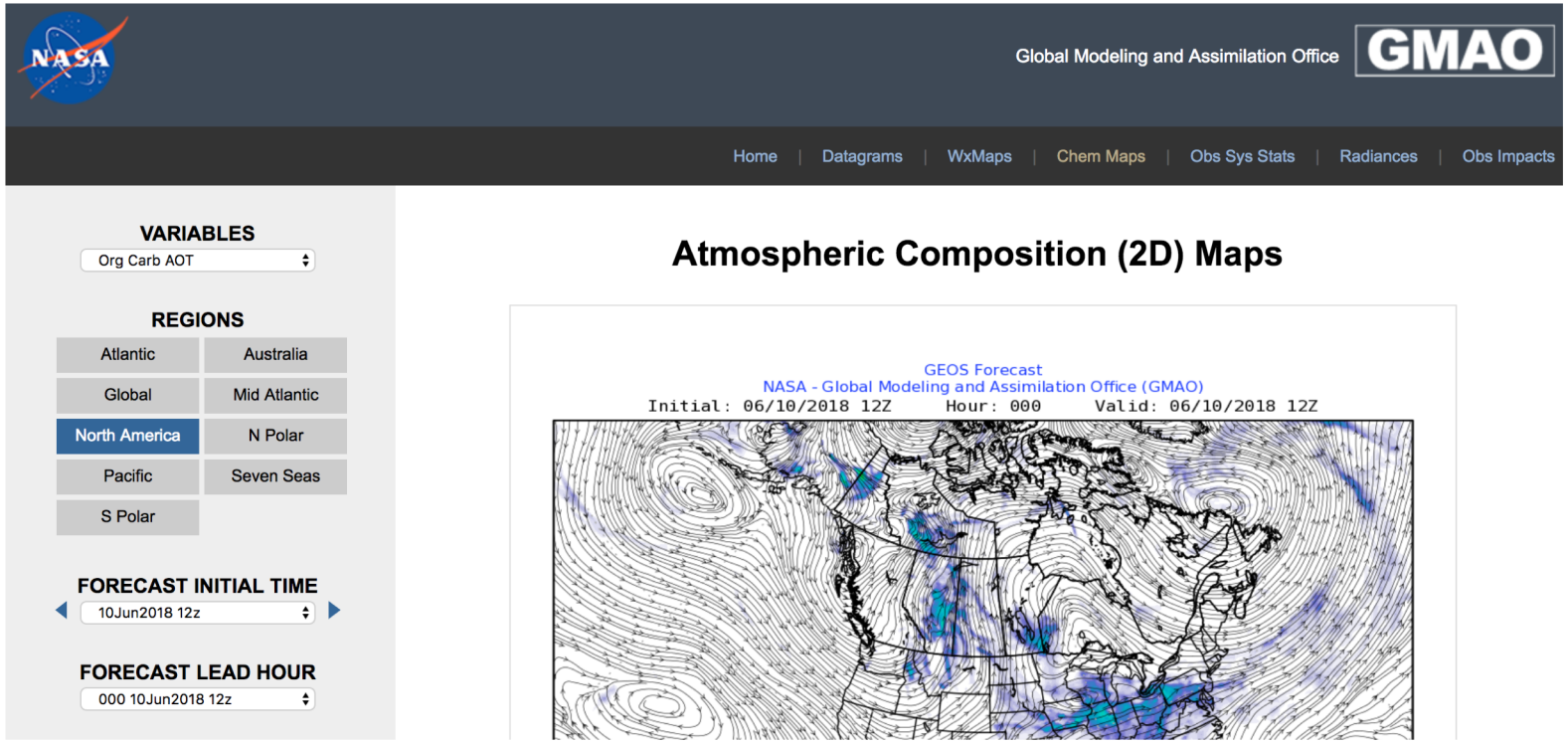
Complication



- **Significant differences between various smoke prediction systems. (Canadian, Bluesky, ESRL HRRR)**
- **Most are only available for a few days out (72hr, which means would only have 60hr)**
- **All based on fire sources, not remote sensing of smoke**

Compromise: Use the NASA GEOS FP System

- Four times a day
- Initialization and forecasts are available
- ~30 km horizontal grid spacing
- Aerosol optical depth and angstrom exponent available

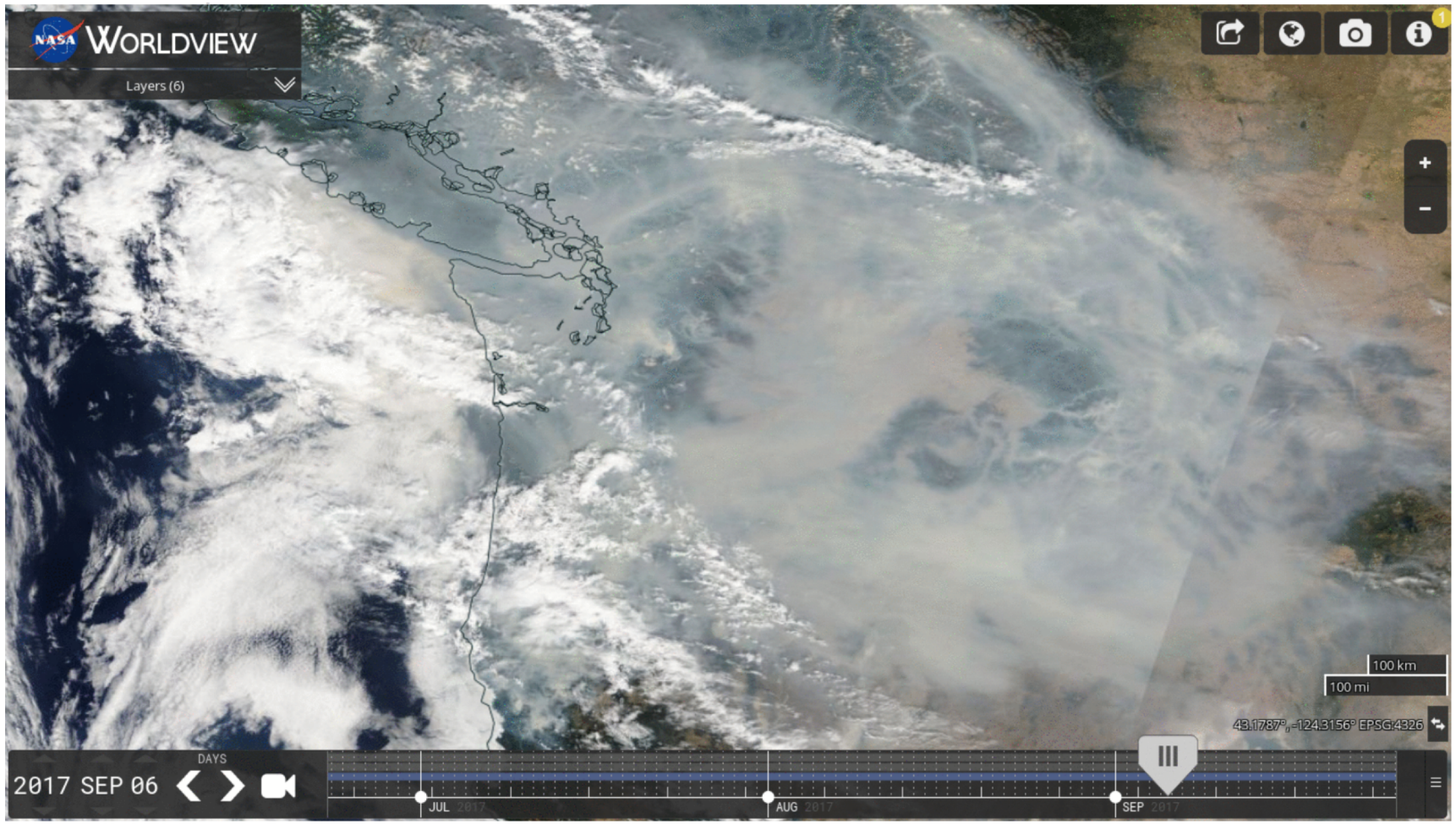


Experimental set up

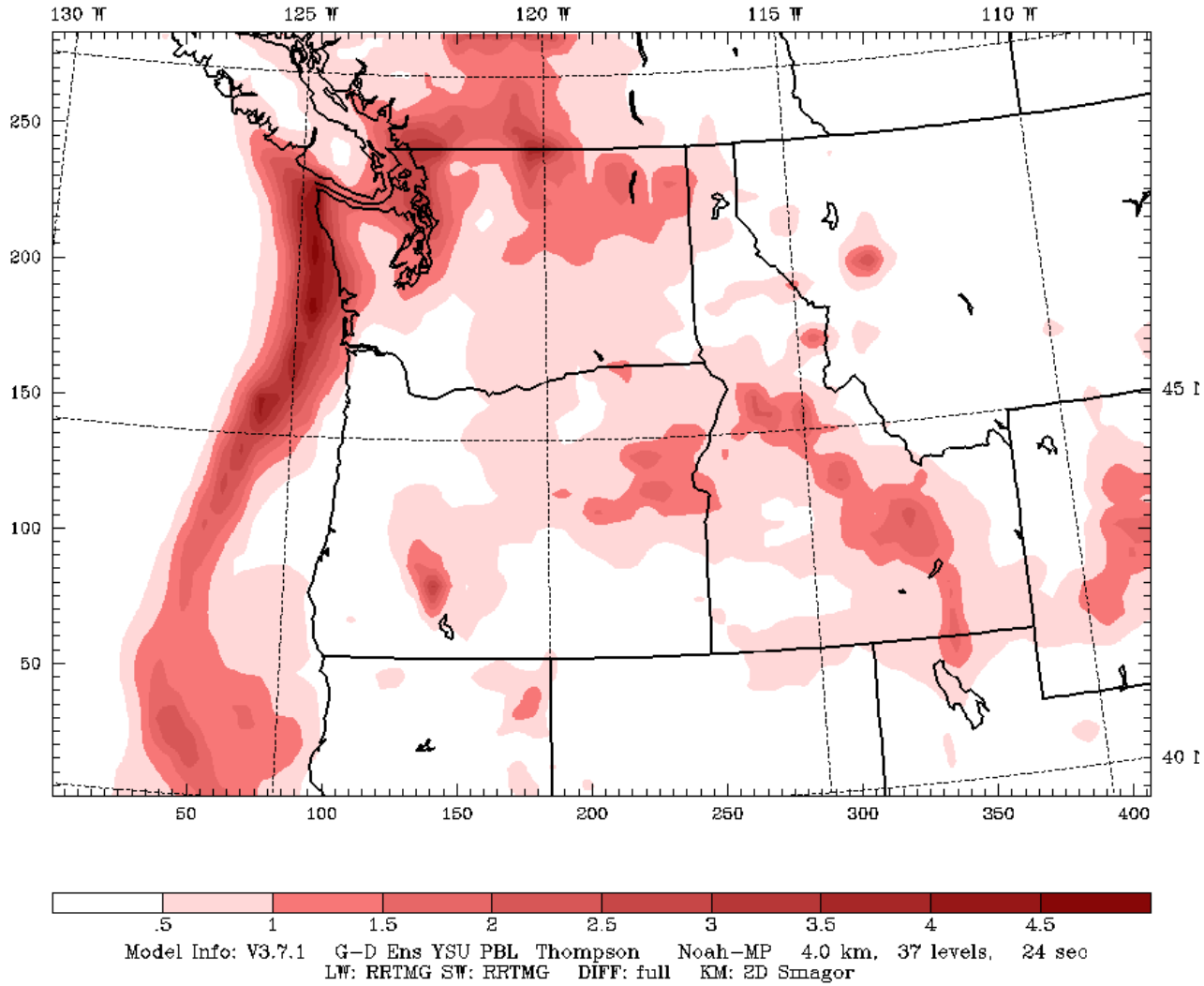
- **4-km domain**
- **GEOS 3-hourly aerosol optical depth initial conditions and forecast.**
- **GEOS 3-hourly aerosol angstrom exponent (**how optical depth changes with wavelength)
- **Fixed single scattering albedo = 0.85**
- **Fixed aerosol asymmetry parameter = 0.9**

Two Events: August 6-7

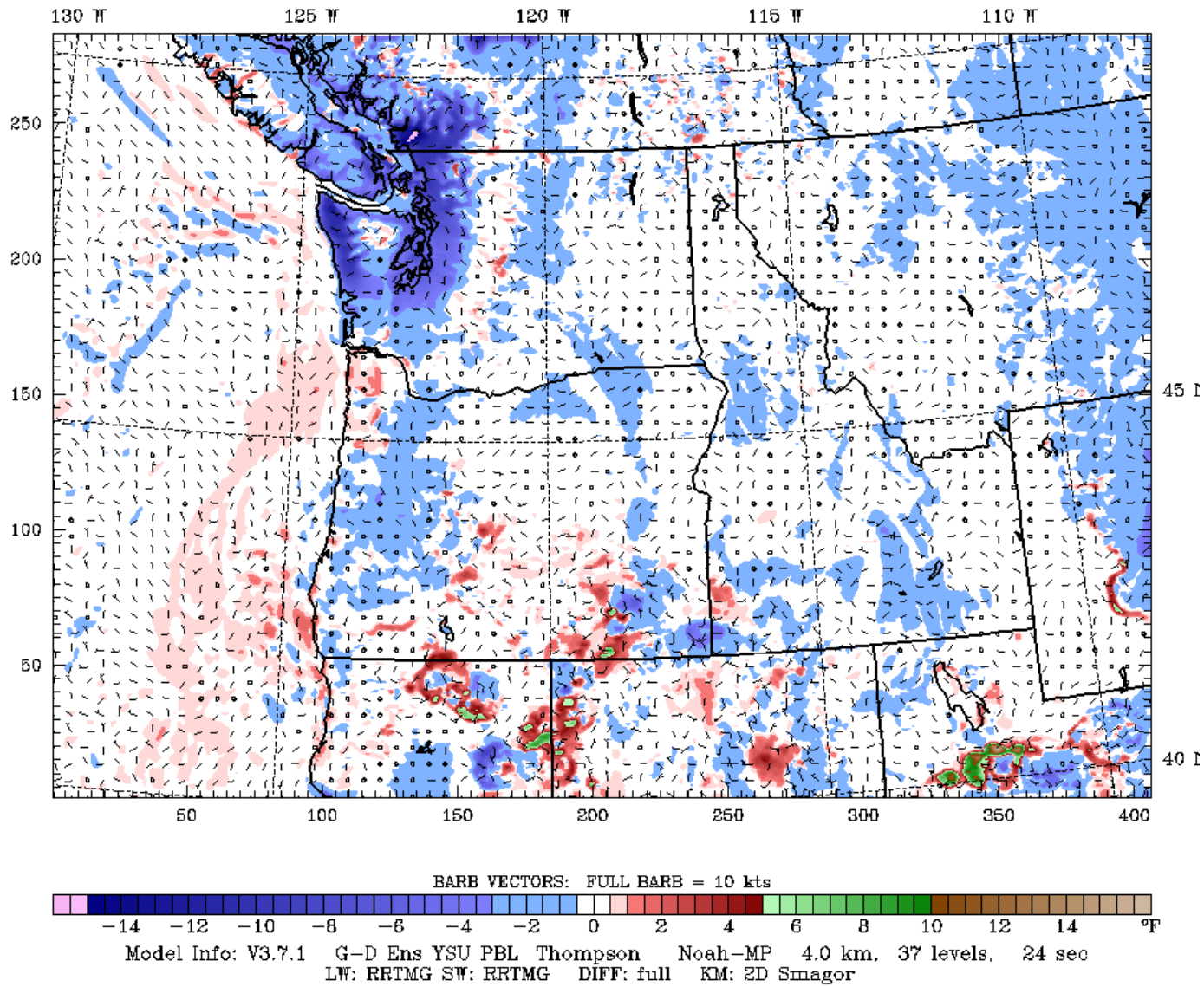
September 6-7, 2017



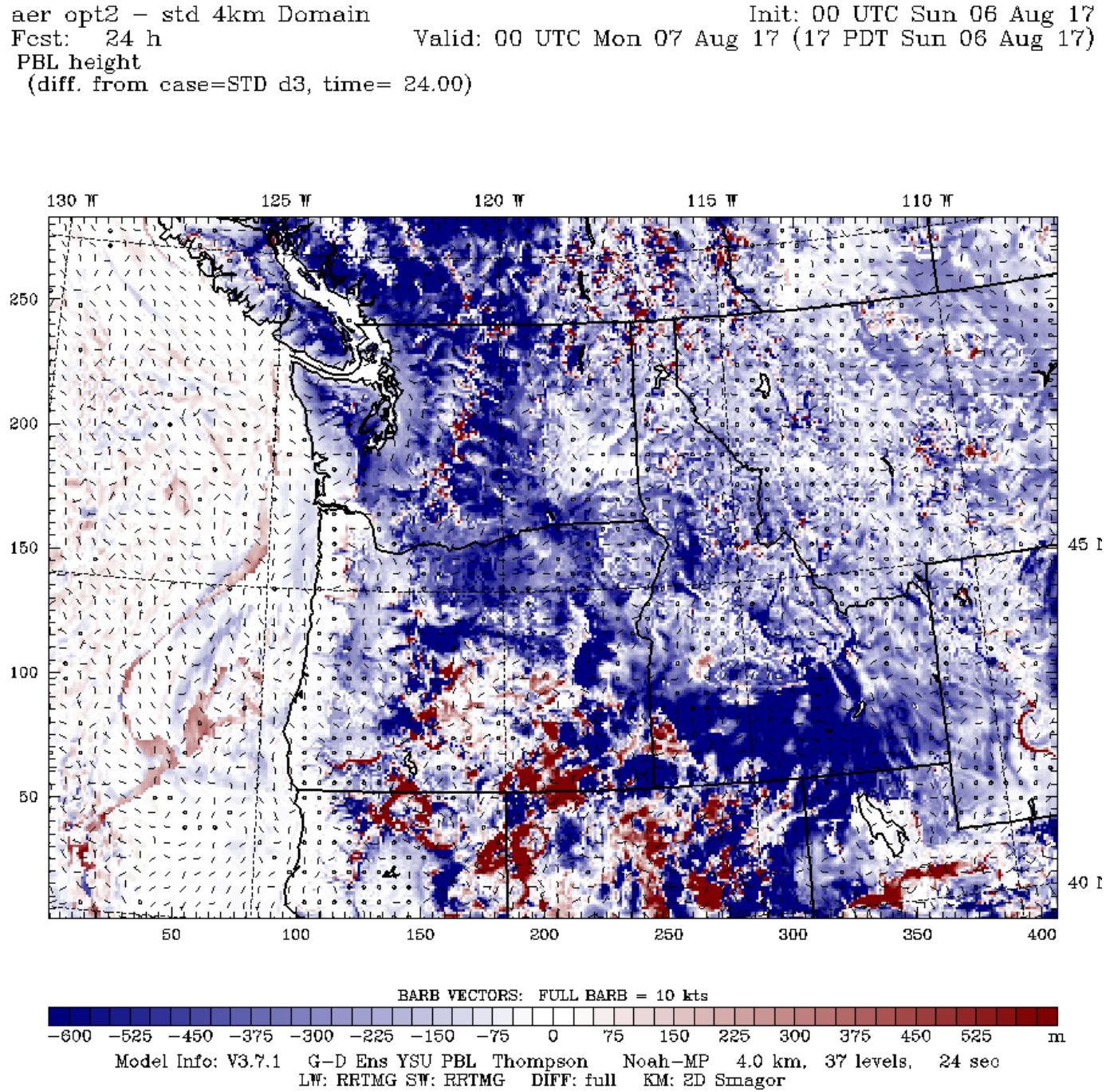
GEOS 5 AOD, 0000 UTC 7 August 2017



Temperature Impact (°F)

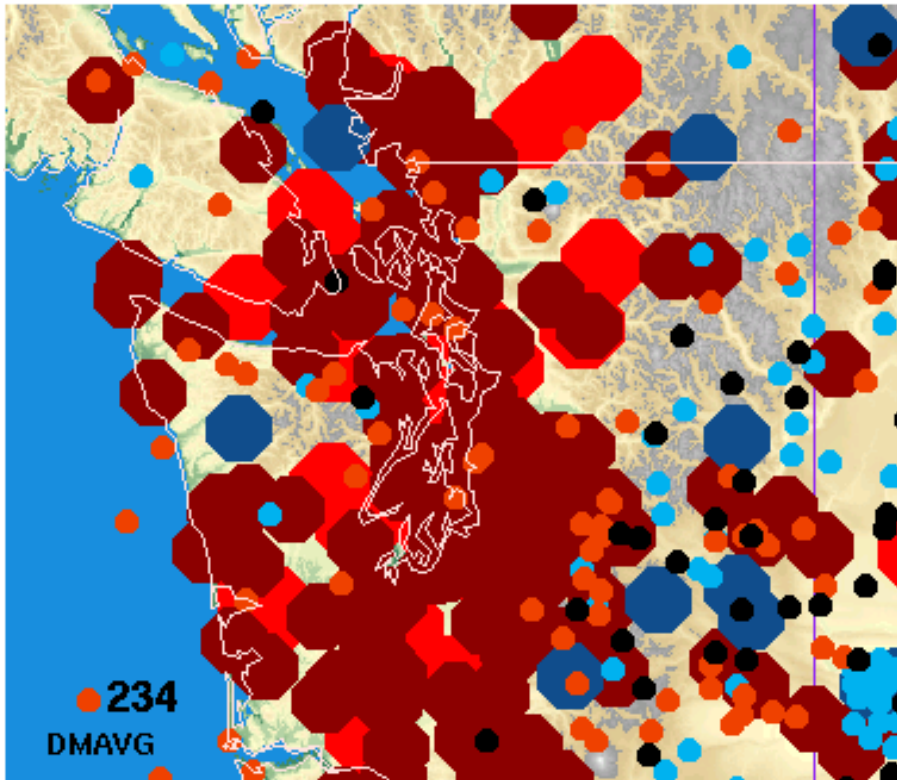


Change in PBL Height

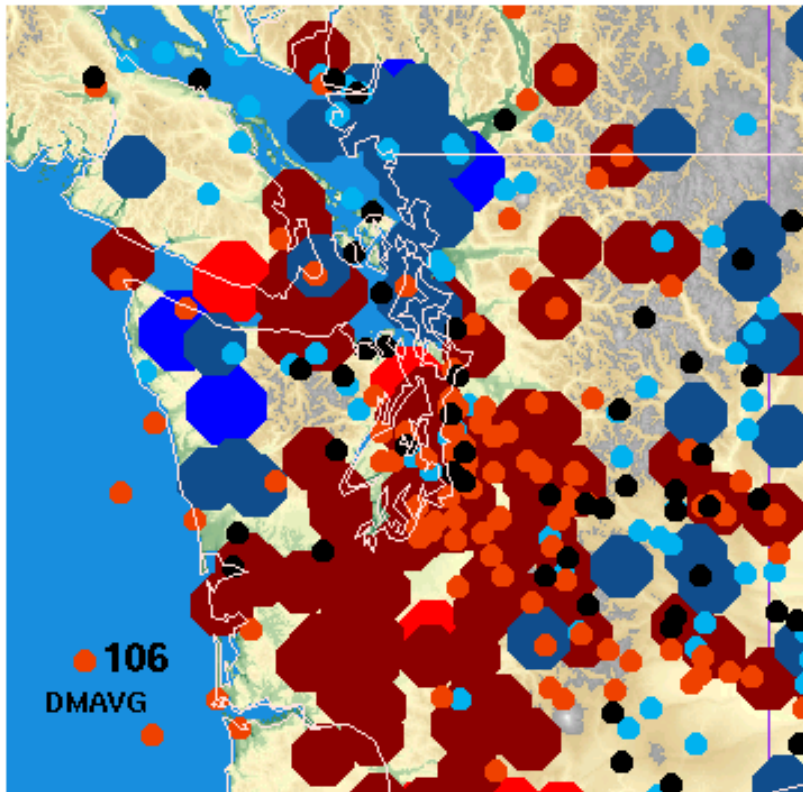


Change in temperature bias

No smoke



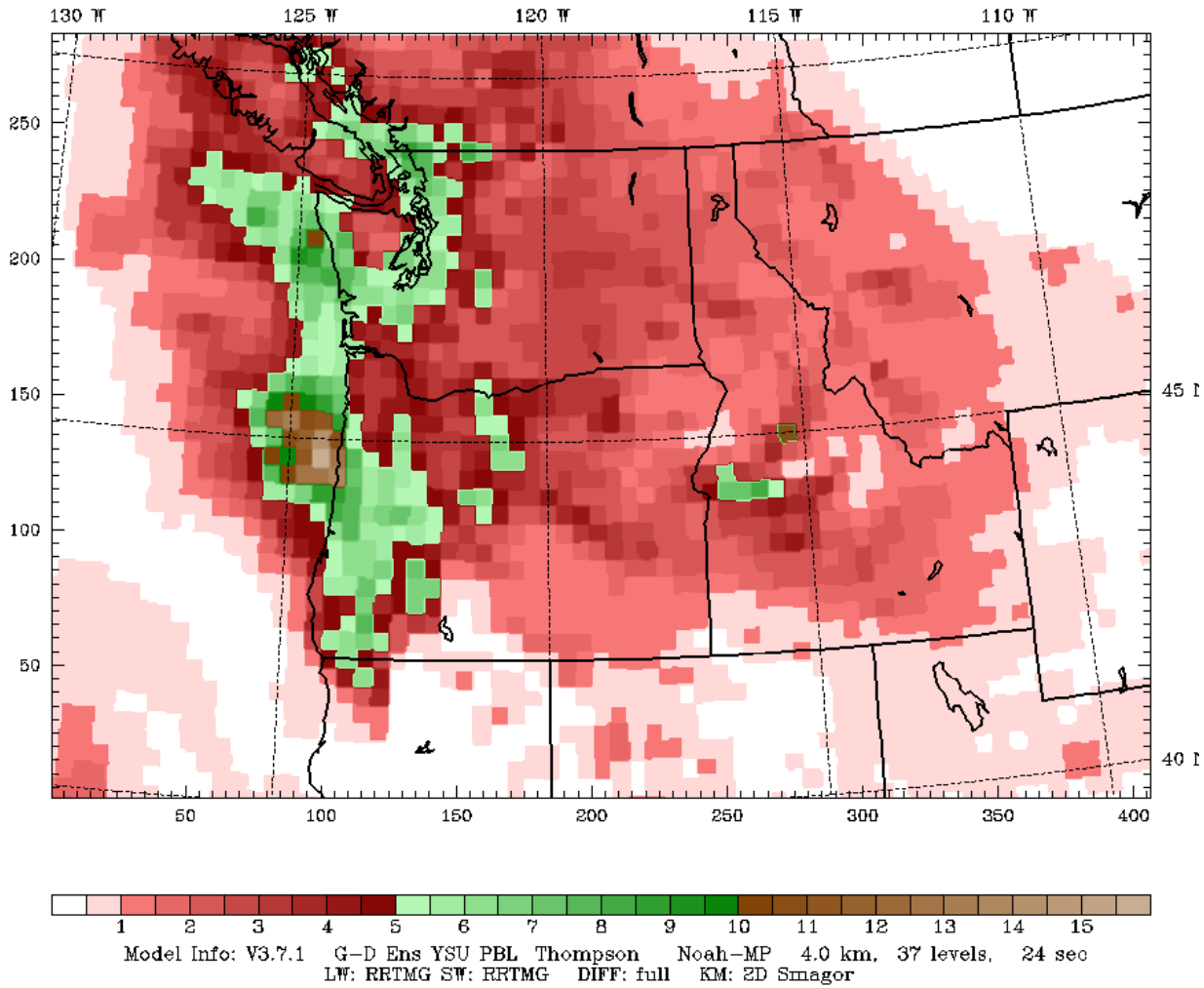
With smoke



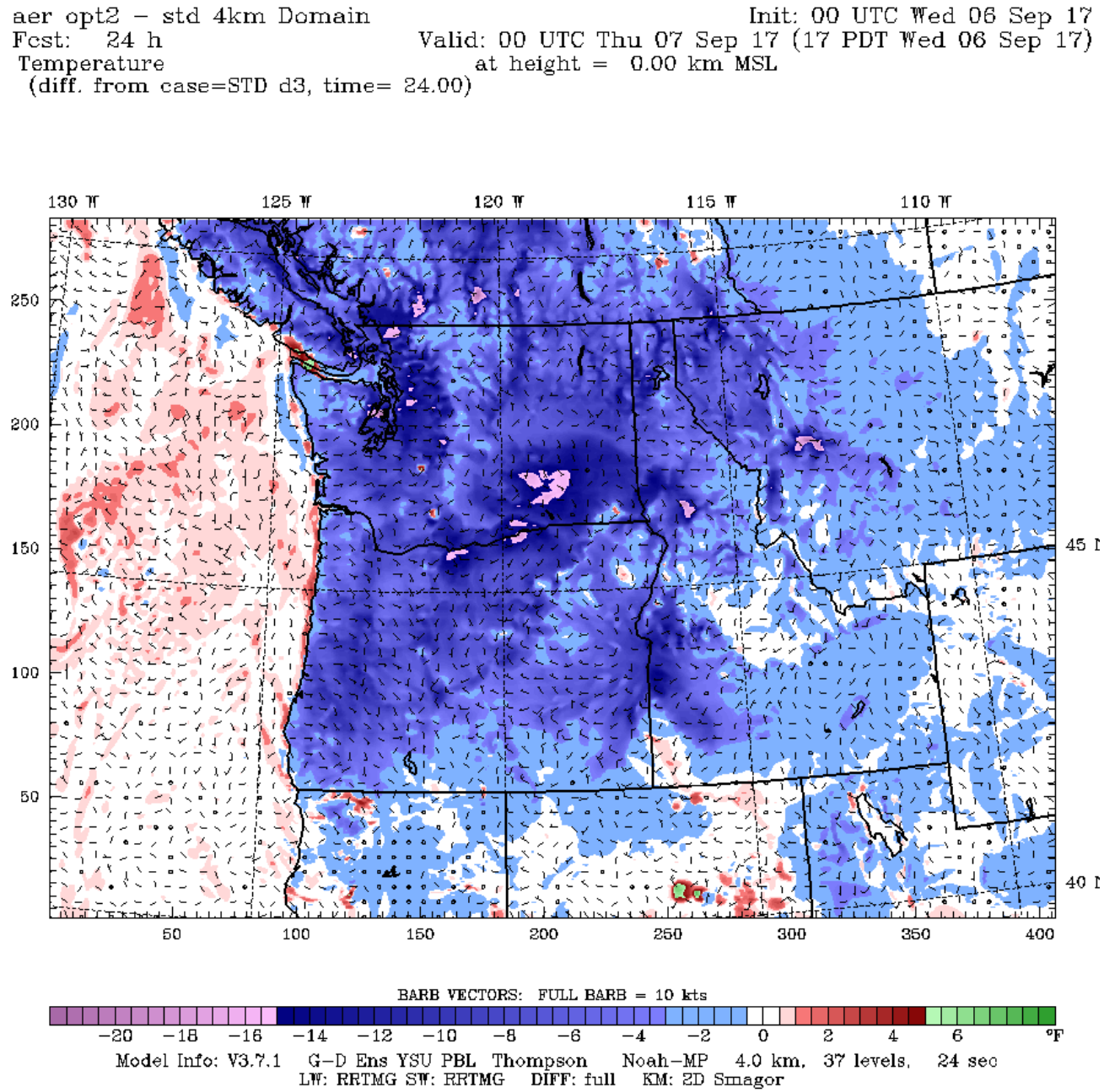
< -10 > -10 < -4 > -4 < -1 > -1 < 1 > 1 < 4 > 4 < 10 > 10

WRFAER 12-km t2m Bias I00Z/F24 2017080600

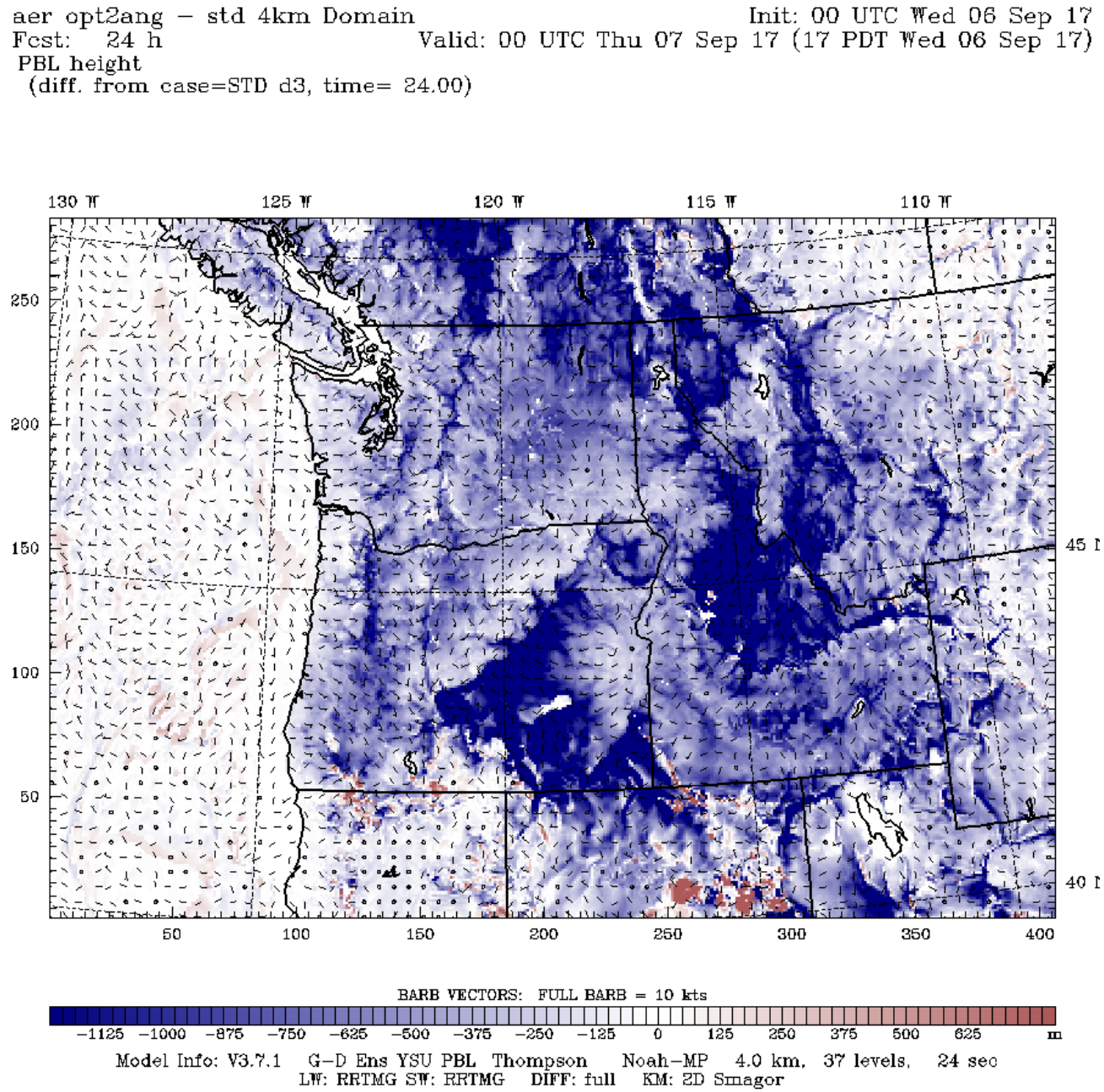
0000 UTC
7 September



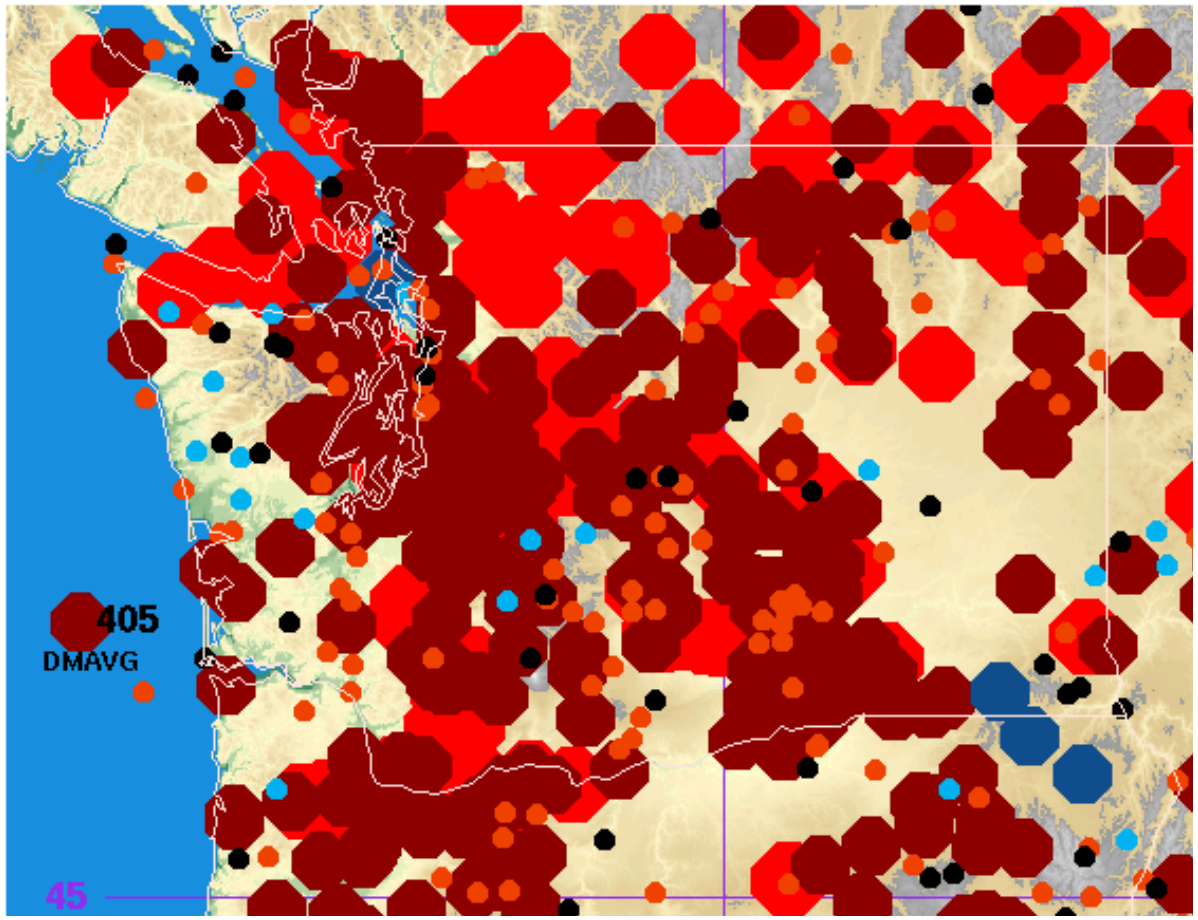
Temp Change


aer opt2 – std 4km Domain
Init: 00 UTC Wed 06 Sep 17
Fcst: 24 h
Valid: 00 UTC Thu 07 Sep 17 (17 PDT Wed 06 Sep 17)
Temperature
at height = 0.00 km MSL
(diff. from case=STD d3, time= 24.00)
130 W
125 W
120 W
115 W
110 W
250
200
150
100
50
45 N
40 N
50
100
150
200
250
300
350
400
BARB VECTORS: FULL BARB = 10 kts
-20 -18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 °F
Model Info: V3.7.1 G-D Ens YSU PBL Thompson Noah-MP 4.0 km, 37 levels, 24 sec
LW: RRTMG SW: RRTMG DIFF: full KM: 2D Smagor

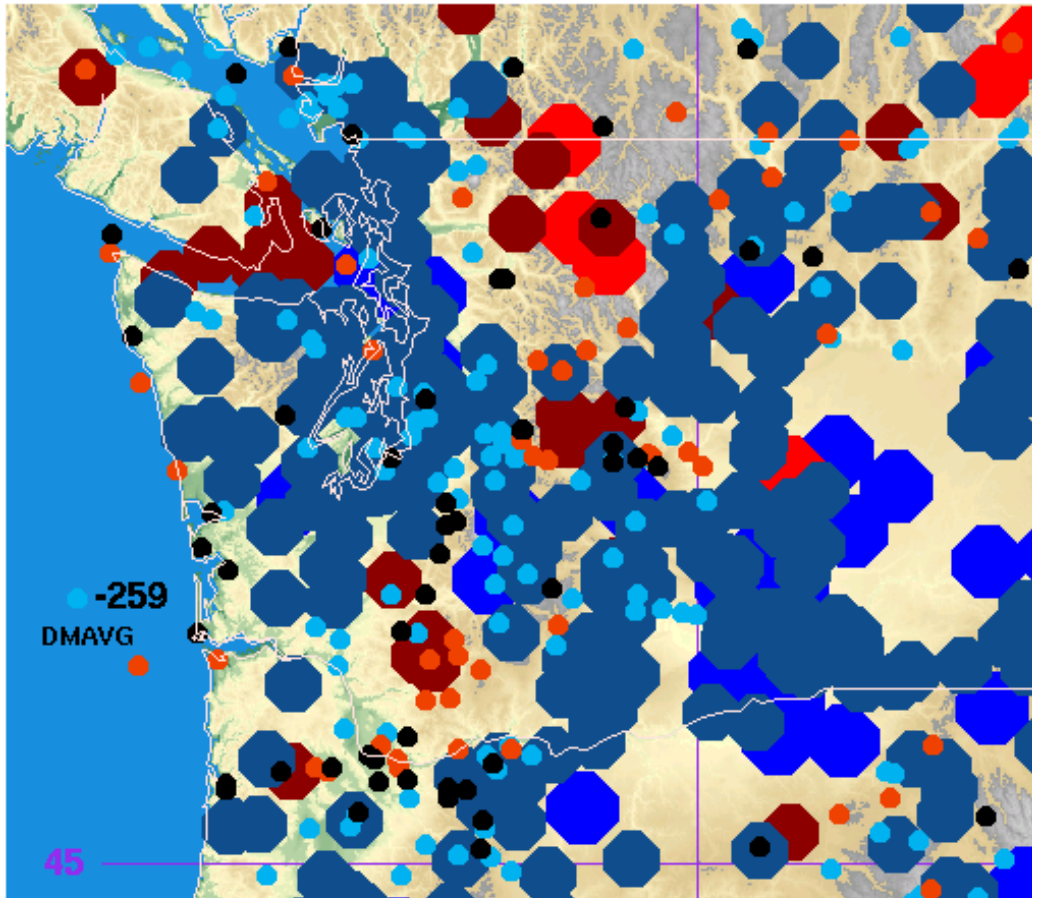
Change in PBL Height



No smoke



Smoke



< -10 > -10 < -4 > -4 < -1 > -1 < 1 > 1 < 4 > 4 < 10 > 10

Appears Viable But Still More Work

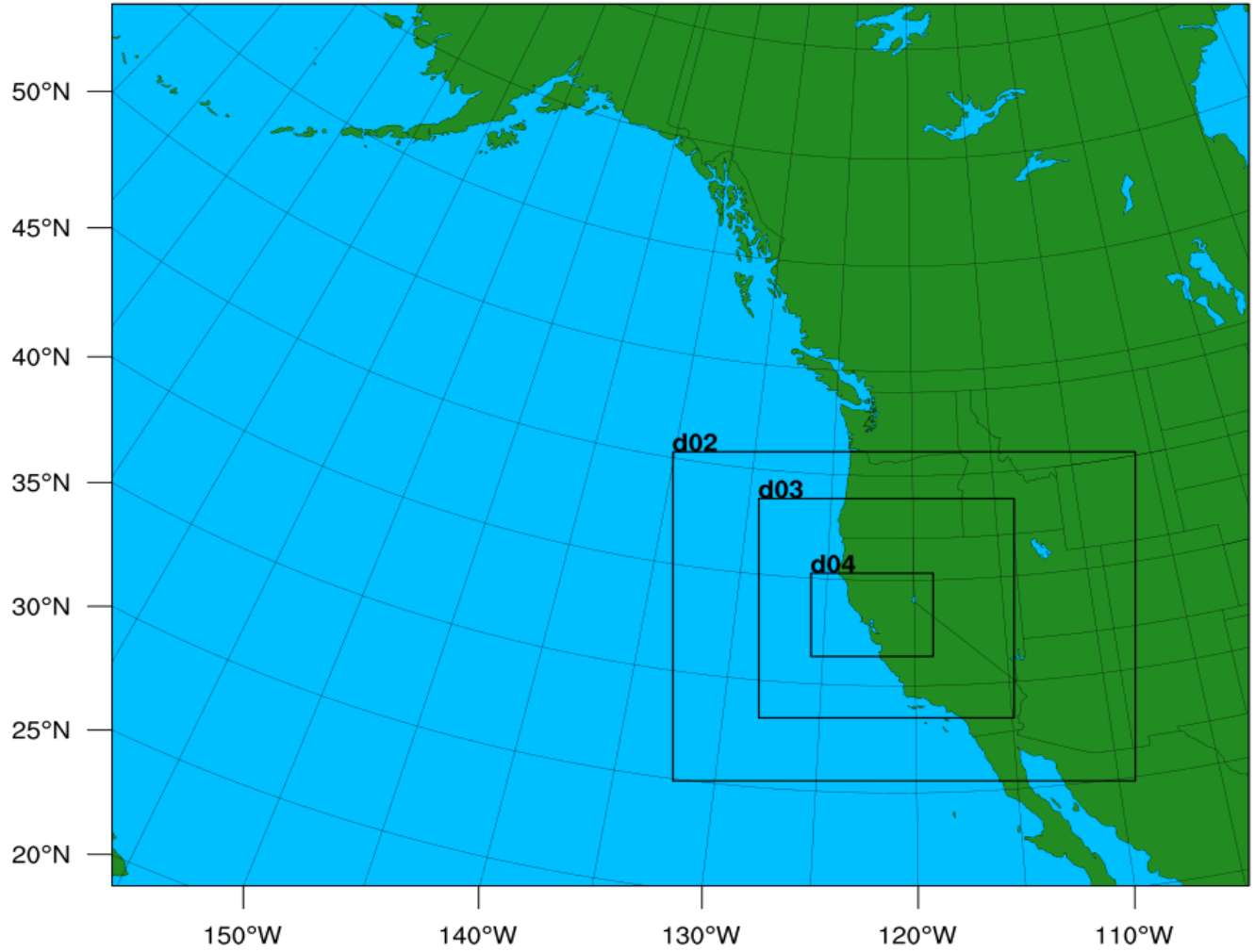
- **Replace with smoke related single scattering albedo**
- **Replace with snow related aerosol asymmetry factor**
- **Testing with more cases**
- **Perhaps needs some empirical calibration**

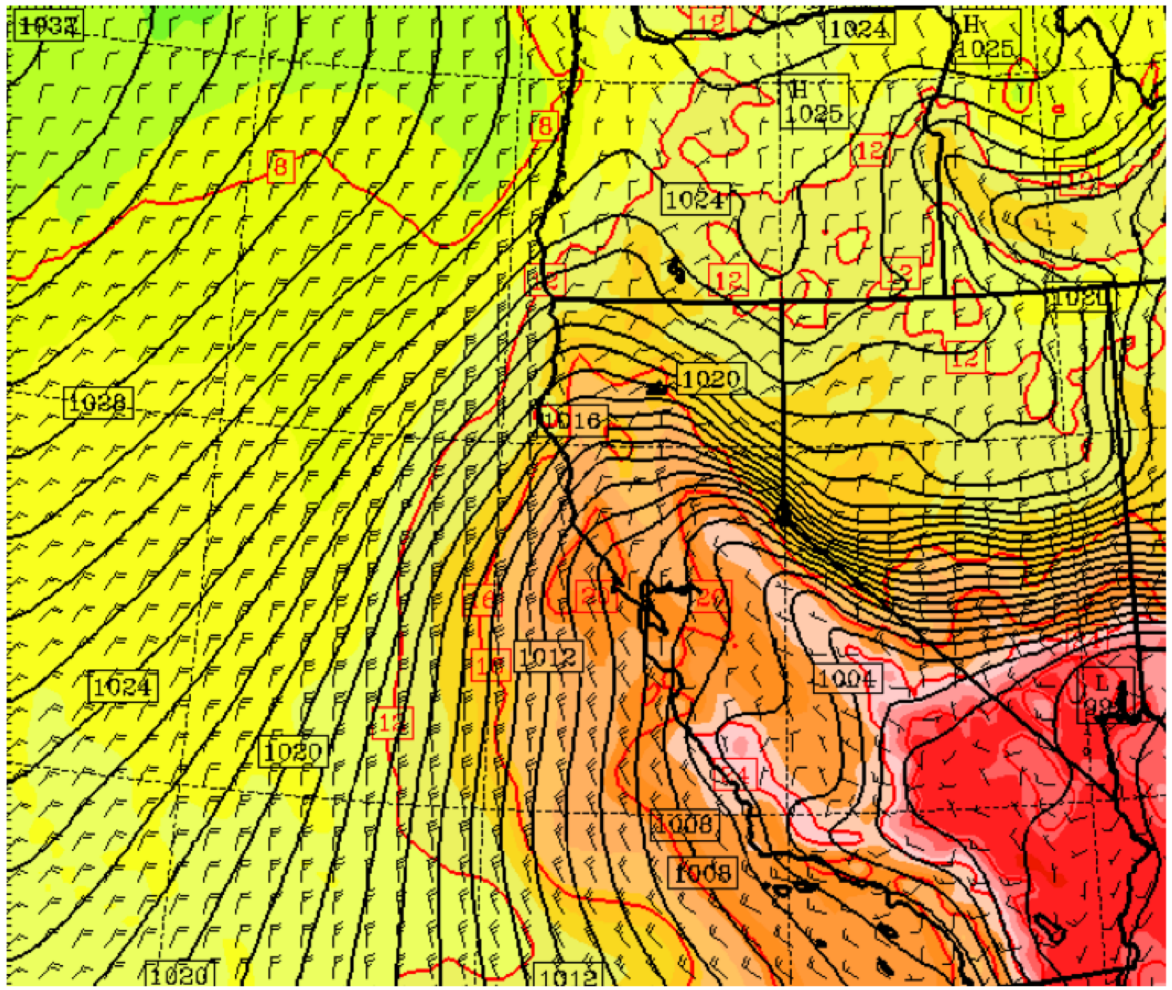
The End

During the evening of Sunday, October 8, 2017, wildfires began in the hills above Santa Rosa, Napa, and other towns of the ”wine country” north of San Francisco

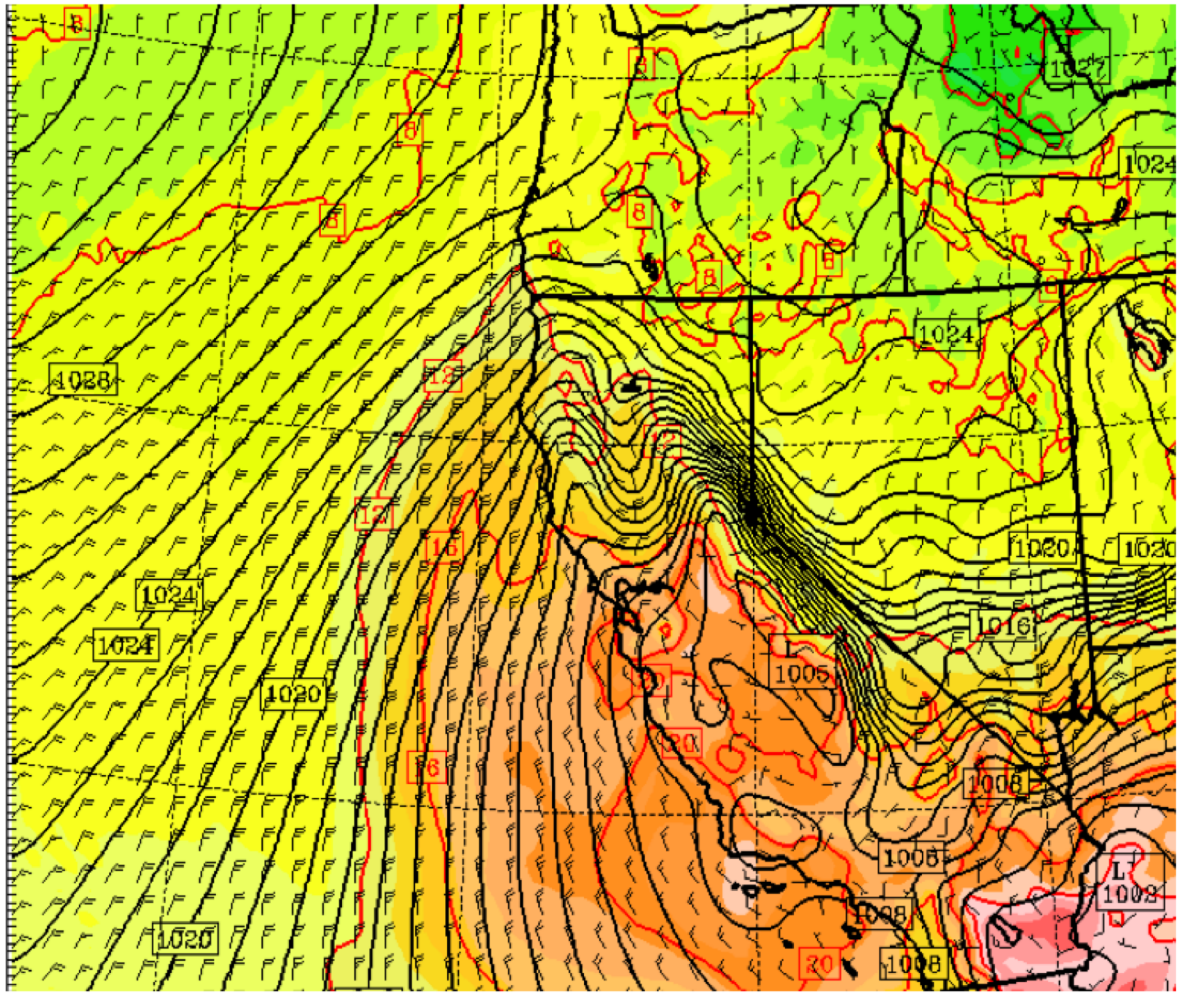
High-Resolution WRF Simulation of the Wind Country Wildfire Event: October 8-9, 2017

- 36-12-4-1.3 km domains
- Initialized at 1200 UTC Oct. 8

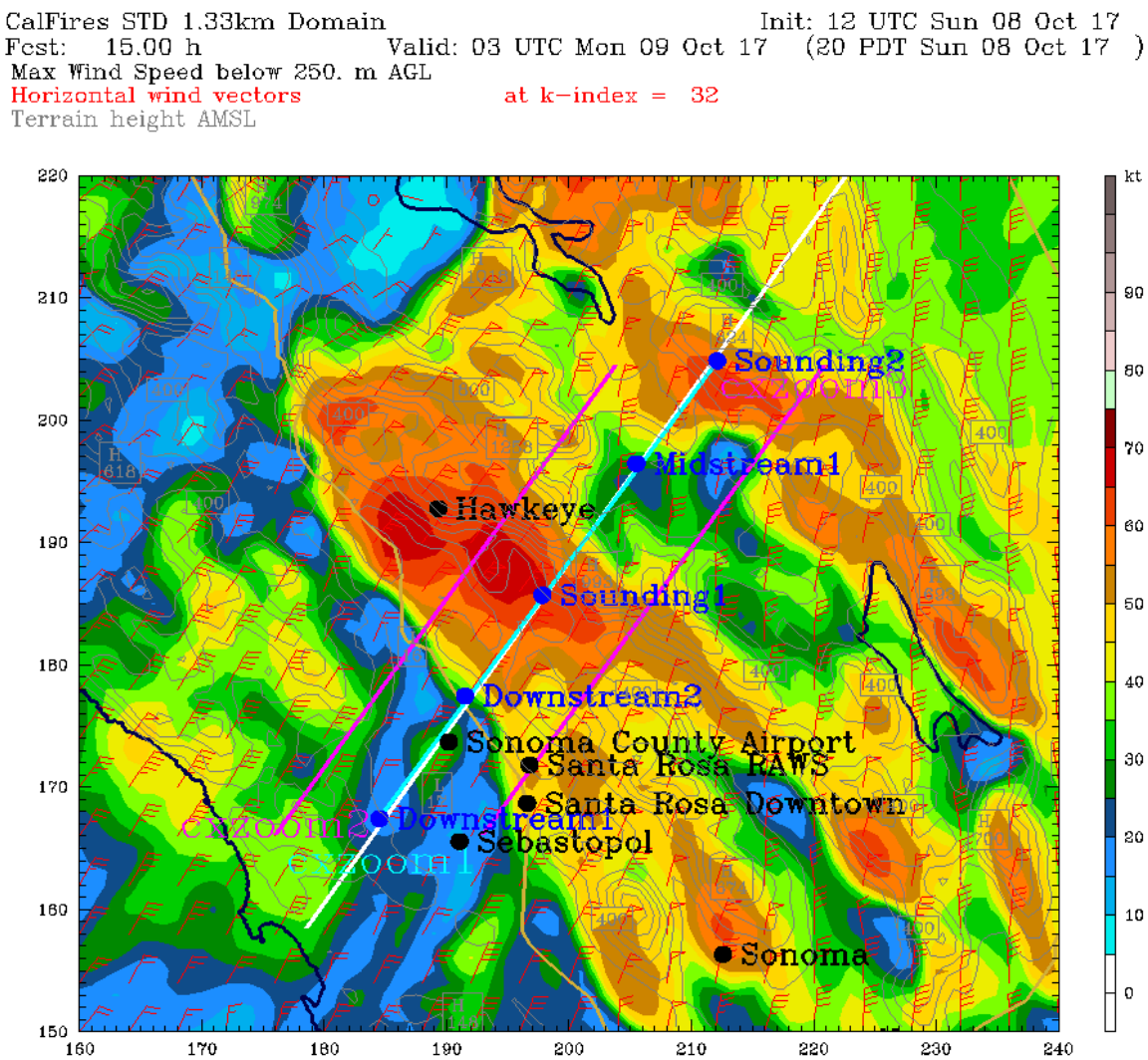




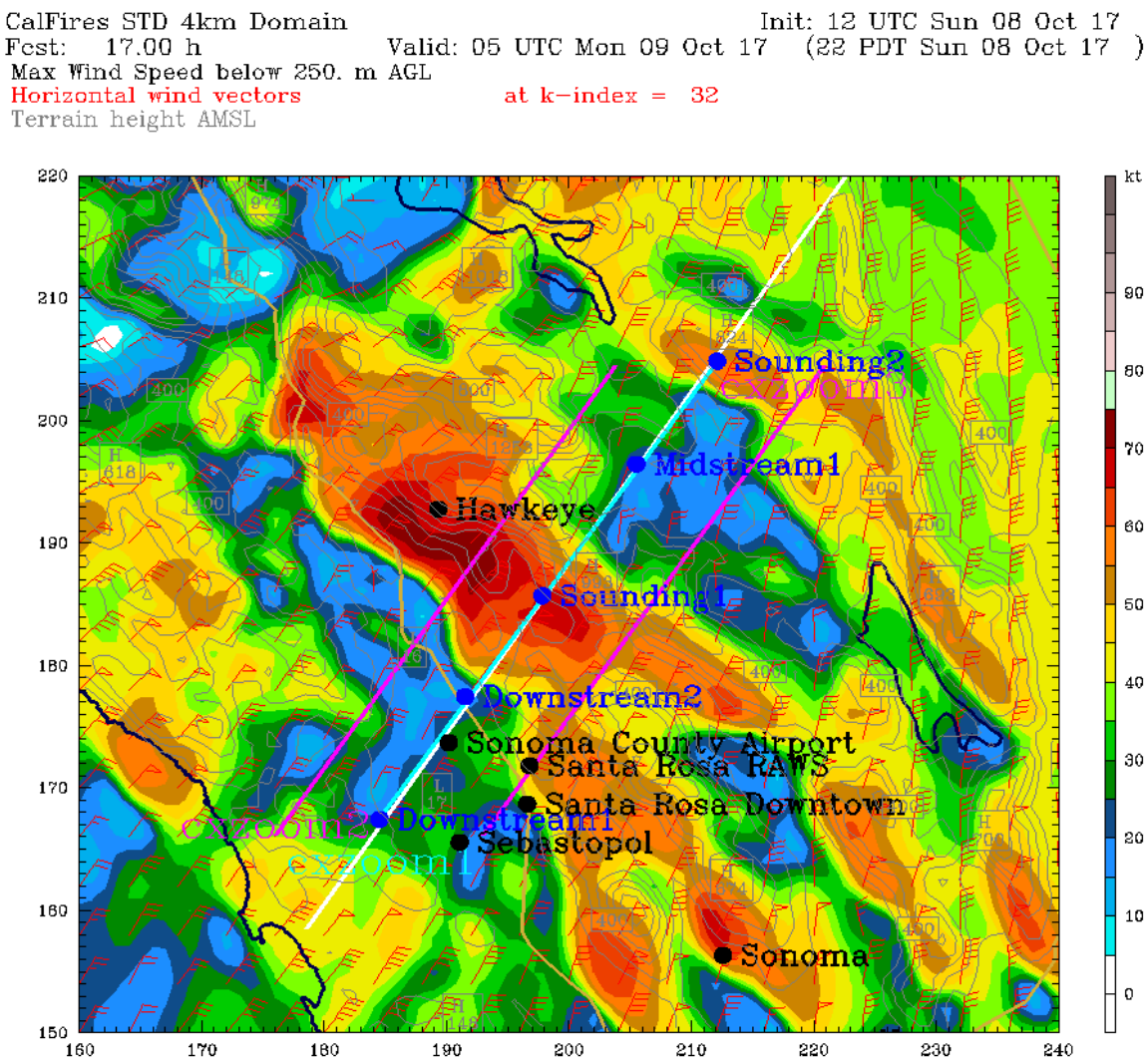
0000 UTC 9 October



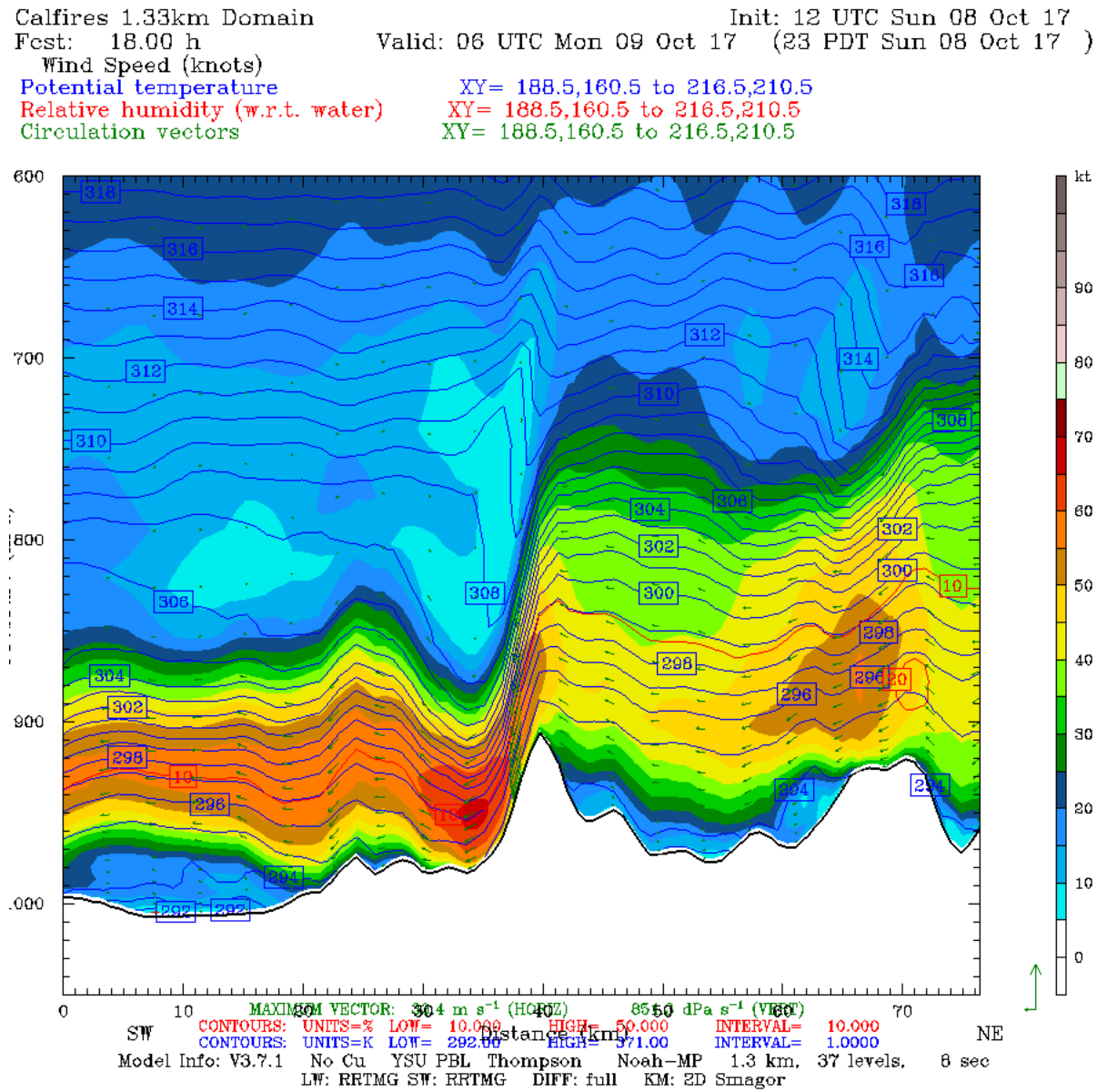
0600 UTC 9 October



8 PM October 8



10 PM October 9



Terrain-Related Downslope Windstorm

The End