Early Onset of the Spring Fine Dust Season in the Southwestern United States

Jenny Hand[1]

B.A. Schichtel[2], K.A. Gebhart[2], W.H. White[3], N.P. Hyslop[3], T.E. Gill[4]

[1] CIRA, Colorado State University
[2] NPS, Air Resources Division
[3] University of California, Davis
[4] University of Texas, El Paso

3/18/2014 MODIS

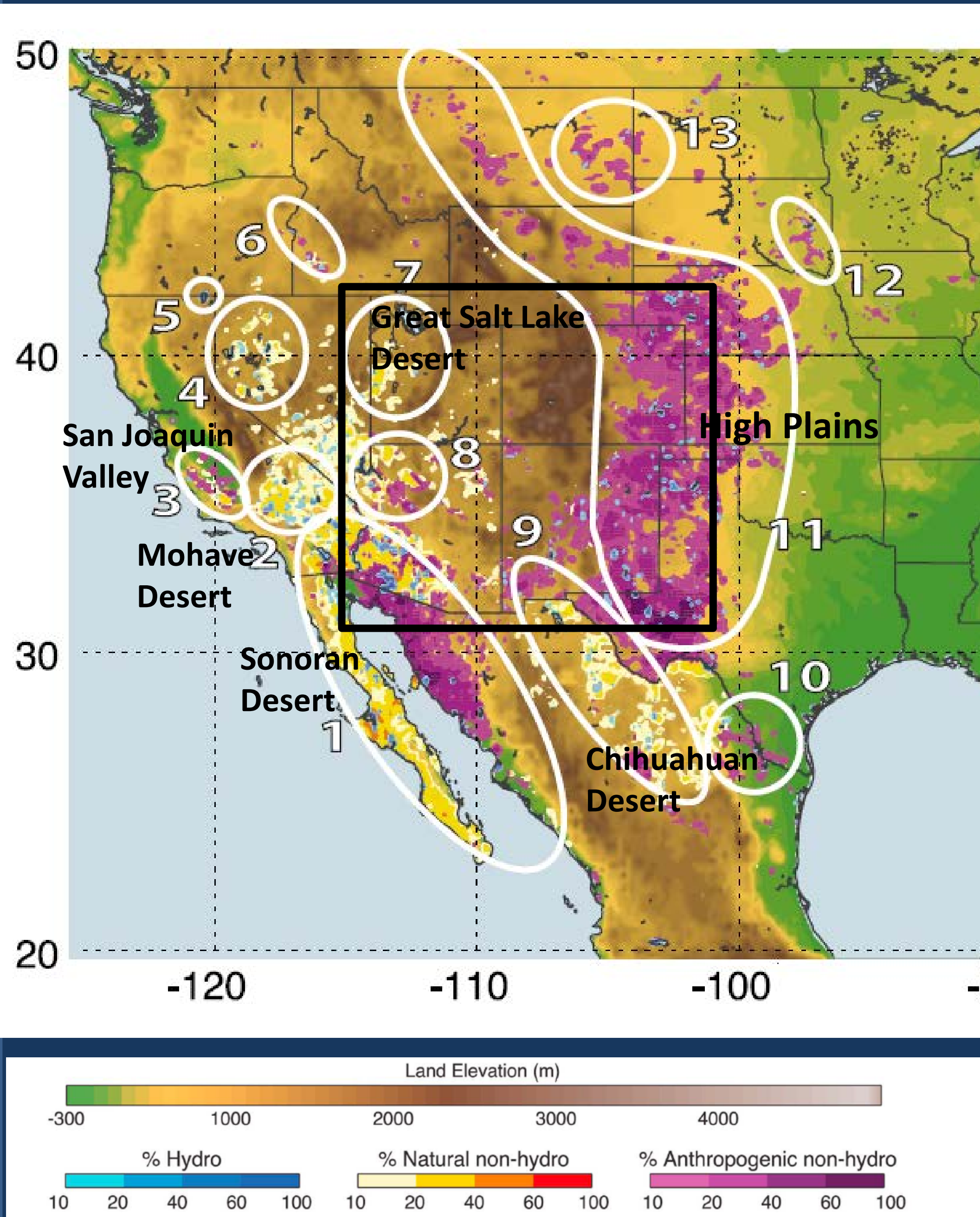
Motivation

- Dust is a significant source of particulate matter in the SW U.S.
- Impacts
  - **Air quality, visibility**, and health
  - Ecology
  - Hydrology
  - Biogeochemistry
  - Heterogeneous chemistry
  - Indirect and direct impacts on climate
- Understanding **magnitude, seasonality, sources, transport, and trends** in dust is important for designing strategies to reduce PM, forecasting, for resource management decisions, and to understand climate impacts

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

March, 2012, El Paso, TX (PM_{10} > 5000 µg m^{-3})

Dust sources over North America (Ginoux et al., 2012)



Dec 15, 2003

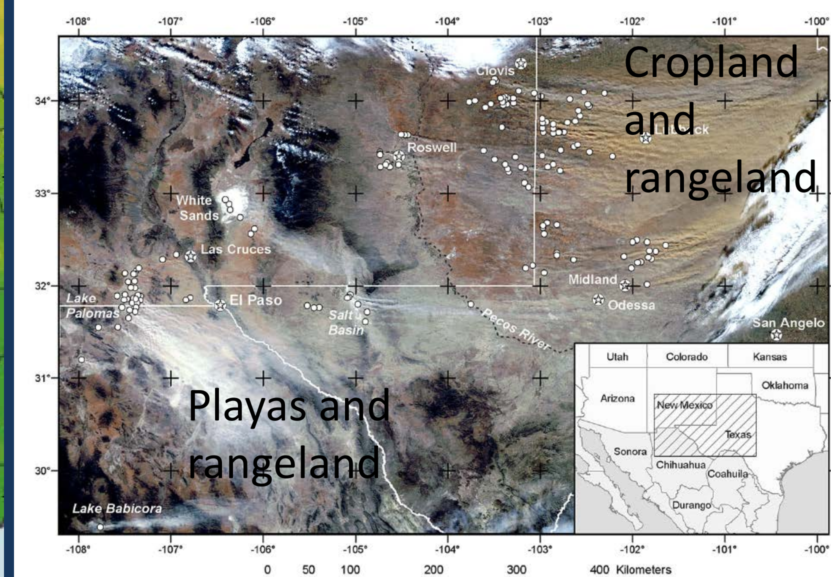
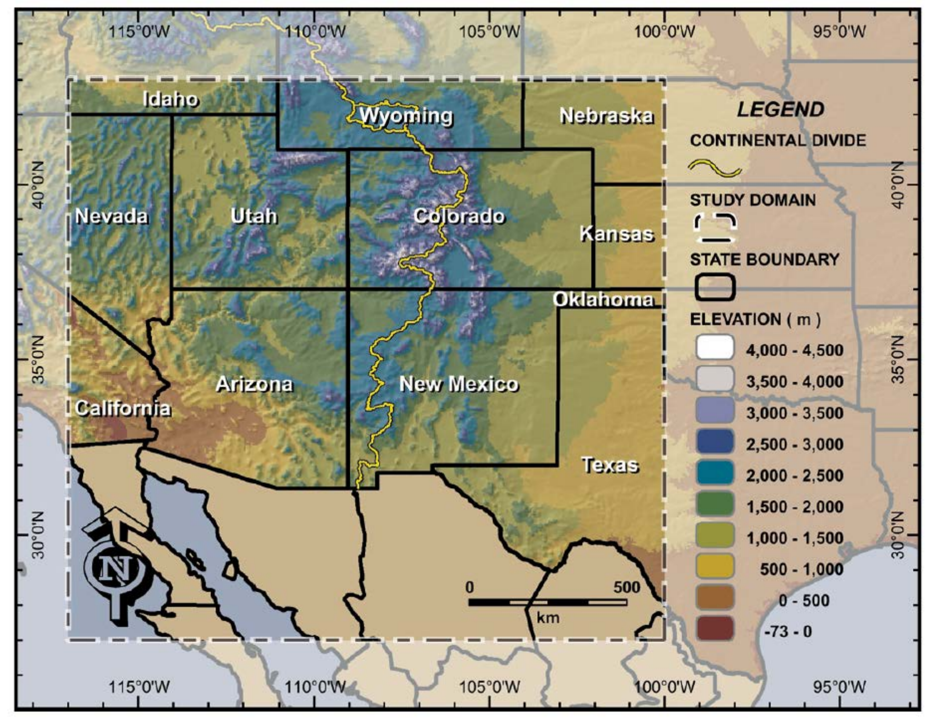


Fig. 1. A MODIS image (sensor: Aqua) of the region during the dust storm; image obtained from: http://visibleearth.nasa.gov/view_rec.php?id=19043. The image used has a pixel si[ze] of 250 m. Political boundaries, cities and points to identify dust sources were added by the authors. The source points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

Lee et al. (2009)

Southwest (SW) United States

- SW: UT, AZ, CO, NM, WTX
- Droughts (e.g., Cook et al., 2015; Prein et al., 2016)
- Increased temperature (Weiss et al., 2009 Munson et al., 2011; Wang et al., 2011;)
- ENSO and PDO impacts on drought- La Niña (Wang and Kumar, 2015; Barnston and Lyon, 2016)
- Economic development (Theobald et al., 2013)



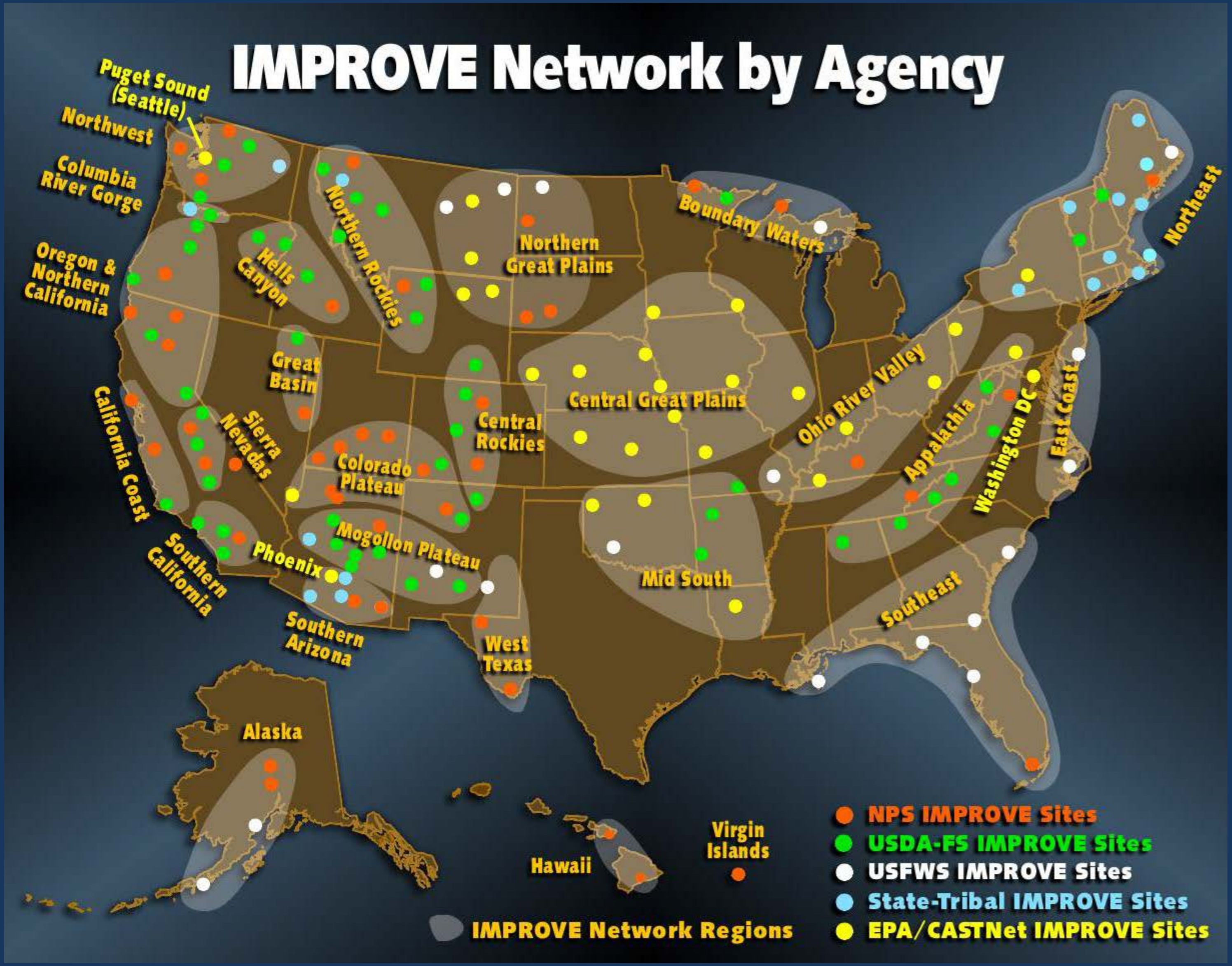
Weiss et al., 2009

→ Changes in climate and land use can lead to drier, less vegetated, and disturbed surfaces that may be more available for dust emission.

This Study:

Investigate changes in dust and meteorological parameters in the SW since 1995

(1) Data: IMPROVE



Download data: http://views.cira.colostate.edu/fed/

(2) Data: IMPROVE, cont'd

- Monthly mean dust trends using linear Theil regression (1995-2014)
- Regional mean: sites with continuous operation over 20 years in UT, CO, AZ, NM, SW TX (15 sites)

Fine Dust = 2.20[Al] + 2.49[Si] + 1.63[Ca] + 2.42[Fe] + 1.94[Ti]

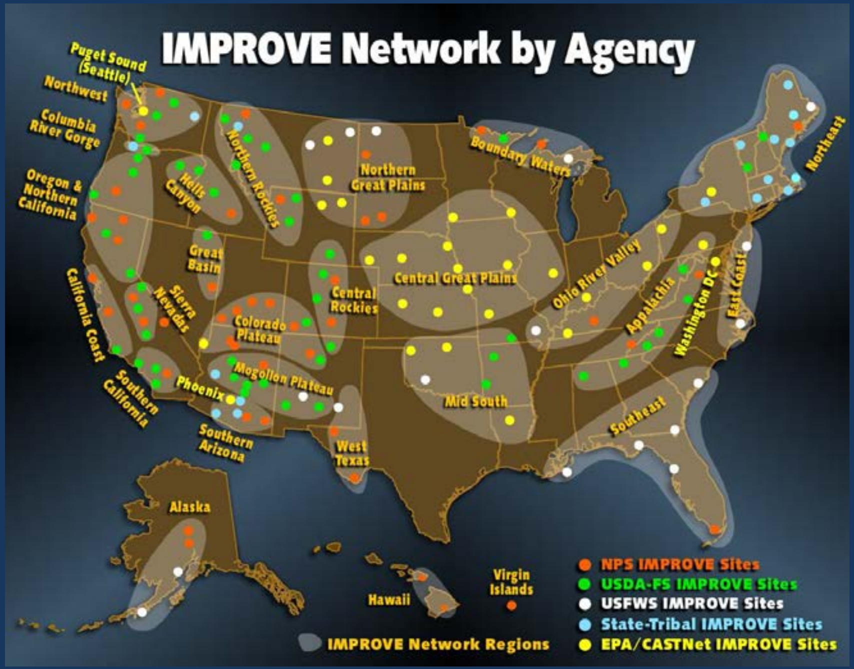
(Malm et al., 1994)

Download data: http://views.cira.colostate.edu/fed/

(3) Data: IMPROVE, cont'd

Advantages:

Consistent methodology
Appropriate for study of regional and long-range impacts



Disadvantages:

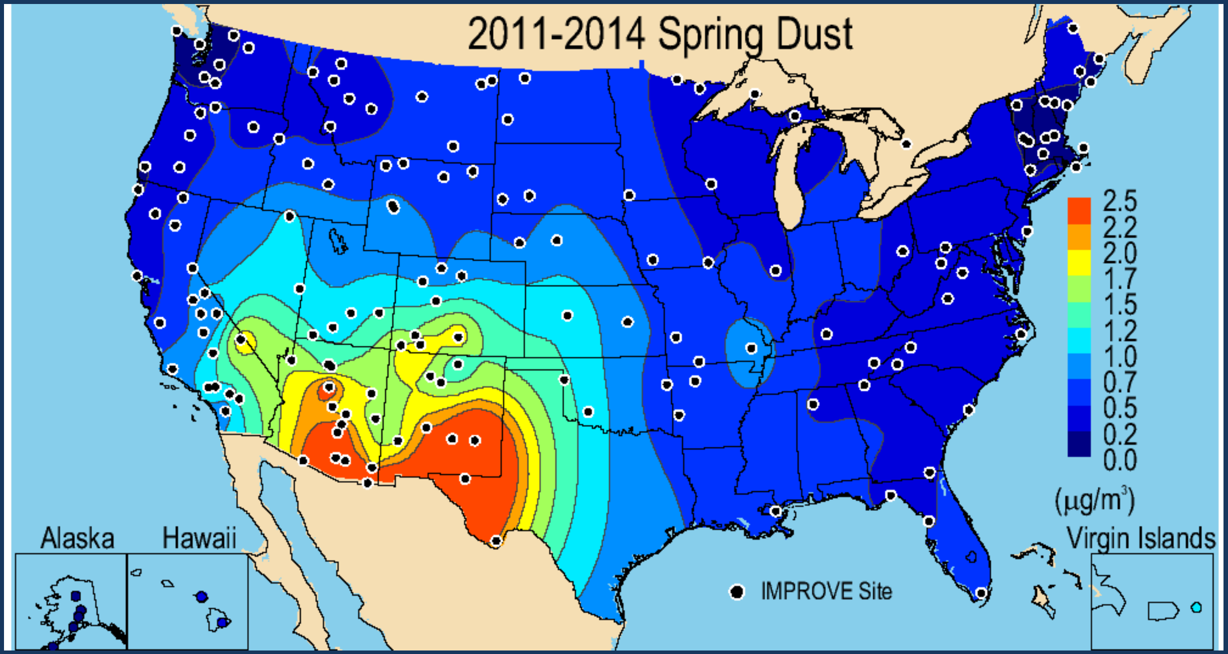
Sampling frequency (1/3 day)
Definition/size: missing contributions to dust?

(4) Data: Meteorological variables (1995-2014)

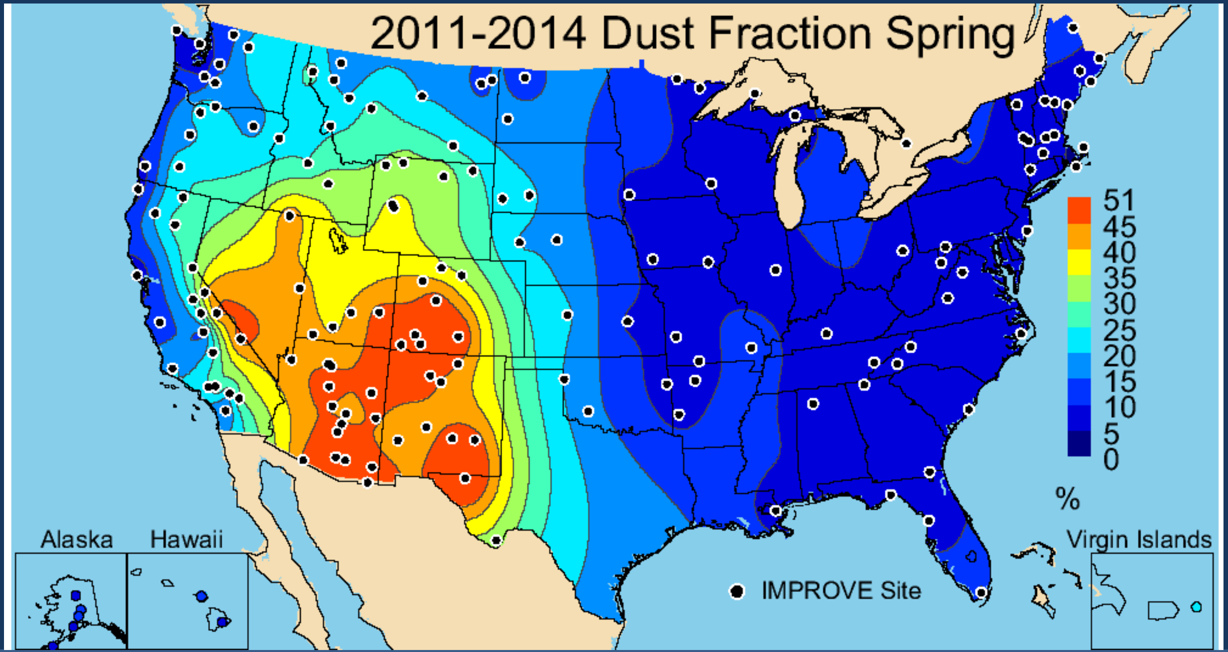
- Precipitation: PRISM 4km gridded- monthly total
- Surface wind speed (2.5° x 2.5°) NCEP/NCAR reanalysis- monthly
- Enhanced Vegetation Index (EVI) from MODIS (0.05° x 0.05°) (2001-2014)-monthly
- Pacific Decadal Oscillation (PDO) index (JISAO)- monthly
- El Niño Southern Oscillation (ENSO) from NOAA CPC, three month running mean-

IMPROVE Current FD Conditions (2011-2014)

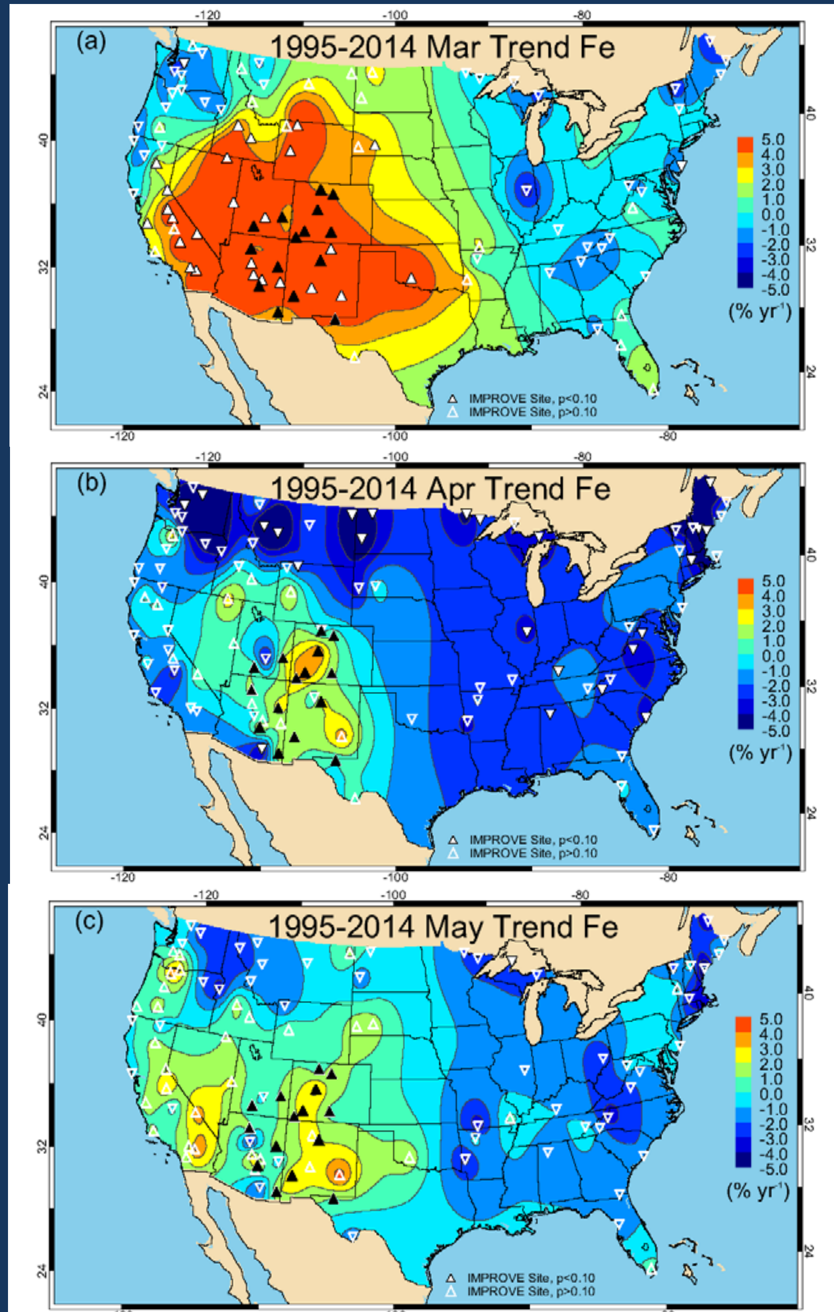
2011-2014 Spring (MAM) FD



2011-2014 Spring FD Fraction of $PM_{2.5}$



1995-2014 Monthly Mean Fine Dust Trends



5.4 % yr^{-1}
(p<0.01)

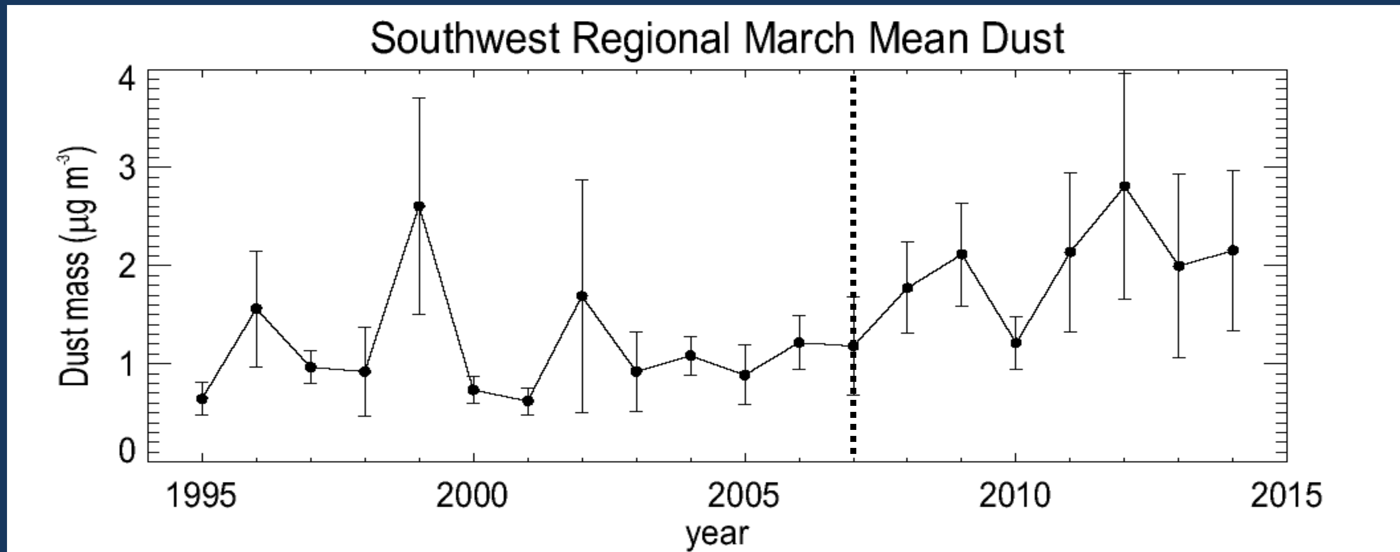
2.0 % yr^{-1}
(p=0.07)

1.5 % yr^{-1}
(p=0.11)

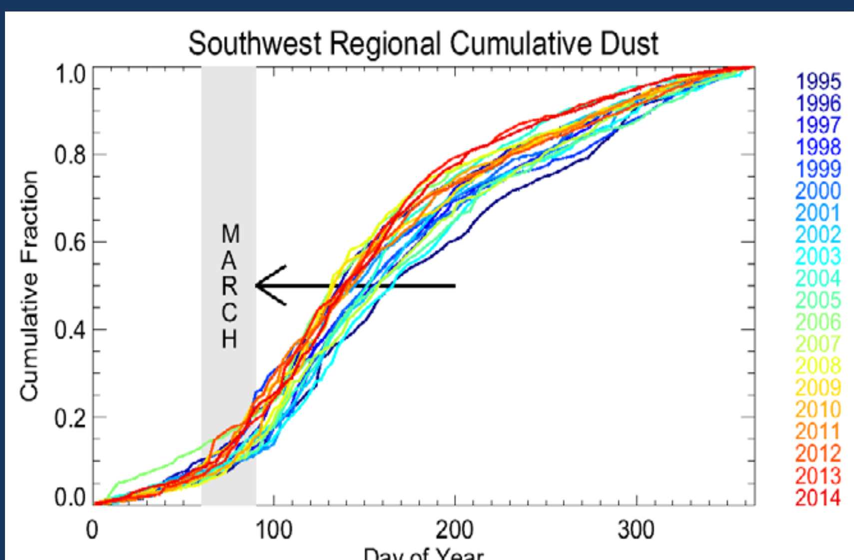
Black triangles: long-term IMPROVE sites

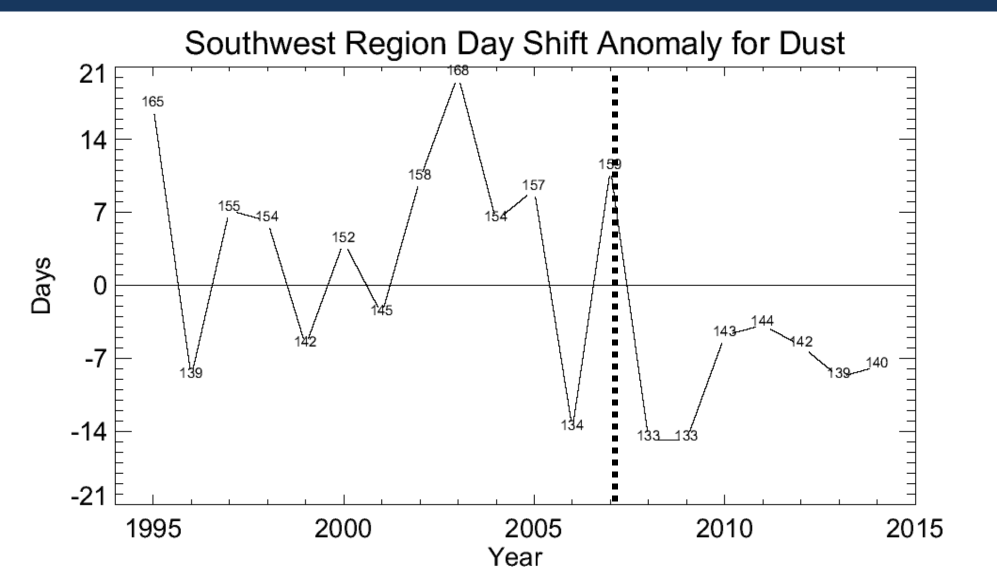
Hand et al. (2016) GRL

Shift to active and earlier dust season around 2007



Day of Year Anomaly: half annual total dust

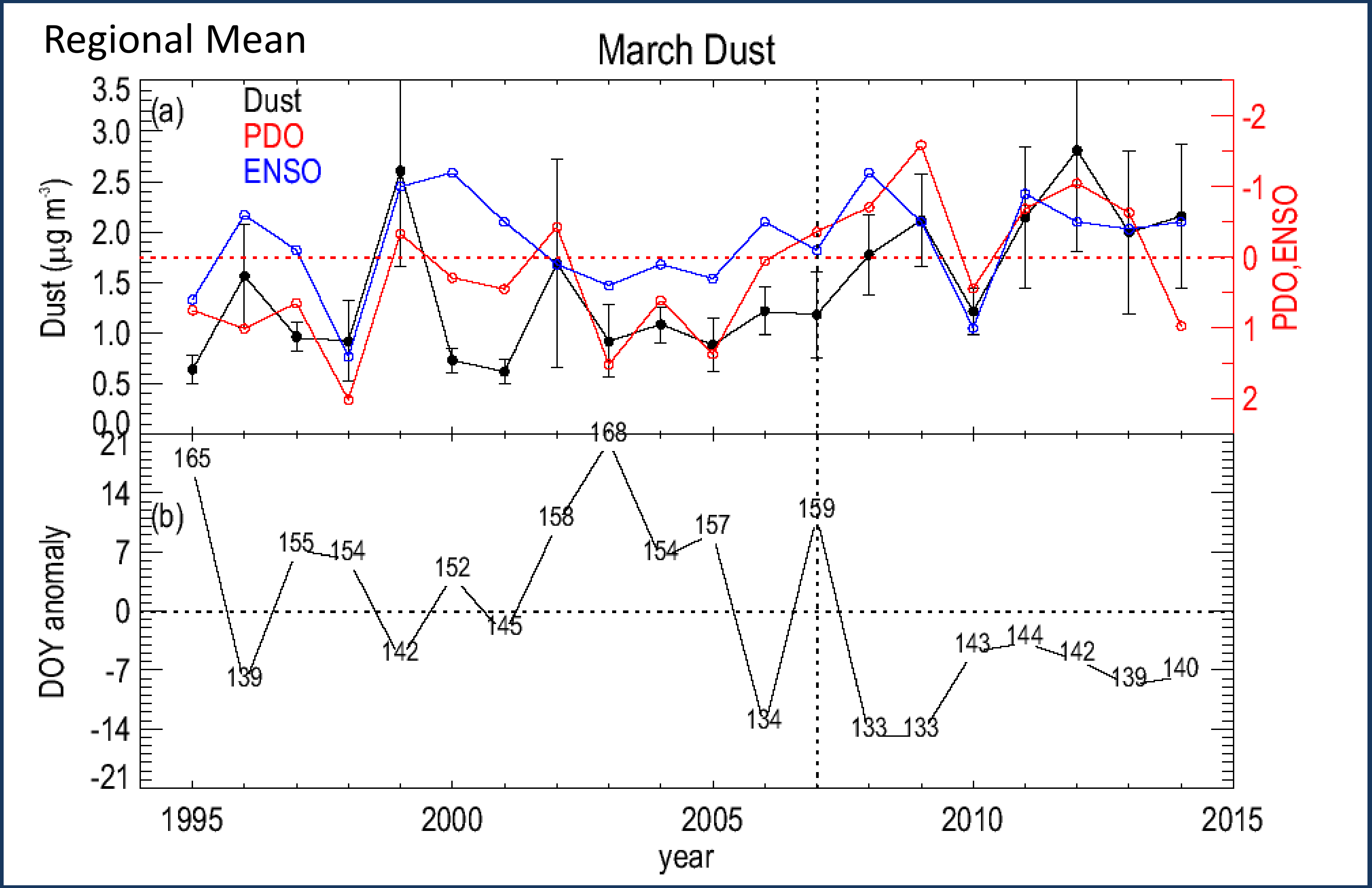




Shift to active and earlier dust season around 2007

Fine Dust &
PDO (r = -0.65)
ENSO (r = -0.47)

Day of Year
Anomaly: half
annual total
dust



SW Region Monthly Dust and Meteorological Indices

1995-2006 vs 2007-2014

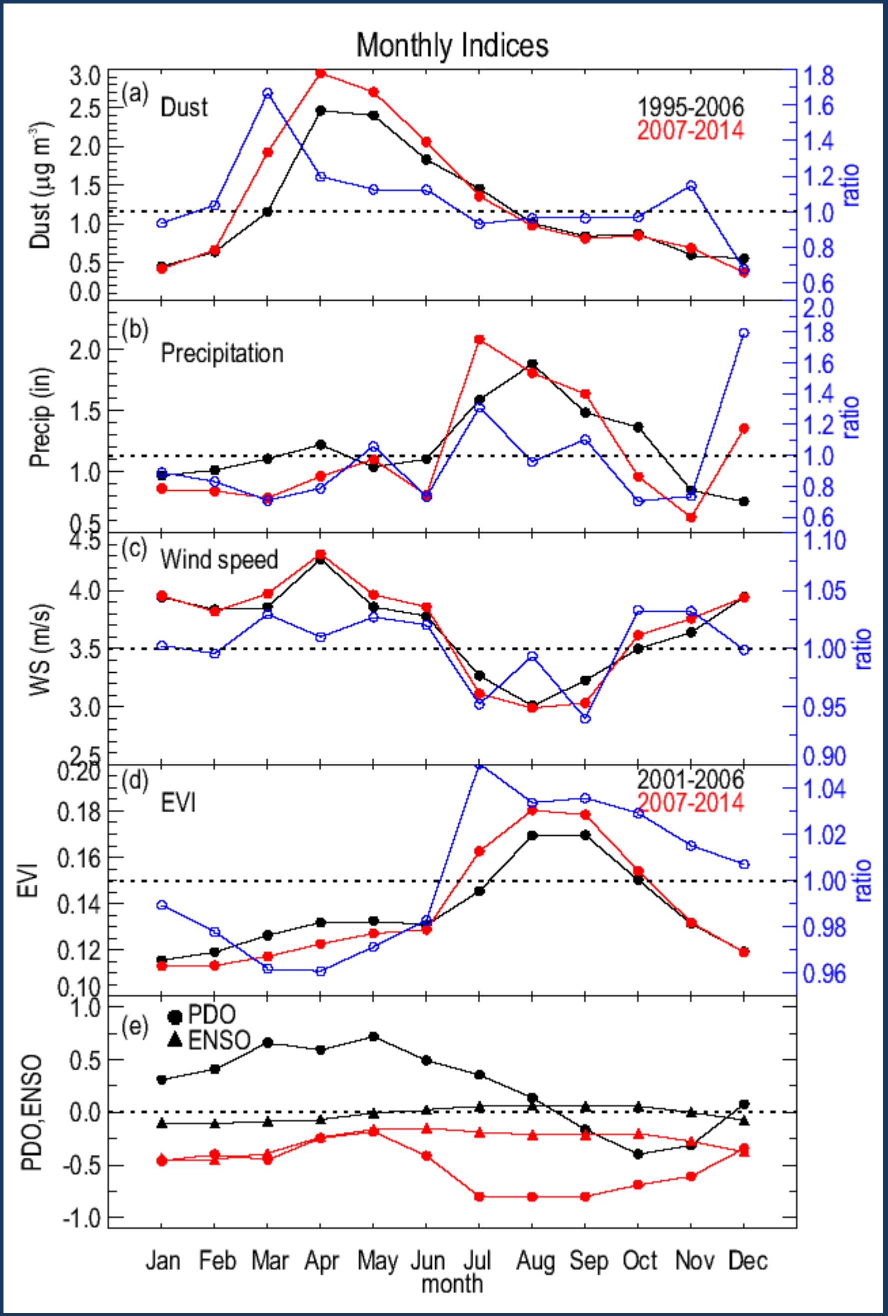
Dustier in March →

Drier in March →

Windier in March →

Less Vegetation →

PDO, ENSO: Negative values → Drier conditions in SW



Hand et al. (2016) GRL

Correlation coefficients between fine dust and meteorological variables

Table 1: Correlation coefficients (r) between various monthly and regional mean indices for March, April, and May for 1995 through 2014, except for EVI (2001–2014).

Correlation Coefficients (r)	March	April	May
Dust and Pacific Decadal Oscillation (PDO)	***-0.65***	**-0.50**	**-0.51**
Dust and El Niño Southern Oscillation (ENSO)*	**-0.47**	**-0.51**	-0.30
Dust and Precipitation	***-0.67***	**-0.54**	-0.41
Dust and Wind Speed	0.35	0.27	0.27
Dust and Enhanced Vegetation Index (EVI)	**-0.55**	-0.10	***-0.66***
PDO and Precipitation	***0.56***	0.07	0.19
PDO and Wind Speed	-0.26	-0.13	-0.12
PDO and EVI	***0.56***	0.52	0.48
ENSO and EVI	0.26	0.46	0.19
EVI and Precipitation	0.47	0.48	0.29

Bold: p = 0.05, ***Bold+Italics***: p < 0.01.

*ENSO indices were correlated with the center month of the three-month running mean.

Implications

- Contributions of dust and coarse mass to reconstructed b_{ext} on haziest days increased from 15% to 30% (1995-2014)
- FD contributions to $PM_{2.5}$ increased in spring from 20% to 50% across the region (1995-2014)
- Health effects: cases of valley fever increased starting around 2007-2008 (CDC)
- Increase in dust deposition (Brahney et al., 2013) and implications for regional hydrology (e.g., Painter et al., 2010)
- Understanding the role of large-scale climate variability is important for accurately predicting and mitigating impacts of anthropogenic perturbations and climate change on dust emission and subsequent impacts in the SW

Acknowledgements

White Sands National Monument

National Park Service
Air Resources Division
IMPROVE

New Mexico

Texas

PRISM: Oregon State University PRISM Climate Group (http://prism.oregonstate.edu/recent/
NCEP/NCAR Reanalysis: NOAA/OAR/ESRL PSD *(*http://www.esrl.noaa.gov/psd/*)*
EVI: United States Geological Survey
(https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod13c2)
PDO: Washington State University (http://research.jisao.washington.edu/pdo/)
ENSO: NOAA
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml)

2/20/2013 MODIS

jlhand@colostate.edu