Satellite Dust Detection and Forecasting

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HAQAST2020

WEBINAR SERIES

The "Dust Bowl"

- Dust Bowl: A period of severe dust storms during the 1930s;
- Causes: Extended droughts and poor land management;
- Impacts:

  ✓ Stripped 75% of top soils over thousands of farms;

  ✓ Destroyed agriculture and ecosystem (~1950s);

  ✓ > 500,000 lost homes and communities;

(Credit: NOAA George E. Marsh Album)

Another "Dust Bowl"?

Yes!

- Central U.S. plains saw severe droughts about once or twice a century over the past 400 years (Woodhouse & Overpeck, 1998).
- Global warming → Precipitation shift from subtropics, greater evaporation, less snow/ice, and earlier spring → amplify the effects of natural climatic variations → intensified droughts and "dust-bowlification" (Romm, 2011).

Probably Not?

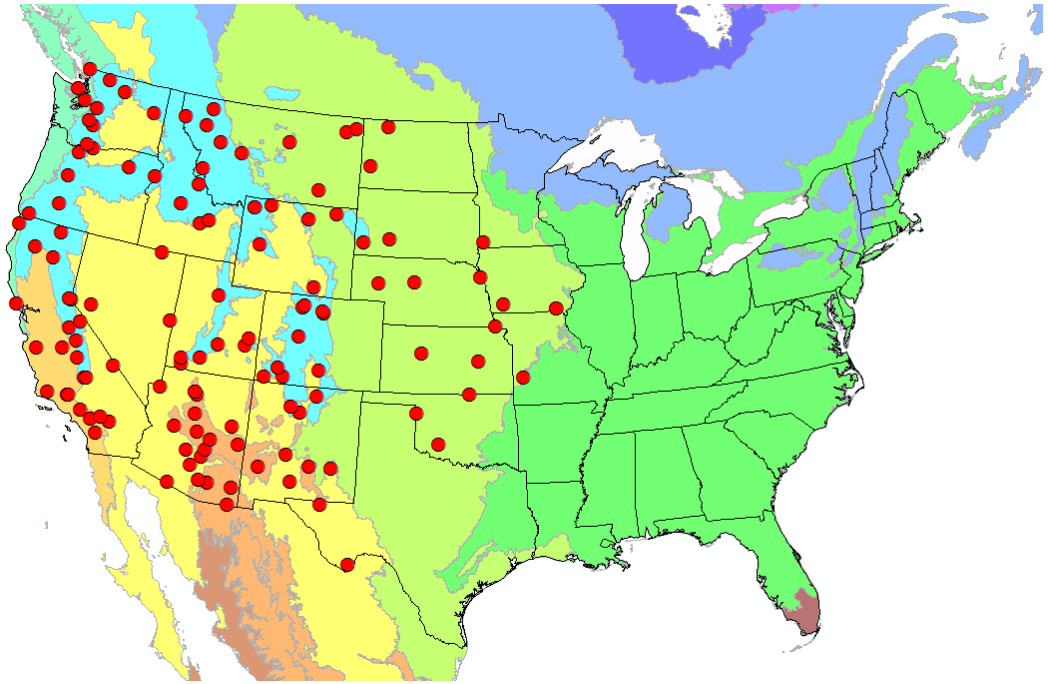
- Partially man-made → Lessons learned (Lee and Gill, 2015).
- Under economic stress in 1930s;
- Many soil conservation measures in places.

Problem: *No long-term dust observations*

Satellite-aided Dust Detection

Method 1: The IMPROVE Approach

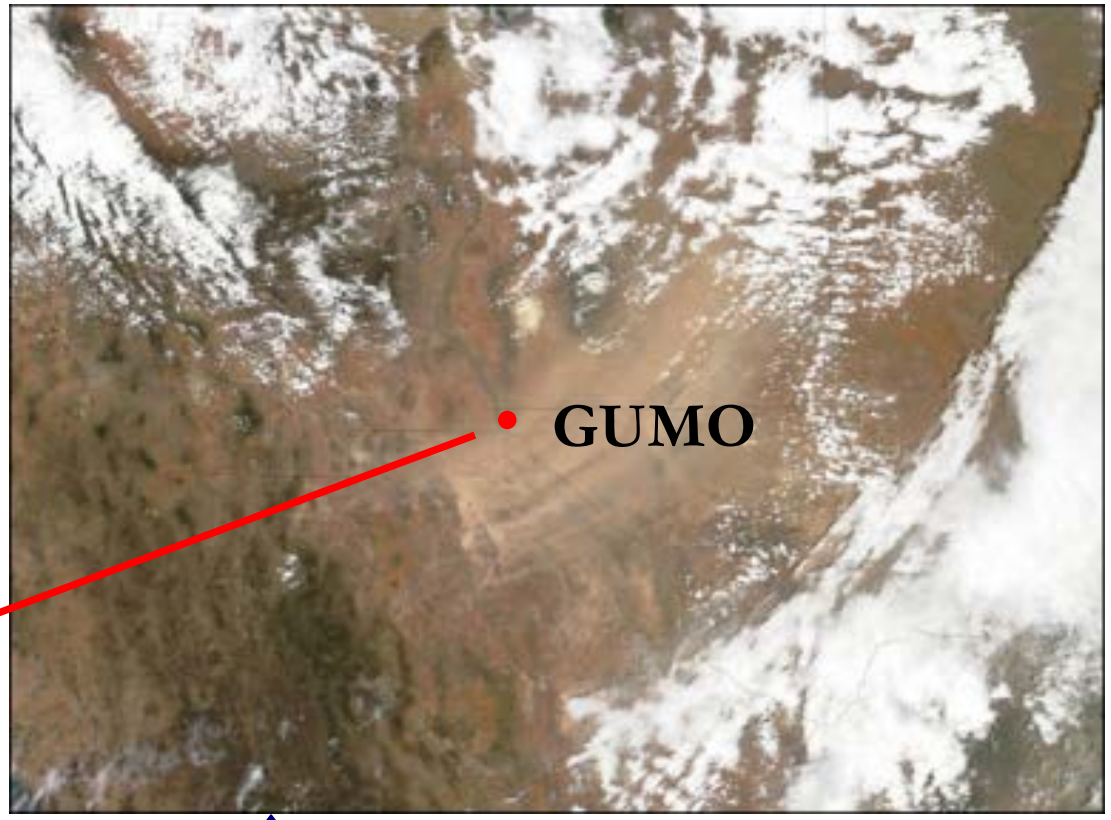
- Data records back to 1988;
- Many sites in close proximity to dust sources;
- Aerosol Chemical composition and size distribution;



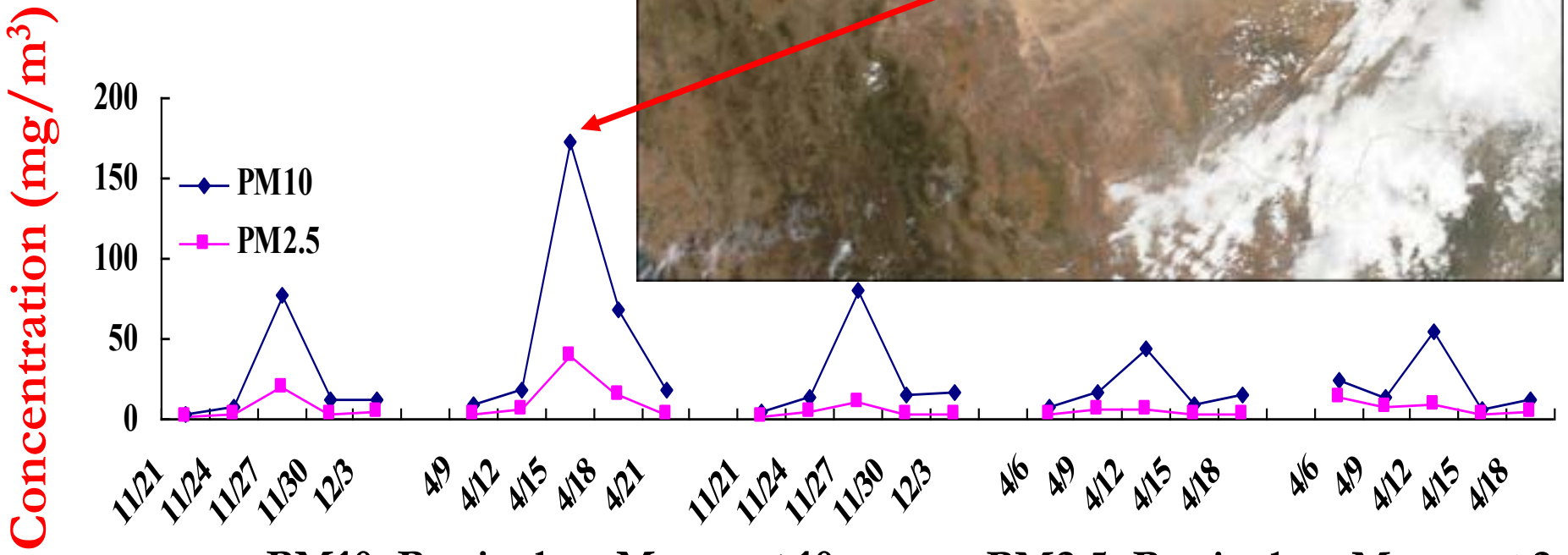
(IMPROVE: Interagency Monitoring of Protected Visual Environment)

Satellite-aided Algorithm Training

MODIS TrueColor, Apr. 15, 2003



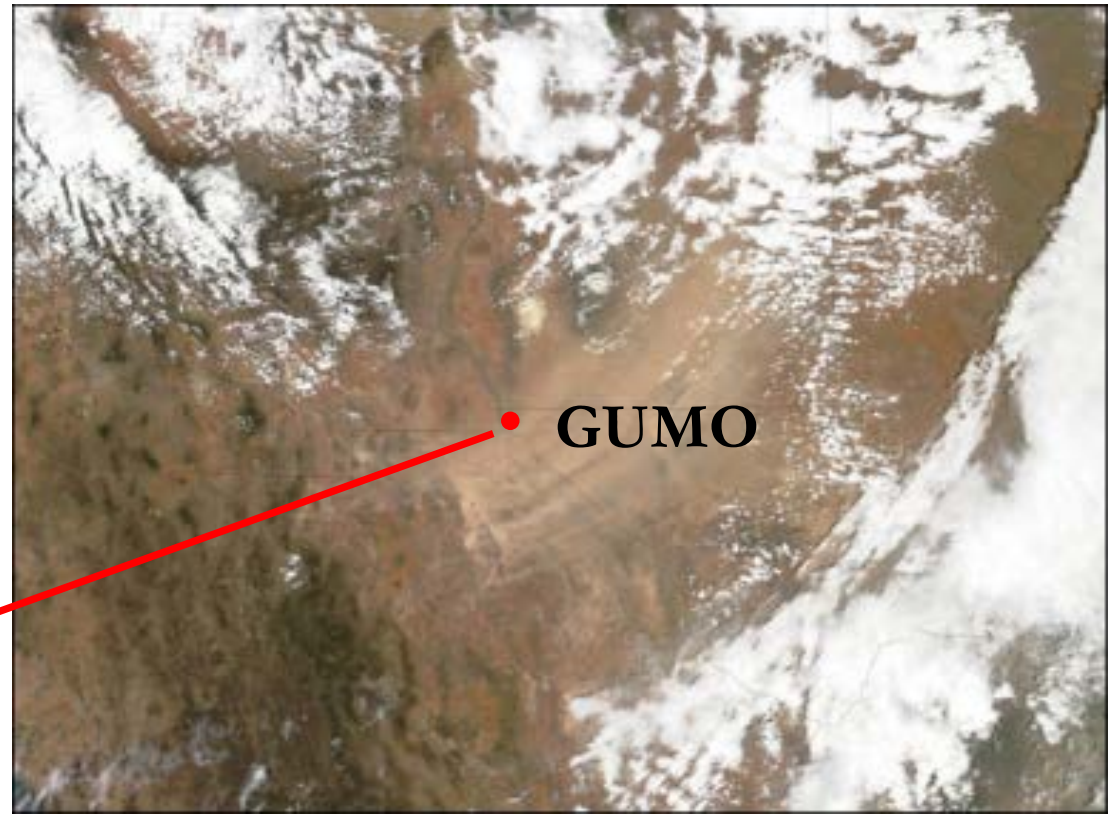
(Source: NASA Earth Observatory)

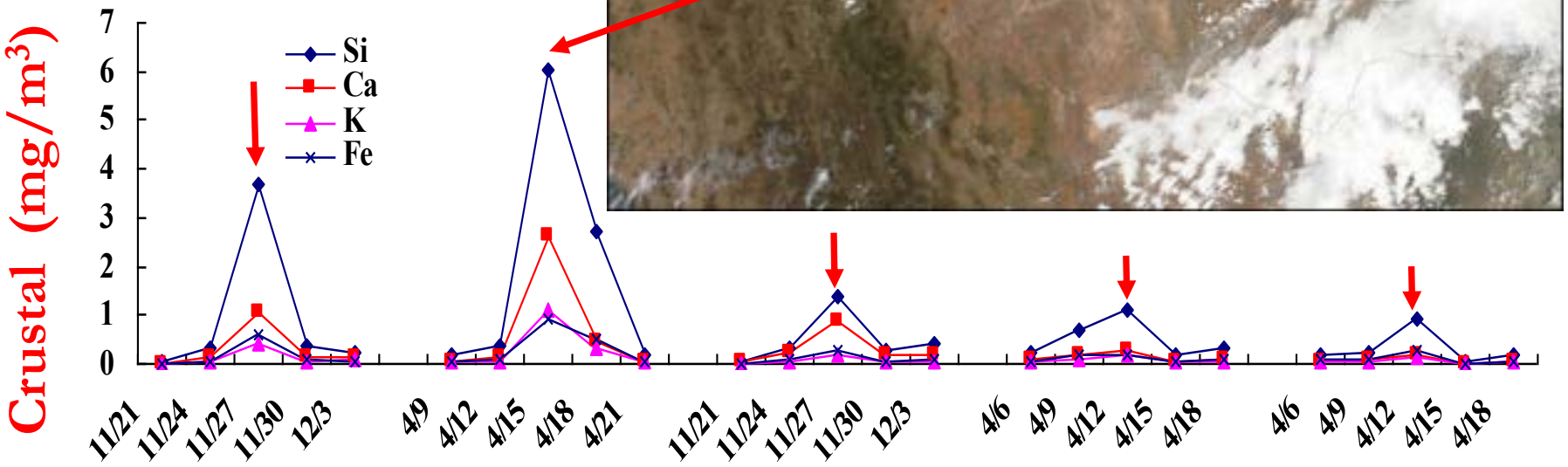


PM10: Particulate Matter < 10 mm **PM2.5: Particulate Matter < 2.5 mm**

Satellite-aided Algorithm Training

MODIS TrueColor, Apr. 15, 2003

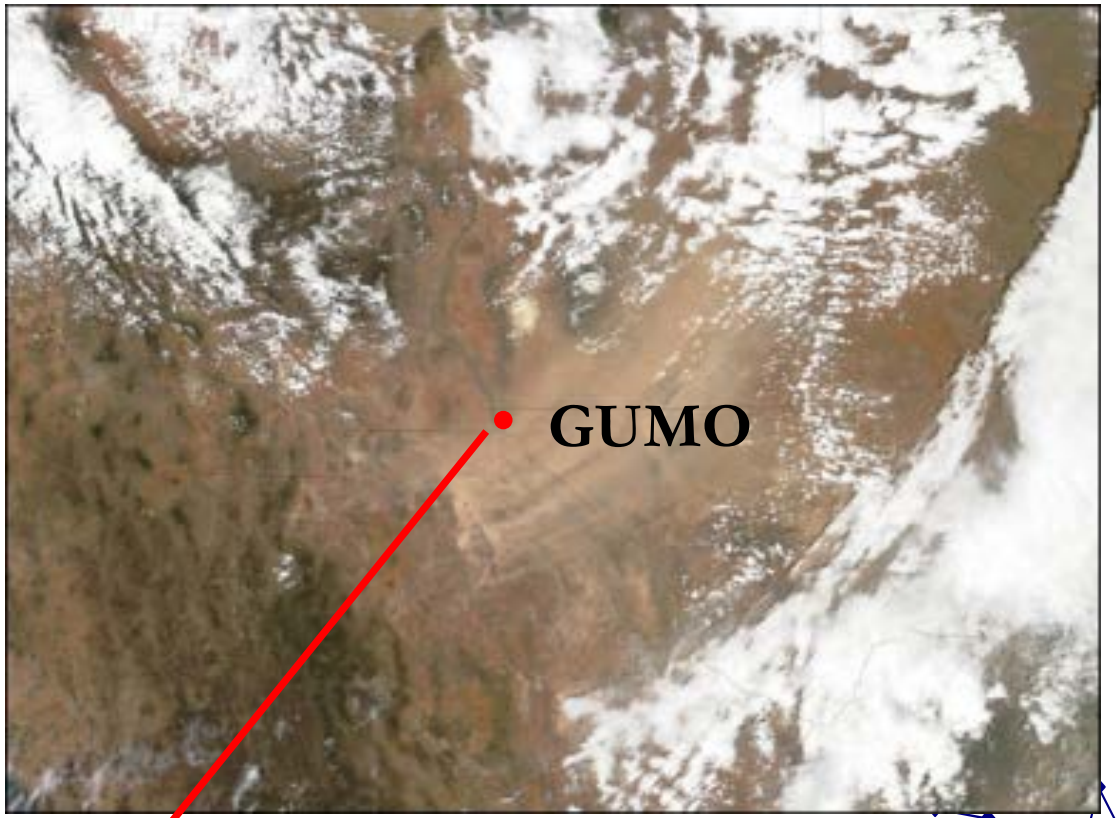


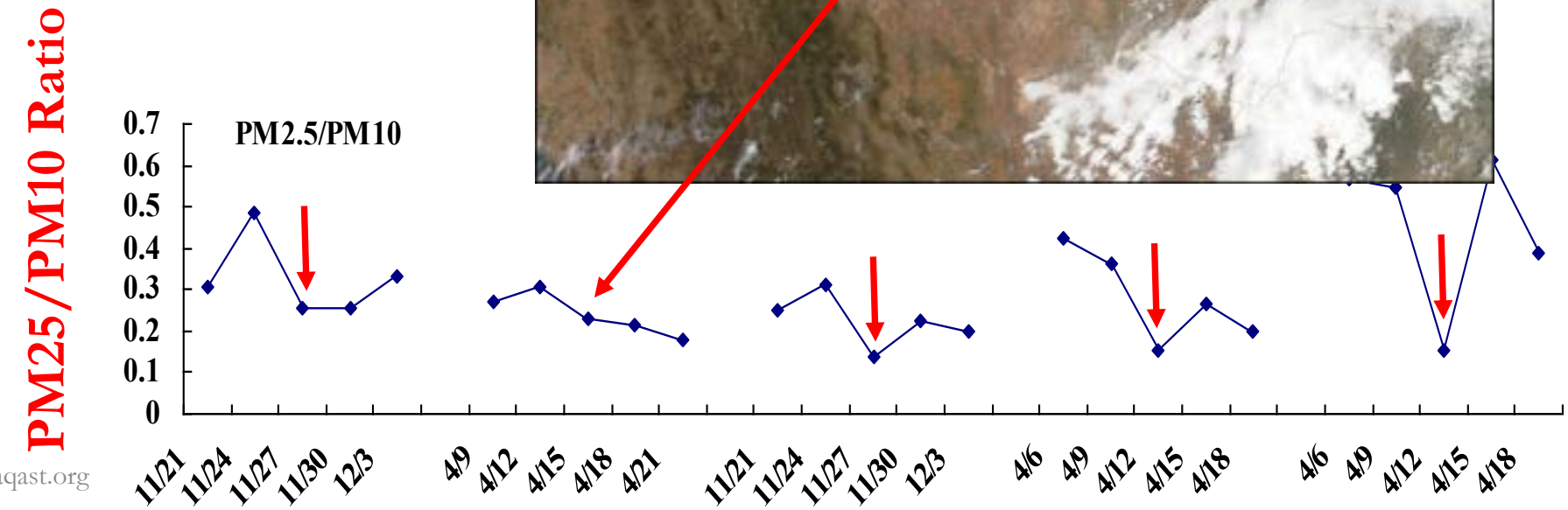


Si – Silicon; Ca – Calcium; K – Potassium; Fe – Iron

Satellite-aided Algorithm Training

MODIS TrueColor, Apr. 15, 2003



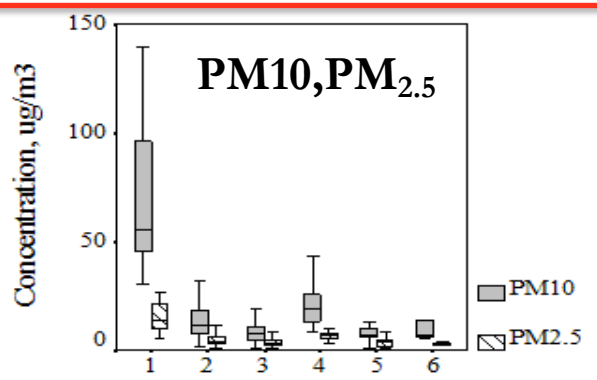


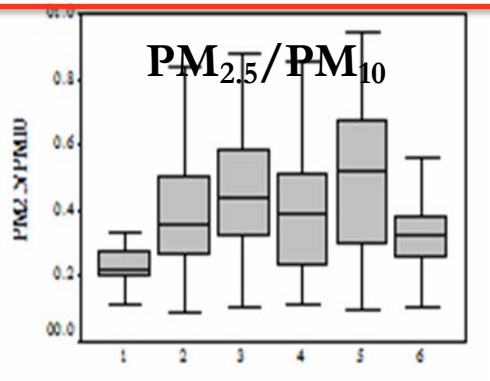
Dust Identification through Cluster Analysis (Contributed by Mo Dan)

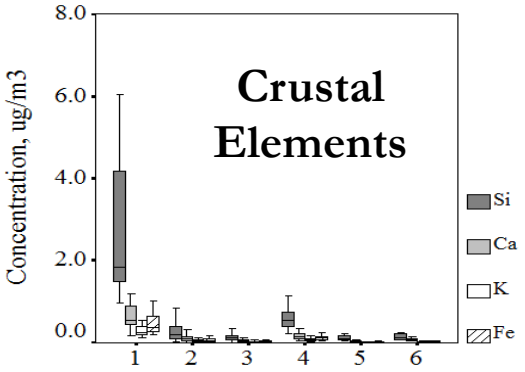
Five Dust Indicators:

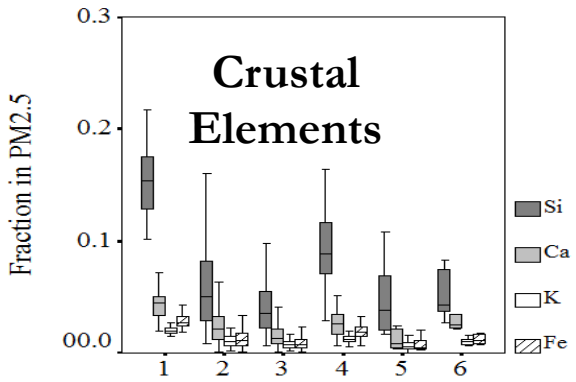
- High PM_{10}, $PM_{2.5}$;
- Low $PM_{2.5}/PM_{10}$ ratio
- High Crustal Fraction
- Low anthropogenic Fraction;
- Low Enrichment Factor;

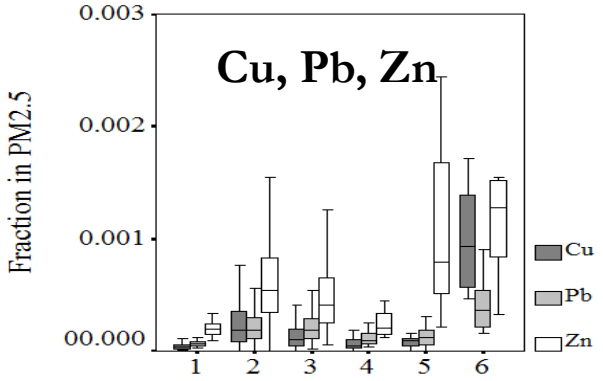
Cu– Copper
Pb – Lead
Zn – Zinc

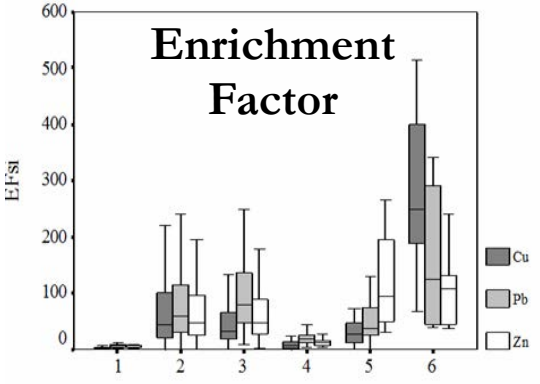












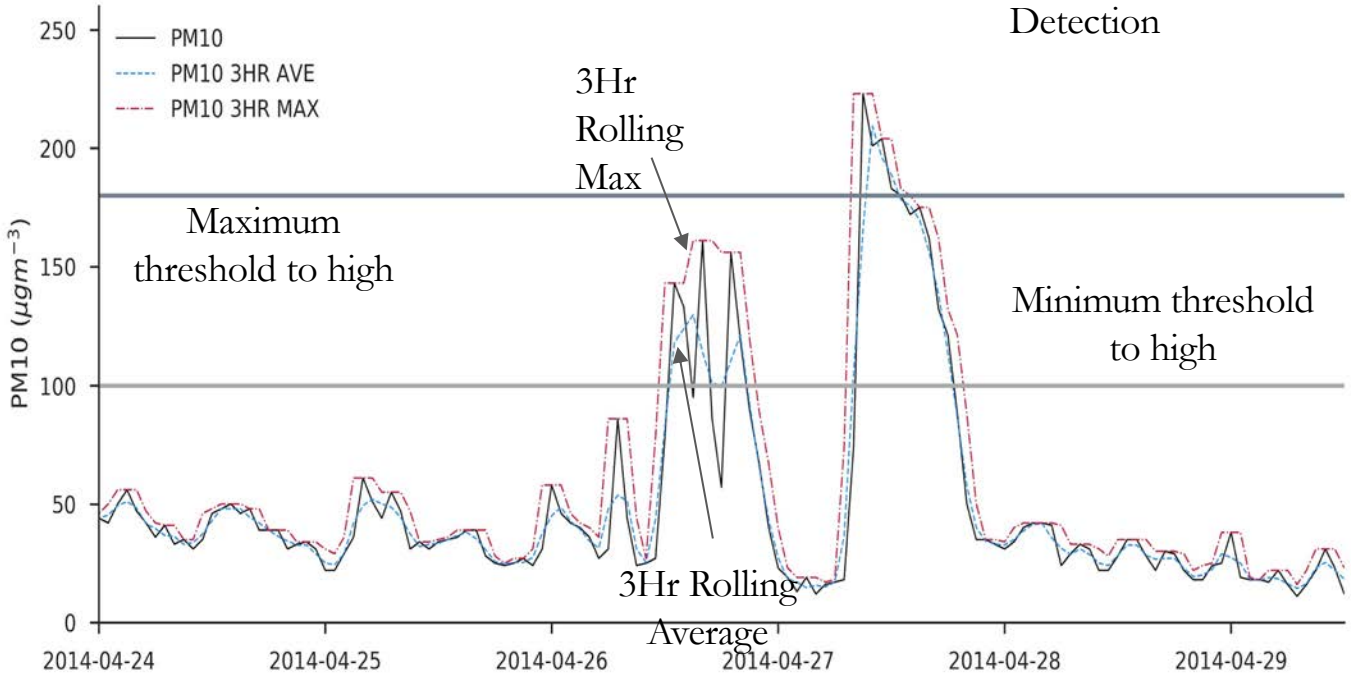
(Source: Tong et al. 2012)

Satellite-aided Dust Detection 2: AirNOW

(Contributed by Barry Baker)

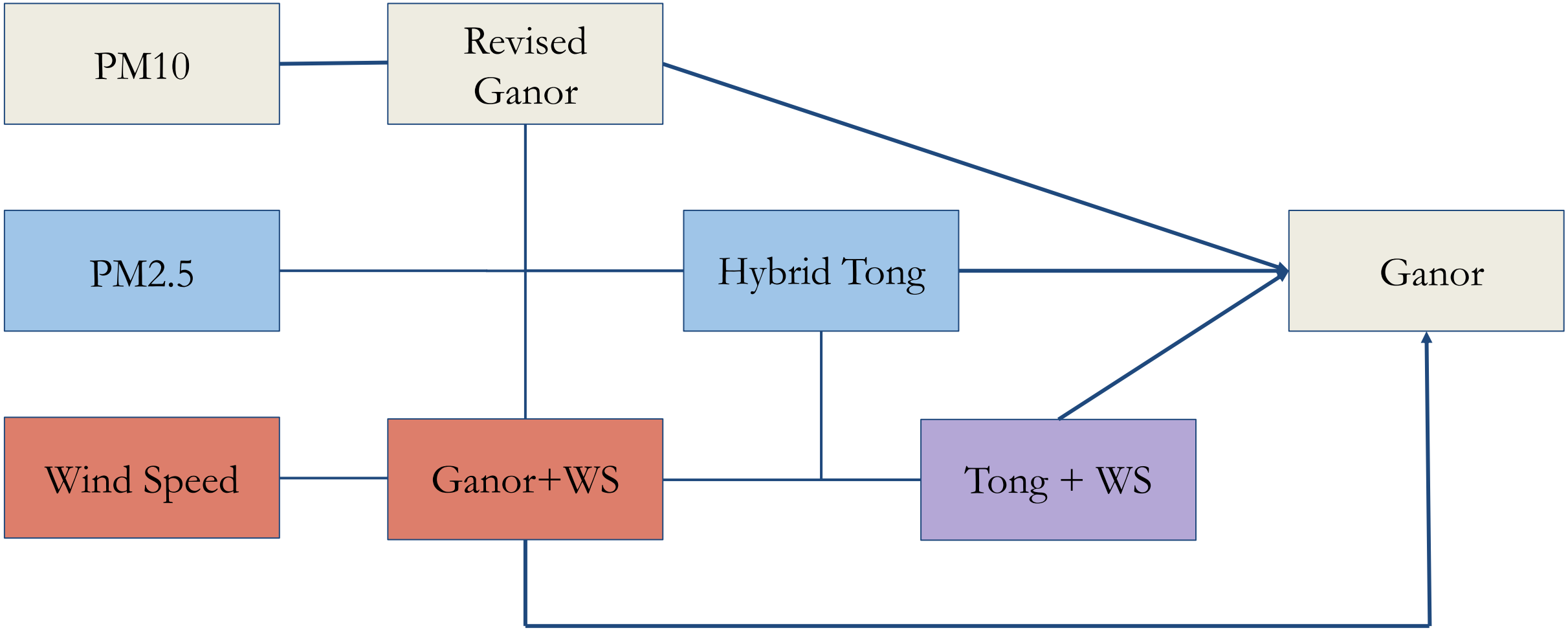
- The new method is based upon a modified Ganor et al. (2009) method
  - Uses hourly averages rather than half hourly data
  - Requires a 3 hour maximum of > 100 ugm-3
  - Requires a minimum 3 hr rolling average of 100 ugm-3 and maintained for 3 hours
- Uses EPA AQS or AirNOW data
  - Could use OpenAQ in the future for global
- Uses the most amount of information at each site
  - If $PM_{2.5}$ is available apply Tong 2012 method
  - If WS is available apply threshold

Ganor et al. Dust Detection



AirNOW Dust Approach

(Contributed by Barry Baker)

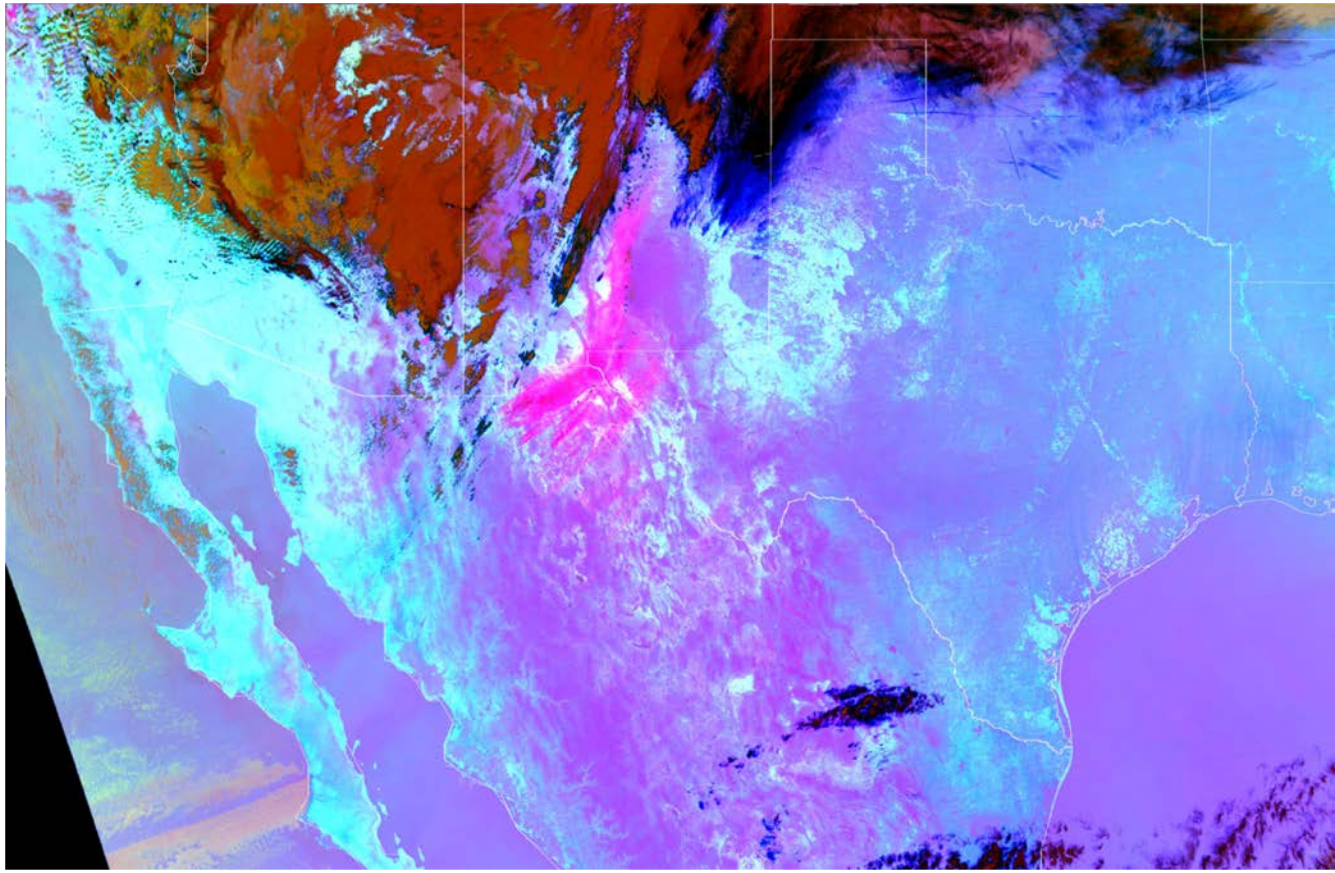


Example Dust Event Detection - March 31 2017

(Contributed by Barry Baker)

Dust Event occurred originating from northern Mexico. The dust plume passed over an AirNOW monitor just outside of El Paso Texas. The new algorithm detected the dust storm at the same time as a VIIRS overpass.

Suomi-VIIRS Dust Detection March 31 2017 19 UTC

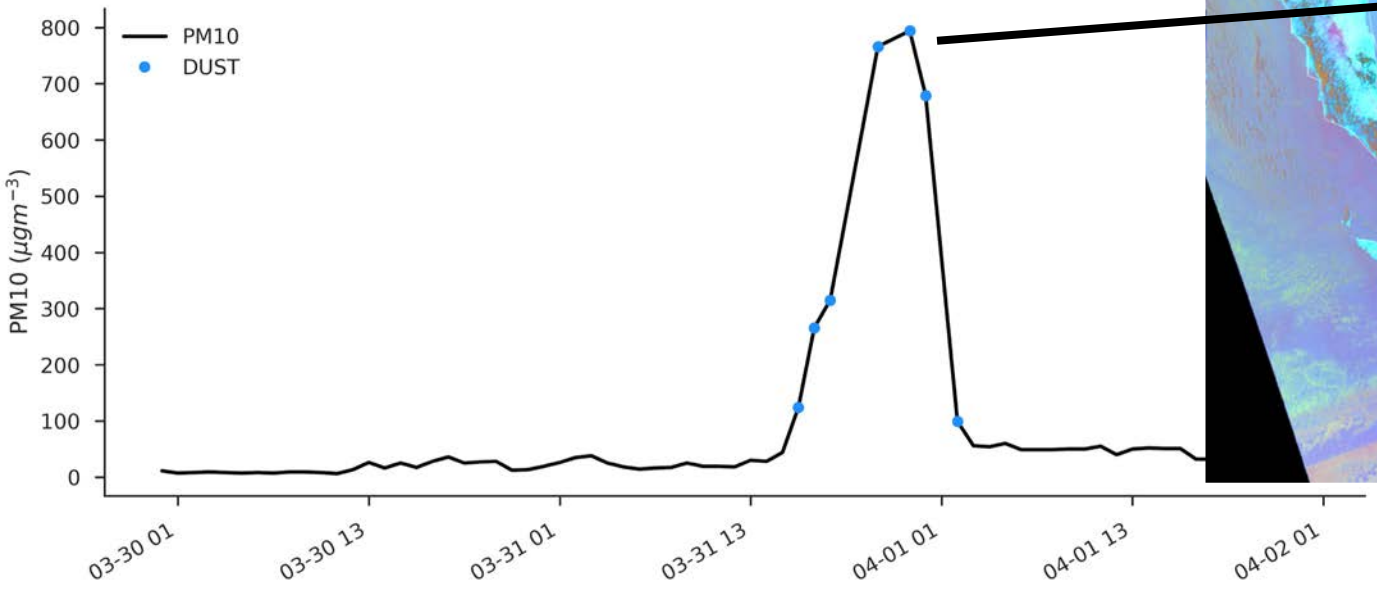


(Courtesy of Shobha Kondragunta)

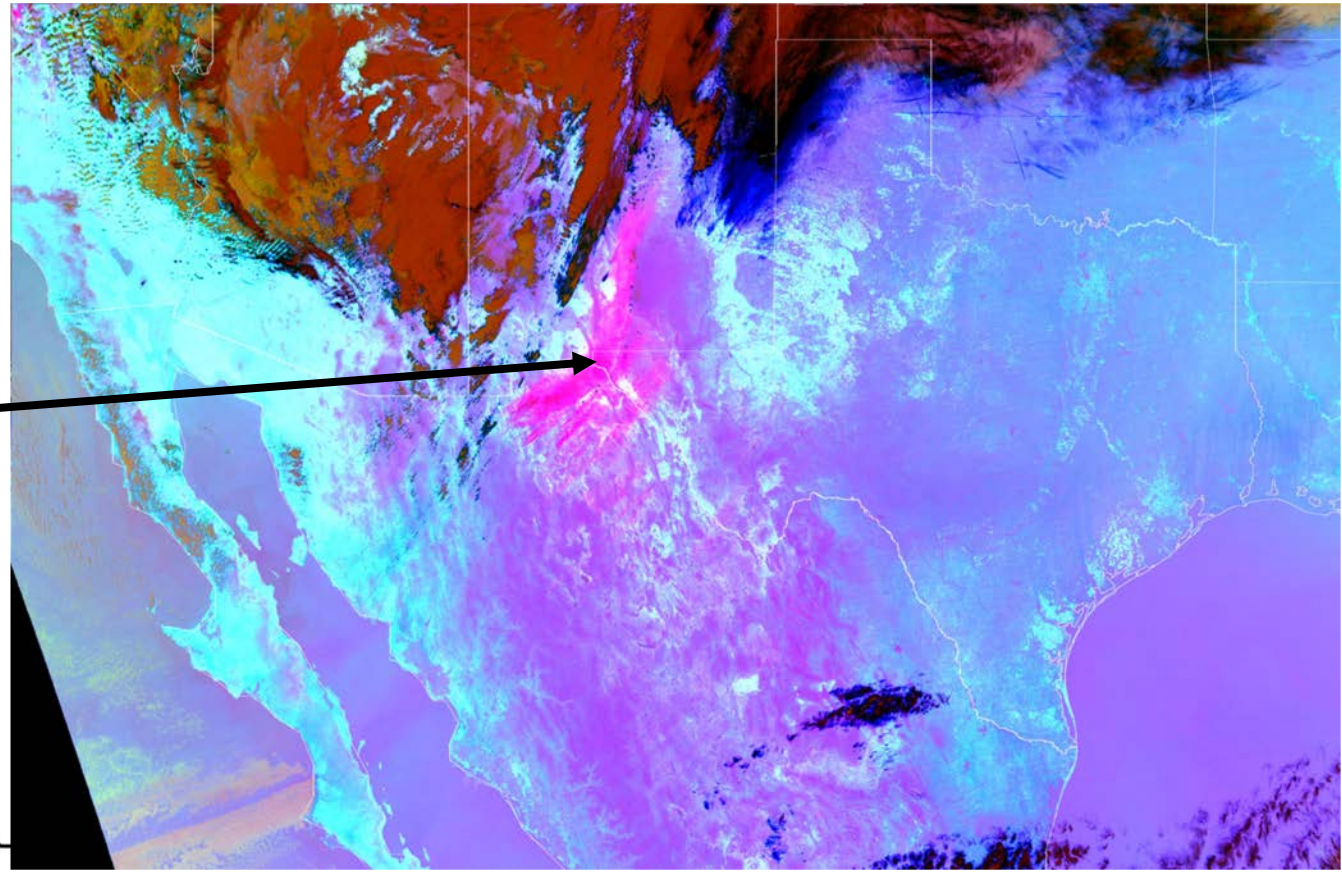
Comparison of VIIRS and Ground Dust Detection

(Contributed by Barry Baker)

AirNOW dust detection provides hourly dust surface concentration at near real time.

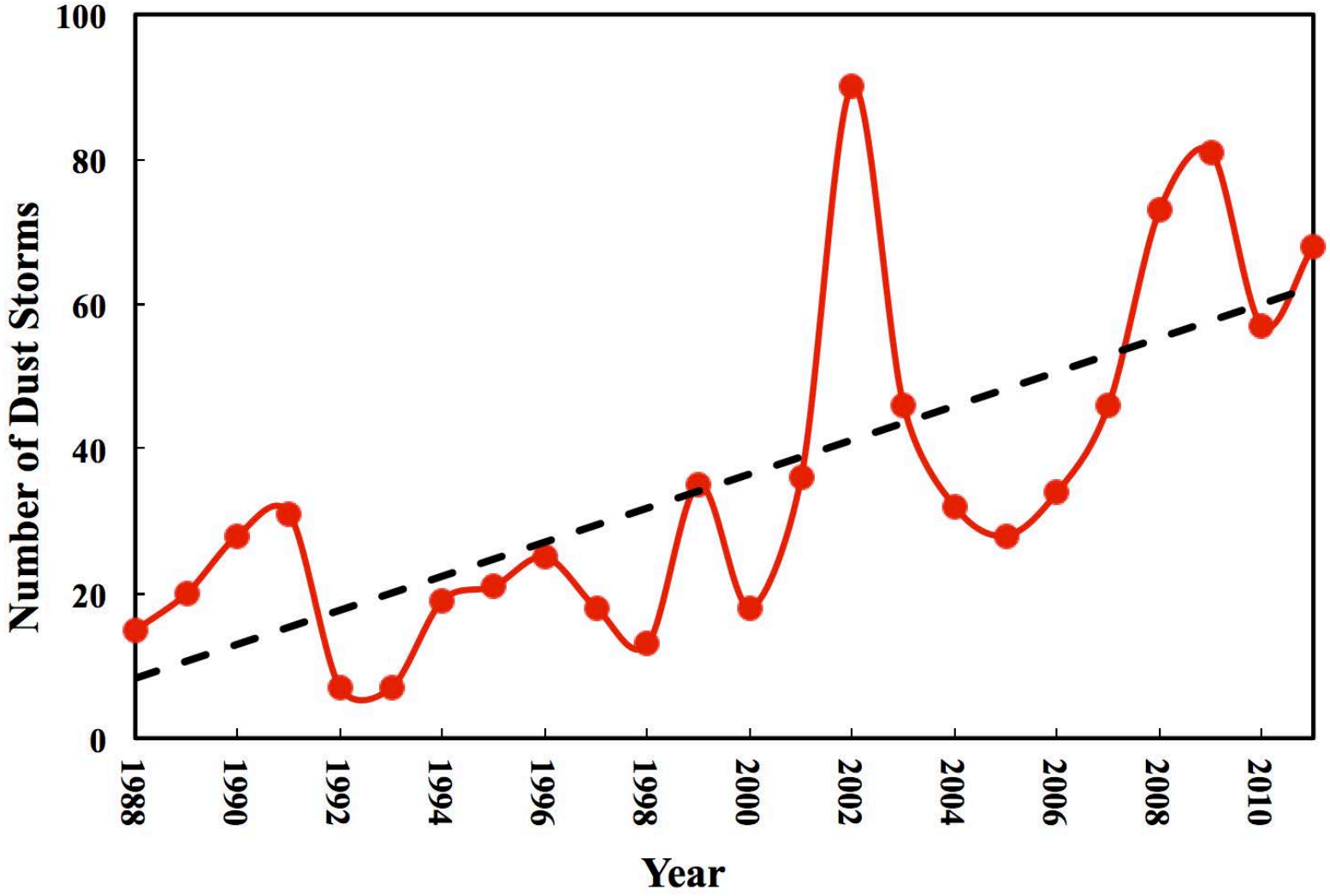


VIIRS Dust Detection March 31 2017 19 UTC



(Courtesy of Shobha Kondragunta)

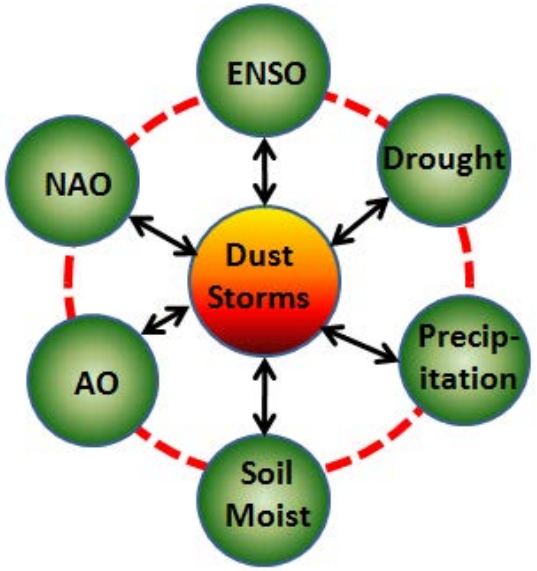
Long-term Dust Trend



(Source: Tong et al., 2017)

20 Giant Storms in 1990s → 48 Storms in 2000s;

What Drives the Dust Trend?



(Contributed by Hang Lei)

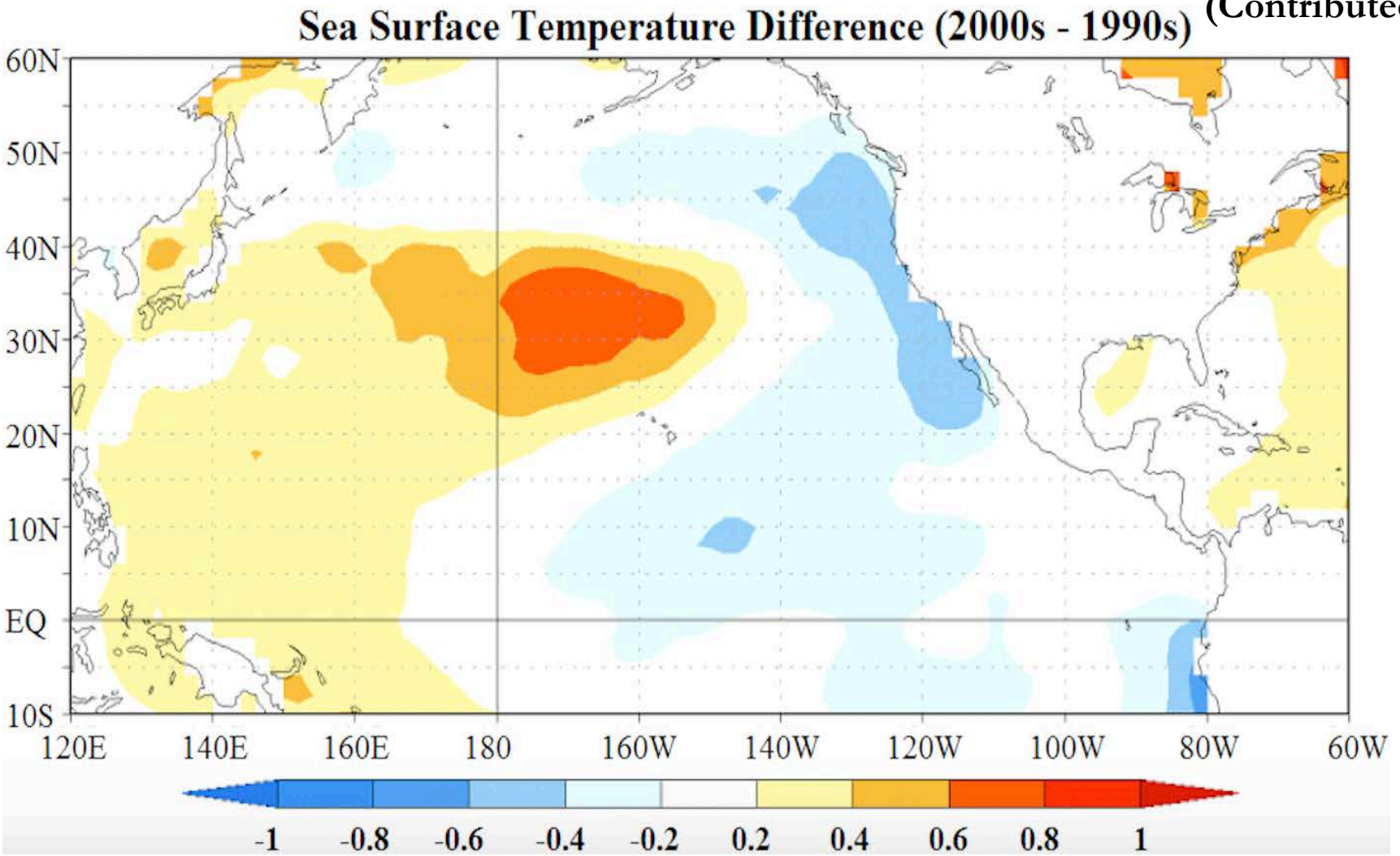
ENSO - El-Nino Southern Oscillation
PDO - Pacific Decadal Oscillation
NAO - North Atlantic Oscillation
PNA - Pacific/North American Oscillation
AO - Arctic Oscillation

	ENSO	PDO	NAO	PNA	AO
LL-dust	-0.44	-0.62	-0.41	-0.33	0.38
HL-dust	-0.32	-0.73	-0.40	-0.56	0.33

LL – Low Latitude North American deserts (Chihuahua, Mojave, and Sonoran);
HL – High Latitude Deserts (Great Basin and Colorado Plateau)

Changes in Sea Surface Temperature

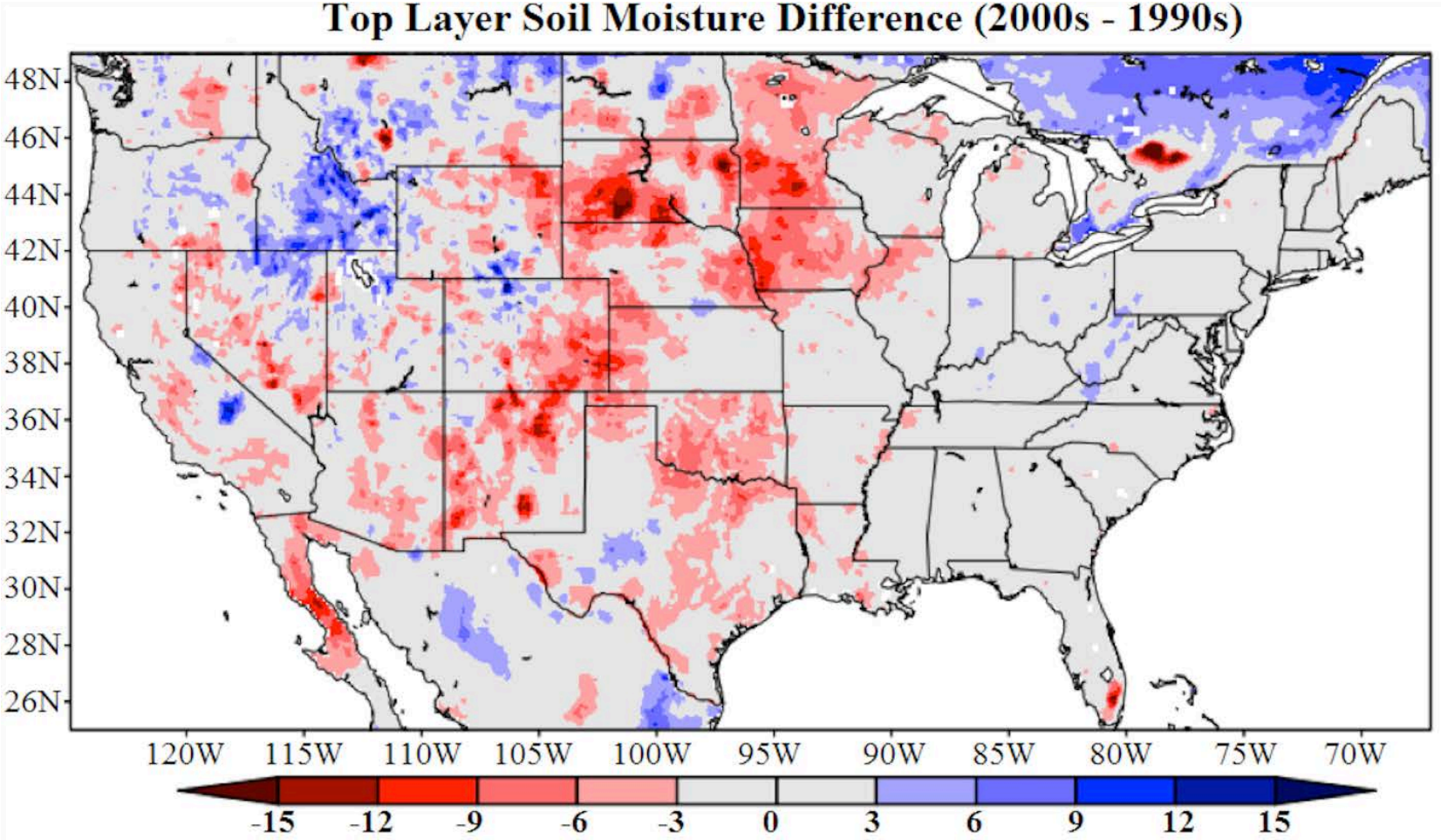
(Contributed by Julian Wang)



(Image created with NASA Giovanni)

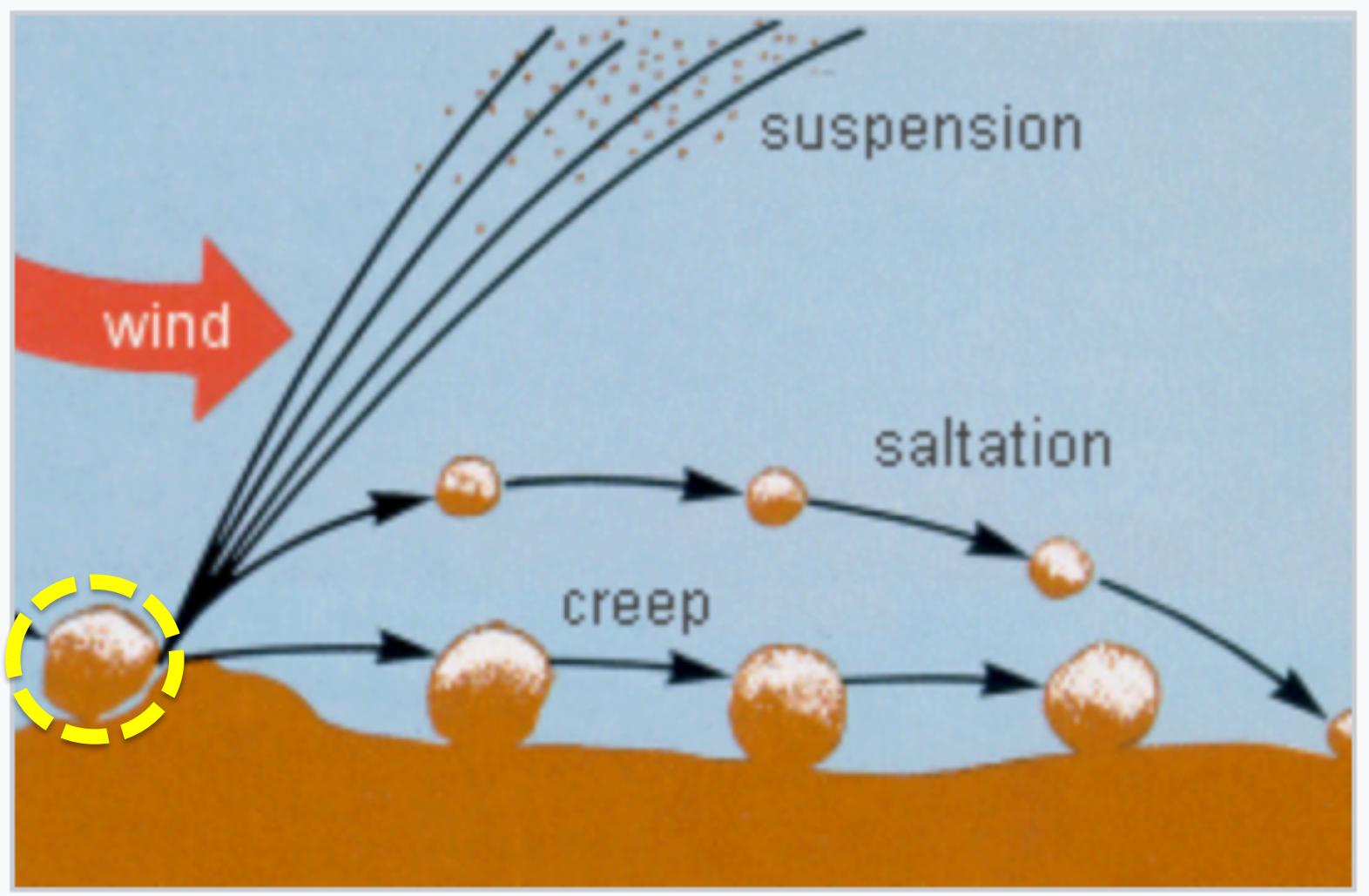
Changes in Soil Moisture

(Contributed by Julian Wang)



(Image created with NASA Giovanni)

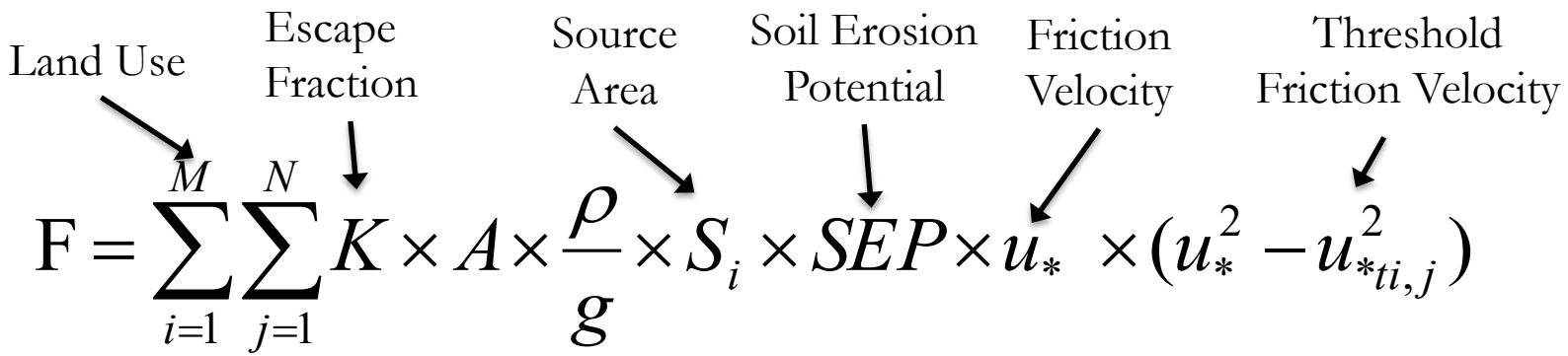
Physics of Dust Emission



https://en.wikipedia.org/wiki/Saltation_(geology)

Dust Emission Parameterization

FENGSHA dust emission scheme:



How does soil moisture affect dust emission?

Path 1: Vegetation cover partitions wind energy;

Path 2: Moist increases cohesive binding (Fecan et al., 1999);

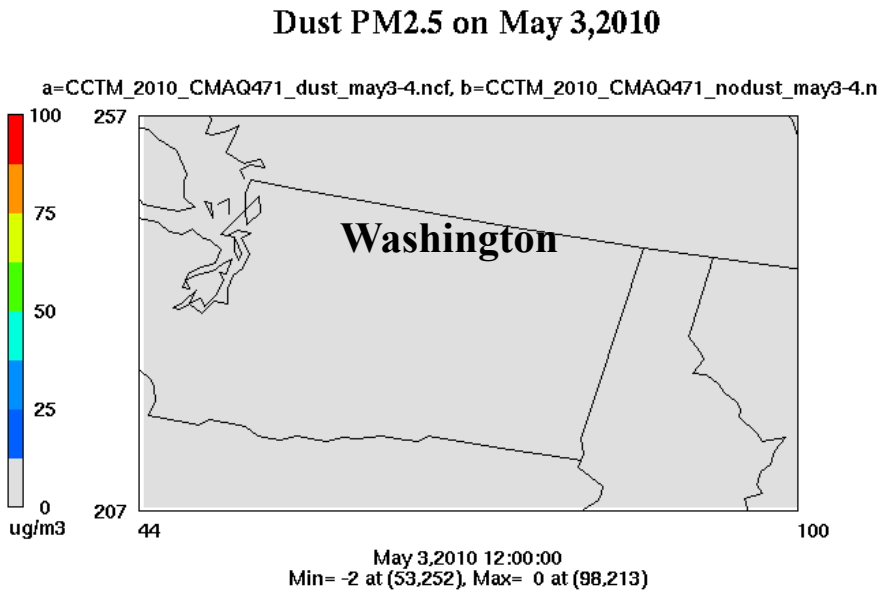
$$u_{*t} = u_{*t} \varkappa f_m$$

$$f_m = (1.0 + 1.21 * (s_m - w')^{0.68})^{0.5}$$

Soil Moisture

Saturation point

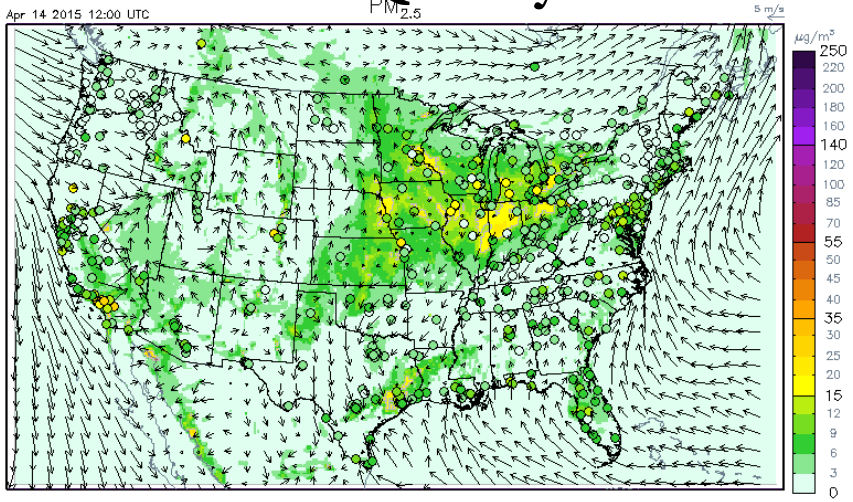
Improving Dust Predictability: FENGSHA



12:30 p.m, May 3,2010

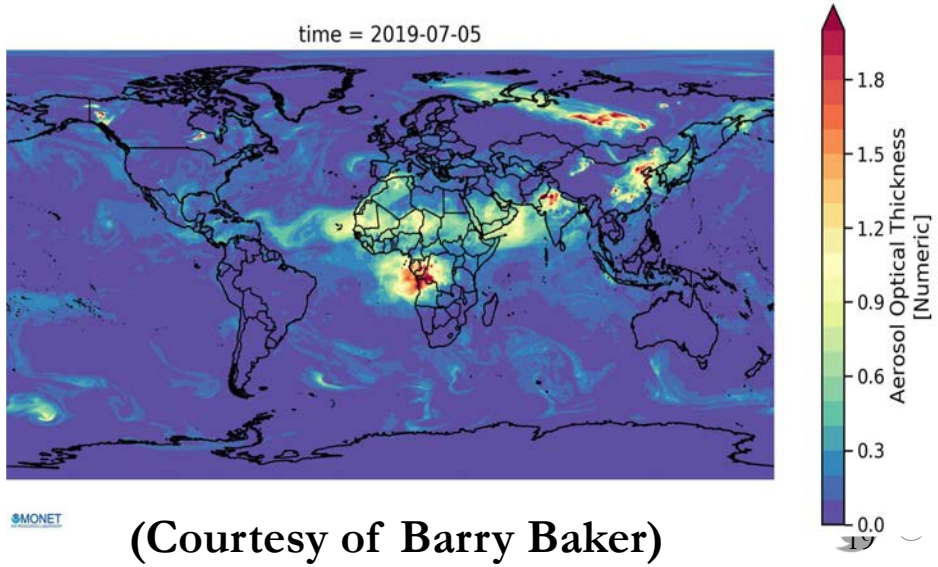
(http://earthobservatory.nasa.gov/NaturalHazards)

National Air Quality Forecast



(Courtesy of Hyuncheol Kim)

Global Dust Forecast System



(Courtesy of Barry Baker)

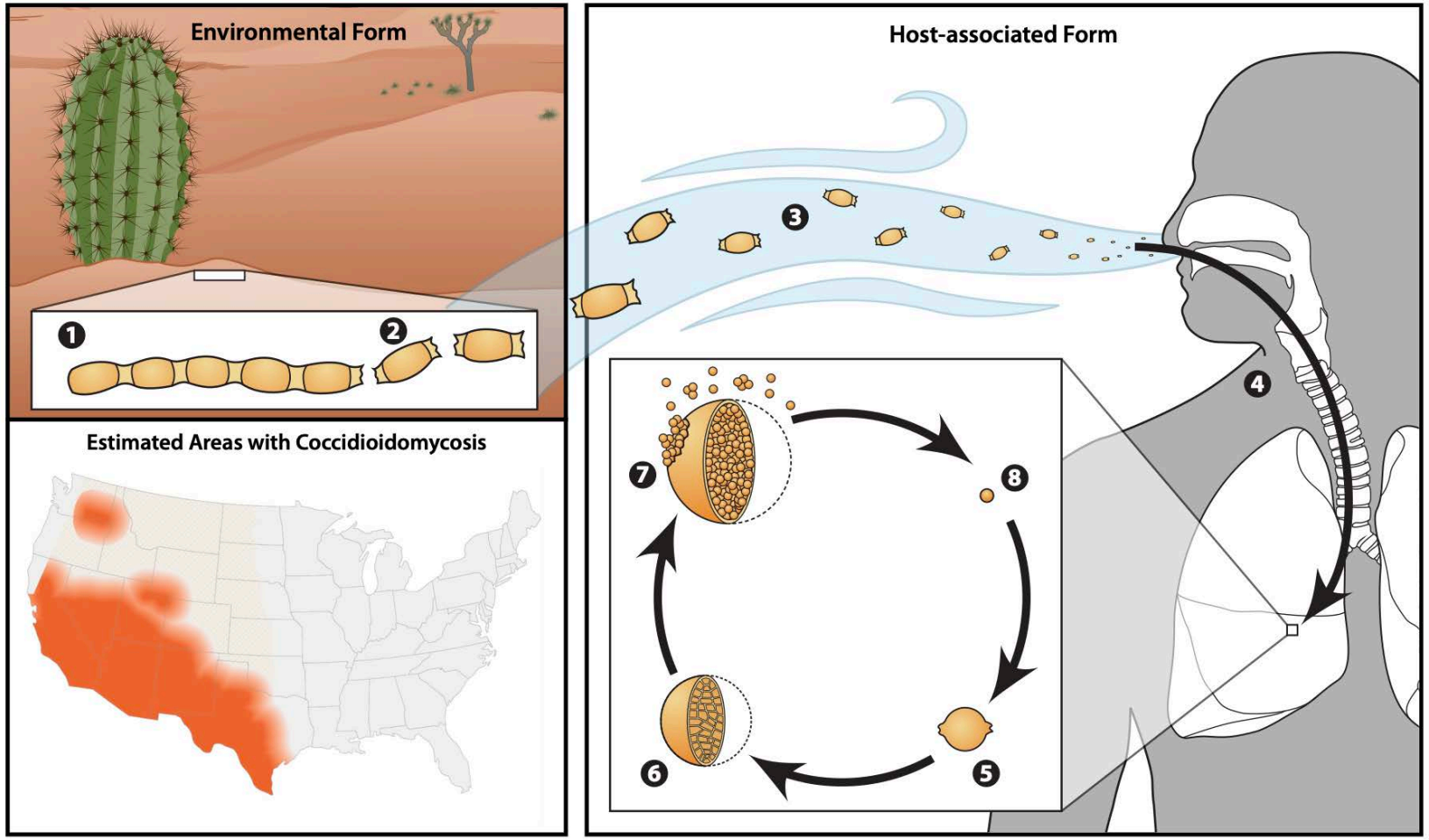
What is inside “dust” storms?

“Whatever is of the right size, in the right place, at the right time, can be part of the ‘dust’ available to be inhaled by someone” -- William Sprigg, WMO, 2017

Dust Storms in Sacaton, Arizona (July 5, 2011).
Photo by NOAA/NWS/Grace Watson

Valley Fever (Coccidioidomycosis)

Infection caused by inhaling the fungus Coccidioides



Coccidioidomycosis:

- Lung infection;

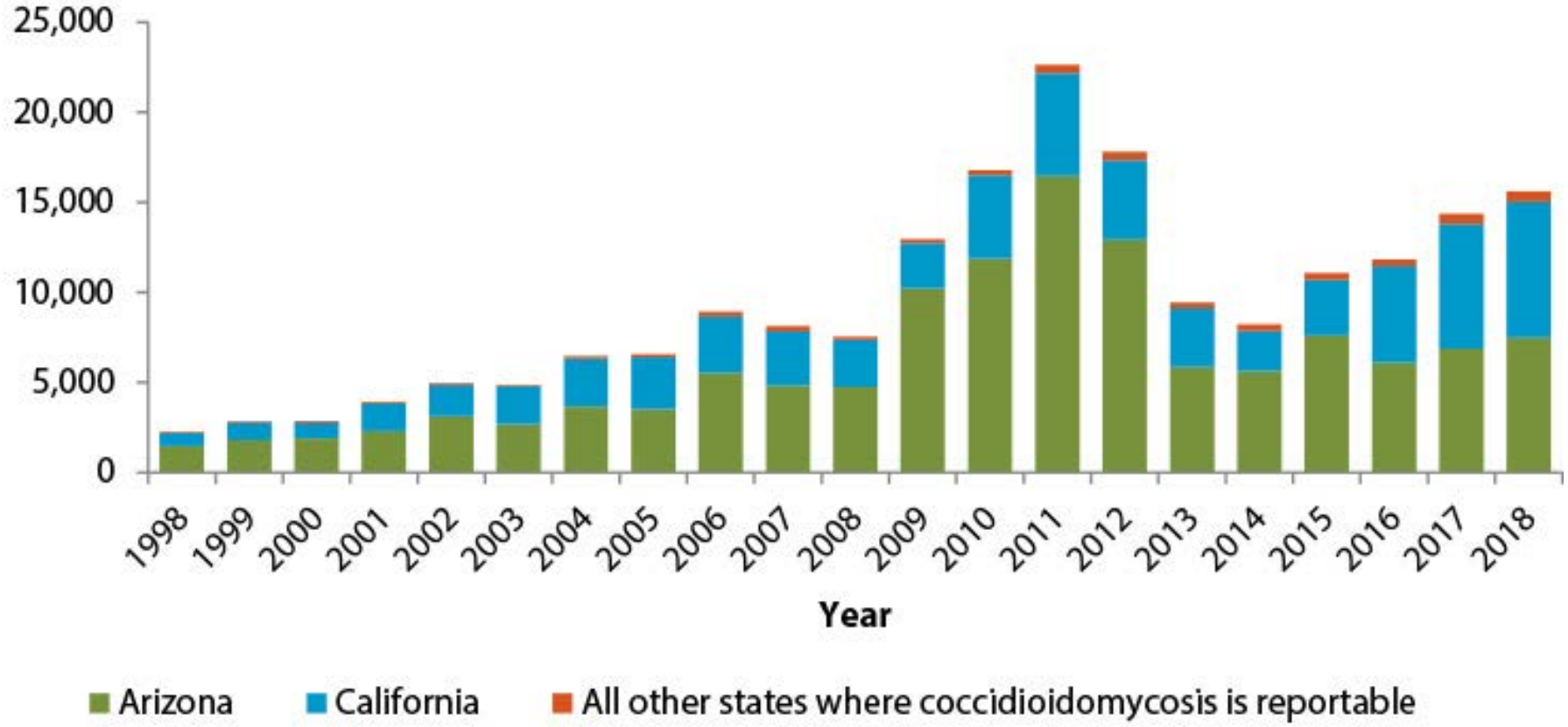
Disseminated Coccidioidomycosis:

- Bloodstream transport to Skin, Brain, Nerve etc

(Source: CDC)
(https://www.cdc.gov/fungal/diseases/coccidioidomycosis/causes.html)

Mysterious Spikes in Valley Fever

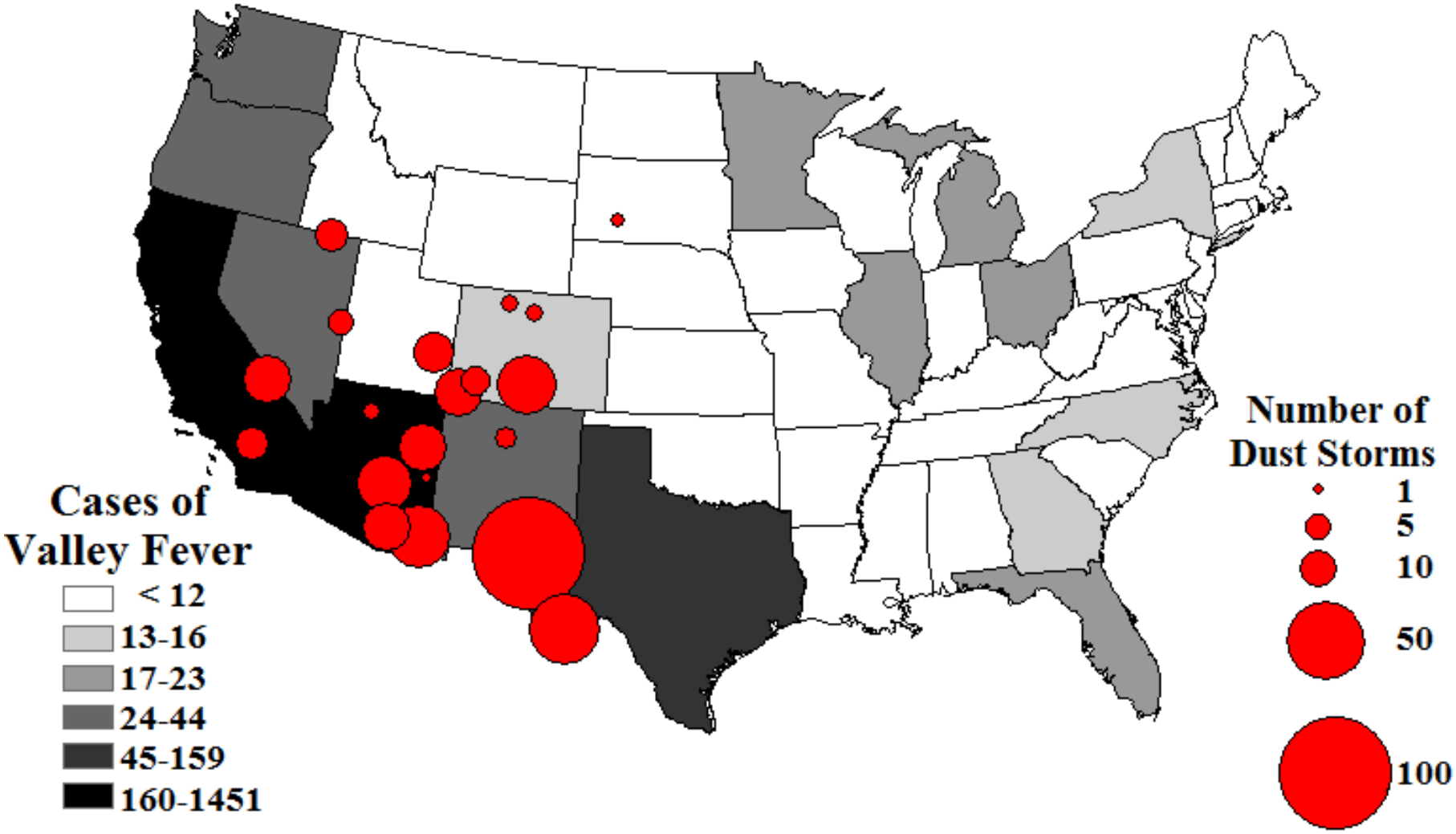
(Source: CDC)



https://www.cdc.gov/fungal/diseases/coccidioidomycosis/statistics.html

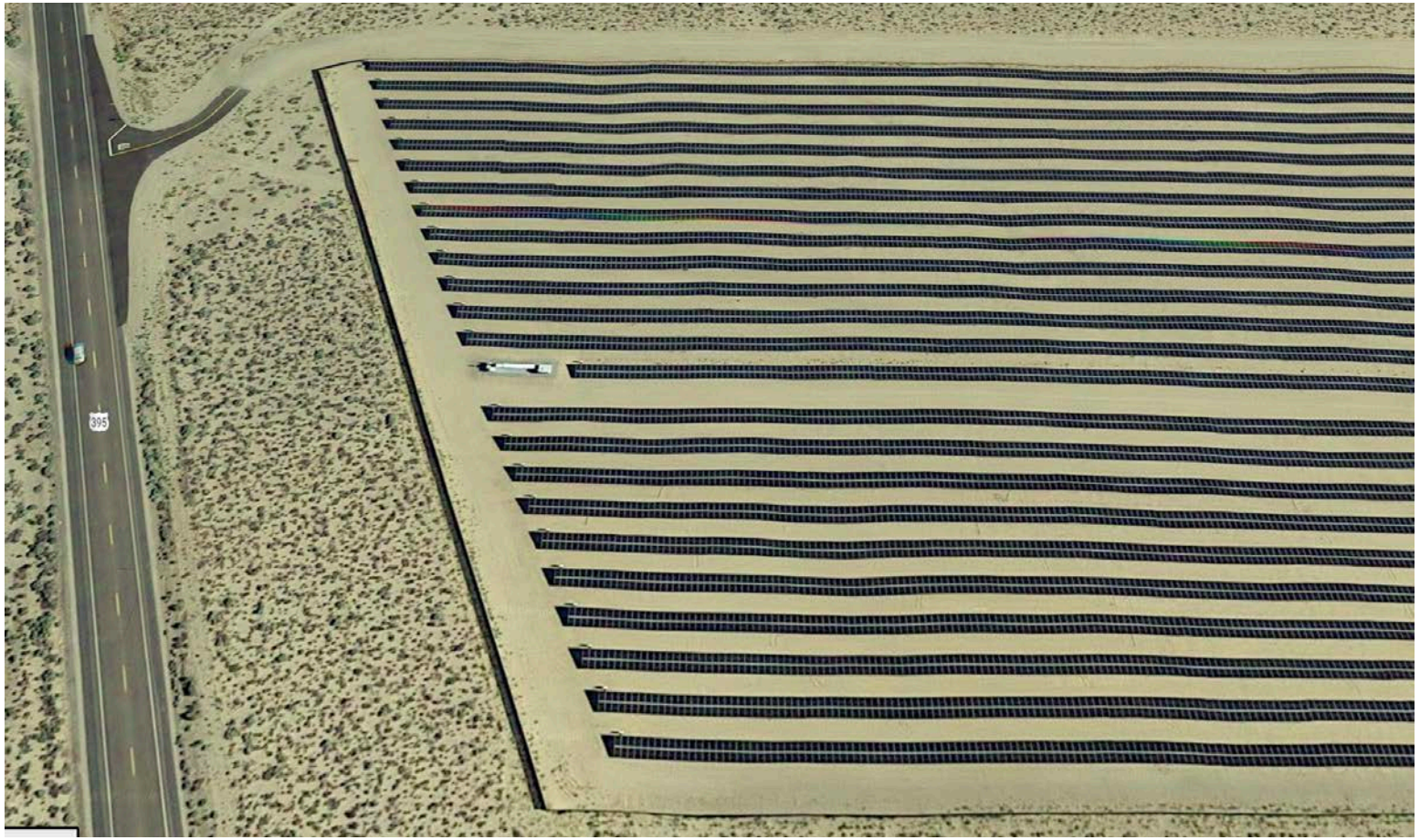
- **2000 – 2011: 800% Increase in Infection;**
- **4000 deaths caused by Valley Fever;**

Collocation of Dust Storms and Valley Fever



Solar Power, Agriculture…

- Large solar farms built near dust sources
- Dust deposition reduces power generation efficiency of solar farms



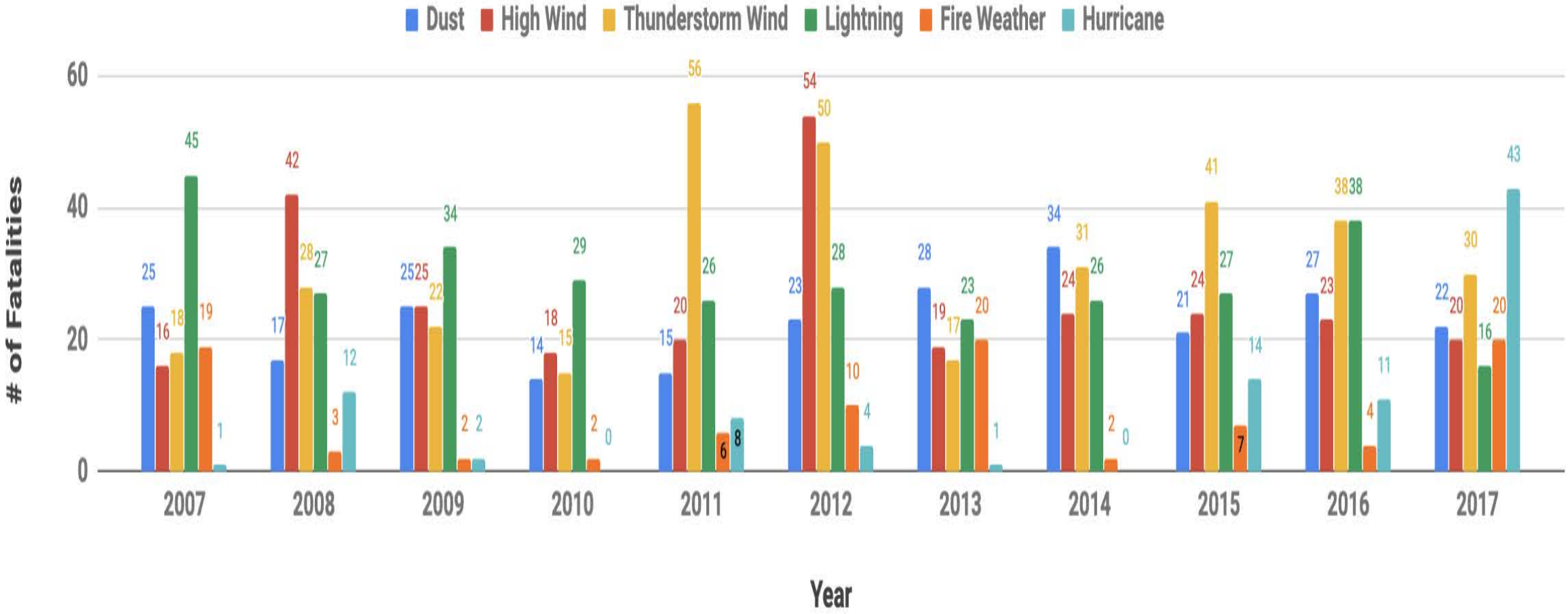
(Credit: Google Maps)

Highway Fatalities Caused by Dust Storms

- **Highway traffic accidents caused by visibility loss, high wind, and slippery road surface**

(Credit: Arizona Department of Public Safety)

Fatalities from Dust vs. Other Extreme Weather Events



In Most Years, Dust Storms Kill More People than Hurricanes.

Resources for Dust Detection and Early Warning

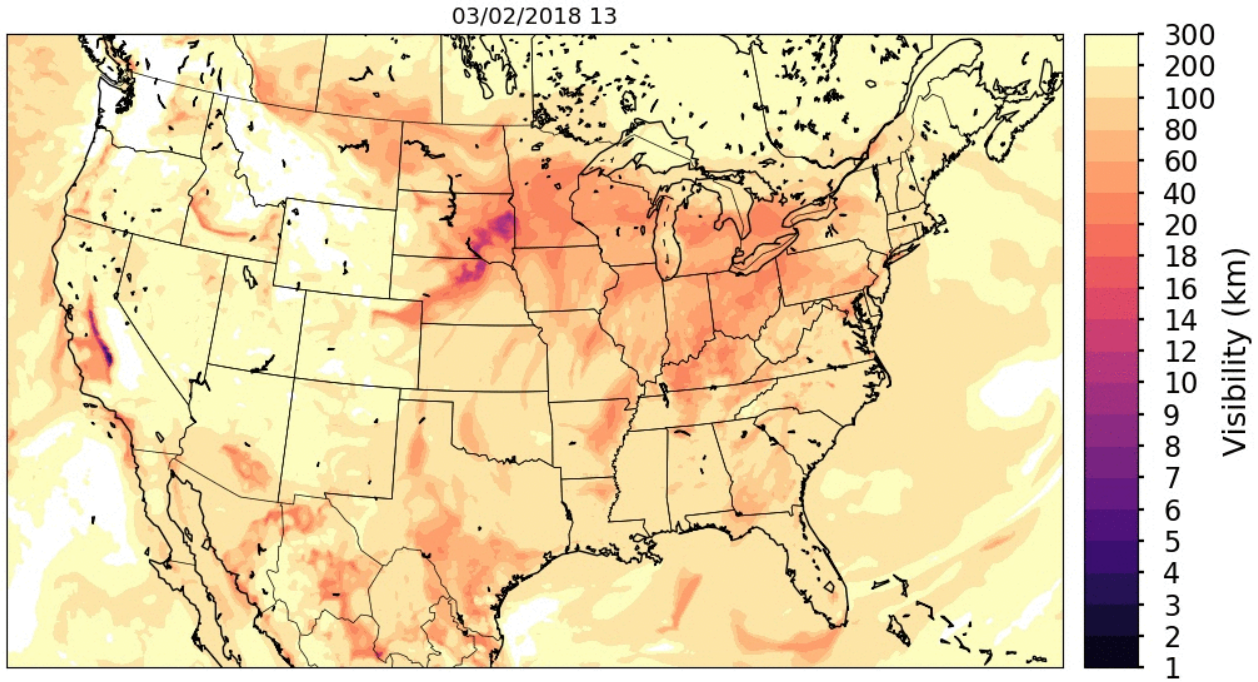
Working with NASA GLOBE Observer to launch a new citizen science campaign to collect dust observations (reports and photos).

NASA GLOBE Observer Contacts:
Marile Colon Robles: marile.colonrobles@nasa.gov
Helen Amos: helen.m.amos@nasa.gov

DustWatch: App for Highway Safety

Highway dust forecasts:

- Visibility
- High Wind
- Dust Concentration
- Inhalable Particle Concentration



(Courtesy: Barry Baker)

DustWatch App:

- Citizen Scientist Project
- Use dust forecasts
- Real-time dust alerts

(Contact Dust App. Team: dustapp2018@gmail.com)

Take Home Message

- As US air quality improves, dust storms (and wildfires) are rising;
- Imminent risks on public health, transportation safety, solar energy etc.
- Satellites offering various capabilities to help monitor and predict dust storms;
- Hands-on training to follow.

NASA WorldView

(More questions: qtong@gmu.edu)