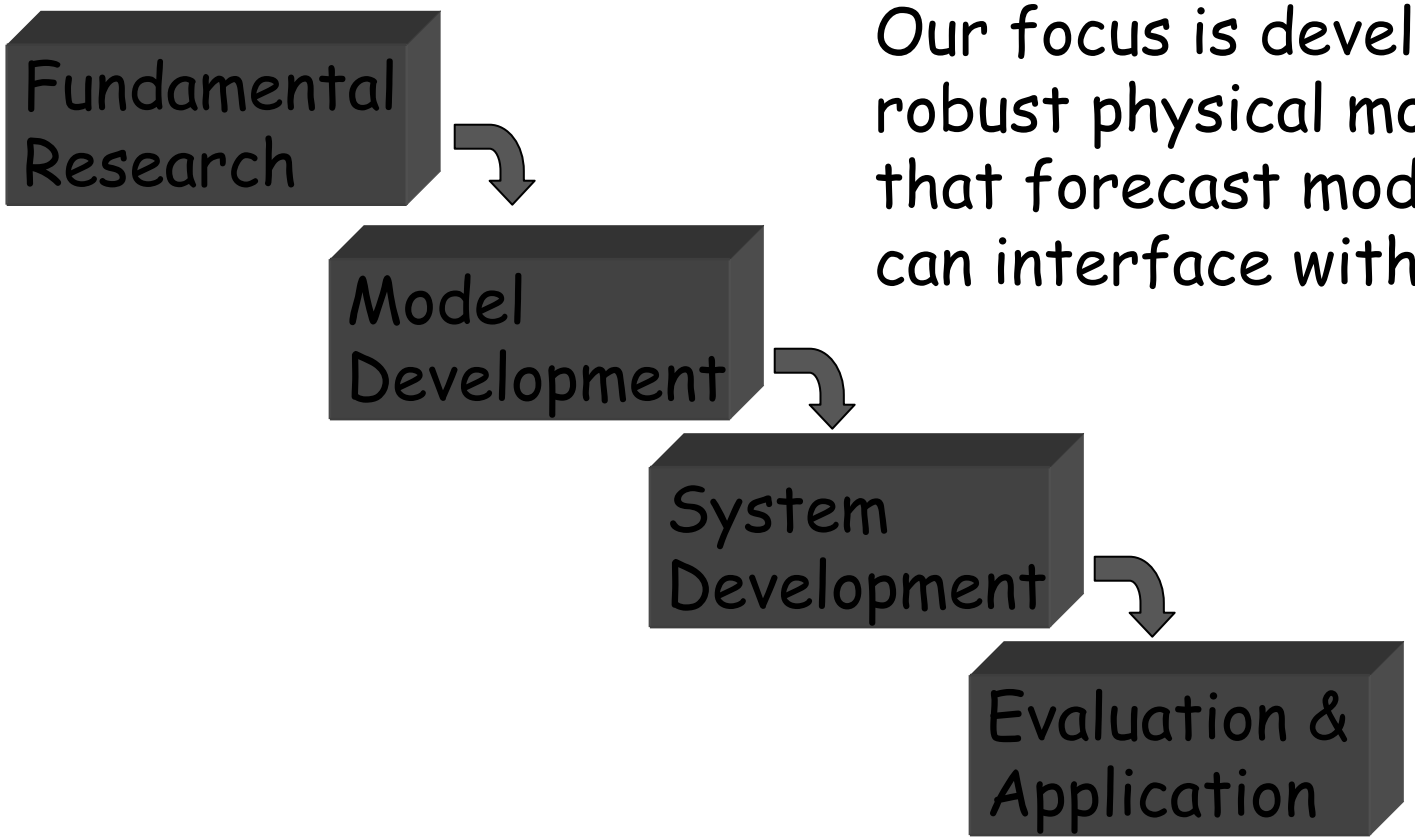
Basics of the National Fire Danger Rating System

Larry Bradshaw
USDA, Forest Service
Rocky Mountain Research Station
Missoula Fire Sciences Laboratory
Fire Behavior Research

Topics

- Fire Behavior Research Overview
- Philosophy
- Development History
- Mechanics and Operation
- Application
- Cautions

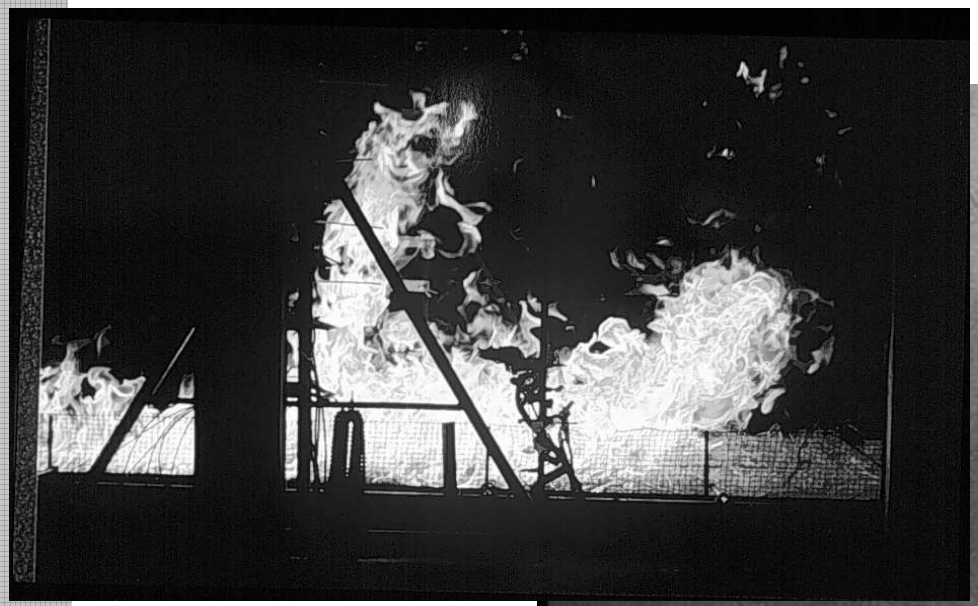
Fire Behavior Research



Our focus is developing robust physical models that forecast models can interface with.

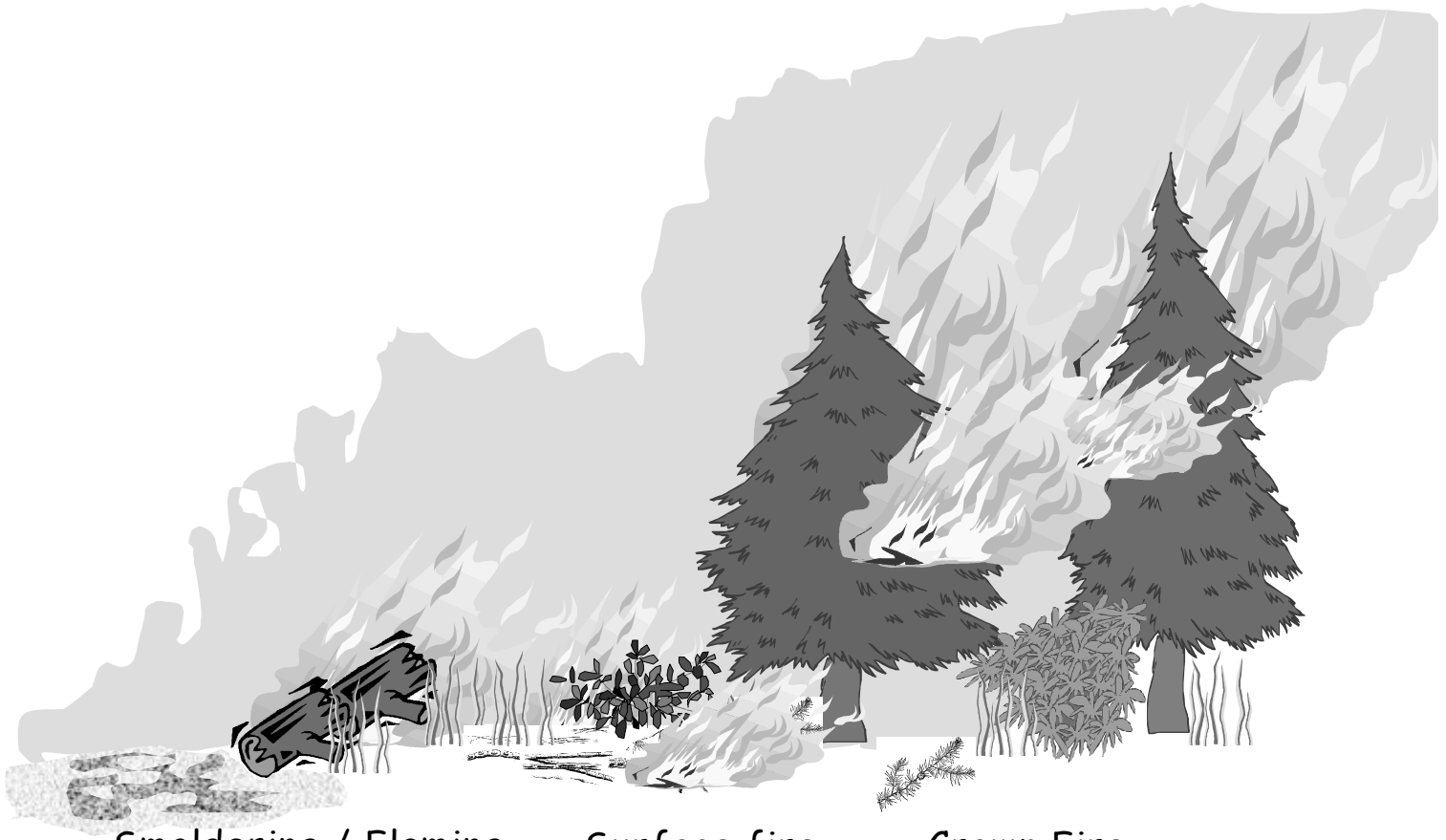
Fundamental Research

Lab and field experiments



Model Development

Surface, crown, post-frontal combustion



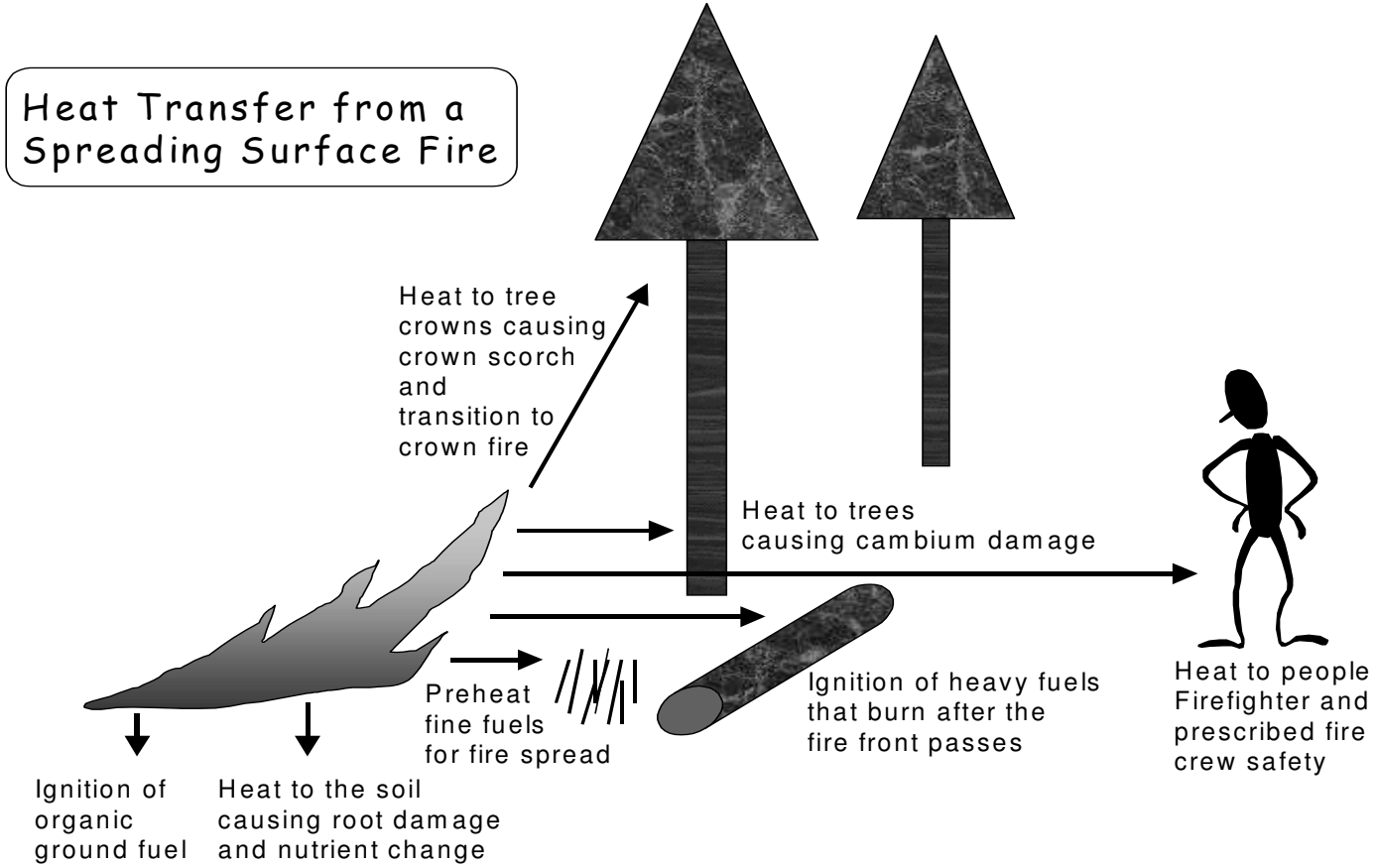
Smoldering / Flaming
Burnout of fuel behind
the fire front

Surface fire
spread

Crown Fire

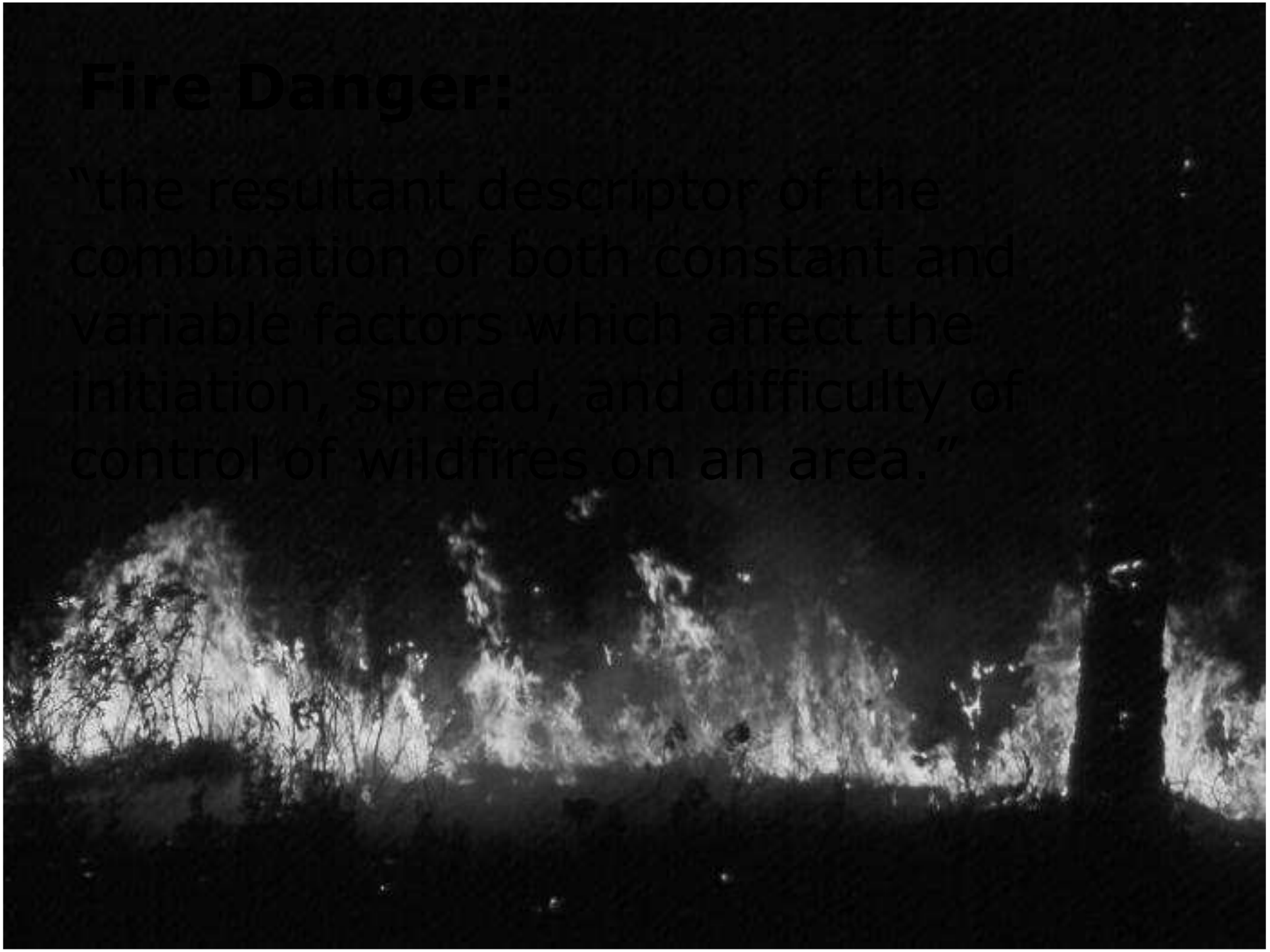
Model Development

Heat transfer, links to fire effects



System Development

- Rothermel Fire Spread Model (1972)
- NFDRS (1972, 1978, 1988)
- Behave & Behave Plus
- FARSITE
- FireFamily Plus
- Wildland Fire Assessment System
- FlamMap


Fire Danger:
"the resultant descriptor of the combination of both constant and variable factors which affect the initiation, spread, and difficulty of control of wildfires on an area."

NFDRS Philosophy

- Science/Physics Based (as opposed to statistical)
- Considers only initiating fires
- Considers containment not extinguishment
- Ratings are to be interpretable and meaningful
- Relates containment job to flame length
- Ratings are relative
- Time and location of weather observations reflect 'worst case'

Development History

- Pre 1964 – Regional Systems
- 1964 - 1st National Build Up Index
- 1972 - Use of Rothermel Model
- 1978 - Update to 1972
- 1988 - Southeast Update (KBDI)

NFDRS Basic Structure

Site and Weather Observations

Inputs

Live and dead fuel moistures

Intermediate Calculated Values

Indices and Components

Outputs

Station Locations as Catalogued in WIMS:

(Inv. Dist.^{2} Interp.)

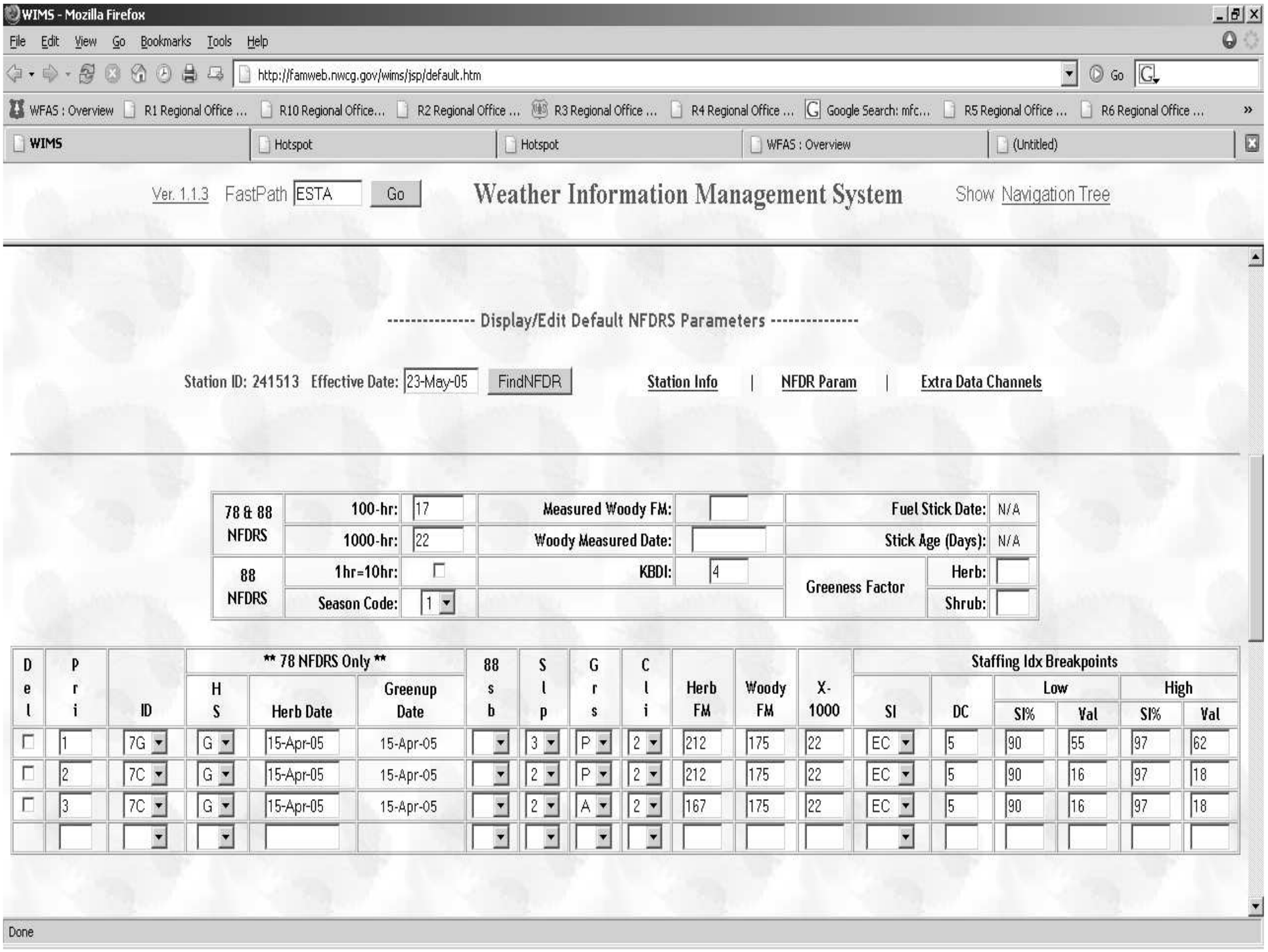
WFAS-MAPS Graphics FIRE BEHAVIOR RESEARCH MISSOULA, MT

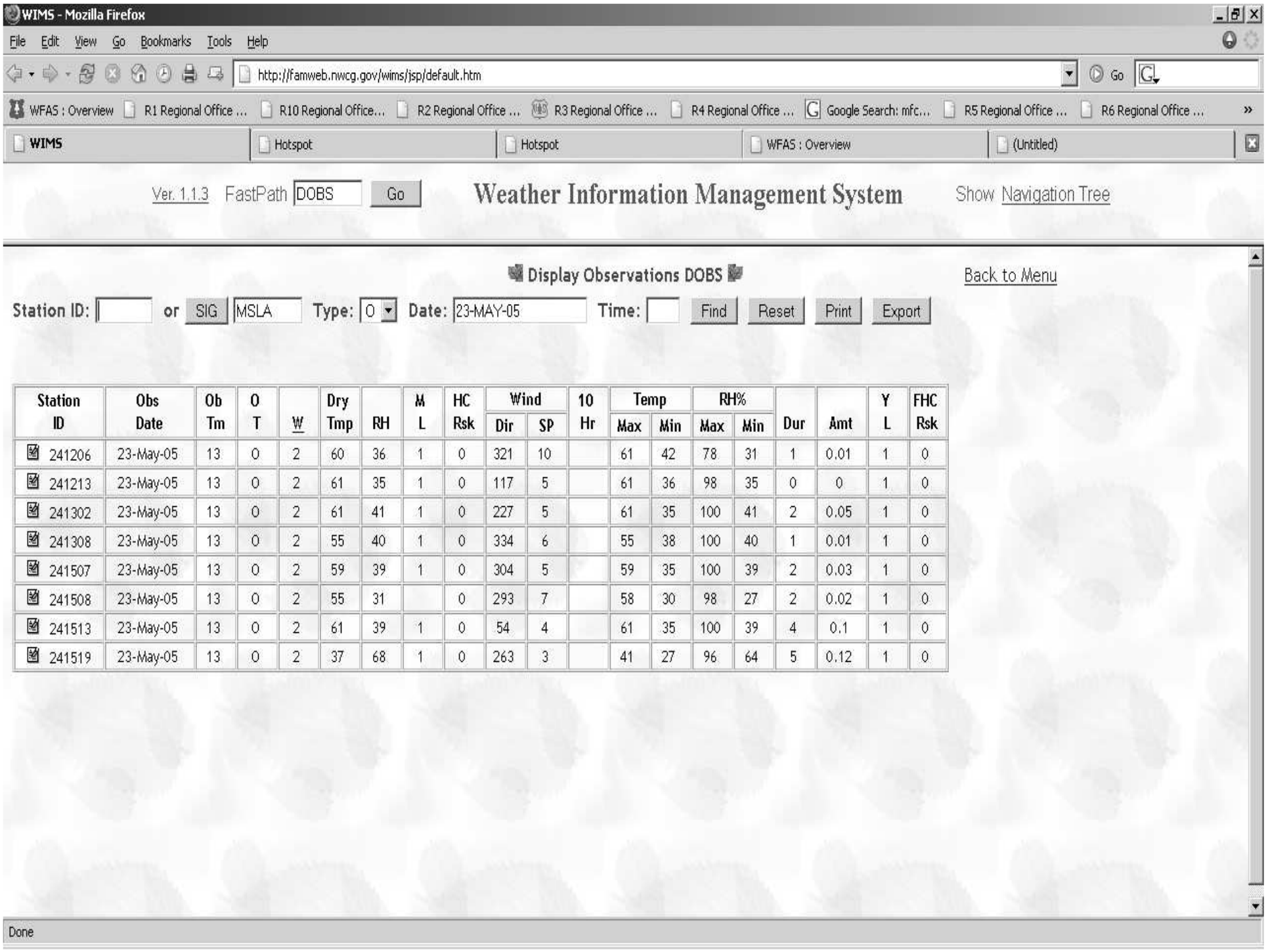
20 Fuel Models

- Grass
- Brush
- Trees
- Slash
- Slightly different for both 78 & 88 systems

Operational Systems

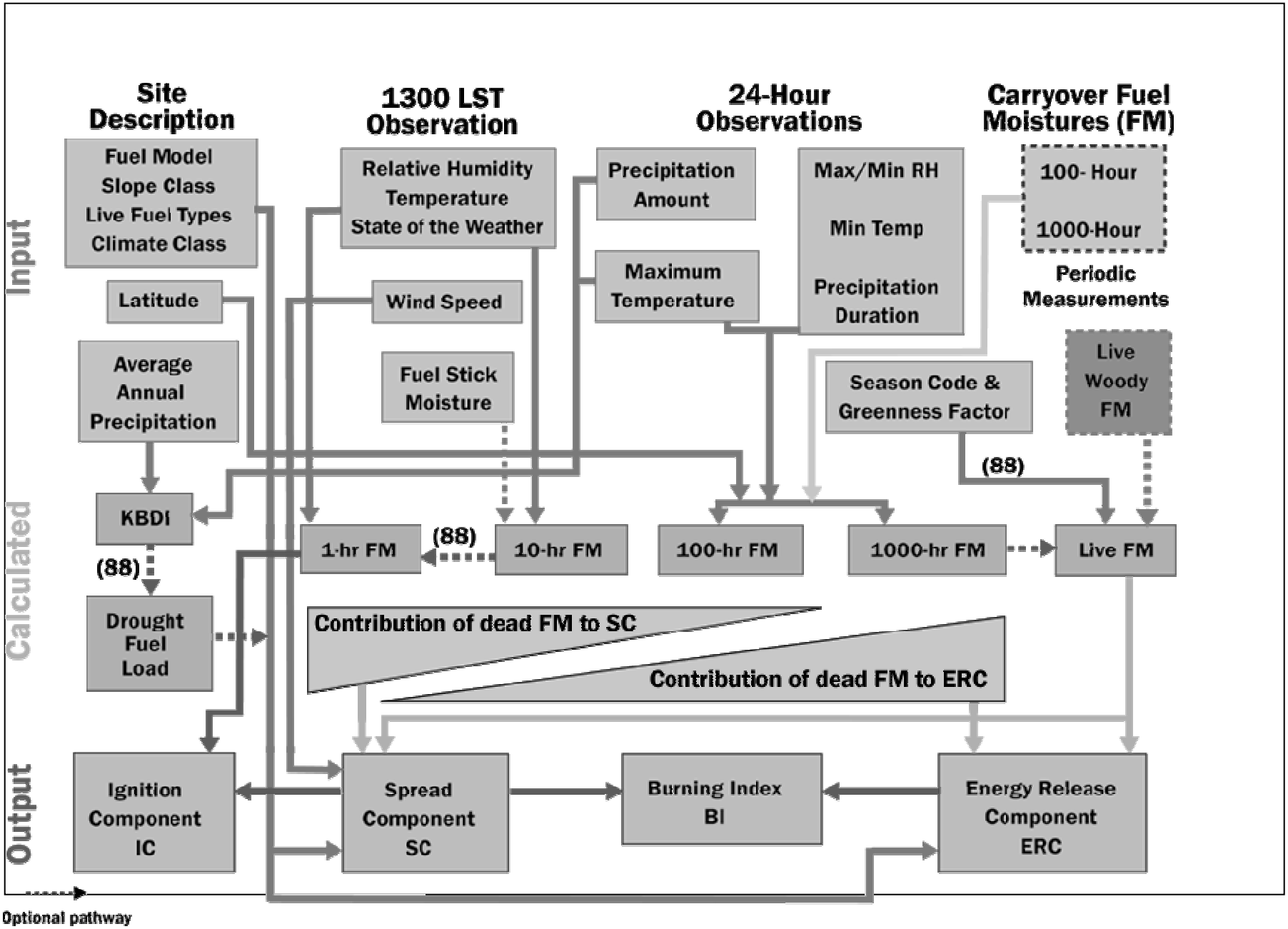
- ASCADS – Delivers RAWS Data
- WIMS – Process NFDRS
- NIFMID – Stores WX & Fire
- KCFAST – Access WX & Fire
- FIREFAMILY – Fire WX Climate


WIMS - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
http://famweb.nwcg.gov/wims/jsp/default.htm
Go
WFAS : Overview
R1 Regional Office ...
R10 Regional Office...
R2 Regional Office ...
R3 Regional Office ...
R4 Regional Office ...
Google Search: mfc...
R5 Regional Office ...
R6 Regional Office ...
WIMS
Hotspot
Hotspot
WFAS : Overview
(Untitled)
Ver. 1.1.3
FastPath ESTA
Go
Weather Information Management System
Show Navigation Tree
---------- Display/Edit Default NFDRS Parameters ----------
Station ID: 241513
Effective Date: 23-May-05
FindNFDR
Station Info | NFDR Param | Extra Data Channels
78 & 88 NFDRS
100-hr: 17
Measured Woody FM:
Fuel Stick Date: N/A
1000-hr: 22
Woody Measured Date:
Stick Age (Days): N/A
88 NFDRS
1hr=10hr:
KBDI: 4
Season Code: 1
Greeness Factor
Herb:
Shrub:
Del
Pri
ID
** 78 NFDRS Only **
HS
Herb Date
Greenup Date
88sb
Slp
Grs
Cli
Herb FM
Woody FM
X-1000
Staffing Idx Breakpoints
SI
DC
Low
SI%
Val
High
SI%
Val
1 7G G 15-Apr-05 15-Apr-05 3 P 2 212 175 22 EC 5 90 55 97 62
2 7C G 15-Apr-05 15-Apr-05 2 P 2 212 175 22 EC 5 90 16 97 18
3 7C G 15-Apr-05 15-Apr-05 2 A 2 167 175 22 EC 5 90 16 97 18
Done

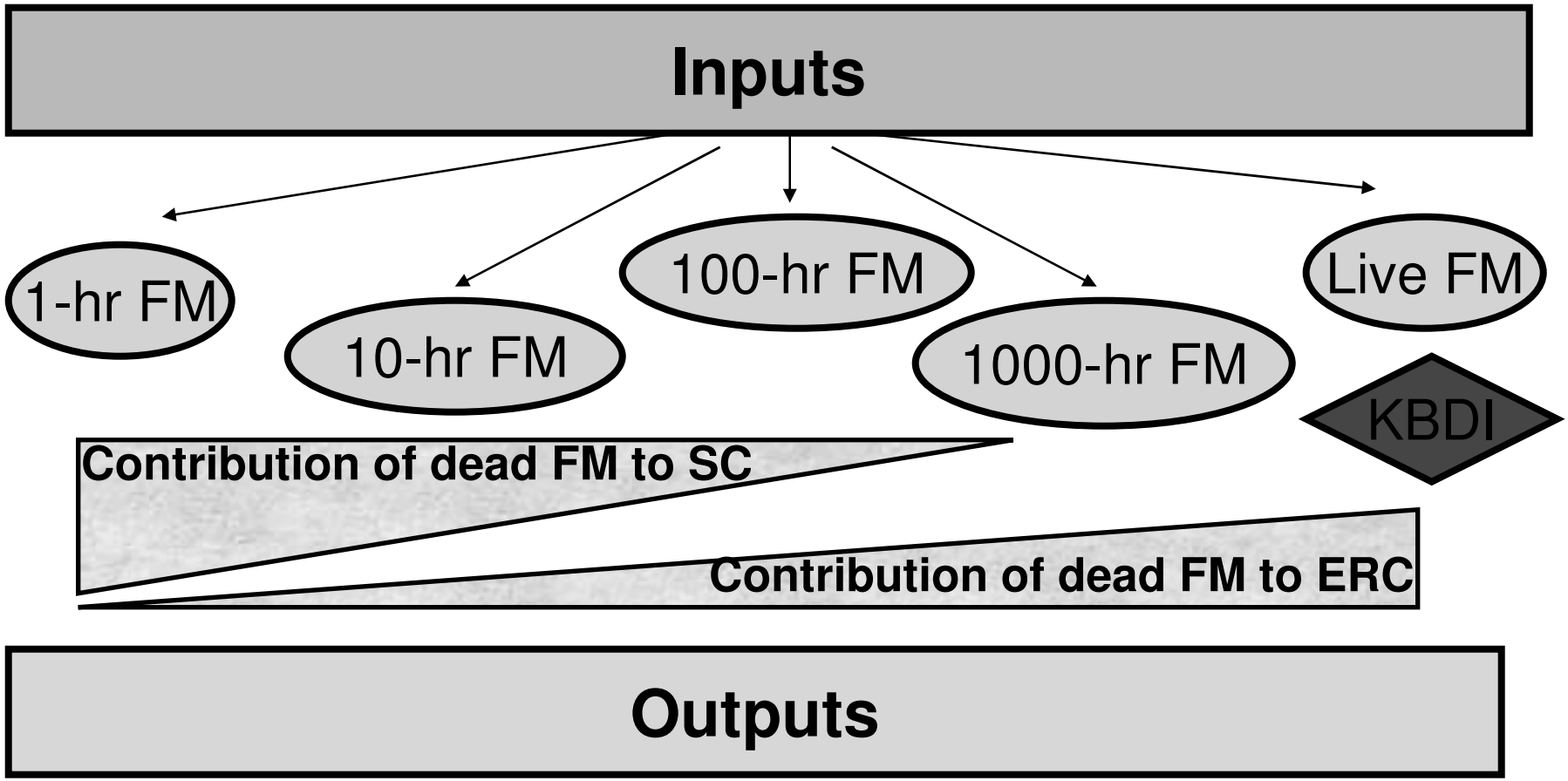


Station ID	Obs Date	Ob Tm	O T	W	Dry Tmp	RH	M L	HC Rsk	Wind		10 Hr	Temp		RH%		Dur	Amt	Y L	FHC Rsk
									Dir	SP		Max	Min	Max	Min				
241206	23-May-05	13	0	2	60	36	1	0	321	10		61	42	78	31	1	0.01	1	0
241213	23-May-05	13	0	2	61	35	1	0	117	5		61	36	98	35	0	0	1	0
241302	23-May-05	13	0	2	61	41	1	0	227	5		61	35	100	41	2	0.05	1	0
241308	23-May-05	13	0	2	55	40	1	0	334	6		55	38	100	40	1	0.01	1	0
241507	23-May-05	13	0	2	59	39	1	0	304	5		59	35	100	39	2	0.03	1	0
241508	23-May-05	13	0	2	55	31		0	293	7		58	30	98	27	2	0.02	1	0
241513	23-May-05	13	0	2	61	39	1	0	54	4		61	35	100	39	4	0.1	1	0
241519	23-May-05	13	0	2	37	68	1	0	263	3		41	27	96	64	5	0.12	1	0

NFDRS Detailed Structure



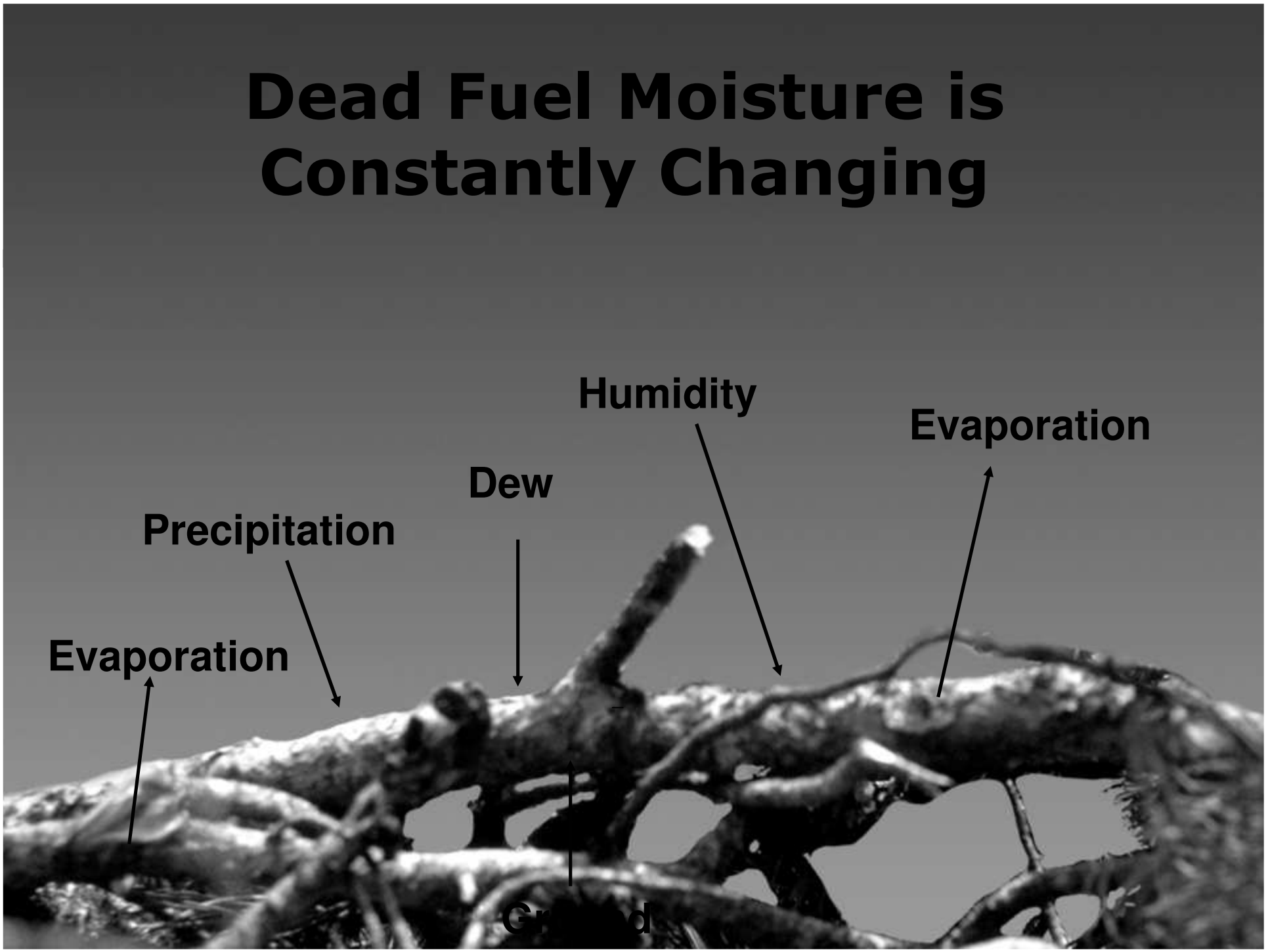
Intermediate Calculated Values



Dead Fuels

Dead Fuels are those fuels whose moisture content is determined by external environmental factors.

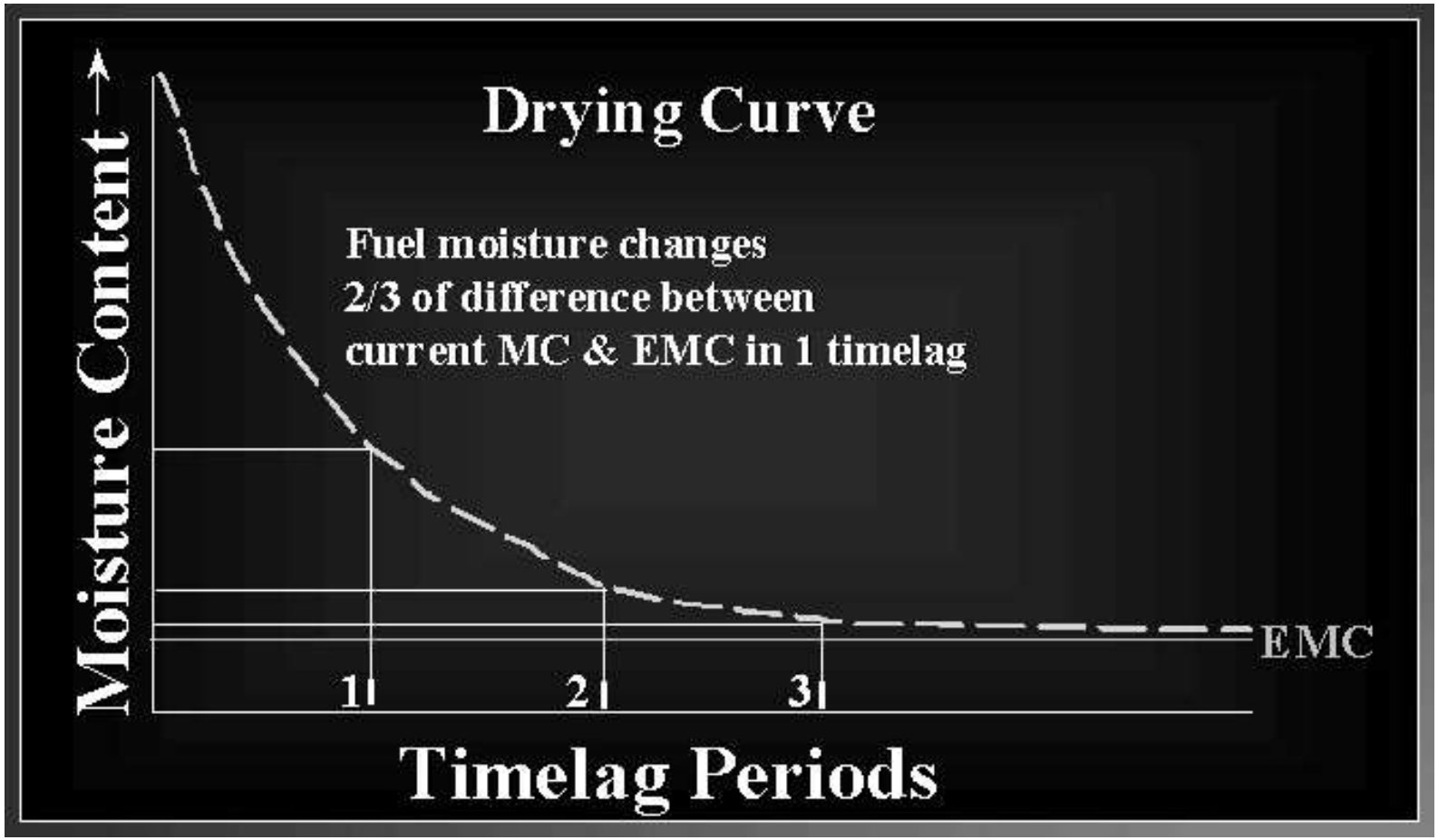
Dead Fuel Moisture is Constantly Changing



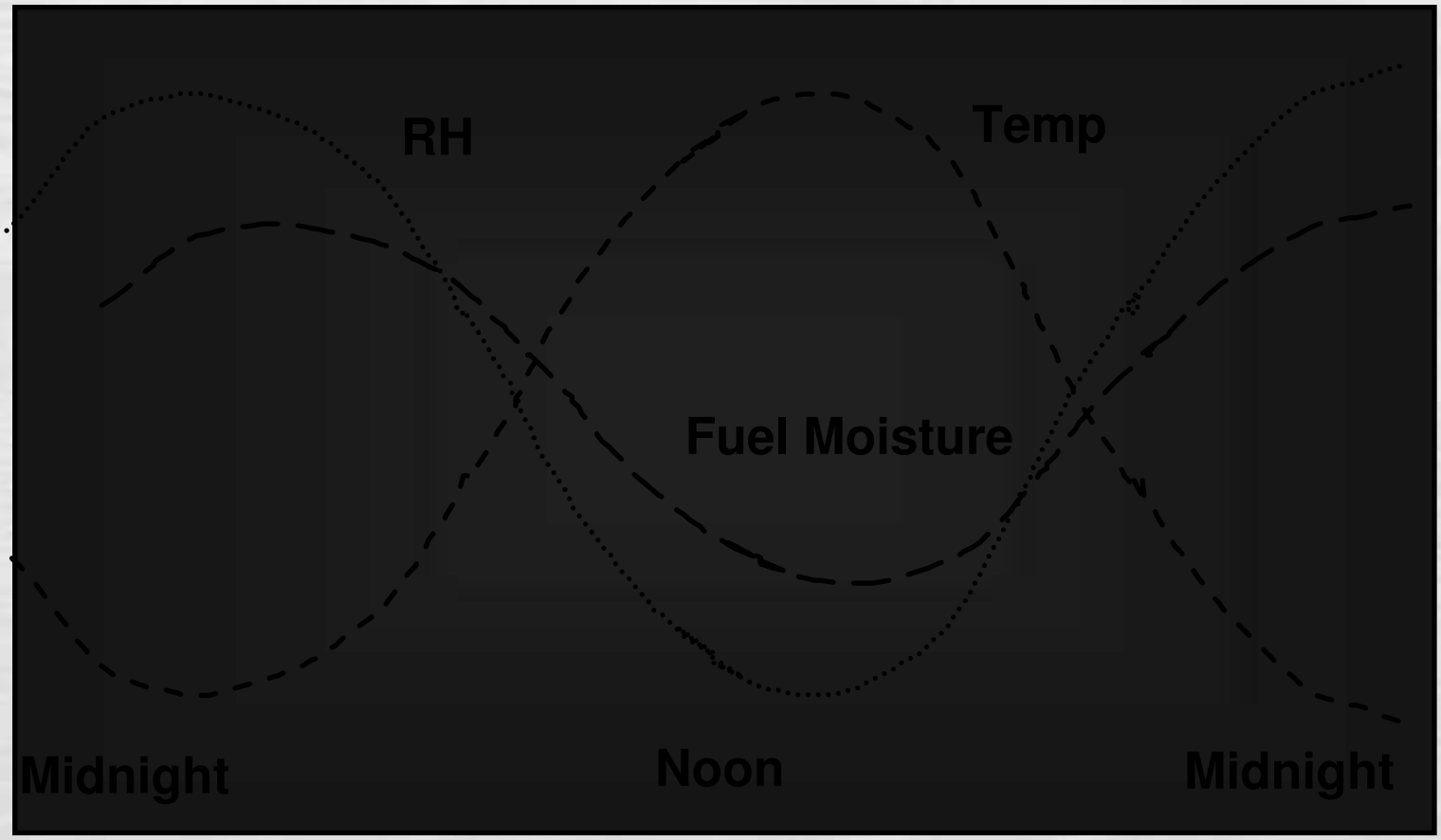
TIMELAG

The length of time it takes a fuel particle to lose (or gain) 63% of the difference between its moisture content and the equilibrium moisture content in a constant environment.

Timelag Concept



The Fuel Moisture Chase



NFDRS Timelag Classes

¼ in. (0.6 cm) dia.	1 hour TL FM
¼ - 1 in. (2.5 cm) dia.	10 hour TL FM
1 - 3 in. (6.7 cm) dia.	100 hour TL FM
3 - 8 in. (20 cm) dia.	1000 hour TL FM

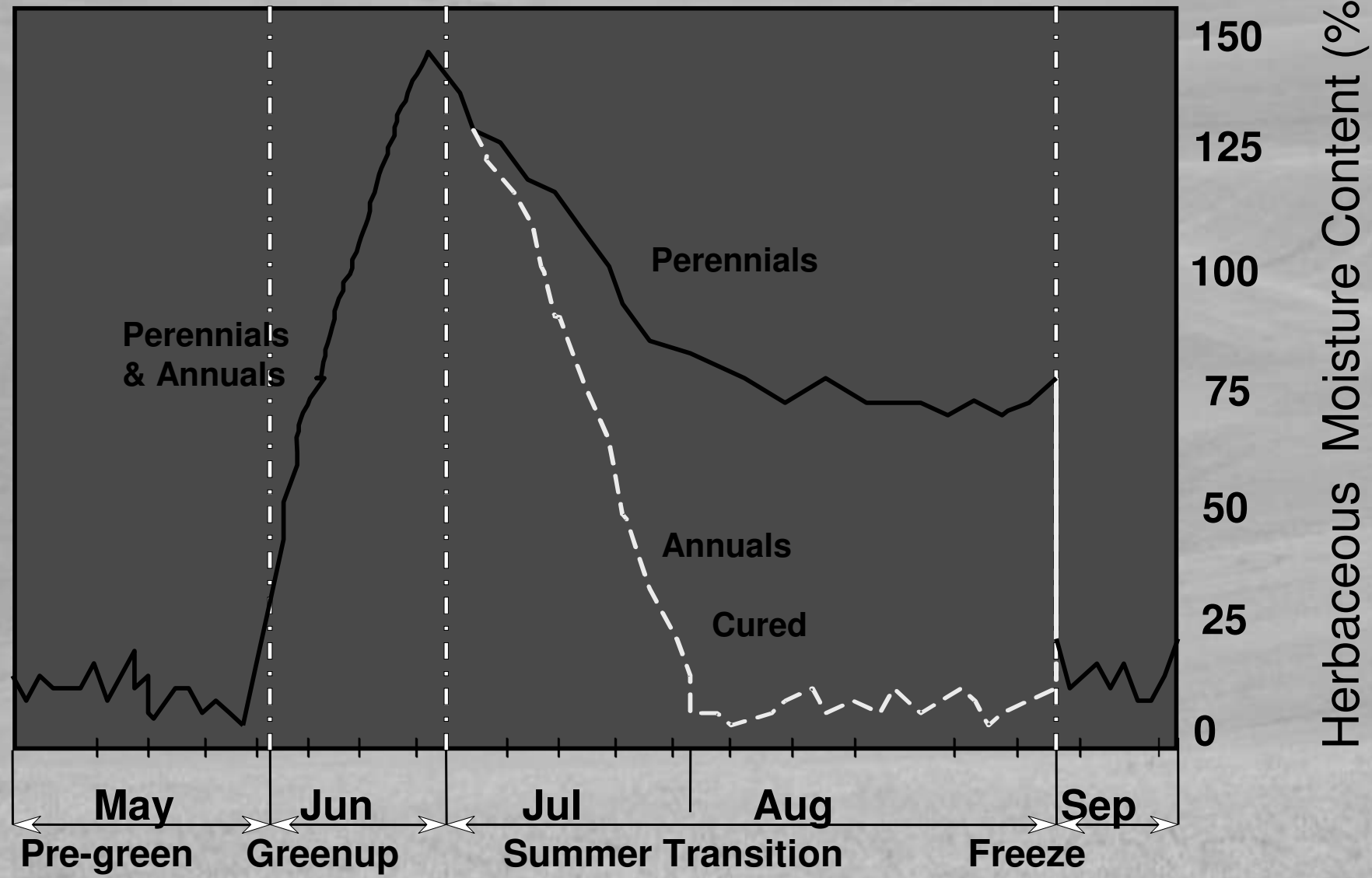
Live Fuels

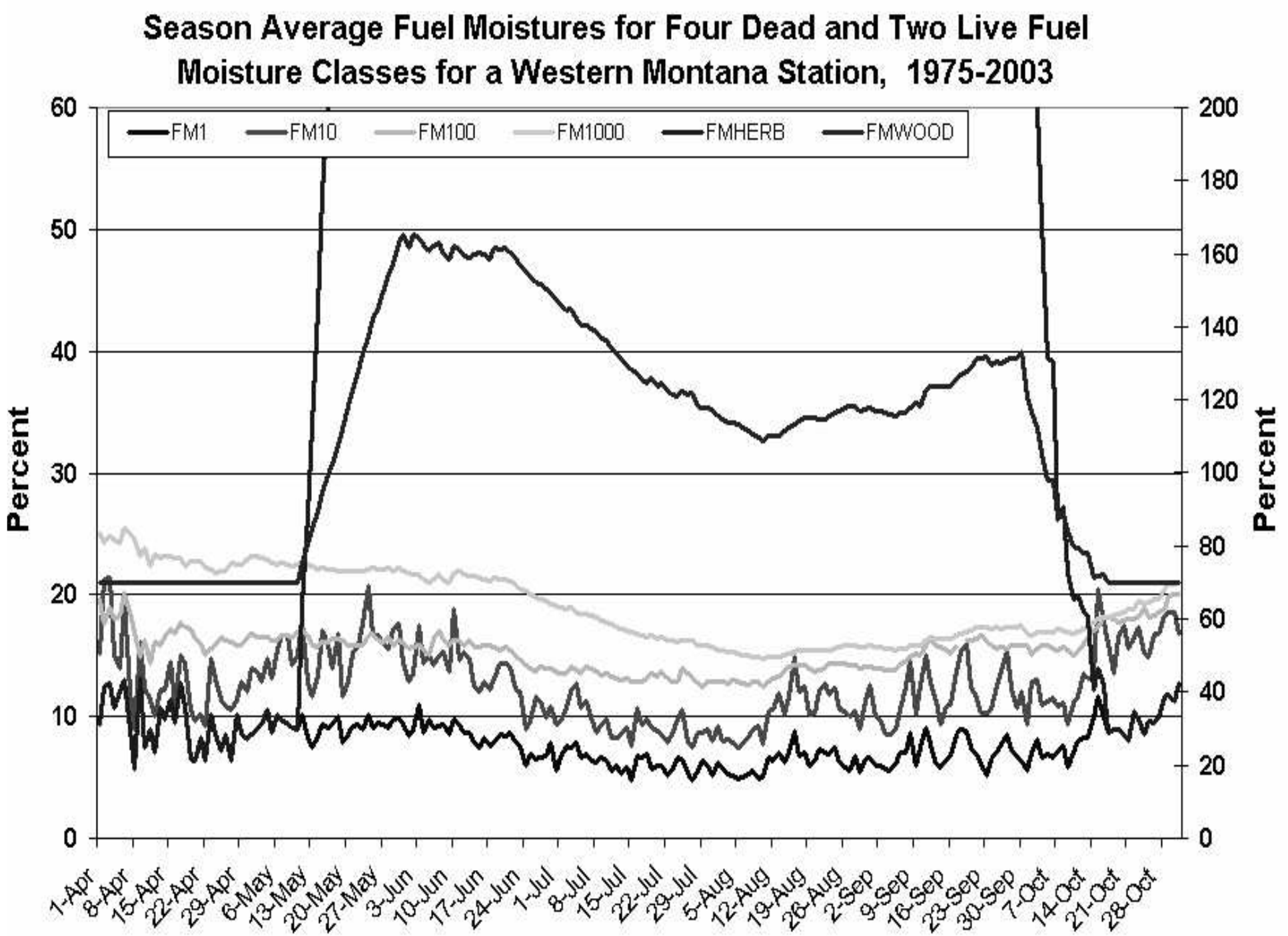
Moisture content is determined by physiological processes within the plant.

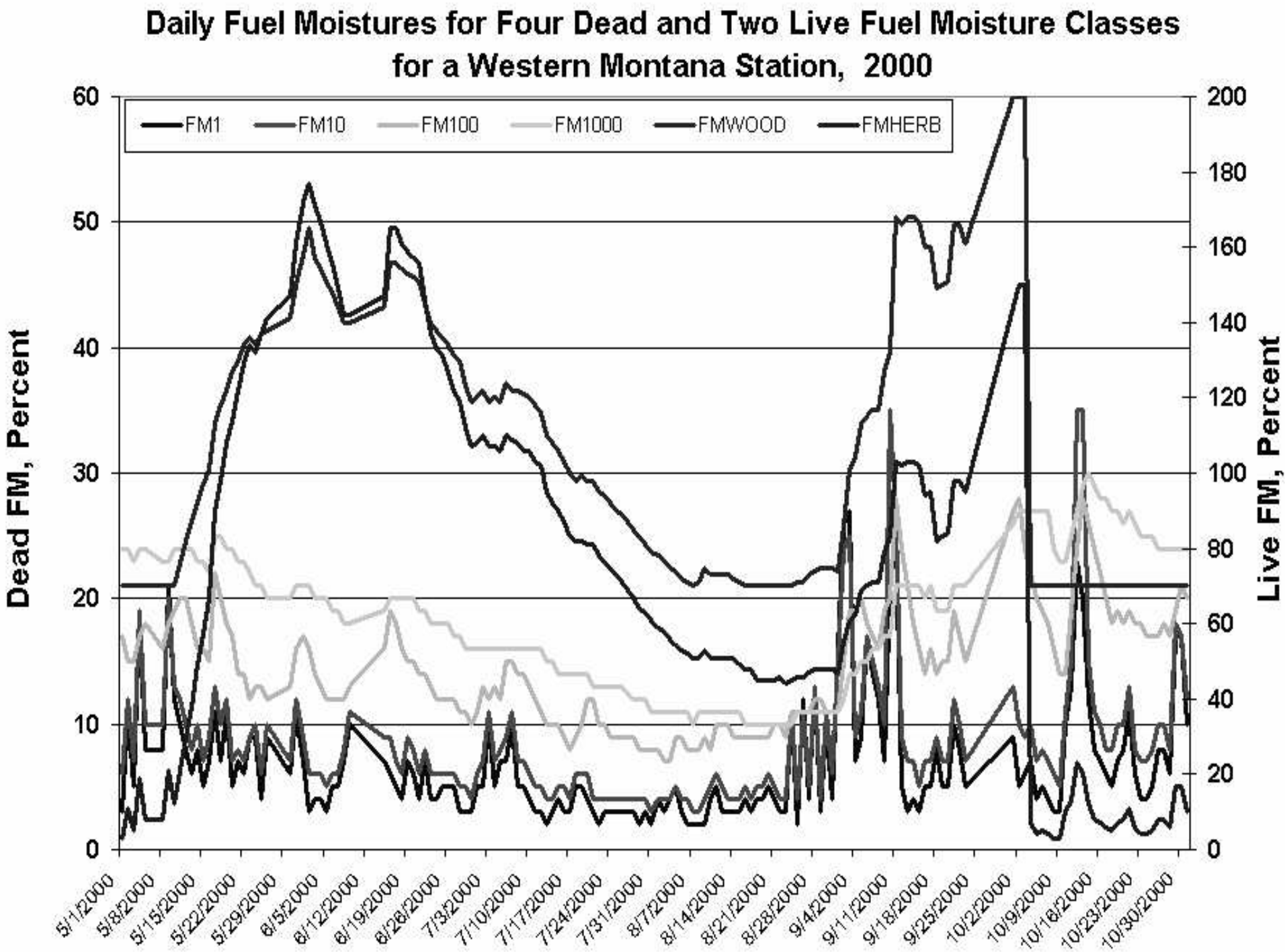
Stages of Plant Development

- Dormancy or frozen – Plant parts are assumed dead.
- Green-up or the growing season – Moisture content rises to its highest.
- Transition – Plant processes start shutting down and growth slows.
- Cured – Normal plant functions have shut down and not growth is occurring (herbaceous plants only).

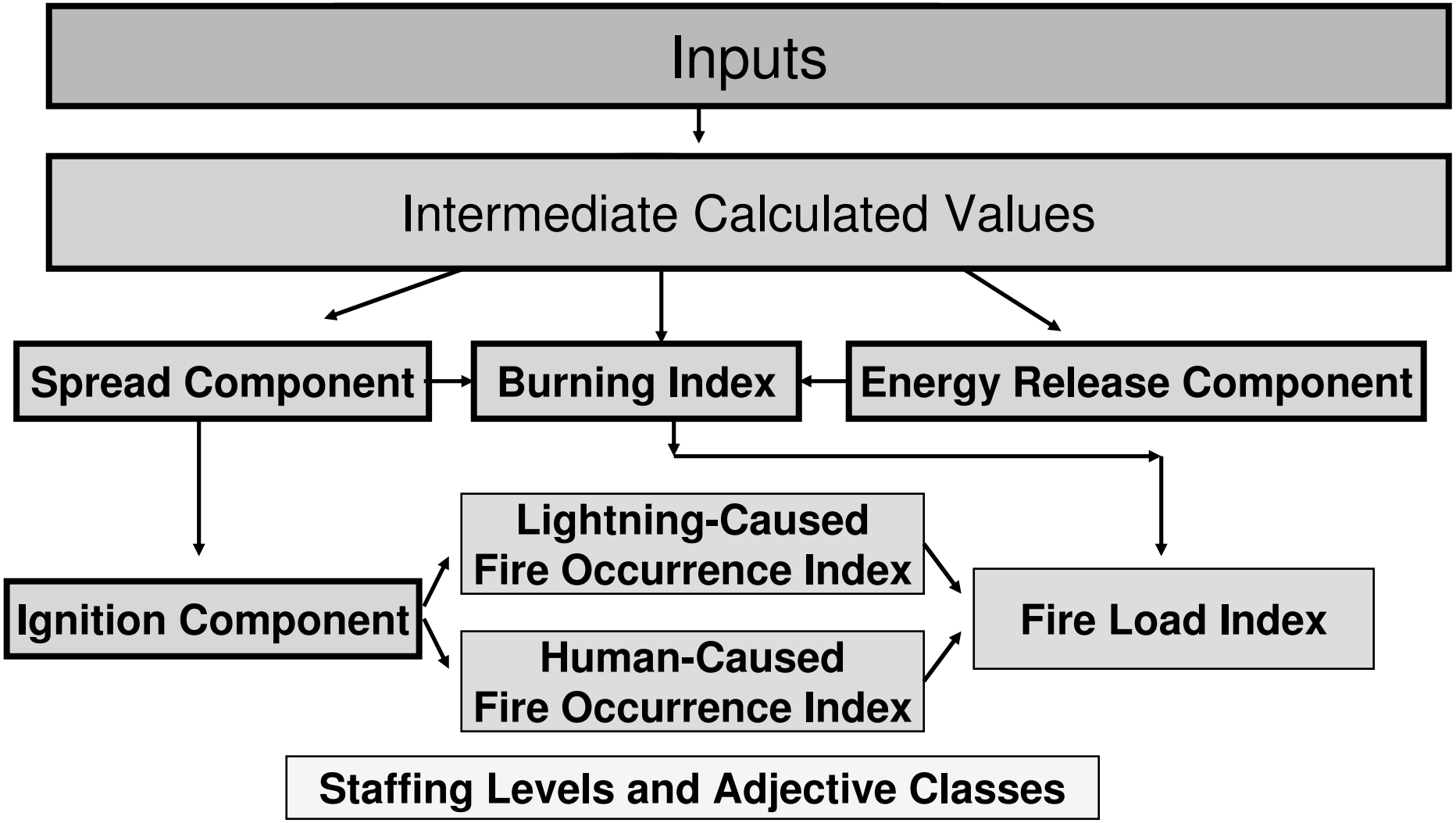
Seasonal Pattern of Plant Development




Season Average Fuel Moistures for Four Dead and Two Live Fuel Moisture Classes for a Western Montana Station, 1975-2003
FM1
FM10
FM100
FM1000
FMHERB
FMWOOD
Percent
Percent
60
50
40
30
20
10
0
200
180
160
140
120
100
80
60
40
20
0
1-Apr
8-Apr
15-Apr
22-Apr
29-Apr
6-May
13-May
20-May
27-May
3-Jun
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
22-Jul
29-Jul
5-Aug
12-Aug
19-Aug
26-Aug
2-Sep
9-Sep
16-Sep
23-Sep
30-Sep
7-Oct
14-Oct
21-Oct
28-Oct


Daily Fuel Moistures for Four Dead and Two Live Fuel Moisture Classes for a Western Montana Station, 2000
FM1
FM10
FM100
FM1000
FMWOOD
FMHERB
Dead FM, Percent
Live FM, Percent
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
160
180
200
5/1/2000
5/8/2000
5/15/2000
5/22/2000
5/29/2000
6/5/2000
6/12/2000
6/19/2000
6/26/2000
7/3/2000
7/10/2000
7/17/2000
7/24/2000
7/31/2000
8/7/2000
8/14/2000
8/21/2000
8/28/2000
9/4/2000
9/11/2000
9/18/2000
9/25/2000
10/2/2000
10/9/2000
10/16/2000
10/23/2000
10/30/2000

NFDRS Outputs



Spread Component (SC)

- A rating related to potential 24-hr worst case head fire forward rate of spread.
- Fire initiating in area with SC = 15 would spread at about half the rate of fires in area with SC of 30.

SC Characteristics

- Surface area weighting gives fine fuel moisture most influence
- Sensitive to fuel model parameters (grass and shrub models more reactive than timber and slash)
- Very sensitive to wind (harder to predict and highly variable)

Ignition Component (IC)

- A rating of the probability (0 to 100%) that a firebrand will cause a fire requiring suppression action
- Ideal example: at an IC of 60, if you dropped 100 matches, 60 would cause fires that resulted in reported suppression action, and 40 would not

Energy Release Component (ERC)

- Related to total energy released per unit area within flaming fire front
- Relates to the amount of available fuel (fuel dryness and load)
- About 25 BTUs per unit value of ERC

ERC Characteristics

- Good characterization of fire season for fuel models with large dead fuels.
- Lower variability because not influenced by wind and slope
- Good predictability

Burning Index (BI)

- An estimate of the potential difficulty of fire containment as it relates to flame length at the head of the fire
- A scaled index to predicted flame length -- BI ÷ 10 estimates flame length

BI Characteristics

- Very high sensitivity to fuel model
- Low to moderate memory depending on fuel model
- Moderate variability
- Lower predictability (because of wind)
- Good characterization of fire season in models with live or a heavy dead component

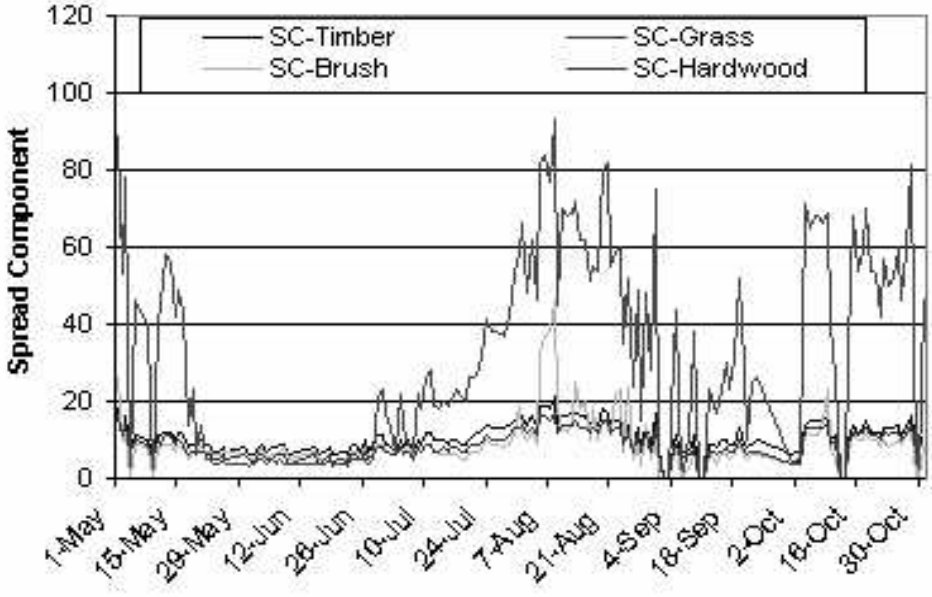
KBDI

KBDI is a number representing the net effect of evapotranspiration and precipitation in producing cumulative moisture deficiency in deep duff and upper (8 inches, 20 cm) soil layers.

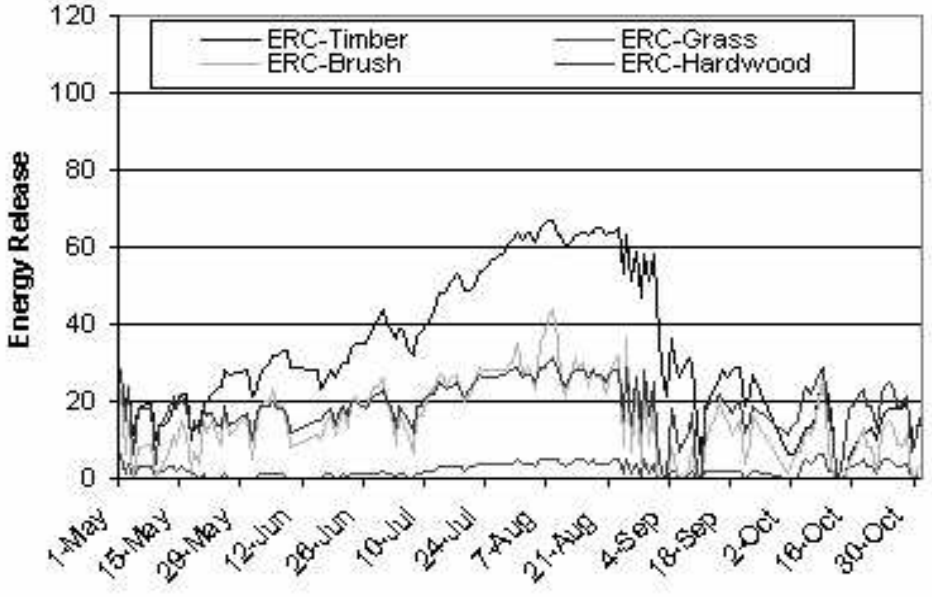
Summary for Indices and Components

Characteristic	**SC**	**IC**	**ERC**	**BI**	**1000-hr**	**KBDI**
Sensitivity to fuel model	High	Mod	High	High	None	None
Memory	Low	Low	Mod/High	Low	High	High
Variability	High	High	Low	Mod	Low	Low
Predictability	Low	Low	High	Low	High	High
Fire season indicator	Low	Low	High	Mod/ High	High in West	Mod/ High
Driver	Wind, 1-hr, Live	SC, 1-hr	moisture - all sizes	SC, ERC	T/RH/ Rain dur/ Lat./FM	Max T, Rain

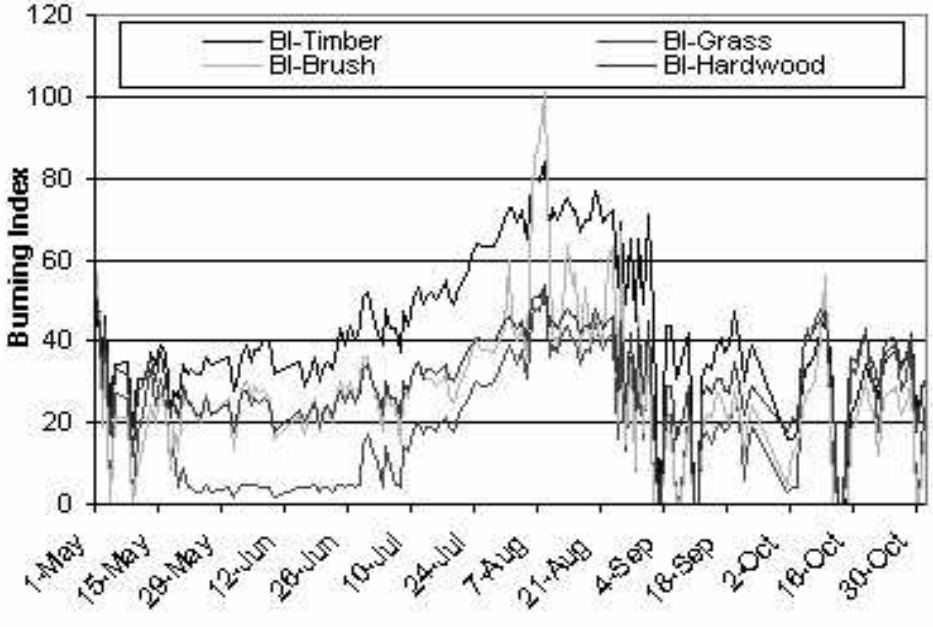
SC for Four Fuel Models



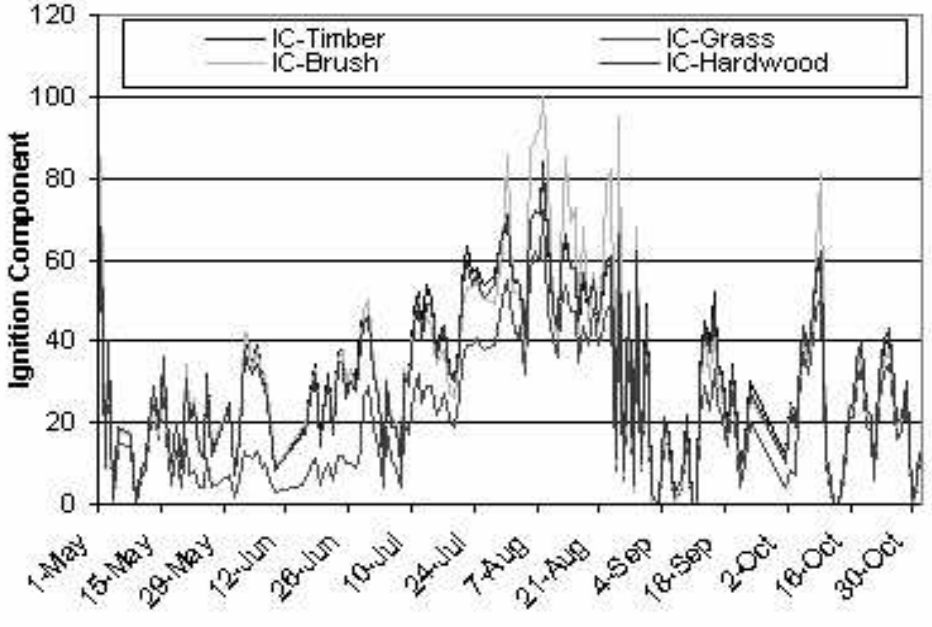
ERC for Four Fuel Models



BI for Four Fuel Models



IC for Four Fuel Models



What do the numbers mean ?

"a system that integrates the effects of existing and expected states of selected fire danger factors into one or more qualitative or numeric indices or components that reflect an area's protection needs."

What do the numbers mean ?

"...the FLI is the culminating index of the NFDRS. It is designed to combine the projections of fire occurrence and behavior into a single number that can be related to the total fire control job.

Because fire managers have not agreed on a common denominator for measuring the total job, the equation for calculating the FLI has been developed intuitively. *The task of attaching meaning to the FLI has been left to the users.* They will have to determine the relationship between the FLI and whatever measure of total fire control effort they choose."

The FLI has become "optional" because of input requirements.

Application:
Staffing Levels and Adjective Classes

- Historically developed based on NFDRS output and unit experience without inclusion of fire occurrence data
- Based on Cumulative Distributions
- Management and budget driven
- Best used within a Fire Danger Rating Area

Fire Danger Rating Area:

A geographic zone where fire danger is assumed uniform due to

- fuels
- weather
- topography

This FDRA is dominated by an expanse of longleaf pines (fuel model C) in NWS climatic zone 14 on a rolling landscape.

Fire Danger Continuum

The range of possible outputs for a fire danger index or component, given a set of NFDRS parameters and weather input.

Examples of Continuum Ranges

Burning Index based on 10+ years weather

Fuel Model G (Timber)

Percentile	0	50	80	97	100
Value	0	48	74	99	103

Fuel Model C (Grass)

Percentile	0	50	80	97	100
Value	0	24	36	50	52

Agency Standards

- **90th/97th percentile**
  - Forest Service, Bureau of Indian Affairs, Fish & Wildlife Service
- **80th/95th percentile**
  - Bureau of Land Management

Staffing Index Values

Computed Class	Upper Value for Class
0	SI = 0
1	(SI 90)/8
2	(SI 90)/4
3	(SI 90)/(3/8)
4	(SI 90)/2
5	(SI 90)/(3/4)
6	SI 90
7	(SI 90 + SI 97)/2
8	SI 97
9	More than SI 97

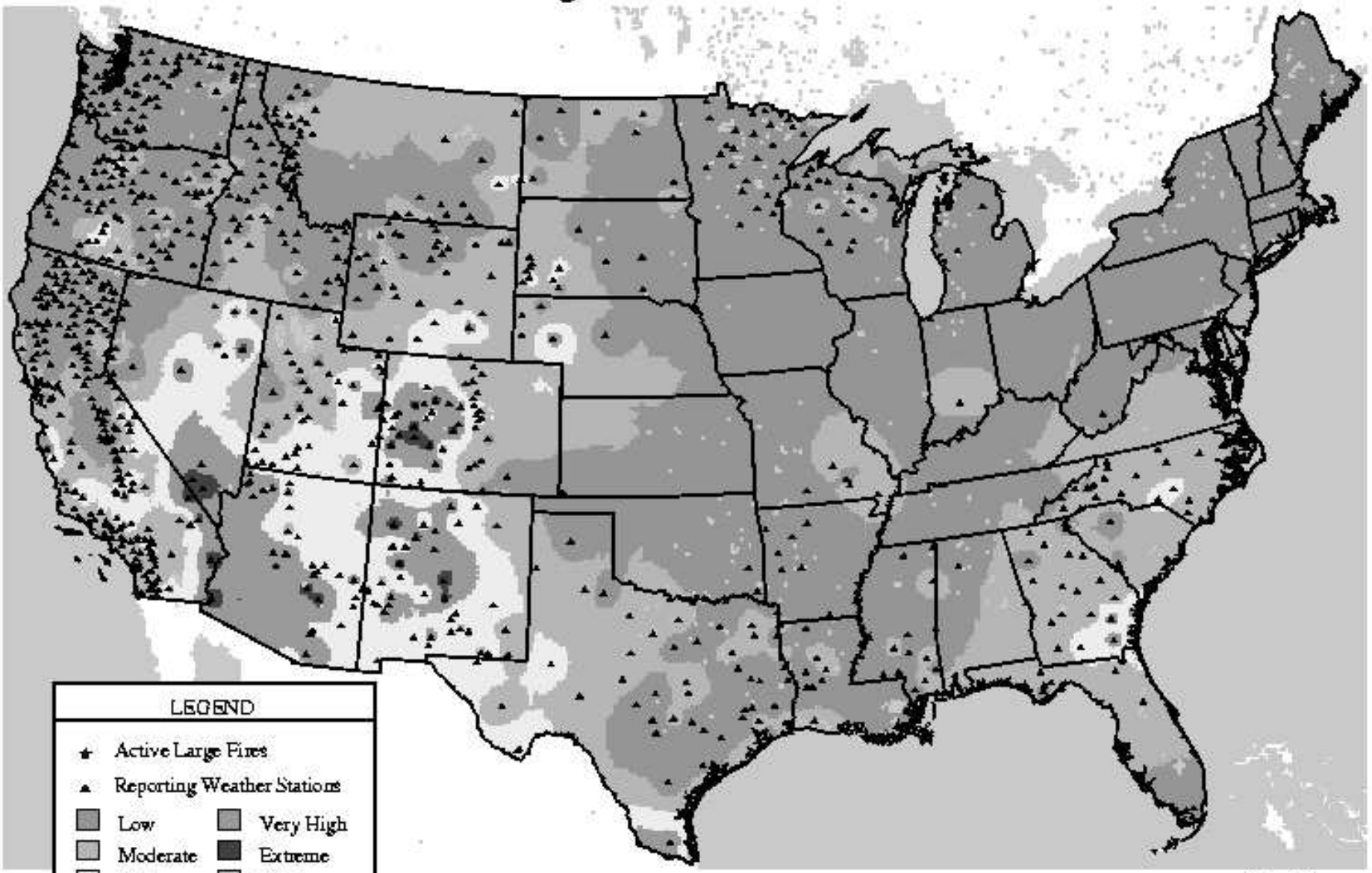
Staffing Class Matrix

Computed Class	0	1	2	3	4	5	6	7	8	9
# Staffing Levels	Displayed Staffing Classes									
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

Adjective Class Matrix

Staffing Level	Adjective Fire Danger				
0	0	0	0	0	0
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-,5,5+	H	VH	VH	E	E
Ignition Component (IC)	0-20	21-45	46-65	66-80	81-100

Observed Fire Danger Class: 23-MAY-05



(Inv. Dist.^{2} Interp.)

WFAS-MAPS Graphics National Interagency Fire Center Boise,ID

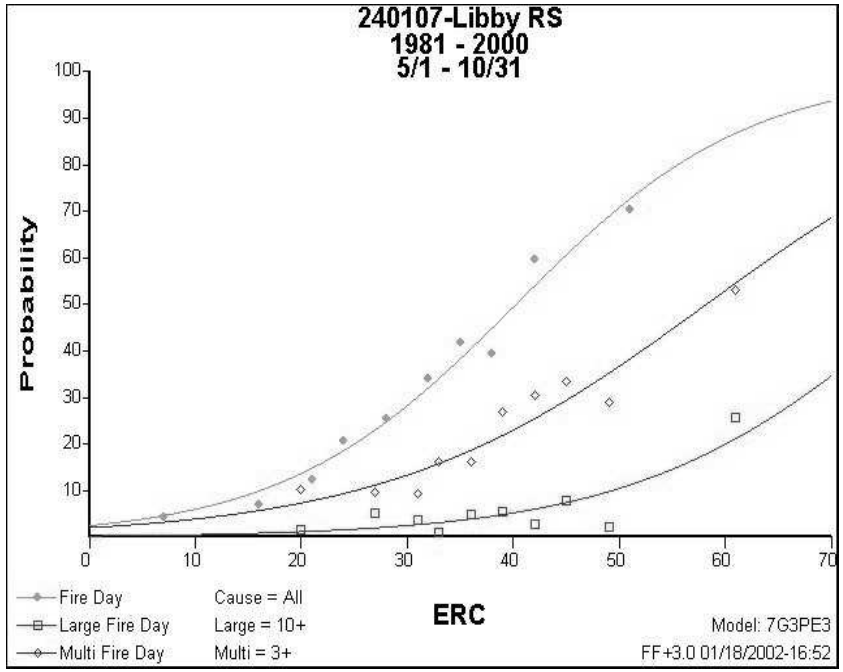
Fire Business Thresholds

- Based on correlations of fire danger climatology and fire occurrence
- This is where statistics come in.
- The FLI requires statistical parameters to tune.

Evaluation of Indexes

Methods in FireFamily Plus

- Compare to fire activity
- Threshold analysis
- Logistic regression
- Percentile analysis



- ROC analysis

- Developing methods for evaluation of spatial fire potential indicators

NFDRS Recap

Weather **Fuel**

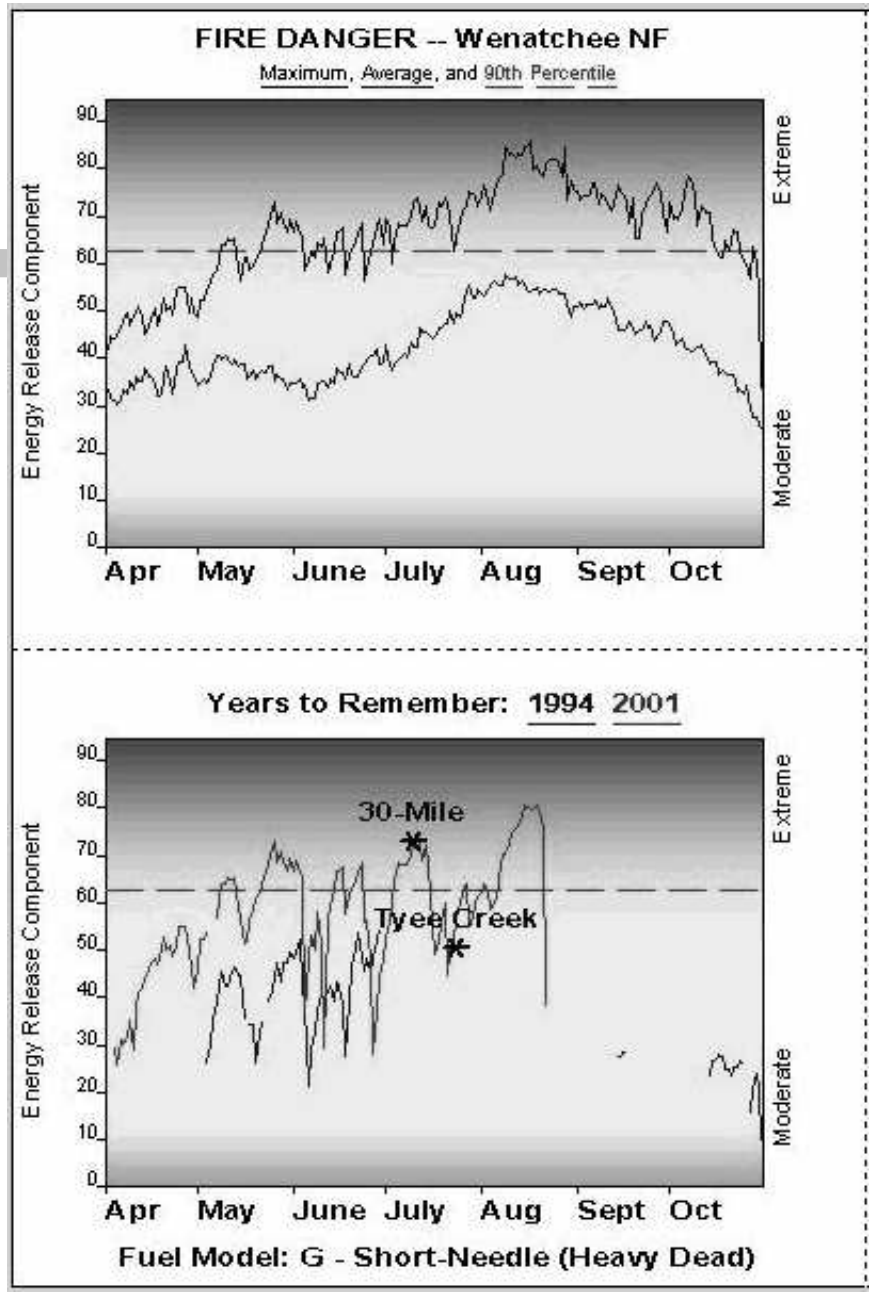
- Climatology
- Observations
- Next day forecast
- Mid and long range forecast

Fuel moisture

- Live, Dead
- Daily, Hourly

Fire danger index

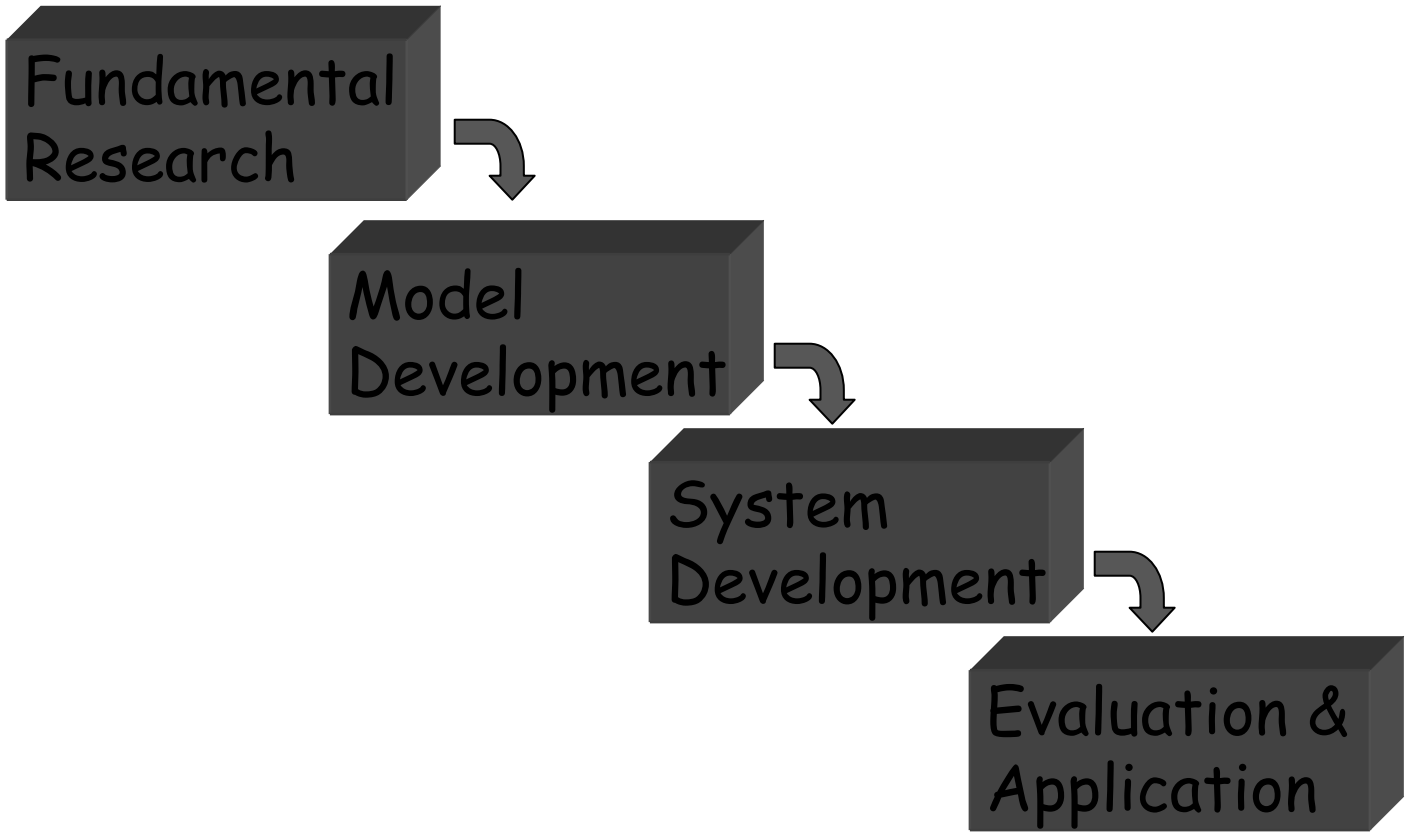
- Climatology-based
- Compare to extremes
- Percentiles
- Years of significance



NFDRS "Watch Out's"

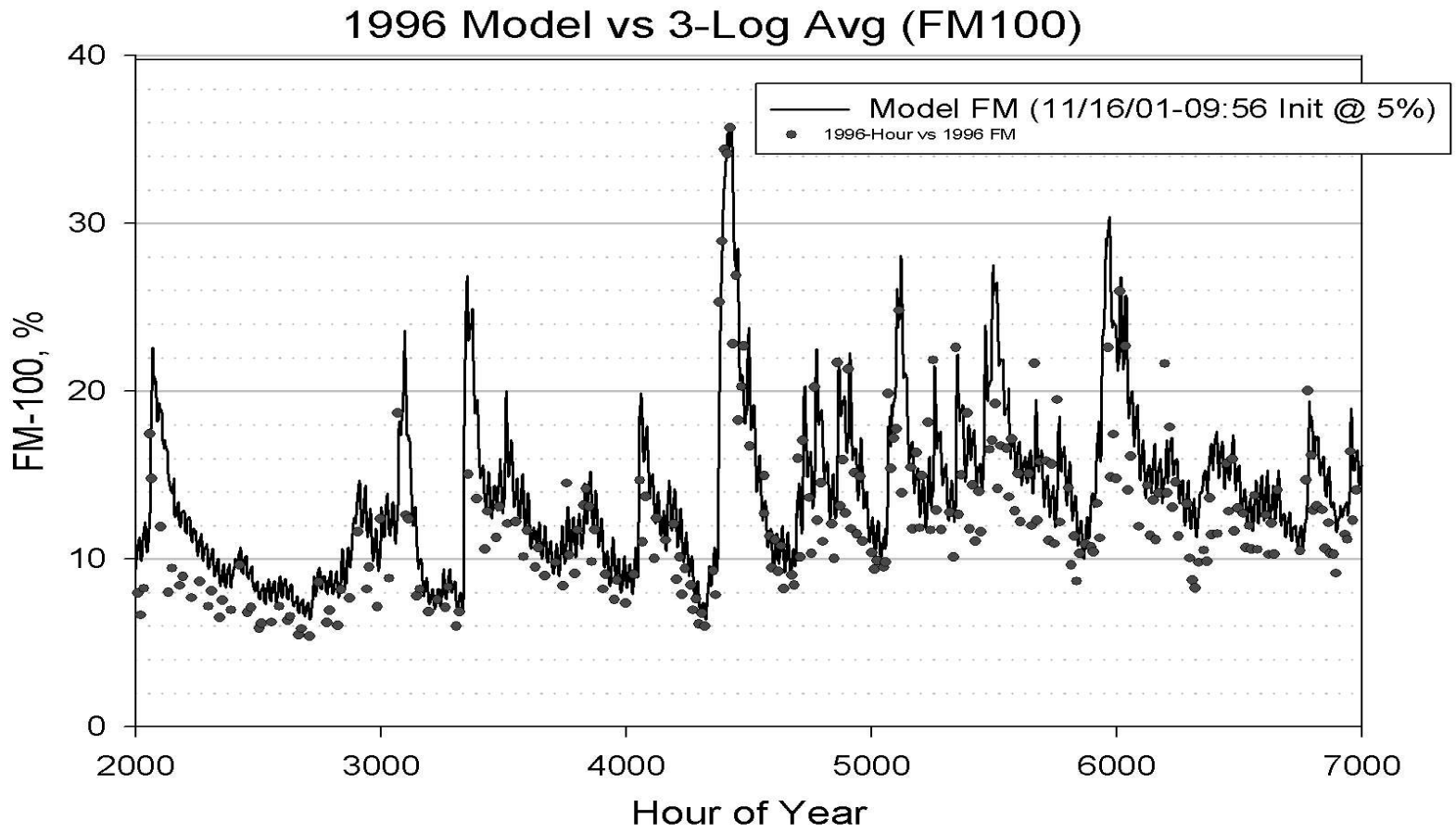
- **Mixing Outputs From Different Fuel Models**
- **Missing Weather Observations**
- **Data Quality**

Current Development Efforts

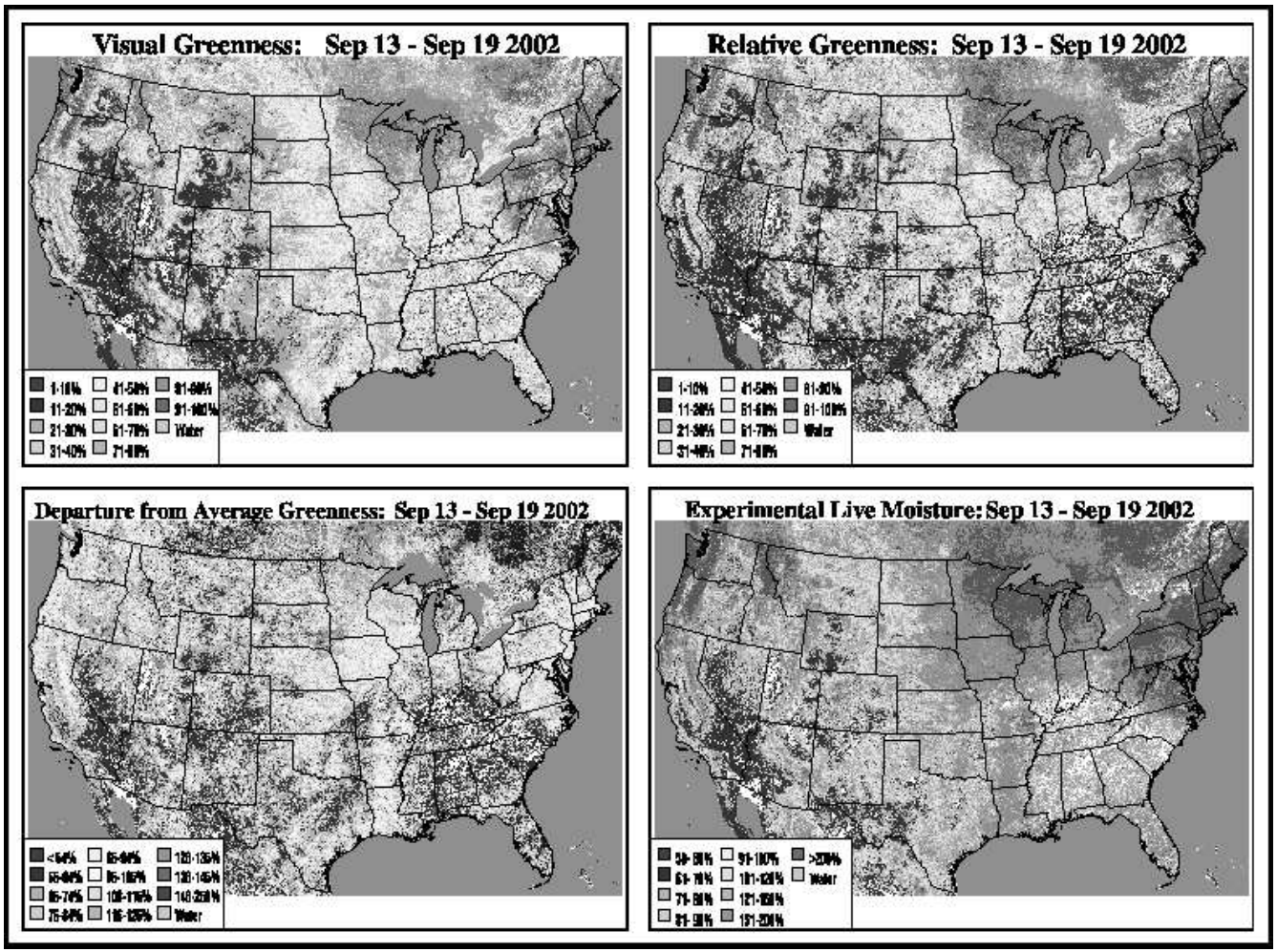


Model Development

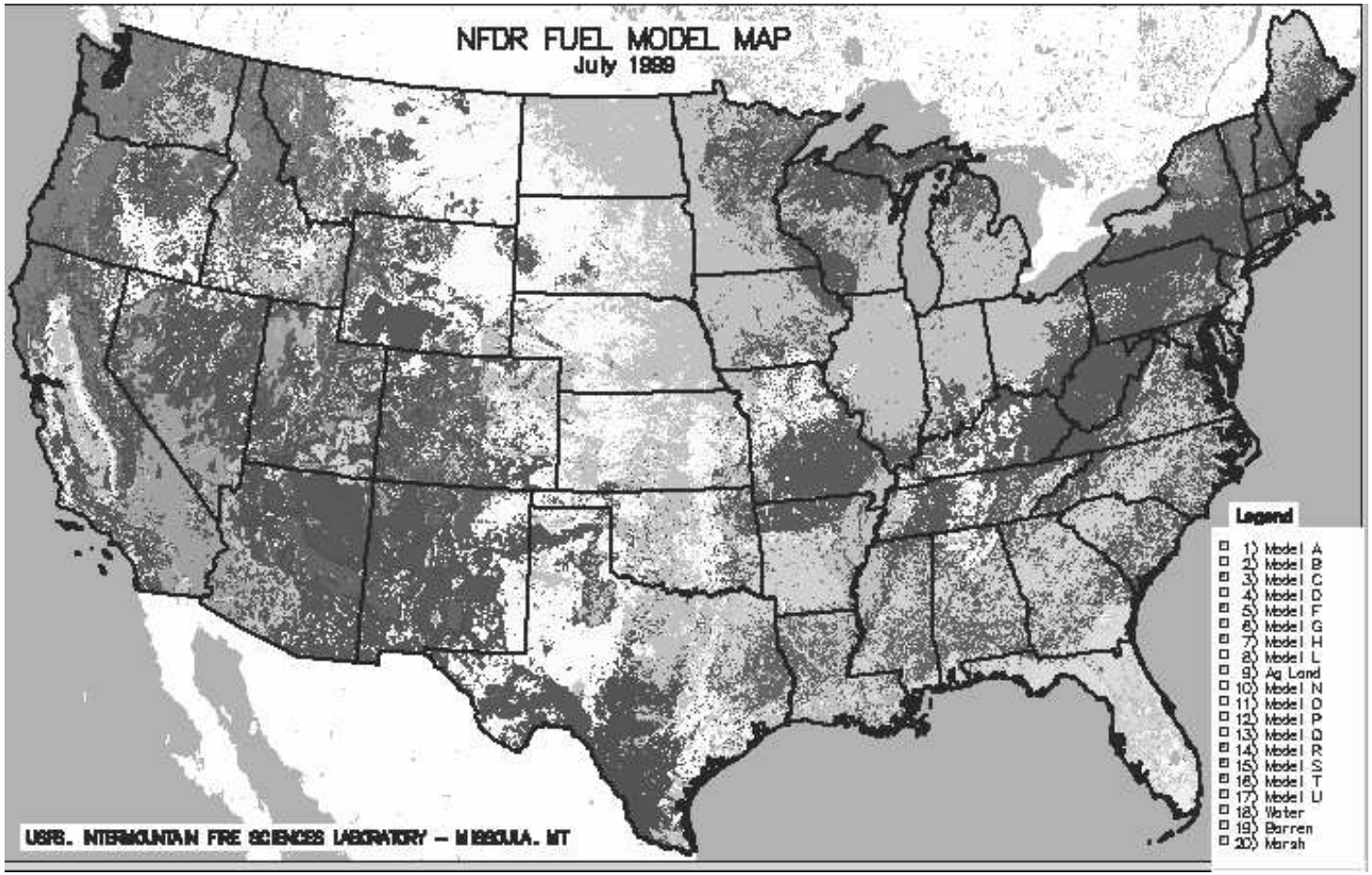
Dead fuel moisture, 100-hour (1"-3" fuels)



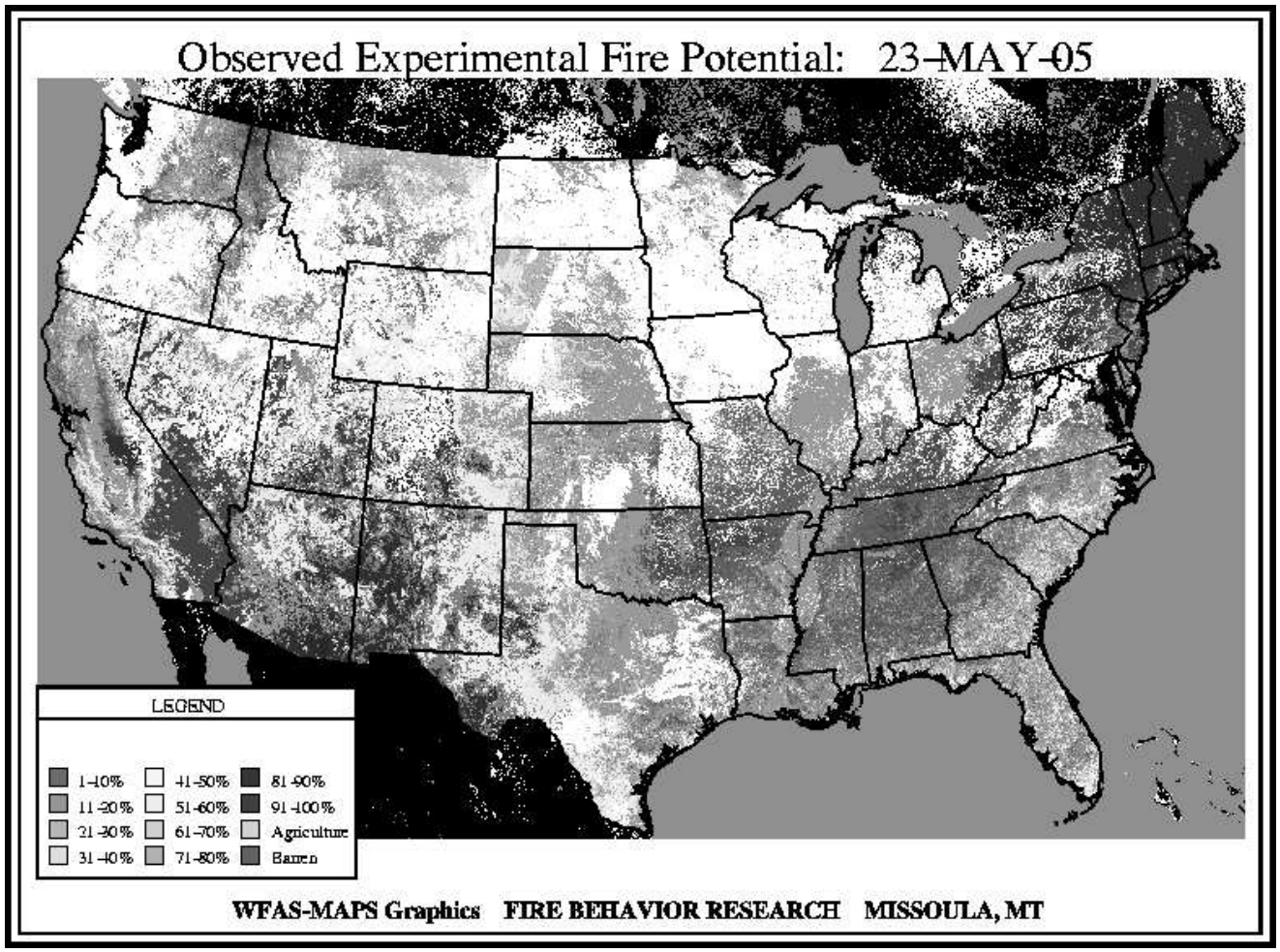
Greenness Products Based on 1-KM AVHRR Imaging



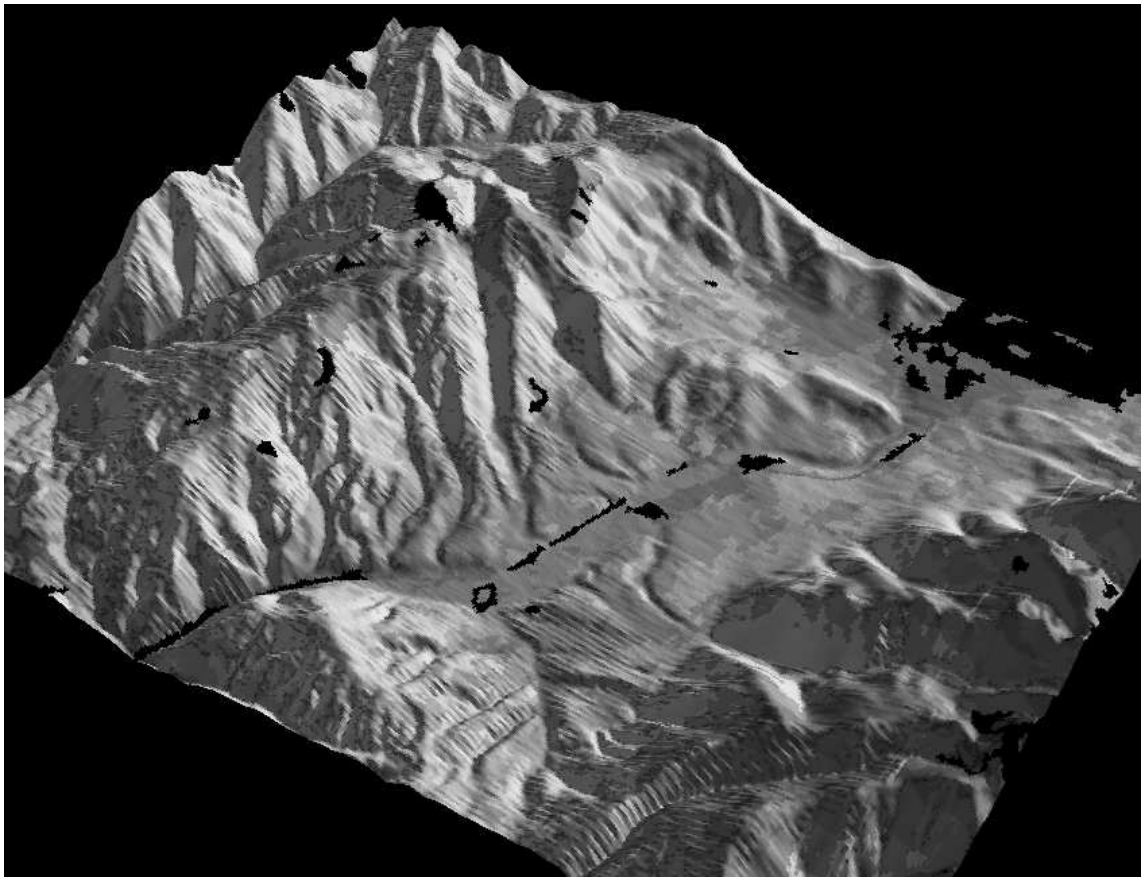
National Fuel Model Map at 1-KM Resolution



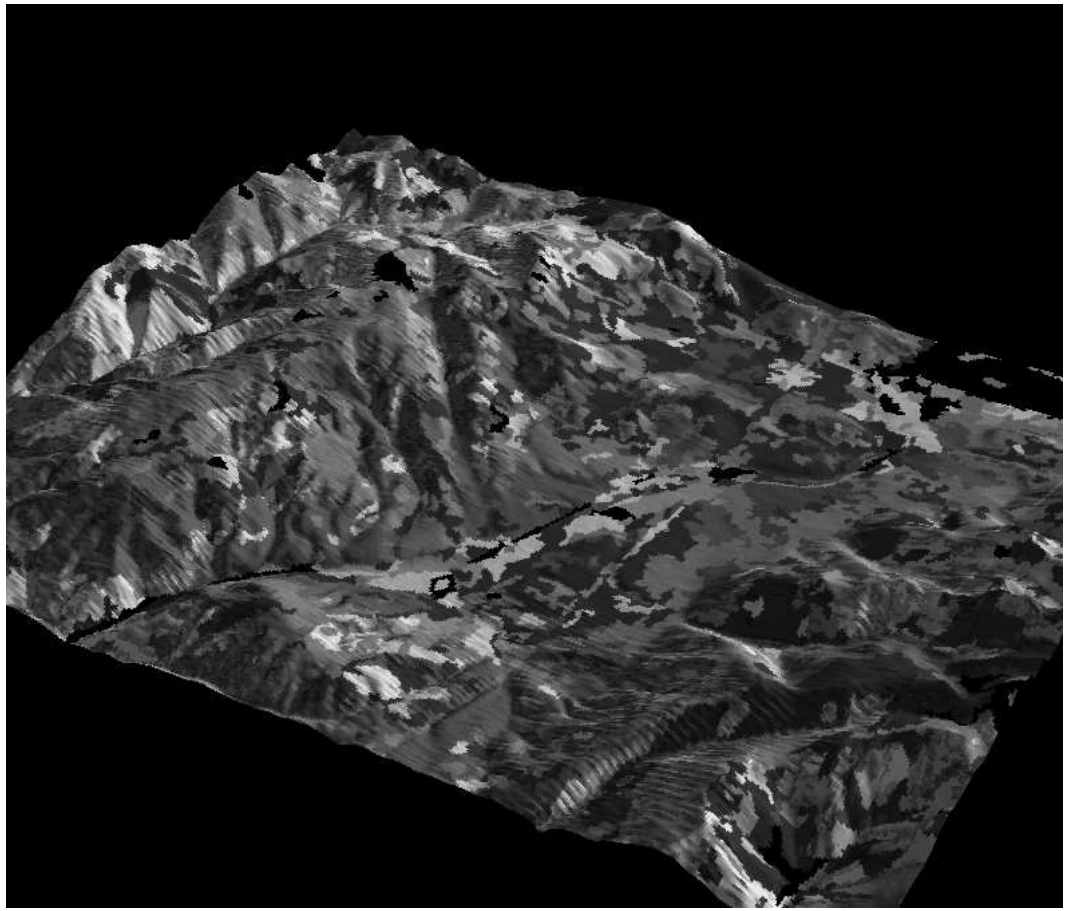
Experimental FPI--No Fire Model Integrates Relative Greenness, Fuel Model, and Dead Fuel Moisture at 1-km resolution



FlamMap – 10 Hour Fuel Moisture



FlamMap -- Potential flame length



Basics of the National Fire Danger Rating System

Questions?