

# Satellites are needed to compliment our sparse surface monitoring network for quantifying dust events

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**COLORADO STATE  
UNIVERSITY**

Image Source: Union of Concerned Scientists

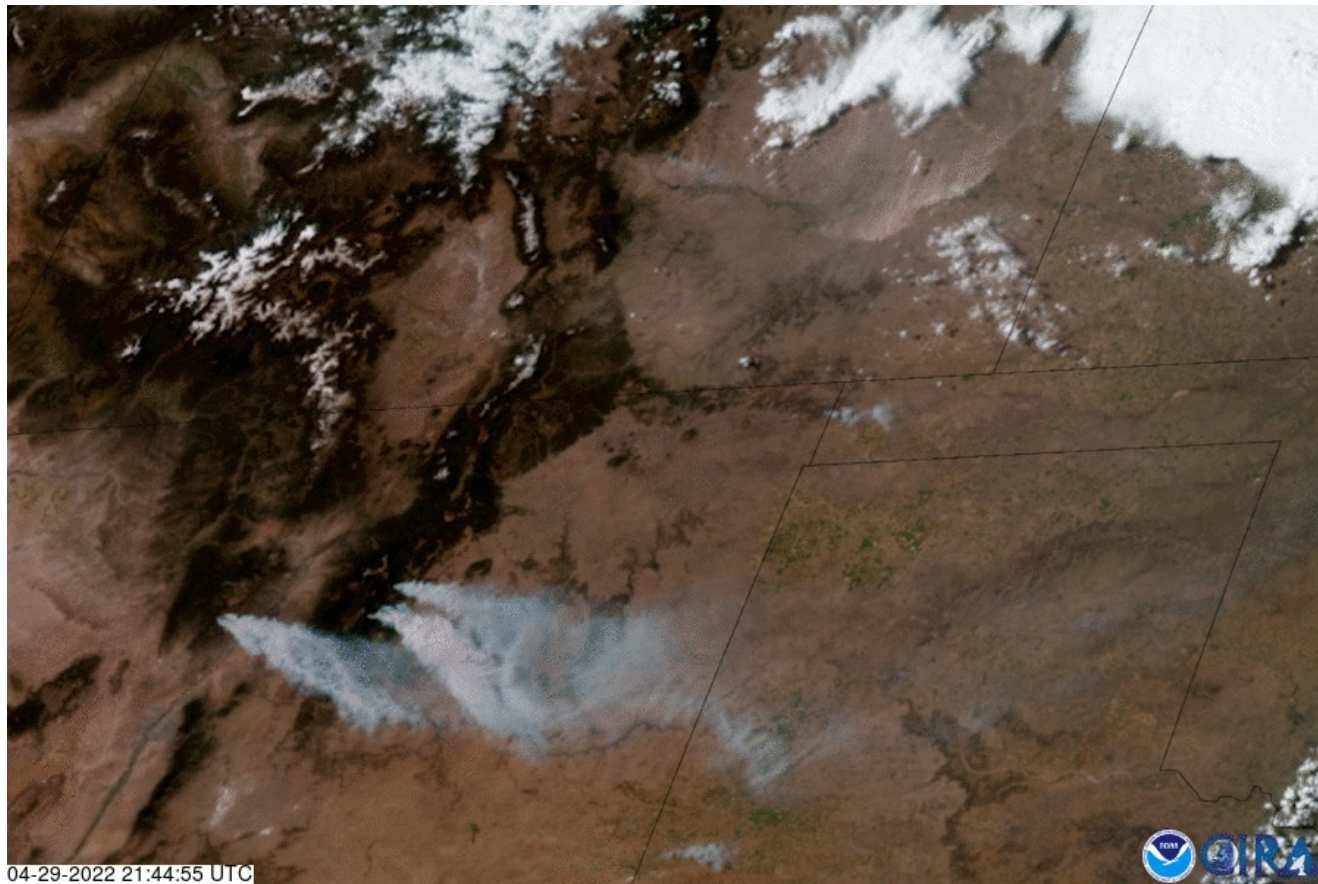
# Credits!



Jennifer McGinnis  
Poster tonight!

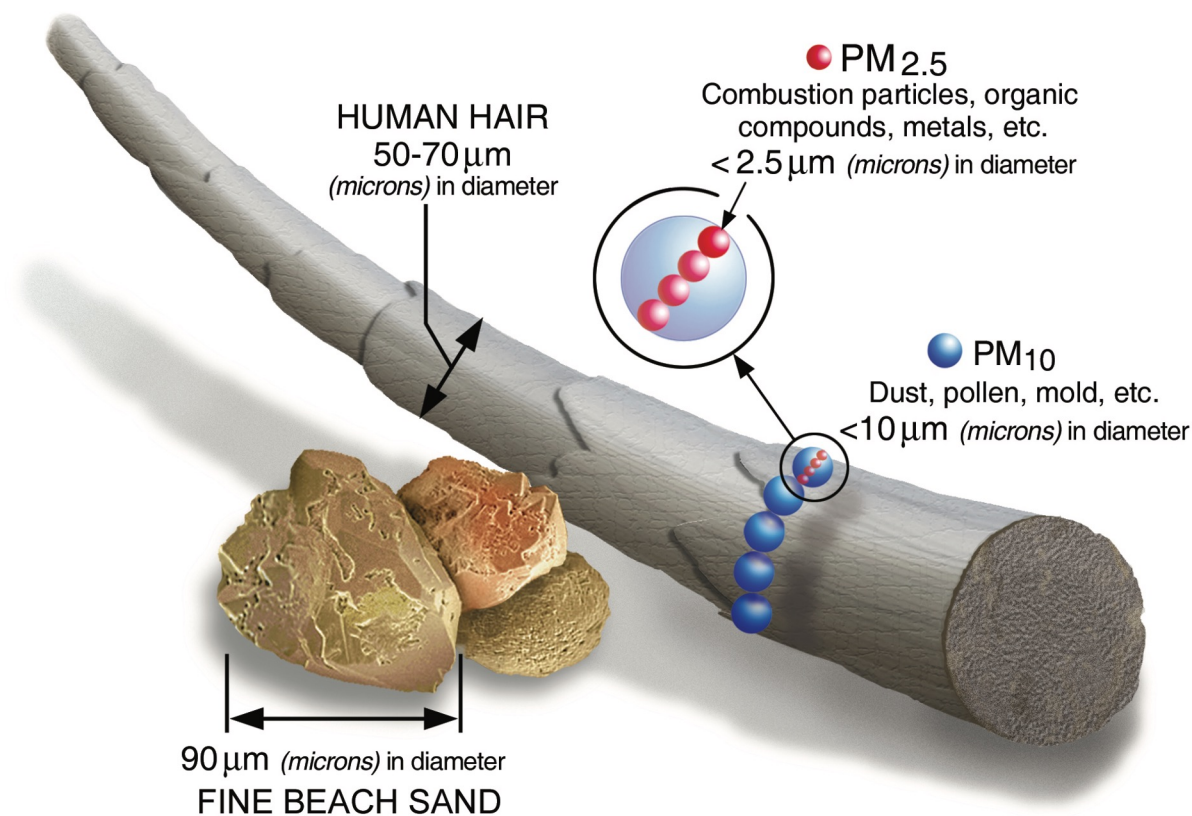
Bonne Ford – National Park Service  
Jenny Hand – National Park Service  
Haihui Zhu – Colorado State University  
Steve Miller – Colorado State University  
Emily Fischer – Colorado State University

## Dust: The ***other*** natural aerosol problem





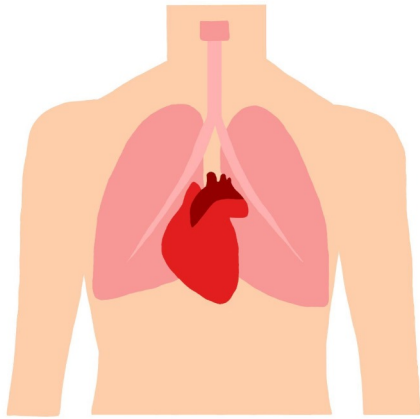
Dust is the main component of coarse particulate matter ( $\text{PM}_{\text{coarse}}$ ;  $\text{PM}_{2.5}$  -  $\text{PM}_{10}$ ) in the US.



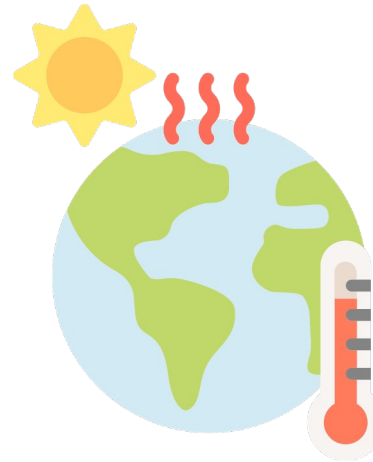
Source: EPA



# Dust PM<sub>coarse</sub> has significant impacts on human health, climate, and ecosystems.



- Mortality
- Cardiovascular Morbidity
- Respiratory Morbidity



- Radiative forcing
- Cloud interactions

- Impacts plant growth

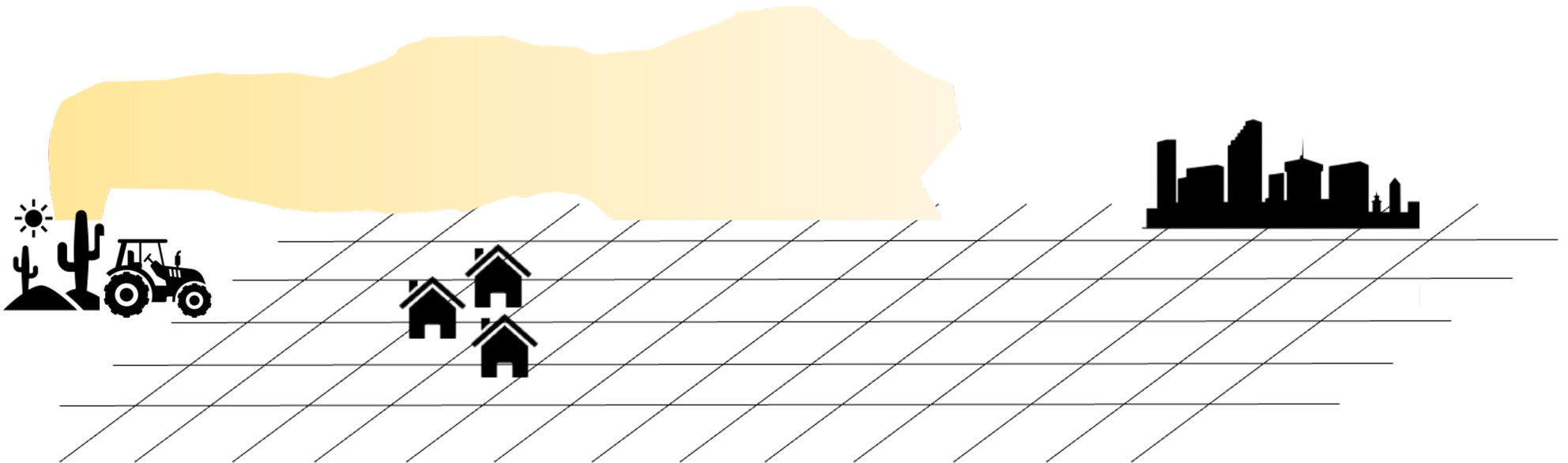


- Reduced visibility

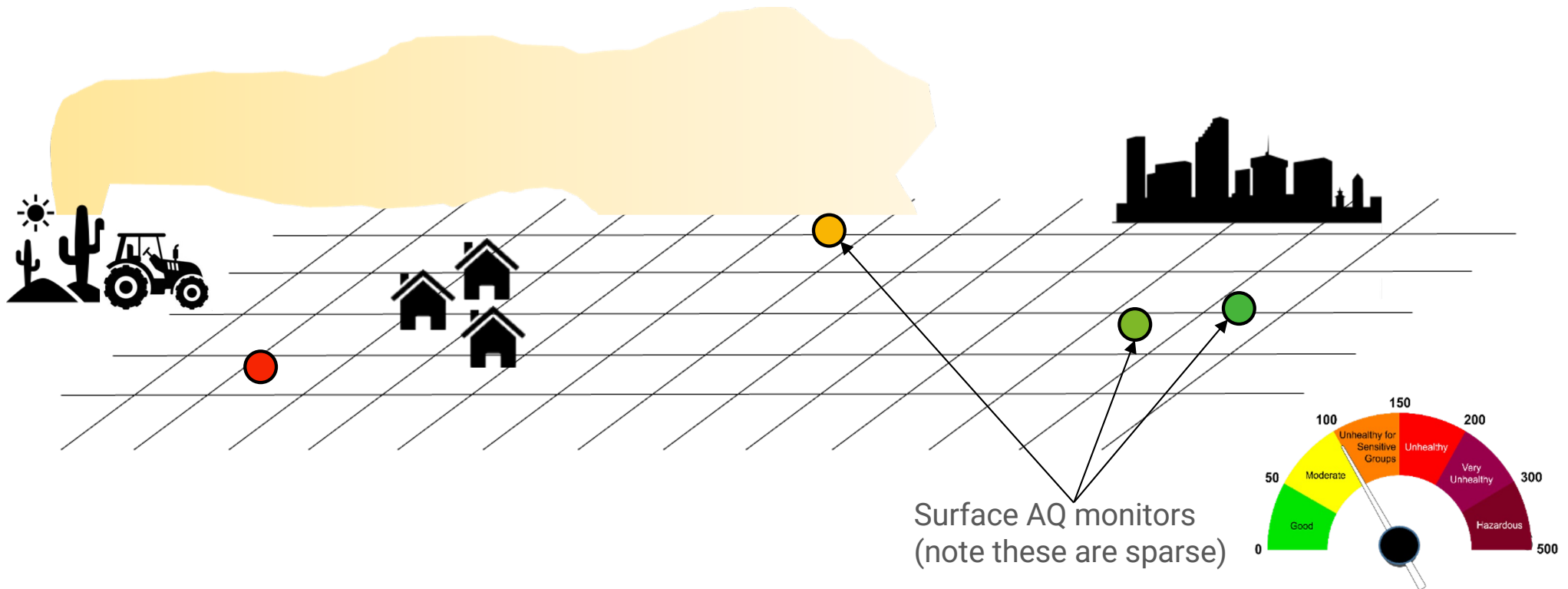


Achakulwisut et al., 2019; Crooks et al., 2016; Liu, Cai, et al., 2022; D. Tong et al., 2023; Ahmadzai et al., 2023; Zia-Khan et al., 2015; Kok et al., 2023; Leung et al., 2025

Previous work uses surface monitors to detect dust and evaluate dust storm frequency and dust concentration.



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Speciated ground monitor data has been used to identify dust events and corresponding dust fatalities.

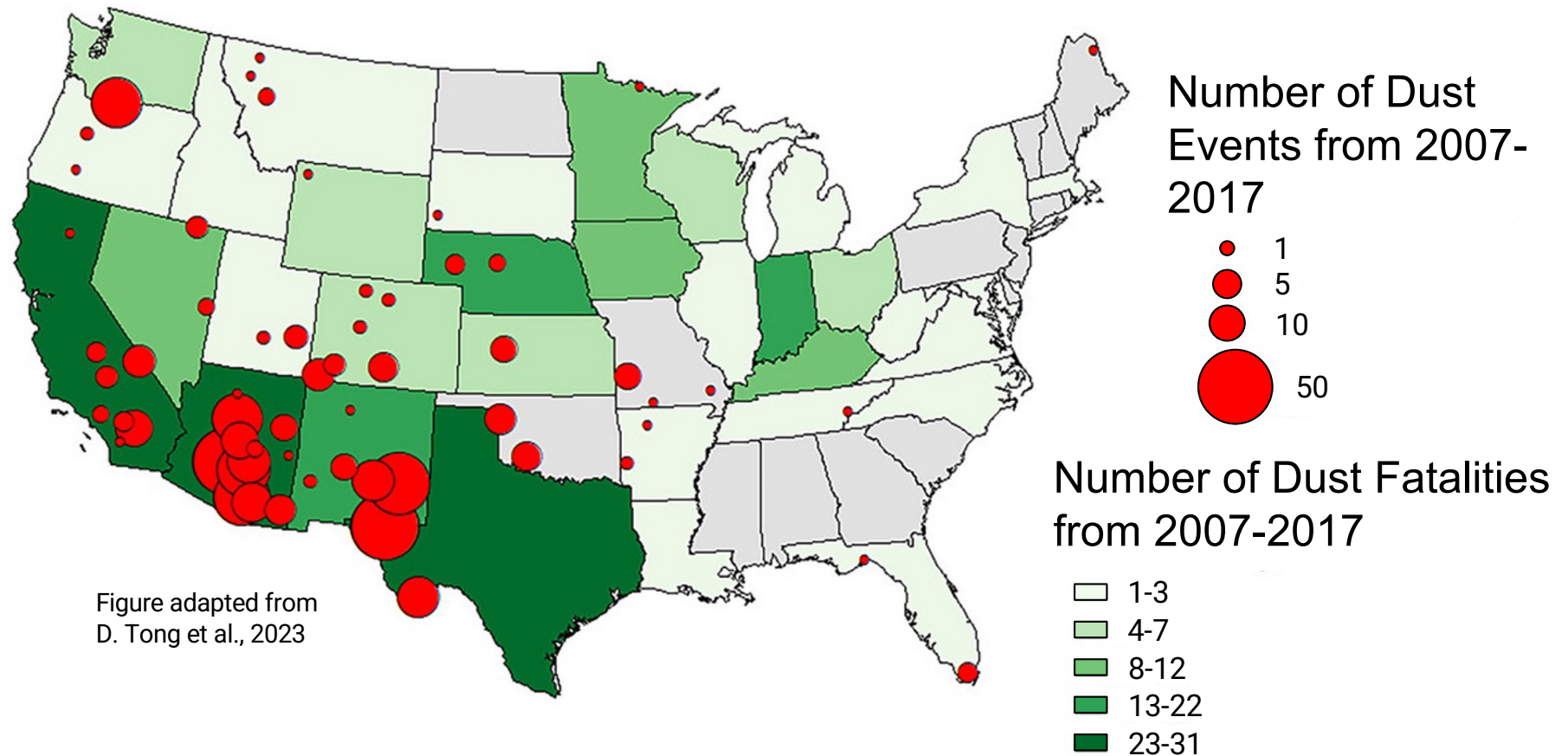
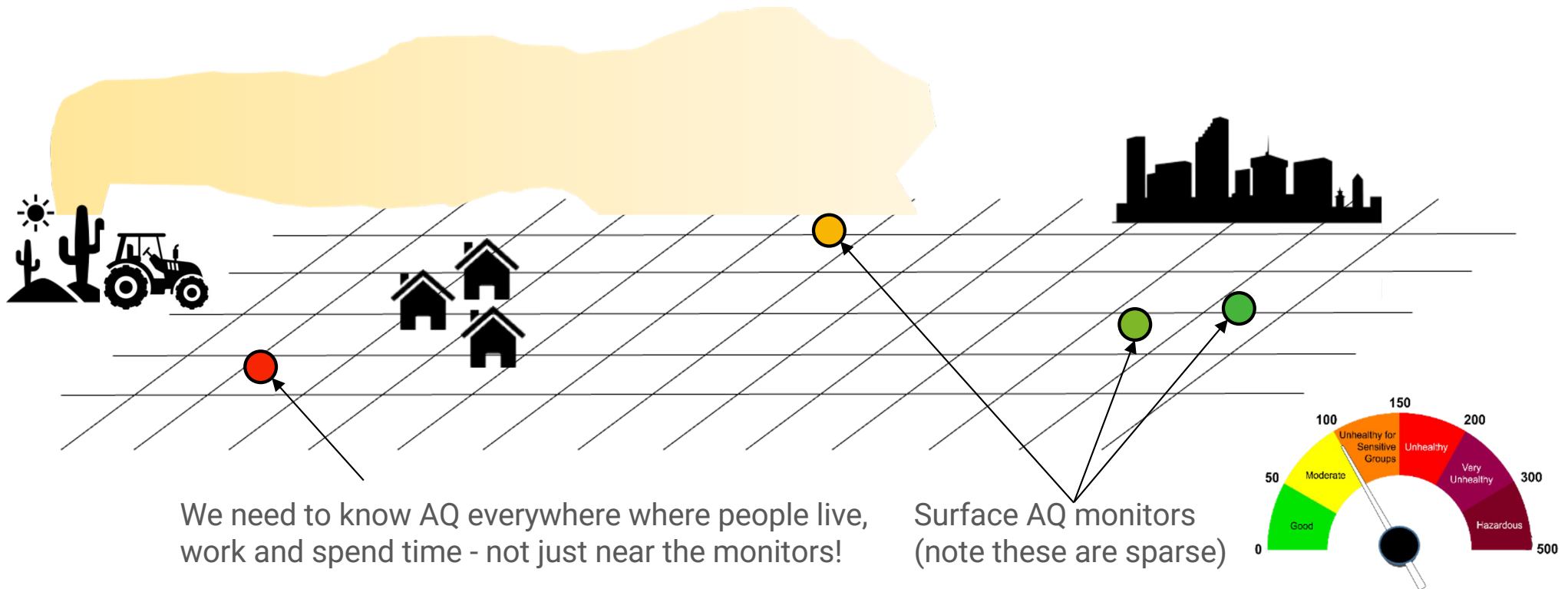


Figure adapted from  
D. Tong et al., 2023

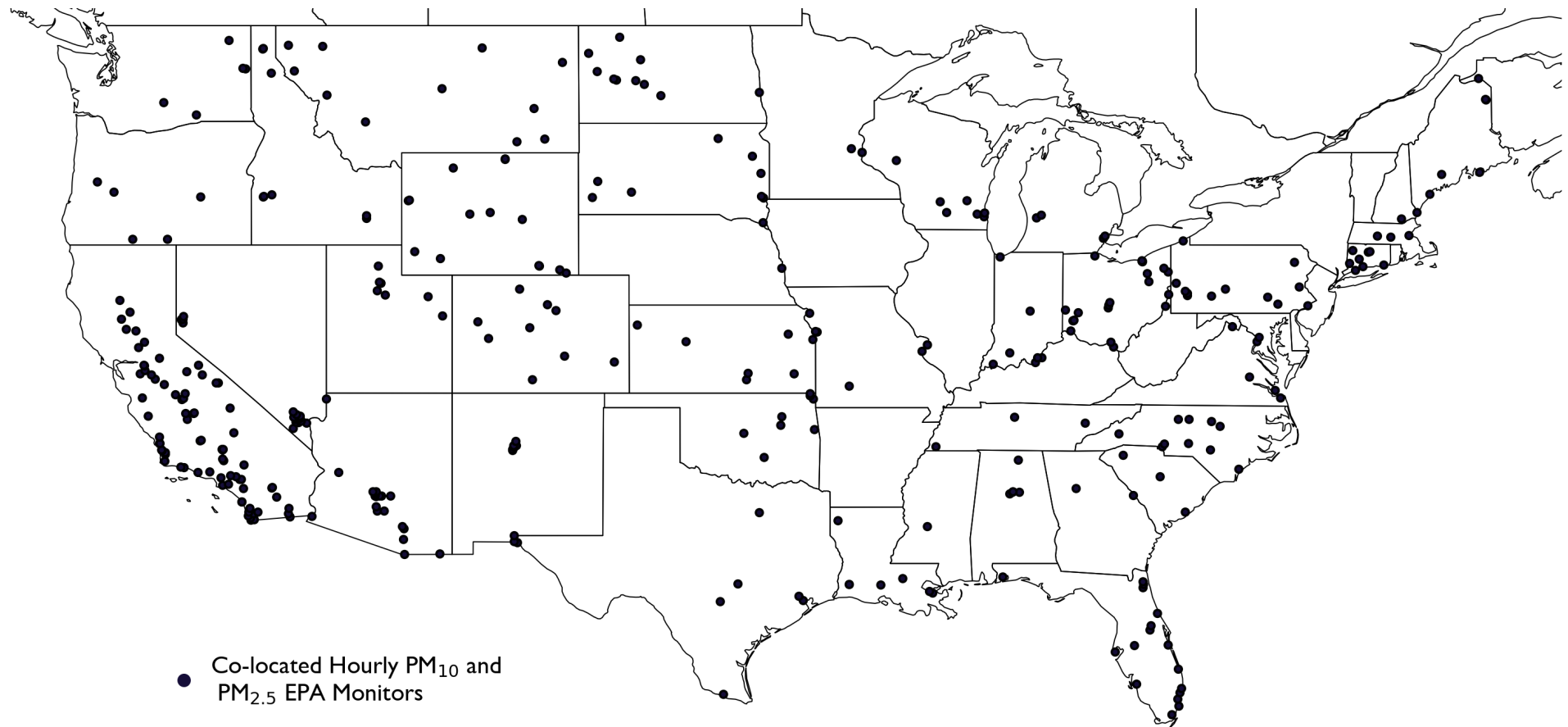
Ardon-Dryer et al., 2023; Crooks et al., 2016; D. Tong et al., 2022, 2023

Previous work uses surface monitors to detect dust and evaluate dust storm frequency and dust concentration.

...but monitors are sparse!



Need co-located  $\text{PM}_{2.5}$  and  $\text{PM}_{10}$  monitors to measure  $\text{PM}_{\text{coarse}}$ , but these are very sparse in some dusty regions!

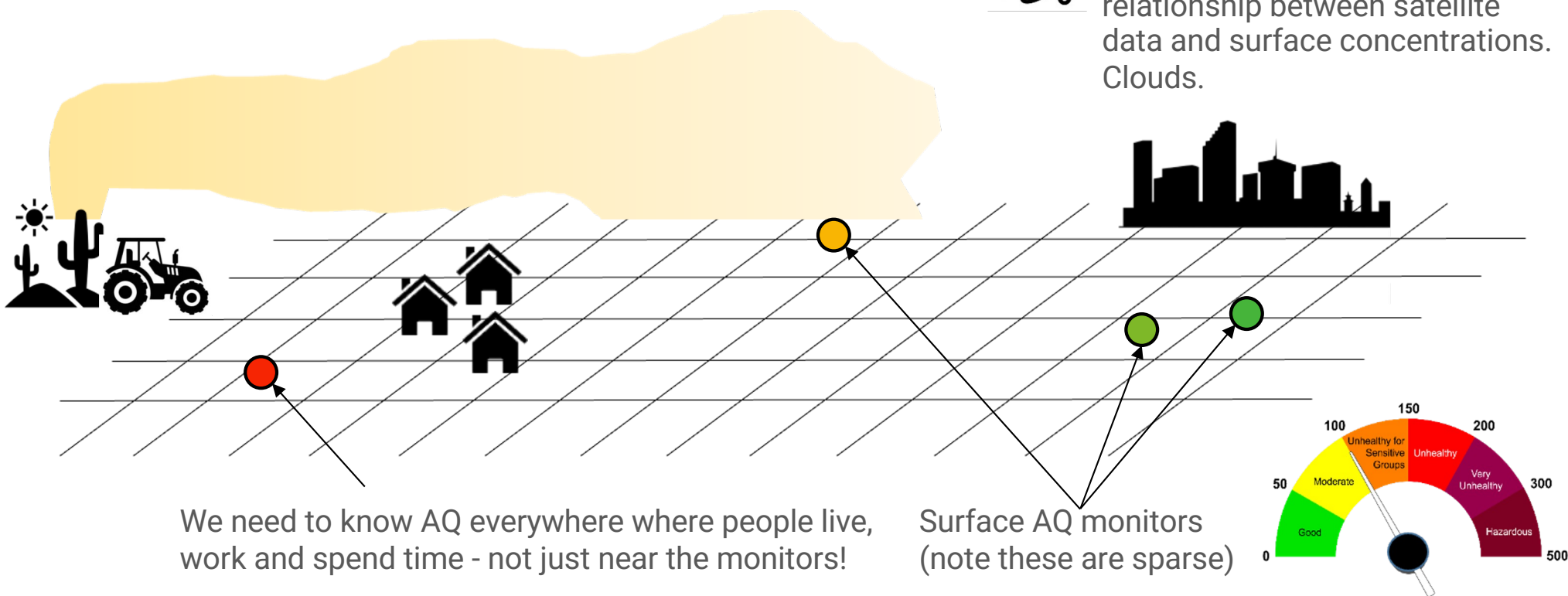


# What can satellites add on dust information?

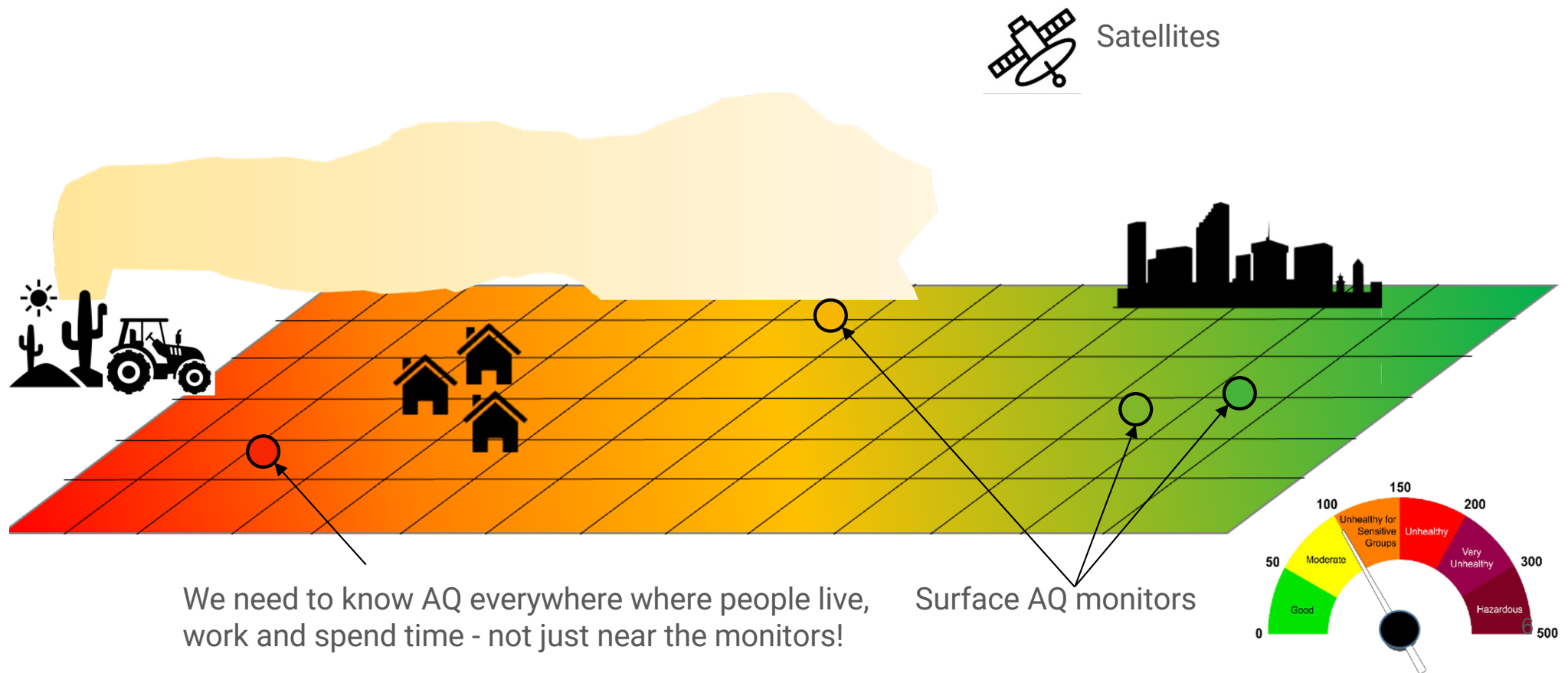
## Satellites

*Advantages:* Increase spatial coverage; offer information about aerosol size and composition.

*Challenges:* Not a direct relationship between satellite data and surface concentrations. Clouds.

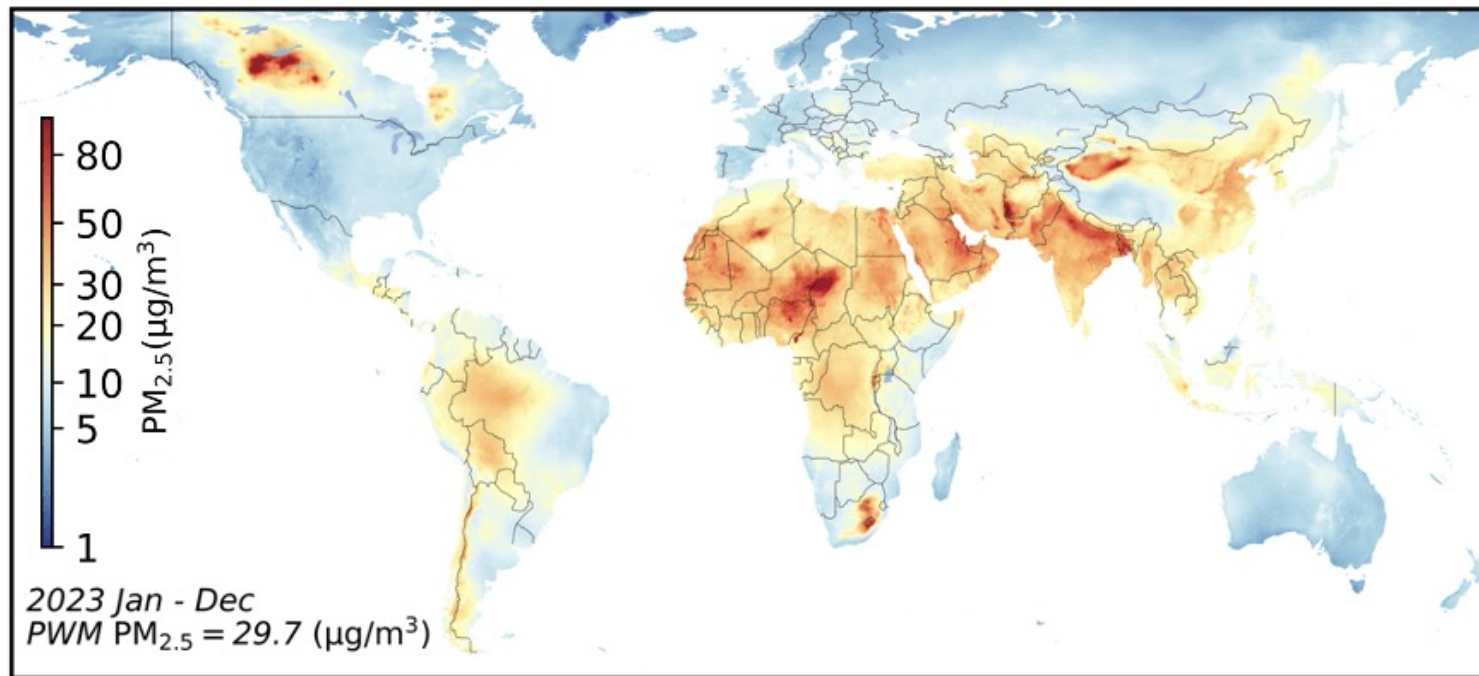


We are working towards combining information from satellites and surface monitors to have a full picture of dust events.



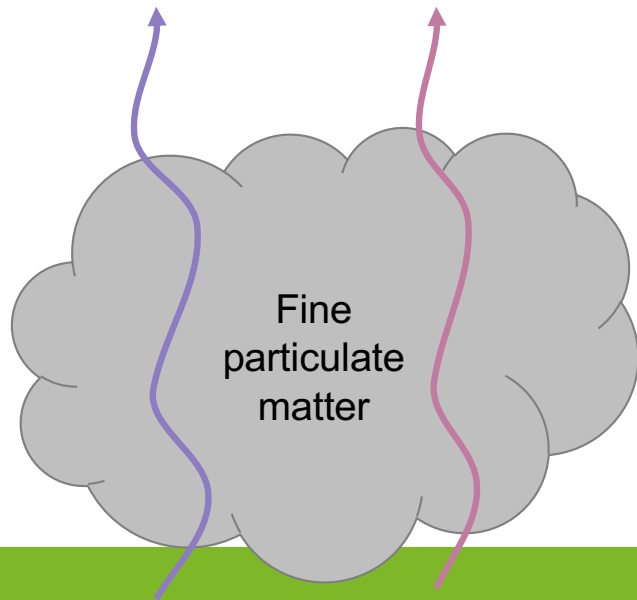


Great advances in  $\text{PM}_{2.5}$  estimates by combining satellite and surface-monitor data, but little done for  $\text{PM}_{\text{coarse}}$  and dust so far!

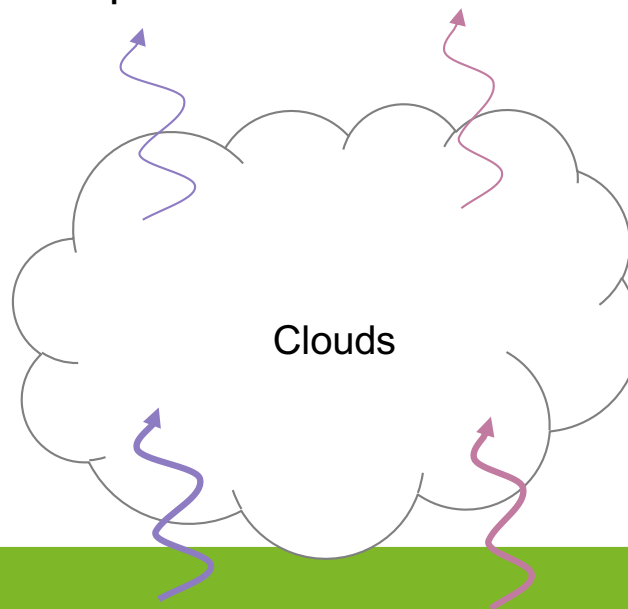


Longwave dust dection can work because it interacts with radiation differently than other aerosols and clouds.

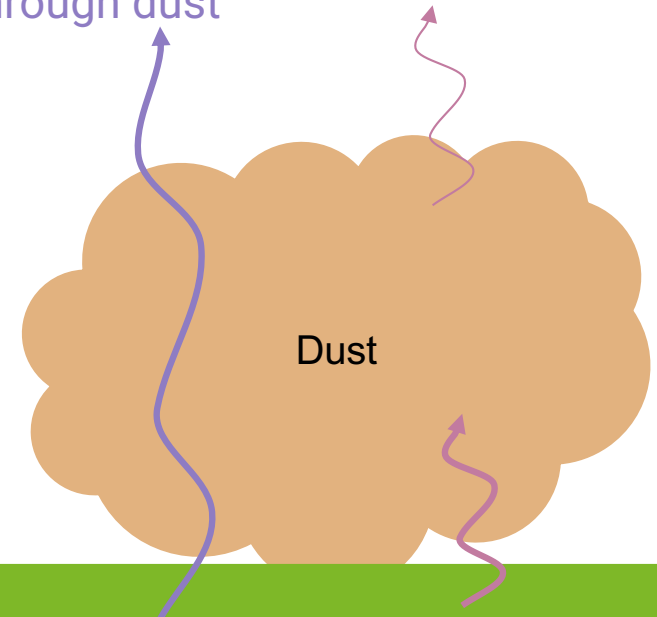
10.3 and 12.3  $\mu\text{m}$  longwave radiation pass through



10.3 and 12.3  $\mu\text{m}$  absorbed and re-emitted at a colder temperature.

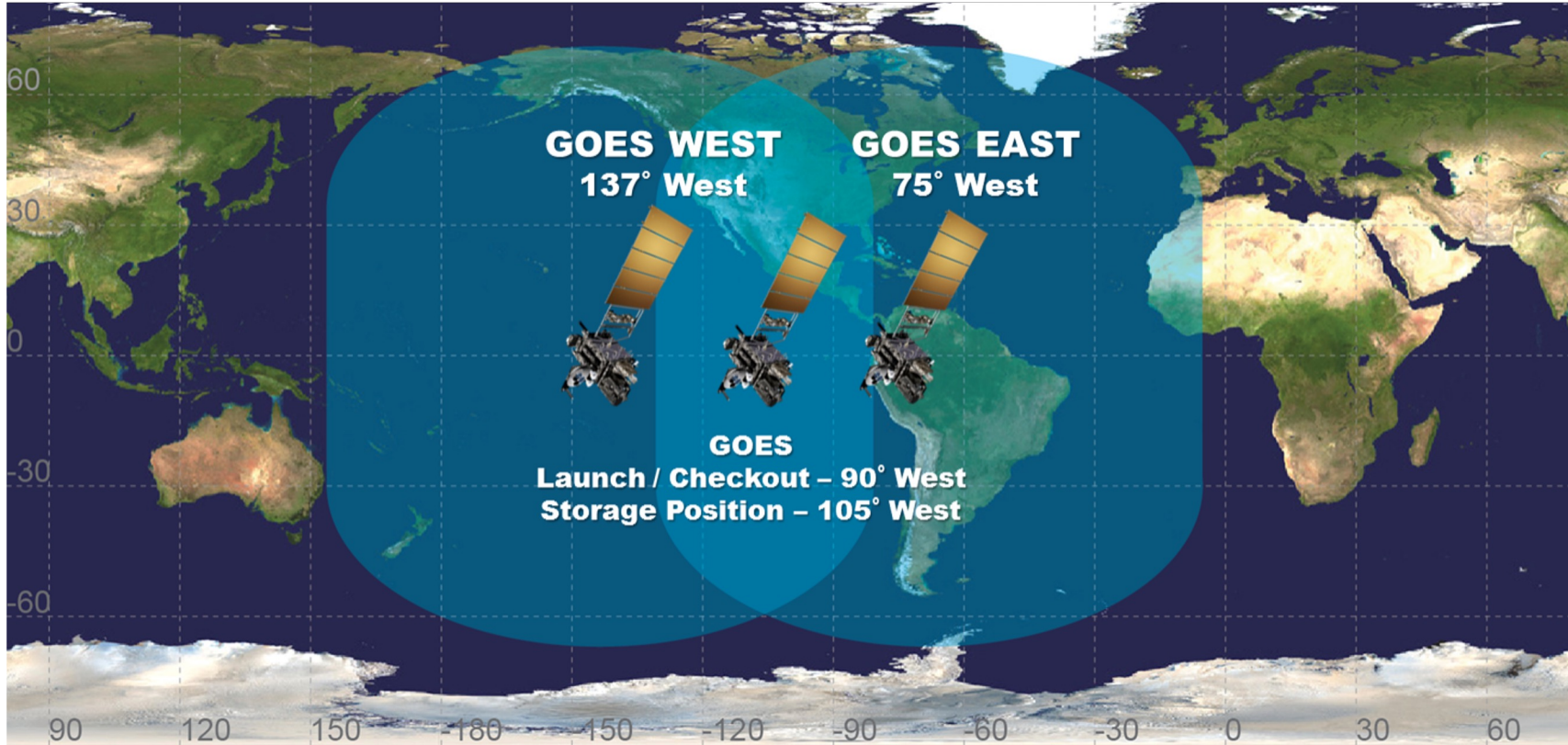


12.3  $\mu\text{m}$  more easily passes through dust



10.3  $\mu\text{m}$  is absorbed and re-emitted at a colder temperature

# Geostationary Operational Environmental Satellite (GOES) East



Source:  
NOAA

Infrared radiation detected by geostationary satellite data can be used to identify dust, but mostly evaluated in case study analyses.

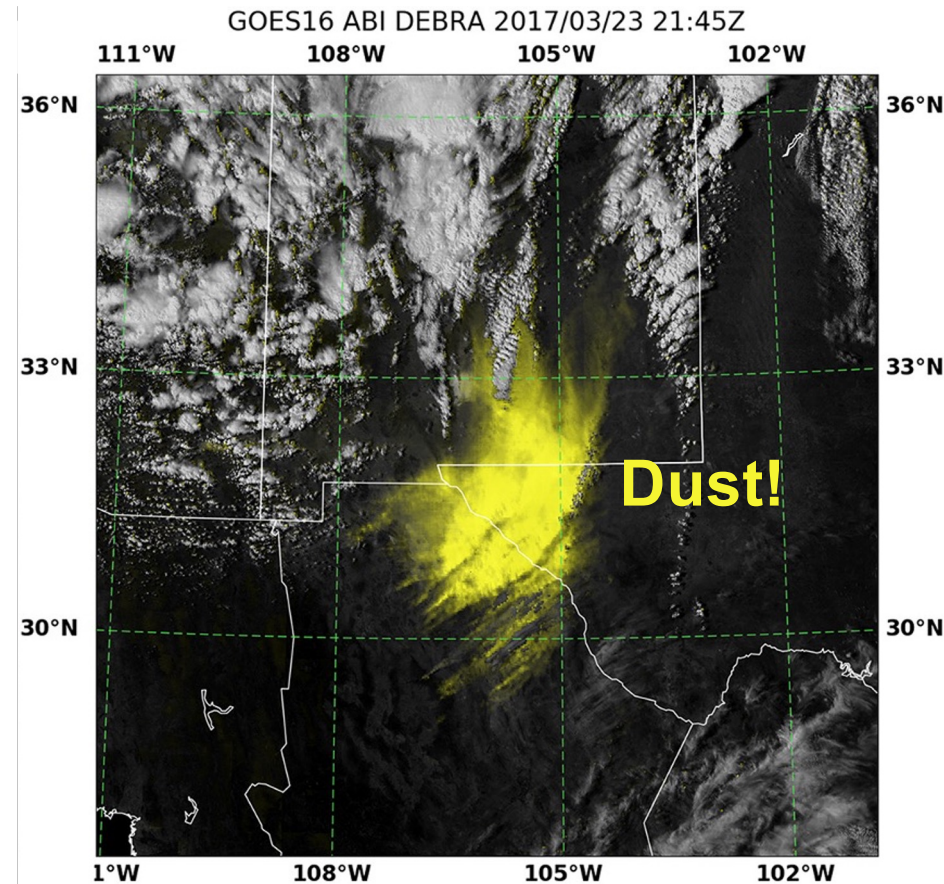
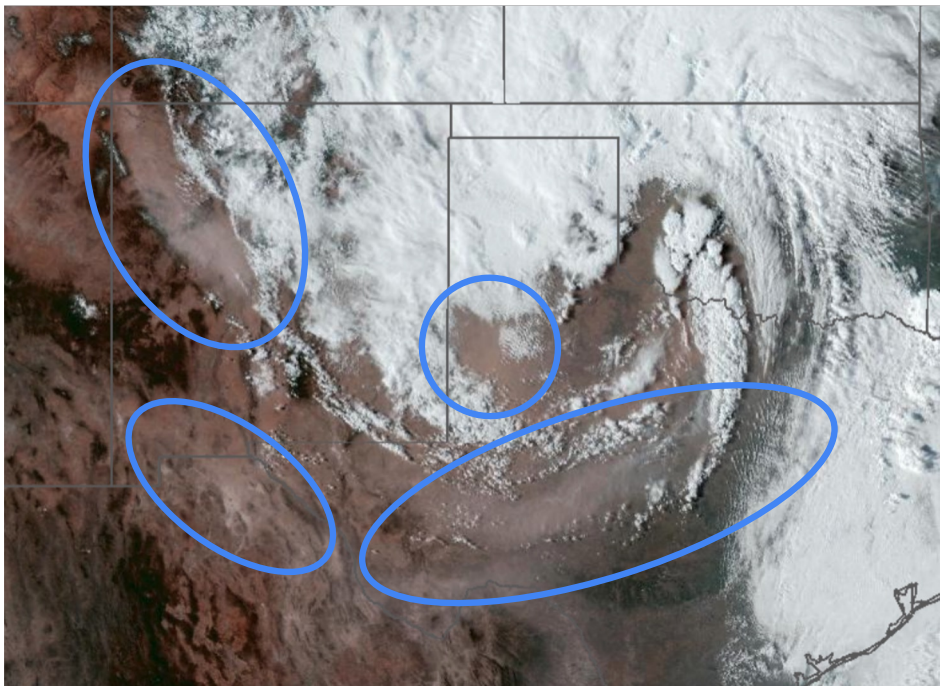


Figure adapted from Miller et al., 2017

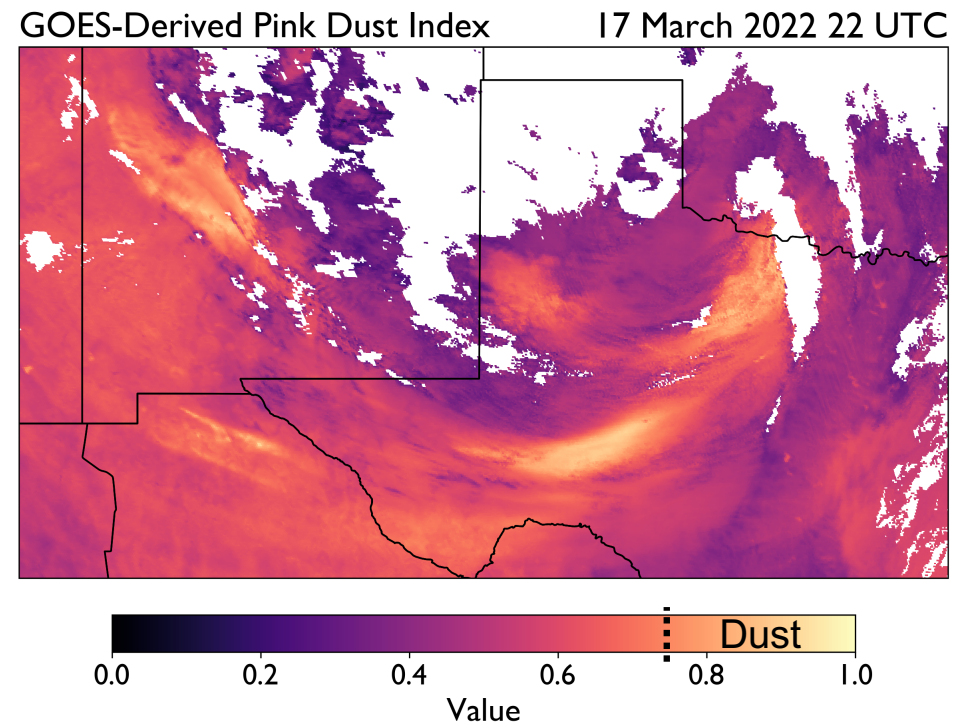
AlNasser & Entekhabi, 2024; Ciren et al., 2024; Miller et al., 2017, 2019



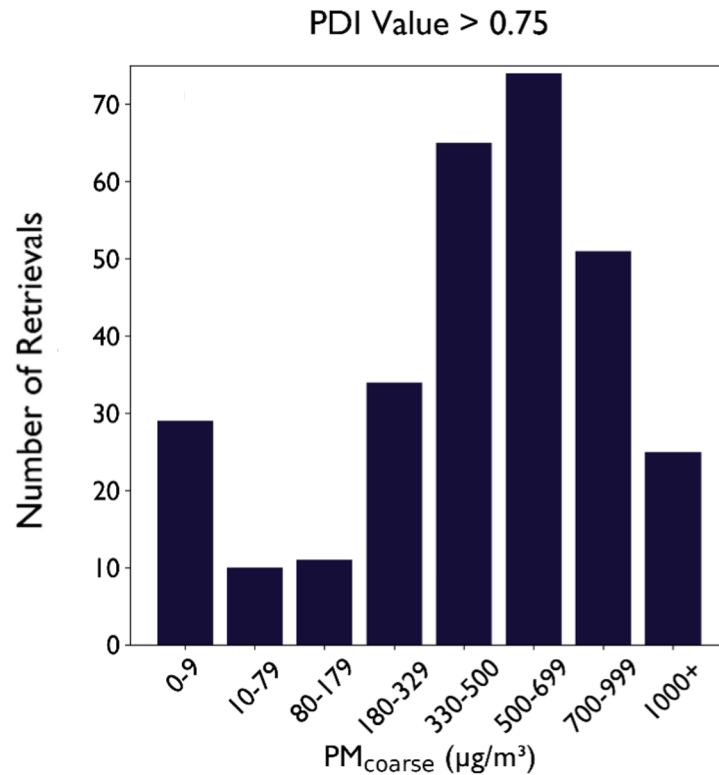
Longwave dust detection products use dust absorption at  $10\text{ }\mu\text{m}$  to separate dust signal from clouds.



Source: Aerosol Watch/Geocolor Imagery

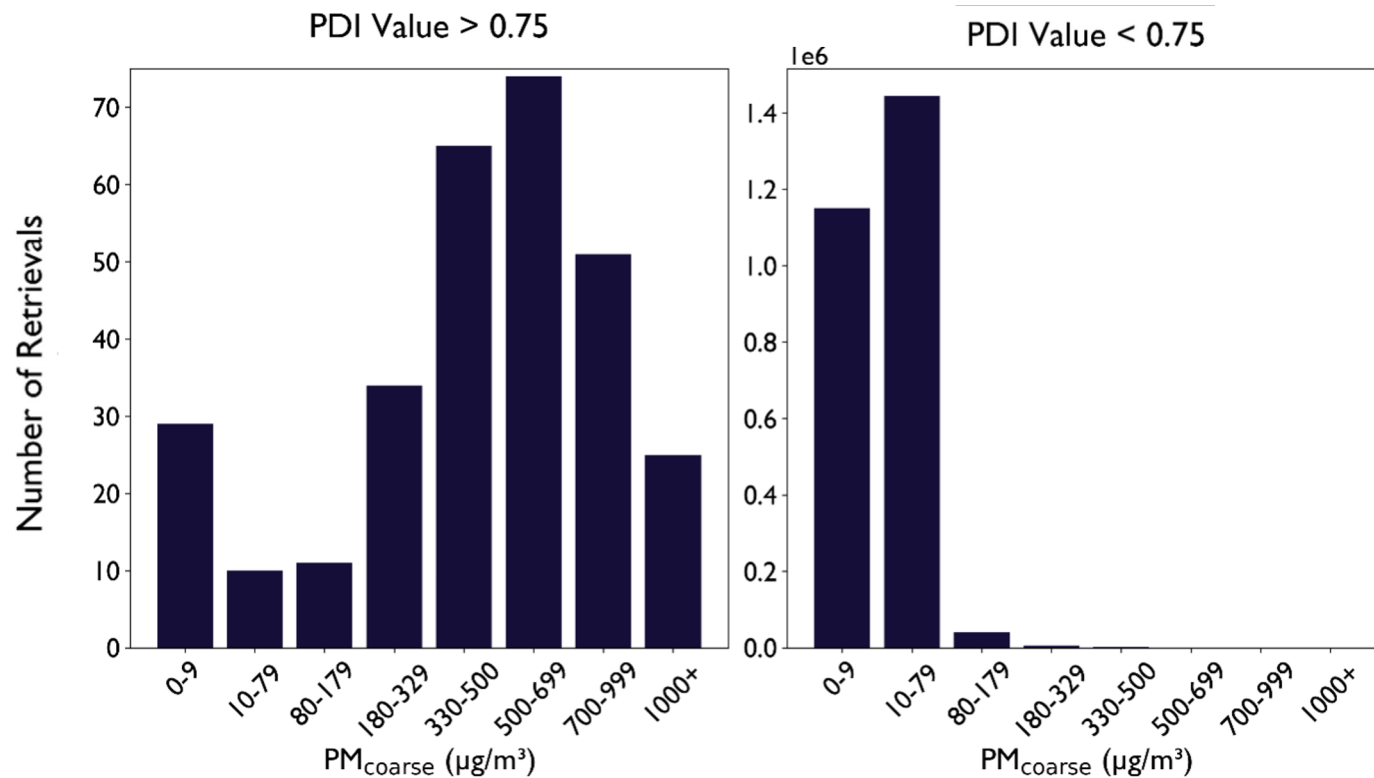


When Pink Dust Index (PDI) values are above a determined threshold generally correspond with high surface PM<sub>coarse</sub>.

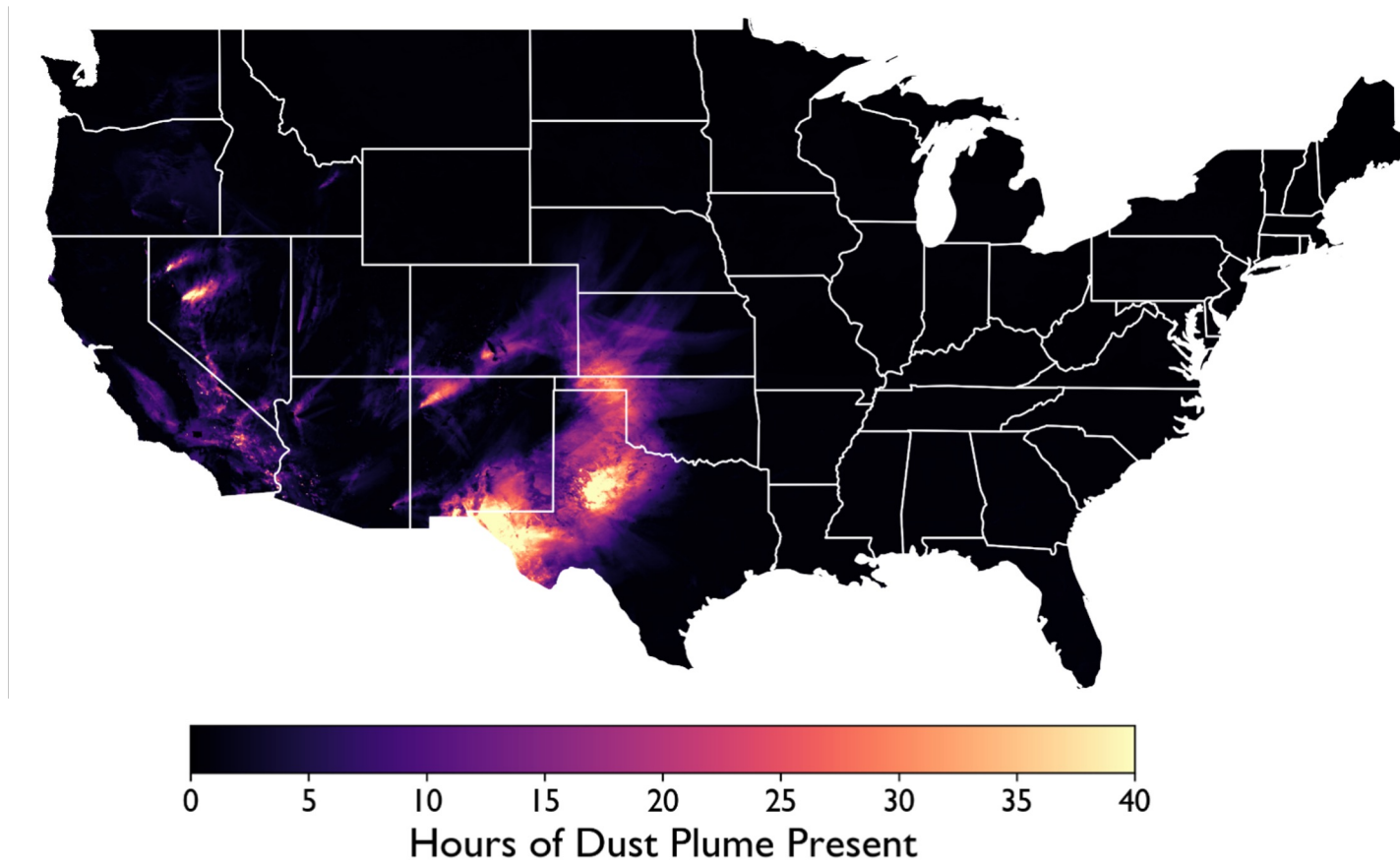




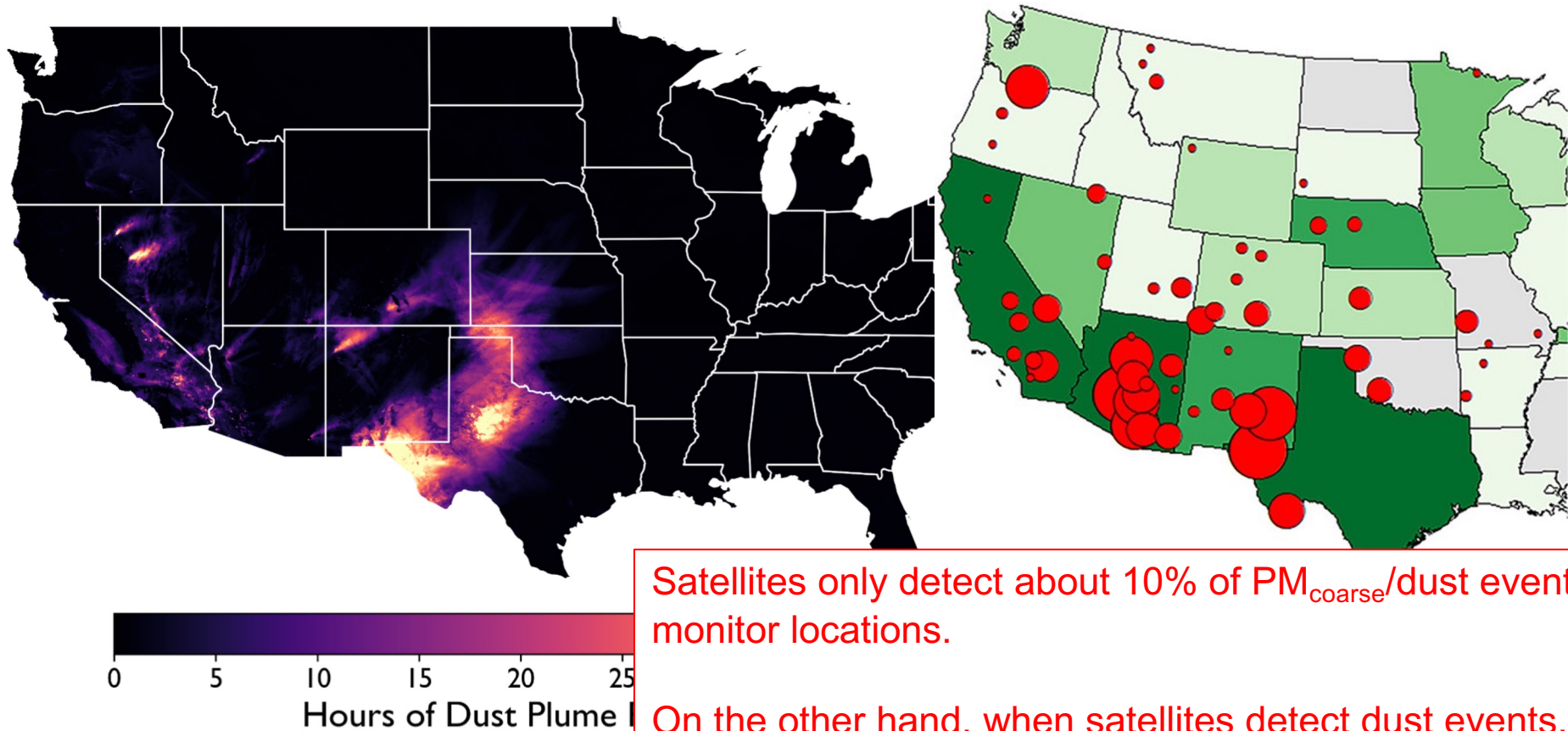
When there is no positive satellite dust detection,  $PM_{coarse}$  estimates are generally low.



Most of the satellite-detected dust plumes in 2018-2024 occur in the Southwest and South Central US regions



Satellites miss dust events in some regions (clouds and other factors).  
But satellite-detected dust events are often away from monitor locations!

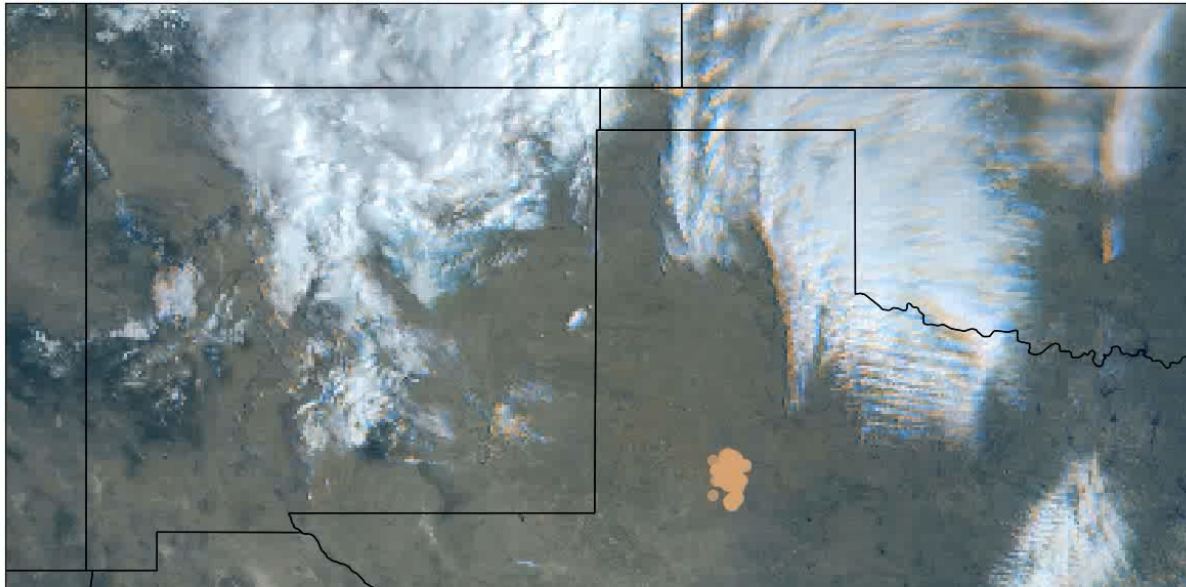


Satellites only detect about 10% of  $PM_{coarse}$ /dust events at monitor locations.

On the other hand, when satellites detect dust events, over 90% of the time, the dust does not hit a ground monitor!

# Use machine learning to cluster dust plumes

GOES-16 True Color 2022-03-17 16:12:00

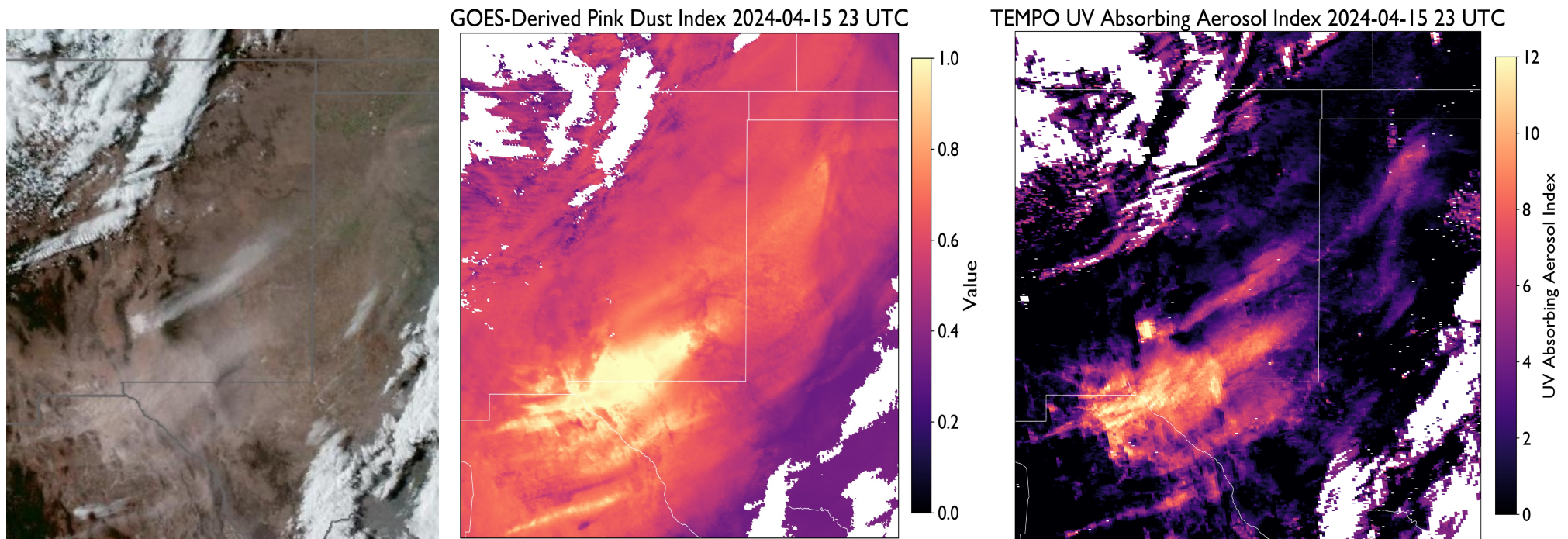


Used this technique to quantify dust event sizes and durations!

~9 dust plumes per year reach a size greater than 10,000 km<sup>2</sup>  
(~the size of Maryland) in the US



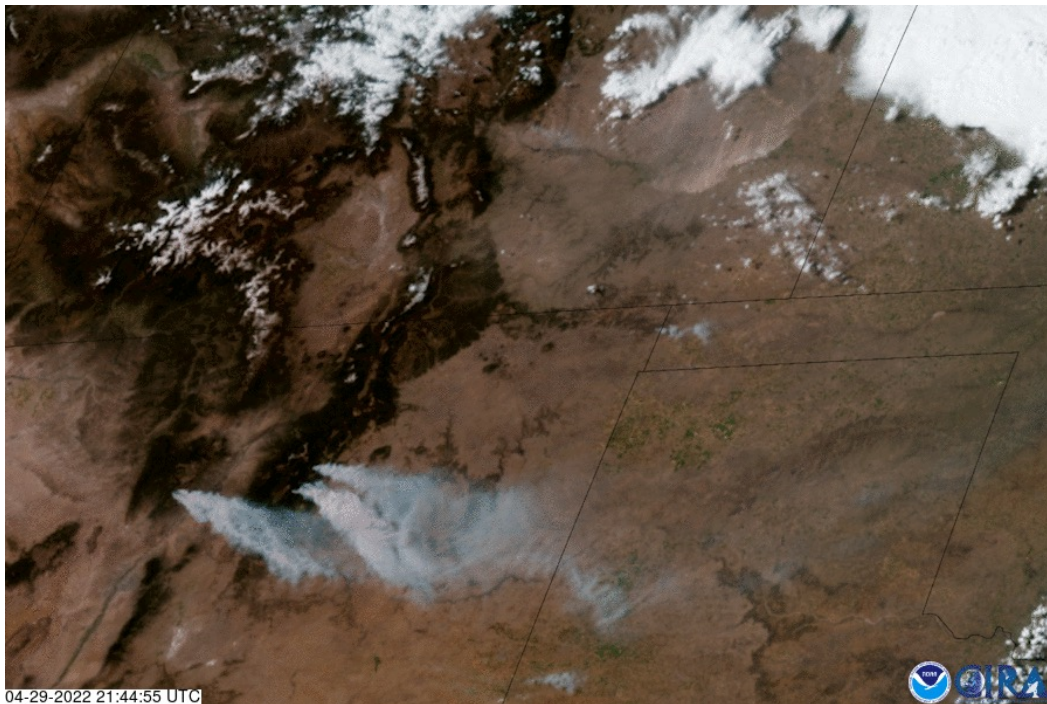
# Big opportunities from combining UV-VIS from TEMPO with longwave from GOES



**Preliminary, non-operational TEMPO aerosol data**



# Conclusions



Satellites offer the potential to augment surface monitoring of dust events

Over 90% of satellite-detected dust events occur away from ground monitors!

Need more work to improve satellite-based dust detection. TEMPO should add a lot of information!