Trends in Seasonal Mean Speciated Aerosol Composition

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Glacier, 1990
Haziest bext

Glacier, 2021
Haziest bext

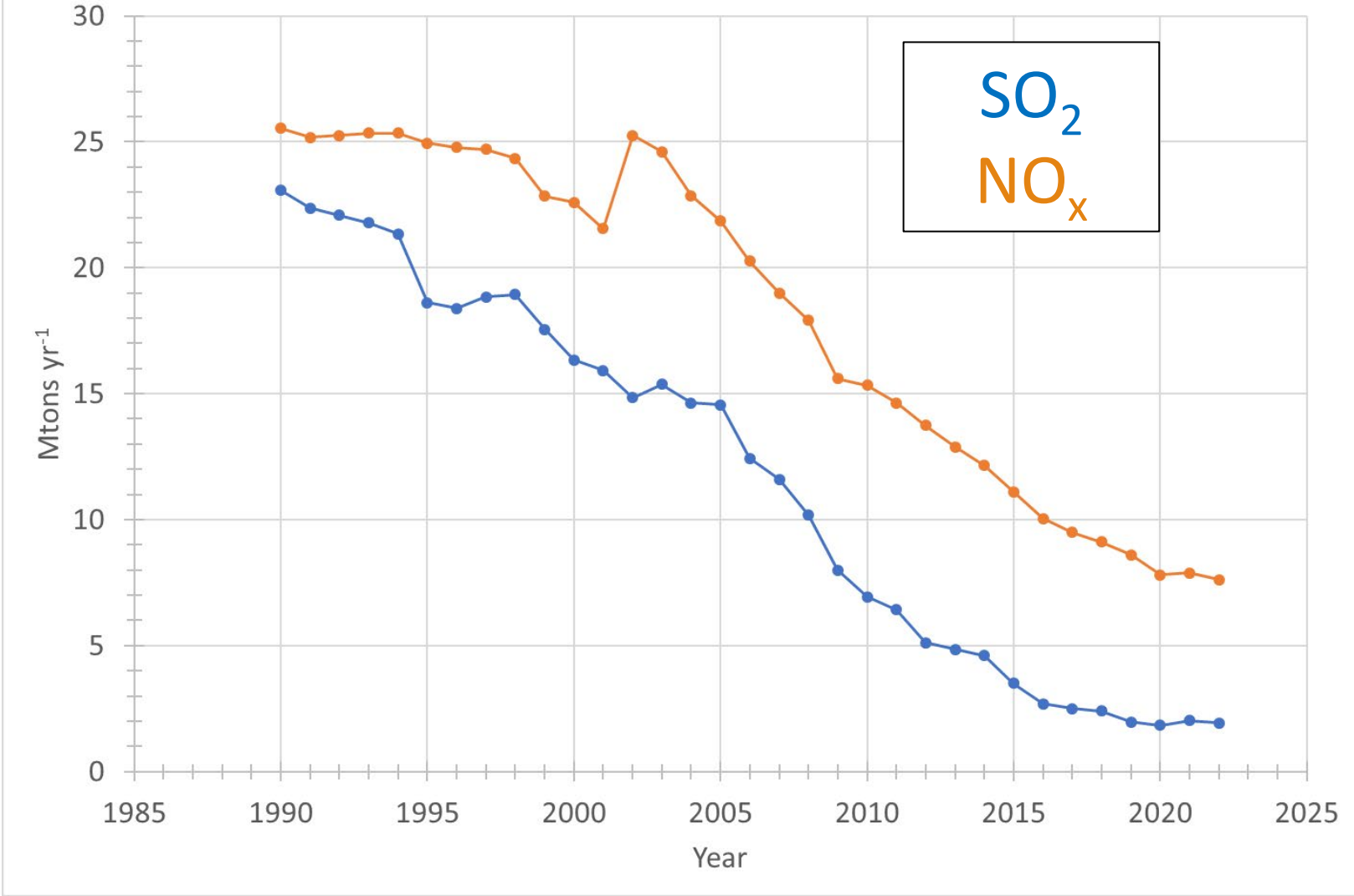
Motivation

From 1990 to 2021:

- 91% Decrease in SO_2
  EGU: 70% to 48%

- 70% Decrease in NOx
  EGU: 26% to 12%
  Transportation ~ 50%

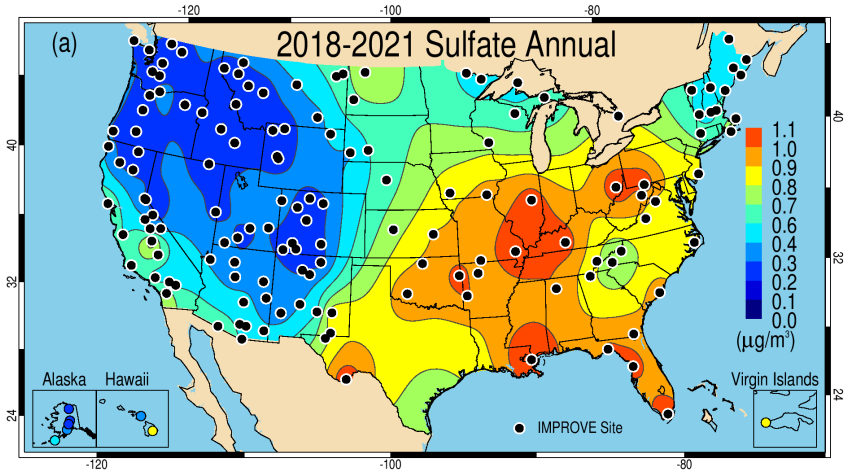
EPA's NEI Total U.S. Annual Emissions

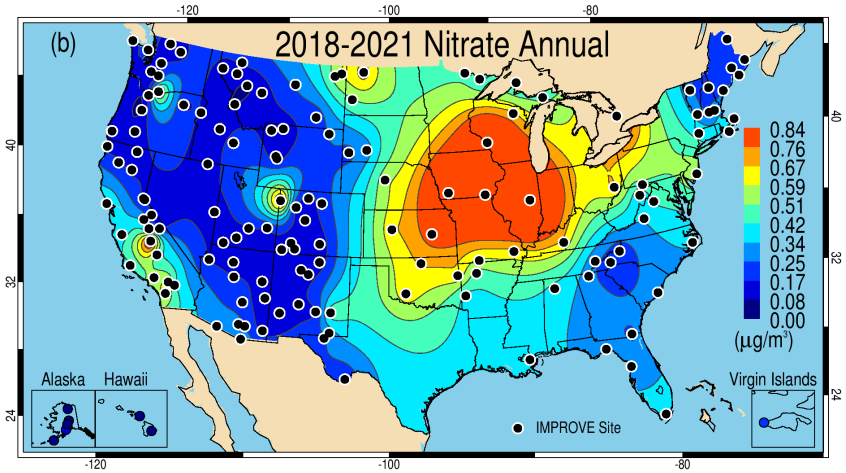


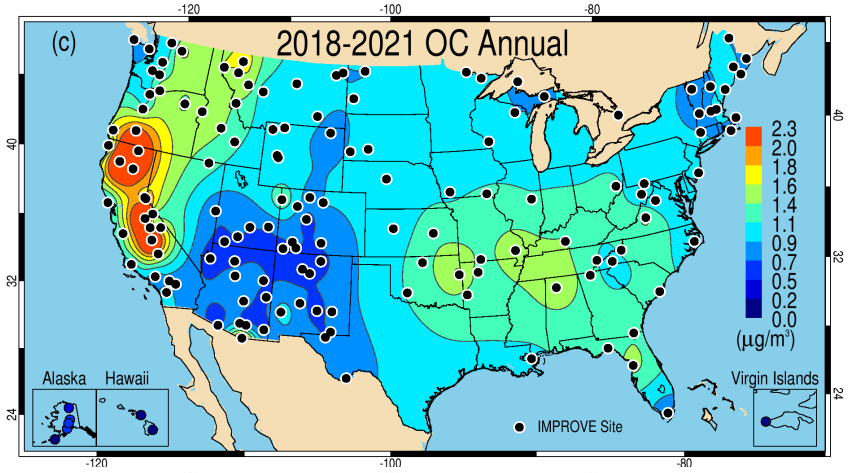
Status and Trends

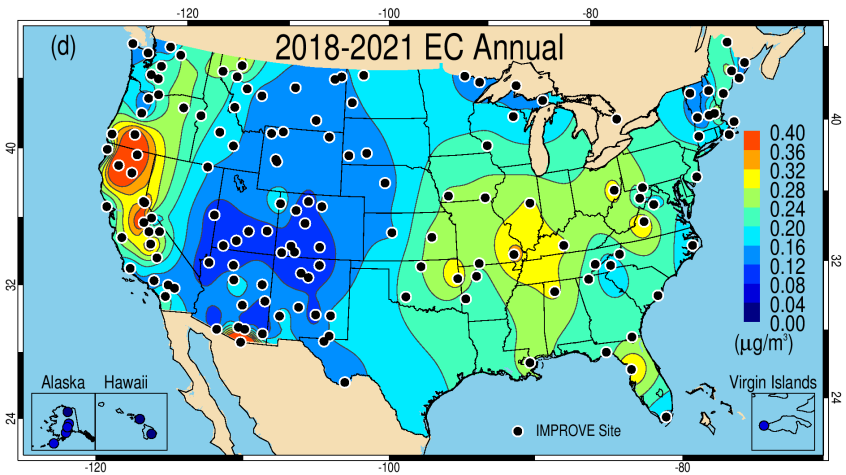
- Current concentrations of major aerosol species (2018-2021)
- Trend analysis: 2000-2021, Theil regression, seasonal and regional analysis
- How has $PM_{2.5}$ mass changed and what is contributing to that change?

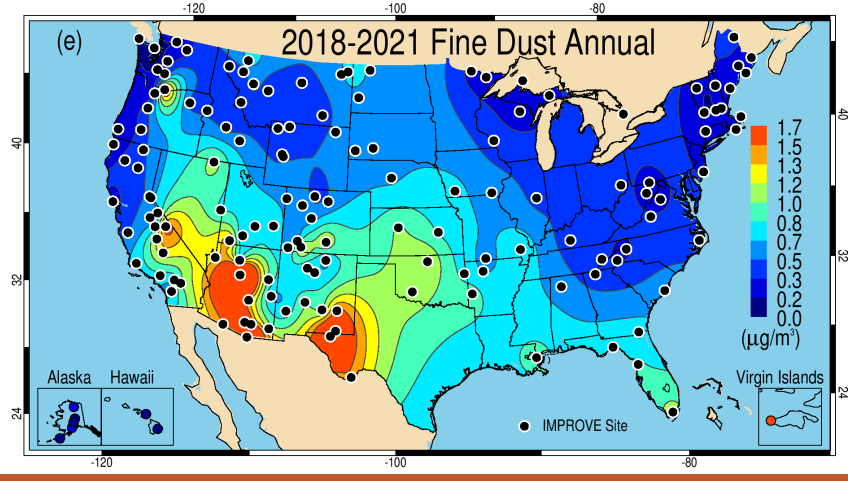
2018-2021 Annual mean

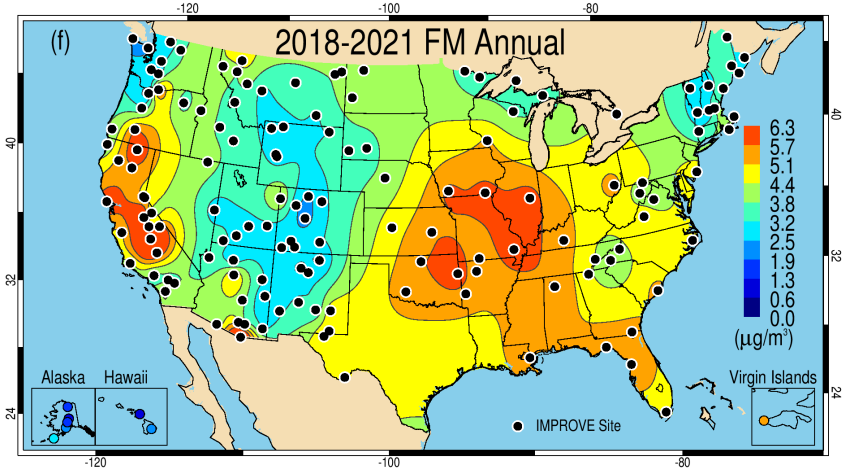




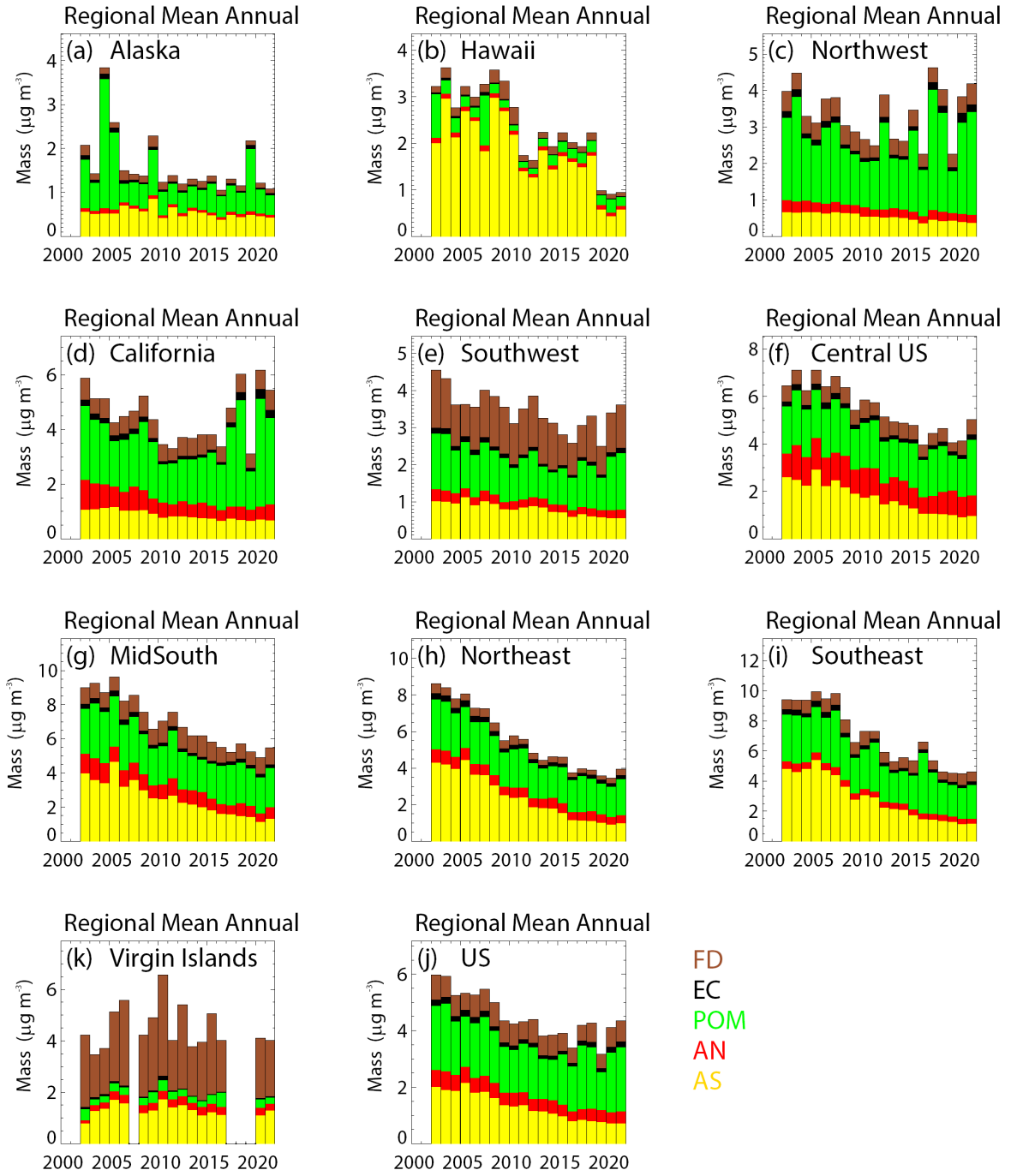




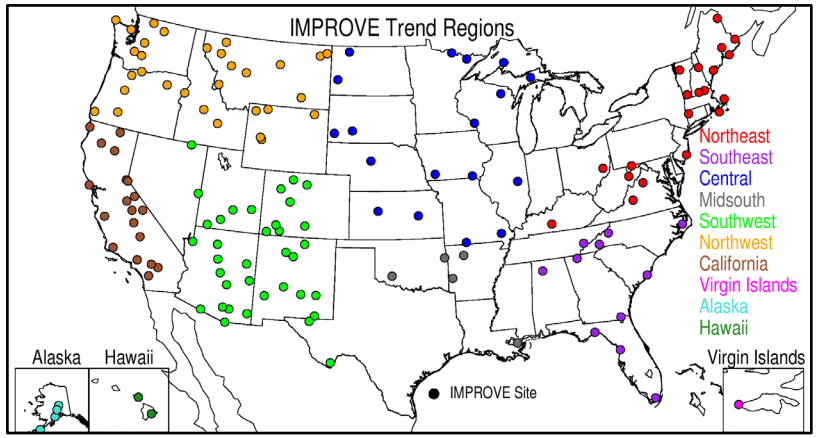




2002-2021 Regional, Annual Mean



Summary Regions



Fine Dust (FD)

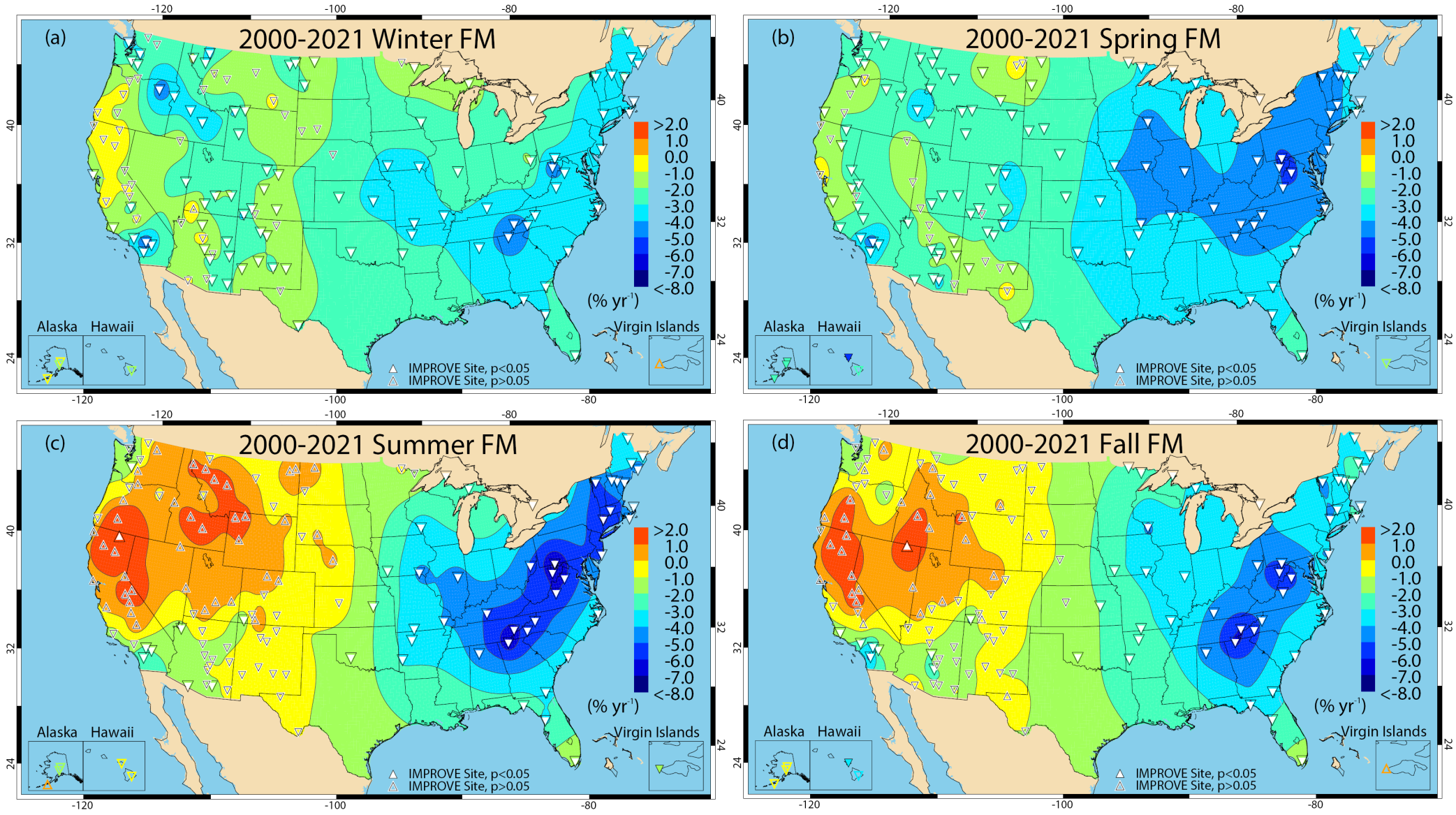
Elemental Carbon (EC)

Particulate Organic Matter (POM= 1.8*OC)

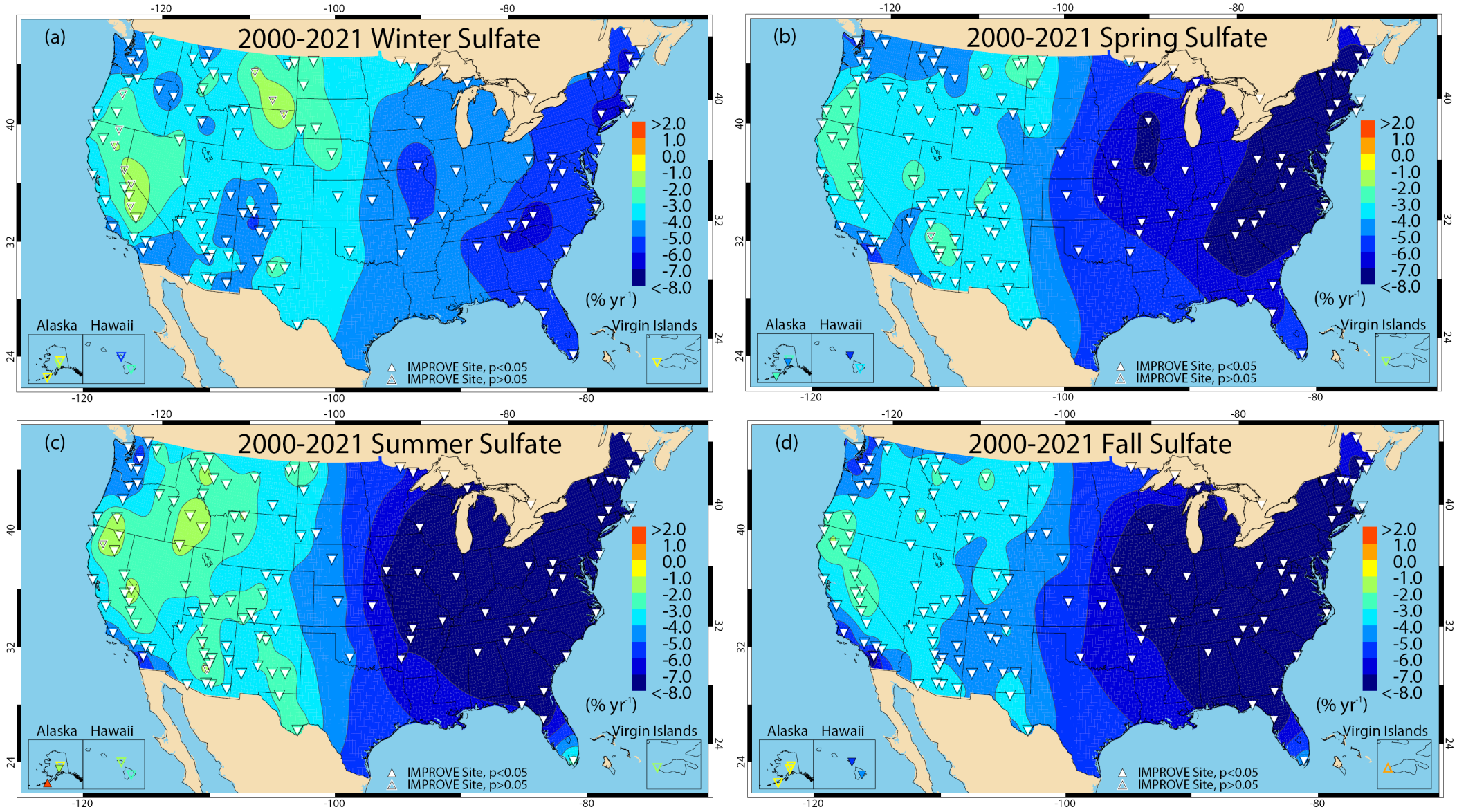
Ammonium Nitrate (AN=1.29*NO3)

Ammonium Sulfate (AS=1.375*SO4)

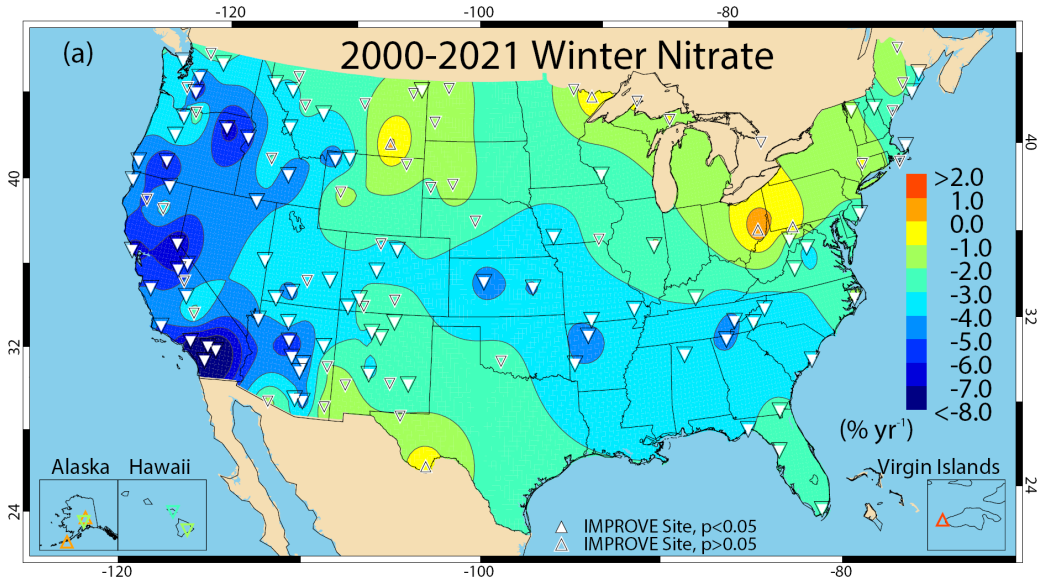
2000-2021 Seasonal Mean FM ($PM_{2.5}$) Trends

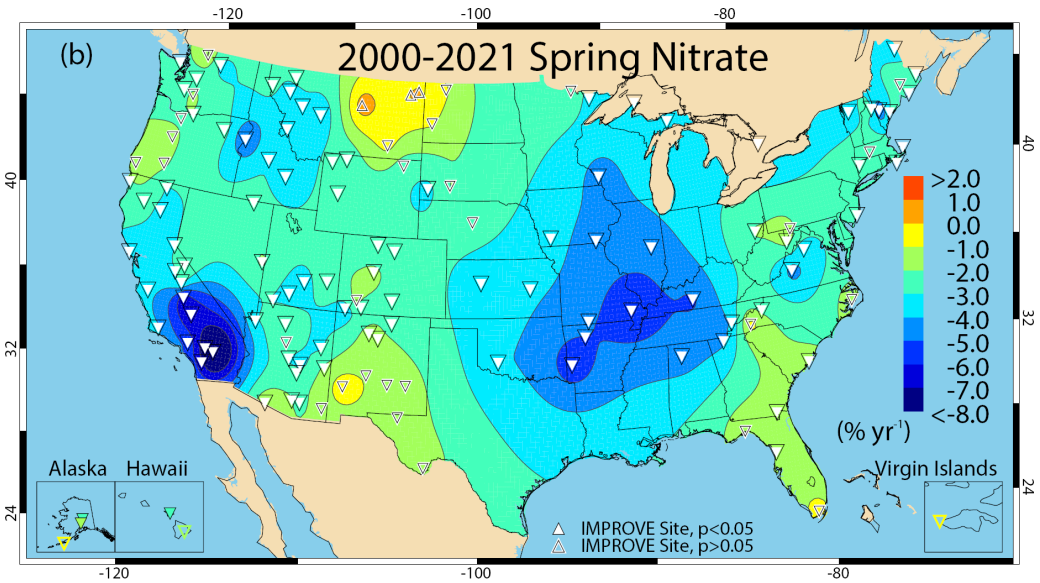


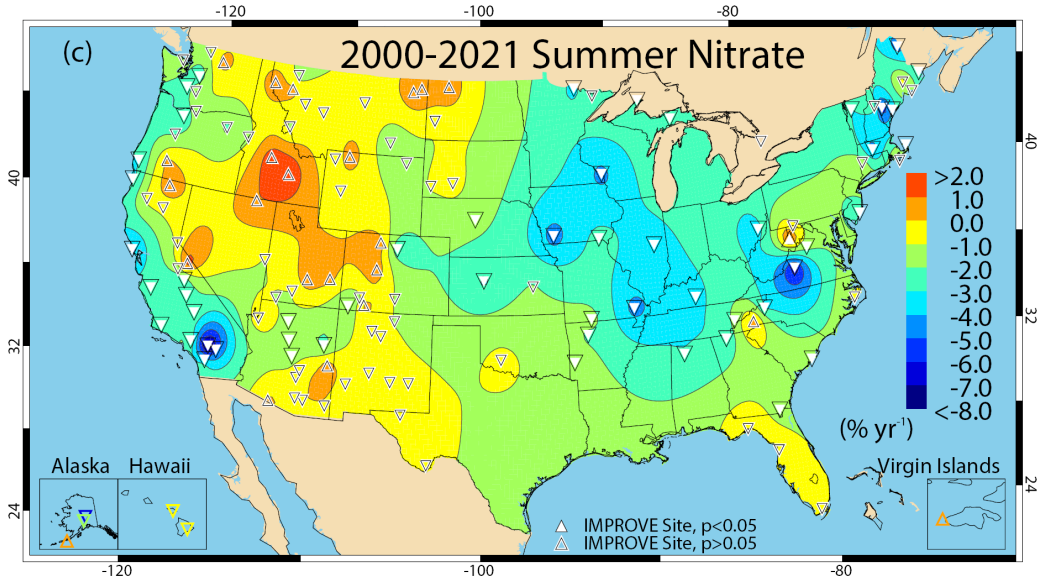
2000-2021 Seasonal Mean Sulfate Trends

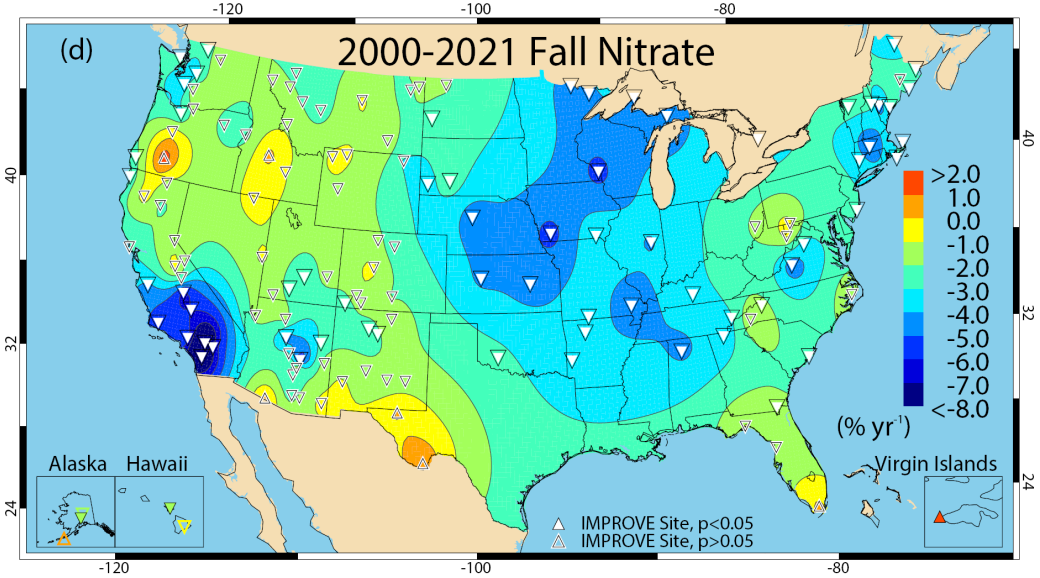


2000-2021 Seasonal Mean Nitrate Trends

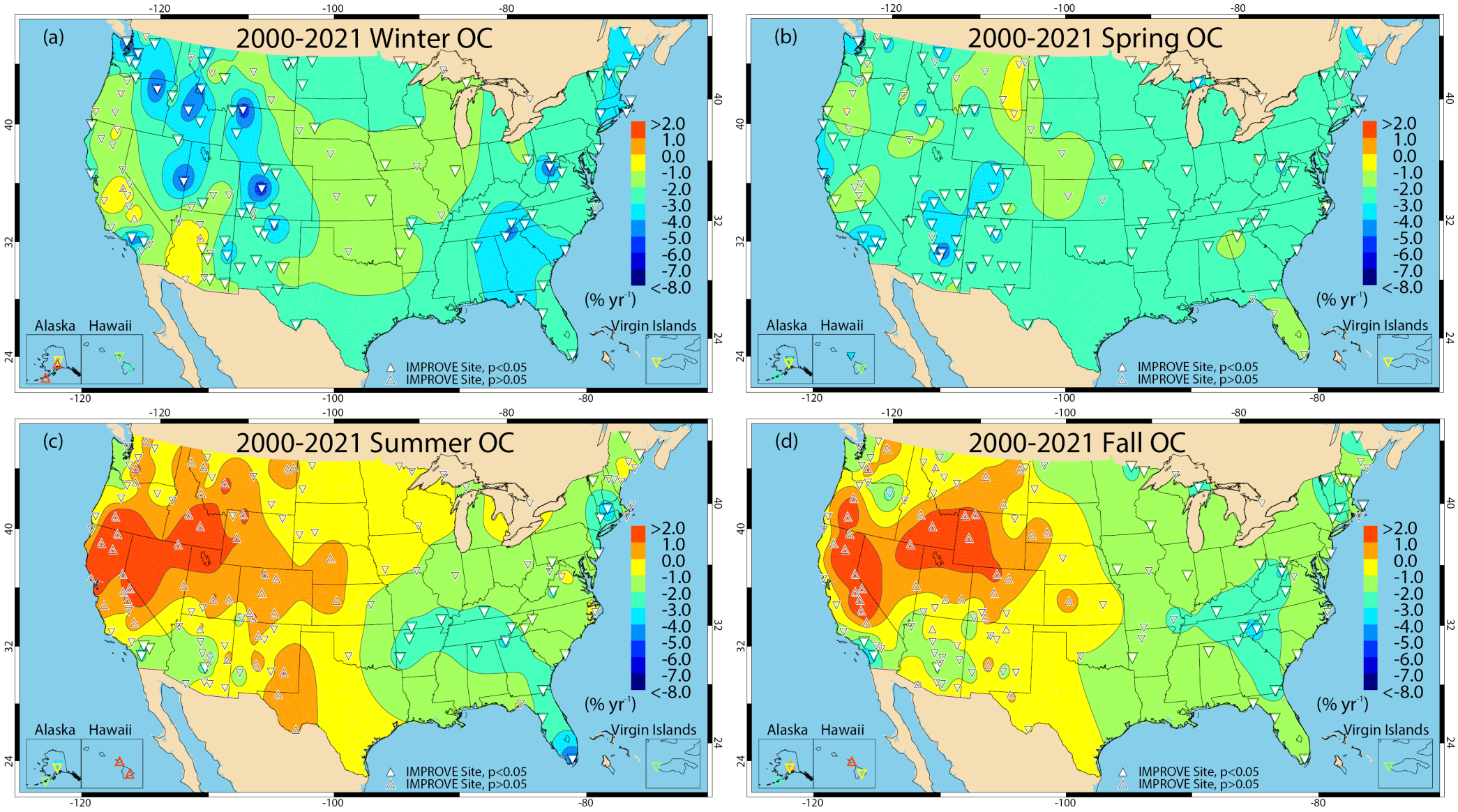




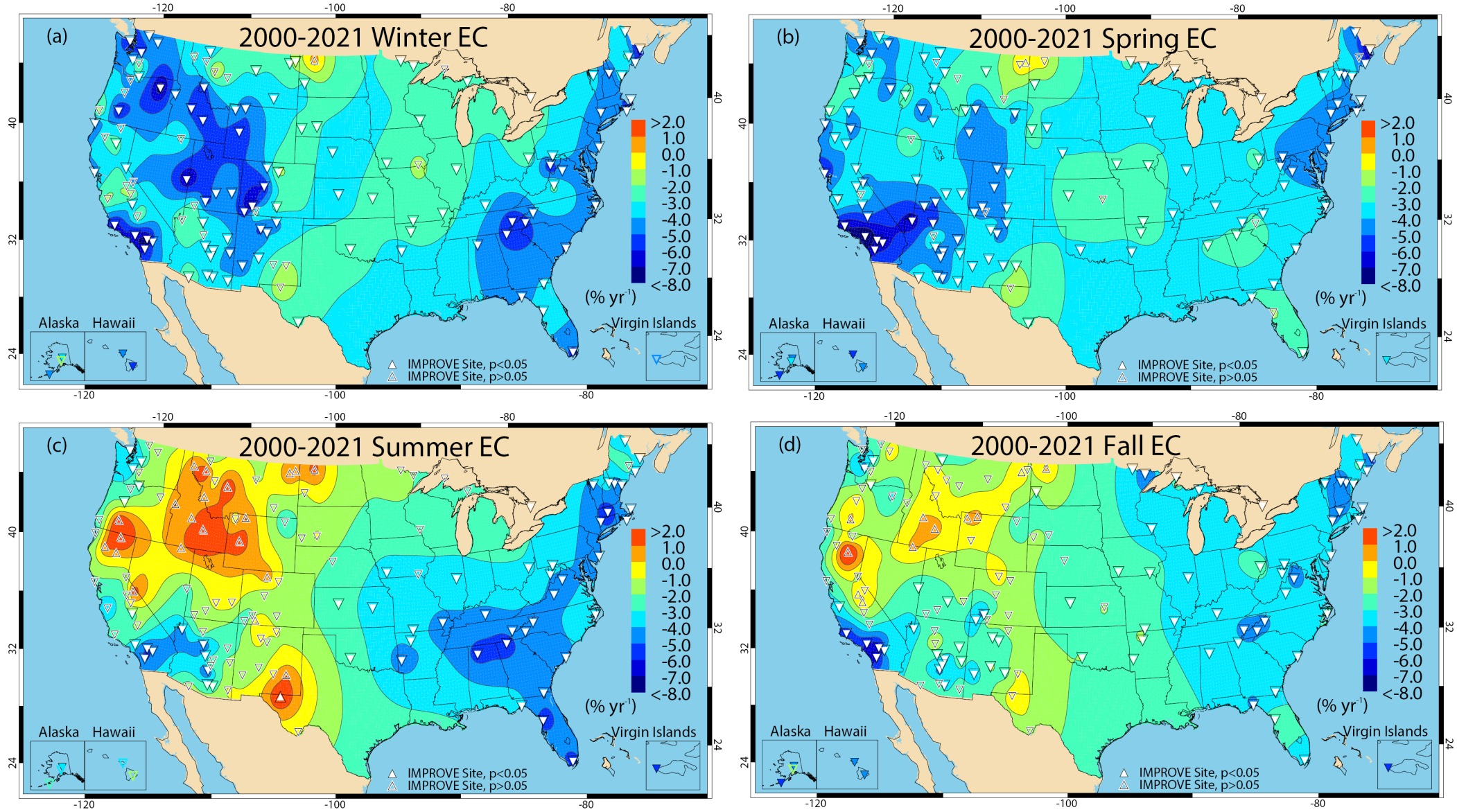




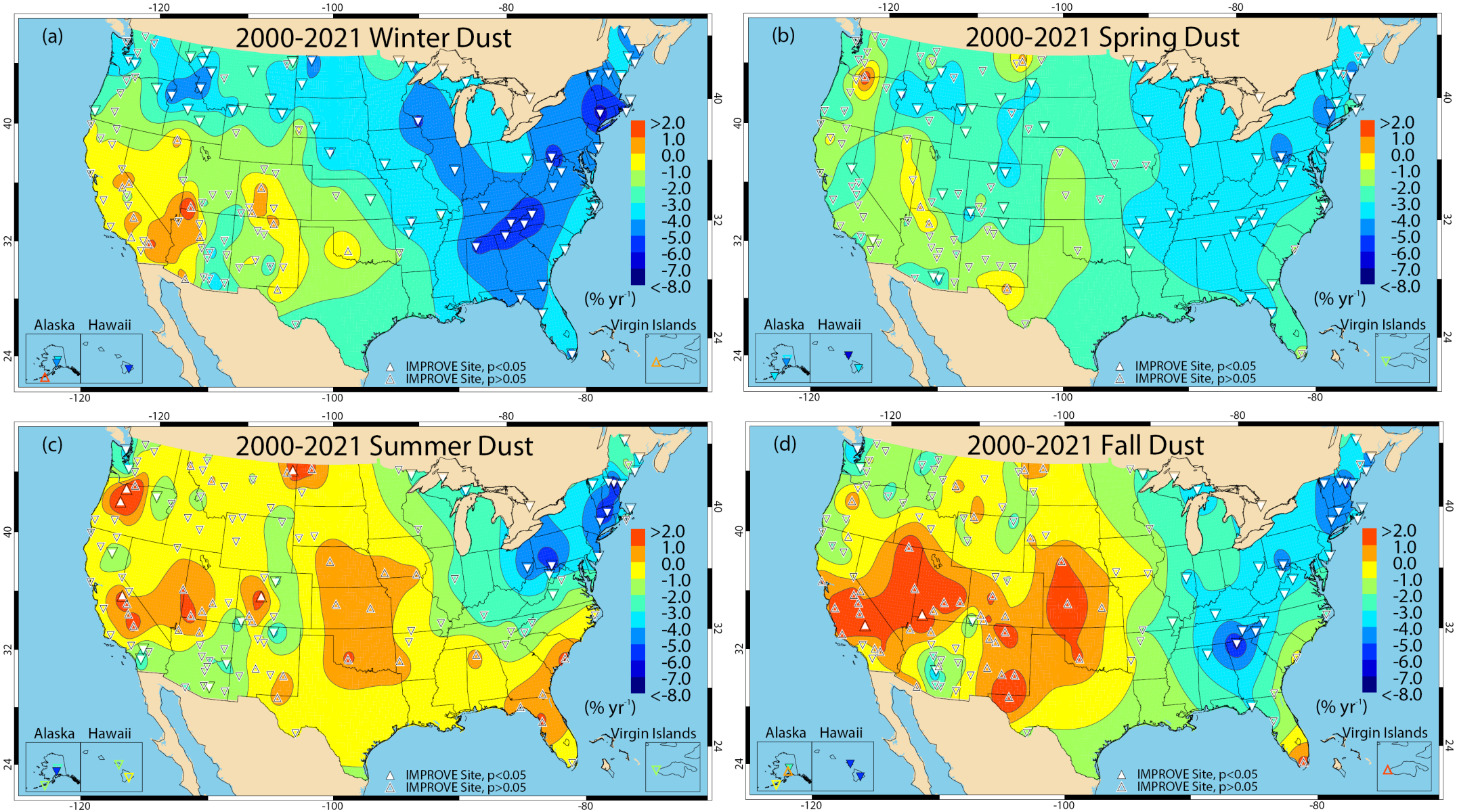
2000-2021 Seasonal Mean Organic Carbon Trends



2000-2021 Seasonal Mean Elemental Carbon Trends



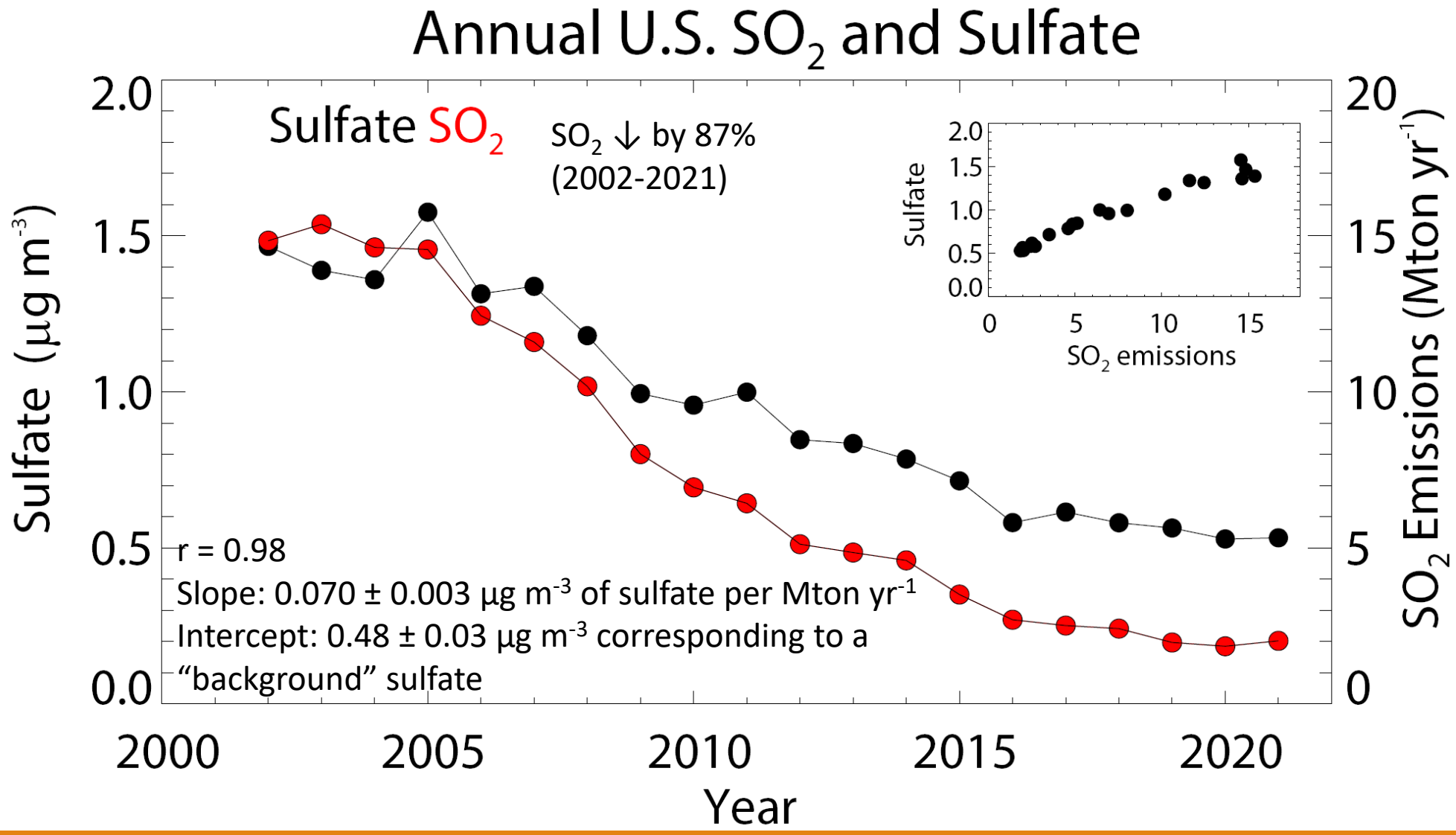
2000-2021 Seasonal Mean Fine Dust Trends



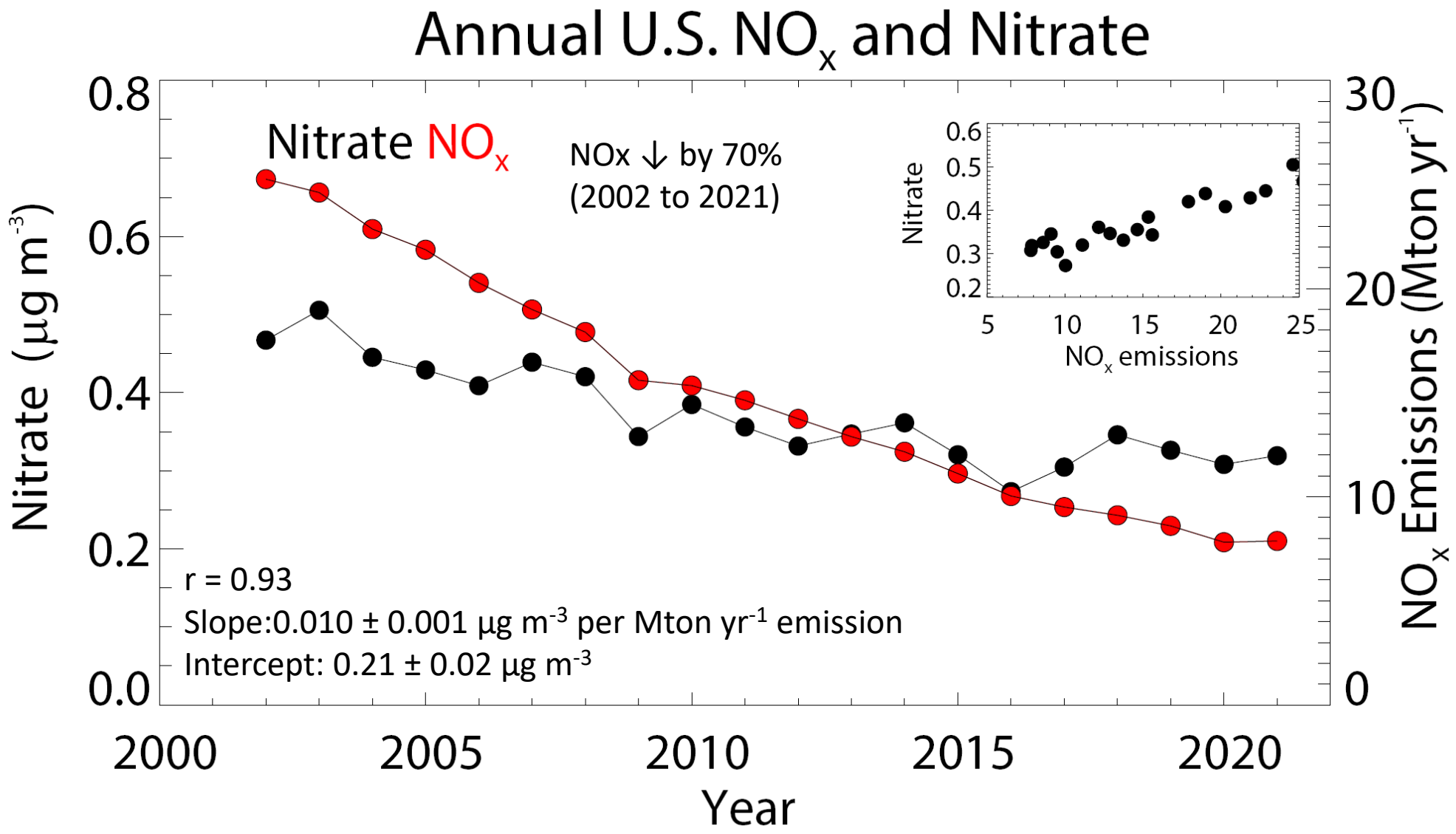
How do these trends reflect changes in emissions?

- EPA National Emission Inventory emissions: SO_2, NO_x, VOC
- NIFC Burn Area
- Large-scale climate variability

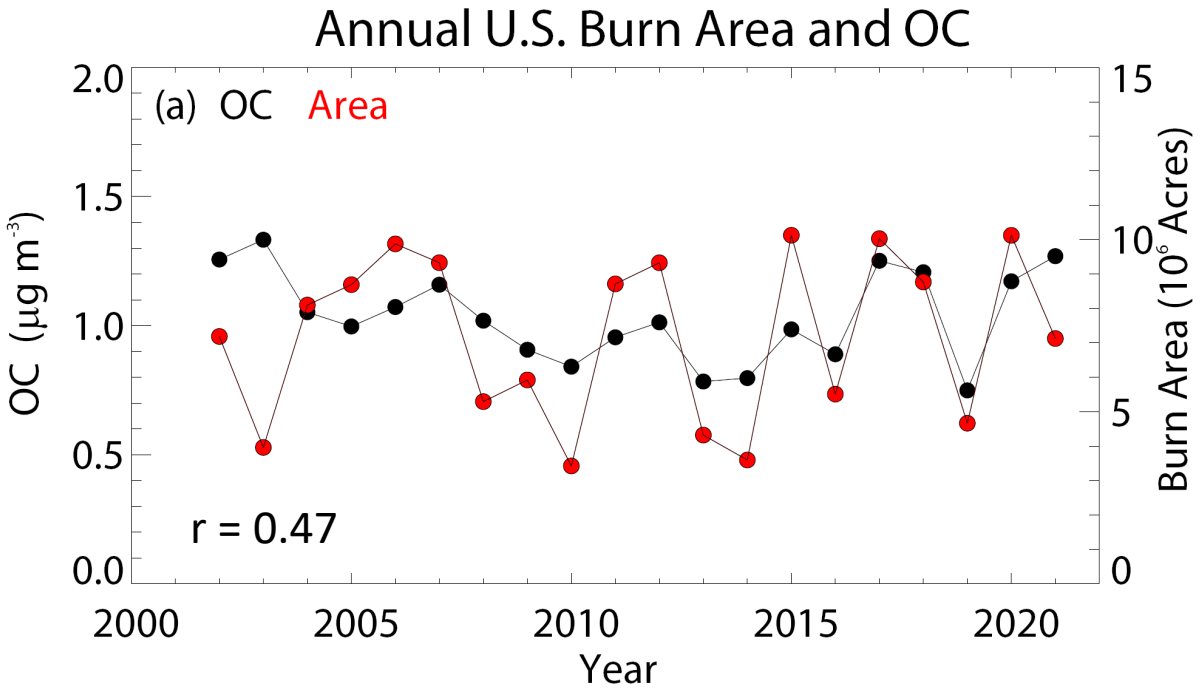
Total U.S. SO_2 Emissions and Annual Mean Sulfate



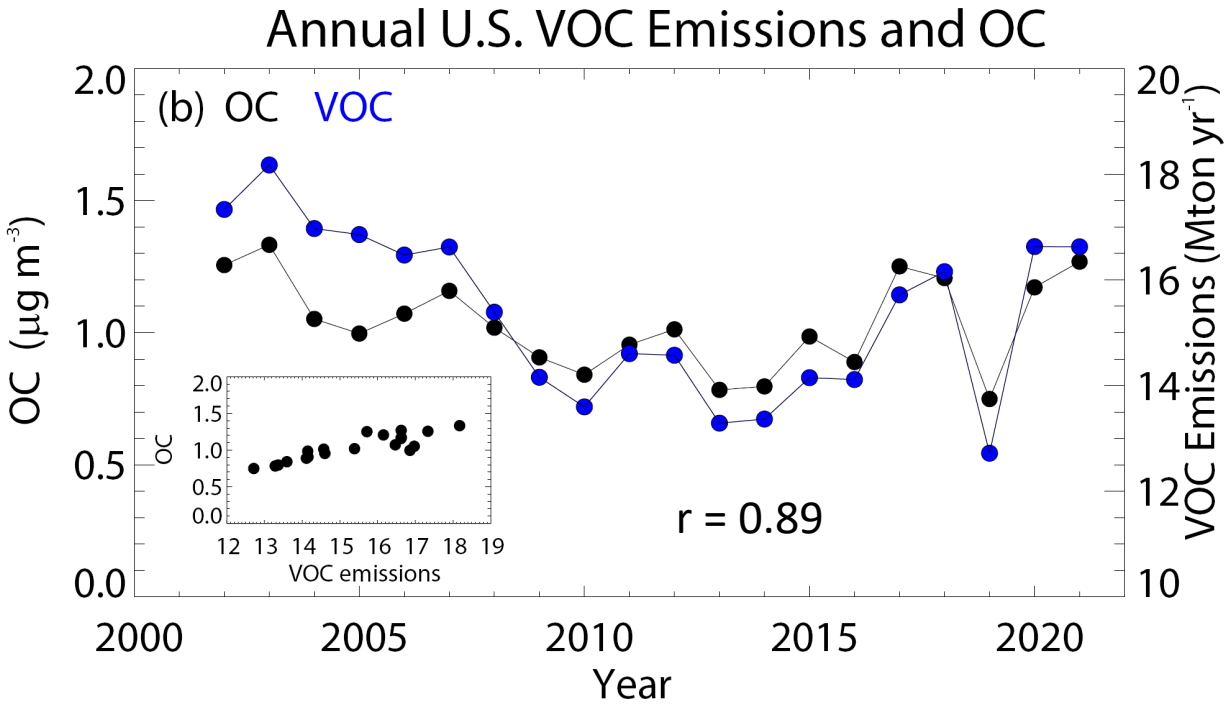
Total U.S. NO_x Emissions and Annual Mean Nitrate



Total U.S. Wildfire Burn Area and VOC Emissions and Annual Mean OC



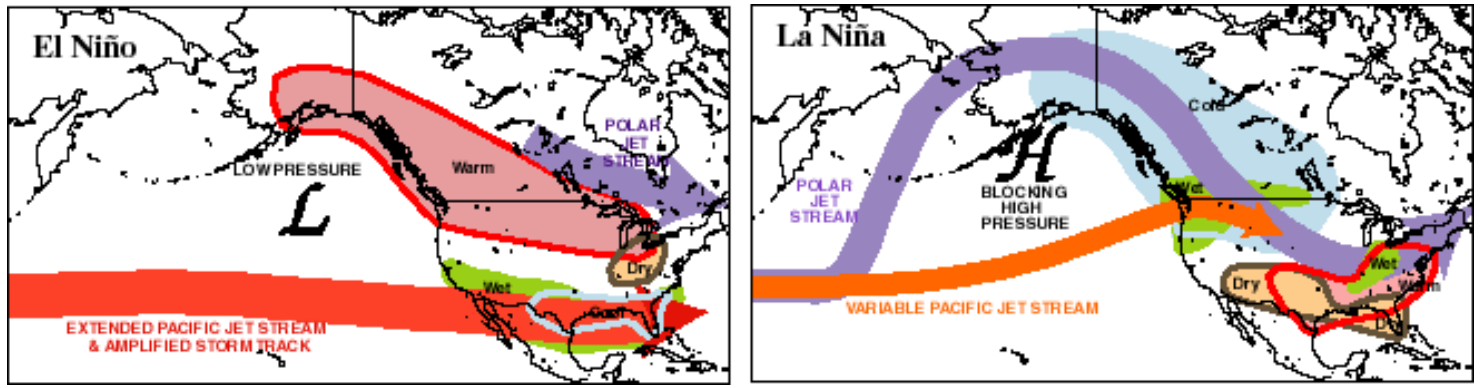
Burn area includes contributions from the entire U.S. and not all OC is due to fire emissions



The fraction of VOC emissions due to wildfires has increased over the last two decades, from 8% in 2002 to 28% in 2021.

Large-Scale Climate Variability

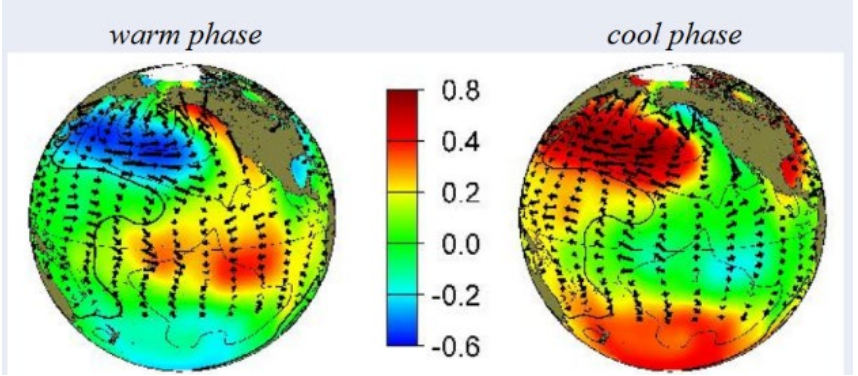
ENSO (El Niño Southern Oscillation)



http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

El Niño: westerly flow shifts southward- storms that travel this branch tap into moisture at low latitudes of the eastern Pacific and bring winter precipitation to the Southwest (SW).
La Niña: Typical flow (northward) resulting in warmer and dryer conditions over the SW (Sheppard et al. 2002).

Pacific Decadal Oscillation (PDO)

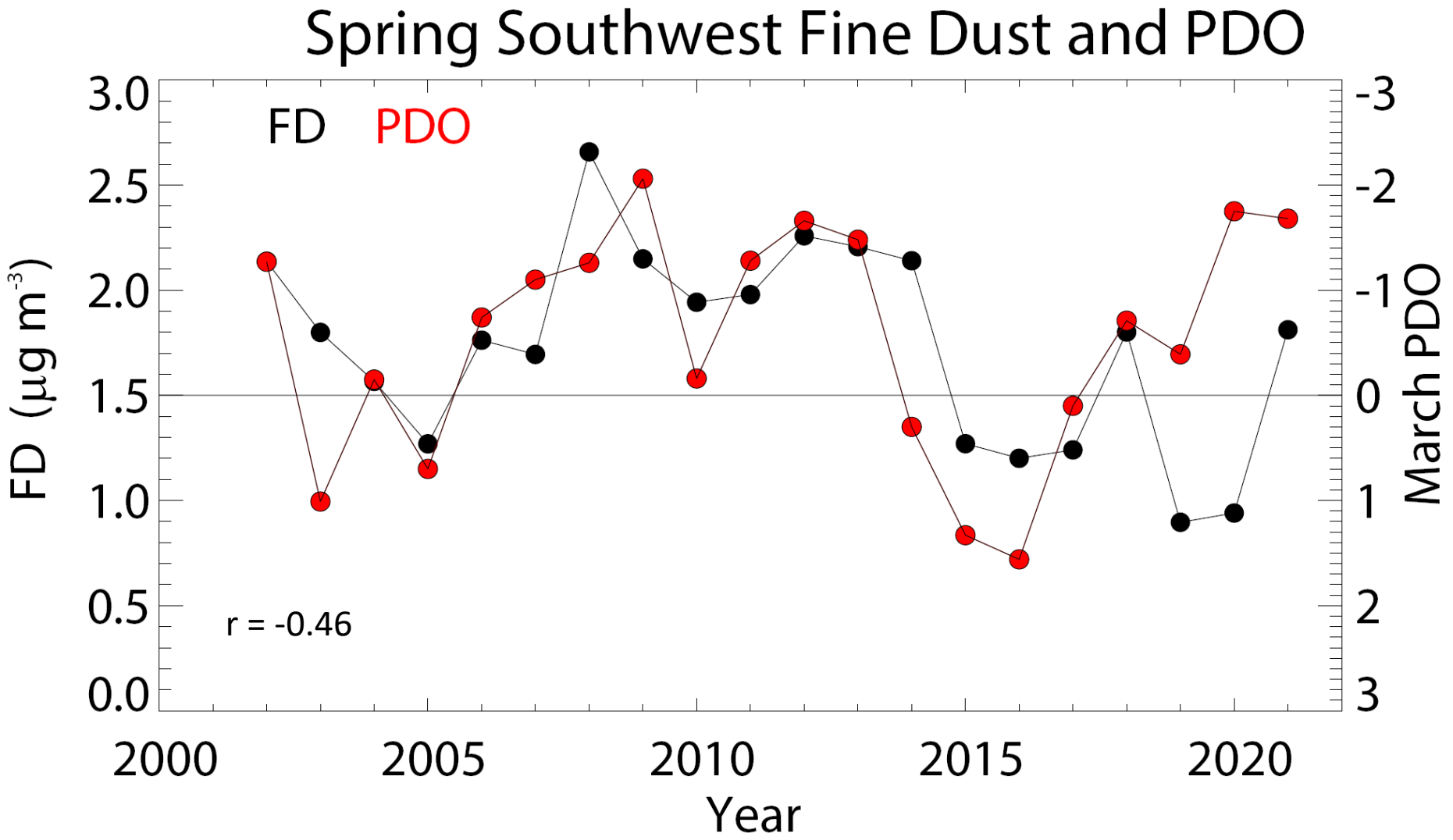


Wintertime SST (colors), SLP (contour) surface windstress (arrows)

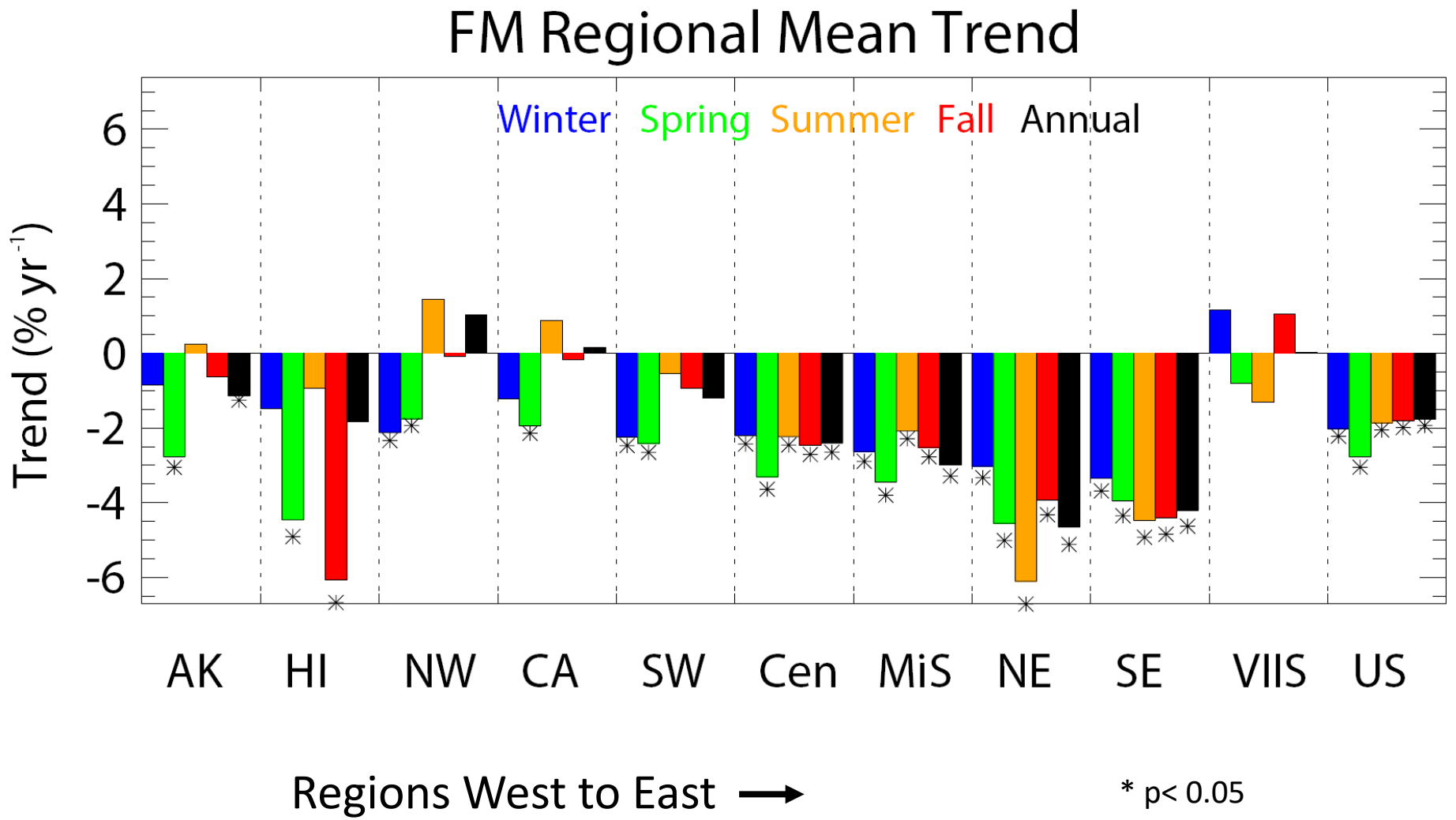
Pacific Decadal Oscillation (PDO): leading principal component of monthly SST anomalies in north Pacific Ocean (poleward of 20N) :
Negative (or cool): similar impacts as La Nina.

The effects of ENSO and the PDO can amplify each other, resulting in increased annual variability in precipitation over the Southwest.

Spring SW Regional Mean FD and March Pacific Decadal Oscillation (PDO)



2002-2021 Seasonal, Regional Mean Fine Mass Trends



Regions:
Alaska
Northwest
California
Southwest
Central US
Midsouth
Northeast
Southeast
Caribbean

Summary

Annual U.S. Trends (2002-2021)

FM:	**-1.8% yr^{-1}***
Sulfate:	-6.1% yr^{-1}*
Nitrate:	-2.7% yr^{-1}*
EC:	-2.2% yr^{-1}*
FD:	-1.3% yr^{-1} *
OC:	-0.9% yr^{-1}

* Statistically significant ($p<0.05$)

- Regulatory activity has been successful in reducing FM, especially in the East
- Unregulated anthropogenic emissions, such as oil and gas and agricultural emissions, are likely influencing FM trends
- Impacts from natural sources- such as dust and smoke- are likely going to increase with climate change

Acknowledgments

Funding:

NPS Air Resources Division

Data:

IMPROVE

(http://views.cira.colostate.edu/fed/)

EPA National Emissions Inventory (NEI)

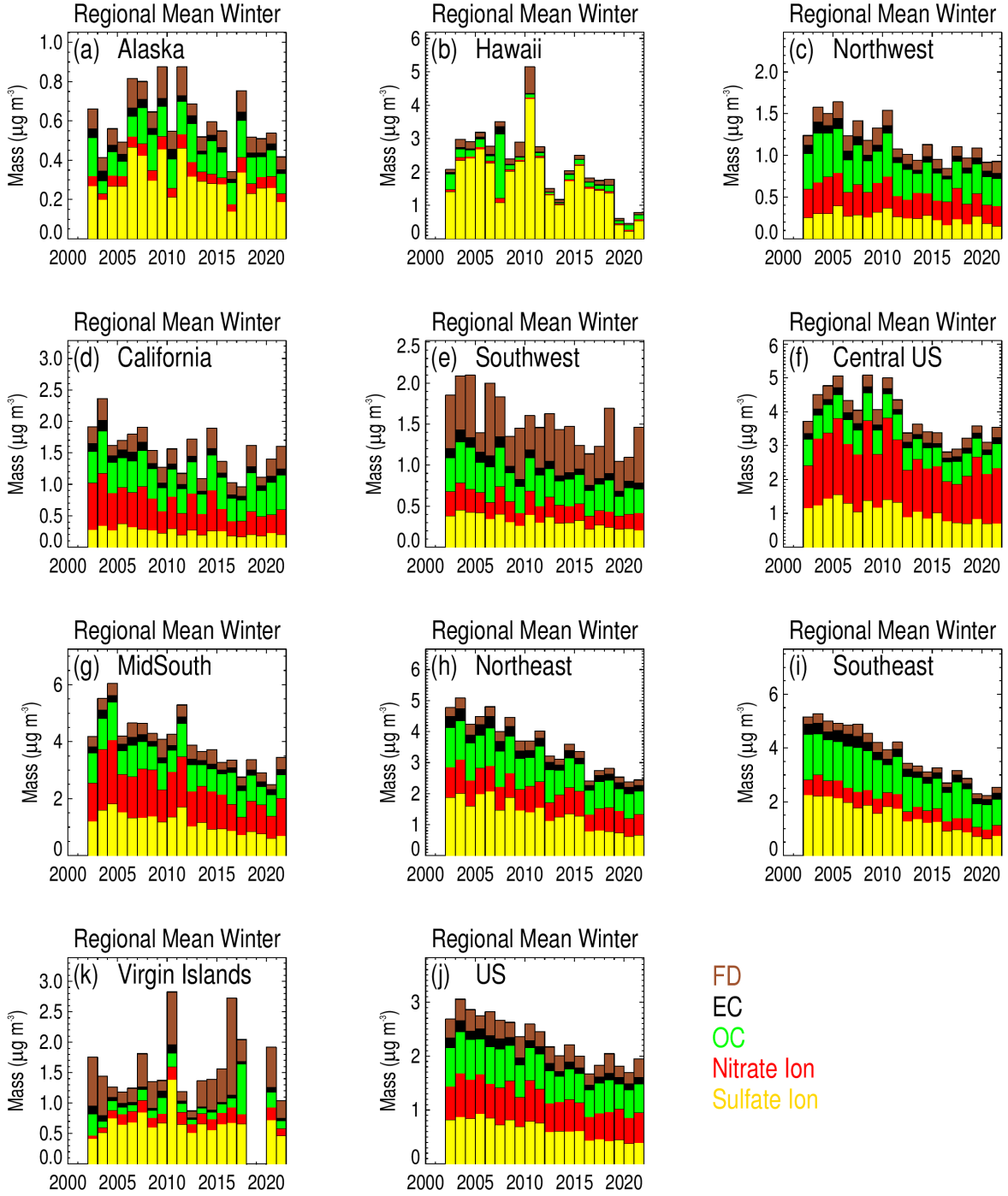
(https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data)

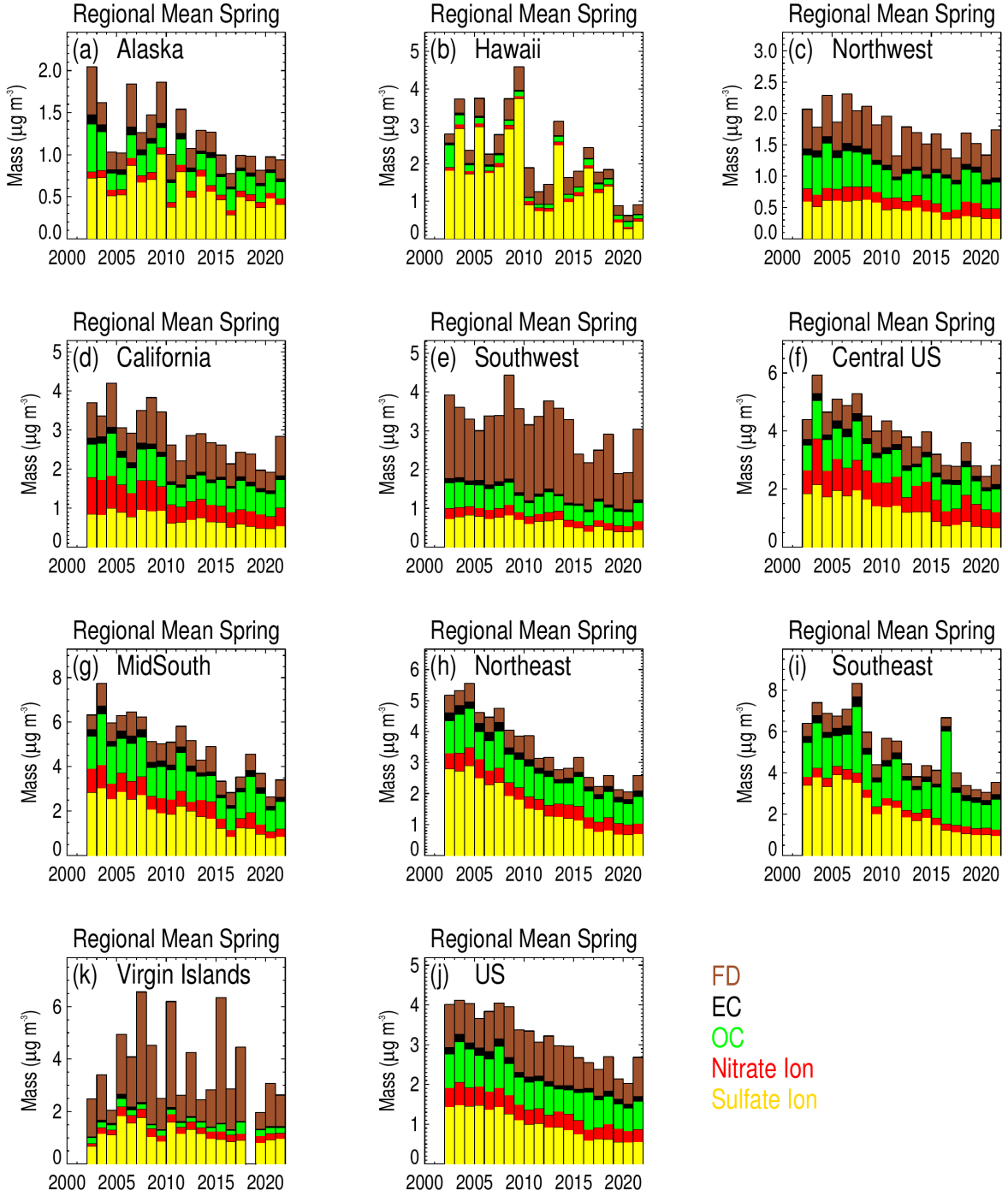
NIFC National Interagency Fire Center

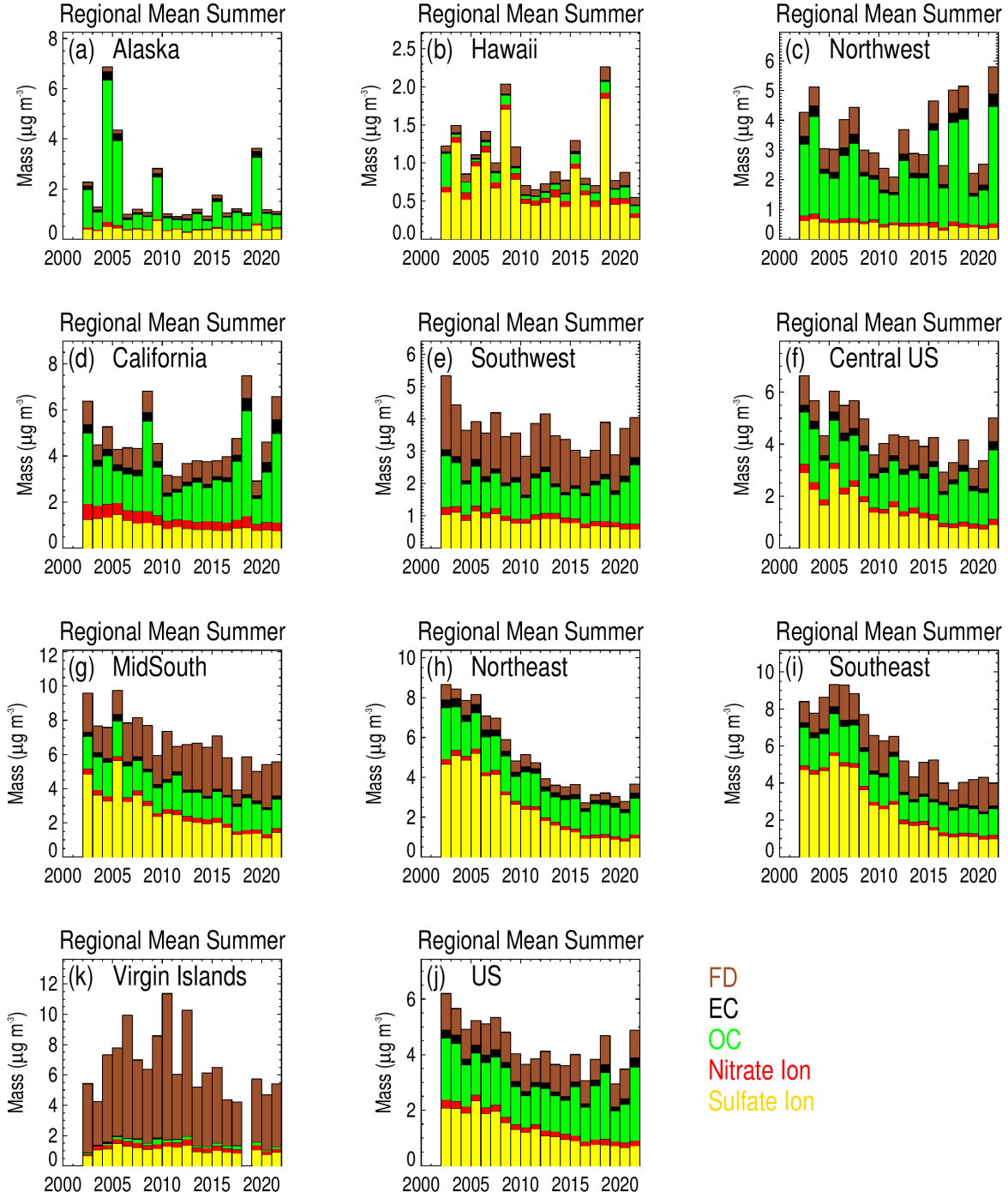
(https://www.nifc.gov/fire-information/statistics/wildfires)

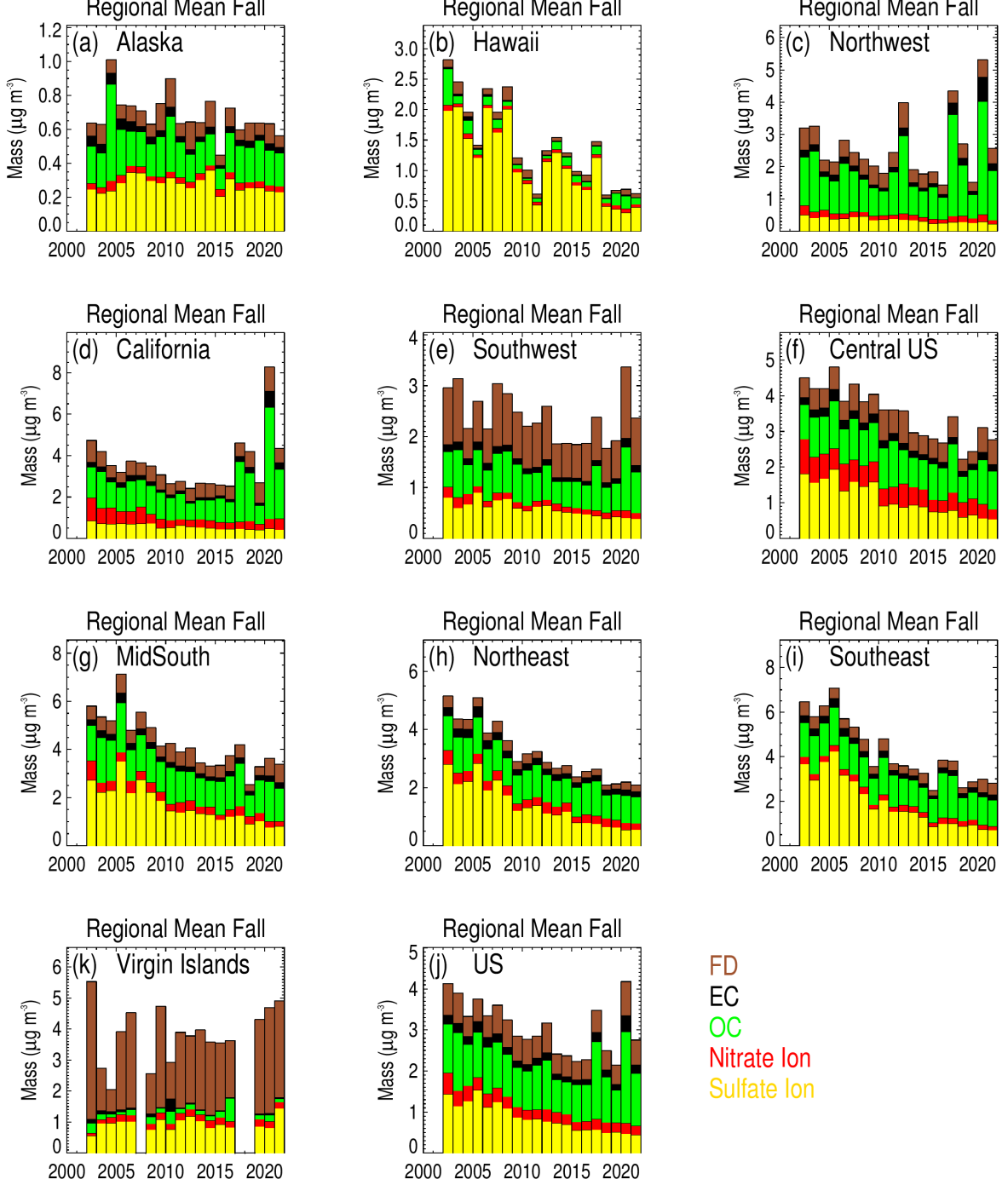
NOAA National Centers for Environmental Information (NCEI)

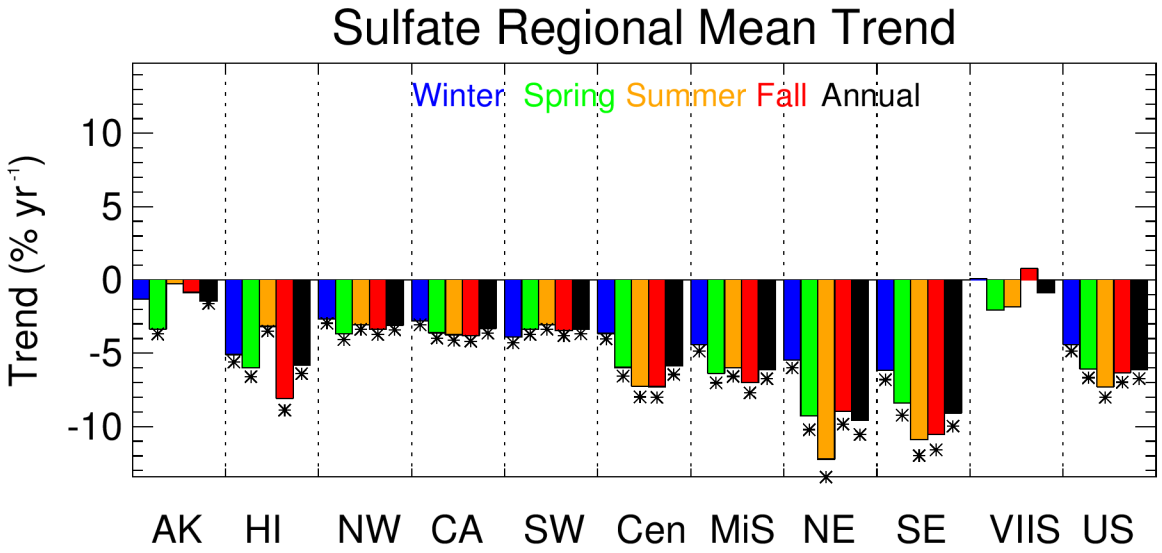
(https://www.ncei.noaa.gov/access/monitoring/pdo/).

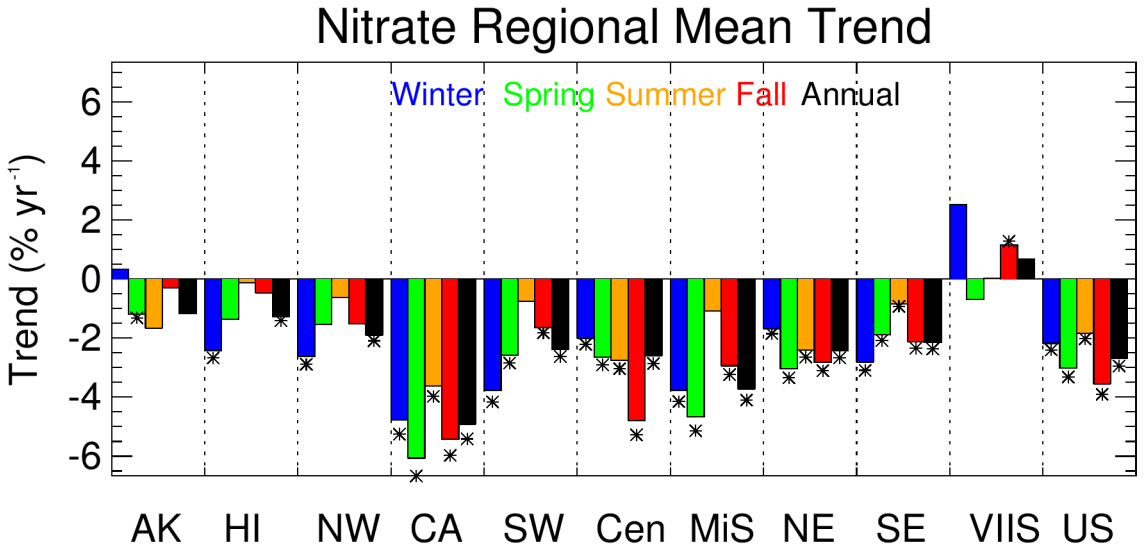

Regional Mean Winter
(a) Alaska
(b) Hawaii
(c) Northwest
(d) California
(e) Southwest
(f) Central US
(g) MidSouth
(h) Northeast
(i) Southeast
(k) Virgin Islands
(j) US
Mass (µg m-3)
2000 2005 2010 2015 2020
FD
EC
OC
Nitrate Ion
Sulfate Ion

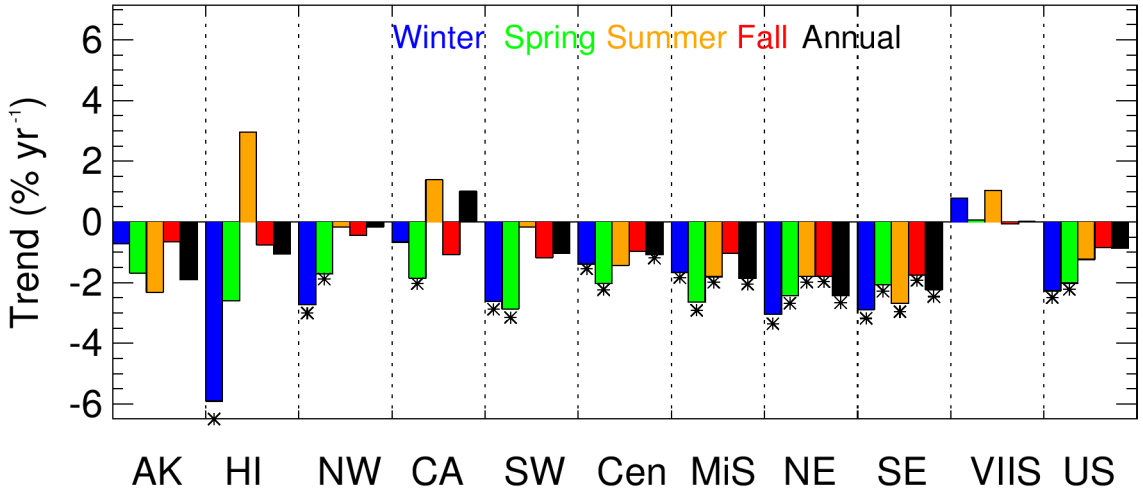

Regional Mean Spring
(a) Alaska
(b) Hawaii
(c) Northwest
(d) California
(e) Southwest
(f) Central US
(g) MidSouth
(h) Northeast
(i) Southeast
(k) Virgin Islands
(j) US
Mass (µg m-3)
2000 2005 2010 2015 2020
FD
EC
OC
Nitrate Ion
Sulfate Ion

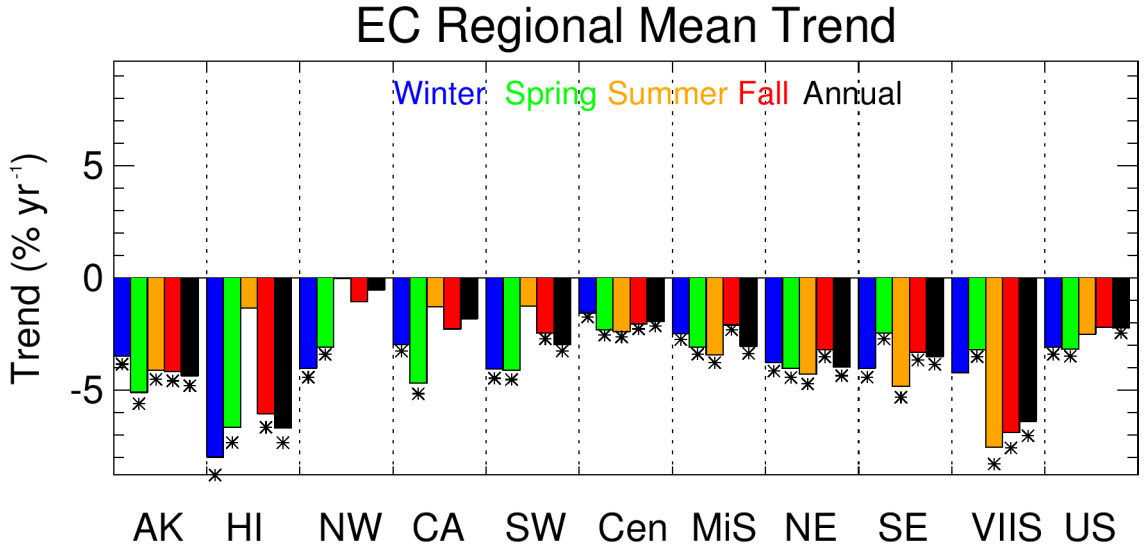

Regional Mean Summer
(a) Alaska
(b) Hawaii
(c) Northwest
(d) California
(e) Southwest
(f) Central US
(g) MidSouth
(h) Northeast
(i) Southeast
(k) Virgin Islands
(j) US
Mass (µg m-3)
2000 2005 2010 2015 2020
FD
EC
OC
Nitrate Ion
Sulfate Ion

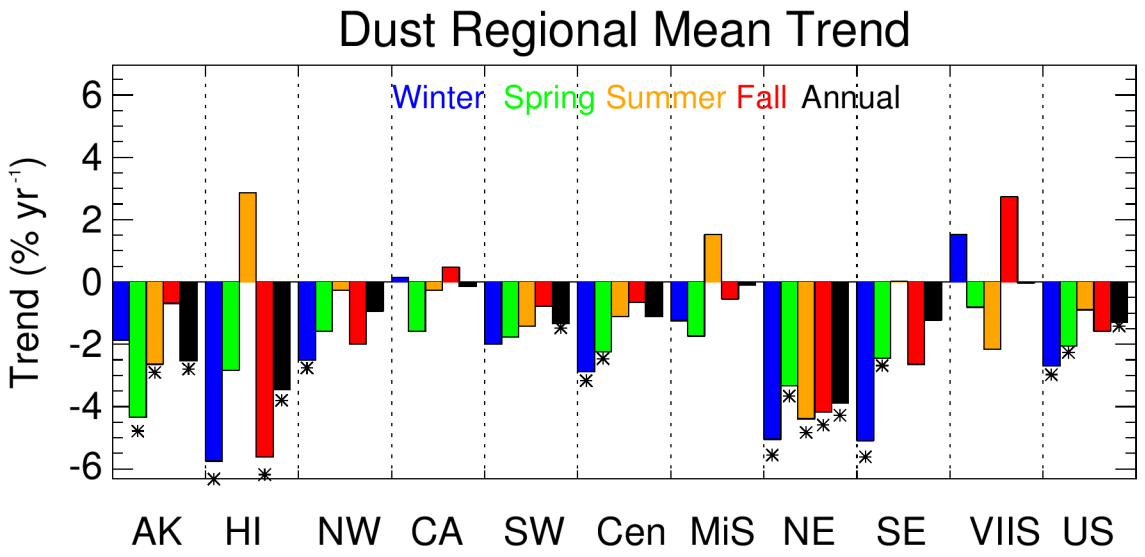

Regional Mean Fall
(a) Alaska
(b) Hawaii
(c) Northwest
(d) California
(e) Southwest
(f) Central US
(g) MidSouth
(h) Northeast
(i) Southeast
(k) Virgin Islands
(j) US
Mass (µg m-3)
2000 2005 2010 2015 2020
FD
EC
OC
Nitrate Ion
Sulfate Ion

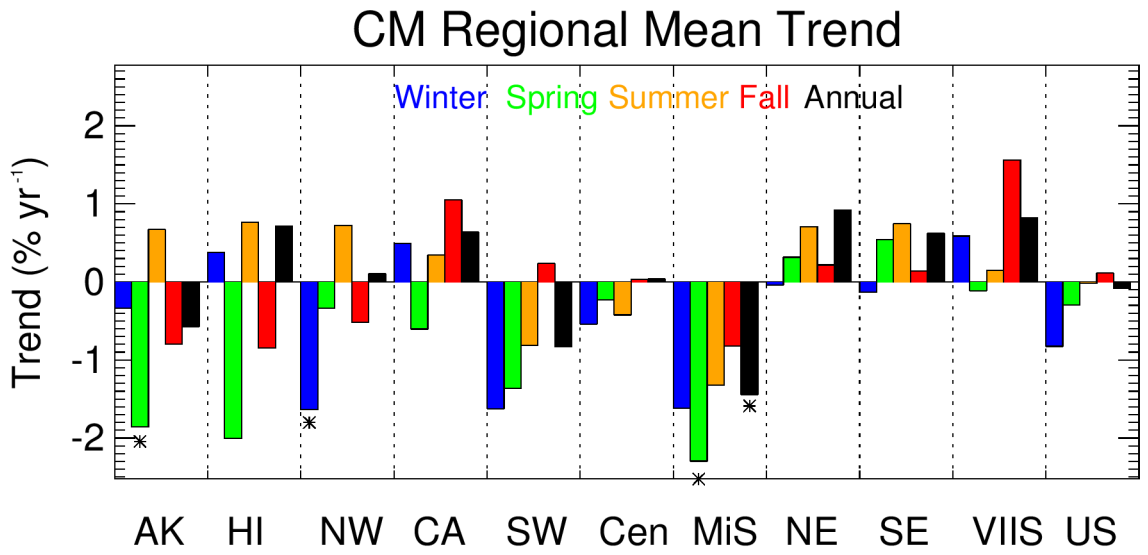

Sulfate Regional Mean Trend
Winter Spring Summer Fall Annual
Trend (% yr-1)
10
5
0
-5
-10
AK HI NW CA SW Cen MiS NE SE VIIS US


Nitrate Regional Mean Trend
Winter Spring Summer Fall Annual
Trend (% yr-1)
6
4
2
0
-2
-4
-6
AK HI NW CA SW Cen MiS NE SE VIIS US


OC Regional Mean Trend
Winter Spring Summer Fall Annual
Trend (% yr-1)
6
4
2
0
-2
-4
-6
AK HI NW CA SW Cen MiS NE SE VIIS US


EC Regional Mean Trend
Winter Spring Summer Fall Annual
Trend (% yr-1)
5
0
-5
AK HI NW CA SW Cen MiS NE SE VIIS US


Dust Regional Mean Trend
Winter Spring Summer Fall Annual
Trend (% yr-1)
6
4
2
0
-2
-4
-6
AK HI NW CA SW Cen MiS NE SE VIIS US


CM Regional Mean Trend
Winter Spring Summer Fall Annual
Trend (% yr-1)
2
1
0
-1
-2
AK HI NW CA SW Cen MiS NE SE VIIS US