Wave-in-Deck Assessment for Fixed Offshore Structures

RAMBOLL

Konstruksjonsdagen 2023

Palle Teis Nielsen
Senior Structural Engineer
Rambøll - Marine Structures
Esbjerg

Hans Fabricius Hansen
Senior Metocean Engineer
HAW MetOcean ApS
Copenhagen

Bjørn Thomas Svendsen
Lead Structural Engineer
Rambøll - Marine Structures
Stavanger

Agenda

- Ramboll in short
- Wave-in-Deck Assessment for Fixed Offshore Structures
- Crest Elevation Calculation

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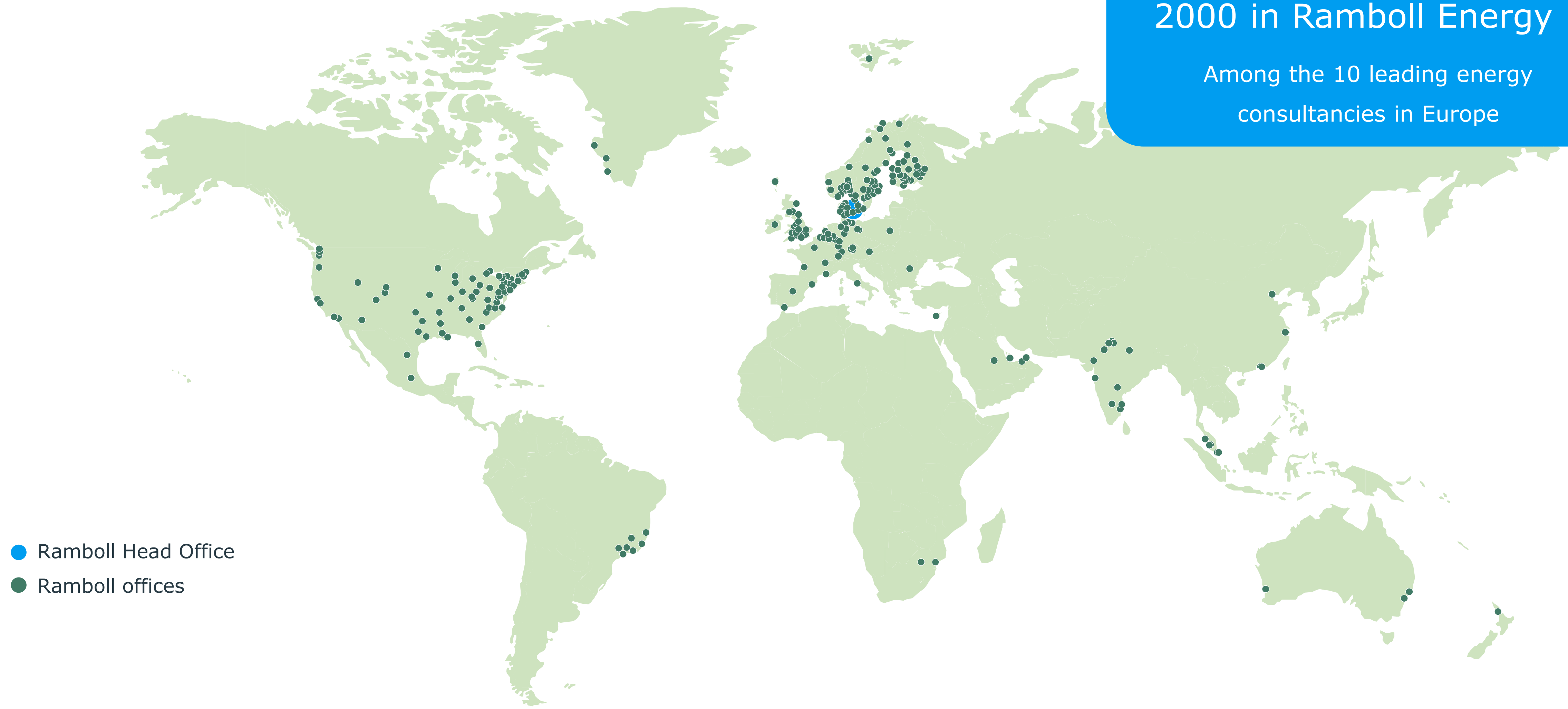


16000 in Ramboll

2000 in Ramboll Energy

Among the 10 leading energy consultancies in Europe

RAMBOLL Energy Transition

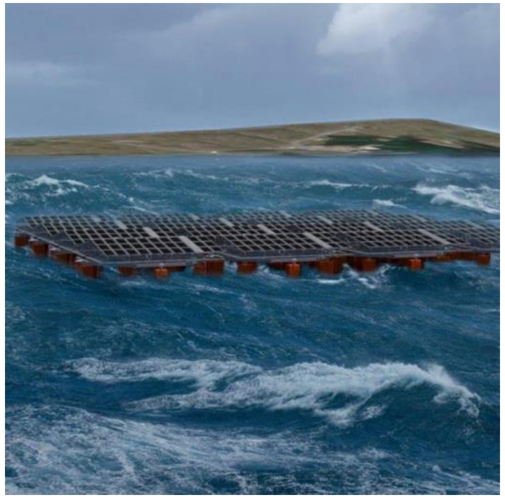
40 years of experience with offshore

Partner for sustainable change

Risk, Safety – Cost reduction

New types of projects

Wind Seegreen Wind Farm
TotalEnergies, Scotland



Solar Floating Solar Power Plant
Equinor, Norway

CCS Carbon Capture & Storage
INEOS, North Sea

P2X Energy Island
Energinet, North Sea

Wave-in-Deck Assessment for offshore structures

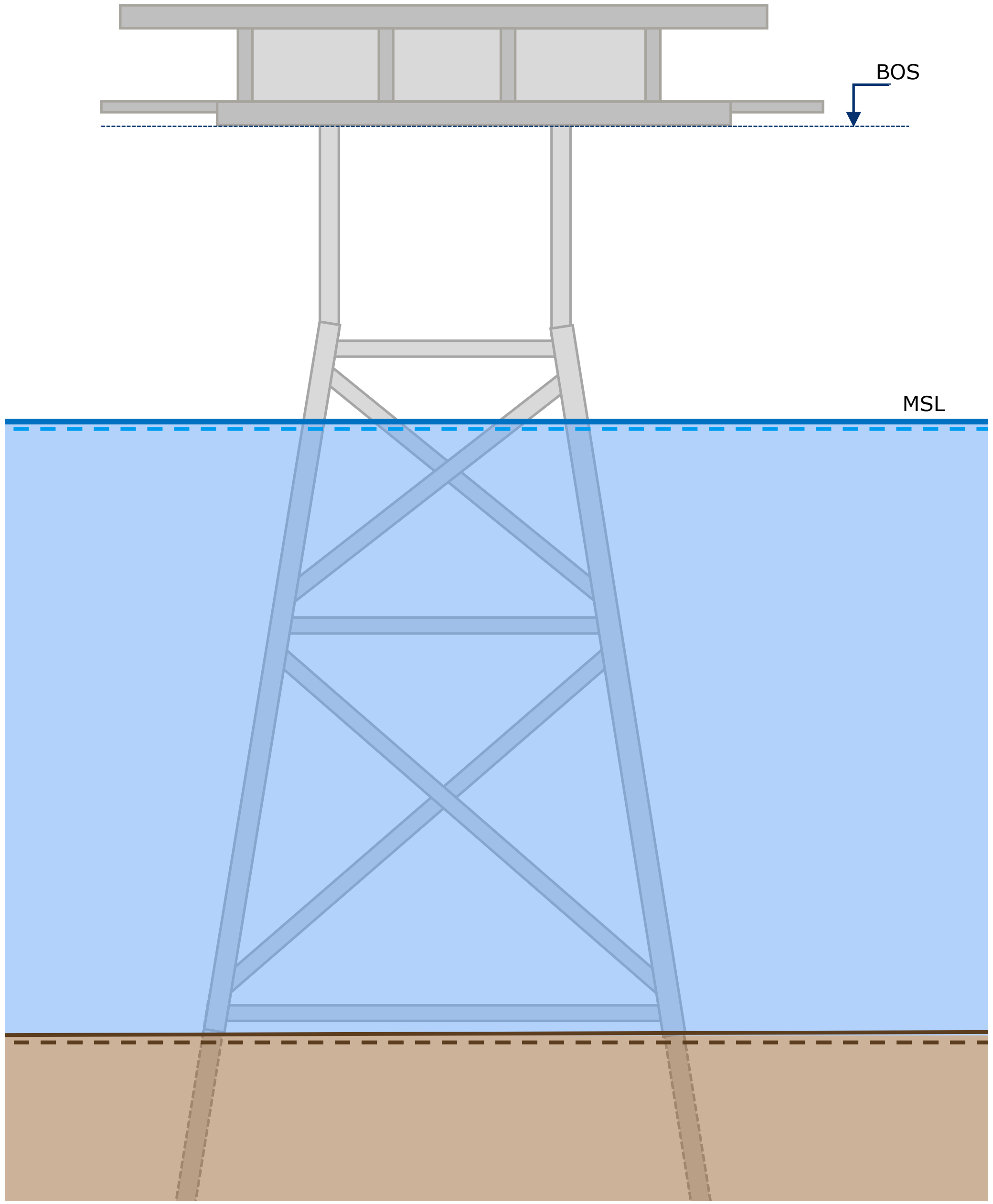
Objective

Give a wide overview of likelihood for wave-in-deck on Norwegian bottom fixed offshore structures

Scope of work

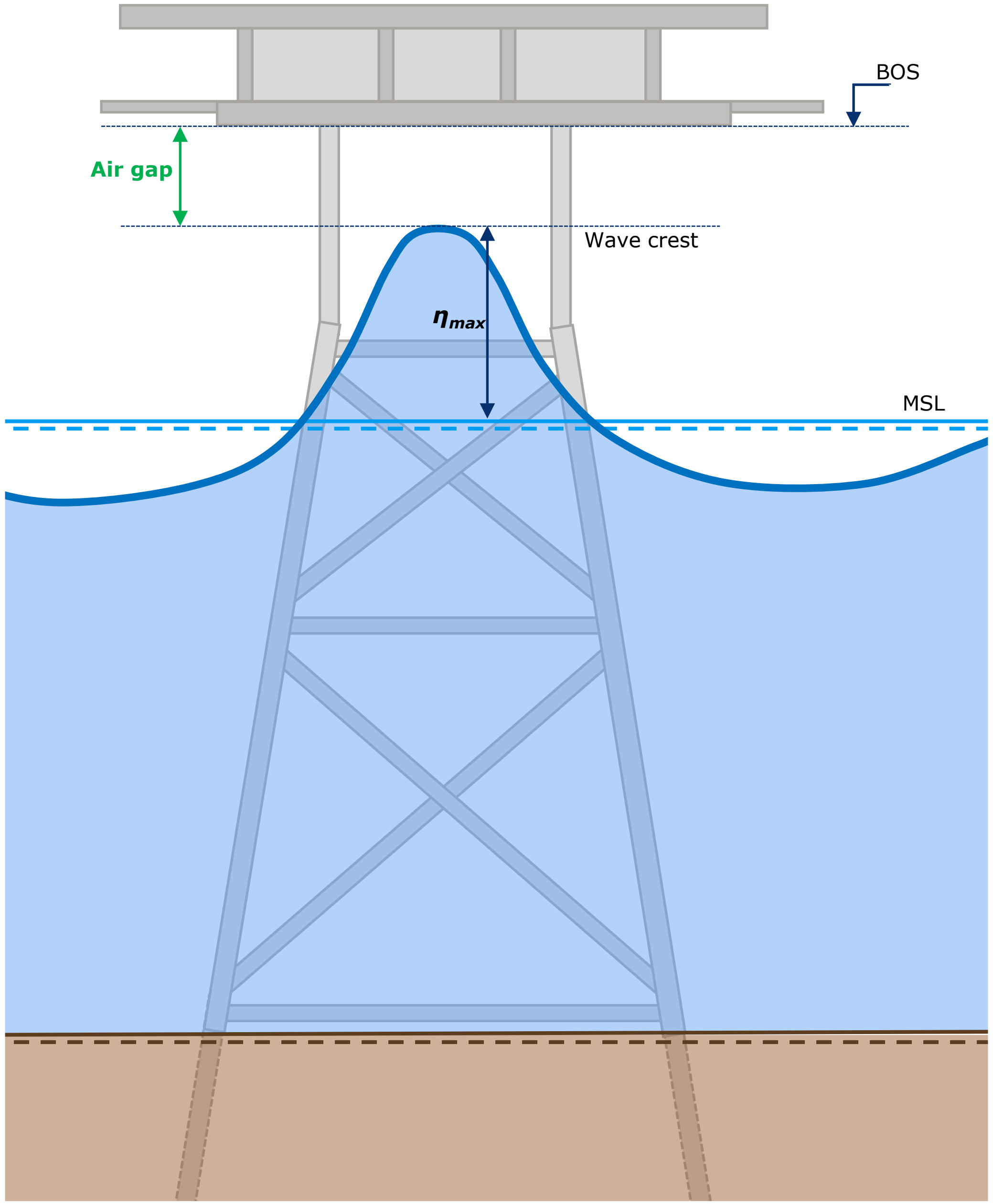
1. Calculation of wave crest elevation for 100-, 1,000- and 10,000 year return period
2. Collection of platform data and calculate platform topside air gap
3. Evaluate on different methods and compare against other projects and measured storm data

Wave crest height and topside air gap



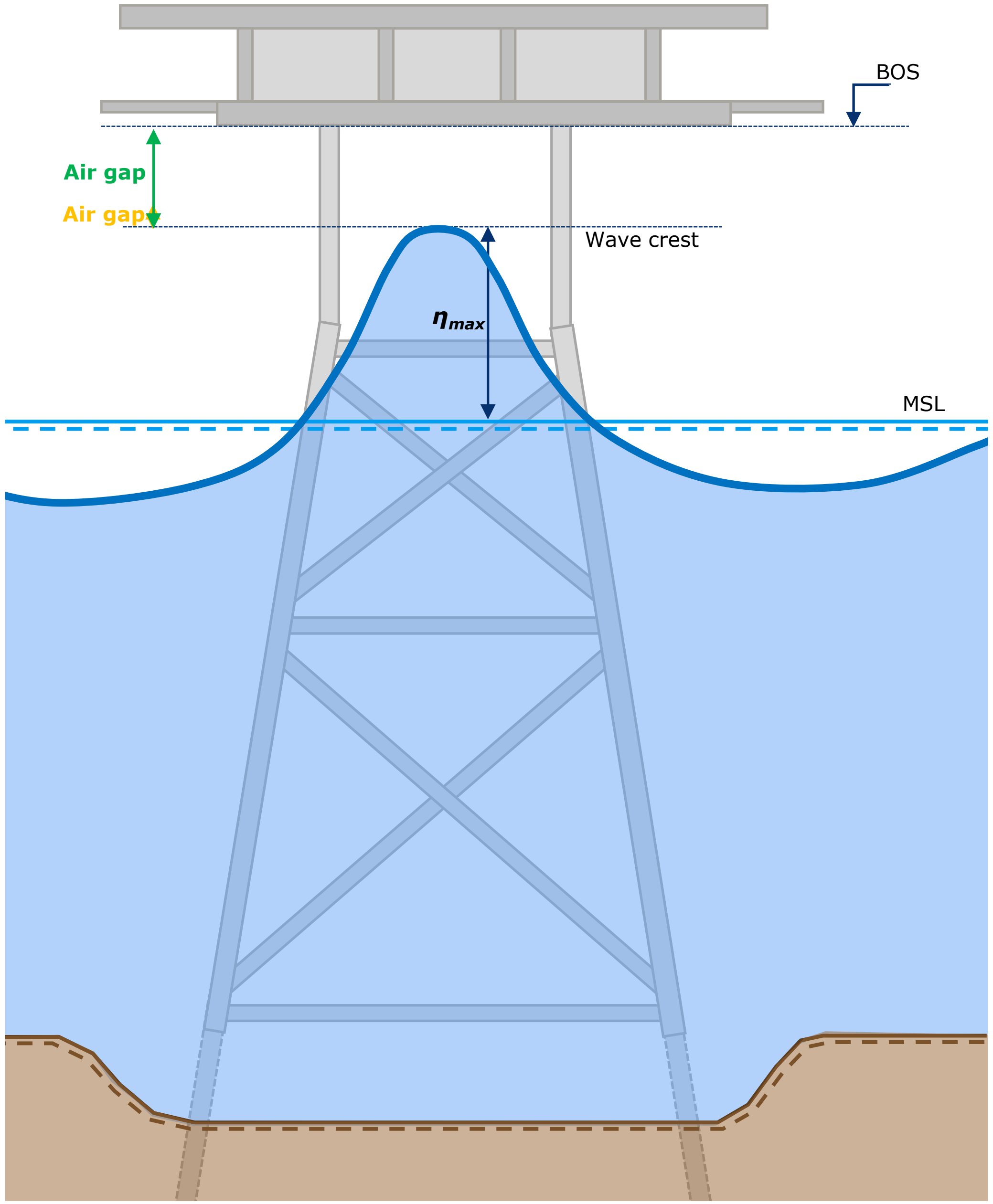
Wave crest height and topside air gap

1. Calculation of wave crest elevation



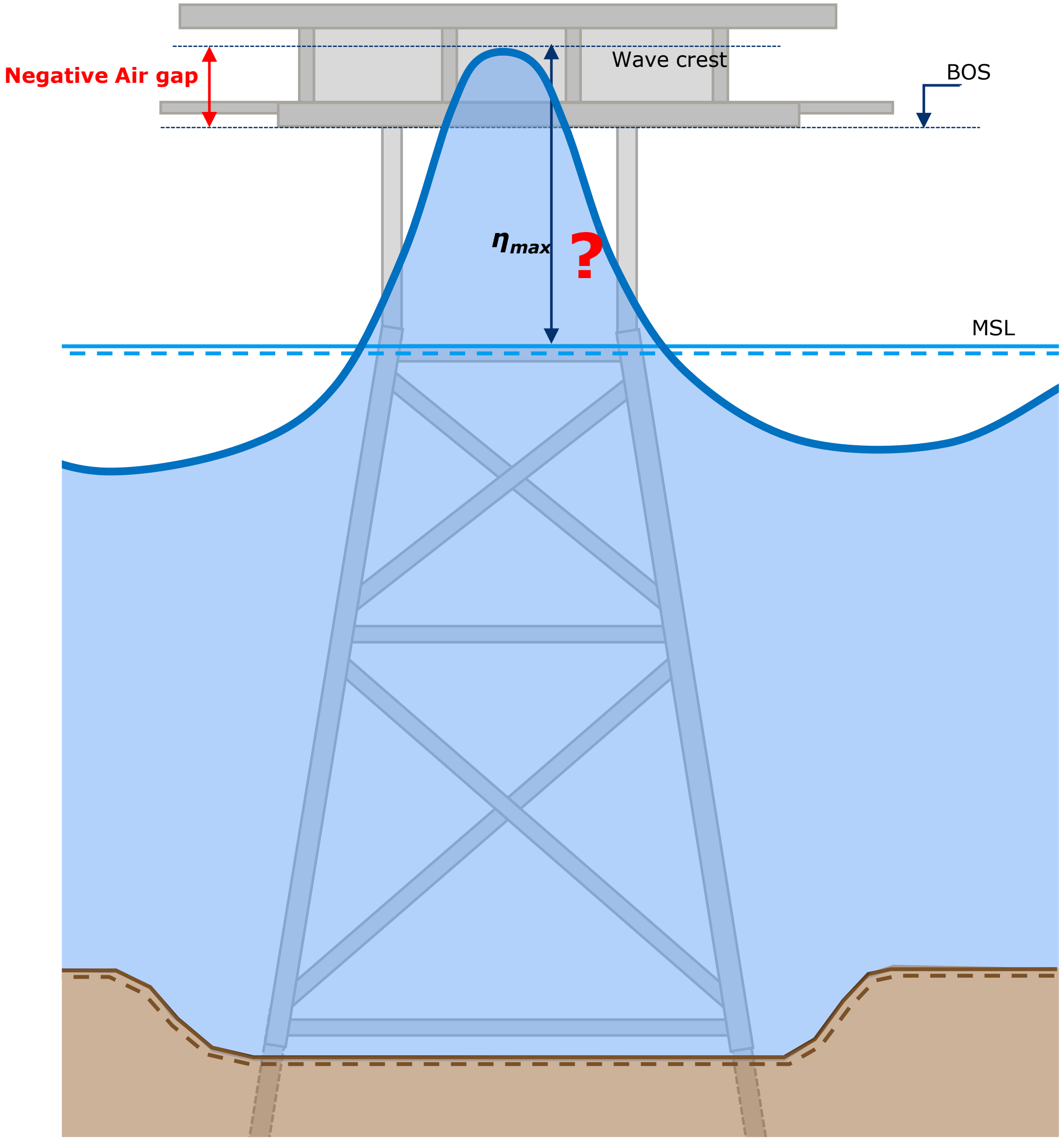
Wave crest height and topside air gap

1. Calculation of wave crest elevation
2. Taking into account subsidence



Wave crest height and topside air gap

1. Calculation of wave crest elevation
2. Taking into account subsidence
3. Extreme event



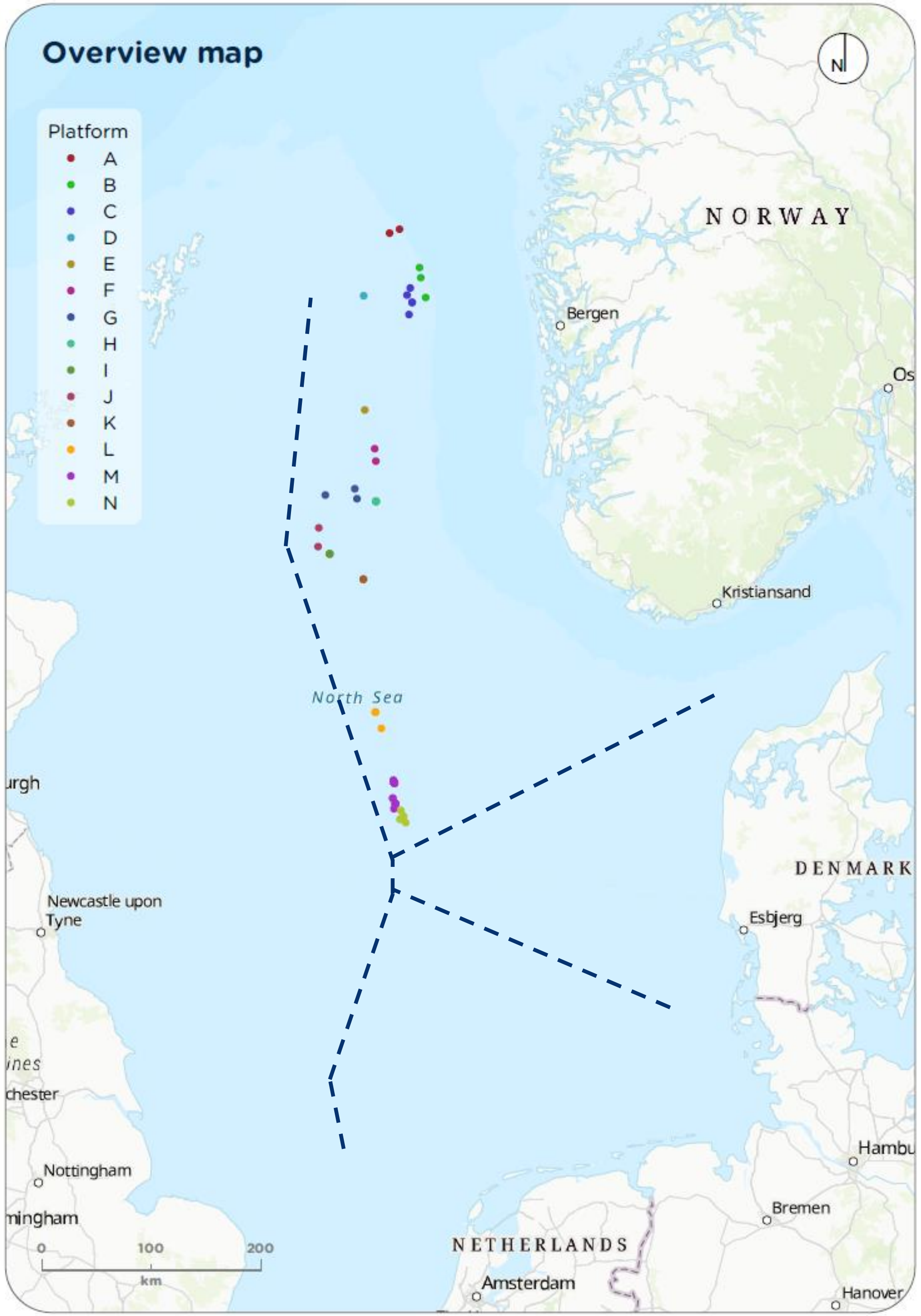
Platform Overview

- North Sea and Norwegian Sea
- In total 59 jackets in operation, split between 5 operators:

equinor	25
ConocoPhillips	19
AkerBP	13
vår energi	1
OKEA	1

PETROLEUMSTILSYNET

- Similar wave crest assessment has been done for platforms in Danish and British part of the North Sea.

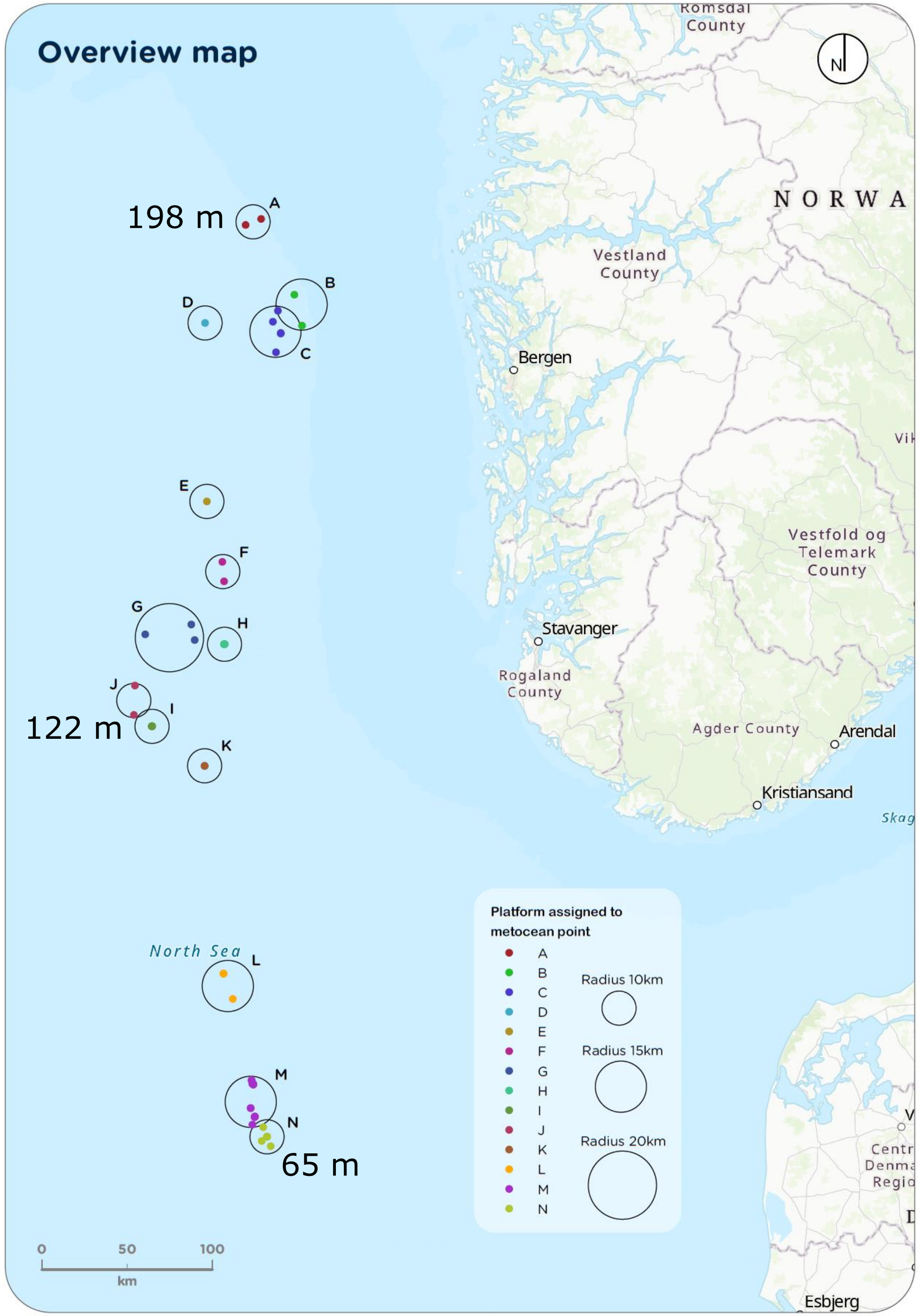


Metocean analysis

- 14 locations on water depth 65-198 m
- 10 methods for calculating elevations

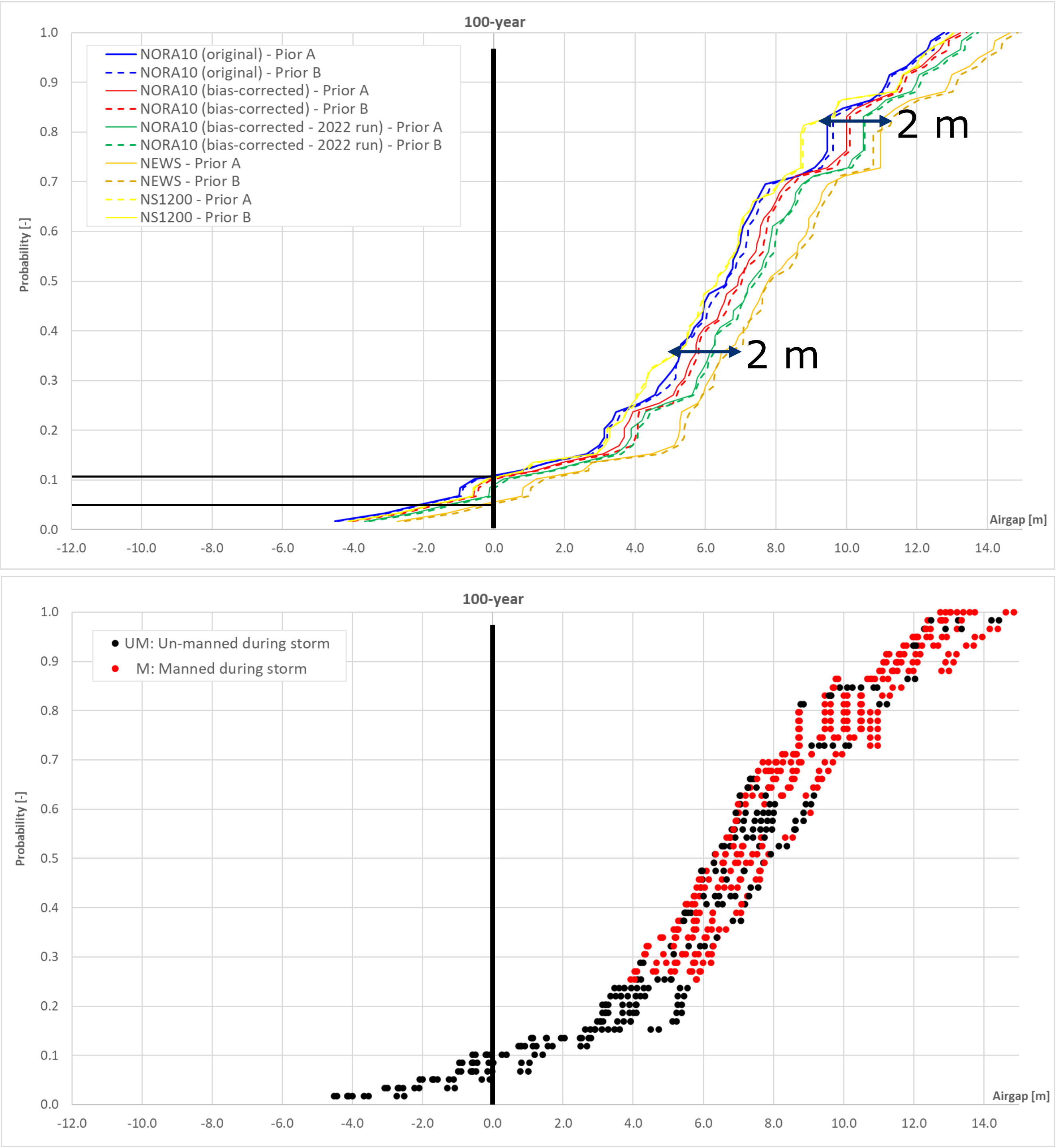
- Note that results are point-statistic results, i.e. for a platform assessment, e.g. point-to-area corrections should be considered to account for topside size.

- Combining results with platform data…



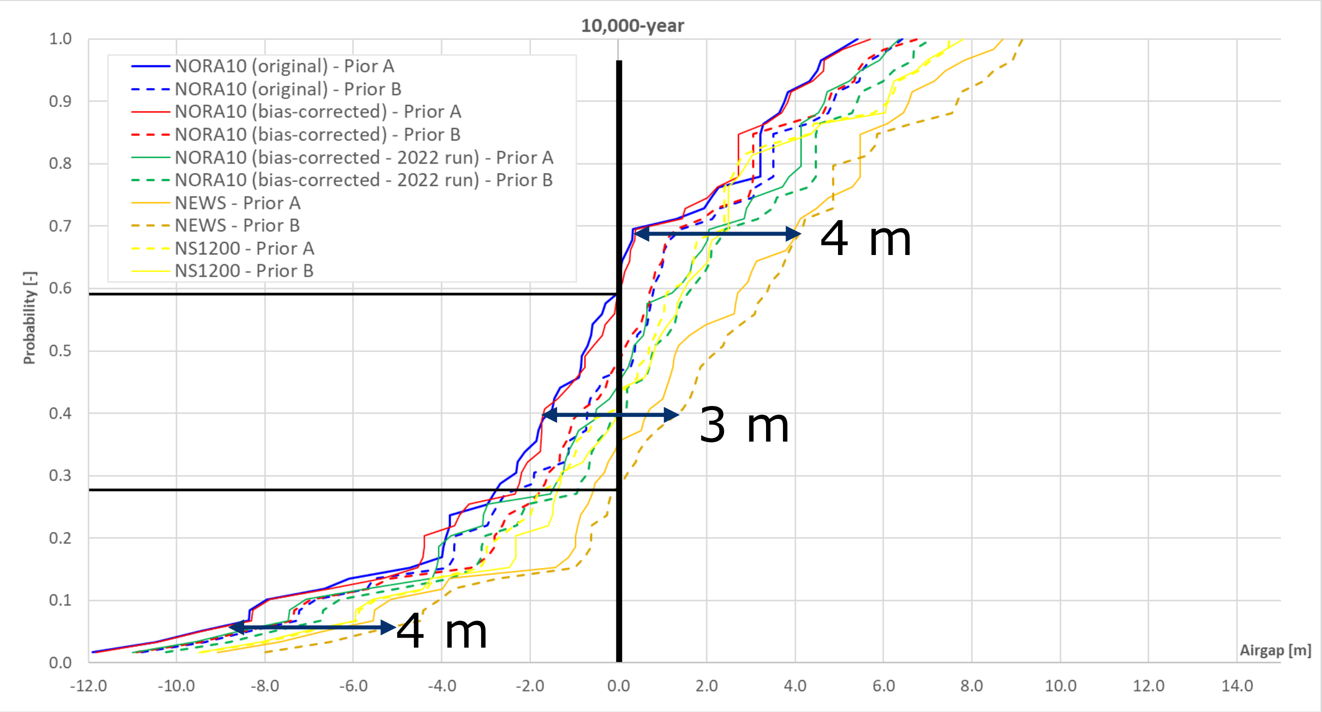
Air gap results – 100y

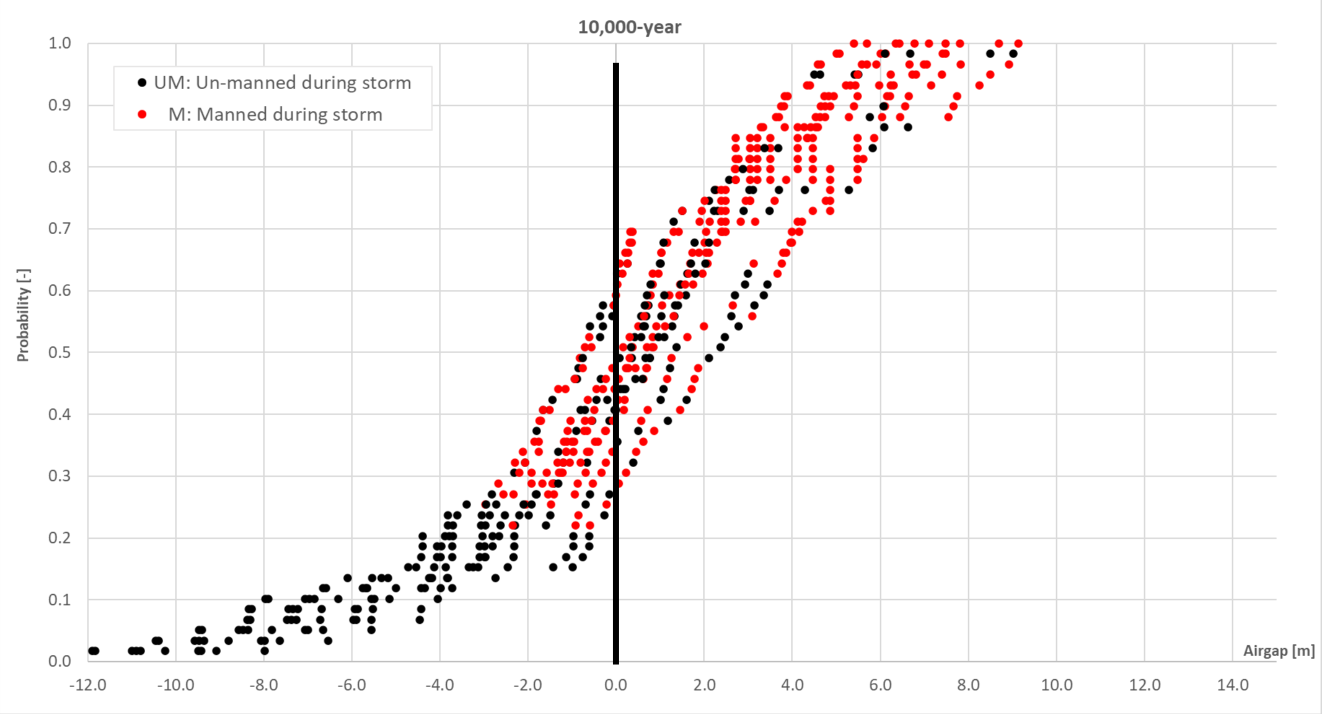
- One line for each metocean calculation method
- Results from the analysis method used varies approx. 2 m for all locations
- 5-10% of all platforms the anual probability for negative air-gap is higher than 10^{-2}
- All platforms with negative air gap are already planned to be un-manned during storms (Operator's inputs)



Air gap results – 10,000y

- Results from the analysis method used varies approx 3-4 m depending on the location
- For 25-60% of all platforms the anual probability for negative air-gap is higher than 10^{-4}
- Multiple platforms are planned manned during storm and is expected to have negative air gap for a 10,000-year occurance

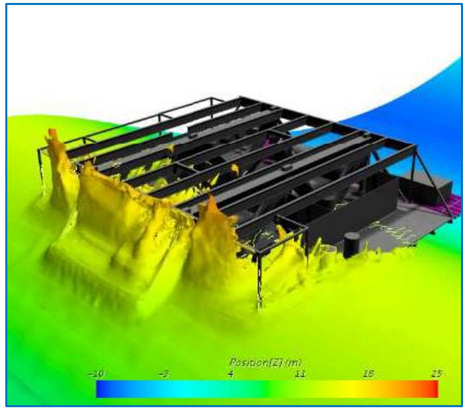
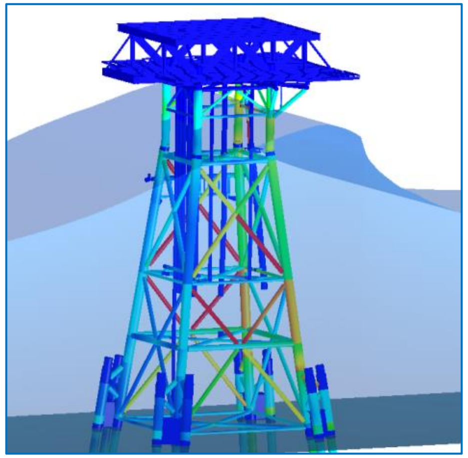


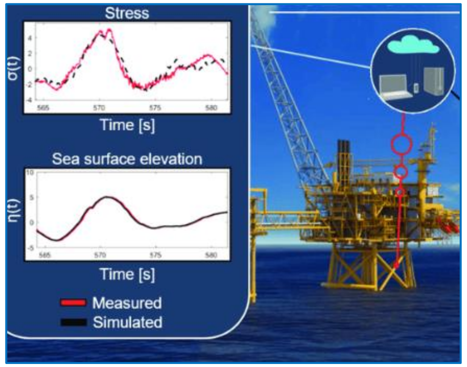


Critical?

- Acceptance criteria for the platforms will be different
- Wave-in-Deck load calculation
- Structural resistance evaluation
- Reinforcements
- Monitoring of platforms





Wave crest height calculation

Objective

Calculate wave crest elevation with return periods up to 10,000 years using latest best-practice

Scope of work

1. Calculate long-term sea state distribution using best-practice statistical methods
2. Convolve with higher-order wave crest height distribution
3. Assess sensitivity of end results

PTIL – WAVE-IN-DECK ASSESSMENT

CREST ELEVATION CALCULATIONS

1034-01-02-A

16 AUGUST 2023.

Revision	Author	Date
A	Hans Fabricius Hansen	16/08/2023

Long-term Maximum Crest Height Distribution

$$P(\eta_{c,max}) = \int_{\Omega} P\left(\eta_{c,max} \middle| \Omega\right) p(\Omega) d\Omega$$

where

$\Omega = \left(H_s, T_p, \dots\right)$: Sea state parameters

$P(\eta_{c,max}|\Omega)$: Probabilty distribution of maximum crest height conditional on sea state

$p(\Omega)$: Probability density of sea state parameters

Extreme value analysis of sea state distribution – Background

- Shell/Lancaster Univ. in 00'es:
  - Covariates (directional- and seasonal- rather than omni-distributions)
  - Generalised Pareto distribution tails (rooted in Extreme Value Theory)
  - 'Extrapolation' uncertainty acknowledged and included
- Shell/Lancaster approach adopted by:
  - Mærsk Oil (Tyra as-is/AWARE) (2015-)
  - LOADS JIP (2016-)
  - UK HSE (Extreme wave study – 2020-2022)
  - bp (2019-)
  - Aker BP (Valhall)
  - TotalEnergies (2021-)

Crest height distribution – Background

- Field data / basin tests analysed
  - JIP’s (CresT -> ShorTCresT -> LOADS)
  - Maersk Oil/TotalEnergies (Tyra as-is/AWARE)
- Conclusions
  - Higher order effects increase crest heights beyond Forristall’s second order distribution
  - Wave breaking reduces crests in severely breaking sea states
  - Uncertainty in measurements
- Number of updated crest height distributions developed
  - LOADS JIP Unified crest height distribution (Swan, Karmpadakis)
  - LOADS JIP OCG distribution (Gibson, 2021)
  - Schubert/Jonathan (2020) (AWARE)

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Work Description – Input

- Long time series of H_s, T_p, etc. required for extreme value analysis
  - NORA10 hindcast
    - Meteorologisk institutt Norge - 65 years hindcast 1957-2022
  - NEWS hindcast
    - Ocean Weather hindcast 1979-2022
  - NS1200 synthetic simulation
    - Climate model simulation of 1200 years worth of present climate

Work Description – Extreme Value Analysis

- Extreme value analysis using SAM JIP code

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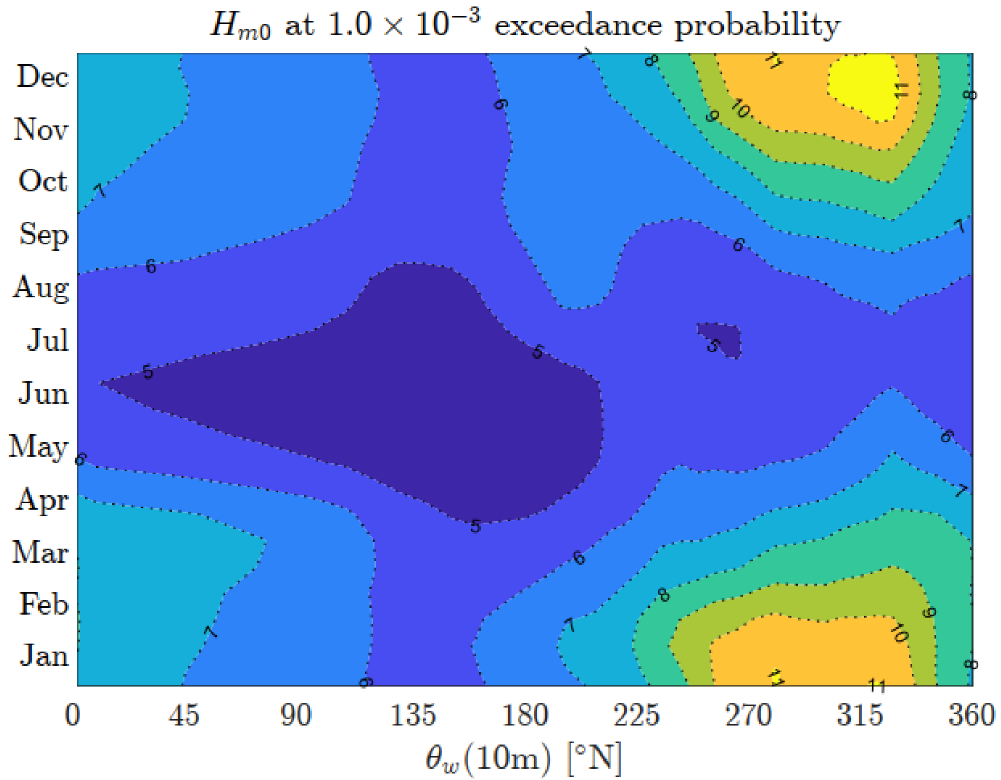
    -> Directional and seasonal covariates



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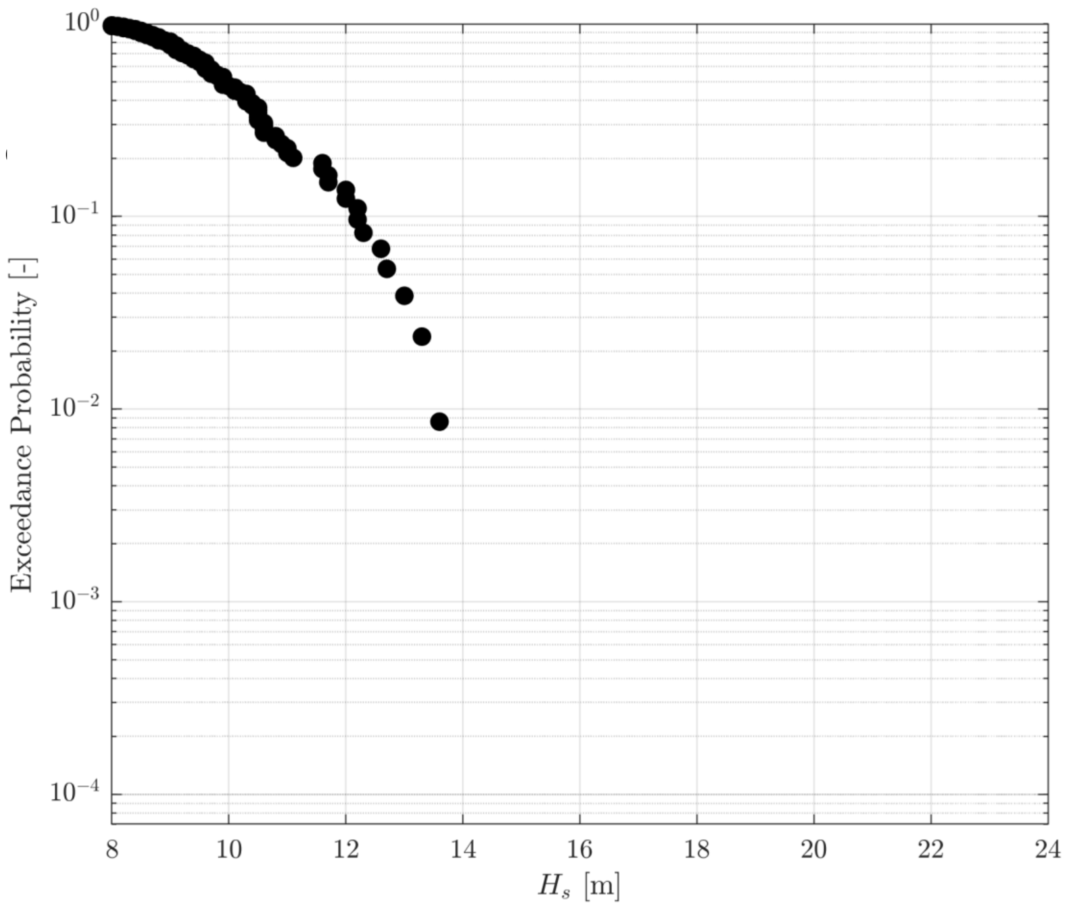

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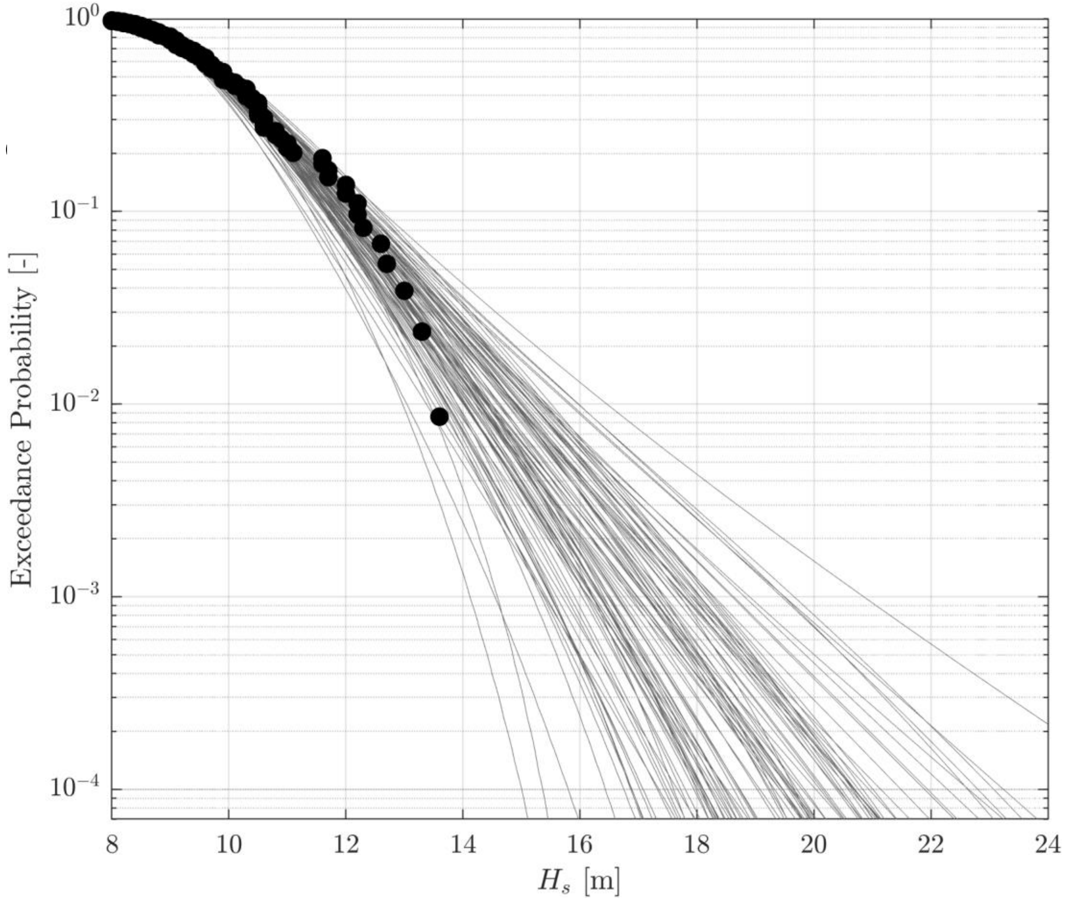

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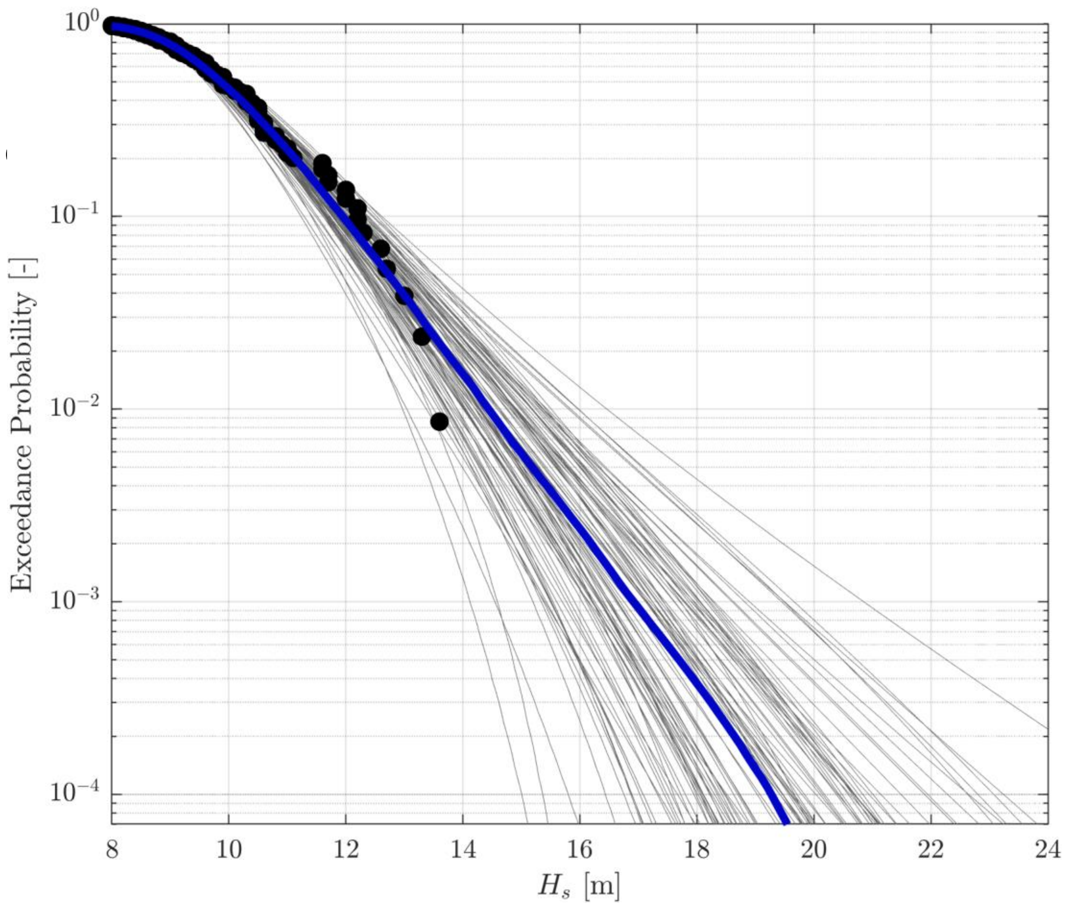

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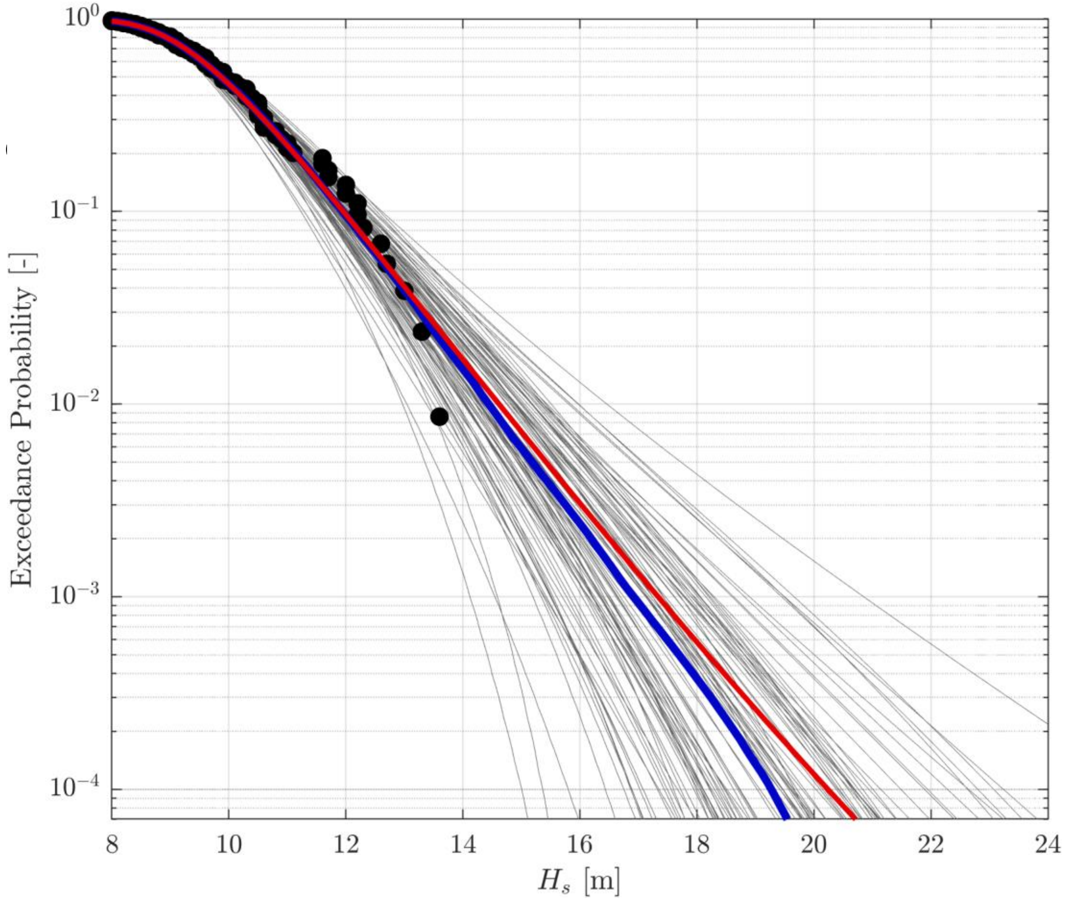

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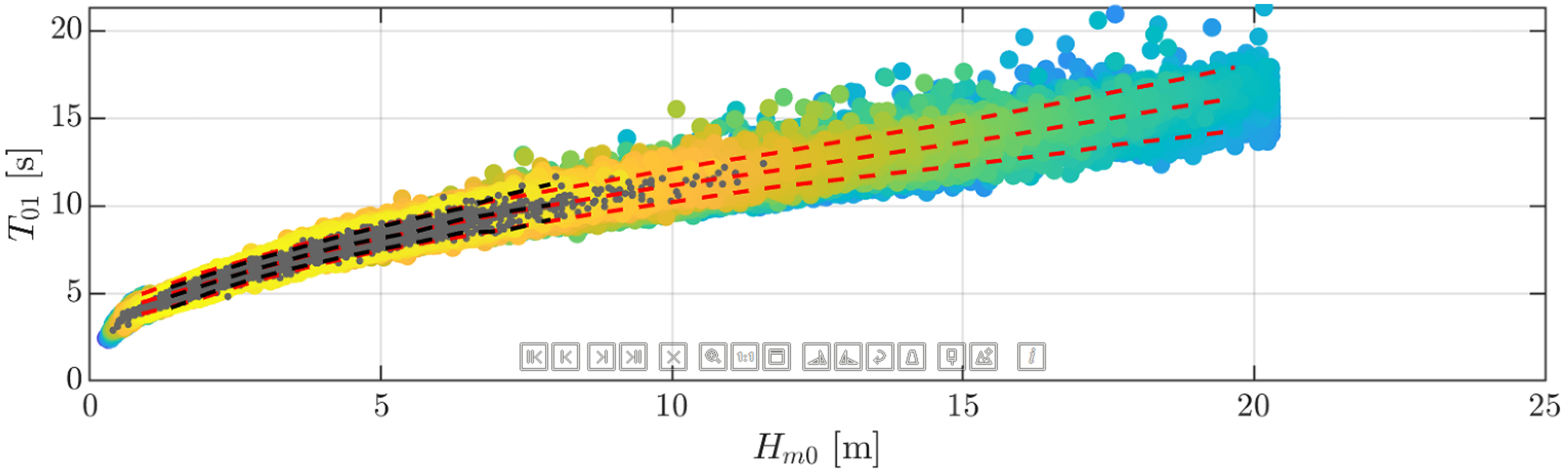

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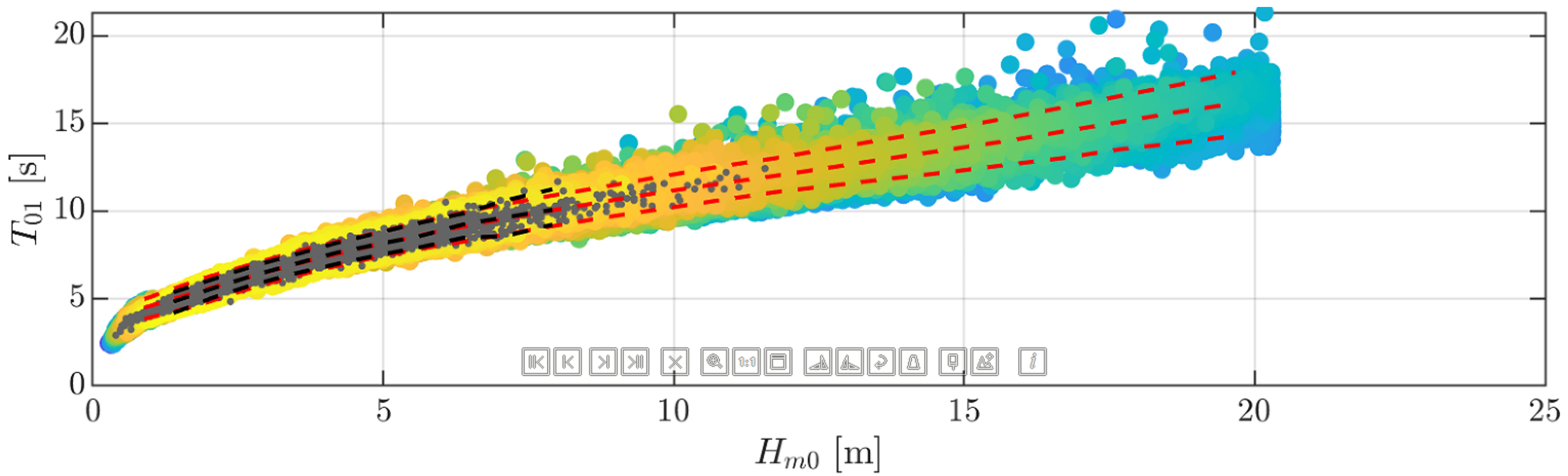
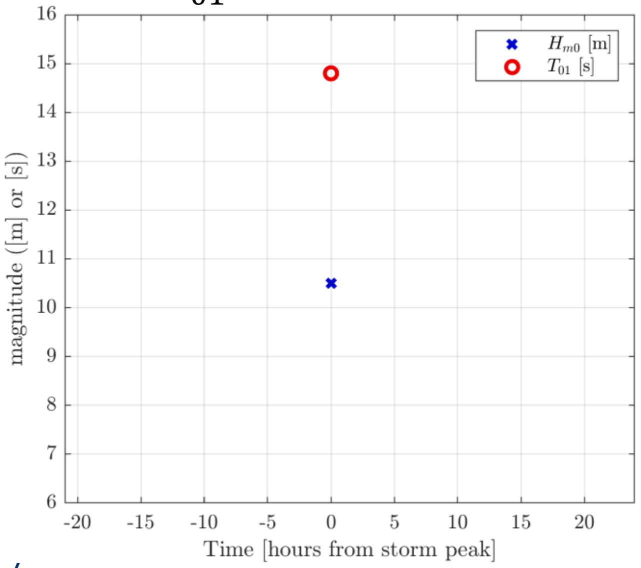


Work Description – Extreme Value Analysis

Storm event with:
$H_{m0} = 10.5m$
$T_{01} = 14.9s$



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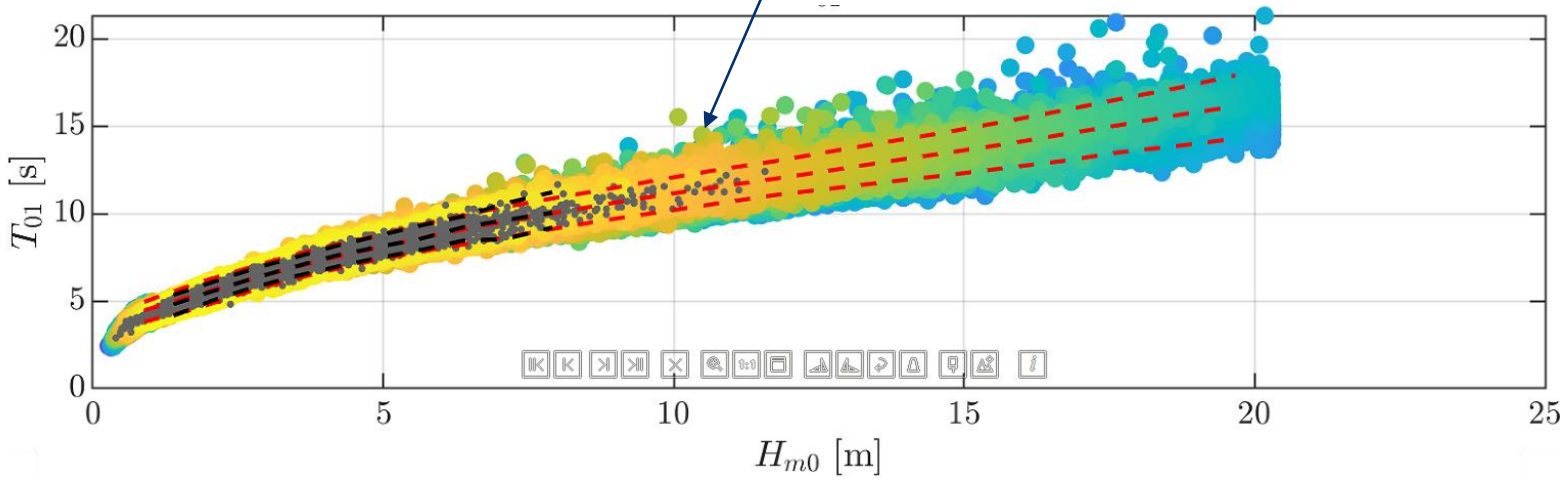

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Storm event with:
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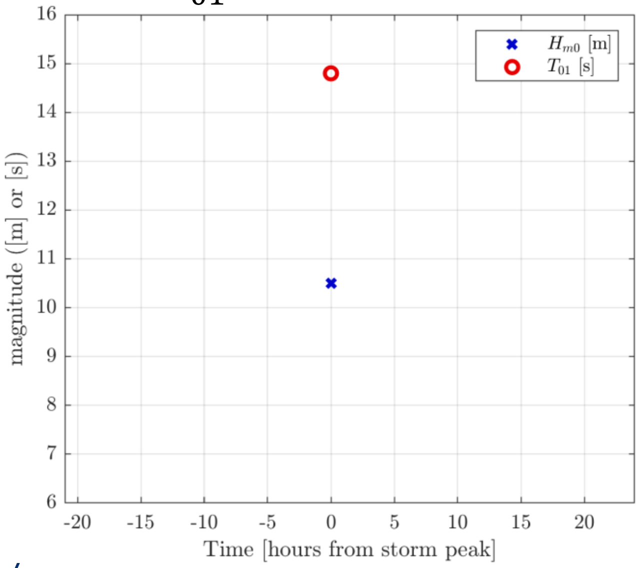

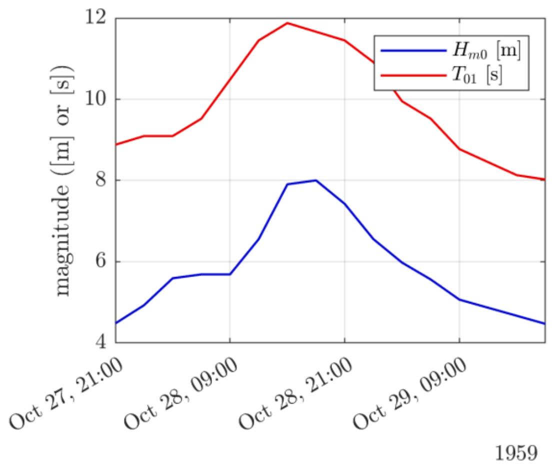

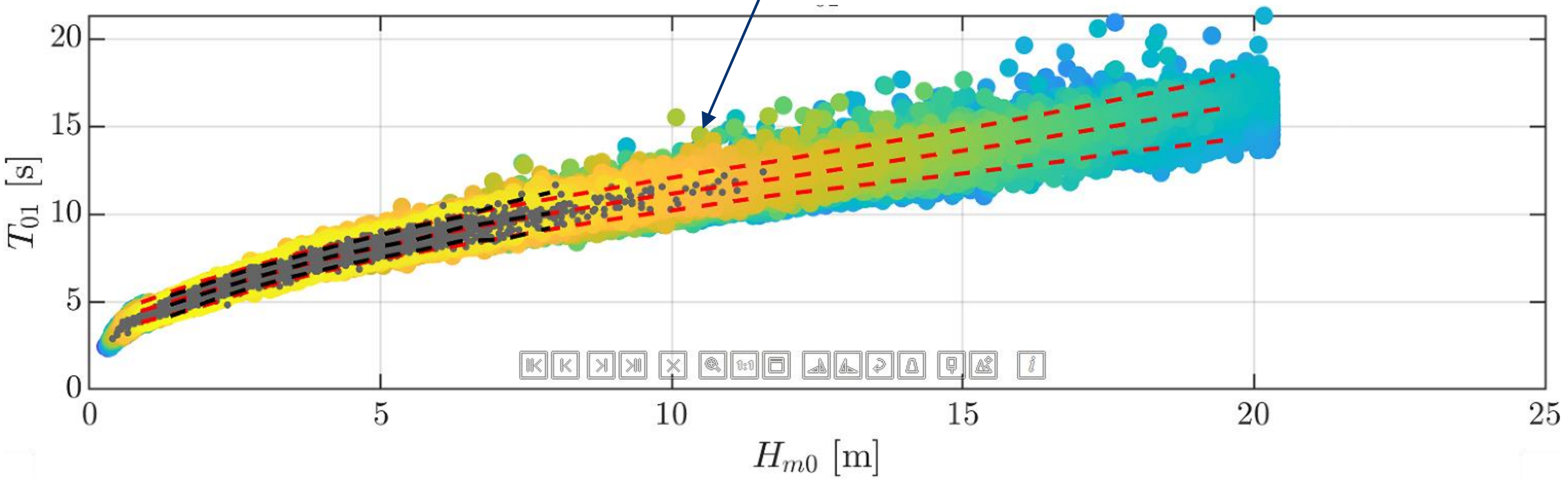

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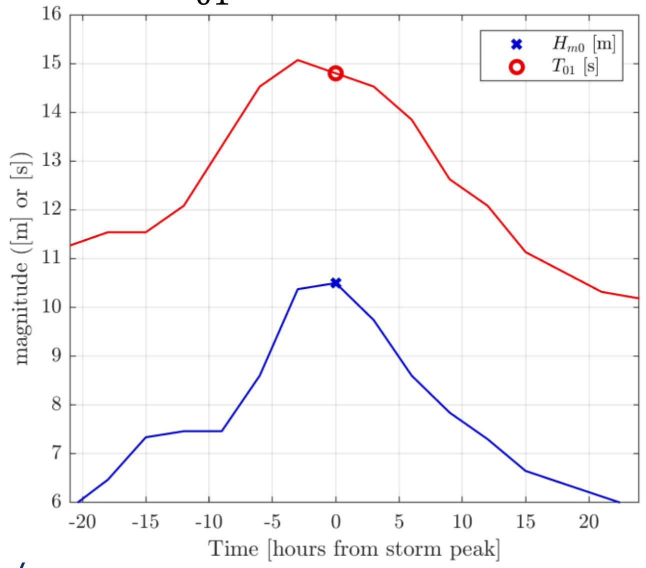

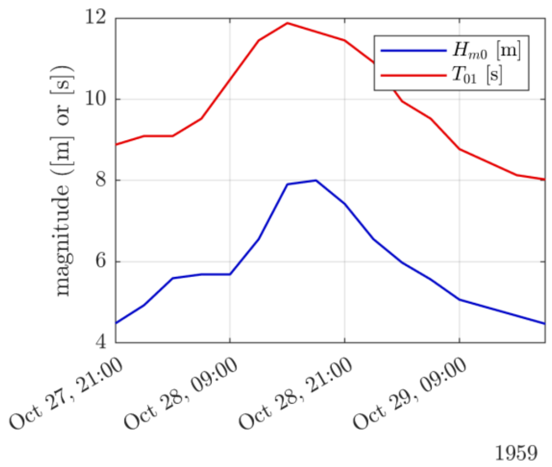

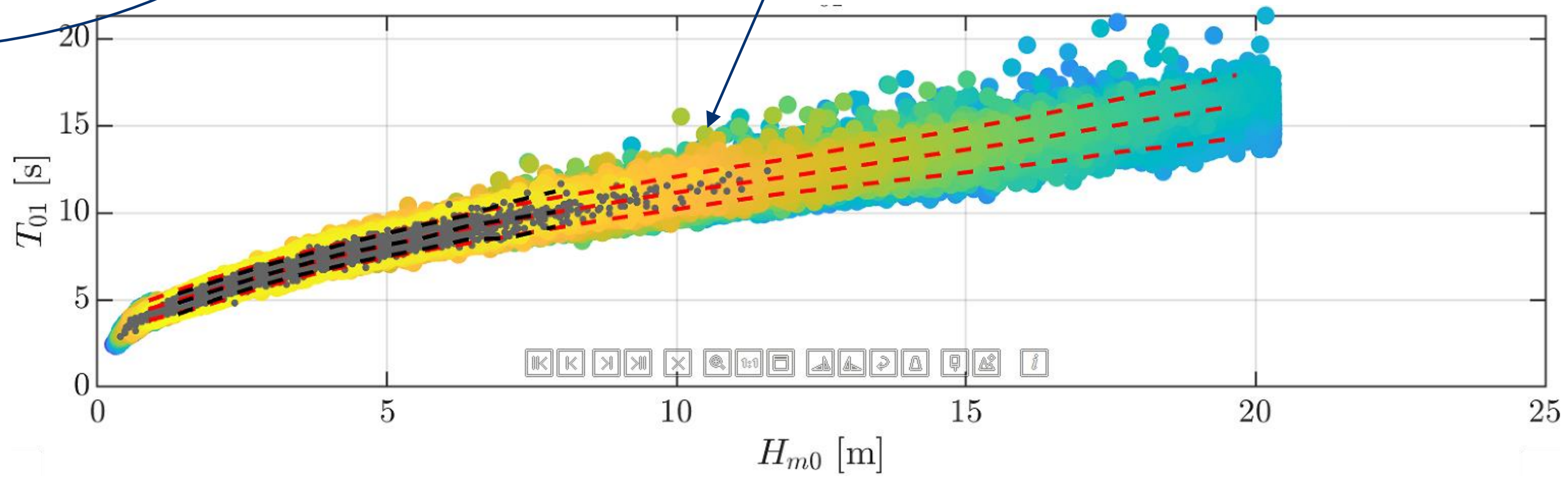

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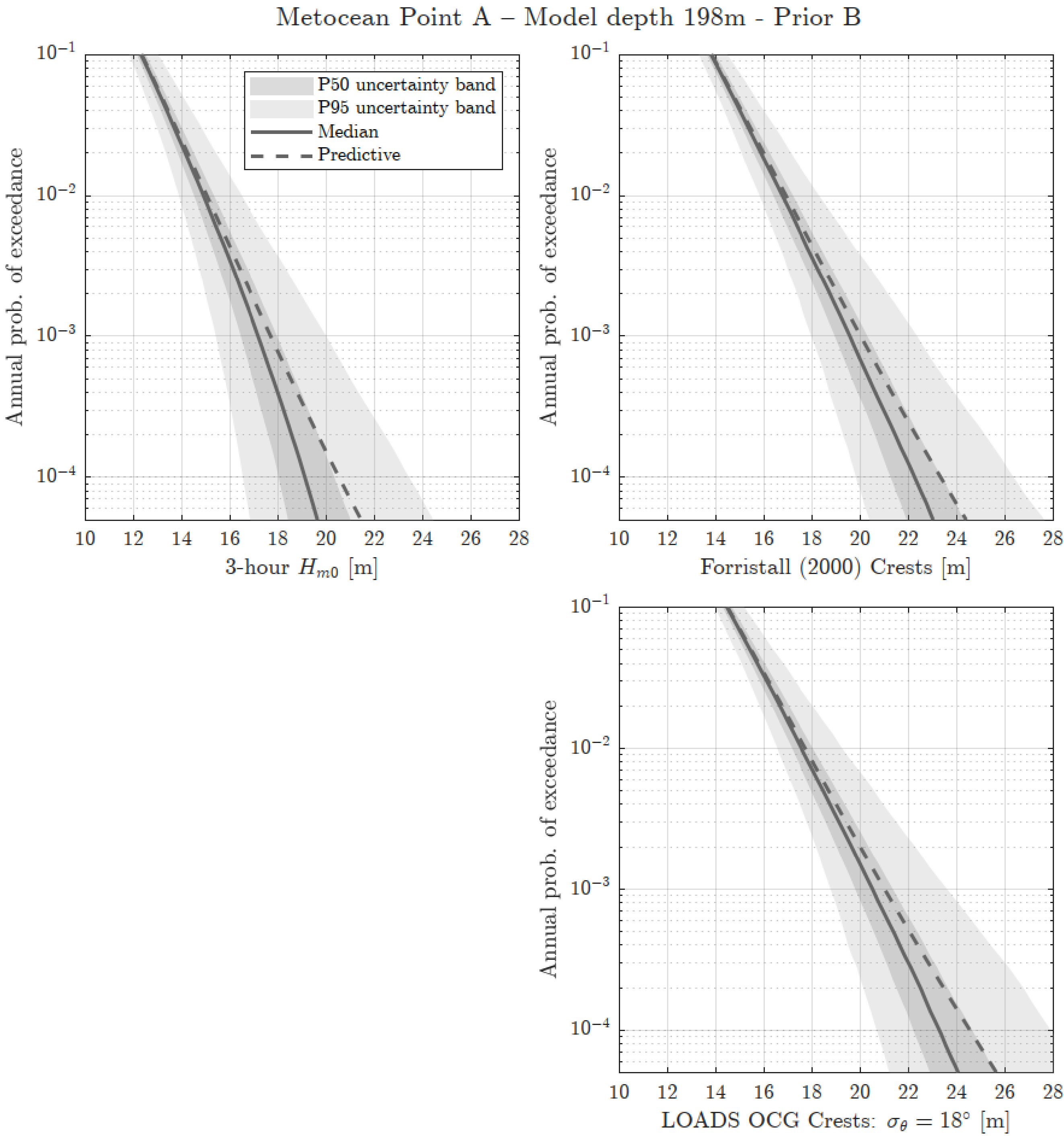
  - Storm ‘trajectory’ sampling to model evolution of storm events
    - Historical storms matched and rescaled
  - Sea state maximum crest height sampled from parametric crest height distribution $P(\eta_c|H_{m0}, T_{01}, \sigma_\theta, d)^N$

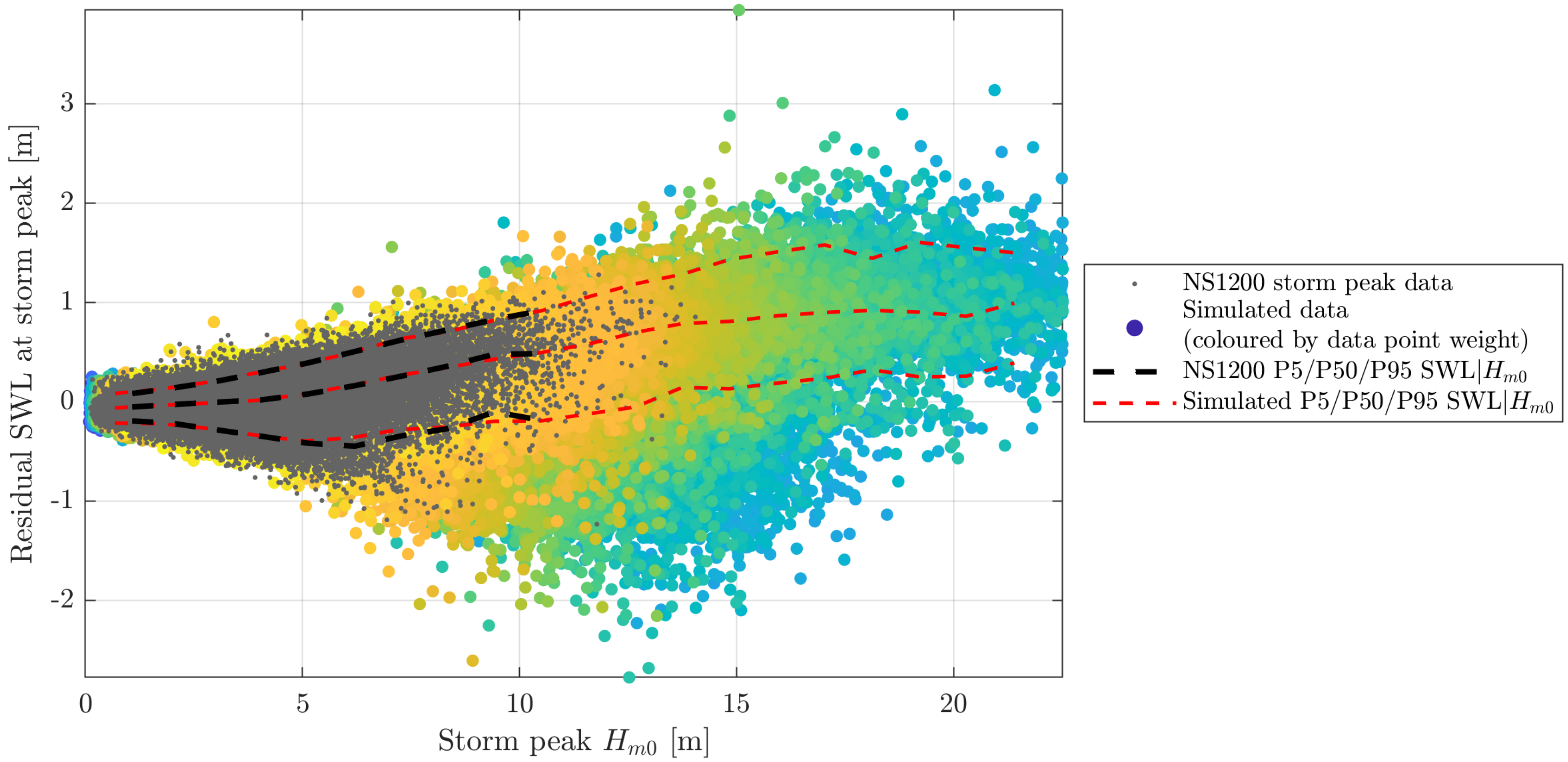
Work Description – Extreme Value Analysis

- Folding with short-term distributions
  - Forristall distribution (for reference)
  - LOADS OCG distribution



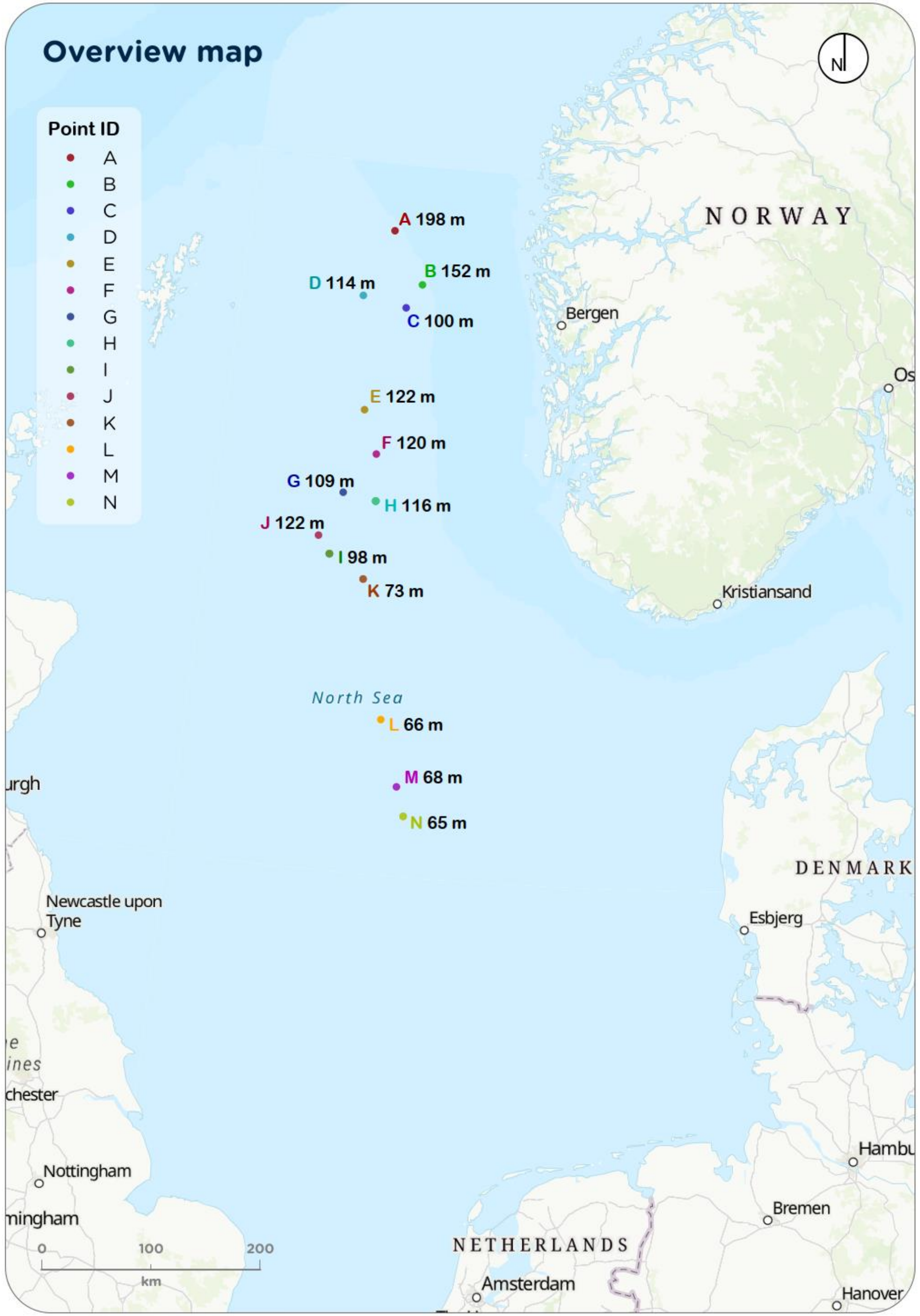
Extreme Value Analysis – Associated storm surge

- Storm surge can correlate with waves -> extra contribution to total water level

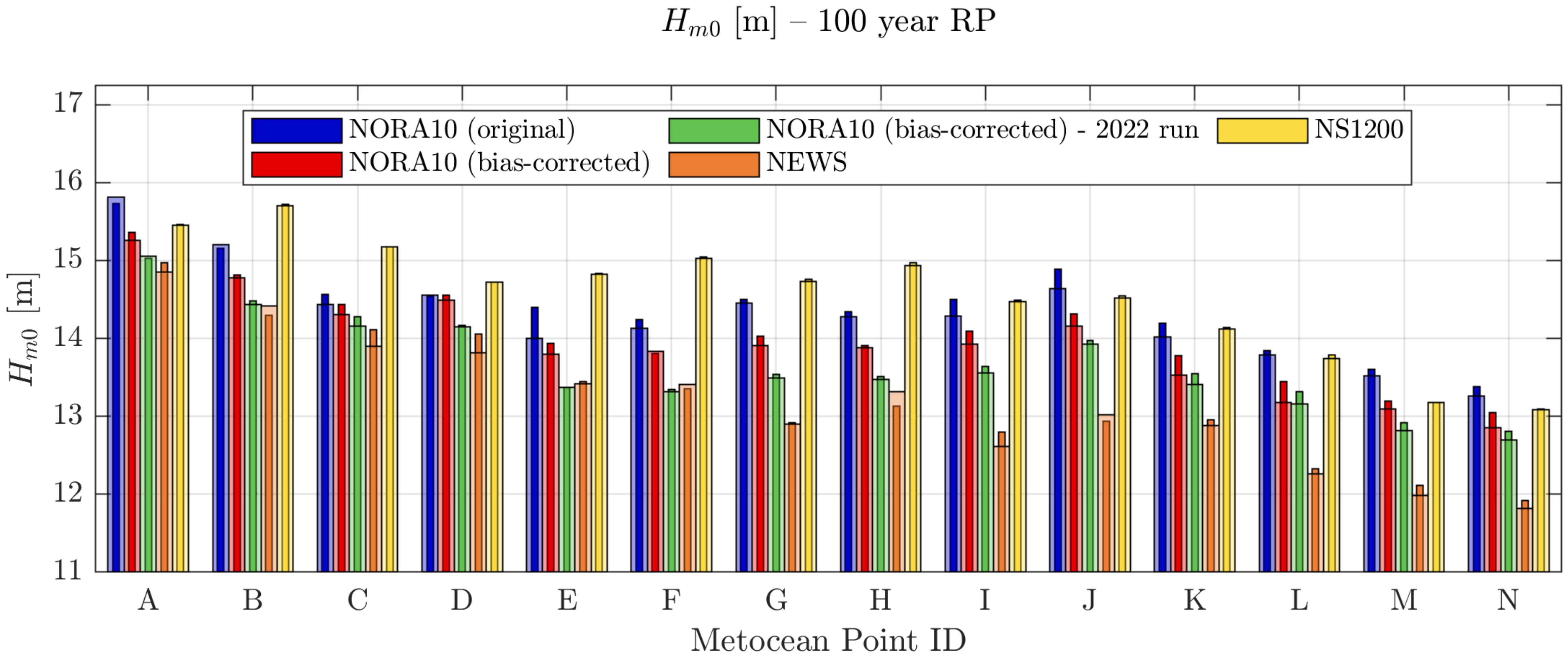


Results

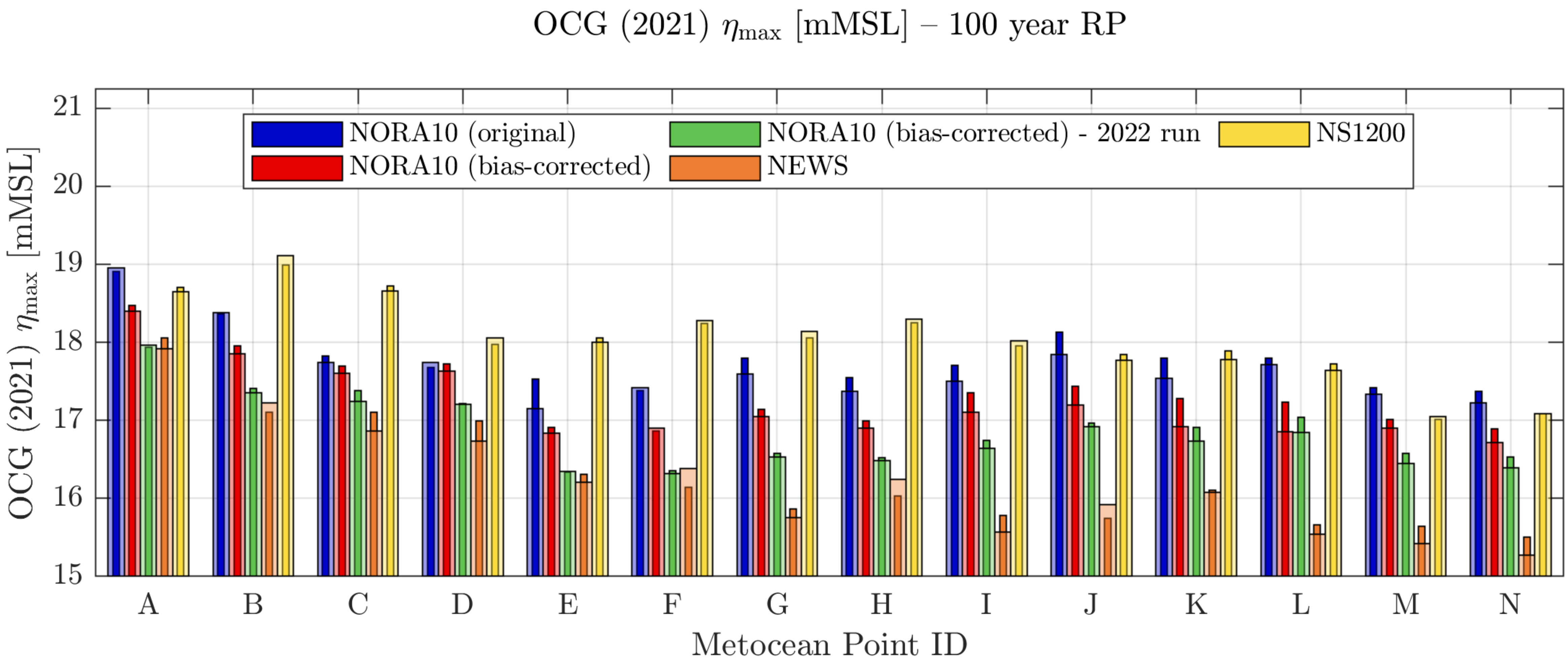
- Analysis at 14 points
- 10 different results at each point
  - 5 different data sets
  - 2 different priors



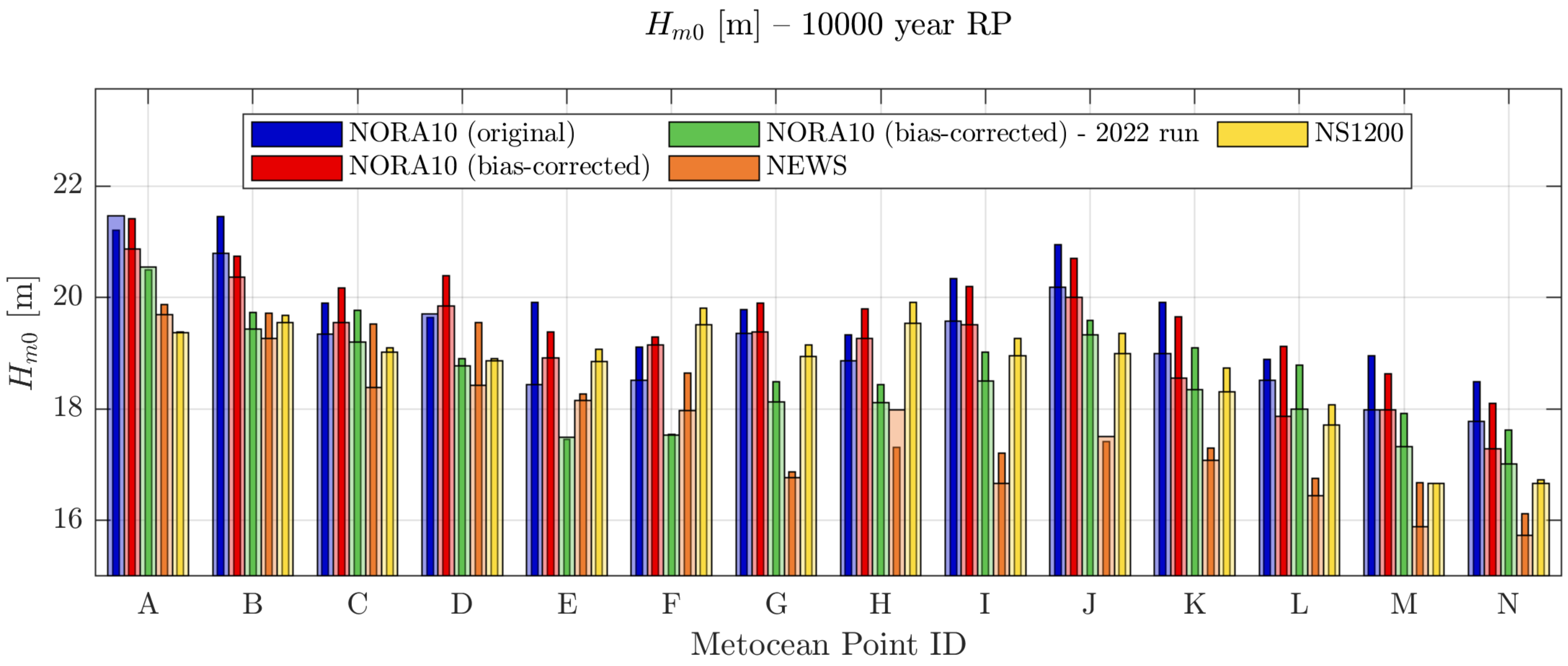
Results – 100 year H_{m0}



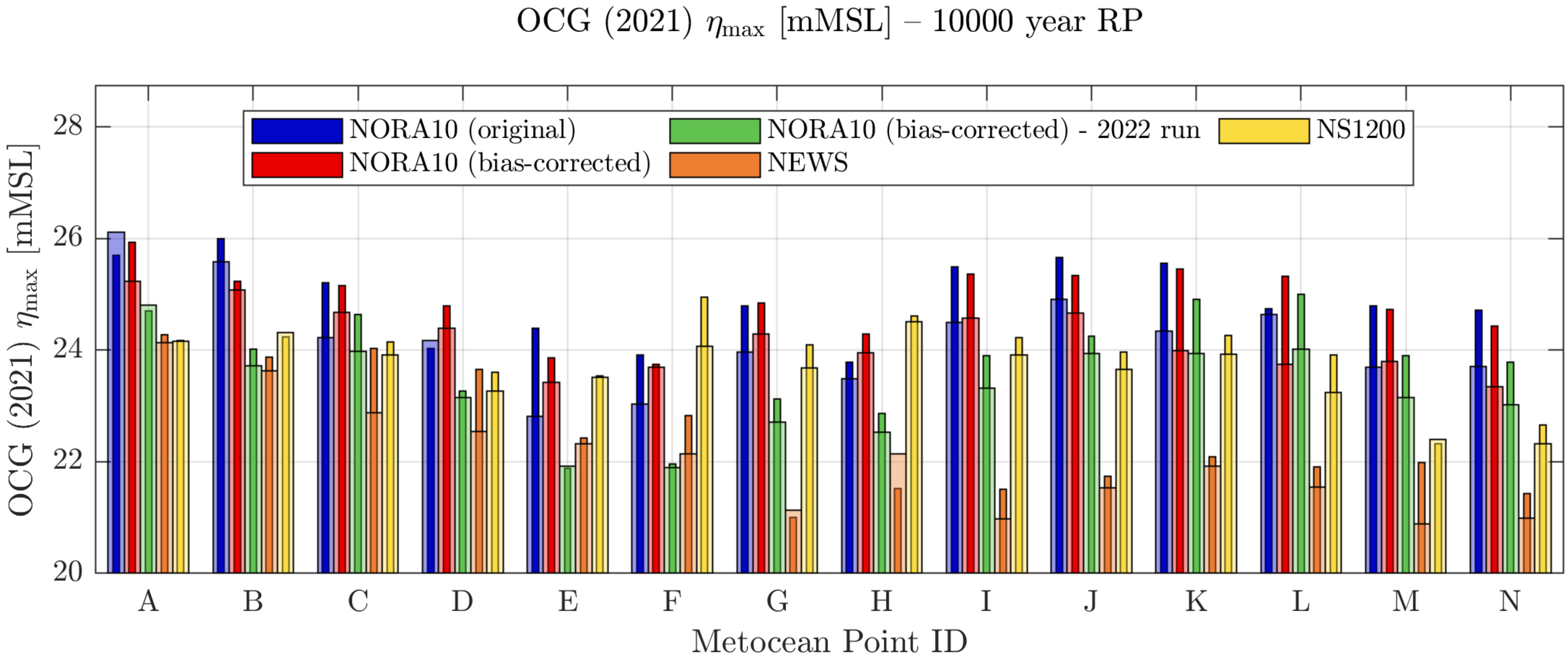
Results – 100 year crest elevation



Results – 10,000 year H_{m0}



Results – 10,000 year crest elevation



Conclusive remarks

- Range of 100 year crest elevation estimates (min-max) from 1.0 to 2.5 meter
- Range of 10,000 year crest elevation estimates (min-max) from 2.0 to 4.5 meter
- Differences due to
  - Input data differences
  - Extrapolation (priors, data set length)
- Uncertainties included
  - Extrapolation (threshold, parameter) uncertainty
  - LOADS OCG crest height distribution uncertainty
- Uncertainties not included
  - Measurement uncertainty and bias (field and basin)
  - Input data uncertainty (hindcast scatter)

Thank you!

Palle Teis Nielsen

Senior Structural Engineer
Marine Structures
Ramboll Energy

D +45 51617320

pltn@ramboll.com

Hans Fabricius Hansen

Senior Metocean Engineer
HAW MetOcean ApS

D +45 61710362
hfh@haw-metocean.com

Questions?