IMPACT OF VESSEL LOGISTICS OVER FLOATING WIND FARM AVAILABILITY

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15 January, 2021

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Advanced tool for O&M activities analysis and optimization

2 **Case of study**

WindFloat Atlantic

3 **Results & conclusions**

1 INGEOCEAN

Advanced tool for O&M activities analysis and optimization

INGEOCEAN

Introduction

1

O&M SIMULATION TOOLS IMPORTANCE

R & D + I for sustainable development

From already existing experiences we conclude that:

- O&M may play a significative role in the **cost of the energy** produced in floating offshore wind farms.
- Personnel transfer has an important impact over O&M
- Metocean conditions rules the personnel transfer
- The **risk associated to personnel transfer** during marine operations depends directly on the interaction fluid–vessel–structure.
- O&M long-term strategies must balance the wind farm downtime with personnel-transfer (**marine operation risks**).

CHALLENGES AND OBJECTIVES

R & D + I for sustainable development

CHALLENGES

- Optimize **Availability**
- Facilitate **the decision-making** during personnel transfer operations
- Improve **personnel safety** access (marine operations)
- Optimize transport **vessel selection**

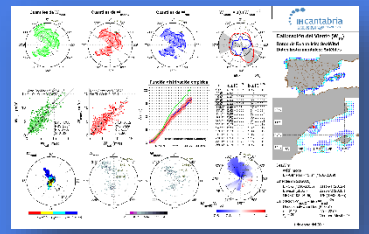
OBJECTIVES

To develop an integrated tool to simulate the marine operations associated to O&M from a long-term perspective

01

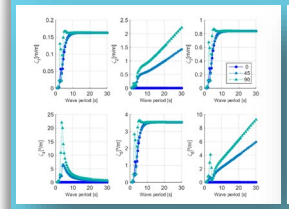
Metocean conditions assessment

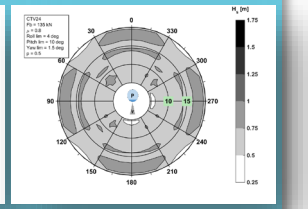
- Hindcast data
- Forecast data (future works)



02

Multi-body Hydrodynamics -Access simulator-

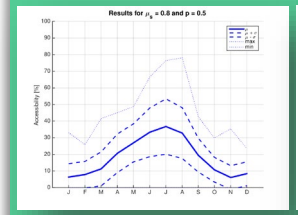


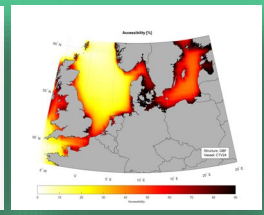


03

O&M Simulator

- Transport model
- Fault model
- Accessibility algorithm

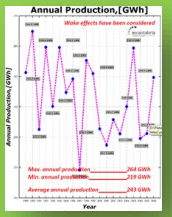


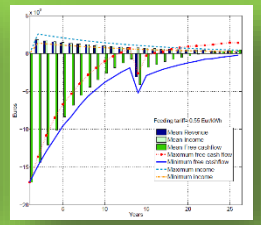


04

Farm Simulator

- Production model
- Cost model





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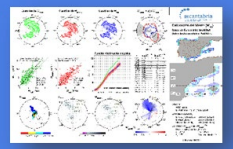
Simulator description

1

OFFSHORE WIND FARM MODEL

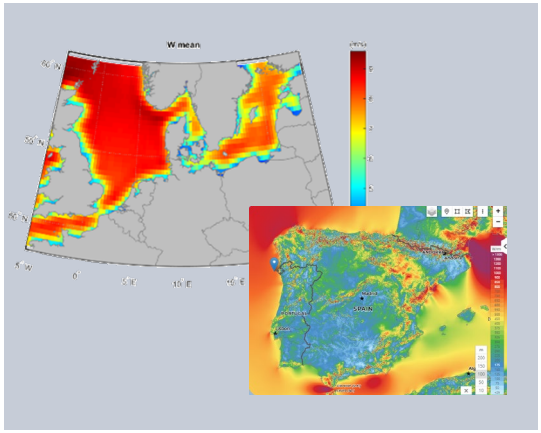
R & D + I for sustainable development

01
Metocean conditions assessment
- Hindcast data
- Forecast data (future works)



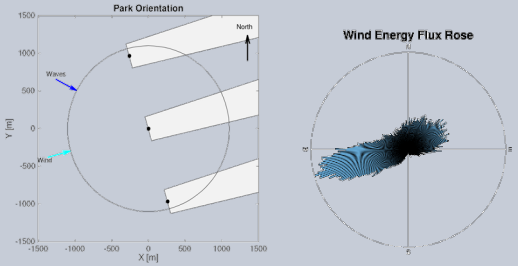
Regional scale

Market intelligence



Local scale

Operational tools



Metocean data

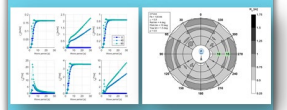
Met-Ocean database: IHDATA (https://www.ihcantabria.com/es/software/item/719-ihdata)
- Regional coverage
  - Cost of Portugal
- 20 years of hourly calibrated data using diverse instrumental information
  - Wind: intensity and direction
  - Waves: T_p, H_s, θ

Wind farm level:
- Any wind farm distribution can be considered
- Any wind turbine can be considered introducing its power and thrust curves.
- Simplified farm model (optional)
  - Wake model: Jensen N. O. 1984
  - Wake overlapping: Katic et al 1986
- Floating wind turbines: operational limits: Michele et al 2016.

OFFSHORE WIND FARM MODEL

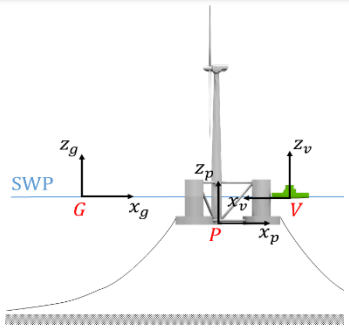
02

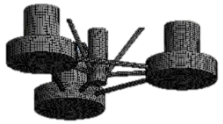
Multi-body Hydrodynamics -Access simulator-

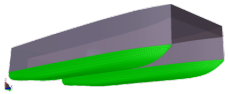


Multibody simulation

NEMOH & SESAM: Open-source and commercial codes to get hydrodynamic response in the frequency domain





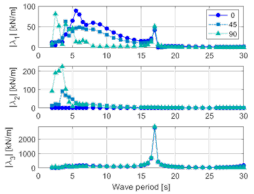


Platform (fixed or floating) Vessel (CTV or SOV)

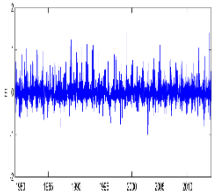
Coupled system RAO

Frequency domain response of both bodies according to the wave heading angle

RAOs

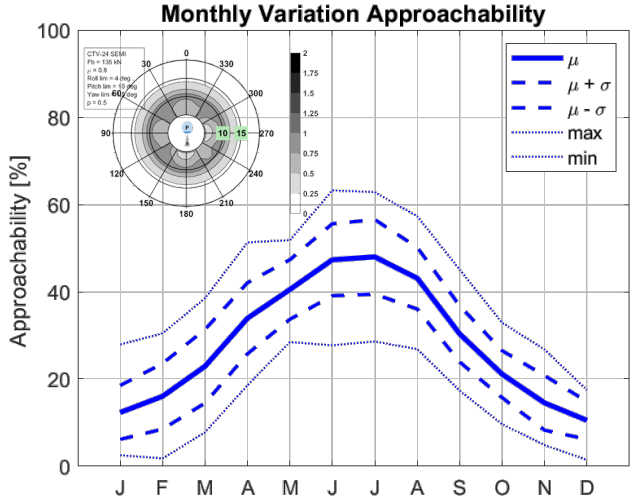


Metocean time series (wave, wind)



Accessibility

- Accessibility polar diagram of limiting wave height depending on wave periods and wave headings.
- Statistical results of accessibility for any
- Accessibility atlas.



W2W strategy: step up to access ladder by CTV (no gangway)

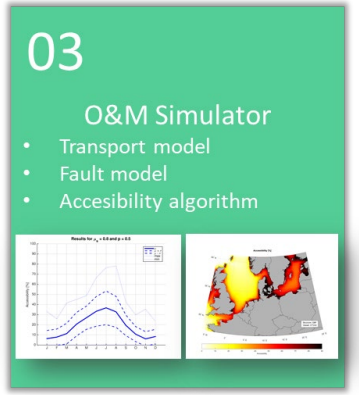
- Hypothesis considered: O&M technicians walk from the vessel to the boatlanding **if and only if** :
  1. There is no-slide condition between both bodies (no relative motion).
  2. There are small relative rotations (thresholds defined by the user).

W2W strategy: SOV with an auto compensated gangway

- Hypothesis considered: gangway tip is infinitely close to the transition piece, allowing O&M technicians to walk to the platform **if and only if**:
  1. Relative motions between the gangway tip and the platform are within operational compensation limits of the gangway.

Guanche, R., Martini, M., Jurado, A., Losada, I.J., (2016) Walk-to-work accessibility assessment for floating offshore wind turbines, Ocean Engineering

OFFSHORE WIND FARM MODEL



Transport analysys:

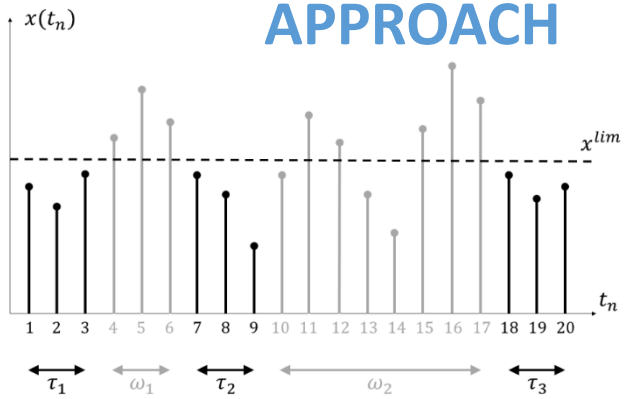
- Find the shortest path between harbor-OWF based on a **Dijkstra algorithm.**
- Output:
  - Shortest route
  - Route Metocean conditions
  - Transportability (Threshold: Hs)

Accessibility is the percentage of time on which it is potentially possible to be working on the OWF.

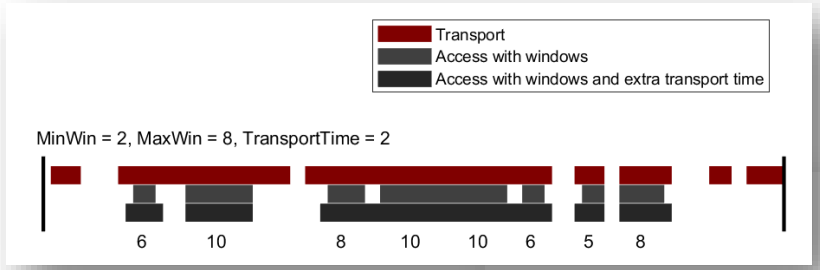
Accessibility is influenced by:

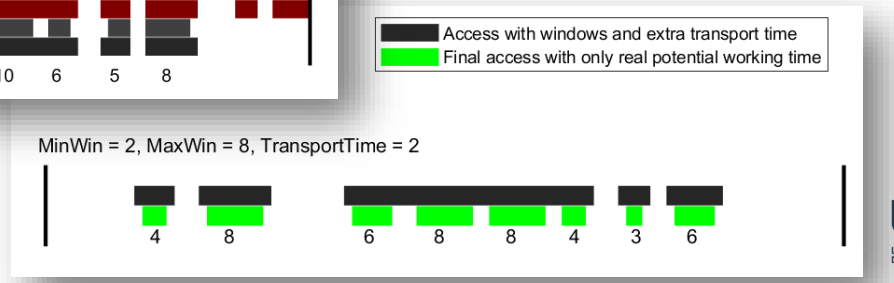
- Approachability and workability.
- Transportability.
- Minimum and maximum working window sizes considered:
  - Minimum: Is the transport justified?
  - Maximum: How long can the crew work?

WAVE-BY-WAVE APPROACH



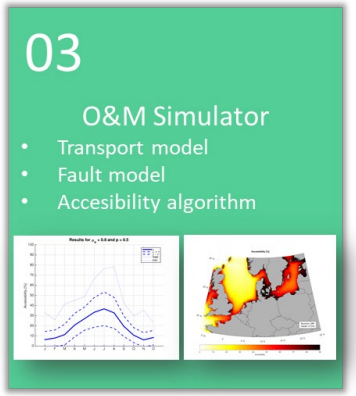
WEATHER WINDOWS ANALYSYS





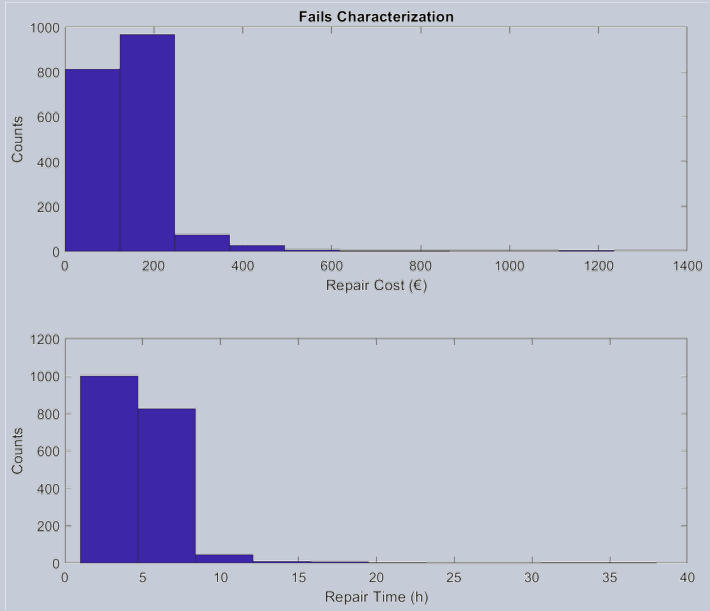
OFFSHORE WIND FARM MODEL

R & D + I for sustainable development



Ingeteam O&M experience has been used to create a database including:

- **Failure rates** per component
- **Repair time** per component
- **Repair cost** per component



01 Vessel availability

02 Weather Window (Transportation, (Personnel Transfer and workability)

03 Reparation time

For each fault:

Assign the fail to a turbine.

While the fault is not REPAIRED:

Find the next weather window (from accessibility module).

For each vessel, while no vessel is ASSIGNED:

If the vessel is free:

If the window is long enough for fully repair:

ASSIGNED AND **REPAIRED.**

If the window is not long enough for fully repair:

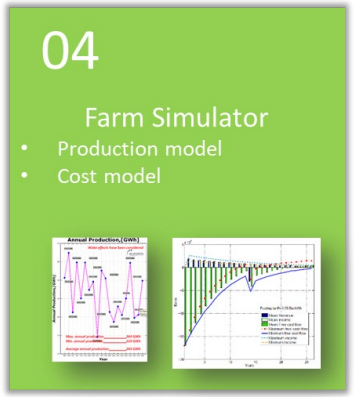
ASSIGNED and repair time reduced.

If the vessel is not free and the window is long enough to fully repair new fail too:

ASSIGNED AND **REPAIRED.**

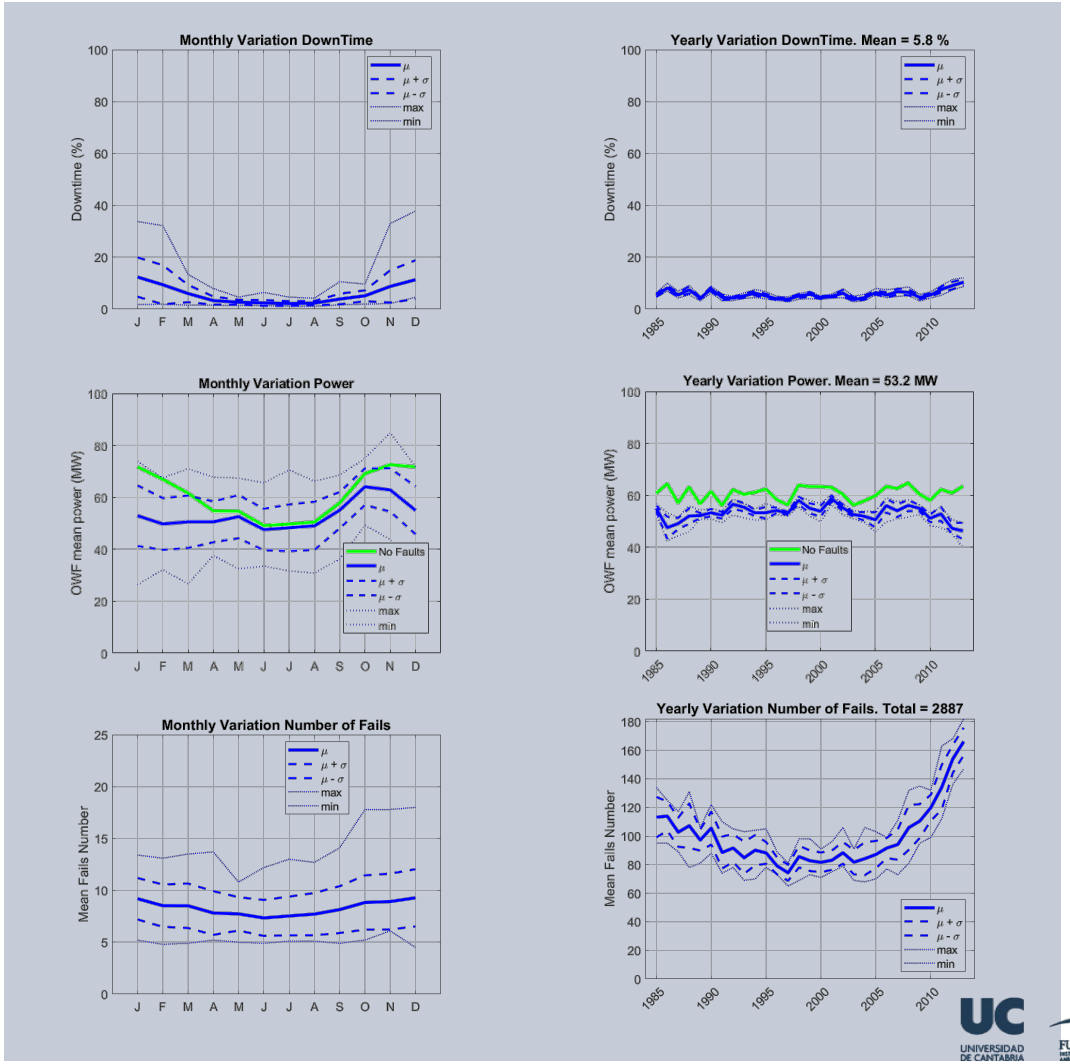
OFFSHORE WIND FARM MODEL

Farm simulator



Performing several life-span simulations with different random faults, the farm simulator provides long-term information to perform a statistical analysis, of:

- Weather downtime
- Time and power availability
- Energy production
- Reparation time
- Number of vessel trips



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2

Case of study

WindFloat Atlantic

2.1 Farm characteristics

2.2 Base Case

2.3 Results

Advanced tool to optimize the O&M activities

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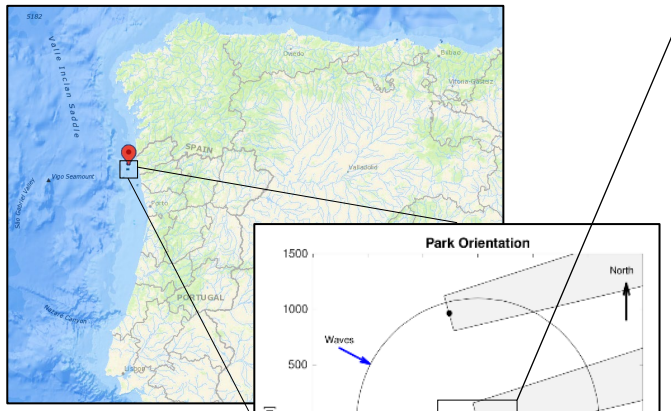
Case of study: WindFloat Atlantic

Farm characteristics

WIND FLOAT ATLANTIC

Farm characteristics

WINDFLOAT ATLANTIC

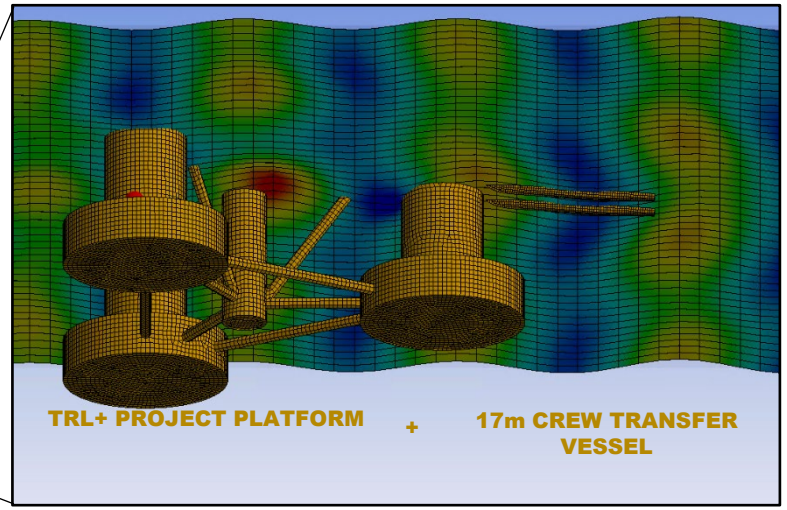


WAVES

WIND

METOCEAN DATA

HYDRODYNAMIC INTERACTION MODEL



- 20km off the coast of Viana do Castelo, Portugal.
- Three V164-8.4MW wind turbines installed on floating foundations.
- Developed by Principle Power.
- Total installed capacity of 25MW
- O&M work centre in Viana do Castelo. (equipped with a storehouse and a CTV)

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Case of study: WindFloat Atlantic

Base Case

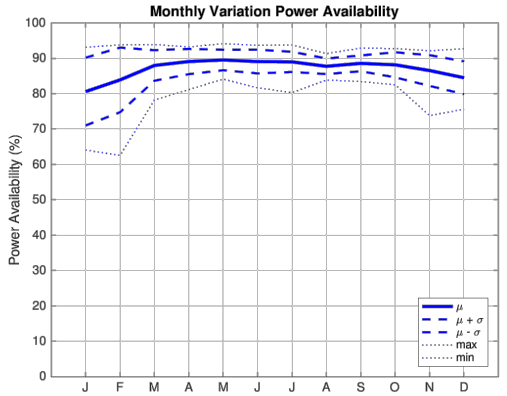
BASE CASE

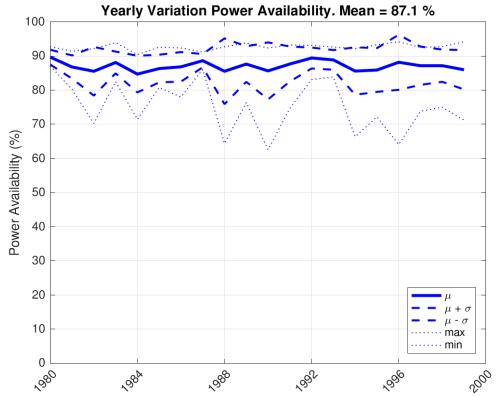
Effects of delays: waiting for a service technician, for a vessel to come and that some spare parts are not in stock.
When the wind turbine shuts down because of a failure, we assume the technician needs a spare part to repair the system.

We consider one base case with the following assumptions:

- We own a vessel of 17 m.
- Storage of both small and medium spare parts in harbor
- Minimum working time of 1 hour

	CTV TYPE	RENTAL CONTRACT CTV	SMALL SPARE PARTS STORAGE	MEDIUM SPARE PARTS STORAGE	LIGHT REPAIR LOGISTIC TIME	MEDIUM REPAIR LOGISTIC TIME	MINIMUM WORKING TIME	AVAILABILITY
BASE CASE	17 m	In property	Yes	Yes	4h	4h	1h	87.1%





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Case of study: WindFloat Atlantic

Results

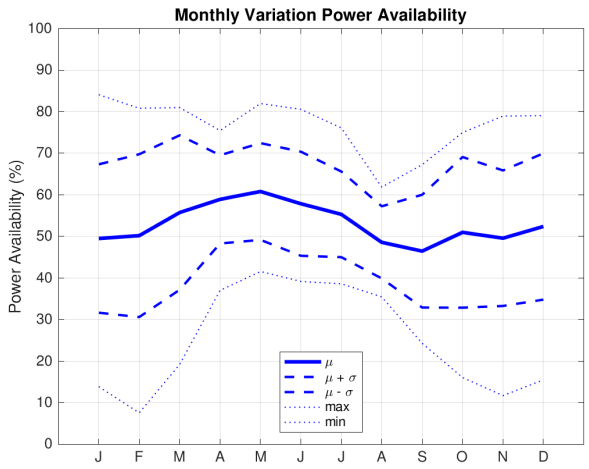
With the objective of studying the impact of logistic times in the availability, we focus in three variables:

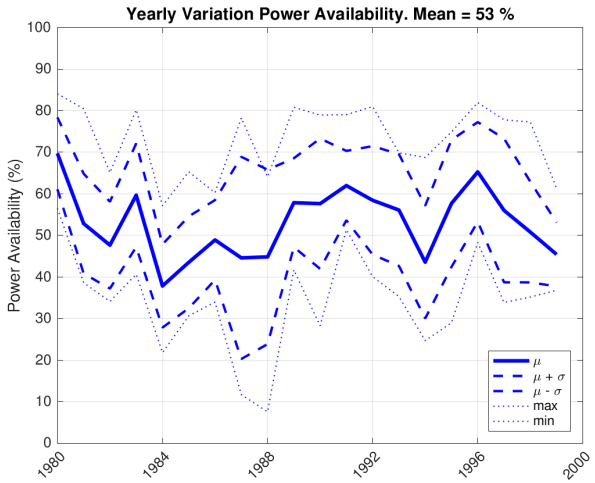
- The minimum working time
- The existence of spare parts storage
- The type of rental contract of the CTV

Minimum working time

We consider a new scenario in which the minimum working time is increased from 1 hour to 2 hours

	CTV TYPE	RENTAL CONTRACT CTV	SMALL SPARE PARTS STORAGE	MEDIUM SPARE PARTS STORAGE	LIGHT REPAIR LOGISTIC TIME	MEDIUM REPAIR LOGISTIC TIME	MINIMUM WORKING TIME	AVAILABILITY
1	17 m	In property	Yes	Yes	4h	4h	2h	53%





BASE CASE AVAILABILITY: 87,1%

Spare parts storage

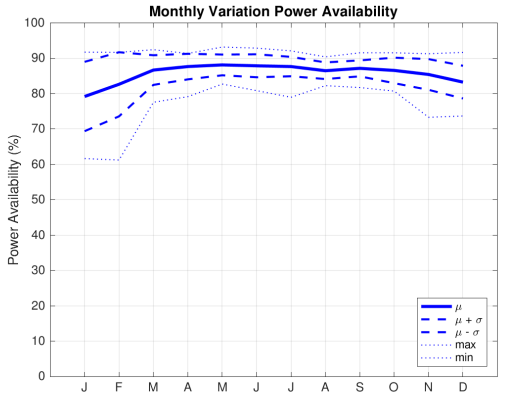
Variation of parameters

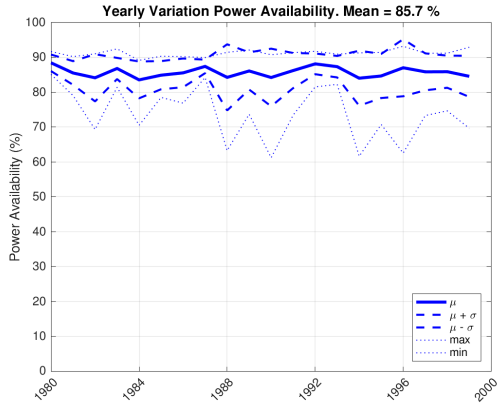
We consider two new scenarios:

- One in which we have a small spare parts storage in harbor, but not a medium spare parts storage
- One in which we don't have any spare part in stock

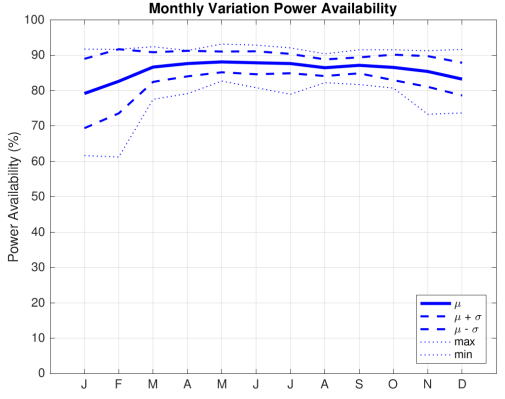
BASE CASE AVAILABILITY: 87,1%

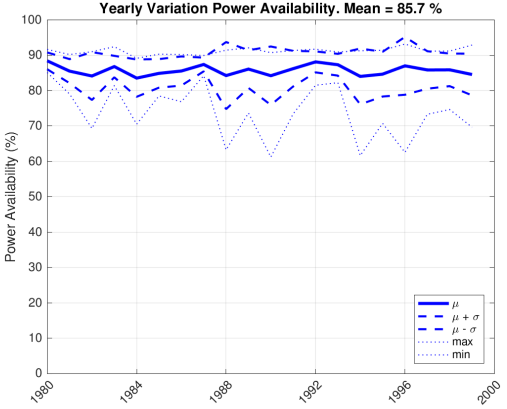
	CTV TYPE	RENTAL CONTRACT CTV	SMALL SPARE PARTS STORAGE	MEDIUM SPARE PARTS STORAGE	LIGHT REPAIR LOGISTIC TIME	MEDIUM REPAIR LOGISTIC TIME	MINIMUM WORKING TIME	AVAILABILITY
2	17 m	In property	Yes	No	4h	24h	1h	85,7%
3	17 m	In property	No	No	24h	24h	1h	85.7%





Only small spare parts storage





No spare parts in stock

Rental contract of CTV

	CTV TYPE	RENTAL CONTRACT CTV	SMALL SPARE PARTS STORAGE	MEDIUM SPARE PARTS STORAGE	LIGHT REPAIR LOGISTIC TIME	MEDIUM REPAIR LOGISTIC TIME	MINIMUM WORKING TIME	AVAILABILITY
4	17 m	8h	Yes	Yes	8h	8h	1h	86.8%
5	17 m	12h	Yes	Yes	12h	12h	1h	86.5%
6	17 m	24h	Yes	Yes	24h	24h	1h	85.7%
7	17 m	48h	Yes	Yes	48h	48h	1h	84.3%

We consider four new scenarios considering the type of rental contract that we have for our CTV.
If the vessel is not our property, it can take 8h, 12h, 24h or 48h for it to be available.

BASE CASE AVAILABILITY: 87,1%

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Conclusions & Future work

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Advanced tool to optimize the O&M activities

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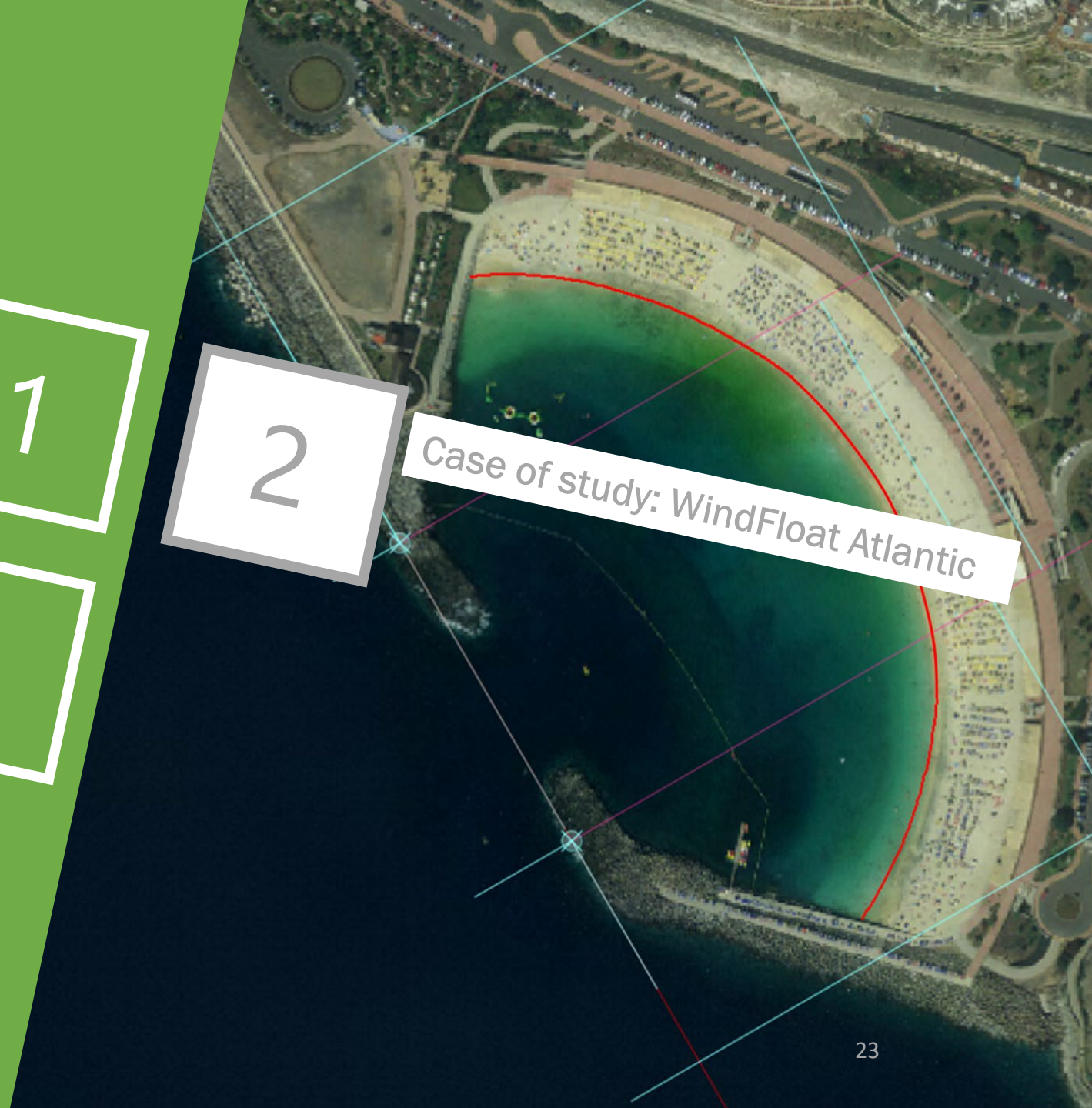
Case of study: WindFloat Atlantic

Conclusions & Future work

Conclusions

3



CONCLUSIONS

A **new O&M tool has been developed**, with specific features:

- The personnel transfer model includes the fluid-structure-vessel interaction problem: wave height, period and direction impact over the marine operations → **Structure and vessel agnostic**
- A transport model that evaluates the feasibility of the sea transport depending on wave conditions along the route.
- Failure model fully parametrizable per component and a time-varying failure rate
- Highly modular implementation that allows to easily adapt to a changing O&M scenario.

The O&M tool can be used for operation and maintenance strategies design, including:

- Boat landing number and orientation
- Support harbor selection
- Vessel type and contract selection

In the case of WindFloat Atlantic,

- The minimum working time considered for the park has a great impact on the power availability.
- Spare parts storage may have an impact of 1.4% in power availability.
- For the vessel rental contract types studied, the power availability had a variance of up to 2.5%.

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Advanced tool to optimize the O&M activities

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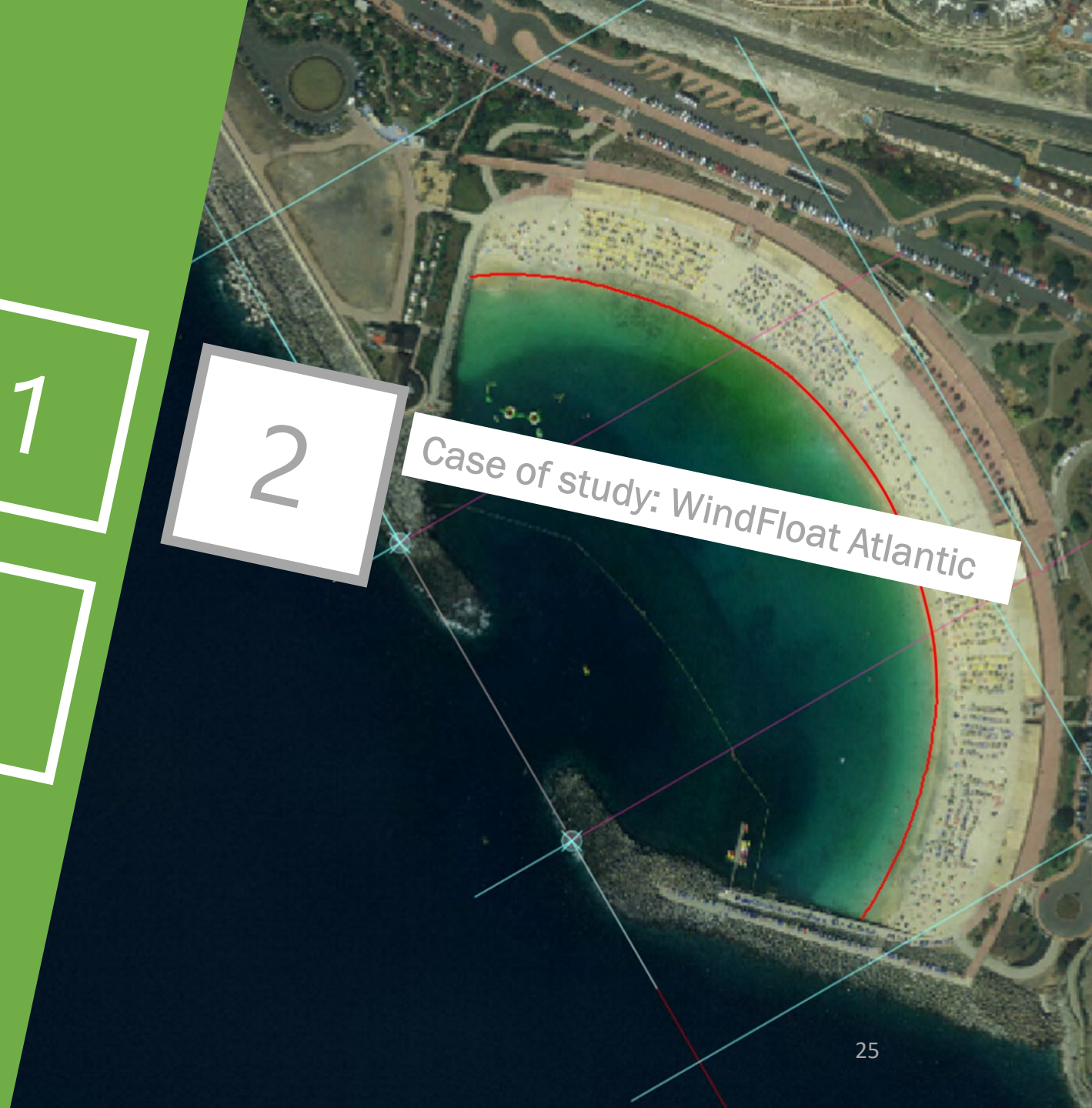
Case of study: WindFloat Atlantic

Conclusions & Future work

Future work

3



FUTURE WORK

- Include a hydrodynamic module for a better representation of the dynamics of the vessel during the sea transport (Not only wave height transportation limits but also wave period and direction).

- Include randomly generated climate data for the following 25 years :**climate change** impact over O&M.

ACKNOWLEDGEMENTS

GOBIERNO DE ESPAÑA
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Proyecto ACOPLE:
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Ingeteam

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