O&M planning for offshore wind farms

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Your perfect team player

Icewind WP3.2 Offshore accessibility and maintenance

- Study accessibility for maintenance vessels to offshore wind turbines using specific wave and wind climates
- Using accessibility model, improve maintenance strategies for offshore wind turbines

Questions

- What is the impact of wind and wave climate on access?
- How is turbine availability affected by vessel choice?
- Maintenance planning when taking access into consideration?

Outline

- How vessels are modeled and wave data used
- How wind turbines are modeled
- Interaction and results
- Perspectives

Calculating access

- 58 years of hindcast wind and wave data from NORA10 at 2 locations.
- Use RAOs and wave data to calculate weather windows
  - No of periods where the turbines are unaccessible
  - Expected duration of non access period

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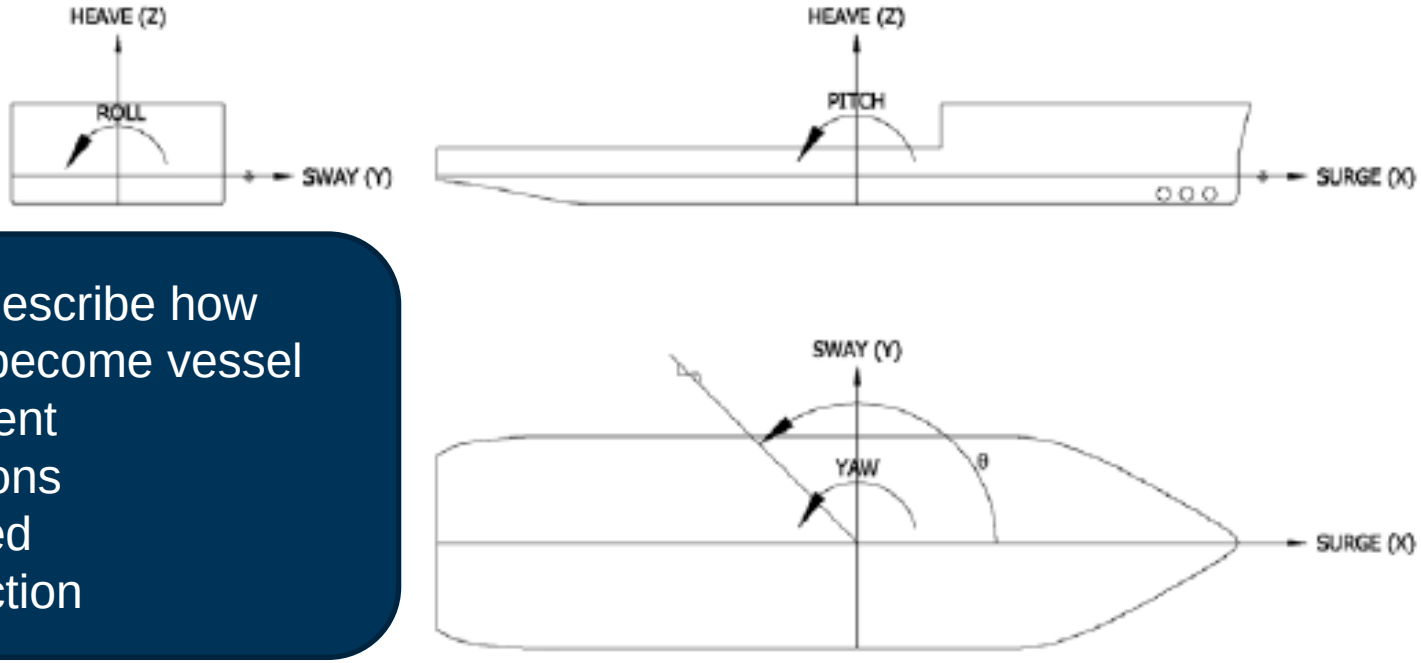
RAO – response amplitude operators



RAOs describe how waves become vessel movement

- Motions
- Speed
- Direction

Figure 2.1.1 – Definition of coordinate system and positive motions

Wave input data:

Using either Total sea / Combined Sea / Wave spectra

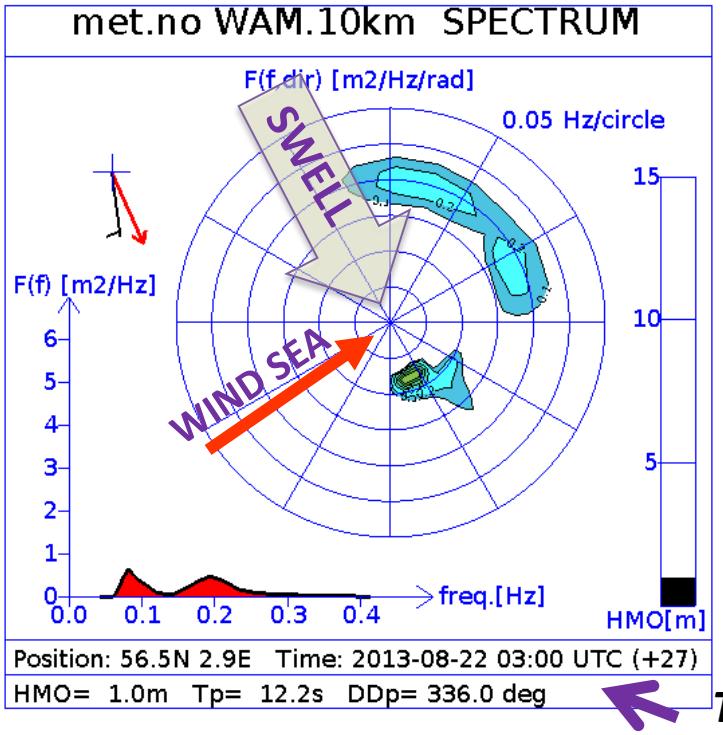
- Different kind of sea states:
  - Unidirectional
  - Bimodal (or several wavesystems)

- Vessel behaviour can be evaluated from

  - **TOTAL sea:** [Hs,Tp,DDP]_{TotSea}

  - **WIND SEA & SWELL parameters**

    [Hs,Tp,DDp] for Windsea and Swell (extracted from the 2D spectrum)



Total sea parameter

LADDER ORIENTATION: → Ladders are often installed so that vessel head against dominant wind or wave direction. At NORA10SW: current is most important: ladder orientation = 330 degrees. At HYWIND: major wind direction: 350 degrees.

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Vessel respons using hindcast weather data

Responses are evaluated for every 3 hours from the NORA10 database, but only for **Hs ≤ 3m**. This is 94.98% of the time at location NORA10SW.

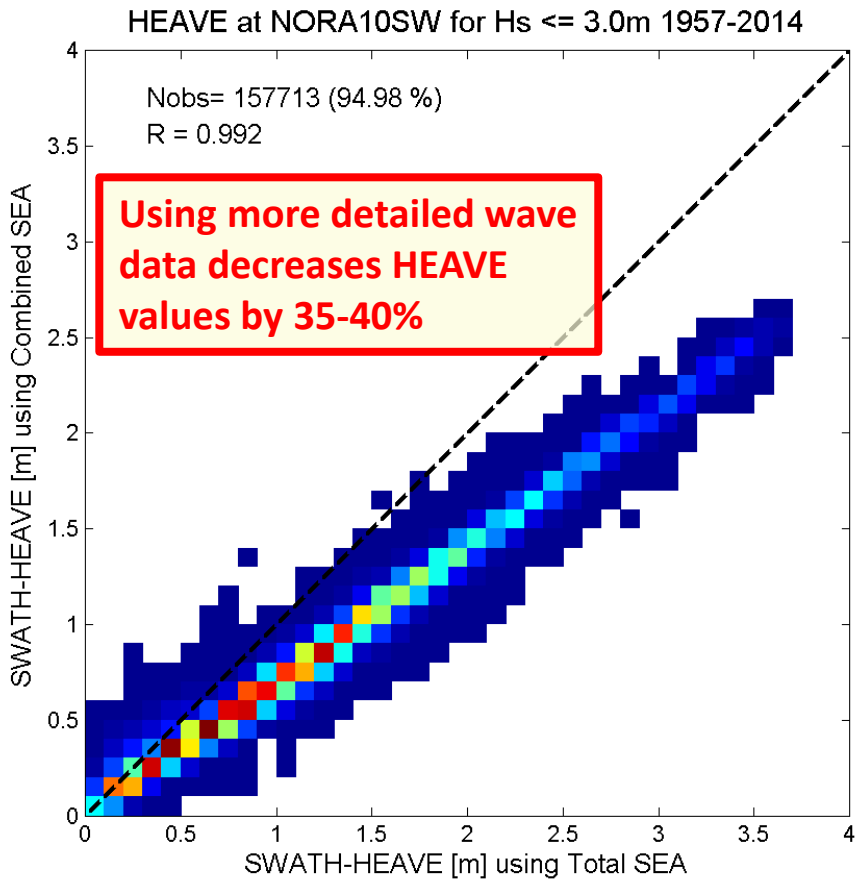
COMPARING HEAVE USING TOTAL SEA OR COMBINED SEA:

a) H = 1.3 · Hs is used in RAO functions

Assuming Rayleigh distribution: 95% of individual waves are below 1.3.Hs.

b) Combining respons from windsea and swell:

R = HEAVE [m]: $R_{comb} = \sqrt{\frac{Rwi^2 + Rsw^2}{2}}$



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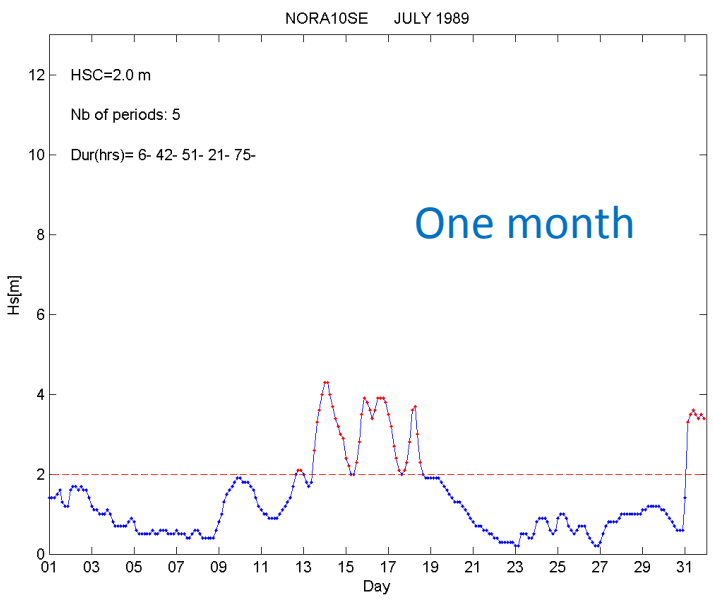
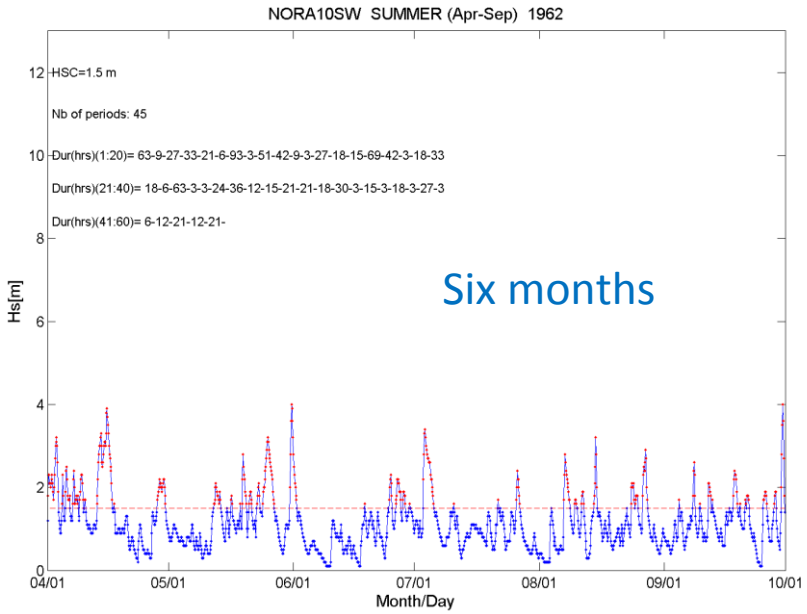
Weather windows

Counting number of weather windows and their durations

Weather window = sufficiently small vessel movement





Summer: April – September

Winter: October - March

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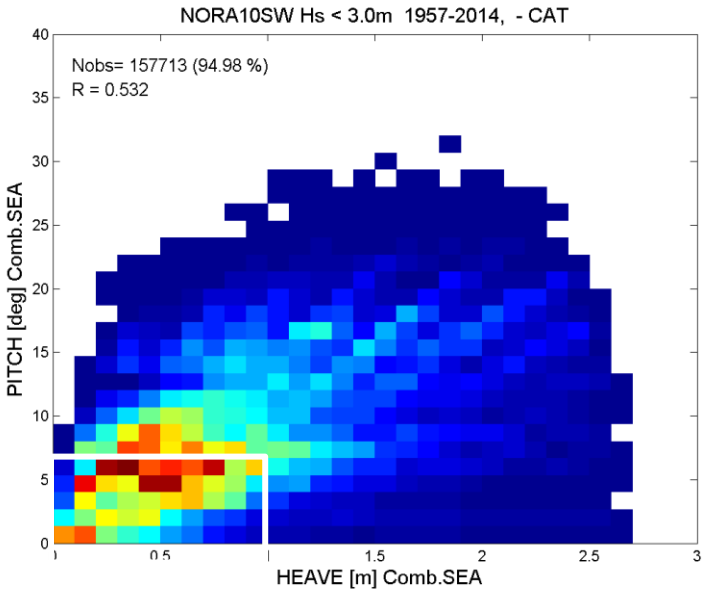
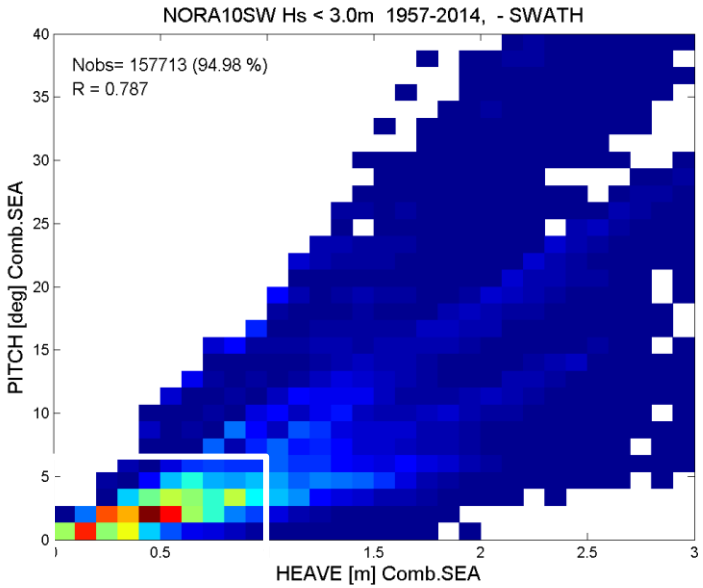
PITCH vs HEAVE, 2 VESSELS

VESSEL A



VESSEL B



Using for example a combination of Heave and pitch, or also with Roll:

Cases (percentage of period with Hs<3m)	VESSEL A	VESSEL B
Heave ≤1 m, Pitch ≤ 7°	35.46 %	50.17 %
Heave ≤1 m, Pitch ≤ 7° And Roll ≤5 °	24.67 %	36.60%

Increase in operable time by ~30% !

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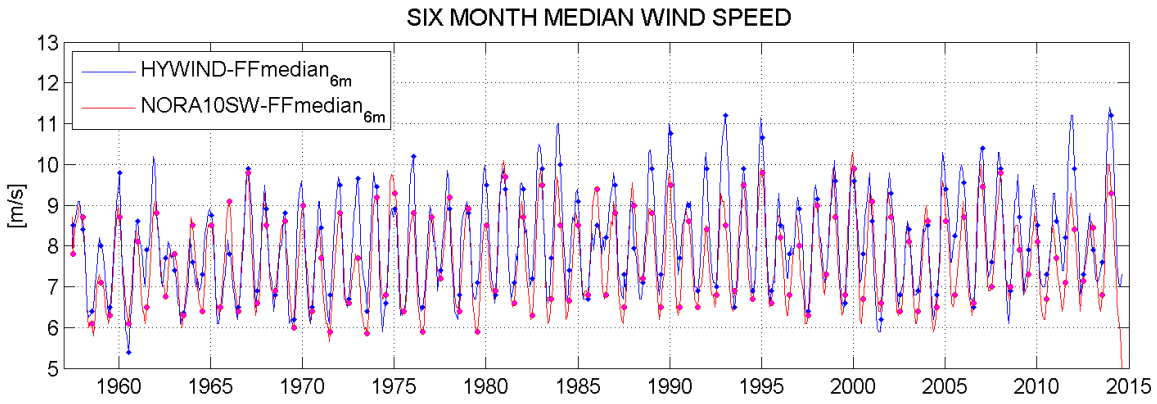
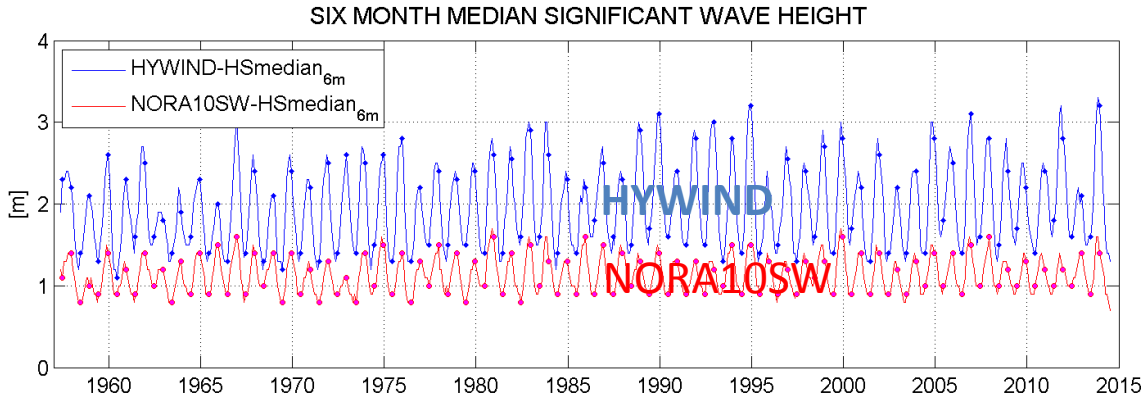
Comparing 2 wave climates

Wind and waves at HYWIND and NORA10SW





FROM 1957 to 2014

Wind 'climate':

Not too different , more often higher winds in winters at HYWIND (blue)

Wave 'climate':

HS 6-month MEDIAN	SUMMER	WINTER
HYWIND	~ 1.5 m	~ 2 - 3 m
NORA10SW	~ 0.9 m	~ 1.4 m

- How wind turbines are modeled

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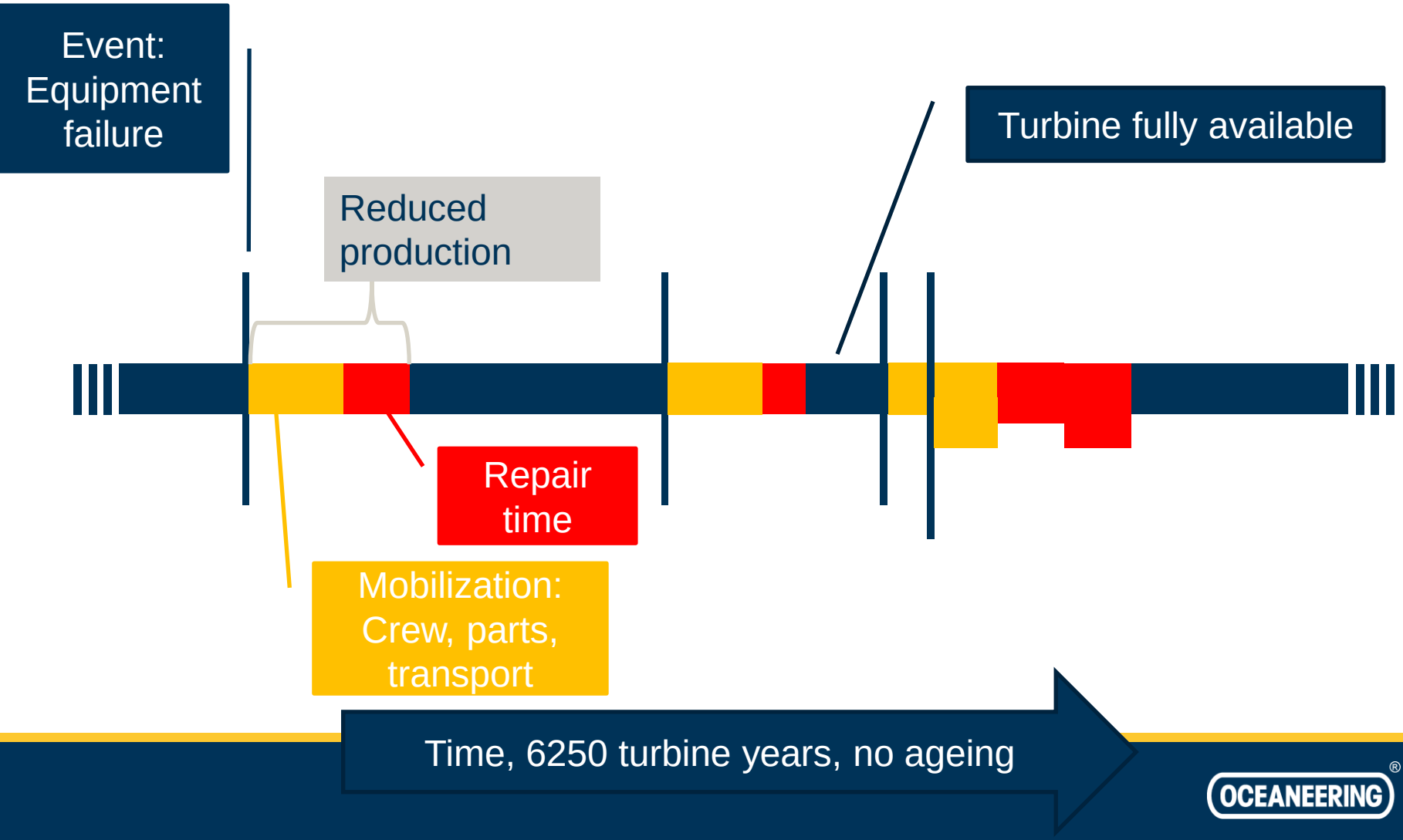
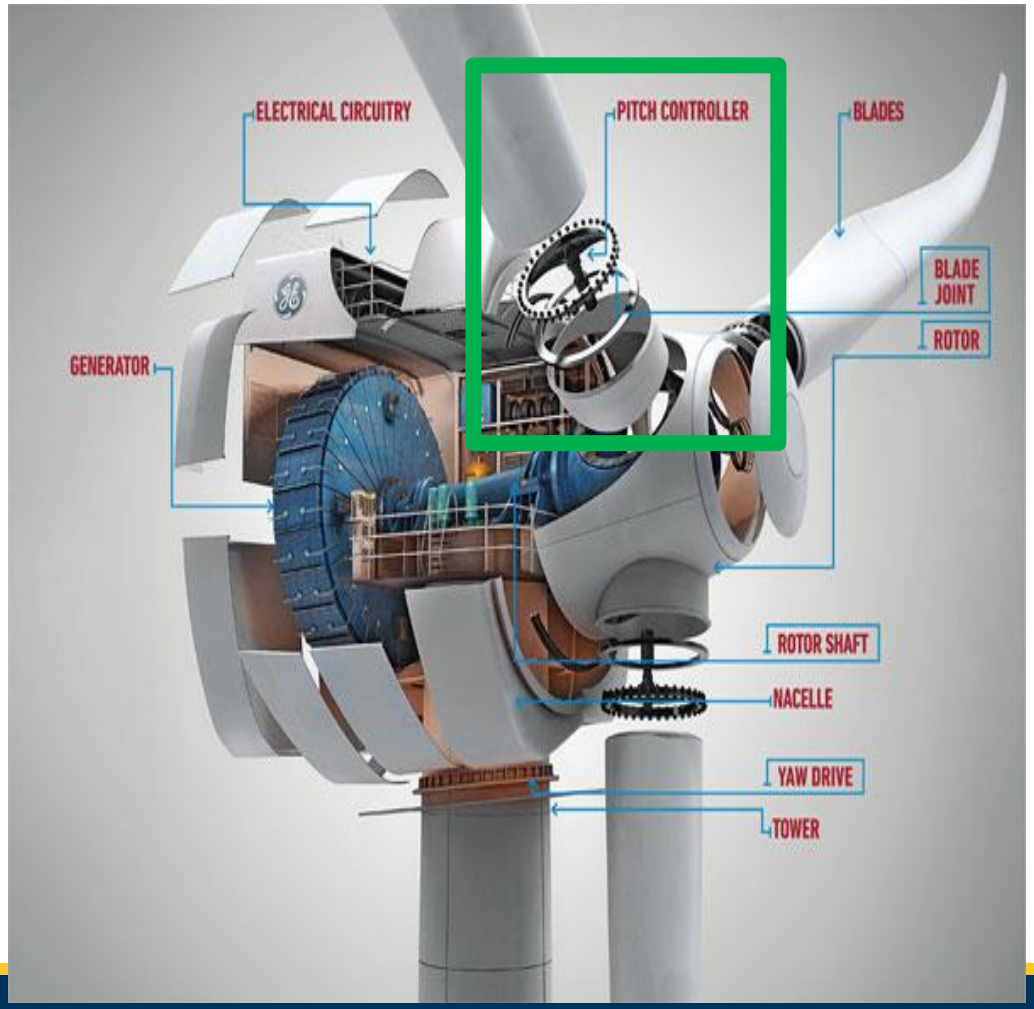
Event based simulation



Model of wind turbine

Divide into maintainable components



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Model of pitch controller

- How often the component fails

  Event:
  Equipment failure

- Effect of failure

  Reduced production

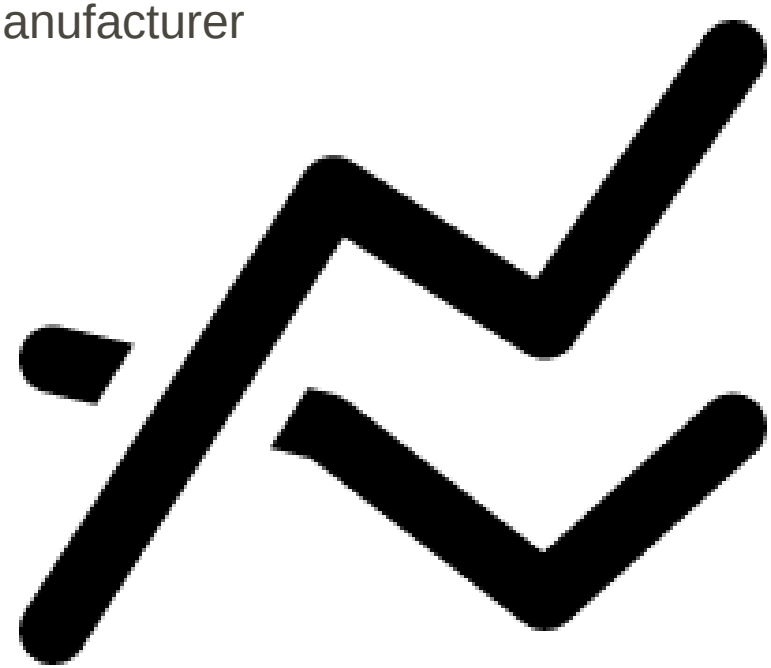
- How long the failure takes to fix

  Repair time

Repeat for all relevant parts of turbine

Data source and assumptions

- All reliability and repair data openly available from Reliawind
  - Based on SCADA data from turbine manufacturer
- Probably too many trips
- All fails reduce production to 0
- View results as relative comparison



Modelling access

Mobilization: Crew, parts, transport

- How often is the weather too poor for transfer of personnel?
- For how long is personnel transfer impossible?

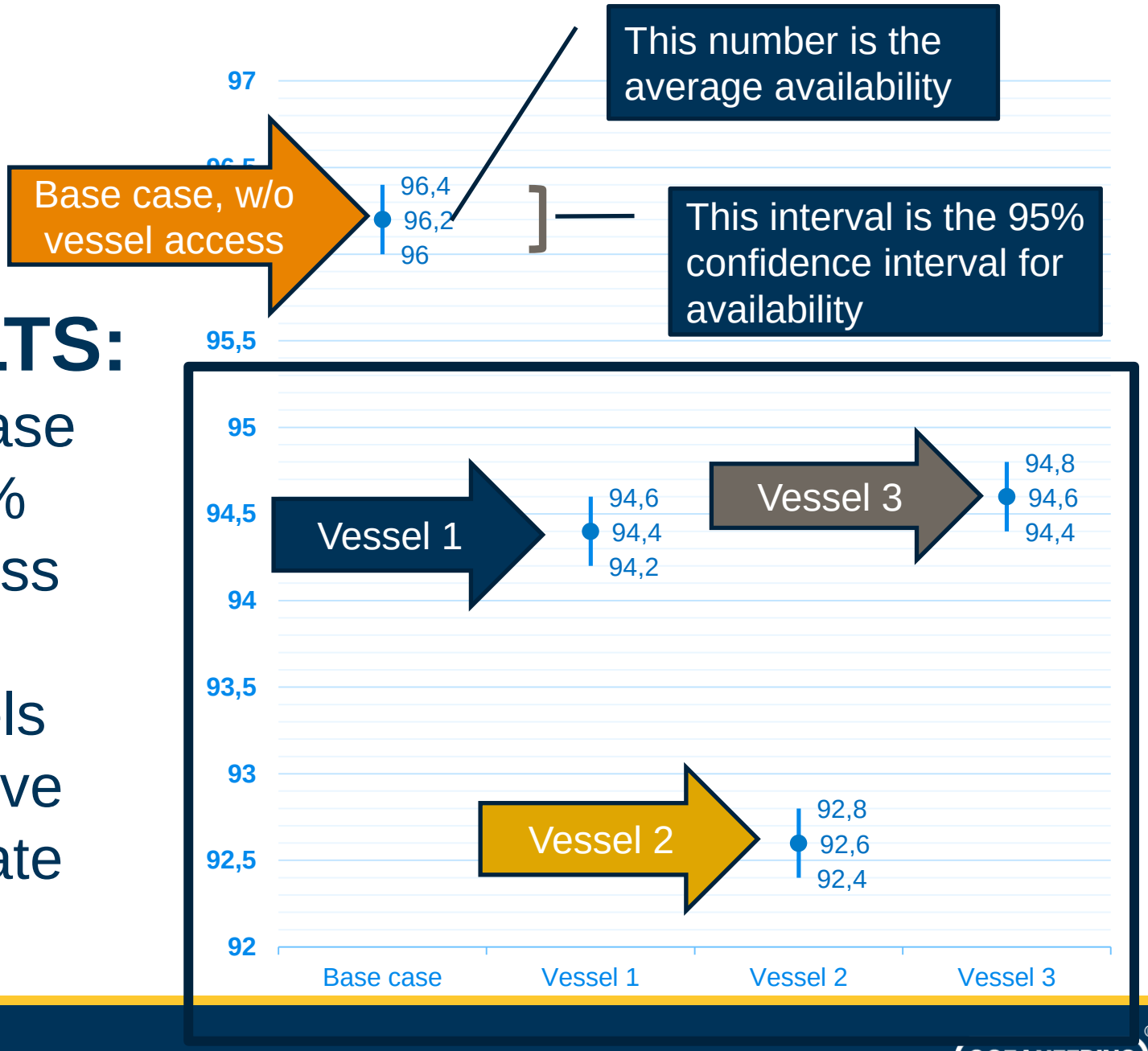
- Interaction and results

Use of weather windows

- Average rate of weather windows used directly
  - 50th percentile
- Distribution of length
  - 50th percentile
  - Normal distribution
  - Half of length in standard variation

RESULTS:

- Base case
  - 100% access
- 3 vessels
  - 1 wave climate



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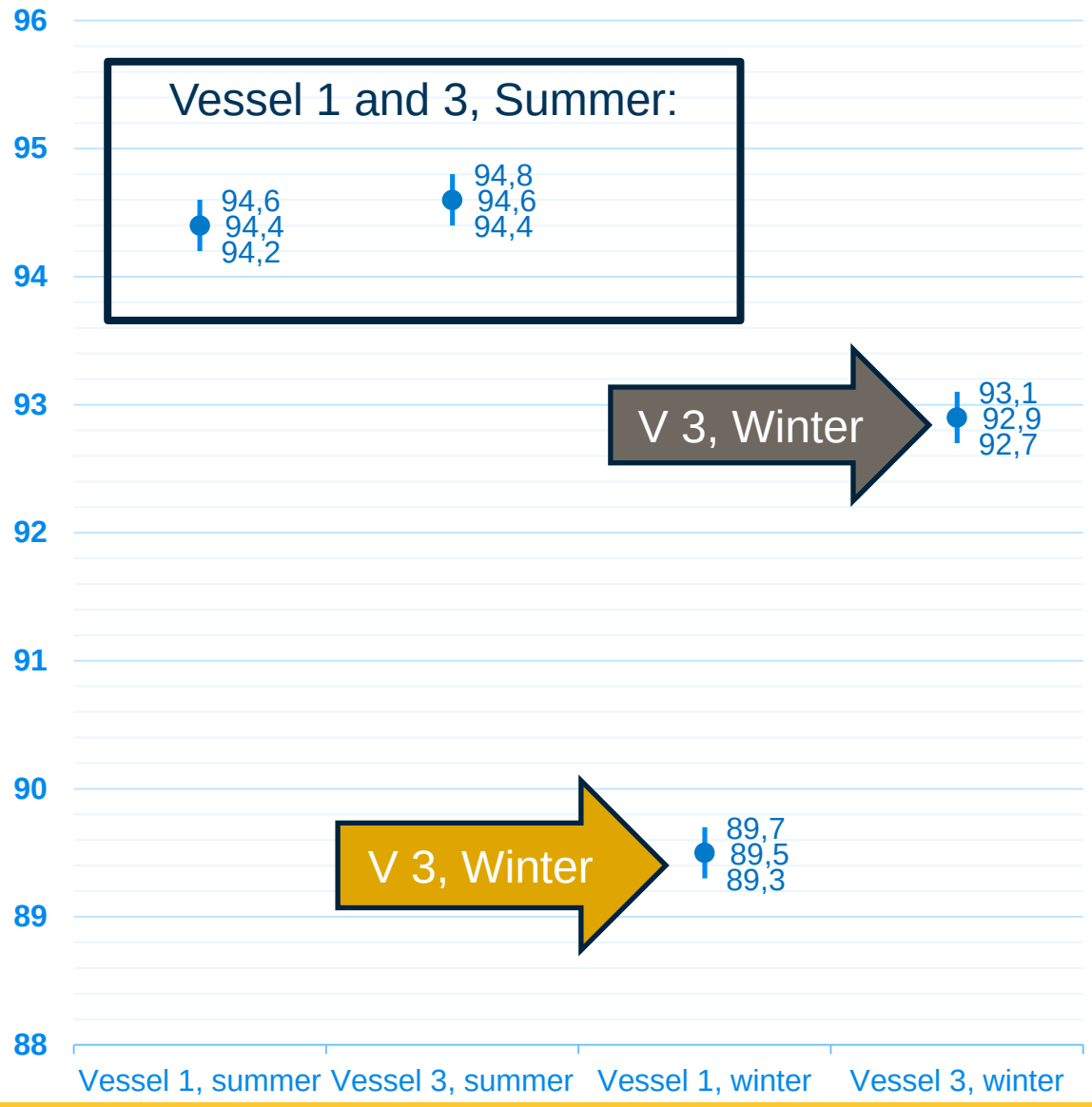
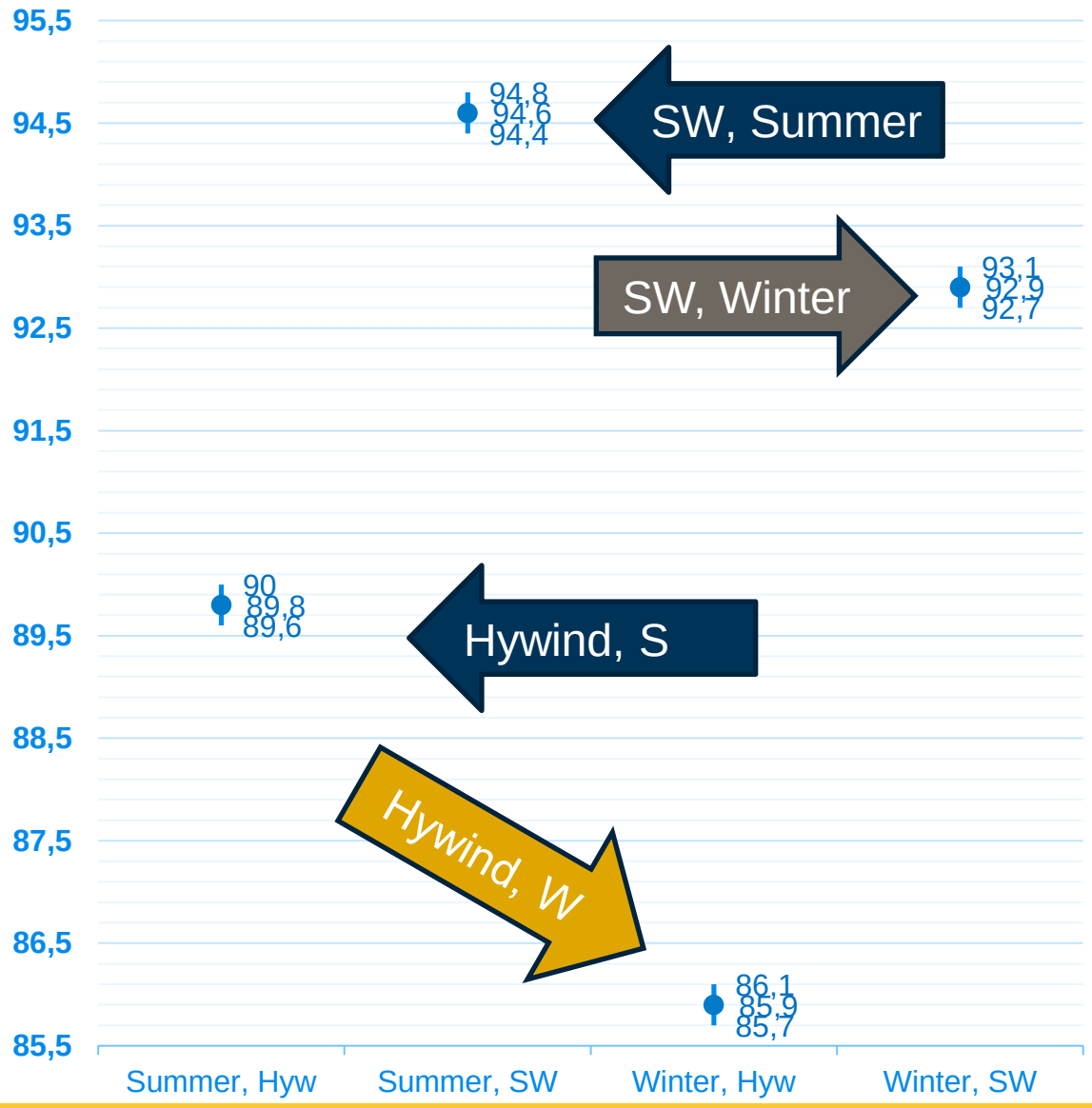
RESULTS:

- 2 vessels
- 1 wave climate
- Summer vs. Winter



RESULTS:

- 1 vessel
- 2 wave climates
  - SW
  - Hywind
- Summer vs. Winter



Conclusions

and ‘conclusions’

- Significant effect of vessel choice, dependent on site
- Variance in access indicates usefulness of
  - Inspection
  - Long lead condition monitoring
  - Preventive maintenance
- Real, detailed reliability data for wind turbines are very difficult to get
  - NCS O&G experience is not directly applicable
  - Very different cost picture
  - Very different production dynamic

- Perspectives

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- Standardisation reduces cost
  - Shale oil and gas experience useful
- Holistic approach
  - Wind farm state
  - Wind and weather
  - Grid
  - Support equipment
- Computation and prediction is cheap

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Thank you for your attention!

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