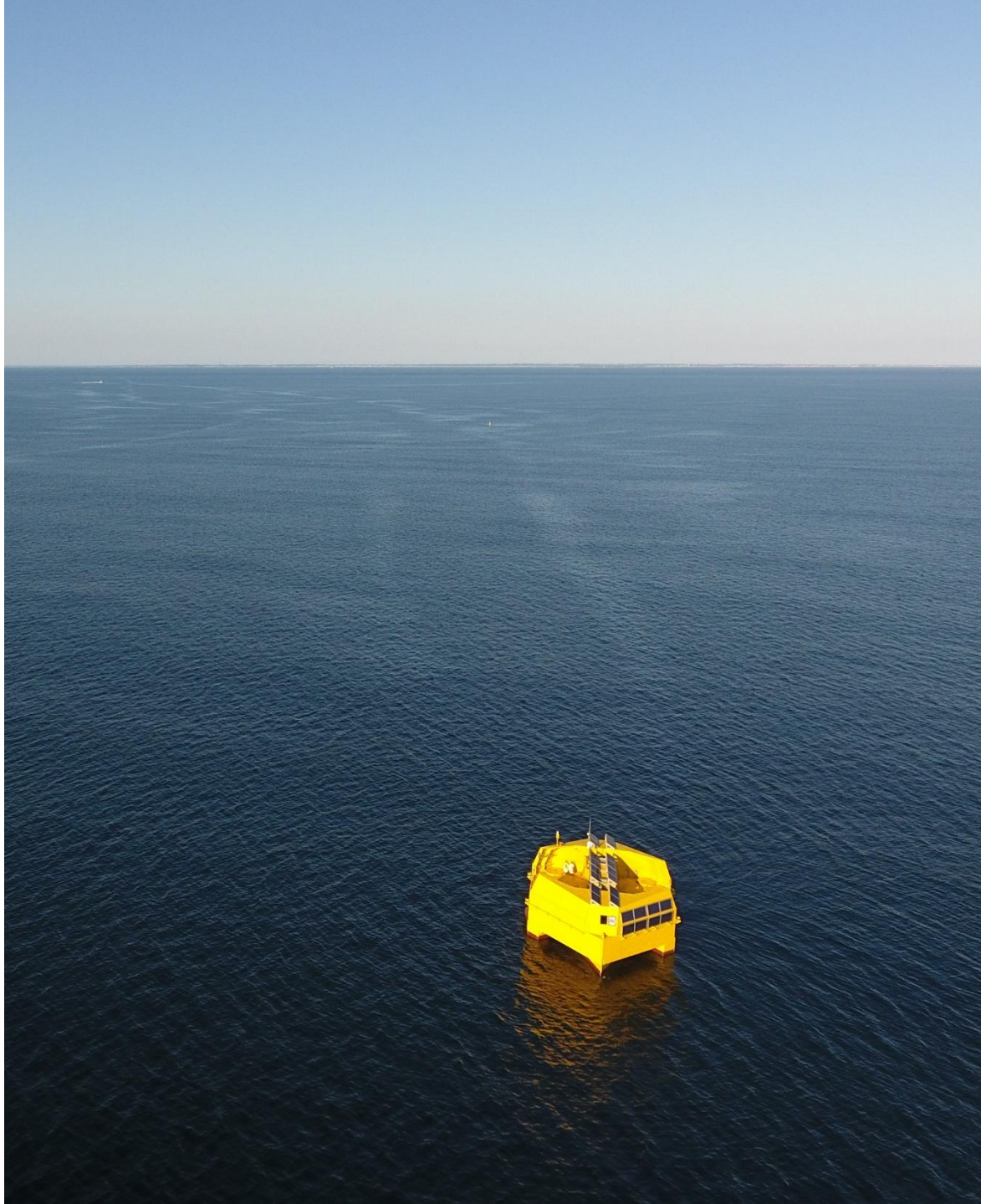
FONDATION OPEN-C

Paimpol Brehat test site: Correlation measure / model Wave statistics and extreme for ebb and flow



Olivia Thilleul

5 OFFSHORE TESTS SITES & MORE

FONDATION OPEN-C

| Coordinates, develops and manages offshore test sites in France

| Dedicated to floating wind turbines and offshore renewable energies

| Offshore testing to accelerate the energy transition

| Research partnerships, studies of interactions between the environment and ORE projects

| Non-profit **public-interest organisation**

| Created in **March 2023**

CREATED IN 2023

5 ENERGIES TESTED

13 PROTOTYPES ALREADY TESTED

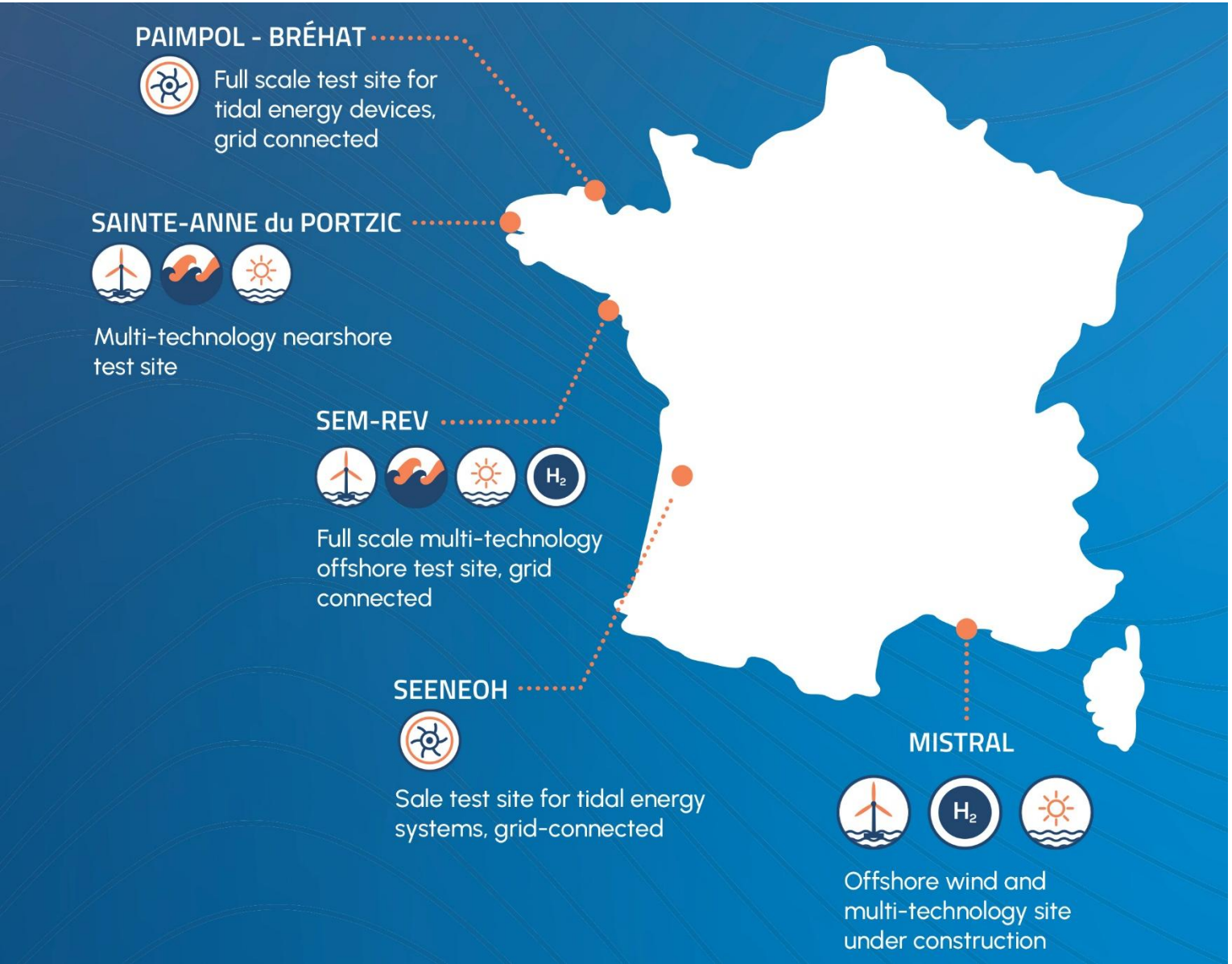
15 PROJETS DE RECHERCHE COLLABORATIFS EN 2024
COLLABORATIVE RESEARCH PROJECTS IN 2024

30 EMPLOYEES

10 INDUSTRIAL & ACADEMIC FOUNDERS

5 REGIONS INVOLVED

5 OFFSHORE TESTS SITES & MORE



1 TEST SITE "VERY HIGH POWER" IN DEVELOPMENT: "TGP"

| A new offshore infrastructure
| Dedicated to high-power floating wind energy
| Location currently being selected

FONDATION OPEN-C
TEST TO ACCELERATE.

What is an offshore test site for MRE?

Host prototypes & technological components

Monitor the marine environment

Collect & predict meteo-ocean data

Host research projects

Connection hub & export cable

Optimize & ensure safe marine operations

Engage with stakeholders & disseminate scientific results

A consented sea area with seabed lease & environmental permit

FONDATION OPEN-C | SITE PAIMPOL BRÉHAT

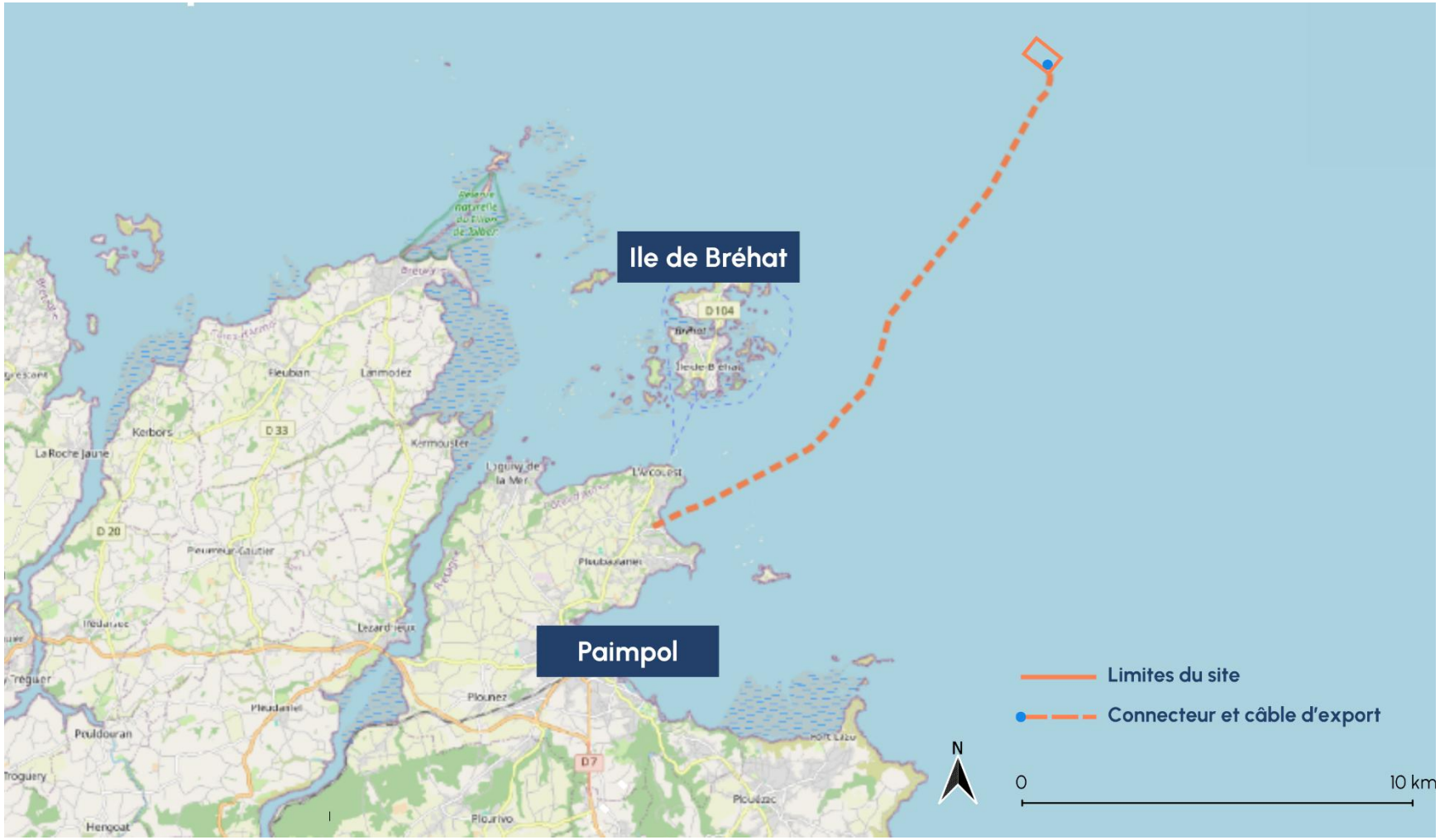
Paimpol Bréhat © Production Perig for BDI

Located on the Horaine plateau, northeast of Bréhat Island, Paimpol-Bréhat is a full-scale, grid-connected tidal turbine test site created in 2011 by EDF.

PAIMPOL BREHAT

TECHINCAL INFORMATIONS

- Location: North-east of Ile de Bréhat
- Distance from coast: 15 km
- Surface area: 3.5 hectares
- Depth: 31-40 m
- Bottom type: rocky
- Bathymetry: 35 - 40 m LAT
- Tidal range: maximum 12.39 m
  Wave height (Hs): 7-8 m
- Maximum average speed at test site, in m/s:
- Spring tides: [2.4 : 3.1]
- Still water: [1.1 : 1.5]
- Power: 1 x 2.5 MW connection to the Enedis grid



PAIMPOL BREHAT

TESTED TECHNOLOGIES

FUTURE TESTS FOR TIDAL

Interreg Co-funded by the European Union
North-West Europe
Offshore Proof

Offshore Proof | 2024-2028

Accredited offshore testing network driving renewable energy uptake at sea

Offshore Proof aims to establish a network of offshore test sites that accelerates the global acceptance and certification of offshore renewable energy innovations, with a focus on wave, tidal, offshore solar, and energy storage technologies.

- **Project leader**: Campus@Sea
- **Partners**: Deftiq, Fraunhofer IFAM, Ghent University, North Sea Farmers, Fondation OPEN-C, West Flanders Development Agency
- **Funding**: European Regional Development Fund (ERDF) - Interreg North-West Europe programme

Interreg Co-funded by the European Union
North-West Europe
SHINES

SHINES | 2025-2028

Showcasing Hydrokinetic Energy Innovations for Northwest European Energy Sovereignty: SHINES focuses on a powerful yet untapped natural force: tidal and river currents. This project will test three innovative technologies in real-world conditions on offshore test sites in France and Netherlands, with a clear goal: to prove that hydrokinetic energy can play a key role in Europe's energy transition.

- **Project leader**: Fondation OPEN-C
- **Partners**: ORPC Ireland, SeaQurrent, Inyanga Tech, Bretagne Développement Innovation, Gemeente Ameland, Amelander Energiecoöperatie, Cerema, Bundesanstalt für Wasserbau, Haute Ecole Spécialisée de Suisse Occidentale, Carl von Ossietzky Universität Oldenburg, ÉireComposites Teo, Foras na Mara – Marine Institute, Université de Liège
- **Funding**: European Regional Development Fund (ERDF) - Interreg North-West Europe programme

Standards framework

- **Standard framework for metocean report**
  - **Paimpol-Brehat metocean report will be released in open access beginning of 2026.**
  - **Under review by DNV**

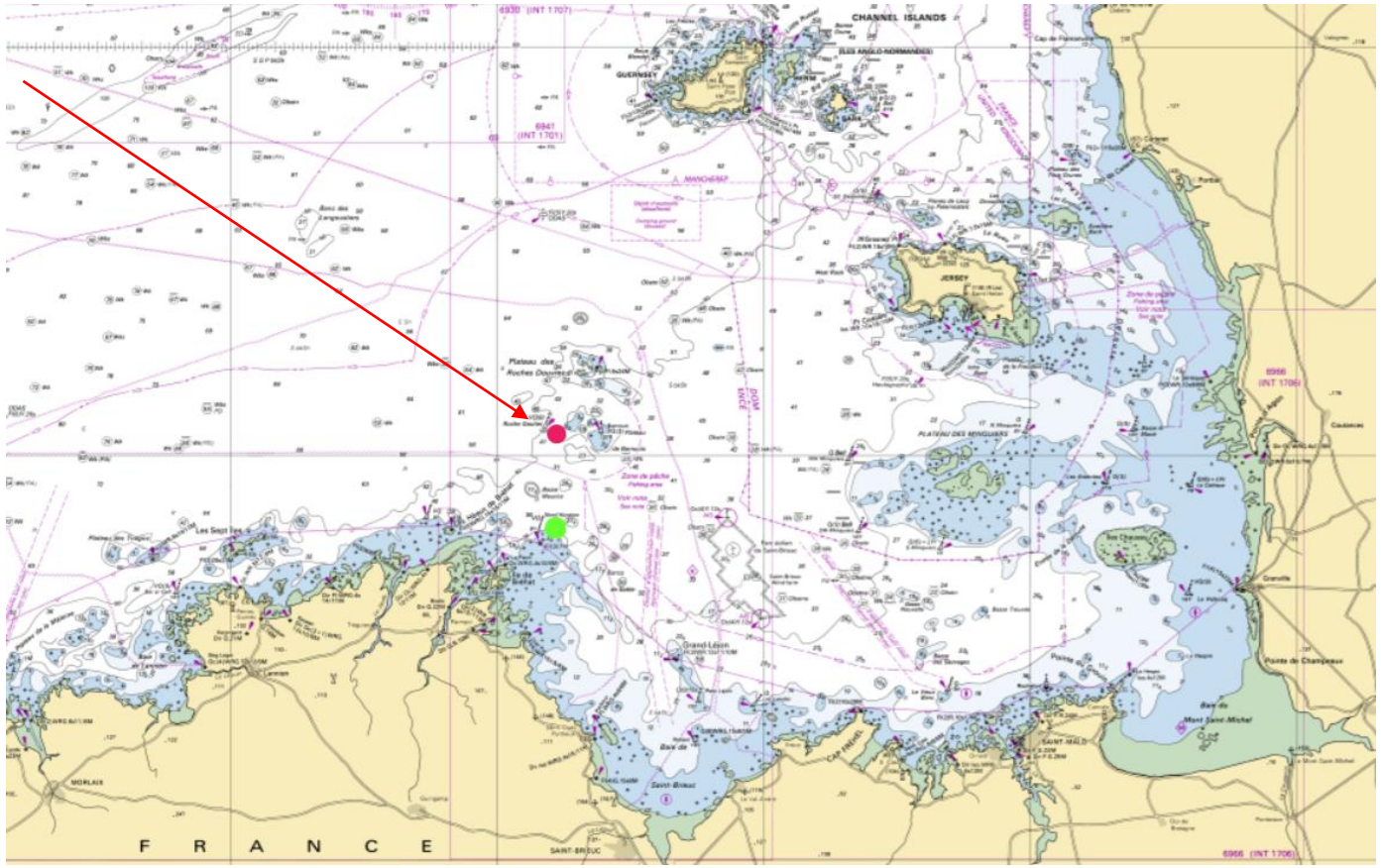
- **Standards framework for developpers which plan to test on site**
  - **IEC 62600-2 Marine Energy systems: design requirements**

  - **IEC 62600-201 Tidal energy resource assessment and characterization**
  - **“**The potential for substantial wave-current interaction to have a material impact on the development on the development of flow conditions shall be considered »

Measurements north of Paimpol Brehat site

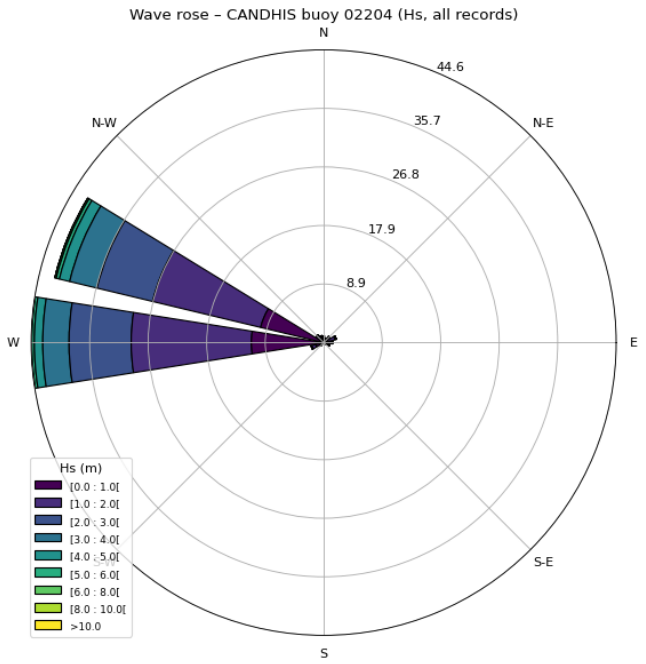
- **Wave buoy measurements: Datawell DWR MKIII Candhis network (Cerema)**
  - 02204 BREHAT_N: 07/2016 - 01/2021
    13 km North from site
  - 02205 BREHAT Nord Horaine: 4.5 months in 2022
- **Model database: Resource Code (Ifremer)**
  - Point BREHAT_N (point 154118) :
  - 1994-2020
- **ADCP campaign TIGER**
  - 6 months winter 2022-2023
  - No wave measurements
  - Turbulence

1



Wave Rose and current north of Paimpol Brehat site

Measurement of Waves (coming from)



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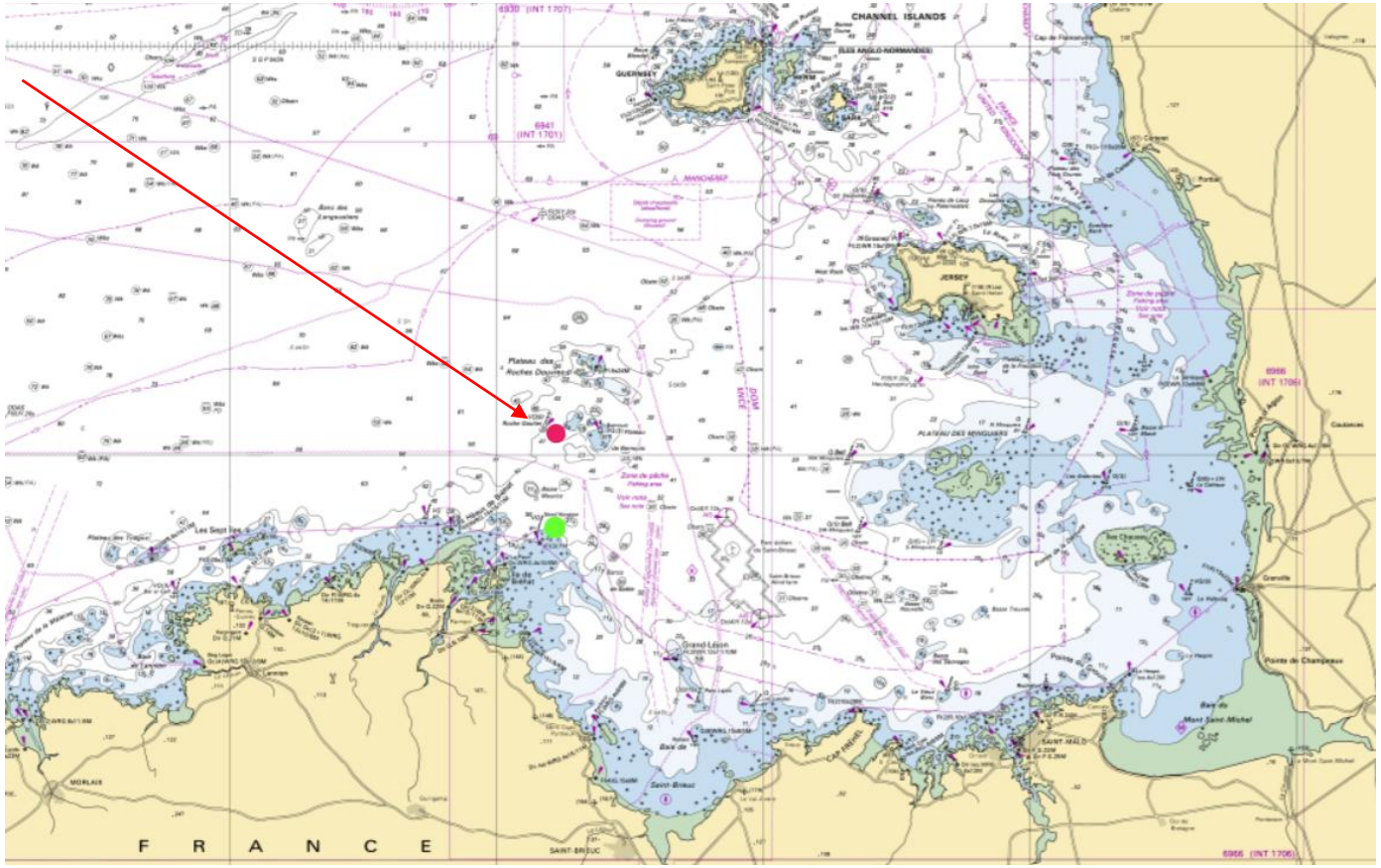
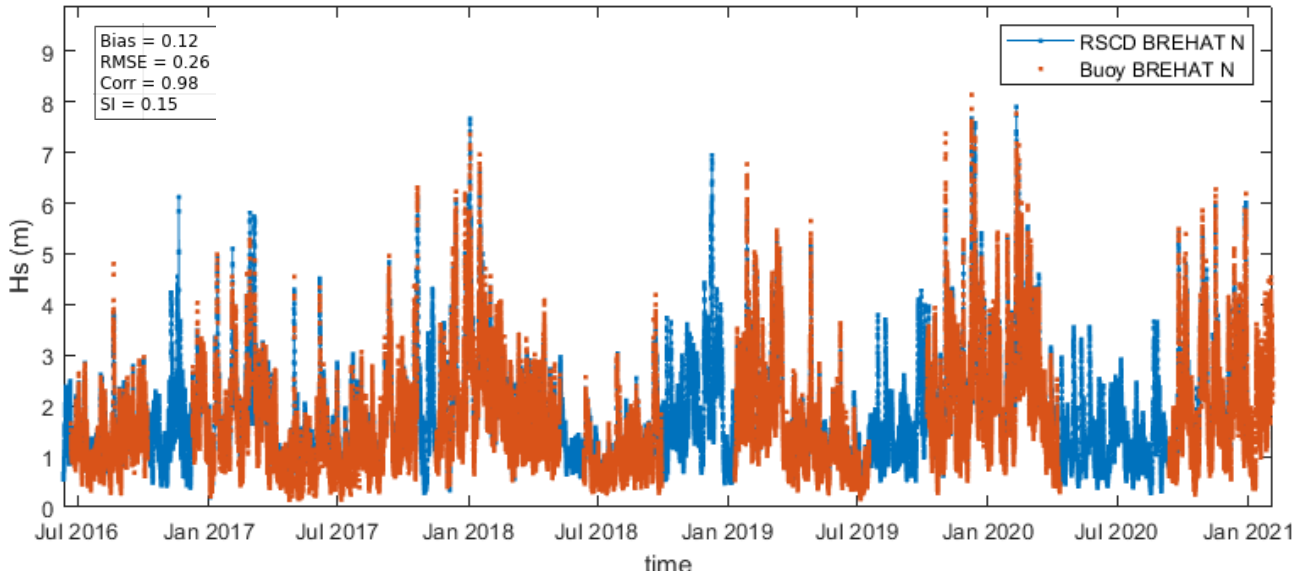
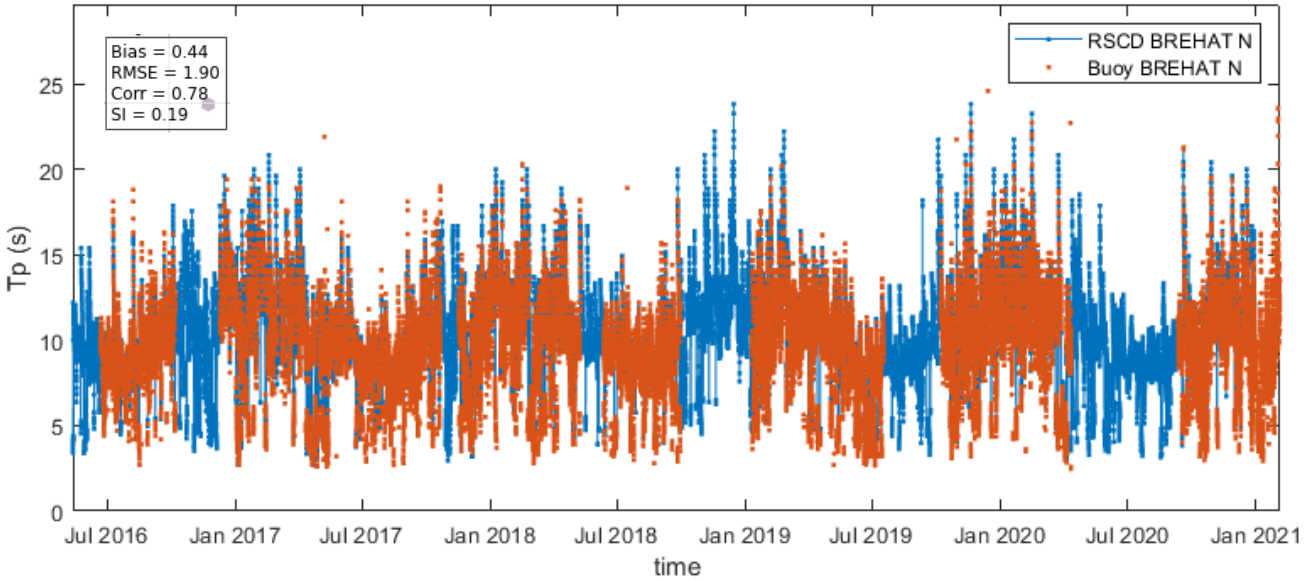


Comparison measurements / model database

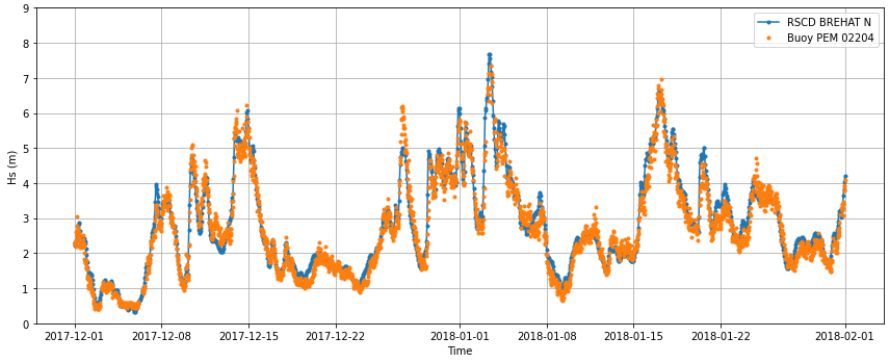
- The monitoring campaign shows several **multi-month gaps** in the time series.
- These interruptions are explained by two major equipment failures and **four** instances of **mooring line breakage** or buoy drift.
- In 2021, CEREMA noted: *"Given the difficulties in maintaining this measurement point, it was decided to terminate the campaign."* This illustrates the operational challenges commonly encountered when deploying floating measurement systems in this area

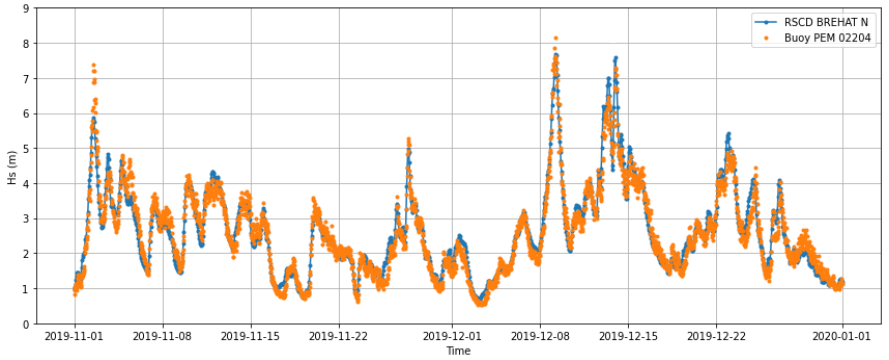


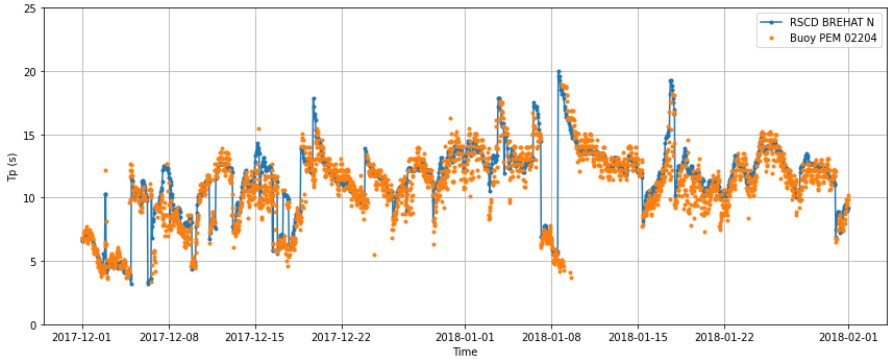


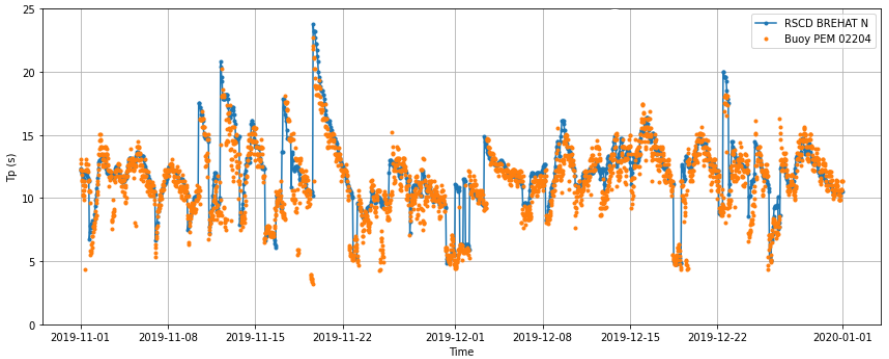
Quality check

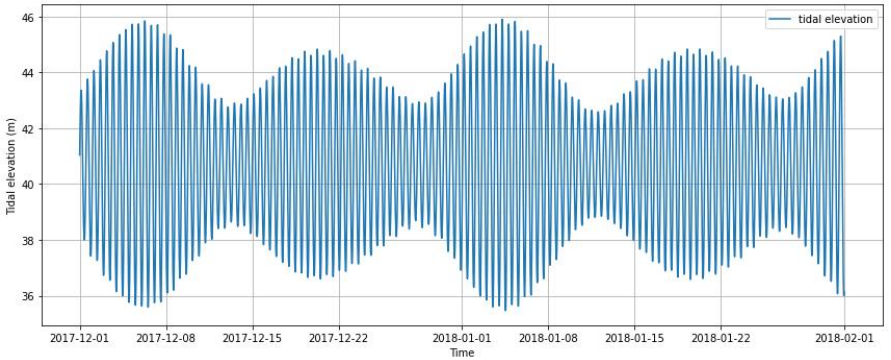
- Review of spectra around Hs where Difference between i Hs_i and Hs_{i+1} is > 1m
- If there is a discontinuity of spectral shapre between consecutive spectra: QC= NOK
- 5 spectra removed occurring on high Hs
- (for example where Hs > 7 m)

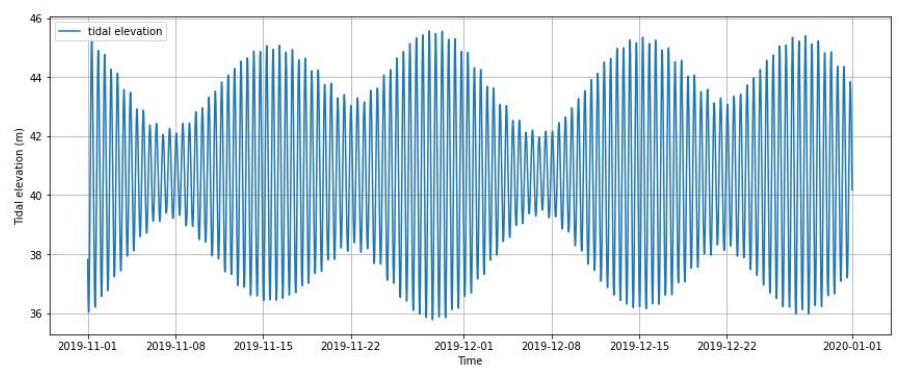












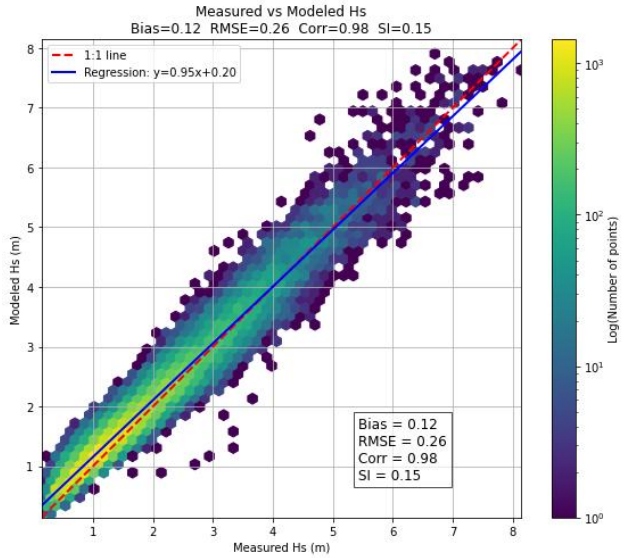
Correlation measurements / model database

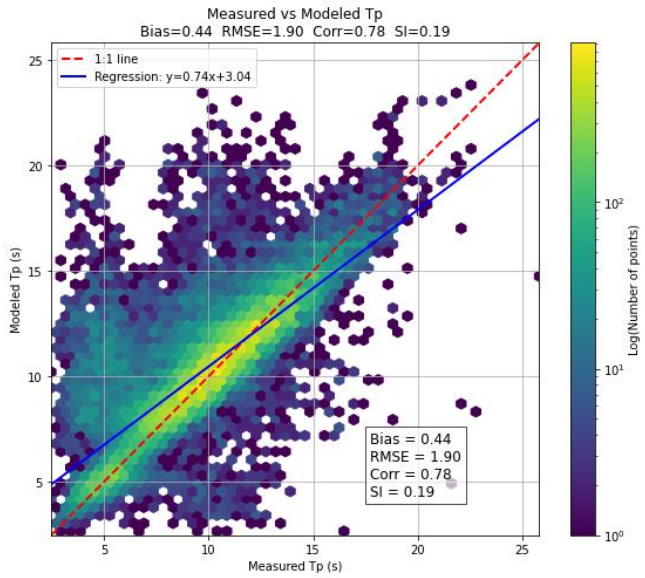
Wave–current interaction in Resource Code (WW3)
Full coupling of tidal currents in the wave action balance equation.

Currents modify wave propagation through:
- **Doppler shift** (frequency change)
- **Refraction** (directional bending)
- **Shoaling / blocking** (energy compression or spreading)
- Effects on **breaking**, **wind input** and **non-linear interactions**

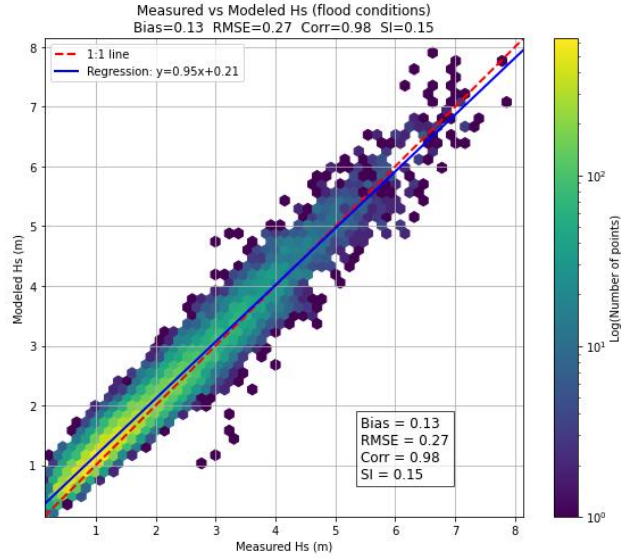
Result: **Hs**, **Tp** and **wave direction** dynamically adjust to the tidal currents from **MARS2D**

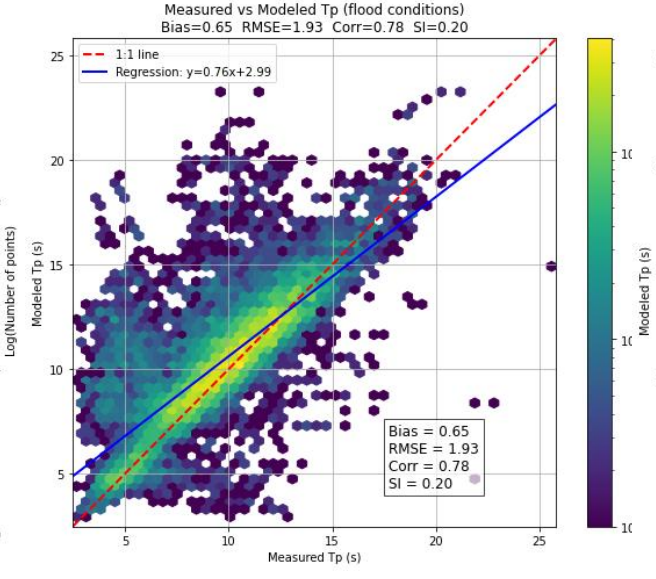
All tides



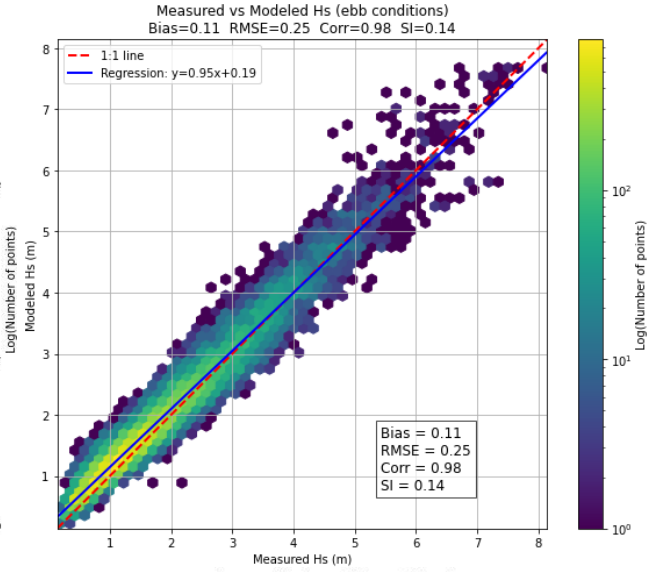


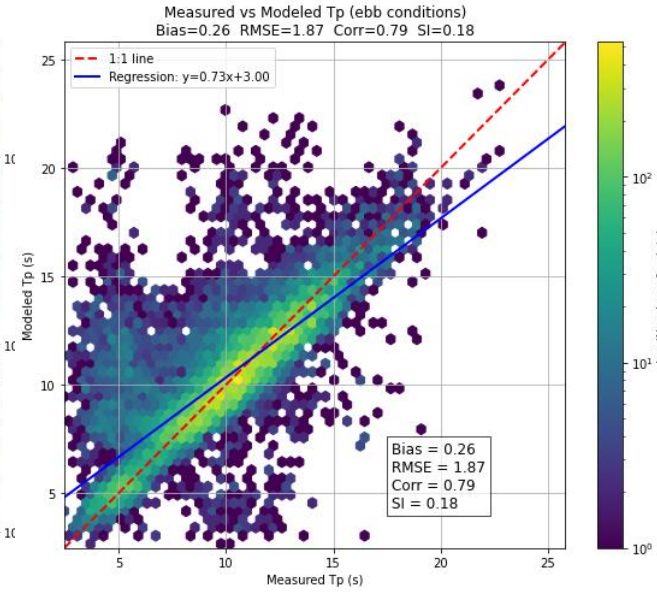
Flood





Ebb

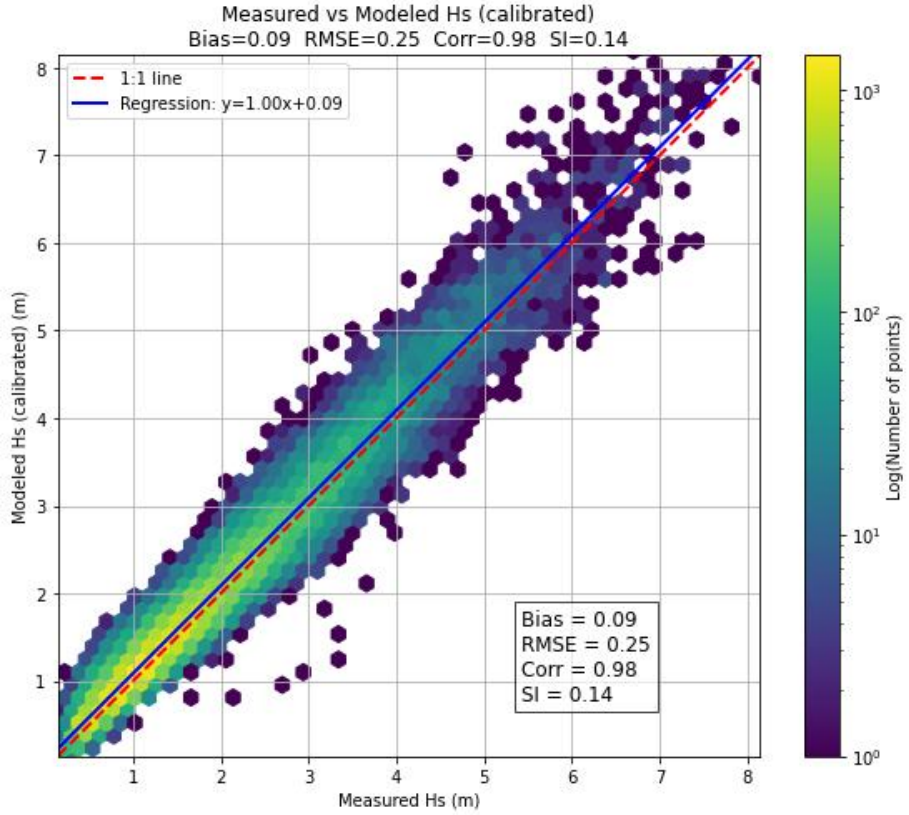




Calibration for design

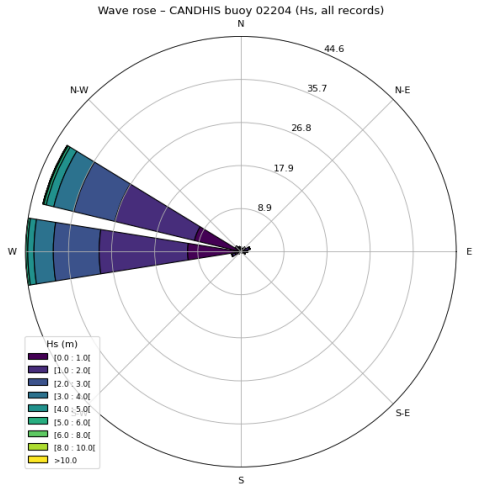
- Metocean database used for design of tidal turbines: reviewed by DNV who asked for calibration
- Model slightly **underestimates significant wave height (Hs)**
- A **linear regression calibration** was derived from the buoy–model comparison
- To ensure **conservative design values**, a **+5% safety gain** was applied to the calibrated Hs,

All tides



Wave Rose and current at Paimpol Brehat site

Measurement Waves (coming from)



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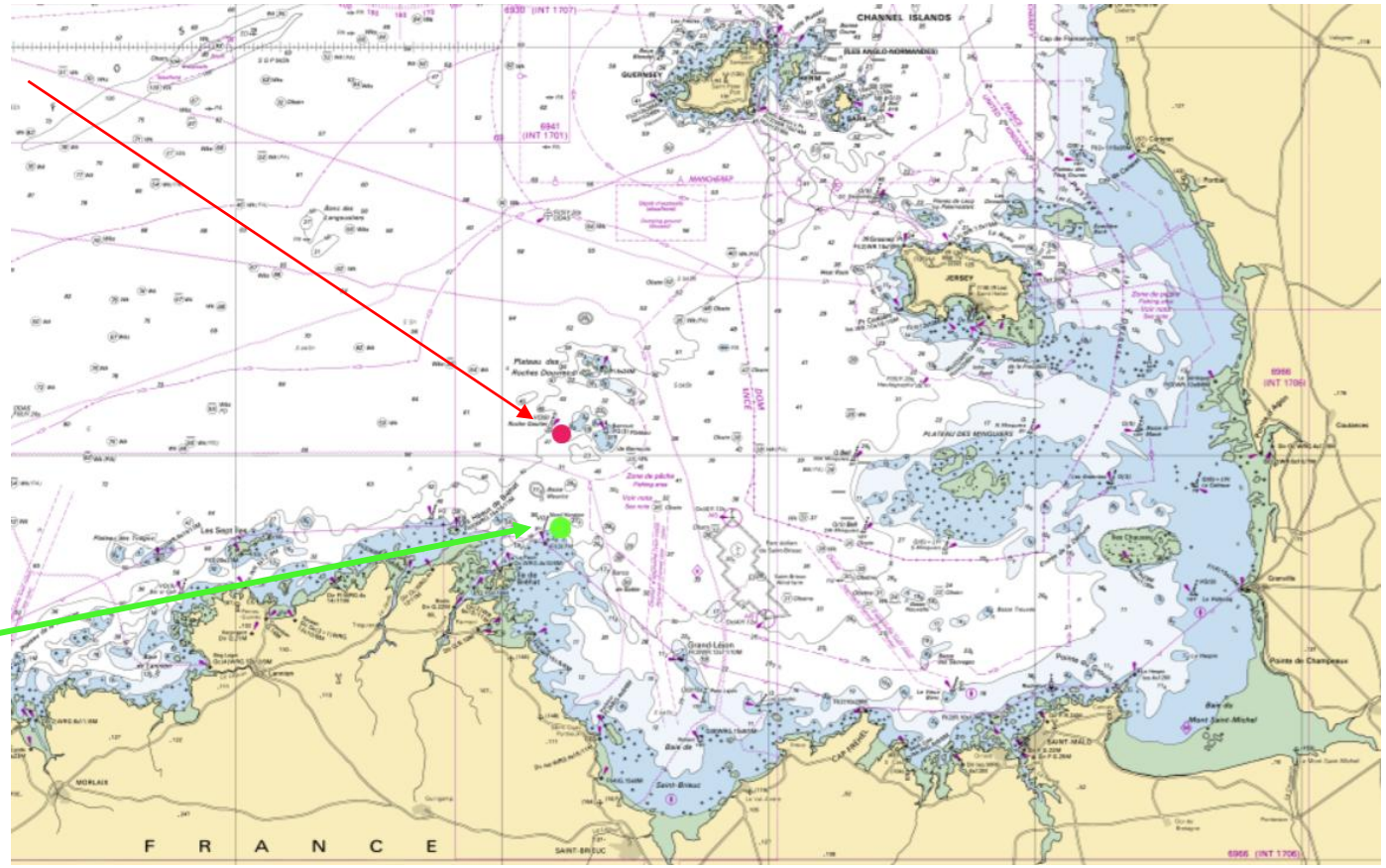
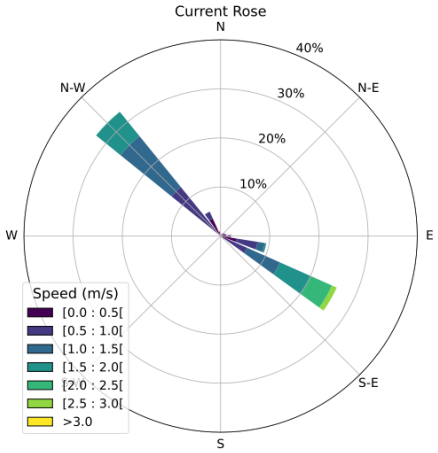
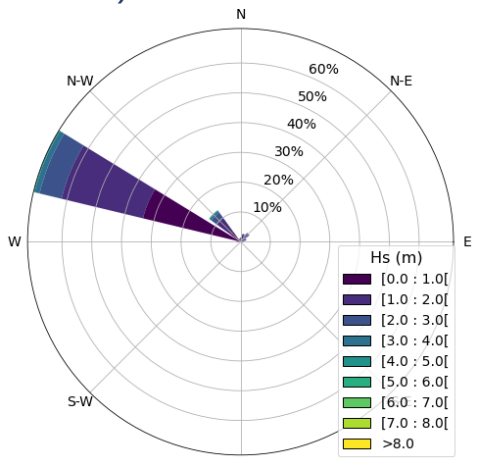


At site: current measurement (“going to”) & wave model (“coming from”): refraction

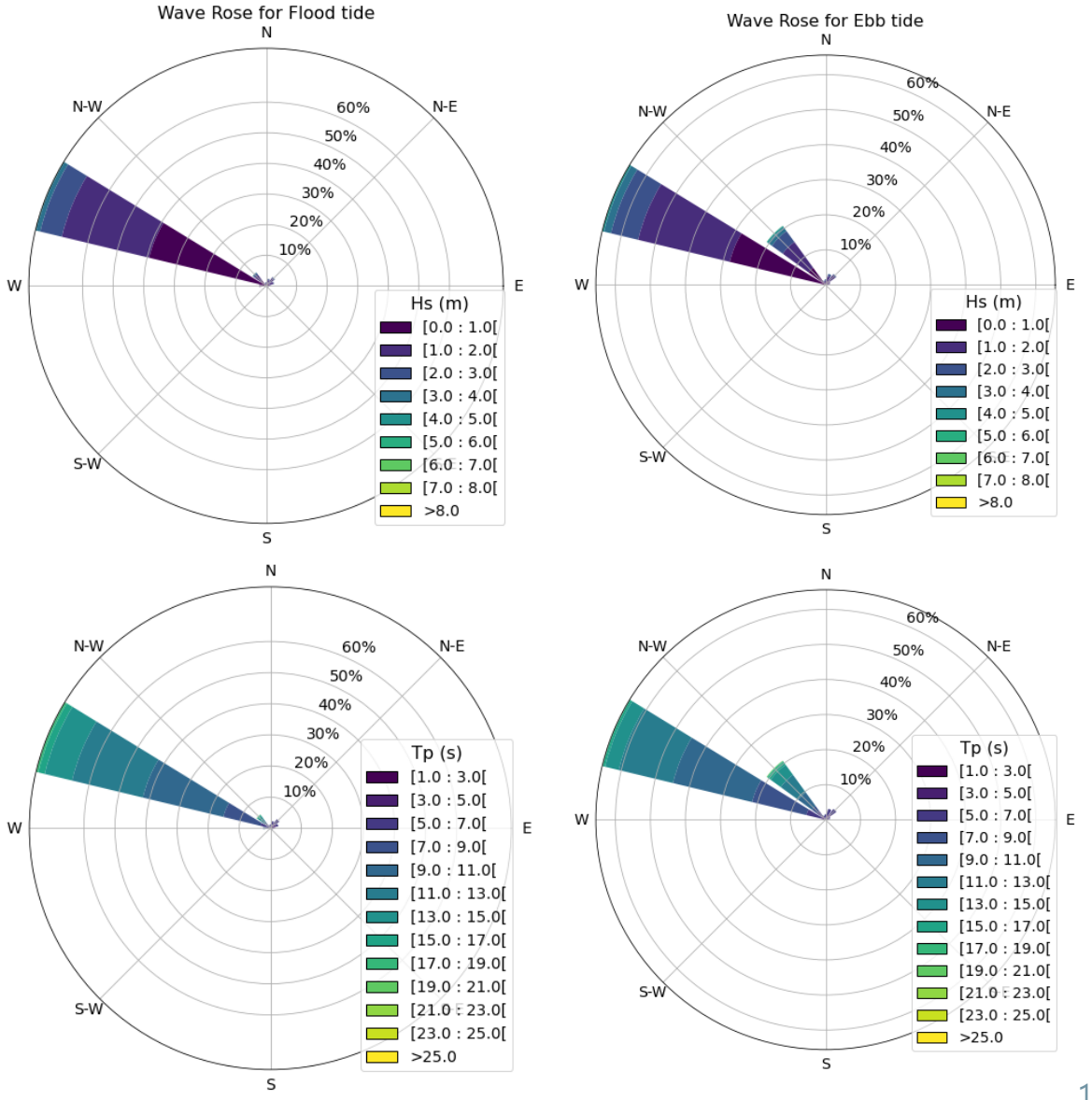




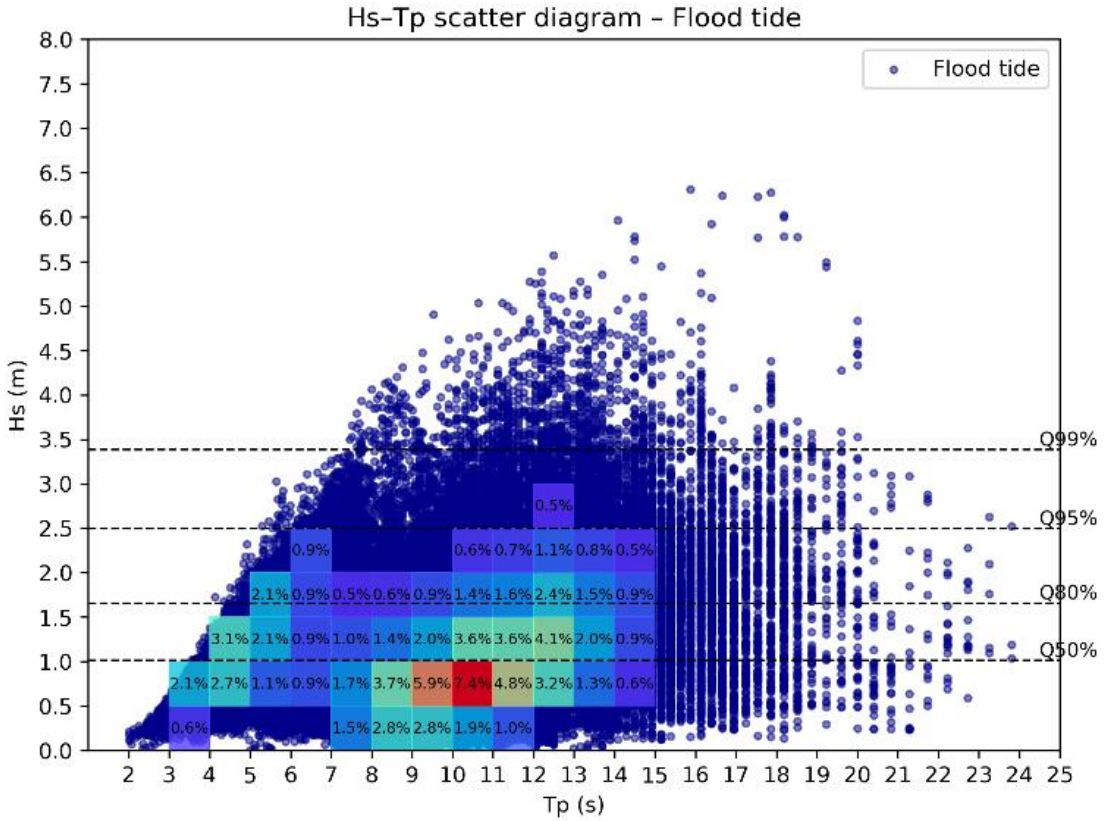
Wave rose during Flood and Ebb

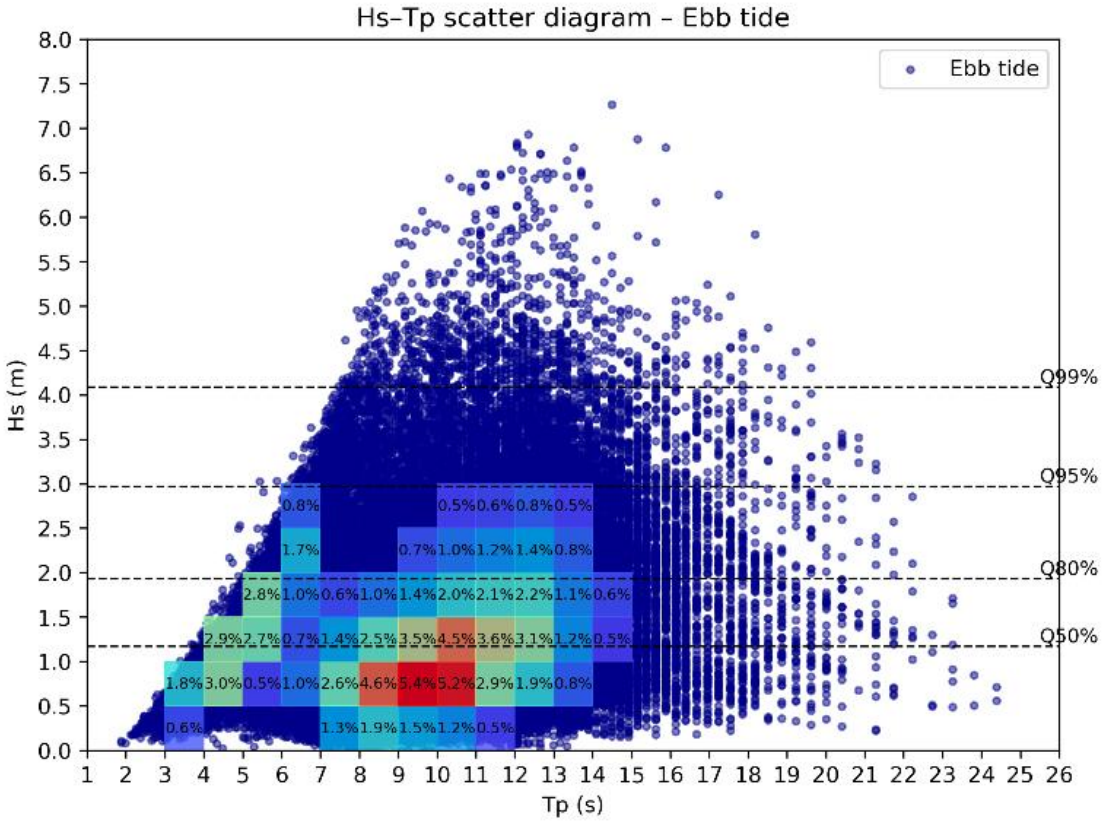
- Ebb current is NW: influence wave direction to NW (20%)

- Ebb:
  - Increase significant wave height (Hs)
  - Decrease peak period (Tp)



Scatter diagram for Flood and Ebb



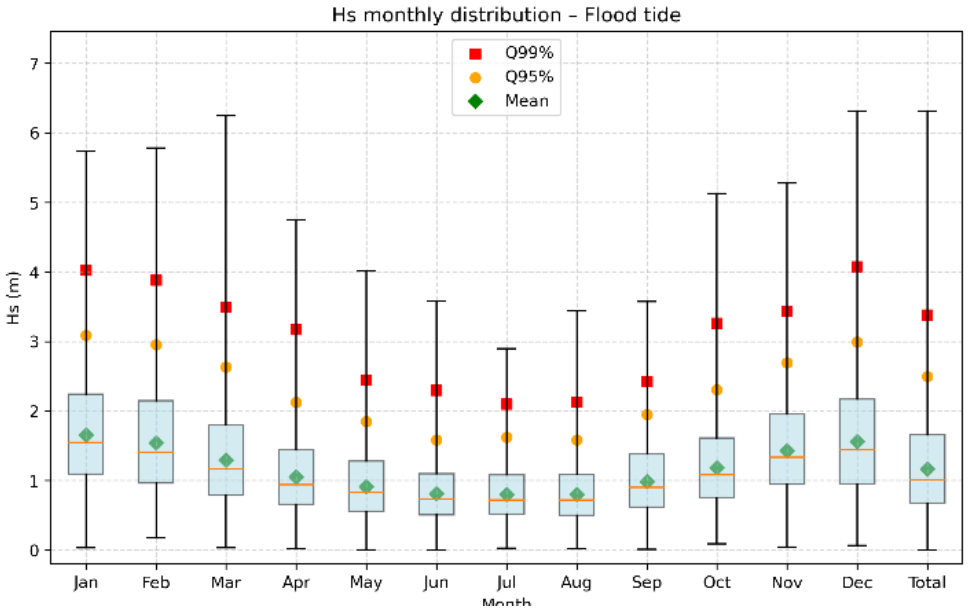


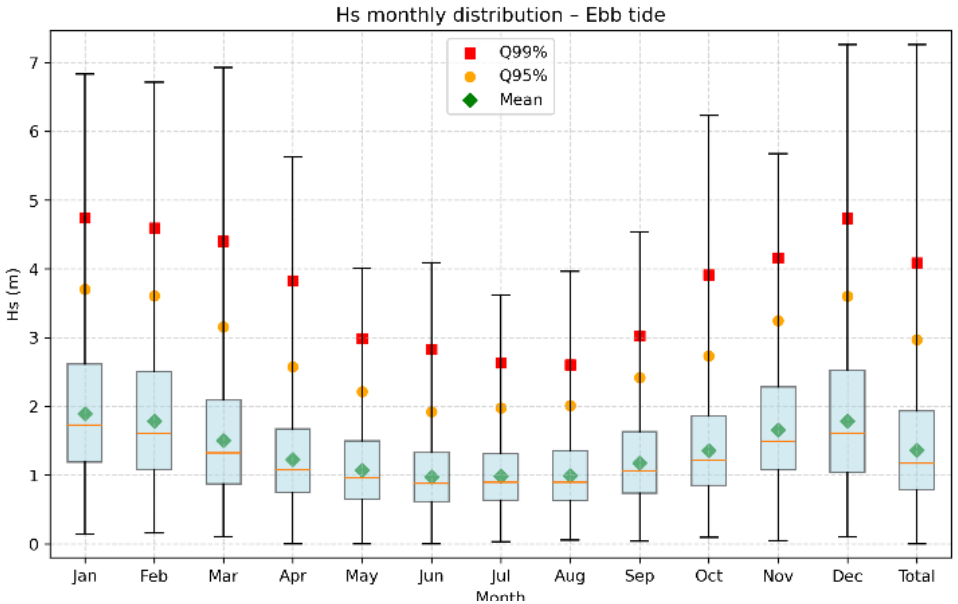
Hs	Flood	Ebb	Δ abs	Δ %
Mean	1.17 m	1.36 m	+0.19	+17.0 %
Median	1.01 m	1.17 m	+0.16	+15.6 %
Q95%	2.49 m	2.97 m	+0.48	+19.1 %
Max	6.31 m	7.26 m	+0.95	+15.1%

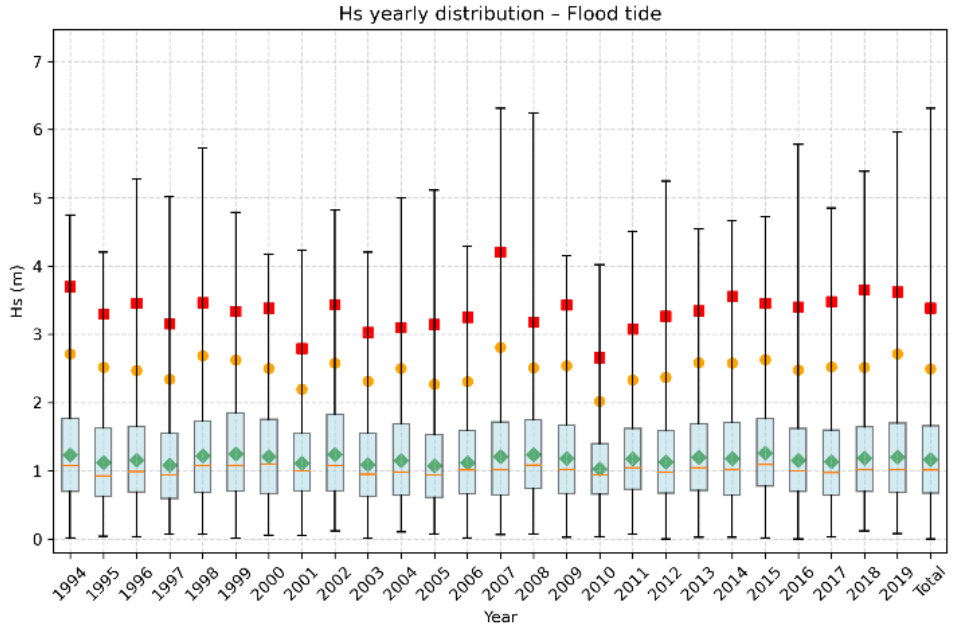
Tp	Flood	Ebb	Δ abs	Δ %
Mean	9.87 s	9.50 s	-0.37	-3.7 %
Median	10.20 s	9.71 s	-0.50	-4.9 %
Q95%	14.71 s	13.89 s	-0.82	-5.6 %
Max	23.81 s	24.39 s	+0.58	+2.4 %

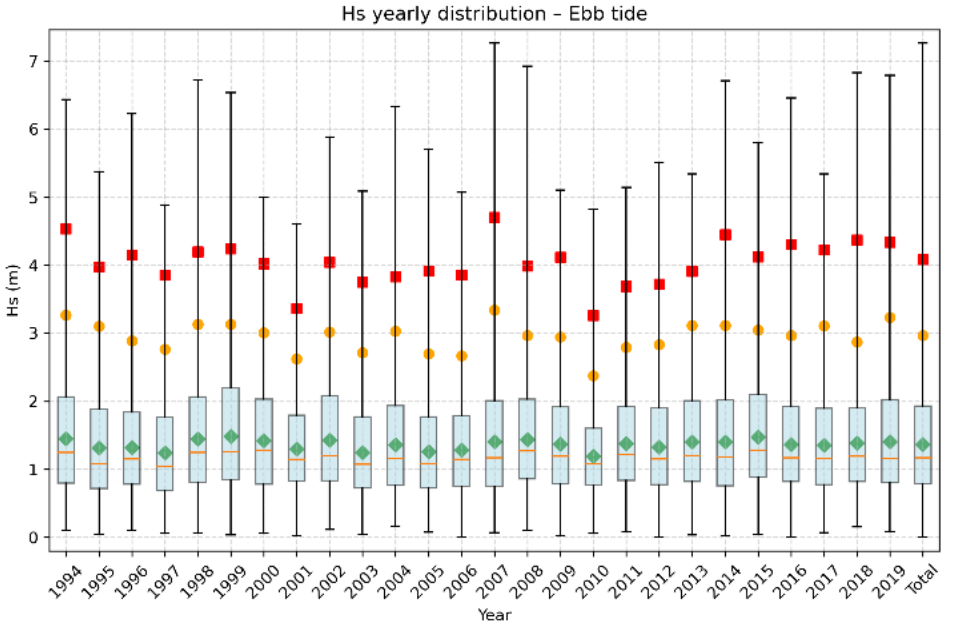
Wave monthly distribution for Flood and Ebb

- Maximum Hs of 7.26 m
- Occurred during Ebb in Dec 2007
- 11 events of Hs > 6 m



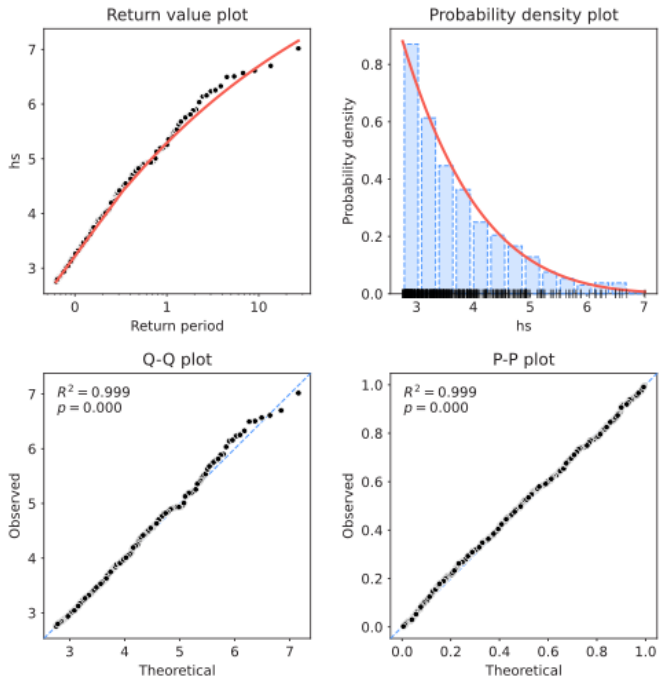






Extreme values at Paimpol Brehat site

- Ebb:
  - Increase significant maximum values of significant wave height (Hs) of 16-17%
  - Decrease peak period (Tp)



	Flood tide			Ebb tide			Diff Hs Ebb/flood
Return period (years)	Hs (m)	Lower 95% CI	Upper 95% CI	Hs (m)	Lower 95% CI	Upper 95% CI	%
1	4.53	4.37	4.69	5.31	5.12	5.50	17%
2	4.92	4.72	5.12	5.77	5.54	5.98	17%
5	5.38	5.11	5.65	6.28	5.99	6.56	17%
10	5.68	5.34	6.03	6.62	6.27	6.94	17%
25	6.03	5.60	6.50	7.00	6.56	7.45	16%
50	6.26	5.76	6.84	7.25	6.74	7.80	16%
100	6.46	5.89	7.18	7.47	6.88	8.11	16%

Role of test site in tidal energy measurements

Open platform for advanced ADCP deployments
Suitable for long-term and short-term campaigns: current profiles, turbulence characterization, wave–current interaction, and directional flow measurements.

R&D and industrial applied research environment
Support for experimental methodologies, prototype sensors, and high-resolution measurements within real tidal conditions.

FONDATION OPEN-C

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fondation-open-c.org

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