Meteorology and Smoke Management

ARB Smoke Management Workshop
November 16 and 17, 2010

Presented by:
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San Joaquin Valley APCD

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Overview: Meteorology and Smoke Management

- Meteorology Review
  - Winds
  - Atmospheric Stability
  - Plume Behavior
- Forecasting Resources
  - 2008 Wildfire Impact (example)
- San Joaquin Valley APCD Air Monitoring Sites
- Wildfire Impacts on Air Quality
- Smoke Management Decisions

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Dispersion Meteorology Terminology

- Winds
- Atmospheric Stability
- Temperature Inversion
- Ventilation / Dispersion / Mixing

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Winds

- Speed and Direction
  - Direction is defined from True North by where the winds come from
  - (N = 360°, E = 90°, S = 180°, W = 270°)
  - Speed is measured in miles per hour (mph), meters per second (mps), or knots

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Winds

- Winds are comprised of:
  - Pressure Gradients (the tighter the isobars, lines of constant pressure, the stronger the winds)
  - Temperature Gradients
    - Frontal, Land / Sea Breeze
  - Terrain
    - Upslope / Downslope flows
    - Mountain / Valley flows

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Winds

- Pressure gradient winds are driven by areas of high and low pressure
- Tight gradient means strong winds

H /// L

- Relaxed (Weak) gradient means light winds

H / L

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Winds

- Thermally driven wind flows
  - Land / Sea Breeze
  - Mountain / Valley Flows
    - Daytime burning is preferred because upslope flow carries smoke emissions away from downslope sensitive receptors.

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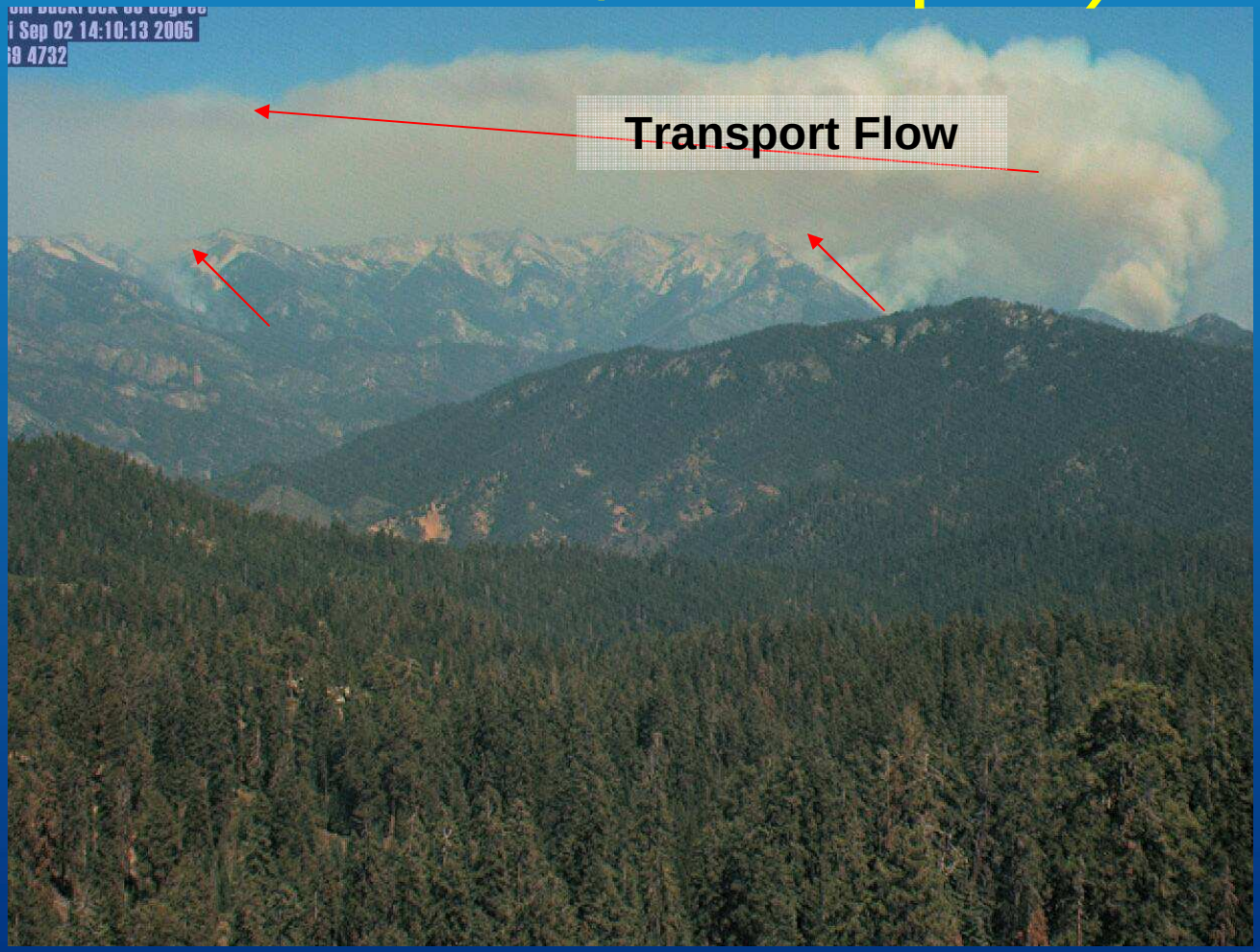
Winds (Drainage, mountain breeze, downslope)

Winds (Upslope, Valley Breeze, Transport)



http://sierrafire.cr.usgs.gov/swfrs

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Effects of Wind Speed on Smoke Plume

- Wind Speed aids in dilution of emissions.
- Wind speed determines the horizontal motion and bending of the plume from vertical.
- Light wind speeds lead to “stagnation” (no horizontal distribution of pollutants).

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Effects of Wind Direction on Smoke Plume

- Wind direction determines transport direction.
- Wind directions are given as the direction from which the wind blows.
  - For example, a northerly wind comes from the north and blows smoke toward the south.

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Atmospheric Stability

- Stability is determined by the vertical temperature profile of the atmosphere.
  - Measurements by profilers, aircraft, remote sensing, or weather balloons
- Stable Air
  - Limits smoke dispersion
  - Resists vertical motion (less mixing)
- Unstable Air
  - Maximizes smoke dispersion
  - Promotes vertical motion (more mixing)

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Atmospheric Temperature Structure

- Vertical temperature profile
  - Temperature decreases with height
  - A temperature inversion occurs when the temperature increases with height
    - Stable conditions that reduce vertical mixing
    - An inversion can cause a lid that traps smoke emissions near the ground

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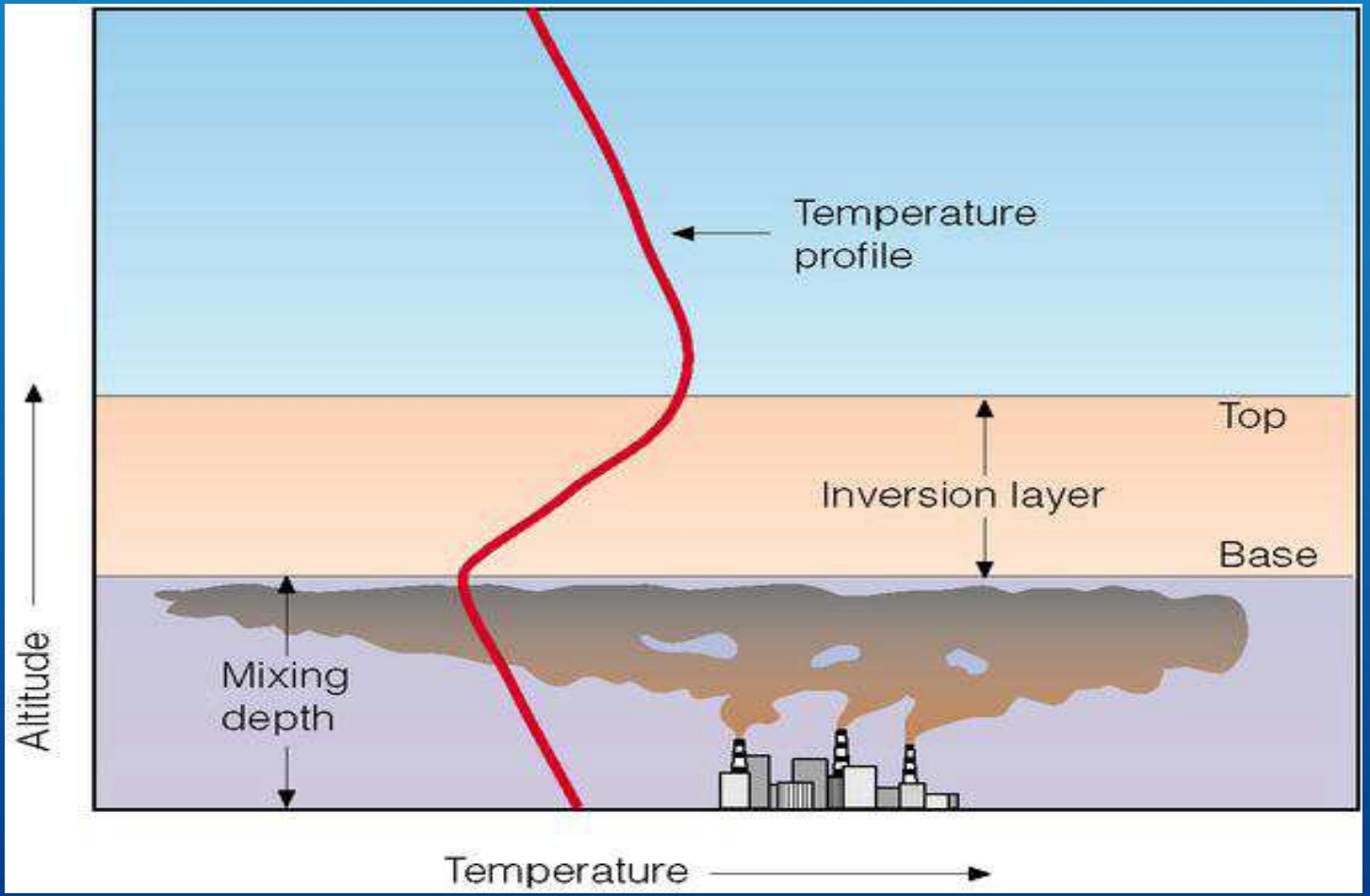
Temperature Inversion



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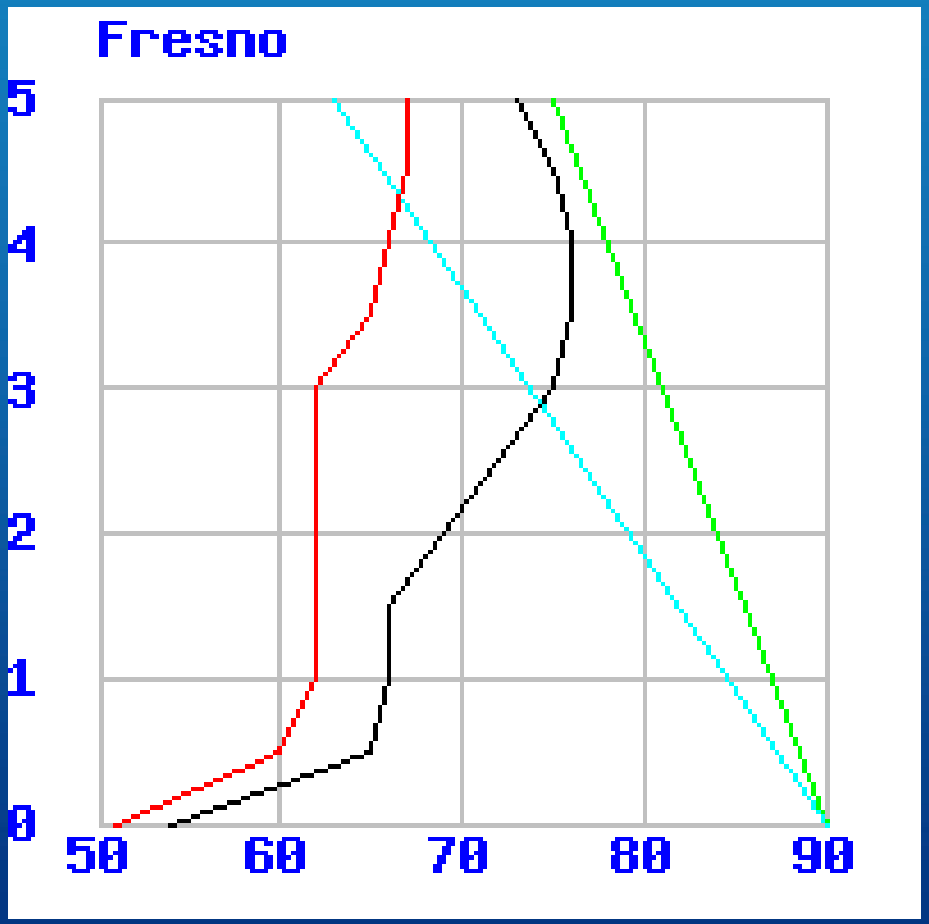
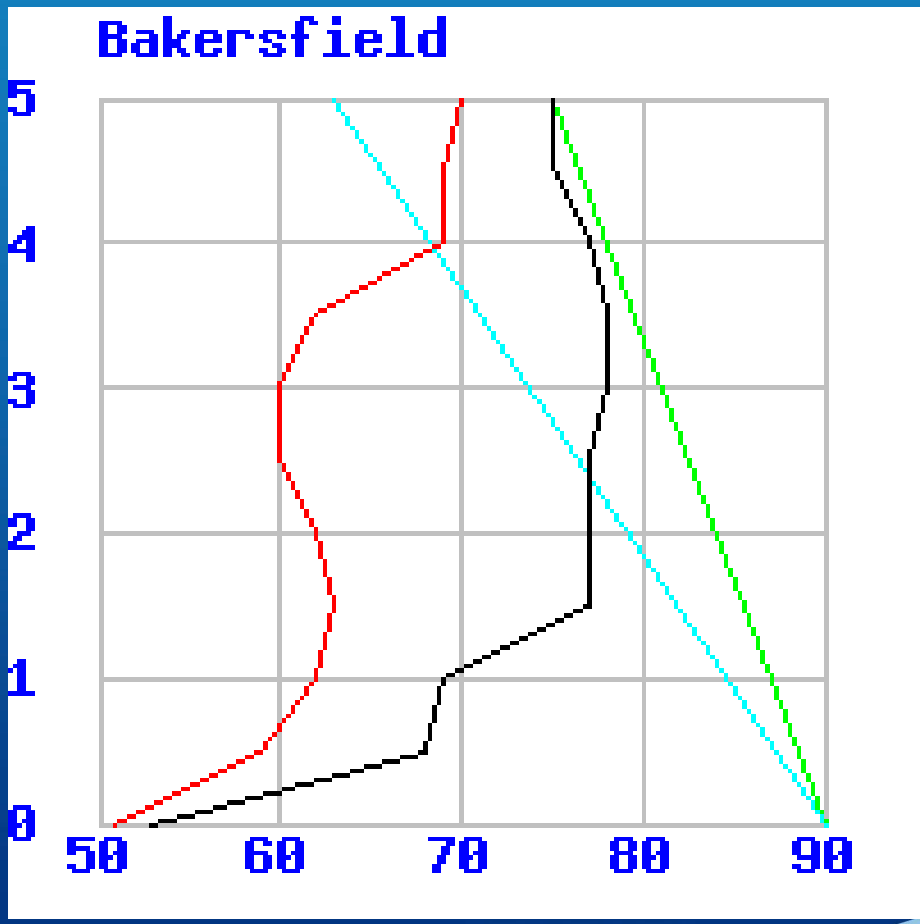
Fresno and Bakersfield Temperature Sounding Example (11-3-2010)





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Stability /Mixing Exercise Example

- See worksheet

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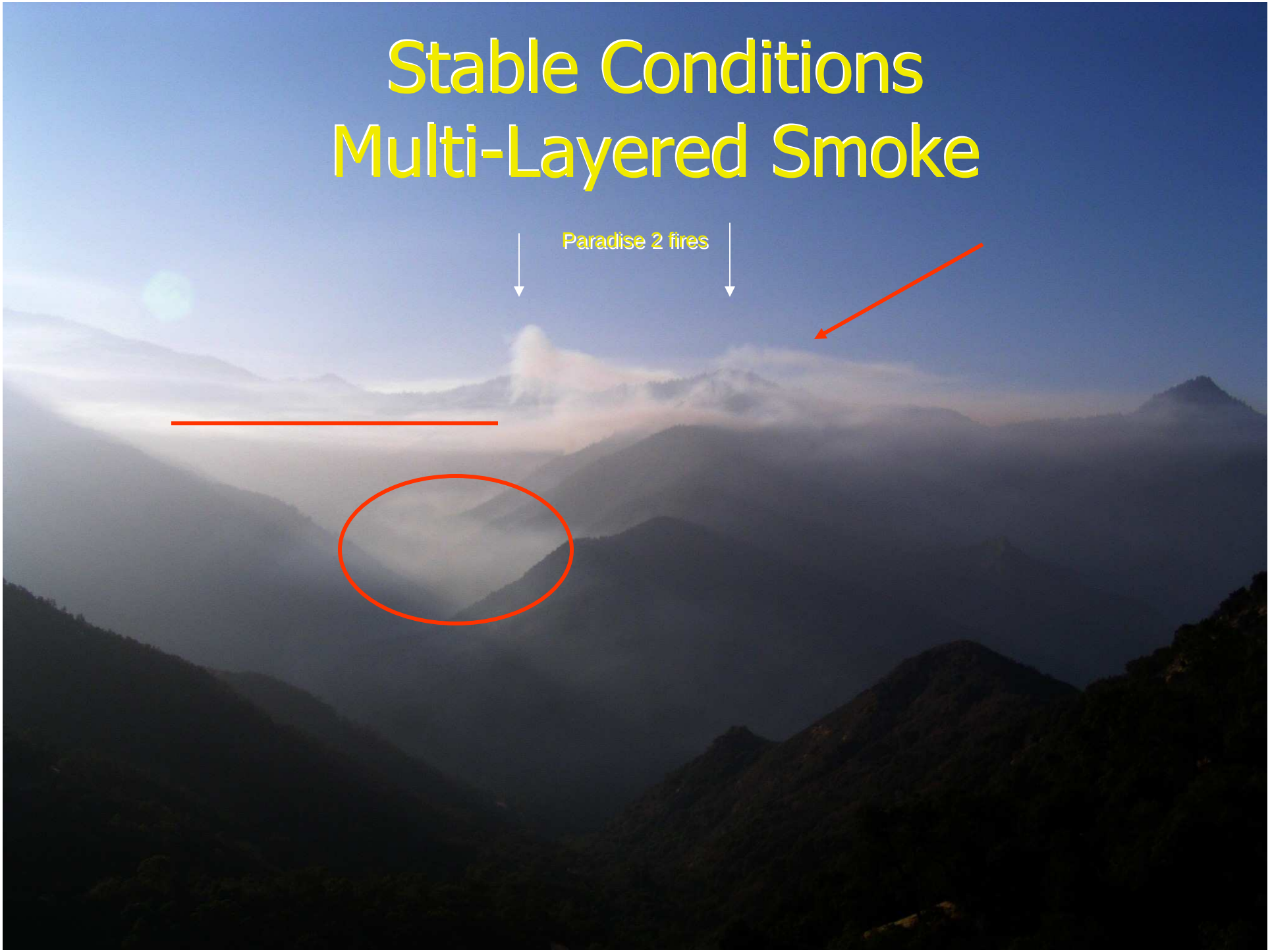
Stable Conditions
Multi-Layered Smoke



Winter Stagnation

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Inversion Types

- Radiation Inversion
  - Due to night-time cooling of surface
  - Colder air tends to pool in drainages
- Subsidence Inversion
  - Due to sinking or subsiding air warmed by compression
  - Occurs with high pressure aloft
- Marine Inversion
  - Occurs when air cooled by water undercuts warm air above
- Frontal Inversion
  - When a cold air mass undercuts a warm air mass and lifts it aloft

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Mixing Height

- The vertical extent that an air parcel will move upward when heated.
- Mixing heights increase as daytime heating occurs.
  - Night-time mixing heights are near the surface until day break.
  - Maximum mixing occurs by late afternoon
  - Mixing heights rapidly lower after sunset
  - Mixing heights are impacted by cloud cover

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Smoke Dispersion Processes

- Advection: Wind-Driven Transport
- Thermal Turbulence and Convection: Driven by heating
- Diffusion: Microscale motions that expand the pollutant cloud
- Mechanical Turbulence: Wind and terrain generated mixing.

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Ventilation Index

- VI = Mixing Height x Wind Speed / 1000
- Example:
  - Mixing Height = 1,000 feet
  - Transport wind = 5 knots
  - Ventilation Index = 1000 feet x 5 knots / 1000 = 5 kt-ft

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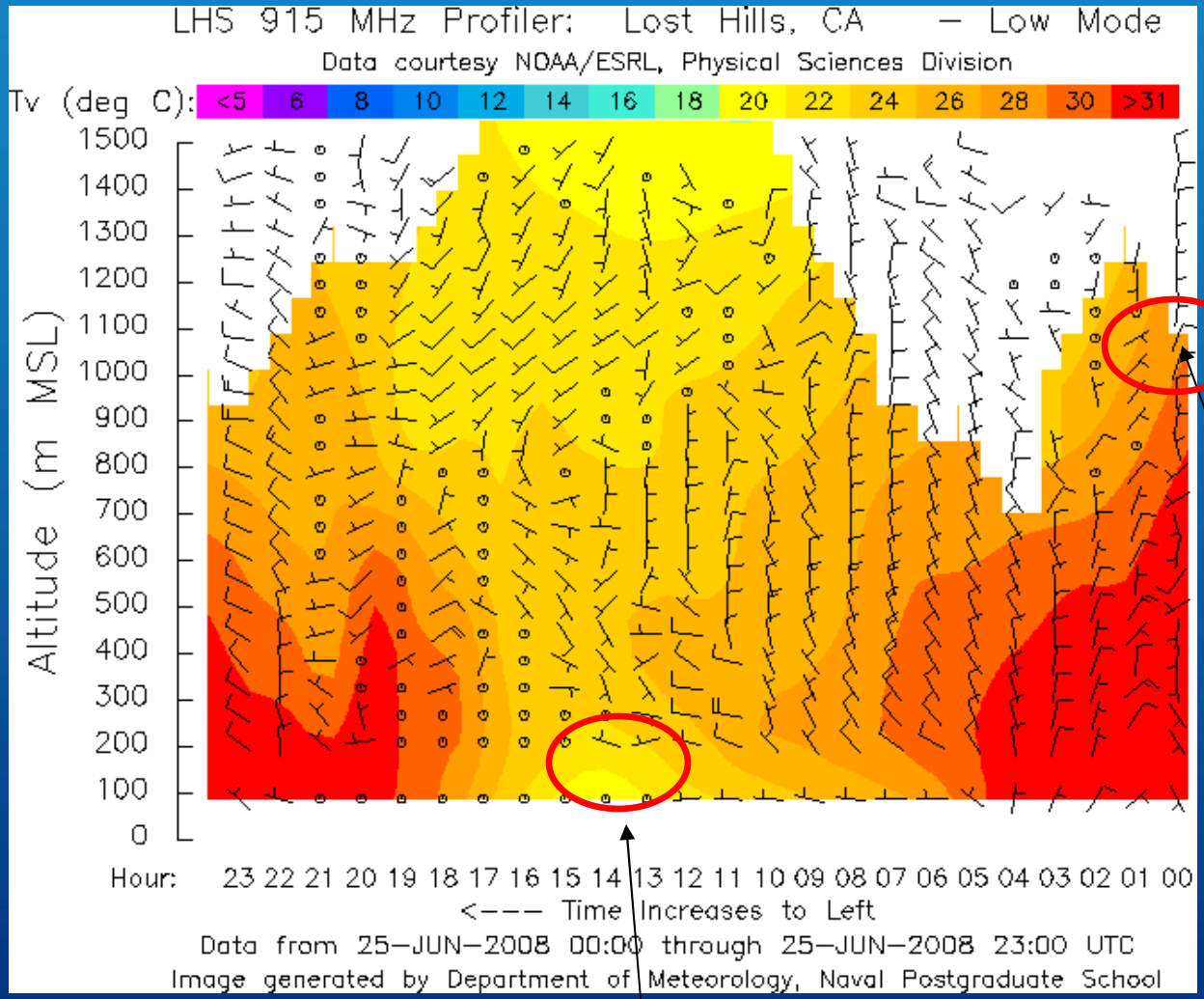
Temperature Profile at Lost Hills on June 25, 2008



Maximum Mixing Depth

Morning inversion

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Stability Effects on Smoke Plumes

- An air parcel or plume is unstable and it will rise if it is more buoyant than the surrounding air.
- An air parcel or plume is stable and it will not rise if it less buoyant than the surrounding air.
- The interaction of the plume with different lapse rates determines the shape of the plume.
- Lapse Rate is the rate at which an atmospheric variable (usually temperature) decreases with height.

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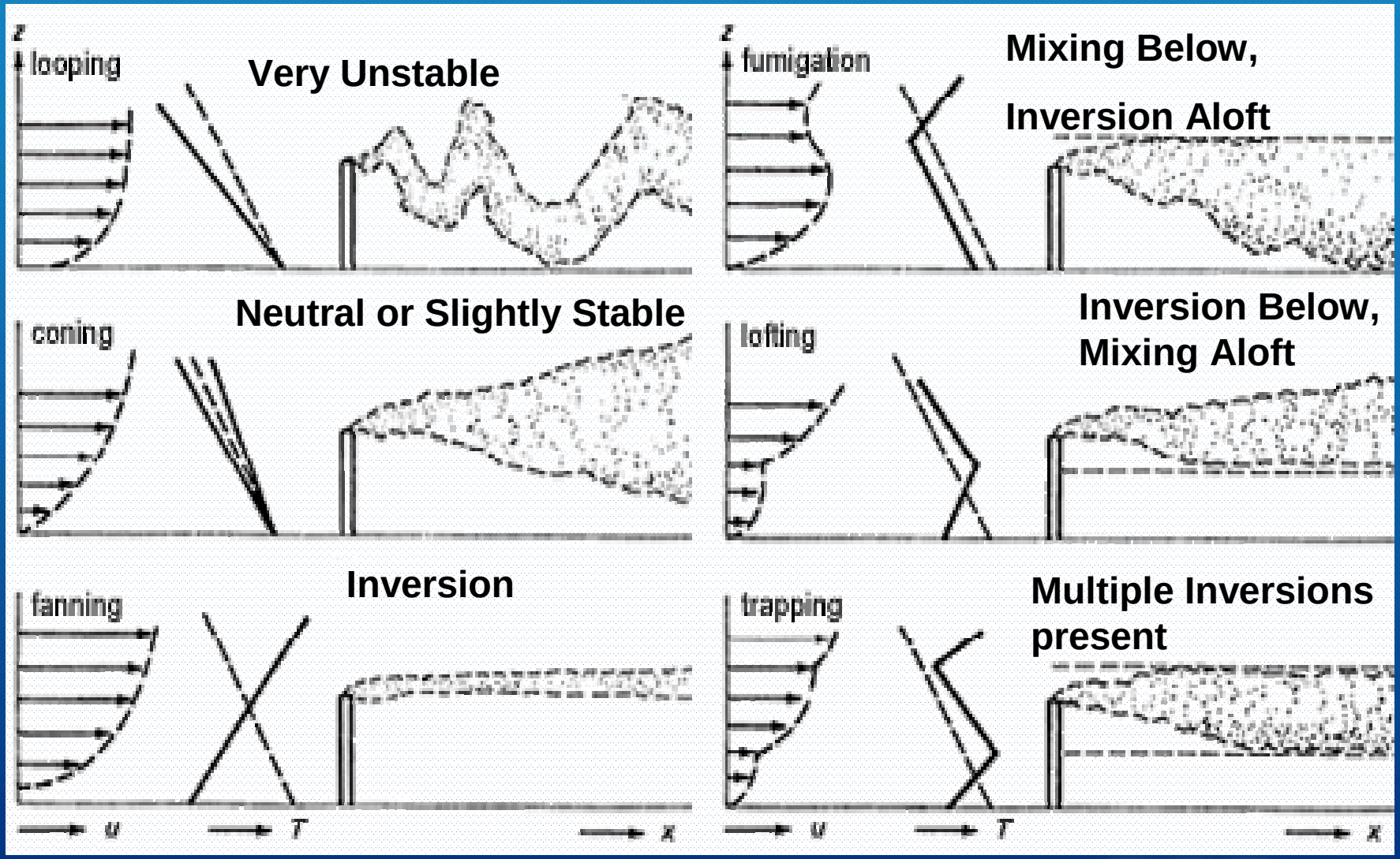
Plume Behavior and Lapse Rate



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Visual Indicators of Stable Air

- Fog
- Calm or Light, Steady Winds
- Stratus clouds – layered with little vertical structure
- Poor visibility at the surface due to the accumulation of smoke or haze
- Smoke column drifts horizontally after limited rise

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Visual Indicator of Stability

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Visual Indicators of Unstable Air

- Vertical Growth of Clouds
  - Cumulus
- Gusty Winds
- Good Visibility

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Visual Indicators of Unstable Air

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Forecasting Resources

- Upper Air Transport and Dispersion
- Satellite Images
- Upper Air Observations
- Weather and Air Quality Models
- Web Cameras
- Local Observers (Fire Lookouts, Inspectors, You)
- Air Quality and Weather Data

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Data Sources to Assess Upper Air Transport and Dispersion

- Lower Air Profilers

http://www.weather.nps.navy.mil/profiler/coastprof.html

- RAOB's

http://www-frd.fsl.noaa.gov/mab/soundings/java/

- CARB Aircraft Sounding

http://www.arb.ca.gov/smp/met/apob.php

- NOAA ARL Forecast Soundings

http://ready.arl.noaa.gov/READYcmet.php

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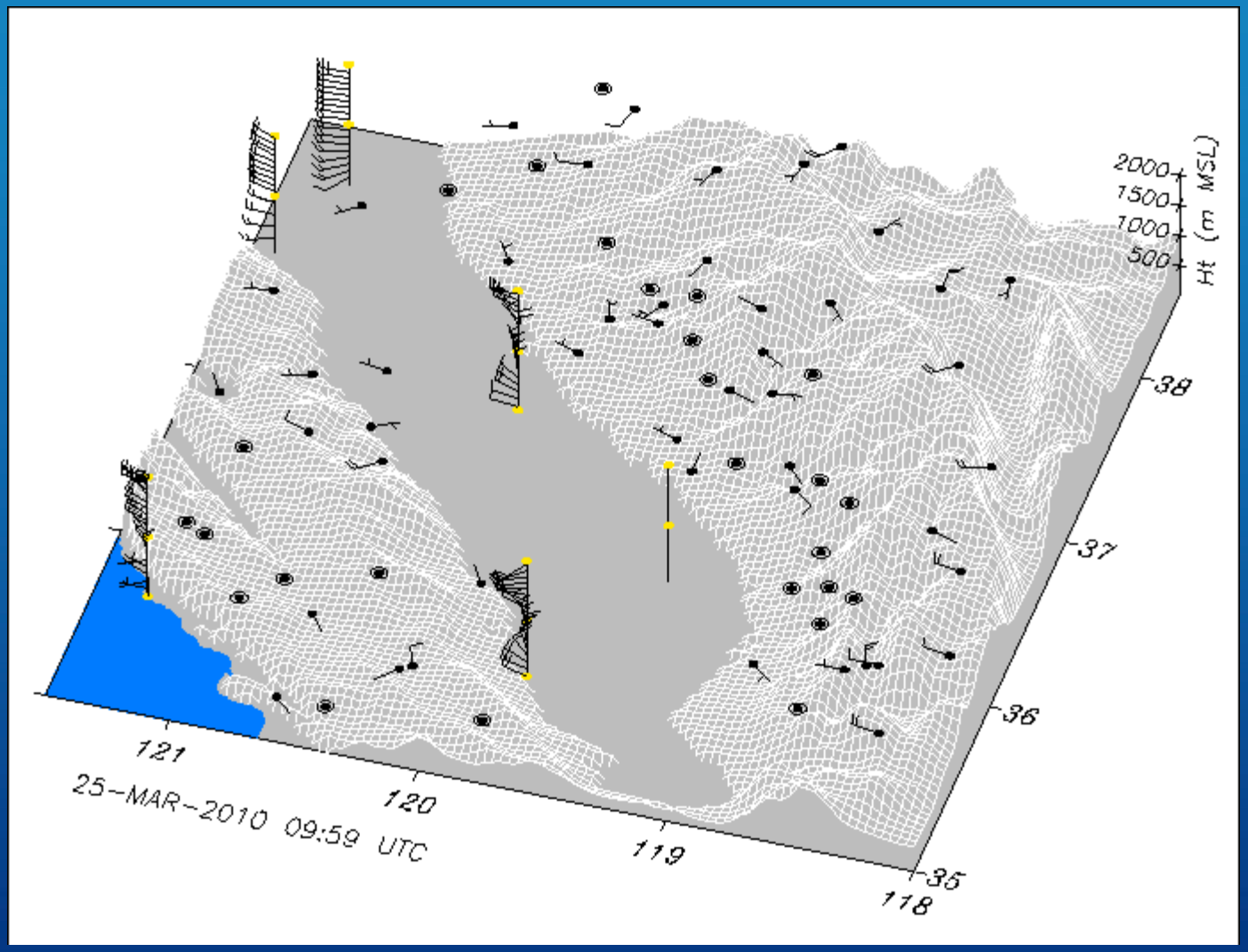
Wind Profilers



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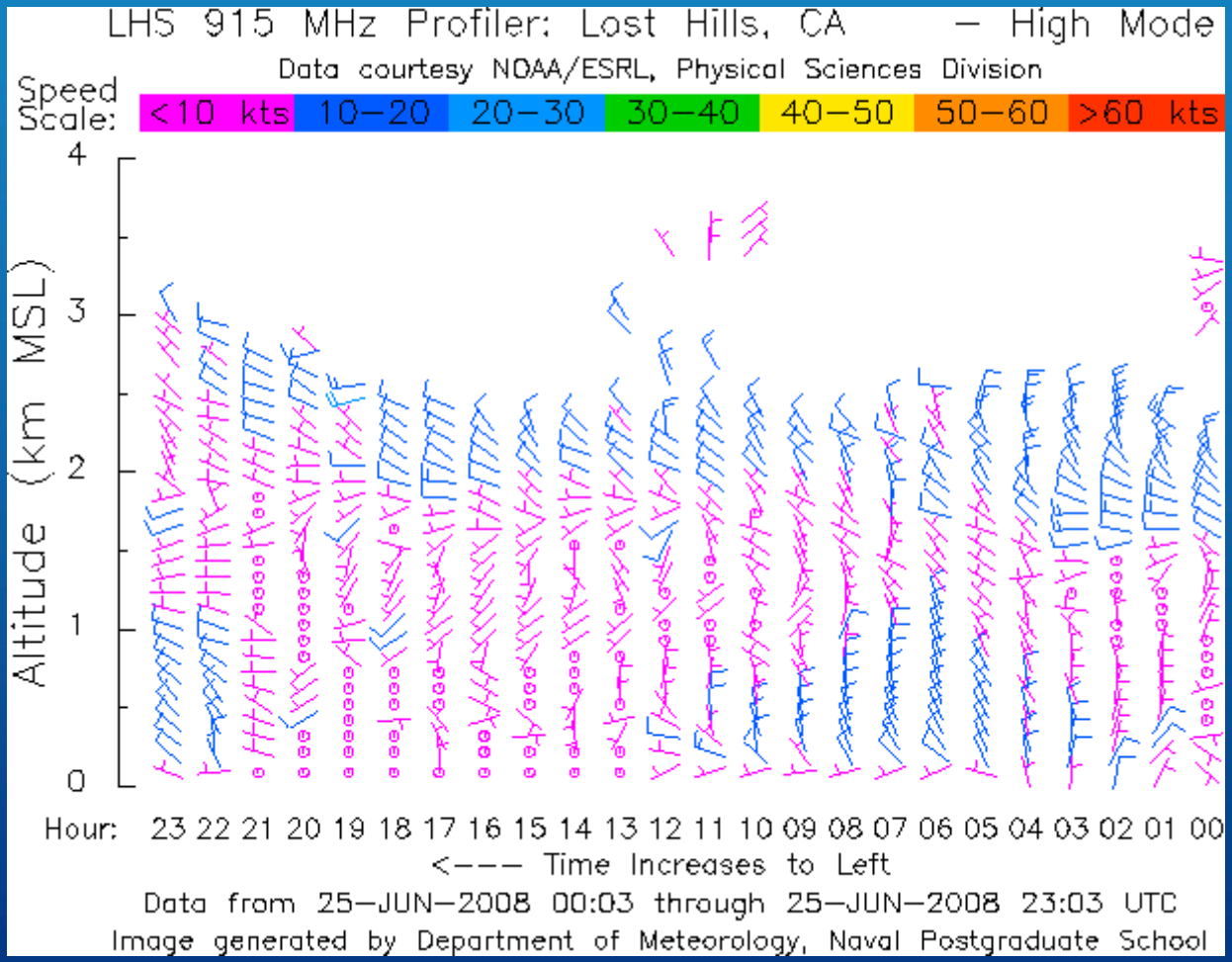
Wind Profile at Lost Hills on June 25, 2008



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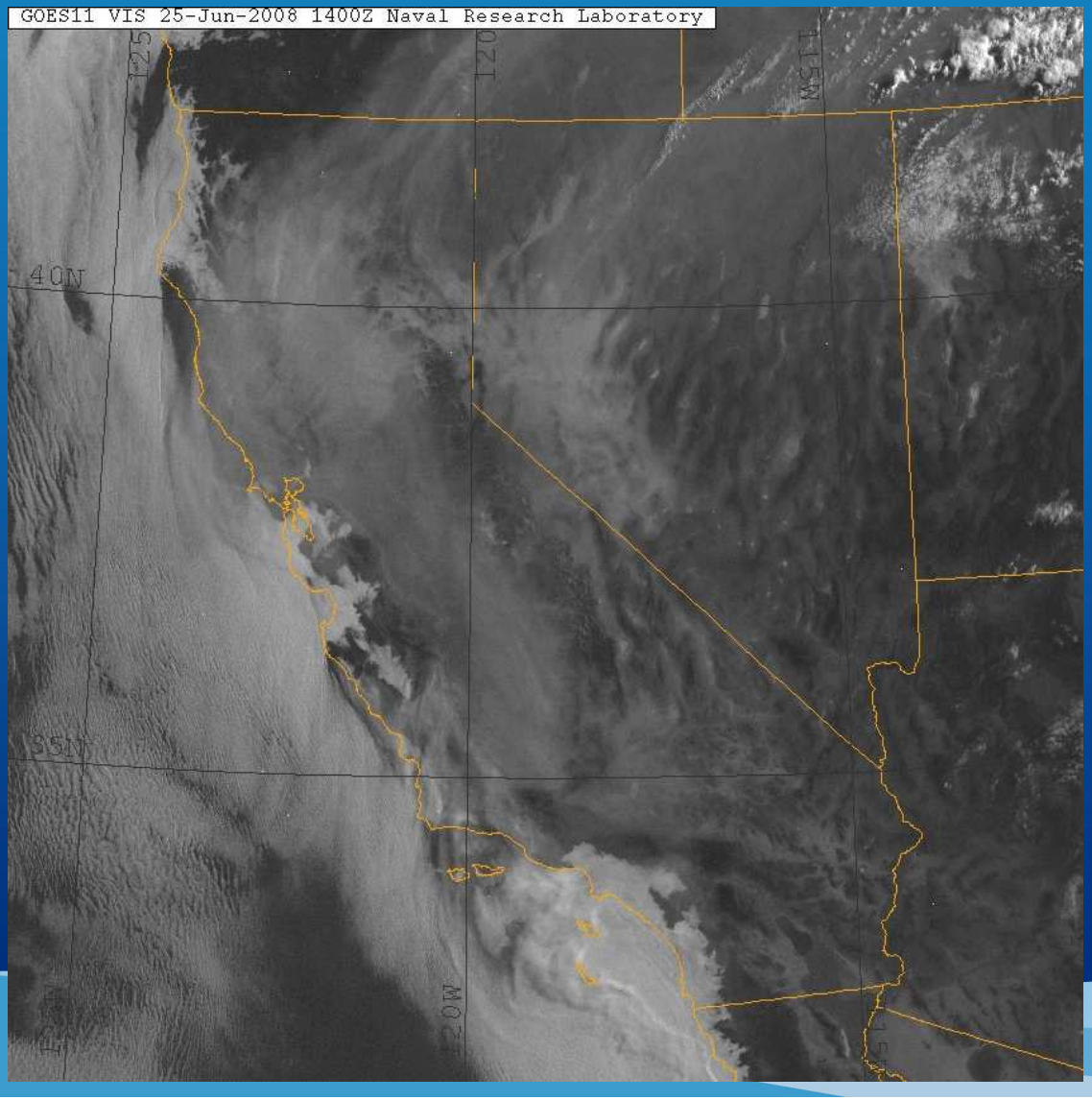
Morning Visible Satellite Imagery

(June 25, 2008)



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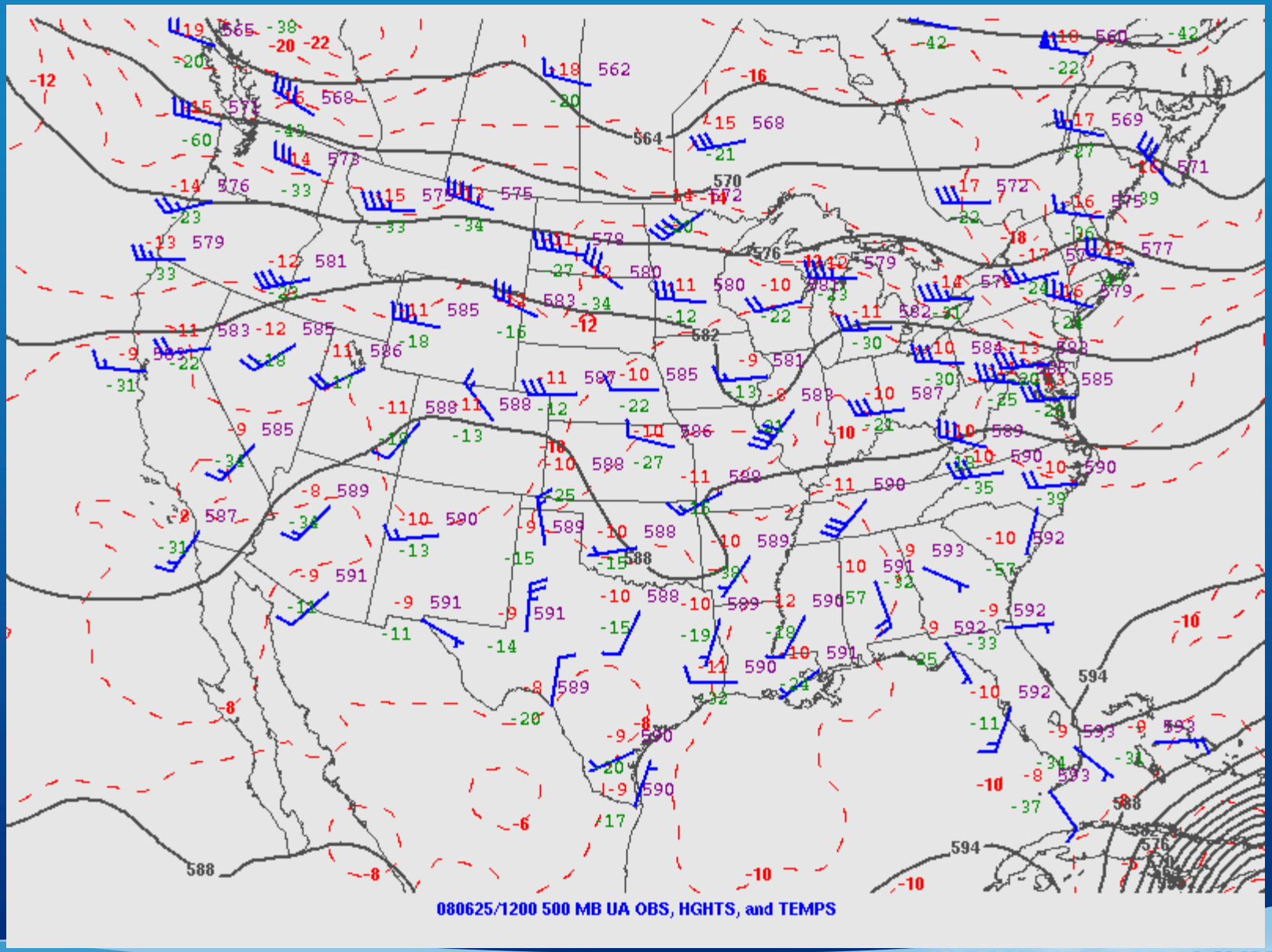
500 MB Pattern for June 25, 2008



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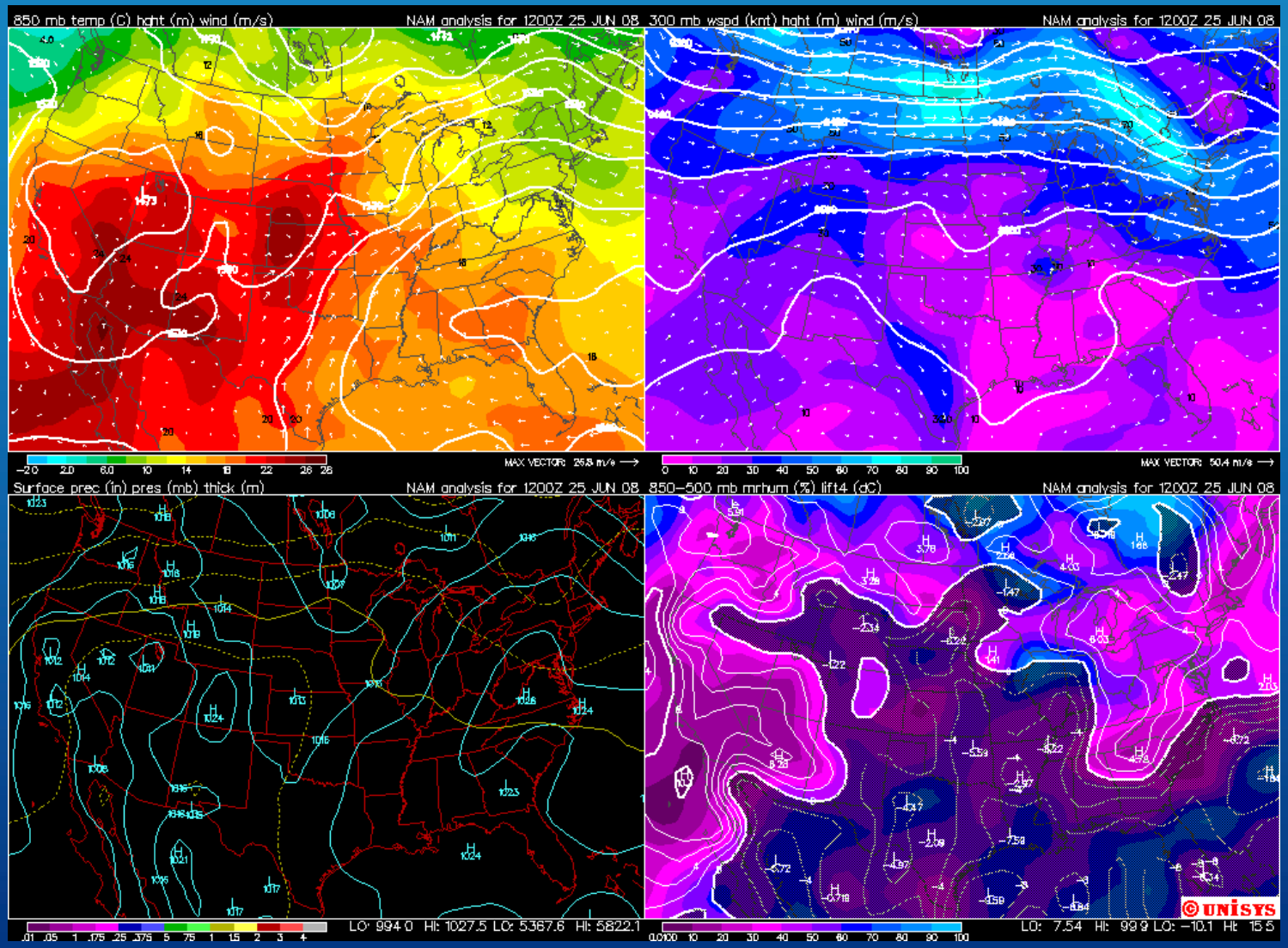
Weather Pattern of June 25, 2008



http://www.weather.unisys.com/

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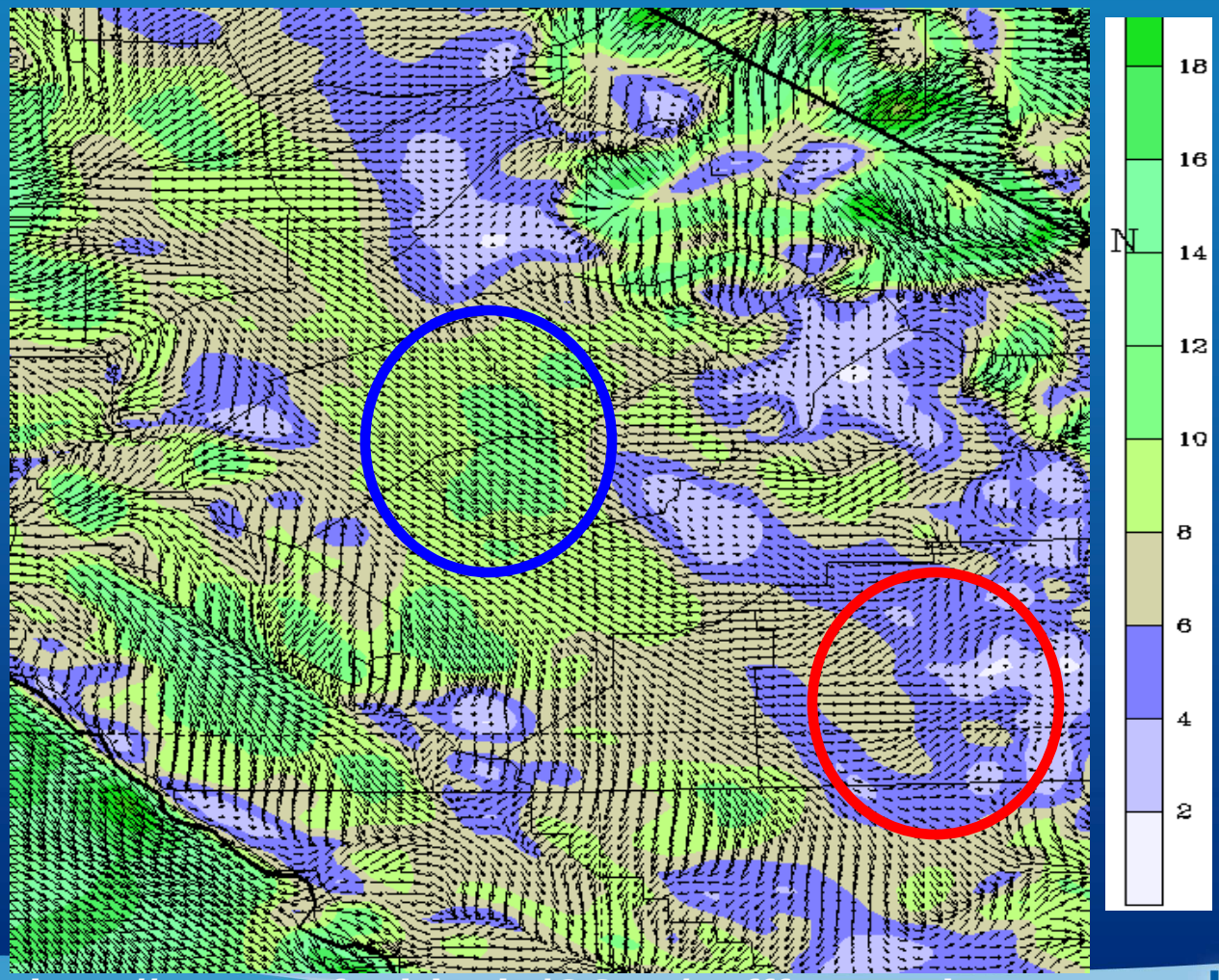
CANSAC: Small Scale Weather Model Specifically Designed for the San Joaquin Valley



http://www.cefa.dri.edu/COFF/coffframe.php

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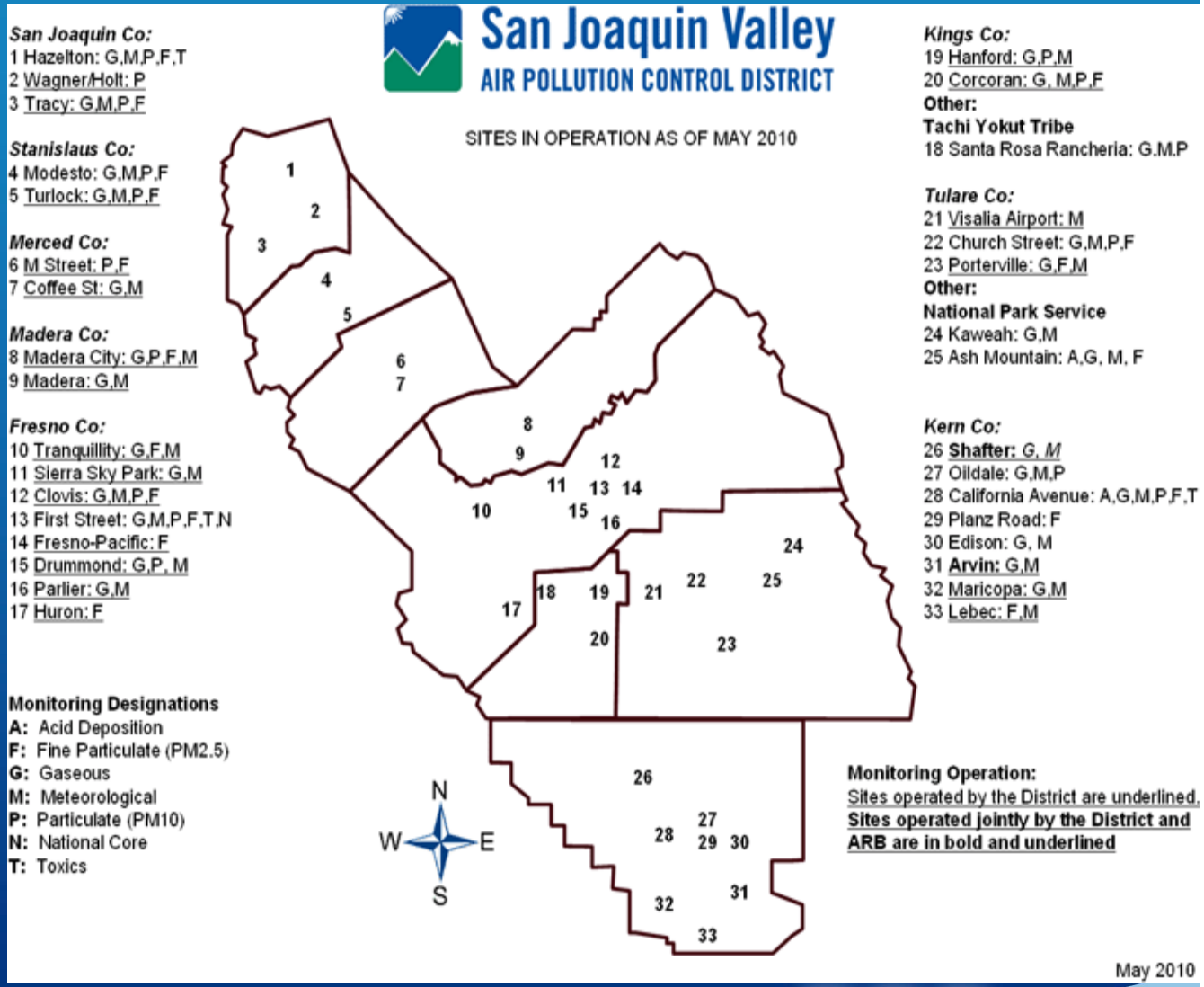
MPH

Air Monitoring Sites

- Population Exposure
- Highest Concentration
- Source Apportionment
- Special Modeling and Air Quality Analyses



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Forecasting Air Quality

Need to predict changes in:

- Atmospheric Chemistry
- Weather
- Emissions
- Human Behavior

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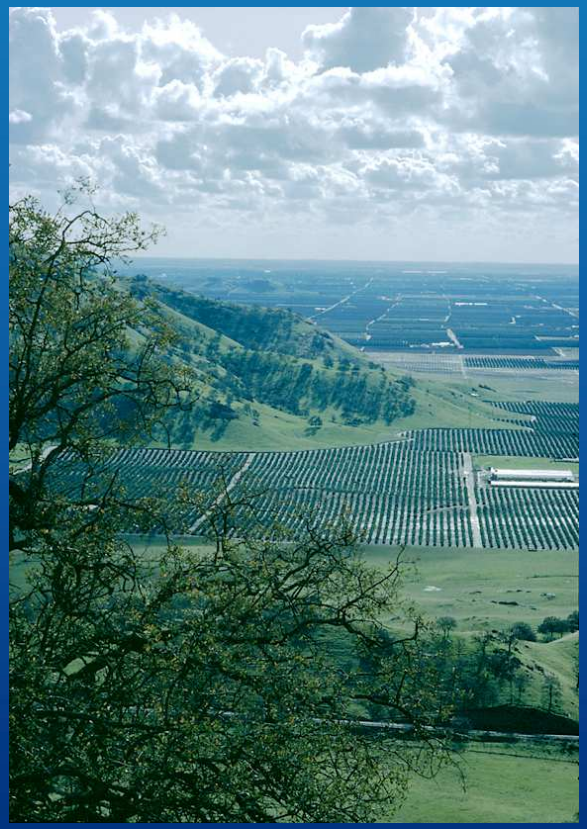
Atmospheric Chemistry

The forecaster predicts variations in:



- Ozone
- Particulate Matter

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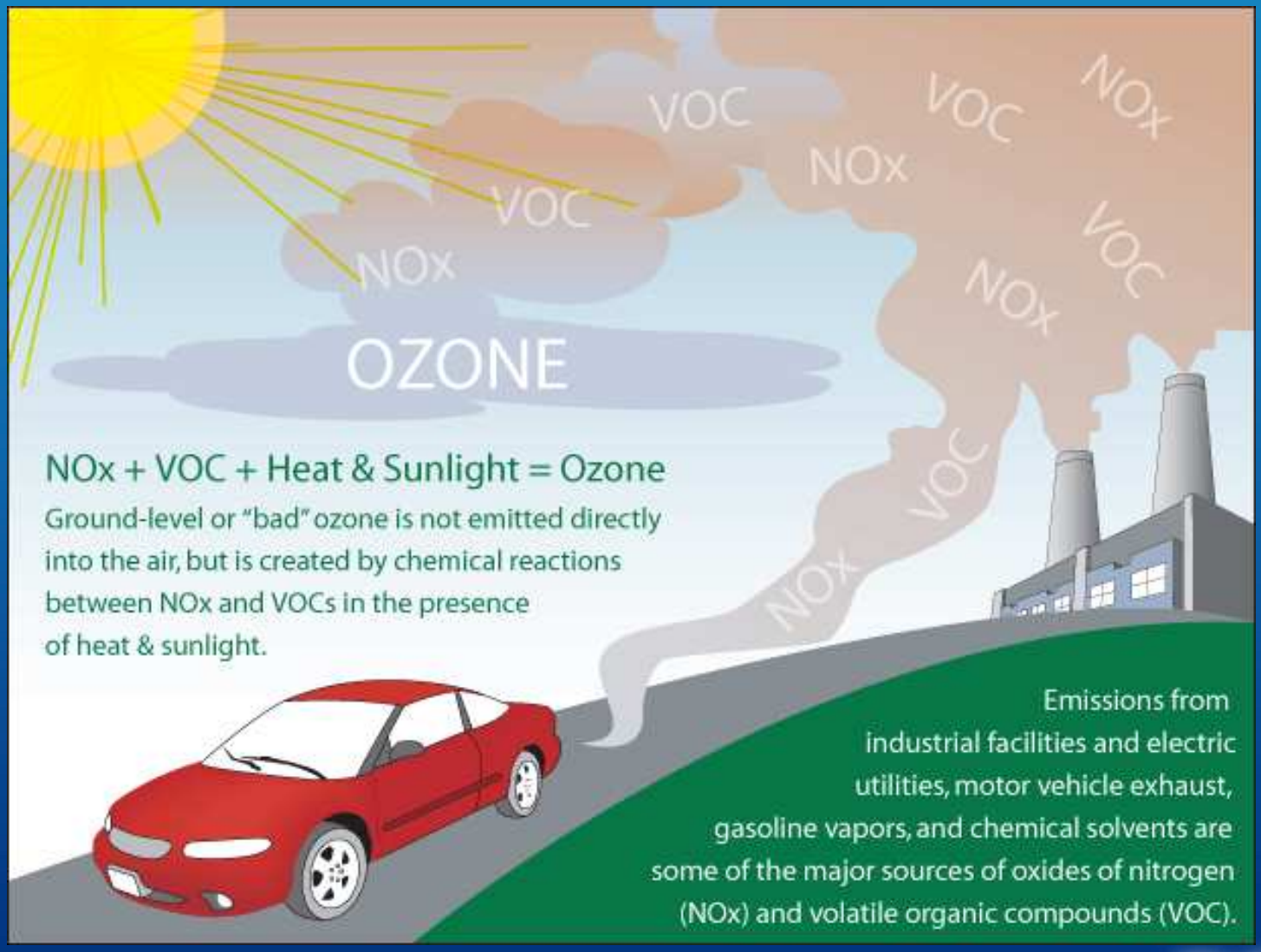
Ozone Formation



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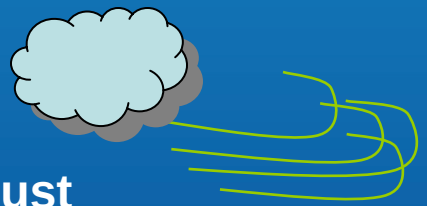
Particulate Matter Comes From Many Sources

Natural

Man Made

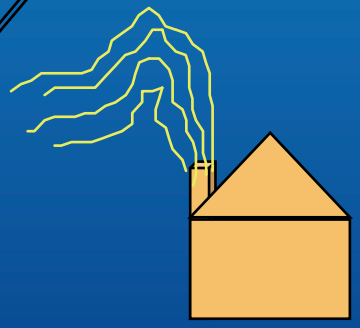


Wind Blown Dust

(Undisturbed Soil)

Wind Blown Dust

(Disturbed Soil)



Wood Burning

Wildfires

Automobiles

Industrial Sources

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Particulate Matter

- PM10 (Coarse) are particles with a diameter of 10 microns or less, whereas PM2.5 (Fine) are particles with a diameter of 2.5 microns or less
- Concentrations gradually build during stagnant conditions
- Concentrations increase rapidly during wind blown dust events and wildfires
- Concentrations vary with time of day

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Emissions
The forecaster must predict:

- Large changes in emissions (wildfires, blowing dust)
- Changes in wind direction & speed during periods of high emissions

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Wildfire Impacts on Air Quality

- Particulate matter (soot & ash)
- Precursors (NOx & VOC) form ozone
- Plume can also block sunlight and reduce surface ozone
- Many fires impact air quality in California every year (including San Joaquin Valley, Great Basin, Mariposa, Tuolumne, and eastern Kern County APCD's)

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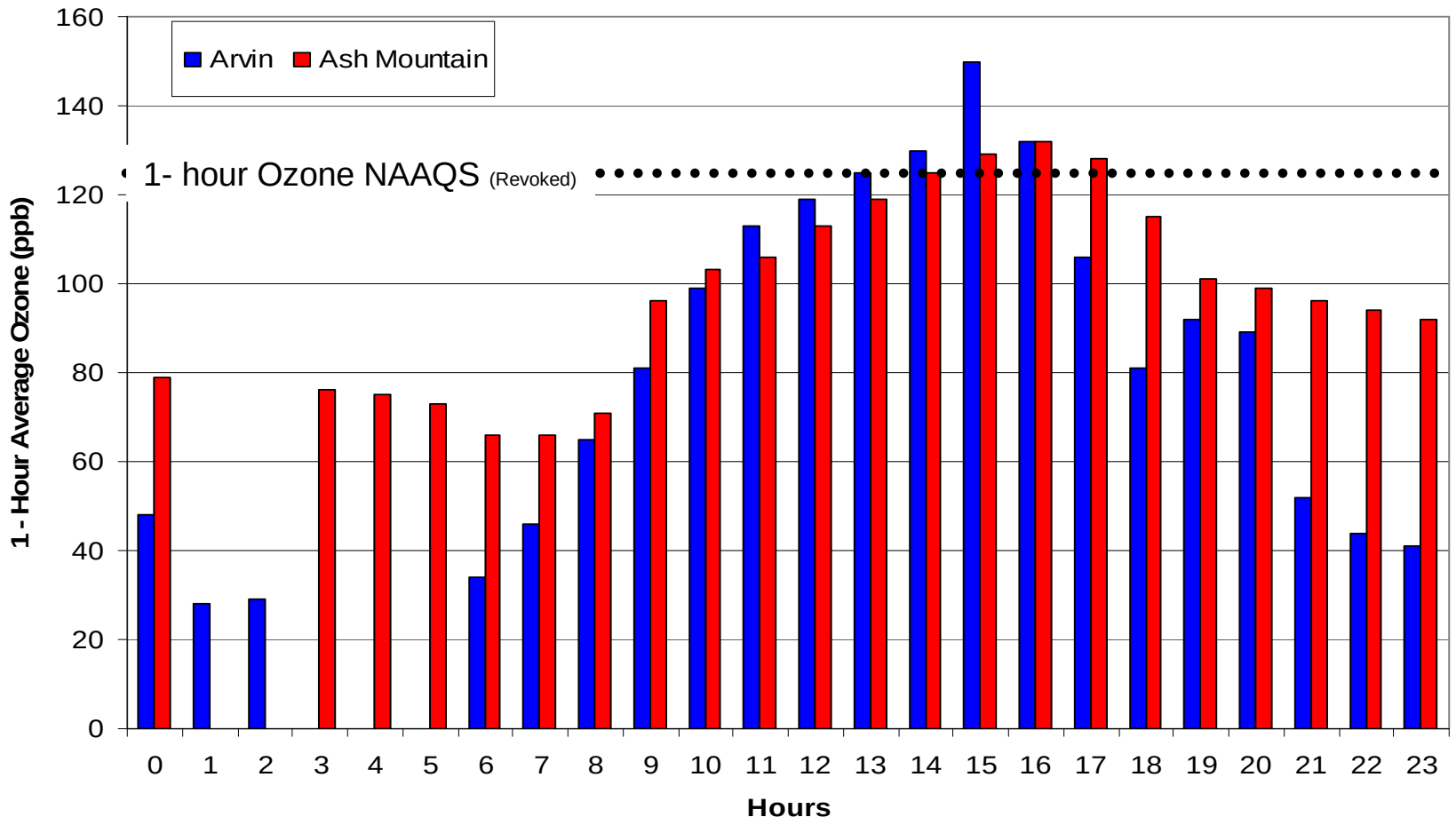
Arvin and Ash Mountain Diurnal Ozone Profile

(June 25, 2008)



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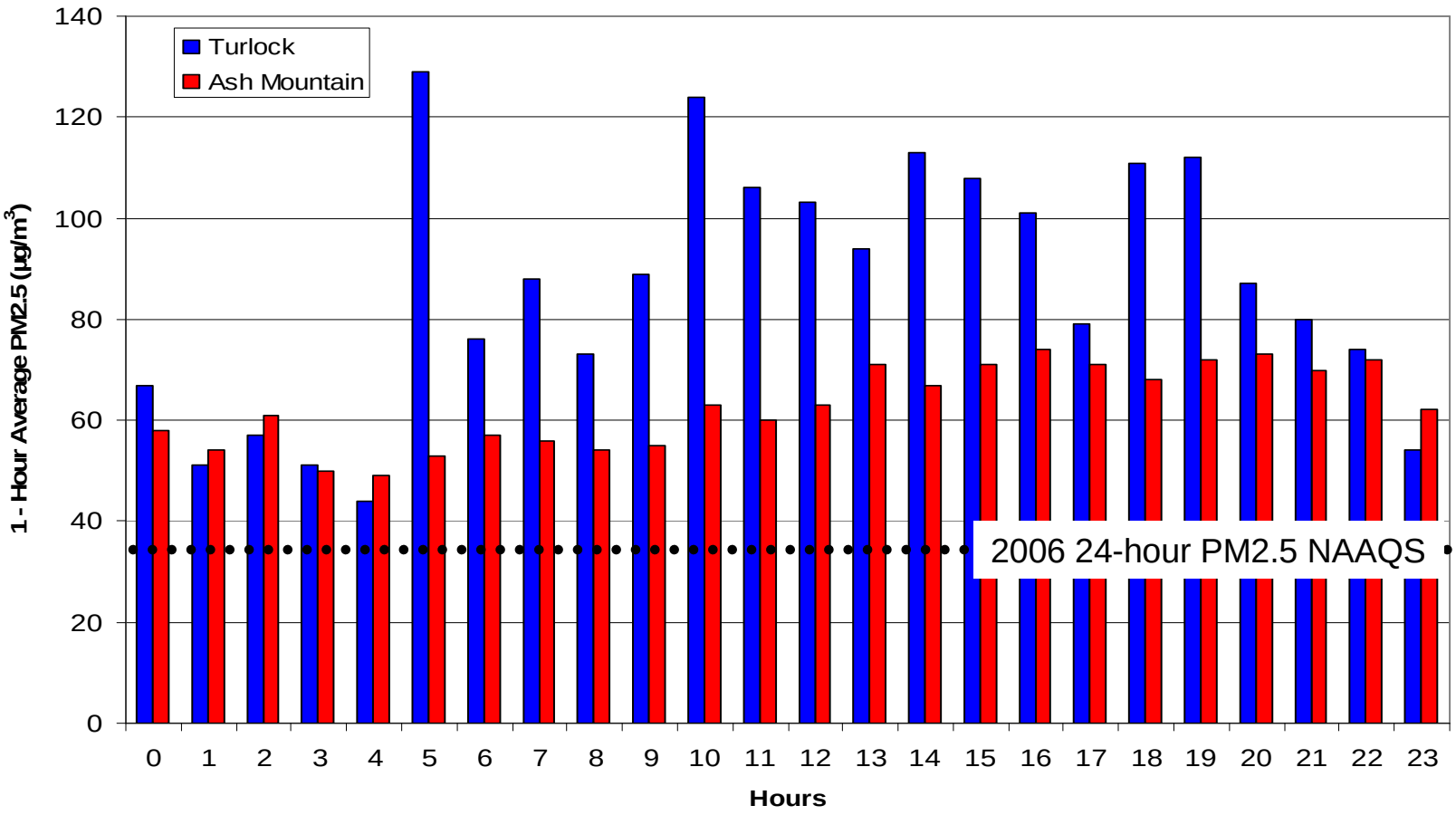
Turlock and Ash Mountain Diurnal PM2.5 Profile

(June 25, 2008)



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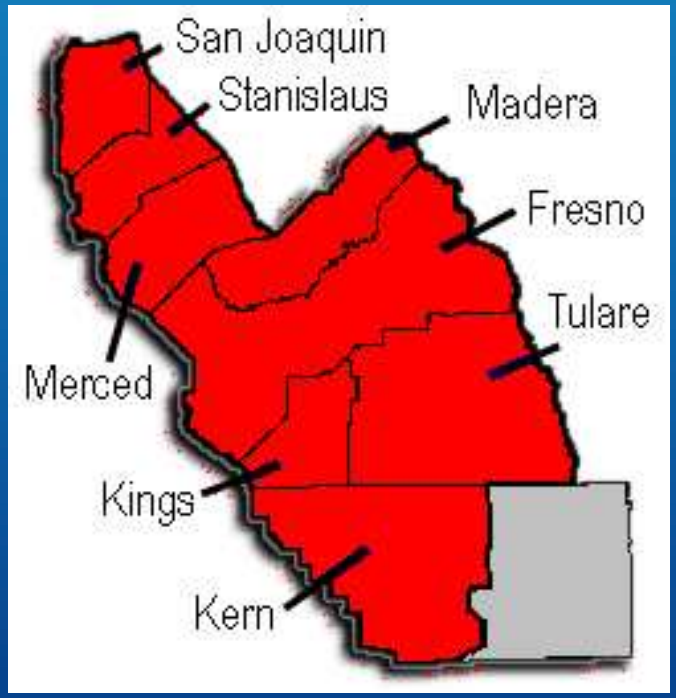
Air Quality Index Forecast

(June 25, 2008)



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Historical Large Emission Sources (Wildfires)

- Air Circulation Patterns Bring Smoke into the San Joaquin Valley.

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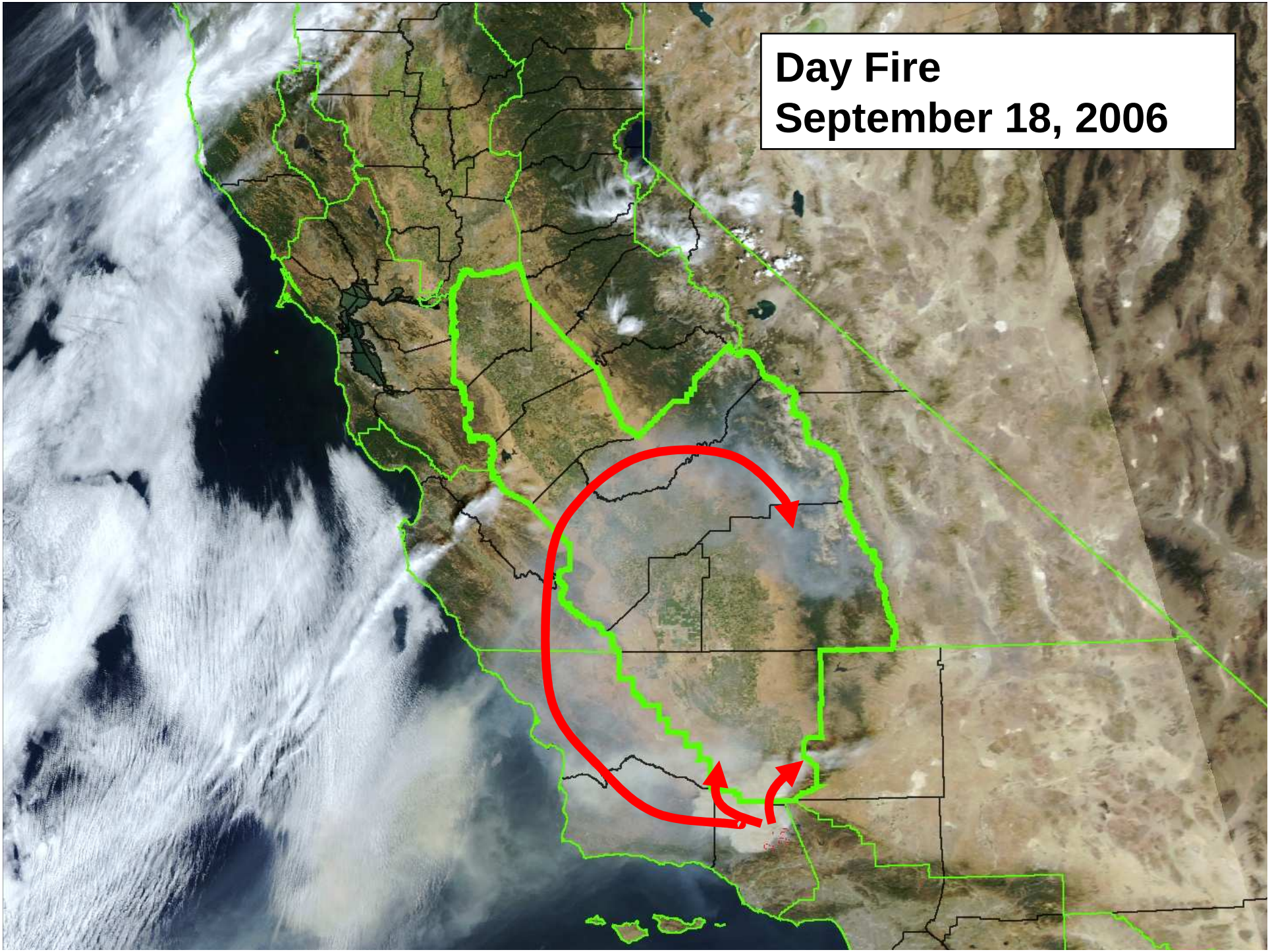
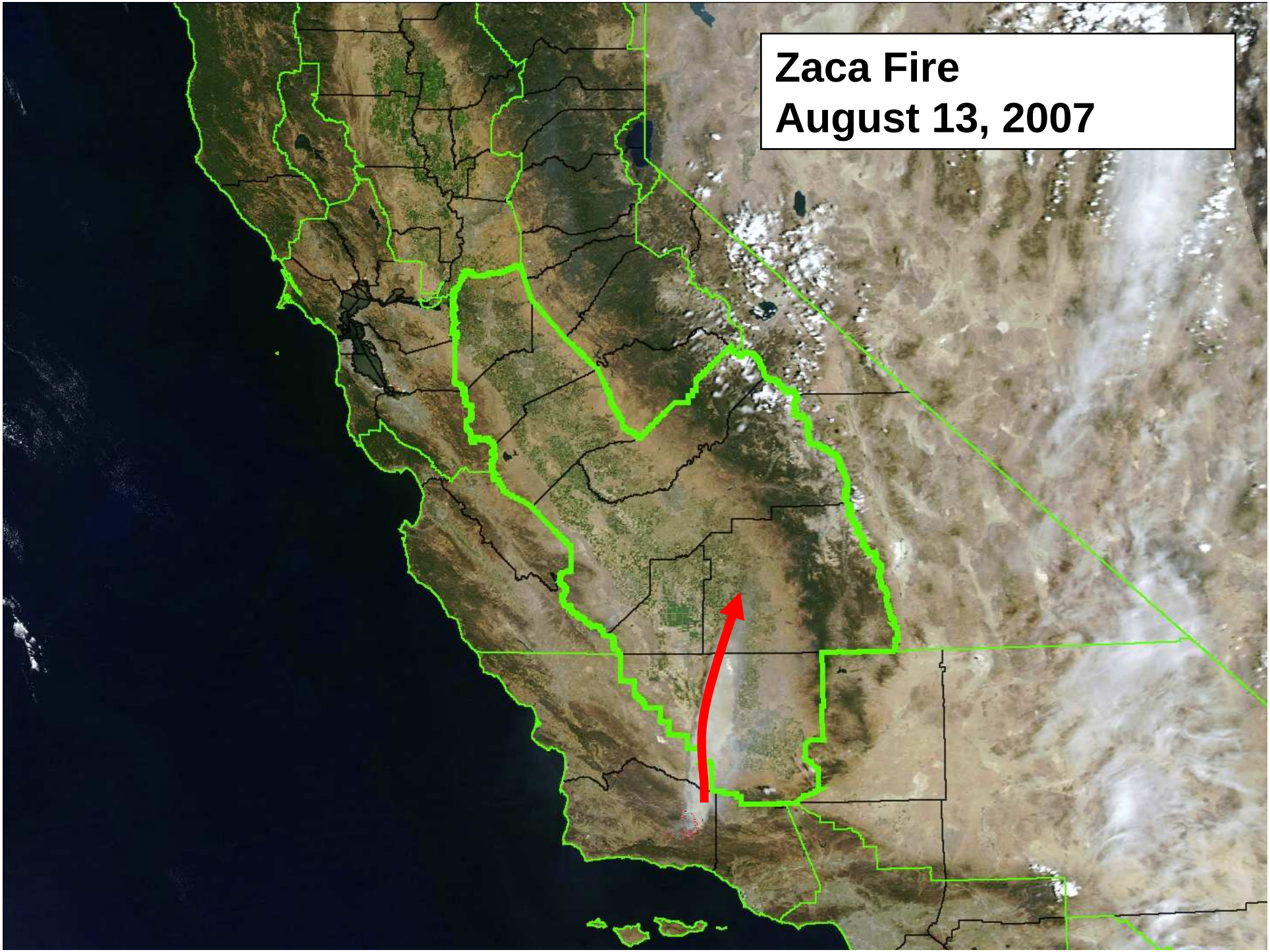
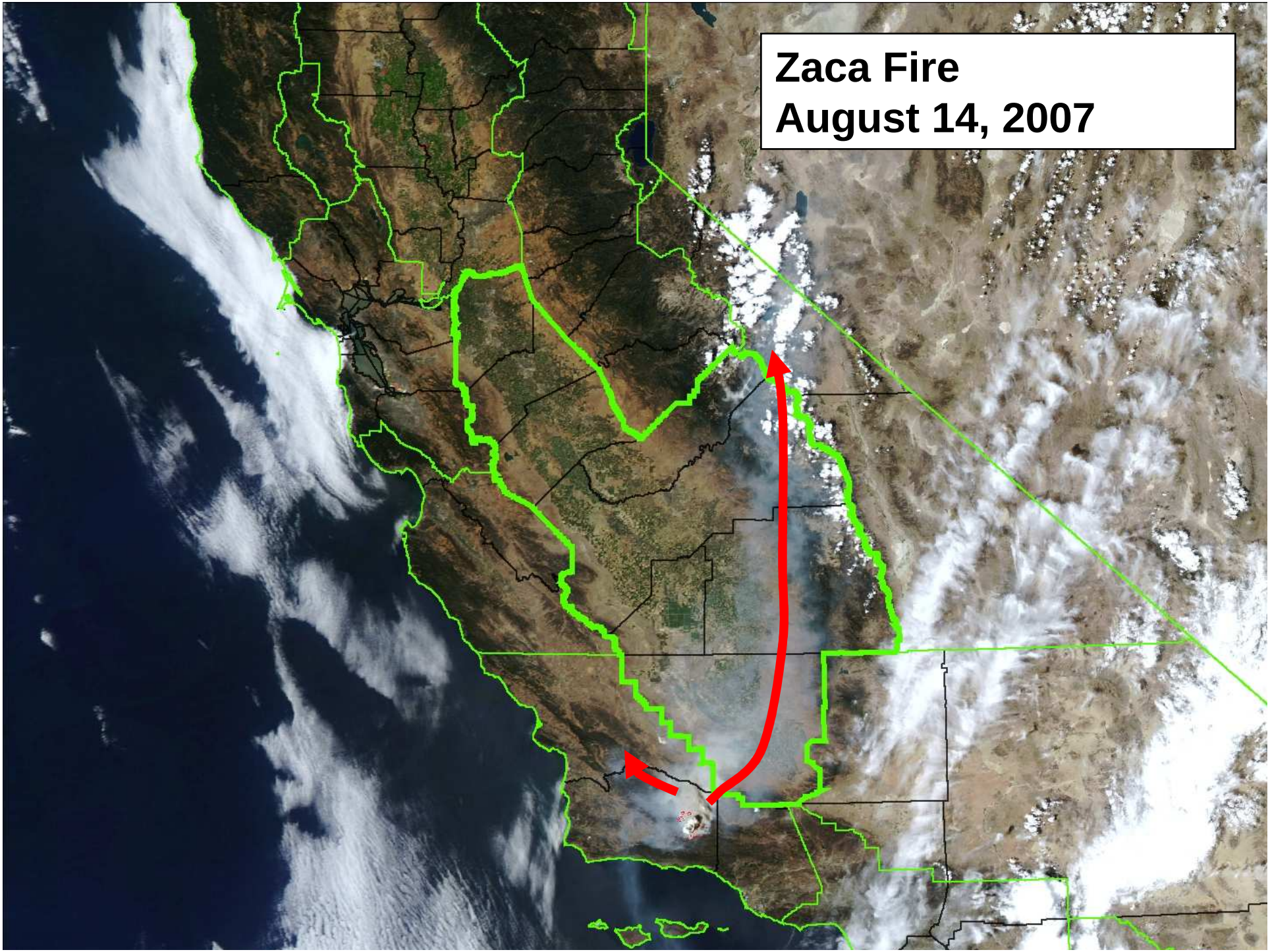
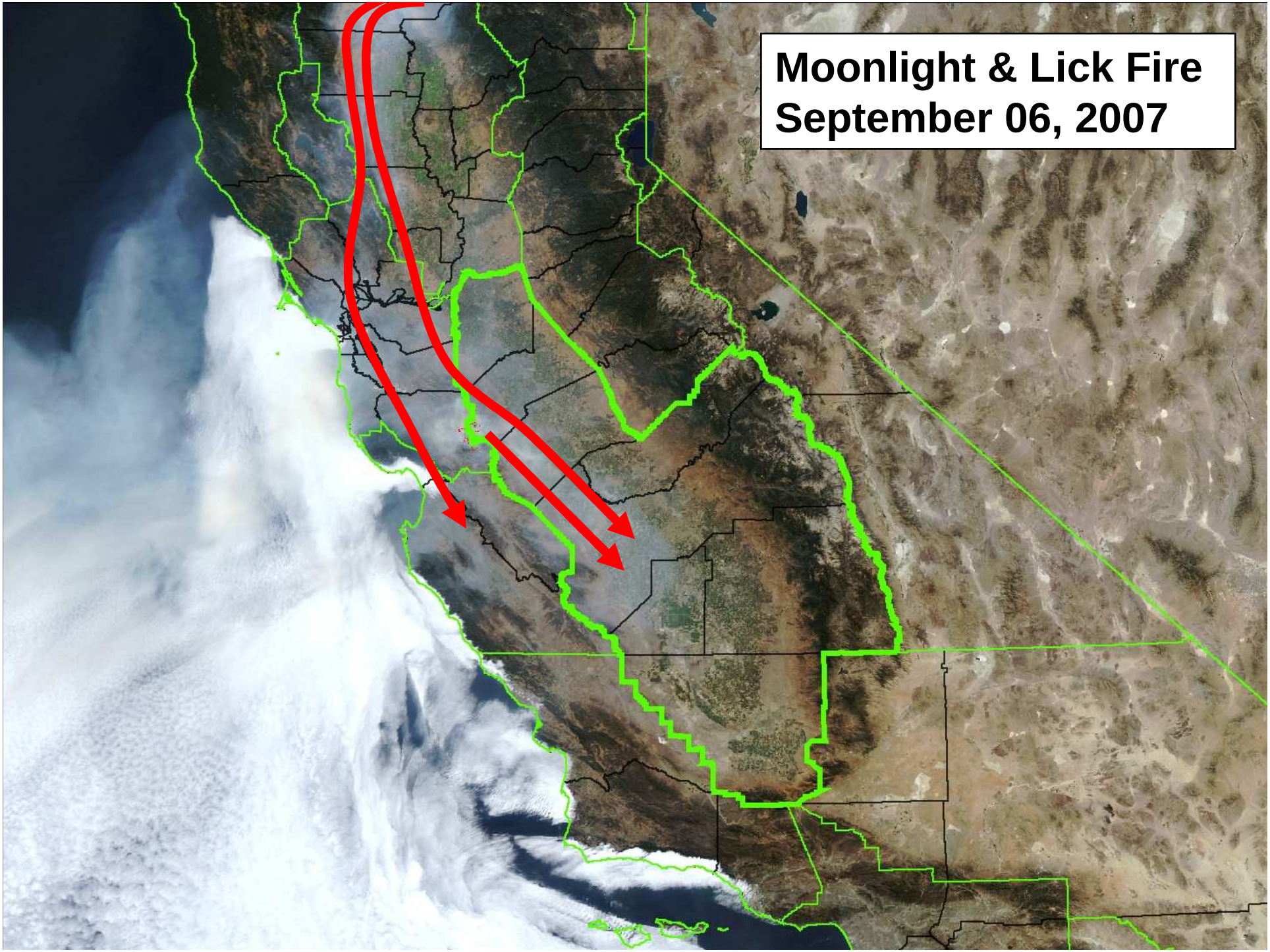
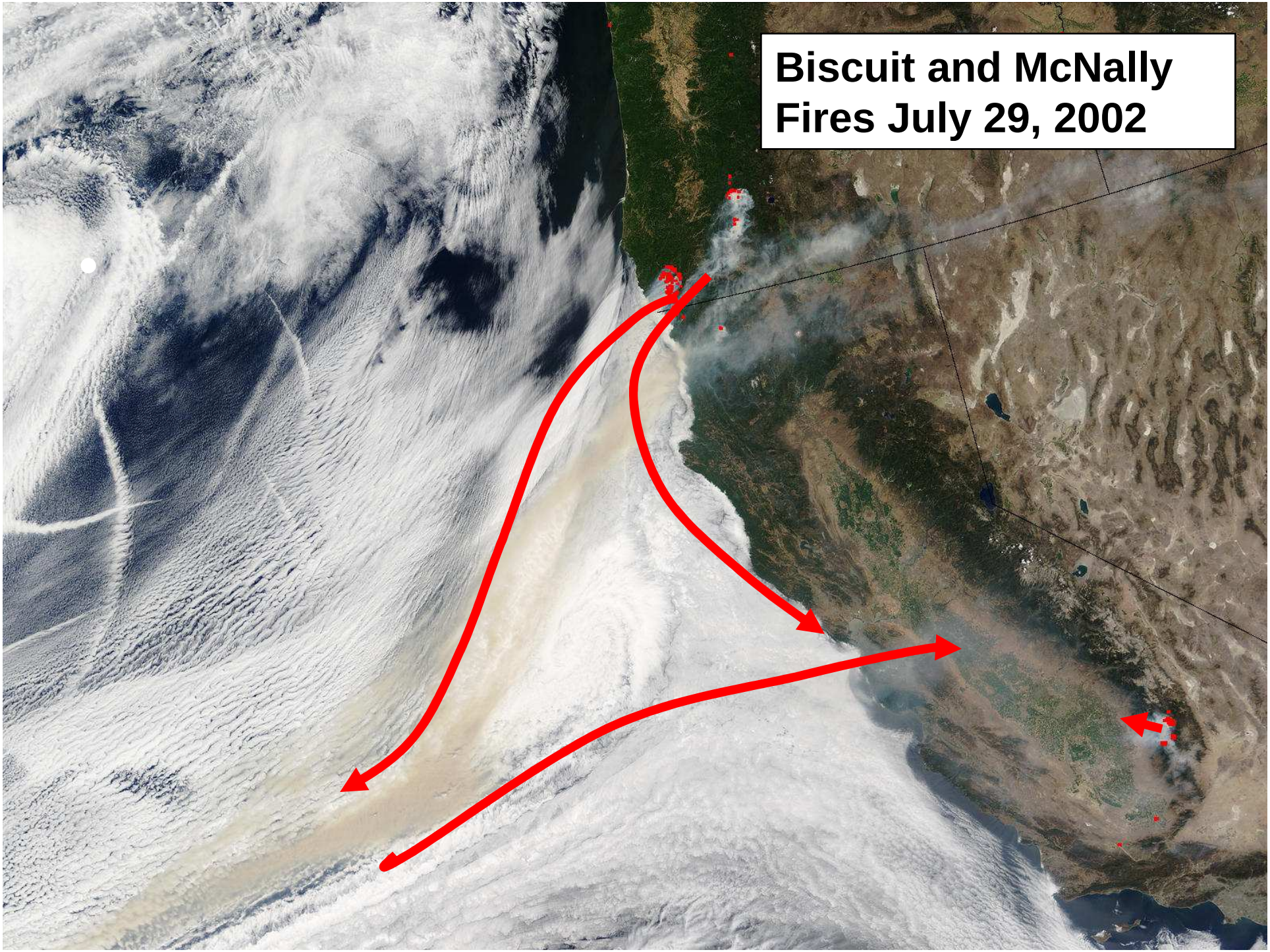

Day Fire
September 18, 2006

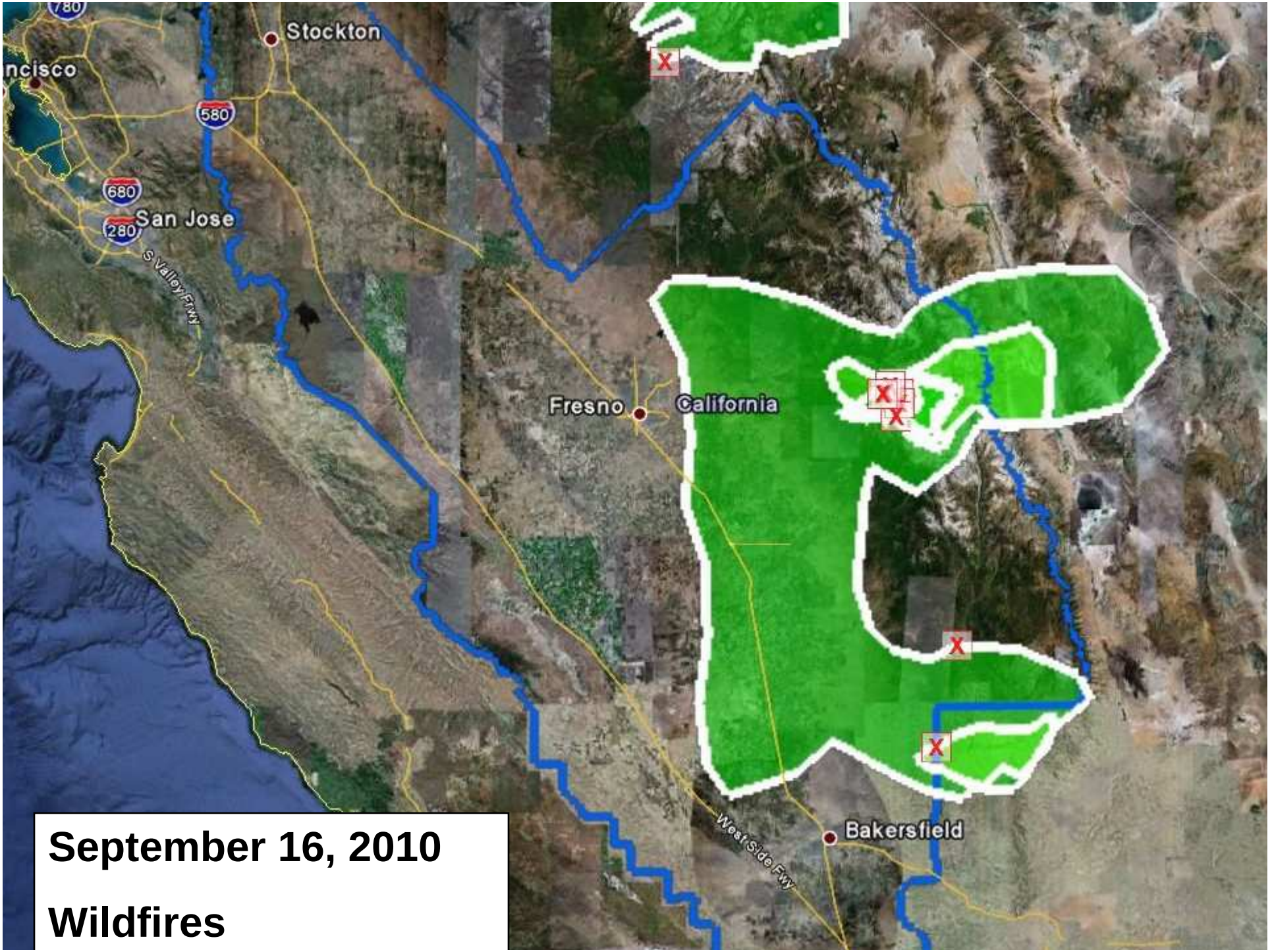

Zaca Fire
August 13, 2007


Zaca Fire
August 14, 2007


Moonlight & Lick Fire
September 06, 2007


Biscuit and McNally
Fires July 29, 2002


Sheep Fire
September 16, 2010


Stockton
ncisco
580
680
San Jose
280
S Valley Fwy
Fresno
California
Bakersfield
West Side Fwy
September 16, 2010
Wildfires

Smoke Management Decisions

- SJVAPCD Rule 4106 (Prescribed Burning and Hazard Reduction Burning), Rule 4103 (Open Burning), and Rule 4901 (Wood Burning Fireplaces and Wood Burning Heaters)
- SJVAPCD Smoke Management System (SMS)
- Title 17 Guidance

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Smoke Management Decisions

- Rule 4106, 4103, and 4901 are more stringent and flexible than Title 17
- Title 17 provides guidance to the SJVAPCD and is the controlling regulation in most of California

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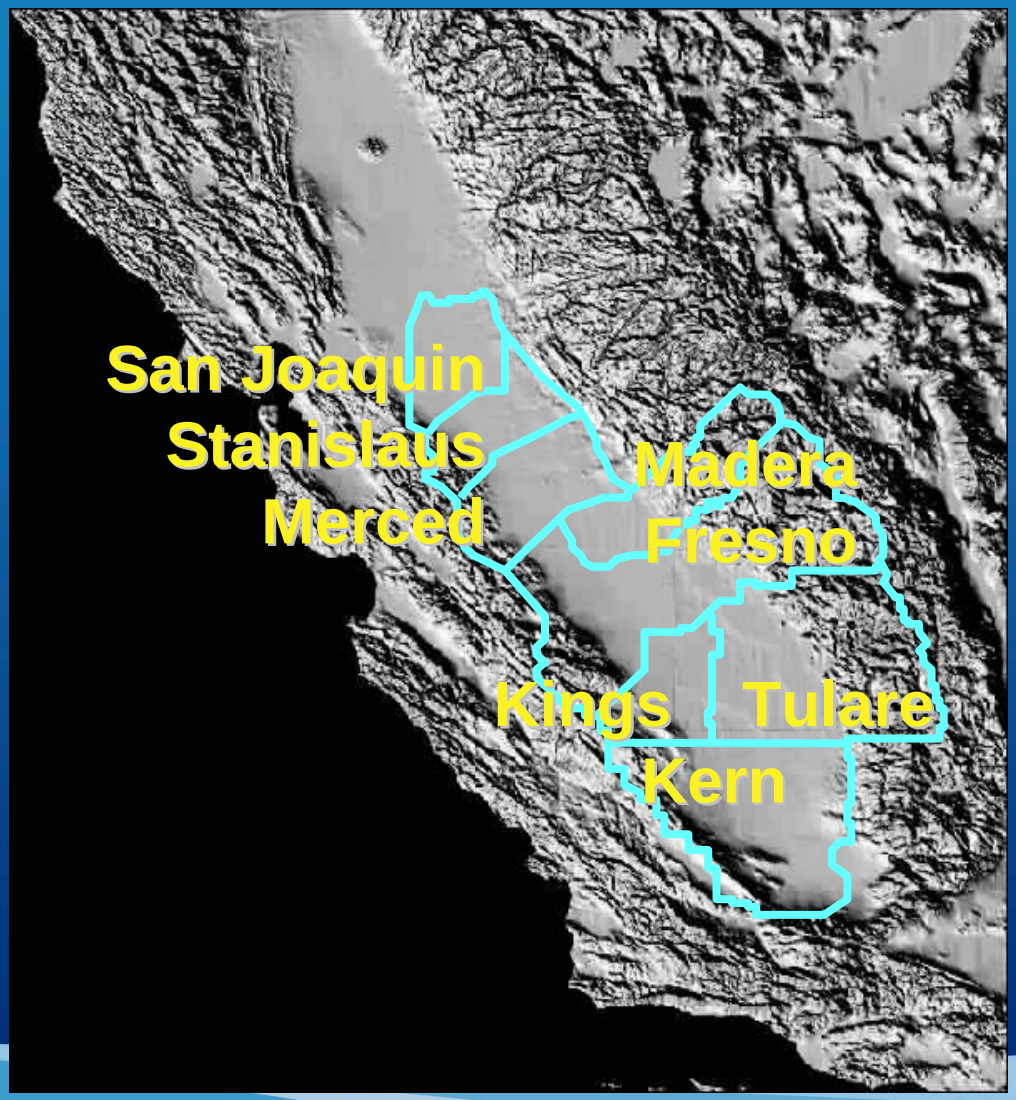
San Joaquin Valley Air Basin



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Title 17 Overview

- Establishes
  - Different burn areas in California
  - Start and stop times
  - Reporting requirements
  - Coordination amongst agencies
  - Meteorology criteria to help in burn day determinations

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Smoke Management System

Distribution of Emissions

- Controls where burning occurs
- Controls when burning occurs
- Improves how burning limits are established
- Increases options and hours for requesting burns
- Increases the number of areas where some amount of burning is allowed

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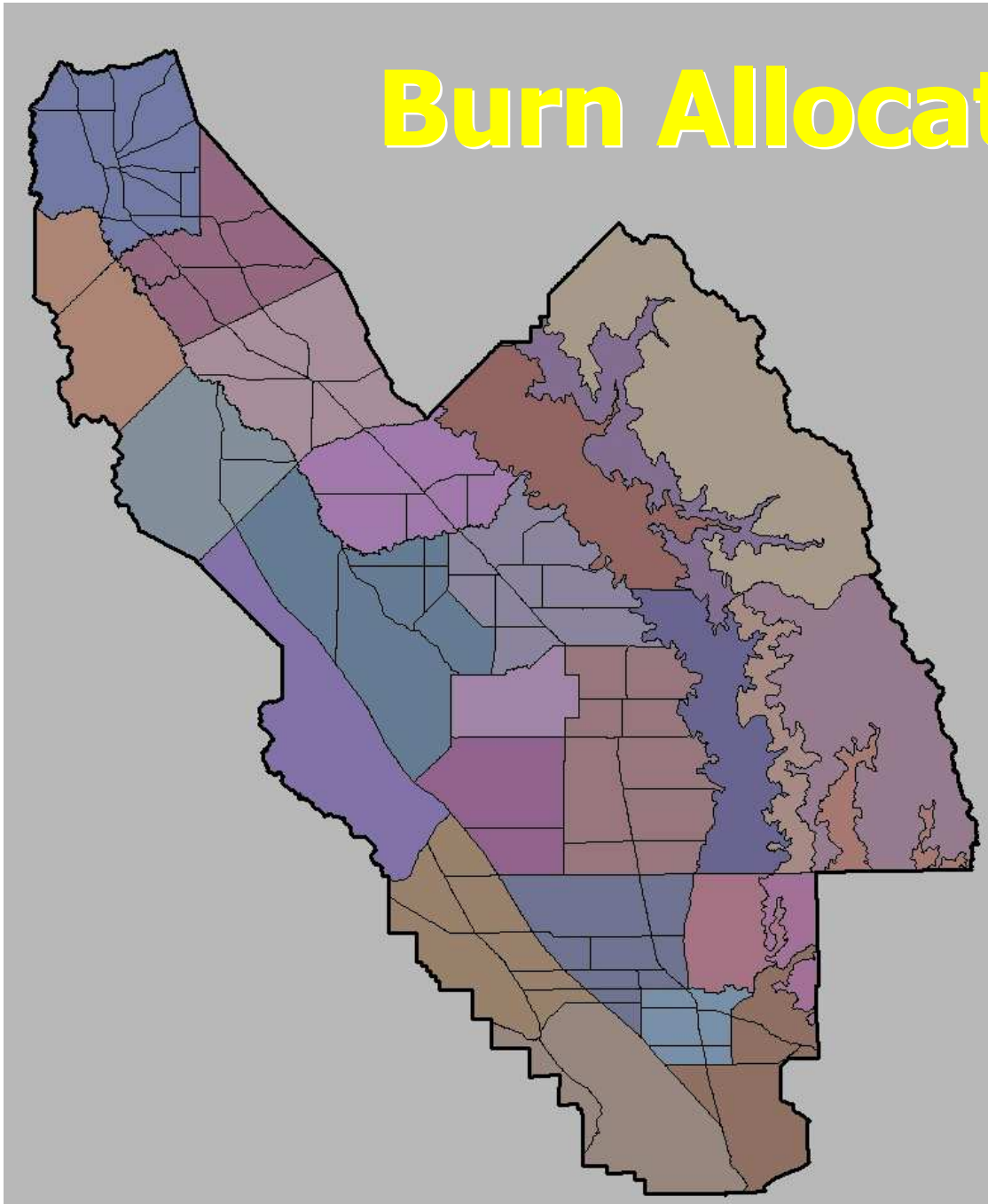
Burn Allocation Zones



- 103 Zones
- Developed from
  - AQFAs
  - Crop Distribution
  - Historical Burning
  - Inspector Knowledge
  - Receptors
  - Known Boundaries

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Emission Allocations

are based on:

- Season (Pollutant)
- Meteorology
- Air Quality
- Projected burning trends
- “Special Events” (Prescribed Fires, Wildfires, Tire Fires, Trash Fires, etc.)
- Historical burn patterns (1998-2003)
- Land use
- Source/Receptor relationships
- California Health and Safety Codes 41855.5 and 41855.6
- SJV District Rules 4106, 4103, 4901

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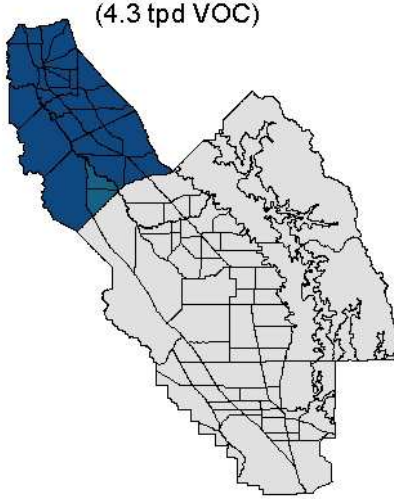
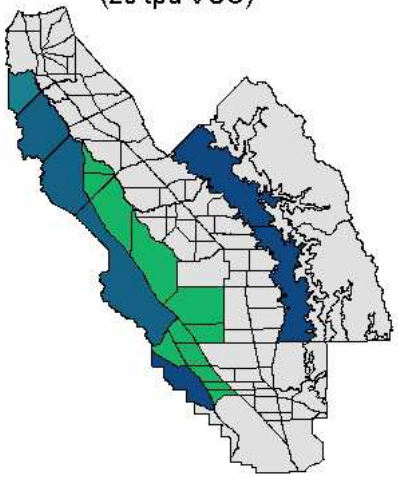
Allocation Scenarios

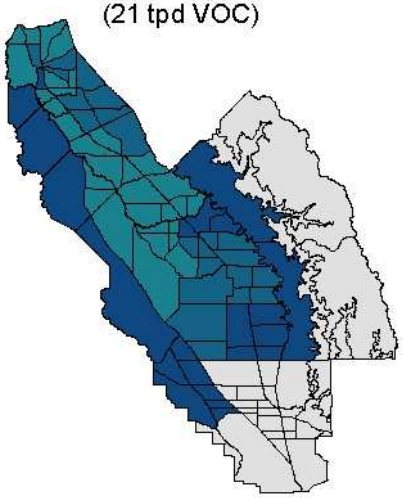
Combo 10
0-400 ac/cnty 0 Madera South
(4.3 tpd VOC)



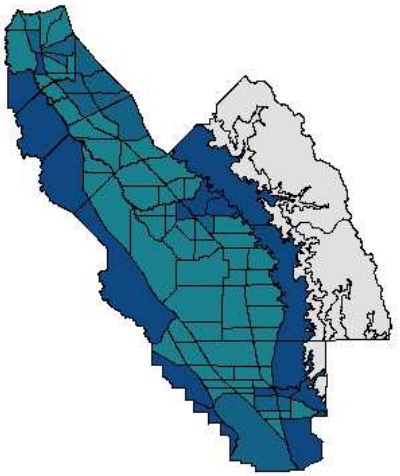
West 4
400 ac/cnty w/o HWY99
(20 tpd VOC)



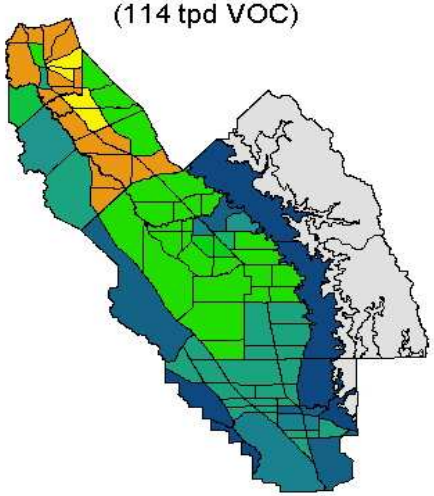
Combo 20
0-600 ac/cnty South Low
(21 tpd VOC)



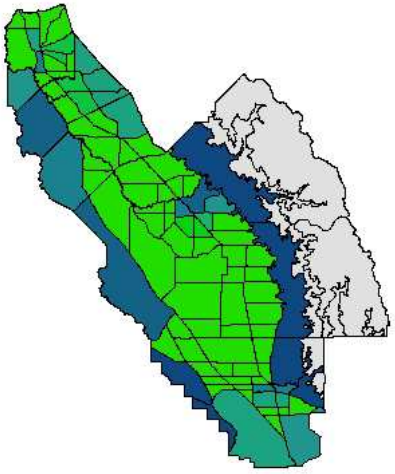
SJV 06
600 ac/cnty (30 tpd VOC)



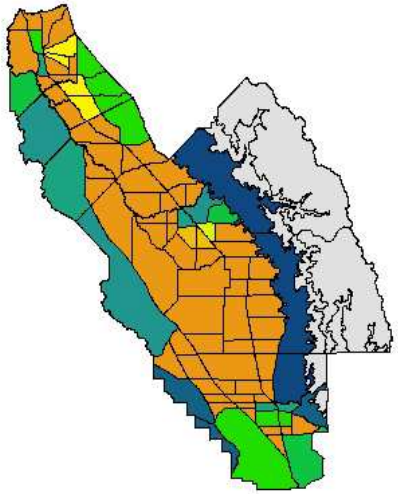
Combo 60
1000-4000 ac/cnty South Low
(114 tpd VOC)



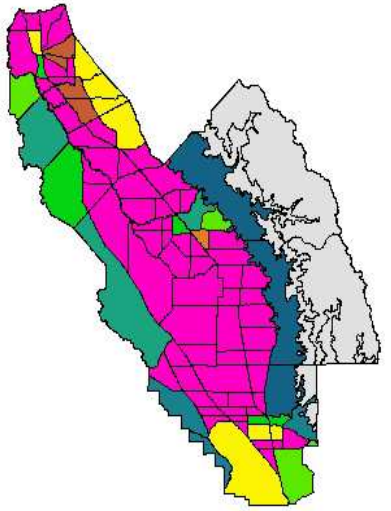
SJV 20
2000 ac/cnty (100 tpd VOC)



SJV 40
4000 ac/cnty (200 tpd VOC)



SJV 60
6000 ac/cnty (300 tpd VOC)



Agricultural Allocation Criteria

- Buffer Zones
- Planned Prescribed Burns
- Wildfires
- Emergency Response Fires

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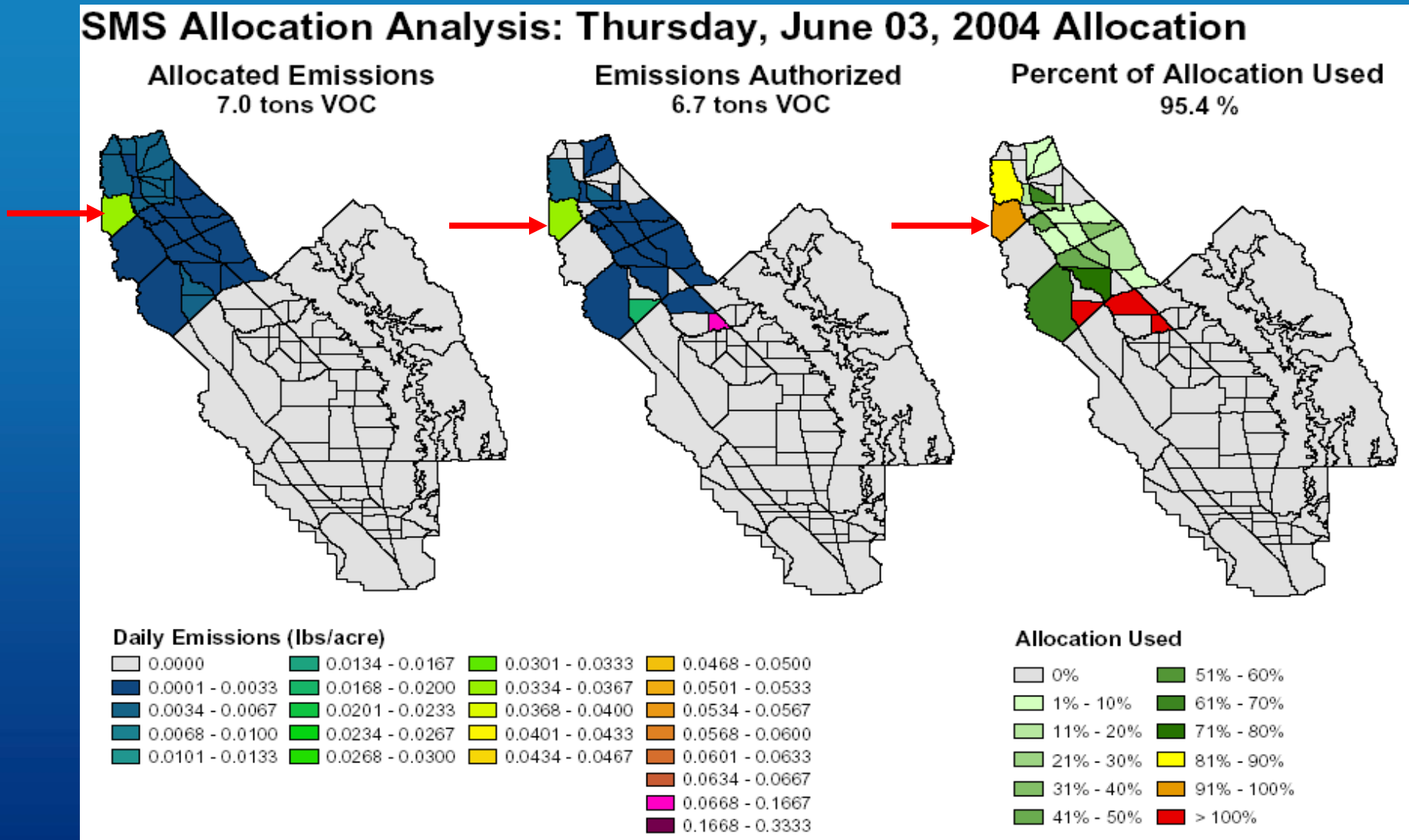
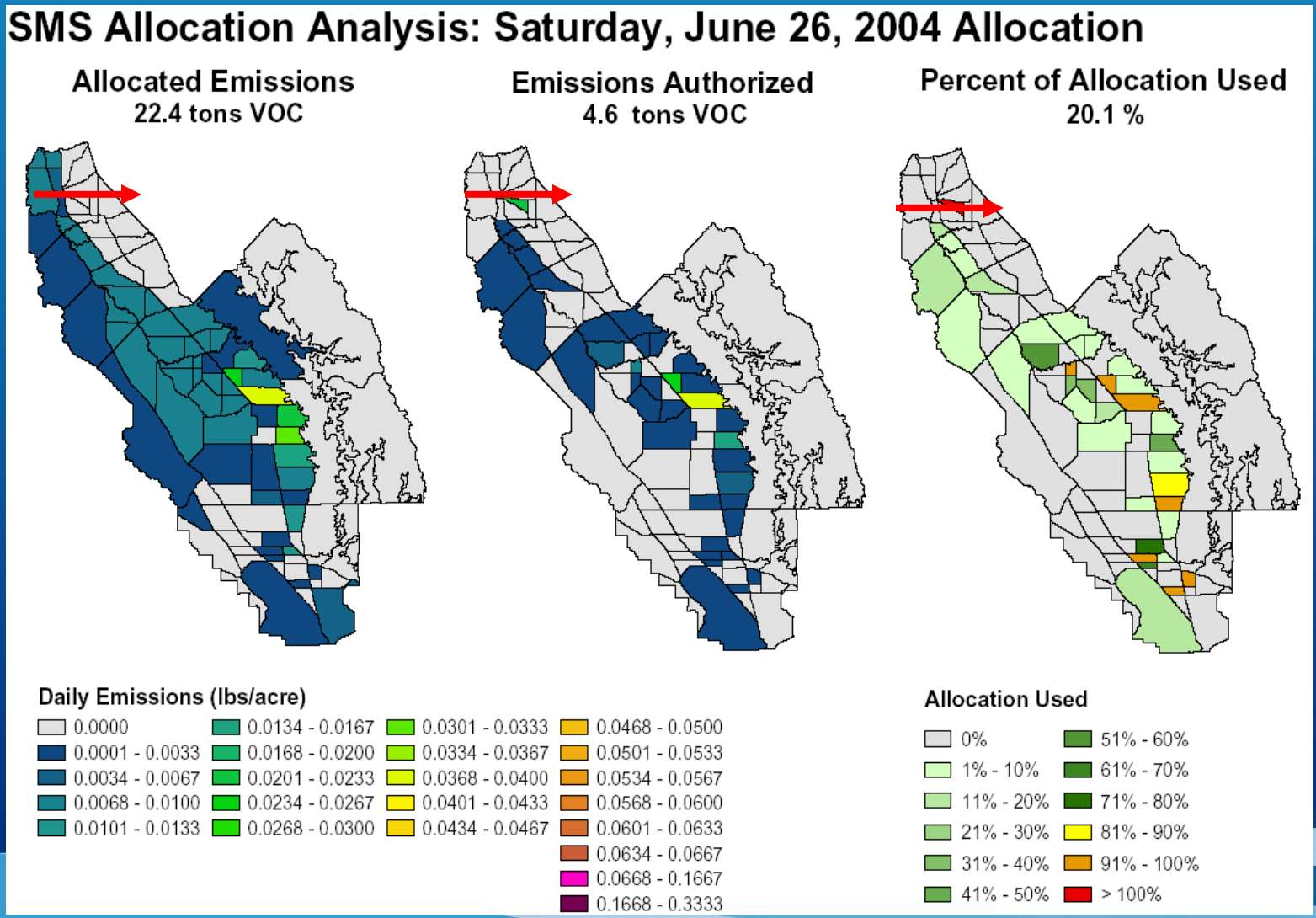
LLNL Prescribed Burn



COMMENTS: 'Emissions Authorized' and 'Percent of Allocation Used' would be lower if Zone allocation limits were observed. 1.89 tons VOC variance authorized for D3-05. An additional 0.49 tons VOC was authorized above the allocation fro C1-03. 2.79 tons VOC authorized for the LLNL prescribed burn in B1-01.

Calaveras County
CDF Prescribed Burn



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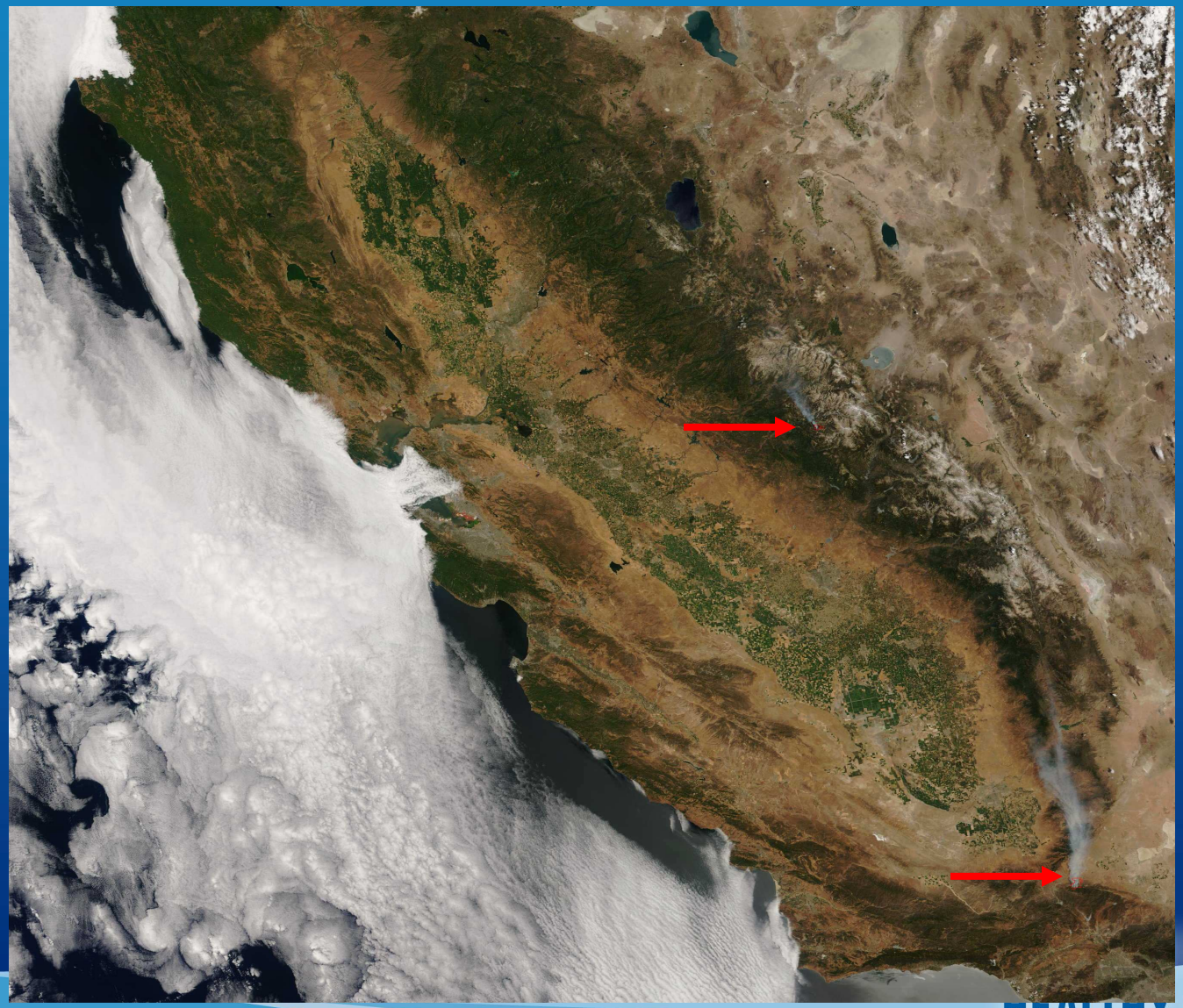
Wildfires in eastern Fresno and northeastern L.A. County on July 13, 2004



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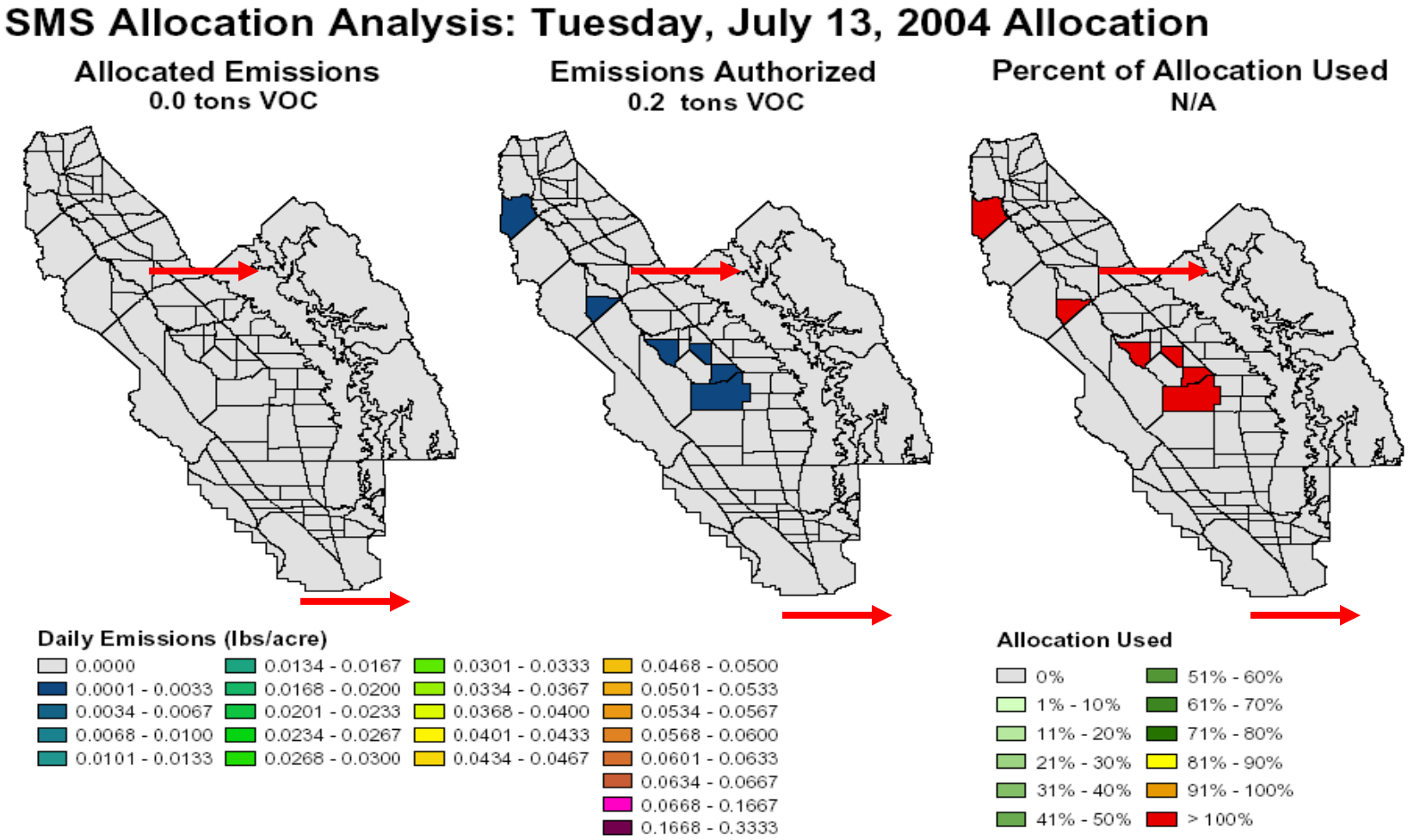
Wildfires in eastern Fresno and northeastern Los Angeles counties



Smoke Management Summary

- Considers Agriculture/Prescribed Burns
- Considers Source Receptor Relationships
- More Control of Emissions Instead of No Emissions
- Equity Between Agriculture & Prescribed Burns
- Allocations of Agricultural Fire Emissions Are Reduced Around Areas of Prescribed Burning
- Prescribed Burn Decisions Can Be Affected By Amount of Agricultural Burn Potential

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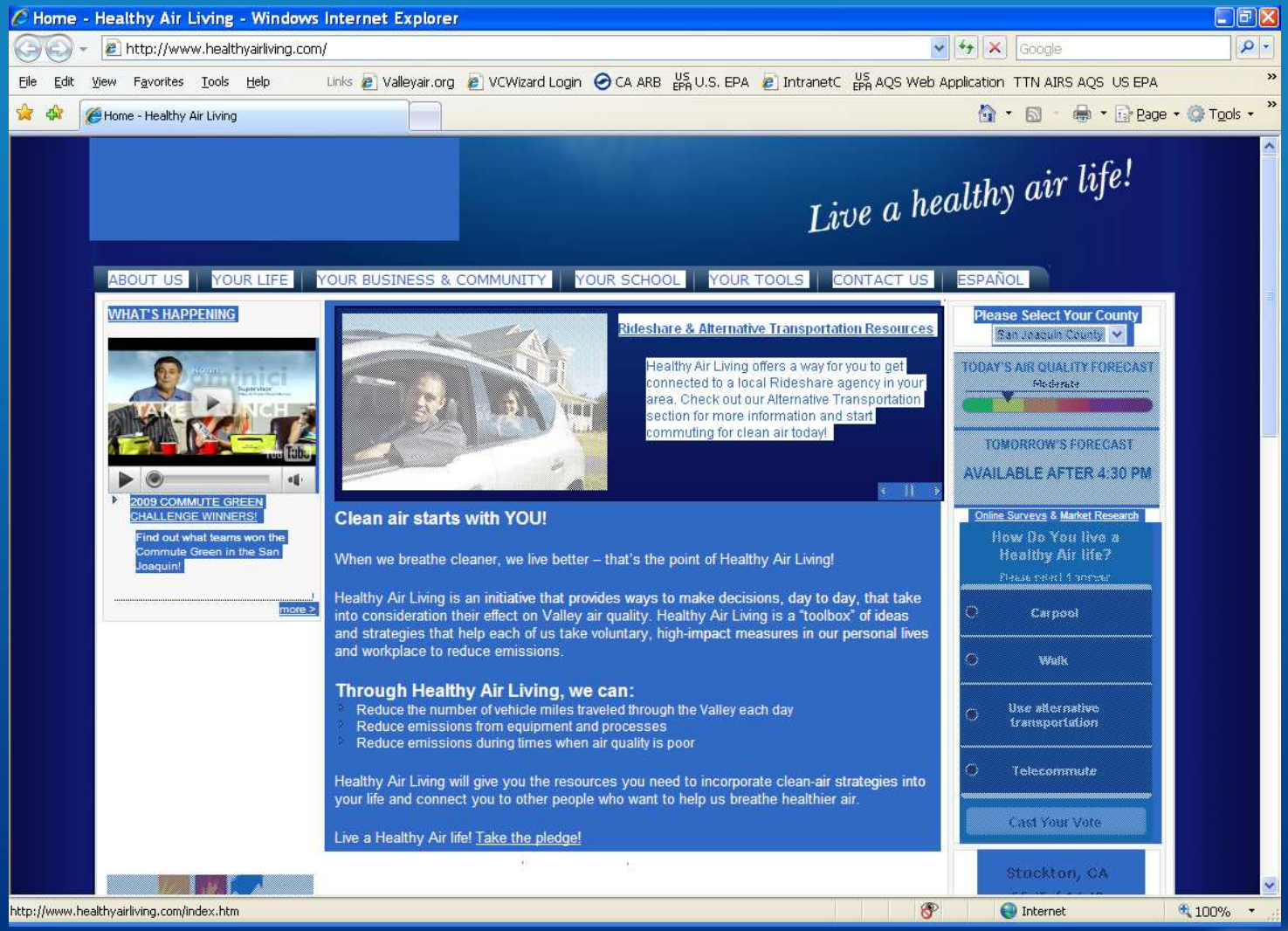

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Questions?

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