Metocean inputs to foundation design: Focus on fatigue/normal conditions

FoundationEx conference

Florent Guinot, Wood Thilsted, May 2022

WOOD THILSTED IS A SPECIALISED OFFSHORE WIND ENGINEERING CONSULTANCY, EXPERIENCED IN OFFSHORE WIND DEVELOPMENTS FROM PROJECT EXPLORATION TO OPERATION, DESIGNING THE GLOBAL ENERGY TRANSITION.

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Agenda

- Introduction to Normal Sea States
- Normal Sea State – Example
- Normal Sea State – How to refine them ?
- Conclusions

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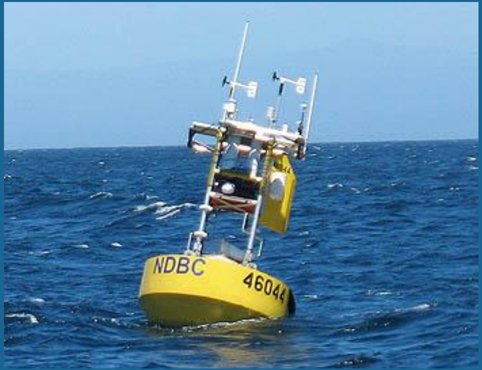
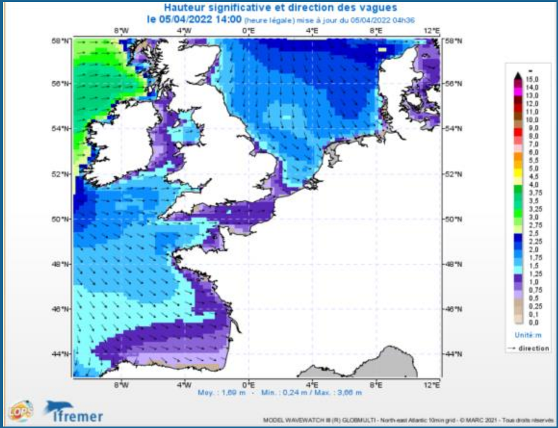
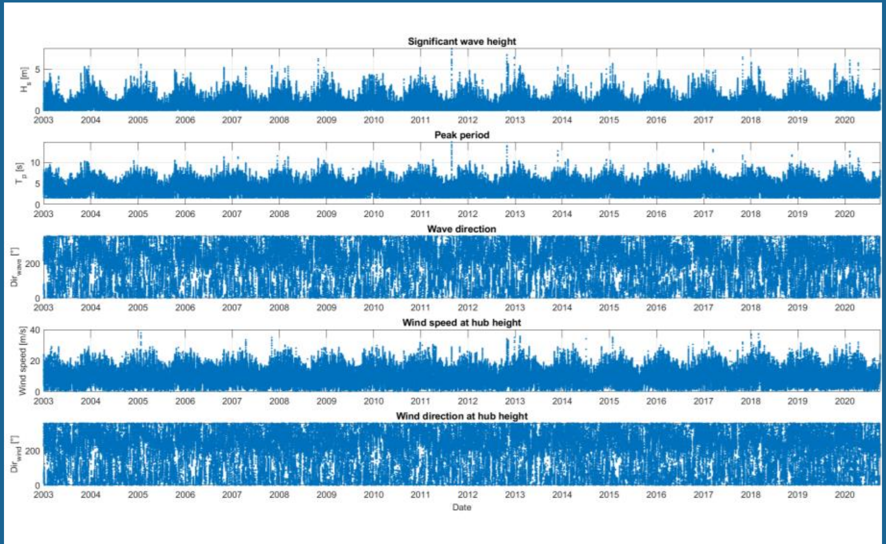
Introduction





Measurements + models allow to get years of metocean data



And then ?

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Introduction – Normal Sea States

Long term time-series needs to be synthetized in a **limited** and **representative** DLC list.
Usually this is done by defining **Normal Sea States.**
=> one single (Hs,Tp) couple per wind bins (wind speed, wind direction).

DNVGL-ST-0437 Edition
November 2016

2.4.4.1 Normal sea state

The *normal sea state (NSS)* is characterised by a significant wave height, a peak period and a wave direction. It is associated with a concurrent mean wind speed. The significant wave height $H_{S,NSS}$ of the normal sea state is defined as the expected value of the significant wave height conditioned on the concurrent 10-minute mean wind speed. The normal sea state is used for calculation of ultimate loads and fatigue loads. For fatigue load calculations a series of normal sea states shall be considered, associated with different mean wind speeds. It shall be ensured that the number and resolution of these normal sea states are sufficient to predict the fatigue damage associated with the full long-term distribution of metocean parameters. The range of peak periods T_P appropriate to each significant wave height shall be considered. Design calculations shall consider a sufficient number and resolution of normal sea states to account for the fatigue damage associated with the full long term distribution of metocean parameters. Alternatively they may be based on values of the peak period which result in the highest loads or load effects in the structure.

IEC 61400-3-1:2019

6.3.3.2.2 Normal sea state (NSS)

The significant wave height, peak spectral period and direction for each normal sea state shall be selected, together with the associated mean wind speed, based on the long-term joint probability distribution of metocean parameters appropriate to the anticipated site.

For fatigue load calculations, the designer shall ensure that the number and resolution of the normal sea states considered are sufficient to account for the fatigue damage associated with the full long-term distribution of metocean parameters.

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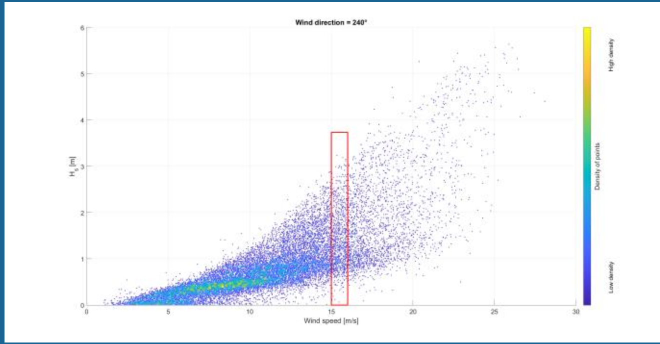
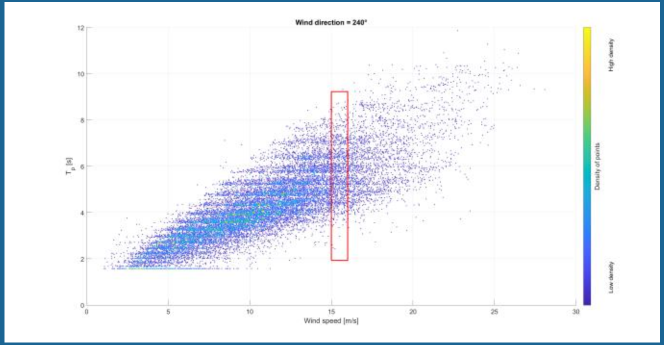
Normal Sea State – Example

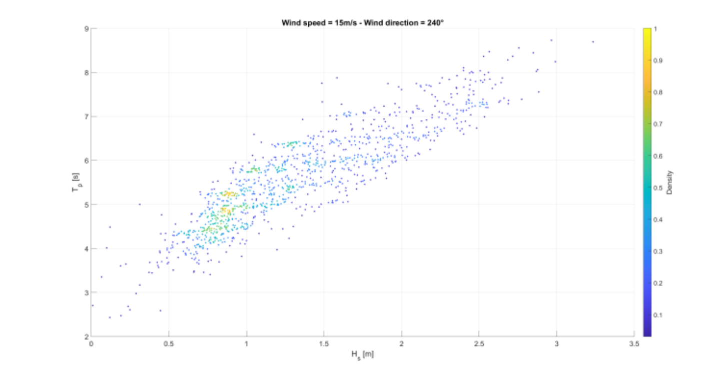
Variability of Hs for one wind bin



Variability of Tp for one wind bin



Variability of (Hs,Tp) couples for one wind bin



How to define a representative (Hs,Tp) considering all the variability?

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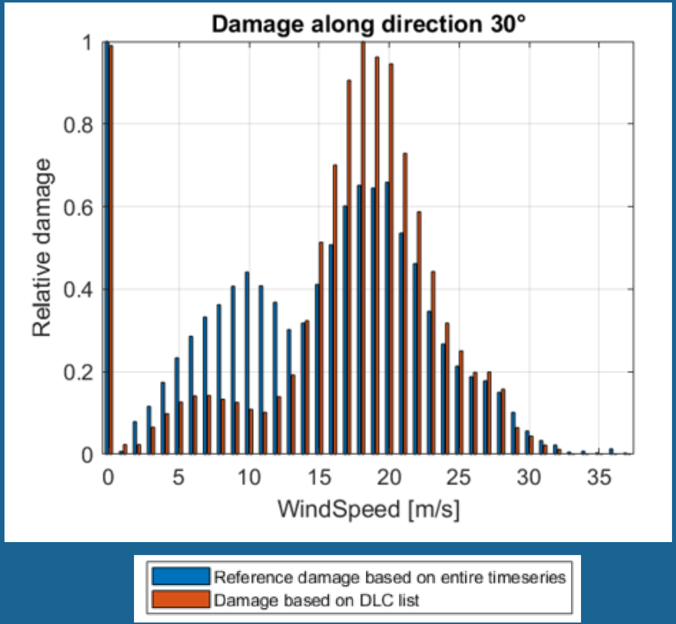
Normal Sea State - Example

Normal sea states purely based on environmental considerations can lead to strongly inaccurate damage estimations (which hopefully will compensate at the end !).

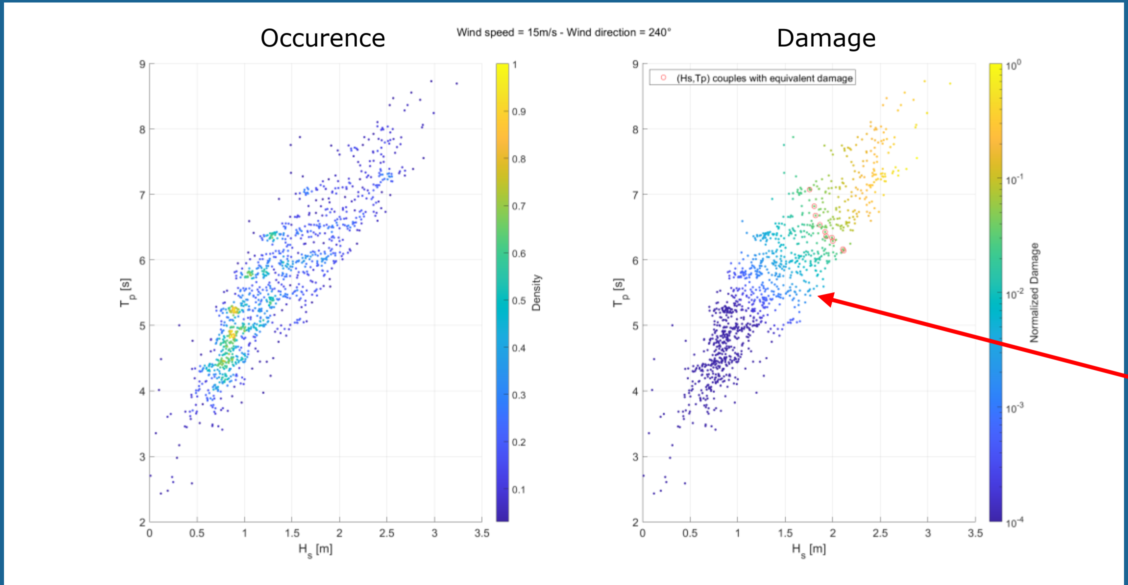


=> Necessity to account for system sensitivity to define normal sea states representative of damage

Normal Sea States – Refinement

How to define a representative (Hs,Tp) considering all the variability?

When the **system/context is simple**, it is possible to define “damage equivalent (Hs,Tp) couples”
- either from dedicated simulations (e.g. Katsikogiannis,2022)
- or from theoretical considerations (e.g. Seidel, 2014)



Some % of difference in Hs and or Tp can lead to several dozens of % in damage, especially when looking at values near the natural frequency of the system.

In this example, associating a “correct” representative Hs with the median Tp would only allow to represent 10% of damage (and in other cases it can be overly conservative)

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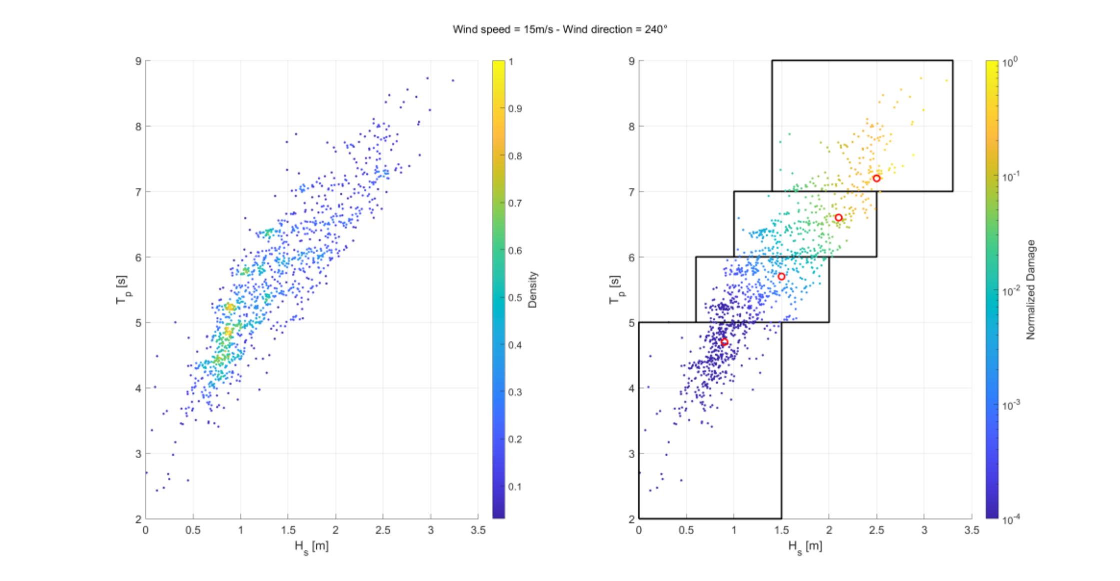
Normal Sea States – Refinement

How to define a representative (Hs,Tp) considering all the variability **when the system/context is not simple** ?

- Subsytems with different natural frequencies (e.g. floating wind turbines)
- Sea states not wind dependent with important misalignments (damage contribution to different structure orientation when waves are coming for different directions for one wind bin)



The only way to consider such situation is to refine the lumping strategy and not consider a single normal sea state per wind bins.

Each wind bin can be divided in several wave bins with their own representative characteristics (Hs, Tp, direction, occurrences…)

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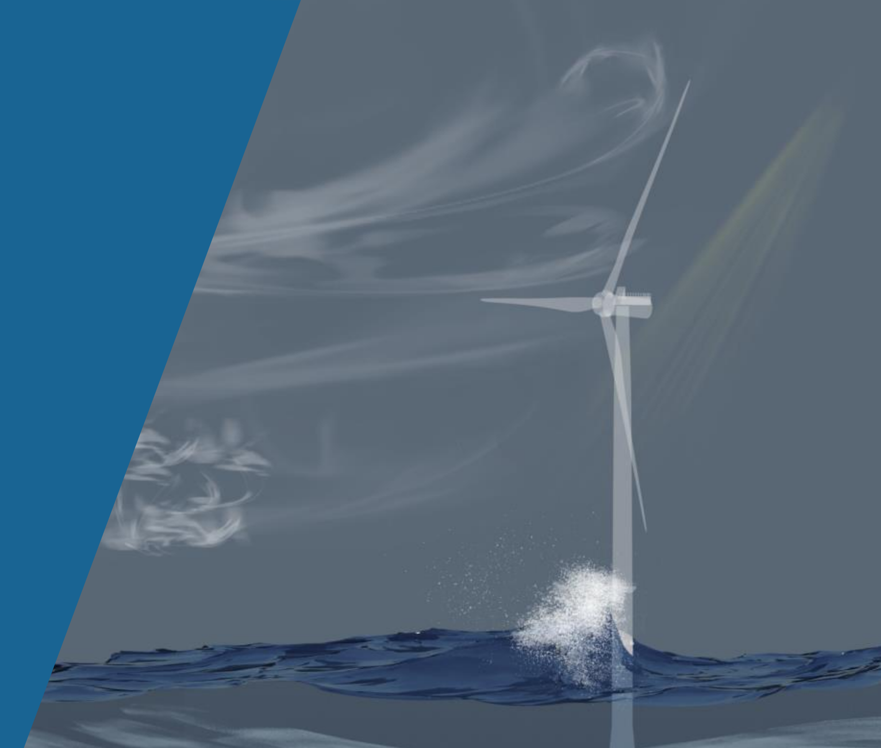
CONCLUSIONS

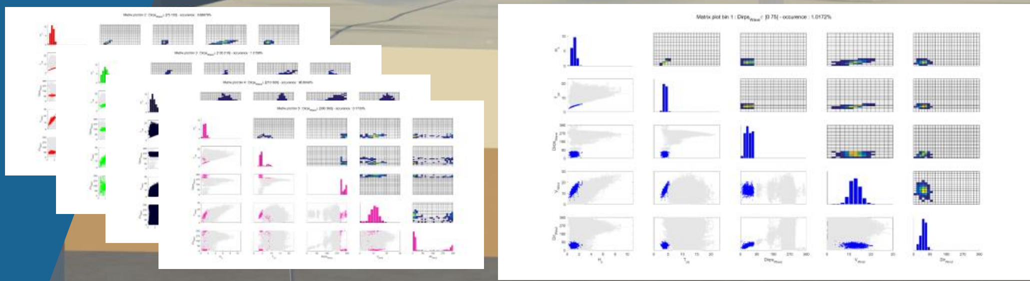
- It’s not because the environment seems well represented that the damage is well represented. Misrepresentation of fatigue damage is common.

- Detailed metocean analyses can be carried out but it is mandatory to consider the system sensitivity when deriving design load cases.

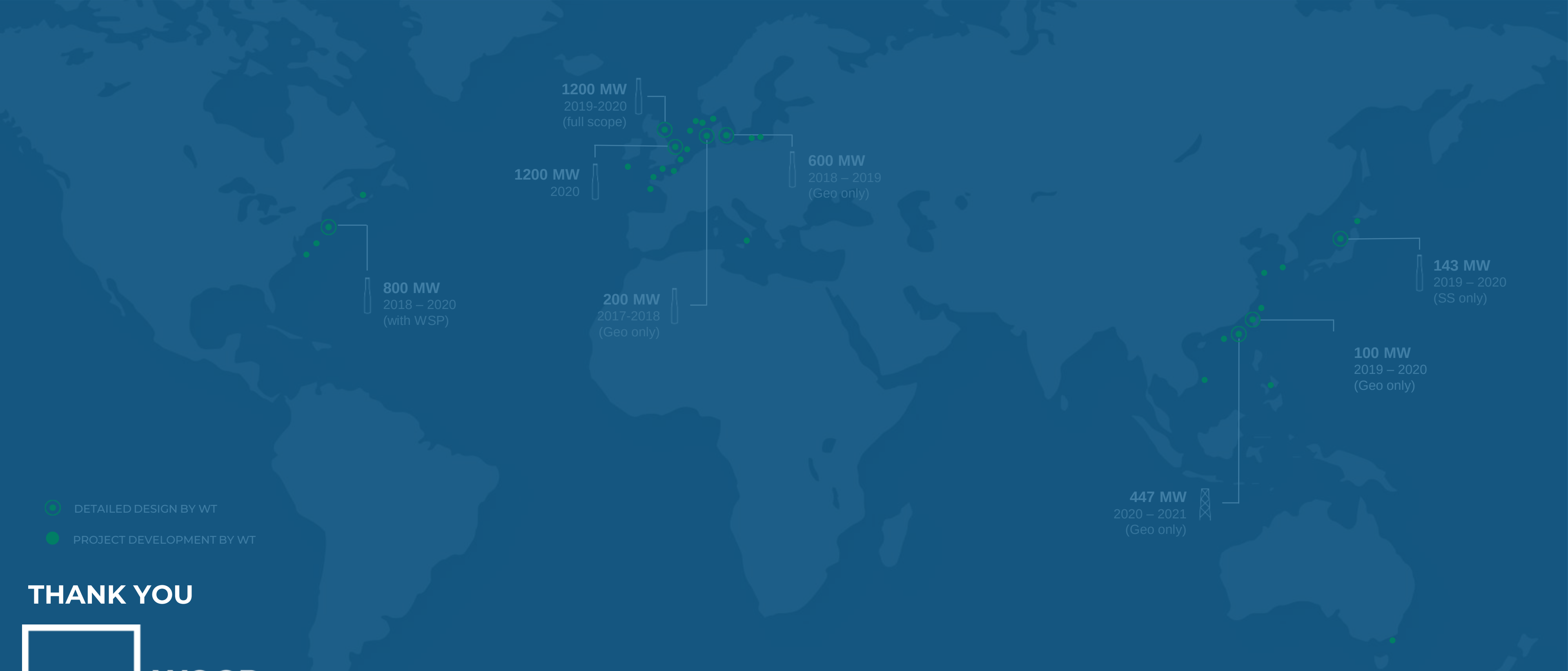
- Classical Normal Sea States approach can only be used in “simple” context. Original lumping strategies are required for more complex situations.



Multivariate binning process



Feel free to reach out if you want to know more about it



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