Fire Growth and Probability Modeling for the 2016 Maple Fire

Diane Abendroth, Long Term Analyst

Long Term Analyst "LTAN"

- Takes observed fire growth and project it forward using fire behavior models and spatial data

Long Term Analyst

LTAN

$$\left(\frac{\text{ft}^2 \text{ of fuel surface area}}{\text{ft}^3 \text{ of fuel volume}}\right) \cdot \left(\frac{\text{lb of fuel}}{\text{ft}^2 \text{ of fuel bed}}\right) = \left(\frac{\text{ft}^2 \text{ of fuel surface area}}{\text{ft}^2 \text{ of fuel bed}}\right)$$

$$\left(\frac{\text{lb of fuel}}{\text{ft}^3 \text{ of fuel volume}}\right)$$

These surface areas will be referred to as:

A_{1h} = ft² of 1-h fuel surface area per ft² of fuel bed

A_{10h} = ft² of 10-h fuel surface area per ft² of fuel bed

A_{100h} = ft² of 100-h fuel surface area per ft² of fuel bed

A_{hb} = ft² of live herbaceous fuel surface area per ft² of fuel bed

A_{wd} = ft² of live woody fuel surface area per ft² of fuel bed.

The theoretical basis for the fire spread model was develope
Frandsen (1971). The terms of Frandsen's equation could not
solved analytically, however, so it was necessary to define new
erms, reformulate the equation, and design experimental meth
valuate the individual terms. The final form of the rate of s
quation, derived by Rothermel (1972), which will be examined
depth is:

$$R = \frac{I_r \xi (1 + \phi_w + \phi_s)}{\rho_b \varepsilon Q_{ig}}$$

where

R is the forward rate of spread of the
feet per minute.

I_r is the reaction intensity--a measure
rate per unit area of fire front (Bt

ξ ('ksē) is the propagating flux ratio
proportion of the reaction intensity
fuel particles to ignition.

ϕ_w (fē wind) is a dimensionless multi
the effect of wind in increasing th

dimensionless multi
reasing t

amount of fuel per

of the proportion of a fuel particle
n temperature at the time flaming
combustion starts.

f heat required to ignite 1 pound

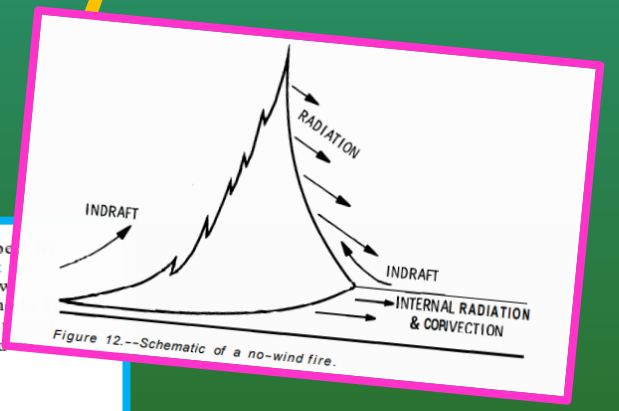
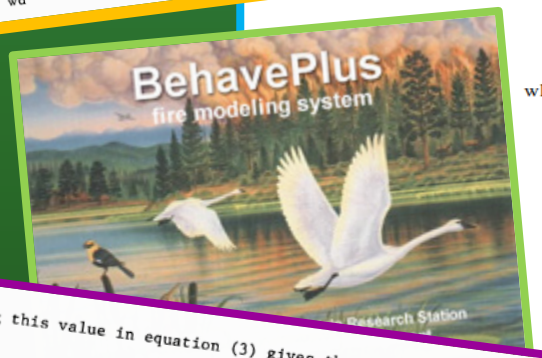


Figure 12.--Schematic of a no-wind fire.



Using this value in equation (3) gives the spotting distance correction as:

$$X = 2.78 \times 5.85 \times (30)^{1/2} = 89 \text{ m} = 0.09 \text{ km}.$$

(15)

$$\text{Area} = A = \frac{\pi b d^2}{2}(a_1 + a_2); \text{ ft}^2, \text{ m}^2, \text{ etc.} \quad (7)$$

$$\text{Perimeter} = P = \frac{\pi k_1 d}{2}(a_1 + b) + \frac{\pi k_2 d}{2}(a_2 + b); \text{ ft, m.} \quad (8)$$

$$k_n = 1 + \frac{M_n^2}{4} + \frac{M_n^4}{64} + \frac{M_n^6}{256} \cdots \quad (9)$$

(Bauneister 1958)

$$M_n = (a_n - b)/(a_n + t) \quad (10)$$

(Bauneister 1958)

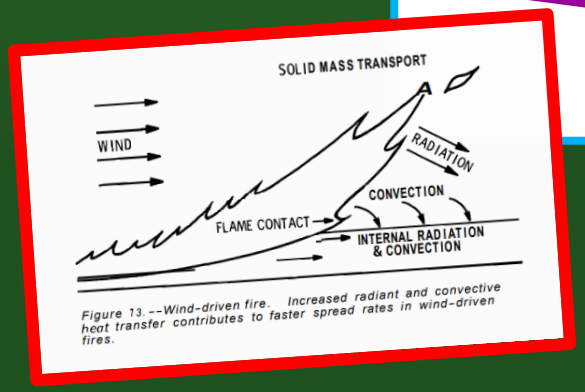


Figure 13.--Wind-driven fire. Increased radiant and convective heat transfer contributes to faster spread rates in wind-driven fires.

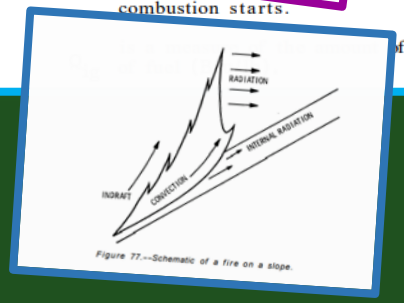
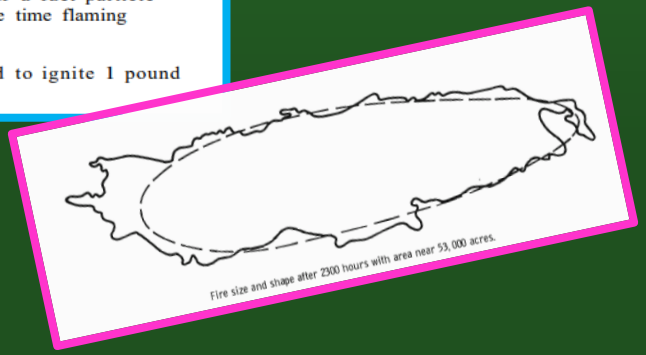
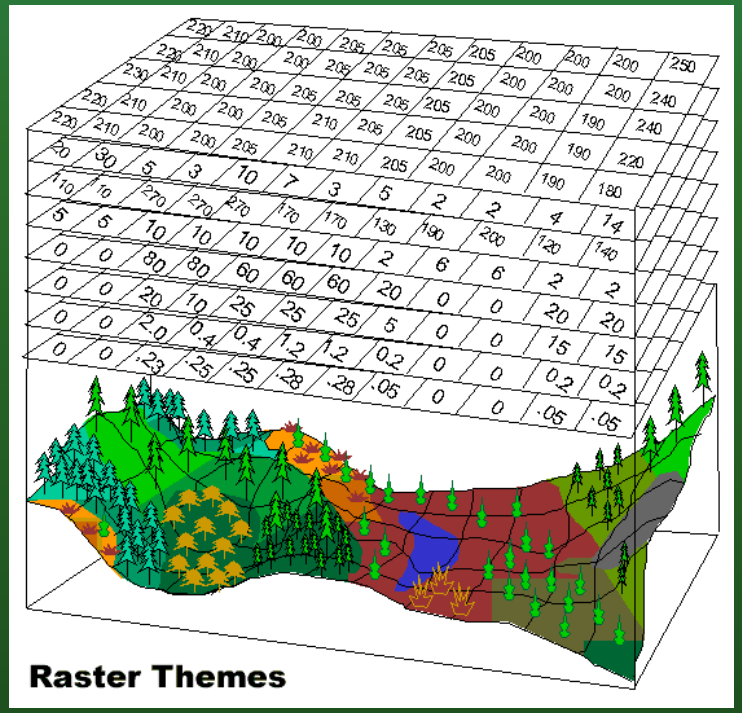


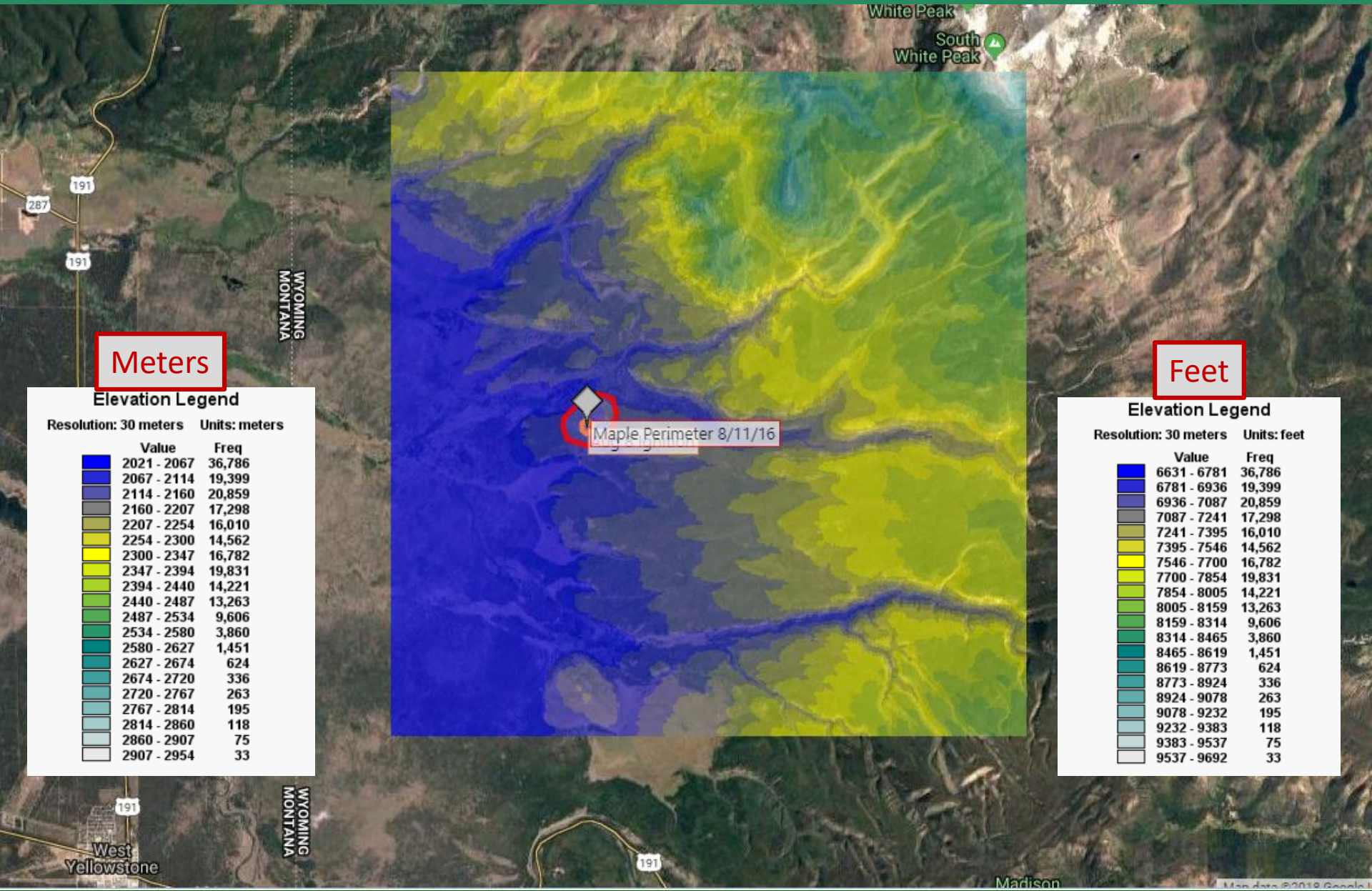
Figure 77.--Schematic of a fire on a slope.


Fire size and shape after 2300 hours with area near 53,000 acres.

Making it Geospatial



Topography: Elevation Data



Meters

Elevation Legend

Resolution: 30 meters Units: meters

Value	Freq
2021 - 2067	36,786
2067 - 2114	19,399
2114 - 2160	20,859
2160 - 2207	17,298
2207 - 2254	16,010
2254 - 2300	14,562
2300 - 2347	16,782
2347 - 2394	19,831
2394 - 2440	14,221
2440 - 2487	13,263
2487 - 2534	9,606
2534 - 2580	3,860
2580 - 2627	1,451
2627 - 2674	624
2674 - 2720	336
2720 - 2767	263
2767 - 2814	195
2814 - 2860	118
2860 - 2907	75
2907 - 2954	33

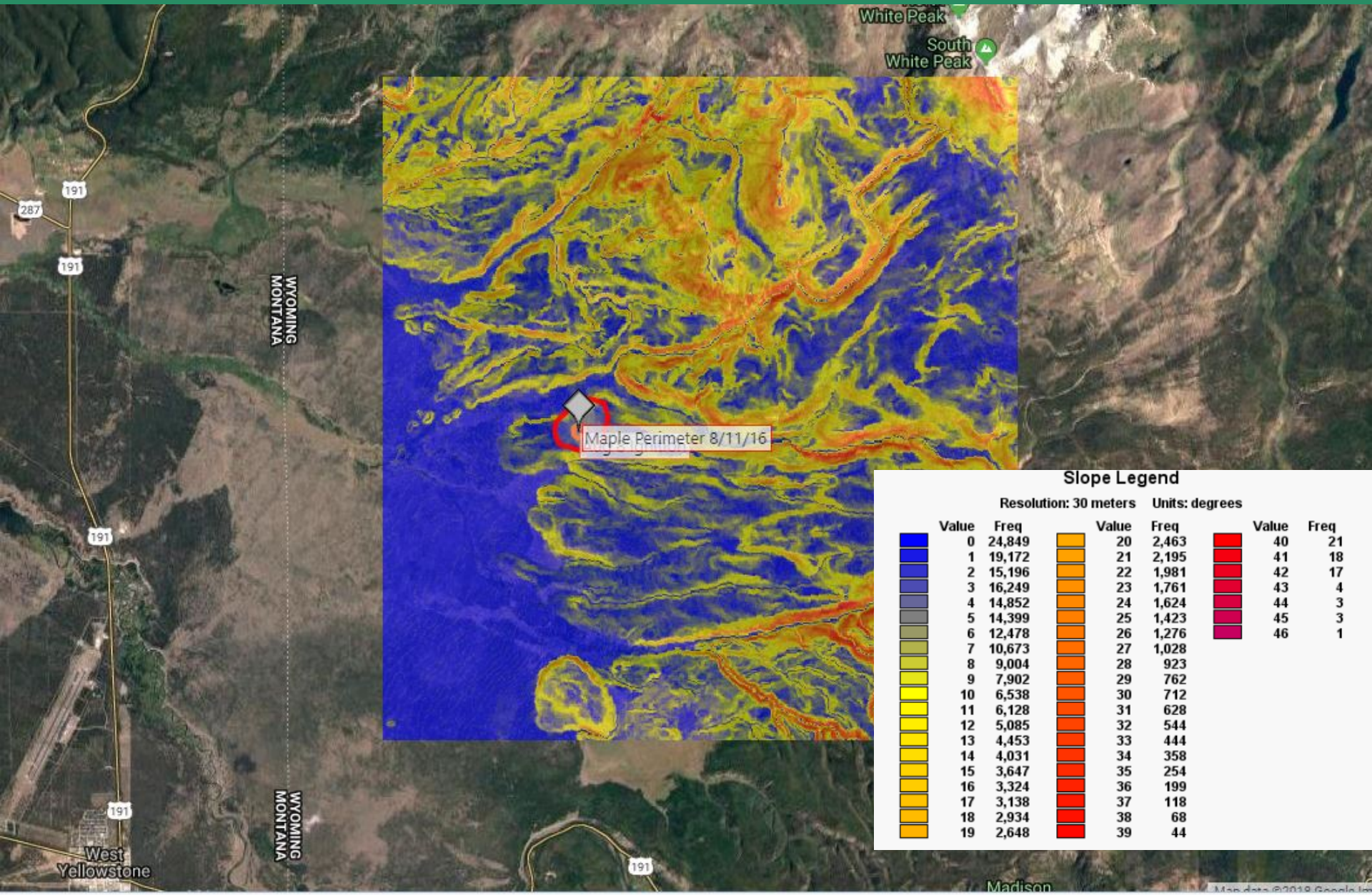
Feet

Elevation Legend

Resolution: 30 meters Units: feet

Value	Freq
6631 - 6781	36,786
6781 - 6936	19,399
6936 - 7087	20,859
7087 - 7241	17,298
7241 - 7395	16,010
7395 - 7546	14,562
7546 - 7700	16,782
7700 - 7854	19,831
7854 - 8005	14,221
8005 - 8159	13,263
8159 - 8314	9,606
8314 - 8465	3,860
8465 - 8619	1,451
8619 - 8773	624
8773 - 8924	336
8924 - 9078	263
9078 - 9232	195
9232 - 9383	118
9383 - 9537	75
9537 - 9692	33

Topography: Slope Data

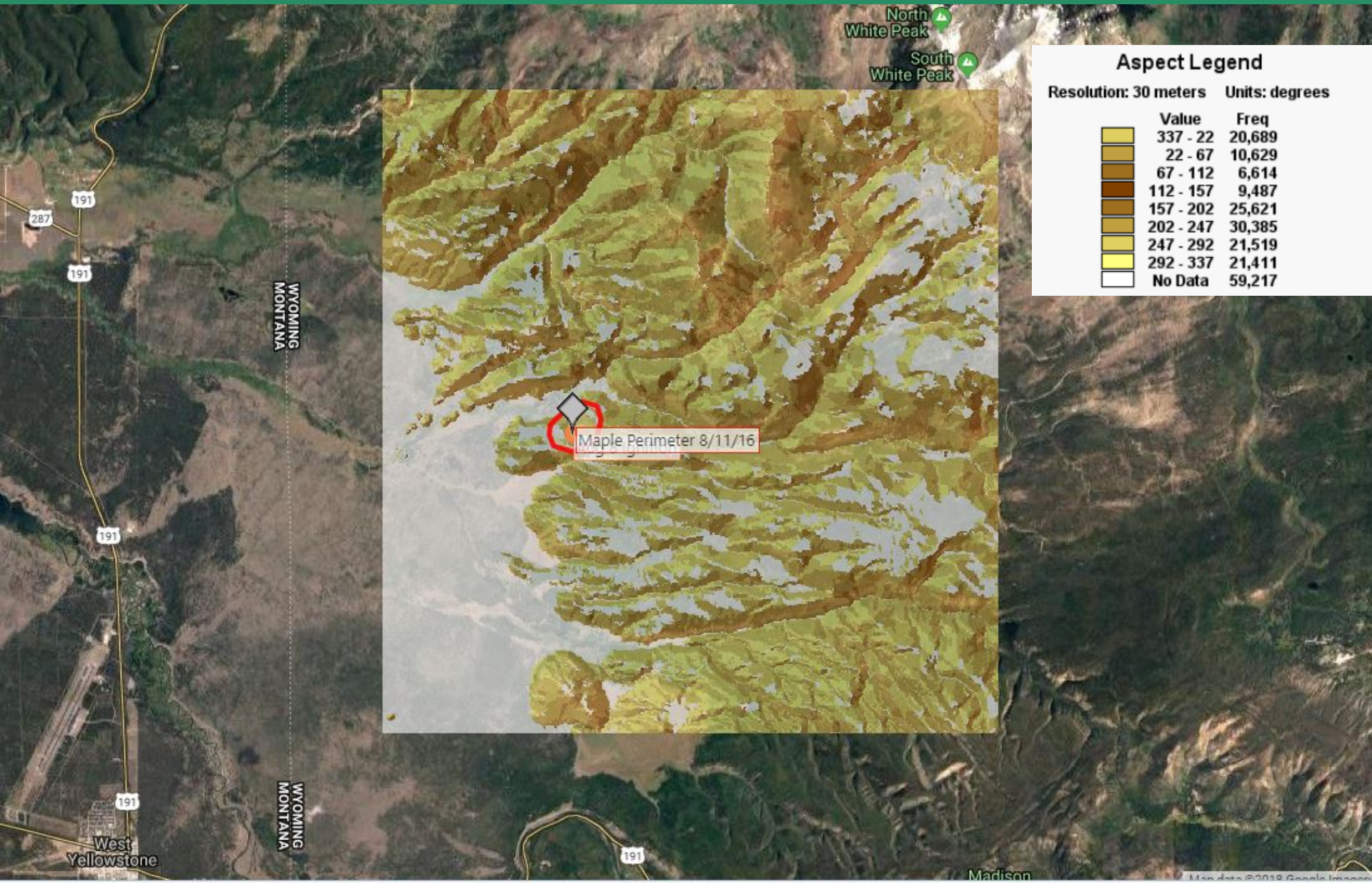


Slope Legend

Resolution: 30 meters Units: degrees

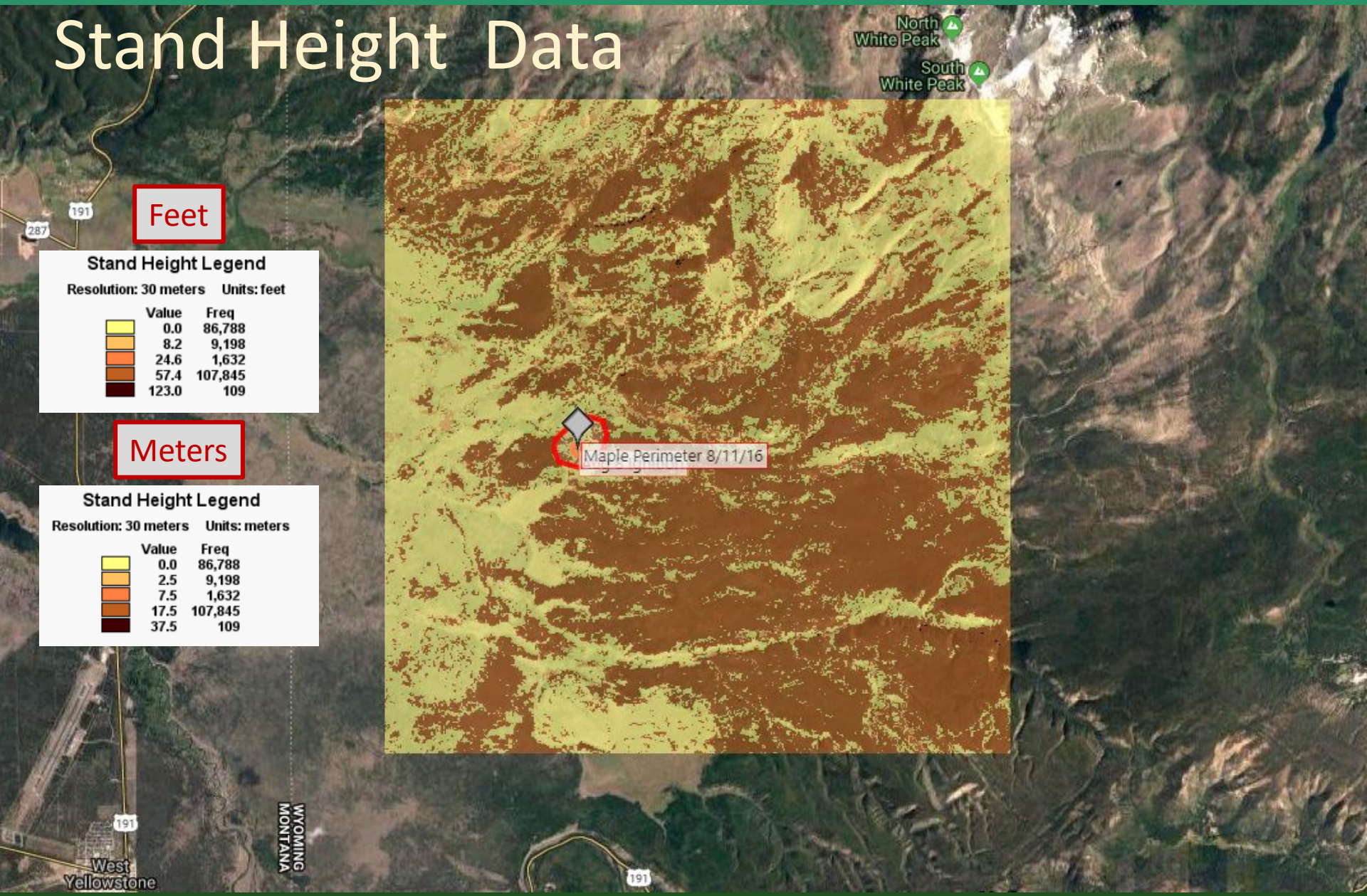
Value	Freq	Value	Freq	Value	Freq
0	24,849	20	2,463	40	21
1	19,172	21	2,195	41	18
2	15,196	22	1,981	42	17
3	16,249	23	1,761	43	4
4	14,852	24	1,624	44	3
5	14,399	25	1,423	45	3
6	12,478	26	1,276	46	1
7	10,673	27	1,028		
8	9,004	28	923		
9	7,902	29	762		
10	6,538	30	712		
11	6,128	31	628		
12	5,085	32	544		
13	4,453	33	444		
14	4,031	34	358		
15	3,647	35	254		
16	3,324	36	199		
17	3,138	37	118		
18	2,934	38	68		
19	2,648	39	44		

Topography: Aspect Data



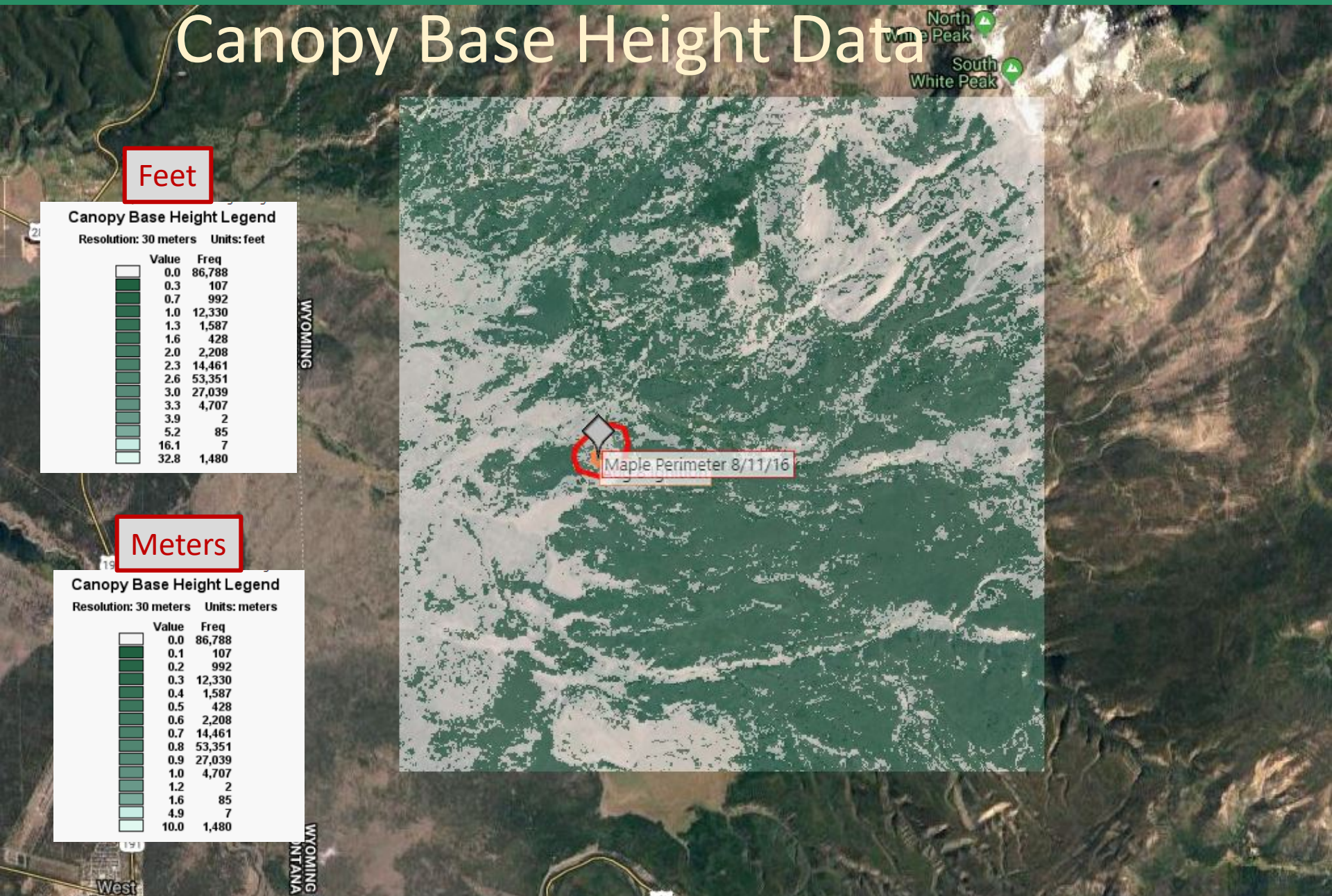
For Crown Fire Behavior:

Stand Height Data



For Crown Fire Behavior:

Canopy Base Height Data



Feet

Canopy Base Height Legend

Resolution: 30 meters Units: feet

Value	Freq
0.0	86,788
0.3	107
0.7	992
1.0	12,330
1.3	1,587
1.6	428
2.0	2,208
2.3	14,461
2.6	53,351
3.0	27,039
3.3	4,707
3.9	2
5.2	85
16.1	7
32.8	1,480

Meters

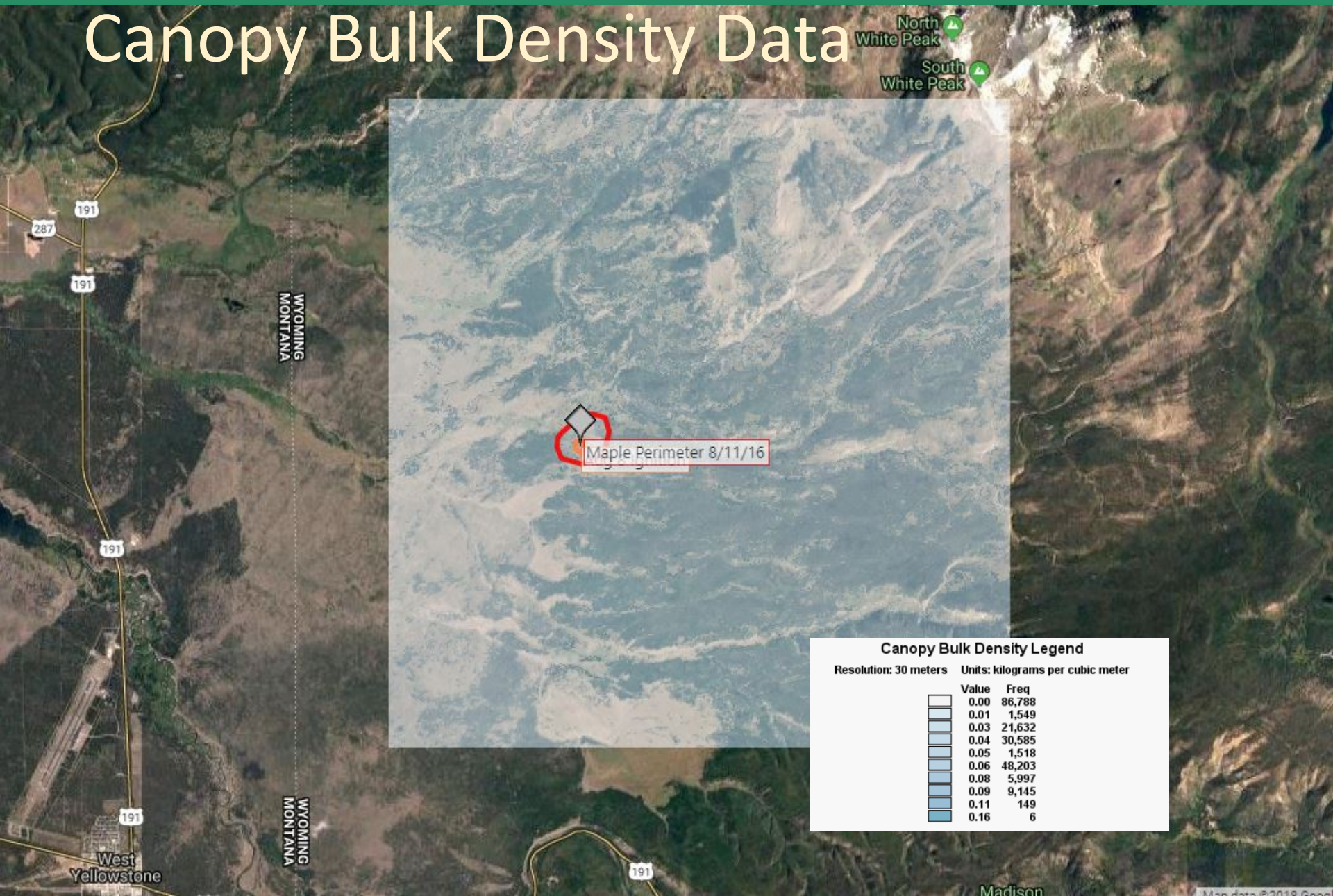
Canopy Base Height Legend

Resolution: 30 meters Units: meters

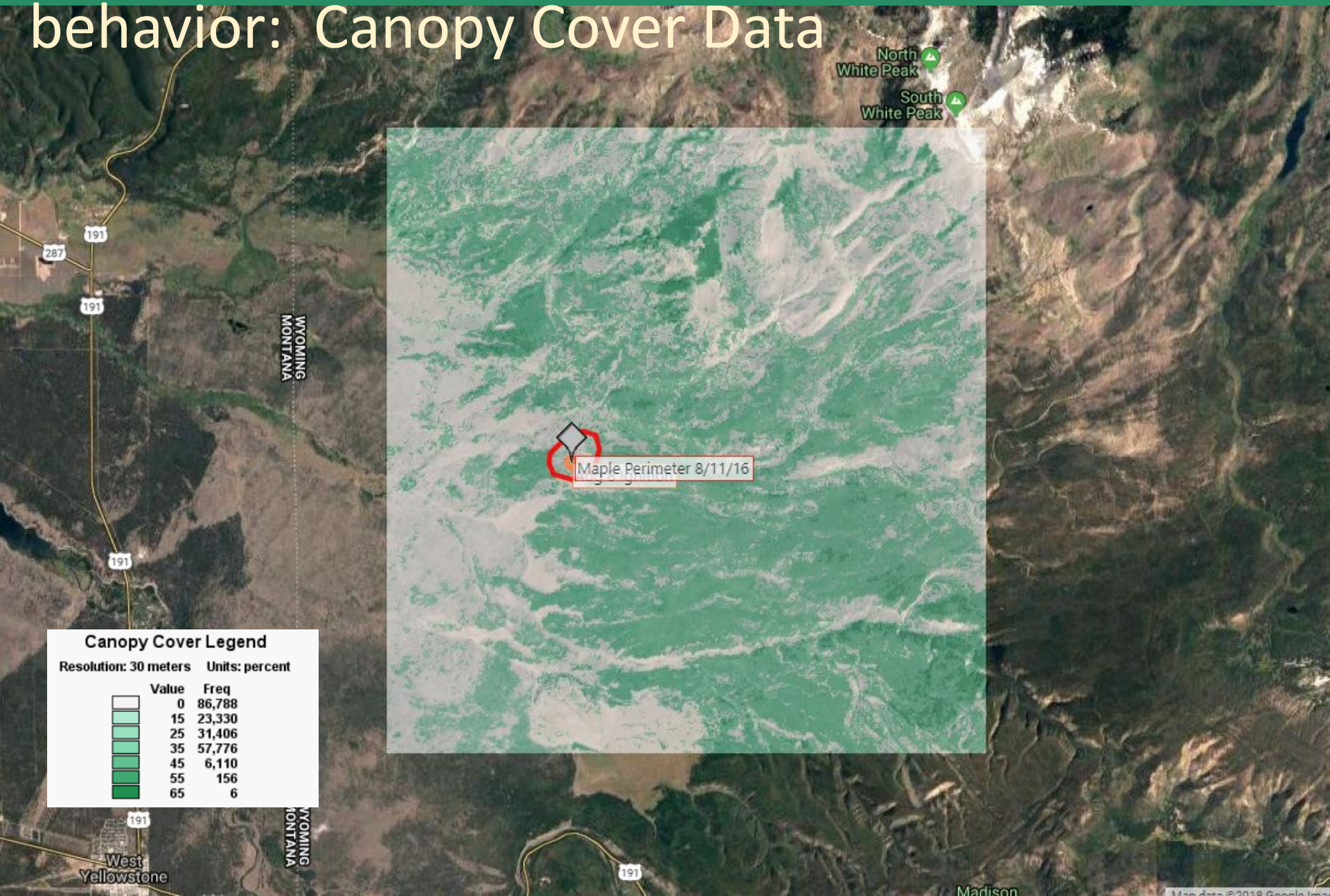
Value	Freq
0.0	86,788
0.1	107
0.2	992
0.3	12,330
0.4	1,587
0.5	428
0.6	2,208
0.7	14,461
0.8	53,351
0.9	27,039
1.0	4,707
1.2	2
1.6	85
4.9	7
10.0	1,480

For Crown Fire Behavior:

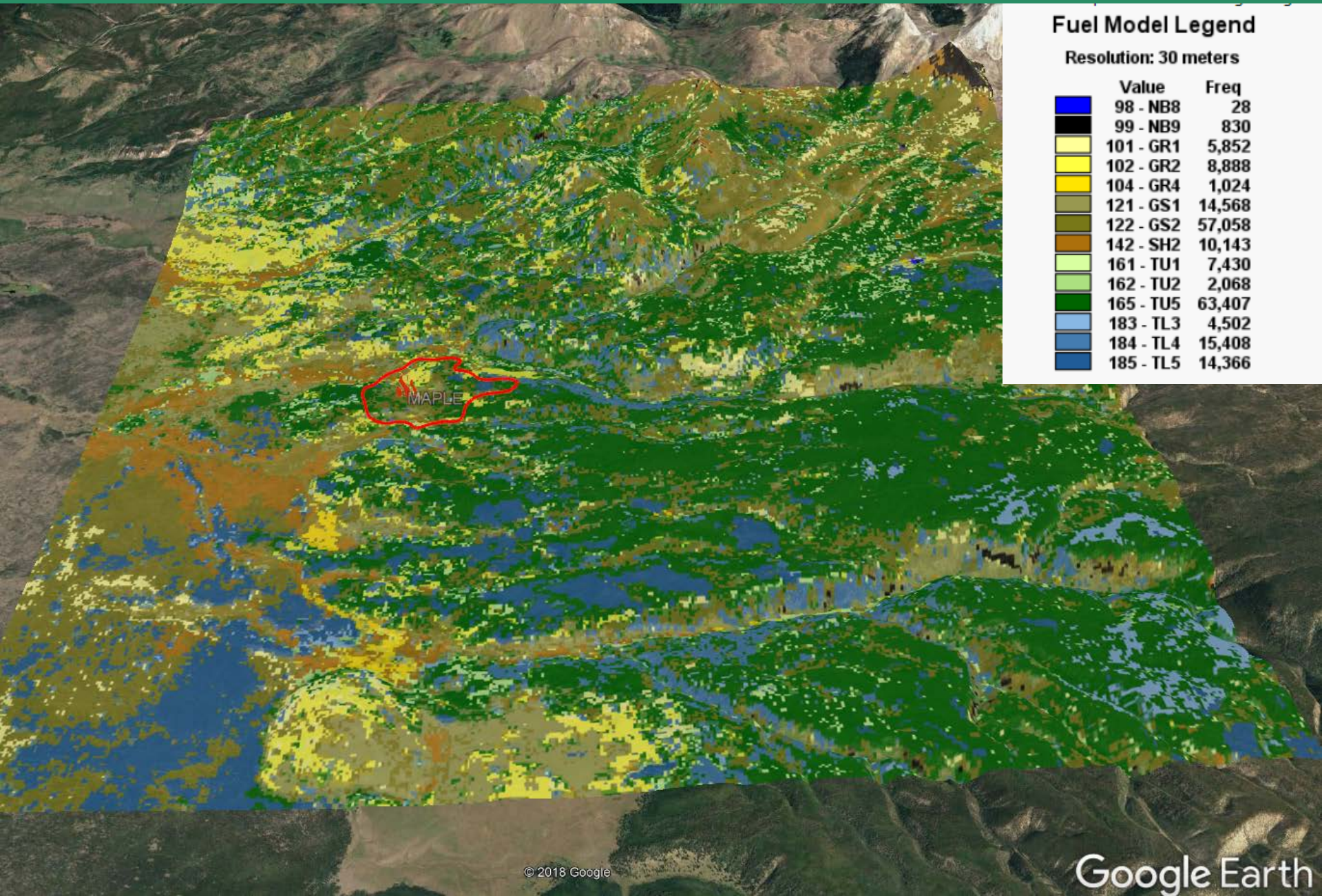
Canopy Bulk Density Data

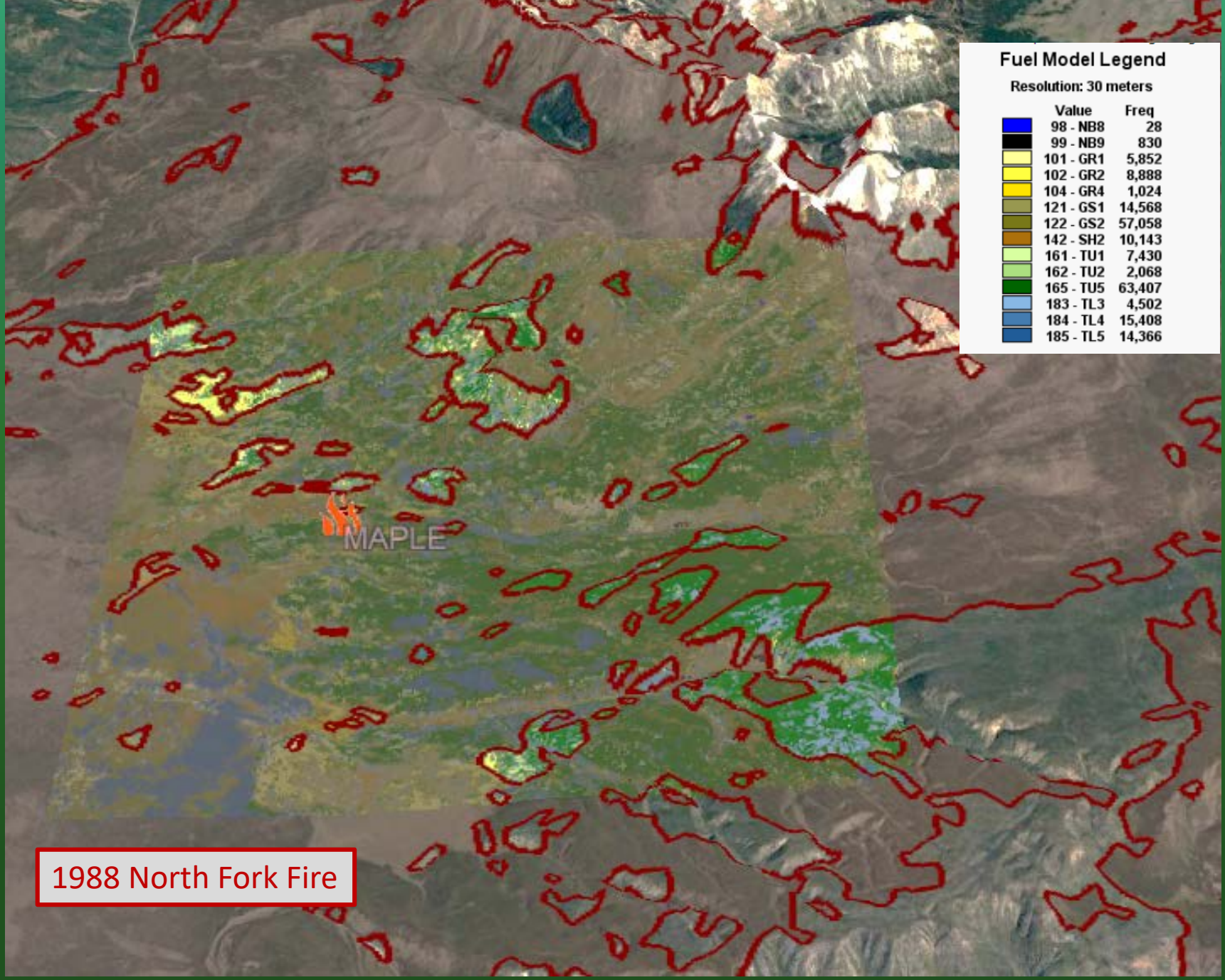


For shading, wind sheltering, and crown fire behavior: Canopy Cover Data



Fuels: Fuel Model Map from LandFire

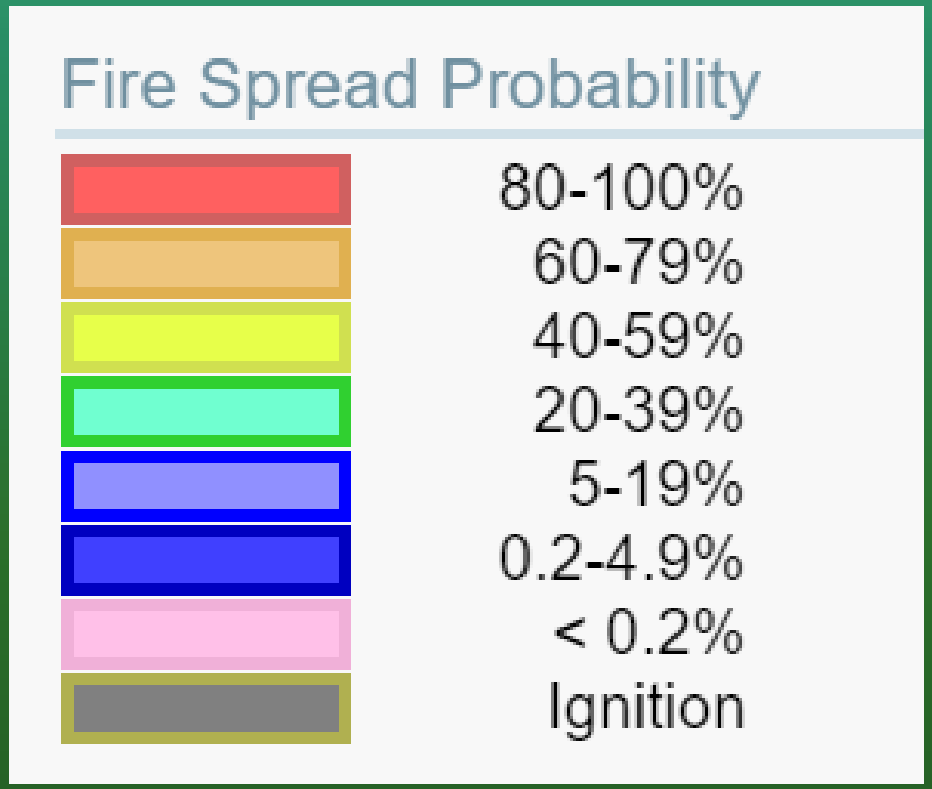



Fuel Model Legend
Resolution: 30 meters
Value Freq
98 - NB8 28
99 - NB9 830
101 - GR1 5,852
102 - GR2 8,888
104 - GR4 1,024
121 - GS1 14,568
122 - GS2 57,058
142 - SH2 10,143
161 - TU1 7,430
162 - TU2 2,068
165 - TU5 63,407
183 - TL3 4,502
184 - TL4 15,408
185 - TL5 14,366
MAPLE
1988 North Fork Fire

Long Term Analyst LTAN

- Takes observed fire growth and project it forward using fire behavior models and spatial data

- Models and maps fire spread probability



- Monte Carlo Method – Thousands of fires
- Simulation weather data includes the short term forecast plus the climatic record for future projections

Long Term Analyst LTAN

- Takes observed fire growth and project it forward using fire behavior models and spatial data
- Models and maps fire spread probability
- Uses weather and climate statistics to better understand the fire season for longer range projections

Long Term Analyst LTAN

- Answers questions about risk to identified values

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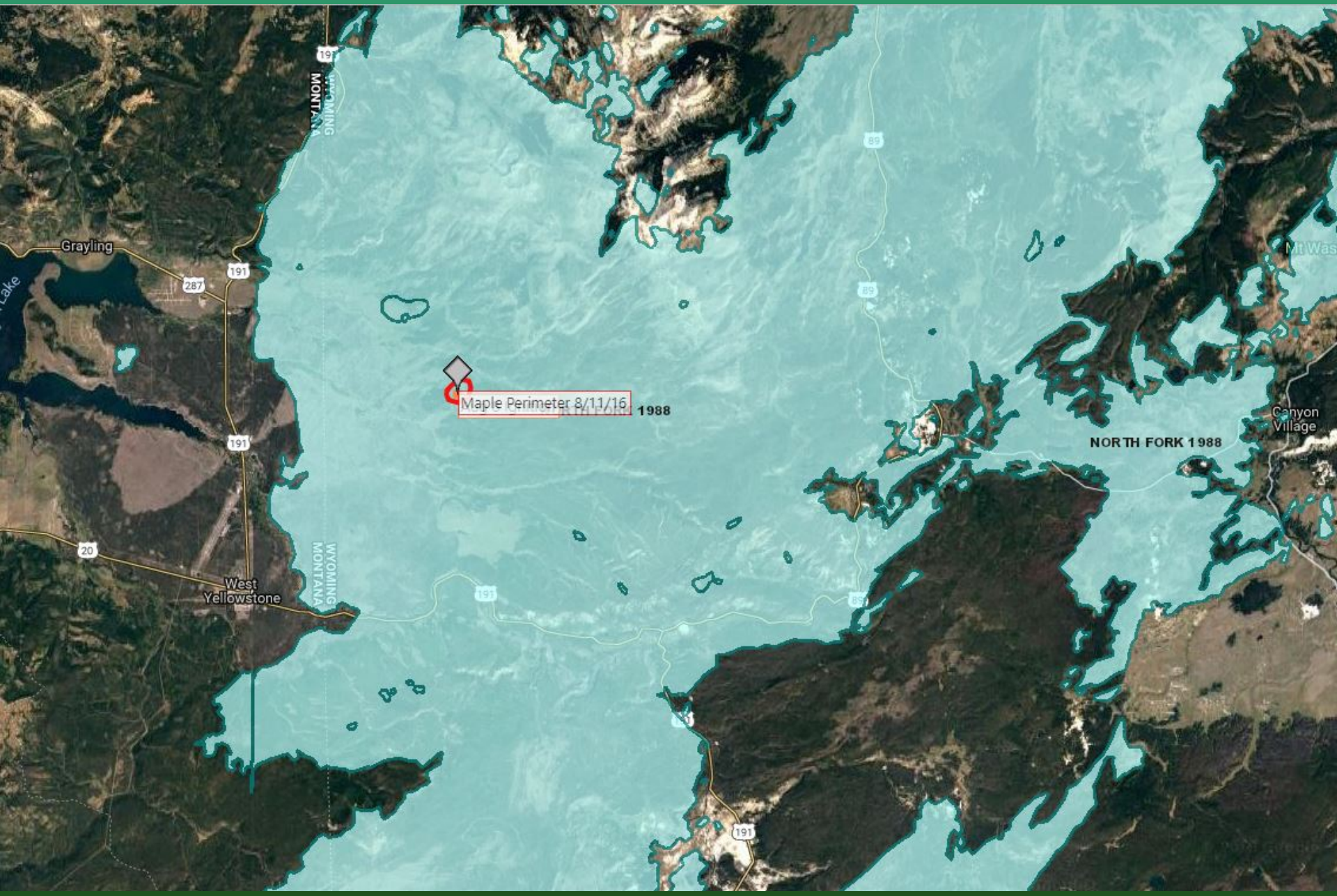
- Answer questions about risk to identified values
- Points out trouble spots on the landscape

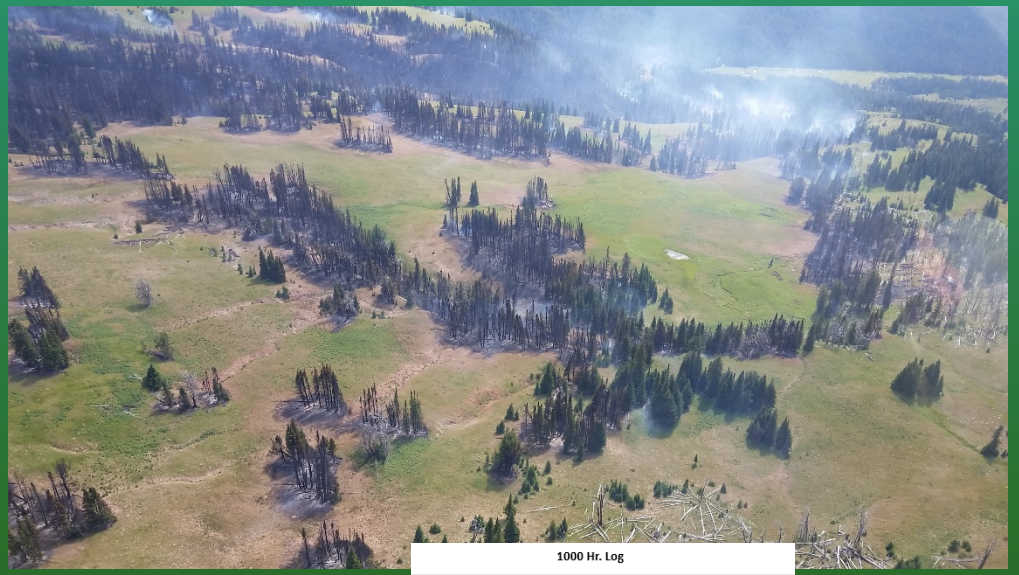
Long Term Analyst LTAN

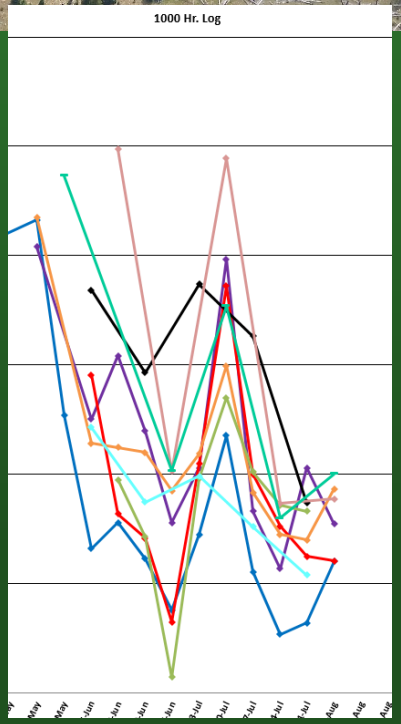
- Answers questions about risk to identified values
- Points out trouble spots on the landscape
- Compares Scenarios… “What if…?”

The Maple Fire
August 15, 2016

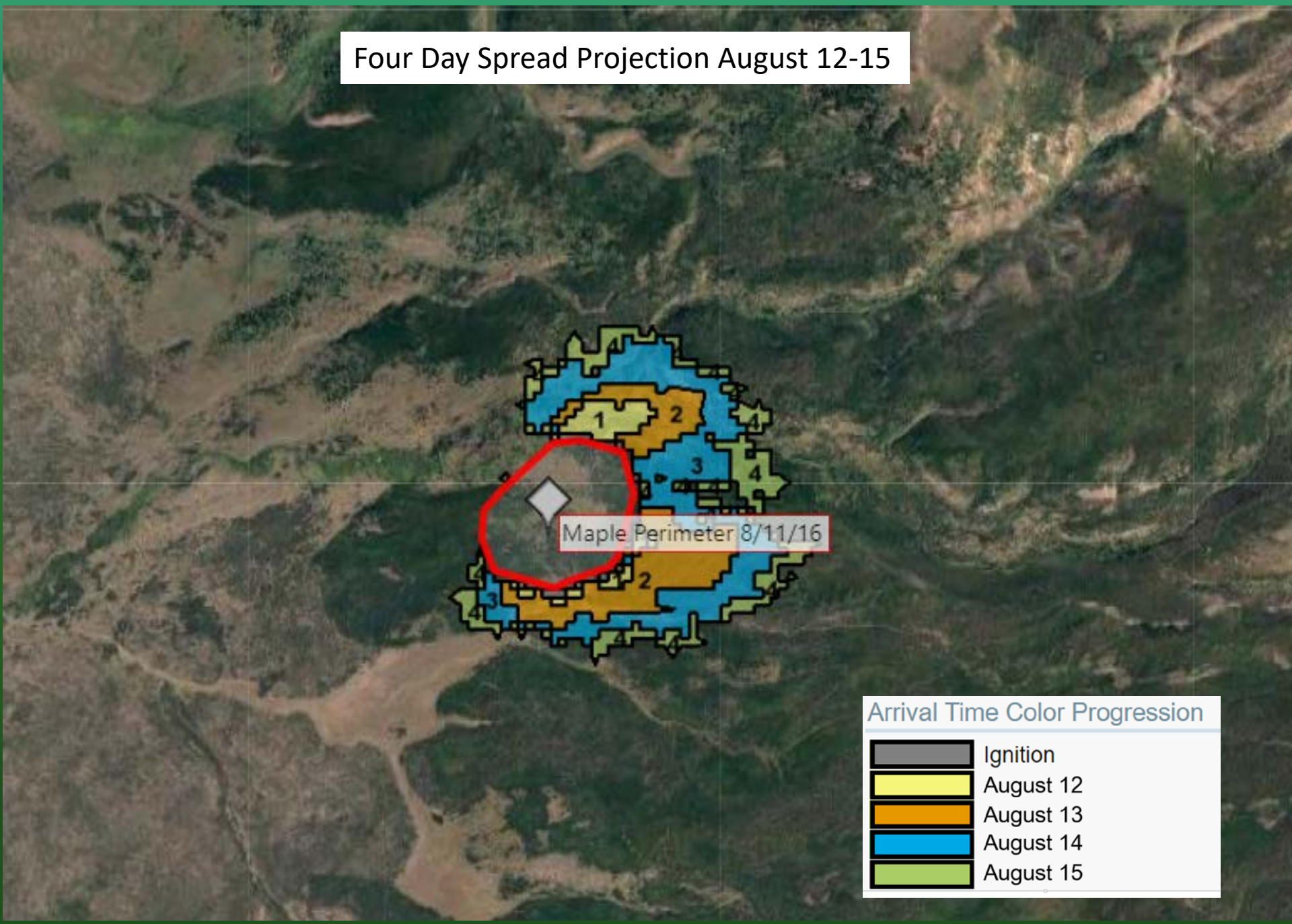

Grayling
191
287
191
20
West
Yellowstone
WYOMING
MONTANA
WYOMING
MONTANA
Maple Perimeter 8/11/16
1988
NORTH FORK 1988
Canyon
Village
191
191
191

October 2, 2015

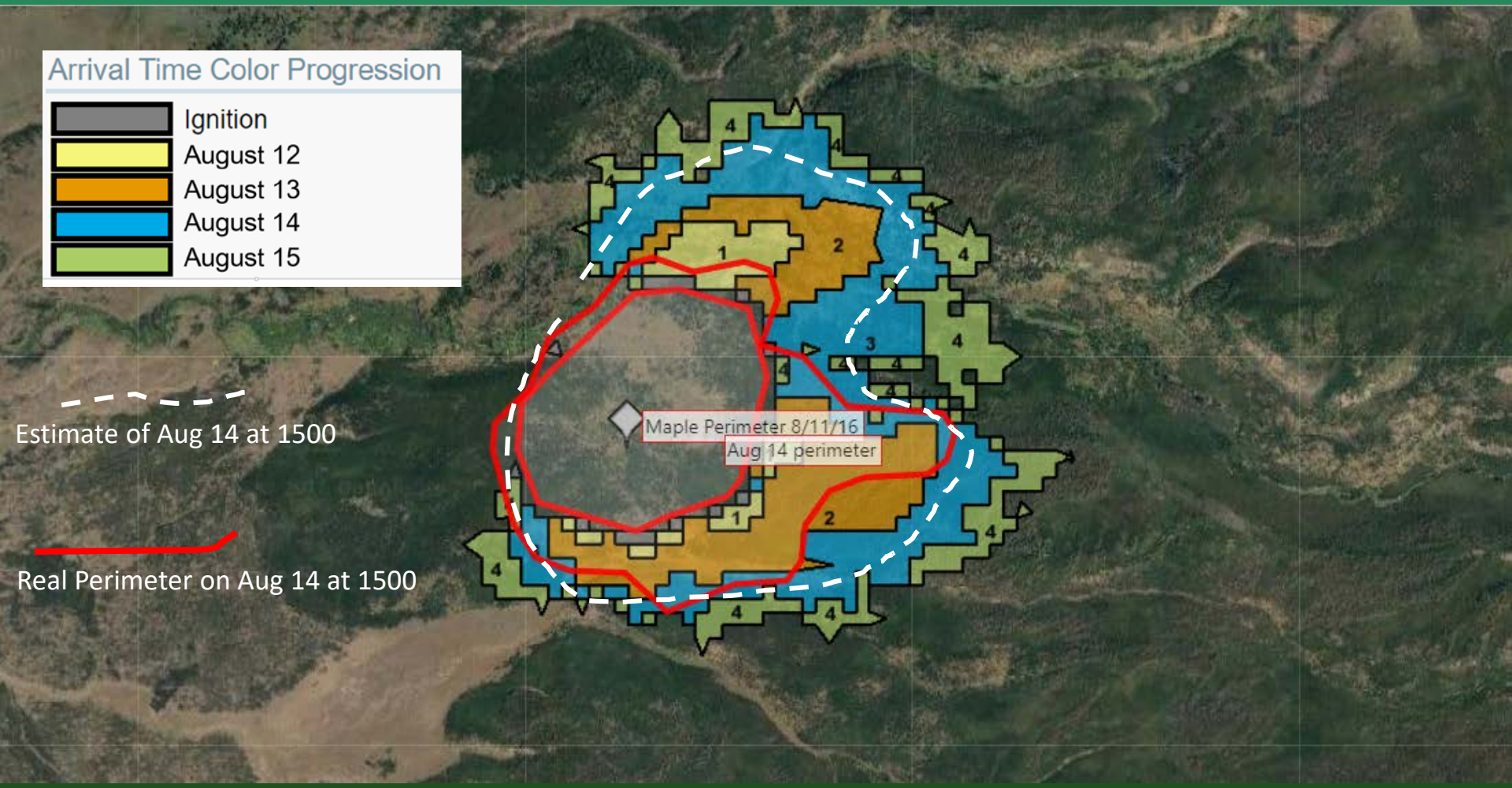



1000 Hr. Log

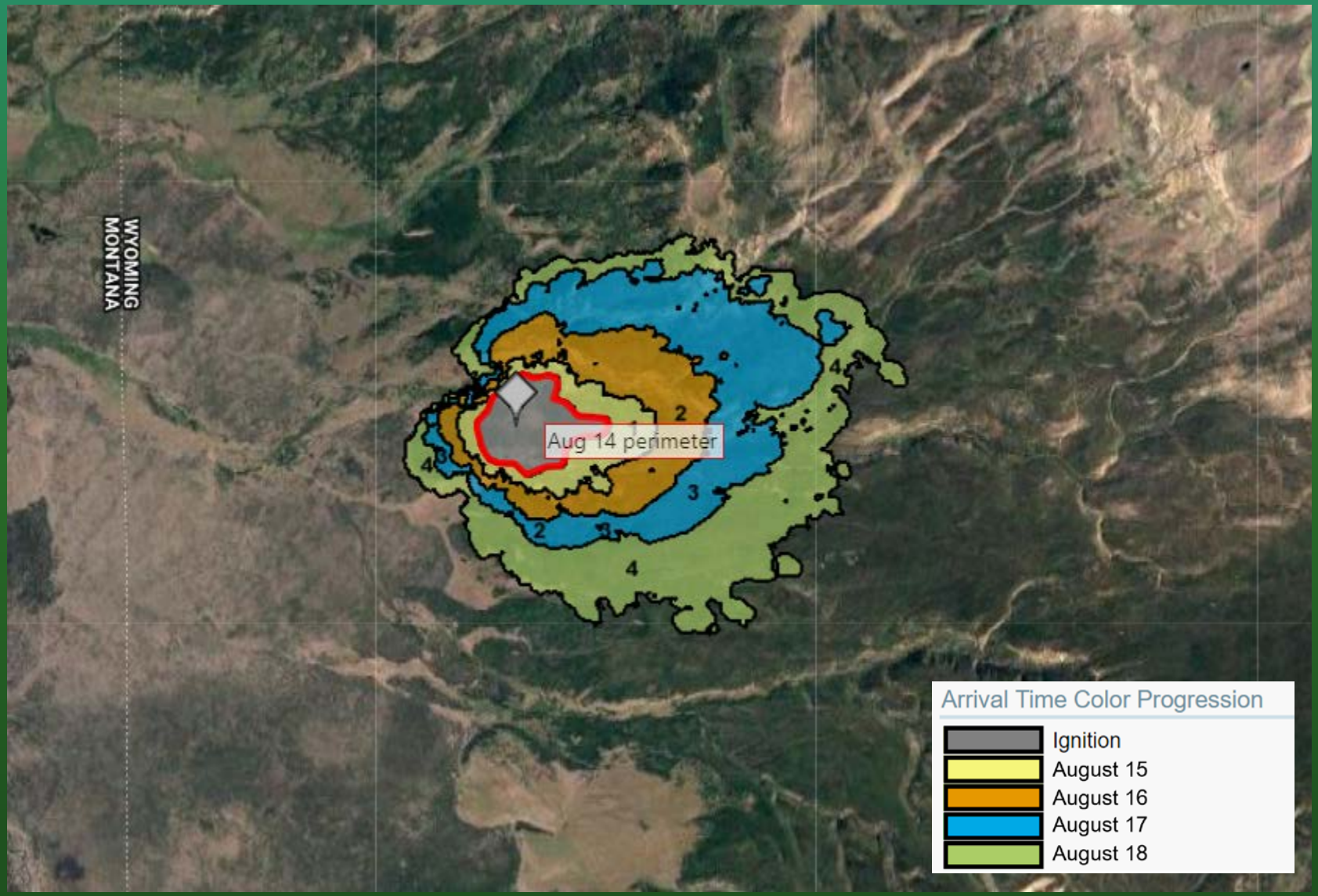
Four Day Spread Projection August 12-15



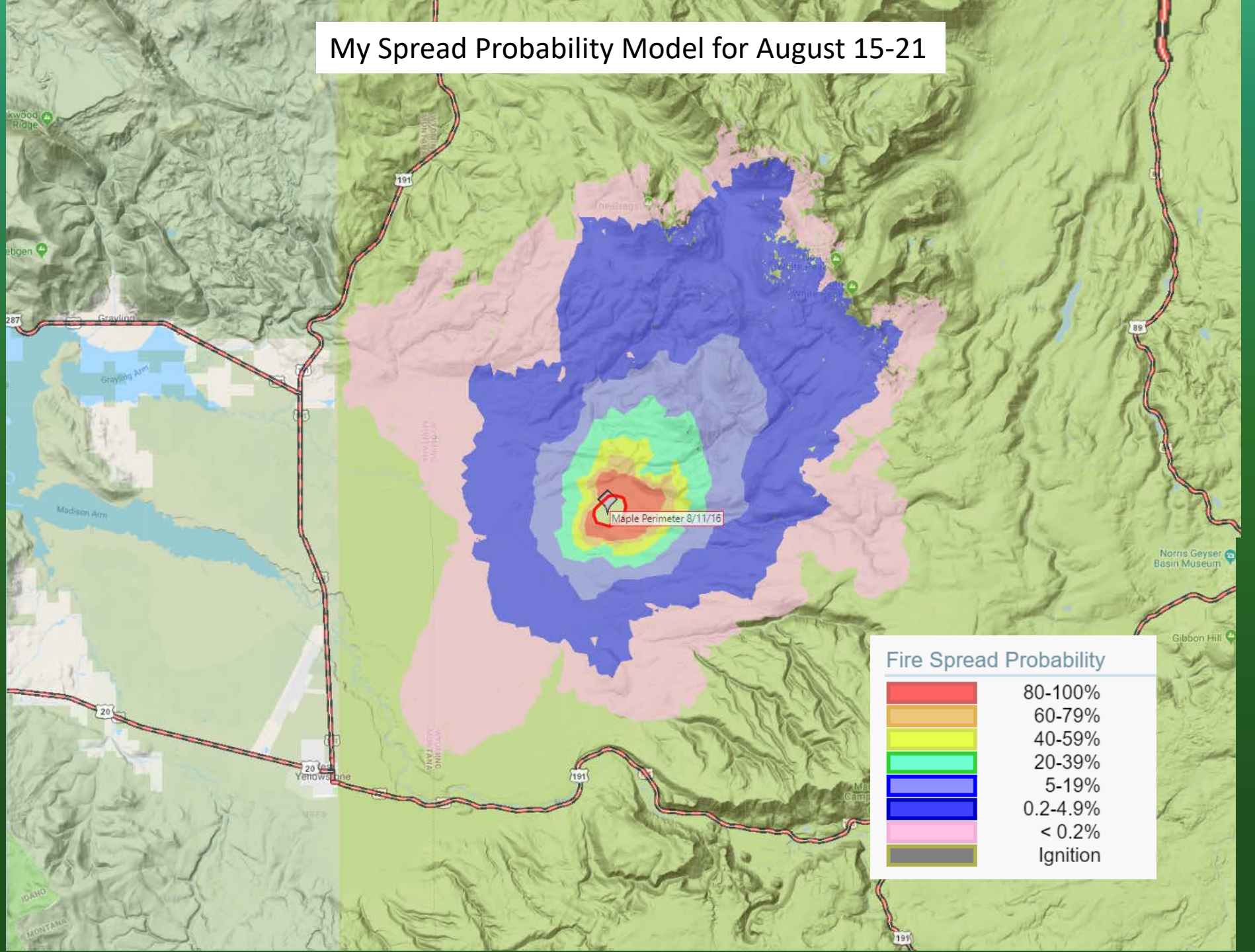
August 14, 15:00 - not too bad



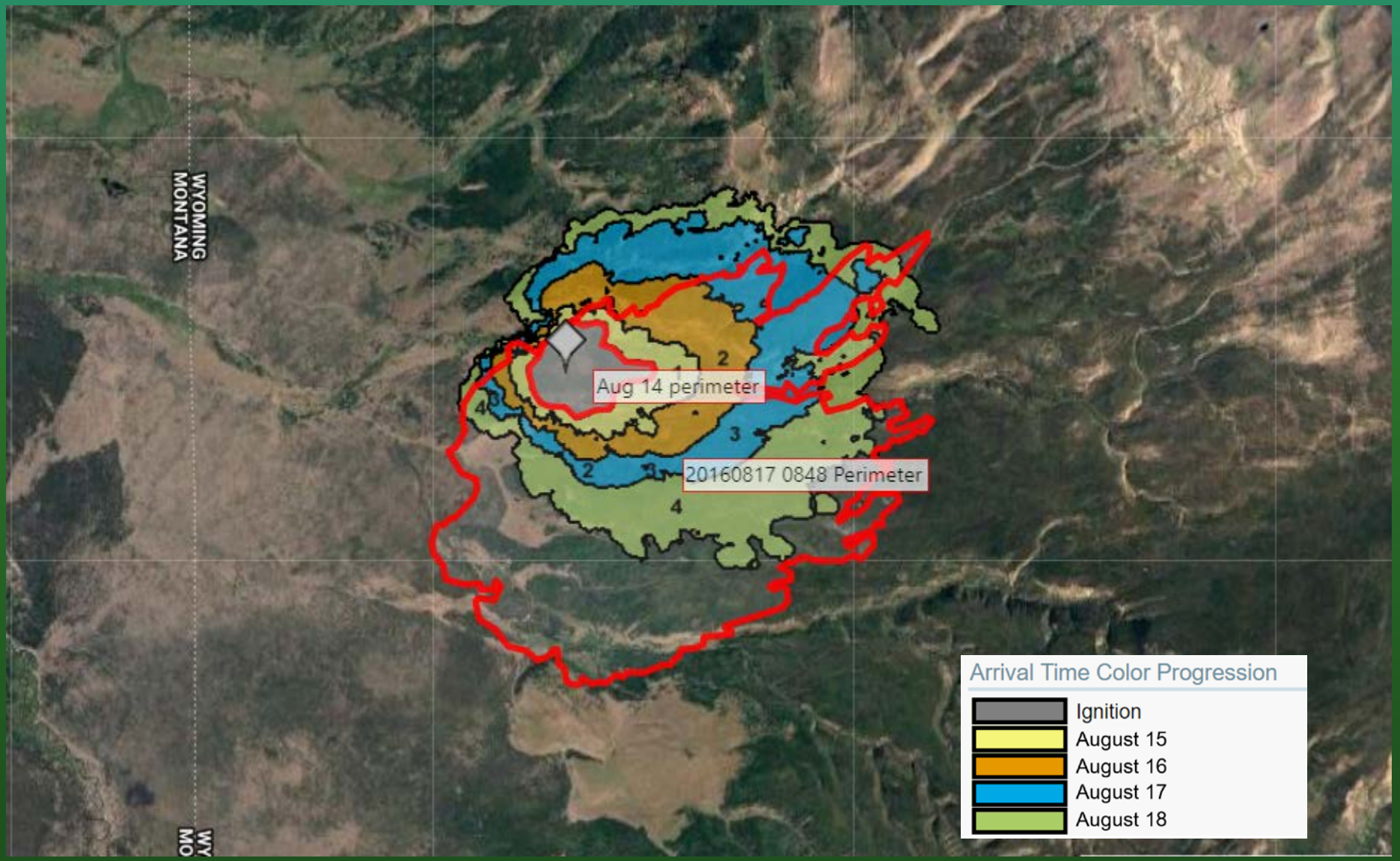
My next update projection for August 15-18



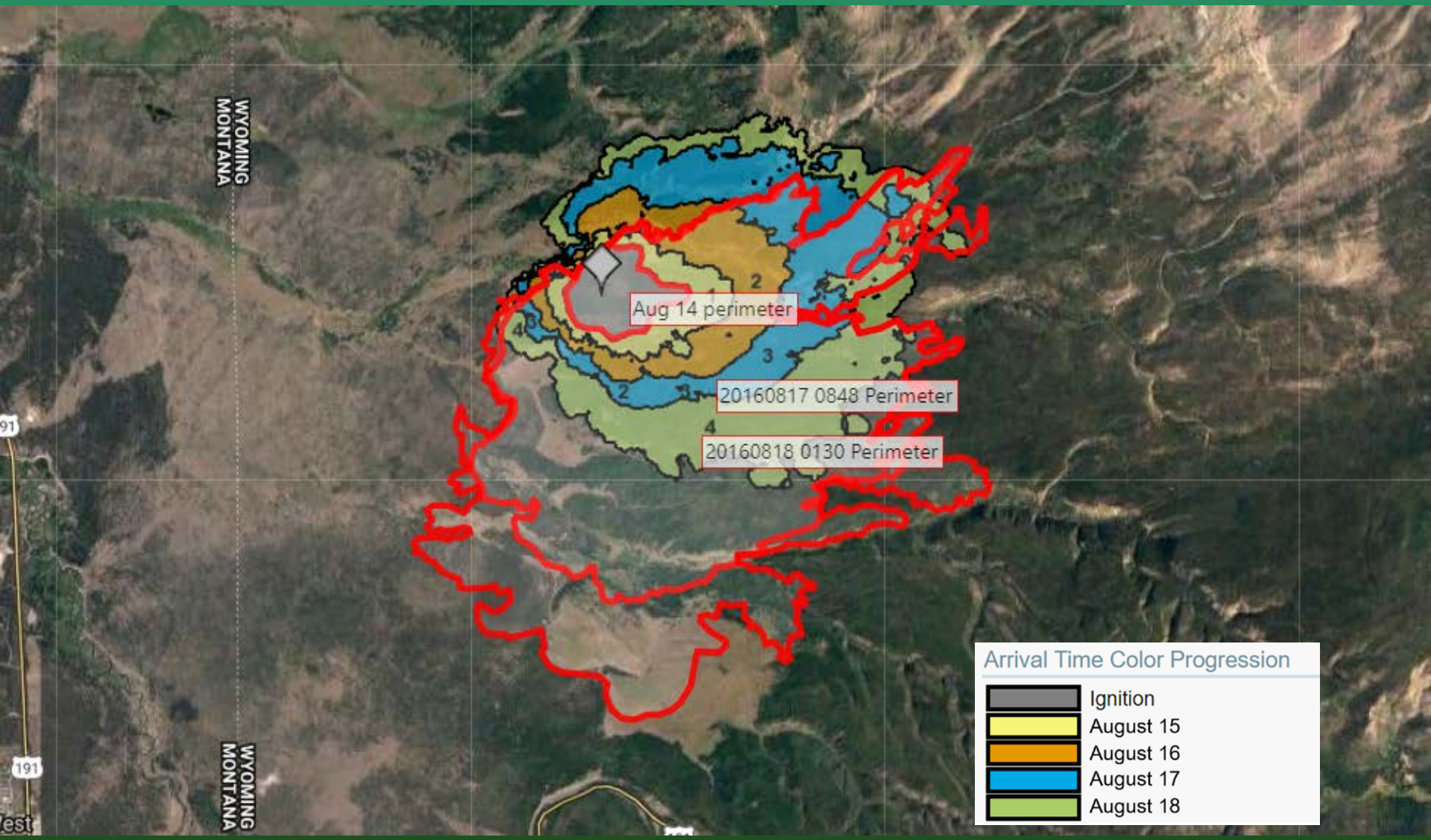
My Spread Probability Model for August 15-21



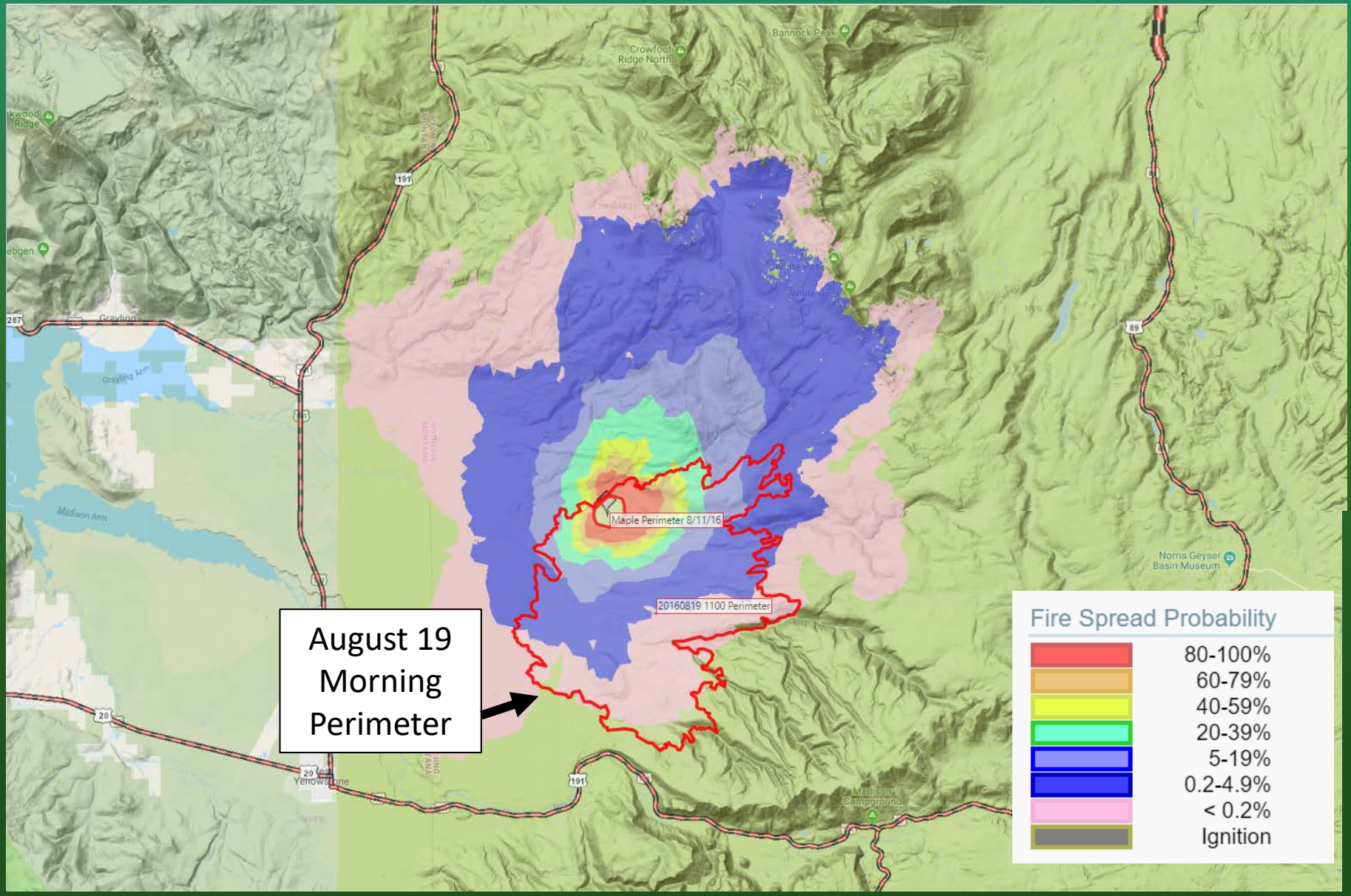
What happened on August 16 – an 8400 acre day



What happened on August 16 – Another 3800 acres!



So much for the Aug 15-21 probability model….



What happened on August 16? Blame the forecast!

Hourly Records for 08/16/2016

Graph View | First Day | Previous Day | Next Day | Last Day

*A Record Type of *Forecast indicates that part of the hourly record is missing. Please review and

Hour	Precip Amt	Temp	RH	Wind Speed	Wind Dir	Cloud Cover (%)	Record Type
0	0.00	60	45	3	60	9	Forecast
1	0.00	55	52	2	60	10	Forecast
2	0.00	51	59	2	40	10	Forecast
3	0.00	48	64	2	60	10	Forecast
4	0.00	46	69	2	60	10	Forecast
5	0.00	42	75	2	70	10	Forecast
6	0.00	39	80	2	340	9	Forecast
7	0.00	39	82	2	0	8	Forecast
8	0.00	42	80	2	350	7	Forecast
9	0.00	47	74	1	90	6	Forecast
10	0.00	54	65	1	100	6	Forecast
11	0.00	63	53	2	130	5	Forecast
12	0.00	71	40	2	150	5	Forecast
13	0.00	78	29	2	180	7	Forecast
14	0.00	82	23	2	250	13	Forecast
15	0.00	83	21	3	240	18	Forecast
16	0.00	83	20	6	240	23	Forecast
17	0.00	83	19	7	250	26	Forecast
18	0.00	82	19	6	250	33	Forecast
19	0.00	80	20	5	260	36	Forecast
20	0.00	77	24	5	260	36	Forecast
21	0.00	73	29	5	260	36	Forecast
22	0.00	69	35	2	130	36	Forecast
23	0.00	65	42	2	130	36	Forecast

Forecast

Hourly Records for 08/16/2016

Graph View | First Day | Previous Day | Next Day | Last Day | Save

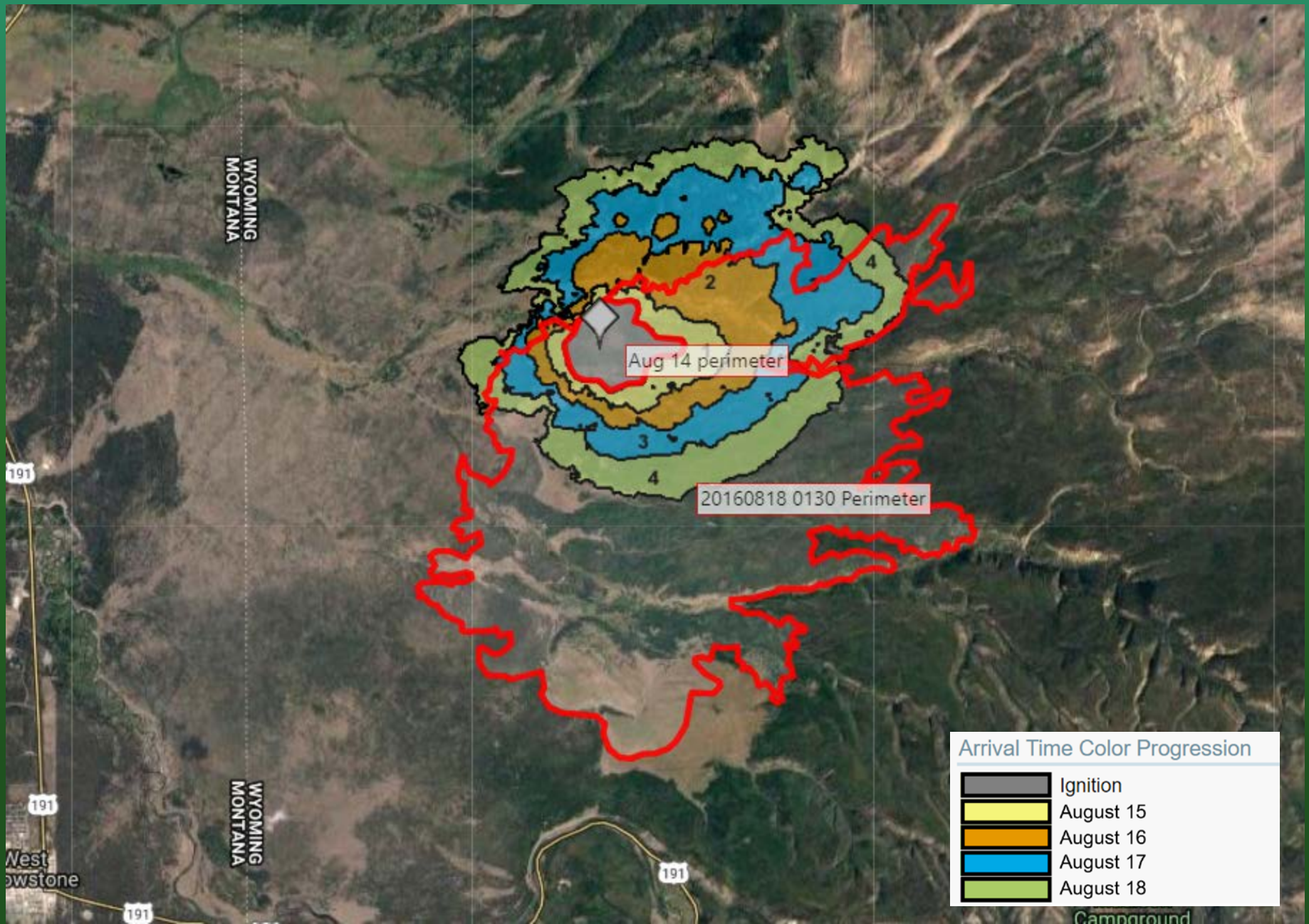
*A Record Type of *Forecast indicates that part of the hourly record is missing. Please review and edit

Hour	Precip Amt	Temp	RH	Wind Speed	Wind Dir	Cloud Cover (%)	Record Type
0	0.00	48	50	0	191	82	RAWS
1	0.00	46	54	0	180	83	RAWS
2	0.00	43	5	0	208	84	RAWS
3	0.00	43		0	170	85	RAWS
4	0.00				185	86	RAWS
5	0.00				157	87	RAWS
6	0.00				283	88	RAWS
7	0.00				143	78	RAWS
8	0.00	6		0	218	69	RAWS
9	0.00	69	31	1	348	59	RAWS
10	0.00	77	24	2	202	50	RAWS
11	0.00	82	19	3	276	40	RAWS
12	0.00	88	16	4	214	31	RAWS
13	0.00	89	12	5	234	39	RAWS
14	0.00	86	13	4	223	48	RAWS
15	0.00	89	12	5	216	57	RAWS
16	0.00	86	12	6	225	65	RAWS
17	0.00	83	13	5	216	74	RAWS
18	0.00	80	14	4	216	83	RAWS
19	0.00	72	21	0	204	83	RAWS
20	0.00	66	27	1	195	83	RAWS
21	0.00	62	33	0	139	84	RAWS
22	0.00	57	37	0	124	84	RAWS
23	0.00	54	41	0	111	84	RAWS

Hotter and Drier

Actual

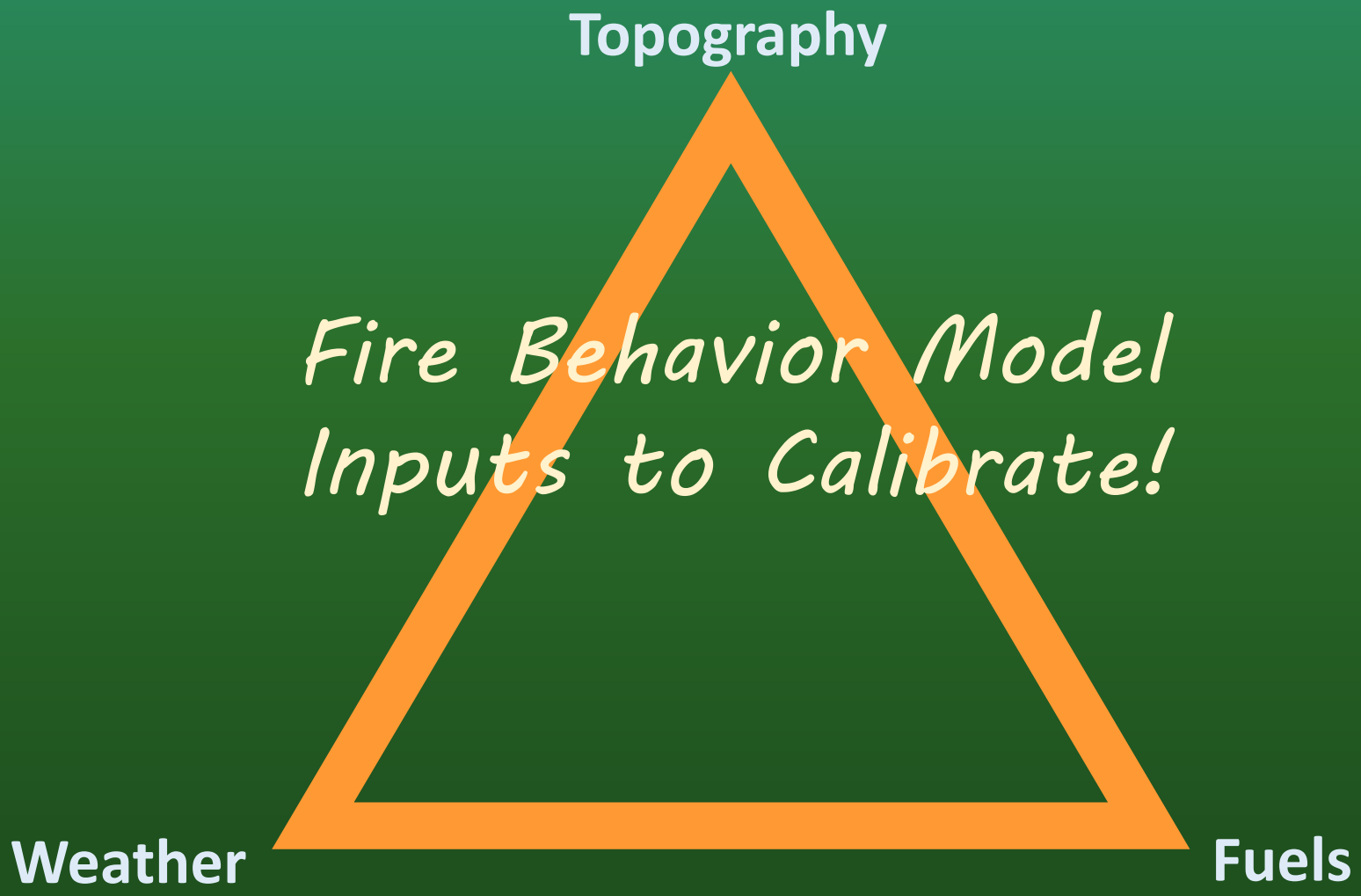
Re-calculated with actual weather vs. the Forecast
– Still Under-predicts by about 5000 acres!



Calibrating the Fire Spread Models

The Fire Behavior Triangle

(Countryman 1972)



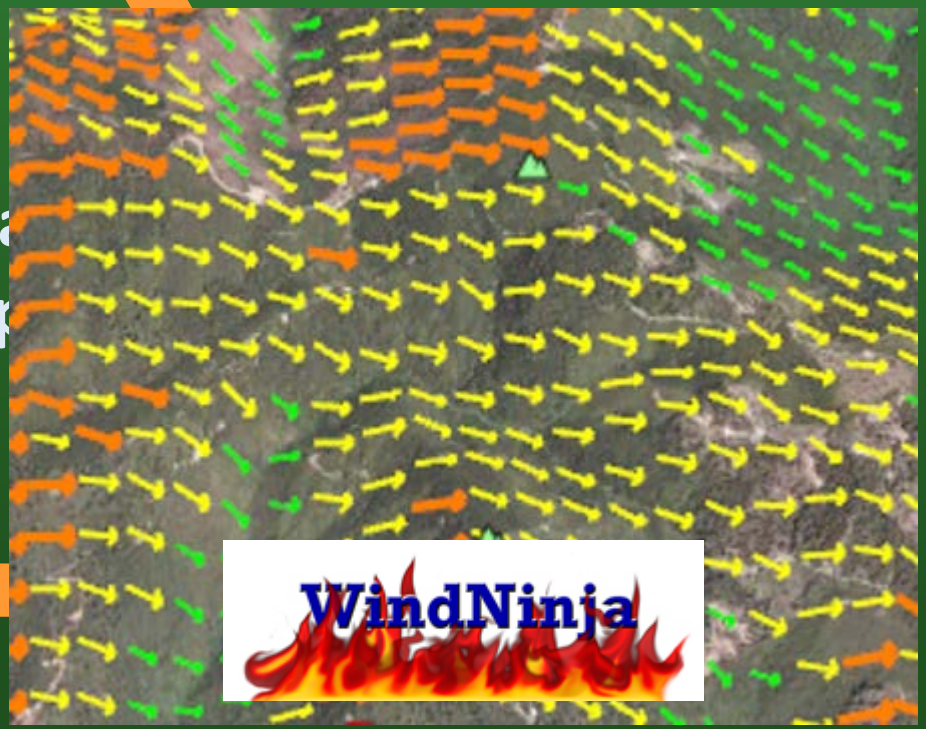
Changing the Topography?

Topography

Changing the Weather?

- Use a different weather station
- Use a different part of the climatic record (seasons or years)
- Use a better forecast and type it in
- Use “Gridded” wind data (for topographic wind effects – Only possible in some models)

Wea
Inp



Changing the Weather?

- Use a different weather station
- Use a different part of the climatic record (seasons or years)
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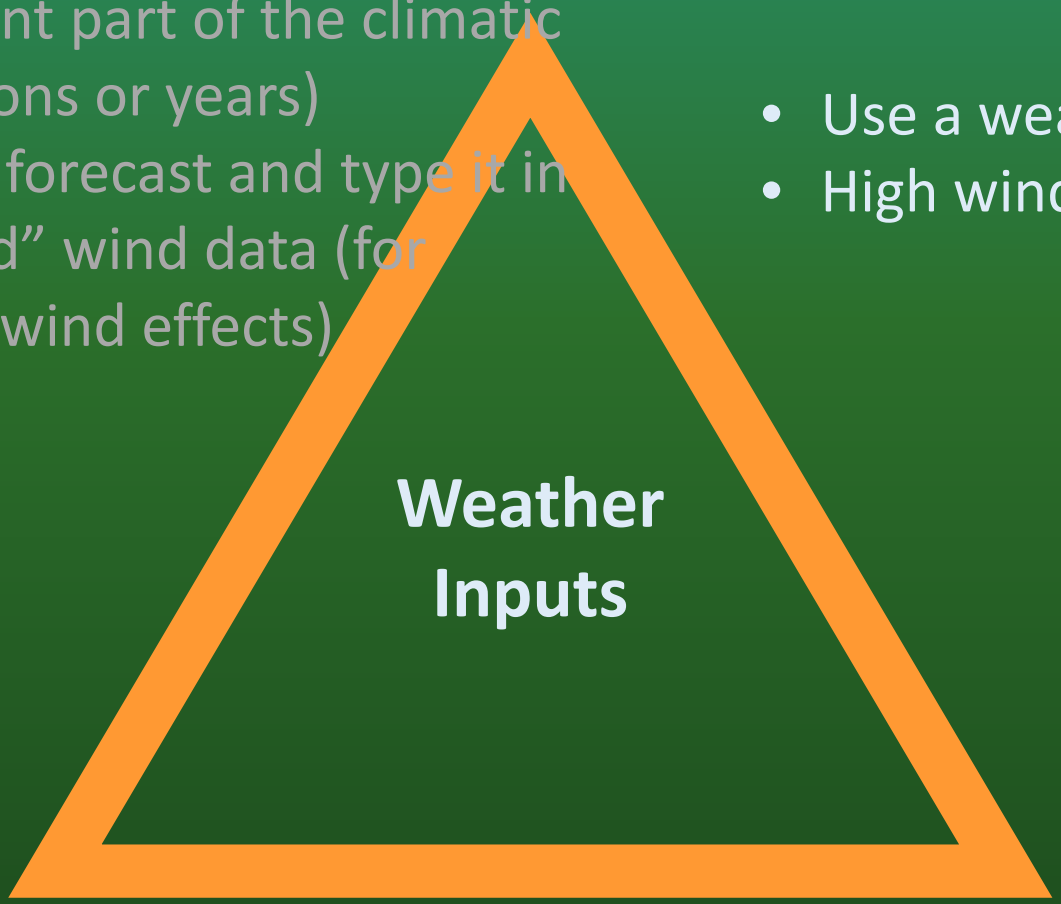
- Use “Gridded” wind data (for topographic wind effects)

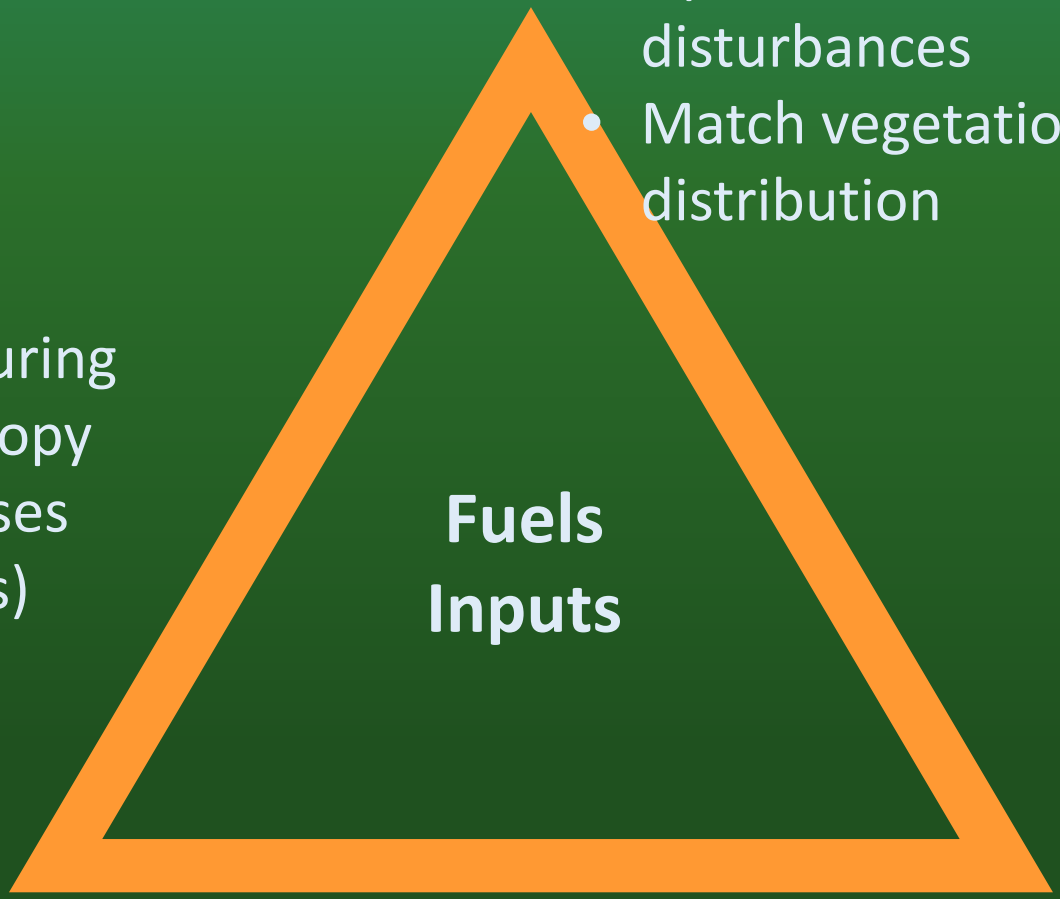


- Use a weather “scenario”
- High winds, for example

Changing the Fuels

- Fuel Models to better match fire behavior observations
- Updates for recent disturbances
- Match vegetation distribution

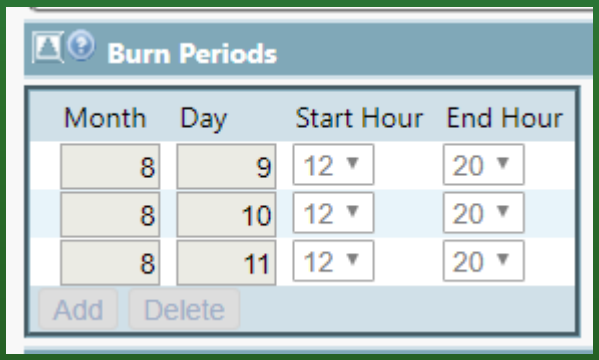
- Live fuel curing levels (canopy fuels, grasses and shrubs)



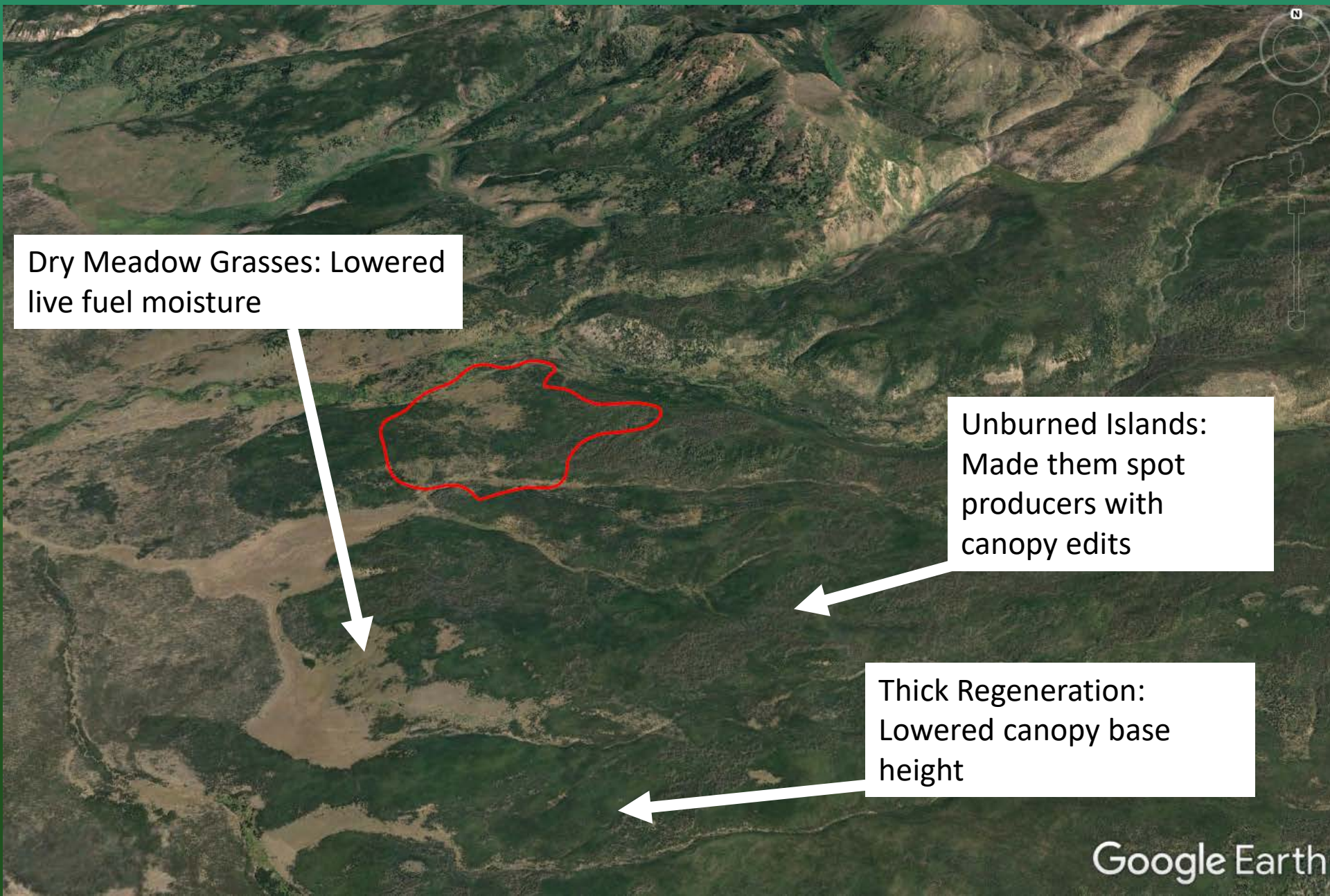
Other Things you can Tweak

- Crown Fire Behavior Models
- Spatial Resolution
- Burn Period length and time
- Spotting Probability

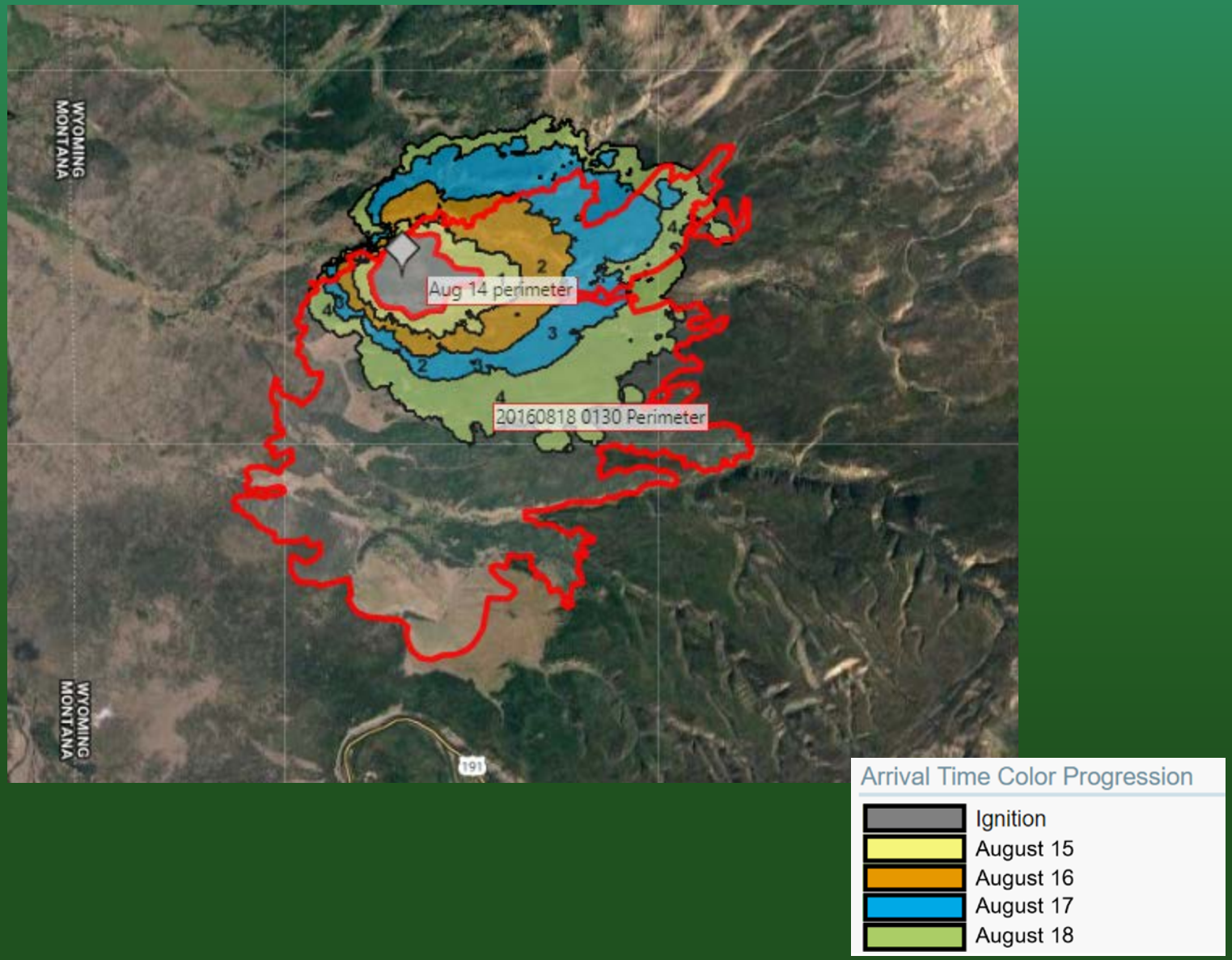
Other Inputs



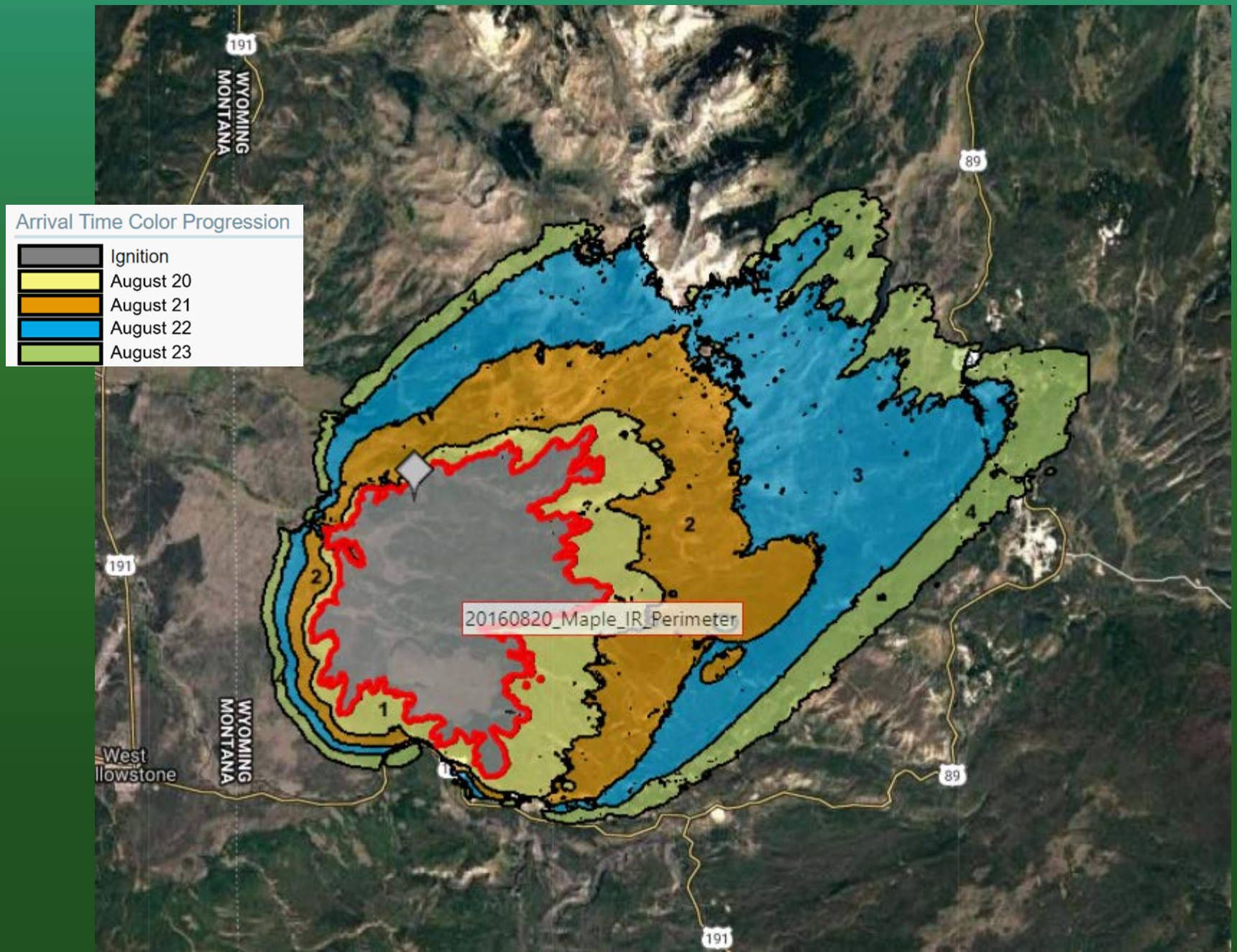
- What I did to calibrate the fire behavior



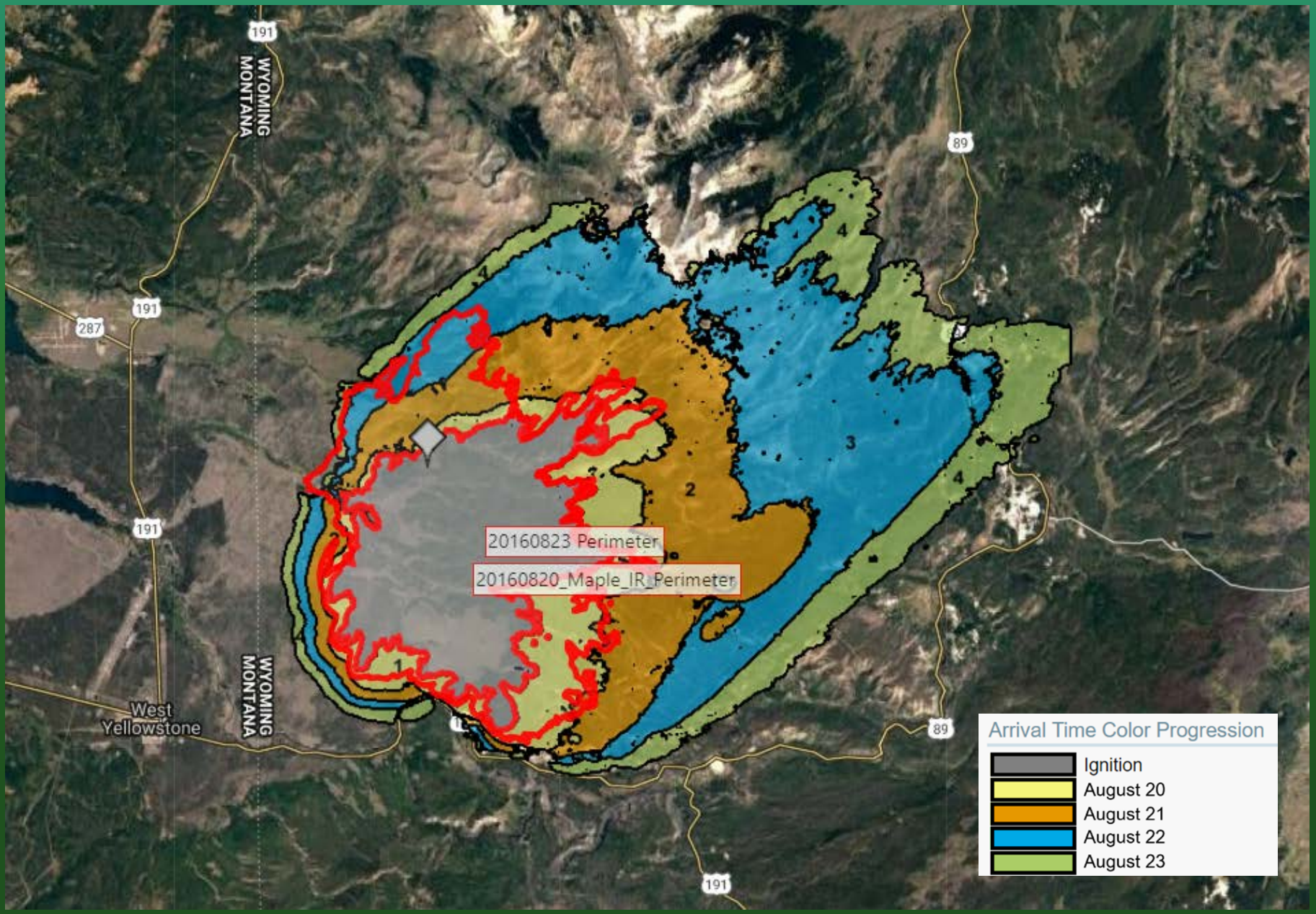
Still the fire was 2x as large as I predicted!!!



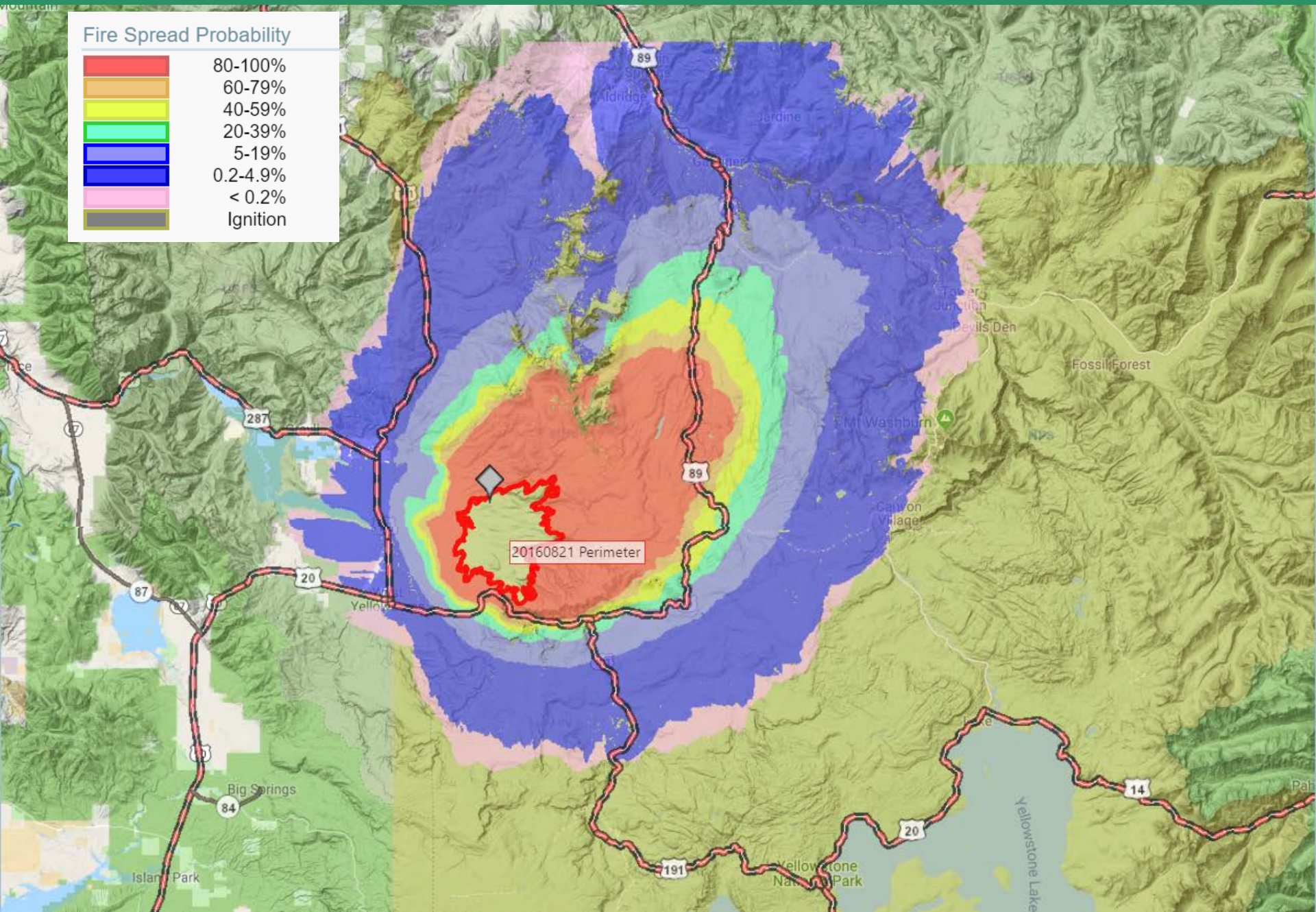
Using those calibration edits on August 20-23



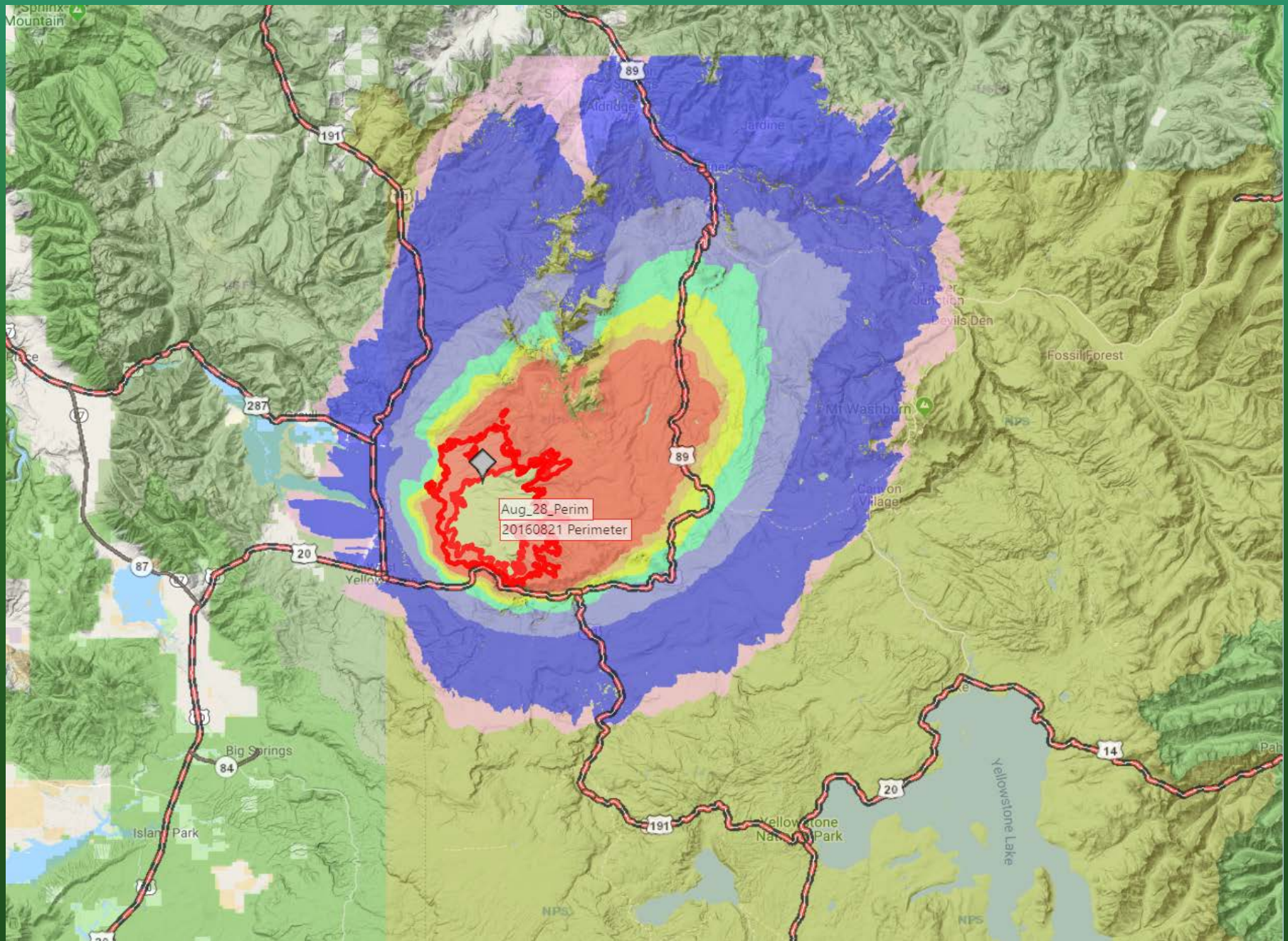
And what really happened Aug 20-23: Major Over Prediction!!!!!



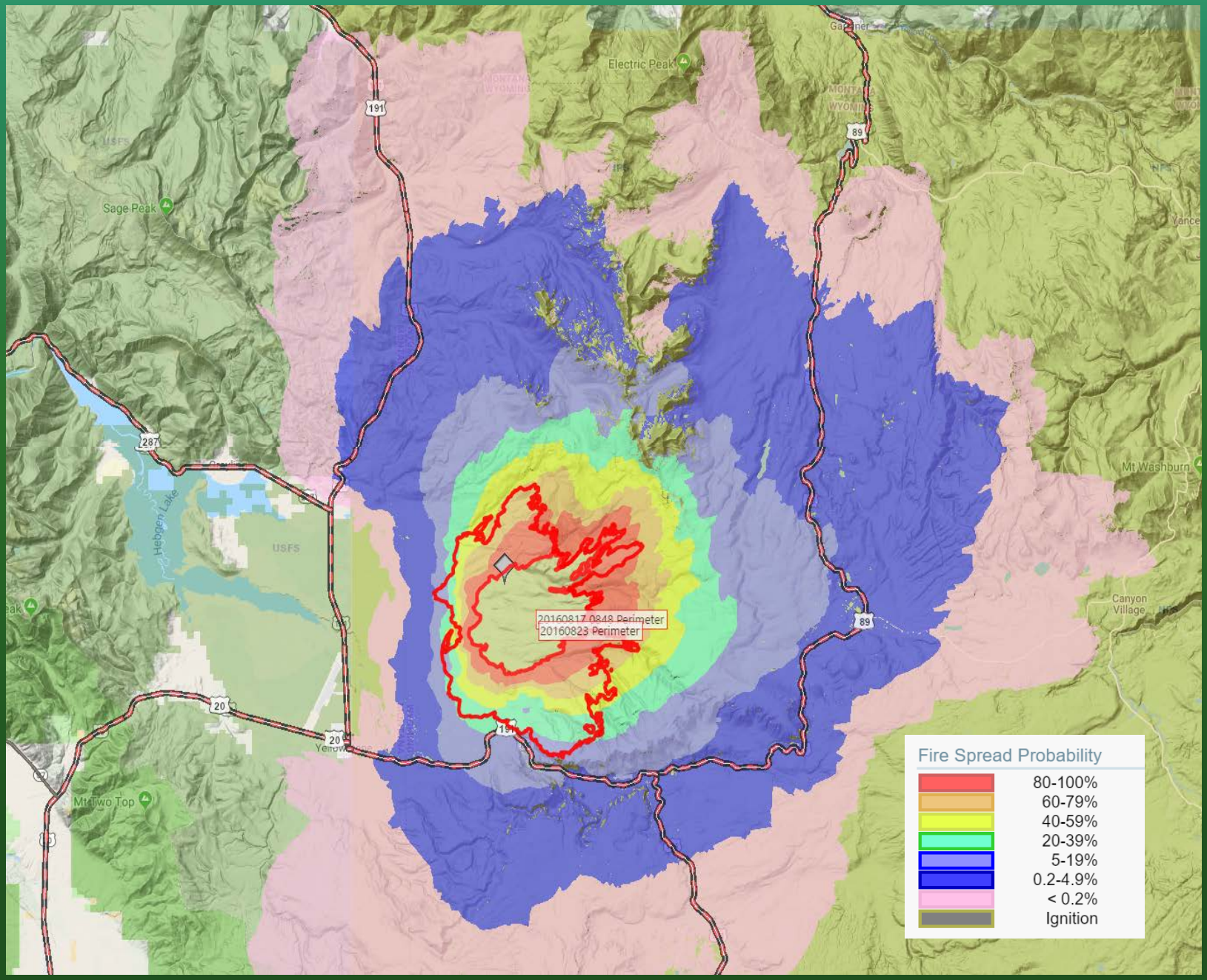
7 day Probability Map using those inputs



7 day Probability Map using those inputs: Major Over-Prediction!!!



Eventual 7 Day Spread Probability and Actual Growth with many tweaks – Still not that great



What happened next?

LTANs on the Maple Fire

Diane Abendroth Aug 11 – August 21
Jon Rieck Aug 22 – Aug 31
Andrew Page Aug 23
Tim Bumgarner Aug 24 – Sept 11
Jonathan Olsen Aug 26 – Sept 10
Eric Morgan Aug 28

What happened next?

LTANs on the Maple Fire

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My thoughts on how to Make Geospatial Fire Behavior Modeling Better for cases like the Maple Fire…

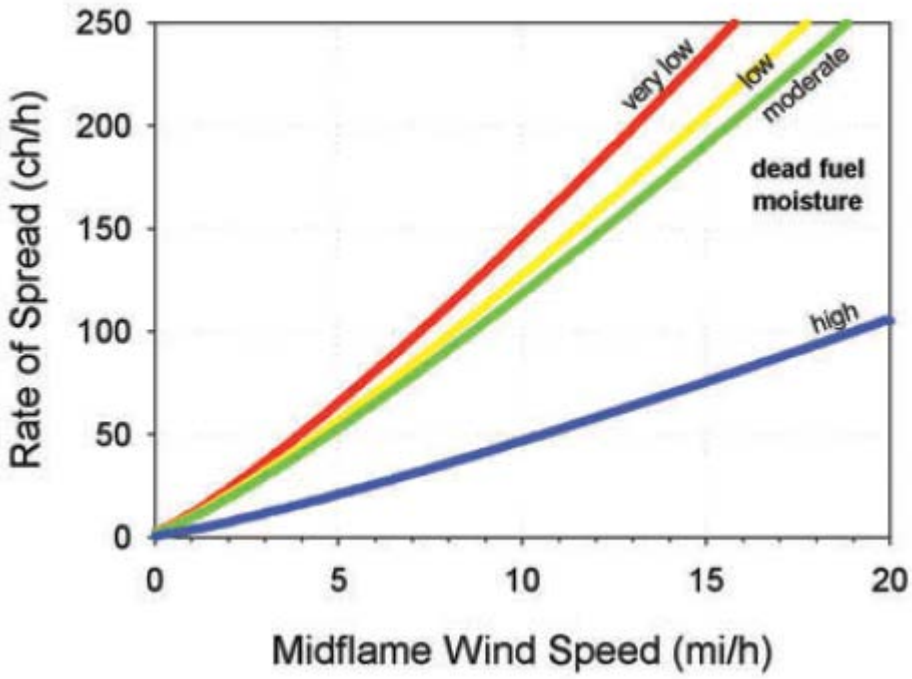
Changing the Fuels

High Load, Dry Climate Shrub

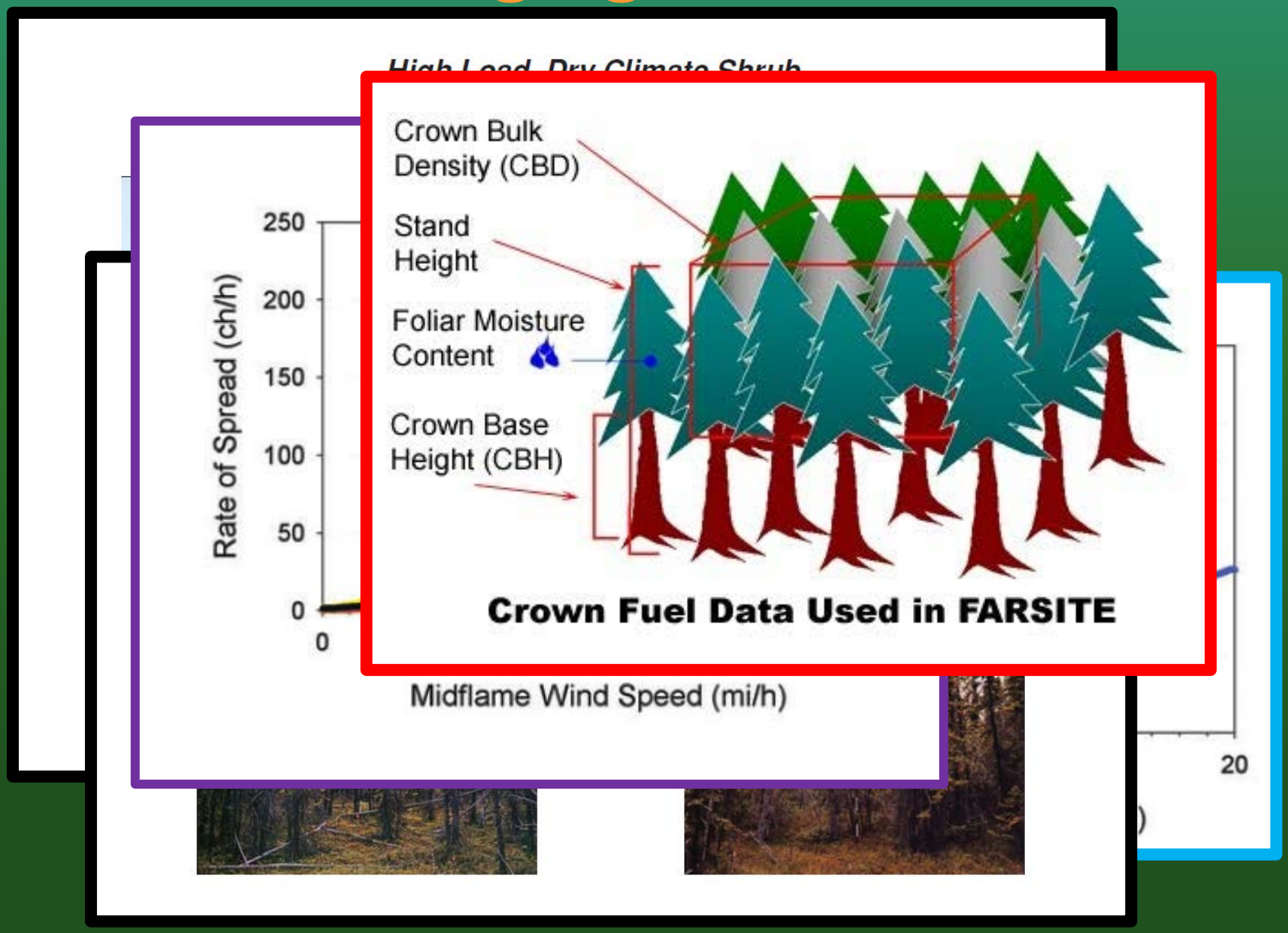
Description: The primary carri

litter. Heavy shrub load, depth

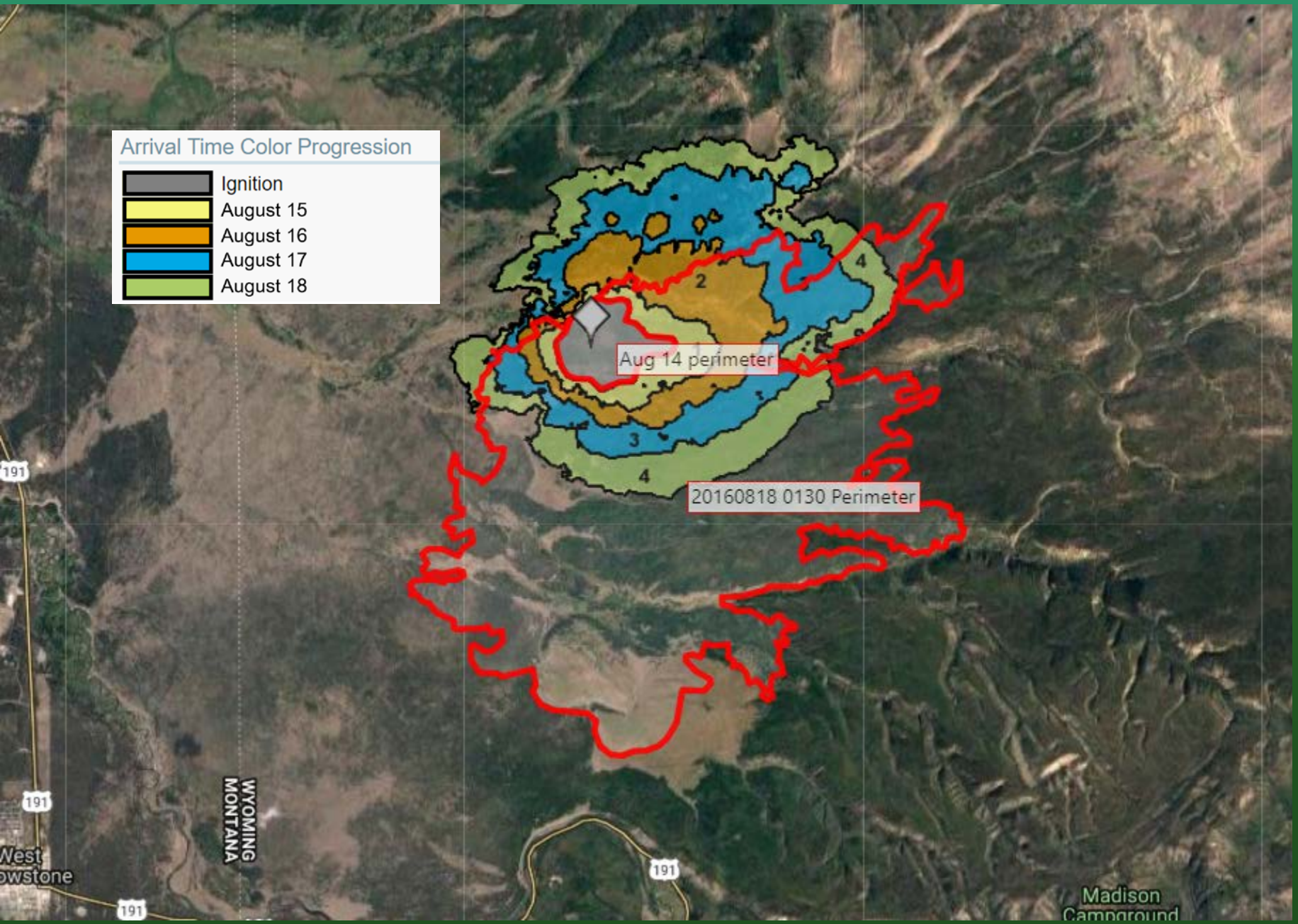
very high. Moisture of extinctio



Changing the Fuels



They all looked like this!



Changing the Fuels...
(At least for the Maple Fire)

What really happened on August 16 and 17? Wind?!

- Better
- Better
- Better
- Better topogr
- Better Extra D

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OUR STRUCTURE

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FANNING THE FLAMES OF MEGAFIRES

Local winds are the key factor in some conflagrations

JUL 24, 2018 - BY DAVID HOSANSKY

The King Fire burning in California in 2014. (Image: U.S. Forest Service)

Discussion Questions?