Sampling complex multidirectional environments: a guide to flexible choices to represent joint conditions

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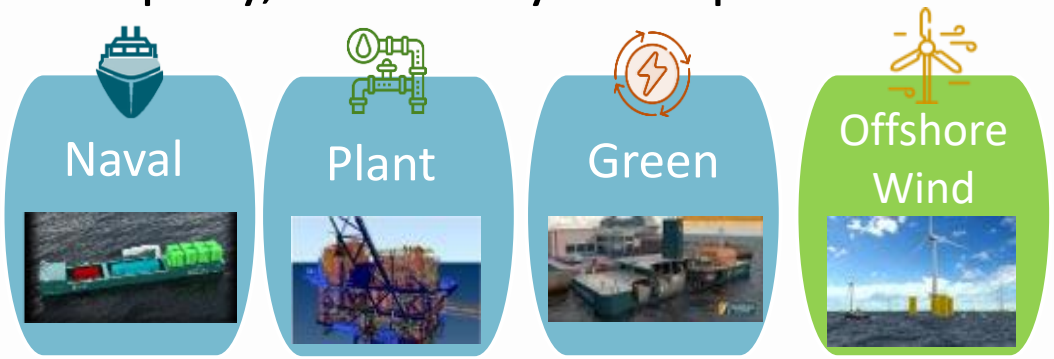
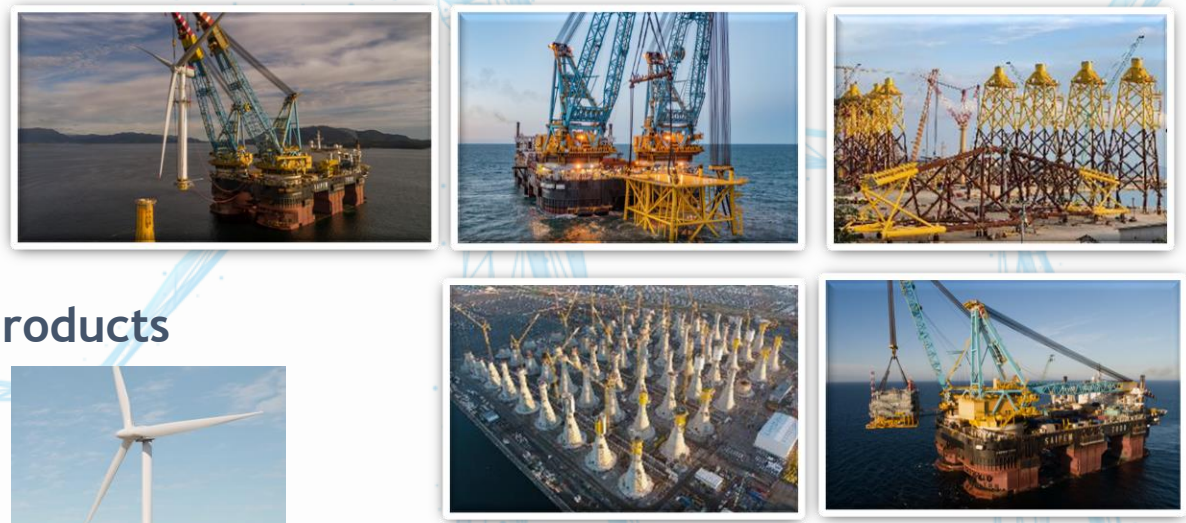
A France based, global engineering company, subsidiary of Saipem



- FOWT floater design (>12 years expertise)
- Offshore Substation (OSS)
- Green H2 from Offshore wind
- Constructability / Modularization

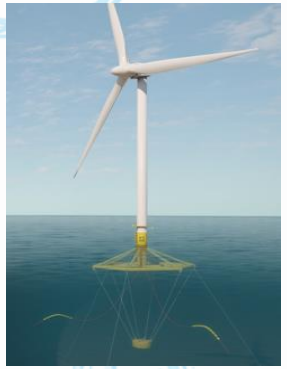
SAIPEM

A leader in offshore wind EPCI, with **2.500MW** of foundations fabricated or installed by our own assets:



Floater Products

STAR 1



HEXAFLOAT

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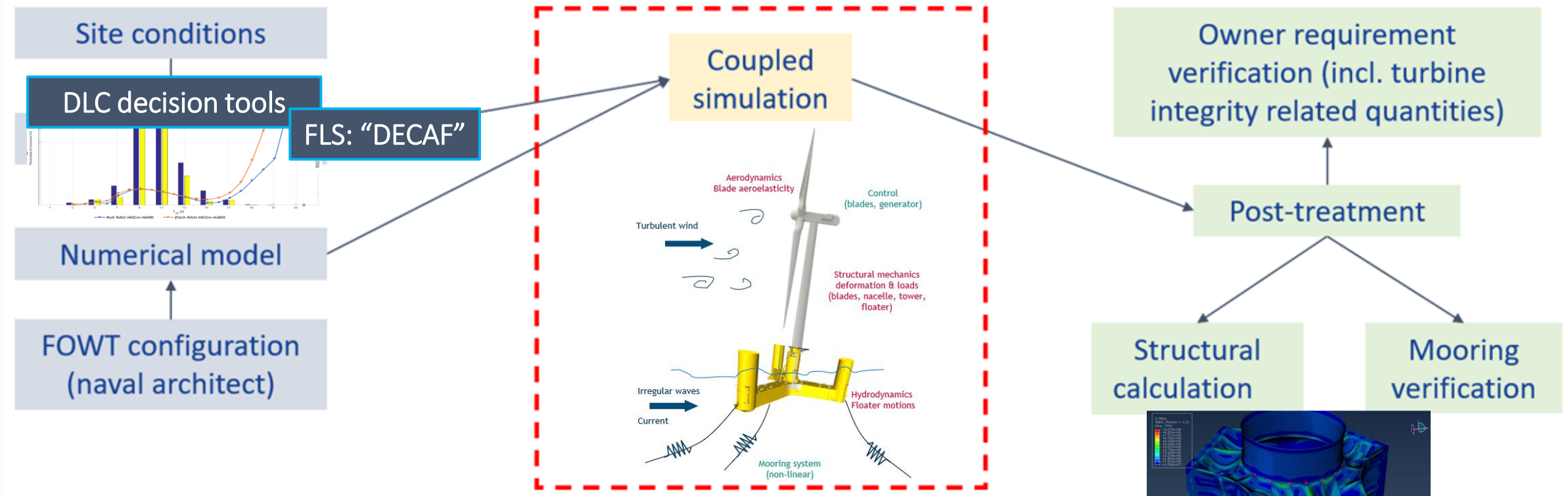
In-house “End-to-end” FOWT calculation chain

Industrialized (robust/qualified/efficient) **calculation chain** to address FOWT challenges, from site conditions to structural details

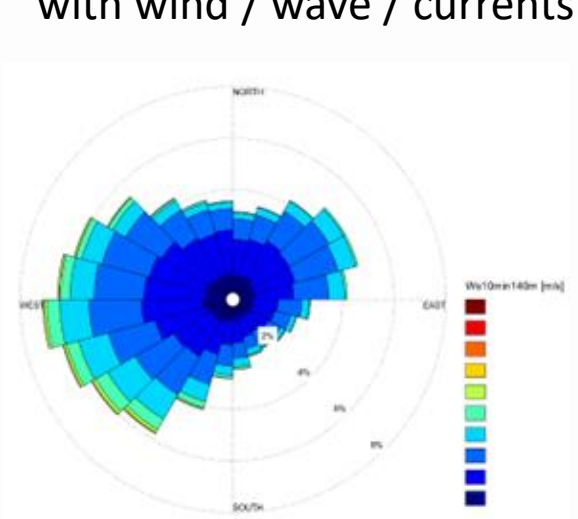


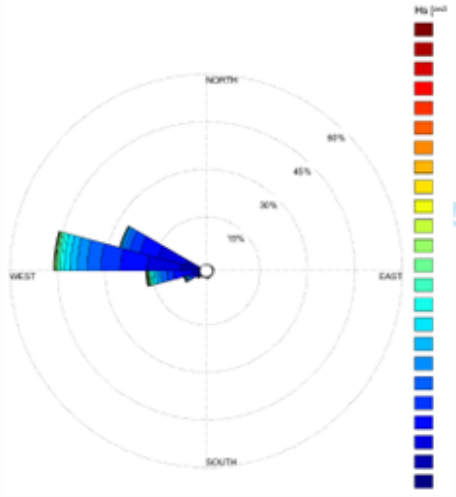
➔ Used to validate **STAR1 15MW optimized weight in Oceanic conditions** - FEED level

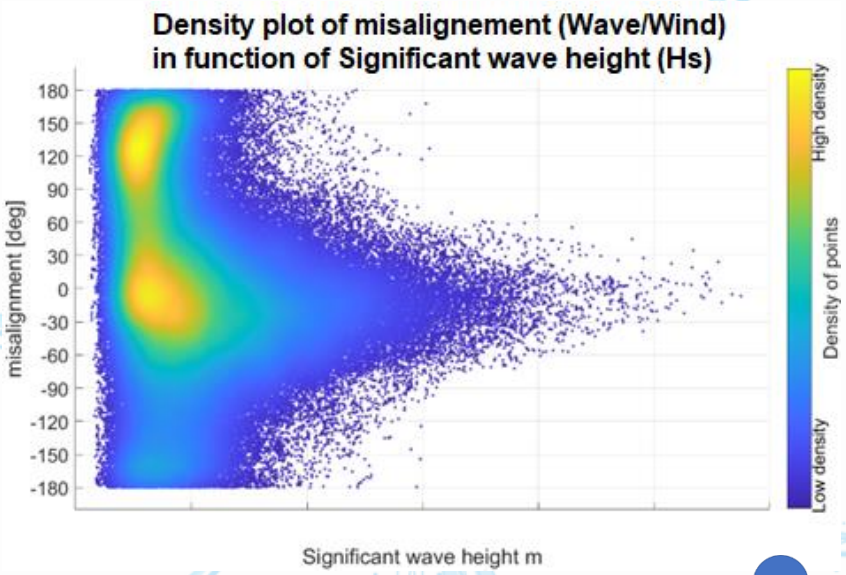
➔ Focus on **Design Load Cases (DLC)** decision tool **for Fatigue “DECAF”**: to reach **high site representativeness and standard compliance** with **limited** number of DLC

FOWT DLC challenge: complex multidirectional environments

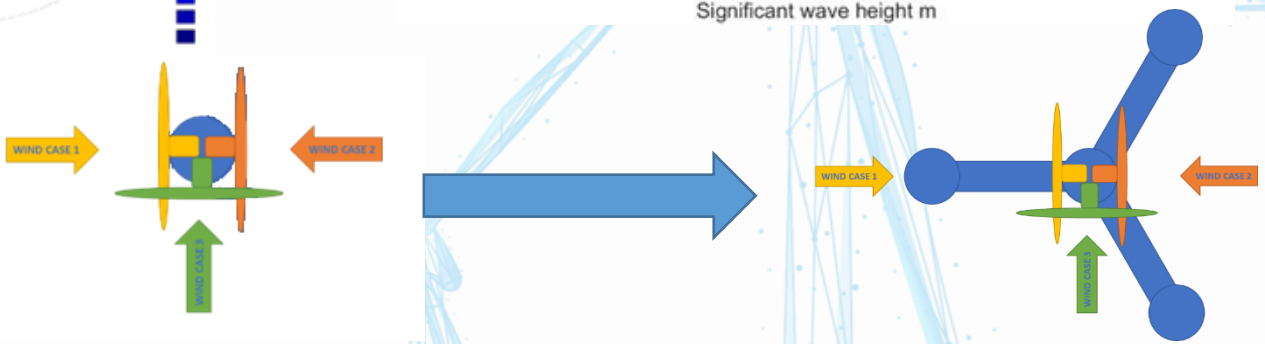
- **Complex multidirectional environmental conditions** in projects with wind / wave / currents







- **"Floating wind" physics… not axisymmetric**:



➔ "Misalignment" insufficient ➔ Joint conditions of wind/wave/current with their absolute directions

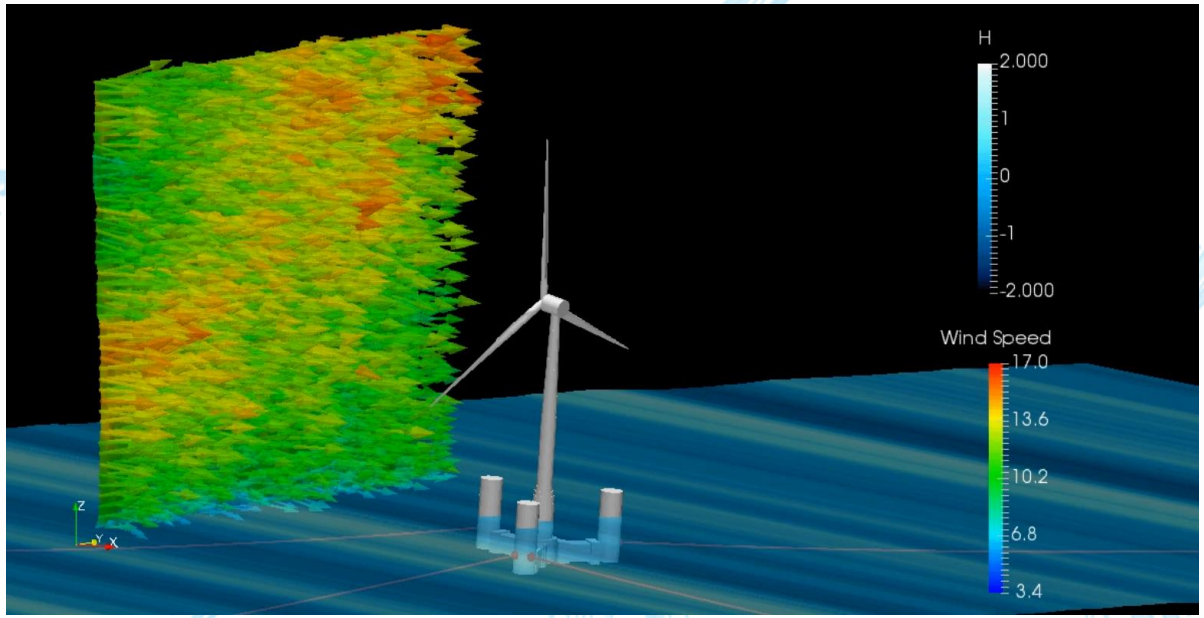
- **High representativity requirements from standards** such as DNV RP 286 (FOWT coupled analysis)…
  …With no methodology defined

High complexity / high number of variables… ➔ Explosion of DLC number ?

Guide to represent joint conditions for FOWT

- **Philosophy:** obtain an **accurate** synthesis of environmental conditions **in a limited number of representative DLC** (for computational cost)
  - innovative methodology to define the combinations of:
    - wind/wave/current
    - With intensity, period, direction… (e.g. Hs, Tp, Dir…)
    - ➔ **Lots of variables to be represented**
  - using **a timeseries** of all variables (not limited) with **full concomitance** information (joint conditions) **instead of scatter diagrams**

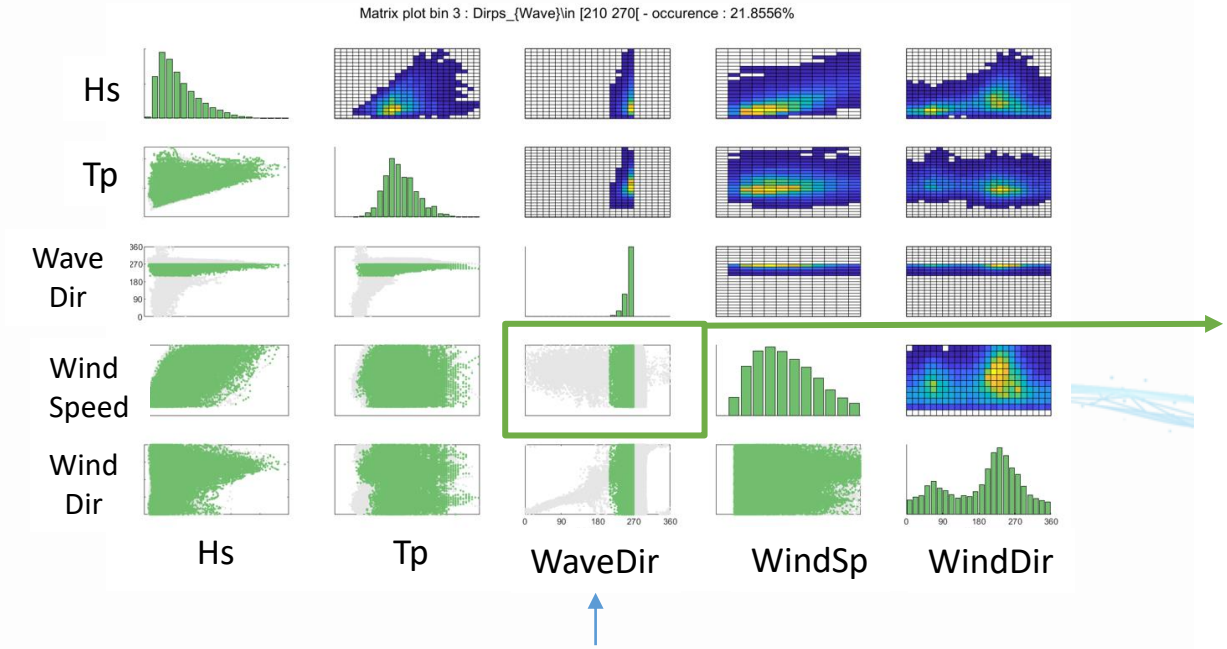
➔High level of accuracy and no “sacrificed” variable

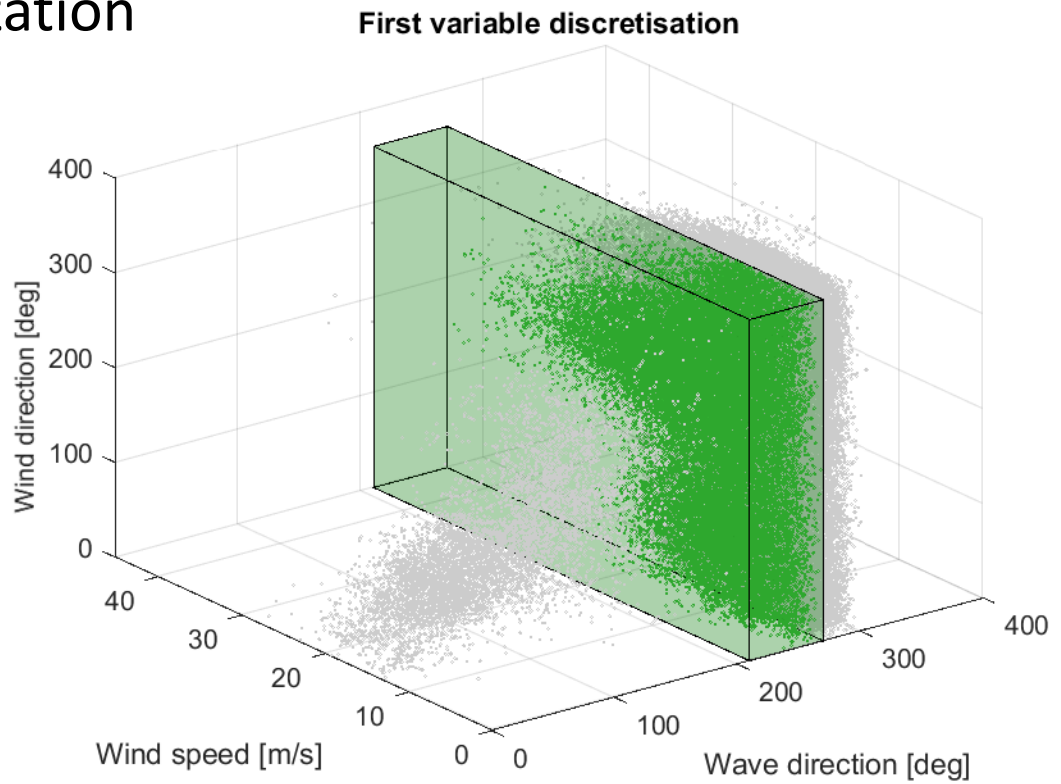


- **Flexible choice:** with options to assess representativity & size of the DLC list
  - Depending on **system responses**: refine DLC where necessary
  - With **proven accuracy and iterative improvement**: check plots & iterations to confirm and reach desired accuracy “at cost”
  - Depending on **design phase and project**: early project derisking at reasonable costs, adaptable to project parameters
  - DECAF dedicated to **fatigue**… but principles (joint conditions/multidirectionality) applicable for **extremes too**.

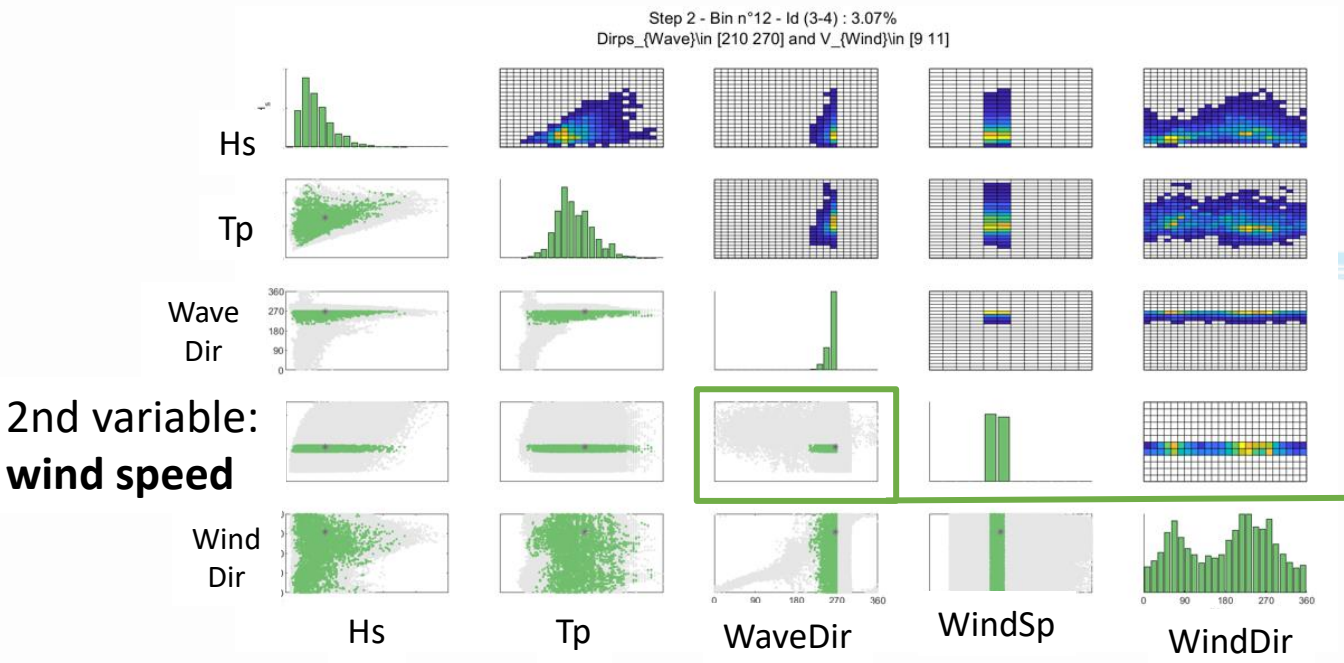
SAIPEM DECAF Method / step1: First discretization

- Method: for n variables (not limited), define "**boxes of data points"** (1 box=1 DLC) of the **time series** with chosen size/repartition/number → by a "variable by variable" approach
- Example for 3 variables: Step1 - First discretization

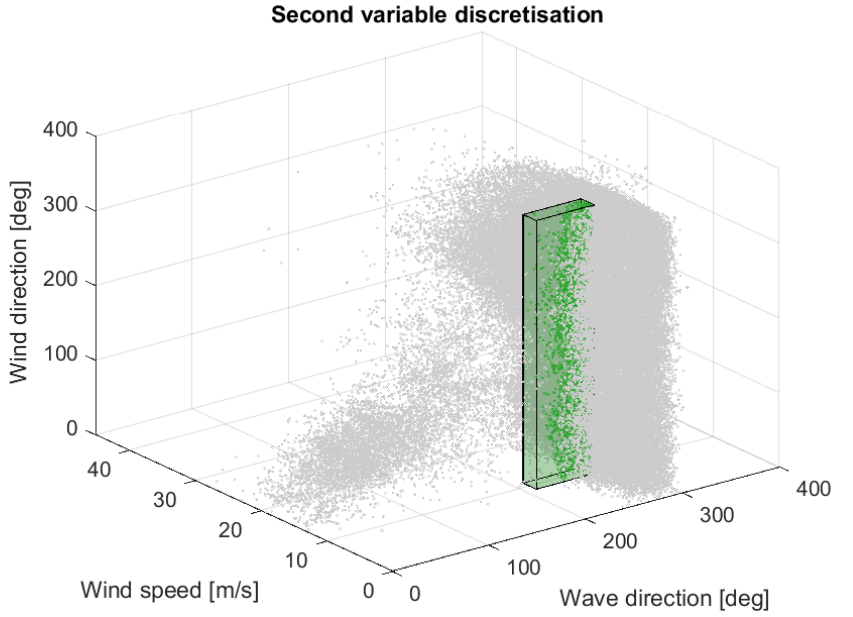




SAIPEM DECAF Method / step2&3: 2nd and 3rd discretization



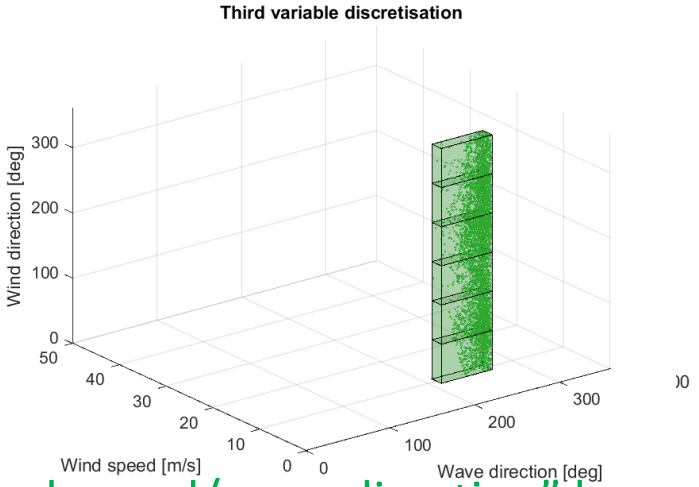
2nd variable:
wind speed



"Wind speed/Wave direction" boxes

1st variable:
wave direction

3rd variable:
wind direction



Data points of the timeseries kept all along the process,
to calculate probability of each DLC (=each "box")

➔ **No data loss, joint conditions kept!**

Etc. with *n* variables

"Wind direction/Wind speed/wave direction" boxes

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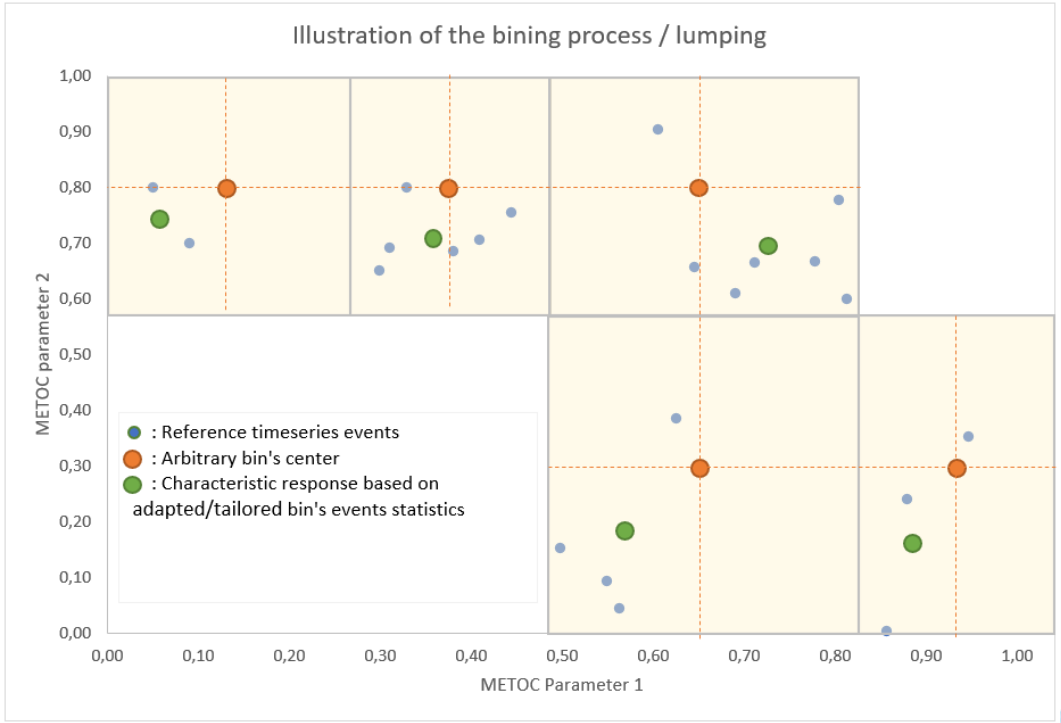
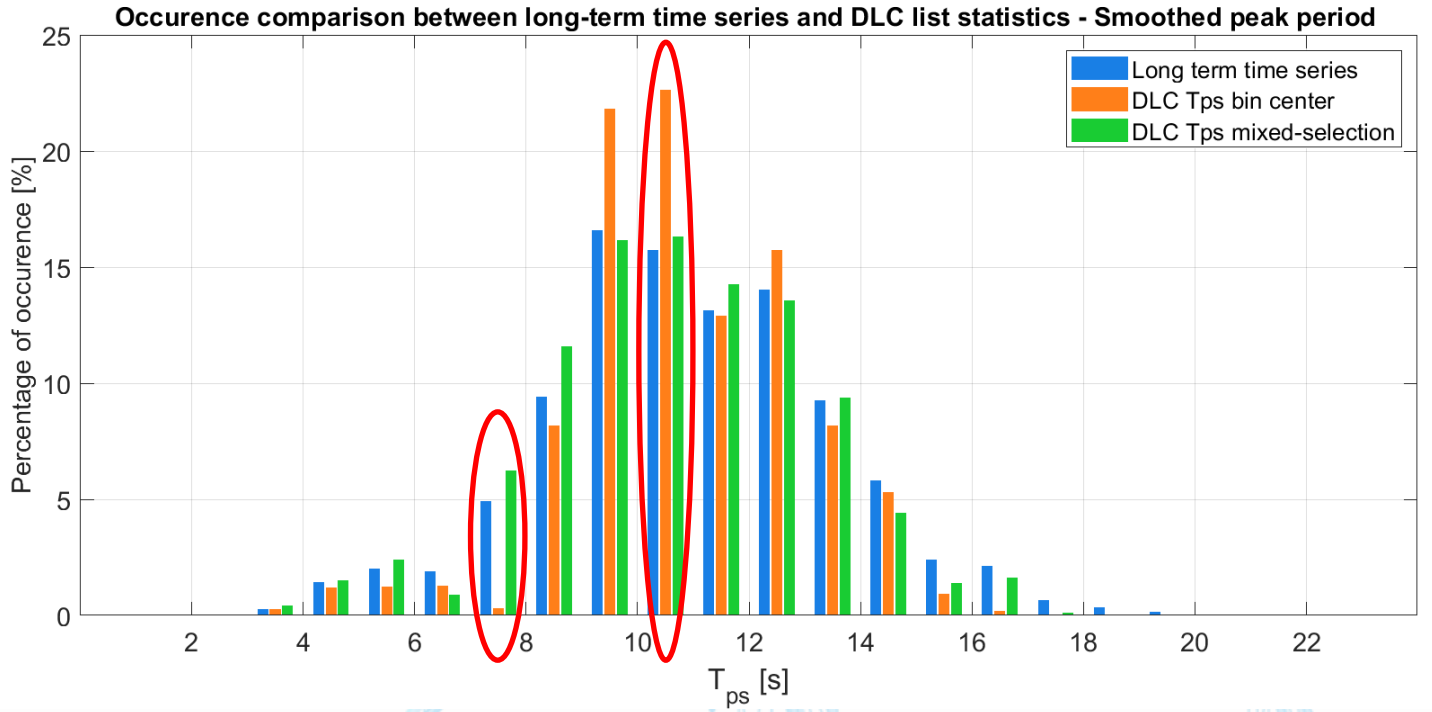
DECAF Method accuracy – binning refinement





Comparison of Tp occurrence representativeness from:

-long timeseries (blue) = REF

-DLC list with characteristic bin values = bin centers (orange)

-DLC list with characteristic bin values calculated from advanced/tailored bin's event statistics (green)

➔ **High gain of accuracy on critical area <u>WITHOUT</u> increasing DLC number**

Example here at Tp~7s an TP~10s: drastic error reduction ~-80%

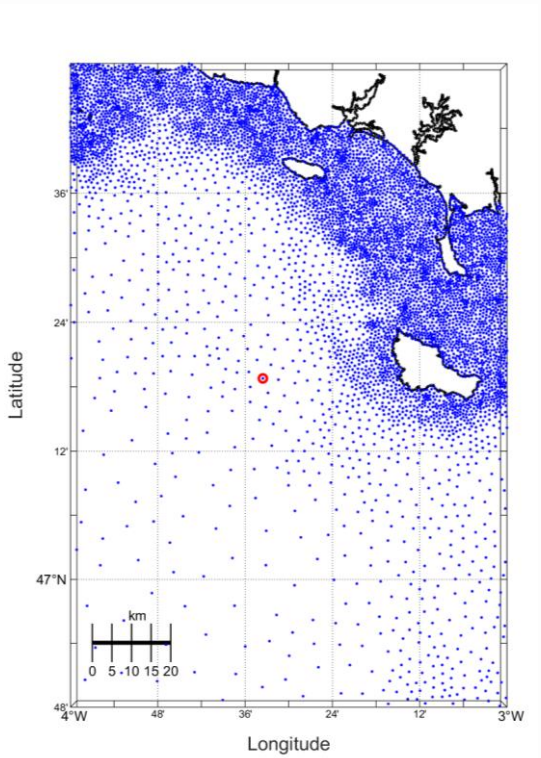
Application on South Brittany

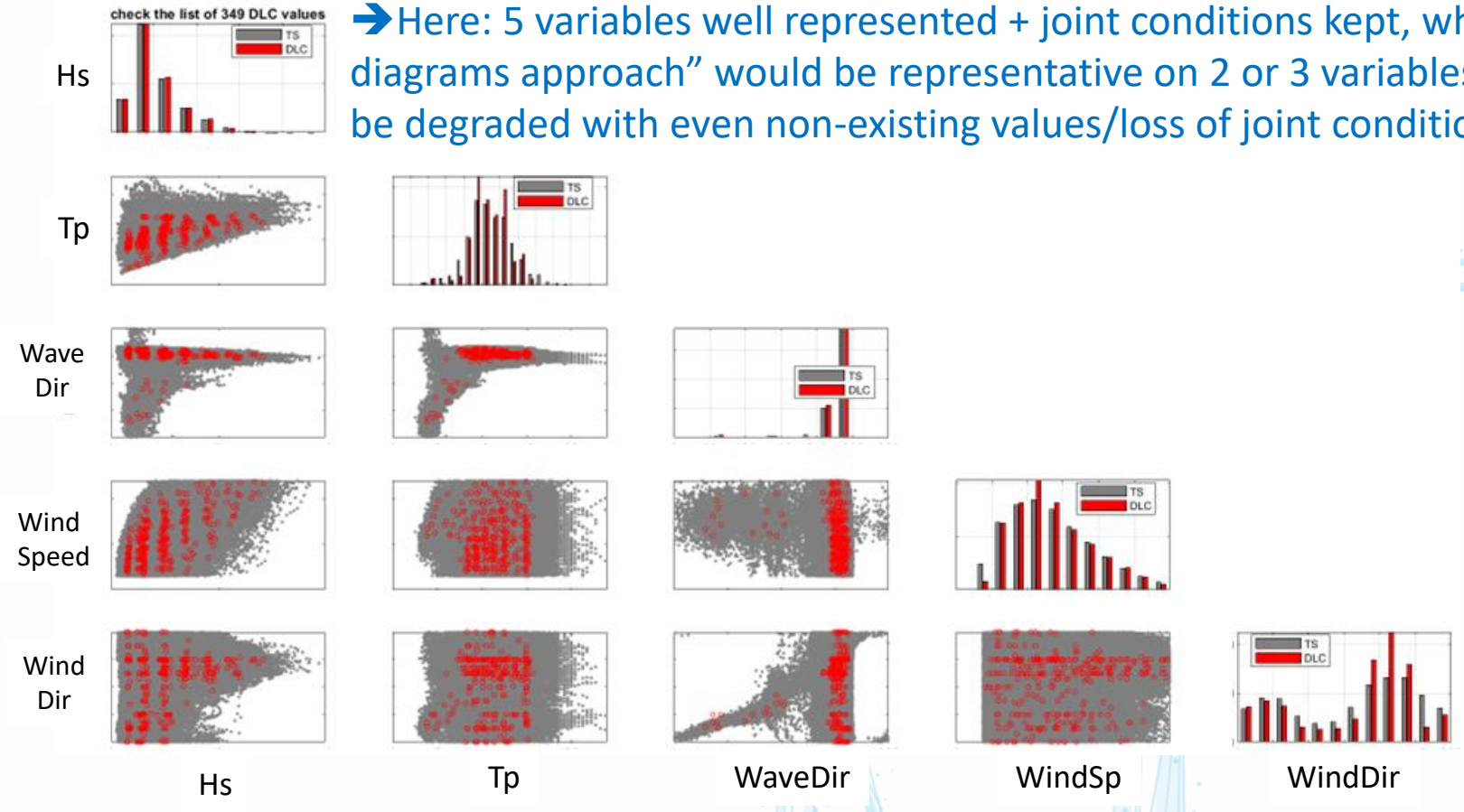
23 years of hindcast data
(200 000 data points)

Only ~350 representative Design Load cases:

- Scatter plots: limited set of 350 DLC (red) compared to 200 000 data points in timeseries (grey)
- Bar graphs: but **DLC list highly accurate on all variables of ref. timeseries**!

➔Here: 5 variables well represented + joint conditions kept, while "scatter diagrams approach" would be representative on 2 or 3 variables but others will be degraded with even non-existing values/loss of joint conditions





FOWT 2023
Floating Offshore Wind Turbines

Conclusions

- Innovative methodology to represent environmental conditions for FOWT with high accuracy AND limited number of DLC:
  - Enable capacity for **accurate fatigue design** from early stage
  - Enable **compliance with specific FOWT Standards & rules**
  - **Flexible** to be adapted to system response and design phase

➔ Robust design from early project phases

- Applied successfully and reviewed by Certification Body during an advanced project phase with a WTG OEM
- Applied on SAIPEM STAR1 optimization:
  - Definition of 350 fatigue DLC representative of South Brittany
  - Coupled with efficient calculation chain from DLC to structural verifications

SAIPEM STAR1 15MW optimized weight validated at "FEED level maturity"

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Thanks for your attention!

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