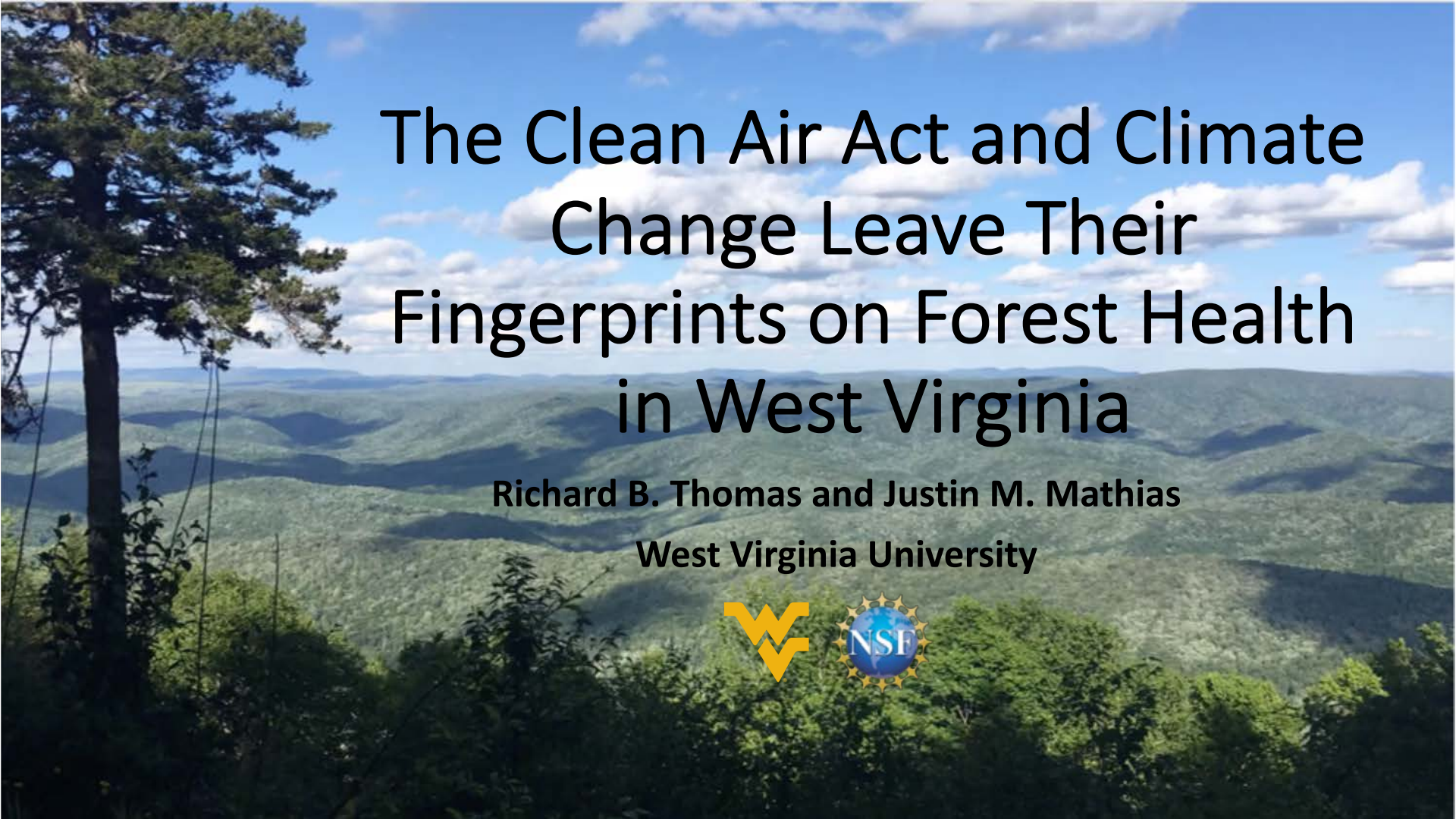


The Clean Air Act and Climate Change Leave Their Fingerprints on Forest Health in West Virginia

Richard B. Thomas and Justin M. Mathias

West Virginia University


West Virginia Wild and Wonderful
Nature, Wildlife, Hunting, Fishing,
Hiking, Biking, Rock Climbing,
Camping, Leaf Watching,
Kayaking, Rafting, Photography,
Skiing, Snowboarding, Art,
Wild Cuisine & Therapeutics

Plants accumulate carbon

Ecosystem	Area (%)	C in Plants (Pg)	C in Soil (Pg)
Trop. Wet Forest	7.2	156.0	255
Trop. Dry Forest	5.3	49.7	59
Temp. Forest	6.3	73.3	142
Boreal Forest	10.3	143.0	179
Trop. Savannah.	16.9	48.8	56
Temp. Steppe	10.4	43.8	173
Desert	12.5	5.9	101
Tundra	7.5	9.0	173
Wetland	2.0	7.8	137
Cultivated	10.9	21.5	178
Total		**558.8**	**1456**

From Houghton and Skole 1990, Schlesinger 1977

Fate of Anthropogenic CO_2 Emissions (2008-2017 average)

34.4 $GtCO_2$/yr 87%

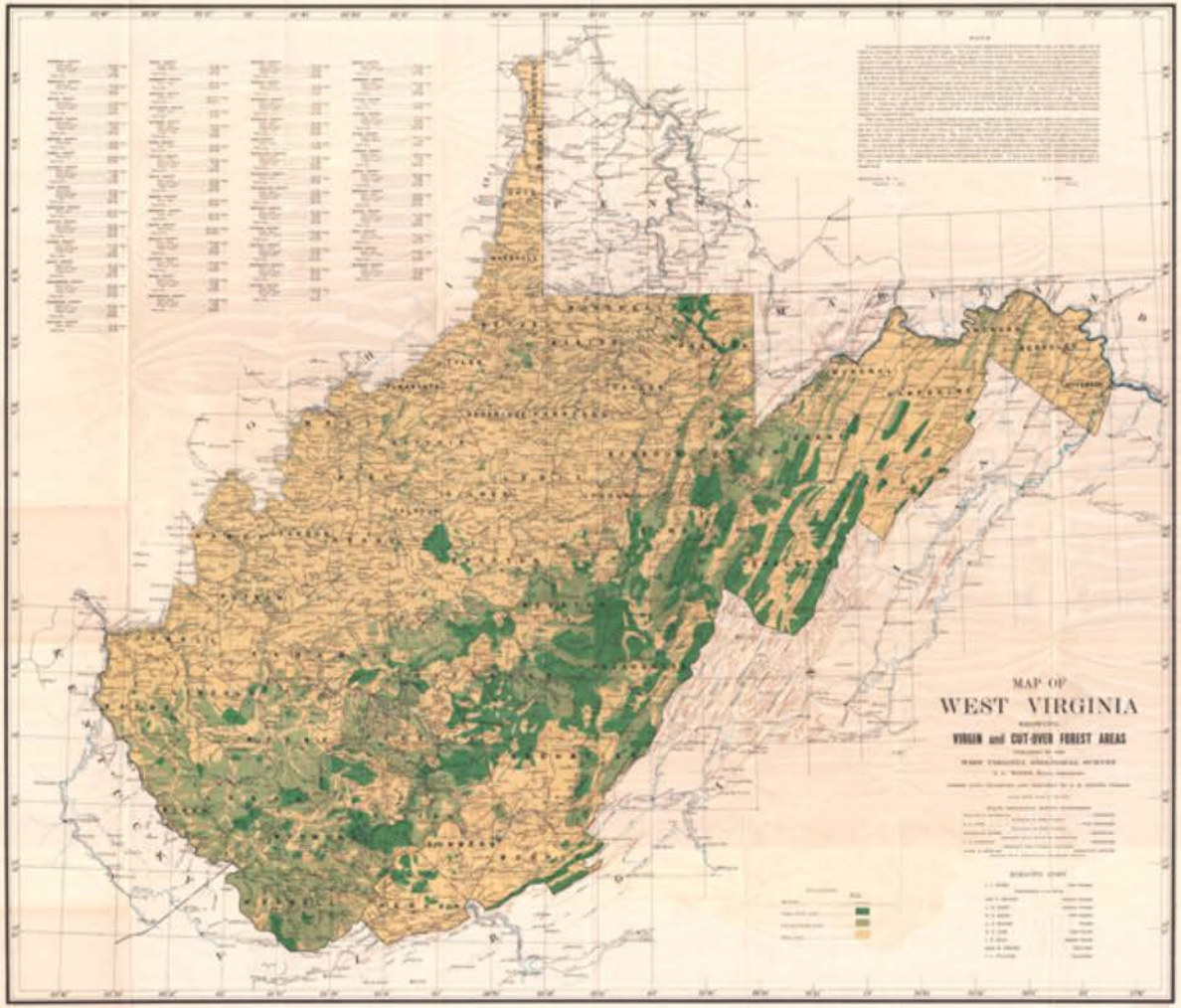
5.3 $GtCO_2$/yr 13%

17.3 $GtCO_2$/yr
44%

11.6 $GtCO_2$/yr
29%

8.9 $GtCO_2$/yr
22%

Source: CDIAC; NOAA-ESRL; Houghton and Nassikas 2017; Hansis et al 2015; Le Quéré et al 2018; Global Carbon Budget 2018



MAP OF
WEST VIRGINIA

SHOWING

VIRGIN and CUT-OVER FOREST AREAS

PUBLISHED BY THE

WEST VIRGINIA GEOLOGICAL SURVEY

I. C. WHITE, STATE GEOLOGIST

FOREST DATA COLLECTED AND PREPARED BY A. B. BROOKS, FORESTER

EXPLANATIONS

New or Additional

Railroads.....

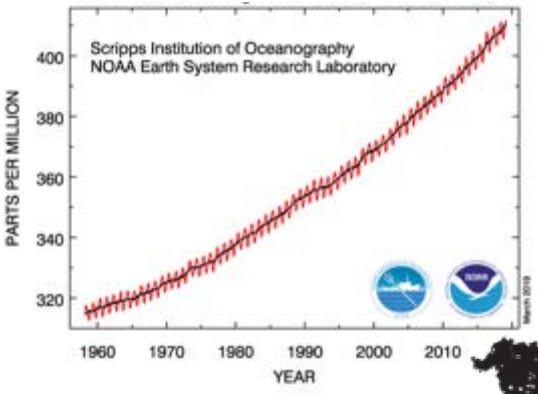
Virgin Forest Areas.....

Cut-over Forest Areas.....

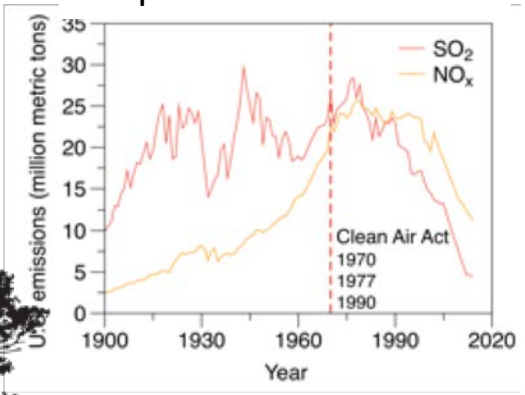
Farm Areas.....

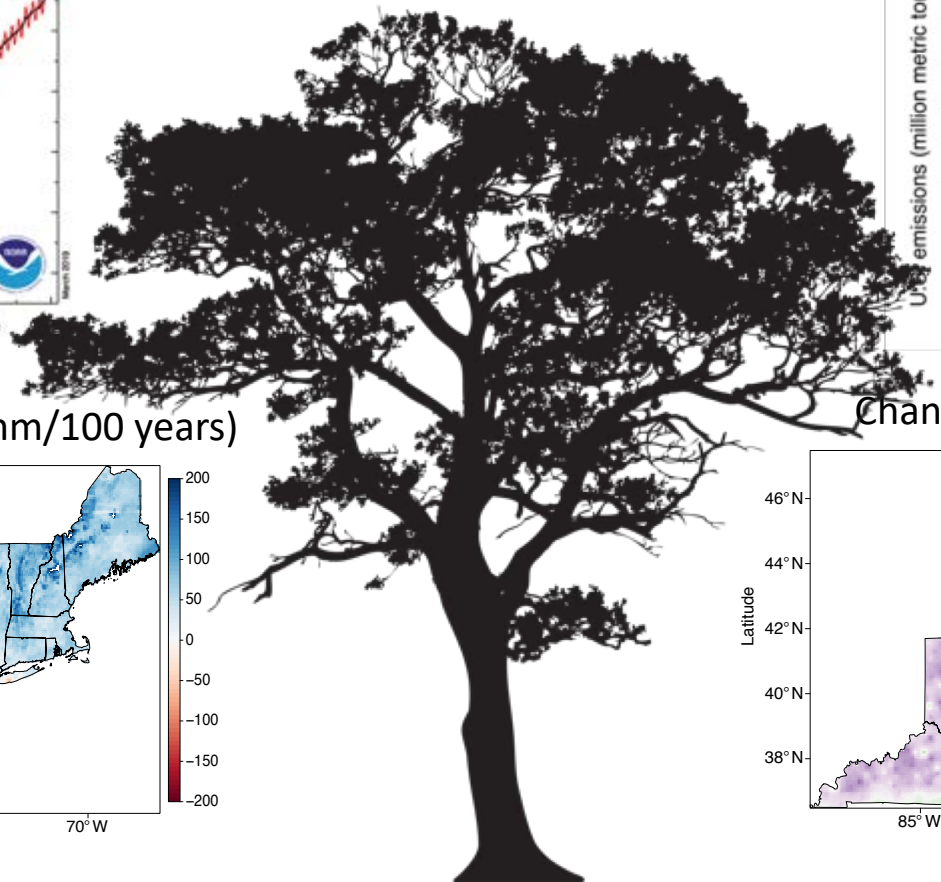
Environmental change and tree growth

Increases in atmospheric CO_2

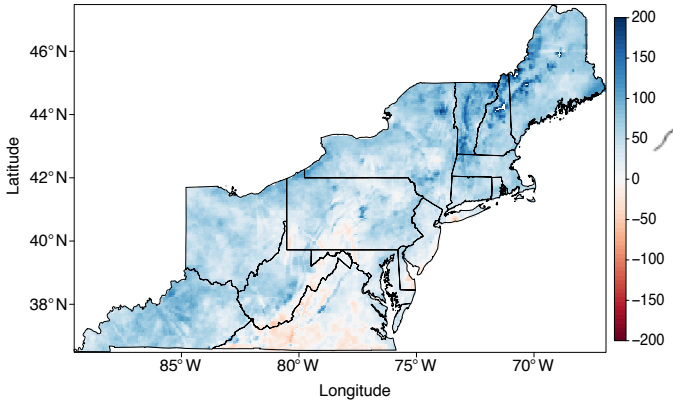


Air pollution since 1900

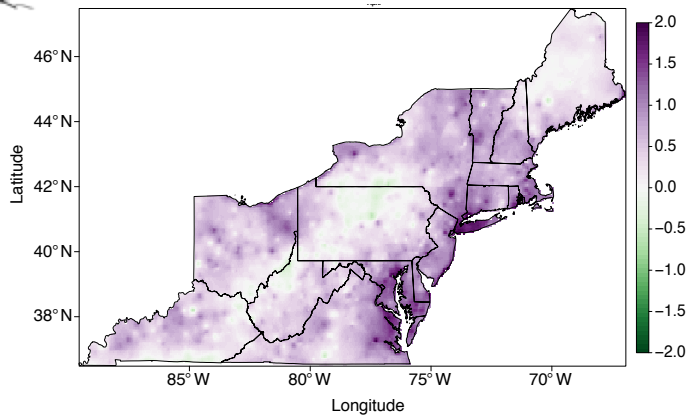


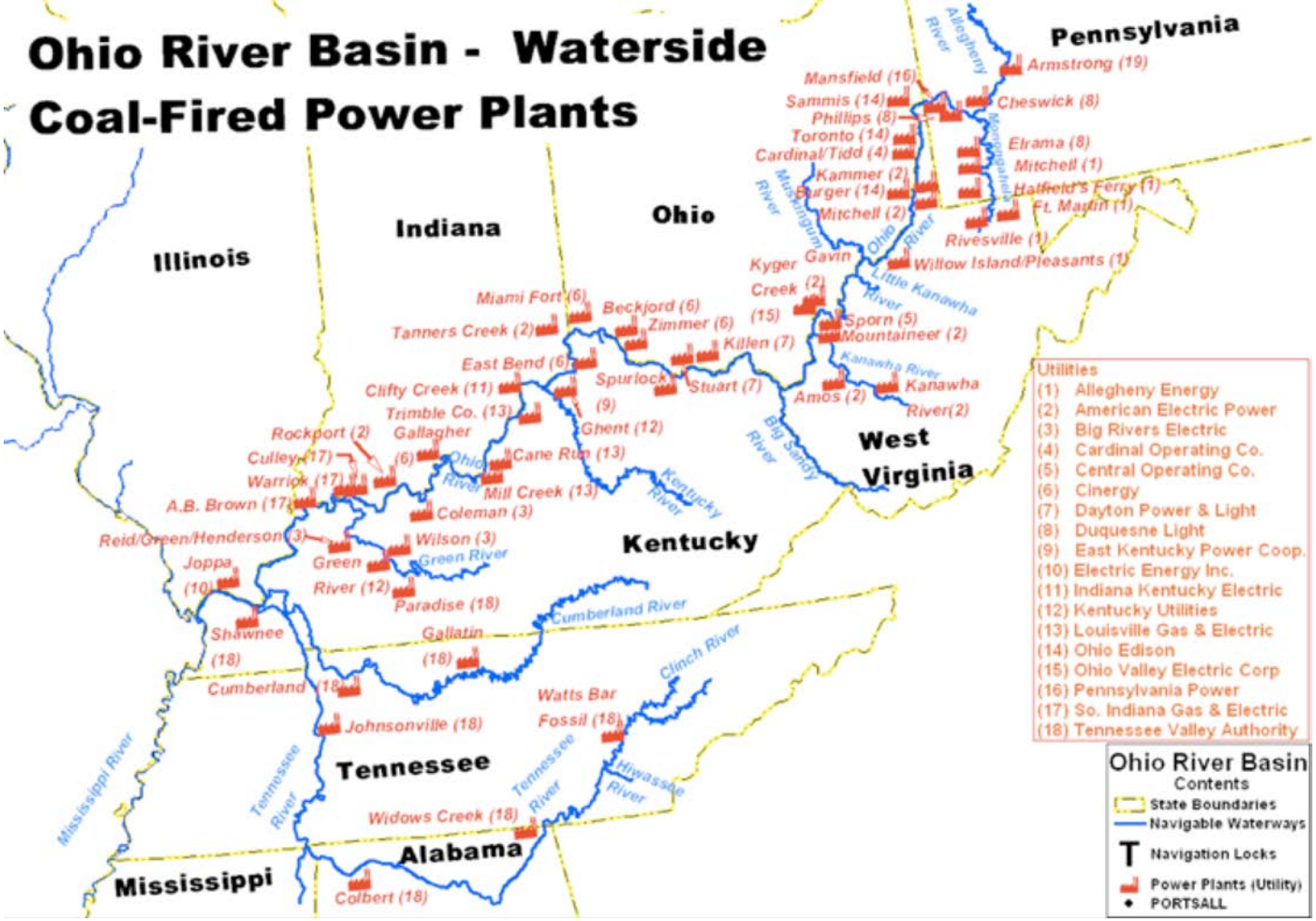


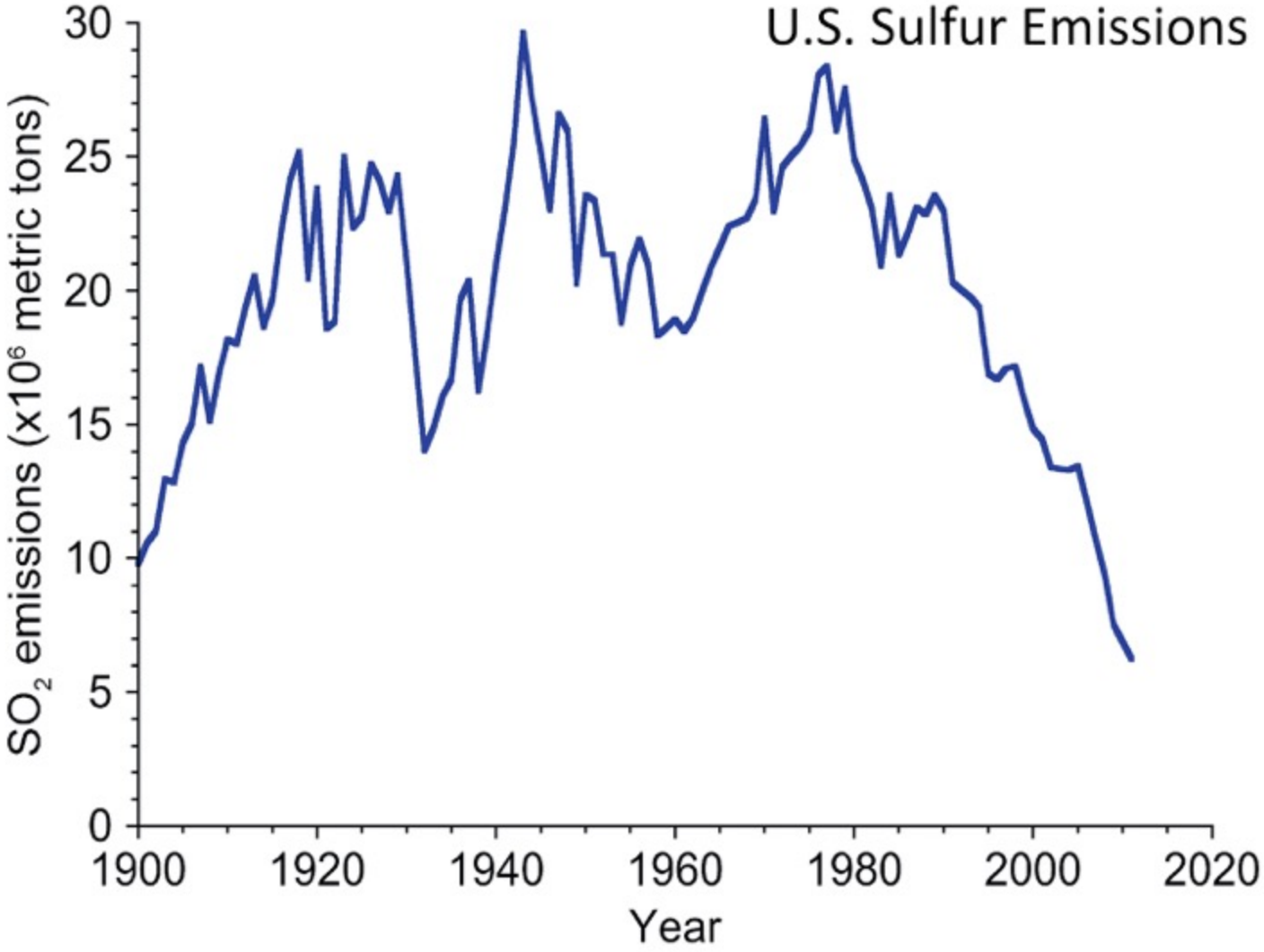
Seasonal precipitation (mm/100 years)

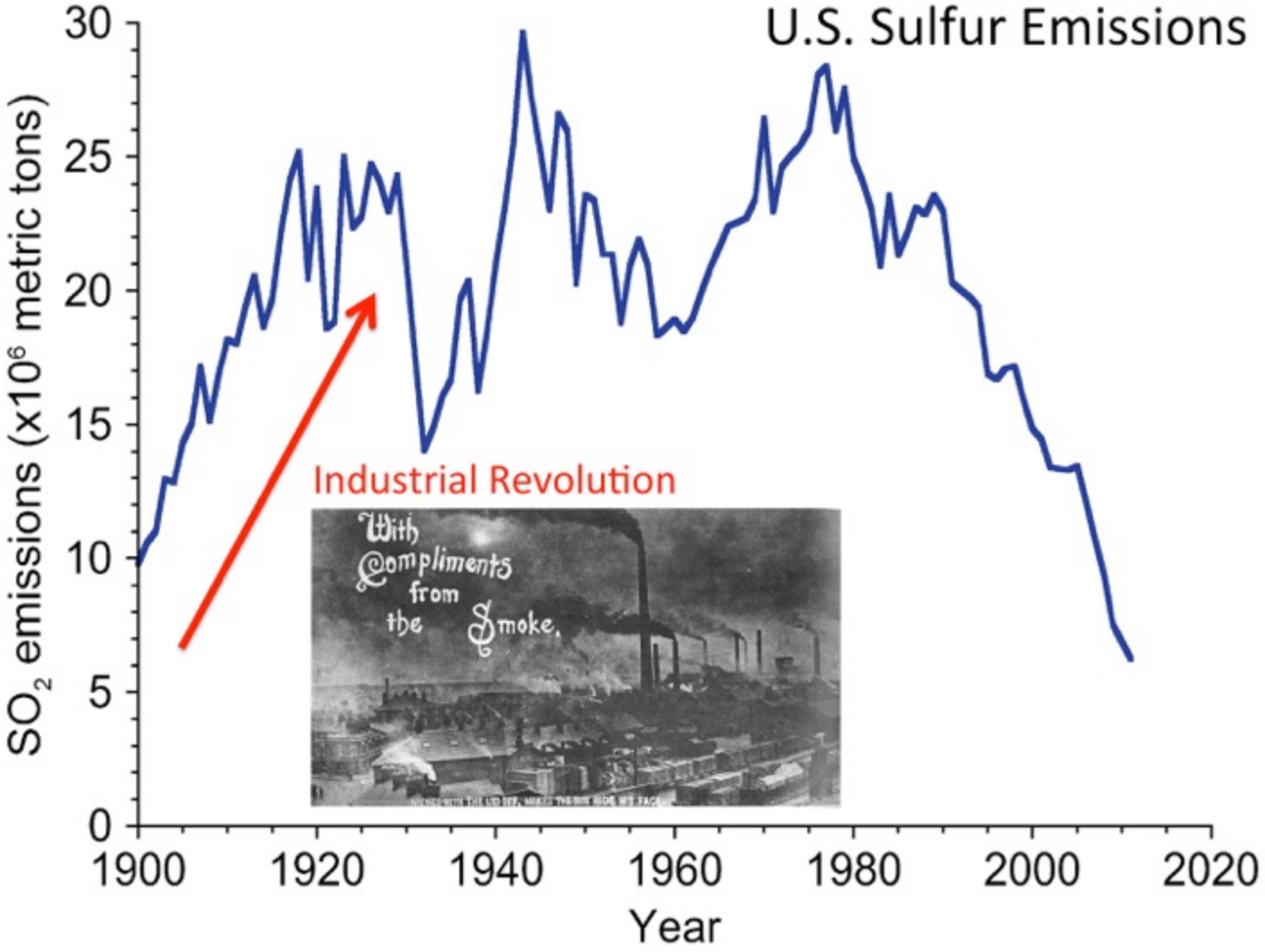


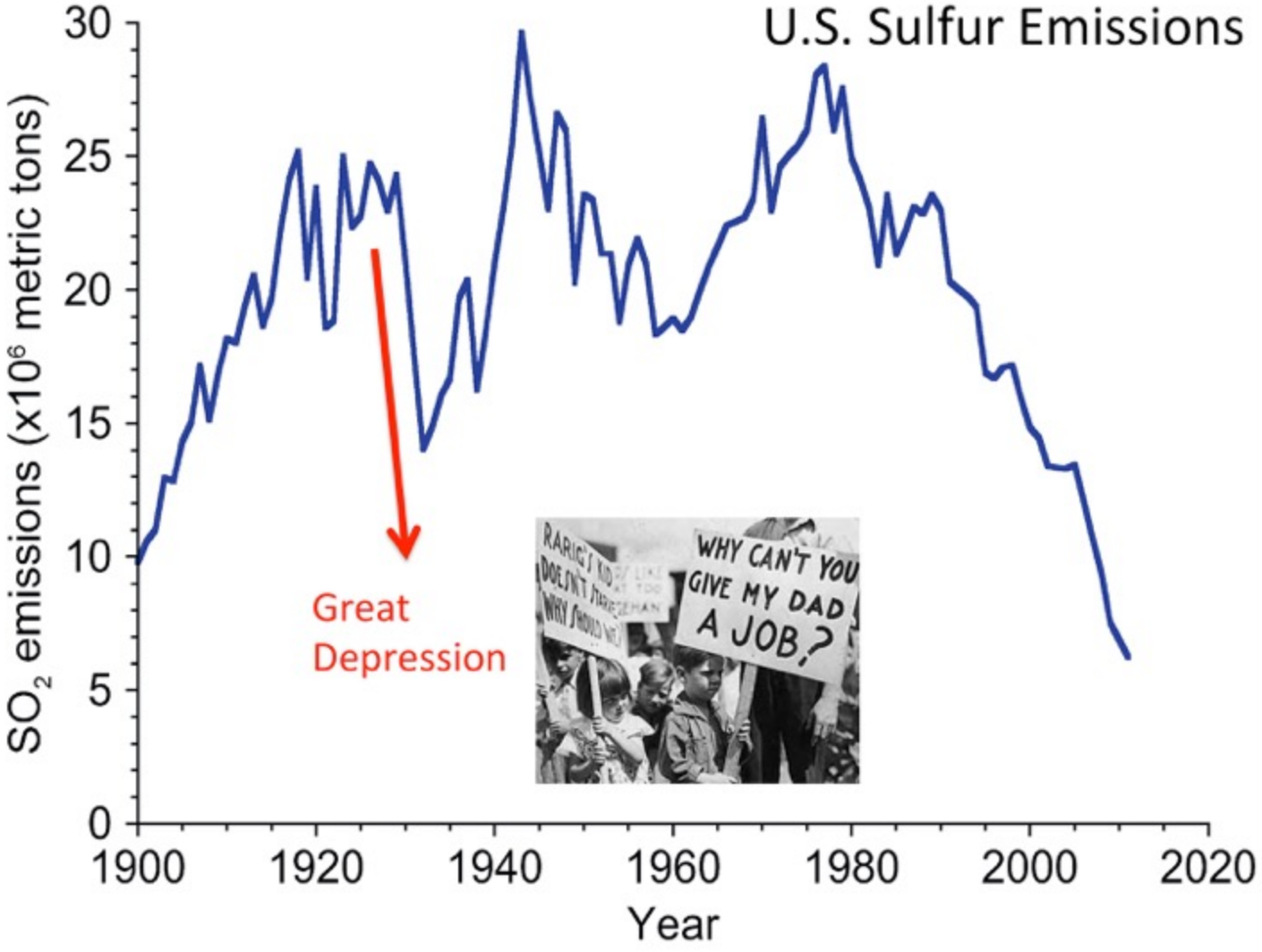
Change in April temperature (°C)

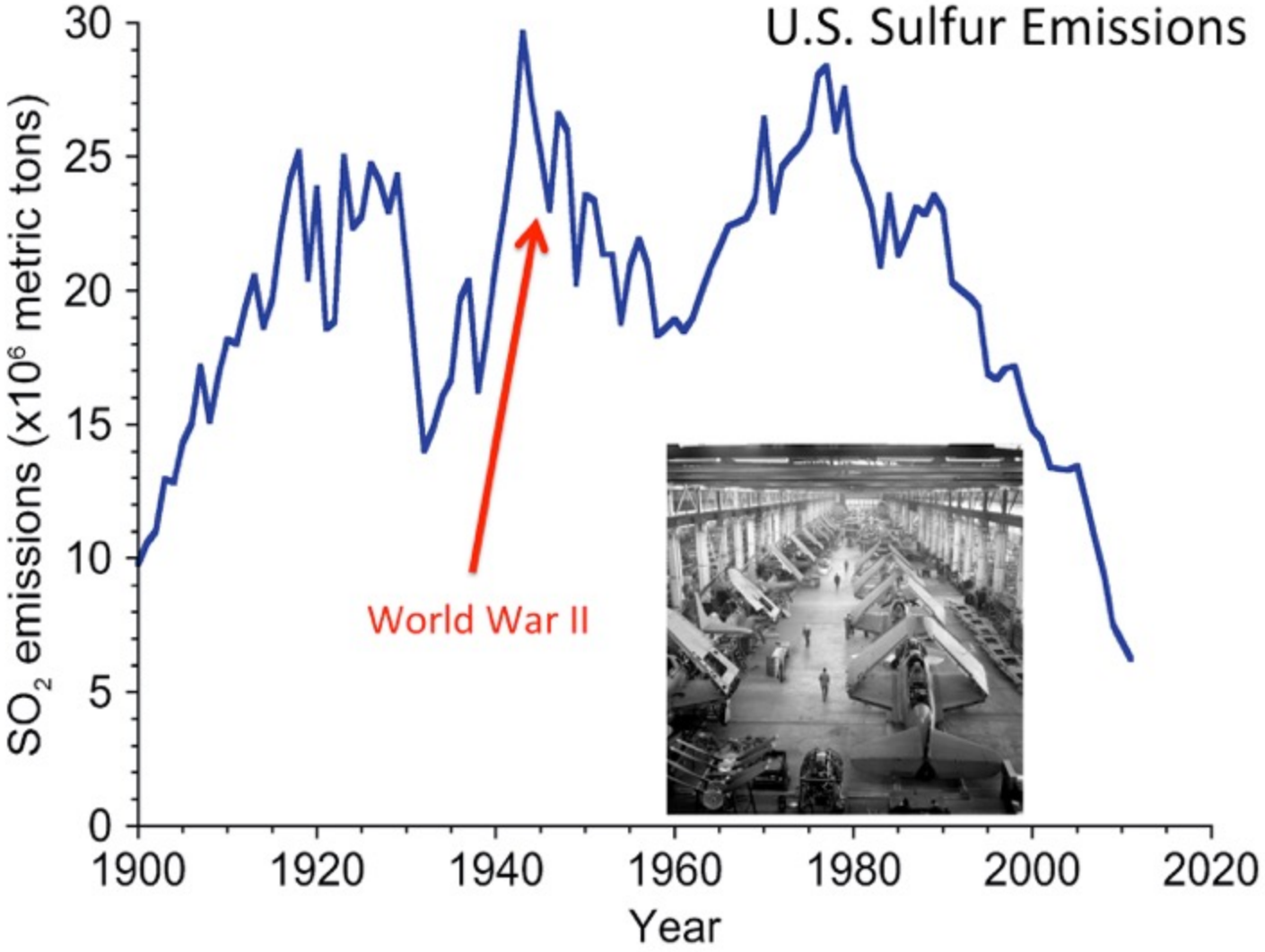


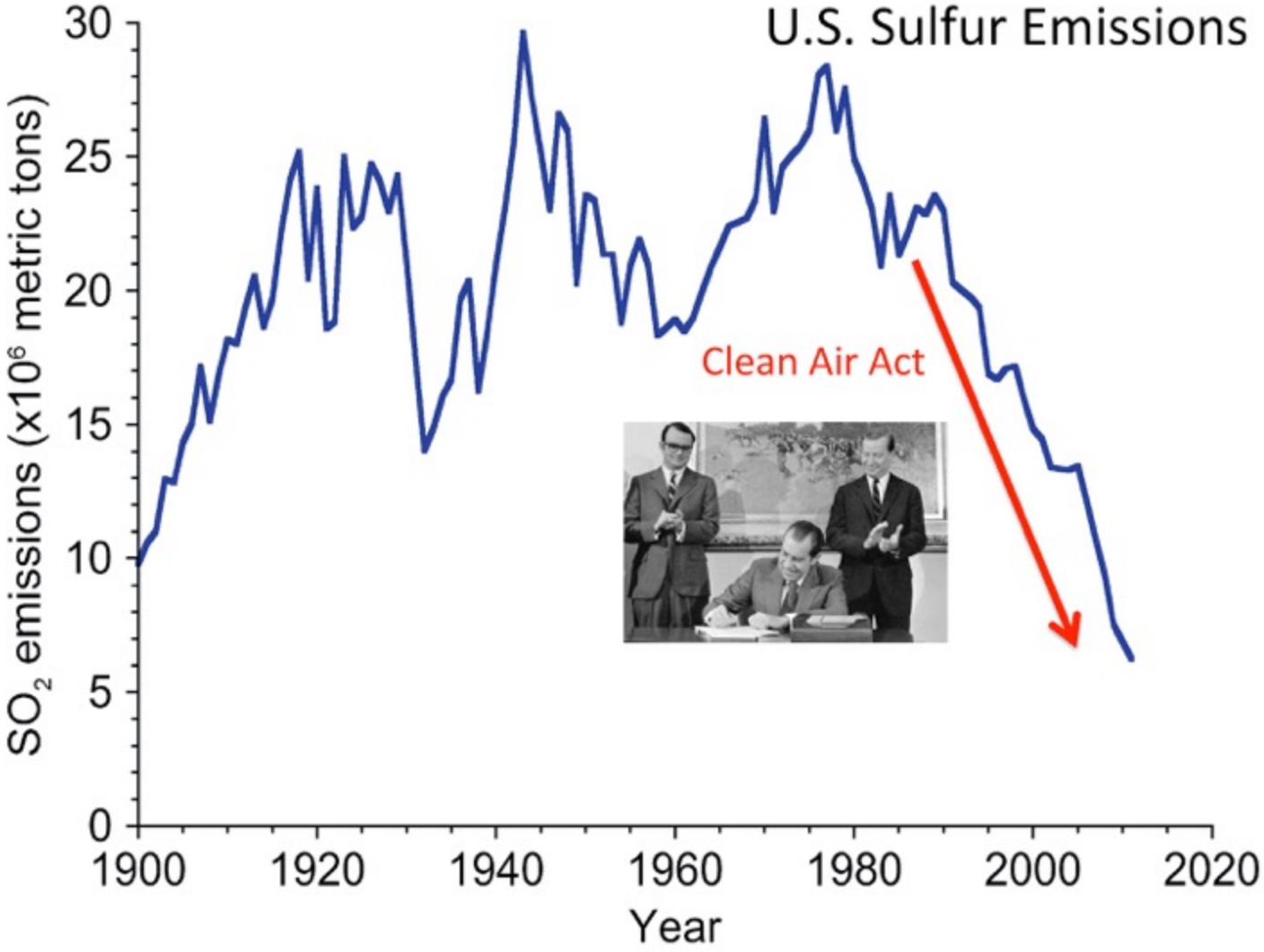

Ohio River Basin - Waterside
Coal-Fired Power Plants
Illinois
Indiana
Ohio
Pennsylvania
West Virginia
Kentucky
Tennessee
Alabama
Mississippi
Mansfield (16)
Sammis (14)
Phillips (8)
Toronto (14)
Cardinal/Tidd (4)
Kammer (2)
Burger (14)
Mitchell (2)
Armstrong (19)
Cheswick (8)
Elrama (8)
Mitchell (1)
Hatfield's Ferry (1)
Ft. Martin (1)
Rivesville (1)
Willow Island/Pleasants (1)
Kyger Creek (2) (15)
Gavin
Sporn (5)
Mountaineer (2)
Kanawha River(2)
Amos (2)
Miami Fort (6)
Beckjord (6)
Zimmer (6)
Killen (7)
Tanners Creek (2)
East Bend (6)
Spurlock (9)
Stuart (7)
Clifty Creek (11)
Trimble Co. (13)
Ghent (12)
Rockport (2)
Gallagher (6)
Culley (17)
Warrick (17)
A.B. Brown (17)
Cane Run (13)
Mill Creek (13)
Coleman (3)
Reid/Green/Henderson (3)
Wilson (3)
Joppa (10)
Green River (12)
Paradise (18)
Shawnee (18)
Gallatin (18)
Cumberland (18)
Johnsonville (18)
Watts Bar
Fossil (18)
Widows Creek (18)
Colbert (18)
Allegheny River
Monongahela River
Muskingum River
Ohio River
Little Kanawha River
Kanawha River
Big Sandy River
Kentucky River
Green River
Cumberland River
Clinch River
Tennessee River
Tennessee River
Tennessee River
Mississippi River
Utilities
(1) Allegheny Energy
(2) American Electric Power
(3) Big Rivers Electric
(4) Cardinal Operating Co.
(5) Central Operating Co.
(6) Cinergy
(7) Dayton Power & Light
(8) Duquesne Light
(9) East Kentucky Power Coop.
(10) Electric Energy Inc.
(11) Indiana Kentucky Electric
(12) Kentucky Utilities
(13) Louisville Gas & Electric
(14) Ohio Edison
(15) Ohio Valley Electric Corp
(16) Pennsylvania Power
(17) So. Indiana Gas & Electric
(18) Tennessee Valley Authority
Ohio River Basin
Contents
State Boundaries
Navigable Waterways
Navigation Locks
Power Plants (Utility)
PORTSALL


U.S. Sulfur Emissions
SO2 emissions (x10^6 metric tons)
0
5
10
15
20
25
30
1900
1920
1940
1960
1980
2000
2020
Year


U.S. Sulfur Emissions
SO_2 emissions (x10^6 metric tons)
30
25
20
15
10
5
0
1900
1920
1940
1960
1980
2000
2020
Year
Industrial Revolution
With Compliments from the Smoke.


U.S. Sulfur Emissions
SO_2 emissions (x10^6 metric tons)
30
25
20
15
10
5
0
1900
1920
1940
1960
1980
2000
2020
Year
Great
Depression
WHY CAN'T YOU
GIVE MY DAD
A JOB?

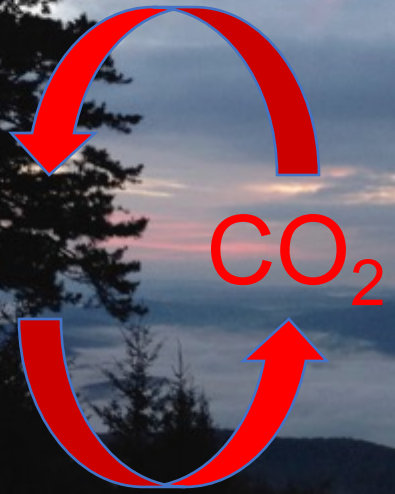

U.S. Sulfur Emissions
SO_2 emissions ($\times 10^6$ metric tons)
30
25
20
15
10
5
0
1900
1920
1940
1960
1980
2000
2020
Year
World War II


U.S. Sulfur Emissions
SO_2 emissions ($\times 10^6$ metric tons)
30
25
20
15
10
5
0
1900
1920
1940
1960
1980
2000
2020
Year
Clean Air Act

Tree growth is complex

Light
Water
CO_2
Nutrients
Temperature
Pathogens
Pollution
Fire
Competition
Herbivory

How do we study forest carbon cycling?

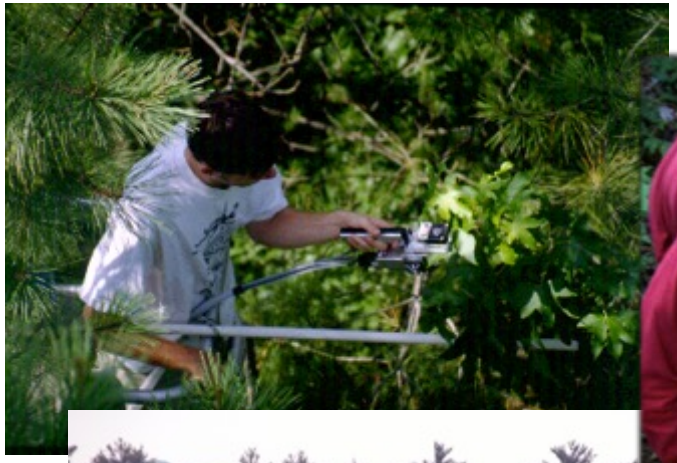


Direct measurements

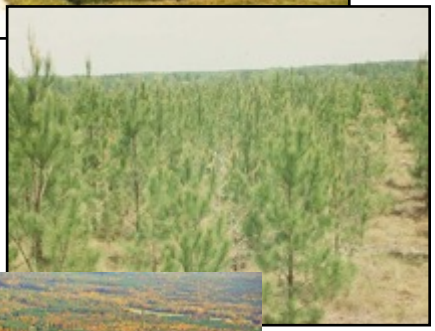
Manipulative experiments

Dendroecology

Direct measurements of carbon cycling

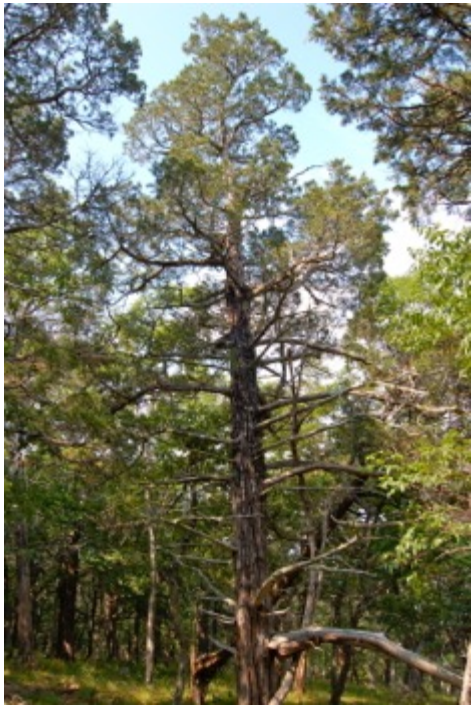


Manipulative experiments at multiple scales



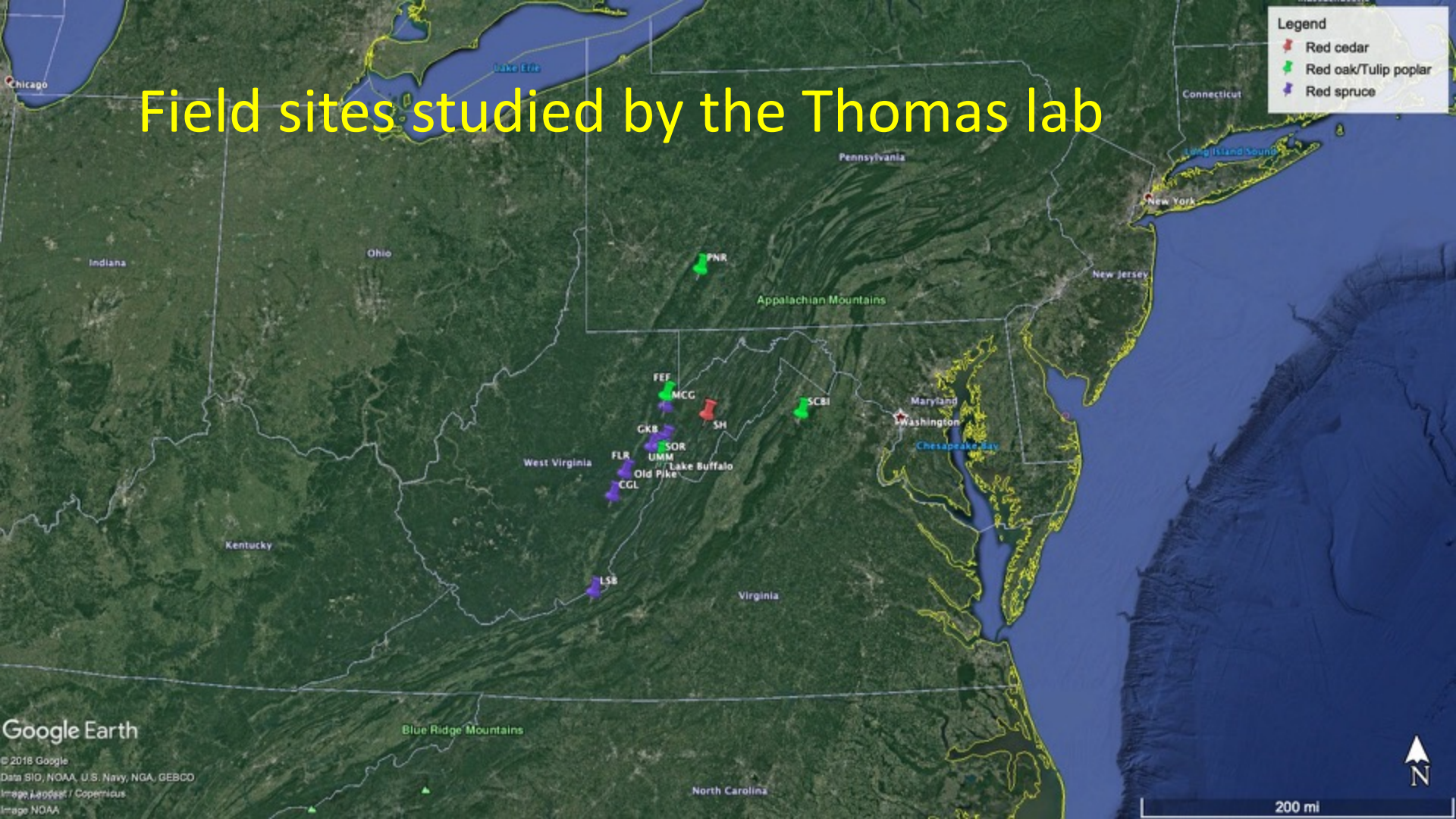
- Laboratory and greenhouse
  - *Weeks to months, cm to dm*
- Open-top chambers and mesocosms
  - *3 to 4 years, m*
- Plantation forests
  - *Decades, 10's m to km*
- FACE (Free-Air Carbon Dioxide Enrichment)
  - *Decades, 10's m to km*

Dendroecology = Using patterns in tree rings to understand environmental impacts on ecological processes



- Land use change
- Fire
- SO_2 emissions/SO_4^{2-} deposition
- NO_x emissions/NO_3^- deposition
- Temperature changes
- Precipitation changes
- Drought (PDSI)
- Increased atmospheric CO_2

Field sites studied by the Thomas lab



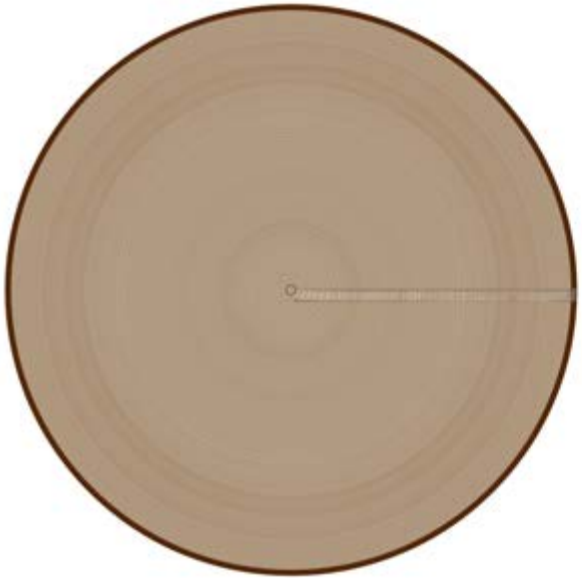

McGowan Mountain
Span Oak Run
Cranberry Glades

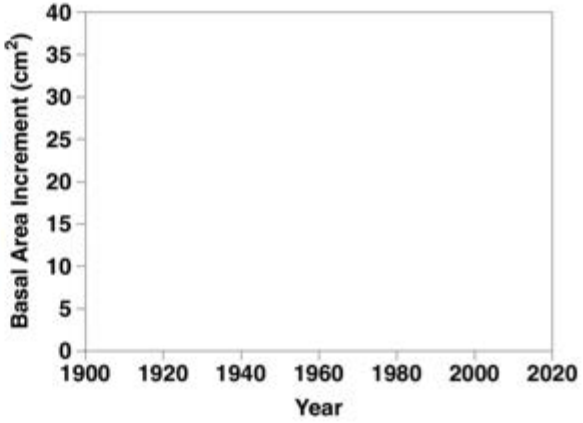

McGowan Mountain


Span Oak Run

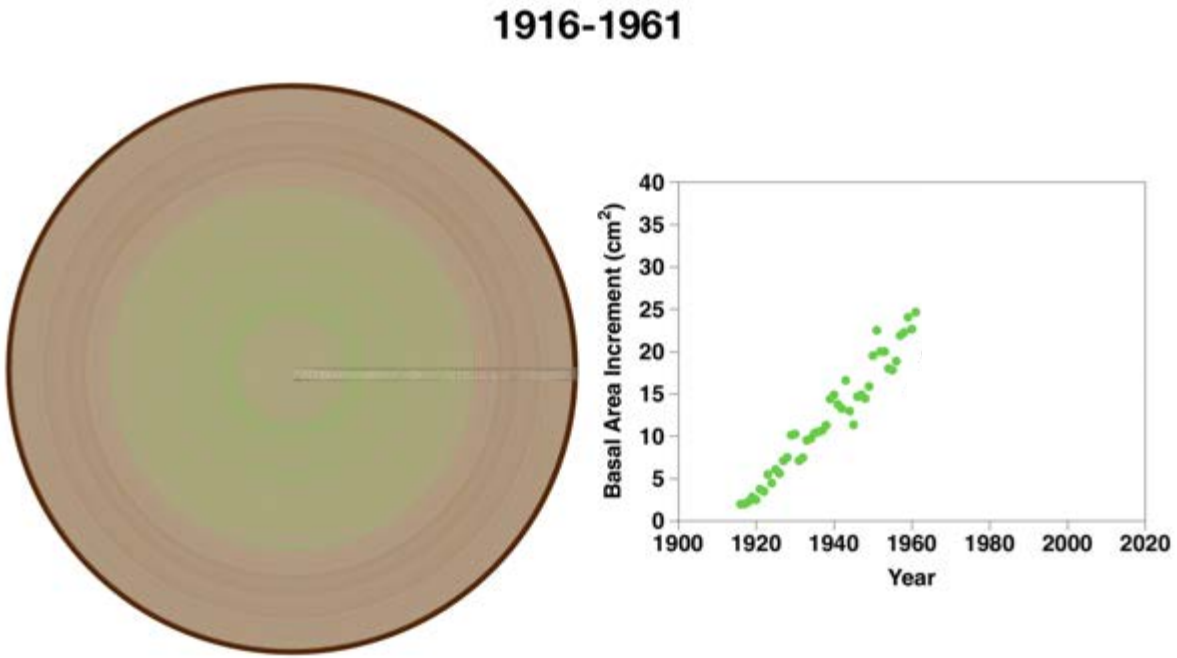

Cranberry Glades

Looking for fingerprints of environmental change

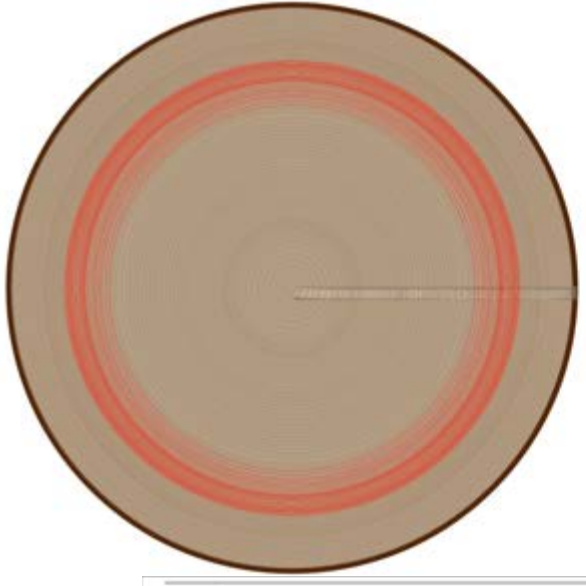


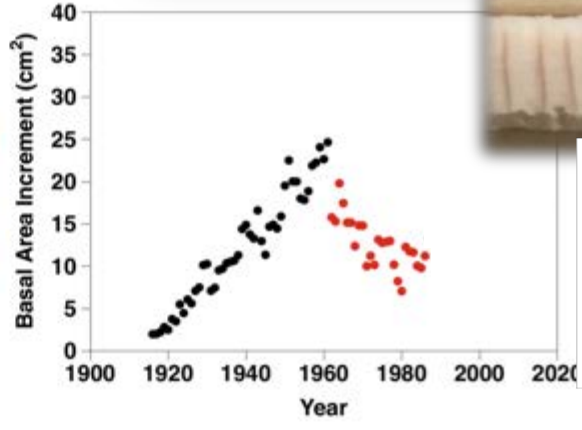


Looking for fingerprints of environmental change



Looking for fingerprints of environmental change





April 23, 1984

ACID RAIN AFFECTS WIDE AREA OF U.S.

By PHILIP SHABECOFF

WASHINGTON, April 22— Acid rain is a problem throughout much of the nation and is not limited to the Northeast, according to a report issued today by the National Wildlife Federation.

The report, compiled from the growing mass of existing data on acid rain, says, "Every state east of the Mississippi, many western states, and every province of Canada has recorded abnormally acid precipitation."

April 15, 1984

DAMAGE TO TREES REPORTED SEVERE

By PHILIP SHABECOFF

WASHINGTON, April 14— Severe deterioration of tree foliage and declining tree growth are being observed throughout the Ohio Valley.

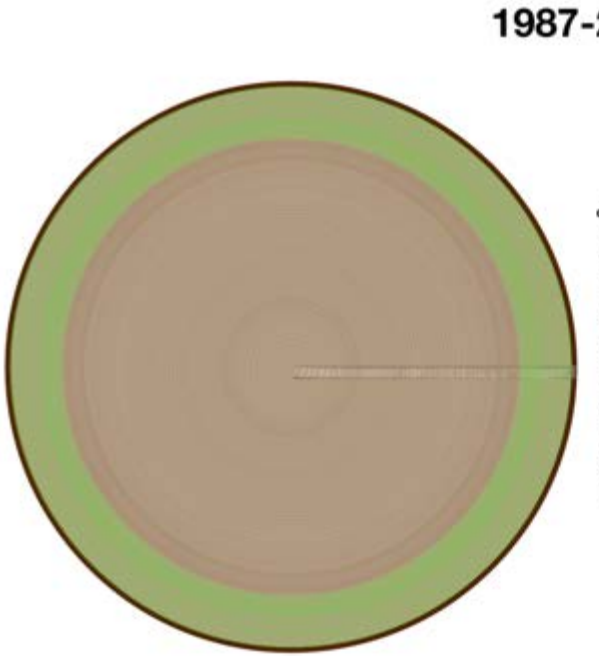
There are also findings that coniferous trees in the valley's urban areas have been dying at an unusually rapid rate in recent years.

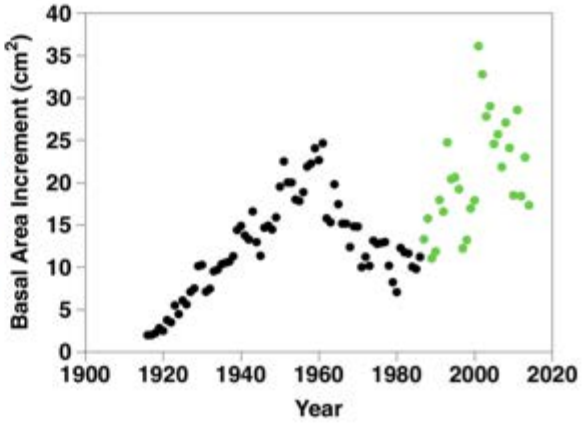
The damage is a result of air pollution more acidic than the acid rain believed to be destroying fresh-water life in the Northeast, according to a scientist who studies the valley's trees.

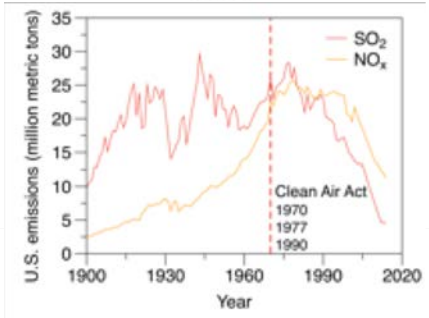

76 L+ THE NEW YORK TIMES, FRIDAY, MAY 23, 1975

Acid Rain and Snow Regarded by Scientists as a Potential Hazard in Eastern U

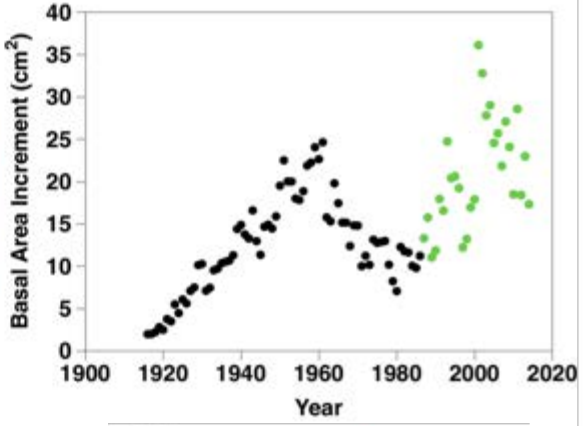
Looking for fingerprints of environmental change

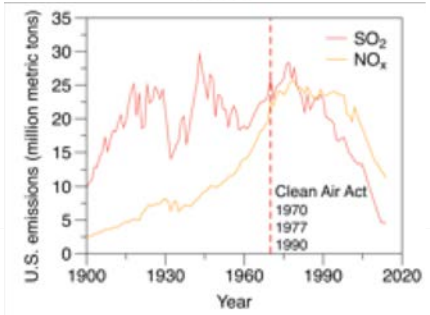


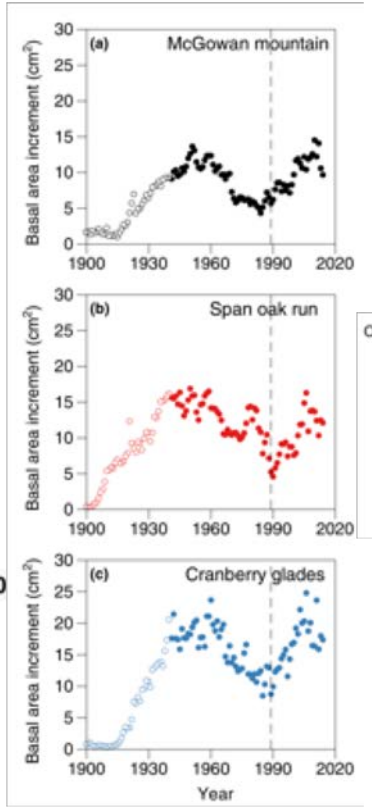


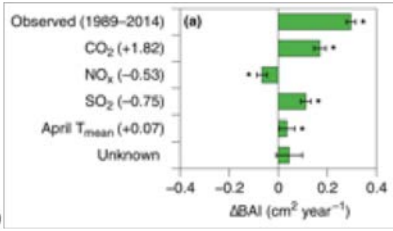


Looking for fingerprints of environmental change





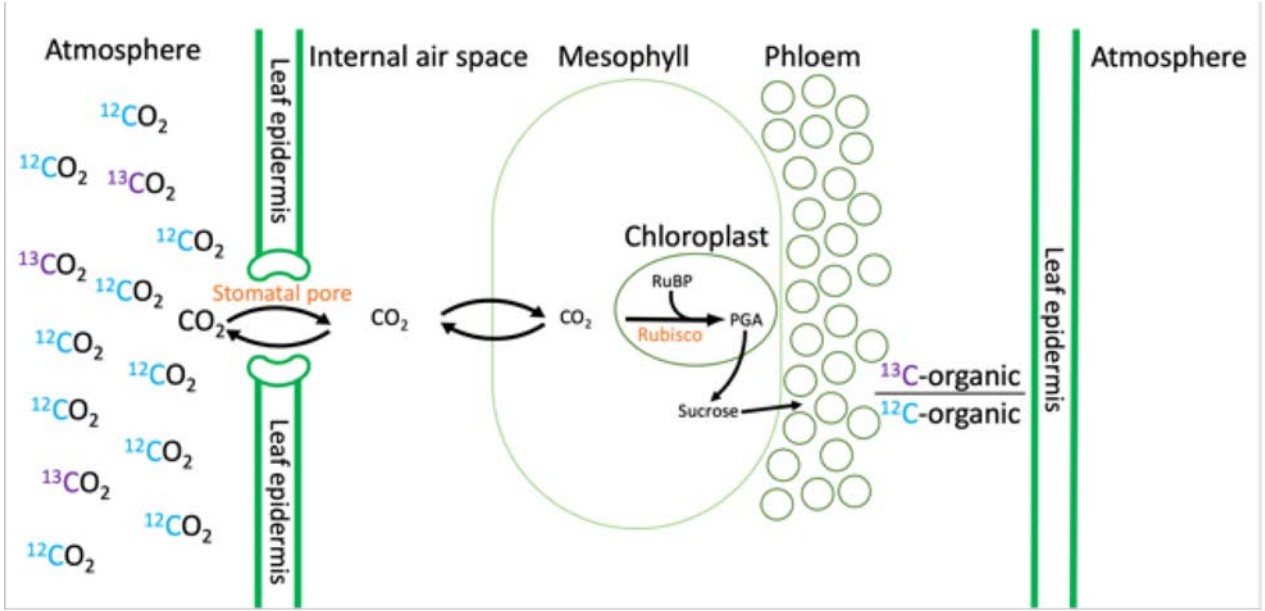




Looking for fingerprints of environmental change with isotopes

$^{12}CO_2$

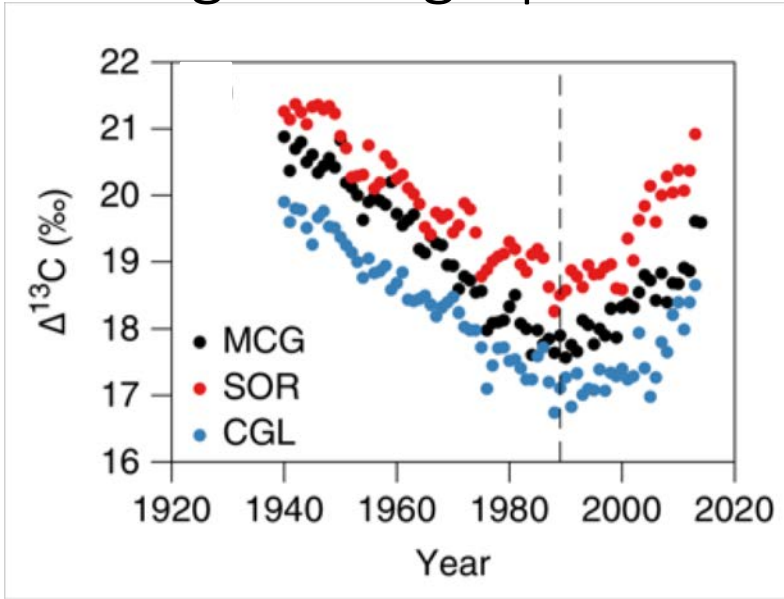
$^{13}CO_2$



Stomatal conductance (g_c) Carbon fixation (A)

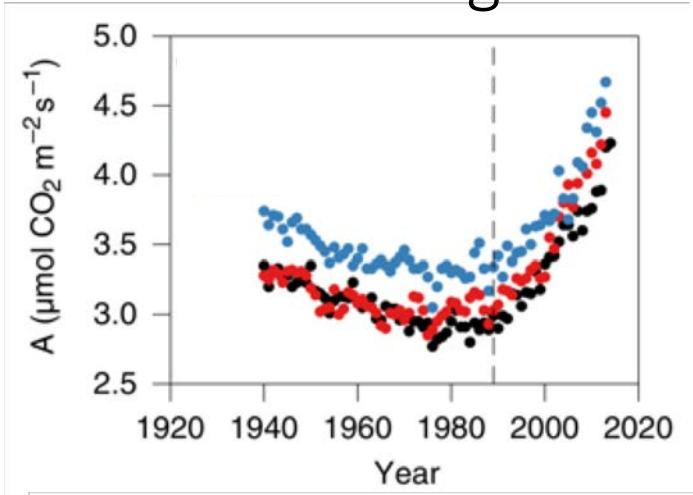
$\frac{^{13}\text{C-organic}}{^{12}\text{C-organic}}$ reflects photosynthetic physiology

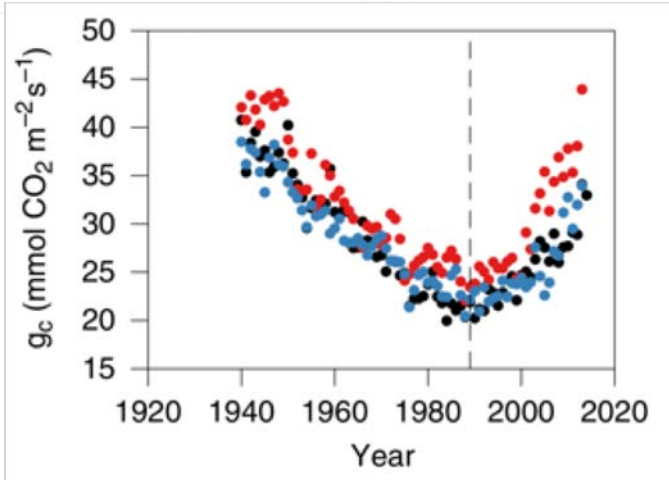
Looking for fingerprints of environmental change with isotopes



Carbon isotopes change at same time as growth.

Indicates an increase in both photosynthesis and stomatal conductance

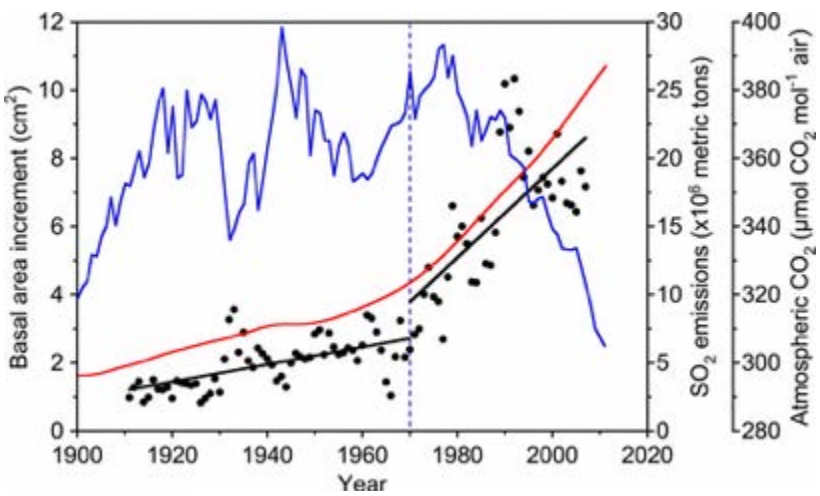


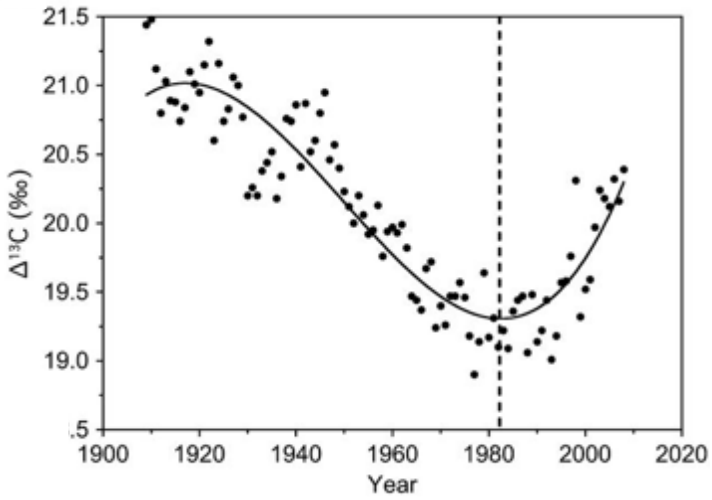


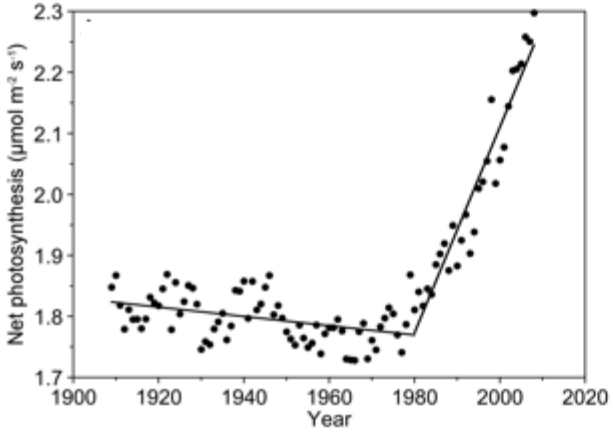
Red cedar trees (*Juniperus virginiana*)

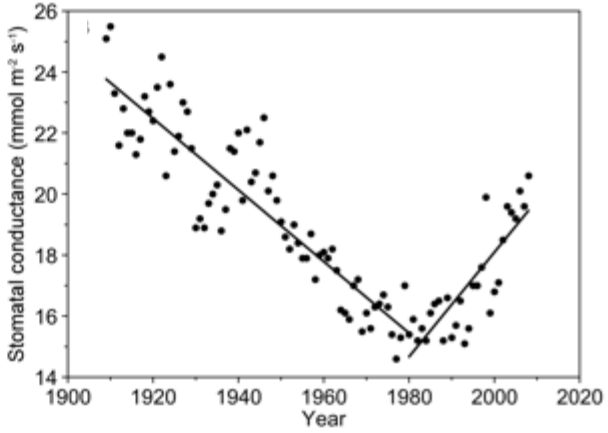
- Trees cored at Smoke Hole Canyon, WV.

Looking for fingerprints of environmental change

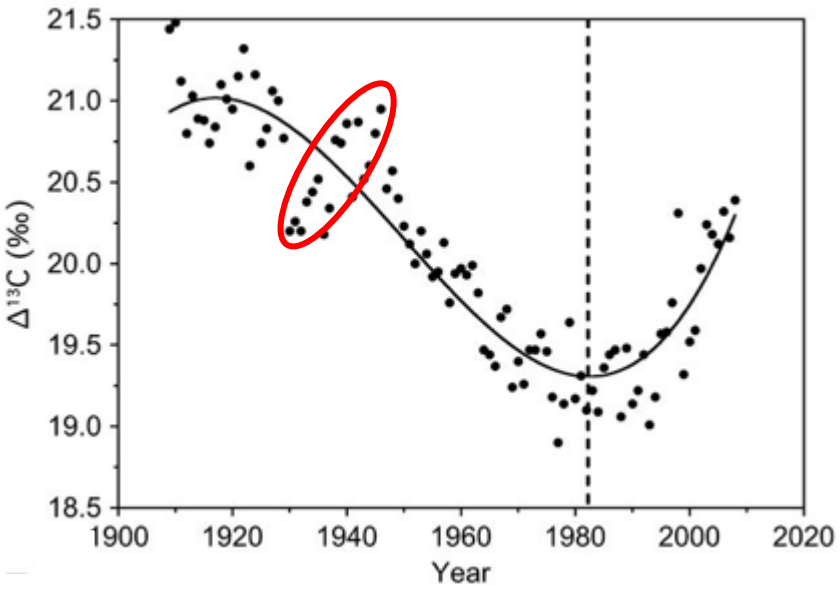


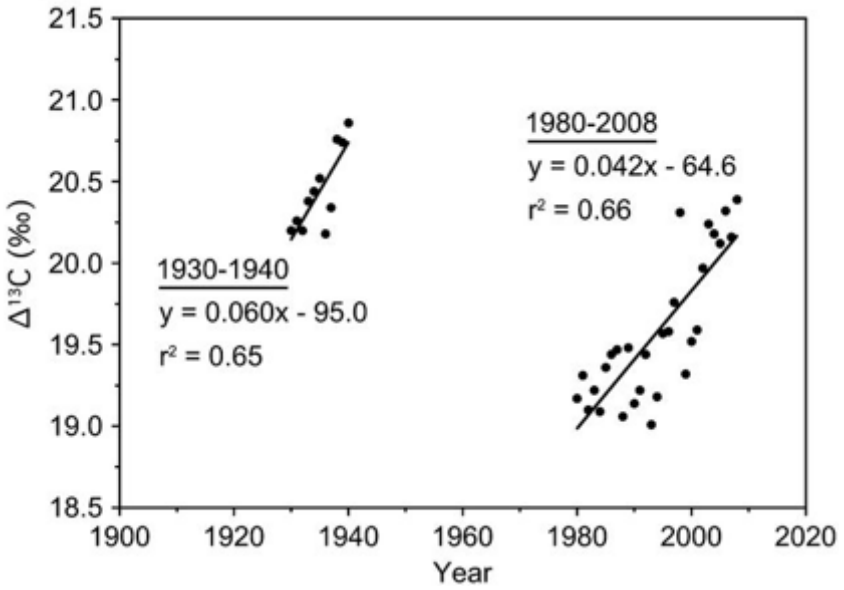






Looking for fingerprints of environmental change

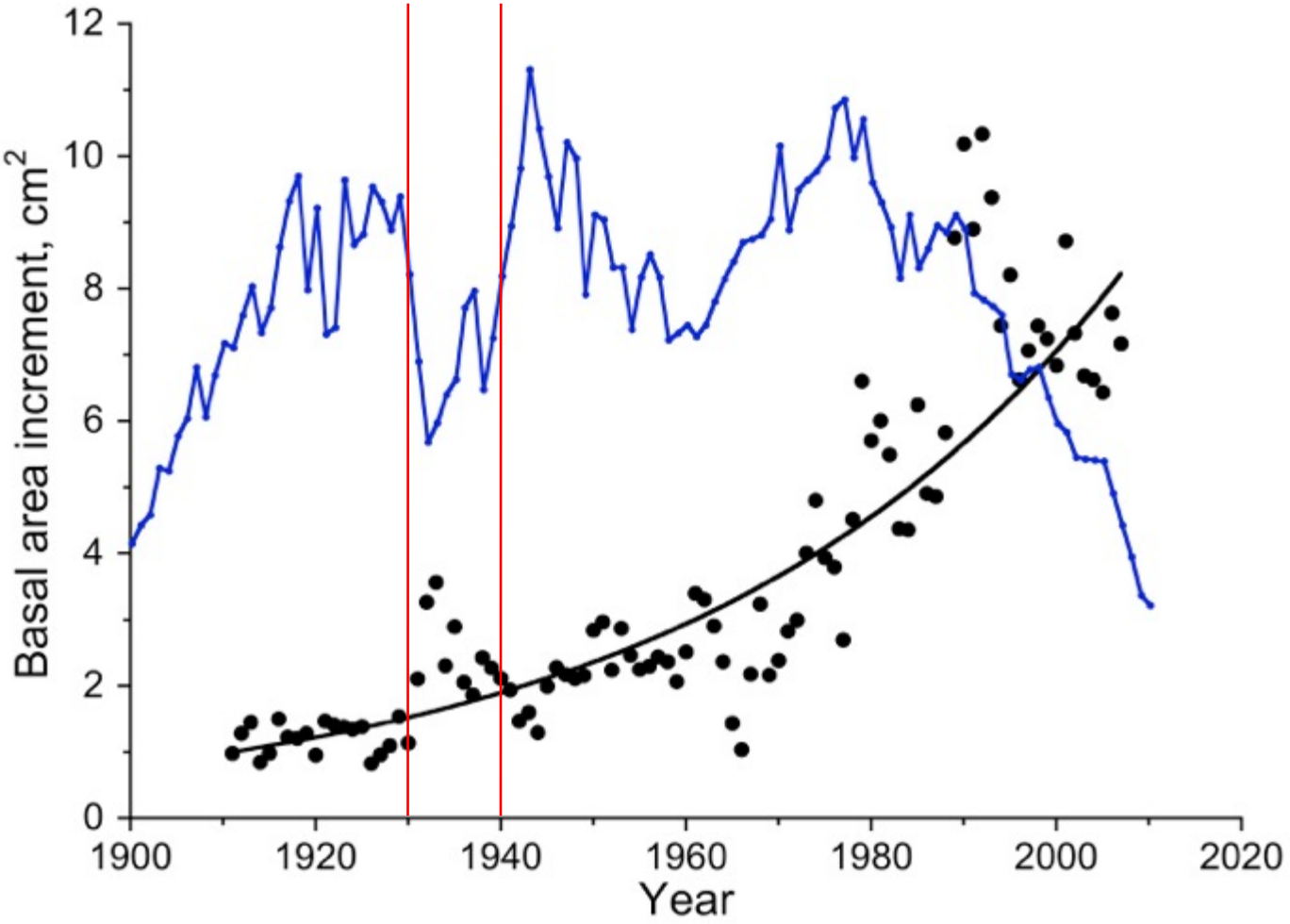




Great Depression Era

6% increase in photosynthesis

15% increase in stomatal conductance


Basal area increment, cm2
12
10
8
6
4
2
0
1900
1920
1940
1960
1980
2000
2020
Year

Conclusions

These studies show the positive impacts of Clean Air Act to facilitate recovery of forest ecosystems from acid deposition.

Both, increased atmospheric CO_2 and small increases in spring temperatures, have been beneficial for trees, leading to greater photosynthesis and growth.


Questions?