Assessing exposure to Atlantic Basin tropical storms in United States counties

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Abstract

There are many important applications for having county-level estimates of exposure to tropical storms over many years. For example, ... Current approaches include . . . but have the following limitations . . . .

Here, we present open source software we have developed to explore county-level exposure to tropical storms in United States counties between 1988 and 2011. Further, we explore the differences in exposure classification when using different metrics (e.g., wind speed, rainfall, distance).

```
library(hurricaneexposure)
```

Introduction

What it means to assess county-level tropical storm exposure.

Why it's important to measure TS exposure for counties.

Examples of using TS exposure estimates for multiple storms.

Examples of other datasets at the county level. If exposure to tropical storms over multiple storms and years can be assessed, these exposure datasets can be joined with other time series to explore the impacts of tropical storms. For example, daily counts of human health outcomes in environmental epidemiology studies are often available aggregated at the county level, and such data has often been paired with time series of environmental exposures (e.g., air pollution, temperature) to determine associated risks.

Data and Methods

Distance-based exposure. We collected "best tracks" data on hurricane tracks for Atlantic basin storms between 1988 and 2014 from the extended best tracks database. . . . This data gives time stamps for each observation in UTC.

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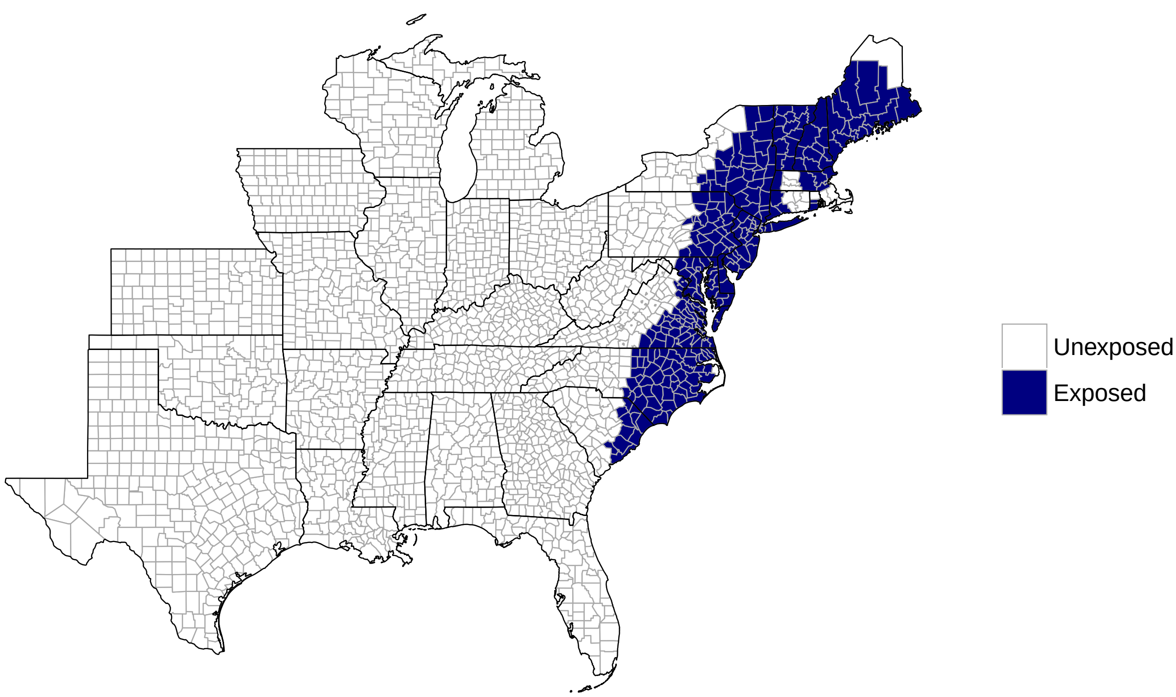
These data typically give measurements of storm center location at 6-hour intervals. We interpolated these location values to every 15 minutes during the period when the storm was active, using a linear interpolation between each measured point.

We calculated the distance between each county's center and each of the 15-minute-interval estimates of a storm's location. To do this, we used the Great Circle method to calculate the distance between pairs of latitude and longitude coordinates, using the R package `sp`. For each county, we used the population mean center, based on the U.S. Census's 2010 Decennial Census, as the center location of the county. From these distance calculations, we identified the date-time and distance between the storm track and the county center at the 15-minute interval when the storm was closest to the county center. We used the `countytimezones` R package to convert each date-time of the closest storm approach for a county to the county's local time zone and identified the local date when the storm was closest to the county. This "closest date" was used to pair the distance estimates with rainfall estimates.

Rain-based exposure.

Wind-based exposure.

Results



Discussion

Distance-based exposure. There are some sources of uncertainty for storm locations from the best track hurricane data. These include ...

However, these best tracks should be fairly reliable for more recent years of storms, as we use here. Many of the uncertainties related to storm positions in best track data are more of a concern for the years before ... (e.g., pre-19[xx]).

While there are often several different “best tracks” datasets, from different sources [?– weather services?] for other ocean basins, the “best tracks” data from . . . , which is the basis of the tracks we use here, are the undisputed primary source of tropical storm track data for the Atlantic basin.

There are a number of limitations to using distance to assess exposure to tropical storms. Tropical storms vary in size and intensity, and a measure of distance from the storm track will not incorporate these differences and so could mis-classify exposure both in terms of generating false positives (counties close to the storm track of very mild or small-radius storms) and false negatives (e.g., during very large or intense storms).

Rain-based exposure. It can be very difficult to reliabily measure rain during extreme rain events, including tropical storms. For example, a heavy rain can wash away [?] rain monitors [?]. It can also be very hard to measure rain during heavy wind, as the rain does not fall straight into the monitor [?].

Some of the other possible sources for estimating rain during tropical storms include . . .

The estimated rainfall amounts from our data are likely underestimates. This data source, however, should be internally consistent and so useful for comparing across different storms when all exposure estimates are based on this rain data.

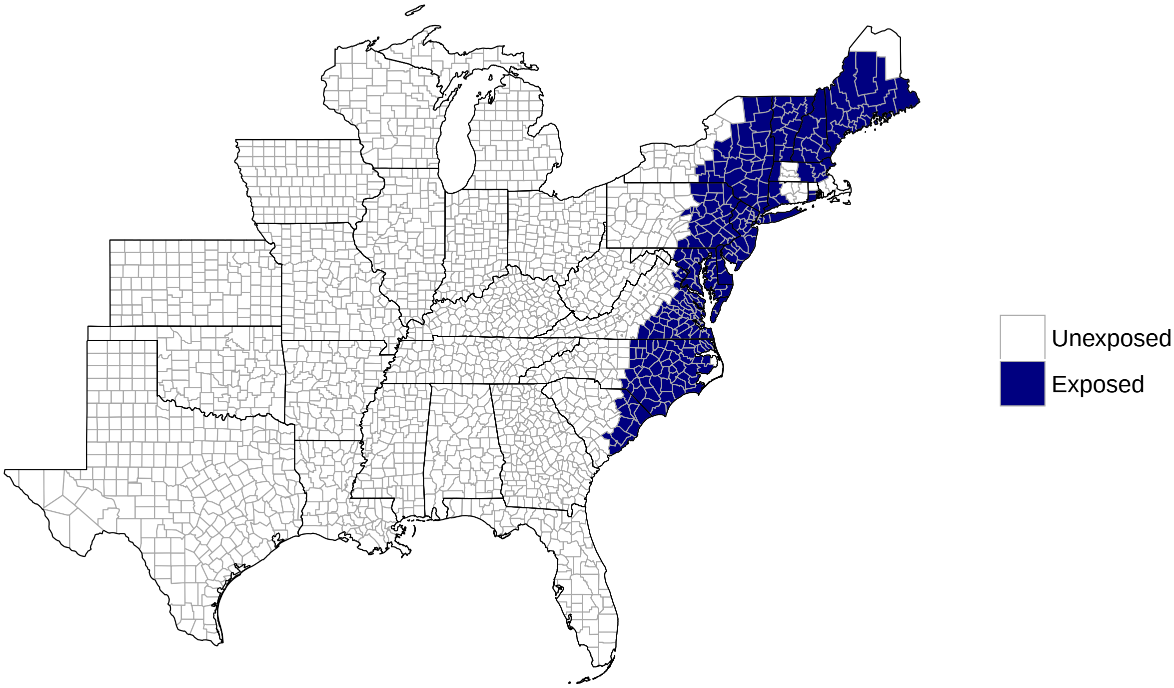
Rainfall estimates are likely underestimates for a few reasons. First, they are based on averaging hourly measurements to a daily mean estimate. This averaging would smooth over shorter periods of very extreme rainfall. Further, this data is averaged over multiple grid points within each county and so would not fully reflect very extreme local precipitation (although this might be less of a concern for classifying exposure to a large-scale storm system, like a tropical storm, compared to more fine-scale storms). Finally, this NLDAS data provides a re-analysis that incorporates measured rainfall, using models, etc., to incorporate that observed data into a spatially and temporally continuous dataset of rainfall. However, during extreme storms, the problems with measuring rainfall using [rain monitors] would propogate into the NLDAS data, so although NLDAS would prevent missing values during the storm if monitors are not able to provide data, if monitors are out, rainfall estimates from NLDAS will be based more on models than on observations.

Exposure classification based on rainfall has some advantages. For example, it allows the identification of exposed counties that are inland, rather than coastal, but that were affected by heavy rainfall during the storm. Often, storm-related deaths are associated with inland flooding. Storms can produce a lot of rain especially in certain topographies, like near mountains, so counties that are well inland can sometimes experience more extreme rain that other counties at similar distances from the storm’s track.

In comparison to the storm track, the areas of extreme rain and extreme wind can vary. For example, storms undergoing an extratropical transition can bring heavy rains to the left of the storm’s center track, while extreme winds are more common to the right of the track (Halverson 2015).

Some storms can be of lower intensity (i.e., on the Saffir-Simpson scale) yet bring dangerous rainfall, including well inland of the storm’s landfall. For example, storms including Floyd in 1999, Gaston in 2004, Irene in 2011, and Lee in 2011, have had severe inland impacts, often through extreme rainfall, as post-tropical storms [Halverson2015]. This rainfall can be particularly severe in the Appalachians [Halverson2015].

For example,



Wind-based exposure. Wind suffers from similar challenges for measuring during tropical storms. In particular, the strong winds of tropical storms can break or blow away the anemometers used to measure wind speed.

Here, we used wind speed models, rather than observed wind speed, to estimate exposure to tropical storms based on winds.

A variety of other wind speed models exist besides the one used here. In particular, there are options for wind speed models as far as ...

Example uses of exposure datasets.

References

Halverson, Jeffrey B. 2015. "Second Wind: The Dealdy and Destructive Inland Phase of East Coast Hurricanes." *Weatherwise* 68 (2): 20–27. doi:10.1080/00431672.2015.997562.