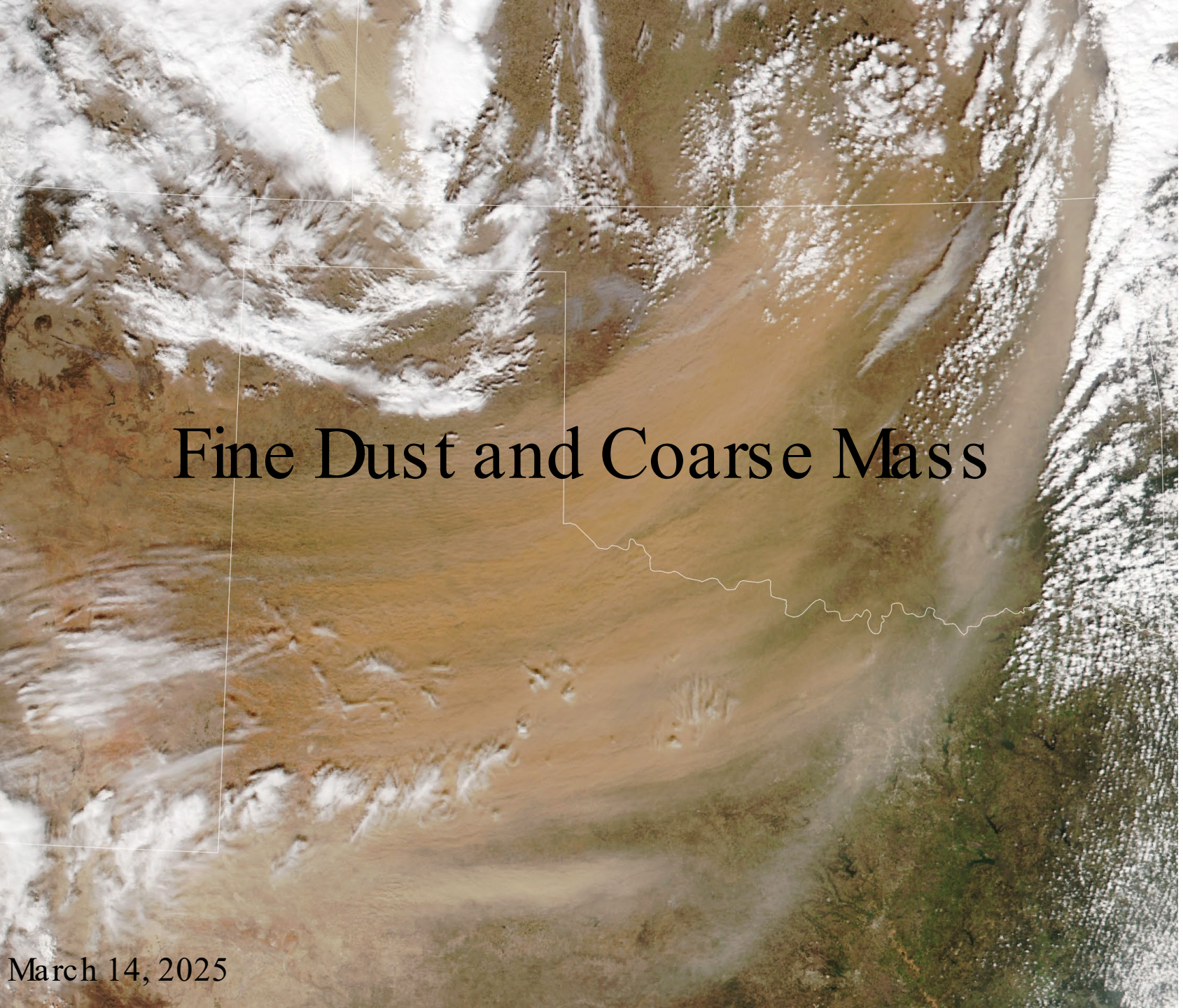


Fine Dust and Coarse Mass

March 14, 2025

Jenny Hand

CIRA

Colorado State University

IMPROVE Virtual Annual Steering Committee Meeting
November 18-19, 2025

Dust Impacts


Near Alta, UT
April 2022

- Air quality, visibility
- Hydrology- snow melt, water supplies
- Biogeochemistry (algal blooms, phytoplankton)
- Ecology (deposits and removes nutrients, deposits toxins and pathogens)
- Heterogeneous chemistry
- Health (cardiovascular mortality, respiratory diseases such as asthma and Valley fever)
- Ground transportation and aviation safety hazard
- Renewable energy
- Ground level ozone- reactions between dust and precursors
- Microplastics
- Indirect and direct impacts on climate
- Economic impacts: ($154.4 billion annually (2017), Feng et al., 2025)

Photo by Joseph Rogash, NOAA-NWS,
courtesy of Tom Gill, UTEP

March, 2012, El Paso, TX
($PM_{10} > 5000\ \mu g\ m^{-3}$)

VIDEO: Multiple Crashes Reported in West Texas During Dust Storm

DUST DEVIL

limate change may be driving an expansion of Valley fever, a deadly fungal infection spread by airborne spores

Why I-10 near Lordsburg keeps killing drivers

Wind, dust, climate change and traffic brew a perfect storm near the Arizona border

The Deleterious Dust of the Salton Sea

Coarse particulate matter deriving from California's largest lake is linked to an increased risk of respiratory-related hospitalizations.

NEWS

Multi-car pileup crash during sandstorm in Reeves County leaves one dead

by: Gabriella Meza

'Blood rain' and diseases in the wind: Is the US prepared for deadly dust storms?

Dust storms and wind erosion cause $154 billion in damages annually, study shows

by University of Texas at El Paso

NEW MEXICO NEWS

Three killed in 11-car pileup west of Lordsburg

by: Audrey Claire Davis

Inhaled agricultural dust disrupts gut health

UC Riverside study highlights need for protective measures for agricultural workers

El Paso Hasn't Seen This Many Dust Storms Since the Dust Bowl

At least 8 dead in Kansas dust storm as 55 vehicles crash during interstate pile-up

Borderland experiencing extreme dust level activity, UTEP professor says

How dangerous are severe dust storms to your health? Here's what doctor has to say

Video shows haboobs, or powerful dust storm, 'brown-out' portions of Texas, New Mexico

Rare Chicago dust storm reignites debates over the role of agriculture, experts say

Haboob tears across Southwest with near-zero visibility, shutting down interstates

Dust storm engulfing much of northern Illinois, weather officials urge caution

Dust from Southwest storm settles in parts of VA Saturday morning

Dust Storms Surprise the Midwest and Raise Worries About Climate Risks

Low visibility during dust storm could have led to I-10 crashes

Drivers Blinded By Dust As Haboob Sweeps Through New Mexico

May 2, 2025

Eastern WA dust storm causes deadly Hwy 395 semi-truck chain-reaction pileup

Red state residents warned that toxic threat lurks in plain sight - why they should worry if a storm is brewing

What is dust?

$$PM_{2.5}\ \text{Fine dust}\ (FD) = 2.53[Al] + 2.86[Si] + 1.87[Ca] + 2.78[Fe] + 2.23[Ti]$$

$$\text{Coarse mass}\ (CM) = PM_{10} - PM_{2.5} \qquad (\mu g\, m^{-3})$$

U.S. Southwest- NM/TX

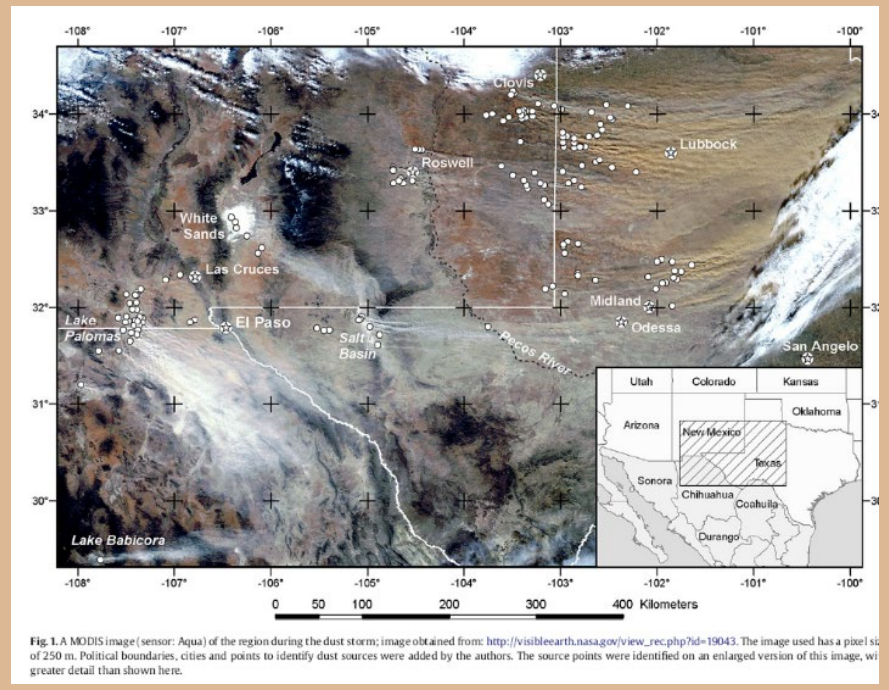
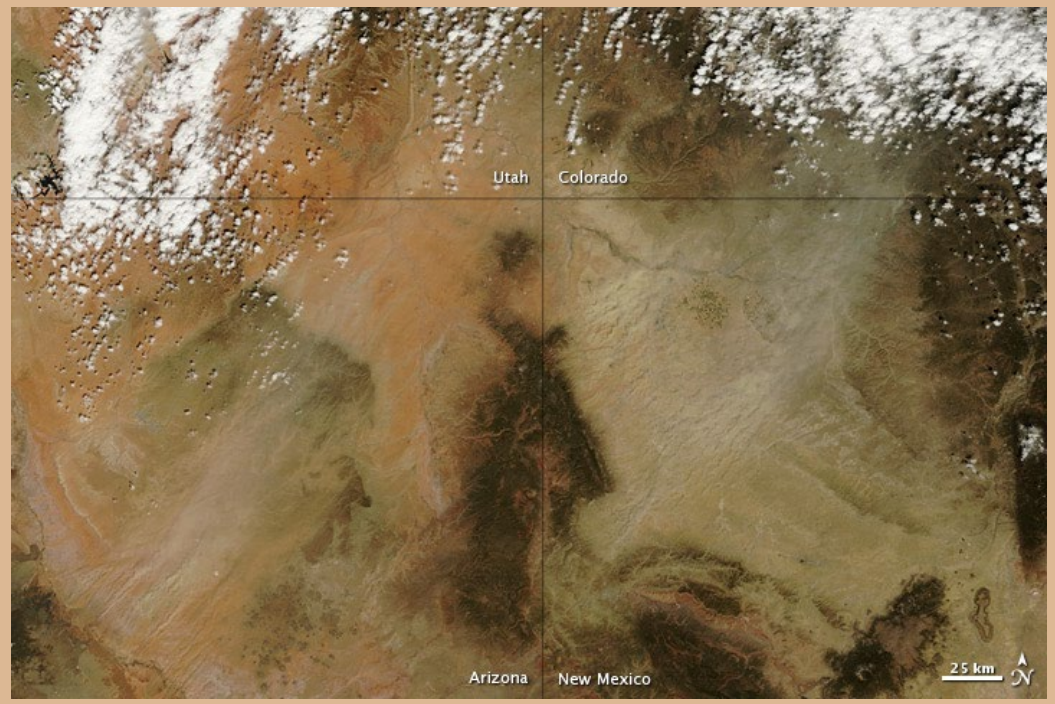


Fig. 1. A MODIS image (sensor: Aqua) of the region during the dust storm; image obtained from: http://visibleearth.nasa.gov/view_rec.php?id=19043. The image used has a pixel si of 250 m. Political boundaries, cities and points to identify dust sources were added by the authors. The source points were identified on an enlarged version of this image, wi greater detail than shown here.

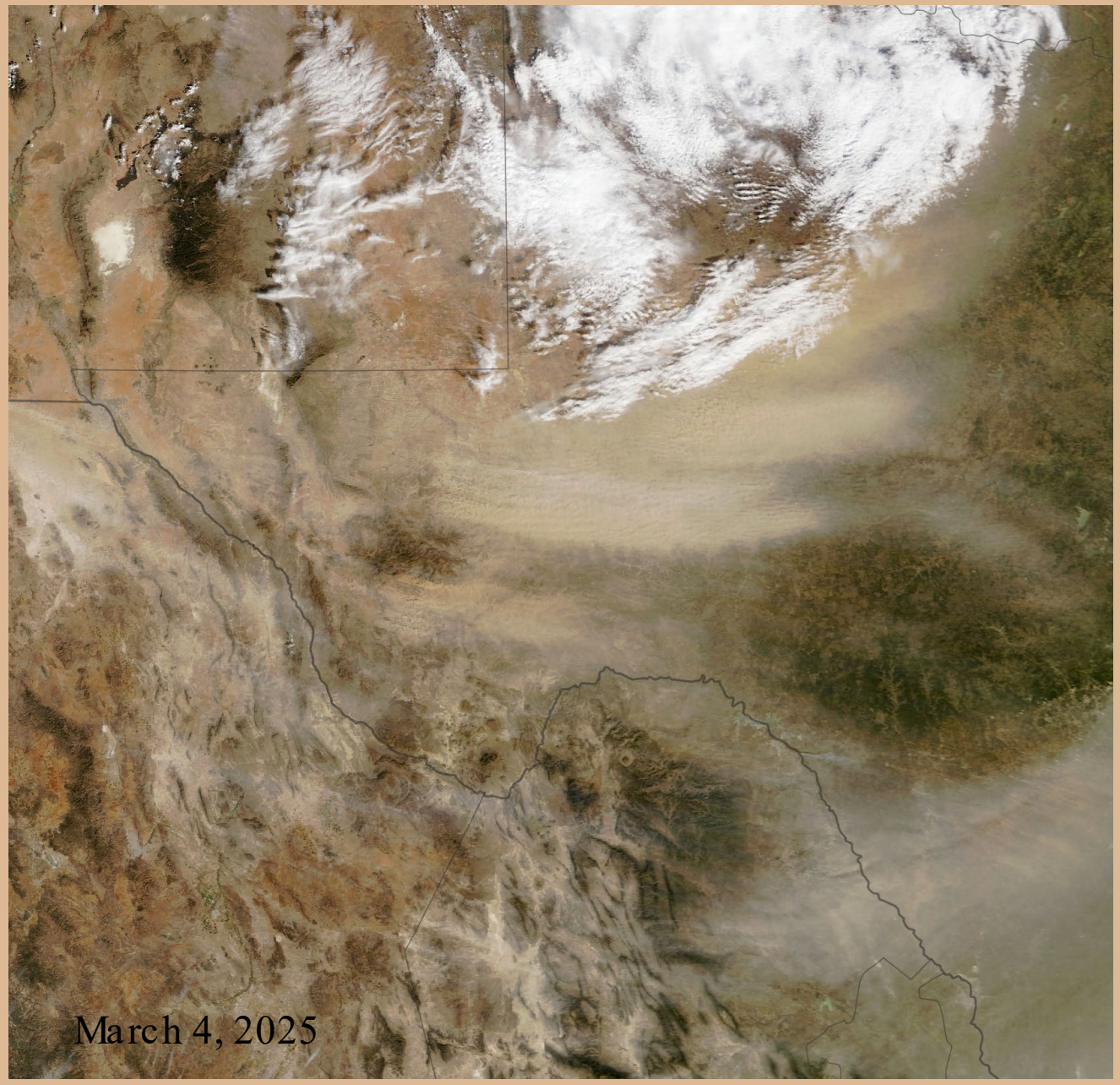
Dec 15, 2003 Lee et al. (2009)

U.S. Southwest

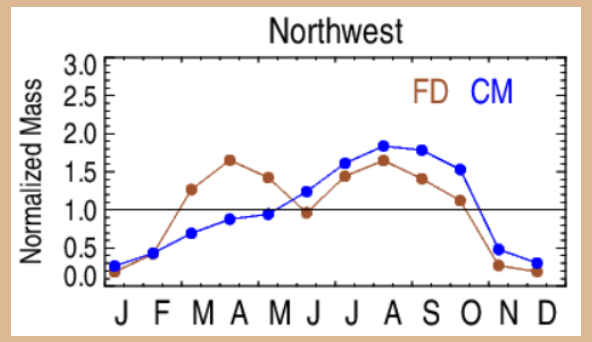


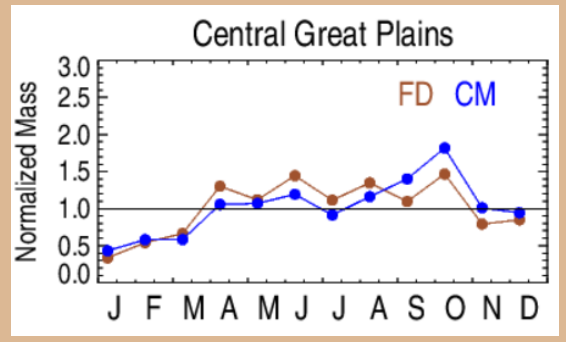
4/26/2013 MODIS

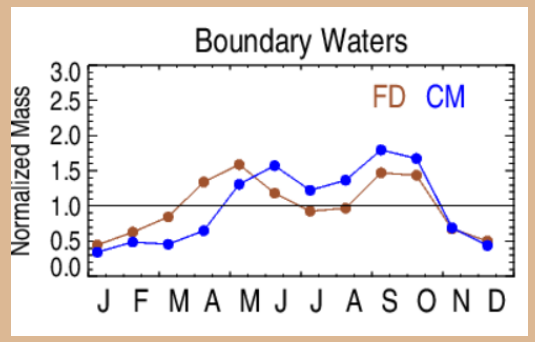
Current status and trends for fine dust and coarse mass at rural/remote sites in the US

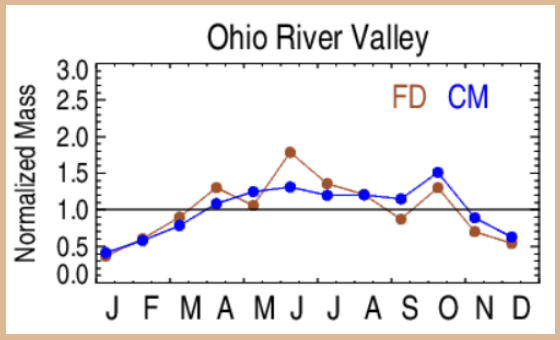


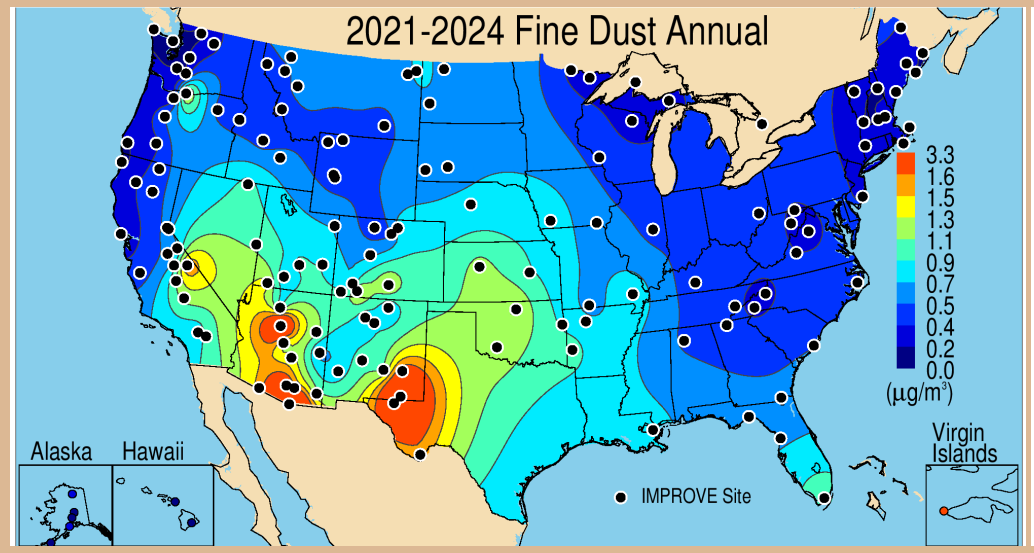
2021-2024 Normalized Monthly Mean Fine Dust and Coarse Mass (CM)

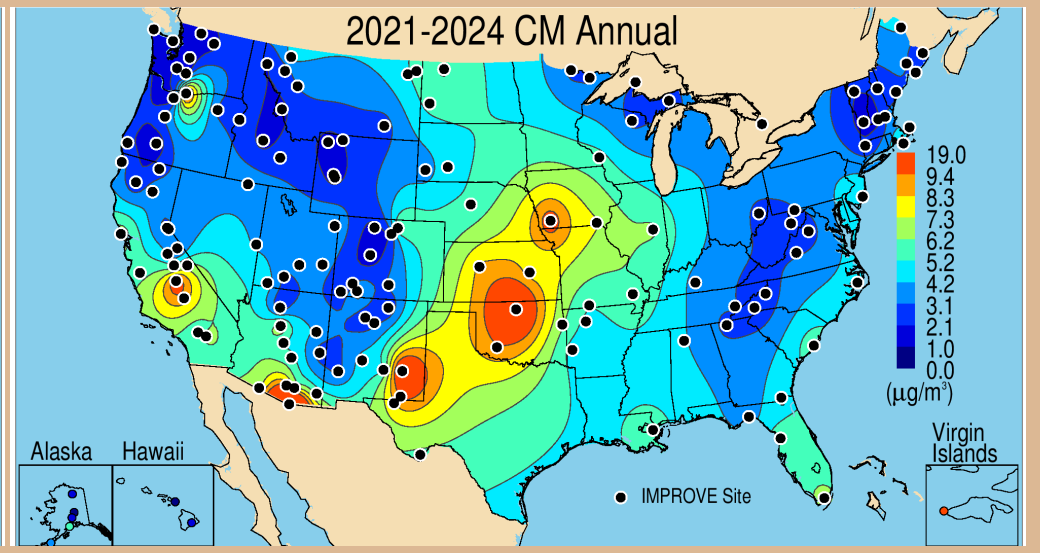


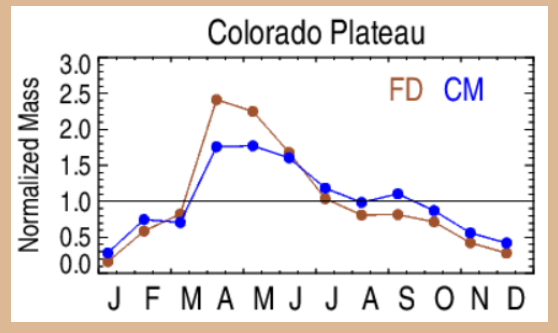


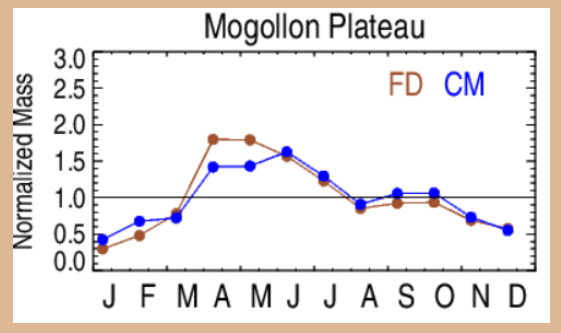


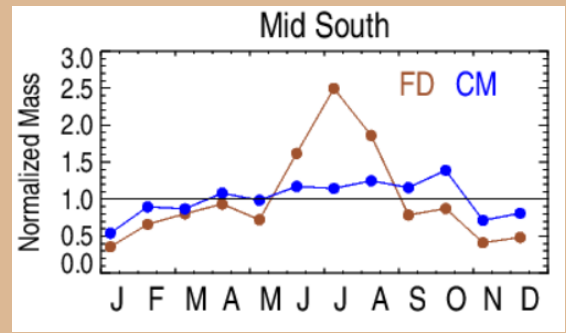


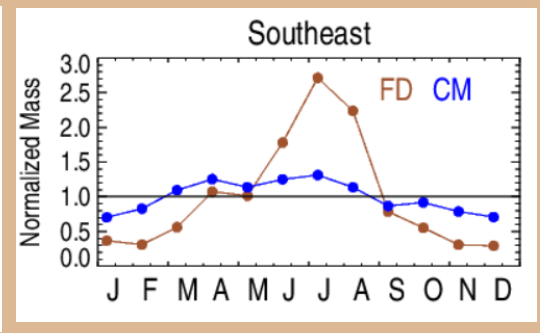




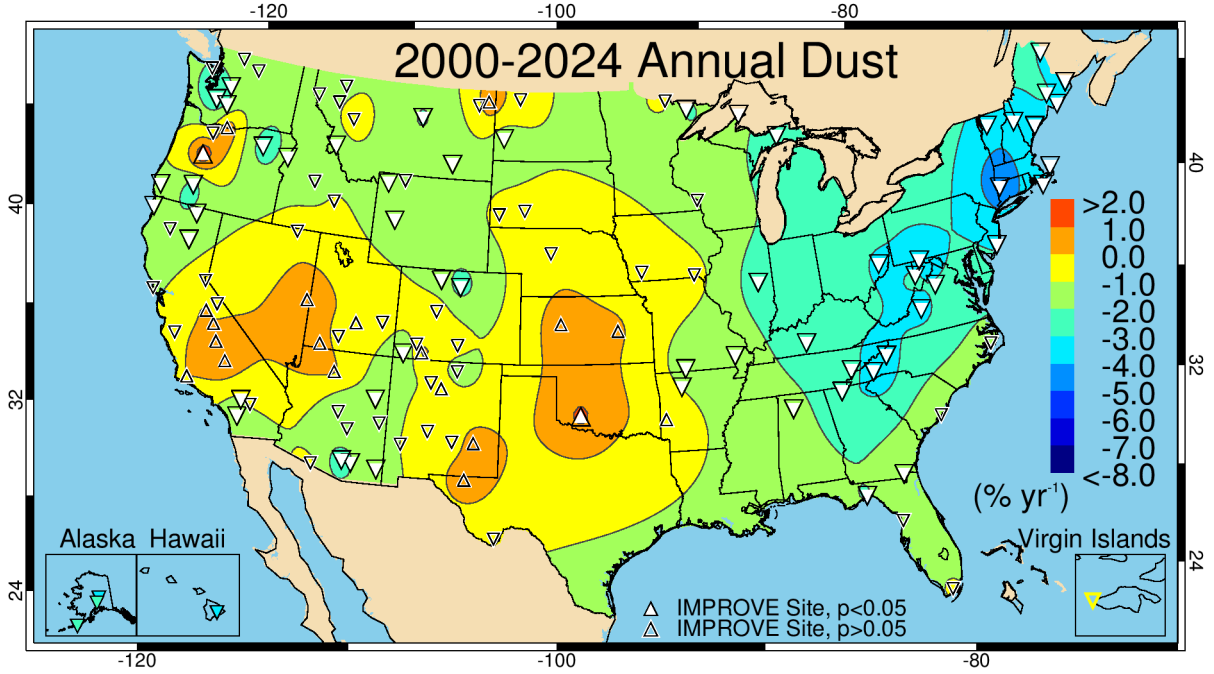


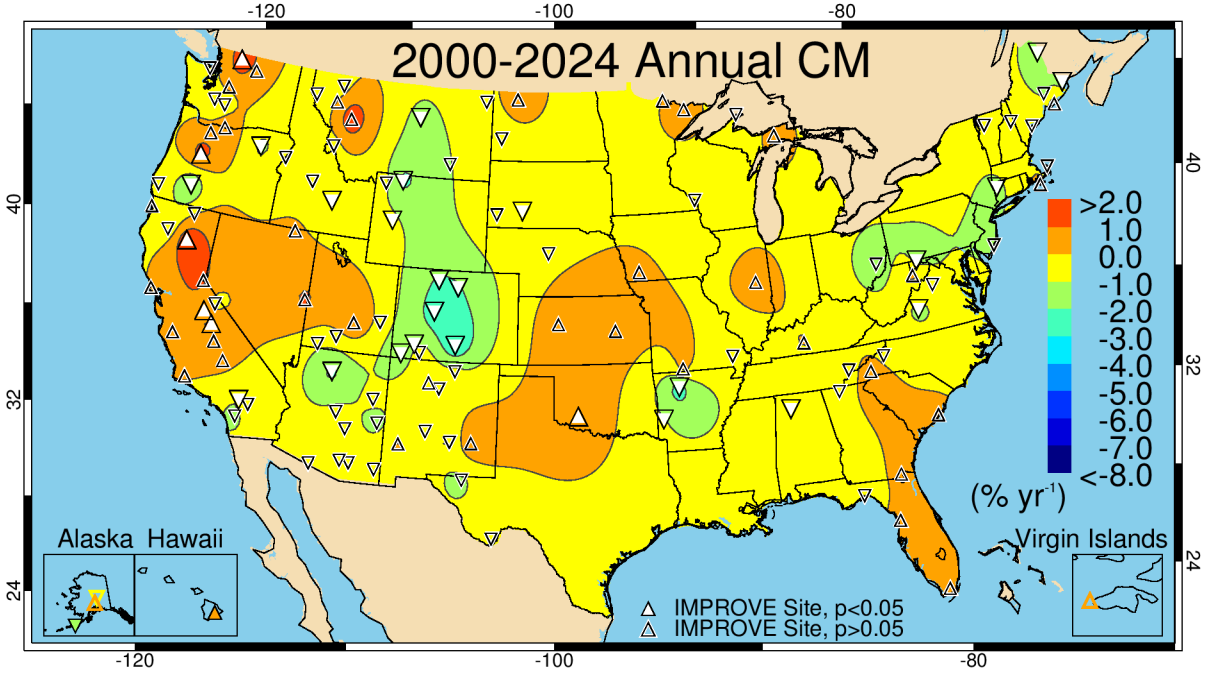






Annual mean trends in Fine Dust and Coarse Mass (2000-2024)



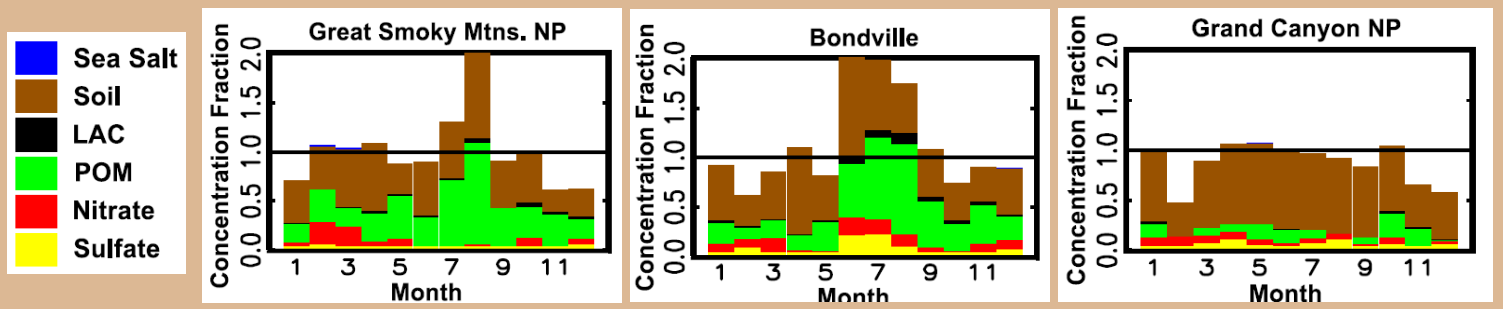


Question: How are CM and FD related?

(Some) Possibilities:

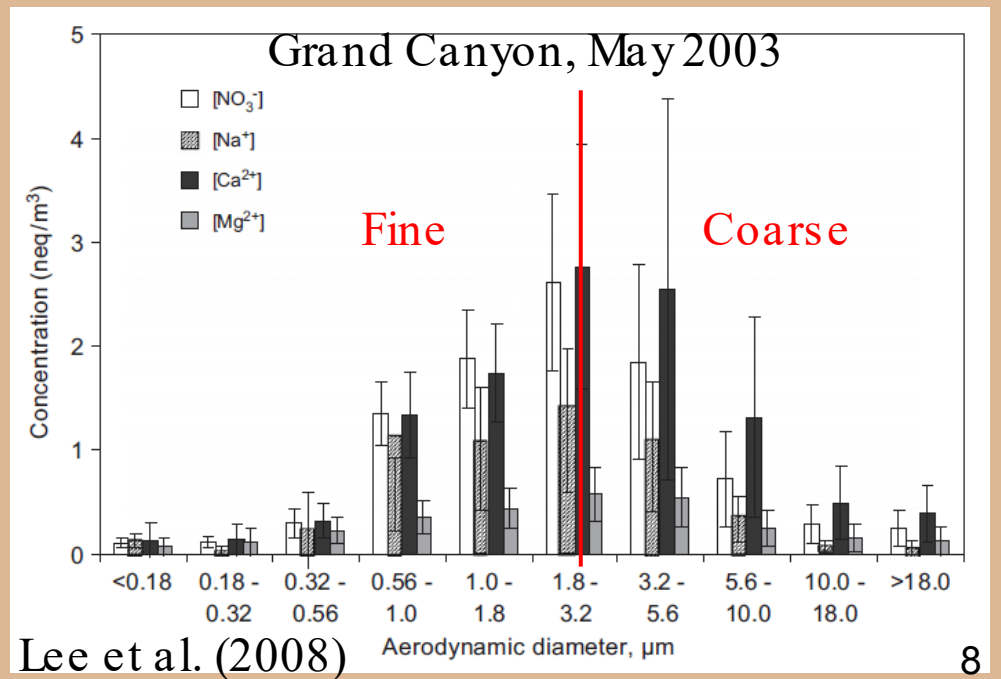
- Related: FD is the tail of the coarse mode dust distribution (assumed in the IMPROVE reconstructed extinction equation)
- Unrelated: Coarse mode dust has a larger size distribution that doesn't reach into the fine mode
- Unrelated: Coarse mass includes non-mineral species (carbon, ions)

2003-2004 Coarse Speciation Study, CM mass fraction



Malm et al. (2007)

MOUDI data



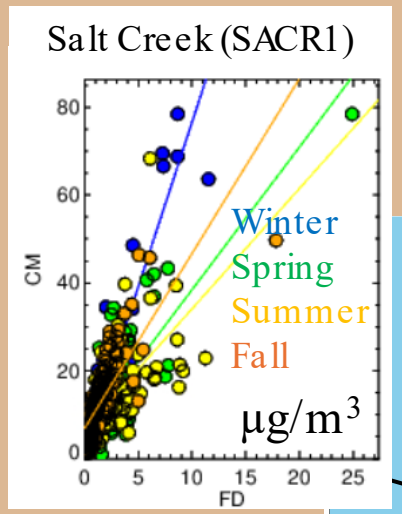
Lee et al. (2008)

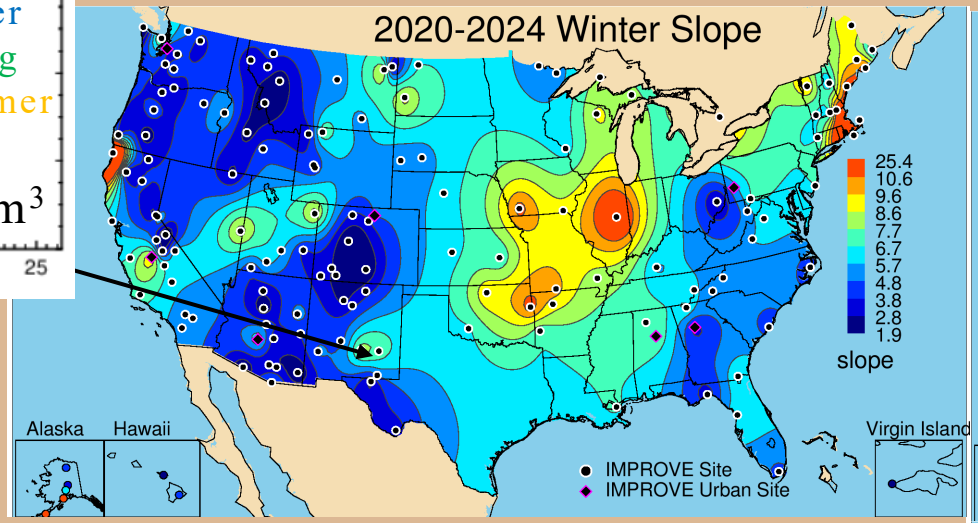
Explore:
Linear Regression of Coarse Mass and Fine Dust:

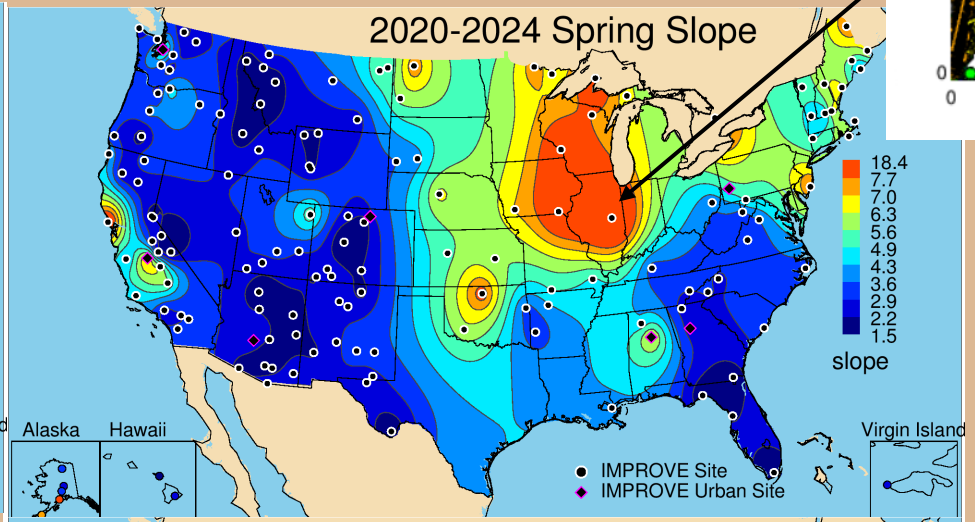
$$CM = mFD + b$$

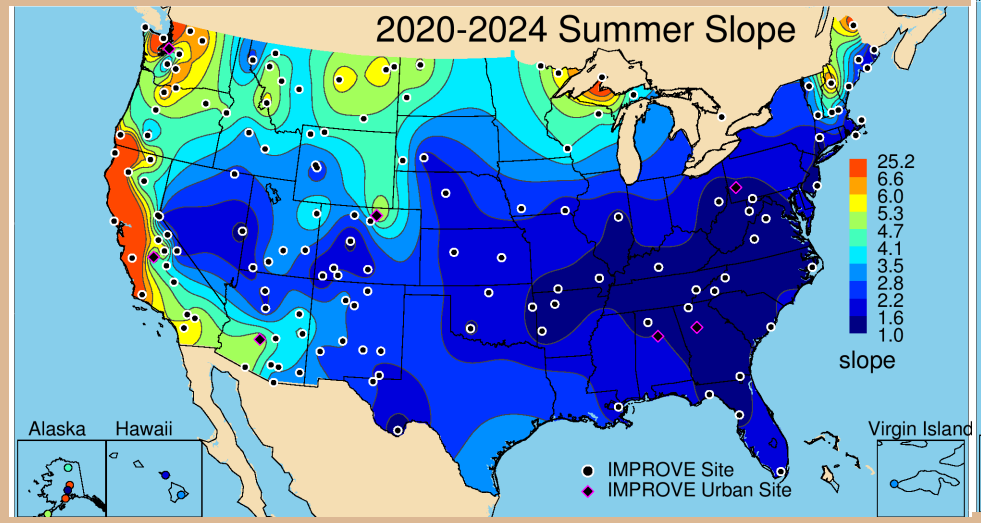
2020-2024
Site specific daily data,
seasonal regression

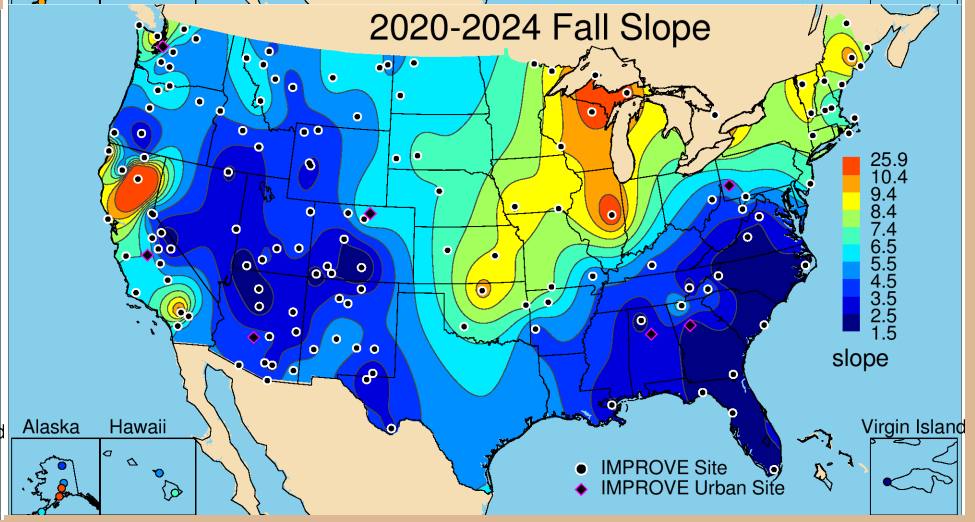
2020-2024 Seasonal mean slope (CM = mFD + b)

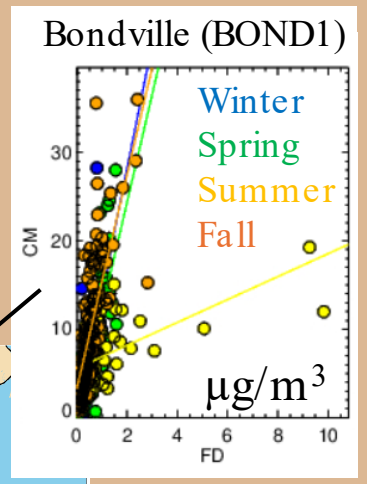




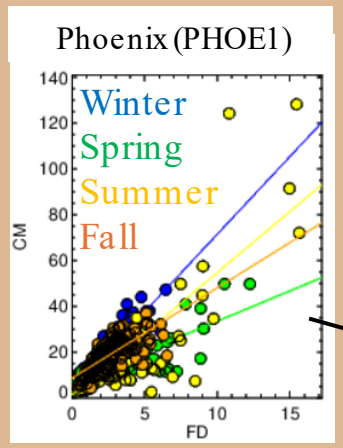


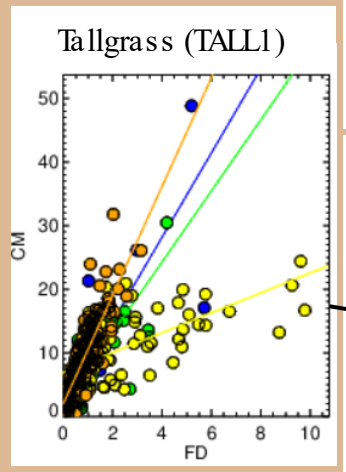


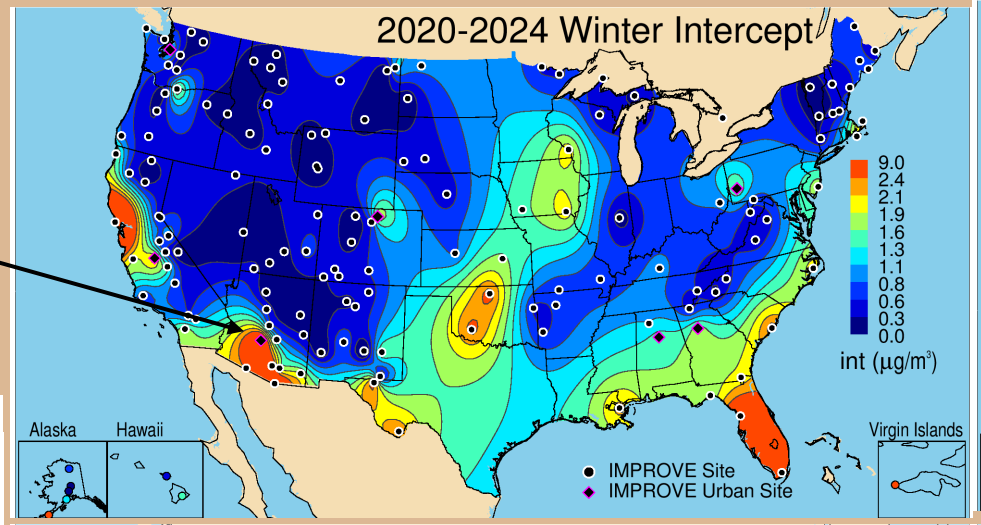


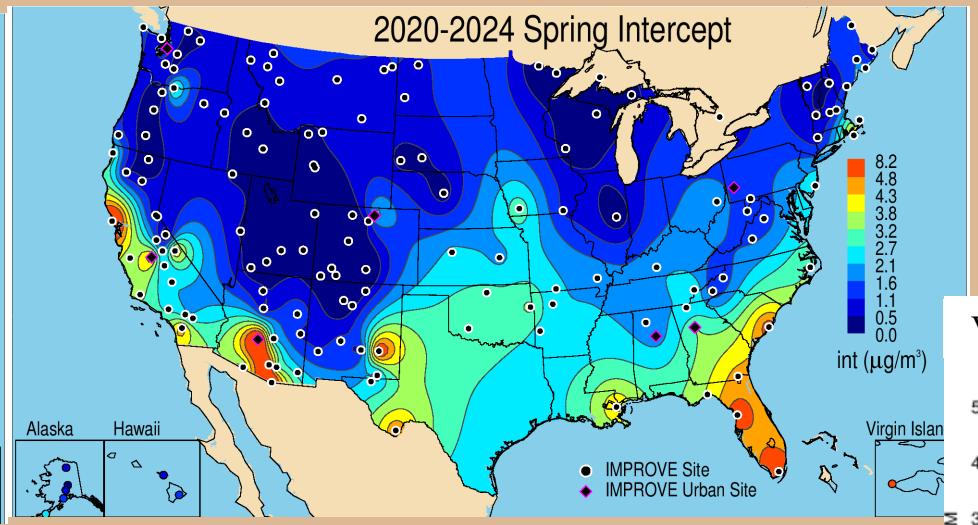


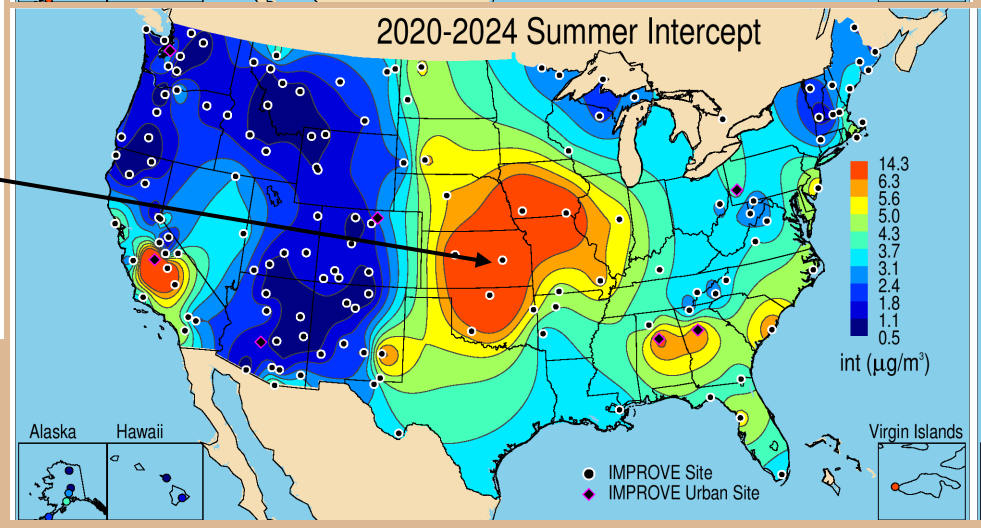
2020-2024 Seasonal mean intercept (CM = mFD + b)

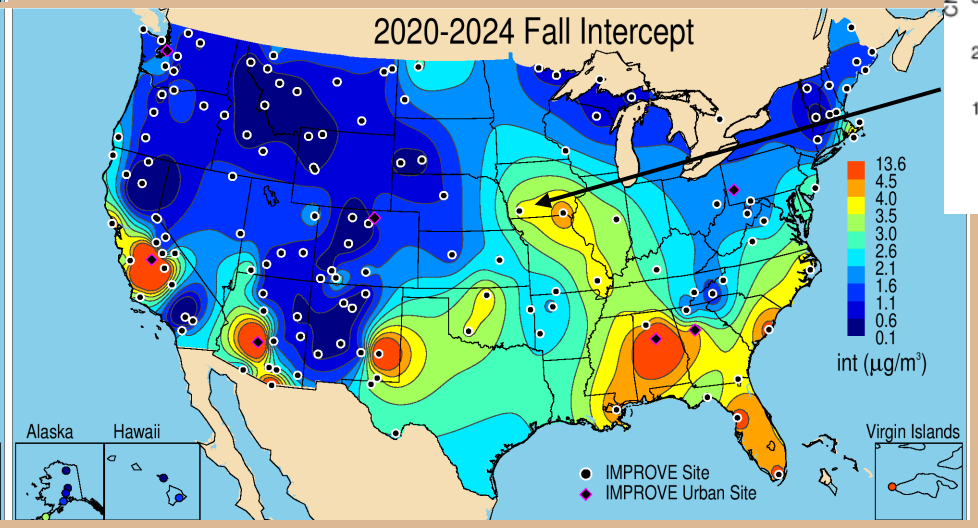


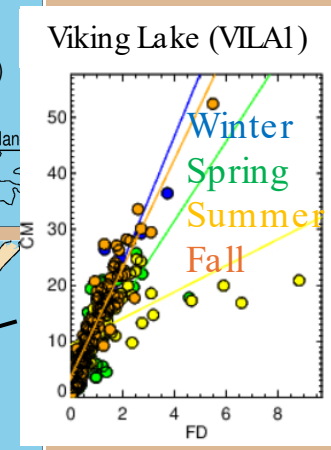












Explore:

Multi-Linear Regression of Coarse Mass and Fine Mode Species:

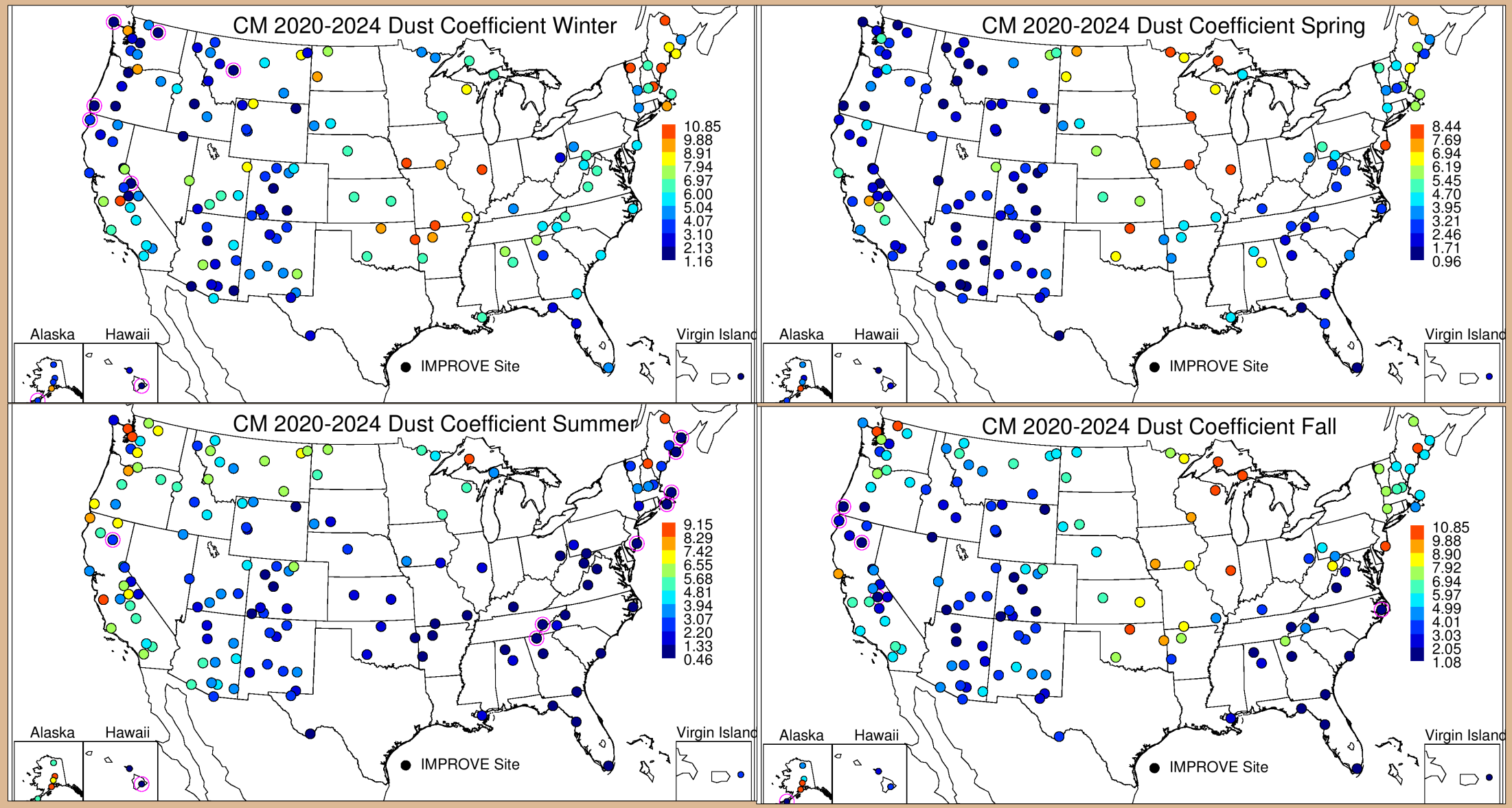
Can we estimate coarse mass speciation from fine mode concentrations?
Maybe, if the fine mode concentrations are the tail of coarse mode components

$$CM\text{–}EC = b_{SO4}[SO4] + b_{NO3}[NO3] + b_{OC}[OC] + b_{FD}[FD] + b_{SS}[SS]$$

2020-2024
Site specific
Daily data, seasonal regression

CM = coarse mass
SO4 = sulfate
NO3 = nitrate
OC = organic carbon
EC = elemental carbon
FD = fine dust
SS = sea salt ($1.8*Cl^-$)

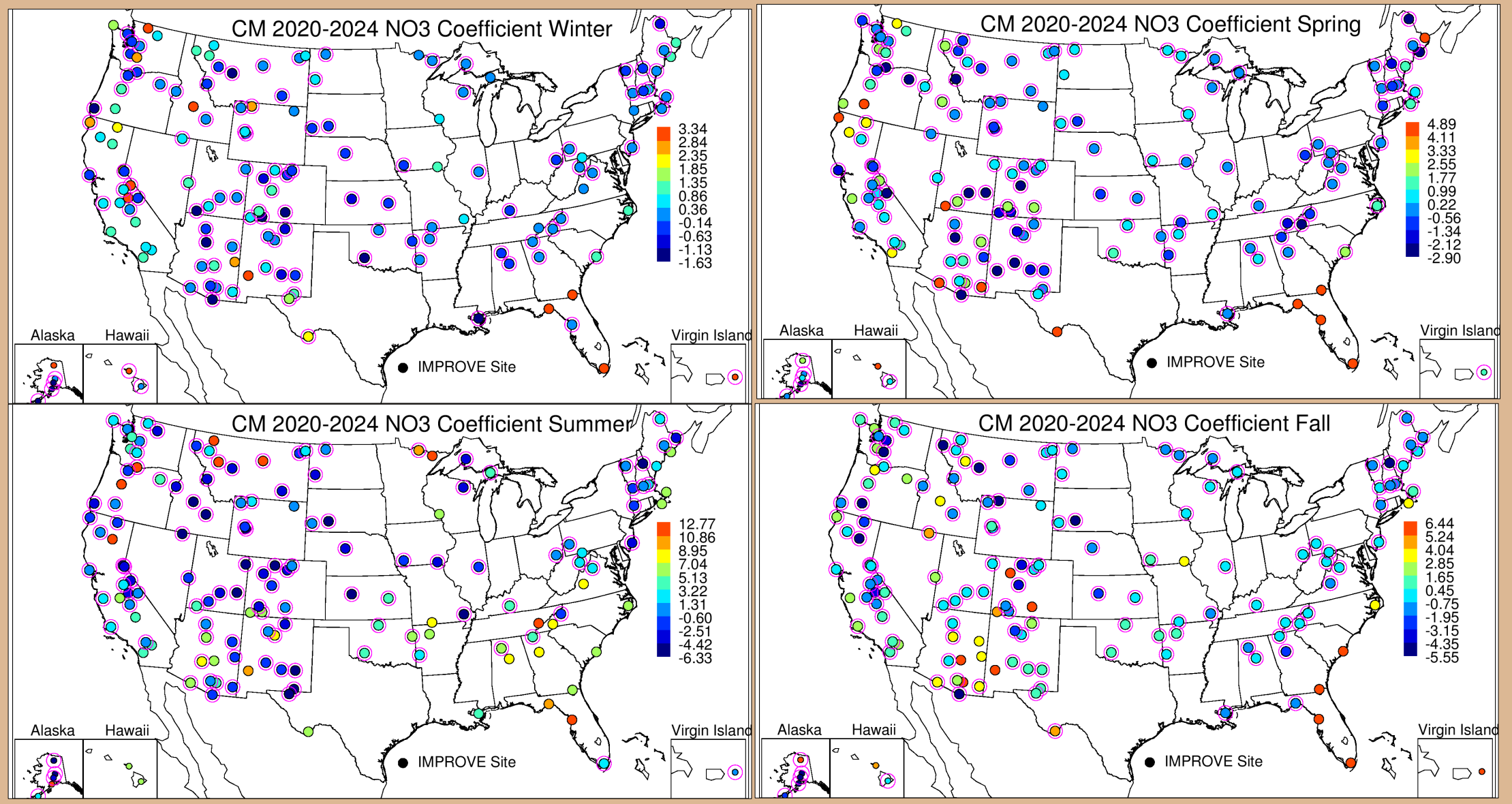
2020-2024 Seasonal Mean Dust Coefficients: b_{FD}



○ $p > 0.05$ or $b_{FD} < 0$

96% site-seasons were significant

2020-2024 Seasonal Mean Nitrate Coefficients: b_{NO3}

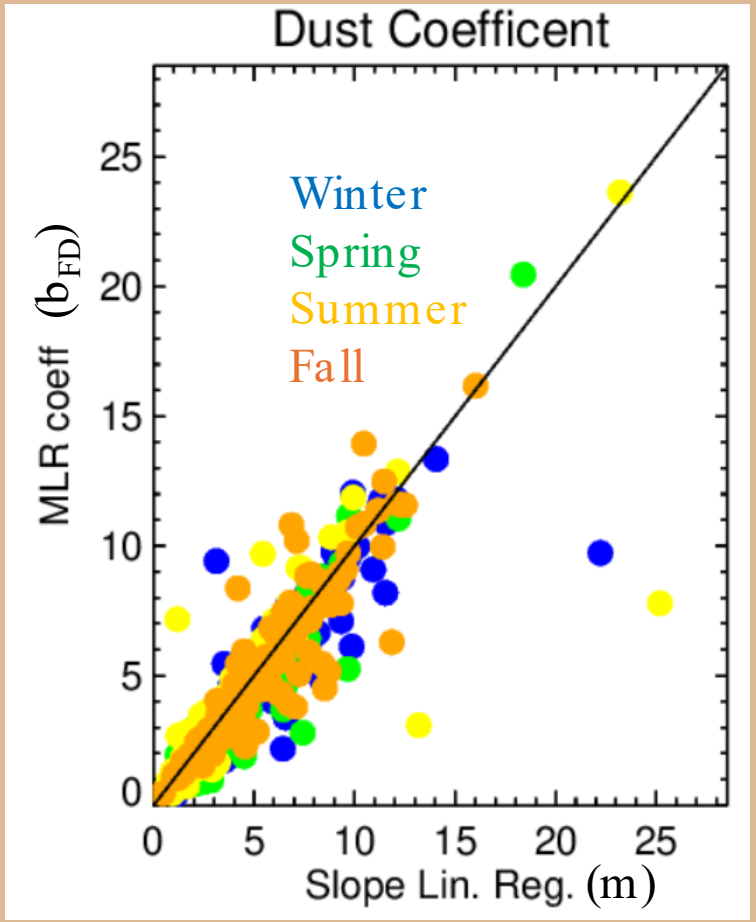


◯ $p > 0.05$ or $b_{NO3} < 0$

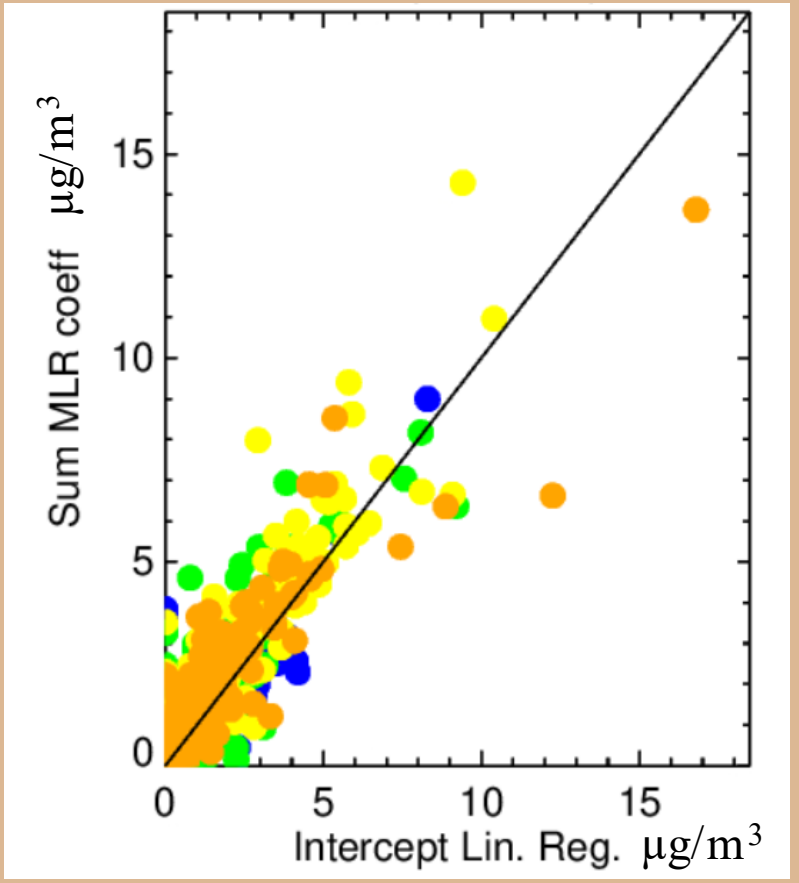
19% site-seasons were significant

Comparison of MLR and LR results:
MLR dust coefficient and LR (slope) and intercepts (no dust)

MLR dust coefficient and LR slope



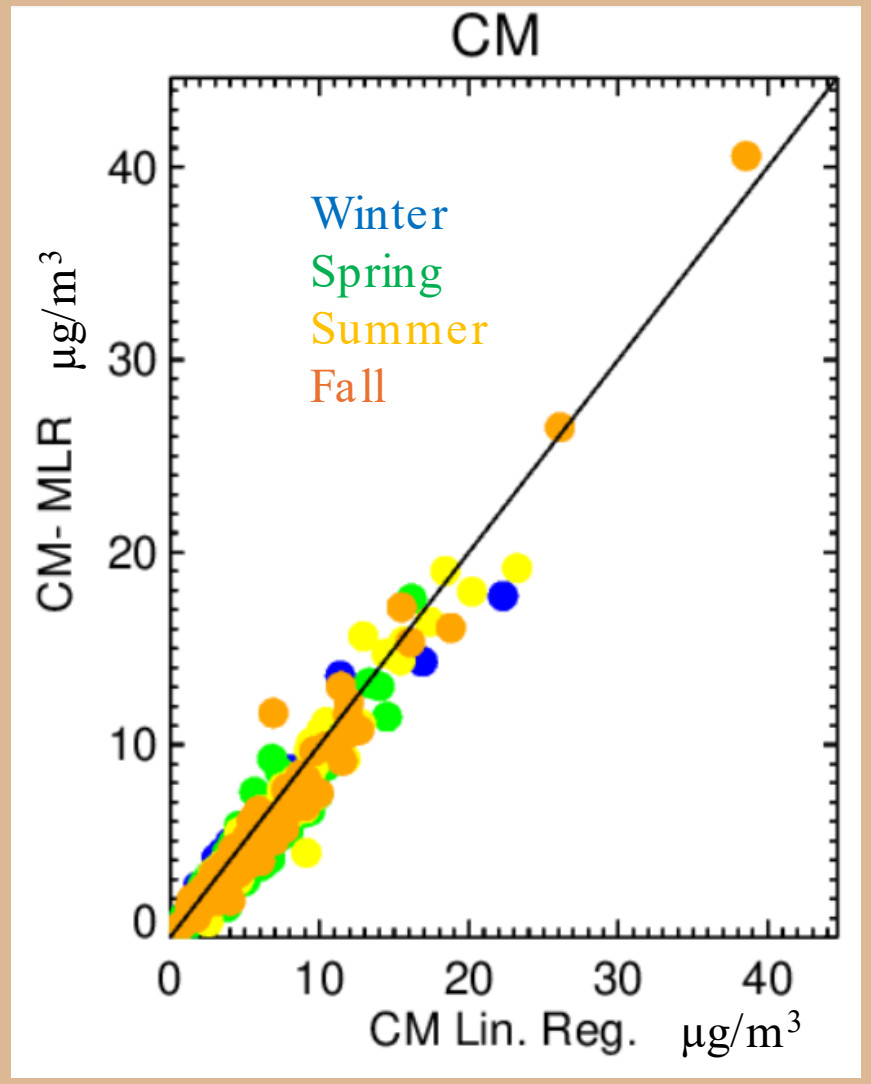
LR intercept and sum of coarse species (no dust)



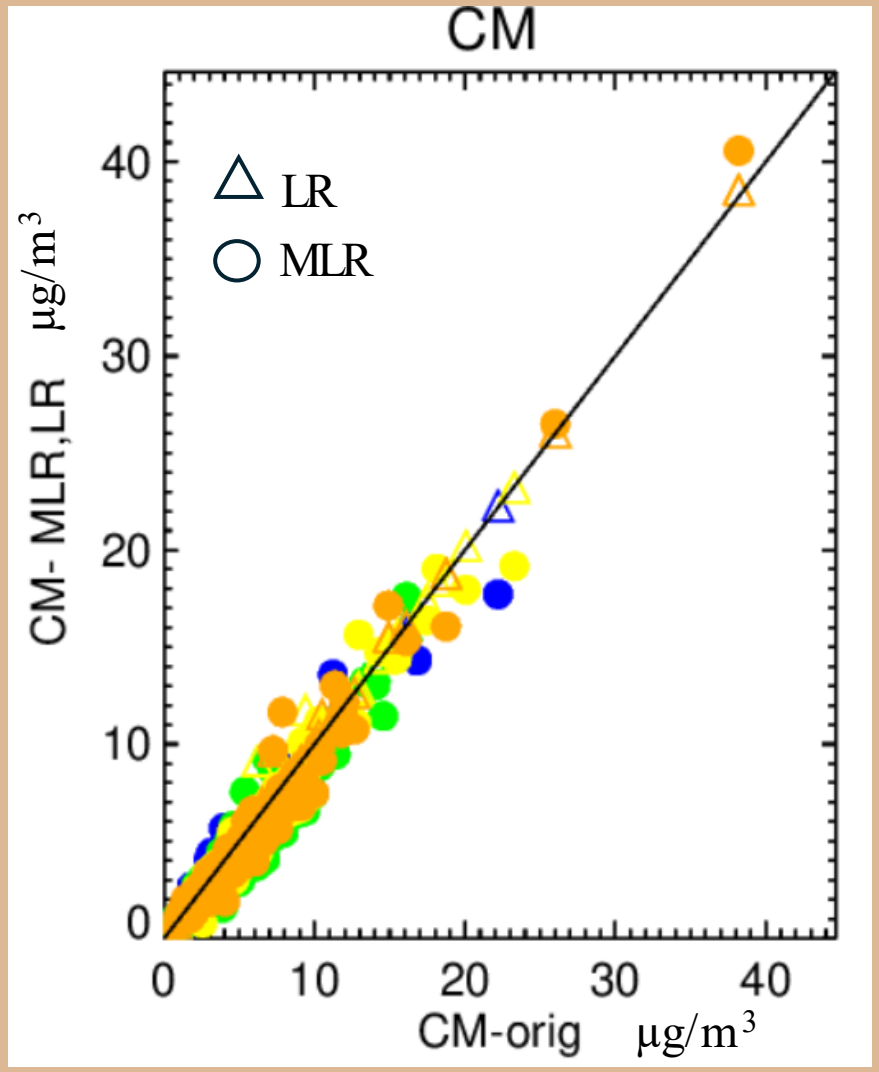
2020-2024: all sites, seasonal means, $p < 0.05$

Comparison of Coarse Mass derived from MLR and LR results

"Reconstructed" CM, both methods

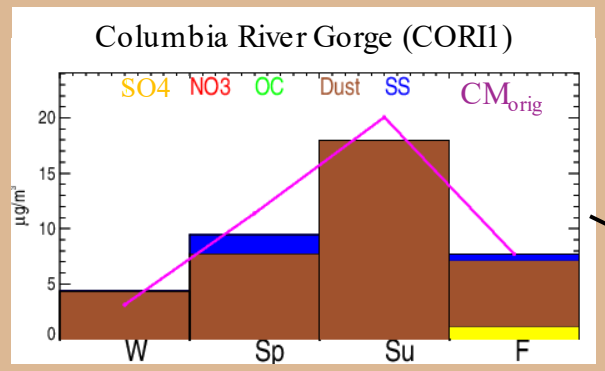


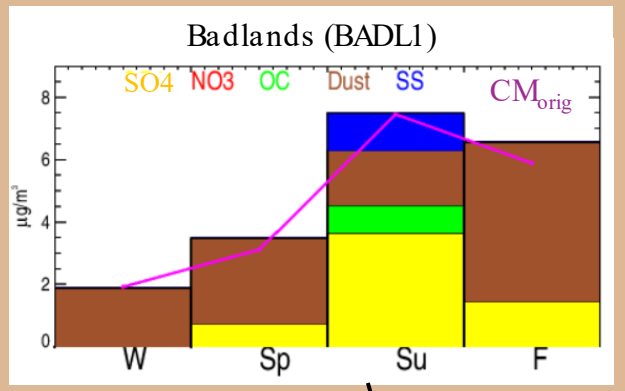
"Reconstructed" CM, Original

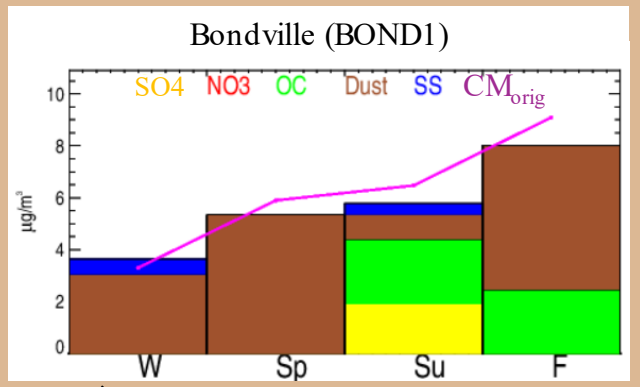


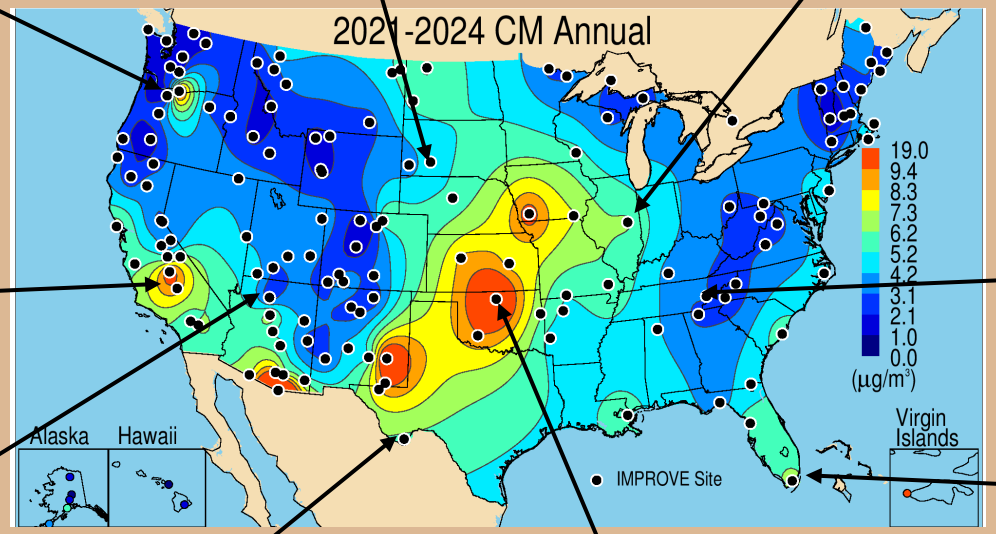
2020-2024: all sites, seasonal means, $p < 0.05$

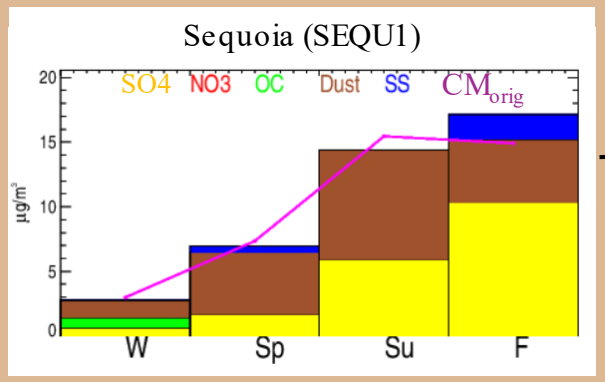
2020-2024 Coase Mass Speciation: $[Species_C] = b_{species} * [Species_F]$ ($p<0.05$)

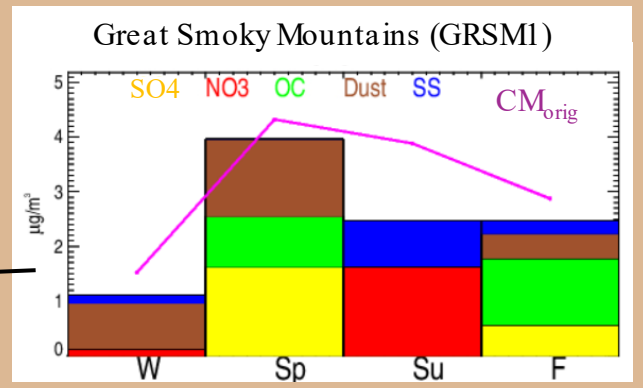


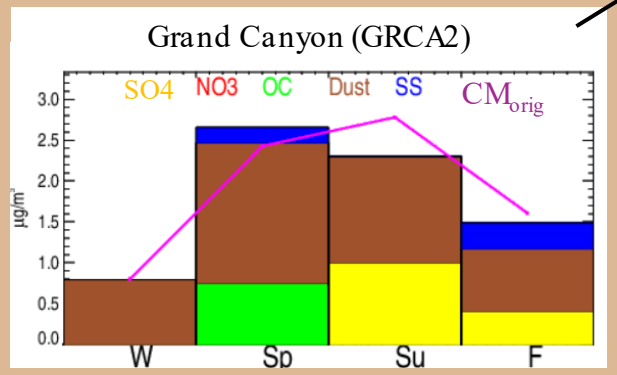


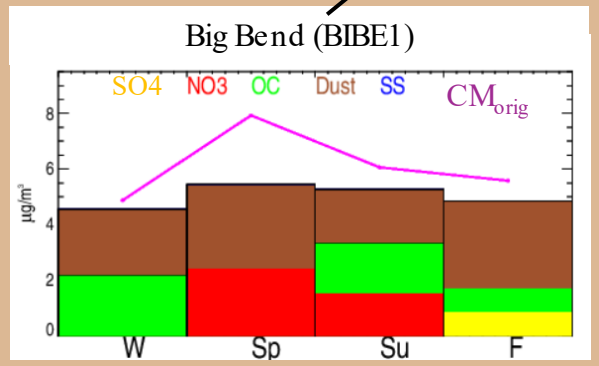


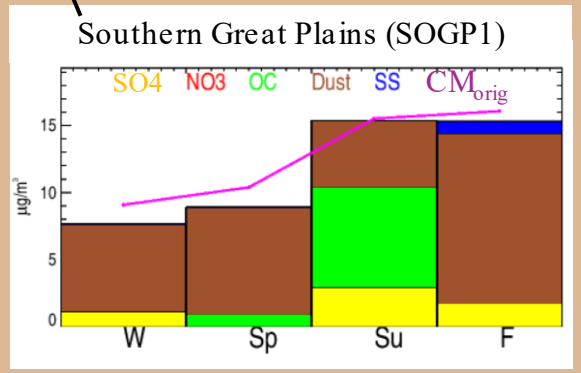


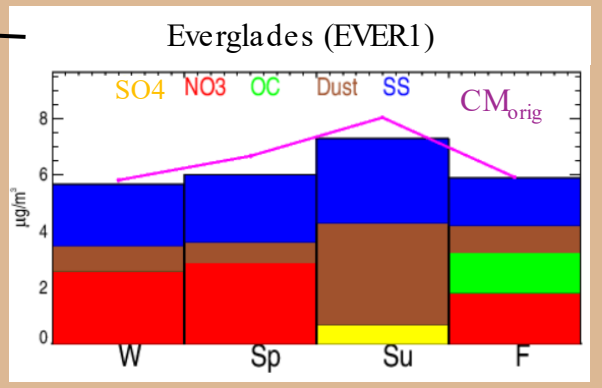












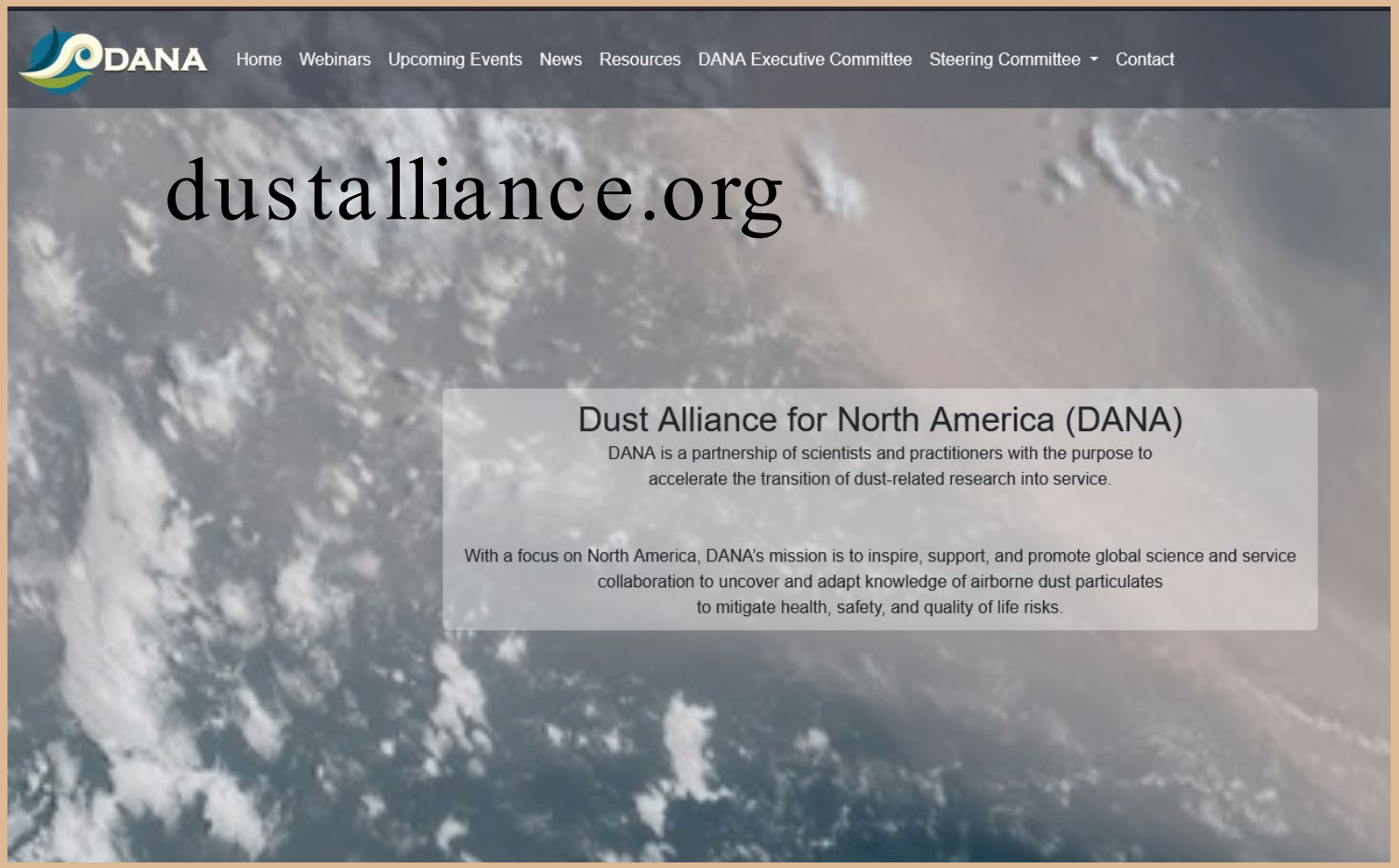
Future Work & Implications

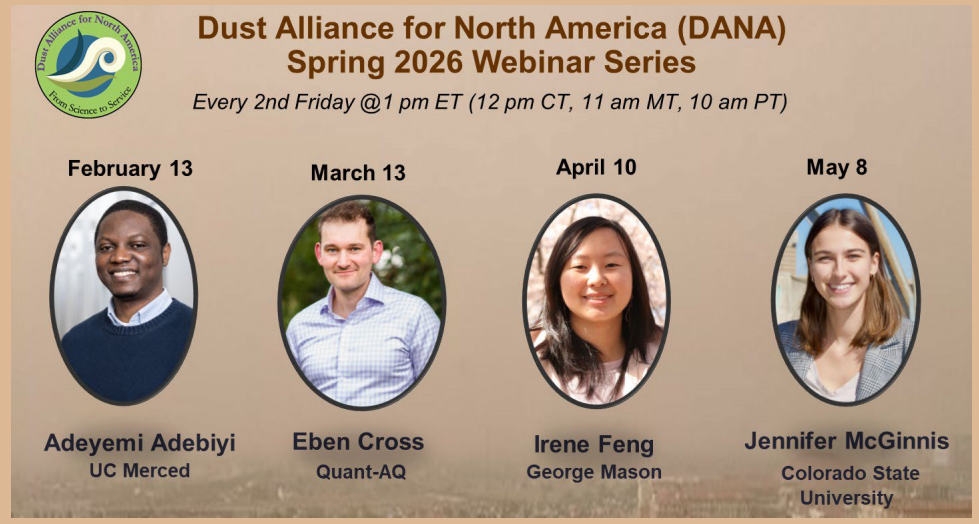
- Repeat analysis with Theil regression
- Sources of CM and dust
- Estimates of "total" (fine + coarse) dust
- Assumed coarse mass scattering efficiencies and hygroscopity in reconstructed extinction
- As concentrations of fine mode species continue to decrease, the "tails" may become more important

Future

- Increased drought in the West → more frequent dust storms (e.g., Stein et al., 2016).
- Drying lake beds and rivers → increased dust production (Owens Lake, Salton Sea, Great Salt Lake; Goodman et al., 2019)
- Modeling studies predict increased dust in the U.S. (e.g., Pu and Ginoux, 2017; Achakulwisut et al., 2018; Brey et al., 2020)
- Large-scale climate variability linked to dust (e.g., AMO, PDO, ENSO; Hand et al., 2016)
- Agriculture expansion impacts on dust loading in the Midwest (e.g., Lambert et al., 2020; Thayer et al., 2021)
- Wildfire impacts on dust emission (e.g., Yu and Ginoux, 2022)
- Understanding the magnitude, seasonality, sources, transport, and trends in dust and coarse mass is important for designing strategies to reduce PM, forecasting, for resource management decisions, and for understanding health and climate impacts.

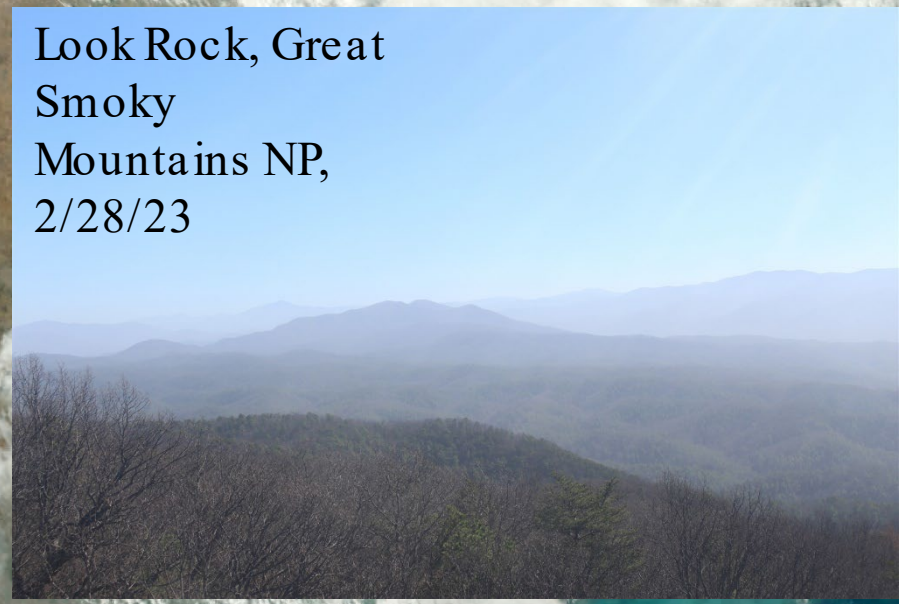
The Dust Alliance for North America is an organization formed as a partnership of scientists and practitioners with the purpose to accelerate the transition of dust-related research into service.





Acknowledgment

NPS Air Resources Division



Look Rock, Great Smoky Mountains NP, 2/28/23

February 2023

PSA: What to do in a dust storm?

PULL OFF! LIGHTS OFF! FOOT OFF!

- Pull off the road immediately.
- Avoid driving into or through a dust storm.
- Completely exit highway if possible.
- Do not stop in the travel or emergency lane- get off the paved roadway.
- Turn off headlines and taillights, put car in park, take your foot off the brake.
- Stay in your vehicle with seatbelt on until storm passes (minutes to ~hour).

Arizona Emergency Information Network
https://ein.az.gov/hazards/dust-storms

Haboob near Phoenix, AZ 8/2/2018,
Washington Post, Tong et al., 2023