# 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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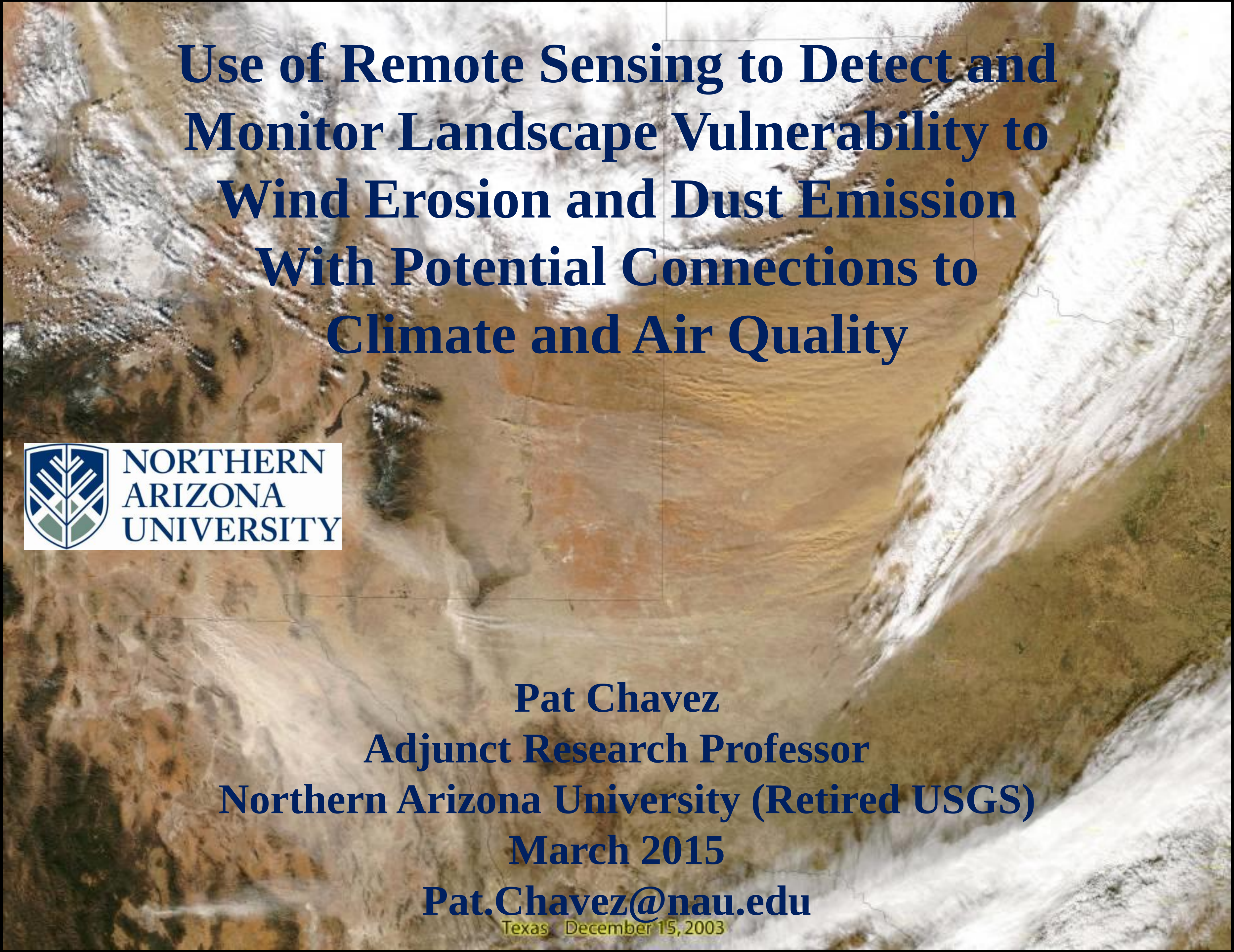


# This presentation will cover

- 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.

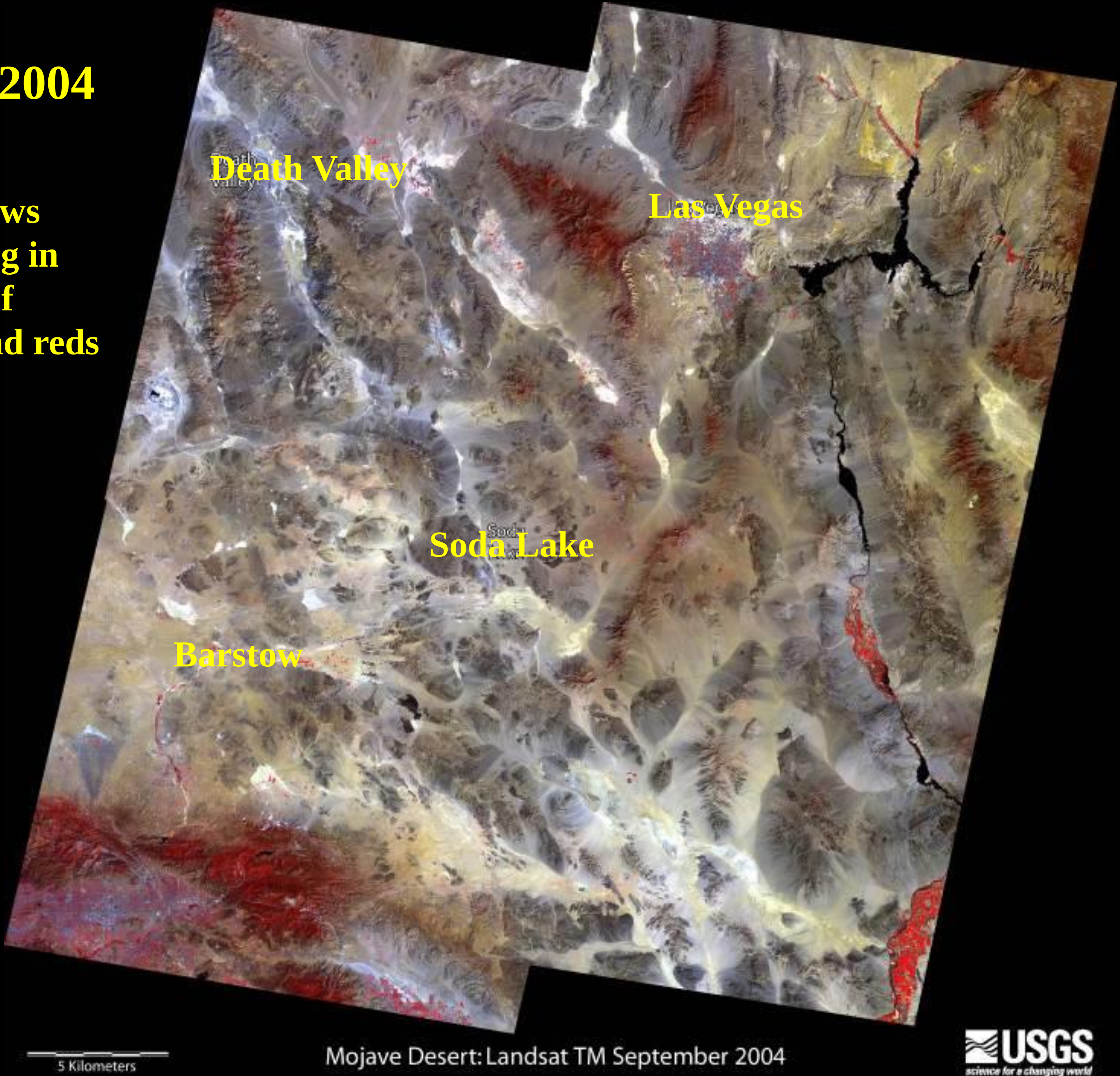
Therefore, methods to detect, map, and monitor the ***temporal*** and ***spatial dynamics of vegetation*** are critical to help map and ***monitor the degree of vulnerability*** to wind and water erosion at any given time.

# Temporal Dynamics

Detecting and mapping ***vegetation dynamics though 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***.

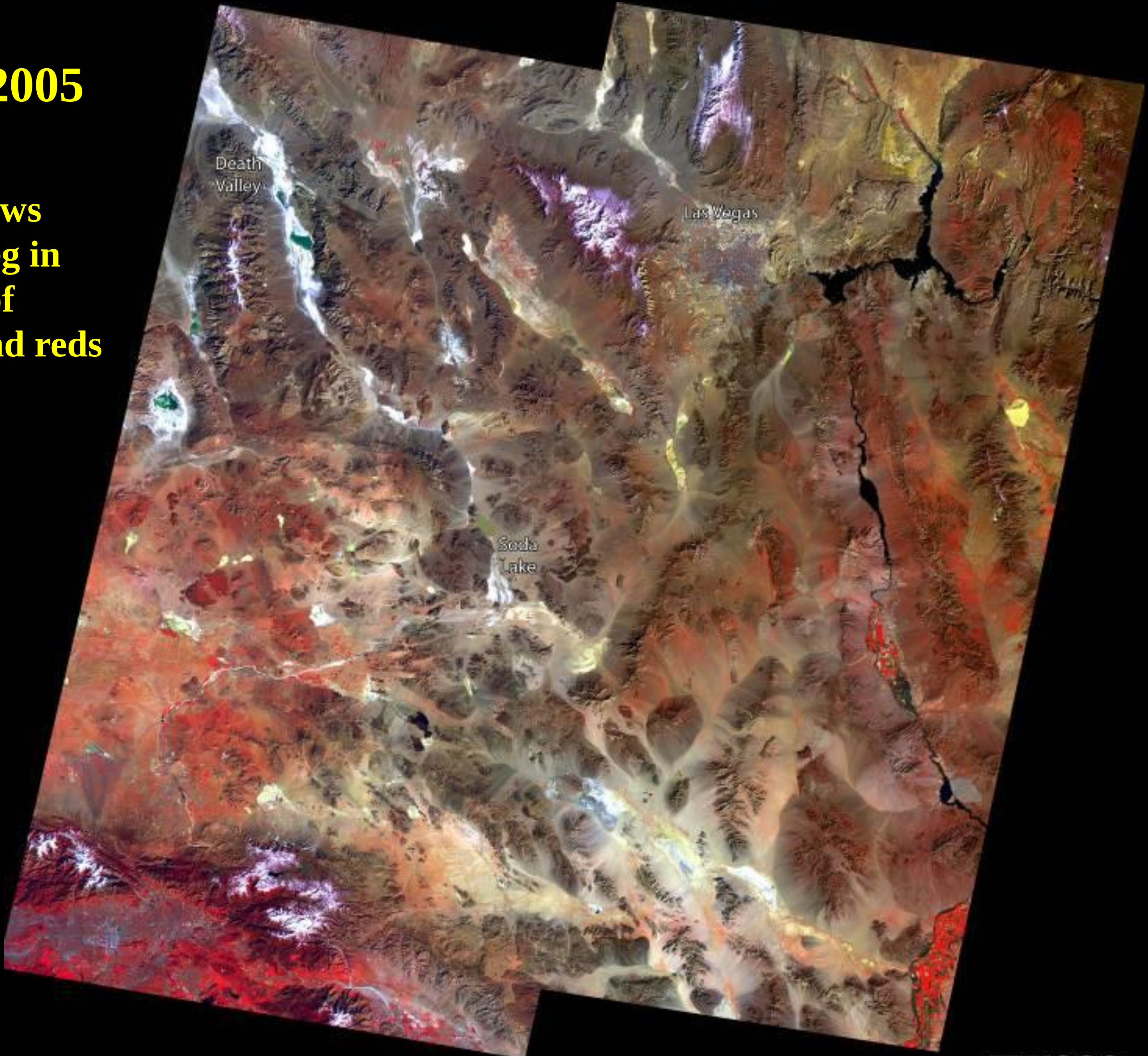
# Sept 2004

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



# Feb 2005

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

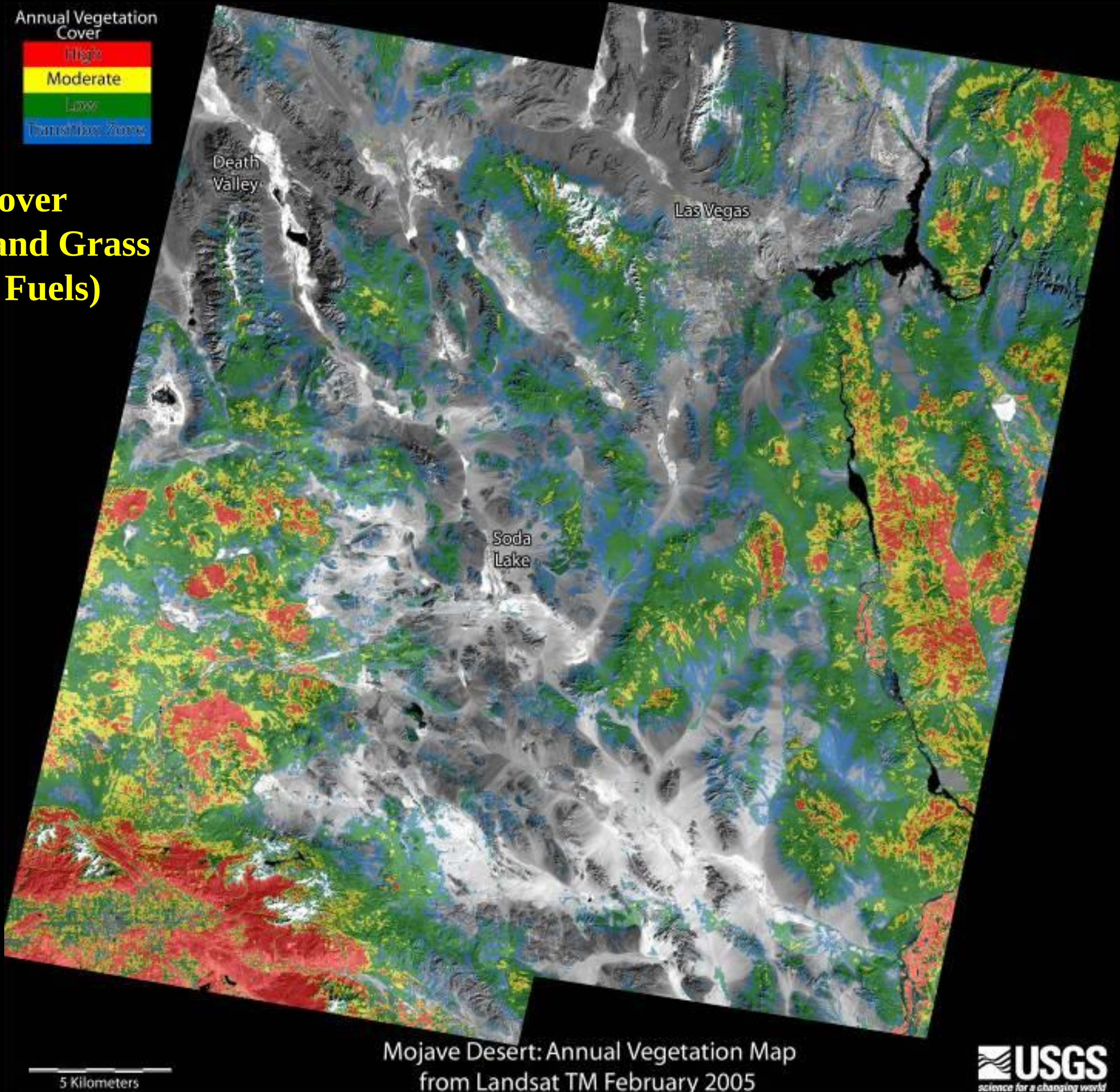



5 Kilometers

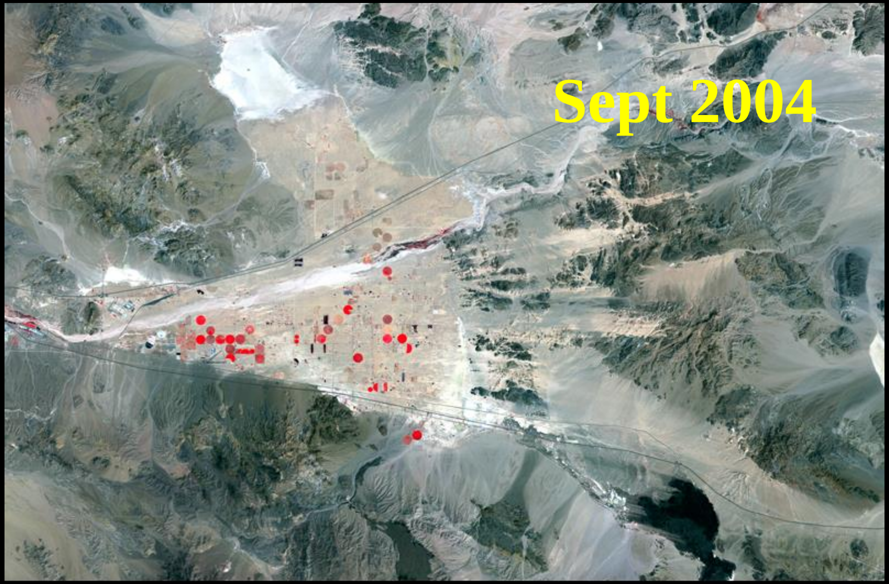
Mojave Desert: Landsat TM February 2005

USGS
science for a changing world

# Veg Cover
# Annuals and Grass
# (Fine Fuels)



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




10 Kilometers

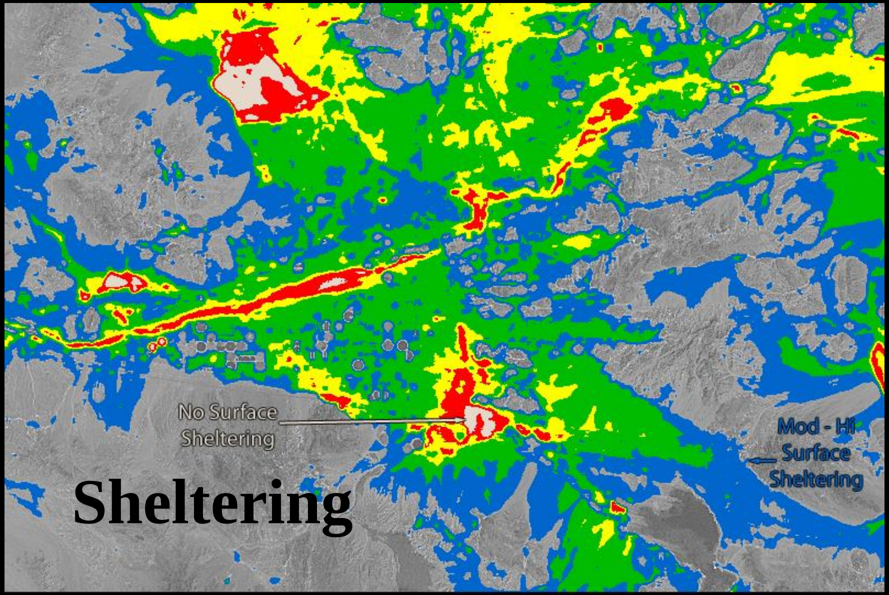
Mojave River Area
Landsat TM - Sep 04

USGS


10 Kilometers

Mojave River Area
Landsat TM - Feb 05

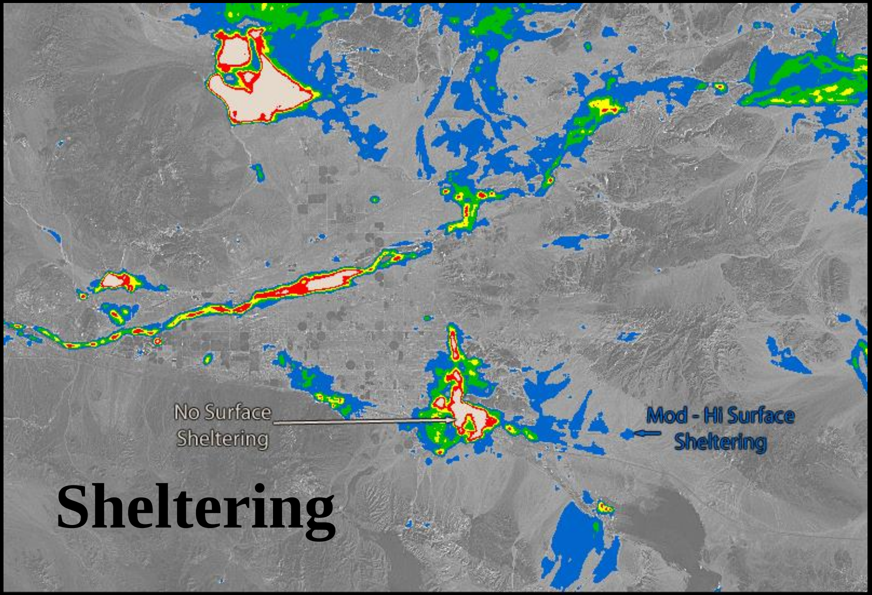
USGS




10 Kilometers

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

USGS




10 Kilometers

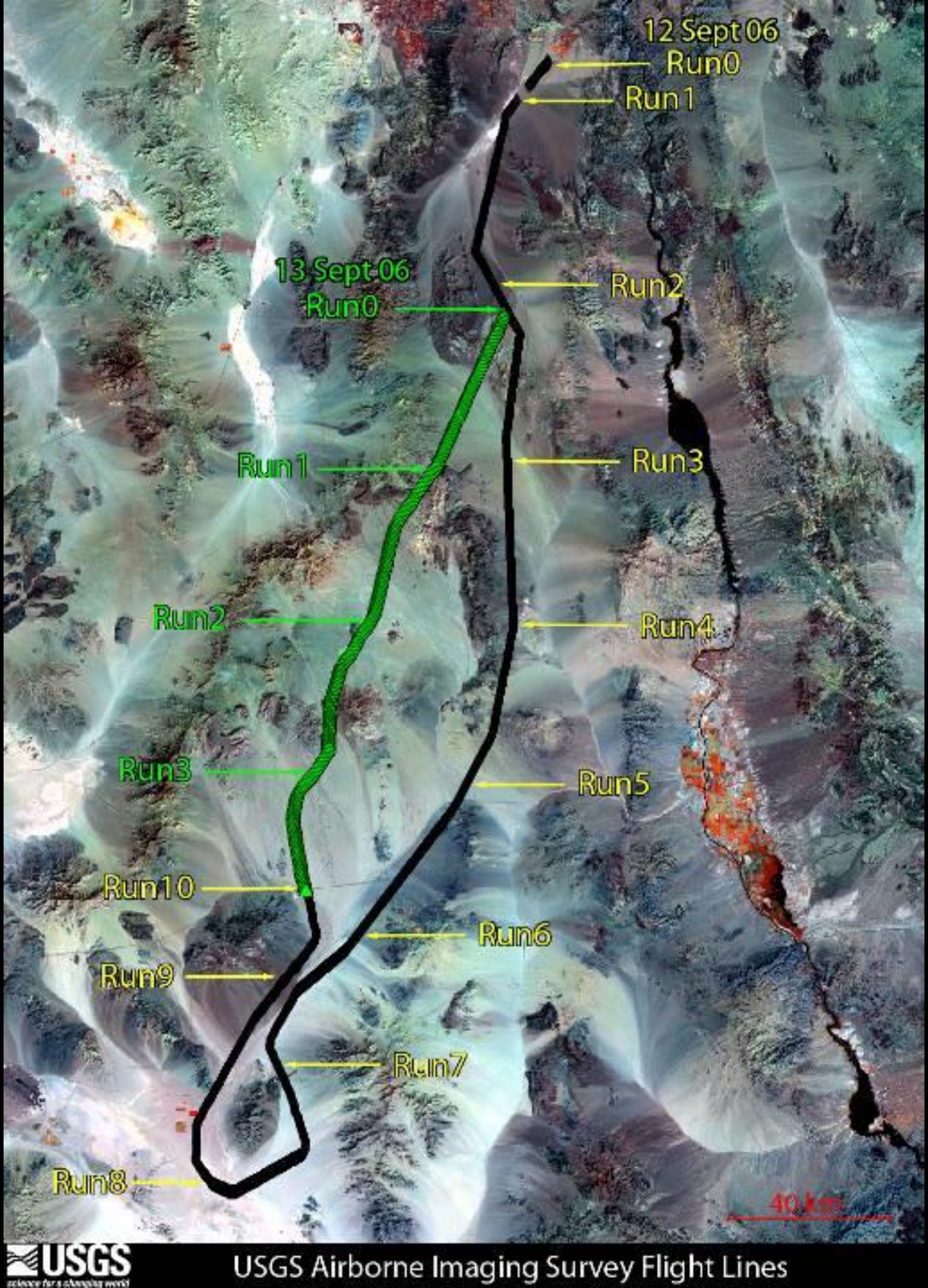
Mojave River Area
Surface Sheltering Index Map from Landsat TM - Feb 05

USGS

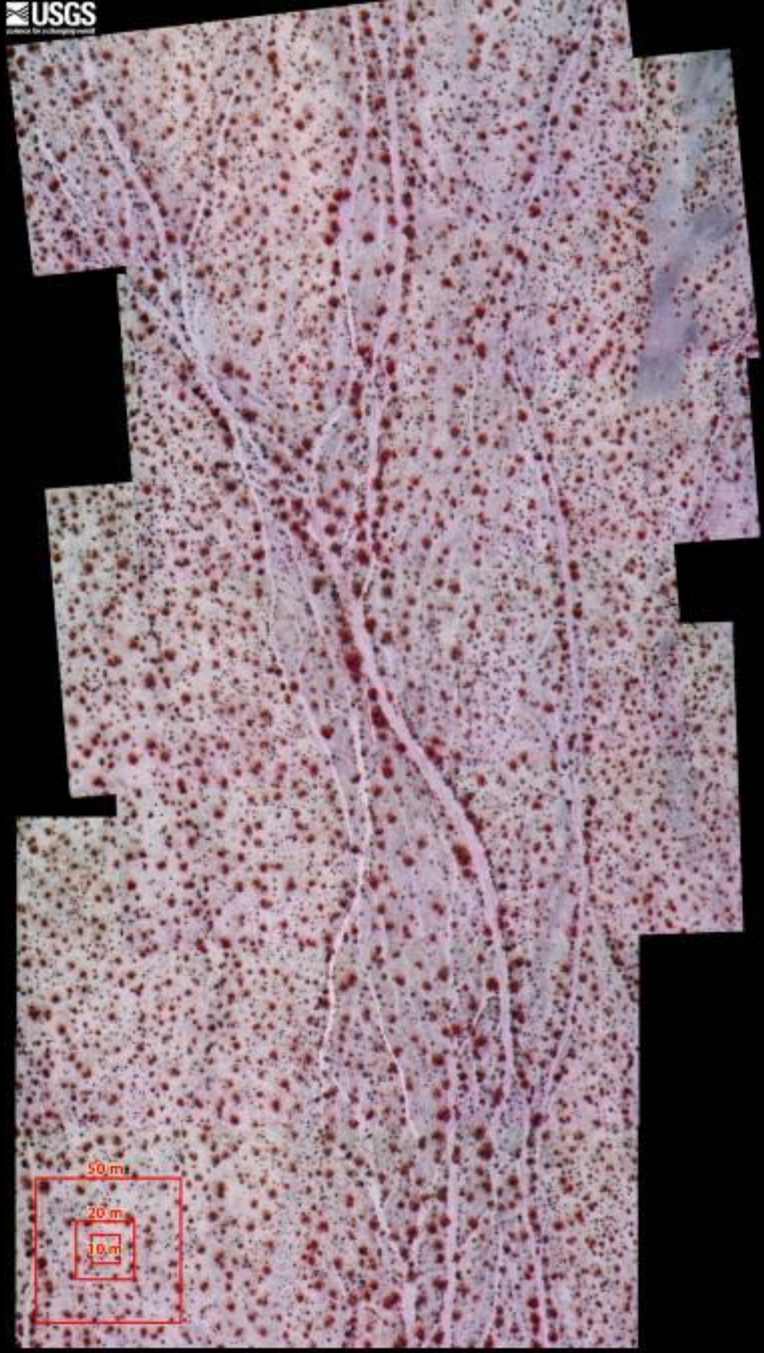
# Spatial Dynamics

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**



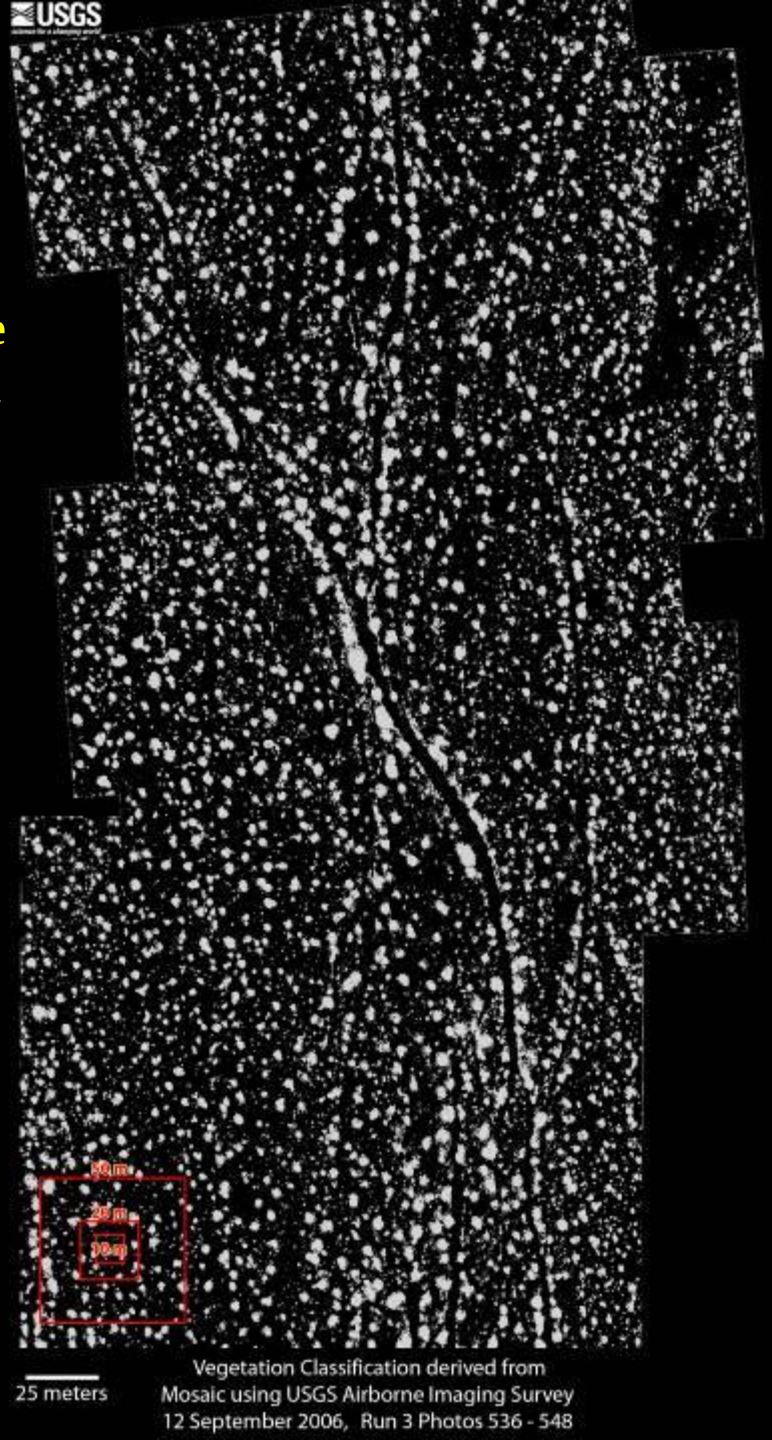
**Digital mosaic of CIR images with woody vegetation shown in shades of pinks and reds**



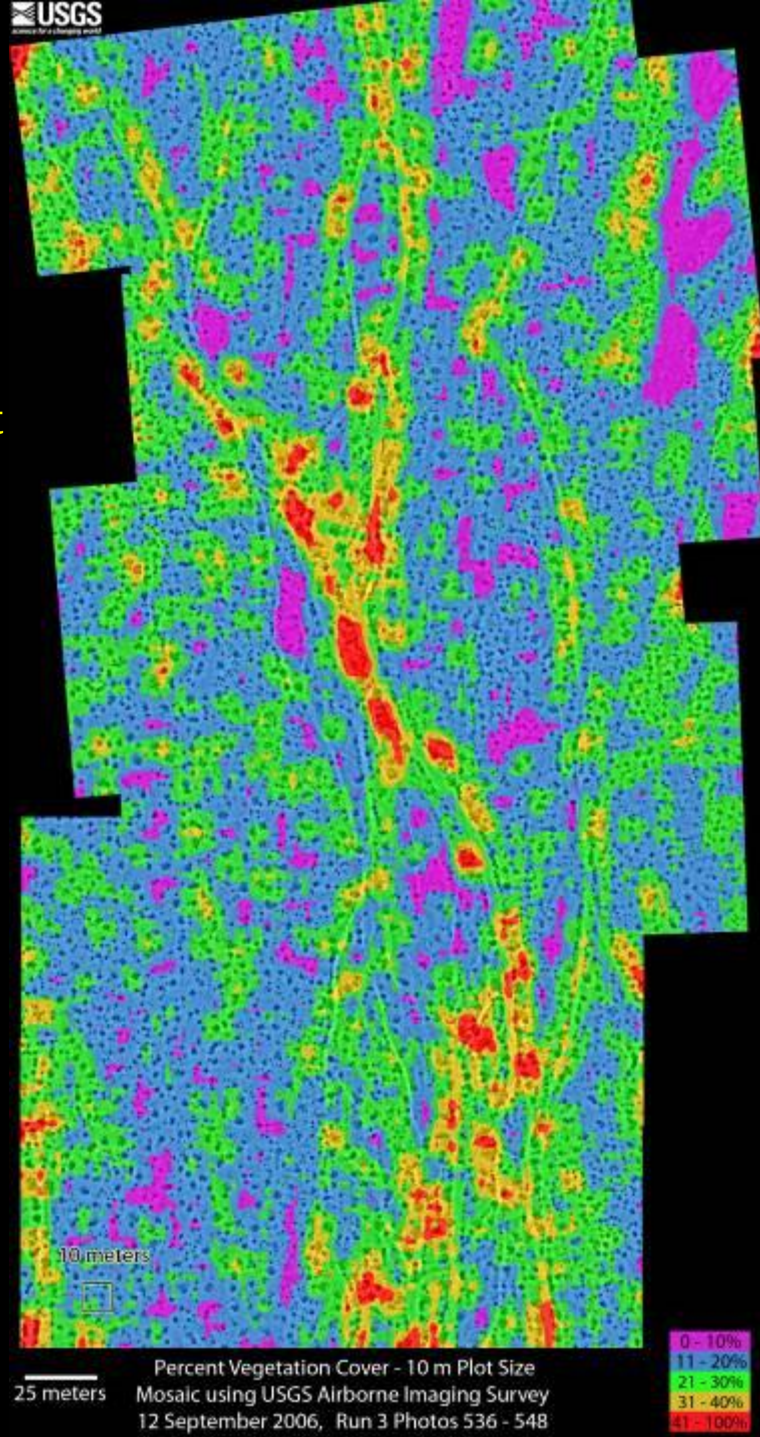

25 meters

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

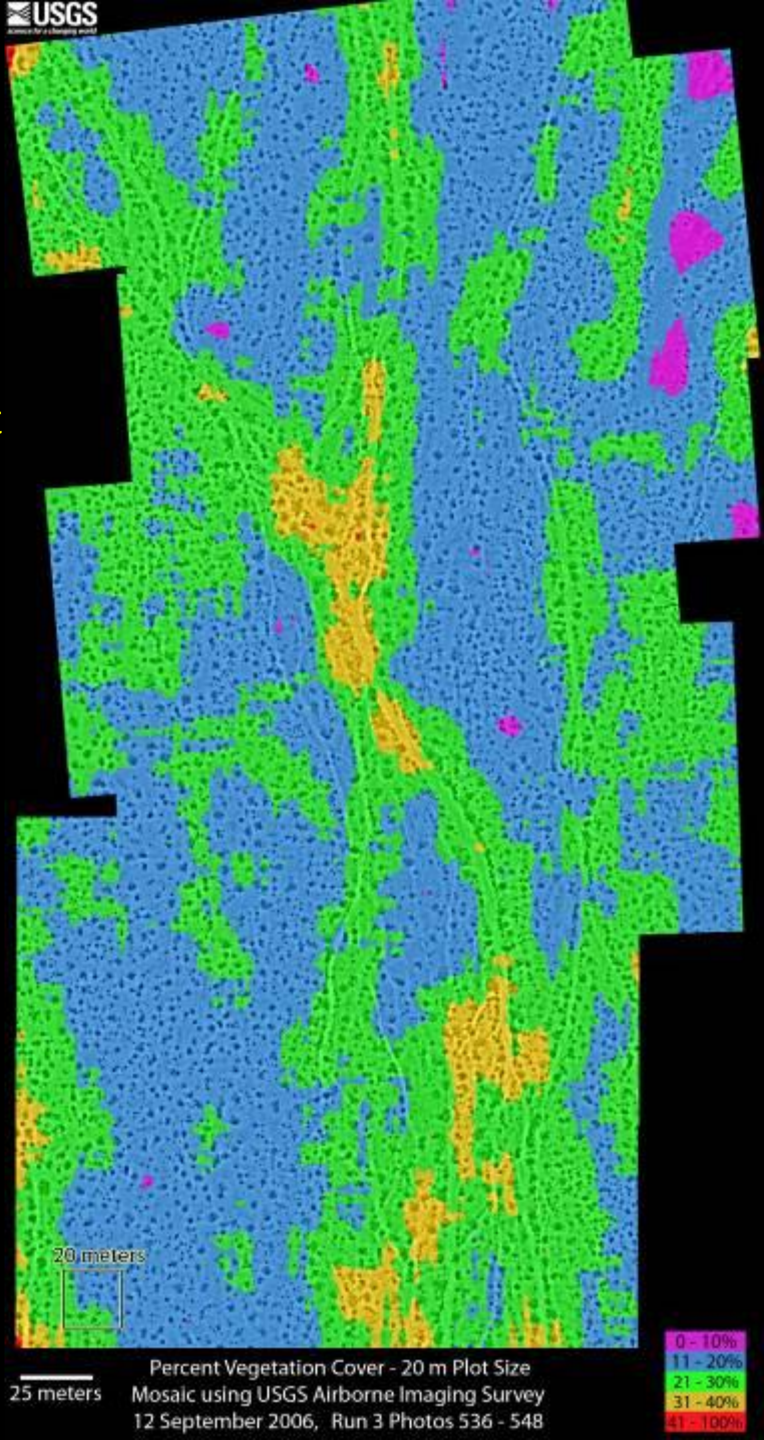
**Vegetated Pixels --- White**
**Not Vegetated --- Black**



**Percent Veg Cover**
**10 by 10 meter foot print**



Percent Veg Cover
20 by 20 meter foot print



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)

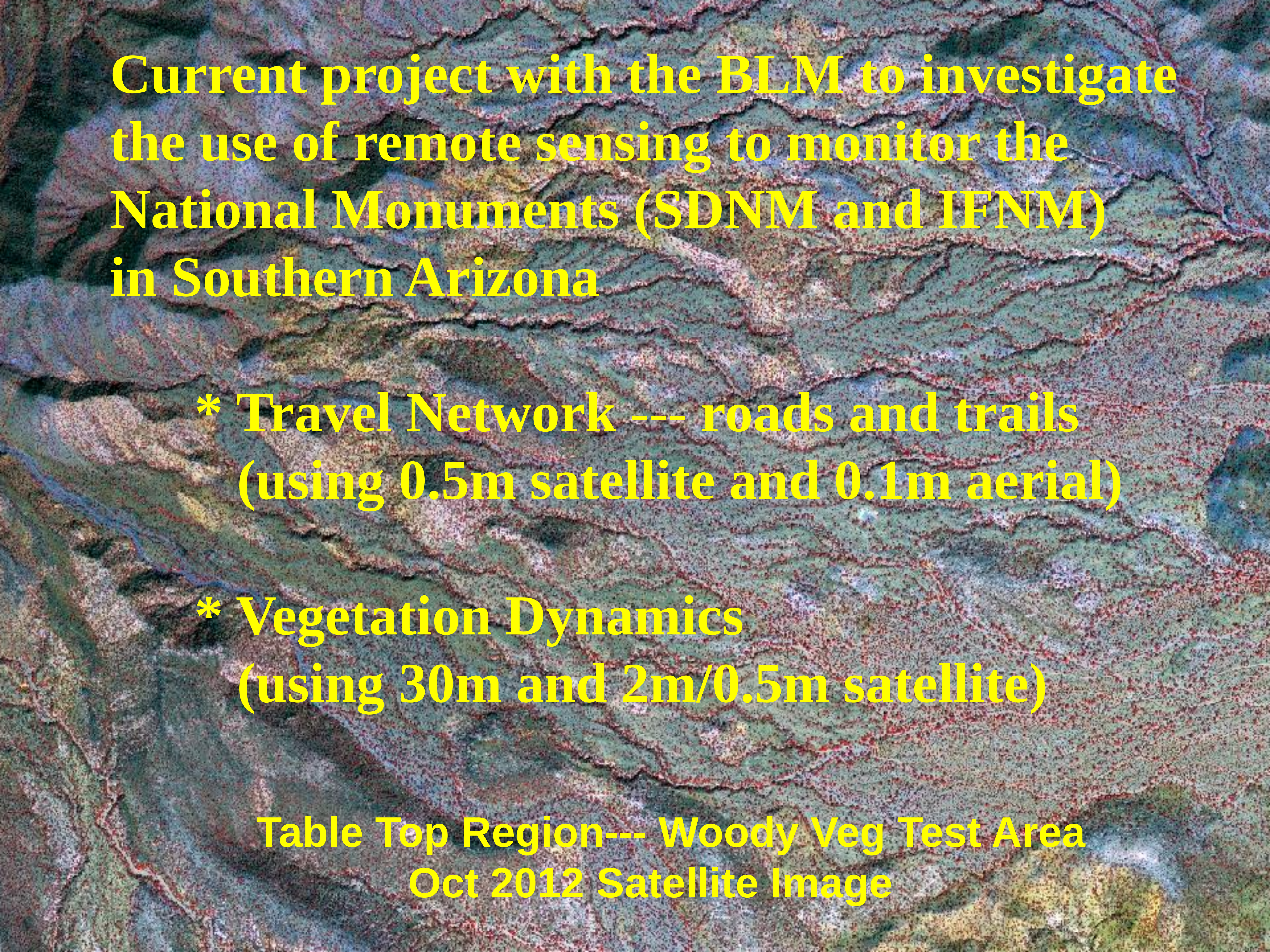
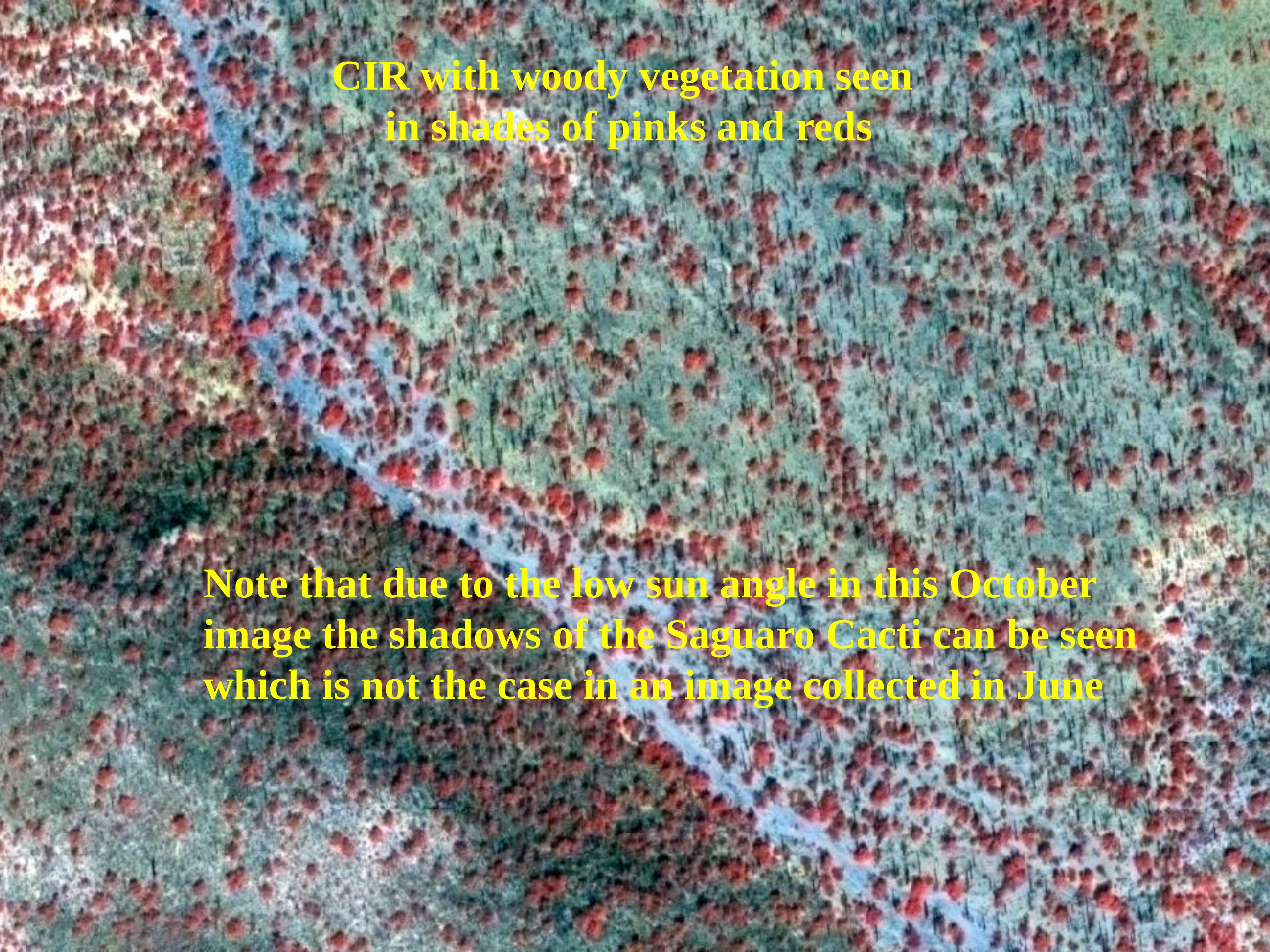
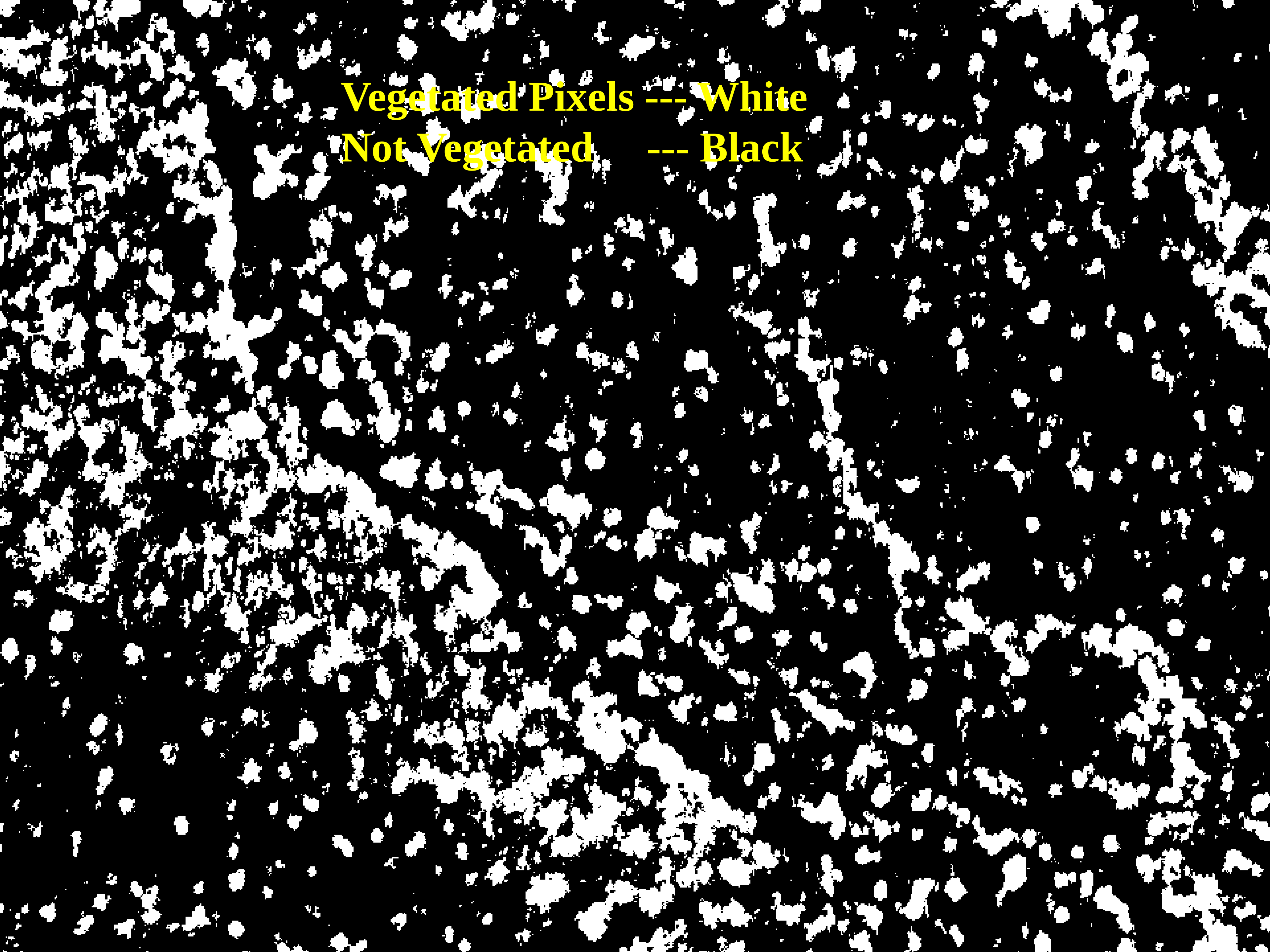


Table Top Region--- Woody Veg Test Area
Oct 2012 Satellite Image


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

# 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

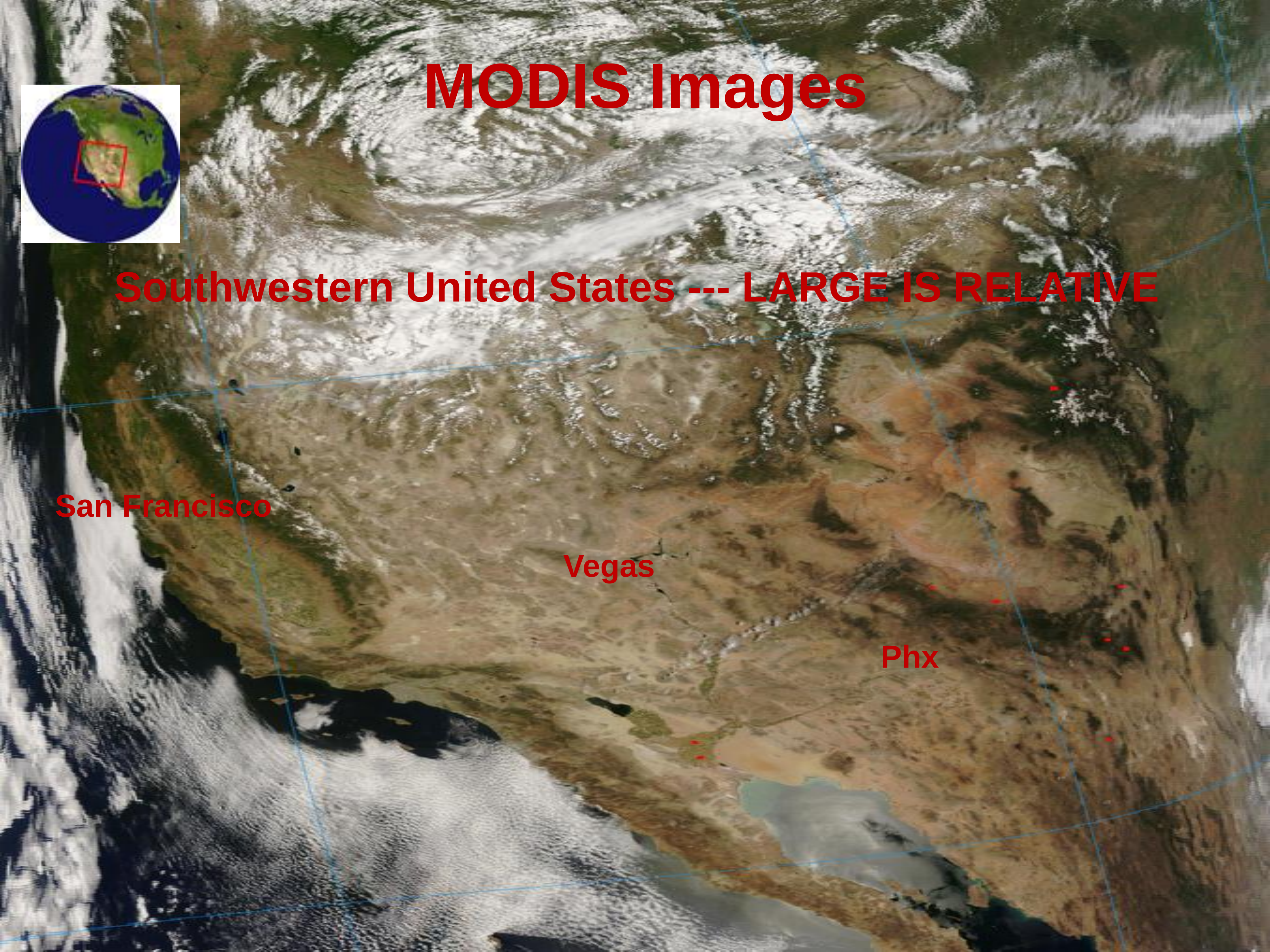
## *Keep in mind*

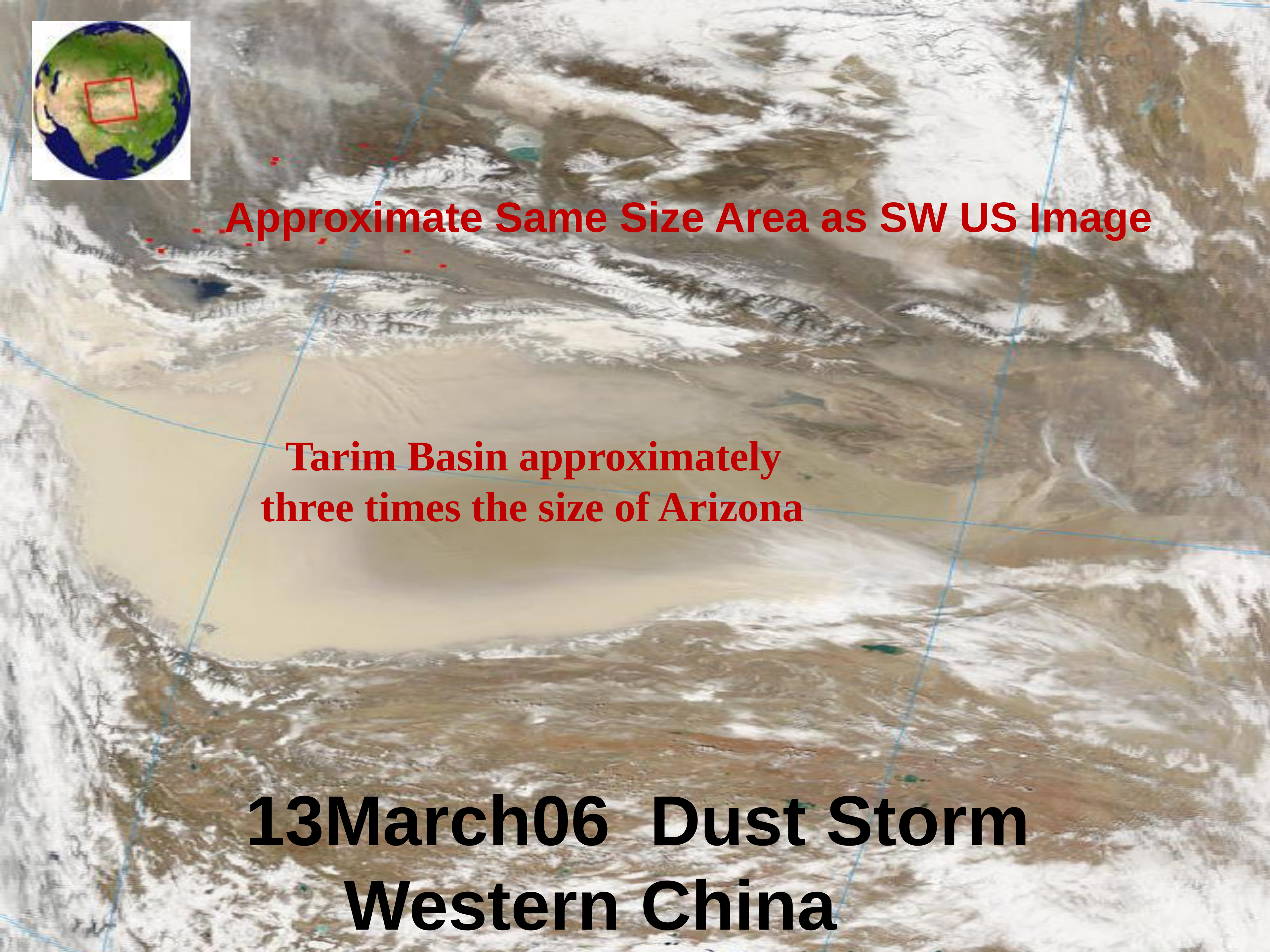
1. The ***temporal resolution*** --- fly over frequency of most satellite imaging systems is not sufficient to monitor relatively short lived events --- the ***only exception is the GOES*** weather satellite.

2. Only ***large and high concentration*** dust storms can usually be detected using either the ***GOES or MODIS*** satellites.

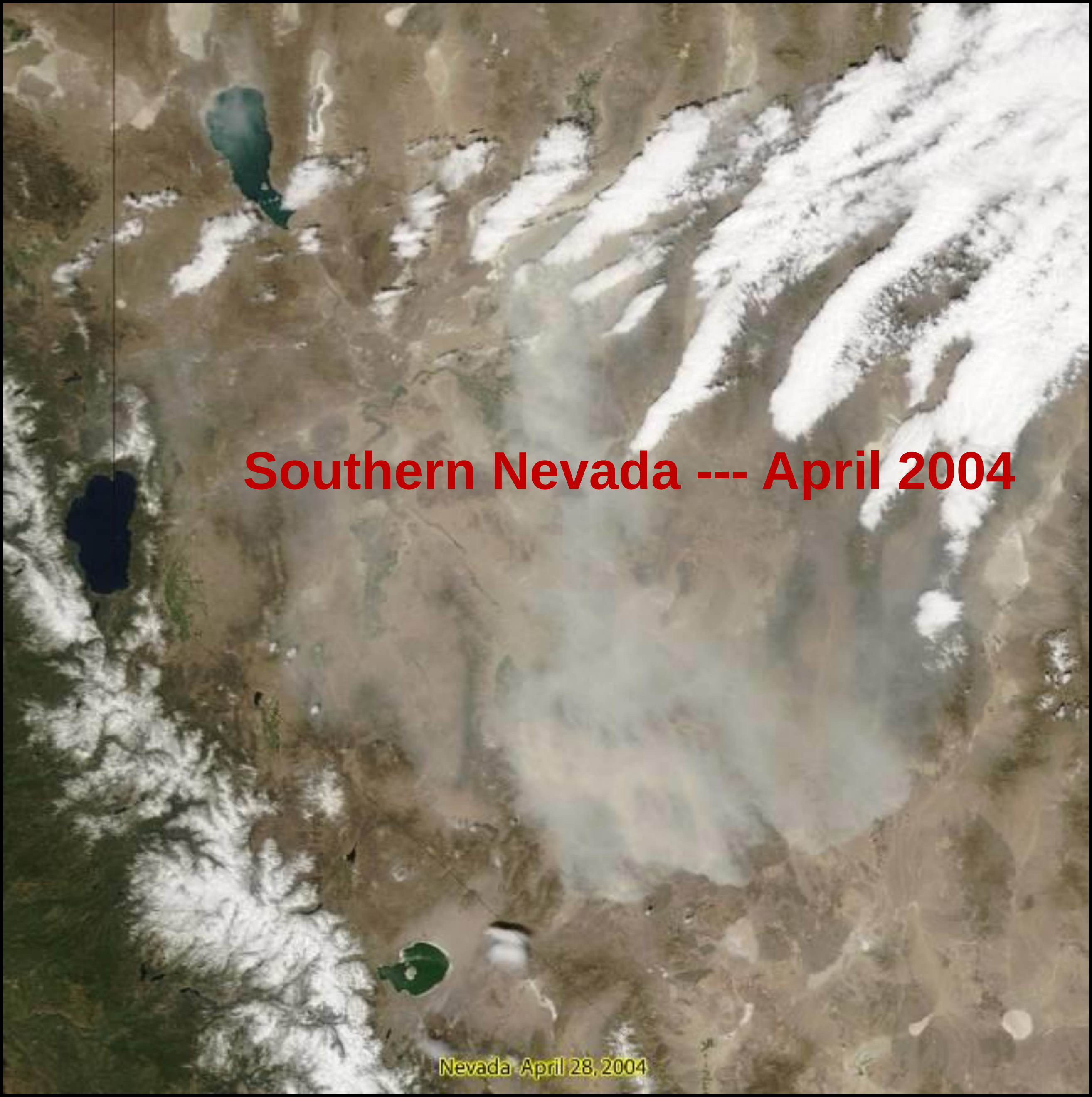
3. ***Can not see thru clouds*** so problems seeing dust storms related to monsoon weather patterns.

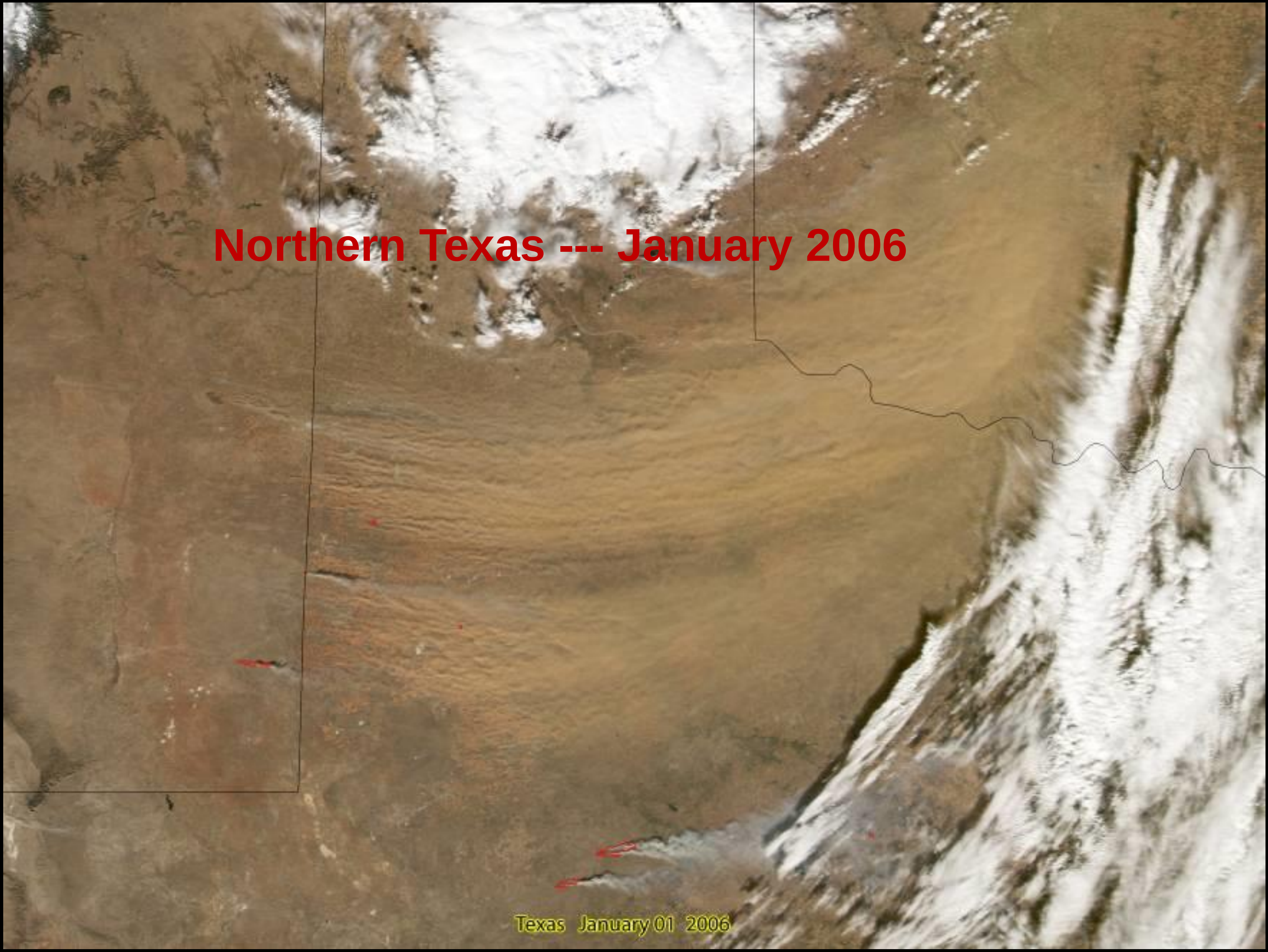
4. ***Over time*** enough large dust storms ***can be detected to help identify*** some of the major dust sources in a given region.


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

# Southern Nevada --- April 2004




Northern Texas --- January 2006
Texas January 01 2006

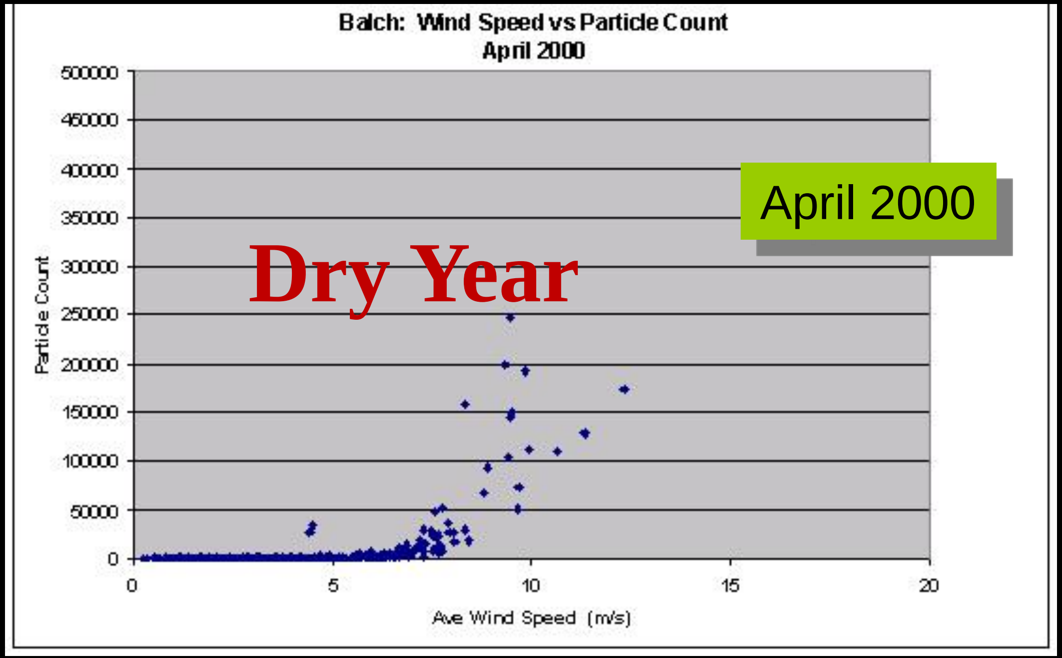
# Influence of *Climate on Landscape Vulnerability* to Wind Erosion and Dust Emission

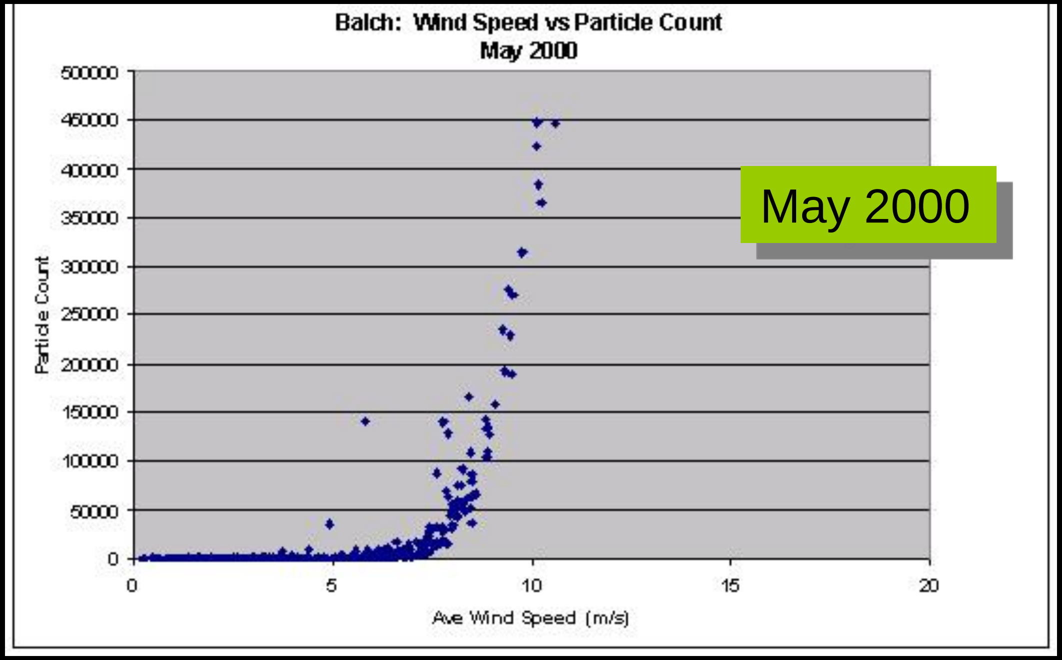
## Droughts in the Southwest

# Cameras, Wind Meters, and Sensit

# Mojave Desert: Balch

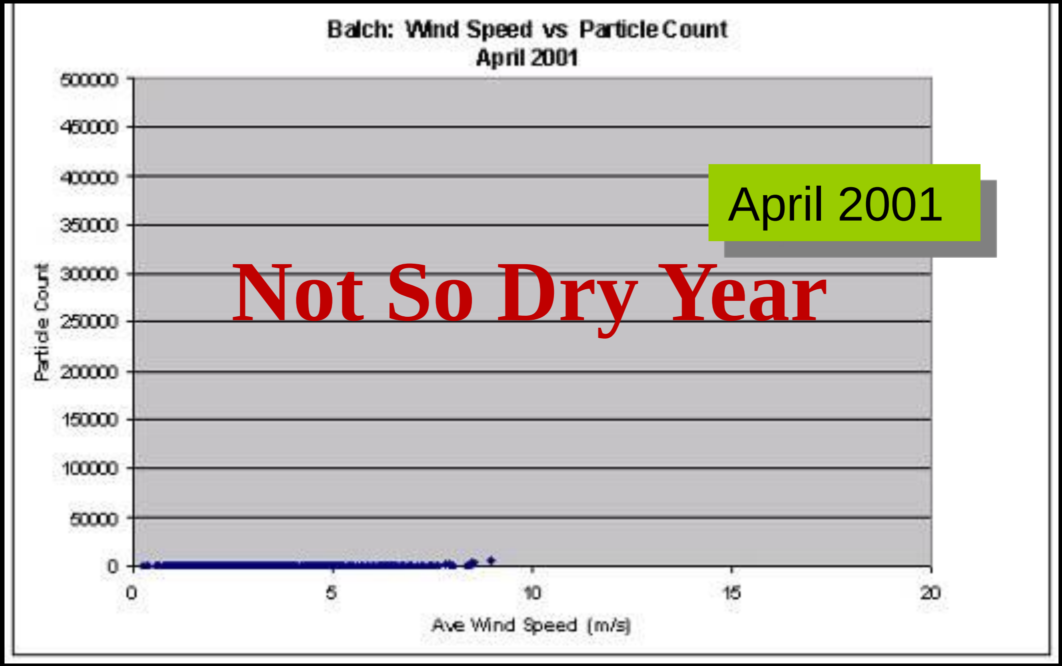
# Wind Speed vs Particle Count

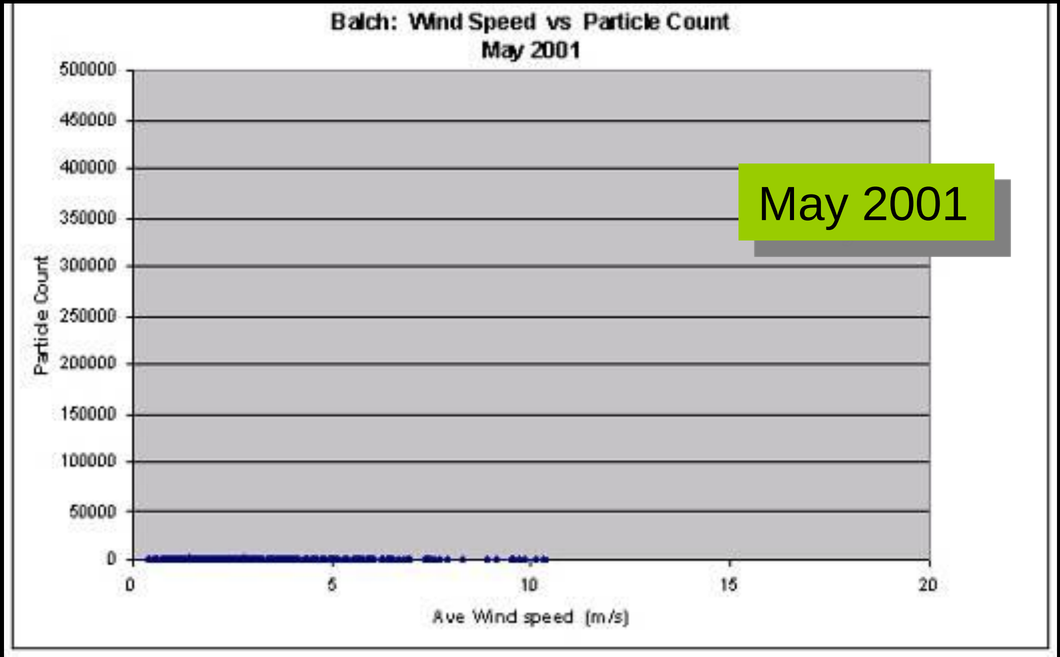


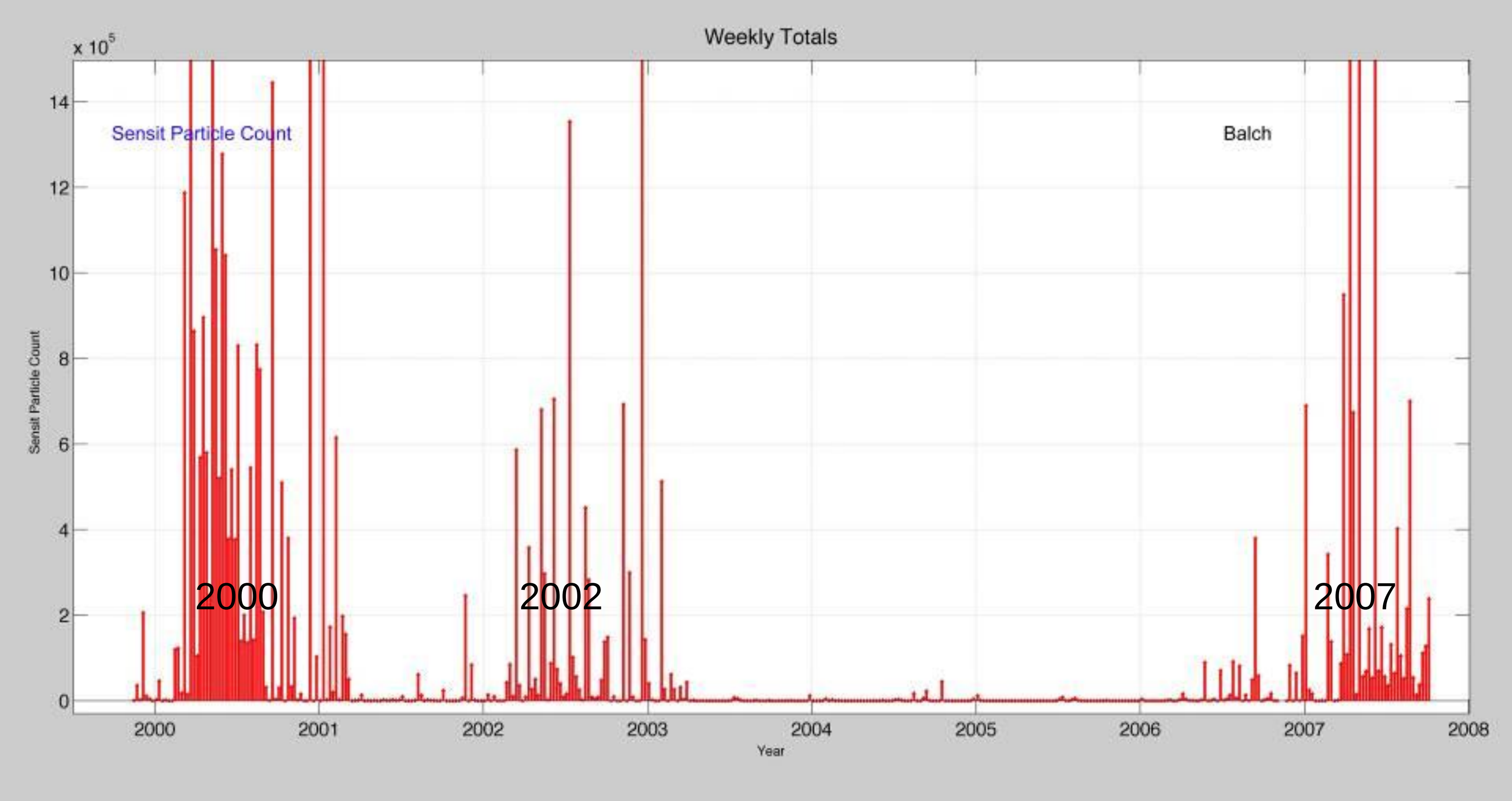
# Mojave Desert: Balch

# Wind Speed vs Particle Count

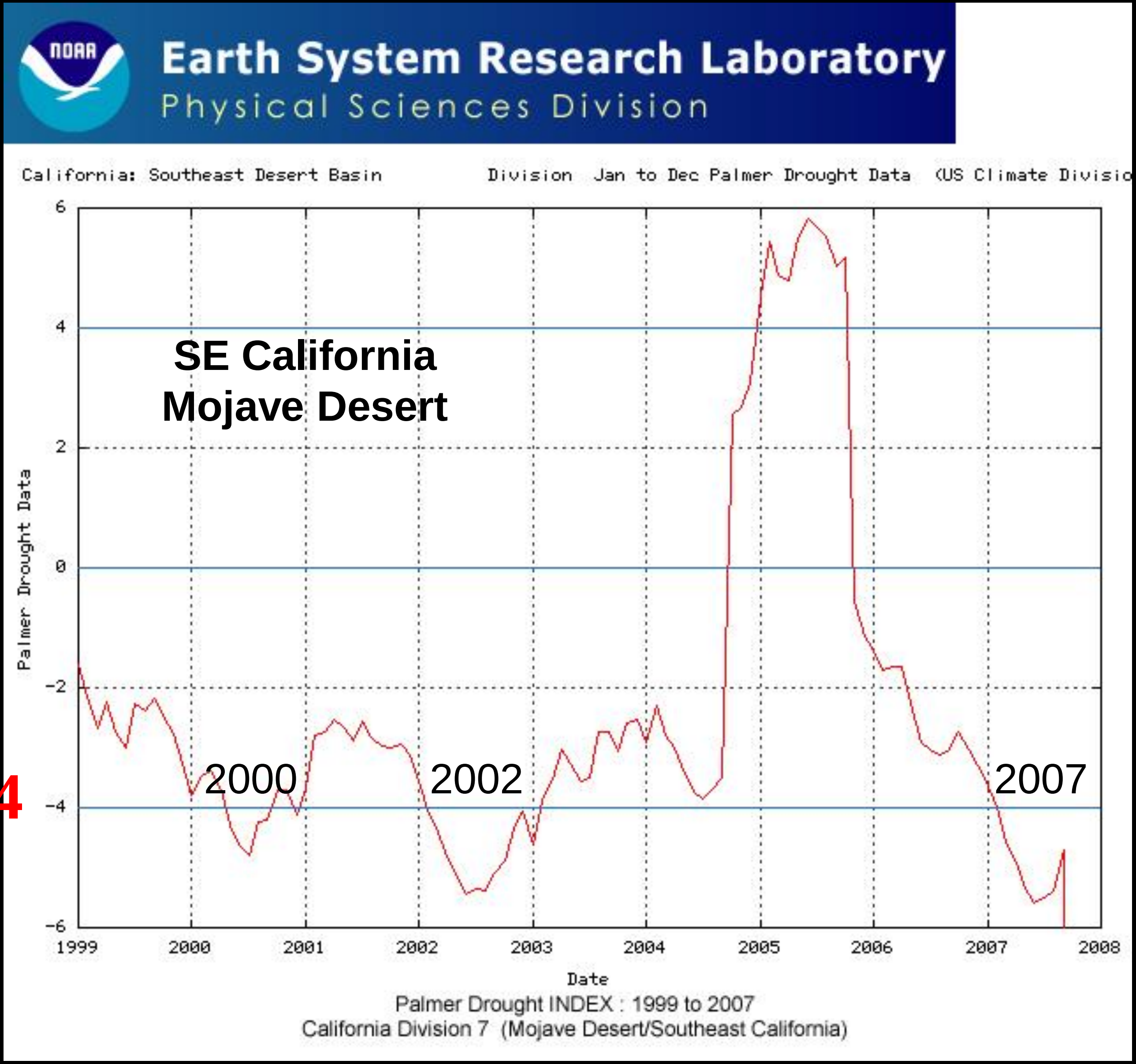


# Sensit Particle Count --- From USGS Instrument at Soda Lake

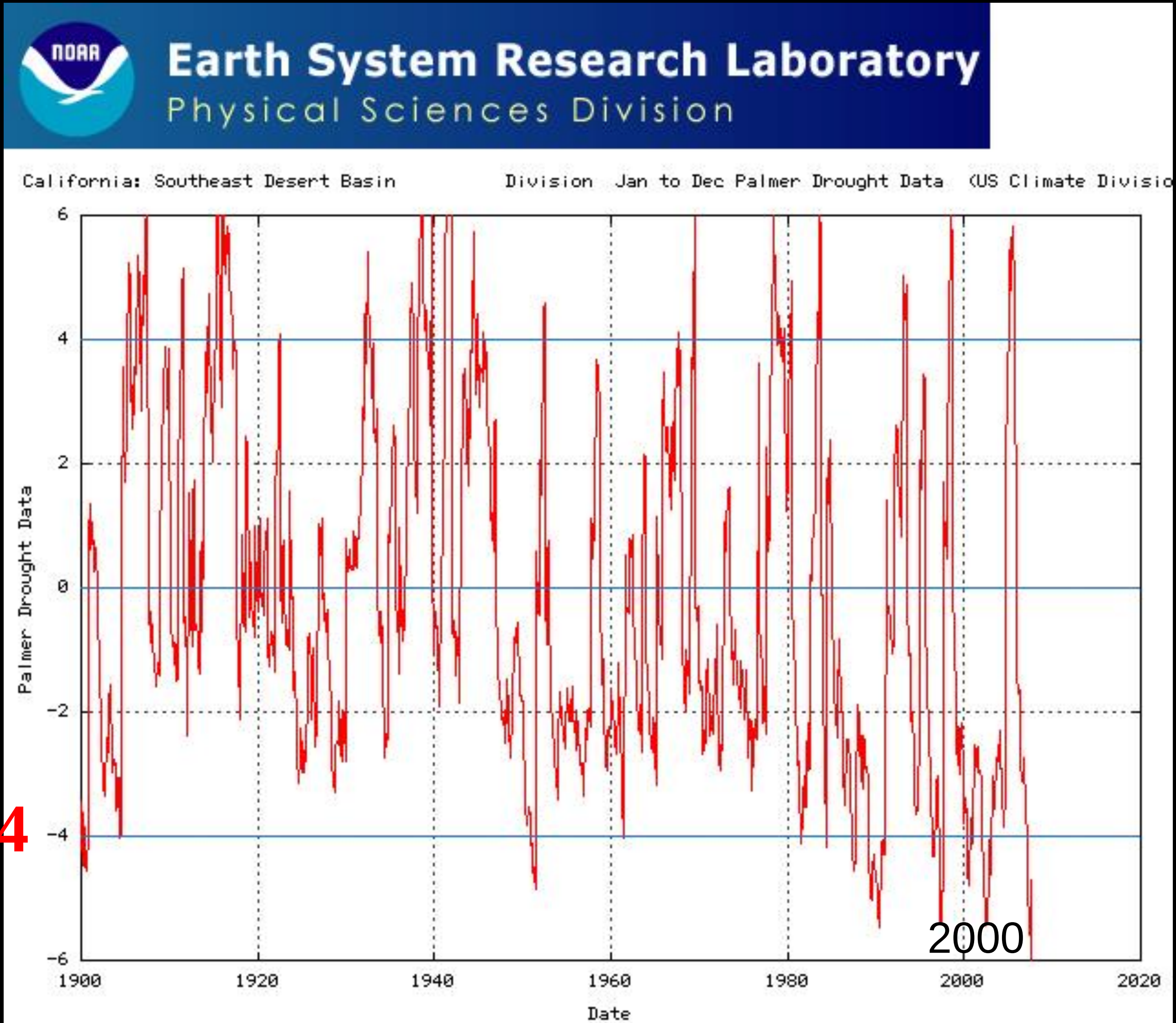


NOAA's PDSI Data --- Note: **-3.5 to -4.0** seems to be a critical threshold

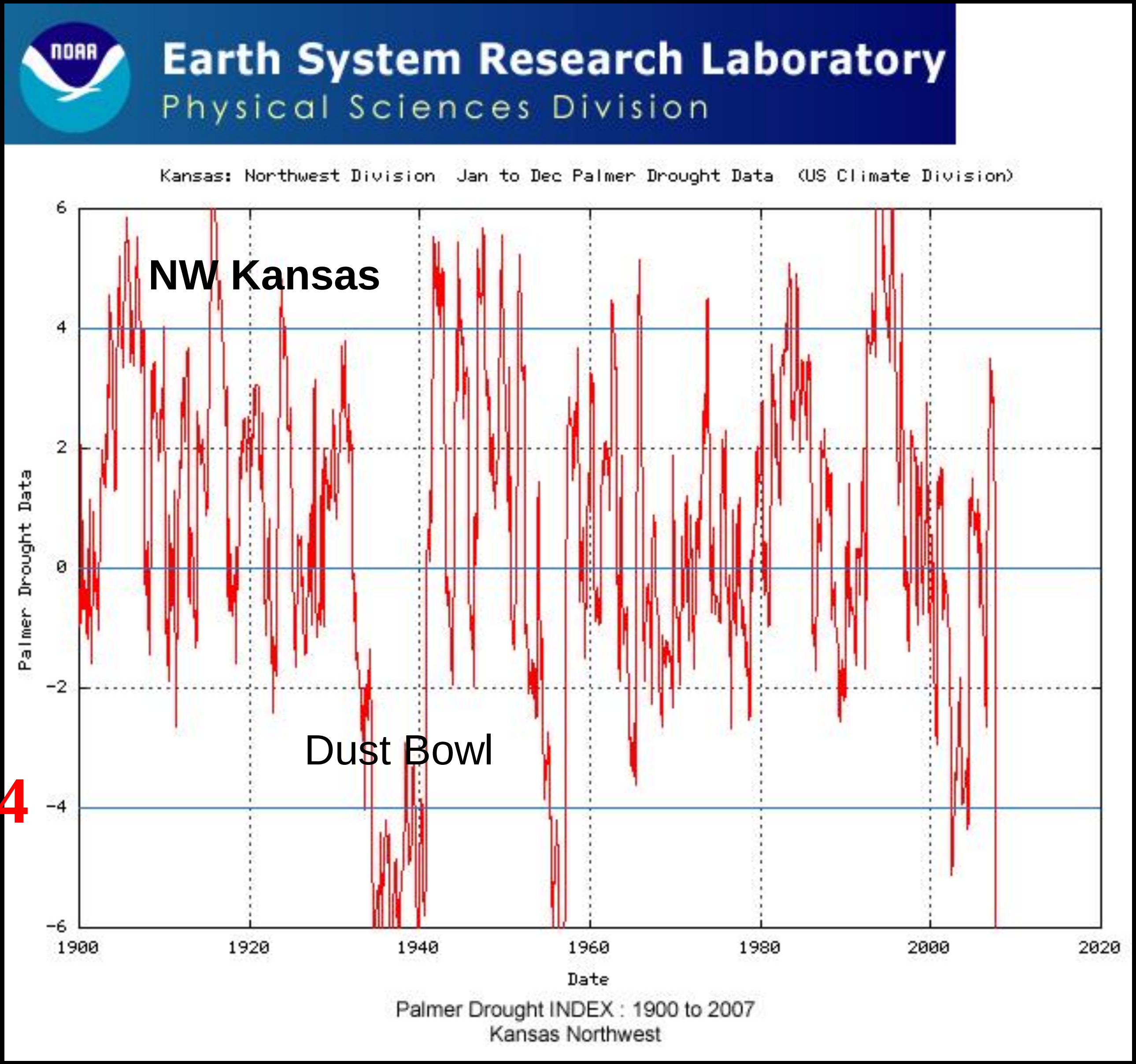



PDSI = -4

PDSI = -4

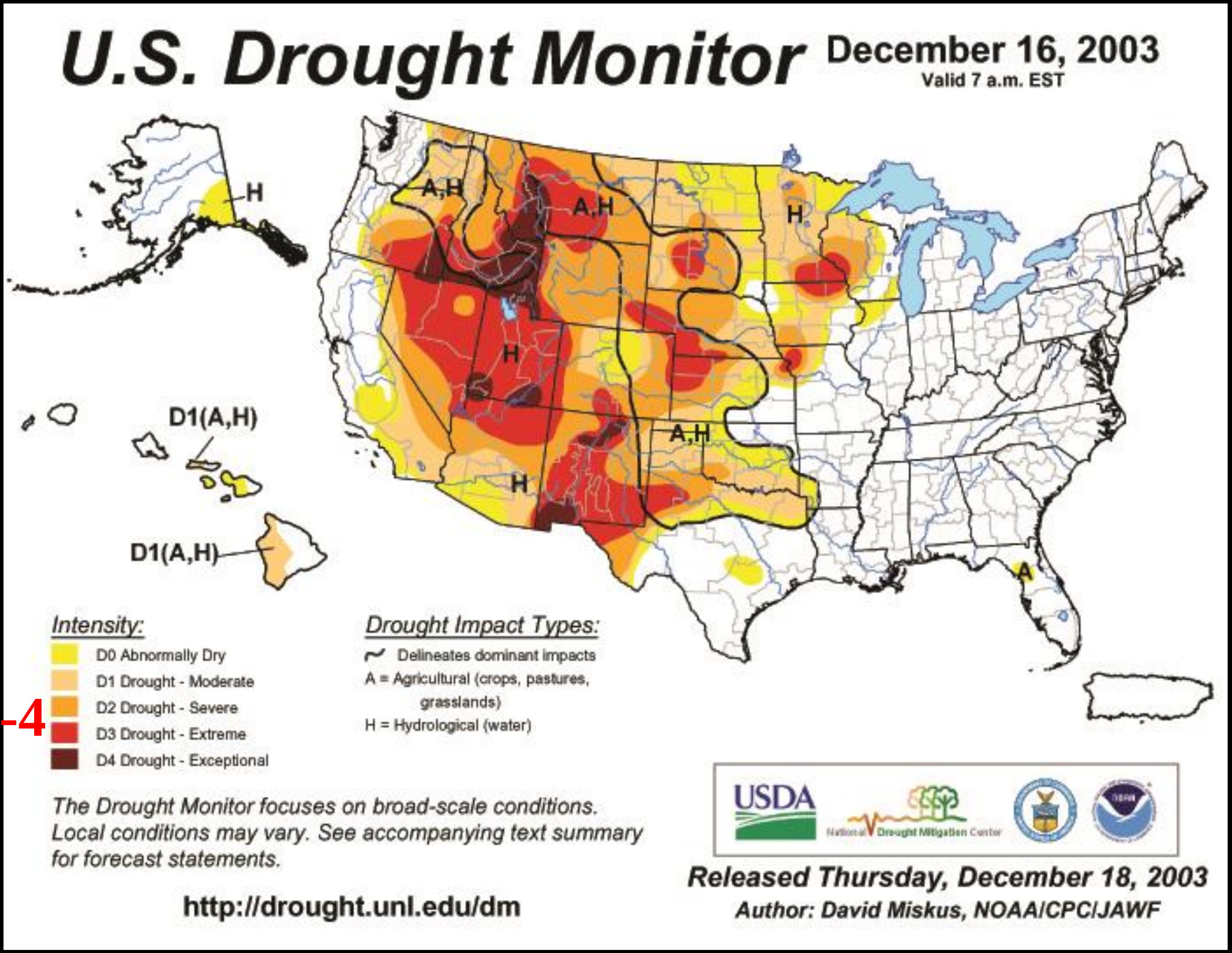



Palmer Drought INDEX : 1900 to 2007
California Division 7 (Mojave Desert/Southeast California)

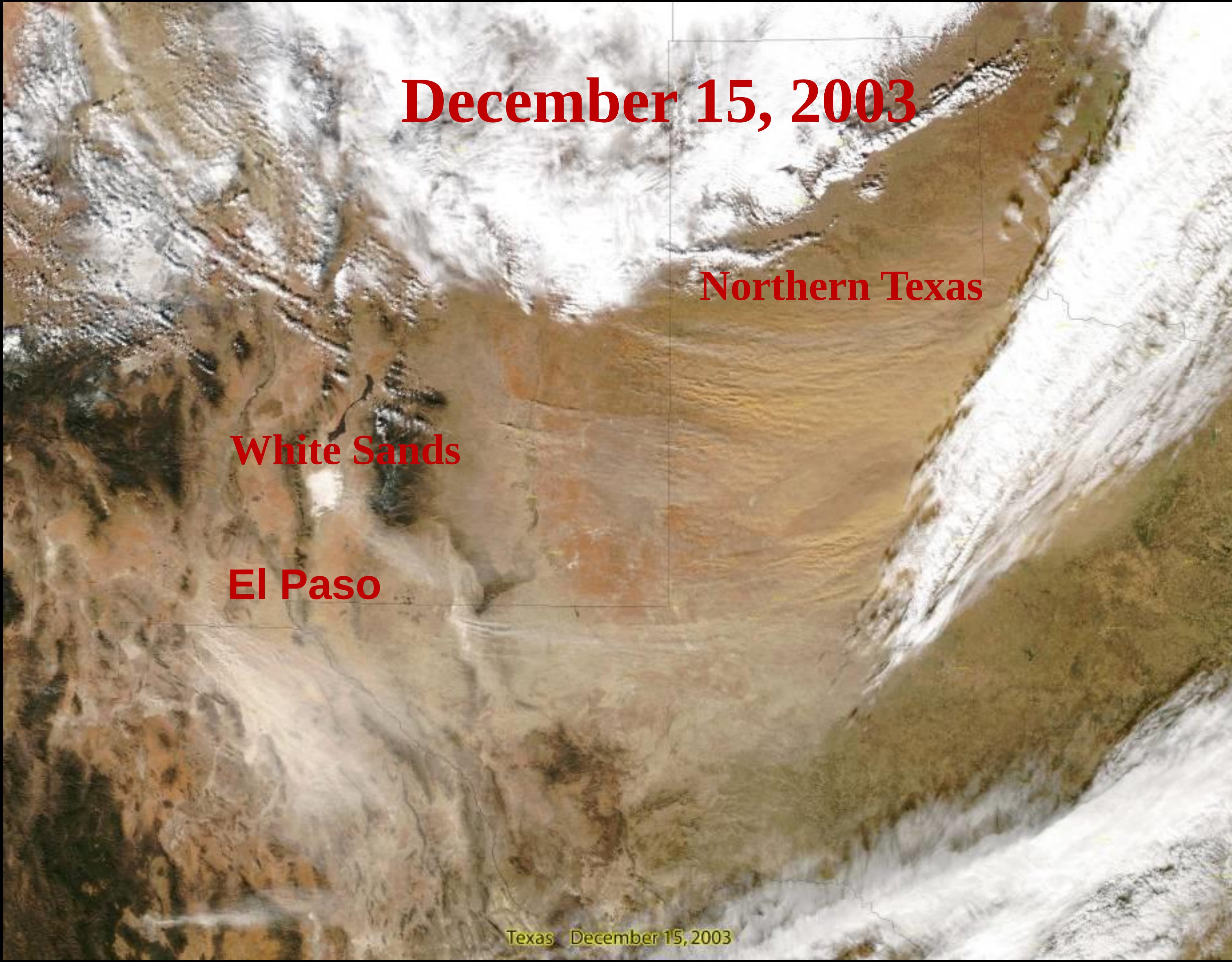

Earth System Research Laboratory
Physical Sciences Division
Kansas: Northwest Division Jan to Dec Palmer Drought Data (US Climate Division)
NW Kansas
Dust Bowl
Palmer Drought Data
6
4
2
0
-2
-4
-6
1900
1920
1940
1960
1980
2000
2020
Date
Palmer Drought INDEX : 1900 to 2007
Kansas Northwest

**PDSI = -4**

Severe -3.0 to -3.9 Extreme -4.0 to 4.9 Exceptional -5.0 to less




PDSI = -4


December 15, 2003
Northern Texas
White Sands
El Paso
Texas December 15, 2003

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

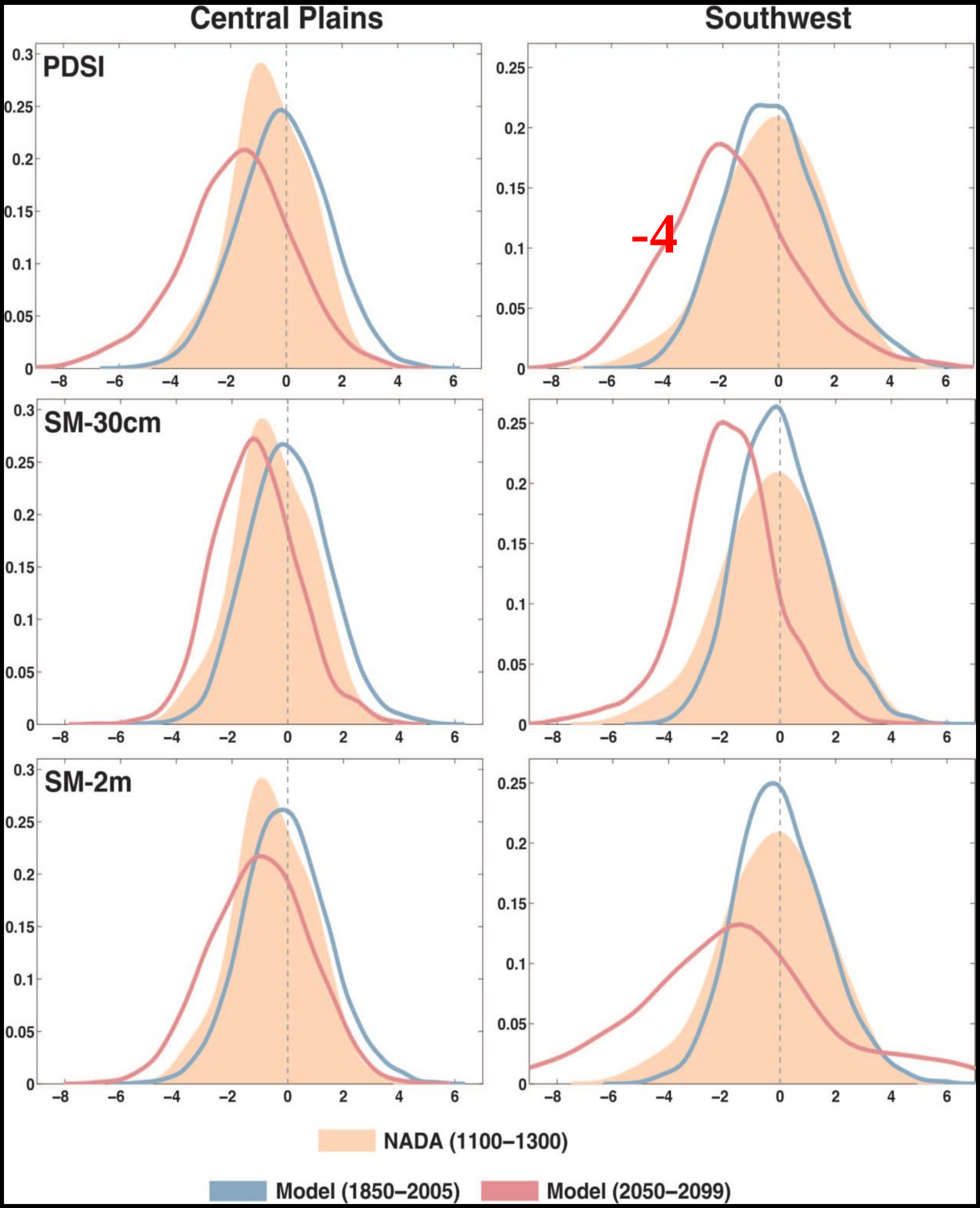
FIG 4

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

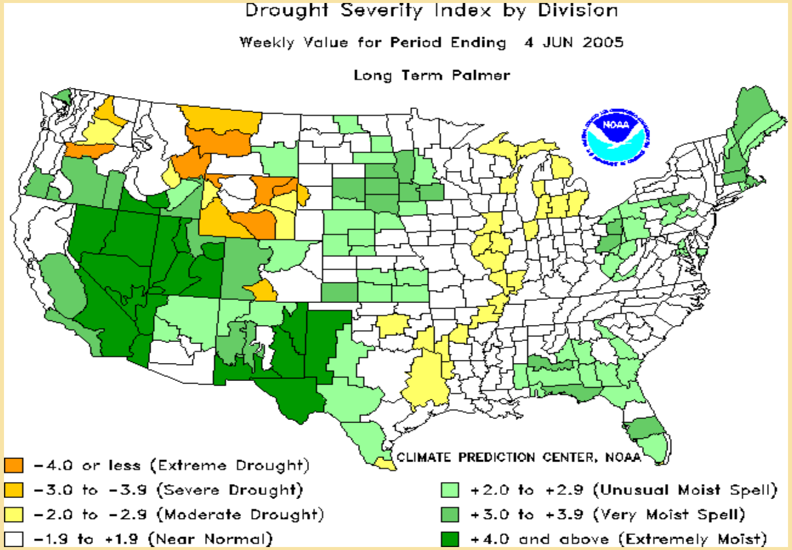
# Phoenix, Arizona

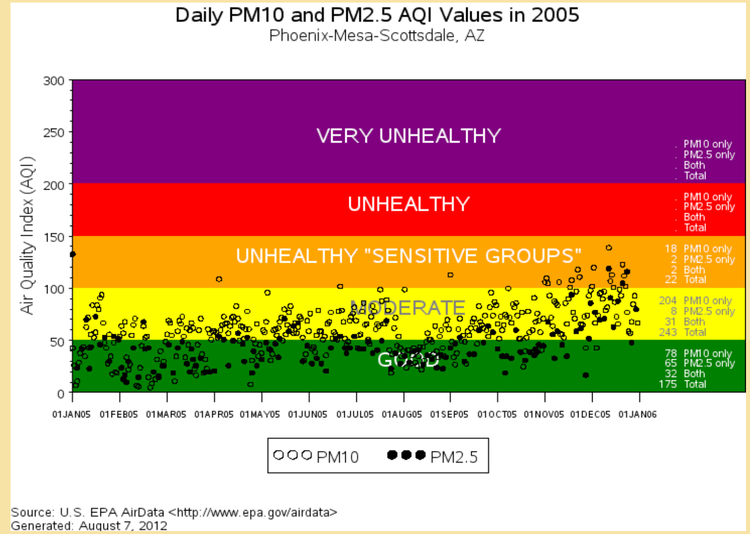
An important parameter in arid landscapes that is ***affected by climate conditions*** is the ***amount of vegetation cover***. As mentioned earlier on a ***short-term basis (months to a few years)*** the amount of ***annuals and grasses (non-woody vegetation)*** is the most temporally dynamic. Change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

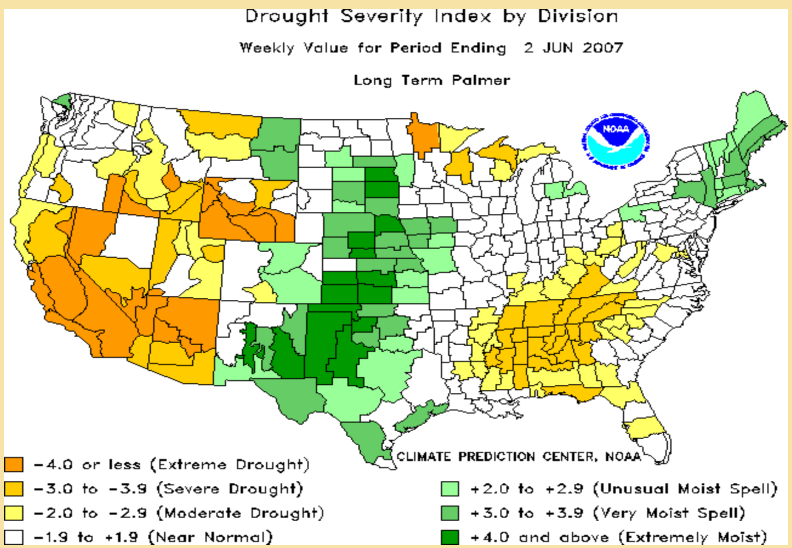
**(Notice air quality conditions when PDSI is -4 or less)**

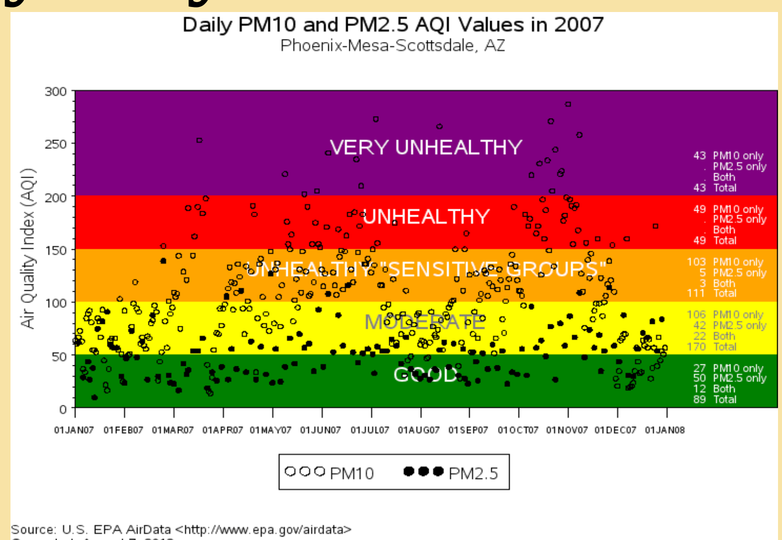
# 2005 --- Very Wet Year



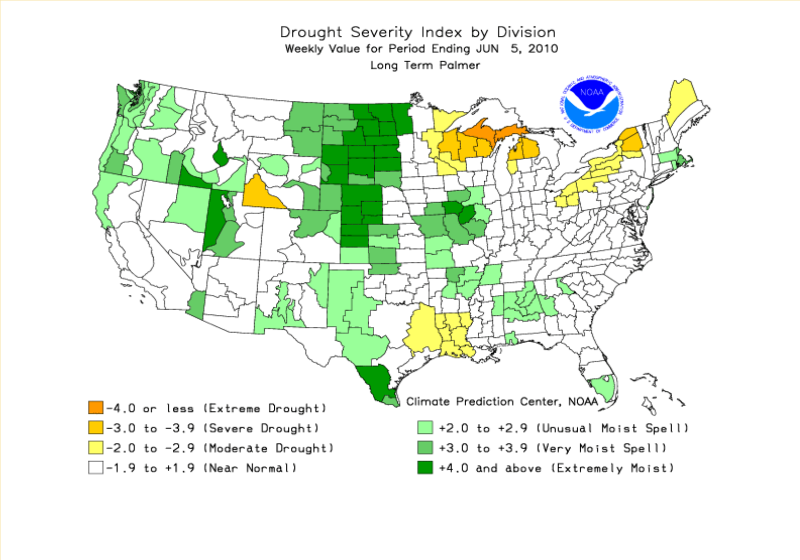



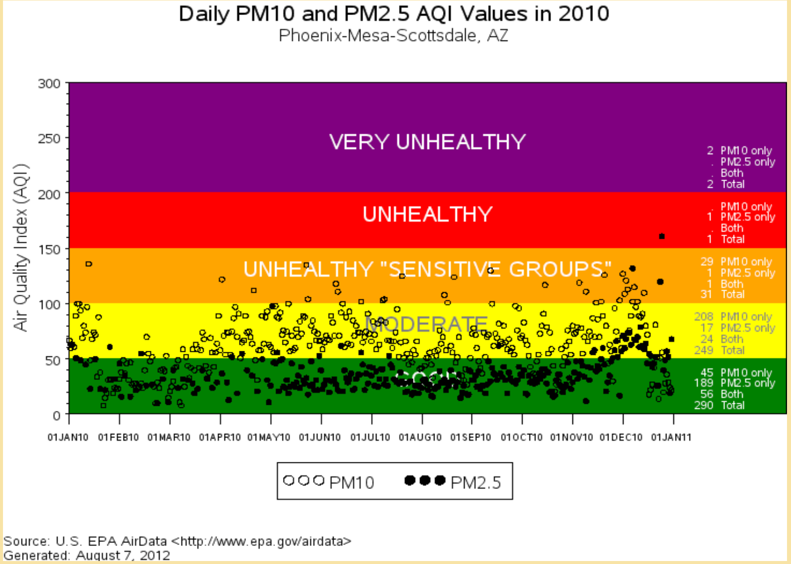

# 2007 --- Very Dry Year



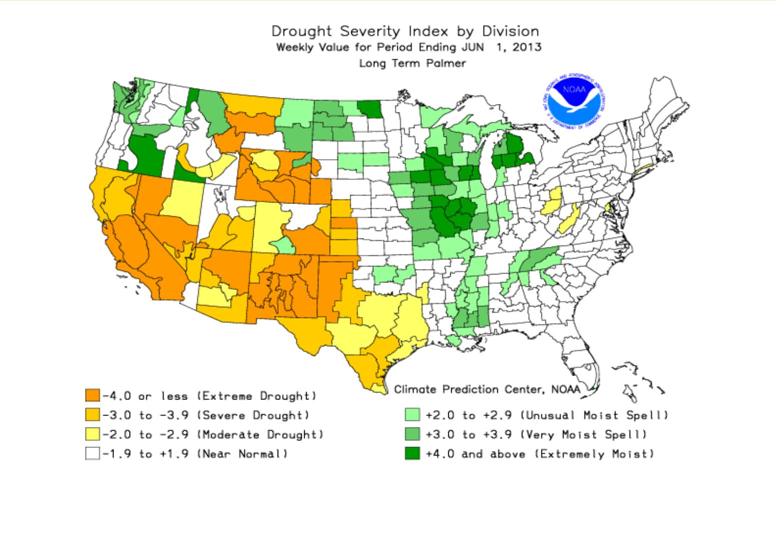



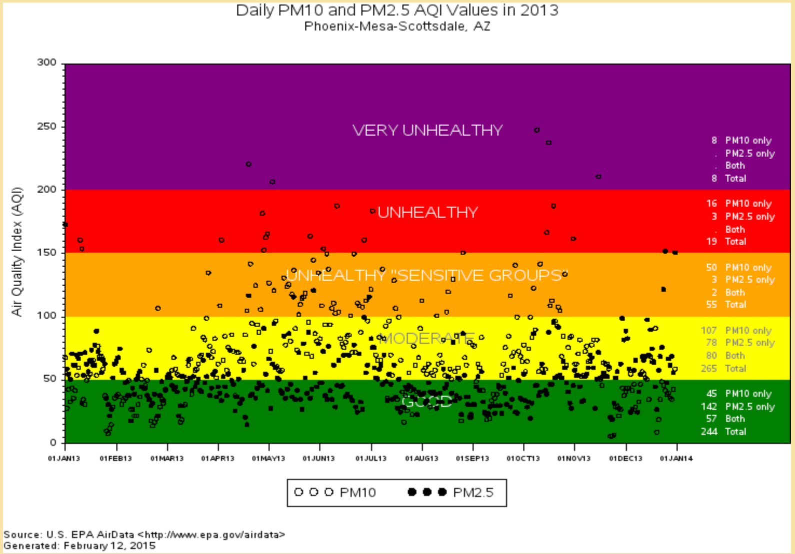
# 2010 --- Normal to Wet Year




# 2013 --- Very Dry Year



# Potential Applications
# Along I-10 and Southern Arizona

## 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.

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

Query: 11/14/11

Data Sources: SDM

| | 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* |
| *Total* | *421,186* | *100,464* | *71,553* | *21,223* | *4,325* | *618,751* |

| | 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.

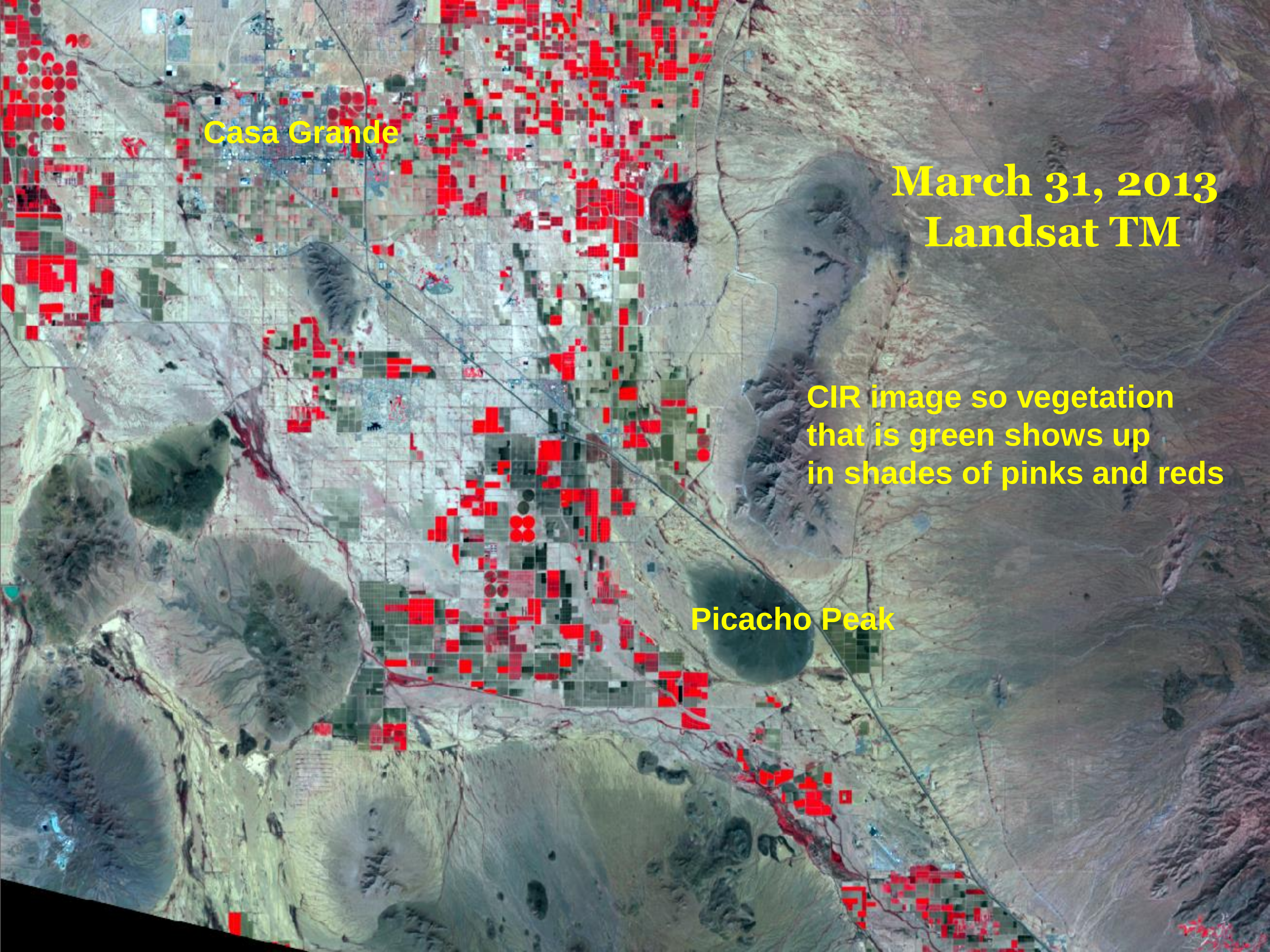
| | **Fatal** | **Total** | **Percent Fatal** | **Ratio With Dusty** |
|---|---|---|---|---|
| ***Clear*** | 3459 | 538,833 | 0.00642 | ***3.87*** |
| ***Snow*** | 20 | 4,261 | 0.00469 | ***5.30*** |
| ***Dusty*** | 16 | 644 | 0.02484 | ***1.00*** |

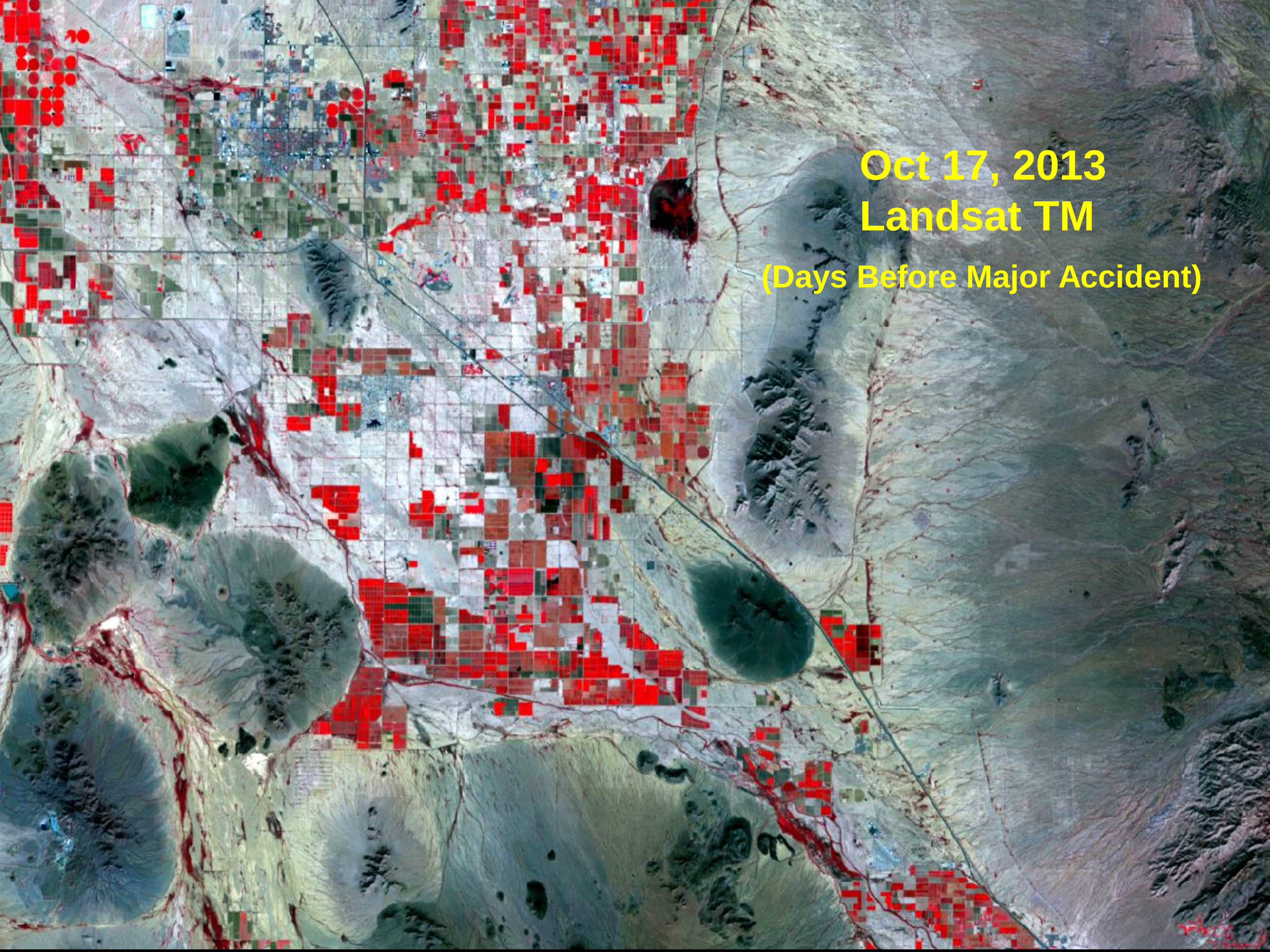
**** Fatal and Total stats from the SDM table***

# Safety Related

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

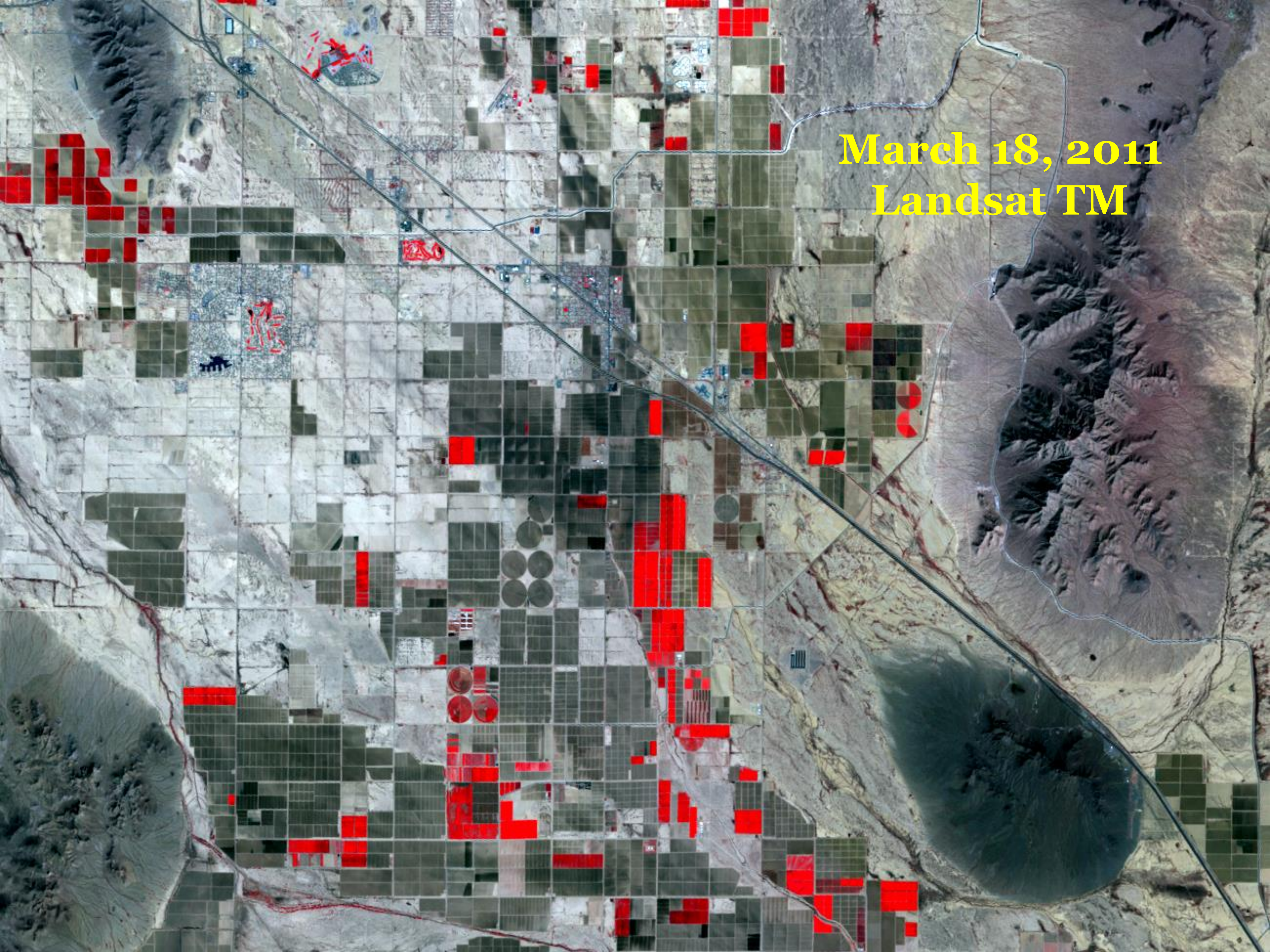
- Analyze and map ***vegetation cover characteristics, including percent vegetation cover, temporal dynamics of annuals and grasses, and temporal dynamics of agricultural fields*** in and around the region where dust storms are a major hazard along I-10 and other highways **---** ***perhaps focus on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

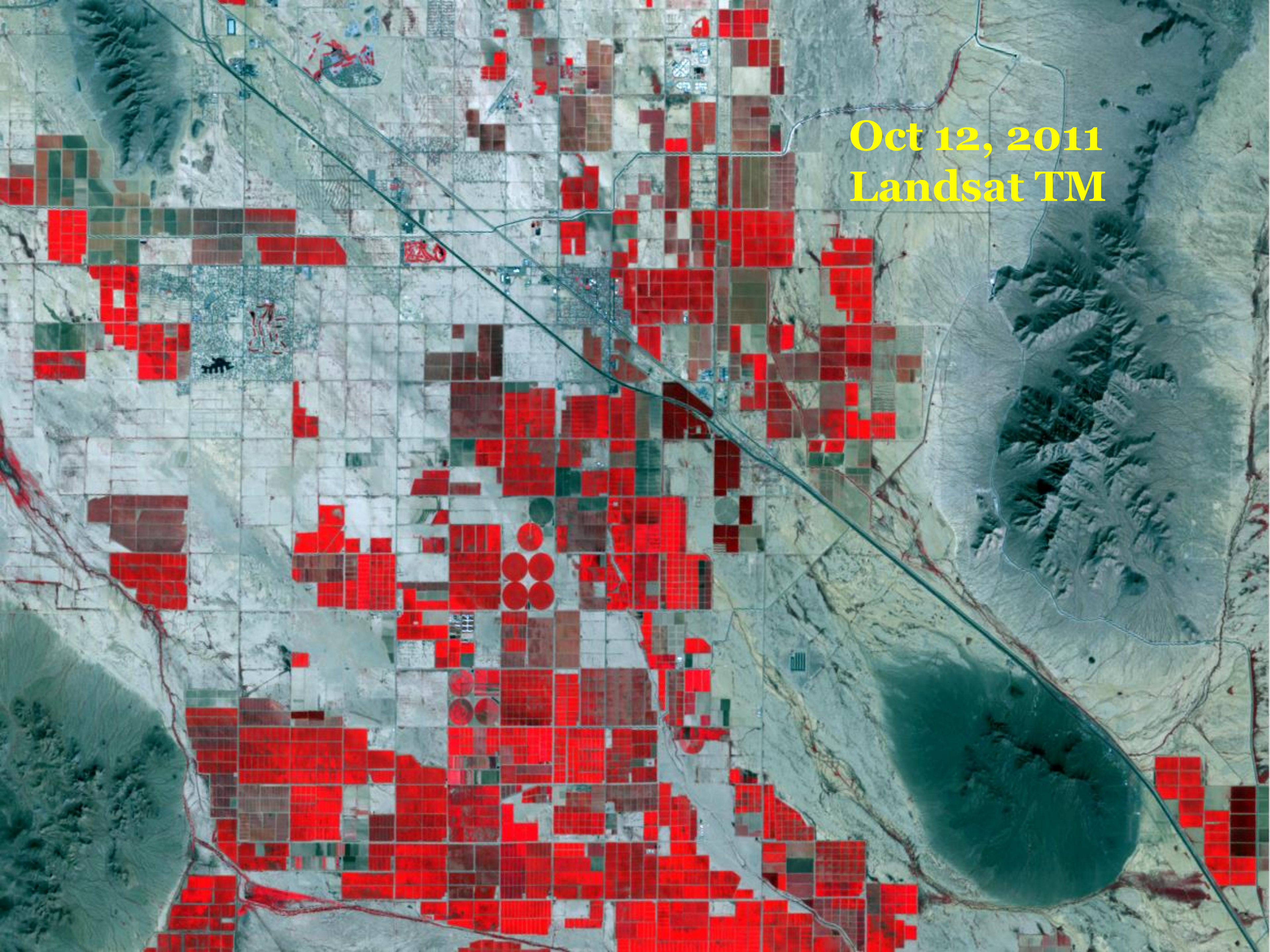

Casa Grande
March 31, 2013
Landsat TM
CIR image so vegetation
that is green shows up
in shades of pinks and reds
Picacho Peak


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

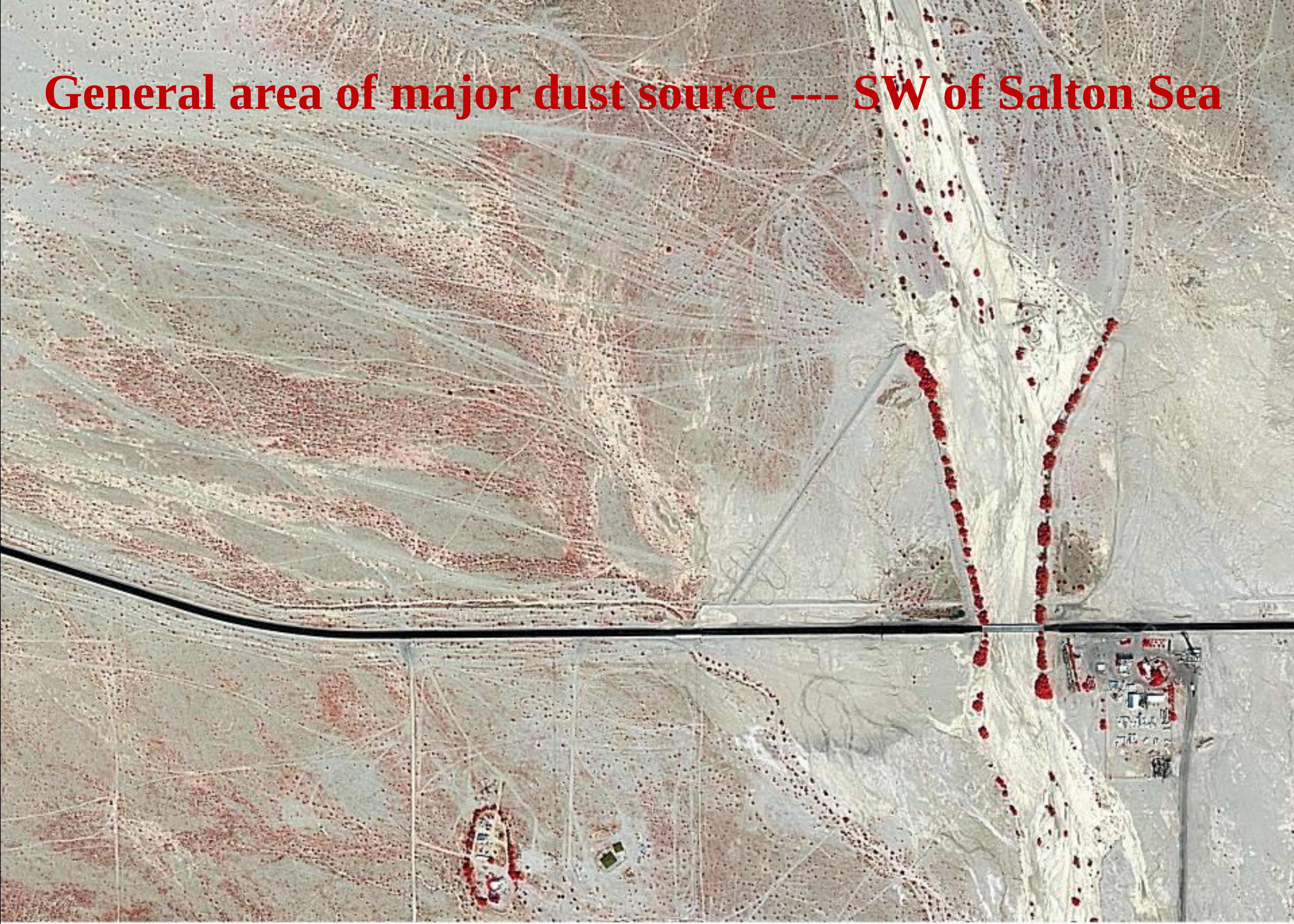

Oct 12, 2011
Landsat TM

# 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

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


12/2014
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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