

# A Preliminary Look at IMPROVE Trends

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Acknowledgments:

The National Park Service funded this work.

Thanks to the IMPROVE and CSN networks for providing data.

# Introduction

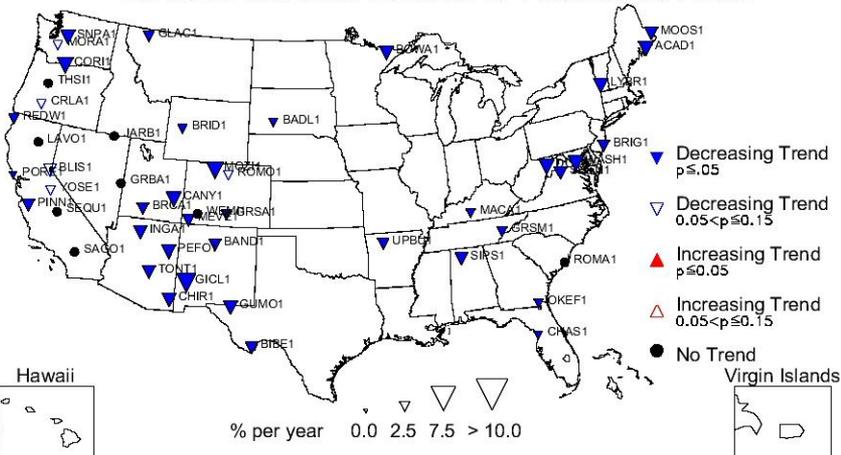
- We examined temporal trends in IMPROVE data over the time periods:
  - 1989-2008 (20 year)
  - 2000-2008 (9 year)
- A 50% completeness criteria was applied to data from any given site.
- Species included:
  - Sulfate ion
  - Nitrate ion
  - Organic carbon (OC)
  - Light absorbing carbon (LAC)
  - Total carbon (OC+LAC)
  - Soil
  - Gravimetric fine mass
  - PM10 and Coarse Mass (PM10-PM2.5)

# Trend Analysis

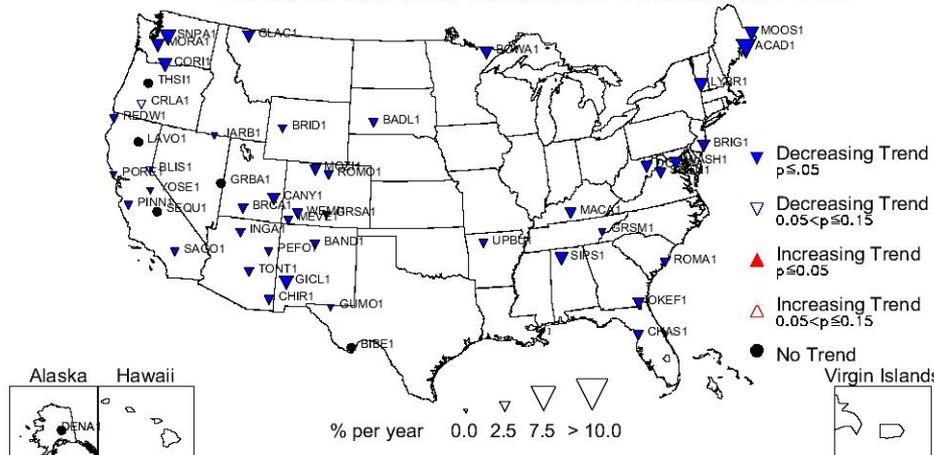
- Trends were computed for 10<sup>th</sup>, 50<sup>th</sup>, 90<sup>th</sup>, Mean, Winter (DJF), Spring (MAM), Summer (JJA) and Fall (SON).
- 70% of the years were required for a given site to be included in the analysis (ranged ~150 sites for 9 yr depending on species, and ~50 sites for 20 yr)
- Theil regression and Kendall's tau statistics were used to compute the slope and the significance, respectively. Theil slope is found by assuming that the true slope is zero and calculating the probability that the estimated slope occurred by chance.
- Significance levels of 0.05 (statistically significant) and 0.15 were used. (A 5 and 15% probability that the differences occurred by chance due to random fluctuations in the time series).

# 20 Year Sulfate Trends

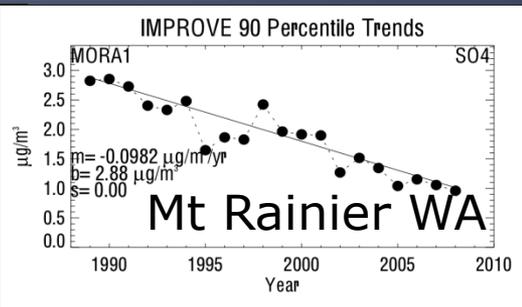
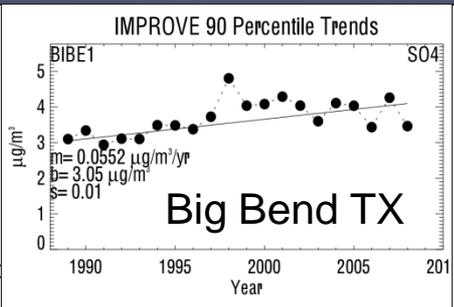
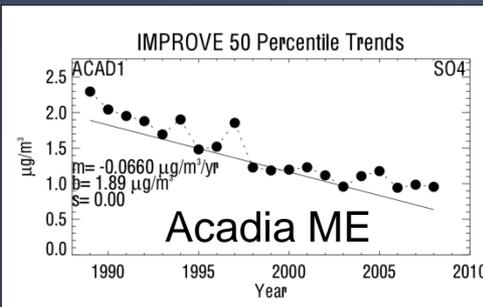
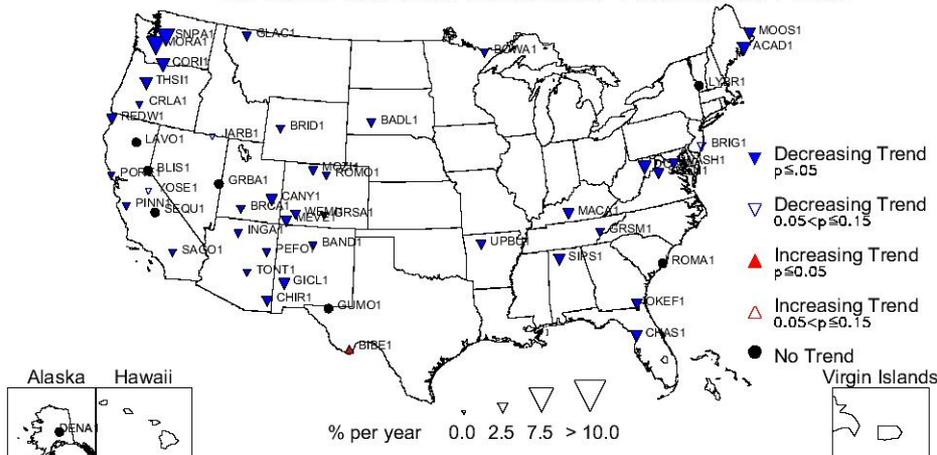
IMPROVE 1989-2008 Trends for 10<sup>th</sup> Percentile SO<sub>4</sub> Mass



IMPROVE 1989-2008 Trends for 50<sup>th</sup> Percentile SO<sub>4</sub> Mass

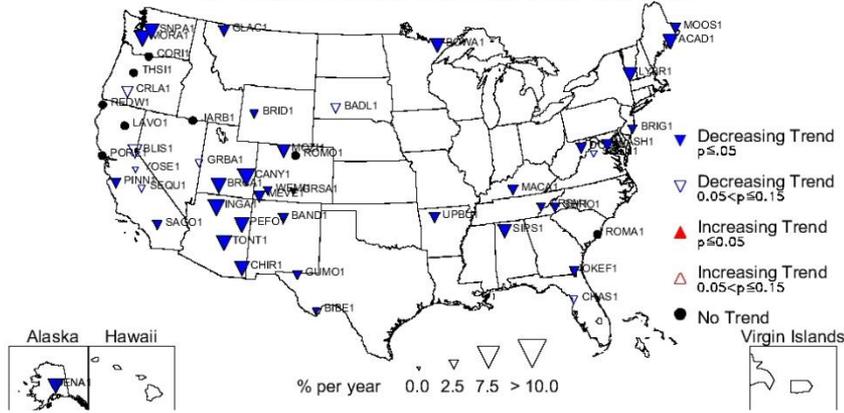


IMPROVE 1989-2008 Trends for 90<sup>th</sup> Percentile SO<sub>4</sub> Mass

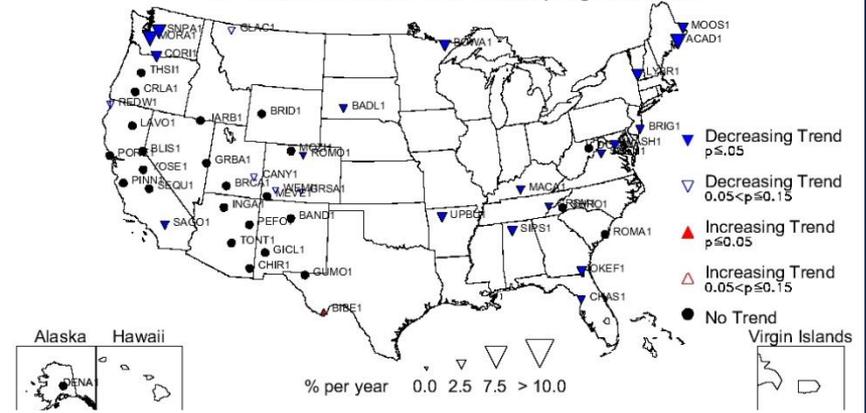


# 20 Year Sulfate Trends

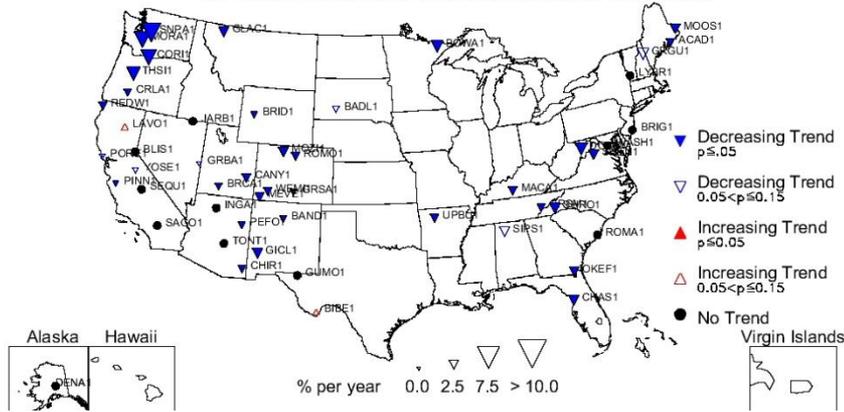
IMPROVE 1989-2008 Trends for Winter SO<sub>4</sub> Mass



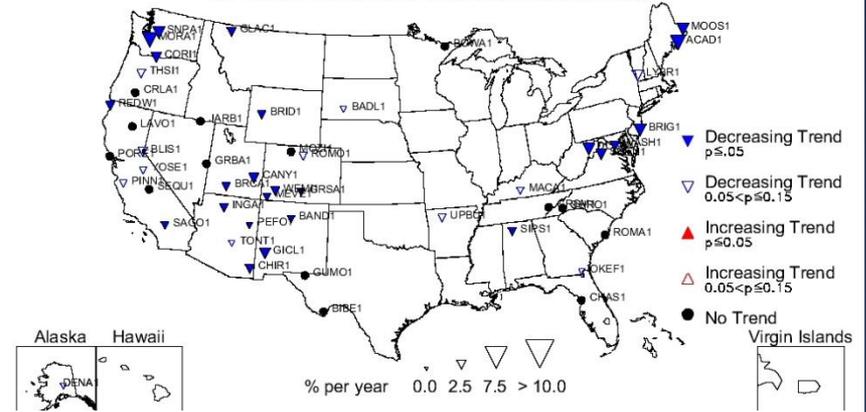
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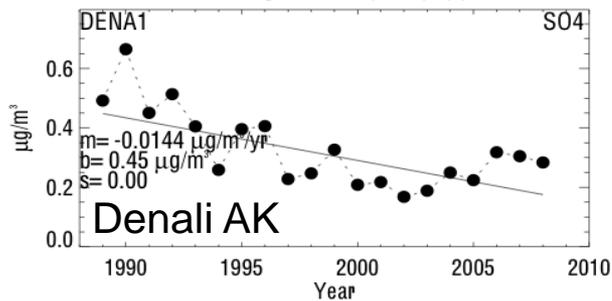
IMPROVE 1989-2008 Trends for Summer SO<sub>4</sub> Mass



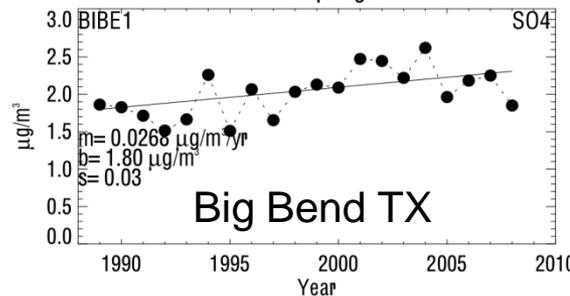
IMPROVE 1989-2008 Trends for Fall SO<sub>4</sub> Mass



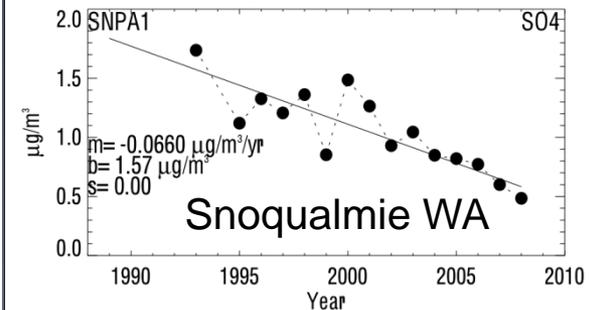
IMPROVE Winter Trends



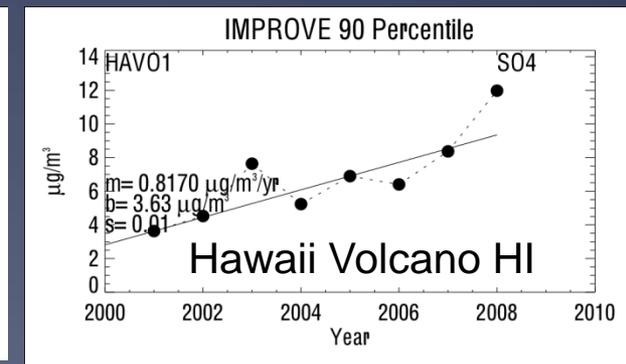
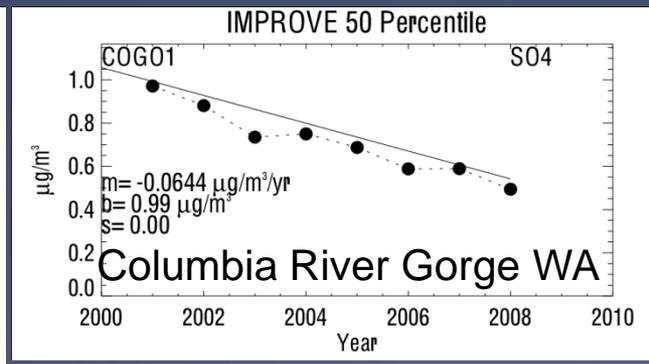
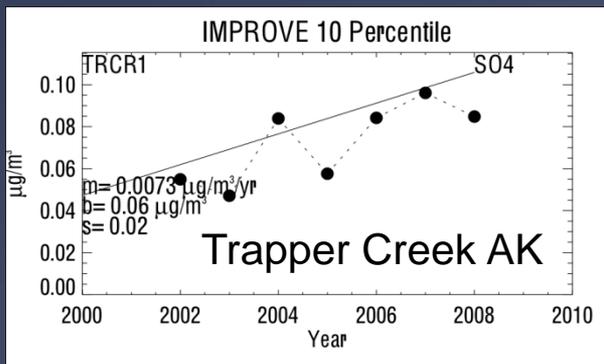
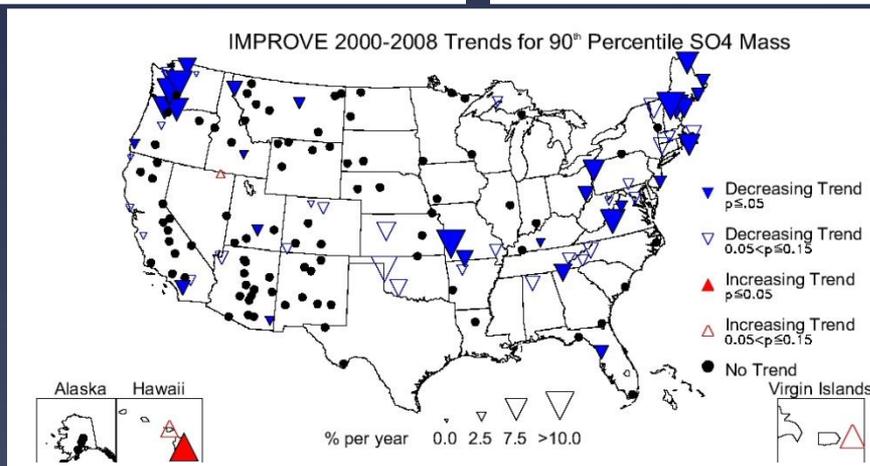
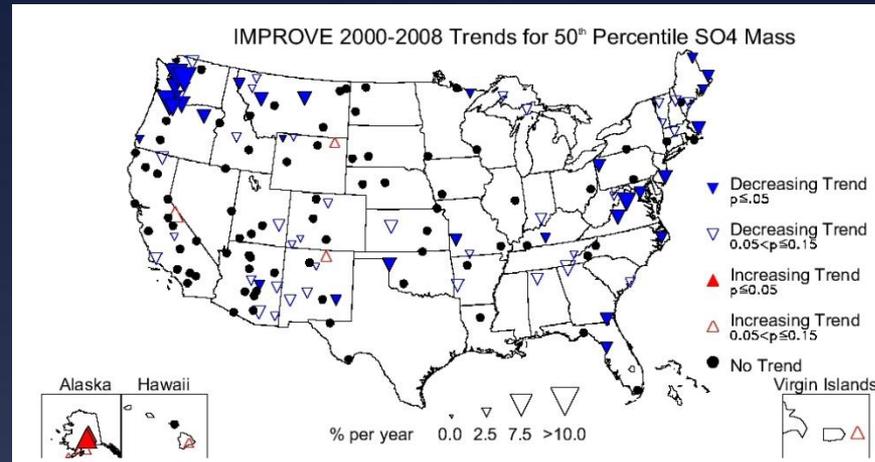
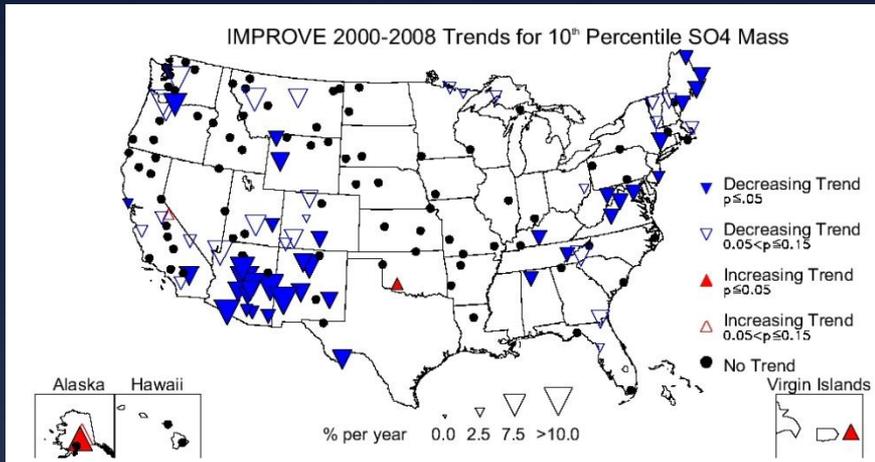
IMPROVE Spring Trends



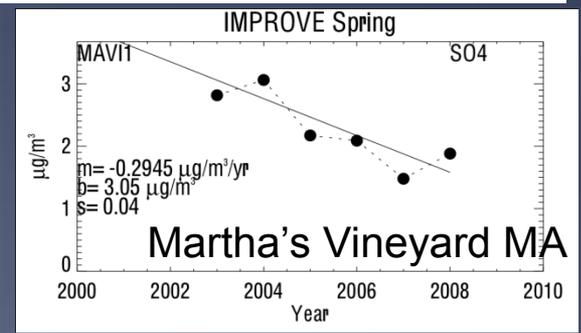
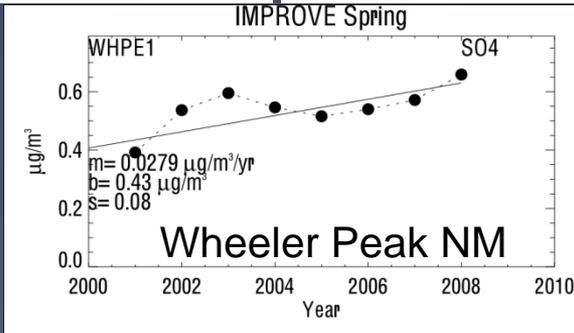
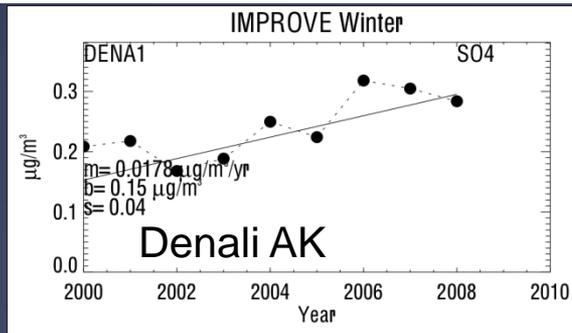
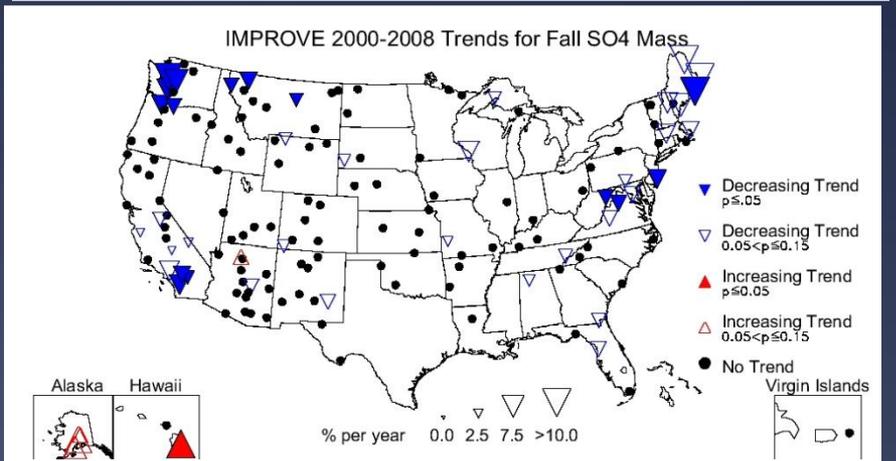
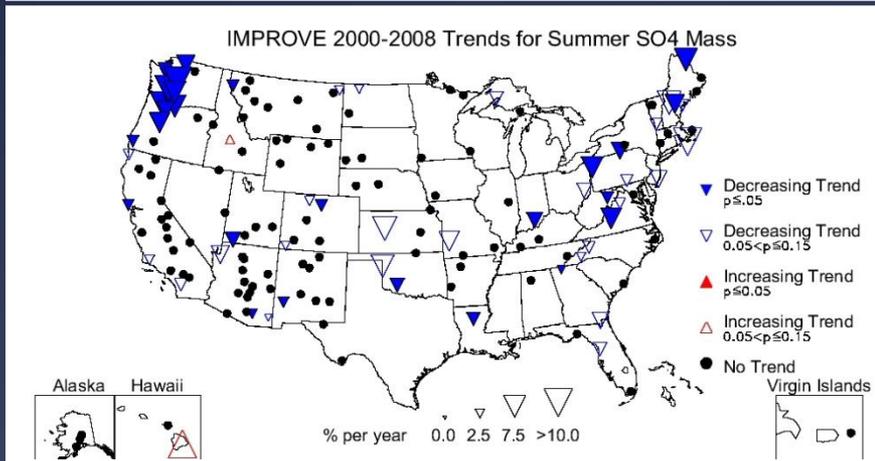
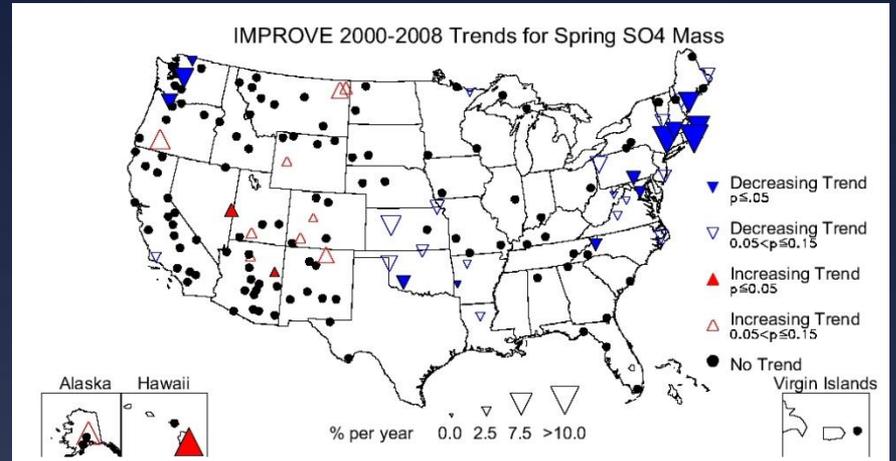
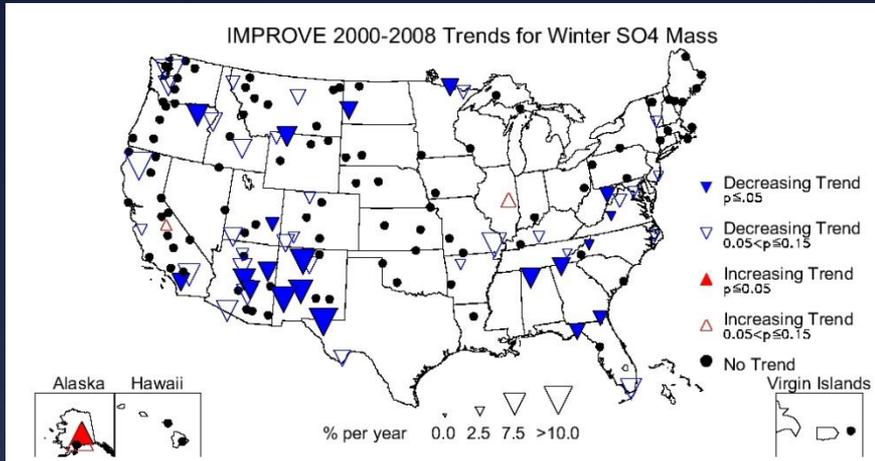
IMPROVE Summer Trends



# 9 Year Sulfate Trends

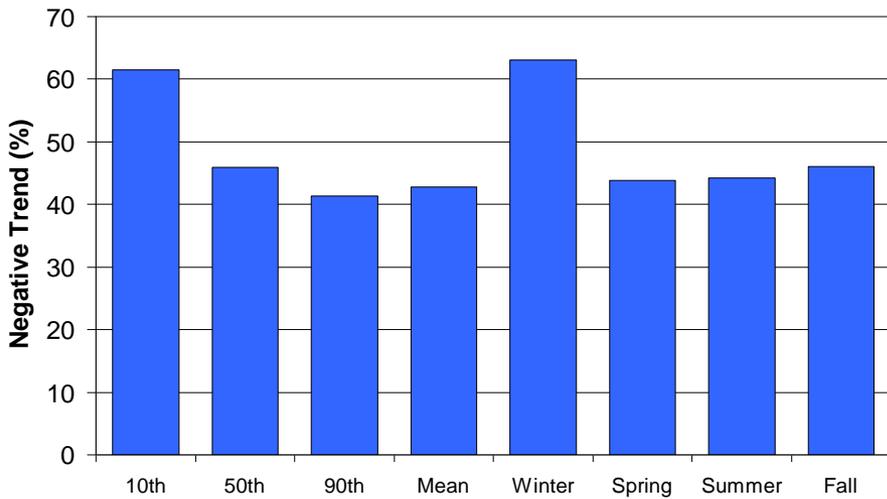


# 9 Year Sulfate Trends

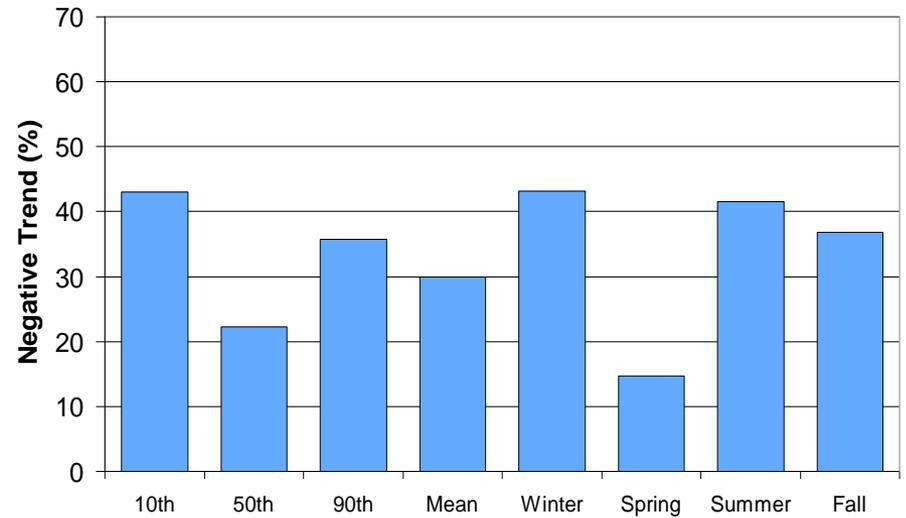


# 9 Year vs 20 Year Sulfate Trends

Sulfate Twenty Year Overall Trend (1989-2008)

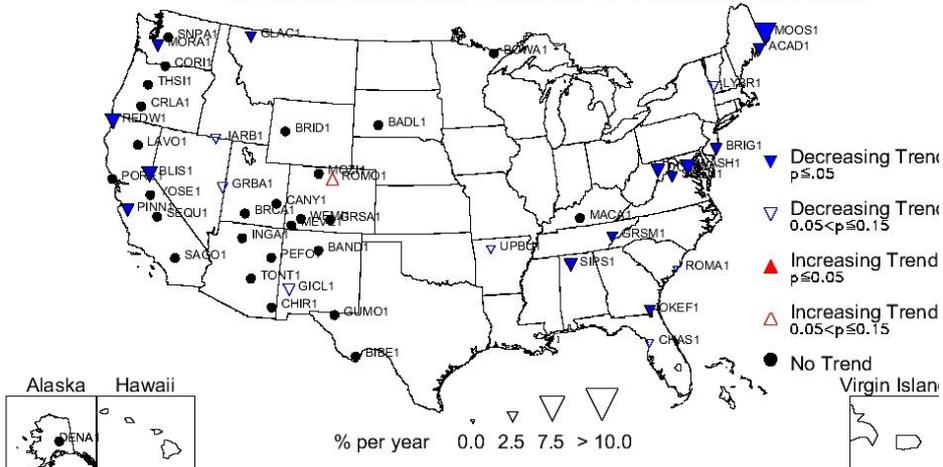


Sulfate Nine Year Overall Trend (2000-2008)

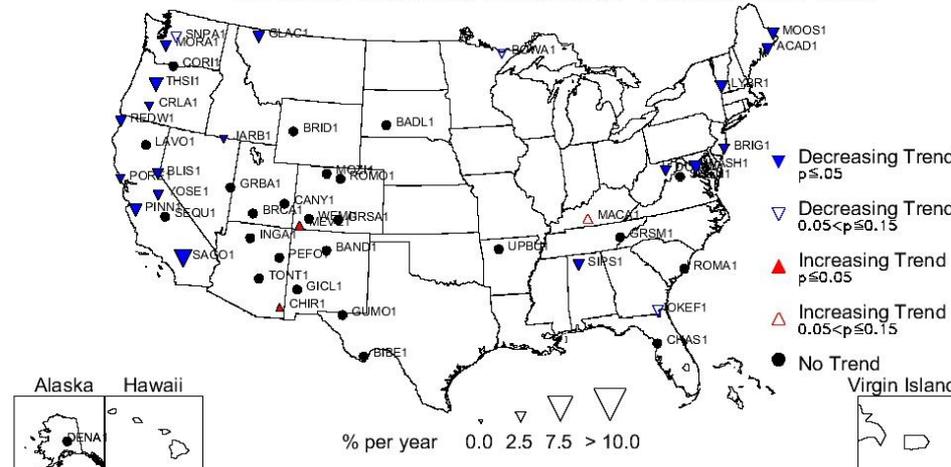


# 20 Year Nitrate Trends

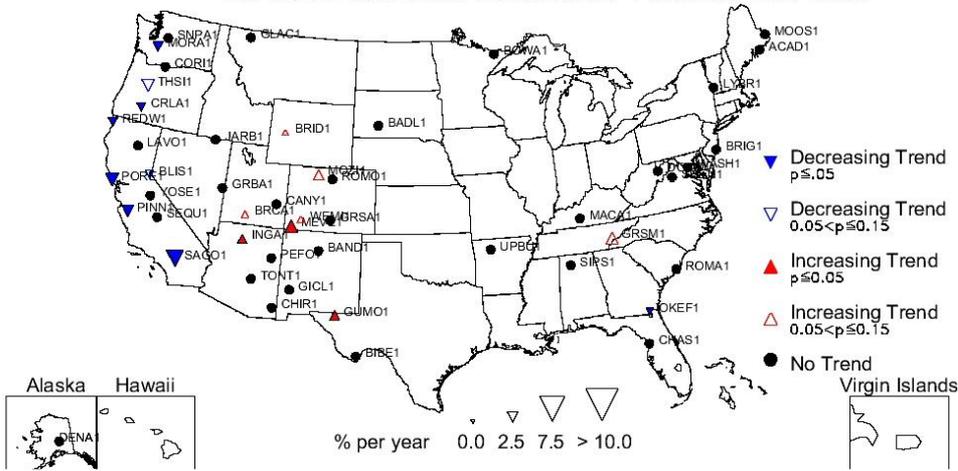
IMPROVE 1989-2008 Trends for 10<sup>th</sup> Percentile NO<sub>3</sub> Mass



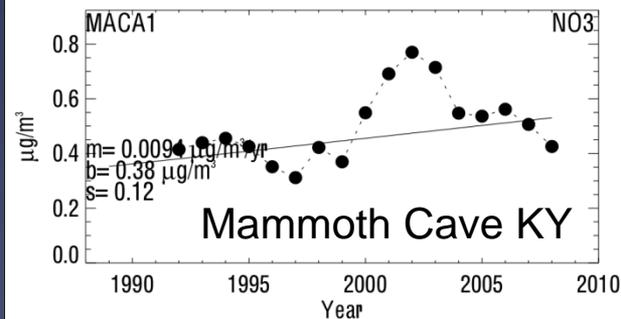
IMPROVE 1989-2008 Trends for 50<sup>th</sup> Percentile NO<sub>3</sub> Mass



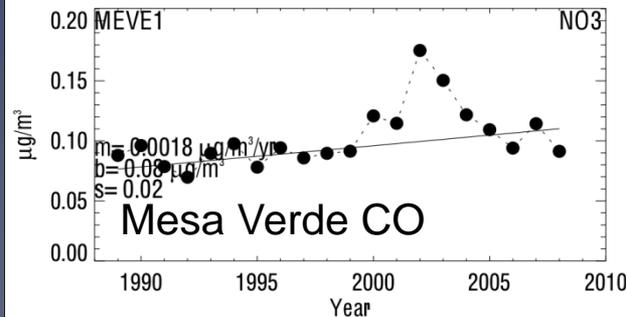
IMPROVE 1989-2008 Trends for 90<sup>th</sup> Percentile NO<sub>3</sub> Mass



IMPROVE 50 Percentile Trends

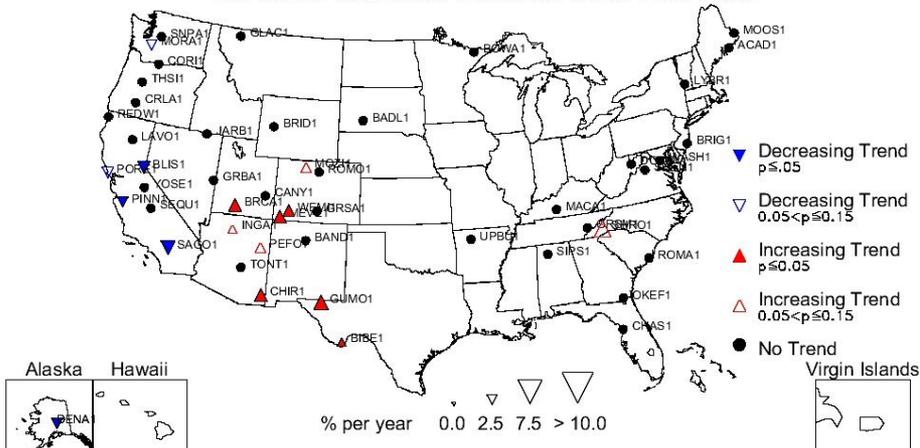


IMPROVE 50 Percentile Trends

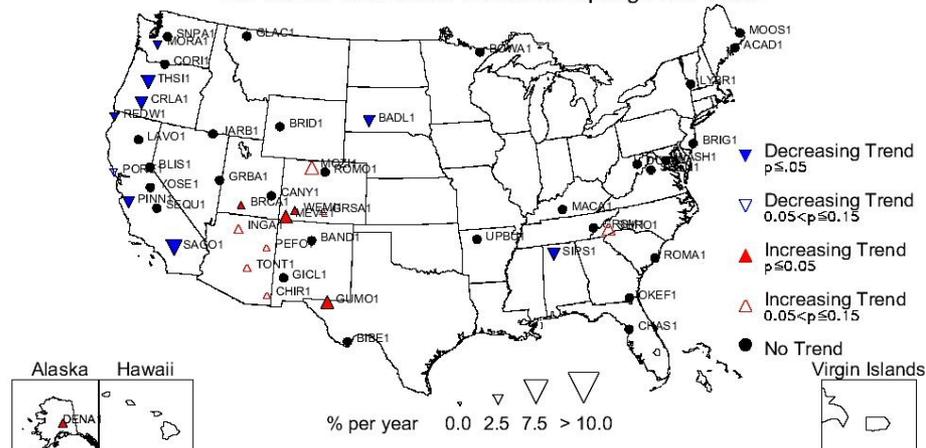


# 20 Year Nitrate Trends

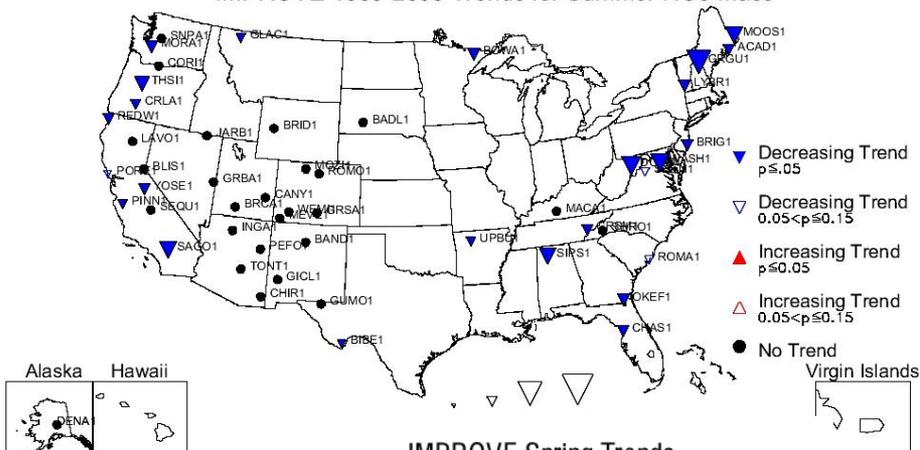
IMPROVE 1989-2008 Trends for Winter NO<sub>3</sub> Mass



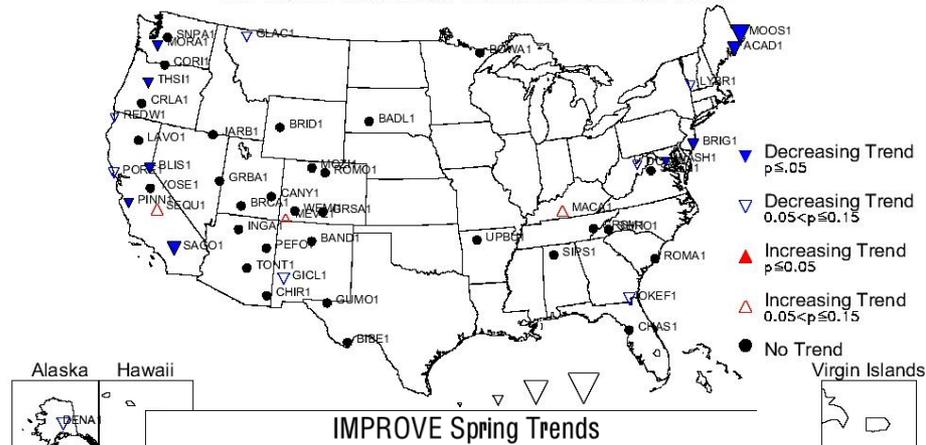
IMPROVE 1989-2008 Trends for Spring NO<sub>3</sub> Mass



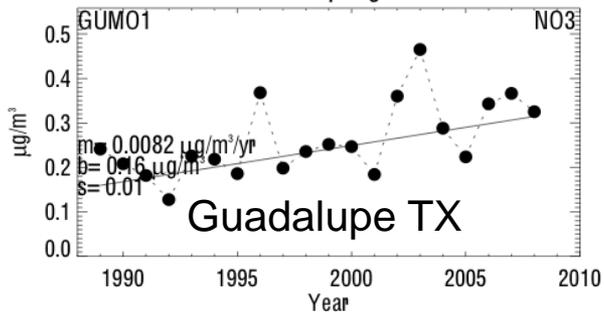
IMPROVE 1989-2008 Trends for Summer NO<sub>3</sub> Mass



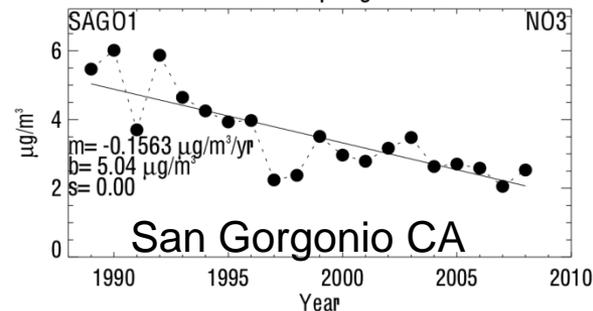
IMPROVE 1989-2008 Trends for Fall NO<sub>3</sub> Mass



IMPROVE Spring Trends

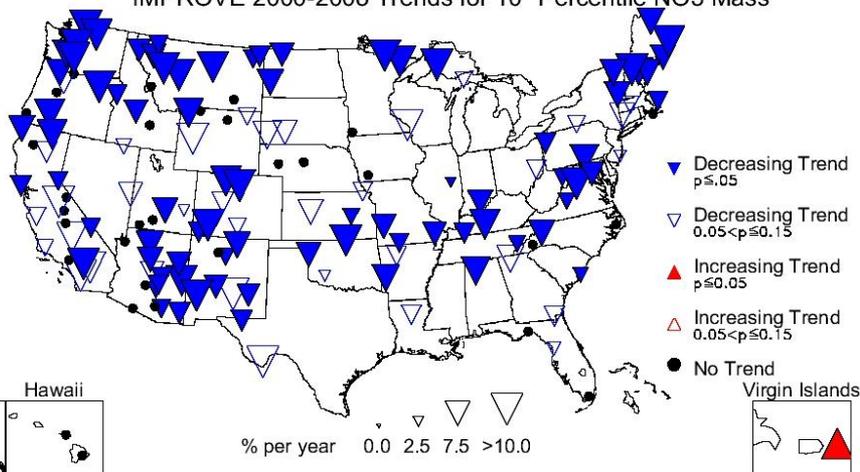


IMPROVE Spring Trends

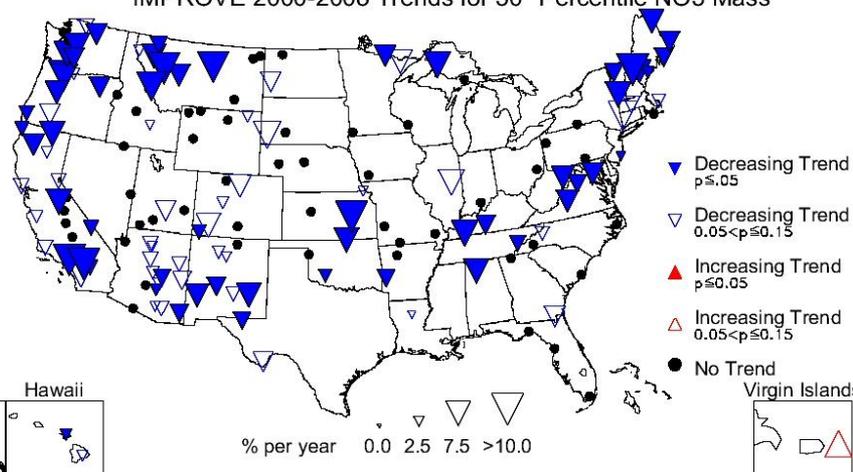


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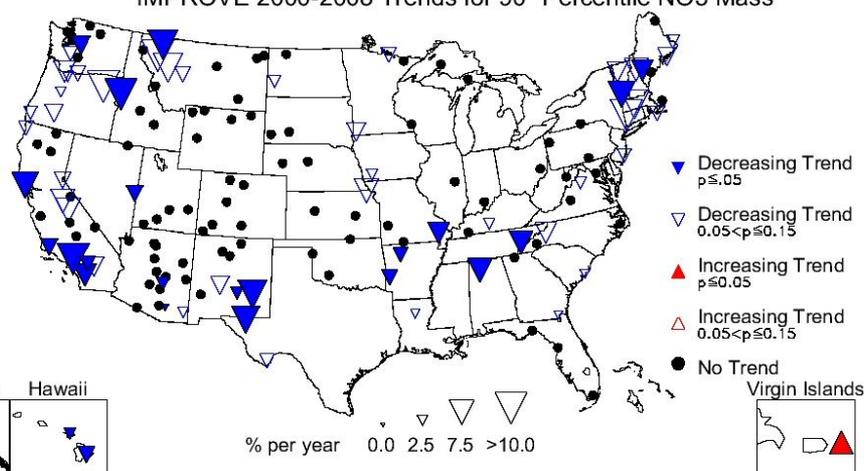
IMPROVE 2000-2008 Trends for 10<sup>th</sup> Percentile NO<sub>3</sub> Mass



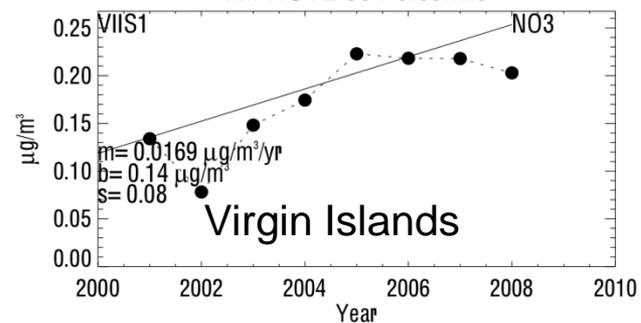
IMPROVE 2000-2008 Trends for 50<sup>th</sup> Percentile NO<sub>3</sub> Mass



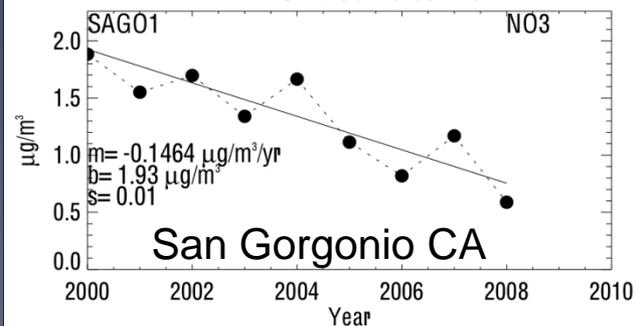
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IMPROVE 50 Percentile

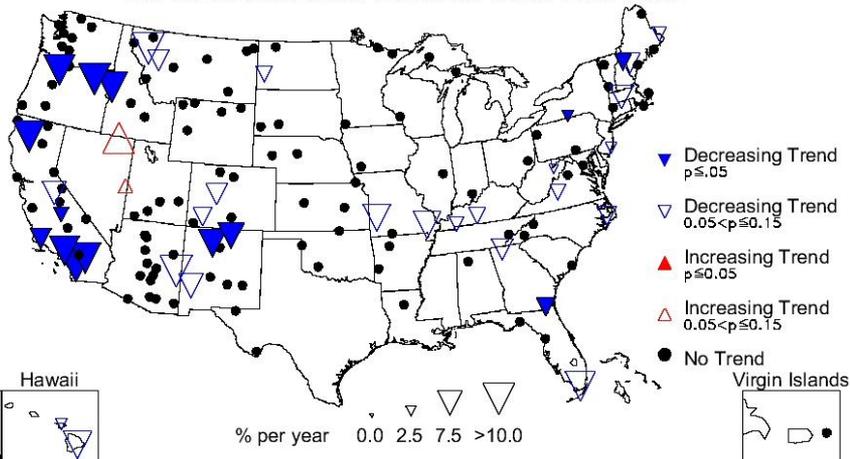


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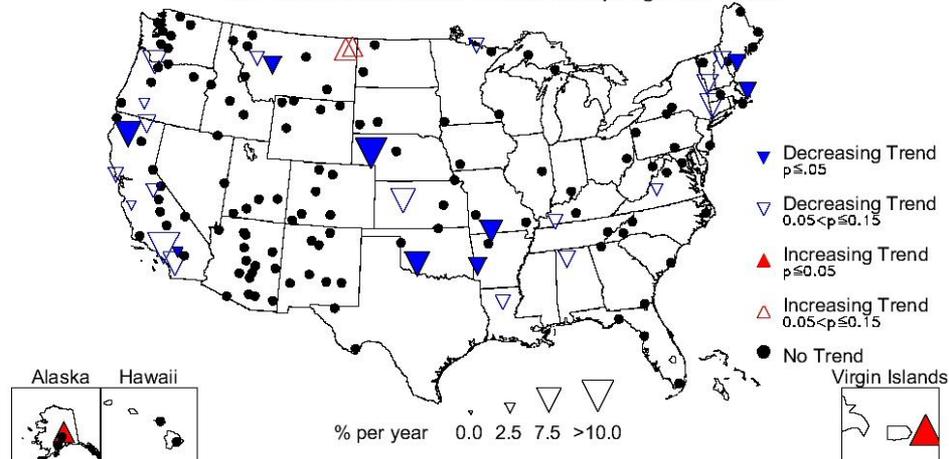


# 9 Year Nitrate Trends

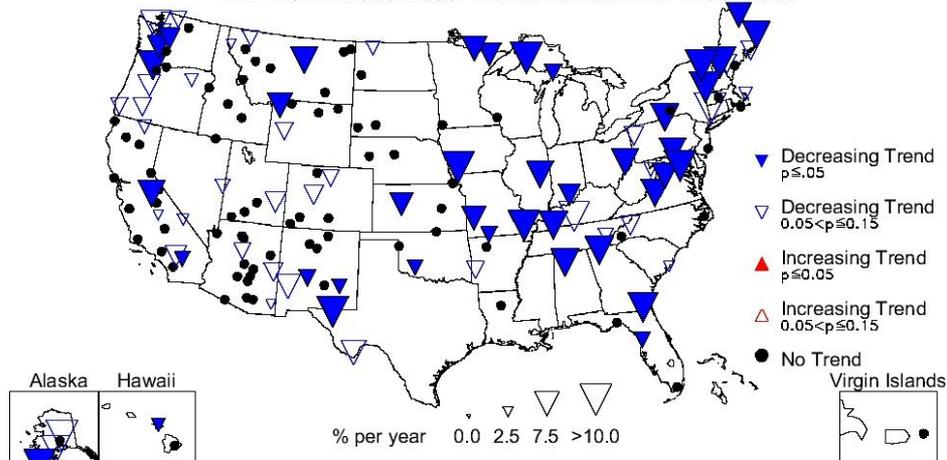
IMPROVE 2000-2008 Trends for Winter NO<sub>3</sub> Mass



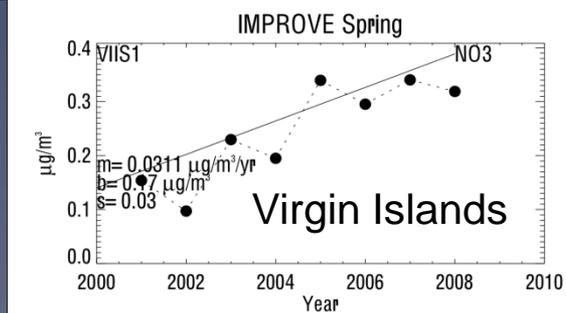
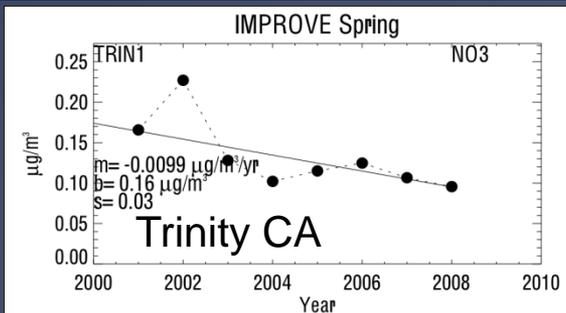
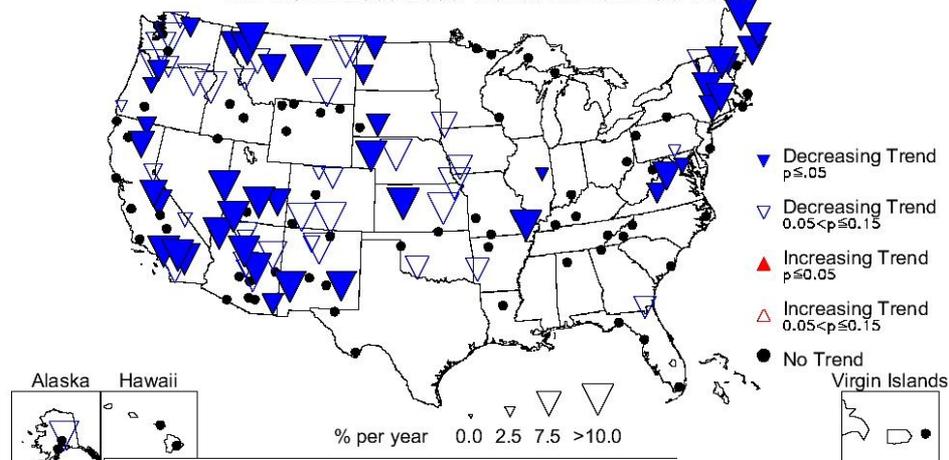
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IMPROVE 2000-2008 Trends for Summer NO<sub>3</sub> Mass

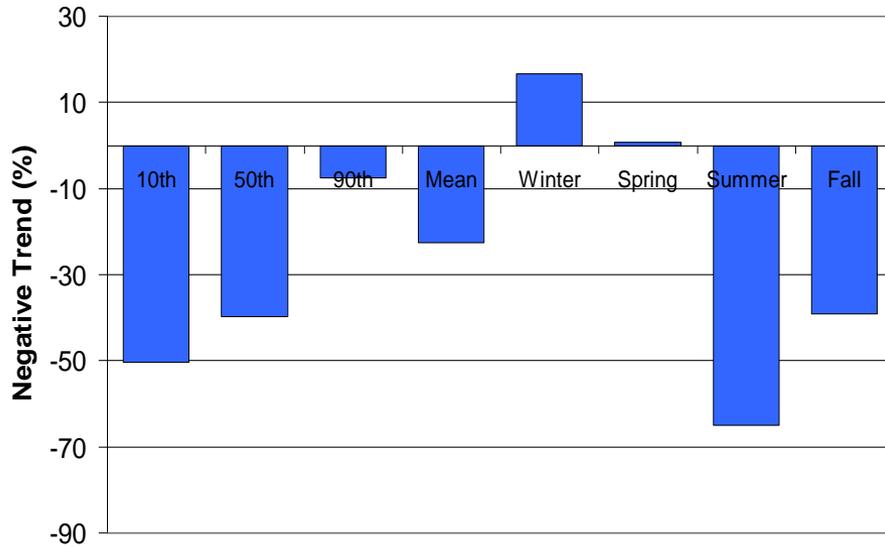


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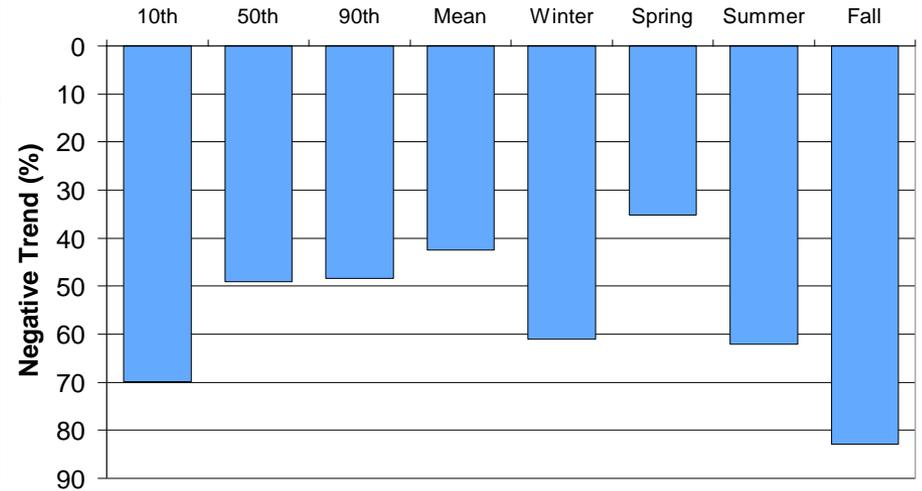


# 9 Year vs 20 Year Nitrate Trends

Nitrate Twenty Year Overall Trend (1989-2008)

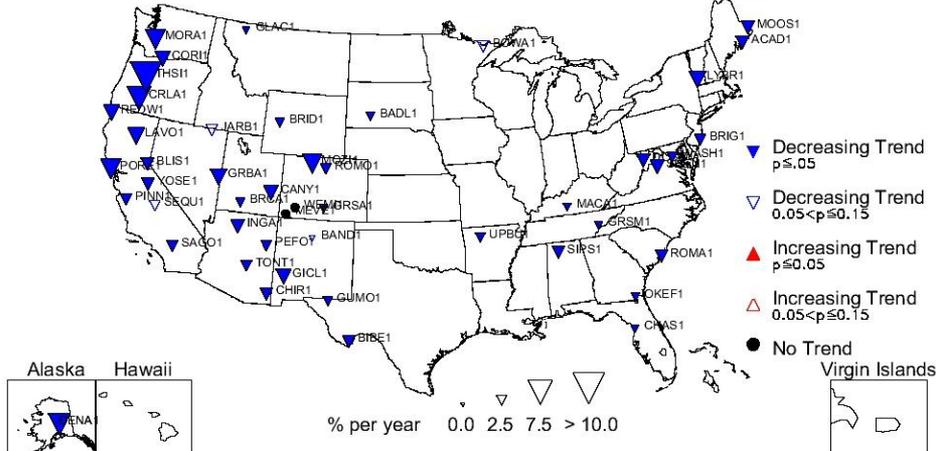


Nitrate Nine Year Overall Trend (2000-2008)

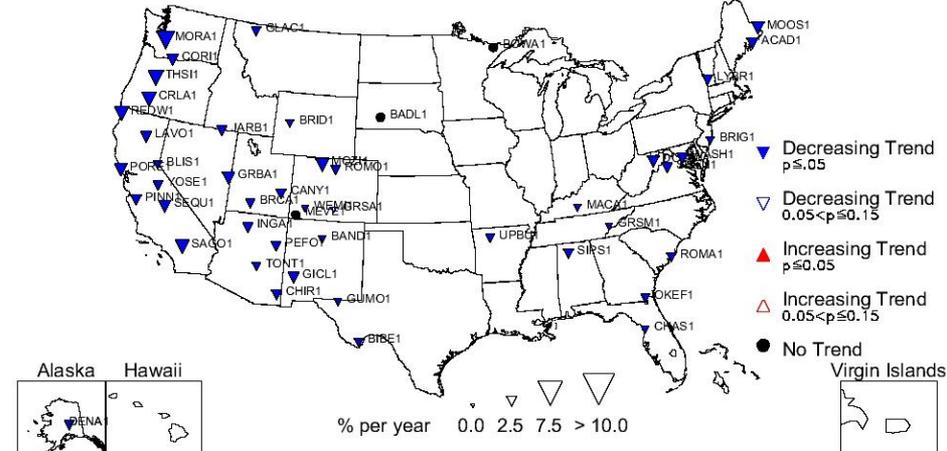


# 20 Year Total Carbon Trends

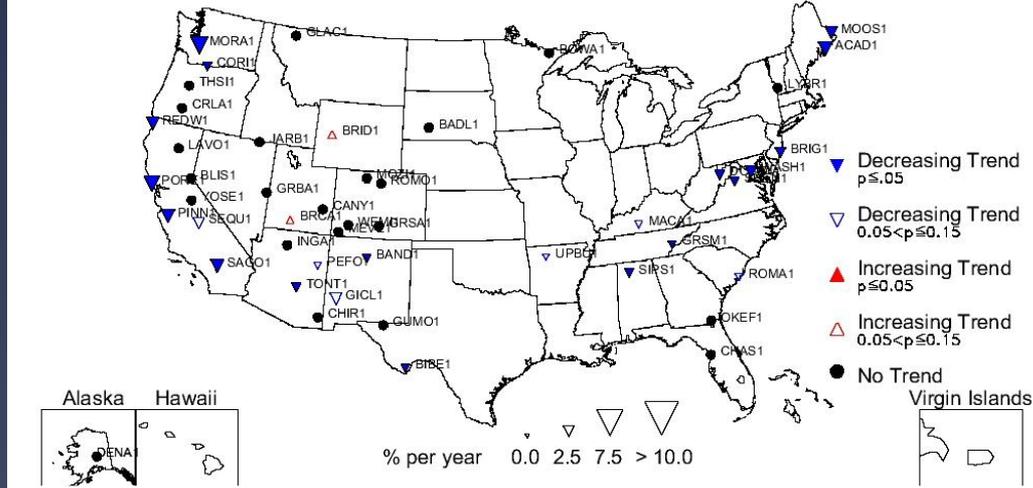
IMPROVE 1989-2008 Trends for 10<sup>th</sup> Percentile TC Mass



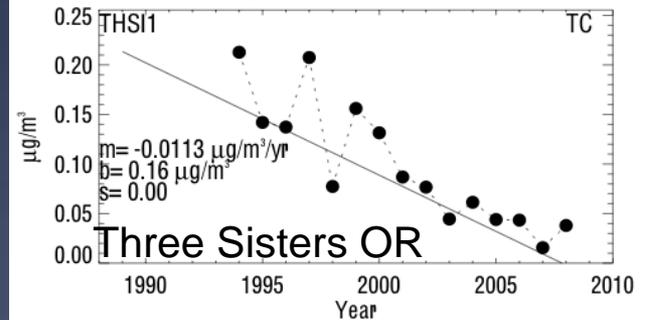
IMPROVE 1989-2008 Trends for 50<sup>th</sup> Percentile TC Mass



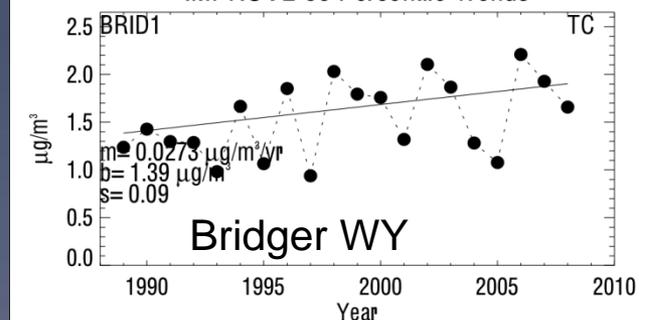
IMPROVE 1989-2008 Trends for 90<sup>th</sup> Percentile TC Mass



IMPROVE 10 Percentile Trends



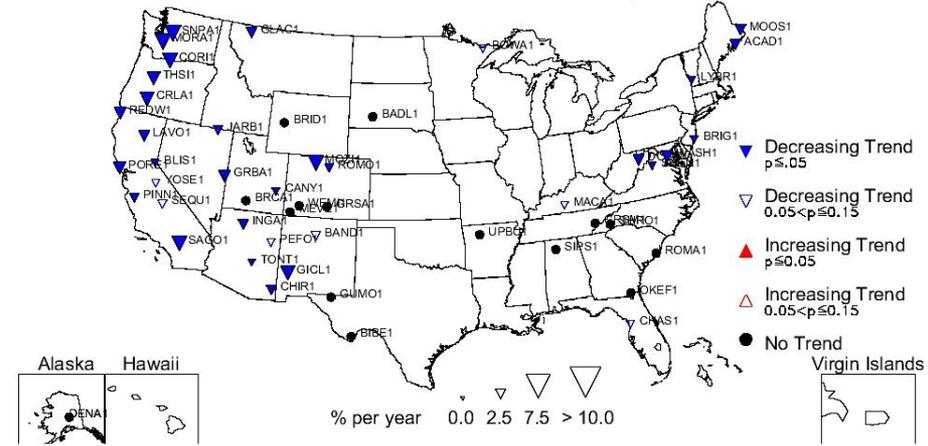
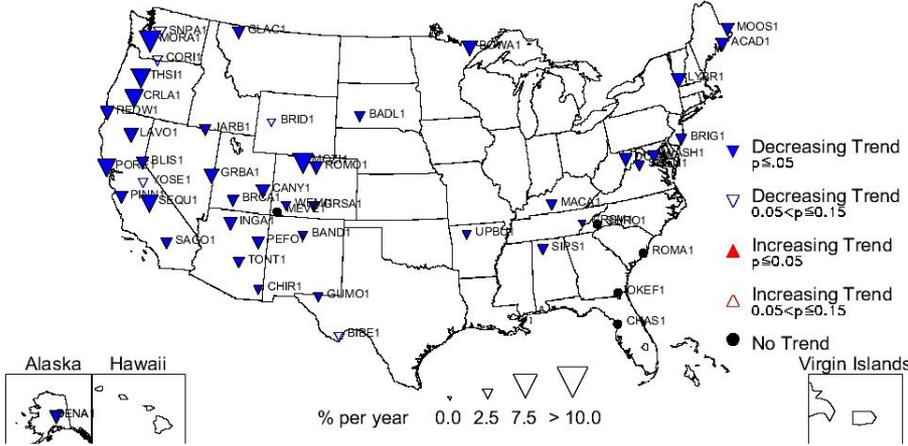
IMPROVE 90 Percentile Trends



# 20 Year Total Carbon Trends

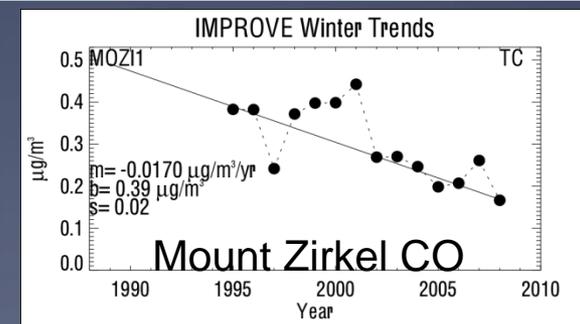
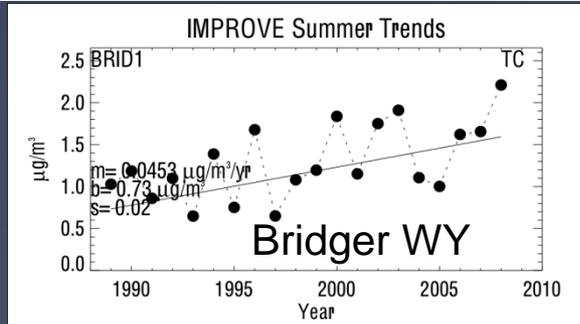
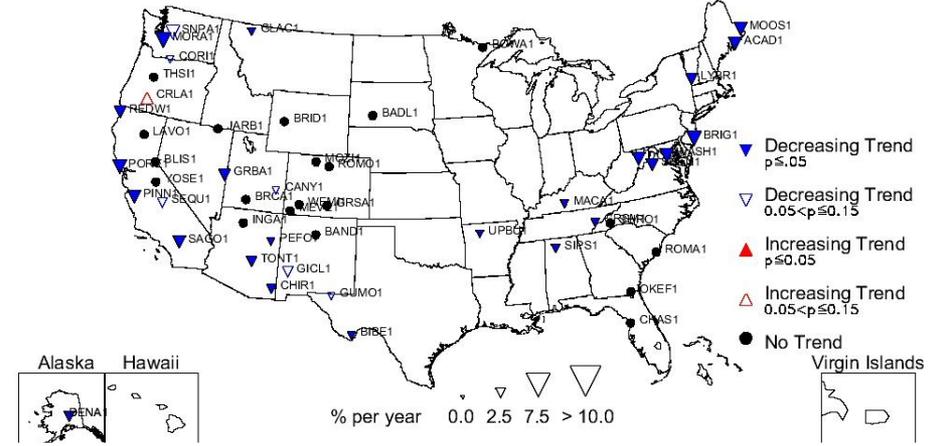
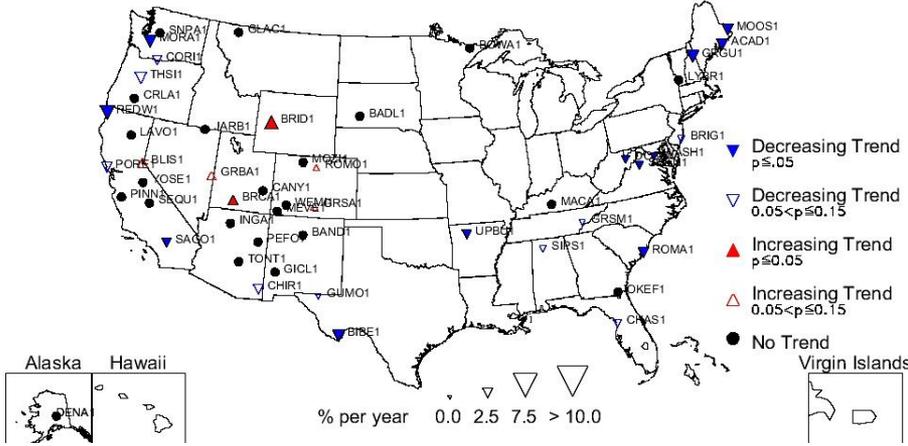
IMPROVE 1989-2008 Trends for Winter TC Mass

IMPROVE 1989-2008 Trends for Spring TC Mass



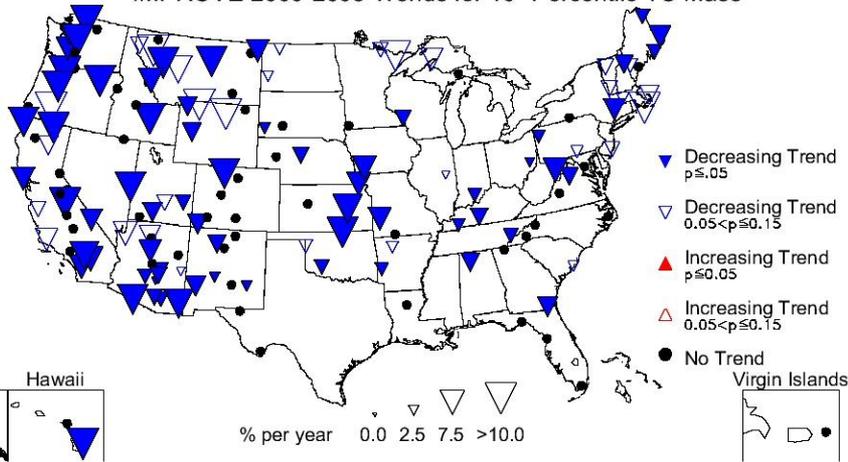
IMPROVE 1989-2008 Trends for Summer TC Mass

IMPROVE 1989-2008 Trends for Fall TC Mass

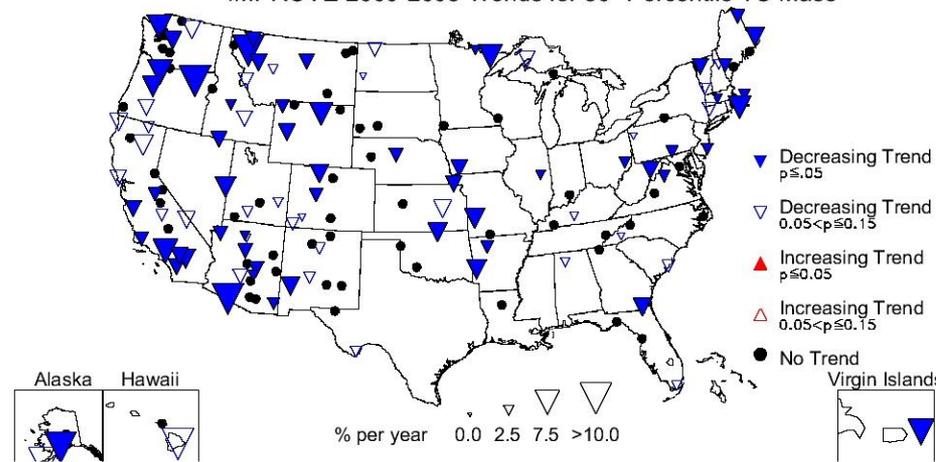


# 9 Year Total Carbon Trends

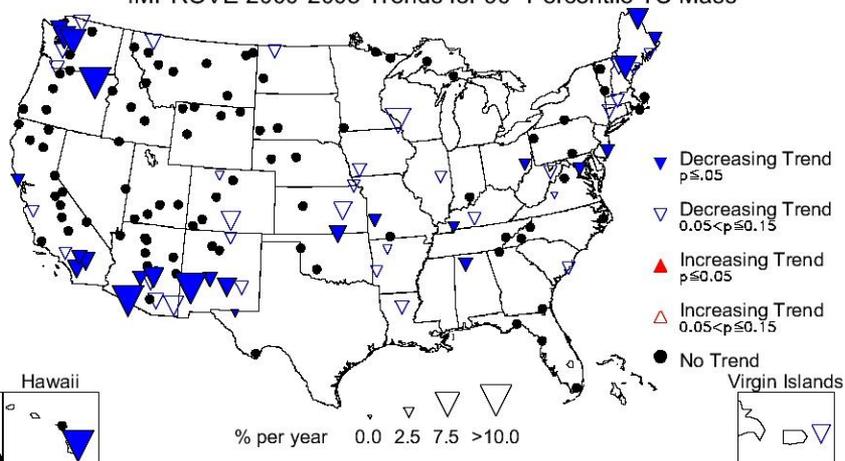
IMPROVE 2000-2008 Trends for 10<sup>th</sup> Percentile TC Mass



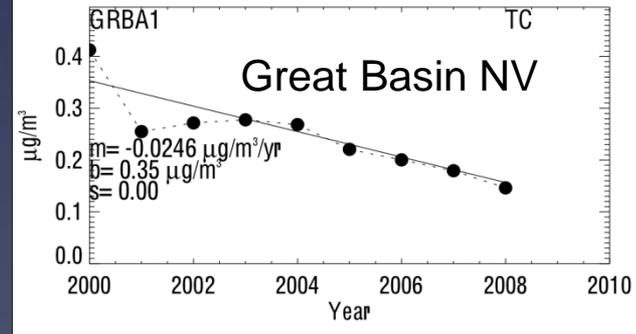
IMPROVE 2000-2008 Trends for 50<sup>th</sup> Percentile TC Mass



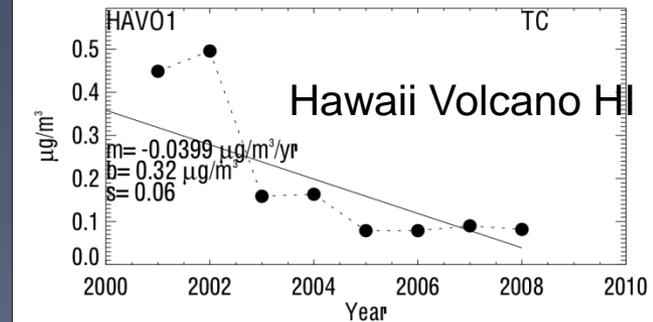
IMPROVE 2000-2008 Trends for 90<sup>th</sup> Percentile TC Mass



IMPROVE 10 Percentile

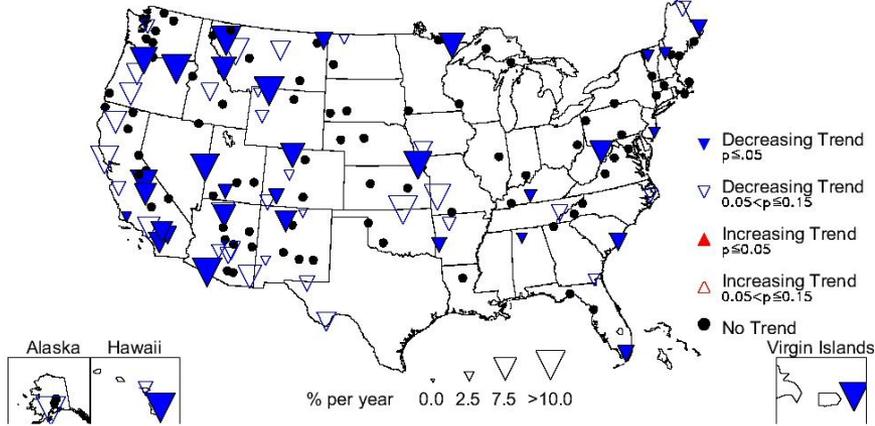


IMPROVE 50 Percentile

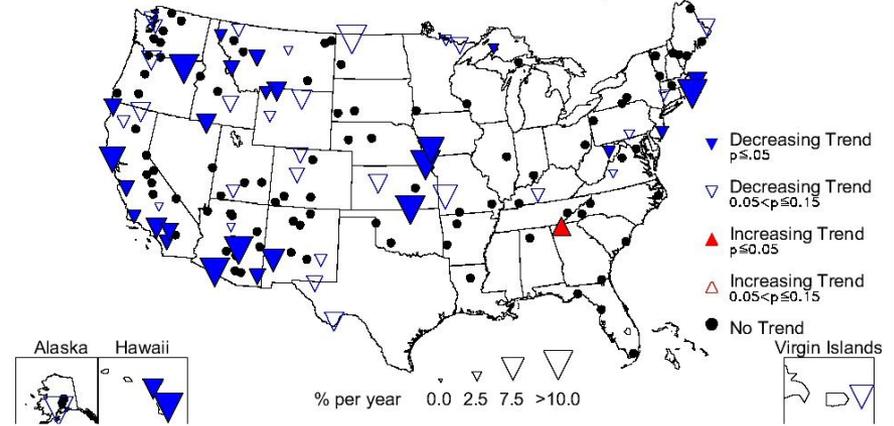


# 9 Year Total Carbon Trends

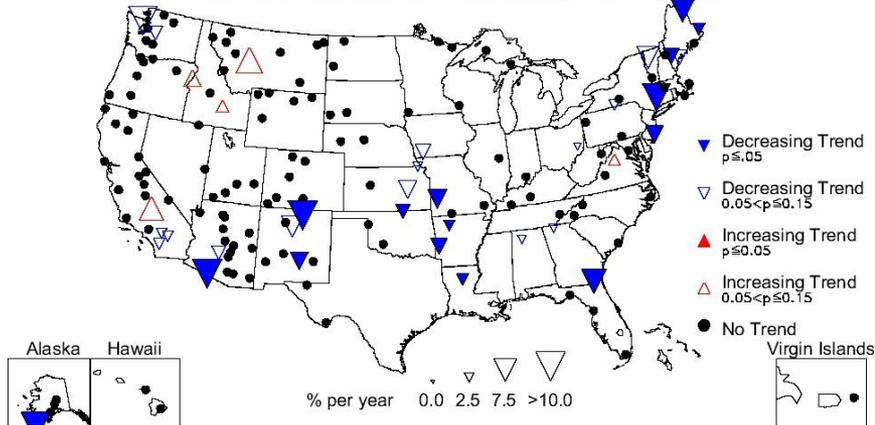
IMPROVE 2000-2008 Trends for Winter TC Mass



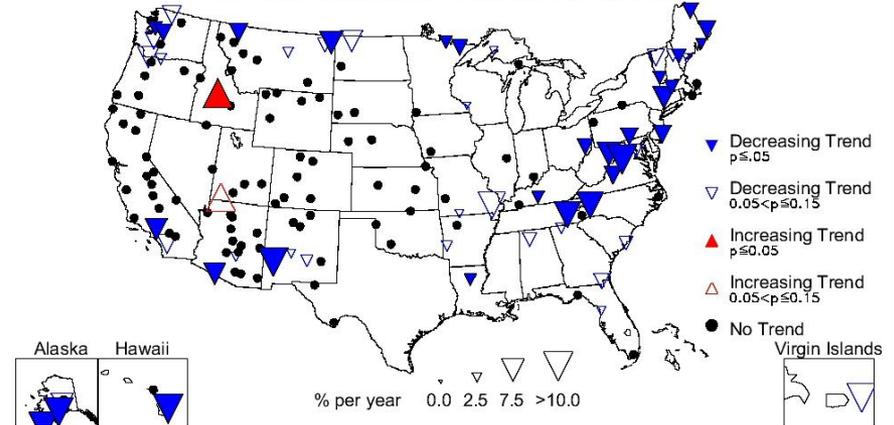
IMPROVE 2000-2008 Trends for Spring TC Mass



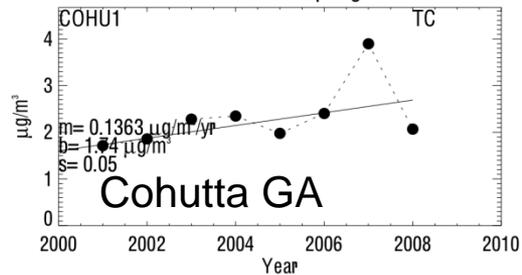
IMPROVE 2000-2008 Trends for Summer TC Mass



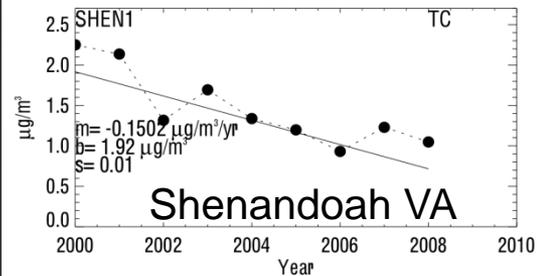
IMPROVE 2000-2008 Trends for Fall TC Mass



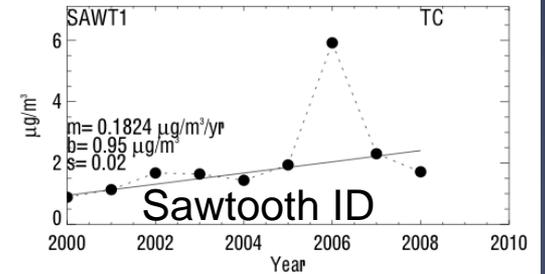
IMPROVE Spring



IMPROVE Fall

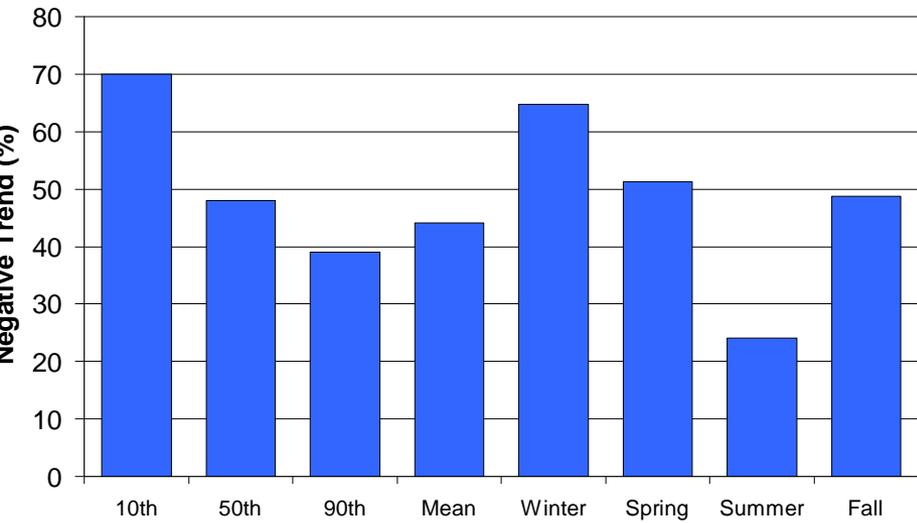


IMPROVE Fall

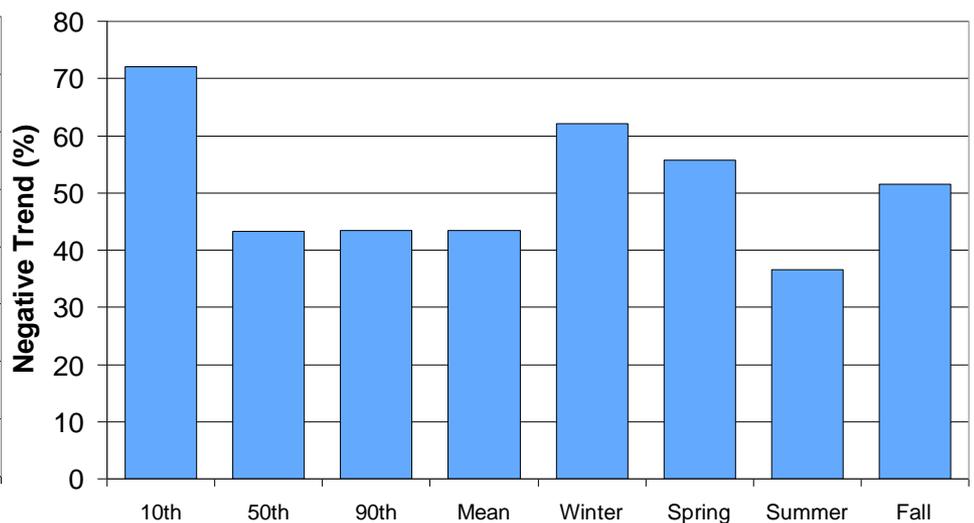


# 20 Year versus 9 Year TC Trends

**Total Carbon Twenty Year Overall Trend (1989-2008)**

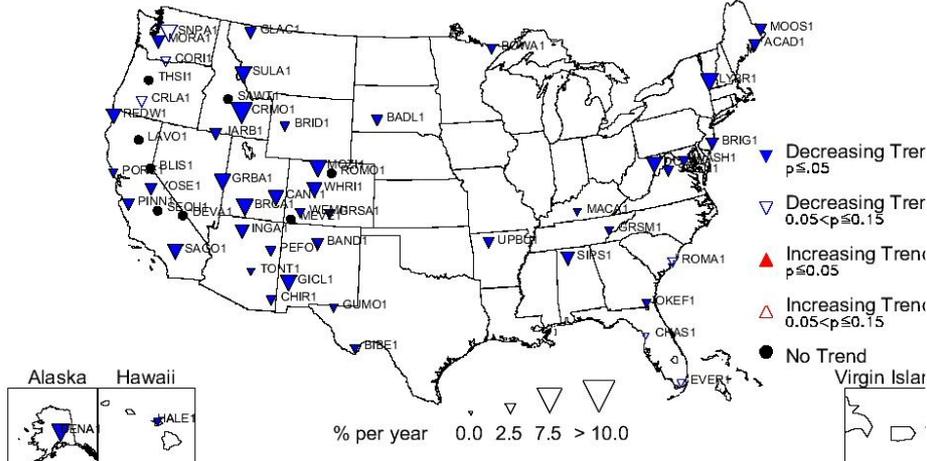


**Total Carbon Nine Year Overall Trend (2000-2008)**

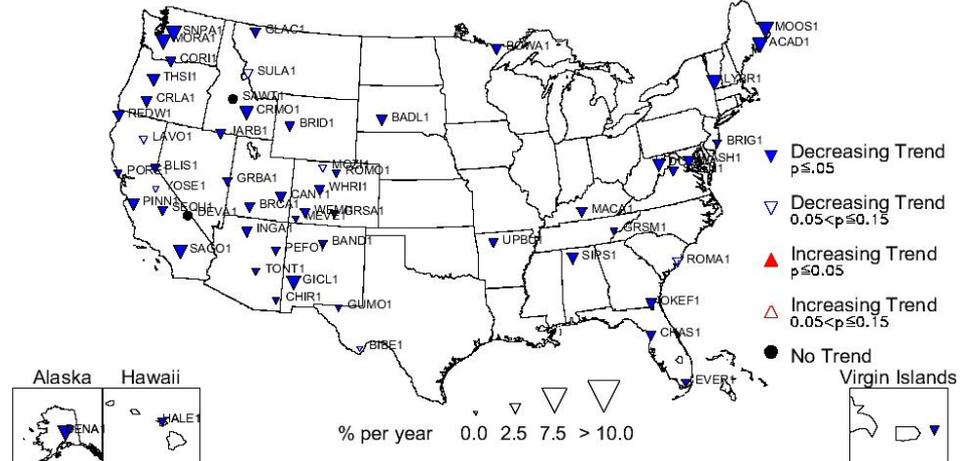


# 20 Year Fine Mass Trends

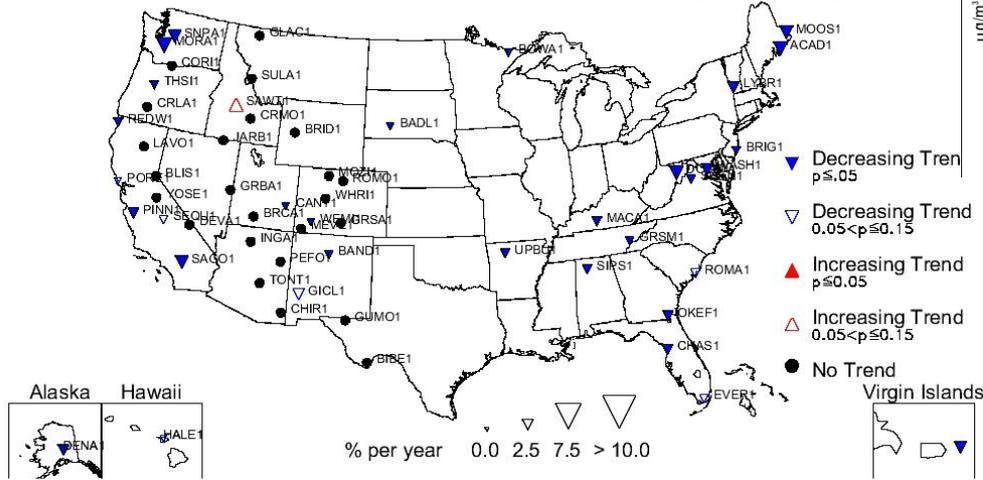
IMPROVE 1989-2008 Trends for 10<sup>th</sup> Percentile FM Mass



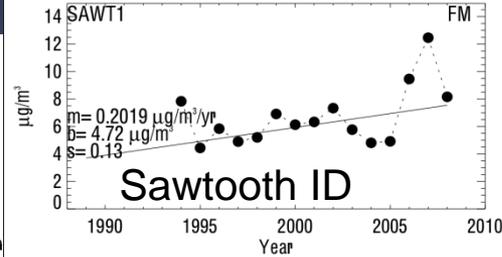
IMPROVE 1989-2008 Trends for 50<sup>th</sup> Percentile FM Mass



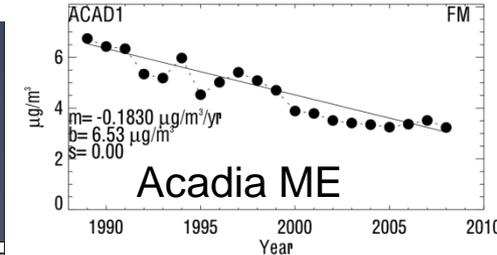
IMPROVE 1989-2008 Trends for 90<sup>th</sup> Percentile FM Mass



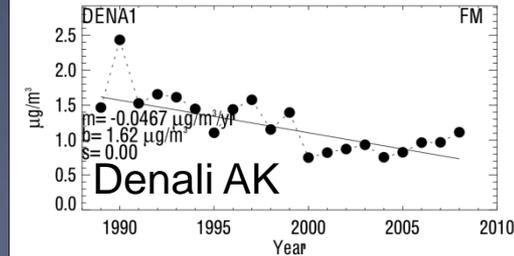
IMPROVE 90 Percentile Trends



IMPROVE 50 Percentile Trends

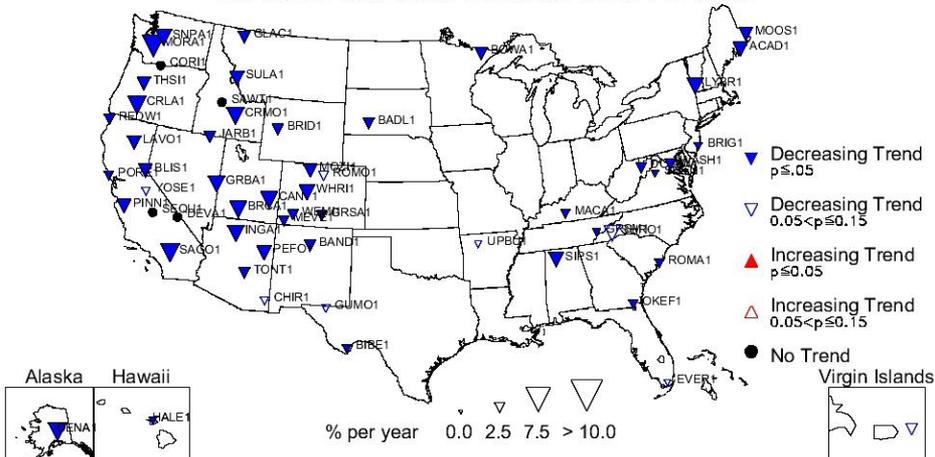


IMPROVE 50 Percentile Trends

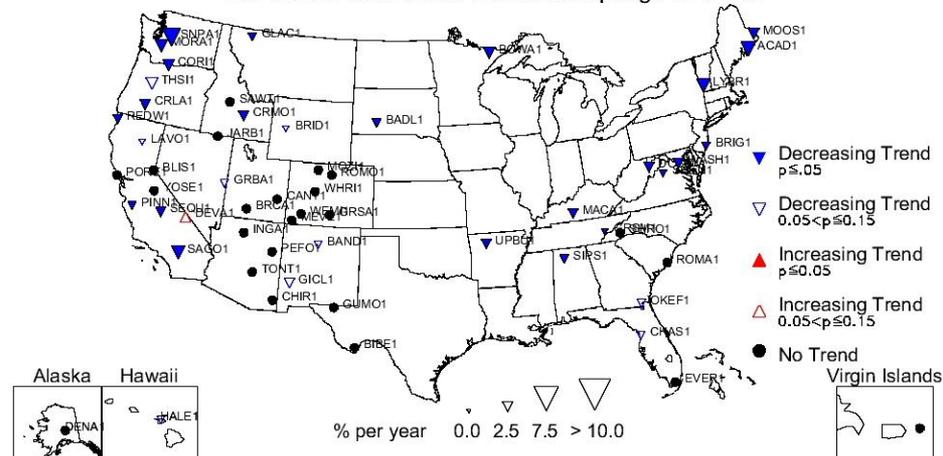


# 20 Year Fine Mass Trends

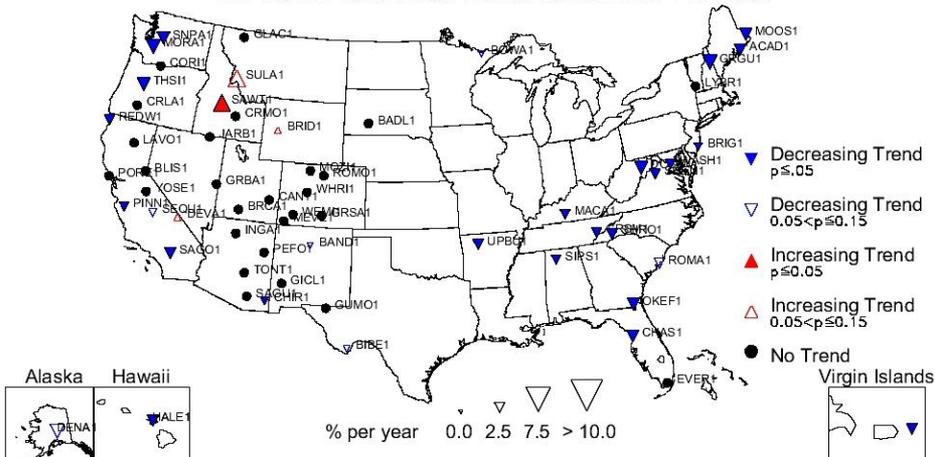
IMPROVE 1989-2008 Trends for Winter FM Mass



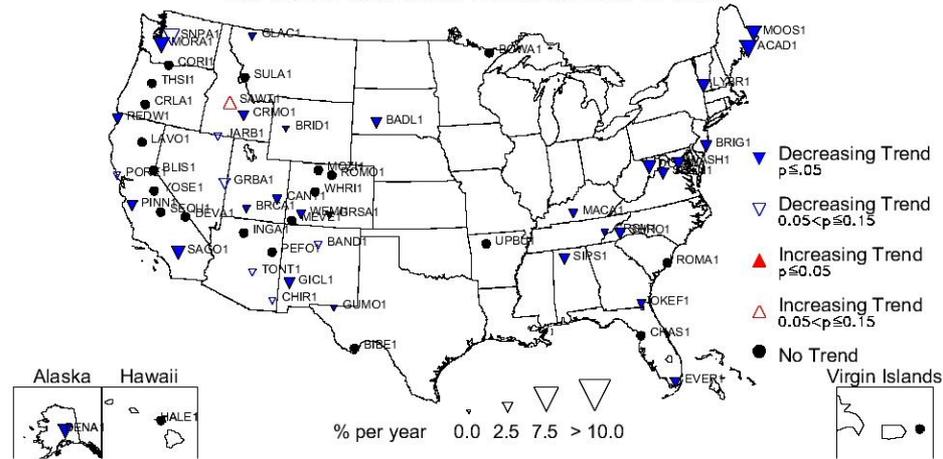
IMPROVE 1989-2008 Trends for Spring FM Mass



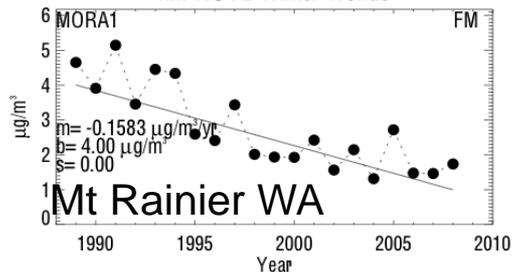
IMPROVE 1989-2008 Trends for Summer FM Mass



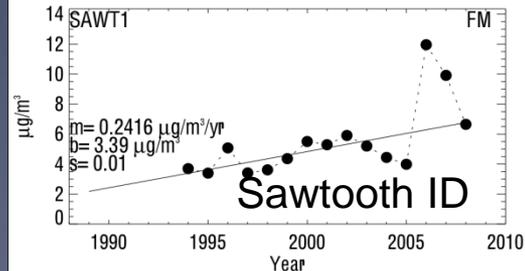
IMPROVE 1989-2008 Trends for Fall FM Mass



IMPROVE Winter Trends

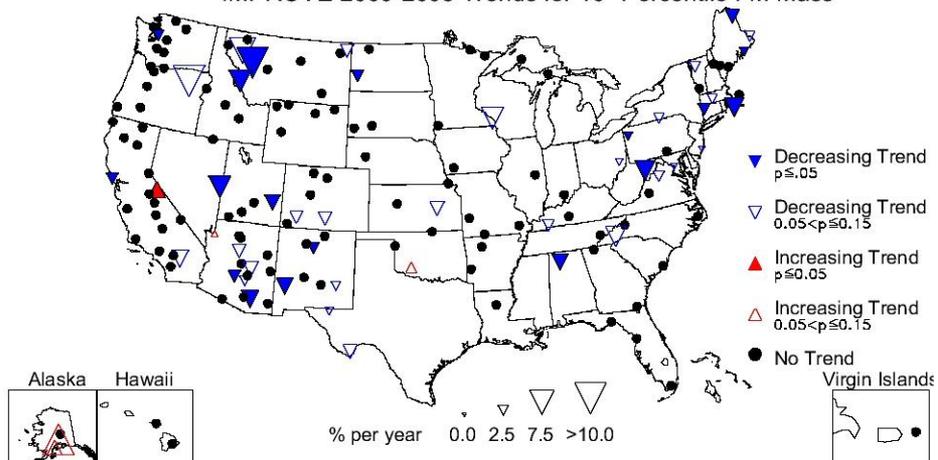


IMPROVE Summer Trends

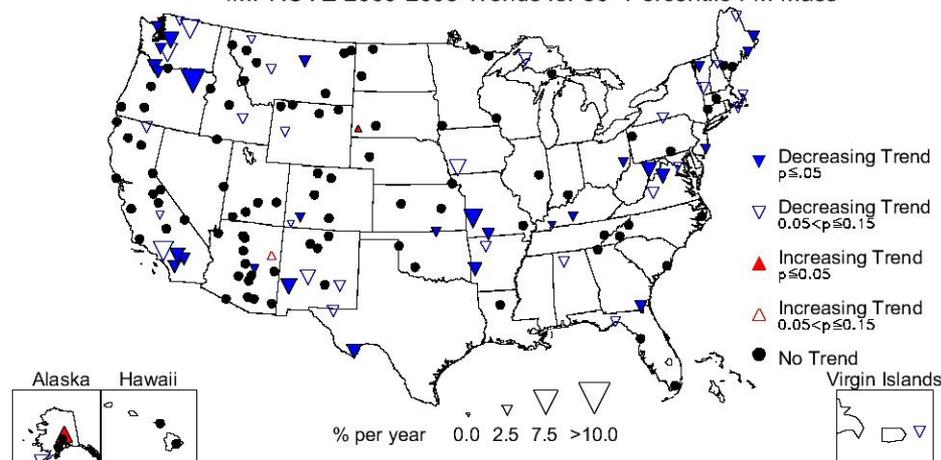


# 9 Year Fine Mass Trends

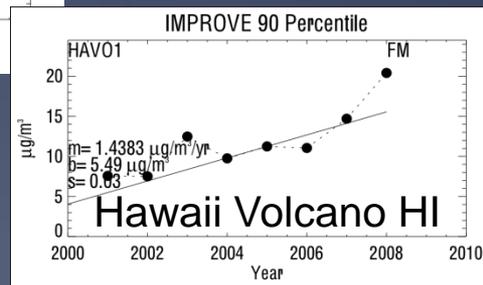
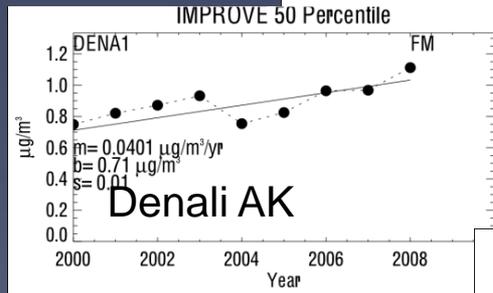
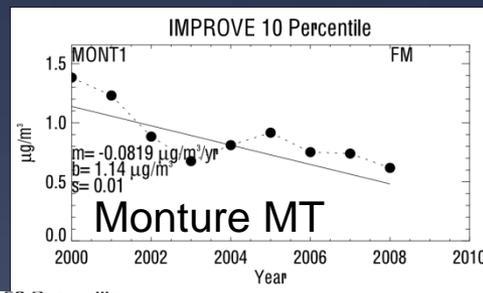
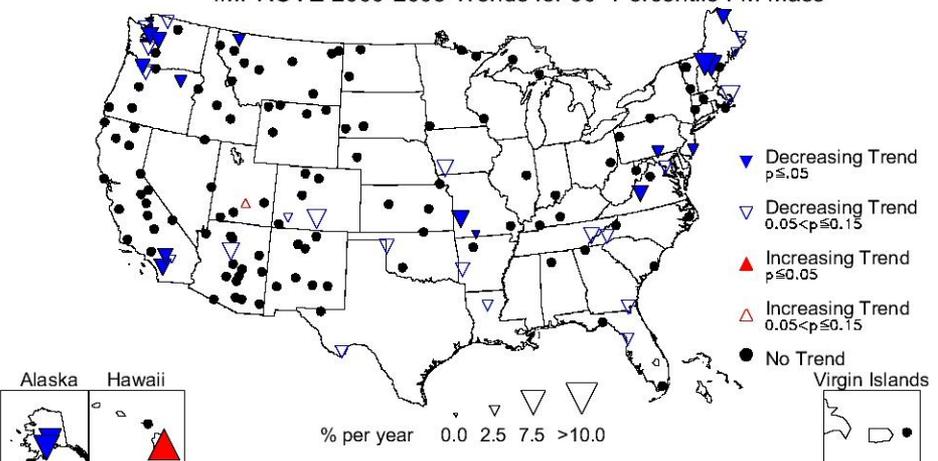
IMPROVE 2000-2008 Trends for 10<sup>th</sup> Percentile FM Mass



IMPROVE 2000-2008 Trends for 50<sup>th</sup> Percentile FM Mass

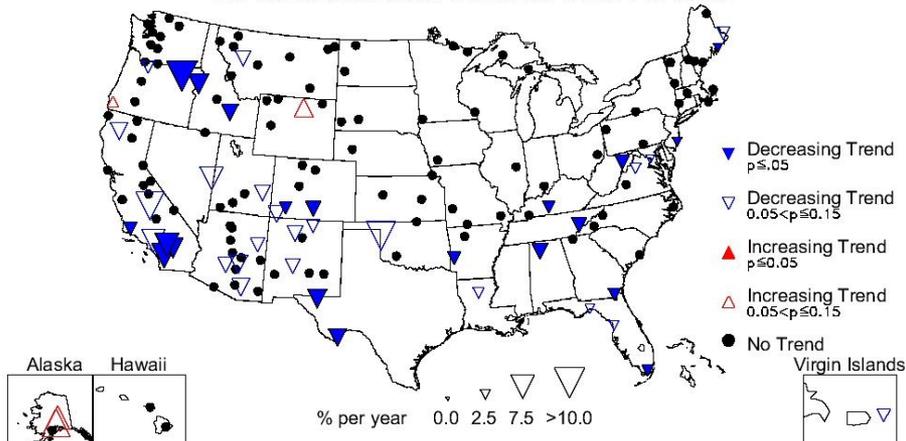


IMPROVE 2000-2008 Trends for 90<sup>th</sup> Percentile FM Mass

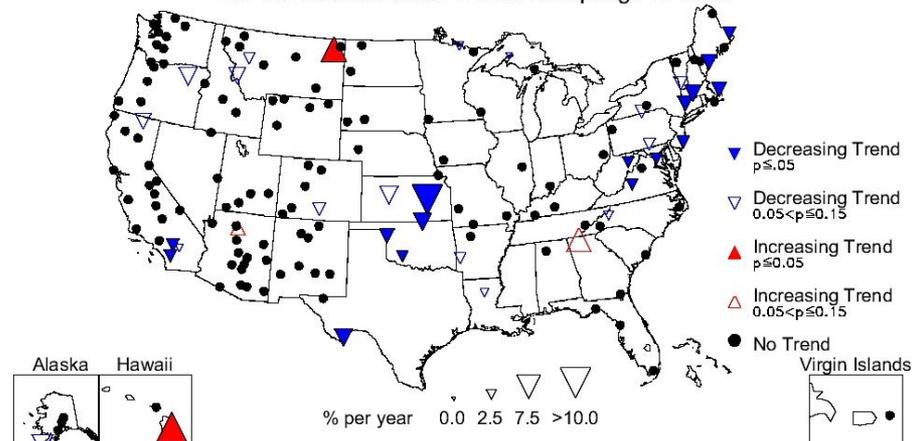


# 9 Year Fine Mass Trends

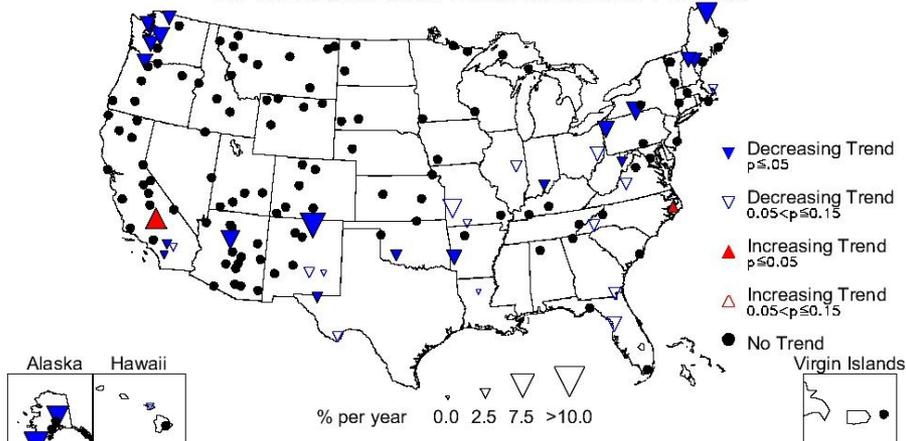
IMPROVE 2000-2008 Trends for Winter FM Mass



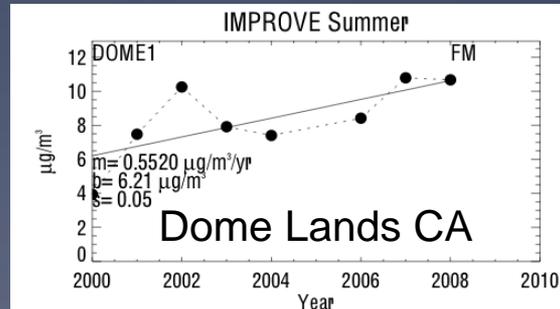
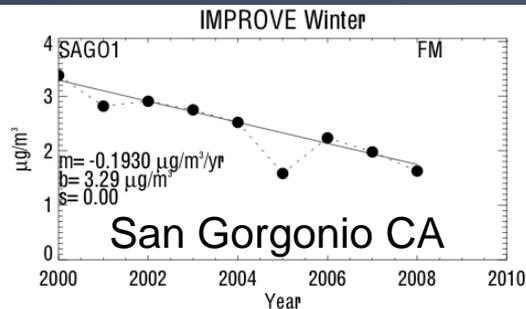
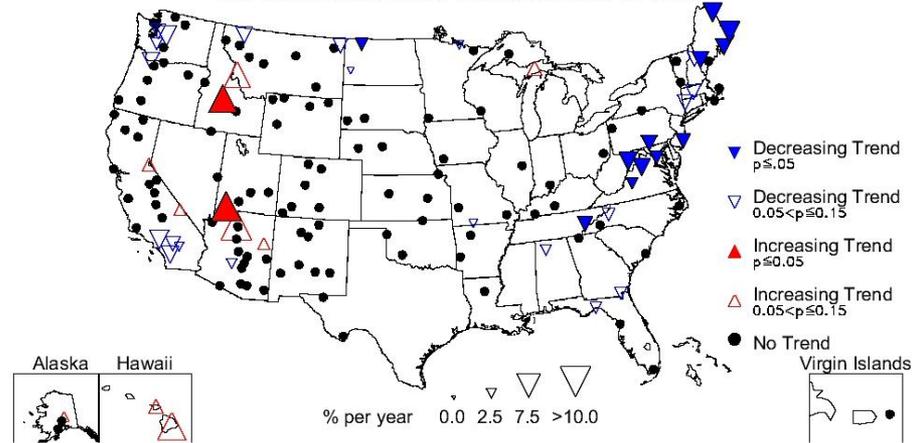
IMPROVE 2000-2008 Trends for Spring FM Mass



IMPROVE 2000-2008 Trends for Summer FM Mass

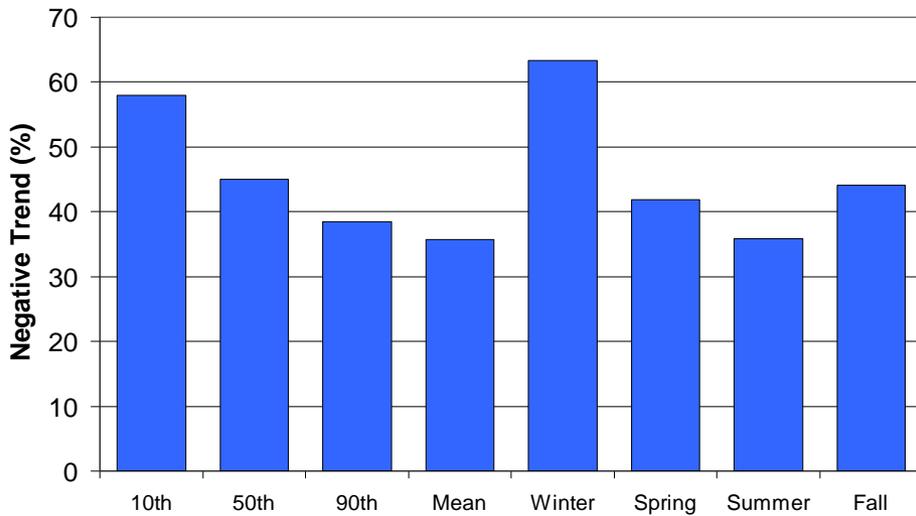


IMPROVE 2000-2008 Trends for Fall FM Mass

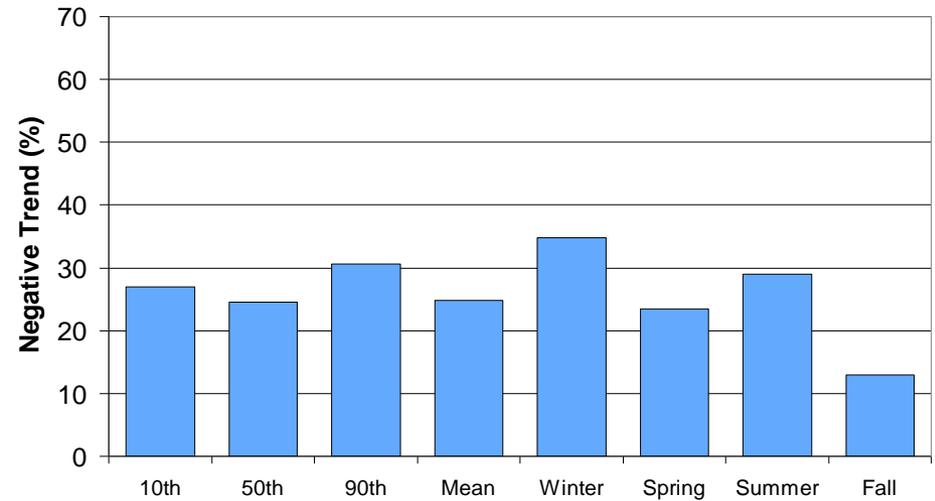


# 20 versus 9 Year Fine Mass Trends

Fine Mass Twenty Year Overall Trend (1989-2008)

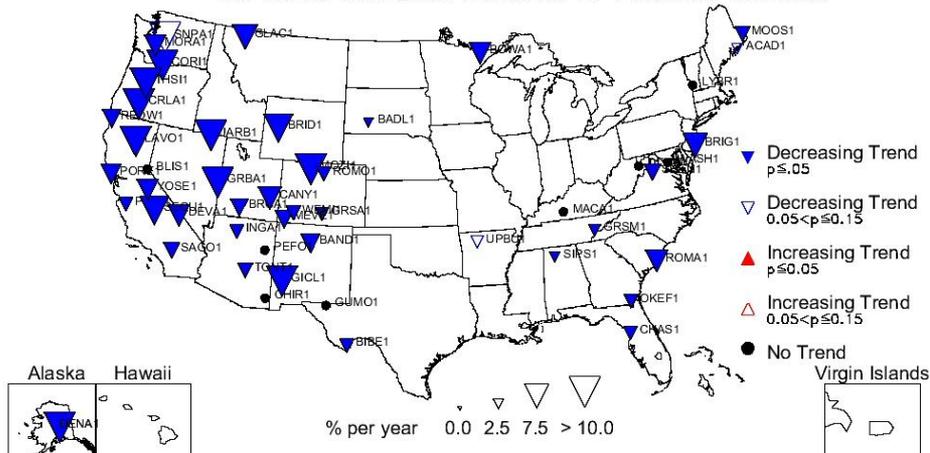


Fine Mass Nine Year Overall Trend (2000-2008)

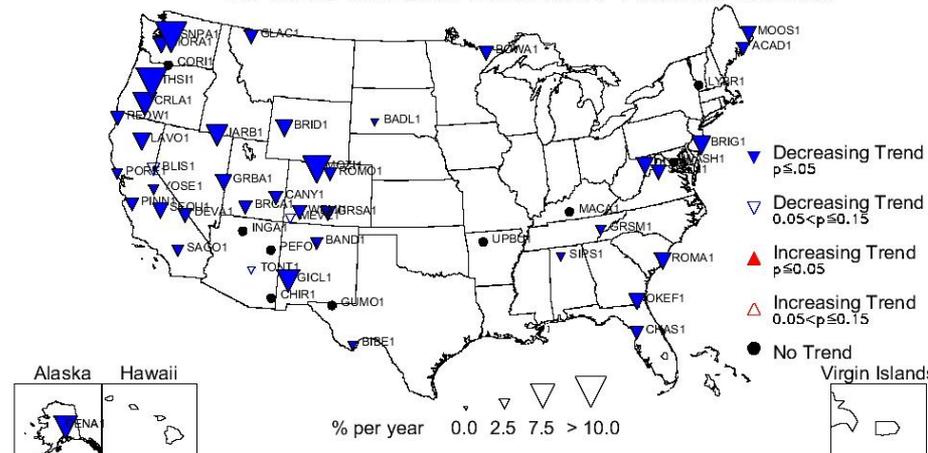


# 20 Year Coarse Mass Trends

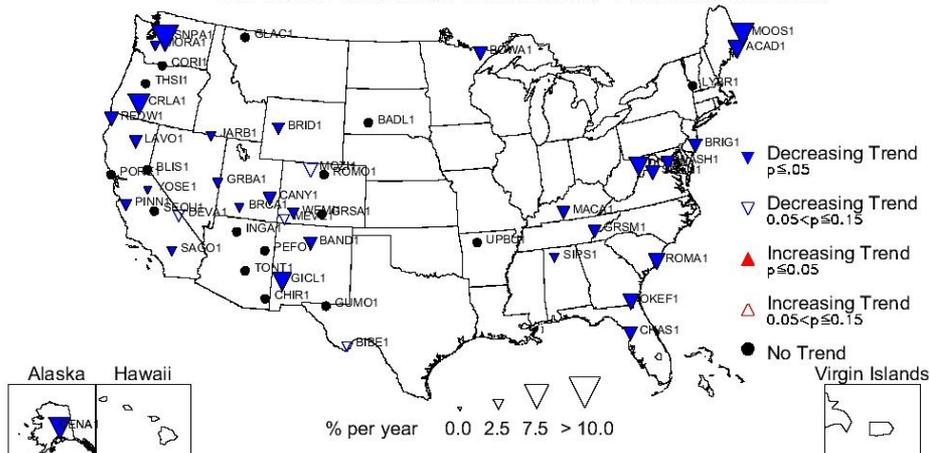
IMPROVE 1989-2008 Trends for 10<sup>th</sup> Percentile CM Mass



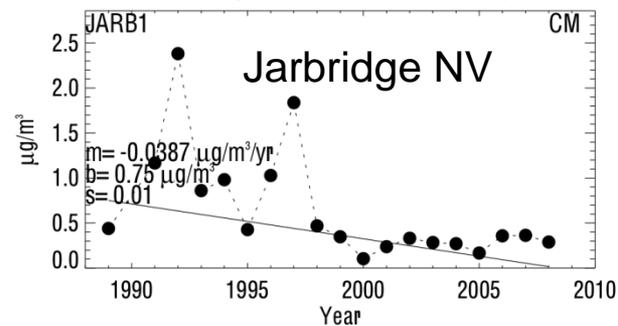
IMPROVE 1989-2008 Trends for 50<sup>th</sup> Percentile CM Mass



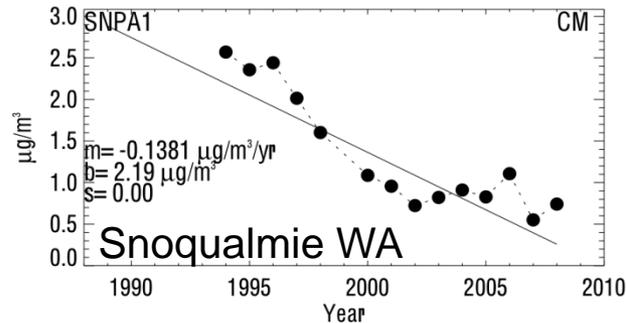
IMPROVE 1989-2008 Trends for 90<sup>th</sup> Percentile CM Mass



IMPROVE 10 Percentile Trends

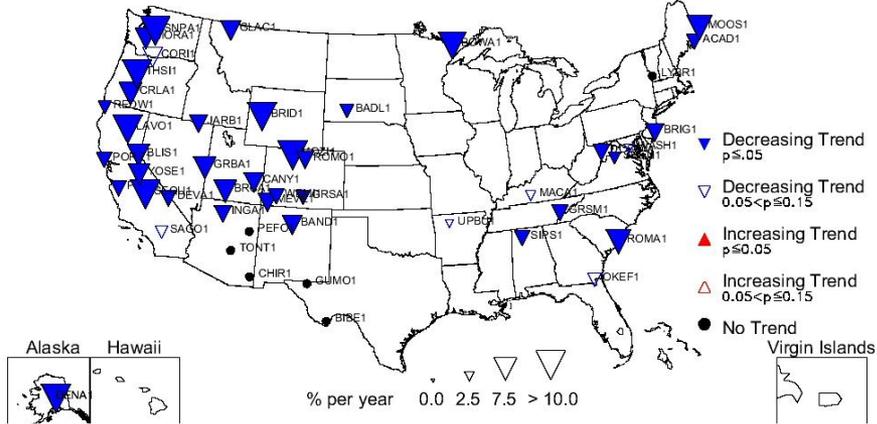


IMPROVE 50 Percentile Trends

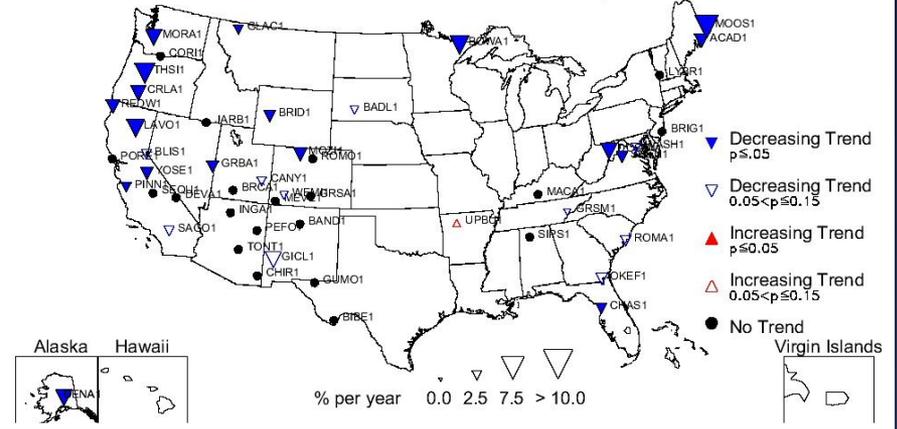


# 20 Year Coarse Mass Trends

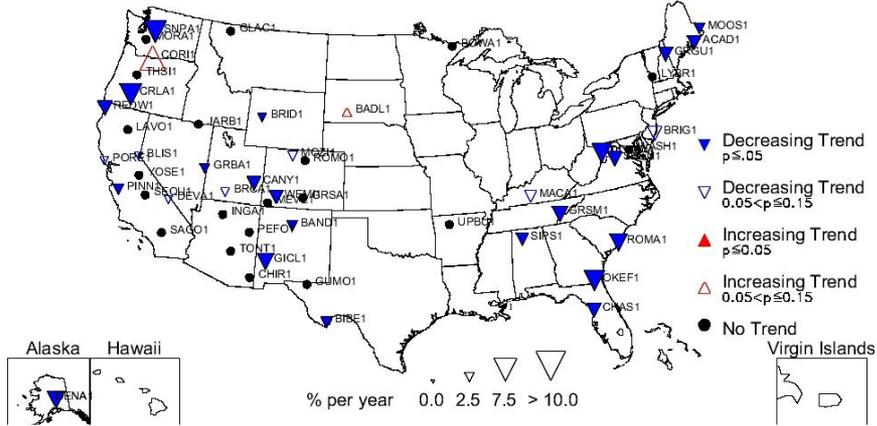
IMPROVE 1989-2008 Trends for Winter CM Mass



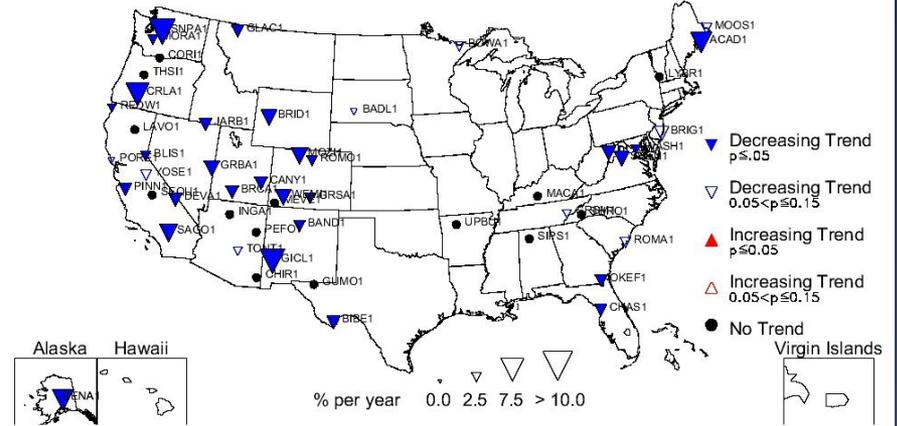
IMPROVE 1989-2008 Trends for Spring CM Mass



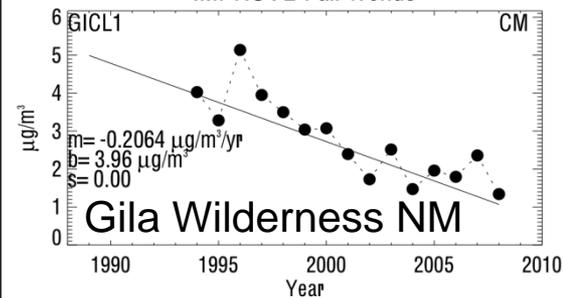
IMPROVE 1989-2008 Trends for Summer CM Mass



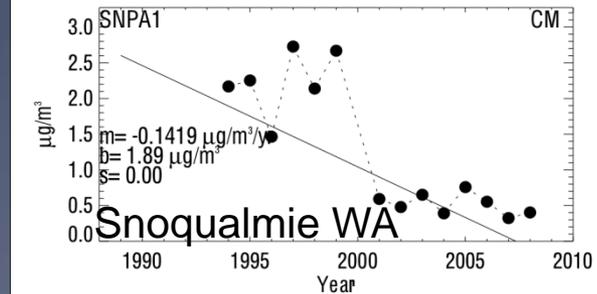
IMPROVE 1989-2008 Trends for Fall CM Mass



IMPROVE Fall Trends

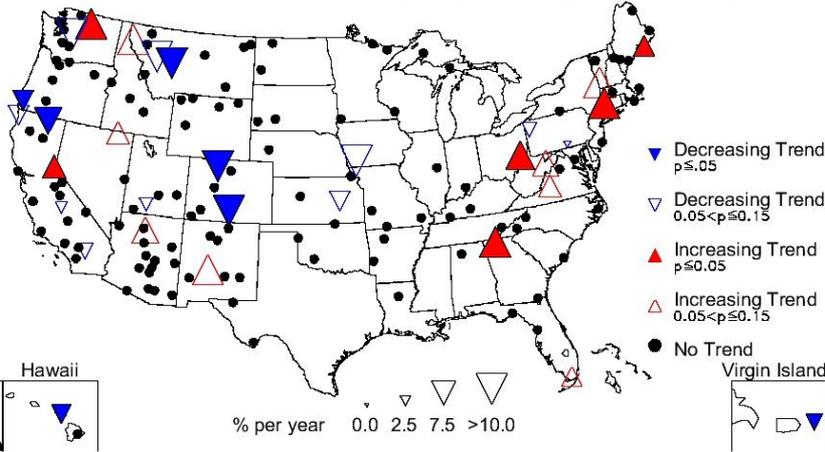


IMPROVE Winter Trends

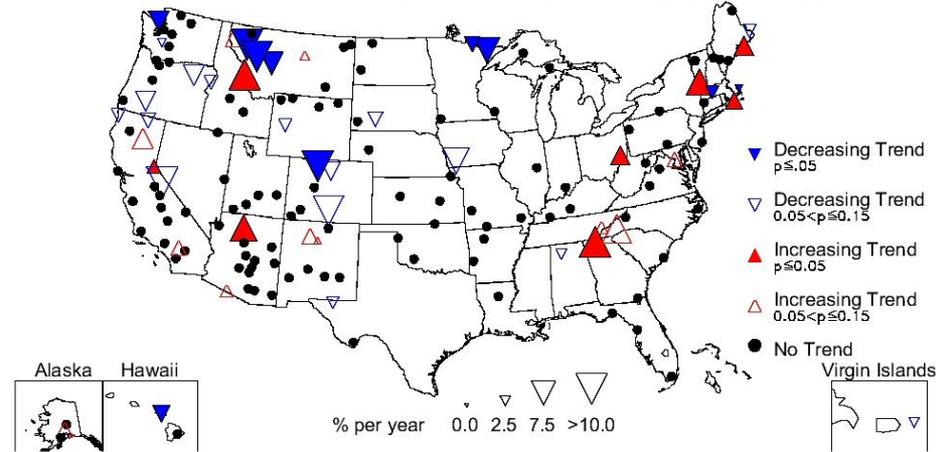


# 9 Year Coarse Mass Trends

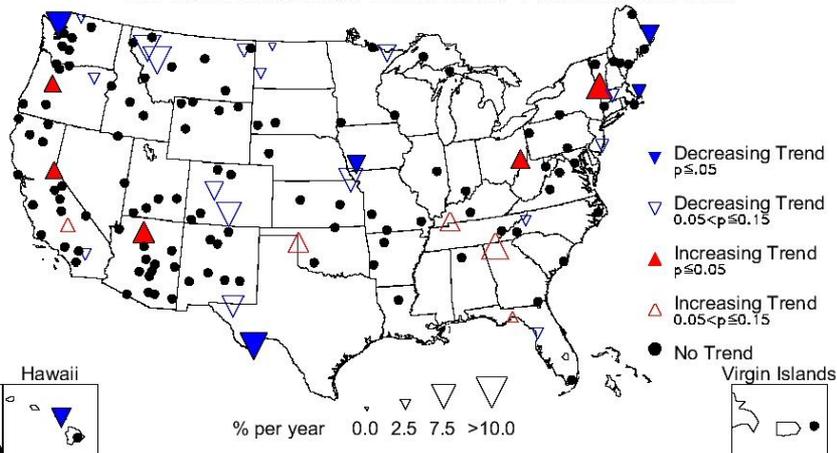
IMPROVE 2000-2008 Trends for 10<sup>th</sup> Percentile CM Mass



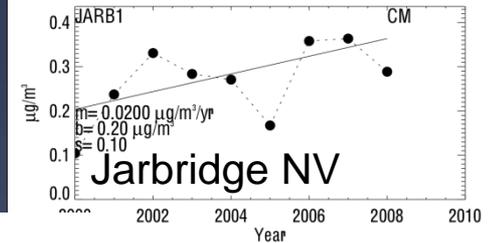
IMPROVE 2000-2008 Trends for 50<sup>th</sup> Percentile CM Mass



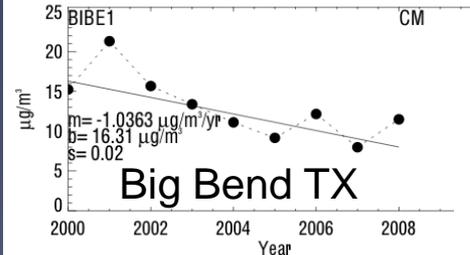
IMPROVE 2000-2008 Trends for 90<sup>th</sup> Percentile CM Mass



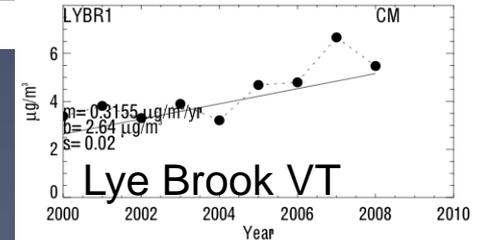
IMPROVE 10 Percentile



IMPROVE 90 Percentile

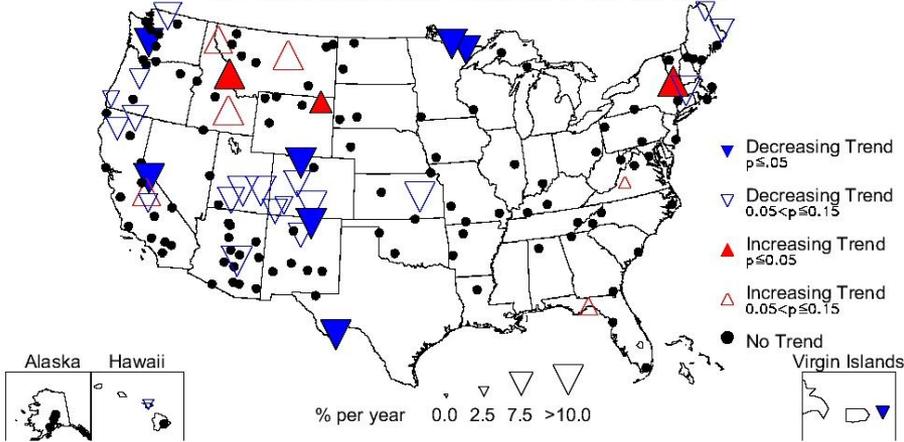


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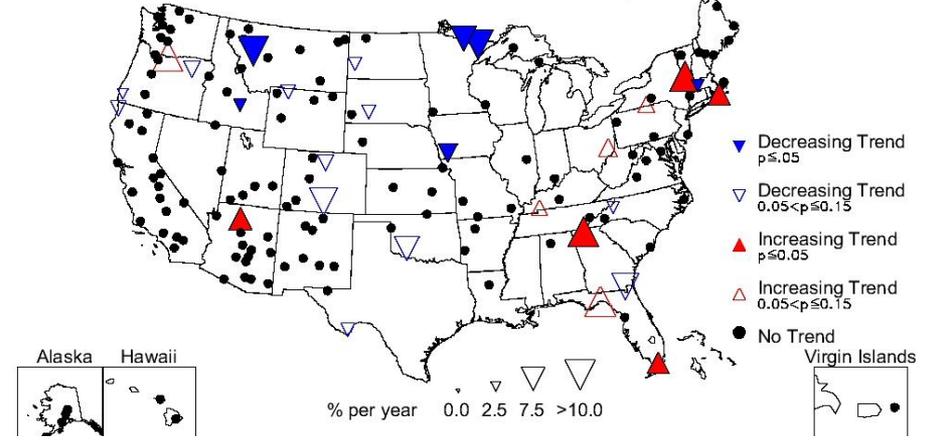


# 9 Year Coarse Mass Trends

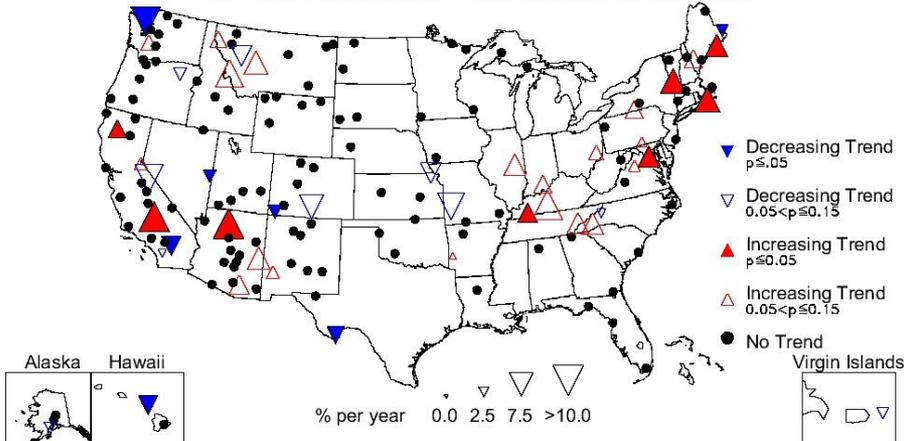
IMPROVE 2000-2008 Trends for Winter CM Mass



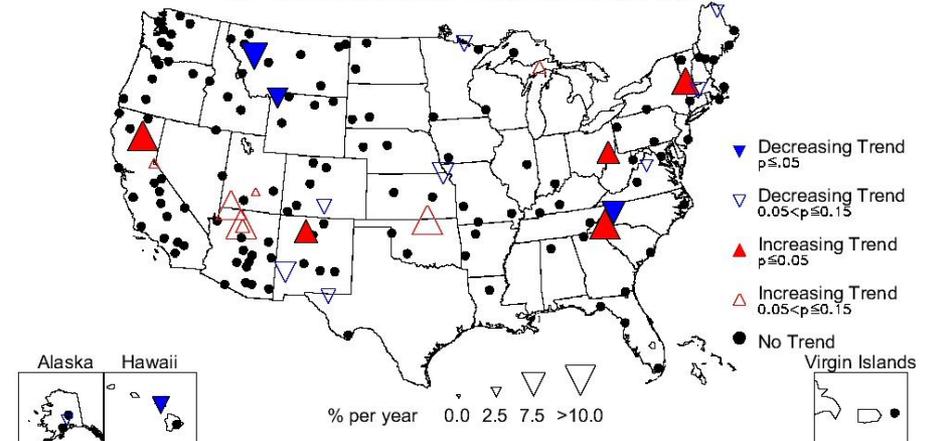
IMPROVE 2000-2008 Trends for Spring CM Mass



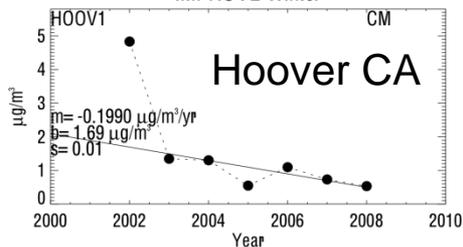
IMPROVE 2000-2008 Trends for Summer CM Mass



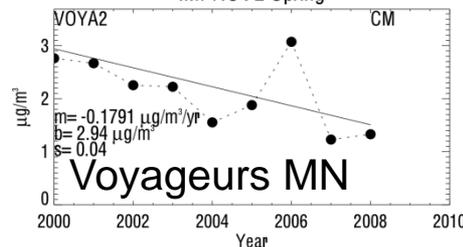
IMPROVE 2000-2008 Trends for Fall CM Mass



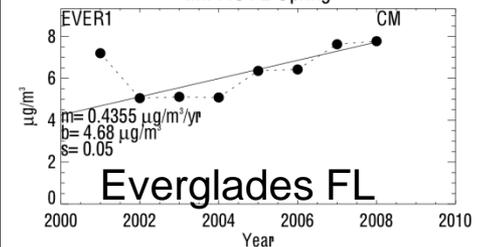
IMPROVE Winter



IMPROVE Spring

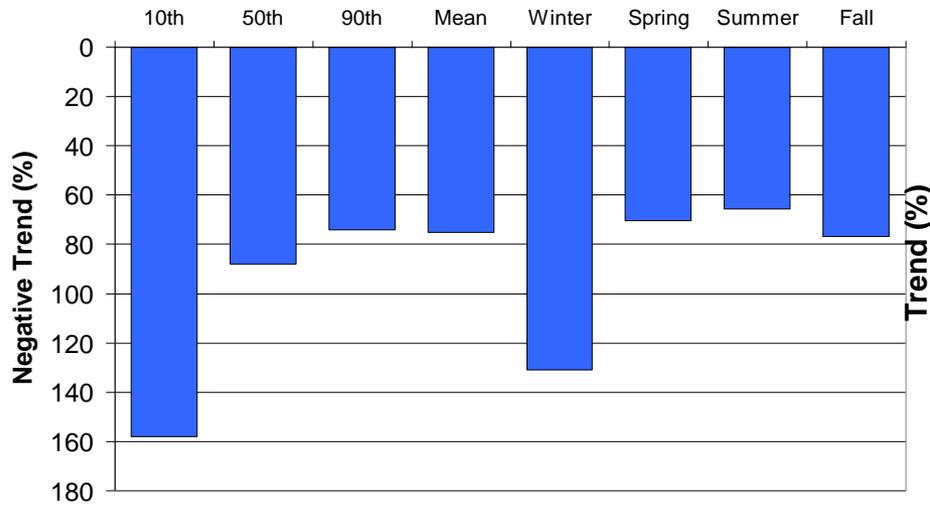


IMPROVE Spring



# 20 versus 9 Year Coarse Mass Trends

Coarse Mass Twenty Year Overall Trend (1989-2008)

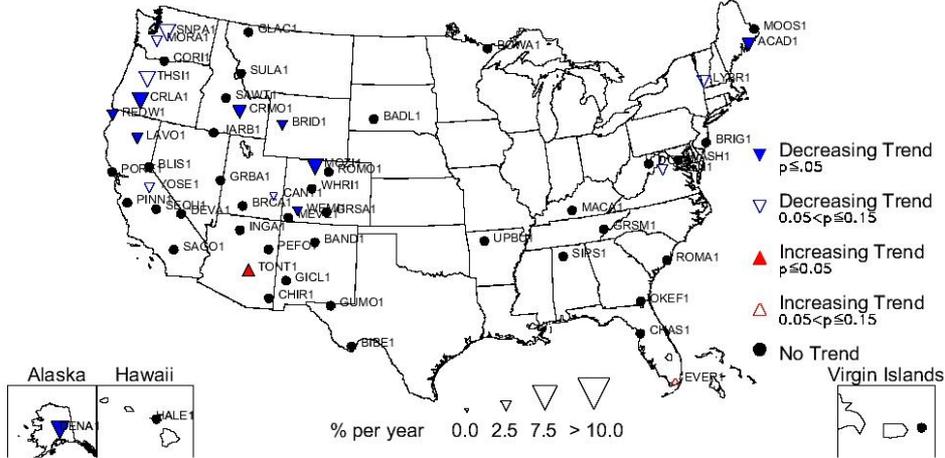


Coarse Mass Nine Year Overall Trend (2000-2008)

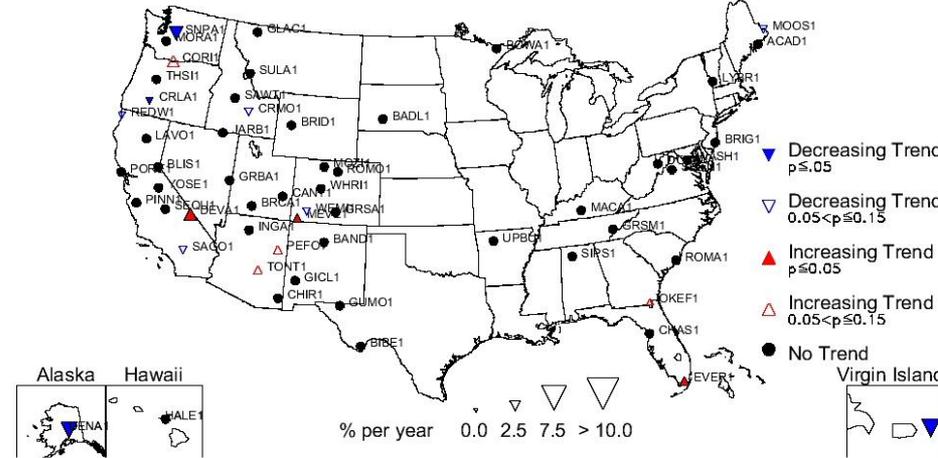


# 20 Year Soil Mass Trends

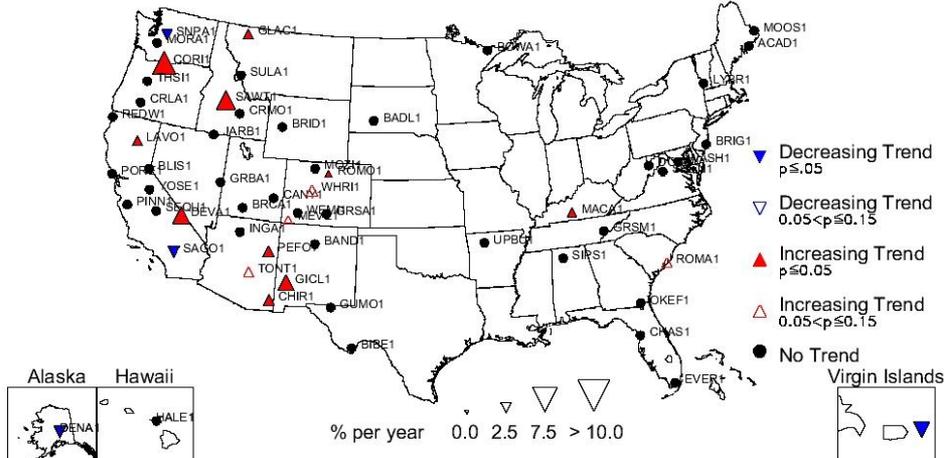
IMPROVE 1989-2008 Trends for 10<sup>th</sup> Percentile Soil Mass



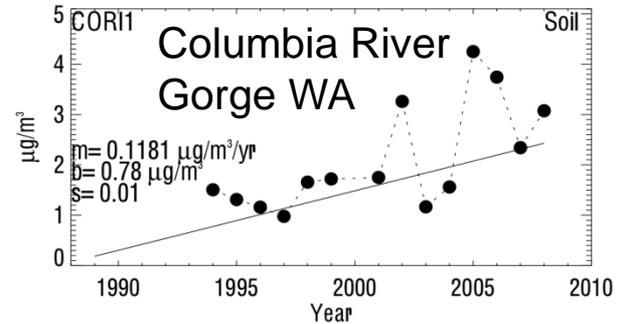
IMPROVE 1989-2008 Trends for 50<sup>th</sup> Percentile Soil Mass



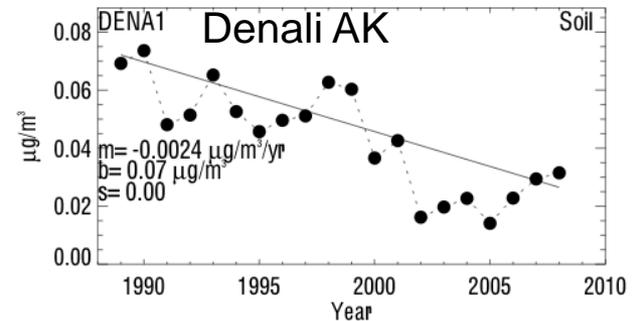
IMPROVE 1989-2008 Trends for 90<sup>th</sup> Percentile Soil Mass



IMPROVE 90 Percentile Trends

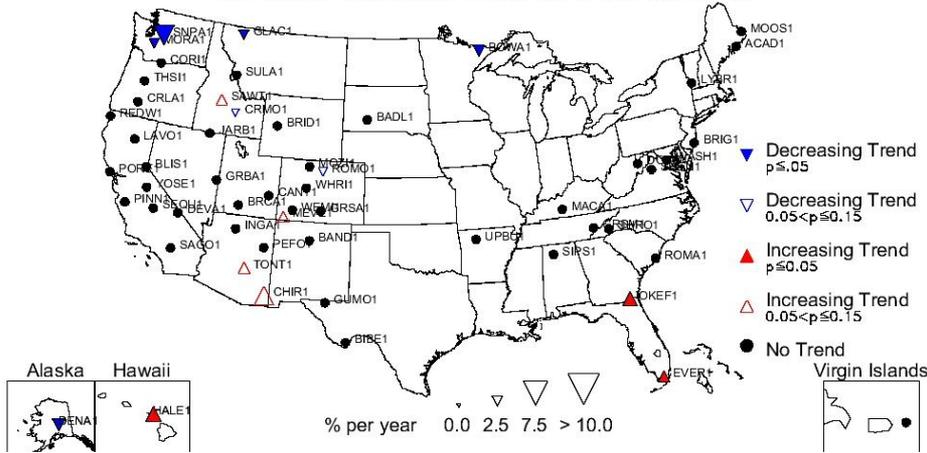


IMPROVE 10 Percentile Trends

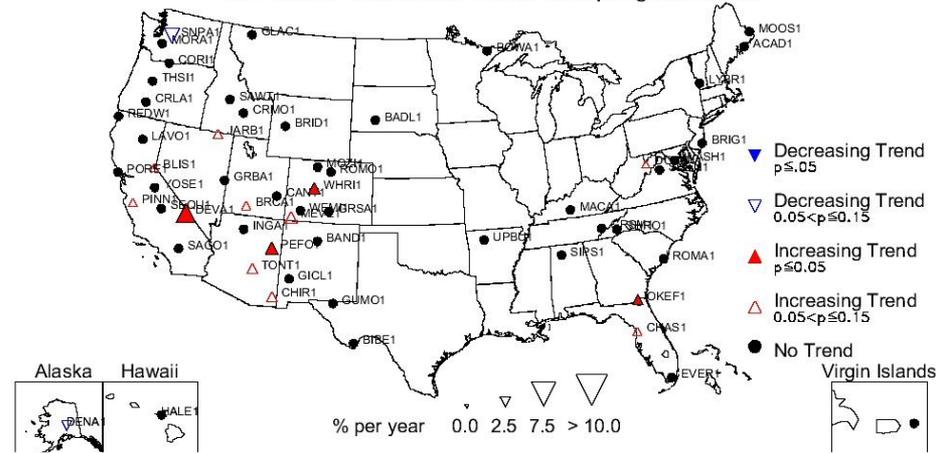


# 20 Year Soil Mass Trends

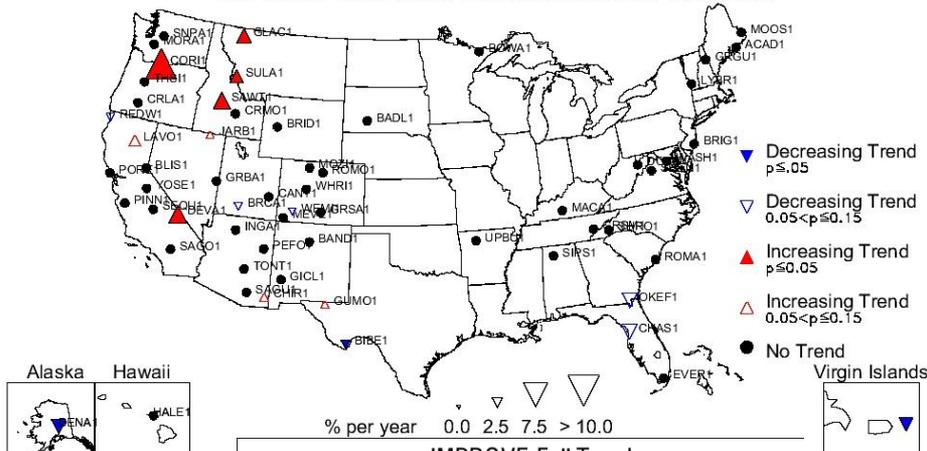
IMPROVE 1989-2008 Trends for Winter Soil Mass



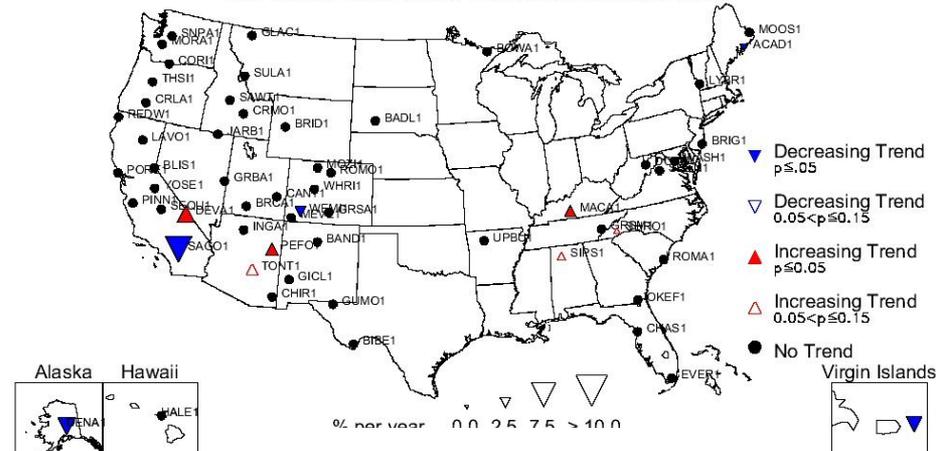
IMPROVE 1989-2008 Trends for Spring Soil Mass



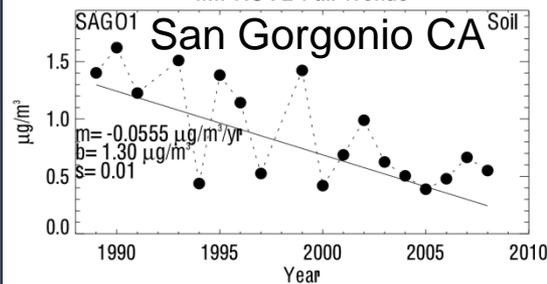
IMPROVE 1989-2008 Trends for Summer Soil Mass



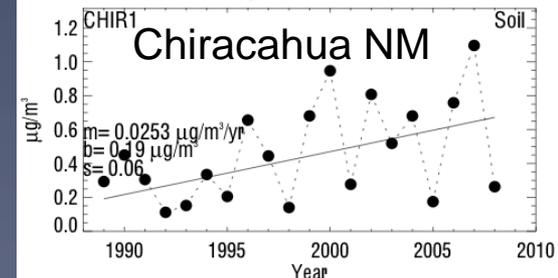
IMPROVE 1989-2008 Trends for Fall Soil Mass



IMPROVE Fall Trends

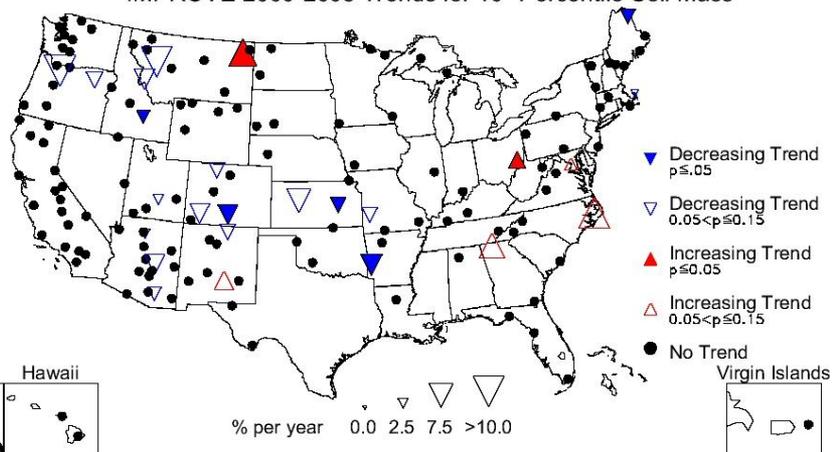


IMPROVE Winter Trends

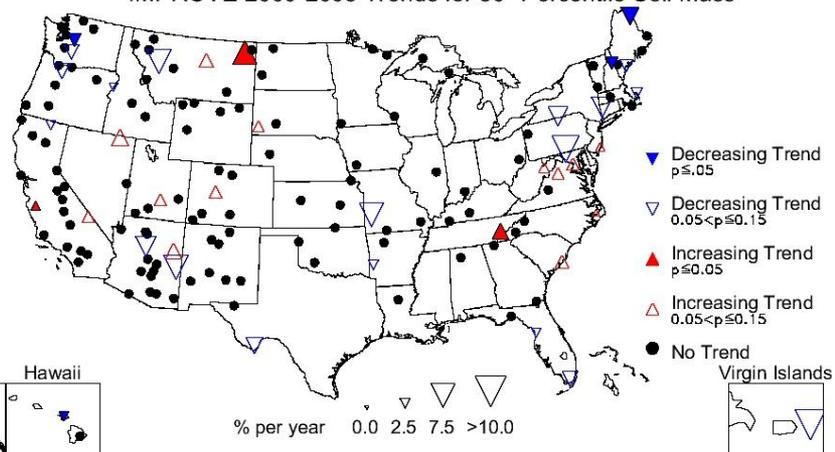


# 9 Year Soil Mass Trends

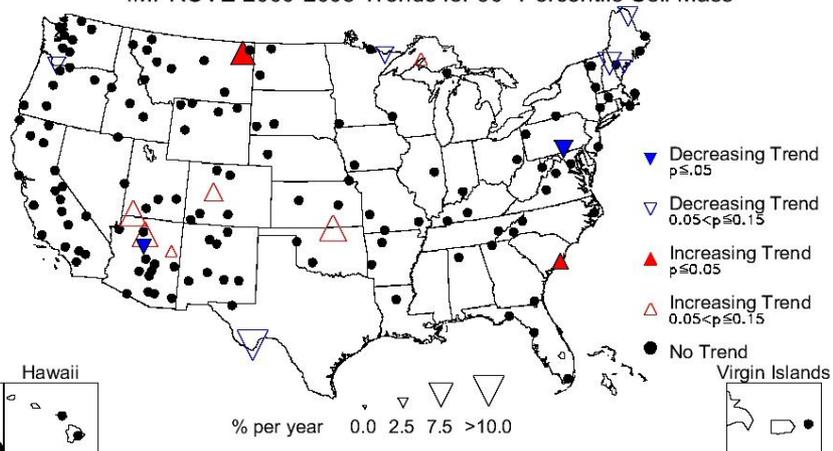
IMPROVE 2000-2008 Trends for 10<sup>th</sup> Percentile Soil Mass



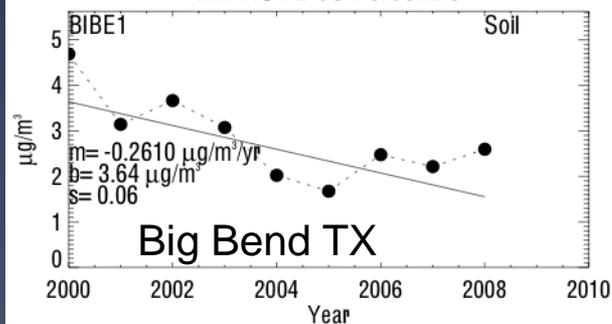
IMPROVE 2000-2008 Trends for 50<sup>th</sup> Percentile Soil Mass



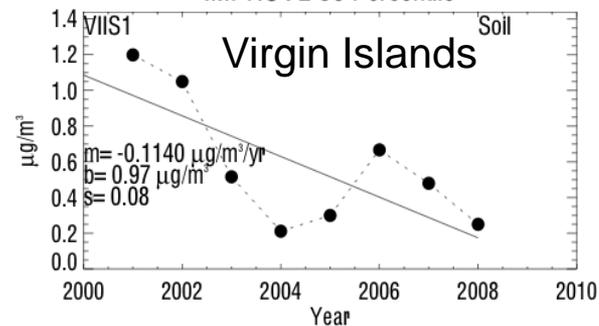
IMPROVE 2000-2008 Trends for 90<sup>th</sup> Percentile Soil Mass



IMPROVE 90 Percentile

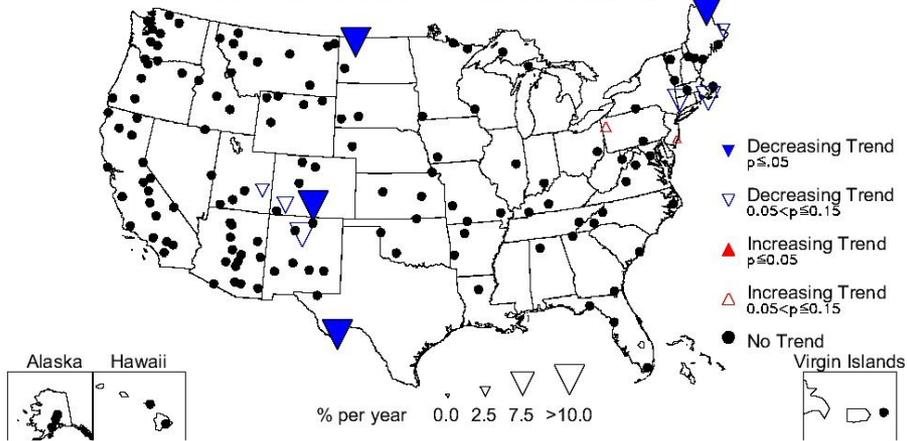


IMPROVE 50 Percentile

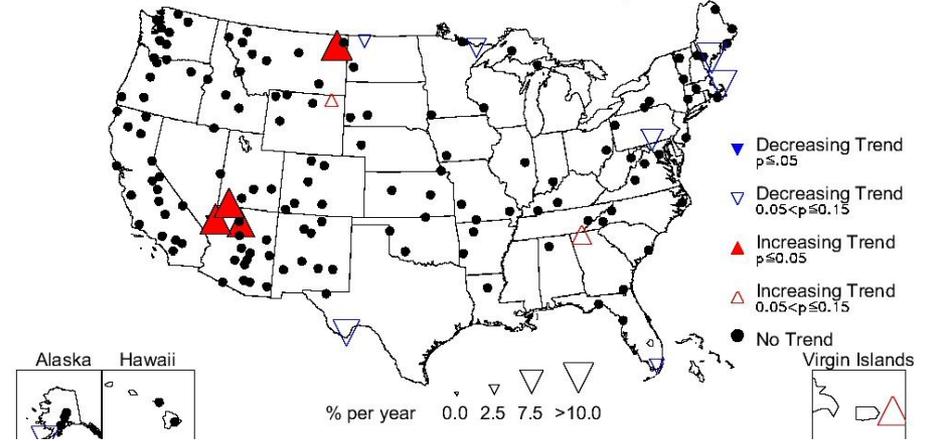


# 9 Year Soil Mass Trends

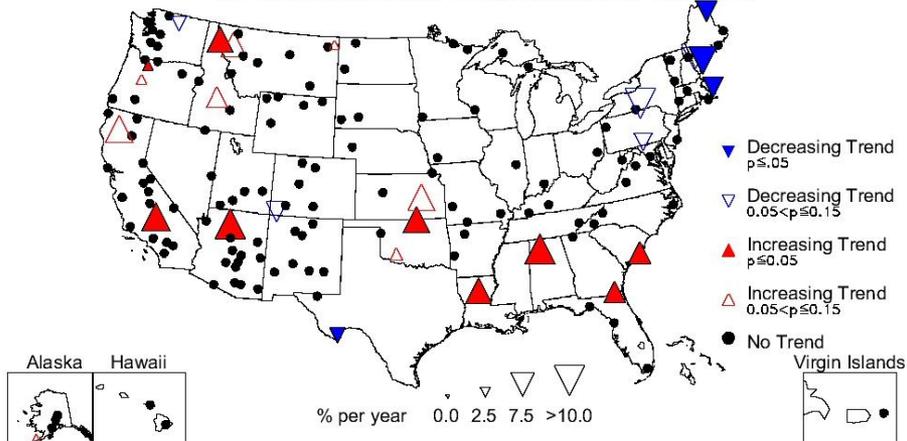
IMPROVE 2000-2008 Trends for Winter Soil Mass



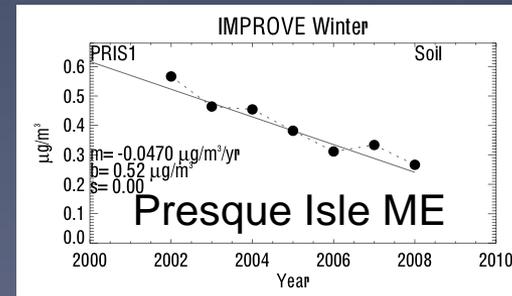
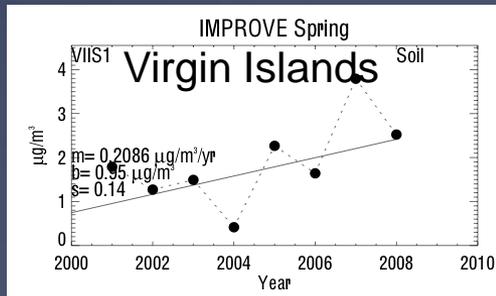
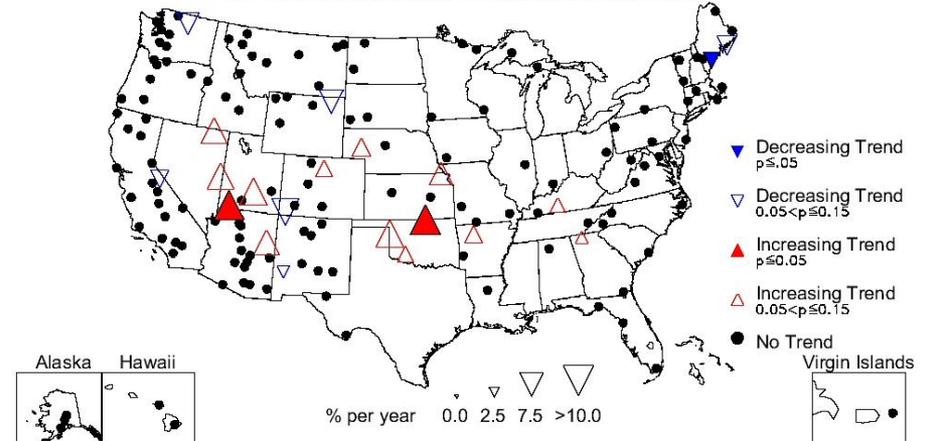
IMPROVE 2000-2008 Trends for Spring Soil Mass



IMPROVE 2000-2008 Trends for Summer Soil Mass

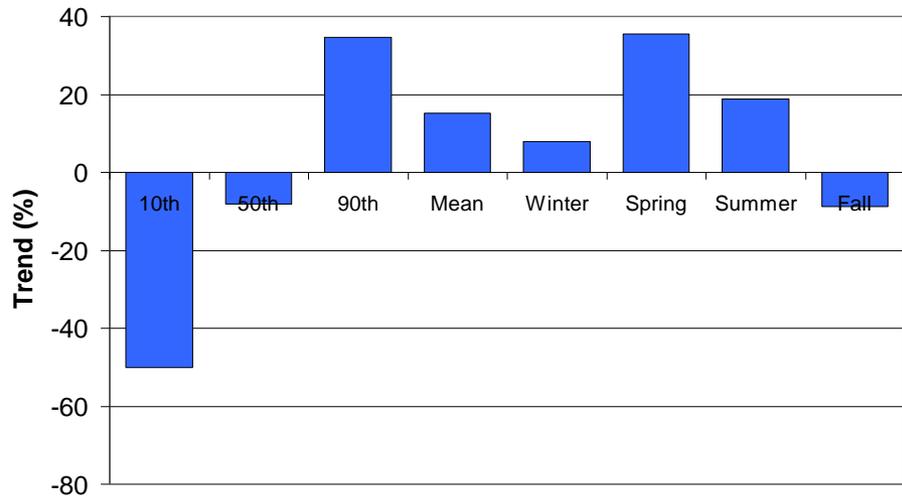


IMPROVE 2000-2008 Trends for Fall Soil Mass

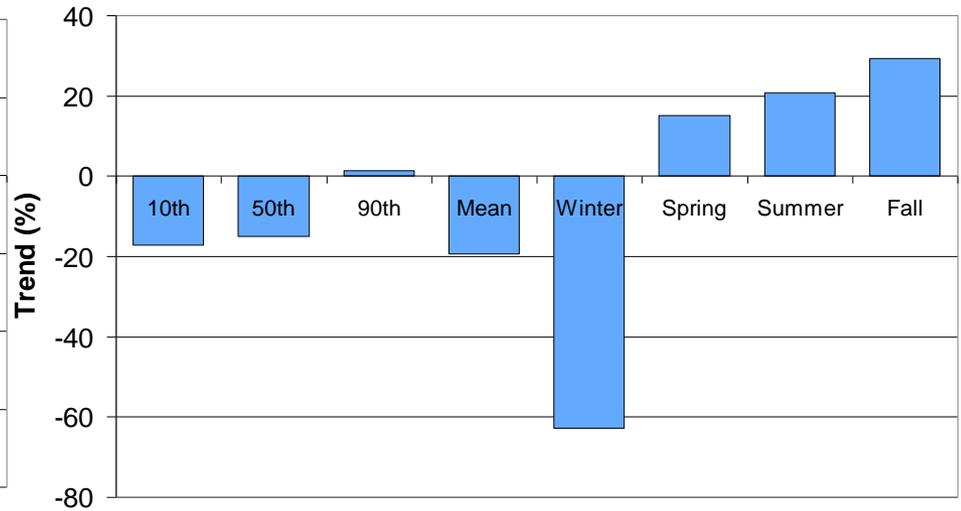


# 9 versus 20 Year Soil Mass Trends

Soil Twenty Year Overall Trend (1989-2008)

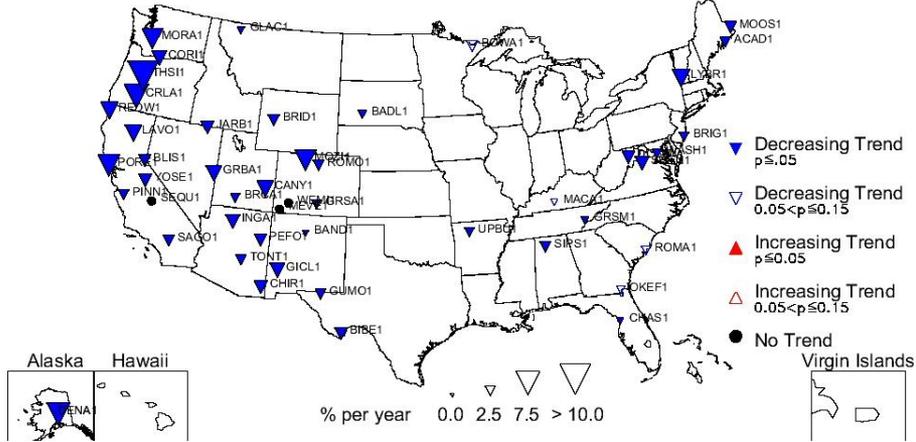


Soil Nine Year Overall Trend (2000-2008)

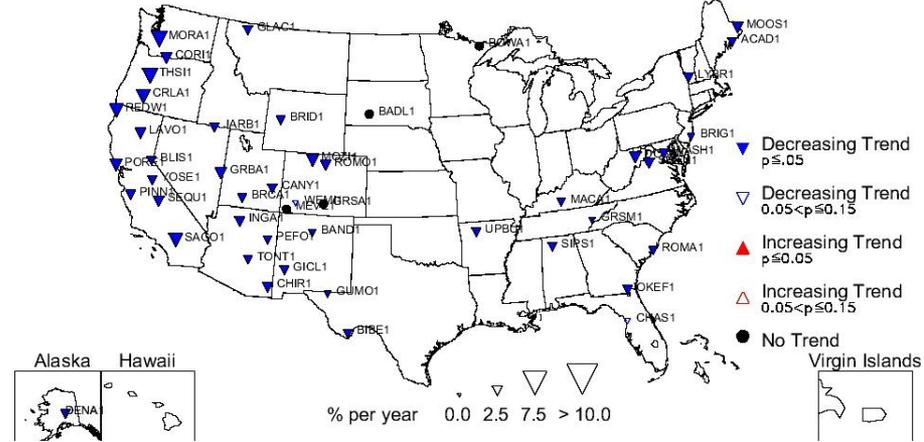


# 20 Year Organic Carbon Trends

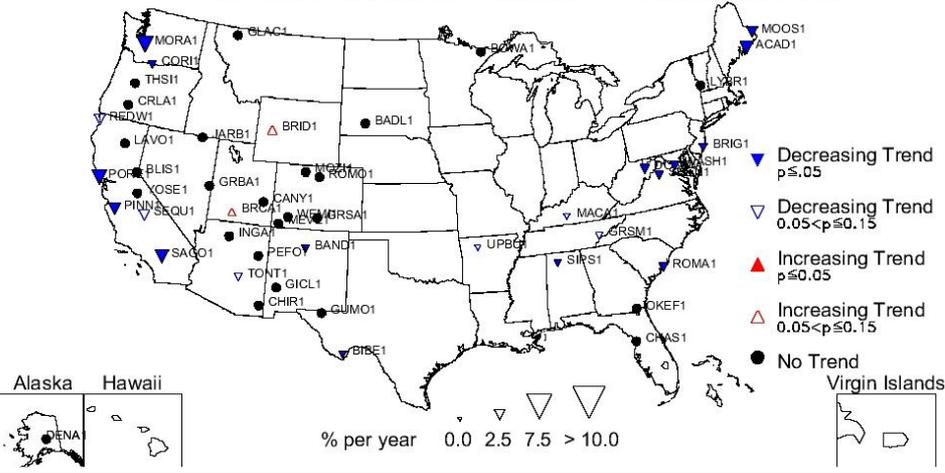
IMPROVE 1989-2008 Trends for 10<sup>th</sup> Percentile OC Mass



IMPROVE 1989-2008 Trends for 50<sup>th</sup> Percentile OC Mass

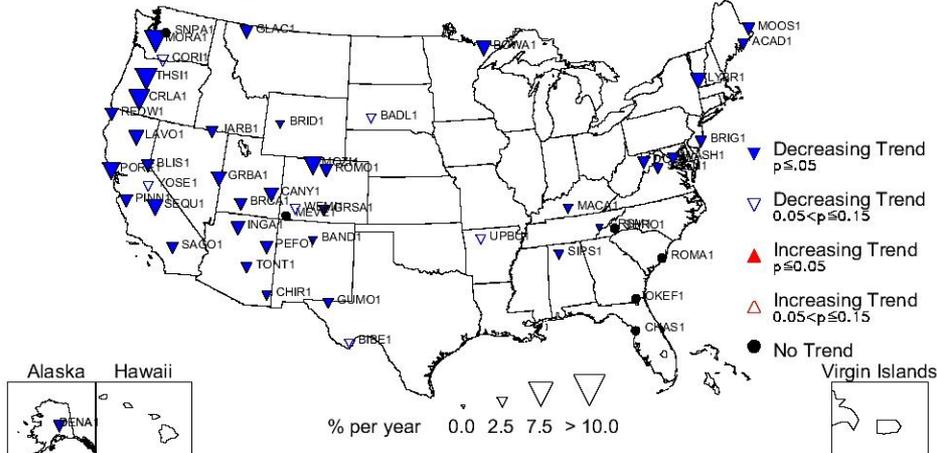


IMPROVE 1989-2008 Trends for 90<sup>th</sup> Percentile OC Mass

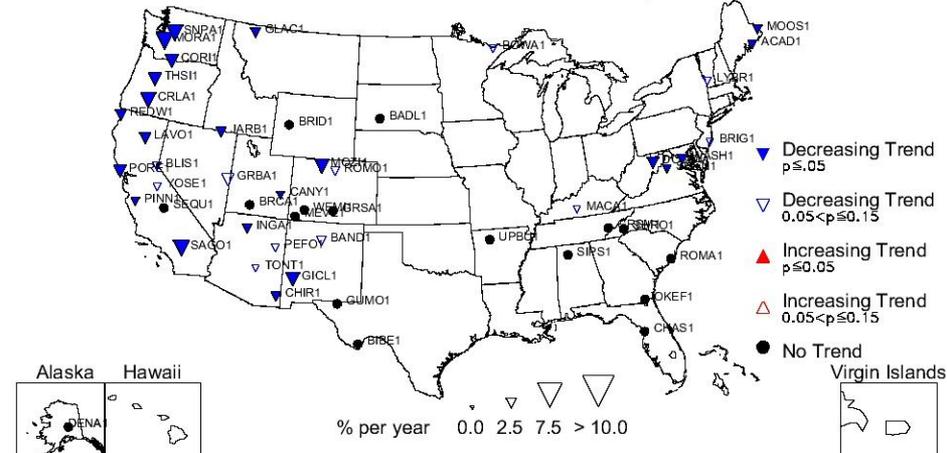


# 20 Year Organic Carbon Trends

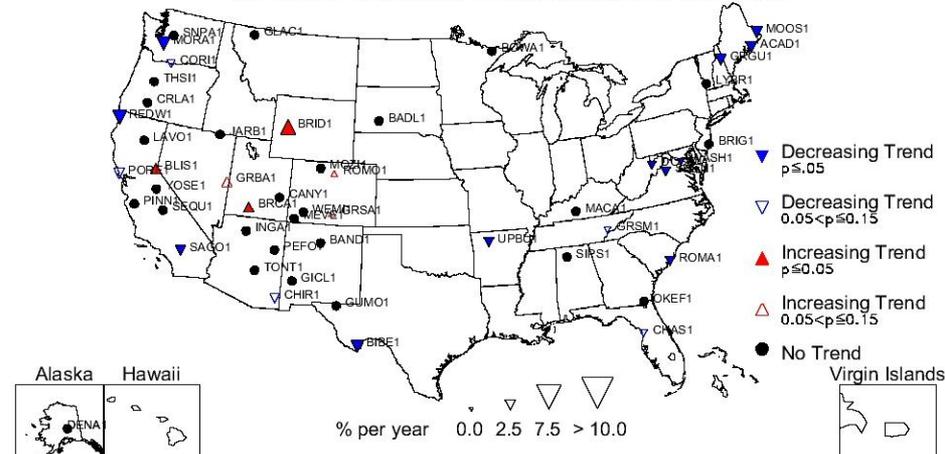
IMPROVE 1989-2008 Trends for Winter OC Mass



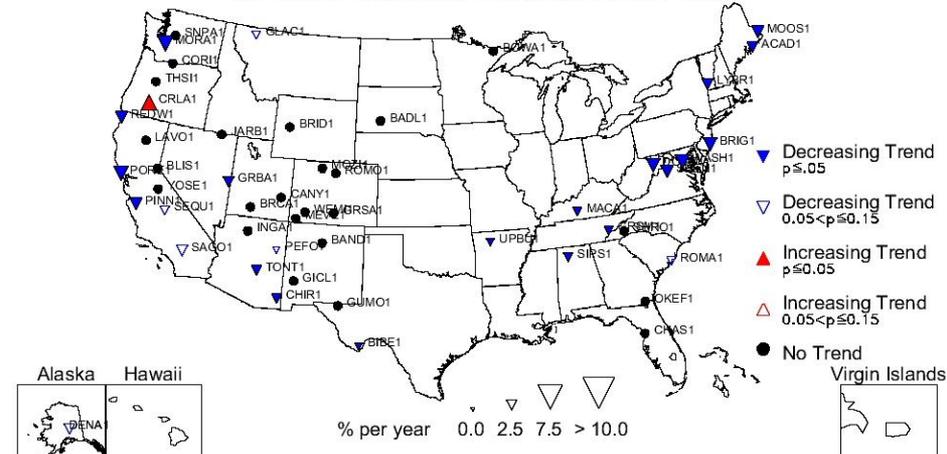
IMPROVE 1989-2008 Trends for Spring OC Mass



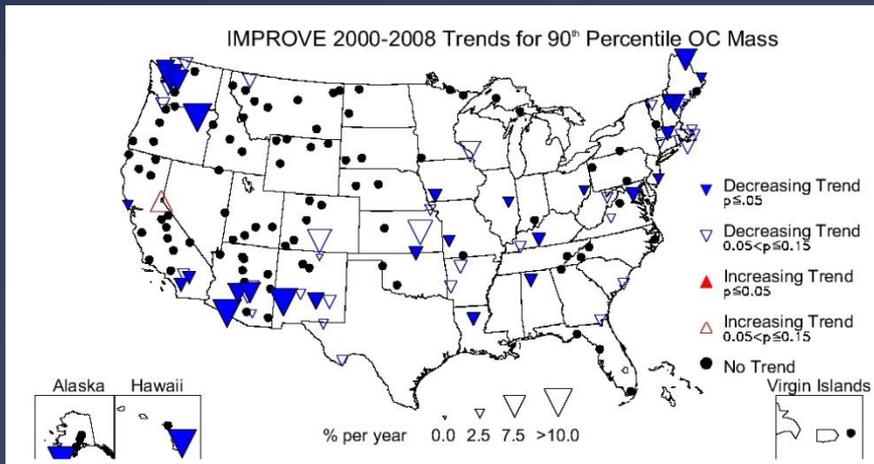
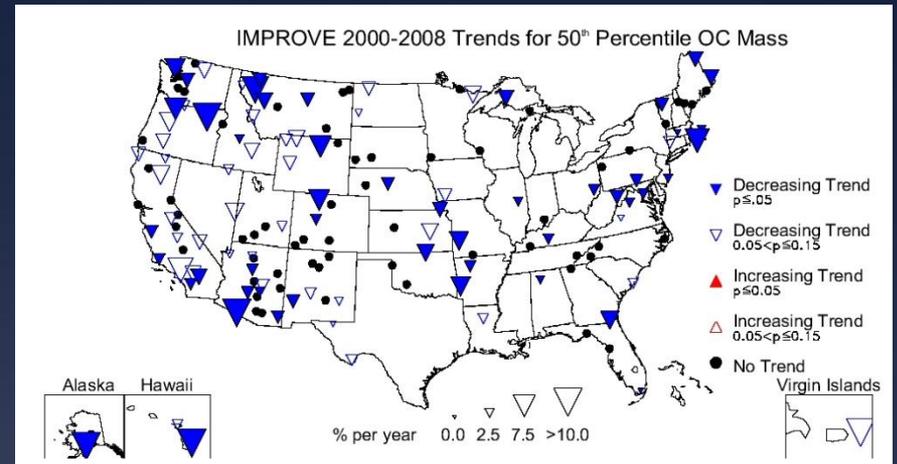
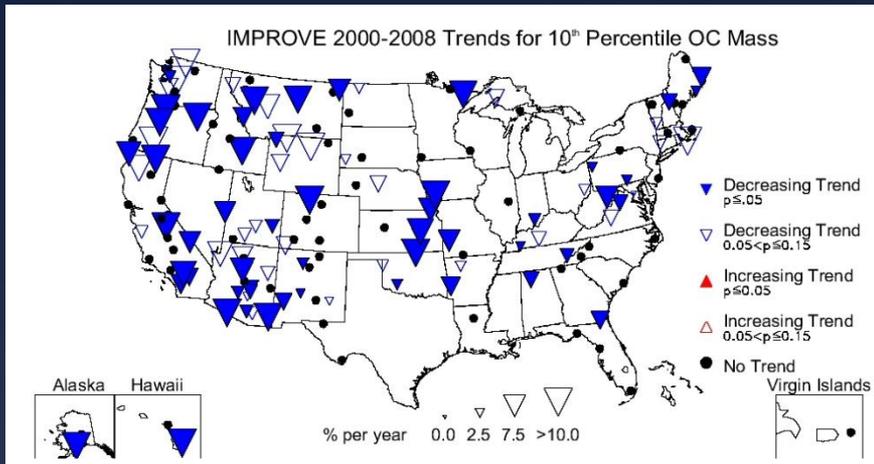
IMPROVE 1989-2008 Trends for Summer OC Mass



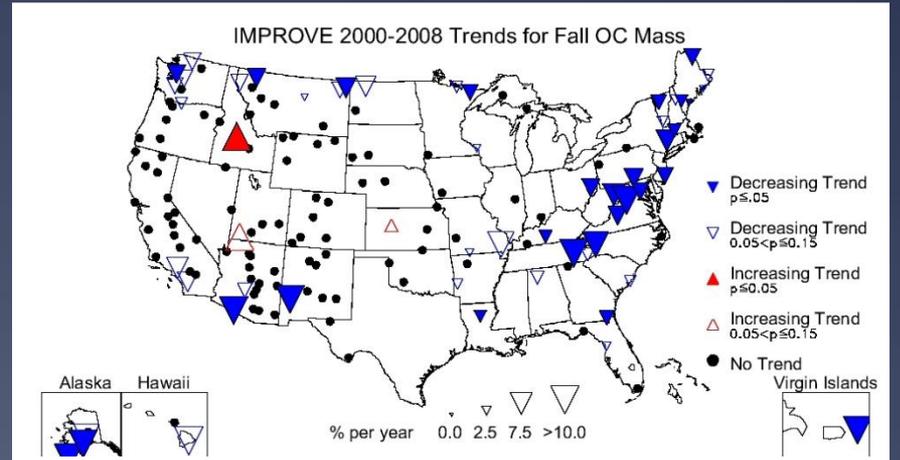
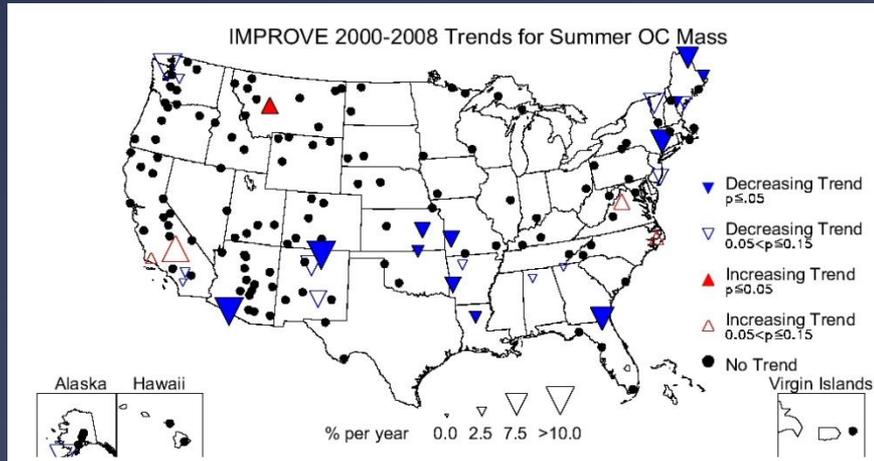
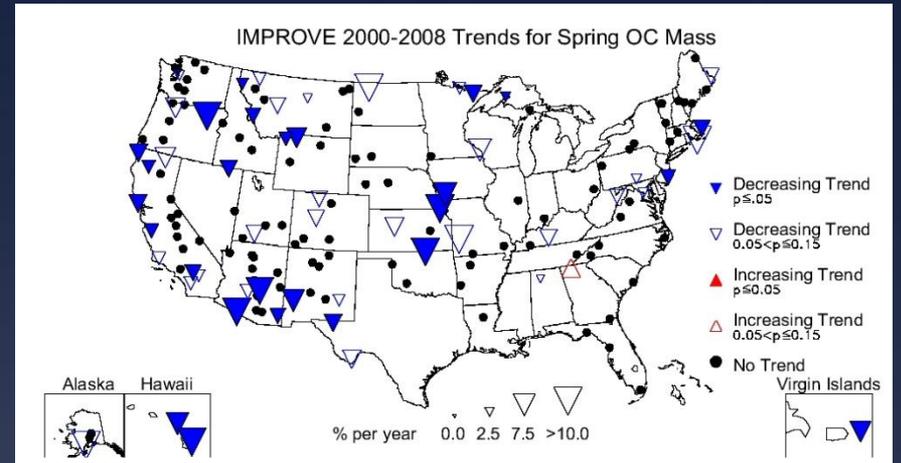
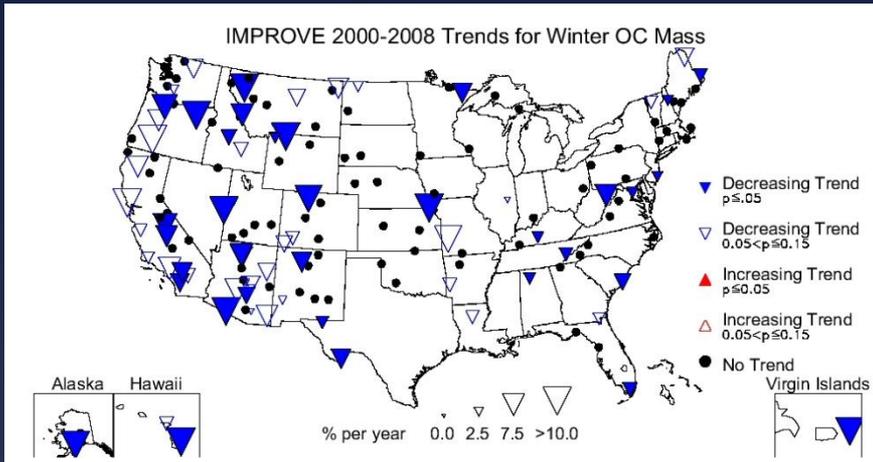
IMPROVE 1989-2008 Trends for Fall OC Mass



# 9 Year Organic Carbon Trends

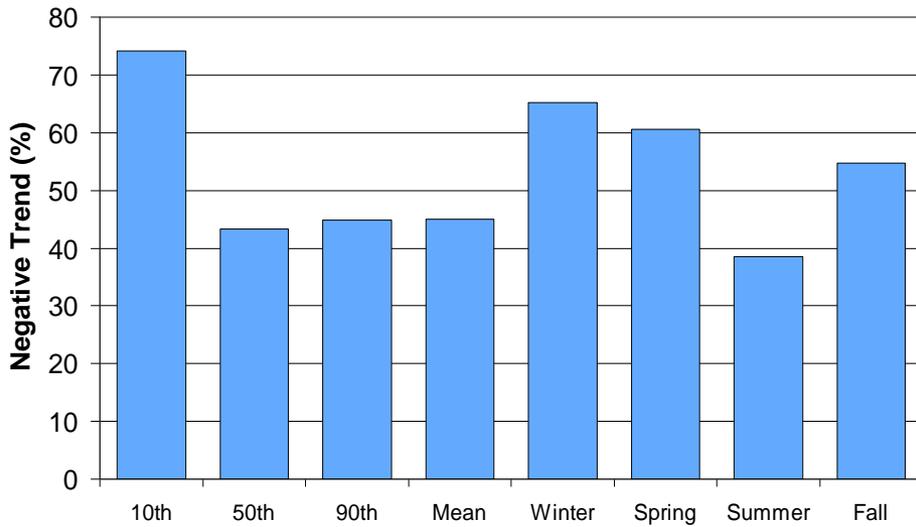


# 9 Year Organic Carbon Trends

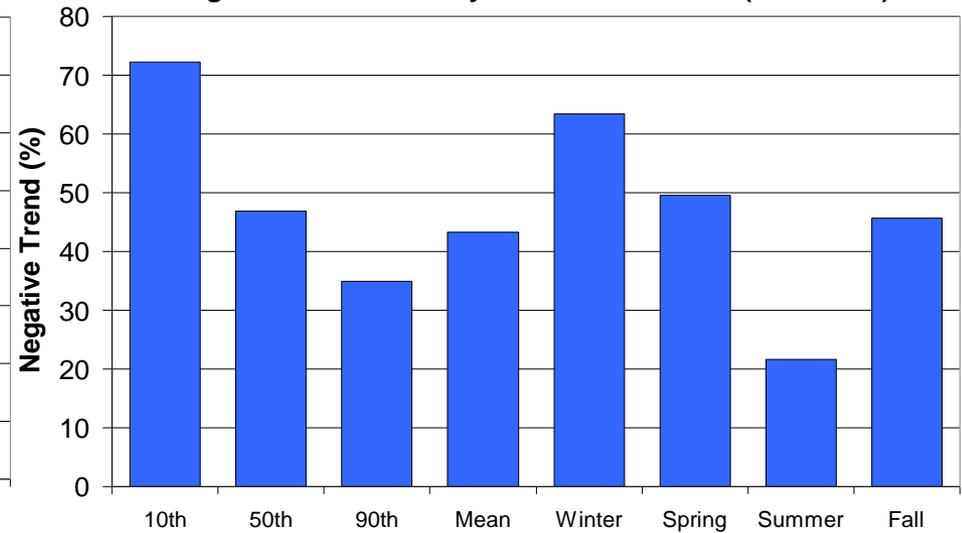


# 9 vs 20 Year Organic Carbon Trends

Organic Carbon Nine Year Overall Trend (2000-2008)

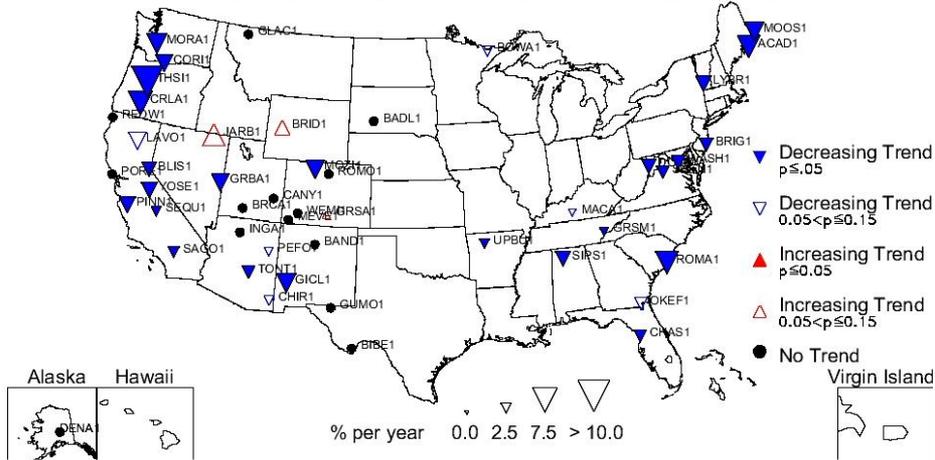


Organic Carbon Twenty Year Overall Trend (1989-2008)

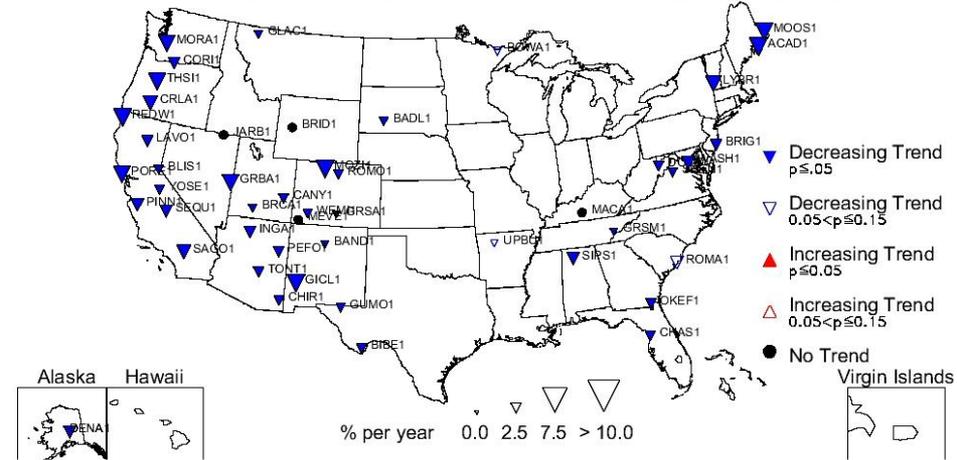


# 20 Year LAC Trends

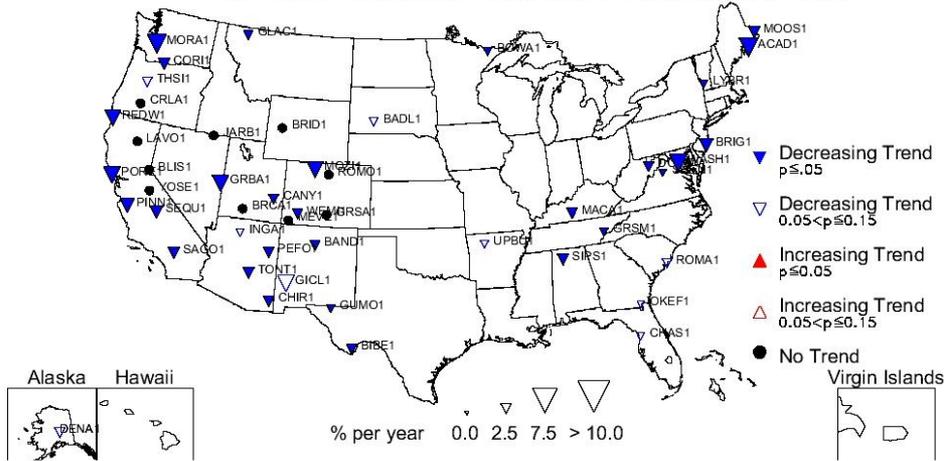
IMPROVE 1989-2008 Trends for 10<sup>th</sup> Percentile LAC Mass



IMPROVE 1989-2008 Trends for 50<sup>th</sup> Percentile LAC Mass

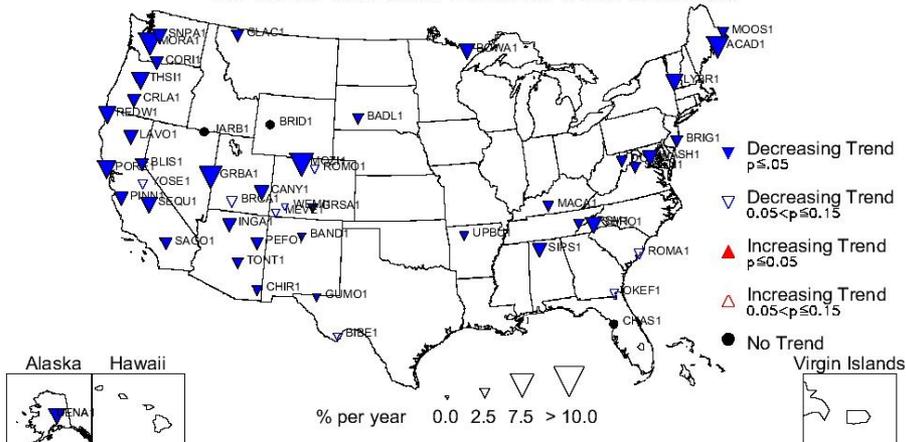


IMPROVE 1989-2008 Trends for 90<sup>th</sup> Percentile LAC Mass

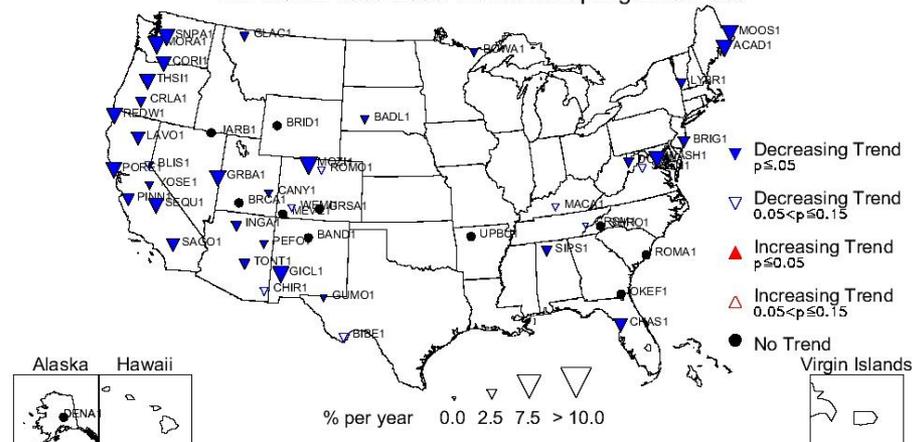


# 20 Year LAC Trends

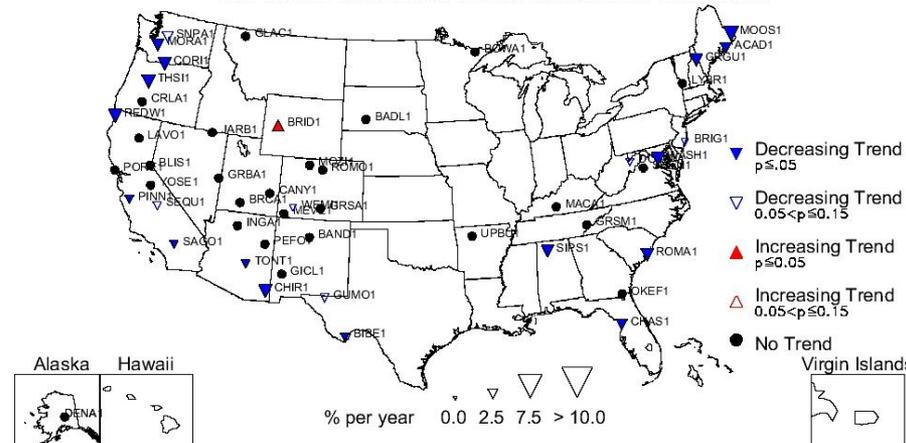
IMPROVE 1989-2008 Trends for Winter LAC Mass



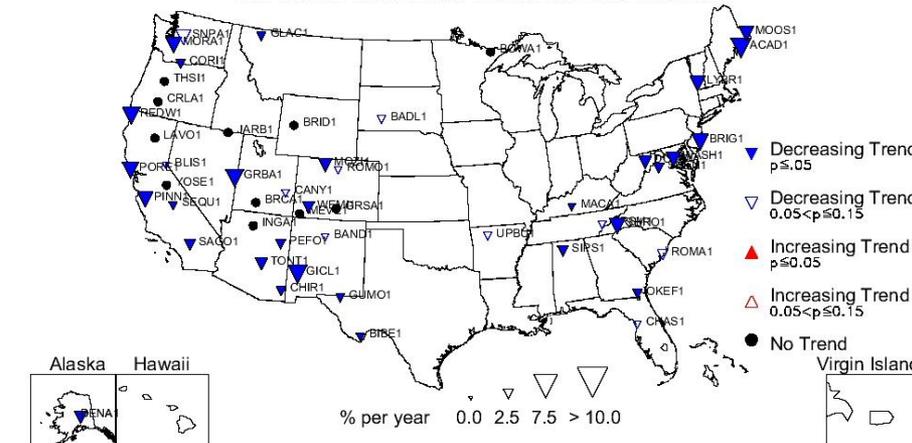
IMPROVE 1989-2008 Trends for Spring LAC Mass



IMPROVE 1989-2008 Trends for Summer LAC Mass

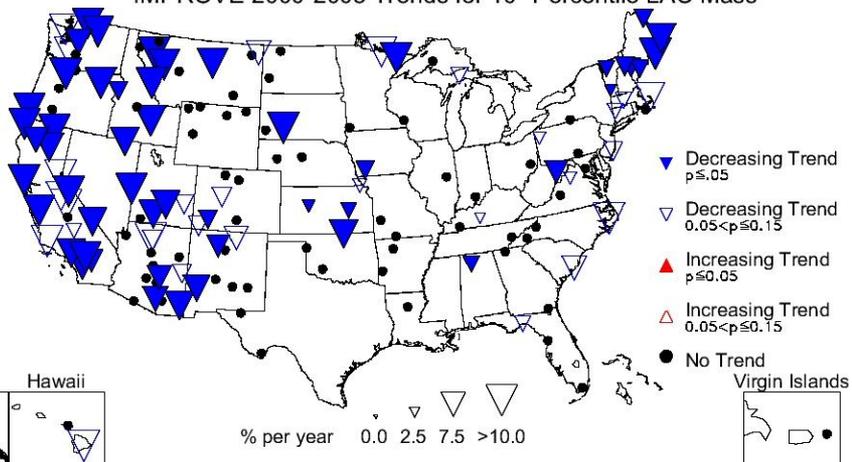


IMPROVE 1989-2008 Trends for Fall LAC Mass

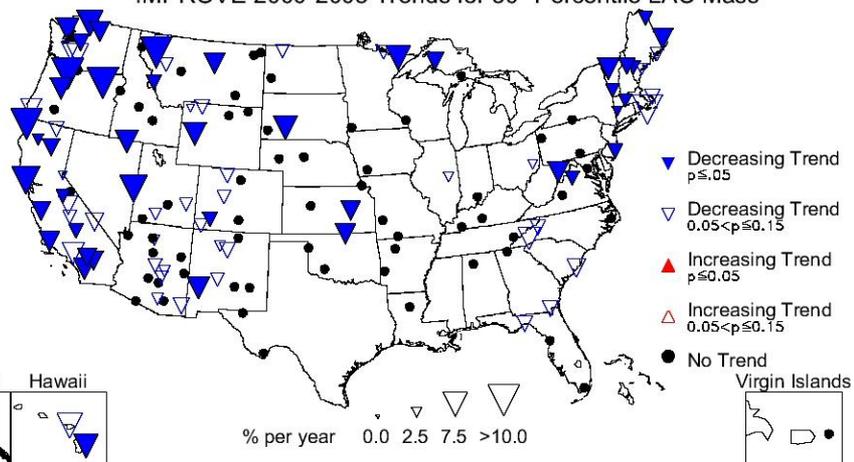


# 9 Year LAC Trends

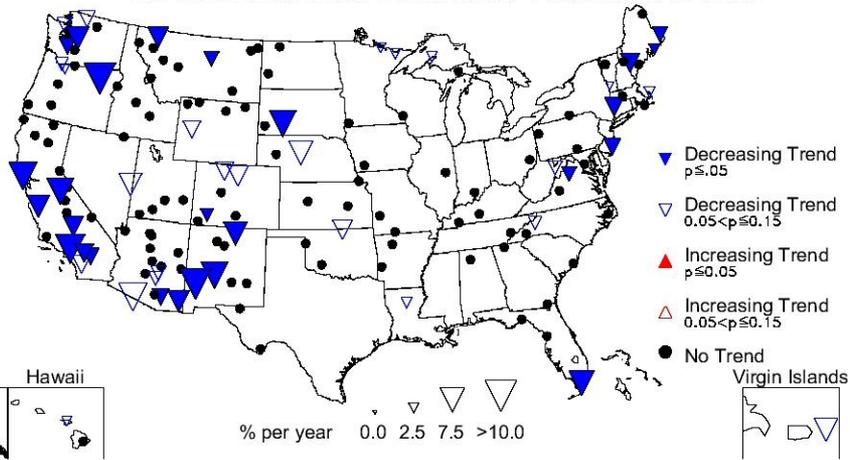
IMPROVE 2000-2008 Trends for 10<sup>th</sup> Percentile LAC Mass



IMPROVE 2000-2008 Trends for 50<sup>th</sup> Percentile LAC Mass

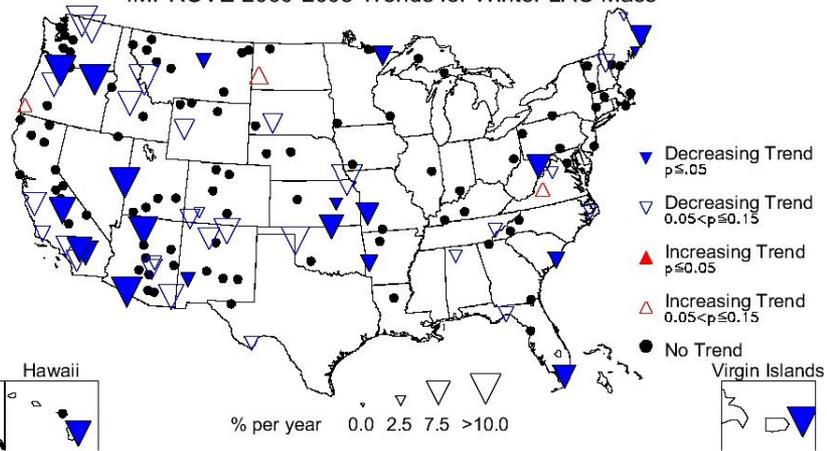


IMPROVE 2000-2008 Trends for 90<sup>th</sup> Percentile LAC Mass

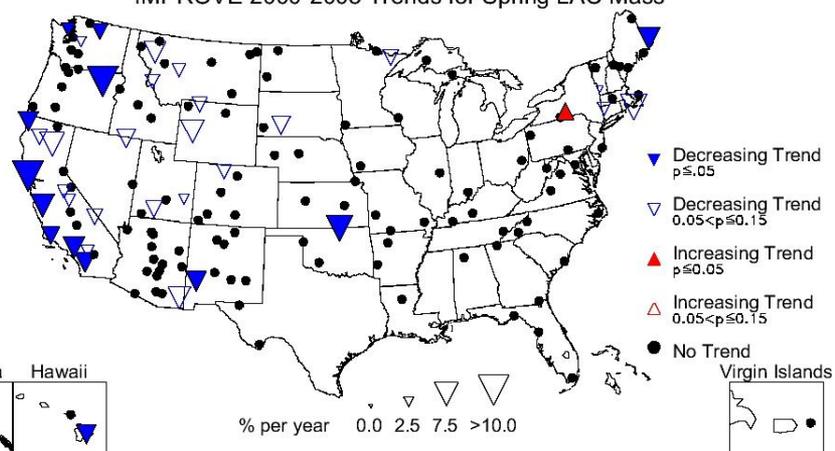


# 9 Year LAC Trends

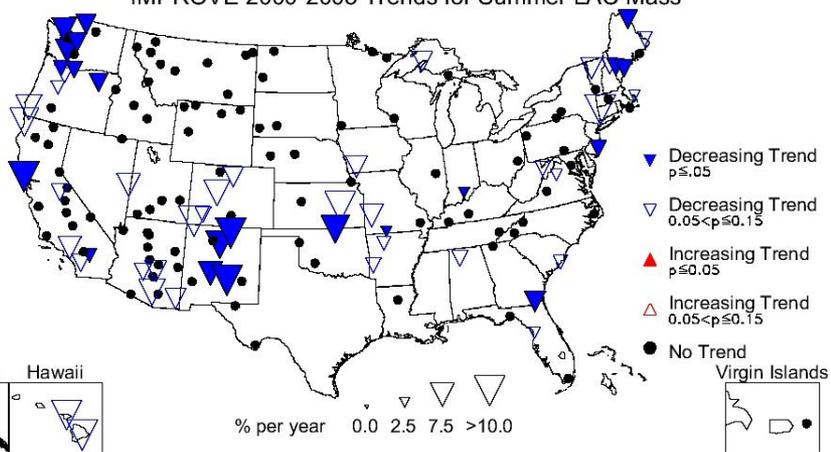
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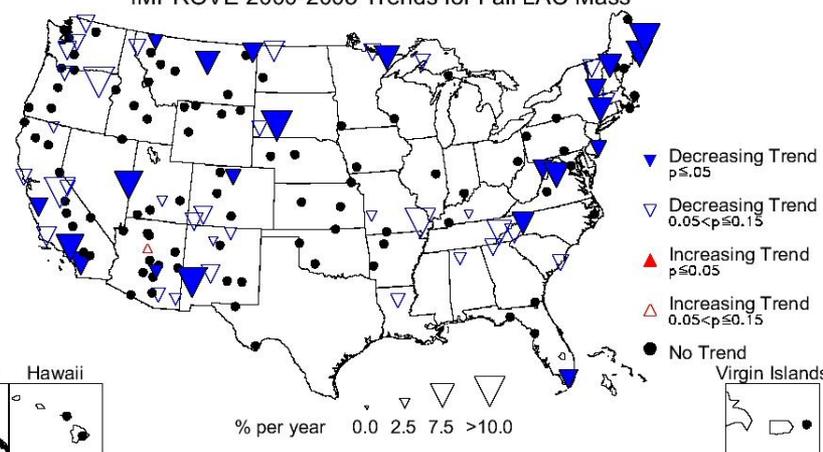
### IMPROVE 2000-2008 Trends for Spring LAC Mass



### IMPROVE 2000-2008 Trends for Summer LAC Mass

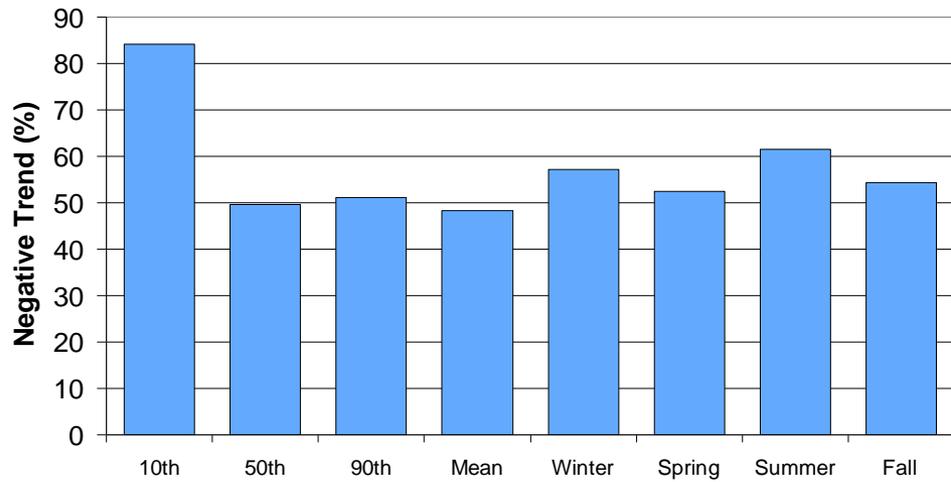


### IMPROVE 2000-2008 Trends for Fall LAC Mass

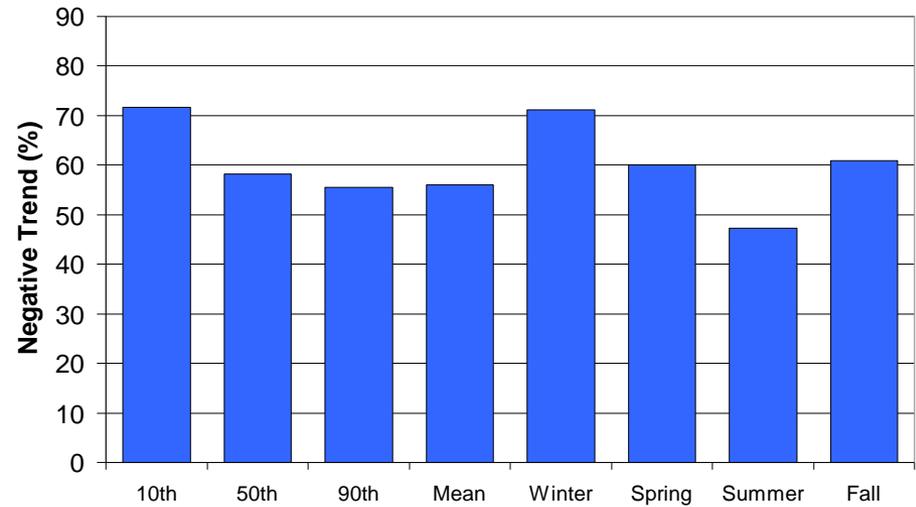


# 20 Year vs 9 Year LAC Trends

LAC Nine Year Overall Trend (2000-2008)

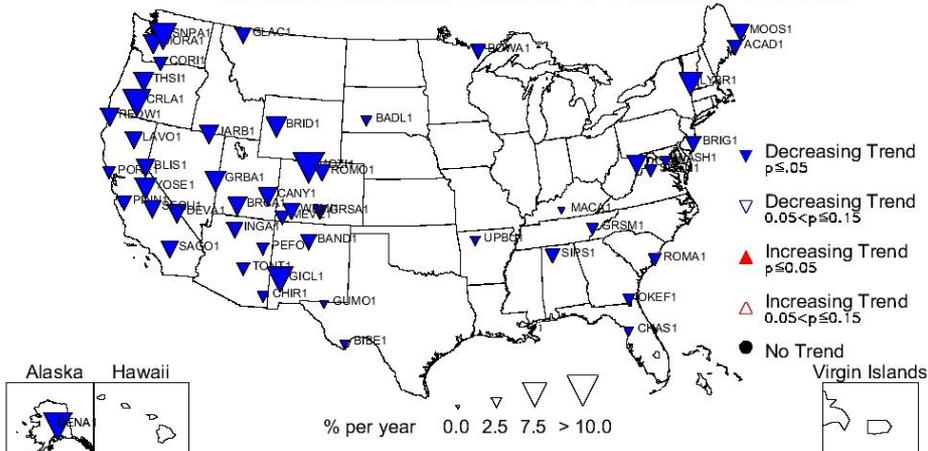


LAC Twenty Year Overall Trend (1989-2008)

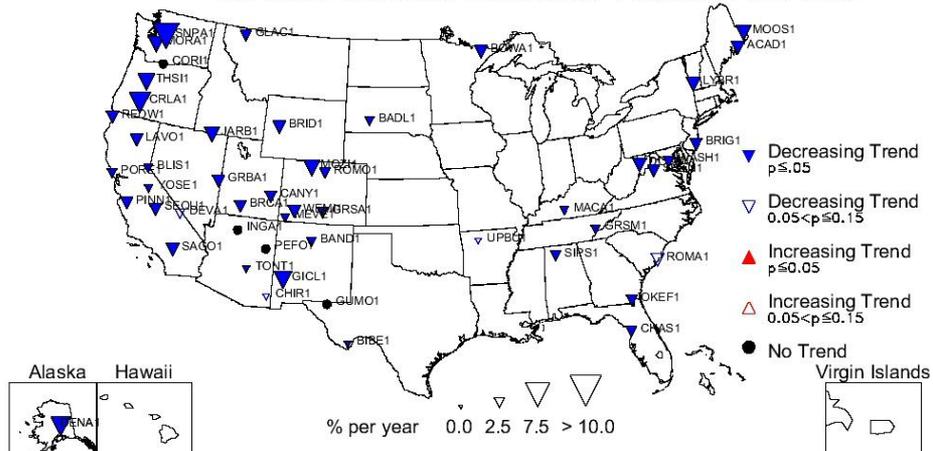


# 20 Year PM10 Trends

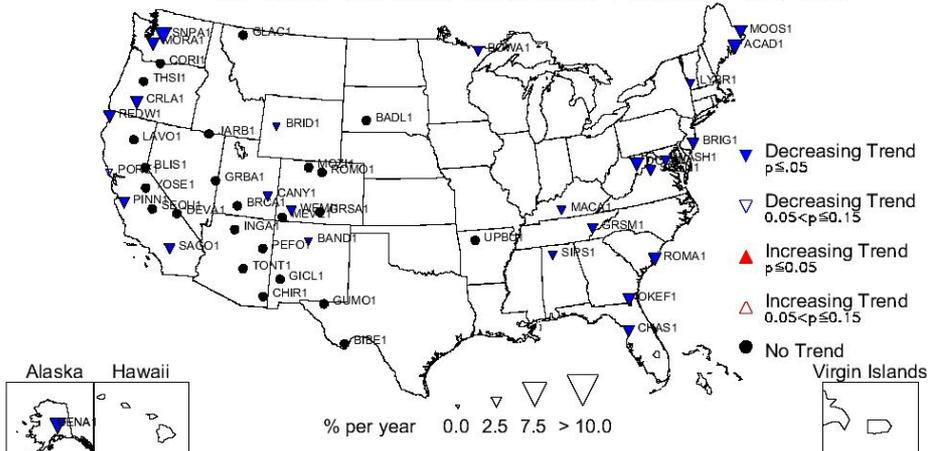
IMPROVE 1989-2008 Trends for 10<sup>th</sup> Percentile PM10 Mass



IMPROVE 1989-2008 Trends for 50<sup>th</sup> Percentile PM10 Mass

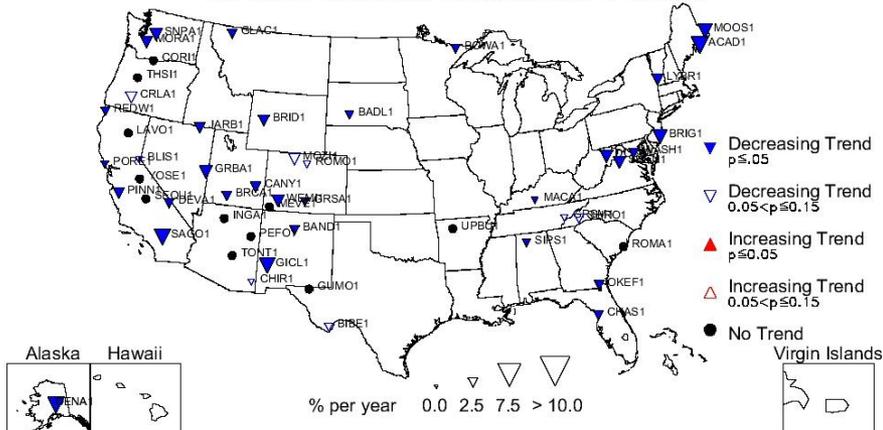


IMPROVE 1989-2008 Trends for 90<sup>th</sup> Percentile PM10 Mass

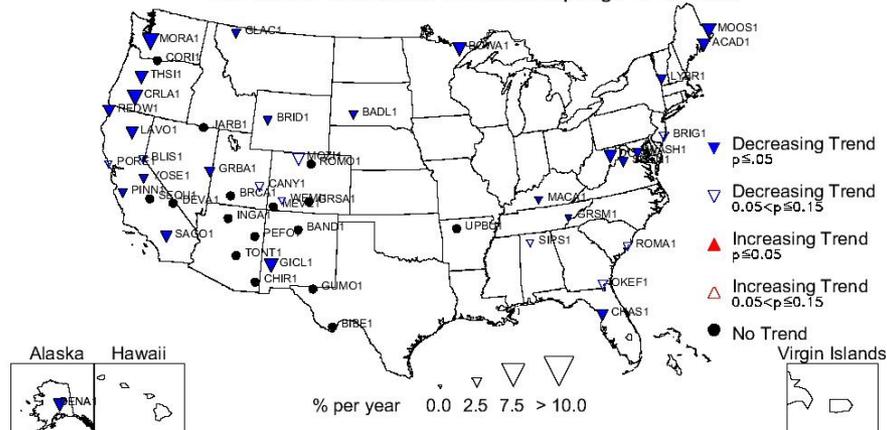


# 20 Year PM10 Trends

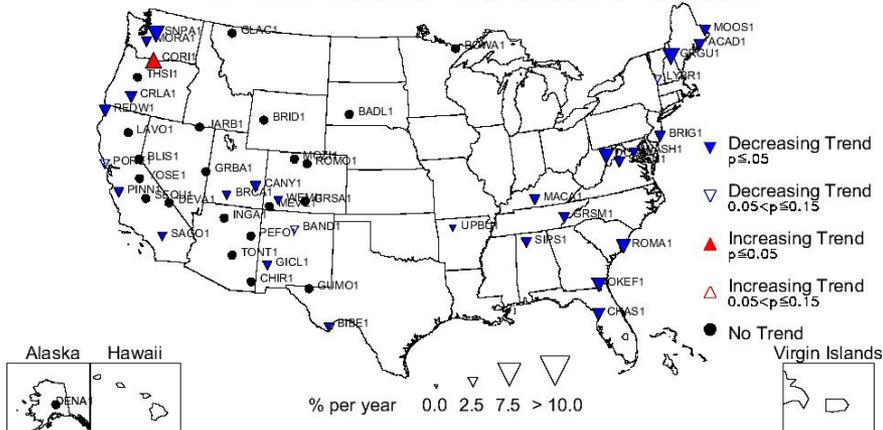
IMPROVE 1989-2008 Trends for Fall PM10 Mass



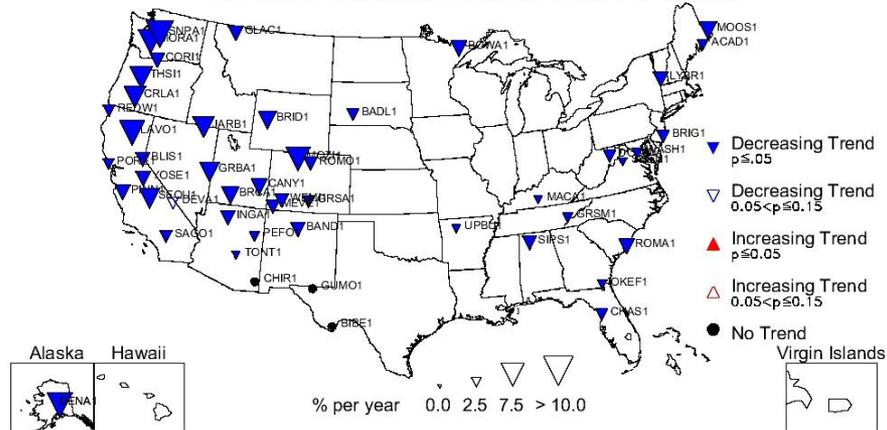
IMPROVE 1989-2008 Trends for Spring PM10 Mass



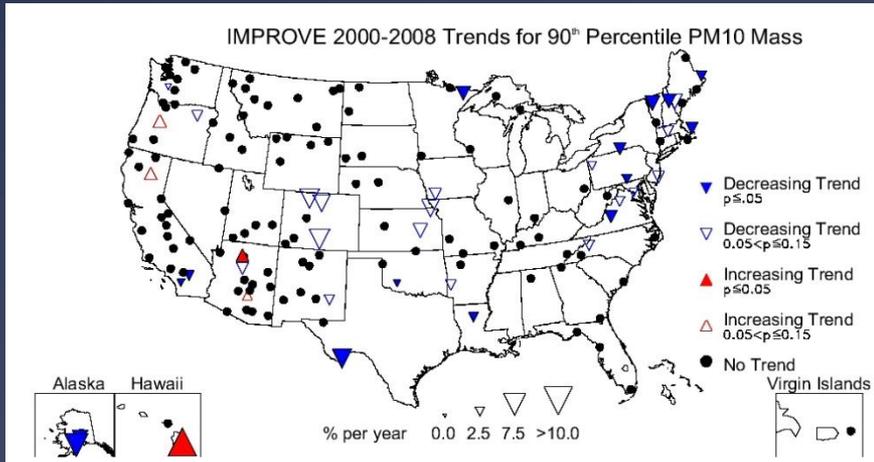
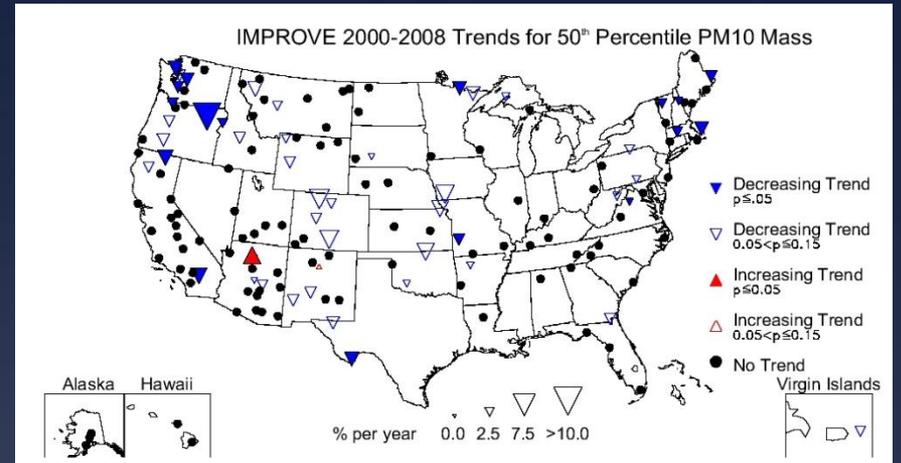
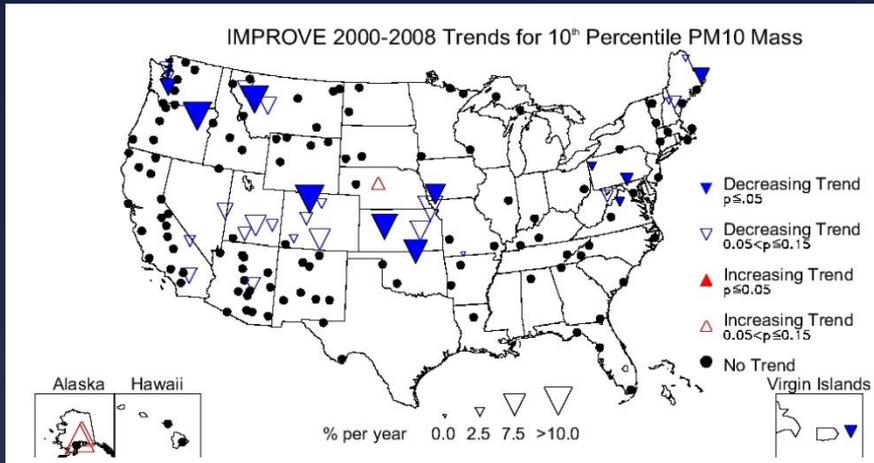
IMPROVE 1989-2008 Trends for Summer PM10 Mass



IMPROVE 1989-2008 Trends for Winter PM10 Mass

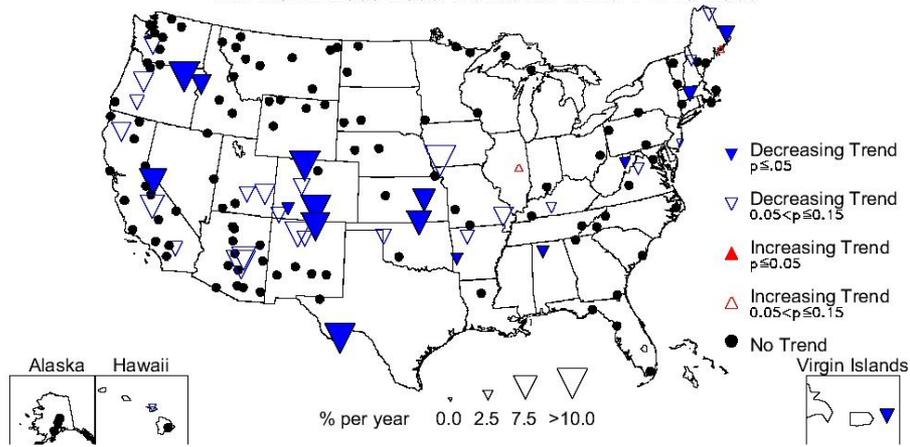


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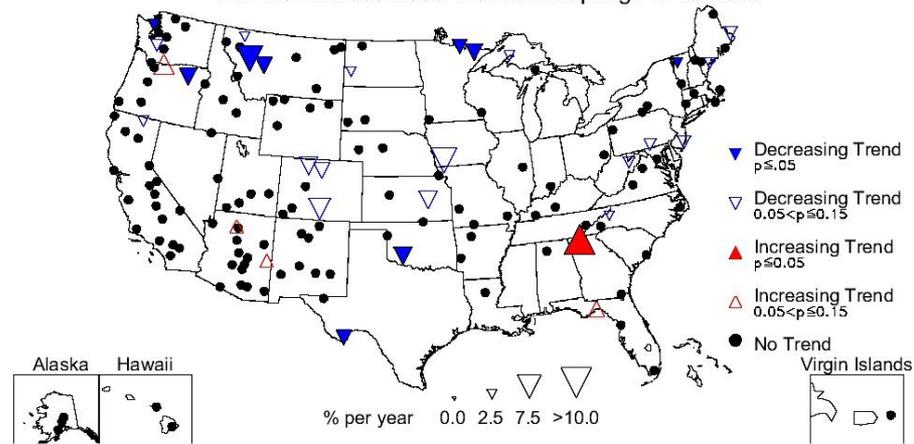


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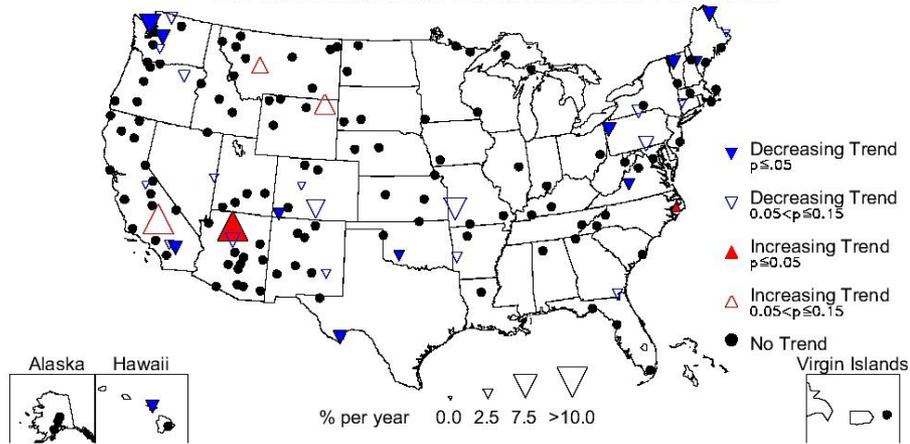
### IMPROVE 2000-2008 Trends for Winter PM10 Mass



### IMPROVE 2000-2008 Trends for Spring PM10 Mass



### IMPROVE 2000-2008 Trends for Summer PM10 Mass



### IMPROVE 2000-2008 Trends for Fall PM10 Mass

