EC-Benchmark

August 10, 2020

Organizers:

Andreas F. Haselsteiner (University of Bremen; a.haselsteiner@uni-bremen.de)
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Lance Manuel (University of Texas, Austin; lmanuel@mail.utexas.edu)

Universität Bremen Sandia National Laboratories TEXAS The University of Texas at Austin

EC-Benchmark

- **When:** Announced at OMAE2019, some participants submitted OMAE2020 papers

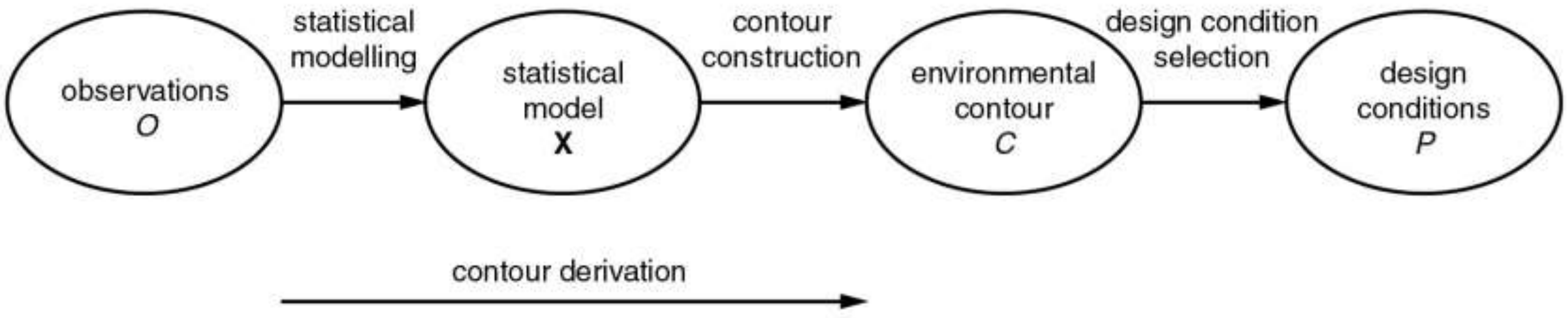
- **Why:** systematic comparison* of contour methods
  - “predictive power”
  - site-specific data
  - uncertainty in relation to limited datasets
  - defining multivariate extremes

Contribution	Authors[1]	Email of corresponding author	Exercise 1	Exercise 2
1	Wei Chai*, Bernt Leira	chaiwei@whut.edu.cn	X	
2	Clarindo Guilherme, Carlos Guedes Soares*	c.guedes.soares@centec.tecnico.ulisboa.pt	X	X
3	Ásta Hannesdóttir*	astah@dtu.dk	X	X
4	Andreas Haselsteiner*, Aljoscha Sander, Jan-Hendirk Ohlendorf, Klaus-Dieter Thoben	a.haselsteiner@uni-bremen.de	X	X
5	Guillaume de Hauteclocque*	guillaume.de-hauteclocque@bureauveritas.com	X	
6	Ed Mackay*, Philip Jonathan	e.mackay@exeter.ac.uk	X	
7	Chi Qiao, Andrew Myers*	atm@neu.edu	X	
8	Anna Rode*, Arndt Hildebrandt, Boso Schmidt	anna.rode@stud.uni-hannover.de	X	
9	Erik Vanem*, Arne Bang Huseby	erik.vanem@dnvgl.com	X	X

[1] Sorted by first author's last name, * Corresponding author

***not “picking a winner”**

Environmental contours

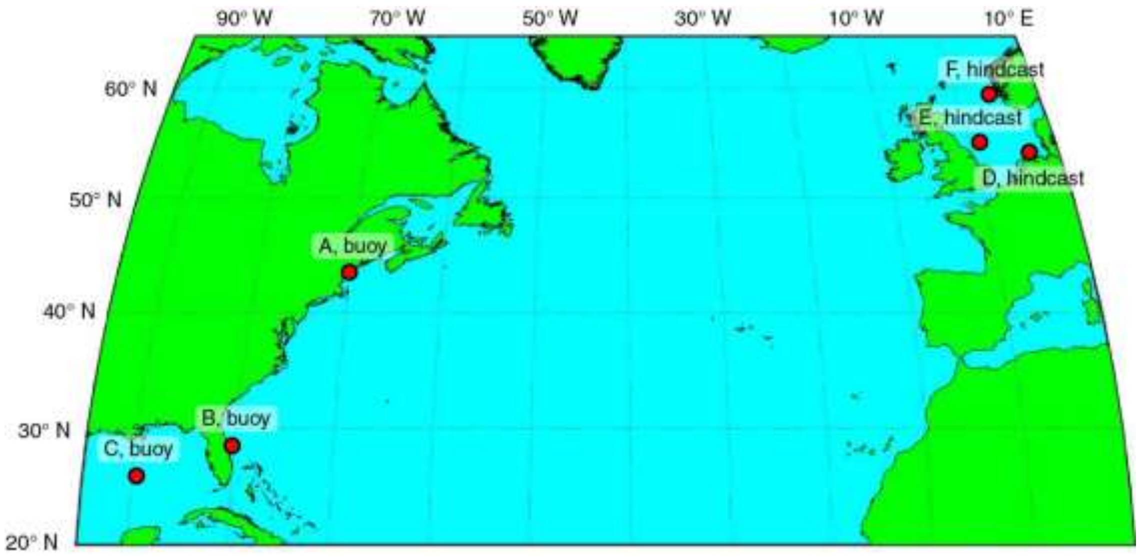


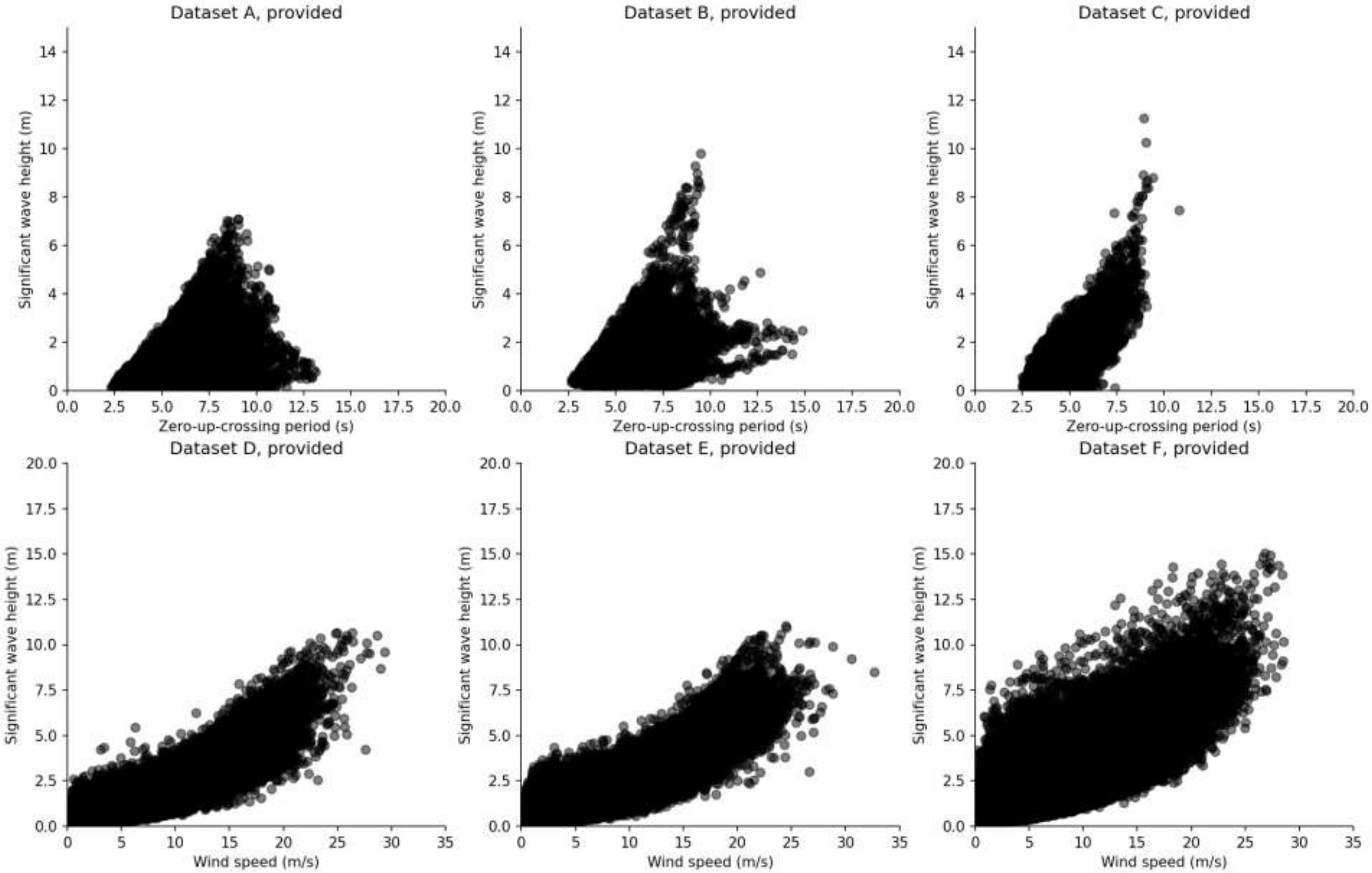
- Different ways to model the joint distribution
  - Different model structures
  - Different parameter estimation techniques
- Different ways to define a contour based on a joint distribution

Exercises & Datasets

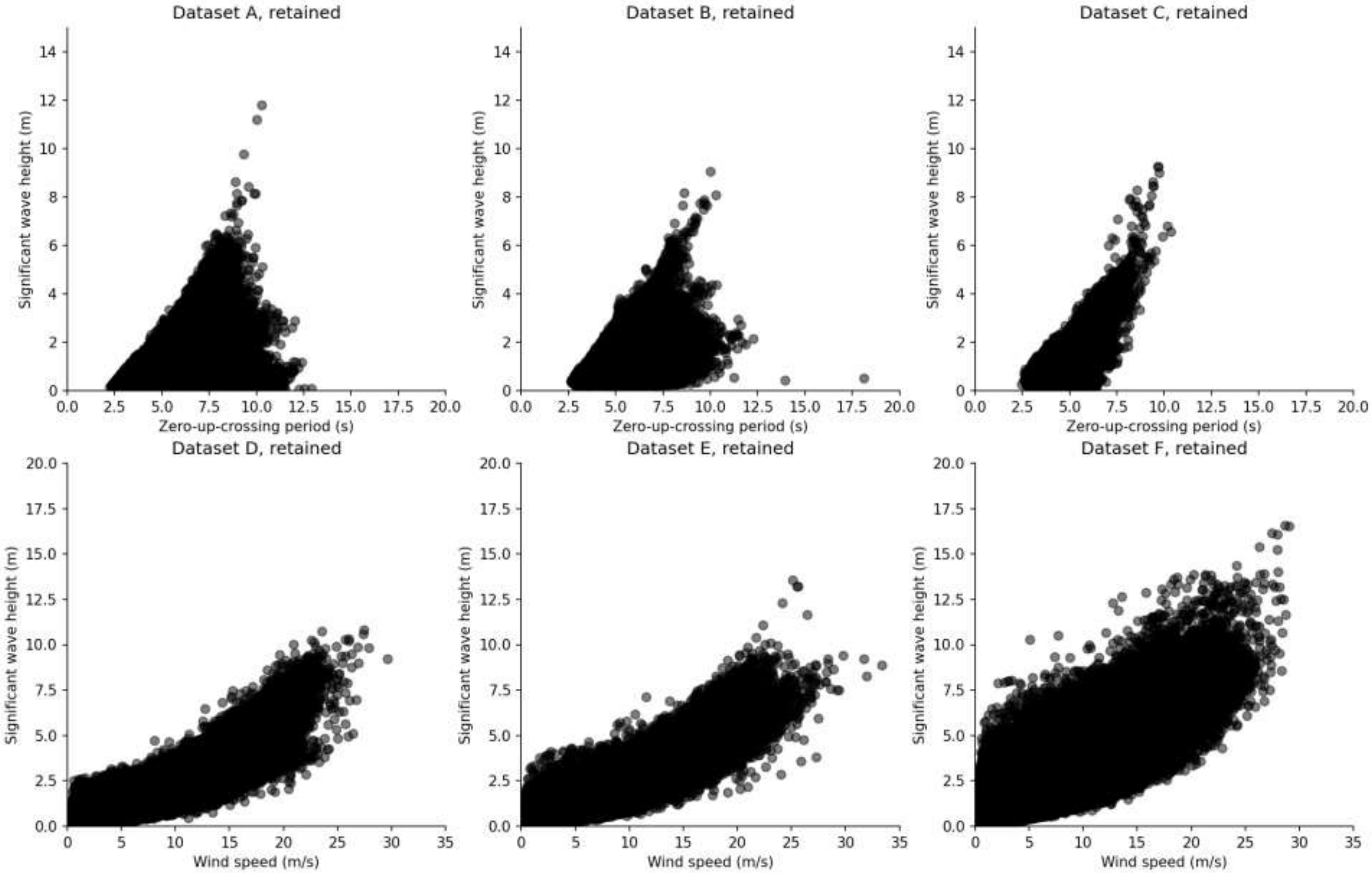
- **Exercise 1:** Calculate 12 contours
  - **(A, B, C):** Significant wave height & zero-crossing period for 1 & 20 yr return periods (10 years of data)
  - **(D,E,F):** Significant wave height & wind speed for 1 & 50 yr return periods (25 years of data)

- **Exercise 2:** Calculate uncertainty in contour for dataset D
  1. Draw random sample from data
  2. Calculate a 50-yr contour from sample
  3. (repeat 1000x)



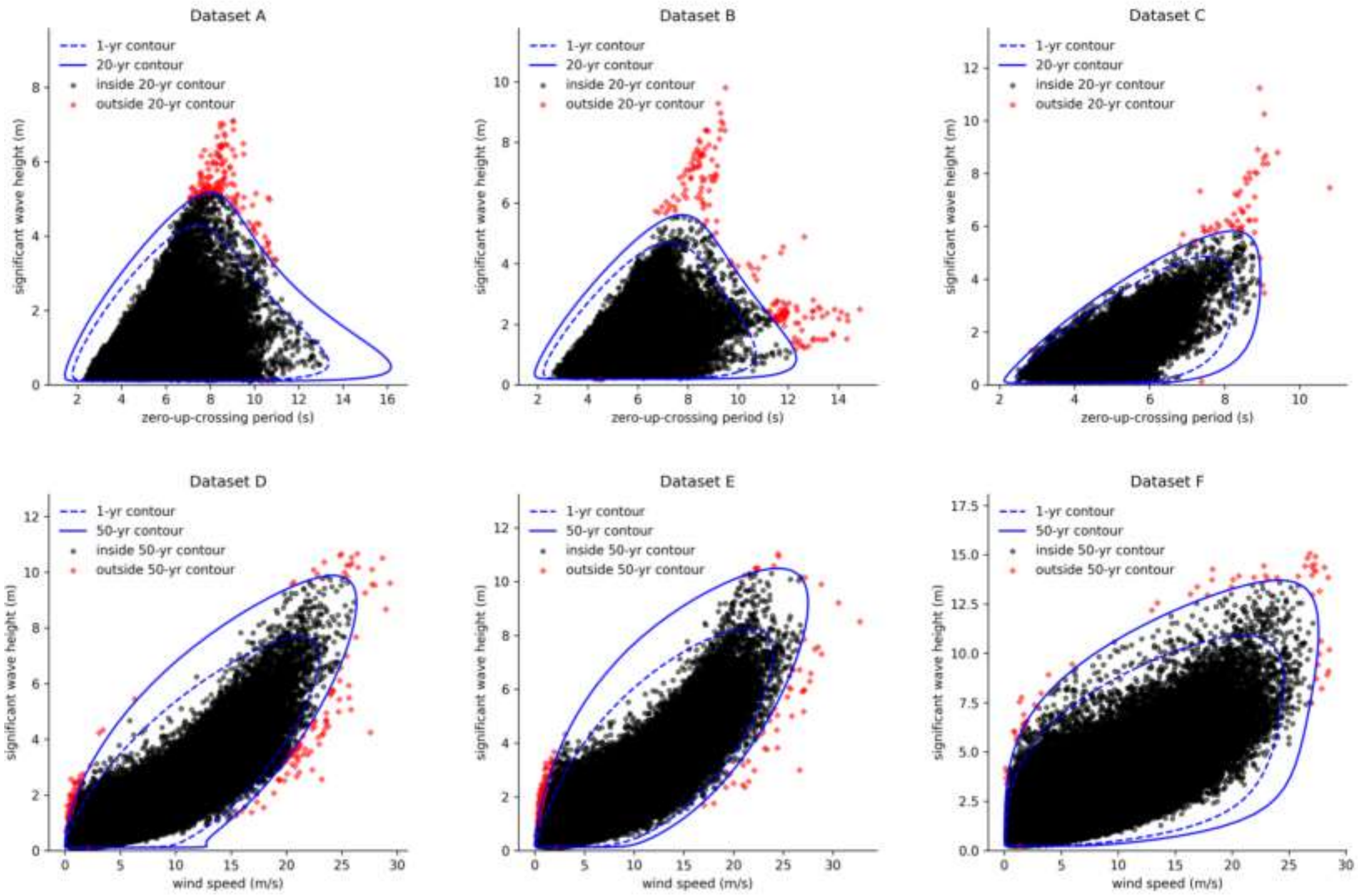


Dataset A, provided
Dataset B, provided
Dataset C, provided
Significant wave height (m)
Zero-up-crossing period (s)
Dataset D, provided
Dataset E, provided
Dataset F, provided
Significant wave height (m)
Wind speed (m/s)

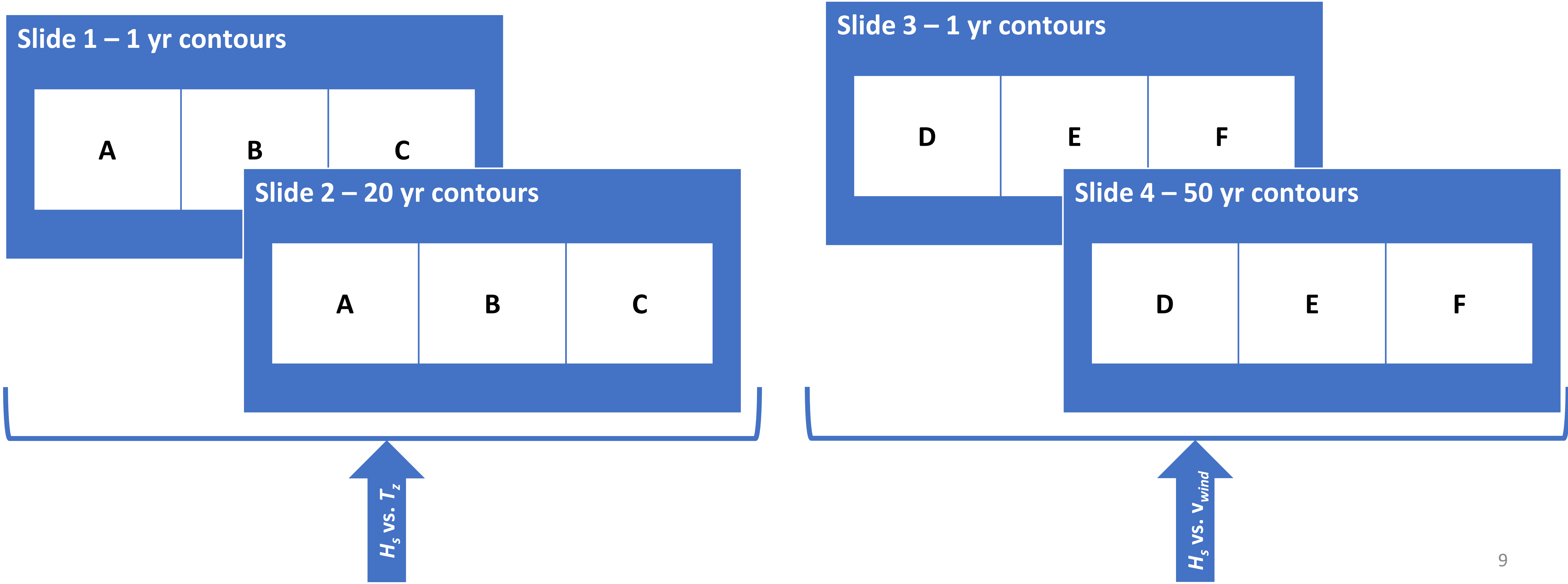

Dataset A, retained
Dataset B, retained
Dataset C, retained
Significant wave height (m)
Zero-up-crossing period (s)
Dataset D, retained
Dataset E, retained
Dataset F, retained
Wind speed (m/s)

ii) Overview about the results

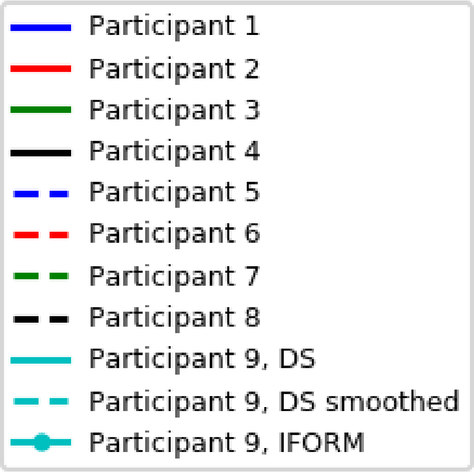
Exercise 1: Baseline results

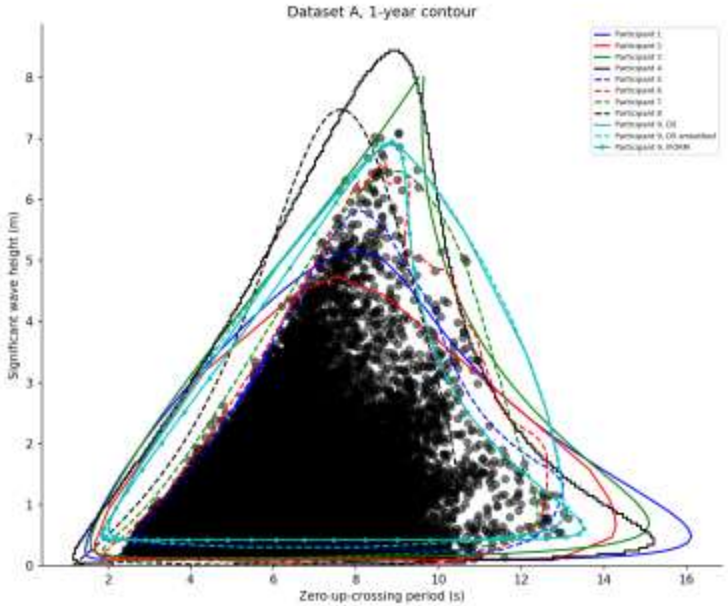


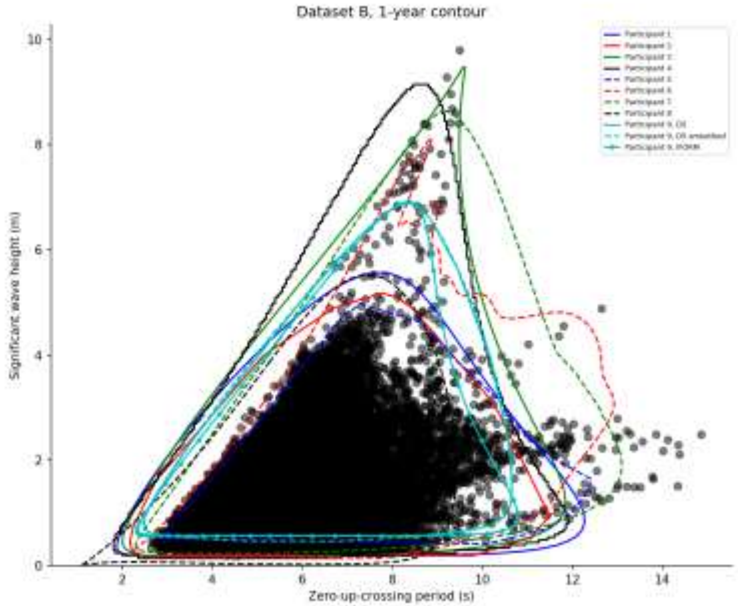
Overlay plots

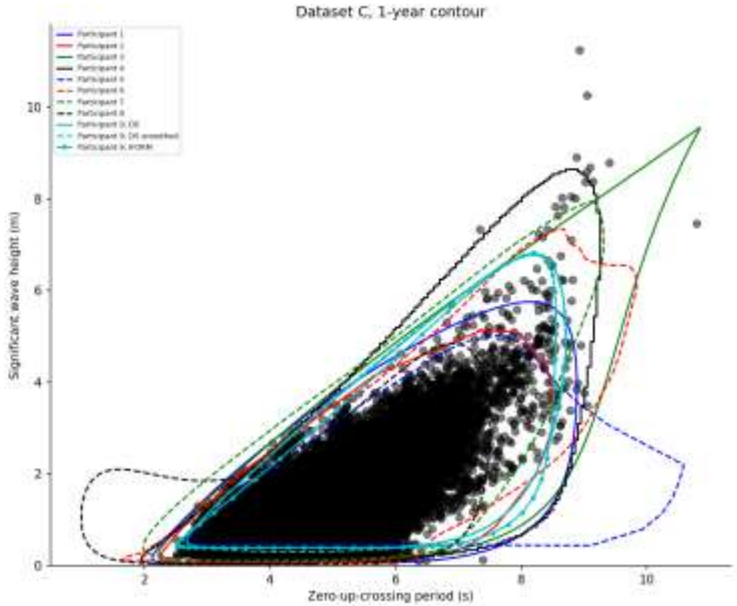


Overlay plots, datasets A-C, 1-yr contour

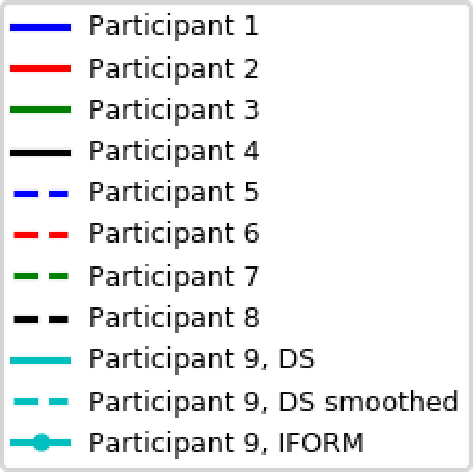


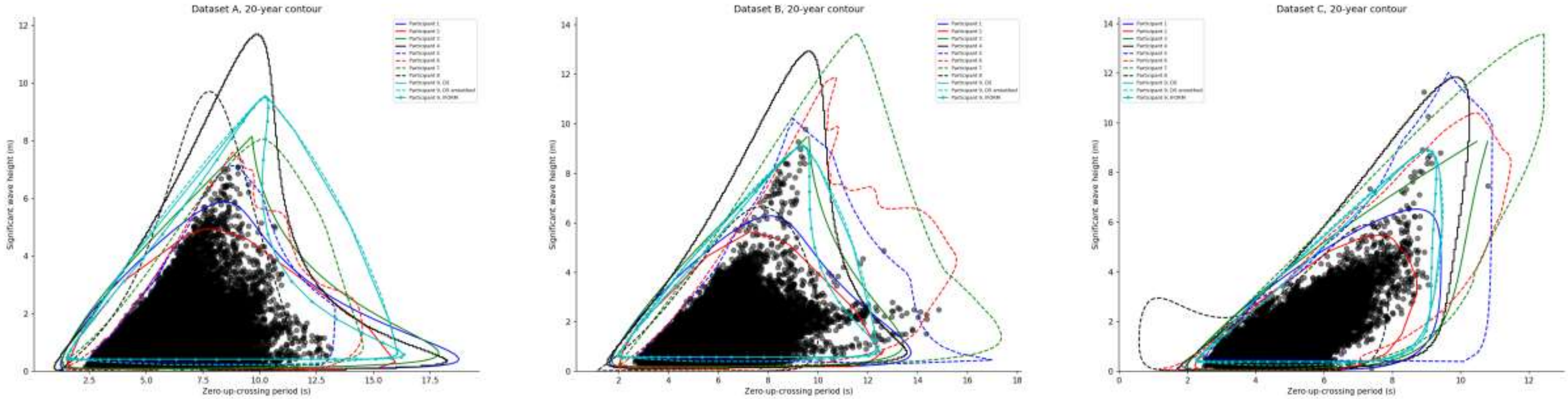




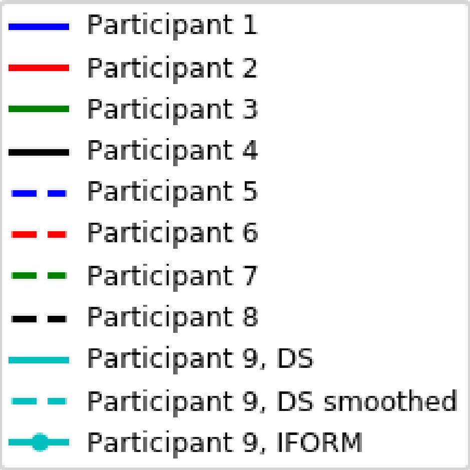


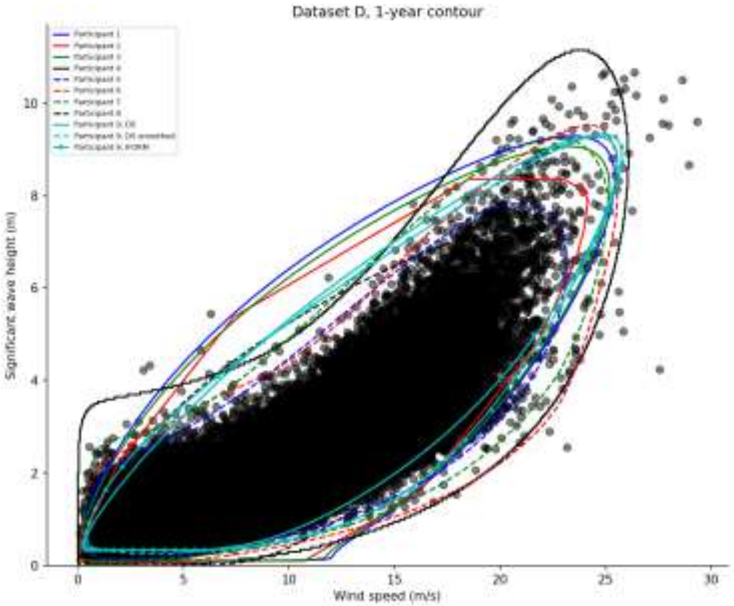
Overlay plots, datasets A-C, 20-yr contour

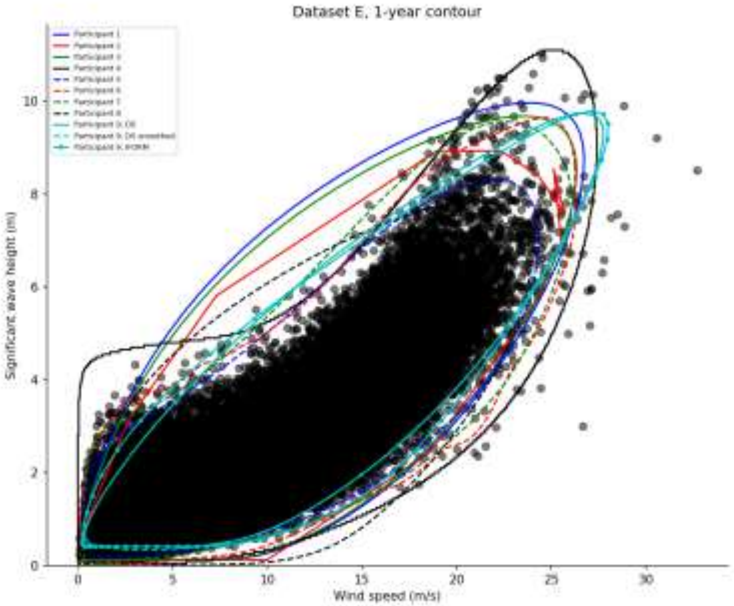


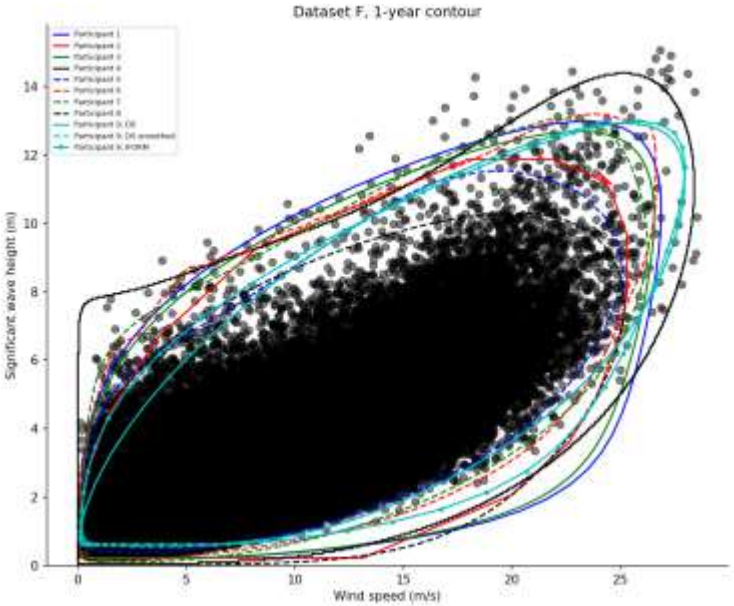


Overlay plots, datasets D-F, 1-yr contour

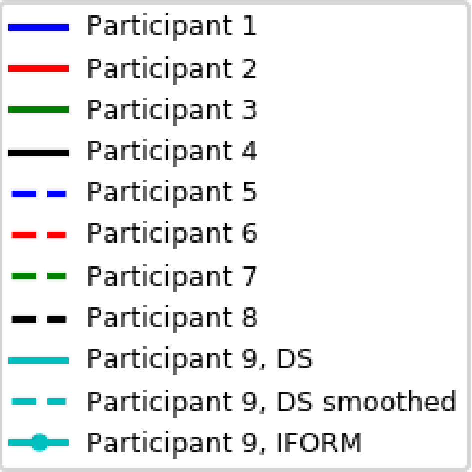


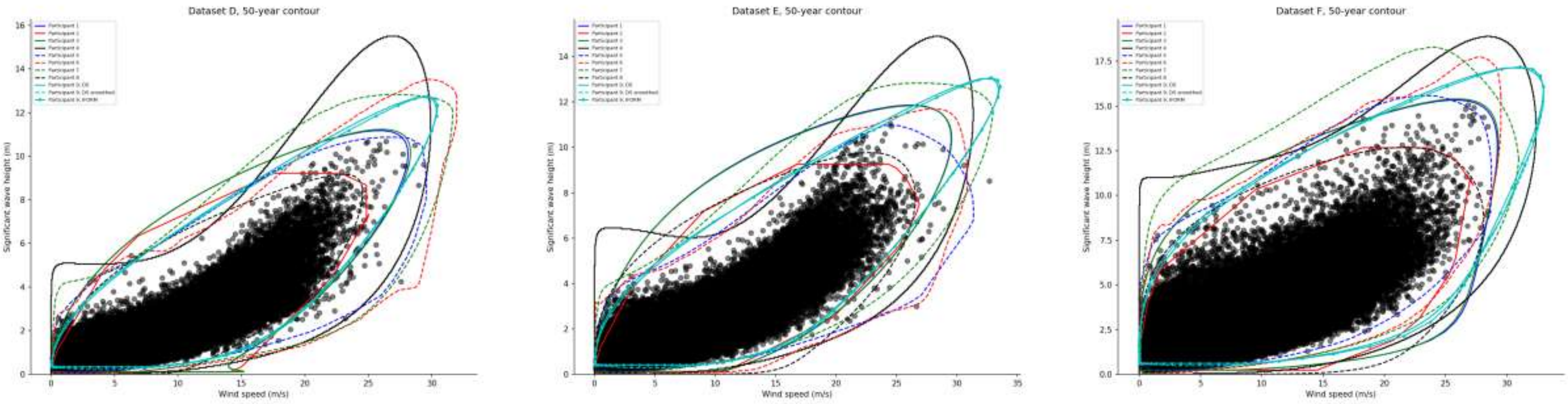




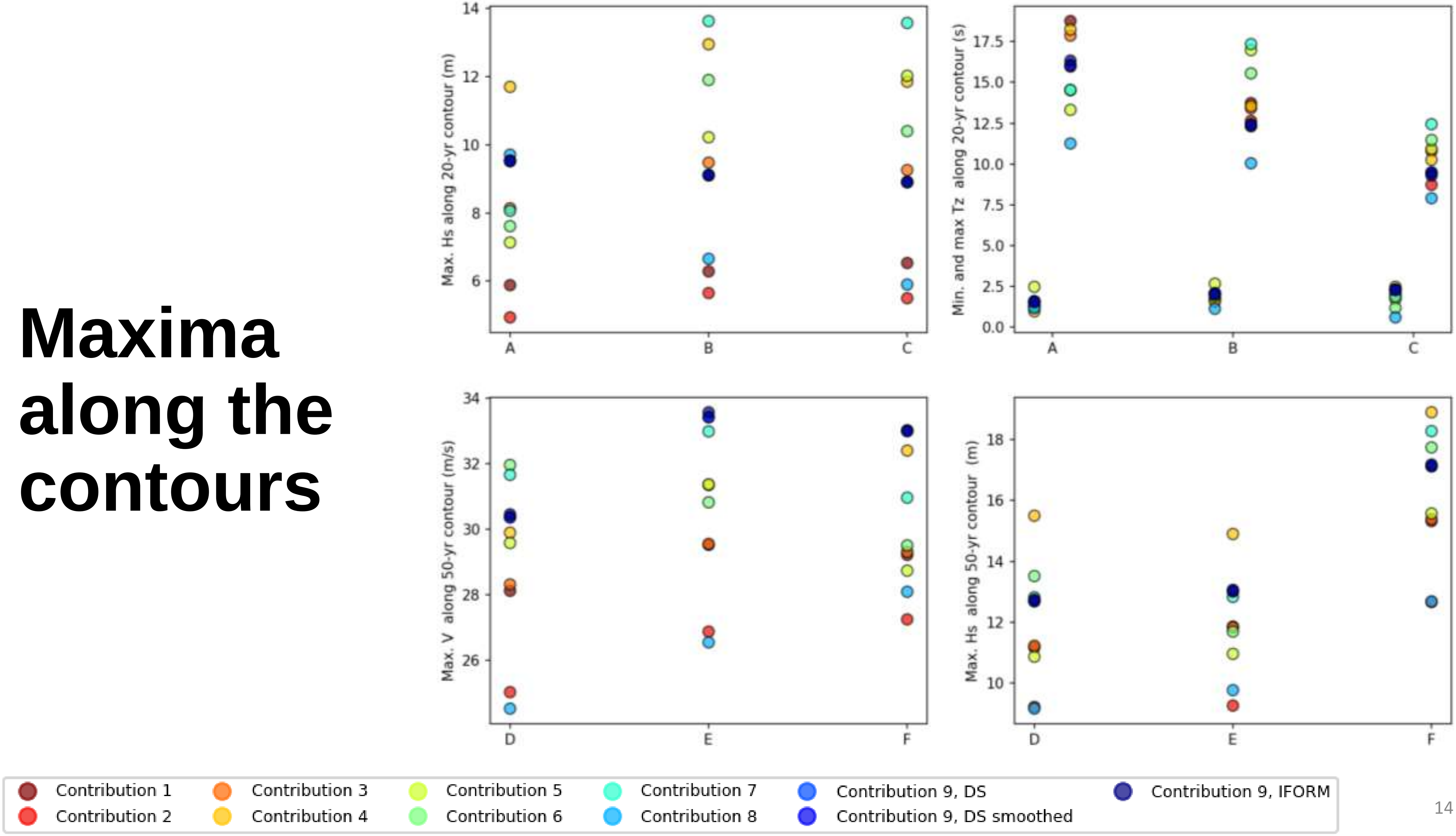


Overlay plots, datasets D-F, 50-yr contour





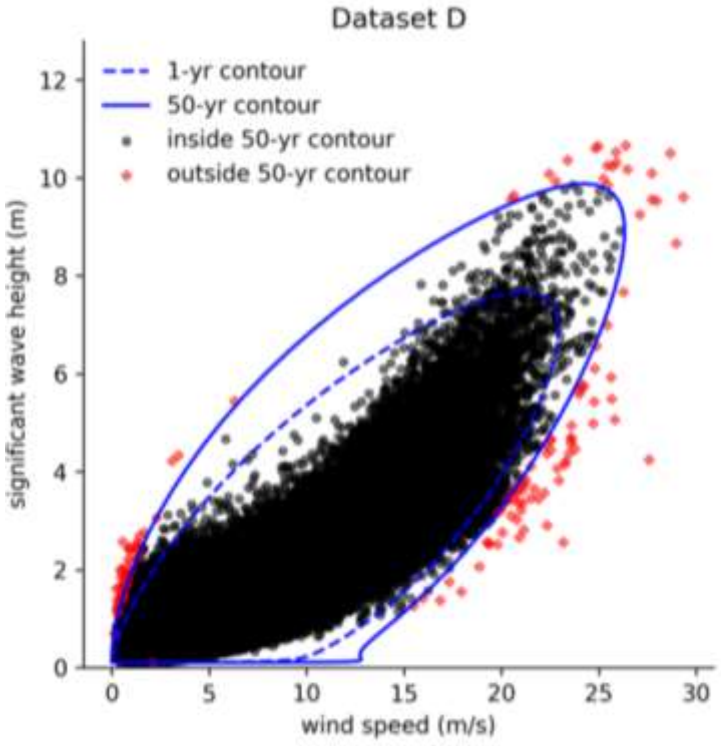
Maxima along the contours



Points outside the contours

- Points exceeding the contour, n_E, at any region are counted
- Expected number of exceeding points can be calculated as $E[n_E] = N \cdot \alpha_T$
  - N = Number of data points a sample holds
  - α_T = Probability that an observations falls anywhere outside the contour
- Contour methods define the exceedance probability, α, differently

  → Contours with same return period can have different expected number of points outside the contour, due to different contour methods



Points outside the contours

→ Contours with same return period can have different expected number of points outside the contour, due to different contour methods

Contour method	α_T (total exceedance probability)
IFORM	$1-\chi_n^2(\beta_F^2)=1-\chi_n^2([\Phi^{-1}(1-\alpha)]^2)$
ISORM	α
Direct Sampling	ca. similar to IFORM
Direct IFORM	ca. similar to IFORM
Highest density	α

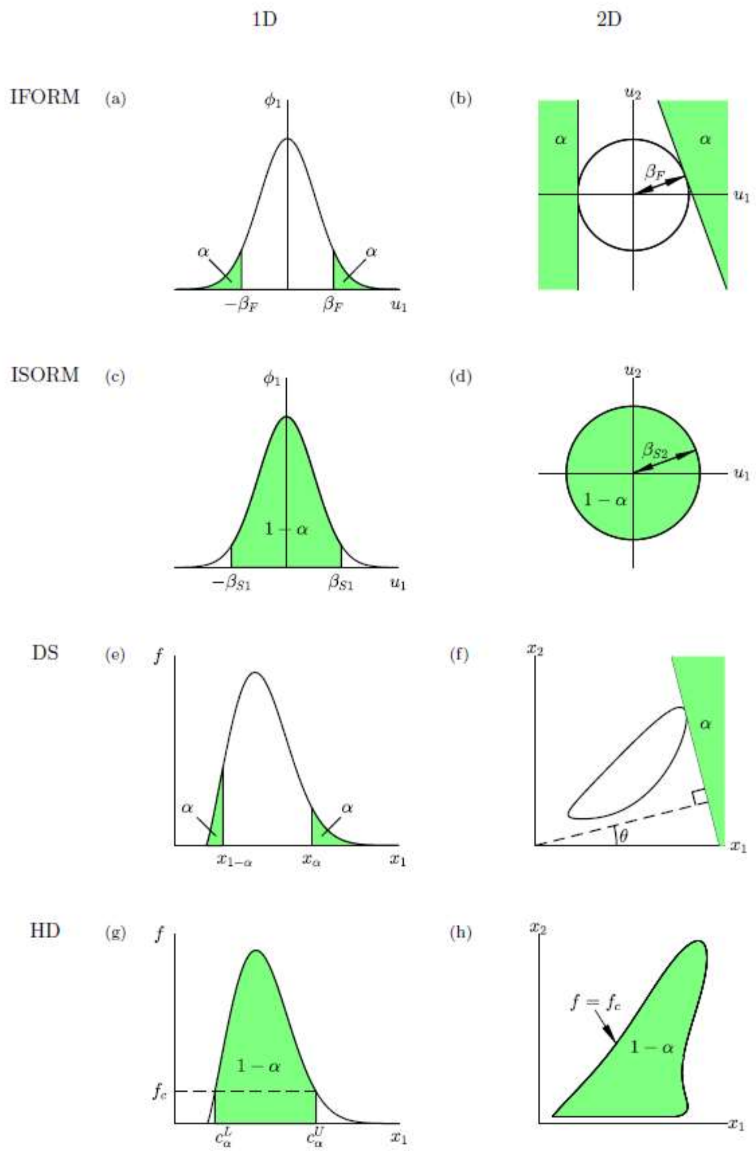


Figure from https://arxiv.org/pdf/2003.05463.pdf

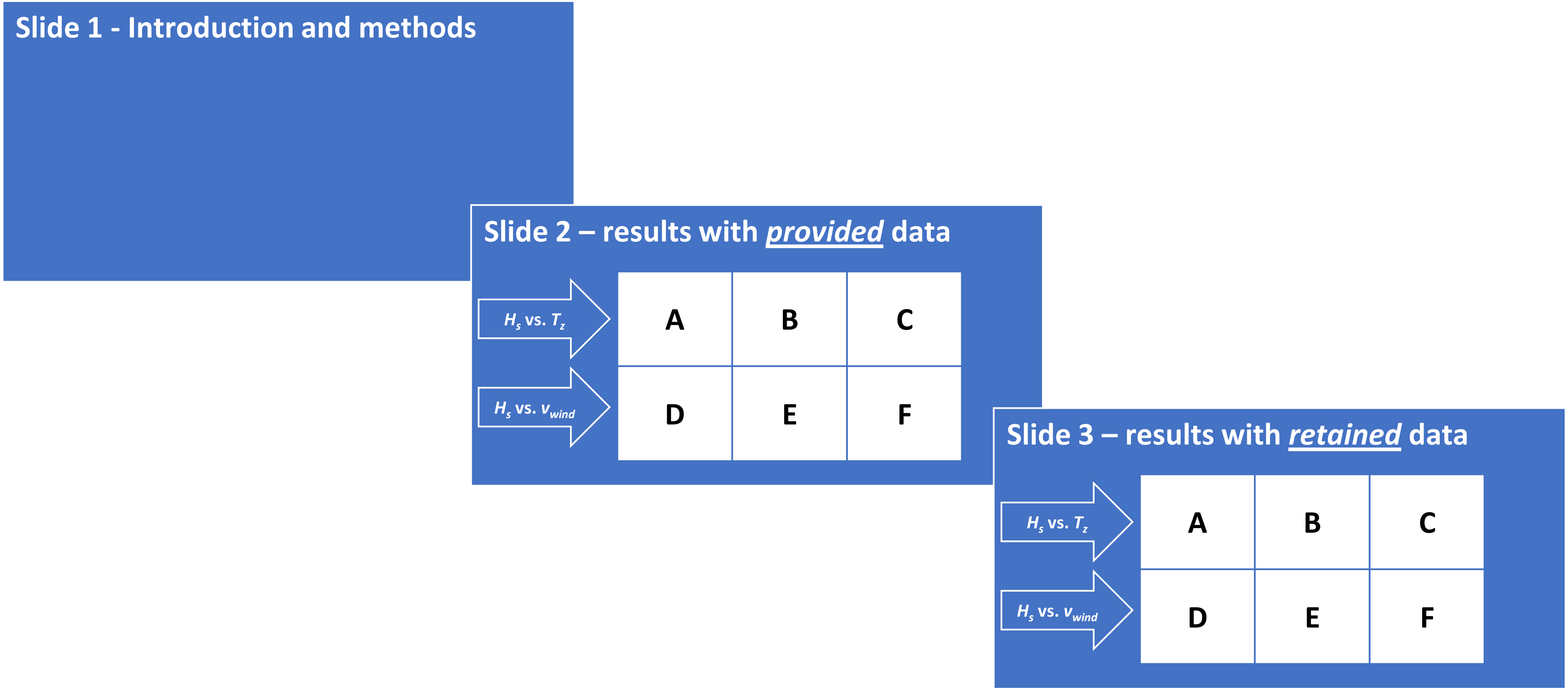
Points outside the H_s-T_z contours (provided & retained datasets)

Contribution	# points outside the 1-yr contour: mean (A, B, C)	Expected # points outside 1-yr contour	# points outside the 20-yr contour: mean (A, B, C)	Expected # points outside 20-yr contour
1	256.3 (388, 259, 122)	20 (ISORM)	114.0 (153, 127, 62)	1 (ISORM)
2	406.7 (596, 360, 264)	ca. 197 (DS)	286.7 (437, 236, 187)	ca. 11.5 (DS)
3	82.3 (97, 92, 58)	? (similar to IFORM?)	33.7 (40, 27, 34)	? (similar to IFORM?)
4	75.0 (25, 134, 66)	20 (HDC)	13.7 (1, 32, 8)	1 (HDC)
5	18295.3 (9381, 14710, 30795)	ca. 197 (Direct IFORM)	16764.0 (8503, 12573, 29216)	ca. 11.5 (Direct IFORM)
6	154.0 (170, 169, 123)	197 (IFORM)	16.7 (27, 14, 9)	11.5 (IFORM)
7	281.3 (370, 299, 175)	197 (IFORM)	35.3 (79, 4, 23)	11.5 (IFORM)
8	762.0 (599, 807, 880)	197 (IFORM)	322.0 (189, 368, 409)	11.5 (IFORM)
9 DS	22127.3 (22562, 23146, 20674)	ca. 197 (DS)	21966.3 (22504, 22933, 20462)	ca. 11.5 (DS)
9 DS smoothed	12031.7 (10459, 13838, 11798)	ca. 197 (DS)	6062.7 (5096, 7716, 5376)	ca. 11.5 (DS)
9 IFORM	22207.7 (22659, 23241, 20723)	197 (IFORM)	21994.7 (22514, 22990, 20480)	11.5 (IFORM)

Points outside the V-H_s contours (provided & retained datasets)

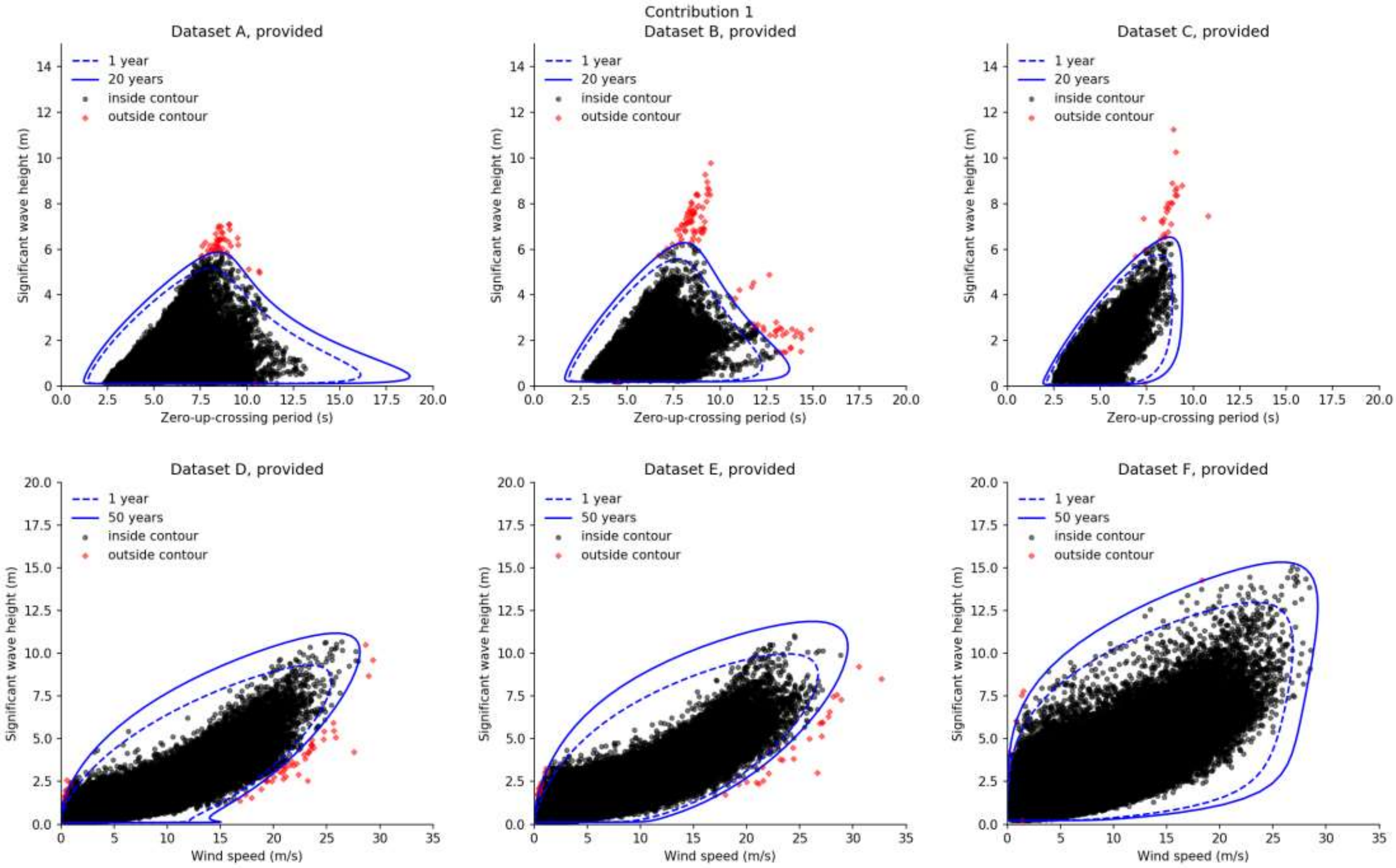
Contribution	# points outside the 1-yr contour: mean (D, E, F)	Expected # points outside 1-yr contour	# points outside the 50-yr contour: mean (D, E, F)	Expected # points outside 50-yr contour
1	424.3 (483, 519, 271)	50 (ISORM)	103.7 (154, 86, 71)	1 (ISORM)
2	1186.3 (1252, 1478, 829)	492 (IFORM)	529.7 (514, 720, 355)	12 (IFORM)
3	524.7 (592, 652, 330)	? (similar to IFORM?)	102.7 (154, 82, 72)	? (similar to IFORM?)
4	88.0 (64, 99, 101)	50 (HDC)	3.7 (3, 8, 0)	1 (HDC)
5	2235.0 (1875, 2036, 2794)	ca. 492 (Direct IFORM)	156.0 (174, 112, 182)	ca. 12 (Direct IFORM)
6	270.7 (265, 289, 258)	492 (IFORM)	8.3 (3, 17, 5)	12 (IFORM)
7	371.3 (294, 446, 374)	492 (IFORM)	8.7 (3, 16, 7)	12 (IFORM)
8	1729.7 (2977, 979, 1233)	492 (IFORM)	262.0 (509, 110, 167)	12 (IFORM)
9 DS	18191.7 (20337, 20481, 13757)	ca. 492 (DS)	15301.0 (17460, 17226, 11217)	ca. 12 (DS)
9 DS smoothed	12819.3 (12862, 14665, 10931)	ca. 492 (DS)	5771.3 (5092, 6782, 5440)	ca. 12 (DS)
9 IFORM	16267.3 (18427, 18404, 11971)	492 (IFORM)	15267.0 (17415, 17184, 11202)	12 (IFORM)

Participant results focus

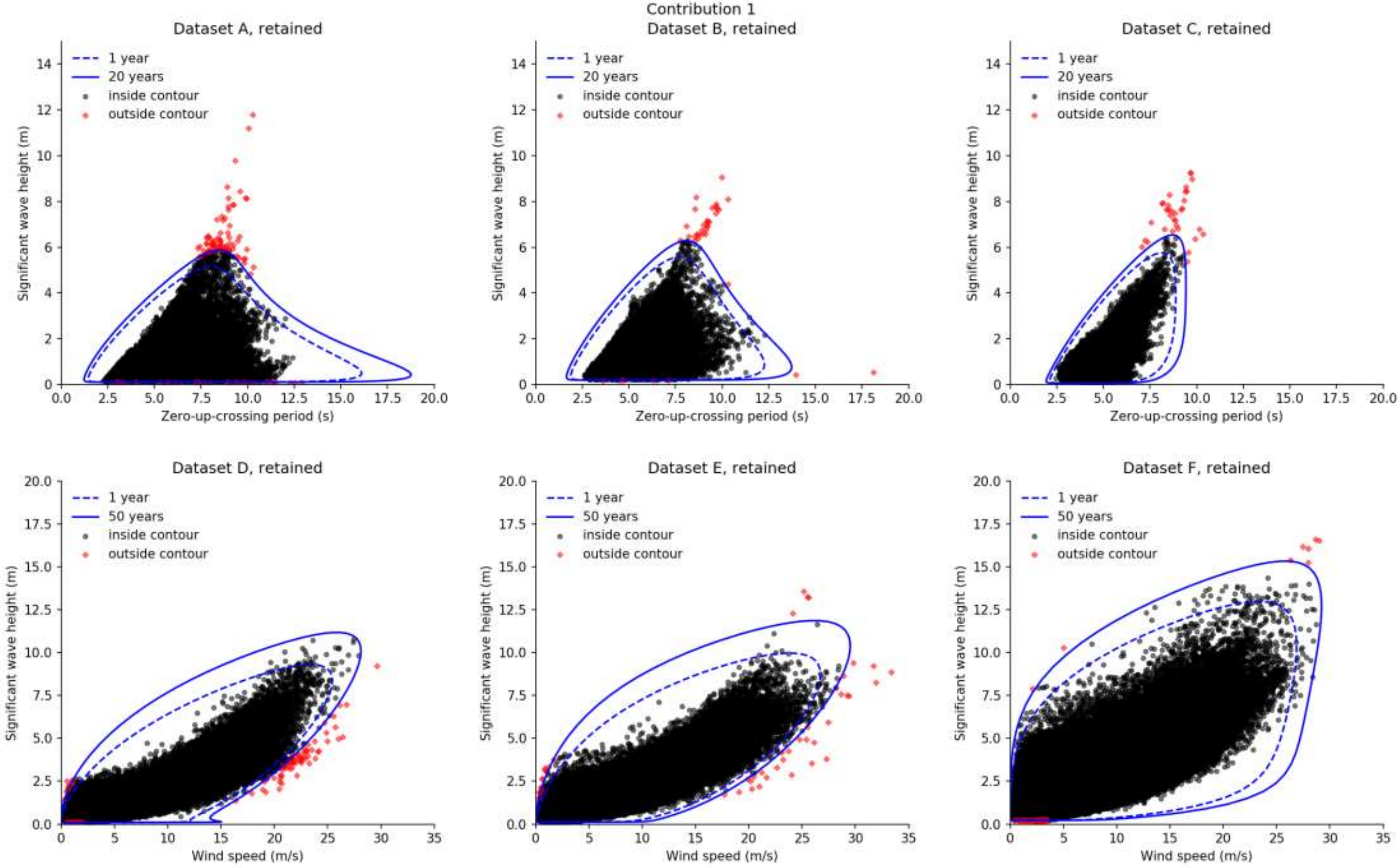


Exercise 1 – contribution 1

- Authors: Wei Chai & Bernt Leira
- Statistical model for datsets A-C: provided models in Table 2 of OMAE2019-96523
    - Previously published: OMAE2019-96523 (Andreas is the first author)
- Method to fit the model to datasets A-C: provided models in Table 2 of OMAE2019-96523
    - Previously published: OMAE2019-96523
- Statistical model for datasets D-F: provided models in Table 2 of OMAE2019-96523
    - Previously published: OMAE2019-96523
- Methods to fit the model to datasets D-F: OMAE2019-96523
    - Previously published: OMAE2019-96523
- Method used for contour construction: Inverse Second Order Reliability Method (ISORM)
    - Previously published: Chai, W, Leira B. J. Environmental contours based on inverse SORM, Marine Structures, 2018, 60: 34-51.
- Comment:



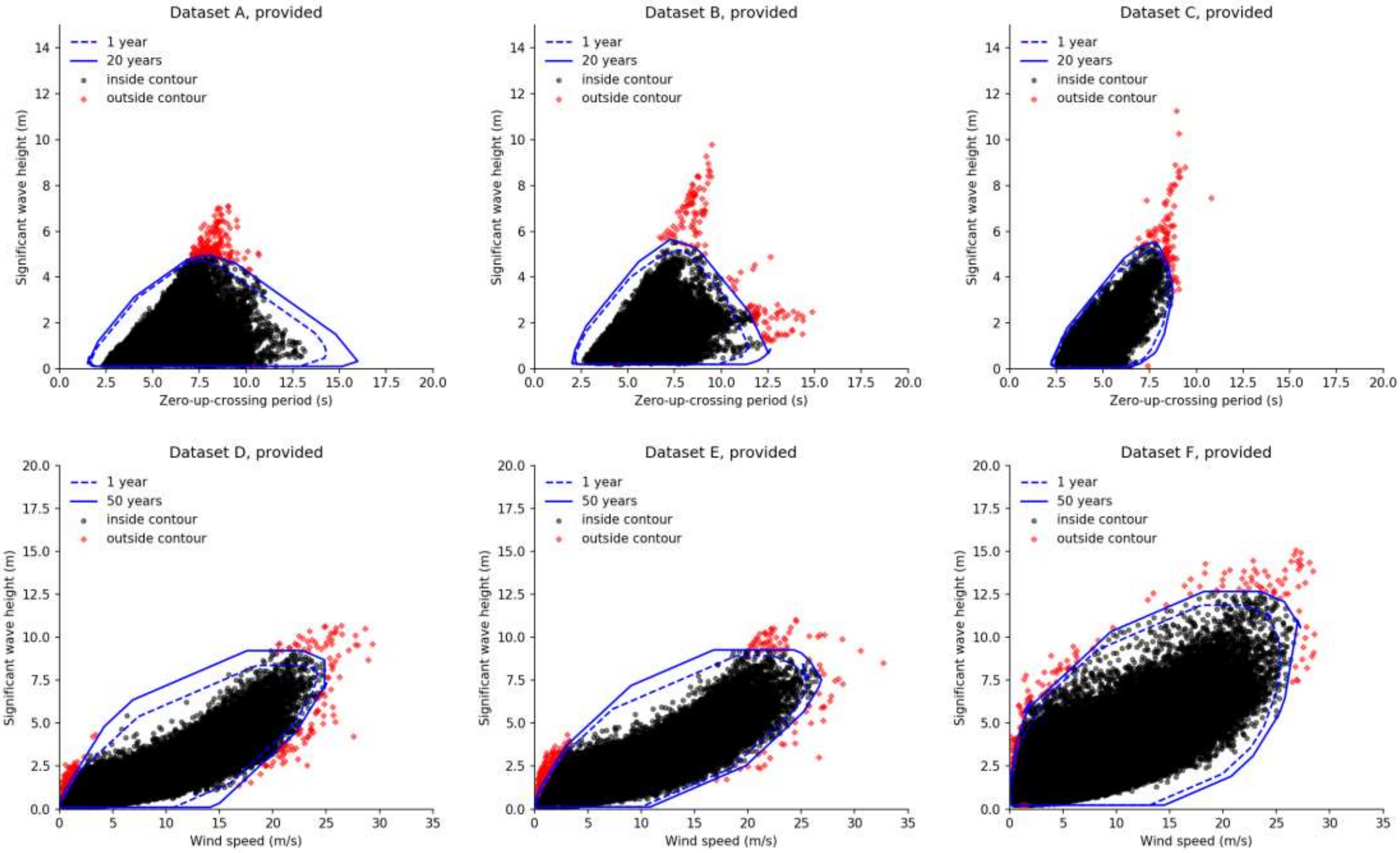
Contribution 1
Dataset A, provided
Dataset B, provided
Dataset C, provided
1 year
20 years
inside contour
outside contour
Significant wave height (m)
Zero-up-crossing period (s)
Dataset D, provided
Dataset E, provided
Dataset F, provided
1 year
50 years
inside contour
outside contour
Significant wave height (m)
Wind speed (m/s)


Contribution 1
Dataset A, retained
Dataset B, retained
Dataset C, retained
1 year
20 years
inside contour
outside contour
Significant wave height (m)
Zero-up-crossing period (s)
Dataset D, retained
Dataset E, retained
Dataset F, retained
1 year
50 years
inside contour
outside contour
Significant wave height (m)
Wind speed (m/s)

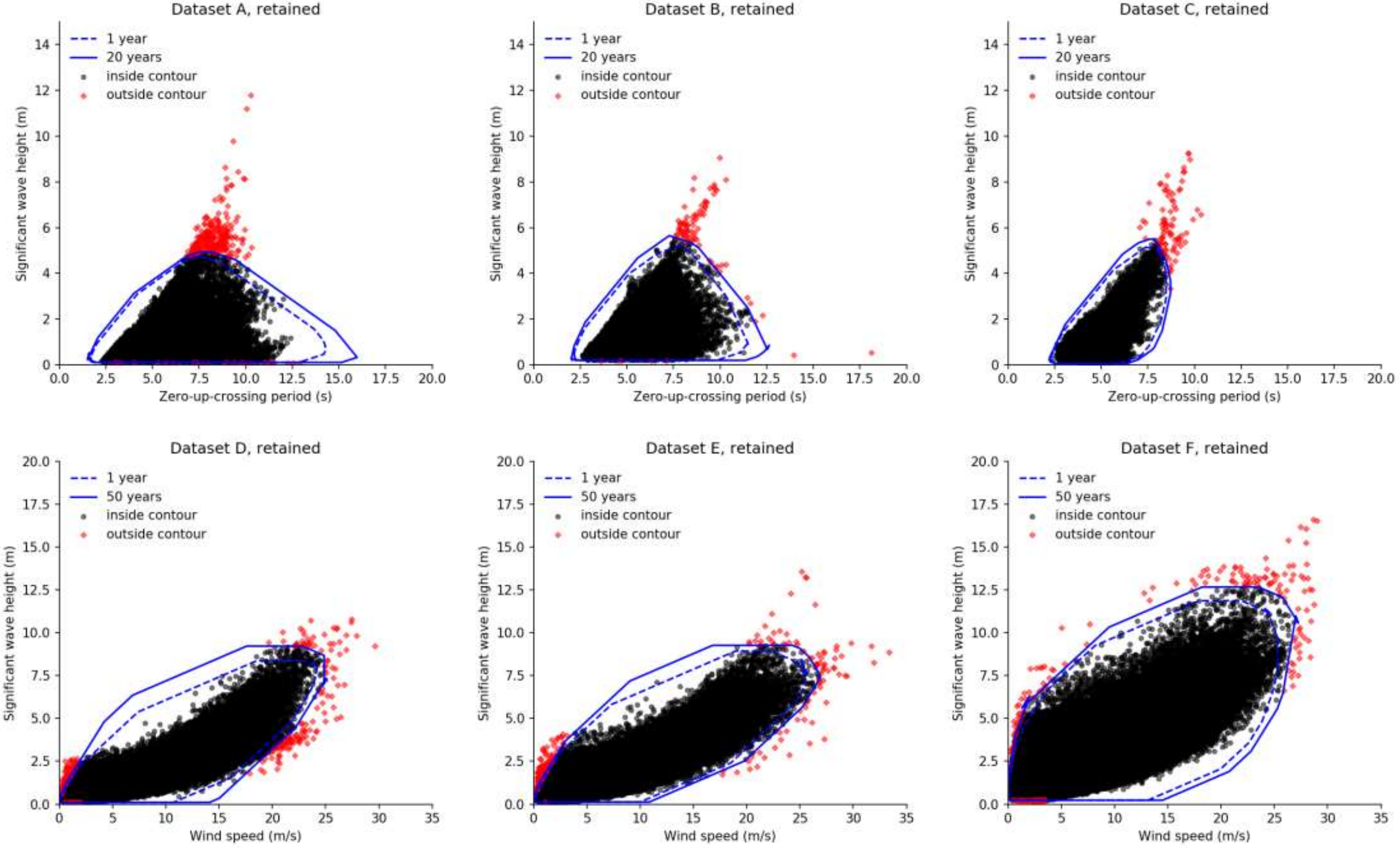
Exercise 1 – contribution 2

- Authors: Guilherme Clarindo & Carlos Guedes Soares
- Statistical model for datsets A-C: CMA joint distribution with 3P Weibull and conditioned lognormal distributions
    - Previously published: DNV-GL. 2017. Recommended practice DNVGL-RPC205: Environmental conditions and environmental loads. Tech report.
- Method to fit the model to datasets A-C: Maximum likelihood for Hs marginals, least squares for Tz dependence
    - Previously published:
- Statistical model for datsets D-F: CMA joint distribution with 3P Weibull and conditioned 2P Weibull distributions
    - Previously published: DNV-GL. 2017. Recommended practice DNVGL-RPC205: Environmental conditions and environmental loads. Tech report.
- Methods to fit the model to datasets D-F: Maximum likelihood for Hs marginals, least squares for U10 dependence
    - Previously published:
- Method used for contour construction: Direct Monte Carlo Simulations Approach
    - Previously published: Huseby, A. B., Vanem, E. & Natvig, B. 2013. A new approach to environmental contours for ocean engineering applications based on direct Monte Carlo simulations. Ocean Engineering. (60): 124–135.
- Comment:

Contribution 2

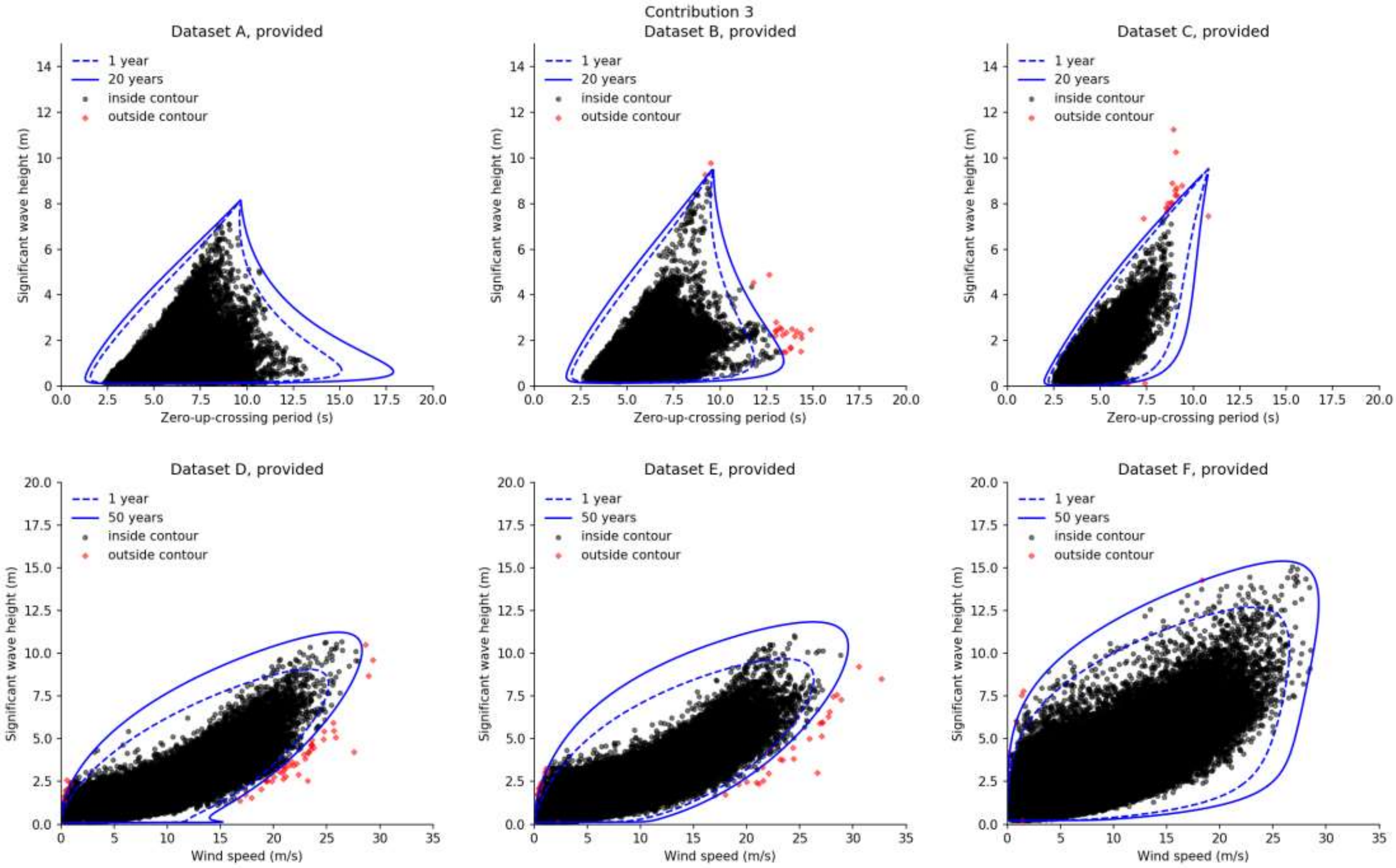


Contribution 2

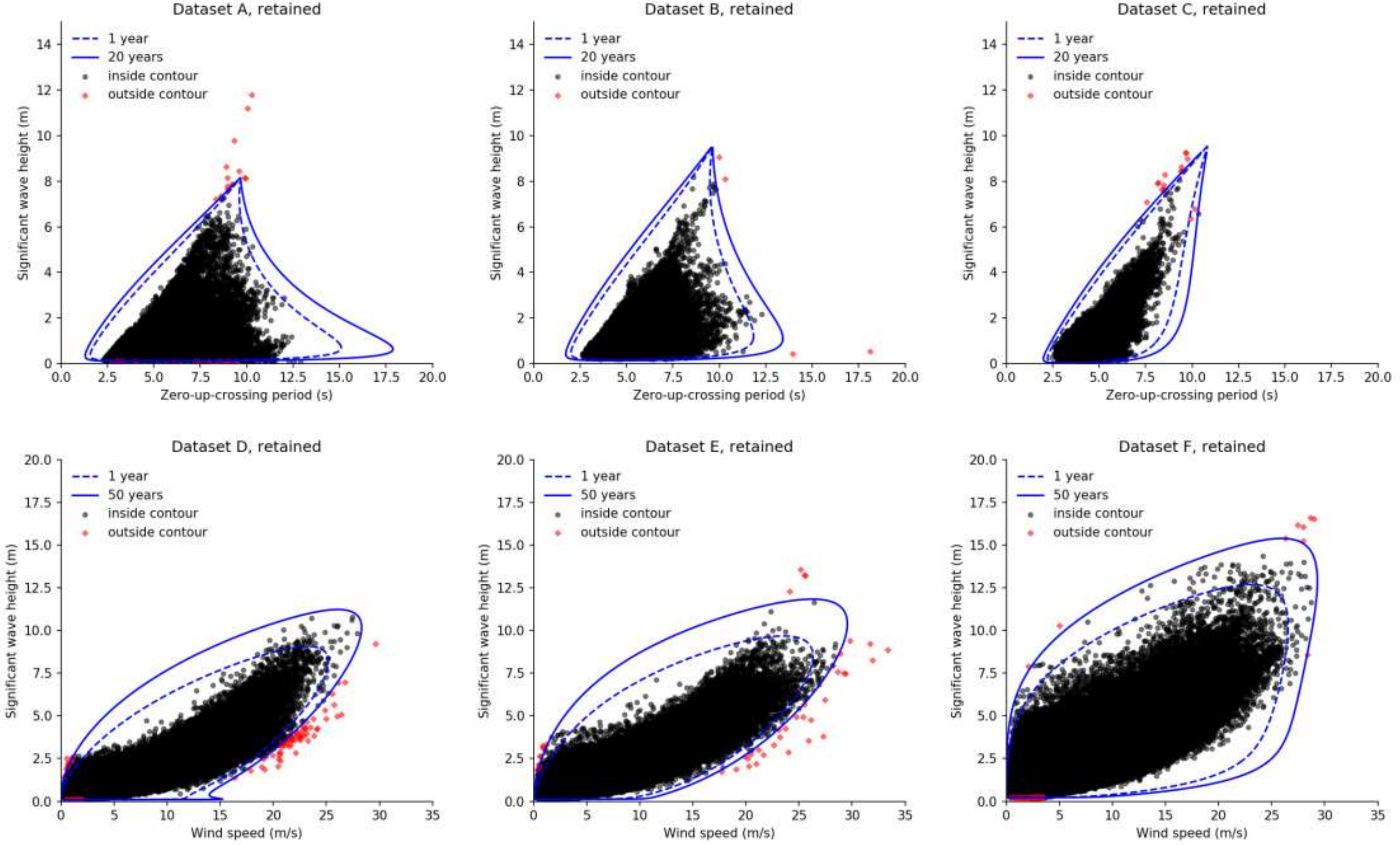


Exercise 1 – contribution 3

- Author: Ásta Hannesdóttir
- Statistical model for datasets A-C: CMA joint distribution with Weibull and lognormal distributions
  - Previously published: DNV-RP-C205, 2010
- Method to fit the model to datasets A-C: MLE for maginals, least squares for dependence functions
  - Previously published: Hannesdóttir, Á., Kelly, M., and Dimitrov, N.: Extreme wind fluctuations: joint statistics, extreme turbulence, and impact on wind turbine loads, Wind Energ. Sci., 4, 325–342, https://doi.org/10.5194/wes-4-325-2019, 2019
- Statistical model for datasets D-F: CMA joint distribution with Weibull 3-p. and Weibull 2-p.
  - Previously published: DNV-RP-C205, 2010
- Methods to fit the model to datasets D-F: MLE for maginals, least squares for dependence functions
  - Previously published:
- Method used for contour construction: Inverse directional simulation (IDS) contour method
  - Previously published: Dimitrov, N.: Inverse Directional Simulation: an environmental contour method providing an exact return period. Manuscript submitted for publication in Journal of Physics: Conference Series, 2020.
- Comment:

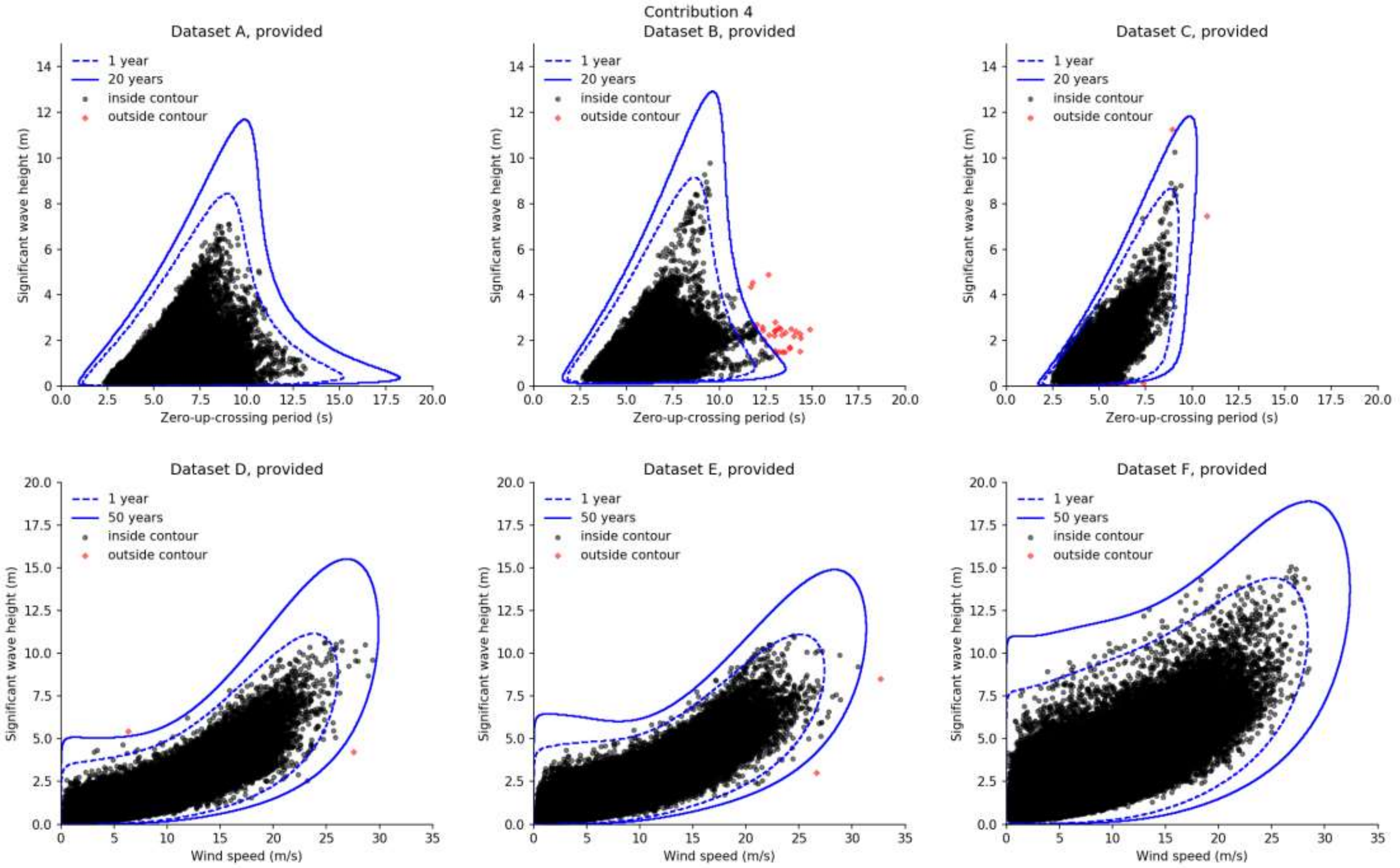

Contribution 3
Dataset A, provided
Dataset B, provided
Dataset C, provided
1 year
20 years
inside contour
outside contour
Significant wave height (m)
Zero-up-crossing period (s)
Dataset D, provided
Dataset E, provided
Dataset F, provided
1 year
50 years
inside contour
outside contour
Significant wave height (m)
Wind speed (m/s)

Contribution 3



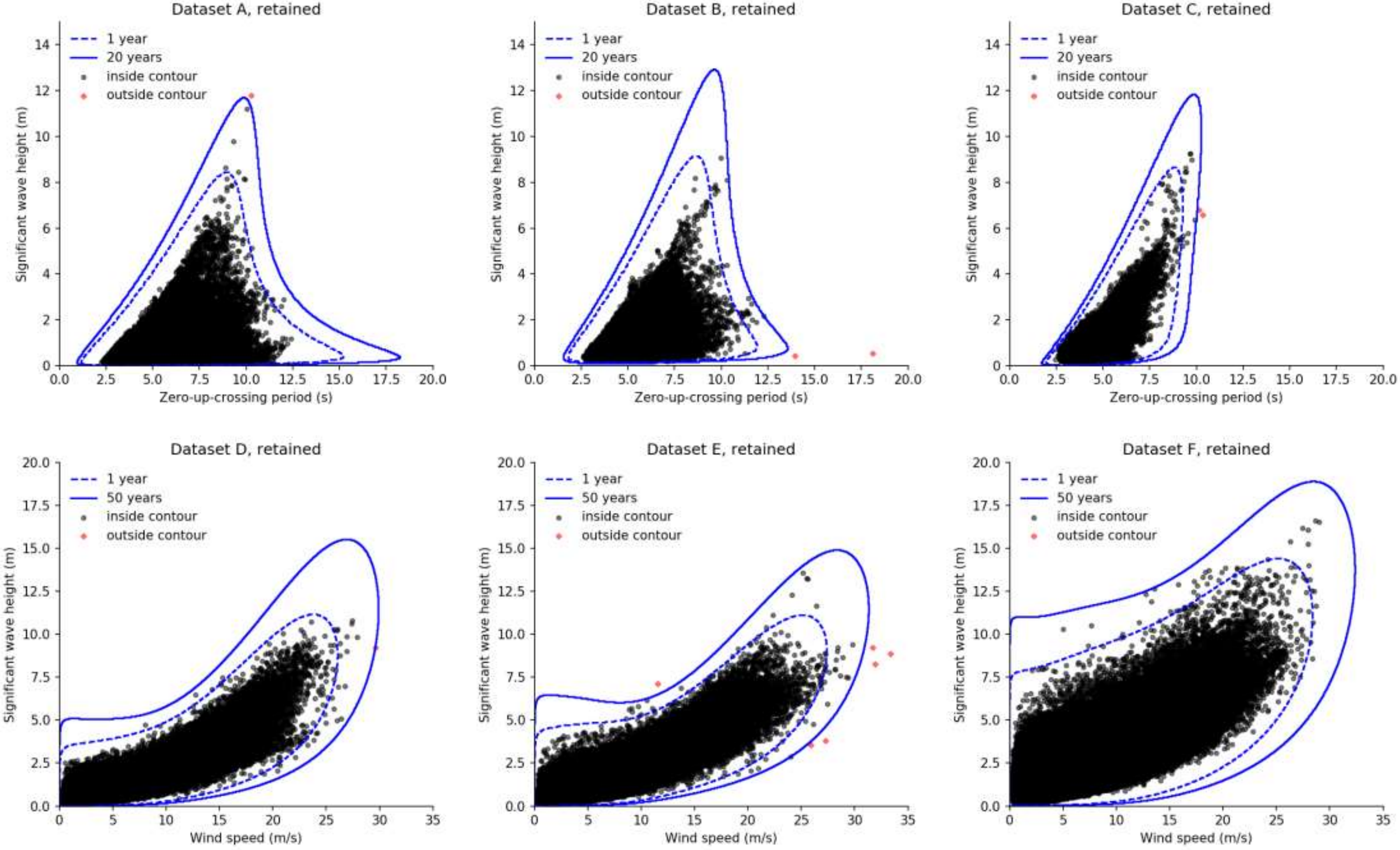
Exercise 1 – contribution 4

- Authors: Andreas Haselsteiner, Aljoscha Sander, Jan-Hendrik Ohlendorf & Klaus-Dieter Thoben
- Statistical model for datasets A-C: Global hierarchical model with an Exp. Wbl. distribution and an LN distribution
    - Previously published:
- Method to fit the model to datasets A-C: Weighted least squares for Hs, MLE for Tz, nonlinear least squares for dependence function
    - Previously published: Weighted least squares for Hs: Haselsteiner, A. F., & Thoben, K.-D. (2020). Predicting wave heights for marine design by prioritizing extreme events in a global model. *Renewable Energy*, *156*, 1146–1157. https://doi.org/10.1016/j.renene.2020.04.112
- Statistical model for datasets D-F: Global hierarchical model with Exp Wbl. for V and Hs
    - Previously published:
- Methods to fit the model to datasets D-F: Weighted least squares for marignals, weighted least square for dependence
    - Previously published: Weighted least squares for Hs: Haselsteiner, A. F., & Thoben, K.-D. (2020). Predicting wave heights for marine design by prioritizing extreme events in a global model. *Renewable Energy*, *156*, 1146–1157. https://doi.org/10.1016/j.renene.2020.04.112
- Method used for contour construction: Highest density contour method
    - Previously published: DOI: 10.1016/j.coastaleng.2017.03.002
- Comment:



Contribution 4
Dataset A, provided
Dataset B, provided
Dataset C, provided
1 year
20 years
inside contour
outside contour
Significant wave height (m)
Zero-up-crossing period (s)
Dataset D, provided
Dataset E, provided
Dataset F, provided
1 year
50 years
inside contour
outside contour
Wind speed (m/s)

Contribution 4

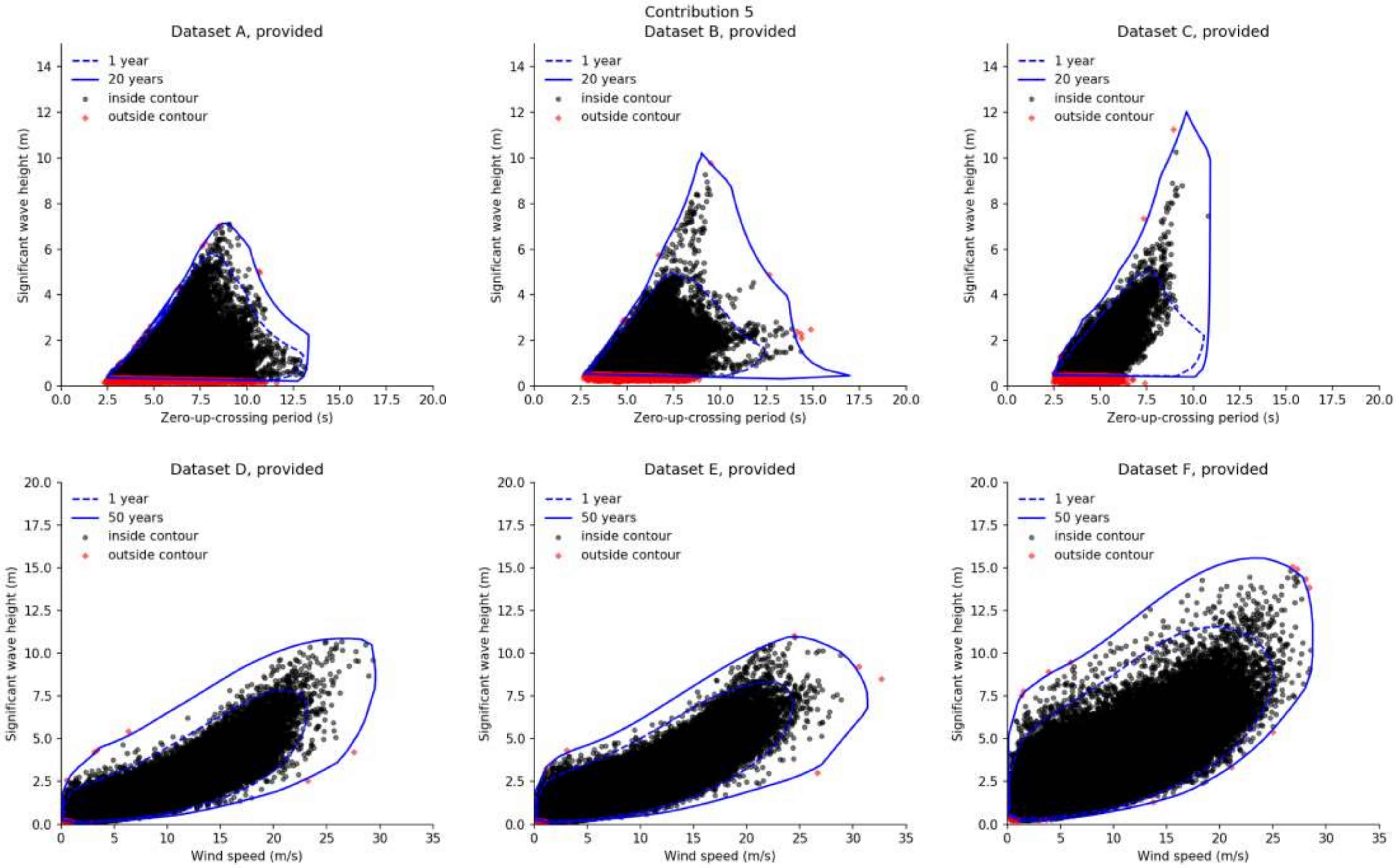


Exercise 1 – contribution 5

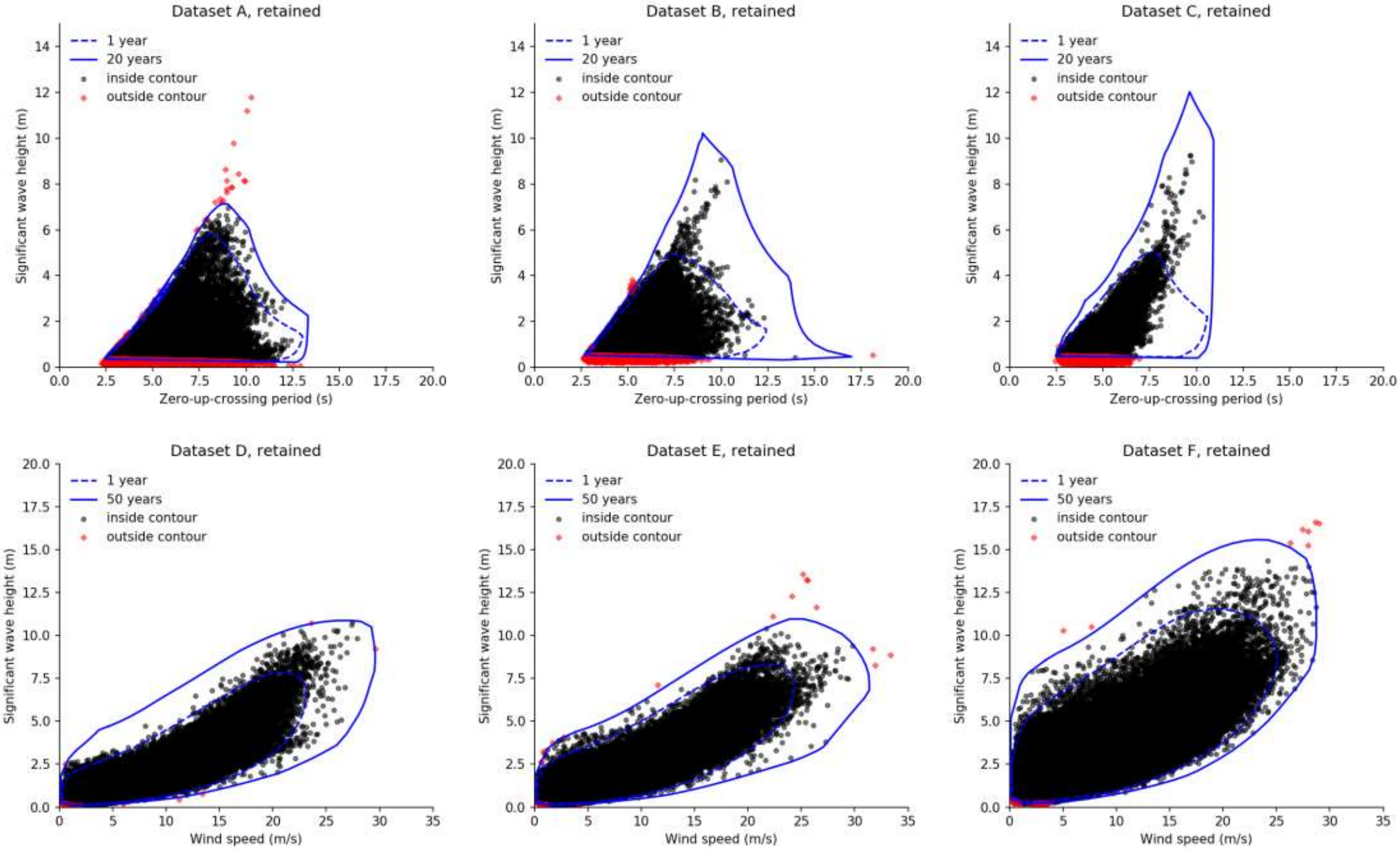
- Authors: Guillaume de Hauteclocque
- Statistical model for datasets A-C: Peak-Over-Threshold, Generalized Pareto Distribution
  - Previously published: Standard text book, used in OMAE2019-95993
- Method to fit the model to datasets A-C: MLE
  - Previously published: Standard text book, used in OMAE2019-95993
- Statistical model for datasets D-F: Peak-Over-Threshold, Generalized Pareto Distribution
  - Previously published: Standard text book, used in OMAE2019-95993
- Methods to fit the model to datasets D-F: MLE
  - Previously published: Standard text book, used in OMAE2019-95993
- Method used for contour construction: Direct IFORM with de-clustering
  - Previously published: OMAE2019-95993
- Comment:

  Compared to OMAE2019-95993, different variable changes have been used to get dataset roughly convex :
  - (Hs, Tz) changed to (Hs , Hs*Tz)
  - (Hs, Ws) changed to (Ws , Hs / f(Ws))

  Attention has been paid only to the relevant part of the contour (the upper part)


Contribution 5
Dataset A, provided
Dataset B, provided
Dataset C, provided
1 year
20 years
inside contour
outside contour
Significant wave height (m)
Zero-up-crossing period (s)
Dataset D, provided
Dataset E, provided
Dataset F, provided
1 year
50 years
inside contour
outside contour
Significant wave height (m)
Wind speed (m/s)

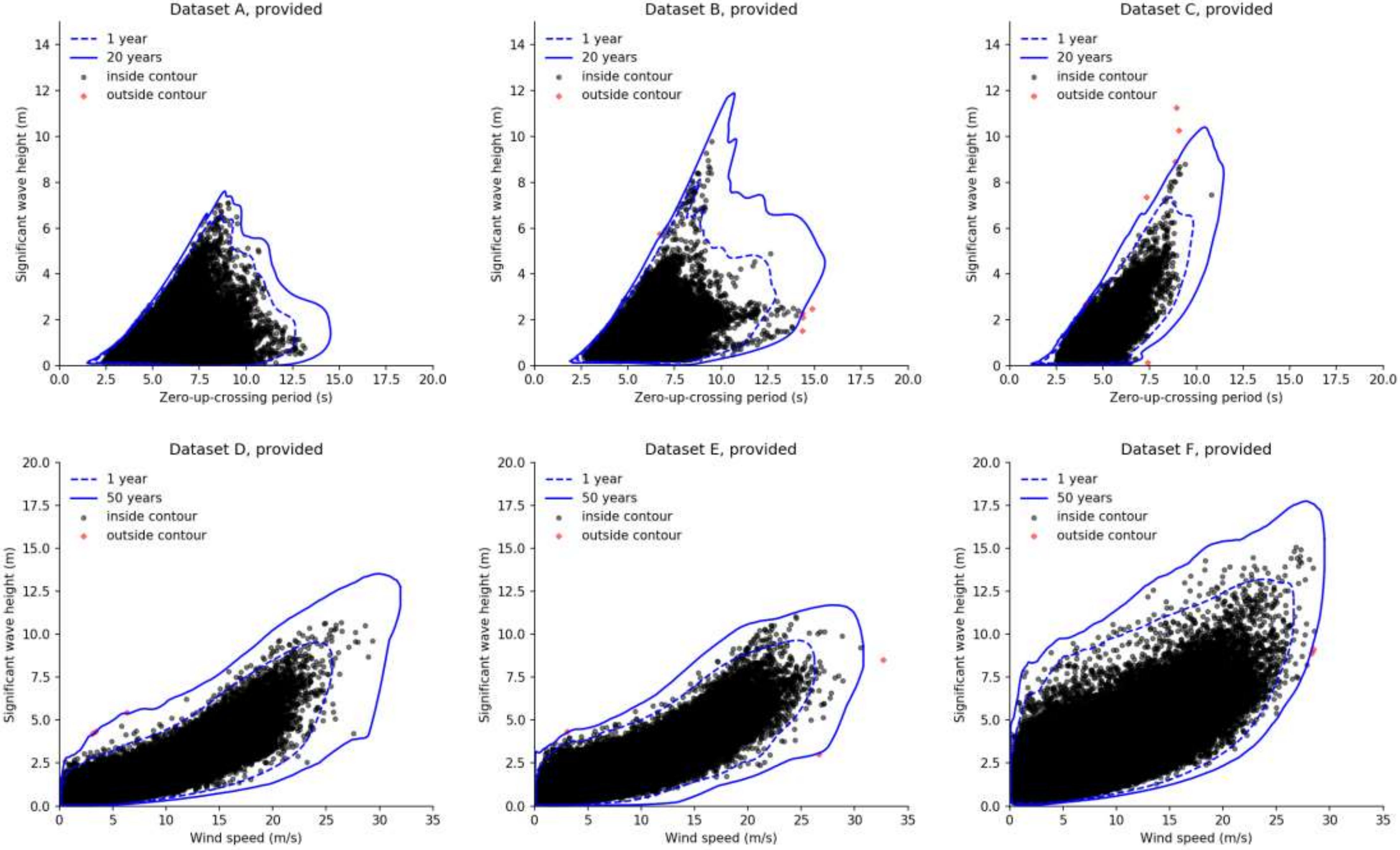
Contribution 5

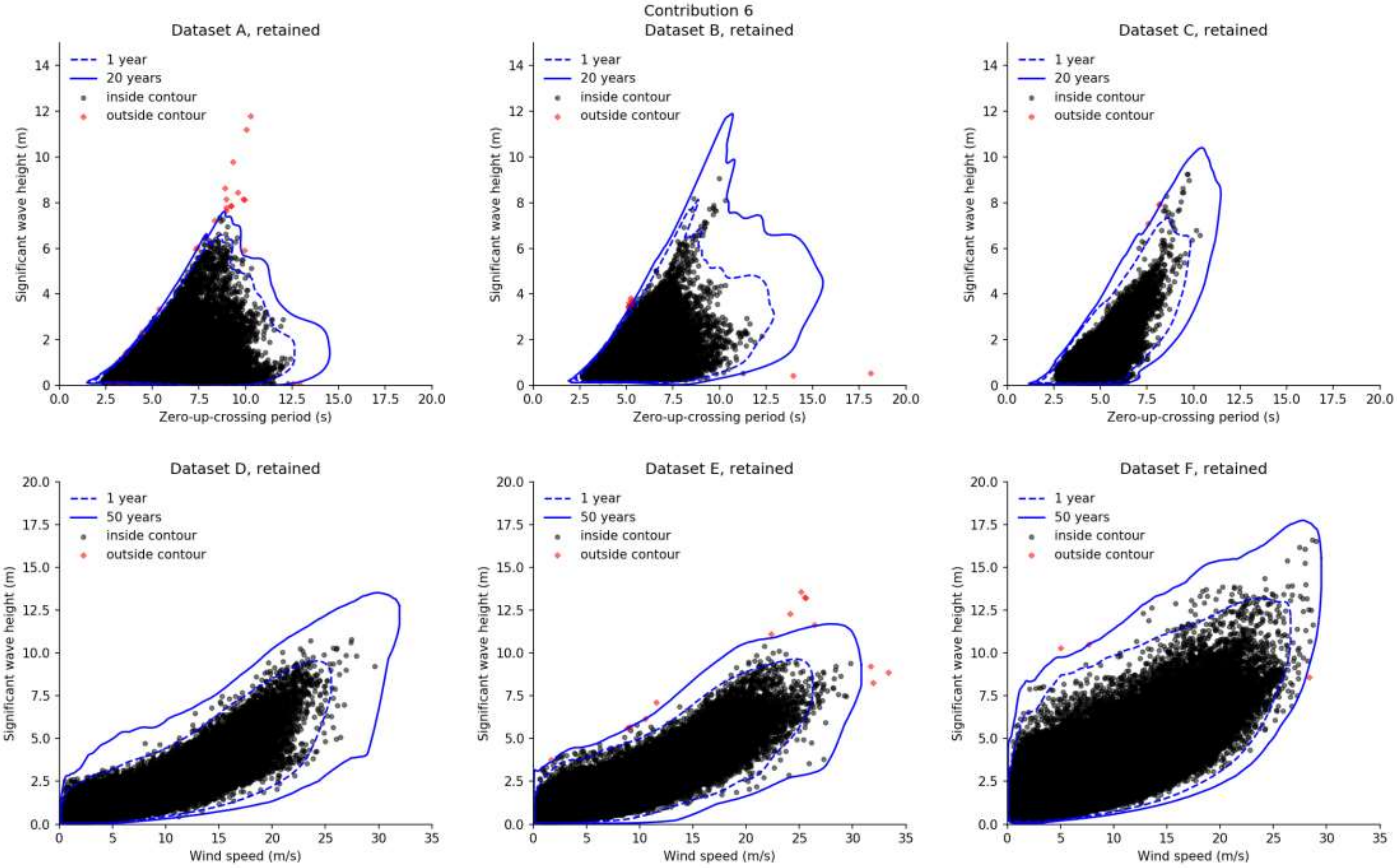


Exercise 1 – contribution 6

- Authors: Ed Mackay & Philip Jonathan
- Statistical model for datasets A-C: Storm resampling with non-stationary model for storms peaks
  - Previously published: Ref [1]
- Method to fit the model to datasets A-C: See reference
  - Previously published:
- Statistical model for datasets D-F: As above
  - Previously published:
- Methods to fit the model to datasets D-F:
  - Previously published:
- Method used for contour construction: IFORM
  - Previously published:
- Comment: [1] Mackay & Jonathan, 2020. Estimation Of Environmental Contours Using A Block Resampling Method. OMAE2020-18308.

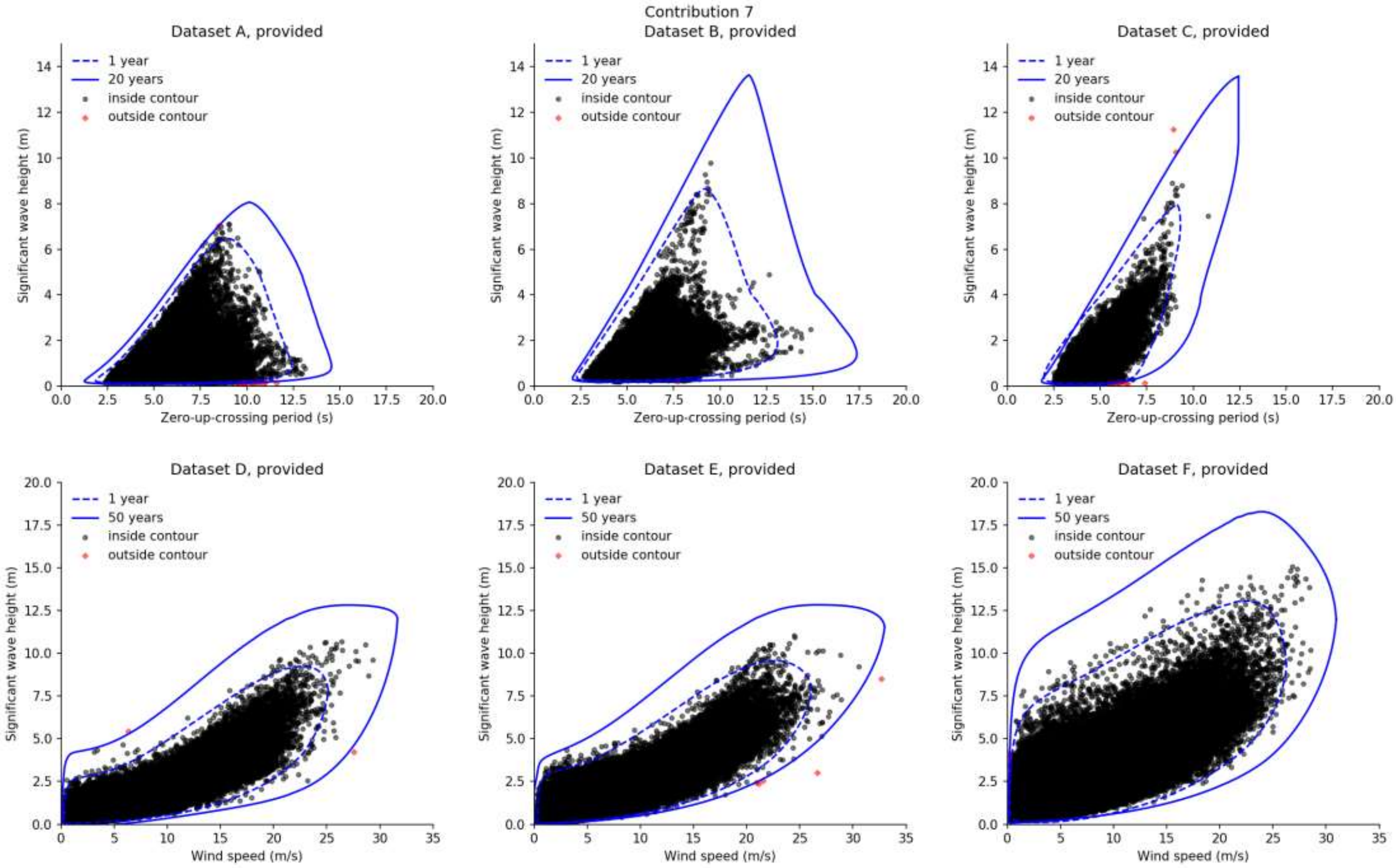
Contribution 6



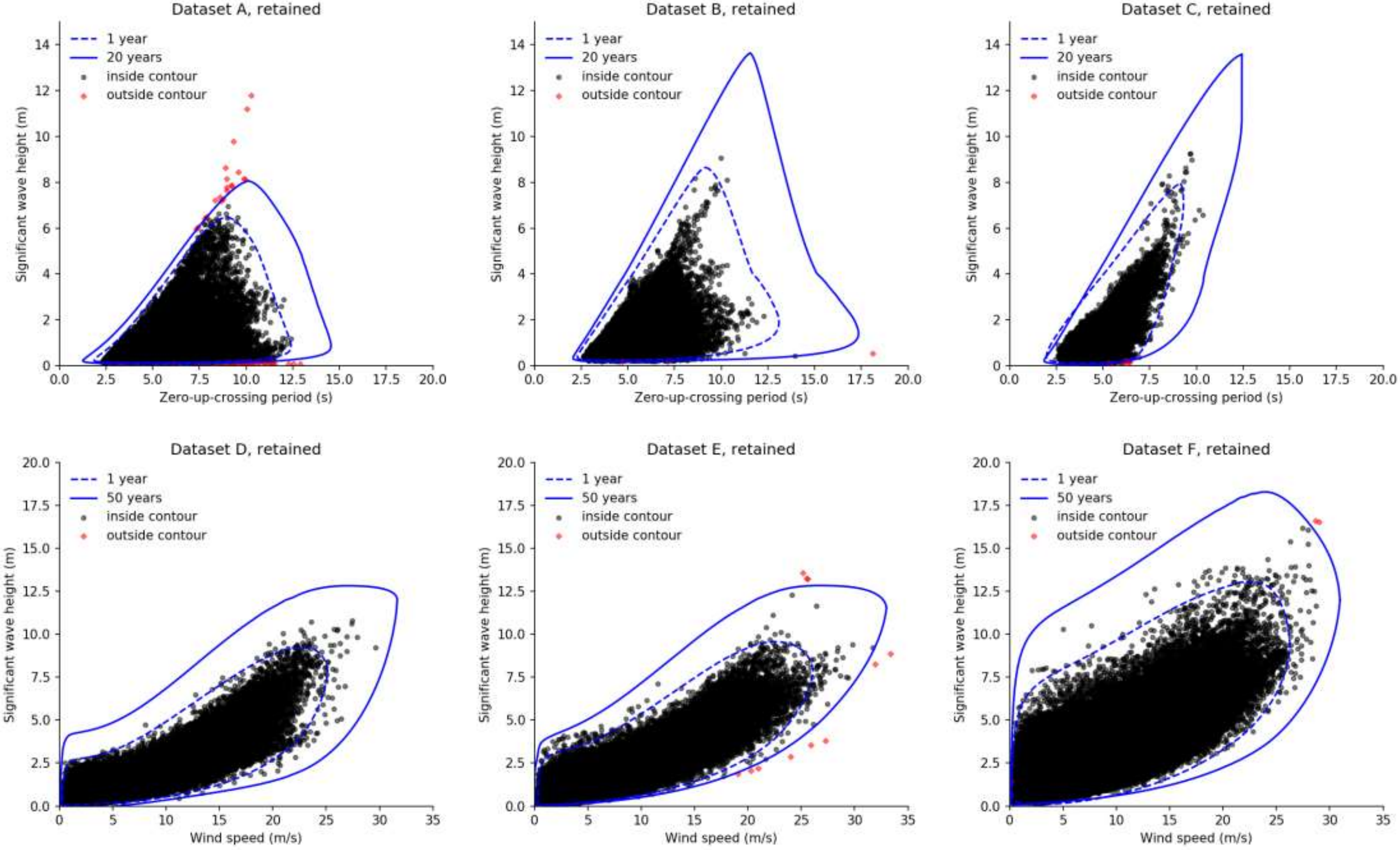

Contribution 6
Dataset A, retained
Dataset B, retained
Dataset C, retained
1 year
20 years
inside contour
outside contour
Significant wave height (m)
Zero-up-crossing period (s)
Dataset D, retained
Dataset E, retained
Dataset F, retained
1 year
50 years
inside contour
outside contour
Significant wave height (m)
Wind speed (m/s)

Exercise 1 – contribution 7

- Authors: Chi Qiao & Andrew Myers
- Statistical model for datasets A-C:
  - Previously published:
- Method to fit the model to datasets A-C:
  - Previously published:
- Statistical model for datasets D-F:
  - Previously published:
- Methods to fit the model to datasets D-F:
  - Previously published:
- Method used for contour construction: IFORM contour method
  - Previously published: Winterstein et al. (1993): Environmental parameters...
- Comment:
  - 1. A new framework based on I-FORM and Rosenblatt transformation is established for contour construction.
  - 2. Univariate distribution fitting is conducted using a method proposed by the authors in a manuscript that is currently under review.
  - 3. Lower half of the contour is constructed by MLE
  - 4. Upper half of the contour is constructed using a re-parameterization method proposed by the authors in Qiao, C., and A. T. Myers. "Re-parameterized Weibull distribution for modeling metocean extremes of multiple hazards with the Rosenblatt transformation."
  - 5. A Python package for interactive environmental fitting is being developed and will be published on PyPI


Contribution 7
Dataset A, provided
Dataset B, provided
Dataset C, provided
1 year
20 years
inside contour
outside contour
Significant wave height (m)
Zero-up-crossing period (s)
Dataset D, provided
Dataset E, provided
Dataset F, provided
1 year
50 years
inside contour
outside contour
Significant wave height (m)
Wind speed (m/s)

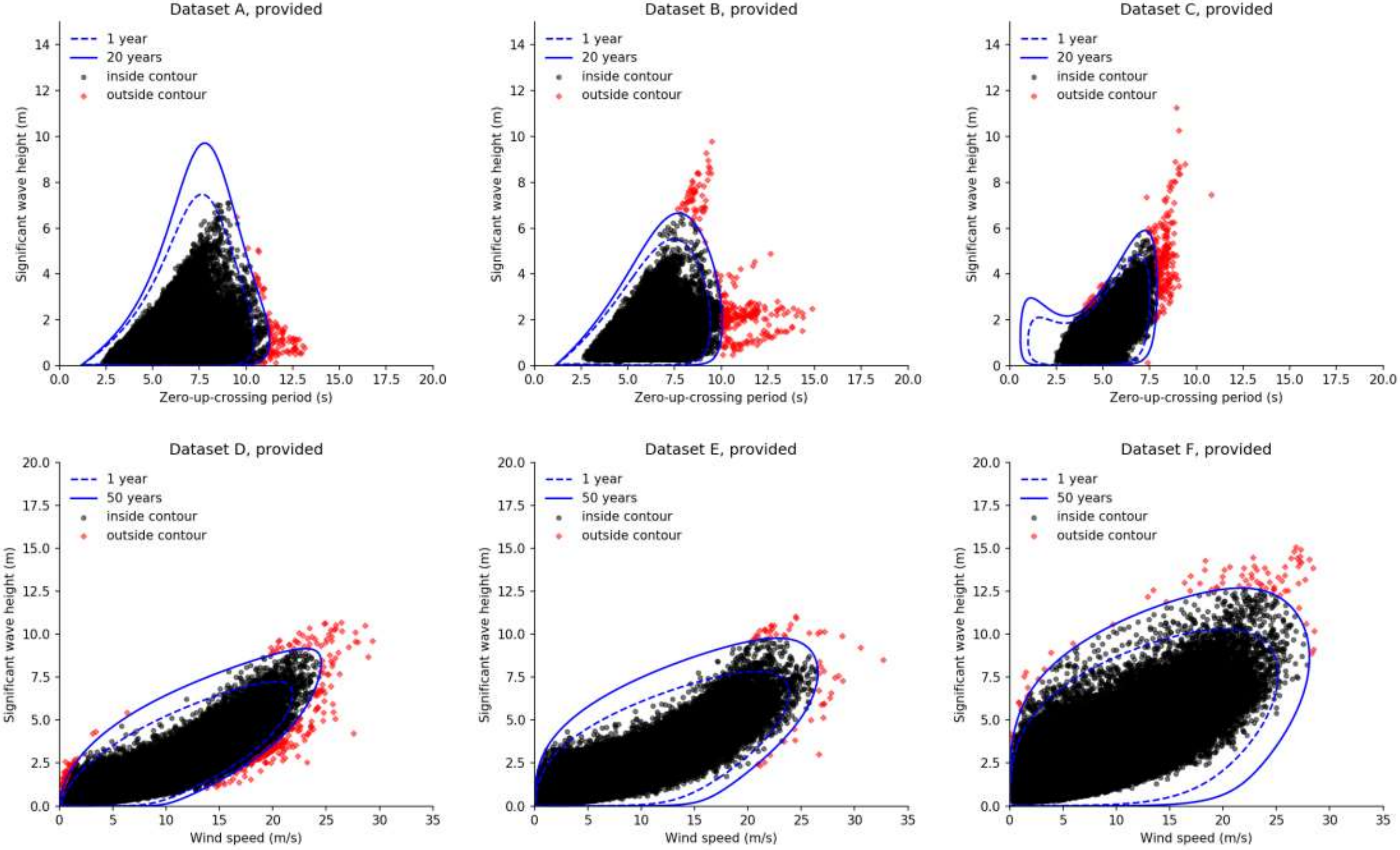
Contribution 7



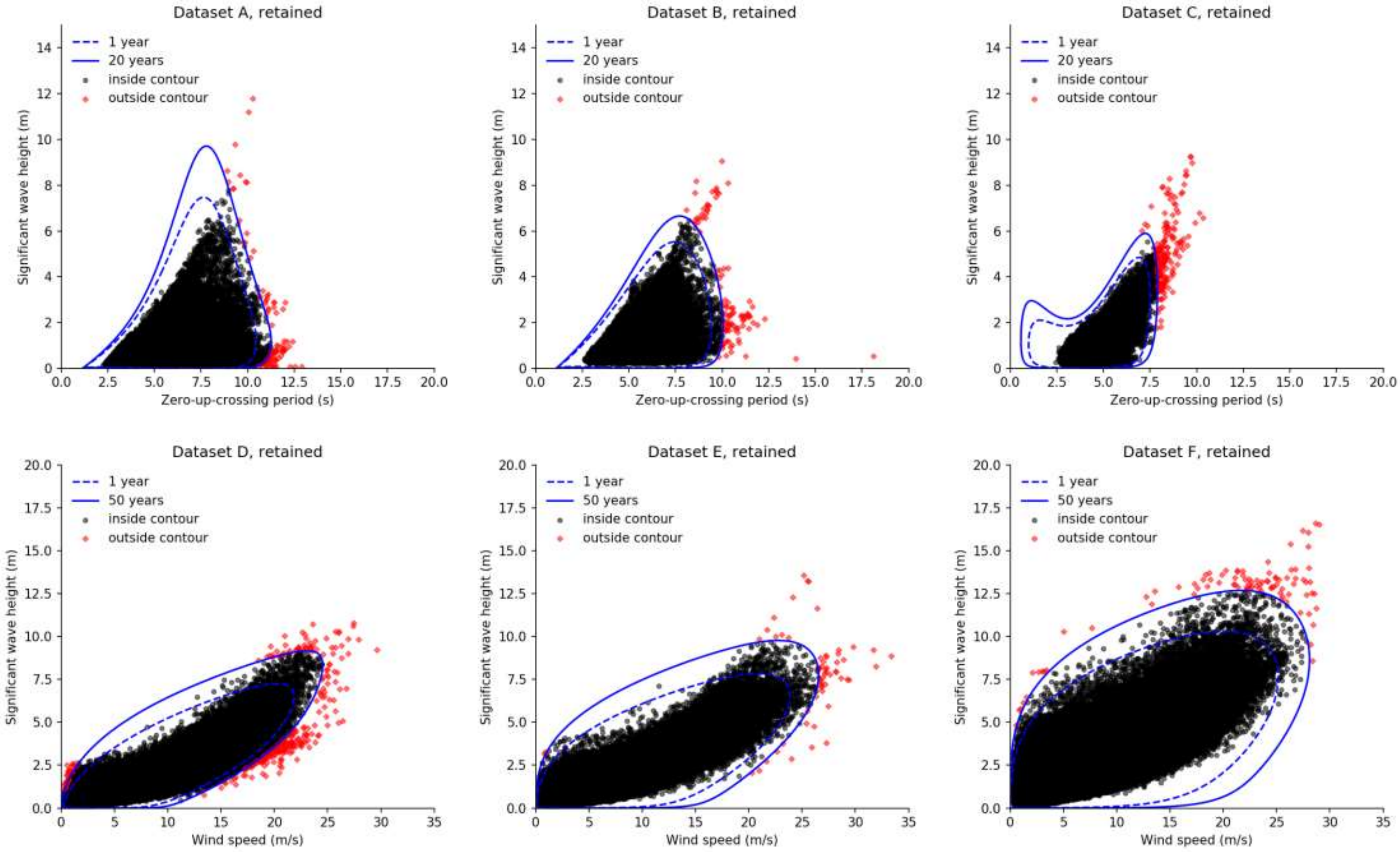
Exercise 1 – contribution 8

- Authors: Anna Rode, Arndt Hildebrandt & Boso Schmidt
- Statistical model for datasets A-C: 2-Parameter Weibull distribution
  - Previously published:
- Method to fit the model to datasets A-C: Maximum-Likelihood for marginals, OLS for dependence
  - Previously published:
- Statistical model for datasets D-F: 2-Parameter Weibull distribution
  - Previously published:
- Methods to fit the model to datasets D-F: Maximum-Likelihood for marginals, OLS for dependence
  - Previously published:
- Method used for contour construction: IFORM contour method
  - Previously published: Winterstein et. al, in "Environmental Parameters for extreme Response
- Comment:

Contribution 8



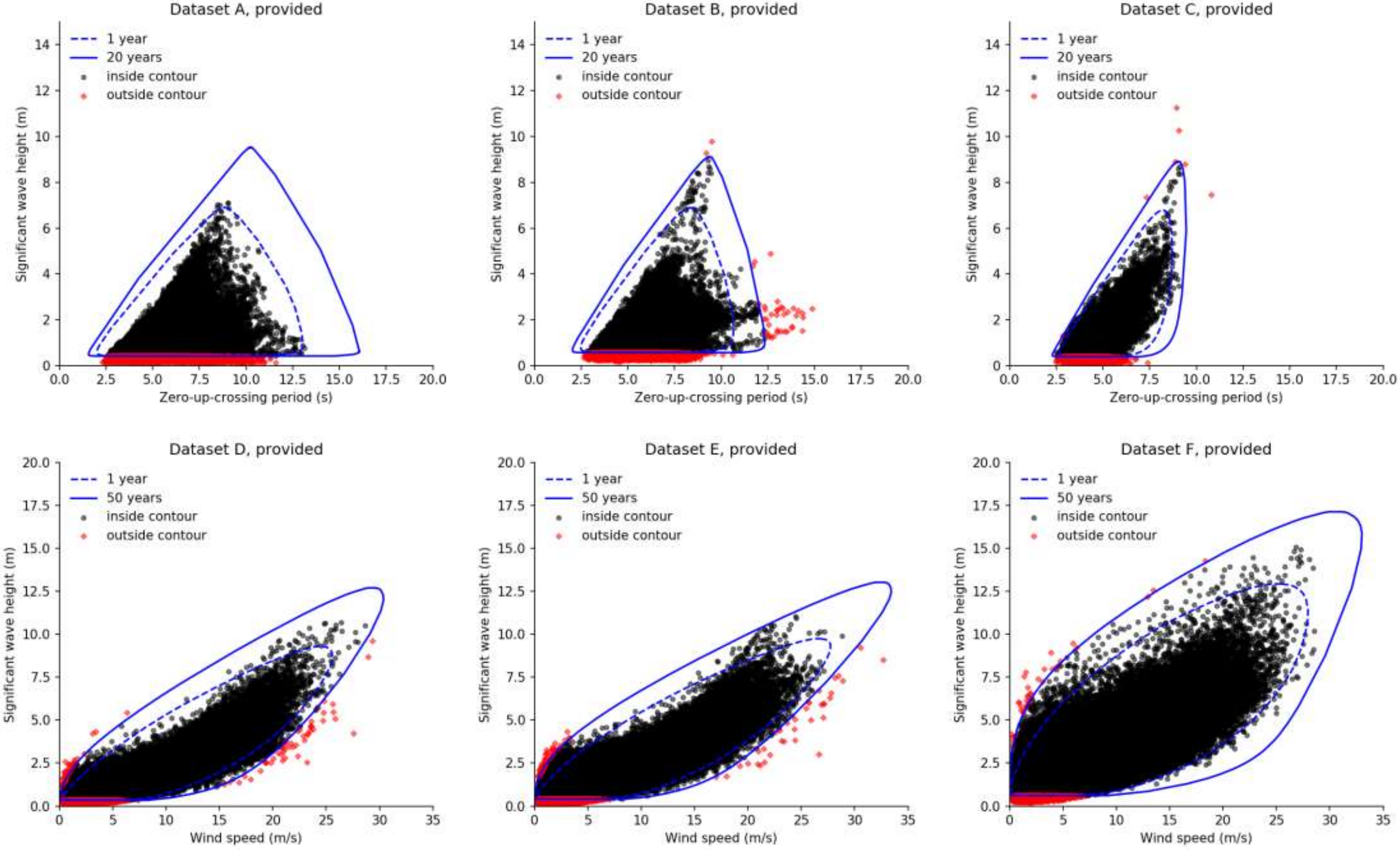
Contribution 8



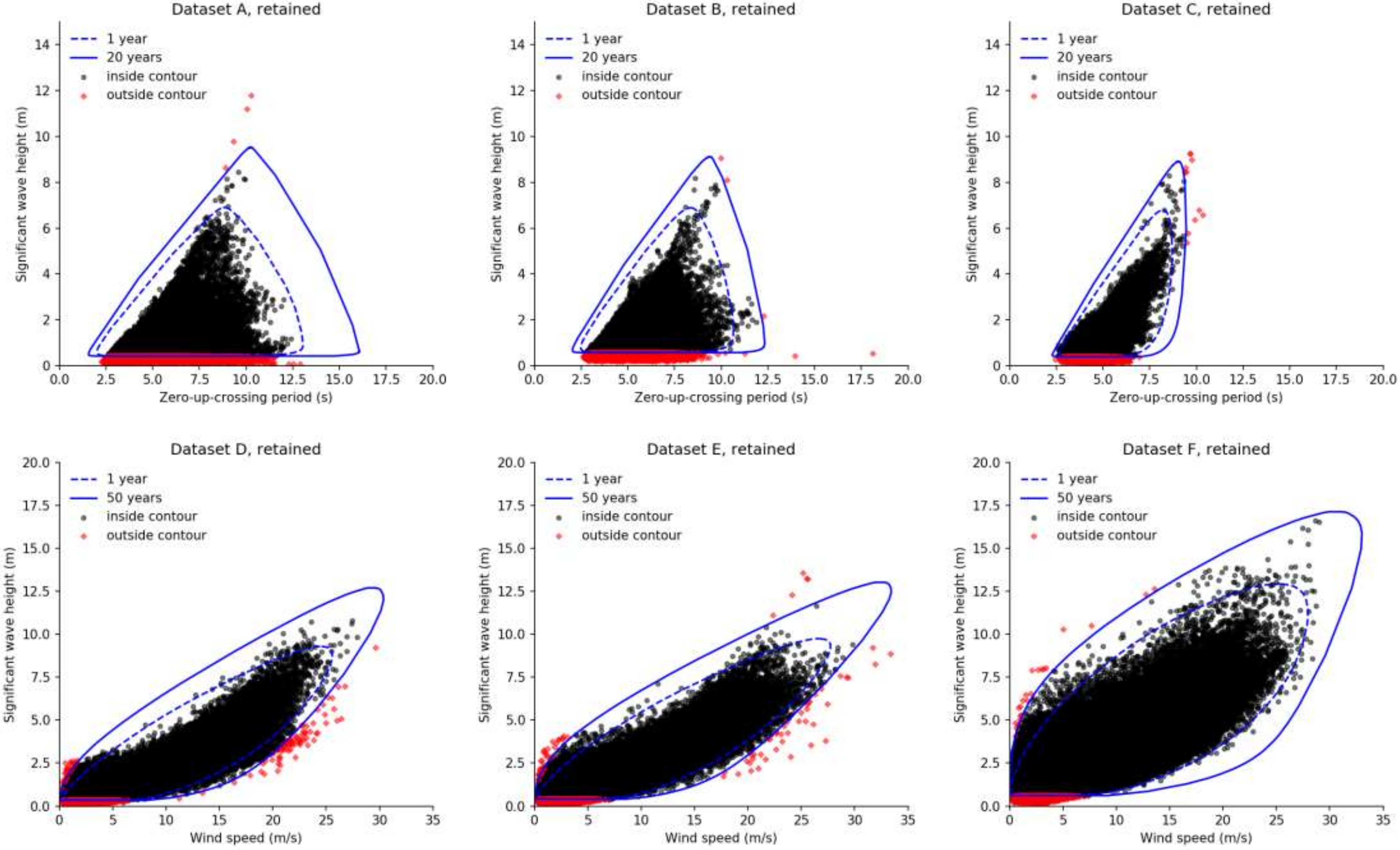
Exercise 1 – contribution 9

- Authors: Erik Vanem & Arne Bang Huseby
- Statistical model for datasets A-C: 3-parameter Weibul and conditional log-normal
  - Previously published: e.g. DNV GL RP C205, but many other places
- Method to fit the model to datasets A-C: GoF statistic and least square to binned data for conditional mod
  - Previously published: e.g. Vanem (2016); Marine Structures. vol. 49, pp. 180-205, 2016
- Statistical model for datasets D-F: 3-parameter Weibull and conditional 2-parameter Weibull
  - Previously published: e.g. DNV GL RP C205, but many other places
- Methods to fit the model to datasets D-F: GoF statistic and ML
  - Previously published: GoF: e.g. in Vanem (2015): . Journal of Ocean Engineering and Marine Energy, vol. 1(4), pp. 339-359, 2015. See also Vanem et al. (2019): Applied Ocean Research, 91, 101870, 2019
- Method used for contour construction: Direct sampling contours and IFORM contours
  - Previously published: E.g. Huseby et al. (2013; 2014): Ocean Engineering, vol 60, pp. 124-135, 2013; Structural Safety, vol. 54, pp. 32-45, 2015; Vanem and Bitner-Gregersen (2015): Journal of Offshore Mechanics and Arctic Engineering, vol. 137(5), 051601, pp. 1-8, 2015; Vanem (2017): Marine Structures. 56, pp. 137-162, 2017 . See also earlier work by Haver and Winterstein.
- Comment:
  - For the direct sampling contours in Ex. 1, there is an initial and a smoothed version of the contours. Possibly, the smoothed versions do not need to enter the exercise.
  - For Ex. 2 results are only submitted for the direct sampling contours, and contours for mean, median, lower and upper are provided (where lower/upper corresponds to the 95% CI. Please note that the CIs are calculated from the C-function and not exactly as prescribed in the announcement.

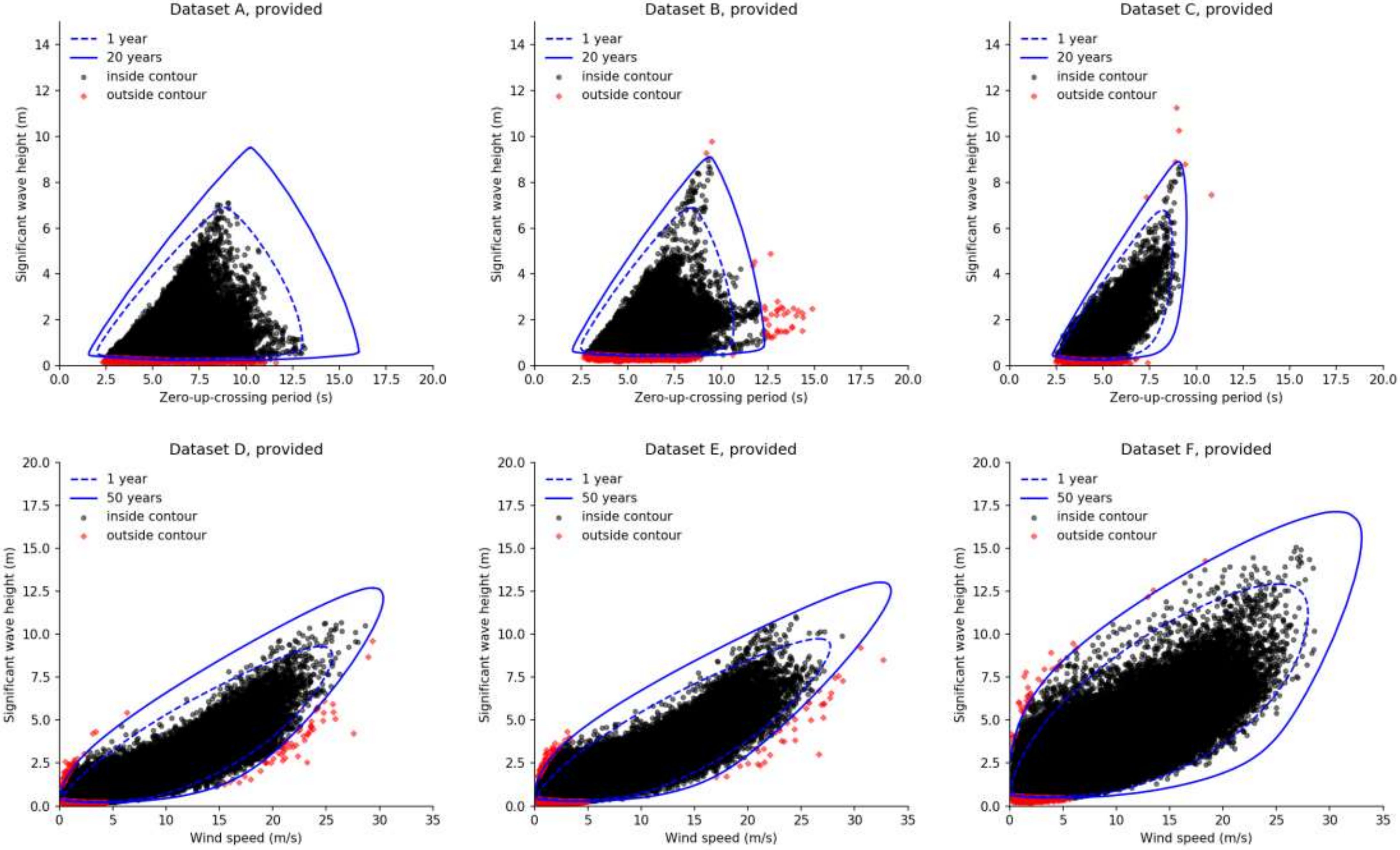
Contribution 9, DS



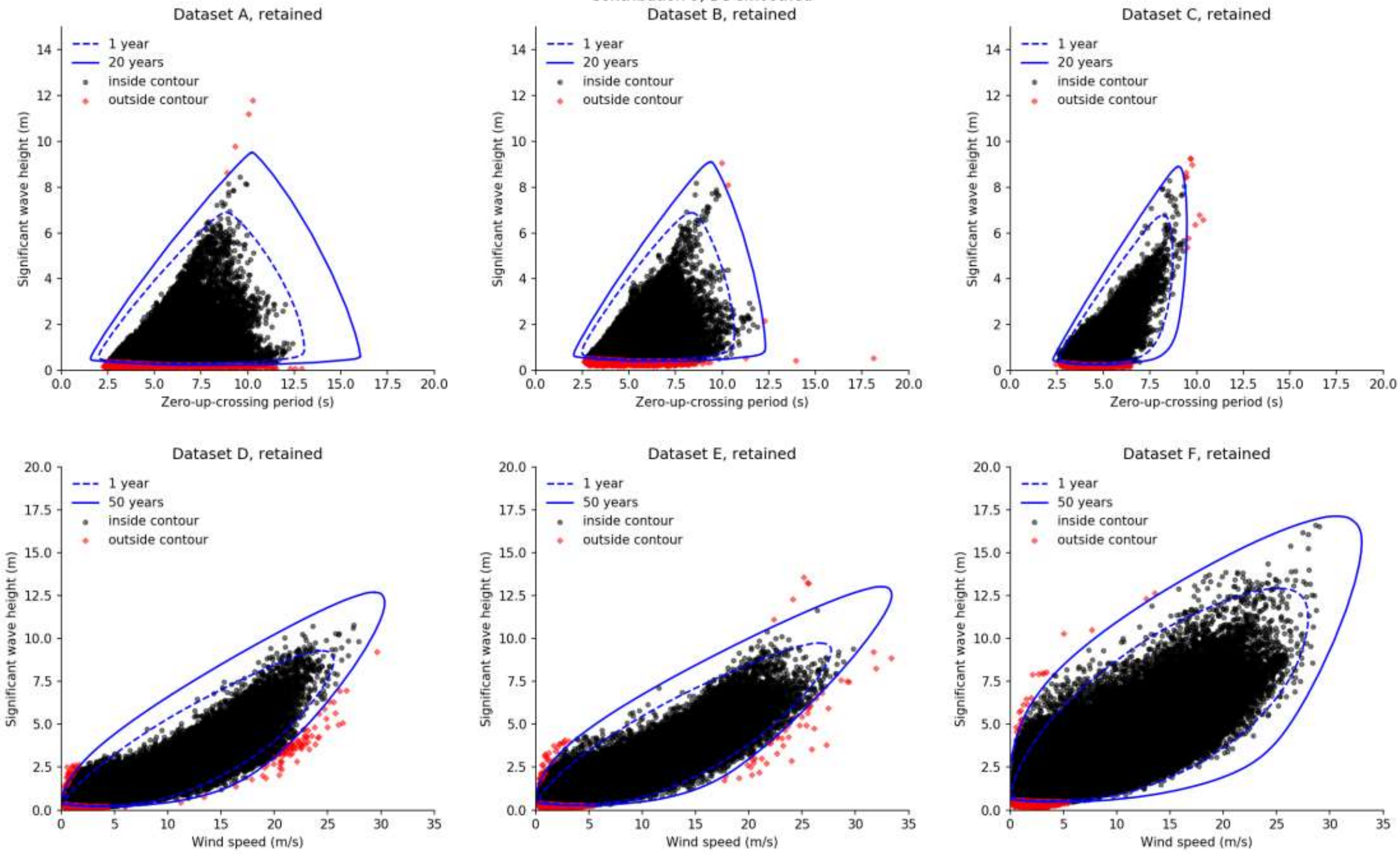
Contribution 9, DS

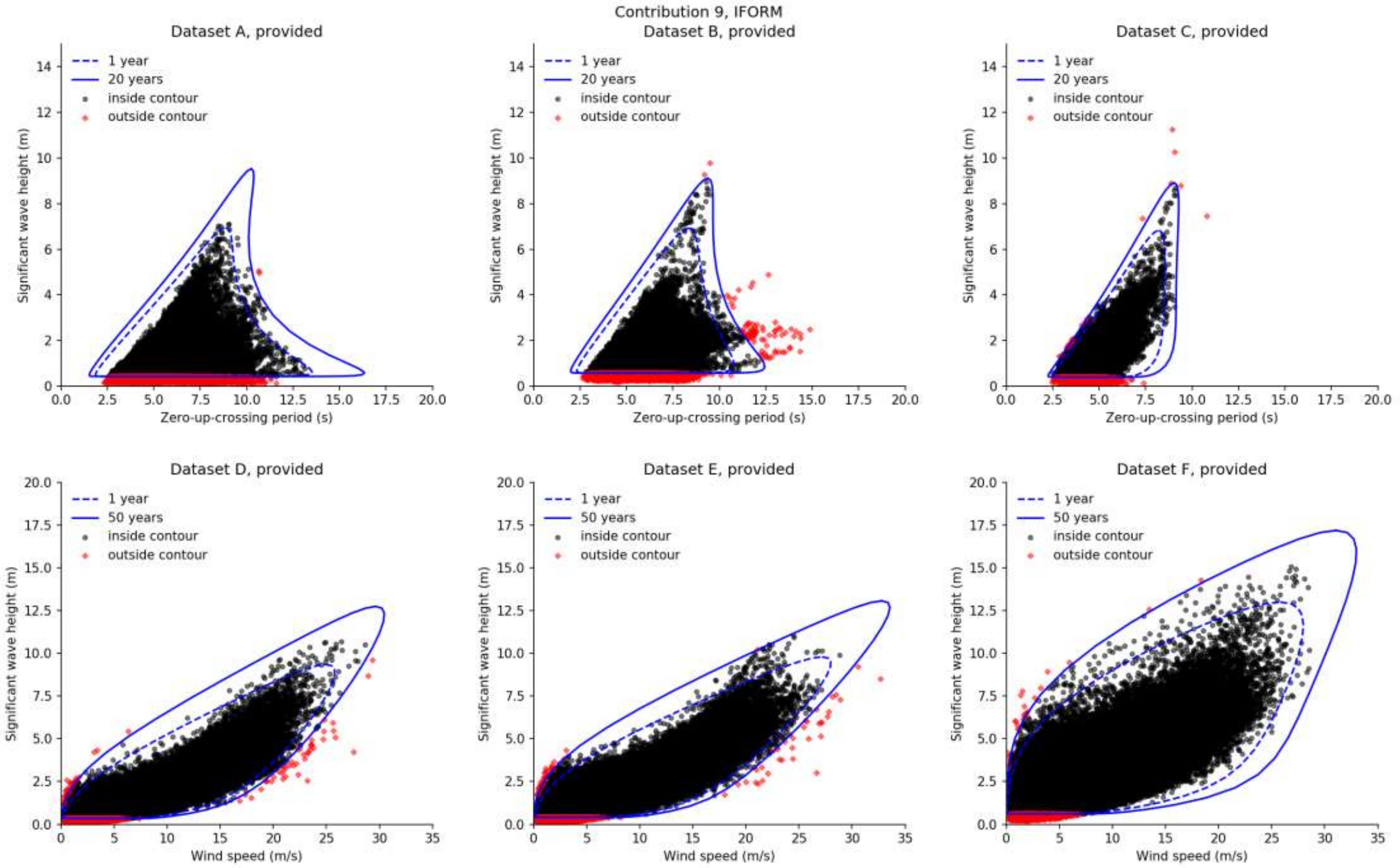


Contribution 9, DS smoothed



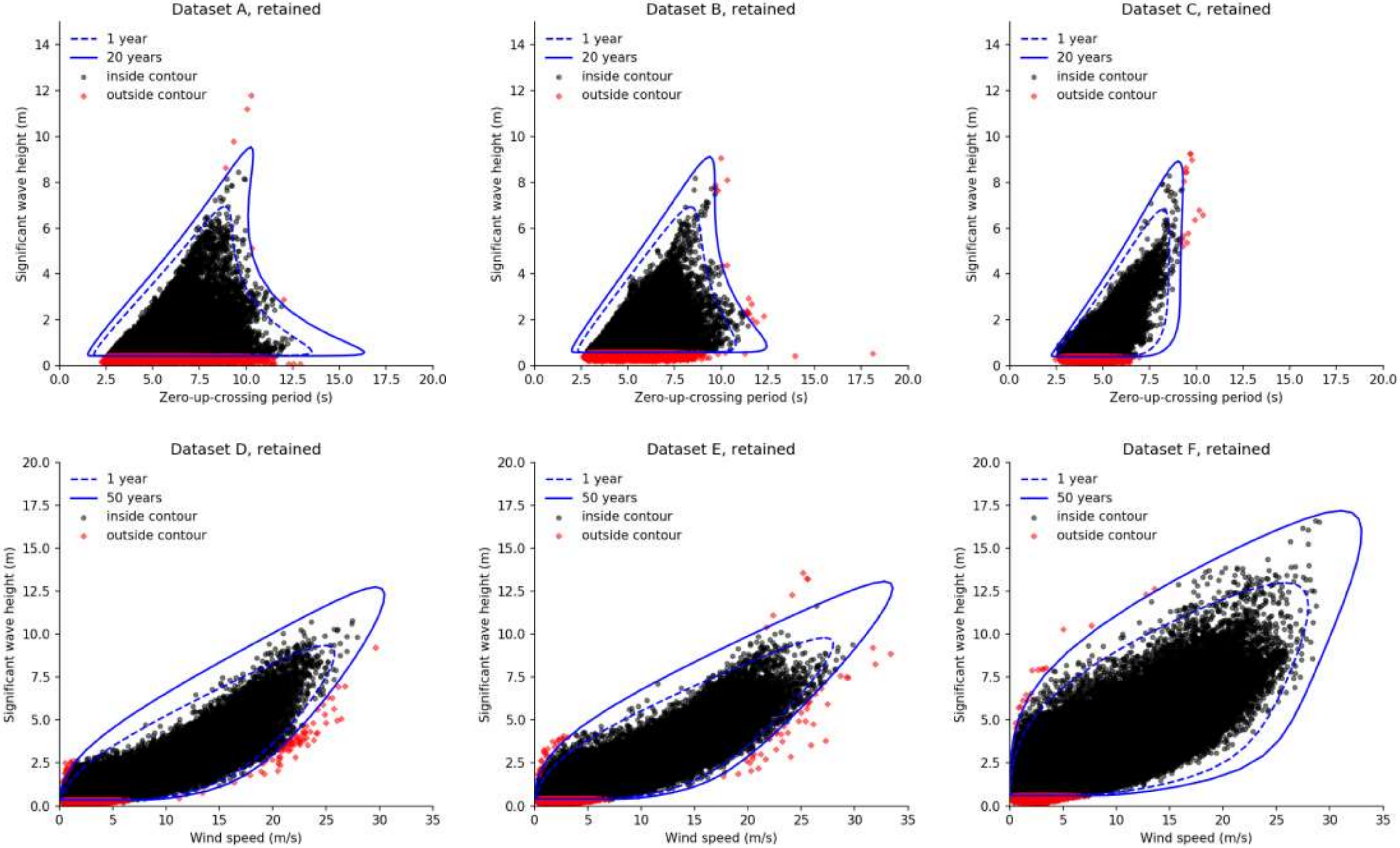
Contribution 9, DS smoothed



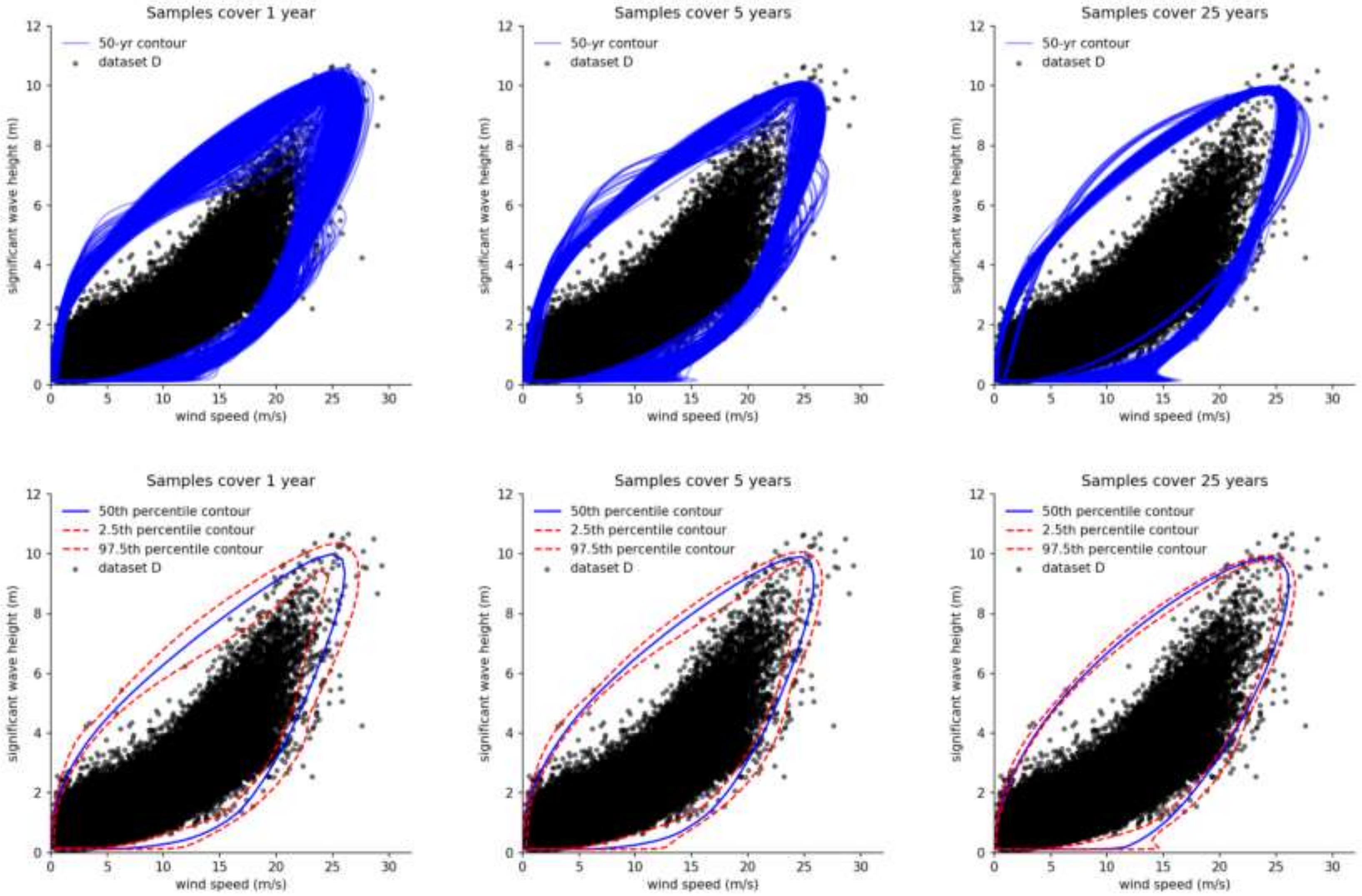


Contribution 9, IFORM
Dataset A, provided
Dataset B, provided
Dataset C, provided
1 year
20 years
inside contour
outside contour
Significant wave height (m)
Zero-up-crossing period (s)
Dataset D, provided
Dataset E, provided
Dataset F, provided
50 years
Wind speed (m/s)

Contribution 9, IFORM



Exercise 2 - uncertainty



Exercise 2 uncertainty

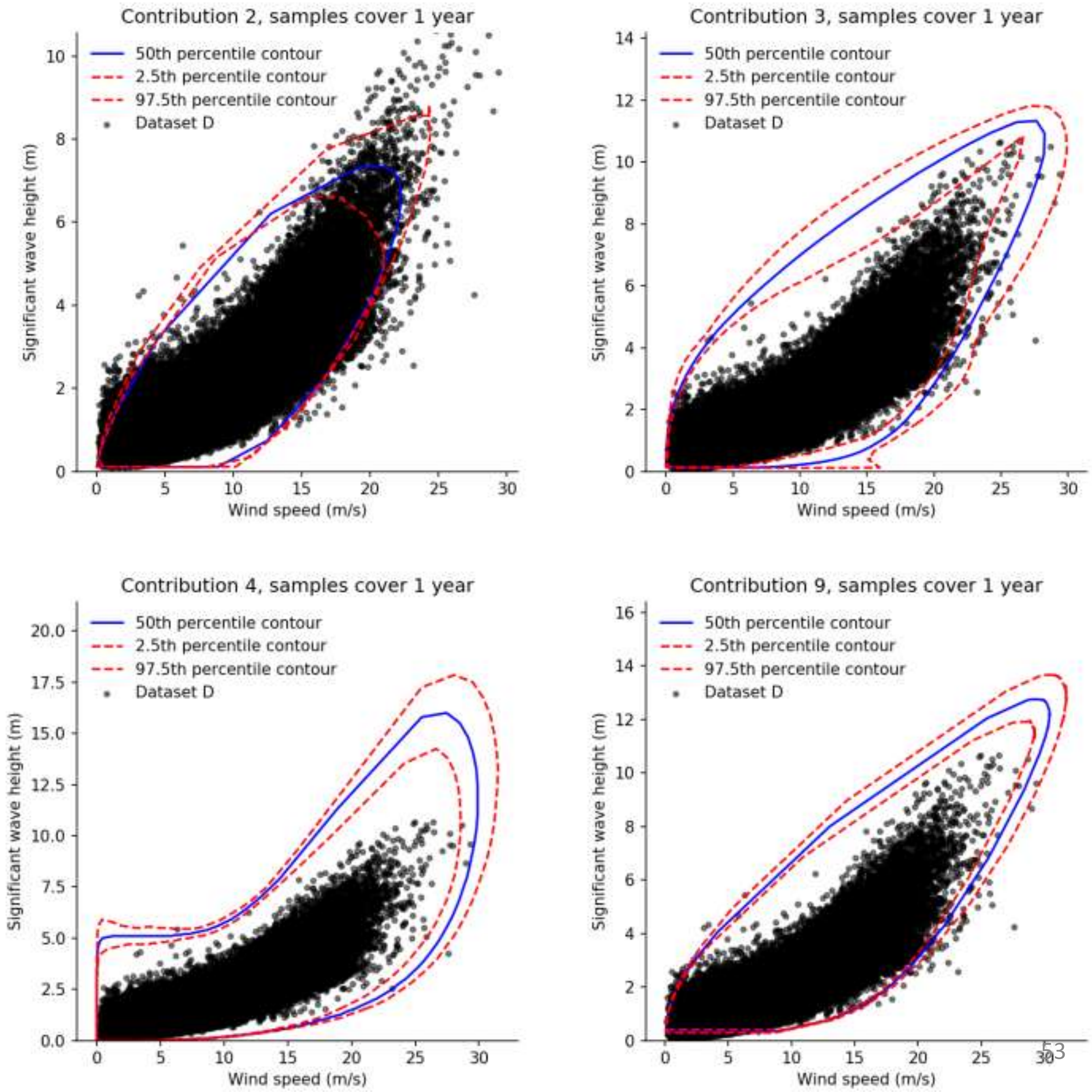
Contribution 2

Contribution 3

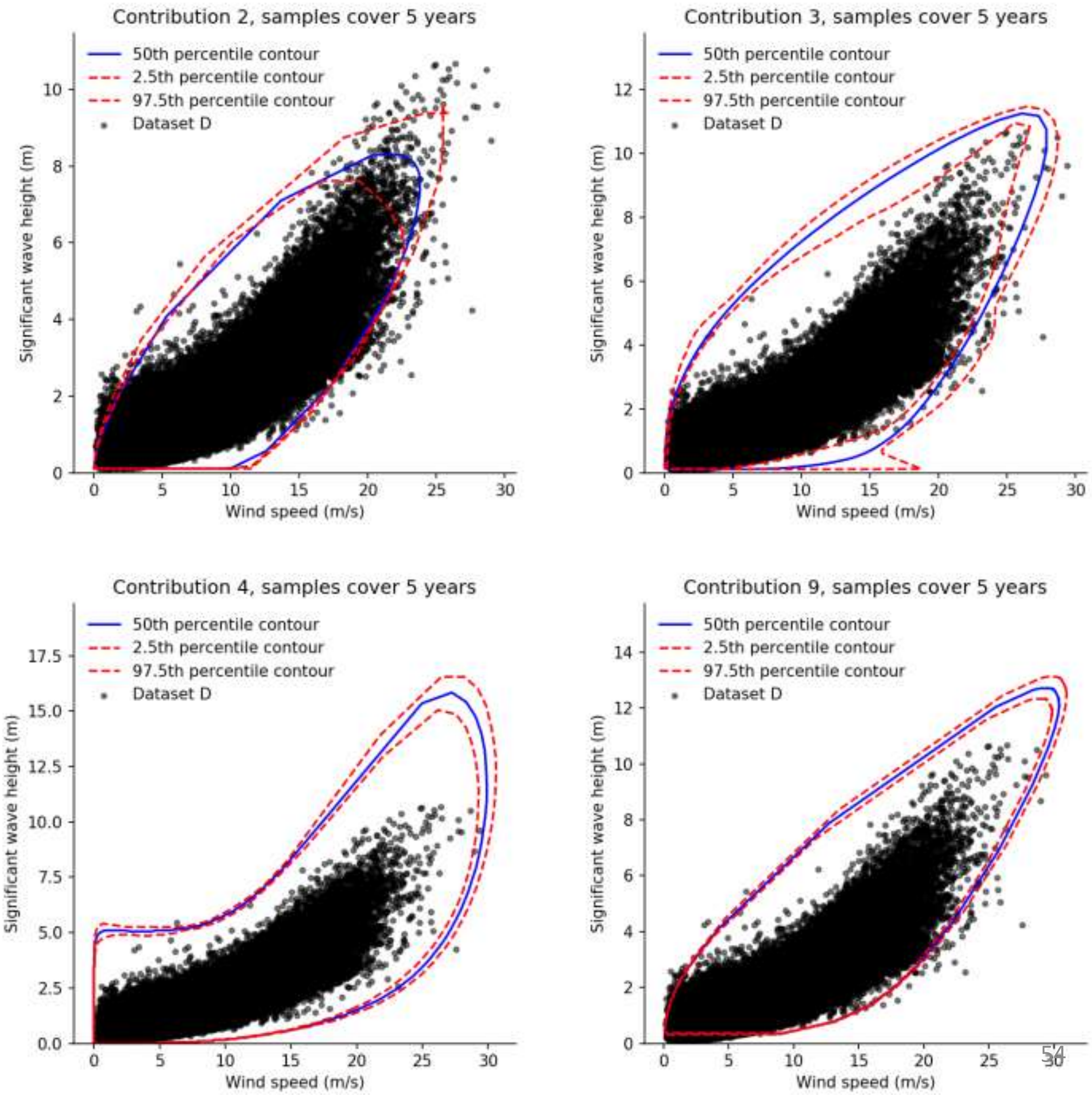
Contribution 4

Contribution 9

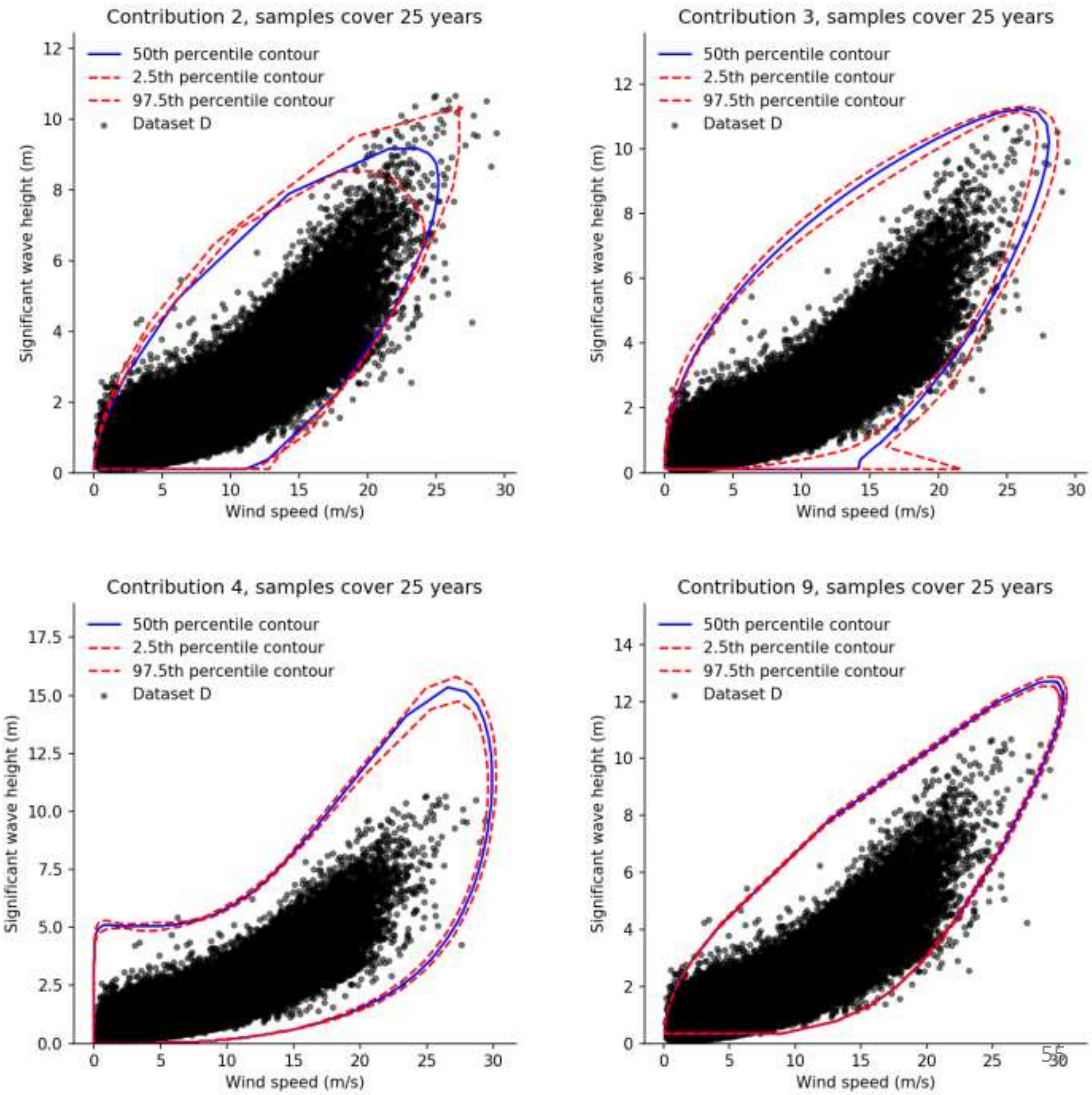
Exercise 2 uncertainty, 1 yr



Exercise 2 uncertainty, 5 yr



Exercise 2 uncertainty, 25 yr



iii) Overview about the proposed structure for the joint paper

Switch to https://github.com/ec-benchmark-organizers/ec-benchmark/blob/master/joint-paper/joint-paper-outline.md

Publishing the results

- We proposed a special issue entitled “Probabilistic Long-Term Extreme Conditions using Metocean Data” to *Ocean Engineering*
- If the journal is interested, we would propose to submit the joint paper
- Timeline
  - August 31st: Deadline for first complete draft
  - September 15th: Deadline for submitting comments on the first draft
  - September 30st: Deadline for revised draft
  - October 15th: Deadline for comments on revised draft
  - October 31st: Submission of the manuscript
- The special issue would also be a good place for standalone papers based on new models & methods that were proposed in individual contributions
- Proposed timeline: initial submissions between September 1 and November 16

iv) Decisions on the proposed structure, decisions on proposals for further analysis

Paper structure & further analysis

- Proposed main content [x]
- Proposal A: Assessment of statistical models in terms of marginal and projected variables [ ]
  - Include the proposed analysis for participants who are interested in it

v) Decisions on the next steps and the timeline

Next steps and time line

- Sharing results
  - Share submitted files on GitHub repository [x]
  - Share whole/subset of this presentation on GitHub repository [x]
- Writing the paper
  - August 31st: Deadline for first complete draft [x]
  - October 31st: Submission of the manuscript [x]
- Move special issue deadline backwards

vi) Discussion and further points

Protocol for discussion

- Schedule another meeting for discussion in ca. two weeks