Implications of Climate Change for Pollen and Allergic Diseases

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May 1, 2016
Allergic Disease: Setting the Stage

• Complex set of diseases influenced by genetics, allergens, and other environmental exposures

• Asthma:
  • 8% of adults and 10% of children in the US
  • $56 billion in medical expenditures, missed work and school days, and early deaths in the US in 2007

• Allergic rhinitis or “hay fever”
  • 7.5% of adults and 9% of children in the US 2012
  • $11.2 billion in health services and prescription medication sales in the US in 2005

Pollen Allergens

- Many types of pollen are known allergens
- Broadly categorized as tree, grass, or weed pollen
Potential Pathways

- CO₂ concentration
- Temperature
- Precipitation

- Pollen season timing
- Pollen production
- Species distribution
- Allergen content

Prevalence, frequency, severity of allergic symptoms

Adapted from: Sheffield et al. MSJM 2011
Potential Pathways

- CO\textsubscript{2} concentration
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Adapted from: Sheffield et al. *MSJM* 2011

Prevalence, frequency, severity of allergic symptoms
Advance of Pollen Season Start Date

- Many studies find:
  - Start date (i.e., days since January 1st) correlated with temperature in months prior to season
  - Advance of start date over the last ~30 years, consistent with increases in temperature

Figure 1. Start date (day of the year from January 1) of the pollen seasons of the 5 plants throughout the study years.

Increase in Pollen Season Length

• Length of the pollen season increases in response to warmer temperatures

• More days of pollen exposure per year

• Strongest evidence comes from species flowering in summer or later (e.g., ragweed)

Ragweed Pollen Season Length, 1995-2013

Data from Ziska et al. PNAS 2011
Increase in Pollen Production

- Increased temperature and precipitation in the months prior to the pollen season leads to higher pollen production in some species

- Higher pollen exposures

Spieksma et al. Aerobiologia 2003; Cecchi et al. Allergy 2010
Shifts in Species Distribution

Climate change is likely to alter the geographic distribution of allergenic plants over long periods of time (i.e., decades)

Prasad et al. 2007: A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States [database]
Potential Pathways

- CO₂ concentration
- Temperature
- Precipitation

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- Pollen production
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Prevalence, frequency, severity of allergic symptoms

Adapted from: Sheffield et al. MSJM 2011
Ragweed Pollen Production as a Function of CO$_2$

Ambrosia artemisiifolia (common ragweed)

280 ppm: Preindustrial
370 ppm: Time of study
600 ppm: Projection for 2050

Photo credit: Guy Robinson (Fordham University)
## Ragweed Allergen Content as a Function of CO$_2$

<table>
<thead>
<tr>
<th>[CO$_2$] (µmol mol$^{-1}$)</th>
<th>Protein concentration (µg mg$^{-1}$ pollen)</th>
<th>Amb a 1 concentration (ELISA mg$^{-1}$ protein)</th>
<th>Amb a 1 concentration (ELISA mg$^{-1}$ pollen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>280</td>
<td>21 ± 2</td>
<td>4490 ± 960$^A$</td>
<td>93 ± 20$^A$</td>
</tr>
<tr>
<td>370</td>
<td>20 ± 2</td>
<td>5290 ± 560$^B$</td>
<td>103 ± 11$^B$</td>
</tr>
<tr>
<td>600</td>
<td>22 ± 2</td>
<td>8180 ± 900</td>
<td>178 ± 20</td>
</tr>
</tbody>
</table>

$^A$P<0.005 when compared with projected 21st century [CO$_2$], t-test using unequal variances.

$^B$P<0.01 when compared with projected 21st century [CO$_2$], t-test using unequal variances.
Potential Pathways

CO₂ concentration → Temperature → Pollen season timing

Precipitation → Pollen production → Prevalence, frequency, severity of allergic symptoms

Species distribution → Allergen content
Development of Allergic Disease

Allergen exposure

Allergic sensitization (IgE to allergen)

Allergic rhinitis
- Exacerbation (nasal congestion, runny nose, itching, sneezing)

Allergic asthma
- Exacerbation (wheezing, difficulty breathing, coughing, chest tightness)
Pollen Exposure and Allergic Disease

• Exposure to pollen is associated with:
  • Development of allergic sensitization
  • Exacerbation of allergic asthma
  • Exacerbation of allergic rhinitis

• Higher pollen exposures could lead to:
  • Increased prevalence of allergic sensitization
  • More frequent and severe symptoms

• Population-level studies suggest most important pollen types differ by region
Daily concentrations of grass and oak pollen associated with increased asthma ED visits.

**FIG 3.** Risk ratios and 95% CIs for categories of 3-day moving average pollen levels. Numbers above the x-axis indicate median pollen concentrations for each category. *Risk ratios for Betulaceae and Pinaceae are controlled for Quercus species concentrations.*

Darrow et al. JACI 2012
ED Visits and Medication Sales – NYC

Asthma ED visits and over-the-counter sales of anti-allergy medications associated with spring tree pollen

Strongest associations:
- Ash
- Sycamore
- Birch

Ito et al. Environ Health 2015
Potential Pathways

Adapted from: Sheffield et al. MSJM 2011
Sources of Uncertainty: Land Use

Decline in grass pollen totals at two sites in the UK linked to decrease in grassland within 40 km

Fig. 1. Five year running means of cumulative yearly grass pollen counts.
Potential Pathways

- CO₂ concentration
- Temperature
- Precipitation
- Land use change
- Pollen season timing
- Pollen production
- Species distribution
- Allergen content
- Prevalence, frequency, severity of allergic symptoms

Adapted from: Sheffield et al. MSJM 2011
Sources of Uncertainty: Air Pollutants

- Altered expression of allergenic proteins within pollen grains - e.g., for ozone:
  - ↑ expression of the birch allergen Bet v 1
  - ↓ expression of the grass allergen Phl p 5

- Ozone, PM$_{2.5}$, and sulfur dioxide exposure leads to increased permeability of mucous membranes, enhancing allergen interaction with immune system cells

- Diesel exhaust particles may facilitating the process of sensitization to allergen

Summary

• Temperature, precipitation, and CO₂ influence multiple aspects of the pollen season

• Future changes in these factors due to climate change could lead to longer and more intense periods of pollen exposure, which in turn could increase the prevalence and severity of allergic disease

• Magnitude of change will likely vary by region due to:
  • Trends in land use and air pollution
  • Differences in regional climate
  • Differences in pollen types across regions
  • The degree to which different pollen types are influenced by climate
  • Regional variation in the dominant pollen types driving allergic disease
  • Mitigation and adaptation strategies