# P8160 - Bayesian Modeling of Hurricane Trajectories

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# Hurricane Ida

CAPITAL WEATHER GANG

## Ida's impact from the Gulf Coast to Northeast — by the numbers

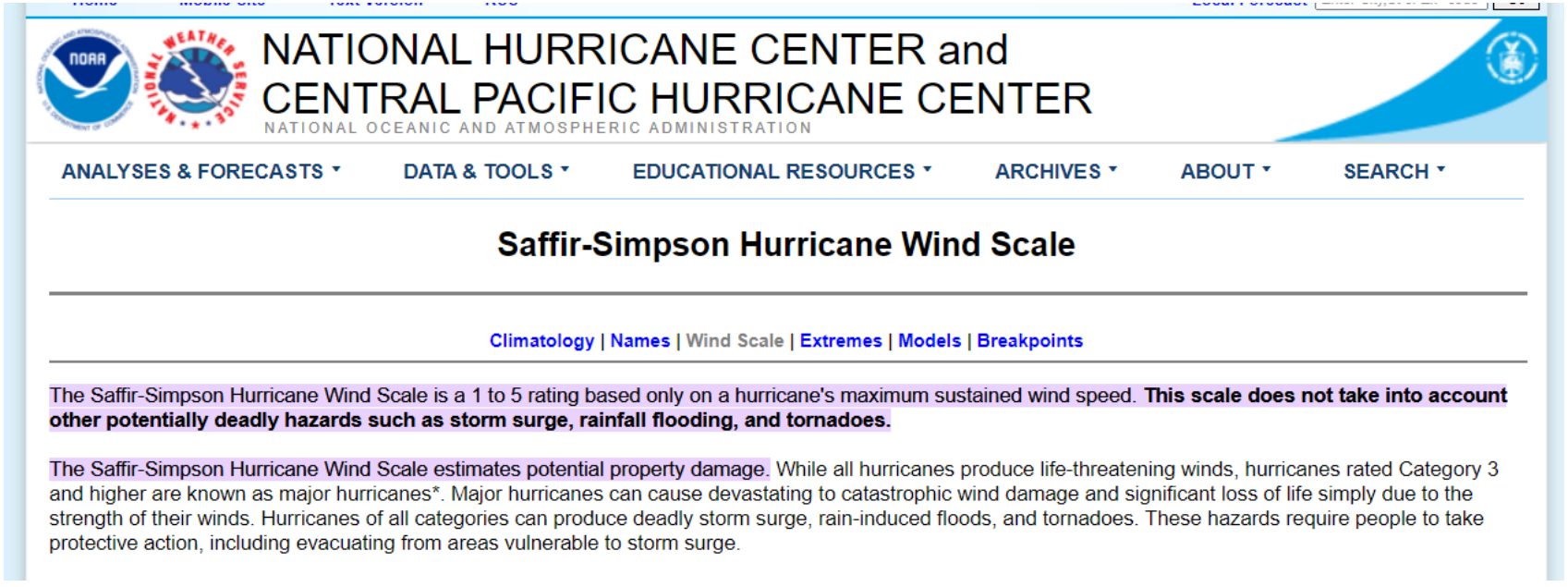
The storm caused more than 40 deaths in the Northeast, brought tornadoes in six states and unleashed 172 mph winds in Louisiana

By Ian Livingston

September 3, 2021 at 11:17 a.m. EDT

From: Livingston, I., *The Washington Post*, 2021

# Saffir-Simpson Wind Scale



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**Saffir-Simpson Hurricane Wind Scale**

Climatology | Names | Wind Scale | Extremes | Models | Breakpoints

The Saffir-Simpson Hurricane Wind Scale is a 1 to 5 rating based only on a hurricane's maximum sustained wind speed. **This scale does not take into account other potentially deadly hazards such as storm surge, rainfall flooding, and tornadoes.**

The Saffir-Simpson Hurricane Wind Scale estimates potential property damage. While all hurricanes produce life-threatening winds, hurricanes rated Category 3 and higher are known as major hurricanes*. Major hurricanes can cause devastating to catastrophic wind damage and significant loss of life simply due to the strength of their winds. Hurricanes of all categories can produce deadly storm surge, rain-induced floods, and tornadoes. These hazards require people to take protective action, including evacuating from areas vulnerable to storm surge.

From: *NHC NOAA*

# Proposed Hierarchical Bayesian Model

The following hierarchical Bayesian model was proposed to predict the wind speed of the $i^{th}$ hurricane at time $t + 6$:

$$Y_i(t+6) = \beta_{0,i} + \beta_{1,i} Y_i(t) + \beta_{2,i} \Delta_{i,1}(t) + \beta_{3,i} \Delta_{i,2}(t) + \beta_{4,i} \Delta_{i,3}(t) + \varepsilon_i(t),$$

where $Y_i(t)$ is the wind speed at time $t$, $\Delta_{i,1}(t)$, $\Delta_{i,2}(t)$, $\Delta_{i,3}(t)$ are the changes in latitude, longitude, and wind speed between times $t$ and $t - 6$, $\varepsilon_i(t)$ is the random error associated with each $Y_i(t + 6)$

We want to estimate the random coefficients,
$\beta_i = (\beta_{1,i}, \beta_{2,i}, \beta_{3,i}.\beta_{4,i})$, for each hurricane.

# Assumed Prior Distributions

The prior distributions for each of these parameters are assumed to be as follows:

$\epsilon_i(t) \sim N(0, \sigma^2)$, which are independent across $t$

$P\left(\sigma^2\right) \propto \frac{1}{\sigma^2}$

$P(\boldsymbol{\mu}) \propto 1$

$P\left(\Sigma^{-1}\right) \propto |\Sigma|^{-(d+1)} \exp\left(-\frac{1}{2}\Sigma^{-1}\right)$, where $d$ is the dimension of $\beta_i$

$\beta_i \sim N(\mu, \Sigma)$

# Goals

1. Construct an MCMC algorithm from which we can sample from a posterior distribution to estimate $\Theta = (\mathbf{B}, \mu, \sigma^2, \circ)$.
2. Conduct analysis using estimated parameters to understand their properties.
    a. Seasonal changes in any of the coefficients
    b. Predictive influence of these coefficients on forecasting hurricane impact.