Meteorology and weather associated with extreme wildfires in coastal California

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Loma Fire, 9/26/16

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7 May 2018
Sonoma State University

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Presentation Overview

- Fire weather basics
- Nocturnal Drying Events
- Diablo Winds
- Observations of Plume Dynamics

What is Fire Weather?

Hot, Dry, and Windy Weather!

AMS (American Meteorological Soc.) Glossary:

fire weather—Weather variables, especially wind, temperature, relative humidity, and precipitation, that influence fire starts, fire behavior, or fire suppression.

What is Fire Weather?

Hot, Dry, and Windy Weather!

These conditions are summed in the NWS Red Flag Warning!

Red Flag Guidance/Verification Matrix

The matrix below assume 10-hour fuel moisture of less than 6%, annual grasses are cured, and no wetting rain (greater than 0.10 inch) has fallen in the past 24 hours.

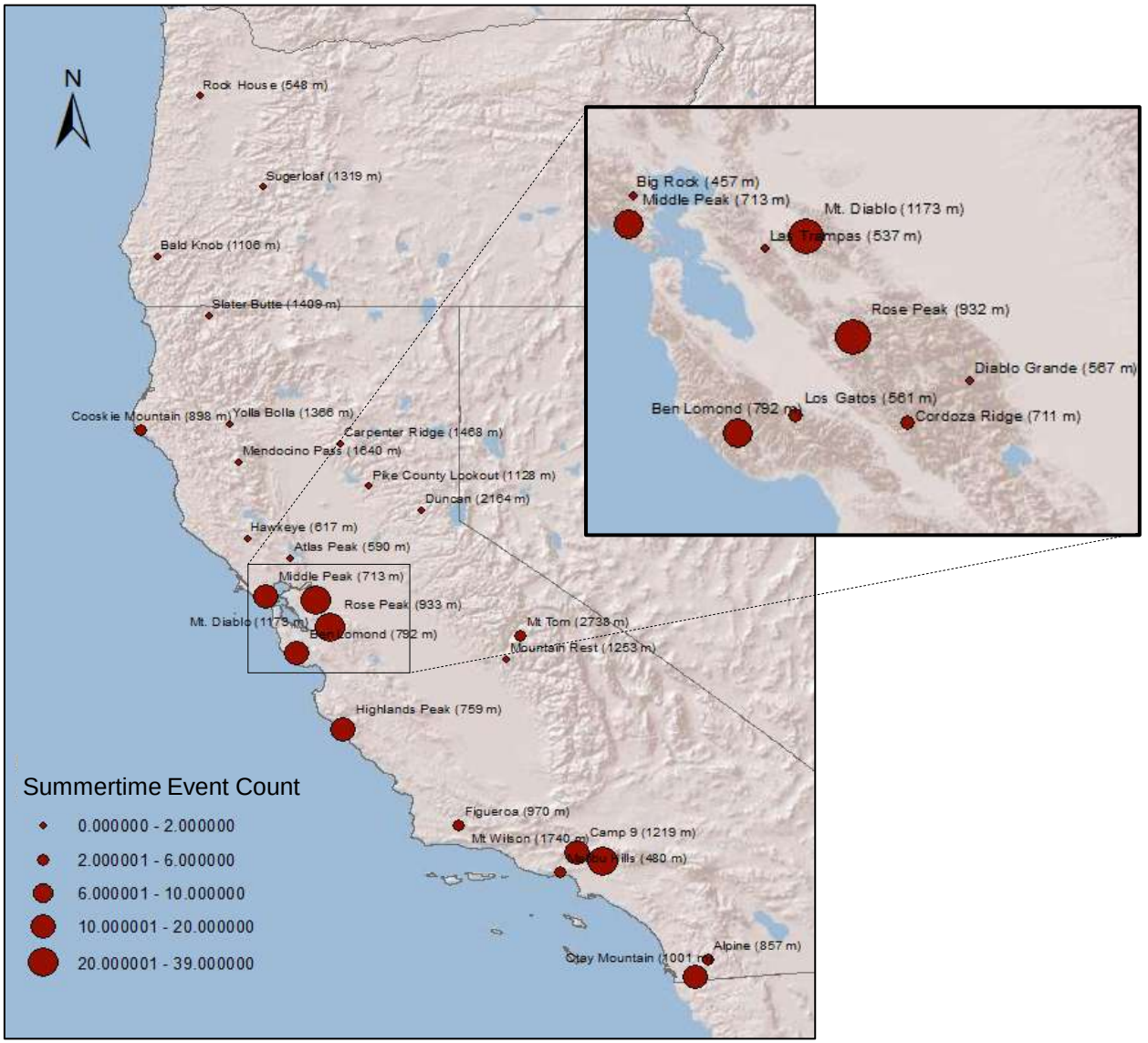
Relative Humidity	Sustained 20 foot Wind Speed (Note: the wind event should be expected to last at least 8 hours)			
	Sustained Wind 6-11 mph	Sustained Wind 12-20 mph	Sustained Wind 21-29 mph	Sustained Wind 30+ mph
Day MIN 29-42% Ngt MAX 61-80%				RED FLAG WARNING
Day MIN 19-28% Ngt MAX 46-60%			RED FLAG WARNING	RED FLAG WARNING
Day MIN 9-18% Ngt MAX 30-45%		RED FLAG WARNING	RED FLAG WARNING	RED FLAG WARNING
Day MIN < 9% Ngt MAX < 30%	RED FLAG WARNING	RED FLAG WARNING	RED FLAG WARNING	RED FLAG WARNING

Nocturnal Drying Events

- A **nocturnal drying event (NDE)** is a weather situation that occurs at night in elevated terrain in Coastal California.
- These events are associated with the onset of extremely dry air (RH < 10%) at nighttime.

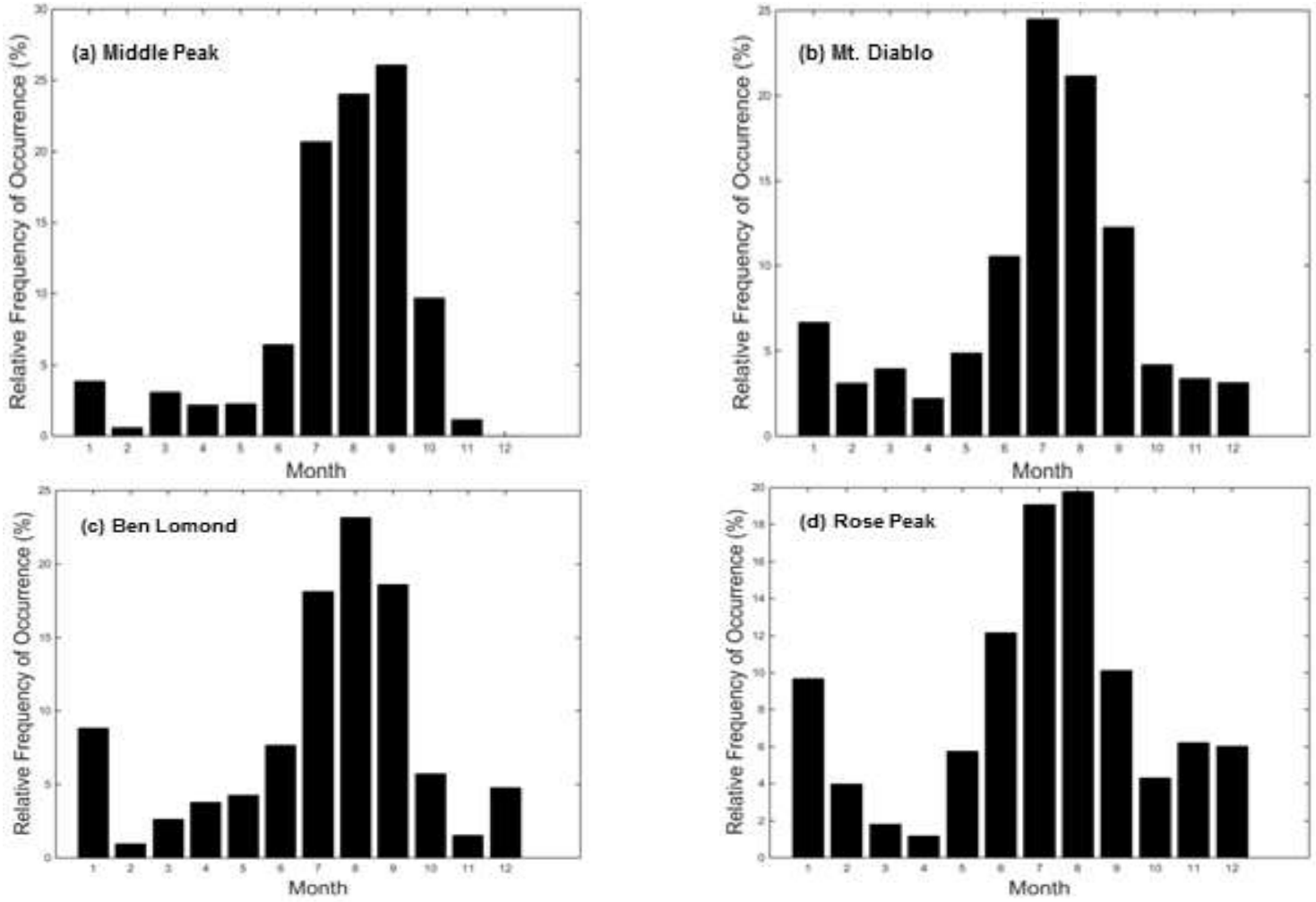
Where do Nocturnal Drying Events occur?

- Most common in Coastal regions in Central California.
- Elevations above 700 m (2,300 ft)
- Do not occur in the Sierra Nevada.



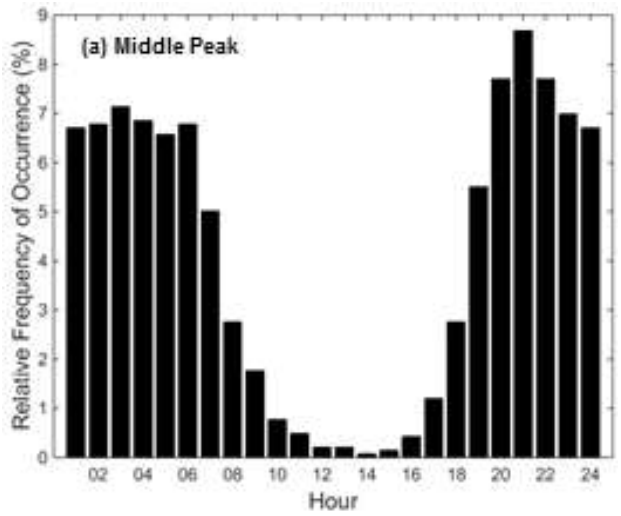
When do Nocturnal Drying Events happen?

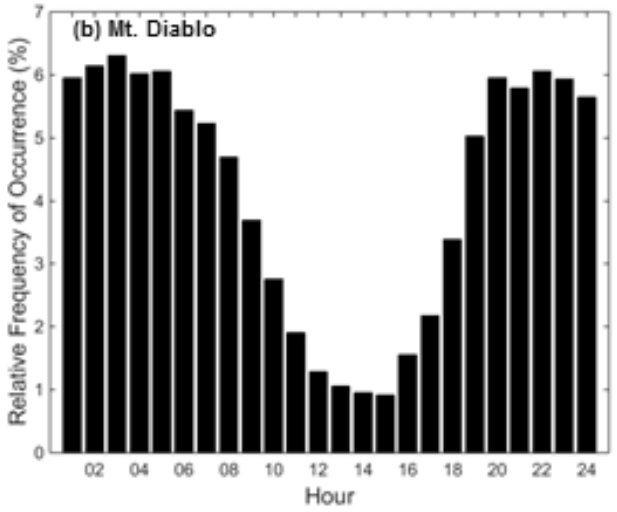
Monthly Average Frequency of Occurrence from RAWS

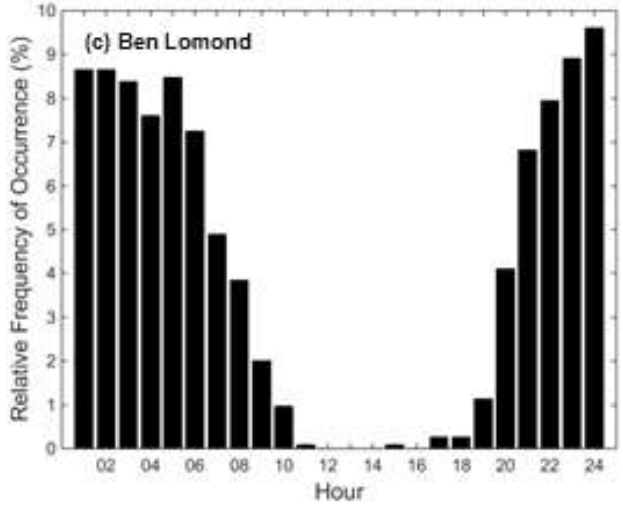


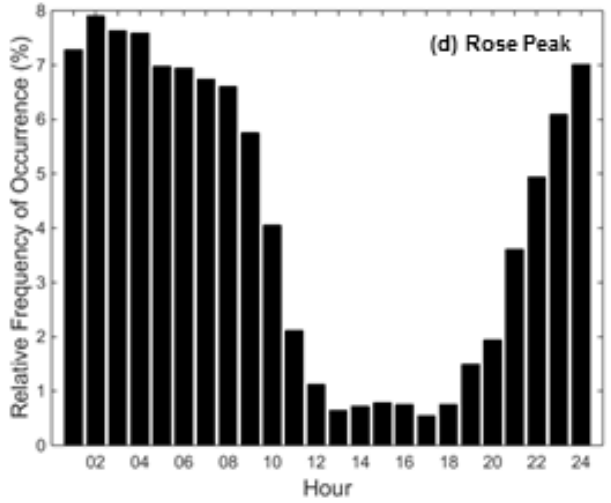
What time of day do NDEs occur?

Hourly Average Frequency of Occurrence from RAWS







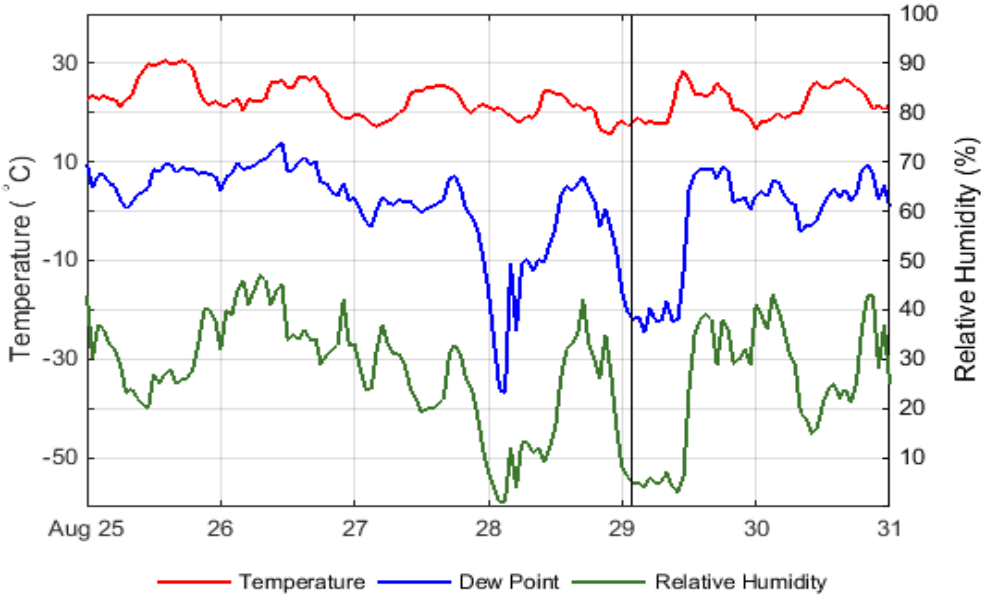


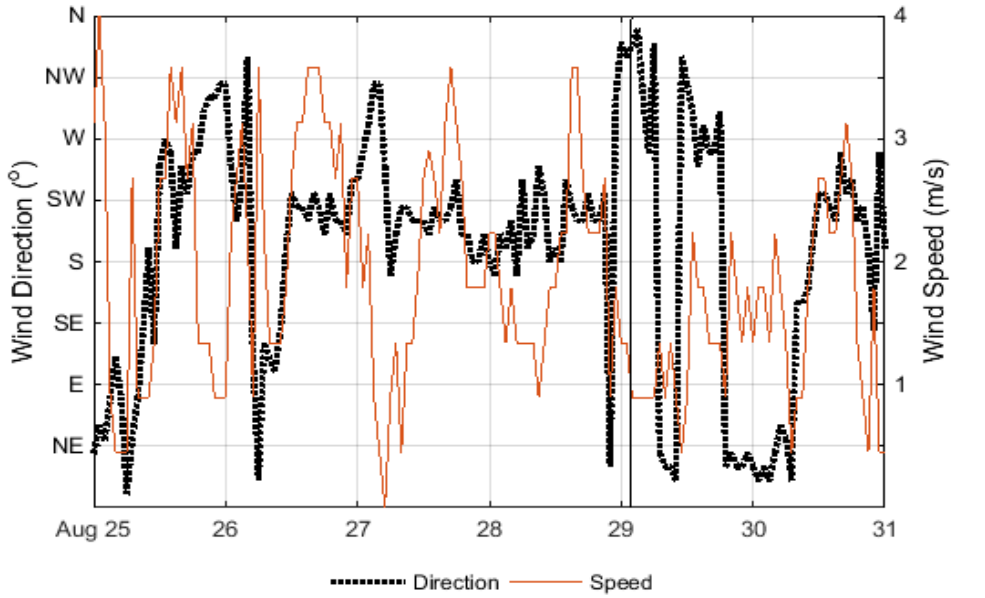
Devil Fire, August 29, 2003

Diablo Range, East of San Jose

2nd largest fire shelter deployment in US history.

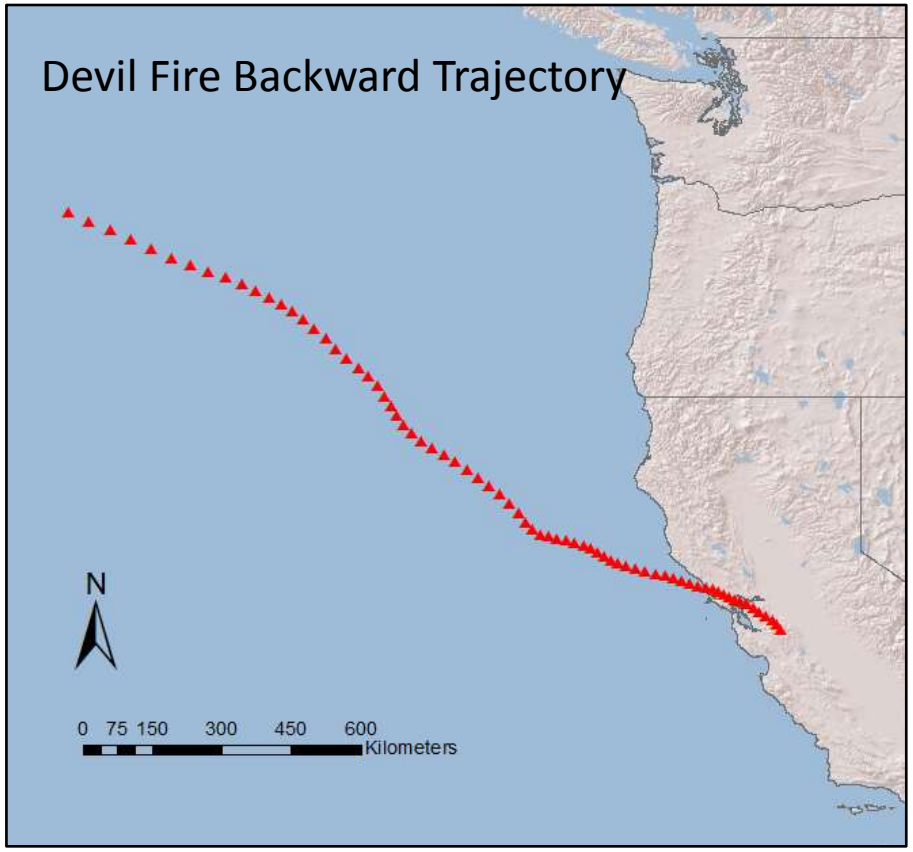
- Nighttime humidity drops to single digits in 3 hours.
- Winds are from northwest, but weak.

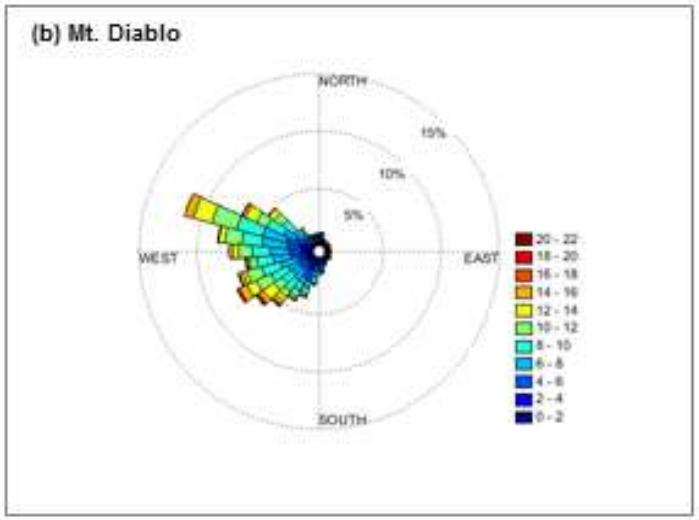


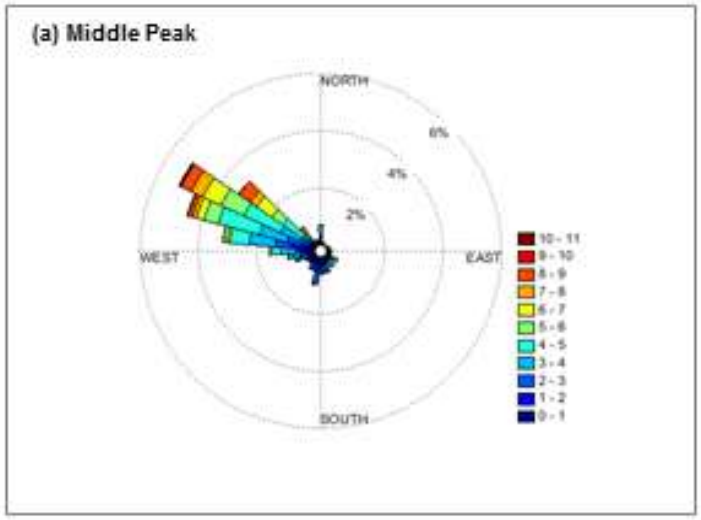


What are the winds during NDE?

Wind directions are Northwesterly

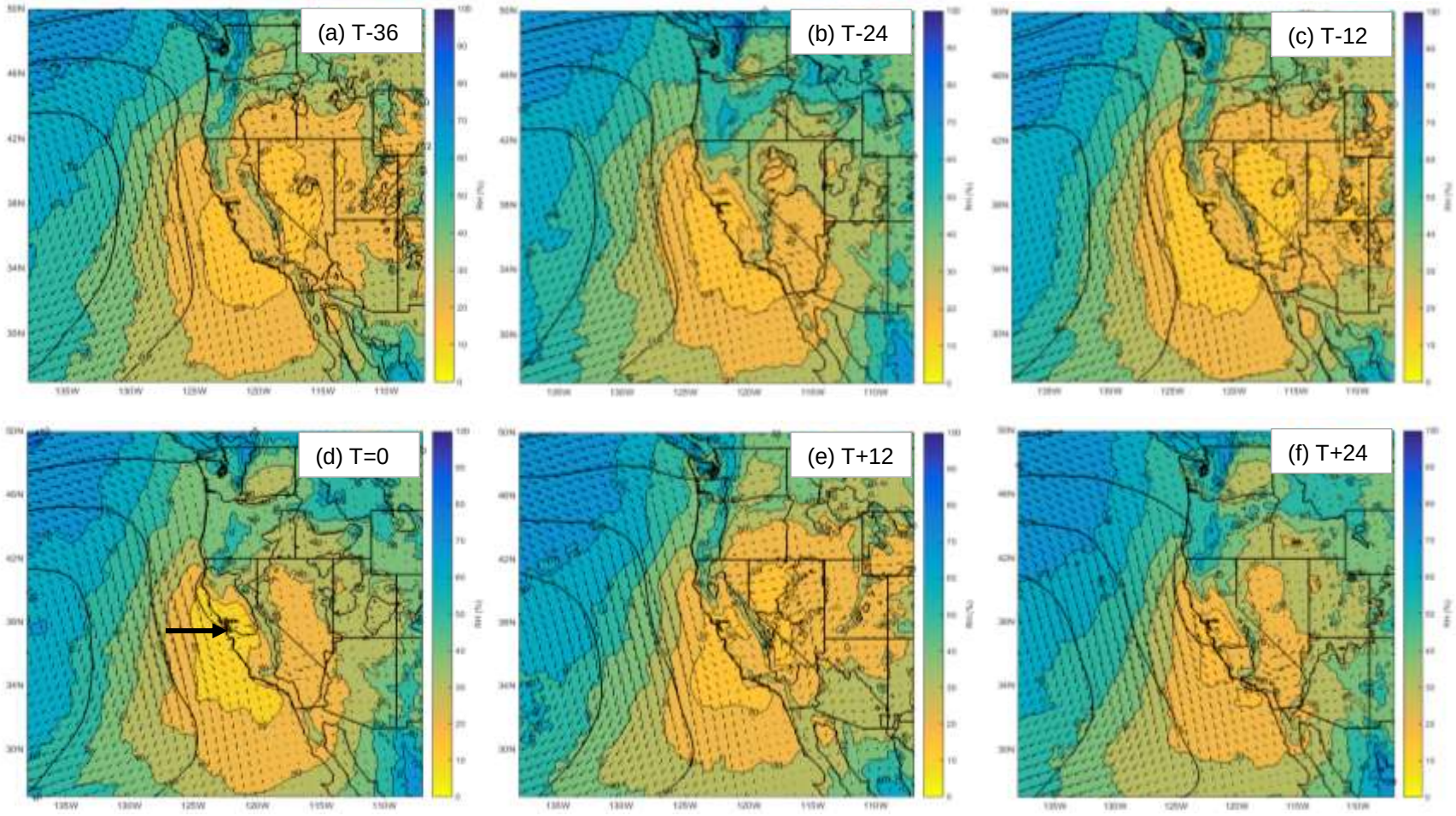






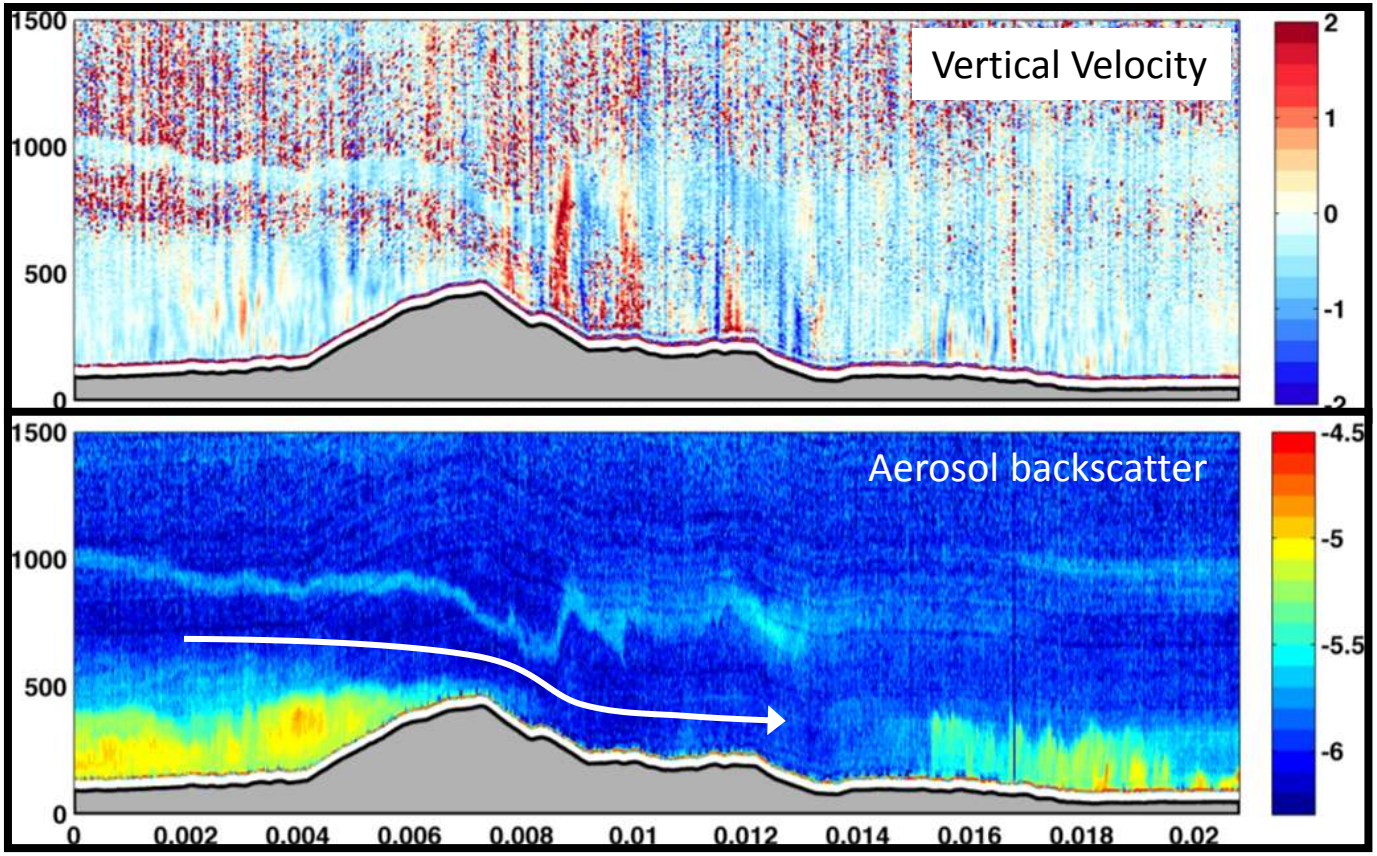
Very dry air off the California coast

Relative Humidity at 850 mb (~5,000 ft)



Dry air above the marine layer

Dry air off shore and above marine layer flows in with marine surge.



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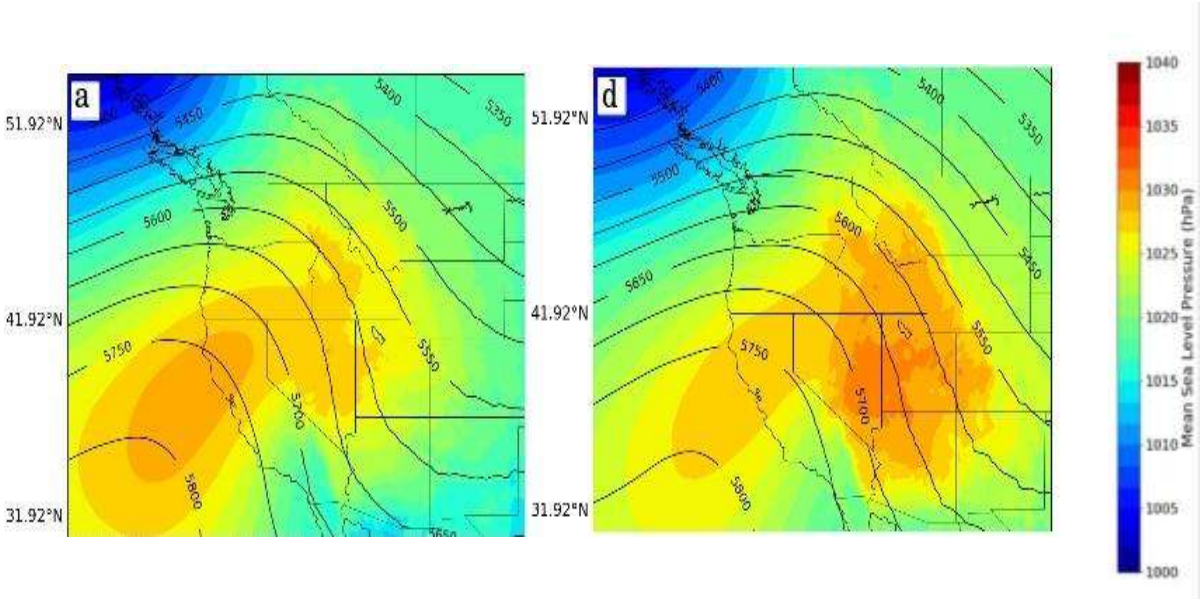
Diablo Winds: Northern California's 'Santa Ana'

Tunnel Fire / Oakland Hills Fire

- 20 October 1991
- One of most destructive fires in US history
- 25 fatalities
- 3100 homes destroyed
- Only 1500 acres burned.

What causes Diablo Winds?

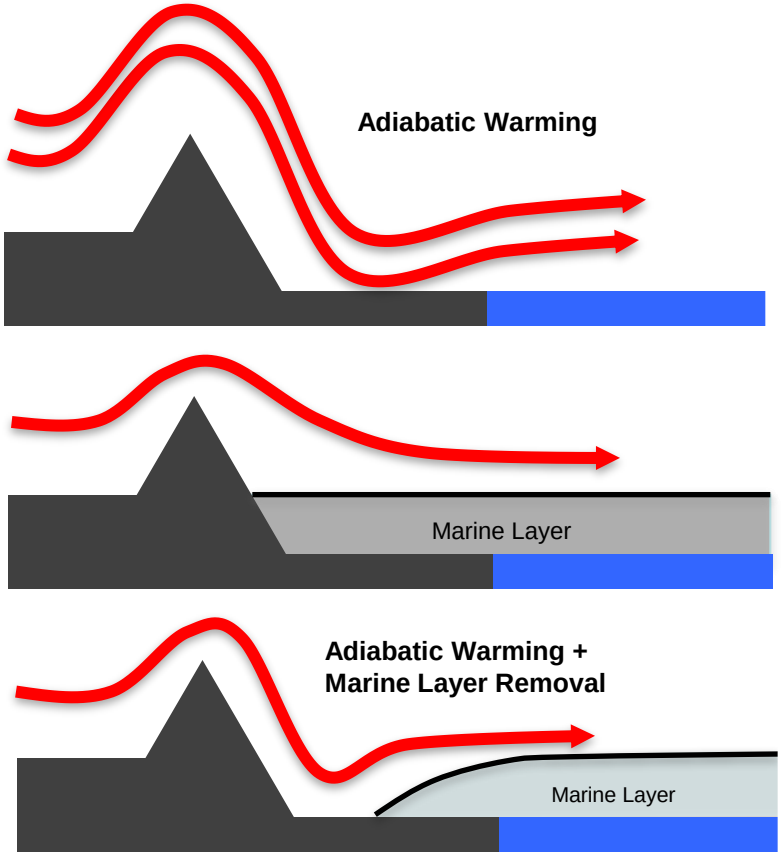
- Pressure gradient from Nevada to lower pressure off California Coast.
- Pressure gradient direction varies in alignment which favors either east bay or north bay areas.
- Flow accelerates over a mountain range.



Downslope Winds: Flow over a Mountain

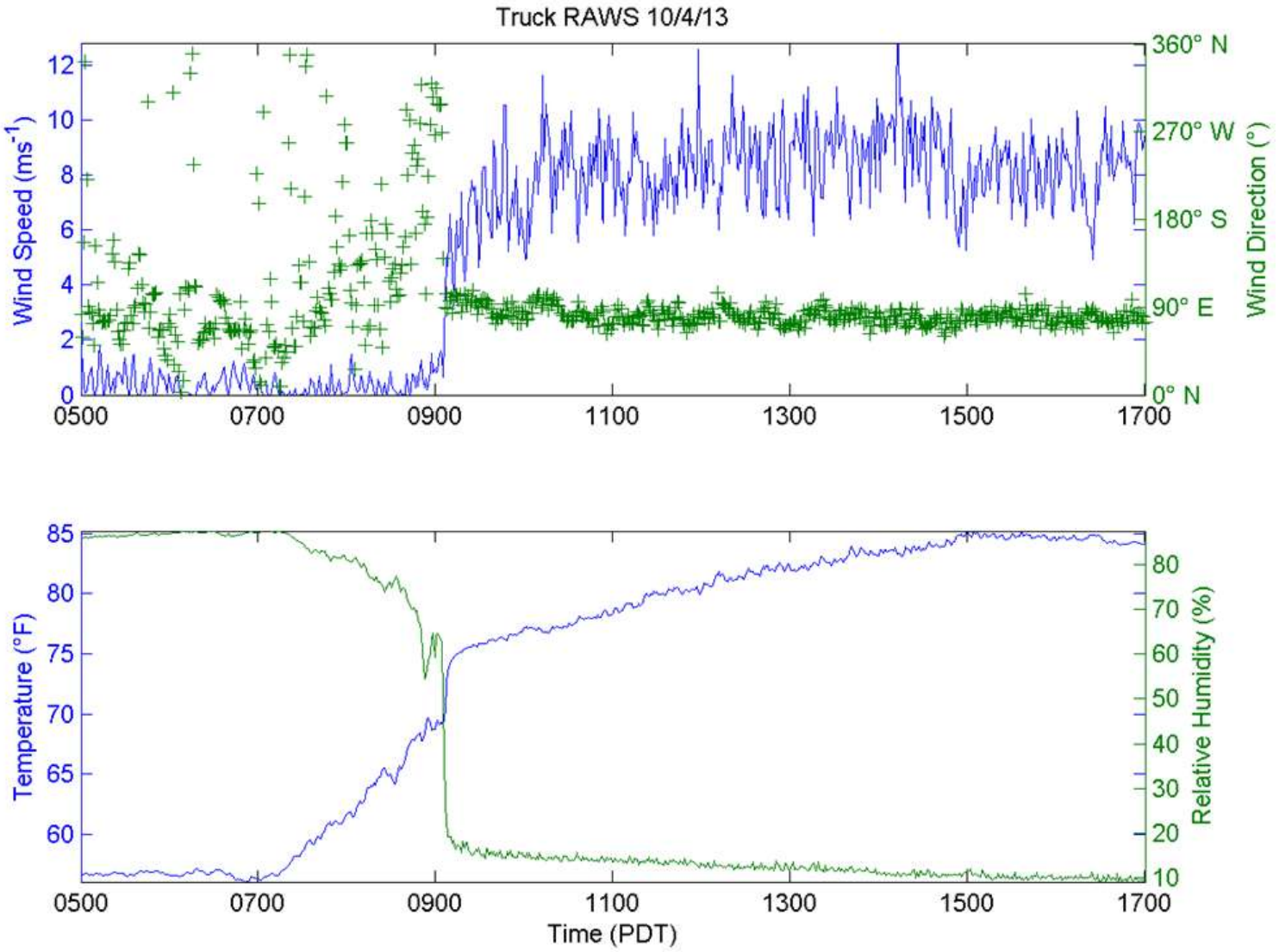
What Causes the Warming and Drying?

- Down Slope Flow:
  - Causes adiabatic warming (5.5 °F/1000 ft.)
  - Warming causes a reduction in *relative humidity*
- Marine Layer Removal
  - Strong winds **erode** and **displace** the cool and moist marine layer
    - Sharp reduction in dew point (and *relative humidity)*
    - Rapid change in surface temperature
    - Wind Reversal



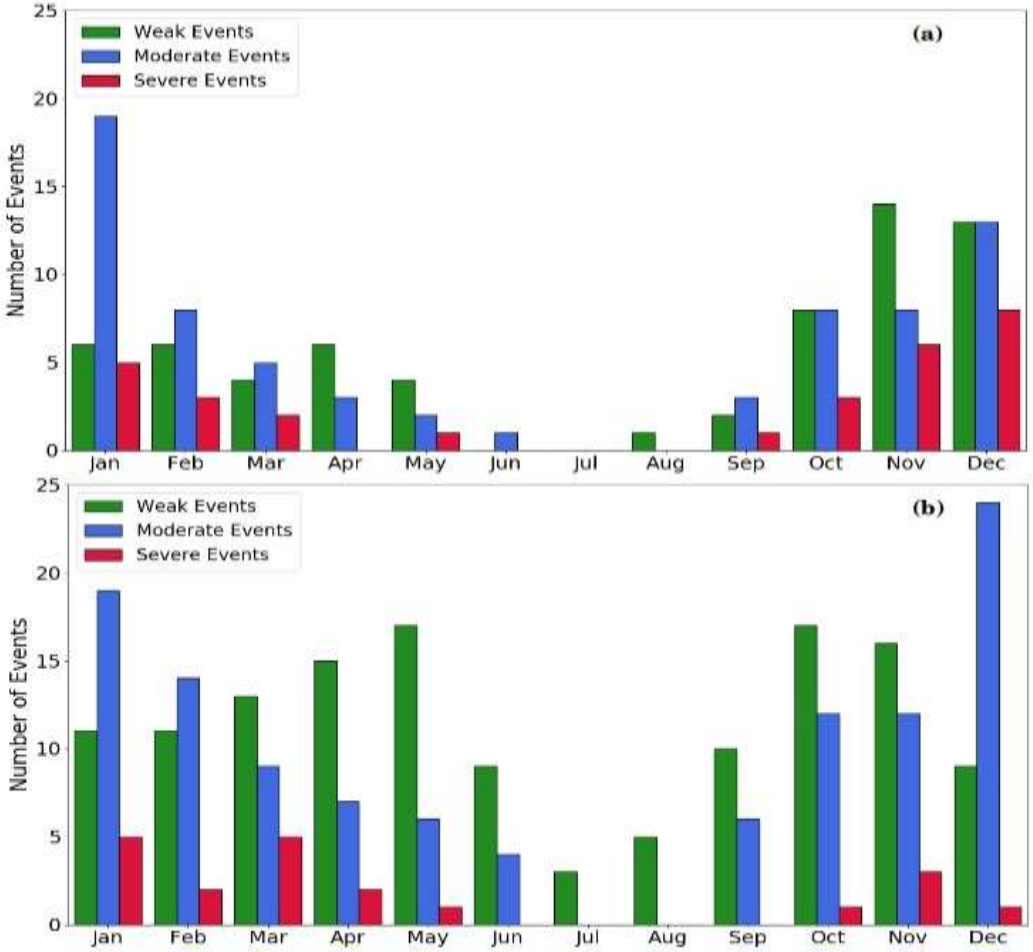
Rapid Onset of Downslope Wind Events

Santa Ana wind, Oxnard



Diablo Wind Definition

Sustained winds of 13 MPH or greater from the northeast quadrant (0-90 degrees), persisting 6 consecutive hours or more.



Severity of Events

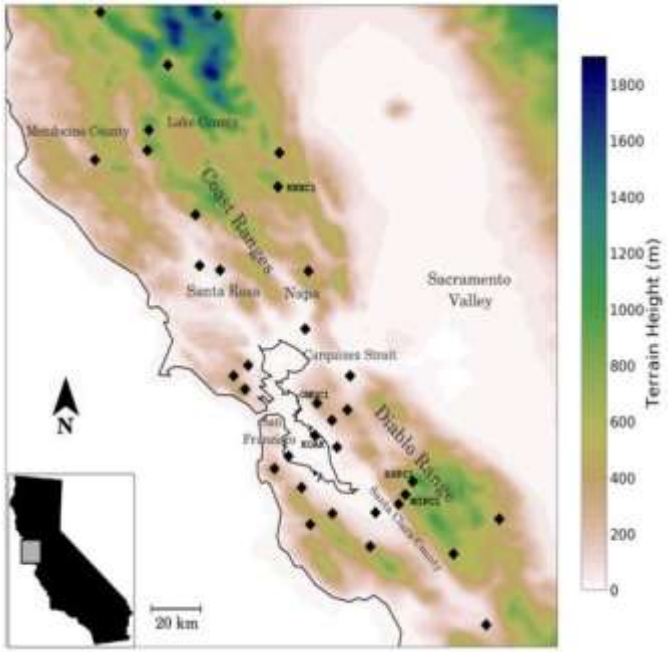
Severity of their maximum sustained wind speed.

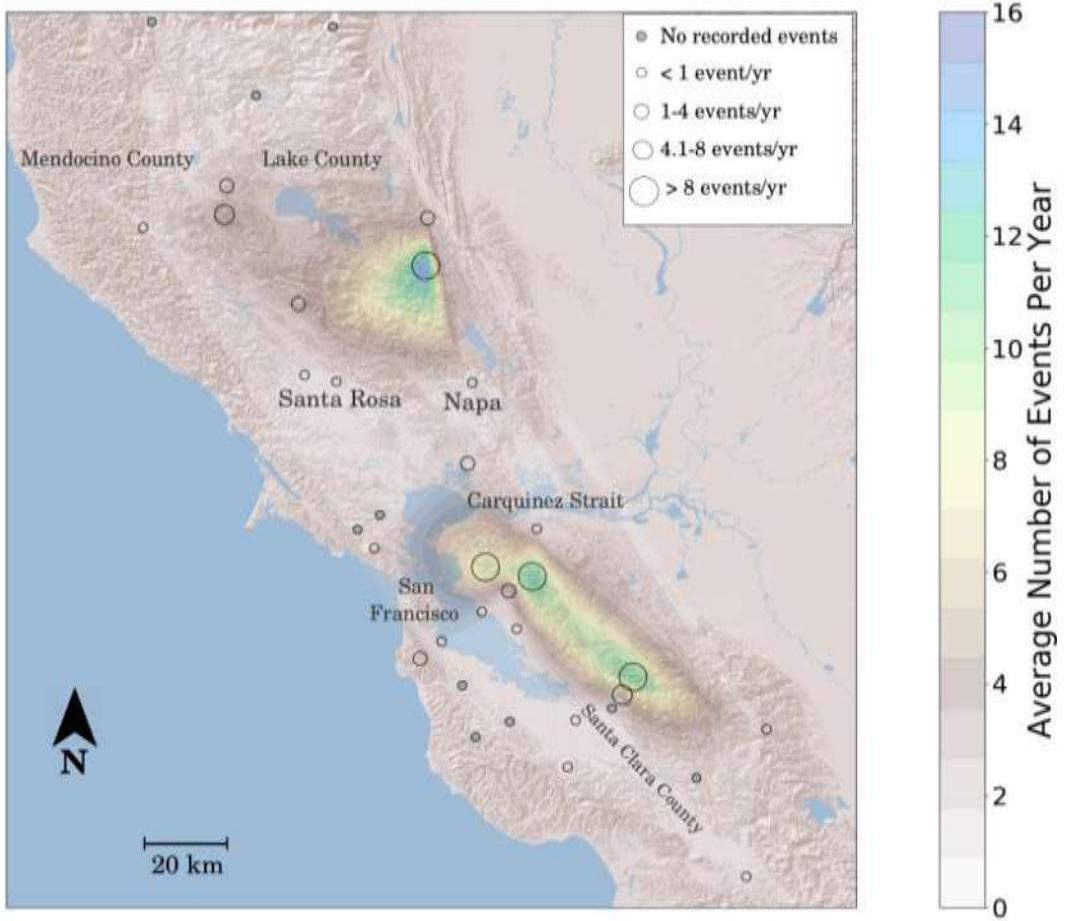
Severe: >14 m s^{-1} (31 mph)

Moderate: 11 to 14 m s^{-1} (24-31mph)

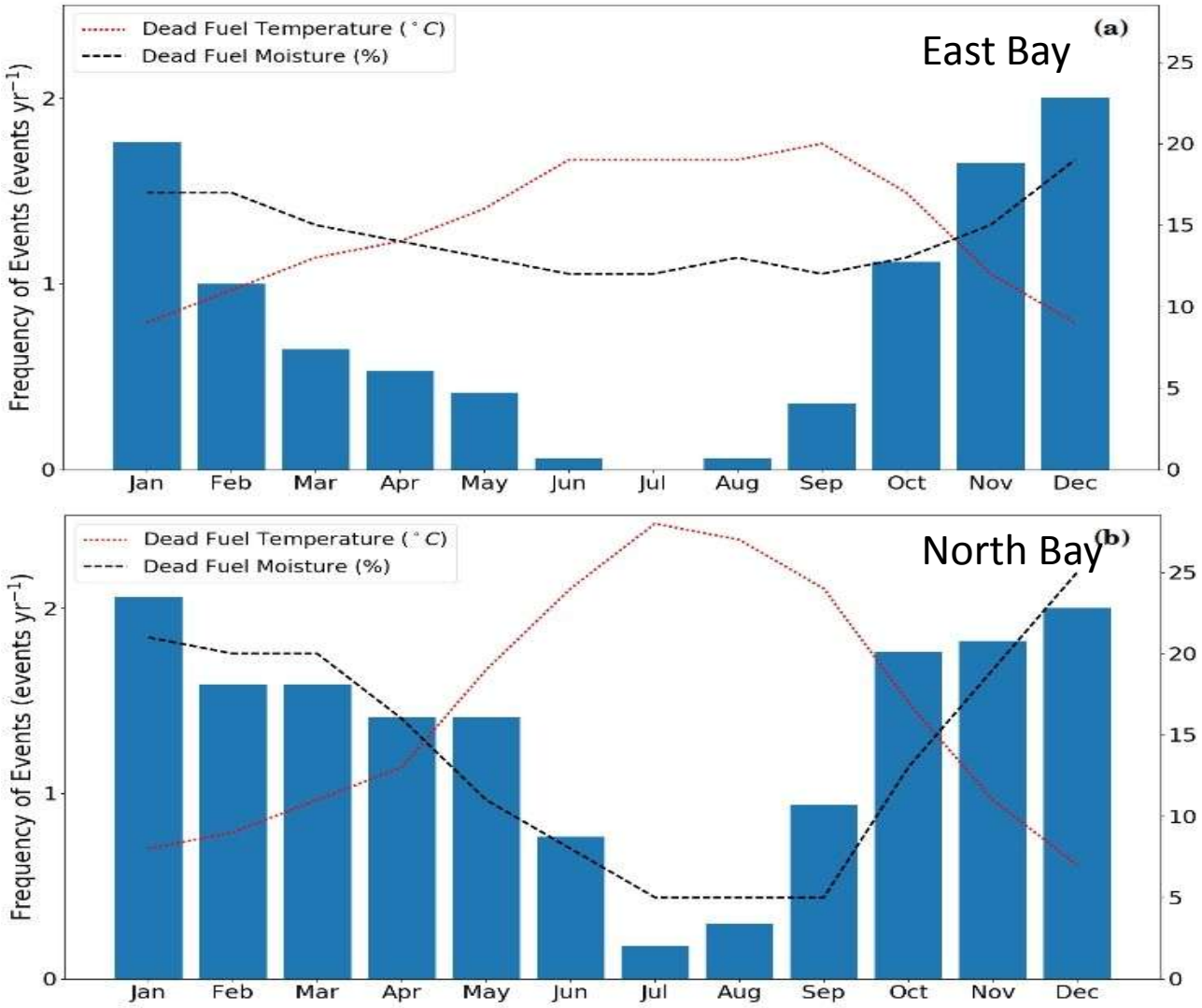
Weak: 6-10 m s^{-1} (13-22 mph)

Spatial distribution of Diablo Wind Events



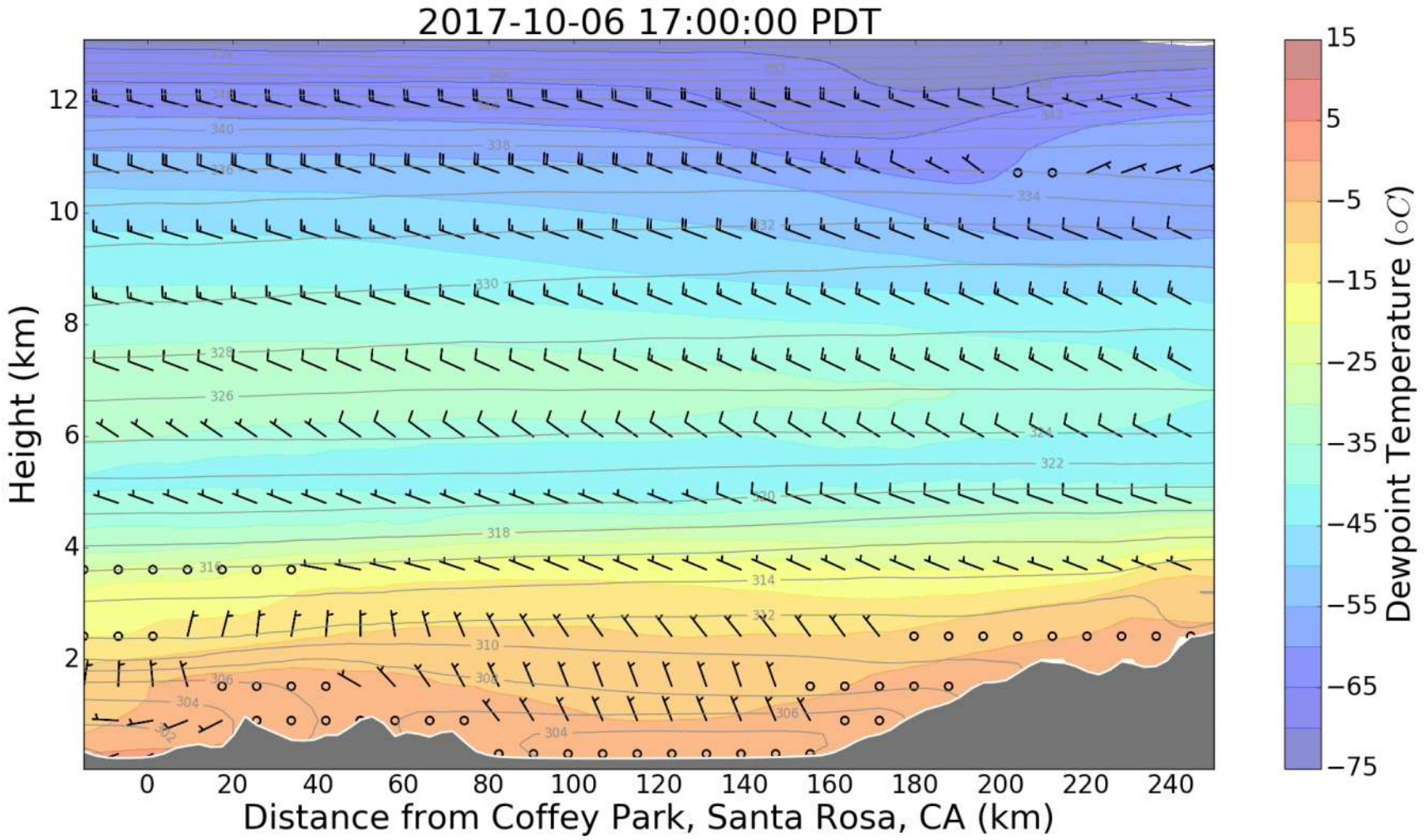


Frequency vs. Season of Diablo winds



As fuel moisture becomes minimum, frequency is also a minimum.

Numerical Simulation of Diablo Wind Event during Tubbs Fire



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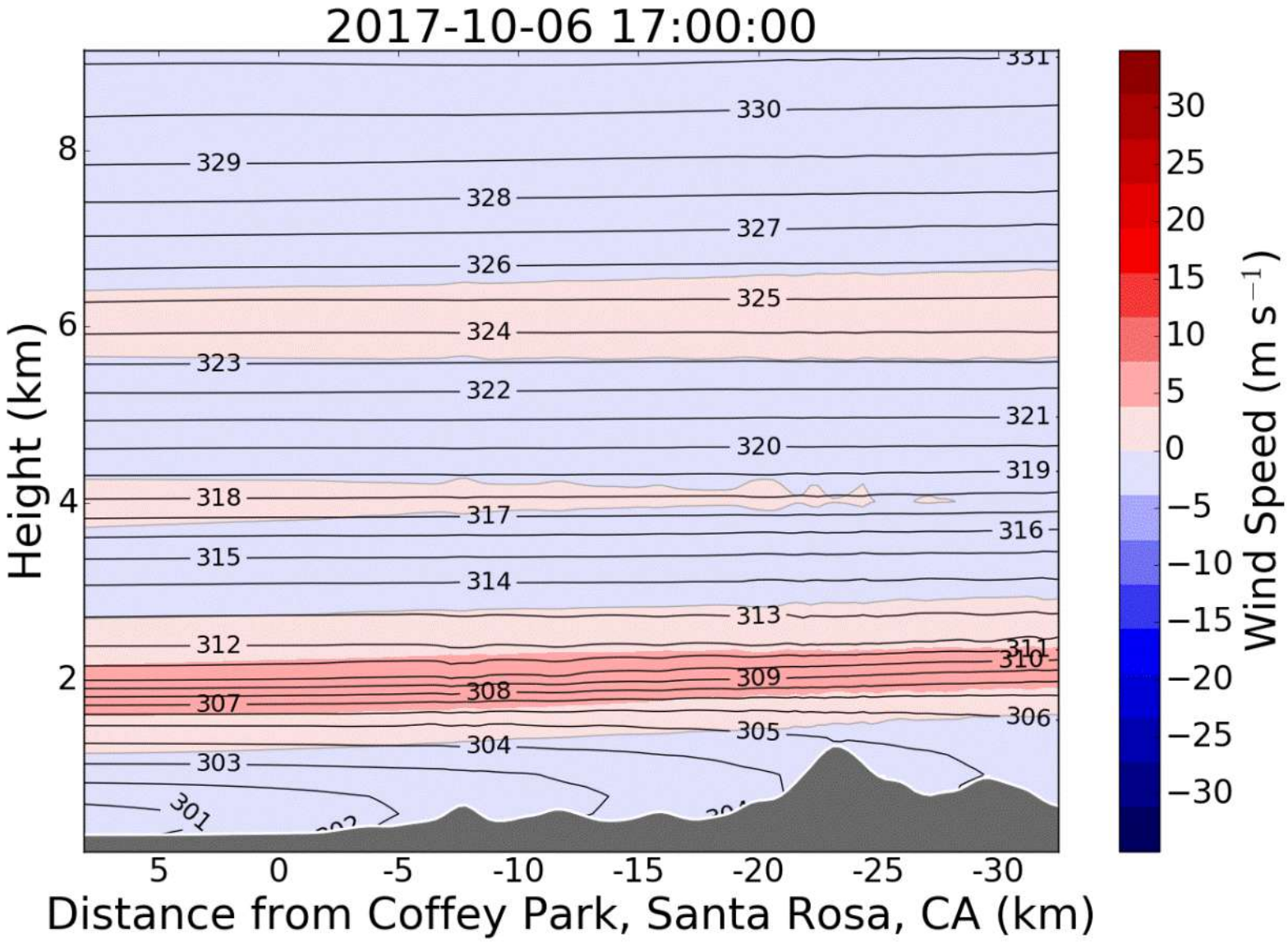

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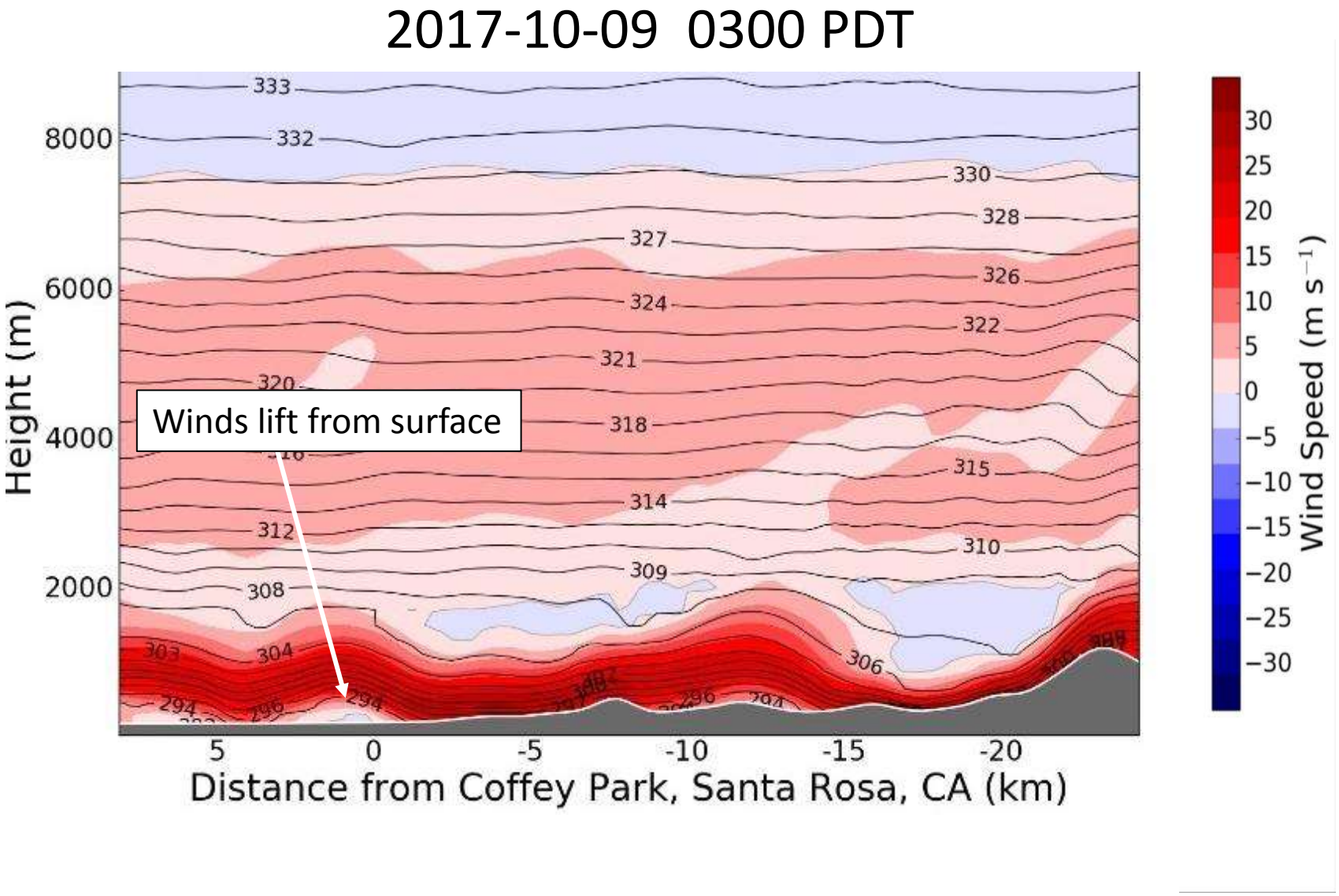


Observations of Wildfire Plume Dynamics using a Mobile Atmospheric Profiling System

- To better understand how wildfires create their own weather.
- Collect meteorological data at active wildfires to help develop next-generation fire behavior models.

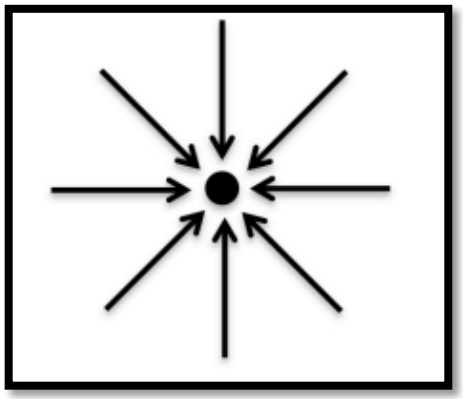
California State University-Mobile Atmospheric Profiling System (CSU-MAPS)

Platform optimized for rapid deployment scenarios and wildfire meteorological research.

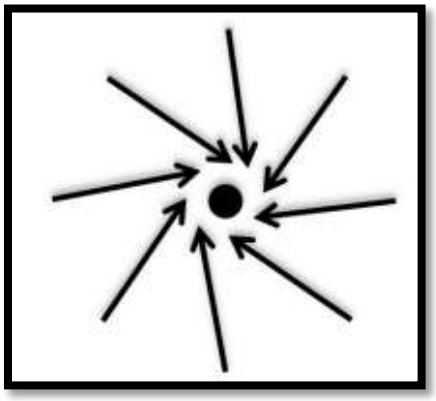
Clements and Oliphant (2014), *BAMS*

Development of Anti-Cyclonic Plume Rotation

Pure Convergence

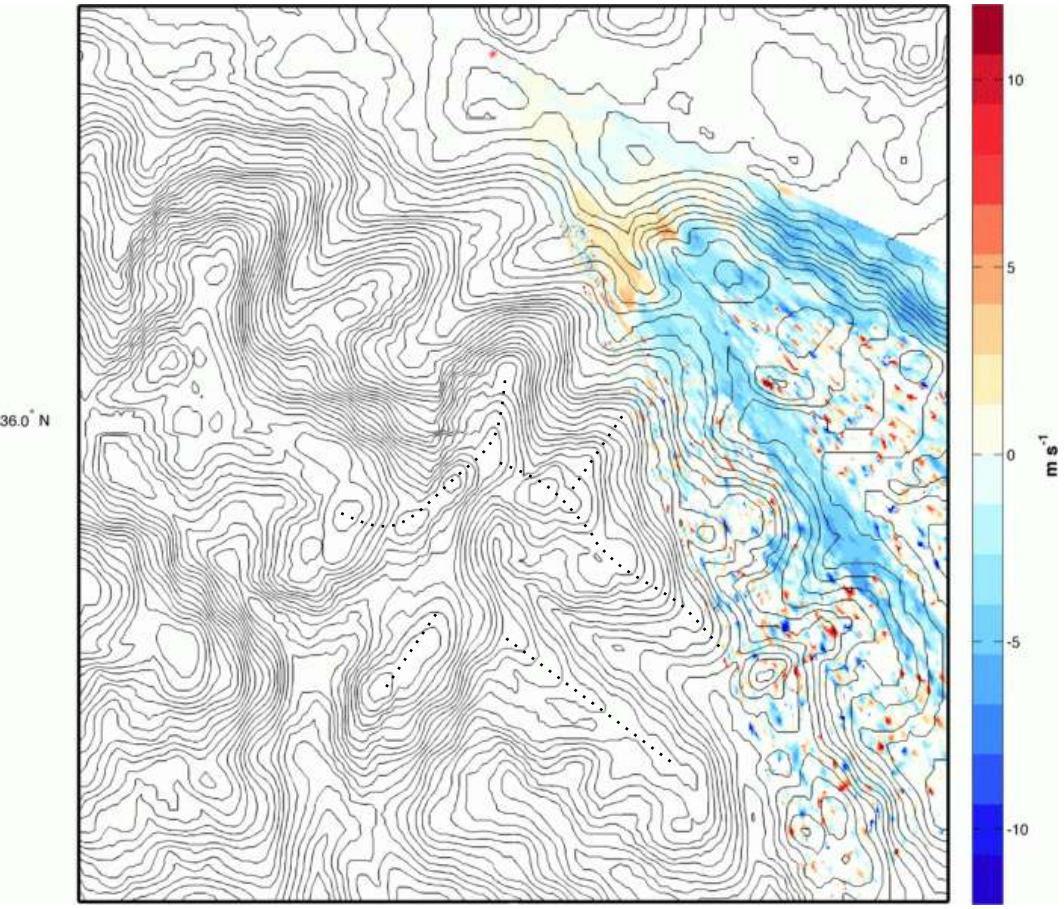


Strong Rotation

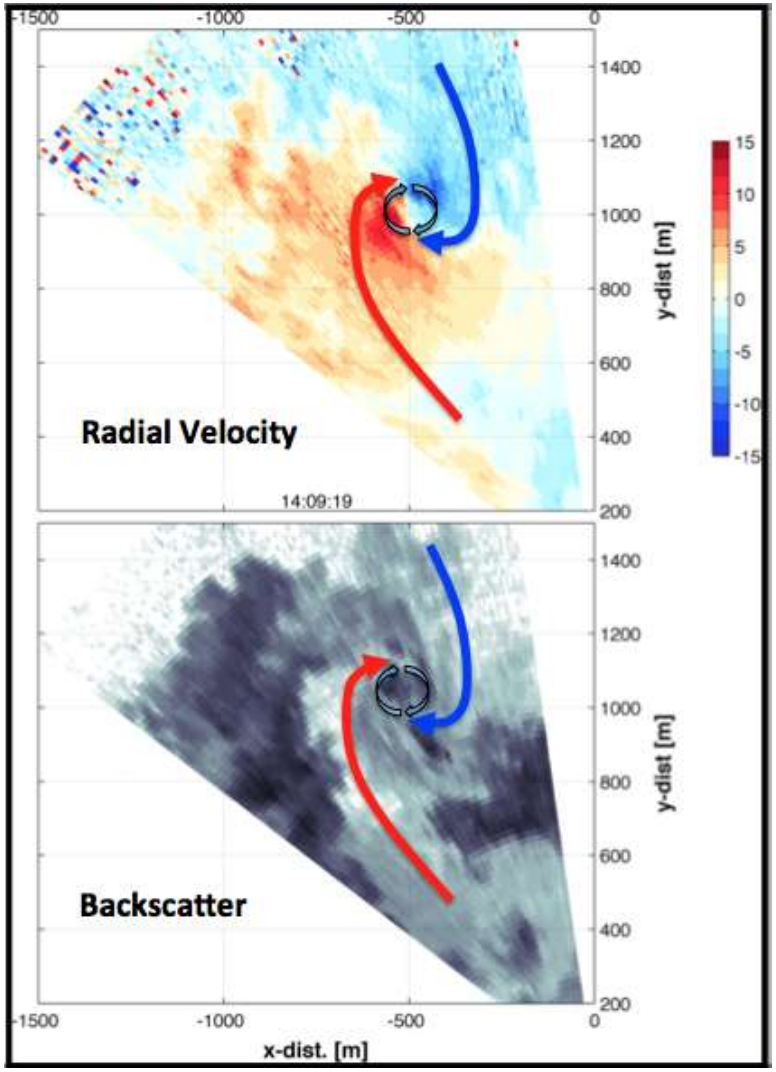


Development of Anti-Cyclonic Plume Rotation

Vortex-Topography Interaction
(Doppler Radial Velocity)



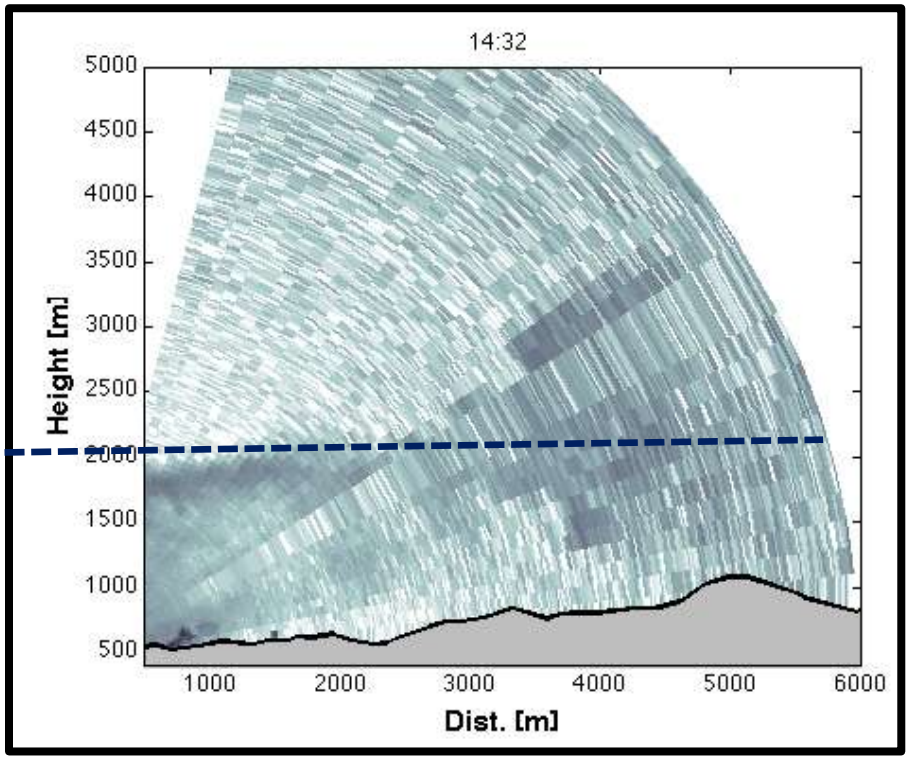
Vortex Structure



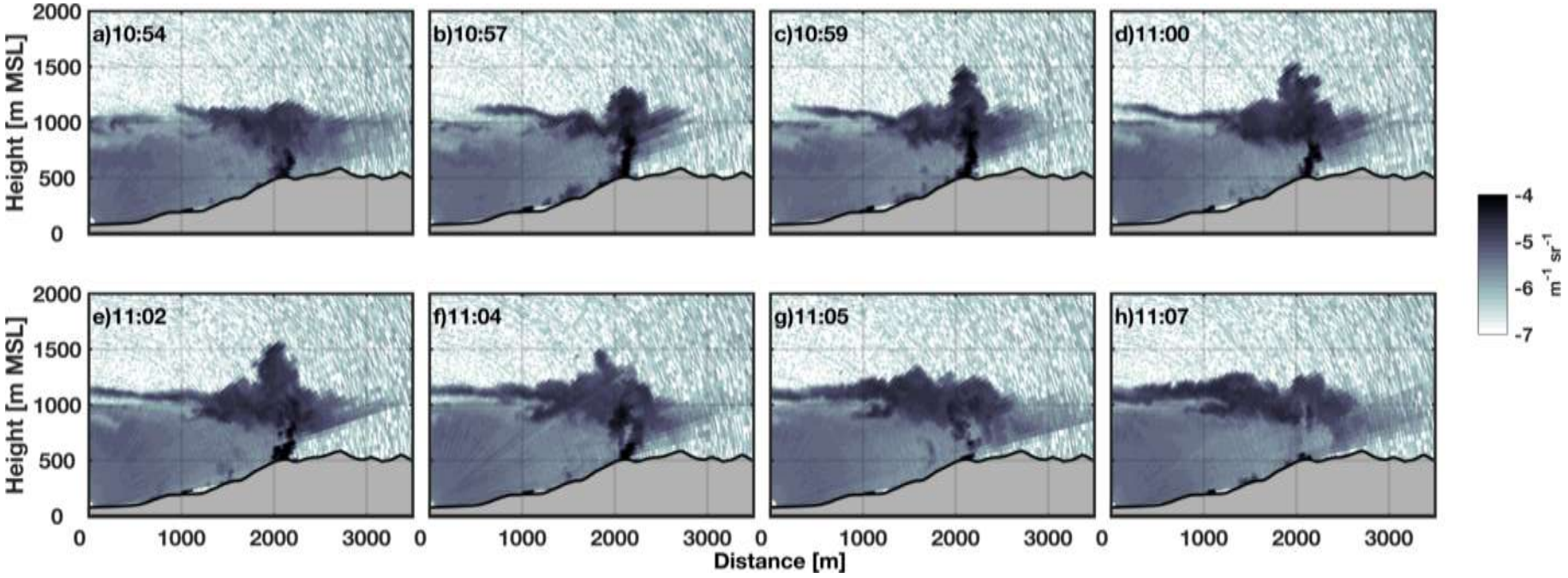
Plume structures associated with temperature inversions.

- Smoke plume can punch through inversion, but smoke falls back down.
- Smoke stays above inversion layer and moves in opposite direction due to wind.

Inversion top



Wragg Fire, 23 July 2015



- Doppler Lidar (Laser Radar) observations of smoke plume evolution.
- Smoky conditions due to smoke being trapped below temperature inversion.

Scanning Ka-band Polarimetric Doppler Radar (SJSU-SKAR)

Delivery: Fall 2018

Features

- 0.3° beamwidth
- 15 km range
- 5 m resolution
- 3° s^{-1} scan rate

Parameter	Specification
Frequency	35.61 GHz (short pulse) / 35.67 GHz (chirp waveform)
Transmitter power	10 W, 25% duty cycle max.
Antenna diameter	1.82 m
Antenna Polarization	Tx: alternating V/H pol Rx: simultaneous V/H pol
Beamwidth	0.32° typical
LNA Noise Figure (typical)	2.8 dB
Radiometer bandwidth	100 MHz
Radar data products	dBZ_V, dBZ_H, LDR, ZDR, ρ_{hv}, ρ_{xh}, K_{dp} power spectra: VV, HH, HV, HH; velocity and spectral width. Dual PRI velocity for alias unwrapping
Radiometer data	Calibrated brightness temperature on horizontally polarized channel

2017 NSF MRI: Acquisition of a Multi-purpose Cloud Radar" (AGS-1727052)

Summary

Nocturnal Drying Events

- Source region of extremely dry air associated with large-scale subsidence over the northeastern Pacific.
- Dry air exists in a canopy above the marine layer and they both move inland overnight.

Diablo Winds

- Diablo winds are downslope winds that form in the lee of the Coastal Ranges.
- Diablo winds are more frequent in winter than fall, however their presence in fall presents extreme fire danger.
- Numerical simulations of the Tubb's Fire indicate that the surface winds decreased due to mountain wave structures.

Summary

- Red flag warning conditions can result from both onshore winds and offshore winds, both associated with low RH.

Thank you!

www.fireweather.org

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Acknowledgements:
National Science Foundation Grants #1151930; 1807774

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