Observing and Forecasting Dust Storms

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1. GMU; 2. NOAA ARL; 3. UMD; 4. UTEP; 5. USDA; 6. NASA GSFC; 7. NOAA GFDL

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Arizona State University, Phoenix, AZ

A Lesson from History: "Dust Bowl" During the Great Depression

- **Dust Bowl: A period of severe dust storms during the 1930s;**
- **Causes: Extended droughts and poor land management;**
  - ✓ **Homestead Acts:** settlement over the Plains for agriculture **;**
  - ✓ **"Rain follows the plow":** unusually wet climate**;**
  - ✓ **New agricultural machinery:** Deep plowing, eliminating native grass;
  - ✓ **Favorable dust storm conditions during 1930s drought;**

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).

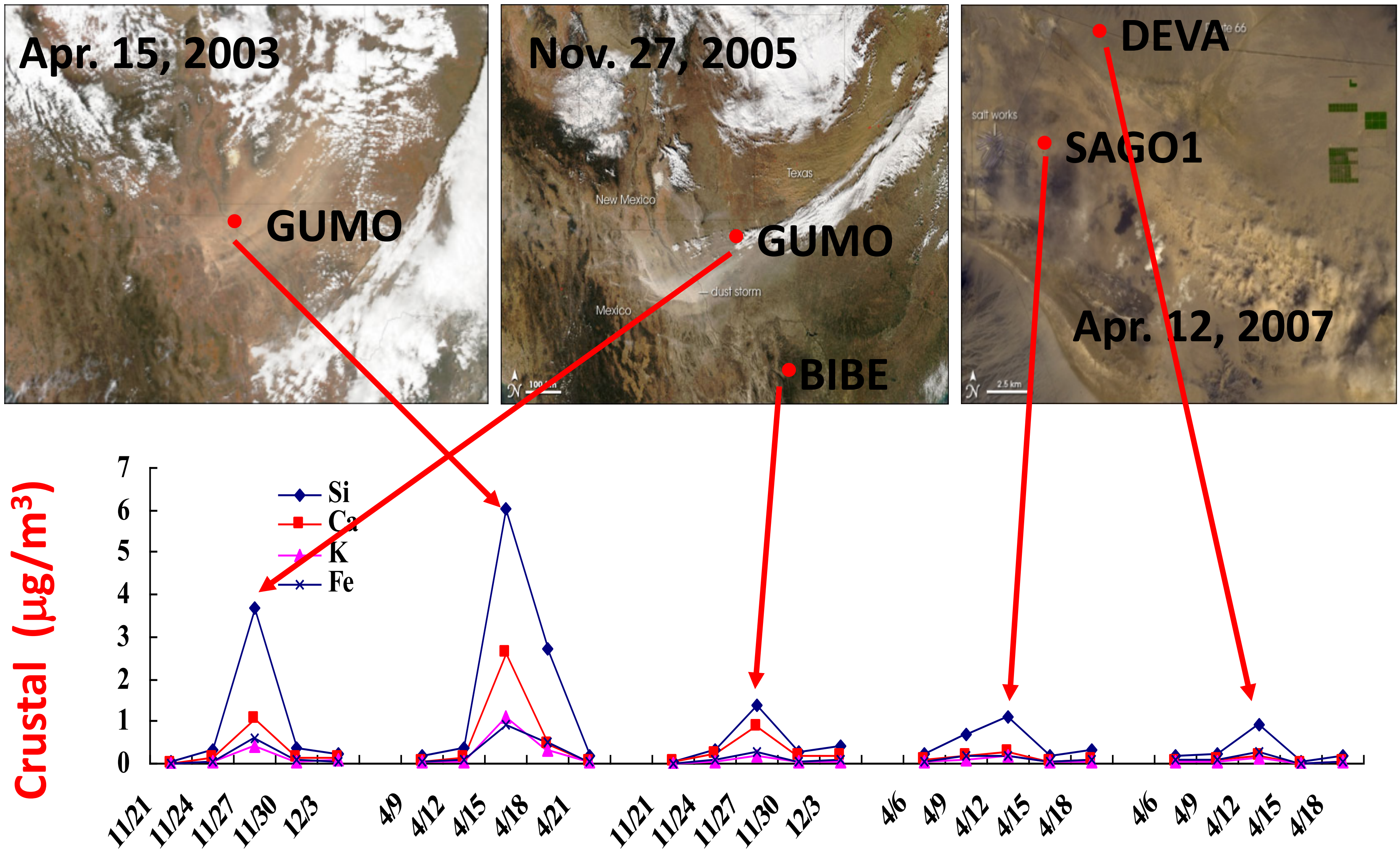
- Global warming → Precipitation shift from subtropics, greater evaporation, less snow/ice, and earlier spring → amplify the effects of natural climatic variations → intensified droughts and “dust-bowlification” (Romm, 2011).

Probably Not?

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

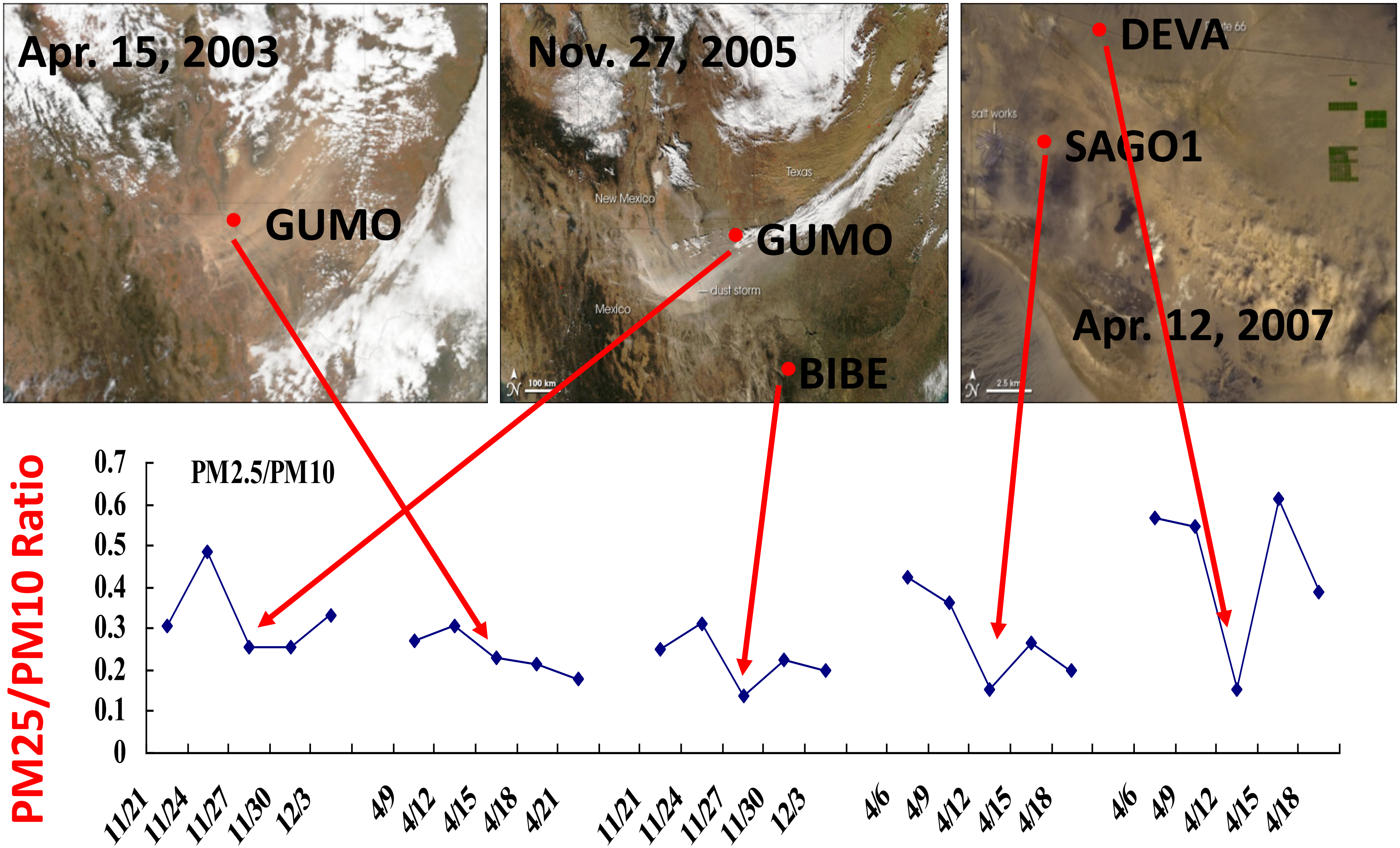
Problem: *No long-term dust observations*

Satellite-aided Algorithm Training



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

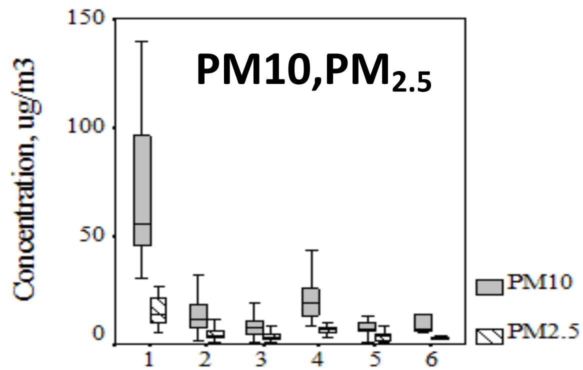
Satellite-aided Algorithm Training

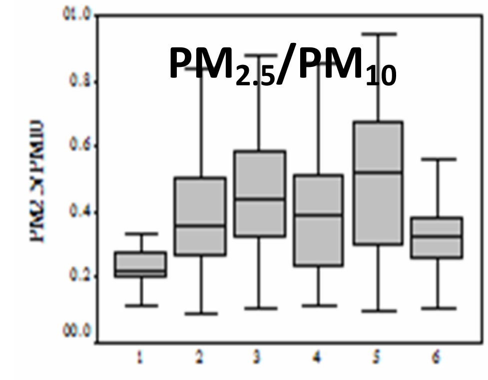


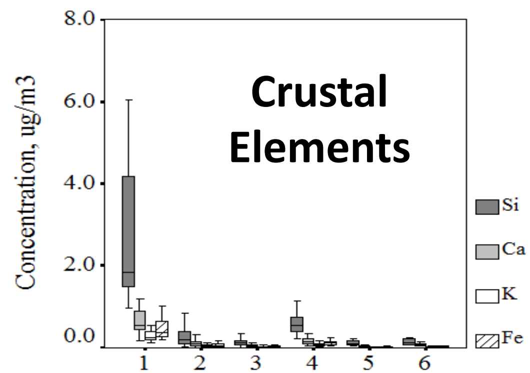
Dust Identification through Cluster Analysis

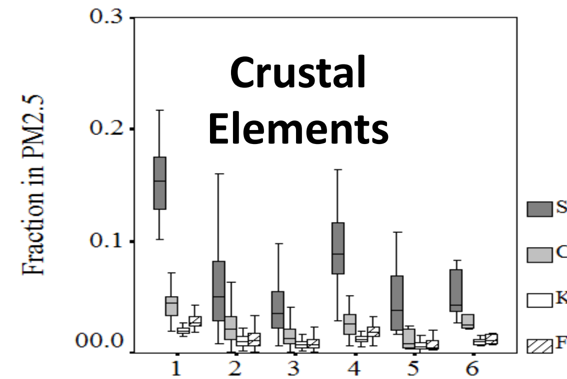
Five Dust Indicators:

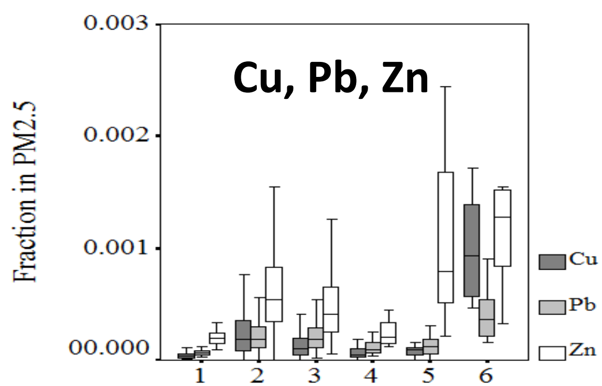
- ❖ High PM_{10}, $PM_{2.5}$;
- ❖ Low $PM_{2.5}/PM_{10}$ ratio
- ❖ High Crustal Fraction
- ❖ Low anthropogenic Fraction;
- ❖ Low Enrichment Factor;

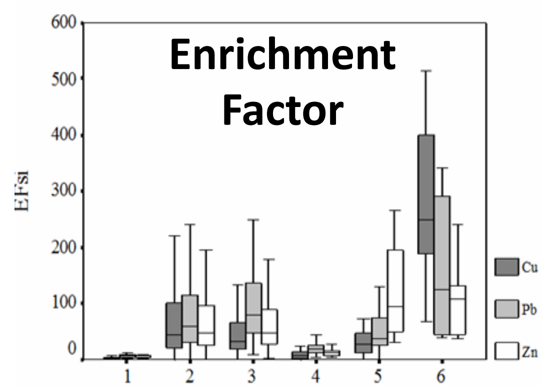








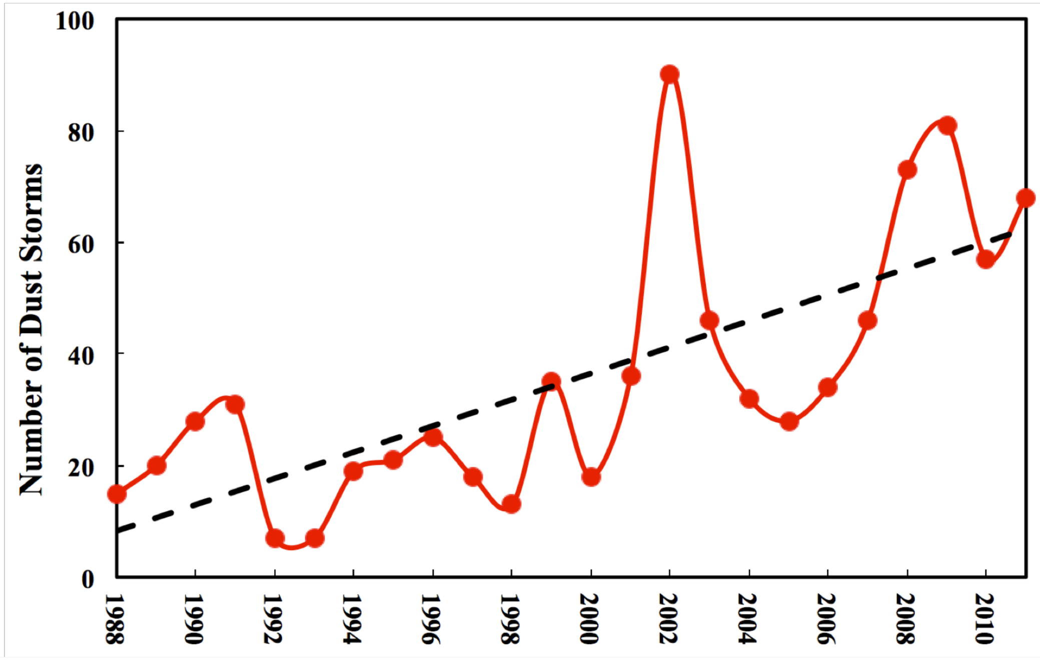




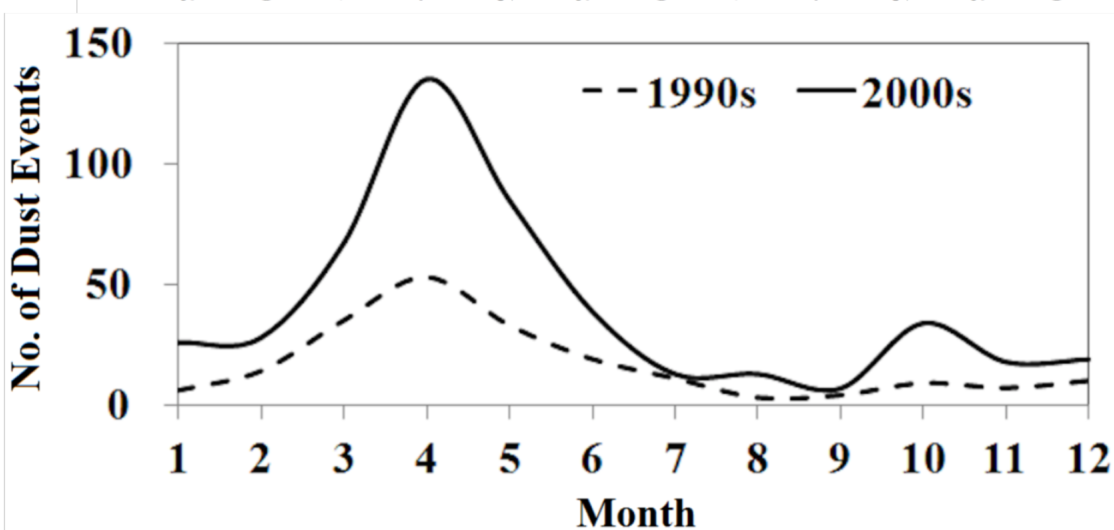
Cu– Copper
Pb – Lead
Zn – Zinc

(Tong et al., 2012)

Long-term Dust Trend



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



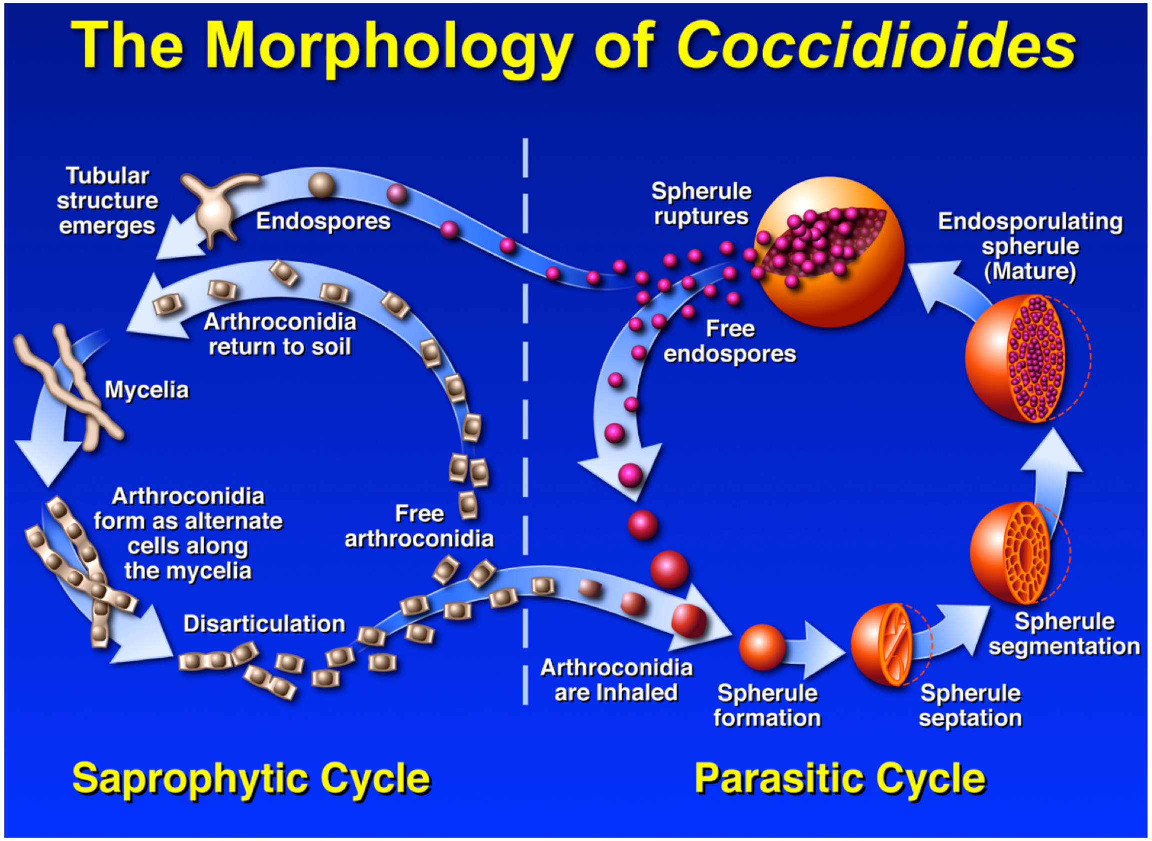
Increase in Spring (mostly) and Fall;

Almost no change in Summer/Wet Season;

(Tong et al., 2017)

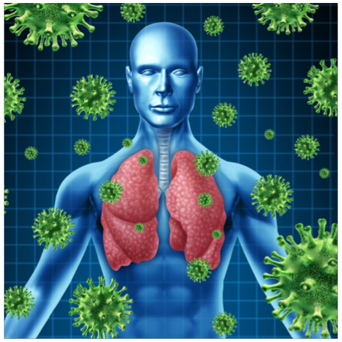
Valley Fever (Coccidioidomycosis)

Infection caused by inhaling the soil-dwelling fungus Coccidioides



(Source: thinklink.com)

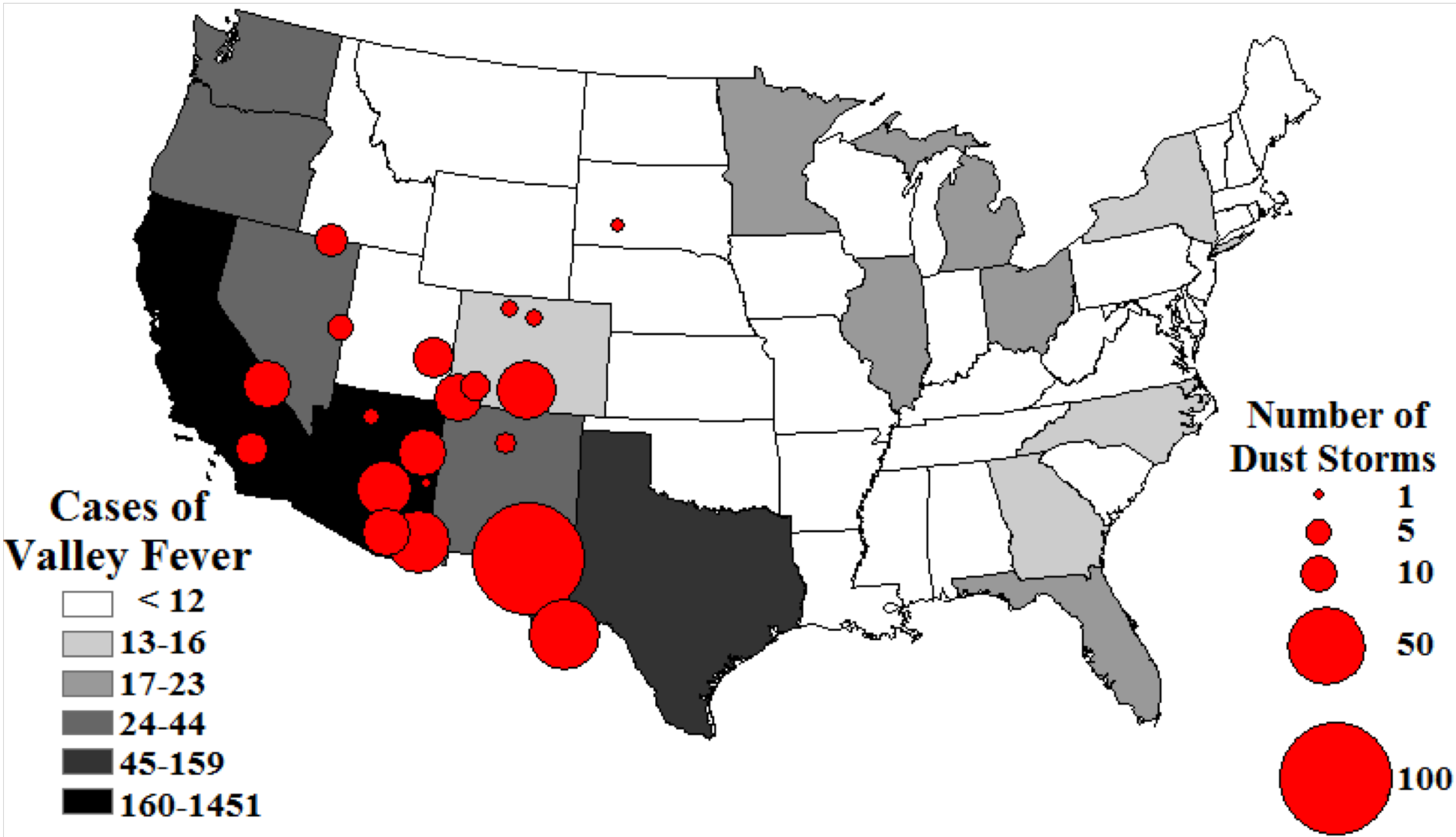
Coccidioidomycosis:
Lung infection;



Disseminated Coccidioidomycosis: Bloodstream transport to Skin, Brain, Nerve etc

- **2000 – 2011: 800% Increase in Infection;**
- **3000 deaths caused by Valley Fever;**

Collocation of Dust Storms and Valley Fever

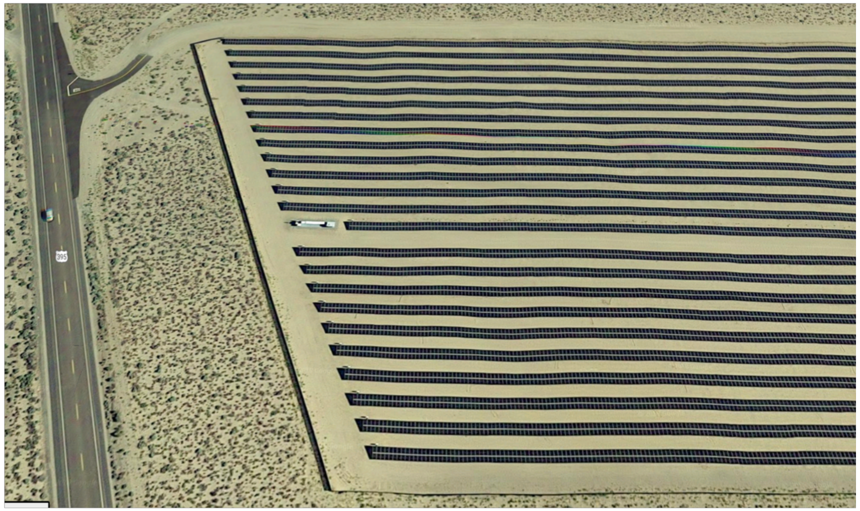


(Tong et al., 2017)

Highway Safety, Solar Power, Agriculture…

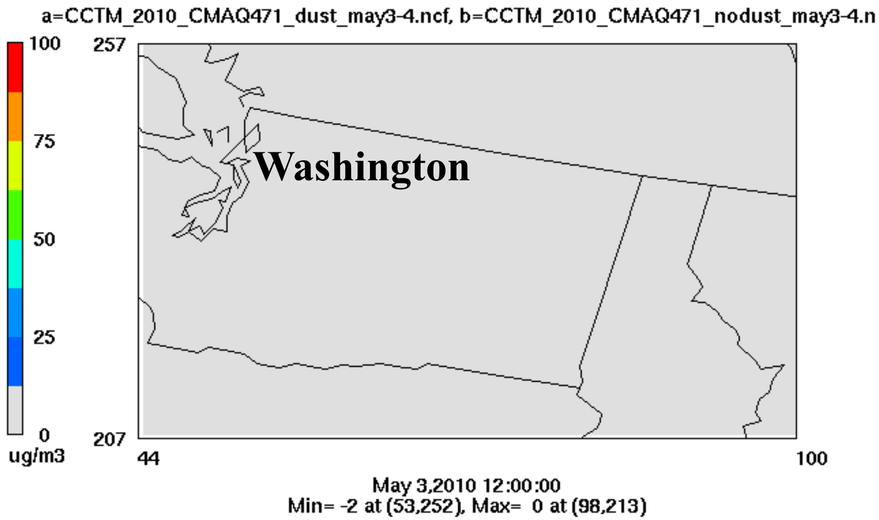
- Highway traffic accidents caused by visibility loss and high wind

- Dust deposition reduces power generation efficiency of solar farms



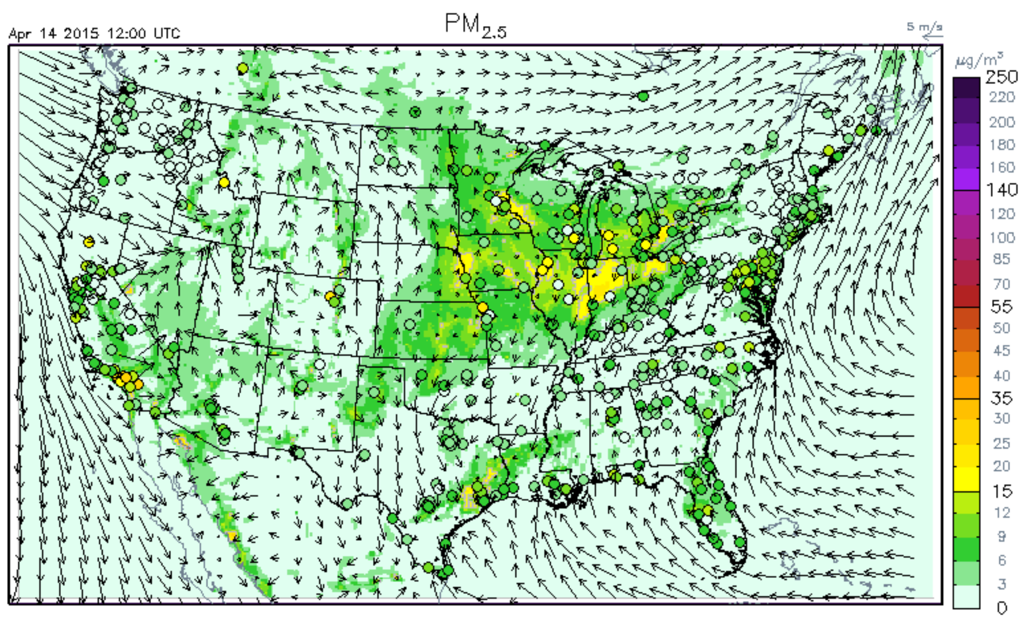
Real-time Dust Forecasting (NAQFC)

Dust PM2.5 on May 3,2010



12:30 p.m, May 3,2010

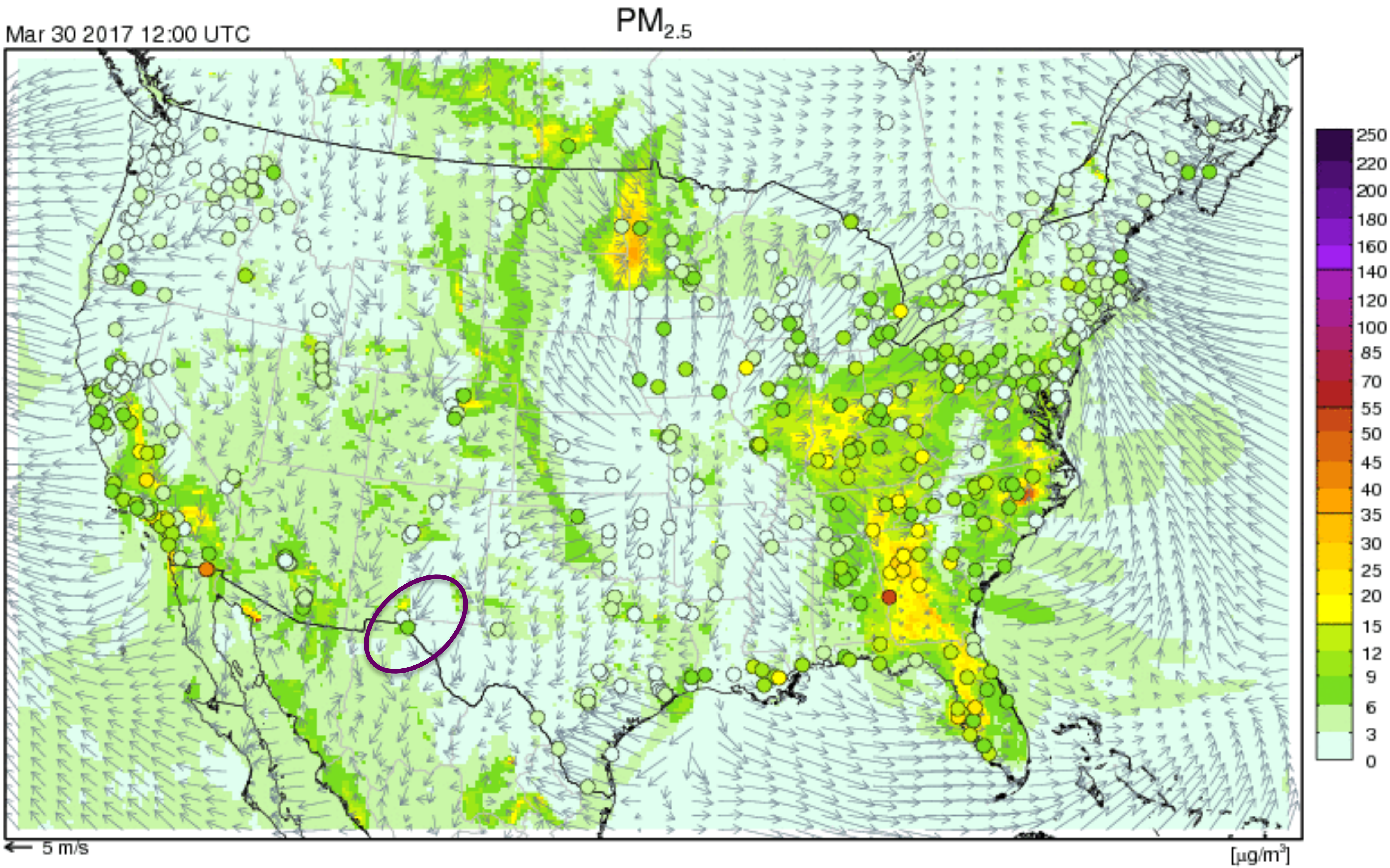
--http://earthobservatory.nasa.gov/NaturalHazards



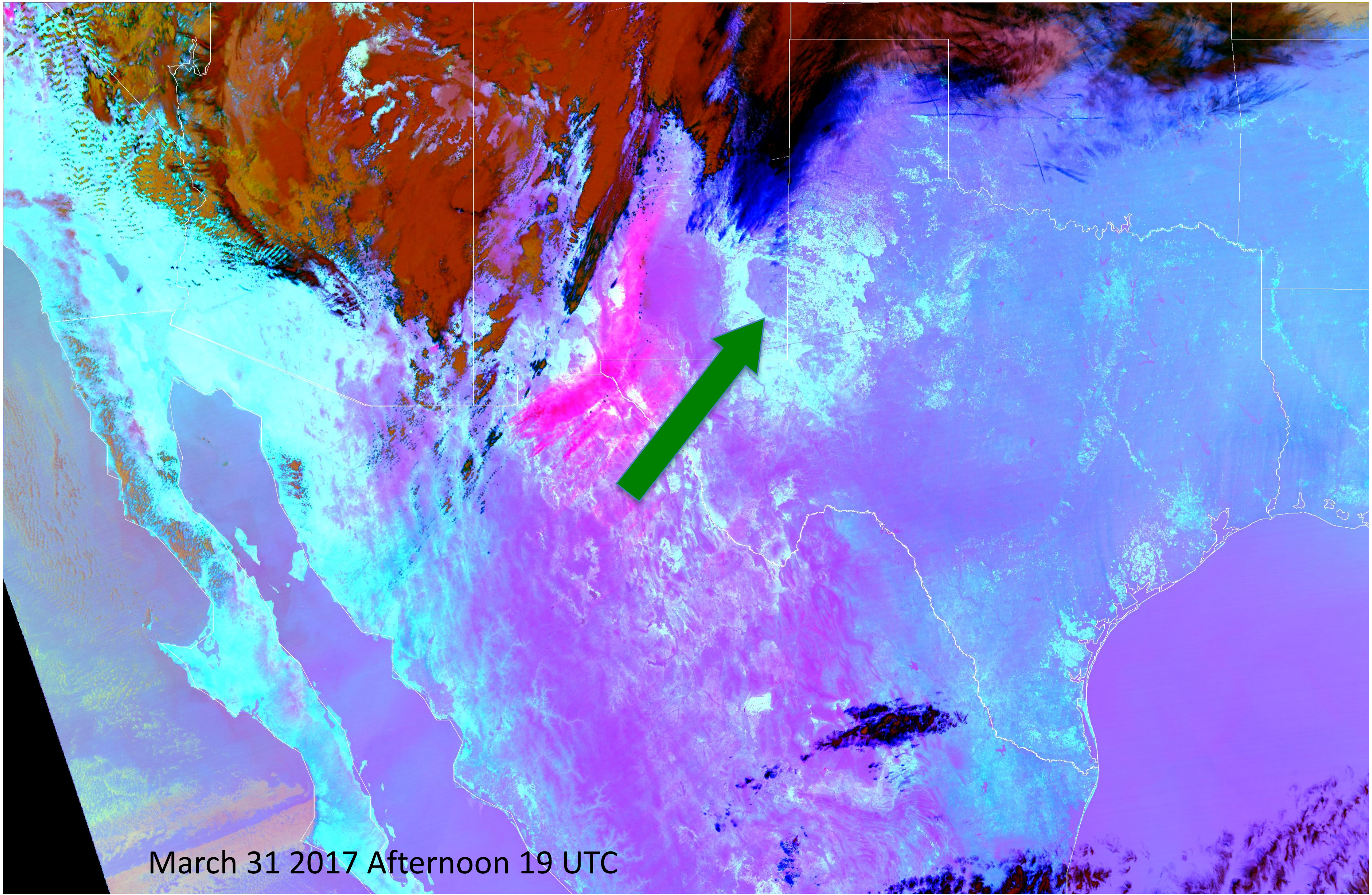
Dust storm in UT/NV

(Courtesy of Hyuncheol Kim)

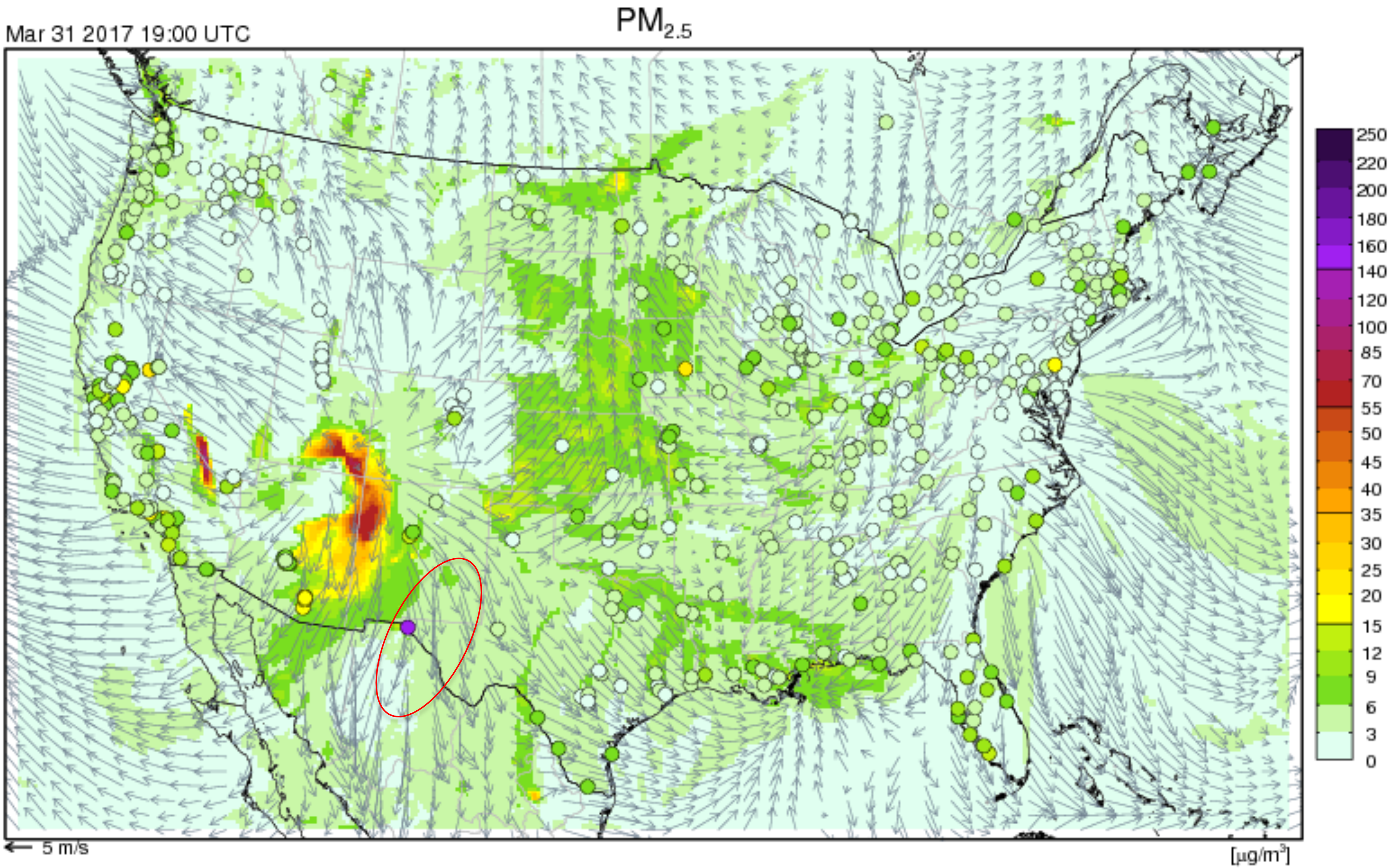
NAQFC Dust Forecast (Surface $PM_{2.5}$)



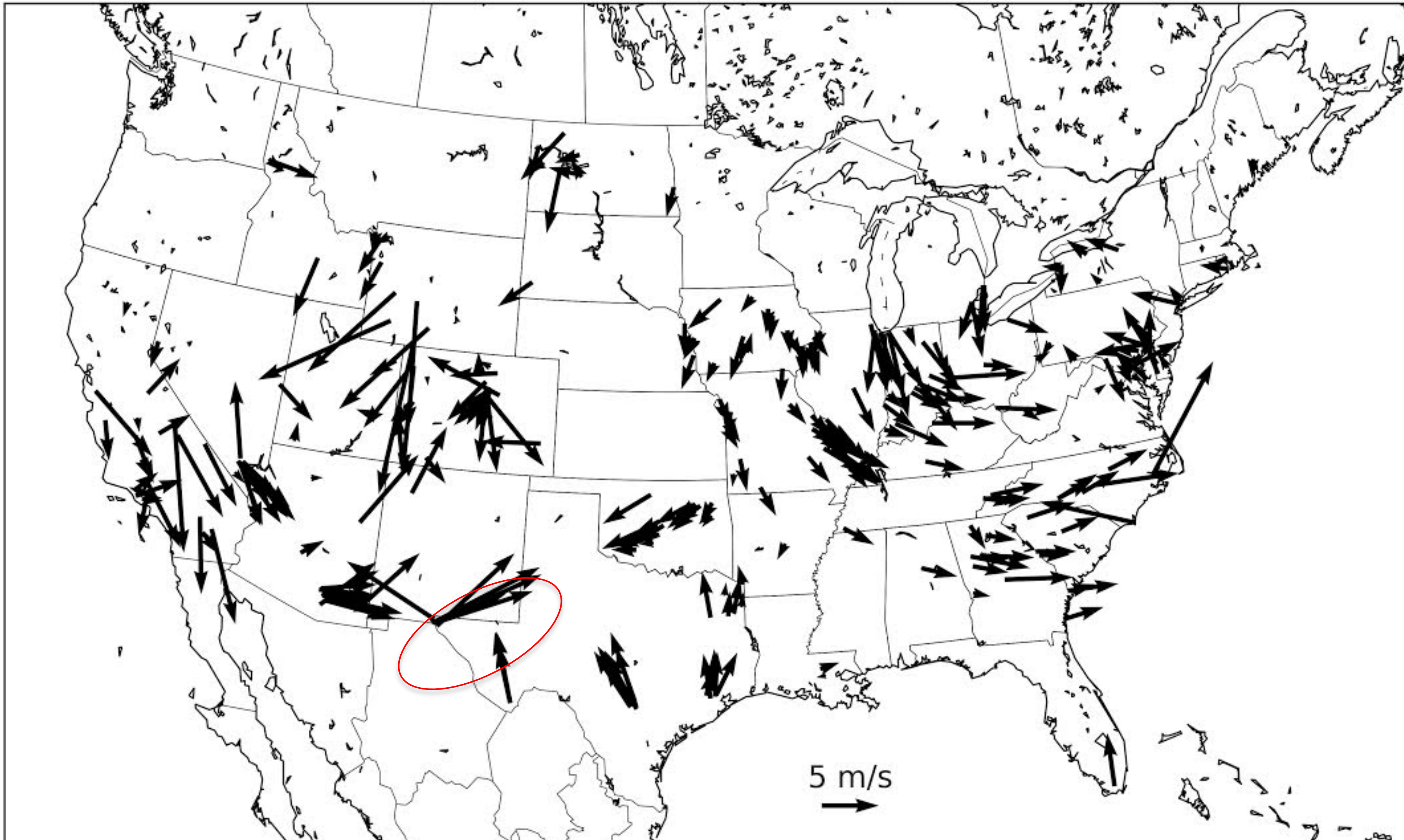
VIIRS Dust driven by Southwesterly wind



NAQFC NAMx Wind Field: Northerly Wind



Satellite vs Model Wind: Which is Right?

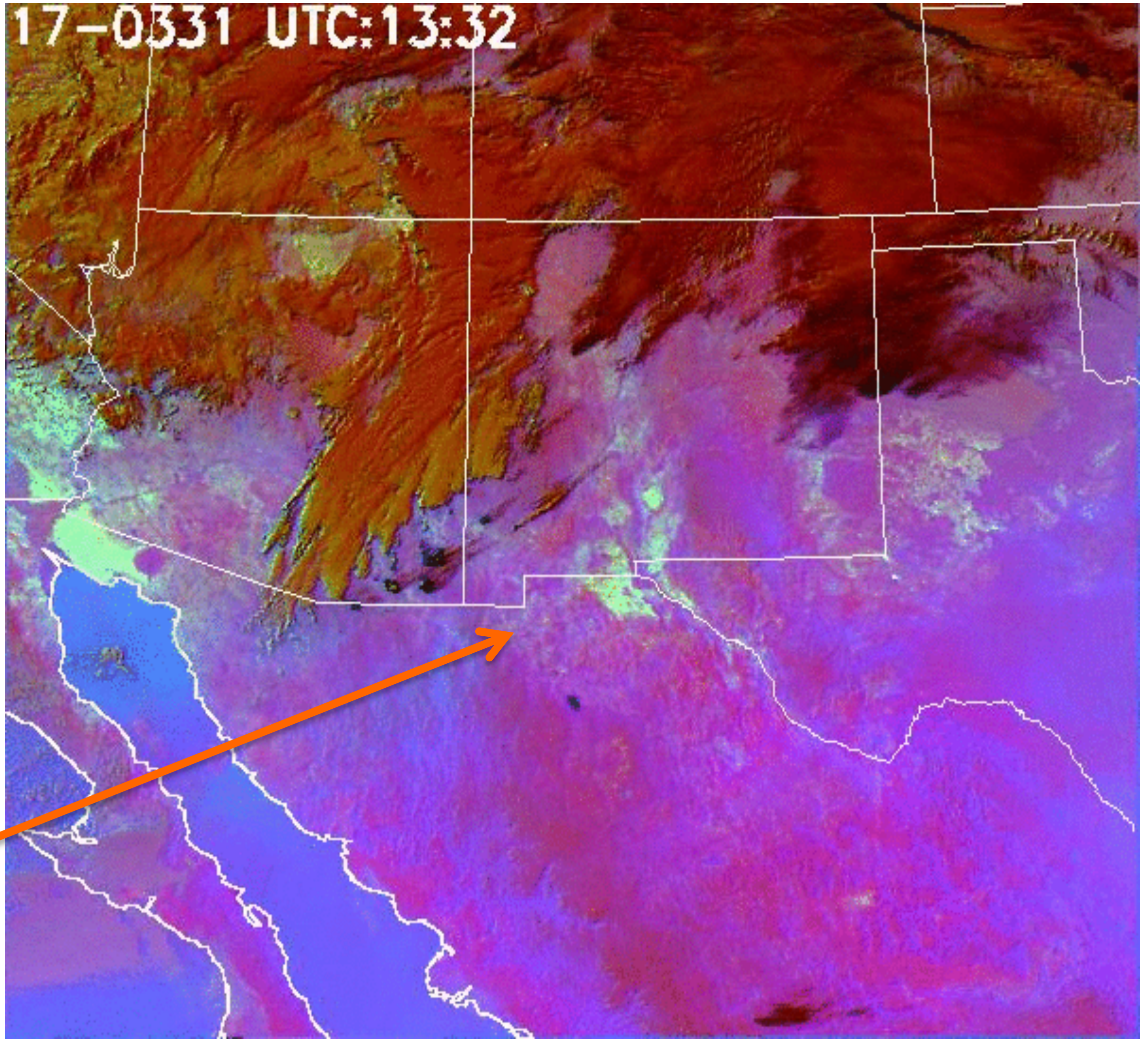


Ground wind observations support VIIRS

Now, Look at GOES-16 ABI Dust Mask

Red 12 µm – 10.8 µm
Green 10.8 µm – 8.7 µm
Blue 10.8 µm

Dust appears as pinkish magenta plume that forms near Mexico/New Mexico border. Cold ground appears as static pink that changes to shades of bluish green when warm



(Kondragunta et al., EM, 2018)

Year 2.5 Progress Update, PI Daniel Tong (GMU)

Novel use of NASA data with emission data assimilation to support U.S. National Air Quality Forecasting Capability and WMO regional chemical reanalysis

- Emission data assimilation: Using NASA observations to improve emission inputs
  - 1 paper on air quality forecasting; 1 paper on NH3 emissions from fires;.
- Regional chemical reanalysis
  - Released version 1 of North American Chemical Reanalysis; 1 paper (with Yang Liu's group).
- Use NASA observations for chemical data assimilation
  - 1 paper published on using MODIS AOD to improve PM2.5 forecasts.
- 10 academic talks; 12+ stakeholder or public talks; Guidance documentation on analyzing satellite NO2 trends for cities; 3 media interviews/outreaches.

Tiger Team Participation

- O'Neal: Health impacts of Cal Fires
  - Develop prototype CMAQ modeling at national scale;
  - Provide lateral boundary conditions to BAAQMD to drive their high-resolution CMAQ modeling.
- Fiore: Regional Haze.
  - Quantify the contribution of windblown dust emission to local air
  - Develop a "guidance" document for stakeholders
- Anenberg: Global Indicators.
  - Provide long-term dust records from ground monitors (2002-2017) over North America;
  - Provide satellite based dust records for a selected period.

3 papers published

3 under review

Take Home Message

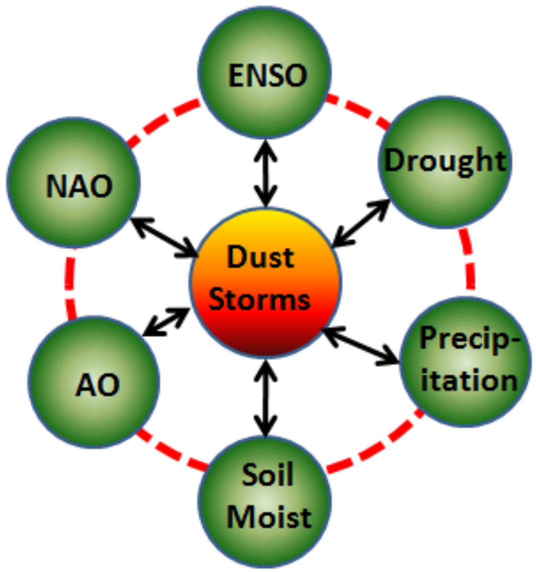
- Dust is rising in Southwest United States, driven by large-scale variations of ocean changes.

- Rising dust poses imminent risks on human health, transportation safety, and local economies.

- Satellite data (MODIS, VIIRS, ABI, etc) are used to train ground dust identification, directly detect dust and help improve model forecast .

Extra Slides

What Drives the Dust Trend?



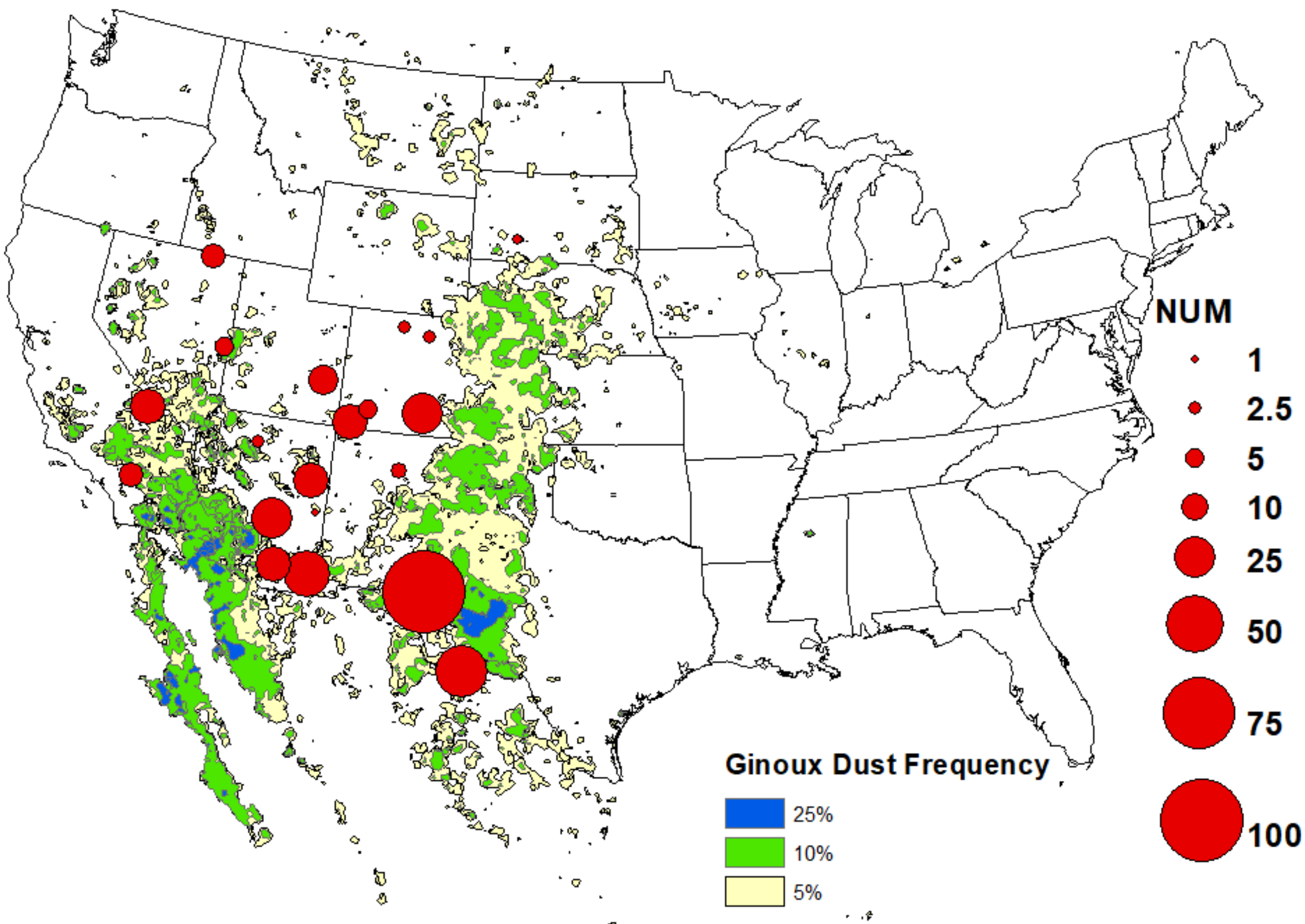
ENSO - El-Nino Southern Oscillation
PDO - Pacific Decadal Oscillation
NAO - North Atlantic Oscillation
PNA - Pacific/North American Oscillation
AO - Arctic Oscillation

	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)

Locations of Dust Storms

(Tong et al., 2017)



Dust storms detected at 29 sites with continuous data records.