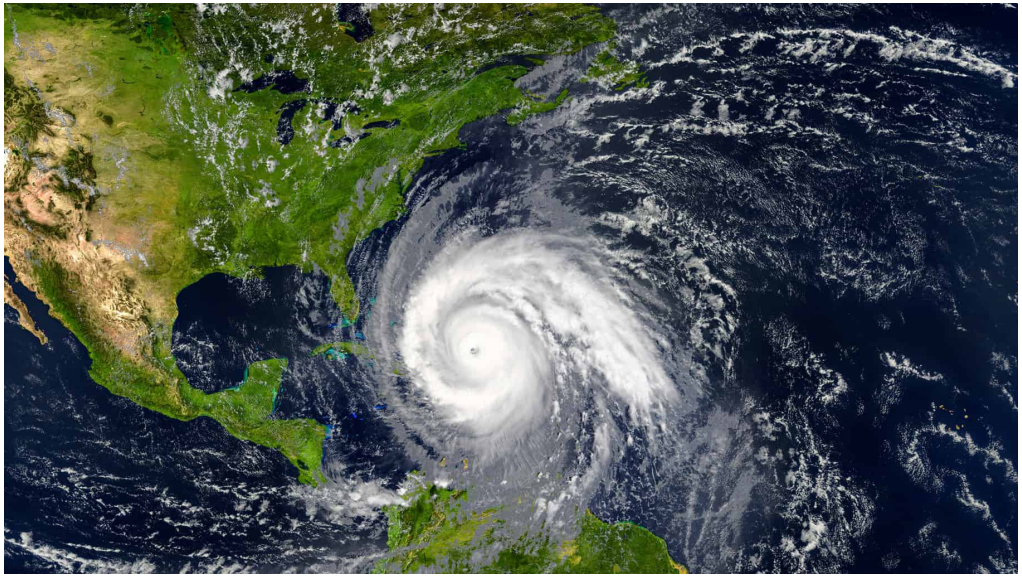
BDA Project: Hurricane forecasting in Stan

José Miguel Ramírez & Jonas Lindblad
Aalto University

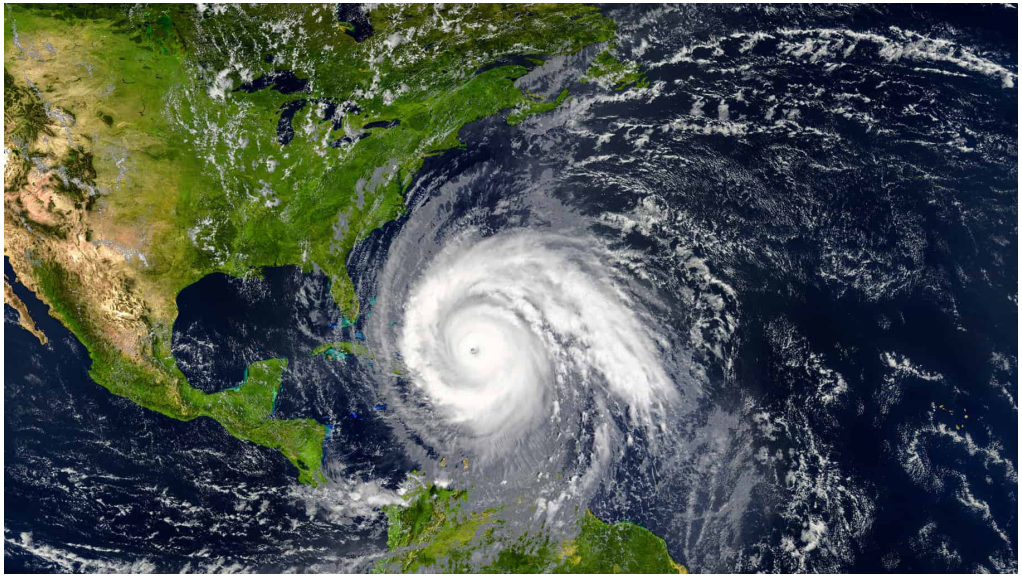
Hurricane introduction

- Destructive storms occuring in the late summer and fall in the northern hemisphere's tropical region.



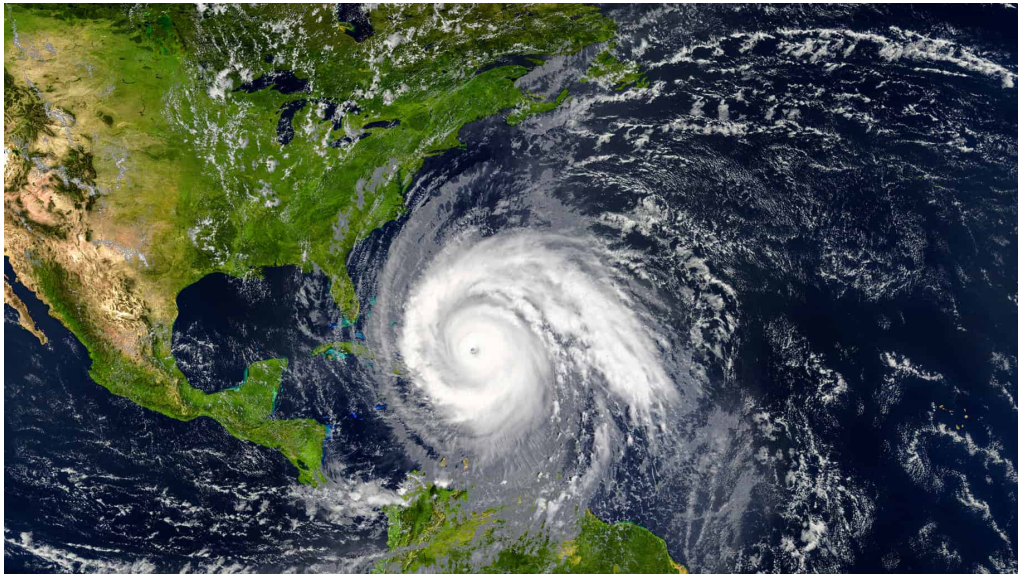
Hurricane introduction

- Destructive storms occuring in the late summer and fall in the northern hemisphere's tropical region.
- Classified by their wind intensity at the eye wall.



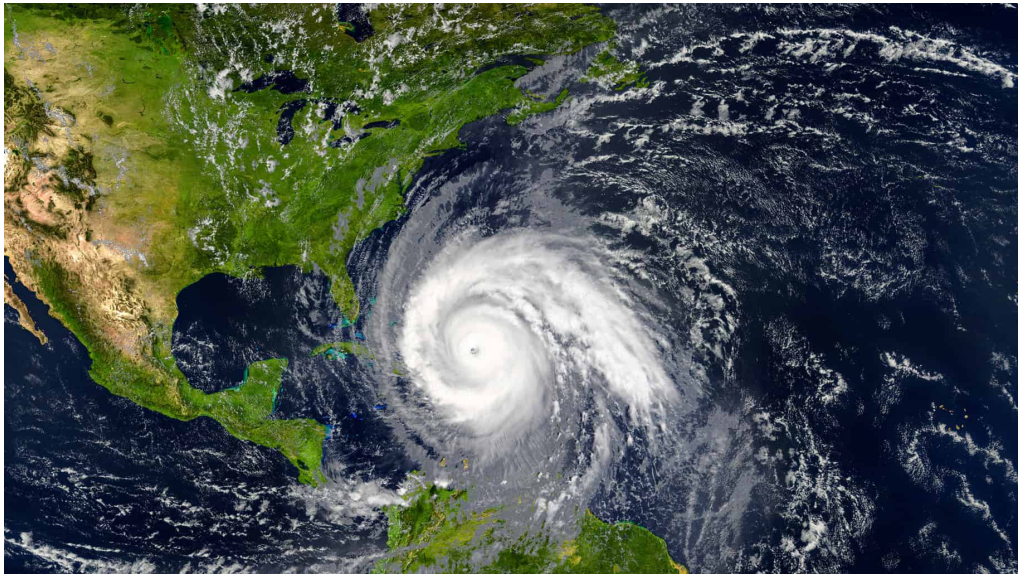
Hurricane introduction

- Destructive storms occuring in the late summer and fall in the northern hemisphere's tropical region.
- Classified by their wind intensity at the eye wall.
- They can cause extreme levels of flooding and destroy many buildings.



Hurricane introduction

- Destructive storms occuring in the late summer and fall in the northern hemisphere's tropical region.
- Classified by their wind intensity at the eye wall.
- They can cause extreme levels of flooding and destroy many buildings.
- Monetary damages and loss of lives increase with an almost exponential character as a function of storm intensity.



Hurricane forecasting basics

- Forecasters predict two quantities: track and intensity

Hurricane forecasting basics

- Forecasters predict two quantities: track and intensity
- Two kinds of models: *dynamical* and *statistical*

Hurricane forecasting basics

- Forecasters predict two quantities: track and intensity
- Two kinds of models: *dynamical* and *statistical*
  - Dynamical: simulate the laws of physics

Hurricane forecasting basics

- Forecasters predict two quantities: track and intensity
- Two kinds of models: *dynamical* and *statistical*
  - Dynamical: simulate the laws of physics
  - Statistical: estimate based on historical data

Hurricane forecasting basics

- Forecasters predict two quantities: track and intensity
- Two kinds of models: *dynamical* and *statistical*
  - Dynamical: simulate the laws of physics
  - Statistical: estimate based on historical data
- Dynamical vs. statistical: good at long- and short-range forecasts respectively

Hurricane forecasting basics

- Forecasters predict two quantities: track and intensity
- Two kinds of models: *dynamical* and *statistical*
  - Dynamical: simulate the laws of physics
  - Statistical: estimate based on historical data
- Dynamical vs. statistical: good at long- and short-range forecasts respectively
- . . . but for hurricane forecasts short-range is usually more interesting

Hurricane forecasting basics

- Forecasters predict two quantities: track and intensity
- Two kinds of models: *dynamical* and *statistical*
  - Dynamical: simulate the laws of physics
  - Statistical: estimate based on historical data
- Dynamical vs. statistical: good at long- and short-range forecasts respectively
- . . . but for hurricane forecasts short-range is usually more interesting
- *Rapid intensification*: forecasted better by dynamical models

Hurricane forecasting basics

- Forecasters predict two quantities: track and intensity
- Two kinds of models: *dynamical* and *statistical*
  - Dynamical: simulate the laws of physics
  - Statistical: estimate based on historical data
- Dynamical vs. statistical: good at long- and short-range forecasts respectively
- . . . but for hurricane forecasts short-range is usually more interesting
- *Rapid intensification*: forecasted better by dynamical models
- This project: a *statistical* model for *intensity*

Hurricane forecasting basics: the SHIPS data

The US government forecasting agency, the National Hurricane Center (NHC), uses a large number of models operationally. The models (together: the *model ensemble*) are used together with experienced meteorologists' judgment to provide the official forecast.

- Surprisingly, the best *single* (short-range) model is a multiple linear regression!

Hurricane forecasting basics: the SHIPS data

The US government forecasting agency, the National Hurricane Center (NHC), uses a large number of models operationally. The models (together: the *model ensemble*) are used together with experienced meteorologists' judgment to provide the official forecast.

- Surprisingly, the best *single* (short-range) model is a multiple linear regression!
- The NHC regression model: Statistical Hurricane Intensity Prediction Scheme (SHIPS)

Hurricane forecasting basics: the SHIPS data

The US government forecasting agency, the National Hurricane Center (NHC), uses a large number of models operationally. The models (together: the *model ensemble*) are used together with experienced meteorologists' judgment to provide the official forecast.

- Surprisingly, the best *single* (short-range) model is a multiple linear regression!
- The NHC regression model: Statistical Hurricane Intensity Prediction Scheme (SHIPS)
- SHIPS: ~140 covariates, many calculated from data sources more easily available to the NHC

Hurricane forecasting basics: the SHIPS data

The US government forecasting agency, the National Hurricane Center (NHC), uses a large number of models operationally. The models (together: the *model ensemble*) are used together with experienced meteorologists' judgment to provide the official forecast.

- Surprisingly, the best *single* (short-range) model is a multiple linear regression!
- The NHC regression model: Statistical Hurricane Intensity Prediction Scheme (SHIPS)
- SHIPS: ~140 covariates, many calculated from data sources more easily available to the NHC
- SHIPS dataset: publically available with no restrictions (link: SHIPS Development)

Hurricane forecasting basics: the SHIPS data

The US government forecasting agency, the National Hurricane Center (NHC), uses a large number of models operationally. The models (together: the *model ensemble*) are used together with experienced meteorologists' judgment to provide the official forecast.

- Surprisingly, the best *single* (short-range) model is a multiple linear regression!
- The NHC regression model: Statistical Hurricane Intensity Prediction Scheme (SHIPS)
- SHIPS: ~140 covariates, many calculated from data sources more easily available to the NHC
- SHIPS dataset: publically available with no restrictions (link: SHIPS Development)
- . . . but the documentation is terrible

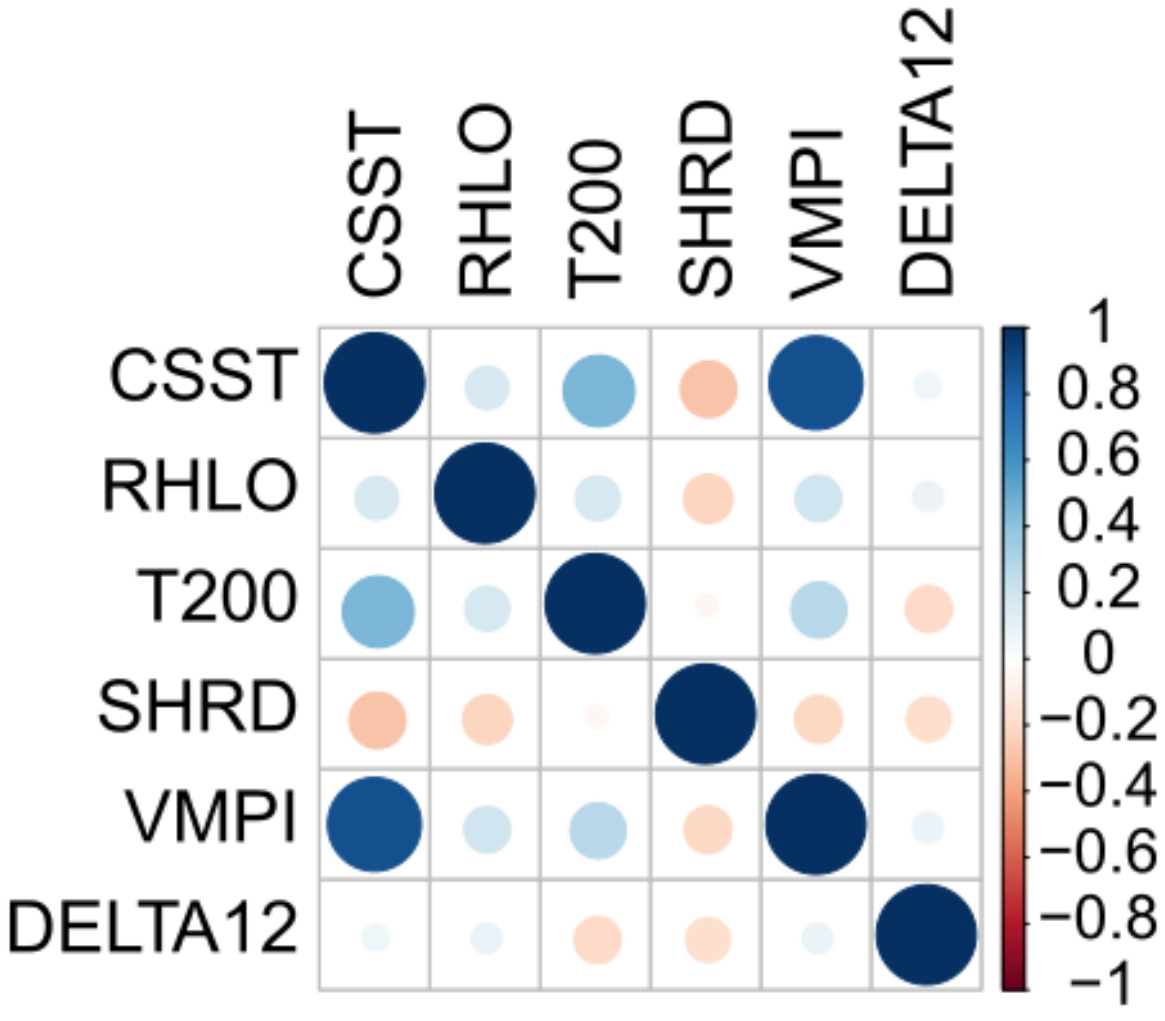
Hurricane forecasting basics: the SHIPS data

The US government forecasting agency, the National Hurricane Center (NHC), uses a large number of models operationally. The models (together: the *model ensemble*) are used together with experienced meteorologists' judgment to provide the official forecast.

- Surprisingly, the best *single* (short-range) model is a multiple linear regression!
- The NHC regression model: Statistical Hurricane Intensity Prediction Scheme (SHIPS)
- SHIPS: ~140 covariates, many calculated from data sources more easily available to the NHC
- SHIPS dataset: publically available with no restrictions (link: SHIPS Development)
- . . . but the documentation is terrible
- SHIPS: only a point estimate; our project: a predictive distribution

Hurricane forecasting basics: the SHIPS data

Hurricane forecasting basics: our selection



Intensity change predictive model

Model: limitations

Model: posterior predictive checking

Model: variables to use

Model: marginal posteriors of coefficients

Model: margin of SHRD and CSST

Forecasting

Forecasting: model comparison

Forecasting: what about the NHC?

Problems to solve & development ideas

- variable selection in full SHIPS dataset

Problems to solve & development ideas

- variable selection in full SHIPS dataset
- more time series autoregressive components

Problems to solve & development ideas

- variable selection in full SHIPS dataset
- more time series autoregressive components
- use LGEM model (will explain)

Conclusions & contact info

Additional information

R Markdown

This is an R Markdown presentation. Markdown is a simple formatting syntax for authoring HTML, PDF, and MS Word documents. For more details on using R Markdown see http://rmarkdown.rstudio.com.

When you click the **Knit** button a document will be generated that includes both content as well as the output of any embedded R code chunks within the document.

Slide with Bullets

- Bullet 1

Slide with Bullets

- Bullet 1
- Bullet 2

Slide with Bullets

- Bullet 1
- Bullet 2
- Bullet 3

Slide with R Output

```
summary(cars)
```

```
##      speed           dist       
##  Min.   : 4.0   Min.   :  2.00  
##  1st Qu.:12.0   1st Qu.: 26.00  
##  Median :15.0   Median : 36.00  
##  Mean   :15.4   Mean   : 42.98  
##  3rd Qu.:19.0   3rd Qu.: 56.00  
##  Max.   :25.0   Max.   :120.00
```

Slide with Plot