

Automating Natural Disaster Impact Analysis:

An Open Resource to Visually Estimate a Hurricane's Impact on the Electric Grid

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Abstract— An ORNL team working on the Energy Awareness and Resiliency Standardized Services (EARSS) project developed a fully automated procedure to take wind speed and location estimates provided by hurricane forecasters and provide a geospatial estimate on the impact to the electric grid in terms of outage areas and projected duration of outages. Hurricane Sandy was one of the worst US storms ever, with reported injuries and deaths, millions of people without power for several days, and billions of dollars in economic impact. Hurricane advisories were released for Sandy from October 22 through 31, 2012. The fact that the geoprocessing was automated was significant – there were 64 advisories for Sandy. Manual analysis typically takes about one hour for each advisory. During a storm event, advisories are released every two to three hours around the clock, and an analyst capable of performing the manual analysis has other tasks they would like to focus on. Initial predictions of a big impact and landfall usually occur three days in advance, so time is of the essence to prepare for utility repair. Automated processing developed at ORNL allowed this analysis to be completed and made publicly available within minutes of each new advisory being released.

Keywords—Hurricane; Electric Grid; EARSS; Python

I. INTRODUCTION

Visualizing Energy Resources Dynamically on Earth (VERDE) [1-2] provides real-time status of power grid outage. The grid outage data within VERDE comes from proprietary sources; hence, limited distribution of critical information. Its non-proprietary relative, the National Outage Map (NOM), is similar, but acquires its real-time status information by automatically crawling public utility websites coupled with Twitter feeds to fill in coverage gaps. Both services provide real-time status, but not prediction.

Figure 1 illustrates that hurricane predictions are fairly accurate up to 2-3 days in advance of landfall. Thus it is possible to take a static known location of electric grid utilities and predict which ones will be impacted during the course of a hurricane, refining the prediction as hurricane advisories are updated. This would aid utility and emergency managers in their decision making regarding where to position supplies and crews.

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II. SOFTWARE SYSTEM

A. Processing

Wind speed estimates [3-4] are overlaid with a static US substation map to determine which substations will be impacted by winds >39 mph. Then, impacted substations are overlaid with a static US service area map to determine which service areas will be impacted by winds >39 mph. Note that 39 mph is chosen because that is the low cutoff for the hurricane strength levels reported by the NHC. Service areas are obtained by a process that uses LandScan [5] population data in 1 km grid. Essentially, a nearest neighbor technique is used to accumulate a spatial region containing customers to satisfy the load offered by each substation. Service area information includes the number of customers and population estimates.

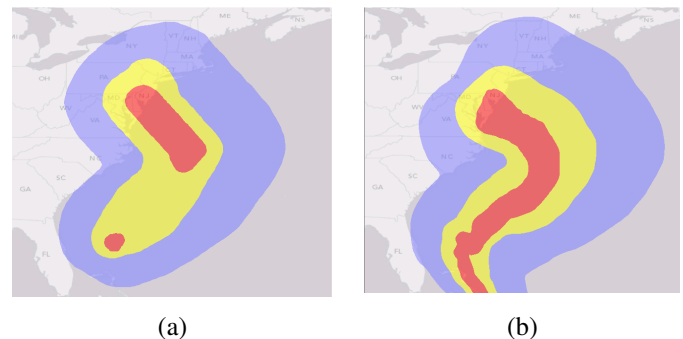


Fig. 1. (a) Predicted path of Sandy from advisory 20A issued at 8:27 AM Oct 27, 2012. (b) Actual path of Sandy from advisory 31 issued at 11:00 PM Oct 29, 2012. Data from National Hurricane Center via HurricaneMapping.com. Blue for 39 mph, yellow for 58 mph, and red for 74 mph or higher maximum winds at the storm center [3-4].

B. Restoration Estimate

A “days until power restoration” estimate is provided, assuming that 200 8-man crews are available each day, and that 1 8-man crew can restore 1 substation in 1 day. Service areas are assumed to be repaired prioritizing the largest number of customers first.

An important interpretation note on the restoration map is that the restoration times are expressed as the time after the storm has passed sufficiently to allow restoration efforts to begin. The usual utility criteria is that restoration begins after the local wind speed drops below 30 mph. Typically, this is a delay of about 24 hours after the storm system passes through the impact area. The 24-hour rule has held for storms on the east coast with one recent exception: Hurricane Isaac was an

exception to the rule about doubling the delay time because the storm moved at a very slow 5 mph for most of its time in southern Louisiana. Current models suggested that Sandy was moving fast enough that the 24-hour rule would apply.

When predicted outage time is on the order of a week, this correction is small. For those areas predicted to be restored in 24-48 hours, this correction would be significant.

Simply put, the restoration times are elapsed times after the wind drops below 30 mph locally and a historic rule of thumb is to add 24 hours post peak outage time.

C. Automation

It was desirable to automate the processing for the following reasons:

1. Hurricanes with U.S. landfall often have >40 advisories issued. For example, Sandy 2012 had 64, and Isaac 2012 had 87.
2. Advisories are issued around the clock.
3. Personnel capable of manually processing the advisories are a scarce resource that is often in high demand during a hurricane event.
4. Repetitive manual processing is prone to error.
5. Manual processing takes ~1 hour per advisory and time is of the essence in making data available to emergency planning personnel.
6. The ESRI ArcGIS software suite used for the manual processing of storm files includes a Python programming language interface specifically for automating GIS processing.

Since ArcGIS includes a native Python command line, and an ArcGIS-specific module called `arcpy.py`, Python was used to script the ArcGIS processing, as well as non-GIS processing such as advisory retrieval off the web, advisory text file parsing, file transfer and registration to the GIS webhosting machine running GeoServer [6], and sending email notifications. Analyzed files were typically available a few minutes after an advisory was released. Figure 2 displays the architecture of the software processing system.

III. ANALYSIS PRODUCTS

Figure 3 displays a map of predicted substations impacted. The analyzed substation files contain the following attributes:

- Substation ID
- Substation Name
- Load in Megawatts (MW)
- State
- Latitude and Longitude
- Wind Speed

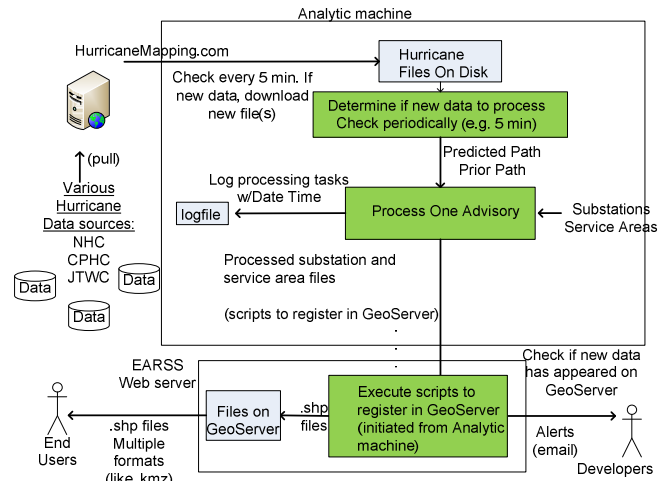


Fig. 2. Software System Processing.

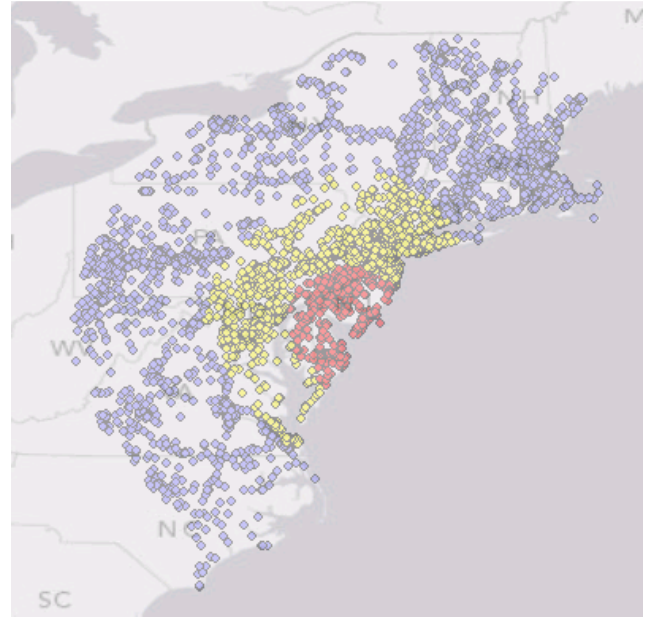


Fig. 3. Substations colorized by wind speed as reported from Sandy advisory 20A.

Figure 4 displays a map of predicted service areas impacted.

Analyzed service area files contain the following attributes:

- Supply ID
- State
- Service Area ID
- Night/day population estimates
- Customer estimates
- Wind Speed
- Running total and percentage of customers when sorted by decreasing customers

- Restoration day estimate

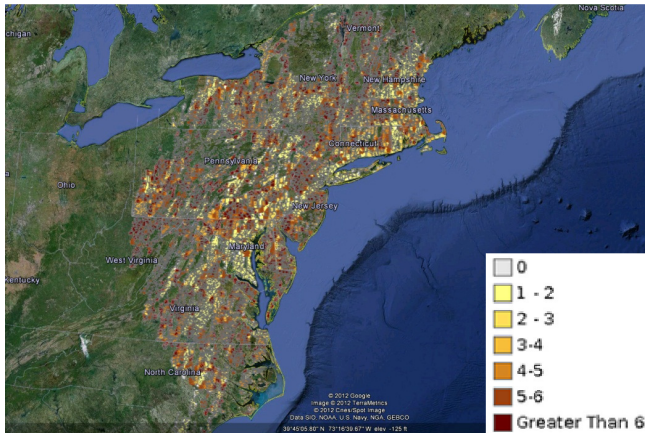


Fig. 4. Service areas colorized by days until restoration estimate based on Sandy advisory 20A.

A. Future Work

The following are areas identified to work on in the future:

- Improve IT structure for scalability/robustness
- Improve availability for mobile users
- Expand to other natural disasters that adversely impact electric grid (e.g. earthquakes, wild fires)
- Expand to process world-wide storms and events
- Continue to update restoration time after landfall based on real-time status instead of prediction
- Improve model to map wind speed to power outage, possibly including additional parameters such as tree density, above/below ground status, etc.
- Improve restoration estimate by prioritizing by additional factors such as infrastructure type
- Allow users to adjust parameter assumptions such as number of repair crews available for different scenarios

IV. CONCLUSIONS

A software system framework was created for quickly providing analysis of how a hurricane will impact the power

grid. Future work will include scaling for more users and robustness, accessibility such as from mobile phones, improvements to modeling such as correlating wind speed to power outages, and possibly adding additional data to the outage estimates like historical data, above or underground lines, tree density, and improvement to restoration time estimates – adding priority based on infrastructure type. It was also learned that there is a desire after landfall to “retune” the restoration estimates based on real-time outage data such as from NOM or VERDE, coupled with other data sources like downed trees, slosh (flooding) files, etc.

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