France Energies Marines

The Institute for the Energy Transition dedicated to Offshore Wind

EERA DeepWind CONFERENCE 2025

Comprehensive Validation of Heavy Lift Maintenance Methods Using Numerical and Basin Test Simulations

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France Energies Marines in short

French National Research Institute fully dedicated to Offshore Wind

Staff **85**

Since **2012**

€8M budget in 2022
100% allocated to R&D

Headquarters in **Brest**
Offices in **Le Havre**, **Nantes** and **Marseille**

Institute supported by **France 2030** investment plan

A public-private partnership

Ownership
50% public
50% private

A joint-stock company with a capital of **€699,000**

Our scientific and technological roadmap

SITE CHARACTERISATION

- Spatialisation of observations
- Characterisation of sea states
- Wind characterisation at sea
- Climate change
- Hydrosedimentary processes

SYSTEMS DESIGN AND MONITORING

- Structure, mooring and electrical cable
- Hydrodynamic and structural coupling
- Digital twins and in-service monitoring
- Technological innovation

4 cross-cutting and complementary **R&D programmes**

ENVIRONMENTAL INTEGRATION

- Effects on ecosystem compartments
- Changing scale in terms of socio-ecosystem, space and time
- Tools for environmental integration

FARM OPTIMISATION

- Farm architecture
- Grid integration (hydrogen...)
- Installation, operation and maintenance

Context of FLOWTOM project

FRANCE ENERGIES MARINES

- **Major Component Replacement** (MCR) is an R&D challenge for Floating wind
  - Despite low failure rates, MCR drive high O&M costs due to expensive materials and long repairs [(1)]
- For FOWT, **accessibility and operability** of maintenance methods increase in complexity
  - Farms are in deeper water, beyond jack-up vessel limits
  - Floater motions demand precise dynamic positioning and limited metocean windows
- Reliable, proven MCR solutions needed
  - Must compete with tow-to-port alternatives for FOWT

(1) Carroll, James, Alasdair McDonald, and David McMillan. 2015. "Failure Rate, Repair Time and Unscheduled O&M Cost Analysis of Offshore Wind Turbines." Wind Energy 19

The FLOWTOM Project

FLoating **O**ffshore **W**ind **T**urbines **O**peration and **M**aintenance

OBJECTIVES

- Heavy lift solution assessment & development for floating offshore wind maintenance
- To provide high resolution short term metocean forecasts in the Gulf of Lion for O&M

SCIENTIFIC CONTENTS

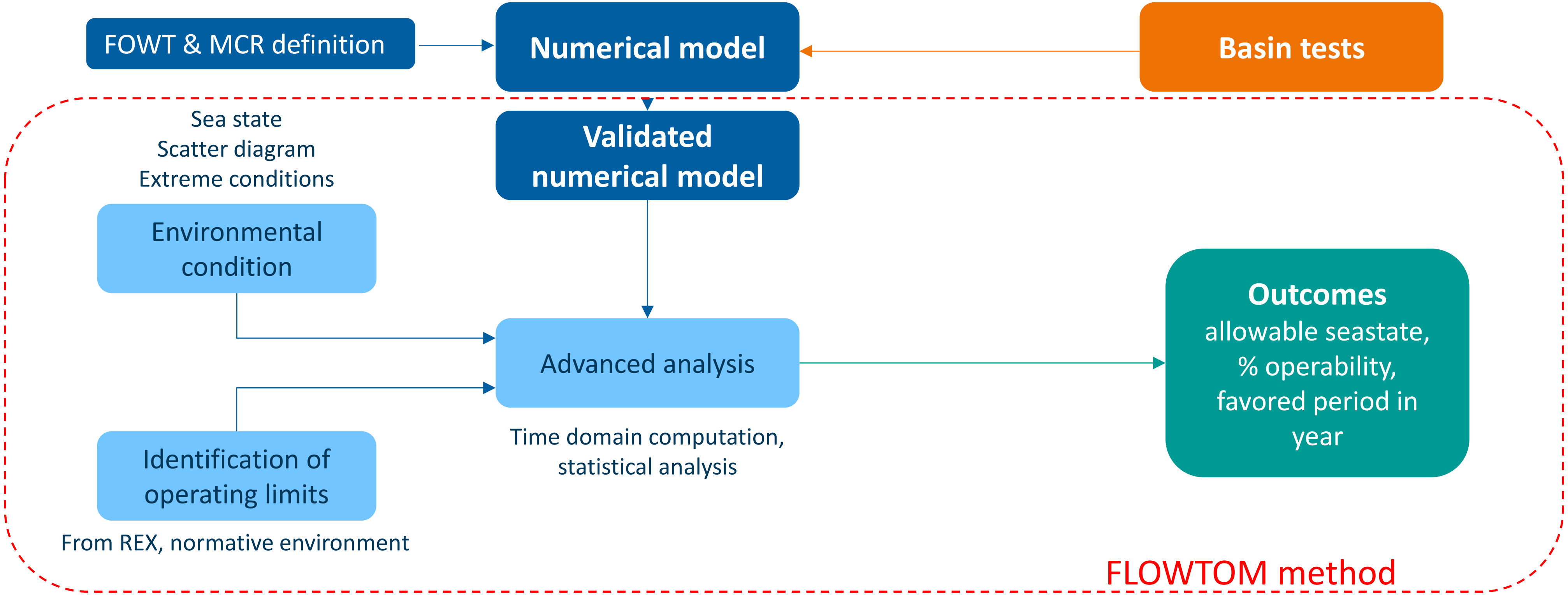
- Heavy lift offshore maintenance methods
  - Investigation of methods and technologies for heavy lift offshore operations
  - Assessment of a selected heavy lift solution through numerical simulations
  - Validation of the method statement through basin tests
- High resolution probabilistic forecasts
  - Construction of the dataset, including implementation of in-situ surveys
  - Development of wind and wave learning-based model
  - Implementation of an online forecasting system with scoring

PARTNERSHIP:

With the financial support of:

Objective & Method

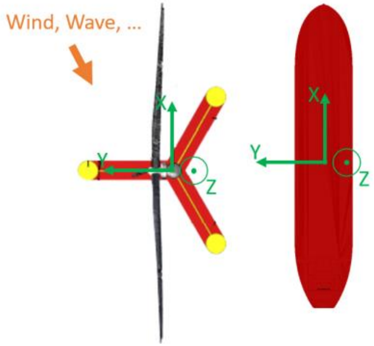
→ Development and assessment of **methodology & simulation tools** for MCR solutions operability evaluation

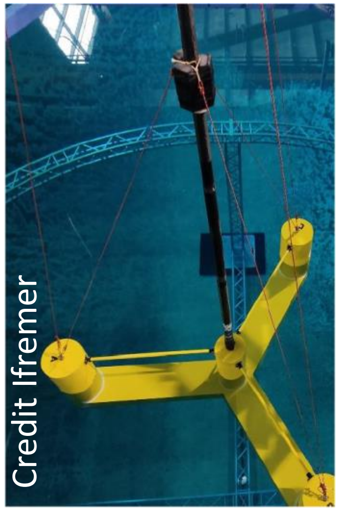


Case study specifications

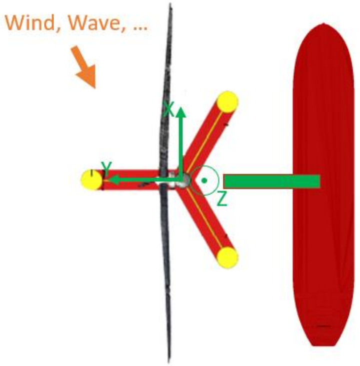
Basin test	Numerical study

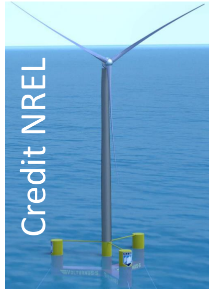
- Comparison Basin test VS dedicated numerical model:
  - Semi submersible VolturnUS-S [(1)] + IEA 15MW [(2)]
  - Mono hull vessel
  - Basin scale 1/50



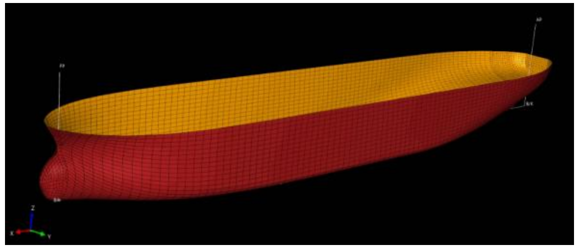


- Complete Numerical study:
  - Semi submersible VolturnUS-S [(1)] + IEA 15MW [(2)] + MCR solution
  - Mono hull vessel including a 1000t crane
  - Float4Wind + IEA 15MW + MCR solution
  - MCR self erecting system
  - Specific lift case studies





Include a self erecting crane solution



(1) C. Allen *et al.*, 'Definition of the UMaine VolturnUS-S Reference Platform Developed for the IEA Wind 15-Megawatt Offshore Reference Wind Turbine', Jul. 2020
(2) E. Gaertner *et al.*, 'Definition of the IEA Wind 15-Megawatt Offshore Reference wind Turbine', Mar. 2020.

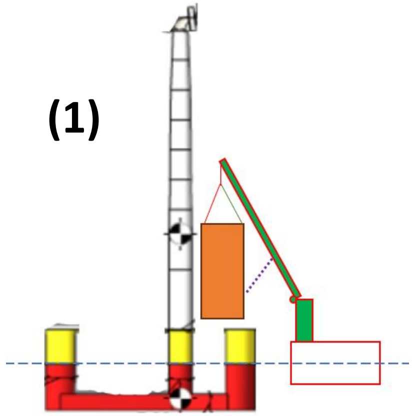
Case study on one MCR solution: Self erecting, turbine mounted crane

- Advocating for the self-erecting technology:
  - **Improved EHS**: Less “floating to floating” transfer
  - **Higher availability > lower downtime**
  - **Resistance to harsh environment**

- The self-erecting lifting solution considered is composed of:
  - A platform
  - A tower + clip
  - A tower top crane

- 2 main operations modes were specifically studied:
  - Float to float transfer of the self-erecting system (1)
  - MCR operation using tower top crane operation (2)

(1)



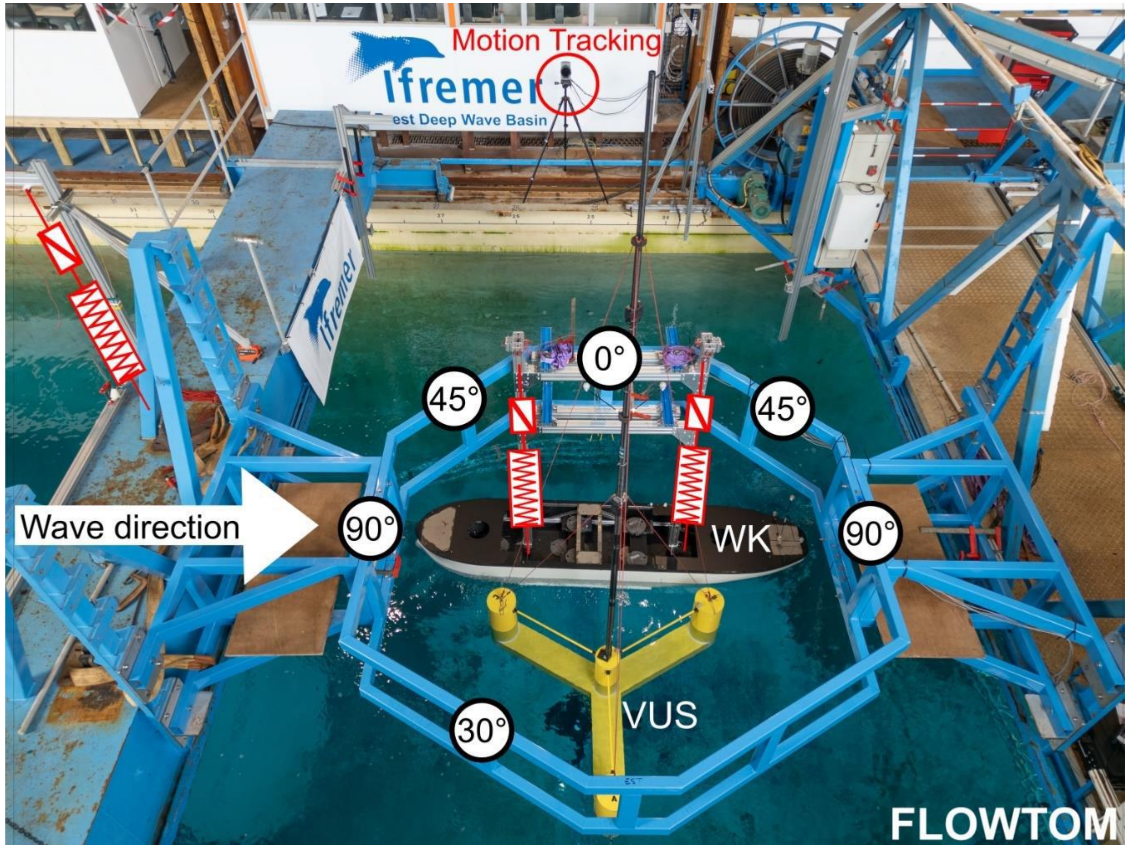
(2)

*The case study is inspired by an MCR solution design and aims at crash-testing the methodology but DOES NOT assess the full system operability

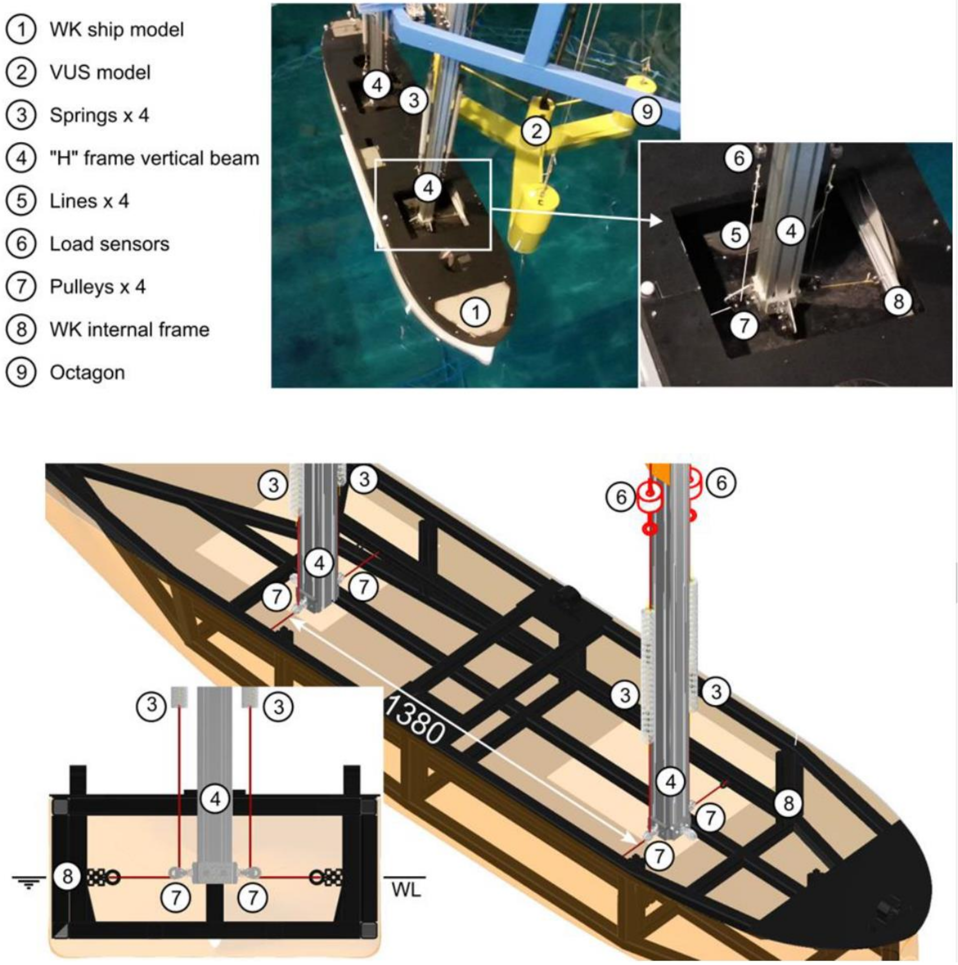
Basin tests for numerical model validation

Basin Test Specification – Objectives

- Objectives
  - Accurate representation of two floating mock-ups with their respective mooring
    - Anchoring system for the VUS
    - DP system for the Vessel
    - Calibration of different sea states (including several wave directions)

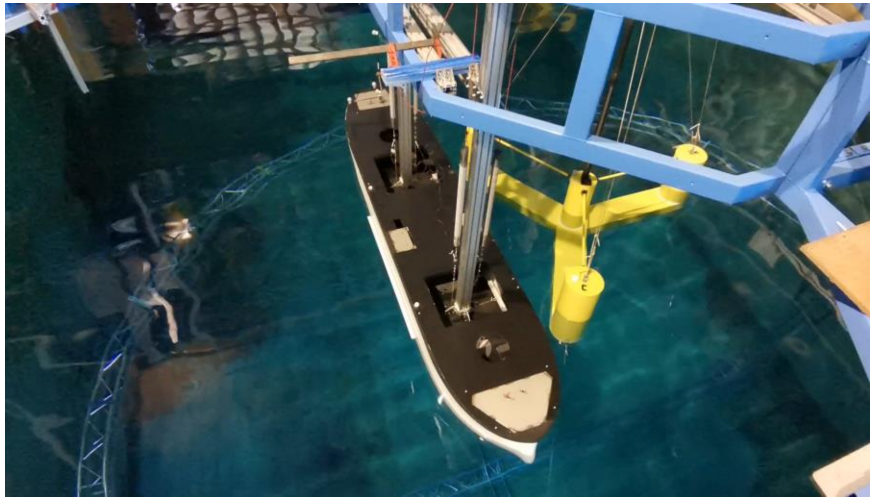


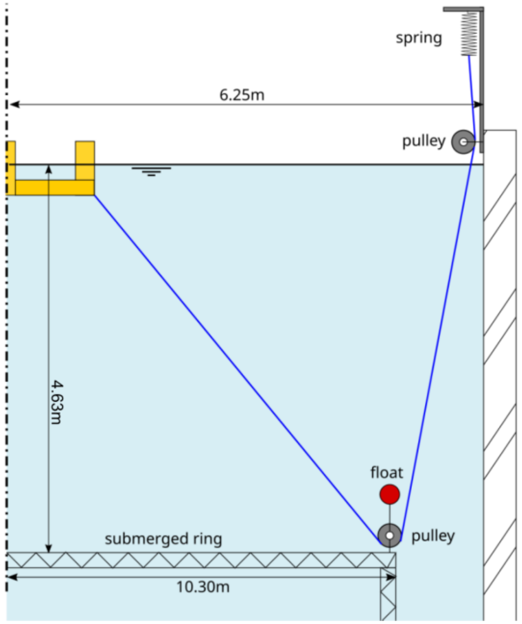
Basin Test Specification – Maintenance Operation Vessel



- Vessel simplified Dynamic Positioning represented with spring
  - 4 lines, 4 springs

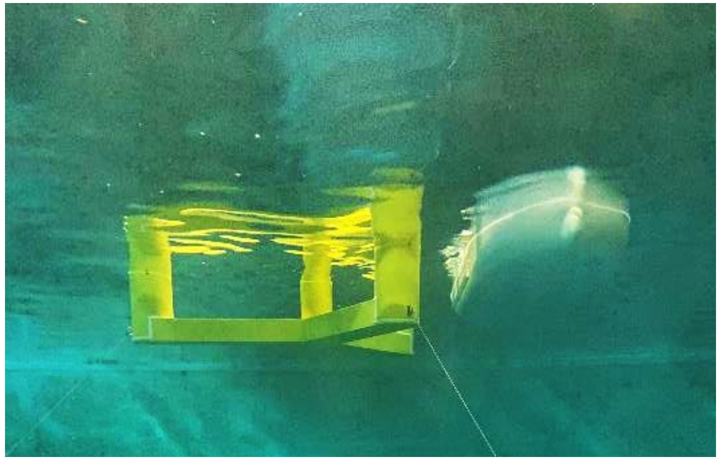
- 3 HMPE lines connected to 3 springs at the surface for the floater



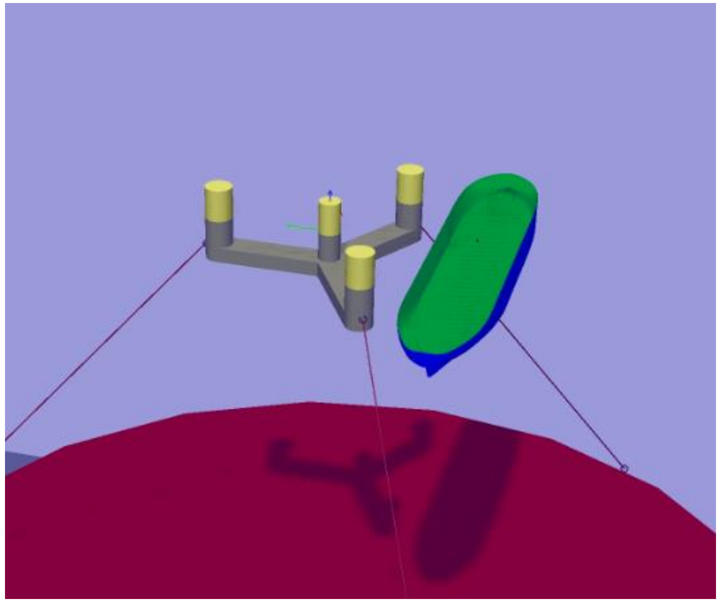


Basin test analysis – Objectives & Numerical model

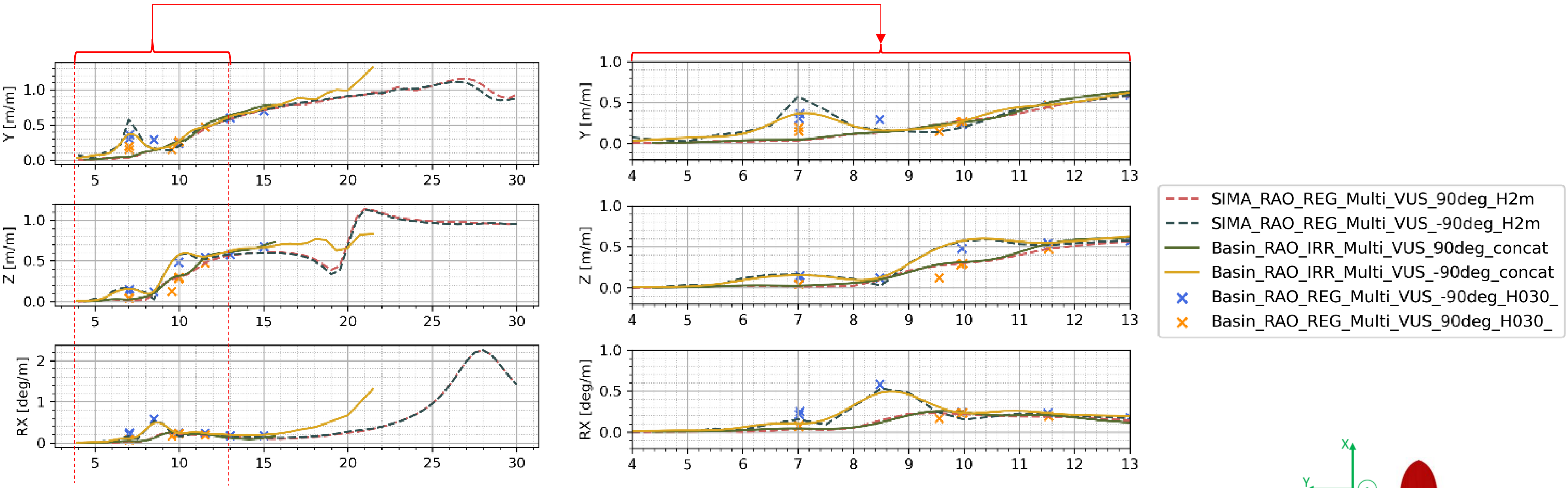
- **Objective**:
  - Validation of a **basin** numerical model
    - Coupling effects, stiffness and damping validation
      - Decay test
      - RAOs comparison
  - Calibration of the **main** FLOWTOM Numerical model:
    - Transfer of specific calibration to the numerical model of the main study

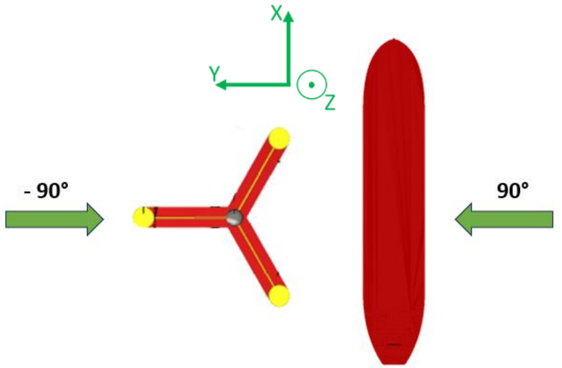


- **Numerical model:**
  - **Floater:** VolturnUS-S Semi-submersible + IEA 15MW turbine
  - **Vessel**: Reduced tanker
  - **Software:** *SIMO v4.26.2* operated in the *SIMA v4.6.3* workbench
  - **Hydro**:
    - Radiation-Diffraction model
    - Linear hydrostatic stiffness
    - Additional quadratic and linear damping
  - **Analysis**: Frequential + Time Domain



Basin test result analysis – Wave Tests – Coupling effect on VUS 90°/-90°





→ **Coupling effects (<15s) are completely captured by the numerical model**

Basin test result analysis – Decay Test – Conclusions

- **Vessel:**
  - The **basin model** was tuned with additional stiffness and damping to accurately capture basin specificities
  - This tuning is not transferable to the main numerical model
  - **No recommendation for the main FLOWTOM vessel model from decay test analysis**

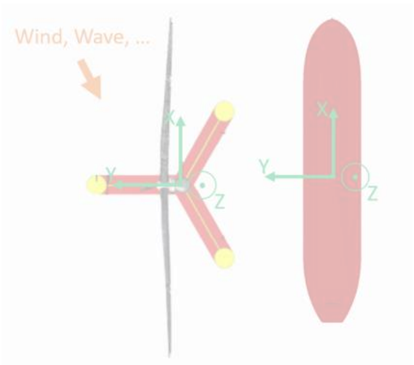
- **Semi-submersible floater:**
  - The strong agreement confirms the numerical model's accuracy for semi-submersible motion
  - **No recommendation for the main FLOWTOM semi-submersible model from decay test analysis**

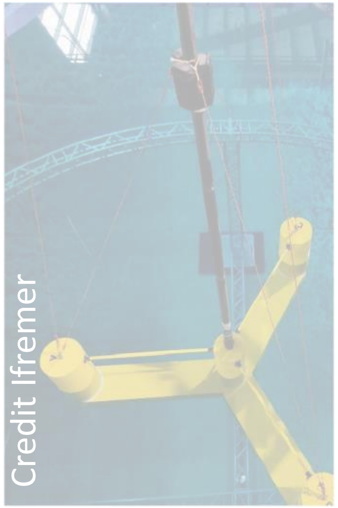
Case study: Operability definition of MCR steps

Case study specifications

Basin test

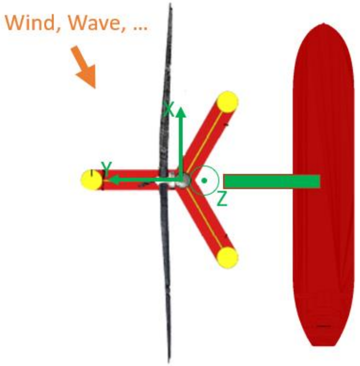
- Comparison Basin test VS dedicated numerical model:
  - Semi submersible VolturnUS-S [1] + IEA 15MW [2]
  - Mono hull vessel
  - Basin scale 1/50

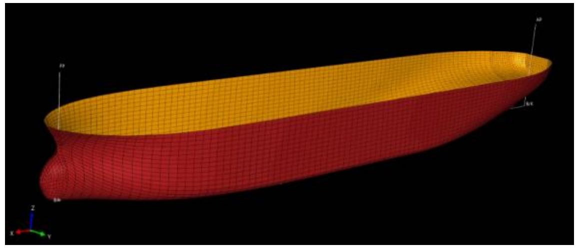




Numerical study

- Complete Numerical study:
  - Semi submersible VolturnUS-S [1] + IEA 15MW [2] + MCR solution
  - Mono hull vessel including a 1000t crane
  - Float4Wind + IEA 15MW + MCR solution
  - MCR self erecting system
  - Specific lift case studies





Include a self erecting crane solution

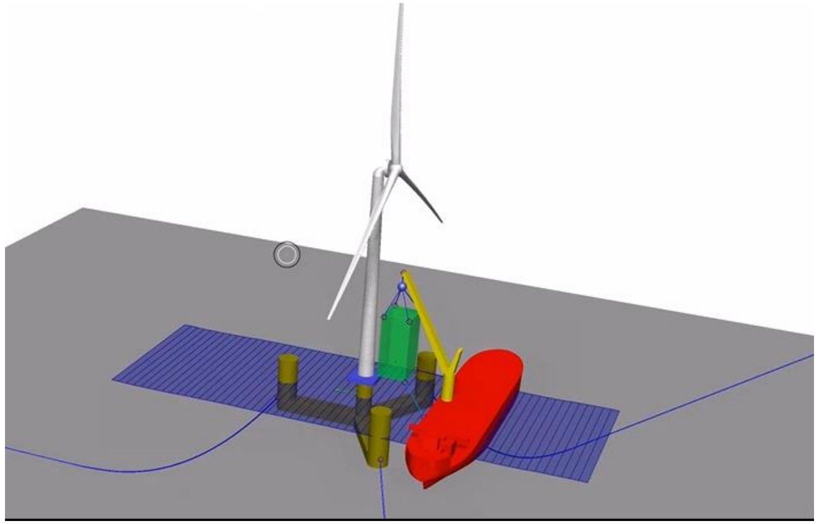
(1) C. Allen *et al.*, 'Definition of the UMaine VolturnUS-S Reference Platform Developed for the IEA Wind 15-Megawatt Offshore Reference Wind Turbine', Jul. 2020
(2) E. Gaertner *et al.*, 'Definition of the IEA Wind 15-Megawatt Offshore Reference wind Turbine', Mar. 2020.

Case study specifications

- **2 Floaters:**
  - FEM/EDF/Basin tests: Semi submersible UMaine VolturnUS-S Reference Platform 15 MW (NREL, 2020)
  - SBM Offshore: TLP FLOAT4WIND
  - Both including the MCR self erecting system
- **1 Vessel and lift crane:**
  - Resized Tanker
  - Equipped with Caballo Marango's crane (1000t lift) at mid ship
- **3 Numerical models:**
  - FEM with SIMA
  - EDF with Diego
  - SBM with Orcaflex
  - The 3 models were benchmarked

Vessel roll period: 10,5s

Pendulum mode: 7s (self hoisting crane) 9s (blade) 15s (package)



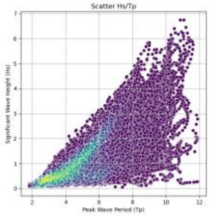
Numerical models overview

	EDF R&D	FEM	SBM Offshore
Software	DIEGO	SIMA	ORCAFLEX
Floater Type	Semi-Sub	Semi-Sub	TLP
Floater Name	VolturnUS-S	VolturnUS-S	Float4Wind
Hydrodynamic 1st order	Radiation/diffraction + additional drag elements	Radiation/diffraction + additional drag elements	Morison
Hydrodynamic 2nd order	MDF + Newman	MDF + Newman	Morison
Mooring	Chain Catenary - FEA	Chain Catenary - FEA	Hybrid Taut -FEA
Vessel	Resized Tanker	Resized Tanker	Resized Tanker
Hydrodynamic 1st order	Radiation/diffraction + additional roll damping	Radiation/diffraction + additional roll damping	Radiation/diffraction + additional roll damping
Hydrodynamic 2nd order	MDF + Newman	MDF + Newman	MDF + Newman
Dynamic positioning	Linearized stiffness + linear damping	Linearized stiffness + linear damping	Linearized stiffness + linear damping
Radiation/Diffraction coupling between the FOWT and the vessel	Yes	Yes	No

Validation method: Synthesis

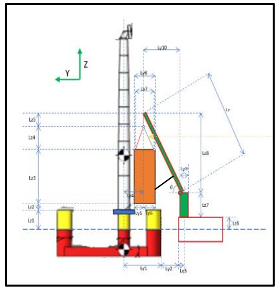
H_s	T_p						Wind @10 m elevation
	5	7	9	11	13	15	case 2
(m)	(s)	(s)	(s)	(s)	(s)	(s)	(m/s)
0.5	X	X	X	X	X	X	5.0
1.0	X	X	X	X	X	X	8.0
1.5	X	X	X	X	X	X	11.0
2.0		X	X	X	X	X	13.0
3.0		X	X	X	X	X	16.0
4.0		X	X	X	X	X	18.0

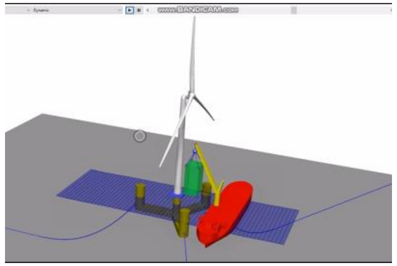
Exhaustive Metocean matrix



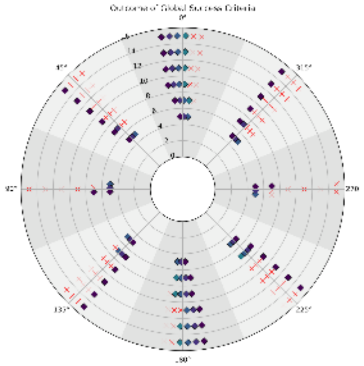
Specific Metocean conditions

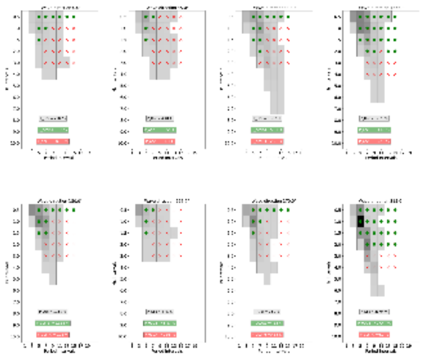
Case Definition → Time domain simulations → Discretization of time domain results → Operability assessment → Operability assessment applied on a specific site





- Example: 10 min windows over 3h simulations

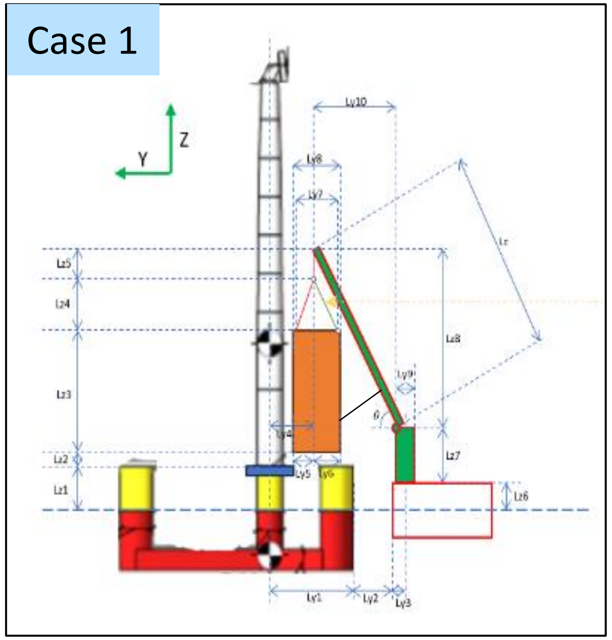


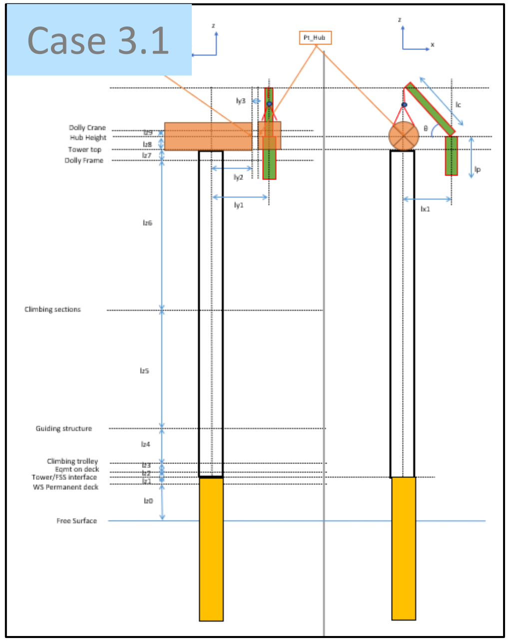


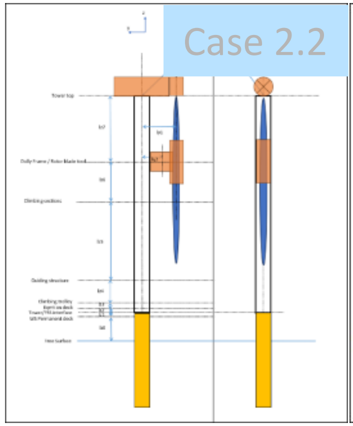
Case study specifications

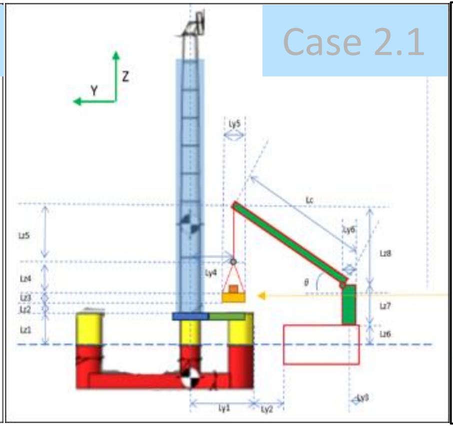
- **3 lift cases + 1 survival case**
  - Case 1: Package system installation
  - Case 2: Blade replacement
    - Case 2.1: blade transfer
    - Case 2.2: blade connection FOWT standalone
  - Case 3: Hub replacement
  - Case 4: Survival case FOWT standalone

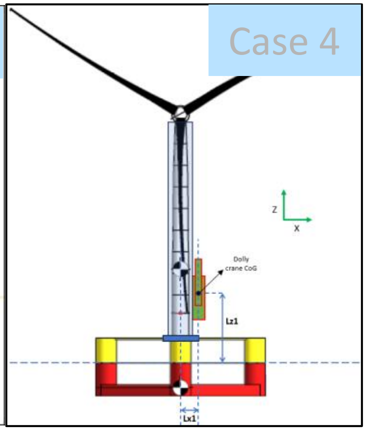
- **2 dof conditions**
  - X.X.1: No constraint on the package
  - X.X.2: Simplified constraints on the package: constant tension tugger line









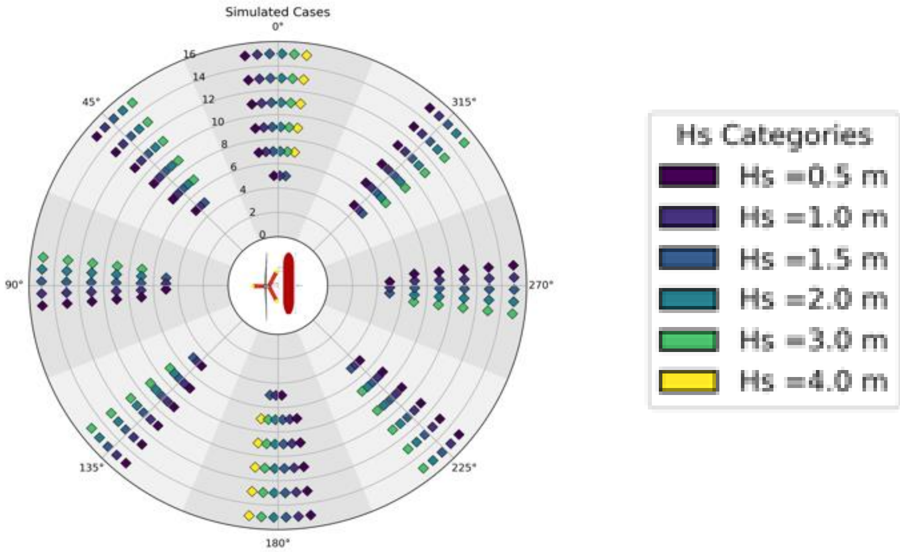


Metocean conditions & Operability criteria

All directions

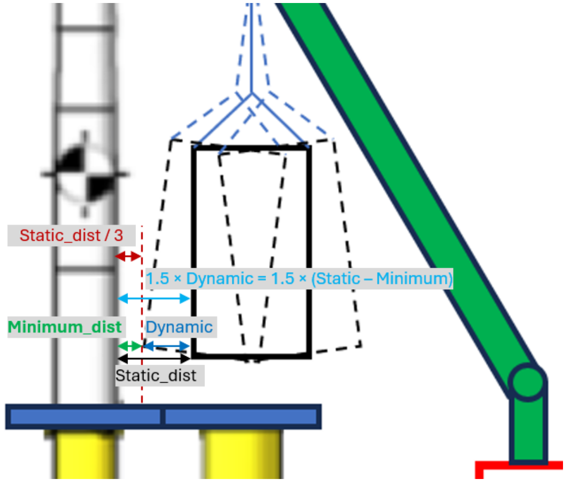
H_s	T_P						Wind @10 m elevation
	5	7	9	11	13	15	case 2
(m)	(s)	(s)	(s)	(s)	(s)	(s)	(m/s)
0.5	X	X	X	X	X	X	5.0
1.0	X	X	X	X	X	X	8.0
1.5	X	X	X	X	X	X	11.0
2.0		X	X	X	X	X	13.0
3.0		X	X	X	X	X	16.0
4.0		X	X	X	X	X	18.0

0° - 180°

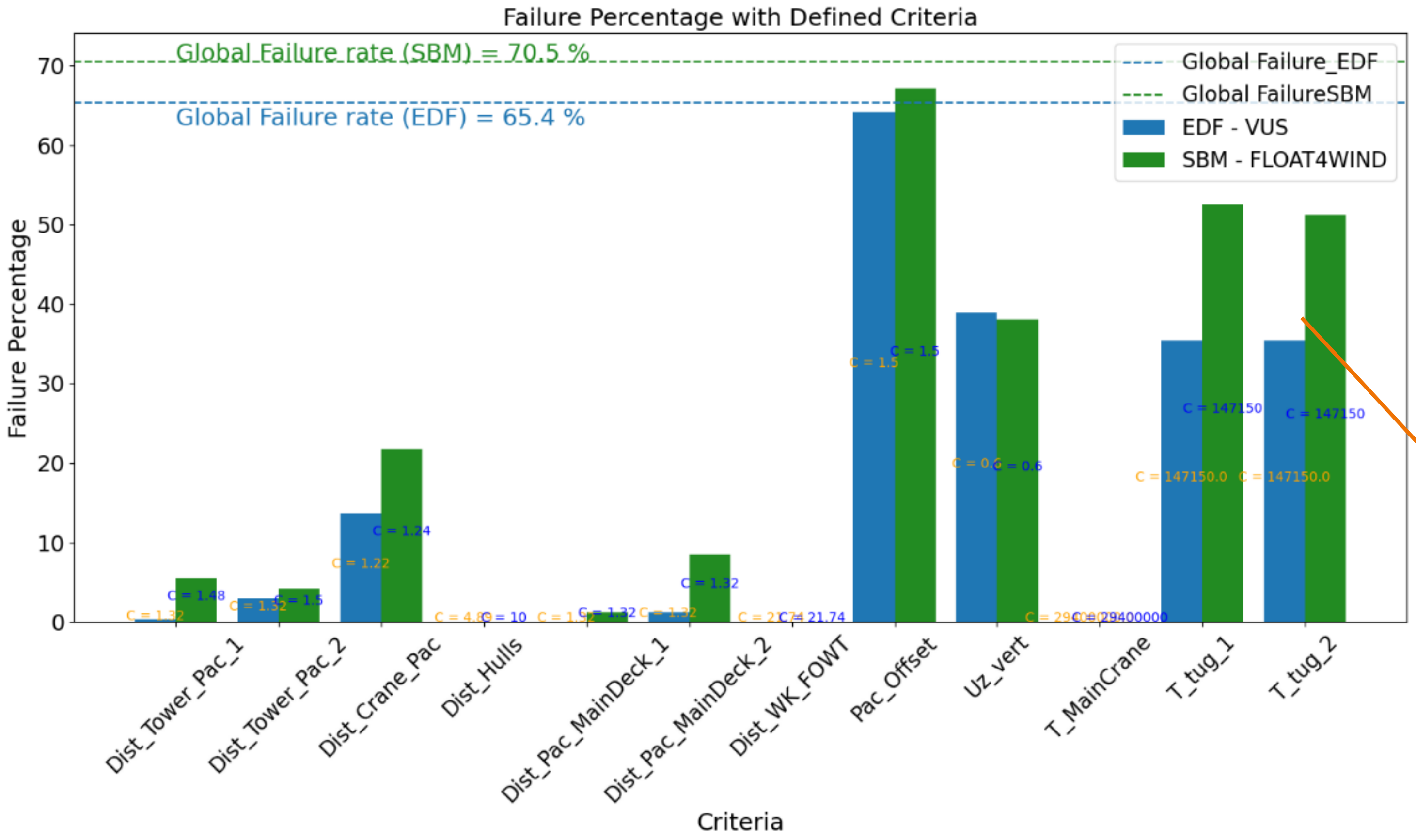


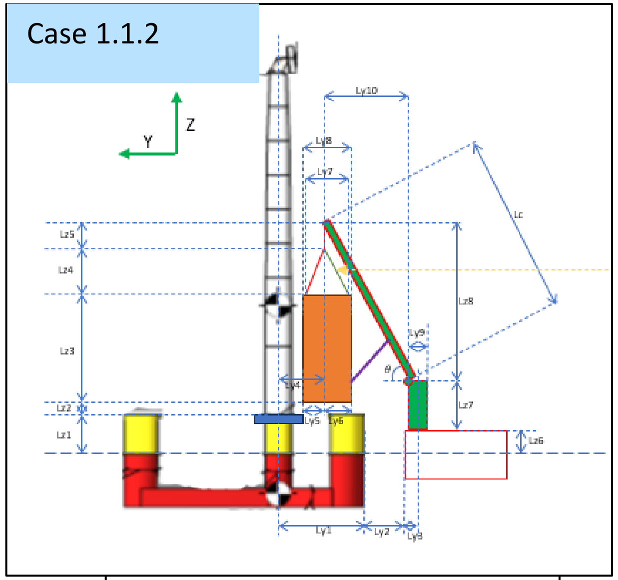
- Each metocean case is tested in one stochastic realization (seed) of 3h, then discretized in 18 windows of 10min.

- **Acceptance criteria:**
  - Min_dist > Static_dist /3 (SF of 1.5)
  - Relative vertical velocity < 0,6m/s
  - Horizontal offset (lift vs center MCR) < 1,5m Case 1&2
  - Horizontal offset (lift vs Nacelle) < 0,5 m Case 3
  - Tugger_tension < MBL/3

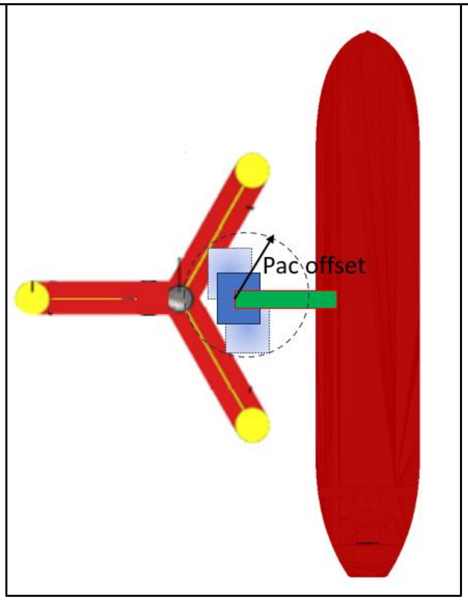


Case 1.1.2: Package system installation with tugger line





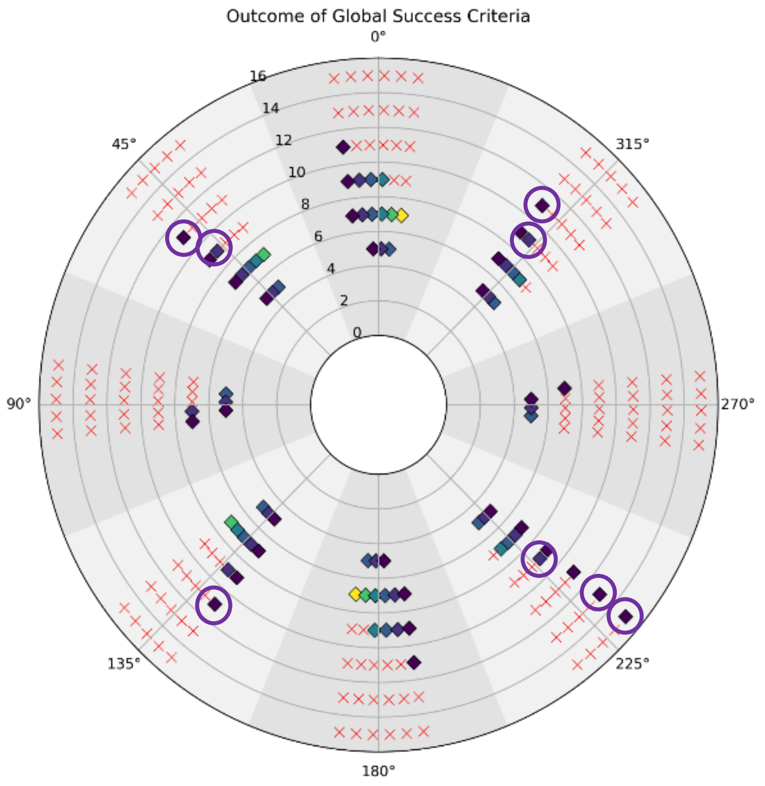
Difference due to different winch modeling



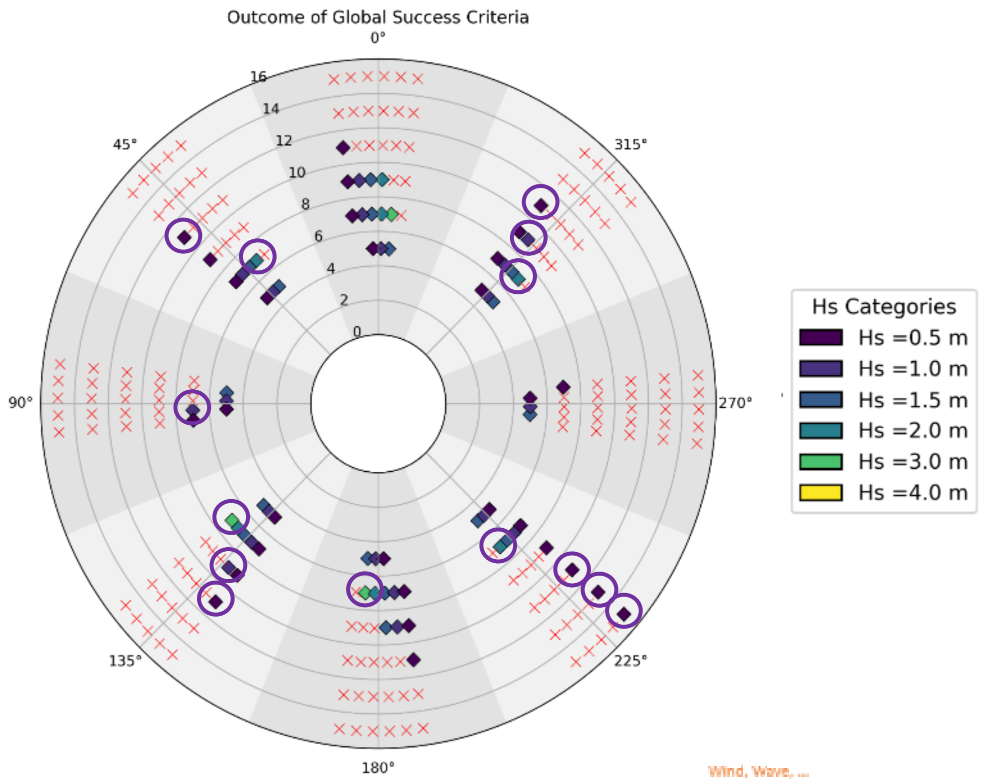
- Package offset is the main limiting criteria
- Tugger lines help, but their tension appear to be a limiting criteria (by design)

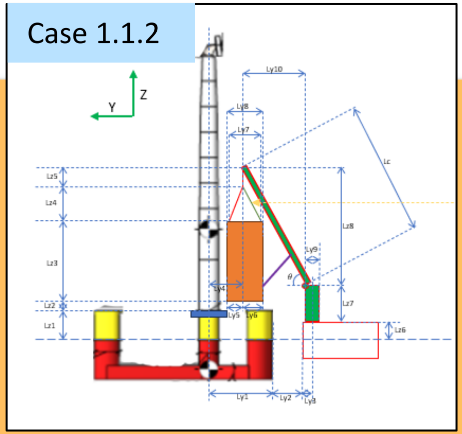
Case 1.1.2: Package system installation with tugger line

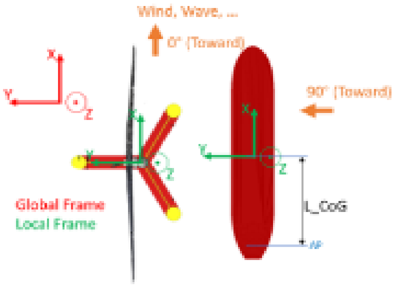
EDF – Semi-sub - VUS



SBM – TLP - F4W™



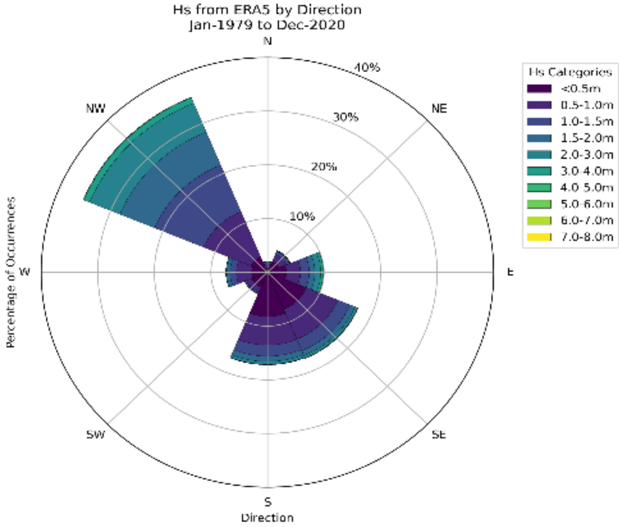


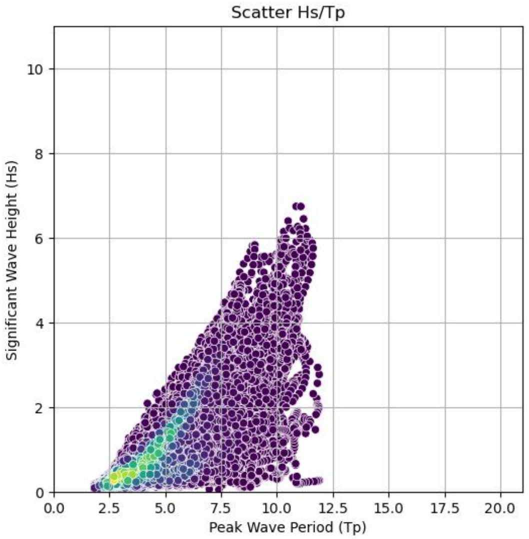


- Same global behavior for the 2 floaters
- **Slightly higher success at Tp ≥ 9s with tugger lines**
- Tugger lines are adding **4%** operability on the overall metocean matrix

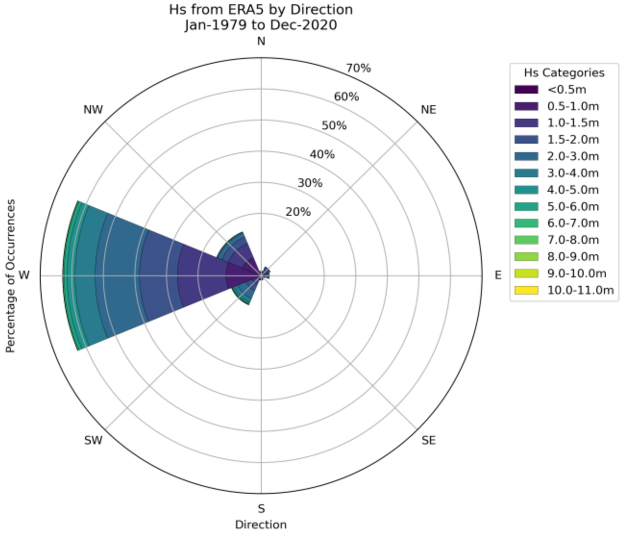
Operability definition: Sites selection

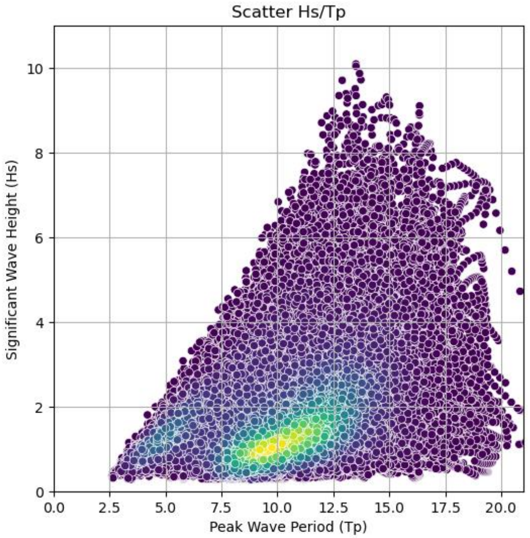
Gulf of Lion (AO6)



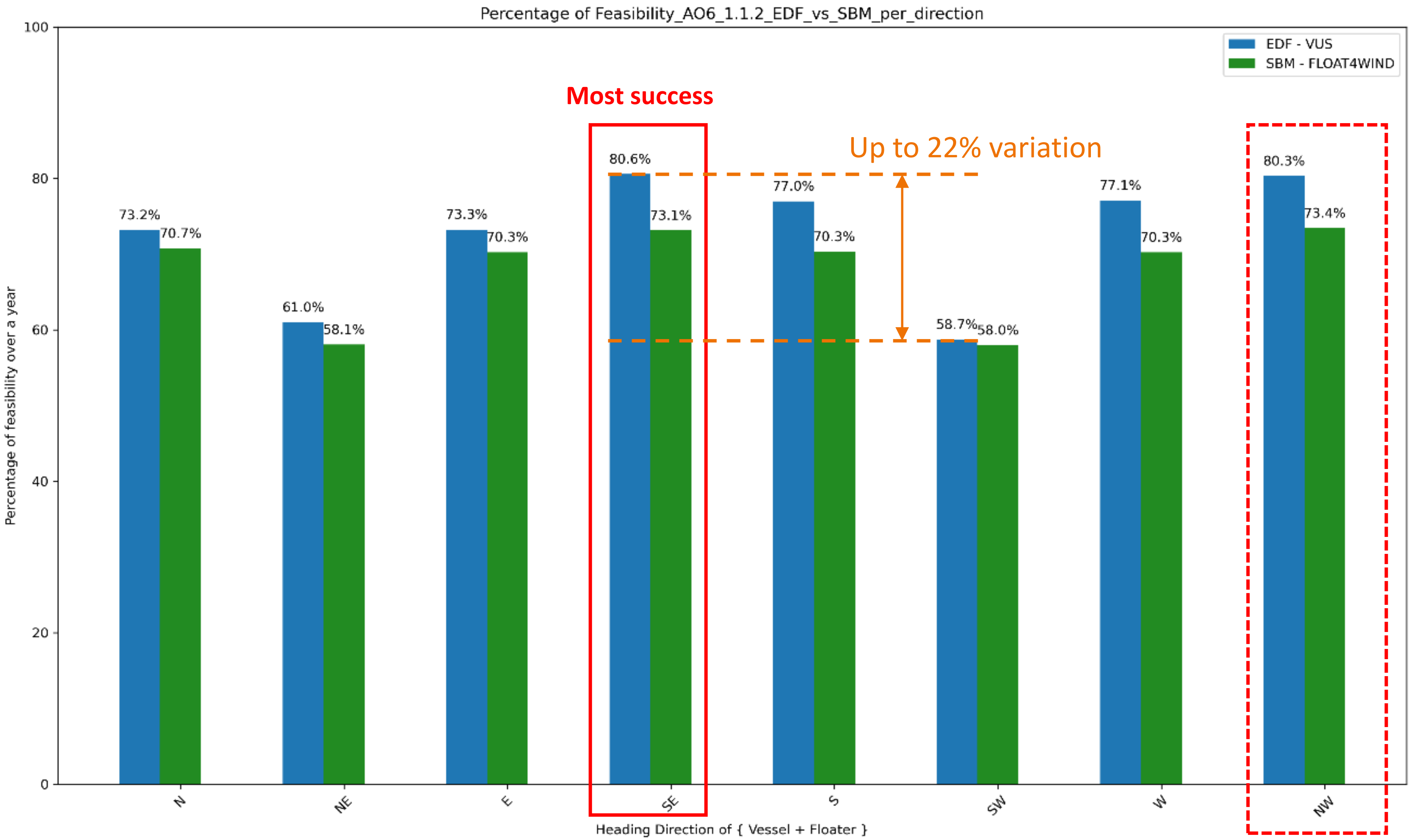


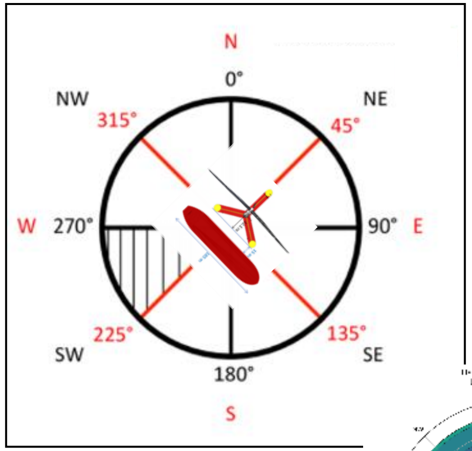
South Brittany (AO5)

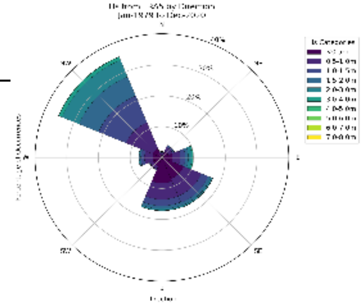




Case 1.1.2: Package system installation with tugger line

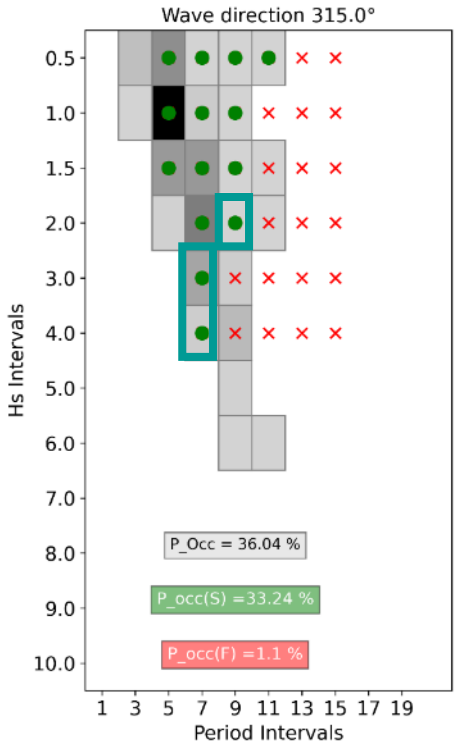




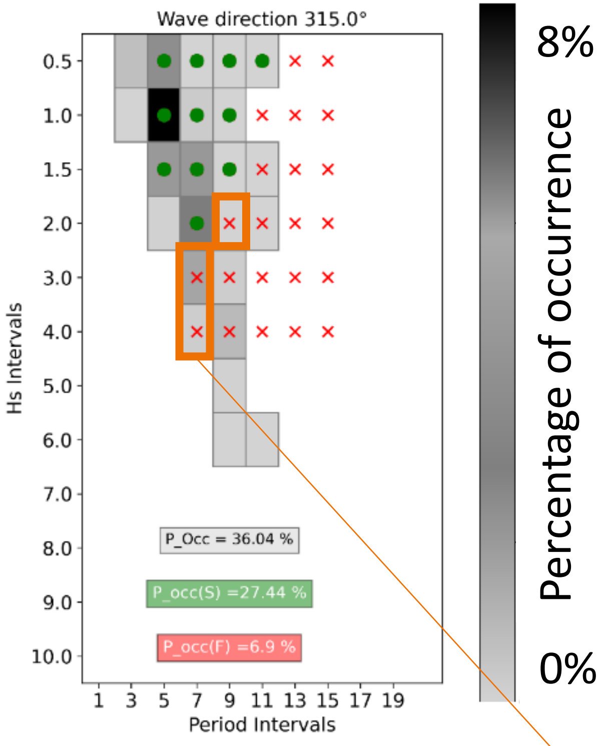


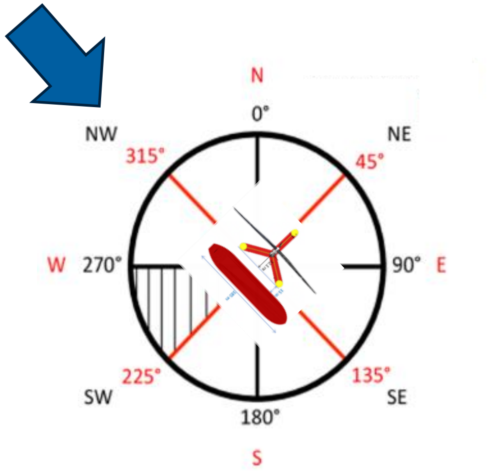
Case 1.1.2: Package system installation with tugger line

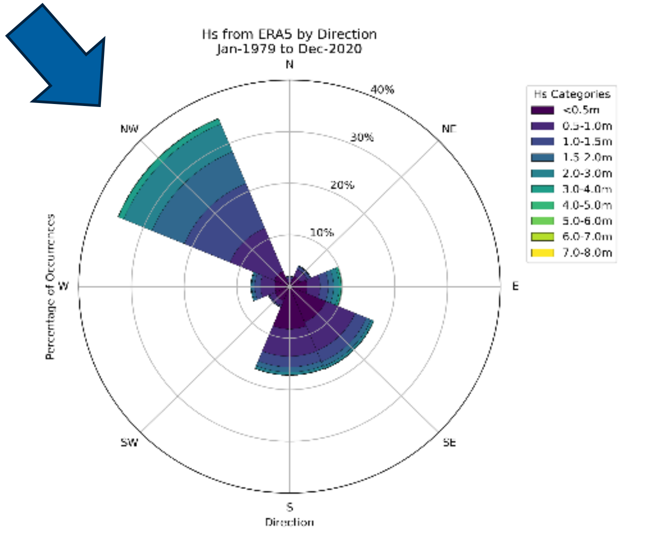
EDF – Semi-sub - VUS

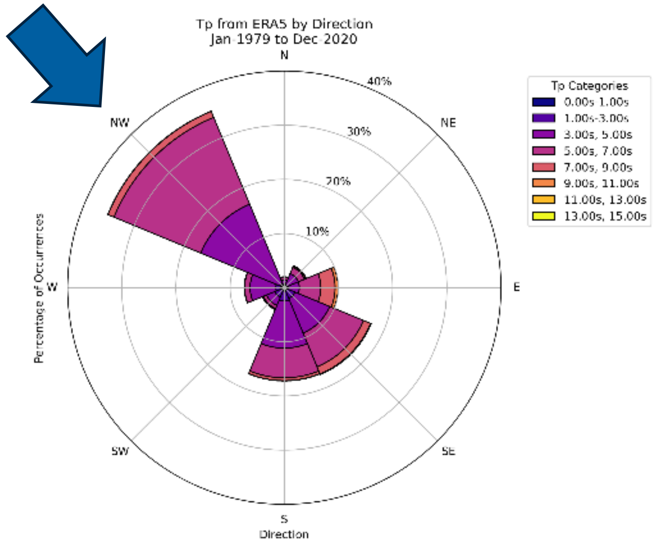


SBM – TLP - F4W™



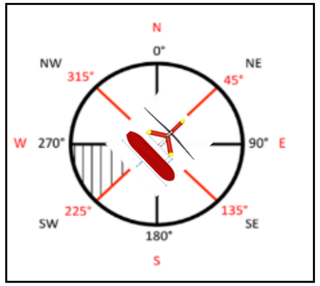


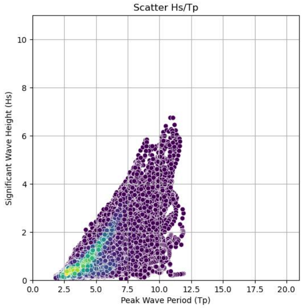


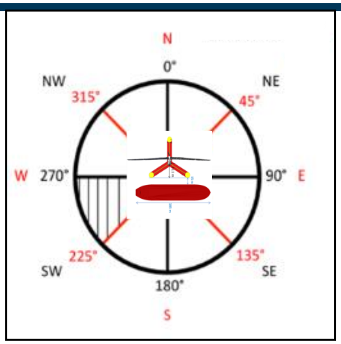


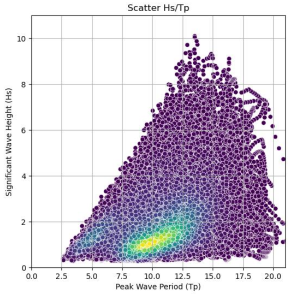
The 6% is caused by:
- Different model assumptions
- Different winch modeling

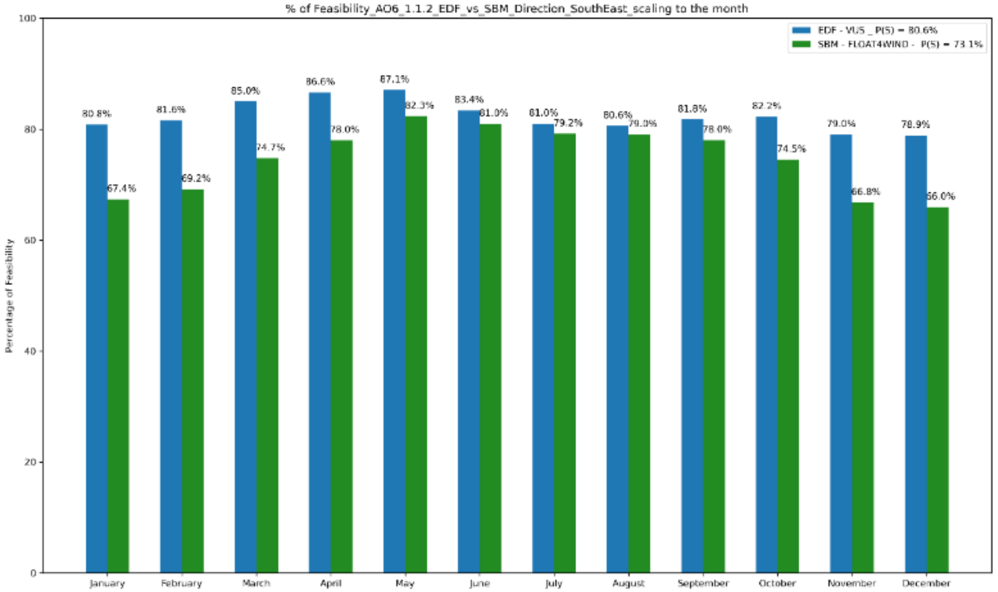
Case 1.1.2: Package system installation <u>with tugger line</u>

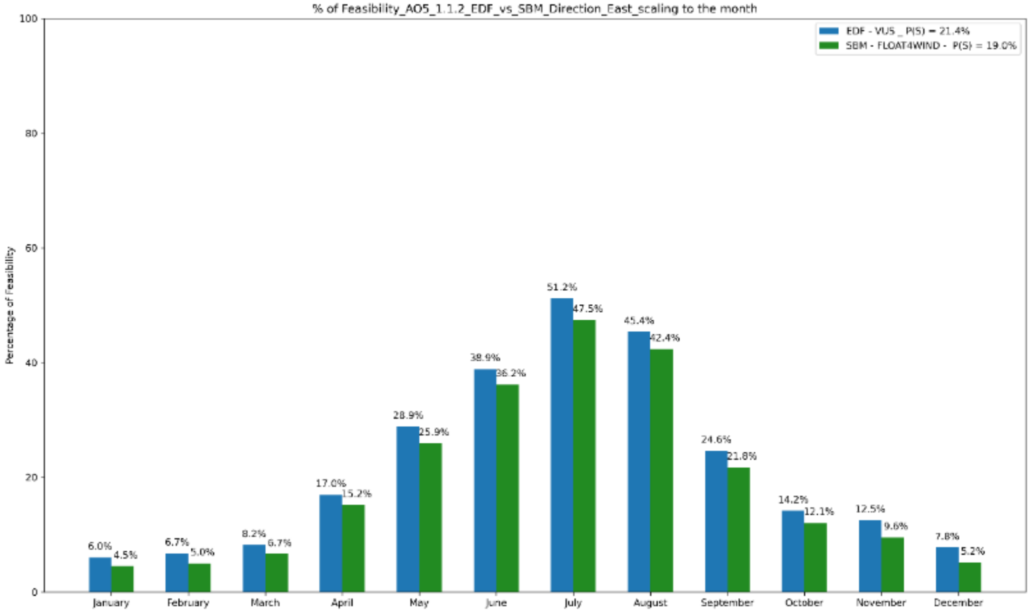










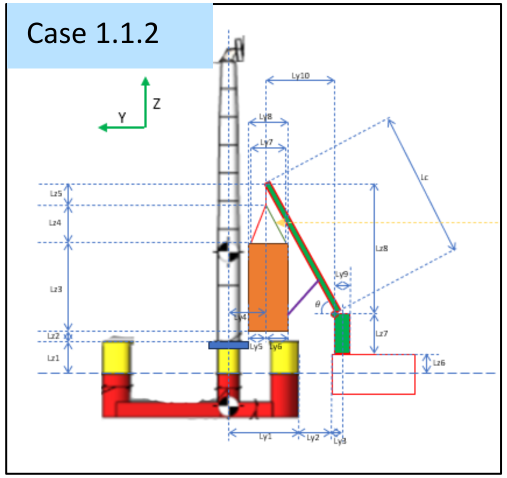


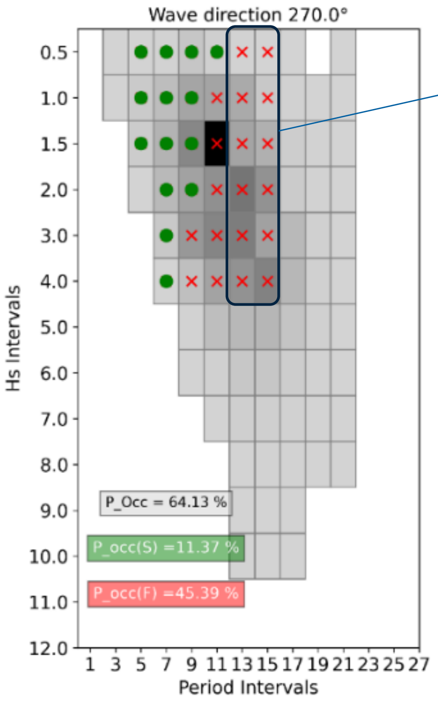
- **Higher rate of success in Mediterranean sea conditions (AO6) due to the wave period**
- **Optimized weather window in summer (June/July/Aug) in South Brittany (AO5), spring/summer in Mediterranean sea (AO6)**

Case 3: Hub replacement – Comparison with case 1

Semi-Sub – Lift 1

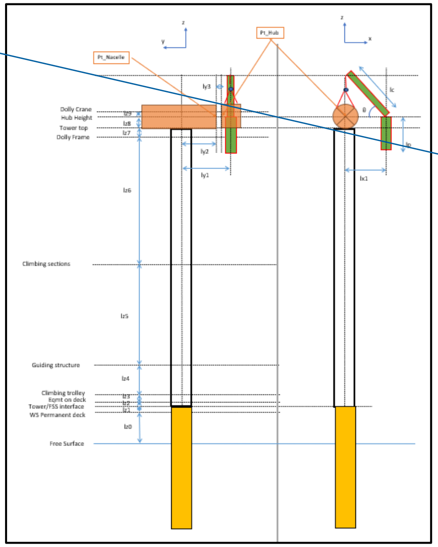
Semi-Sub – Lift 2 (Hub)

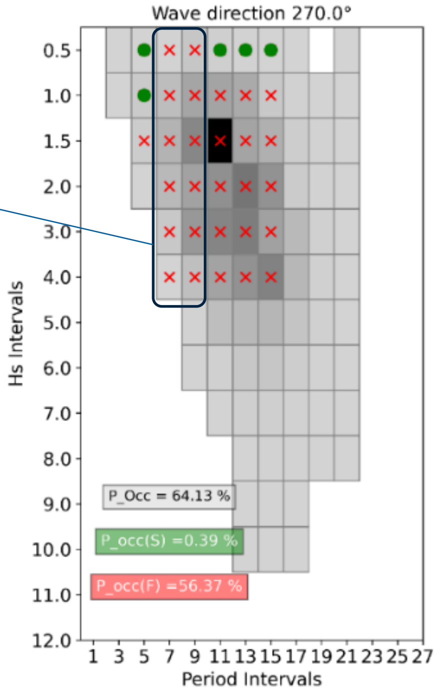




Case: 300 t lift weight

Pendulum natural period





Case: 190 t lift weight, using a self hoisting crane

- **The success rate & operability of a case are highly corelated with the case definition**
- **In the particular case of the hub replacement, the “operability scatter” does not reflect the real operability (contact of the hub with bumpers is not considered)**

Take away messages & Way forward

- FLOWTOM project worked at validating **engineering and R&D simulation tools for the assessement of MCR solutions operability** via basin test and models wide benchmark

- The case study revealed a **robust methodology**:
  - **To assess operability of heavy lifting operation** and proposed leverages of improvement toward an industrial solution

- Toward the validation of simulation tools for more complex floating to floating operations:
  - 2^{nd} order motions
  - Precise dynamic positioning representation
  - Complex tugger line control (damping tuned)
  - Critical phases analysis "package take-off or landing"
  - Toward the assessment of detailed MCR operations
  - SOV W2W transfer operation → **STORM project**

Thank you, questions?

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