The paths of extratropical cyclones associated with wintertime high wind events in the Northeast United States

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Motivation

Northeast Wind storms cause power outages and generate life-threatening hazards.

If we can link the wind storms to a typical pathway of extratropical storms, it will improve our understanding and forecasting of the events.

Characteristic Paths of Storms in Winter

From Reitan, 1974

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Methods

Track extratropical storm centers with automated scheme

Examples of extratropical cyclone tracks for different weeks of Jan. 2010.

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Methods

Analyze surface station wind data

VARIABLE USED: maximum sustained wind speed (.1 knots); converted to m/s

Stations used in study: NOAA NE Region

Color: percent of DJF data available for 1979-2012.
Yellow x: “sparse set” of stations, to test of station density in the NE creates a bias.

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Methods

- Peak over Threshold (POT) analysis based on Generalized Pareto Distribution (GPD)

\[
F(x) = 1 - \left(1 + \frac{\xi(x - u)}{\sigma}\right)^{-1/\xi}
\]

- Return Period: 
  \[ R(x) = \frac{1}{\omega \left[1 - F(x)\right]} \]

ω is the average sampling frequency

For each station, we calculate the 1-, 3- and 5-year return period.

APPLICATION OF EXTREME VALUE THEORY

- Return Period: \( R(x) = \frac{1}{\omega \left[1 - F(x)\right]} \)
Algorithm

I. EVT wind analysis
- Identify all sites within NOAA’s Northeast Region – based on states.
- Identify all stations with at least 60% of data for 1979 – 2012 (i.e., the years of the ERA-Interim cyclone track dataset).
- At each site, identify extreme events using a peak over threshold approach.

II. Identify simultaneous exceedances: “multi-station event”
- Find multi-station events, i.e., all exceedances that occur on +/- 1 day. (note: strong wind storms occurring near midnight might be counted on two different days at nearby stations.

III. Associate multi-station events with extratropical cyclones
- For events that occur at multiple stations on the same day, identify cyclones occurring on same day, within a reasonable radius of the wind event.

IV. Separate the storms based on their paths

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Cyclone Track Analysis

The storm dataset.
- ERA-Interim DJF 1979 – 2012
- Grab all storms that pass through the green box →

Track count:
Hodges: 1034
MCMS: 1020

Spaghetti plot of tracks

Track Density: Count per DJF

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Extratropical Cyclone Attribution Algorithm

1. Find cyclones that occur within +/- 12 hours of 12Z on date of multi-station event (track data is 6-hourly).

2. Keep cyclones that are within 1500 km of the center of the wind event.

3. If there are multiple cyclones found for a given date:
   - Area-average reanalysis winds at 700-hPa winds and use avg wind direction to determine which cyclone is likely associated with wind event.
   - e.g., if wind is blowing south, then the cyclone to the east of the center of the wind event is chosen.

This analysis can be carried out on any set of events.

Here I show results for many different sets of Multi-station events.

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Events defined here as:

- High wind event (HWE) exceed 3-year return levels at exactly 3 stations.
- Associated tracks and stations are given in same color.
- Green dot on each track shows location of storm at date of HWE.
- Legend shows the full date extent of each track and date of HWE in parentheses.
Track associated with multi-station events based on different criteria

Take-home: as the definition of multi-station event becomes more strict, a preferred path emerges

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CONCLUSIONS:

1. Over 90% of the multi-station wind events are associated with the circulation within an extratropical cyclone.

2. The most common cyclone path that creates wind storms in the northeast is the southwest-2-northeast path.

3. The reason for this is that storms tend to generate their strongest winds in the area south of the storm center, at the Cold Front, and for storms that take the southwest-2-northeast path this region passes directly over the NE US.

4. This result does not imply that southwest-2-northeast storms have stronger winds than the other storms. Instead it relates to the relative location of the storms strong wind region, relative to the geographical location of interest.