"Thunderstorm Asthma": Respiratory Emergencies during Thunderstorm Events

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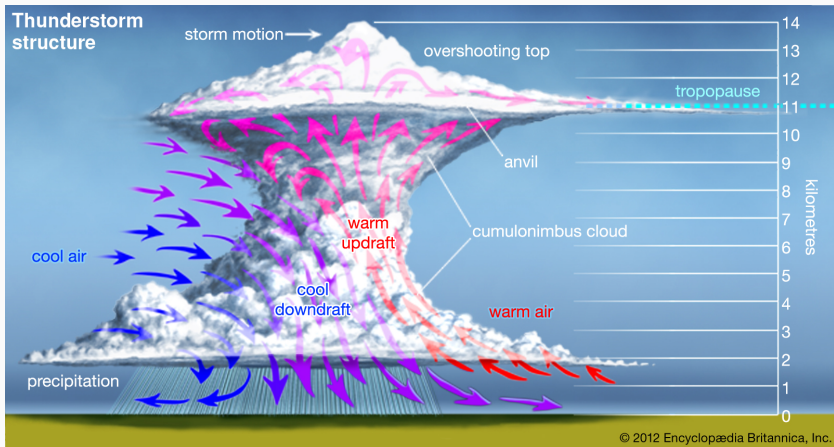**Nolan Miller** (Illinois & NBER)
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Thunderstorm structure

- storm motion
- overshooting top
- tropopause
- anvil
- cumulonimbus cloud
- warm updraft
- cool downdraft
- cool air
- warm air
- precipitation

kilometres: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
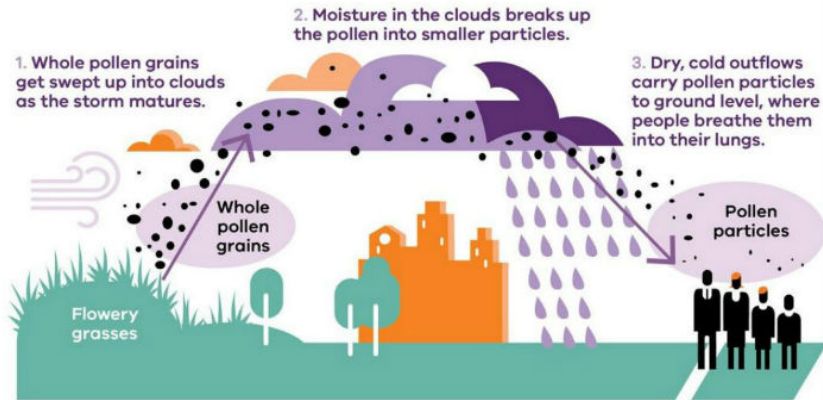
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"Thunderstorm asthma"

- Epidemic outbreaks of acute asthma exacerbations temporally associated with a thunderstorm
    - 1983, Birmingham, England: 106 patients with asthma patients within 2 days after a thunderstorm
    - 2016, Victoria, Australia: 8,000 asthmatics, 8 asthma deaths
    - Similar epidemics in North America, UK, Europe, Australia, Kuwait, etc.

The working hypothesis

- The "perfect storm" theory
    - High pollen/spore stock before the event
    - Updraft winds bring up pollen spores from the ground
    - Precipitation causes pollen to rupture and release small allergenic particles
    - Downdraft winds help release smaller particles to ground level
    - Large number of susceptible people in the storm area
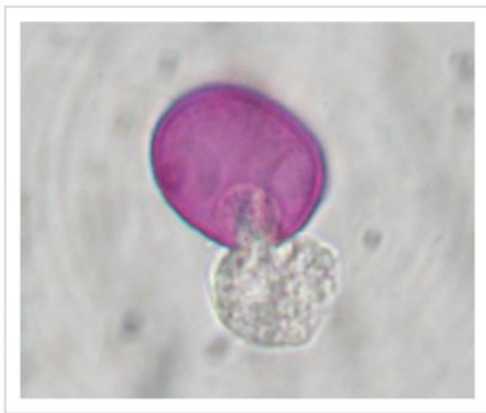
What is thunderstorm asthma?

1. Whole pollen grains get swept up into clouds as the storm matures.

2. Moisture in the clouds breaks up the pollen into smaller particles.

3. Dry, cold outflows carry pollen particles to ground level, where people breathe them into their lungs.

Whole pollen grains

Pollen particles

Flowery grasses

Figure 1

Parietaria pollen bursting under osmotic shock with release of cytoplasmic fragments carrying allergens.

Primary contributions

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  - Event studies of 2.6 million thunderstorms at county×day level, 1992-2012
 - Track elderly's emergency room (ER) visits for respiratory complaints

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- Mechanism: "calm before the storm"
  - Thunderstorms are preceded by a week of significant slow air motion
  - Meanwhile, significant build-up of particulates pollution
  - Correspondingly, gradual increase of respiratory ER in the week leading to the storm
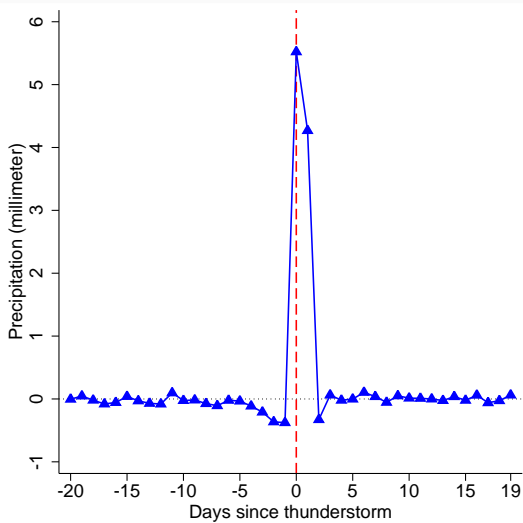
Data

- Thunderstorms
    - U.S. National Lightning Detection Network (NOAA & Viasala)
    - Near-universal coverage: 98% of cloud-to-ground lightning flashes
    - High accuracy in time (0.5 microseconds) and space (200 meters)
    - We define a "thunderstorm" = any county×day with lighting flashes

- Atmospheric conditions

- Emergency room visits among the eldelry

Annual Number of Thunderstorm Days

Annual Number of Thunderstorm Days
- 0 - 36
- 37 - 45
- 46 - 51
- 52 - 55
- 56 - 59
- 60 - 63
- 64 - 68
- 69 - 74
- 75 - 87
- 88 - 150
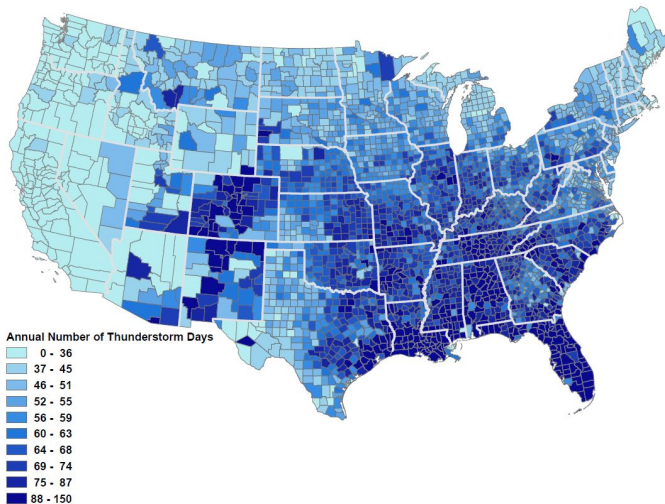
Notes: Days with cloud-to-ground lightning flashes and positive precipitation.

Precipitation around thunderstorms

Precipitation (millimeter) vs. Days since thunderstorm

Notes: Mean daily precipitation = 2.90 millimeter.

Data

- Thunderstorms
- Atmospheric conditions
    - Weather: NOAA Global Historical Climatology Network
    - Air pollution: U.S. EPA Air Quality System
    - Pollen counts (61 cities): American Academy of Allergy Asthma & Immunology
- Emergency room visits among the eldelry

Data

- Thunderstorms
- Atmospheric conditions
- Emergency room (ER) visits among the eldelry
  - Medicare inpatient and outpatient records (100% claims)
  - Covers 98% of U.S. population aged 65+
  - Observe all ER visits, whether or not ended up hospitalization
  - For each visit: patient's county of residence, date of visit, primary diagnosis, preexisting medical conditions

Weather and health around thunderstorms

- Event study of thunderstorm

$$Y_{ct} = \overbrace{\sum_{d=[-20,20]} \beta_d \cdot \text{Thunderstorm}_{c(t+d)}}^{\text{leads \& lags of t-storm indicators}} + \text{Covariates}_{ct} + \varepsilon_{ct}$$

- Covariates$_{ct}$ include FEs indicators
  - County FEs
  - Year, month, day-of-week FEs

- Cluster standard errors at the county level
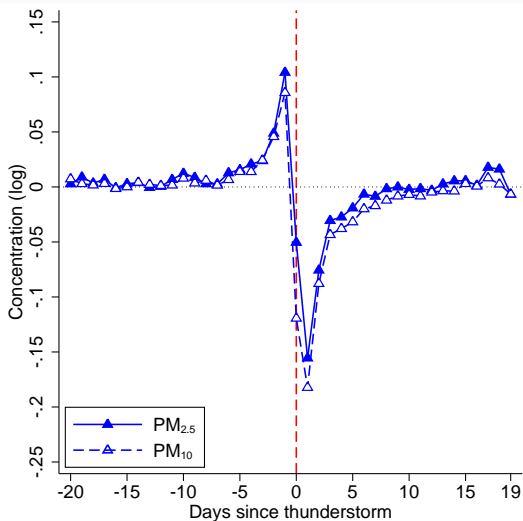
Wind speed around thunderstorms
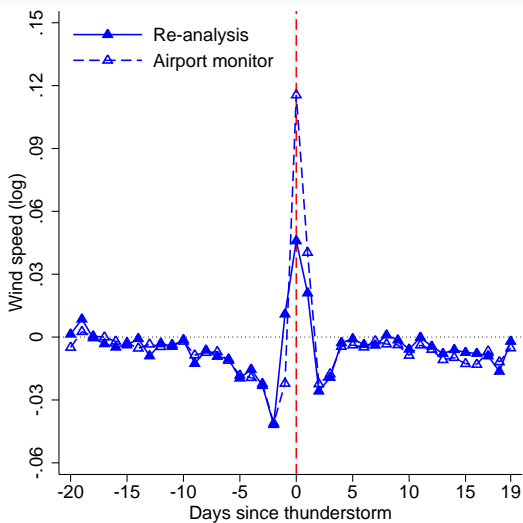
Notes: Average daily wind speed = 3.51 m/s (near-airport measure).

Wind speed around thunderstorms (L) vs. rainstorm (R)
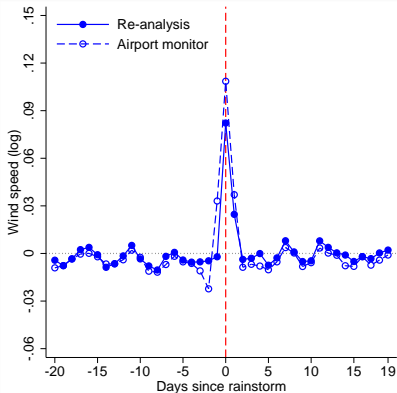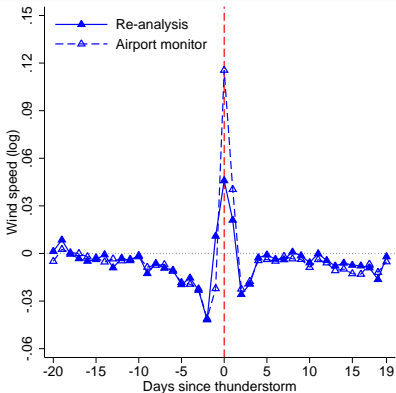
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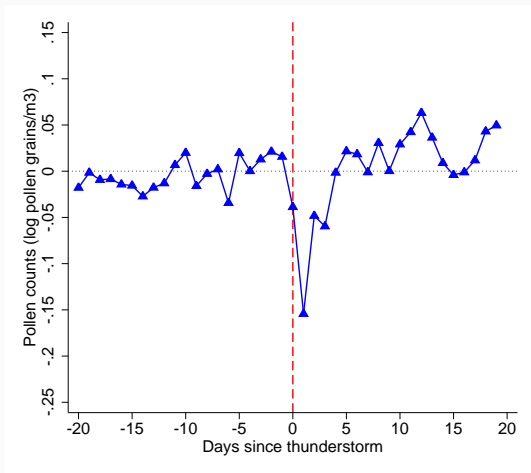
Particulate matter around thunderstorms

Concentration (log)

Days since thunderstorm

PM$_{2.5}$
PM$_{10}$

Notes: Average PM$_{2.5}$ (PM$_{10}$) = 12.1 (24.8) ug/m3.

Other (gaseous) pollutants around thunderstorms
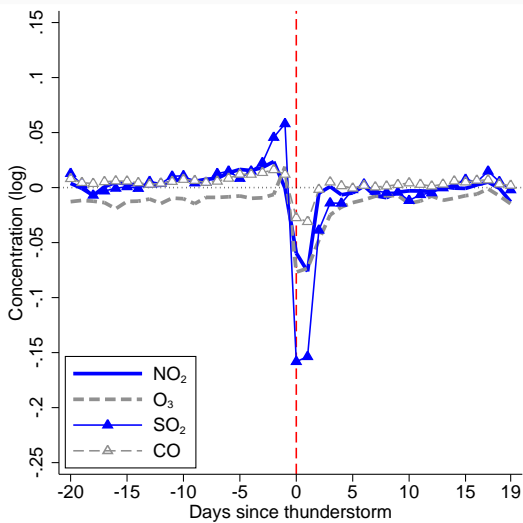
Notes: Average $NO_2 = 15.0$ ppm.
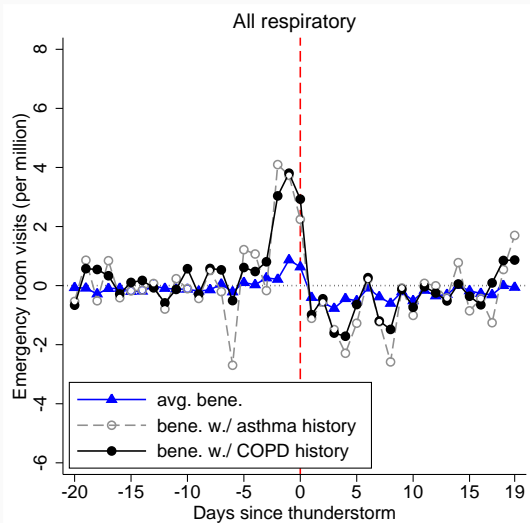
Pollen counts around thunderstorms (61 cities)

Respiratory ER visits around thunderstorms
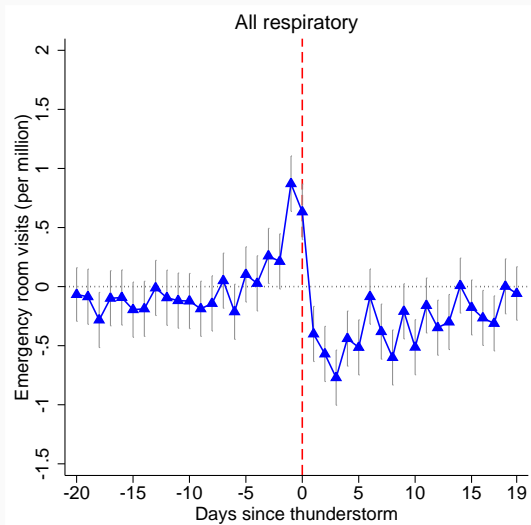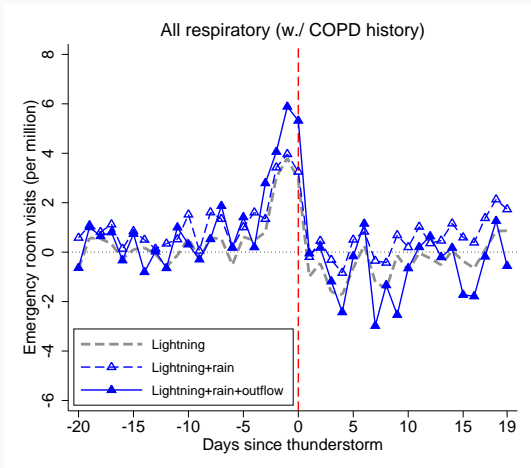

All respiratory

Notes: Mean = 152.7 visits per million. Range bars show 95% CIs constructed using SEs clustered at the county level.

Respiratory ER visits around thunderstorms: COPD patients

Notes: Mean = 562.9 visits per million. Range bars show 95% CIs constructed using SEs clustered at the county level.

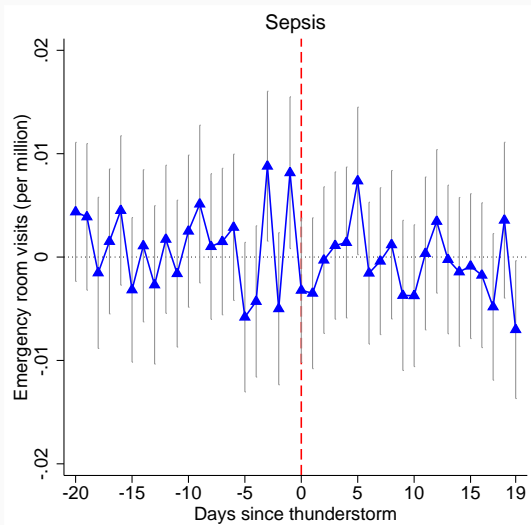# Respiratory ER visits around thunderstorms: Storm intensity

All respiratory (w./ COPD history)

Legend:
- Lightning
- Lightning+rain
- Lightning+rain+outflow

Y-axis: Emergency room visits (per million)
X-axis: Days since thunderstorm

Robustness and falsification checks

- No "build-up" effect for rainstorm (precipitation without lightning)
- **Placebo tests using broad diagnoses unrelated to pollution**

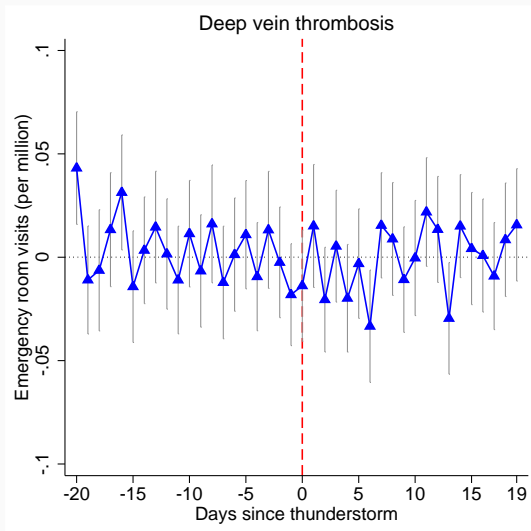## "Placebo" ER visits around thunderstorms: Sepsis

Notes: Mean = 0.18 visits per million. Range bars show 95% CIs constructed using SEs clustered at the county level.

"Placebo" ER visits around thunderstorms: PE
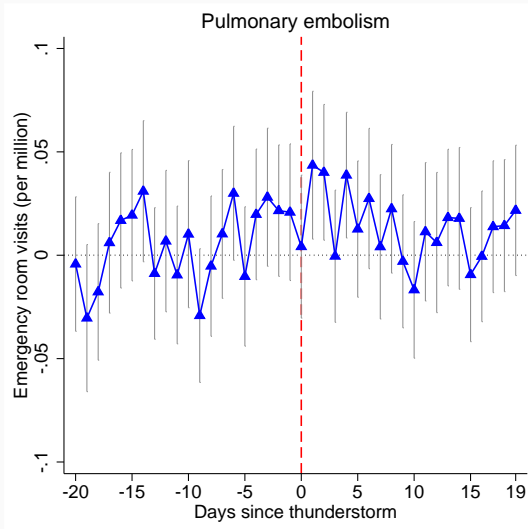
Notes: Mean = 3.92 visits per million. Range bars show 95% CIs constructed using SEs clustered at the county level.

"Placebo" ER visits around thunderstorms: DVT

Deep vein thrombosis

Conclusion

- Emergency visits for respiratory problems among Medicare beneficiaries were increased in the days surrounding thunderstorms in the U.S., particularly among patients with a history of COPD

- Older patients with reactive airway disease are less sensitive to airway hyperreactivity compared to younger patients
  - The amount of additional acute respiratory illness related to lightning and thunderstorms requiring emergency care is likely higher among children and younger adults