

Fire Behavior

Why is Understanding/Predicting Fire Behavior Important?

- Need to predict fire behavior in order to meet our goals and objectives of the burn
- Need to predict fire behavior to insure the prescribed burn is safe and stays within the burn unit
- Need to predict fire behavior in case fire escapes and turns into a wildfire.



Growing season burn under
dry conditions



Cool season burn under the
80-20-20 rule





Temp>100; R.H.<25%, Wind-speed= 6-15 mph,
Dead 1-hr fuel moisture <6%, Fuel Load>1000 lbs/ac

08/18/2003

How Does Fire Spread Through the Fuel?

- Fire spreads as a result of fuels ahead of the fire being preheated to their ignition point.
- Heat is required to drive moisture from fuels before they can support combustion.

How Does the Environment Affect Fuel Moisture?

- Fuels are constantly exchanging moisture with the surrounding air.
- During periods of high humidity and precipitation there is a net gain in fuel moisture.
- However, when the air is dry, with low humidity, fuels are giving up moisture.
- Also, shade either from woody plants or clouds will affect fine fuel moisture as well as damp or wet soils.

Five critical factors determine appropriate burning conditions in rangelands (Wright & Bailey 1982)

- Temperature
- Relative humidity
- Wind speed
- Fuel load
- Fuel moisture

Critical factors are often condensed into three measured variables.

Temperature, Relative humidity, and wind speed

80-20-20 (West Texas)

80-40-15 (Oklahoma)

Most variable over
space and time

WEATHER

TOPOGRAPHY

- Terrain

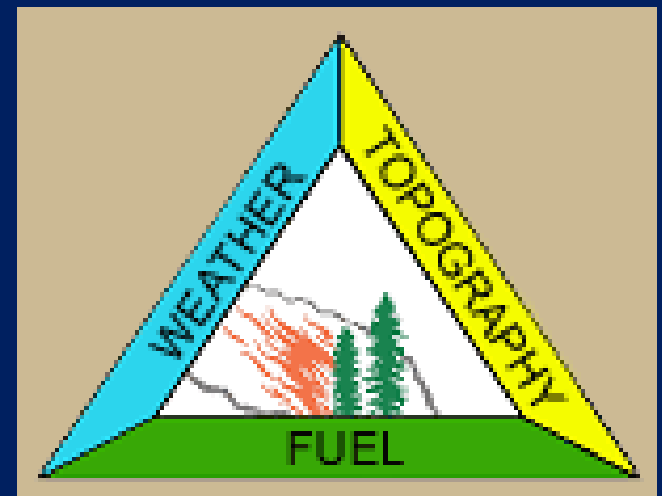
**Fire
Behavior**

FUELS

- Fuel Moisture
- Fuel Characteristics

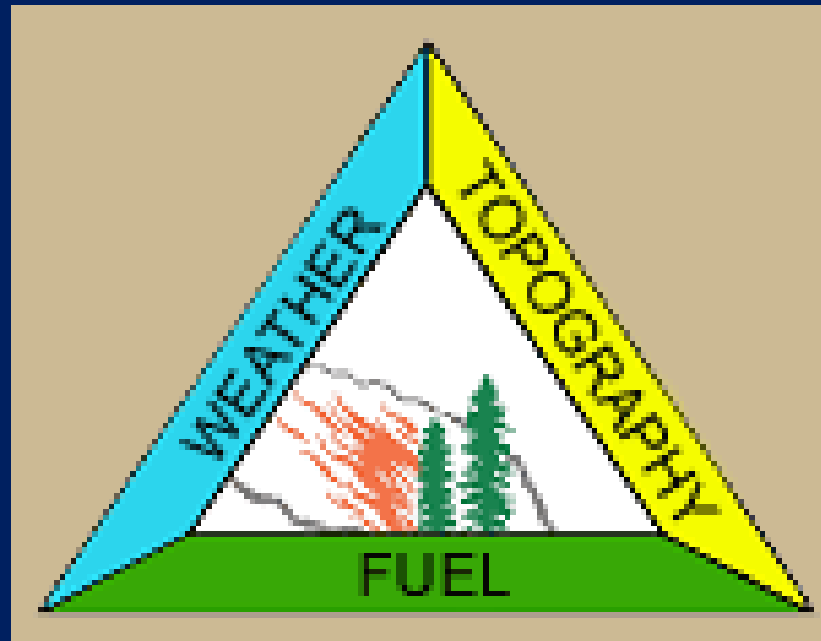


A basic knowledge
and awareness of
weather is essential
for making critical
fire management
decisions.

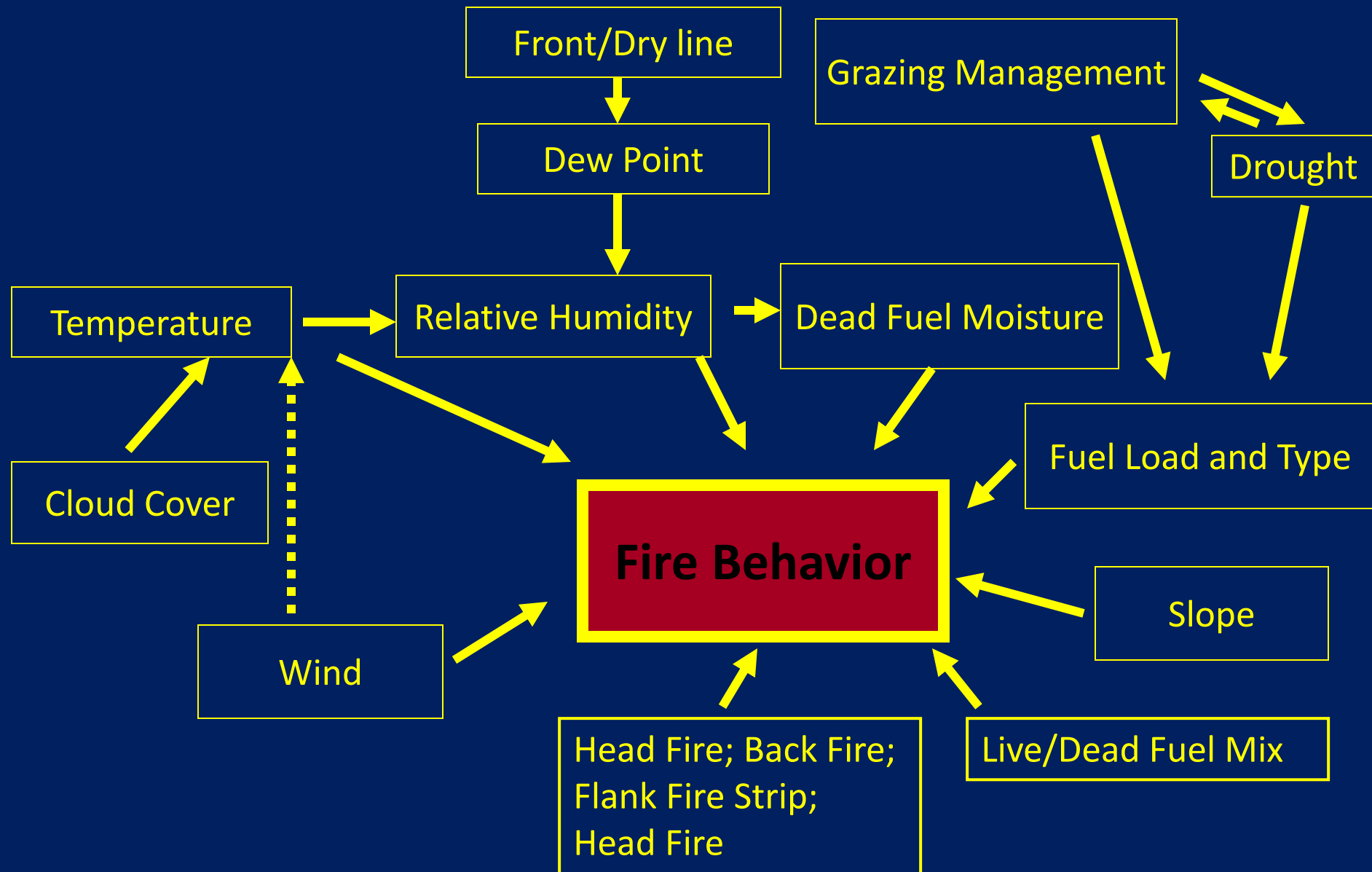


Two of the most critical
weather elements:

*Wind and Relative
Humidity*

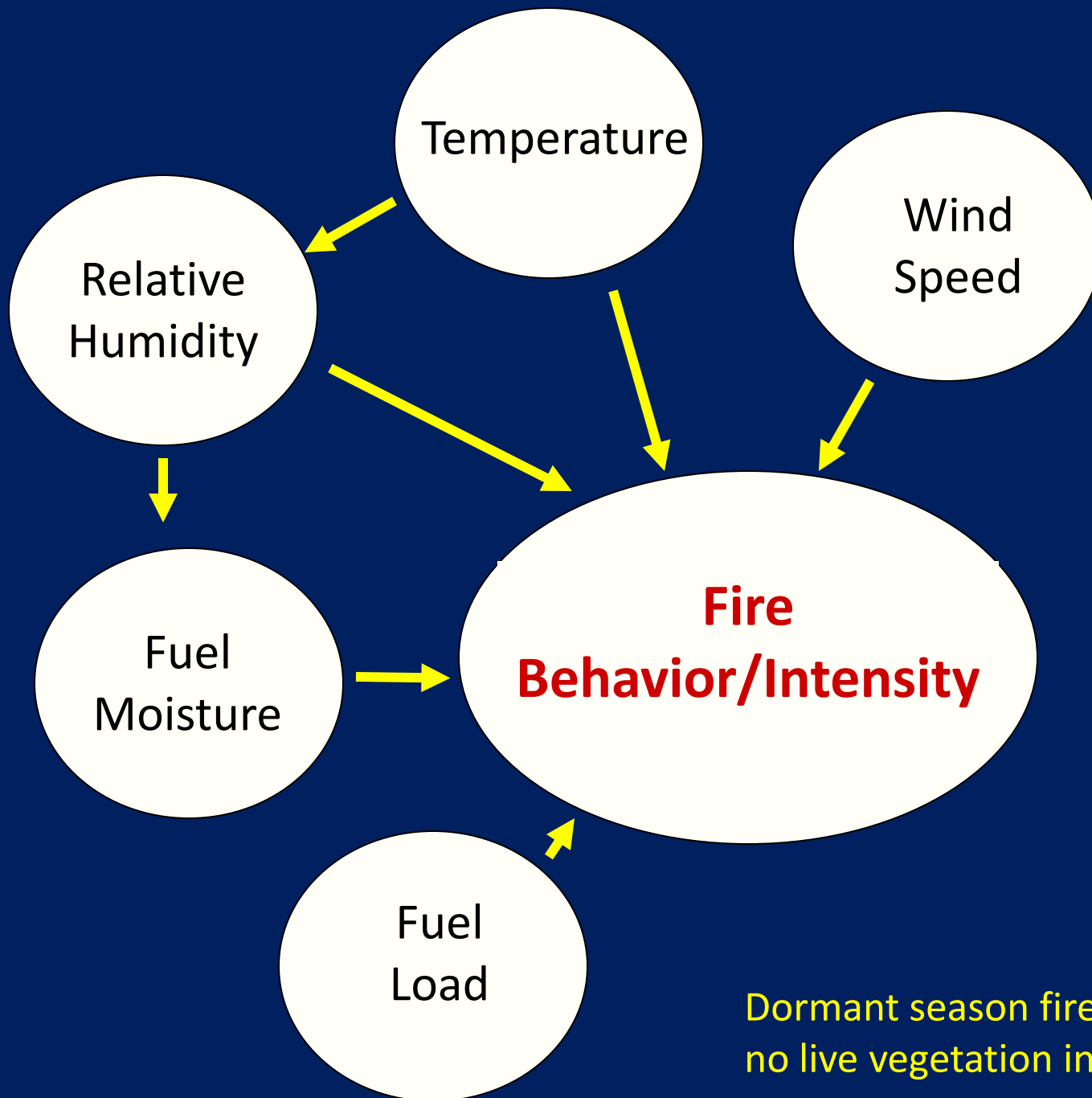


Factors Affecting Fire Behavior

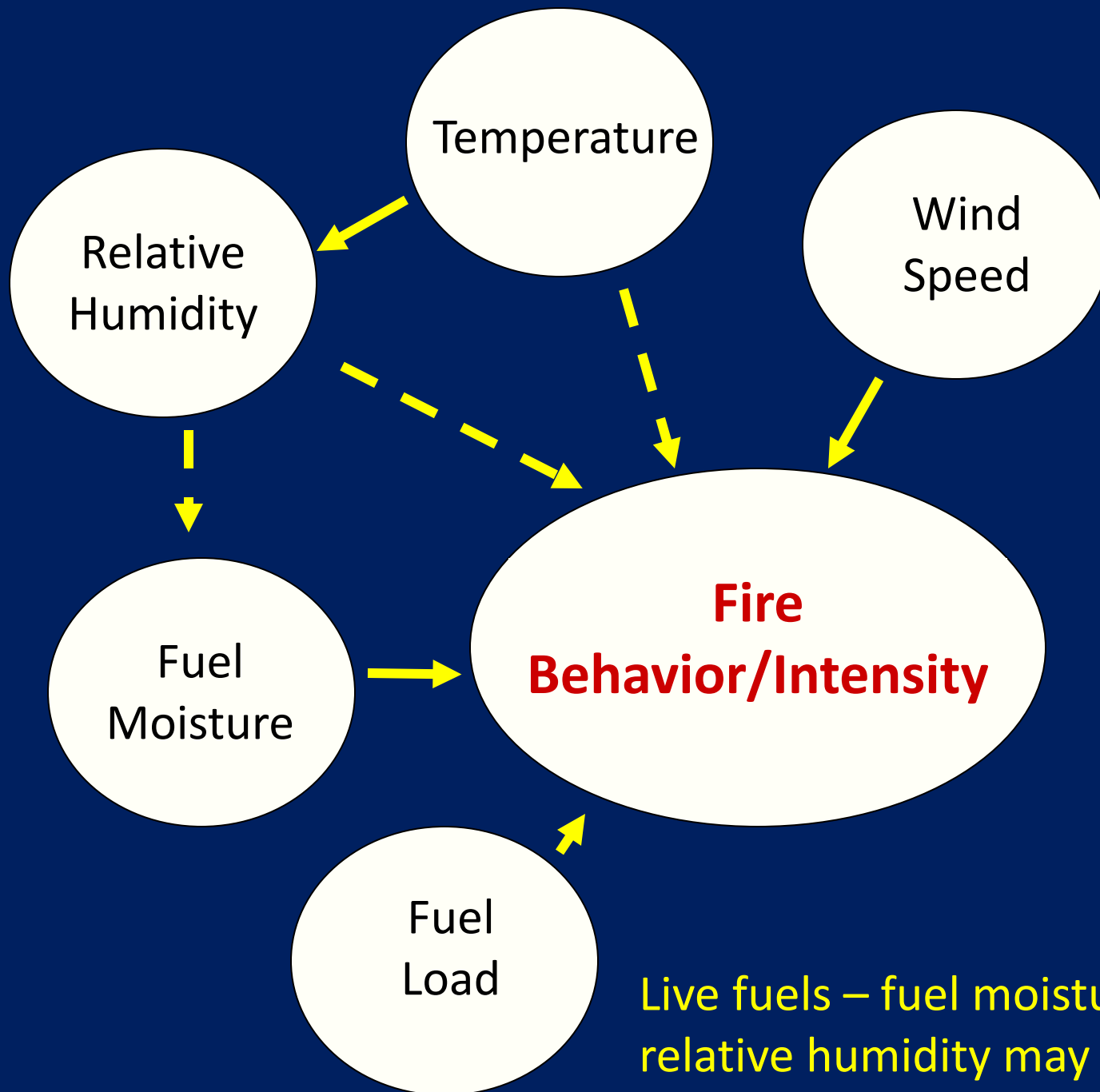


How does fire spread through the fuel?

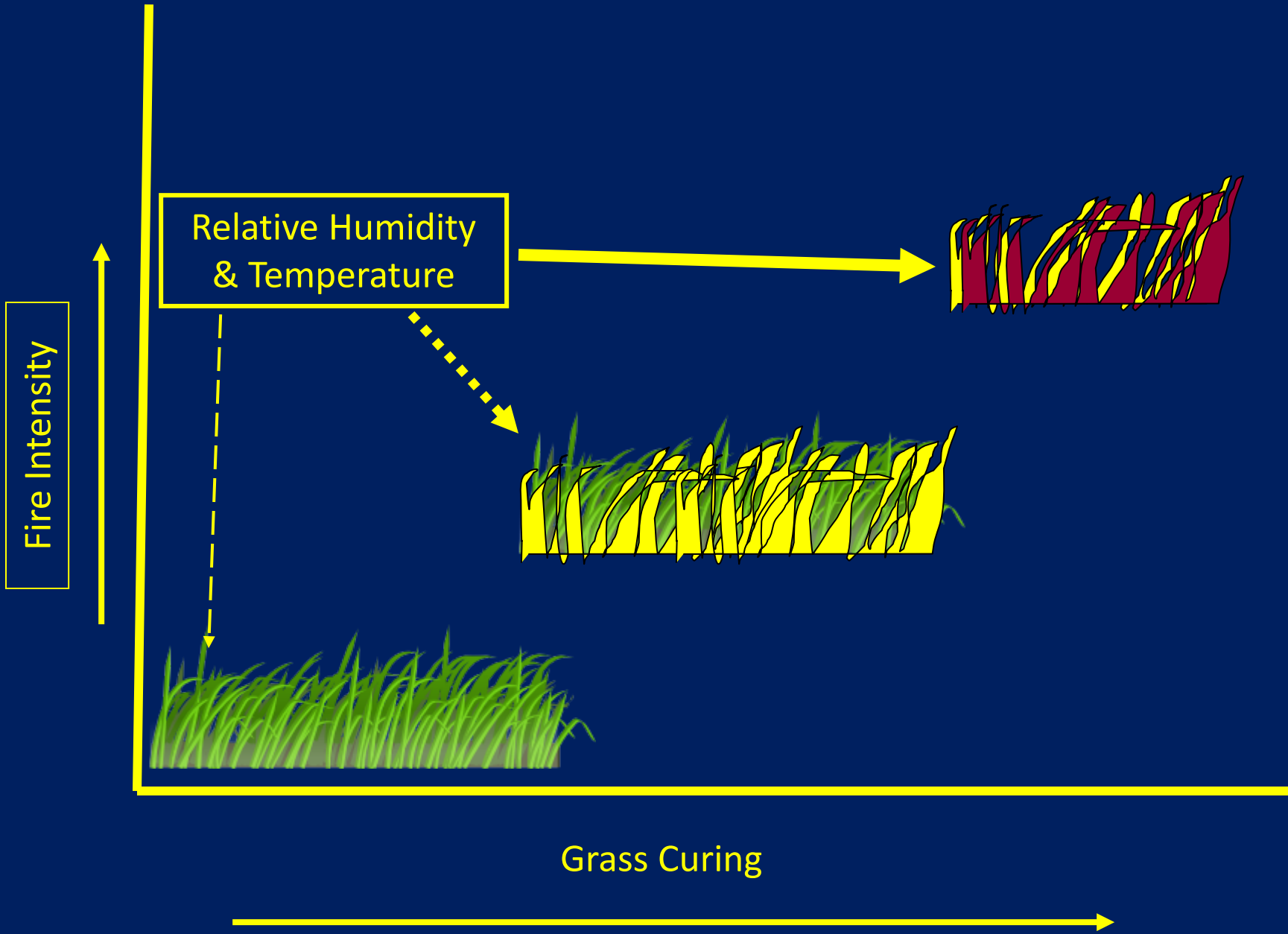
- Fire spreads as a result of fuels ahead of the fire being preheated to their ignition point.
- Heat is required to drive moisture from fuels before they can support combustion.



Dormant season fire with little to no live vegetation in the fuel load



Live fuels – fuel moisture and relative humidity may be decoupled



Burn Bans are Limiting the Restoration of Texas' Rangelands

Keetch/Byram Drought Index

- Is a measure of the relative dryness of an area.
- It depicts the degree of drought on a scale that ranges from 0 to 800.
- It assumes vegetation on an area will be at its wilting point when the index is 800.
- When KBDI exceeds 400 consumption of the duff layer is likely.
- KBDI is a drought index – not necessarily a fire behavior index.
- Even when the KBDI is high, it is possible to conduct safe prescribed burns.
- Driving factors
 - Mean annual precipitation
 - Maximum dry bulb temperatures (increases KBDI)
 - Last 24 hours of rainfall (decreases KBDI when net rainfall exceeded)

Keetch-Byram Drought Index

$$w = w_c \exp(-r/t)$$

- **w** - inches of water available for plant in soil duff layer
- **w_c** - corresponding field capacity in inches of available water in layer
- **r** - time in days during soil has lost water
- **t** - evapotranspiration timelag in days

*From Liacos in J Range Mngt (1962);
Keetch & Byram in USDA For Ser Res SE-38 (1968)*

Ketch-Byram Drought Index

Melton 1989

• KBDI 0-150

- *During this stage of drought, the fuels and ground are quite moist. Fine fuels exhibit daily drying, burning readily at times but also recovering to a high moisture content at night.*

• KBDI 150-300

- *Scattered patches of surface litter remain in low-lying or damp areas following a fire, and the organic layer remains basically undisturbed*

• KBDI 300-500

- *Fire consumes most **surface litter** along with a **significant loss in organic soil material.***

• KBDI 500-700

- *All surface litter and most of the organic layer is consumed by fire.*

• KBDI 700+

- *Understory species with shallow root systems continue to exhibit extensive wilting and contribute to fire activity by acting as ladder fuels and increasing the chance of extreme fire behavior*

Melton 1996

• KBDI 0-200

- *Soil moisture levels are high and fuel moistures in the 100- and 1,000-hour fuel classes are sufficiently high, so these larger fuel classes do not significantly contribute to prescribe fire intensity in most cases.*

• KBDI 200-400

- *Lower litter layers and duff begin to show signs of water loss and will begin to contribute to fire intensity. Humidity recovery at night will have some positive effect on moisture recovery in the fuel profile. Daily temperature and humidity variations under normal burning conditions will quickly reverse this recovery.*

• KBDI 400-600

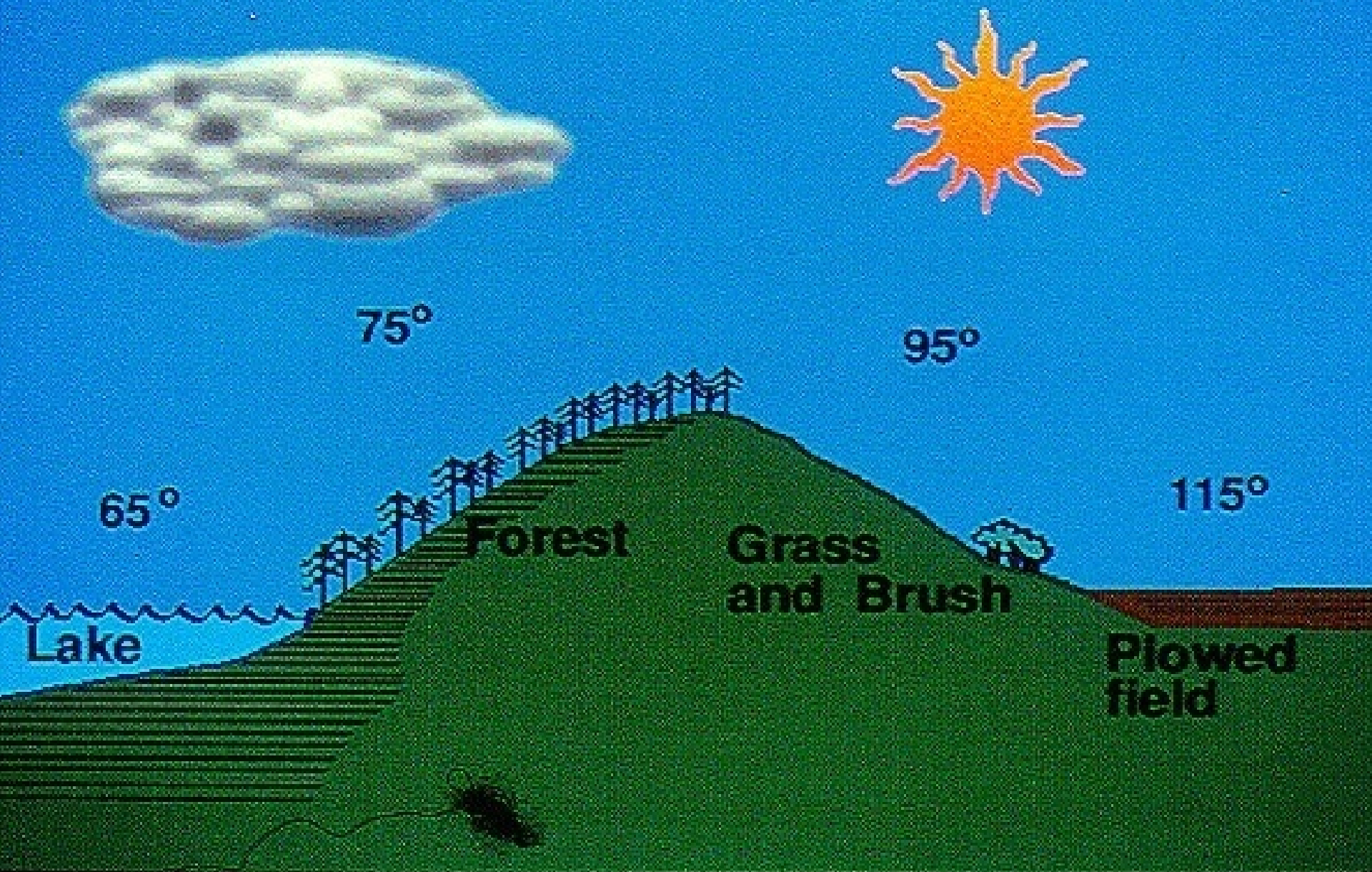
- *Very Intense fires can be generated with burns ignited in this range of conditions. Under these levels, most of the duff and associated organic layers will be sufficiently dry to ignite and contribute to the fire intensity and will actively burn.*

• KBDI 600- 800

- *Fires ignited within this range will be characterized by intense, deep-burning fires.*



HEATING DIFFERENT SURFACES



Effects of Wind on Wildland Fire Behavior

1. Wind carries away moisture-laden air and thus hastens the drying of wildland fuels.
2. Once a fire ignites, wind aids combustion by increasing the supply of oxygen.
3. Wind increases fire spread by carrying heat and burning embers to new fuels – Spotting.
4. Wind bends the flames closer to the unburned fuels, thus preheating the fuels ahead of the fire front.

Effects of Wind on Wildland Fire Behavior - *continue*

5. The direction of the fire spread is determined mostly by direction of the wind.
6. Wind influences the amount of fuel consumed by affecting the residence time of the flaming front of the fire. The stronger the wind, the shorter the residence time and the less fuel is consumed.

Wind

Generally the wind prescription for a successful burn is:

6 to 23 mph

and a

Steady wind direction



Wind

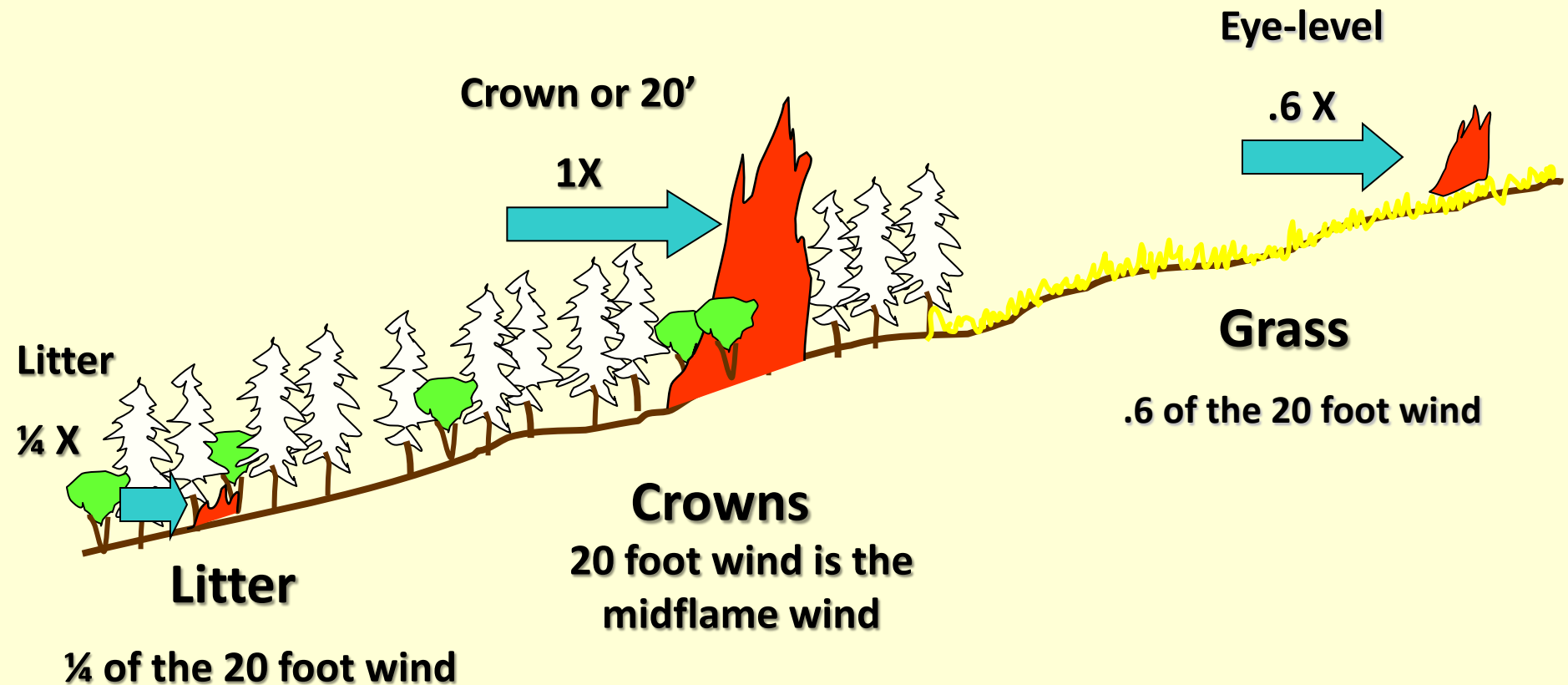
6 to 23 mph
and a
Steady wind
direction

- Light and variable winds create poor burning conditions and an unpredictable direction of spread.
- High wind speeds may reduce fuel consumption, increase chances of escape, and increase risk of spotting.



Wind Adjustments

Midflame Calculations Based On Fuel Type



Wind-driven Fire

Power of wind =
power of fire



Wind-Driven Fires

- Often those that escape initial attack and become the largest.
- Easier to predict direction of spread.
- Wind shift poses a problem.
- Smoke column bent over by wind
- Spotting downwind.
- Flanks and heel generally safe.

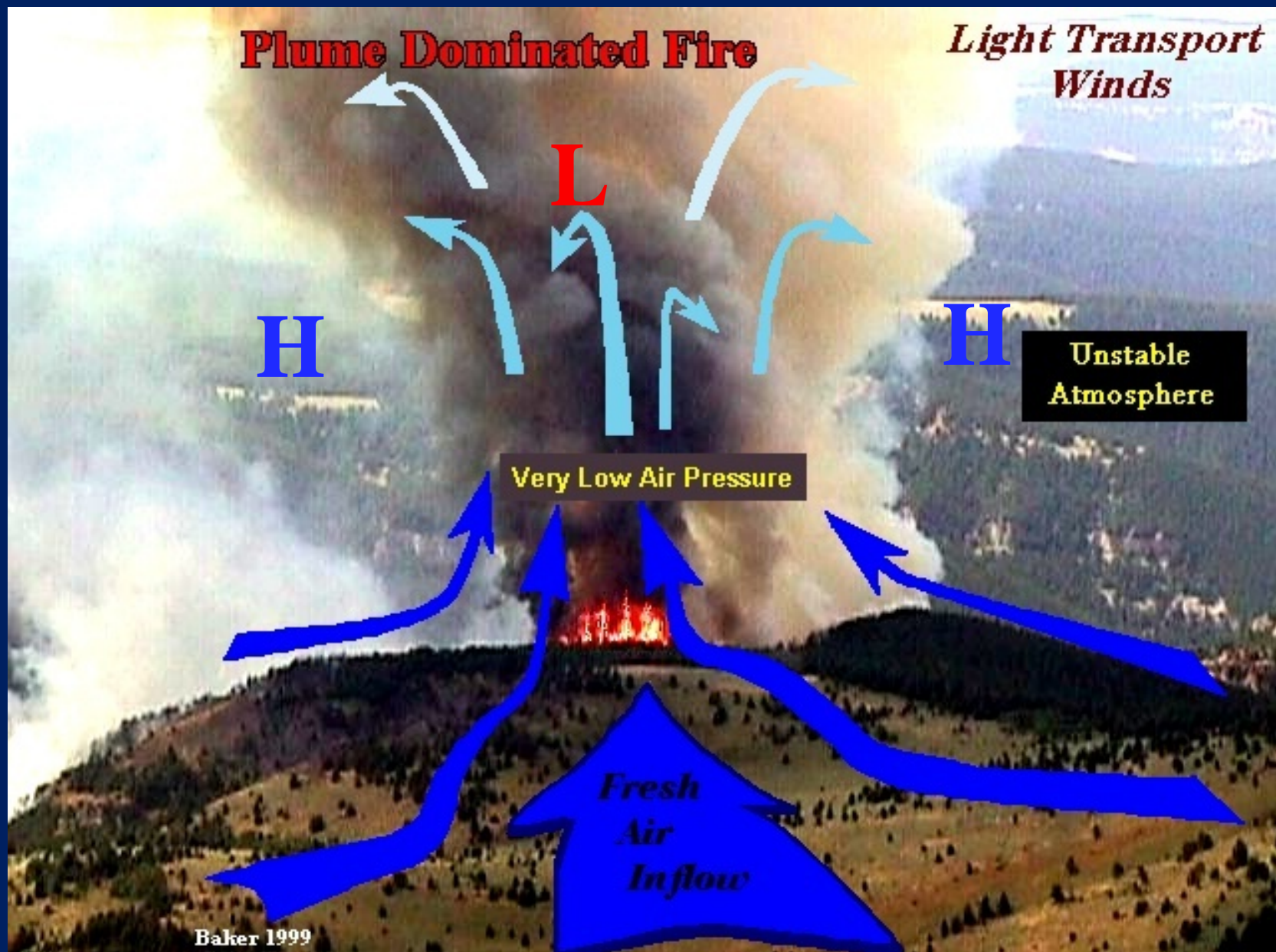
Plume-Dominated Fire



Power of fire =
power of wind

Plume-Dominated Fire

- Fire activity result of convective activity of the plume.
- Spread rate and direction very unpredictable.
- Spotting can be in all directions.
- Generally low wind speeds, low transport wind speeds.
- Generally pulses – can build, collapse, build, etc.



Critical Winds

Thunderstorm Winds

- **Two Characteristics important to fire weather**
 - Lightning
 - Indraft and downdraft winds are most important

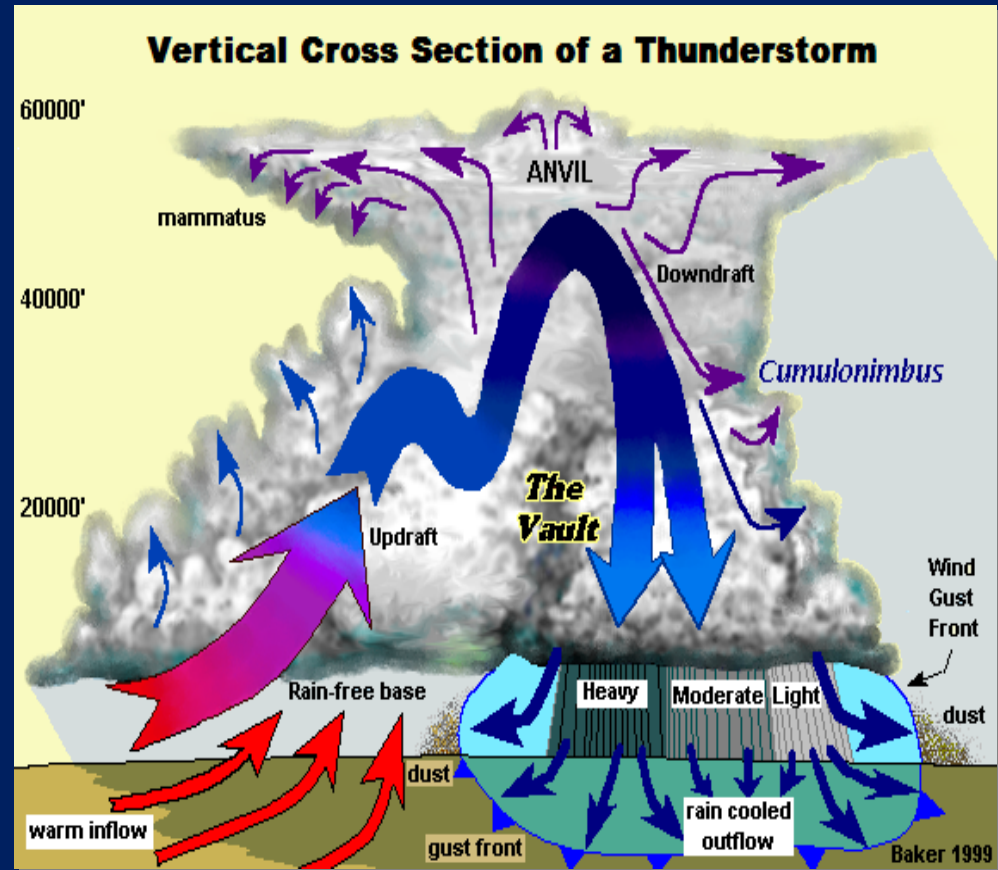


Critical Winds

Thunderstorm Winds

- **Thunderstorm Winds**

- Indrafts and downdrafts can change both direction and speed suddenly.
- Result in sudden changes in rate and direction of fire as well as intensity.
- Indraft speeds range from 10 to 20 mph and gusty.
- Downdrafts speeds range from 25 to 35 mph with gusts over 60 mph.





An unstable atmosphere is most often associated with critical or extreme wildland fire behavior.

The Effects of Unstable Atmospheric Conditions on Wildland Fire Behavior

- A. Increased likelihood of fire winds and dust devils (both indicators of very unstable conditions.
- B. Increased likelihood for gusty and erratic surface winds.
- C. The height and strength of convection and smoke columns often increase significantly, and;
- D. Increased likelihood of fire brands being lifted to great heights.

Critical Fire Weather Patterns

Red Flag Criteria for South Texas



Inland Counties

RH at or below 25%

And

20-Foot winds sustained
or frequently gusting at or
above **25 mph**

These conditions have been determined to be critical to
wildfire potential and growth across South Texas

Fuels

- Fuel Models
 - Thirteen fuel models have been described.
 - Each has characteristics that influences fire behavior.

Table 1. — Description of fuel models used in fire behavior as documented by Albini (1976)

Fuel model	Typical fuel complex	Fuel loading				Fuel bed depth	Moisture of extinction dead fuels	Flame Length ft.	Rate of Spread (mph)
		1 hour	10 hours	100 hours	Live				
		-----Tons/acre-----				Feet	Percent		
Grass and grass-dominated									
1	Short grass (1 foot)	0.74	0.00	0.00	0.00	1.0	12	4	1.0
2	Timber (grass and understory)	2.00	1.00	.50	.50	1.0	15	6	.50
3	Tall grass (2.5 feet)	3.01	.00	.00	.00	2.5	25	12	1.3
Chaparral and shrub fields								1	
4	Chaparral (6 feet)	5.01	4.01	2.00	5.01	6.0	20		1.0
5	Brush (2 feet)	1.00	.50	.00	2.00	2.0	20		.25
6	Dormant brush, hardwood slash	1.50	2.50	2.00	.00	2.5	25		.40
7	Southern rough	1.13	1.87	1.50	.37	2.5	40		.25
Timber litter									
8	Closed timber litter	1.50	1.00	2.50	0.00	0.2	30		.02
9	Hardwood litter	2.92	.41	.15	.00	.2	25		.10
10	Timber (litter and understory)	3.01	2.00	5.01	2.00	1.0	25		.10
Slash									
11	Light logging slash	1.50	4.51	5.51	0.00	1.0	15		.10
12	Medium logging slash	4.01	14.03	16.53	.00	2.3	20		.20
13	Heavy logging slash	7.01	23.04	28.05	.00	3.0	25		.20

Relative Humidity

- The Ratio of the amount of moisture (water vapor) in the air to the amount the air could hold when saturated at the same air temperature.

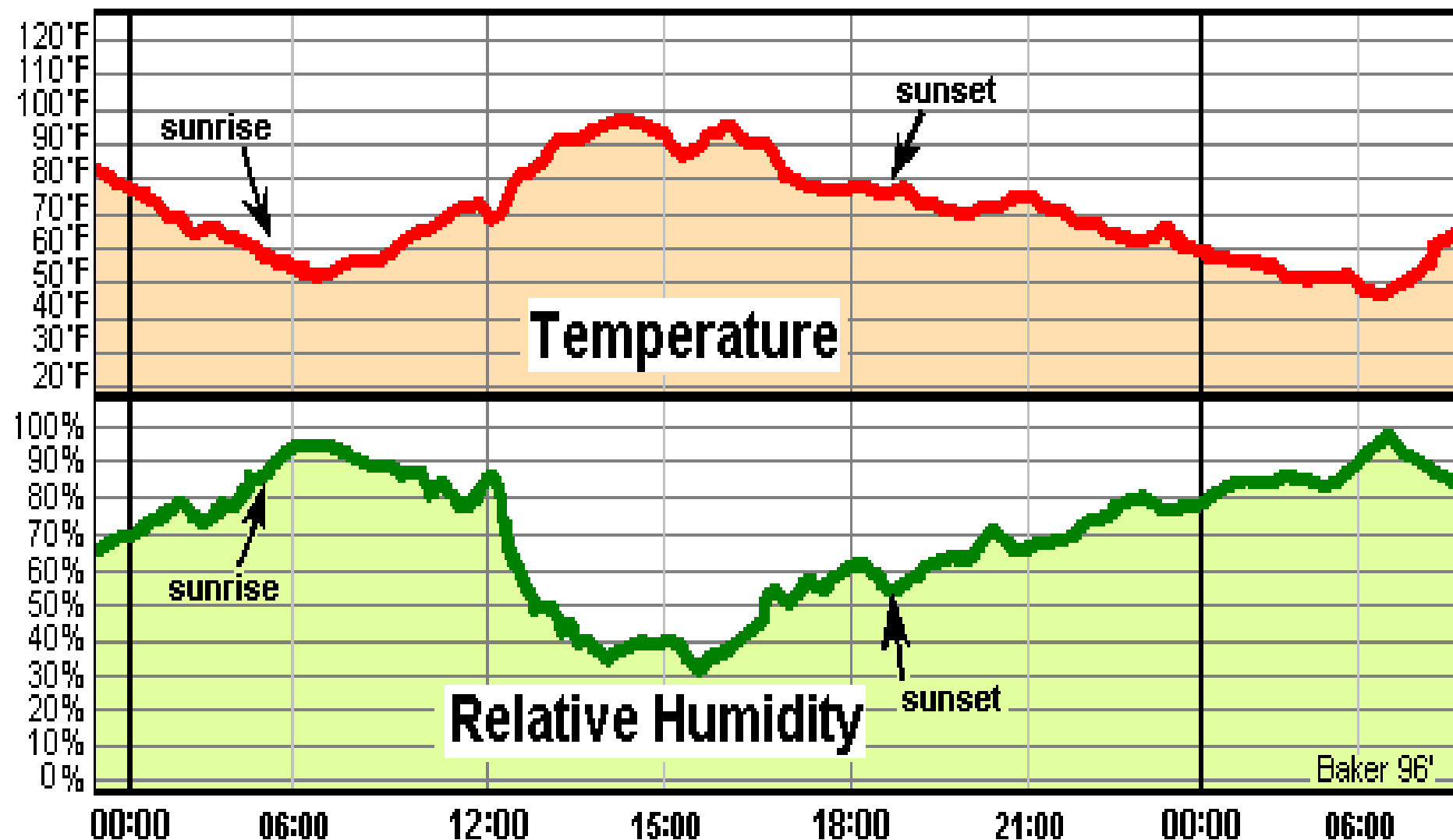
Relative Humidity Facts

- Is only a relative measure of atmospheric moisture as related to temperature.
- Do not confuse it with dewpoint .
- Is always expressed as a percentage.

Effects of RH on Wildland Fire Behavior

- **Affects fuel moisture**
 - as RH increases, fuel moisture increases.
- **Affects fire intensity**
 - fires of different intensity can be achieved by selecting different times of day or night as well as different weather conditions.
- **Affects rate of spread**
- **Some fuels will not burn adequately if RH is too high**
- **Fire becomes difficult to control if RH is too low**

Thermograph depicting 24 hours of temperature and relative humidity.



Note the diurnal relationship between temperature and relative humidity.

Slope

- It is very important to understand how slope can modify fire intensity.

TOPOGRAPHY



Fire moves more quickly upslope. This is because the flames are closer to fuels on the uphill side, which preheats them. Also, hot convective air from the fire moves upslope drying out fuels.

As a rule of thumb, each 10% increase in slope, doubles the rate of fire spread.

Elevation Affects Fuel Moisture (Daytime)

Elevation	Temp	Relative Humidity	Fuel Moisture
6000'	69 F	39%	8%
5000'	73 F	35%	7%
4000'	76 F	31%	6%
3000'	80 F	27%	5%
2000'	83 F	25%	5%
1000'	87 F	22%	4%

Fire Severity Related to Moisture

Remember that wind and higher fuel loads increase fire intensity

Relative Humidity	1-hour Fuel Moisture	10-hour fuel Moisture	Ignition	Remedy
>60%	>20%	>15%	Difficult	Burn brush piles along fireguards.
45-60%	15-19%	12-15%	Low	Burn brush piles along fireguards.
30-45%	11-14%	10-12%	Medium	Could get some spotting from brush piles. Tall grasses will burn.
26-40%	8-10%	8-9%	High	Moderate burning conditions
15-30%	5-7%	5-7%	Quick	Effective burning conditions. Need good fireguards.
<15%	<5%	<5%	Rapid	Fire spreads rapidly- burning under these conditions requires trained crews with good fireguards. Fire may move up bark of trees, igniting aerial fuels. Could result in long distance spotting.

Summary

- An understanding of fire behavior is critical to successful implementation of prescribed burning.
- Experience is more important than information in tables and lectures.