Overview of NFDRS2016

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NATIONAL NFDRS 2016 ROLLOUT WORKSHOP

28 APR 2018

Outline

- Introduce the NFDRS changes
- Talk about some elements relating to model comparison and evaluation
- Look at the future
- Why we should care……

A horse walks into a bar...

- The bartender says, "Hey."
- The horse replies, "Sure."

Fire weather conditions are changing

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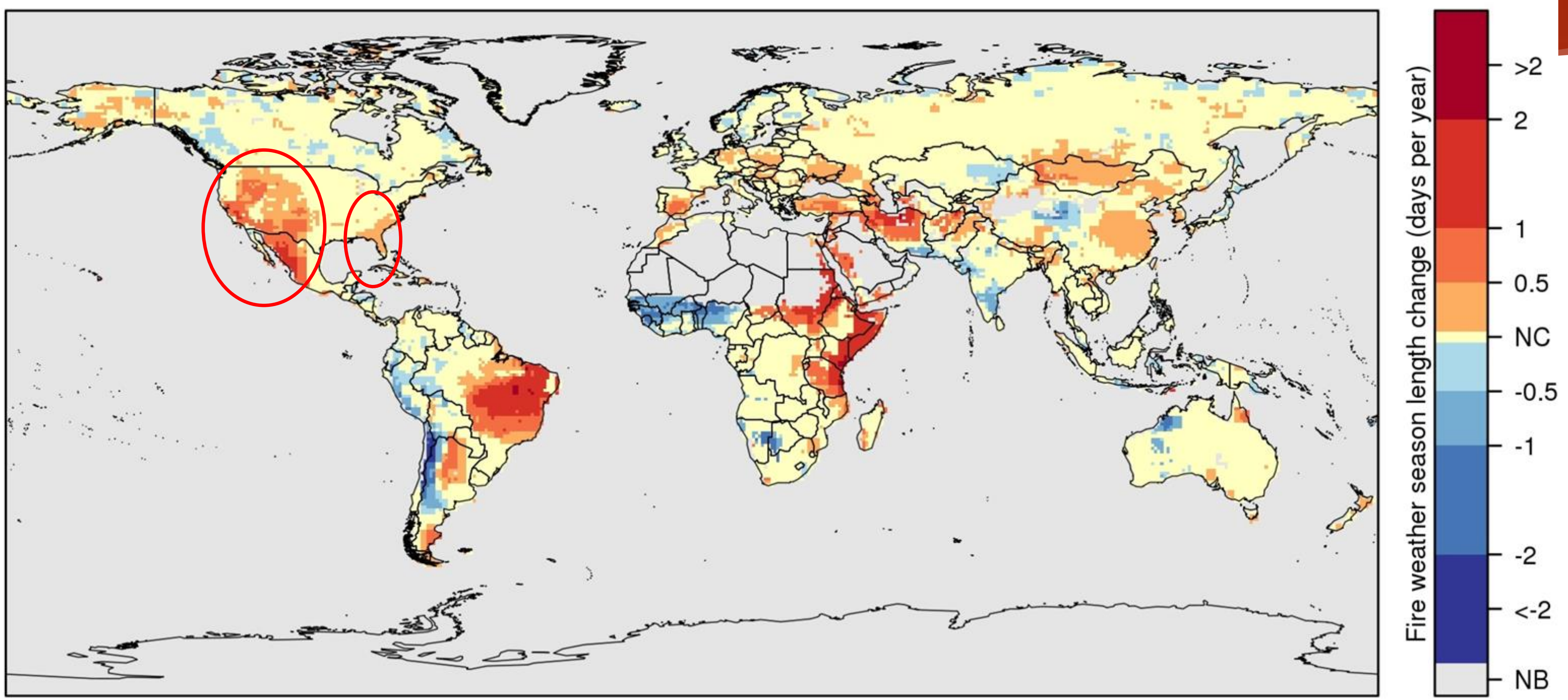
NATURE COMMUNICATIONS | ARTICLE OPEN

Climate-induced variations in global wildfire danger from 1979 to 2013

W. Matt Jolly, Mark A. Cochrane, Patrick H. Freeborn, Zachary A. Holden, Timothy J. Brown, Grant J. Williamson & David M. J. S. Bowman
Affiliations | Contributions | Corresponding author

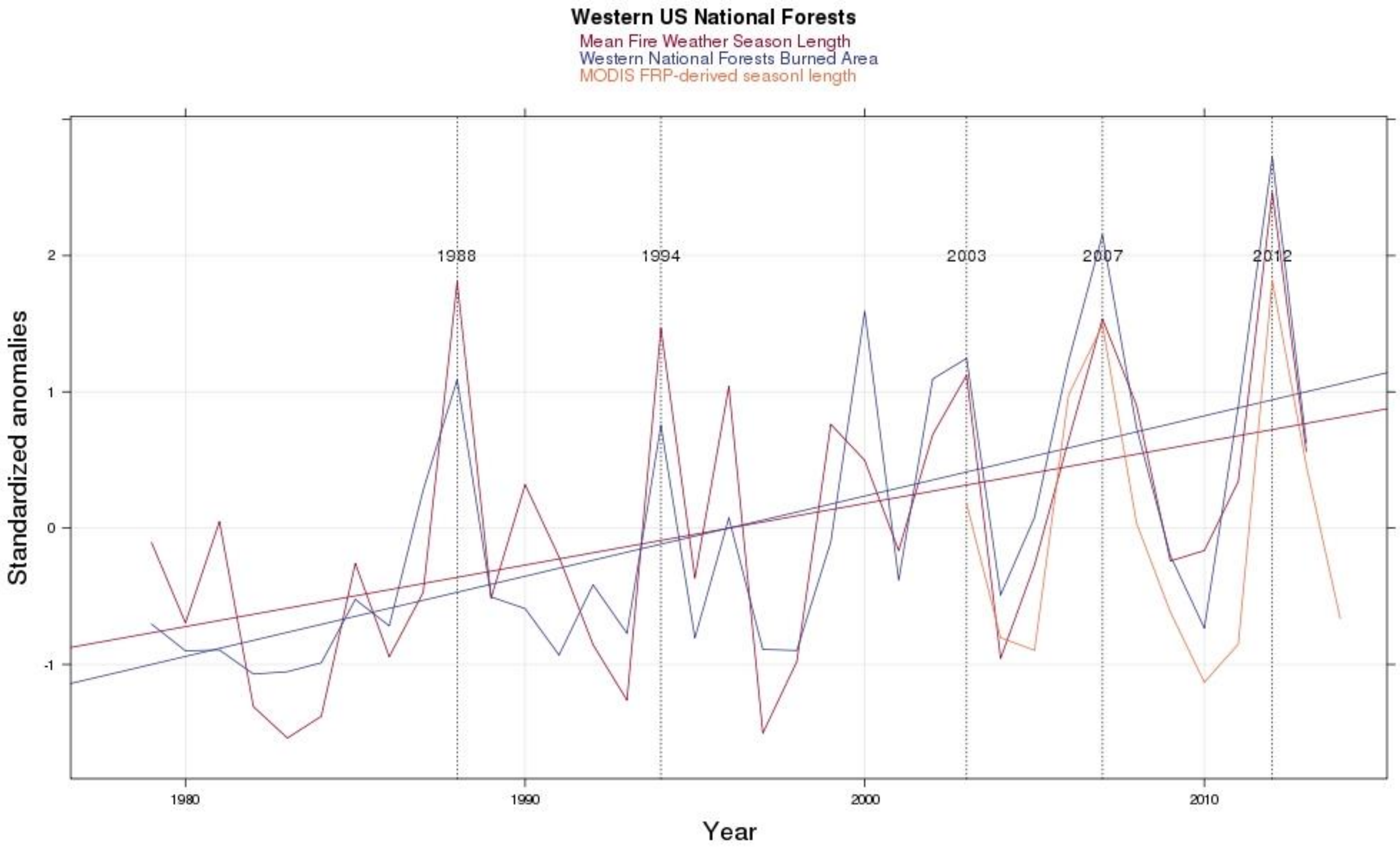
Nature Communications 6, Article number: 7537 | doi:10.1038/ncomms8537
Received 24 November 2014 | Accepted 15 May 2015 | Published 14 July 2015

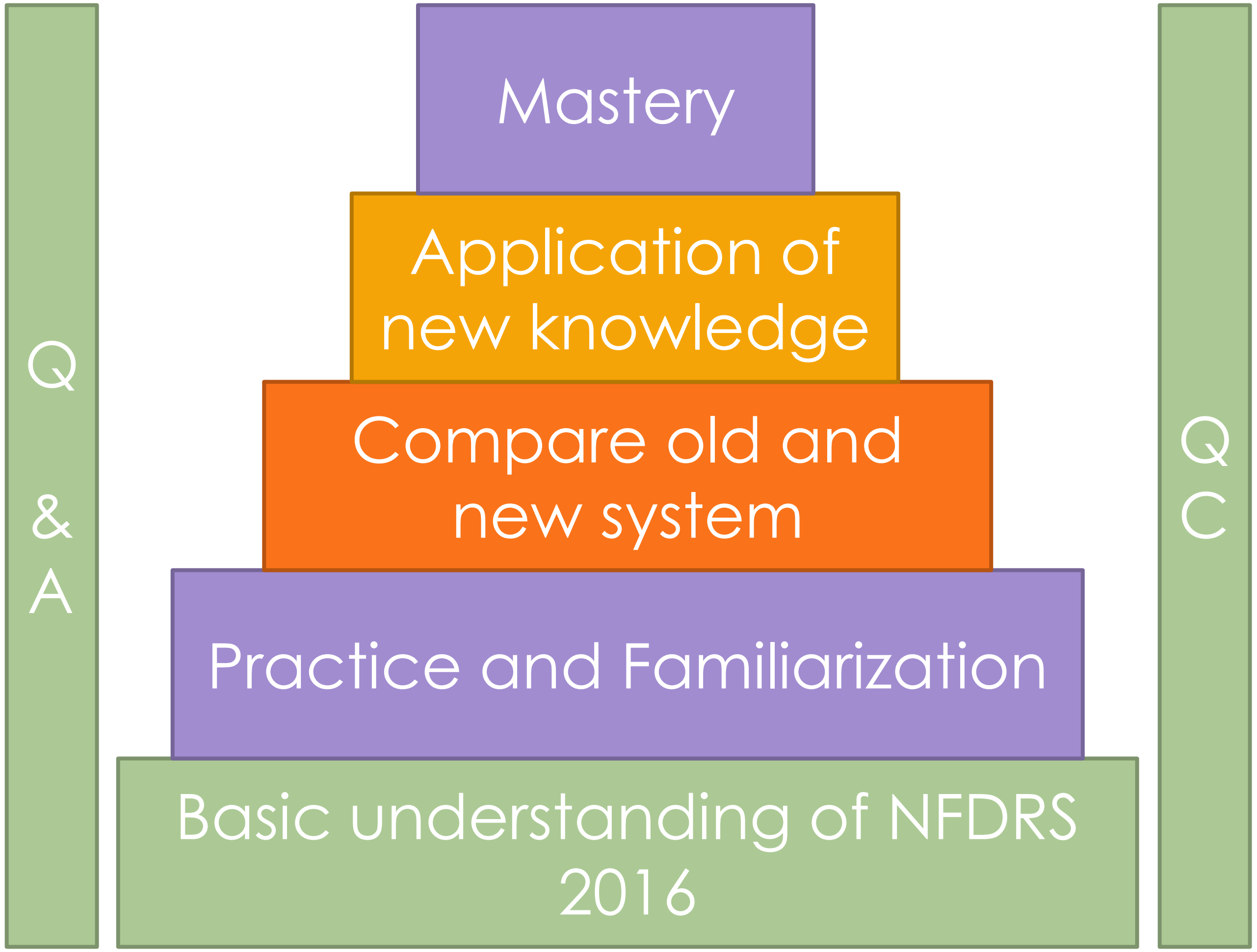
A



Fire weather seasons have lengthened across 29.6M km2 (25.3%) of the Earth's vegetated surface. (Jolly et al 2015, Nature Communications)

Climatic changes account for 85% of the burned area variations across Western National Forests (Jolly et al, unpublished)



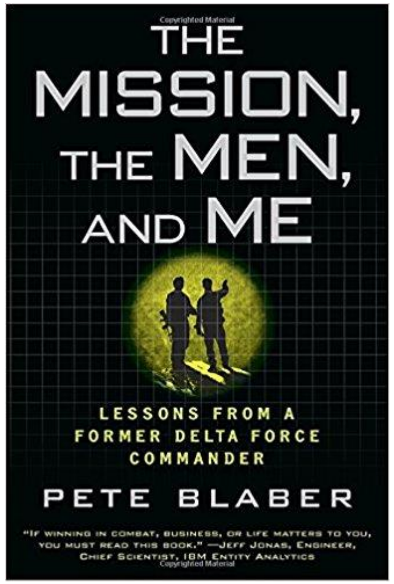

Mastery
Application of new knowledge
Compare old and new system
Practice and Familiarization
Basic understanding of NFDRS 2016
Q & A
QC

Philosophy

- Two desires for today:
  - **Learn:** About the new model and how to use the tools to explore it
  - **Commit:** To be a part of a learning community

A learning model:

1. **Saturate**
2. **Incubate**
3. **Illuminate**



Fire Danger Rating: The Next 20 Years, 1987
John E. Deeming

Abstract: For the next 10 years, few changes will be made to the fire-danger rating system. During that time, the focus will be on the automation of weather observing systems and the streamlining of the computation and display of ratings. The time horizon for projecting fire danger will be pushed to 30 days by the late 1990's. A close alignment of the fire-danger rating system with the fire-behavior and fire-planning systems will occur with the release of the second-generation fire model in the late 1990's. Improved utilization of all of these systems will be delayed until more structured approaches to decision making are adopted by management. By 2007, expert systems utilizing real-time direct and remotely sensed weather and fuel moisture data will be on line.

https://www.fs.usda.gov/treesearch/pubs/28099

Four guidelines of a fire danger rating system

- To develop consistency among protection agencies, the National Fire Danger Rating System (NFDRS) was developed in the early 70’s. It was designed around four basic guidelines. The research charter said the National Fire Danger Rating System would be:

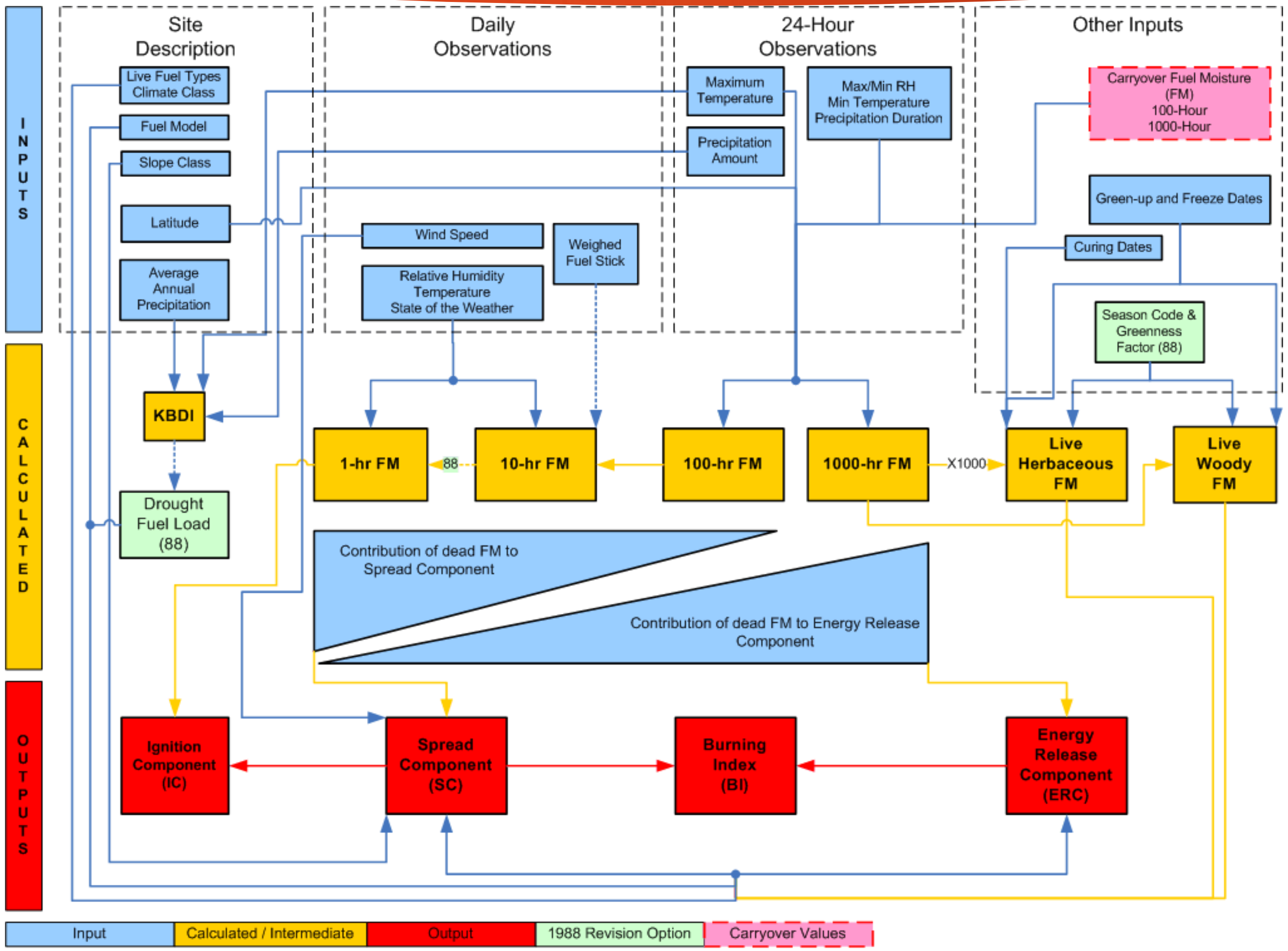
A. **Scientifically based.**
B. **Adaptable to the needs of local managers.**
C. **Applicable anywhere in the country.**
D. **Reasonably inexpensive to operate.**

Components of a fire danger rating system

- **Modular:** New science can easily be added
- **Integrative:** Fire danger indices integrated over both space (FDRA) and multiple time horizons (today -> season -> inter-annual)
- **Generalized:** Same system performs across a range of climates. It should work everywhere.
- **Applicable:** Normalize index scales and apply indices across a spectrum of fire management decisions. Maintain a 'common language' across all agencies.

https://kahoot.it

Structure of the 1978/88 National Fire Danger Rating System



Check-in Question

- What are the required user inputs to NFDRS?
- Daily?
- Seasonal?

Case for Change

- Prepares NFDRS to integrate into future uses of weather data
  - Described in the FENC/CEFA RAWS Network Analysis of 2011, including increasing use of gridded data in analysis products like NFDRS
- Preparing to do this for over a decade:
  - Installing solar radiation sensors on RAWS
  - Evaluating new model performance
  - Lessons learned in extensive analysis in Fire Danger Operating Plans correlating NFDRS Indices, fuel models and fire activity.

Outline

- Major Changes
  - Fuel moisture models and fuel models
- Minor Changes
  - Drought fuel loading and Herbaceous curing
  - Other fuel model and site description changes
- Simplifications and parameter elimination summary

New live fuel moisture model

Check-in Question

- What are the current inputs / drivers of live fuel moisture models in NFDRS 78/88?

New Live Fuel Moisture Model

- Live fuel moisture model in the 1978 / 1988 NFDRS is acknowledged as the weakest sub-model in NFDRS. The original NFDRS developers intended to replace it at the earliest possible convenience.
- The new herbaceous and woody fuel moisture calculations will use the Growing Season Index and it will transform that index into to live fuel moisture values

Growing Season Index (GSI)

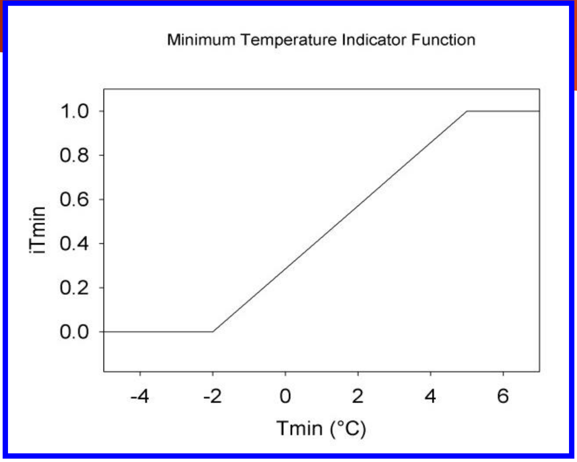
- **Growing Season Index – GSI –** is a meteorologically-based, generalized phenology model
- It requires no constant human intervention yet accurately reflects within season and between season live fuel conditions from daily weather observations.
  - Predicts green-up date and shows herbaceous curing
  - Automatically integrates freezing and dormancy
  - Eliminates the need for Climate Class, Green-up date, freeze date, season codes and greenness factors (88 system)

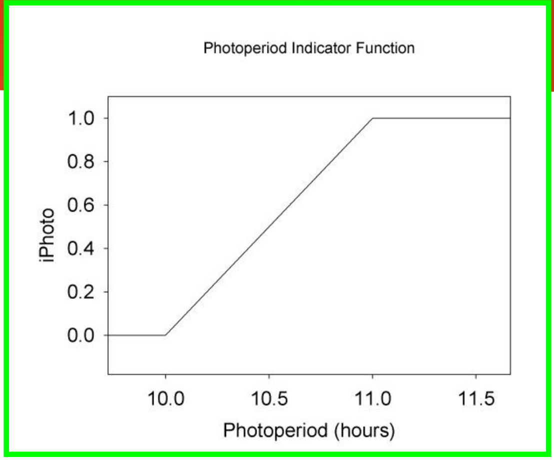
Jolly, W.M., Nemani, R., Running, S.W., 2005. A generalized, bioclimatic index to predict foliar phenology in response to climate. Global Change Biology 11, 619-632.

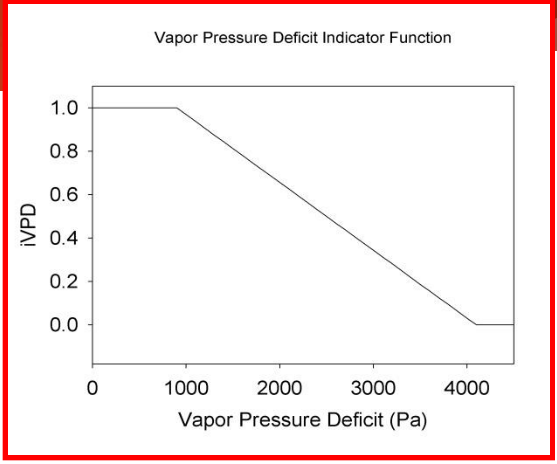
Growing Season Index (GSI) …

- Calculated DAILY
- GSI has 3 inputs:
  - 24 hour minimum temperature (TMIN)
  - Vapor pressure deficit (VPD)
    - Calculated from relative humidity and air temperatures
      - RH = (VPact / VPsat) * 100
      - VPD = VPsat – Vpact
    - Can be calculated from either 24 hour maximum or 24 hour average temperature (VPDmax and VPDavg, respectively)
  - Photoperiod or Daylength
    - Calculated from station latitude and yearday

The Growing Season Index

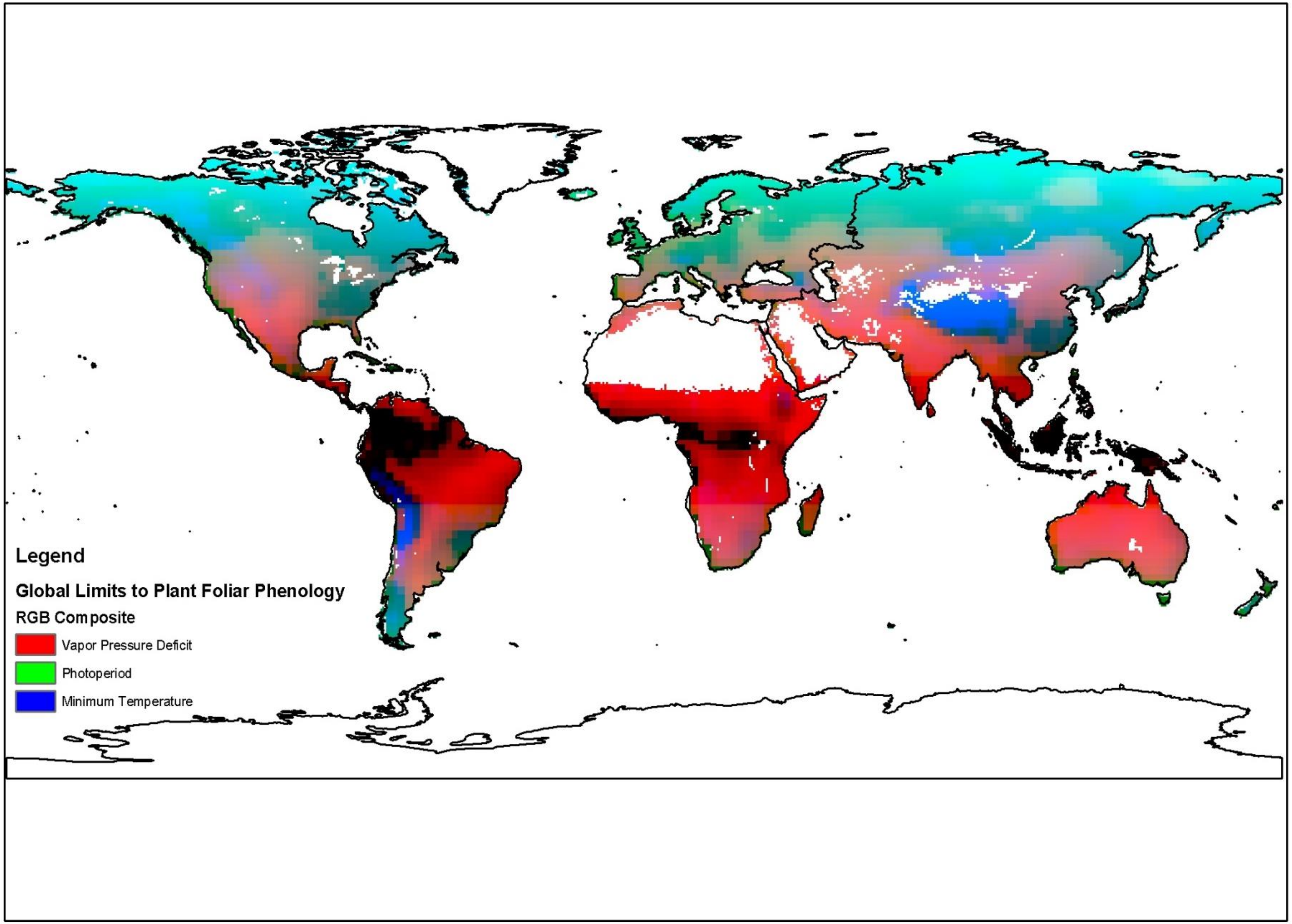


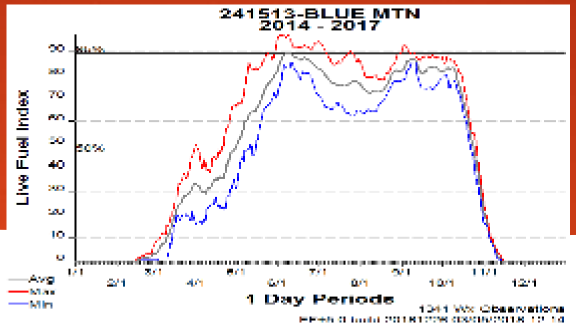


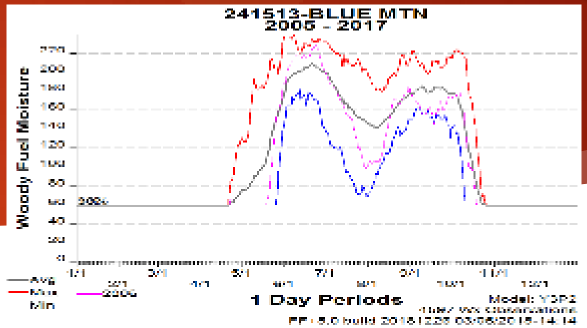


Growing Season Index (iGSI) = iTmin * iPhoto * iVPD

The final index varies continuously from zero (limiting) to one (unconstrained)


Legend
Global Limits to Plant Foliar Phenology
RGB Composite
Vapor Pressure Deficit
Photoperiod
Minimum Temperature





Minimum Temperature

Vapor Pressure Deficit

Photoperiod

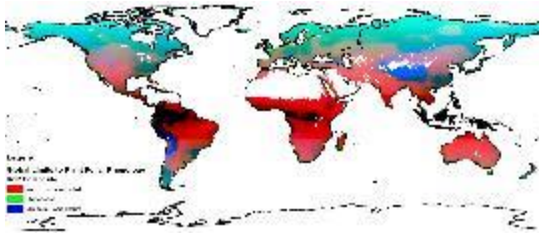
Daily Weather Inputs

Model

Site Parameters

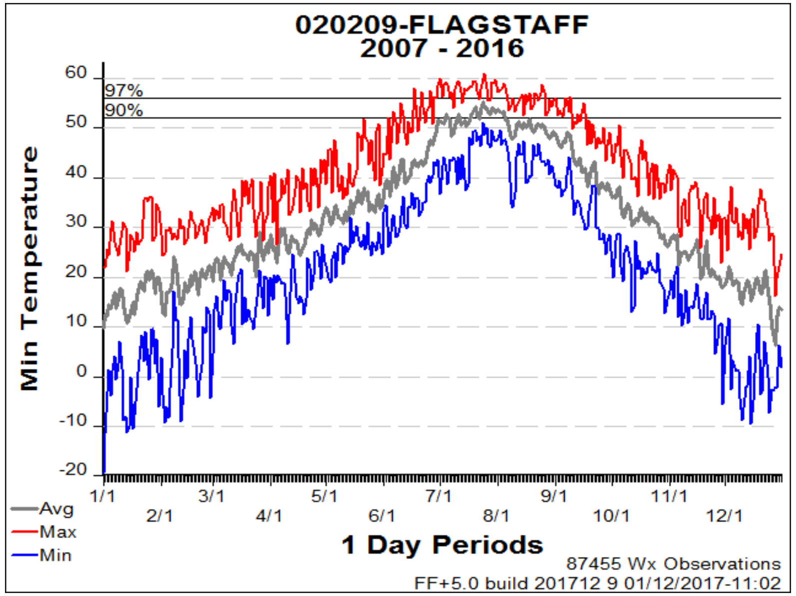
Growing Season Index

Live Fuel Moisture

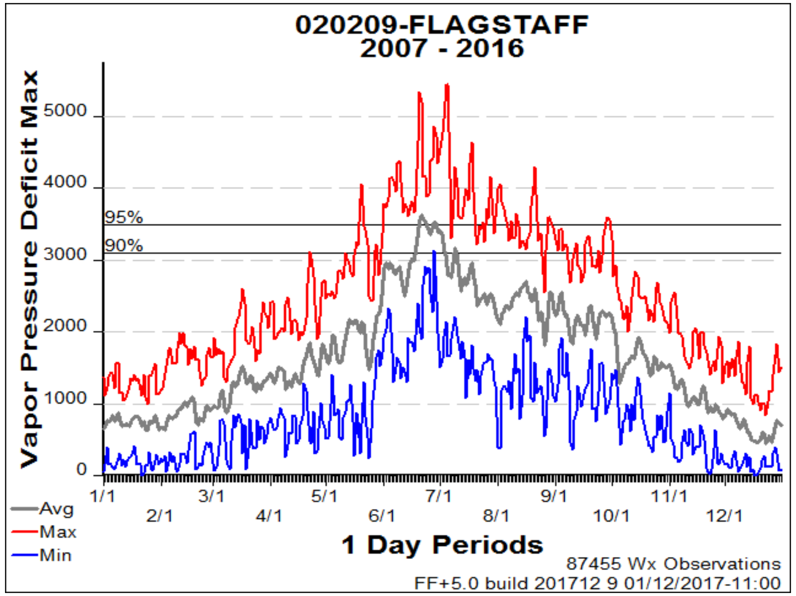


Example weather inputs to GSI

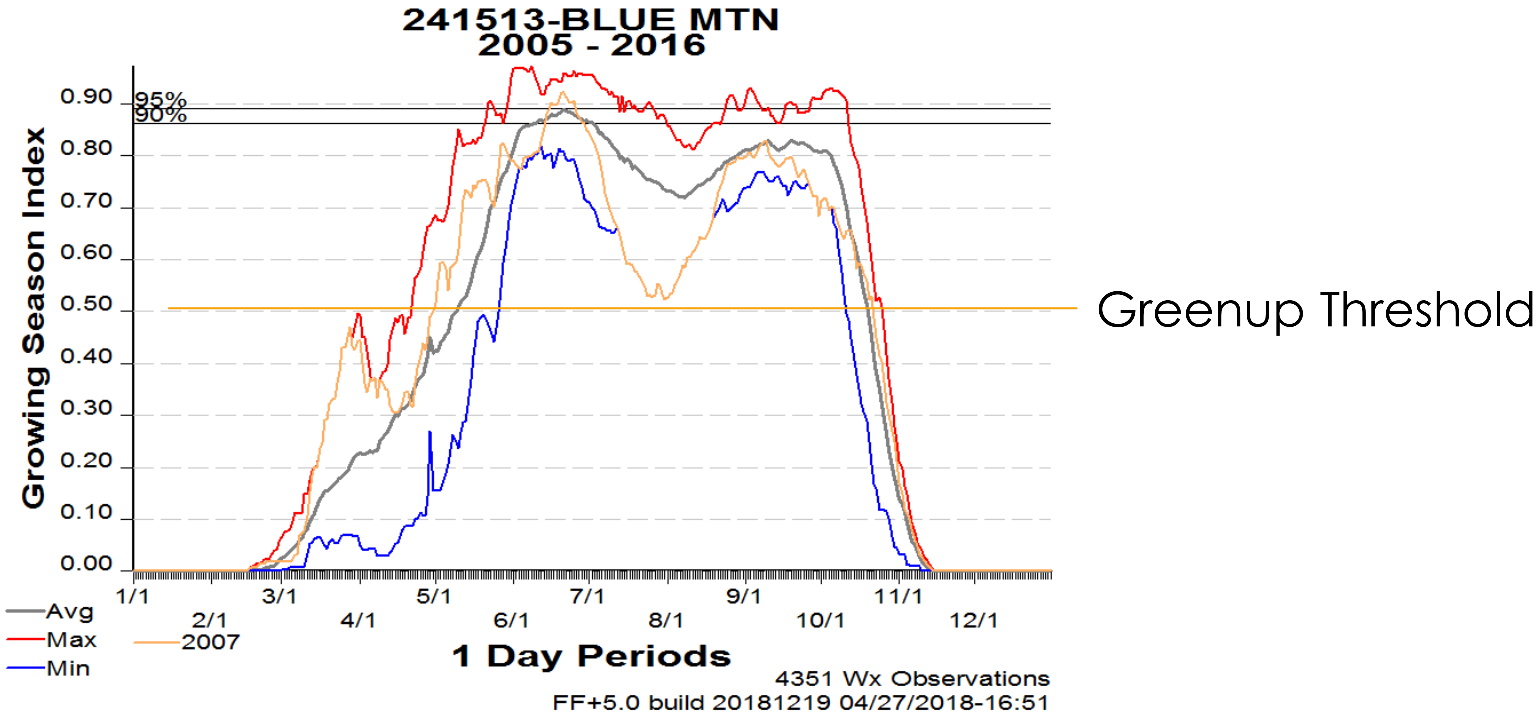
Minimum temperature



Vapor pressure deficit



Example GSI plot



Note: NO MORE LFI….. From now on, it will ONLY be called GSI

Growing Season Index

Rules-of-thumb for interpreting GSI values

GSI Value	Classification / Interpretation
GSI Increasing	
0 to .5	Pre-greenup; dormancy
> .5	Green-up
.75 to 1.0	Full plant canopy development
GSI decreasing	
1.0 to .5	Curing herbaceous vegetation
< 0.5	Leaf senescence
Below 0.5	Entering complete curing or dormancy


Calculate GSI
Rescale GSI
Calculated LFM from GSI

LFM model parameters

- LFM model parameters:
  - GSI indicator thresholds
  - Maximum GSI value
    - Default is 1.0 but can be used for model calibration
  - Green-up threshold
    - Default is 0.5
  - Minimum and maximum live herbaceous and woody fuel moistures
    - Minimum herbaceous FM is 30% and Maximum herbaceous FM is 250%
    - Minimum woody FM is 60% and maximum herbaceous FM is 200%
      - These are the same maximum values used in NFDRS 1978 / 1988

	Lower Limit	Upper Limit
Minimum Temperature	28.4° F (-2°C) (T_{MMin})	41° F (5°C) (T_{MMax})
Vapor Pressure Deficit	900Pa (VPD_{Min})	4100Pa (VPD_{Max})
Photoperiod	36000 sec ($Photo_{Min}$)	39600 sec ($Photo_{Max}$)

$$iVPD = \begin{cases} 0, \text{If } VPD \geq VPD_{Max} \\ 1 - \dfrac{VPD - VPD_{Min}}{VPD_{Max} - VPD_{Min}}, \text{If } VPD_{Max} > VPD > VPD_{Min} \\ 1, \text{If } VPD \leq VPD_{Min} \end{cases}$$

Vapor Pressure Deficit

$$iPhoto = \begin{cases} 0, \text{If } Photo \leq Photo_{Min} \\ \dfrac{Photo - Photo_{Min}}{Photo_{Max} - Photo_{Min}}, \text{If } Photo_{Max} > Photo > Photo_{Min} \\ 1, \text{If } Photo \geq Photo_{Max} \end{cases}$$

Photoperiod

$$iT_{\min} = \begin{cases} 0, \text{If } T_{\min} \leq T_{MMin} \\ \dfrac{T_{\min} - T_{MMin}}{T_{MMax} - T_{MMin}}, \text{If } T_{MMax} > T_{\min} > T_{MMin} \\ 1, \text{If } T_{\min} \geq T_{MMax} \end{cases}$$

Minimum Temperature

	Lower Limit	Upper Limit
Minimum Temperature	28.4° F (-2°C) (T_{MMin})	41° F (5°C) (T_{MMax})
Vapor Pressure Deficit	900Pa (VPD_{Min})	4100Pa (VPD_{Max})
Photoperiod	36000 sec ($Photo_{Min}$)	39600 sec ($Photo_{Max}$)

GSI Example

	Lower Limit	Upper Limit	Default GSI Greenup Threshold
Live Herbaceous Fuel Moisture	30% (Min_H)	250% (Max_H)	0.5 (GU_H)
Live Woody Fuel Moisture	60% (Min_W)	200% (Max_W)	0.5 (GU_W)

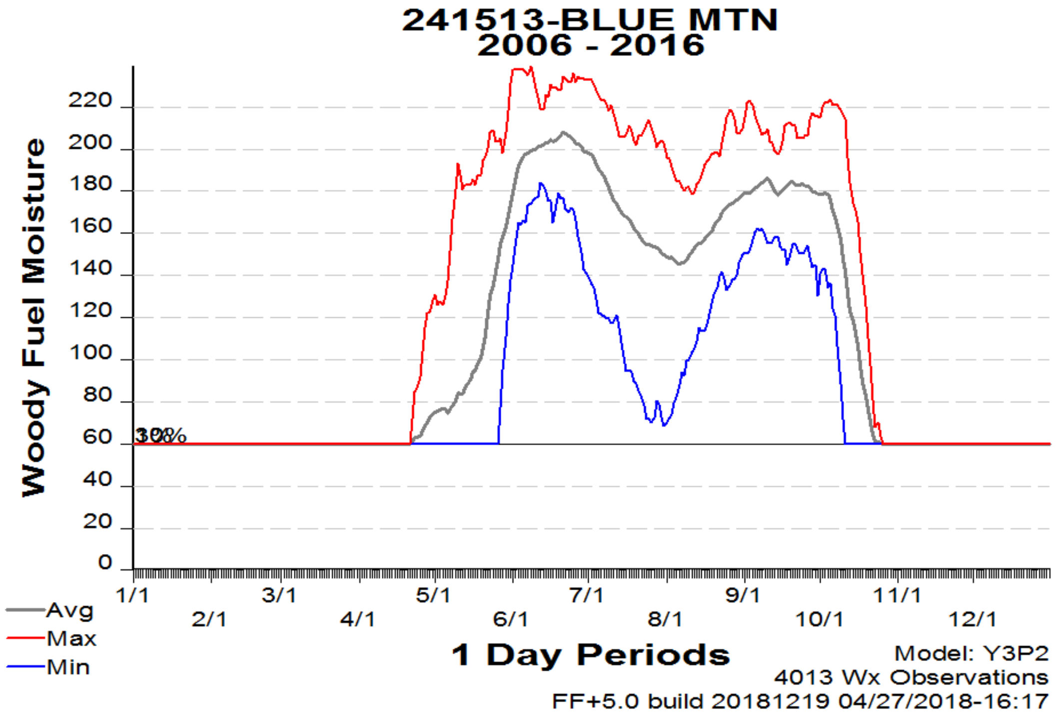
Calculating LFM from GSI

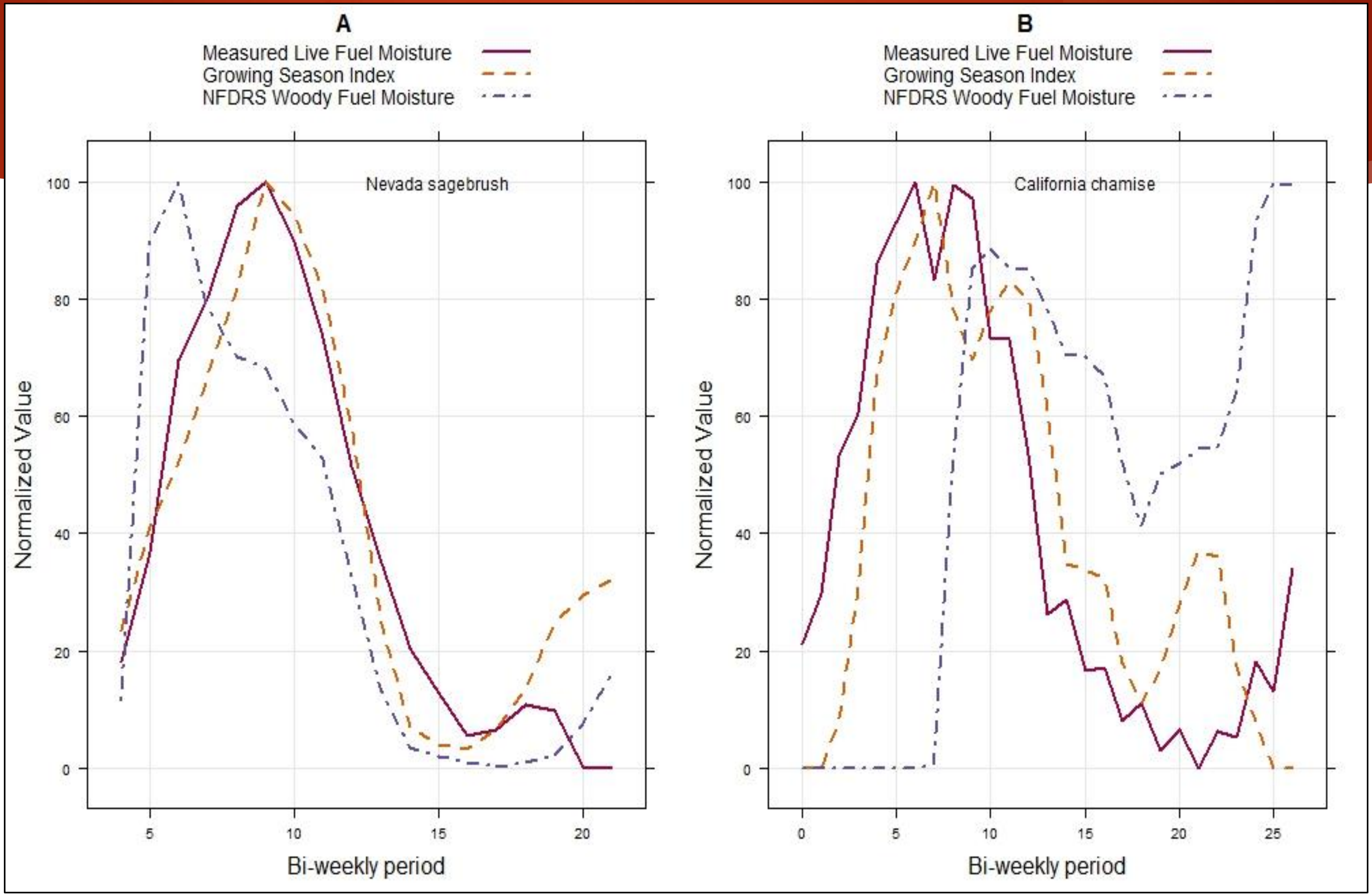
- $$LFM_{W|H} = \begin{pmatrix} GSI'_{W|H} < GU_{W|H} & Min_{W|H} \\ GSI'_{W|H} \geq GU_{W|H} & m * GSI'_{W|H} + b \end{pmatrix}$$

$$m = \frac{Max_H - Min_H}{1.0 - GU_H}$$

$$b = Max_H - m$$

Example GSI-derived herbaceous fuel moisture




A
Measured Live Fuel Moisture
Growing Season Index
NFDRS Woody Fuel Moisture
Nevada sagebrush
Normalized Value
Bi-weekly period
B
Measured Live Fuel Moisture
Growing Season Index
NFDRS Woody Fuel Moisture
California chamise
Normalized Value
Bi-weekly period

Display/Edit Default NFDRS Parameters

Back to Menu

Station ID: 241513 **Effective Date:** 02-Oct-17 Find Reset Save View Change Archive

Info: Standard Defaults for GSI Herb and Woody FM Options have been loaded.

NFDR Parameters | **GSI Herb FM Options** | GSI Woody FM Options | Nelson Dead Fuel Moisture Options | Load Fuel Model Percentiles

Temp Min Index Min (C):	-2
Temp Min Index Max (C):	5
VPD Index Min:	900
VPD Index Max:	4100
Day Length Index Min (sec):	36000
Day Length Index Max (sec):	39600

VPD Usage
- (•) VPD Max
- ( ) VPD Avg

GSI Average Running Length (days):	21
Max GSI (for scaling):	1
Greenup Threshold:	0.5
Max Herb FM:	250
Min Herb FM:	30

Load Standard Defaults | Load Saved Defaults | Save As Defaults

New dead fuel moisture model

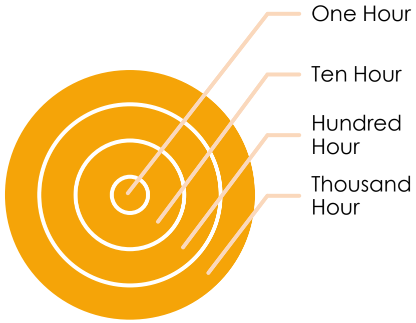
New Dead Fuel Moisture Model

- The previous version of NFDRS required direct user input of State-of-the-Weather (SOW) and changing R to O in WIMS to calculate fine dead fuel moisture before any indices are produced.
- It also required a separate model for calculating 1/10 hr and 100/1000hr dead fuel moistures.
- The old 1hr – 1000hr fuel moistures models will be replaced by the scalable Nelson Dead Fuel Moisture Model

New Fine Dead Fuel Moisture Model
Nelson

- Nelson Model:
  - More accurately models diurnal and seasonal dead fuel moisture using hourly fire weather observations
  - Requires no daily human intervention (I.E. No state-of-the-weather)
  - Has been running in a prototype mode in operational WIMS since December, 2011 and has been part of fire behavior prediction tools (FARSITE, FlamMap) for over a decade

Nelson Dead Fuel Moisture Model



- Calculated HOURLY
- Nelson has 4 weather inputs:
  - Temperature
  - Relative Humidity
  - Solar Radiation
  - Precipitation

- We define an instance of the Nelson model of the four timelag dead fuel classes used in NFDRS:

Time Lag	Stick Diameter (inches/cm)
1 hour	0.16 in / 0.4 cm
10 hour	0.5 in / 1.28 cm
100 hour	1.6 in / 4.0 cm
1000 hour	3 in / 7.62 cm

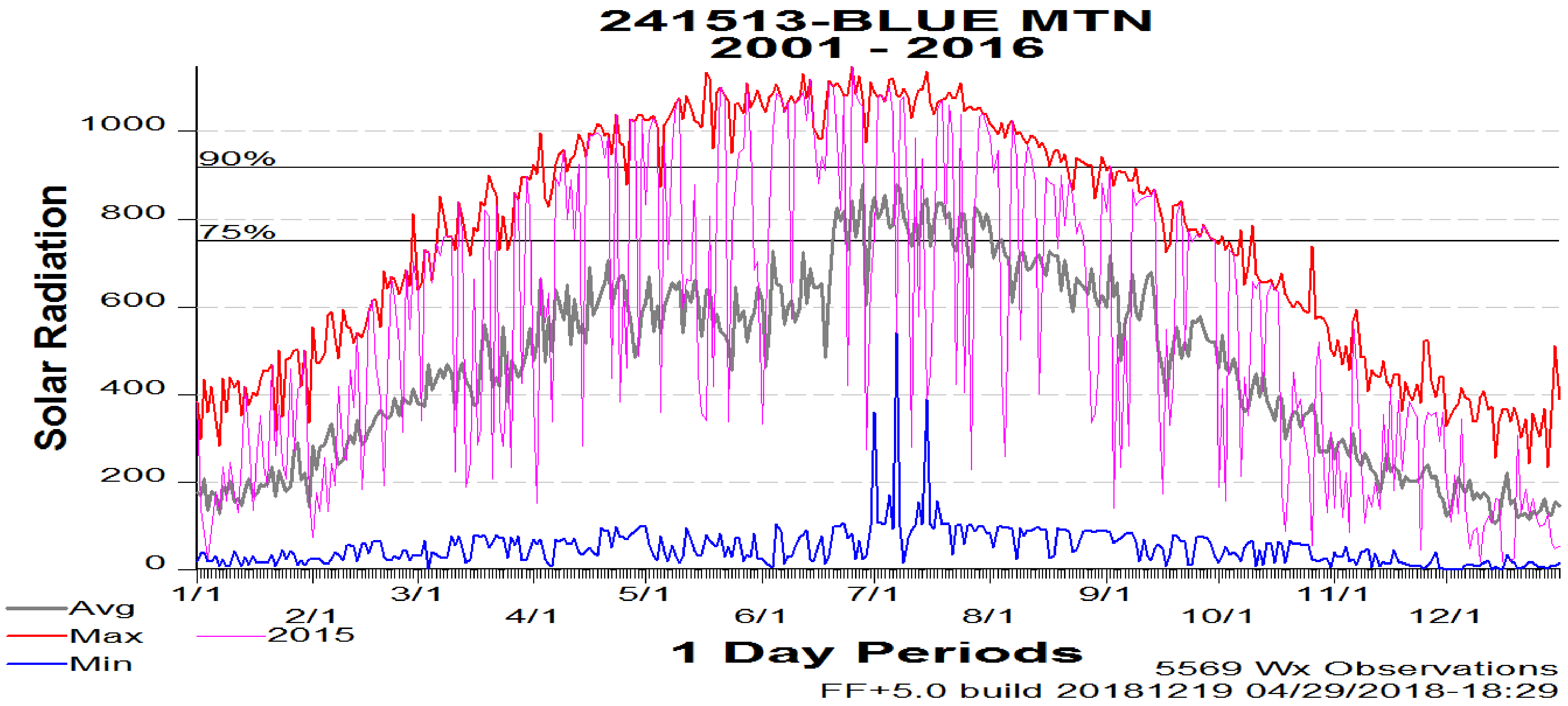
Nelson Model Specifics

- Accounts for diffusive and capillary water transport between the fuel and the atmosphere
- Derives surface temperature from an energy balance
  - Net input of heat gains and losses
- Accounts for dew formation on fuel surface
- Scalable to any size dead fuel

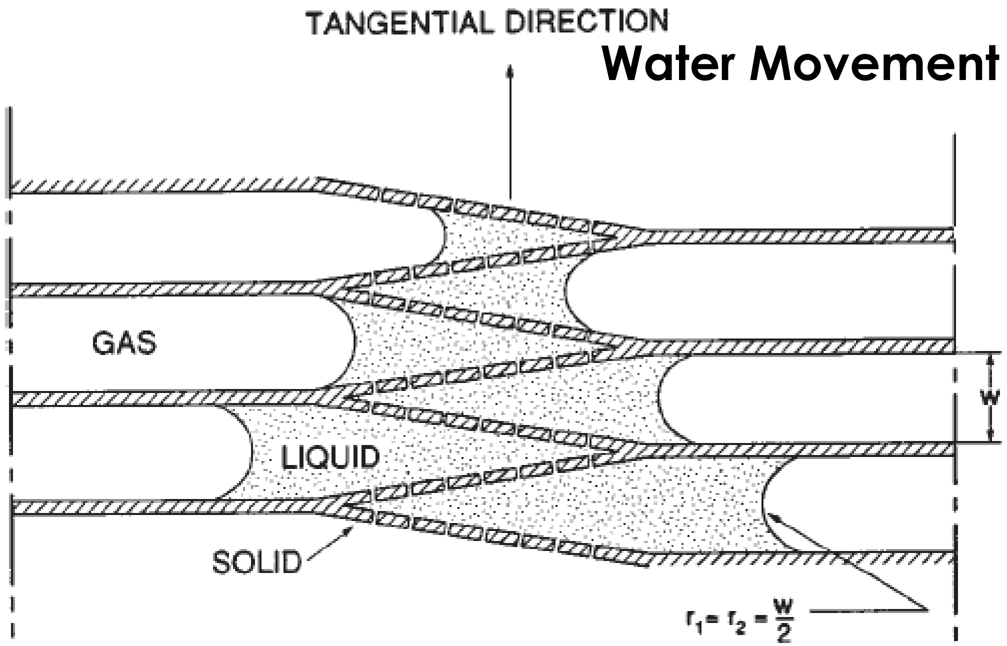
Fuel Energy Balance

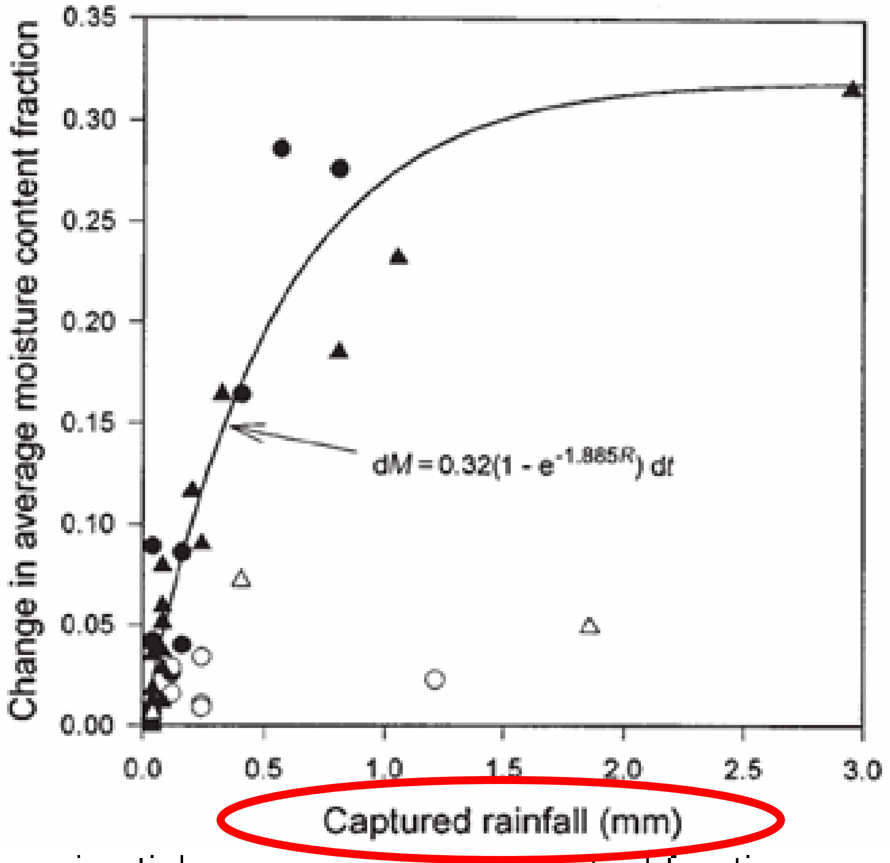
Heat Loss = Heat Gain

- **Conduction + Longwave Radiation + Evaporation = Solar Heating + Convective Heating**

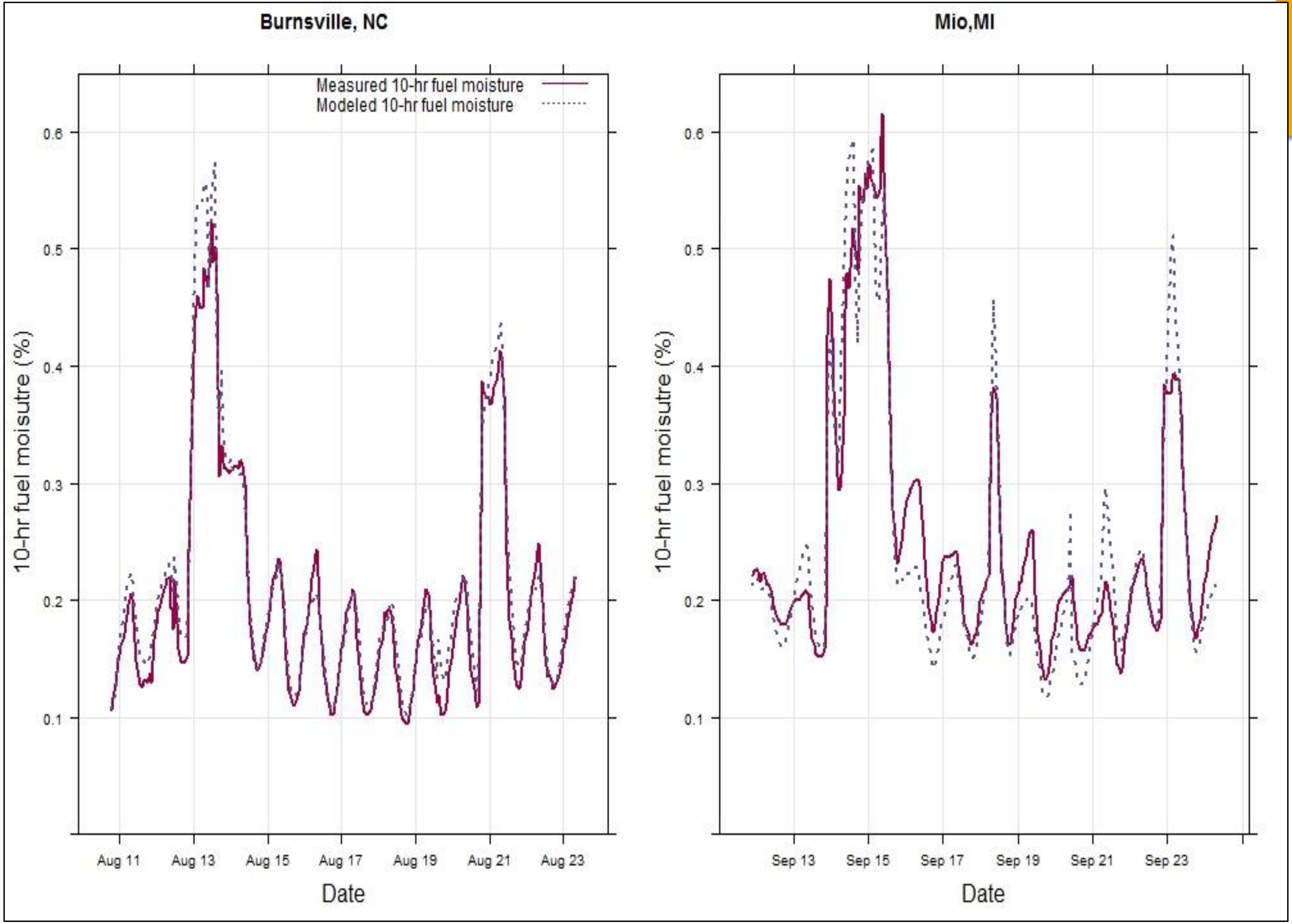

241513-BLUE MTN
2001 - 2016
Solar Radiation
1000
800
600
400
200
0
90%
75%
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
1 Day Periods
Avg
Max
Min
2015
5569 Wx Observations
FF+5.0 build 20181219 04/29/2018-18:29

Capillary water transport in Nelson



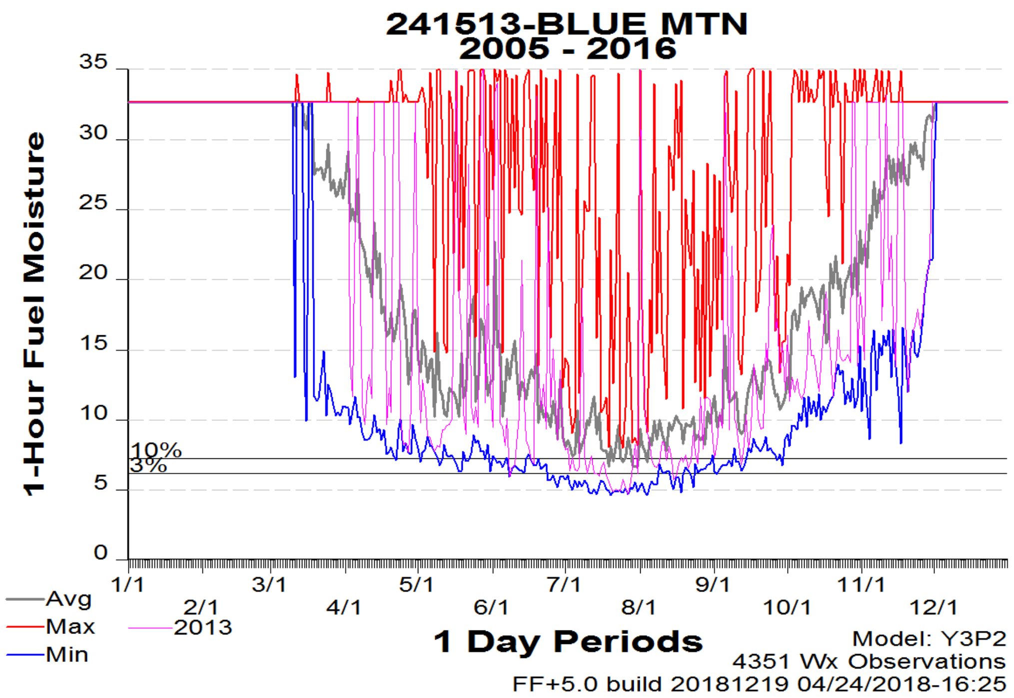


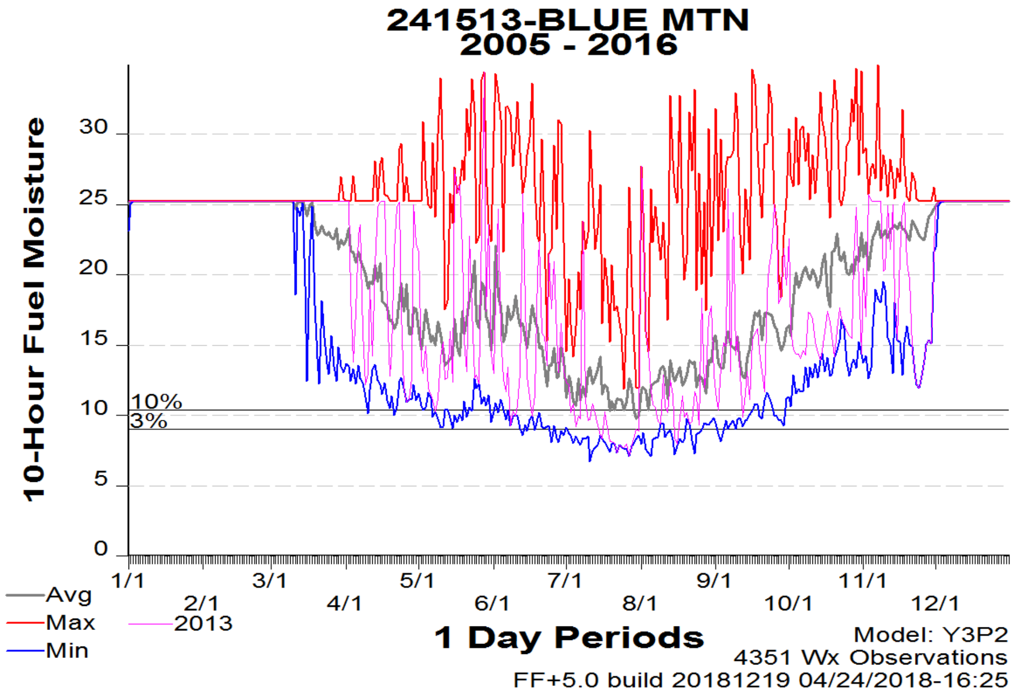
Changes in stick average moisture content fraction versus hourly captured rainfall (dt = 1 h) during field experiments in Burnsville, N.C. (circles), and Mio, Mich. (triangles). Solid symbols,initial moisture fraction smaller than 0.4; open symbols, initial fraction greater than 0.4 (from Nelson, 2000).



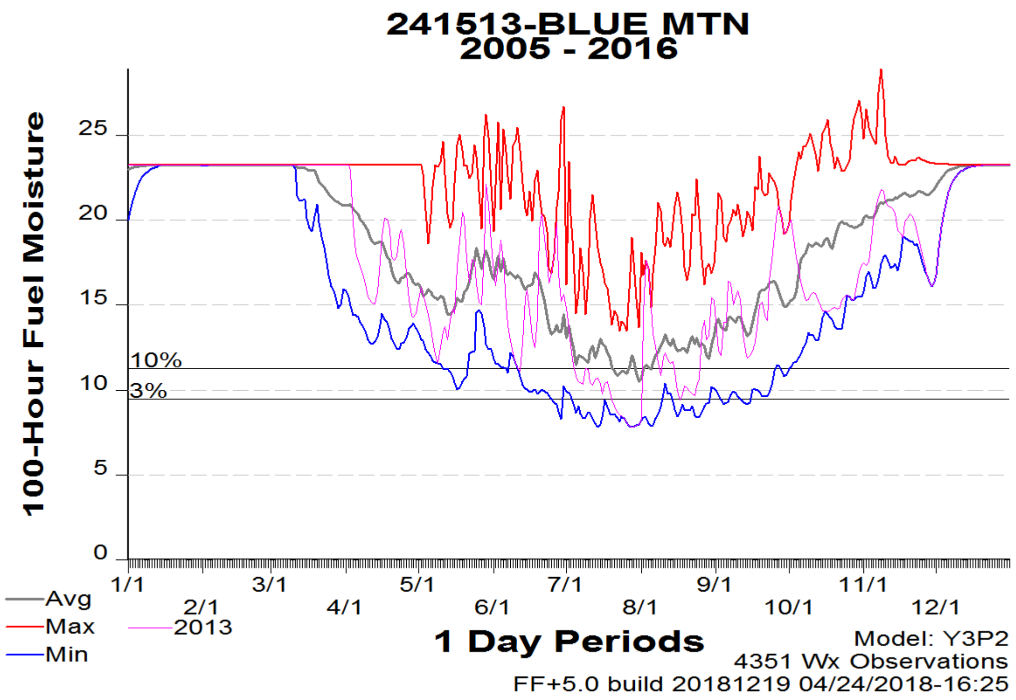
Burnsville, NC
Mio,MI
Measured 10-hr fuel moisture
Modeled 10-hr fuel moisture
10-hr fuel moisutre (%)
0.1
0.2
0.3
0.4
0.5
0.6
Aug 11
Aug 13
Aug 15
Aug 17
Aug 19
Aug 21
Aug 23
Sep 13
Sep 15
Sep 17
Sep 19
Sep 21
Sep 23
Date

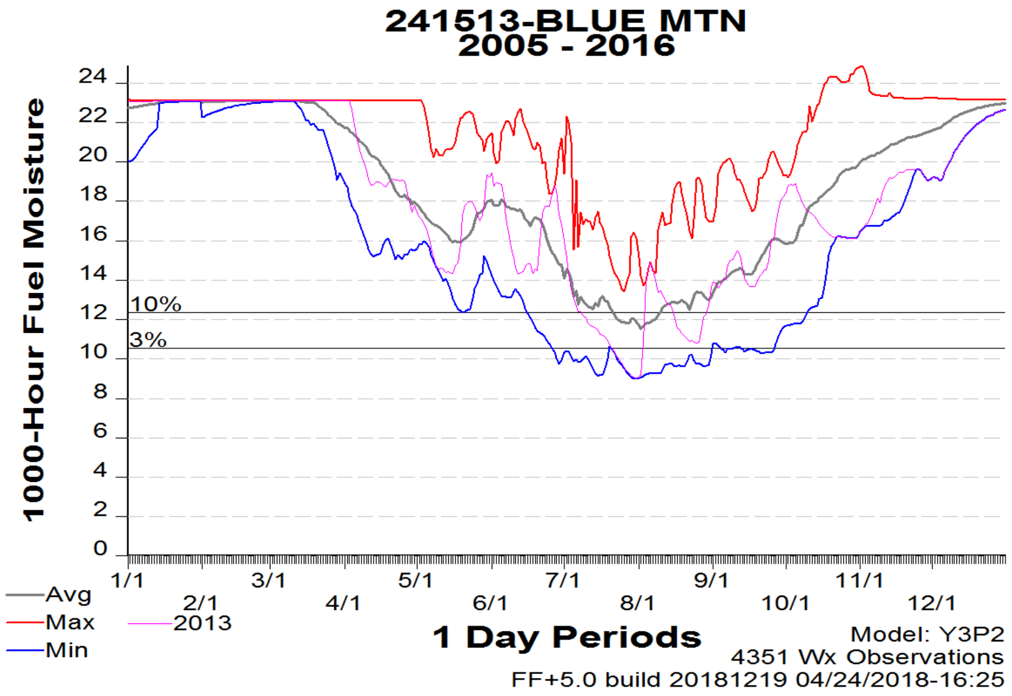
Example Nelson 1hr and 10 hr fuel moistures





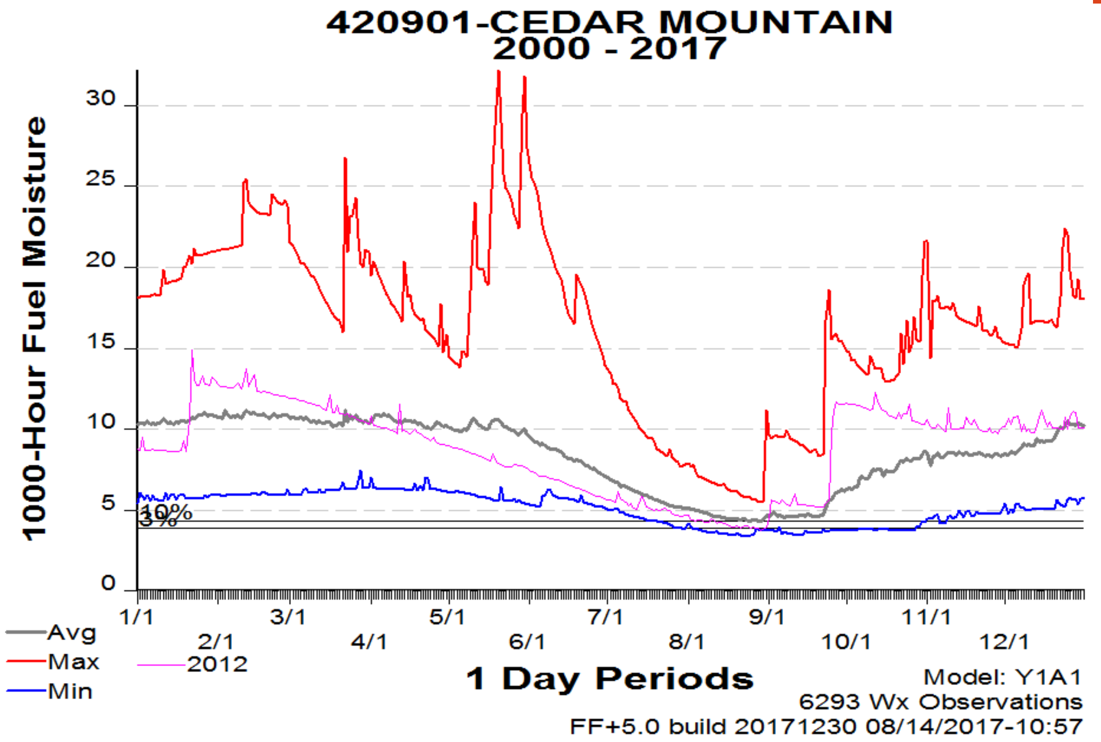
Example Nelson 100hr and 1000hr fuel moistures

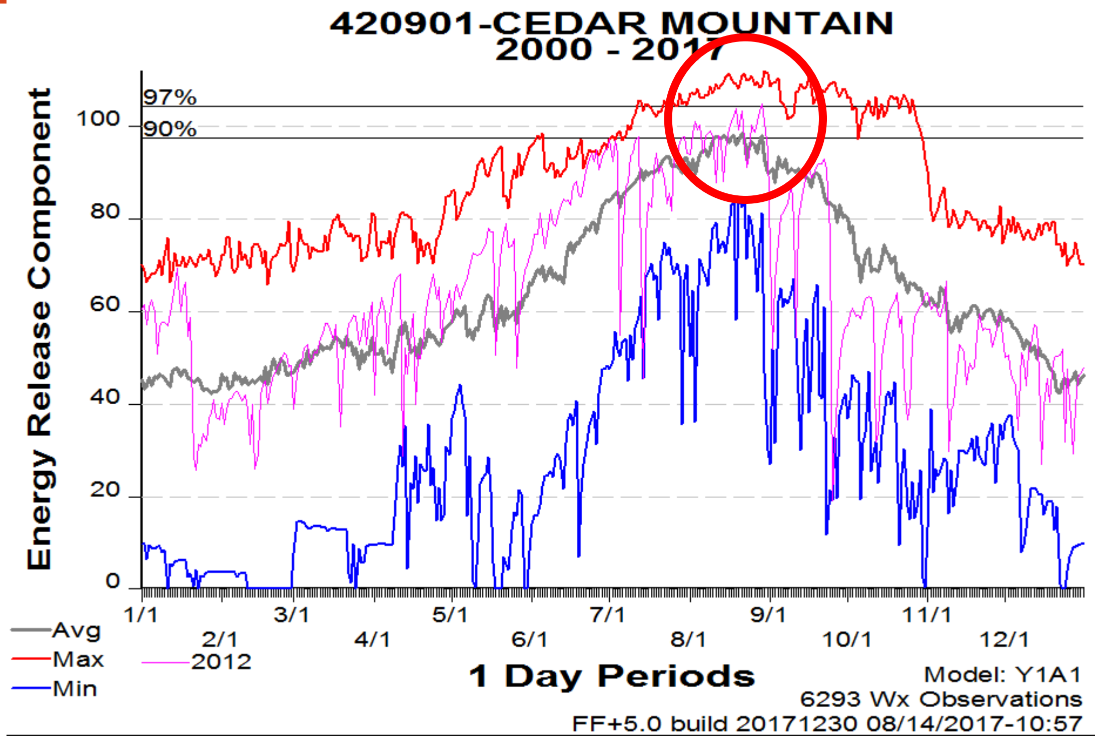




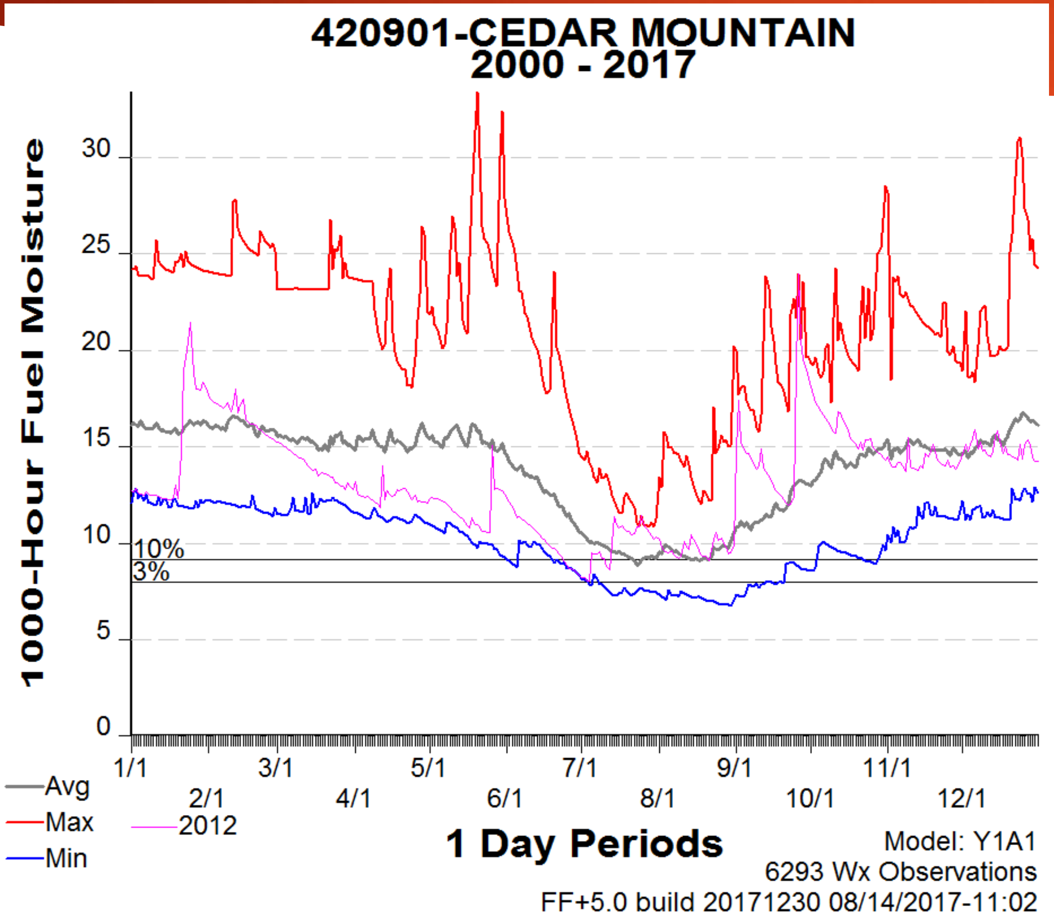
Recent Nelson 1000-hr Model Modifications

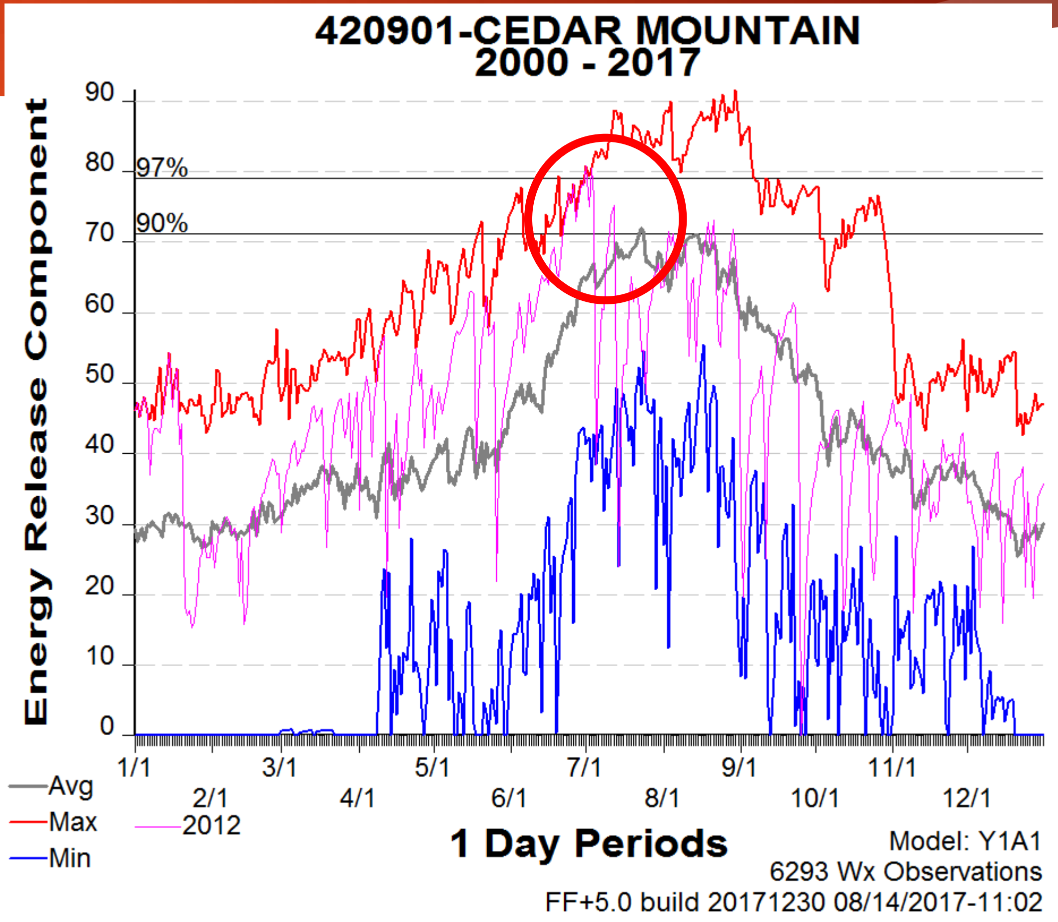
Uncorrected Nelson 1000hr and subsequent ERC



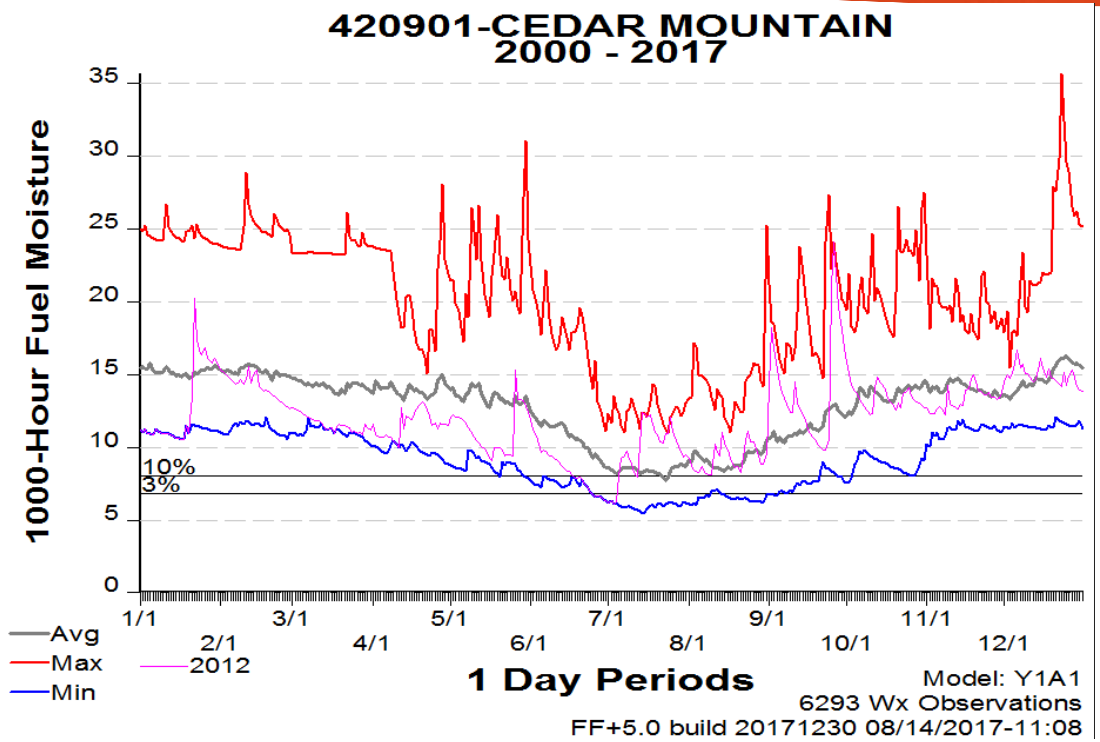


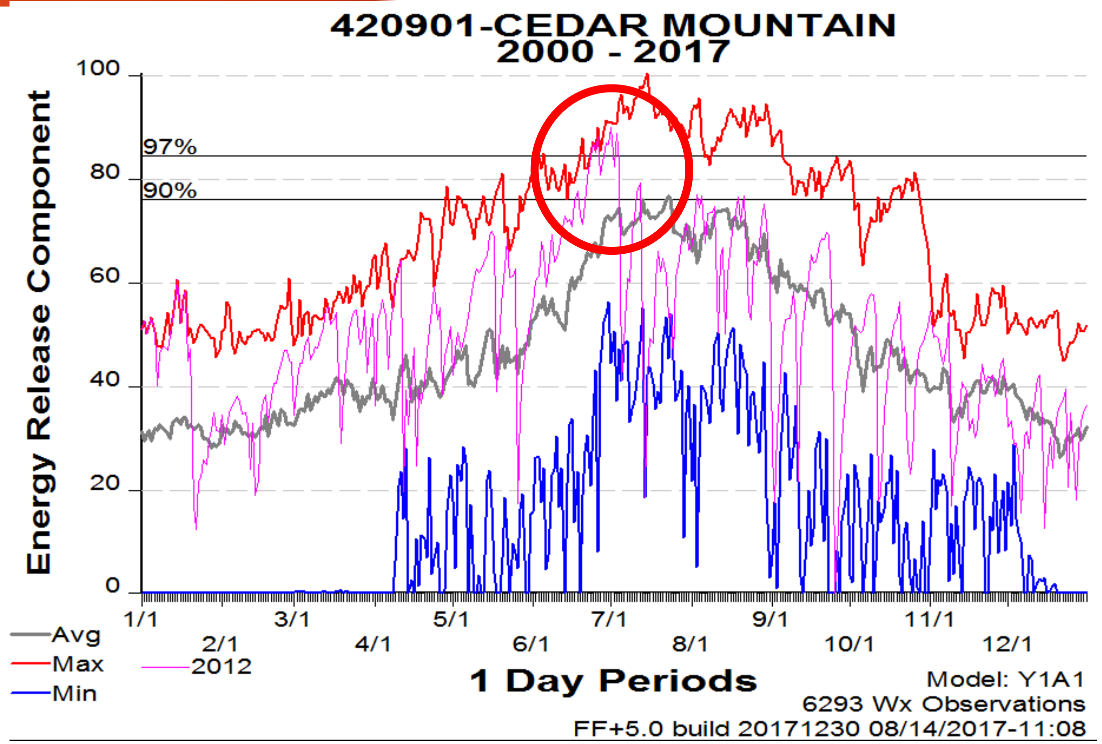
New Minimum Adsorption Rate



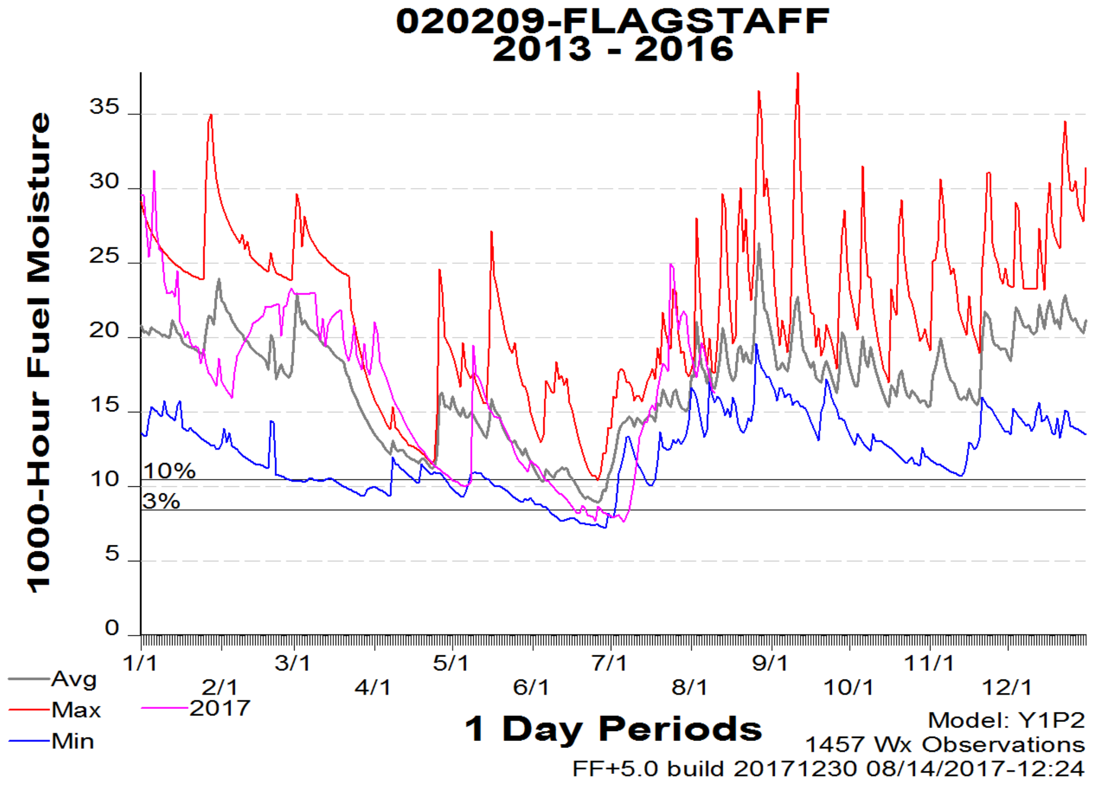


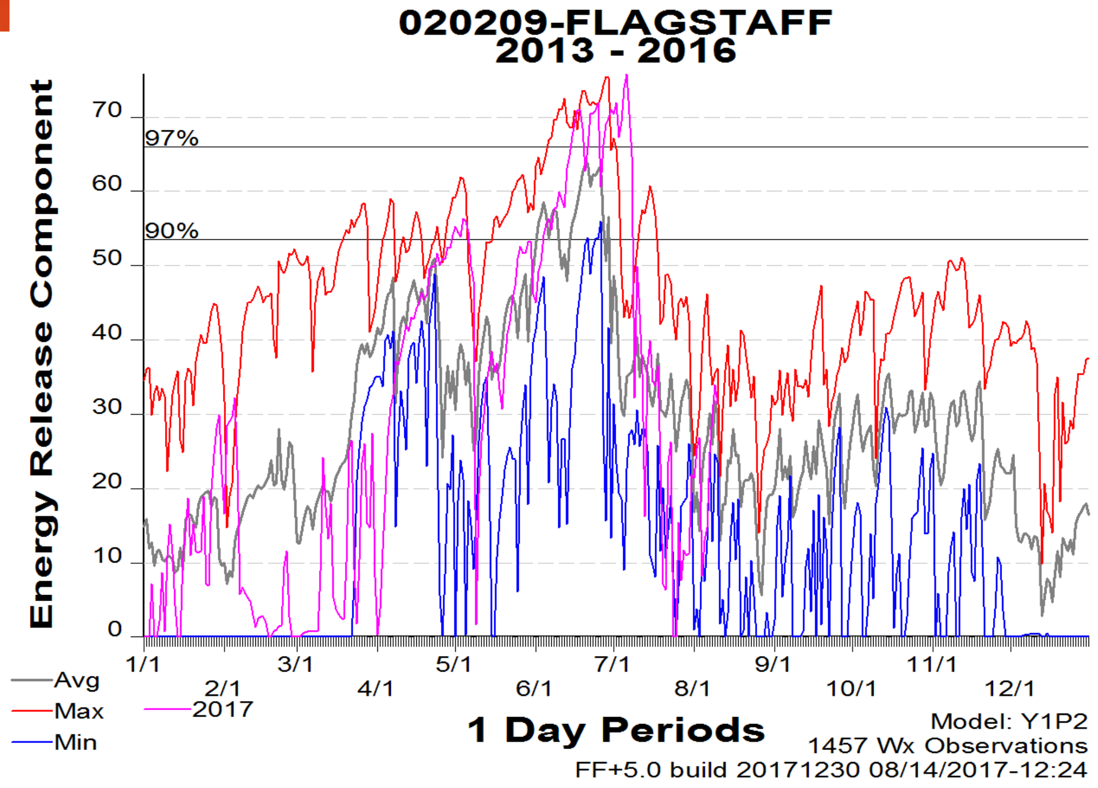
New minimum Adsorption Rate and Realigned fuel stick diameters



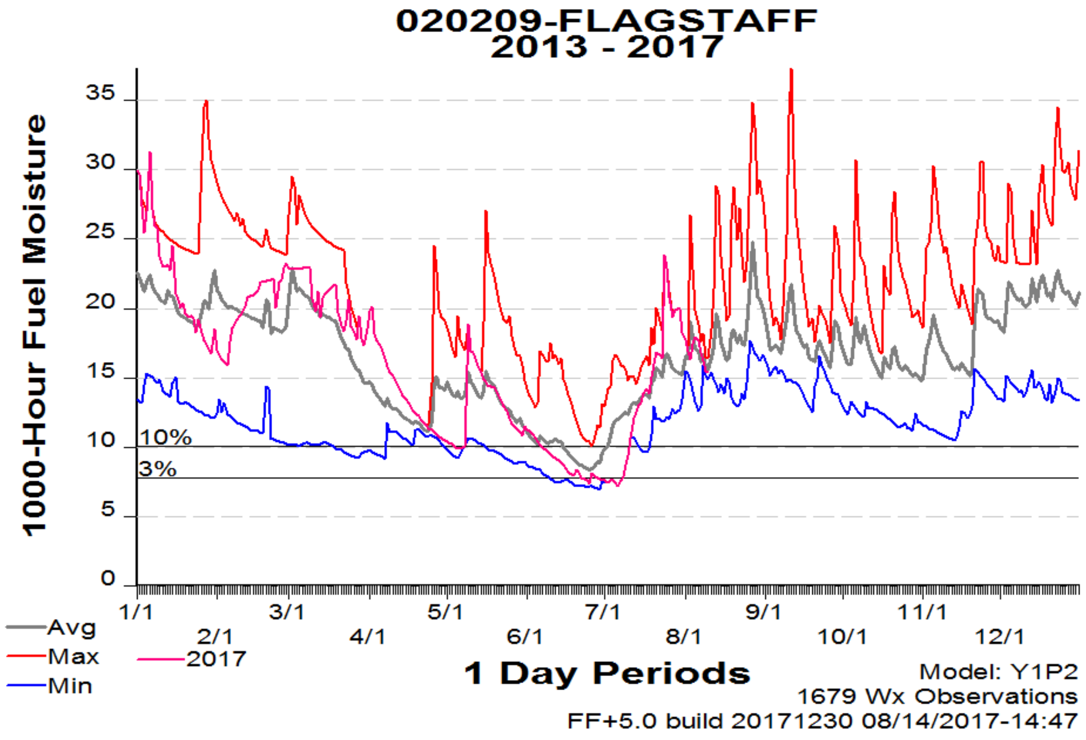


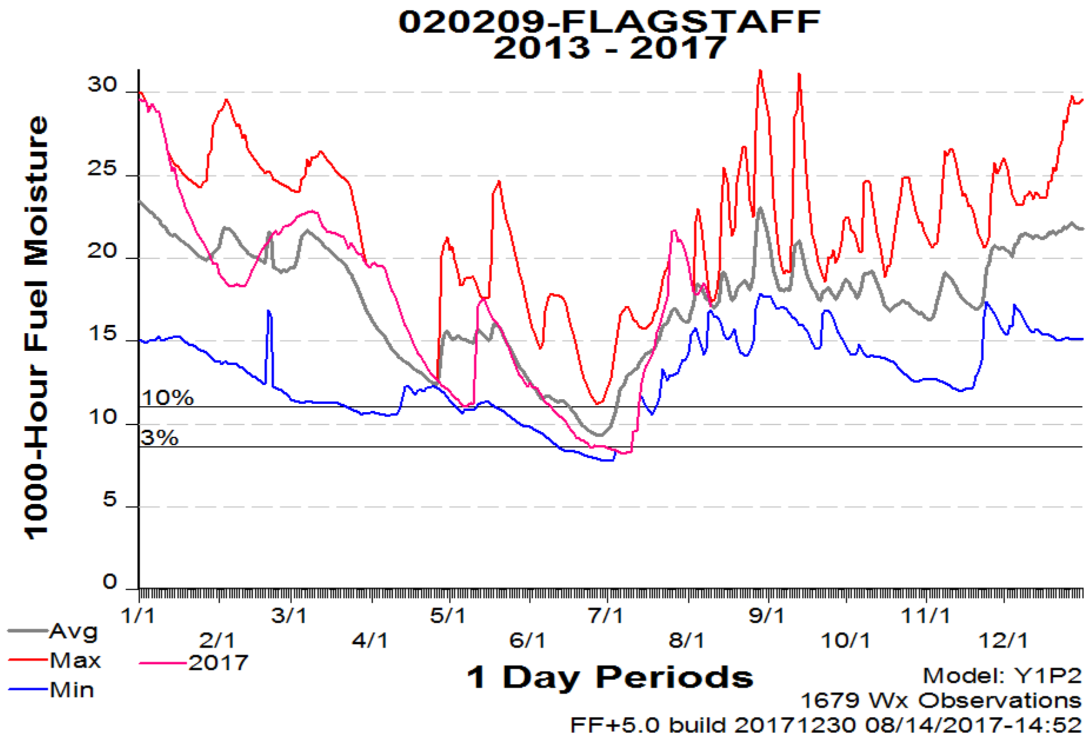
Flagstaff example: New Model with 2017

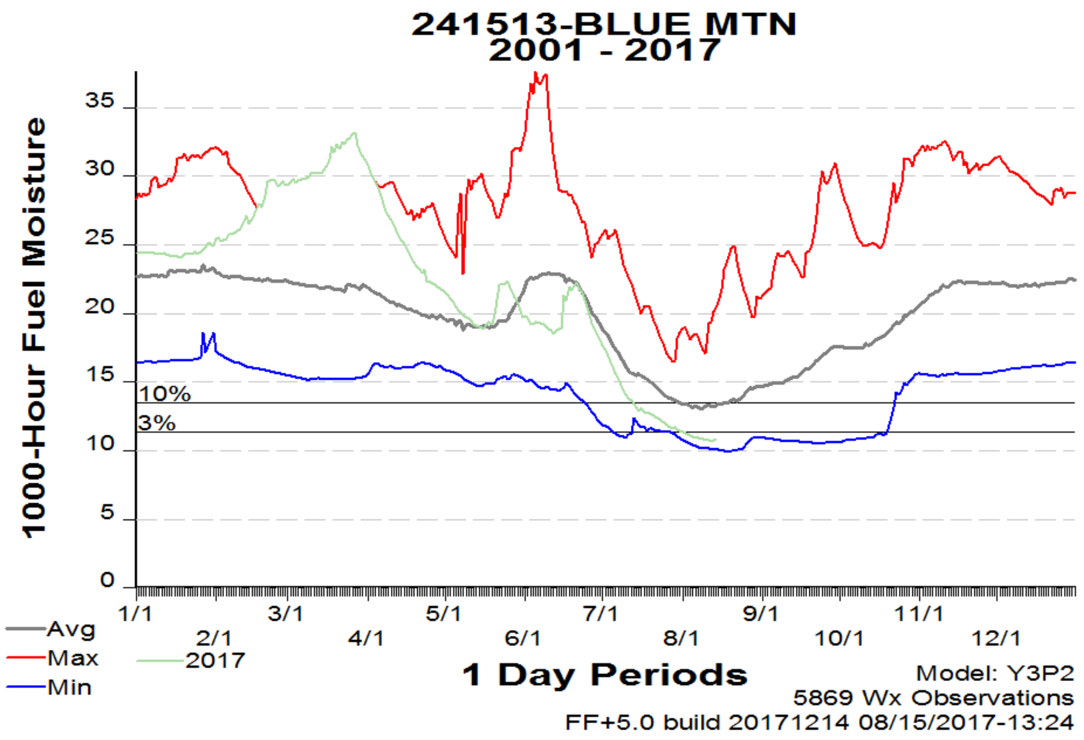


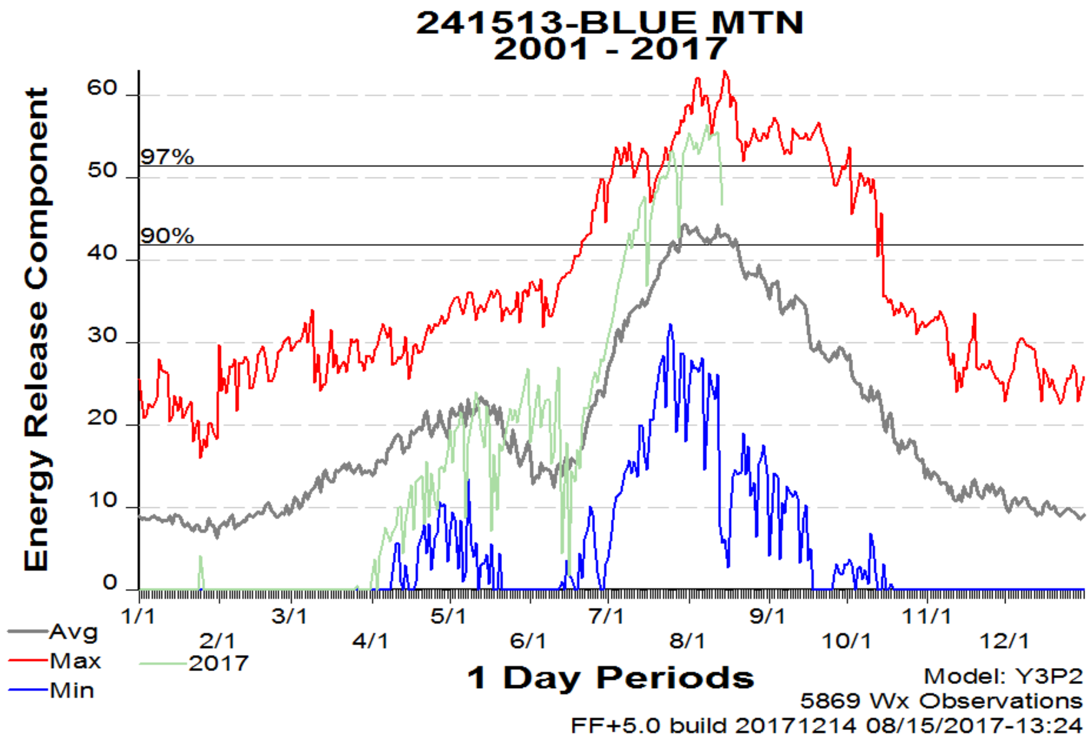


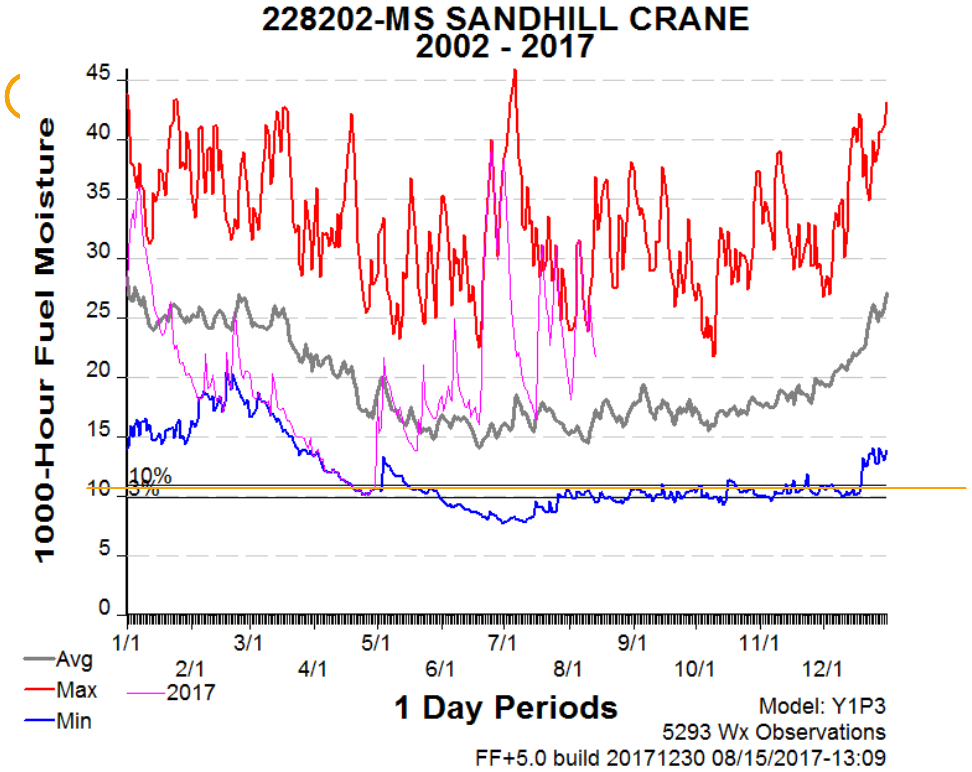
Determining stick moisture from nodes



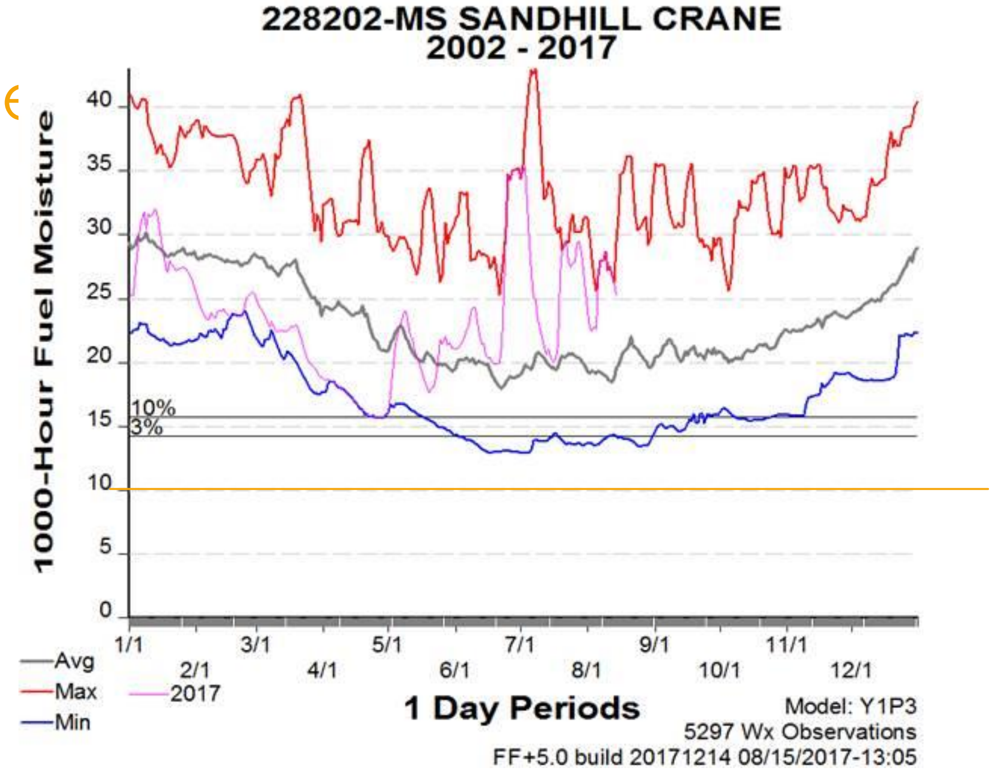


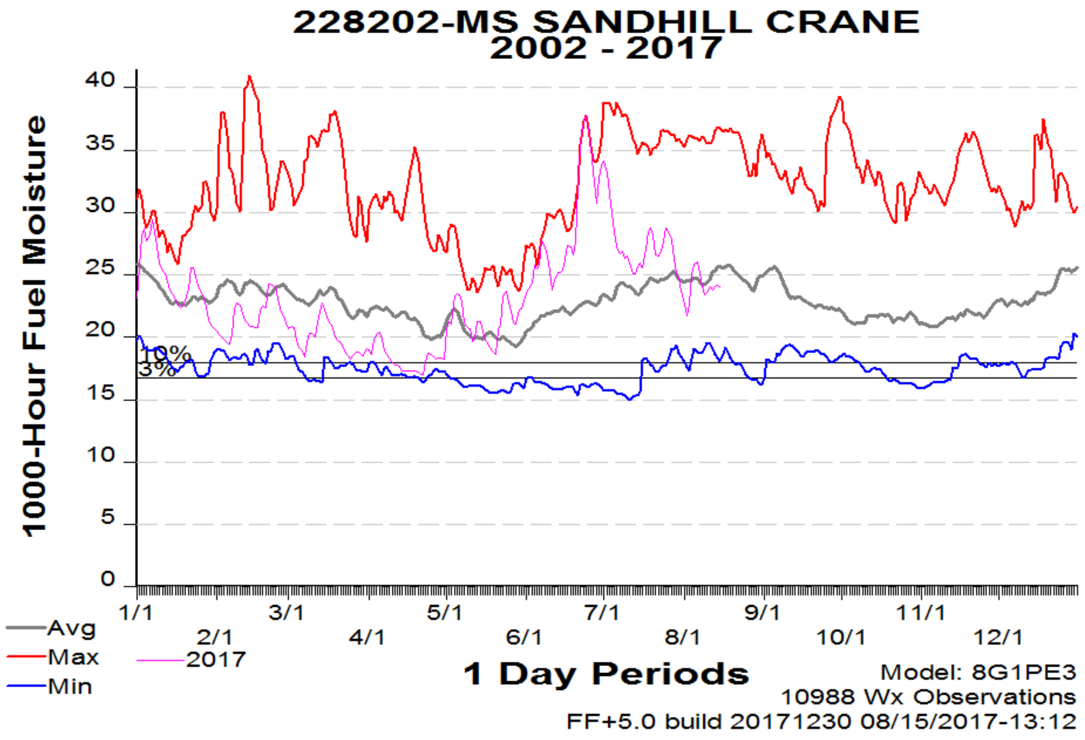

241513-BLUE MTN
2001 - 2017
1000-Hour Fuel Moisture
35
30
25
20
15
10
5
0
10%
3%
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2017
1 Day Periods
Model: Y3P2
5869 Wx Observations
FF+5.0 build 20171214 08/15/2017-13:24

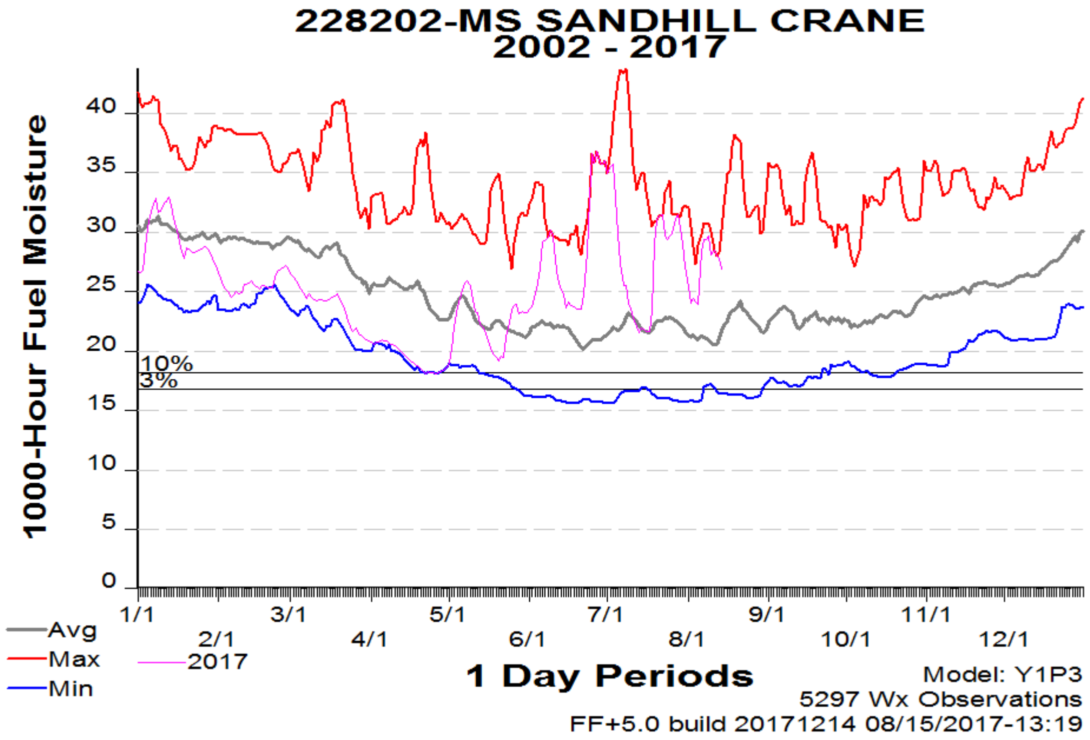

241513-BLUE MTN
2001 - 2017
Energy Release Component
60
50
40
30
20
10
0
97%
90%
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2017
1 Day Periods
Model: Y3P2
5869 Wx Observations
FF+5.0 build 20171214 08/15/2017-13:24

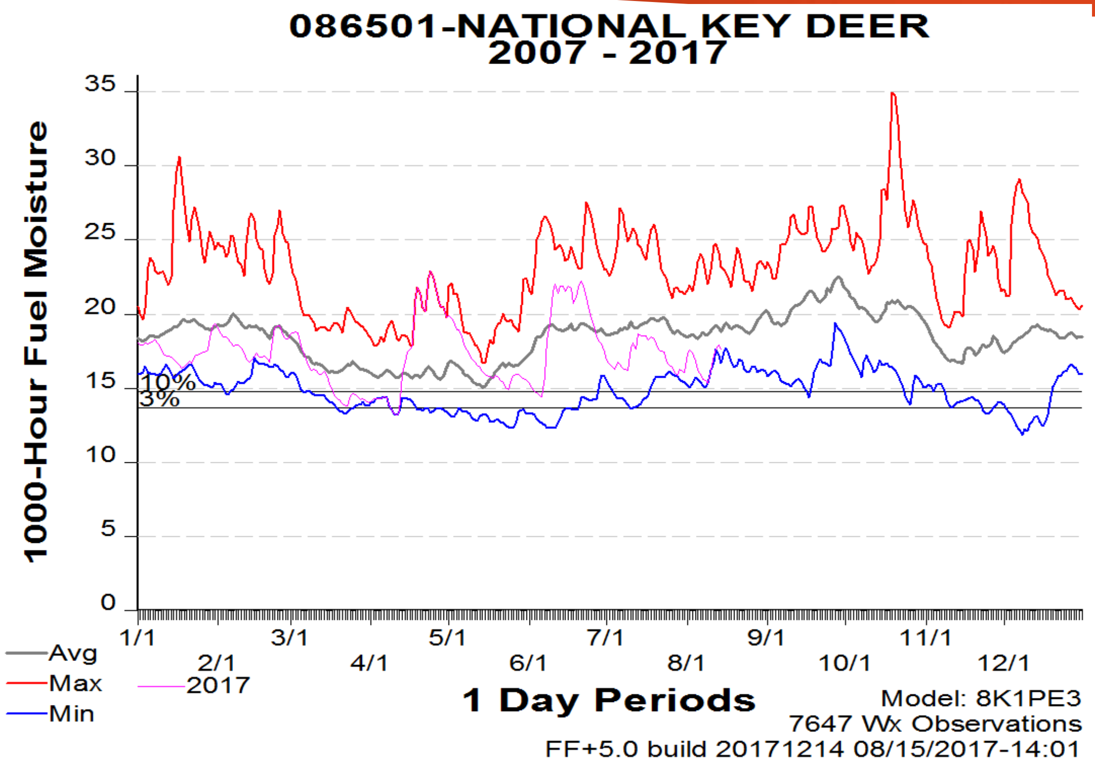

228202-MS SANDHILL CRANE
2002 - 2017
1000-Hour Fuel Moisture
10%
3%
Avg
Max
Min
2017
1 Day Periods
Model: Y1P3
5293 Wx Observations
FF+5.0 build 20171230 08/15/2017-13:09

Ne

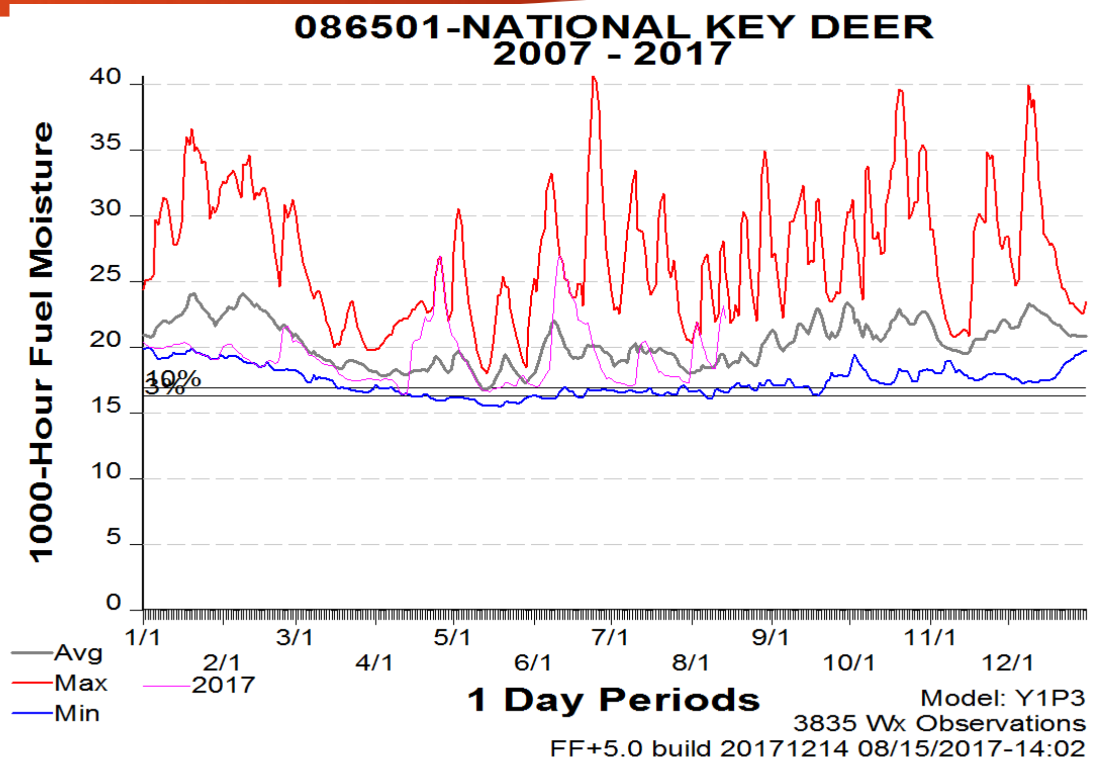

228202-MS SANDHILL CRANE
2002 - 2017
1000-Hour Fuel Moisture
10%
3%
Avg
Max
Min
2017
1 Day Periods
Model: Y1P3
5297 Wx Observations
FF+5.0 build 20171214 08/15/2017-13:05


228202-MS SANDHILL CRANE
2002 - 2017
1000-Hour Fuel Moisture
40
35
30
25
20
15
10
5
0
10%
3%
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2017
1 Day Periods
Model: 8G1PE3
10988 Wx Observations
FF+5.0 build 20171230 08/15/2017-13:12

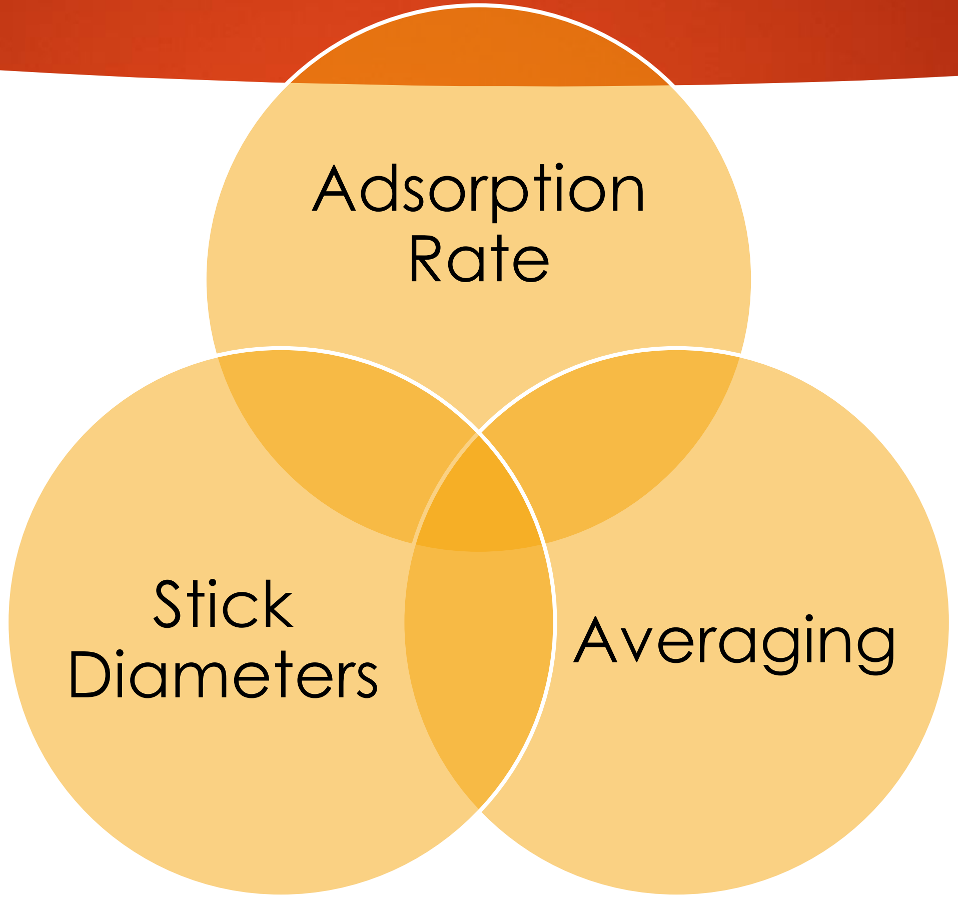

228202-MS SANDHILL CRANE
2002 - 2017
1000-Hour Fuel Moisture
40
35
30
25
20
15
10
5
0
10%
3%
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2017
1 Day Periods
Model: Y1P3
5297 Wx Observations
FF+5.0 build 20171214 08/15/2017-13:19



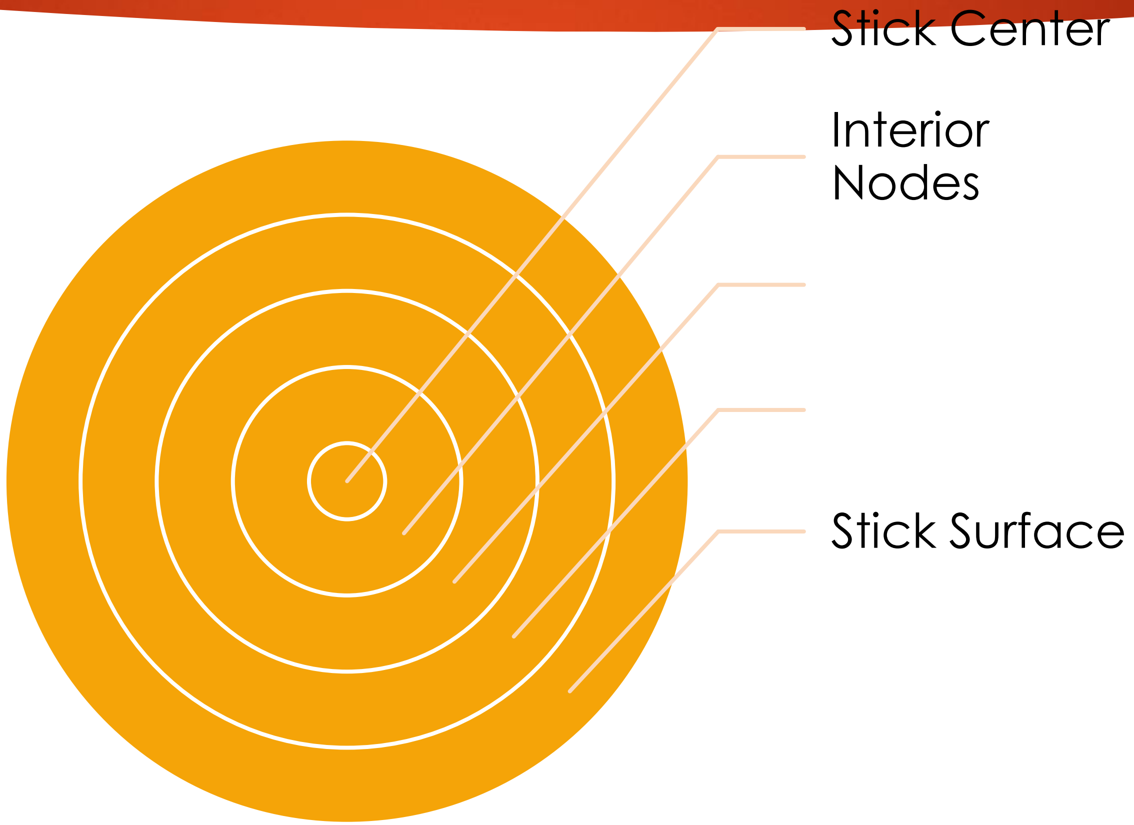
086501-NATIONAL KEY DEER
2007 - 2017
1000-Hour Fuel Moisture
35
30
25
20
15
10
5
0
10%
3%
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2017
1 Day Periods
Model: 8K1PE3
7647 Wx Observations
FF+5.0 build 20171214 08/15/2017-14:01

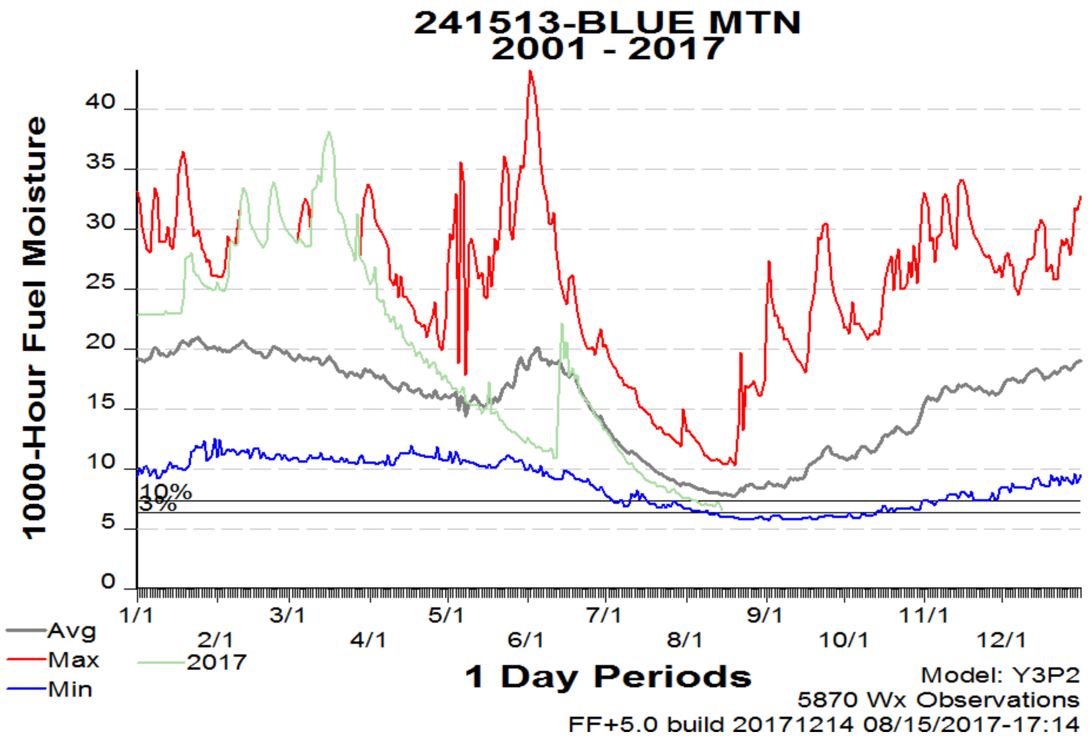


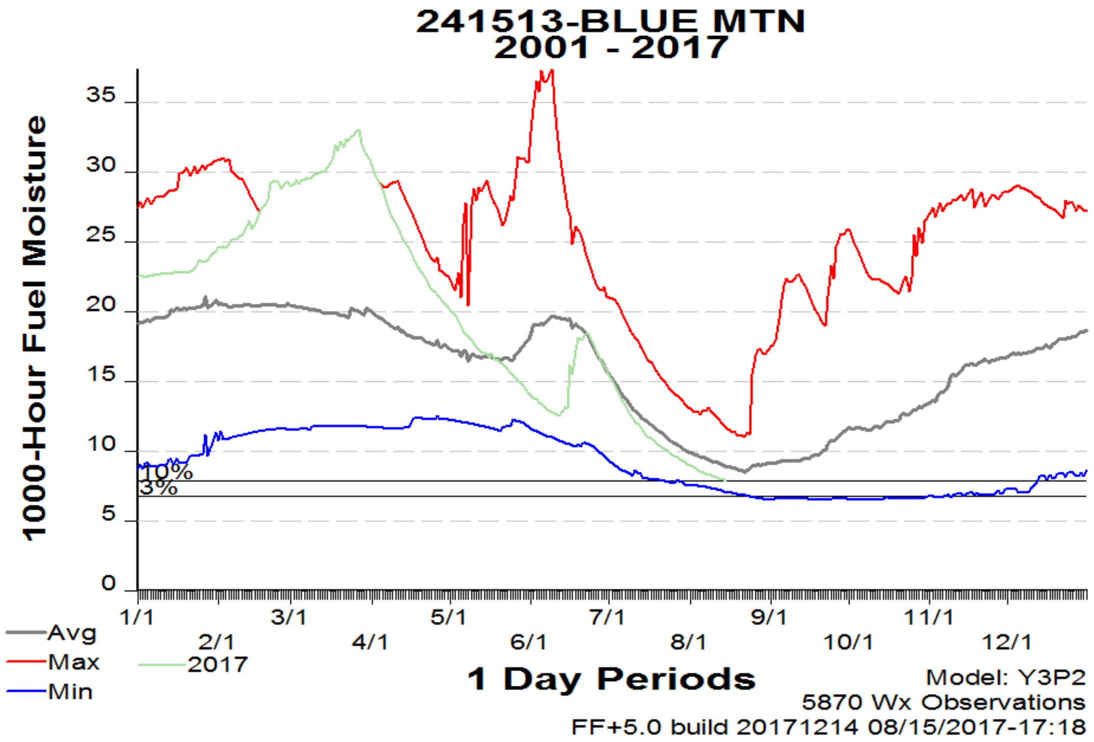
086501-NATIONAL KEY DEER
2007 - 2017
1000-Hour Fuel Moisture
40
35
30
25
20
15
10
5
0
10%
3%
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2017
1 Day Periods
Model: Y1P3
3835 Wx Observations
FF+5.0 build 20171214 08/15/2017-14:02


Adsorption Rate
Stick Diameters
Averaging

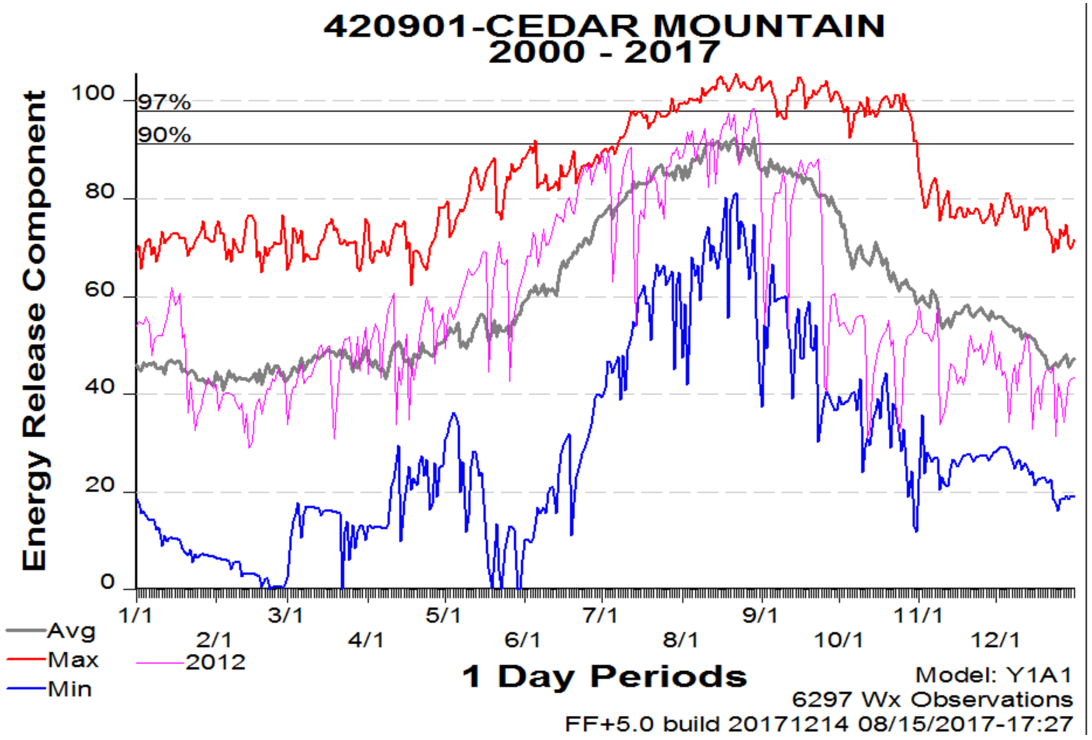
Nelson Model

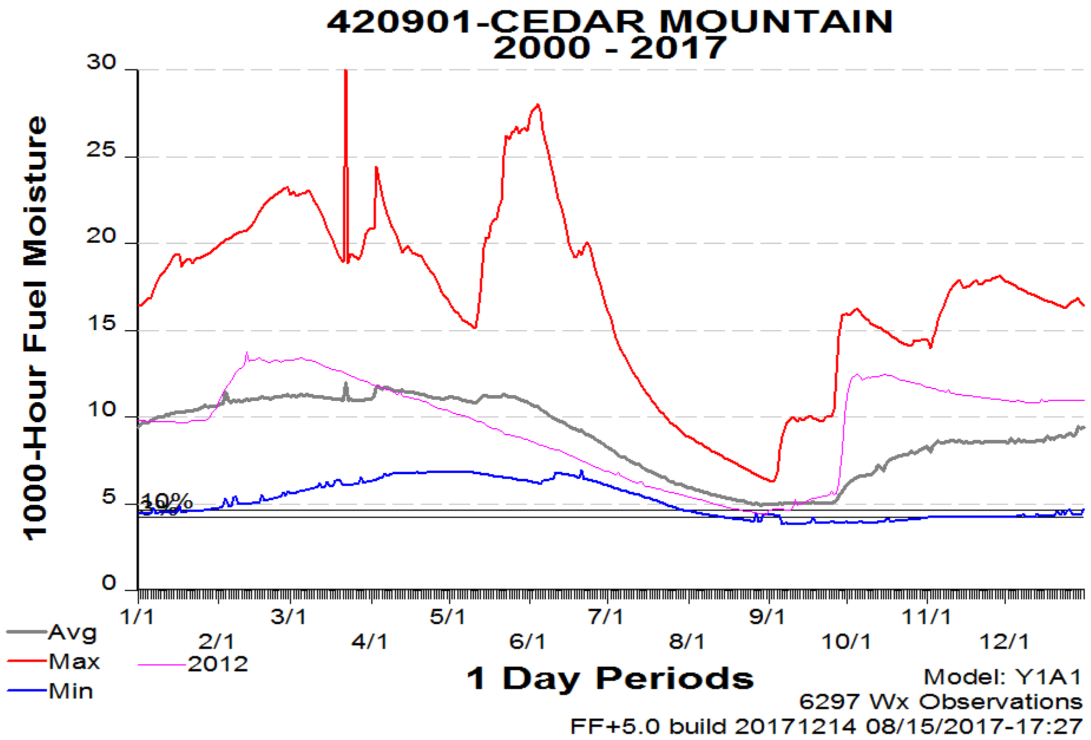



241513-BLUE MTN
2001 - 2017
1000-Hour Fuel Moisture
40
35
30
25
20
15
10
5
0
10%
3%
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2017
1 Day Periods
Model: Y3P2
5870 Wx Observations
FF+5.0 build 20171214 08/15/2017-17:14

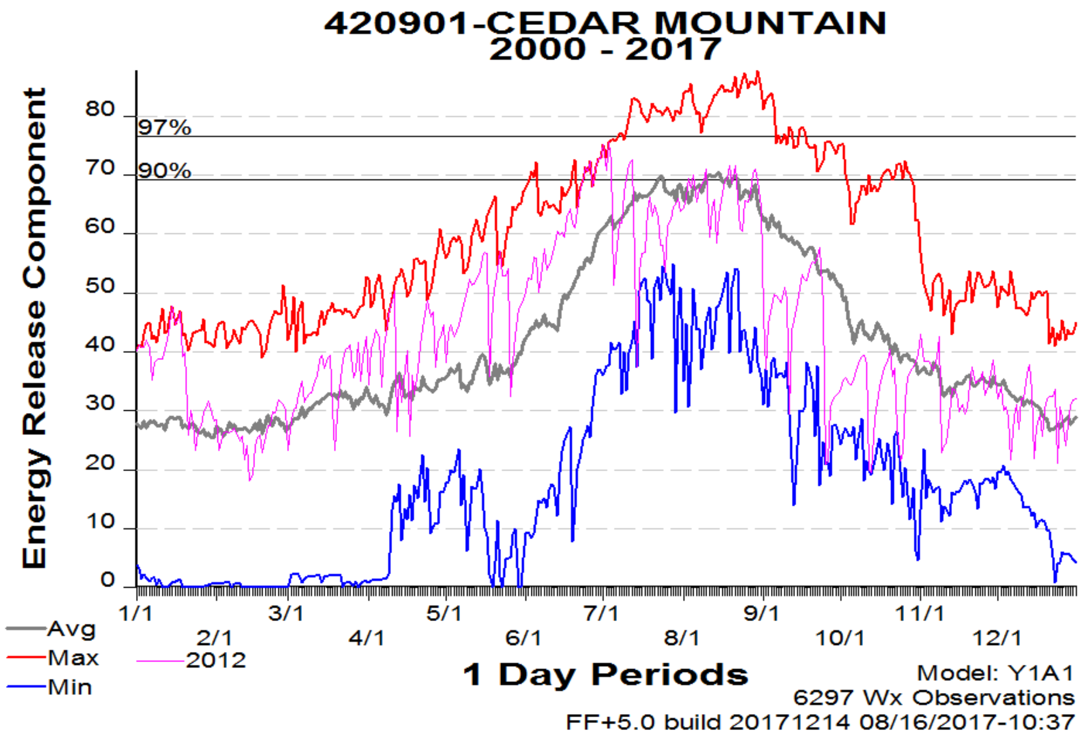

241513-BLUE MTN
2001 - 2017
1000-Hour Fuel Moisture
35
30
25
20
15
10
5
0
10%
3%
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2017
1 Day Periods
Model: Y3P2
5870 Wx Observations
FF+5.0 build 20171214 08/15/2017-17:18

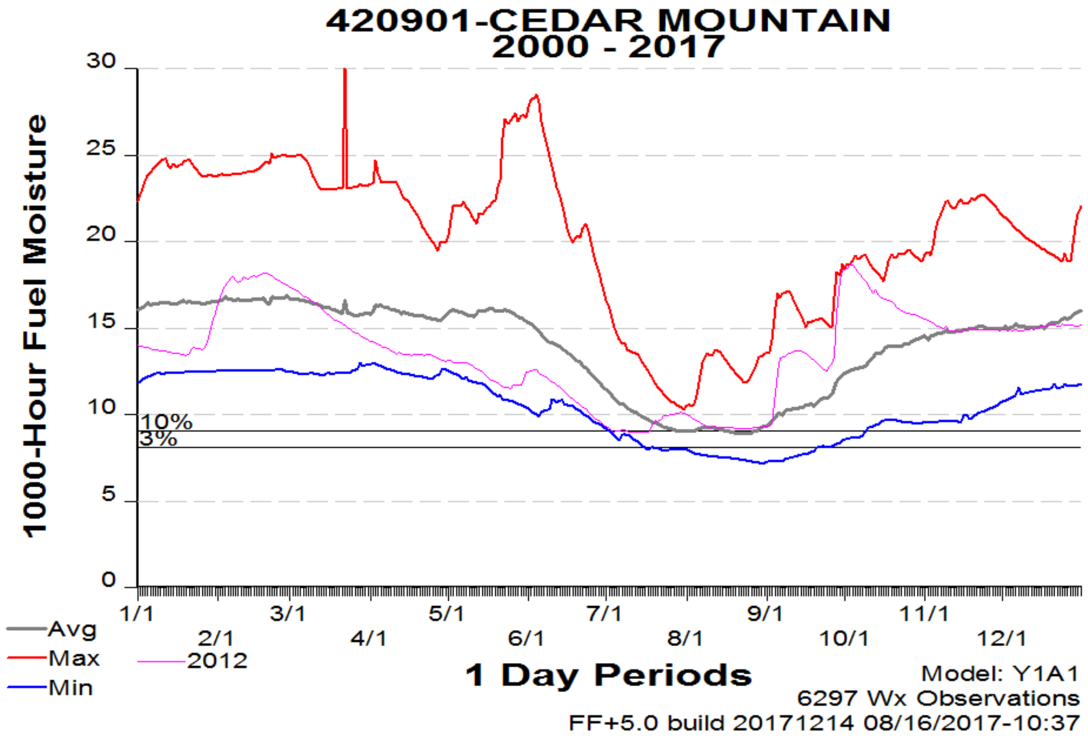
New model with Radial Median



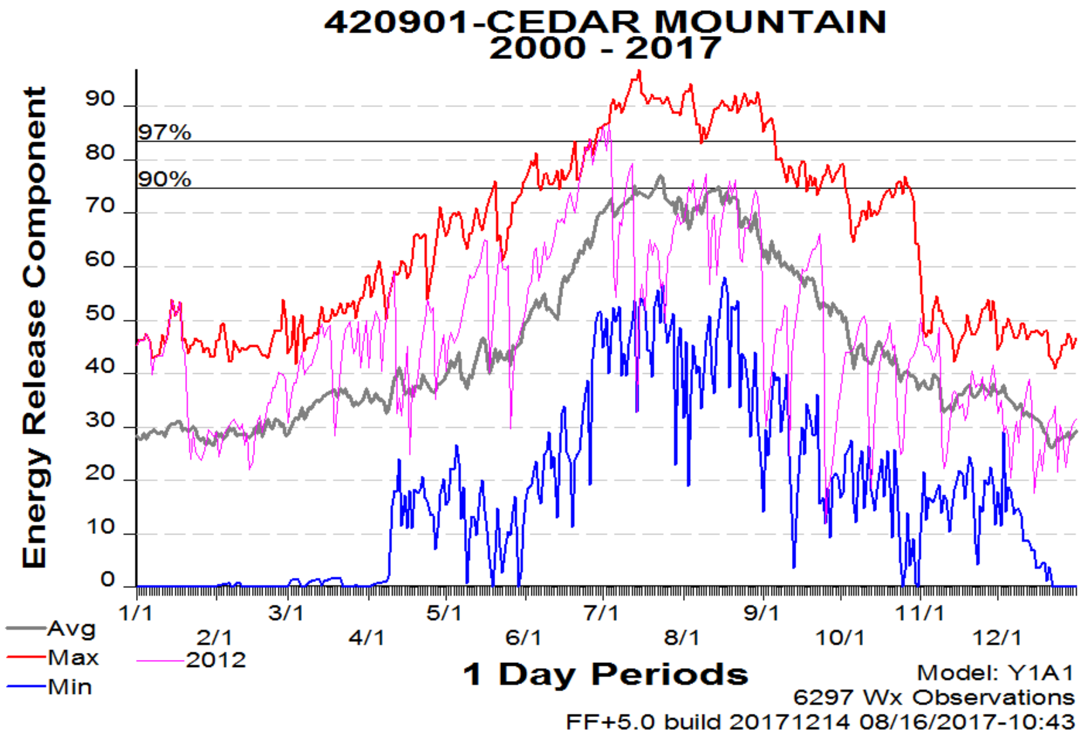


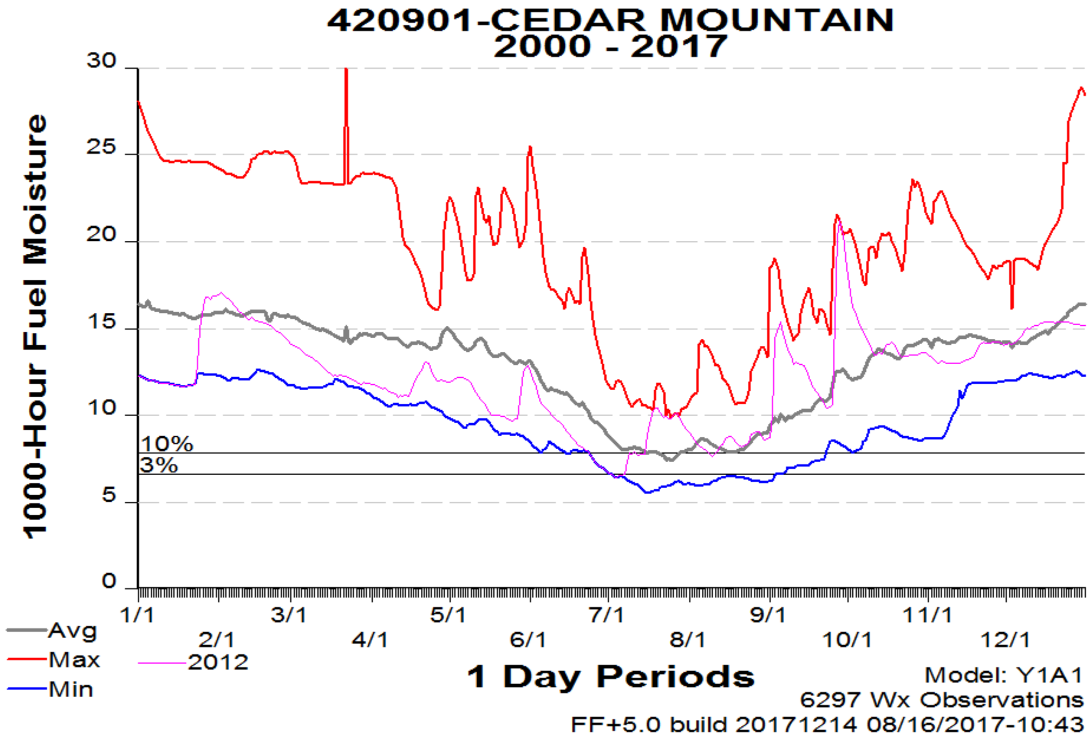
New model with Radial Median and Adsorption Correction



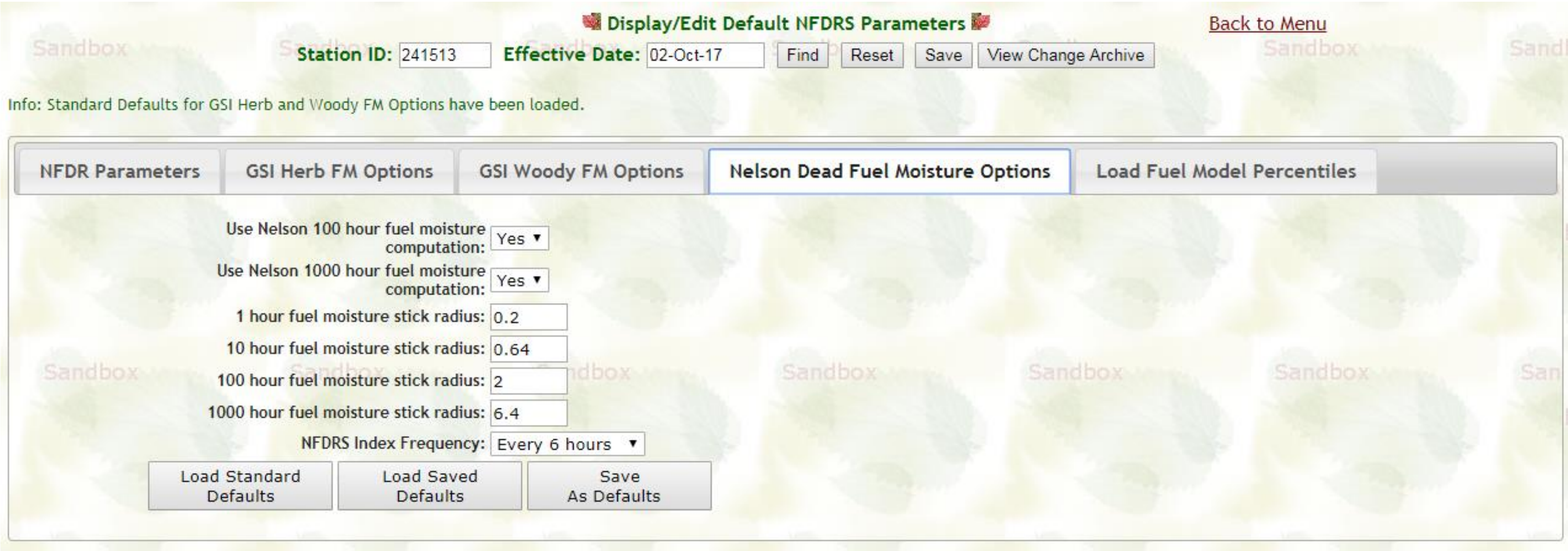


New model with Radial Median, Adsorption Correction and modified stick radii





- Change the Minimum Adsorption Rate
- Change the stick diameters
- Change the radial averaging method


Display/Edit Default NFDRS Parameters
Back to Menu
Station ID: 241513
Effective Date: 02-Oct-17
Find
Reset
Save
View Change Archive
Info: Standard Defaults for GSI Herb and Woody FM Options have been loaded.
NFDR Parameters
GSI Herb FM Options
GSI Woody FM Options
Nelson Dead Fuel Moisture Options
Load Fuel Model Percentiles
Use Nelson 100 hour fuel moisture computation: Yes
Use Nelson 1000 hour fuel moisture computation: Yes
1 hour fuel moisture stick radius: 0.2
10 hour fuel moisture stick radius: 0.64
100 hour fuel moisture stick radius: 2
1000 hour fuel moisture stick radius: 6.4
NFDRS Index Frequency: Every 6 hours
Load Standard Defaults
Load Saved Defaults
Save As Defaults

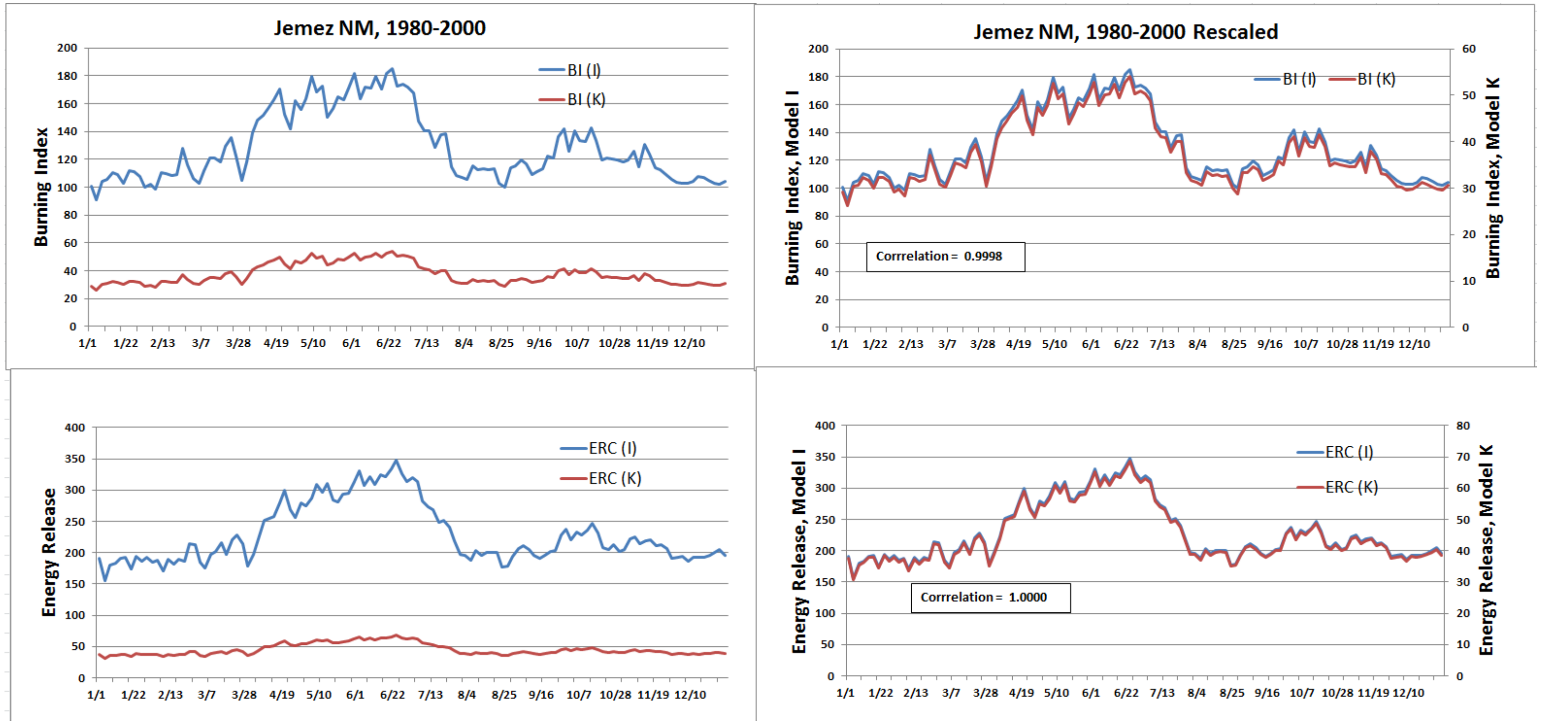
- // Initialize the dead fuel moisture models
- OneHourFM.initializeParameters(0.2, "One Hour");   // 1hr Dead FM model init
- TenHourFM.initializeParameters(0.64, "Ten Hour");   // 10hr Dead FM model init
- HundredHourFM.initializeParameters(2.0, "Hundred Hour");   // 100hr Dead FM model init
- ThousandHourFM.initializeParameters(3.81, "Thousand Hour");

NFDRS Fuel Models

Consolidate Fuel Models

- John Deeming, the lead developer of the NFDRS in use today, proposed reducing the 9 fuel models in the 1972 system to 4 in the 1978 update
  - He negotiated to 20 with his steering committee
  - In the 1988 update, essentially 20 more were added
- Outputs from most NFDRS fuel models are not unique
  - Similarity analysis of output distributions revealed just four really unique fuel model types.

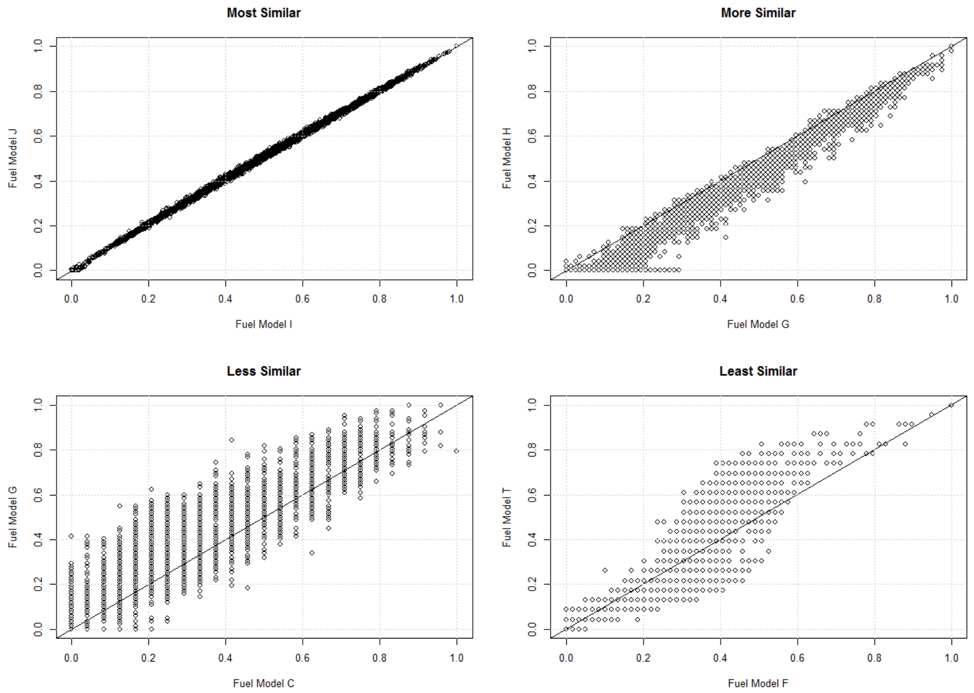
Indexes from different fuel models are correlated though their ranges may differ significantly



ERC correlation analysis between four model pairs

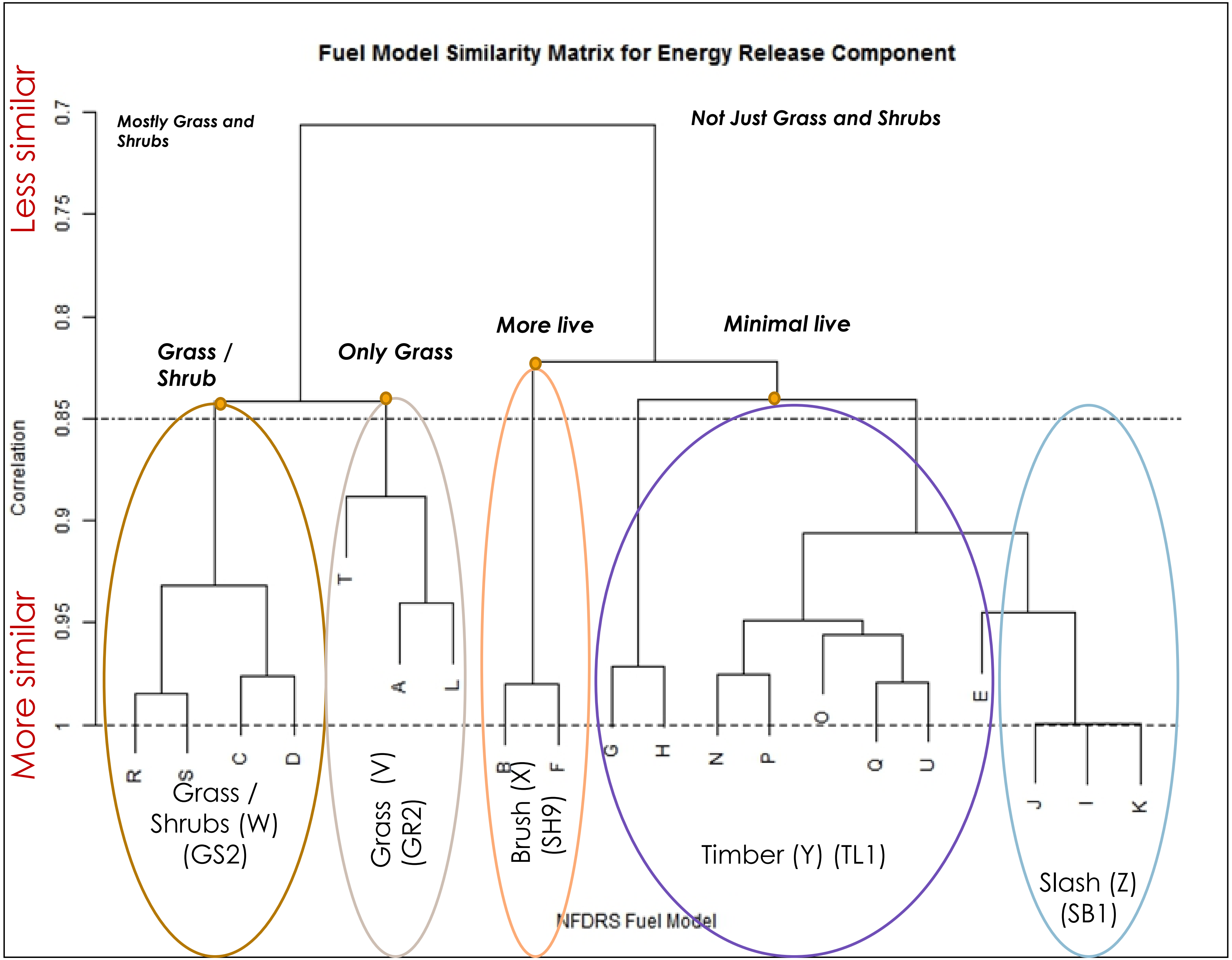
I versus K
Correlation = 1.0

G versus H
Correlation = 0.9885



G versus C
Correlation = 0.6825

F versus T
Correlation = 0.6784



Fuel Model Similarity Matrix for Energy Release Component
Less similar
More similar
Correlation
0.7
0.75
0.8
0.85
0.9
0.95
1
Mostly Grass and Shrubs
Not Just Grass and Shrubs
Grass / Shrub
Only Grass
More live
Minimal live
R
S
C
D
T
A
L
B
F
G
H
N
P
O
Q
U
E
J
I
K
Grass / Shrubs (W) (GS2)
Grass (V) (GR2)
Brush (X) (SH9)
Timber (Y) (TL1)
Slash (Z) (SB1)
NFDRS Fuel Model

Deeming, 1987

- The standard fire-danger rating fuel models will be a subset of the fuel models used for fire-behavior predictions and fire planning.
- Live-fuel moisture models will certainly be improved as will dead-fuel moisture models (Rothermel and others 1986). More importantly for some areas of the country, will be a better understanding and modeling of the effects of living plants on fire danger.

New Five Fuel Models

- Fuel models are derived from existing 40 FBPS fuel models with addition of a 1000 hour and drought fuel loading
  - No new fuel models to learn
    - V – GR2 (Grass)
    - W – GS2 (Grass/Shrub)
    - X – SH9 (Brush)
    - Y – TL1 (Timber)
    - Z – SB1 (Slash)

NFDRS 2016 Fuel Type	NFDRS 2016 Fuel Model	Equivalent NFDRS 1978 Fuel Model
Grass	V	A,L,T
Grass / Shrub	W	R,S,C,D
Brush	X	B, F
Timber	Y	G,H,N,P,O,Q,U,E
Slash	Z	I,J,K

Fuel Model Parameters

Model Selection

Fuel Model: Y - Timber

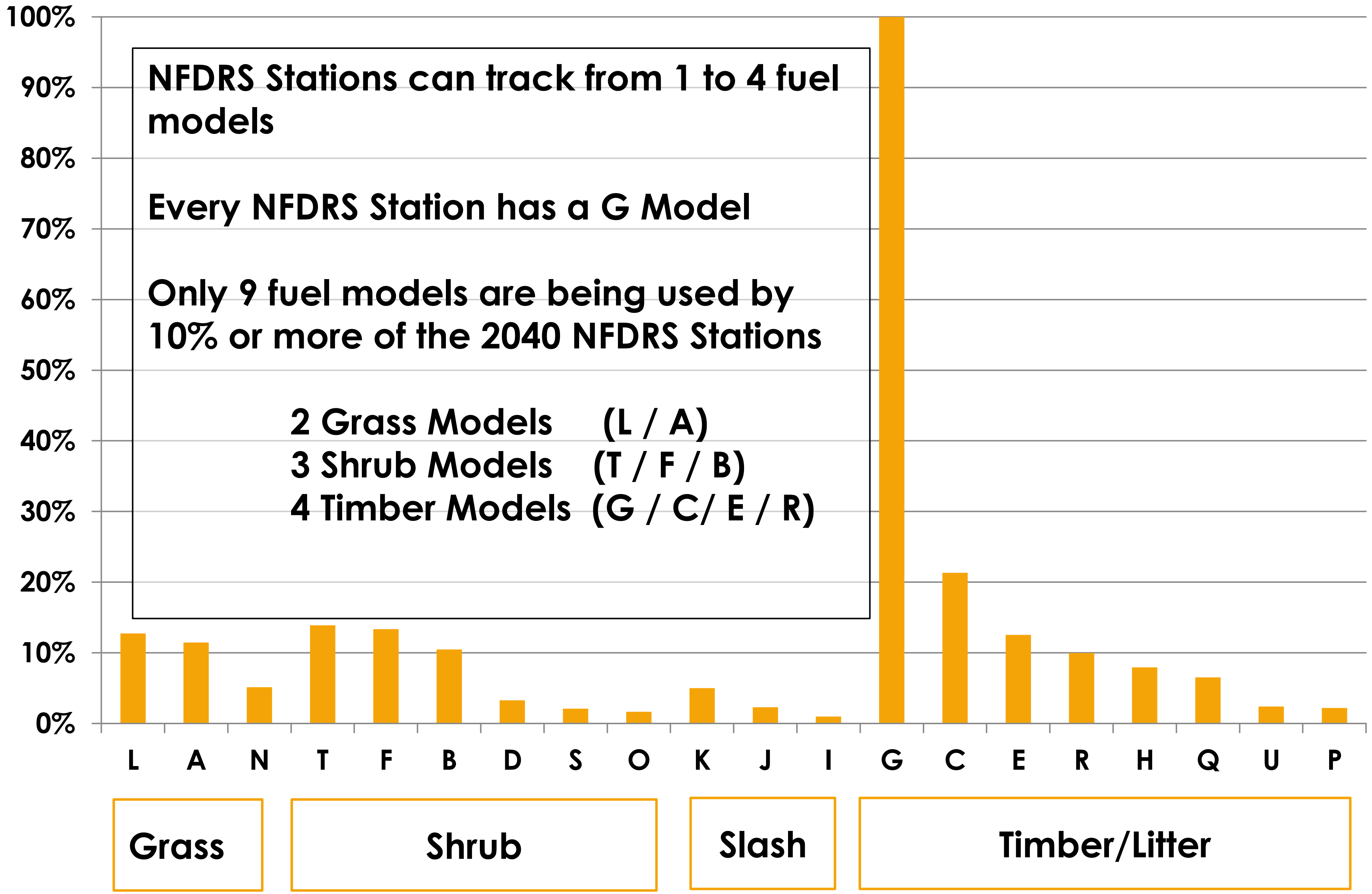
Use 88 Model: ☐

Add To Table | Remove Current | Clear Table | Close

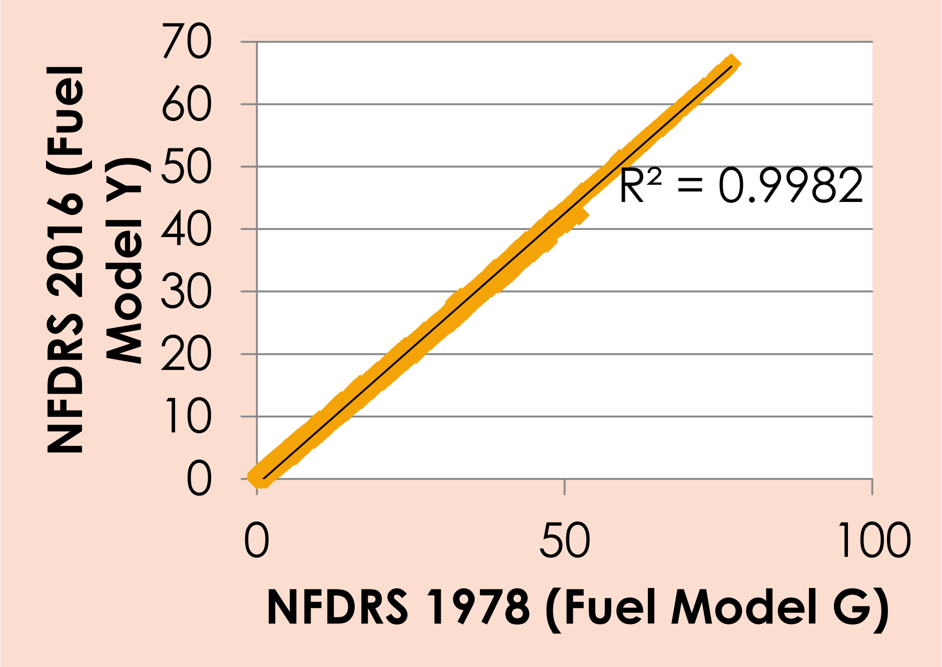
Fuel Model	88 Model	1 Hour Loading	10 Hour Loading	100 Hour Loading	1000 Hour Loading	Herb Loading	Woody Loading	Drought Loading	1 Hour SA : Vol	10 Hour SA : Vol	100 Hour SA : Vol	1000 Hour SA : Vol	Herb SA : Vol	Woody SA : Vol	Heating #	Moisture Extinction	Depth	Wind Factor	Max SC
G	☐	2.5	2	5	12	0.5	0.5	0	2,000	109	30	8	2,000	1,500	8,000	25	1	0.4	30
Y	☐	2.5	2.2	3.6	10.16	0	0	5	2,000	109	30	8	2,000	1,500	8,000	25	0.6	0.2	5

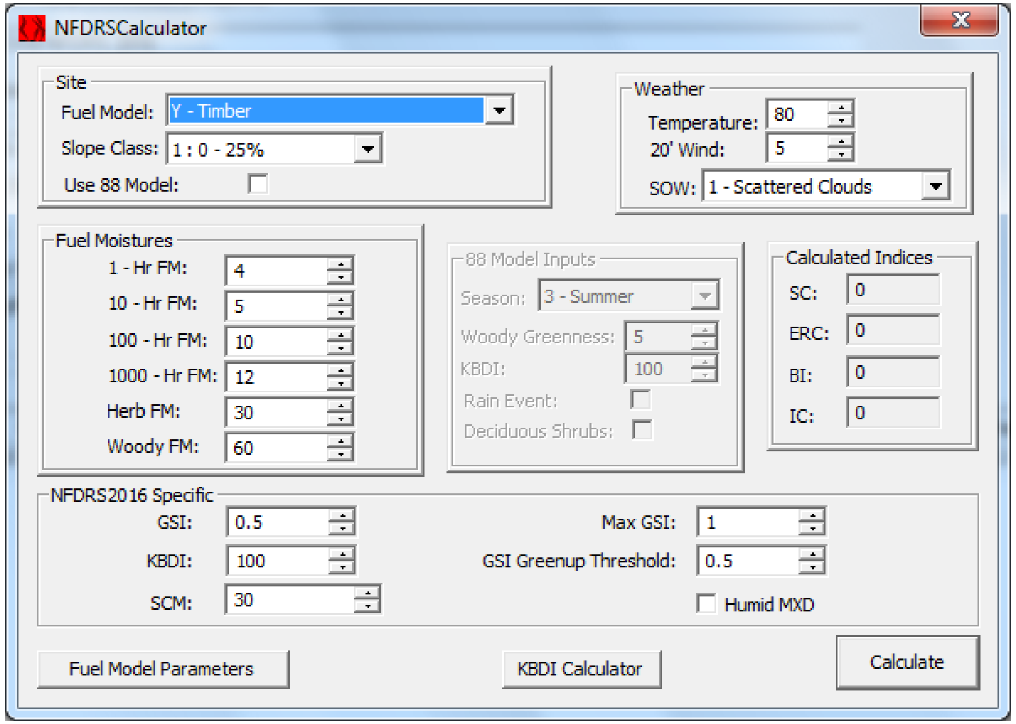
NFDRS Fuel Model	Scott and Burgan Equivalent	Fuel Loading (tons ac^{-1})							Surface Area to Volume Ratio (ft^{-1})						Fuel Heat Content (btu lb^{-1})	Moisture Extinct (%)	Depth (ft)	Wind Adjustment Factor (DIM)	Max SC
		1 Hr	10 Hr	100 Hr	1000 Hour	Herb	Woody	Drought	1 Hr	10 Hr	100 Hr	1000 Hour	Herb	Woody					
Code	Code	L1	L10	L100	L1000	LHERB	LWOOD	LDROUGHT	SG1	SG10	SG100	SG1000	SGHERB	SGWOOD	HD	MXD	DEPTH	WNDFC	SCM
V	GR2	0.1	0	0	0	1.0	0	1.1	2000	109	30	8	2000	1500	8000	15(40)	1.0	0.6	108
W	GS2	0.5	0.5	0	0	0.6	1	1.6	2000	109	30	8	2000	1500	8000	15(40)	1.5	0.4	62
X	SH9	4.5	2.45	0	0	1.55	7	8.5	2000	109	30	8	2000	1500	8000	25(40)	4.4	0.4	104
Y	TL1	2.5	2.2	3.6	8.64	0	0.2	15.44	2000	109	30	8	2000	1500	8000	25(40)	1	0.2	5
Z	SB2	4.5	4.25	4	4	0	0	16.75	2000	109	30	8	2000	1500	8000	25(40)	1	0.4	19

Percent of Active NFDRS Stations in WIMS (n=2040) with Each Fuel Model, Grouped by Type



Fuel Model Comparison Exercise

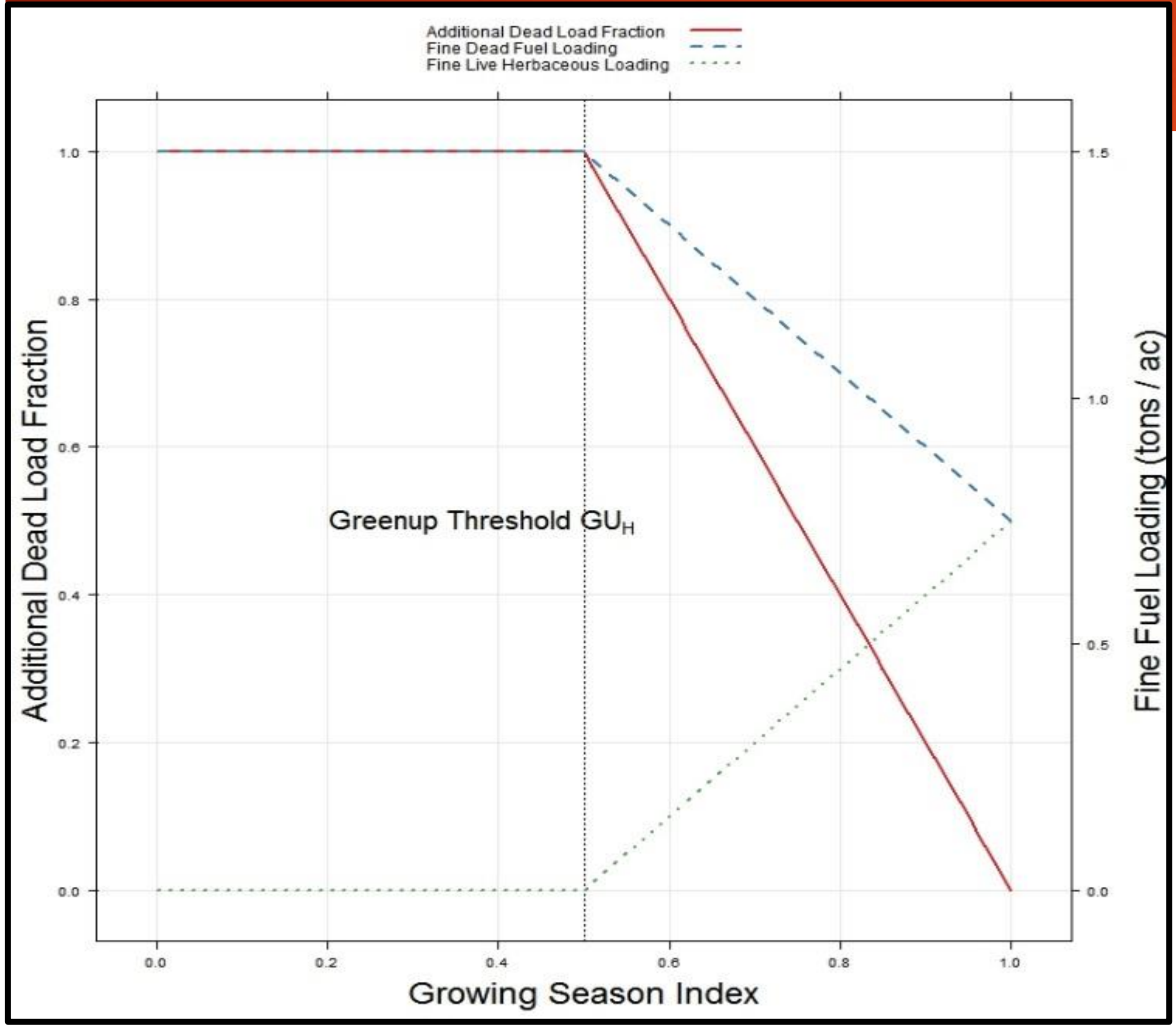



NFDRSCalculator
Site
Fuel Model: Y - Timber
Slope Class: 1 : 0 - 25%
Use 88 Model:
Weather
Temperature: 80
20' Wind: 5
SOW: 1 - Scattered Clouds
Fuel Moistures
1 - Hr FM: 4
10 - Hr FM: 5
100 - Hr FM: 10
1000 - Hr FM: 12
Herb FM: 30
Woody FM: 60
88 Model Inputs
Season: 3 - Summer
Woody Greenness: 5
KBDI: 100
Rain Event:
Deciduous Shrubs:
Calculated Indices
SC: 0
ERC: 0
BI: 0
IC: 0
NFDRS2016 Specific
GSI: 0.5
KBDI: 100
SCM: 30
Max GSI: 1
GSI Greenup Threshold: 0.5
Humid MXD
Fuel Model Parameters
KBDI Calculator
Calculate

Minor Changes

- GSI-driven curing function
  - Replaces load transfer logic
- Maintain the drought fuel loading
- Moisture of extinction
- Site-specific maximum spread component and variable slope input

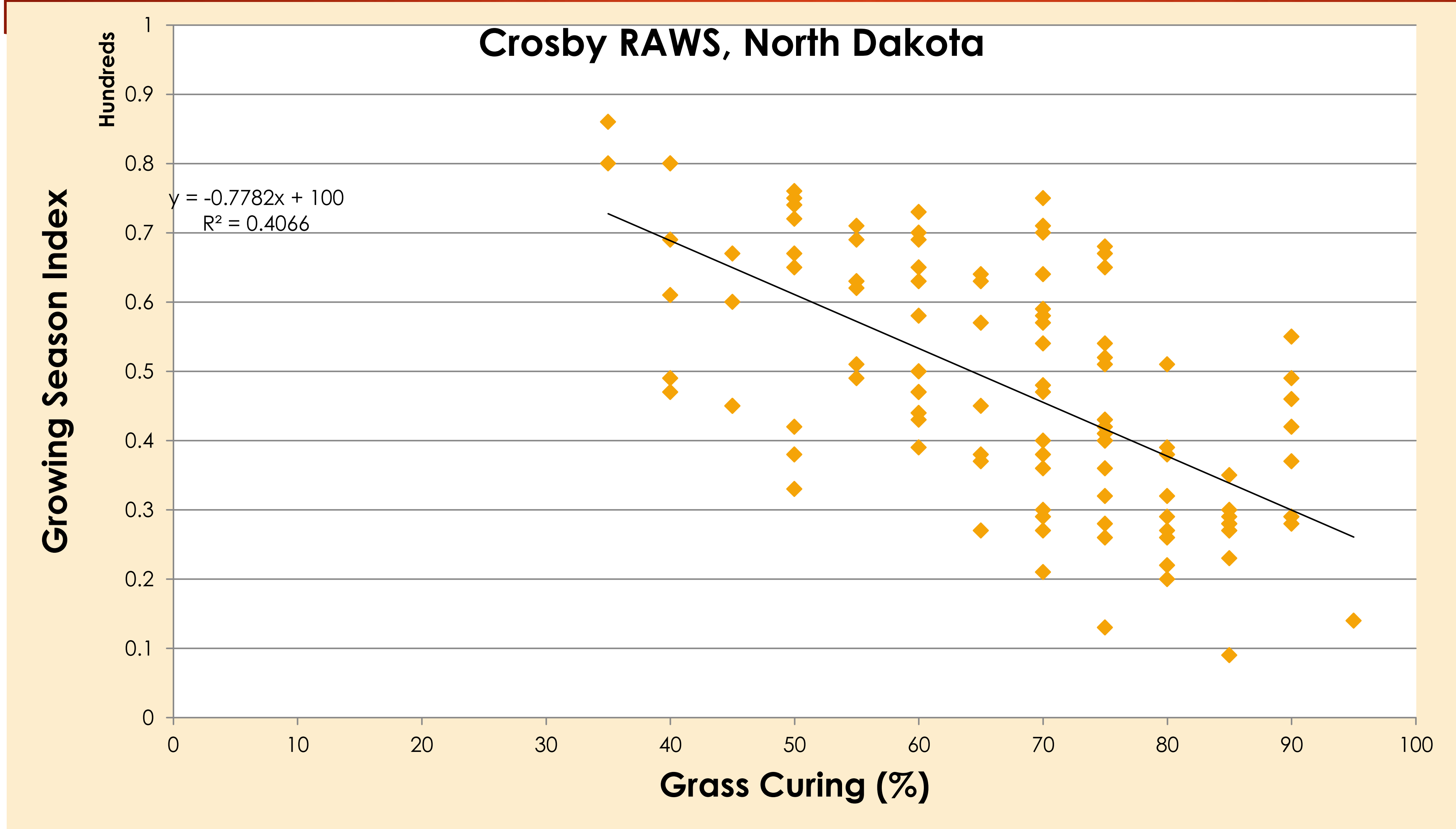
Curing



- Remove the ‘Load Transfer’ for dynamic fuel models and replace with ‘Curing’
- Calculated as a function of GSI
- Only applies to fuel models with live herbaceous loading

Back to the calculator…….

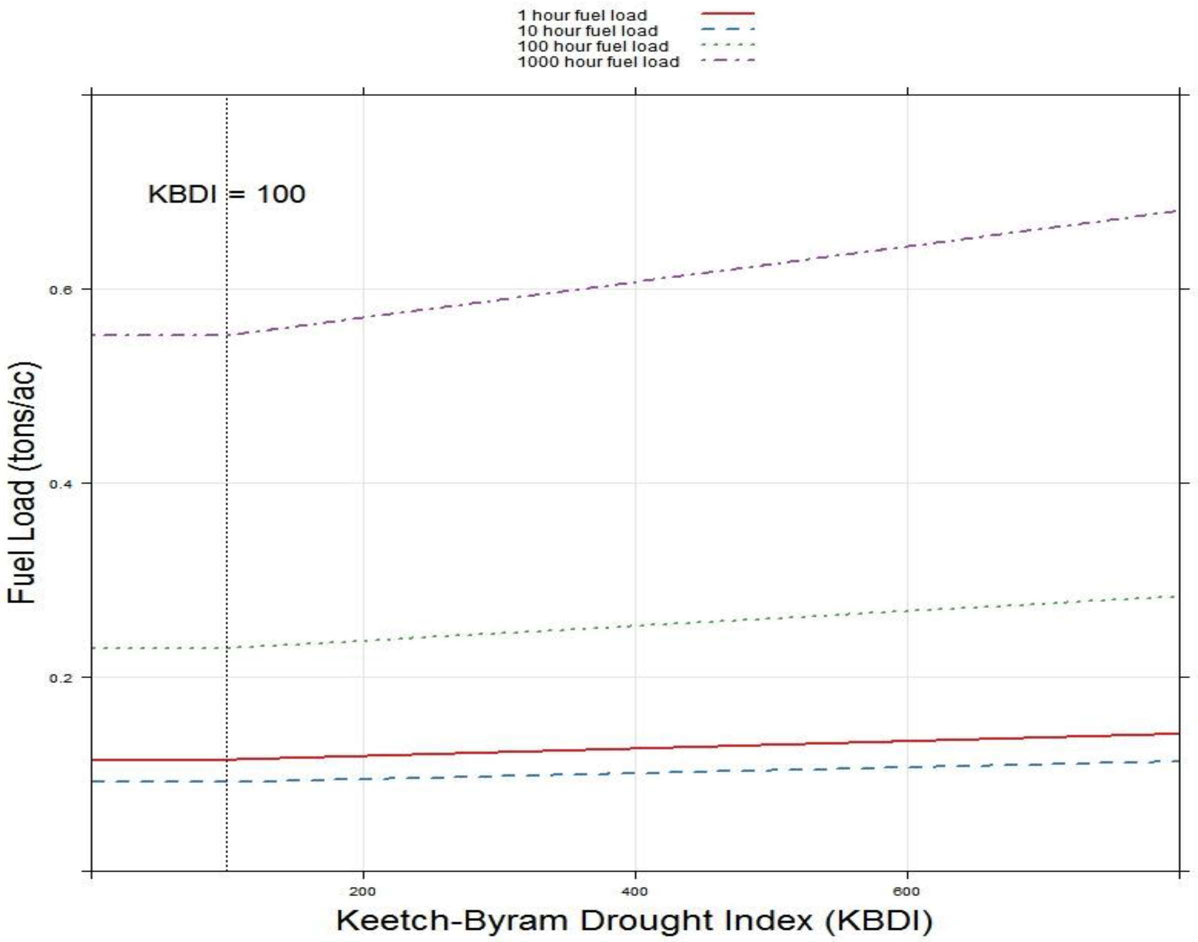
We can predict curing with GSI



GSI-driven curing function

- Curing is expressed as the ratio of fine dead fuel to total loading
- $C = \frac{w_{dead}}{w_{total}}$
- Additional loading is calculated based on the running average of the herbaceous GSI value
- $\left(\begin{matrix} GSI < HerbGreenup \\ GSI \geq HerbGreenup \end{matrix} \middle| \begin{matrix} C = 1 \\ \mathrm{C} = -\left(\left(\frac{1.0}{(1.0 - GU_H)*}\right) * \mathrm{GSI}'\right) + \left(\frac{1.0}{1.0 - GU_H}\right) \end{matrix} \right)$
- Once C is calculated the 1hr and herbaceous loadings are calculated as follows:
- **W1P = W1 + WHERB * C**
- **WHERBP = WHERB * (1 - C)**

Drought fuel loading



Example increase in fuel load for fuel model Y

- Additional fuel loading added to fuel moisture in response to drought
- We expect to improve drought representation in future versions
  - KBDI is currently being utilized as a place-holder for improved drought metrics

```
if (tmpKBDI > 100 )
{
        WTOTD = W1 + W10 + W100;
        WTOTL = WHERB + WWOOD;
        WTOT = WTOTD + WTOTL;
        PackingRatio = WTOT / fDEPTH;
        WTOTD = WTOTD + W1000;
        DroughtUnit = WDROUGHT / 700.;
        W1 = W1 + (W1 / WTOTD) * (tmpKBDI - 100) * DroughtUnit;
        W10 = W10 + (W10 / WTOTD) * (tmpKBDI - 100) * DroughtUnit;
        W100 = W100 + (W100 / WTOTD) * (tmpKBDI - 100) * DroughtUnit;
        W1000 = W1000 + (W1000 / WTOTD) * (tmpKBDI - 100) * DroughtUnit;
        WTOT = W1 + W10 + W100 + W1000 + WTOTL;
        fDEPTH = (WTOT - W1000) / PackingRatio;

}
```

- How much drought fuel loadings is added to the 1000 hour loading when the KBDI is 650?

Other modifications

- Adjective Rating calculations often work poorly in humid regions here the Spread Component does not approve the SCMax value of the fuel model
  - We have added the ability to allow SCMax to vary by location
- Also, moisture of extinction values for all fuel models are too low to allow proper system operation in more humid areas
  - We have added a 'humid' switch in WIMS to allow the user to set MXD to 40%
- Finally, we have added an option to allow the direct input of slope into NFDRS. This paves the way for gridded fire danger applications in the future.

Why change SCMax?

Computed class level	Upper value for class
0	SI = 0
1	SI-low/8
2	SI-low/4
3	(SI-low)(3/8)
4	SI-low/2
5	(SI-low)(3/4)
6	SI-low
7	(SI-low + SI-high)/2
8	SI-high
9	> SI-high

Desired Number of Staffing Classes	Displayed Staffing Class									
3	0	1	1	1	1	1	1	4	4	5
4	0	1	1	1	1	3	3	4	4	5
5	0	1	1	2	2	3	3	4	4	5
6	0	1	1	2	2	3-	3+	4	4	5
7	0	1	1	2	2	3-	3+	4-	4+	5
8	0	1	1	2-	2+	3-	3+	4-	4+	5
9	0	1-	1+	2-	2+	3-	3+	4-	4+	5
Computed 9-Class Level	0	1	2	3	4	5	6	7	8	9

Adjective Rating in WIMS / WFAS

Staffing Levels (SL)	Adjective Fire Danger Rating (R)				
1-, 1, 1+	L	L	L	M	M
2-, 2, 2+	L	M	M	M	H
3-, 3, 3+	M	M	H	H	VH
4-, 4, 4+	M	H	VH	VH	E
5	H	VH	VH	E	E
Ignition Component	**0-20**	**21-45**	**46-65**	**66-80**	**81-100**

ESTA

Adopt 2016 Models ☐

Del	Active Fuel Models	Pri	ID	** 78 NFDRS Only **			88 sb	Slp	Grs	Cli	MXD	SCM	Herb FM	Woody FM	X-1000	Staffing Idx Breakpoints					
				HS	Herb Date	Greenup Date										SI	DC	Low		High	
																		SI%	Val	SI%	Val
☐	☑	1	7G	P	01-Apr-15	30-Mar-15	▾	3=41-55%	P	2	L	30	7.2	60	18	EC	5	90	55	97	62
☐	☑	2	7C	P	01-Apr-15	30-Mar-15	▾	2=26-40%	A	2	L	32	7.2	60	18	EC	5	90	16	97	18
	☑		▾	▾			▾	▾	▾	▾	▾					▾					
	☑		▾	▾			▾	▾	▾	▾	▾					▾					
	☑		▾	▾			▾	▾	▾	▾	▾					▾					
	☑		▾	▾			▾	▾	▾	▾	▾					▾					
	☑		▾	▾			▾	▾	▾	▾	▾					▾					
	☑		▾	▾			▾	▾	▾	▾	▾					▾					
	☑		▾	▾			▾	▾	▾	▾	▾					▾					

Snow Flags

- Carried over from NFDRS 78/88
- Sets air temperature to 0 C / 32 F
- Sets RH to 99.99%
- Sets Solar Radiation to 0
- PPT = 0

	StationID	ObsDate	Type	OMC 10	Season	GreenHerb	GreenShrub	SR_SOW	SR_WetFlag	SnowFlag
861	241513	02/10/17 13:00	O					2	1	1
862	241513	02/11/17 13:00	O					3	0	1
863	241513	02/12/17 13:00	O					2	0	1
864	241513	02/13/17 13:00	O					2	0	1
865	241513	02/14/17 13:00	O					2	0	1
866	241513	02/15/17 13:00	O					2	0	1
867	241513	02/16/17 13:00	O					3	0	1
868	241513	02/17/17 13:00	O					0	0	1
869	241513	02/18/17 13:00	O					3	0	1
870	241513	02/19/17 13:00	O					3	0	1
871	241513	02/20/17 13:00	O					3	0	1
872	241513	02/21/17 13:00	O					4	1	1
873	241513	02/22/17 13:00	O					3	0	1
874	241513	02/23/17 13:00	O					3	0	1
875	241513	02/24/17 13:00	O					3	0	1
876	241513	02/25/17 13:00	O					2	0	1
877	241513	02/26/17 13:00	O					3	0	1
878	241513	02/27/17 13:00	O					3	0	1
879	241513	02/28/17 13:00	O					2	0	1
880	241513	03/01/17 13:00	O					3	0	1
881	241513	03/02/17 13:00	O					2	0	1
882	241513	03/03/17 13:00	O					2	0	1
883	241513	03/04/17 13:00	O					3	0	1
884	241513	03/05/17 13:00	O					3	0	1
885	241513	03/06/17 13:00	O					2	0	1
886	241513	03/07/17 13:00	O					3	0	1
887	241513	03/08/17 13:00	O					3	0	1
888	241513	03/09/17 13:00	O					3	0	1
889	241513	03/10/17 13:00	O					3	1	1
890	241513	03/11/17 13:00	O					3	0	1
891	241513	03/12/17 13:00	O					2	0	1
892	241513	03/13/17 13:00	O					3	0	1
893	241513	03/14/17 13:00	O					2	1	1
894	241513	03/15/17 13:00	O					3	0	1
895	241513	03/16/17 13:00	O					2	0	1
896	241513	03/17/17 13:00	O					2	0	0
897	241513	03/18/17 13:00	O					3	0	0
898	241513	03/19/17 13:00	O					2	0	0
899	241513	03/20/17 13:00	O					2	0	0
900	241513	03/21/17 13:00	O					3	0	0
901	241513	03/22/17 13:00	O					3	0	0
902	241513	03/23/17 13:00	O					3	0	0

- Already export from WIMS
- Will work on automated input value
- Pre-loaded in the WRCC DRI RAWS points from 2001-2016 for the Continental United States

What doesn't change?

- Most of the same weather inputs
- All the same output components and indices: still have ERC, BI, SC and IC
- The look, feel and use of both FireFamily+ and WIMS

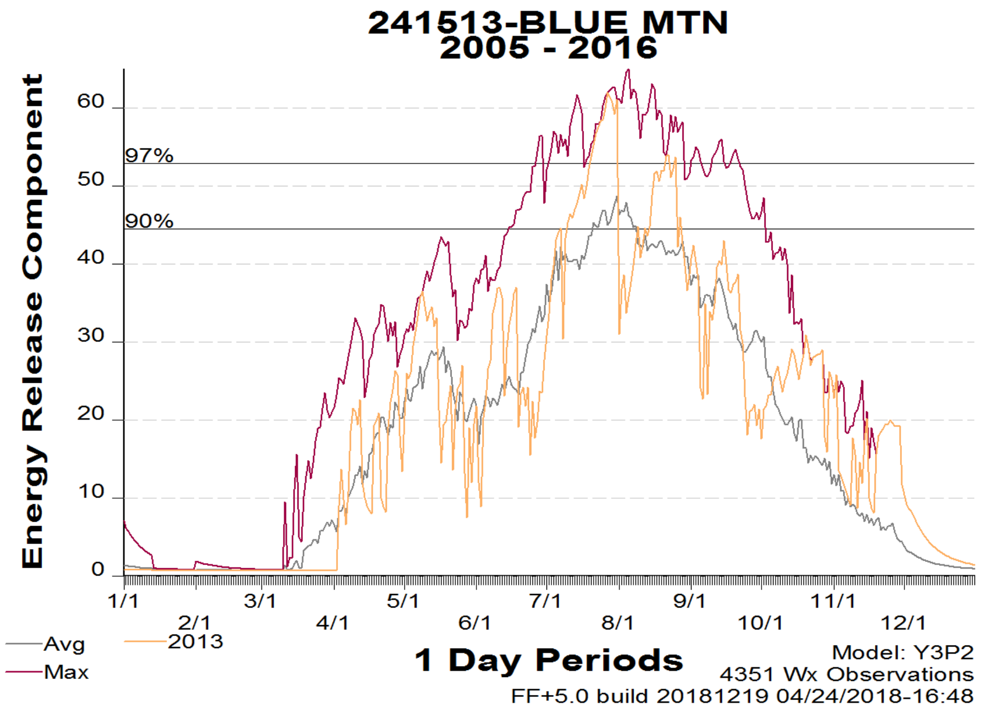
Summary of simplifications

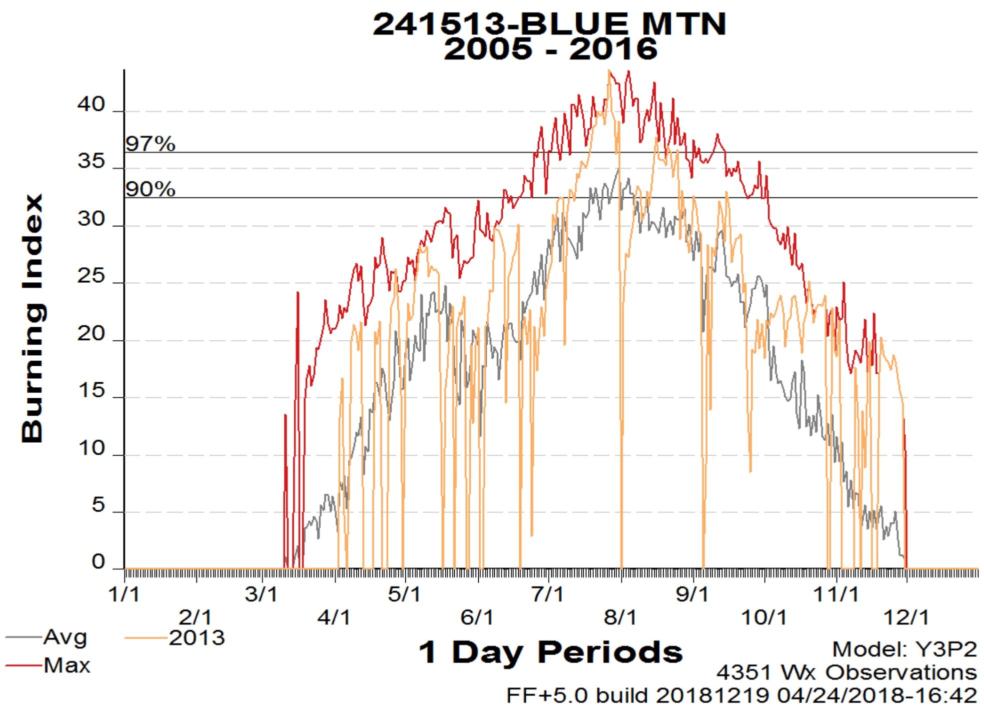
- No need for:
  - Climate class
  - No required manual entries:
    - Green-up, freeze and dormant dates
    - State-of-the-weather
  - All of the revisions in the 1988 system
    - Deciduous WAF, season codes, greenness factors, 1hr=10hr
  - Weighed sticks
  - Fosberg 1 and 10 hour fuel moisture model
  - Burgan live fuel moisture model
  - Dynamic Load Transfer
- Total of 35 fuel models eliminated

End result of changes:

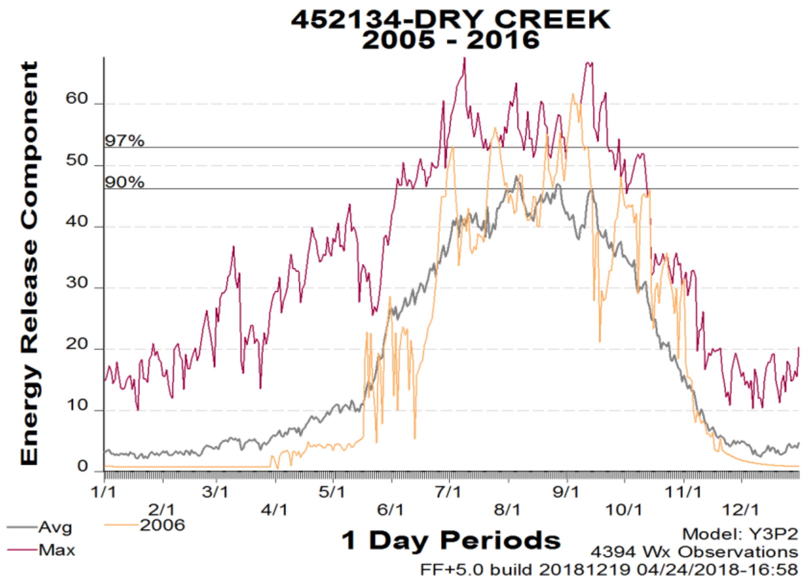
- **What doesn't change?**
  - Most of the same weather inputs
  - All the same output components and indices: still have ERC, BI, SC and IC
  - The look, feel and use of both FireFamily+ and WIMS
- **How it's better?**
  - Fully automated NFDRS and more consistent
  - Improved response to drought
  - More easily applied to gridded weather
  - Ready for future work
  - Reduced workload (No R/O, SOW daily entries or seasonal entries)

Example ERC and BI from NFDRS2016

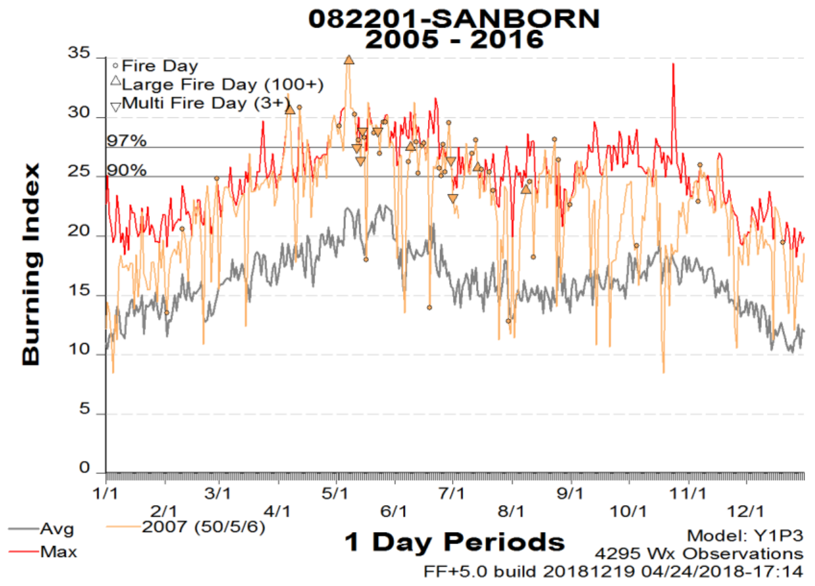


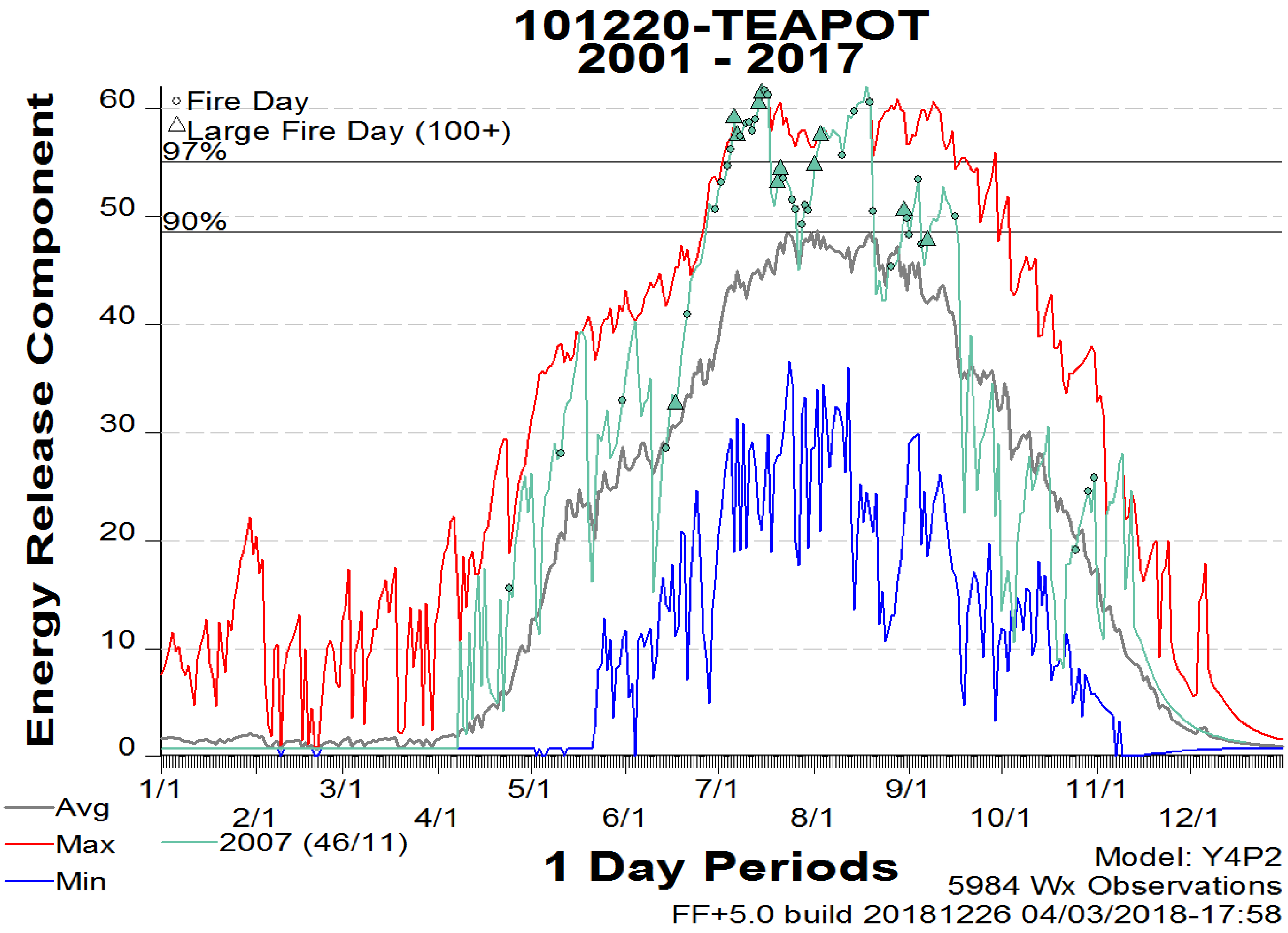


Central Washington



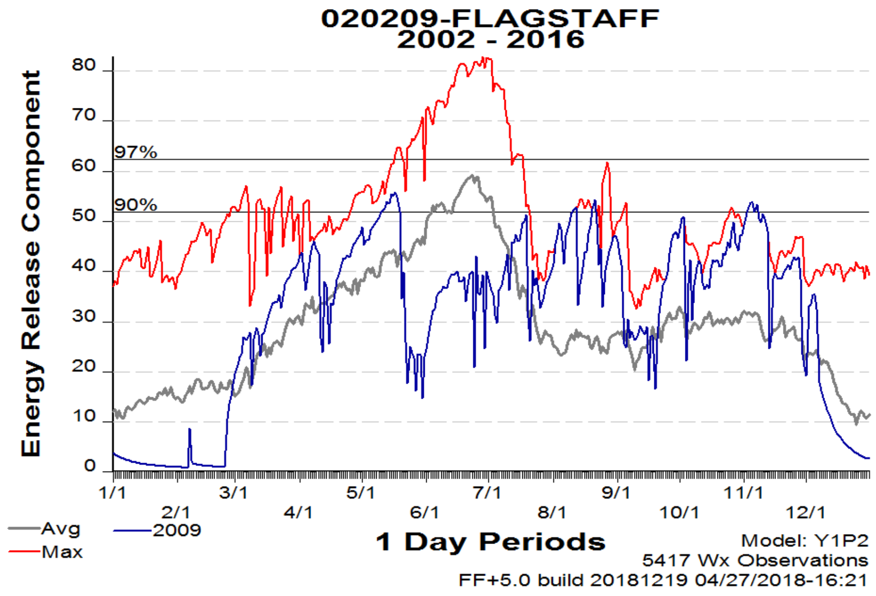
Florida



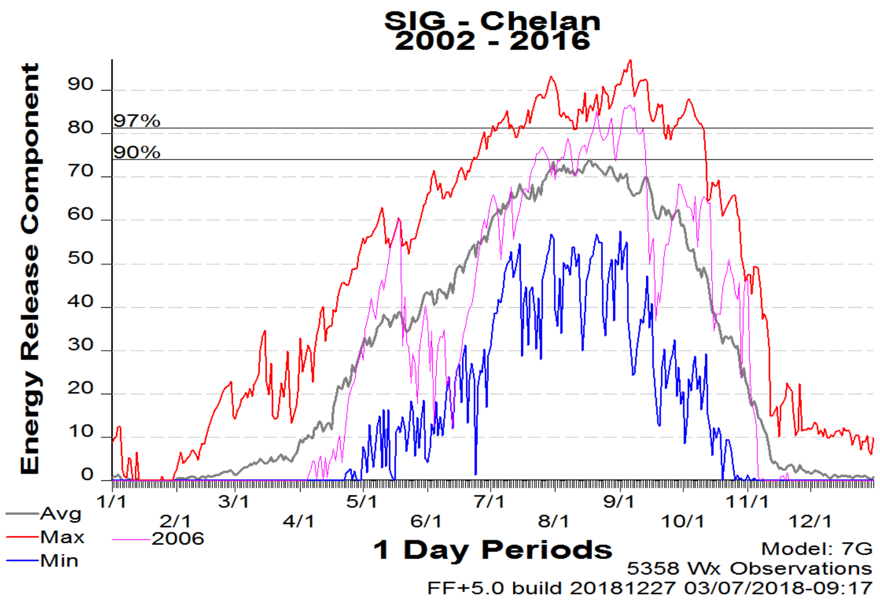


101220-TEAPOT
2001 - 2017
Energy Release Component
60
50
40
30
20
10
0
Fire Day
Large Fire Day (100+)
97%
90%
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2007 (46/11)
1 Day Periods
Model: Y4P2
5984 Wx Observations
FF+5.0 build 20181226 04/03/2018-17:58

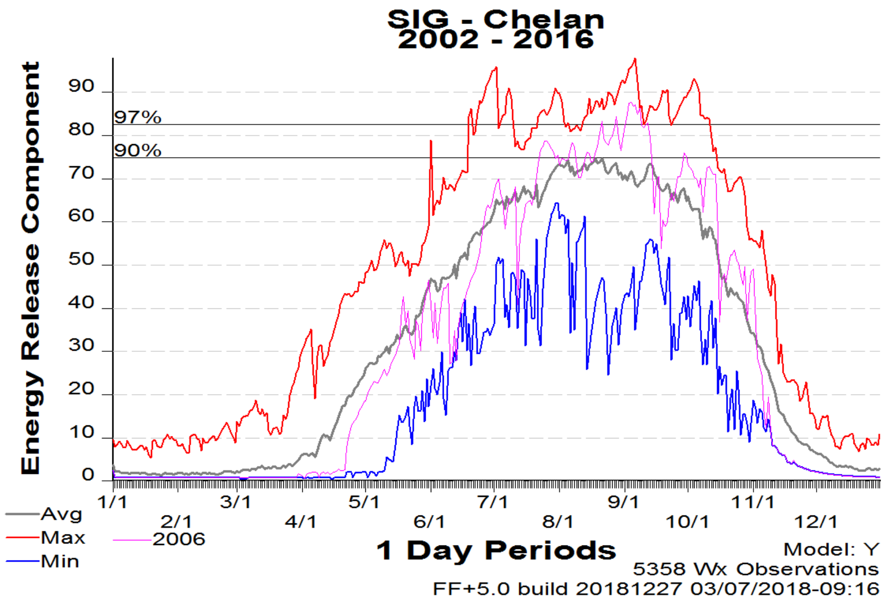
Flagstaff, AZ

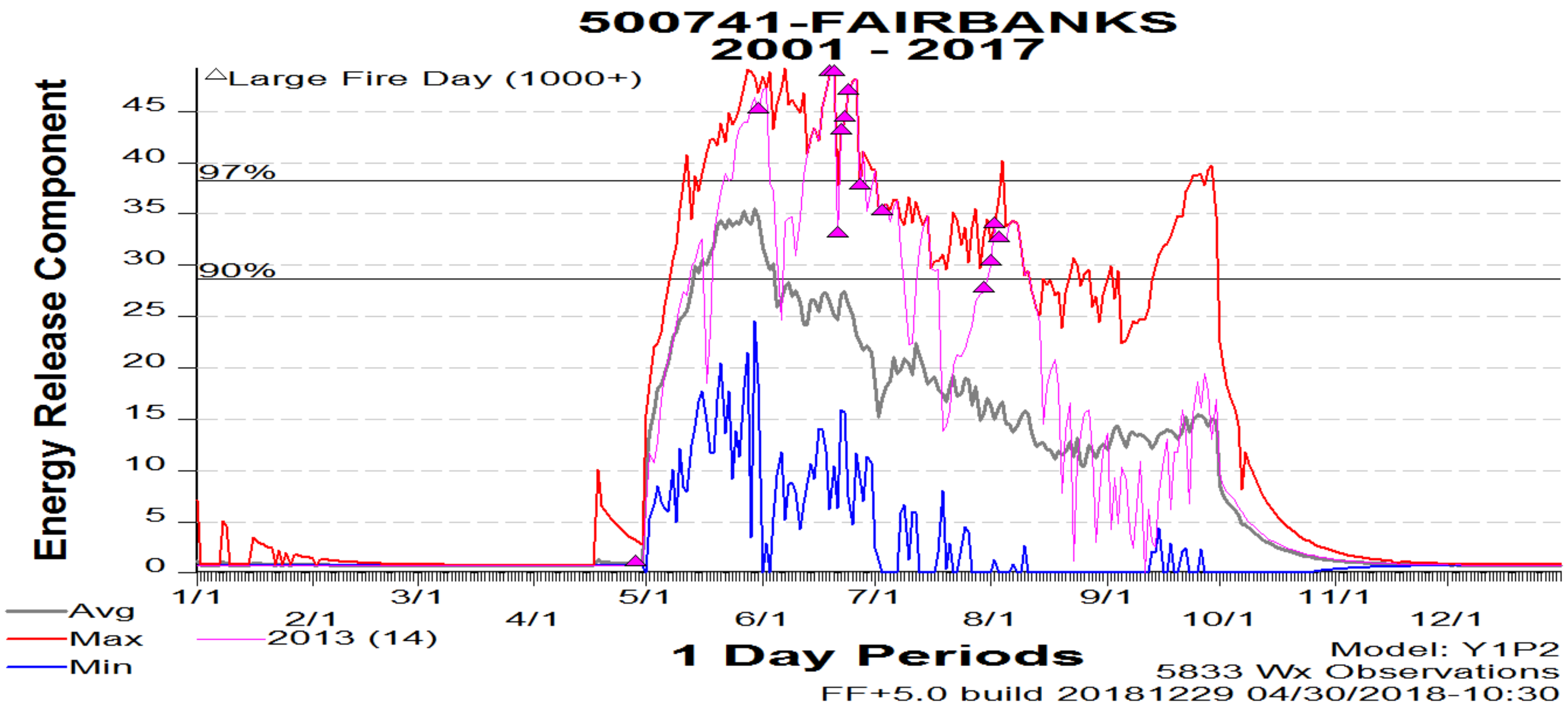


ERC Fuel Model G

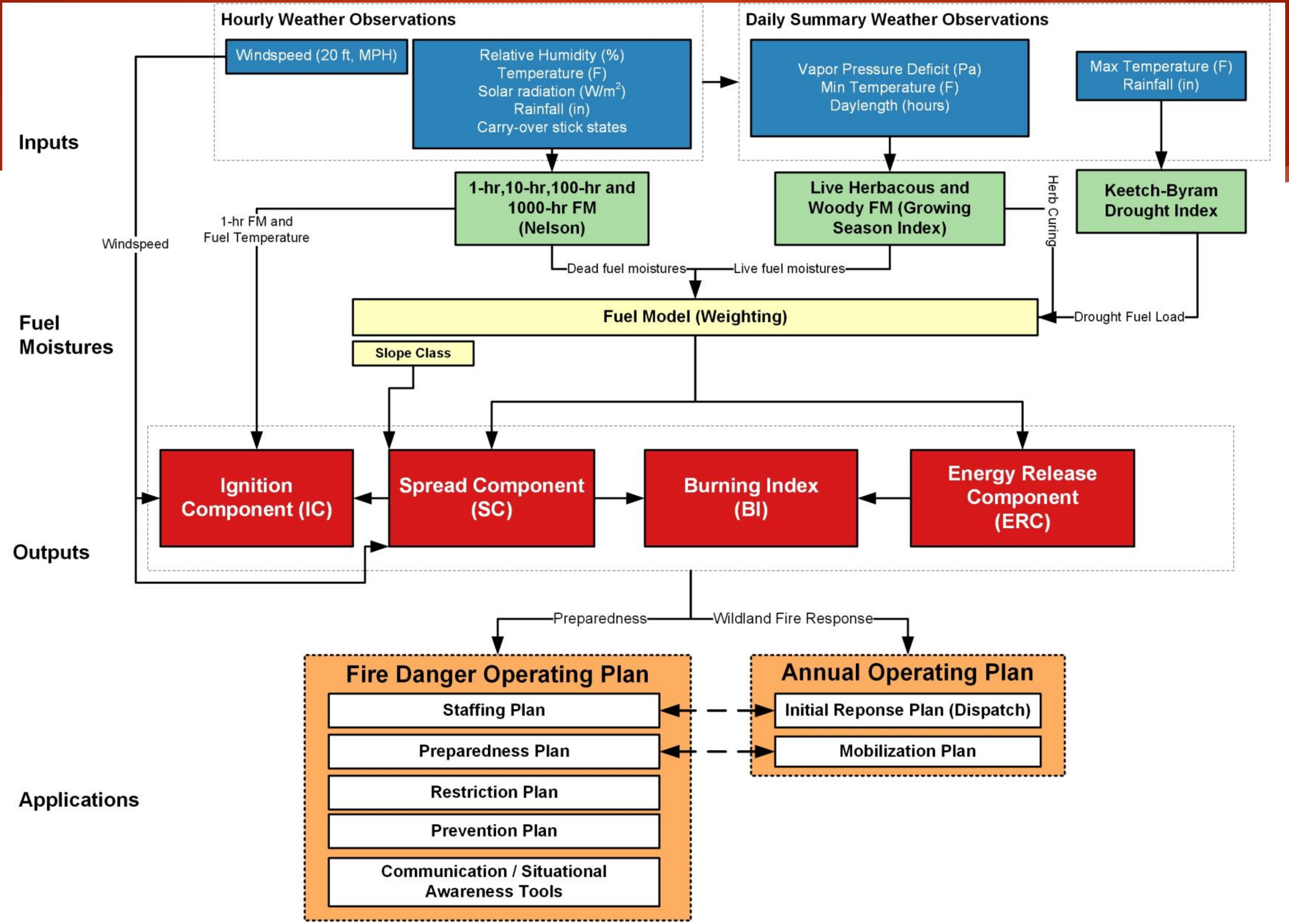


ERC Fuel Model Y





500741-FAIRBANKS
2001 - 2017
Large Fire Day (1000+)
Energy Release Component
45
40
35
30
25
20
15
10
5
0
97%
90%
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
1 Day Periods
Avg
Max
Min
2013 (14)
Model: Y1P2
5833 Wx Observations
FF+5.0 build 20181229 04/30/2018-10:30


Hourly Weather Observations
Windspeed (20 ft, MPH)
Relative Humidity (%)
Temperature (F)
Solar radiation (W/m2)
Rainfall (in)
Carry-over stick states
Daily Summary Weather Observations
Vapor Pressure Deficit (Pa)
Min Temperature (F)
Daylength (hours)
Max Temperature (F)
Rainfall (in)
Inputs
Windspeed
1-hr FM and
Fuel Temperature
1-hr,10-hr,100-hr and
1000-hr FM
(Nelson)
Live Herbacous and
Woody FM (Growing
Season Index)
Herb Curing
Keetch-Byram
Drought Index
Dead fuel moistures
Live fuel moistures
Fuel Moistures
Fuel Model (Weighting)
Drought Fuel Load
Slope Class
Ignition
Component (IC)
Spread Component
(SC)
Burning Index
(BI)
Energy Release
Component
(ERC)
Outputs
Preparedness
Wildland Fire Response
Fire Danger Operating Plan
Staffing Plan
Preparedness Plan
Restriction Plan
Prevention Plan
Communication / Situational
Awareness Tools
Annual Operating Plan
Initial Reponse Plan (Dispatch)
Mobilization Plan
Applications

Things to know

- The absolute numbers will change!
- The absolute numbers will change!
- The absolute numbers will change!
- The percentiles should be comparable
- Consider comparing frequency in each staffing class
- Decimals matter and they are a good thing
- Fire Danger doesn't tell me anything about potential fire behavior
  - Not true…. That's next
- Fire Danger can be used to quantify actual energy release, spread rates or flame length? NO!

Contingency Plans

- Make the KBDI drought fuel loading optional
- Swap back in the old FM100 and FM1000 models
- Revert back to representative fuel models from the 1978 system

All future applications should consider….

- NEVER discussing absolute index values but rather use percentiles for all communications
- Consider selecting and calibrating TWO indices for a given area: one for preparedness decisions and the other for response decisions
- Objective criteria for Decision Points
  - Logistics regressions are meant to predict a yes or no response
- Bivariate evaluations or more (All we want is the best predictor

This is ONLY THE BEGINNING, GET USED TO CHANGE!

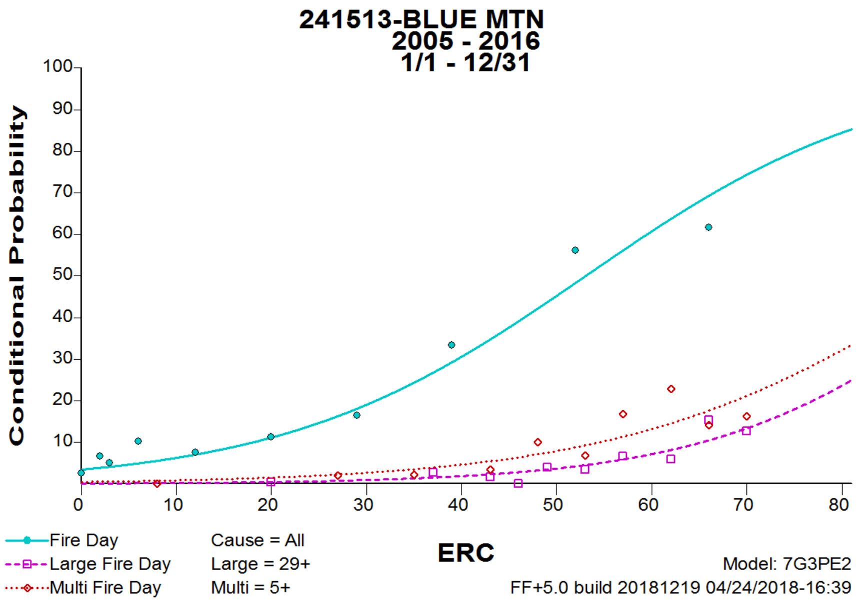
- But with less impact to you as a user / manager of NFDRS

Model Evaluation

Energy Release Component

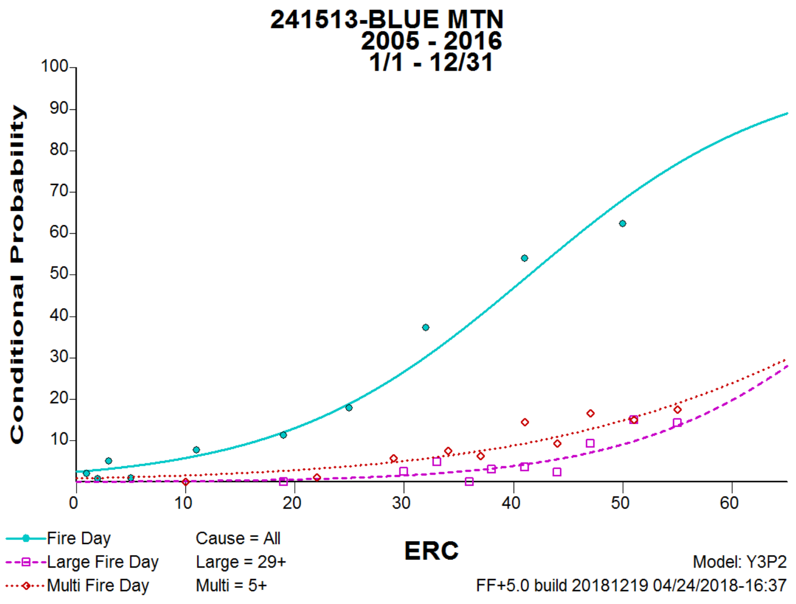
Fuel Model G

Chi Square	DF	P-Value	R(L)-Sq.
33.3	8	0.0001	0.97

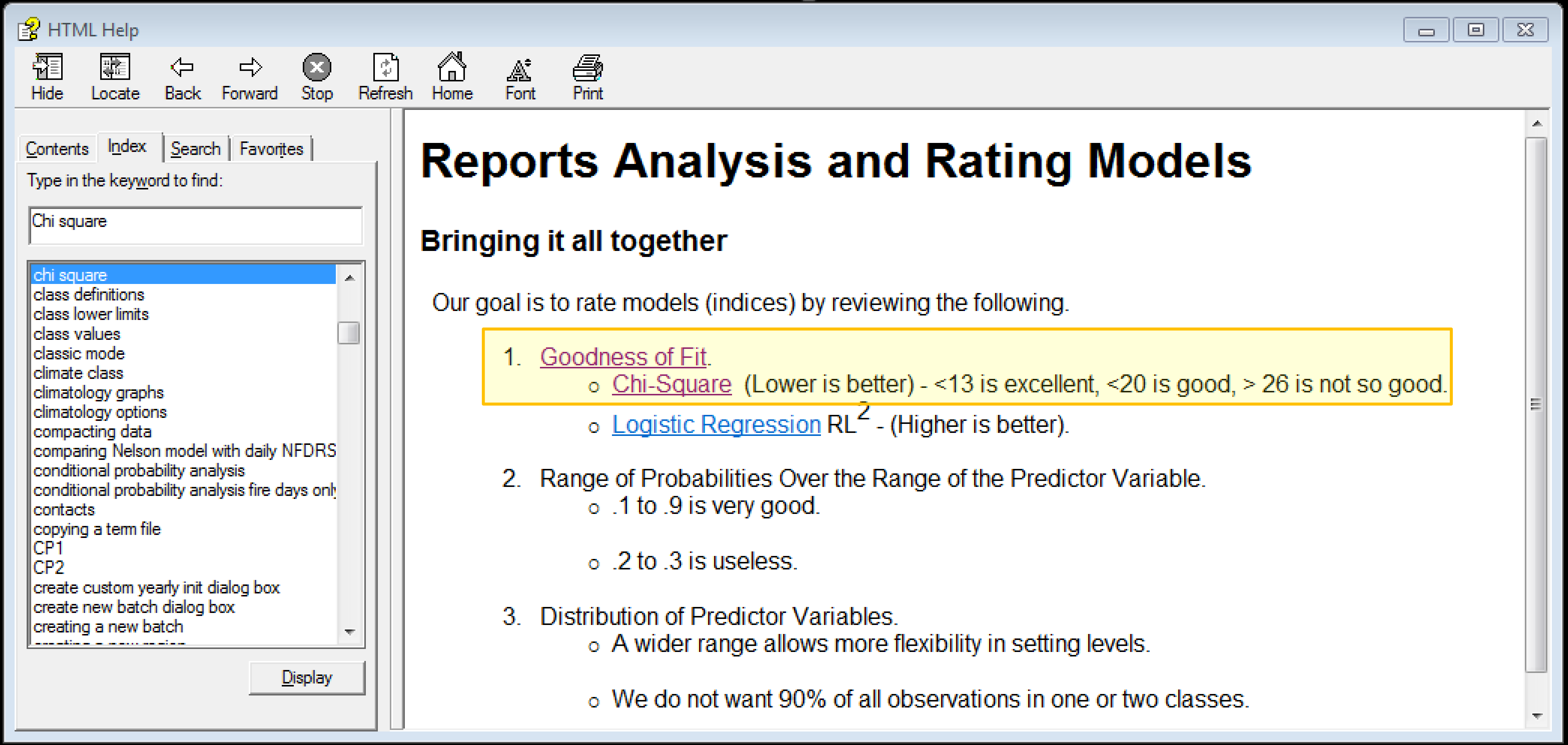


Fuel Model Y

Chi Square	DF	P-Value	R(L)-Sq.
33.3	8	0.0001	0.97

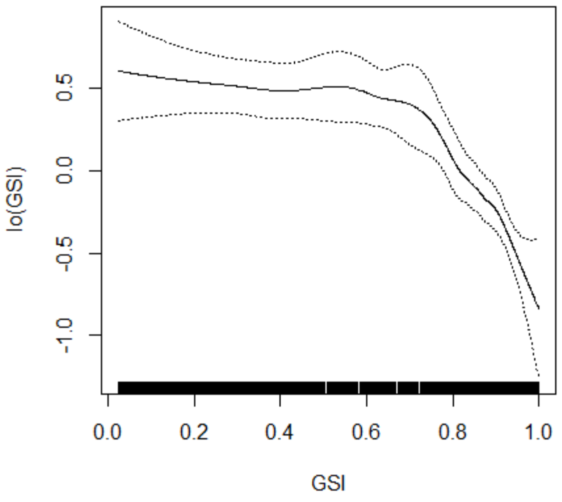


FireFamilyPlus 4.1



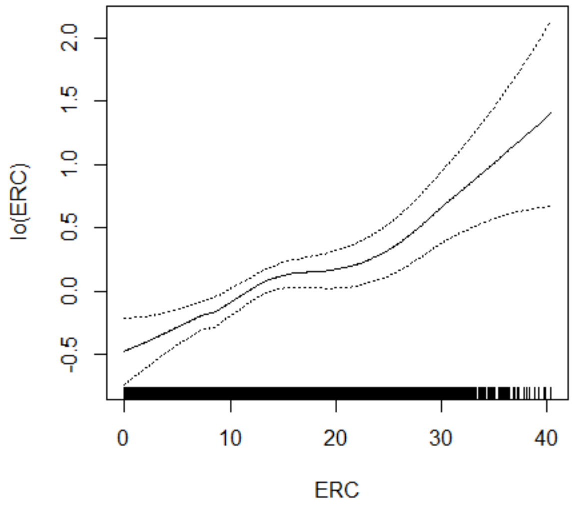
Predicting fire dangers as combinations of variables

GSI

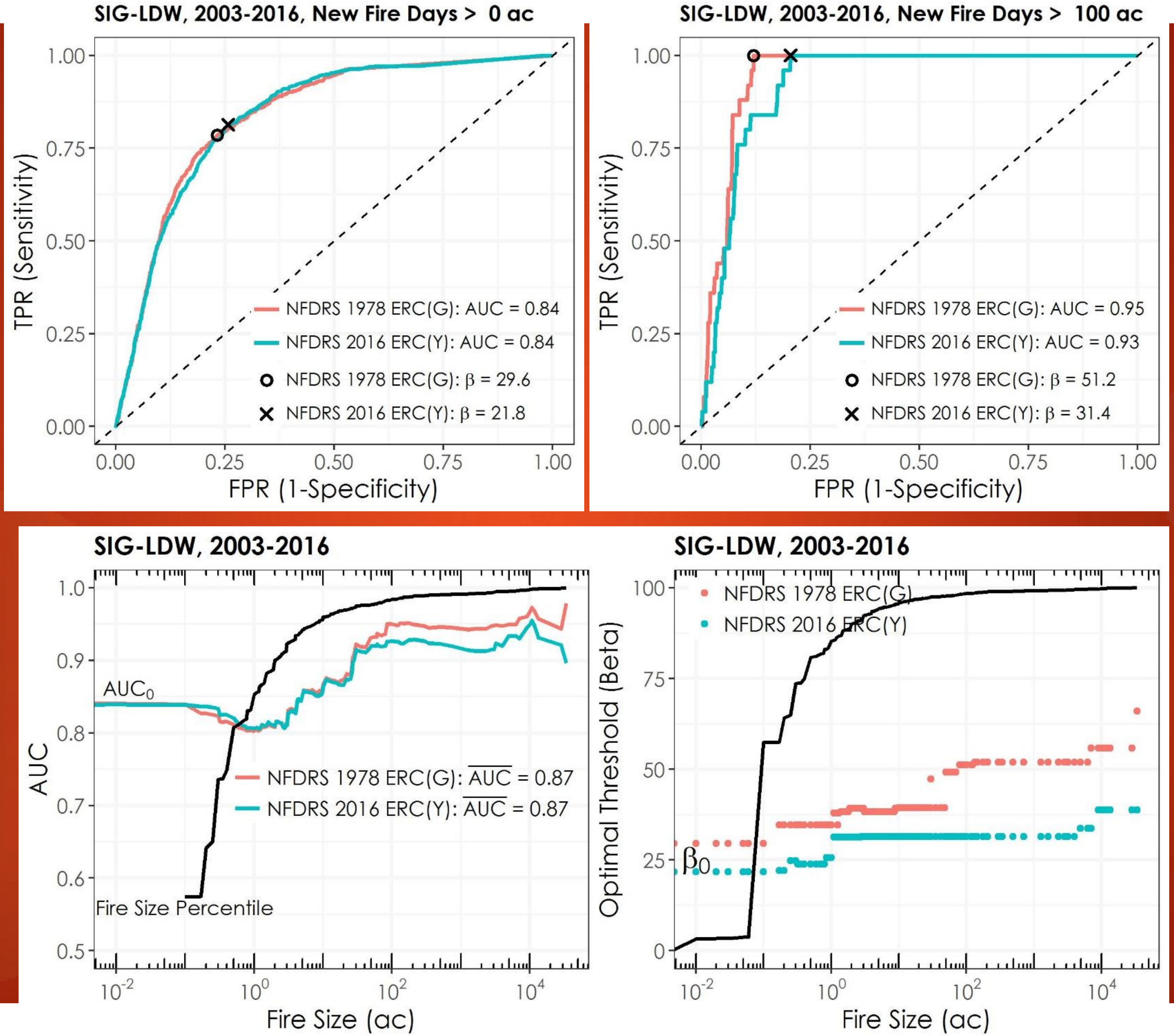


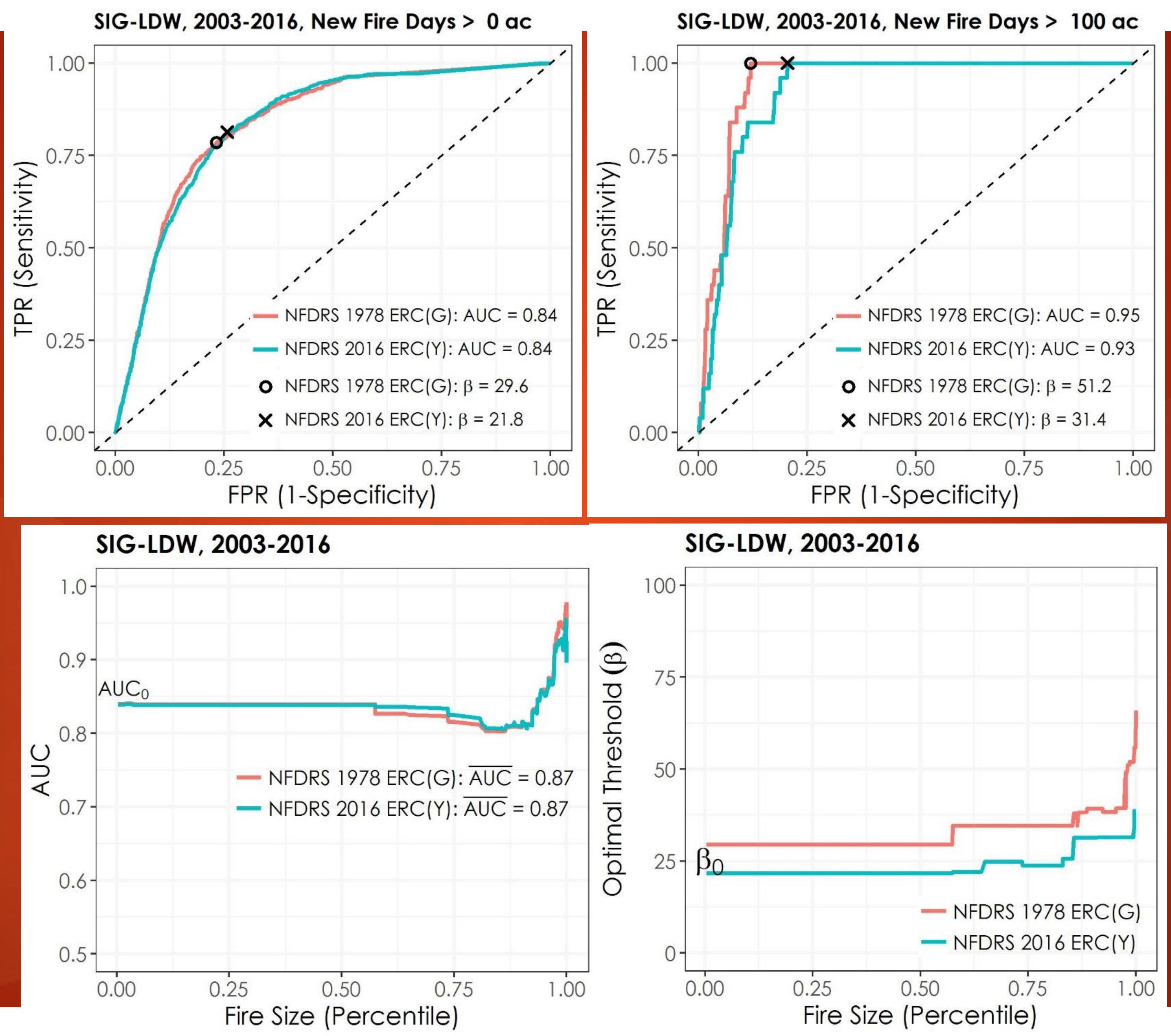
Not Linear

ERC

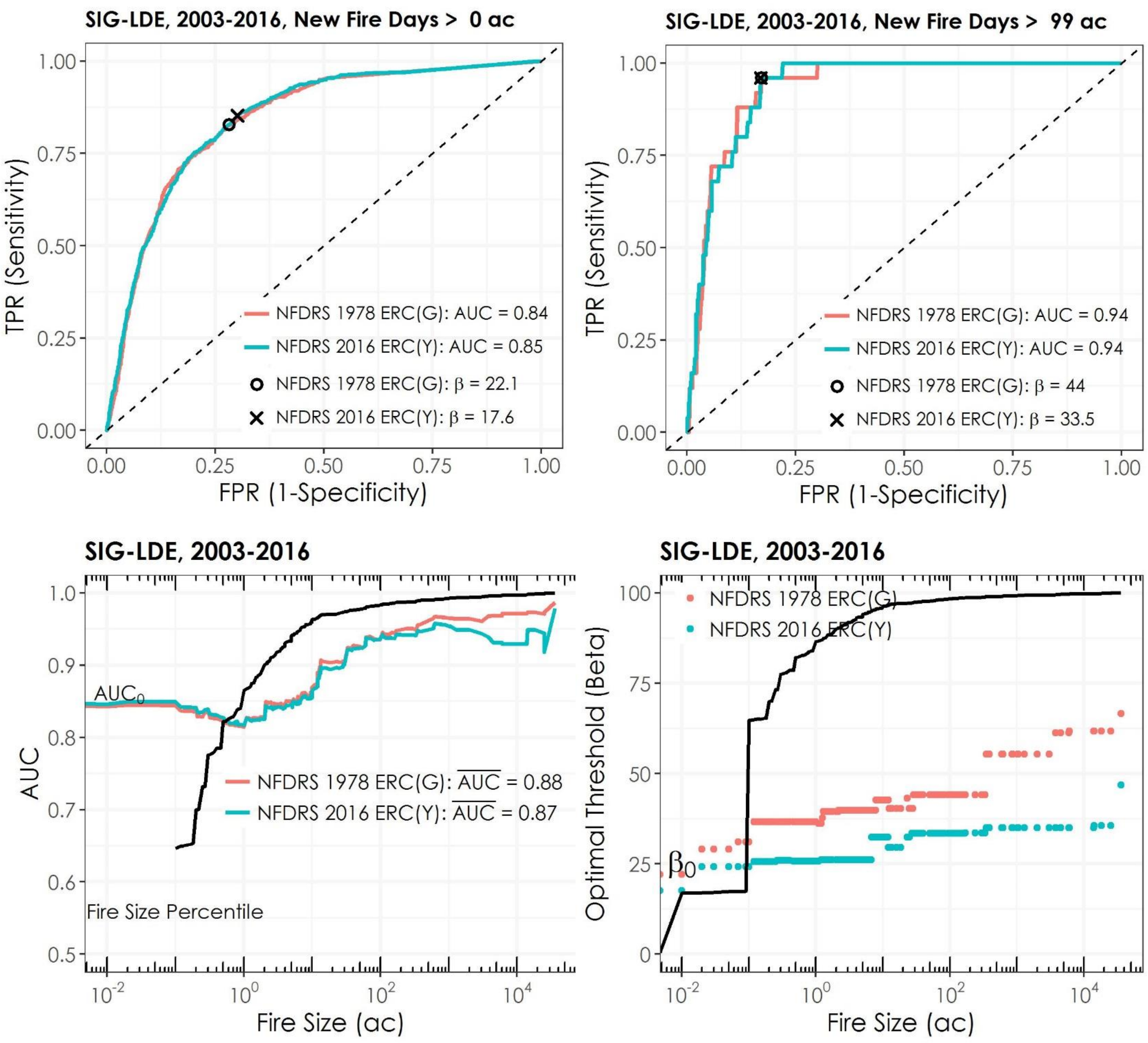


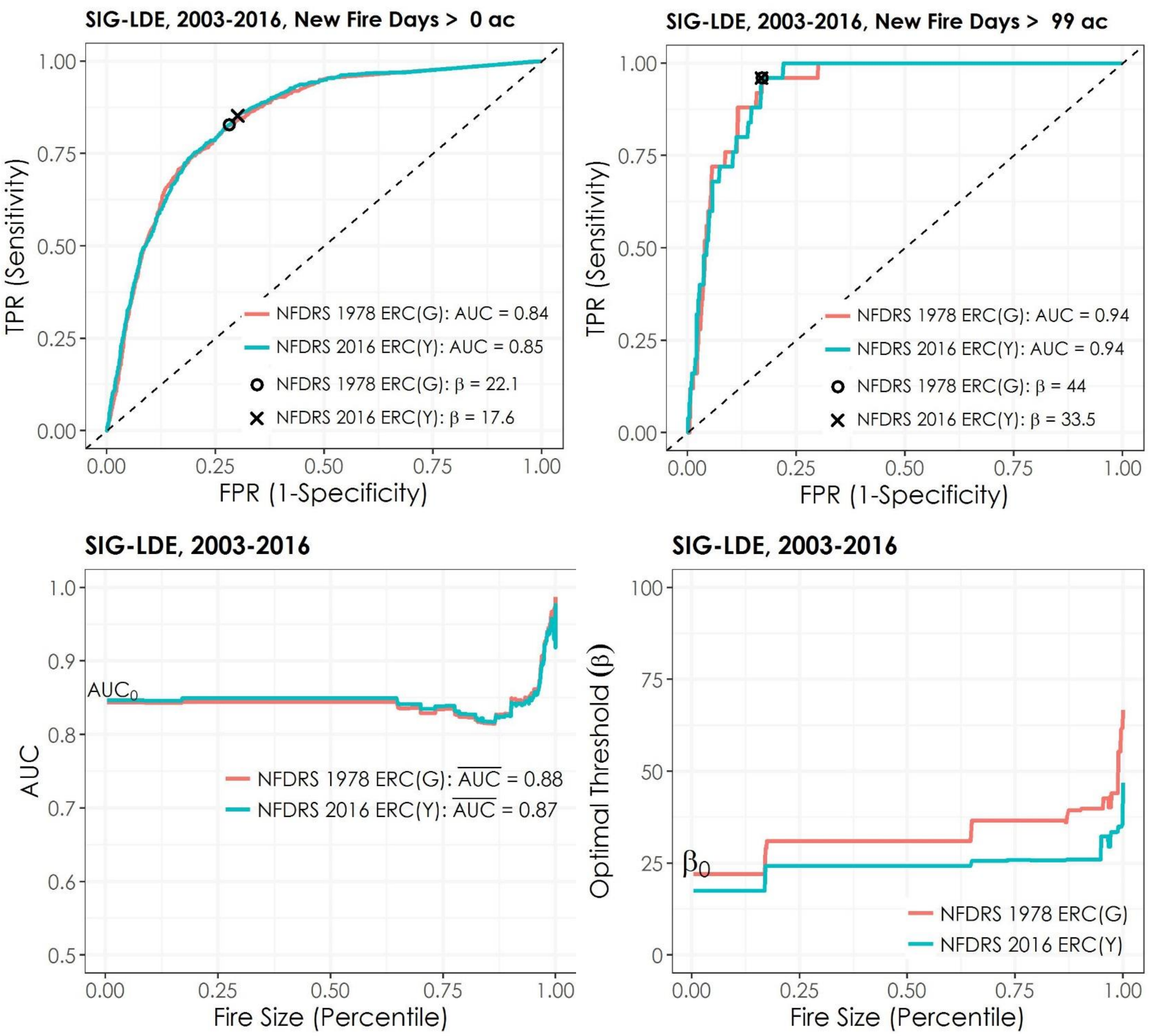
Linear


SIG-LDW, 2003-2016, New Fire Days > 0 ac
TPR (Sensitivity)
FPR (1-Specificity)
NFDRS 1978 ERC(G): AUC = 0.84
NFDRS 2016 ERC(Y): AUC = 0.84
NFDRS 1978 ERC(G): β = 29.6
NFDRS 2016 ERC(Y): β = 21.8
SIG-LDW, 2003-2016, New Fire Days > 100 ac
TPR (Sensitivity)
FPR (1-Specificity)
NFDRS 1978 ERC(G): AUC = 0.95
NFDRS 2016 ERC(Y): AUC = 0.93
NFDRS 1978 ERC(G): β = 51.2
NFDRS 2016 ERC(Y): β = 31.4
SIG-LDW, 2003-2016
AUC
AUC0
NFDRS 1978 ERC(G): AUC = 0.87
NFDRS 2016 ERC(Y): AUC = 0.87
Fire Size Percentile
Fire Size (ac)
SIG-LDW, 2003-2016
Optimal Threshold (Beta)
NFDRS 1978 ERC(G)
NFDRS 2016 ERC(Y)
β0
Fire Size (ac)

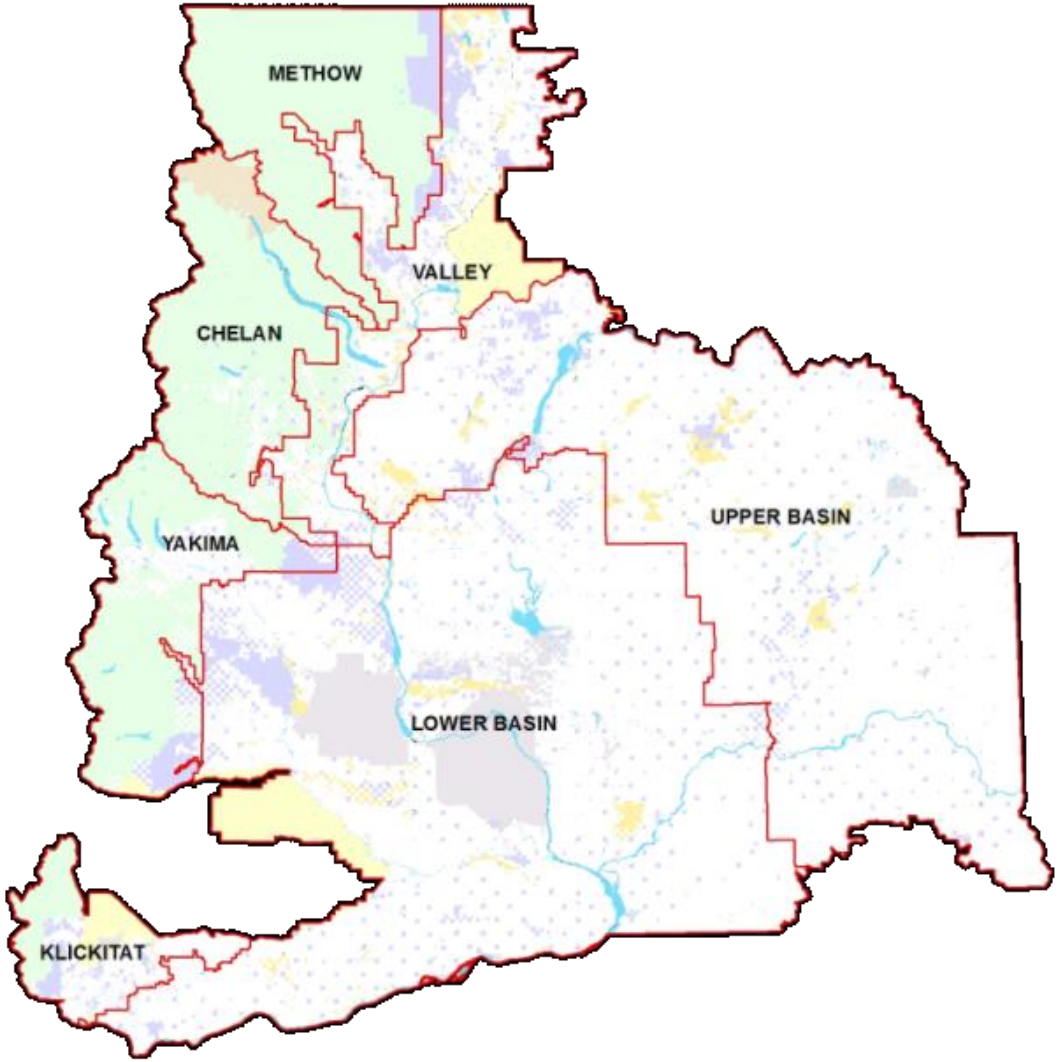


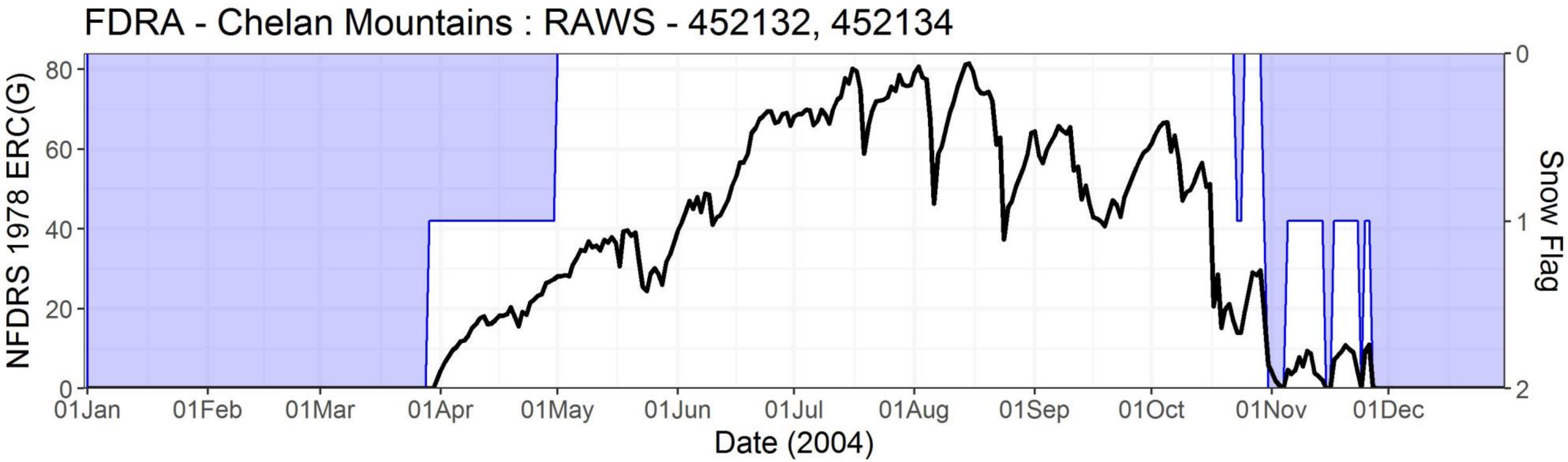
SIG-LDW, 2003-2016, New Fire Days > 0 ac
TPR (Sensitivity)
FPR (1-Specificity)
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
NFDRS 1978 ERC(G): AUC = 0.84
NFDRS 2016 ERC(Y): AUC = 0.84
NFDRS 1978 ERC(G): β = 29.6
NFDRS 2016 ERC(Y): β = 21.8
SIG-LDW, 2003-2016, New Fire Days > 100 ac
TPR (Sensitivity)
FPR (1-Specificity)
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
NFDRS 1978 ERC(G): AUC = 0.95
NFDRS 2016 ERC(Y): AUC = 0.93
NFDRS 1978 ERC(G): β = 51.2
NFDRS 2016 ERC(Y): β = 31.4
SIG-LDW, 2003-2016
AUC
Fire Size (Percentile)
1.0
0.9
0.8
0.7
0.6
0.5
0.00
0.25
0.50
0.75
1.00
AUC0
NFDRS 1978 ERC(G): AUC = 0.87
NFDRS 2016 ERC(Y): AUC = 0.87
SIG-LDW, 2003-2016
Optimal Threshold (β)
Fire Size (Percentile)
100
75
50
25
0
0.00
0.25
0.50
0.75
1.00
β0
NFDRS 1978 ERC(G)
NFDRS 2016 ERC(Y)

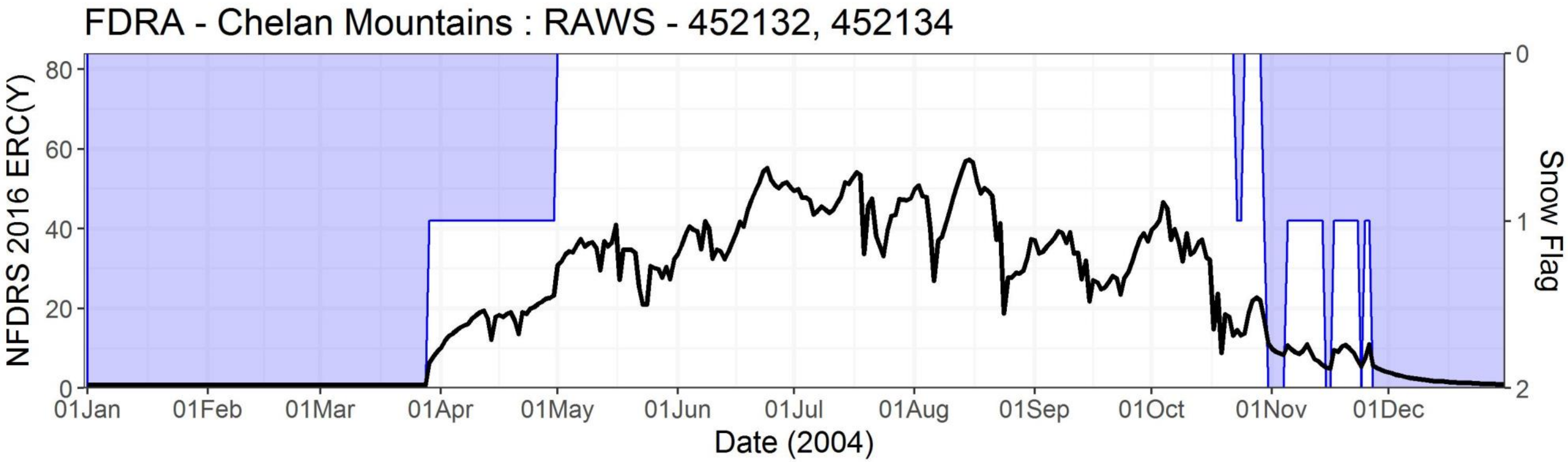

SIG-LDE, 2003-2016, New Fire Days > 0 ac
TPR (Sensitivity)
FPR (1-Specificity)
NFDRS 1978 ERC(G): AUC = 0.84
NFDRS 2016 ERC(Y): AUC = 0.85
NFDRS 1978 ERC(G): β = 22.1
NFDRS 2016 ERC(Y): β = 17.6
SIG-LDE, 2003-2016, New Fire Days > 99 ac
TPR (Sensitivity)
FPR (1-Specificity)
NFDRS 1978 ERC(G): AUC = 0.94
NFDRS 2016 ERC(Y): AUC = 0.94
NFDRS 1978 ERC(G): β = 44
NFDRS 2016 ERC(Y): β = 33.5
SIG-LDE, 2003-2016
AUC
AUC0
NFDRS 1978 ERC(G): AUC = 0.88
NFDRS 2016 ERC(Y): AUC = 0.87
Fire Size Percentile
Fire Size (ac)
SIG-LDE, 2003-2016
Optimal Threshold (Beta)
NFDRS 1978 ERC(G)
NFDRS 2016 ERC(Y)
β0
Fire Size (ac)

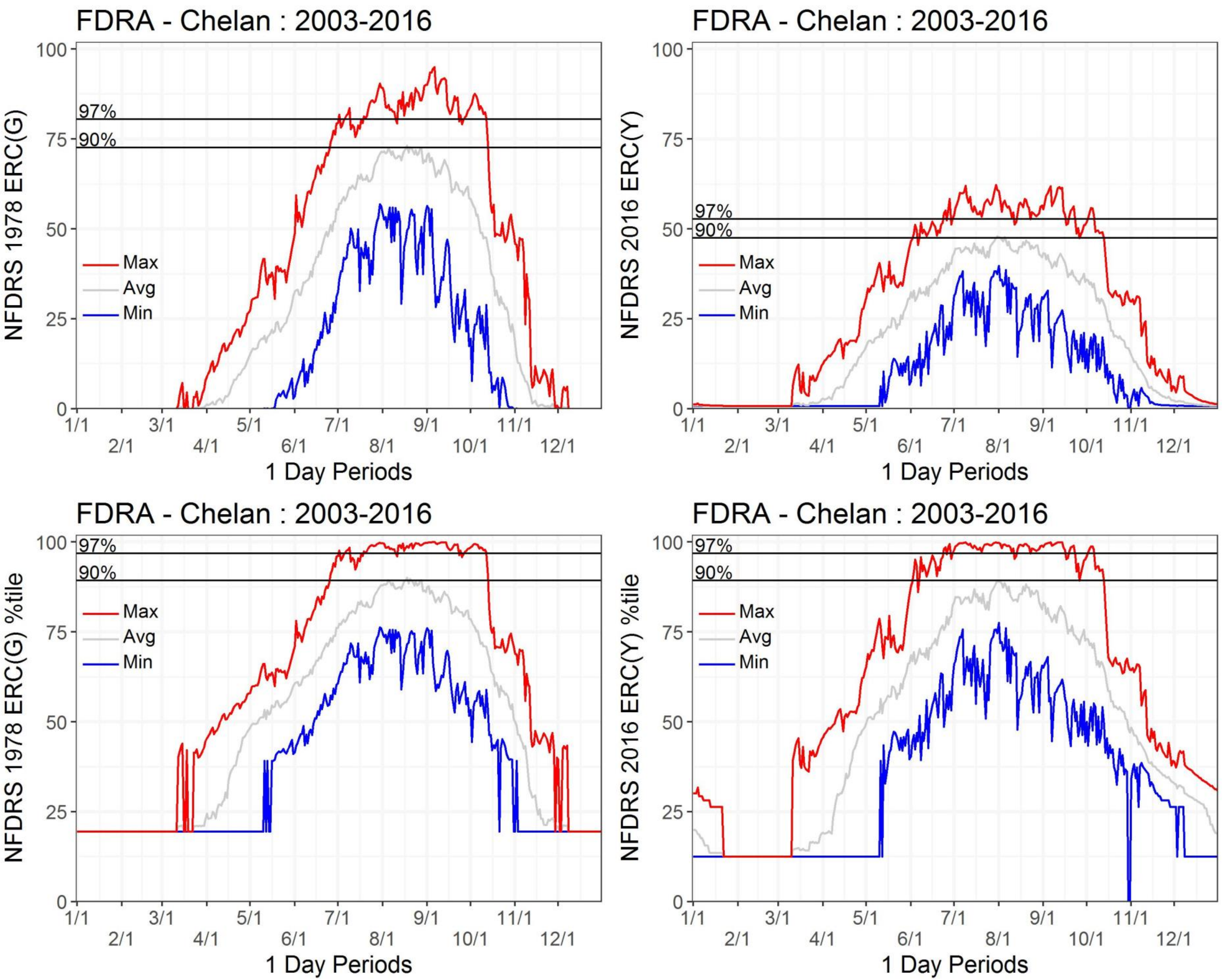

SIG-LDE, 2003-2016, New Fire Days > 0 ac
TPR (Sensitivity)
FPR (1-Specificity)
NFDRS 1978 ERC(G): AUC = 0.84
NFDRS 2016 ERC(Y): AUC = 0.85
NFDRS 1978 ERC(G): β = 22.1
NFDRS 2016 ERC(Y): β = 17.6
SIG-LDE, 2003-2016, New Fire Days > 99 ac
TPR (Sensitivity)
FPR (1-Specificity)
NFDRS 1978 ERC(G): AUC = 0.94
NFDRS 2016 ERC(Y): AUC = 0.94
NFDRS 1978 ERC(G): β = 44
NFDRS 2016 ERC(Y): β = 33.5
SIG-LDE, 2003-2016
AUC
AUC0
Fire Size (Percentile)
NFDRS 1978 ERC(G): AUC = 0.88
NFDRS 2016 ERC(Y): AUC = 0.87
SIG-LDE, 2003-2016
Optimal Threshold (β)
β0
Fire Size (Percentile)
NFDRS 1978 ERC(G)
NFDRS 2016 ERC(Y)

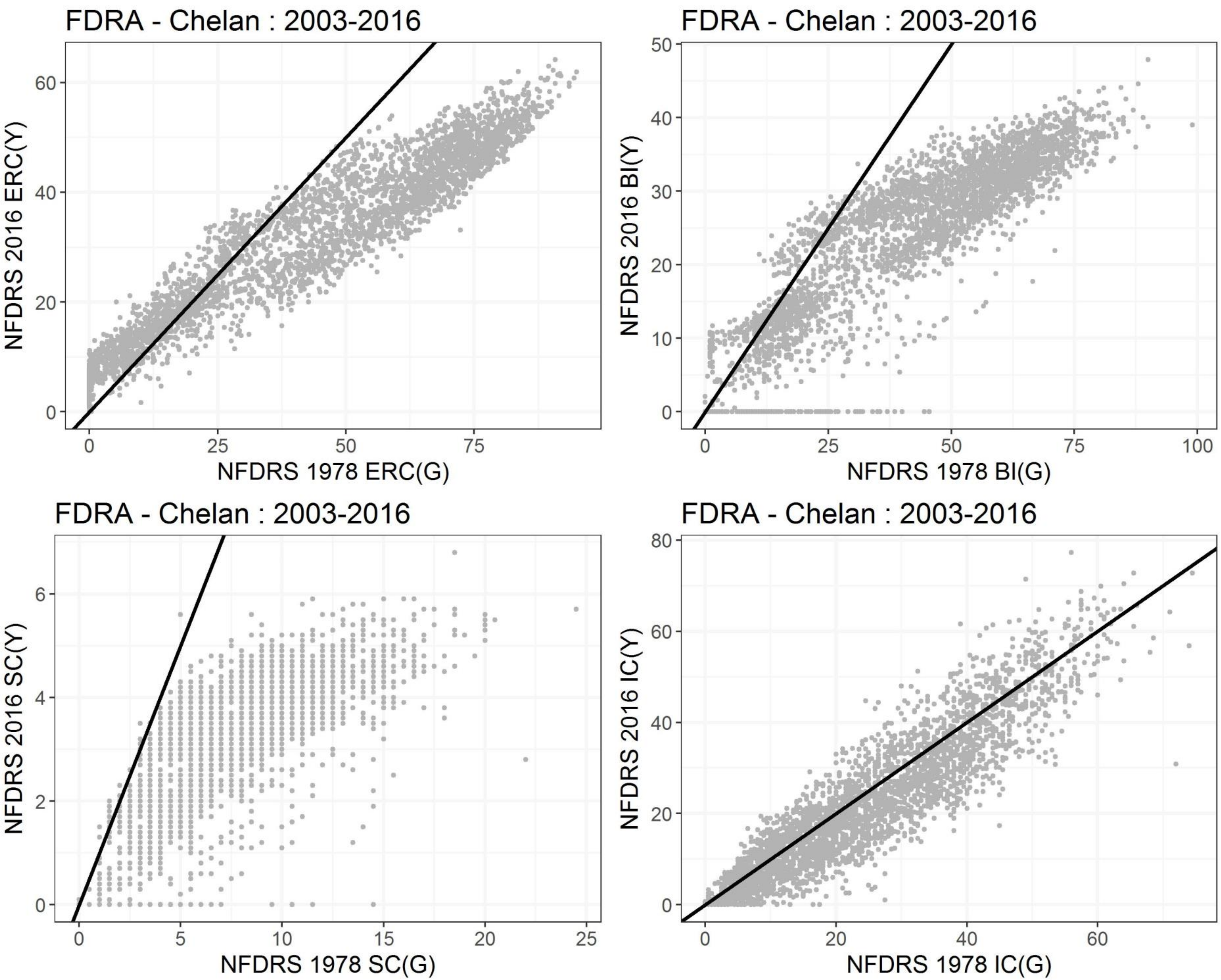
https://gacc.nifc.gov/nwcc/districts/CWICC/FDRA.html

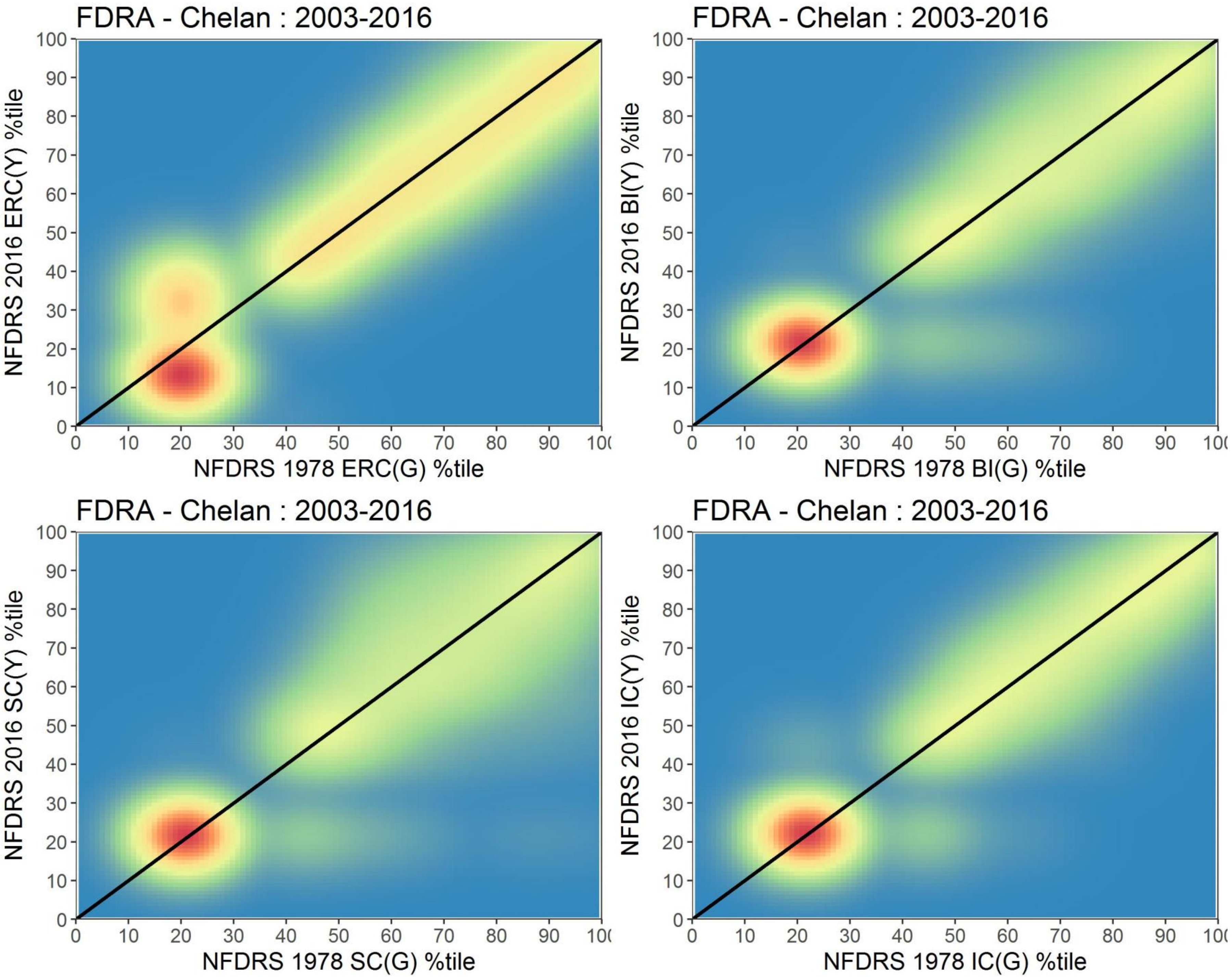



FDRA - Chelan Mountains : RAWS - 452132, 452134
NFDRS 1978 ERC(G)
Snow Flag
80
60
40
20
0
0
1
2
01Jan
01Feb
01Mar
01Apr
01May
01Jun
01Jul
01Aug
01Sep
01Oct
01Nov
01Dec
Date (2004)


FDRA - Chelan Mountains : RAWS - 452132, 452134
NFDRS 2016 ERC(Y)
Snow Flag
80
60
40
20
0
0
1
2
01Jan
01Feb
01Mar
01Apr
01May
01Jun
01Jul
01Aug
01Sep
01Oct
01Nov
01Dec
Date (2004)


FDRA - Chelan : 2003-2016
NFDRS 1978 ERC(G)
97%
90%
Max
Avg
Min
1 Day Periods
FDRA - Chelan : 2003-2016
NFDRS 2016 ERC(Y)
97%
90%
Max
Avg
Min
1 Day Periods
FDRA - Chelan : 2003-2016
NFDRS 1978 ERC(G) %tile
97%
90%
Max
Avg
Min
1 Day Periods
FDRA - Chelan : 2003-2016
NFDRS 2016 ERC(Y) %tile
97%
90%
Max
Avg
Min
1 Day Periods


FDRA - Chelan : 2003-2016
NFDRS 2016 ERC(Y)
NFDRS 1978 ERC(G)
FDRA - Chelan : 2003-2016
NFDRS 2016 BI(Y)
NFDRS 1978 BI(G)
FDRA - Chelan : 2003-2016
NFDRS 2016 SC(Y)
NFDRS 1978 SC(G)
FDRA - Chelan : 2003-2016
NFDRS 2016 IC(Y)
NFDRS 1978 IC(G)



FDRA - Chelan : 2003-2016
NFDRS 2016 ERC(Y) %tile
NFDRS 1978 ERC(G) %tile
FDRA - Chelan : 2003-2016
NFDRS 2016 BI(Y) %tile
NFDRS 1978 BI(G) %tile
FDRA - Chelan : 2003-2016
NFDRS 2016 SC(Y) %tile
NFDRS 1978 SC(G) %tile
FDRA - Chelan : 2003-2016
NFDRS 2016 IC(Y) %tile
NFDRS 1978 IC(G) %tile
0
10
20
30
40
50
60
70
80
90
100

FDRA – Chelan : 2003 – 2016 : 5607 days

			NFDRS 2016 ERC(Y)					
			(0,22.5]	(22.5,45]	(45,90]	(90,97]	(97,100]	
			SL 1	SL 2	SL 3	SL 4	SL 5	
NFDRS 1978 ERC(G)	(0,22.5]	SL 1	**1406**	**777**	0	0	0	2183
	(22.5,45]	SL 2	**1**	**266**	**72**	0	0	339
	(45,90]	SL 3	0	**72**	**2292**	**141**	**17**	2522
	(90,97]	SL 4	0	0	**153**	**190**	**52**	395
	(97,100]	SL 5	0	0	**4**	**64**	**100**	168
			1407	1115	2521	395	169	5607

From WIMS User's Guide Appendix E. NFDRS Technical Reference

http://pnwnfdr.pythonanywhere.com/wacwc/chelan/

Staffing Levels (1-5) - Divisions of Energy Release Component Fuel Model-G (37|52|69|76) based on historic Problem Fire occurrence:

-60% of Problem Fires were discovered at Staffing Level 5

-30% of Problem Fires were discovered at Staffing Level 4

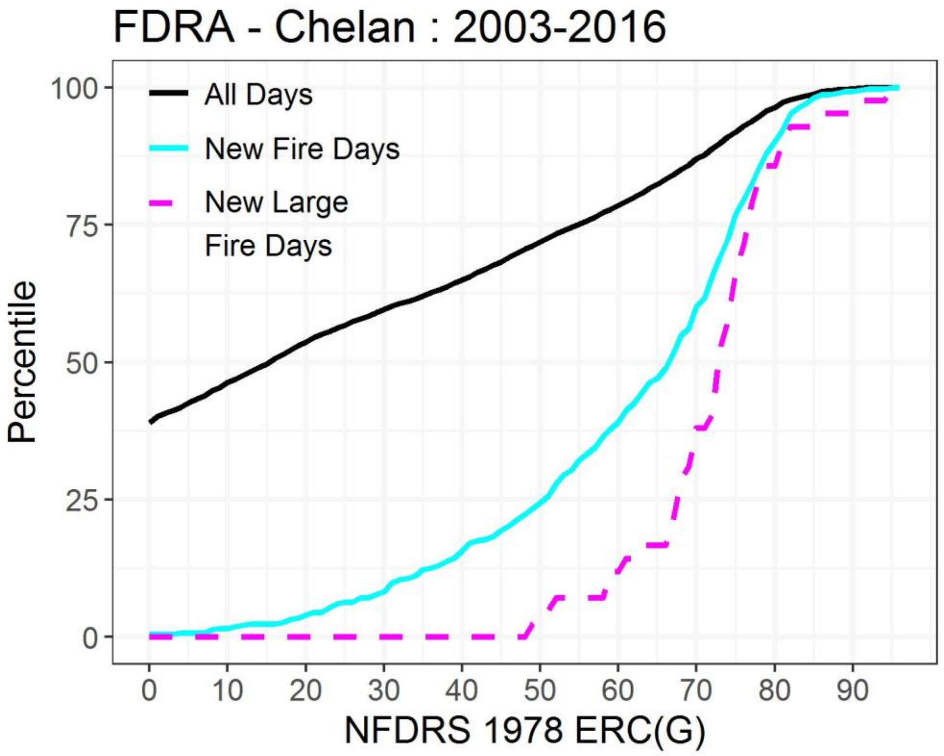
-10% of Problem Fires were discovered at Staffing Level 3

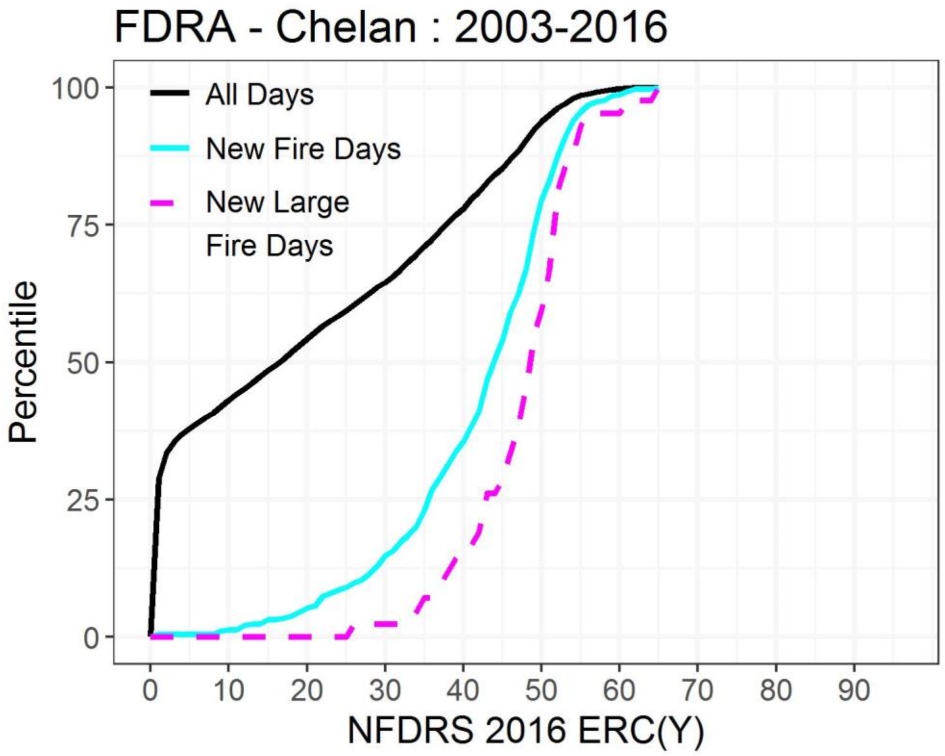
-No Problem Fires have been discovered at Staffing Level 1 or 2

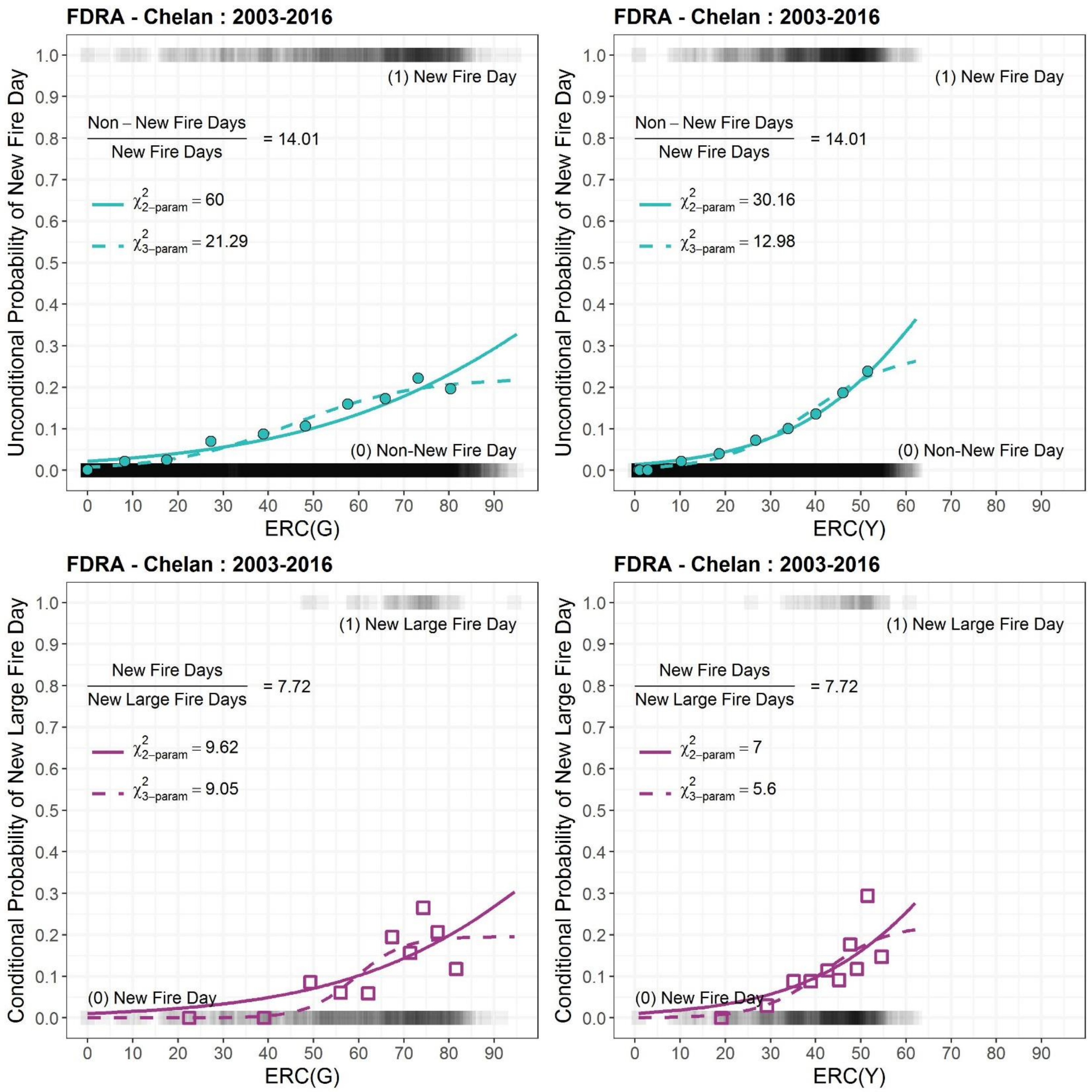
**Note that Staffing Level is date limited such that Levels 3, 4, and 5 will not be reached until 3, 2, and 1 week prior to the earliest historic occurrence of a Problem Fire (6/26).*

http://pnwnfdr.pythonanywhere.com/wacwc/chelan/

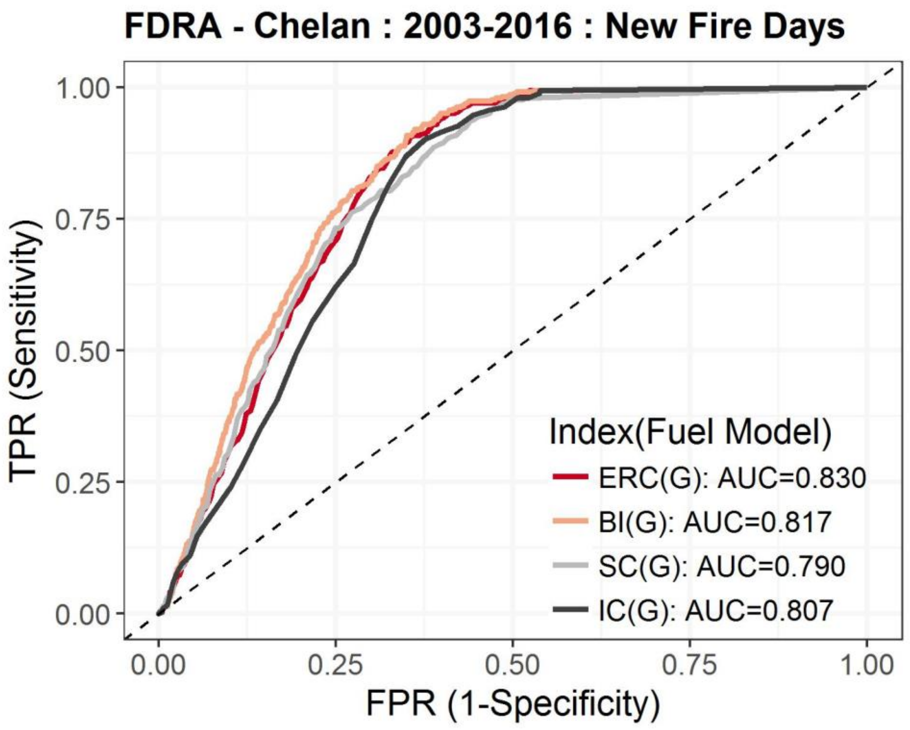
Problem Fire - A fire with a final size of 100+ acres, fires of this size are considered a problem for typical resource staffing.

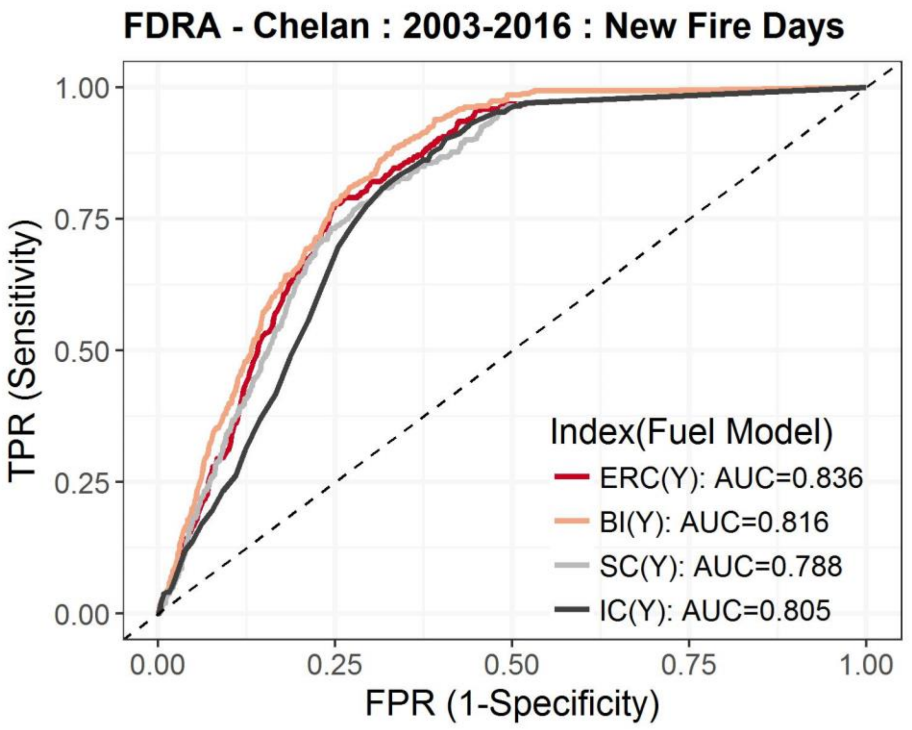




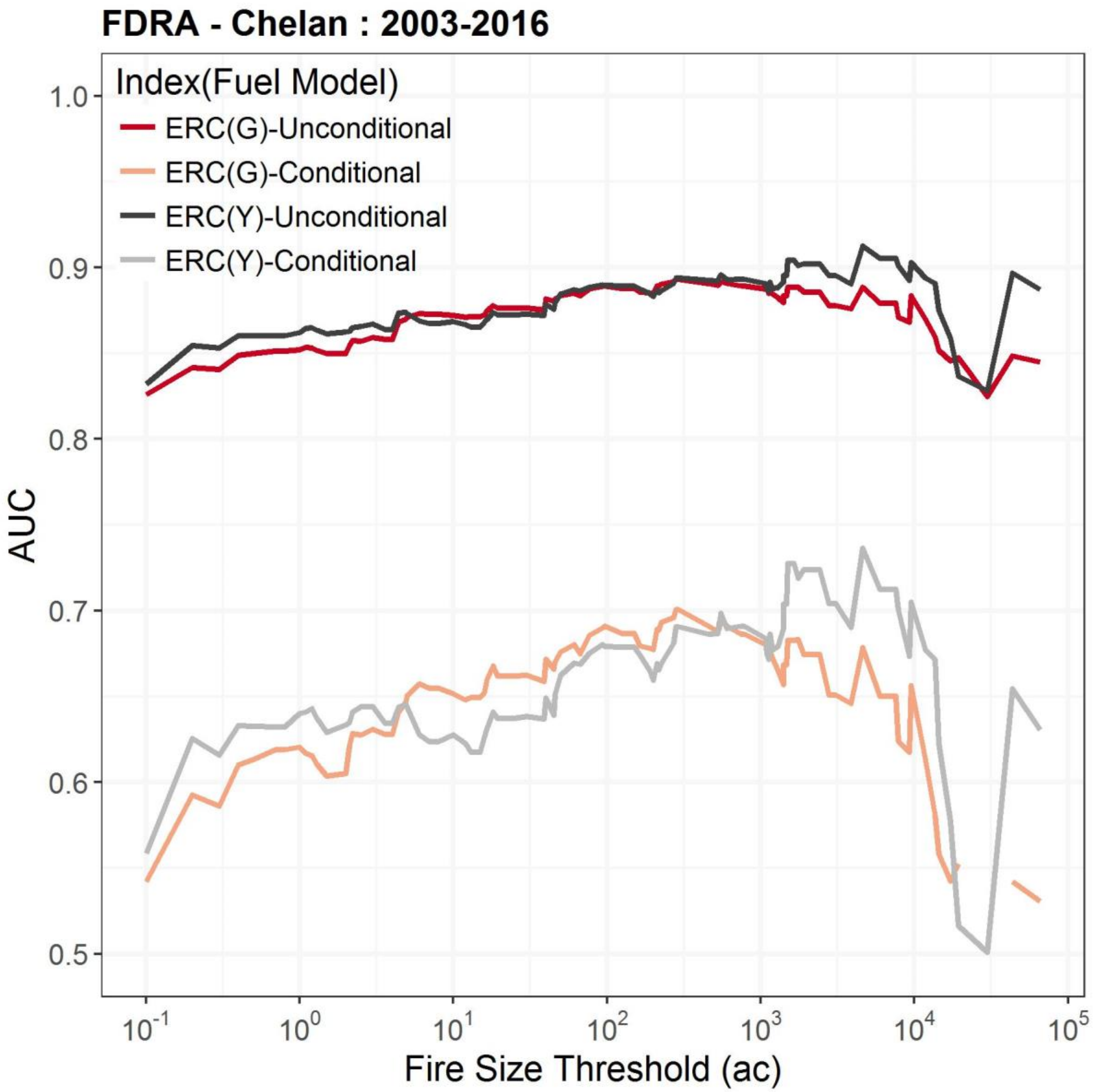


FDRA - Chelan : 2003-2016
Unconditional Probability of New Fire Day
(1) New Fire Day
Non – New Fire Days / New Fire Days = 14.01
$\chi^2_{2-param}$ = 60
$\chi^2_{3-param}$ = 21.29
(0) Non-New Fire Day
ERC(G)
FDRA - Chelan : 2003-2016
Unconditional Probability of New Fire Day
(1) New Fire Day
Non – New Fire Days / New Fire Days = 14.01
$\chi^2_{2-param}$ = 30.16
$\chi^2_{3-param}$ = 12.98
(0) Non-New Fire Day
ERC(Y)
FDRA - Chelan : 2003-2016
Conditional Probability of New Large Fire Day
(1) New Large Fire Day
New Fire Days / New Large Fire Days = 7.72
$\chi^2_{2-param}$ = 9.62
$\chi^2_{3-param}$ = 9.05
(0) New Fire Day
ERC(G)
FDRA - Chelan : 2003-2016
Conditional Probability of New Large Fire Day
(1) New Large Fire Day
New Fire Days / New Large Fire Days = 7.72
$\chi^2_{2-param}$ = 7
$\chi^2_{3-param}$ = 5.6
(0) New Fire Day
ERC(Y)





SIG	Index	Fuel_Model	Years	Number_Yrs	FD_AUROCC	Num_All_Days	Num_Fire_Days
Chelan	ERC	G	2003_2016	14	0.830	5104	340
Chelan	BI	G	2003_2016	14	0.817	5104	340
Chelan	SC	G	2003_2016	14	0.790	5104	340
Chelan	IC	G	2003_2016	14	0.807	5104	340
Chelan	ERC	Y	2003_2016	14	0.836	5104	340
Chelan	BI	Y	2003_2016	14	0.816	5104	340
Chelan	SC	Y	2003_2016	14	0.788	5104	340
Chelan	IC	Y	2003_2016	14	0.805	5104	340

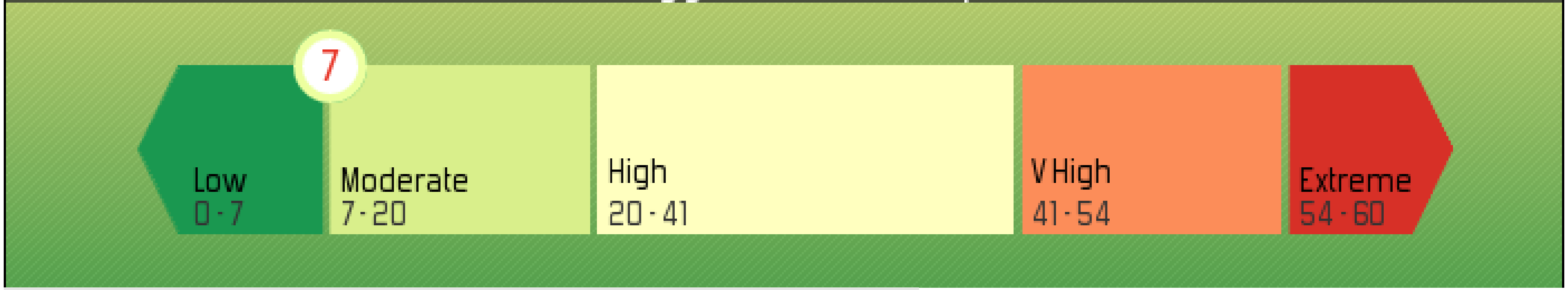

FDRA - Chelan : 2003-2016
Index(Fuel Model)
ERC(G)-Unconditional
ERC(G)-Conditional
ERC(Y)-Unconditional
ERC(Y)-Conditional
AUC
1.0
0.9
0.8
0.7
0.6
0.5
10^-1
10^0
10^1
10^2
10^3
10^4
10^5
Fire Size Threshold (ac)

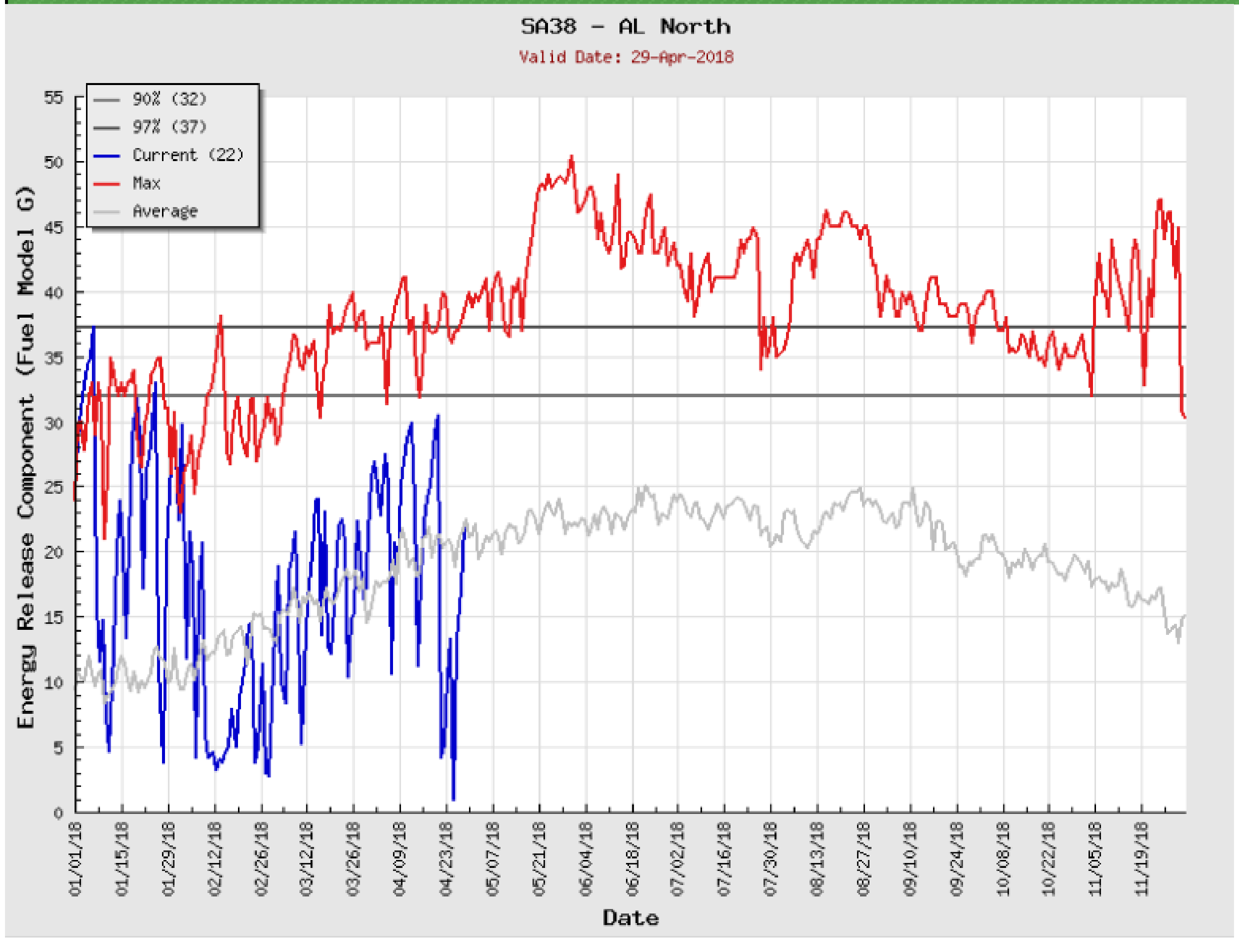
The Future of Fire Danger in the United States

The future of NFDRS

- Integrate overstory into Fire Danger Calculation
- Spatial WIMS
  - With password-free data access
- Seven day forecasts from the NWS NDFD
- Two week forecasts from GFS
- Better evaluation data (growth days versus report days)

Fire Environment Indicator - Energy Release Component (NR03) (04/30/2018)



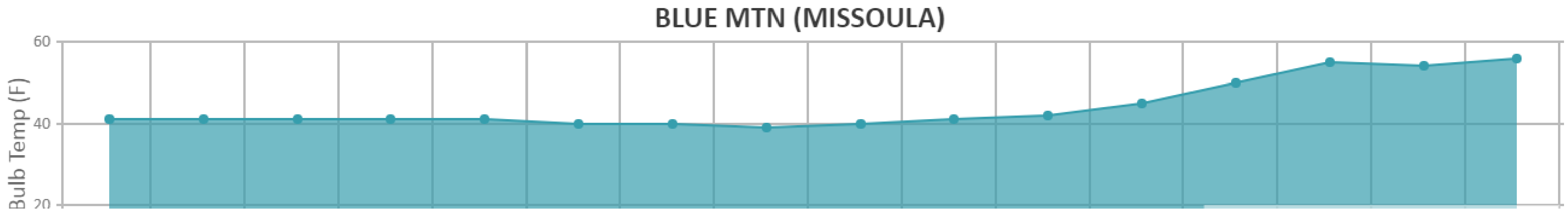


Secure | https://m.wfas.net/wims.php?StationID=241513

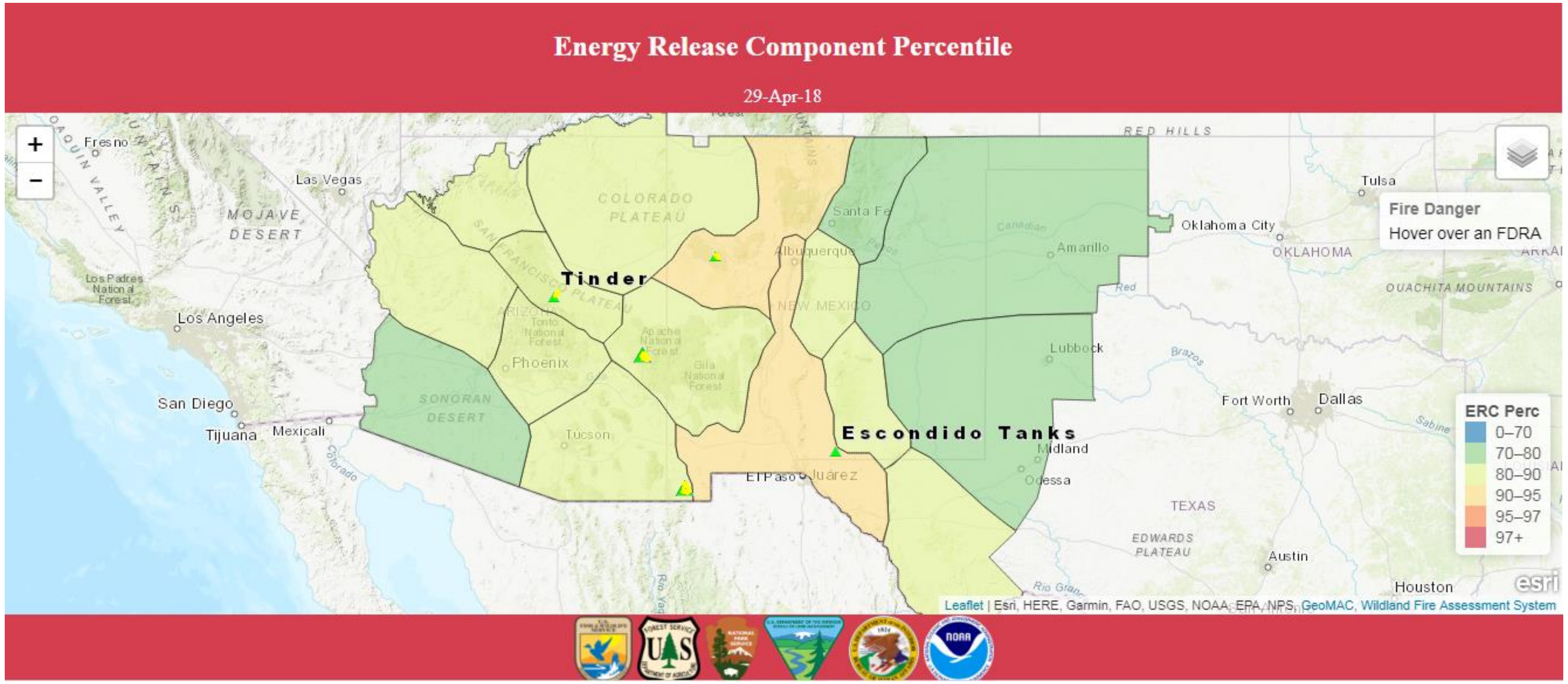
Apps Southern Bite - Stac SnipSave - Online co RAWS FW13 WFDSS app.climateengine.o RMRS Missoula - Ho Scrible Golden Gate Weathe » Other boo

BLUE MTN (MISSOULA) (241513)

Date	Hour	Dry Bulb (F)	RH (%)	Windspeed (mph)	Wet Flag	Snow Flag
04/30/2018	0	41	100	0	N	N
04/30/2018	1	41	100	0	N	N
04/30/2018	2	41	100	0	N	N
04/30/2018	3	41	100	0	N	N
04/30/2018	4	41	100	0	N	N
04/30/2018	5	40	99	0	N	N
04/30/2018	6	40	100	0	N	N
04/30/2018	7	39	98	1	N	N
04/30/2018	8	40	98	0	N	N
04/30/2018	9	41	95	0	N	N
04/30/2018	10	42	97	1	N	N
04/30/2018	11	45	88	1	N	N
04/30/2018	12	50	77	2	N	N
04/30/2018	13	55	62	2	N	N
04/30/2018	14	54	53	3	N	N
04/30/2018	15	56	49	1	N	N



https://www.wfas.net/prototypes/swcc/

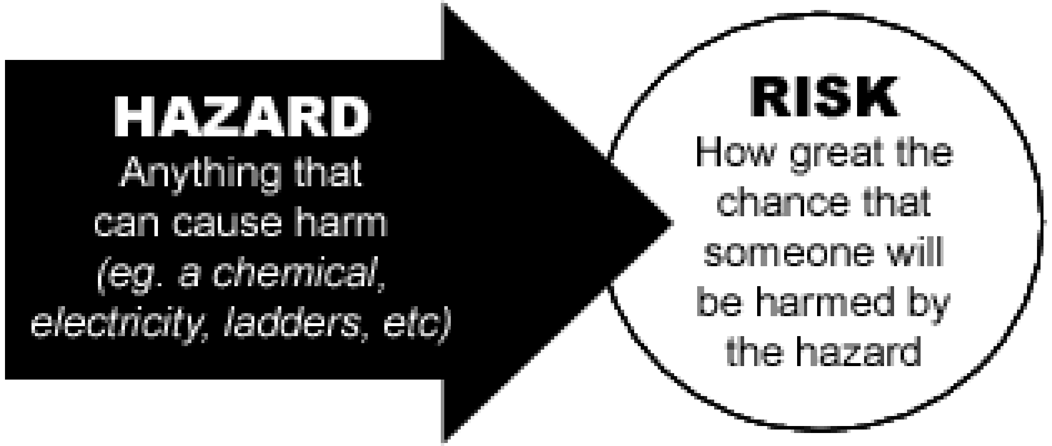


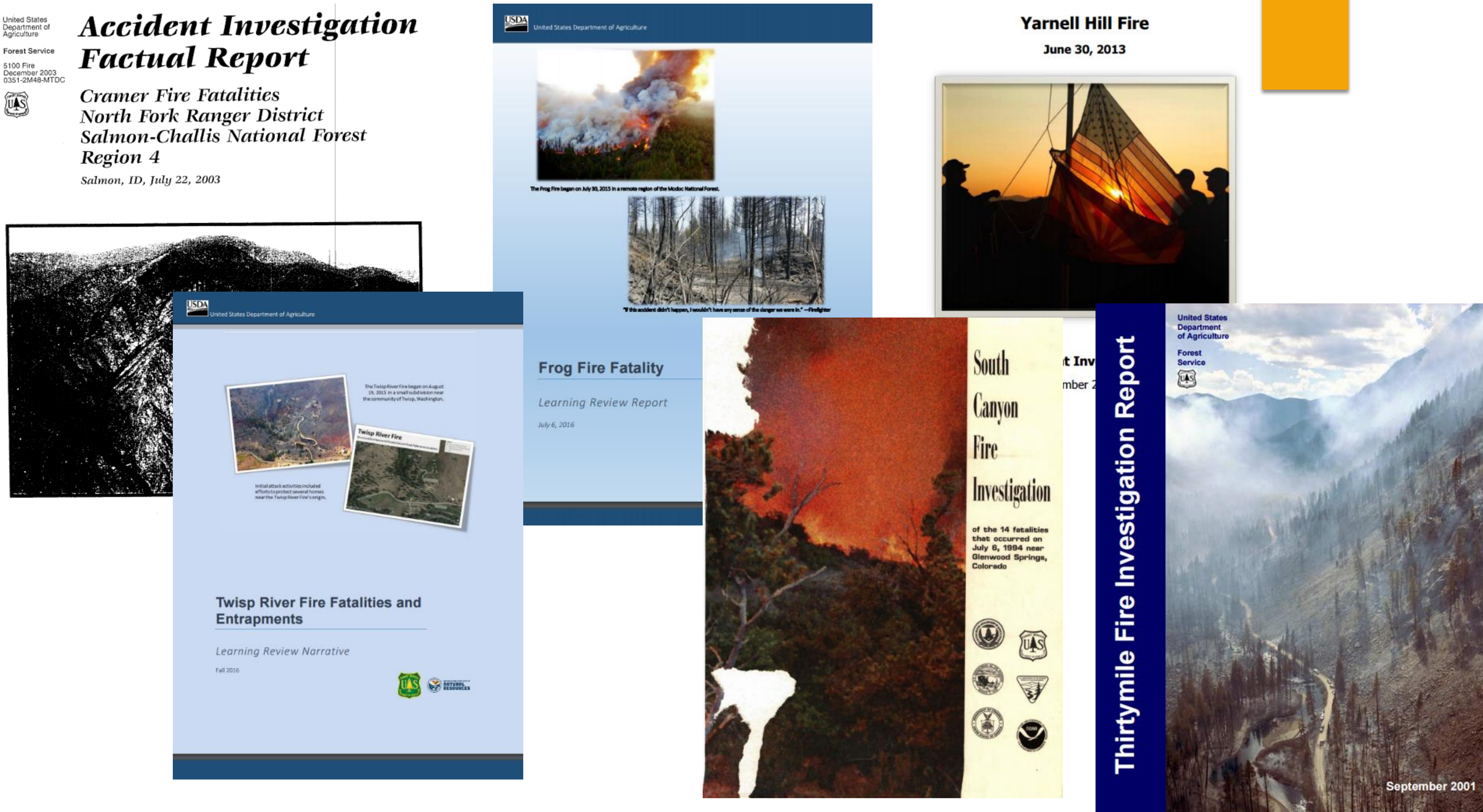
Risk = Hazard X Exposure

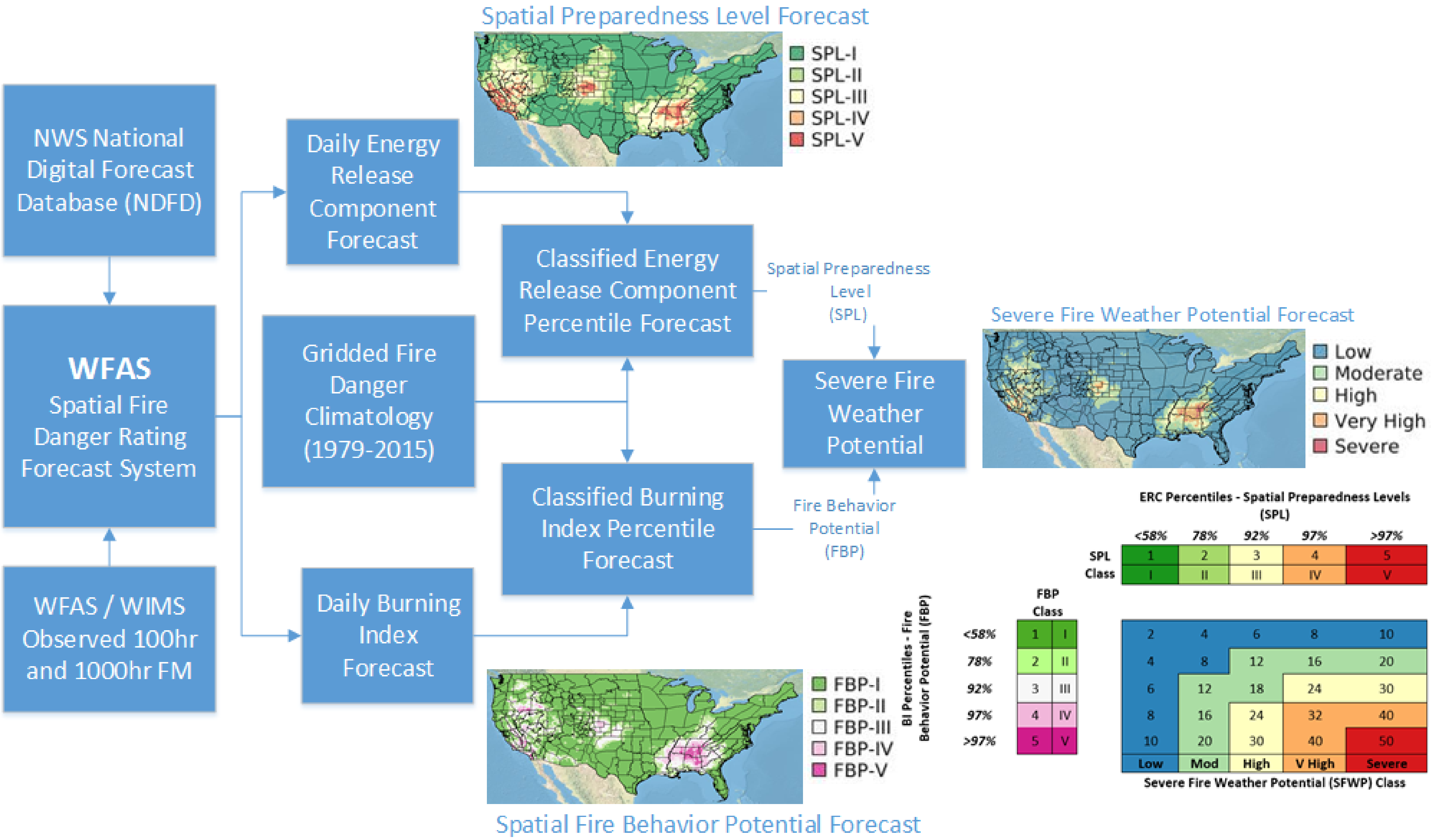
Hazard: Anything that can cause harm

Exposure: Dose, duration, frequency

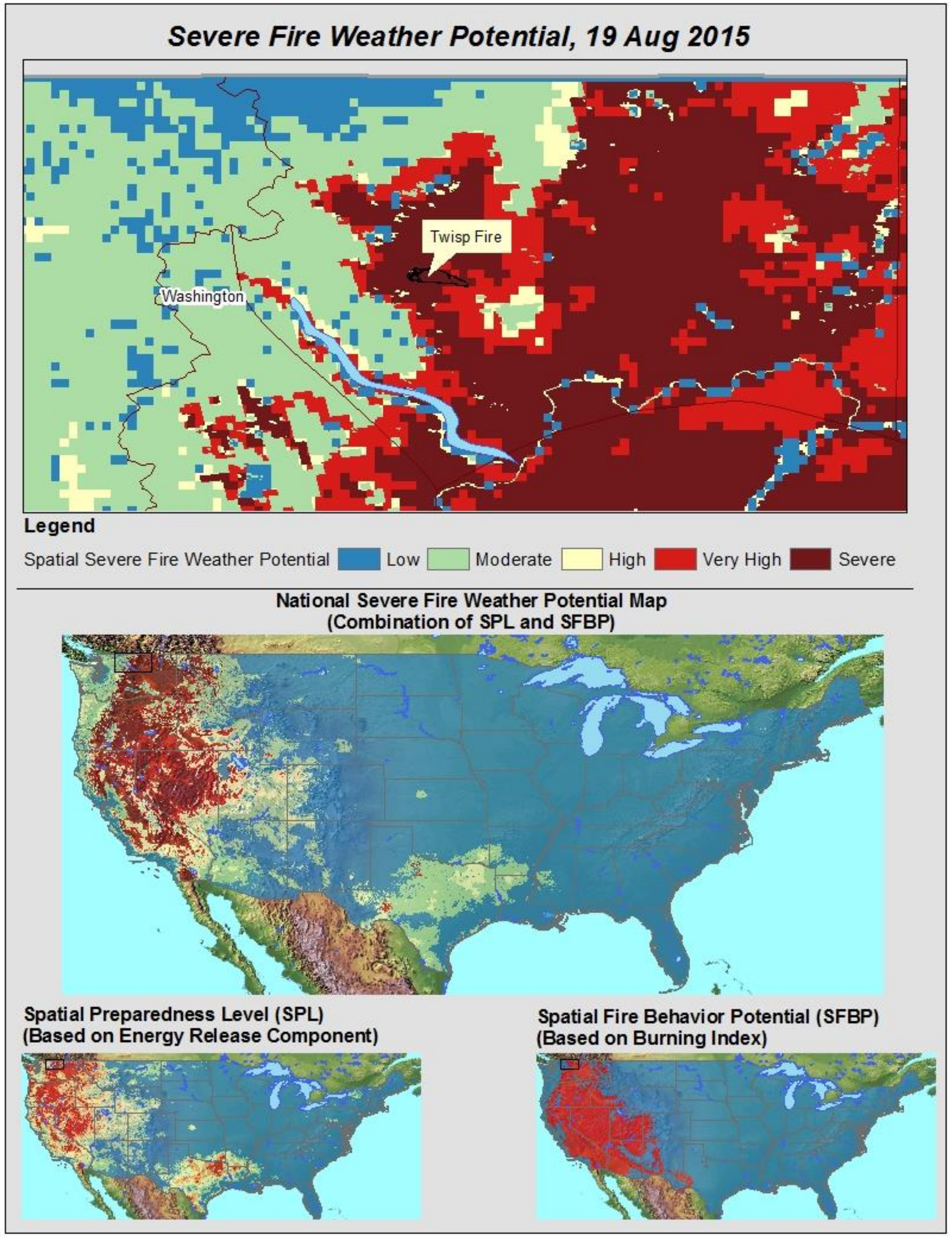
We will focus on Operational Risk

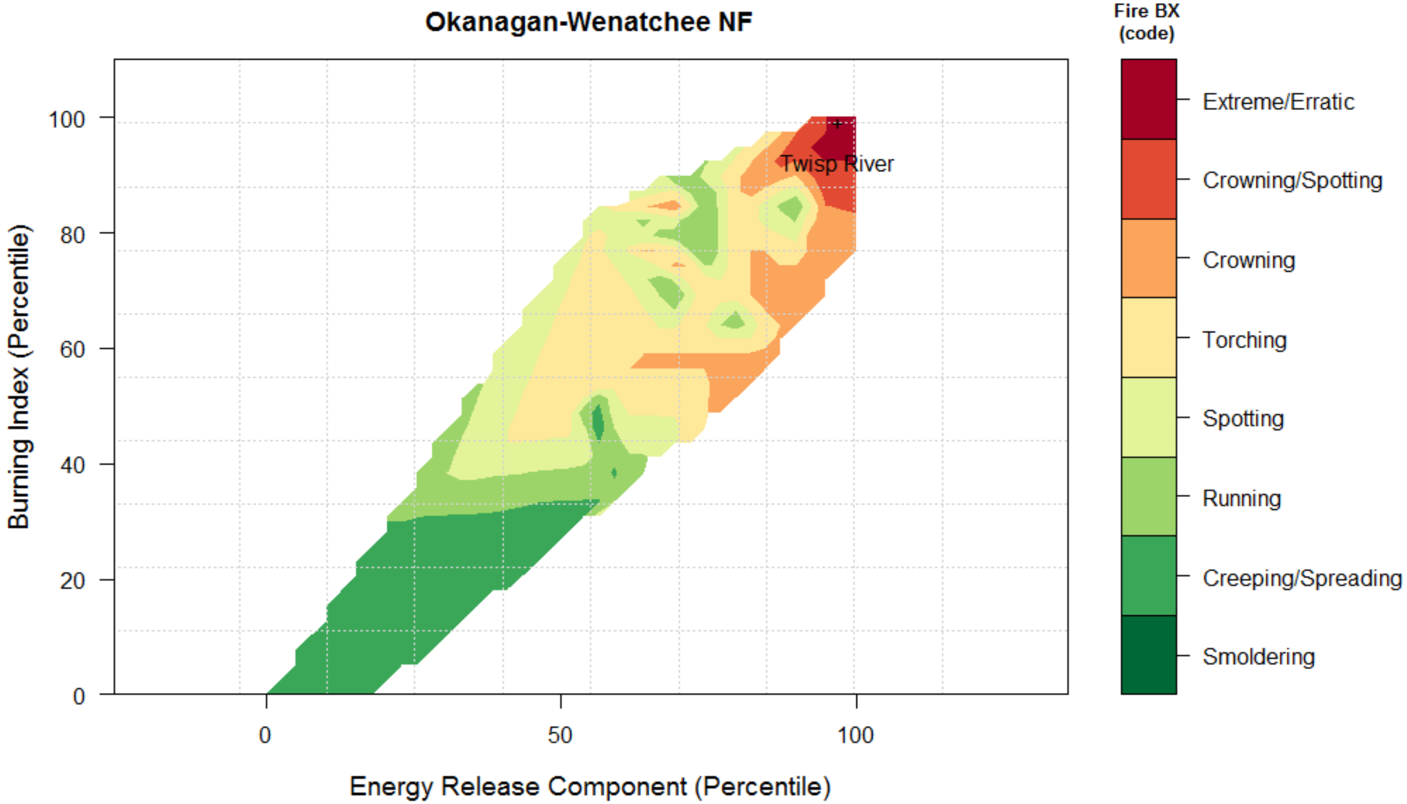



United States Department of Agriculture
Forest Service
5100 Fire
December 2003
0351-2M48-MTDC
Accident Investigation Factual Report
Cramer Fire Fatalities
North Fork Ranger District
Salmon-Challis National Forest
Region 4
Salmon, ID, July 22, 2003
USDA United States Department of Agriculture
The Frog Fire began on July 30, 2015 in a remote region of the Modoc National Forest.
"If this accident didn't happen, I wouldn't have any sense of the danger we were in." —Firefighter
Frog Fire Fatality
Learning Review Report
July 6, 2016
Yarnell Hill Fire
June 30, 2013
USDA United States Department of Agriculture
The Twisp River Fire began on August 19, 2015 in a small subdivision near the community of Twisp, Washington.
Twisp River Fire
Initial attack activities included efforts to protect several homes near the Twisp River Fire's origin.
Twisp River Fire Fatalities and Entrapments
Learning Review Narrative
Fall 2016
South Canyon Fire Investigation
of the 14 fatalities that occurred on July 6, 1994 near Glenwood Springs, Colorado
Thirtymile Fire Investigation Report
United States Department of Agriculture
Forest Service
September 2001



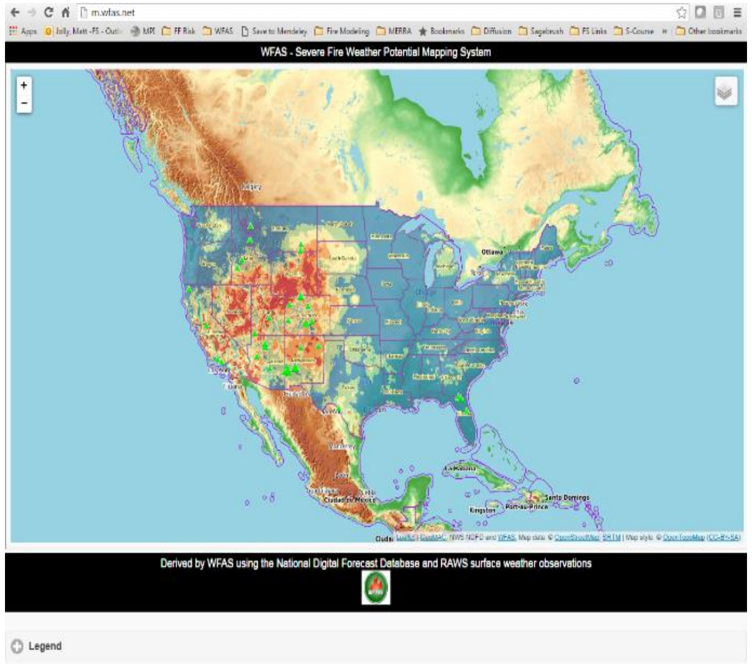
Spatial Preparedness Level Forecast
SPL-I
SPL-II
SPL-III
SPL-IV
SPL-V
NWS National Digital Forecast Database (NDFD)
WFAS
Spatial Fire Danger Rating Forecast System
WFAS / WIMS Observed 100hr and 1000hr FM
Daily Energy Release Component Forecast
Gridded Fire Danger Climatology (1979-2015)
Daily Burning Index Forecast
Classified Energy Release Component Percentile Forecast
Classified Burning Index Percentile Forecast
Spatial Preparedness Level (SPL)
Fire Behavior Potential (FBP)
Severe Fire Weather Potential
Severe Fire Weather Potential Forecast
Low
Moderate
High
Very High
Severe
ERC Percentiles - Spatial Preparedness Levels (SPL)
<58% 78% 92% 97% >97%
SPL 1 2 3 4 5
Class I II III IV V
BI Percentiles - Fire Behavior Potential (FBP)
FBP Class
<58% 1 I
78% 2 II
92% 3 III
97% 4 IV
>97% 5 V
2 4 6 8 10
4 8 12 16 20
6 12 18 24 30
8 16 24 32 40
10 20 30 40 50
Low Mod High V High Severe
Severe Fire Weather Potential (SFWP) Class
FBP-I
FBP-II
FBP-III
FBP-IV
FBP-V
Spatial Fire Behavior Potential Forecast


Severe Fire Weather Potential, 19 Aug 2015
Twisp Fire
Washington
Legend
Spatial Severe Fire Weather Potential
Low
Moderate
High
Very High
Severe
National Severe Fire Weather Potential Map
(Combination of SPL and SFBP)
Spatial Preparedness Level (SPL)
(Based on Energy Release Component)
Spatial Fire Behavior Potential (SFBP)
(Based on Burning Index)


Okanagan-Wenatchee NF
Twisp River
Burning Index (Percentile)
0
20
40
60
80
100
Energy Release Component (Percentile)
0
50
100
Fire BX
(code)
Extreme/Erratic
Crowning/Spotting
Crowning
Torching
Spotting
Running
Creeping/Spreading
Smoldering

From Fire Danger to Fire Behavior

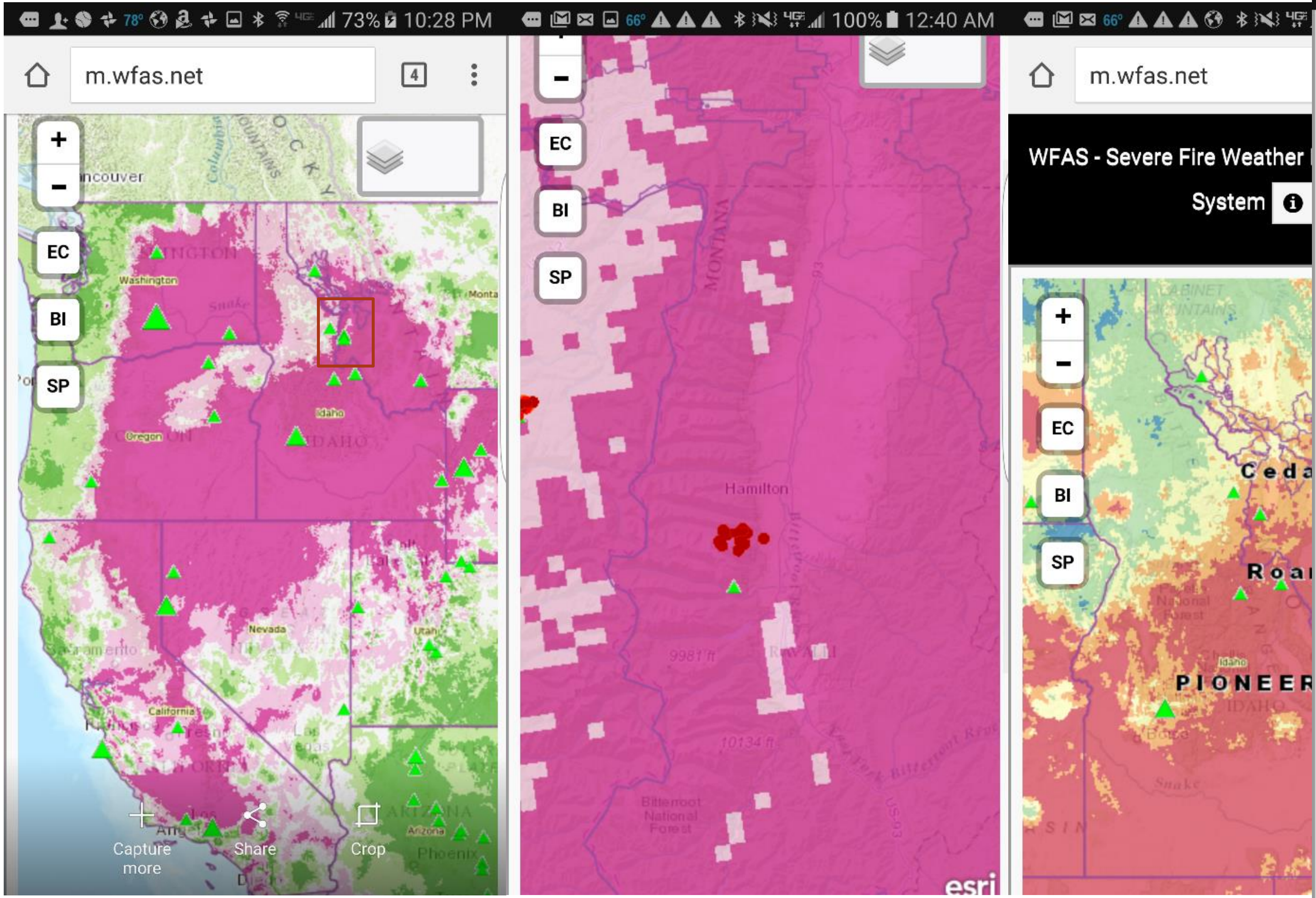
Severe Fire Weather Potential Mapping

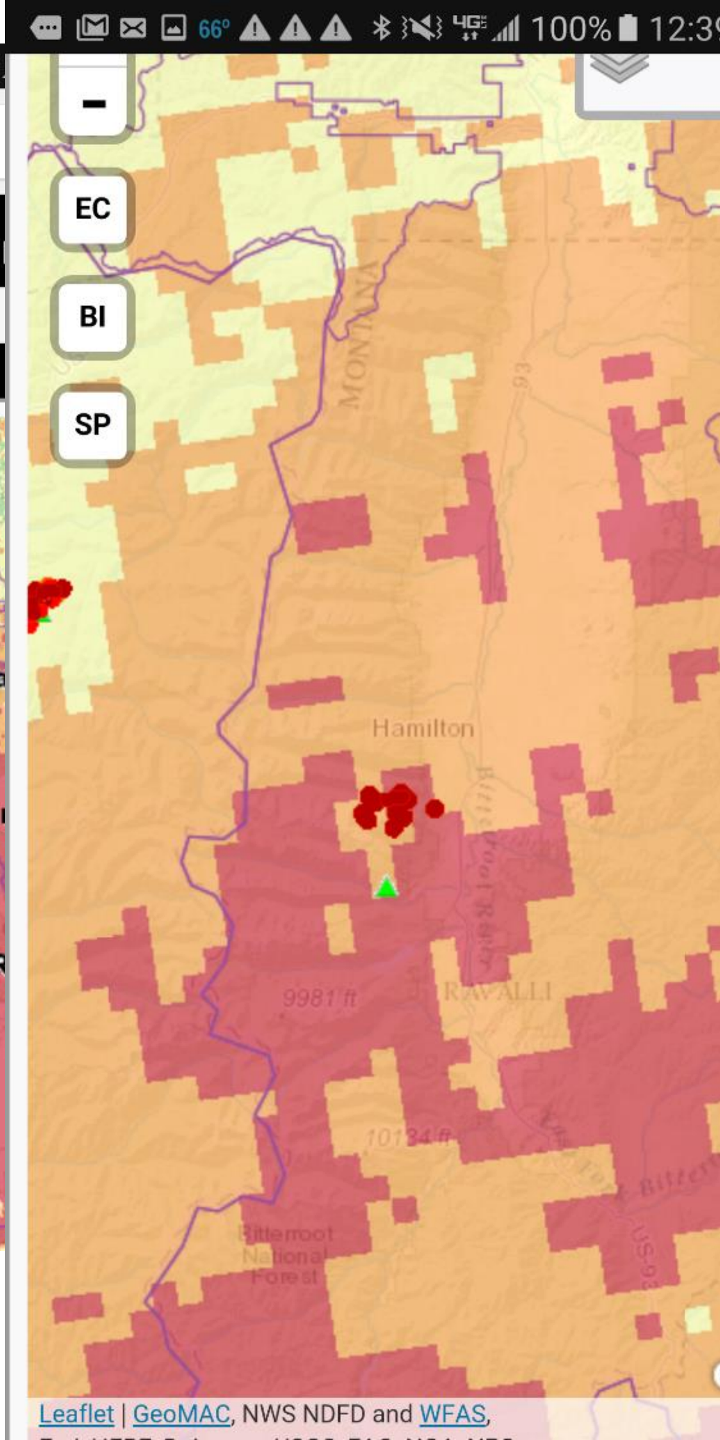


https://m.wfas.net

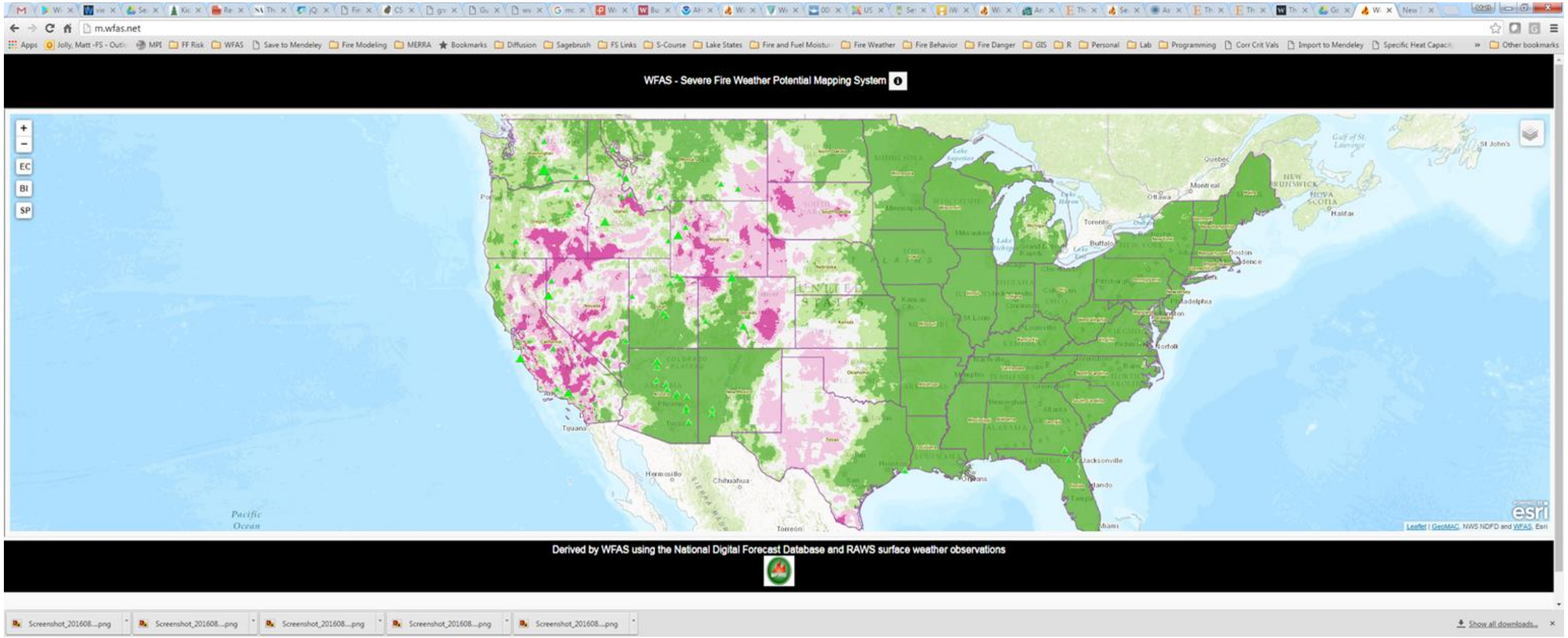
- Mobile-enabled but works on everything
- Geo-located in the future
- Incorporates GeoMAC fire locations and perimeters, MODIS and VIIRS active fire products from RSAC Active Fire Mapping Program, fuels and slope maps
- Operational and available daily @ ~0630MT
- Currently provides forecast for next three days

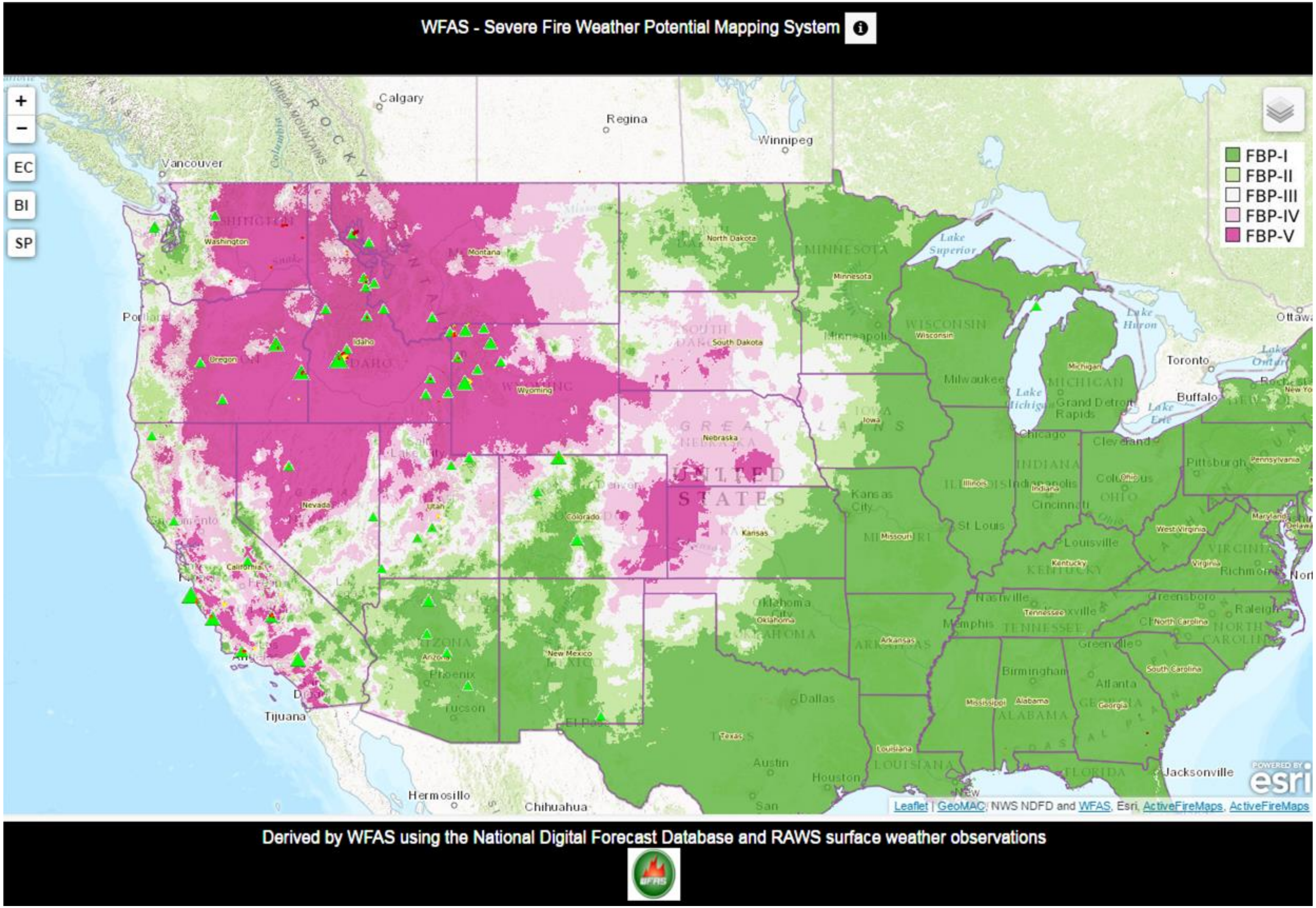
Severe Fire Weather Potential Map Examples



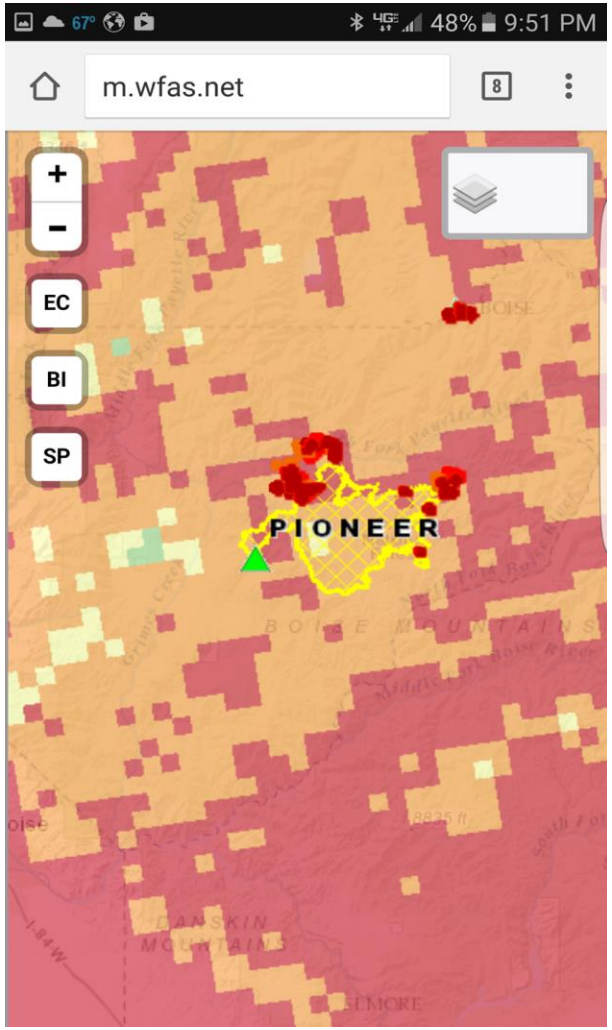


https://www.youtube.com/watch?v=NIj4b1nRfds

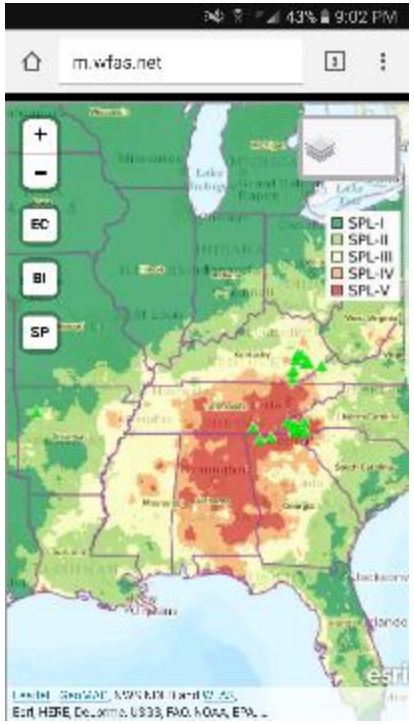

m.wfas.net
WFAS - Severe Fire Weather Potential Mapping System
Derived by WFAS using the National Digital Forecast Database and RAWS surface weather observations


WFAS - Severe Fire Weather Potential Mapping System
EC
BI
SP
FBP-I
FBP-II
FBP-III
FBP-IV
FBP-V
Calgary
Regina
Winnipeg
Vancouver
Toronto
Buffalo
Chicago
Milwaukee
Minneapolis
Cleveland
Pittsburgh
Kansas City
St Louis
Louisville
Nashville
Memphis
Atlanta
Dallas
Austin
Houston
Jacksonville
Richmond
Raleigh
Greensboro
Birmingham
Phoenix
Tucson
Tijuana
Hermosillo
Chihuahua
UNITED STATES
Leaflet | GeoMAC, NWS NDFD and WFAS, Esri, ActiveFireMaps, ActiveFireMaps
Derived by WFAS using the National Digital Forecast Database and RAWS surface weather observations
WFAS

Pioneer Fire



Southeast fall fire season 2016




CBS/AP December 4, 2016, 10:45 PM

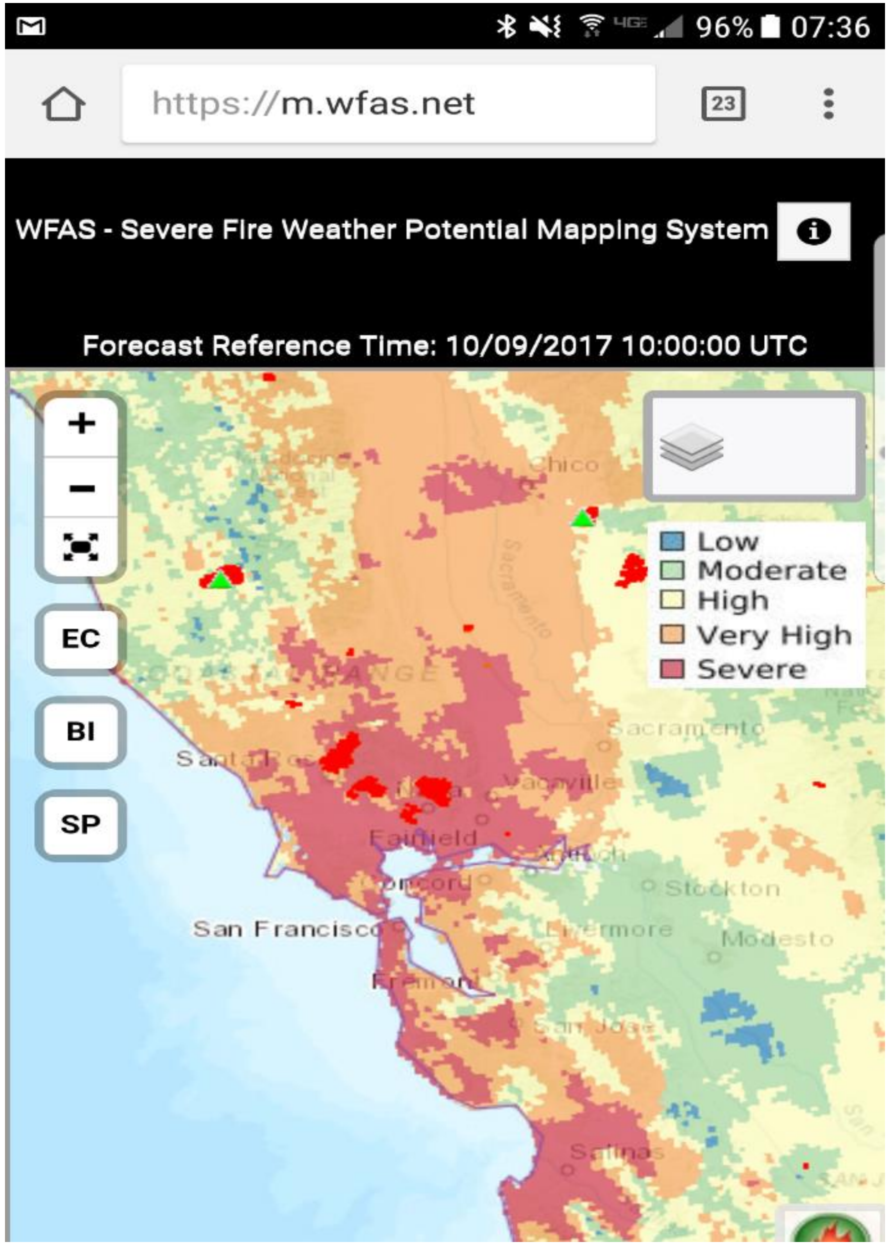
Death toll from Tenn. wildfires rises to 14

Some walls of a burned-out business remain Wednesday, Nov. 30, 2016, in Gatlinburg, Tenn., after a wildfire swept through the area Monday. MARK HUMPHREY/AP

Share / Tweet / Reddit / Flipboard / Email

GATLINBURG, Tenn. -- The death toll from the Gatlinburg area fires has risen to 14.

Santa Rosa Fires



Fires in Sonoma County leave at least nine dead and about 180 more missing

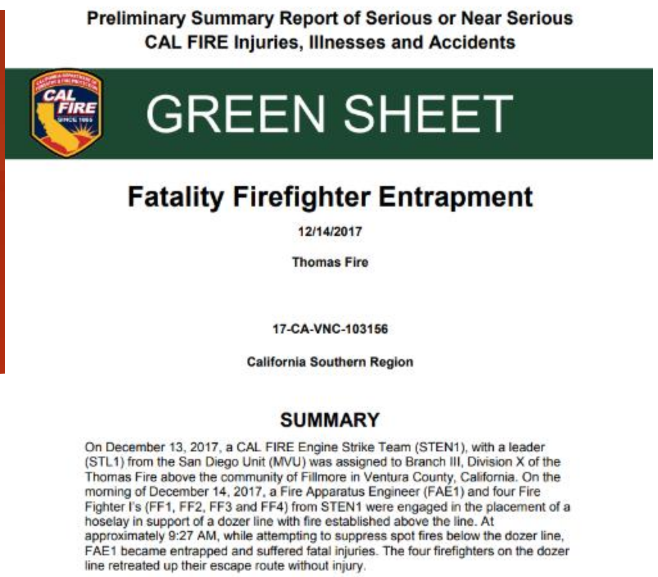
Phil Willon @philwillon

Sonoma County Sheriff Rib Giardano confirms nine fire-related death in the wildfires. Still many people missing,he said

3:19 PM - Oct 10, 2017

3 See Phil Willon's other Tweets

Thomas Fire, 2017



Preliminary Summary Report of Serious or Near Serious
CAL FIRE Injuries, Illnesses and Accidents

GREEN SHEET

Fatality Firefighter Entrapment

12/14/2017

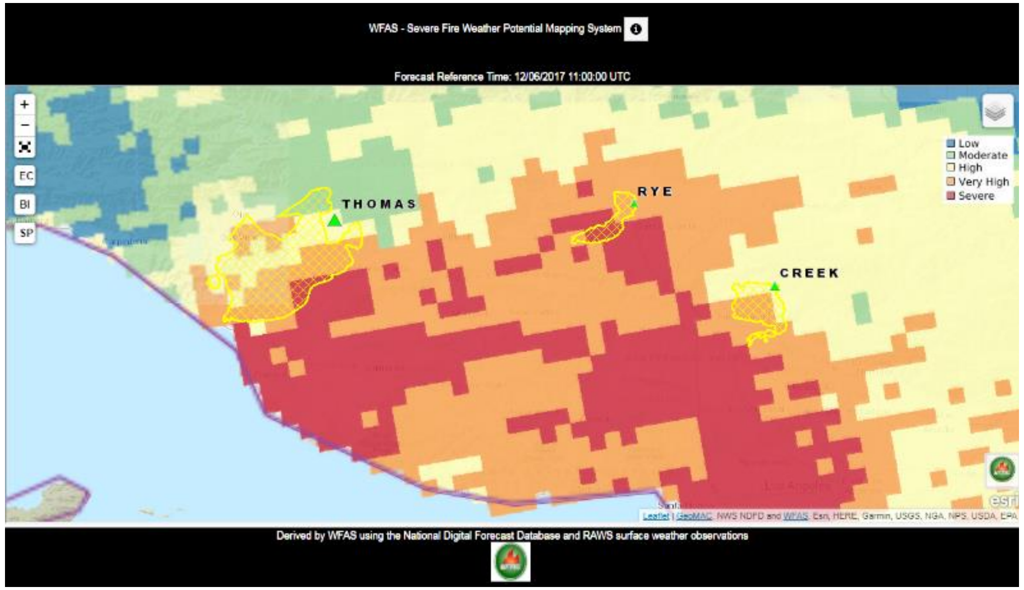
Thomas Fire

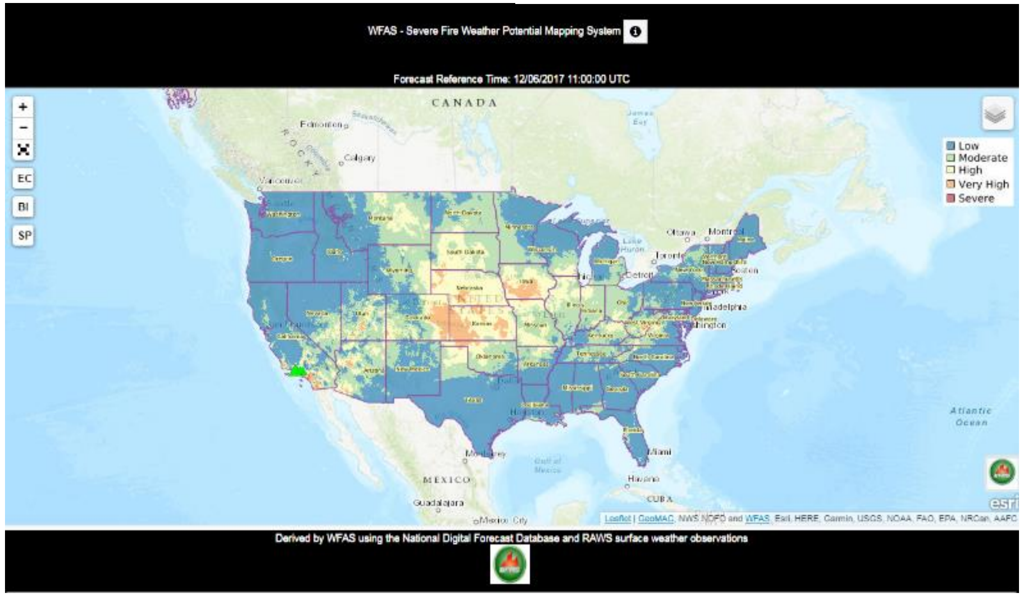
17-CA-VNC-103156

California Southern Region

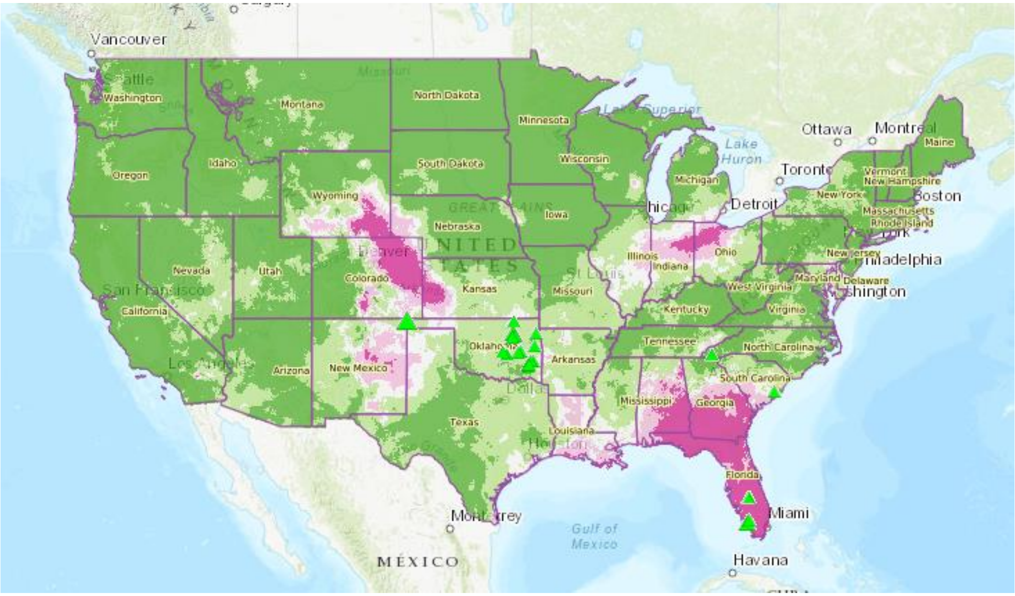
SUMMARY

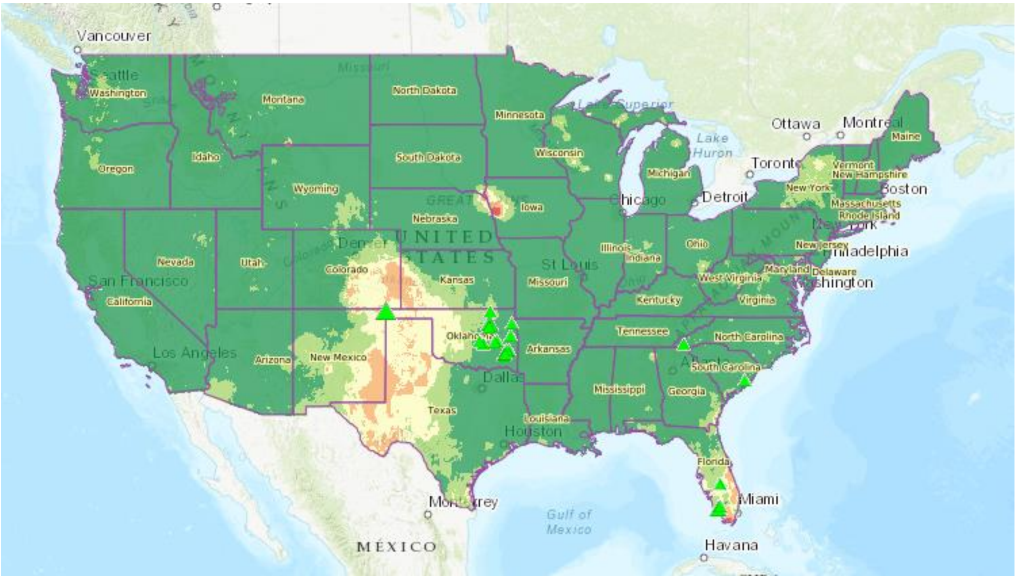
On December 13, 2017, a CAL FIRE Engine Strike Team (STEN1), with a leader (STL1) from the San Diego Unit (MVU) was assigned to Branch III, Division X of the Thomas Fire above the community of Fillmore in Ventura County, California. On the morning of December 14, 2017, a Fire Apparatus Engineer (FAE1) and four Fire Fighter I's (FF1, FF2, FF3 and FF4) from STEN1 were engaged in the placement of a hoselay in support of a dozer line with fire established above the line. At approximately 9:27 AM, while attempting to suppress spot fires below the dozer line, FAE1 became entrapped and suffered fatal injuries. The four firefighters on the dozer line retreated up their escape route without injury.

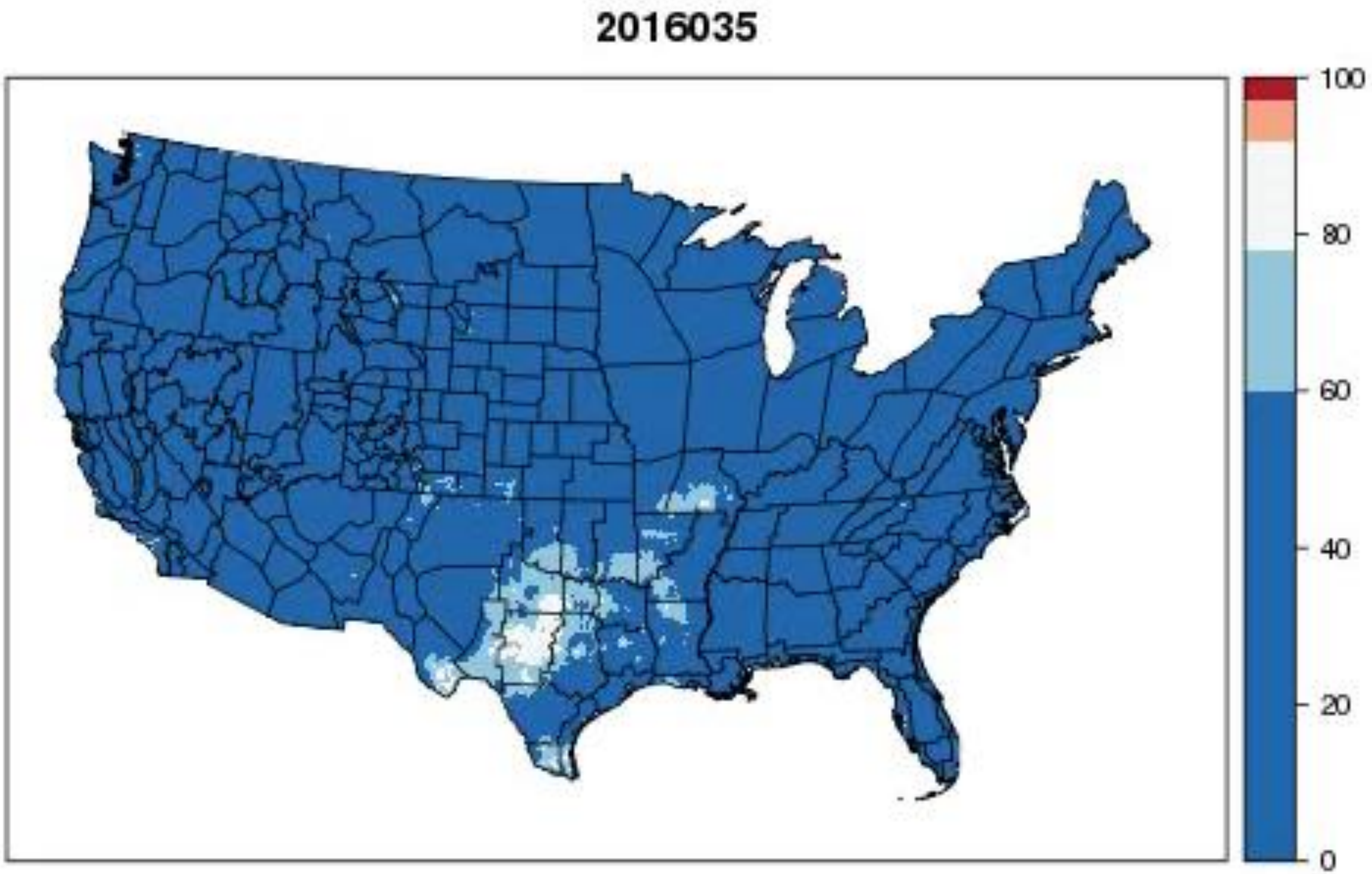




20 Mar 2018

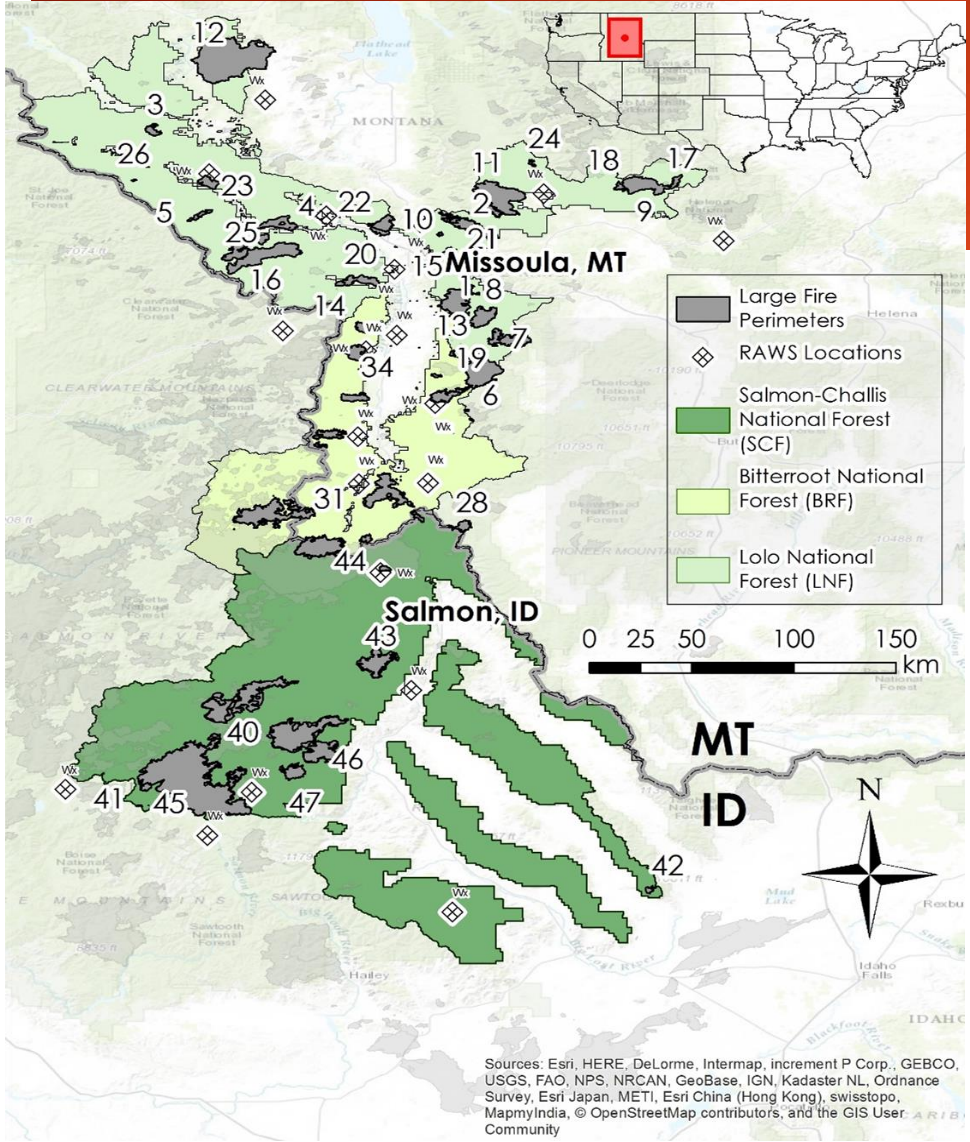

Vancouver
Washington
Montana
North Dakota
Minnesota
Oregon
Idaho
South Dakota
Wisconsin
Wyoming
Michigan
Ottawa
Montreal
Maine
Toronto
Detroit
Boston
Nebraska
Iowa
Nevada
Utah
Colorado
Kansas
Missouri
Illinois
Indiana
Ohio
Philadelphia
California
Kentucky
Virginia
Tennessee
North Carolina
Arizona
New Mexico
Oklahoma
Arkansas
South Carolina
Mississippi
Georgia
Texas
Louisiana
Florida
Miami
Gulf of Mexico
MÉXICO
Havana

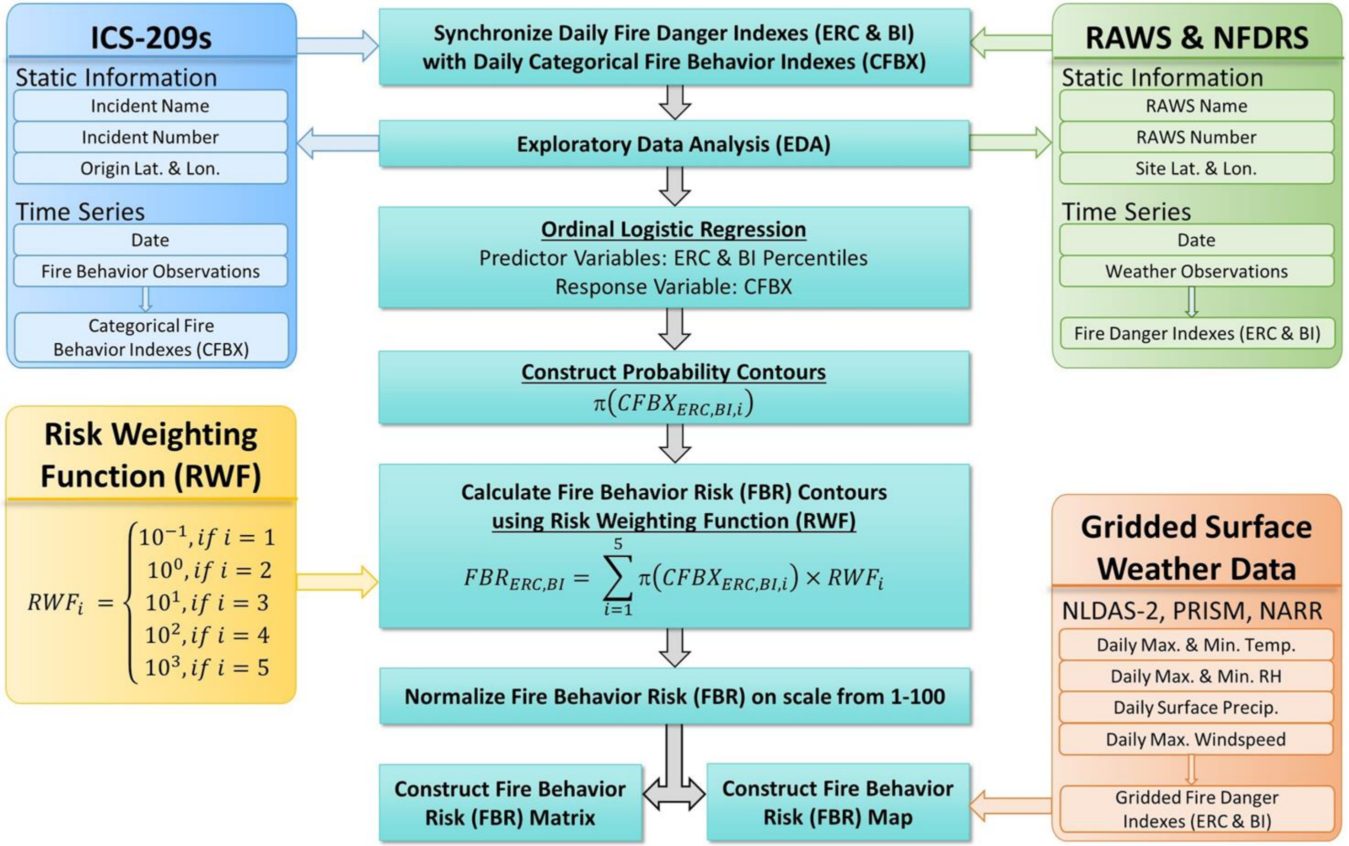

Vancouver
Washington
Montana
North Dakota
Minnesota
Oregon
Idaho
South Dakota
Wisconsin
Wyoming
Michigan
Ottawa
Montreal
Maine
Toronto
Detroit
Boston
Nebraska
Iowa
Nevada
Utah
Colorado
Kansas
Missouri
St Louis
Illinois
Indiana
Ohio
Philadelphia
San Francisco
California
Kentucky
Virginia
Tennessee
North Carolina
Los Angeles
Arizona
New Mexico
Oklahoma
Arkansas
South Carolina
Mississippi
Georgia
Dallas
Texas
Louisiana
Houston
Florida
Miami
Gulf of Mexico
MÉXICO
Havana

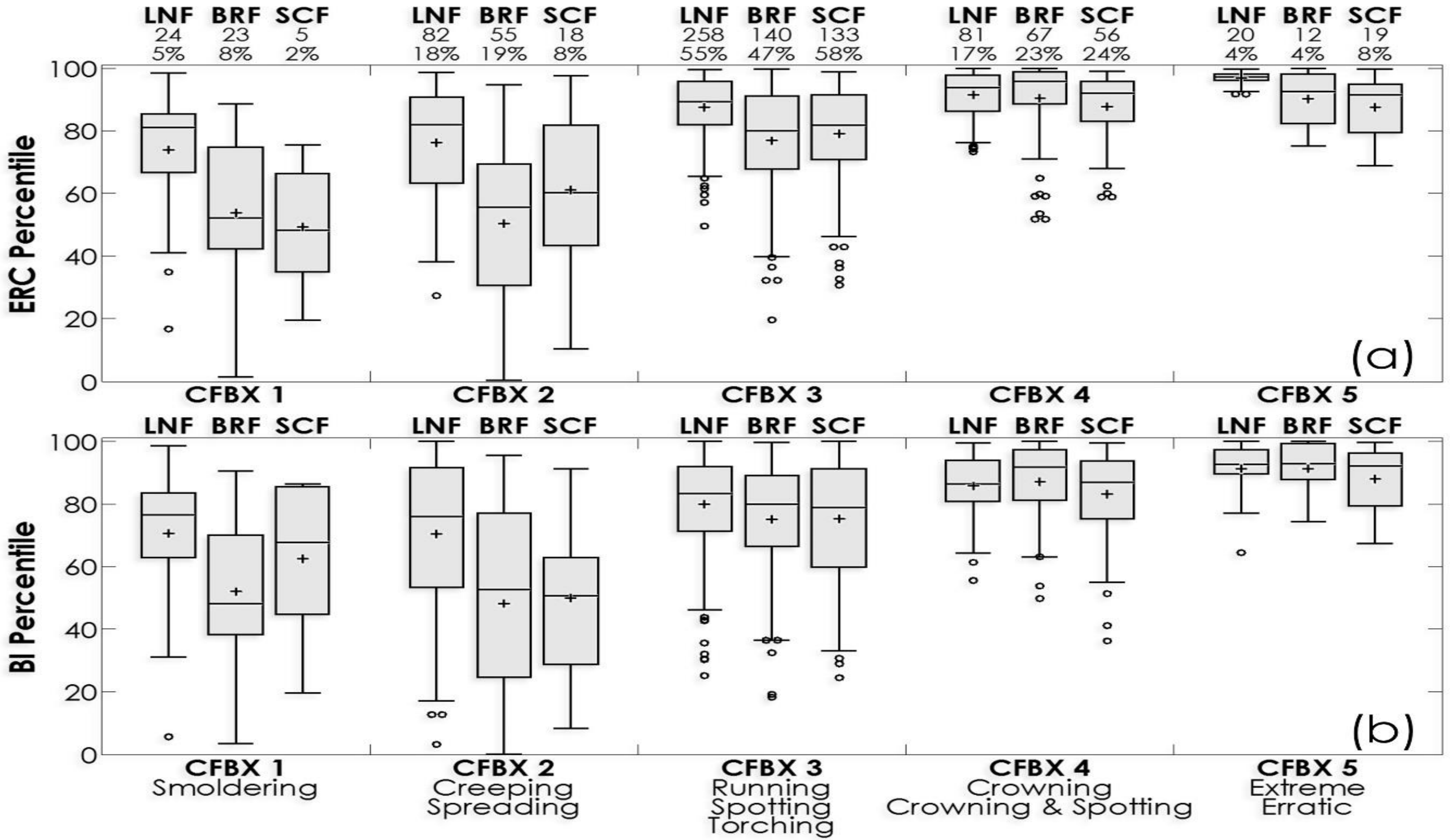

2016035
100
80
60
40
20
0

From Fire Danger to Fire Behavior

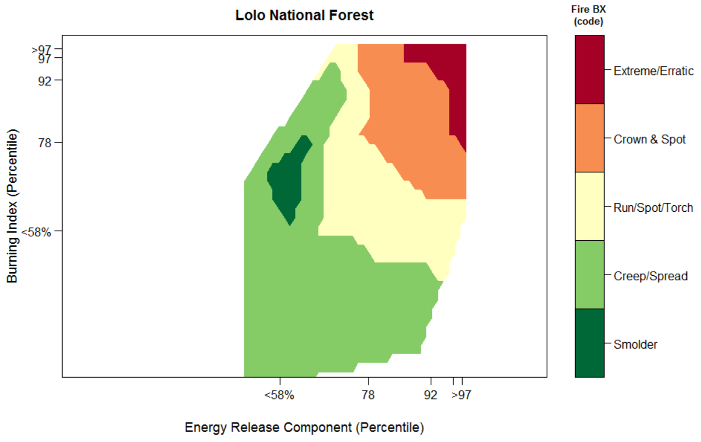
This process can be followed by any National Forest. All the necessary data already exists.

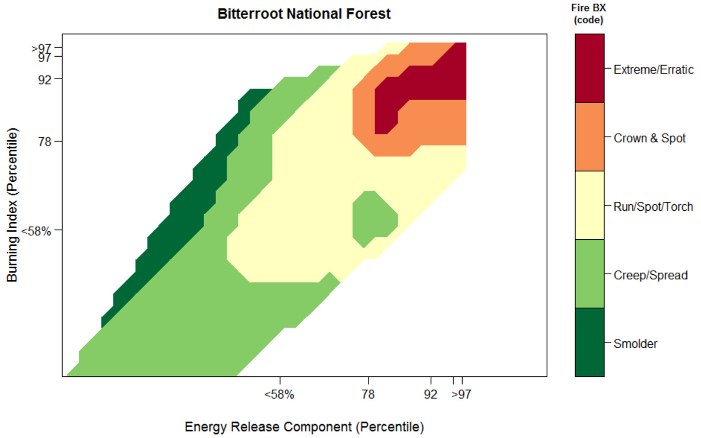


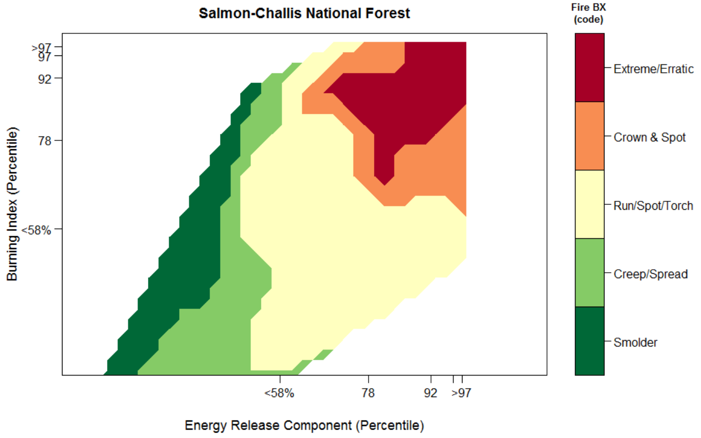


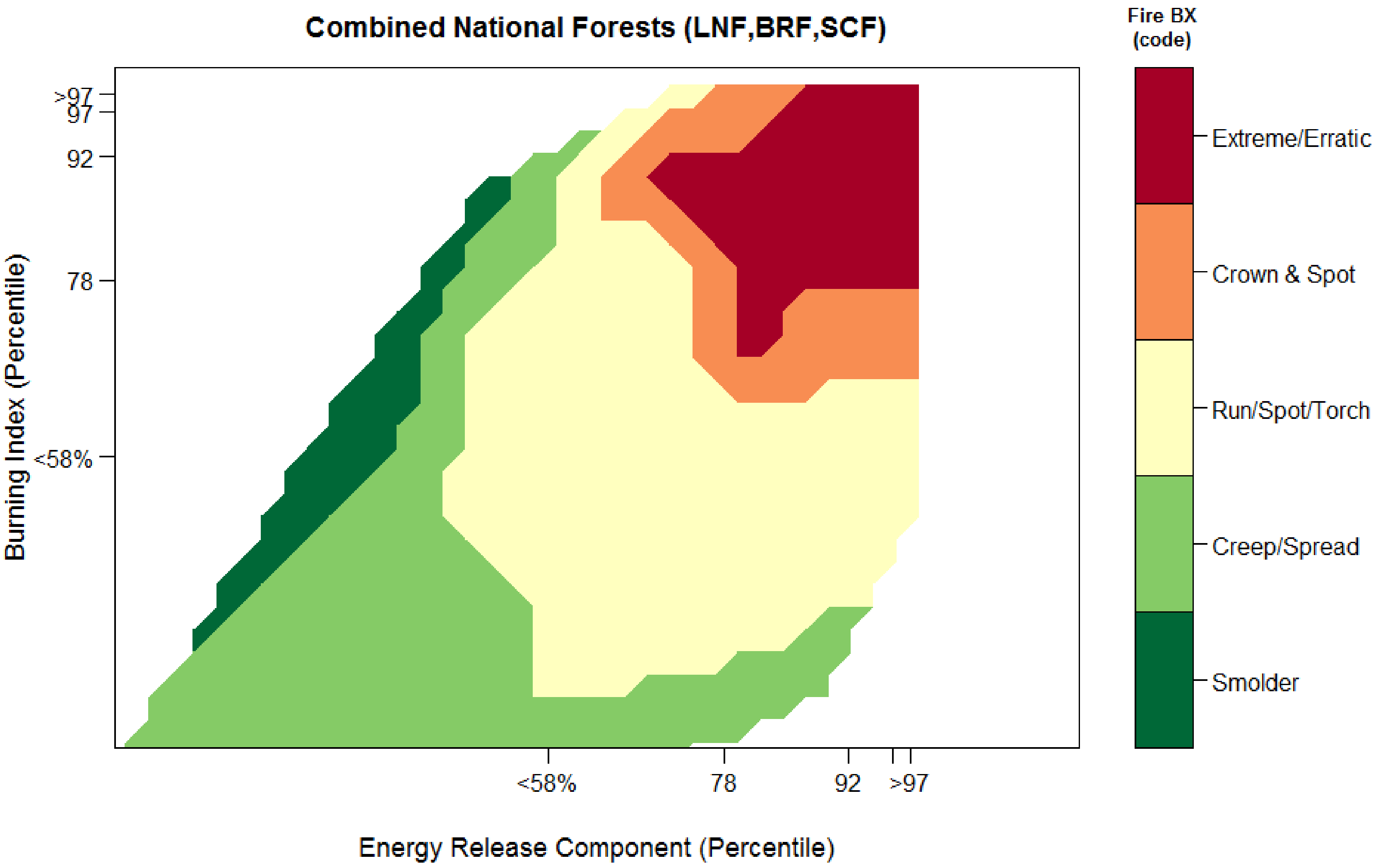


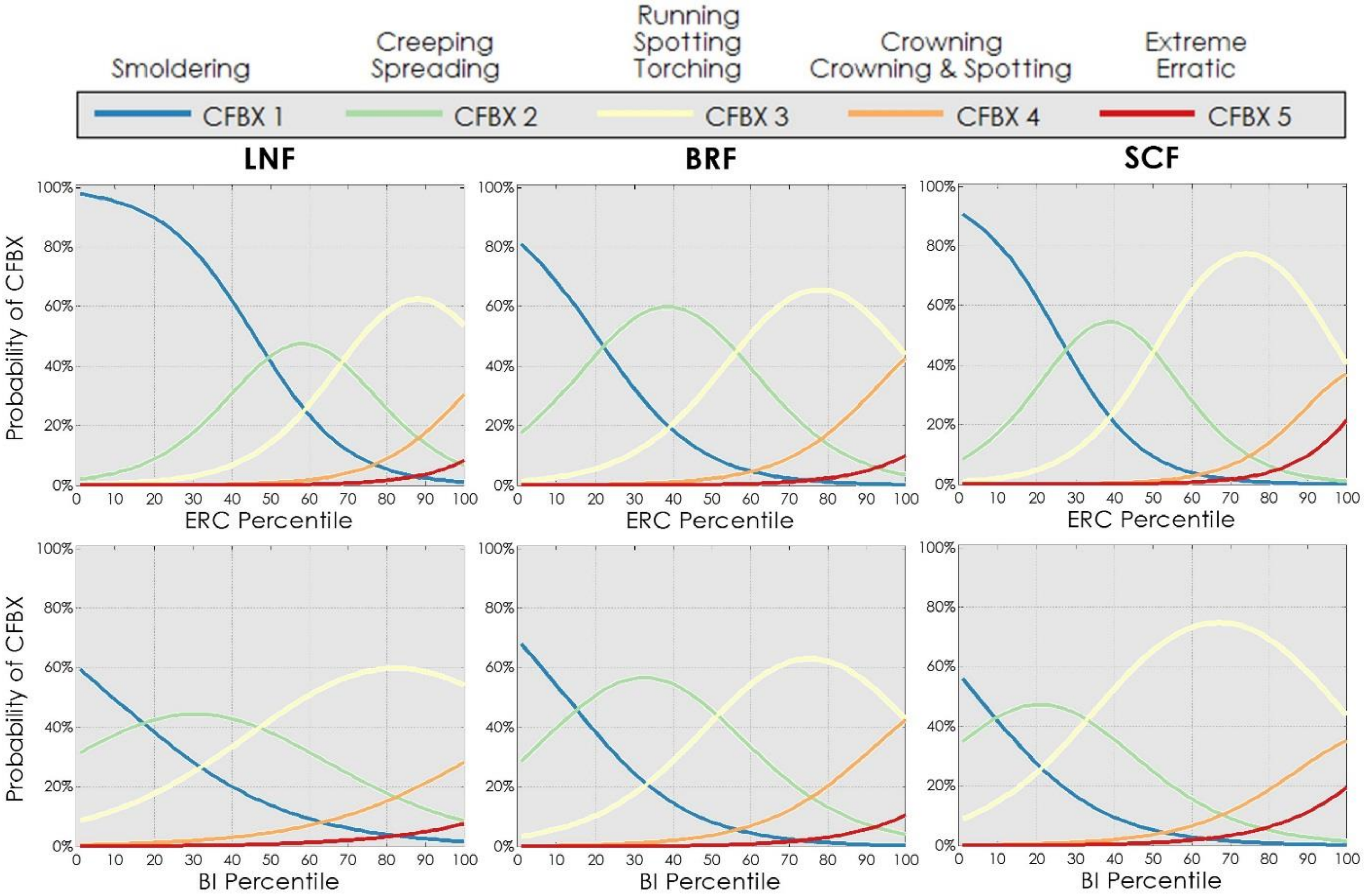
LNF BRF SCF
24 23 5
5% 8% 2%
82 55 18
18% 19% 8%
258 140 133
55% 47% 58%
81 67 56
17% 23% 24%
20 12 19
4% 4% 8%
ERC Percentile
(a)
CFBX 1
CFBX 2
CFBX 3
CFBX 4
CFBX 5
BI Percentile
(b)
CFBX 1
Smoldering
CFBX 2
Creeping
Spreading
CFBX 3
Running
Spotting
Torching
CFBX 4
Crowning
Crowning & Spotting
CFBX 5
Extreme
Erratic


Lolo National Forest
Burning Index (Percentile)
>97
97
92
78
<58%
<58%
78
92
>97
Energy Release Component (Percentile)
Fire BX (code)
Extreme/Erratic
Crown & Spot
Run/Spot/Torch
Creep/Spread
Smolder

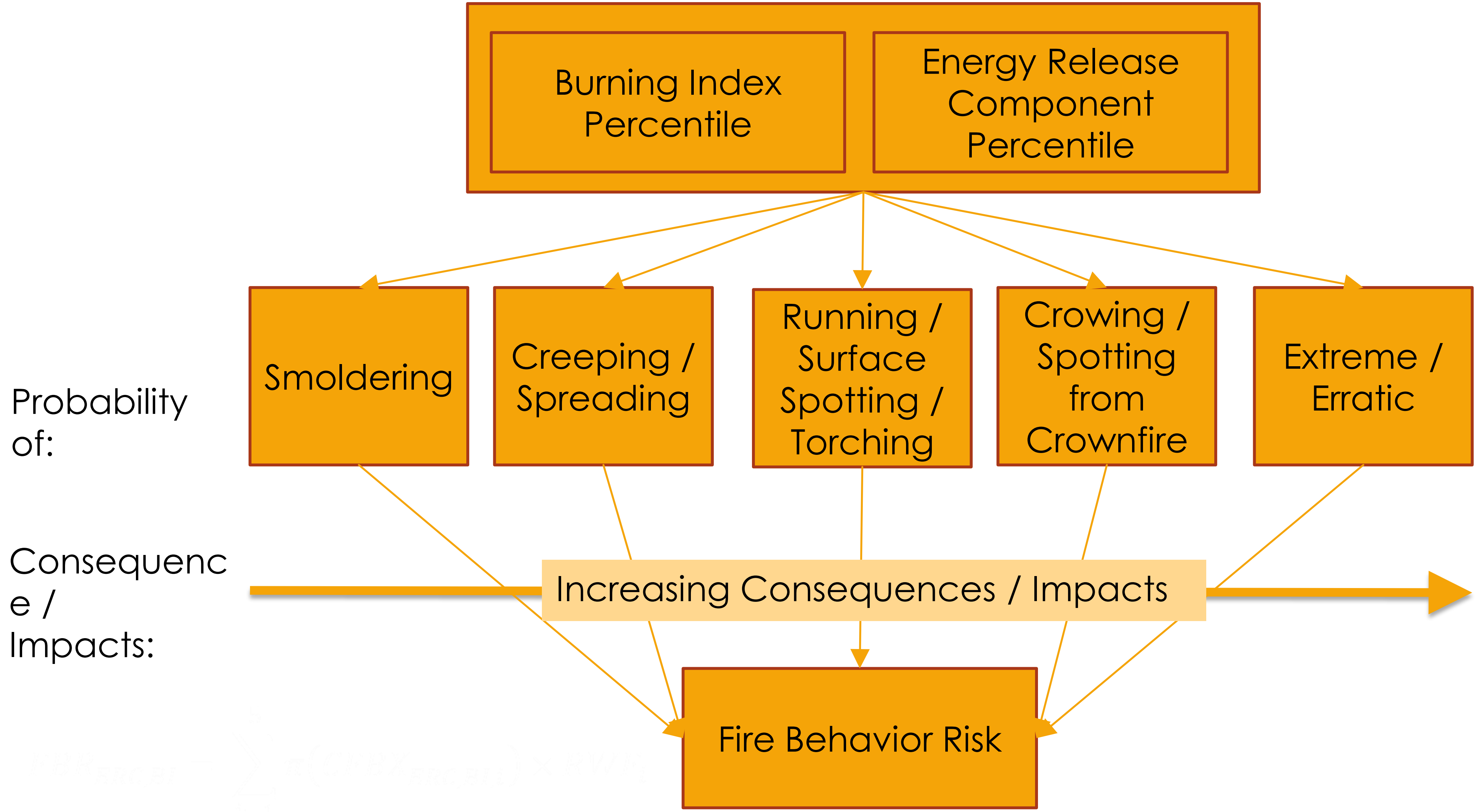

Bitterroot National Forest
Burning Index (Percentile)
>97
97
92
78
<58%
<58%
78
92
>97
Energy Release Component (Percentile)
Fire BX (code)
Extreme/Erratic
Crown & Spot
Run/Spot/Torch
Creep/Spread
Smolder


Salmon-Challis National Forest
Burning Index (Percentile)
>97
97
92
78
<58%
<58%
78
92
>97
Energy Release Component (Percentile)
Fire BX (code)
Extreme/Erratic
Crown & Spot
Run/Spot/Torch
Creep/Spread
Smolder


Combined National Forests (LNF,BRF,SCF)
Burning Index (Percentile)
>97
97
92
78
<58%
<58%
78
92
>97
Energy Release Component (Percentile)
Fire BX (code)
Extreme/Erratic
Crown & Spot
Run/Spot/Torch
Creep/Spread
Smolder

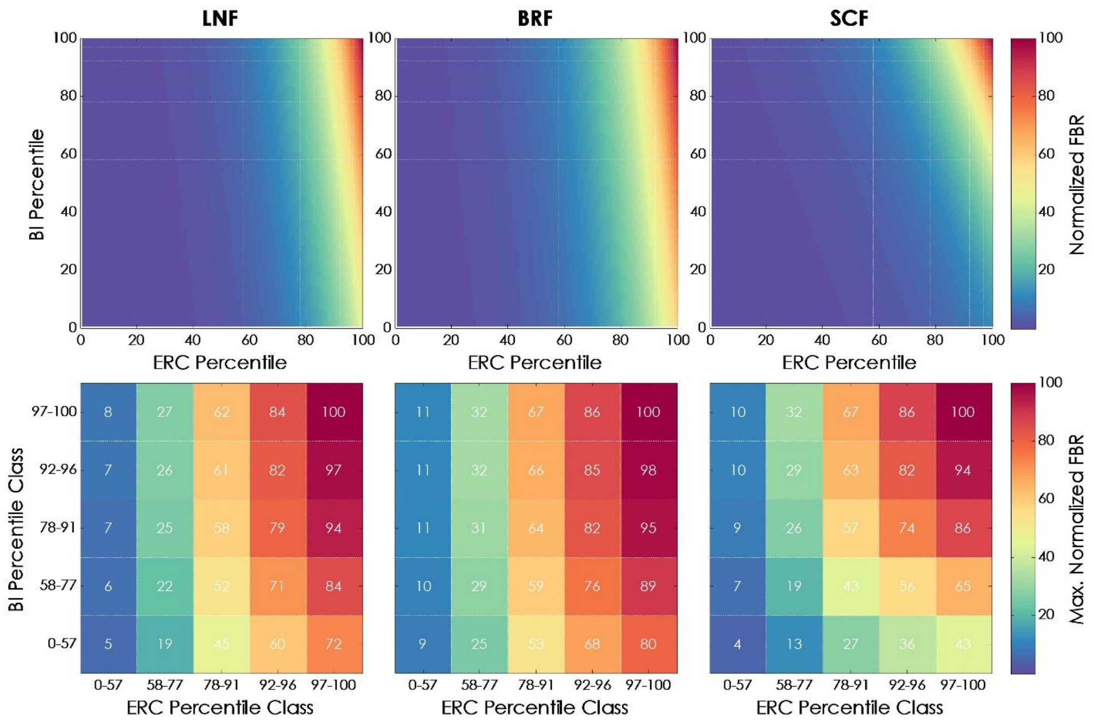


Smoldering
Creeping Spreading
Running Spotting Torching
Crowning Crowning & Spotting
Extreme Erratic
CFBX 1
CFBX 2
CFBX 3
CFBX 4
CFBX 5
LNF
BRF
SCF
Probability of CFBX
ERC Percentile
BI Percentile



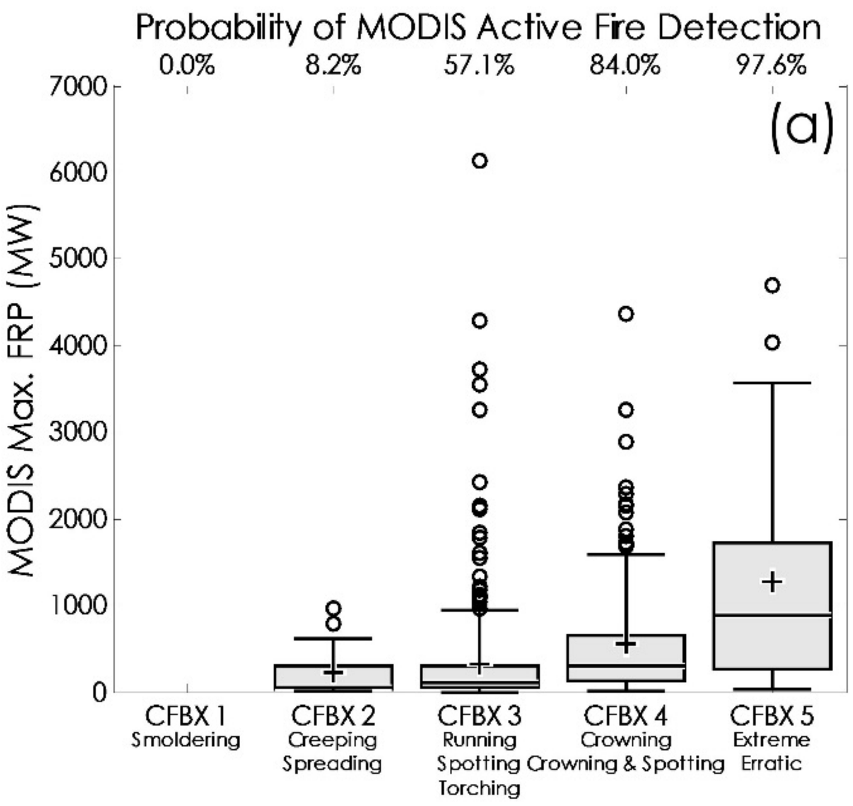
Burning Index Percentile
Energy Release Component Percentile
Probability of:
Smoldering
Creeping / Spreading
Running / Surface Spotting / Torching
Crowing / Spotting from Crownfire
Extreme / Erratic
Consequence / Impacts:
Increasing Consequences / Impacts
Fire Behavior Risk

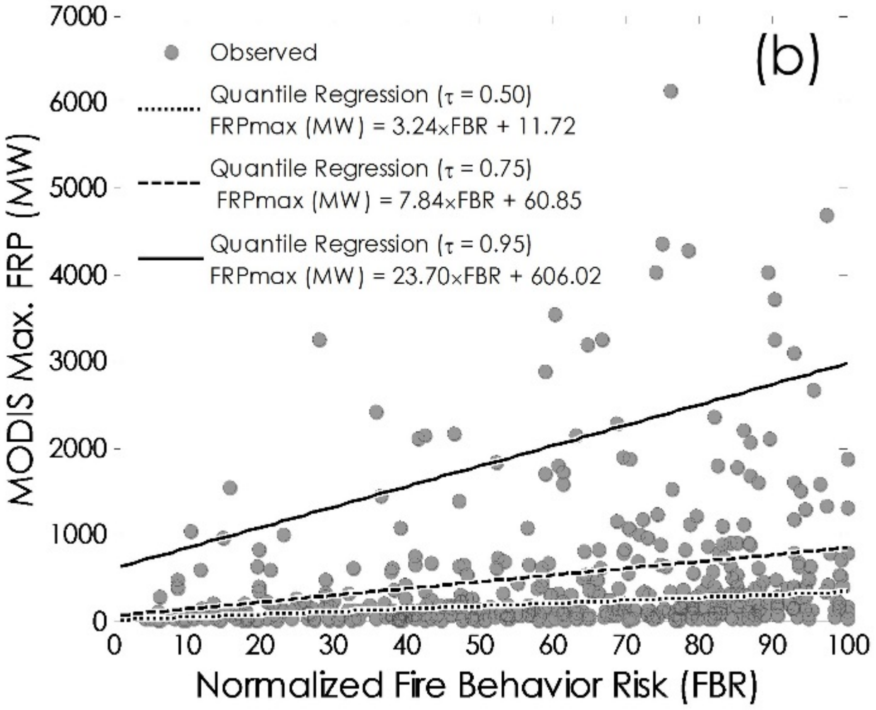
From CFBX probabilities to Fire Behavior Risk

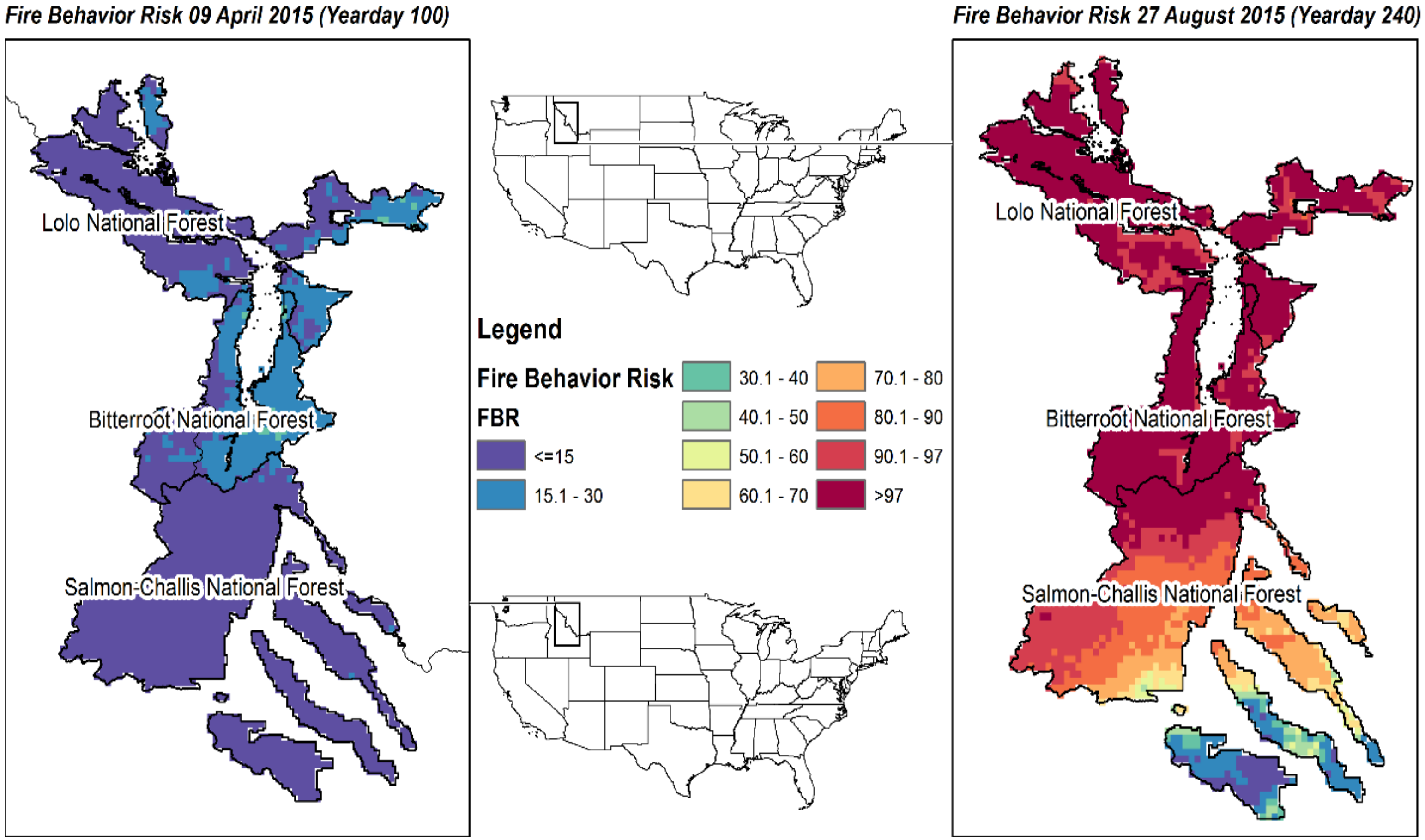


Different sensitivity
To windspeeds

Fire behavior observations also compare well with satellite-derived fire intensity





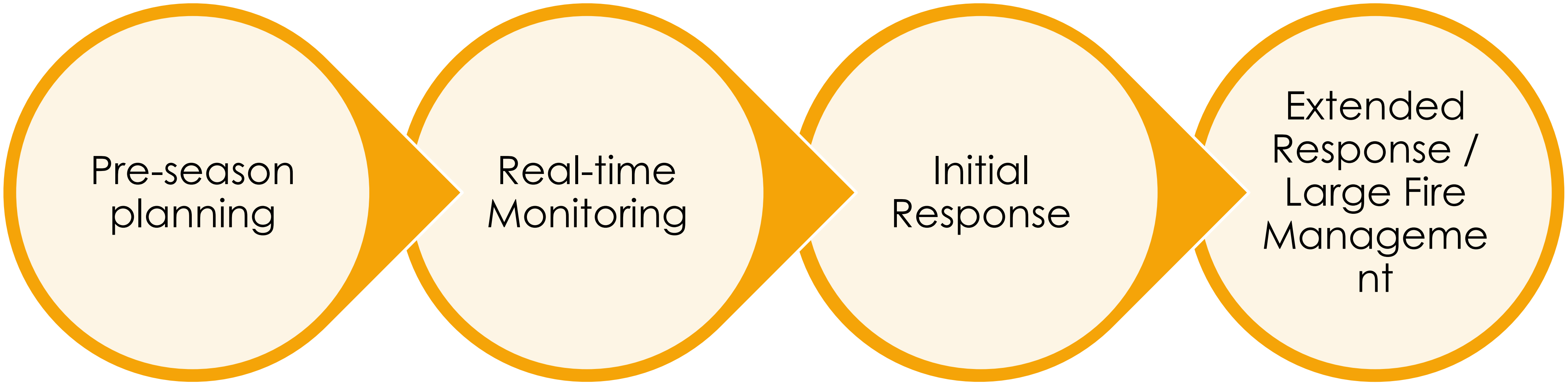


Fire Behavior Risk 09 April 2015 (Yearday 100)
Fire Behavior Risk 27 August 2015 (Yearday 240)
Lolo National Forest
Bitterroot National Forest
Salmon-Challis National Forest
Lolo National Forest
Bitterroot National Forest
Salmon-Challis National Forest
Legend
Fire Behavior Risk
FBR
<=15
15.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
60.1 - 70
70.1 - 80
80.1 - 90
90.1 - 97
>97

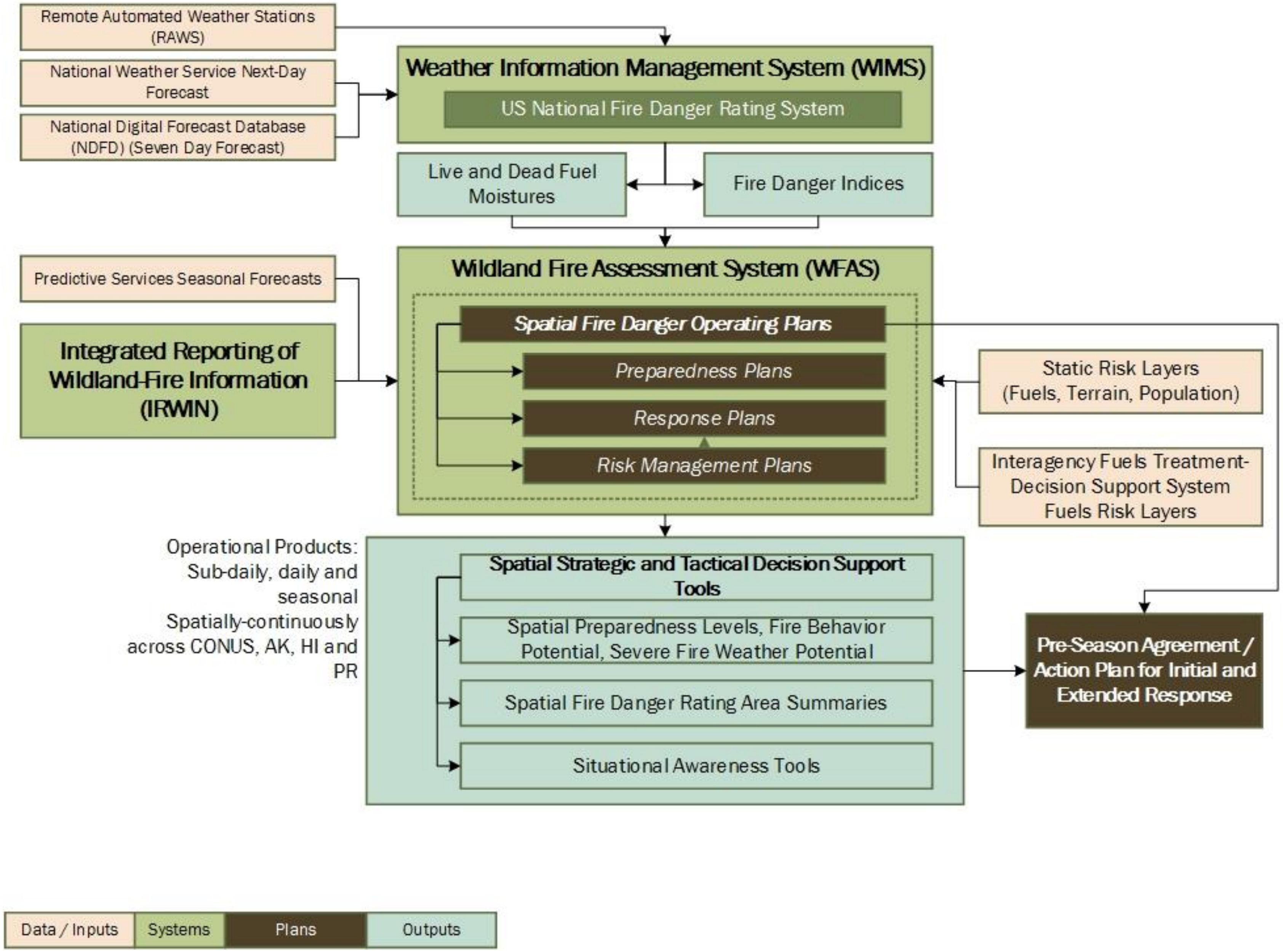
How do we make this part of daily business?

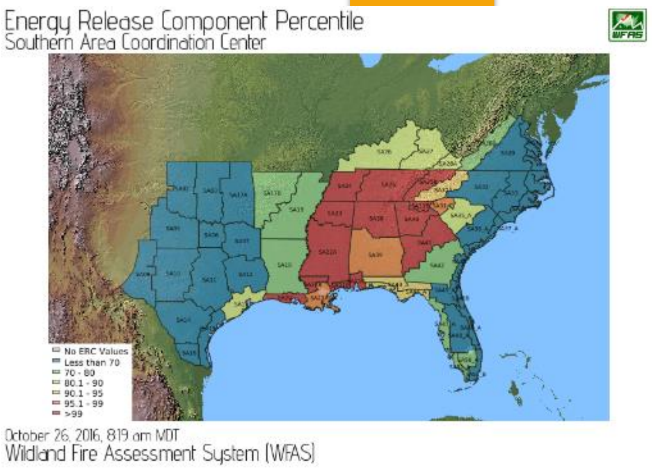
- Mobile-enabled maps are made available before the start of the duty day
- Contributes to a common operating picture
- Use of information is written into the Delegation of Authority (DOA) letters for Type 3,4 and 5 ICs and Duty Officers
- Used to brief at the National, Regional, State, Forest and District levels
- Fire management, line officers and cooperators have a common picture

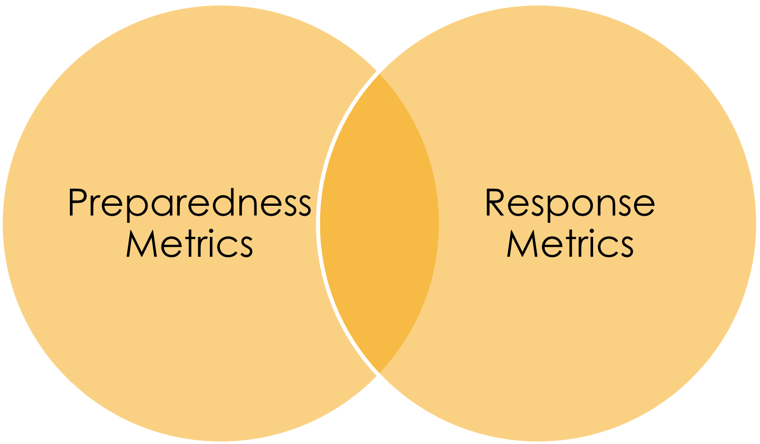
Fire Management Decision Support Continuum



National Wildland Fire Preparedness and Response System



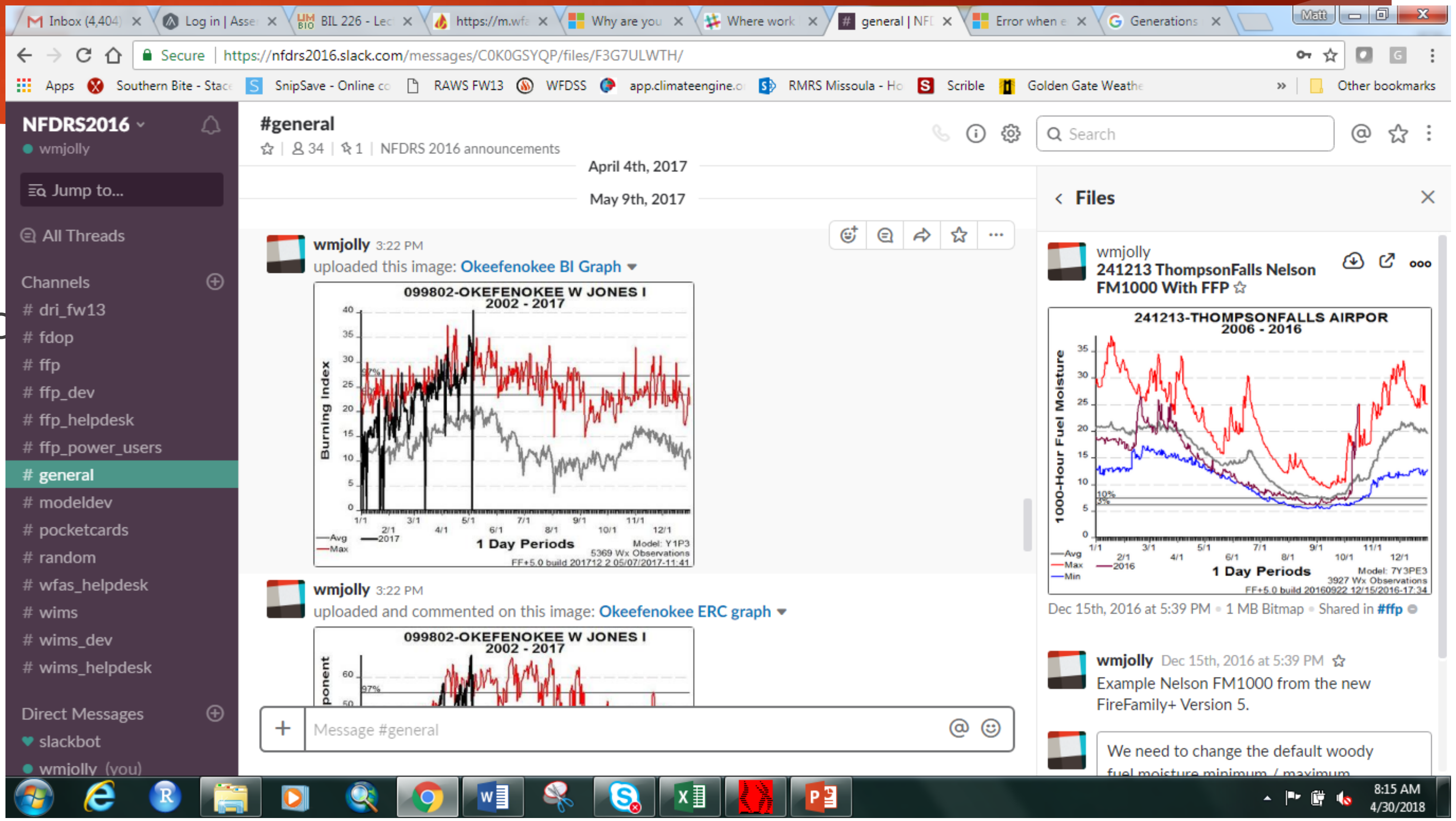




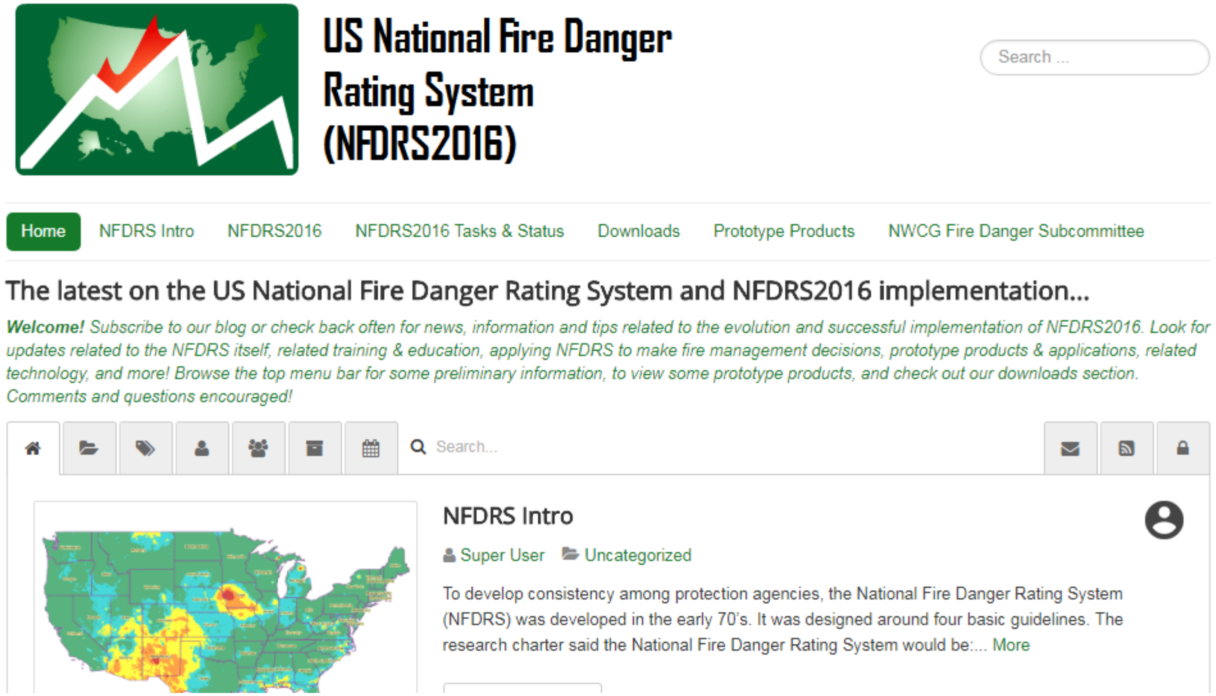
- Build a culture of LEARNED centered around NFDRS and its applications
- Create a community of users that can learn together
- Learn to adapt to change because more is coming!

Slack

- https://nfdrs2016.slack.com/
- All online and open to the anyo
- Mobile-friendly

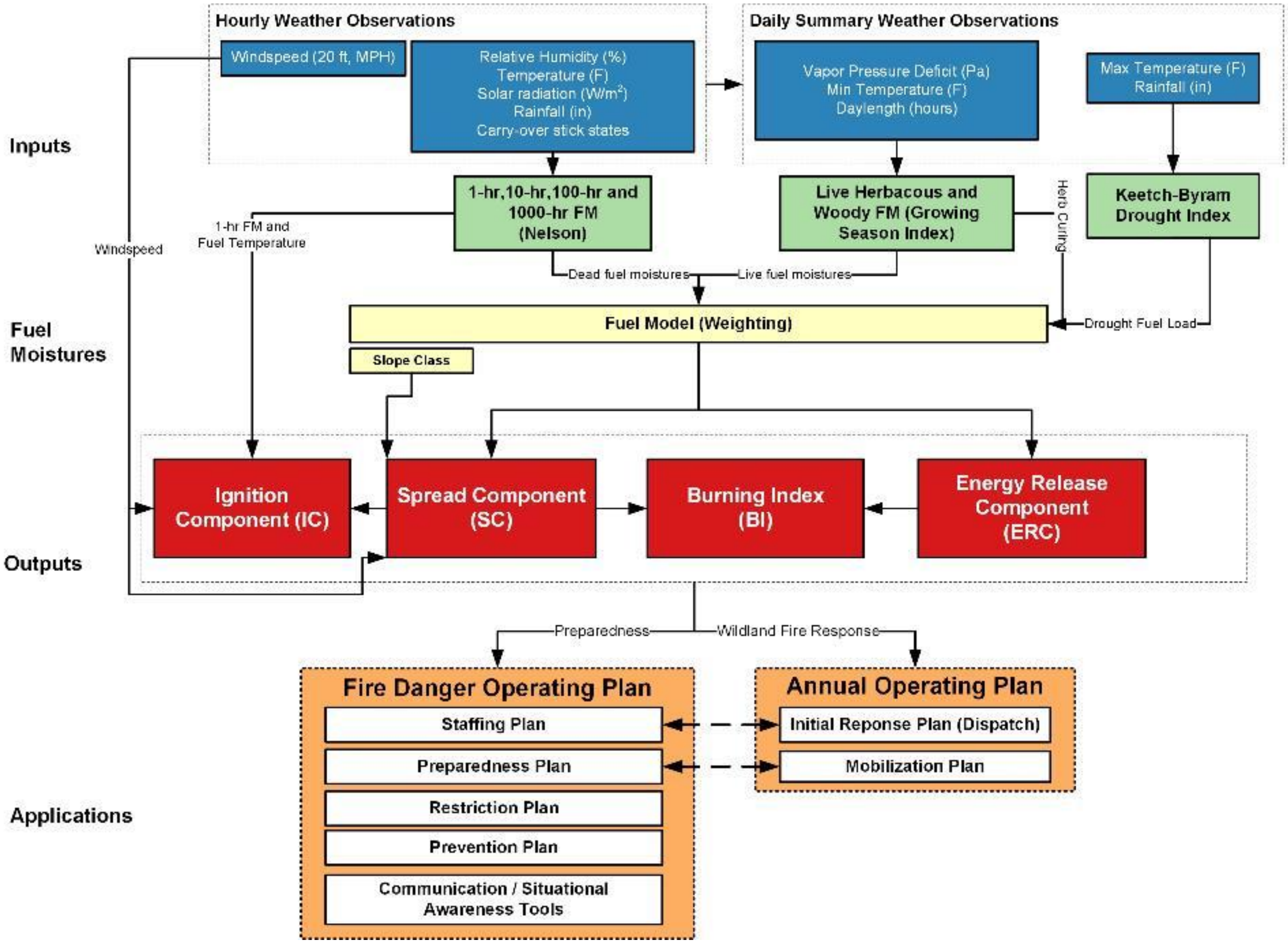


https://www.wfas.net/nfdrs2016



TOPOFIRE: A topographically resolved drought and wildfire danger monitoring system for the conterminous United States

- NASA Applied Sciences Funding (ROSES A.35)
- Project Goals:
  - Develop topographically resolved gridded fire danger products for the USA to support the Wildland Fire Assessment System (WFAS) and Wildland Fire Decision Support System (WFDSS)
  - Integrate eco-hydrologic indices into wildfire danger assessment



Hourly Weather Observations
Windspeed (20 ft, MPH)
Relative Humidity (%)
Temperature (F)
Solar radiation (W/m²)
Rainfall (in)
Carry-over stick states
Daily Summary Weather Observations
Vapor Pressure Deficit (Pa)
Min Temperature (F)
Daylength (hours)
Max Temperature (F)
Rainfall (in)
Inputs
1-hr,10-hr,100-hr and 1000-hr FM (Nelson)
Live Herbacous and Woody FM (Growing Season Index)
Herb Curing
Keetch-Byram Drought Index
Windspeed
1-hr FM and Fuel Temperature
Dead fuel moistures
Live fuel moistures
Fuel Model (Weighting)
Drought Fuel Load
Fuel Moistures
Slope Class
Ignition Component (IC)
Spread Component (SC)
Burning Index (BI)
Energy Release Component (ERC)
Outputs
Preparedness
Wildland Fire Response
Fire Danger Operating Plan
Staffing Plan
Preparedness Plan
Restriction Plan
Prevention Plan
Communication / Situational Awareness Tools
Annual Operating Plan
Initial Reponse Plan (Dispatch)
Mobilization Plan
Applications

TOPOFIRE: A topographically resolved drought and wildfire danger monitoring system for the conterminous United States

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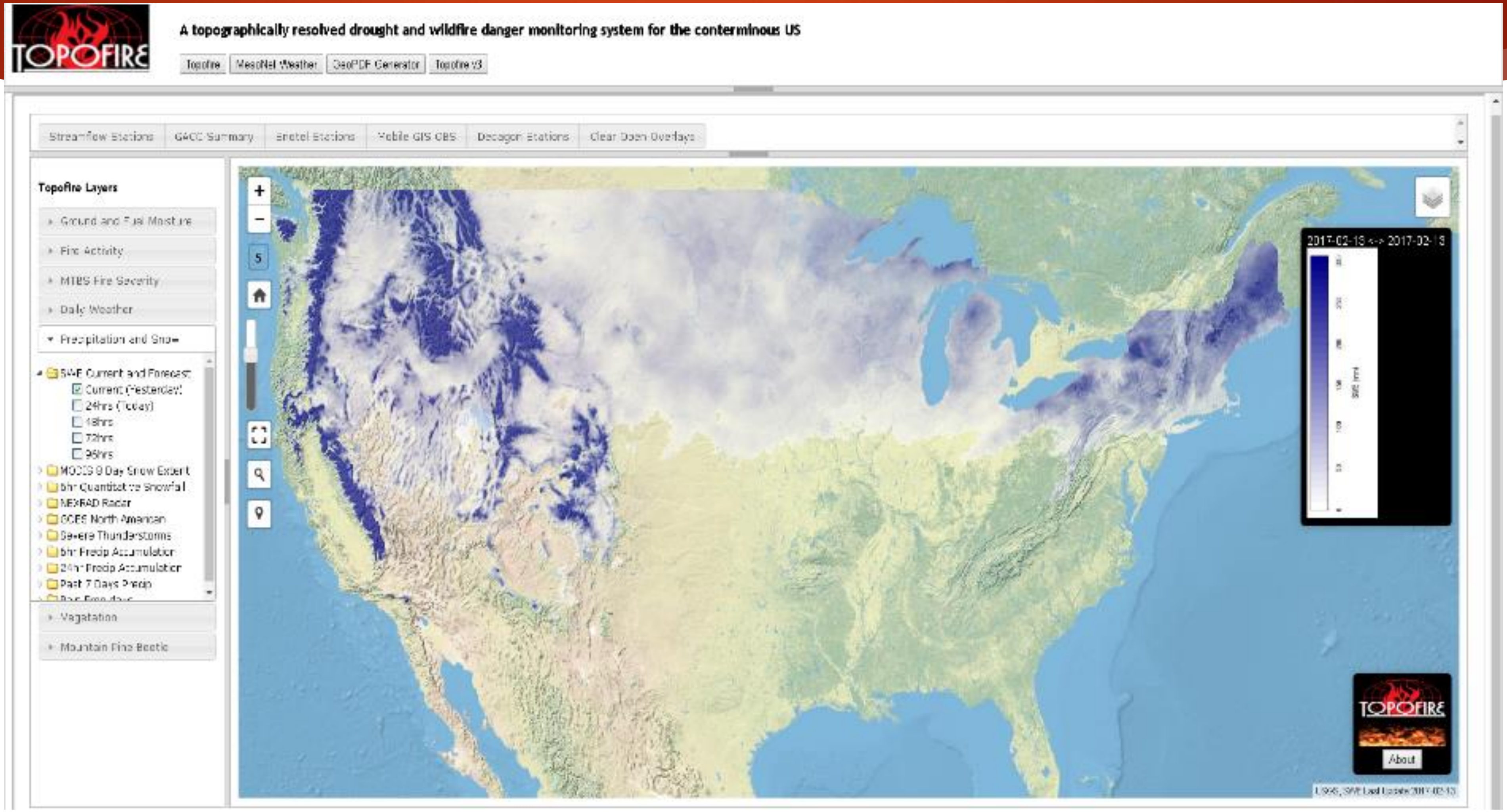
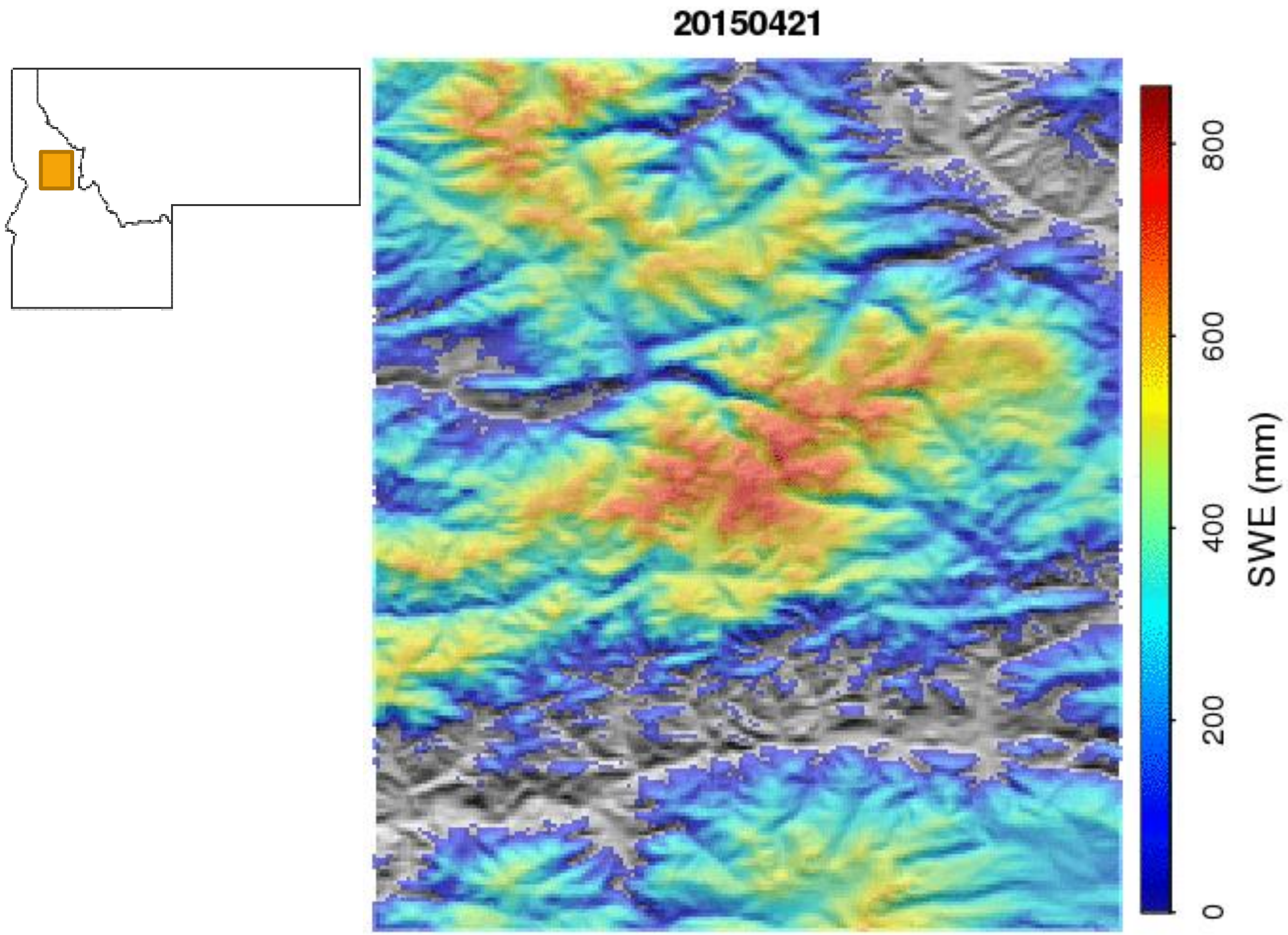
Modified SWAT snow model calibrated with gridded radiation data

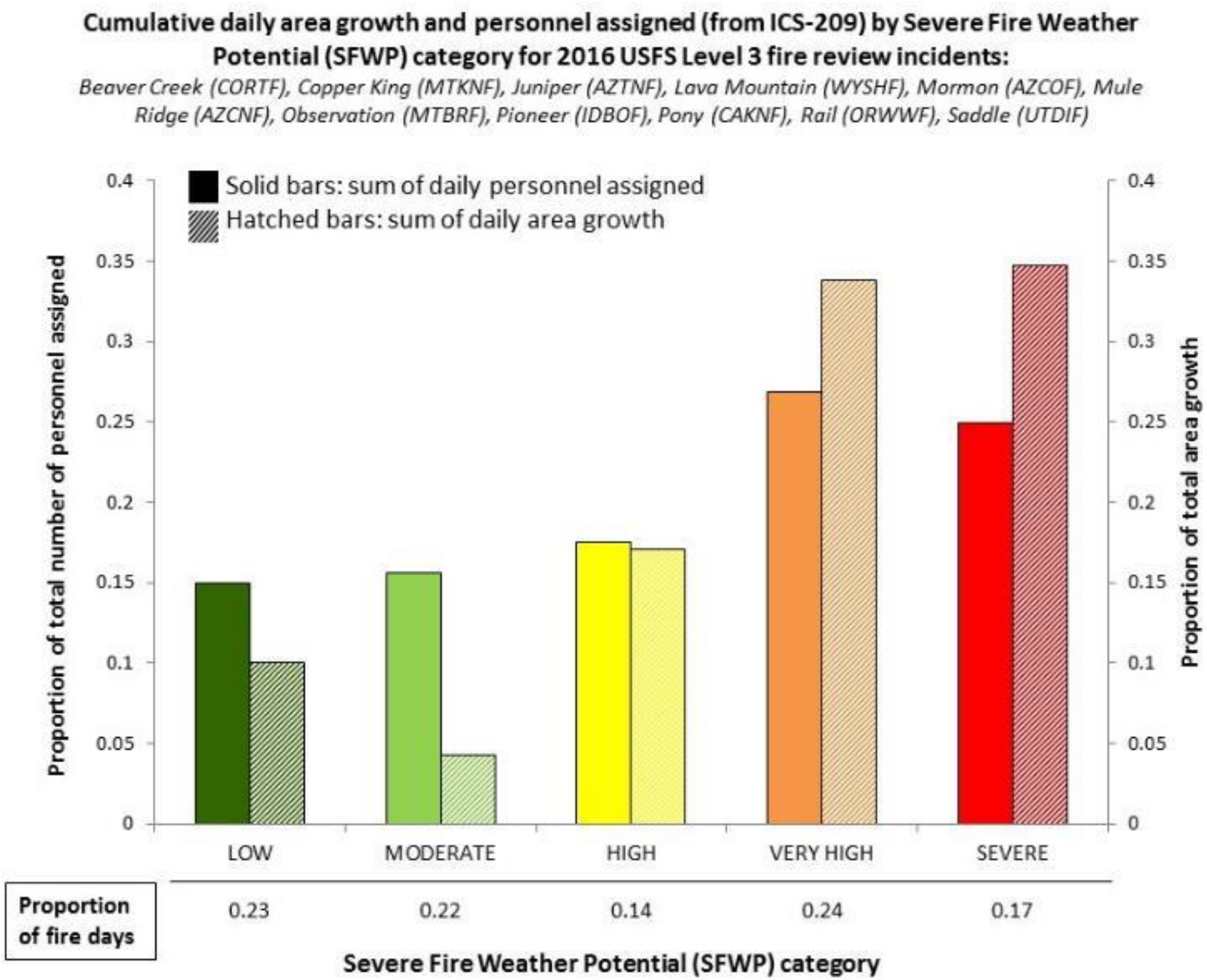


Modeled SWE – current + 4 day forecasts

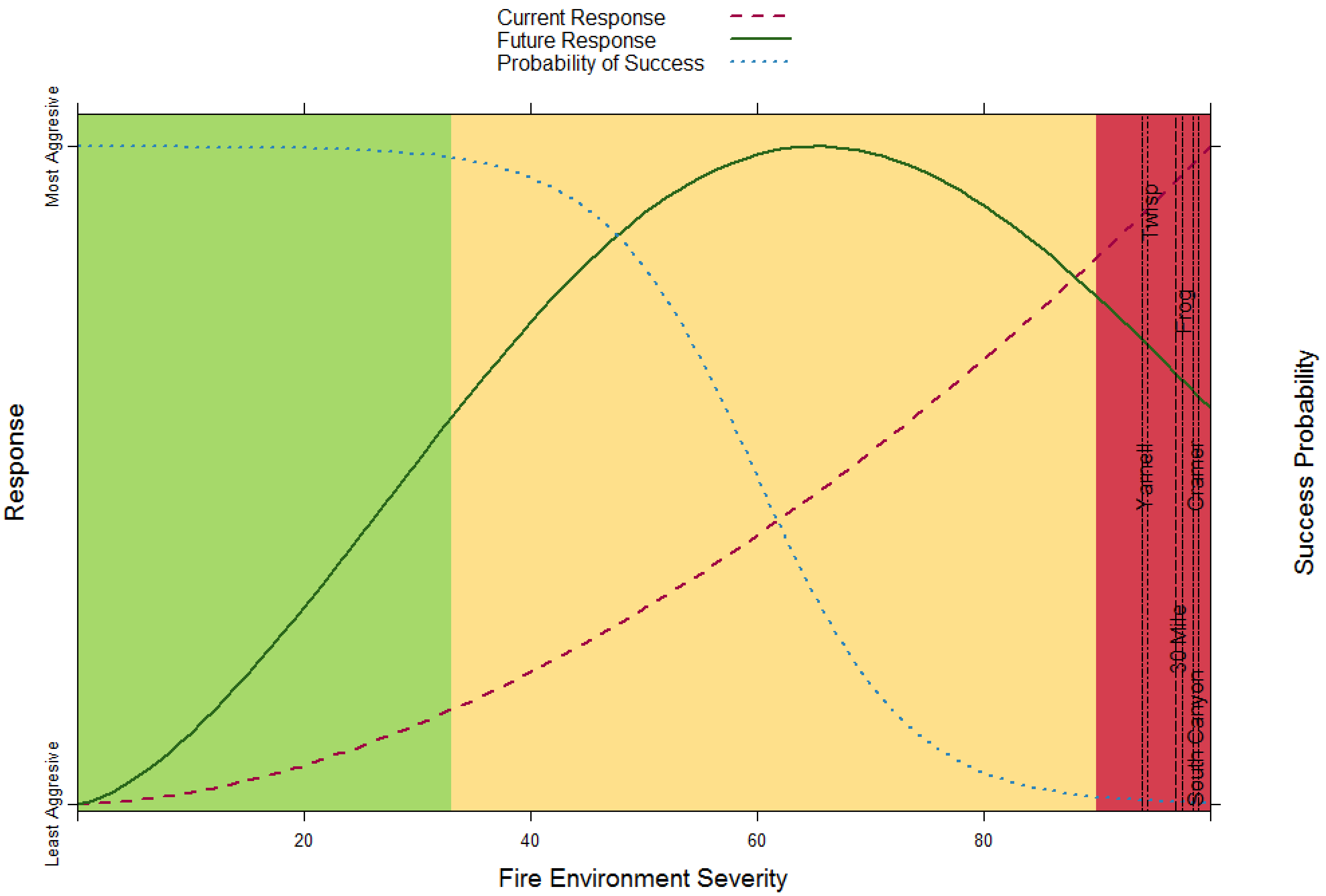
Snowmelt timing and topography



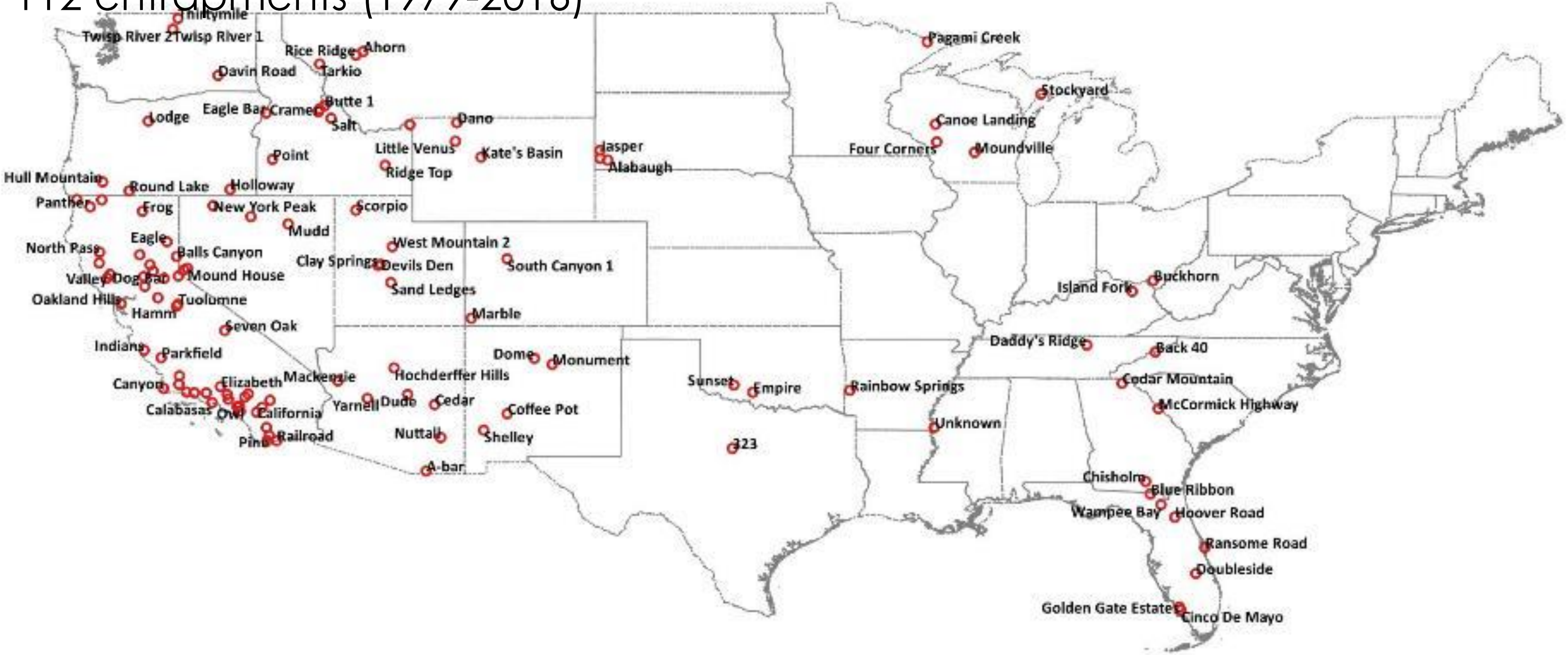
Why does it matter?



Cumulative daily area growth and personnel assigned (from ICS-209) by Severe Fire Weather Potential (SFWP) category for 2016 USFS Level 3 fire review incidents:
Beaver Creek (CORTF), Copper King (MTKNF), Juniper (AZTNF), Lava Mountain (WYSHF), Mormon (AZCOF), Mule Ridge (AZCNF), Observation (MTBRF), Pioneer (IDBOF), Pony (CAKNF), Rail (ORWWF), Saddle (UTDIF)
Solid bars: sum of daily personnel assigned
Hatched bars: sum of daily area growth
Proportion of total number of personnel assigned
Proportion of total area growth
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
LOW
MODERATE
HIGH
VERY HIGH
SEVERE
Proportion of fire days
0.23
0.22
0.14
0.24
0.17
Severe Fire Weather Potential (SFWP) category


Current Response
Future Response
Probability of Success
Most Aggresive
Least Aggresive
Response
Success Probability
20
40
60
80
Fire Environment Severity
Twisp
Frog
Yarnell
Gramer
30 Mile
South Canyon

112 entrapments (1979-2016)



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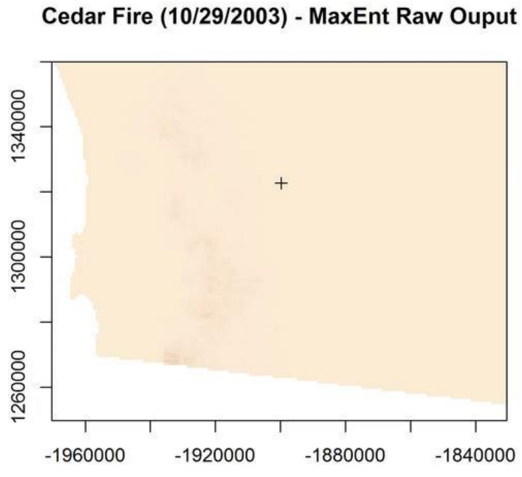
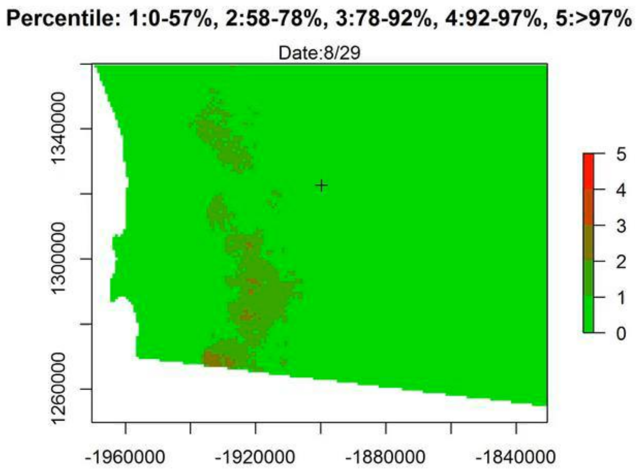
https://doi.org/10.1071/WF17147

Fuel and topographic influences on wildland firefighter burnover fatalities in Southern California

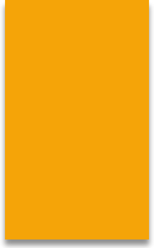
Wesley G. Page[A] *and Bret W. Butler*[A]

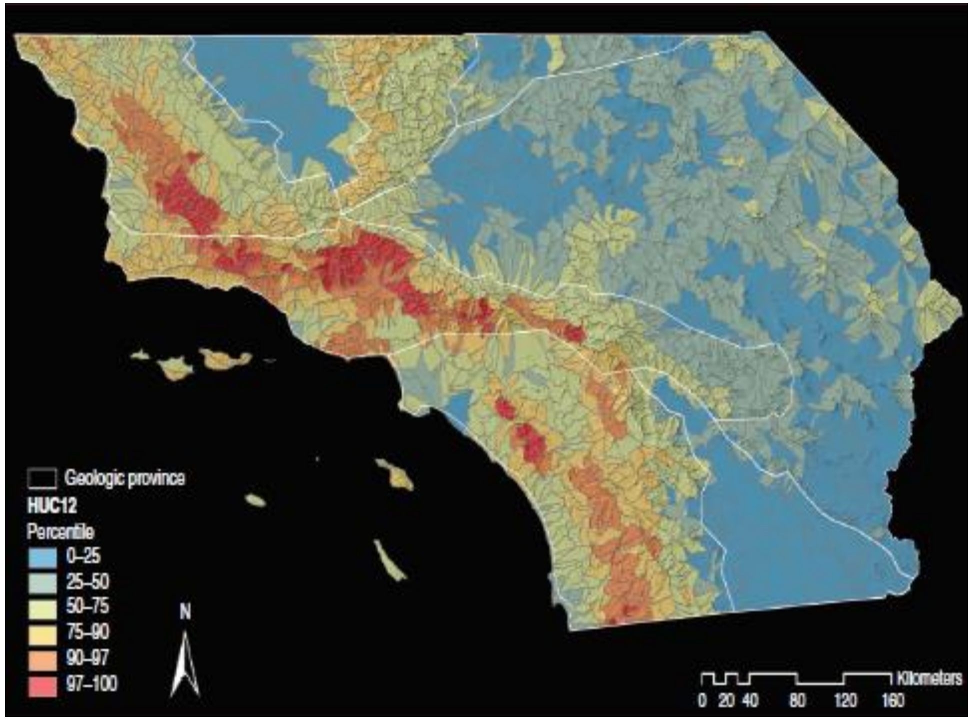
[A]USDA Forest Service, Rock
5775 Highway 10 W, Mis
[B]Corresponding authors. En





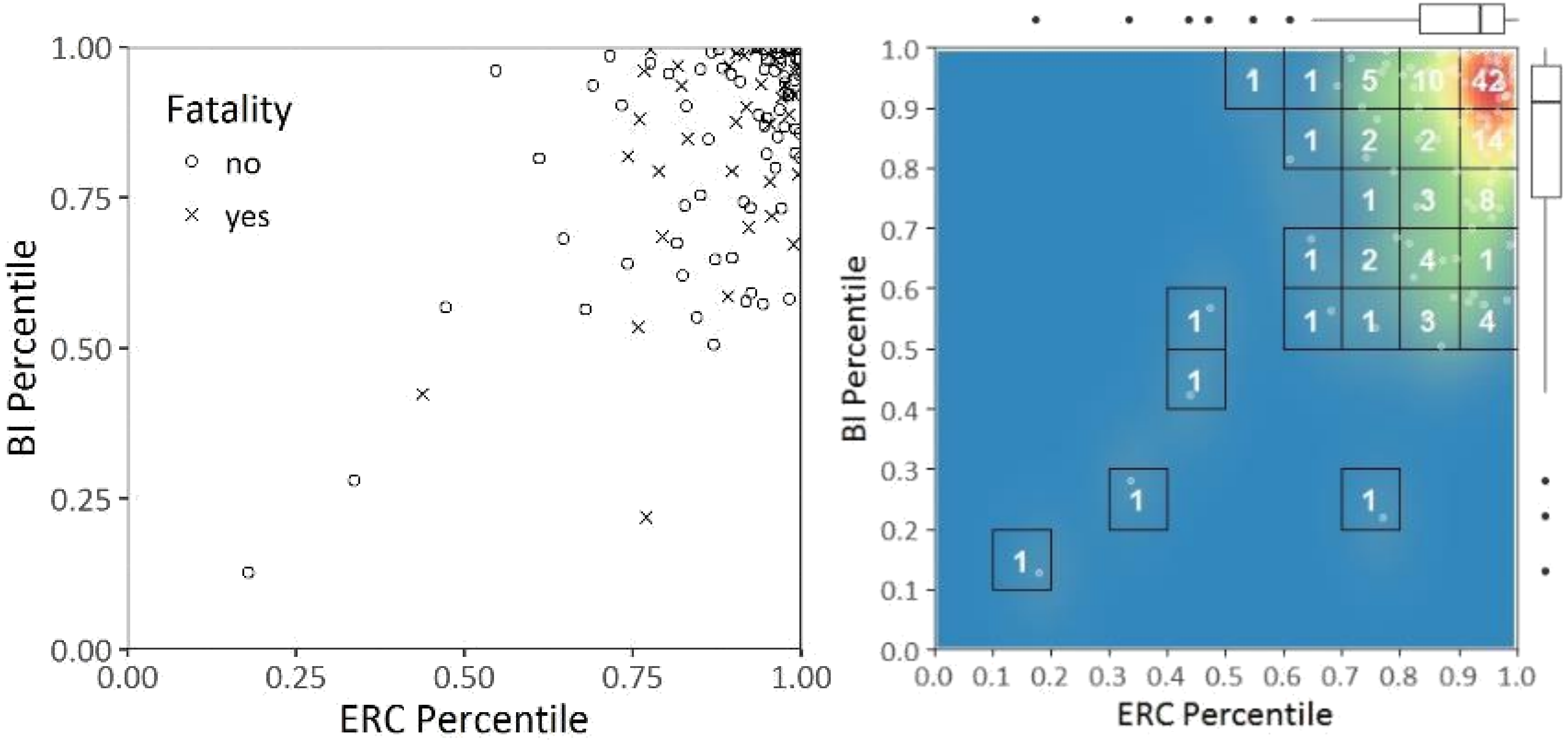
Cedar Fire 2003: By the time the fire was fully contained on November 4, it had destroyed 2,820 buildings (including 2,232 homes) and killed 15 people, including one firefighter.[2]



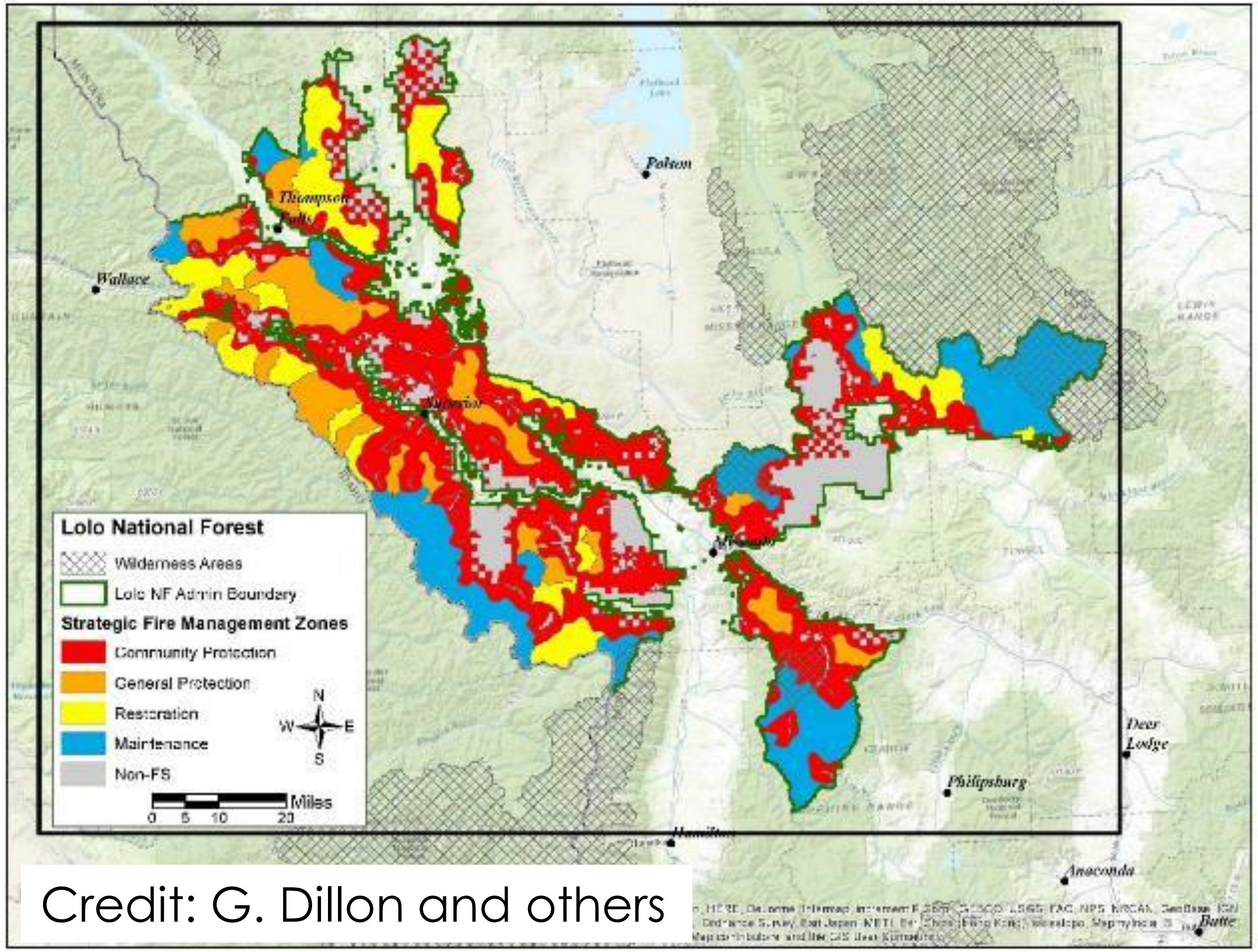


Relationships between fire danger indices and firefighter entrapments

Page, Freeborn and Jolly, Unpublished Data



Forest-wide risk assessment for the Lolo National Forest



Credit: G. Dillon and others

Framework for discussion

Fire Environment	Low/Moderate	High/Very High	Extreme
Risk Zones			
Community Protection			
General Protection			
Restoration			
Maintenance			

What strategies usually work?
How would tactics be modified? (Line production, Burnouts, etc..,)

Thank you…… Question?

MJOLLY@FS.FED.US

Thanks