

Long-term joint probability estimation for multiple offshore hazards induced by hurricanes

Chi Qiao, Andrew Myers

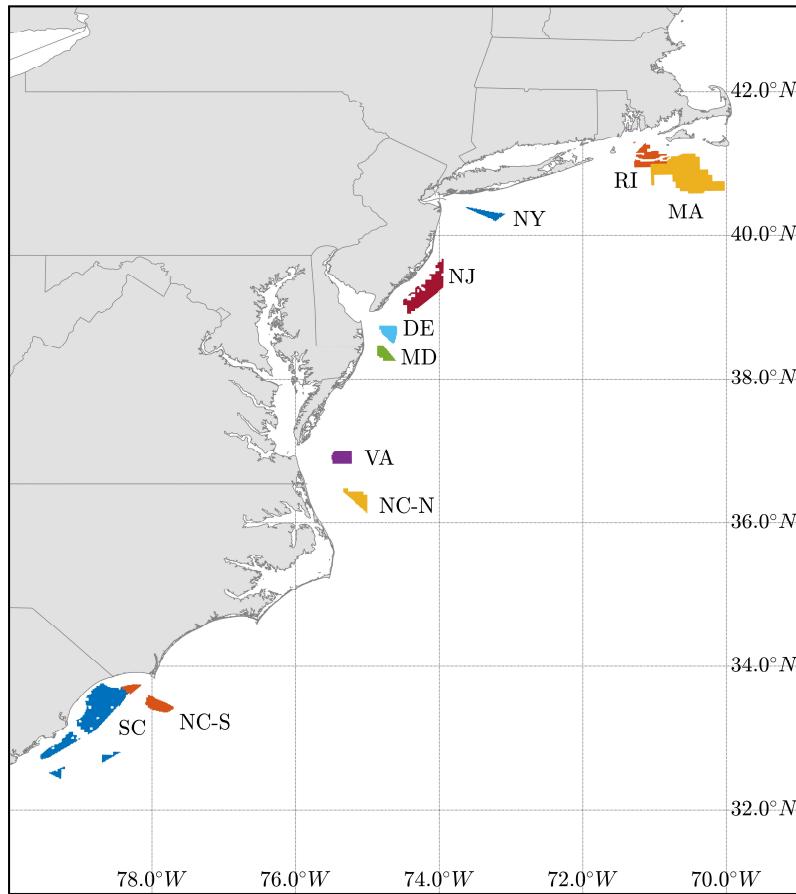
October 17, 2019



Northeastern University

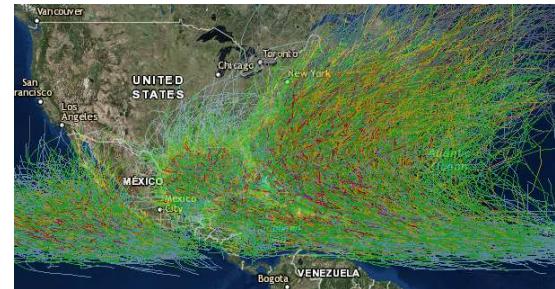


Hurricane offshore multi-hazard



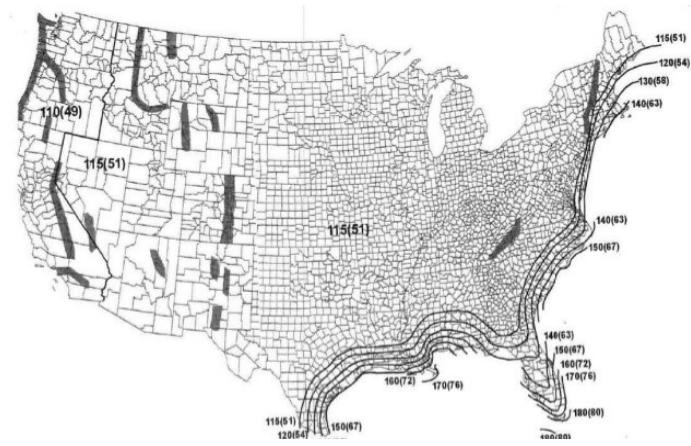
Proposed wind energy areas

Data reference: www.boem.gov



All hurricane track records

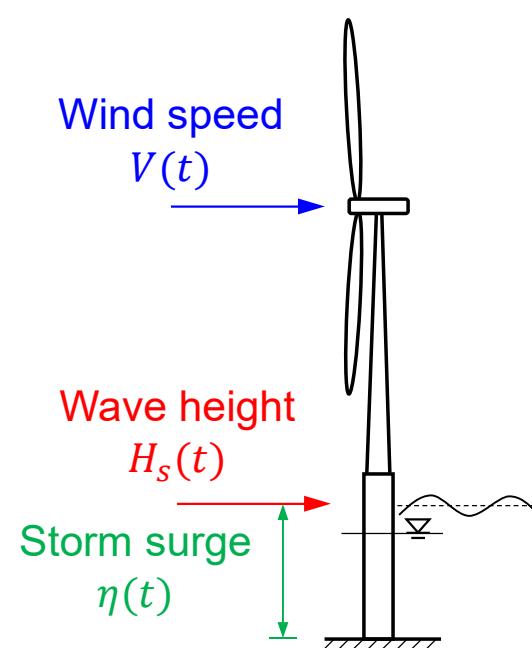
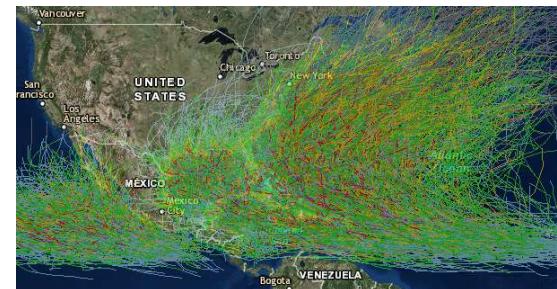
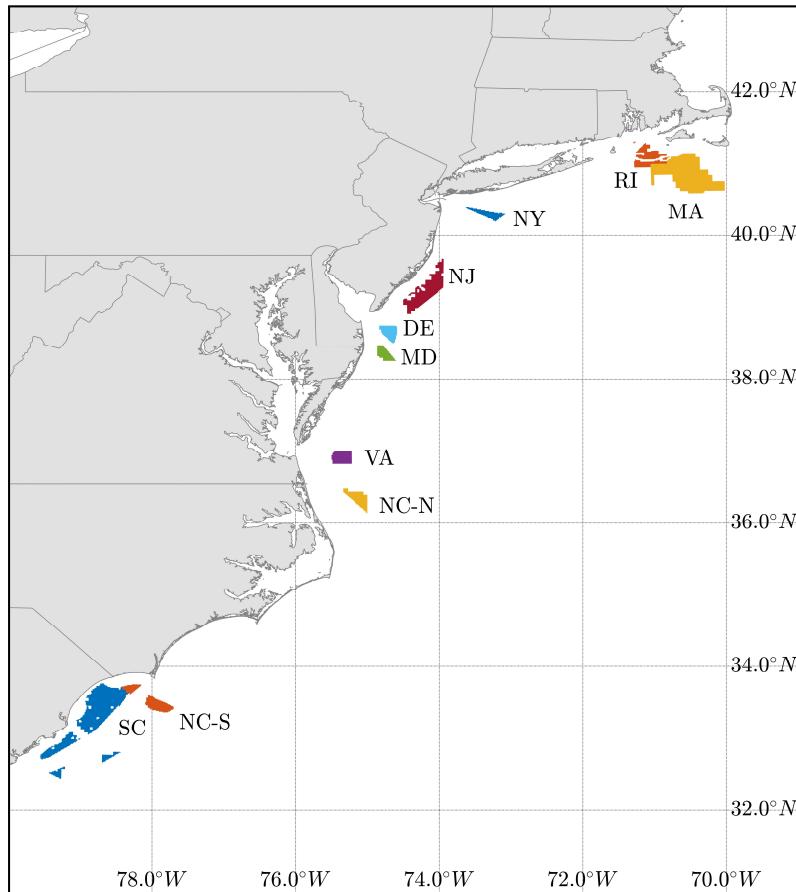
Image reference: coast.noaa.gov



Design wind speed in ASCE 7-10

Image reference: [ASCE 7-10](#)

Hurricane offshore multi-hazard



The background image shows an aerial perspective of several wind turbines standing in a row on a light blue ocean surface under a sky filled with white and grey clouds.

Overview

- 01 | Metocean data
- 02 | Mean return period
- 03 | Hybrid Rosenblatt-Nataf transformation
- 04 | Hazard map for offshore engineering

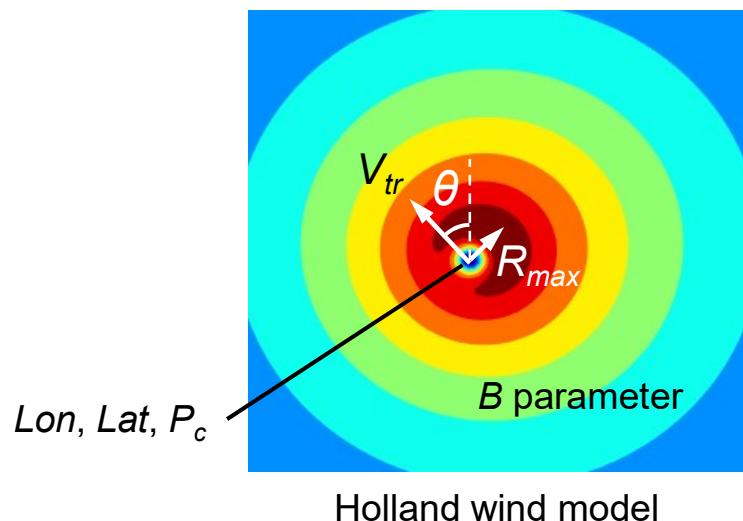
01 |

Metocean data

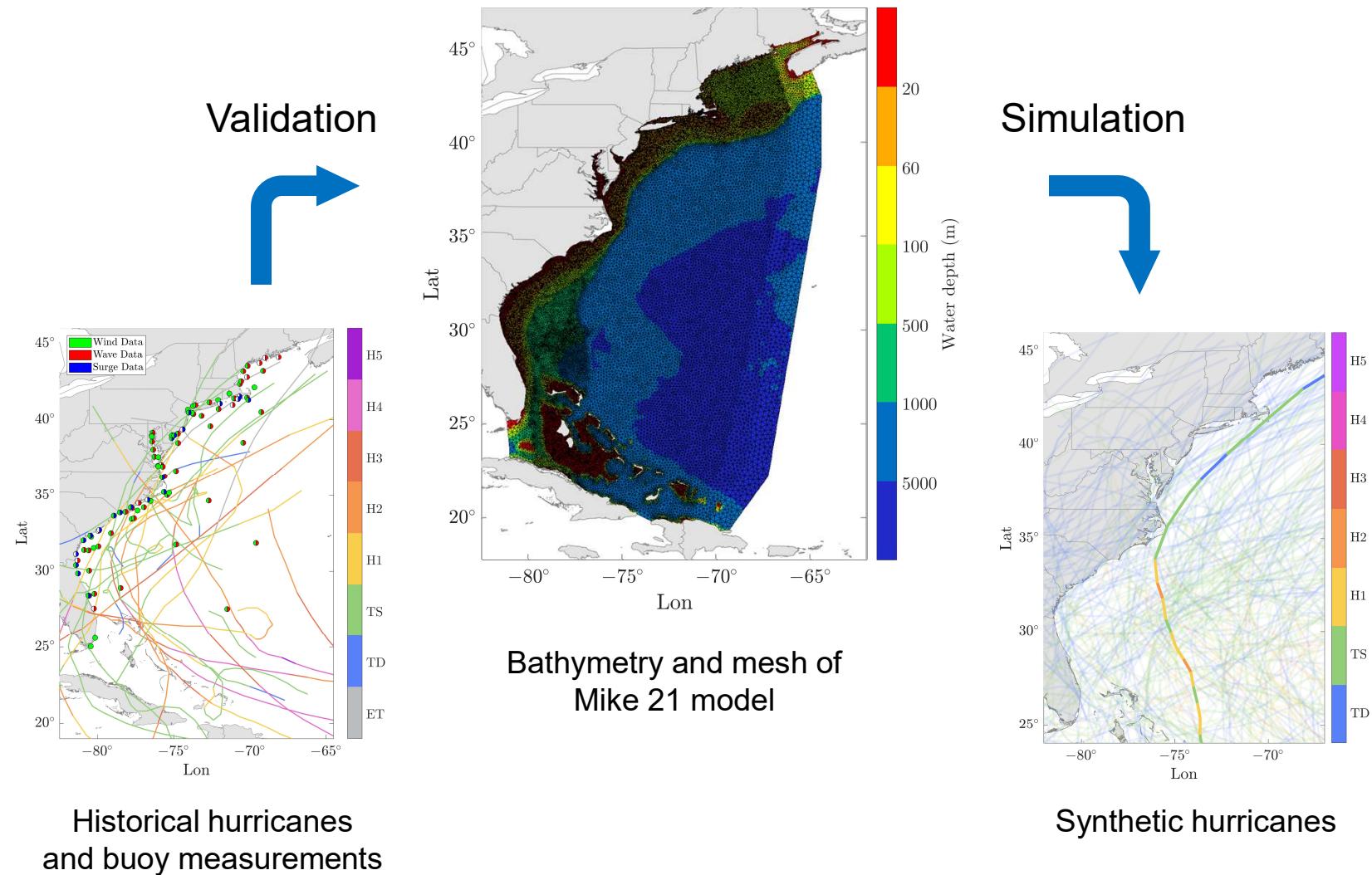


More hurricane data

- 100,000-yr synthetic hurricane catalog developed by Prof. Pang in Clemson University
 - Empirical hurricane wind field model in 6-hr intervals

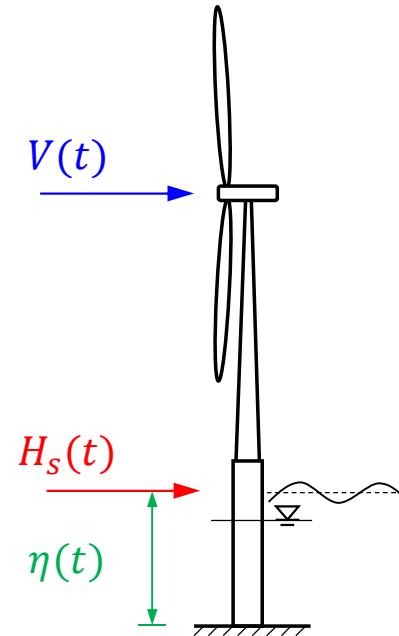


Metocean data under hurricane



Hurricane offshore multi-hazard analysis

- Empirical model → fast
 - Main driving force
-
- Numerical model → slow



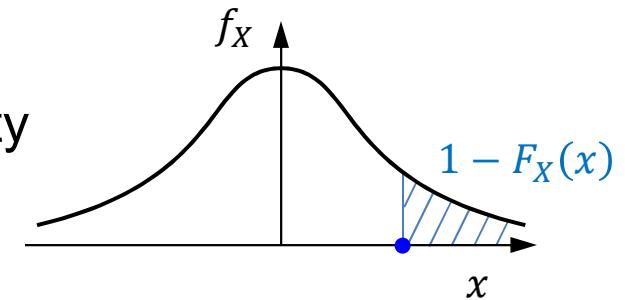
02 |

Mean return period

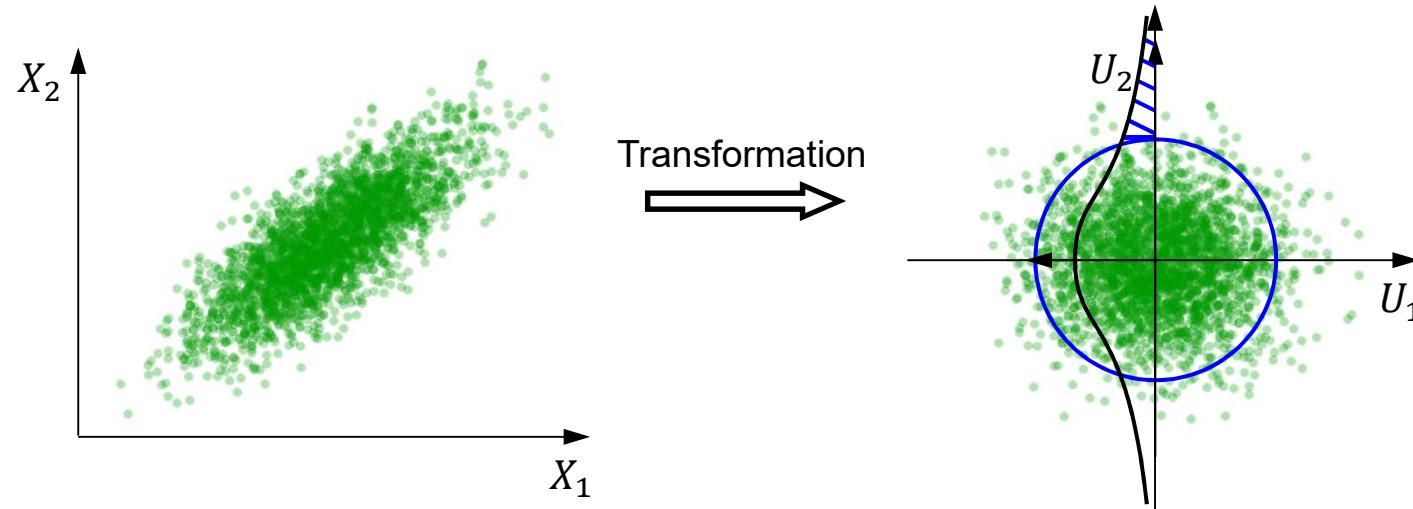


Mean return period (MRP) of hazard

- Single variable: $\text{MRP} = \frac{1}{1 - F_X(x)}$
 $1 - F_X(x)$: Annual exceedance probability

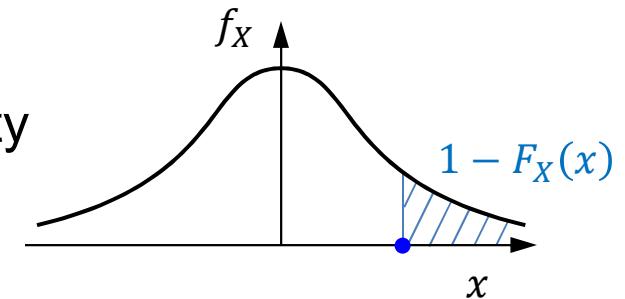


- Multiple variables
 - Joint probability function (Environmental contour)

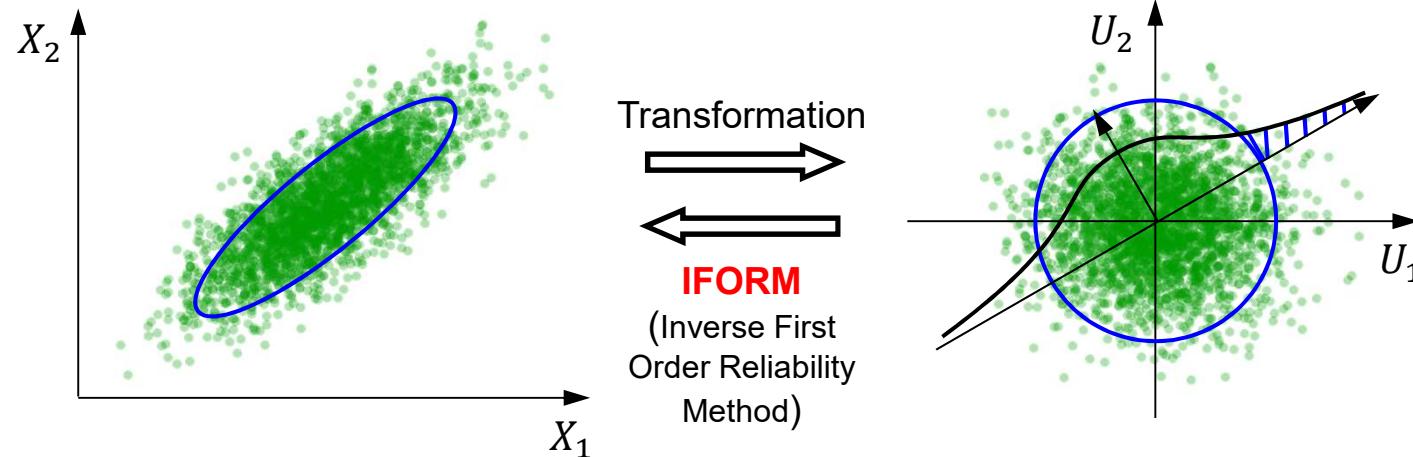


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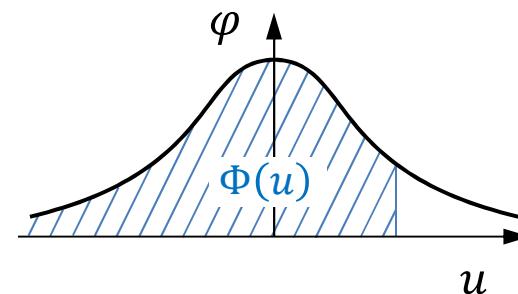
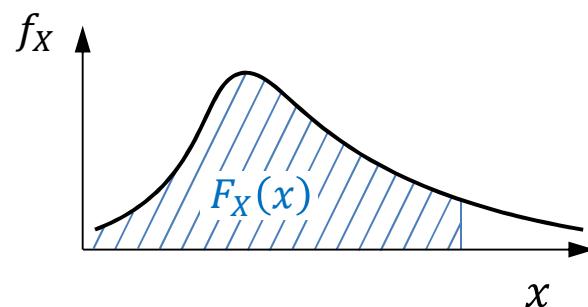
- Multiple variables
 - Joint probability function (Environmental contour)



Transformation methods in IFORM

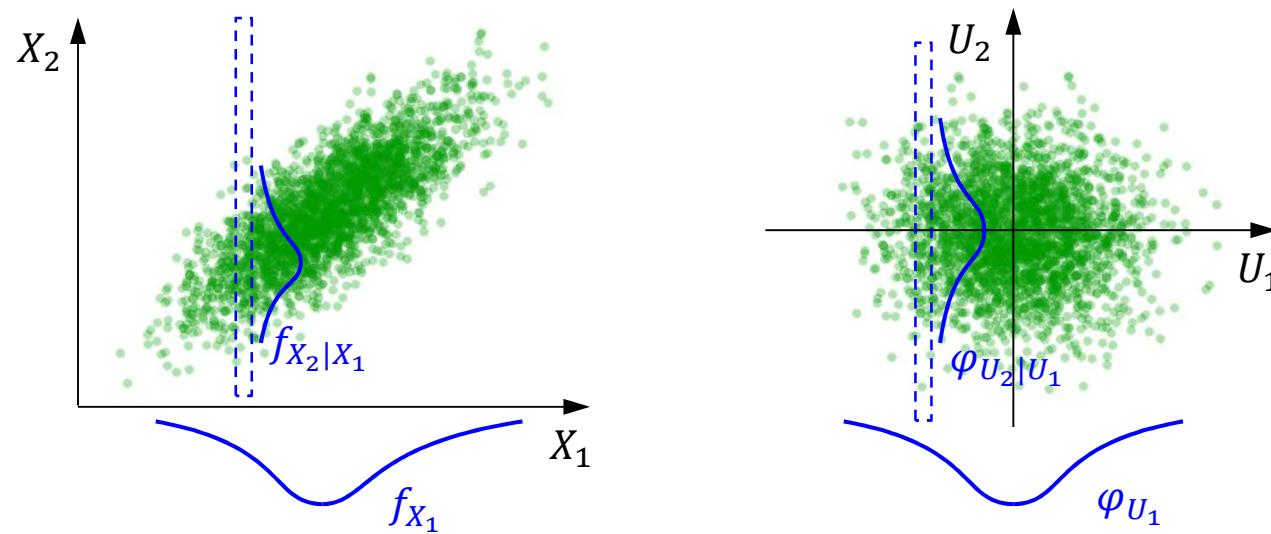
- Univariate case

- $F_X(x) = \Phi(u) \Rightarrow u = \Phi^{-1}[F_X(x)]$



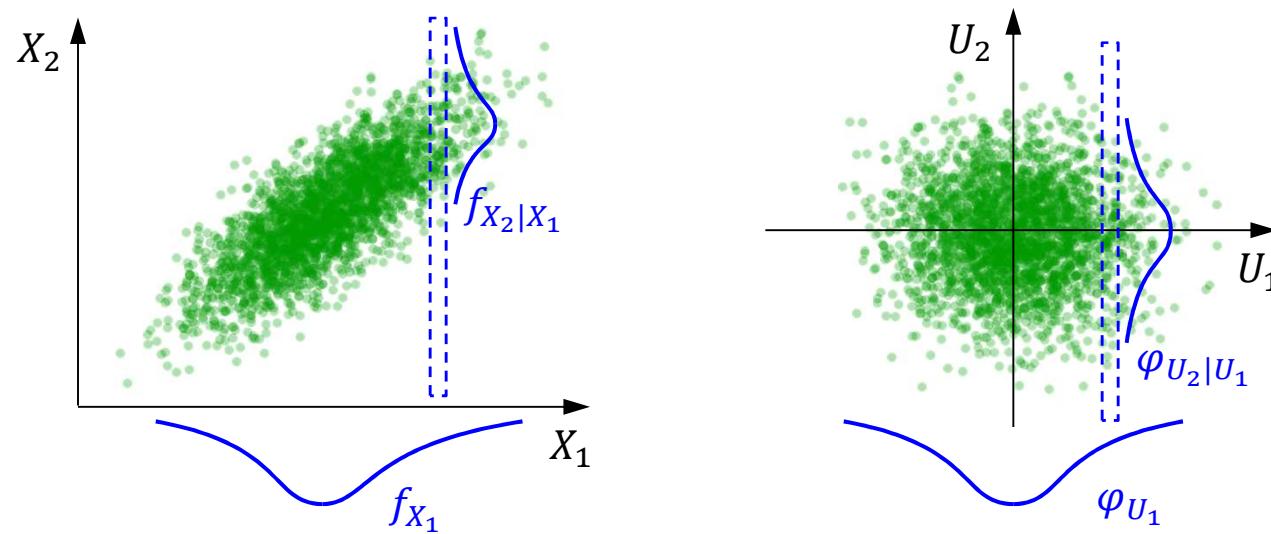
Transformation methods in IFORM

- Rosenblatt transformation



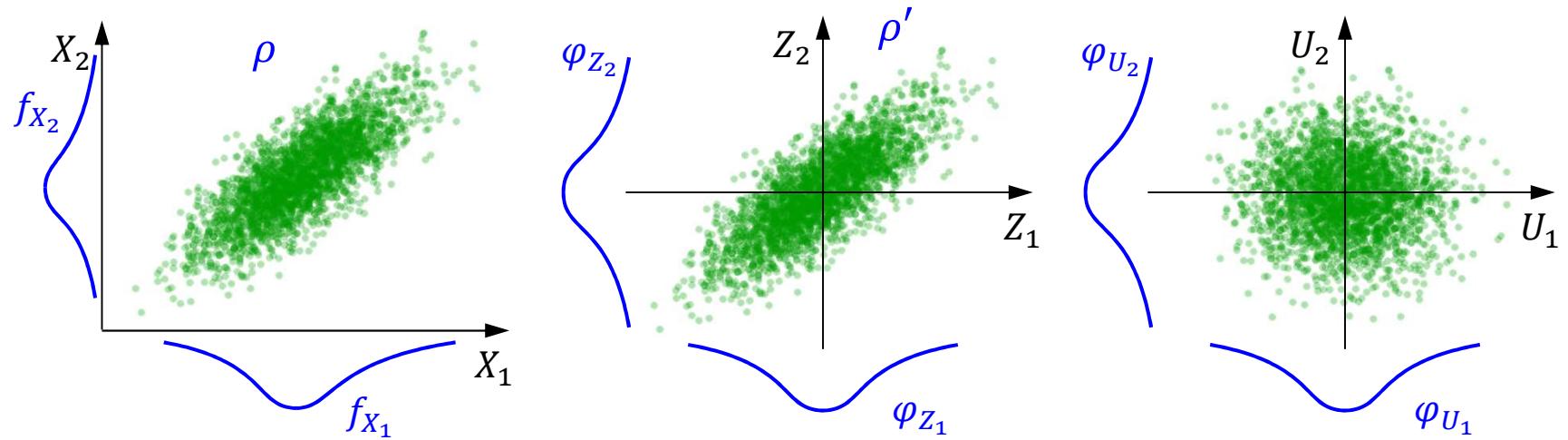
Transformation methods in IFORM

- Rosenblatt transformation
 - Pros: Fit data well
Support partial contour
 - Cons: Few data for $f_{X_n|X_1X_2\dots X_{n-1}}$
Large uncertainty for distribution parameter extrapolation



Transformation methods in IFORM

- Nataf transformation
 - Pros: Easy to implement for high dimension variables
 - Cons: Capture linear relationship only
Less accurate comparing to Rosenblatt

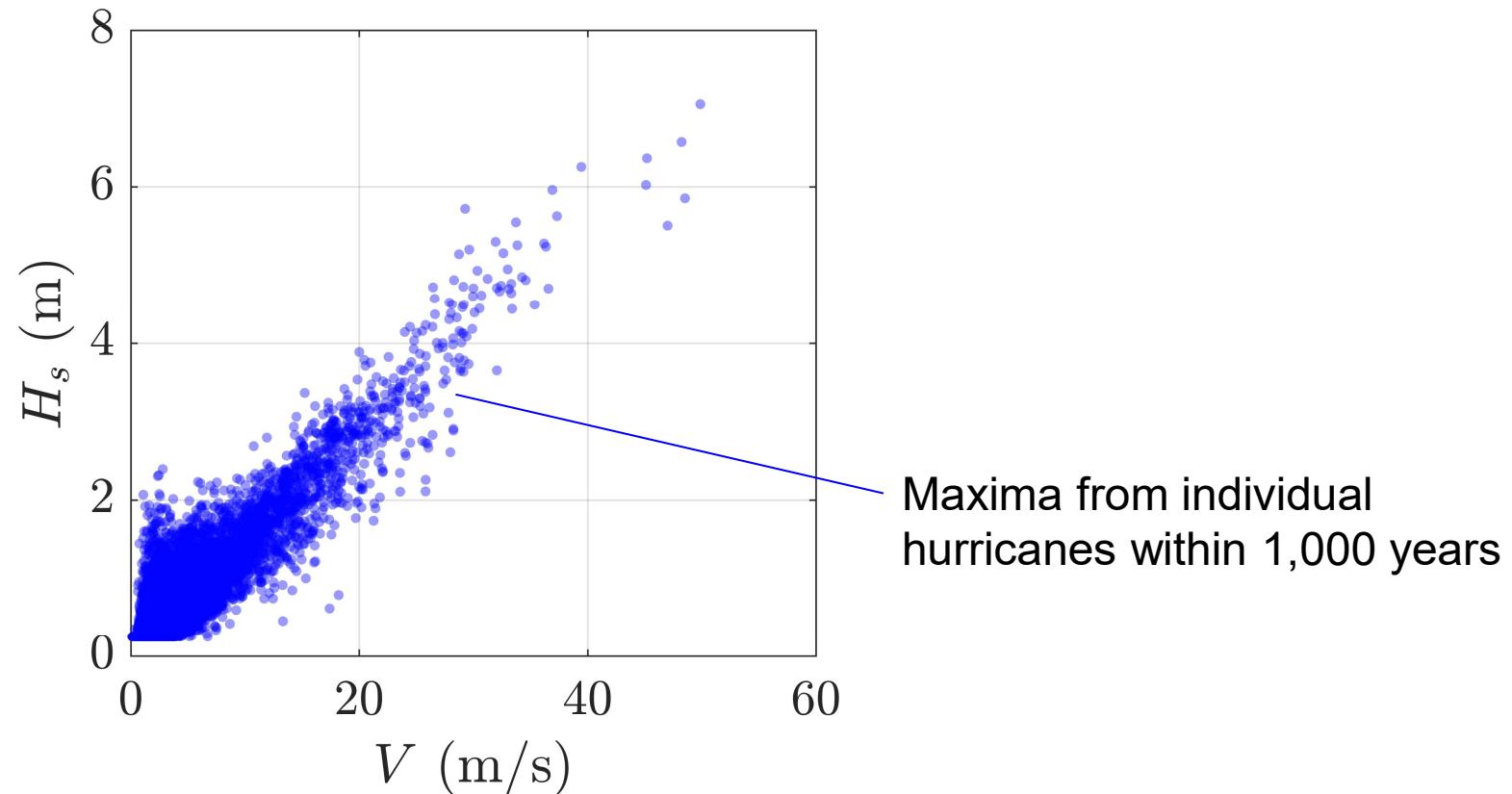


03 |

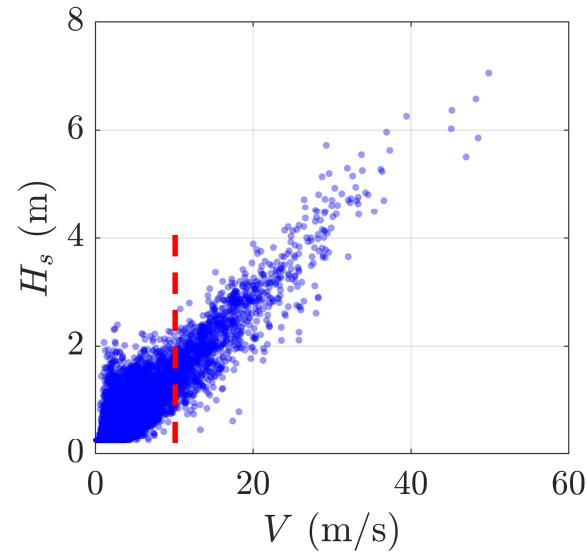
Hybrid Rosenblatt-Nataf transformation



Challenges in environmental contour



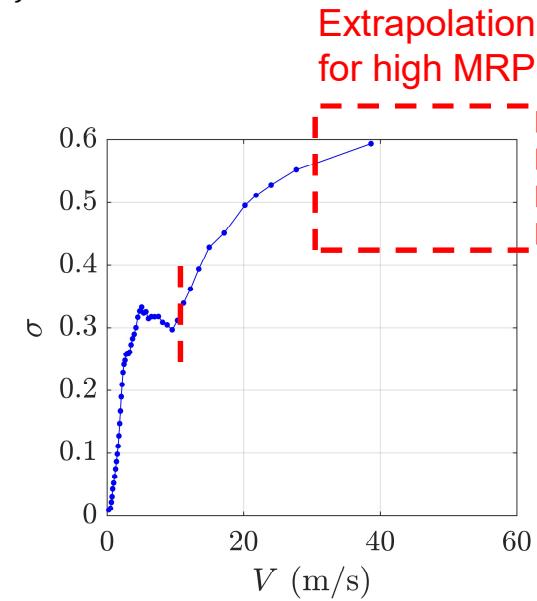
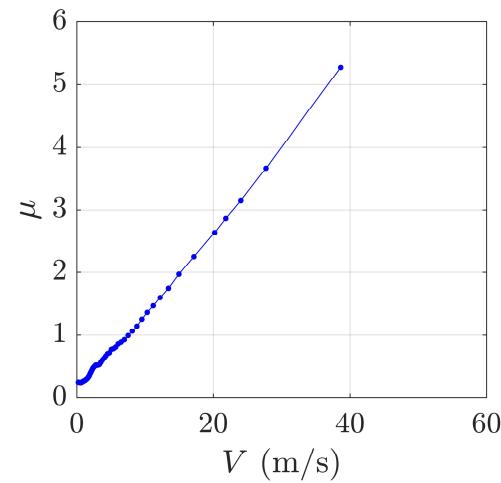
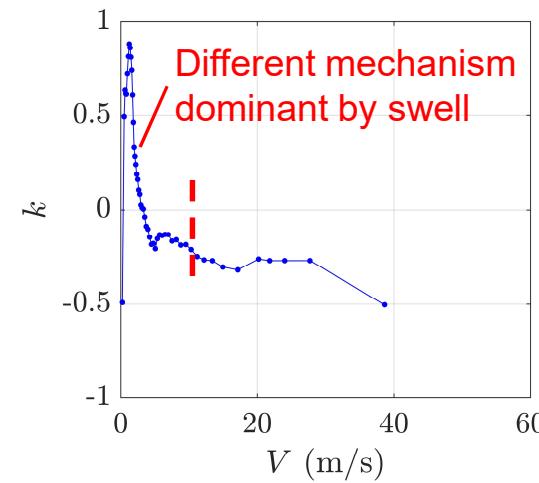
Challenges in environmental contour



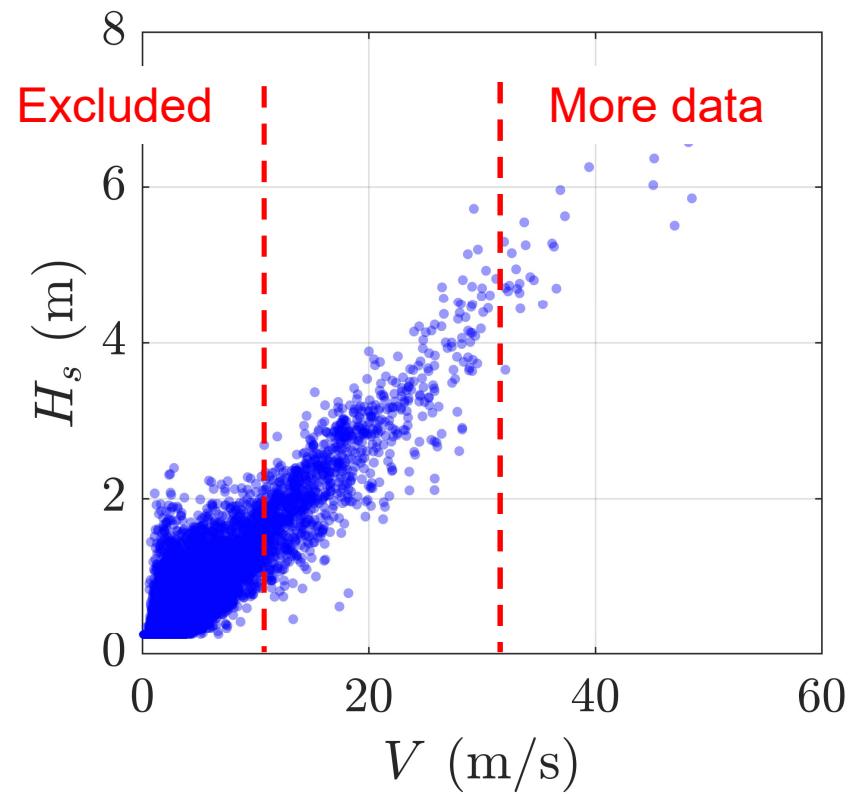
Generalized Extreme Value distribution
for $f(H_s|V)$:

$$f(x) = \frac{1}{\sigma} t(x)^{k+1} e^{-t(x)}$$

$$t(x) = \begin{cases} \left(1 + k \frac{x - \mu}{\sigma}\right)^{-\frac{1}{k}} & \text{if } k \neq 0 \\ e^{-(x-\mu)/\sigma} & \text{if } k = 0 \end{cases}$$

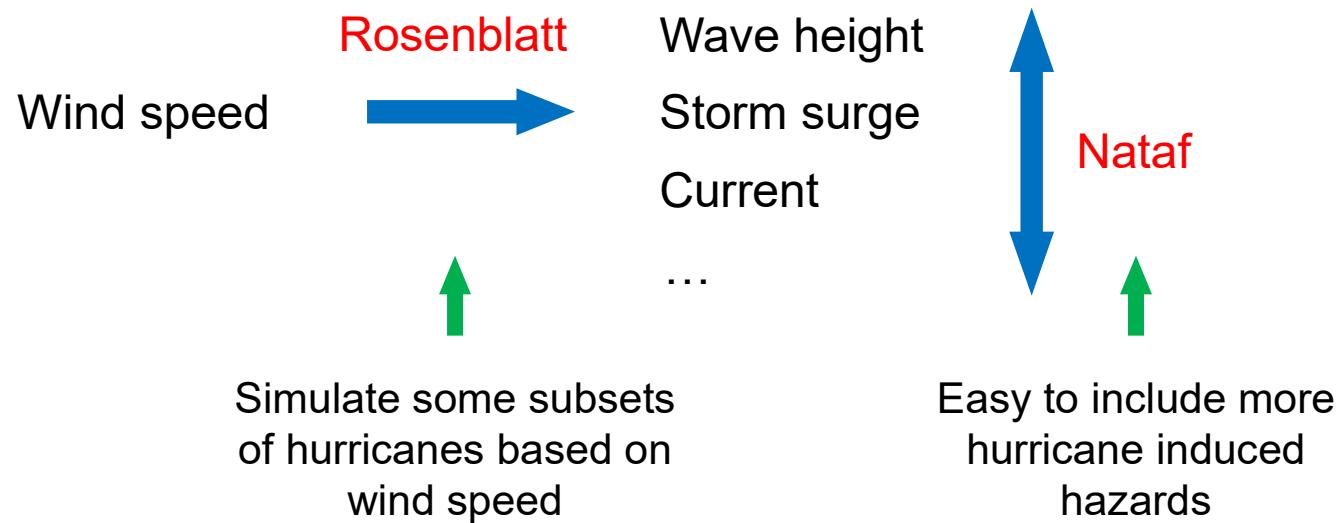


Challenges in environmental contour

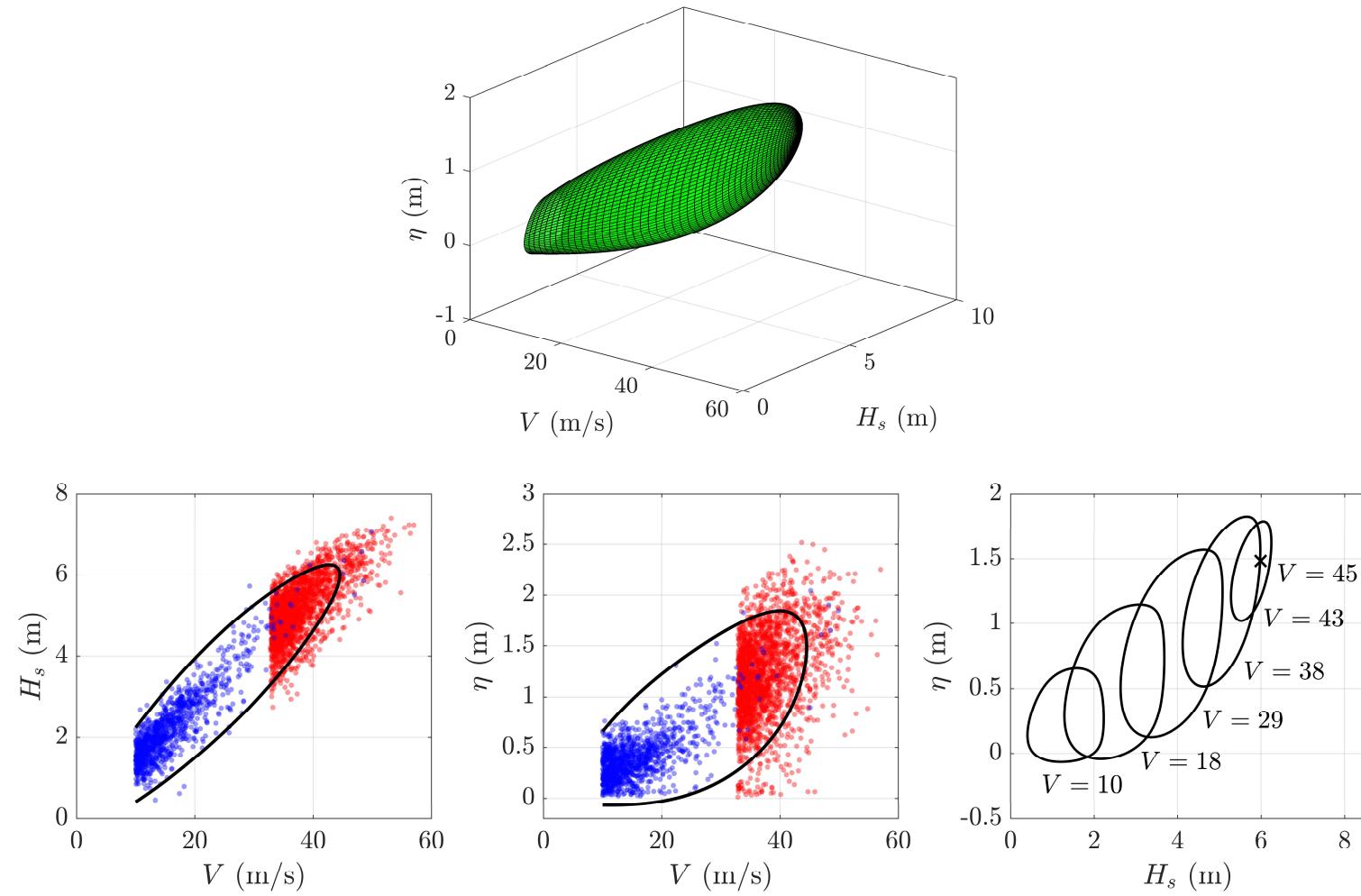


Hybrid Rosenblatt-Nataf transformation

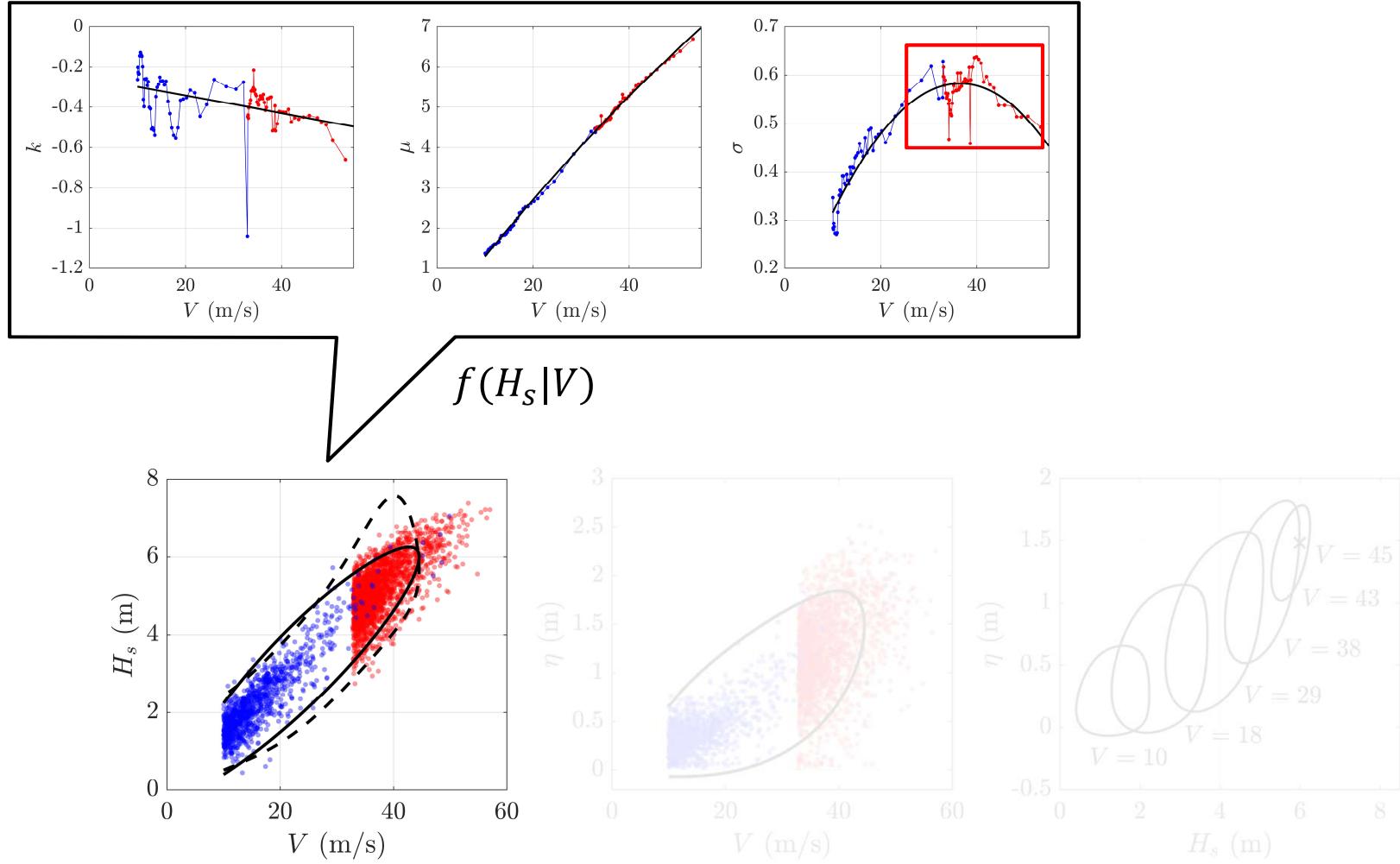
| | Pros | Cons |
|------------|-----------------------------|--|
| Rosenblatt | Accurate Partial contour | Parameter extrapolation; Requires more data |
| Nataf | Easy to implement | Less accurate |



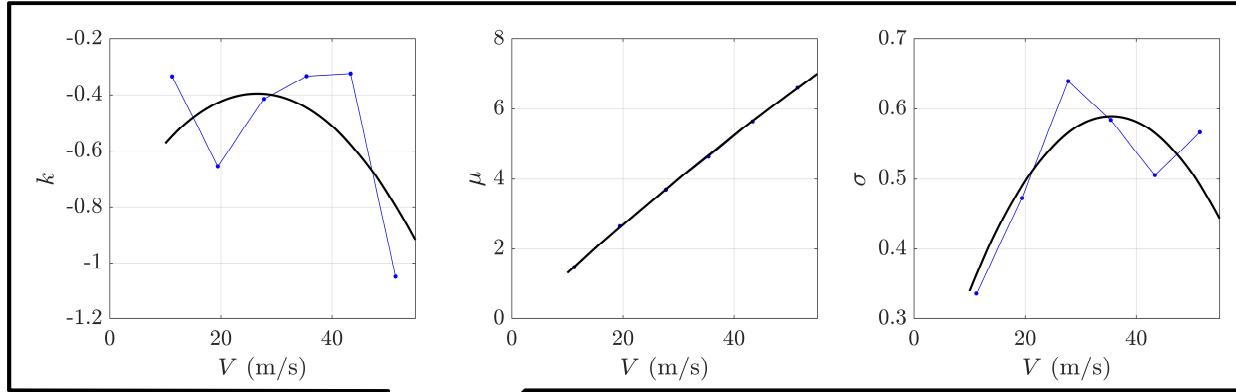
Hybrid Rosenblatt-Nataf transformation



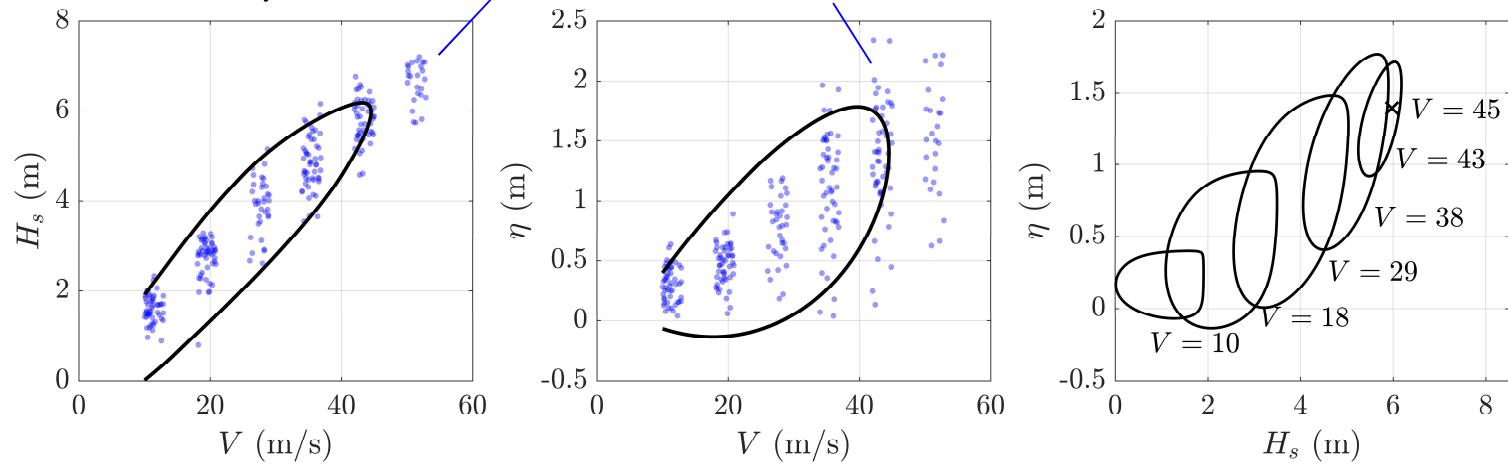
Hybrid Rosenblatt-Nataf transformation



More efficient way to construct contour



50 simulations
for each bin of V

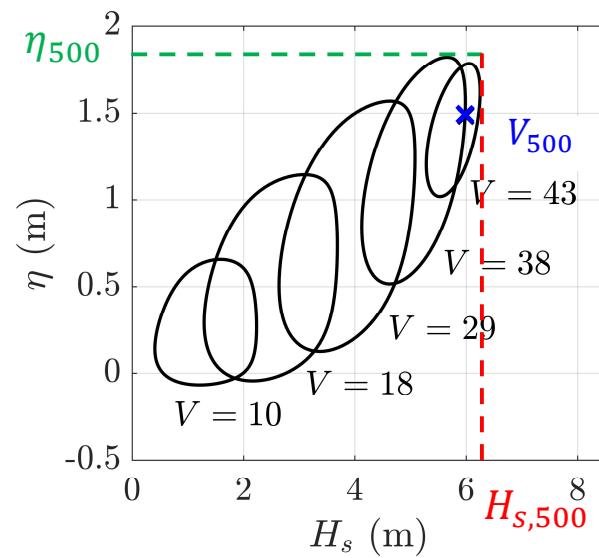
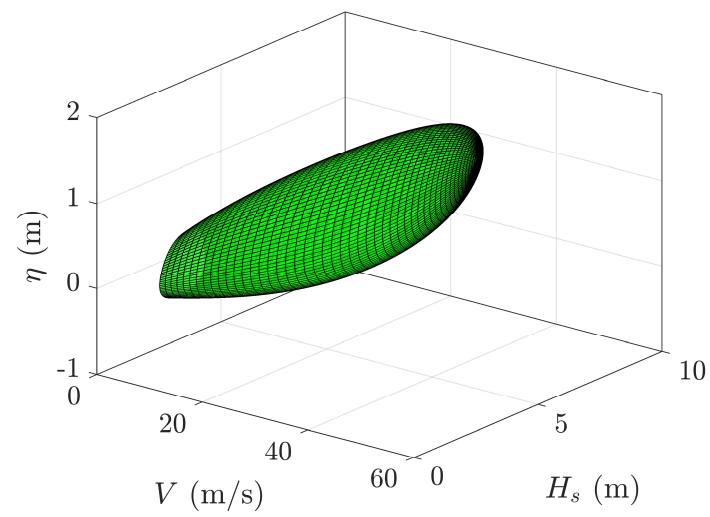


04

Hazard map for offshore engineering

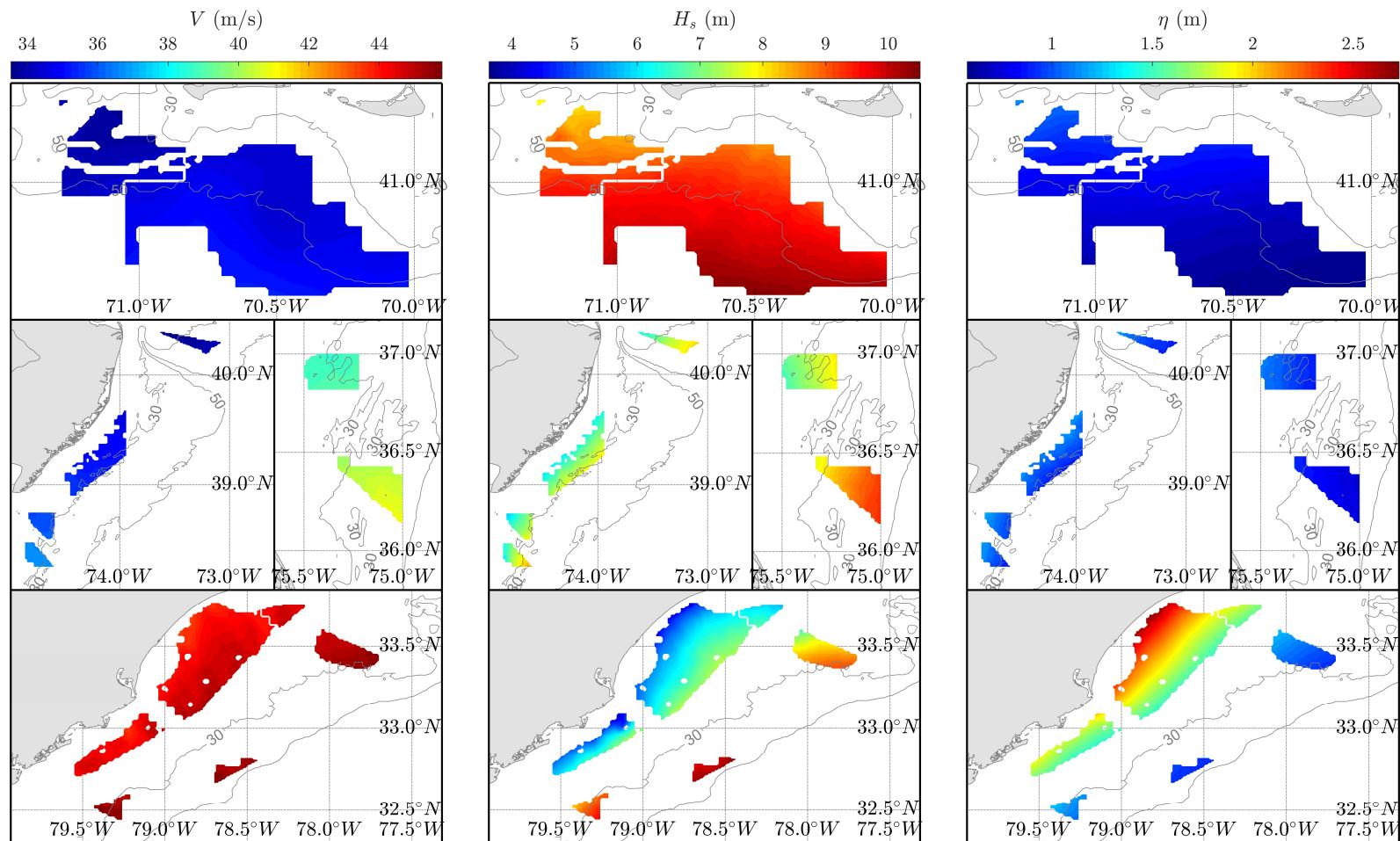


Independent hazard map

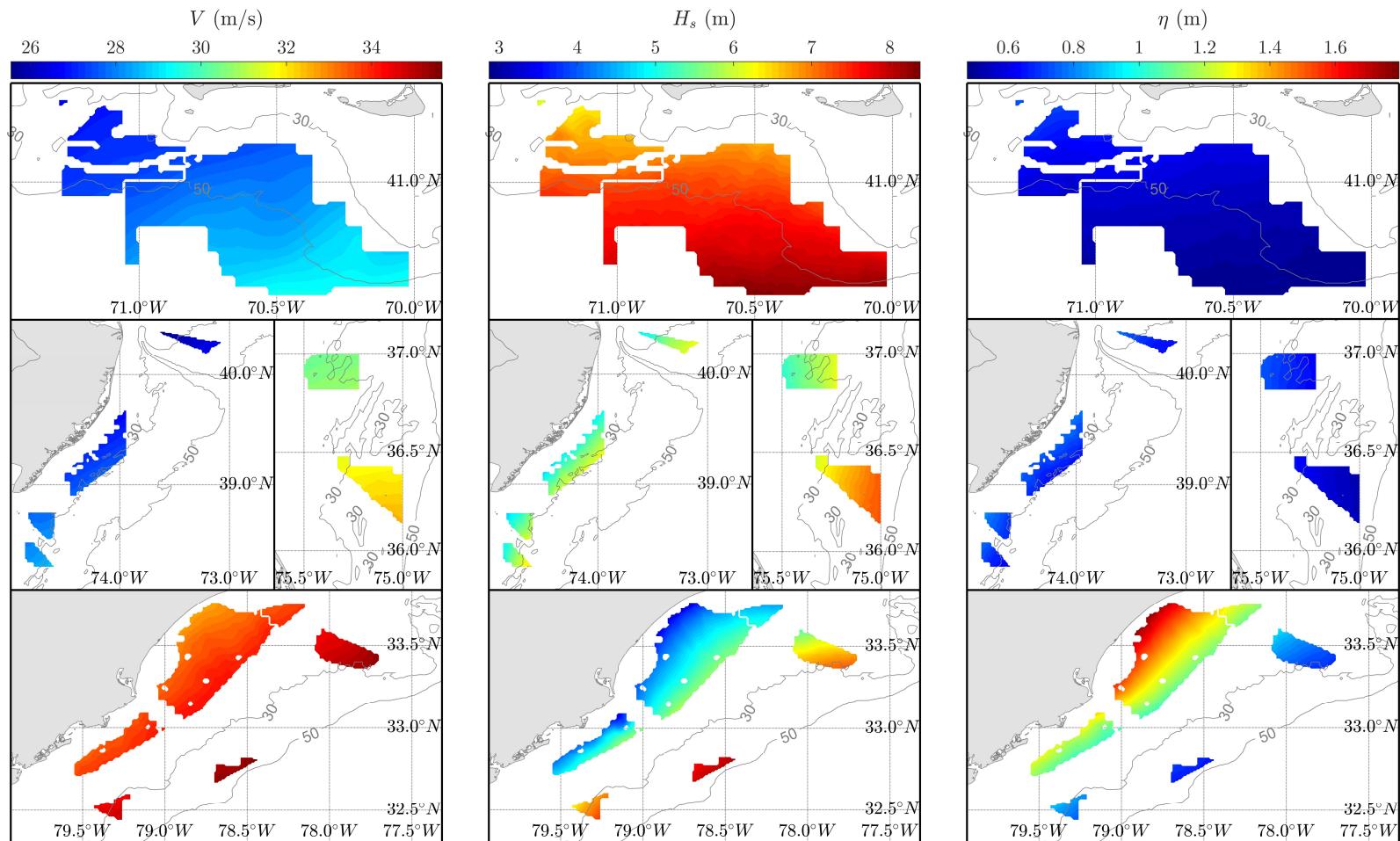


500-yr contour

500-yr independent hazard map



50-yr independent hazard map



Summary

- Numerical metocean model + Synthetic hurricane catalog
→ More offshore hurricane multi-hazard data
- Rosenblatt + Subsets of metocean simulation → Exclude influence of swell + Avoid parameter extrapolation
- Rosenblatt + Nataf → High dimensional environmental contour
- Express environmental contour in hazard map?



Thank you