Extremes in economic damage from U.S.-landfalling hurricanes: considering hurricane climatology, exposure, and vulnerability effects

AGU SCIENCE POLICY CONFERENCE
Washington, DC, USA | 16-18 June 2014

NH-06

Emmi Yonekura[1], Ning Lin[1], Daniel Chavas[1], Michael Oppenheimer[2]

[1] Princeton University Dept. of Civil and Environmental Engineering; [2] Princeton University Woodrow Wilson School of Public and International Affairs

Email: yonekura@princeton.edu

PRINCETON
School of Engineering and Applied Science

1 INTRODUCTION

Economic damage from landfalling hurricanes is determined by a complex combination of physical characteristics of hurricane climatology, exposure, and vulnerability. Here, we aim to model the extremes in damage by first isolating the physical storm-related portion and then considering differences in regional variability. This allows for an analysis of the effects of climate change and changes in vulnerability, or resilience.

2 DAMAGE FRACTION: Separating out exposure

Physical characteristics of storms and economic value (exposure) at landfall should be independent. The Damage Fraction—the percentage of exposed wealth damaged—removes the variability in damages due to variations in economic value along the coast.

$$Base\ damage\ (\$) = \frac{Base\ damage}{Economic\ value} * Economic\ value$$

Neumayer et al. (2011)

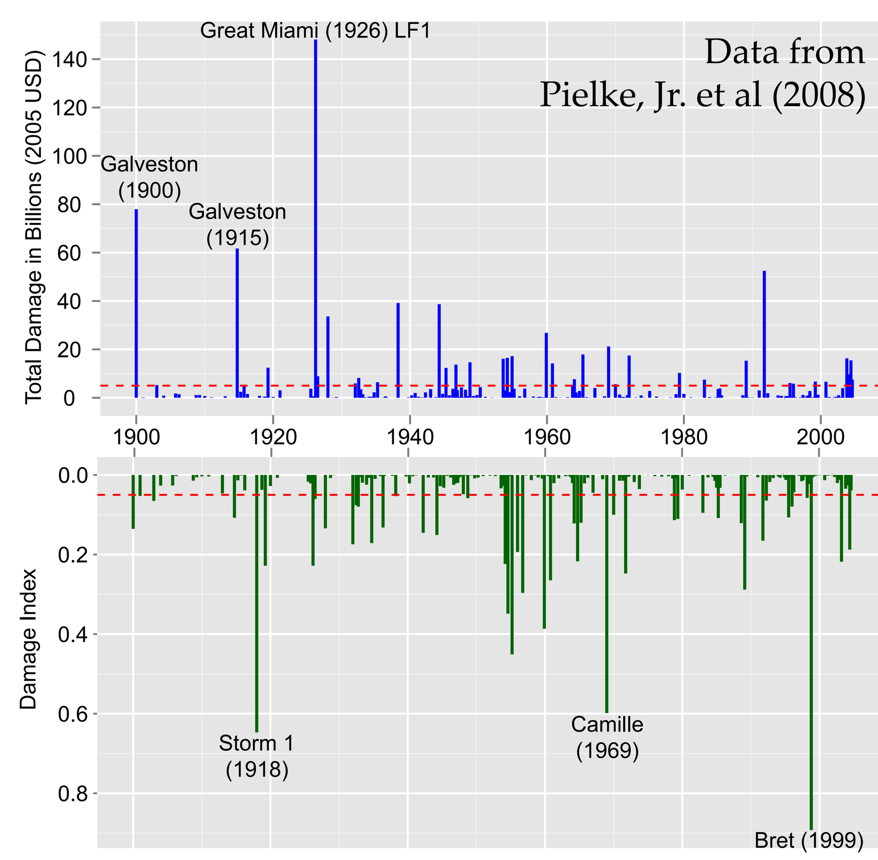
Physical * Economic

corr = -0.1

Damage Fraction (DF)

Fraction of possible damage [0,1]

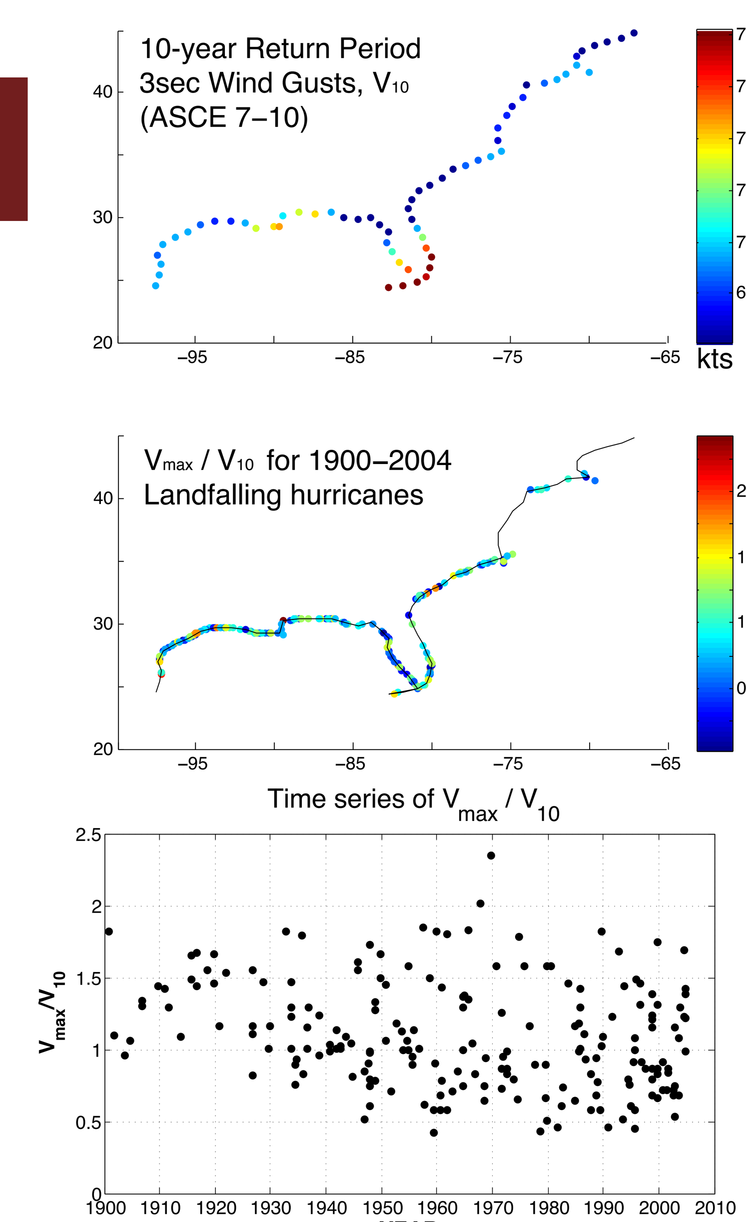
i.e. "damage capacity" of storm



(Fig. 1. Chavas et al. 2013) Time series of damages caused by U.S. landfalling hurricanes as measured by total damage in 2005 dollars (top) and DF (bottom) Dashed red line denotes 0.05 DF threshold.

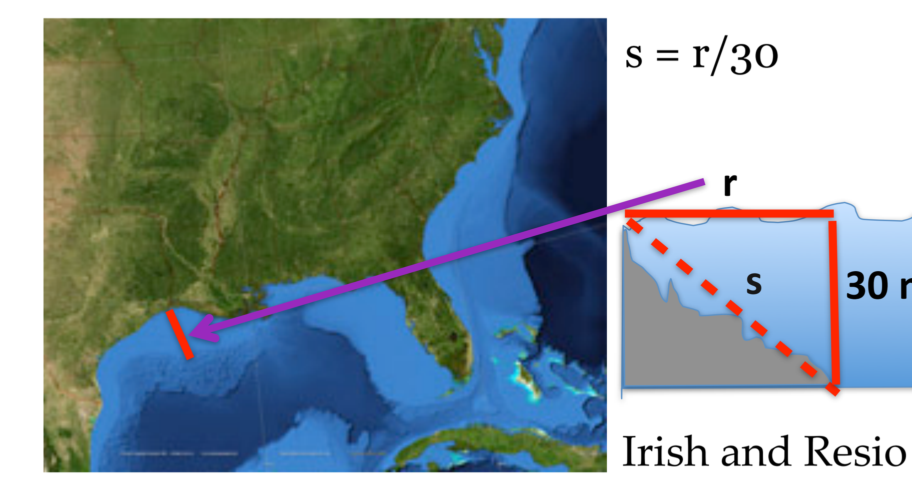
4 HURRICANE HAZARD-RELATED VARIABLES AS PREDICTORS IN GPD MODEL OF DF

Wind Intensity and Vulnerability (V_{max}/V_{10})

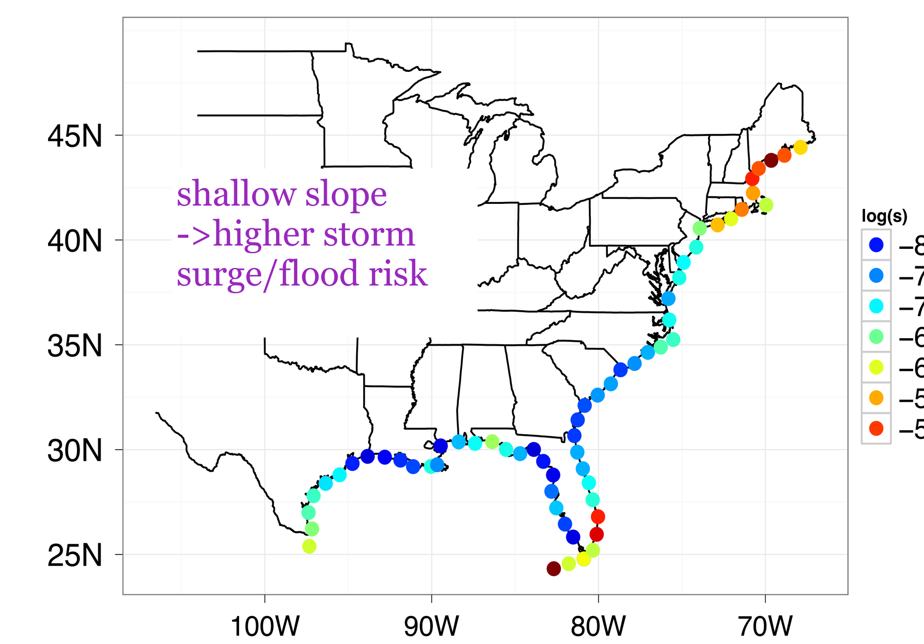


The ASCE 7-10 specifies a wind map that shows the expected wind event with a 10-year return period (V_{10}). This severity of the wind event varies regionally (FL>NJ). Wind maps like these are used to inform **building code policies.** We use V_{10} as a *vulnerability proxy* and normalize hurricane wind intensity V_{max} by V_{10} to create a variable that indicates the severity of the wind hazard relative to the regional expectations.

Storm Surge Proxy (s)



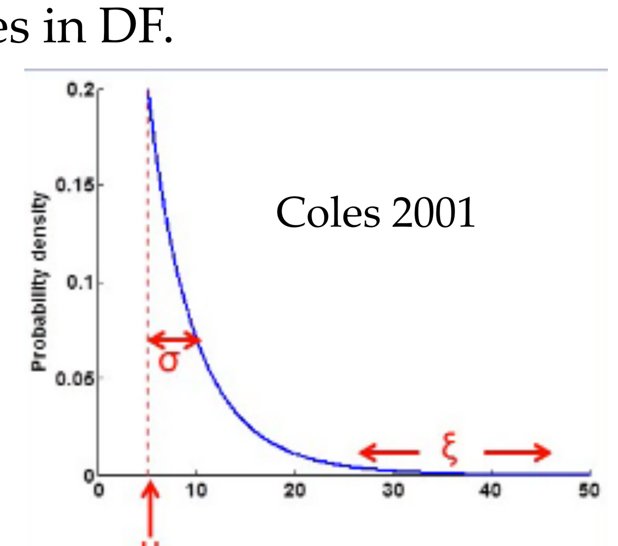
Irish and Resio 2010



3 EXTREME VALUE ANALYSIS – Linking Climate Effects

Given a time series of data, X, and a high threshold μ, the "excess" over the threshold follows an approximate **Generalized Pareto Distribution (GPD).** We use this to model extremes in DF.

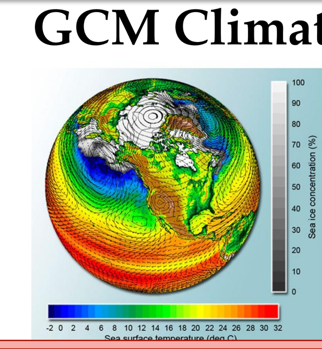
$$P(x|x>u) = \begin{cases} \frac{1}{\sigma}\left(1+\xi\frac{x-u}{\sigma}\right)^{-1-\frac{1}{\xi}} & \text{if } \xi \neq 0 \\ \frac{1}{\sigma}exp\left(-\frac{x-u}{\sigma}\right) & \text{if } \xi = 0 \end{cases}$$



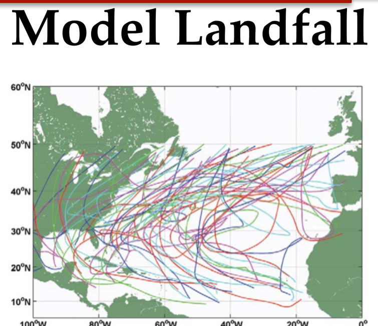
μ: threshold
σ: scale parameter (spread)
ξ: shape parameter (upper tail behavior)
ξ > 0 "fat" tail (power law)
ξ < 0 bounded
ξ = 0 "thin" tail (exponential)

Climate-to-DF Framework

GCM Climate



Hurricane Model Landfall Data
(Emanuel 2006)



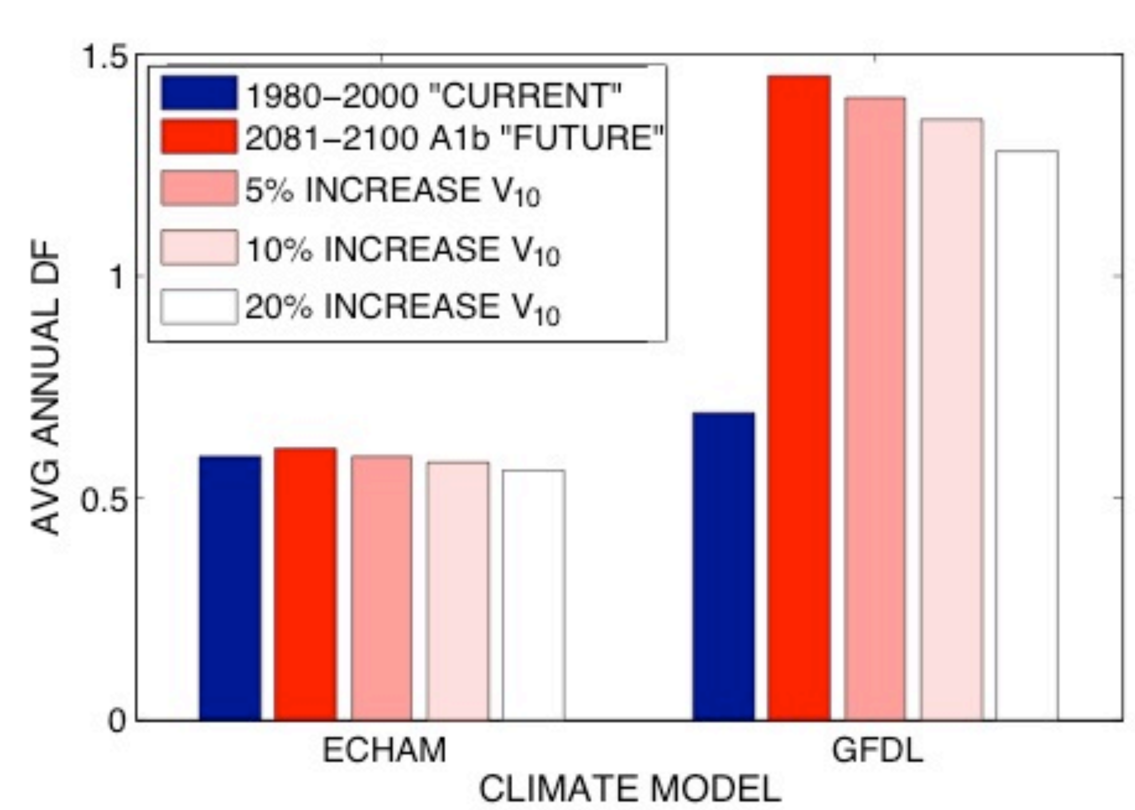
GPD Model of DF

$\mu = 0.05$ (threshold parameter)

$\ln\sigma = \sigma_0 + 0.33\frac{V_{max}}{V_{10yr}} - 0.25\bar{s}$ (scale parameter)

$\xi = -0.04$ (shape parameter)

5 CLIMATE CHANGE AND VULNERABILITY



Using the Climate-to-DF framework, we input "current" and "future" climate backgrounds from two climate models, ECHAM and GFDL, into a hurricane model that generates 5000 landfalling storms. In the figure to the left, we show the average annual DF (damage % of exposed wealth) given by the landfall data input into the GPD model.

- In both climate models, the future climate yields higher damage (average annual DF).
- Increasing V_{10} (decreasing vulnerability by raising building codes) may decrease damages in the future.
- For ECHAM climates, a V_{10} increase can decrease damage to lower than it is in the current climate.

REFERENCES

Coles, S. (2001). An introduction to statistical modeling of extreme values, Vol. 97, Springer, New York.
Chavas, D.R., Yonekura, E., et al. (2013). "U.S. hurricanes and economic damage: Extreme value perspective." Nat. Hazards Rev., 14(4), 237-246.
Emanuel, K., et al. (2006). "A statistical deterministic approach to hurricane risk assessment." BAMS., 87(3), 299–314.
Irish, J. L., and Resio, D. T. (2010). "A hydrodynamics-based surge scale for hurricanes." Ocean Eng., 37(1), 69–81.
Pielke, R. A., Jr., et al. (2008). "Normalized hurricane damages in the United States: 1900–2005." Nat. Hazards Rev., 9(1), 29–42.
Neumayer, E., and Barthel, F. (2011). "Normalizing economic loss from natural disasters: A global analysis." Glob. Environ. Change, 21(1), 13–24.