

Use of Remote Sensing to Detect and Monitor Landscape Vulnerability to Wind Erosion and Dust Emission With Potential Connections to Climate and Air Quality



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This presentation will cover

- Use of satellite and airborne imaging to detect and monitor *temporal and spatial dynamics* of vegetation which is *critical to wind erosion vulnerability*
- *Monitoring dust storms* using satellite imaging, field based cameras, wind meters, and sensit
- Potential relationships between *climate, dust, and air quality*
- Potential applications *along I-10 and Southern Arizona*

In many landscapes the potential vulnerability to *wind and water erosion* is a critical issue with *vegetation sheltering and dynamics* being important components that influence the level of vulnerability.

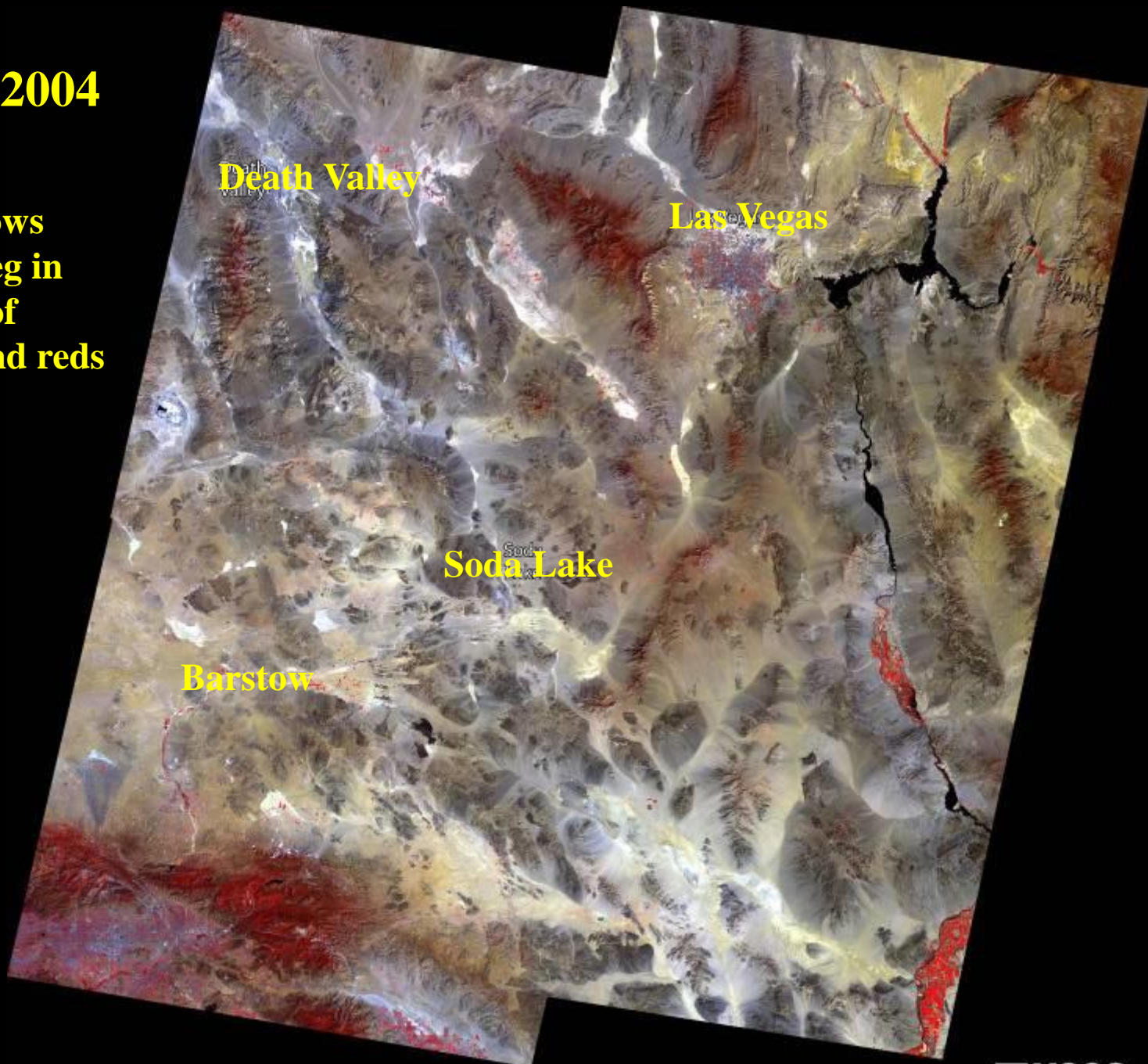
Therefore, methods to detect, map, and monitor the *temporal and spatial dynamics of vegetation* are critical to help map and *monitor the degree of vulnerability* to wind and water erosion at any given time.

Temporal Dynamics

Detecting and mapping *vegetation dynamics through time* using 30m resolution Landsat TM satellite images. In arid regions most of the short-term (*months to a few years*) dynamics are related *mostly to annuals and grasses --- fine fuels*.

Sept 2004

**Note:
CIR shows
green veg in
shades of
pinks and reds**

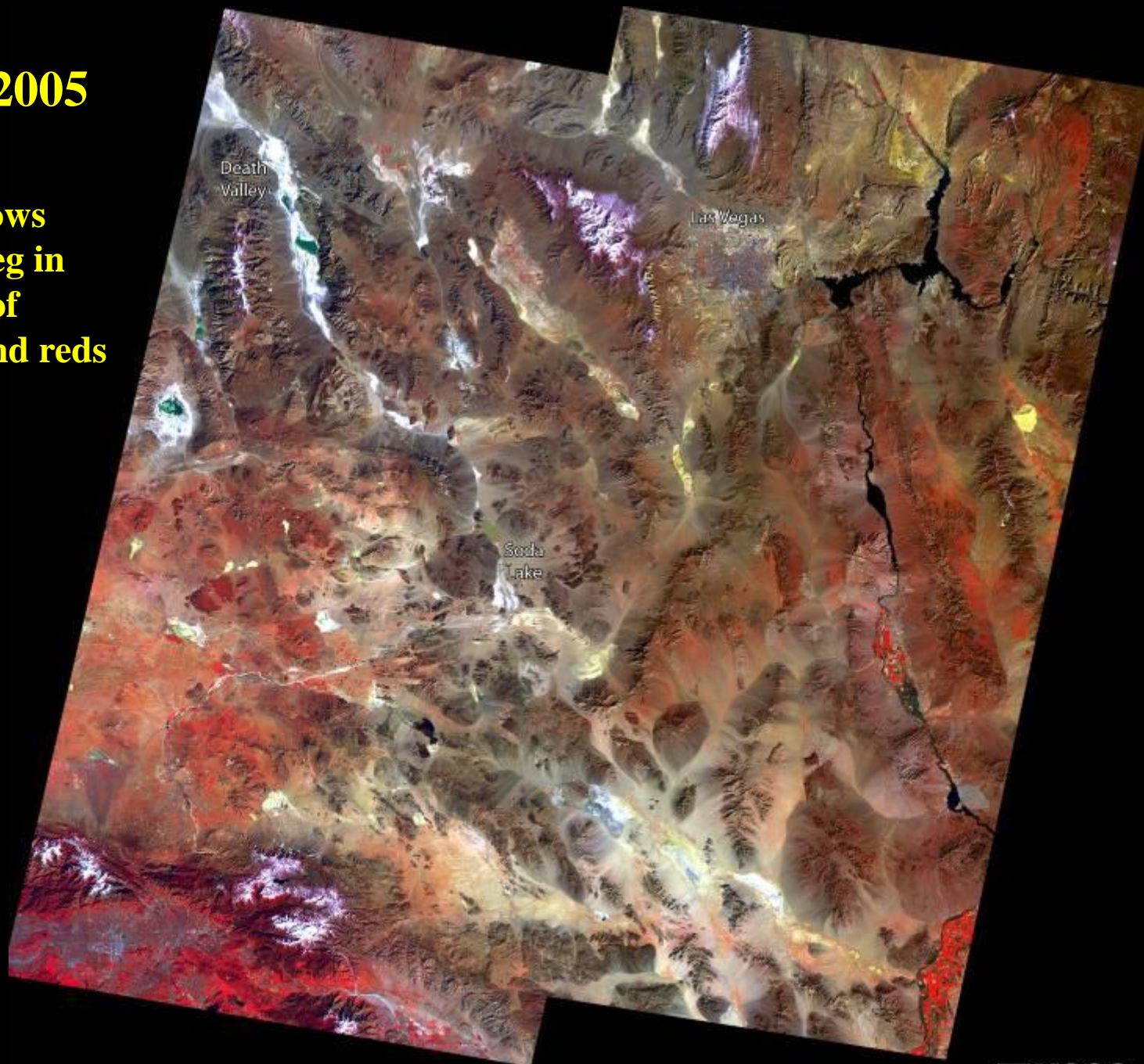


5 Kilometers

Mojave Desert: Landsat TM September 2004

Feb 2005

**Note:
CIR shows
green veg in
shades of
pinks and reds**

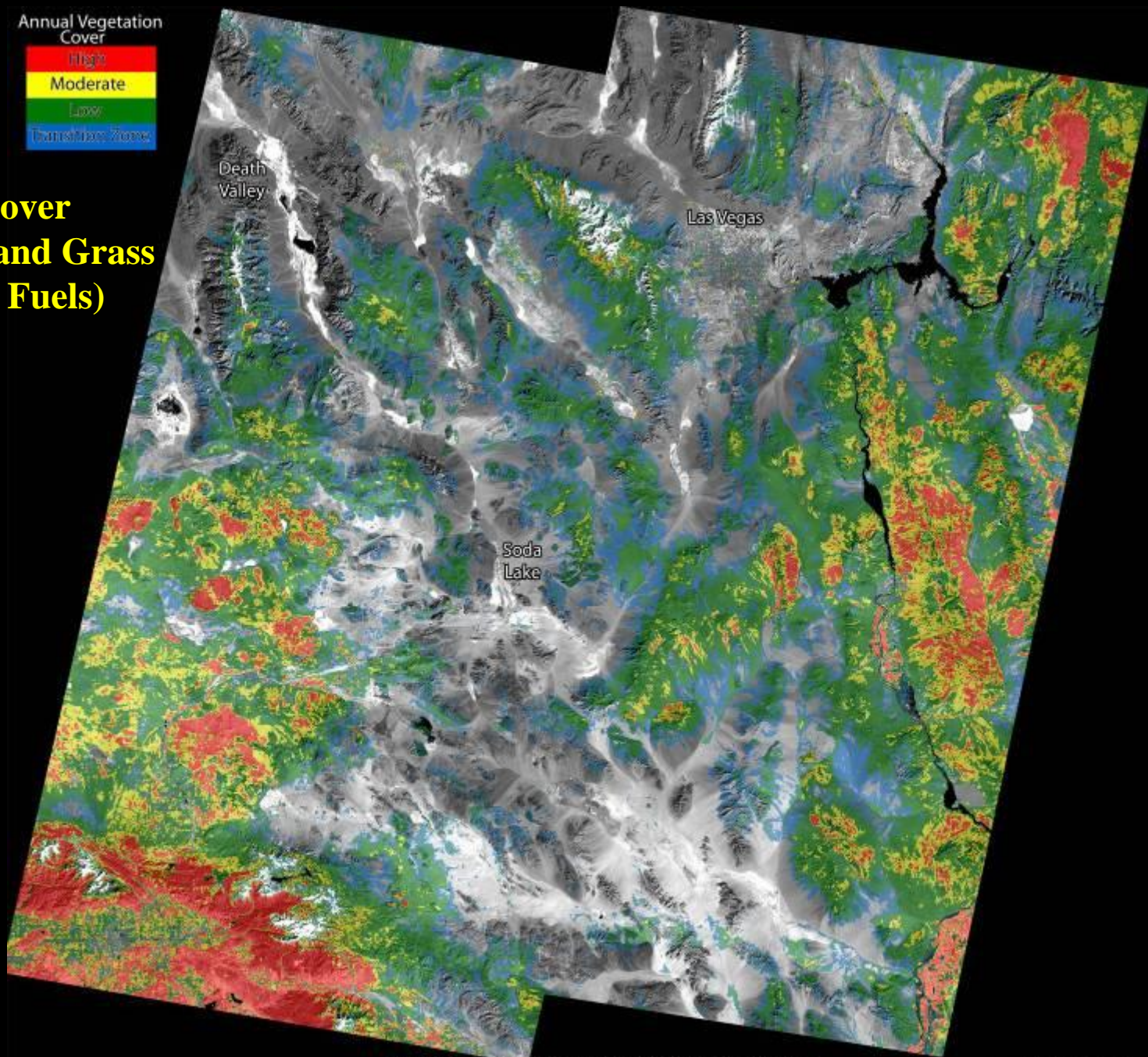


5 Kilometers

Mojave Desert: Landsat TM February 2005



Veg Cover Annuals and Grass (Fine Fuels)



5 Kilometers

Mojave Desert: Annual Vegetation Map
from Landsat TM February 2005



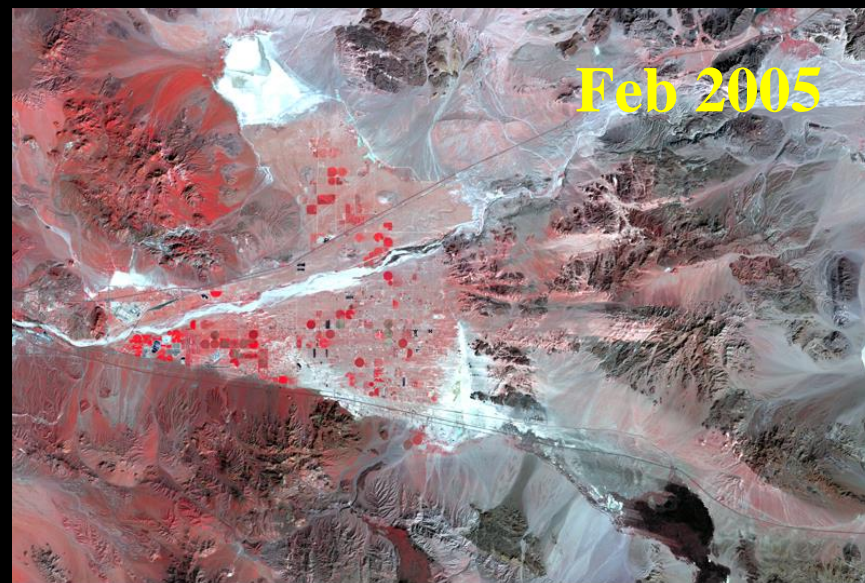
Bottom Images --- Amount of Sheltering with Grey/Blue High and Red/Yellow Low



Sept 2004

10 Kilometers

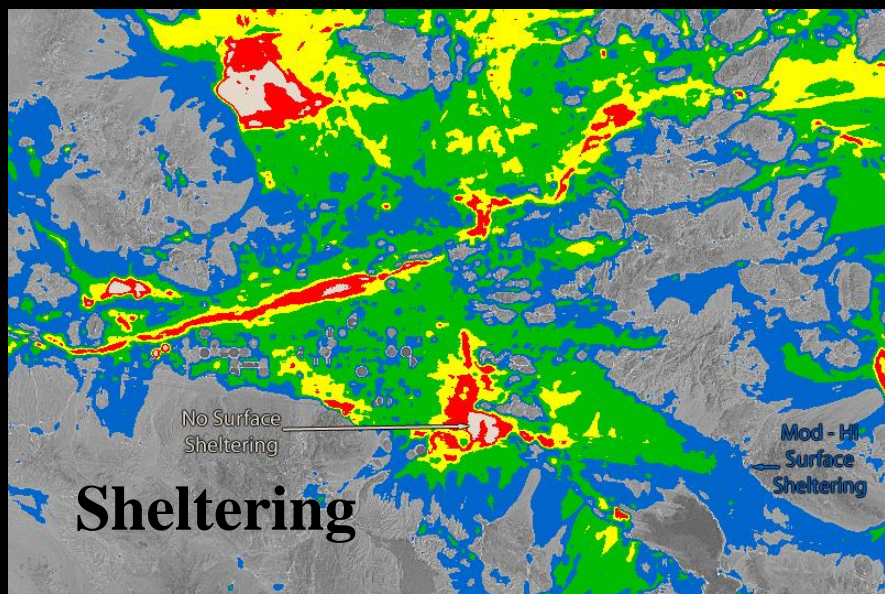
Mojave River Area
Landsat TM - Sep 04



Feb 2005

10 Kilometers

Mojave River Area
Landsat TM - Feb 05



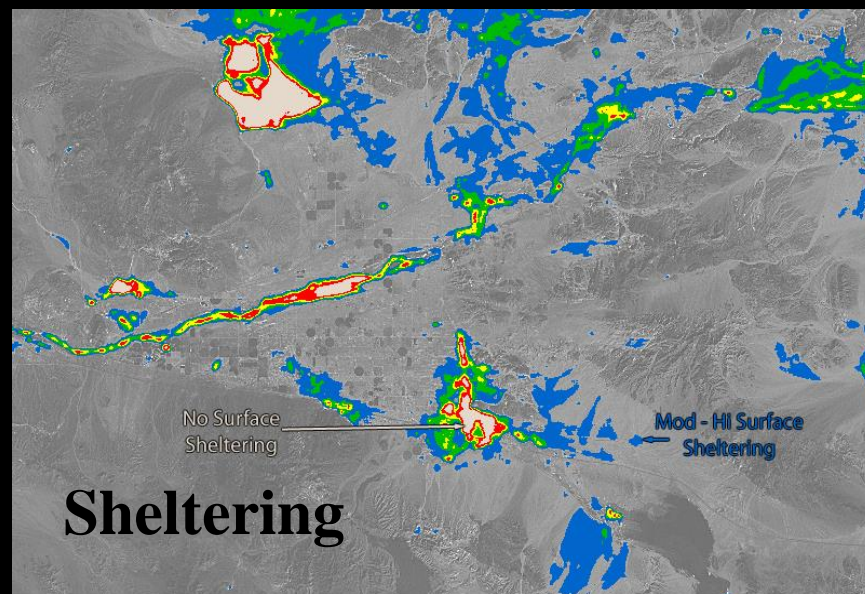
Sheltering

No Surface
Sheltering

Mod - Hi
Surface
Sheltering

10 Kilometers

Mojave River Area
Surface Sheltering Index Map from Landsat TM - Sep 04



Sheltering

No Surface
Sheltering

Mod - Hi Surface
Sheltering

10 Kilometers

Mojave River Area
Surface Sheltering Index Map from Landsat TM - Feb 05



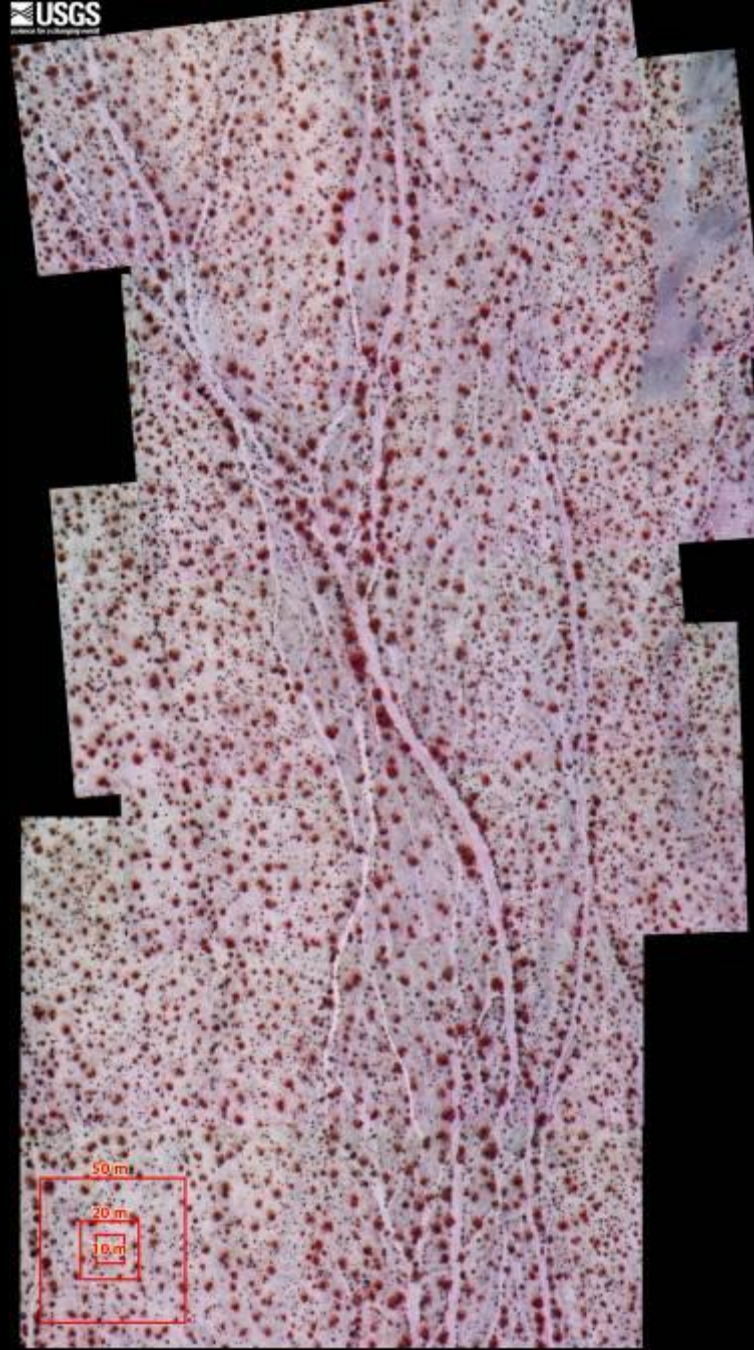
Spatial Dynamics

Detecting and mapping spatial dynamics in *arid lands* is typically related to *percent woody vegetation cover* and very-high resolution airborne or satellite images are needed (in arid lands these vegetation types are mostly *bushes, srubs, and small trees -- - coarse fuels*)

An airborne digital imaging system was used to collect images with 2 to 4 inch resolution south of Boulder, NV



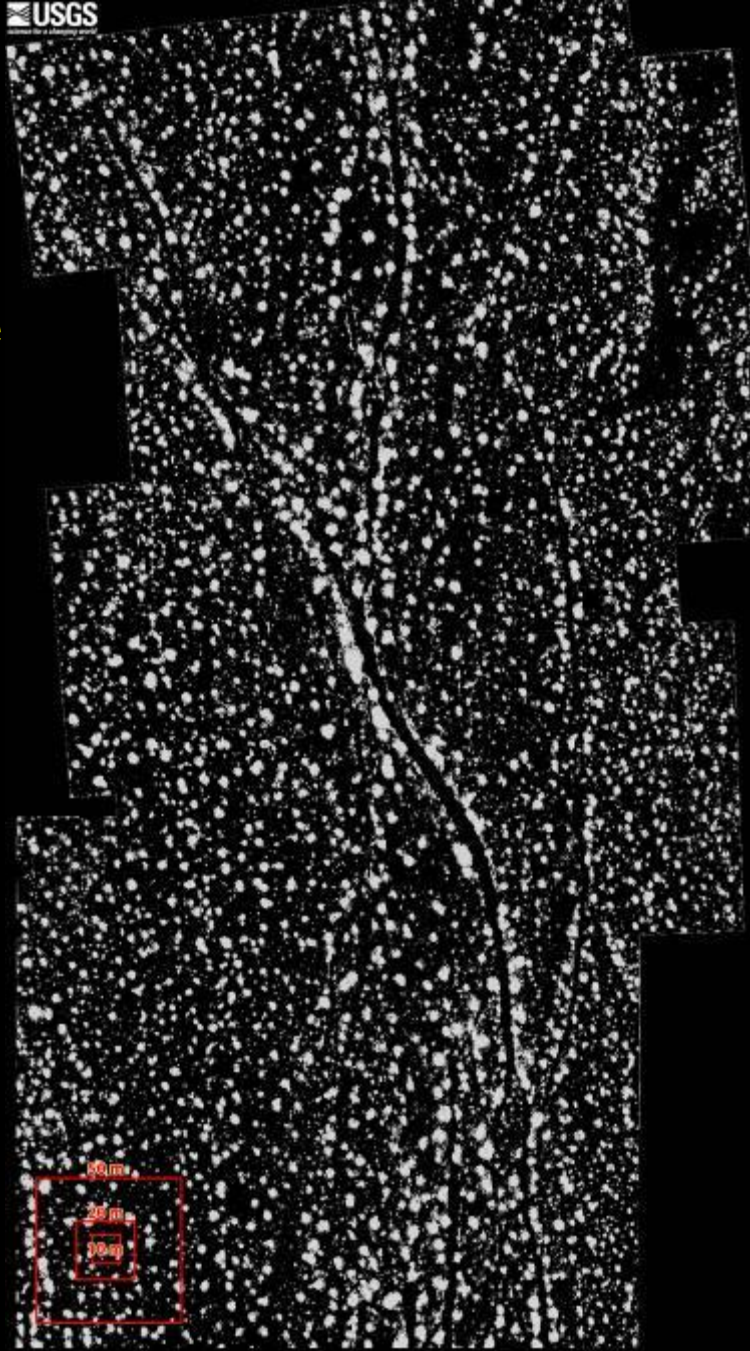
**Digital mosaic of
CIR images with
woody vegetation
shown in shades
of pinks and reds**



25 meters

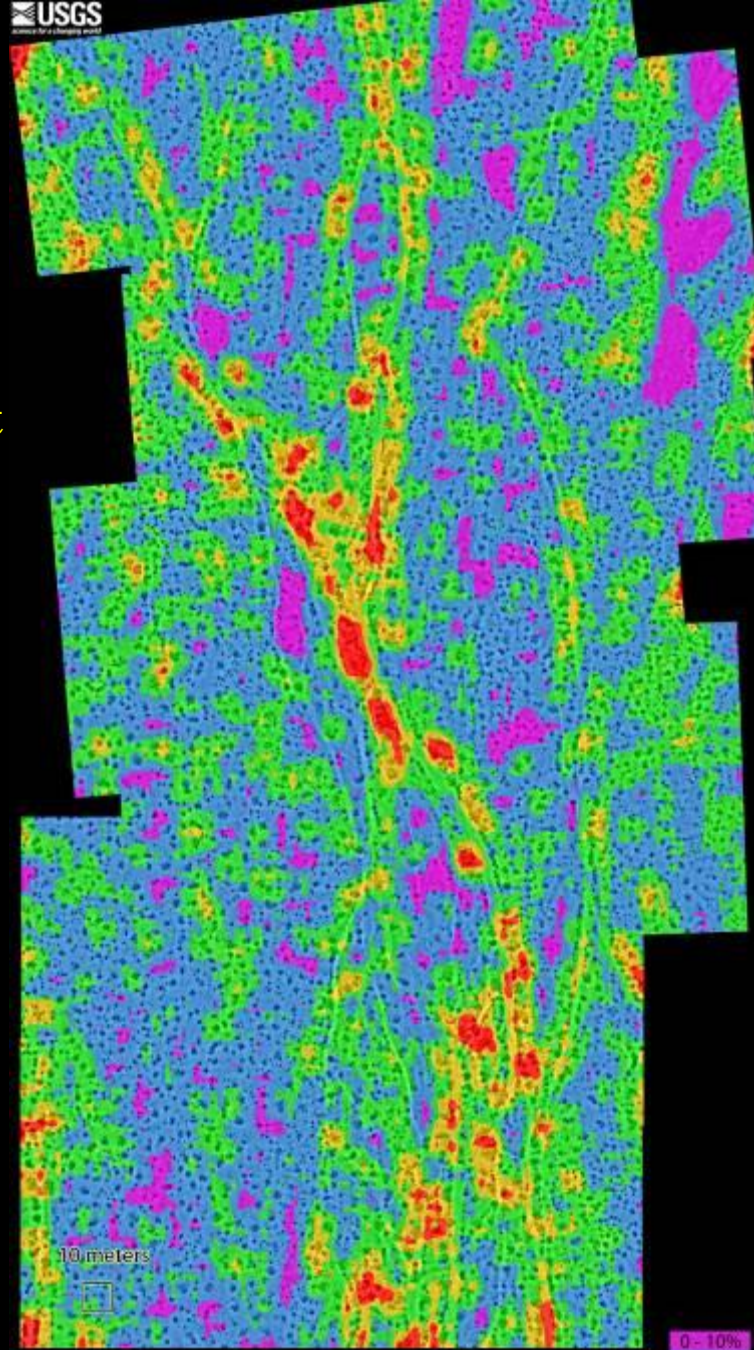
Mosaic using USGS Airborne Imaging Survey
12 September 2006, Run 3 Photos 536 - 548

Vegetated Pixels --- White
Not Vegetated --- Black



25 meters
Vegetation Classification derived from
Mosaic using USGS Airborne Imaging Survey
12 September 2006, Run 3 Photos 536 - 548

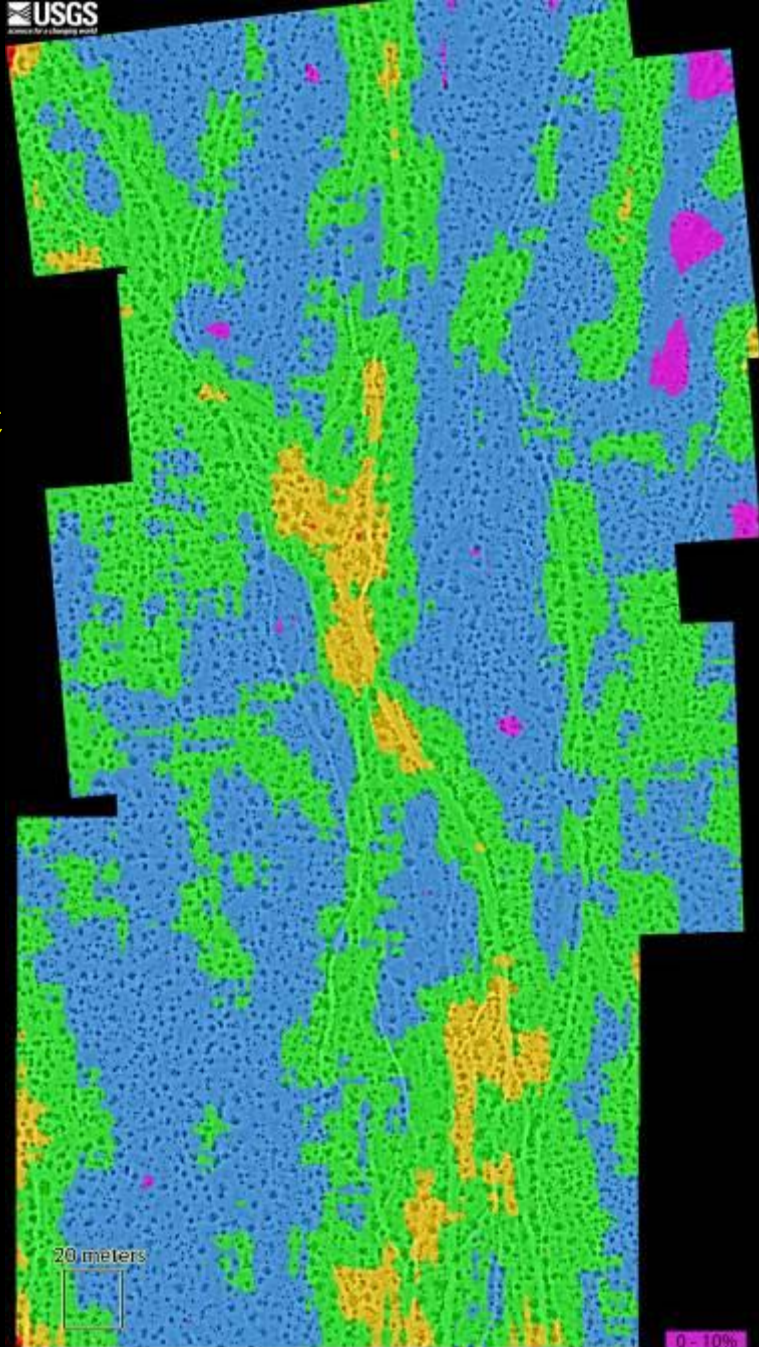
Percent Veg Cover 10 by 10 meter foot print



Percent Vegetation Cover - 10 m Plot Size
Mosaic using USGS Airborne Imaging Survey
12 September 2006, Run 3 Photos 536 - 548

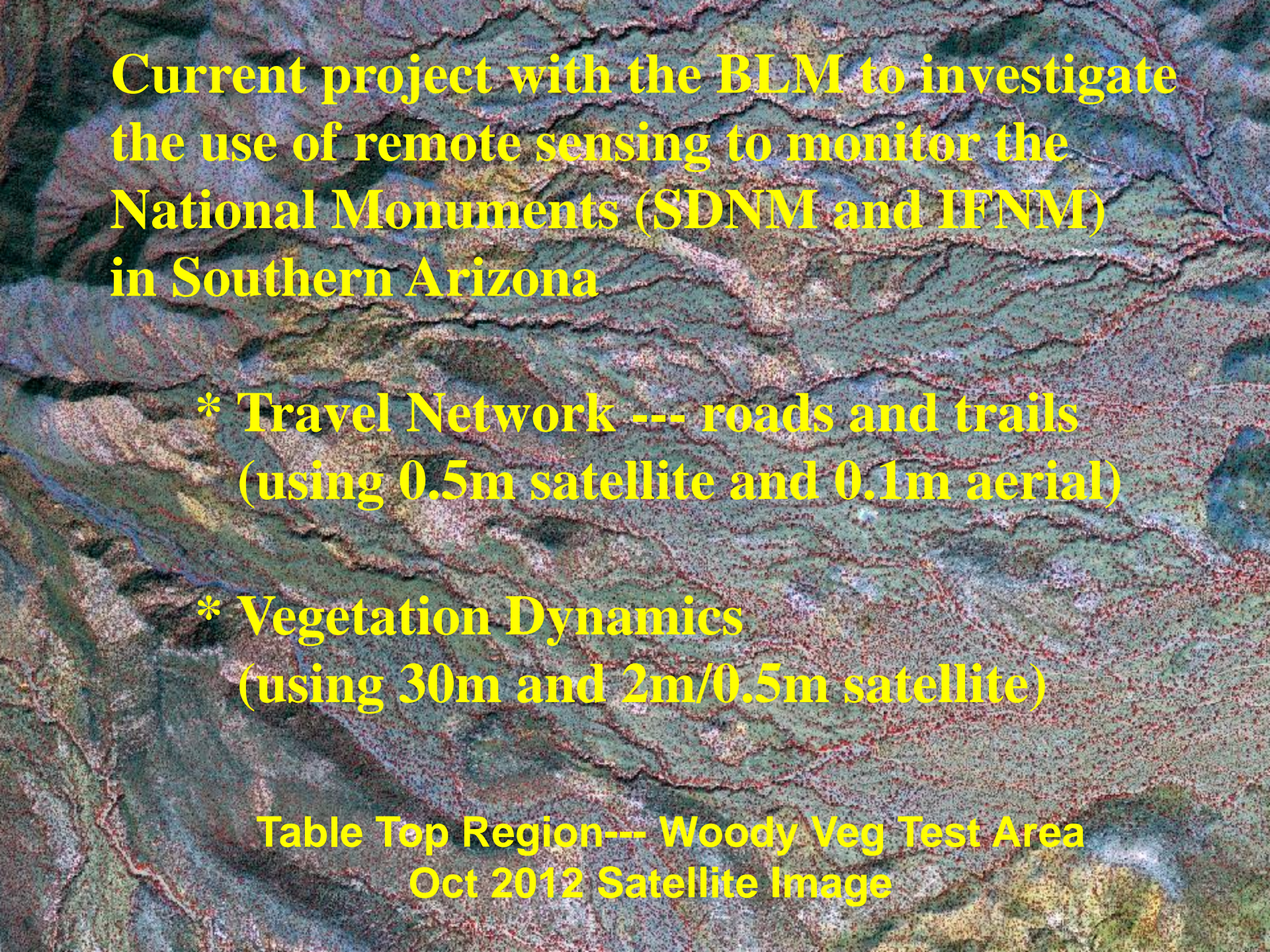
0 - 10%
11 - 20%
21 - 30%
31 - 40%
41 - 100%

Percent Veg Cover 20 by 20 meter foot print



Percent Vegetation Cover - 20 m Plot Size
Mosaic using USGS Airborne Imaging Survey
12 September 2006, Run 3 Photos 536 - 548

0 - 10%
11 - 20%
21 - 30%
31 - 40%
41 - 100%

A satellite image of a rugged, rocky landscape. The terrain is characterized by dark, jagged rock formations and a network of roads and trails. The colors are primarily dark blues, greys, and browns, with some lighter patches of vegetation or soil. The overall appearance is that of a high-altitude or mountainous region.

**Current project with the BLM to investigate
the use of remote sensing to monitor the
National Monuments (SDNM and IFNM)
in Southern Arizona**

*** Travel Network --- roads and trails
(using 0.5m satellite and 0.1m aerial)**

*** Vegetation Dynamics
(using 30m and 2m/0.5m satellite)**

**Table Top Region--- Woody Veg Test Area
Oct 2012 Satellite Image**

An aerial composite image showing a desert landscape. A winding river, appearing in shades of blue and cyan, flows through the scene. The surrounding terrain is covered with dense vegetation, which in this Composite Image Ratio (CIR) appears as a mix of green and red. The red areas represent woody vegetation, while the green areas represent other types of plants. The overall texture is highly detailed, showing individual plants and their shadows.

**CIR with woody vegetation seen
in shades of pinks and reds**

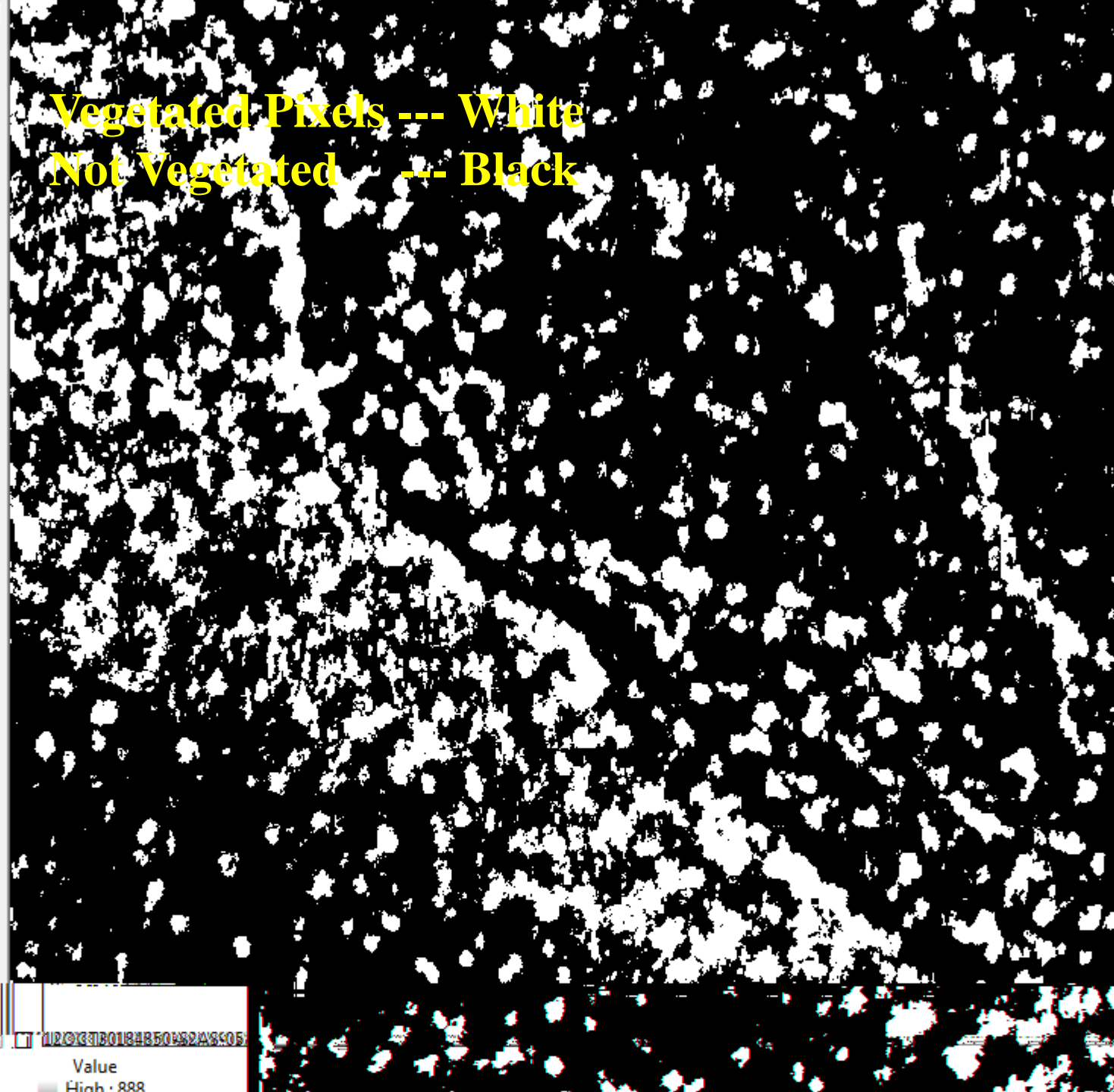
**Note that due to the low sun angle in this October
image the shadows of the Saguaro Cacti can be seen
which is not the case in an image collected in June**

Vegetated Pixels --- White
Not Vegetated --- Black

Layers

- 12OCT30184850-S2AS-05
RGB
 - Red: Band_4
 - Green: Band_3
 - Blue: Band_1
- ratio-oct2012-b4tob3.img
Value
High : 190
Low : 90
- ratio-oct2012-b4tob3.img
Value
High : 141
Low : 140
- ratio-oct2012-b4tob3.img
Value
High : 160
Low : 159
- 12OCT30184850-S2AS-05
Value
High : 534
Low : 0
- 12OCT30184850-S2AS-05
Value
High : 693
Low : 0

12OCT30184850-S2AS-05
Value
High : 888
Low : 0



Detecting and Monitoring Dust Storms

- An important objective in a previous project was to *detect and monitor active dust storms* in the southwestern United States.
- Besides satellite and airborne imaging, *field based instruments* were used at several locations to do *high temporal monitoring* of the surface *during high wind events* (photos every 15 mins).
- *Movies* were generated using both *GOES satellite and ground-based images* of dust storms.

Examples of Satellite Imaging of Dust Storms

Keep in mind

1. The *temporal resolution* --- fly over frequency of most satellite imaging systems is not sufficient to monitor relatively short lived events --- the *only exception is the GOES* weather satellite.
2. Only *large and high concentration* dust storms can usually be detected using either the *GOES or MODIS* satellites.
3. *Can not see thru clouds* so problems seeing dust storms related to monsoon weather patterns.
4. *Over time* enough large dust storms *can be detected to help identify* some of the major dust sources in a given region.

MODIS Images

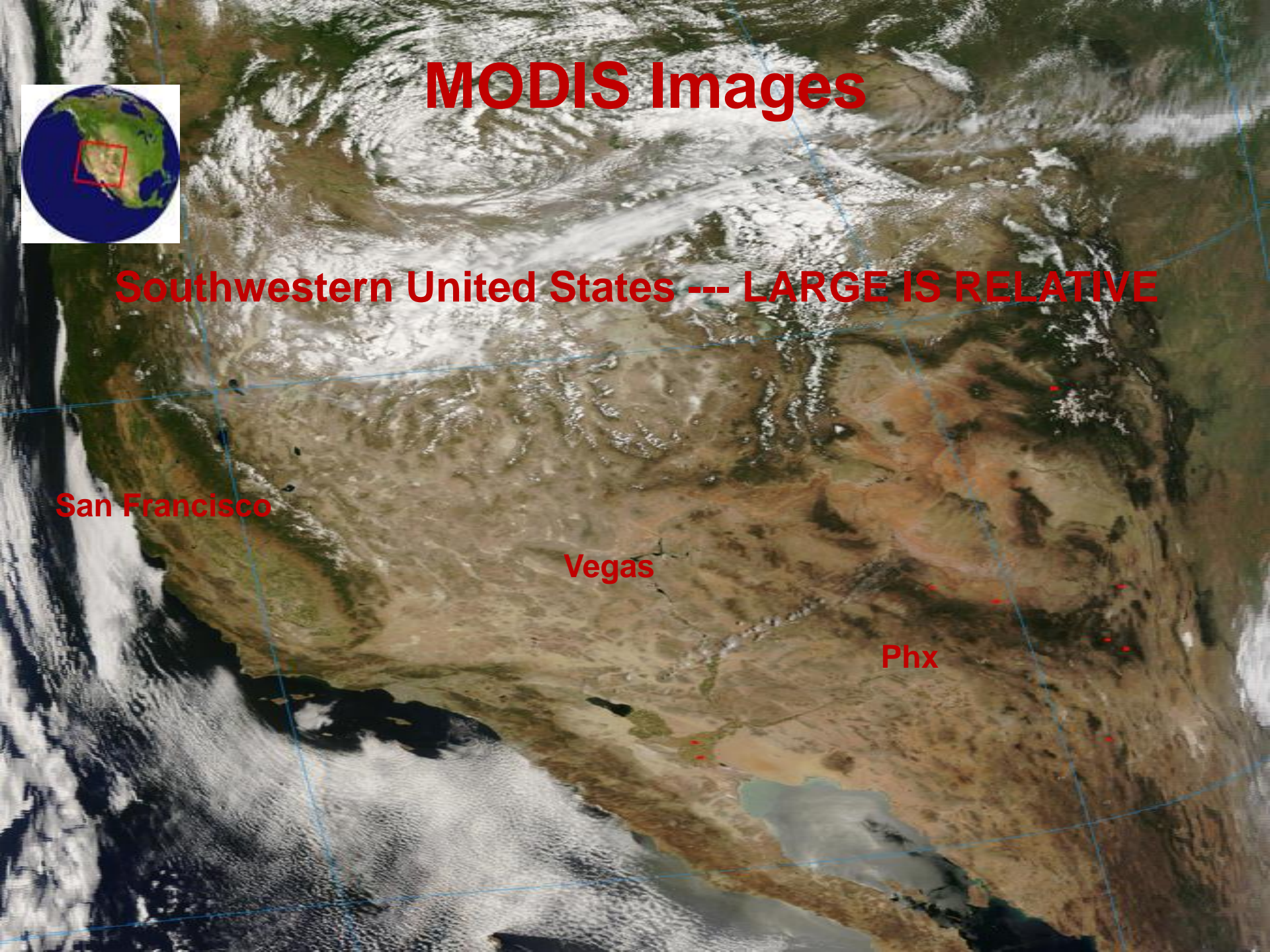


Southwestern United States --- LARGE IS RELATIVE

San Francisco

Vegas

Phx





Approximate Same Size Area as SW US Image

**Tarim Basin approximately
three times the size of Arizona**

**13March06 Dust Storm
Western China**

A satellite image of Southern Nevada, showing a large area of snow cover in the mountainous regions. The terrain is rugged and brownish, with several green lakes scattered throughout. The snow is most prominent in the upper right and lower left areas, following the mountain ridges. The text "Southern Nevada --- April 2004" is overlaid in red in the center of the image.

Southern Nevada --- April 2004

Nevada April 28, 2004

A satellite image of Northern Texas in January 2006. The image shows a large area of snow cover in the northern and eastern parts of the state, contrasting with the brown, snow-free ground in the west and south. The state boundaries of Texas are outlined in black. The text "Northern Texas --- January 2006" is overlaid in red in the upper center. At the bottom center, the text "Texas January 01 2006" is overlaid in yellow.

Northern Texas --- January 2006

Texas January 01 2006

Influence of *Climate on Landscape Vulnerability to Wind Erosion and Dust Emission*

Droughts in the Southwest

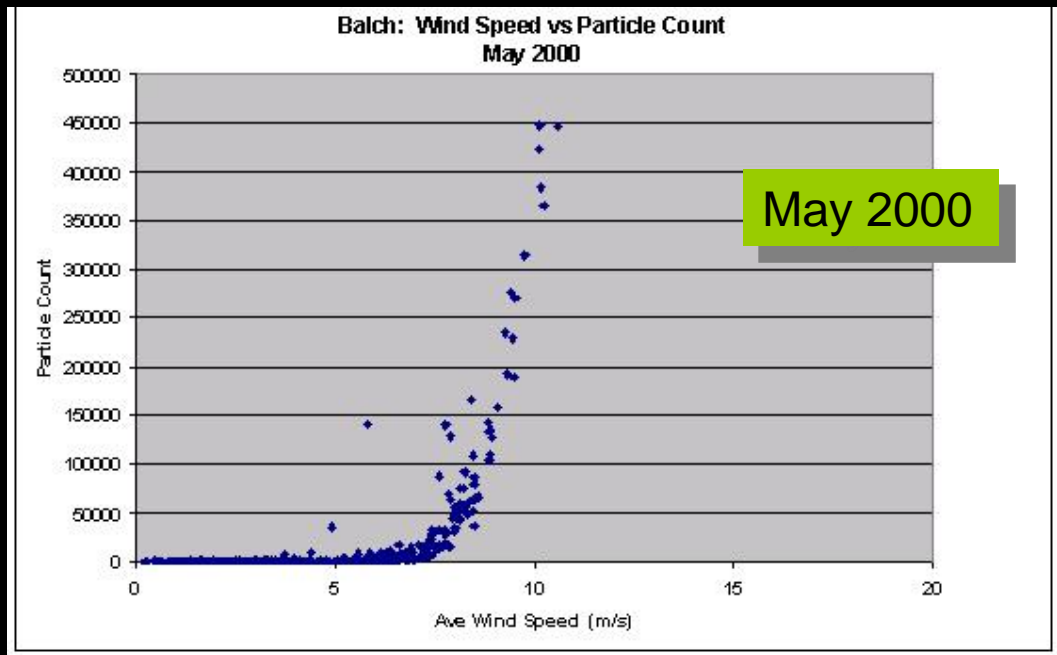
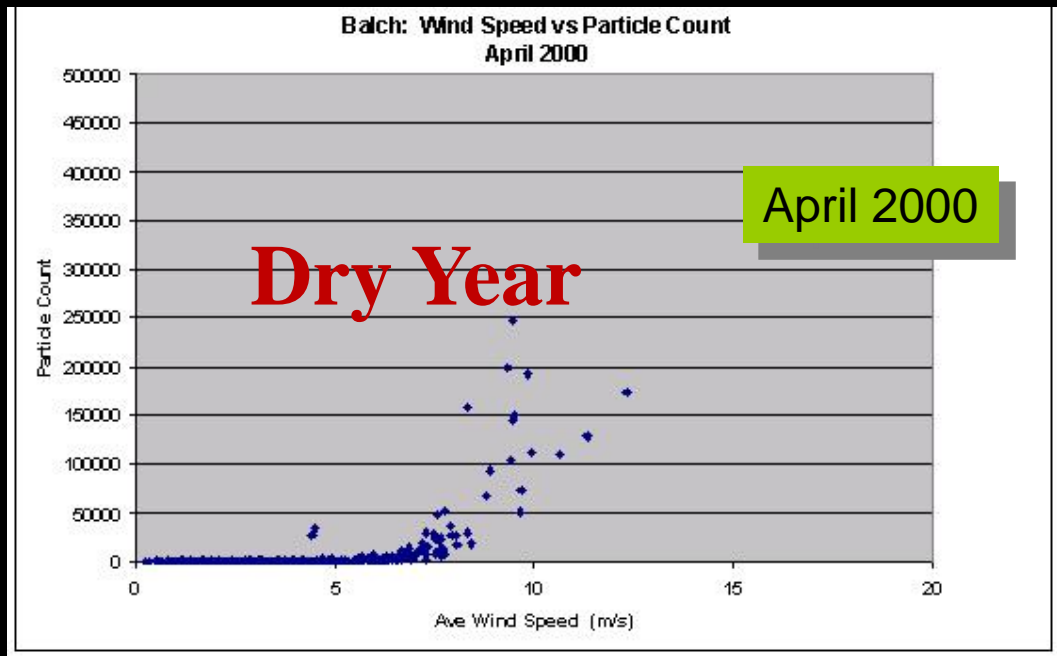
Cameras, Wind Meters, and Sensit





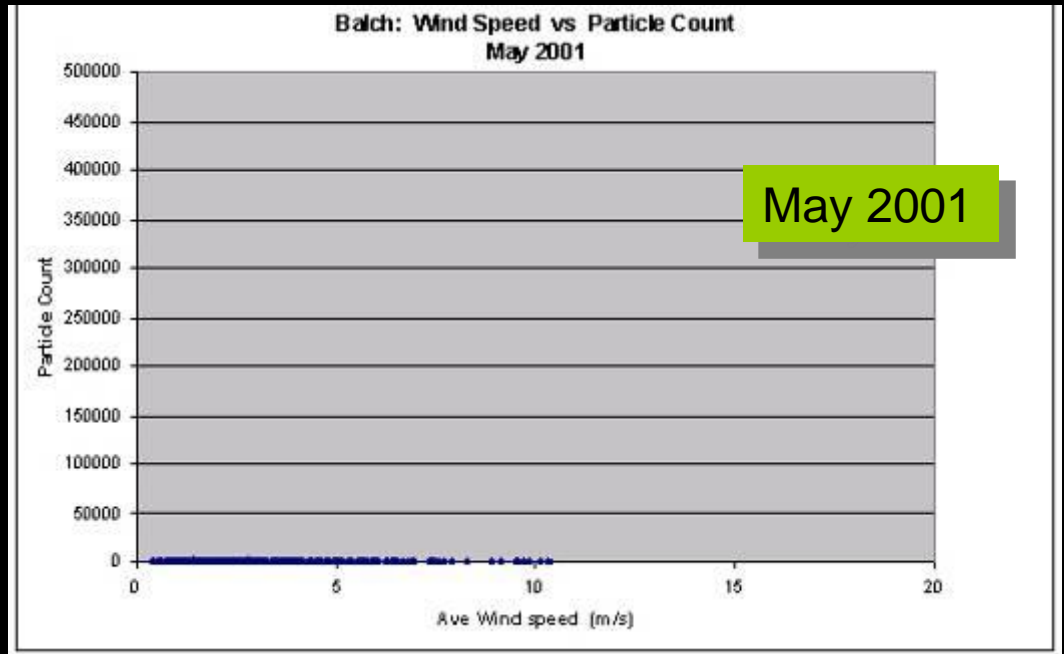
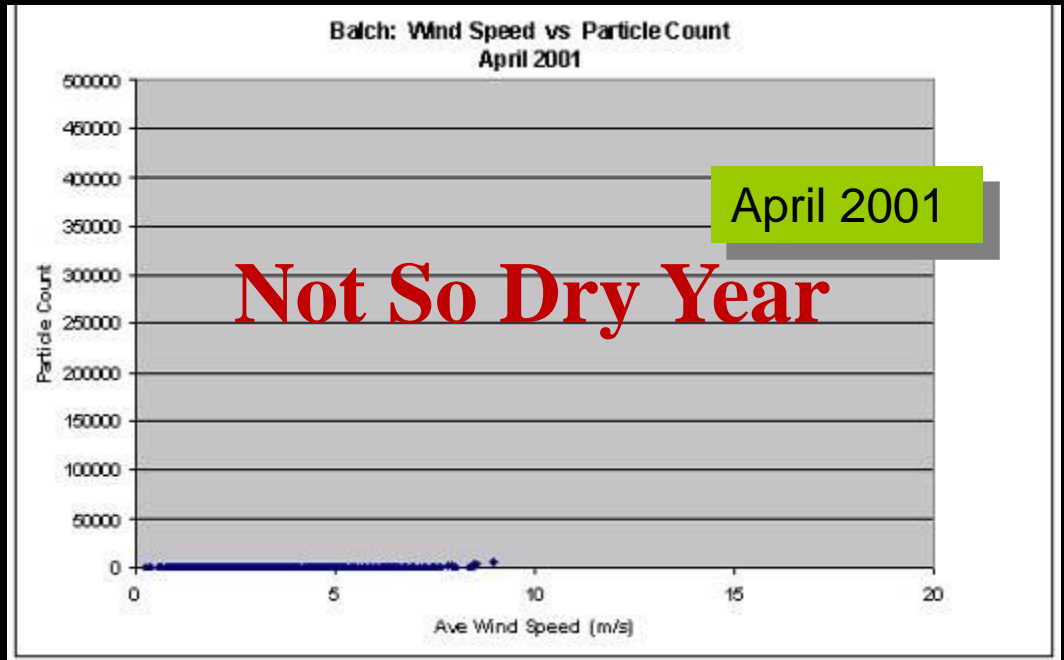
Mojave Desert: Balch

Wind Speed vs Particle Count

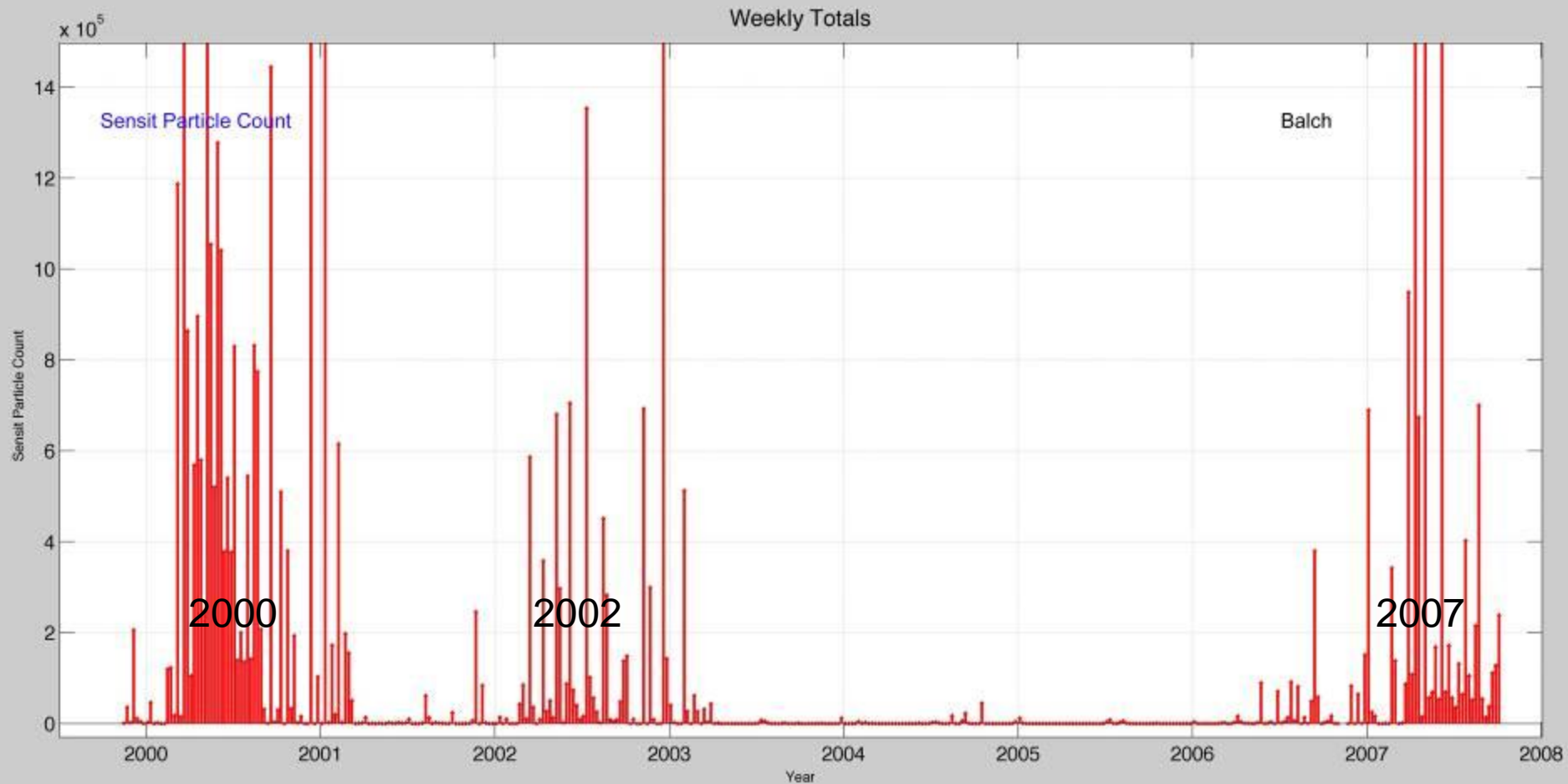


Mojave Desert: Balch

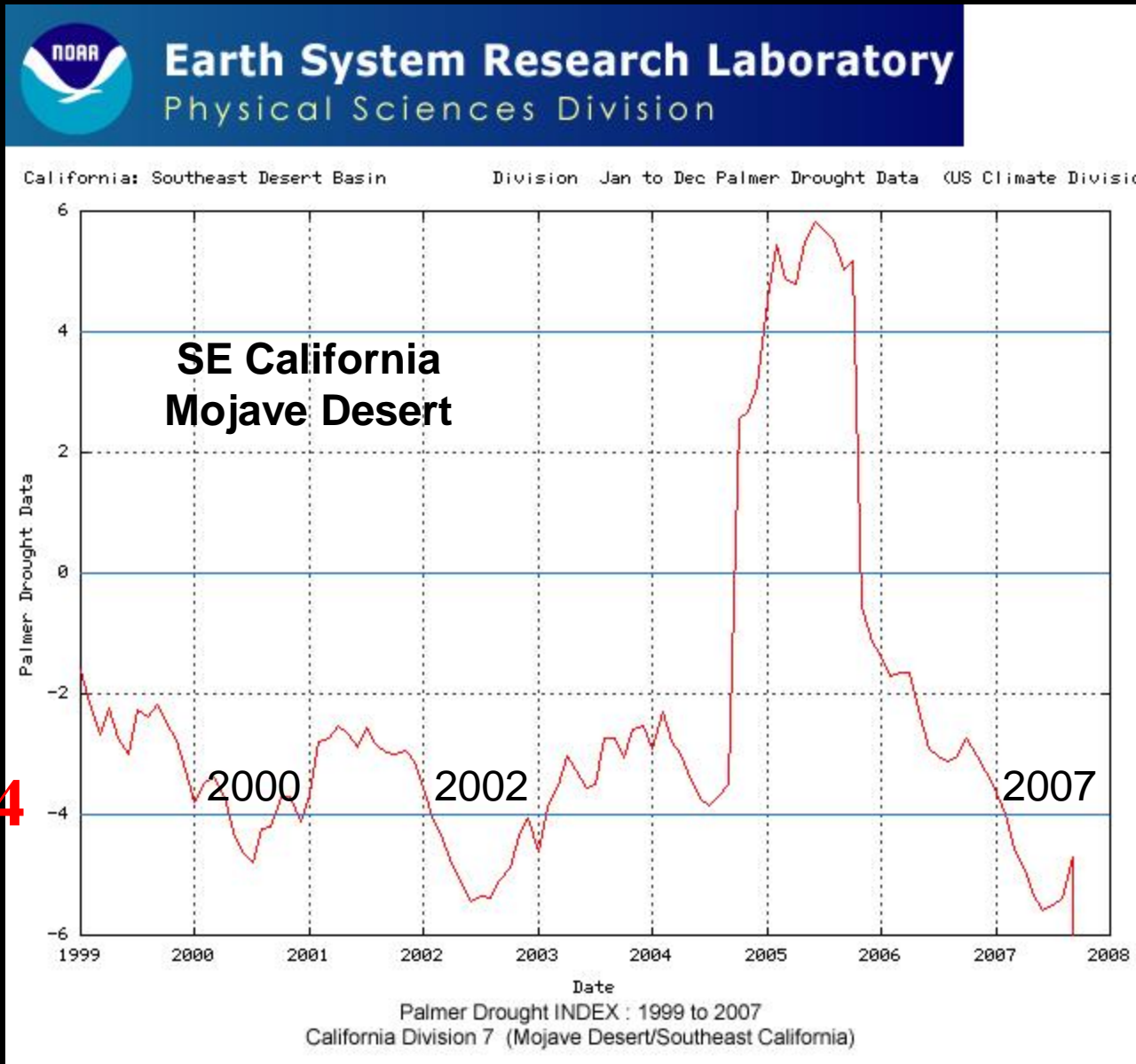
Wind Speed vs Particle Count



Sensit Particle Count --- From USGS Instrument at Soda Lake



NOAA's PDSI Data --- Note: **-3.5 to -4.0** seems to be a critical threshold



PDSI = -4

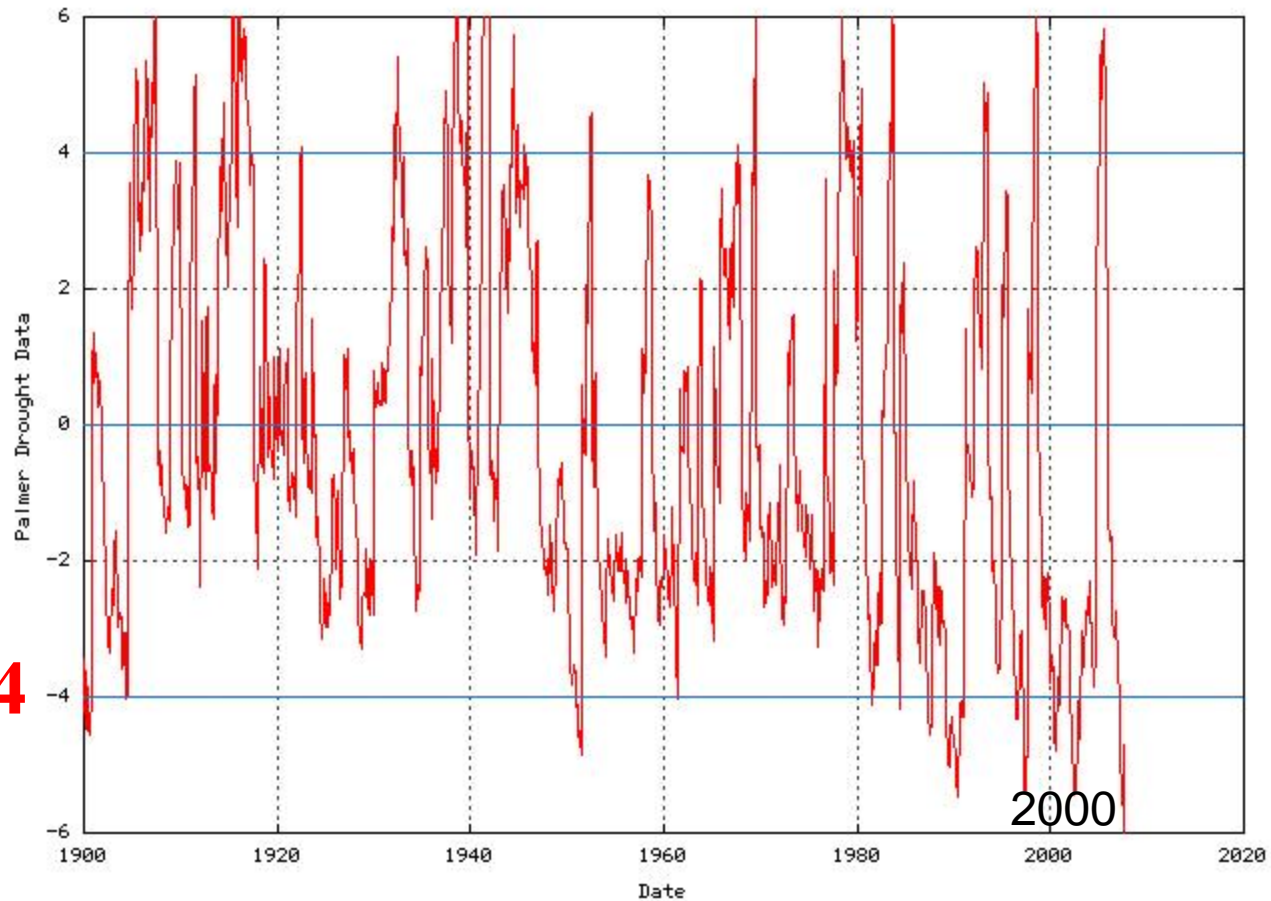


Earth System Research Laboratory

Physical Sciences Division

California: Southeast Desert Basin

Division Jan to Dec Palmer Drought Data (US Climate Division)



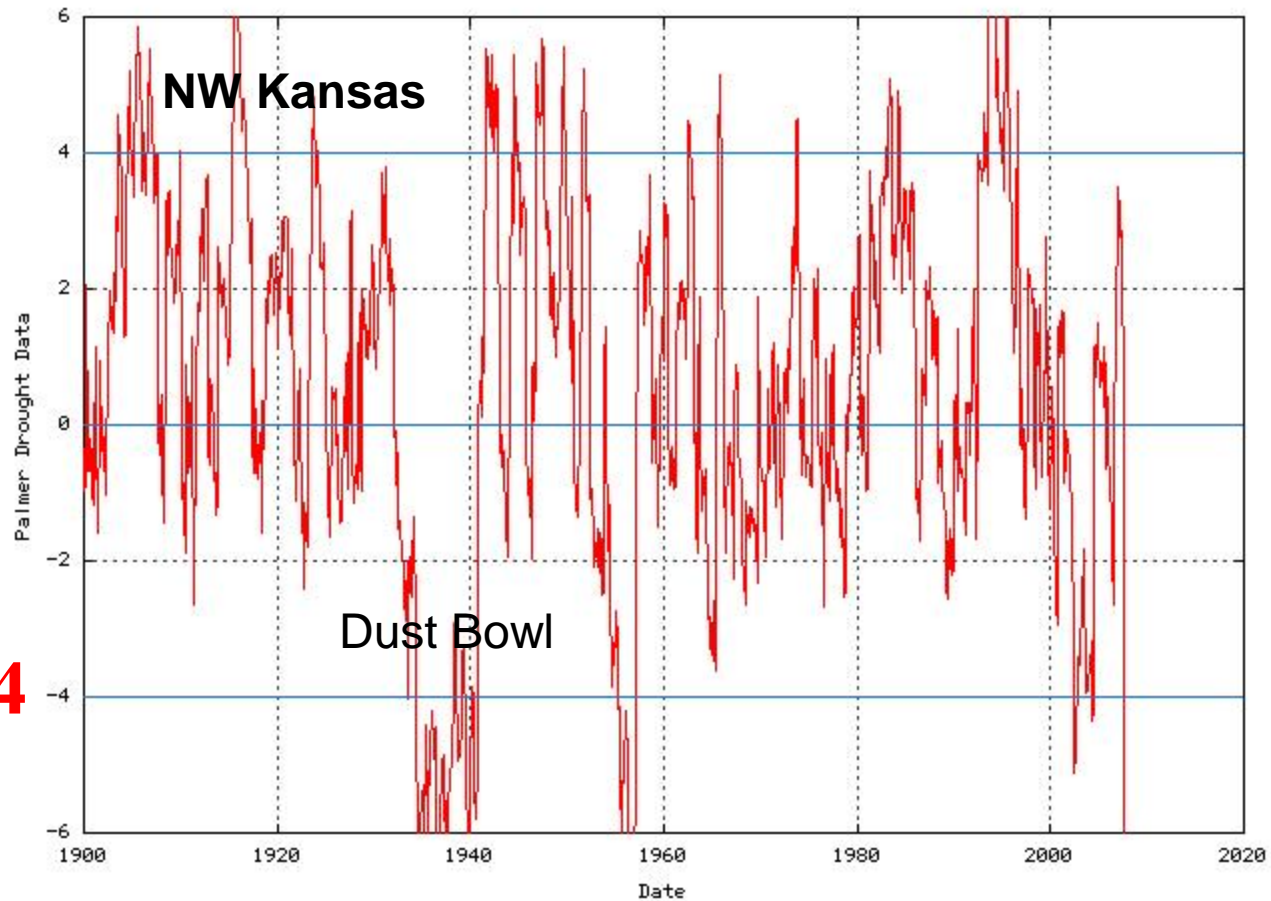
PDSI = -4



Earth System Research Laboratory

Physical Sciences Division

Kansas: Northwest Division Jan to Dec Palmer Drought Data (US Climate Division)



PDSI = -4

Palmer Drought INDEX : 1900 to 2007
Kansas Northwest

Severe -3.0 to -3.9

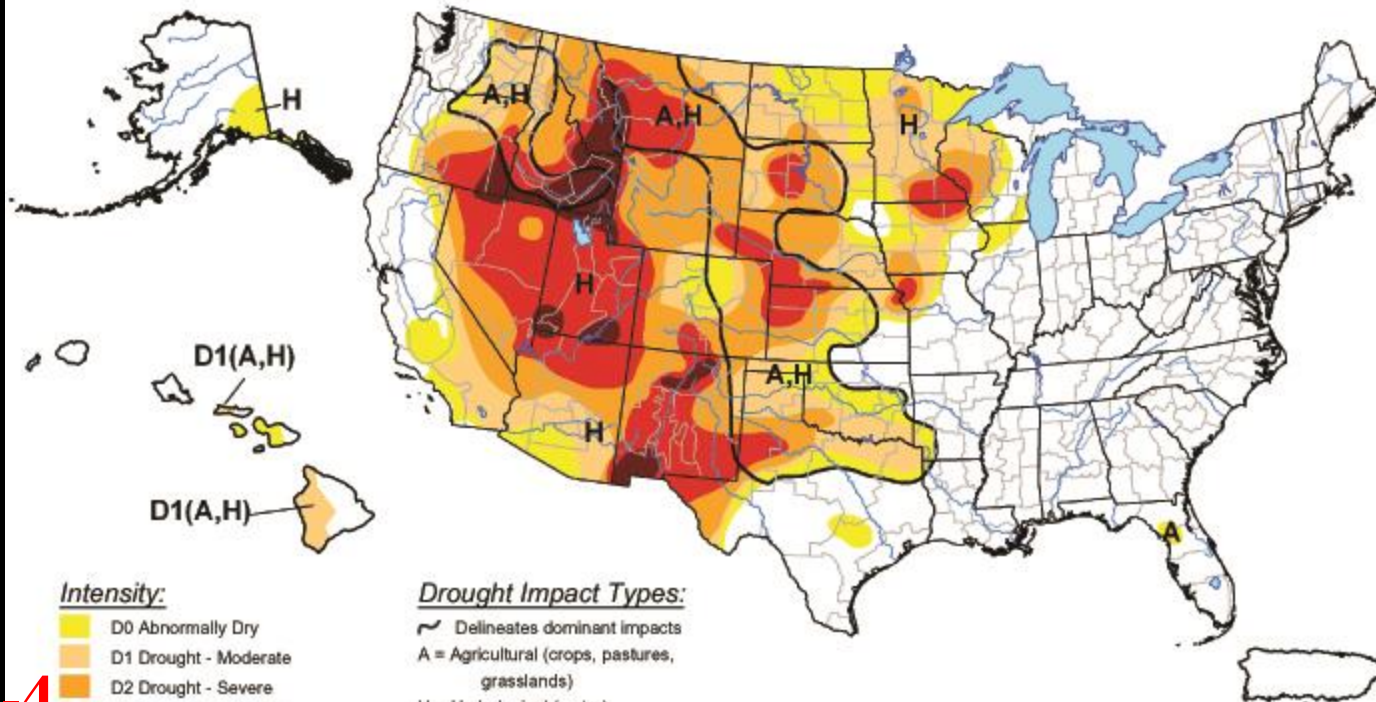
Extreme -4.0 to -4.9

Exceptional -5.0 to less

U.S. Drought Monitor

December 16, 2003

Valid 7 a.m. EST



PDSI = -4

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

<http://drought.unl.edu/dm>



Released Thursday, December 18, 2003

Author: David Miskus, NOAA/CPC/JAWF

A satellite-style map of Texas with a red outline highlighting the northern portion of the state. The map shows terrain features, including the Rio Grande on the right and the White Sands desert area on the left. The text is overlaid in red.

December 15, 2003

Northern Texas

White Sands

El Paso

Unprecedented 21st century drought risk in the American Southwest and Central Plains

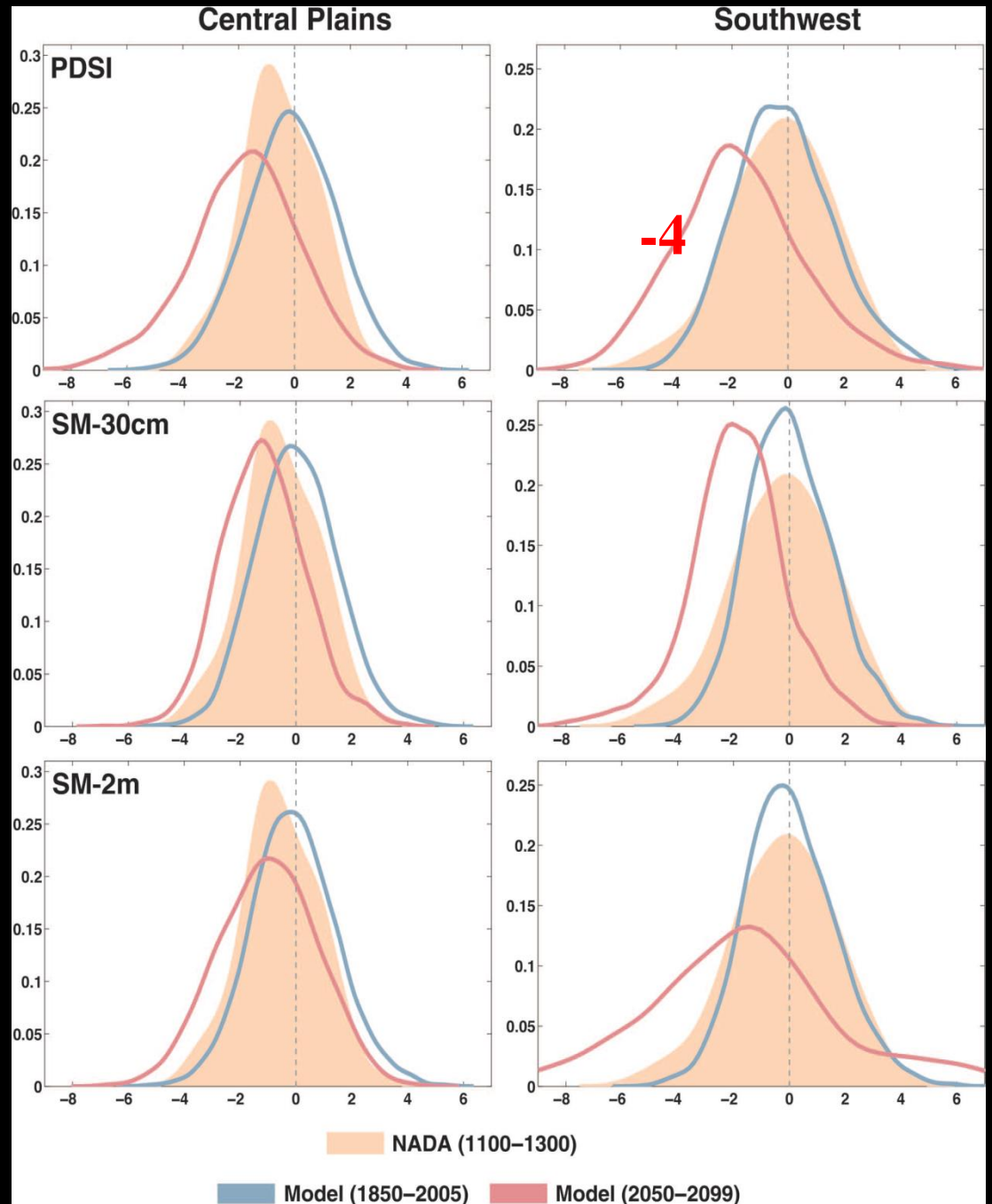
FIG 4

Cook et al. Sci. Adv.
12 February 2015

Brown shading --- 1100–1300 -- timing of the medieval mega droughts

Blue lines represent all models historical scenario 1850–2005

Red lines are for all model years scenario 2050–2099



Climate and Air Quality in Arid Regions

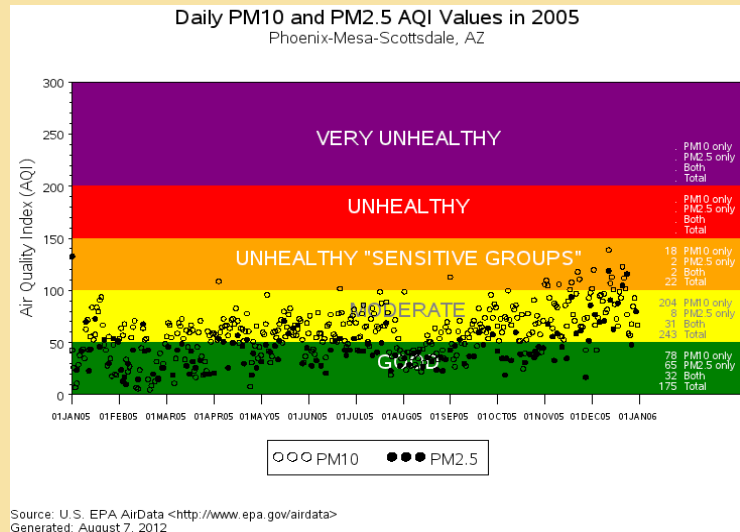
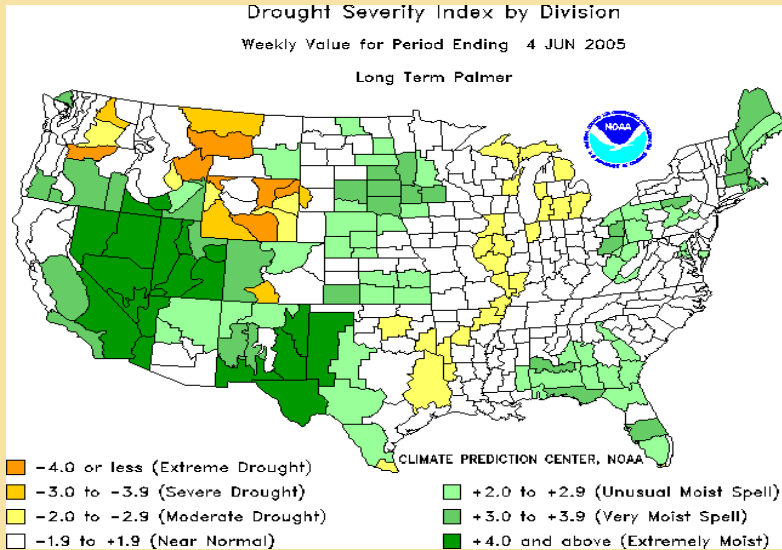
Phoenix, Arizona

An important parameter in arid landscapes that is *affected by climate conditions* is the *amount of vegetation cover*. As mentioned earlier on a *short-term basis (months to a few years)* the amount of *annuals and grasses (non-woody vegetation)* is the most temporally dynamic. Change in the amount of cover of these vegetation types can be dramatically affected by *wet-to-normal-to-dry climate cycles*.

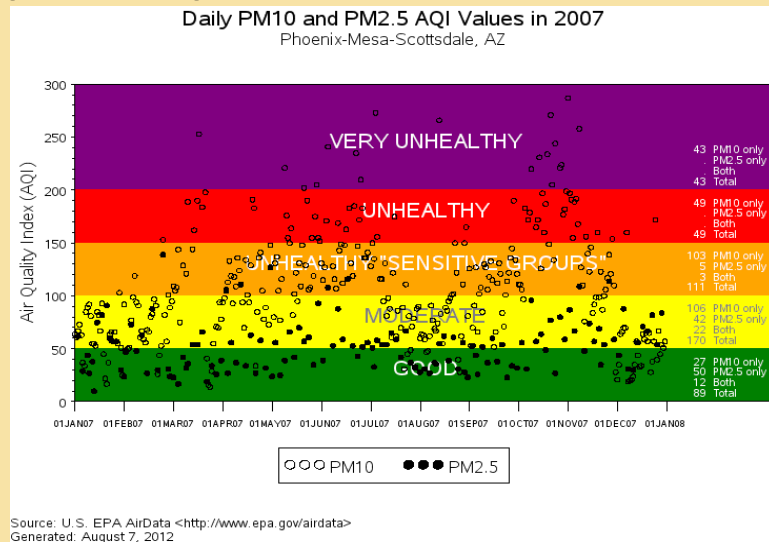
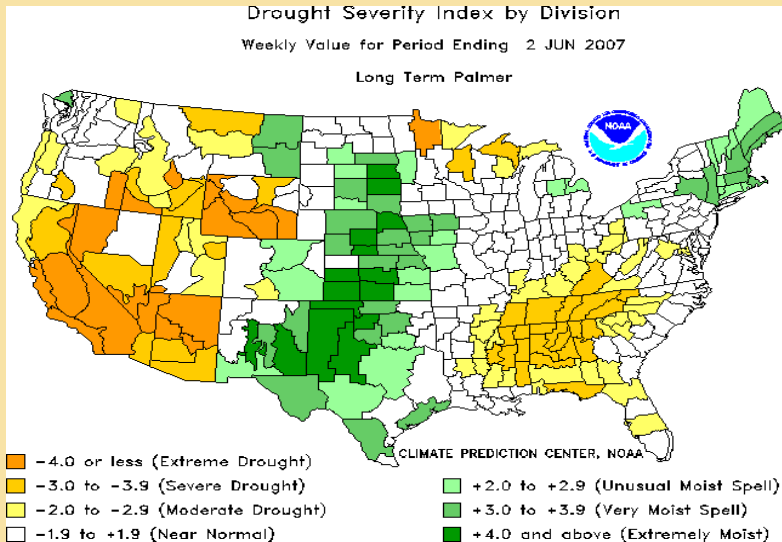
**Could this be impacting air quality
in Southern Arizona ?**

(Notice air quality conditions when PDSI is -4 or less)

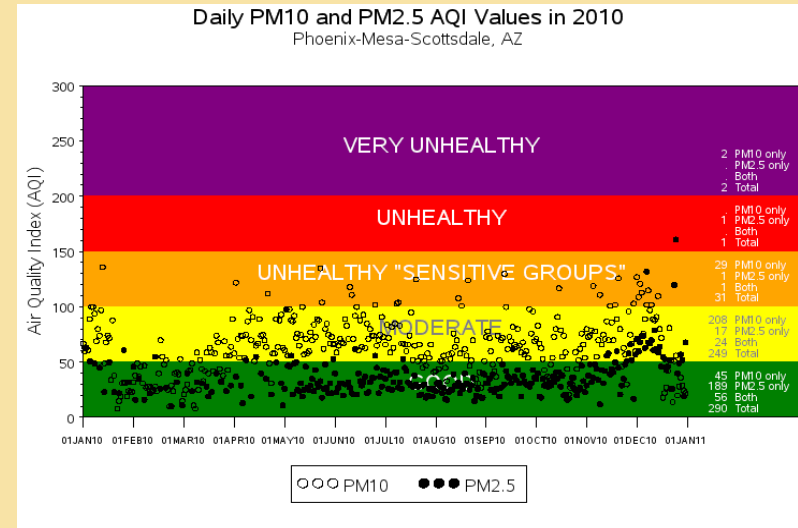
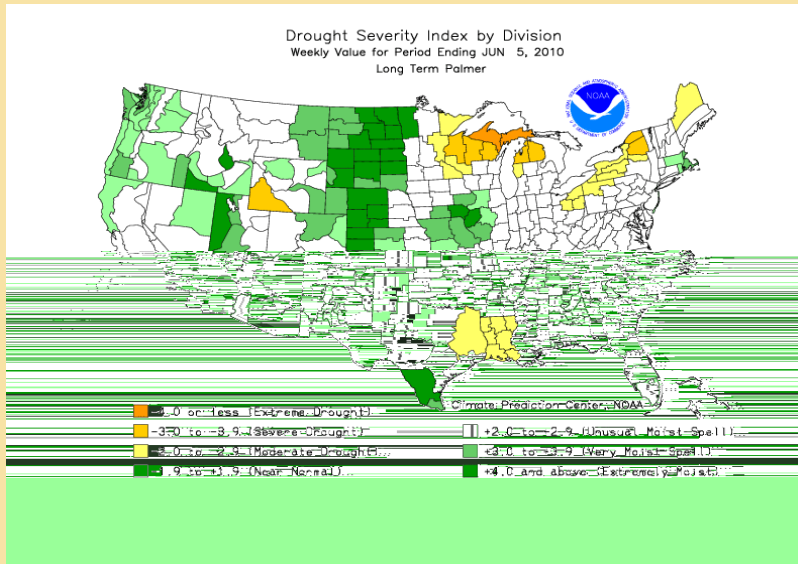
2005 --- Very Wet Year



2007 --- Very Dry Year

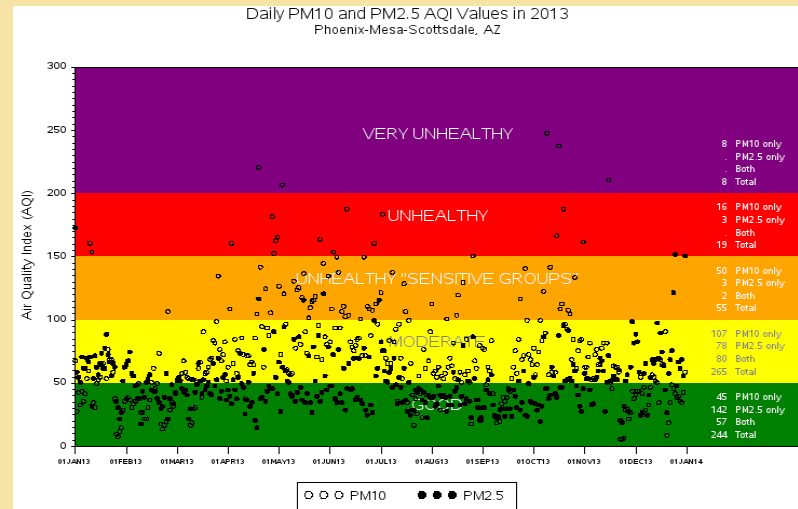
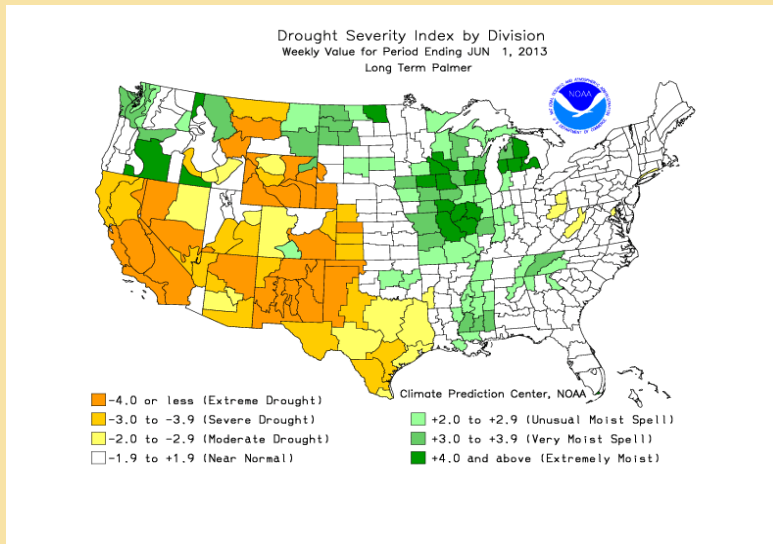


2010 --- Normal to Wet Year



Source: U.S. EPA AirData <<http://www.epa.gov/airdata>>
Generated: August 7, 2012

2013 --- Very Dry Year



Source: U.S. EPA AirData <<http://www.epa.gov/airdata>>
Generated: February 12, 2015

**Potential Applications
Along I-10 and Southern Arizona**

**Number of Crashes by Weather, by Injury Severity
2006 - 2010**

Query: 11/14/11

Data Sources: SDM

Dust --- Safety Related:

The stats published by SDM related to *crashes by weather types (clear, snowy, dusty conditions)* indicate that those related to dusty conditions are a *relatively small percentage of the total number of fatal crashes* state wide.

	No Injury	Possible Injury	Non Incapacitating Injury	Incapacitating Injury	Fatal	Total
Clear	365,969	88,374	62,485	18,546	3,459	538,833
Cloudy	33,125	7,883	5,900	1,831	398	49,137
Sleet Hail Freezing Rain Or Drizzle	448	59	93	29	8	637
Rain	14,592	3,117	2,101	542	106	20,458
Snow	3,370	367	428	76	20	4,261
Severe Crosswinds	426	78	113	44	13	674
Blowing Sand Soil Dirt	408	94	89	37	16	644
Fog Smog Smoke	160	37	26	9	1	233
Blowing_Snow	90	8	8	1	1	108
Other	88	22	15	6	1	132
Unknown	2,510	425	295	102	302	3,634
<i>Total</i>	<i>421,186</i>	<i>100,464</i>	<i>71,553</i>	<i>21,223</i>	<i>4,325</i>	<i>618,751</i>

	No Injury	Possible Injury	Non Incapacitating Injury	Incapacitating Injury	Fatal
Clear	86.9%	88.0%	87.3%	87.4%	80.0%
Cloudy	7.9%	7.8%	8.2%	8.6%	9.2%
Sleet Hail Freezing Rain Or Drizzle	0.1%	0.1%	0.1%	0.1%	0.2%
Rain	3.5%	3.1%	2.9%	2.6%	2.5%
Snow	0.8%	0.4%	0.6%	0.4%	0.5%
Severe Crosswinds	0.1%	0.1%	0.2%	0.2%	0.3%
Blowing Sand Soil Dirt	0.1%	0.1%	0.1%	0.2%	0.4%
Fog Smog Smoke	0.04%	0.04%	0.04%	0.04%	0.02%
Blowing_Snow	0.02%	0.01%	0.01%	0.00%	0.02%
Other	0.02%	0.02%	0.02%	0.03%	0.02%
Unknown	0.6%	0.4%	0.4%	0.5%	7.0%

However, the stats show that if you are involved in a crash caused by *blowing sand-soil-dirt* your *chances of getting killed* are approximately *3.9 times greater* than a crash that occurs during *clear* conditions and *5.3 times* as likely than a crash caused by *snowy* conditions.

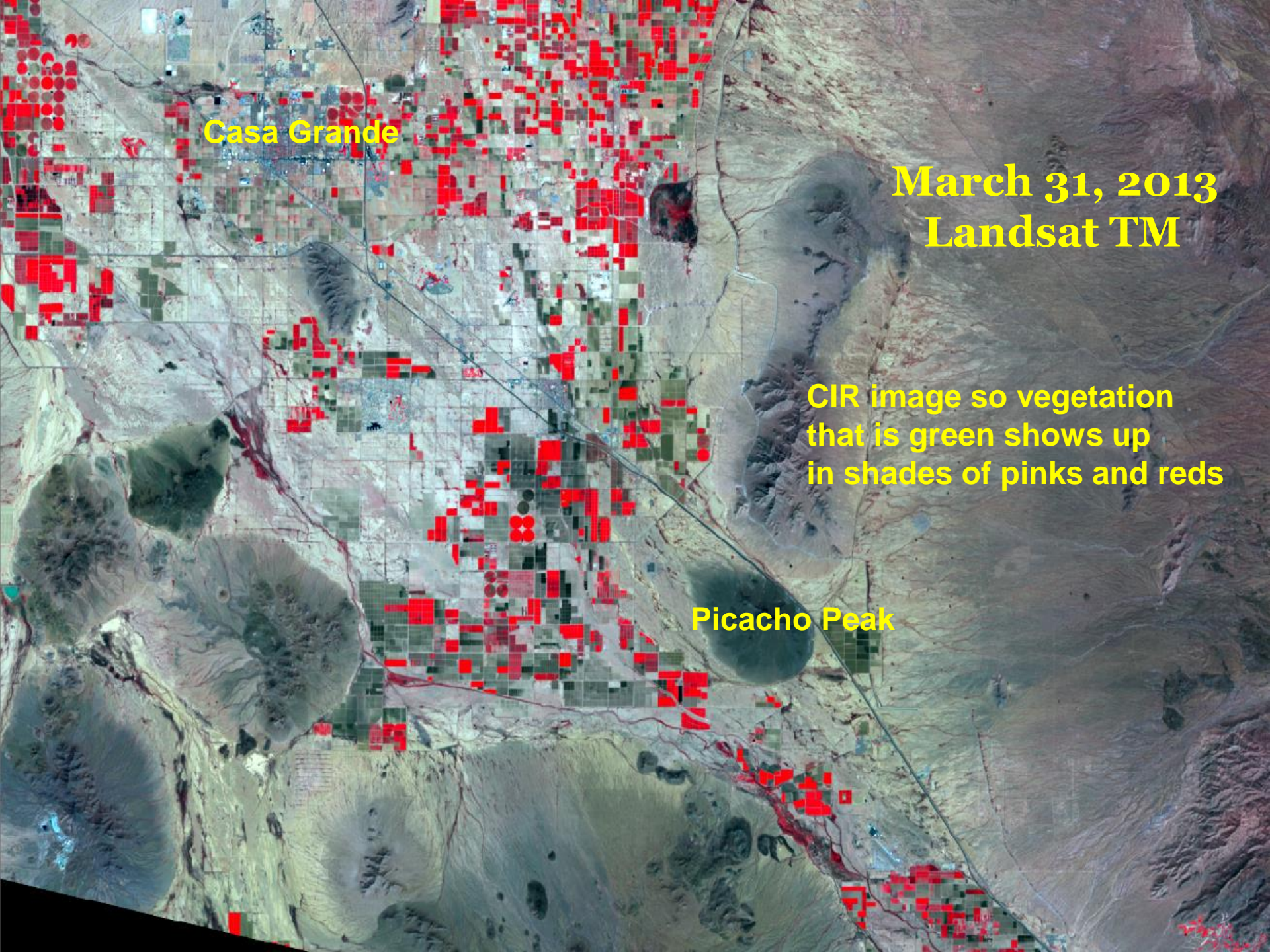
	Fatal	Total	Percent Fatal	Ratio With Dusty
<i>Clear</i>	3459	538,833	0.00642	3.87
<i>Snow</i>	20	4,261	0.00469	5.30
<i>Dusty</i>	16	644	0.02484	1.00

** Fatal and Total stats from the SDM table*

Safety Related

Potential applications of satellite remote sensing that could help with *safety related issues* includes:

- Analyze and map *vegetation cover characteristics, including percent vegetation cover, temporal dynamics of annuals and grasses, and temporal dynamics of agricultural fields* in and around the region where dust storms are a major hazard along I-10 and other highways --- *perhaps focus on the west side of I-10* at first.

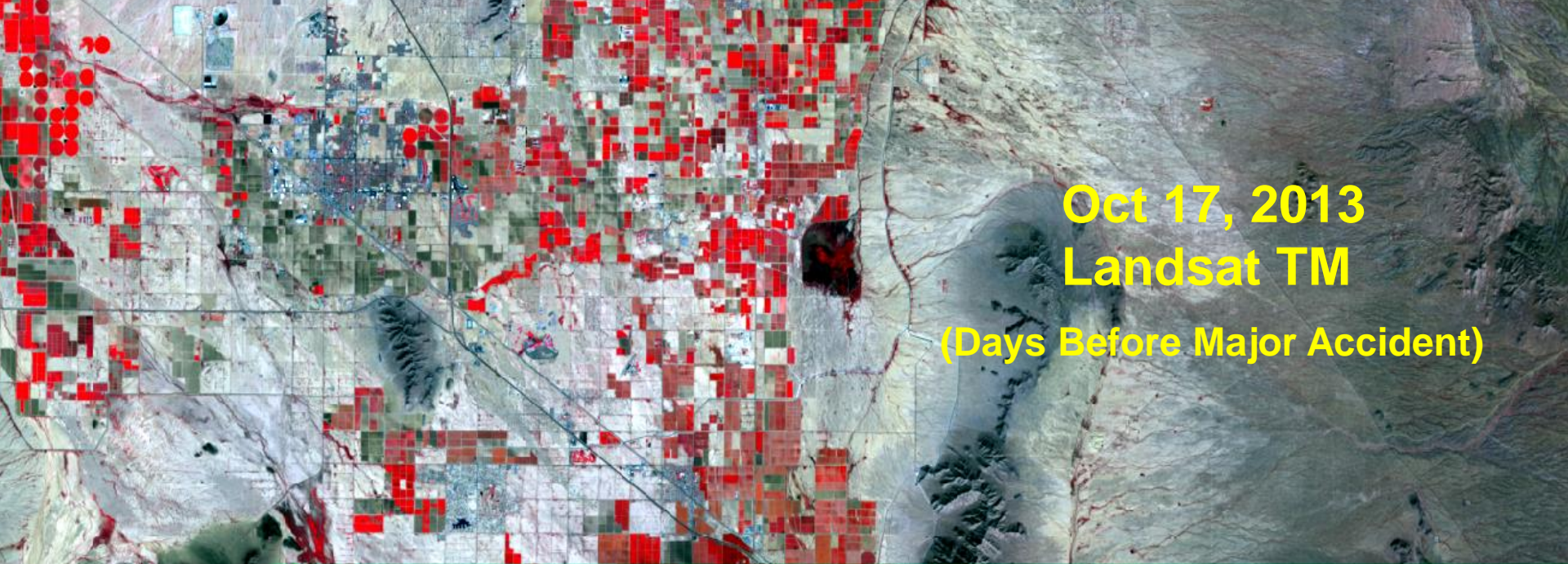


Casa Grande

March 31, 2013
Landsat TM

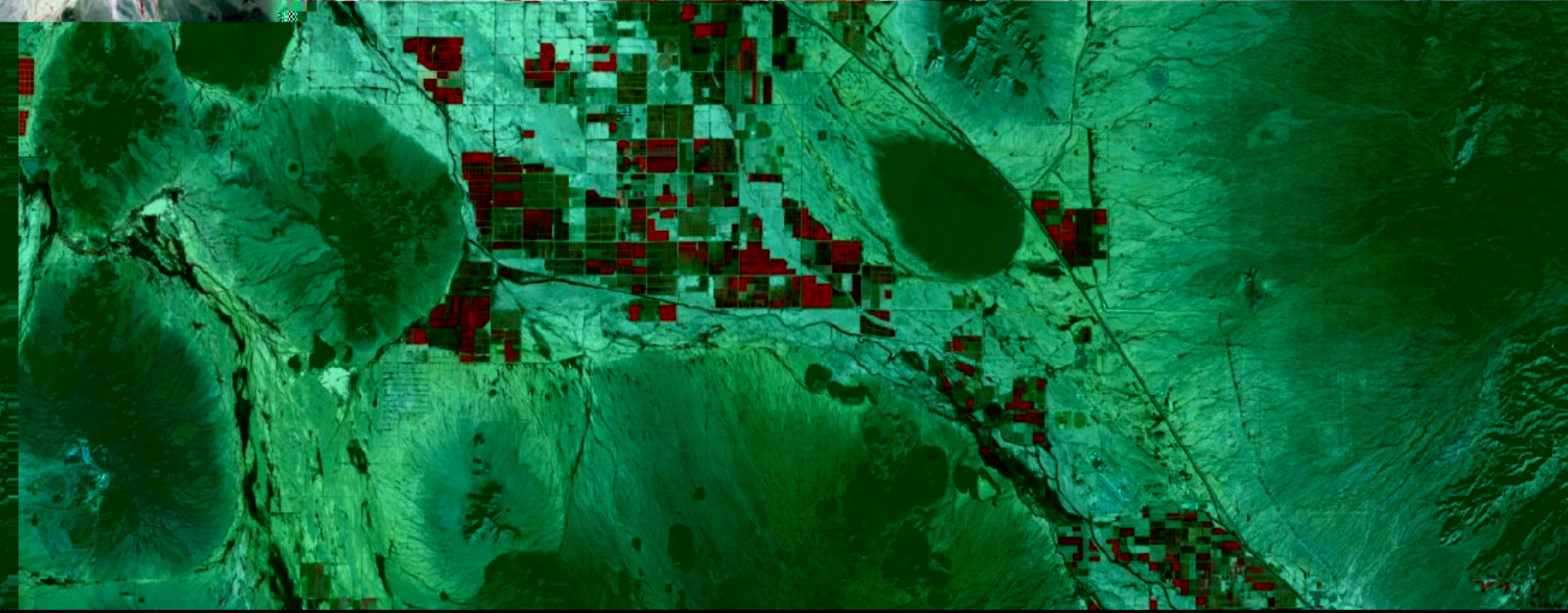
CIR image so vegetation
that is green shows up
in shades of pinks and reds

Picacho Peak



Oct 17, 2013
Landsat TM

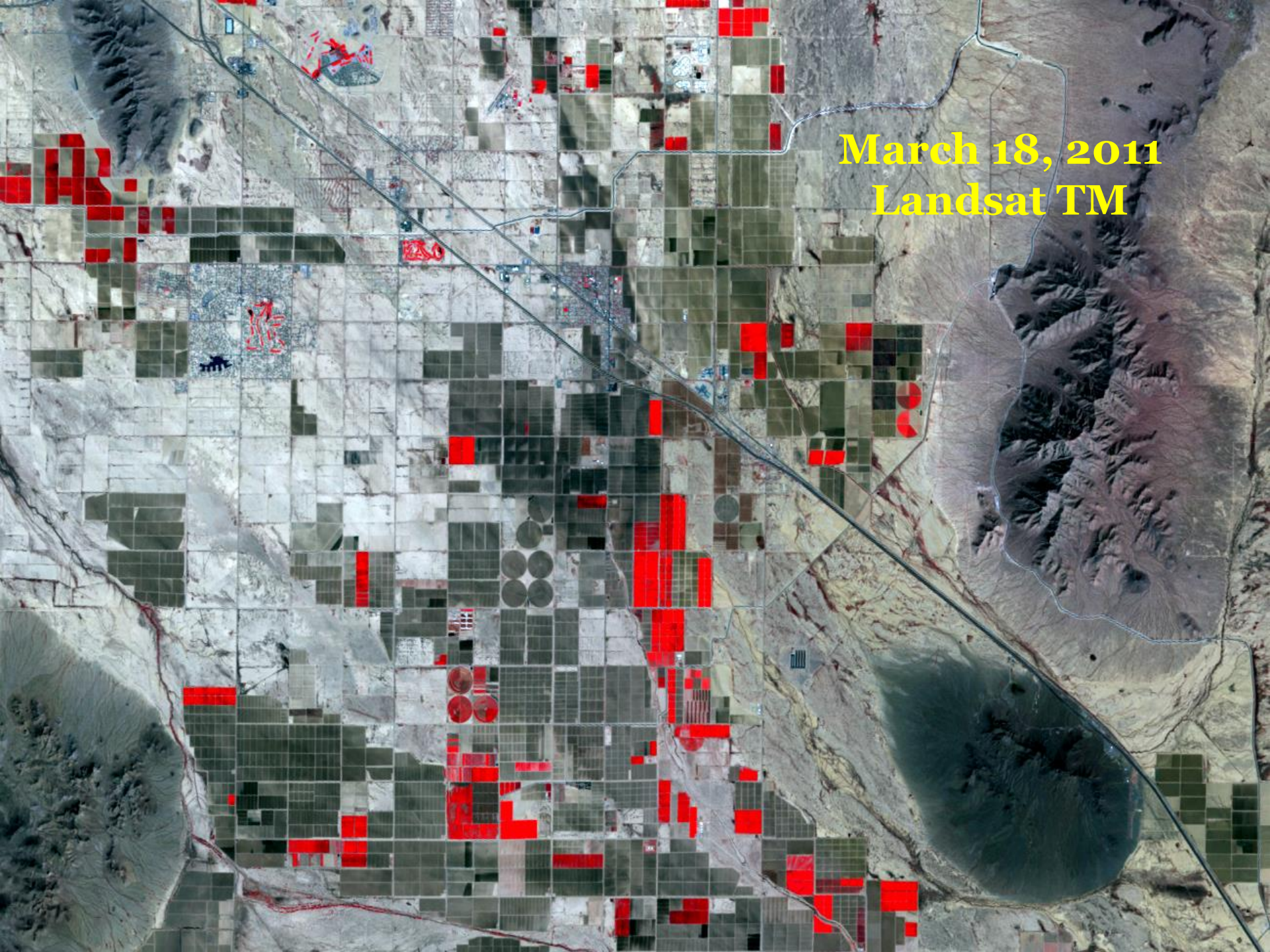
(Days Before Major Accident)



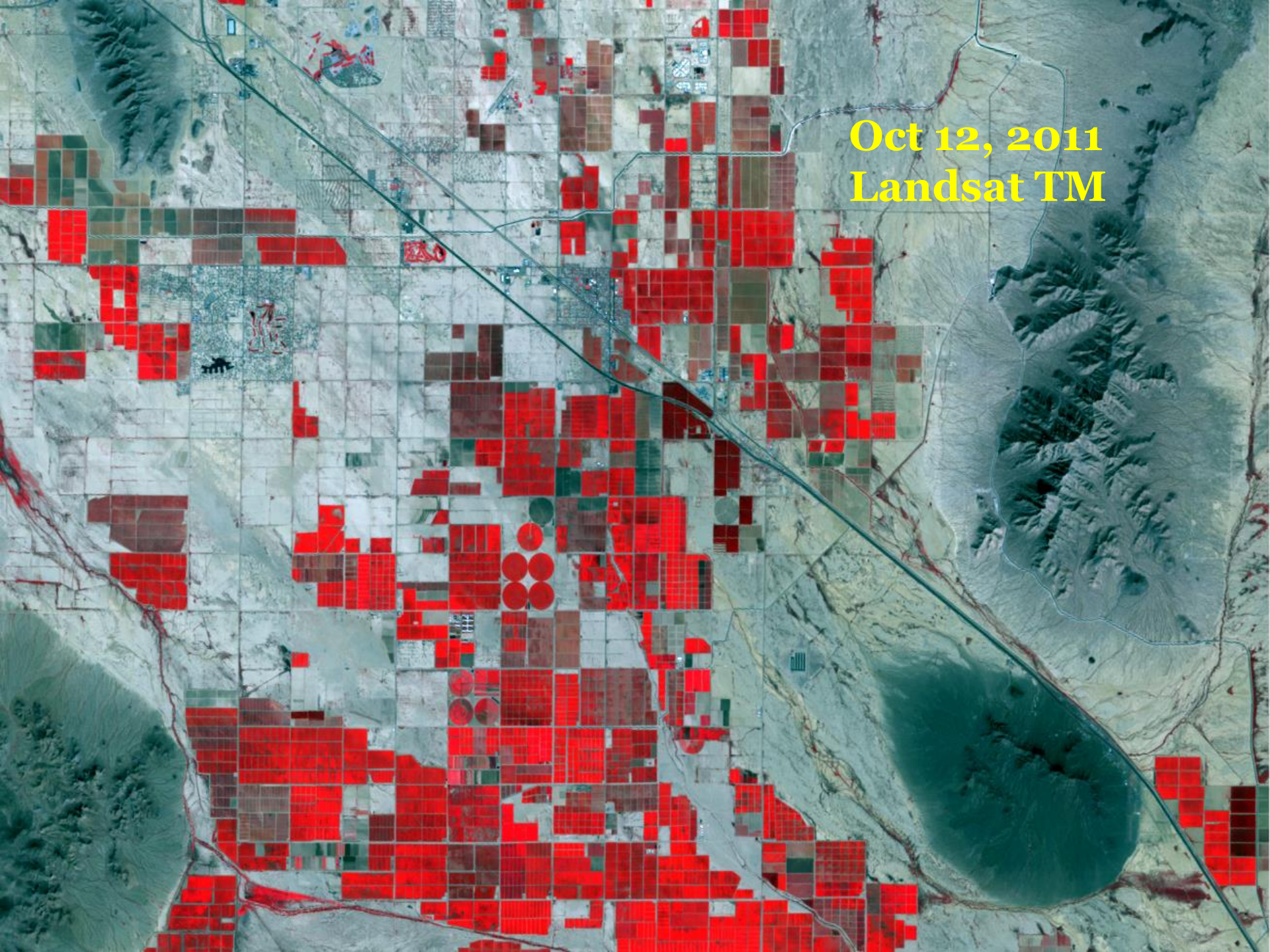
- *Monitor the agricultural fields* monthly (or more often if needed) to determine the amount and location of fields that are *vegetated versus not vegetated* at any given time and *study the trend throughout the year and different seasons* to see how this might be related to wind erosion and dust emission vulnerability. Investigate the potential of *using this information to help predict dust emission potential* in a given area at any given time.

--- FOR EXAMPLE ---

March 18, 2011
Landsat TM



Oct 12, 2011
Landsat TM

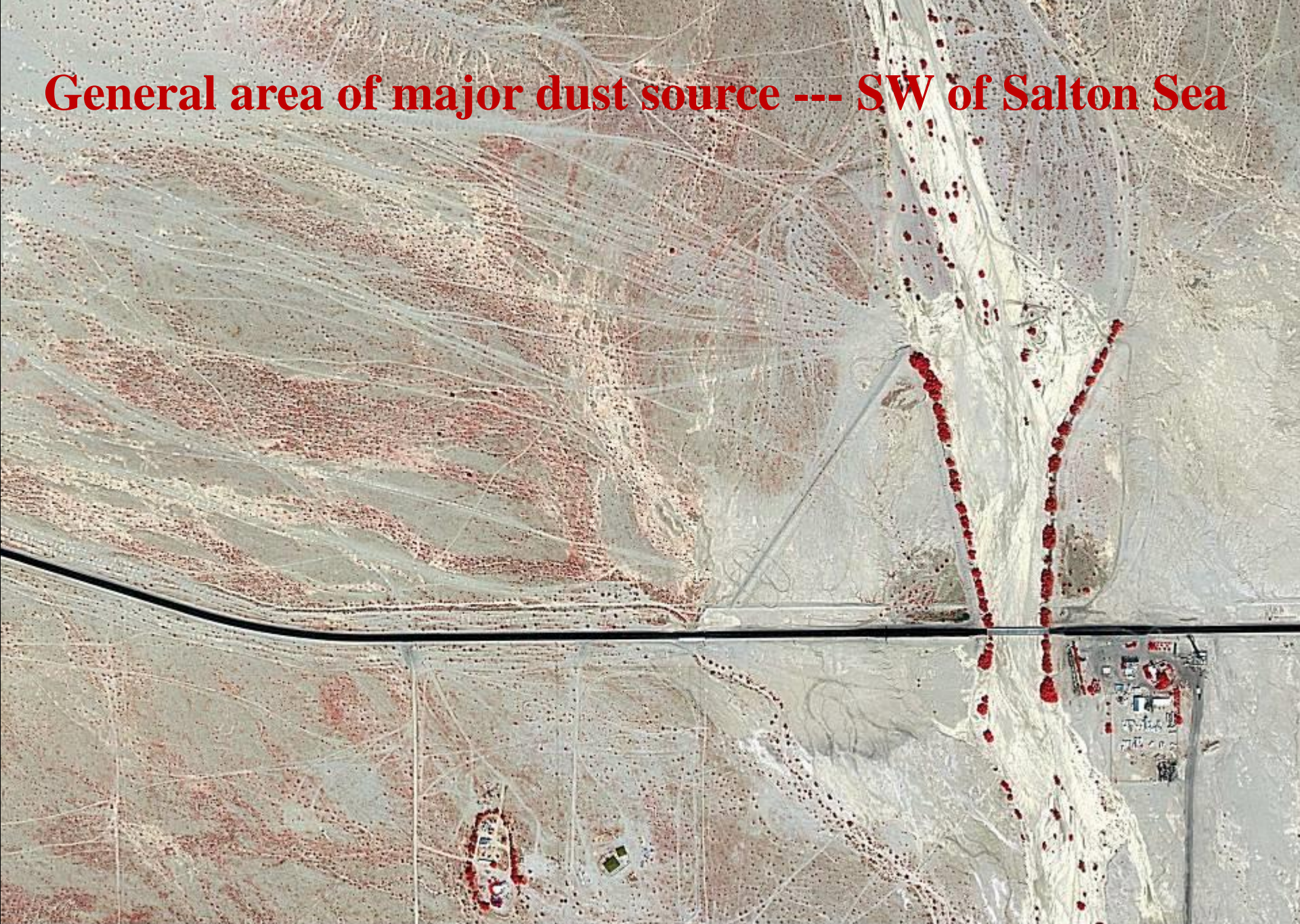


What About the Potential Impact by Non-Agricultural Land Use ?

- Investigate the *potential impact* to landscape vulnerability to dust emission by *Non-Agricultural land use* patterns

--- FOR EXAMPLE ---

General area of major dust source --- SW of Salton Sea



500 Meters

Southwest of Salton Sea - Quickbird 13 September 2005
On-land dust source area



USGS
science for a changing world

Picacho Area --- Google Earth ----- I-10



Google Earth



Air Quality Related Issues

(NOT SURE THERE WILL BE ENOUGH TIME FOR THE NEXT FEW SLIDES)

From some initial data mining it appears like there is a *good distribution of ground-based air quality monitoring stations* within the counties in the region and some *excellent reports have been generated* using data collected by those stations.

One of the issues that impacts analyzing and monitoring air quality is related to the fact that *ground-based stations have excellent temporal resolution* but even with the current good distribution they have *relatively poor spatial resolution*.

Potential applications of satellite remote sensing that may help with *air quality related issues* includes:

- Investigate the potential to *generate haze maps* using Landsat 8 satellite images. Resulting haze maps could be *correlated to PM10 and PM2.5 data* collected by ground-based instruments to calibrate and convert the haze maps to *PM10 (or 2.5) maps of the region*. There have been some initial *discussions of this with the BLM* and potential use to analyze the impact to visibility within national monuments in southern Arizona.

The results could have several applications including generating *much higher spatial resolution* PM10 and/or PM2.5 maps that could be used to *help identify air quality hot spots and transport patterns* within the image area (a single Landsat image with 30m resolution has a foot print of 110 miles by 110 miles).

Multi-temporal maps such as these could be used to *help identify where ground-based monitoring stations should be placed* in order to collect data that are *representative of the areas* that need to be monitored.

Combining the excellent *temporal resolution* of the ground-based stations with the excellent *spatial resolution* of satellite images could provide an enhancement for air quality mapping and monitoring.

**THANK YOU FOR YOUR TIME AND THE
OPPORTUNITY TO PRESENT AT THIS
IMPORTANT WORKSHOP**

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