

# Extreme weather and chemical facilities: A disastrous combination

Susan Anenberg, PhD

Collaborative on Health and the Environment  
November 20, 2019



Milken Institute School  
of Public Health

THE GEORGE WASHINGTON UNIVERSITY

# West Fertilizer Company explosion – April 2013

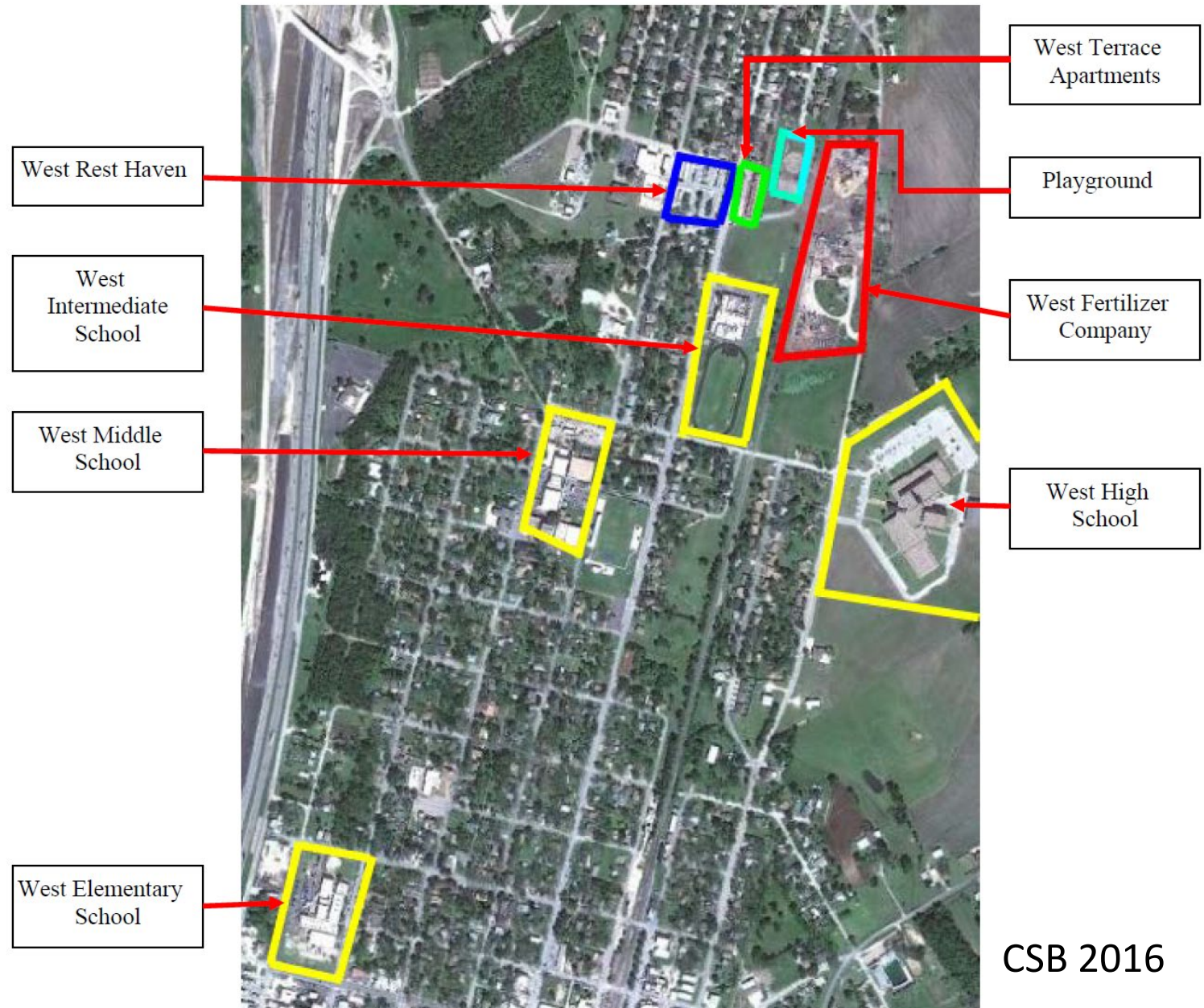


Damage at West Intermediate School

Milken Institute School  
of Public Health

THE GEORGE WASHINGTON UNIVERSITY

West, TX



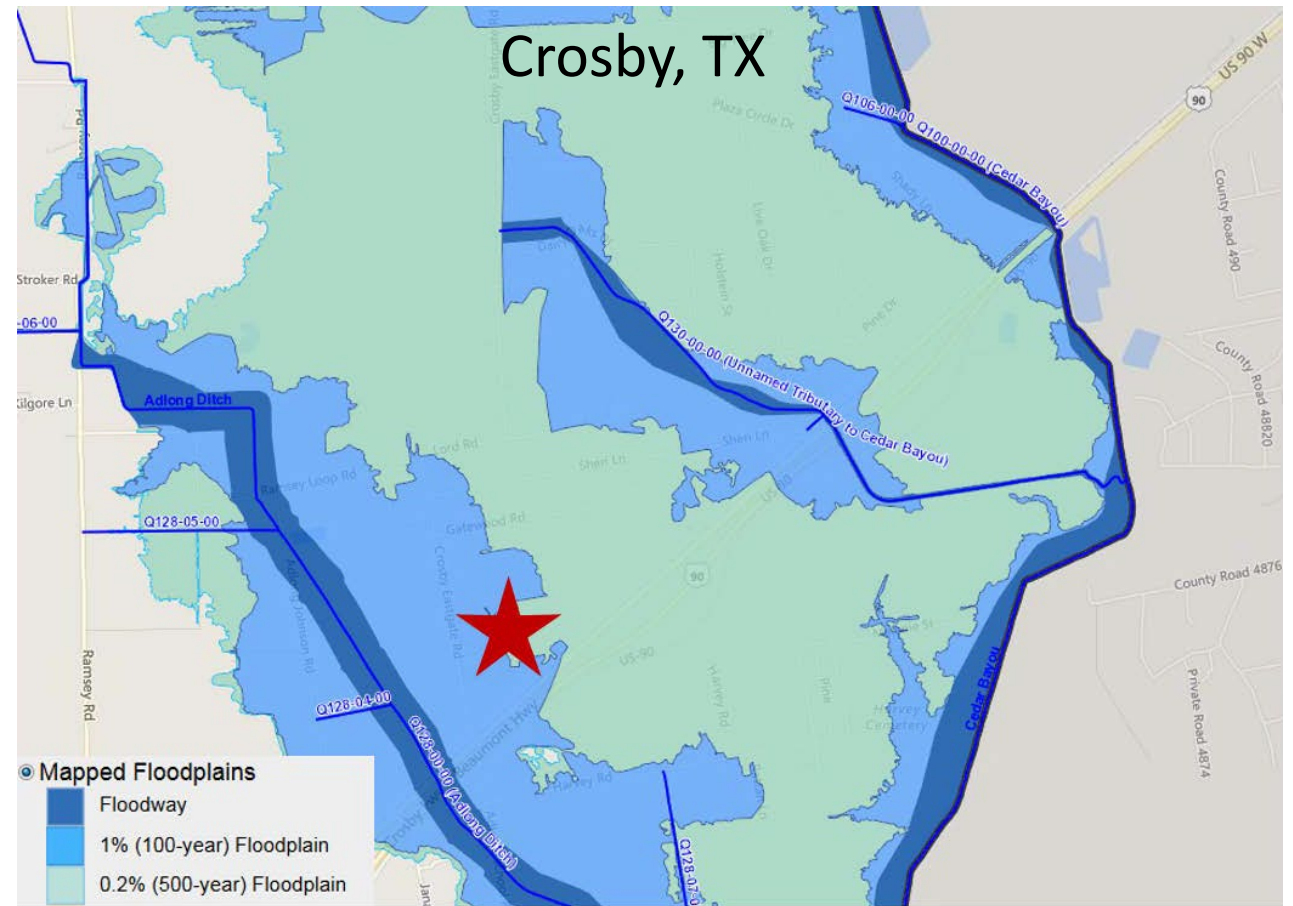
CSB 2016

WASHINGTON, DC

# Arkema chemical fire following Hurricane Harvey, Aug. 2017

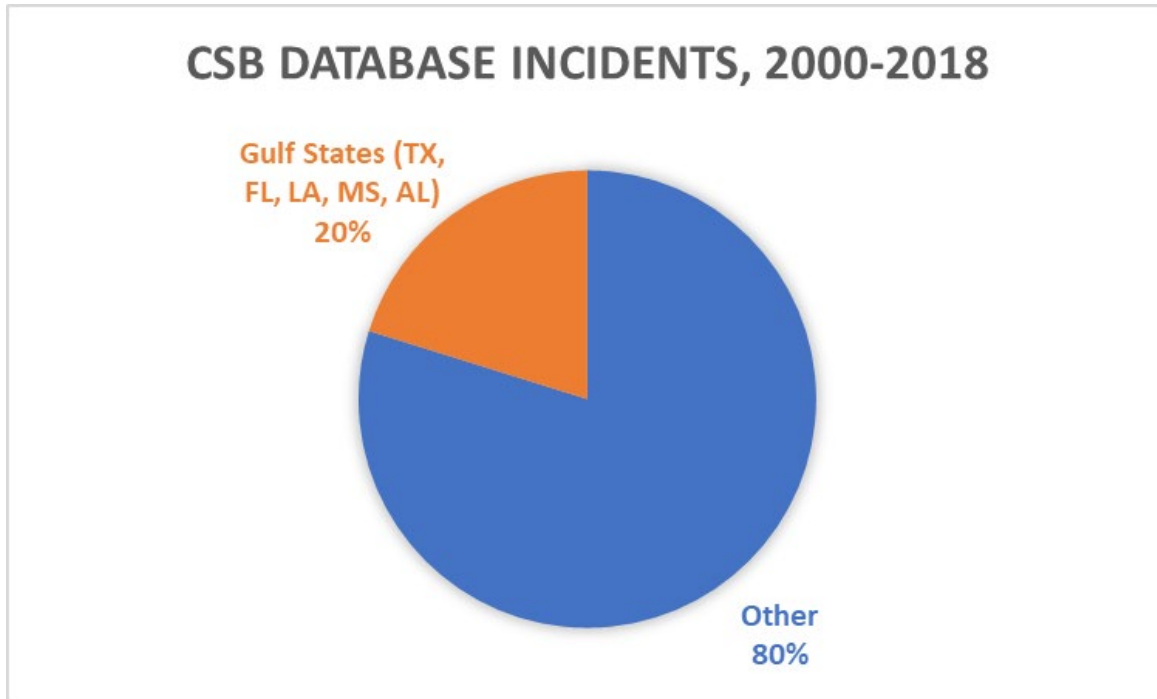


Flooded chemical storage trailers  
(animation)

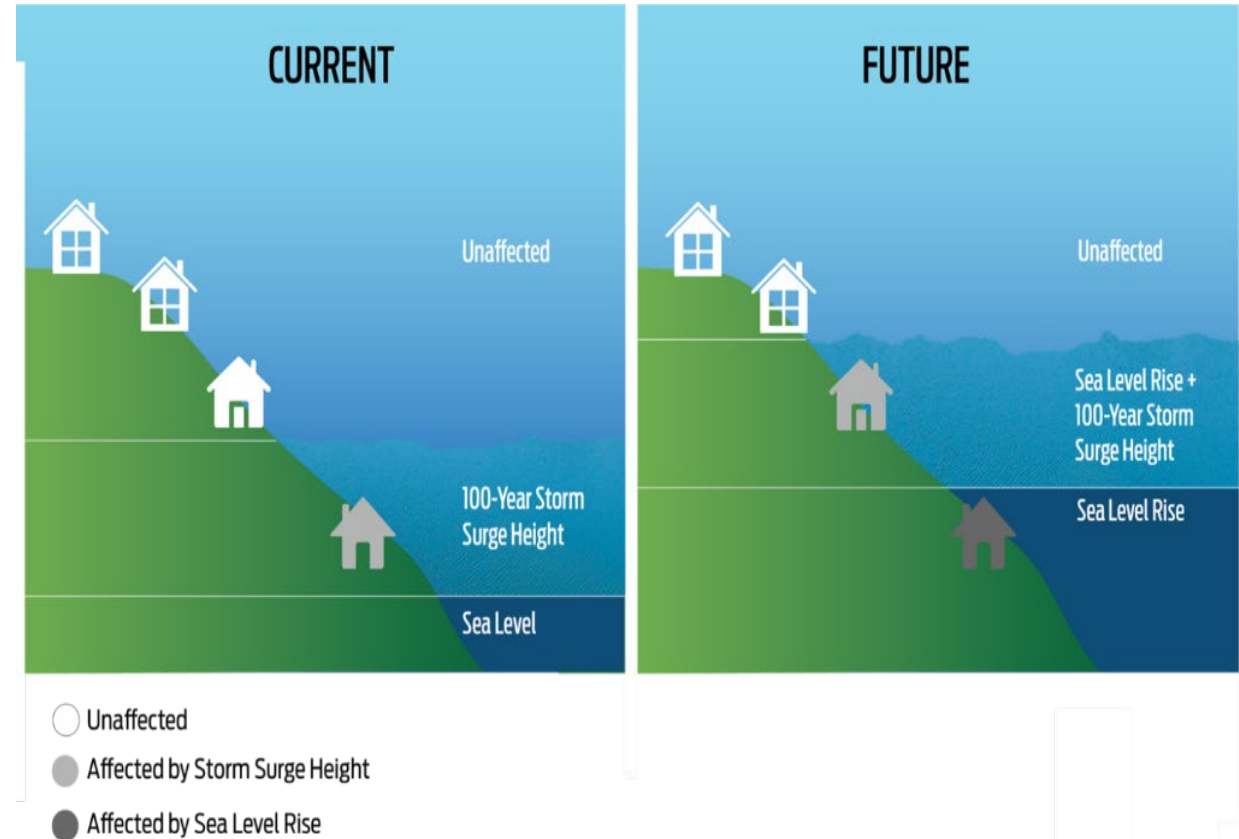


Location within 100- and 500-year floodplain

# Extreme weather, chemical facilities, and vulnerable populations: A disastrous combination

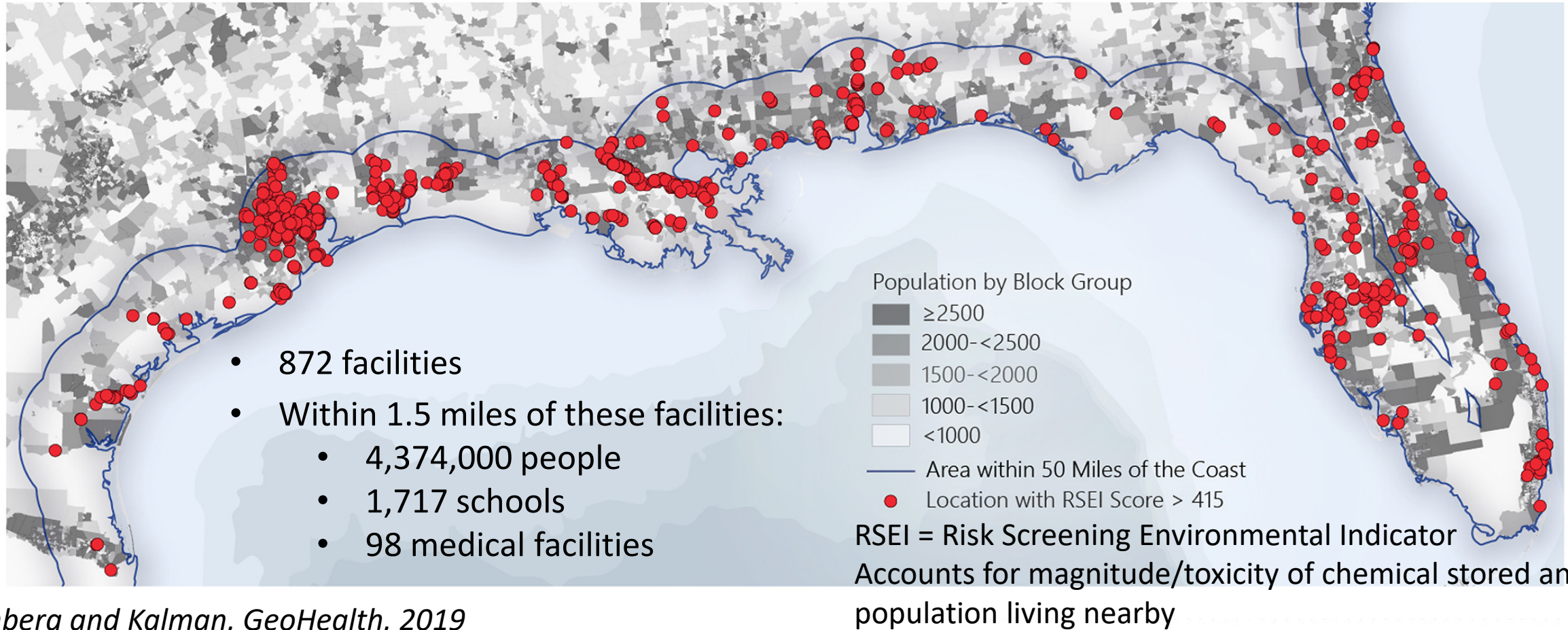


From 2001 to 2018, the CSB Incidence Screening database captured 9,404 incidents (1.5/day), ~40% had death/injury



National Climate Assessment 2018

# Locations of highly hazardous chemical facilities within 50 miles of Gulf Coast overlaid on census block group population size for 2016



Anenberg and Kalman, *GeoHealth*, 2019

Milken Institute School  
of Public Health

THE GEORGE WASHINGTON UNIVERSITY

THE GEORGE  
WASHINGTON  
UNIVERSITY  
WASHINGTON, DC

# Anticipating future chemical events

The New York Times

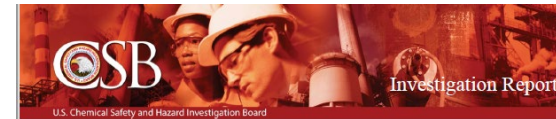
**BUSINESS** | Chemical Maker and Its Chief Indicted for Explosions During Hurricane H...

Houston area into Louisiana, bringing with it [50 inches of rainfall in some places and killing at least 39 people](#).

A lawyer for Arkema North America, Rusty Hardin, said the indictment was unprecedented, adding that the company and its workers were victims of the hurricane as much as everyone else in the county.

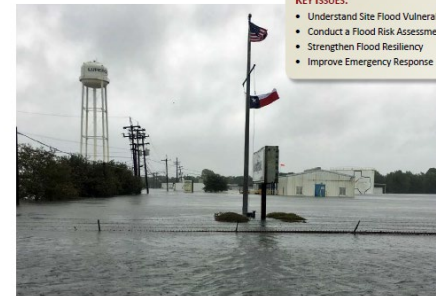
“All the experts agreed this was an act of God of biblical proportions, never before seen and never anticipated by anyone,”

Mr. Hardin said. “It would set an ominous precedent if a company could be held criminally liable for impact suffered as a result of the historic flooding of Hurricane Harvey that no one, including Harris County itself, was prepared for.”



## Organic Peroxide Decomposition, Release, and Fire at Arkema Crosby Following Hurricane Harvey Flooding Crosby, Texas

Incident Date: August 31, 2017  
Exposures to Emergency Responders, Community Evacuation, and Property Damage



- KEY ISSUES:**
- Understand Site Flood Vulnerability
  - Conduct a Flood Risk Assessment
  - Strengthen Flood Resiliency
  - Improve Emergency Response

Report Number: 2017-08-I-TX  
May 2018

“...no clear and specific regulatory requirement calls for flood risk to be assessed in relation to process safety under the regulation language in either the PSM standard or RMP rule.”

Milken Institute School  
of Public Health

THE GEORGE WASHINGTON UNIVERSITY

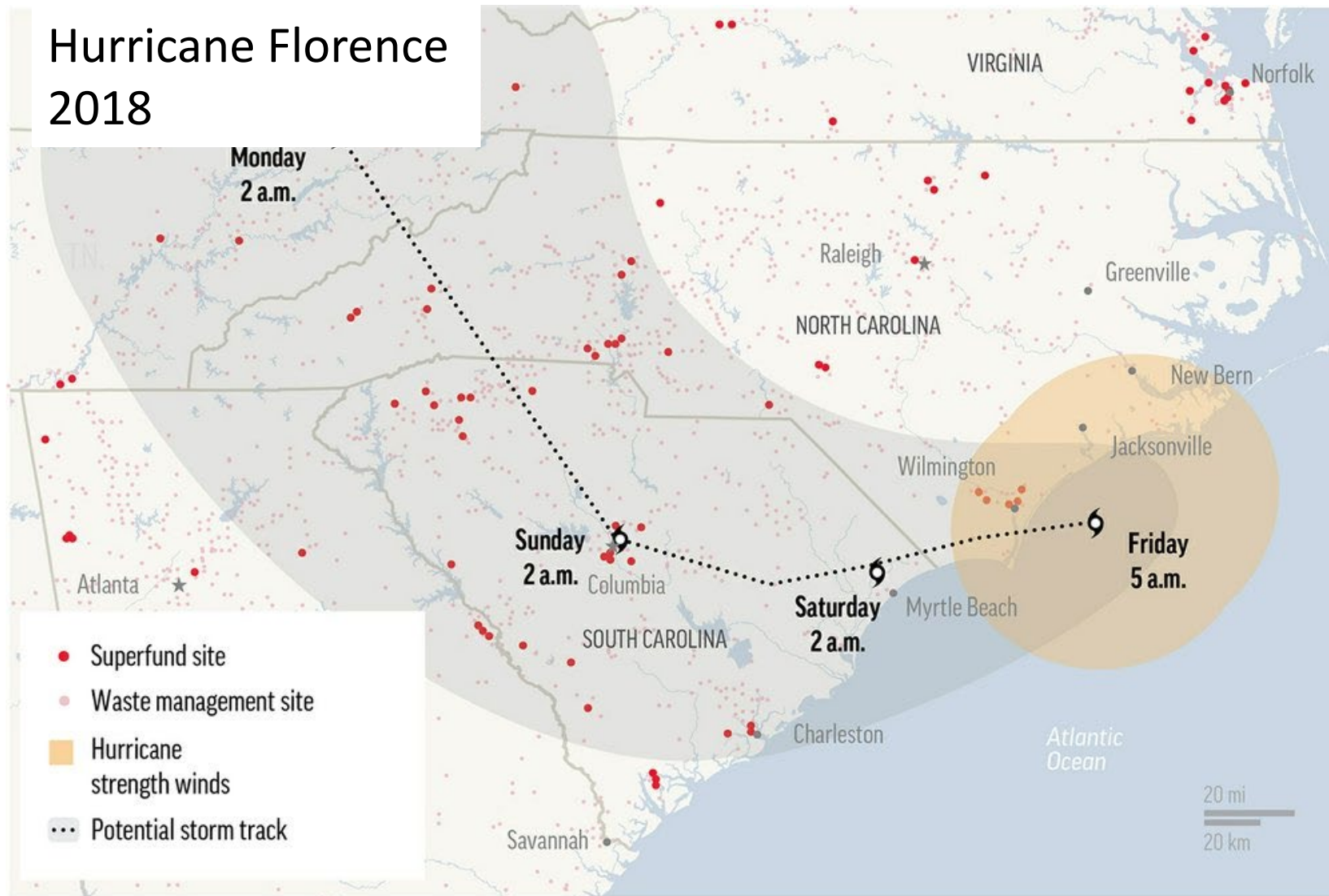
THE GEORGE  
WASHINGTON  
UNIVERSITY

WASHINGTON, DC

# Hog farms, Superfund sites in the path of hurricanes



NPR 2018



SOURCES: Maps4News/HERE; National Institutes of Health, Department of Health & Human Services; National Hurricane Center

AP 2018

GAO recommends EPA provide direction on integrating climate information into site-level decision making to ensure long-term protection of health and the environment

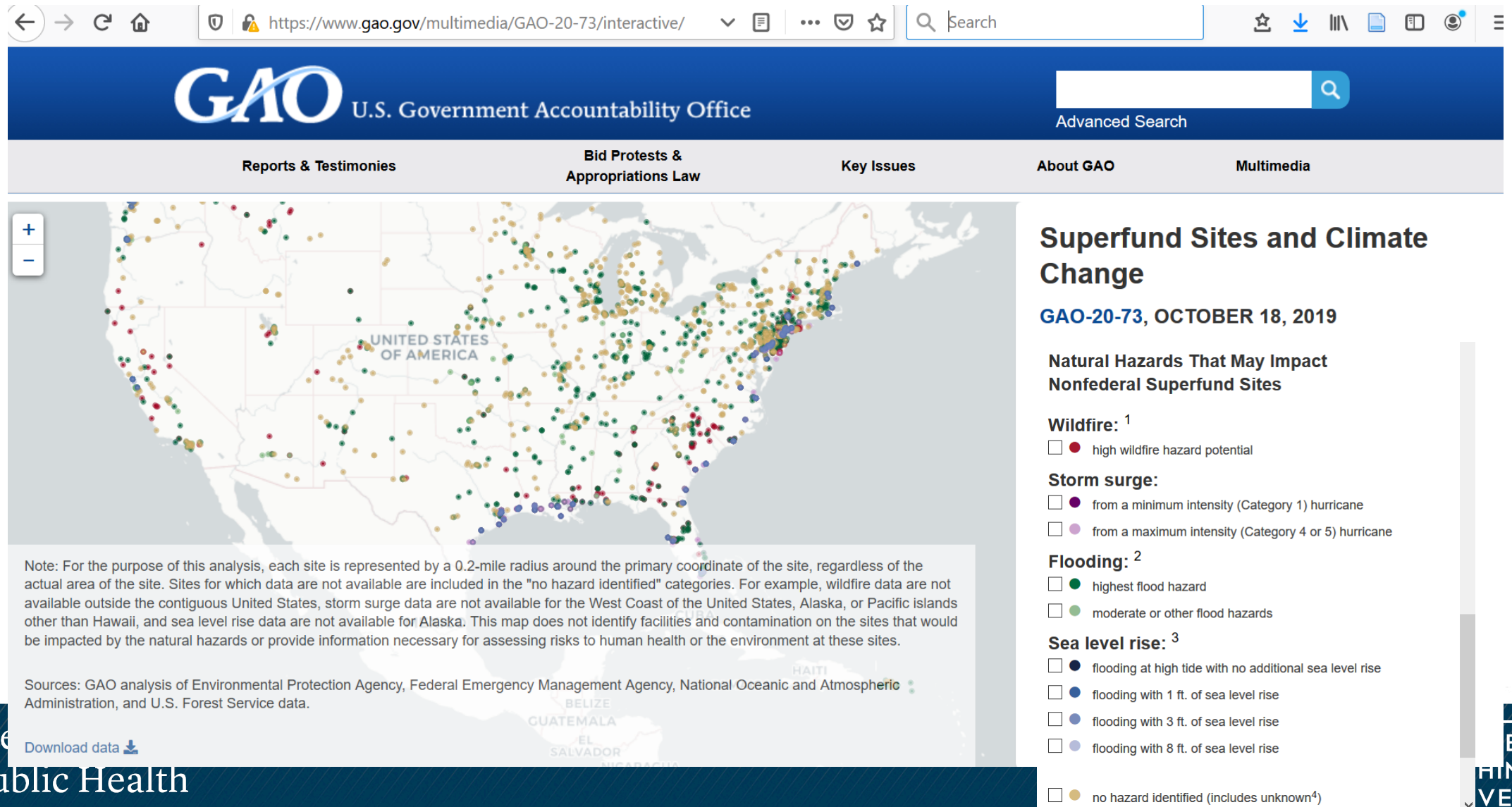






Photo: Joseph Platz | NOAA

# Sensitivity of Airborne Dust to Drought in the US Southwest: What Are the Implications for Public Health under Climate Change?

Ploy Pattanun Achakulwisut, **Susan C. Anenberg**, James E. Neumann, Stefani L. Penn, Natalie Weiss, Allison Crimmins, Neal Fann, Jeremy Martinich, Henry Roman, and Loretta J. Mickley

Milken Institute School  
of Public Health

THE GEORGE WASHINGTON UNIVERSITY

THE GEORGE  
WASHINGTON  
UNIVERSITY

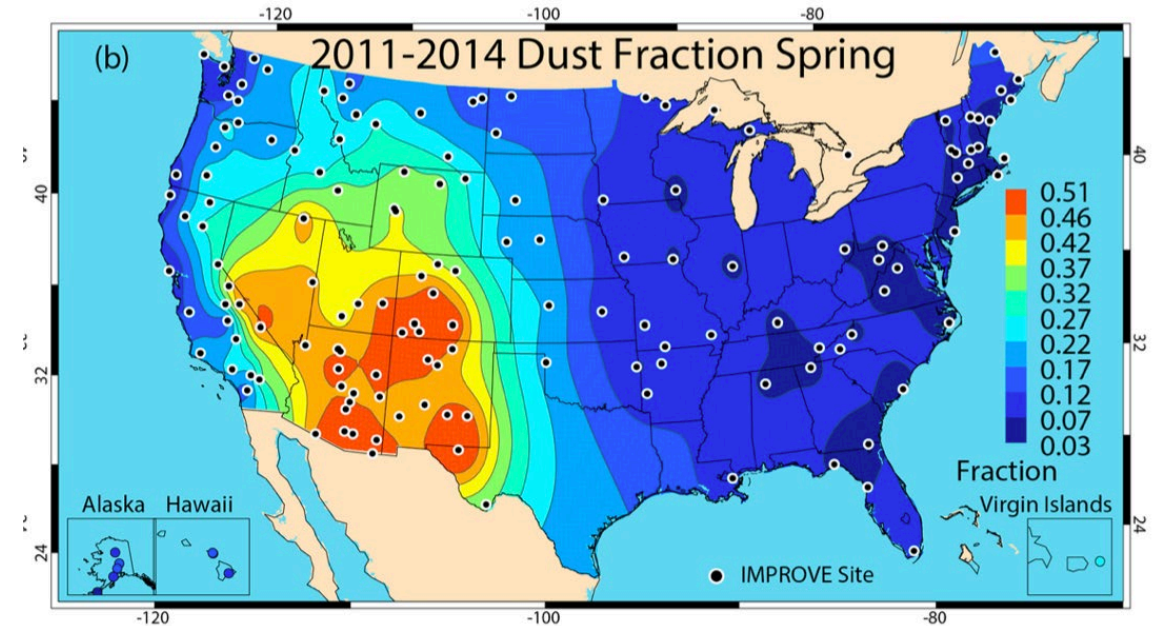
WASHINGTON, DC

# Soil-derived particulate matter (PM) are major contributors to air pollution and visibility degradation in the US Southwest



Major dust sources: North American deserts, and the semi-arid Columbia Plateau, Colorado Plateau, southern Great Plains

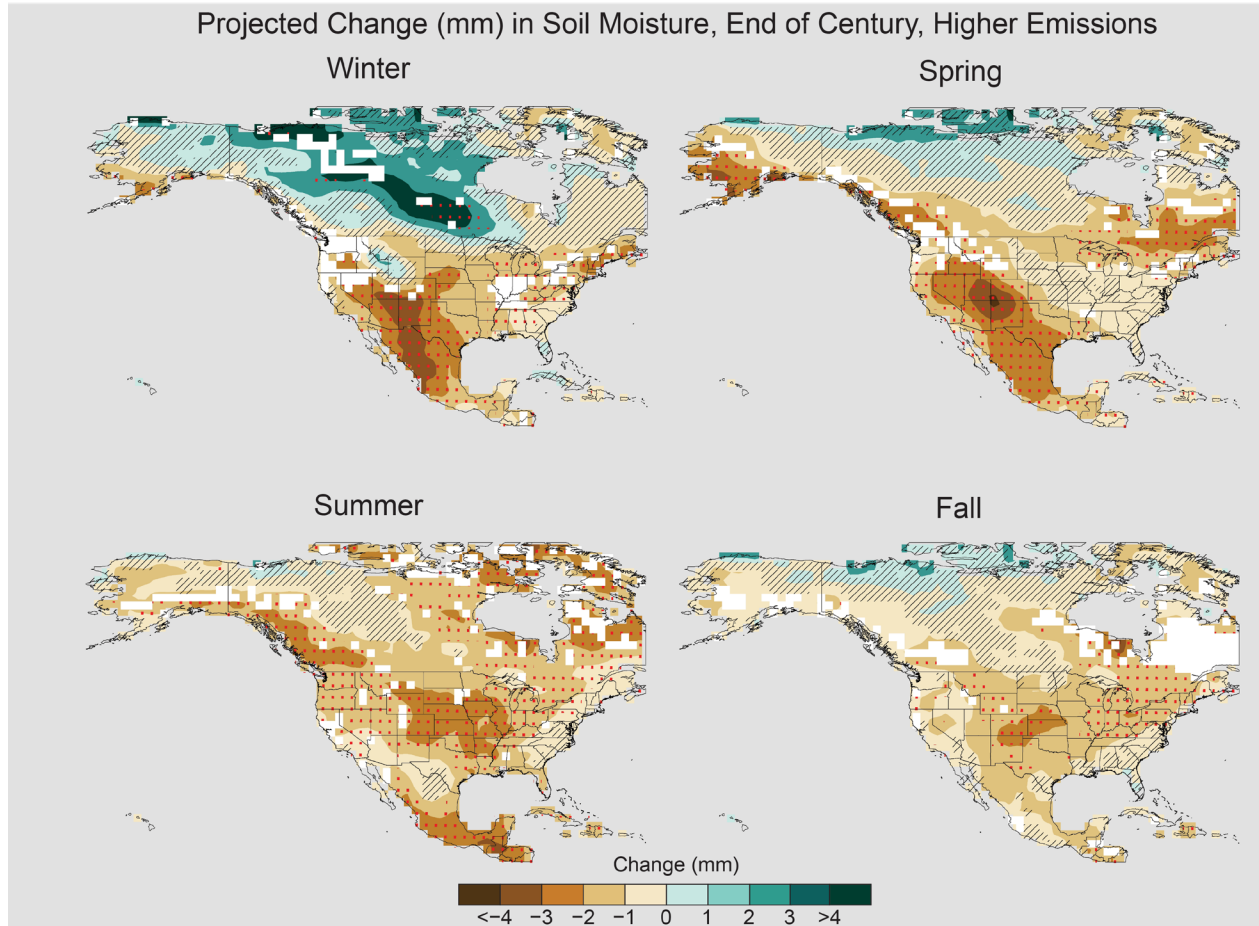
<https://geoalliance.asu.edu/Dust>



In southwestern states, mineral dust can make up ~50% of fine PM (PM<sub>2.5</sub>) monthly mean concentrations

Hand et al., 2017, J. Geophys. Res.

# Understanding the relationship between wind-blown dust and droughts is critical for constraining the climate-sensitivity of PM

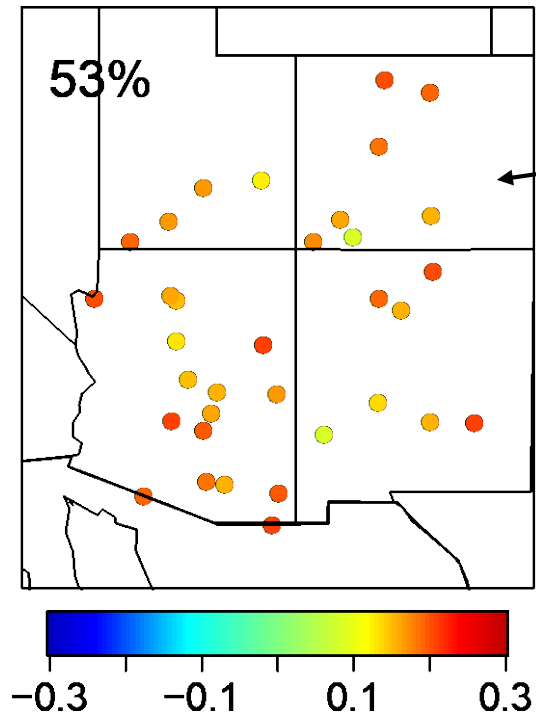


Wehner et al., 2017 (Climate Science Special Report: NCA4)

Without substantial reductions in greenhouse gas emissions, southwestern North America will experience increasingly severe drought conditions [e.g., Wehner et al., 2017; Ault et al., 2016].

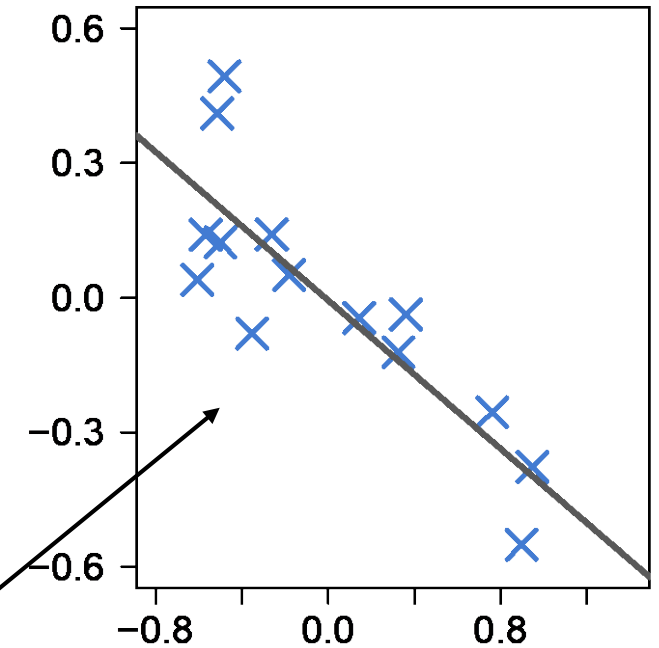
Recent studies suggest that such changes may lead to enhanced dust activity in the US Southwest [Achakulwisut et al., 2017, 2018; Tong et al., 2017], but the impacts are not yet well quantified.

# How sensitive are fine dust concentrations to local/regional drought conditions?



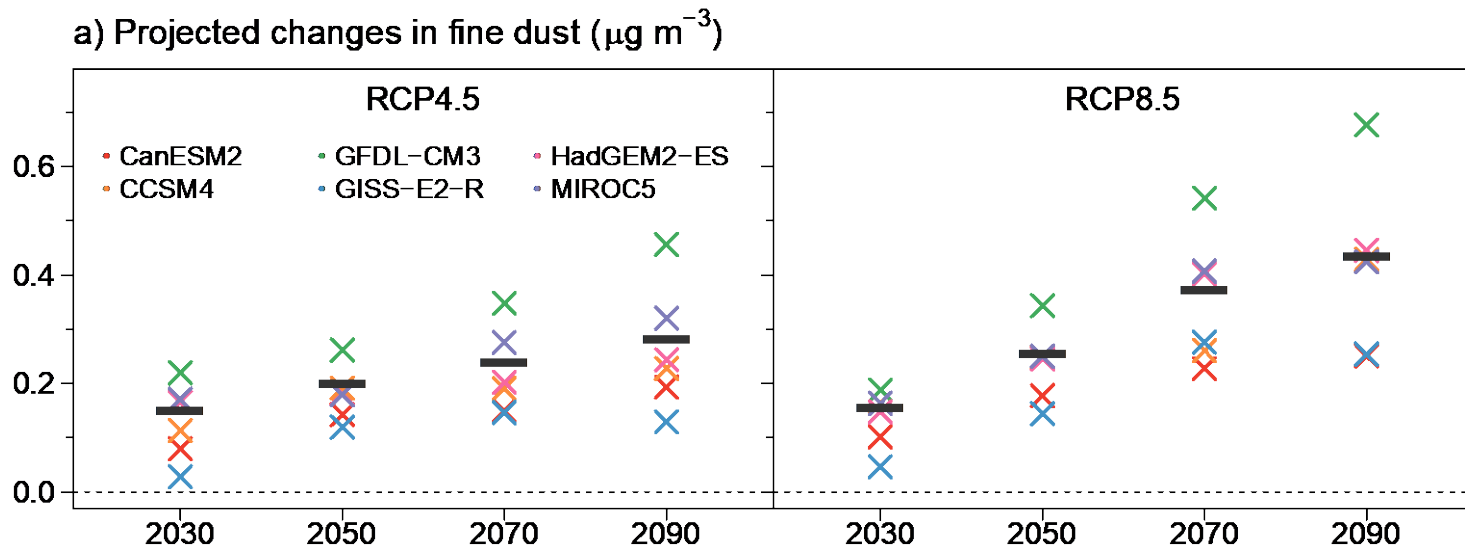
Monthly mean fine dust anomalies in each season during 2000-2013 show a dominant spatial pattern of regional co-variability, capturing 53% of the total variance. This is indicative of large-scale influence.

A unit decrease in regional mean SPEI02 is associated with increases of 0.2-0.4  $\mu\text{g m}^{-3}$  in regional mean fine dust ( $p < 0.05$ ), depending on the season.



Achakulwisut et al. GeoHealth, 2019

# How will dust levels change due to projected drought conditions for each season, model, and RCP scenario (relative to 1986-2005)?

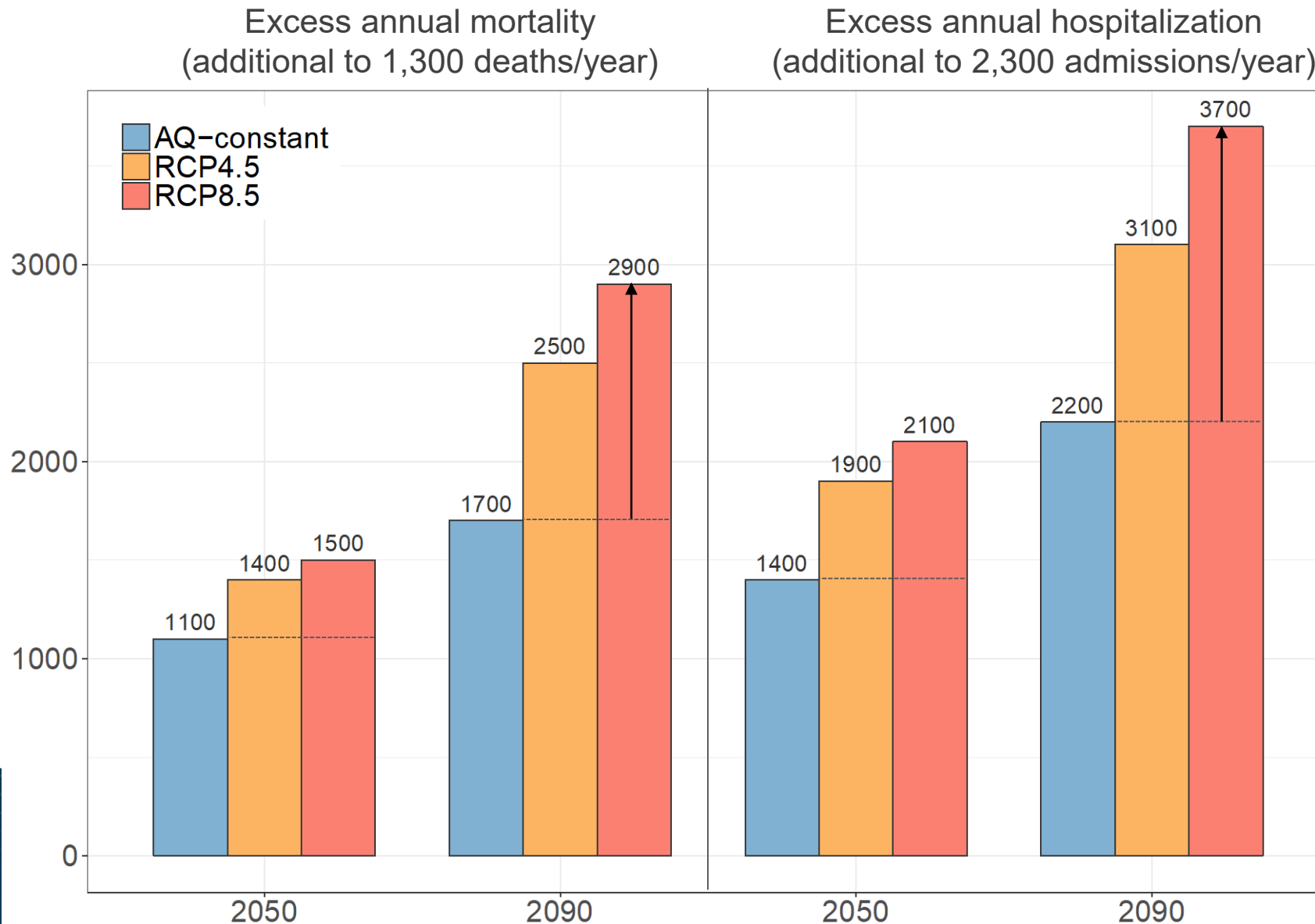


Projected decreases in soil moisture could **increase fine dust levels by 57%** over the US Southwest in 2090 under RCP8.5.

Under RCP8.5 relative to RCP4.5, increases in dust concentrations are 30% larger in 2050 and 60% larger in 2090.

Achakulwisut et al., GeoHealth 2019

# What are the magnitudes and economic values of the health impacts attributable to dust exposure?

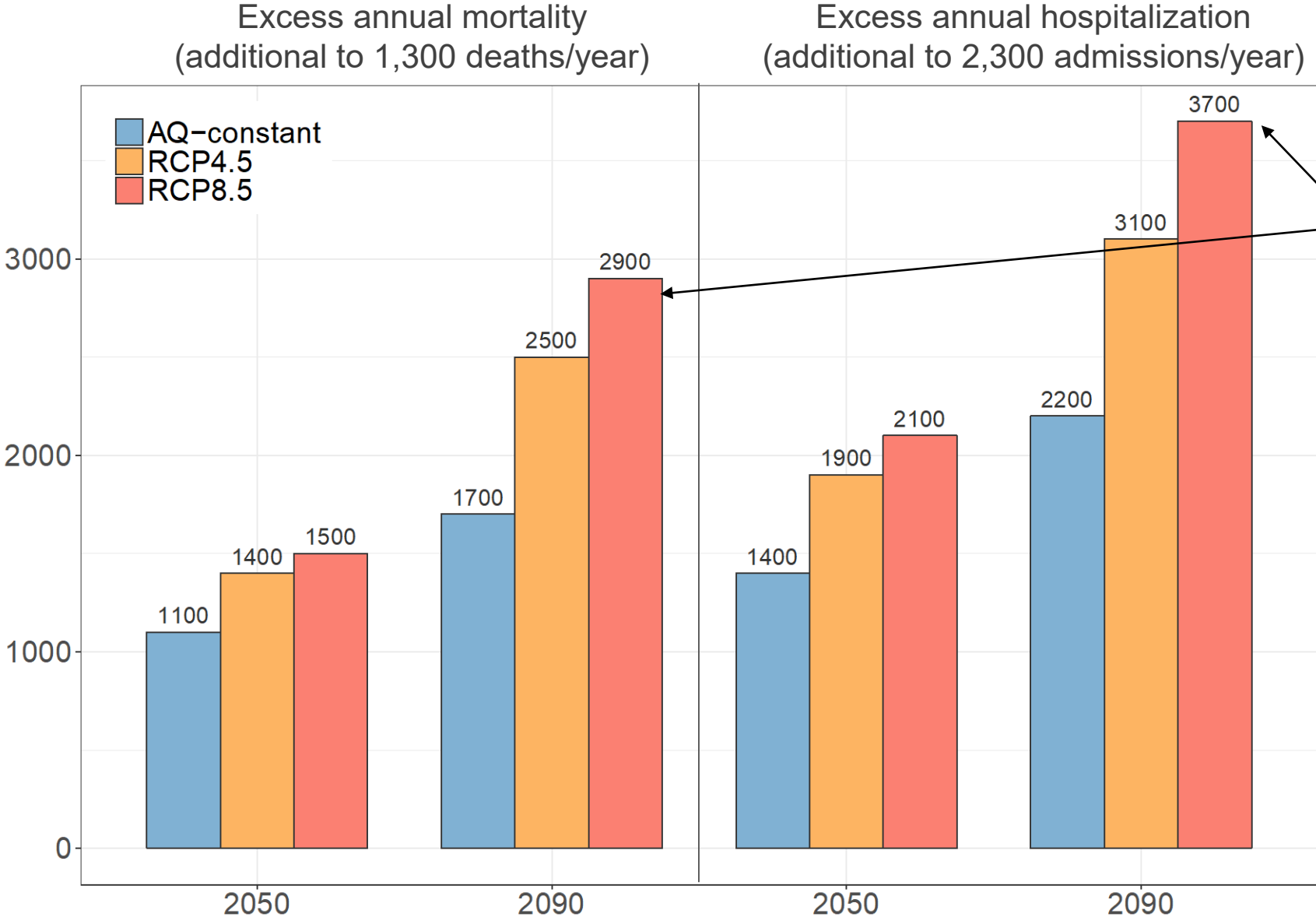


In 2090, dust-attributable mortality could increase by 220% and morbidity by 160% due to rises in dust, population, and baseline disease rates.

Climate-driven changes in dust concentrations alone can account for ~40% of these increases.

Achakulwisut et al., GeoHealth 2019

# What are the magnitudes and economic values of the health impacts attributable to dust exposure?



The economic damages of these dust-related health impacts in 2090 are estimated to be **\$47 billion/year** (additional to the historical burden of \$13 billion/year).

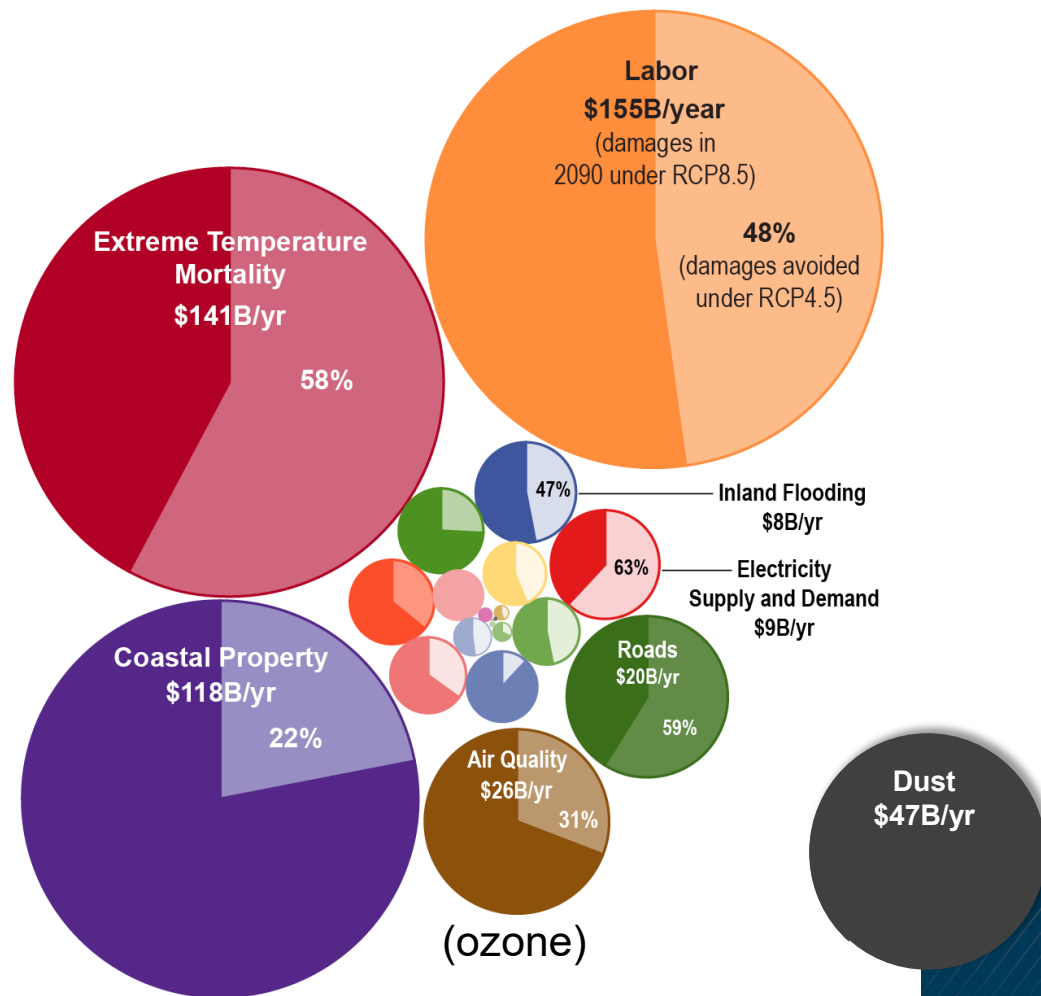
These excess damages under RCP8.5 are \$6.4 billion/year larger than those under RCP4.5.

# The EPA's Climate Change Impacts and Risk Analysis (CIRA) framework quantifies damages across different US sectors using consistent greenhouse gas concentration and socioeconomic scenarios

The Fourth National Climate Assessment reported that climate change is expected to cause substantial damages to multiple US sectors, with the largest risks in 2090 related to extreme temperature mortality, labor productivity decline, and coastal property loss.

Compared to these projected national-scale climate impacts, **our estimated dust-related health damages of \$47 billion/year for four southwestern states rank 4<sup>th</sup>**, and is ~2 times larger than ozone-related health impacts.

*Email: [sanenberg@gwu.edu](mailto:sanenberg@gwu.edu)*





---

THE GEORGE  
WASHINGTON  
UNIVERSITY

---

WASHINGTON, DC

# How will increasing aridity affect ambient dust levels and public health risks in the US Southwest?

## 1. How sensitive are surface dust concentrations to local/regional drought conditions?

- Conduct statistical analysis using 2000-2013 observations and the Standardized Precipitation-Evapotranspiration Index (SPEI, 1-48 months) to represent droughts in different hydrological sub-systems.

# How will increasing aridity affect ambient dust levels and public health risks in the US Southwest?

1. How sensitive are surface dust concentrations to local/regional drought conditions?

2. How may dust concentrations change between 2006-2099 (relative to 1986-2005) due to projected drought conditions under intermediate (RCP4.5) and high (RCP8.5) greenhouse gas concentration scenarios?

- Estimate changes by applying derived sensitivities to downscaled meteorological output from 6 global climate models and 2 RCP scenarios.

# How will increasing aridity affect ambient dust levels and public health risks in the US Southwest?

1. How sensitive are surface dust concentrations to local/regional drought conditions?
2. How may dust concentrations change between 2006-2099 (relative to 1986-2005) due to projected drought conditions under intermediate (RCP4.5) and high (RCP8.5) greenhouse gas concentration scenarios?
3. What are the magnitudes and economic values of associated public health impacts?
  - Perform assessment using projections of dust concentrations, population, and baseline incidence rates, combined with concentration-response and economic valuation functions.