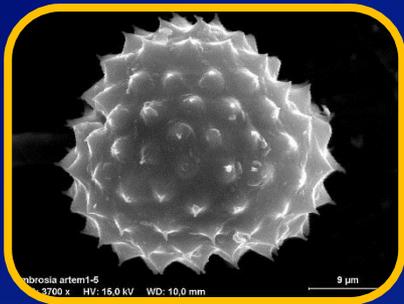


Pollen Seasonality - A Methodology to Assess the Timing of Pollen Seasons Throughout the US



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Pollen Summit Webinar- April 23rd, 2015

National Center for Environmental Health
Division of Environmental Hazards and Health Effects



Outline

- ❑ Pollen and Health
- ❑ Purpose of Study
- ❑ Data and Methods
- ❑ Results
- ❑ Conclusions

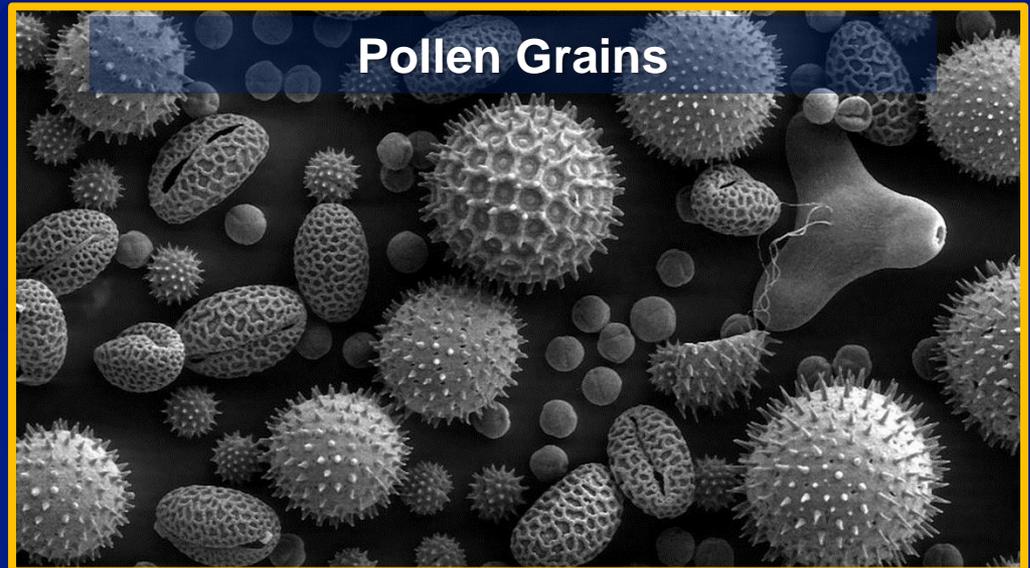
Pollen and Health

- ❑ **Outdoor allergenic pollen and mold are the primary cause for allergic rhinitis or hay fever (Grammer, Greenberger, 2009).**
- ❑ **Annual treatment costs for allergic rhinitis are \$11.2B (Blaiss, 2010) ; annual economic costs \$5.4B (Kessler et al., 2001).**
- ❑ **As pollen count increases, allergic-related illnesses also increase (Heguy et al. 2008, Darrow et al., 2011).**

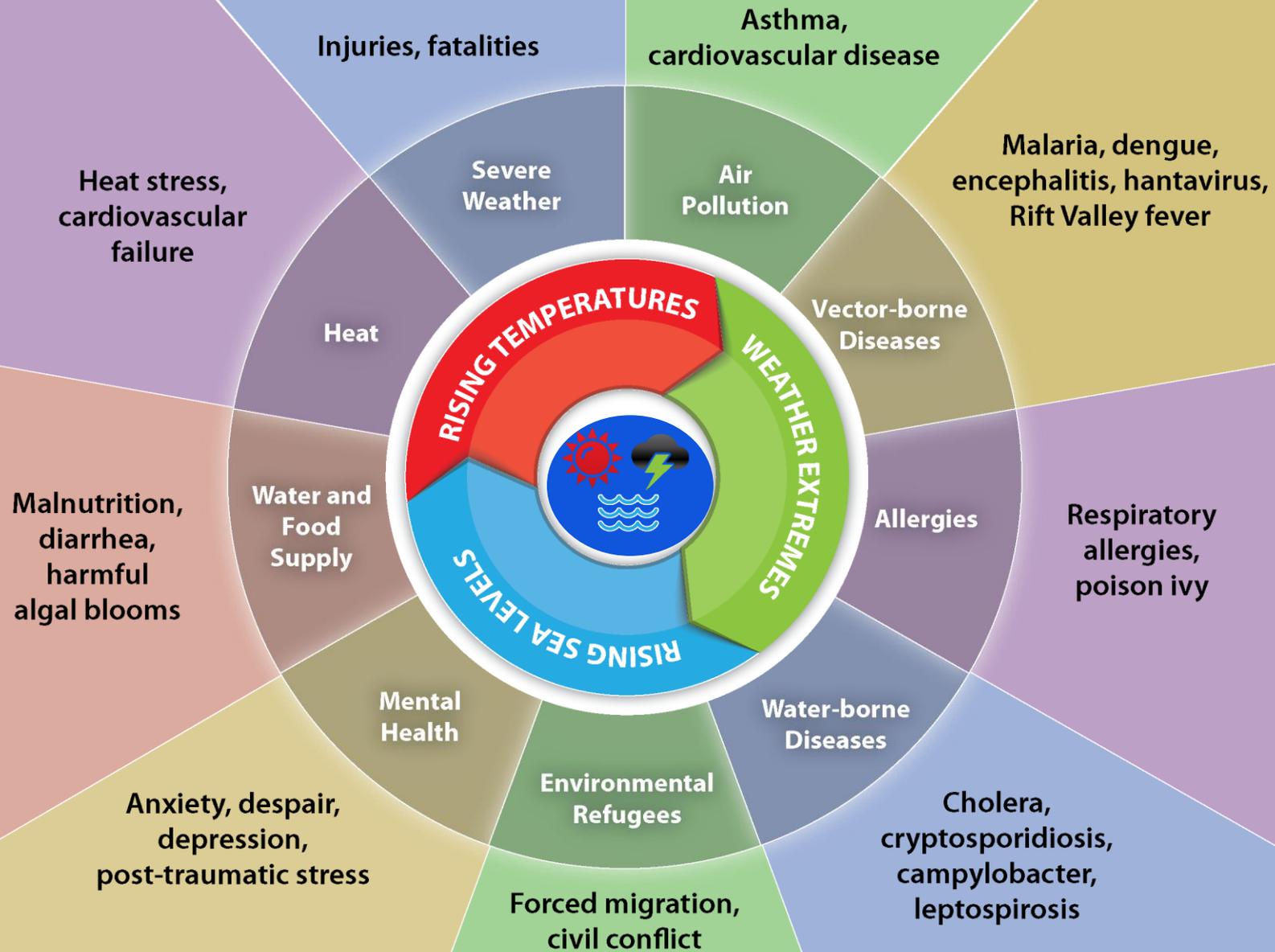


Pollen and Health

- ❑ **Increased allergy medication sales were associated with peaks in tree pollen** (Sheffield, et al., 2011)
- ❑ **Seasonal Allergic Rhinitis affects 15%-20% of adults, and up to 42% of children.** (Grammer, Greenberger, 2009)



Impact of Climate Change on Human Health



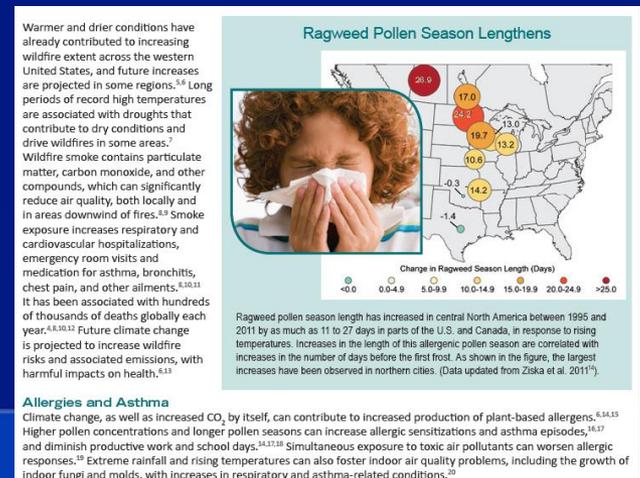
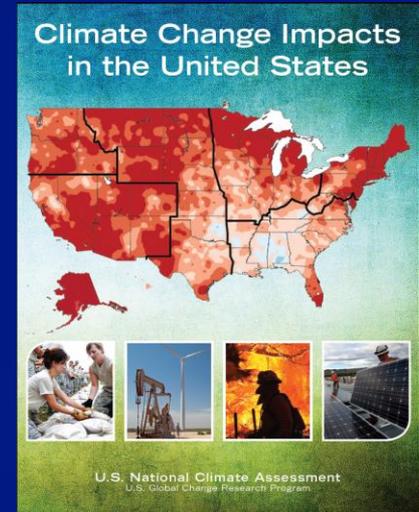
Climate Affects Pollen

Recent shifts in climate, weather, and atmospheric composition:

- More frost-free days
- Warmer seasonal air temperatures
- Shifts in precipitation
- Increased atmospheric CO₂

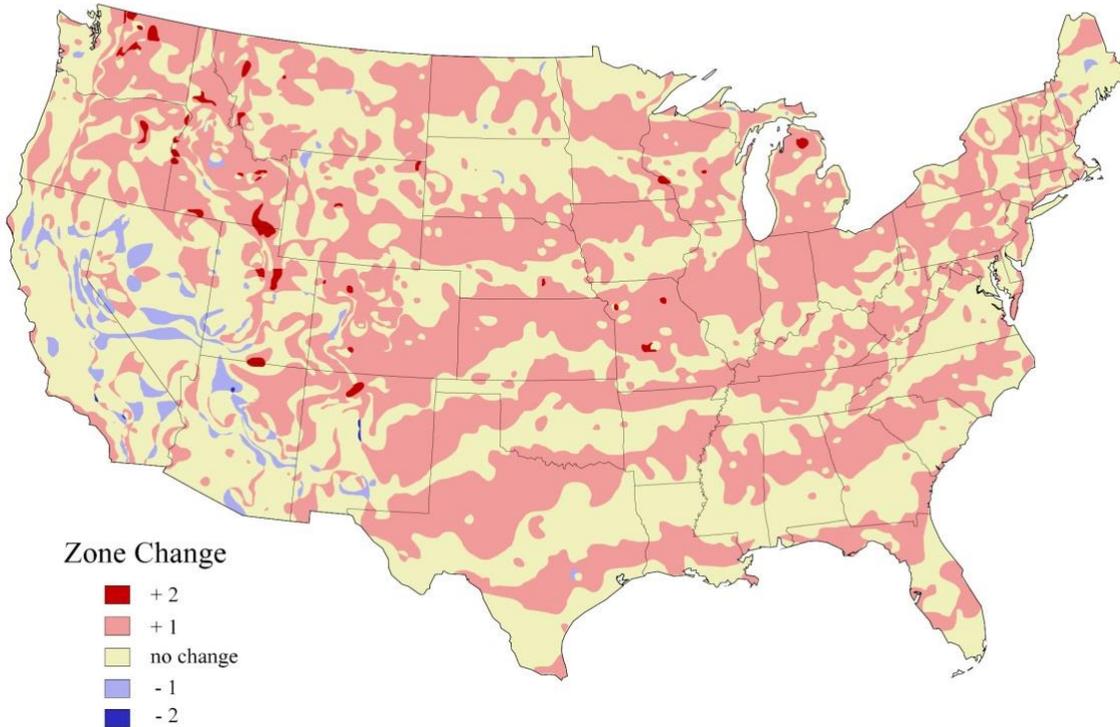
Can result in changes in:

- Pollen seasonality (season length, season start date or end date, peak pollen date)
- Quantity of pollen produced
- Allergenicity of pollen
- Pollen species distribution

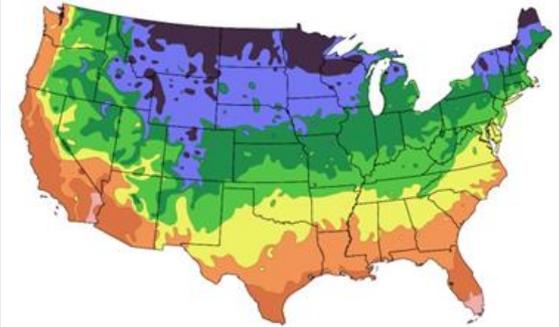


Shifts in Growing Seasons

Differences between 1990 USDA hardiness zones and 2006 arborday.org hardiness zones reflect warmer climate

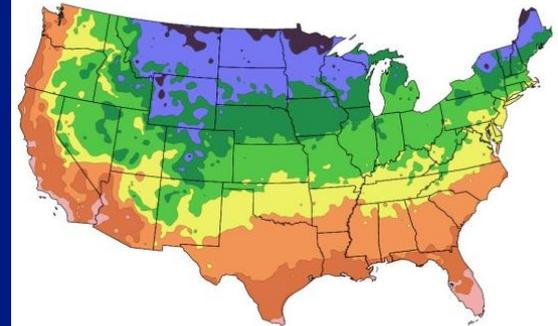


1990 Map



After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued January 1990

2006 Map



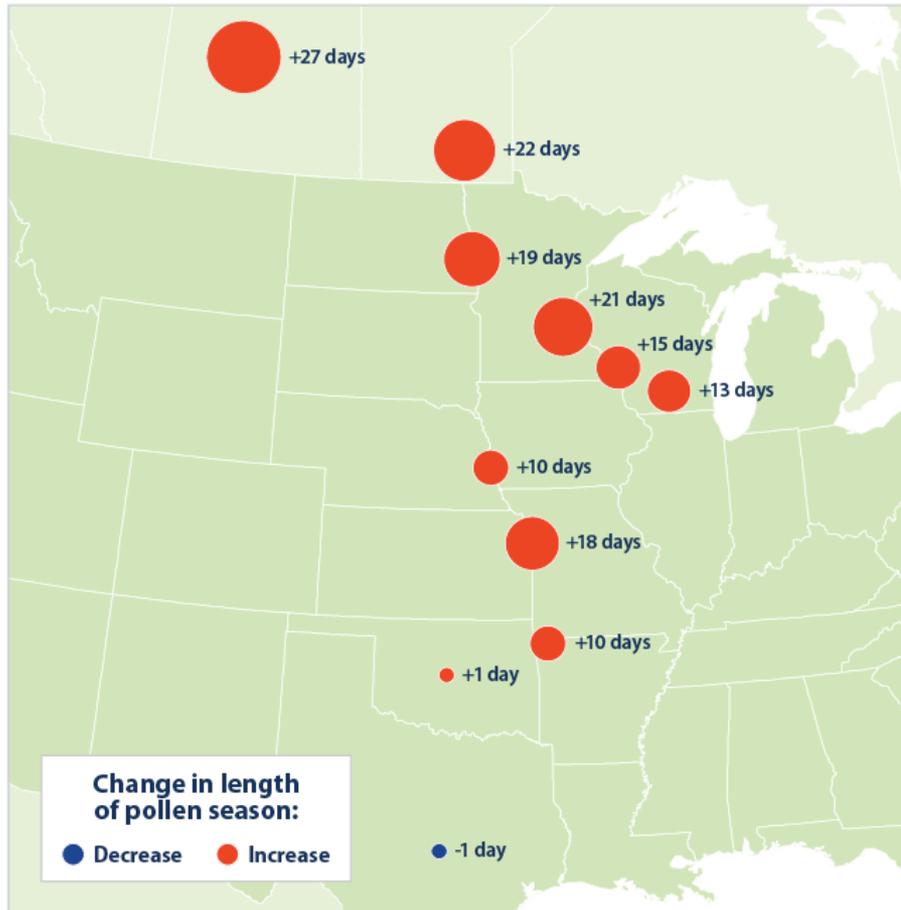
National Arbor Day Foundation Plant Hardiness Zone Map published in 2006.



© 2006 by The National Arbor Day Foundation®

Shifts in Pollen Production

Change in Ragweed Pollen Season, 1995–2013

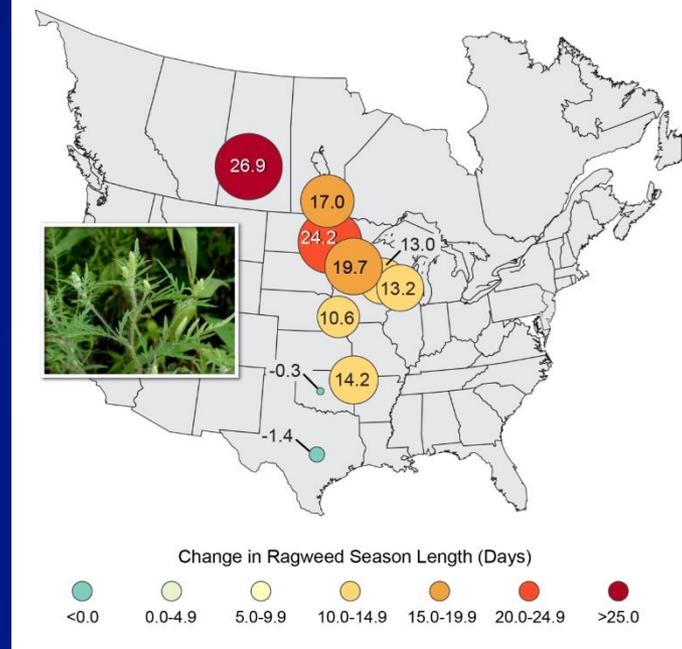


Data source: Ziska, L., K. Knowlton, C. Rogers, National Allergy Bureau, Aerobiology Research Laboratories, Canada. 2014 update to data originally published in: Ziska, L., K. Knowlton, C. Rogers, D. Dalan, N. Tierney, M. Elder, W. Filley, J. Shropshire, L.B. Ford, C. Hedberg, P. Fleetwood, K.T. Hovanky, T. Kavanaugh, G. Fulford, R.F. Vrtis, J.A. Patz, J. Portnoy, F. Coates, L. Bielory, and D. Frenz. 2011. Recent warming by latitude associated with increased length of ragweed pollen season in central North America. *P Natl. Acad. Sci. USA* 108:4248–4251.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climatechange/indicators.

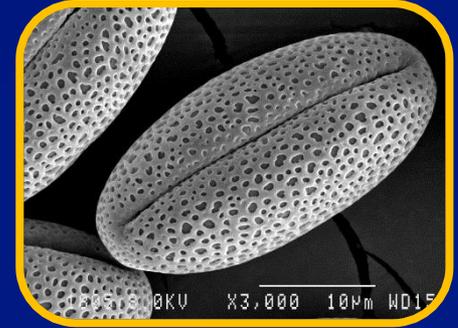
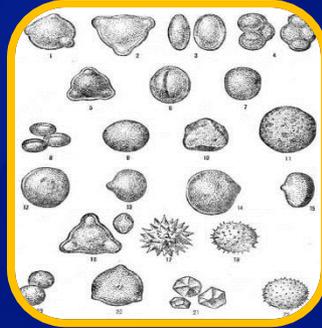
Ziska et al., 2012

Ragweed Pollen Season Lengthens



Luber et al, National Climate Assessment, Health Chapter, 2014; Ziska et al., 2012

Purpose Of Study

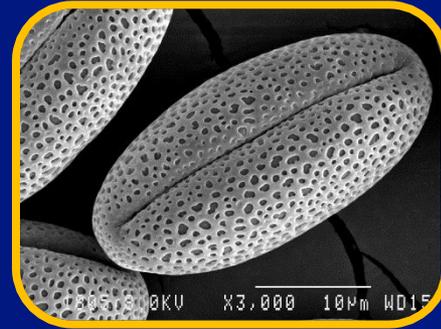


- ❑ For each pollen site, determine the average date for pollen season onset, peak, and end

- ❑ Develop a methodology to compare pollen season timing across multiple sites

- ❑ Compare pollen season timing across sites

Purpose Of Study



- ❑ **Identify potential enviro-climatic factors that may be associated with timing of pollen season for trees, weeds, and grasses**
 - Previous knowledge of a linkage between pollen count and climate for certain tree taxa (Emberlin et al., 2002 and 2007; Corden et al., 1999; Fairley, 1986)

Data and Methods

□ Analyzed pollen data from multiple monitoring stations:

- Albuquerque, NM
- Atlanta, GA
- Baltimore, MD
- Bangor, ME
- Detroit, MI
- Madison, WI
- Minneapolis, MN
- Raleigh, NC
- Sarasota, FL



Data and Methods

□ Pollen Data, Years of Coverage

Station Location	Years of Coverage	Type of Data
Albuquerque, NM	2001-2014 (14 Years)	Taxa
Atlanta, GA	1991-2011 (21 Years)	Taxa
Baltimore, MD	1997-2012 (16 Years)	Grouped
Bangor, ME	2005-2002 (8 Years)	Grouped
Detroit, MI	2000-2008 (9 Years)	Taxa
Madison, WI	2004-2010 (7 Years)	Taxa
Minneapolis, MN	1993-2013 (21 Years)	Taxa
Raleigh, NC	1999-2012 (14 Years)	Grouped
Sarasota, FL	2001-2012 (12 Years)	Taxa

Data and Methods

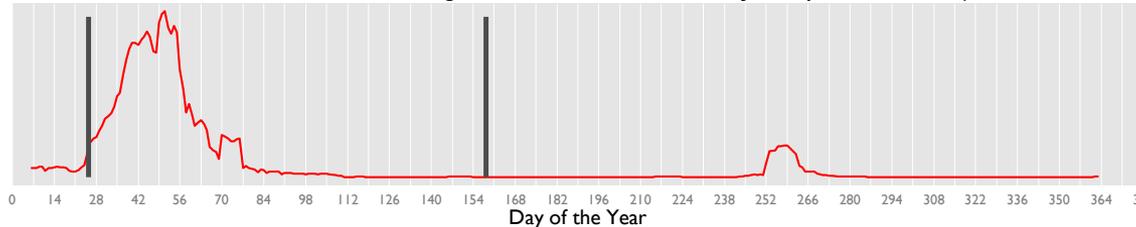
- ❑ **Used a cumulative percentage approach to define pollen season timing (Ziska et al., 2011; Emberlin et al., 2007)**
 - Pollen Season Onset – day when 5% of cumulative pollen count occurred, per season
 - Season Peak – day of maximum pollen count
 - Season End – day when 95% of cumulative pollen count occurred, per season

Data and Methods

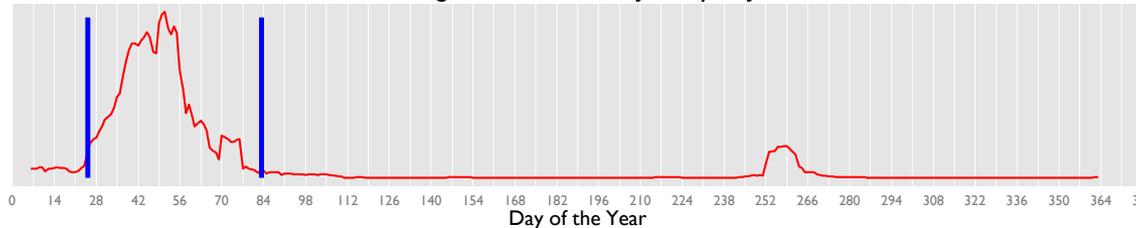
- Divided bimodal pollen data into two seasons per year: Spring (Jan. – June) and Fall (July-Dec.)

Comparison of Different Pollen Data Subsets in the Calculation of Pollen Seasonal Timing

A. Calculated Season Onset and End Using Pollen Data from All Year (January to December)



B. Calculated Season Onset and End Using Pollen Data from January to June



C. Calculated Season Onset and End Using Pollen Data from July to December

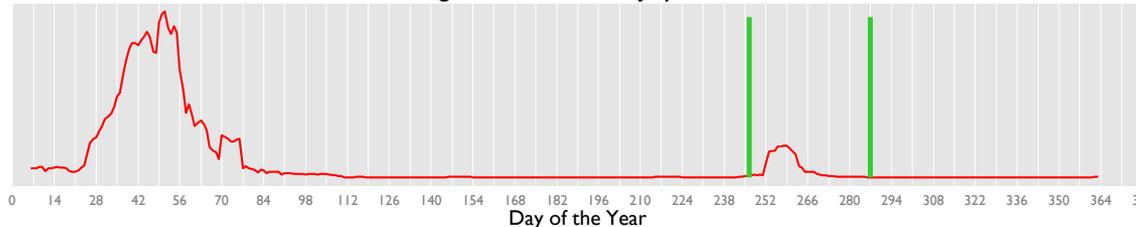
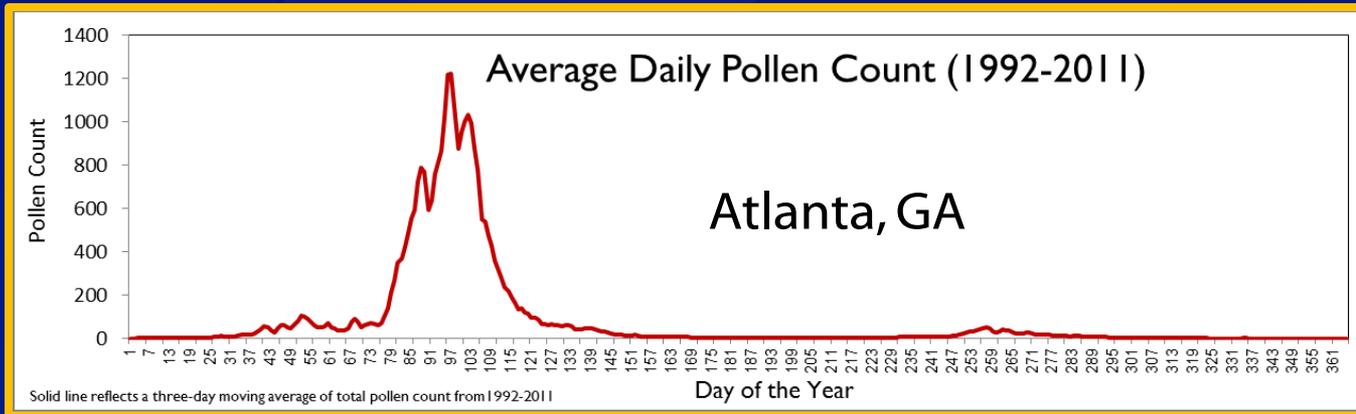


Figure 2. Alder pollen season onset and end as calculated by using different pollen data subsets: January-June, July-December, January-December. Vertical lines denote pollen season onset and end dates using data subsets from (A) January-December, (B) January to June, and (C) July-December.

Source (Manangan, et al. Forthcoming)

Atlanta, GA – Types of Pollen



Typically Spring pollen count much larger than Fall pollen count.

Pollen Type	Spring Season	Fall Season
Oak	39%	<1%
Pine	30%	2%
Juniper	3%	2%
Elm	2%	5%
Grasses	2%	6%
Ragweed	<1%	56%

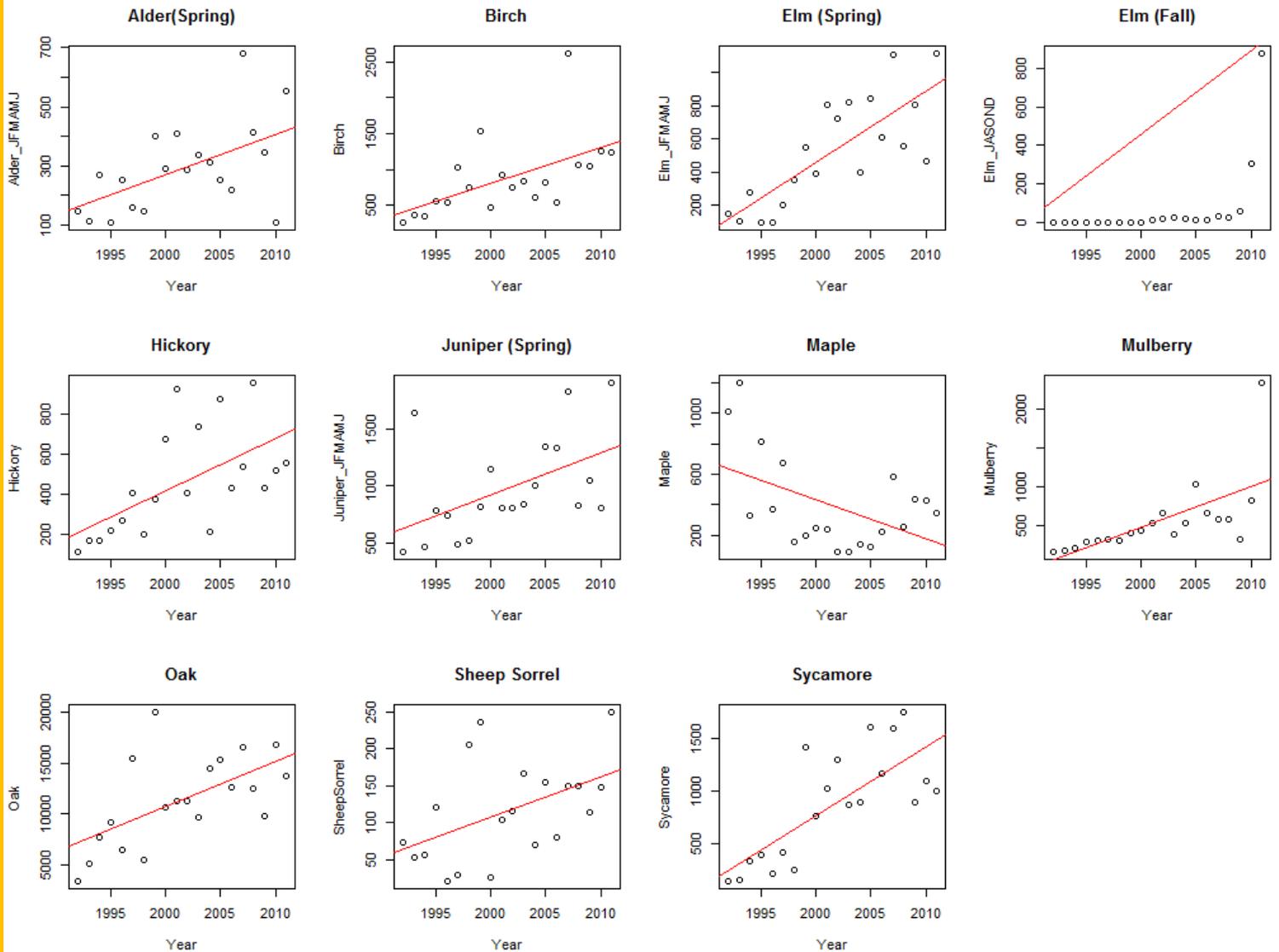
Percentage of Total Pollen for the Spring and Fall Pollen Seasons

Atlanta – Pollen Count Trends

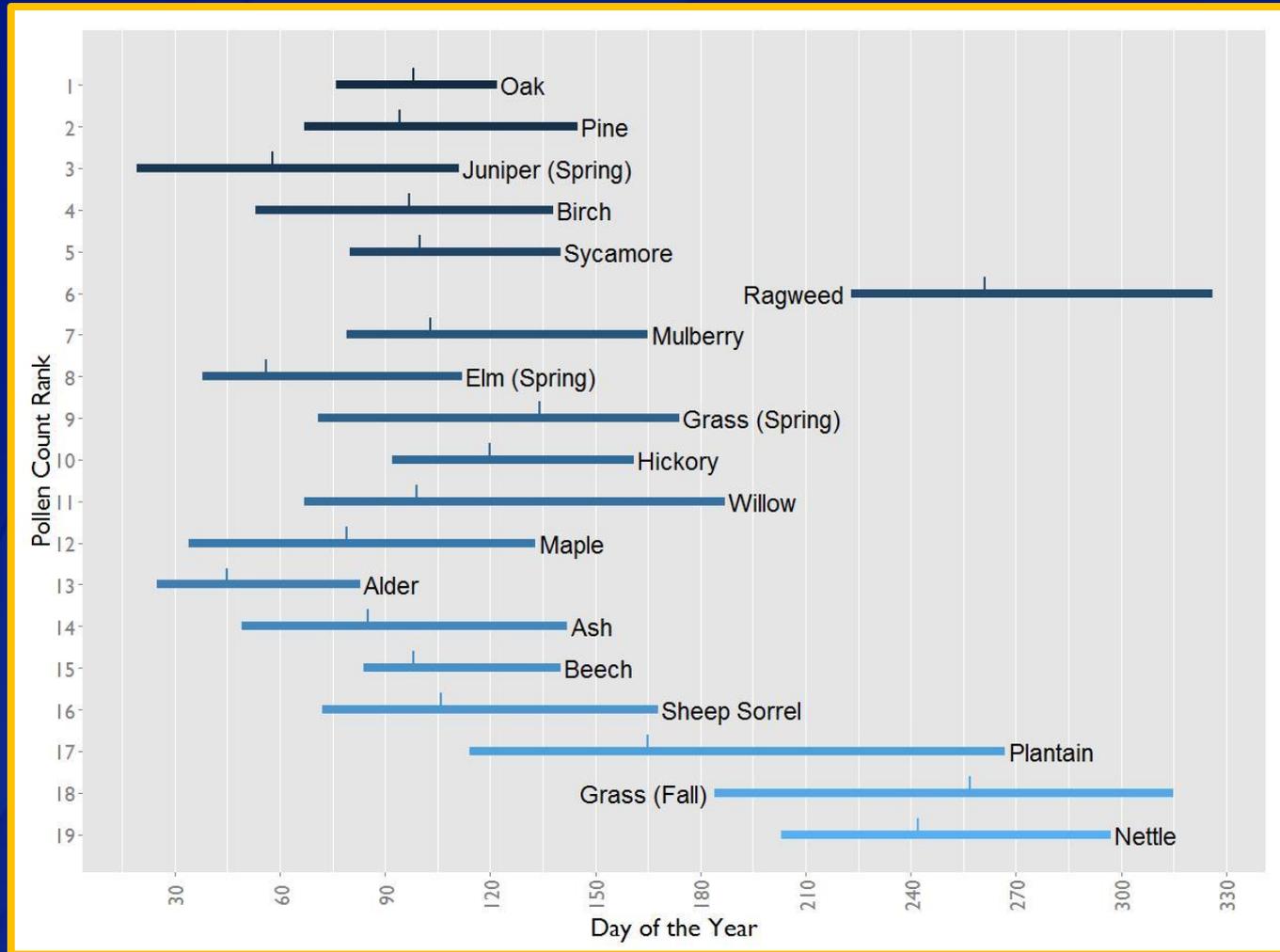
Pollen Count Trends per Taxa

Pollen Group	Trend	R ²	p-value	Change per Year
Alder (Spring)	Increase	.25	0.015	14 PPCM
Birch	Increase	.31	.01	50 PPCM
Elm (Spring)	Increase	.61	.00005	43 PPCM
Elm (Fall)	Increase	.28	.016	18 PPCM
Hickory	Increase	.35	.006	26 PPCM
Juniper (Spring)	Increase	.25	.03	37 PPCM
Maple	Decrease	.24	.03	26 PPCM
Mulberry	Increase	.43	.001	53 PPCM
Oak	Increase	.34	.005	445 PPCM
Sheep Sorel (Spring)	Increase	.24	.03	6 PPCM
Sycamore	Increase	.57	.0001	66 PPCM

Atlanta – Pollen Count Trends



Atlanta – Average Pollen Seasons



Seasonal timing for 19 allergenic pollen

Atlanta – Average Pollen Seasons

Avg. Pollen Count and Seasonal Timing per Year (Selected)

Taxa	Avg. Pollen Count PPCM	Onset	Peak	End
Alder (Spring)	290	Jan 25	Feb 14	Mar 24
Birch	876	Feb 22	Apr 7	May 18
Elm (Spring)	523	Feb 7	Feb 25	Apr 22
Elm (Fall)	79*	NA*	NA*	NA*
Grass (Spring)	502	Mar 12	May 14	Jun 23
Grass (Fall)	85	July 3	Sep 14	Nov 11
Juniper	979	Jan 19	Feb 27	Apr 21
Maple	397	Feb 3	Mar 20	May 13
Oak	11,365	Mar 17	Apr 8	May 2
Pine	8,647	Mar 8	Apr 4	May 25
Ragweed (Fall)	779	Aug 11	Sep 18	Nov 22
Willow	451	Mar 8	Apr 9	July 6

Atlanta – Pollen Season Timing

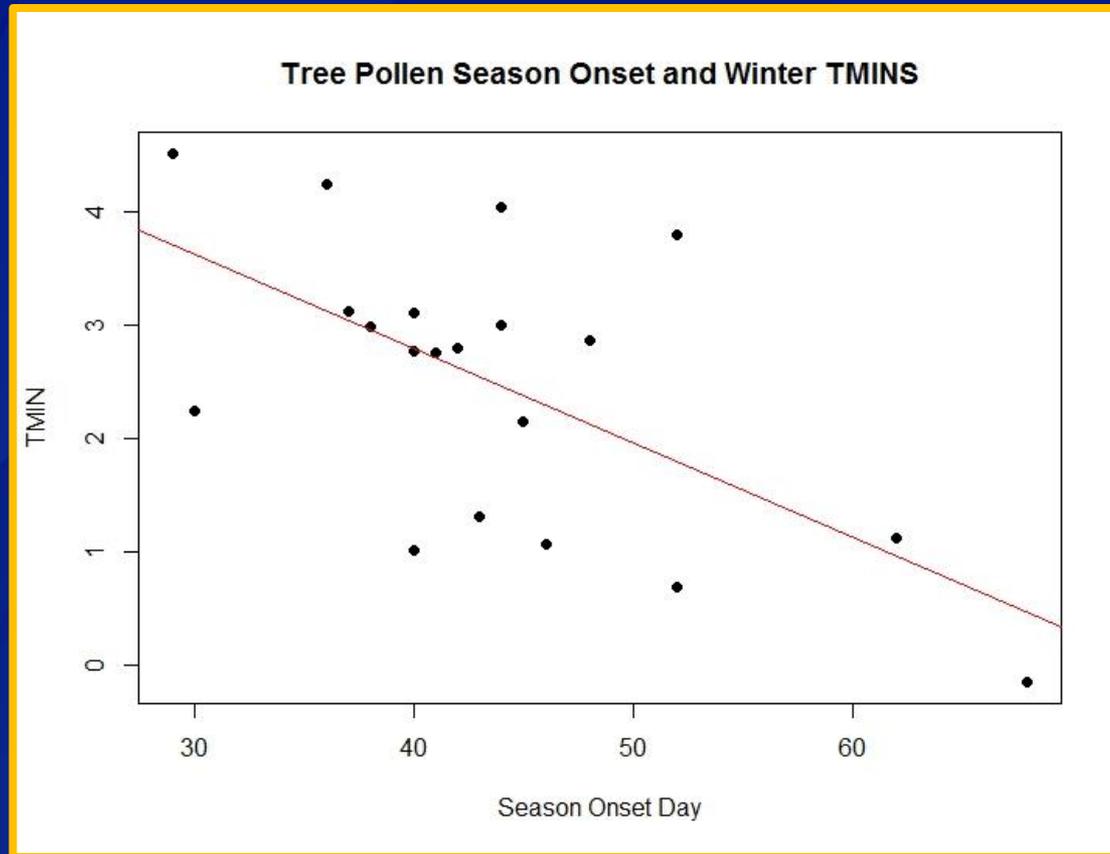
Trends in Pollen Season Timing

Pollen Group	Trend	p-value	R ²	DF
Ash	4.3 days	0.015	0.287	18
Beech	4.1 days	<0.001	0.67	18
Sycamore	1.3 days	.048	0.1997	18
Willow	6.3 days	<0.001	0.51	18

Atlanta – Tree Pollen Season and Winter Cooling

□ Delayed Spring Tree Pollen Season

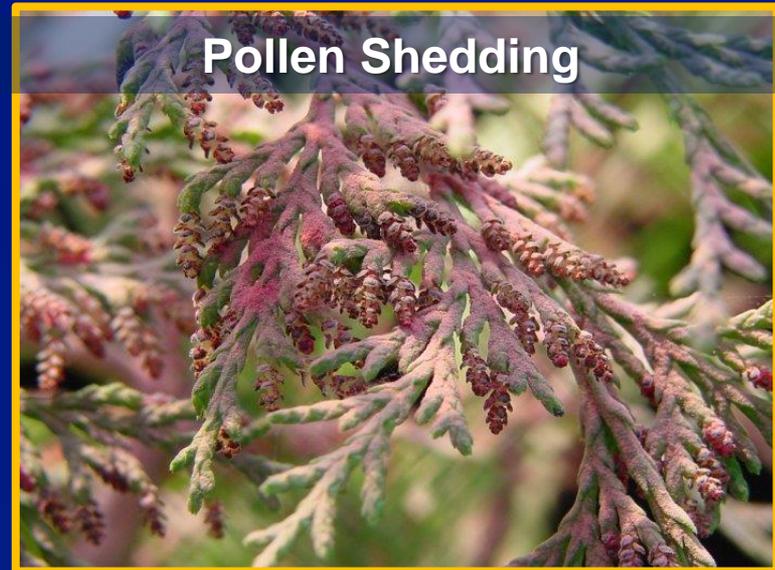
- Decreasing Wint. TMINs delay season onset ($R^2= 0.38$, $p\text{-value}<0.004$, $df=18$)



Atlanta - Conclusions

❑ 9 of the 18 plants exhibited a long-term increase in pollen count

- Alder (4.7%)
- Birch (5.7%)
- Elm - Spring (8.2%)
- Elm – Fall (23%)
- Hickory (5.7%)
- Juniper (3.8%)
- Mulberry (9.6%)
- Oak (3.9%)
- Sheep sorrel (4.7%)
- Sycamore (7.6%)

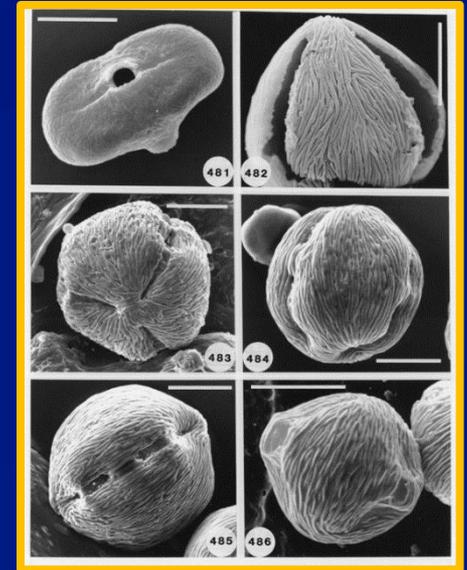


❑ Maple pollen decreased 6.5% over the 20-year period

Atlanta - Conclusions

❑ Four plants exhibited lengthier pollen seasons

- Ash
- Beech
- Sycamore
- Willow



❑ No association between pollen count and cooling winters

❑ Cooler winter TMINs delayed the onset of tree pollen season

Results

- ❑ **Predominant Types of Pollen for each monitoring location**
- ❑ **Average Pollen Seasonal Timing (Onset, Peak, End) Comparison of pollen season across stations**
- ❑ **Climate and Pollen Relationships**

Results - Predominant Spring Pollen

Predominant Species During the Spring (Jan-Jun) Pollen Season

Location	Spring
Albuquerque, NM	Oak (30%); Juniper (18%)
Atlanta, GA	Oak (39%); Pine (30%)
Detroit, MI	Mulberry (17%), Ash (15%); Oak (13%)
Madison, WI	Mulberry (56%); Maple (14%)
Minneapolis, MN	Oak (16%); Ash (15%); Juniper(9%); Birch(9%)
Sarasota, FL	Oak (72%); Juniper (11%)

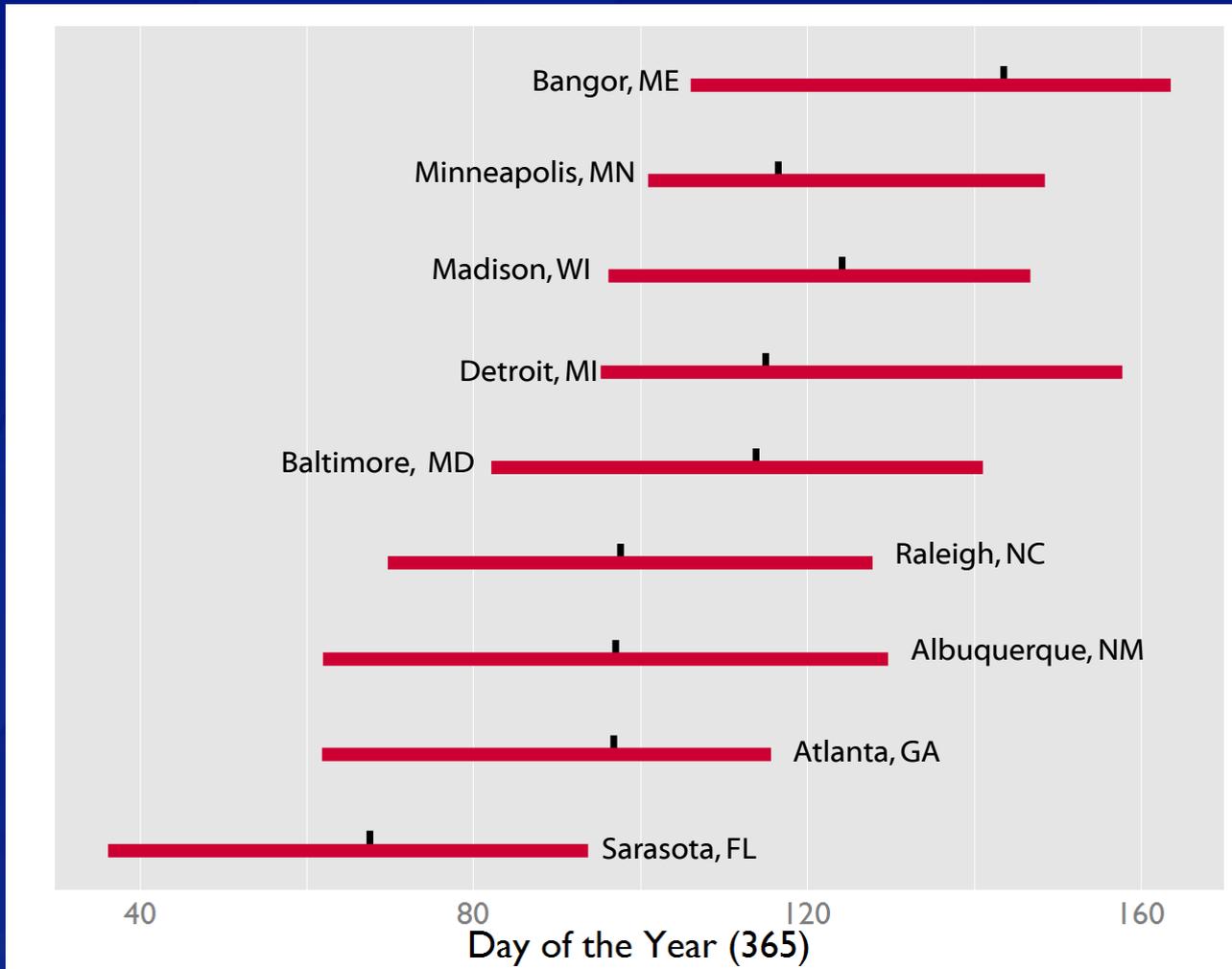
Results - Predominant Fall Pollen

Predominant Species During the Fall (Jul-Dec) Pollen Season

Location	Fall
Albuquerque, NM	Goosefoot (34%); Ragweed (7%)
Atlanta, GA	Ragweed (56%); Grasses (6%)
Detroit, MI	Ragweed (52%); Nettle (14%)
Madison, WI	Ragweed (48%); Nettle (30%)
Minneapolis, MN	Ragweed (38%); Nettle (23%)
Sarasota, FL	Ragweed (22%); Grasses (17%);

Results – Spring Tree Pollen Season Timing

Spring Tree Pollen Season - Season Onset, Peak, Length, and End



Pollen season represented by the red horizontal line, pollen peak data represented by black vertical line

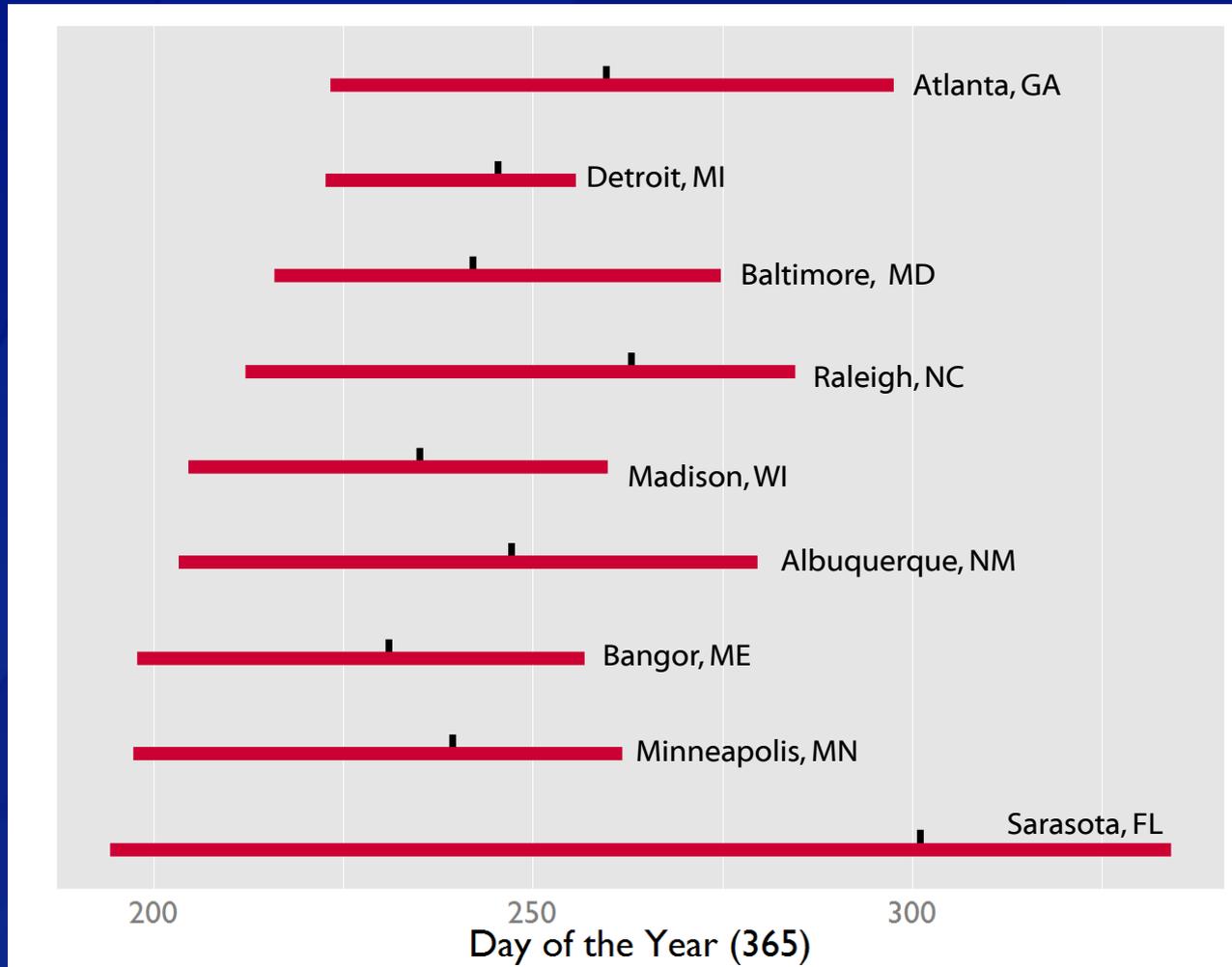
Results – Spring Tree Pollen Season Timing

Spring Tree Pollen Season - Season Onset, Length, and End

Name	Pollen Count	Onset	End	Peak	Length
Albuquerque	20,076	01 Mar	08 May	06 Apr	68
Atlanta (Marietta, GA)	26,681	01 Mar	24 Apr	05 Apr	54
Baltimore, MD	18,521	22 Mar	20 May	22 Apr	59
Sarasota, FL	92,474	05 Feb	02 Apr	07 Mar	58
Madison, WI	12,169	05 Apr	25 May	03 May	51
Bangor, ME	8,418	15 Apr	11 Jun	22 May	58
Detroit (St Clair Shores, MI)	9,734	04 Apr	05 Jun	24 Apr	63
Minneapolis, Minnesota	12,698	09 Apr	27 May	25 Apr	48
Raleigh, NC	40,919	09 Mar	06 May	06 Apr	58

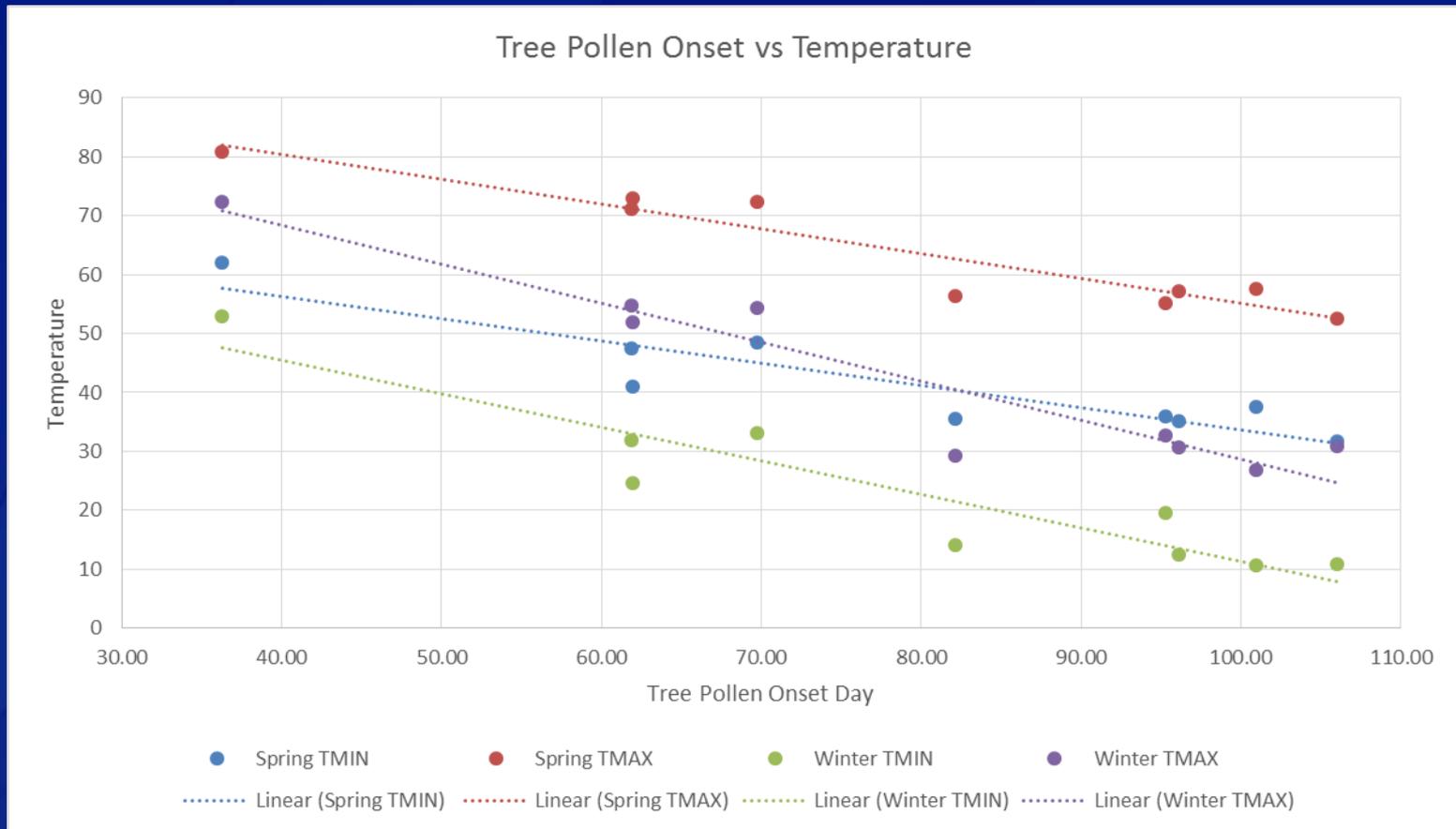
Results – Fall Weed Pollen Season Timing

Fall Weed Pollen Season - Season Onset, Length, and End



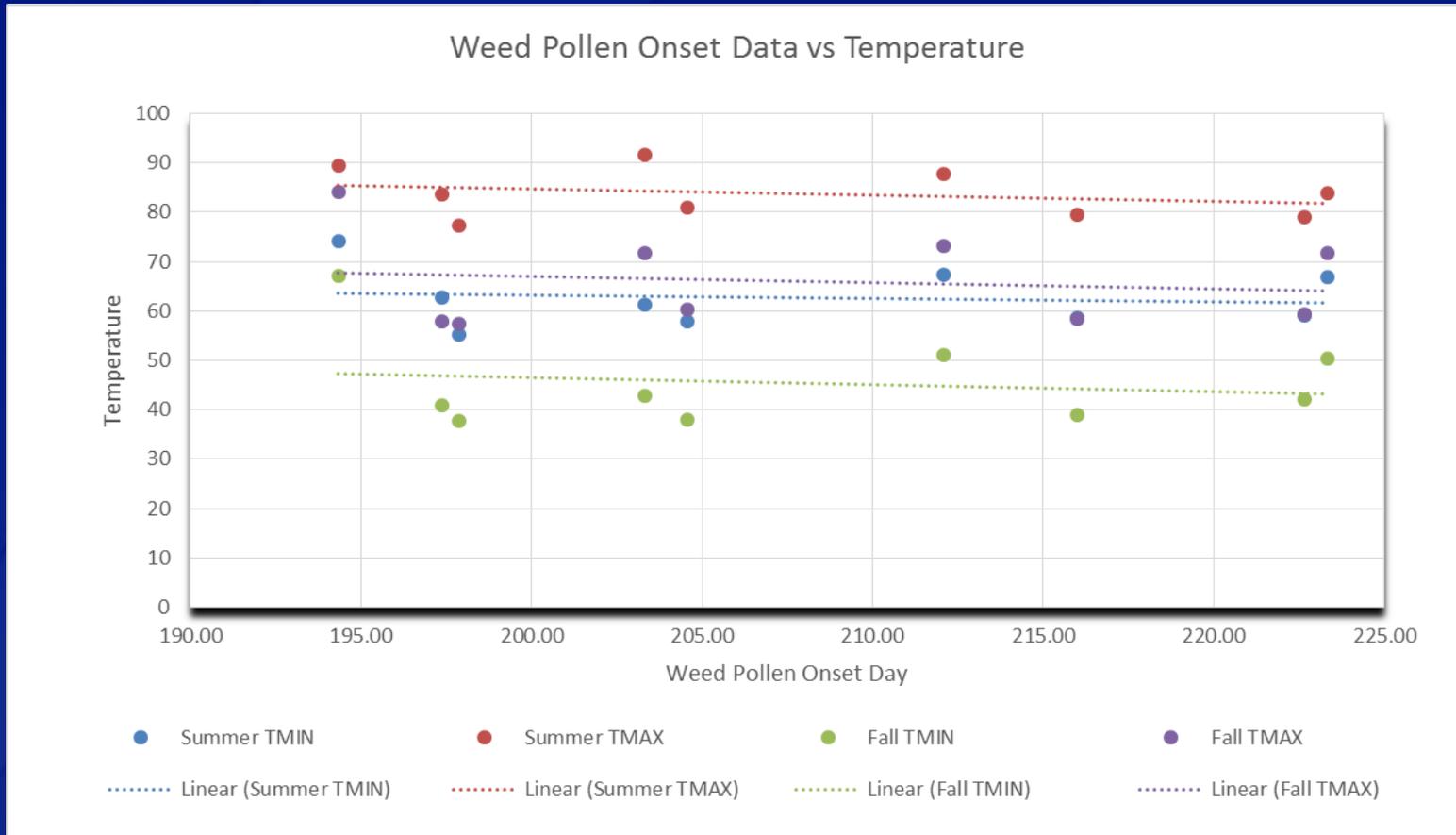
Results – Climate and Pollen Relationship

Spring Tree Pollen Season Onset and Temperature



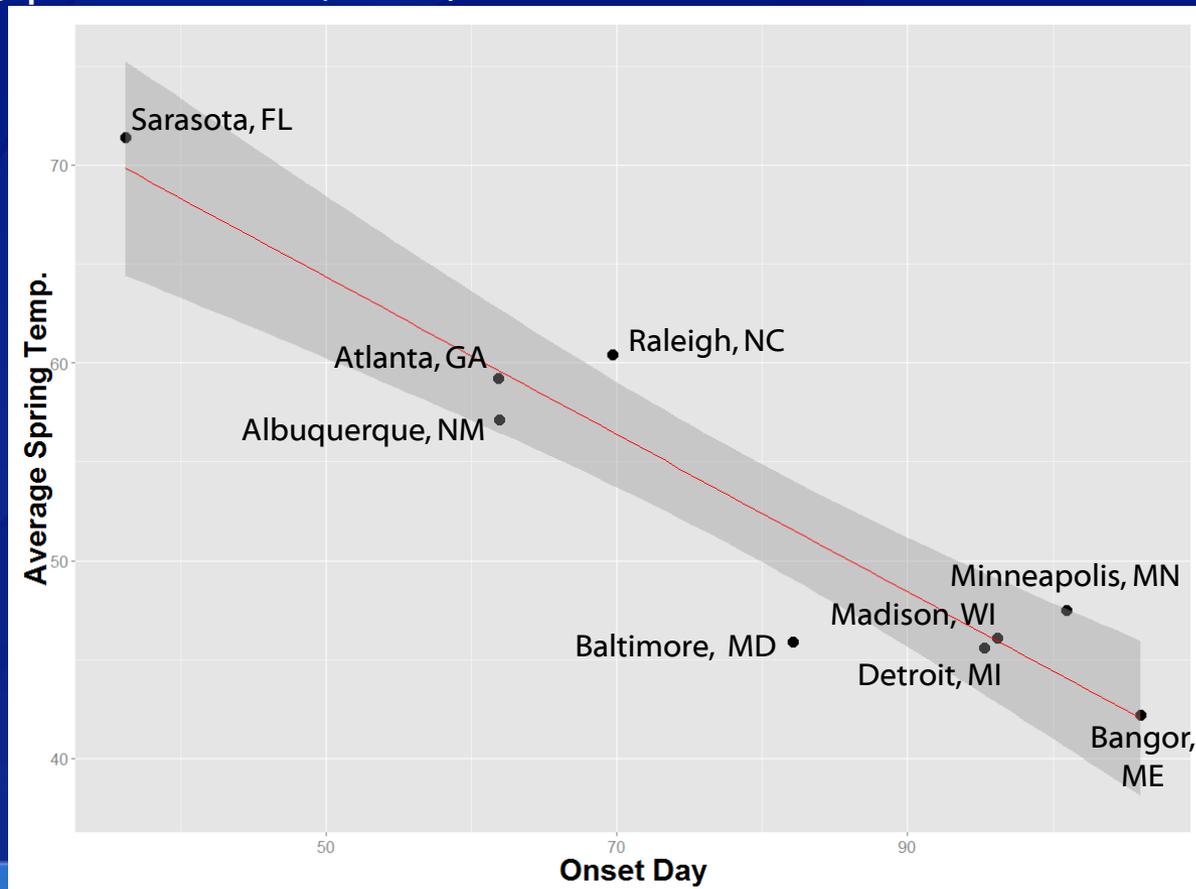
Results – Climate and Pollen Relationship

Fall Weed Pollen Season Onset and Temperature



Results – Tree Pollen Season Onset vs Spring Temp

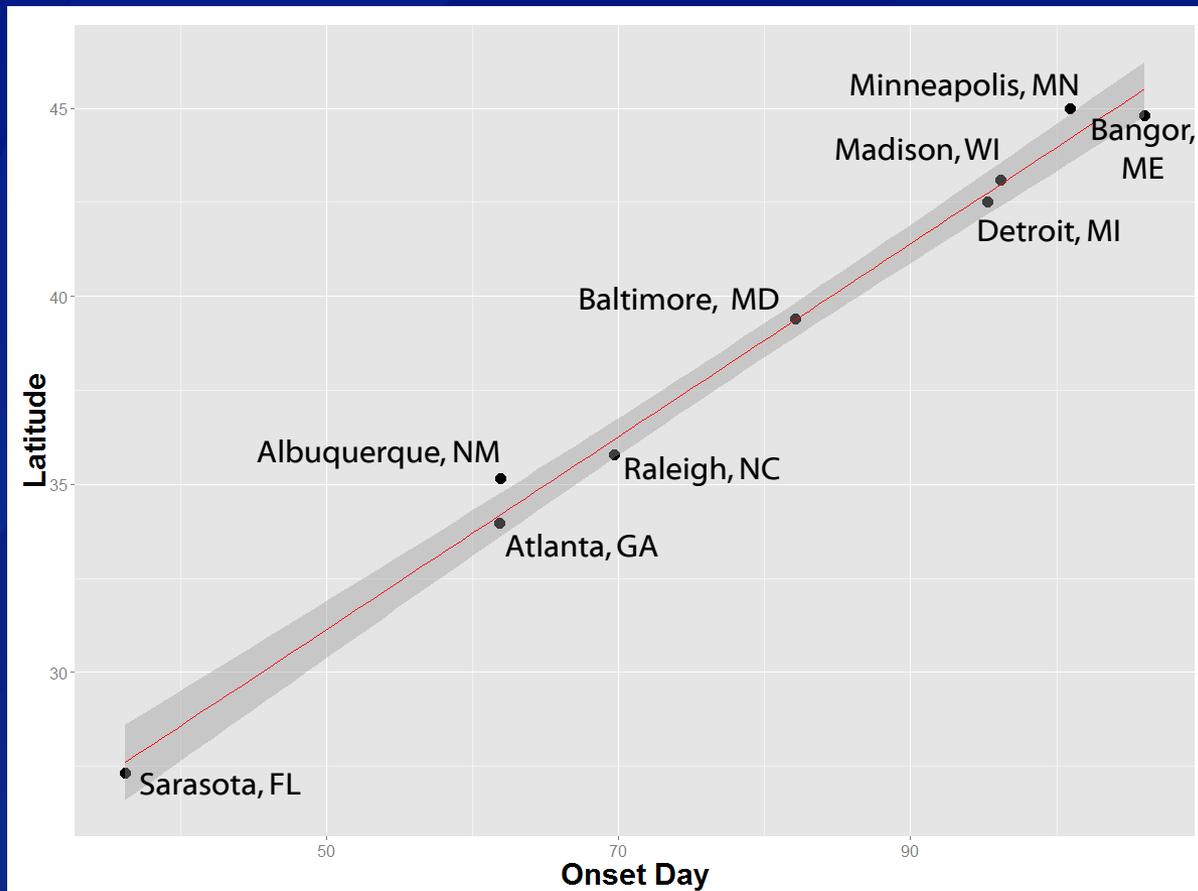
- Linear relationship between season onset (Spring) and temperature
 - Locations with warmer Spring temperatures have earlier pollen season ($R^2=0.91$, $p\text{-value}<0.001$, $df=7$)



Results –Tree Pollen Season Onset vs Latitude

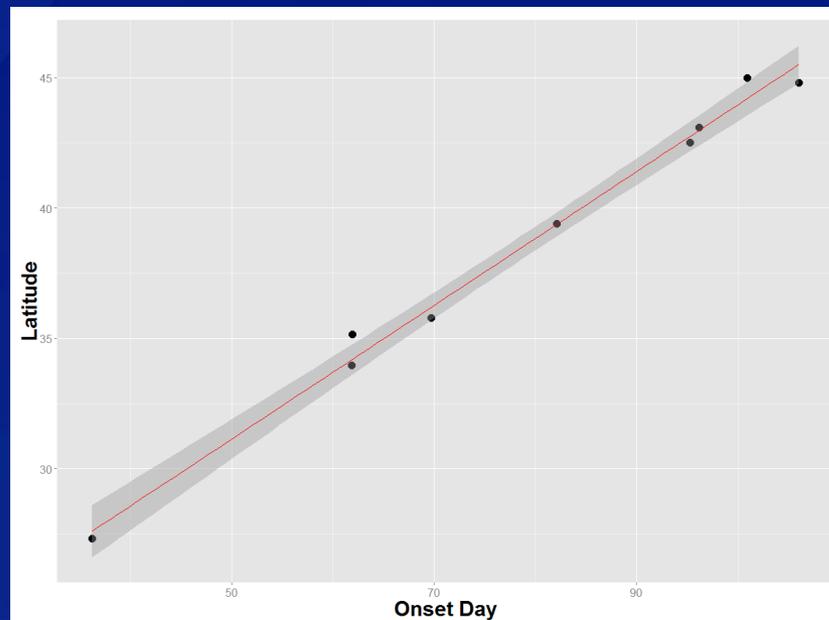
□ Linear relationship between season onset (Spring) and latitude

- As latitude increases, onset is delayed ($R^2= 0.99$, $p\text{-value}<0.0001$, $df=7$)



Results –Tree Pollen Season Onset vs Latitude

- For every one degree increase (Northward), tree pollen season onset is delayed by 3.9 days
 - ($R^2= 0.99$, $\beta=3.9$, $p\text{-value}<0.001$, $df=7$)

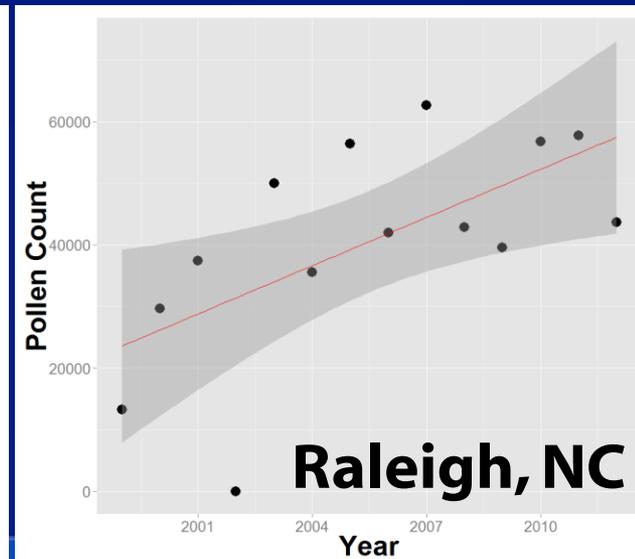
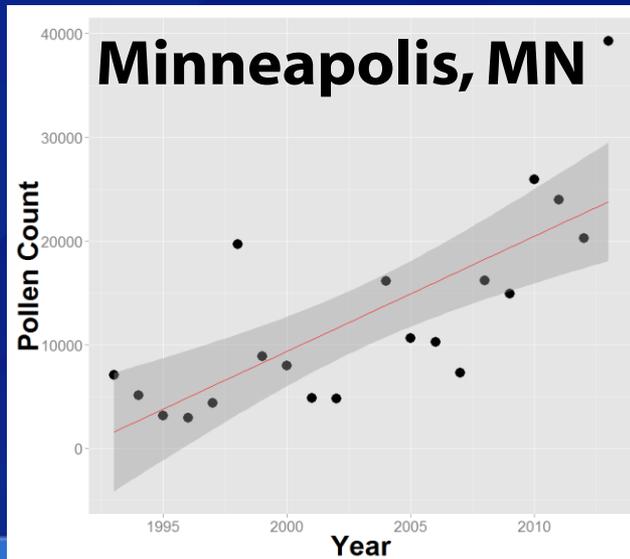
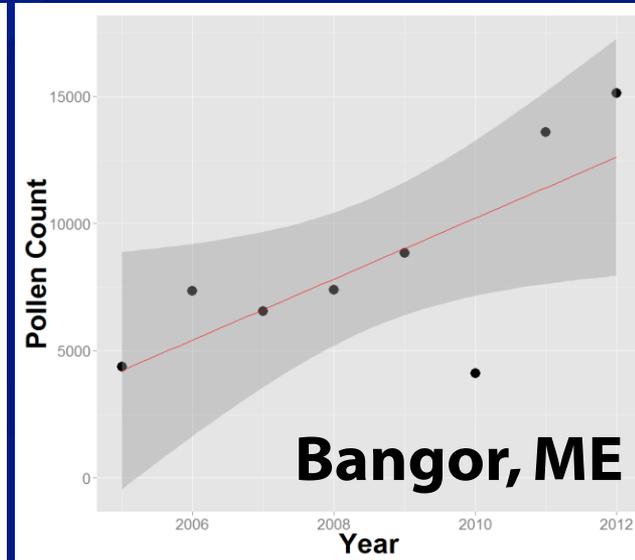
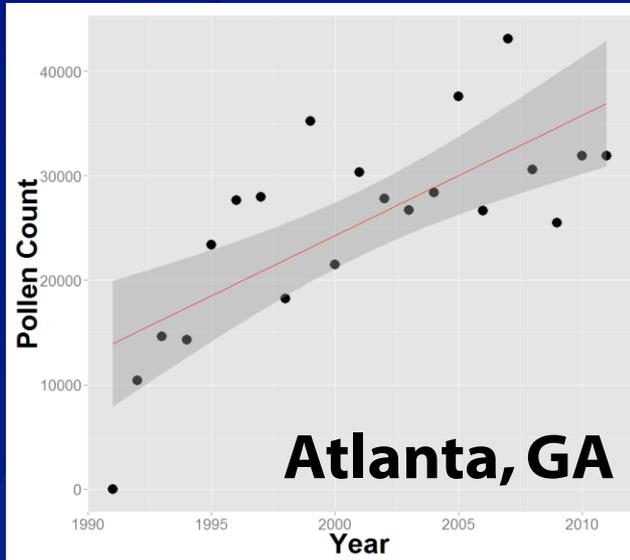


Results –Tree Pollen Count Trends Over Time

□ Tree Pollen Trends Spring

Location	Annual Increase	R ²	Sig.	DF
Atlanta, GA	930	0.47	0.0008	19
Bangor, ME	1199	0.54	0.039	7
Minneapolis, MN	1110	0.56	0.0001	20
Raleigh, NC	2608	0.39	0.016	11

Results – Tree Pollen Count Trends Over Time



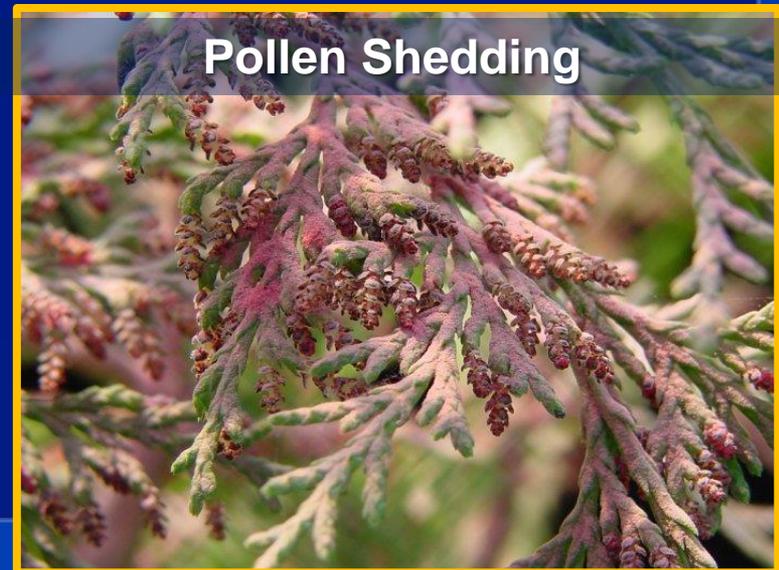
Summary of Results

- ❑ **Oak is the predominant pollen throughout the Spring Pollen season, except in Detroit, MI and Madison, WI**
- ❑ **Ragweed is the predominant pollen throughout the Fall pollen season, except for Albuquerque, NM.**
- ❑ **Spring Temperatures are significantly correlated with the timing of pollen season (onset)**



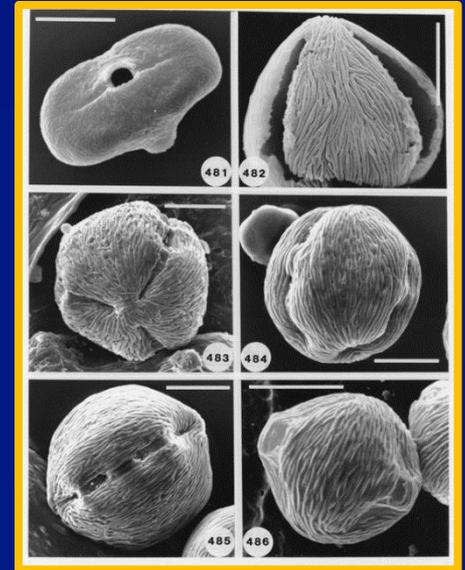
Conclusions

- ❑ **Latitude is a better predictor of pollen season onset than any climate variable.**
- ❑ **Climate (Spring Temps.) is an important factor, but it is only one of the many that may play a role in timing of pollen seasons.**



Future Directions

- ❑ **Analysis incorporating more pollen stations with speciated pollen data.**
- ❑ **Examine the effect of year-to-year climate variability on pollen counts and pollen season timing**
- ❑ **Determine long-term trends in pollen count and pollen season timing**
- ❑ **Assess the effectiveness of using proxy data to estimate pollen counts.**



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"The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the Centers for Disease Control and Prevention."