Natural dust emissions over cropland and rangeland of the United States in 2014

Daniel Tong, Barry Baker, Pius Lee, Youhua Tang and Li Pan

NOAA Air Resources Laboratory, College Park, MD

(2017 IEC, Baltimore, MD)

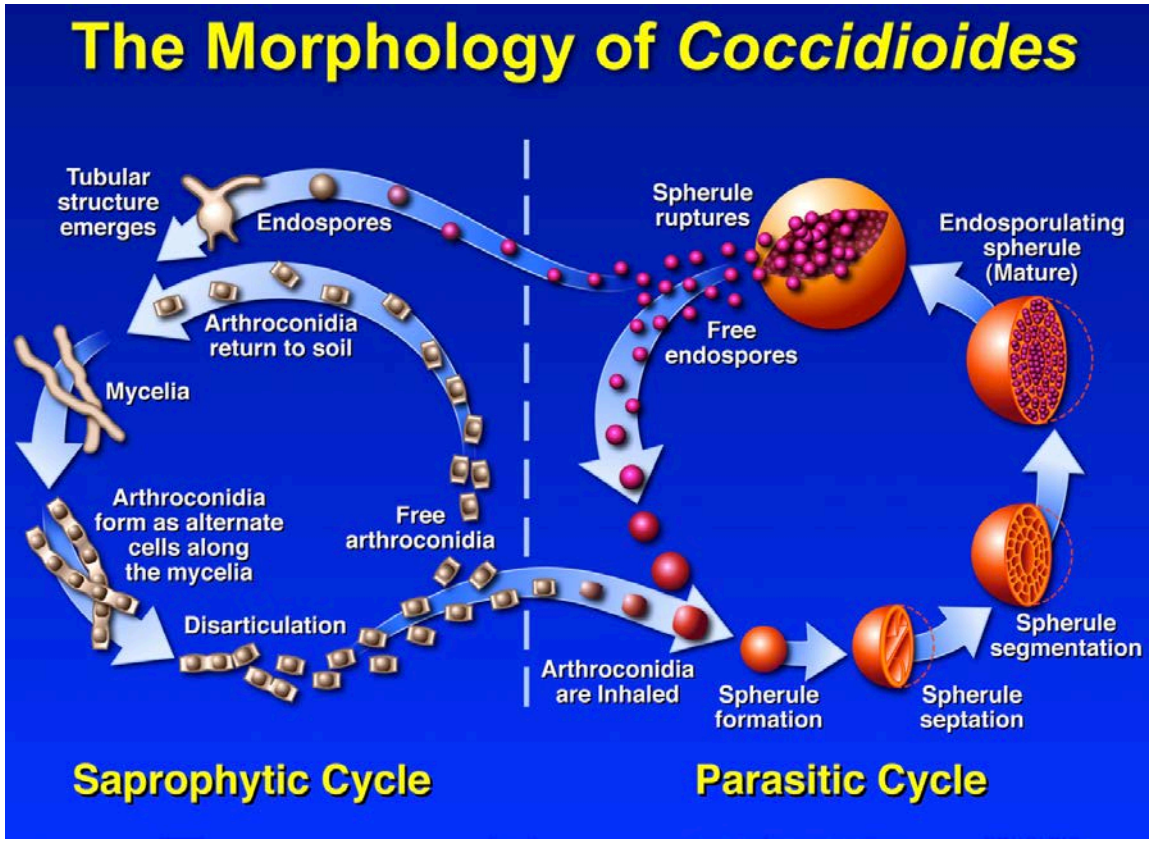
Societal Impacts of Natural Dust Emission

- Highway accidents (No. 3 disaster in Southwest US);
- Loss of top soil;
- Air Quality;
- Solar farm operation;
- Earlier snow melting;

25-vehicle pileup and 6-deaths in New Mexico on June 19, 2017. Six people were killed. *(Photo: Courtesy of Bob Yacone)*

Valley Fever (Coccidioidomycosis)

Infection caused by inhaling the fungus Coccidioides



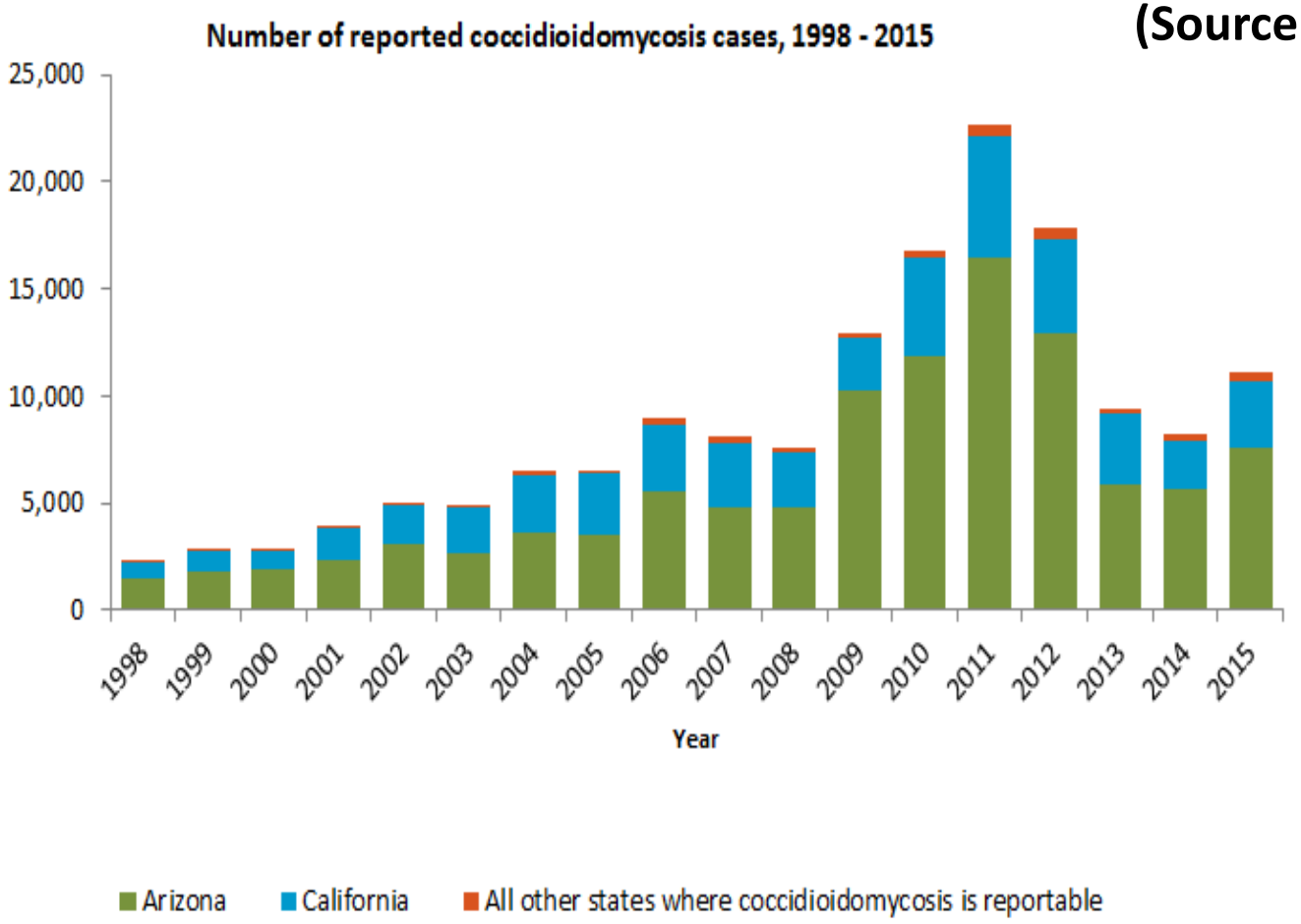
(Source: thinklink.com)

Coccidioidomycosis: Lung infection;

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

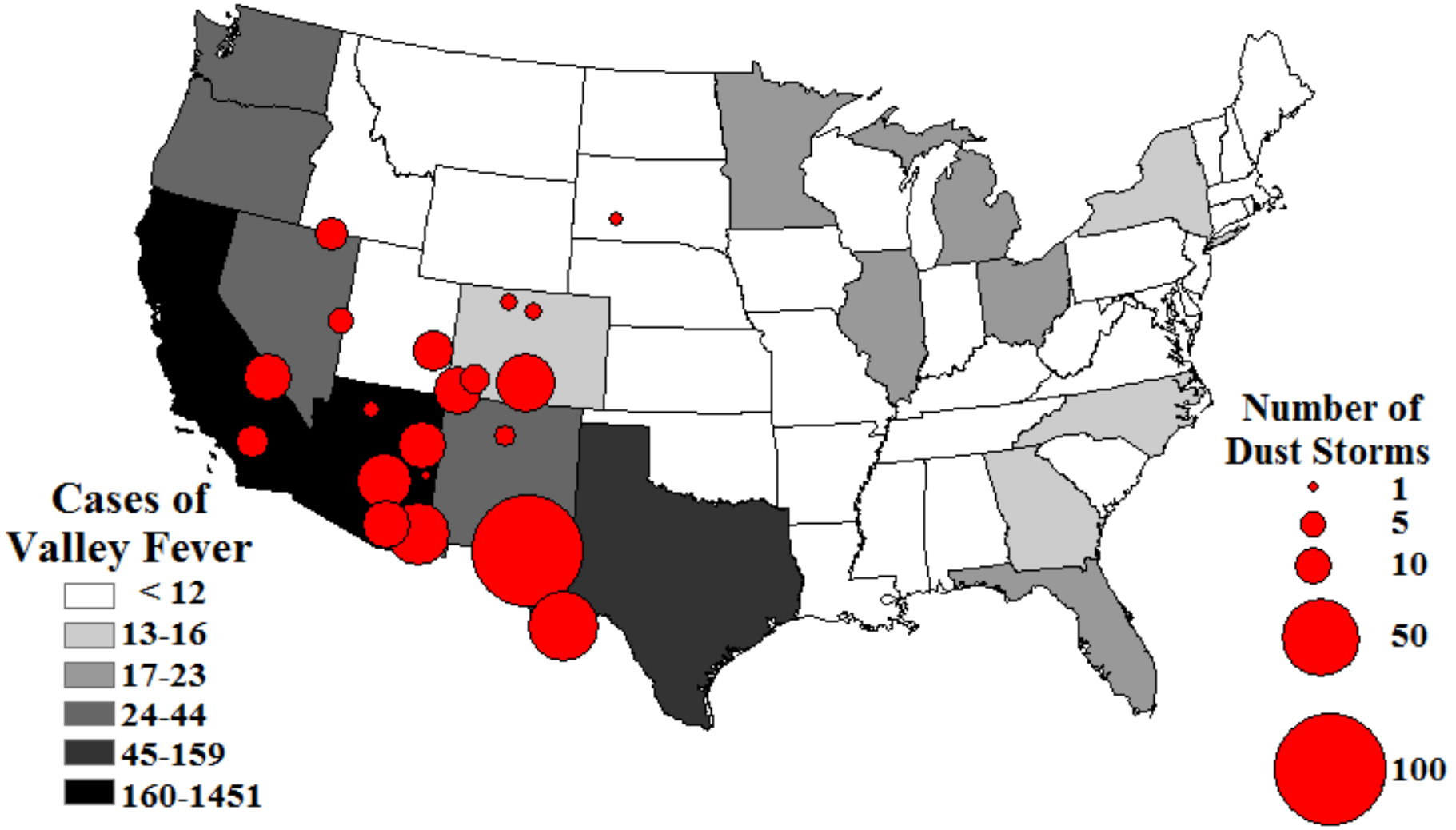
Mysterious Spike in Valley Fever

(Source: CDC)



- **2000 – 2011: 800% Increase in Infection;**
- **3000 deaths caused by Valley Fever;**
- **Over 10,000 infection cases each year.**

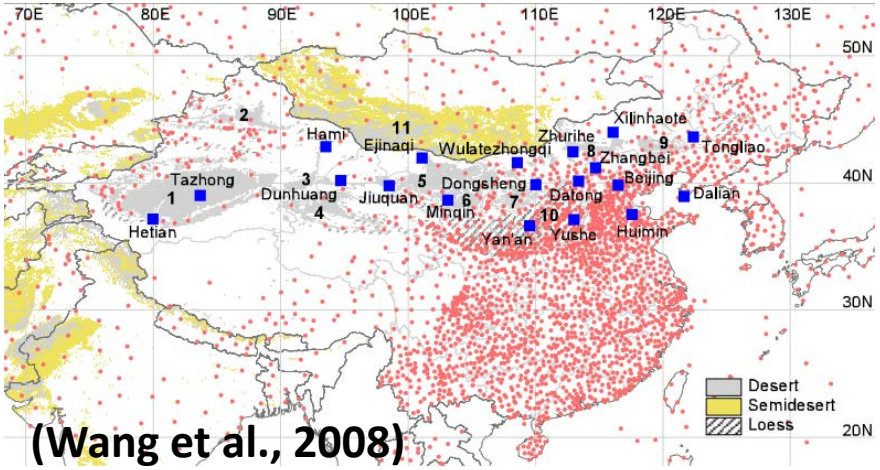
Collocation of Dust Storms and Valley Fever



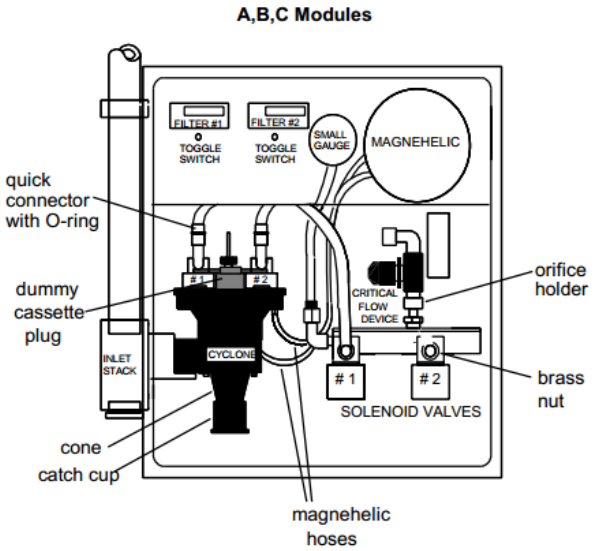
(Source: Tong et al., 2017)

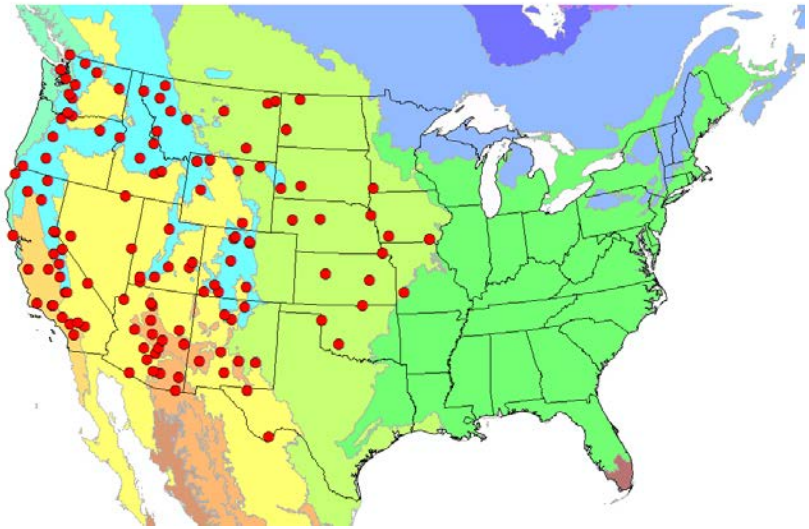
Observations of Dust Trend

Chinese Sand and Dust Network

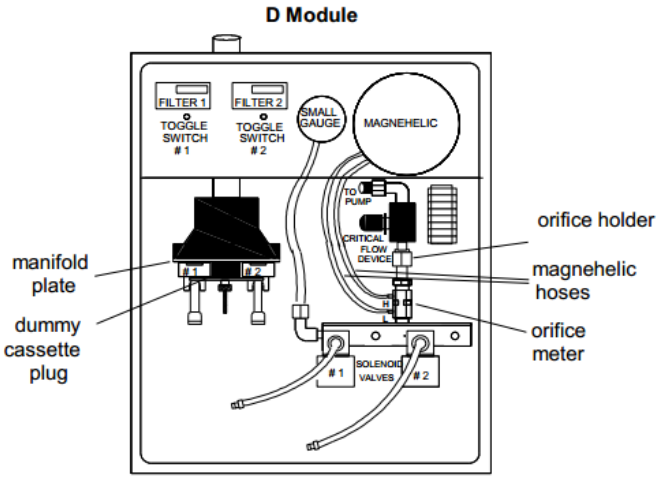


(Wang et al., 2008)



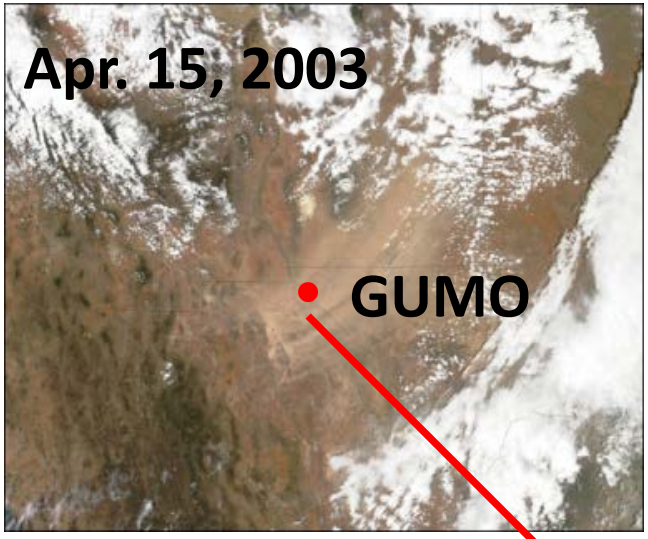


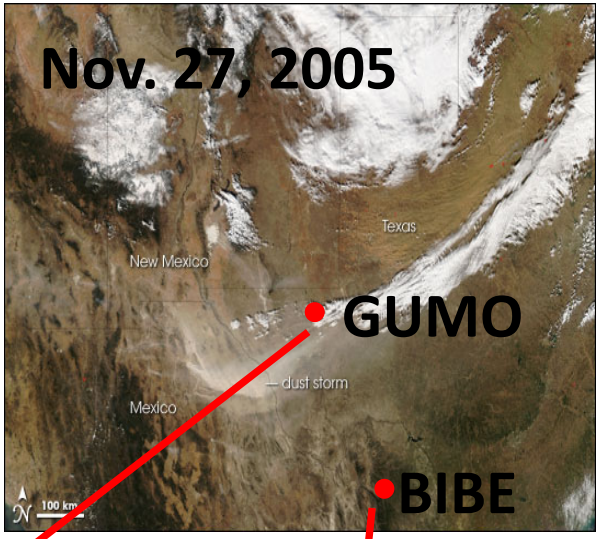
The US Aerosol Network IMPROVE

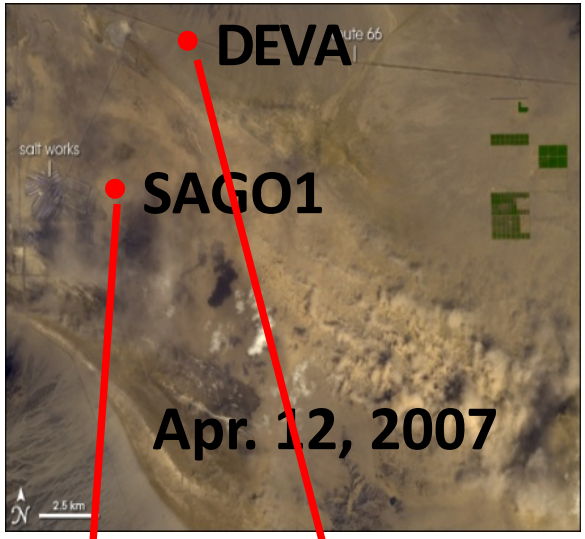


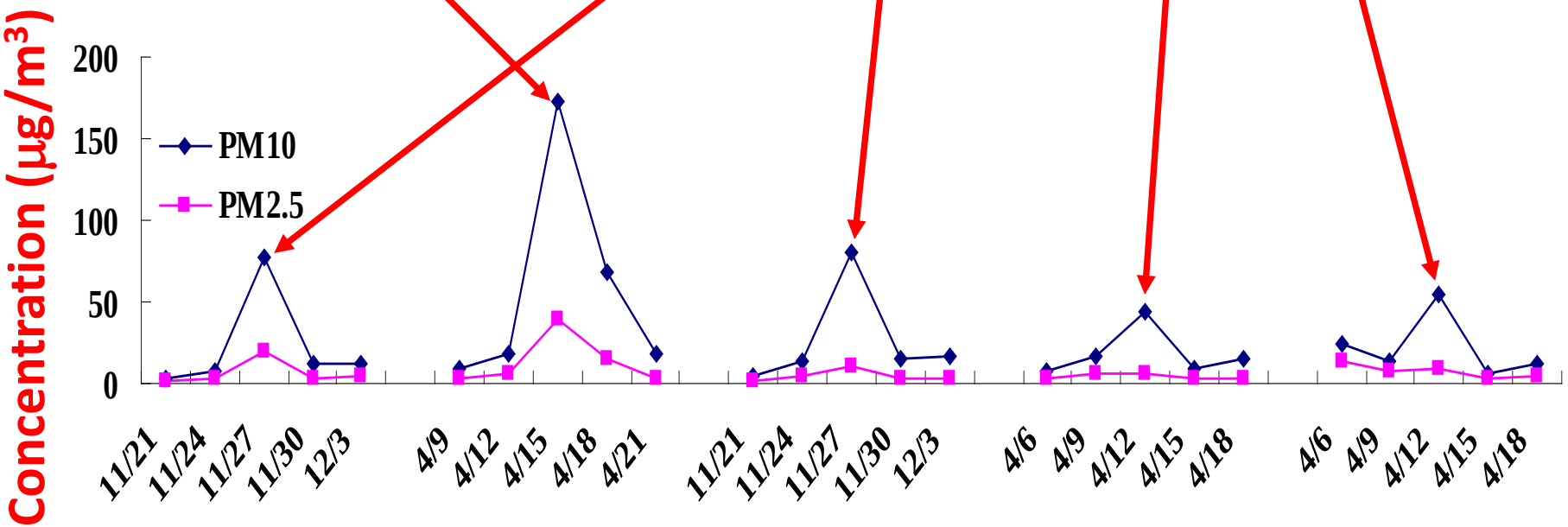
IMPROVE Samplers
Samples Analyzed at UC-Davis

Satellite-aided Algorithm Training



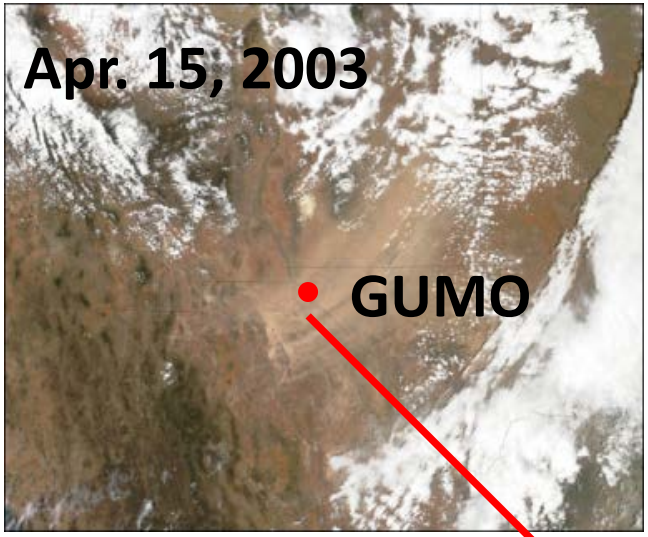


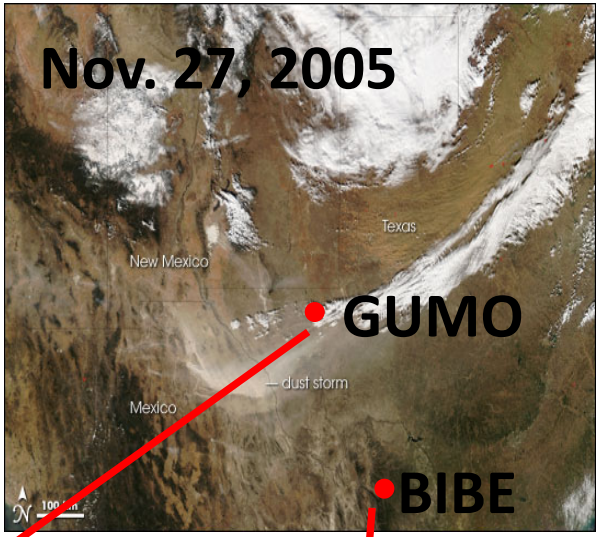


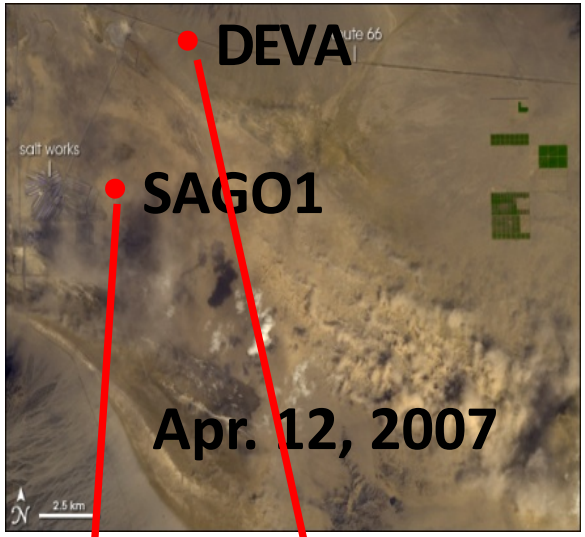


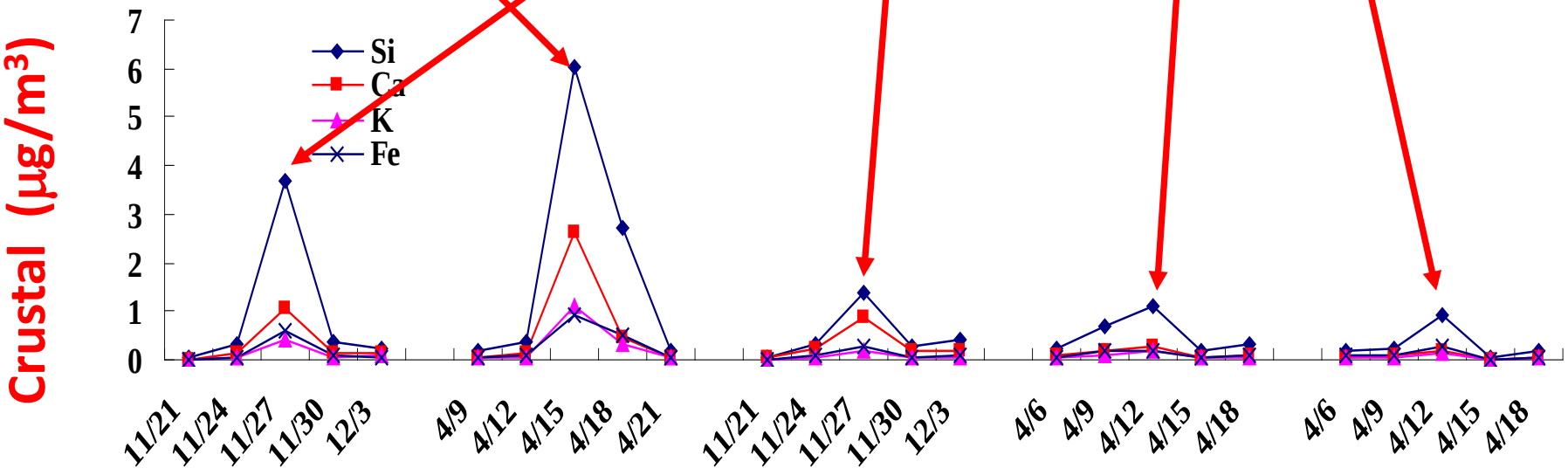
PM10: Particulate Matter < 10 μm **PM2.5: Particulate Matter < 2.5 μm**

Satellite-aided Algorithm Training









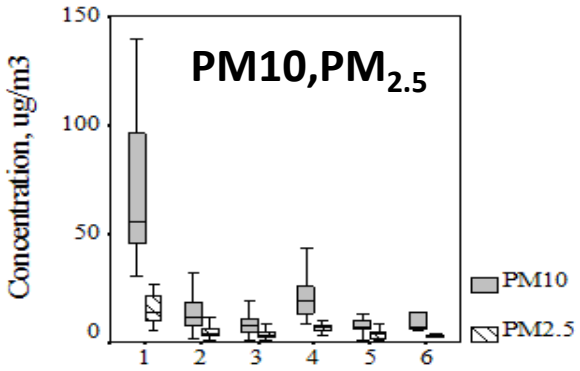
Si – Silicon; Ca – Calcium; K – Potassium; Fe – Iron

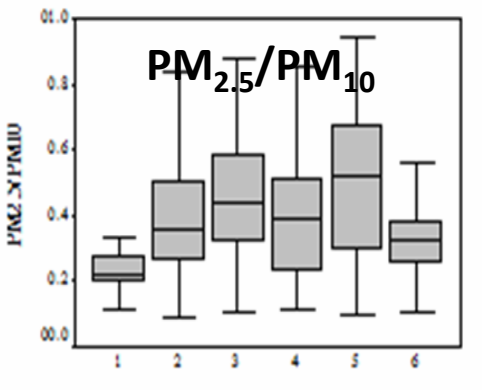
Dust Identification through Cluster Analysis

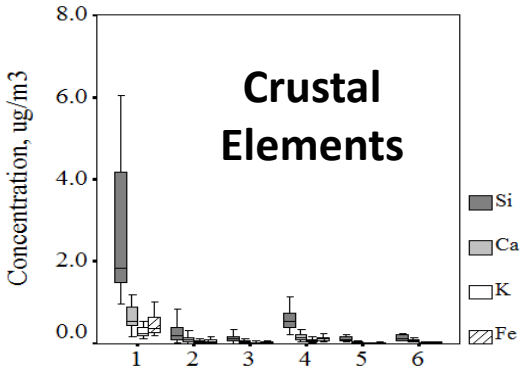
Five Dust Indicators:

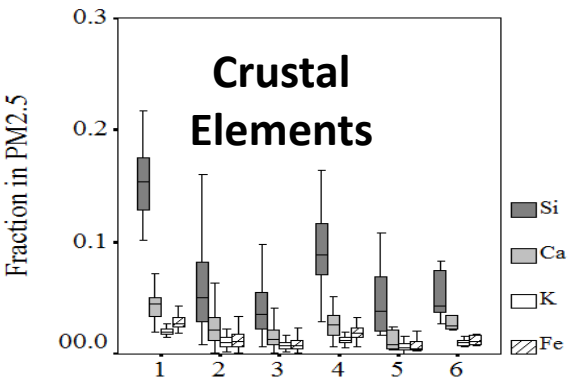
- High PM_{10}, $PM_{2.5}$;
- Low $PM_{2.5}/PM_{10}$ ratio
- High Crustal Fraction
- Low anthropogenic Fraction;
- Low Enrichment Factor;

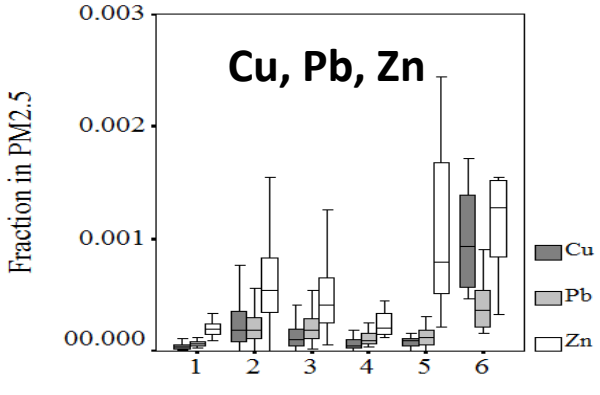
Cu– Copper
Pb – Lead
Zn – Zinc

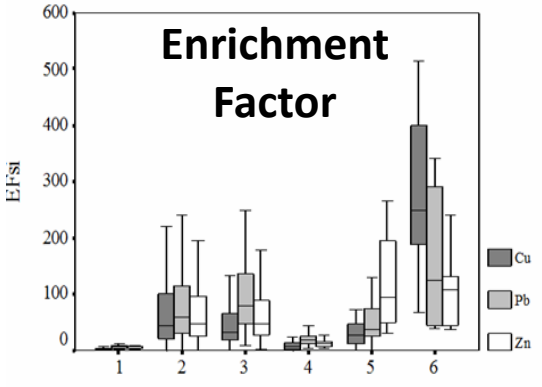




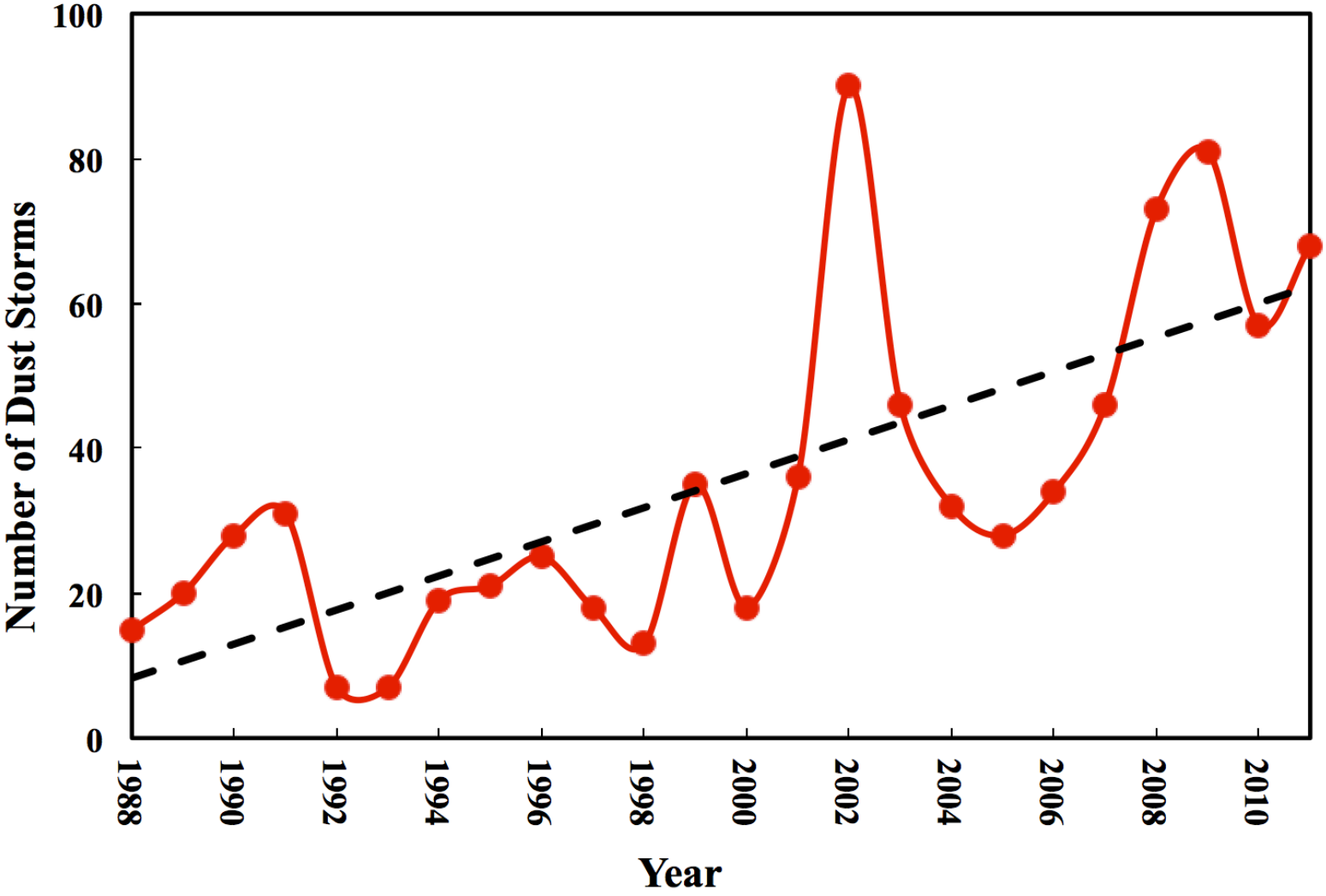






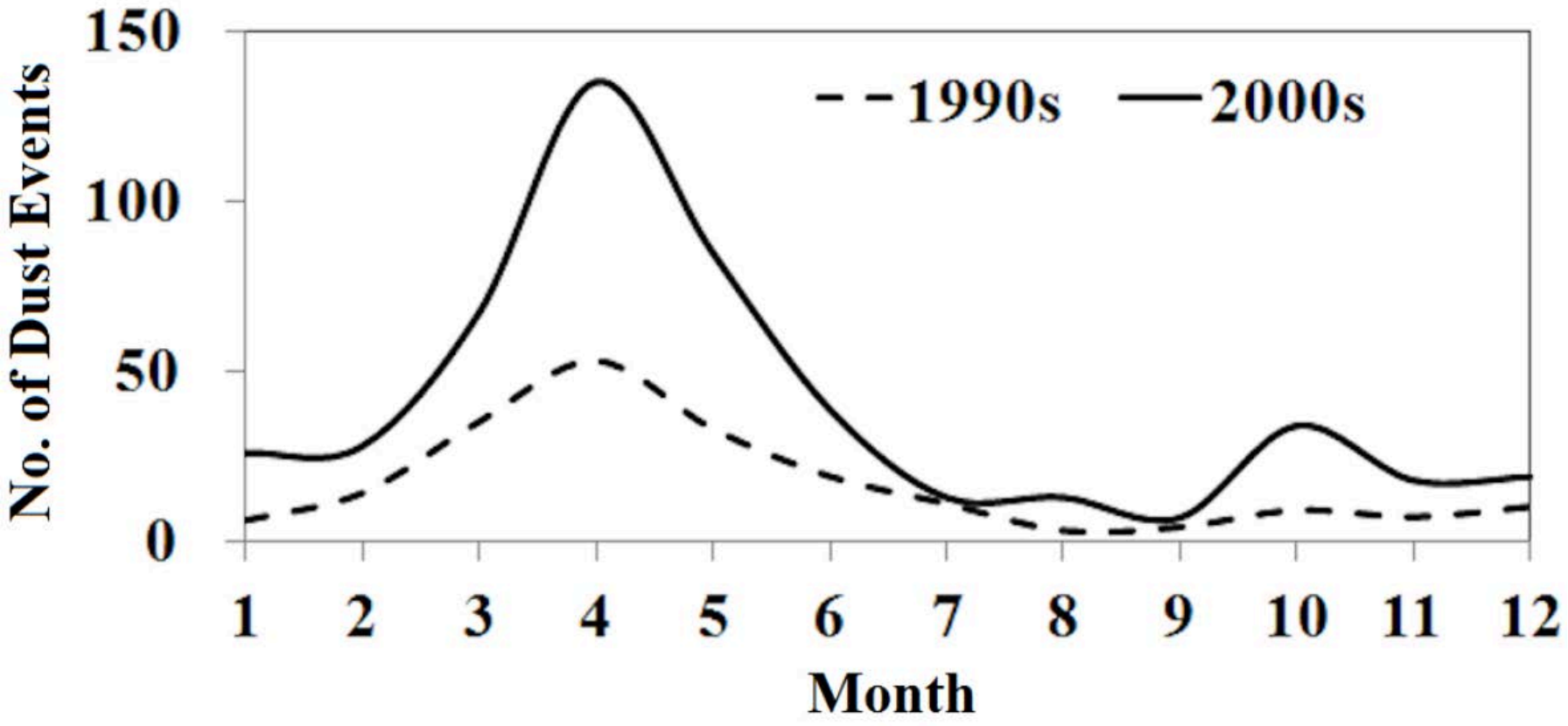


Long-term Dust Trend



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

Seasonal Variation

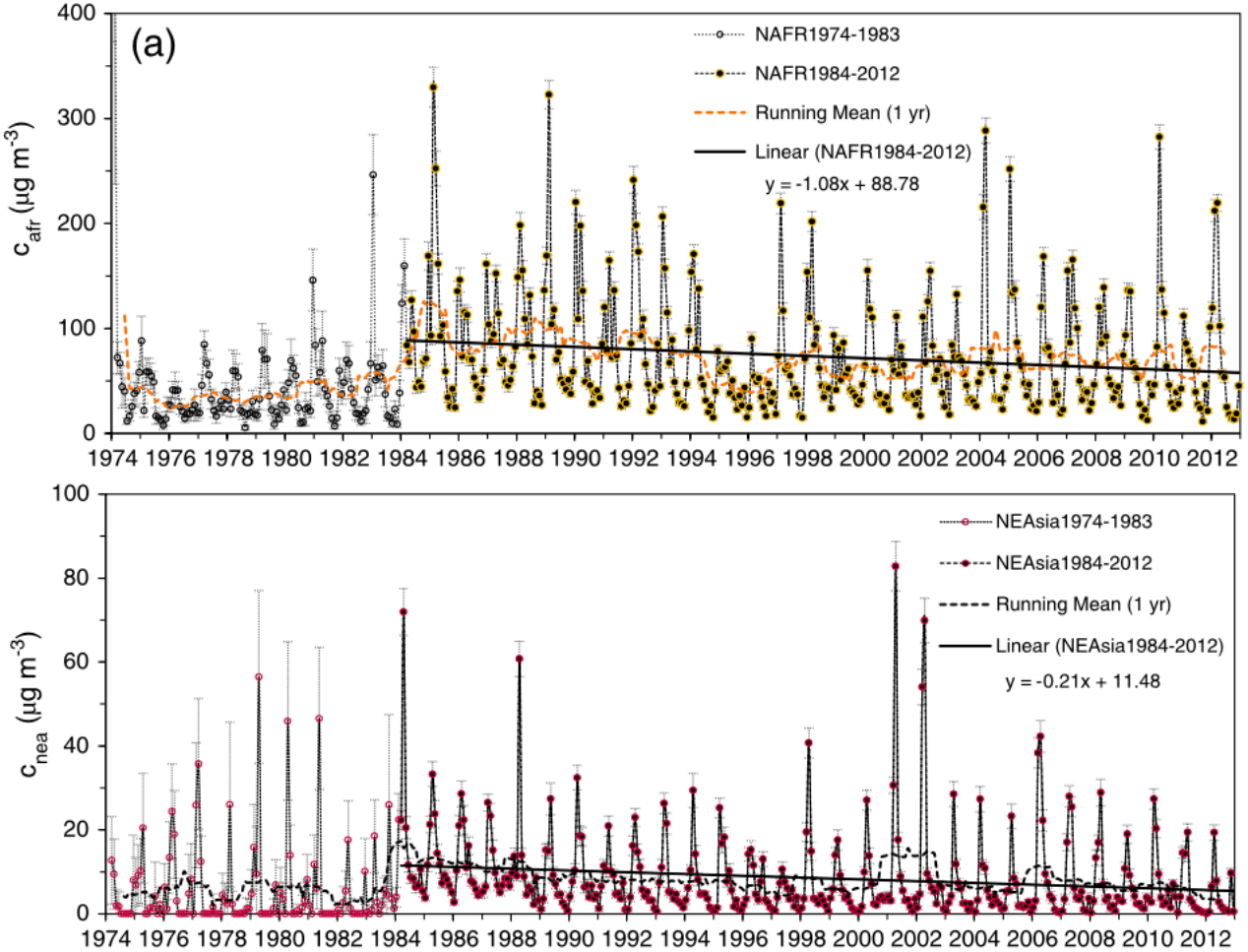


Increase in Spring (mostly) and Fall;

Almost no change in Summer/Wet Season;

Decreasing Dust Trends in Asia and Africa

(Shao et al., 2013)

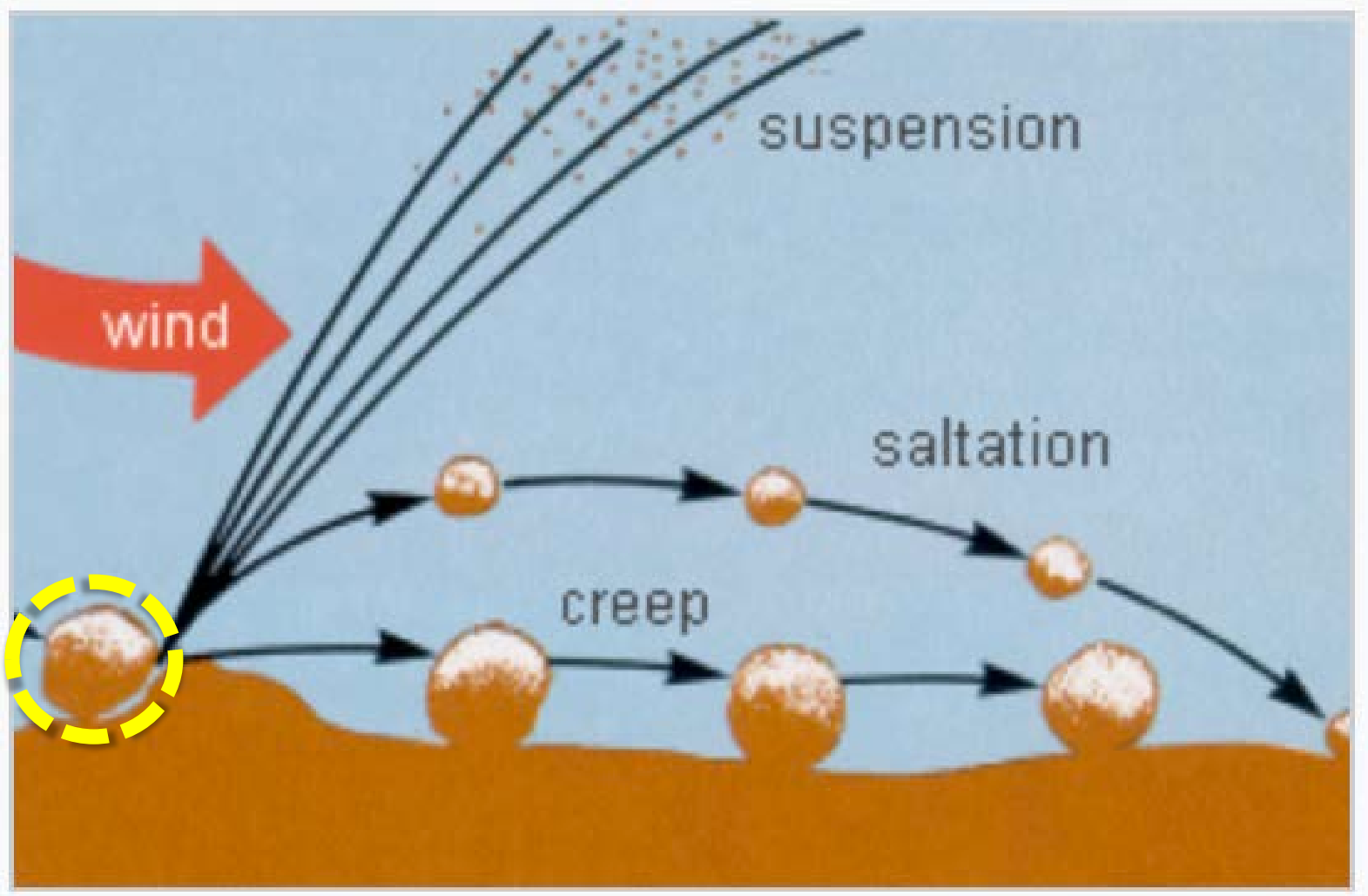


Northern Africa

Northern Asia

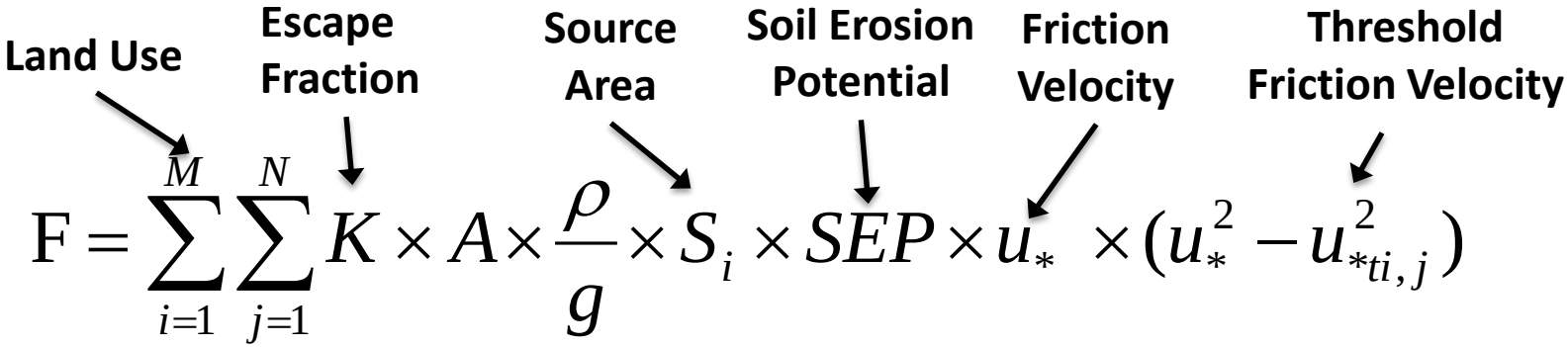
Global dust concentration decreased at 1.2%/yr from 1984 –2012

Physics of Dust Emission



Numeric Modeling of Dust Emission

Dust emission model FENGSHA:



How does soil moisture affect dust emission?

Path 1: Vegetation cover partitions wind energy;

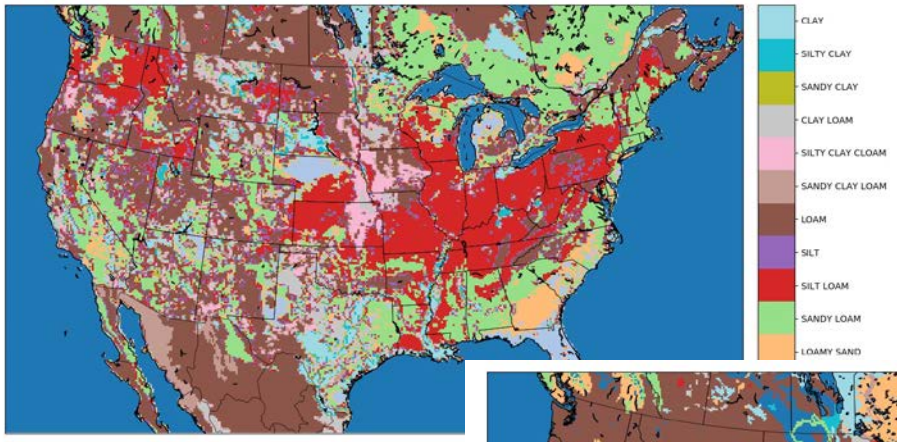
Path 2: Moist increases cohesive binding (Fecan et al., 1999);

$$u_{*t} = u_{*t} \; x \; f_m$$

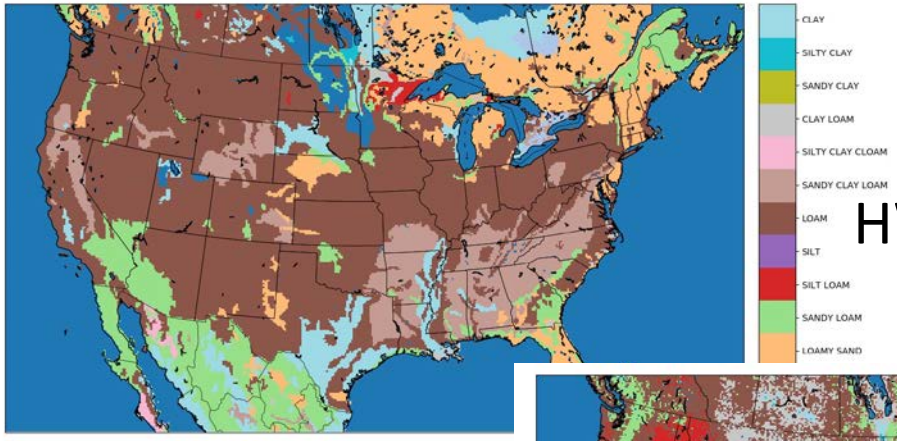
$$f_m = (1.0 + 1.21 * (s_m - w')^{0.68})^{0.5}$$

Soil Moisture **Saturation point**

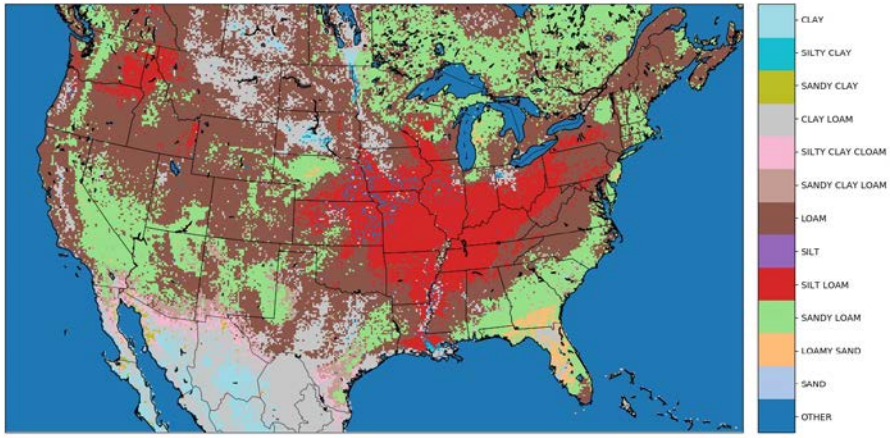
Soil Classification Update



STATSGO-FAO – 1km North America



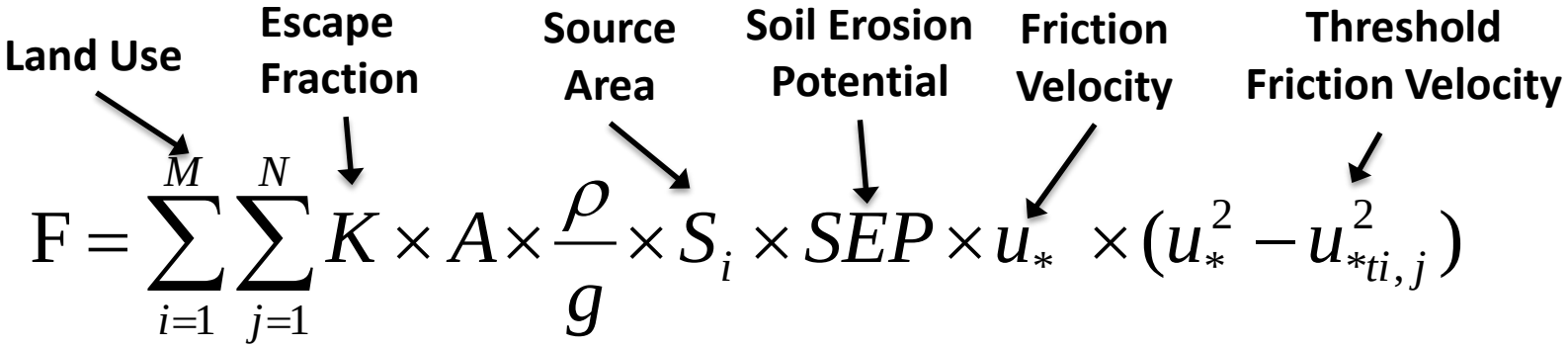
HWSD – Global 5km



ISRIC (http://www.isric.org/)
up to 250m resolution

Numeric Modeling of Dust Emission

Dust emission model FENGSHA:



$$\mathrm{F} = \sum_{i=1}^{M}\sum_{j=1}^{N} K \times A \times \frac{\rho}{g} \times S_i \times SEP \times u_* \times (u_*^2 - u_{*ti,j}^2)$$

Update to the Threshold Friction Velocity

$$u_{*_t} = \frac{u_{*_{ts}}}{f_{eff}} R(w)$$

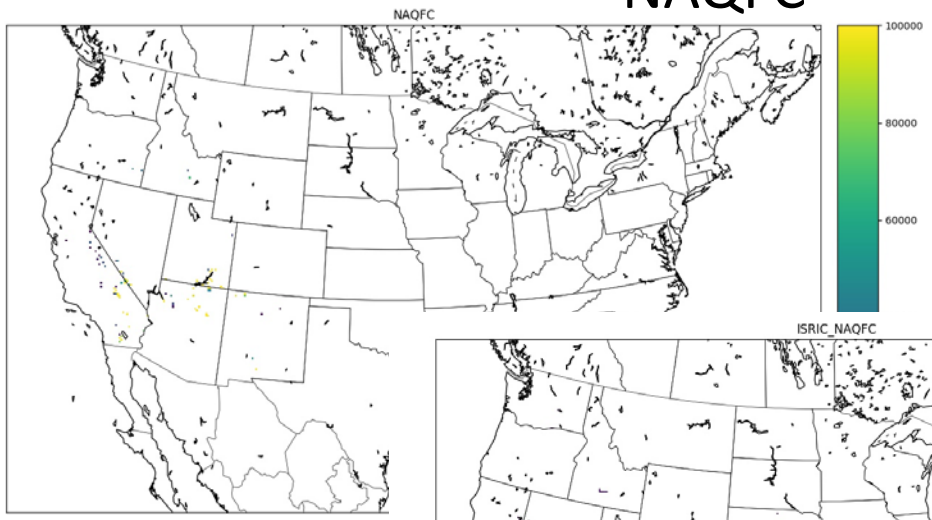
Update feff to that of MacKinnon et al. 2004

$$f_{eff} = 1 - \frac{ln\left(\frac{z_0}{z_{0s}}\right)}{ln\left[0.7\left(\frac{12255cm}{z_{0s}}\right)^{0.8}\right]}$$

DOI:10.1016/j.geomorph.2004.03.009

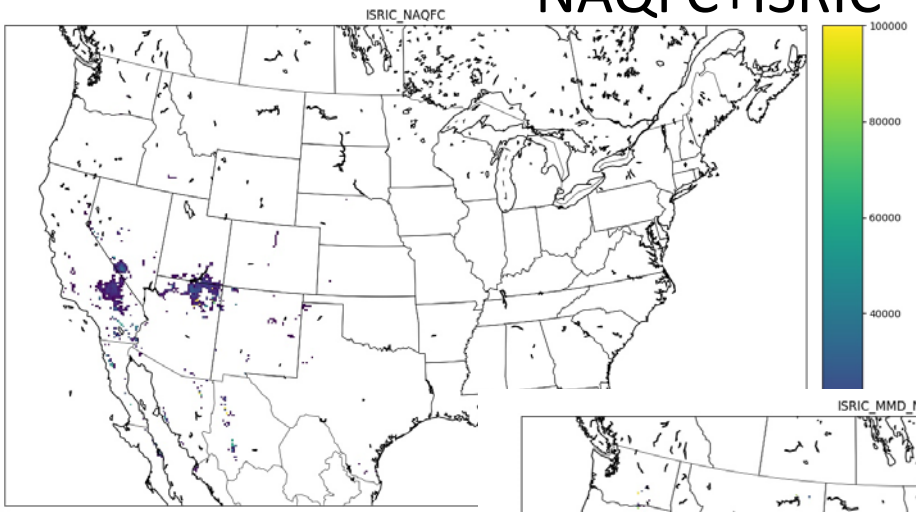
Total Updates to FENGSHA

NAQFC



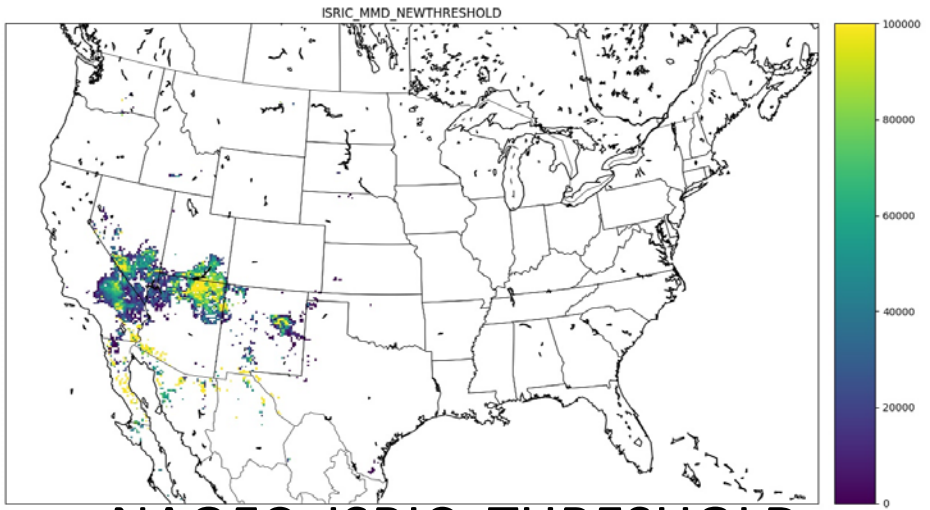
NAQFC base gives sparse but strong emissions in relevant areas but spatial extent small.

NAQFC+ISRIC



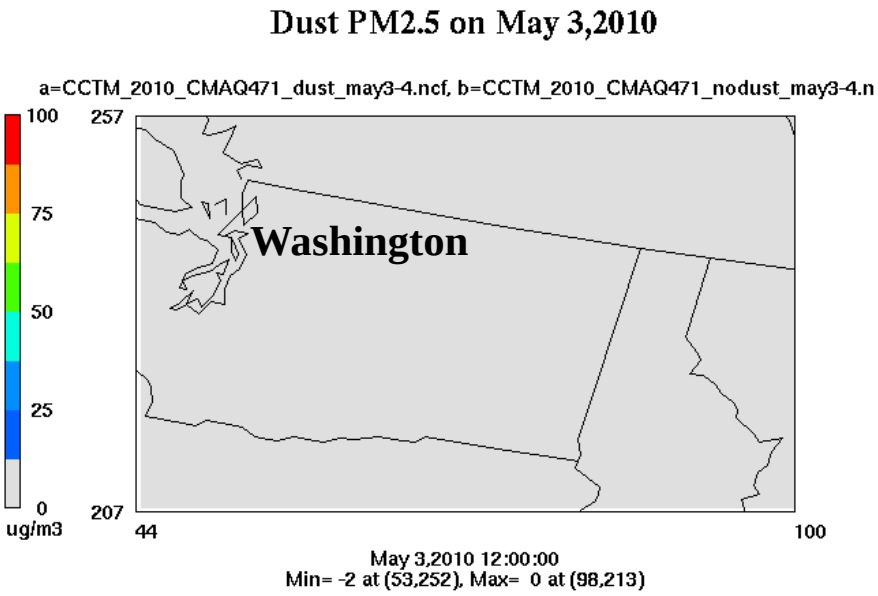
NAQFC+ISRIC improves spatial coverage but decreases emission strength

NAQFC+ISRIC+THRESHOLD improves spatial coverage further plus maintains the correct strength of emissions. Also includes more emissions in Mexico and the Yucatan Peninsula



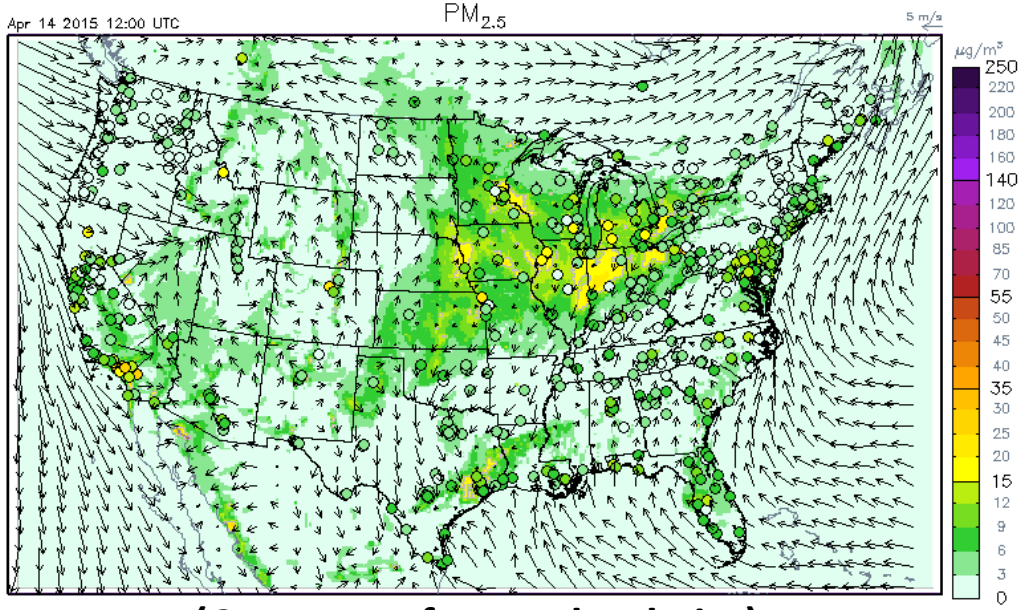
NAQFC+ISRIC+THRESHOLD

NOAA Dust Emission Modeling



12:30 p.m, May 3,2010

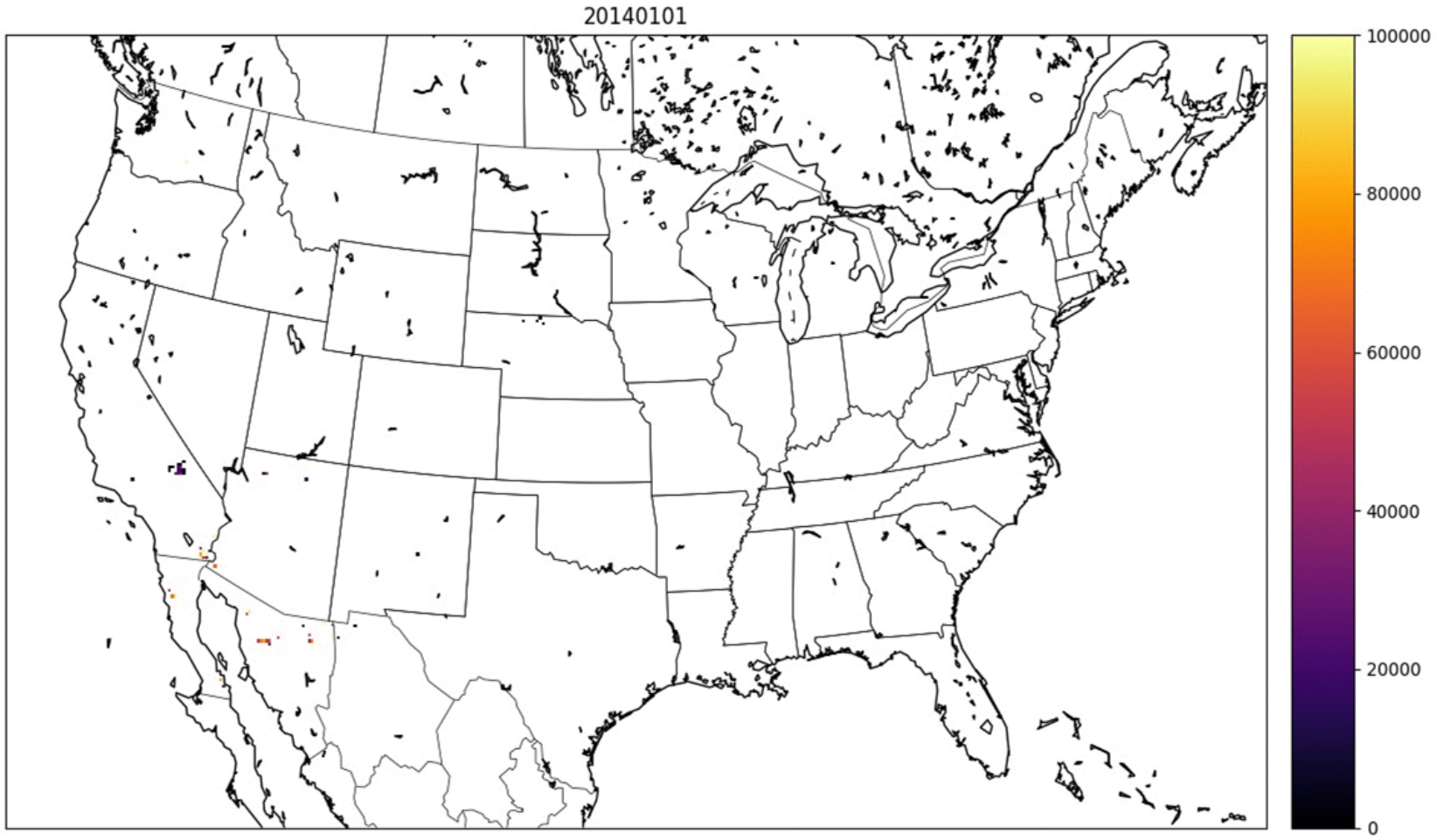
--http://earthobservatory.nasa.gov/NaturalHazards



(Courtesy of Hyuncheol Kim)

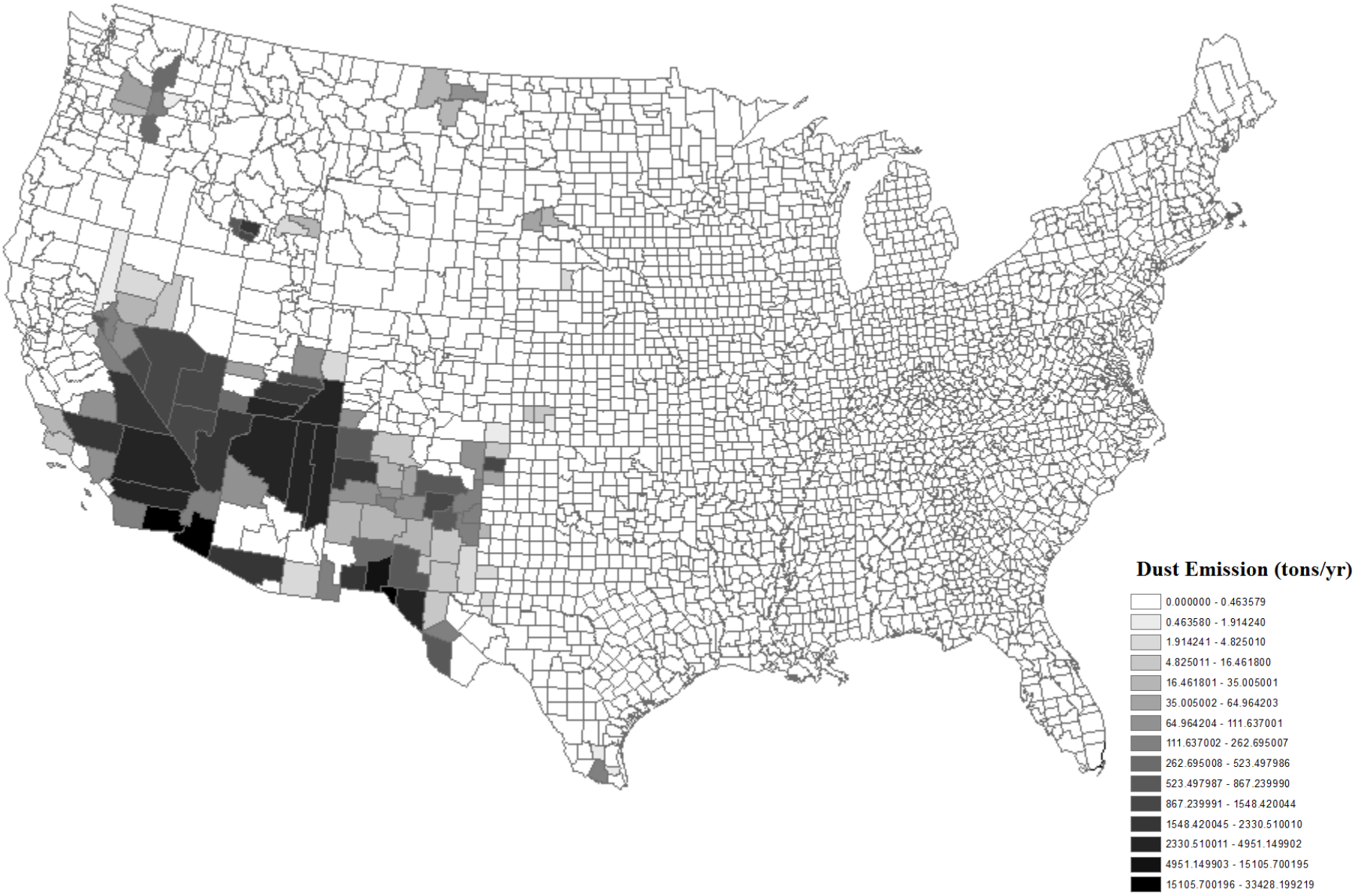
Dust storms in UT/NV

Monthly Wind Erosion Simulated by the FENGSHA model

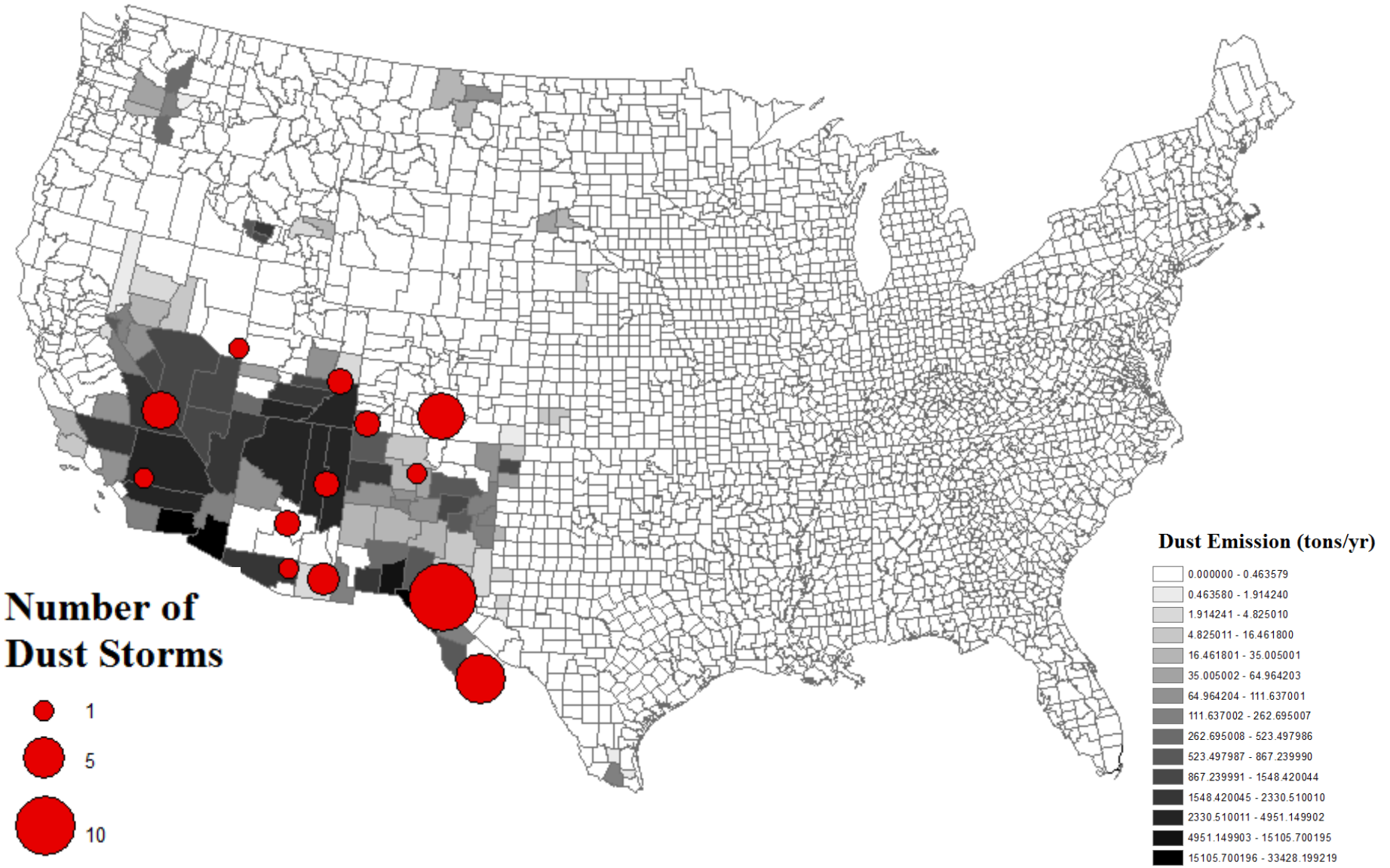


(Contributed by Barry Baker)

Annual Natural Dust Emission by County



Natural Dust Emission and IMPROVE Observations



Summary

- **Dust storms increased 240% from 1990s to 2000s in the western United States.**
- **Increased natural dust emissions pose many threats to air quality and public health.**
- **Ongoing efforts to develop a county-level inventory of natural dust emissions using the FENGSHA model and remotely sensed land surface data.**
- **Preliminary results show good agreement between dust emission and observed dust from the IMPROVE network.**

Acknowledgment & Data Access

- **Funding Support: NASA ROSES and NOAA USWRP;**
- **Data: EPA, NOAA, NASA, CDC, Arizona DHS and ISRIC;**
- **Many colleagues for inspiring discussion.**

- **Data Access: Email qtong@gmu.edu**
- **Project Website: http://ws.laits.gmu.edu/nca**

Controlling Factors of Valley Fever

Factors		Correlation (r) with Cocci. Incidence Rate	
		Maricopa	Pima
PM_{10} ($\mu g/m^3$)		-0.39	-0.53
$PM_{2.5}$ ($\mu g/m^3$)		-0.35	-0.60
Dust Number		0.51	0.36
Dust Frequency		0.51	0.41
Precipitation Anomaly (mm/mon)	Annual	-0.25	-0.18
	Spring (MAM)	-0.28	-0.45
	Early Spring (JF)	-0.12	-0.12
	Prior Winter (NDJ)	-0.10	-0.19

- Dust frequency is one of the best indicator to Valley fever;
- Unlike PM_{10} (previously used in health models), dust is positively correlated to the disease.

Satellite Comparisons