

SMSS First Year Graduate Student Seminar

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School of
**MATHEMATICAL AND
STATISTICAL SCIENCES**
Clemson® University

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Agenda

My Background

My Research

Some General Advice

About Me

- ▶ **Current Role:** Sixth-year Assistant Professor of Statistics. Primarily teach in the Data Science and Analytics (DSA) program, plus a Time Series course (MATH 8090 or 4070)
- ▶ **Background:** Born in Laramie, Wyoming, and raised in Taiwan



- ▶ **Academic Path:** Started with a B.S. in Mechanical Engineering and transitioned to Statistics for graduate studies

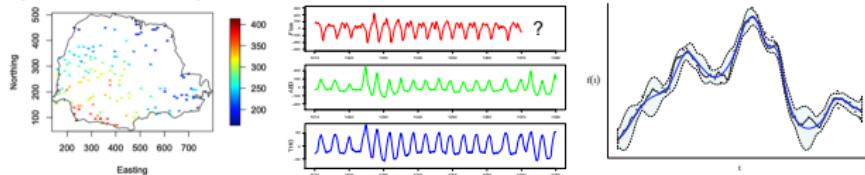
- ▶ **Doctorate:** Ph.D. in Statistics, 2017, from



Completed a postdoc before joining Clemson

Overview of My Research

► Spatio-Temporal Statistics

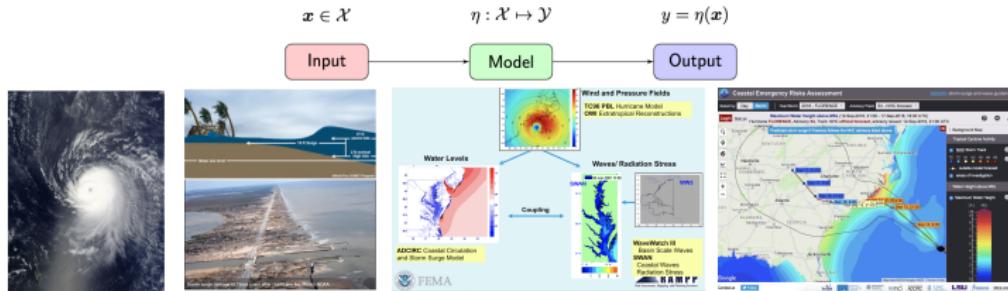


► Extreme Value Analysis

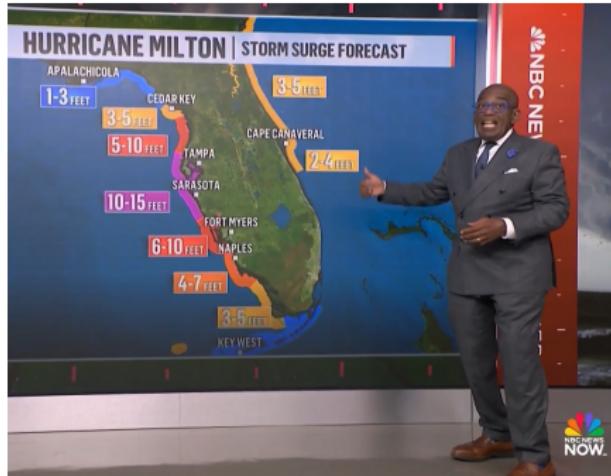
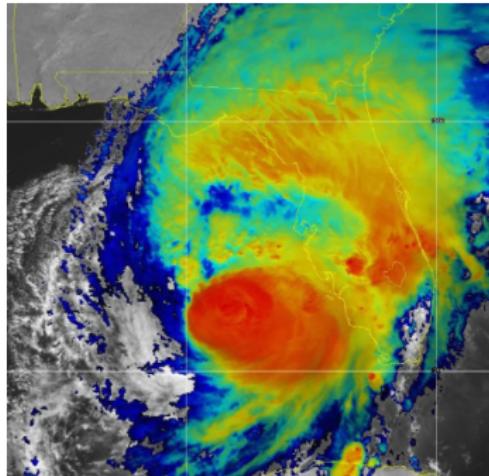


Source: NASA (Left); National Weather Service (Right)

► Surrogate Modeling of Computer Experiments

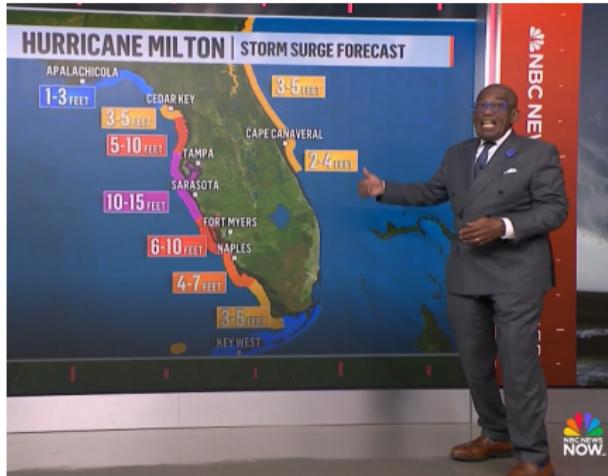
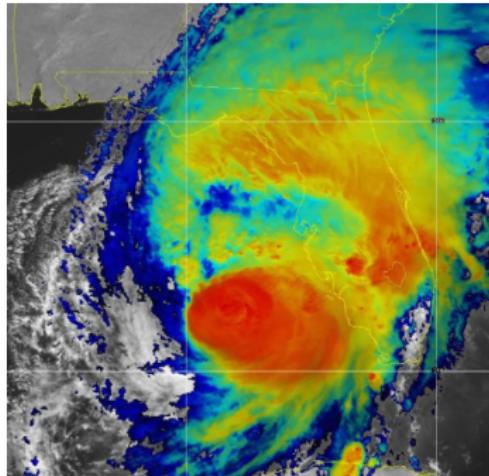


Hurricane and Storm Surge



Storm surge is typically the most devastating part of a hurricane; therefore, it is crucial to accurately quantify **storm surge risk**

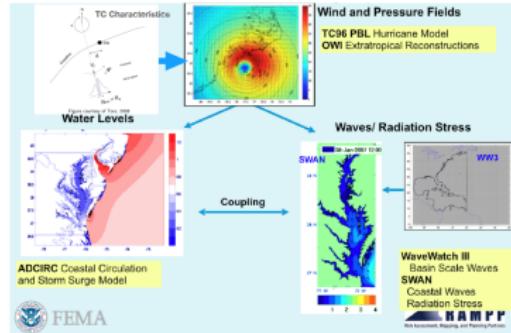
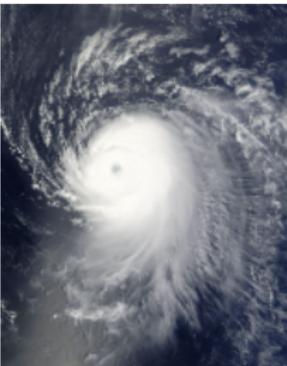
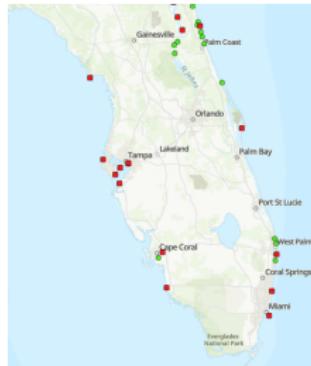
Hurricane and Storm Surge



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Quantifying Storm Surge Risk: Data Sources

Variable Data	y ("Output")	x ("Input")
Observation	Observed storm surges ⇒ Very limited in space and time	Storm (TC) characteristics ⇒ Limited but well observed
Computer Model	Simulated storm surge responses	"Synthetic" storm characteristics



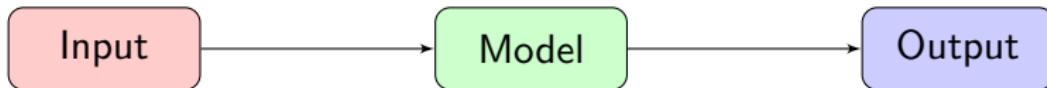
Courtesy of Gangai (Dewberry) & Danforth (FEMA)

Estimating Extreme Surges: Physical-Statistical Approach

$$x \in \mathcal{X}$$

$$\eta : \mathcal{X} \mapsto \mathcal{Y}$$

$$y = \eta(x)$$



TC Characteristics

- ▶ Records are more complete than surge levels
- ▶ **Input** to simulate storm surge levels

Task: **Estimating $f(x)$**

Computer Model

- ▶ Simulate high fidelity surge response
- ▶ computationally extensive

Task: **Estimating $\eta(x)$**

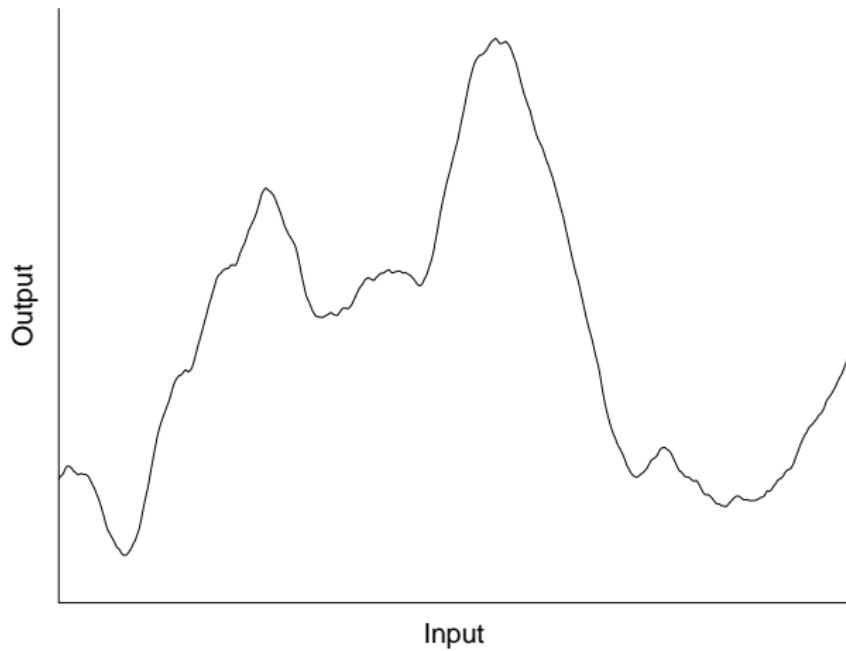
Surge Level

- ▶ simulate synthetic storms
- ▶ generate surge response for risk analysis

Task: **Estimating y_r**

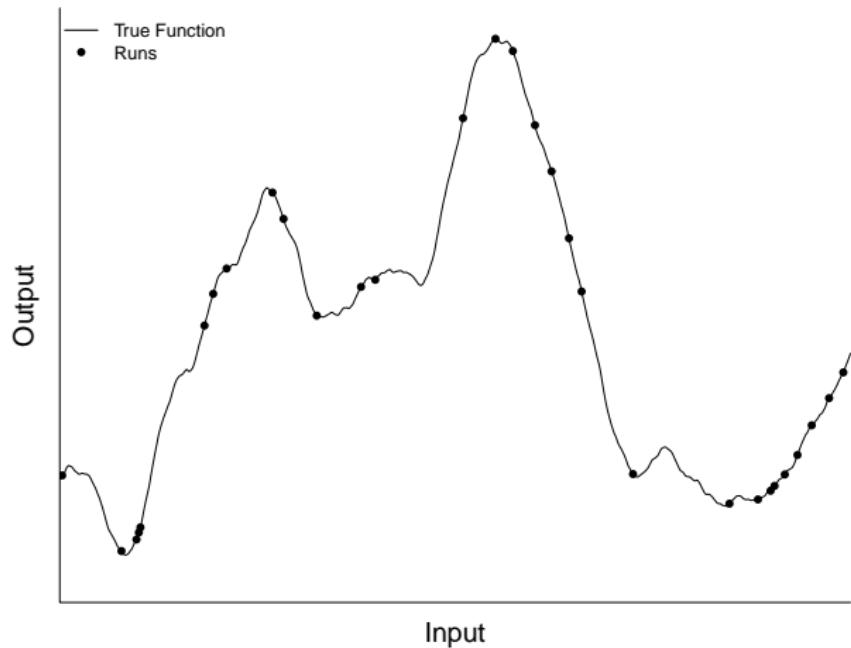
Statisticians build **statistical models**, which are mathematical representations that describe how **data** is generated from the underlying **process**

$\eta : \mathcal{X} \mapsto \mathcal{Y} \Rightarrow$ True Input-Output Relationship



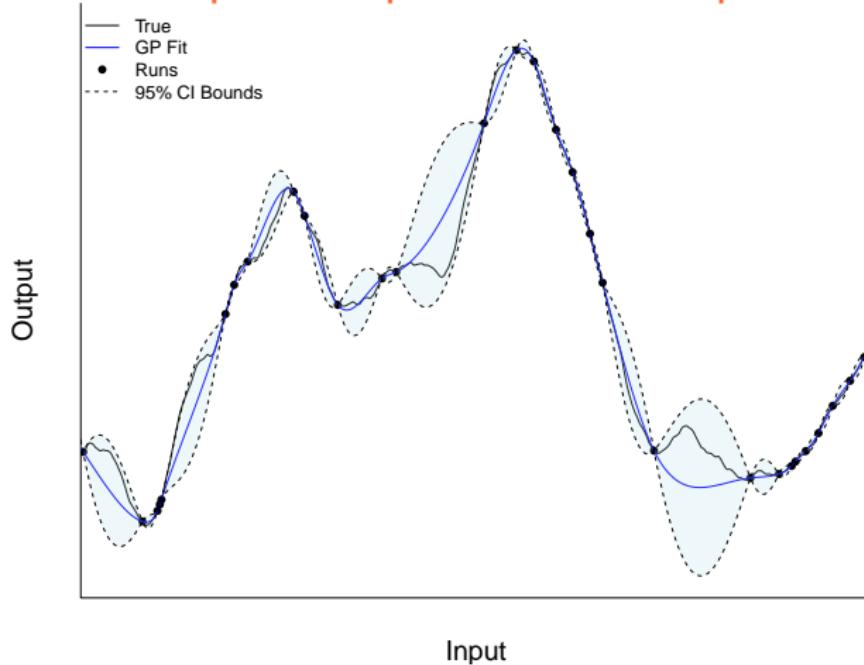
Such a function is informed by physics 😊 (fluid dynamics, shallow water equations...)

(Incomplete) $\eta(x)$ from Computer Model



Running the computer model is **time-consuming**, so model runs are **limited** 😞. \Rightarrow **We need a model to fill in the missing pieces**

Estimated Input-Output Relationship and its Uncertainty



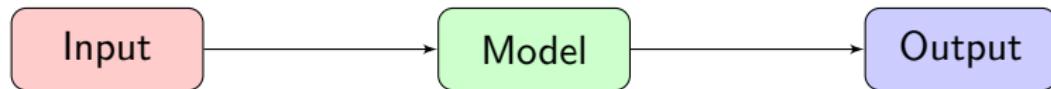
- ▶ Function estimation achieved by Gaussian process (GP):
$$\eta(\mathbf{x}) \sim \text{GP} \left(m(\mathbf{x}), K(\mathbf{x}, \mathbf{x}') \right), \quad \mathbf{x} \in \mathcal{X}$$
- ▶ GP offers an “optimal” estimate $\hat{\eta}(\mathbf{x})$ with “localized” uncertainty (error bars)

Finishing the Workflow of Estimating Extreme Surge

$$x \in \mathcal{X}$$

$$\eta : \mathcal{X} \mapsto \mathcal{Y}$$

$$y = \eta(x)$$



TC Characteristics
Estimating $f(x)$ ✓

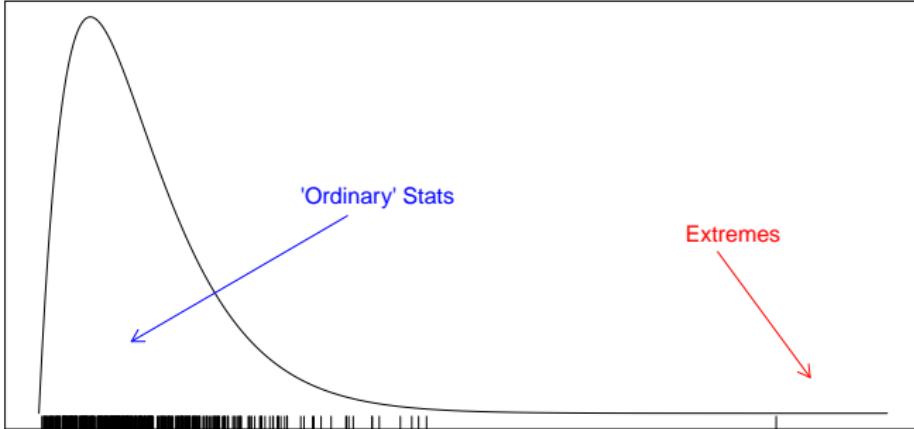
Computer Model
Estimating $\eta(x)$ ✓

Surge Level
Task: Estimating y_r

Workflow:

- ▶ Simulate x (synthetic storms) from $\hat{f}(x)$ (estimated probability distribution of TC characteristics)
- ▶ Input x into $\hat{\eta}(x)$ (estimated computer model input-output relationship) to obtain $[Y]$ (storm surge response distribution)
- ▶ Estimate extremes (e.g., one-in-100 surge level) of $[Y]$ via extreme value analysis

Extreme Value Analysis¹



	Target	Theory	Distribution
Ordinary Stats	bulk distribution	CLT	Normal
Extreme Stats	tail distribution(s)	?	?

Let's examine the distribution of the **sample maximum** to learn about extremes

¹ I have delivered several short courses on this topic nationally and internationally, e.g.,

https://whitneyhuang83.github.io/EVA/Slides/WhitneyHuang_ShortCourse2_Longer_V2.pdf

Central Limit Theorem Demonstration

1. Generate 100 random numbers ($n = 100$) from an Exponential distribution
2. Compute the **sample mean** of these 100 random numbers
3. Repeat this process 120 times

Demo: Distribution of the Sample Maximum

1. Generate 100 random numbers ($n = 100$) from an Exponential distribution
2. Compute the **sample maximum** of these 100 random numbers
3. Repeat this process 120 times

Extremal Types Theorem [Fisher–Tippett 1928, Gnedenko 1943]

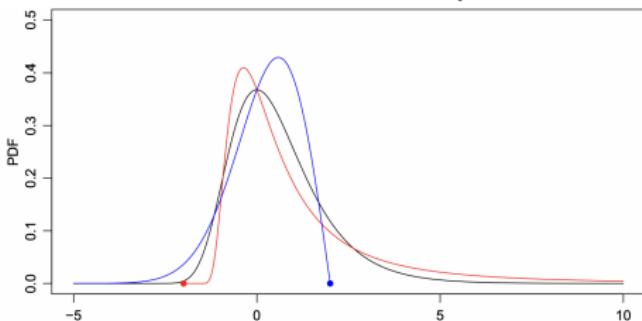
Define $M_n = \max\{X_1, \dots, X_n\}$ where $X_1, \dots, X_n \stackrel{\text{i.i.d.}}{\sim} F$. If $\exists a_n > 0$ and $b_n \in \mathbb{R}$ such that, as $n \rightarrow \infty$, if

$$\mathbb{P}((M_n - b_n)/a_n \leq x) \xrightarrow{d} G(x)$$

then G must be the same type of the following form:

$$G(x; \mu, \sigma, \xi) = \exp \left\{ - \left[1 + \xi \left(\frac{x - \mu}{\sigma} \right) \right]_+^{-\frac{1}{\xi}} \right\}$$

where $x_+ = \max(x, 0)$ and $G(x)$ is the distribution function of the **generalized extreme value distribution (GEV(μ, σ, ξ))**, where μ and σ are location and scale parameters, and ξ is the shape parameter



- ▶ $\xi > 0$: Fréchet (heavy-tail)
- ▶ $\xi = 0$: Gumbel (light-tail)
- ▶ $\xi < 0$: reversed Weibull (short-tail)

Pickands–Balkema–de Haan Theorem [1974, 1975]

If $M_n = \max_{1 \leq i \leq n} \{X_i\} \approx \text{GEV}(\mu, \sigma, \xi)$, then, for a “large” u (i.e., $u \rightarrow x_F = \sup\{x : F(x) < 1\}$),

$$\mathbb{P}(X > u) \approx \frac{1}{n} \left[1 + \xi \left(\frac{u - \mu}{\sigma} \right) \right]^{\frac{-1}{\xi}}$$

$F_u = \mathbb{P}(X - u < y | X > u)$ is well approximated by the generalized Pareto distribution (GPD). That is:

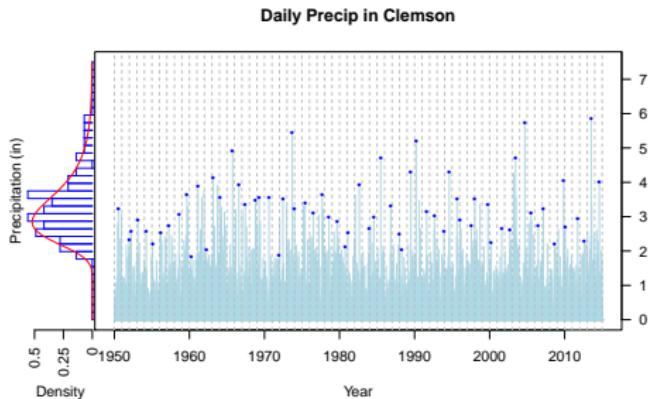
$$F_u(y) \xrightarrow{d} H_{\tilde{\sigma}, \xi}(y) \quad u \rightarrow x_F$$

where

$$H_{\tilde{\sigma}, \xi}(y) = \begin{cases} 1 - (1 + \xi y / \tilde{\sigma})^{-1/\xi} & \xi \neq 0; \\ 1 - \exp(-y / \tilde{\sigma}) & \xi = 0. \end{cases}$$

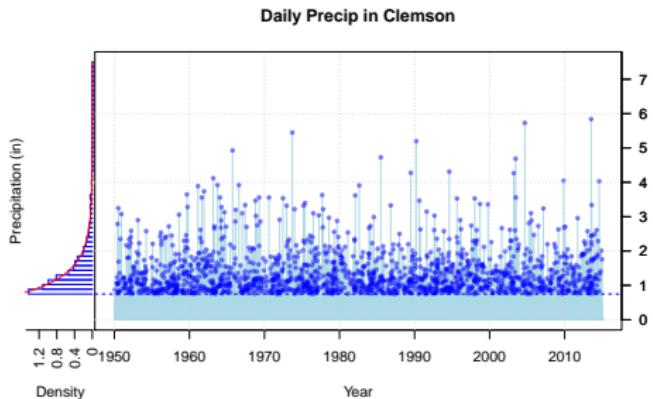
and $\tilde{\sigma} = \sigma + \xi(u - \mu)$

Univariate Extreme Estimation: Two Main Approaches



- ▶ **Block Maxima:** Fit a generalized extreme value (GEV) distribution to block maxima (given block size big enough)

$$Y_{(n)} \xrightarrow{n \rightarrow \infty} \text{GEV}(\mu, \sigma, \xi)$$



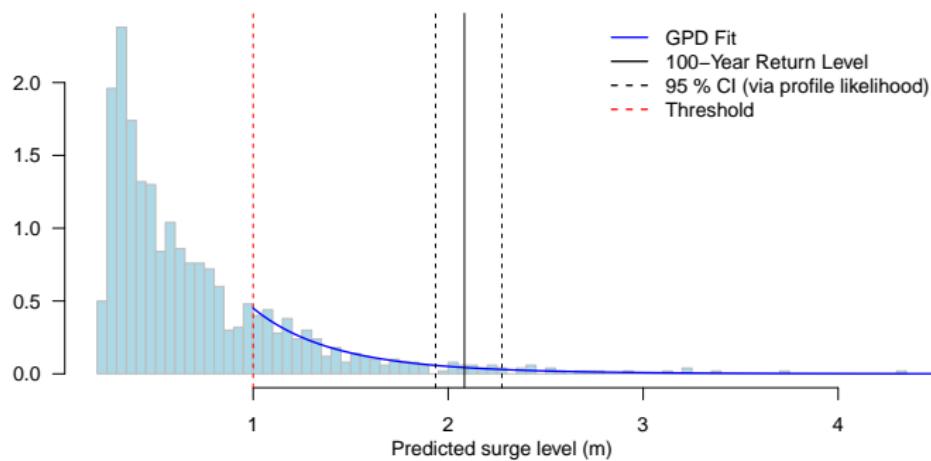
- ▶ **Threshold Exceedances:** Fit a generalized Pareto distribution (GPD) to exceedances over (a sufficiently high) threshold

$$Y - u | Y > u \xrightarrow{u \rightarrow y_F} \text{GPD}(\tilde{\sigma}, \xi)$$

Estimating Extreme Surges: Extreme Value Analysis

We employed the threshold exceedances method [Davison and Smith, 1990] to estimate the r-year return levels

- ▶ Assuming upper tail follow a generalized Pareto distribution (GPD)
- ▶ Using profile likelihood method to construct confidence interval (CI), which gives asymmetric interval



Some General Research Questions

- ▶ How to overcome the “data poor” situation when modeling extremes? [H., Nychka, Zhang, 2019]
- ▶ How to model extremes when the process of interest involves several variables? [H., Monahan, Zwiers, 2021]
- ▶ How extremes vary in space? How extremes may change in future climate conditions? [H. et al., 2016]; [H. et al., 2019]

Research Group Members

- ▶ **Eva Murphy**, PhD, Aug. 2023 "*Modeling of Wind Speed and Wind Direction.*"
Current Position: Postdoc at Wake Forest University
- ▶ **Kanon Kamronnaher**, PhD, Dec. 2023 "*Estimating Financial and Environmental Risk*"
- ▶ **Adam Diaz**, MS, May 2022 "*Analysis of Climate-Wildfire Interaction.*" Current Position: Principal Research Statistician at Northern California Institute for Research and Education
- ▶ **Emily Tidwell**, MS, May 2021 "*Physical-Statistical Approach for Estimating r-year Storm Surge.*" Current Position: Dynetics, Huntsville, Alabama
- ▶ **Andrew Bellucco**, MS, Dec. 2019 "*Estimating Financial Risk.*" Current Position: Senior Discovery Analyst at Credit Karma, Charlotte, NC
- ▶ **Peiying Li, MS**, May 2024 "*Modeling Financial Time Series.*" Current Position: Banking industrial in China

Current Members:

- ▶ **Jiyun (Joyce) Huang**, PhD Candidate (expected graduation date Aug. 2025), "*New Models and Methods for Estimating Rainfall Intensity-Duration-Frequency Curve*"
- ▶ **Katherine Kreuser**, MS, May 2022; PhD Candidate (expected graduation date Aug. 2025), "*Uncertainty Quantification for Rare Geophysical Extremes and Dynamical Engineering Applications*"
- ▶ **Actively looking for motivated PhD/MS students interested in a environmental data science career in academic, government, or industry sectors. Feel free to email me or stop by (I am usually in the office unless traveling)**

Some General Advice

“Survival Guide” for Graduate Students

- ▶ “How to Succeed in Graduate School” by Marie desJardins
<http://www.ai.sri.com/~marie/papers/advice-summary.html>
- ▶ “Notes on the PhD Degree” by Douglas Comer
<https://www.cs.purdue.edu/homes/dec/essay.phd.html>
- ▶ “Writing and Presenting your Thesis or Dissertation” by S. Joseph Levine
<http://www.learnerassociates.net/dissthes/>

Some Useful Computing Skills

- ▶  (<https://www.r-project.org>),  R Studio (<https://www.rstudio.com>), and R markdown (<http://rmarkdown.rstudio.com>)
- ▶  and  Overleaf (<https://www.overleaf.com/project>)
- ▶ Python and  Jupyter (<https://jupyter.org/>)
- ▶  GitHub
- ▶ High-performance computing



Attend Seminars!

- ▶ Graduate Student Seminars
<http://siam.people.clemson.edu/gss/schedule.php>
- ▶ Research Seminars (Statistics, Analysis, OR, ADM, Computational Math) & School Colloquia
- ▶ Many One World Seminar Series (e.g., Extremes, Spatial and spatio-temporal Point processes and beyond, Approximate Bayesian Computation, Probability, PDF, Mathematical Game Theory, Optimization, Mathematics of Machine Learning,...)

Join Us for the 75th Joint Clemson-UGA Colloquium



Speaker: [Xiao-Li Meng](#)

Whipple V. N. Jones Professor of
Statistics, Harvard University

Date: [4/9, 2025](#)

There will be two talks: one in
Clemson U the other one in
Clemson outdoor lab.

This event will be sponsored by

NISS | National Institute of
Statistical Sciences



Attend Workshops!

- ▶ NSF-CBMS Regional Research Conferences in the Mathematical Sciences
<https://www.cbmsweb.org/regional-conferences/>
- ▶ NSF funded mathematical sciences institutes
<https://mathinstitutes.org/>
- ▶ Specialized workshops in your area

Attend Conferences! (and Give a Talk)

- ▶ Joint Mathematics Meetings (JMM): [January](#)
- ▶ Society for Industrial and Applied Mathematics (SIAM) Annual Meeting: [July](#)
- ▶ Institute for Operations Research and the Management Sciences (INFORMS) Annual Meeting: [October or November](#)
- ▶ Joint Statistical Meetings (JSM): [Late July or early August](#)
- ▶ Conference on Neural Information Processing Systems (NIPS): [December](#)

How to Reach Me?

- ▶ **Websites** 🖥:
<https://whitneyhuang83.github.io/>
- ▶ **Email** ✉: wkhuang@clemson.edu
- ▶ **Office:** O-221 Martin Hall



Go Tigers!

