2.5

Effects of topography on fire behavior

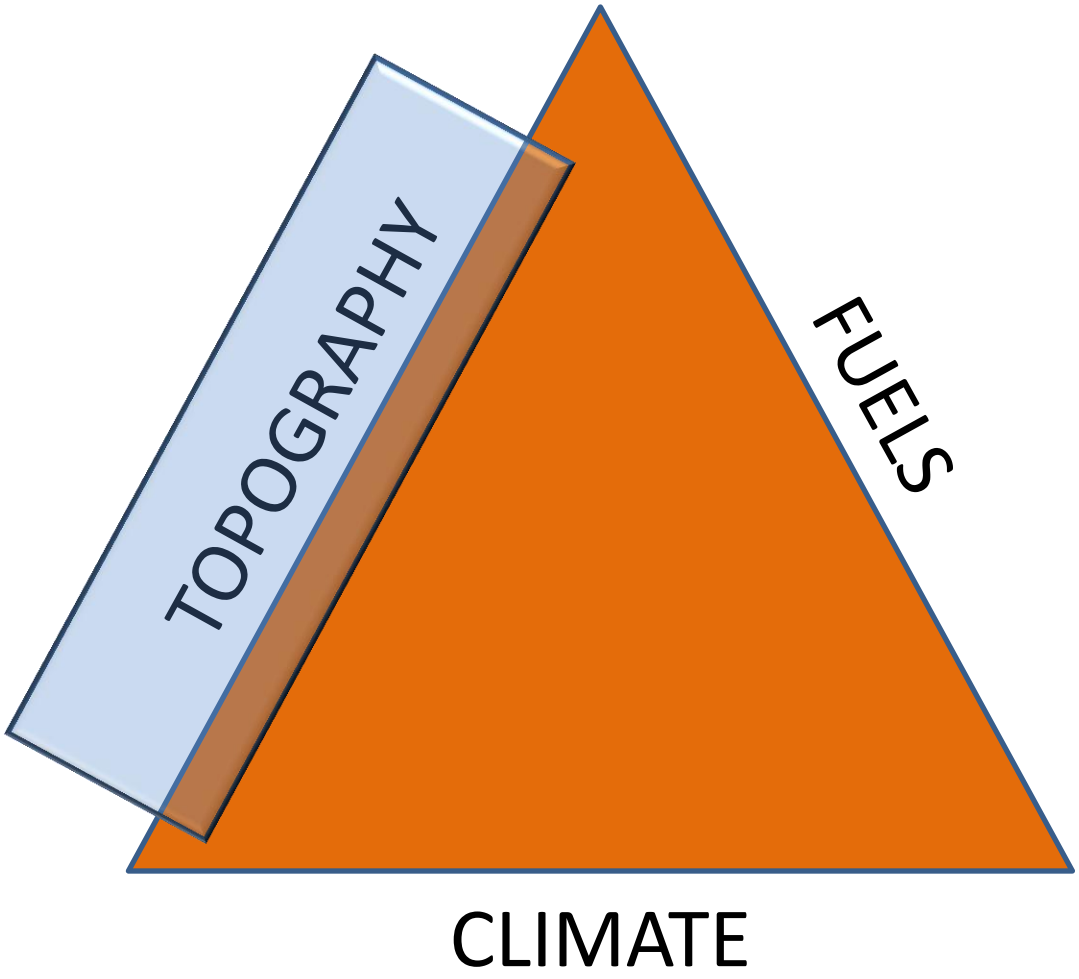
Review: What controls fire behavior?

1. Weather (short- to medium-term)
   - Relative humidity, temperature, wind, atmospheric stability
     - Main natural source of ignition (lightning)
     - Regulates fuel moisture, humidity
     - Influences energy (heat) transfer
     - Affects fuel pre-heating, flammability
     - Mass transport of flaming objects (spotting, rapid fire extension)

2. Fuels

1. Combustible biomass to sustain the combustion chain reaction
2. Key properties:
    1. Mass (fuel load)
    2. Shape and size (surface/volume ratio, fuel time lag class)
    3. Spatial configuration or arrangement (packing ratio)
    4. Heat content (MJ/kg, energy in chemical bonds)
    5. Moisture (% dry weight)

The fire behavior triangle



3. Topography

What is “topography”?

Gk. *topos* (place) + *graphein* (carve, write)

The configuration of a surface, including its relief and features (landform)

What are the main topographic variables?

1. Aspect (0-360°, defined looking downslope)
2. Slope (%), defined as (rise/run * 100)
   - 60 m rise / 100 m lateral = (60/100) * 100 = 60% slope
3. Slope position:
   - Various systems for describing this, e.g.:
     - Ridge top, upper hillslope, midslope, lower hillslope, valley bottom
4. Landform (describes or characterizes shape):
   - Canyons, ridges, bowls, cirques, plateaus…

How would topography influence fire behavior?*

"*Let me count the ways*" – W. Shakespeare

1. Influences incoming solar radiation (slope, aspect, elevation), strong effect on fuel moisture
2. Affects local wind patterns
3. Orographic lifting of air masses (leading to lightning, convective storms)
4. Slope affects fuel pre-heating, thus rate and direction of spread
5. Certain landforms attract lightning ignition

* Know these mechanisms!

Effect of Aspect on Fuel Temperature and Moisture

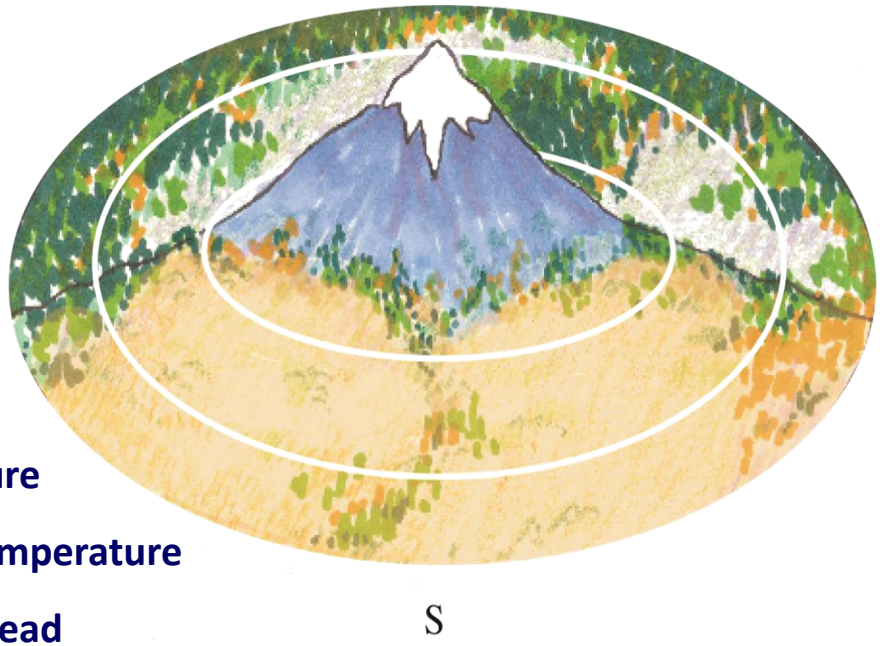
Highest Fuel Moisture

Lowest Average Temperature

Lowest Rate of Spread

Later Curing of Fuels

Late Snow Melt



Later Heating

Later Cooling

Earlier Heating

Earlier Cooling

Lowest Fuel Moisture

Highest Average Temperature

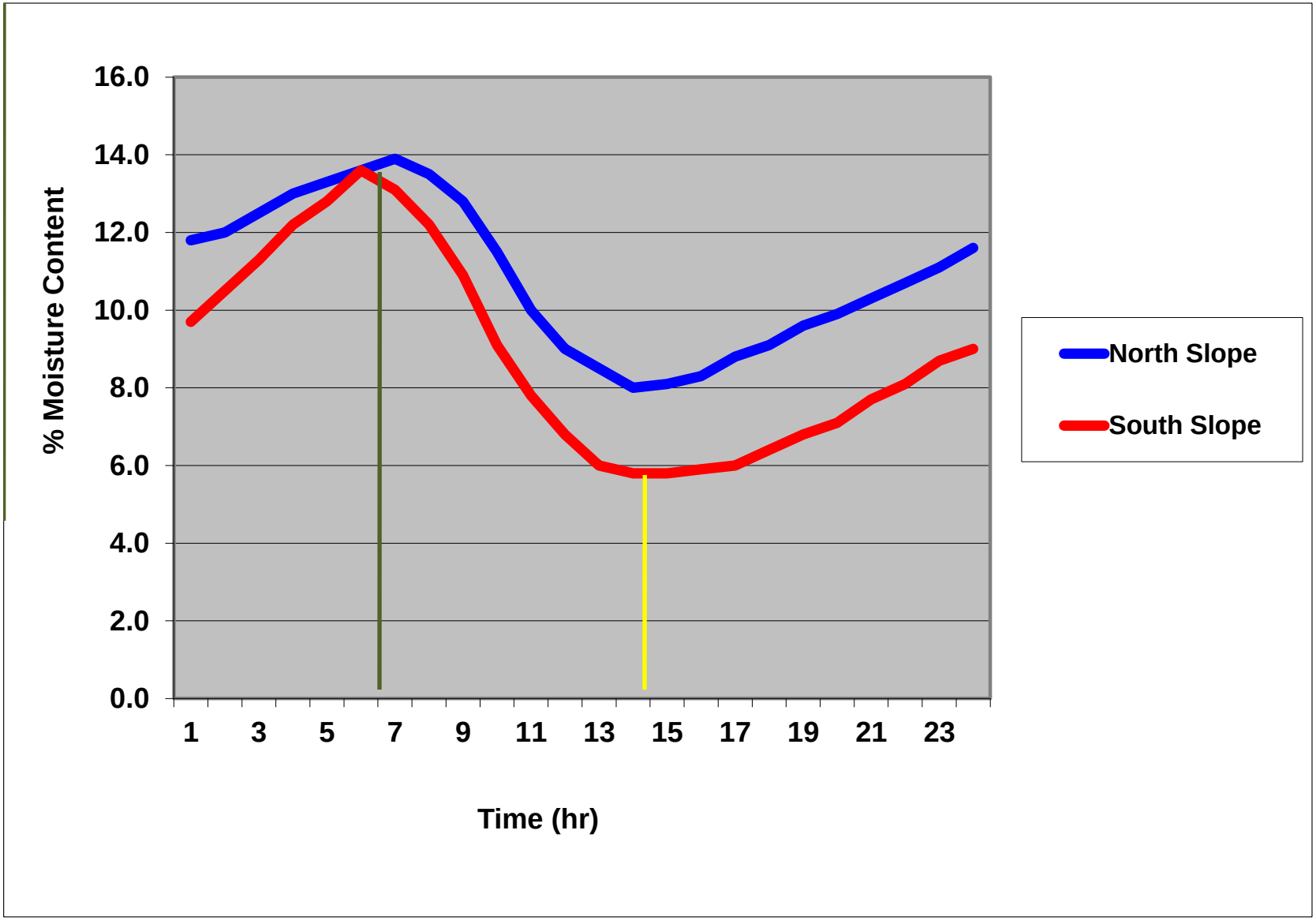
Highest Rate of Spread

Earlier Curing of Fuels

Earlier Snow Melt

These orientations for the northern hemisphere, of course!

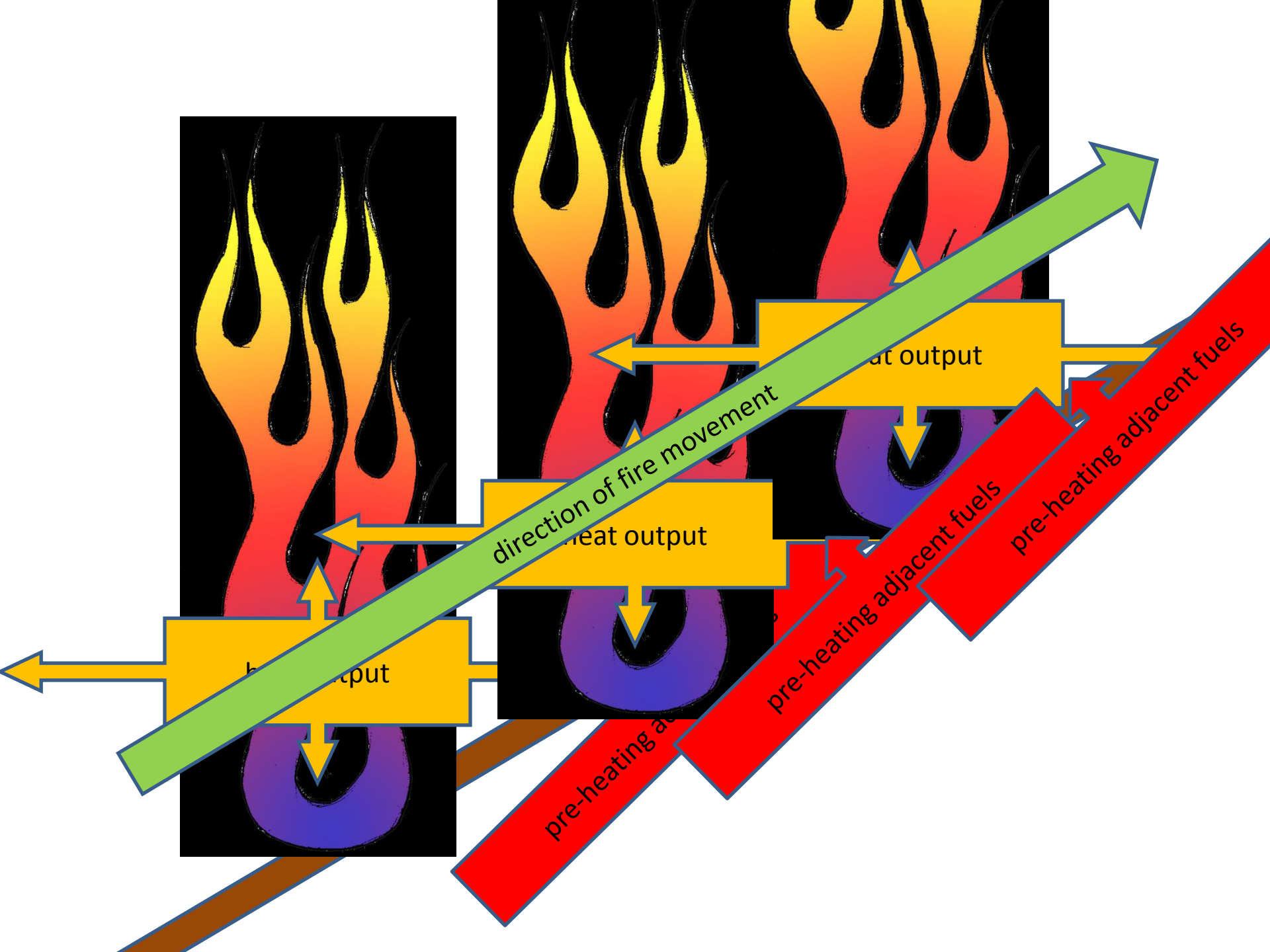
Aspect Affects Fuel Moisture



How slope affects rate of spread

Rate of spread (m min^{-1}) =

$$\frac{(\text{reaction intensity}) \times (\text{energy flux}) \times (1 + \textbf{slope coefficient} + \textbf{wind coefficient})}{(\text{fuelbed bulk density}) \times (\text{heat of pre-ignition}) \times (\text{proportion of fuel pre-heated})}$$


direction of fire movement
pre-heating adjacent fuels
pre-heating adjacent fuels
pre-heating adjacent fuels

Head Fire

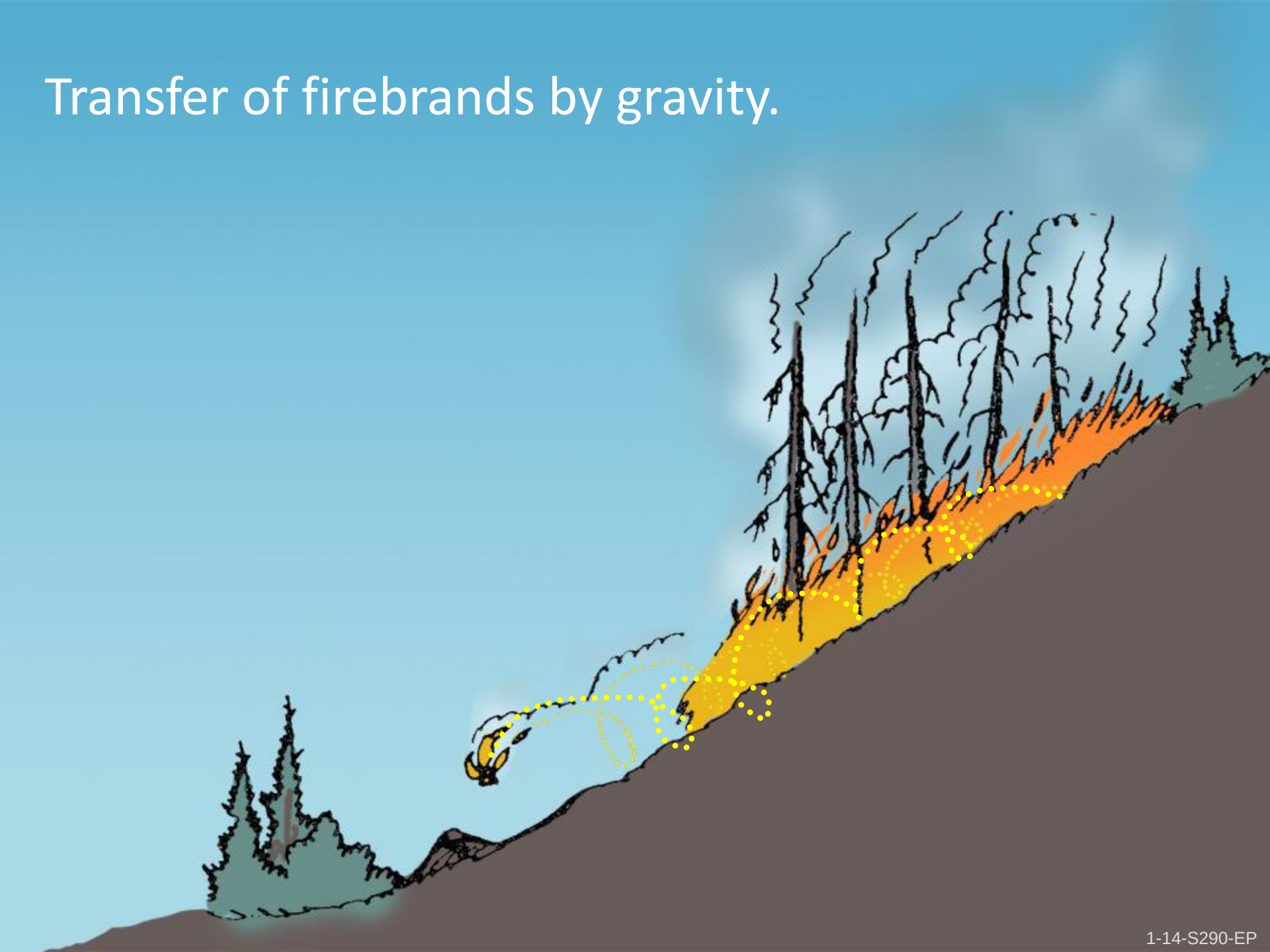
Wind and/or slope affect fire spread with radiant and convective heat.

Backing Fire

Conduction/radiation within fuel bed is dominant factor
in fire spread. Much less dependent on wind and slope.

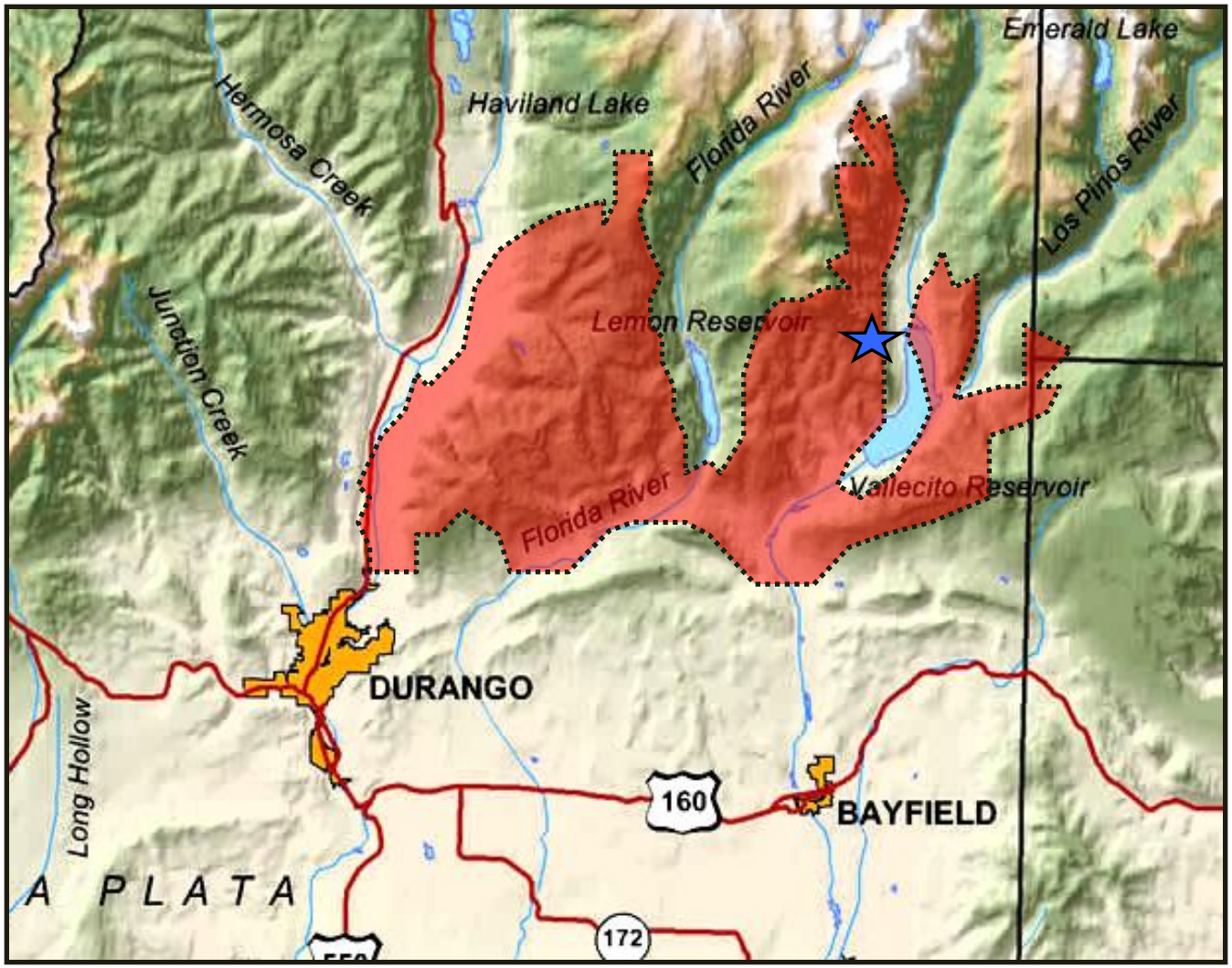

Which direction is this fire spreading? How do you know?

Transfer of firebrands by gravity.



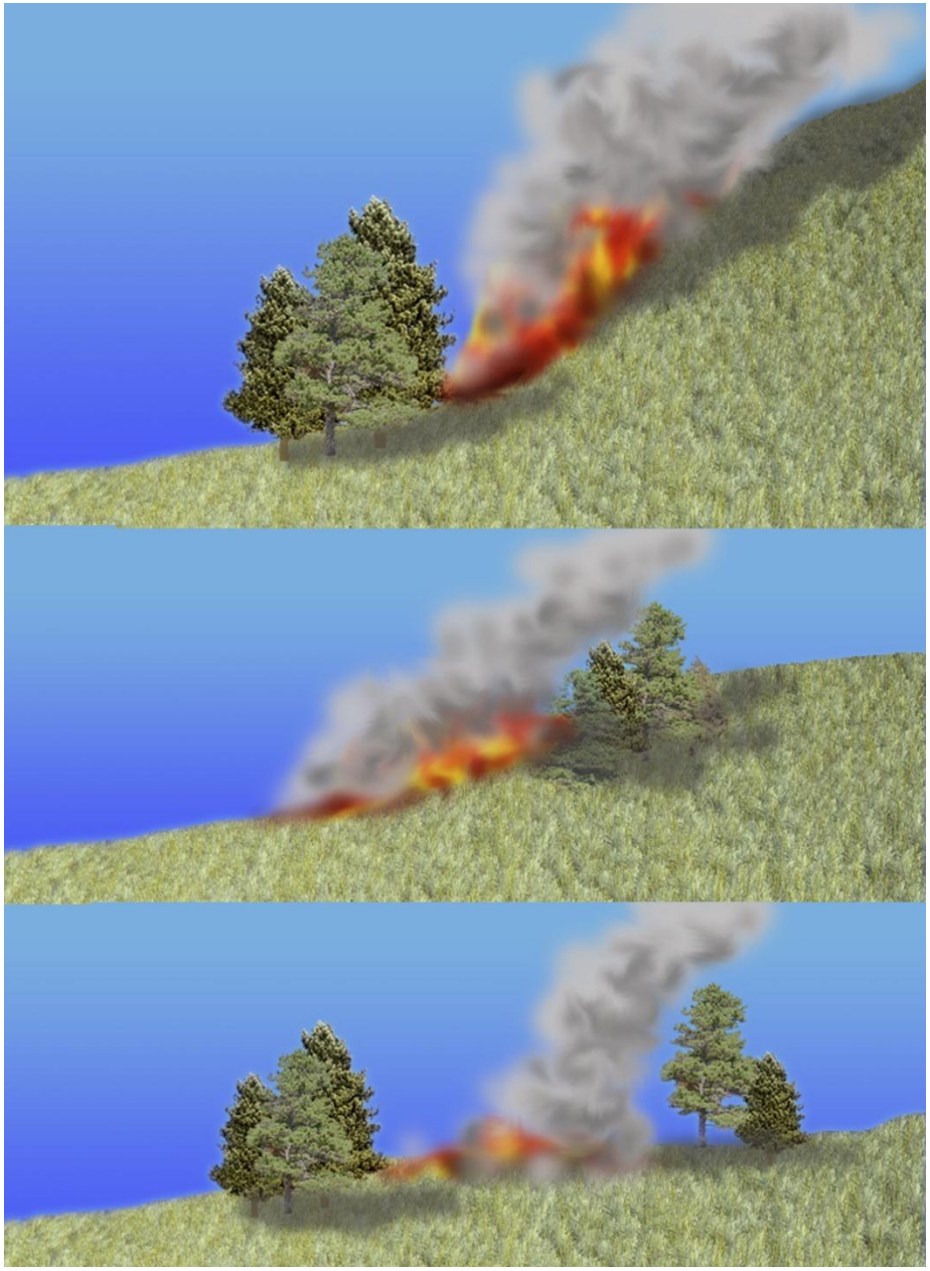
Missionary Ridge Fire, June 2002

Durango, Colorado



What about slope position?

Fires starting at base of slope often become the largest fires.



Effects of slope position: where does the fire have room to move?

National Park Service, Point Reyes National Seashore

Landform example: Fires in the bottom of narrow canyons are very dangerous.

Bottom of a narrow canyon

Some topographic features that can be important to fire spread:

- Narrow, steep canyons
  - Act as “chimneys”, create strong updrafts of air
  - Increase convective and radiative heat transfer, pre-heating of upslope fuels
  - If very narrow, can radiate heat to opposite side
- Rock outcrops, ridges, lakes, rivers
  - Create barriers to fuel spread (why?)
  - Interrupt continuity of fuel (“fuel breaks”)

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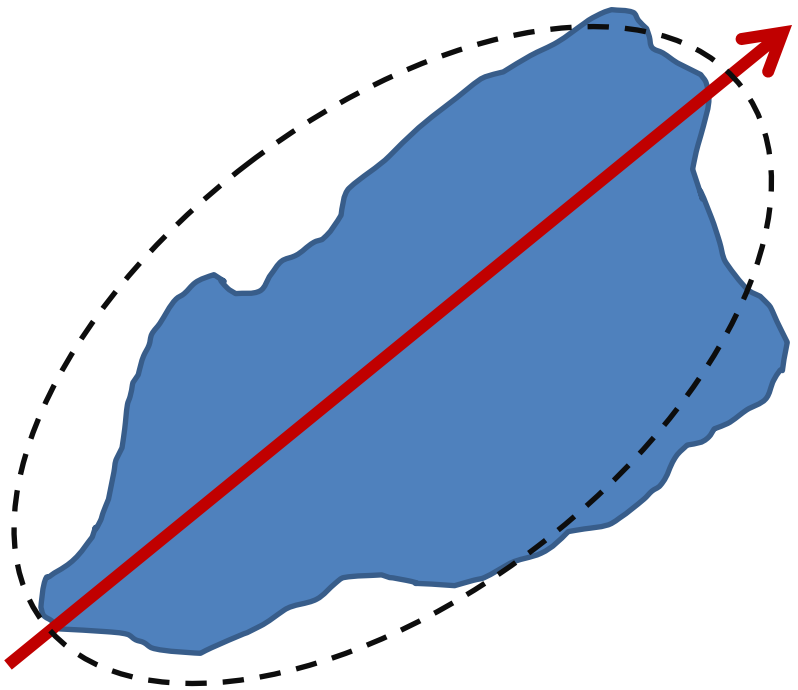
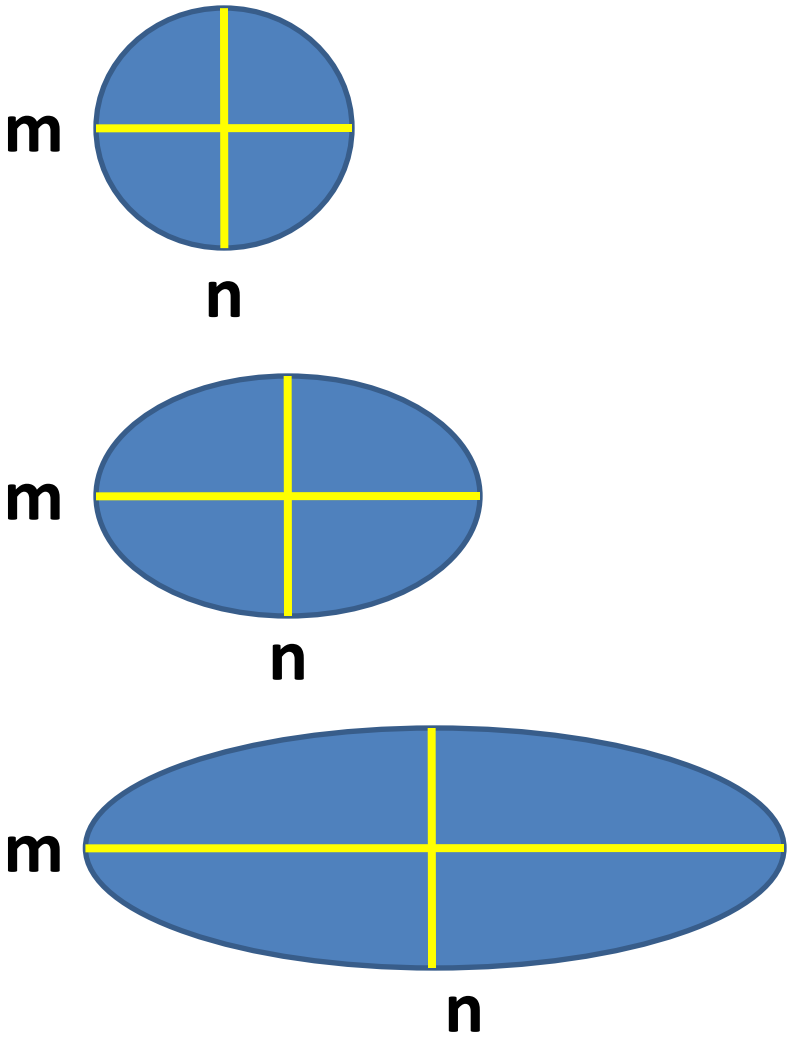
The shape of a spreading fire

- Note the generally elliptical shape of many fire patches
- The direction of fire spread often driven by two main factors:
  - TOPOGRAPHY
  - WIND



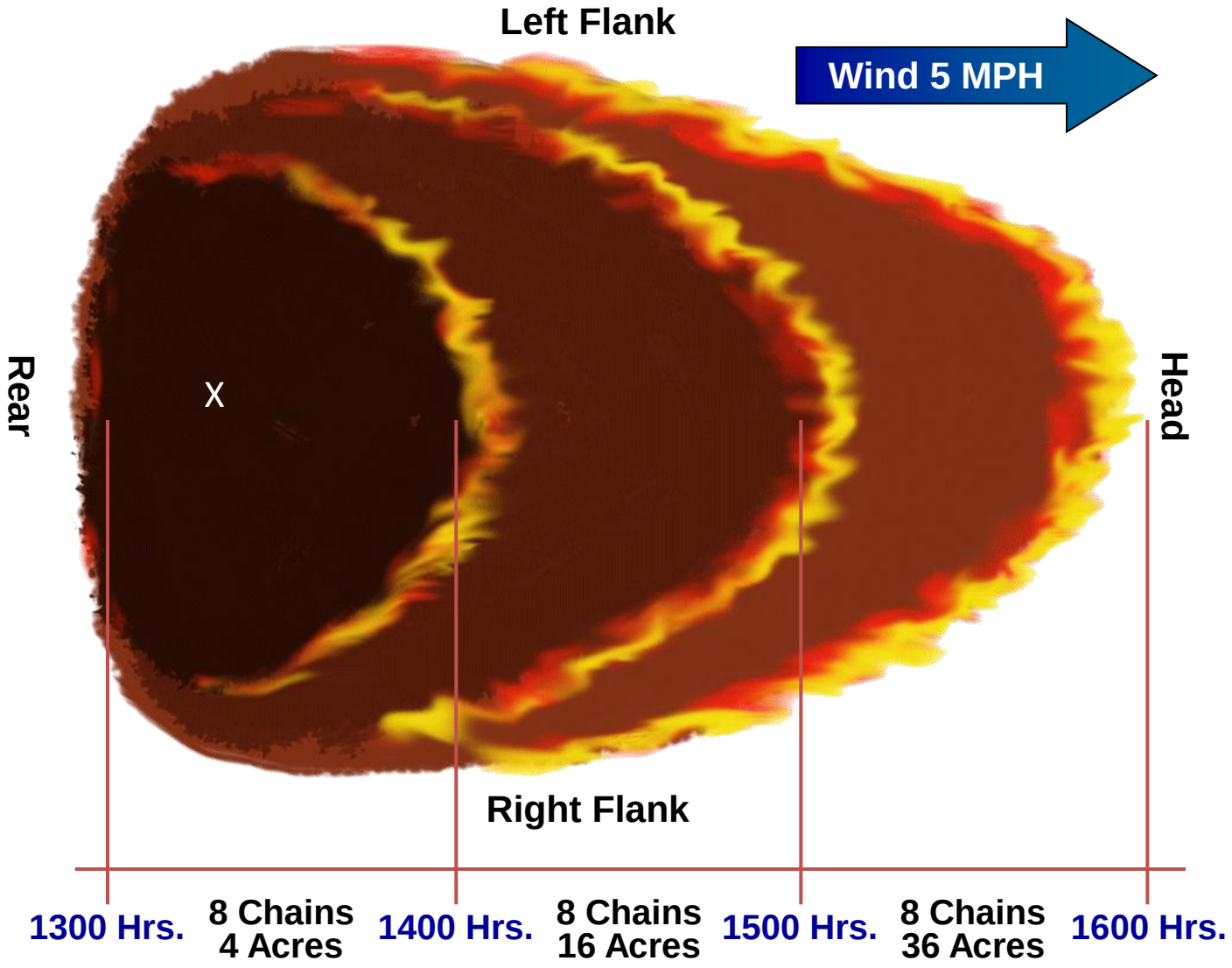
What is an ellipse?

- Defined by major and minor axes (diameters)
- Let *m* = major axis and *n* = minor axis
- Then if *m* = *n* what do we have?
- As *m* >> *n* ellipse gets longer and thinner



Fire Spread and Area Growth

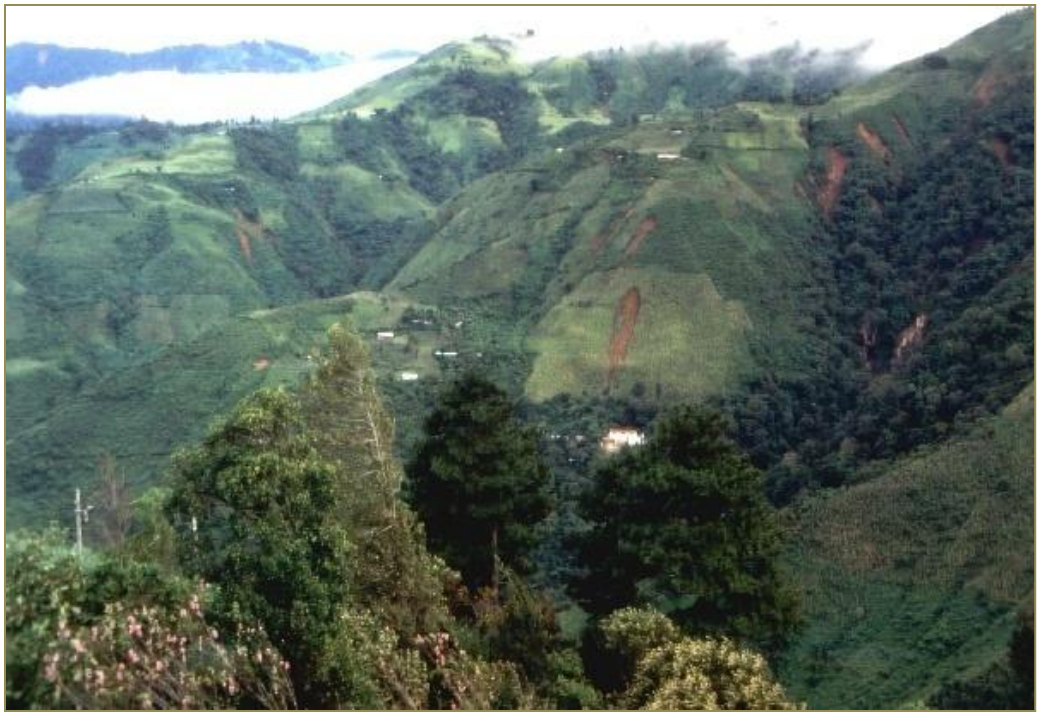
In 3 hours the fire will have burned 4 X (3 X 3) acres or 36 acres



Fire spread pathways, Aspen Fire, Santa Catalina Mountains, 2003

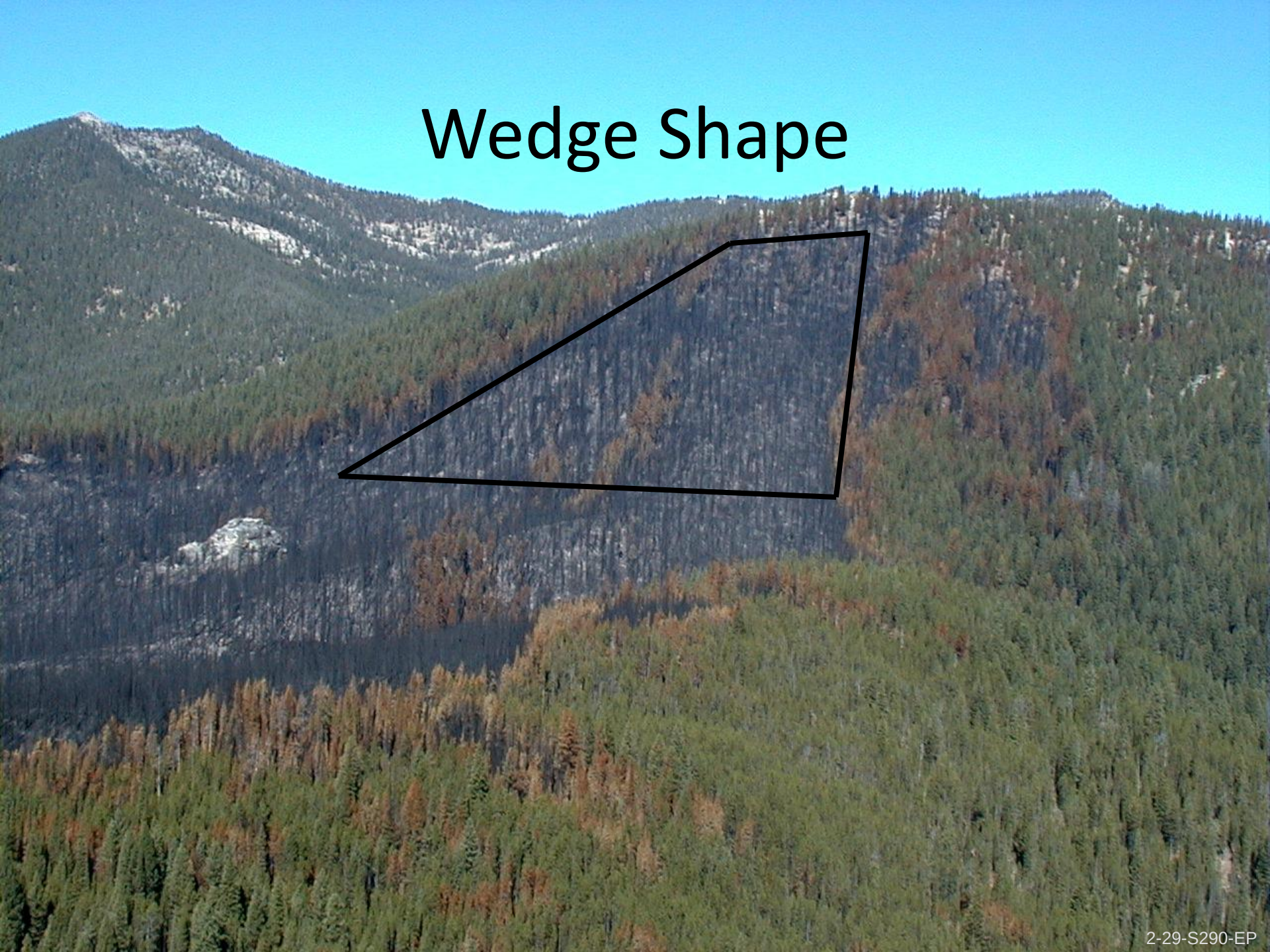
What factors would cause the ellipse to become elongated?

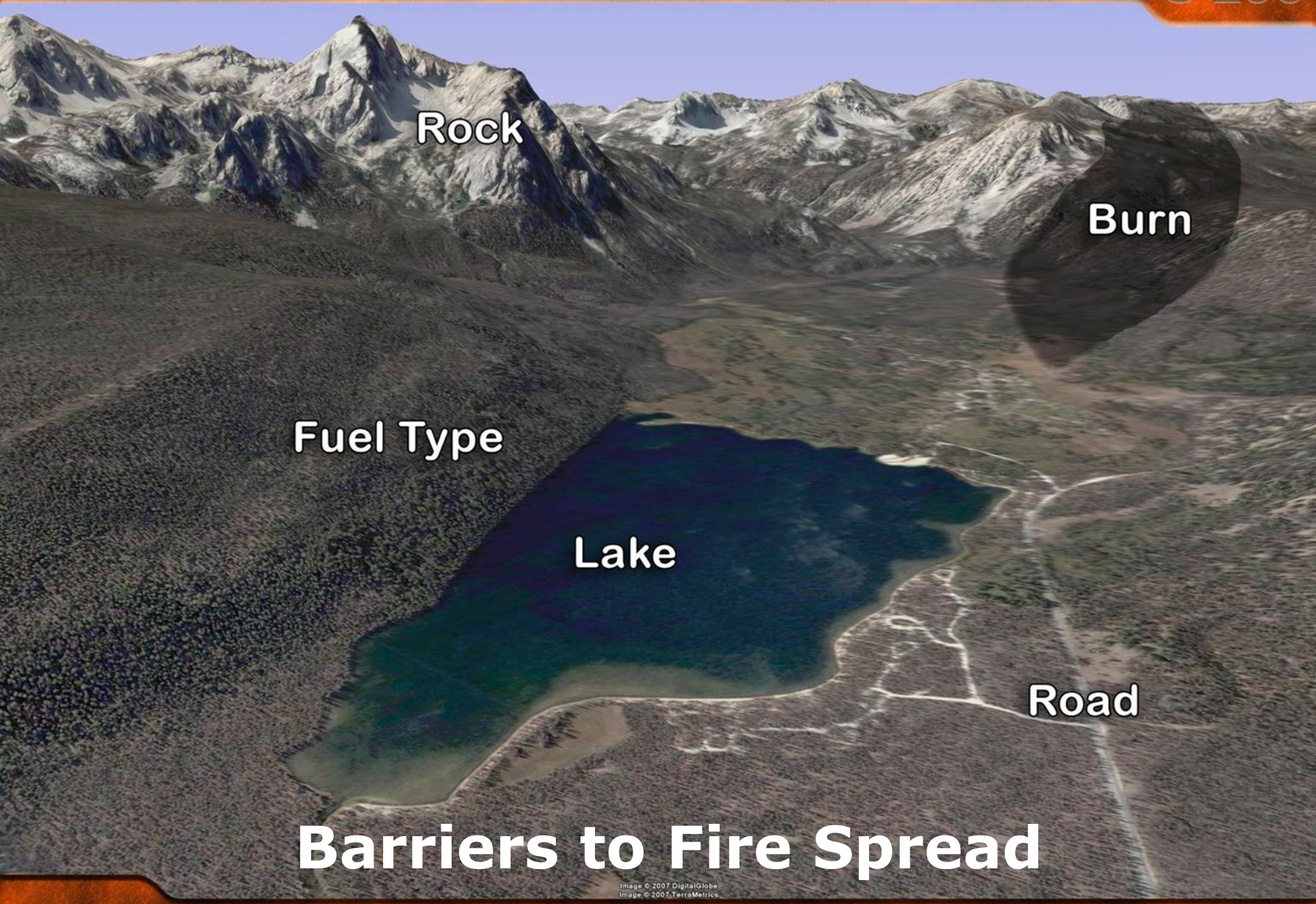
- Strong winds ("wind-driven fire")
- Strong topographic effect (upslope spread)
- Maybe also a gradient in fuel types or condition (*e.g.* moving toward an area of low fuel moisture)




Uphill fire runs can be seen in post-fire landscape scars

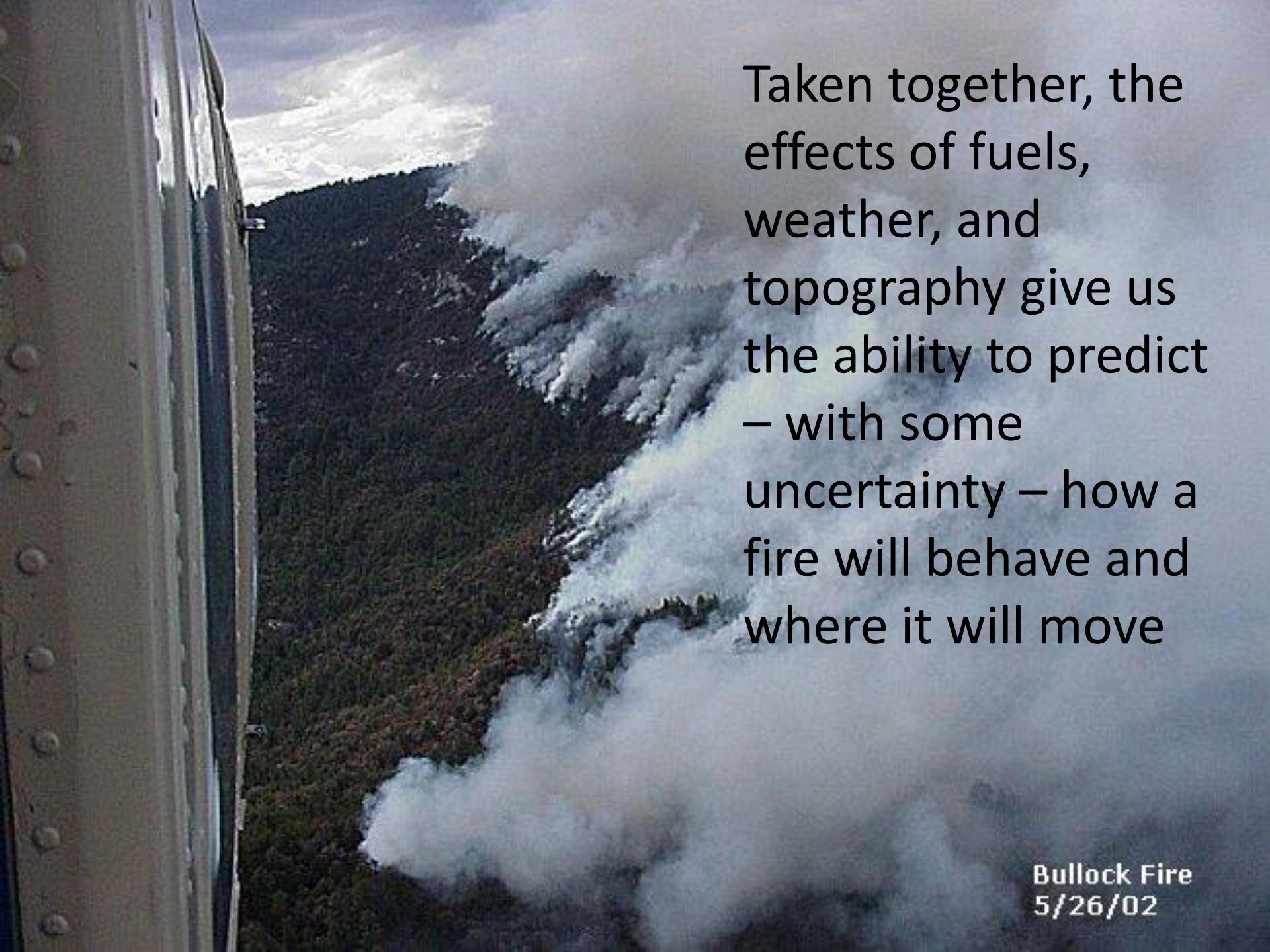
Wedge Shape





Barriers to Fire Spread

Is this a good barrier to fire spread?



Taken together, the effects of fuels, weather, and topography give us the ability to predict – with some uncertainty – how a fire will behave and where it will move

Wednesday: Unit 2 Quiz!