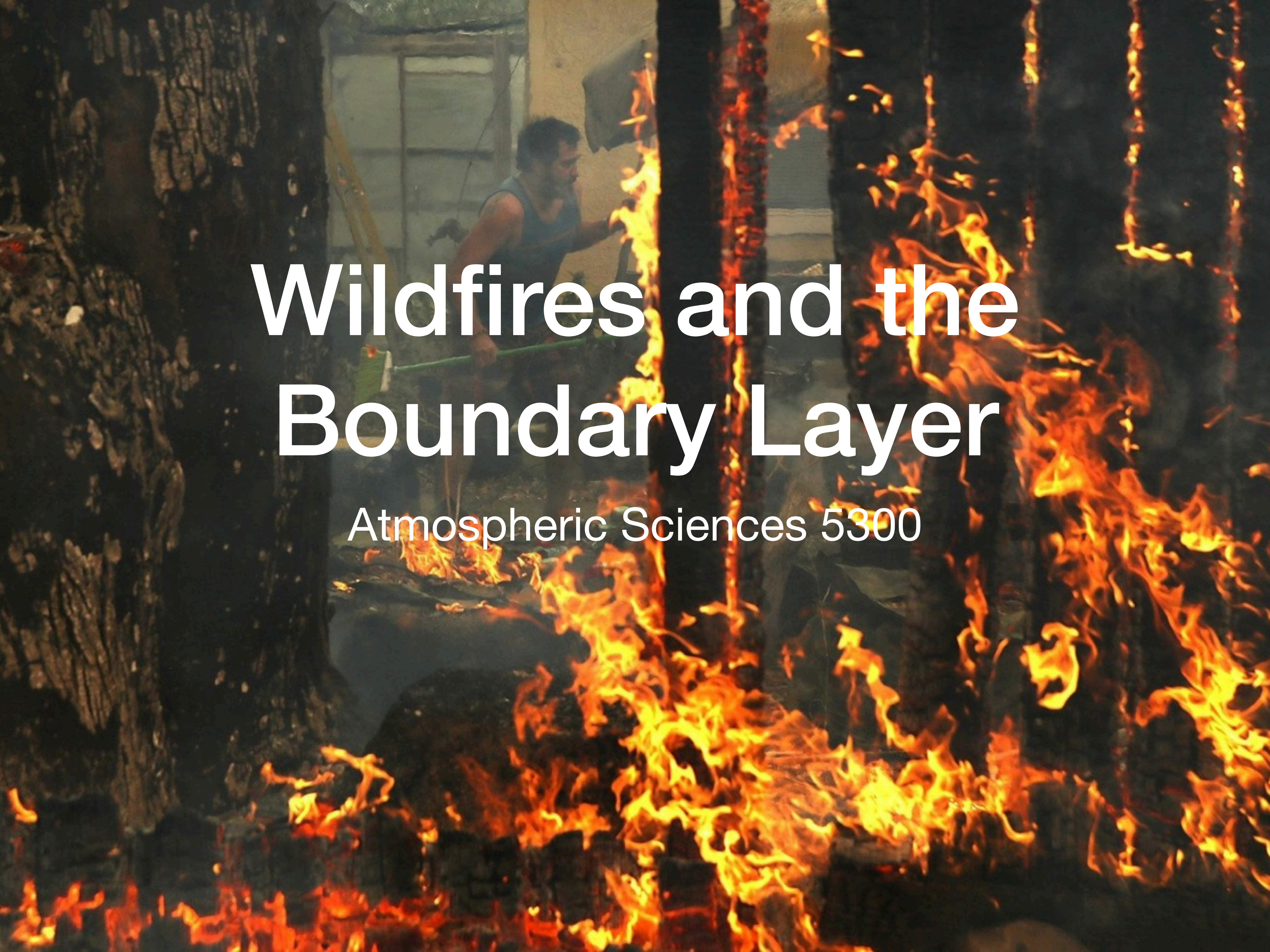


Wildfires and the Boundary Layer

Atmospheric Sciences 5300

Obtain observed rate of spread (FF2)

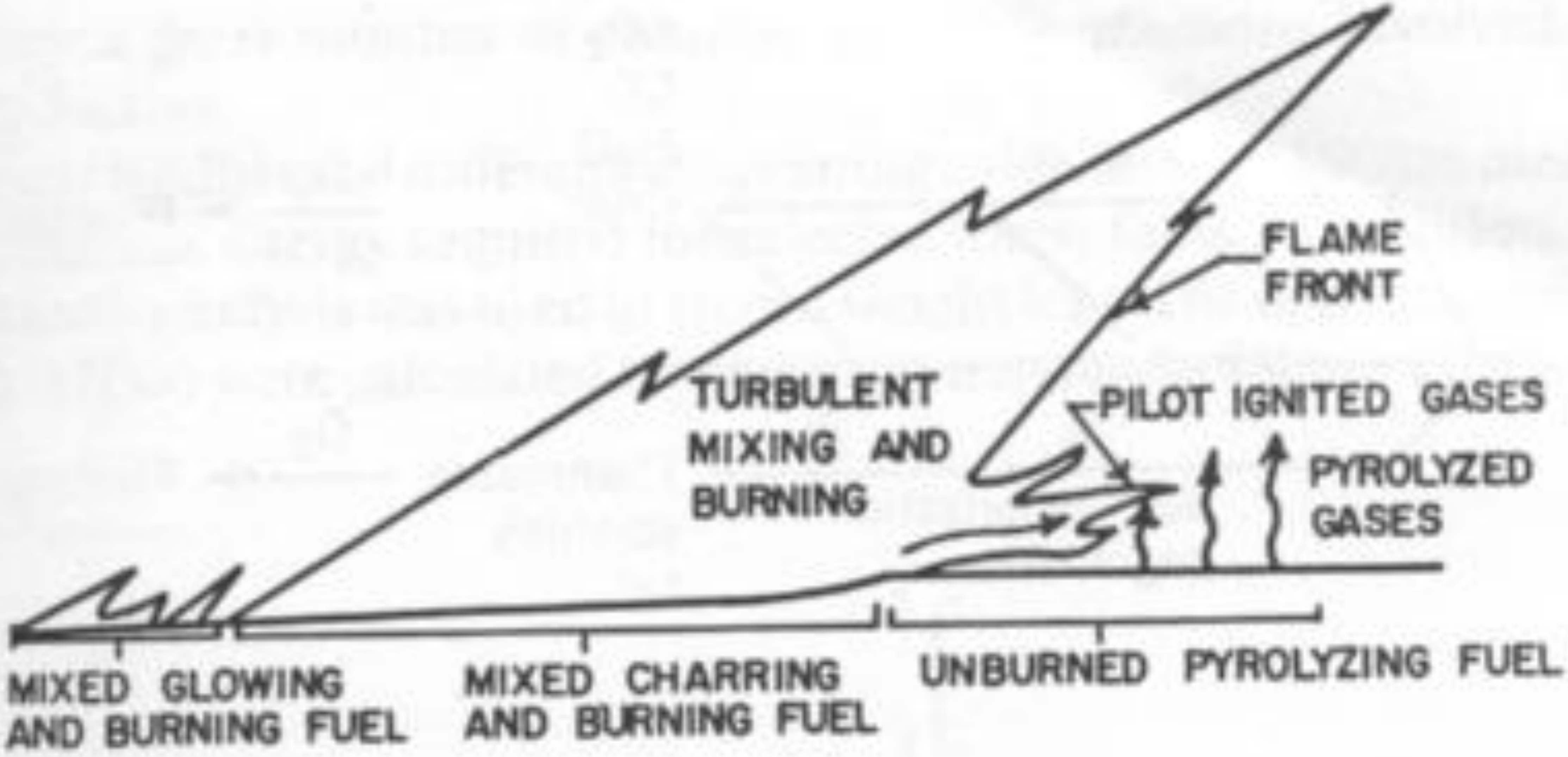
Characterize fuel and ambient wind for FF2

Use these in a firespread model based on fuel & ambient wind

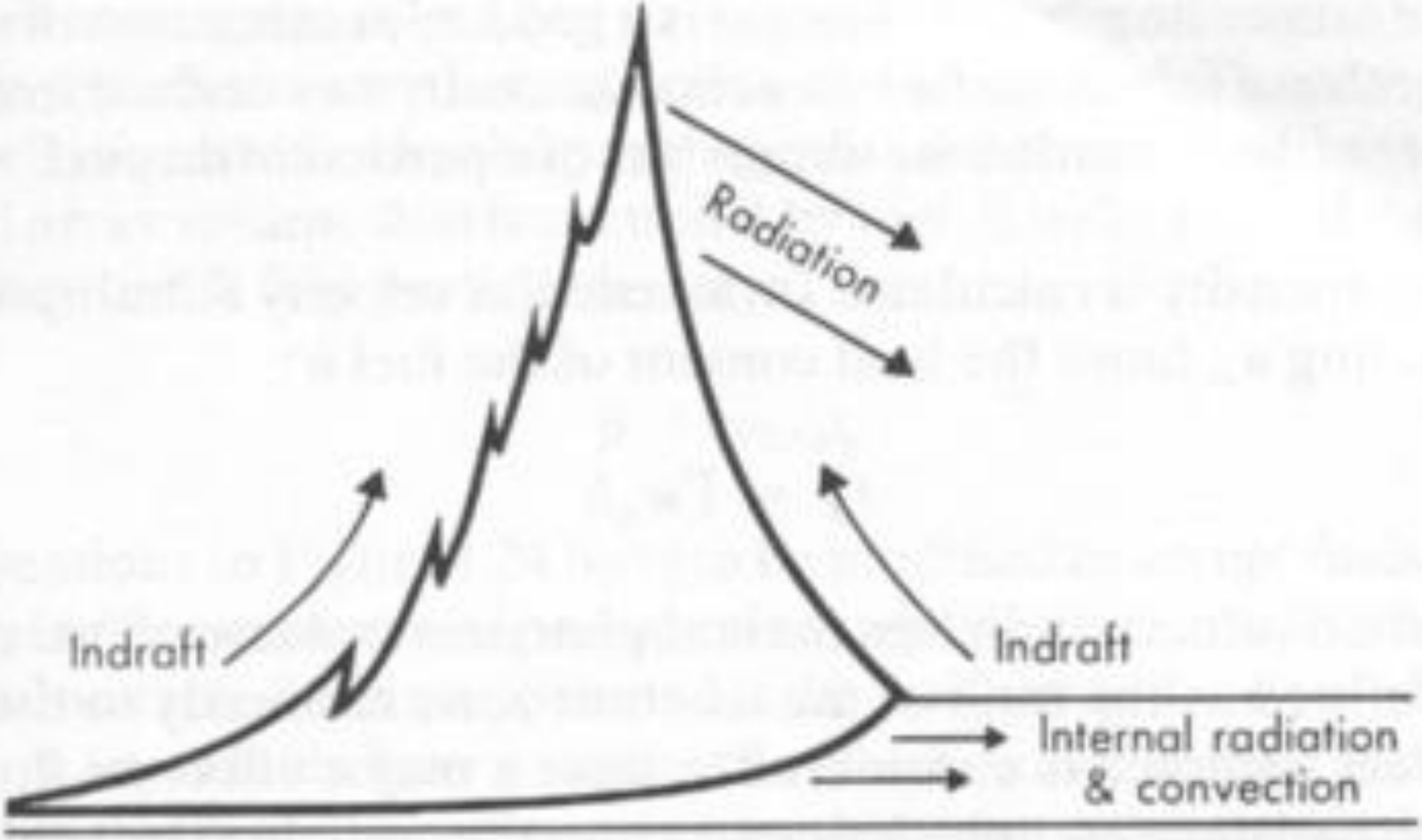
Include the fire-induced wind in a more complete firespread model

Include the fire-induced wind by coupling the firespread model to an atmospheric large-eddy simulation (LES) model

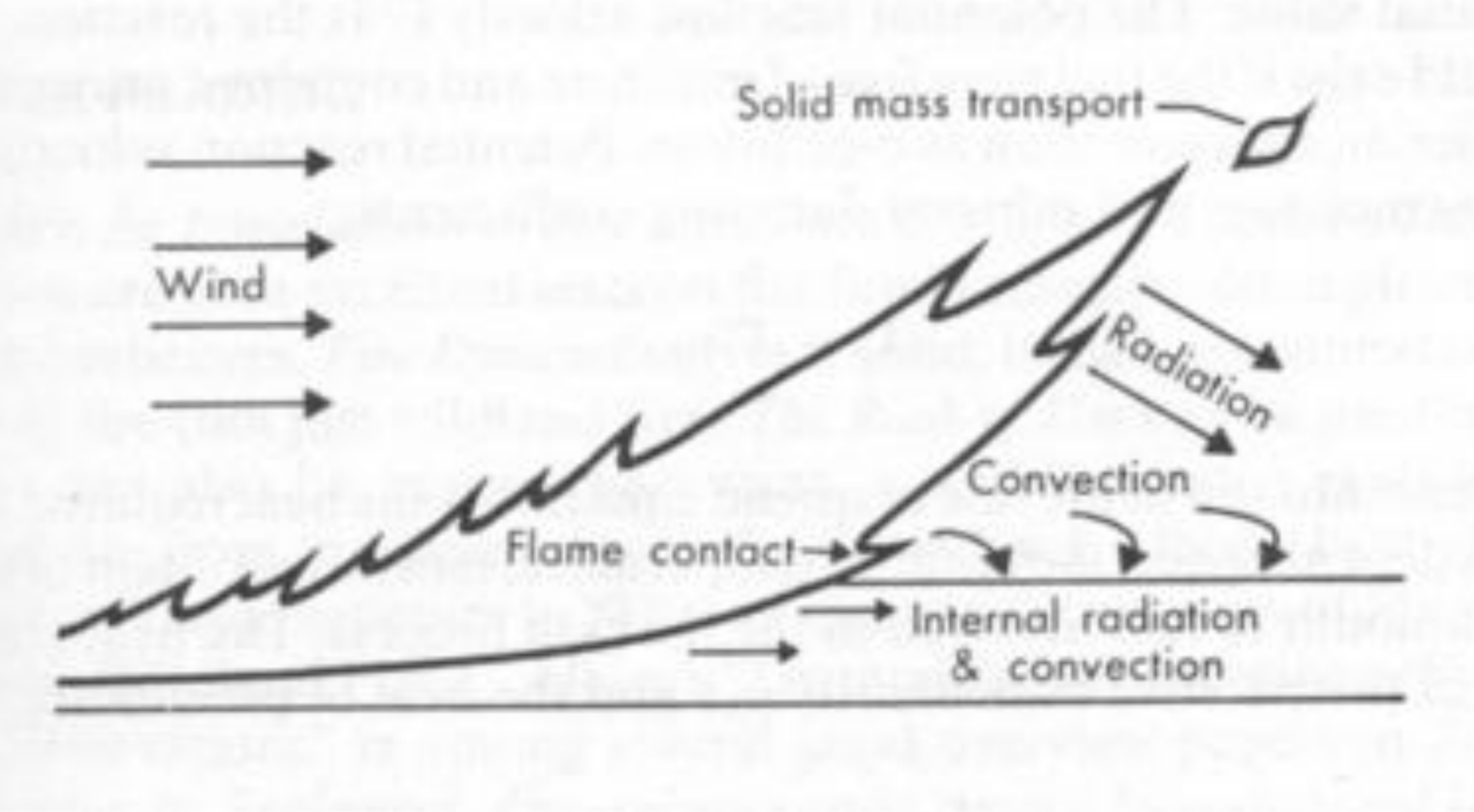
Use the LES models to study fire spread when affected by boundary layer turbulence


FLAME FRONT
TURBULENT MIXING AND BURNING
PILOT IGNITED GASES
PYROLYZED GASES
MIXED GLOWING AND BURNING FUEL
MIXED CHARRING AND BURNING FUEL
UNBURNED PYROLYZING FUEL

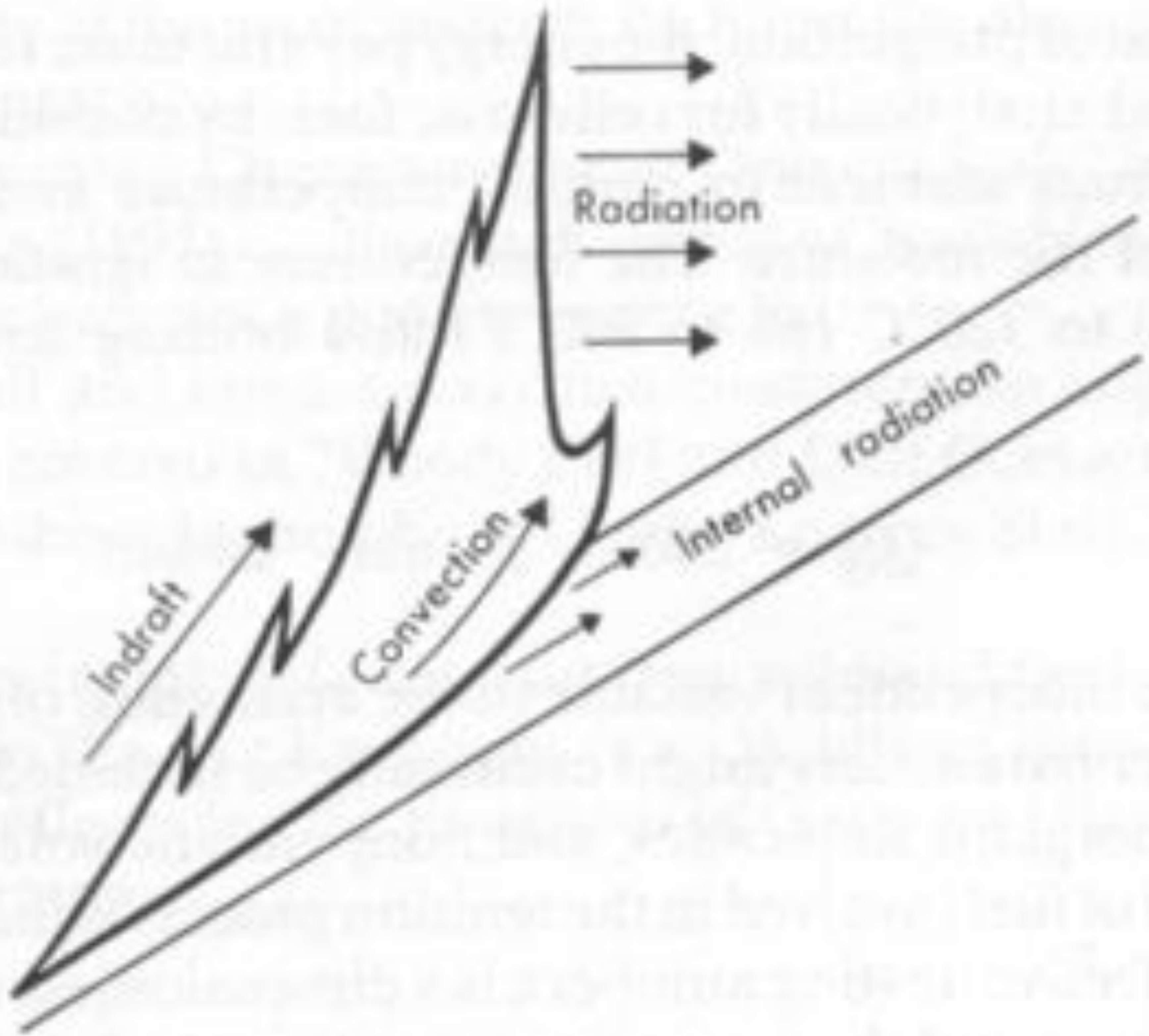
no ambient wind, no terrain slope



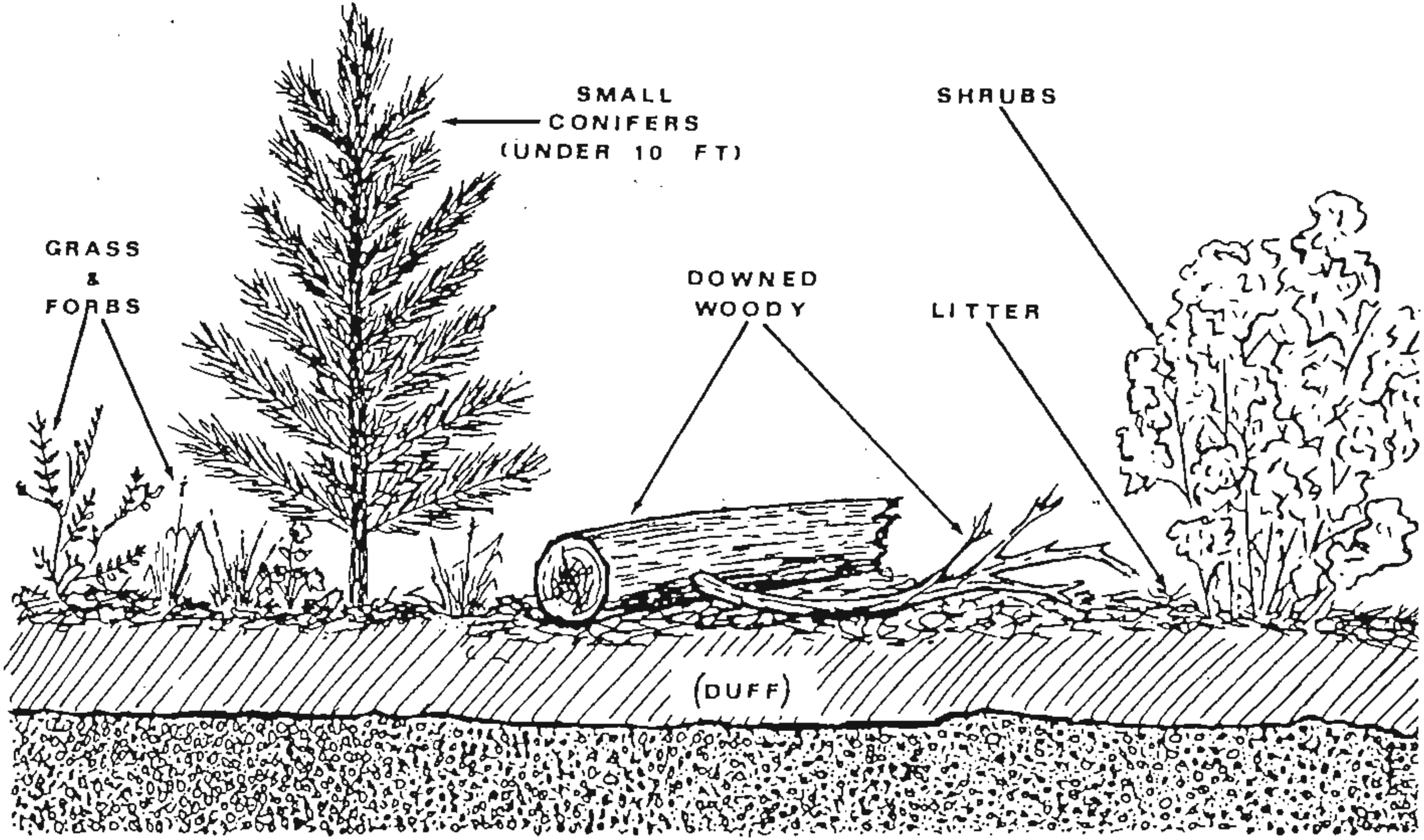
ambient wind, no terrain slope

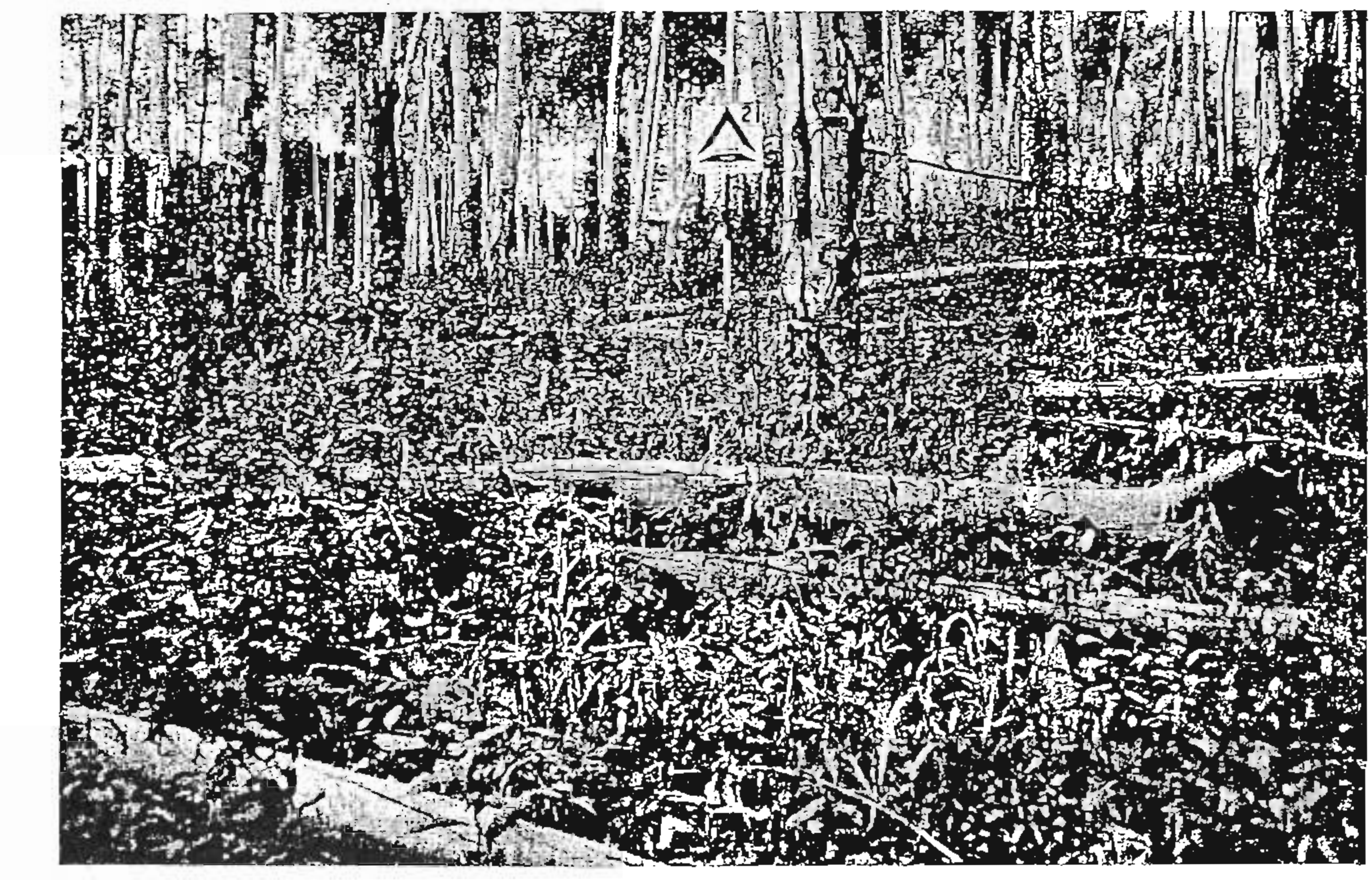


terrain slope, no ambient wind,



- Factors that influence fire spread and fire intensity
    - Wind, slope, fuel (amount and dryness)
- Fuel
    - Surface to volume ratio: fuel burns via volatilization.
    - Before this can happen, moisture must be removed by heating and vaporization, which takes extra energy.
    - Fuel bed = fuel per unit area = heat release per unit area. [Add table.]
    - Types of fuels: litter, shrubs, trees (trunks versus leaves).
    - Geometry of fuels (ladder fuels). [Show diagram.]


SMALL CONIFERS (UNDER 10 FT)
SHRUBS
GRASS & FORBS
DOWNED WOODY
LITTER
(DUFF)



Fuel class: Aspen/tall forb Stand No. 21

Community type: *Populus tremuloides/Ligusticum filicinum*

Fuel class: Aspen/tall forb Stand No. 21

Community type: *Populus tremuloides/Ligusticum filicinum*

FUEL LOADINGS

	Lb/acre	*kg/m²*
a. Herbaceous	1,060	0.119
b. Shrub	40	.004
c. Litter	1,130	.127
Downed woody		
d. 0 to ¼	180	.020
e. ¼ to 3	16,030	1.797
f. 3 +	59,510	6.670
Subtotals		
Fines	2,400	.270
D. woody 0-3	16,210	1.816

VEGETATION CHARACTERISTICS

Shrub cover, %	3
Basal area, ft²/acre	
Aspen	203
Conifer	0

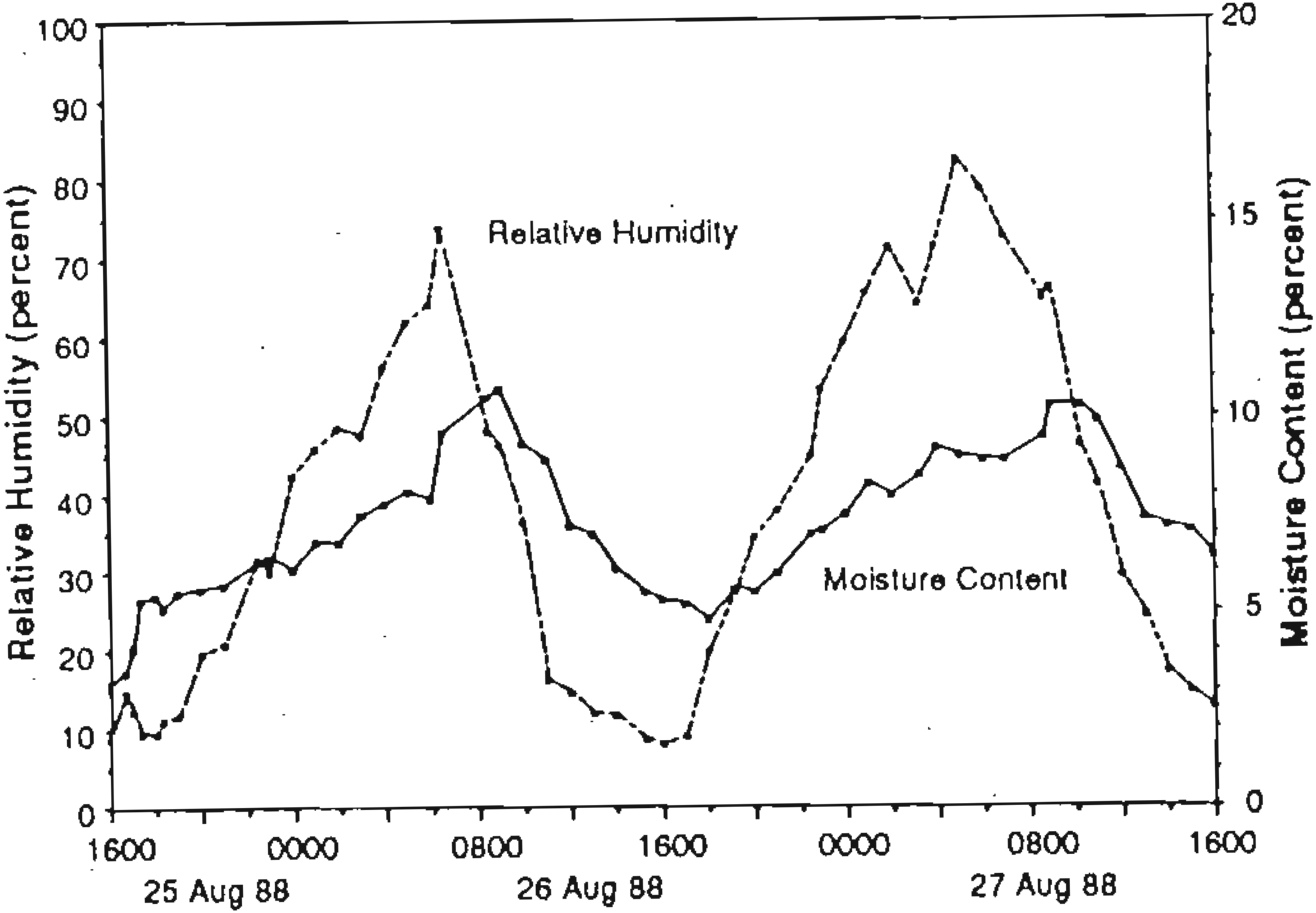
FIRE RATING

Intensity	Low-Med
Rate of spread	Low
Torching	Low
Resistance to control	Medium
Overall	Low-Med
Probability of a successful burn	Moderate

STAND LOCATION

National Forest	Bridger-Teton
Ranger District	Jackson
Drainage	Little Dry Cottonwood Creek
Photo date	September 1983

Figure 3.24. *Example from the photo series for aspen fuels.* From Brown and Simmerman (1986).

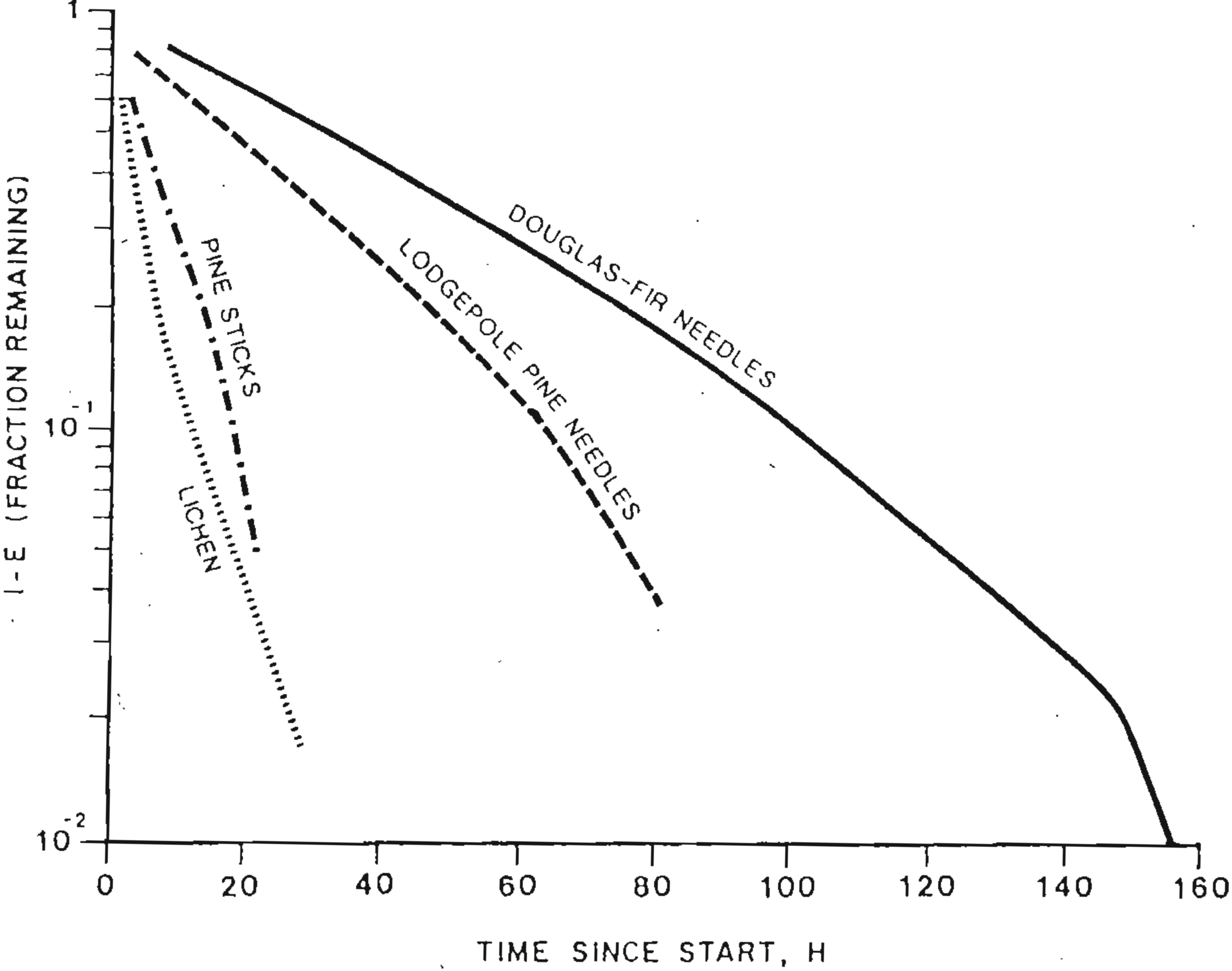

Relative Humidity
Moisture Content
Relative Humidity (percent)
Moisture Content (percent)
100
90
80
70
60
50
40
30
20
10
0
20
15
10
5
0
1600
0000
0800
1600
0000
0800
1600
25 Aug 88
26 Aug 88
27 Aug 88

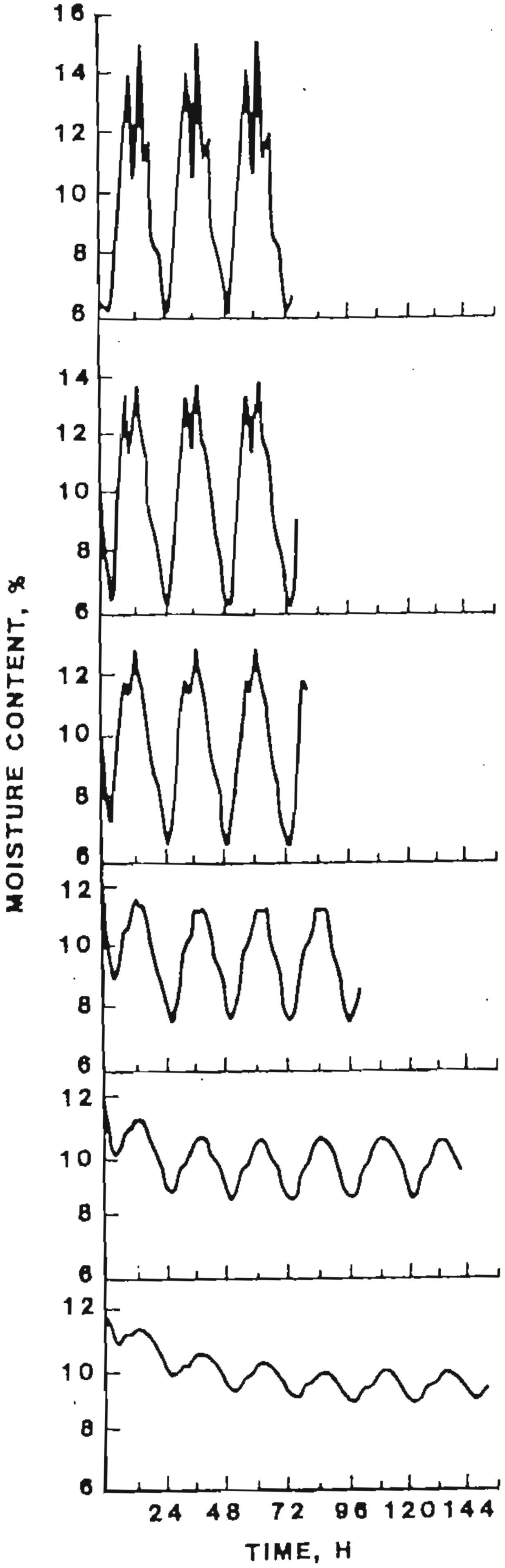
Fuel model	Typical fuel complex	Surface-area-to-volume ratio(ft^{-1})/ fuel loading (tons/acre) 1-h	10-h	100-h	Live	Fuel bed depth	Moisture of extinction dead fuels	Characteristic surface area-to-volume ratio	Packing ratio
						Ft	Percent	Ft^{-1}	
	Grass and grass-dominated								
1	Short grass (1 ft)	3,500/0.74	—	—	—	1.0	12	3,500	0.00106
2	Timber (grass and understory)	3,000/2.00	109/1.00	30/0.50	1,500/0.50	1.0	15	2,784	.00575
3	Tall grass (2.5 ft)	1,500/3.01	—	—	—	2.5	25	1,500	.00172
	Chaparral and shrub fields								
4	Chaparral (6 ft)	2,000/5.01	109/4.01	30/2.00	1,500/5.01	6.0	20	1,739	.00383
5	Brush (2 ft)	2,000/1.00	109/0.50	—	1,500/2.00	2.0	20	1,683	.00252
6	Dormant brush, hardwood slash	1,750/1.50	109/2.50	30/2.00	—	2.5	25	1,564	.00345
7	Southern rough	1,750/1.13	109/1.87	30/1.50	1,500/0.37	2.5	40	1,562	.00280
	Timber litter								
8	Closed timber litter	2,000/1.50	109/1.00	30/2.50	—	.2	30	1,889	.03594
9	Hardwood litter	2,500/2.92	109/0.41	30/0.15	—	.2	25	2,484	.02500
10	Timber (litter and understory)	2,000/3.01	109/2.00	30/5.01	1,500/2.00	1.0	25	1,764	.01725
	Slash								
11	Light logging slash	1,500/1.50	109/4.51	30/5.51	—	1.0	15	1,182	.01653
12	Medium logging slash	1,500/4.01	109/14.03	30/16.53	—	2.3	20	1,145	.02156
13	Heavy logging slash	1,500/7.01	109/23.04	30/28.05	—	3.0	25	1,159	.02778

[1] Heat content = 8,000 Btu/lb for all fuel models.

Figure 3.8. *Fuel model parameters and calculated fuel bed descriptors for the standard 13 fire behavior fuel models.* From Andrews (1986).

Response time to moisture change





Forcing function of EMC for weather data at O'Neill, NE, on Aug. 13 and 14, 1956.

One-hour fine fuel design:
Desorption and adsorption timelag = 1 hour

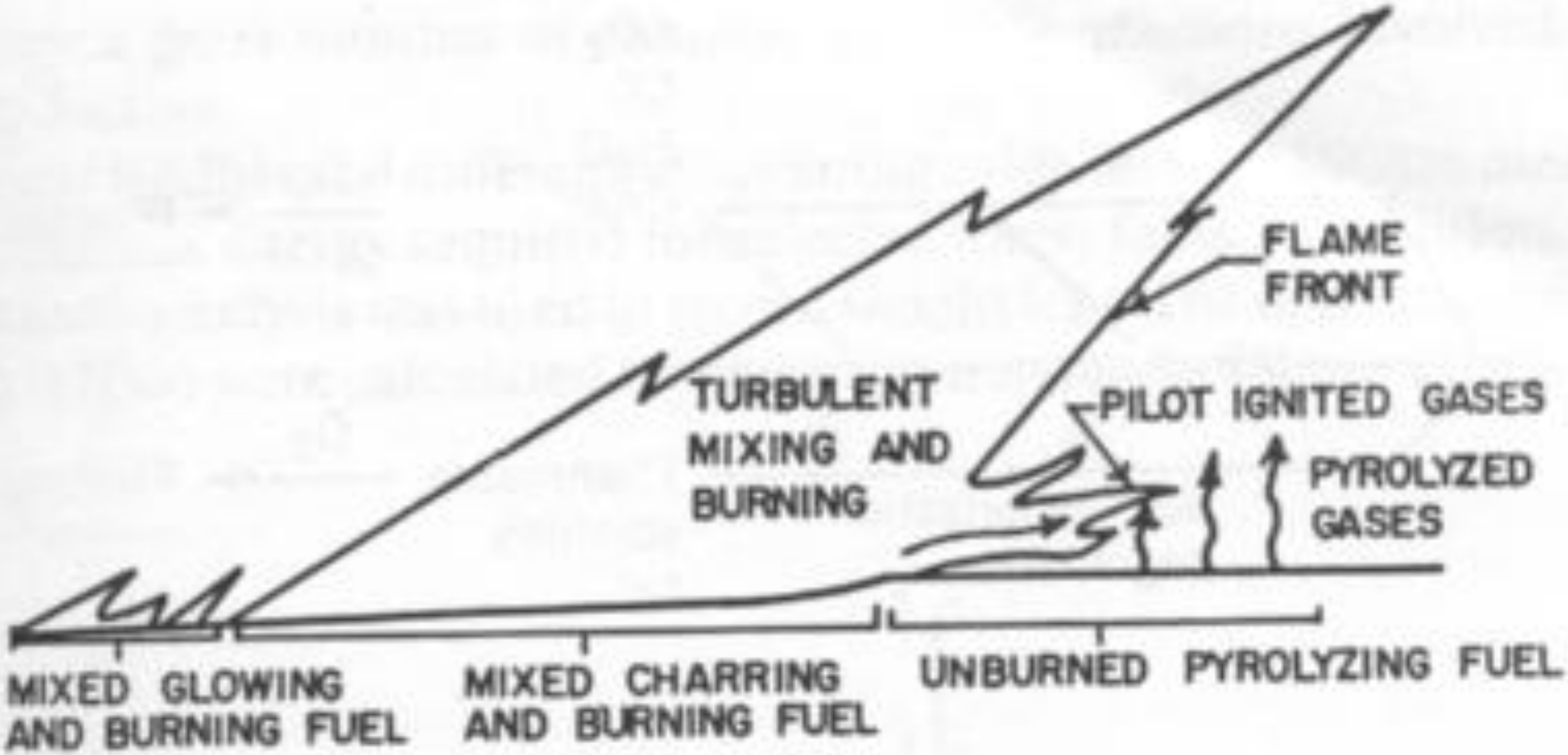
Fine fuel moisture response for grasses—fescues, wheatgrass:
Desorption timelag 1.88 hours
Adsorption timelag 2.71 hours

Fine fuel moisture response for needles—pondero pine, western white pine, and western redcedar:
Desorption timelag 5.18 hours
Adsorption timelag 7.29 hours

Fine fuel moisture response for needles—Engelma spruce, subalpine fir, and grand fir:
Desorption timelag 11.36 hours
Adsorption timelag 14.83 hours

Fine fuel moisture response for needles—Douglas fir, lodgepole:
Desorption timelage 19.9 hours
Adsorption timelag 31.4 hours

- Wind
  - How does a fire spread? By contact of flames with fuel. (show FF2 grass fire movie.]
  - Wind tilts the flames, making it easier to ignite nearby fuels. [diagram]
  - Once ignited, most fuels take a fixed amount of time to combust (for a given fuel type) = fixed heat release per unit area.
  - The more rapid the rate of spread (ROS), the greater the area of fuel burning at once, so greater fire intensity, and greater flame heights, which will accelerate the ROS. [table of fire line width versus flame height]


FLAME FRONT
TURBULENT MIXING AND BURNING
PILOT IGNITED GASES
PYROLYZED GASES
MIXED GLOWING AND BURNING FUEL
MIXED CHARRING AND BURNING FUEL
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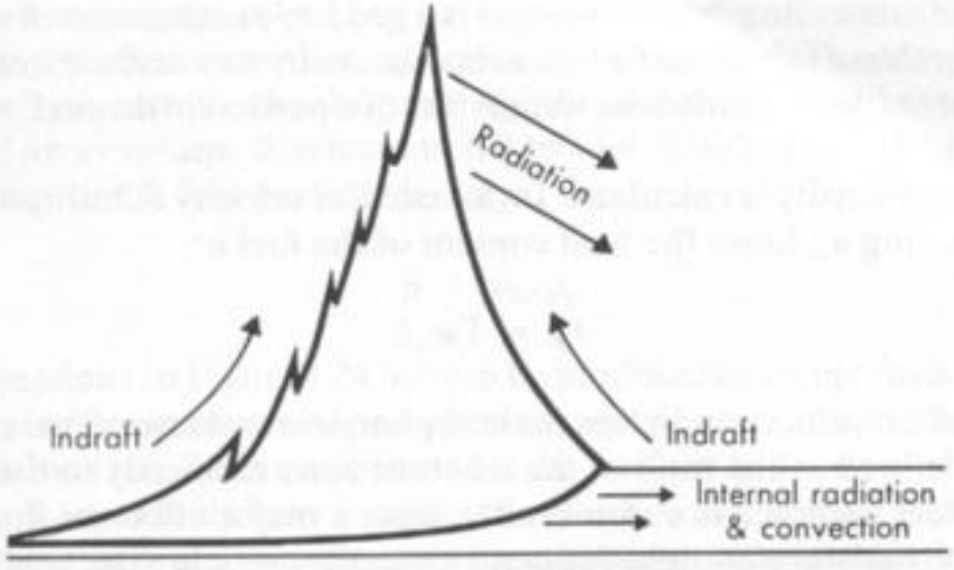
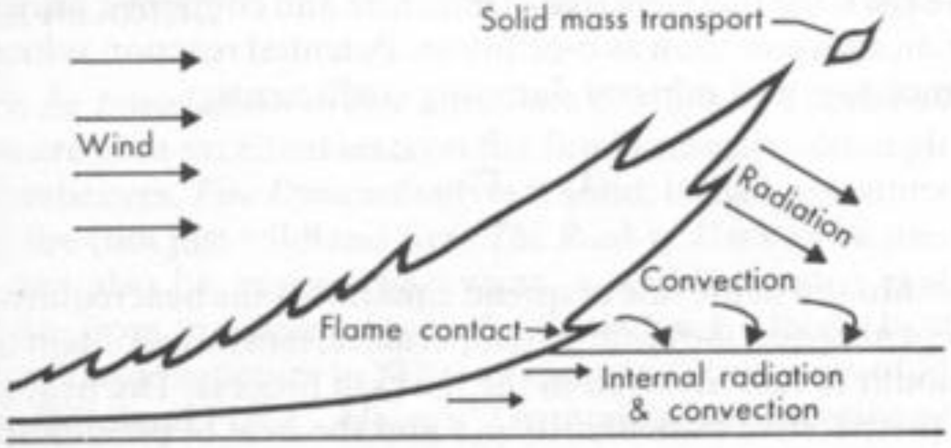
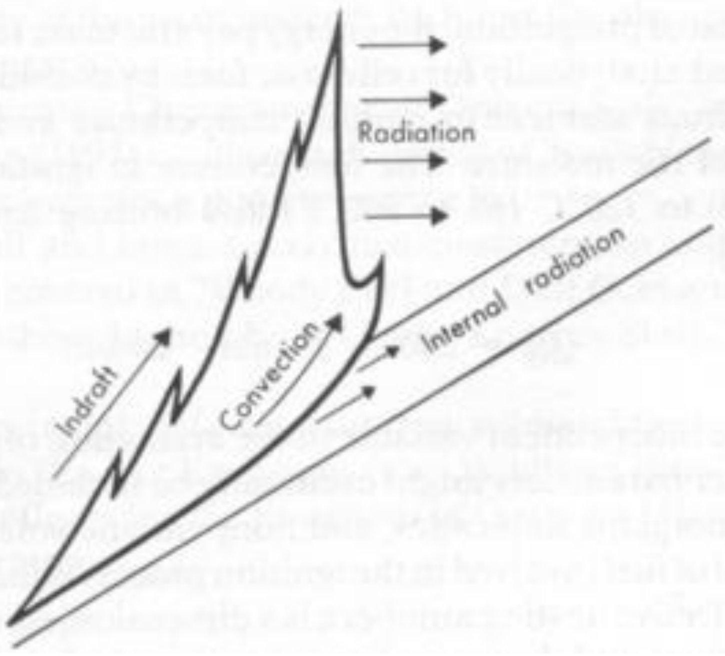

Radiation
Indraft
Indraft
Internal radiation
& convection


Solid mass transport
Wind
Radiation
Convection
Flame contact
Internal radiation
& convection


Radiation
Internal radiation
Convection
Indraft

CSIRO PUBLISHING

International Journal of Wildland Fire
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The FireFlux II experiment: a model-guided field experiment to improve understanding of fire–atmosphere interactions and fire spread

Craig B. Clements[A,L], *Adam K. Kochanski*[B], *Daisuke Seto*[A], *Braniff Davis*[A], *Christopher Camacho*[A], *Neil P. Lareau*[A], *Jonathan Contezac*[A], *Joseph Restaino*[C], *Warren E. Heilman*[D], *Steven K. Krueger*[B], *Bret Butler*[E], *Roger D. Ottmar*[F], *Robert Vihnanek*[F], *James Flynn*[G], *Jean-Baptiste Filippi*[H], *Toussaint Barboni*[H], *Dianne E. Hall*[A], *Jan Mandel*[I], *Mary Ann Jenkins*[B], *Joseph O'Brien*[J], *Ben Hornsby*[J] and *Casey Teske*[K]

United States
Department
of Agriculture

Forest Service

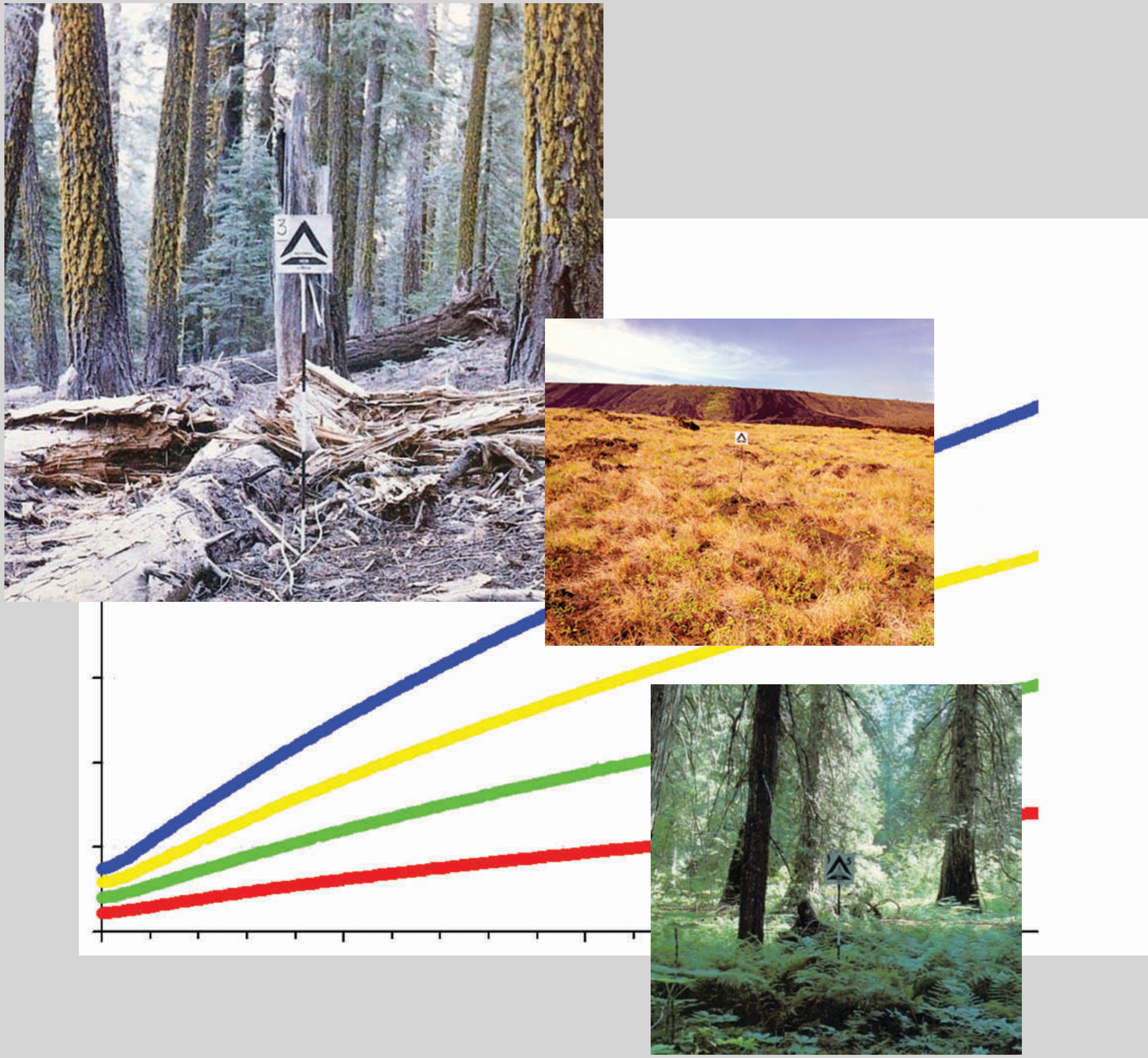
**Rocky Mountain
Research Station**

General Technical
Report RMRS-GTR-153

June 2005

Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model

Joe H. Scott
Robert E. Burgan



Dynamic Fuel Models

In this new set, all fuel models that have a live herbaceous component are “dynamic,” meaning that their herbaceous load shifts between live and dead depending on the specified live herbaceous moisture content. In the Fuel Models section, refer to the model parameters list (“fuel model type” column) to see which models contain live herbaceous load and are therefore dynamic.

The dynamic fuel model process is described by Burgan (1979); the method is outlined and outlined below, with graphic presentation in figure 1.

- If live herbaceous moisture content is 120 percent or higher, the herbaceous fuels are green, and all herbaceous load stays in the live category at the given moisture content.
- If live herbaceous moisture content is 30 percent or lower, the herbaceous fuels are considered fully cured, and all herbaceous load is transferred to dead herbaceous.
- If live herbaceous moisture content is between 30 and 120 percent, then part of the herb load is transferred to dead. For example, if live herb moisture content is 75 percent (halfway between 30 and 120 percent), then half of the herbaceous load is transferred to dead herbaceous, the remainder stays in the live herbaceous class.

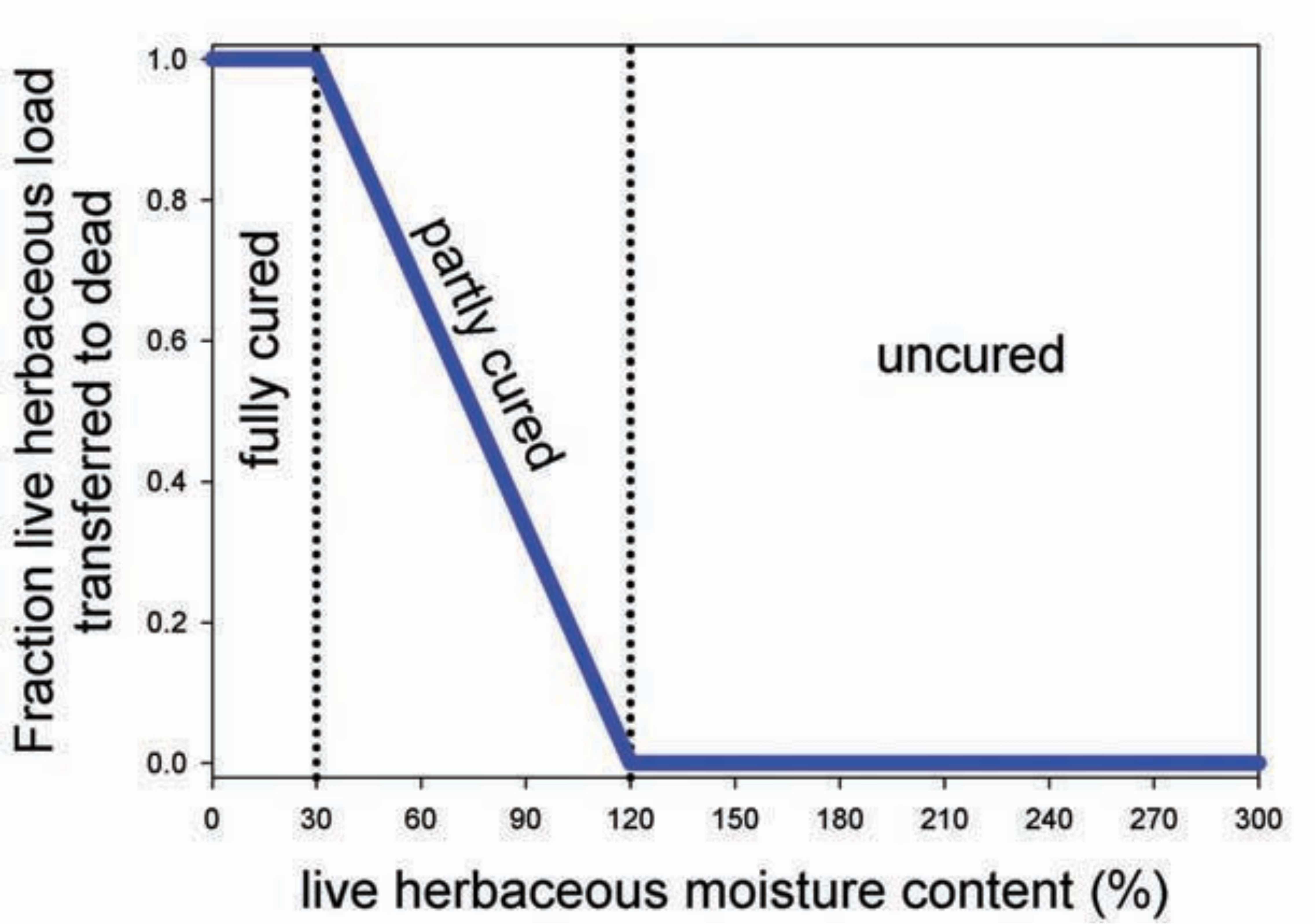


Figure 1—Graphical representation of the dynamic fuel model process.

Load transferred to dead is not simply placed in the dead 1-hr timelag class. Instead a new dead herbaceous class is created so that the surface-area-to-volume ratio of the live herbaceous component is preserved. However, for simplicity the moisture content of the new dead herbaceous category is set to the same as that for the dead 1-hr timelag class.

When evaluating dynamic models, be aware that live herbaceous moisture content significantly affects fire behavior because herbaceous load shifts between live and dead, and dead fuel usually has much lower moisture content than live. It will often be preferable to estimate live herbaceous moisture content by working backward from observed or estimated degree of herbaceous curing (table 2). For example, if the fuelbed is observed to be 50 percent cured, use a value of 75 percent for live herbaceous moisture content.

Table 2—Level of curing versus live herbaceous moisture content.

Level of curing		Live herbaceous moisture content
Uncured	0 percent	120 percent or more
One-quarter	25	98
One-third	33	90
One-half	50	75
Two-thirds	66	60
Three-quarters	75	53
Fully cured	100	30 or less

Fuel Model Selection Guide

To select a fuel model:

1. Determine the general fire-carrying fuel type: grass, grass-shrub, shrub, timber litter, timber with (grass or shrub) understory, or slash or blowdown fuels. Estimate which stratum of surface fuels is most likely to carry the fire. For example, the fire may be in a forested area, but if the forest canopy is open, grass, not needle litter, might carry the fire. In this case a grass model should be considered.

2. The dead fuel extinction moisture assigned to the fuel model defines the moisture content of dead fuels at which the fire will no longer spread. This fuel parameter, unique to the Rothermel surface fire spread model, is generally associated with climate (humid versus dry). That is, fuel models for dry areas tend to have lower dead fuel moistures of extinction, while fuel models for wet humid areas tend to have higher moistures of extinction.

3. Note the general depth, compactness, and size of the fuel, and the relative amount of live vegetation.

4. Do not restrict your selection by fuel model name or fuel type. After selecting a fuel model, view its predicted fire behavior to be sure the predicted behavior agrees with your expectation or observation.

In this guide we refer to spread rates and flame lengths as being very low, low, moderate, high, very high, and extreme—assuming two-thirds cured herbaceous, dry dead fuels (moisture scenario D2L2), a midflame wind speed of 5 mi/h, and zero slope (table 5).

Table 5—Adjective class definitions for predicted fire behavior.

Adjective class	ROS (ch/h)	FL (ft)
Very Low	0-2	0-1
Low	2-5	1-4
Moderate	5-20	4-8
High	20-50	8-12
Very High	50-150	12-25
Extreme	>150	>25

1 chain/hr = 20.117 m / 3600 s = 0.0056 m/s
1 m/s = 179 chains/hr

Table 3—Dead fuel moisture content values (percent) for the dead fuel moisture scenarios.

	D1 **Very low**	D2 **Low**	D3 **Moderate**	D4 **High**
1-hr	3	6	9	12
10-hr	4	7	10	13
100-hr	5	8	11	14

Table 4—Live fuel moisture content values (percent) for the live fuel moisture scenarios.

	L1 **Fully cured**	**L2** **Two-thirds cured**	**L3** **One-third cured**	**L4** **Fully green (uncured)**
	Very low	**Low**	**Moderate**	**High**
Live herbaceous	30	60	90	120
Live woody	60	90	120	150

start here Monday Dec 6

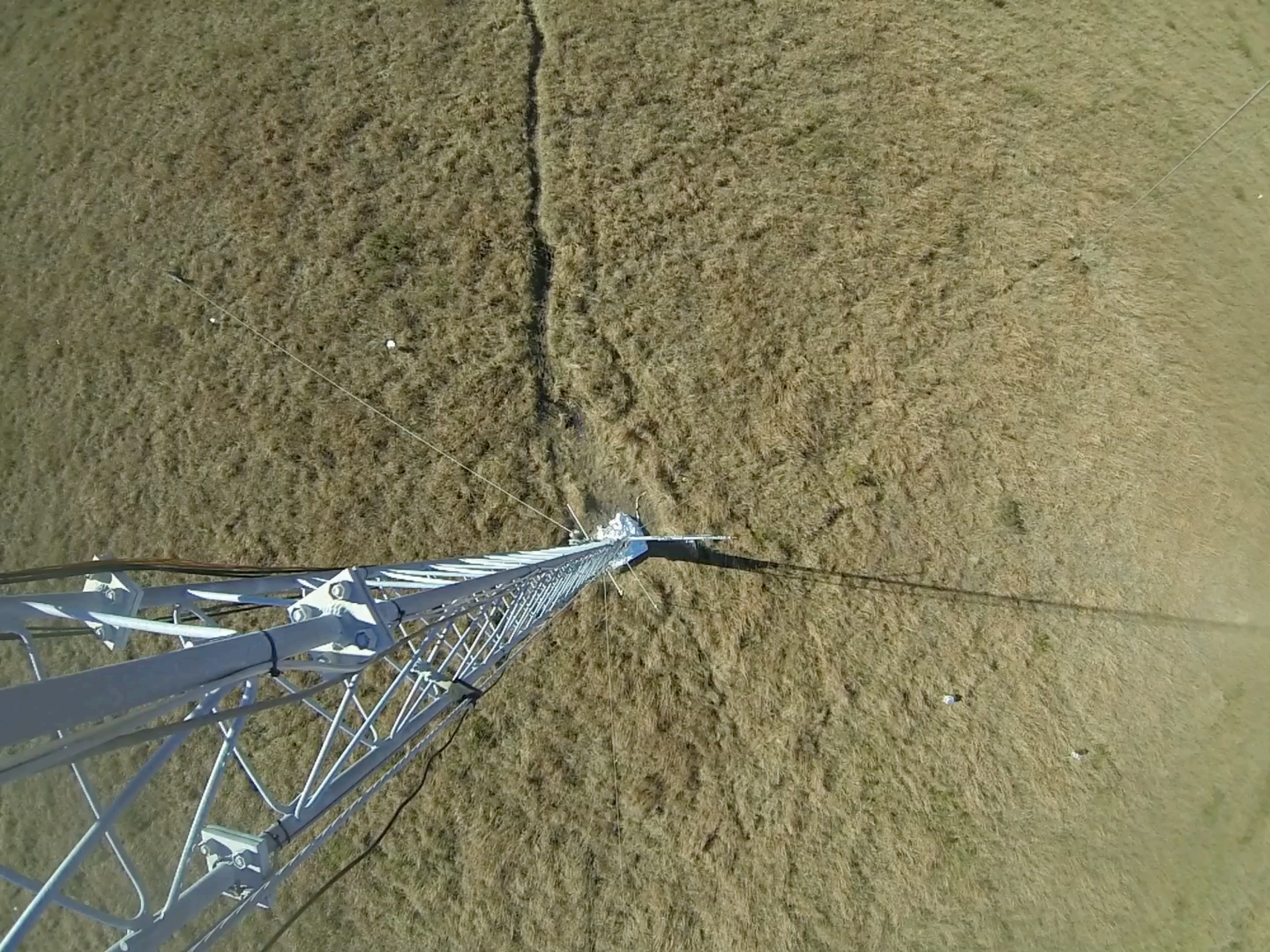
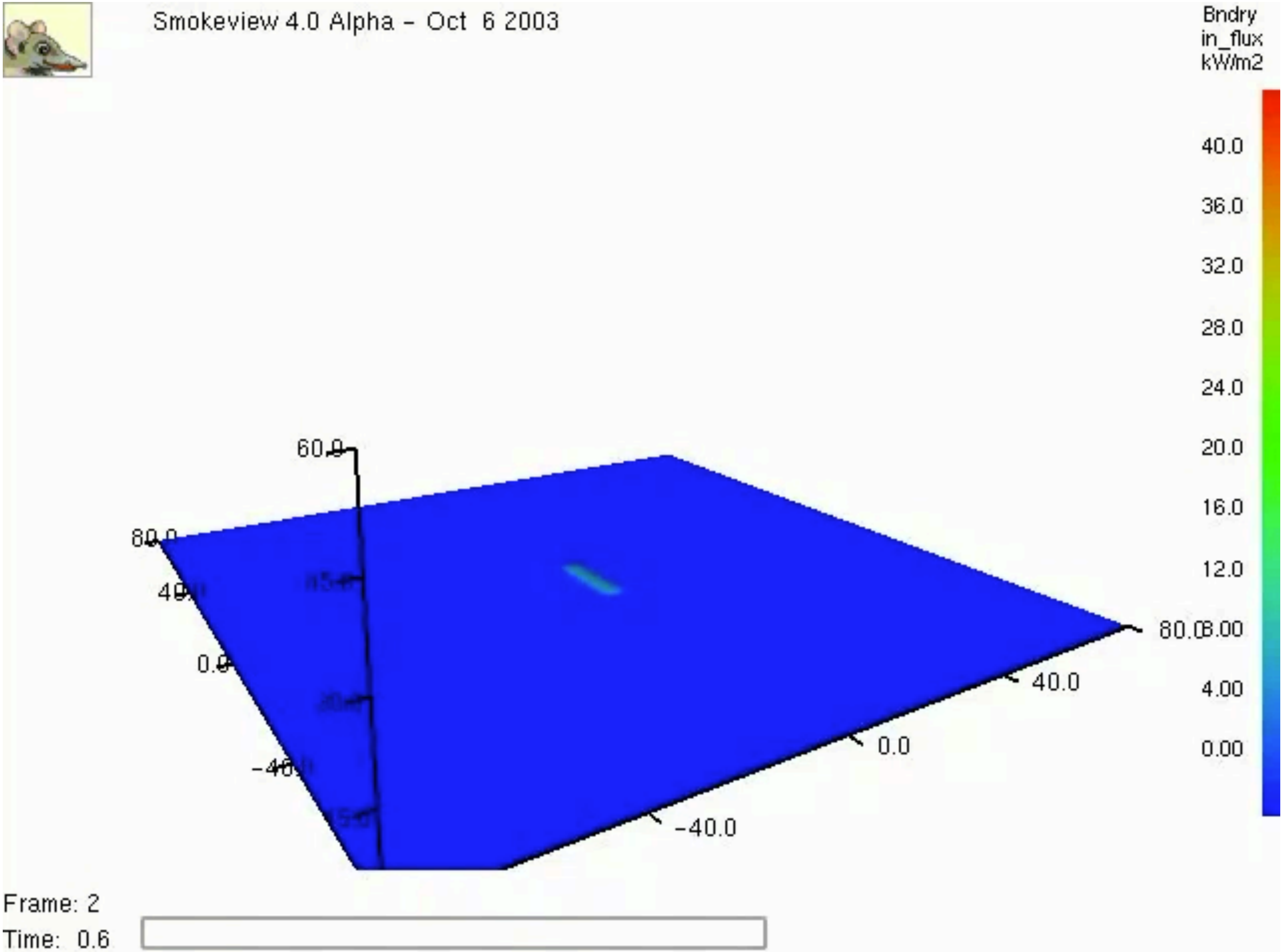


Table 1.—Fire suppression interpretations of flame length and fireline intensity

Flame length	Fireline intensity	Interpretation
Feet	*Btu/ft/s*	
< 4	< 100	Fire can generally be attacked at the head or flanks by persons using handtools. Handline should hold the fire.
4-8	100-500	Fires are too intense for direct attack on the head by persons using handtools. Handline cannot be relied on to hold fire. Equipment such as plows, dozers, pumpers, and retardant aircraft can be effective.
8-11	500-1,000	Fires may present serious control problems—torching out, crowning, and spotting. Control efforts at the fire head will probably be ineffective.
> 11	> 1,000	Crowning, spotting, and major fire runs are probable. Control efforts at head of fire are ineffective.

- Wind
  - The fire affects the winds, even on flat ground.
    - The plume of heated air produced by the fire draws surface air into and through the fire line [see movie of simulated fire].
    - Different parts of a complex geometry fire can interact via the fire-induced flows. [diagram?]
  - Modifications of fuel also affect the wind:
    - The roughness height is reduced after burning, which reduces the surface drag on the fire inflow. This is an important effect. [Refer to FF2 movie from obs tower.]
    - Fuel breaks also allow higher speed winds to penetrate into the adjacent areas with fuel.


Smokeview 4.0 Alpha – Oct 6 2003
Bndry
in_flux
kW/m2
40.0
36.0
32.0
28.0
24.0
20.0
16.0
12.0
8.00
4.00
0.00
60.0
80.0
40.0
0.0
-40.0
80.0
40.0
0.0
-40.0
Frame: 2
Time: 0.6

- Wind
  - Boundary layer turbulence affects the fire spread, making it less predictable, especially for small fires in afternoon conditions. [Show CBL fire slides.]
  - Terrain-induced winds are often very important.
    - Upslope during the day (conducive to rapid fire spread).
    - Downslope during the night (opposes upslope fire spread).
    - [Show slides on these wind regimes.]

Wildfire Evolution in the Convective Boundary Layer

Ruiyu Sun, Steven K Krueger, Michael A Zulauf
University of Utah

Mary Ann Jenkins
York University

Joseph J Charney
USDA Forest Service

Diurnal Mountain Winds

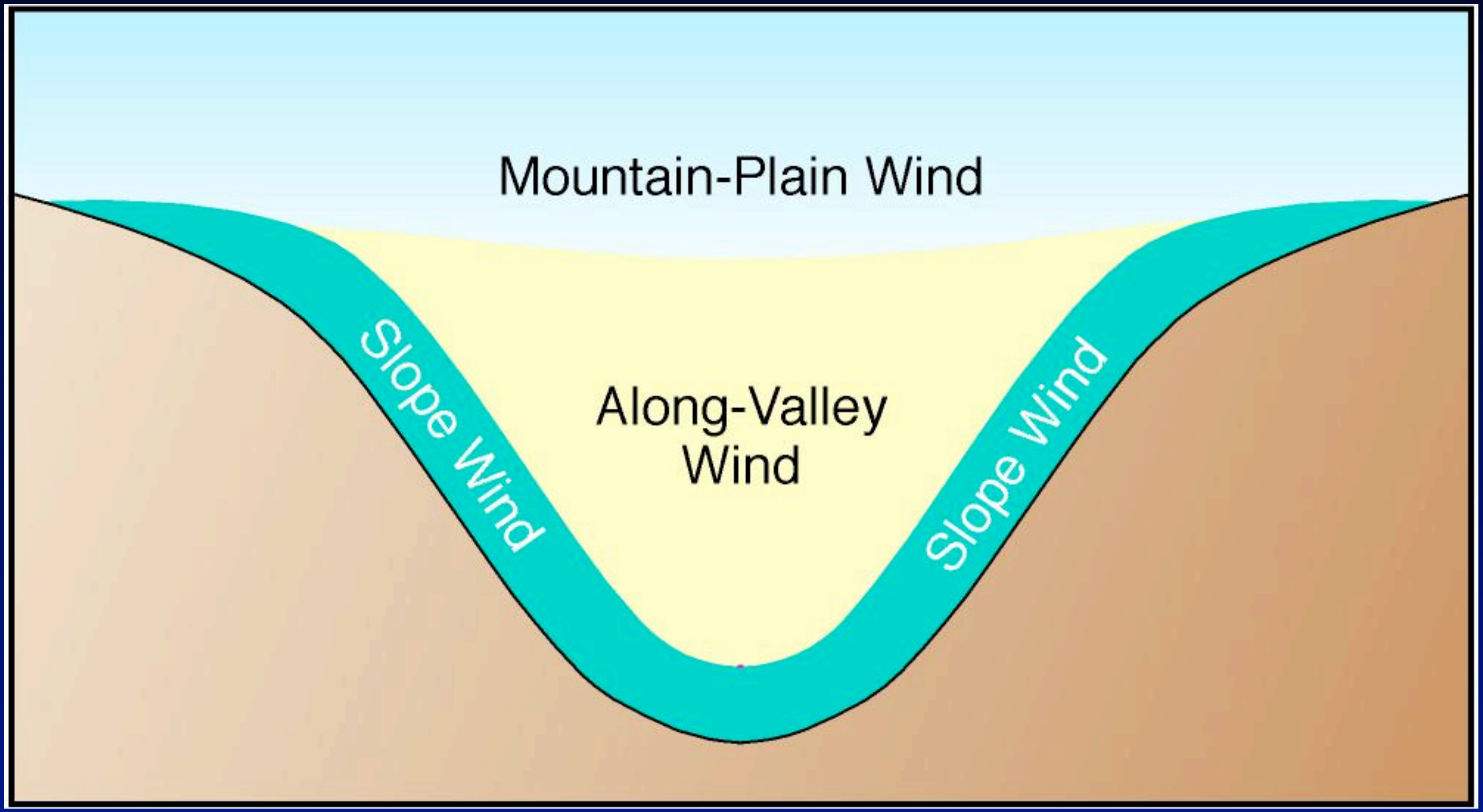
C. David Whiteman

Meteorology 3000
Mountain Weather and Climate
Spring 2005

The mountain wind system

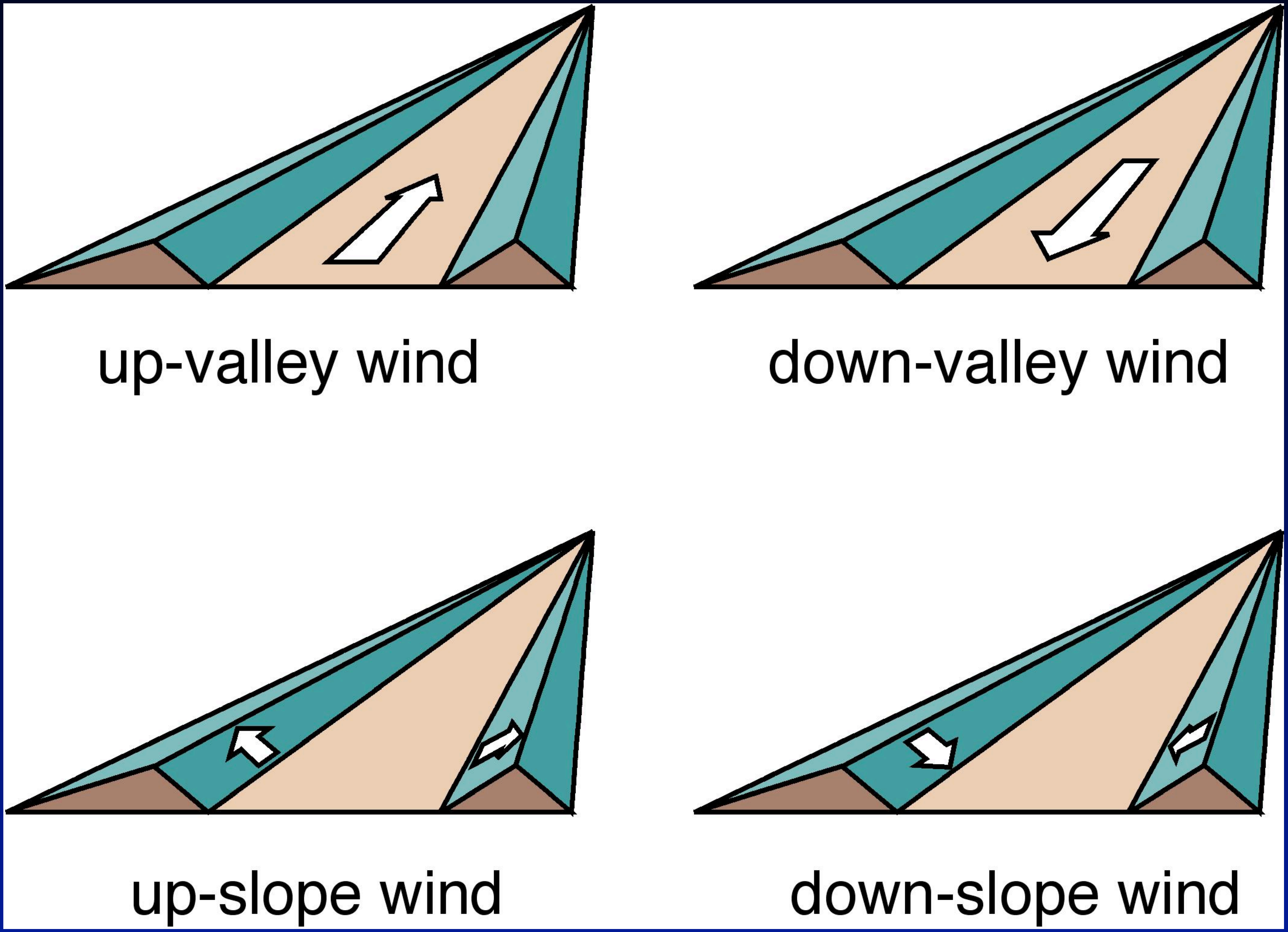
- Four interacting wind systems are found over mountain terrain:
  - Slope wind system (upslope and downslope winds)
  - Along-valley wind system (up-valley and down-valley winds)
  - Cross-valley wind system (from the cold to warm slope)
  - Mountain-plain wind system (plain-mtn and mtn-plain winds)
- Because diurnal mountain winds are driven by horizontal temperature differences, the regular evolution of the winds in a given valley is closely tied to the thermal structure of the atmospheric boundary layer within the valley, which is characterized by a diurnal cycle of buildup and breakdown of a temperature inversion.

Wind regimes



Whiteman (2000)

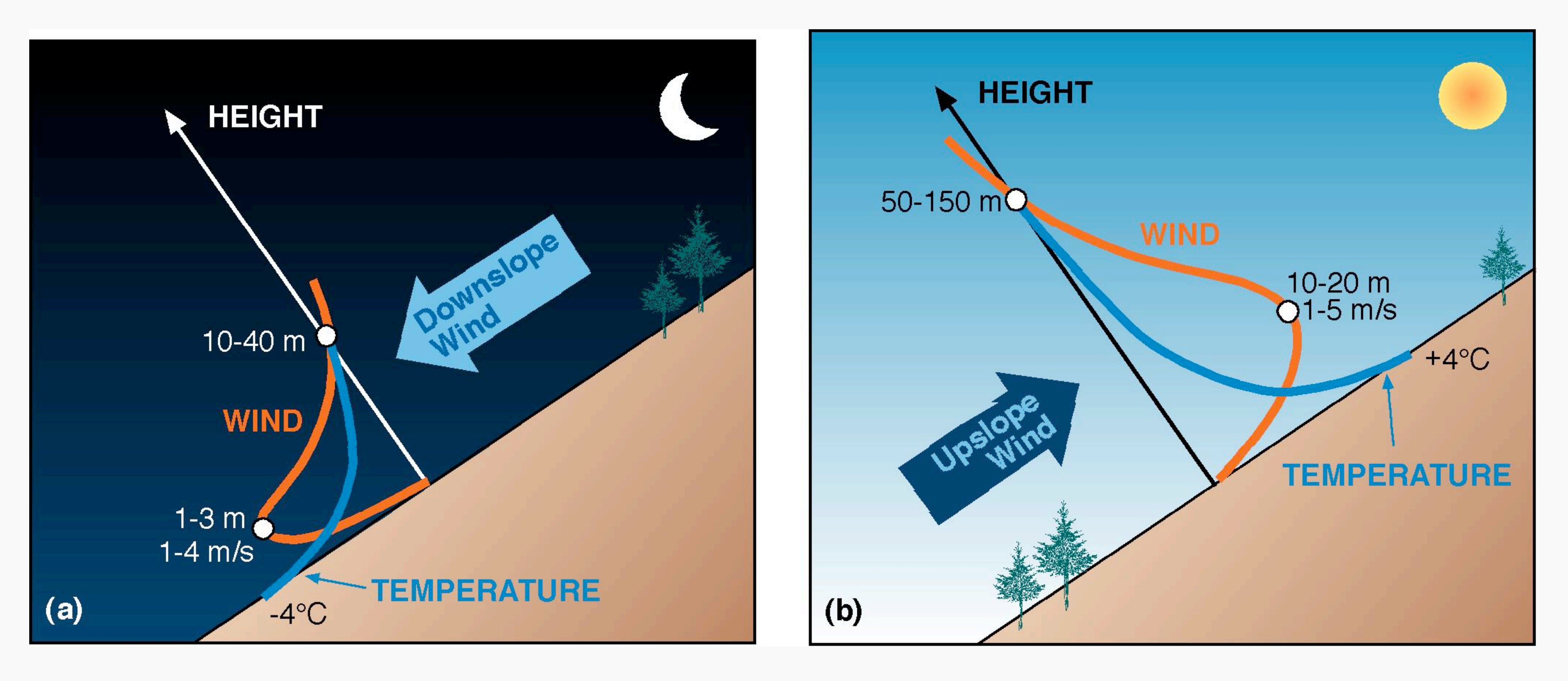
Wind Terminology



Slope winds

- Gravity or buoyancy currents following the dip of the underlying slope
- Caused by differences in temperature between air heated or cooled over the mountain slopes and air at the same altitude over the valley center
- Best-developed in clear, undisturbed weather
- Difficult to find in a pure form. Affected by along-valley wind system, weather (radiation budget, ambient flows), changing topography or surface cover

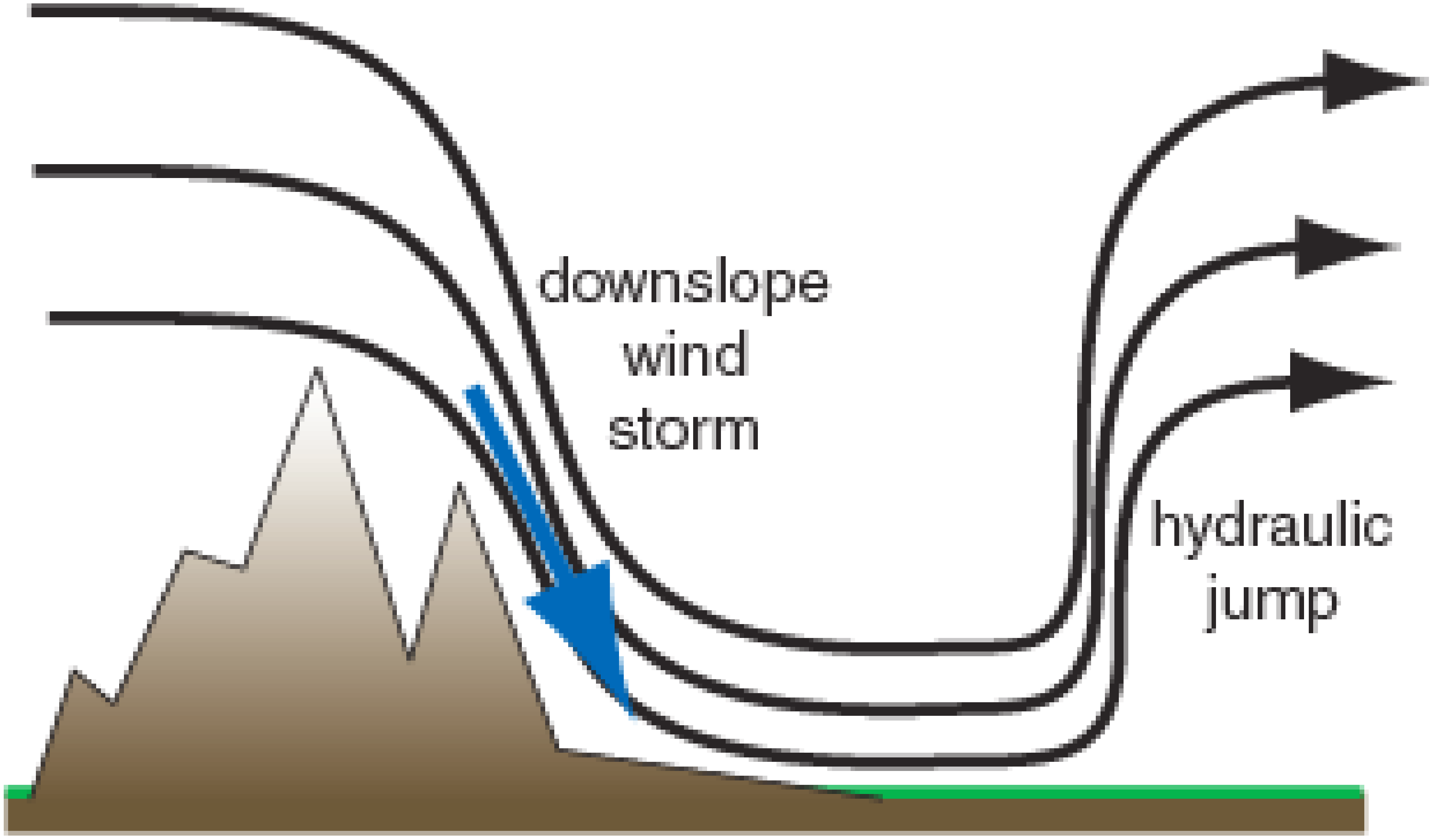
Slope flows



Whiteman (2000)

7-03 AM - 13 Aug 13.jpg

Terrain Effects




Ventura
Los Angeles

- Slope
    - Slope brings flames closer to unburned fuels ahead of the fire, making it easier to ignite them.
    - Heating of the air by the combustion produces buoyancy, which accelerates air upwards, and also along the slope.
    - Both of these factors increase the ROS.
    - So fires burn quickly up slopes, and slowly down slopes. [Show neffs fire video; incendiary wind tunnel movie]

Incendiary (Fire) Wind Tunnel Science Day demonstration:

Rate of spread is determined by

- wind
- slope
- fuel properties

The next three slides show how slope affects rate of spread:

- Moderate uphill
- Steep uphill
- Moderate downhill

YELLOWSTONE
NATIONAL PARK
SWIM TEAM

Next is a 40-sec clip of the steep uphill fire, which spreads quite rapidly.

- Putting it all together: Types of fires
    - Wind-driven: Slope does not matter much; ambient wind drives the fire. [refer to FF2 grass fire]
    - Plume-dominated: Large integrated heat release so buoyant air produces a strong updraft that rises to great heights. {show examples]
    - Slope-dominated: Can produce large integrated heat release due to fire-induced upslope flow, regardless of ambient wind, but is favored during daytime. [show example]

from Dugway/Skullvalley side 4-05 PM - 11 Aug 13.jpg

- Putting it all together: Smoke production and plume height
    - An important question is whether smoke will remain trapped in the boundary layer, or penetrate into the free atmosphere.
    - The answer depends on the fire intensity and fire regime. Plume-dominated fires are more likely to penetrate into the FA.

from the Wasatch crest 9-26 PM - 11 Aug 13.jpg

www.StrangeDangers.com