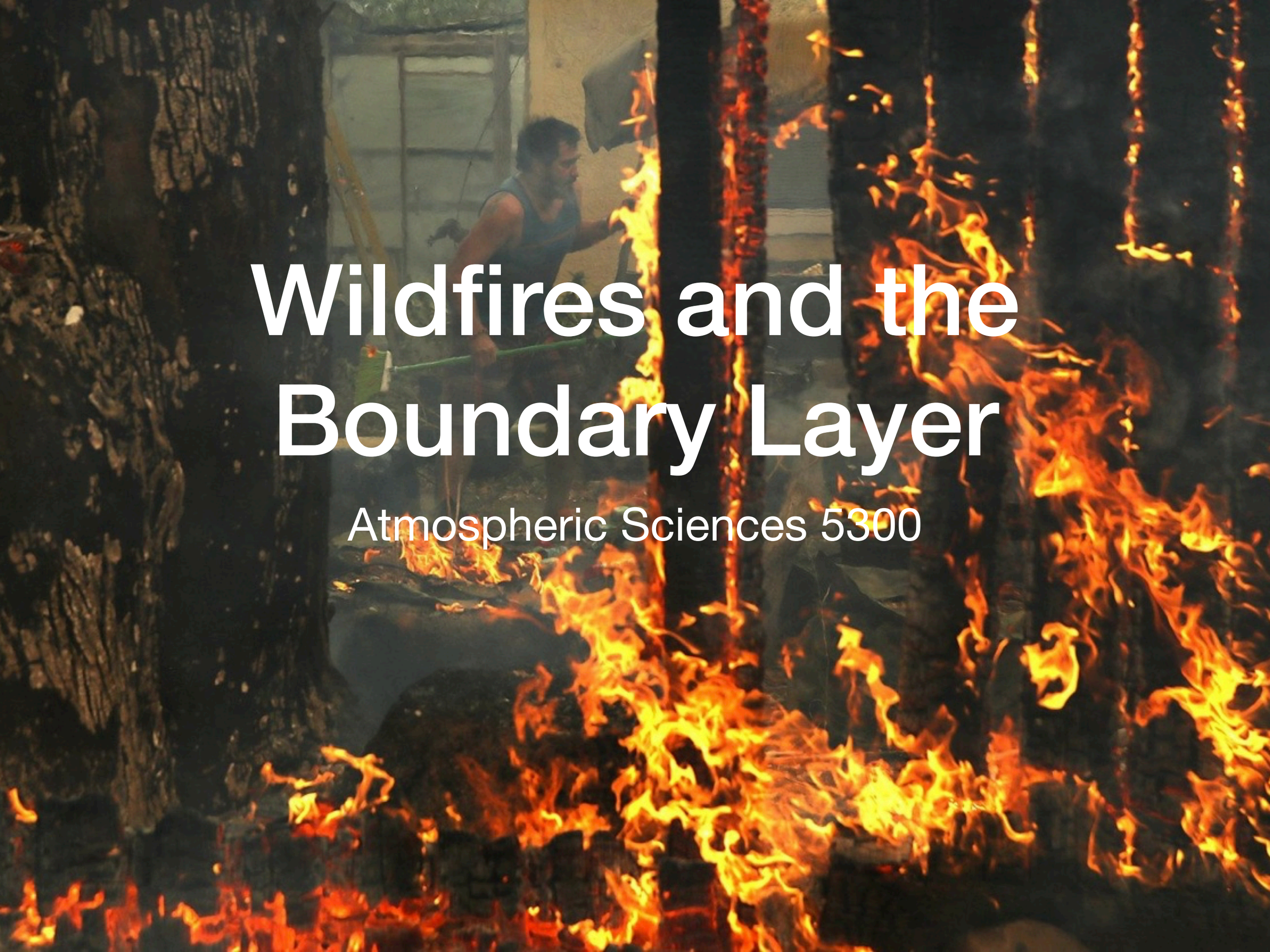


Wildfires and the Boundary Layer

Atmospheric Sciences 5300

Wildfire Impacts

- Wildfires are increasing in frequency and size and the associated destruction of structures, loss of life, and impacts on air quality are also increasing.

- Heat waves, droughts, earlier snowmelt associated with global climate change have strong impacts and yield more favorable conditions for longer fire seasons and more extreme fire behavior, as have decades of fire suppression in the western U.S. that has allowed fuels to build up.

- Population growth in the wildland-urbant interface (WUI) without adequate consideration of wildfire risks has also contributed to wildfire losses.

Types of Wildfires

- **<u>Wind-driven</u>**: Slope does not matter much; ambient wind drives the fire.

- **<u>Plume-dominated</u>**: Large <u>integrated heat release</u> so buoyant air produces a strong updraft that rises to great heights.

- **<u>Slope-dominated</u>**: Can produce large integrated heat release due to fire-induced upslope flow, regardless of ambient wind, but is favored during daytime.

Extreme Fire Behavior

- **What leads to extreme fire behavior?**

- **There is increasing evidence that, as in severe thunderstorms, the low-level wind profile affects fire behavior.**

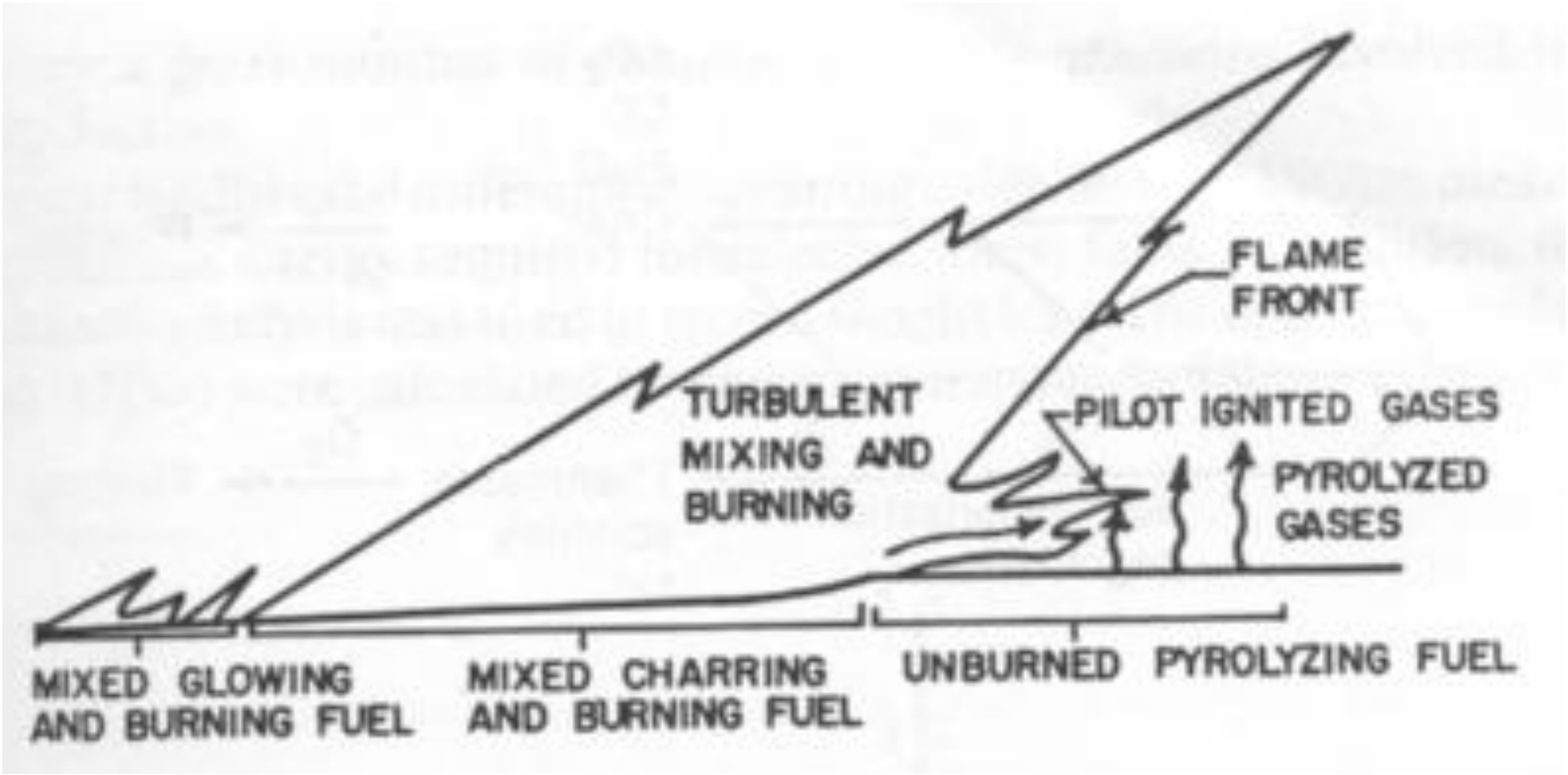
- **Pyrocumulonimbus clouds are thunderstorms initiated by large wildfires.**

Incendiary (Fire) Wind Tunnel

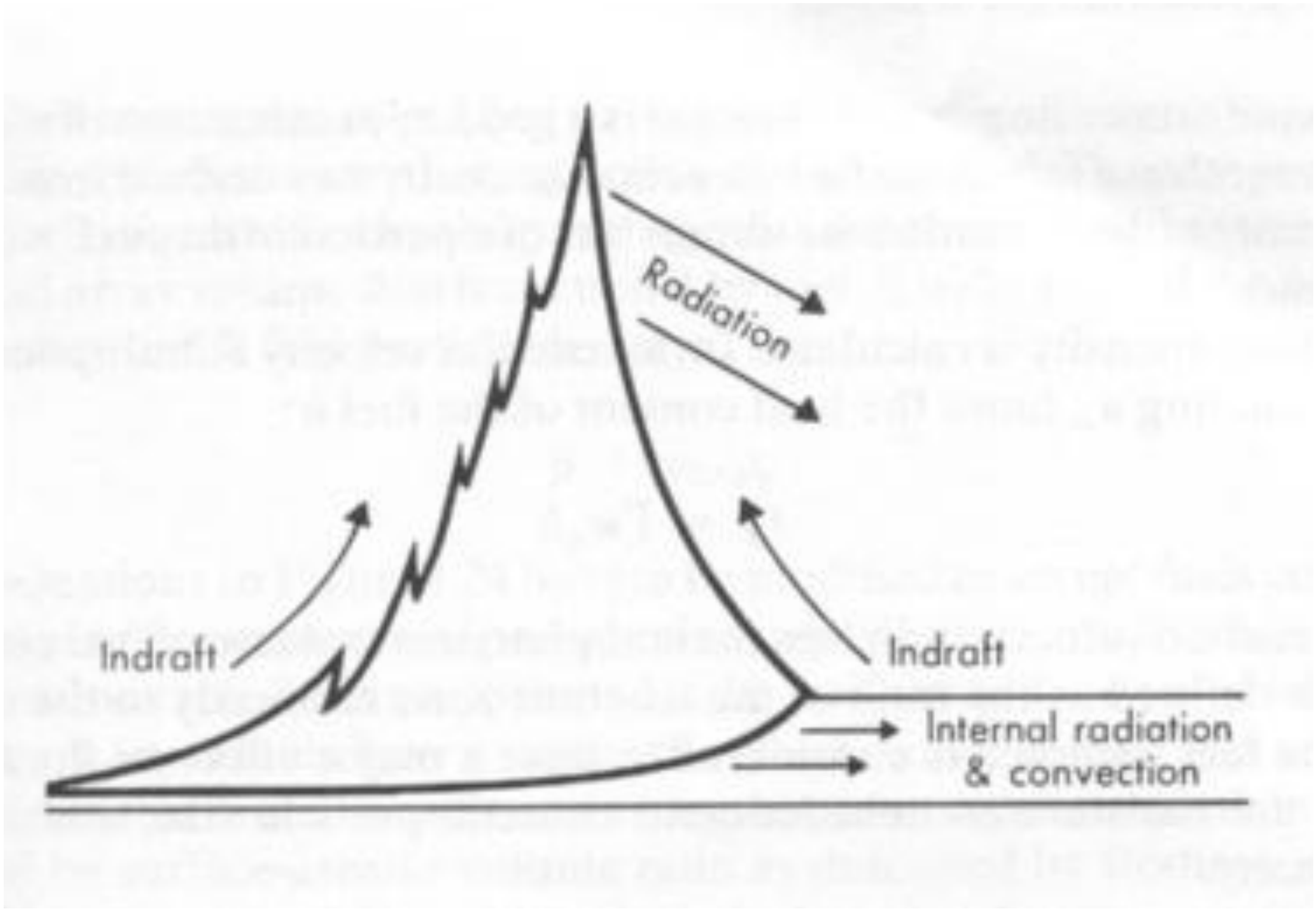
How does a fire spread?

- 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]

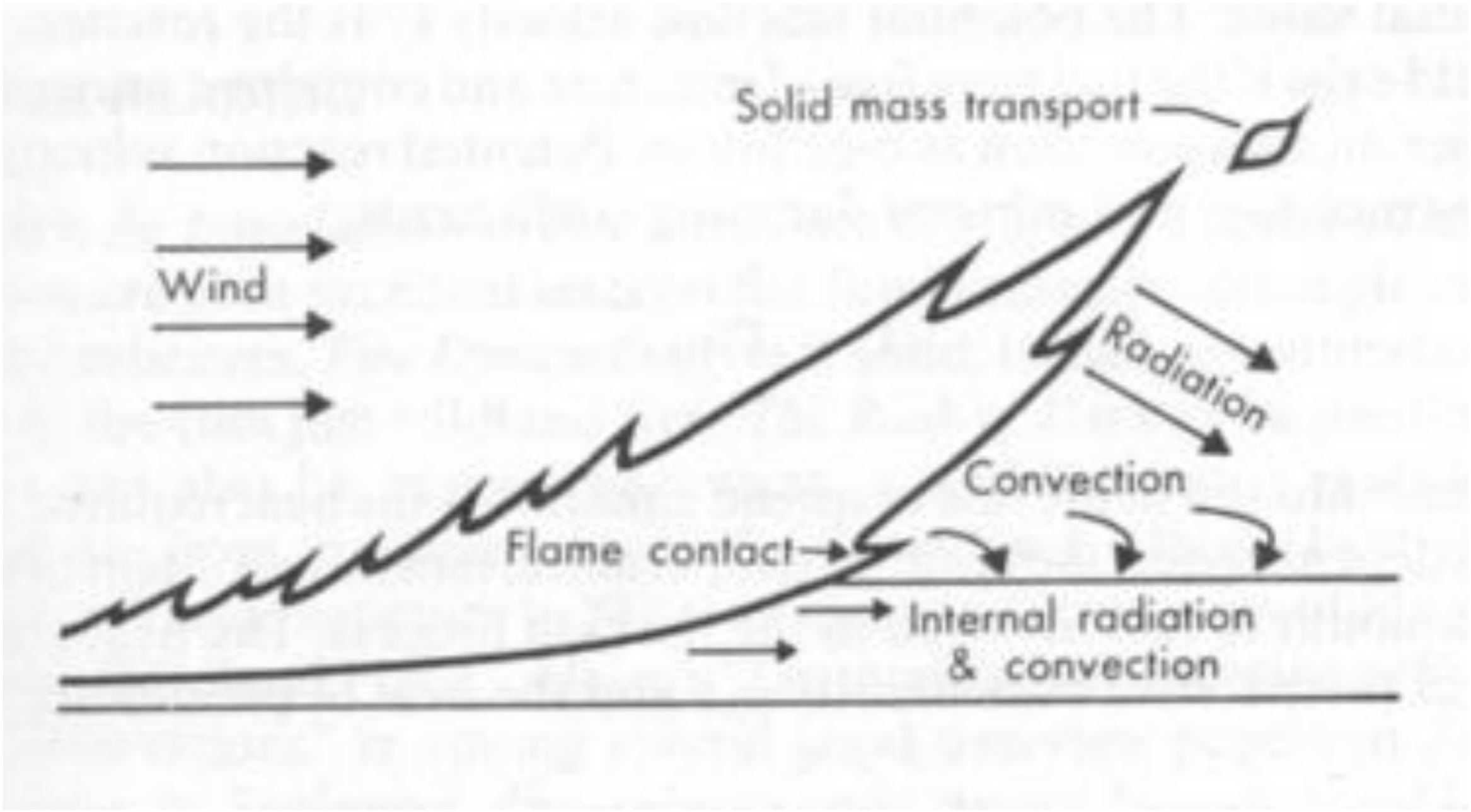
Fire Spread Physics



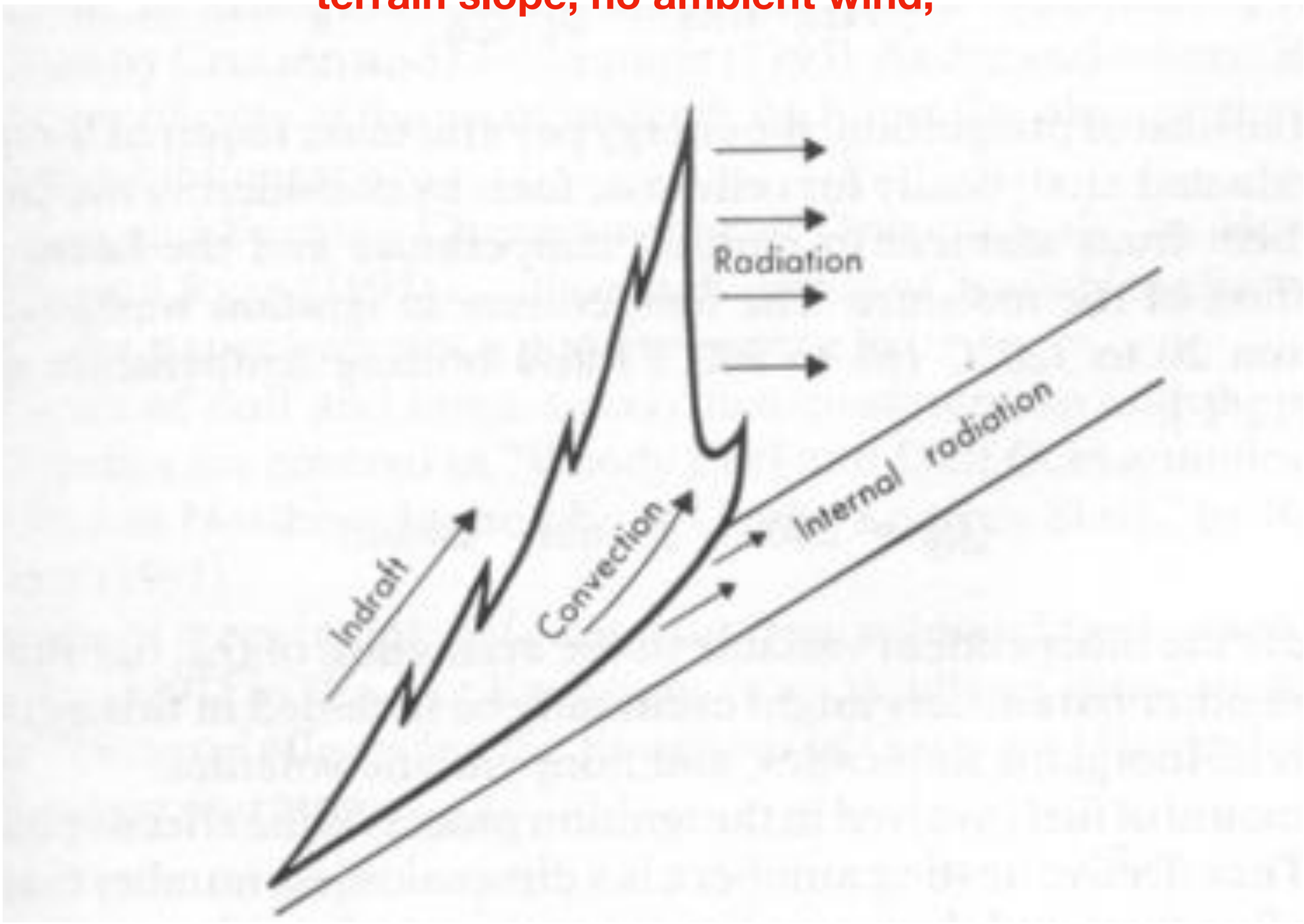
no ambient wind, no terrain slope



ambient wind, no terrain slope

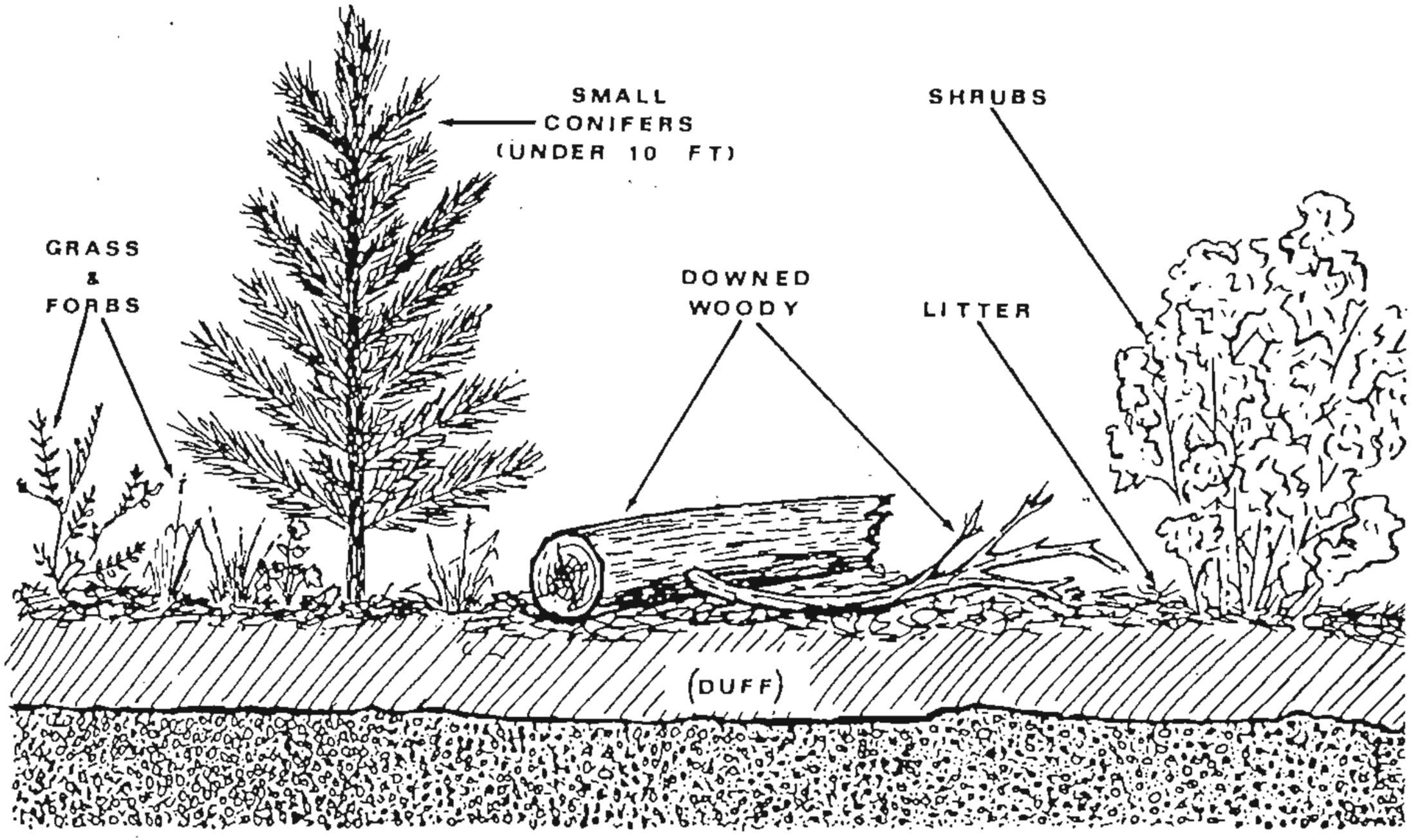


terrain slope, no ambient wind,

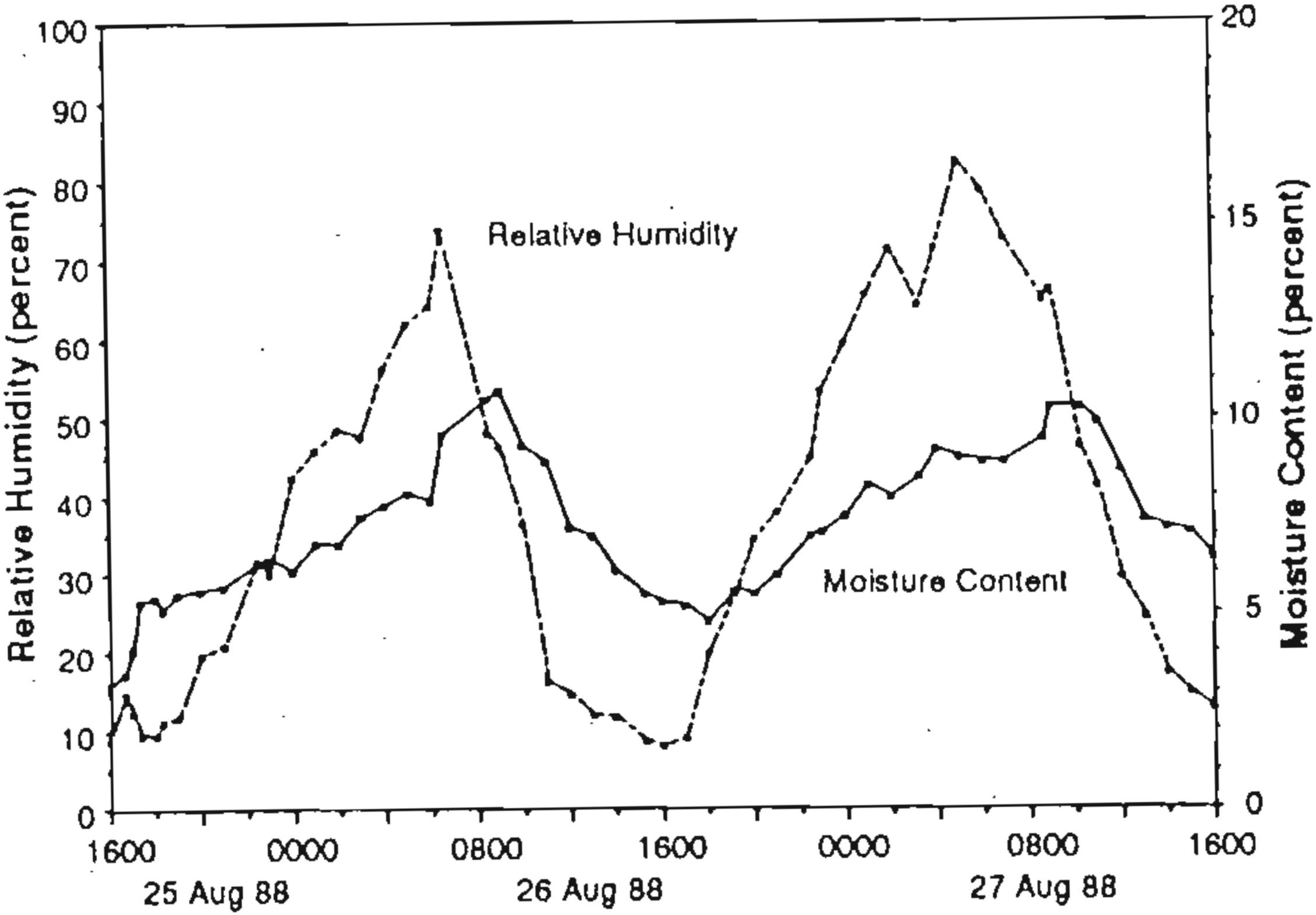


Factors that influence fire spread and fire intensity

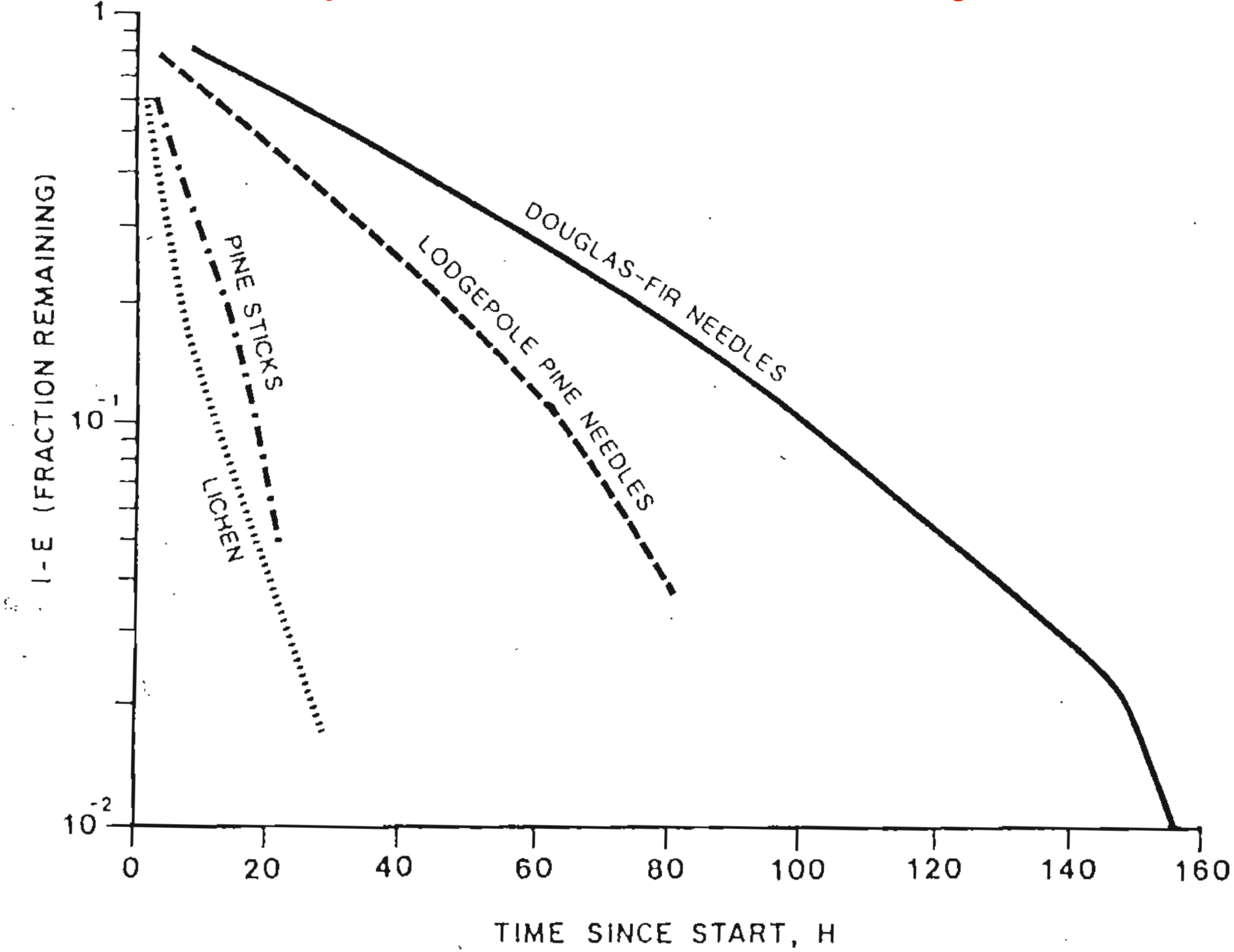
- **Wind, slope, fuel** (amount and dryness)
- **Fuel**
  - *Surface to volume ratio:* fuel burns via volatilization.
  - Before this can happen, *moisture must be removed* by heating and vaporization, which takes extra energy.
  - Fuel bed = *fuel per unit area* = heat release per unit area. [Add table.]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

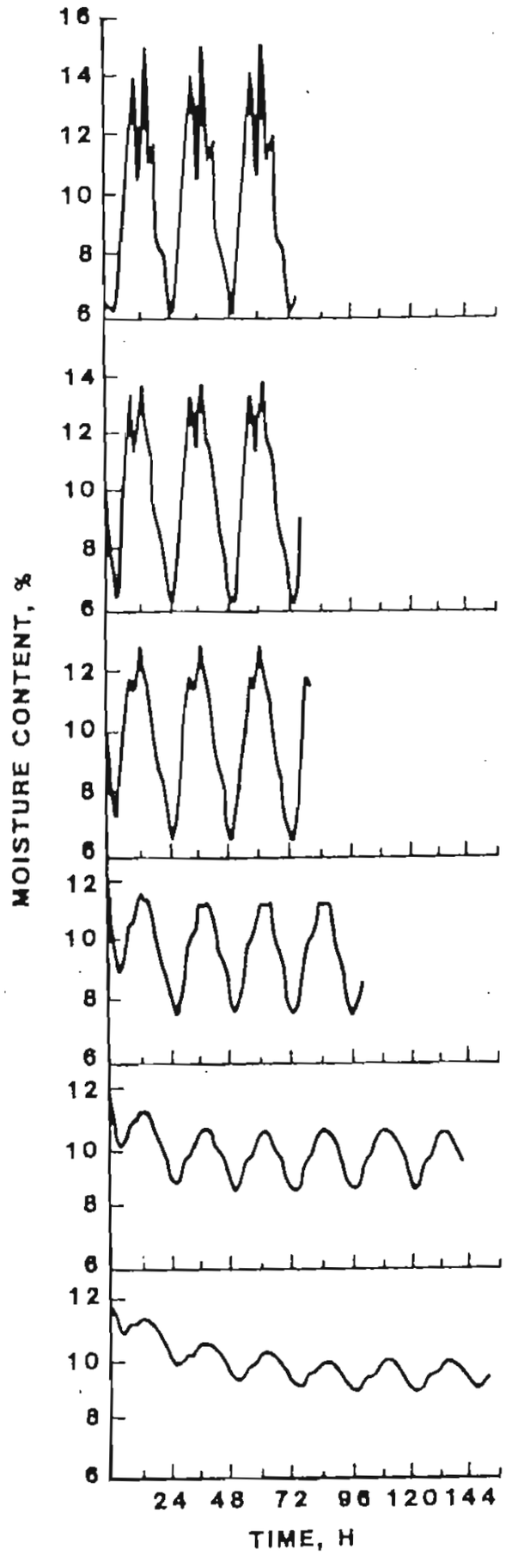

SMALL
CONIFERS
(UNDER 10 FT)
SHRUBS
GRASS
&
FORBS
DOWNED
WOODY
LITTER
(DUFF)

Moisture Content of Fuel versus Relative Humidity of Air



Response time of fuel moisture to RH 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—ponderosa pine, western white pine, and western redcedar:
Desorption timelag 5.18 hours
Adsorption timelag 7.29 hours

Fine fuel moisture response for needles—Engelmann 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

CSIRO PUBLISHING

International Journal of Wildland Fire
https://doi.org/10.1071/WF18089

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]

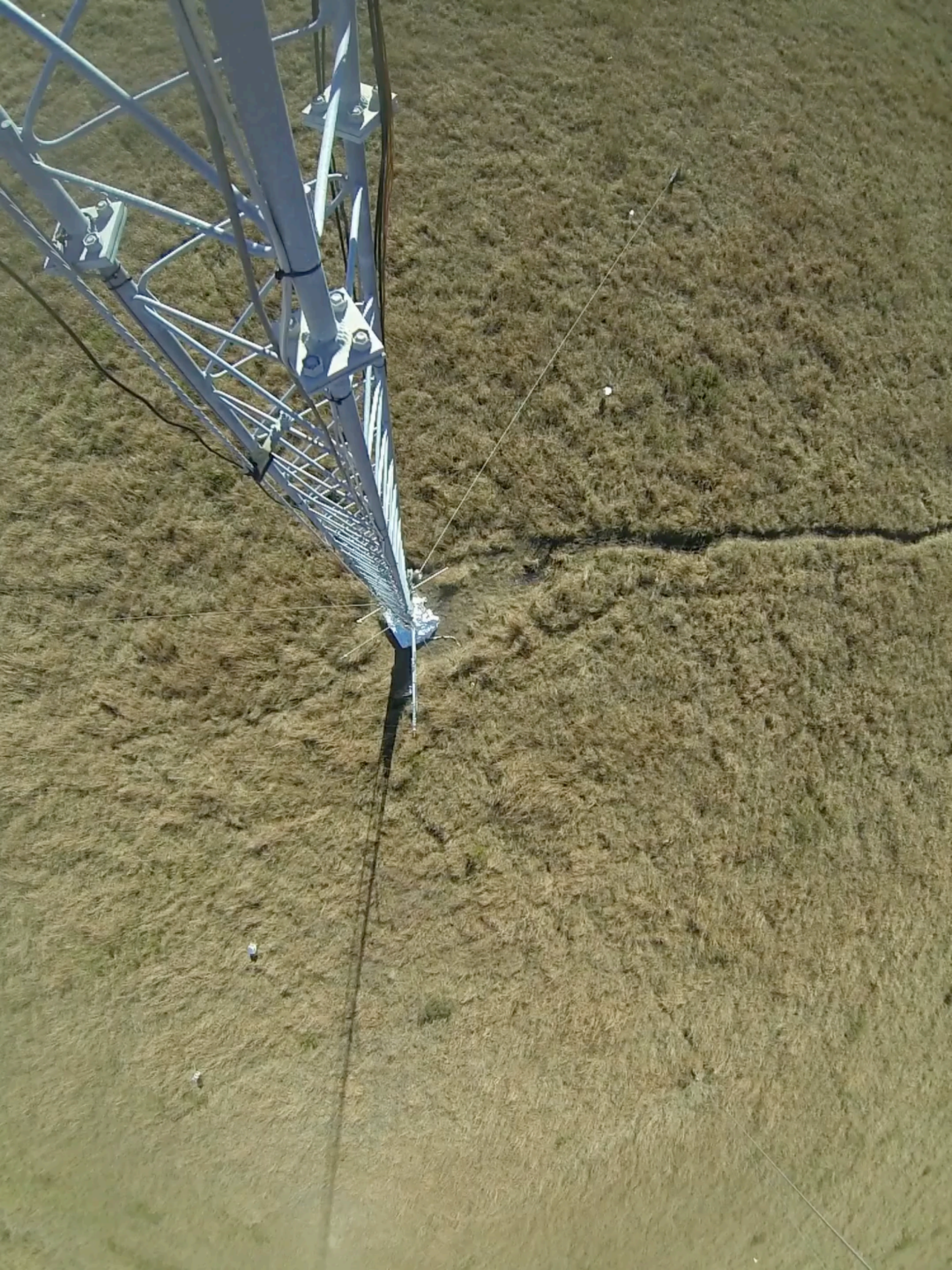
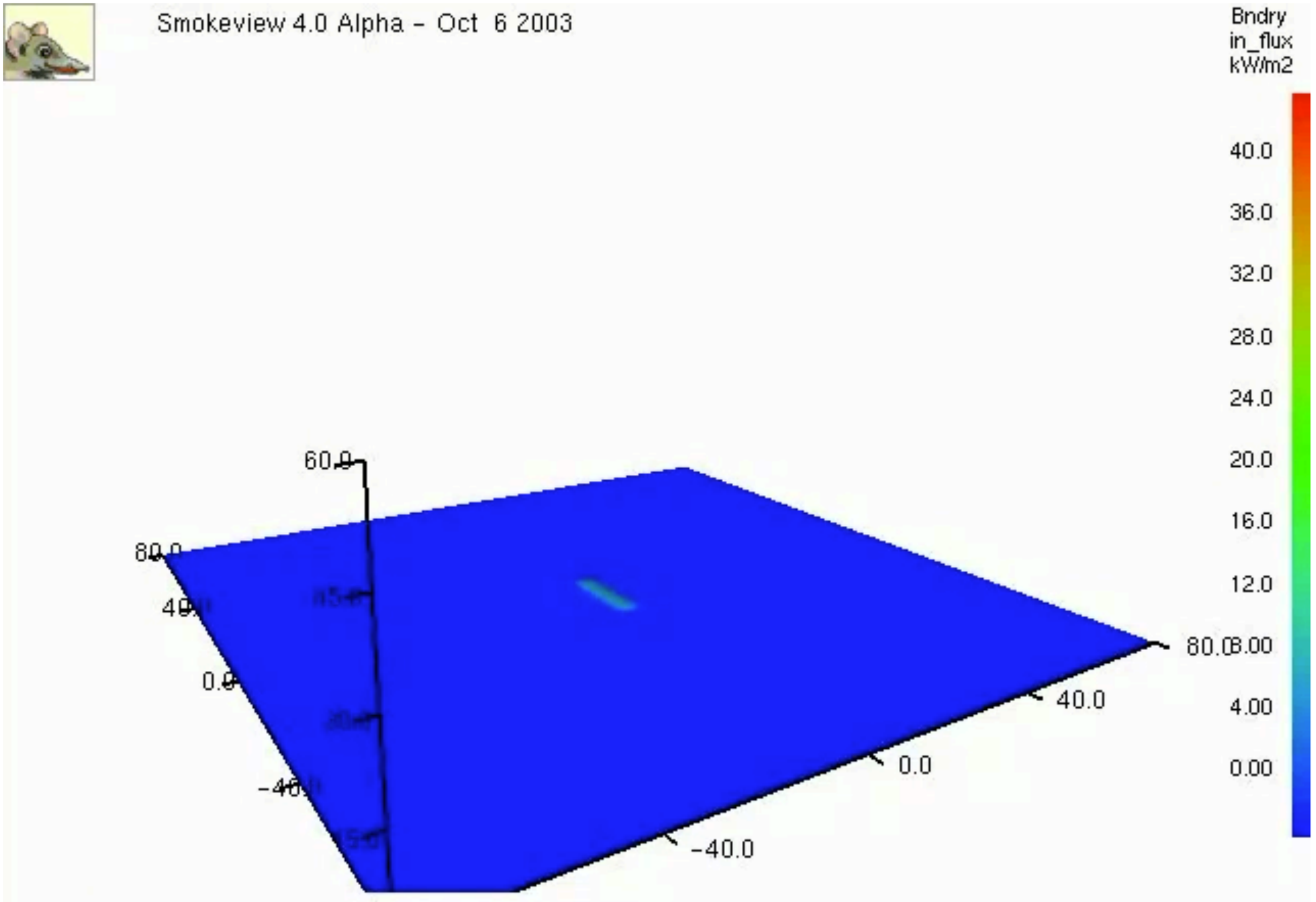


Table 1.—Fire suppression interpretations of flame length and fireline intensity

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



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

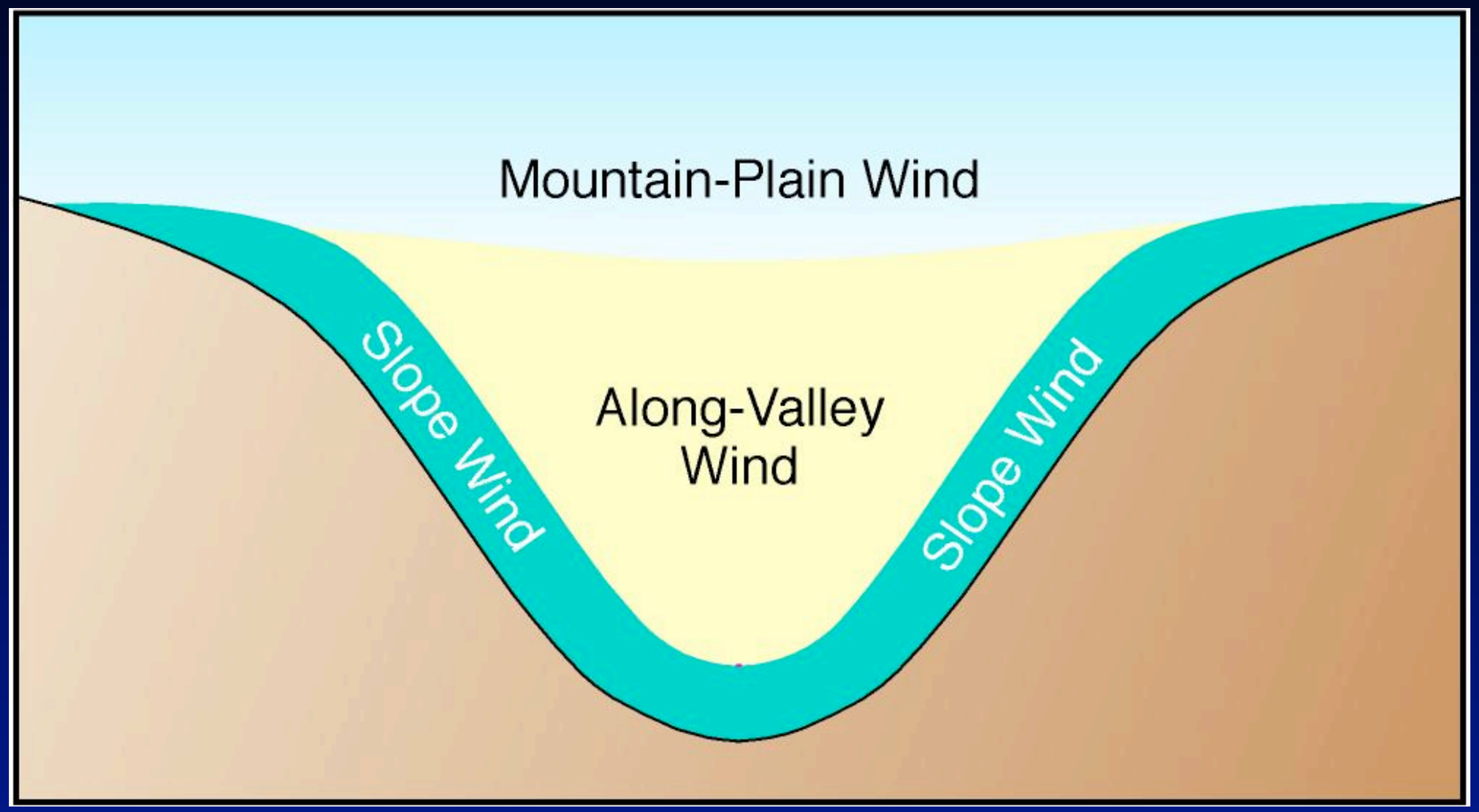
C. David Whiteman

Meteorology 3000
Mountain Weather and Climate
Spring 2005

The mountain wind system

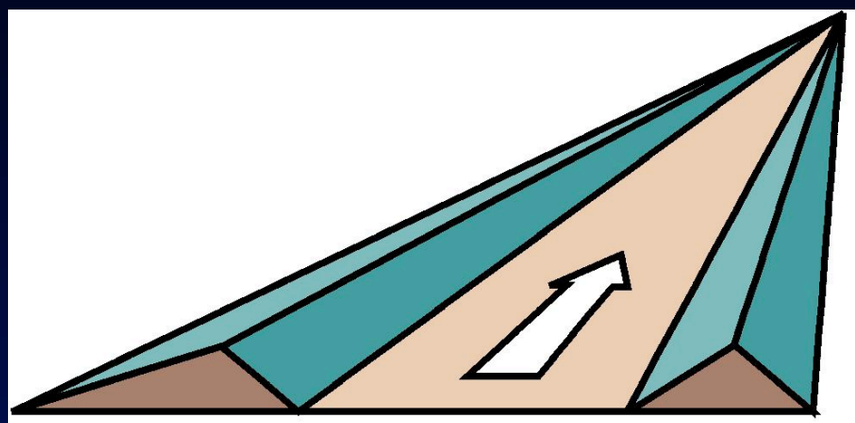
- Four interacting wind systems are found over mountain terrain:
  - Slope wind system (upslope and downslope winds)
  - Along-valley wind system (up-valley and down-valley winds)
  - Cross-valley wind system (from the cold to warm slope)
  - Mountain-plain wind system (plain-mtn and mtn-plain winds)
- 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

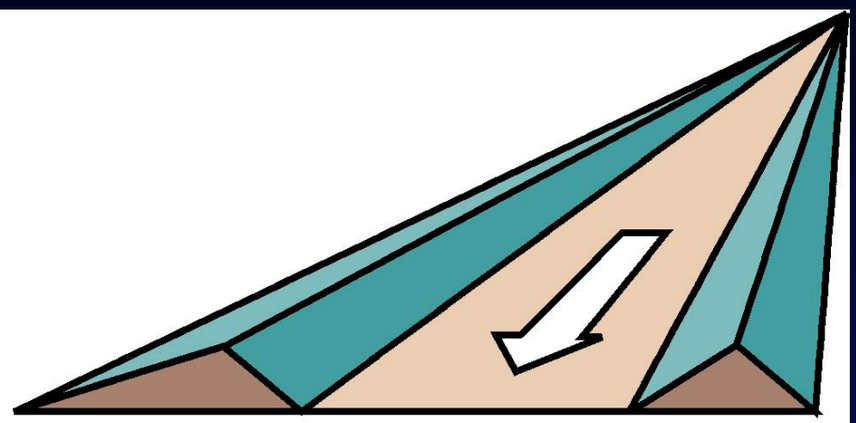


Whiteman (2000)

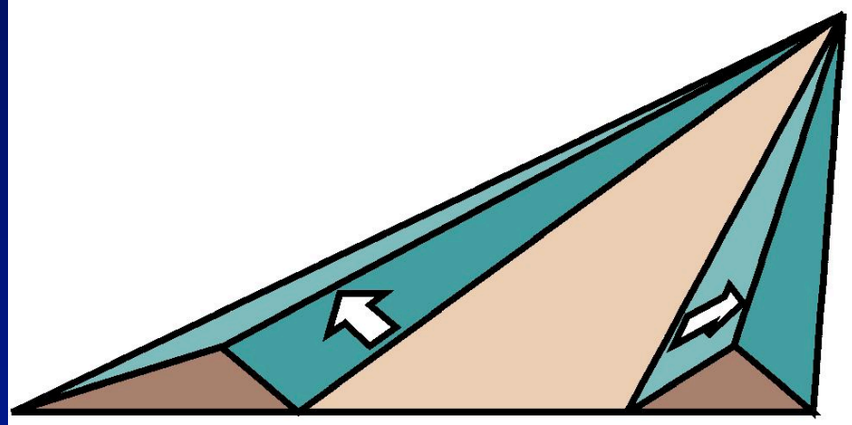
Wind Terminology



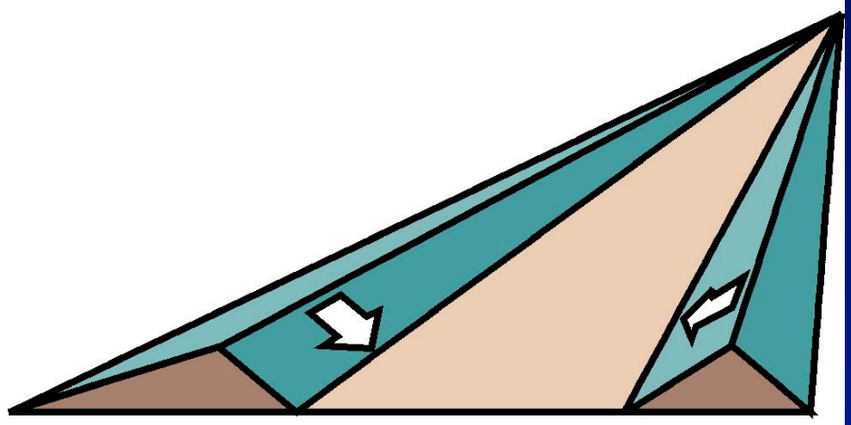
up-valley wind



down-valley wind



up-slope wind



down-slope wind

Slope winds

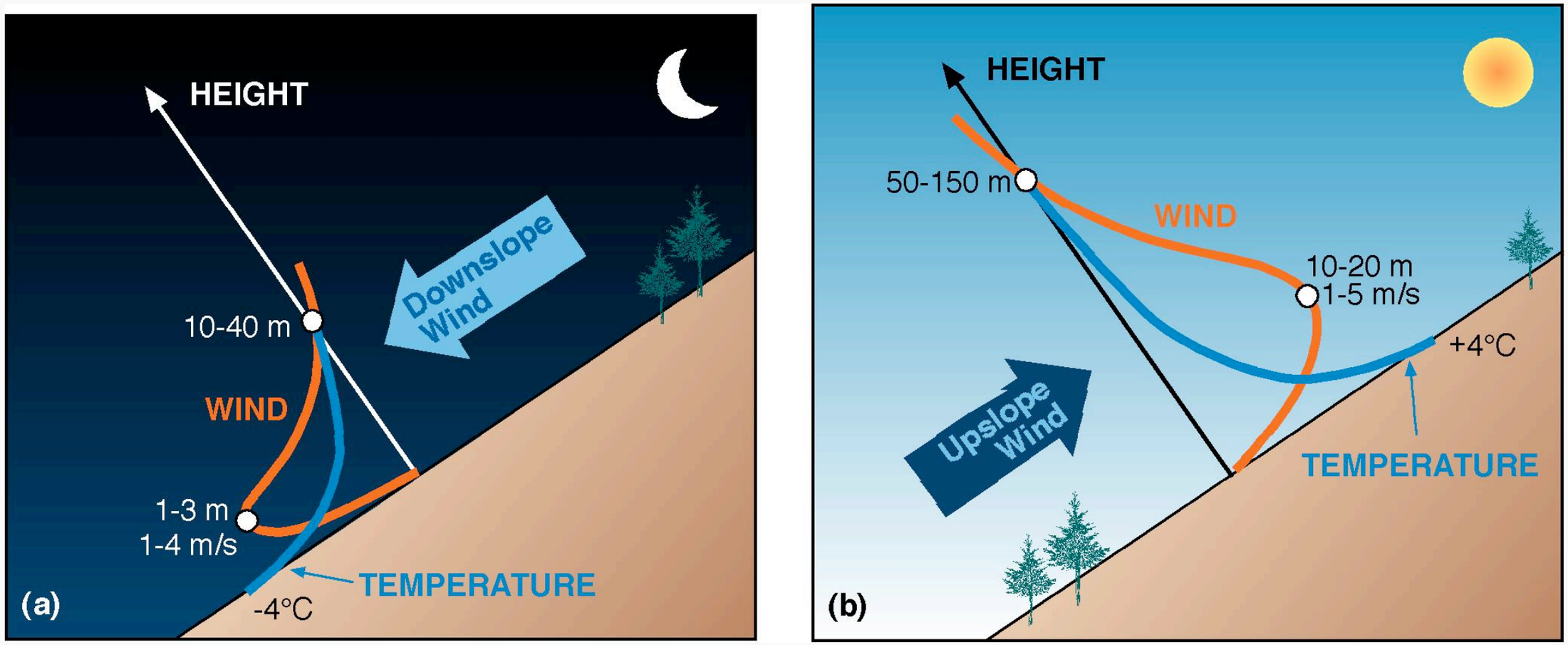
- Gravity or buoyancy currents following the dip of the underlying slope

- 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

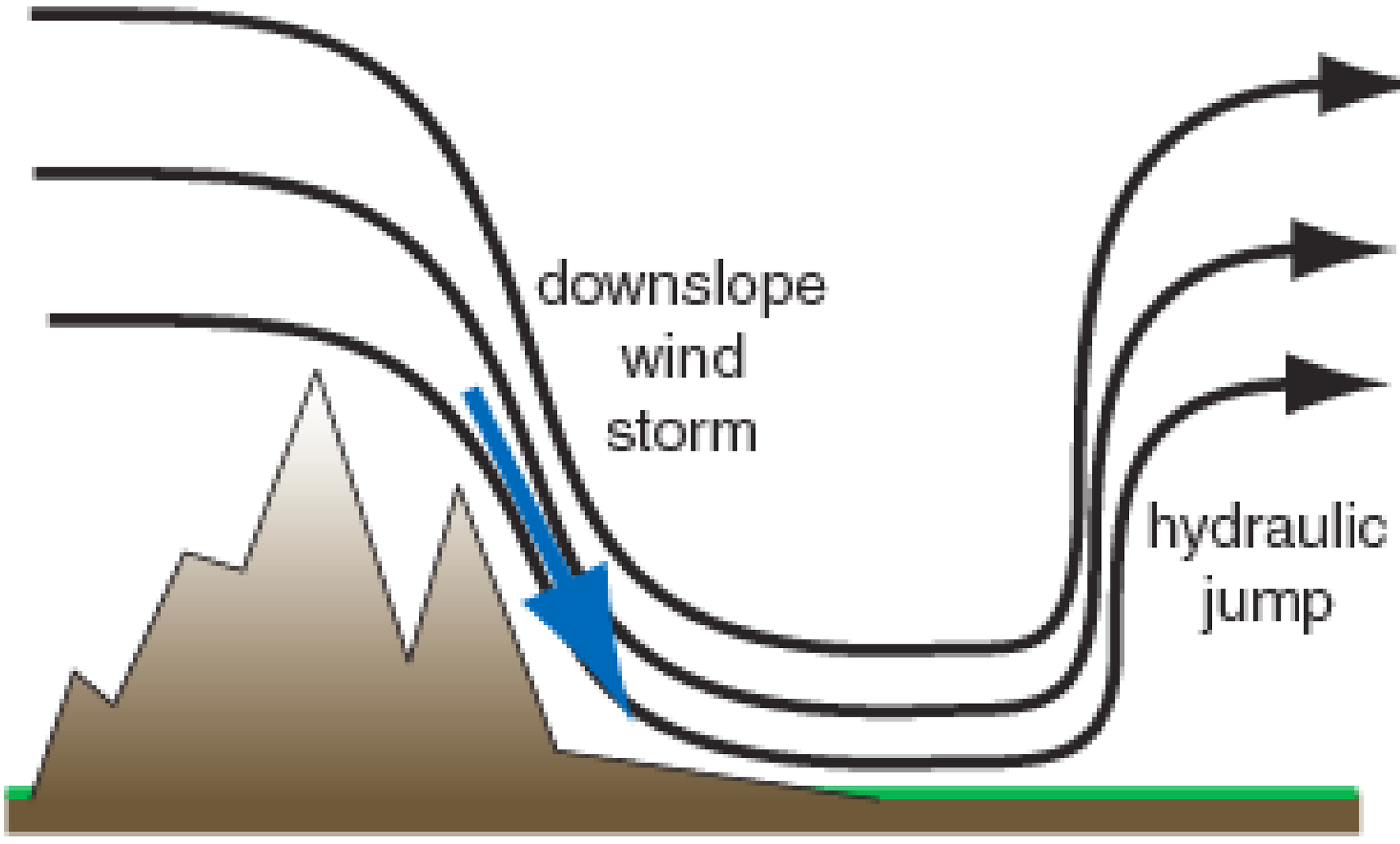
Slope flows



Whiteman (2000)

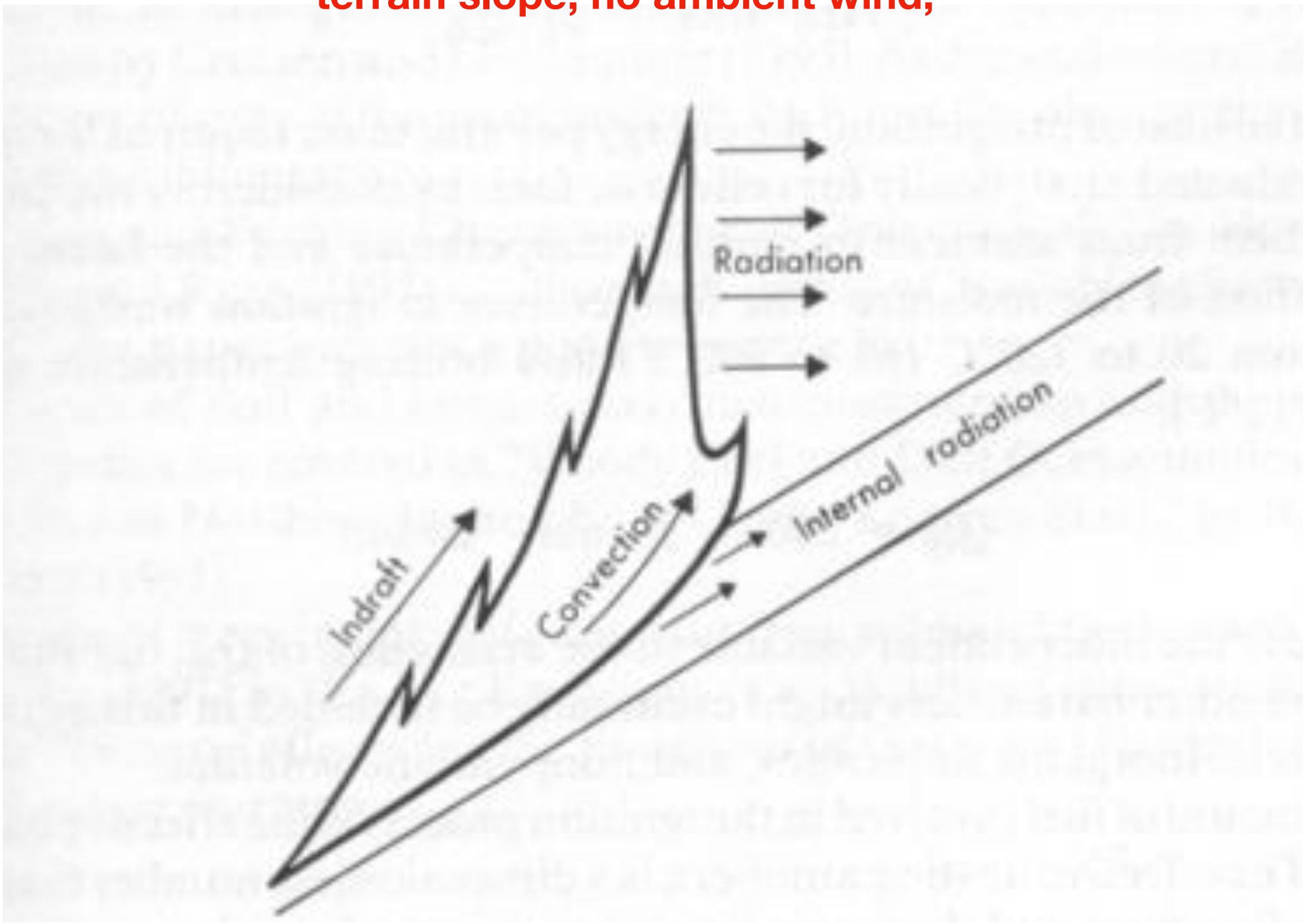
7-03 AM - 13 Aug 13.jpg

Terrain Effects



Santa Ana winds in Southern California

terrain slope, no ambient wind,



- **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


EXIT


EVOLUTION
DEMOGOR
EAGLES
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