A benchmarking exercise on estimating extreme environmental conditions: Methodology & baseline results

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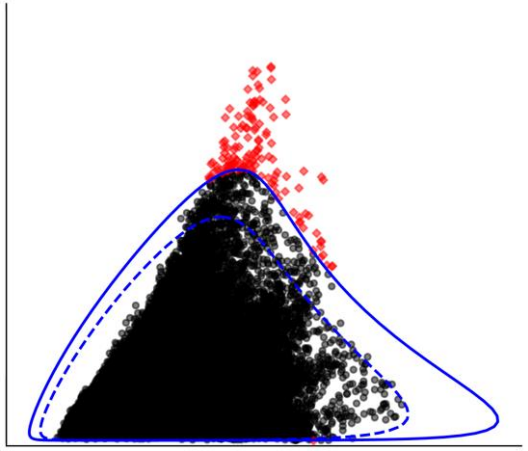
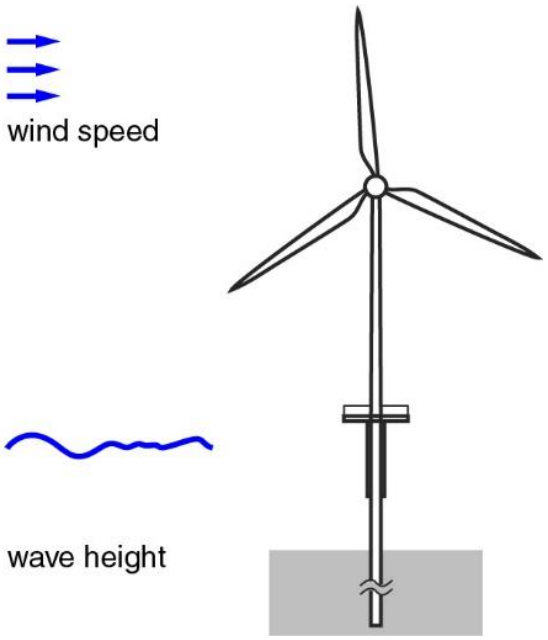


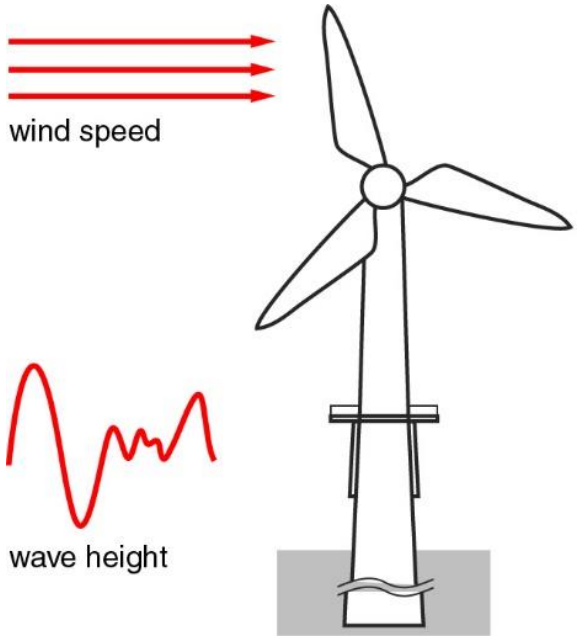
Presented on June 12, 2019 at OMAE 2019 in Glasgow, UK

Organizations at University of Bremen

Motivation

We need to predict future extreme environmental conditions to design reliable marine structures.





Motivation

We need to predict future extreme environmental conditions to design reliable marine structures.

- Estimating long-term extremes is difficult
  - Complex physical processes
  - Extrapolation often necessary
  - Multivariate extreme values
- Many methods exist: how do they compare?

Environmental contour method

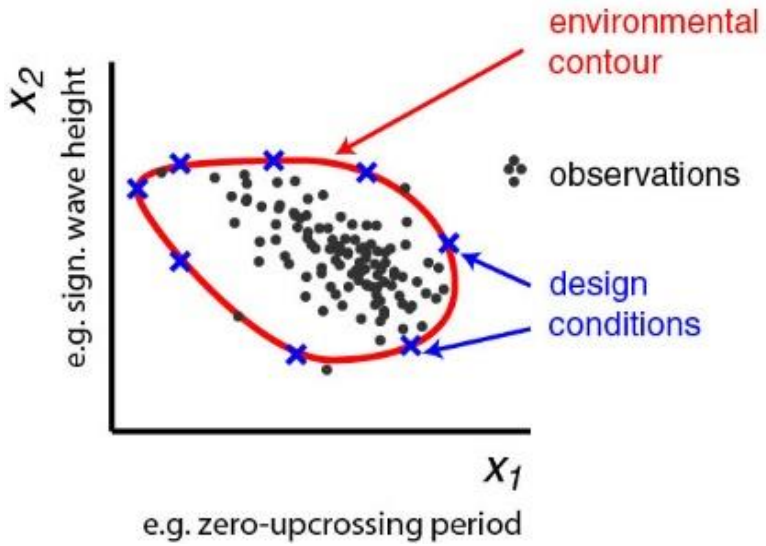
An environmental contour is a set of joint extremes of environmental conditions associated with a target return period.

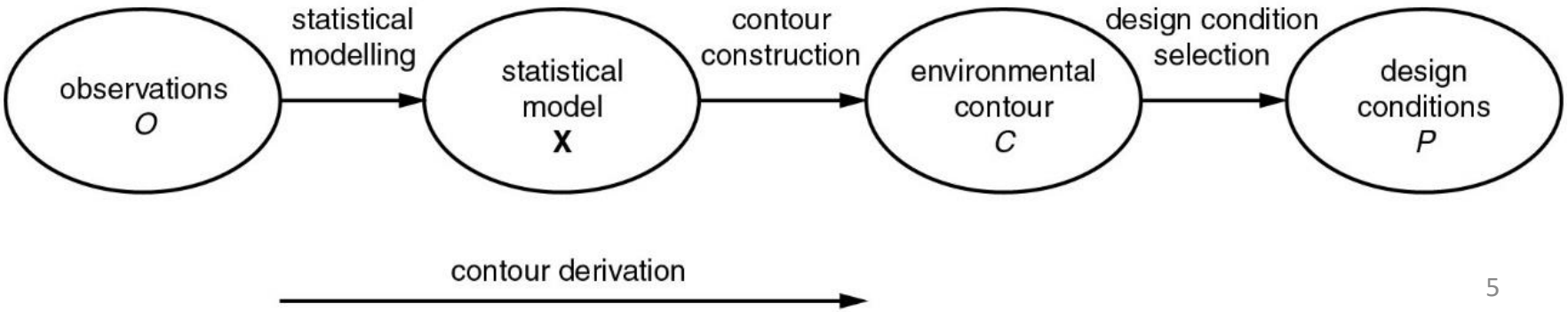
- Roots of the method in the 1980s and 1990s
  - “Design curve” (Haver, 1985)
  - “Environmental contour” (Winterstein *et al*., 1993)
- Received much interest recently
  - Applied to vessels, wave energy converters, wind turbines
  - New statistical models for the environment proposed
  - New statistical definitions for the contour proposed

Haver, S. (1985). Wave climate off northern Norway. Applied Ocean Research, 7(2), 85–92. https://doi.org/10.1016/0141-1187(85)90038-0

Winterstein, S. R., Ude, T. C., Cornell, C. A., Bjerager, P., & Haver, S. (1993). Environmental parameters for extreme response: Inverse FORM with omission factors. In Proc. 6th International Conference on Structural Safety and Reliability (ICOSSAR 93). Innsbruck, Austria.

From observations to design conditions



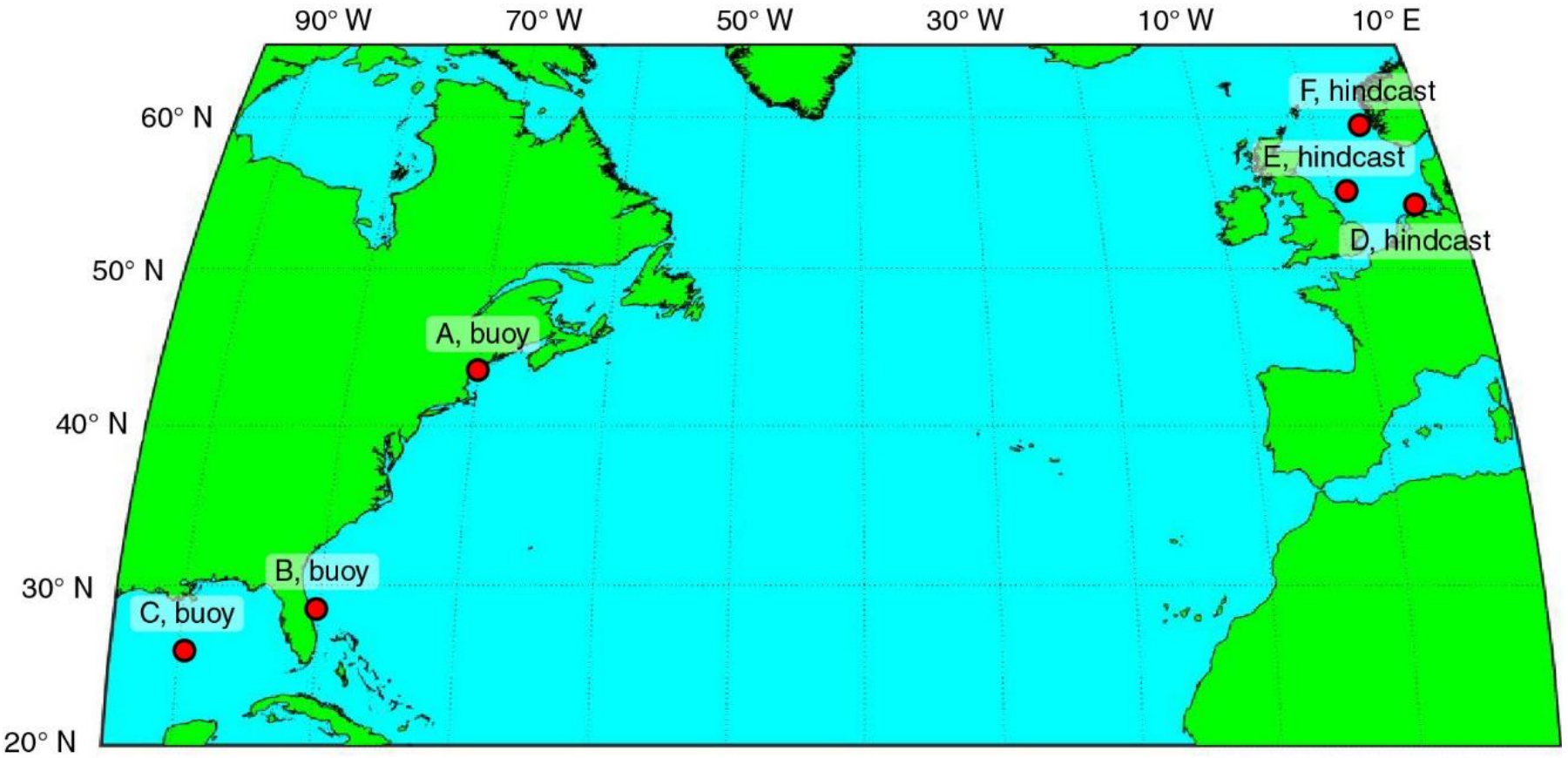


Open comparison of contour methods

- Goal: Systematic comparison → benchmarking exercise
- Benchmark defines:
  - Datasets
  - Return periods
  - Method for uncertainty characterization (Gramstad *et al., 2018*)
- Differences between the contours from:
  - Statistical modelling of the environment
  - Contour construction (mainly due to different definitions)

Gramstad, O., Vanem, E., & Bitner-Gregersen, E. M. (2018). Uncertainty of environmental contours due to sampling variability. In Proc. 37th International Conference on Ocean, Offshore and Arctic Engineering (OMAE 2018). Madrid, Spain: American Society of Mechanical Engineers (ASME). https://doi.org/10.1115/OMAE2018-77810

Datasets: US east coast and North Sea



Buoy data: NDBC
Main coast, Florida coast, Gulf of Mexico

Hindcast data: coastDat-2
German coast, UK coast, Norwegian coast

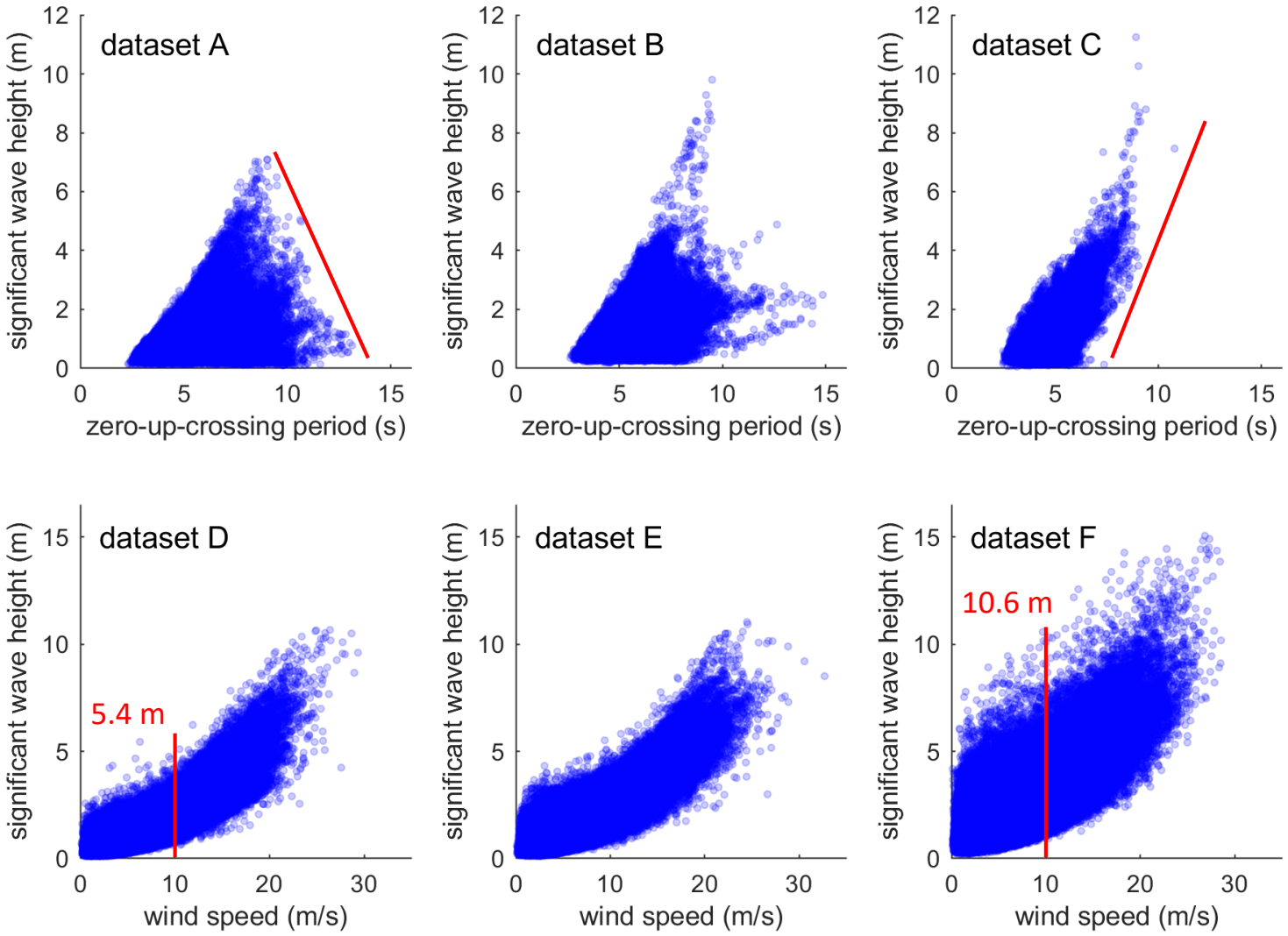
Datasets and contours

- A-C: Sea states (H_s-T_z, common variable combination)
- D-F: Wind-wave states (H_s-U_{10}, e.g. required in IEC 61400-3)
- Exercise 1: Calculate 12 prescribed contours
- Exercise 2: Characterize uncertainty for dataset D

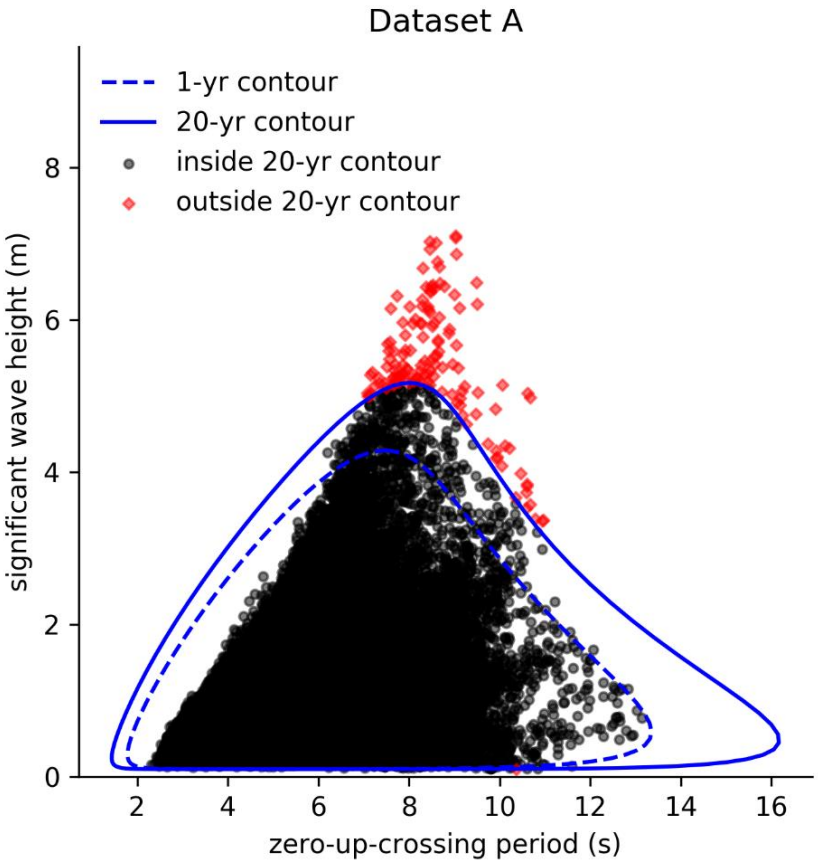
Dataset	Data source	Site	Provided data	Retained data	Env. contour
A	NDBC 44007	Off Maine coast	82,805 data p.*	92,515 data p.	1-yr H_s-T_z, 20-yr H_s-T_z
B	NDBC 41009	Off Florida coast	83,917 data p.*	91,403 data p.	1-yr H_s-T_z, 20-yr H_s-T_z
C	NDBC 42001	Gulf of Mexico	81,749 data p.*	93,571 data p.	1-yr H_s-T_z, 20-yr H_s-T_z
D	coastDat-2	Off German coast	25 years	25 years	1-yr H_s-U_{10}, 50-yr H_s-U_{10}
E	coastDat-2	Off UK coast	25 years	25 years	1-yr H_s-U_{10}, 50-yr H_s-U_{10}
F	coastDat-2	Off Norwegian coast	25 years	25 years	1-yr H_s-U_{10}, 50-yr H_s-U_{10}

* 10 years

Datasets have different characteristics



Baseline results: A

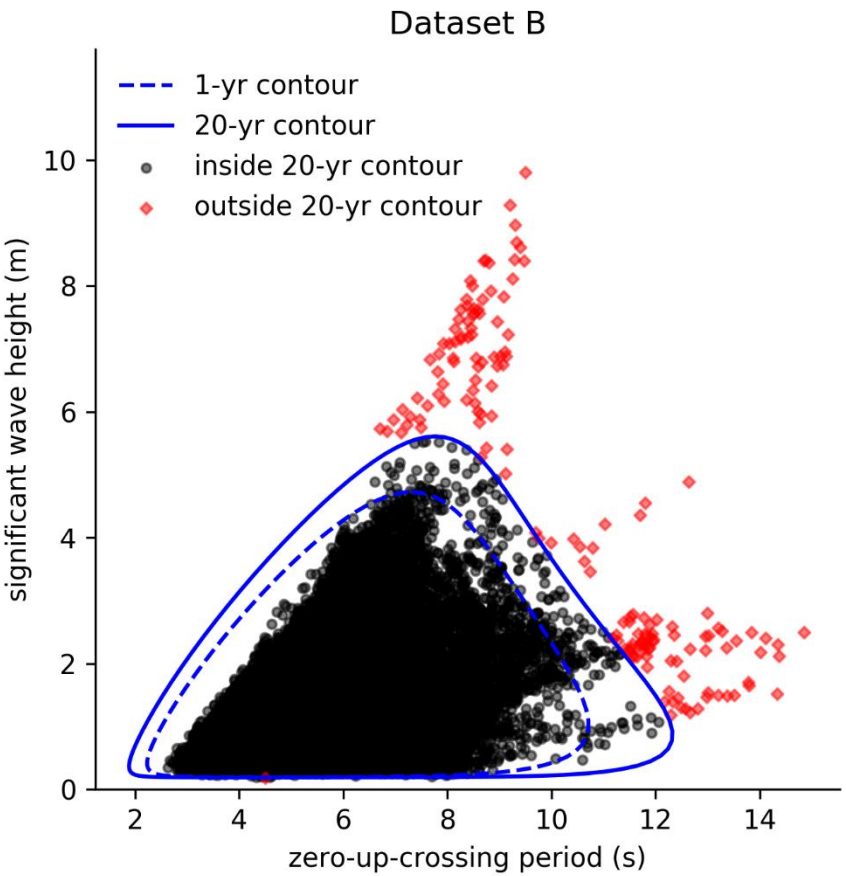


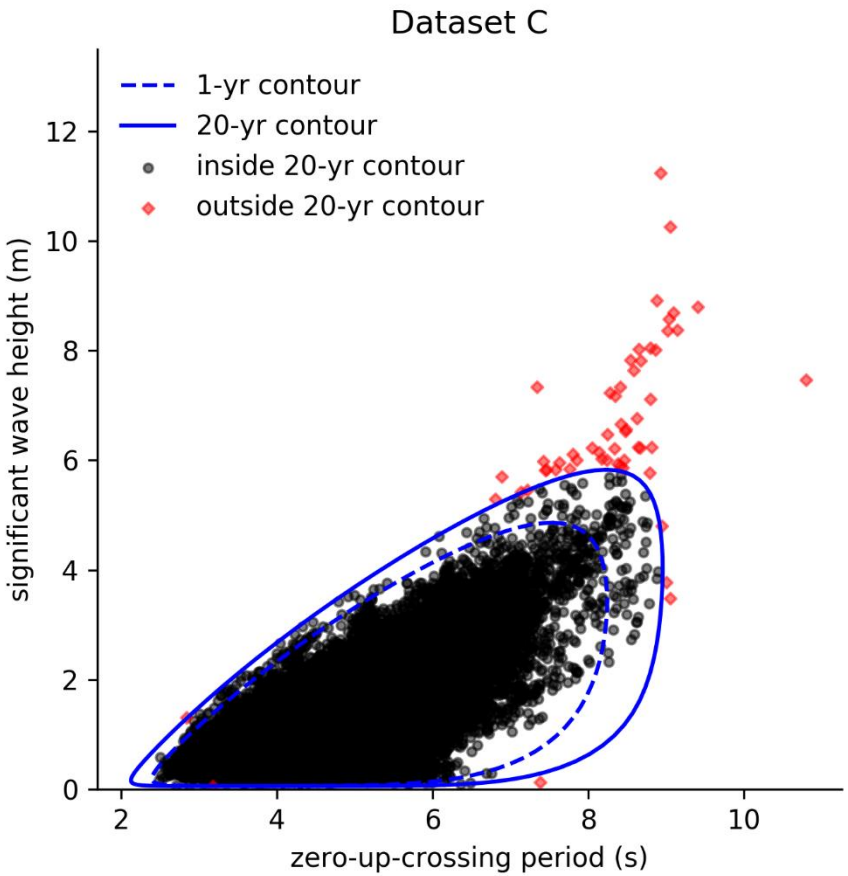
- Sea state model recommended in DNVGL-RP-C205:2017
  - H_s: 3-p. Weibull distribution
  - T_z: Log-normal distribution with two dependence functions
- IFORM-contours (Winterstein *et al.*, 1993)
- Computed with viroconcom 1.2.0 (Haselsteiner *et al.*, 2019)

Winterstein, S. R., Ude, T. C., Cornell, C. A., Bjerager, P., & Haver, S. (1993). Environmental parameters for extreme response: Inverse FORM with omission factors. In Proc. 6th International Conference on Structural Safety and Reliability (ICOSSAR 93). Innsbruck, Austria.

Haselsteiner, A. F., Lehmkuhl, J., Pape, T., Windmeier, K.-L., & Thoben, K.-D. (2019). ViroCon: A software to compute multivariate extremes using the environmental contour method. SoftwareX, 9, 95–101. https://doi.org/10.1016/j.softx.2019.01.003

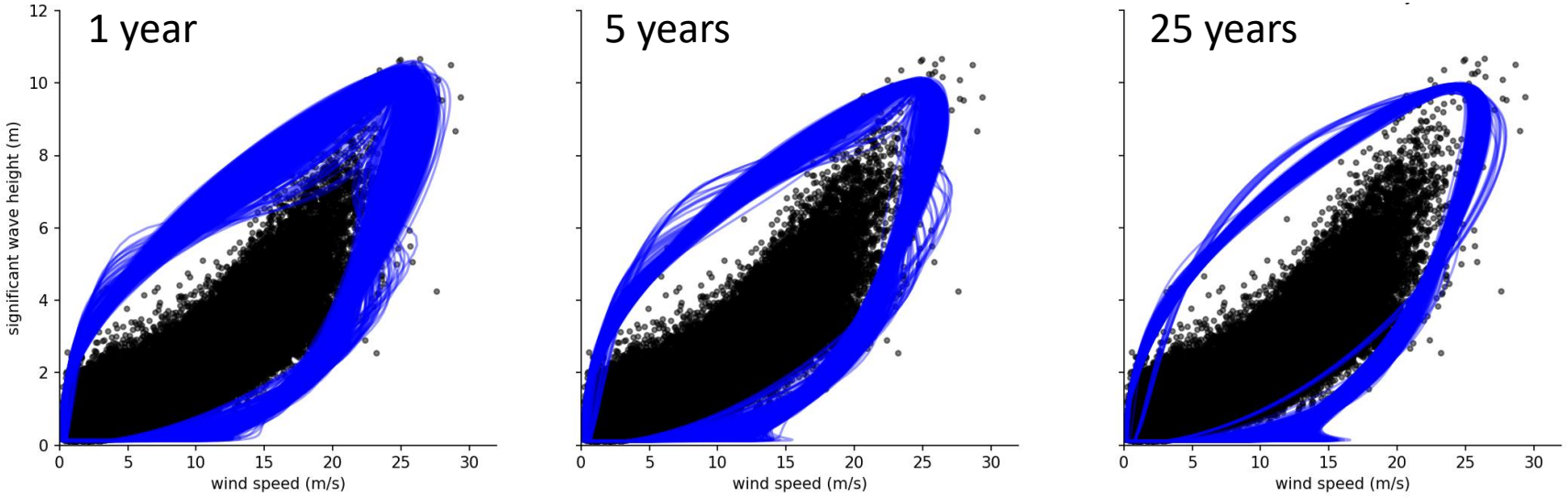
Baseline results: B & C





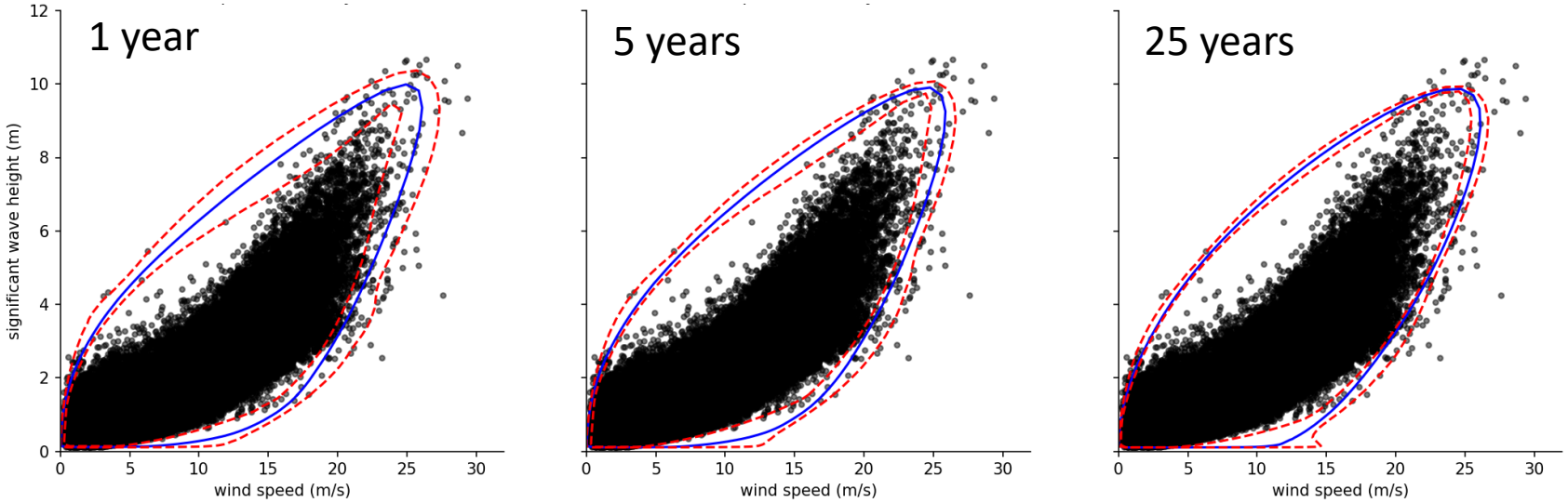
Baseline results: Uncertainty

- Draw a random sample of 1, 5 or 25 years from dataset D
- Derive a 50-yr contour from this subset
- Repeat the process 1000 times



Baseline results: Confidence intervals

- Define lines at angle $\theta \in [0, 360°)$ to the abscissa and compute intersections with the contours
- Order the intersections by the distance to the dataset's mean
- Plot median contour, 2.5th percentile contour, 97.5th percentile contour



How to participate

- Indicate interest by email: ecbenchmark@gmail.com
- GitHub repository holds:
  - Datasets
  - Baseline results (and code to reproduce them)
  - Up-to-date information
  - https://github.com/ec-benchmark-organizers/ec-benchmark
- Submit results by March 31, 2020
- Participants can present results at OMAE 2020
- All results will be presented at OMAE 2021

Thank you for the attention.

Hi organizers,
I am considering to participate.
Best, John Tour

ecbenchmark@gmail.com

https://github.com/ec-benchmark-organizers/ec-benchmark

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