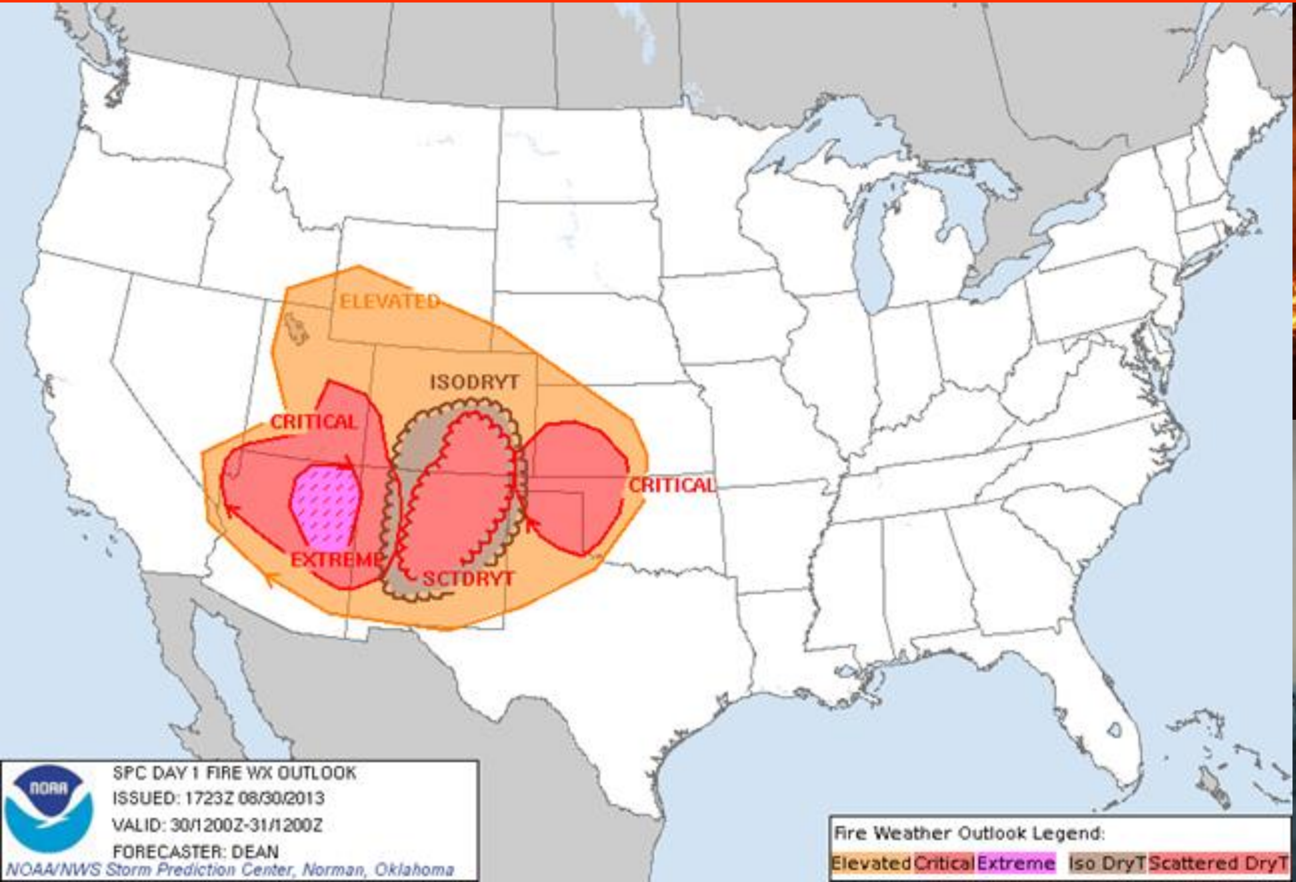
SPC Fire Weather Forecasts



The Basics

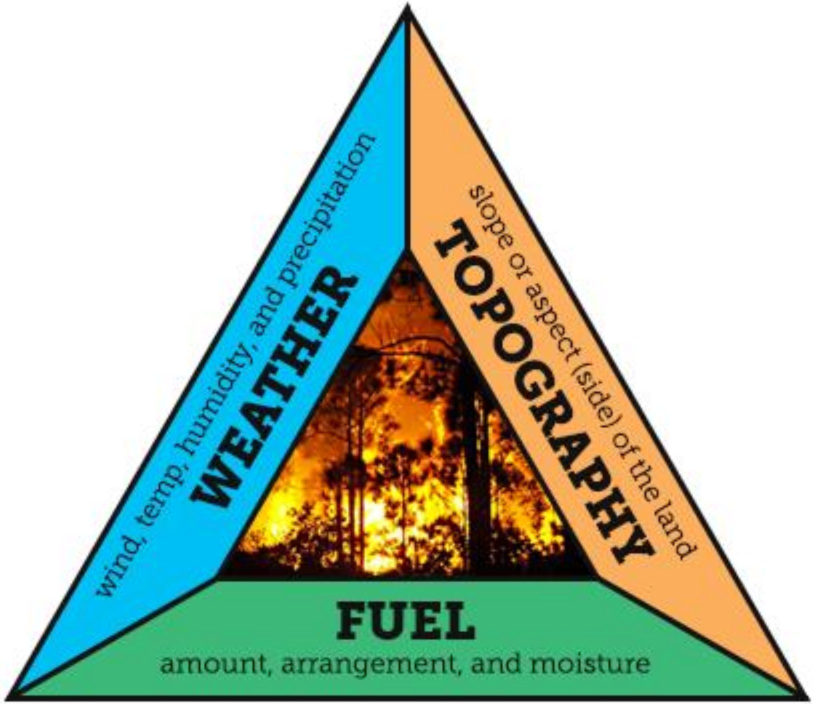
- Like severe weather, fire weather can be thought of in an ingredients based framework.

- Ingredients can take several forms but the most common are:

1. Low humidity
2. Low fuel moisture
3. High winds
4. Warm temperatures
   (optional)

The Two Triangles

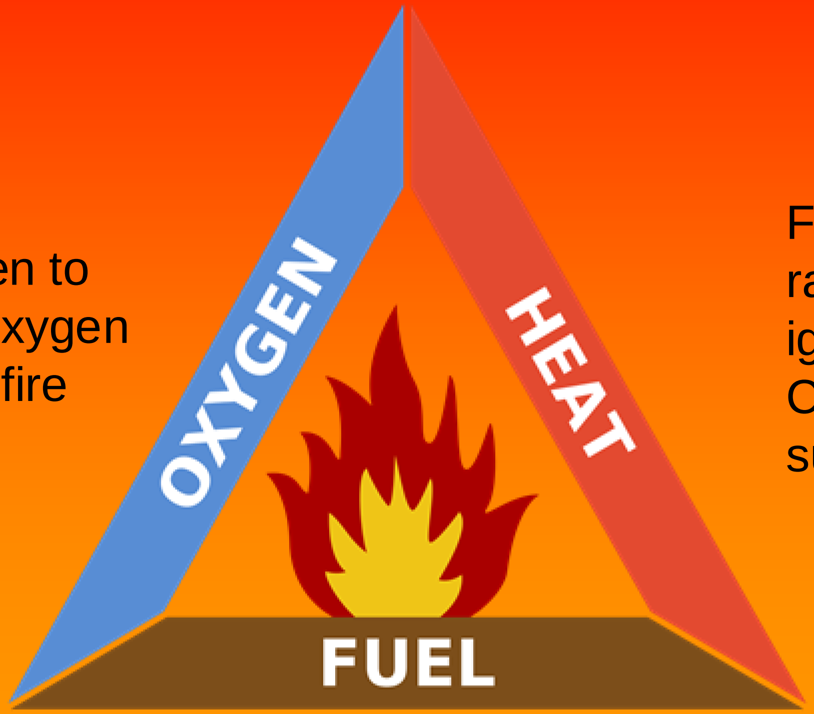
Combustion



Fire Behavior

Combustion Triangle

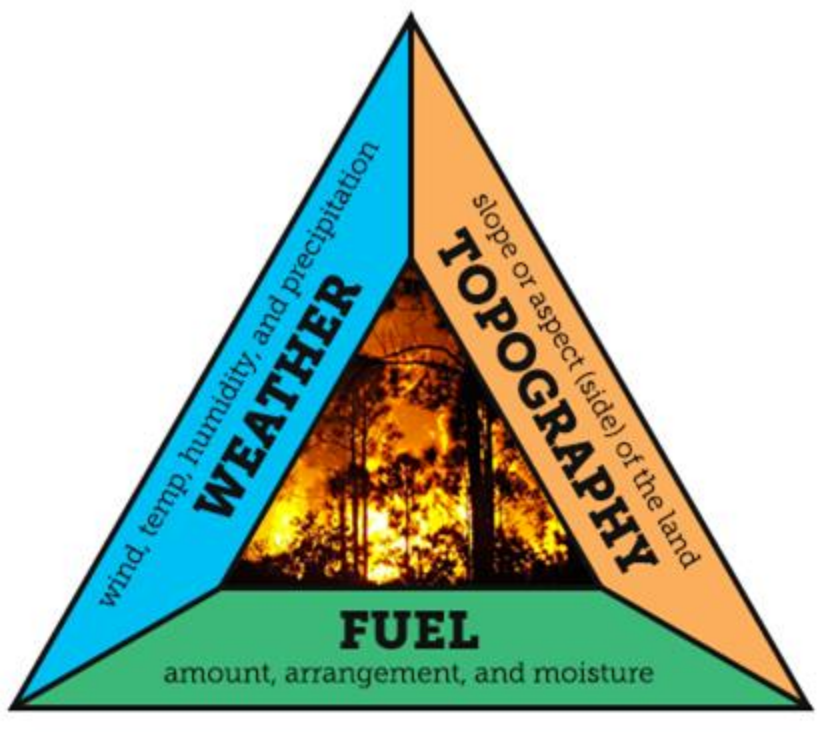
Fire needs oxygen to burn, removing oxygen can extinguish a fire



Fire requires heat to raise fuels to their ignition temperature. Cooling fuels can suppress a fire.

Fire needs something to burn!
If there is no fuel (sticks, leaves, buildings), there can be no fire.

Fire Behavior Triangle



Weather influences:

- Fire movement
- Plume structure
- Probability of ignition
- Rates of spread

Topography influences:

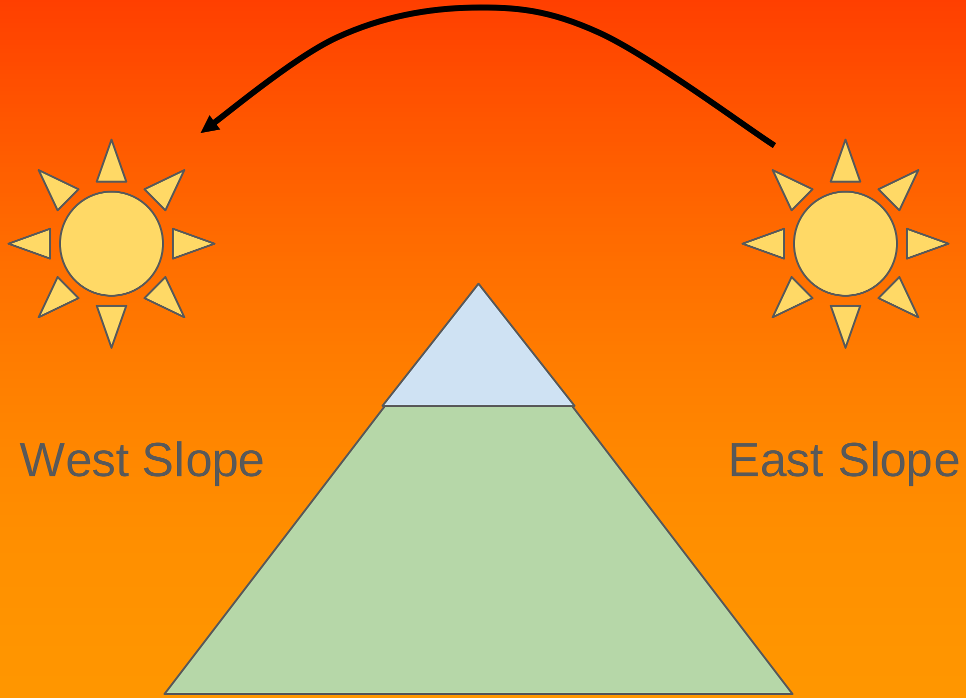
- Fire movement
- Preheating of fuels
- Fuel dryness

Fuels influence:

- Fire intensity
- Rates of spread
- Probability of ignition

Topography

Topographic Influence



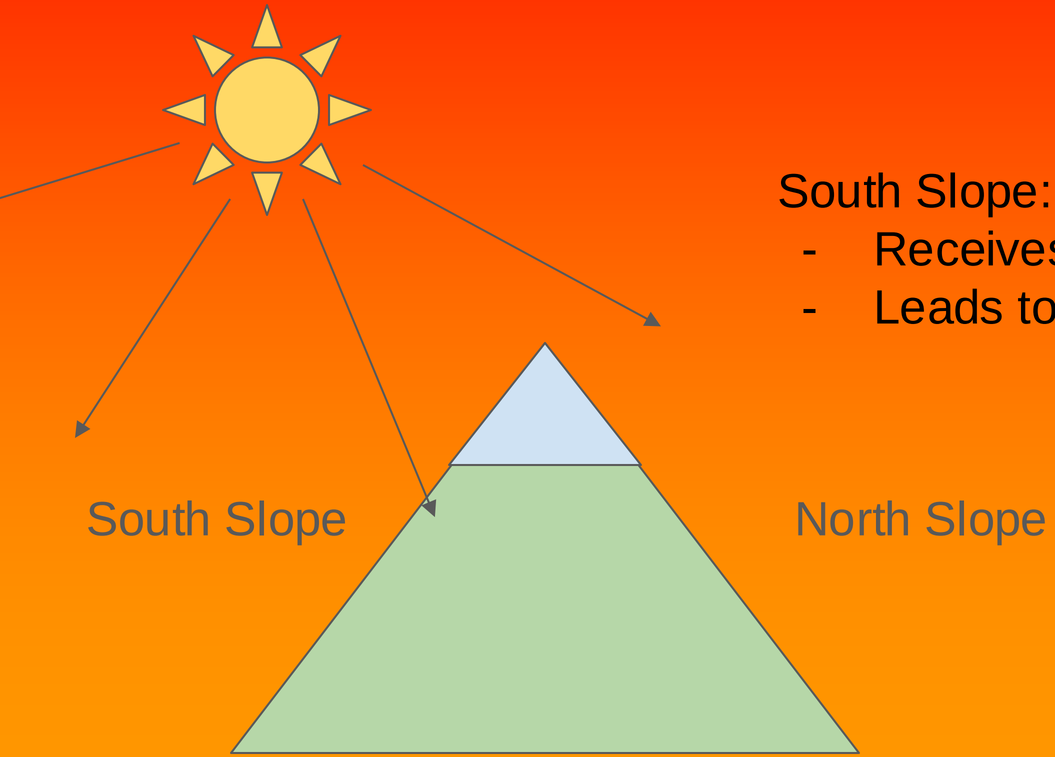
East Slope:

- Warms earlier in the morning
- Cools earlier in the evening.

West Slope:

- Warms later in the morning
- Cools later in the evening.

Topographic Influence



South Slope:

- Receives more sunlight throughout the year*
- Leads to drier fuels than other slopes

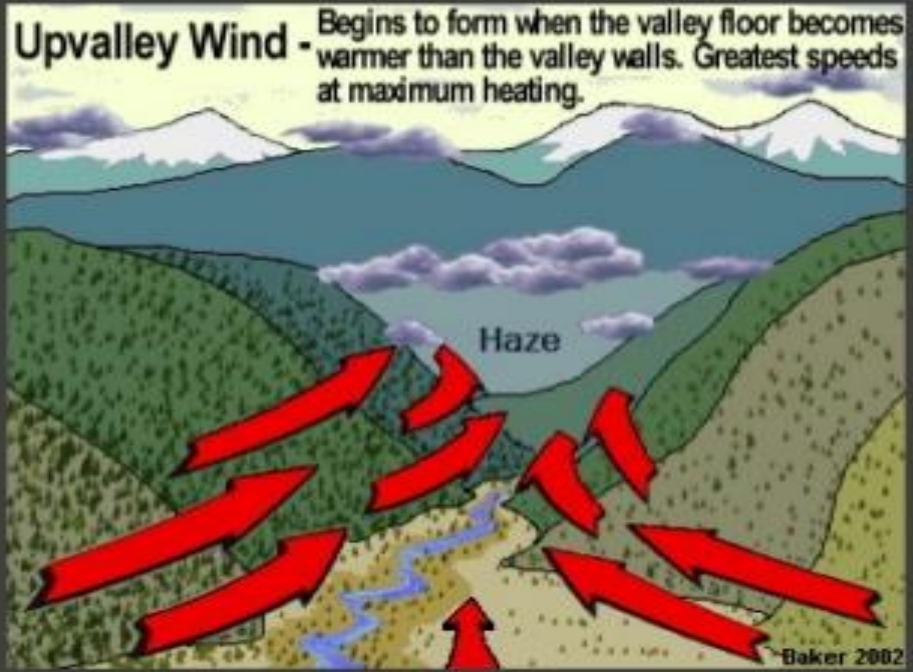
North Slope:

- Receives less sunlight throughout the year*
- Leads to more moist fuels than other slopes

*In the northern hemisphere!

Local Winds

Upslope/Upvalley

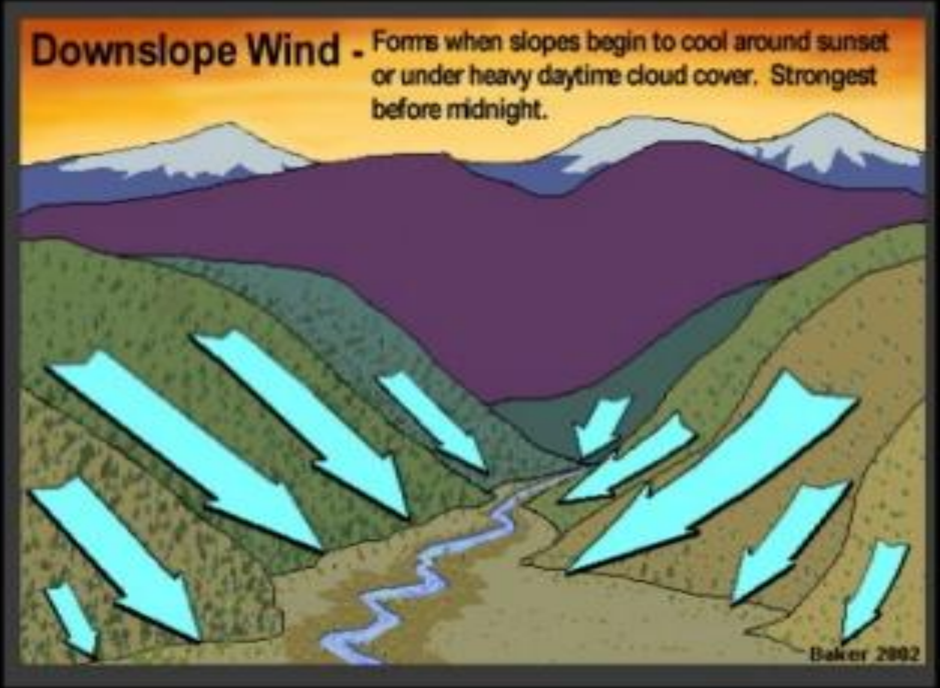


Early to Mid-Morning- 3 to 8 mph

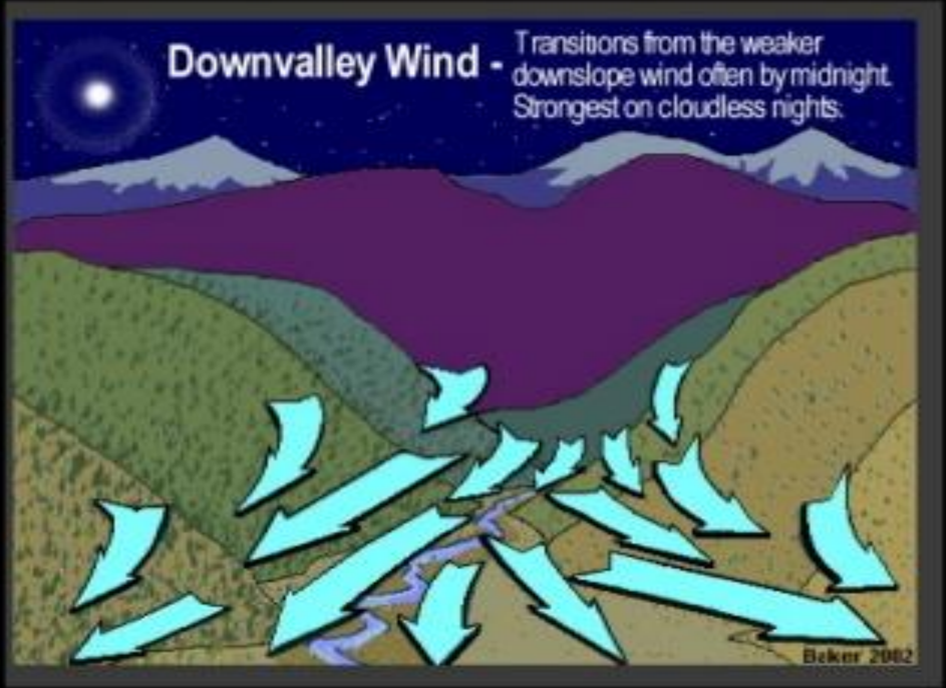
Late Morning and Afternoon- 10 to 15 mph

Local Winds

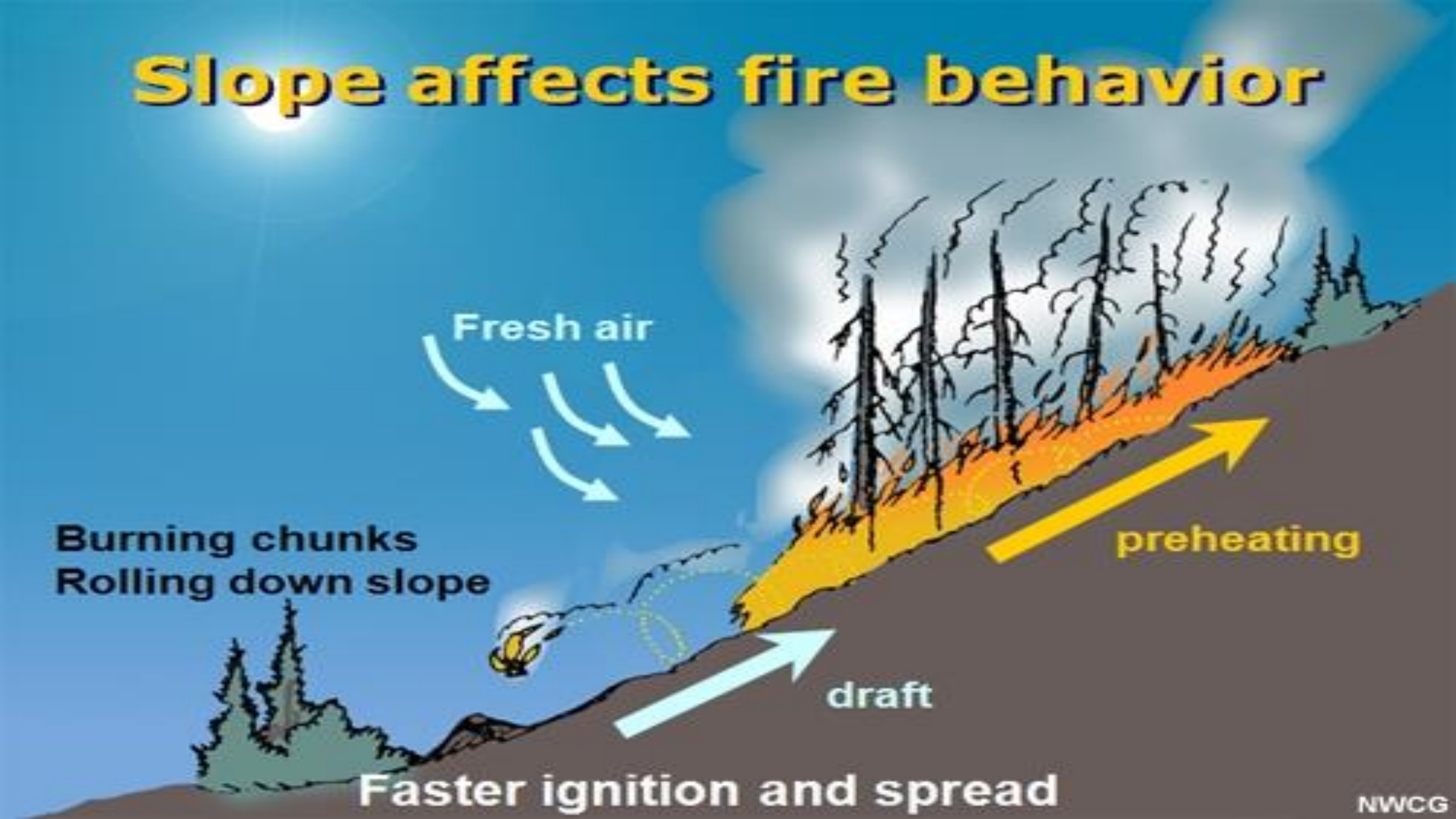
Downslope/Downvalley



Late Afternoon and Evening- 2 to 5 mph



Late Evening and Overnight- 5 to 10 mph


Slope affects fire behavior
Fresh air
Burning chunks
Rolling down slope
preheating
draft
Faster ignition and spread
NWCG

Quiz Time!

I’ll show you a picture - you decide where in the U.S. the picture is from.

Picture 1

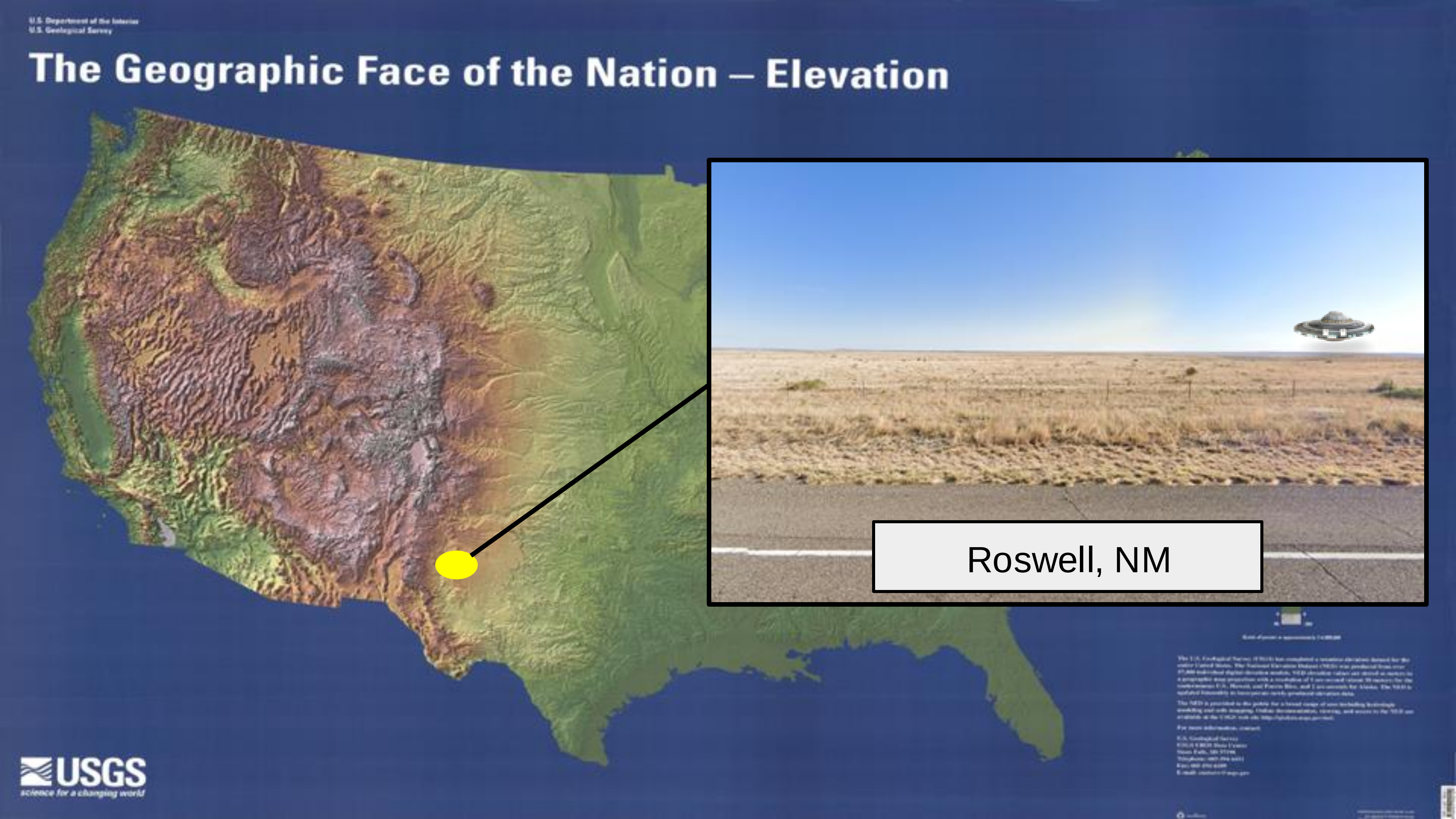

U.S. Department of the Interior
U.S. Geological Survey
The Geographic Face of the Nation – Elevation
USGS
science for a changing world

Southern CA

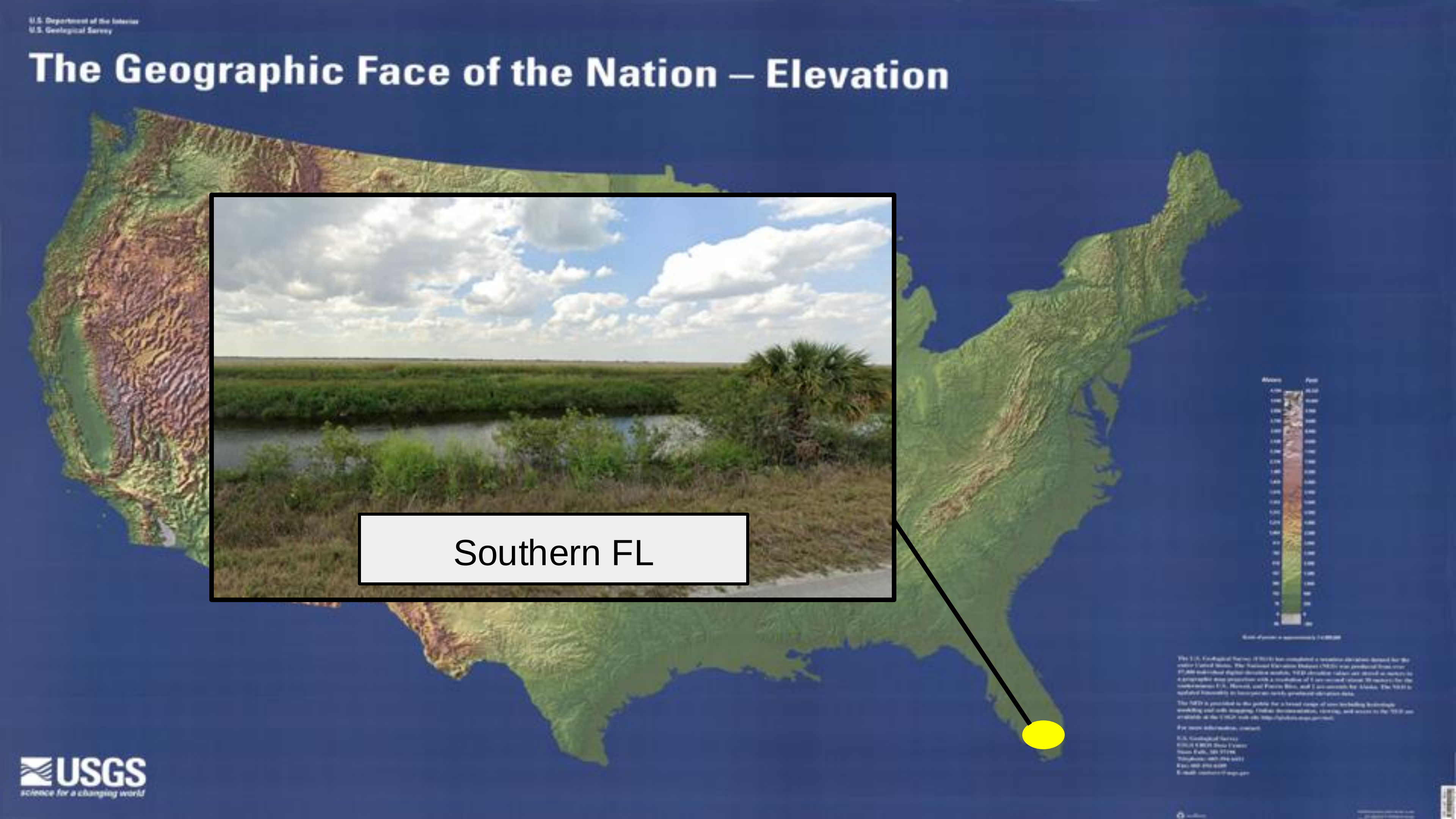
Picture 2

Smoky Mtns. National Park

Picture 3


U.S. Department of the Interior
U.S. Geological Survey
The Geographic Face of the Nation – Elevation
Roswell, NM
USGS
science for a changing world

Picture 4


U.S. Department of the Interior
U.S. Geological Survey
The Geographic Face of the Nation – Elevation
Southern FL
USGS
science for a changing world

Picture 5

Willamette National Park, OR

Fuels - Will they burn?

Forecasting Fuels: Fuel Types

- A fuel's time lag classification is proportional to its diameter and is loosely defined as the time it would take for 2/3 (67%) of the dead fuel to respond to atmospheric moisture.

- For example, if a fuel had a "1-hour" time lag, one could expect its wildfire susceptibility to change after only 1 hour of humid weather.

TIME LAG	FUEL SIZE	DETERMINATION
1–hour	<0.25 inch diameter	Fine flashy fuels that respond quickly to weather changes. Computed from observation time temperature, humidity, and cloudiness.
10–hour	0.25 to 1 inch diameter	Computed from observation time temperature, humidity, and cloudiness. Can also be an observed value, from a standard set of fuel sticks that are weighed as part of the fire weather observation.
100–hour	1 to 3 inches diameter	Computed from 24–hour average conditions composed of day length, hours of rain, and daily temperature/humidity ranges.
1000–hour	3 to 8 inches diameter	Computed from a 7–day average conditions composed of day length, hours of rain, and daily temperature/humidity ranges.

Spring – Grass Calibration

GRASS (Spring)	ISI < 2.0	ISI 2 to 5.9	ISI 6.0 to 7.9	ISI 8.0+
FFMC < 86.0	LOW	MODERATE	MODERATE	VERY HIGH
FFMC 86.0 to 91.9		MODERATE	HIGH	VERY HIGH
FFMC 92.0+ & FWI < 36.0			VERY HIGH	VERY HIGH
FFMC 92.0+ & FWI 36.0+				EXTREME

Fuel indices

- ERC (Energy Release Component)
- BI (Burning Index)
- Fossberg Index
- Haines index
- Spread Component (SC)
- FFMC (Fine Fuel Moisture Code)
- HDWI (Hot Dry Windy Index)

As with severe parameters, use with caution! Composites can lead you astray!

Fire Weather Indices: ERC SC and BI

Energy Release Component (ERC) is a calculated output of the National Fire Danger Rating System (NFDRS). The ERC is a number related to the available **energy** (BTU) per unit area (square foot) within the flaming front at the head of a fire.

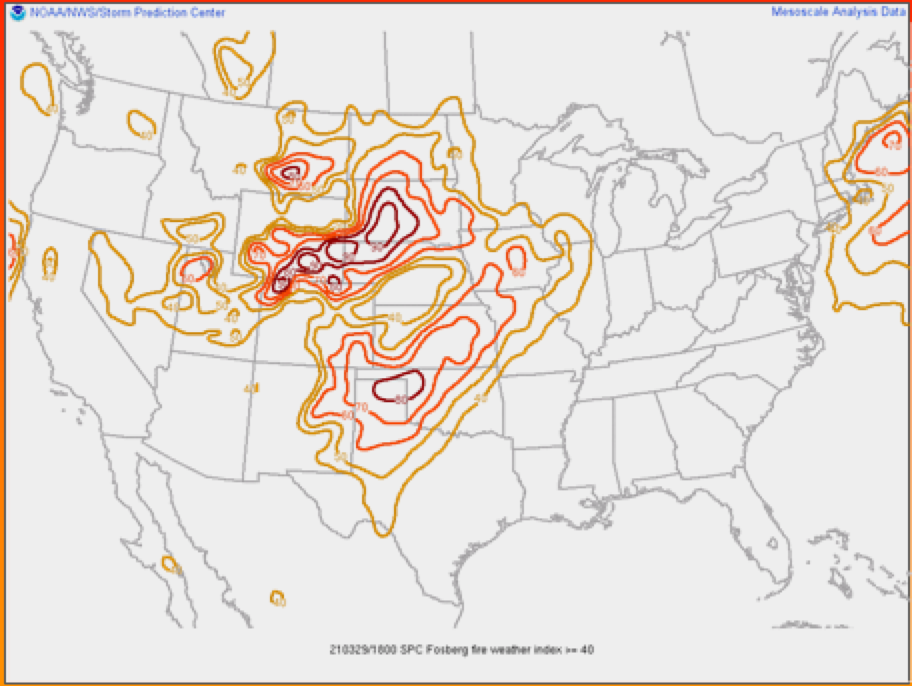
Spread Component (SC) "the spread component is numerically equal to the theoretical ideal rate of spread expressed in feet-per-minute.

Burning Index (BI) is a number used by the National Oceanic and Atmospheric Administration (NOAA) to describe the potential amount of effort needed to contain a single fire in a particular fuel type within a rating area. The National Fire Danger Rating System (NFDRS) uses a modified version of Bryam's equation for flame length – based on the Spread Component (SC) and the available energy (ERC) – to calculate flame length from which the Burning Index is computed.[1]

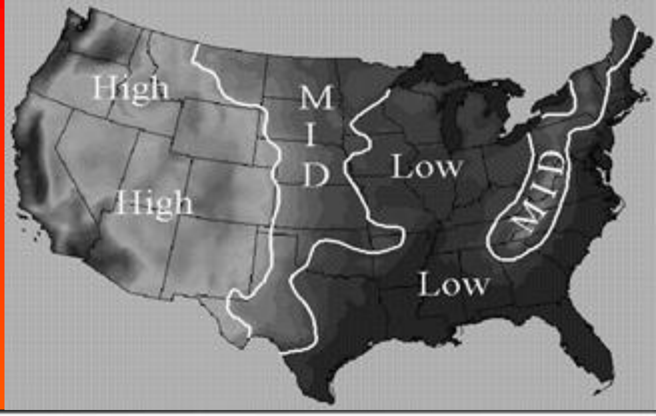
$$BI = j_1 \, F_L \qquad F_L = j\left[\left(\frac{SC}{60}\right)(25(ERC))\right]^{0.46}$$

Fire Weather Indices: Fossberg FWI

- It is a non-linear filter of meteorological data developed by first transforming temperature and relative humidity to equilibrium moisture content, then transforming the equilibrium moisture content to combustion efficiency. The index is approximated by F = D((Rate of Spread) (Energy Release)) ^0.46
- Scaled to represent 0% moisture with a 30 mph wind.
- Values of 0-100, greater than 50 is considered significant.
- Most commonly used for strong wind driven fire events. (Plains/Southeast)



Fire Weather Indices: Haines Index



- Haines index is a multi regional fire weather tool used to assess the likelihood of plume dominated fire behavior from atmospheric stability and moisture.

Hi = Stability term + Moisture term

Stability term = T1 - T2

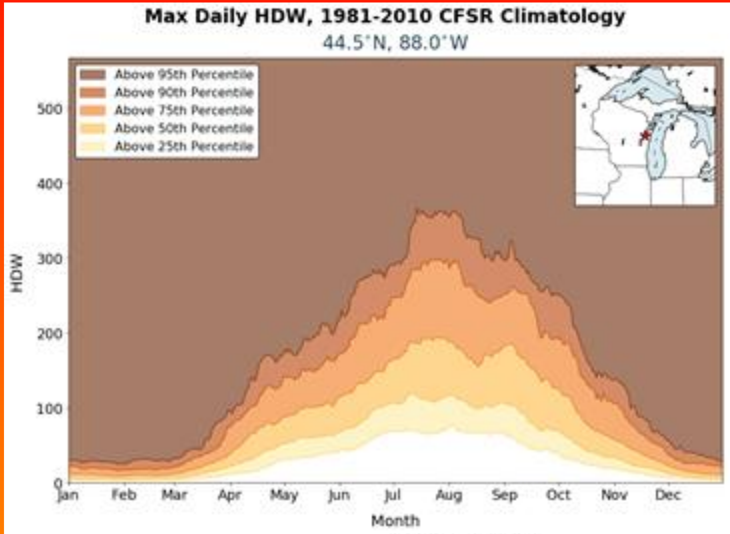
Moisture (Td Depression) Term =T1 - Td1

- Each term is scored based on the values. The added scores are the final haines index value.

table 1 : CALCULATION of the HAINES INDEX

LEVEL	STABILITY TERM	STABILITY SCORE	MOISTURE TERM	MOISTURE SCORE
LOW	950hPa Temperature - 850hPa Temperature =< 3 degrees C 4 to 7 degrees C => 8 degrees C	 1 2 3	850hPa Temperature - 850hPa Dewpoint =< 5 degrees C 6 to 9 degrees C => 10 degrees C	 1 2 3
MID	850hPa Temperature - 700hPa Temperature =< 5 degrees C 6 to 10 degrees C => 11 degrees C	 1 2 3	850hPa Temperature - 850hPa Dewpoint =< 5 degrees C 6 to 12 degrees C => 13 degrees C	 1 2 3
HIGH	700hPa Temperature - 500hPa Temperature =< 17 degrees C 18 to 21 degrees C => 22 degrees C	 1 2 3	700hPa Temperature - 700hPa Dewpoint =< 14 degrees C 15 to 20 degrees C => 21 degrees C	 1 2 3

Fire Weather Indices: HDWI Hot Dry Windy Index

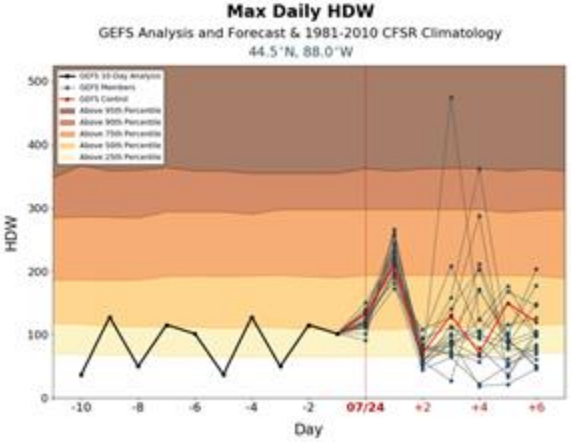


"HDW was designed to be very simple – a multiplication of the maximum wind speed and maximum vapor pressure deficit (VPD) in the lowest 50 or so millibars in the atmosphere. <u>Because HDW is affected by heat, moisture, and wind, seasonal and regional variability can be found when comparing HDW values from different locations and times.</u>"

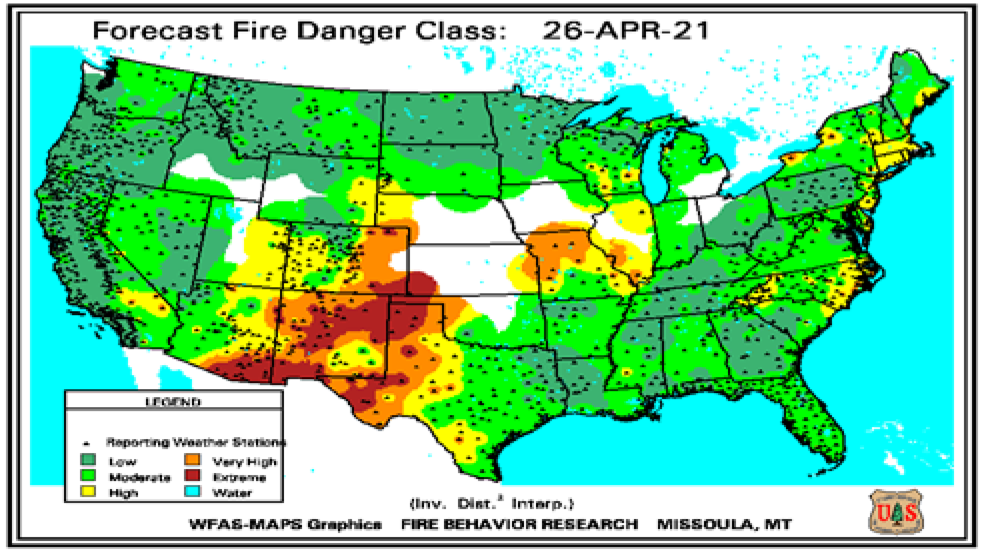
HDW = Wmax * VPD

Wmax = 50 mb max wind

VPD = Es - E Vapor Pressure deficit. Very similar to RH



National Fire Danger Rating System (NFDRS)



A fire assessment system used to provide a daily estimate of wildfire risk.

This uses a system of equations with variables that include weather inputs, topography, and fuel types to determine the fire danger category.

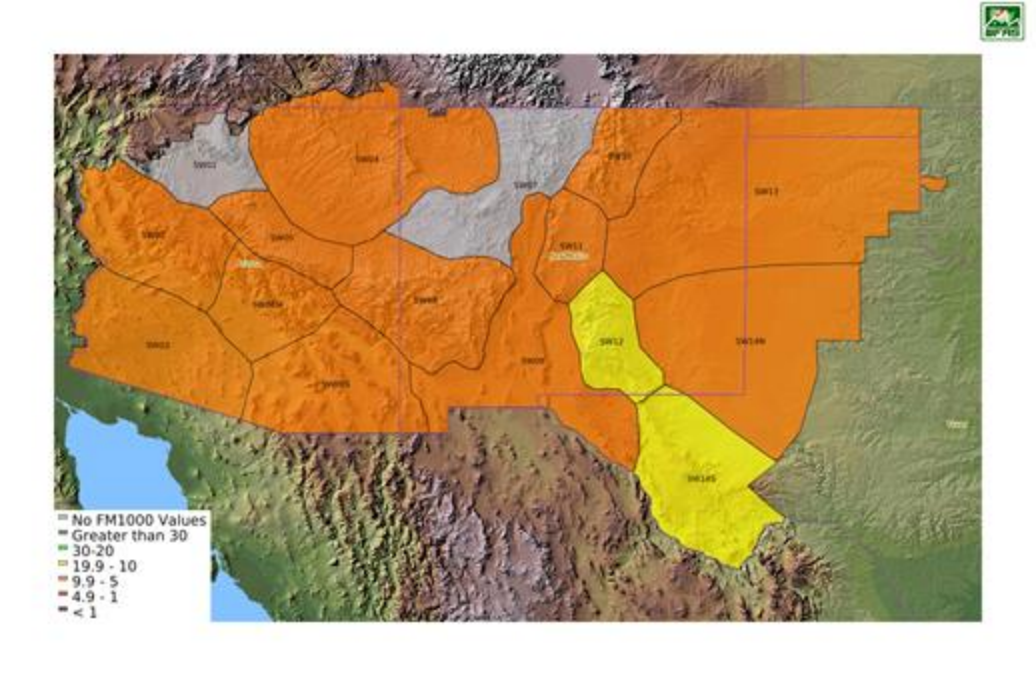
Easy-to-interpret categories allow for easier communication of fire risk.

Fine Fuel Moisture Code FFMC

The Fine Fuel Moisture Code (FFMC) represents fuel moisture of forest litter fuels under the shade of a forest canopy.

It is intended to represent moisture conditions for shaded litter fuels, the equivalent of 16-hour timelag. It ranges from 0-101. Subtracting the FFMC value from 100 can provide an estimate for the equivalent (approximately 10h) fuel moisture content.

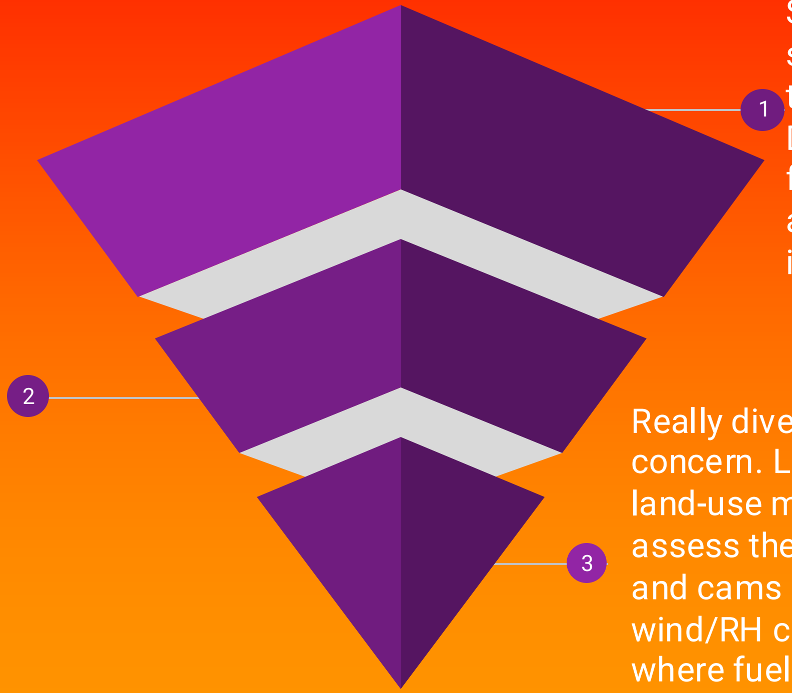
Most accurate when FFMC values are roughly above 80.



Forecasting Fuels

- Geographic Area Coordination Centers predictive service specialists produce fuel and fire forecasts for specific areas of the US.
- Controlled by the National interagency Fire Council (NIFC)
- Planning levels determine the threat on a scale of 1 to 5.

Basic Fire Weather Forecasting Workflow



The "Big Picture"
Start with a broad overview of the synoptic weather conditions. Know the climo. Find your major features. Do a quick fuels assessment. Look for favorable fuel areas. Get rid of any areas with QPF greater than .25 inches over the last 1-2 days.

Narrow your focus

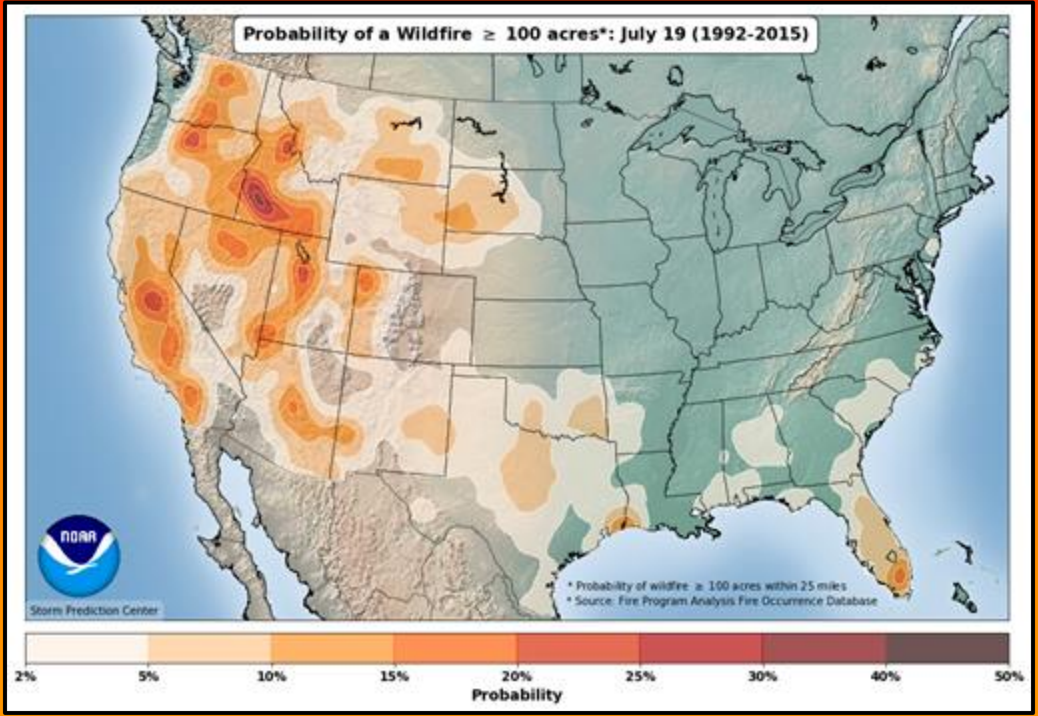
Begin looking for more focused/intense fire weather corridors. Forecast soundings offer a great tool to quickly assess stability and fire danger. Look more closely at the fuels. How dry are they?

The details

Really dive into the areas of potential concern. Look for terrain features using land-use maps. FInd the fuel rich areas and assess the conditions over them. HREF and cams can give you powerful details on wind/RH combos. Remember to only draw where fuels can burn. Urban/wilderness interfaces.

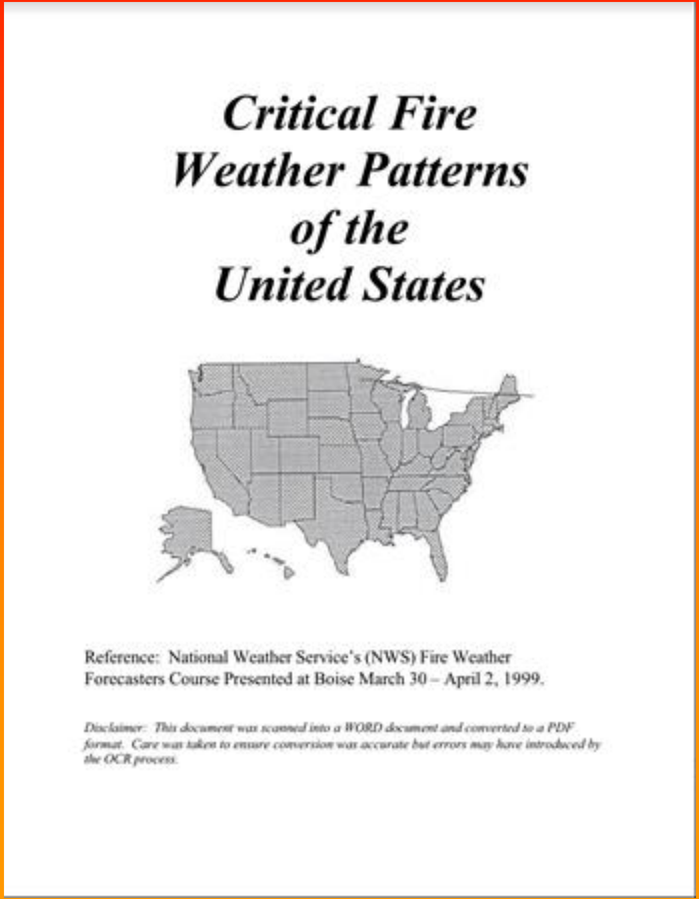
Climatology

When and where do big fires occur?



https://youtu.be/Zr5-H6j9f7A

Fire Weather Regimes

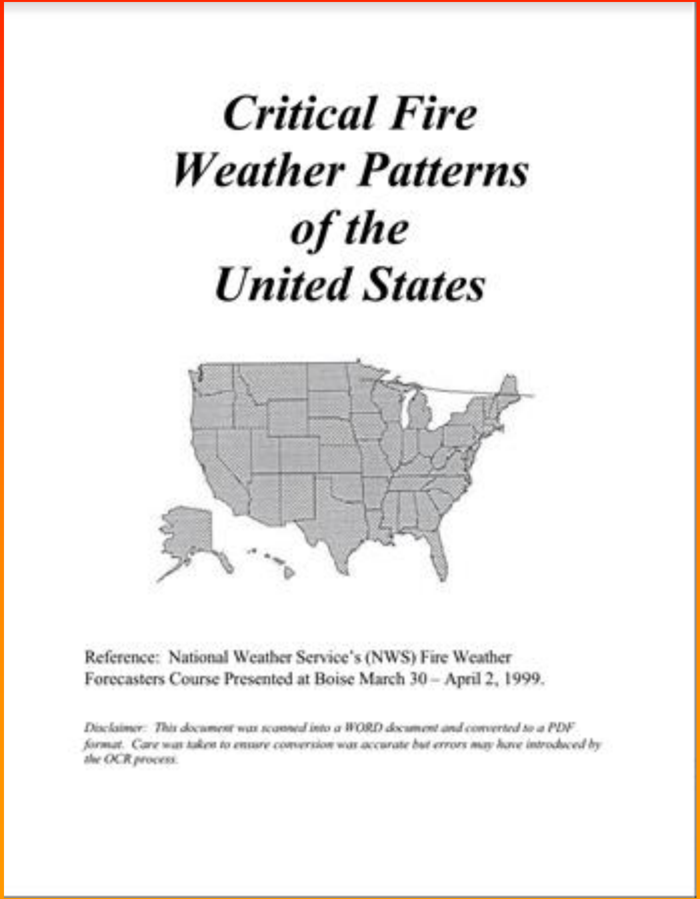

Critical Fire Weather Patterns of the United States

Reference: National Weather Service's (NWS) Fire Weather Forecasters Course Presented at Boise March 30 – April 2, 1999.

Disclaimer: This document was scanned into a WORD document and converted to a PDF format. Care was taken to ensure conversion was accurate but errors may have introduced by the OCR process.

- See this document for an excellent dive into different types of fire weather patterns.
- A variety of fire weather regimes exist across the CONUS.
- Every state has some sort of fire weather pattern or response.
- Much of the western CONUS is the “big leagues” for fire weather forecasting.
- Internationally: Australia, Brazil, Portugal/Spain, Russia, Indonesia, and others are among some of the most active fire weather areas in the world.

Fire Weather Regimes



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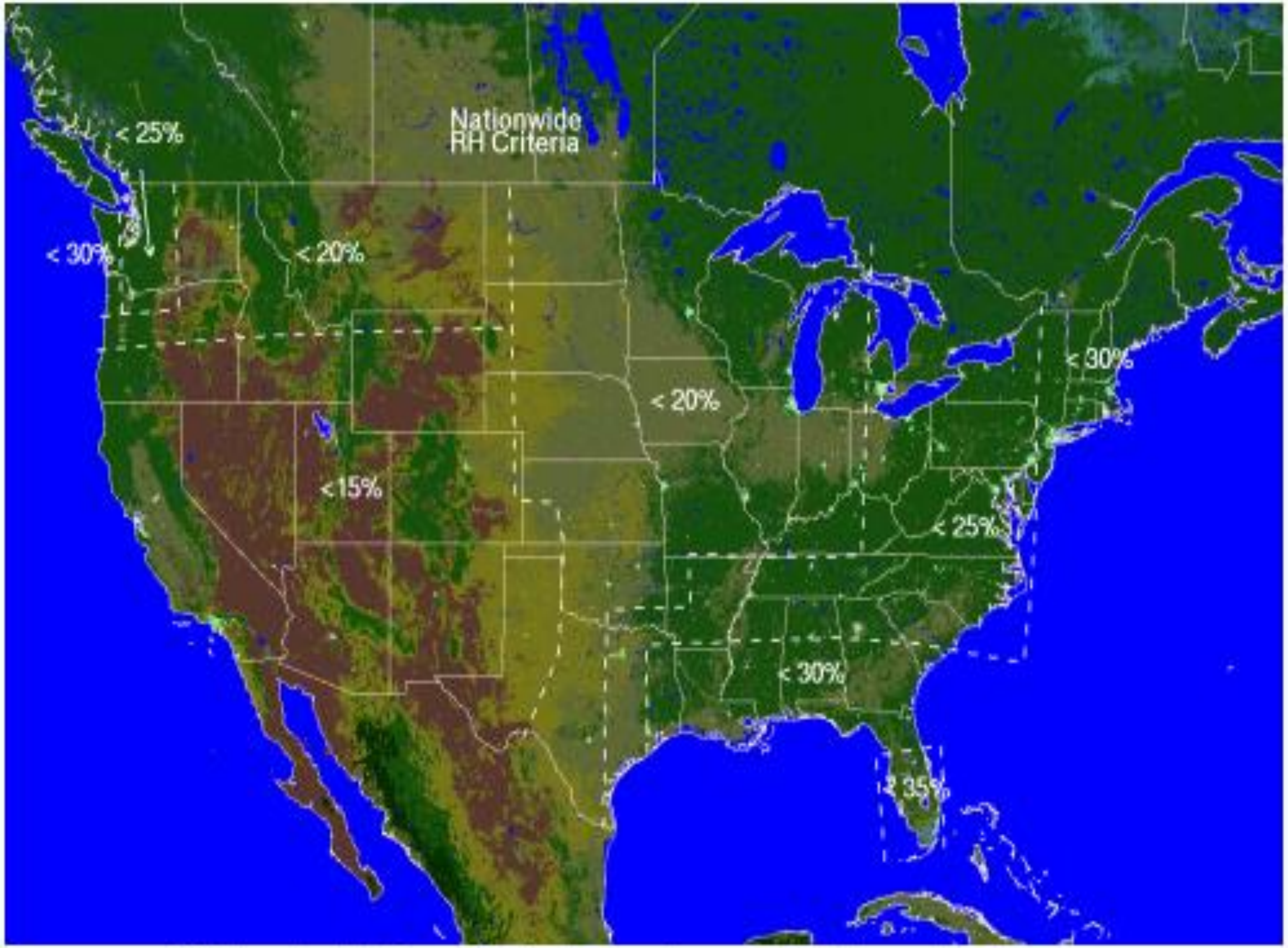
Keep in mind the fire weather ingredients:

1. Low humidity
2. Low fuel moisture
3. High winds
4. Warm temperatures (optional)



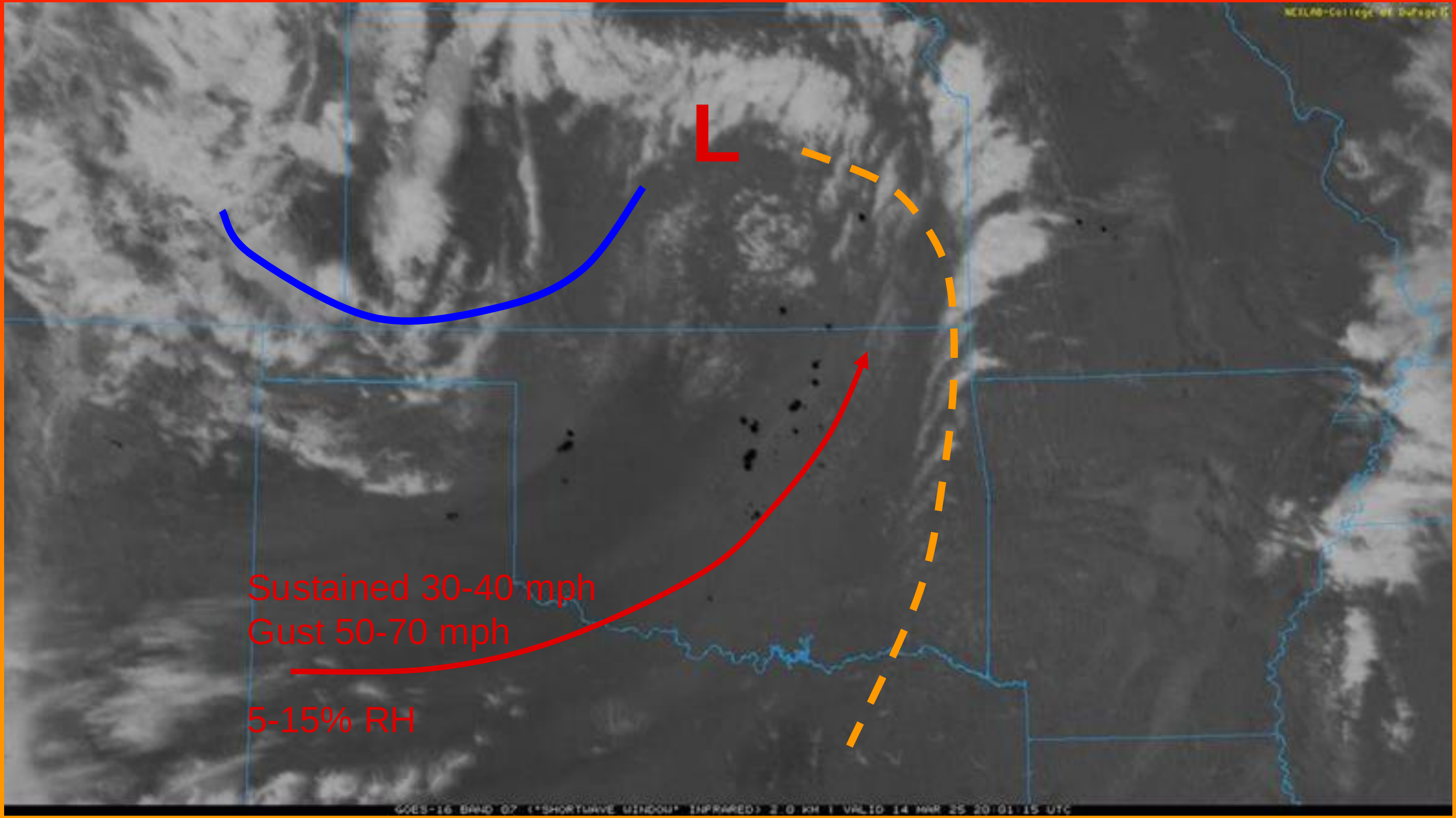
RH thresholds for critical designation overlaid on a landuse map

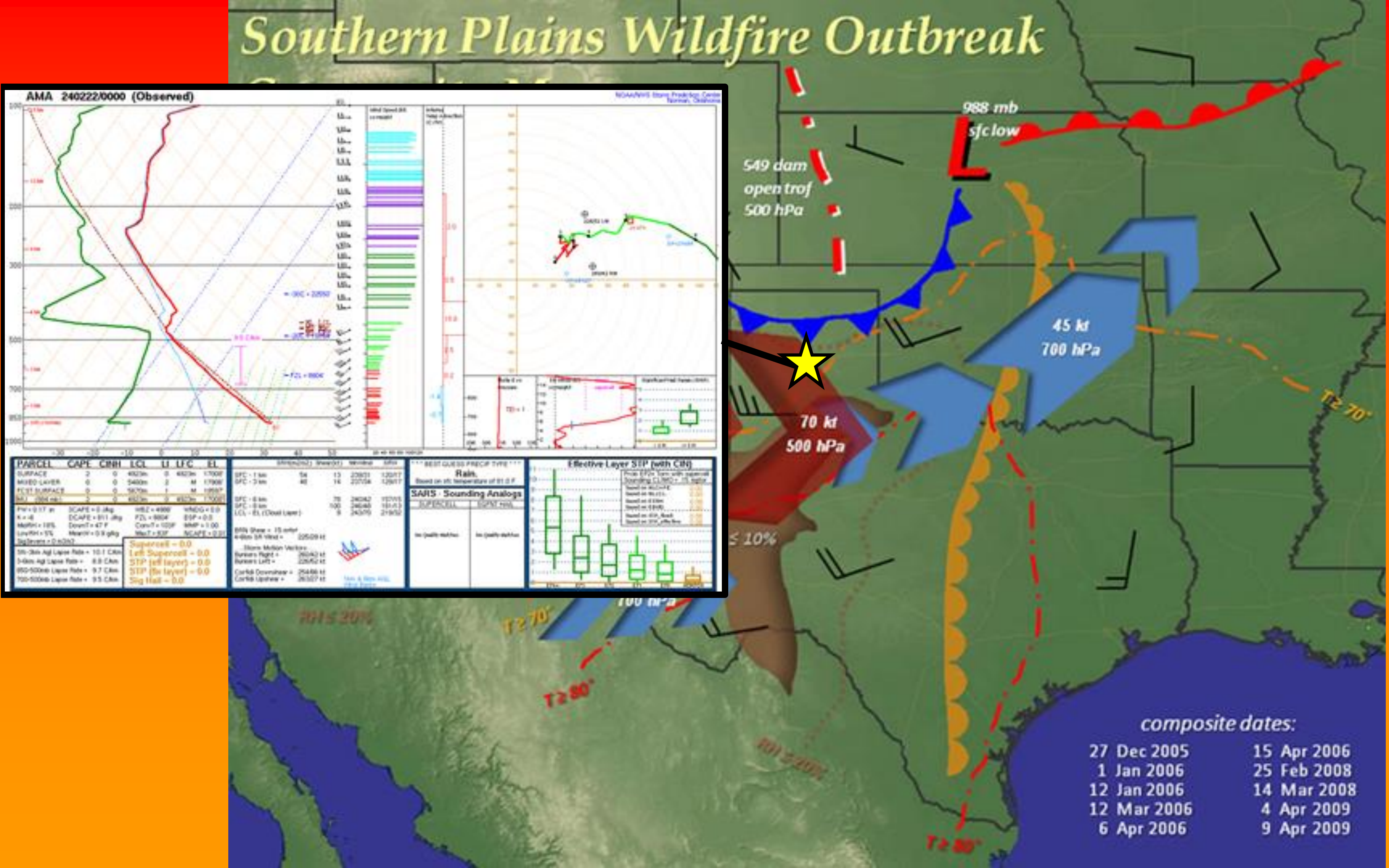
- Red Flag Warnings have different thresholds for different areas of the country.
- Why?
  - **Variety of fuels**
  - **Variety of land use**
- These differences are driven by:
  - Terrain
  - Precip distributions

Southern Plains

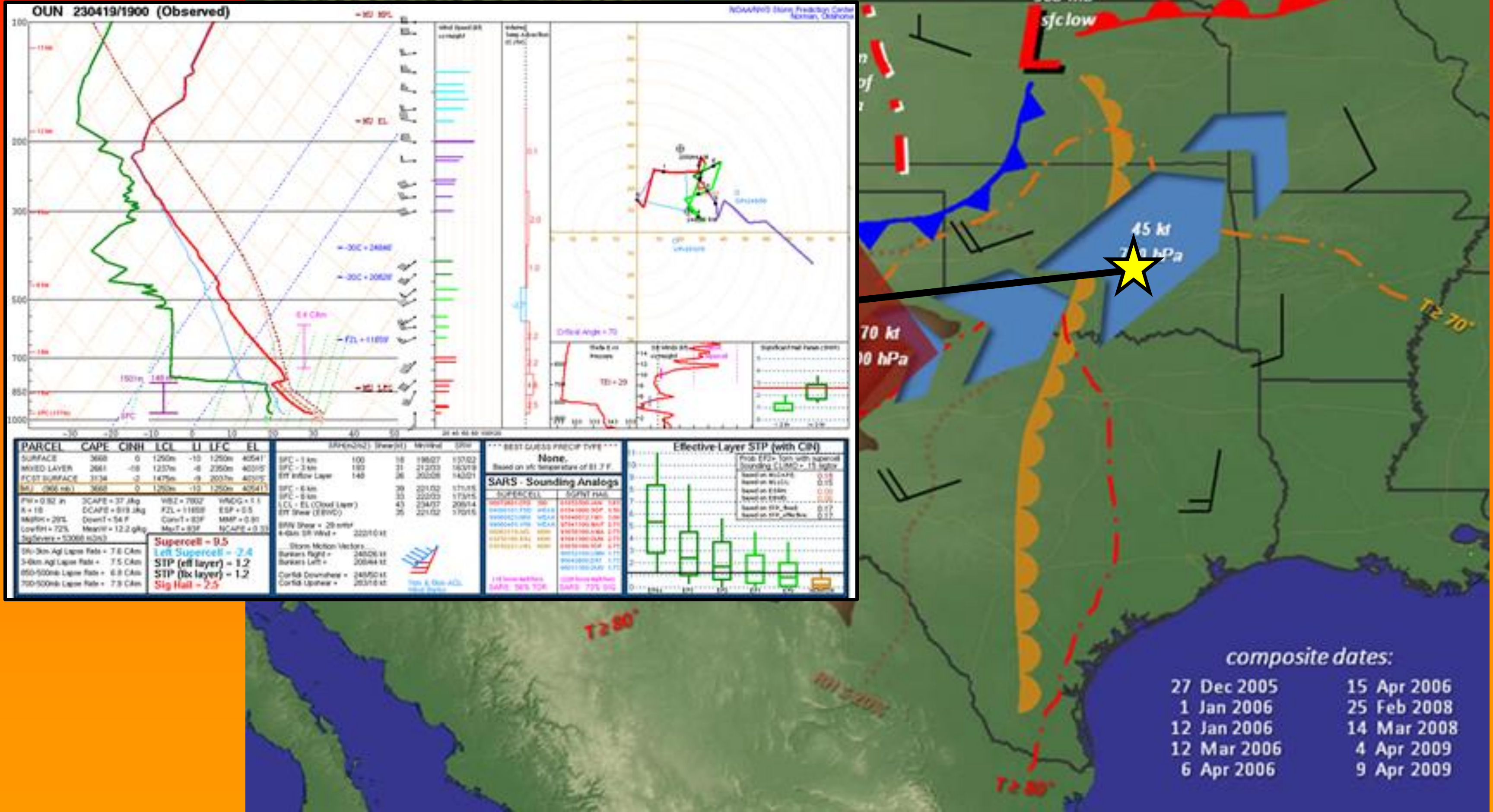
- Dominated by fast moving shrub and grass fires.
- Occur ahead of deep 500 mb troughs with strong low and mid-level flow.
- Dryline acts as eastward boundary.
- Most common during the “pre and post greenup ” periods of late winter/ early spring and early to mid fall.
- Western US drought usually a significant predictor.

Southern Plains Fire Outbreak - March 14, 2025

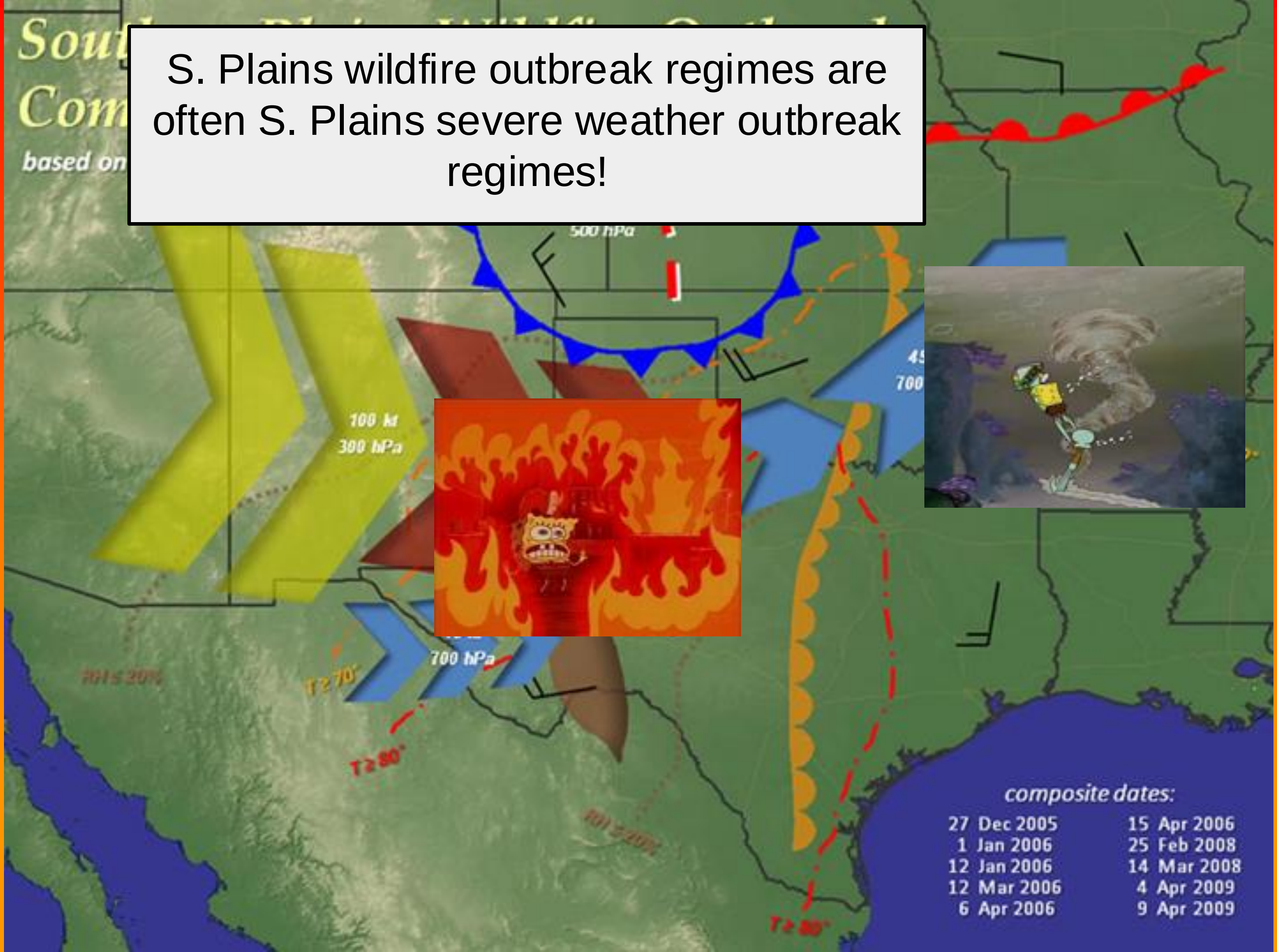



Southern Plains Wildfire Outbreak
AMA 240222/0000 (Observed)
PARCEL CAPE CINH LCL LI LFC EL
Rain.
SARS - Sounding Analogs
Effective Layer STP (with CIN)
988 mb
sfc low
549 dam
open trof
500 hPa
45 kt
700 hPa
70 kt
500 hPa
≤ 10%
700 hPa
RH ≤ 20%
T ≥ 70°
T ≥ 80°
RH ≤ 20%
T ≥ 70°
T ≥ 80°
composite dates:
27 Dec 2005
1 Jan 2006
12 Jan 2006
12 Mar 2006
6 Apr 2006
15 Apr 2006
25 Feb 2008
14 Mar 2008
4 Apr 2009
9 Apr 2009

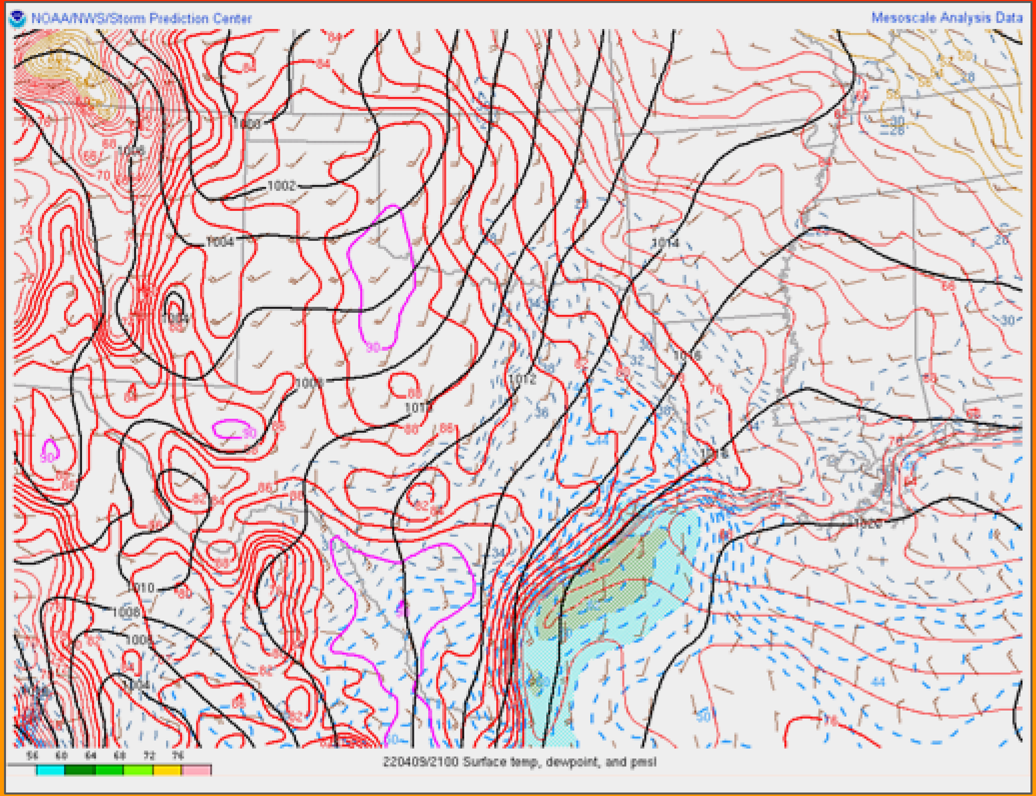
Southern Plains Wildfire Outbreak Composite Map



S. Plains wildfire outbreak regimes are often S. Plains severe weather outbreak regimes!

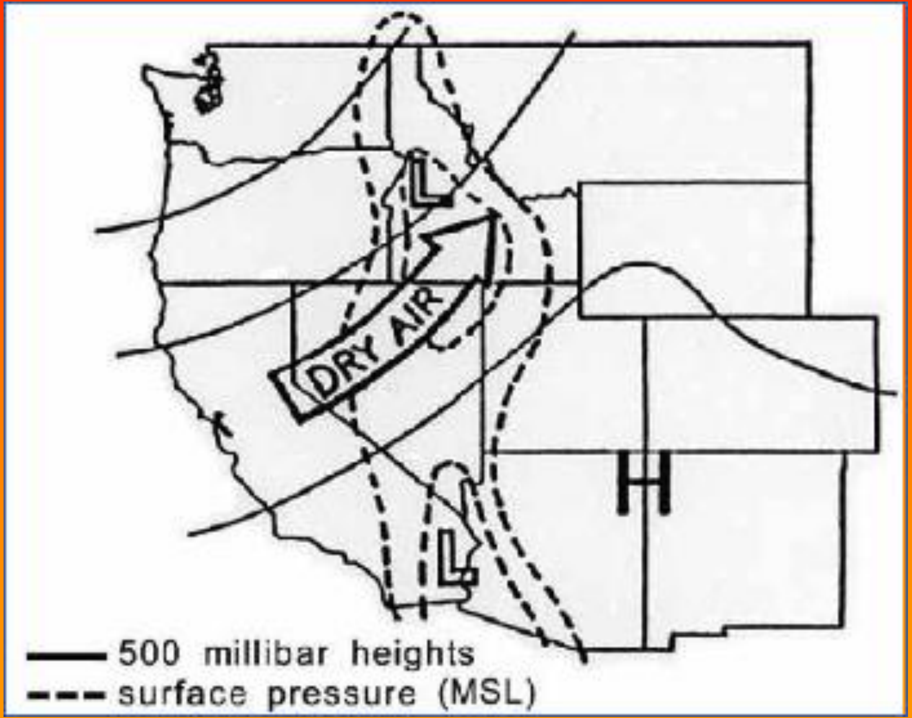


Southern Plains - Dry Return Flow



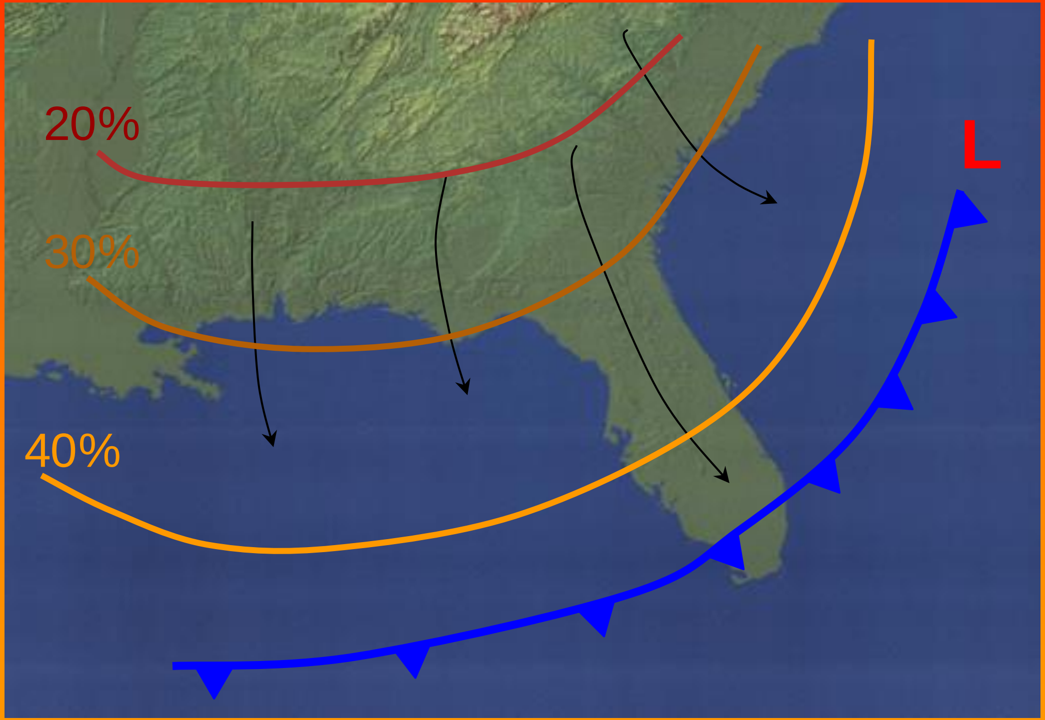
- Dry return flow is characterized by gusty southerly winds across the southern and central High Plains in the absence of deep gulf moisture.
- Usually driven by low-amplitude mid-level troughs crossing the Rockies.
- Enhanced by lee troughing/cyclogenesis, surface winds of 20-30 mph are common.
- Low- level thermal ridge contributes to low RH (<20%)

Rockies and Southwest



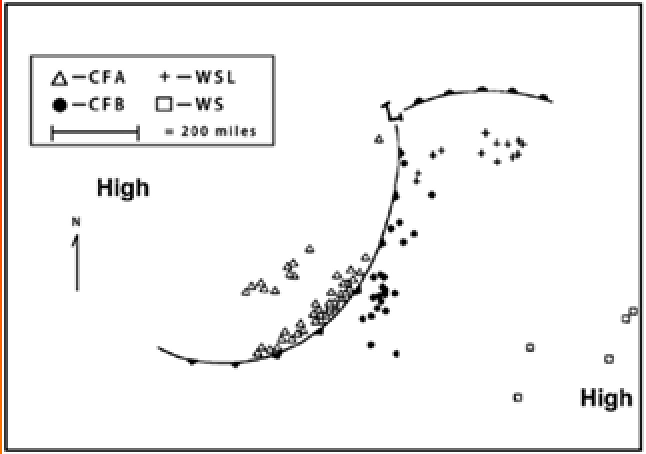
- “Big Bubble no Trouble” -An old forecasterism also known as ridge breakdown
- A mid-level ridge is broken down (partially or fully) by an advancing shortwave trough.
- A deceptive pattern with important implications for fire potential.
  - Winds aloft may not be that strong.
  - Quiescent but hot weather
  - Dry frontal passages
  - Dry Thunderstorms and gusty outflow
- Very common throughout summer and early fall before and after Monsoon.

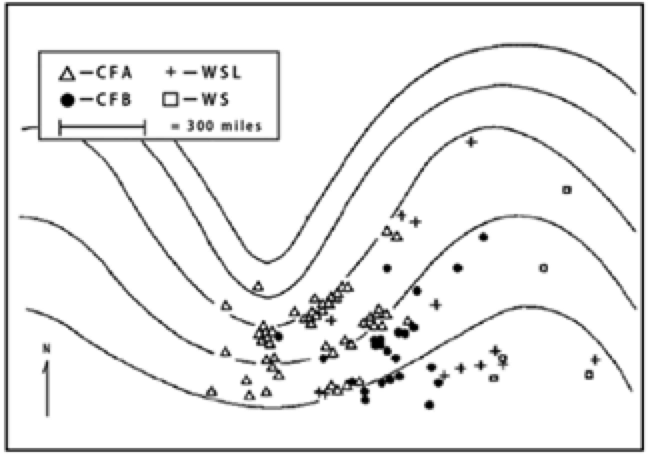
Southeastern U.S.

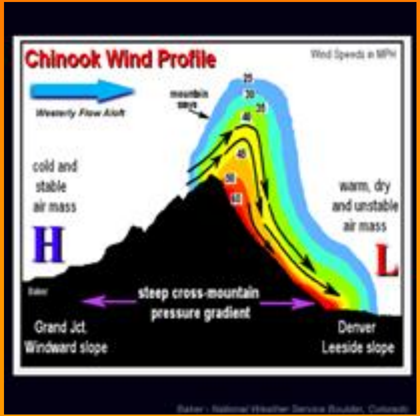


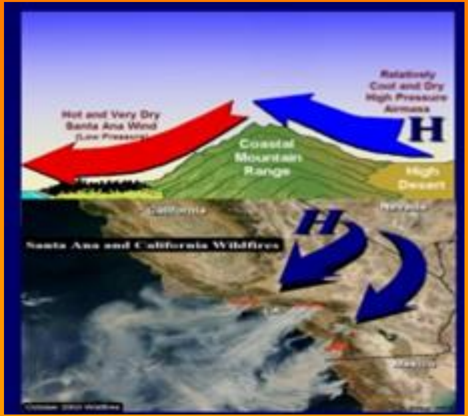
- Northerly winds behind a cold frontal passage ushers in drier air.
- Relative Humidity values may be higher than you would expect (30-40%)
- Winds may be lighter than normally expected (15-20 mph)

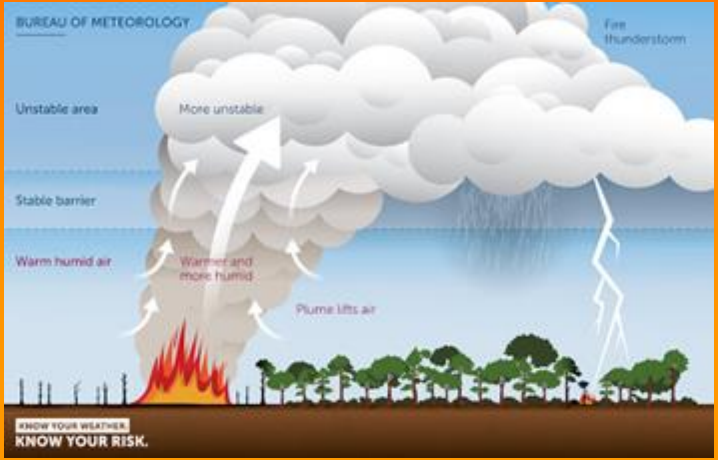
Smaller-Scale Details



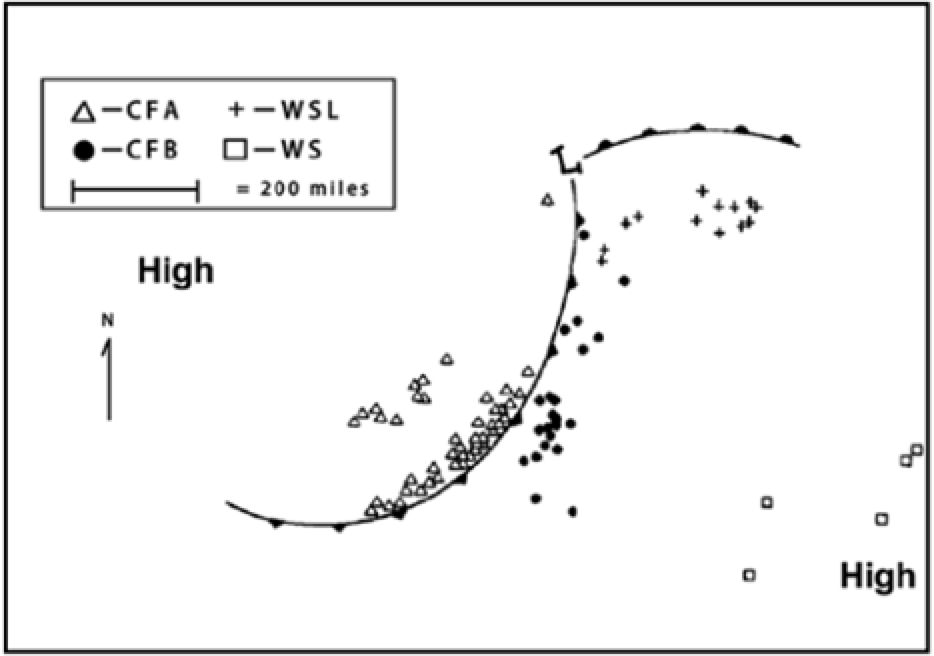


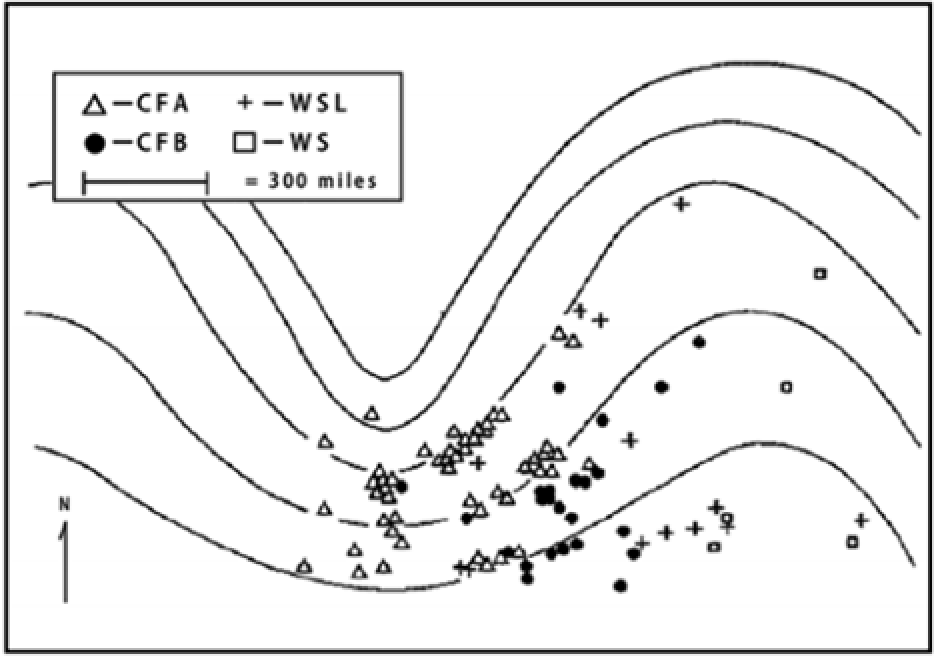






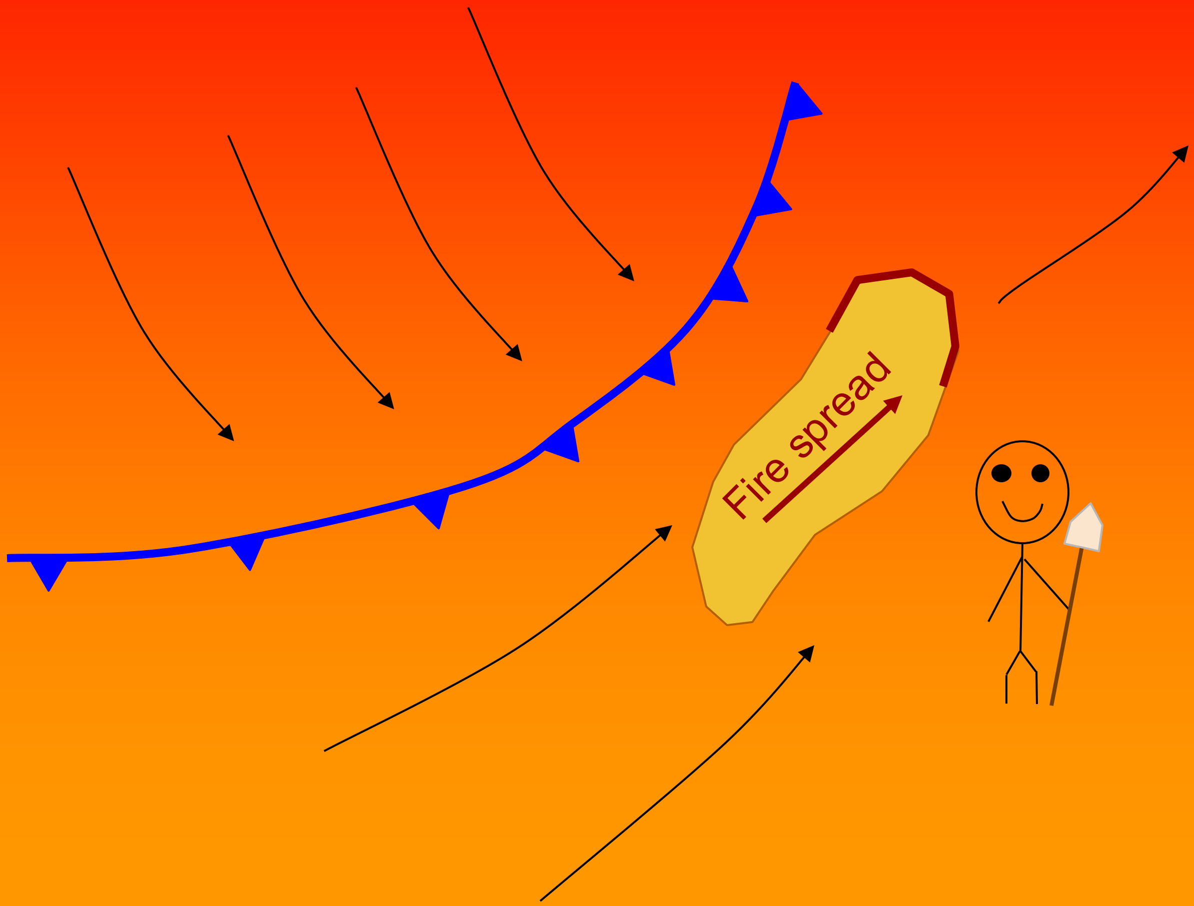
Dry Cold Fronts



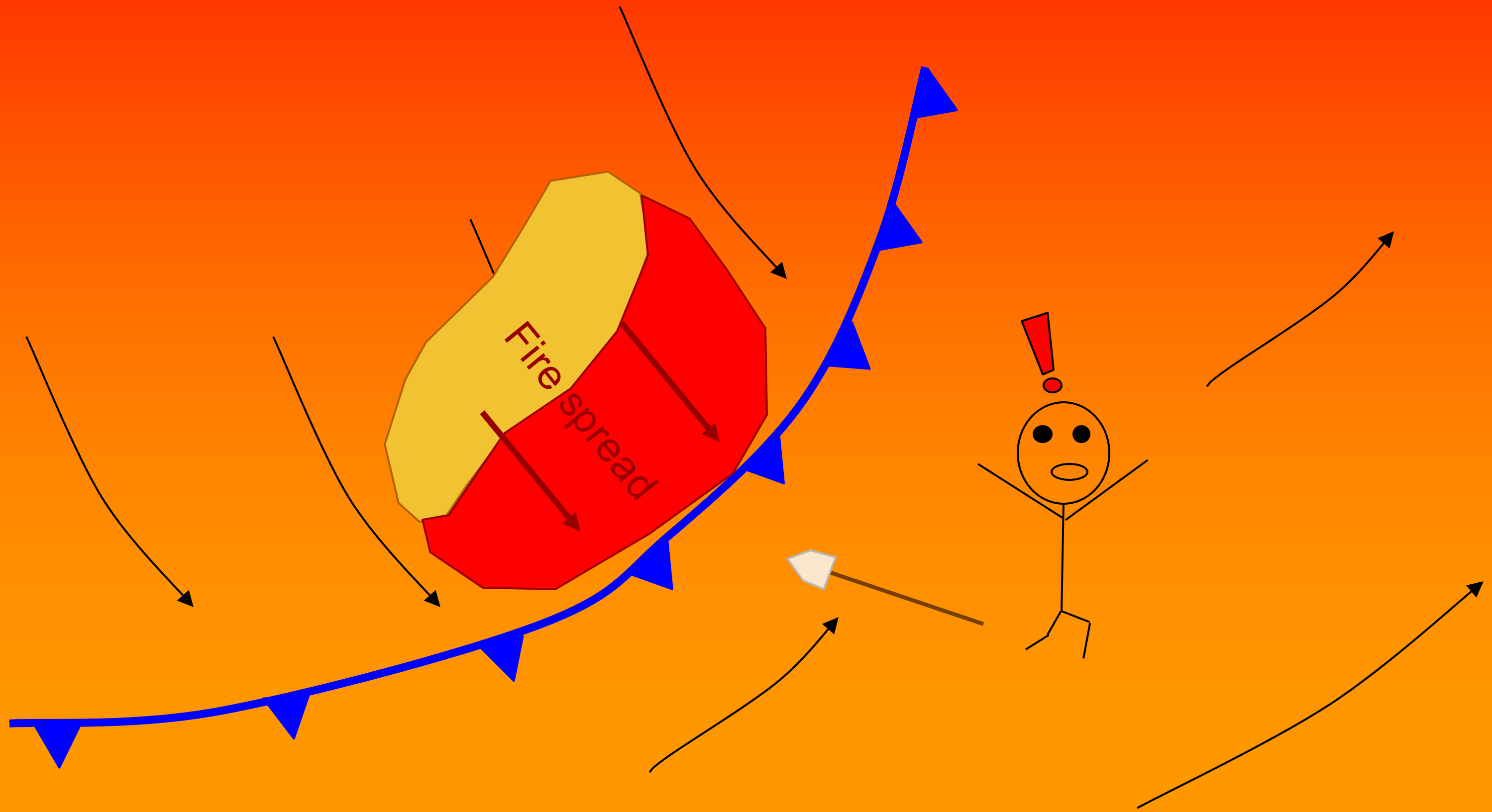


- Cold fronts producing very little rainfall but strong wind shifts.
- Common across the western US and southern Plains.
- Can cause rapid fire spread/spotting.
- South Canyon Fire (Storm King Mountain Colorado burnover 14 smoke jumpers killed)

Dry Cold Front Fire Direction Changes



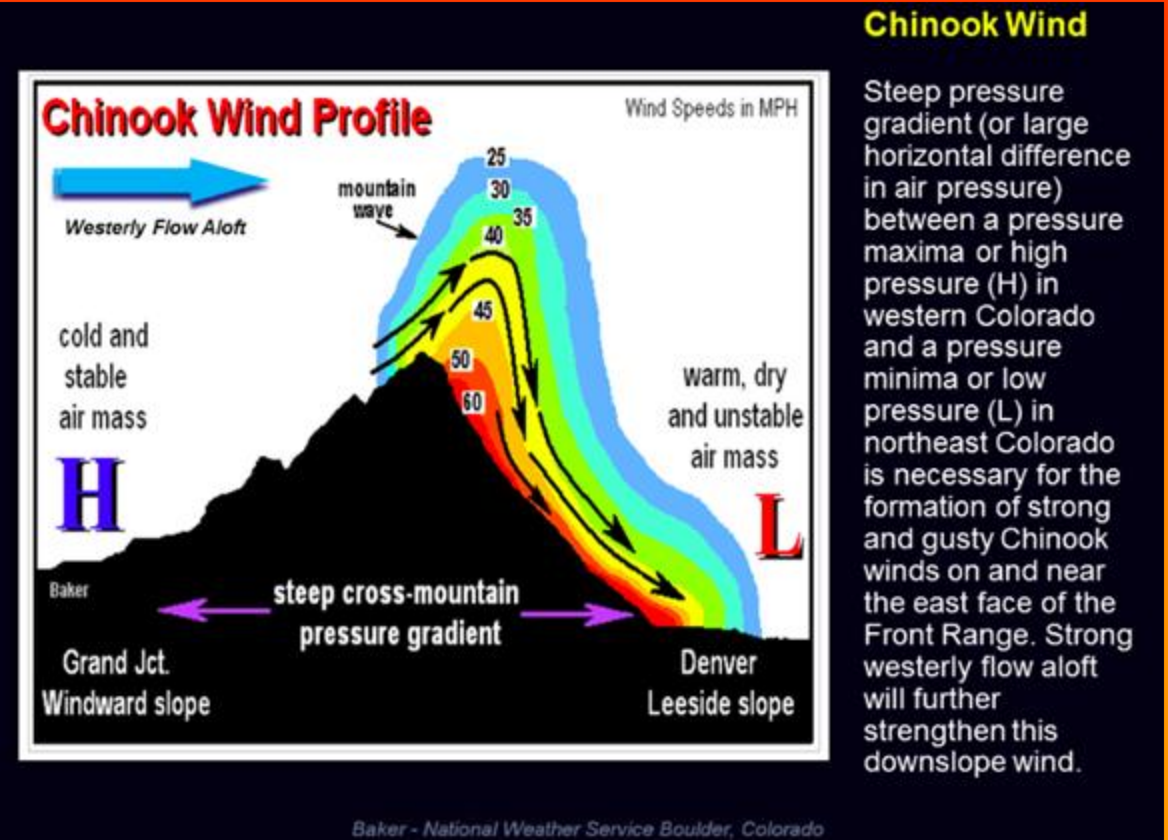
Dry Cold Front Fire Direction Changes



Dry Cold Front Fire Direction Changes
March 6-7, 2017 S. Plains Wildfire Outbreak

https://www.youtube.com/watch?v=h11A0zbCrM0&t=1s

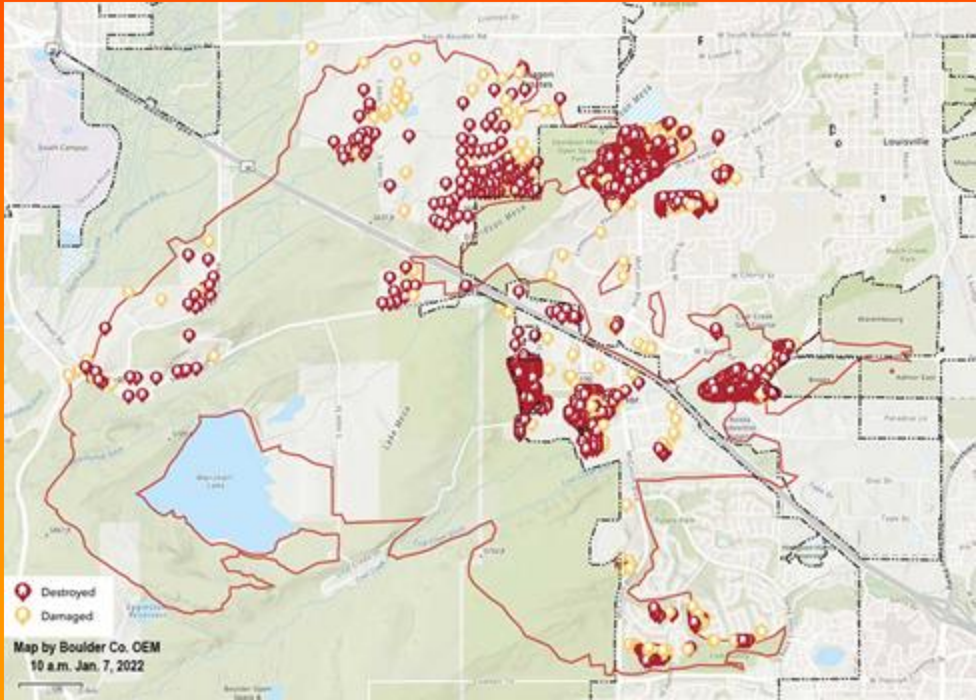
Lee of the Rockies



- Downslope winds
- Common through Colorado Wyoming and Montana.
- Weaker during the summer when flow retreats northward but early/ late Season Events (Aug-Oct & May-June) can drive very strong wildfire events.
- Winds may exceed 150 mph through terrain gaps and at ridge top level.

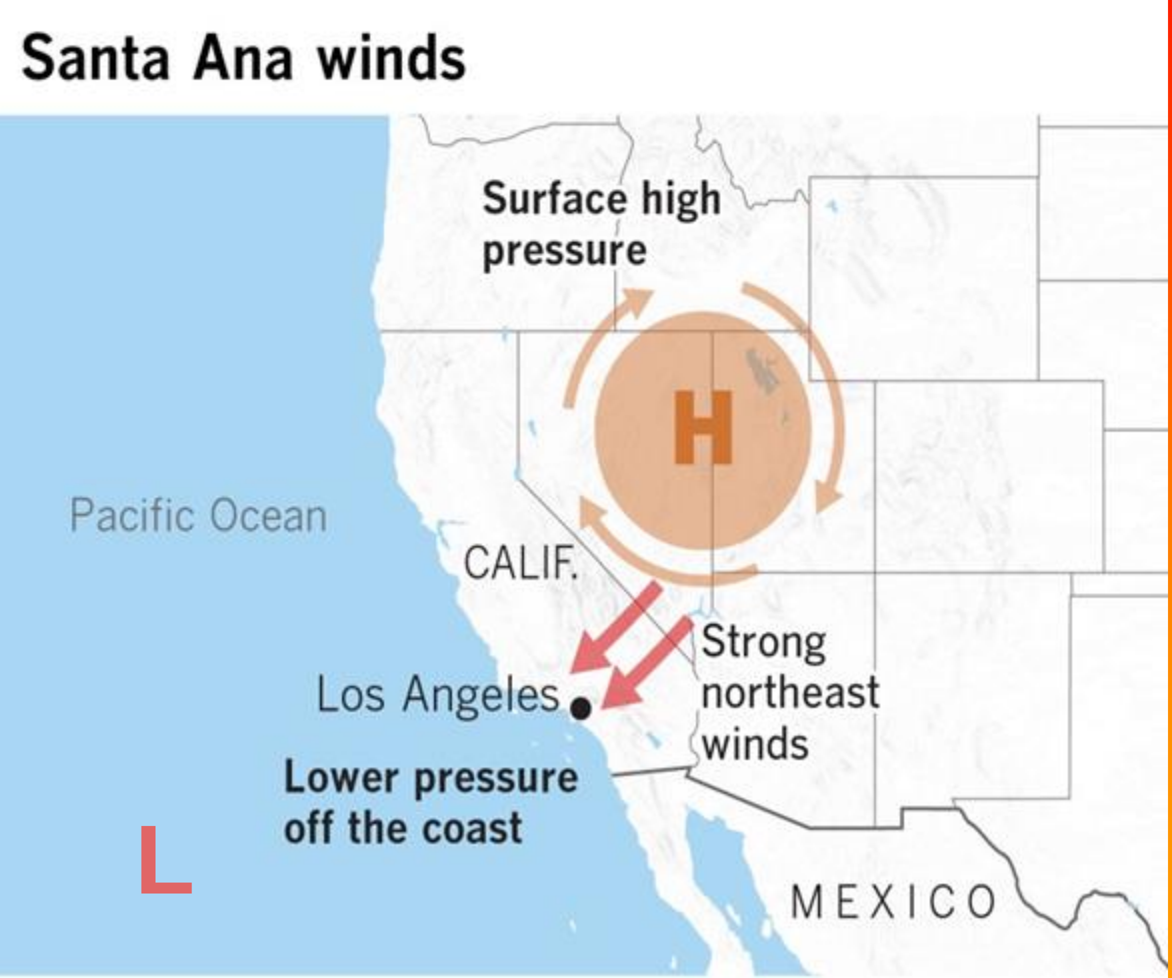
2022 Marshall Fire boulder County, CO

- Unusual time of year Dec 31-Jan downslope wind storm gusts to 115 mph supported rapid spread.
- $513+ million in damages.
- 1k structures destroyed and 6k acres 2 fatalities.
- Most damaging fire in CO history after only 12 hours.
- Exacerbated by expanding Wildland Urban Interface and poor open space management practices.



California

Santa Anas



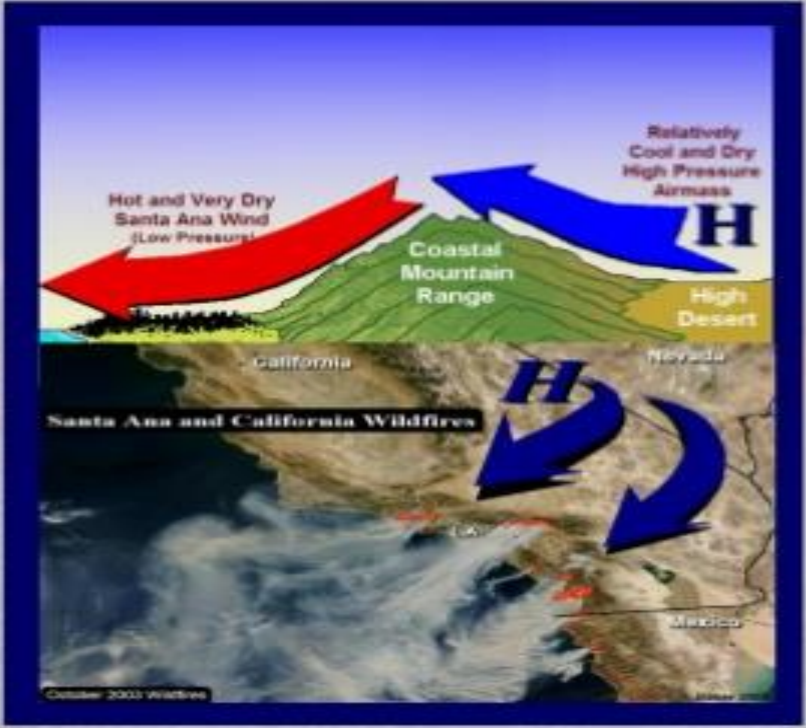
- A localized type of Foehn wind driven by offshore pressure gradients.
- Adiabatic drying and advective drying over the Great Basin produce extremely low RH as low as 1-3%
- Winds may exceed 80 mph through terrain and gaps.
- Extreme fire behavior develops as a combination of very combustible fuels and extreme winds.

Critical Winds

Foehn Winds

Santa Ana Winds

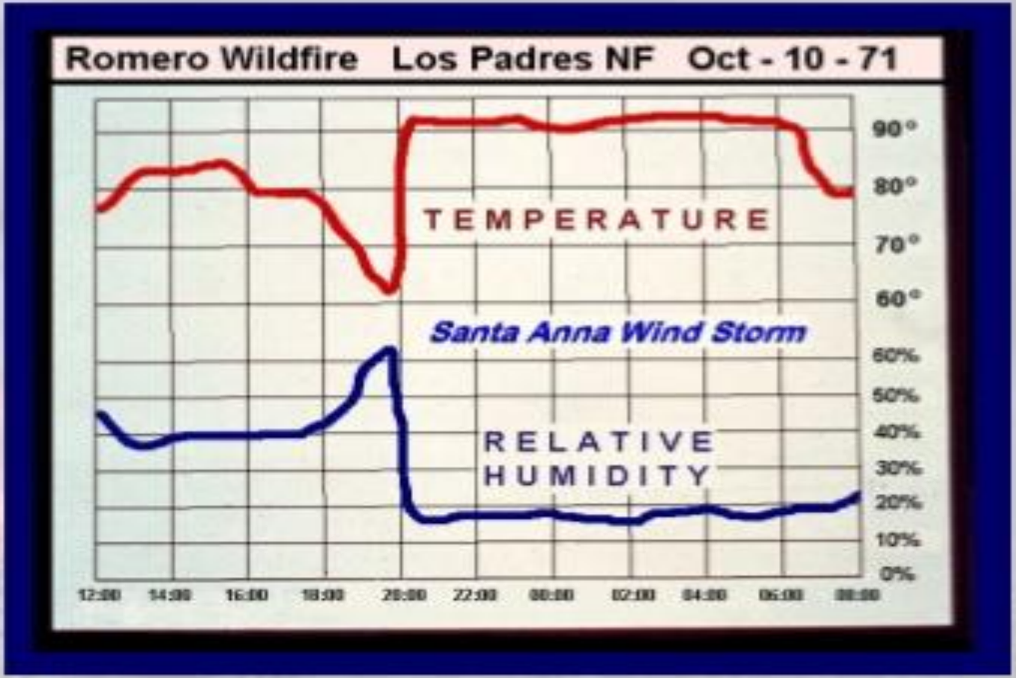
- Originates in the high deserts of southern California.
- steep pressure gradient exists between high pressure in the Great Basin and low pressure off the coast of southern California.
- Downslope off shore flow develops.
- Can create critical fire weather situations in southern California.



Critical Winds
Santa Ana Wind Storm

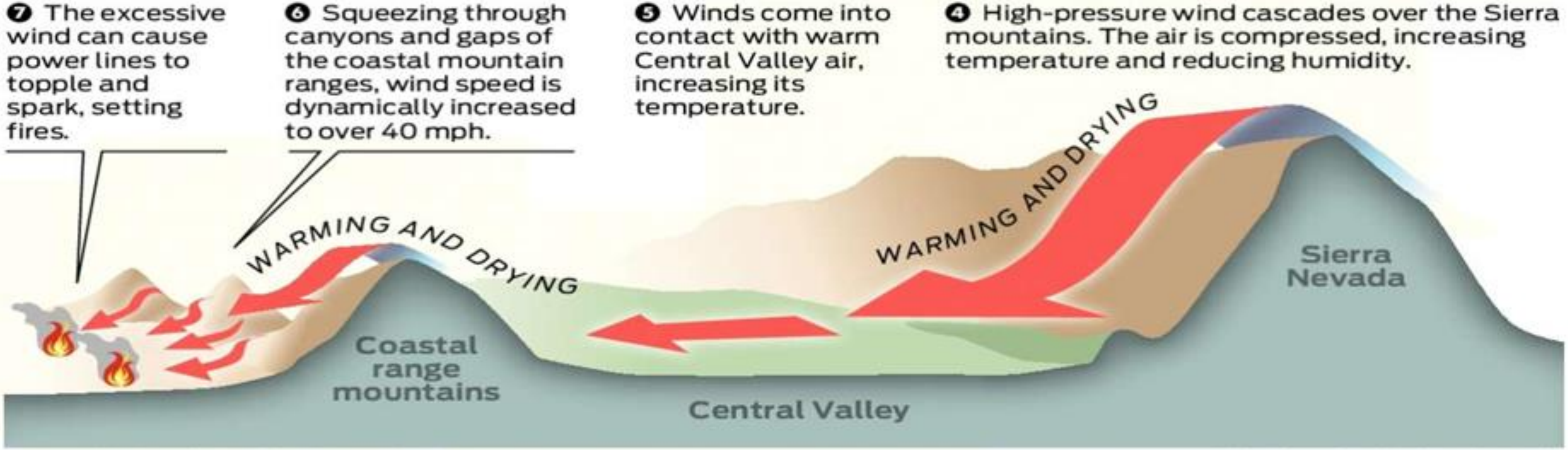
Santa Ana Wind Storm

- Romero fire October 10, 1971
- Note the sudden temperature rise and RH drop when the Santa Ana winds develop



What creates dangerous winds

The Diablo winds that were forecast for Northern California usually come in the fall, but their behavior is hard to predict because mountains, valleys and even cloud formations can alter their speed and directon.



Sources: National Weather Service; NOAA

John Blanchard / The Chronicle

Sundowners

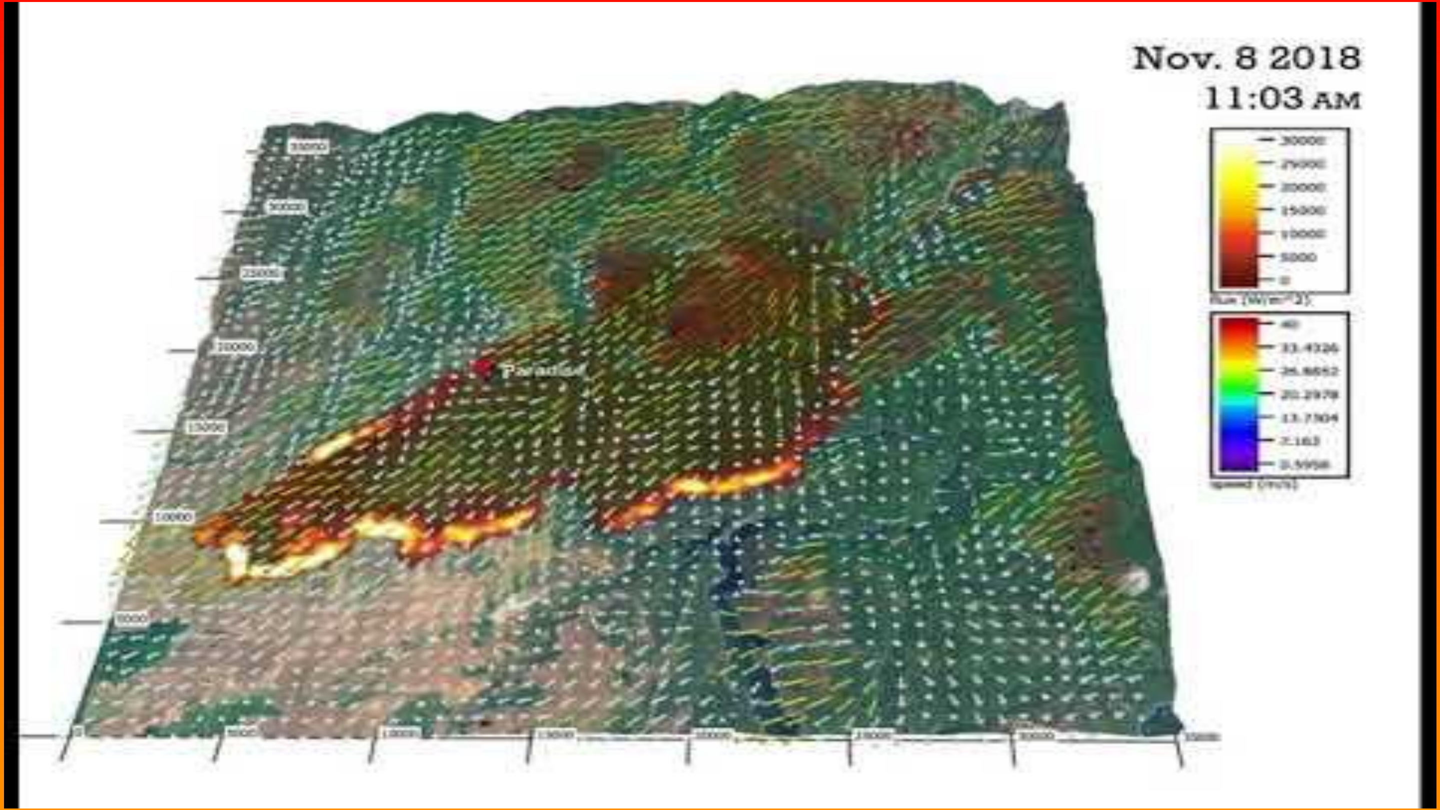
- Special case of Santa Ana winds with an offshore low
- Small but very impactful area with high population

Camp Fire Nov 2018

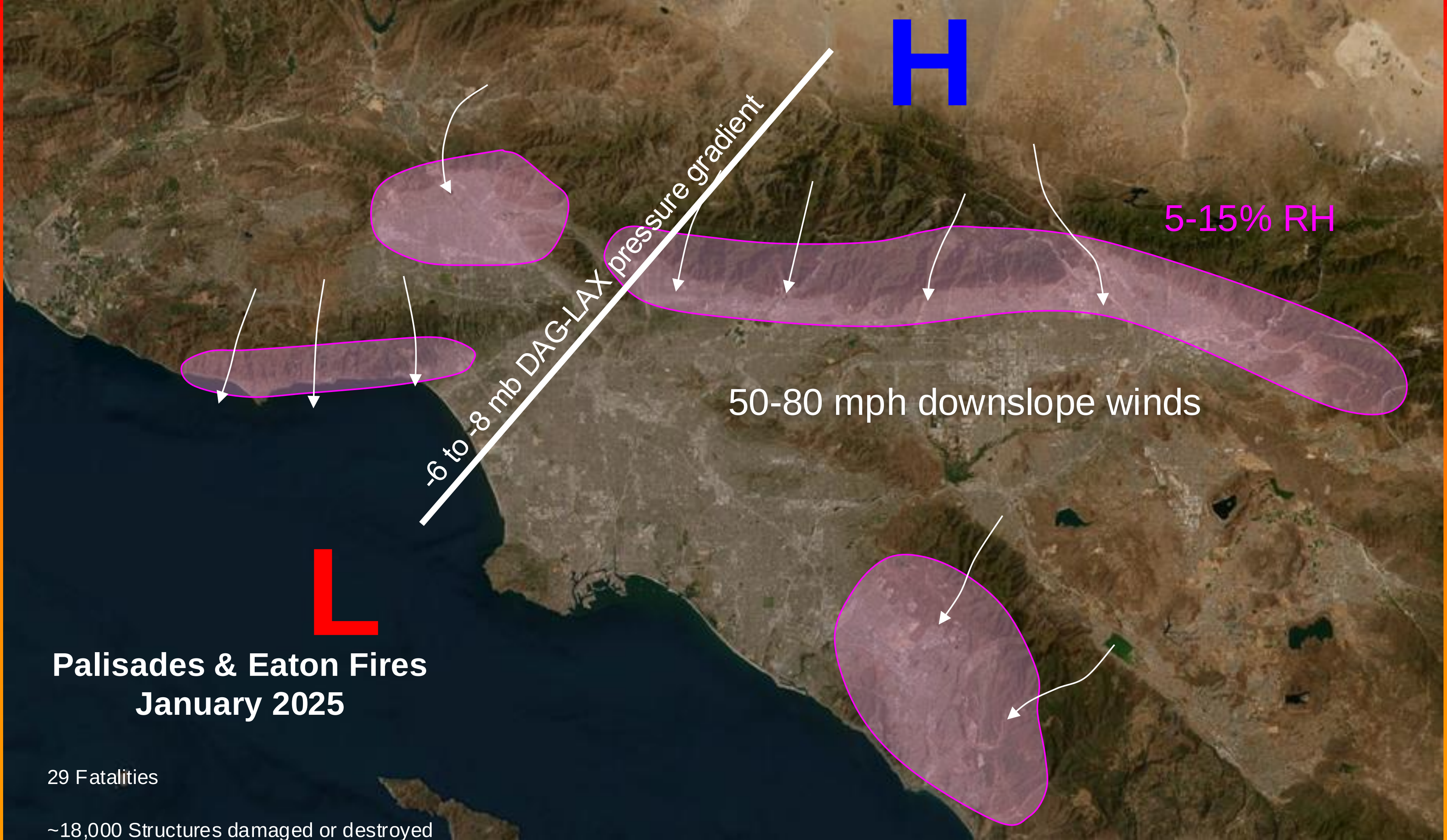
153,000 Acres

18,000 Buildings Destroyed

85 Fatalities $16.5 Billion



https://www.youtube.com/watch?v=dyfJYOZgiyA



Palisades & Eaton Fires
January 2025

29 Fatalities

~18,000 Structures damaged or destroyed

Palisades & Eaton Fires
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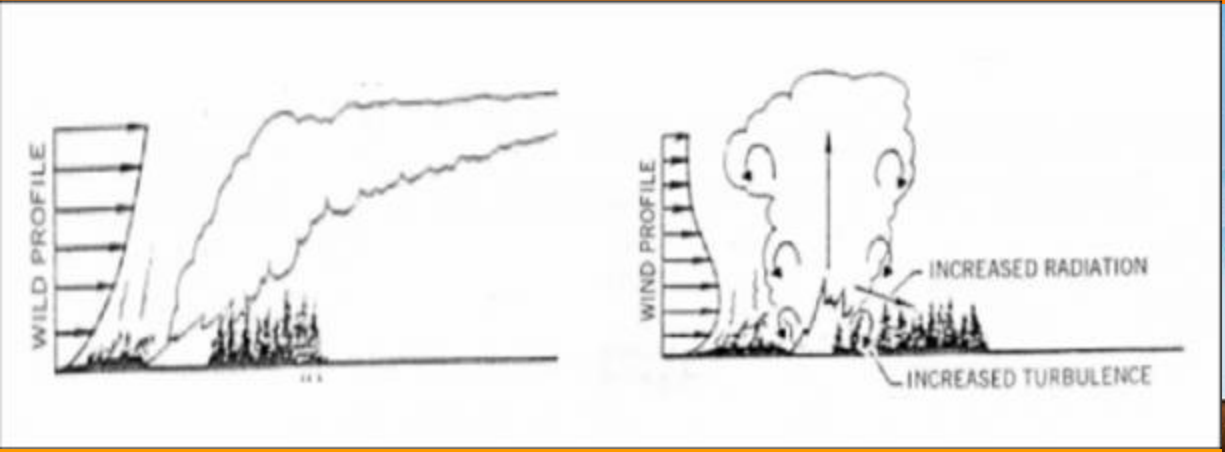
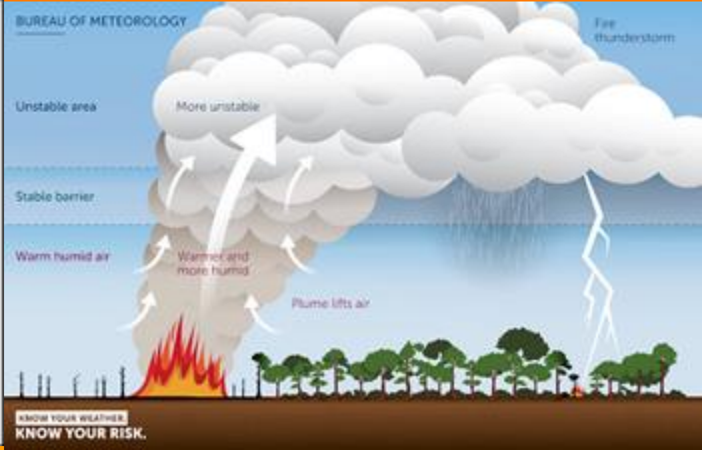
“Plume Dominated” vs “Wind Driven” events

- Prototypical fire regimes are often characterized by warm temperatures, low relative humidity, and strong boundary-layer winds. AKA “Hot Dry Windy”
- Low RH cures fuels by increasing the potential energy of a material. High winds bring oxygen and spread flames/sparks creating spot fires. Literally fanning the flames.
- Just like thunderstorms atmospheric instability can also drive fire weather. Hot dry and unstable conditions can be just as dangerous as hot dry and windy.
- Fires can create their own environment from strong buoyant updrafts collapsing and reforming.
- Plumes can loft embers for miles and create strong inflow/outflow winds on collapse leading to long range spotting, new fires, and rapid burnovers.



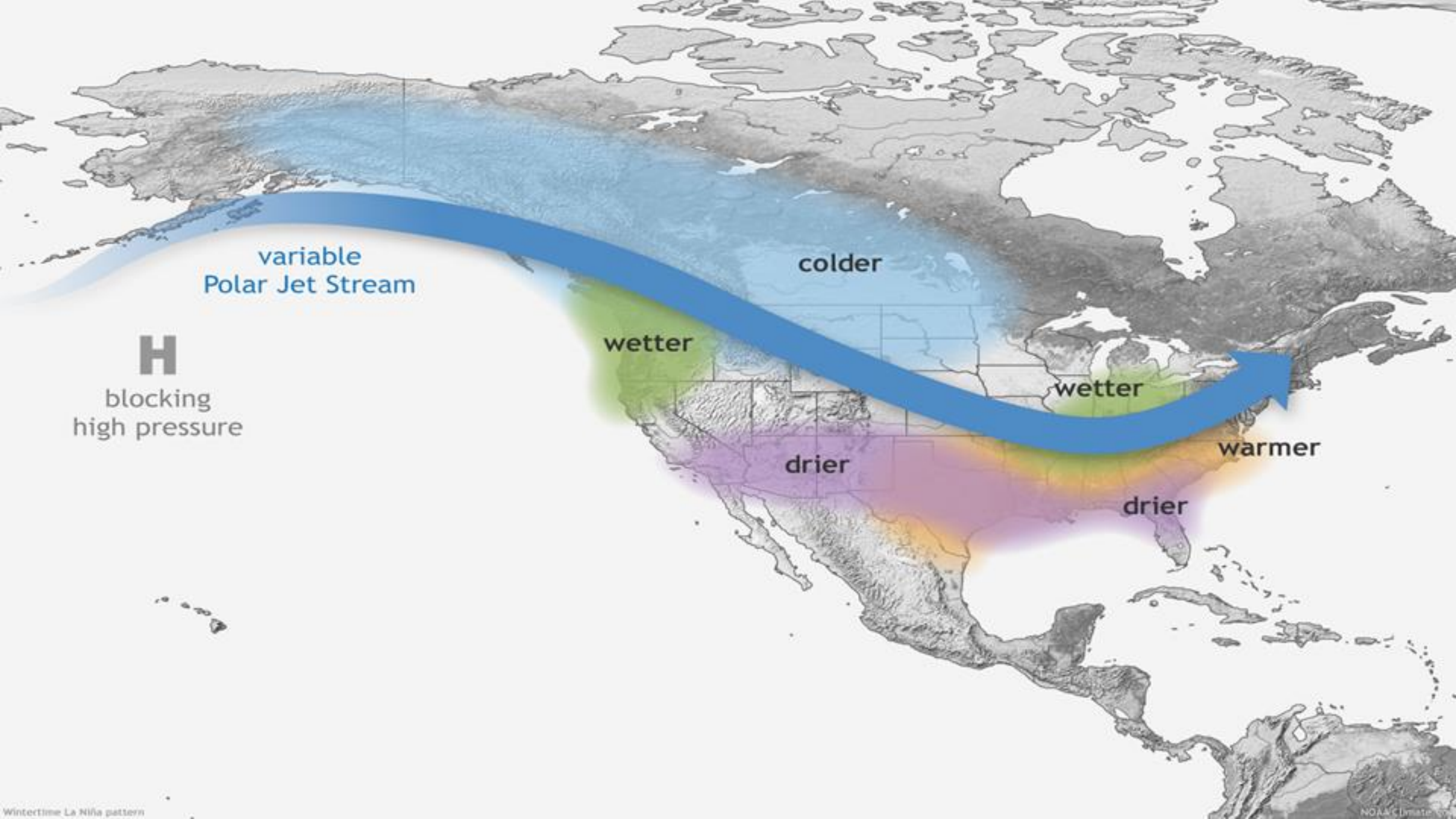


Pyro Cumulus

Other less common patterns

- In the northern plains, Great Lakes, and the northeastern US, pre-frontal high pressure from the Pacific, Northwestern Canada, and Hudson Bay all can produce very dry conditions. Cold fronts produce relatively short lived periods of high winds and instability that can produce extreme fire behavior.

- In the southeastern US, drought is frequently associated with the La Niña state of the southern oscillation pattern or a blocking ridge aloft near the Atlantic coast. Often critical weather patterns follow the frontal passage that brings extremely dry air due to a strong westerly or northwesterly flow. Look for strong winds that accompany the flow. Beware of advancing tropical storms as well as sea breeze boundaries across Florida.

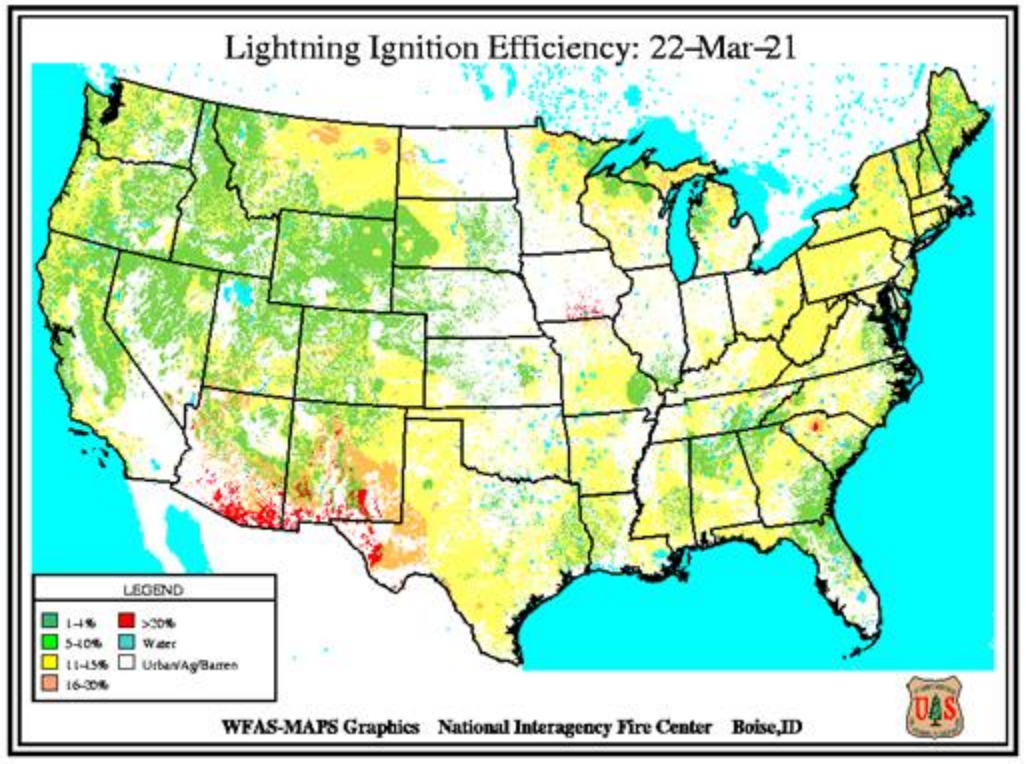

variable
Polar Jet Stream
H
blocking
high pressure
colder
wetter
wetter
drier
drier
warmer
Wintertime La Niña pattern

Dry Thunderstorms

- A fast moving or high based thunderstorm producing cloud to ground lightning and less than 0.10 inches of precipitation accumulation in 1 hour.

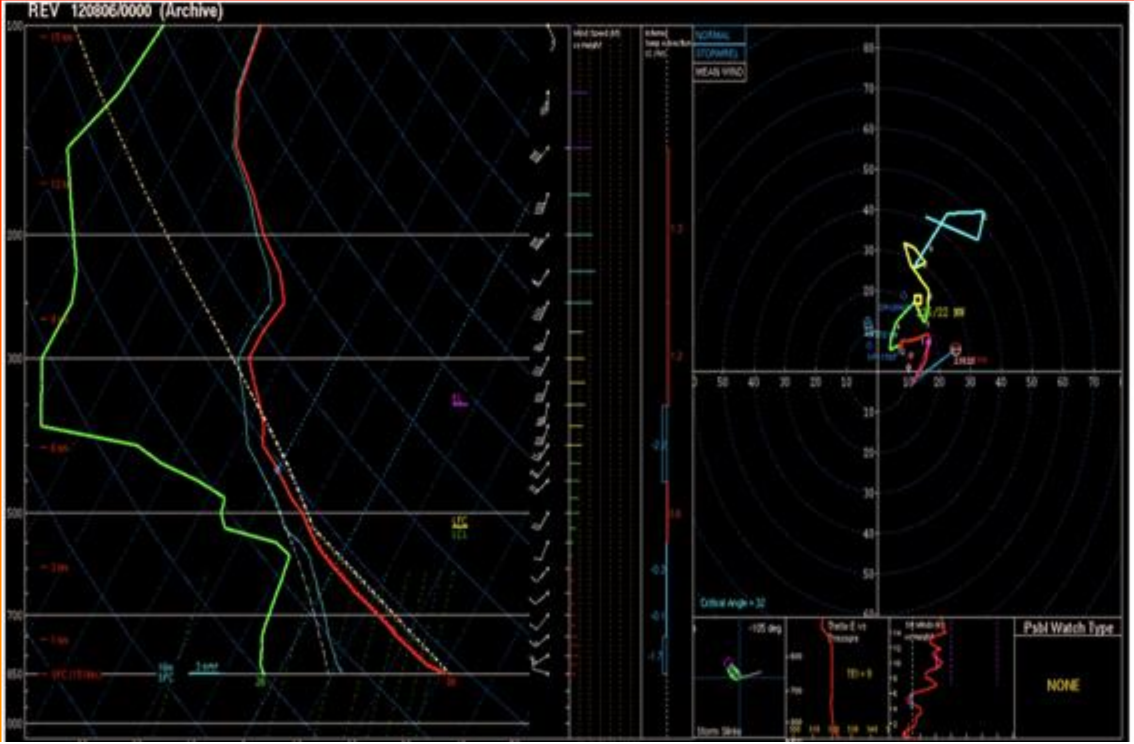
- Lightning ignitions account for a significant fraction of wildfires.

- Climate change suggests dry thunder/lightning ignition outbreaks may increase.



Dry Thunderstorms

- Deep and dry boundary layer. As much as 5-600 mb!
- Mid Level moisture advection results in destabilization. PW values of 0.5 to 0.75 inches most common
- Low CAPE and low shear (storms move slowly)
- Mixed storm modes most frequent

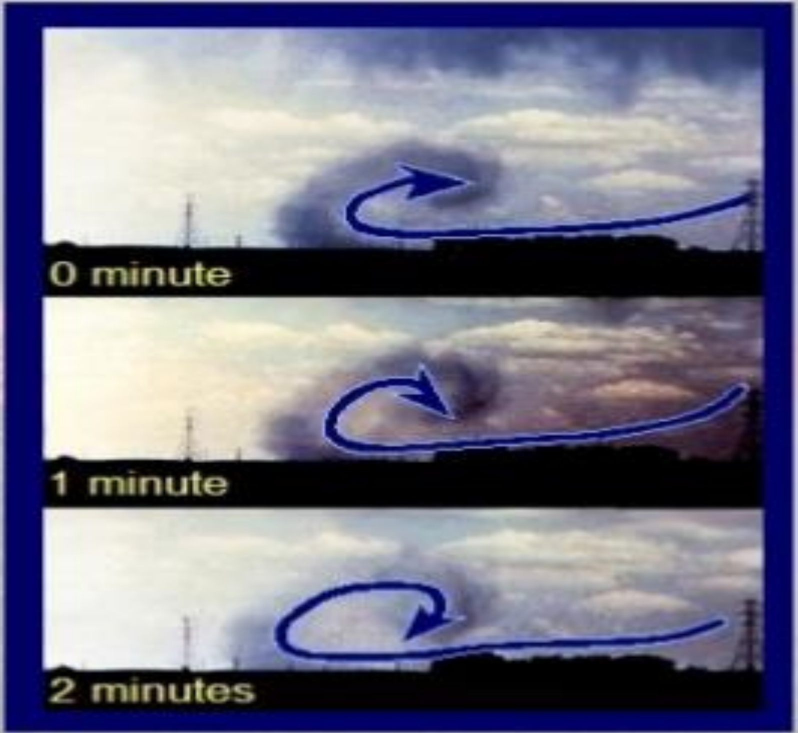


Thunderstorm Mode	Precipitation Amounts (in.)	Characteristic PW Values (in.)
Dry	0.00-0.10	0.50-0.75
Mixed Wet-Dry	0.10-0.20	0.75-1.00
Wet	>0.20	>1.00

Critical Winds
Thunderstorm Winds

Gust Front

- Leading edge of the downdraft
- Boundary between two dissimilar air masses, similar to a cold front
- Most of the time, marked by a wind shift, decrease in temperature and increase in RH



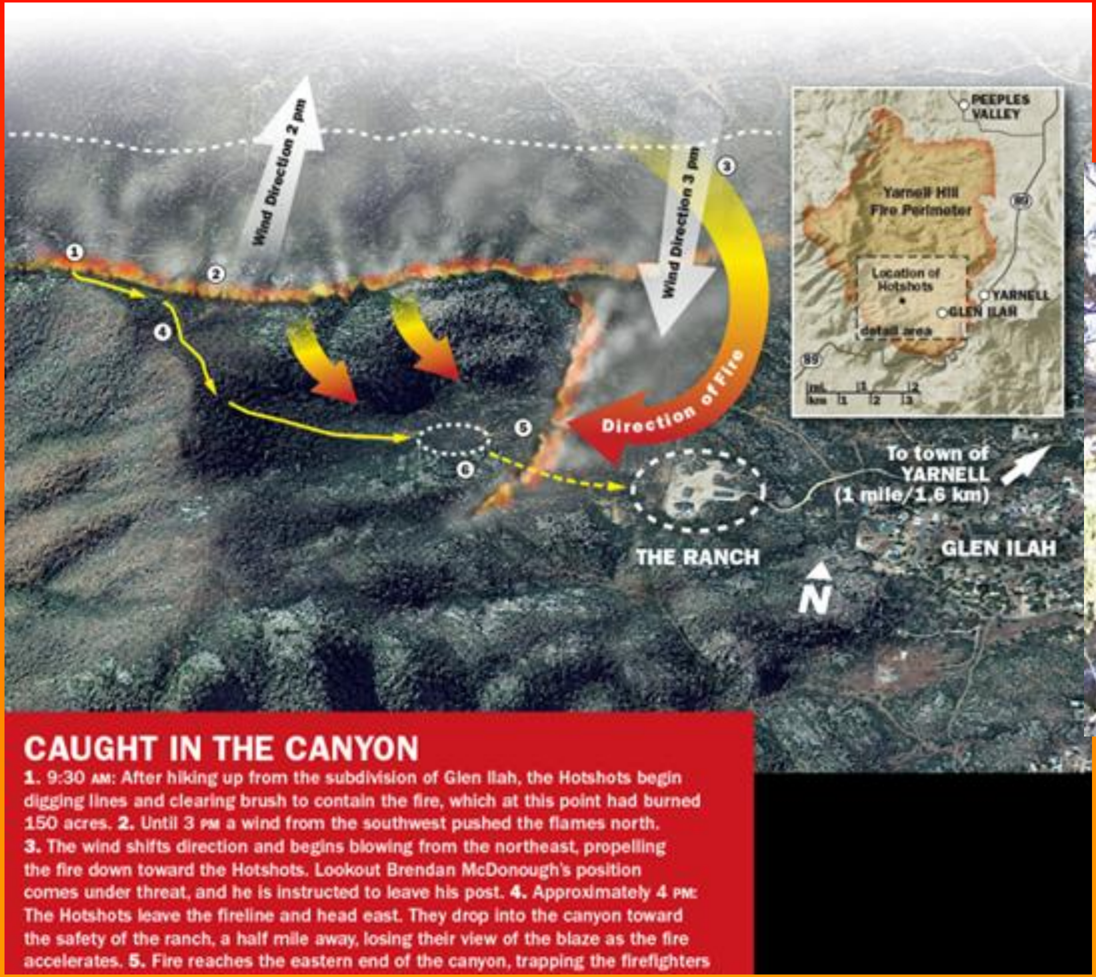
Critical Winds
Thunderstorm Winds

Outflow Winds

- Outflow wind strongest in the direction the storm is moving

- Outflow wind weakest in the opposite direction the storm is moving

Yarnell Hill Fire
June 30, 2013



- Ignited by dry lightning
- Erratic behavior on June 30th due to outflow winds

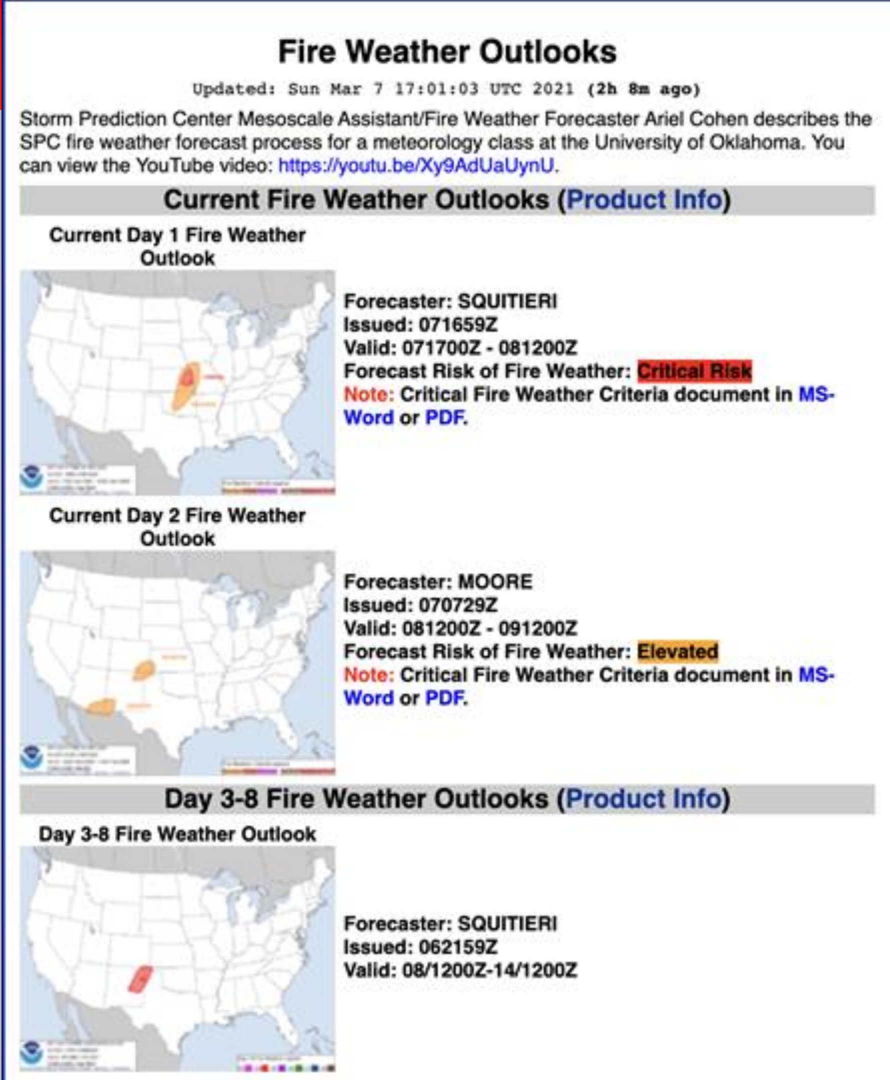
SPC Fire Products

Fire Weather Outlooks

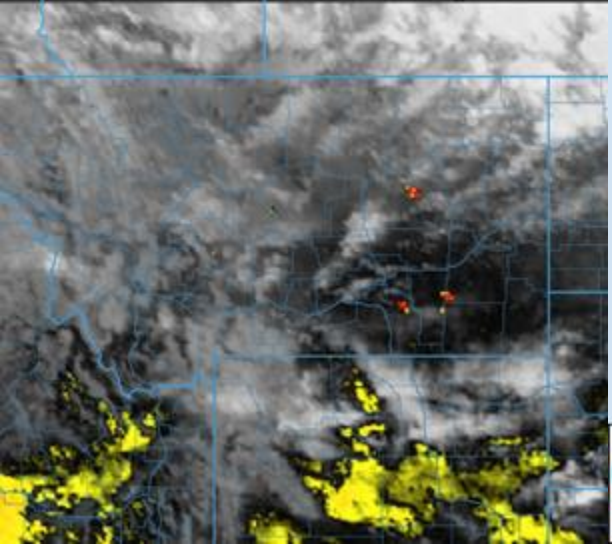
The Fire Weather Outlooks are intended to delineate areas of the continental U.S. where pre-existing fuel conditions, combined with forecast weather conditions during the next 8 days, will result in a significant threat for the ignition and/or spread of wildfires. This product is designed for use in the NWS, as well as other federal, state, and local government agencies.

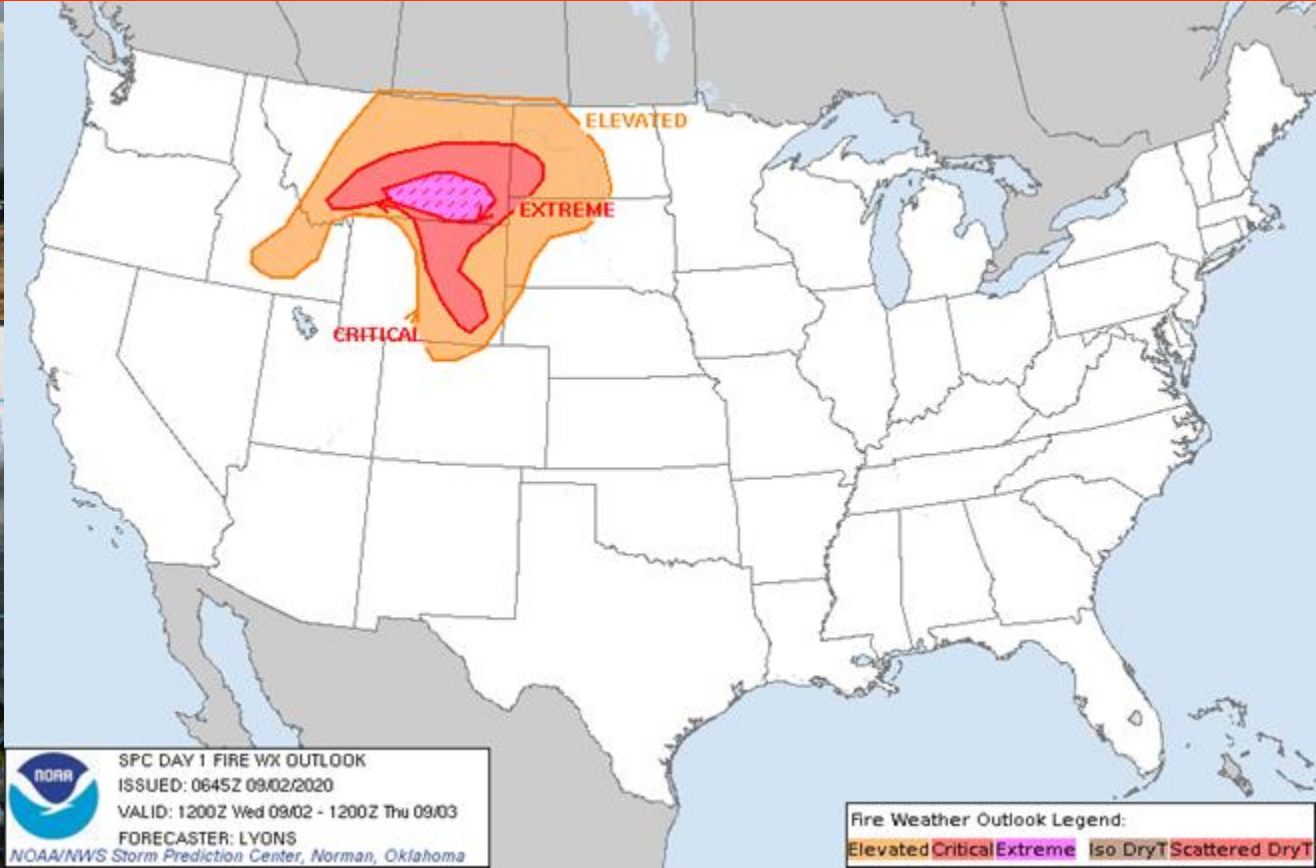
Each outlook consists of a categorical forecast that graphically depicts fire weather risk areas across the continental United States, along with a text narrative. Through various labels and colors on the graphic, the five types of Fire Weather Outlook risk areas are:

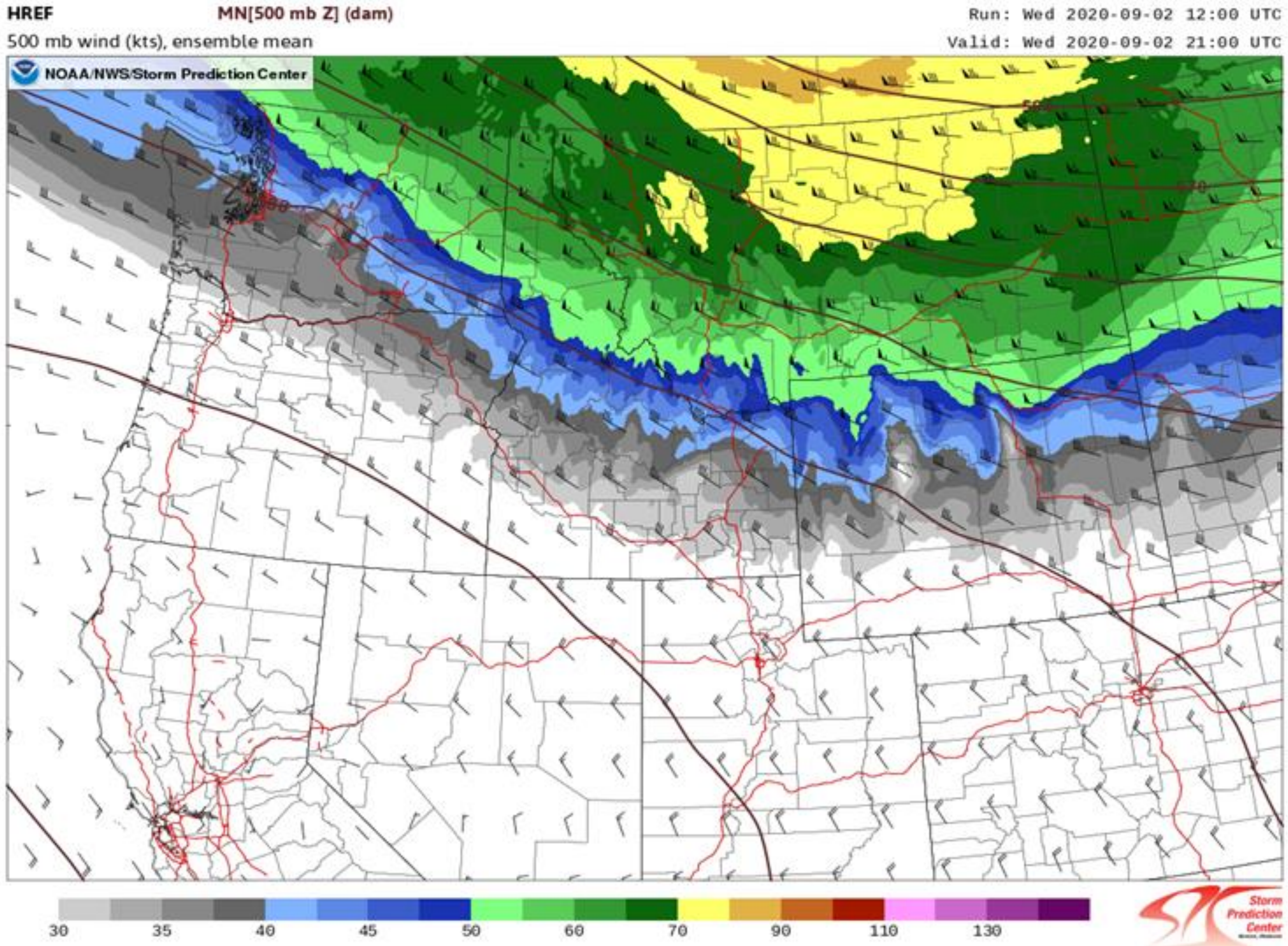
- **ELEVATED** (orange) - Elevated risk from wind and relative humidity
- **CRITICAL** (red) - Critical risk from wind and relative humidity
- **EXTREME** (magenta) - Extremely Critical risk from wind and relative humidity
- **ISODRYT** (brown) - Elevated risk from dry thunderstorms
- **SCTDRYT** (red) - Critical risk from dry thunderstorms

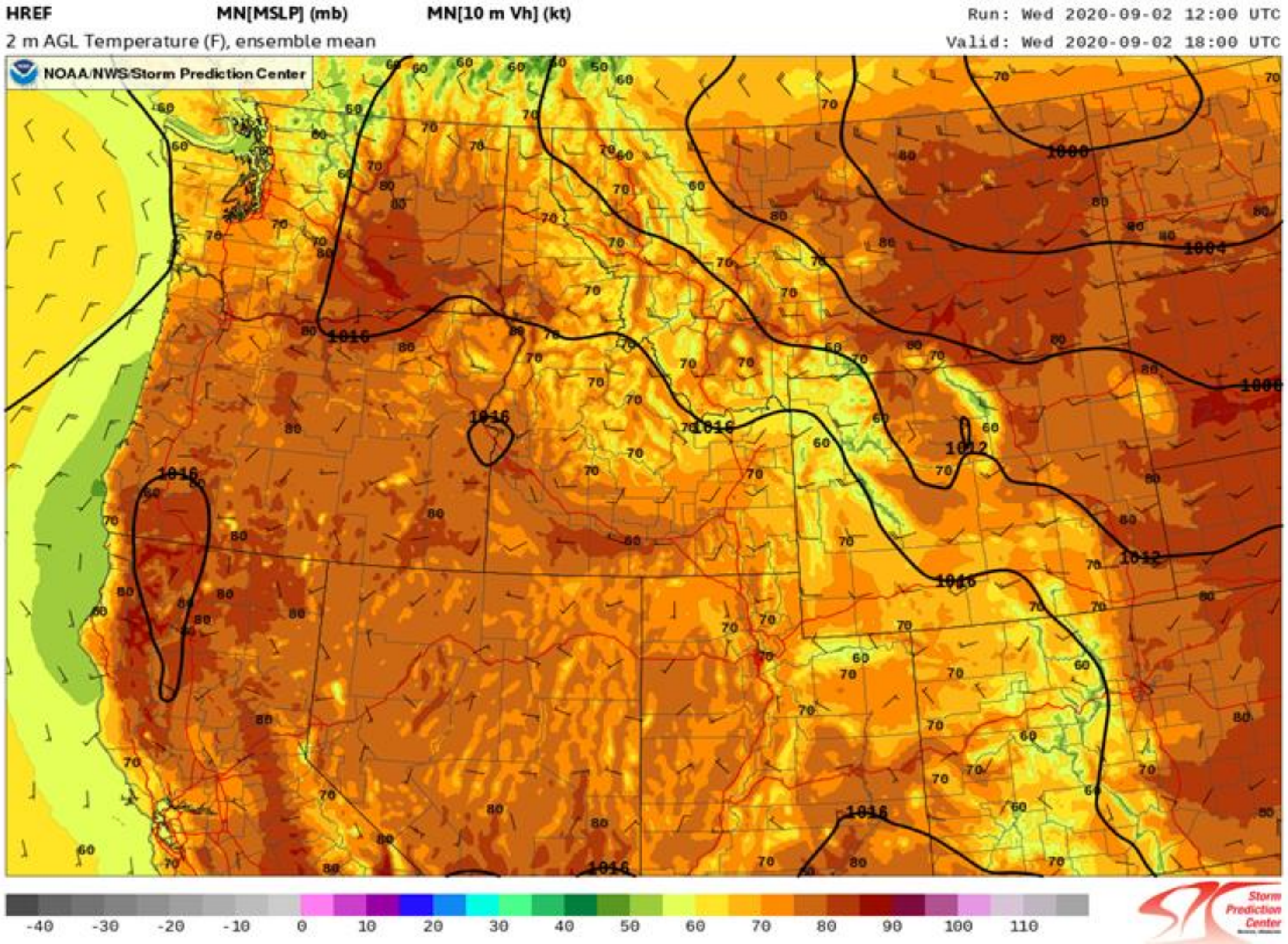


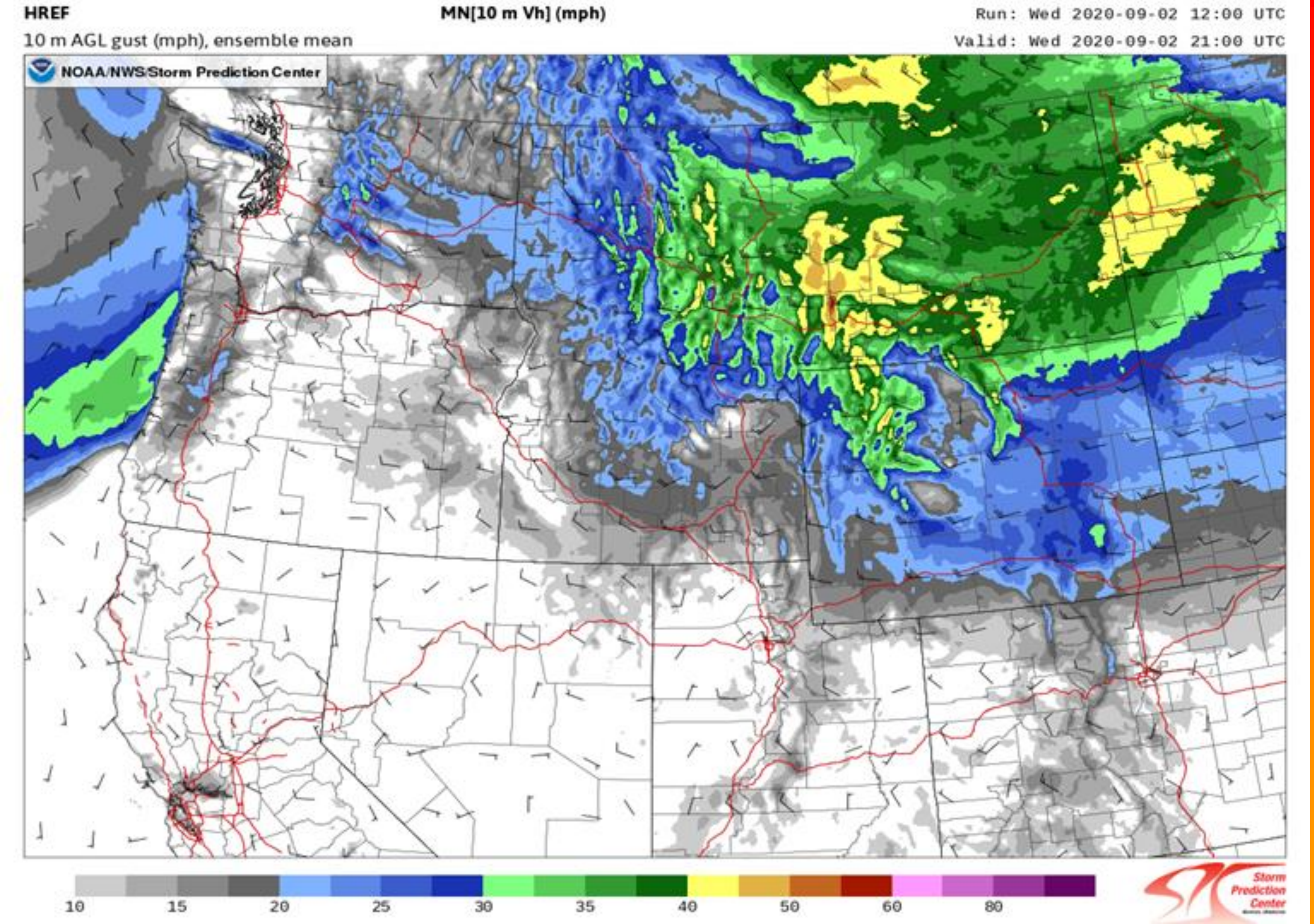
September 2nd 2020 Montana fire outbreak

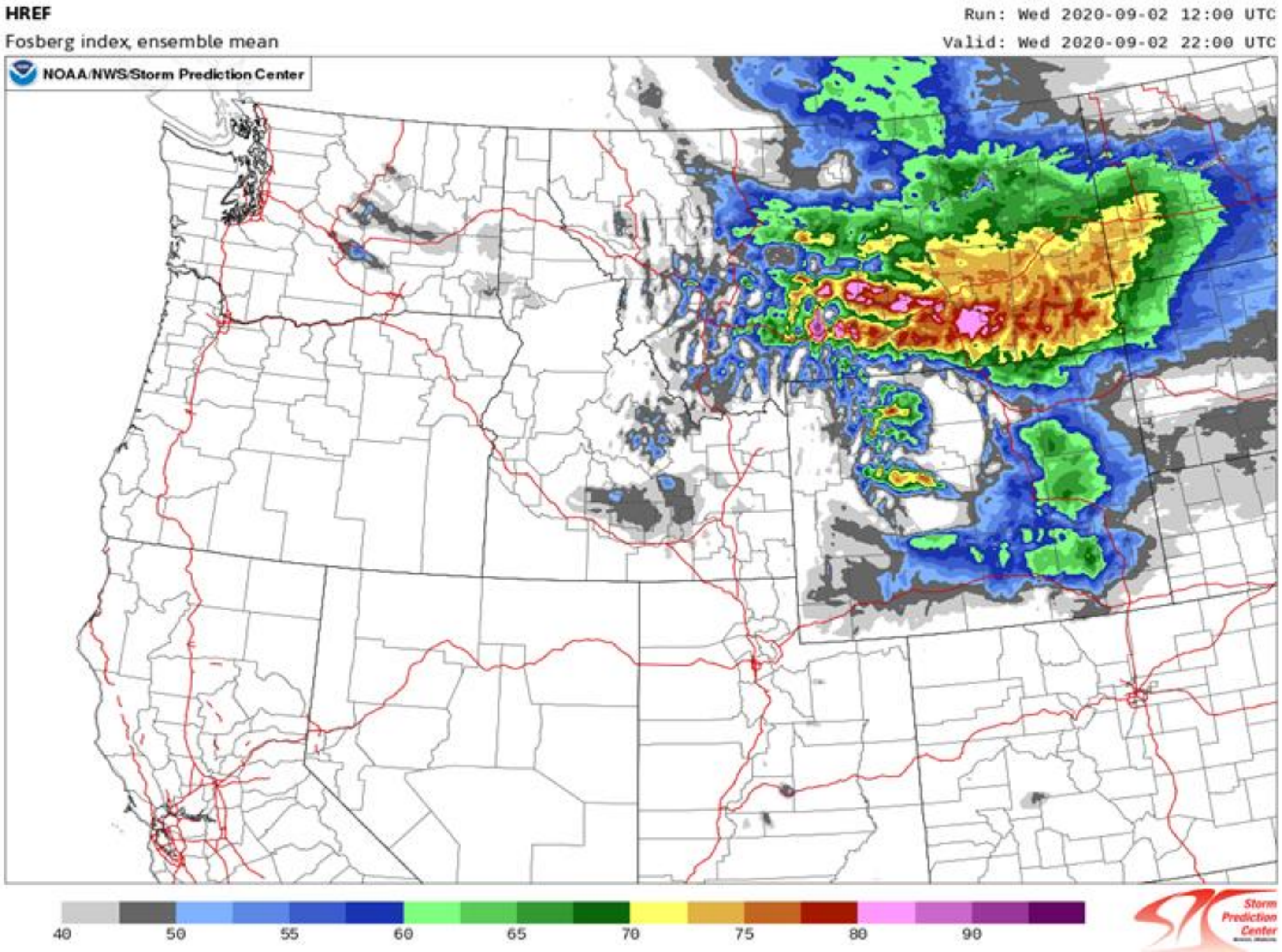




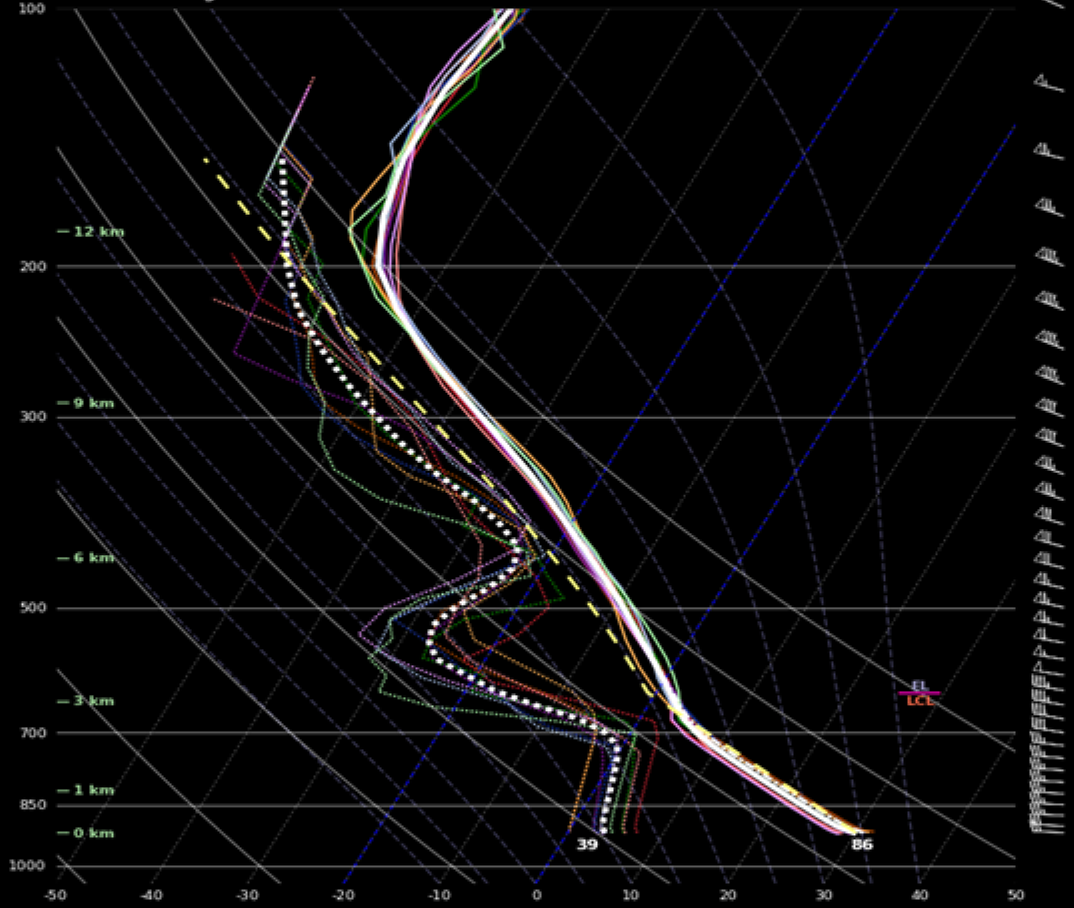

HREF
MN[500 mb Z] (dam)
Run: Wed 2020-09-02 12:00 UTC
500 mb wind (kts), ensemble mean
Valid: Wed 2020-09-02 21:00 UTC
NOAA/NWS/Storm Prediction Center
30
35
40
45
50
60
70
90
110
130
Storm Prediction Center


HREF
MN[MSLP] (mb)
MN[10 m Vh] (kt)
Run: Wed 2020-09-02 12:00 UTC
2 m AGL Temperature (F), ensemble mean
Valid: Wed 2020-09-02 18:00 UTC
NOAA/NWS/Storm Prediction Center
-40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110
Storm Prediction Center


HREF
MN[10 m Vh] (mph)
Run: Wed 2020-09-02 12:00 UTC
10 m AGL gust (mph), ensemble mean
Valid: Wed 2020-09-02 21:00 UTC
NOAA/NWS/Storm Prediction Center
10
15
20
25
30
35
40
50
60
80
Storm Prediction Center


HREF
Fosberg index, ensemble mean
Run: Wed 2020-09-02 12:00 UTC
Valid: Wed 2020-09-02 22:00 UTC
NOAA/NWS/Storm Prediction Center
40
50
55
60
65
70
75
80
90
Storm Prediction Center

HREF Sounding at KMLS   Init: 2020-09-02 1200 UTC   Valid: 2020-09-02 2000 UTC

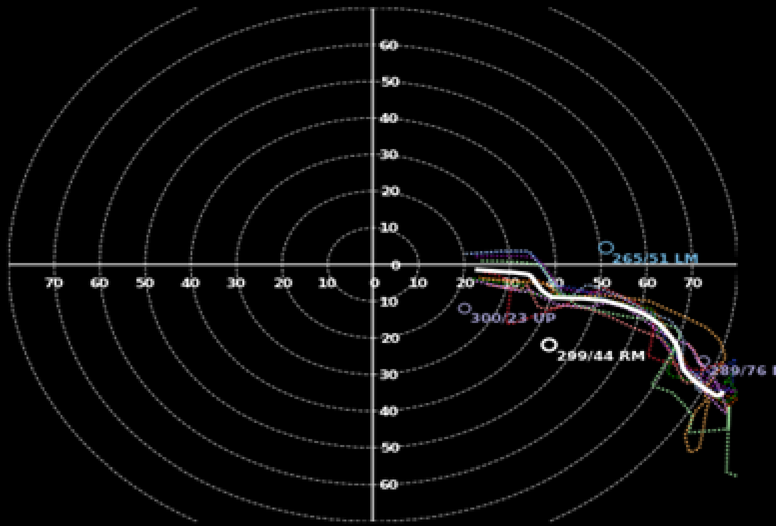


Parcel	CAPE	CINH	LCL (m)	LI	LFC (m)	EL (m)
SFC	0.0	0	3205	3	--	3205
ML	0.0	0	3172	3	--	3172
MU	0.0	0	3205	3	--	3205

LR (C/km) 700-500: 5.9 | 0-3km: 7.4 | 3-6km: 6.0

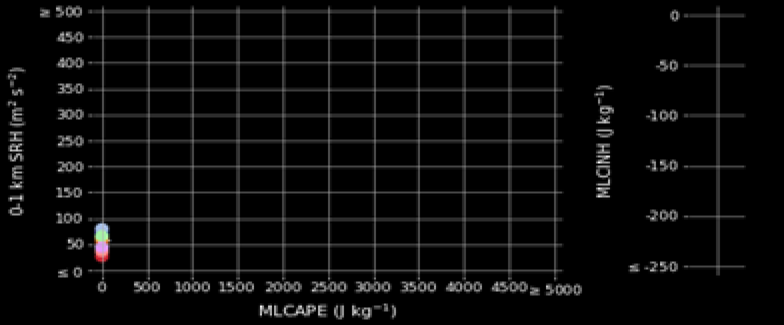
	SRH ($m^2 s^{-2}$)	Shear (kt)	MnWind	SRW
SFC-1 km	55	11	274/32	161/21
SFC-3 km	88	22	277/35	167/18
SFC-6 km	--	48	280/43	194/15
Eff Inflow Layer	--	--	---/--	---/--

Sounding Powered by SHARPpy



Ensemble member legend

HRRR	HRW NSSL	HRW ARW	HRW NMMB	NAM Nest
HRRR -6h	HRW NSSL -12h	HRW ARW -12h	HRW NMMB -12h	NAM Nest -12h



Wrap Up

- **Fire weather can be thought of in an ingredients based framework.**
- **Fuels are one of the most important but difficult aspects of forecasting.**
- **Forecasting should follow a similar flow to severe weather.**
  - **Big Picture**
    - **Narrow your focus**
      - **The details**
- **Fire weather regimes vary widely across the CONUS.**
- **Fire weather is one of the most difficult and poorly understood aspects of severe weather forecasting.**