Importance of tree type and precipitation estimates for modeling hurricane-induced power outages

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Purpose

To improve upon a regression model used by Dr. Seth Guikema (Johns Hopkins University) and Dr. Steven Quiring (Texas A&M University) to predict power outages resulting from hurricanes prior to landfall.

An Overview of Hurricane Power Outage Modeling

Types of regression models:

- Classification and regression trees (CART)
- Generalized linear models (GLM)
- Generalized additive models (GAM)

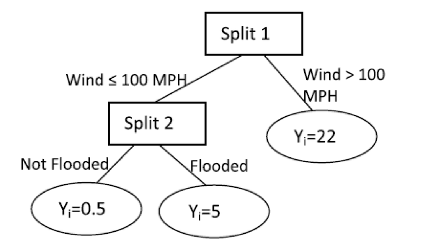


Figure 1. Hypothetical CART tree (from Guikema, Quiring, & Han 2010)

Variables used in the previous hurricane power outage model:

- Hurricane variables (maximum wind speed, minimum central pressure)
- Power system variables
- Precipitation (mean annual and standardized precipitation index, SPI)
- Land cover (not as specific as tree type)
- Topographic variables
- Soils variables

Research Question

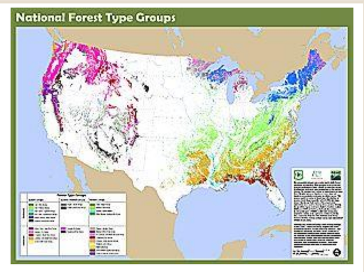
Will the addition of tree type and storm total precipitation increase the accuracy of the power outage model?

Objectives:

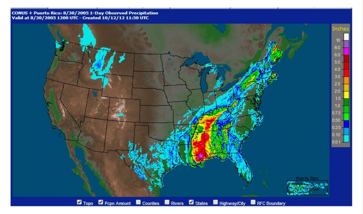
1. Determine the region of interest (in this case, the coverage area of the utility company), and acquire tree type and precipitation data for that area.
2. Process the data and using a sampling method (ArcGIS Zonal Statistics), assign values to each grid cell.
3. Integrate new variables into the model and retrieve results.
4. Compare model accuracy with results from older model versions using a holdout analysis (as mentioned in Quiring et al 2010).

Data

- Tree type: USDA Forest Service – Forest Type database (2008)



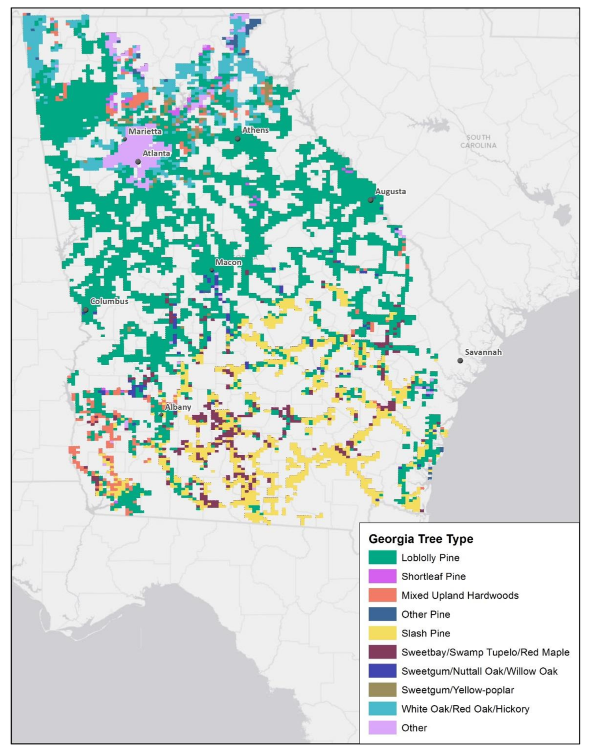
- Precipitation: NOAA Advanced Hydrologic Prediction Service, AHPS (2005-Present)

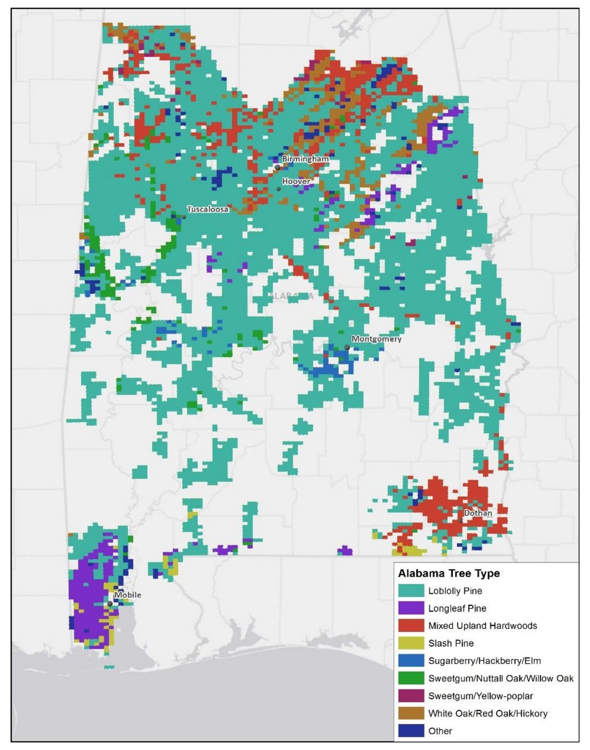


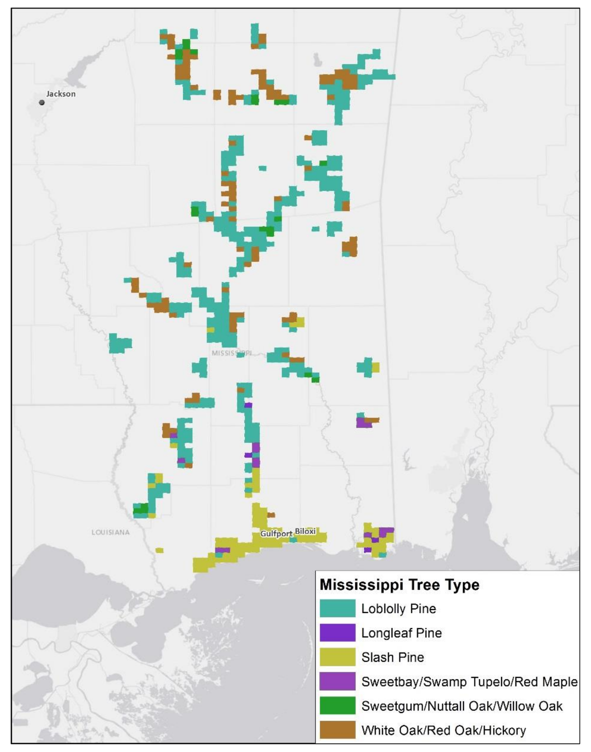
- Model will be run for Hurricanes Danny (1997), Dennis (2005), Georges (1998), Ivan (2004), and Katrina (2005). These are also the same hurricanes used to test the previous model.

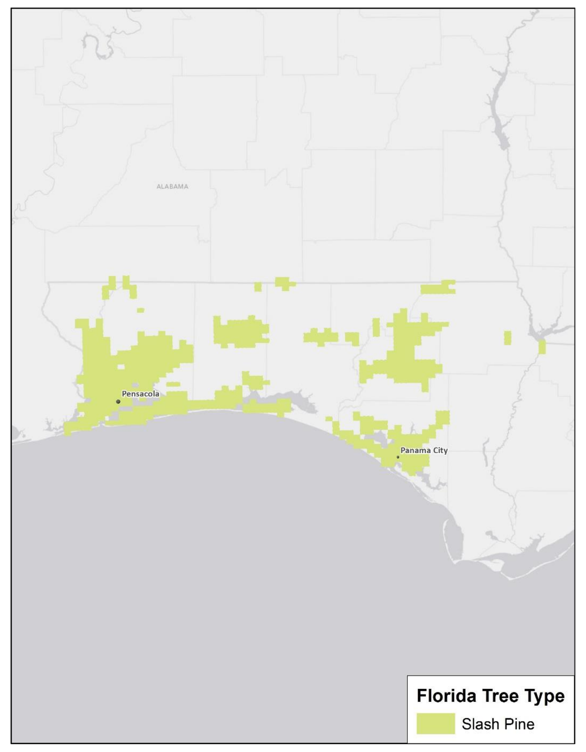
Tree type

Dominant species









Precipitation

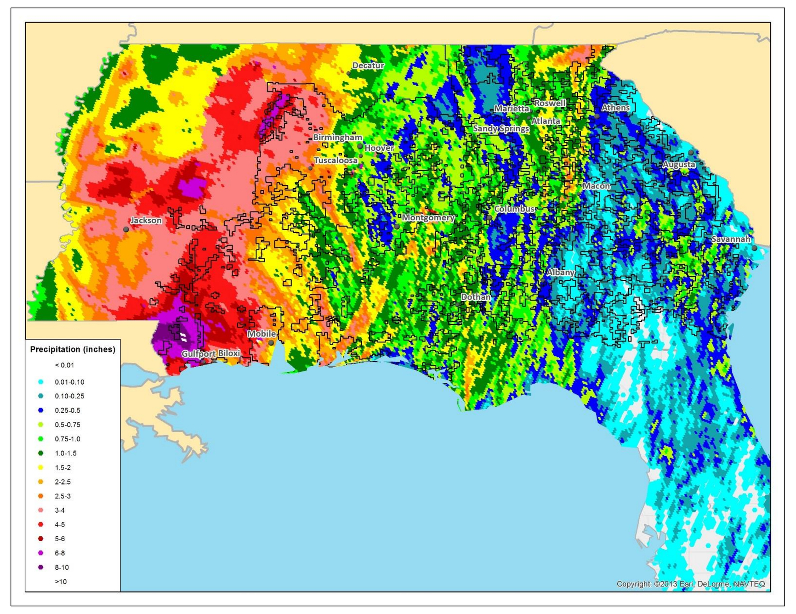


Figure 2. Precipitation from Hurricane Katrina, August 30, 2005

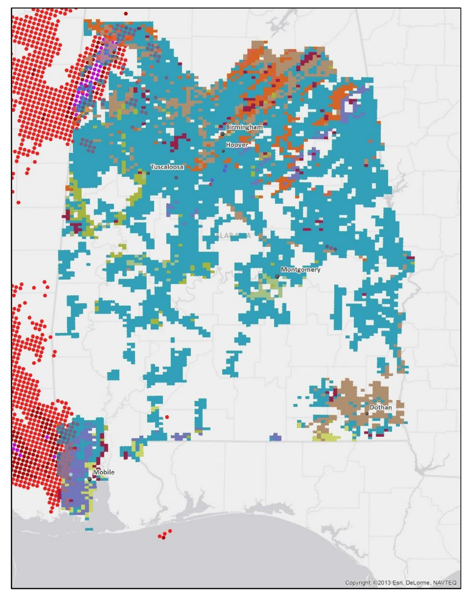


Figure 3. Alabama precipitation > 4 in. and tree type

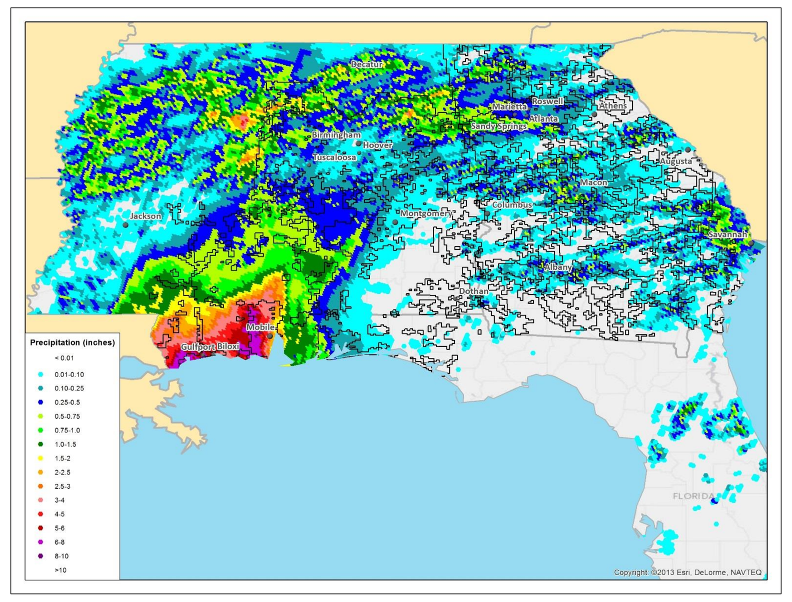


Figure 4. Precipitation from Hurricane Dennis, July 6, 2005

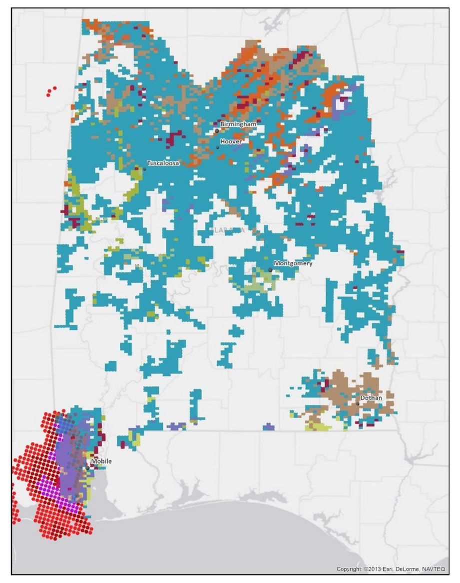


Figure 5. Alabama precipitation > 4 in. and tree type

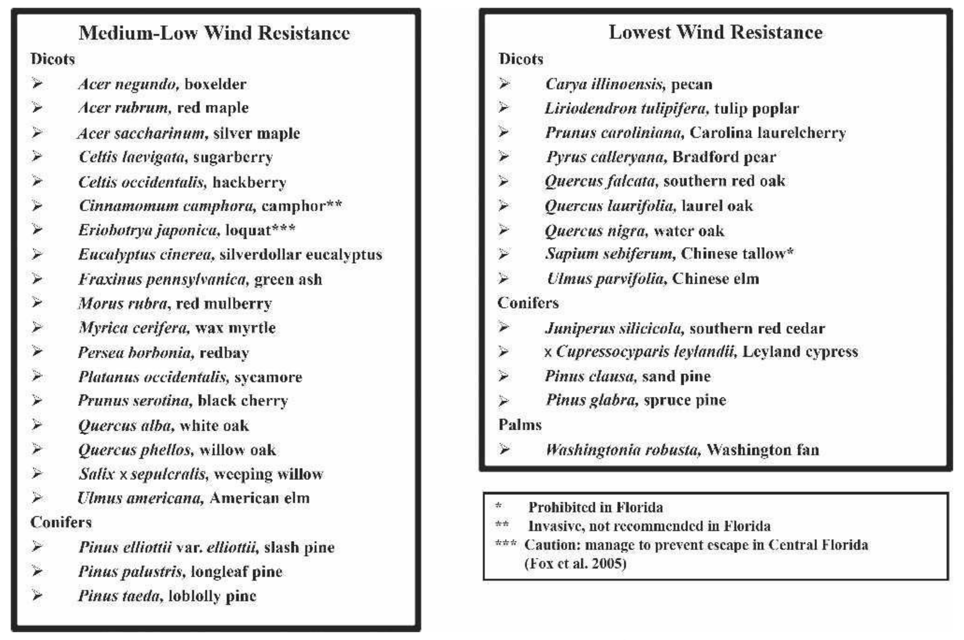
Anticipated Results

Past findings:

1. Hurricane variables (maximum wind gust and duration of strong winds) are the most influential predictors (Quiring et al 2010; Liu et al 2005).
2. Soil type and soil texture are good predictors because they provide information on soil stability, which determines the ability of power poles to remain upright (Quiring et al 2010).
3. Land cover variables can be substituted for power system variables in areas where power system data is unavailable (Quiring et al 2010).

Anticipated findings:

1. Areas with certain tree types (see Figure 7) will have an increased number of outages (which we will discover during the holdout analysis). These tree types are more susceptible to damage from hurricane winds (tree fall and broken branches).
2. Areas with greater storm total precipitation will also have an increased number of outages (due to ground saturation, leading to tree fall).
3. The addition of tree type and precipitation estimates (storm total and rain rate) will result in a more accurate hurricane power outage model that can benefit both utility companies and the general public.



Medium-Low Wind Resistance

Dicots

- *Acer negundo*, boxelder
- *Acer rubrum*, red maple
- *Acer saccharinum*, silver maple
- *Celtis laevigata*, sugarberry
- *Celtis occidentalis*, hackberry
- *Cinnamomum camphora*, camphor**
- *Eriobotrya japonica*, loquat***
- *Eucalyptus cinerea*, silverdollar eucalyptus
- *Fraxinus pennsylvanica*, green ash
- *Morus rubra*, red mulberry
- *Myrica cerifera*, wax myrtle
- *Persea borbonia*, redbay
- *Platanus occidentalis*, sycamore
- *Prunus serotina*, black cherry
- *Quercus alba*, white oak
- *Quercus phellos*, willow oak
- *Salix* x *sepulcralis*, weeping willow
- *Ulmus americana*, American elm

Conifers

- *Pinus elliottii* var. *elliottii*, slash pine
- *Pinus palustris*, longleaf pine
- *Pinus taeda*, loblolly pine

Lowest Wind Resistance

Dicots

- *Carya illinoensis*, pecan
- *Liriodendron tulipifera*, tulip poplar
- *Prunus caroliniana*, Carolina laurelcherry
- *Pyrus calleryana*, Bradford pear
- *Quercus falcata*, southern red oak
- *Quercus laurifolia*, laurel oak
- *Quercus nigra*, water oak
- *Sapium sebiferum*, Chinese tallow*
- *Ulmus parvifolia*, Chinese elm

Conifers

- *Juniperus silicicola*, southern red cedar
- x *Cupressocyparis leylandii*, Leyland cypress
- *Pinus clausa*, sand pine
- *Pinus glabra*, spruce pine

Palms

- *Washingtonia robusta*, Washington fan

* Prohibited in Florida
** Invasive, not recommended in Florida
*** Caution: manage to prevent escape in Central Florida (Fox et al. 2005)

Figure 7. Tree species with low wind resistance (from Duryea et al 2007)

Implications and Improvements

Implications:

- More accurate and efficient placement of power crews before a hurricane strikes
- Public benefit

Improvements:

- More detailed tree type dataset (with less data gaps)
- Integration of more precipitation variables (such as rain rates)

References

Duryea, M.L., E. Kampf, and R.C. Littell. 2007. Hurricanes and the Urban Forest: I. Effects on Southeastern United States Coastal Plain Tree Species. *Arboriculture & Urban Forestry* 33(2):83-97.

Liu, H., R.A. Davidson, D.V. Rosowsky, and J.R. Stedinger. 2005. Negative Binomial Regression of Electric Power Outages in Hurricanes. *Journal of Infrastructure Systems* 11:258-267.

Quiring, S.M., L. Zhu, and S.D. Guikema. 2010. Importance of soil and elevation characteristics for modeling hurricane-induced power outages. Natural Hazards 58(1): 365-390.