$PM_{2.5}$ light absorbing carbon concentrations and filter-based light absorption measurements from major monitoring networks in the United States

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1990 2010

San Gorgonio, CA
20% worst visibility days

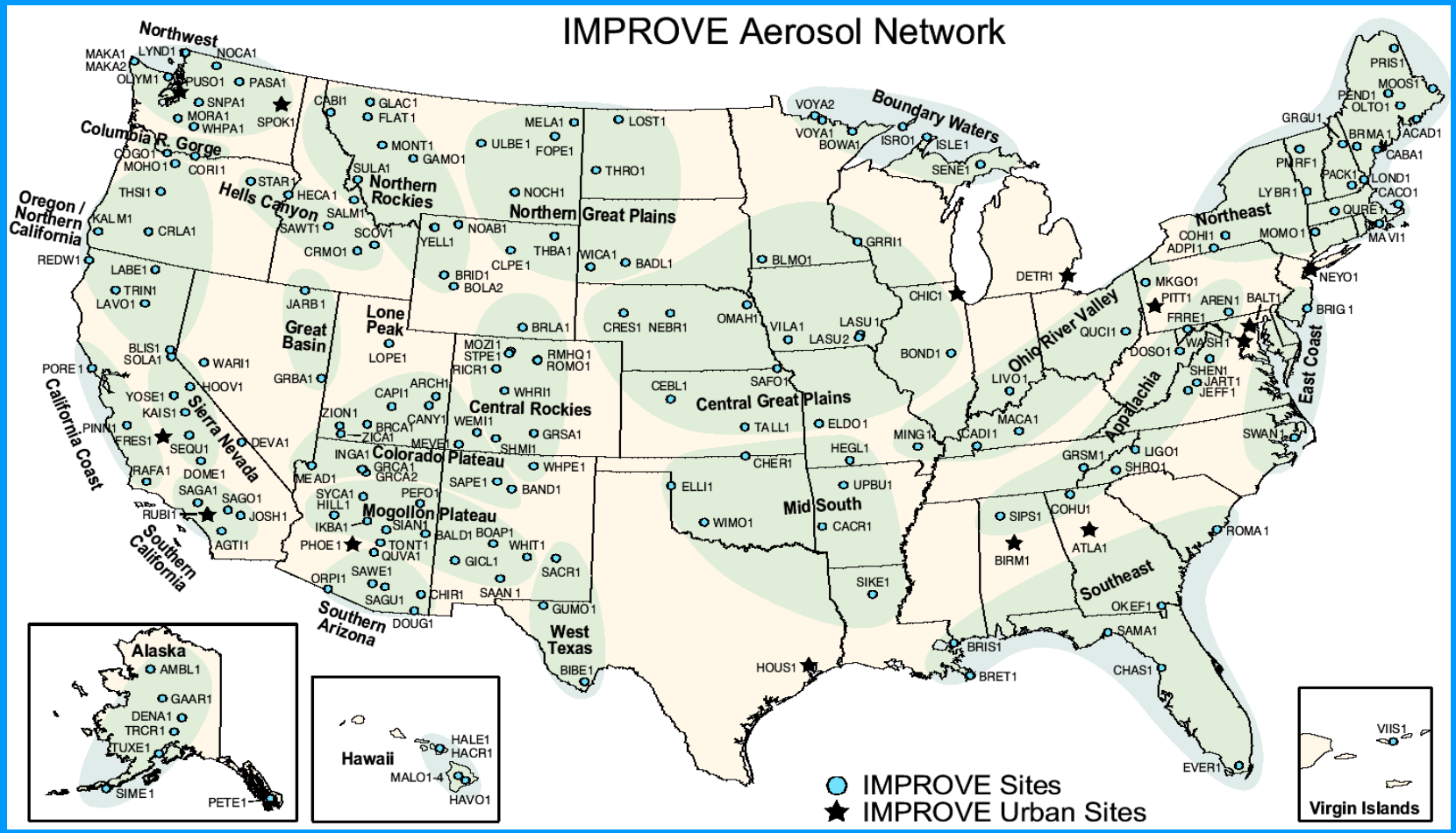
Motivation

- **Incorporate carbon data from two major networks in the US to understand the spatial and seasonal patterns in light absorbing carbon (LAC) at remote and urban sites.**

Outline

- Describe networks
  - IMPROVE network (remote/rural)
  - CSN network (urban/suburban)
- LAC concentrations and seasonality
- Filter-based light absorption
- Temporal trends in LAC

Interagency Monitoring of Protected Visual Environments (IMPROVE)



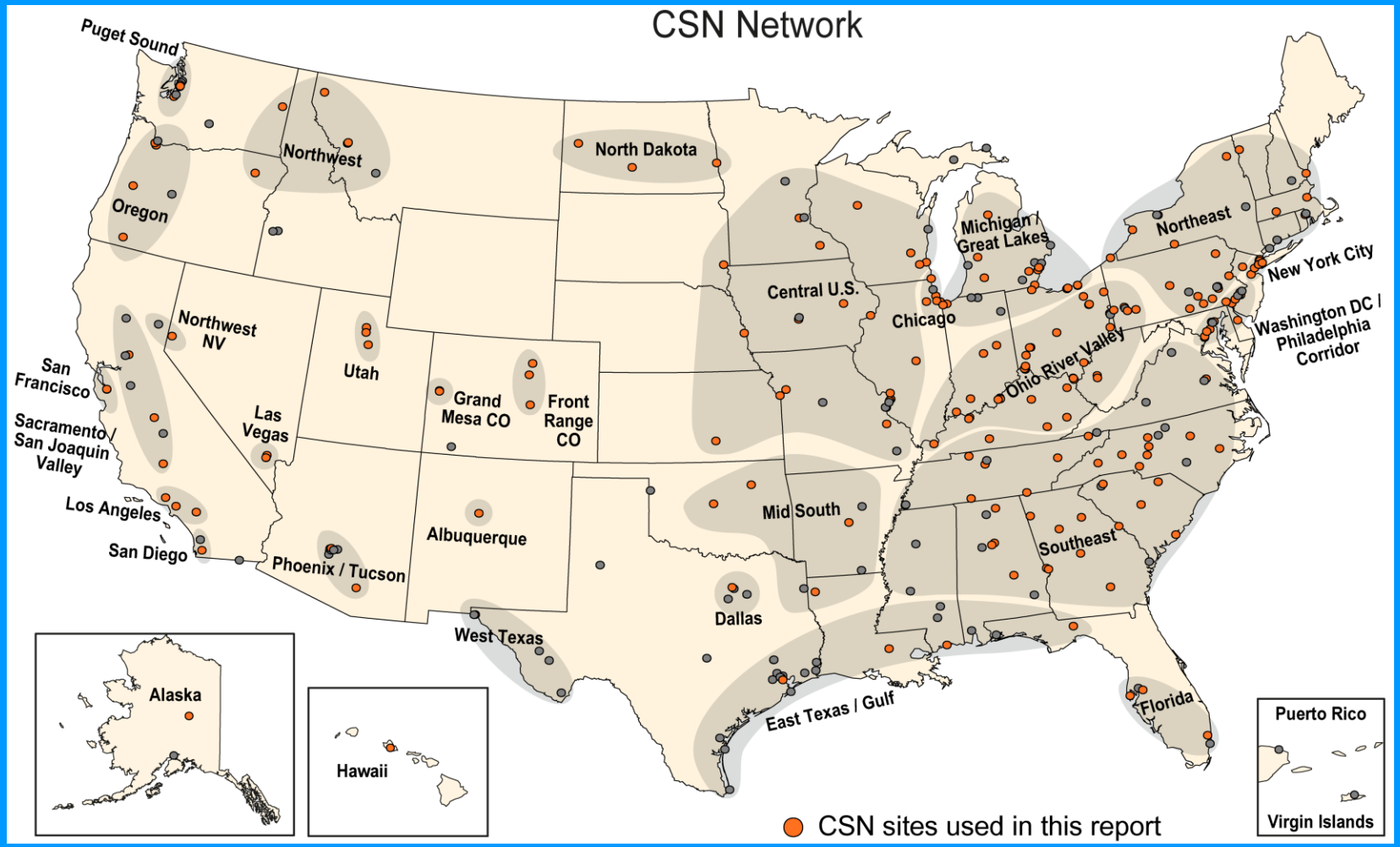
IMPROVE program began operation in 1988, currently ~170 sites operating

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

Always check advisories: http://vista.cira.colostate.edu/improve/Data/QA_QC/Advisory.htm

IMPROVE report: http://vista.cira.colostate.edu/improve/Publications/Reports/2011/2011.htm

EPA's Chemical Speciation Network (CSN)

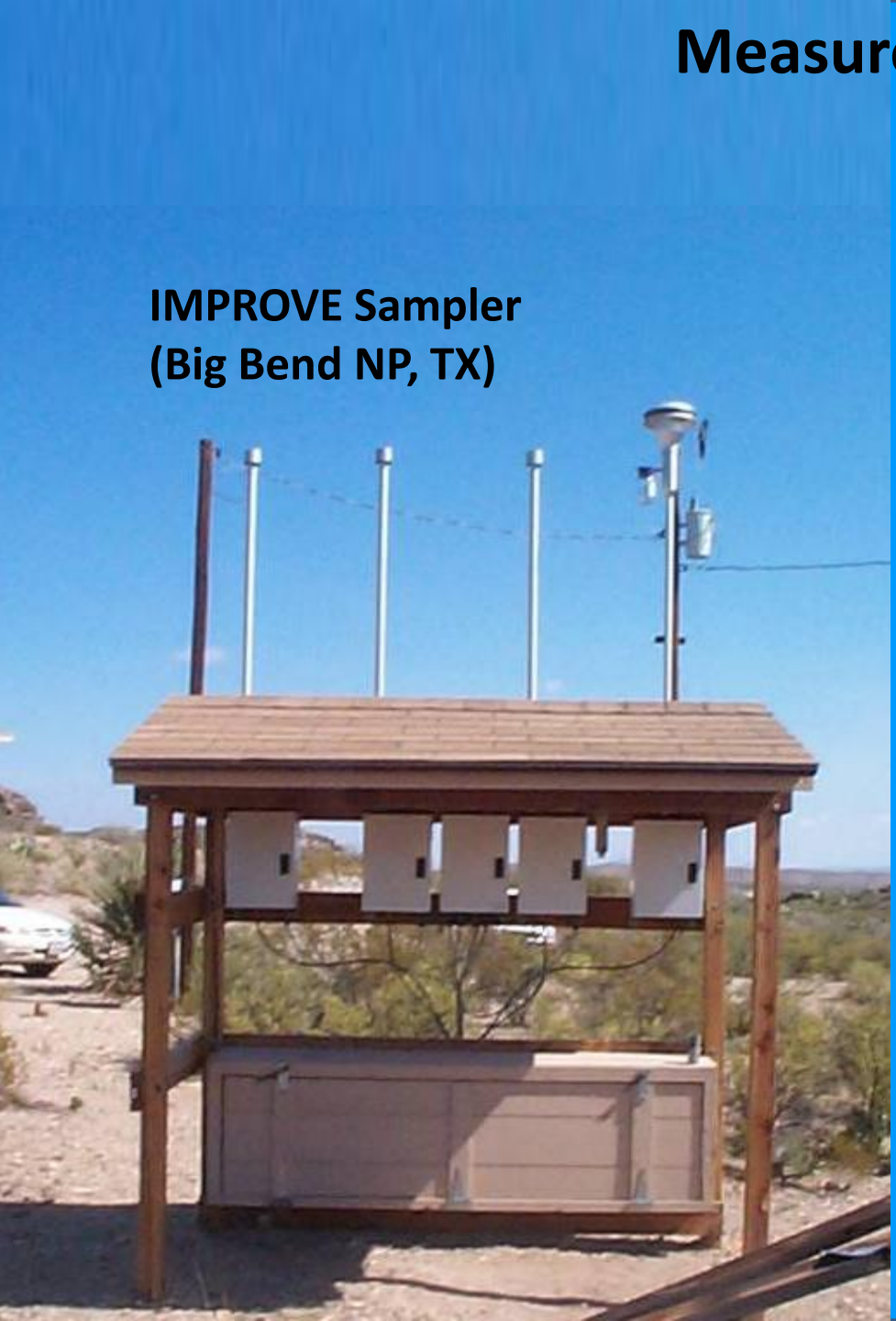


CSN sites began operating in 2000

Over ~200 sites

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

Measurements



IMPROVE Sampler (Big Bend NP, TX)

IMPROVE

- Frequency: Every 3rd day, 24hr
- Species: Inorganic ions, gravimetric $PM_{2.5}$ and PM_{10}, elemental species, carbon (OC and LAC)
- Filter-based light absorption (HIPS)

CSN

- Frequency: Every 3rd or 6th day, 24hr
- Species: Inorganic ions, gravimetric $PM_{2.5}$, elemental species, carbon (OC and LAC)

Carbon Sampling Issues

- Different samplers (Malm et al., 2011)
- Different analyses (TOR vs TOT) (Chow et al., 2004)
- Different artifact corrections (Chow et al., 2010)
- EPA transitioned to an IMPROVE-like sampler and TOR analyses starting in 2007 through 2010.

- 3 protocols:
  - -IMPROVE: TOR, artifact corrected
  - - pre-transition CSN (before 2007) : variety of samplers, TOT, uncorrected for artifacts
  - -post-transition CSN (2007-2010): IMPROVE-like sampler and TOR, uncorrected for artifacts

Carbon Data Reconciliation

- Need for reconciliation for data prior to the transition.

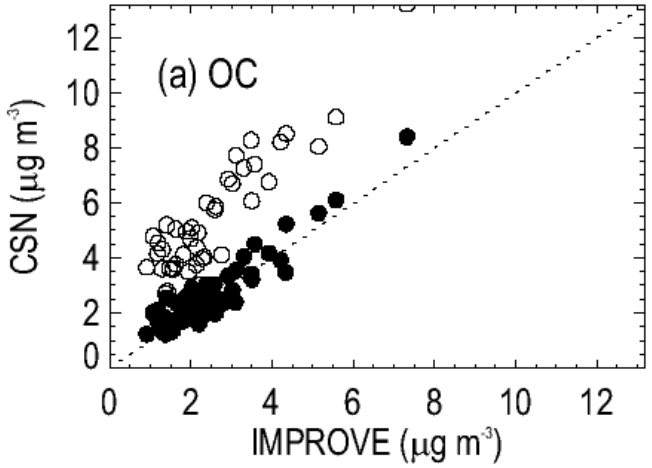
- Collocated IMPROVE and CSN data from 2005-2006 were used to determine multiplicative and additive biases/artifacts (Malm et al. 2011).

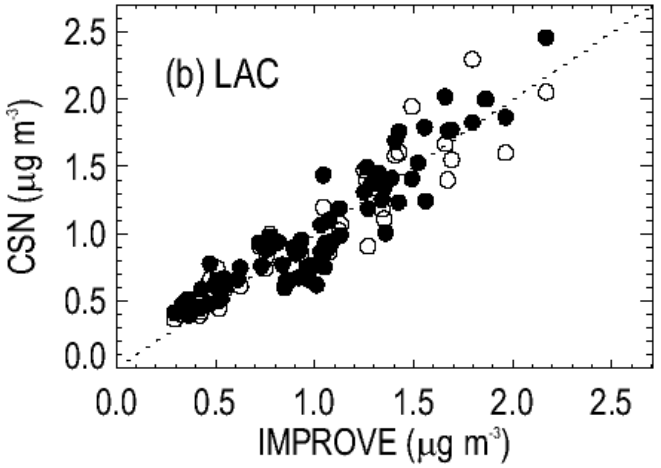
- Monthly adjustment factors applied for specific samplers.

- Positive artifact correction applied to CSN data (0.35 $\mu g/m^3$) based on back up filters.

Collocated Carbon Comparisons

2007-2010 Monthly Means





Sites:

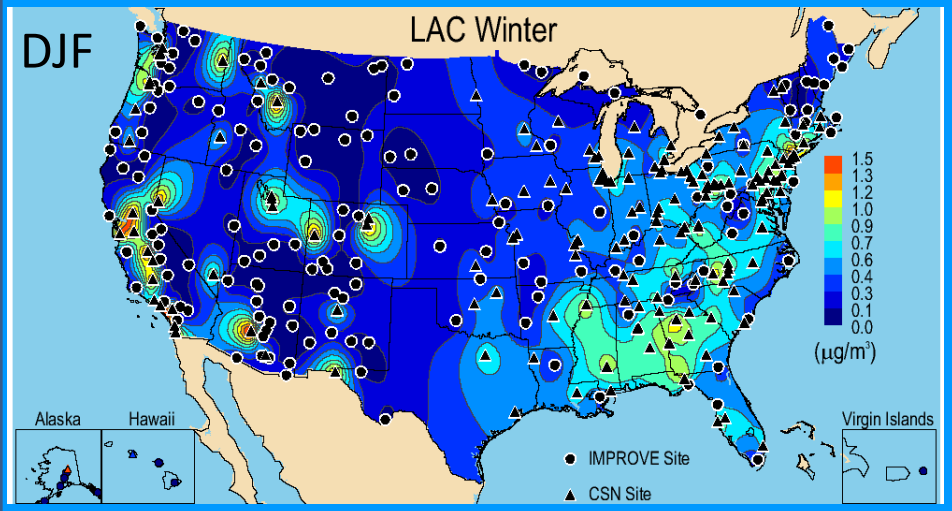
Birmingham, AL; Fresno, CA; New York, NY; Phoenix, AZ; Seattle, WA; Washington, D.C.

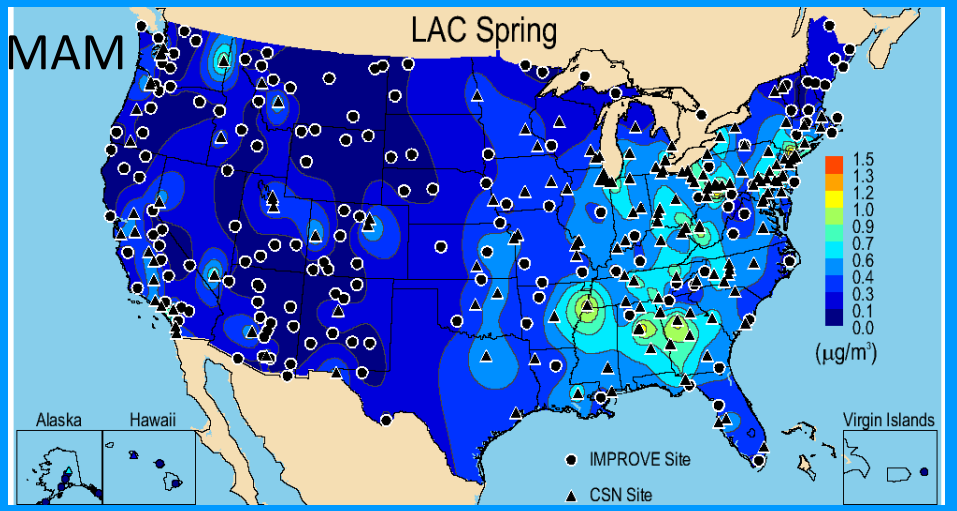
Species	Error (%)	Bias (%)	IMPROVE Mean (µg m^{-3})	CSN Mean (µg m^{-3})	r	Ratio (imp/csn)	N
OC	12.4	8.14*	2.36	2.50	0.93	0.94	72
LAC	14.6	3.7*	1.00	1.01	0.92	0.99	72

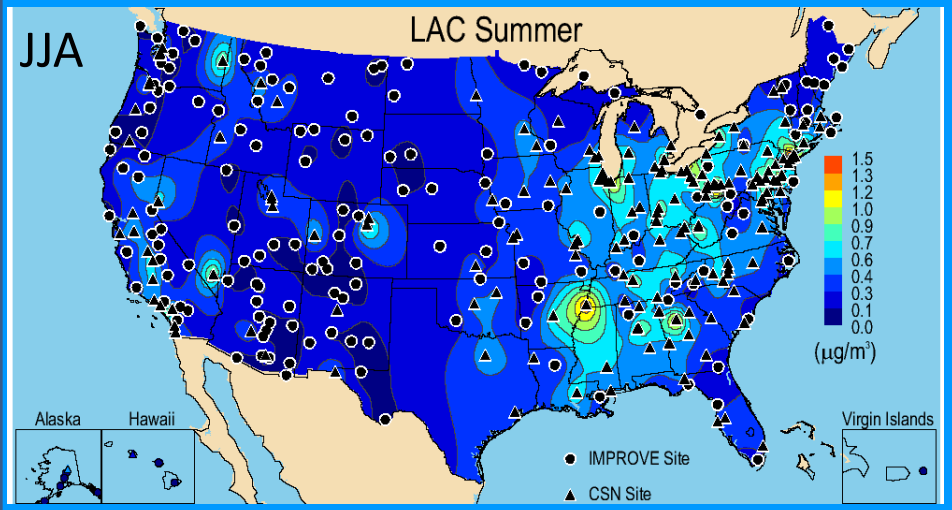
* CSN higher

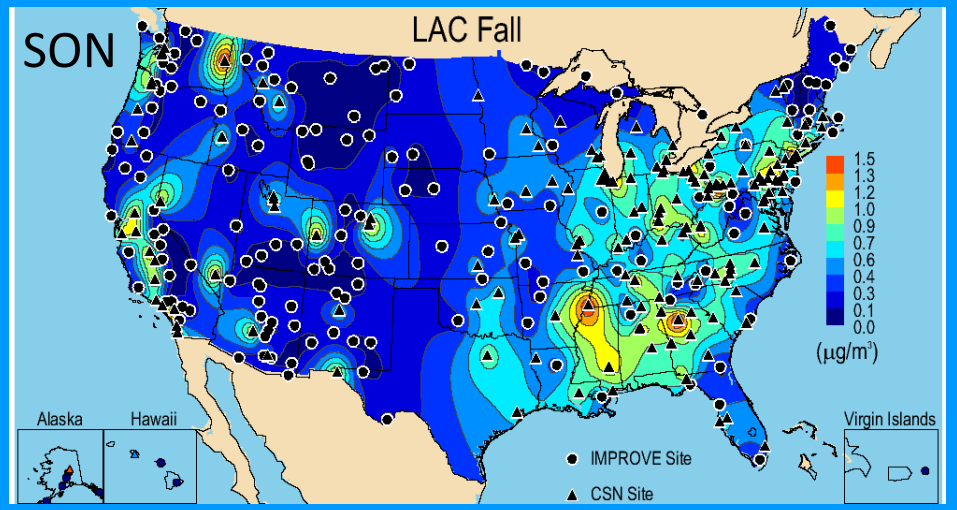
Hand et al., 2012

2007-2010 Seasonal Mean Urban and Rural LAC Mass









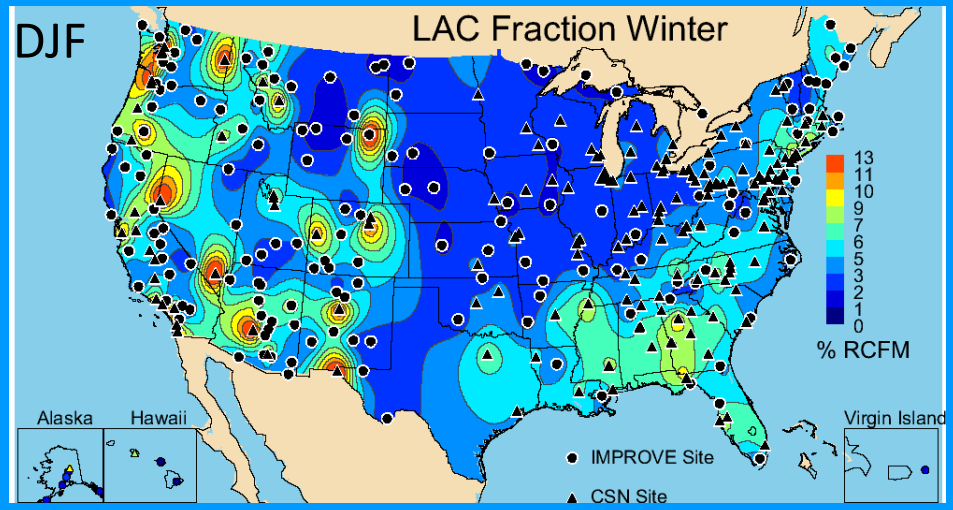
Western U.S.

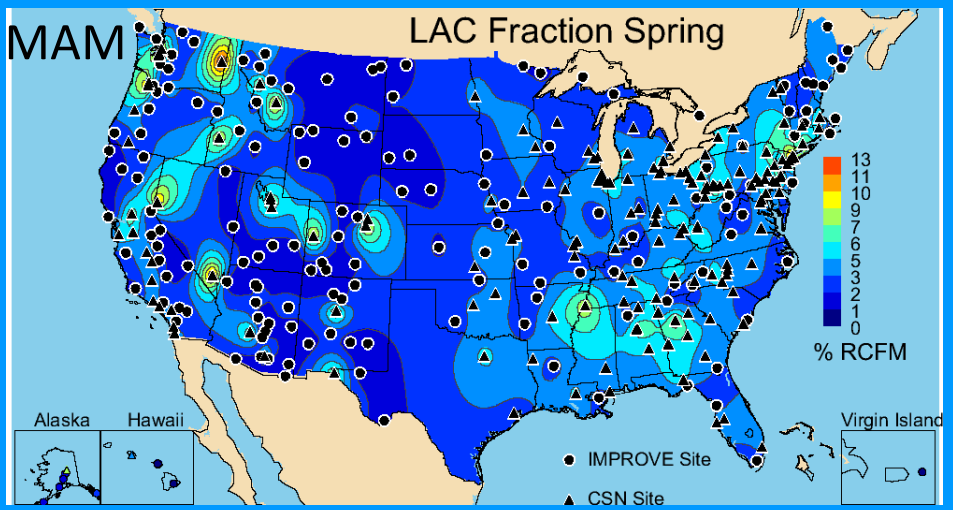
- Large urban excess- localized
- Winter urban peak
- Summer rural peak

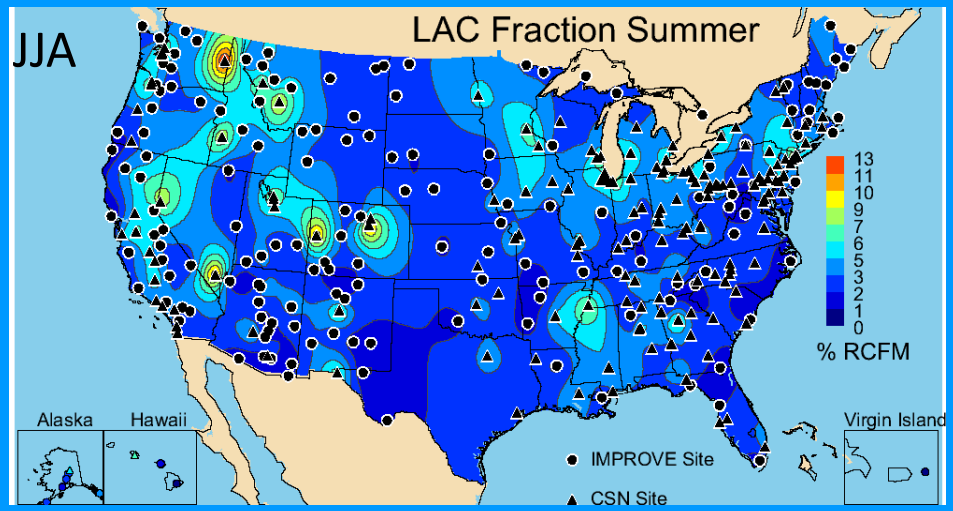
Eastern U.S.

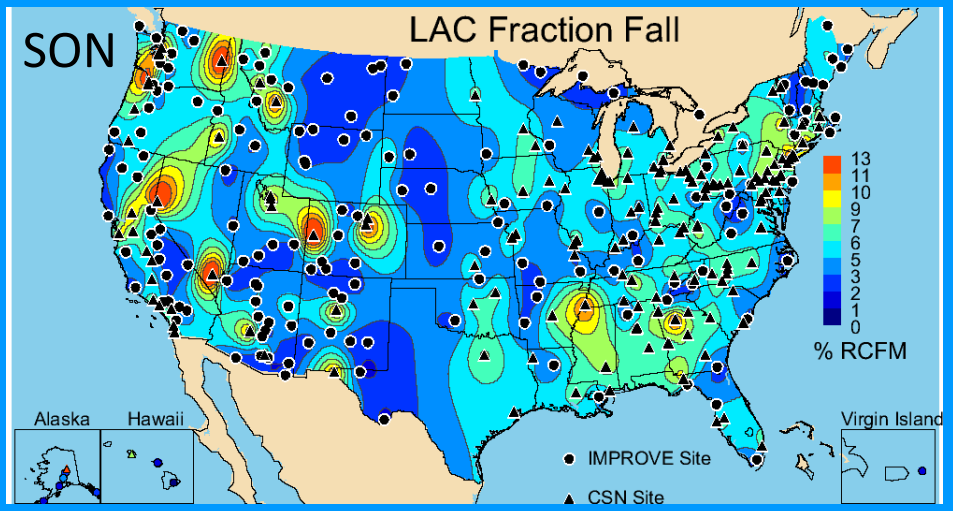
- Smaller urban excess
- Winter/fall urban peak
- Varied rural seasonality

2007-2010 Seasonal Rural and Urban LAC $PM_{2.5}$ Mass Fraction



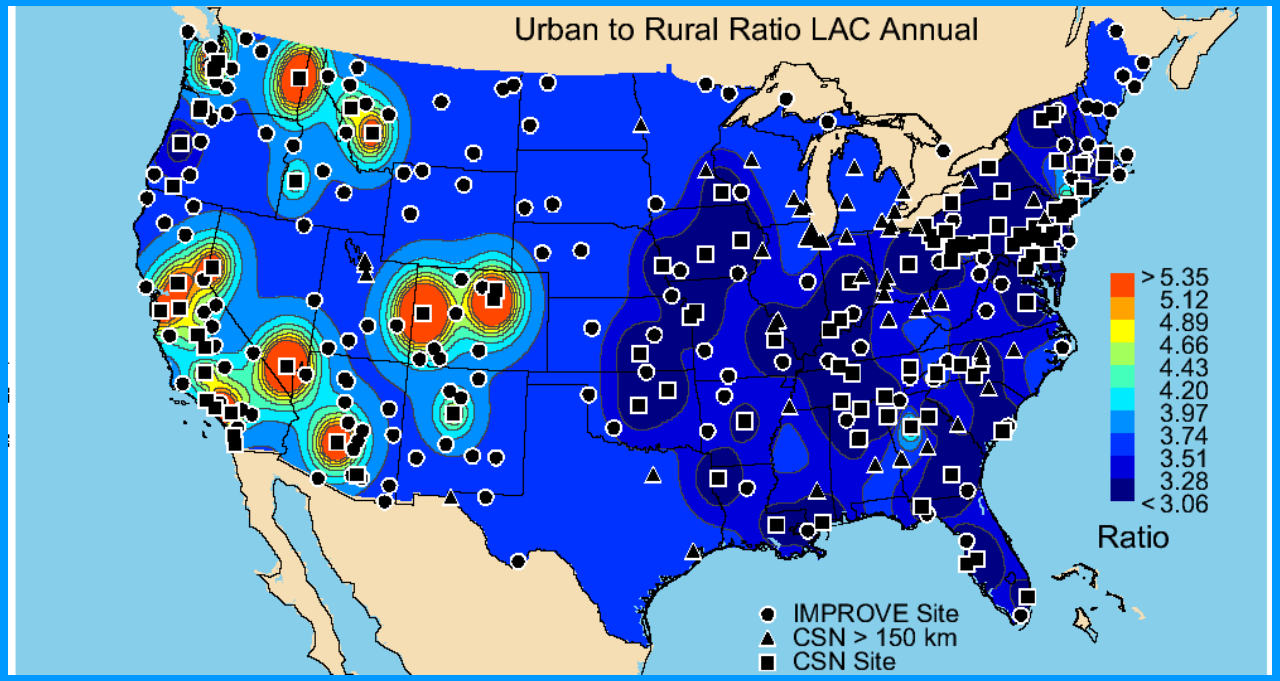


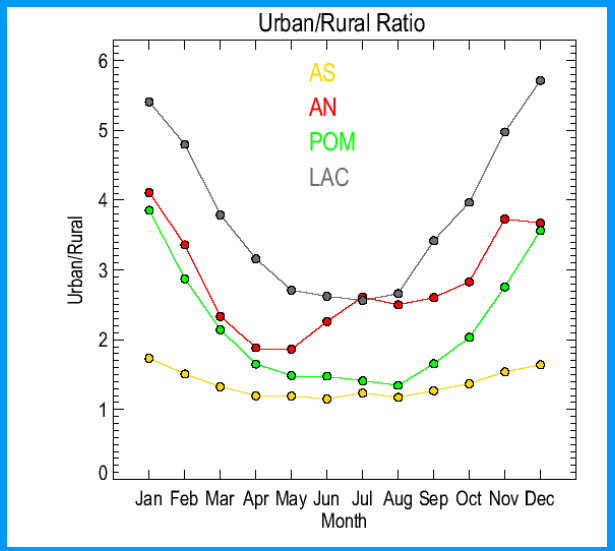




Localized urban mass fractions are highest in fall and winter (> 10%)

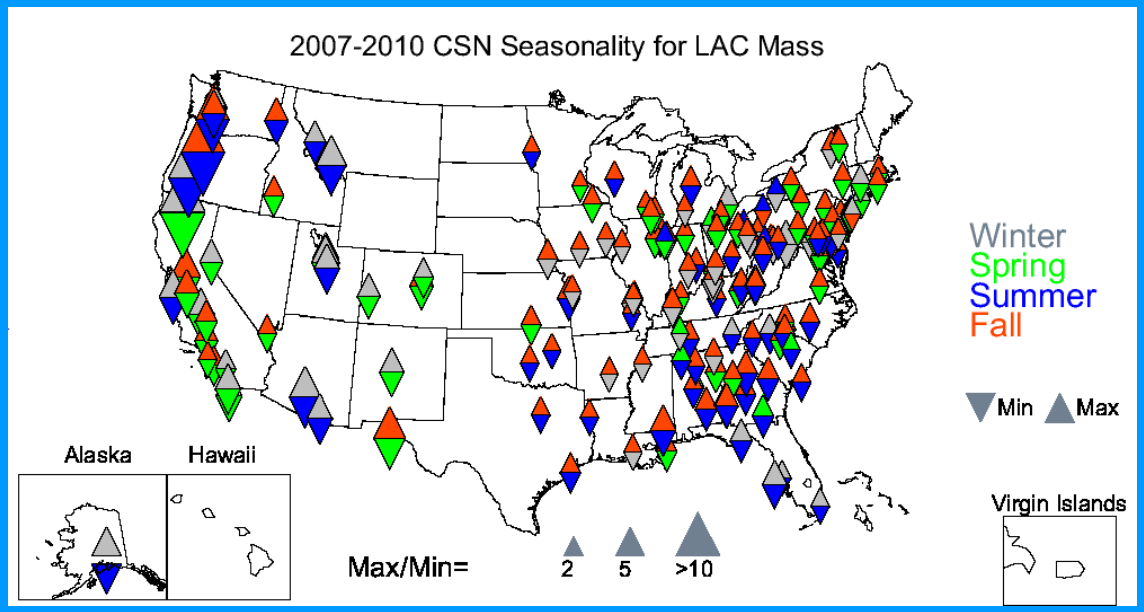
2007-2010 Annual Mean LAC Urban Excess (urban/rural)

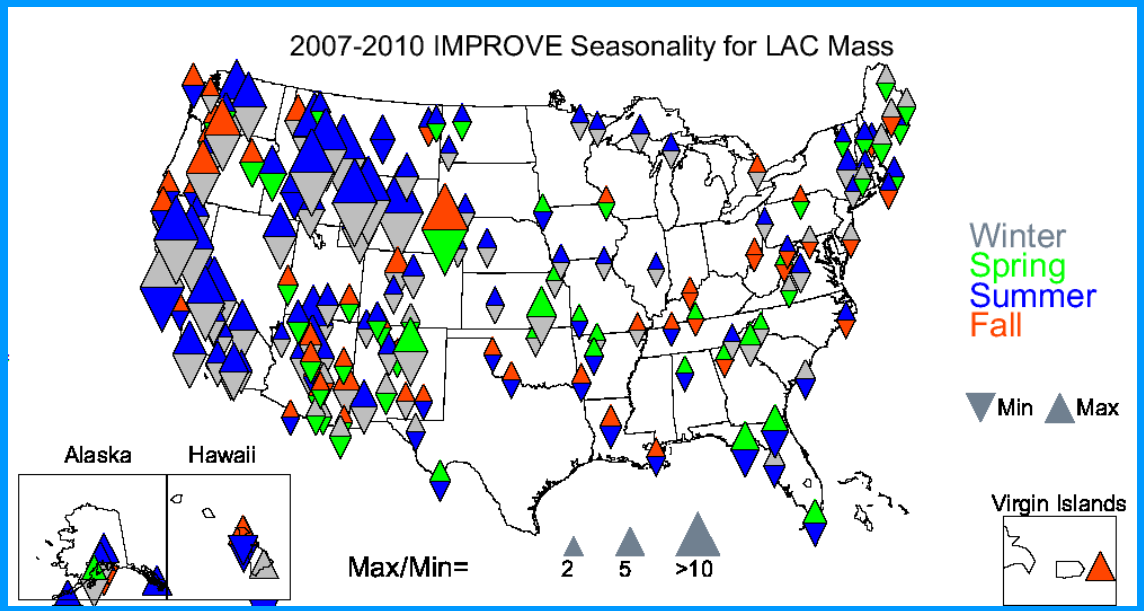




- LAC urban excess is greatest in the West and highly localized.
- Winter excess is double summer excess.

2007-2010 Urban and Rural Seasonality





Urban

- West: Higher seasonality
  - -Spring/summer minima
  - -Winter/fall maxima
- East: Lower seasonality
  - -Summer minima
  - -Fall/winter maxima

Rural

- West: Higher seasonality
  - - Winter minima
  - - Summer/fall maxima
- East: Lower seasonality
  - - Variable

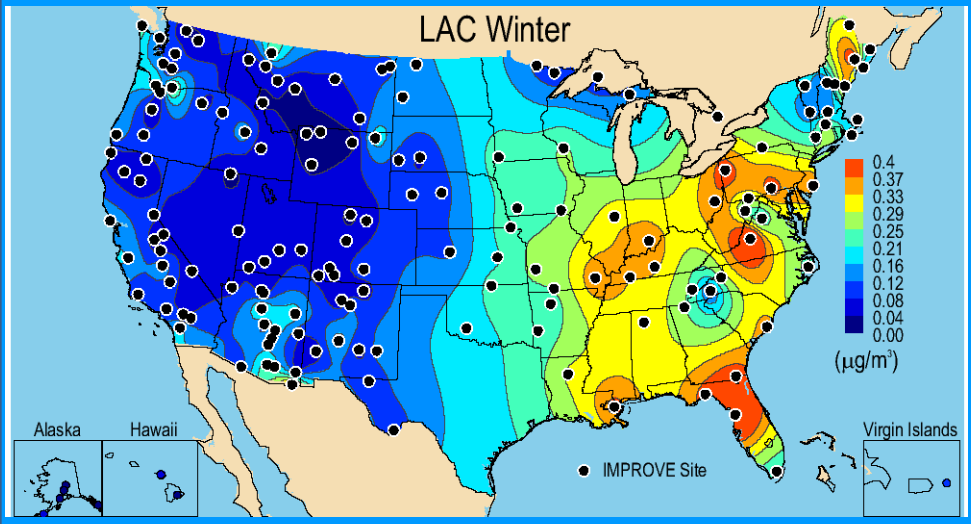
IMPROVE Light absorption (f_{abs}) measurements from HIPS (hybrid integrating plate/sphere)

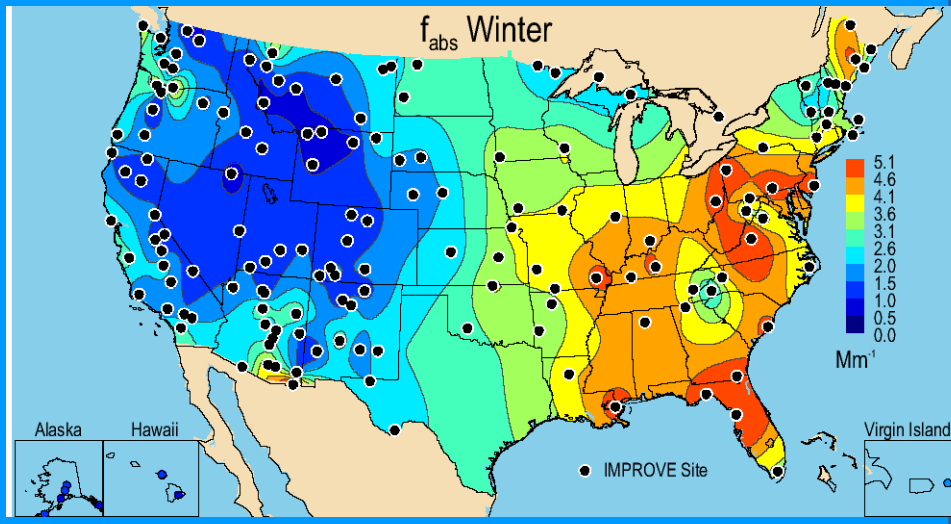
- Designed to measure the absorption thickness of a Teflon filter
- LIPM from March 1988-March 1994
- HIPS from April 1994 to present
- Similar artifact issues as any filter light absorption method
- Masking of filters introduced biases (before 2008)
- LAC and f_{abs} highly correlated (Chow et al., 2010)

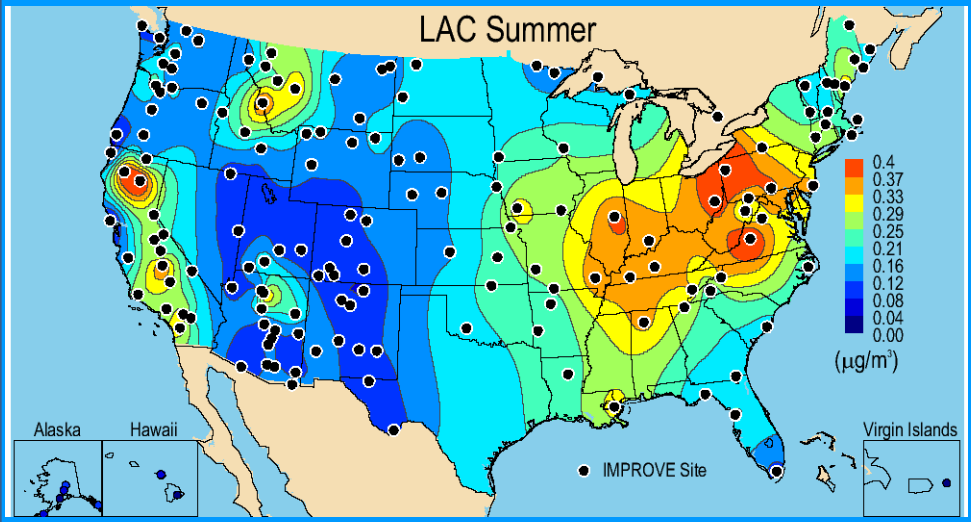
2007-2010 LAC and HIPS Comparisons

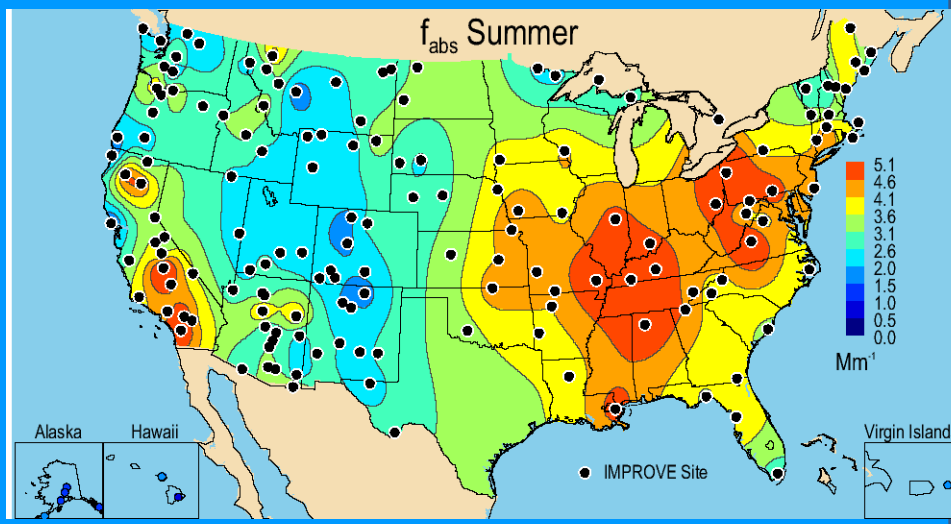
LAC (TOR)

f_{abs} (HIPS)









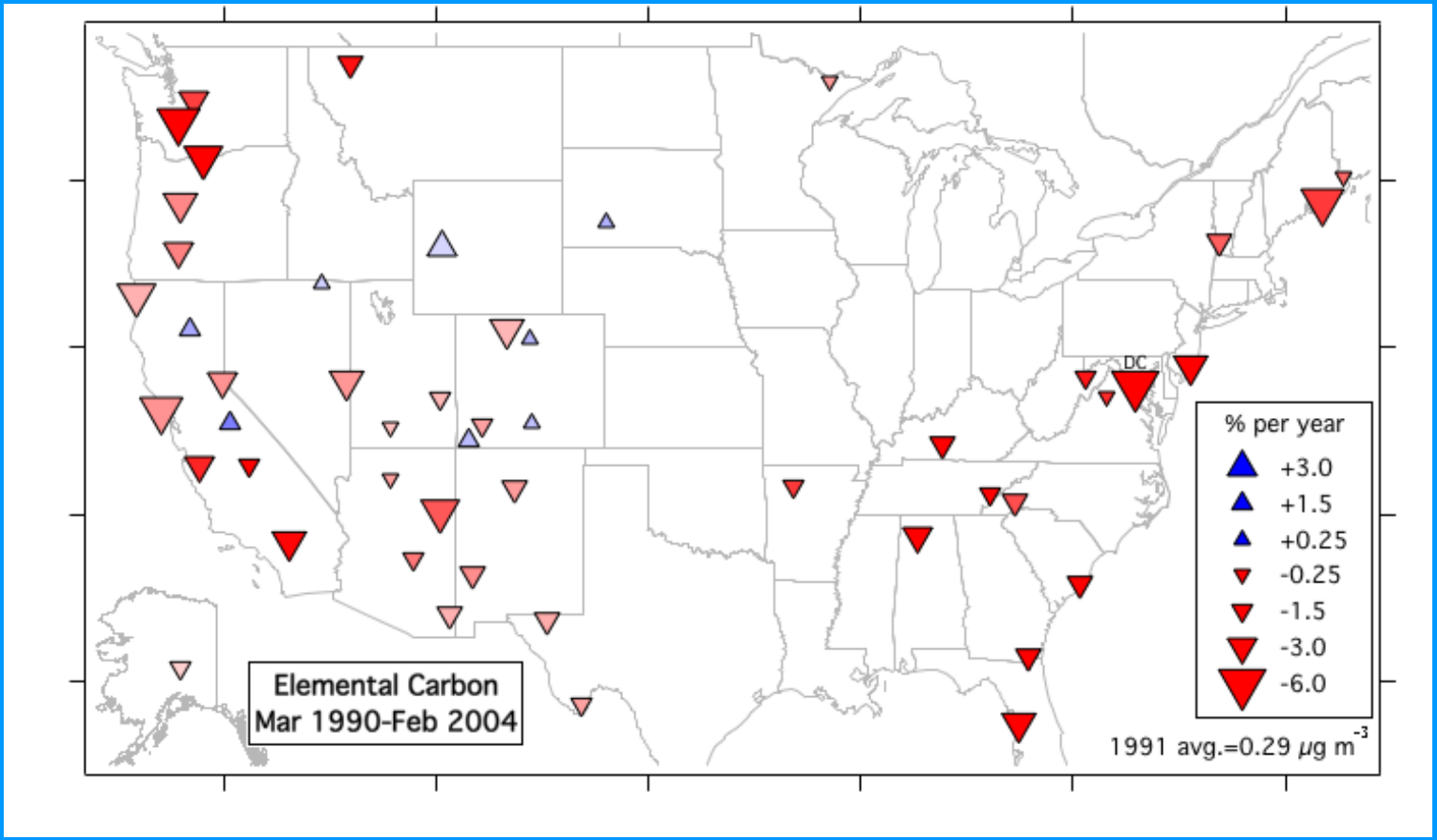
Spatial patterns are somewhat similar

LAC and f_{abs} are highly correlated for all sites, r = 0.84 to 0.98; Annual: r=0.96

Absorption efficiencies are high: 15 to 18 m^2/g; Annual: 16.5 m^2/g

Widespread Decreases in Annual LAC

LAC trends from 1990 – 2004



Symbol size: magnitude of trend
Color saturation: absolute amount of LAC

Murphy et al., 2011

Summary

- Reconciliation of carbon data from IMPROVE and CSN have provided detailed spatial patterns in urban and rural concentrations.
  - West: Opposite seasonality (urban winter max, summer rural max)
  - East: Urban winter/fall maxima, varied rural seasonality
  - Urban excess is greatest in the West, especially in winter, and highly localized.
- Filter-based measurements reproduce similar spatial and seasonal patterns to LAC and are highly correlated but need additional artifact corrections to account for biases in derived absorption efficiencies
- Widespread decrease in annual mean LAC concentrations from 1990-2004.

Acknowledgements

National Park Service

IMPROVE

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1990 2010

Acadia National Park, ME
20% worst days