Satellite-aided Regional Dust Forecasting for Valley Fever Surveillance, Highway Safety and Air Quality Management

Daniel Tong

George Mason University, Fairfax, VA

NASA Health and Air Quality Annual Review Meeting
October 20, 2021

Project Information

Lead PIs: Daniel Tong (GMU), Orion McCotter (Formerly CDC), Pius Lee (NOAA), and Jesse Bell (UNMC)

Co-Investigators/Collaborators

Thomas Gill, UTEP
William Sprigg, SPC
Junran Li, University of Tulsa
Zhong Liu, NASA/GSFC & GMU
Ziheng Sun, GMU
Robert Levy, NASA
Liping Di, GMU
Ralph Kahn, NASA
Nicolas Webb, USDA
Adrain Chappell, Cardiff University (UK)
Julian Wang, NOAA

Stakeholders (New):

Jonny Malloy, ADEQ
Matthew Roach, ADHS
David Hadwiger, NM DOT
Scott Van Pelt, USDA ARS
Scott DiBiase, Pinal County AQCD
Beth Gorman, Pima County DEQ
Andy Edman, NWS
Jeff McQueen, NWS
Dale Griffin, USGS
Mariana Singletary, Pinal County DoH
Alexander Baklanov, WMO
Andrea Sealy, WMO Pan-America
Michael Lewis, US Army ERDC
Brooke Doman, NM DoH
TuSimple (Autonomous Trucking)
10+ new ones added in 2021

Satellite-aided Dust Forecasting
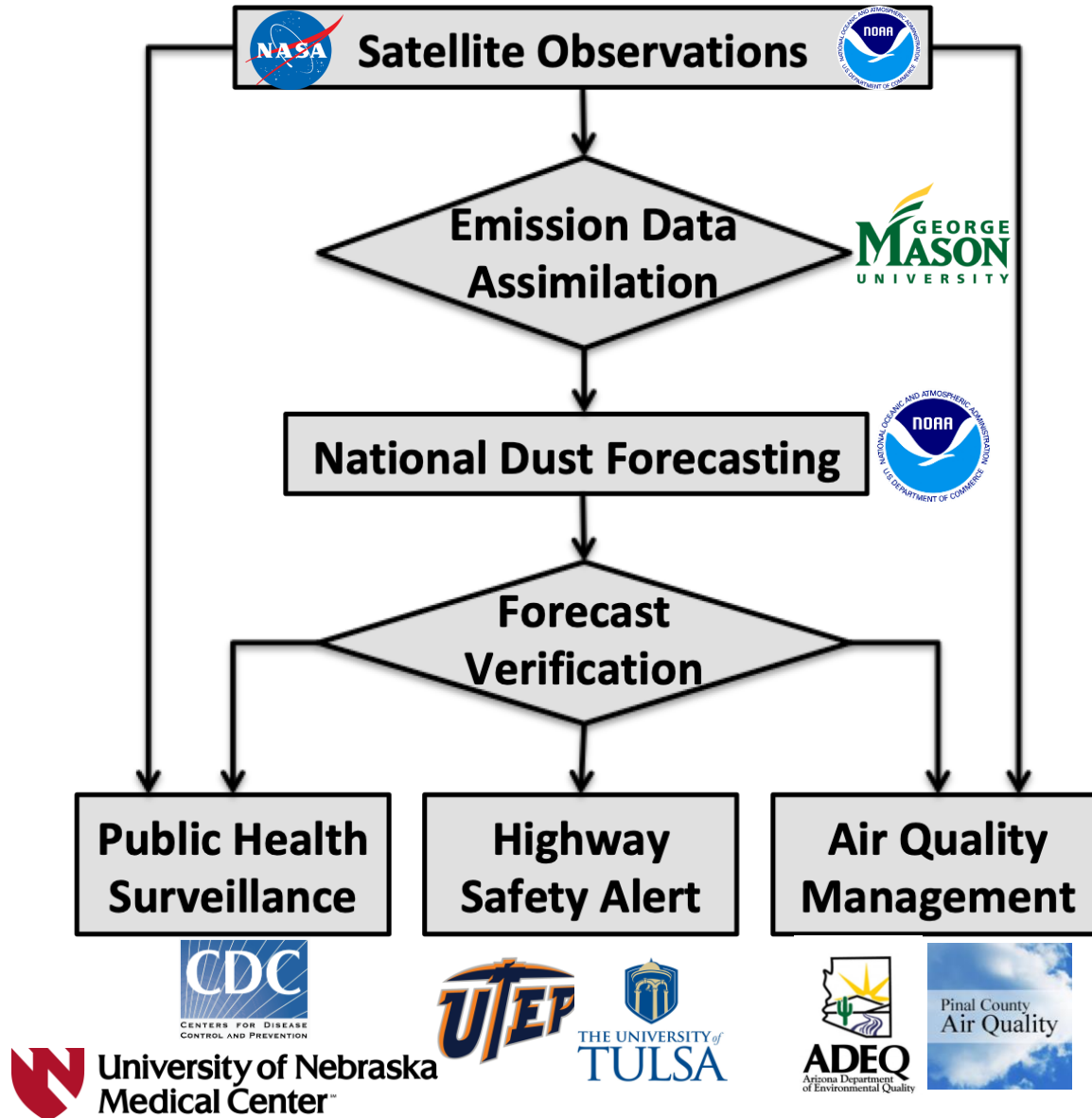
Objectives:

1. Improve national dust forecasting with satellite observations;
2. Support three dust services:
   a) Valley fever surveillance;
   b) Highway safety alert;
   c) Air quality management.

Summary of Team Achievements

- **Publications:** Eleven journal papers, Three in review; New "Dust and Health Review" under WHO & WMO.
- **Presentations:** 17 Presentations; 4 AGU/AMS sessions organized on GeoHealth and Air Quality;
- **Stakeholder meetings:** 12 small groups; Western US Dust Workshop;
- **Capability transfer**: National Weather Service albedo-based dust forecasting; Pima County air quality forecast advisory;
- **Media/Outreach:** 11 interviews and many republications; WMO news release; etc.

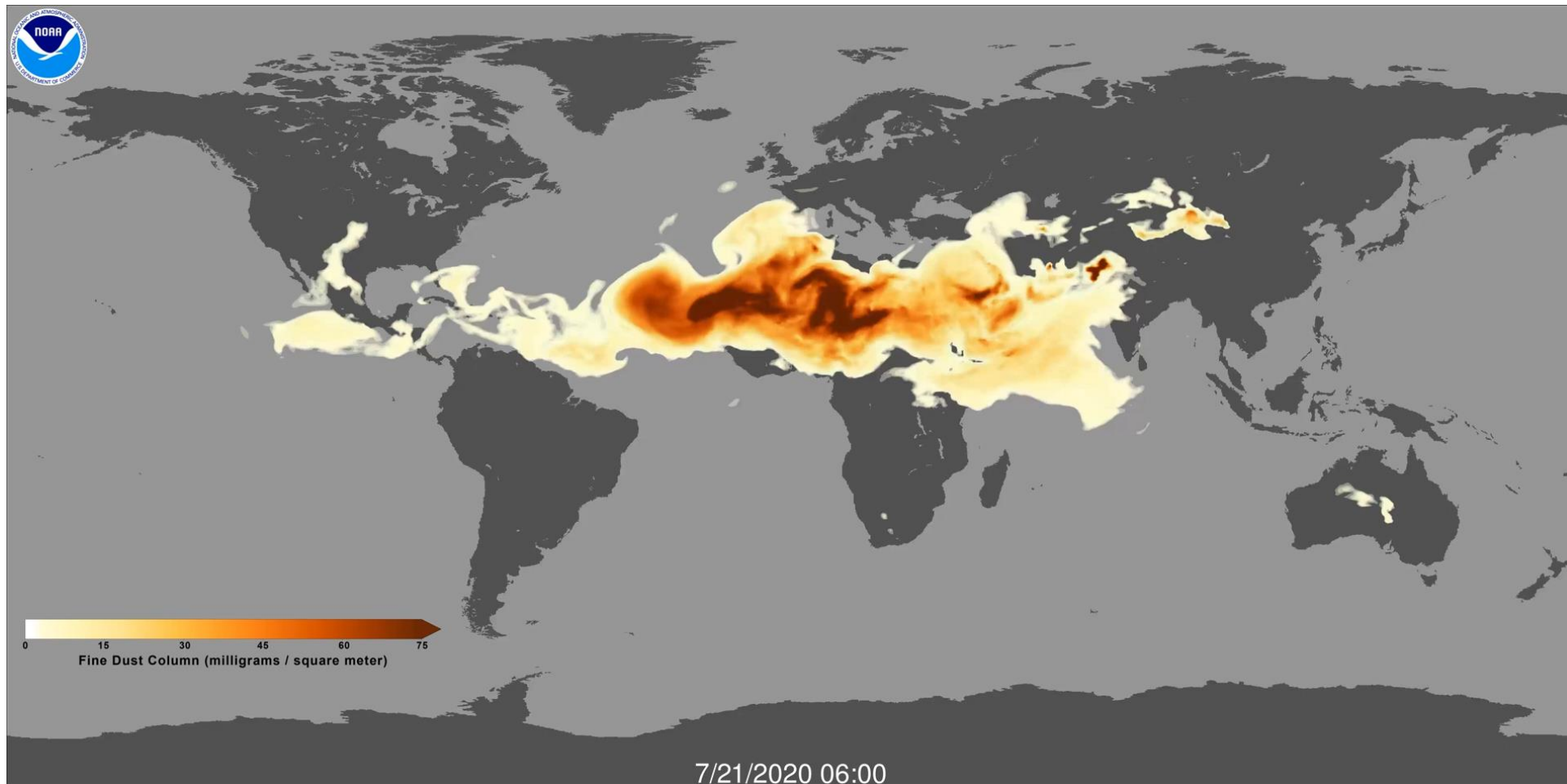# PM$_{2.5}$ Forecast during the March 15 Dust Storm
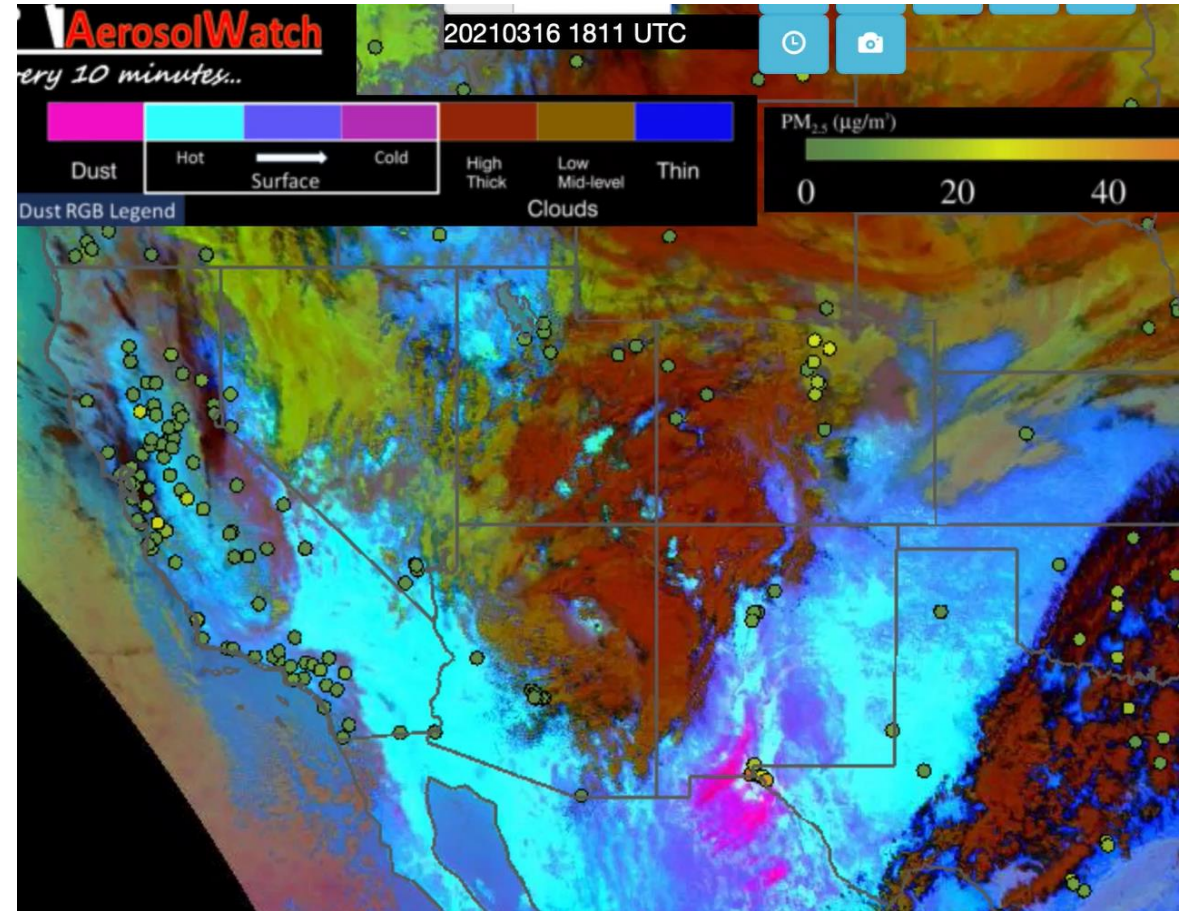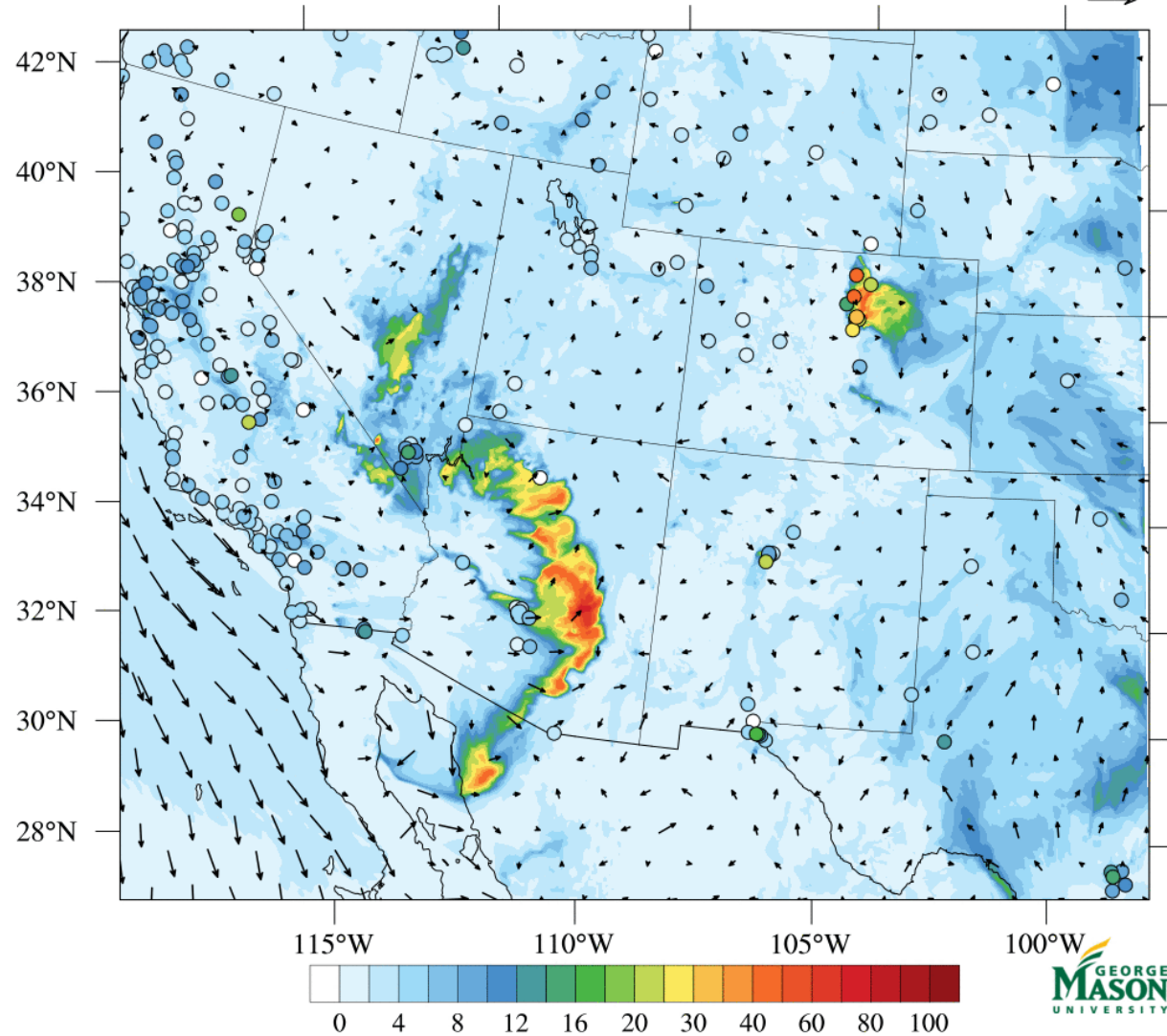
Capability Transfer: Albedo-based Dust Forecast
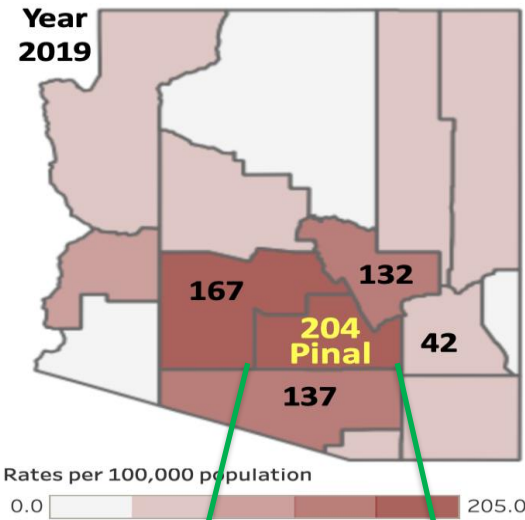
- FENGSHA dust code into NOAA operational models: GEFS-Aerosol, NAQFC CMAQ;
- Additional NOAA models: HYSPLIT and RAP-Chem; USFS and RRFS-CMAQ.
- NASA GOCART_v2 through NOAA-NASA joint venture;
- MODIS/VIIRS albedo and BRDF used for dust source map and drag partition.
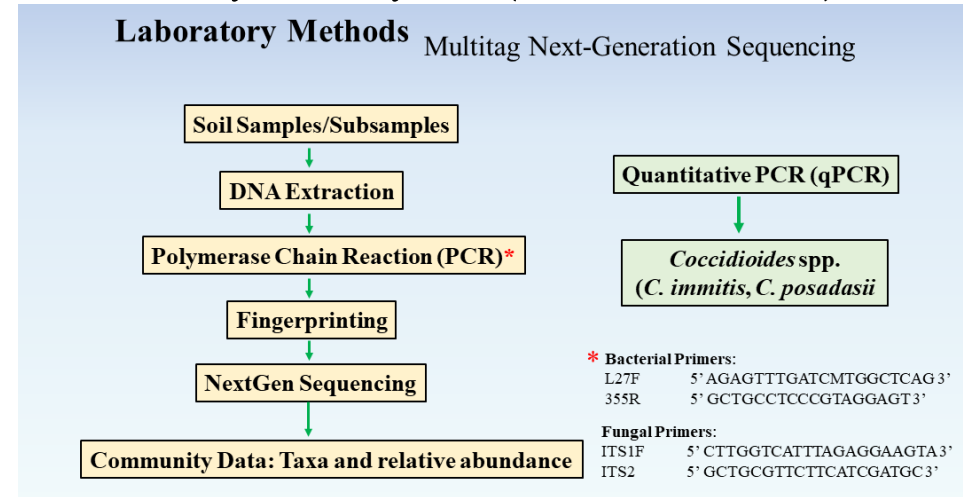

(Courtesy of Barry Baker)

Fine Dust Column (milligrams / square meter)

0   15   30   45   60   75

7/21/2020 06:00

Detecting Dust Microbes

Objective: Develop forecast capability of airborne microbes, including *Coccidioides*.

Laboratory Analysis (GMU/CDC)

Laboratory Methods — Multitag Next-Generation Sequencing

- Soil Samples/Subsamples
- DNA Extraction
- Polymerase Chain Reaction (PCR)*
- Fingerprinting
- NextGen Sequencing
- Community Data: Taxa and relative abundance

- Quantitative PCR (qPCR)
- *Coccidioides* spp. (*C. immitis*, *C. posadasii*)

* Bacterial Primers:
L27F   5' AGAGTTTGATCMTGGCTCAG 3'
355R   5' GCTGCCTCCCGTAGGAGT 3'

Fungal Primers:
ITS1F   5' CTTGGTCATTTAGAGGAAGTA 3'
ITS2   5' GCTGCGTTCTTCATCGATGC 3'

Year 2019

167   132
204 Pinal   42
137

Rates per 100,000 population
0.0 — 205.0

Soil and Dust Collection

MDCO

Filters

Arizona, 2020

Pinal County Public Health Department

Florence

Maricopa

Pima

SW Tucson

BSNE

PurpleAir

Bacterial Genera

Feature Volcano[Genus]
Colored by fold-change direction

Cupriavidus, Spirosoma, Sphingobium, Flavisolibacter, Noviherbaspirillum, Naasia, Succinivibrio, Treponema, Hymenobacter, Roseburia, Lactobacillus, Marinobacter, Butyricicoccus, Anaerofilum, Undibacterium, Sporomusa, Blautia, Alloprevotella, Georgenia, Alistipes, Caryophanon, Salinimicrobium, Clostridium_iv, Bhargavaea, Nocardiopsis, Halomonas, Parabacteroides, Oscillibacter, Alkalibacterium

AZ_Filter
AZ_Marble
common

Method: kruskal_wallis

How Many People Were Killed by Dust Events on Highways?
A Myth of Two Tales

The New York Times

8 Are Killed as Sandstorm in Utah Causes a Highway Pileup

Officials said 22 vehicles were involved in a crash after high winds created a sandstorm that limited visibility on Interstate 15. Some of those killed were children, the highway patrol said.
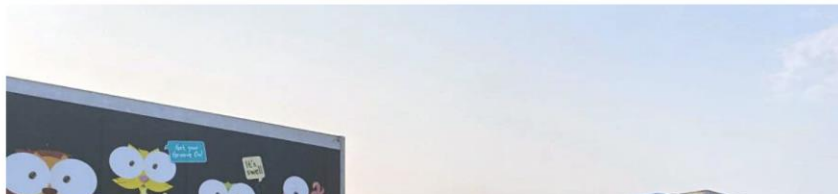
6 killed in 25-vehicle pileup at New Mexico-Arizona line

UPDATED ON: JUNE 20, 2017 / 6:51 AM / AP

LORDSBURG, N.M. -- Authorities in New Mexico say six people are dead after a 25-vehicle pileup on I-10 was caused by sudden blowing dust in New Mexico near the Arizona state line.

Summary of Natural Hazard Statistics for 2017 in the United States

This National Weather Service (NWS) report summarizes fatalities, injuries and damages caused by severe weather in 2017. The NWS Office of Climate, Water and Weather Services and the National Climatic Data Center compiled this Summary of U.S. Natural Hazard Statistics from Storm Data, a report comprising statistics from NWS forecast offices in the 50 states, Puerto Rico, Guam, and the Virgin Islands.

Summary of 2017 Weather Events, Fatalities, Injuries, and Damage Costs

Weather Event	Fatalities	Injuries	Property Damage (million $)	Crop Damage (million $)	Total Damage (million $)
Other					
Drought	0	0	0.05	0.31	0.36
Dust Storm	0	0	0.35	0.00	0.35
Dust Devil	0	0	0.06	0.00	0.06

Source: https://www.nws.noaa.gov/om/hazstats/sum17.pdf

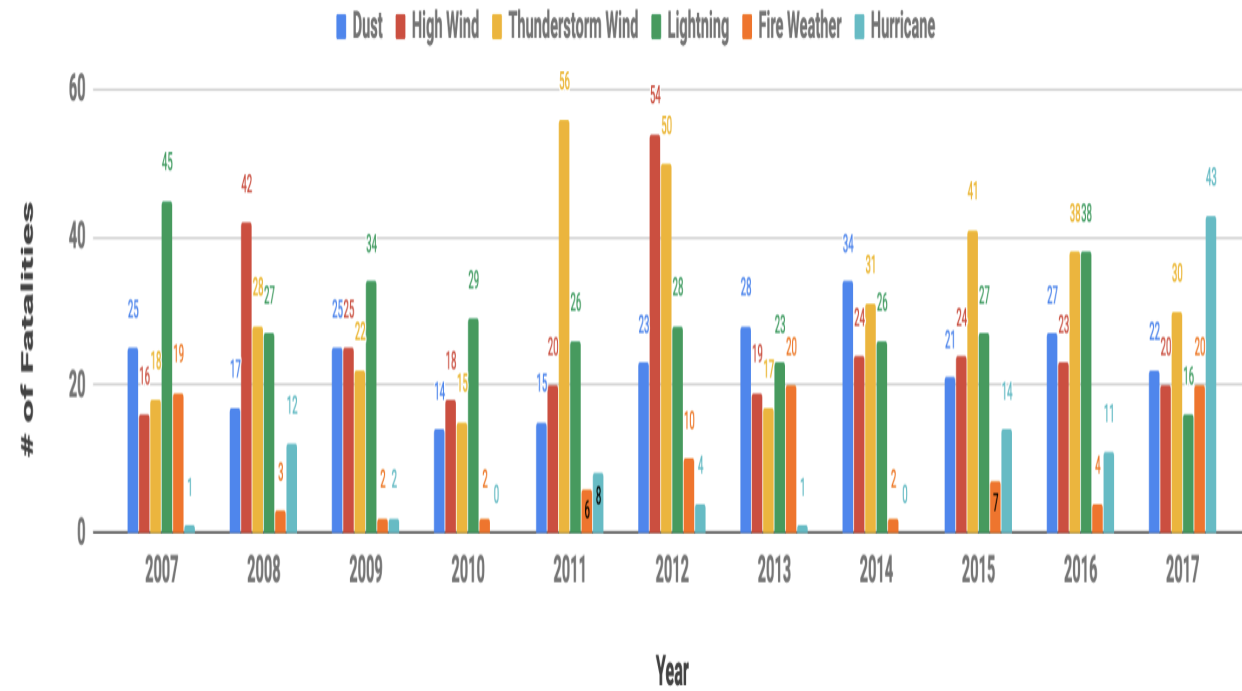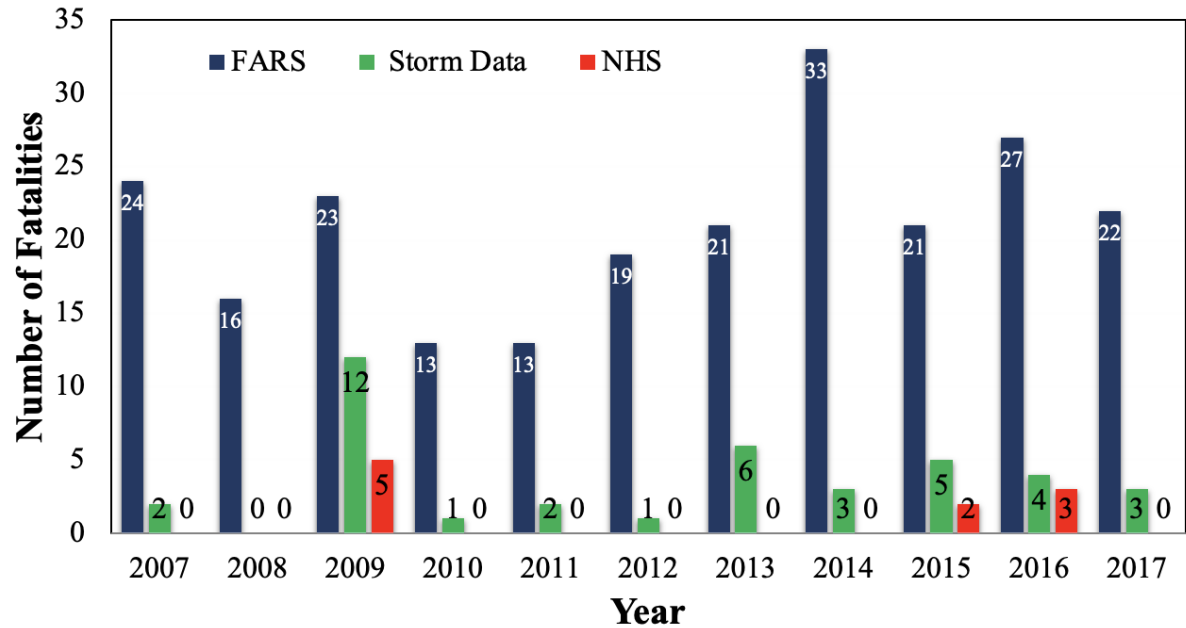# A Lot of People Killed by Dust Storms!

(Irene Feng, Thomas Gill & Kerstin Schepanski)

Three datasets:

NHS: Natural Hazard Statistics (NOAA)

Storm Data: Storm Event Dataset (NOAA)
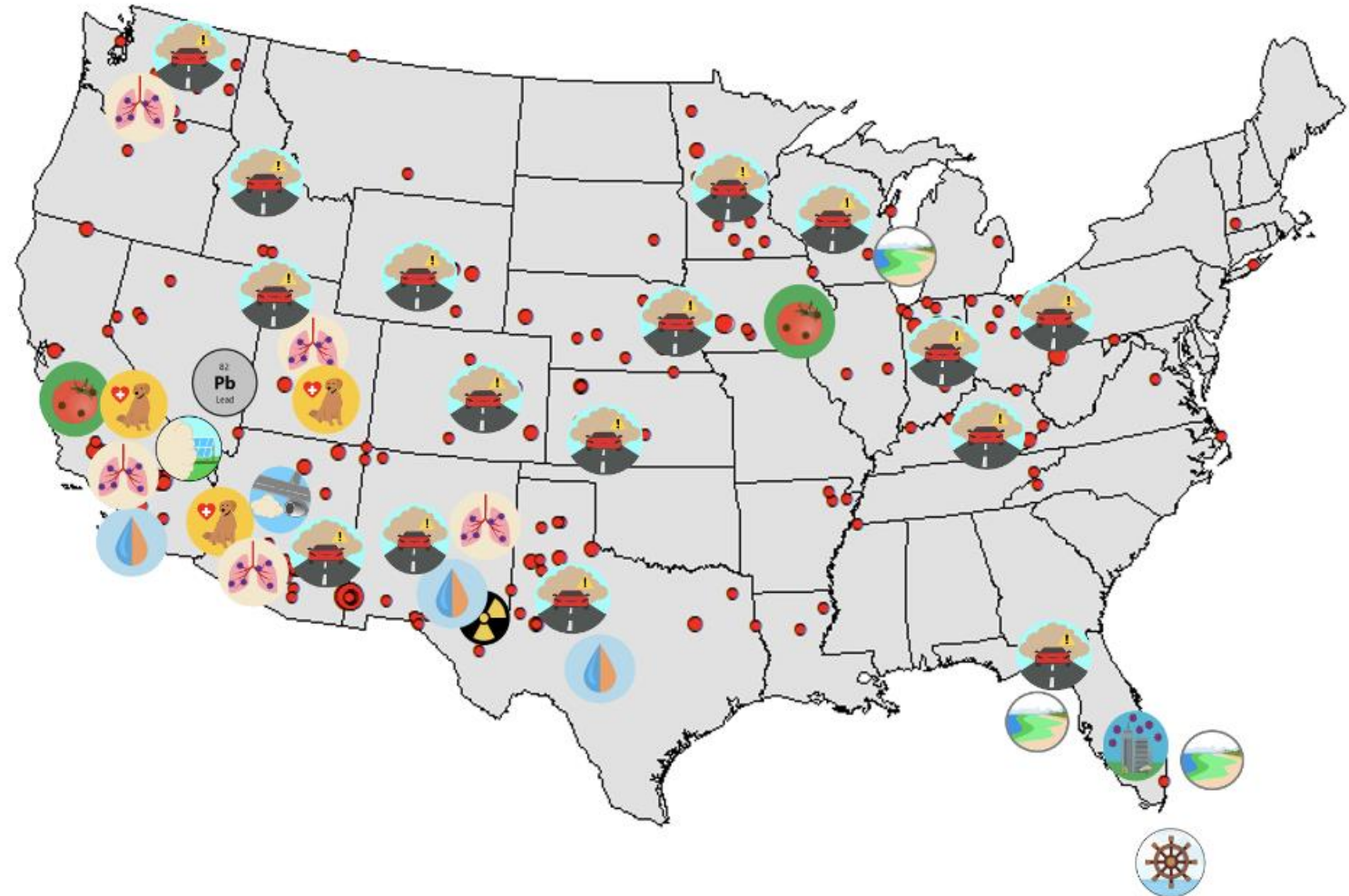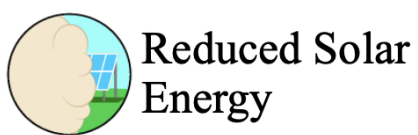
FARS: Fatality Analysis Report System (DOT)

How did NHS go wrong?

1) Incomplete reporting;
2) Miscategorized statistics;

National Weather Service has changed their dust reporting system.

Dust Effects on Health and Safety in the US

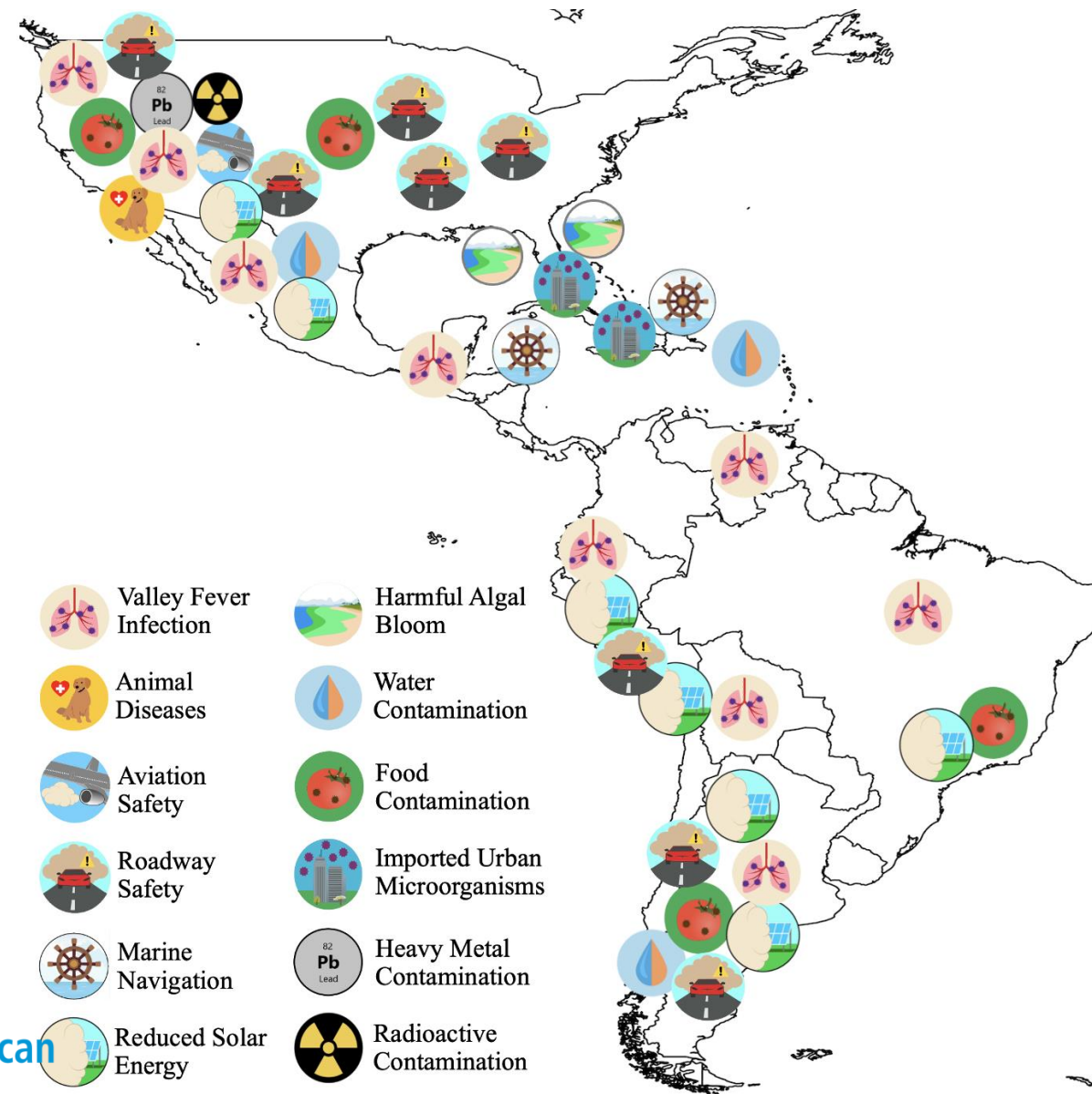## A Joint Review by NASA Dust Team and WMO SDS-WAS Pan-American Center

WHO/WMO Dust Health Review

A Joint Review by NASA Dust Team, WHO, PAHO, and WMO

➢ WHO Guidance for Medical Practitioners;

➢ Submitted to Review of Geophysics;

Health and Safety Effects of Airborne Soil Dust in the Americas

Daniel Q. Tong[1], Alexander Baklanov[2], Bridget Marie Barker[3], Juan Castillo[4], Santiago Gassó[5], Cassandra Gaston[6], Thomas E. Gill[7], Dale W Griffin[8], Nicolas Huneeus[9], Ralph A. Kahn[10], Arunas P. Kuciauskas[11], Luis A. Ladino[12], Junran Li[13], Olga L. Mayol-Bracero[14], Orion Z. McCotter[15], Pablo A. Méndez-Lázaro[16], Pierpaolo Mudu[17], Slobodan Nickovic[18], Damian Oyarzun[19], Joseph Prospero[6], Graciela B. Raga[12], Amit U. Raysoni[20], Ling Ren[1], Nikias Sarafoglou[1], Andrea Sealy[21], William A. Sprigg[22], Ziheng Sun[1], Robert Scott Van Pelt[23], Ana Vukovic Vimic[24]

Valley Fever Infection
Animal Diseases
Aviation Safety
Roadway Safety
Marine Navigation
Reduced Solar Energy
Harmful Algal Bloom
Water Contamination
Food Contamination
Imported Urban Microorganisms
Heavy Metal Contamination
Radioactive Contamination

Project Stakeholder Workshop

SOUTHERN NM & WESTERN U.S. DUST SYMPOSIUM

October 25 – 27, 2021
Las Cruces, NM

The purpose of this symposium is to ultimately answer one question: "Are opportunities to apply dust research being missed?" Federal, state, and local agencies create policies for clean and healthy air, which benefit from both national and international research. However, difficulties arise in translating research results into policy. This symposium will attempt to bridge the gap between research and applications into policy-making that results in tangible public benefits. Topics on the agenda include dust and PM$_{10}$ mitigation issues in Southern New Mexico and beyond; dust impacts on environmental quality, transportation safety, and public health; and the state-of-the-science in airborne dust research. This symposium focuses on windblown dust in the southwestern U.S. and North America, but with a global context.

THEMES

- Dust Research
- Mitigation
- Transportation
- Health

REGISTER TO ATTEND OR SUBMIT AN ABSTRACT HERE:

https://tinyurl.com/dustworkshop

DEADLINE TO SUBMIT AN ABSTRACT:
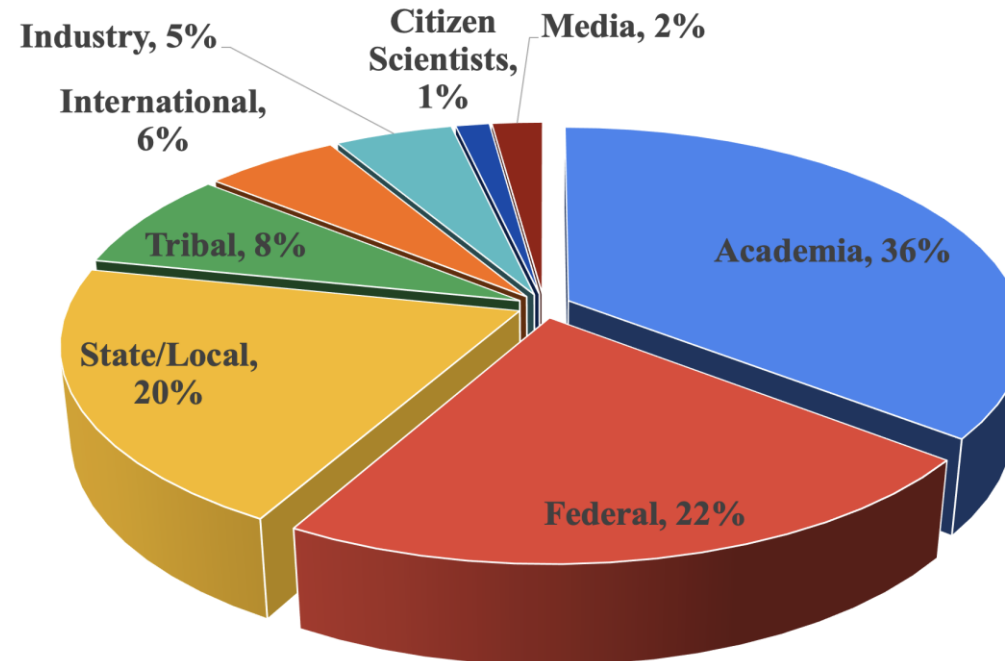OCT 8, 2021

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- Team up with stakeholder NM Dept. of Environ.
- Networks: HAQ Dust Team; Southern NM Symposium; Arizona Dust Workshop; WMO Sand and Dust Storms Warning Advisory and Assessment System (SDS-WAS); European COST inDust.
- 150+ registered participants;

Pie chart: Academia, 36%; Federal, 22%; State/Local, 20%; Tribal, 8%; International, 6%; Industry, 5%; Citizen Scientists, 1%; Media, 2%

Outreach and Media Reports
A dozen interviews and numerous republications

Eos *Science News by AGU*

ABOUT   SPECIAL REPORTS   TOPICS ∨   PROJECTS ∨   NEWSLETTER   SUBMIT TO *EOS*

Saving Lives by Predicting Dust Storm

In the southwestern United States, dust storms form suddenly, quickly reducing visibility to zero. A new motorists to avoid these deadly hazards.

By Jackie Rocheleau   14 December 2020

Tong's forecasting system, part of a larger project with the Applied Sciences program at NASA, will not only help reduce highway accidents but could also improve disease surveillance for valley fever and air quality management. "If we do things right," said Tong, "then we can save people's lives."

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May 6, 2021

Dust Storms and Valley Fever in the American West

Valley fever is a dangerous threat to human health – and cases are on the rise in the arid southwestern United States, as wind from increasing dust storms can transport the fungal spores that cause the disease. Valley fever is caused by the *Coccidioides* fungus, which grows in dirt and fields and can cause fever, rash and coughing. Using NASA research and satellite data, the World Meteorological Organization is refining its Sand and Dust Storm Warning Advisory and Assessment System to help forecast where dust risk is greatest.

George Mason University's Daniel Tong, one of the first scientists to discover the link between dust storms and Valley fever, leads a NASA-funded team to track the airborne spread of Valley fever across the United States for the first time.

There are about 15 thousand cases of Valley fever in the U.S. each year, and approximately 200 deaths, according to the U.S. Centers for Disease Control (CDC). Funded by NASA's Earth Science Division, Tong's team is helping track disease risk for epidemiologists, health care providers and public health decision makers.

"Our paper was the first one to reveal the positive relationship between dust storms and Valley fever," said Tong. "So now we're asking the question: How can we detect that dust in the air?"

Tong and his team are combining NASA satellite data and high-end computer modeling with homemade dust catchers made of pans for baking cakes and marbles. Previously, on-site dust sampling was only available through expensive monitors, such as the ones used by the CDC. When

A cake pan filled with marbles is one of the sa...

■ HEALTH

Scientists work to unravel fungus ecology as Valley fever expands throughout West

by **Shaena Montanari**   September 28, 2021

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WMO issues Airborne Dust Bulletin

Tags: Environment   Sand and Dust Storms

7   Published 7 July 2021

One of the major regional developments this year is the funding of a new ensemble dust forecasting project by the US National Aeronautics and Space Agency (NASA), in partnership with WMO SDS-WAS Pan American Center, WHO/Pan-American Health Organization, and several federal and local agencies, to provide real-time forecasts of dust storms and wildfires over North America. Although air quality continues to improve in this region, the

"We want to have a solution," said Daniel Tong, a NASA researcher and associate professor of atmospheric chemistry and aerosols at George Mason University. In 2017, Tong published a paper linking increased dust storm activity in Arizona to an increase in Valley fever cases.

Now, he is trying to capture fungus from dust in the air to potentially lay the groundwork for a warning system.

ARL, Risks and Budget

Application Readiness Level:
- 6 for Valley fever surveillance system (CDC);
- 7 for the highway warning system (NMDOT);
- **9** for the dust forecasting system (NWS, Pima County);

Risks and Mitigation Strategies:
- Technical issues: Technical risks exist for health surveillance and transportation systems; Some may not work out as expected;
- Operations challenges: Staff changes in stakeholder offices; COVID-19 responses push everything else aside in health agencies.
- Management challenges: Large team; Stakeholders trippled; May not be able to address additional requests;

Backup Slides

Low-Cost Air Samplers

Marble Dust Collector (MDCO)

PurpleAir Air Quality Sensor

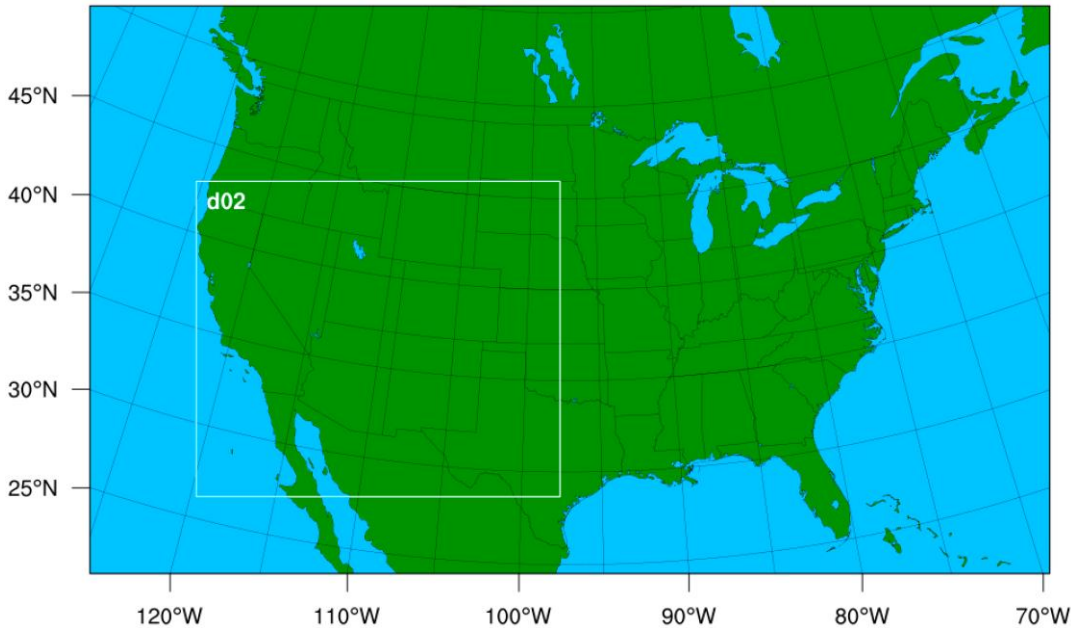**Big Spring Number Eight (BSNE)**

Aspirated Air Sampler

(Contributed by Scott Van Pelt)

Satellite-Aided Dust Storm Forecasting

- Outer domain (12km): CONUS;
- Inner domain (3km): Southwest.

- Emission: EPA NEI2016 + Biogenic + Dust + Wildfires
- Meteorology: WRF4.1
- Full chemistry (CMAQv5.3.1) – capable of predicting general air quality (O_3, NO_x, CO, VOCs, PM);
- Satellite-aided prediction of extreme events: Dust Storms and Wildfires.

FENGSHA Dust Emission Model

(Contributed by Janak Joshi)

❖ FENGSHA ("Windblown Dust" in Mandarin), initially developed at EPA based on measurements by Dale Gillette;

❖ FENGSHA emission algorithm :

Land Use — Soil Texture — Escape Fraction — Dust Source — Soil Erosion Potential — Friction Velocity — Threshold Friction Velocity

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

❖ Threshold friction velocity is further controlled by soil moisture and surface roughness.

❖ Special treatments for the Southwest domain:
  • Cropland updated with GMU/USDA CropScape dataset (30m);
  • Dust sources adjusted based on vegetation cover (MODIS NDVI);
  • Soil texture data from soilGrids (250m);
  • Roughness effect based on Darmenova et al. (2009).

Where Did Fatal Accidents Occur?

Phoenix-Tuscan Corridor

Lordsburg Playa
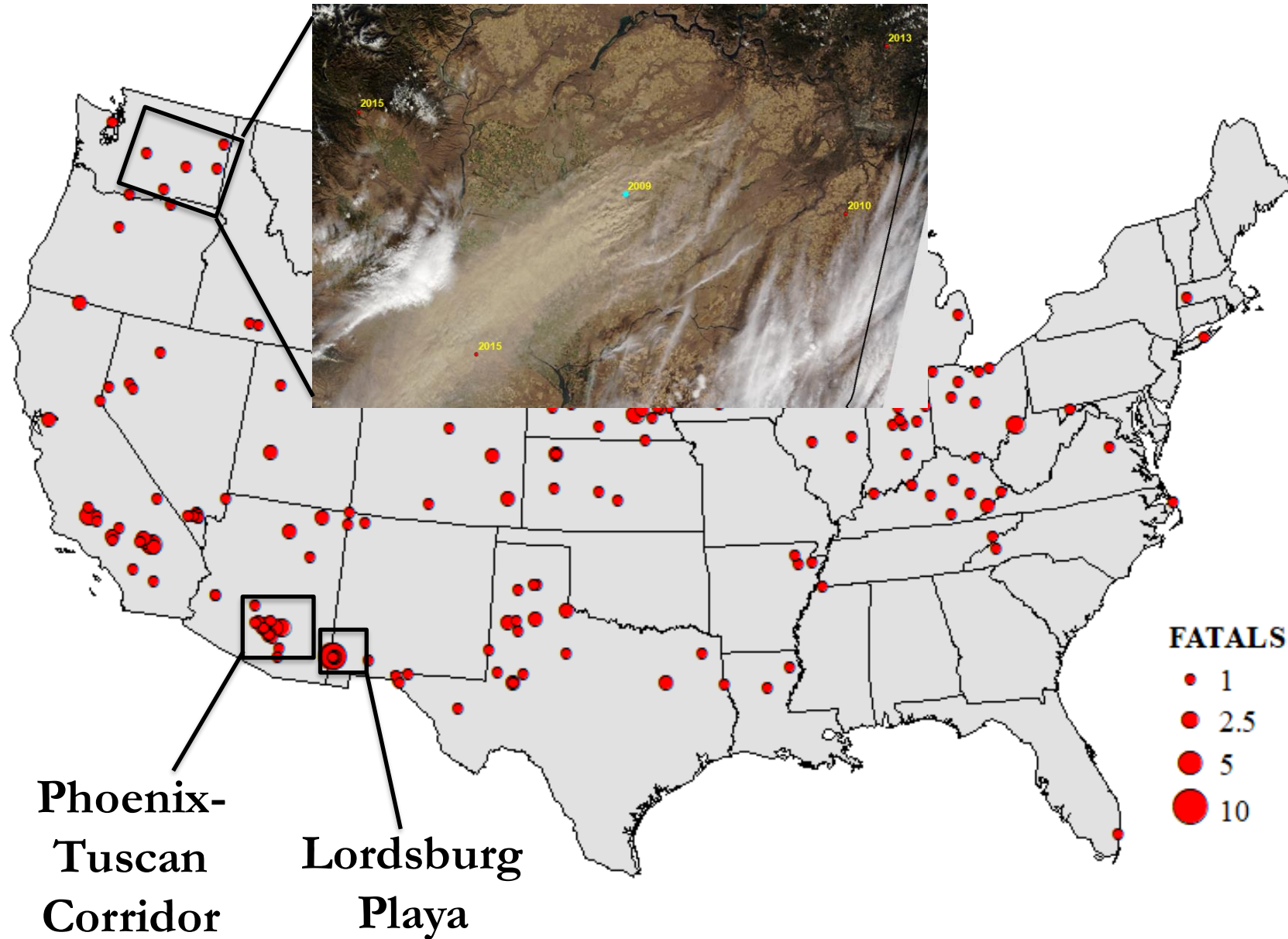
FATALS
- 1
- 2.5
- 5
- 10

- 14-33 dust fatalities each year (2007-2017);
- 30% of top-ranking fatal accidents in Arizona;
- 60% of deadliest accidents along I-10.

Windblown Dust vs Other Weather Hazards
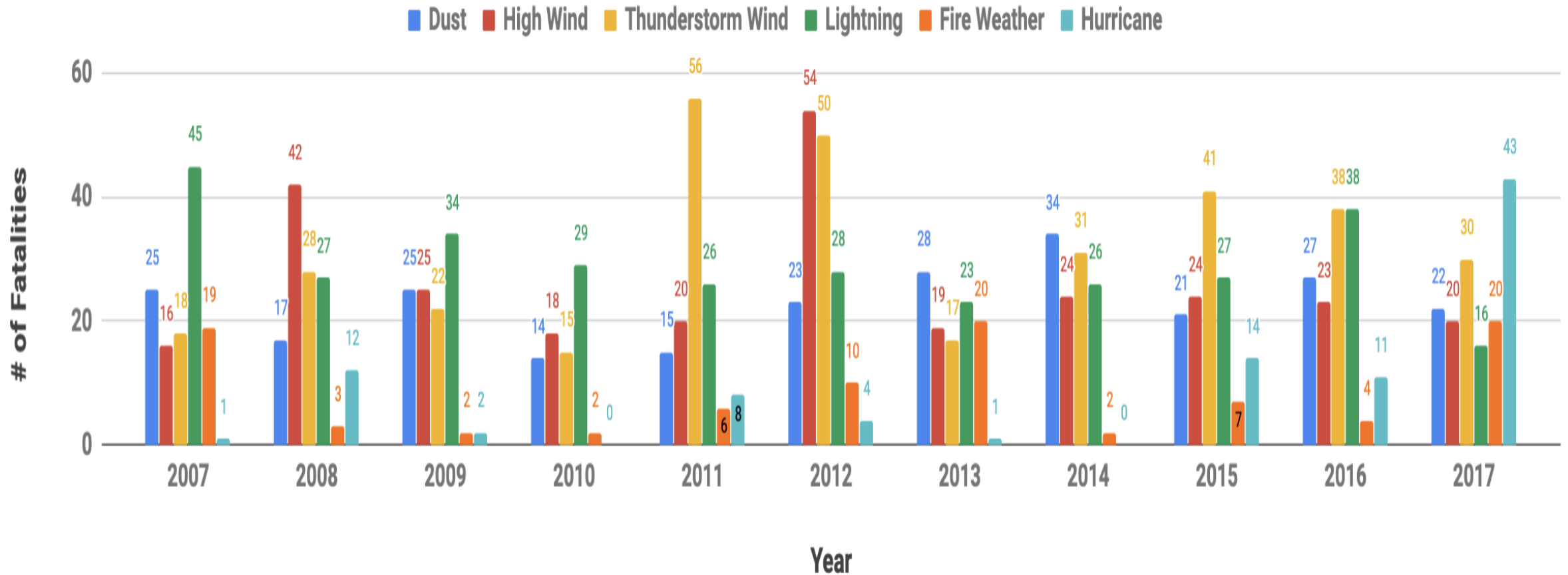
(Contributed by Irene Feng, Thomas Gill and Kerstin Schepanski)