# Miniaturized drifting buoy for ocean sea surface monitoring and satellite calibration and validation

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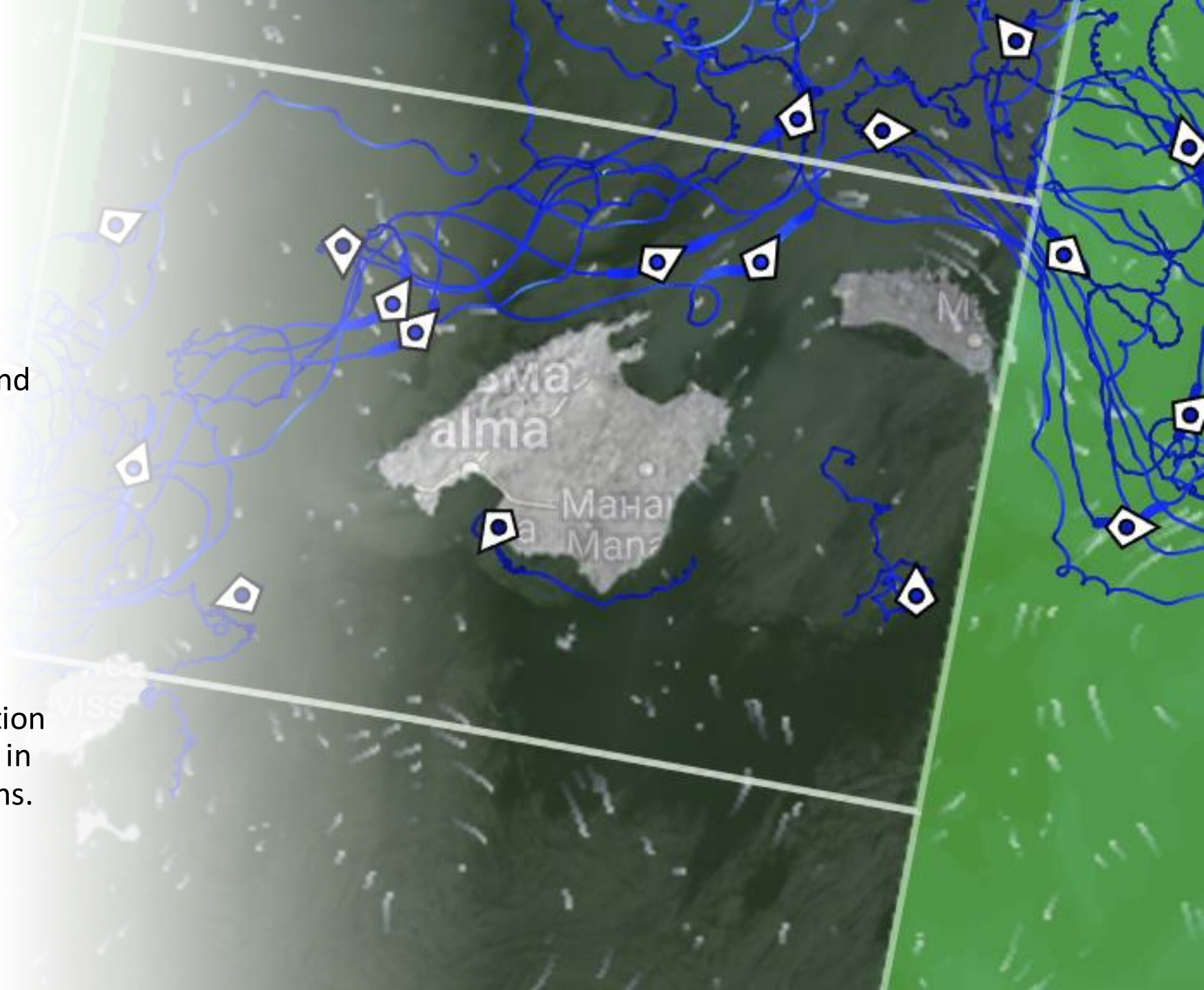
# Introduction

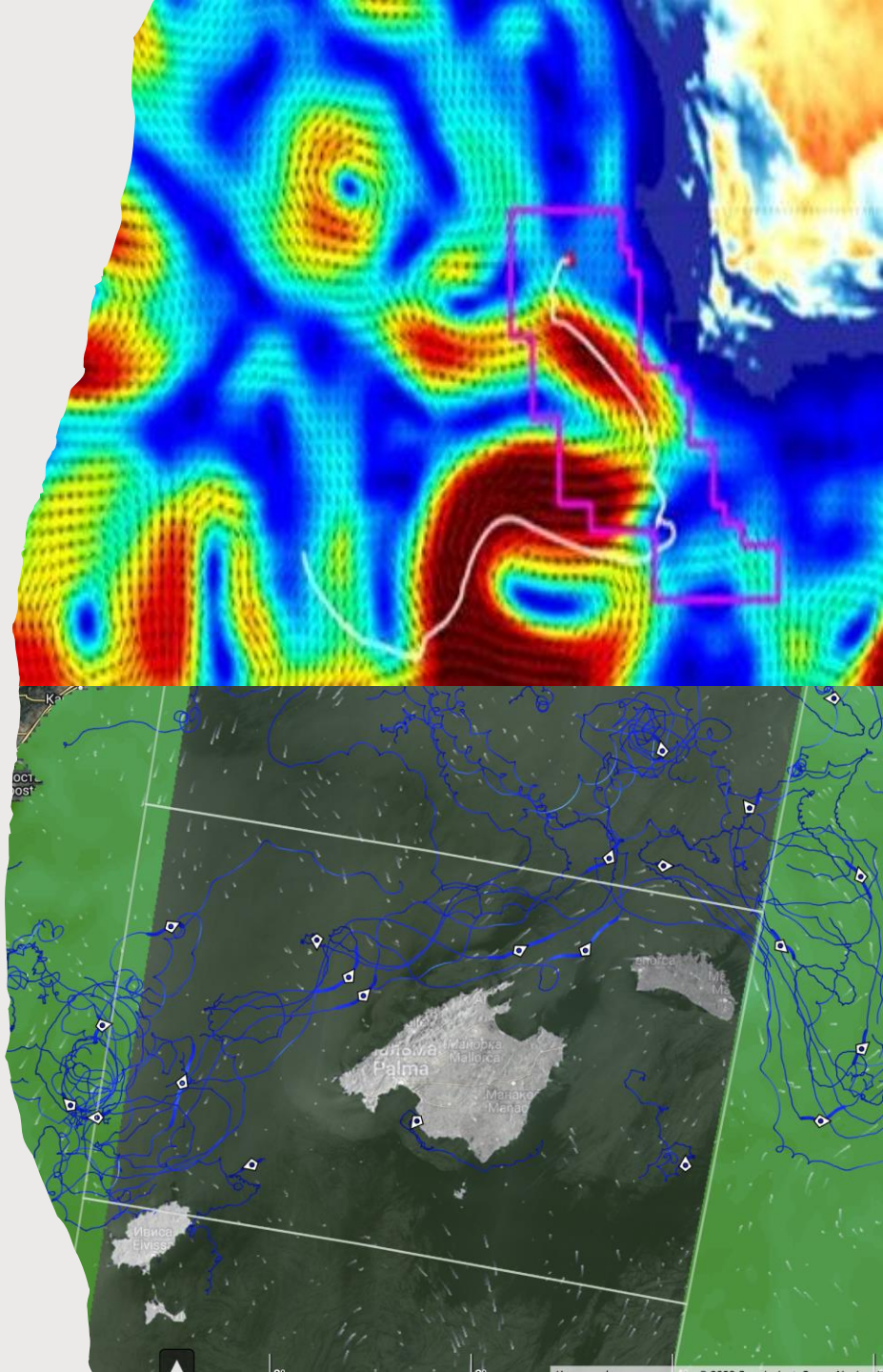
Ocean buoys remain to be the primarily source of in-situ observations providing "ground truth" for ocean monitoring, model validation and satellite calibration and validation.

Growing number of numerical models and spaceborne instruments together with improving time-spatial resolution requires more measurements in different geographical locations.



# Motivation points

- Buoy network deployment is costly (lack of in-sutu data)
- Existing  buoy measurements do not always match satellite measured values
- Buoy single point time series measurements should be interpreted for satellite-measures spatial "frozen" field.
- Buoy measurements are not always  collocated in time and space with satellite swath
- Different-type buoys are needed to access different key sea surface parameters: wave spectrum, current, temperature, atmospheric pressure etc.



# MELODI project

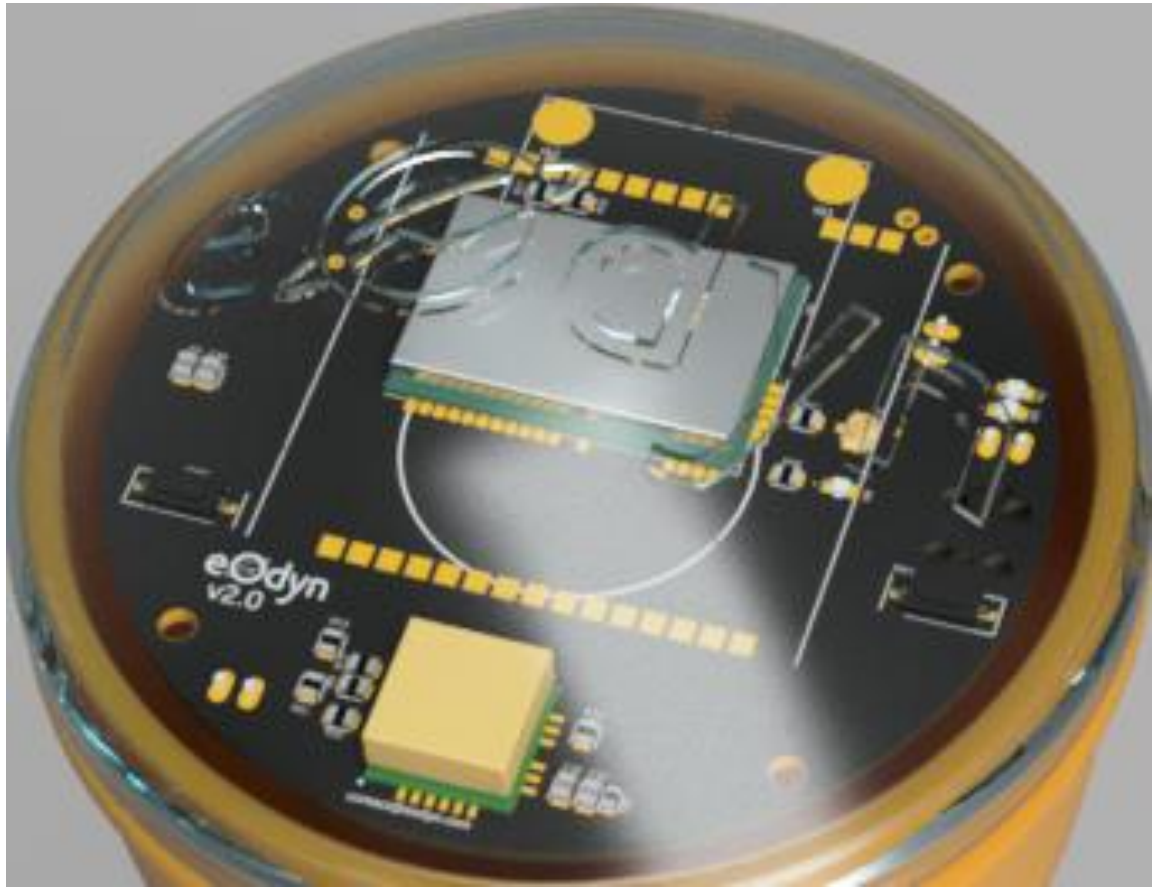
The Miniaturized Electronics Lagrangian Ocean Drifter (MELODI) project is aimed to propose a flexible polyvalent solution for ocean monitoring undersatellite calibration/validation tasks.

**Objectives:**

- Highly configurable platform to rapidly fit most of task-specific requirements
- Cost-effective solution to enable mass and long series deployments
- Extensive use of biodegradable materials, reduced $CO_2$ footprint
- Scientific quality for measured data. Reduce engineering/scientific excellence compromises.

# Electronics and onboard sensors

- Low-power energy efficient controller
- Onboard low-power FFT
- Satellite connectivity (different providers available)
- GNSS positioning
- 3-axis accelerometer
- 3-axis gyroscope
- 3-axis magnetometer
- water temperature sensor
- air pressure sensor
- SD-card with full data available



# Selection of buoy hull

The shape, size, and weight of the floater are critical for performance

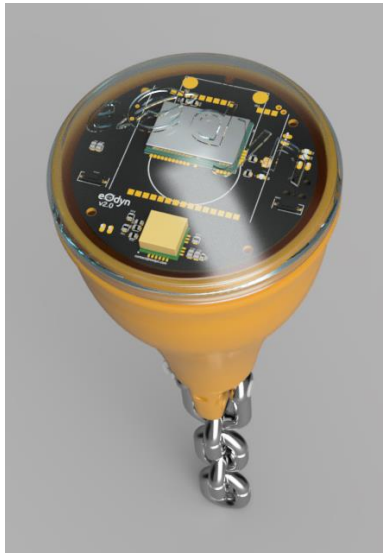
Every shape designed to fit a specific requirements of every problem

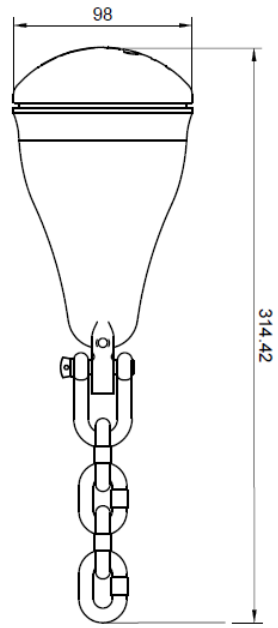
Main parameters:

Weight: 800 gr

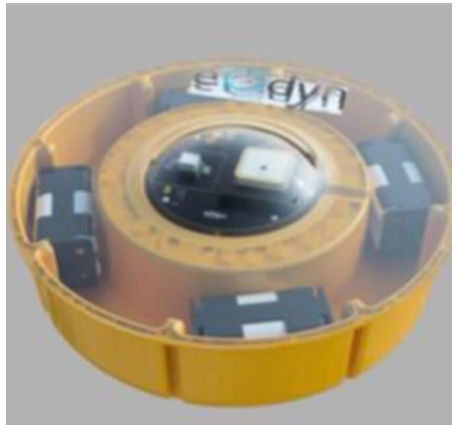
Size: ~10-20 cm

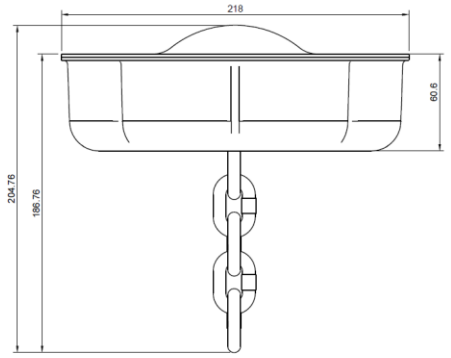
**Wave spectrum version**






**Surface drift version**

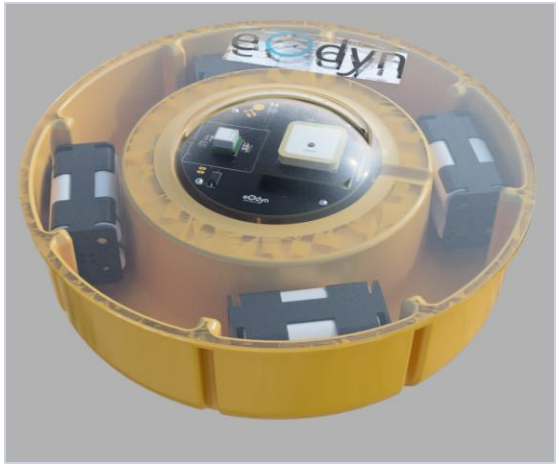


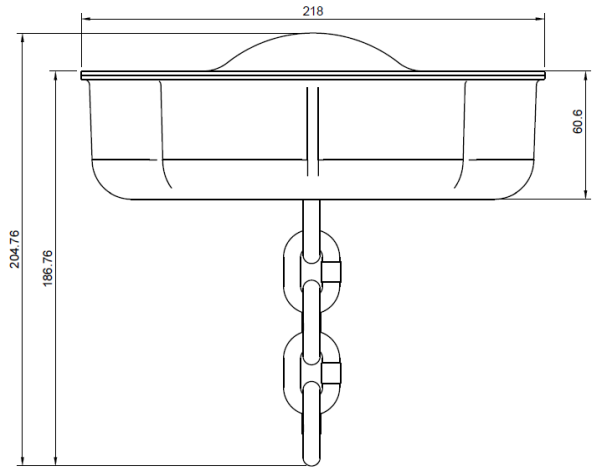


# MELODI Drifters Technical Summary

**MELODI drifter:** ***Miniature buoy for real-time sea surface tracking***

Dedicated for real-time measurement of sea state variables i.e. **sea surface current** and **wave parameters**



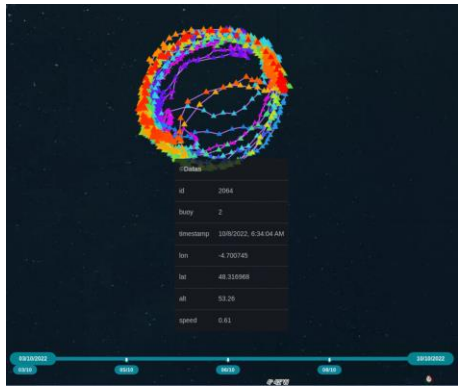



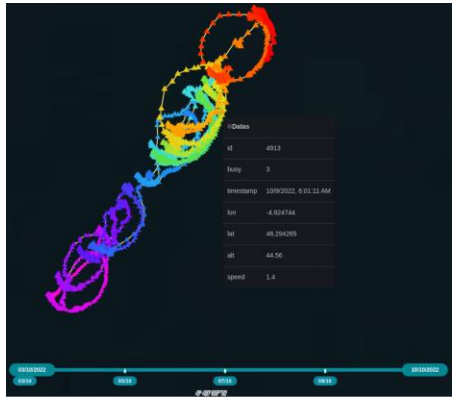

- Buoy overview
  - Satellite Connected
  - Small size (~20 cm in diameter), weight (> 1 kg)
  - Low hull profile with reduced wind drag
  - Real-time data visualization
  - Onboard full data log on SD card
  - Cost-effective conception
  - Biodegradable hull and low carbon footprint

- Measured parameters
  - Wave data sampling 3Hz
  - GPS displacements every 10 min
  - Significant wave height every 30 min
  - Omnidirectional wave spectrum (0.02-0.8 Hz) every 1h
  - Wind speed / friction velocity estimation (under validation)
  - Sea surface temperature
  - Atmospheric air pressure (under validation)

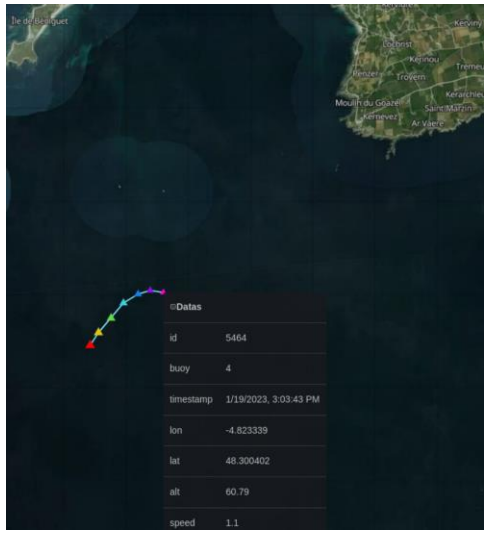
# Validation: positioning and drifting properties

**Moored buoy long observation series**




**Free floating drifting tests**





Very low direct wind impact!

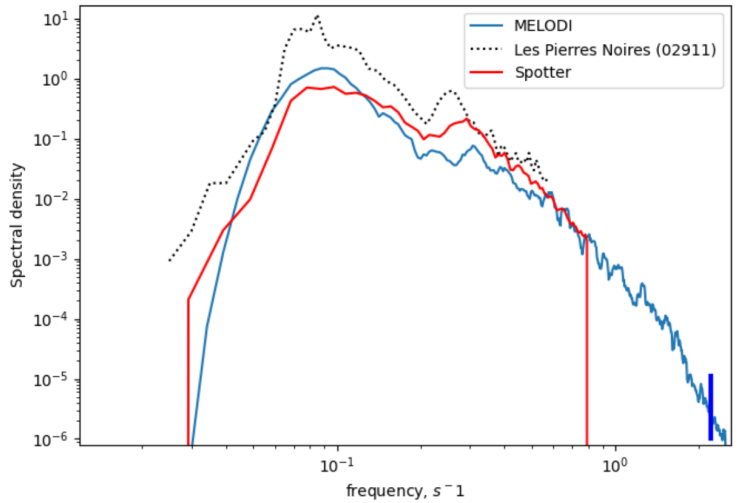
# Validation: ocean wave state

The onboard accelerometer, gyroscope and magnetometer allow us to estimate integral wave properties, i.e. significant wave height, mean wave period or full wave spectrum, including the directional part.

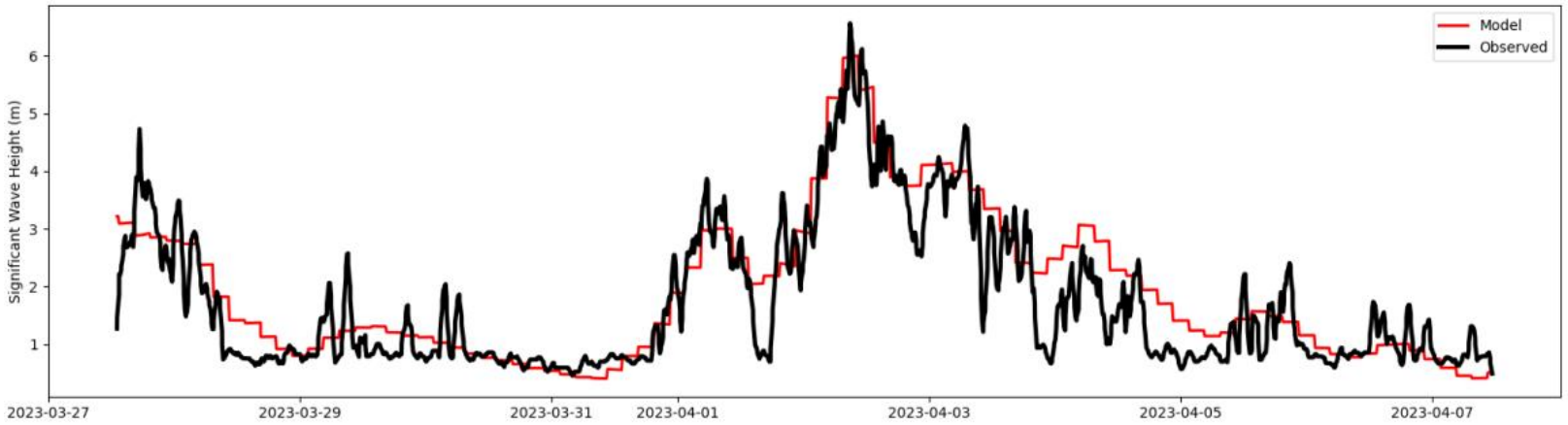
$$S(f) = C_{\zeta\zeta} = \frac{C_{zz}}{(2\pi f)^4}$$

The spectrum could be expressed through the co-spectrum of vertical axis measurements series of onboard buoy accelerometer

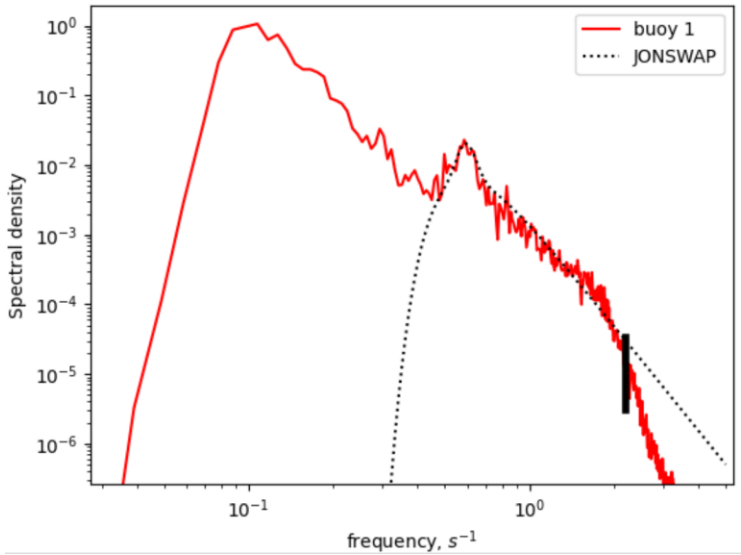
**Wave spectrum cross-validation**




**Significant wave height against Wave Watch 3 model**




**Wave spectrum and model cross-validation**



# SWOT calibration and validation campaigns in the Mediterranean sea

## C-SWOT / WENSWOT

- Date : 21/03 to 18/04/23
- 2 buoys deployed

*C-SWOT buoy trajectories*

*Atalante & Téthis II Ships in Mahon Port @Shom*

*Photo of buoys before the deployments*

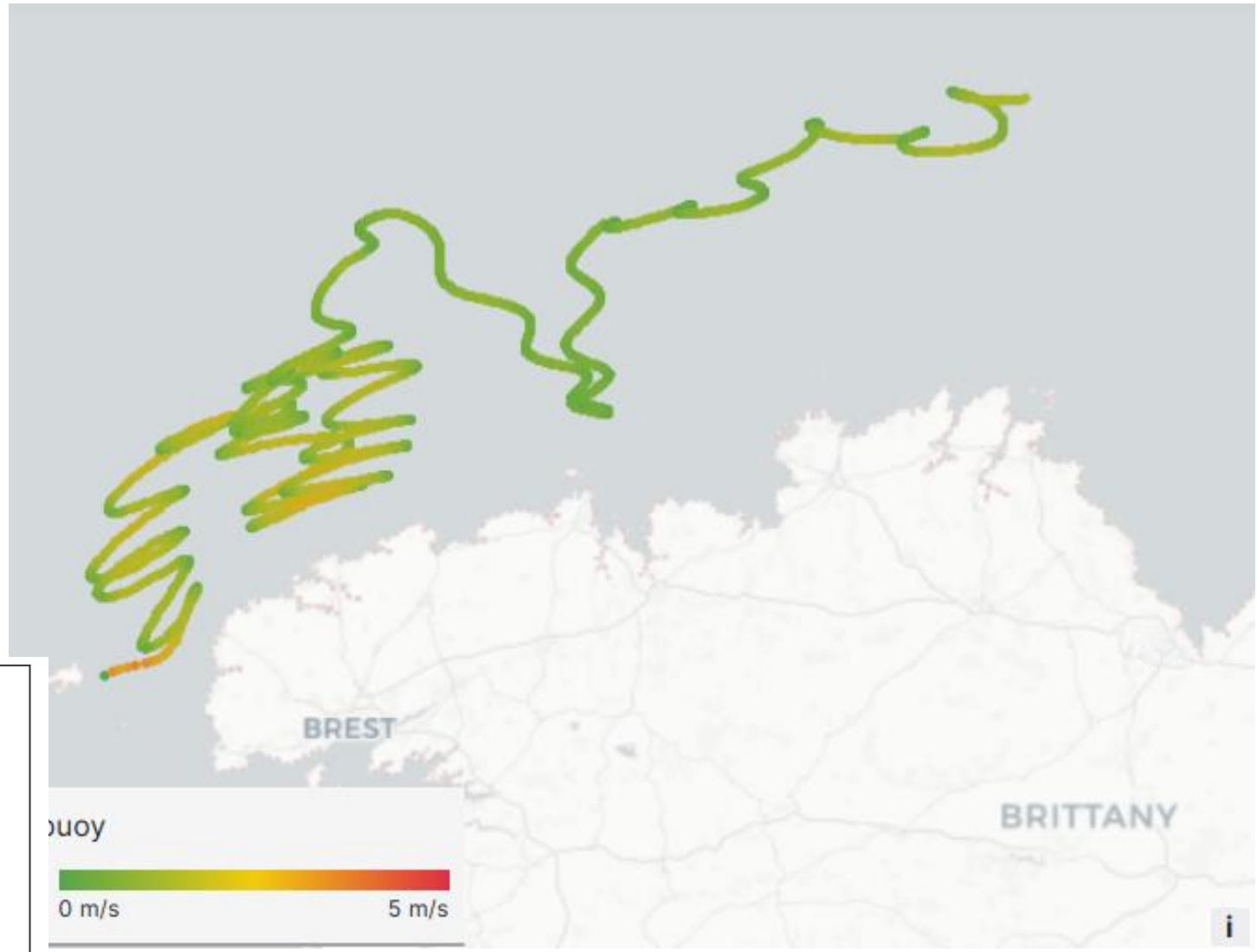
## BioSWOT-Med

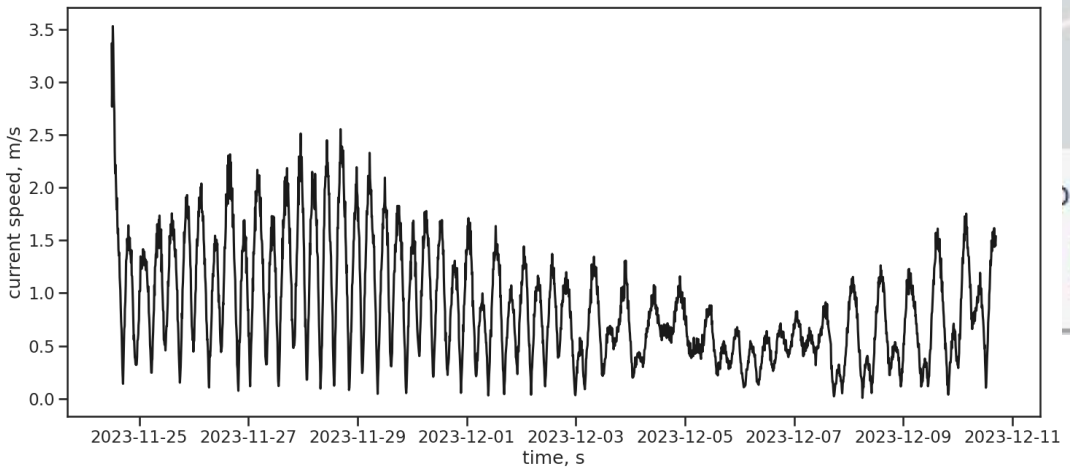
- Date : 21/04 to15/05/23
- 15 buoys deployed
- Data set publicly available


*Bio-SWOT buoy trajectories*

# Buoy real-time data reporting

The trajectory and speed of the test buoy last 24 days

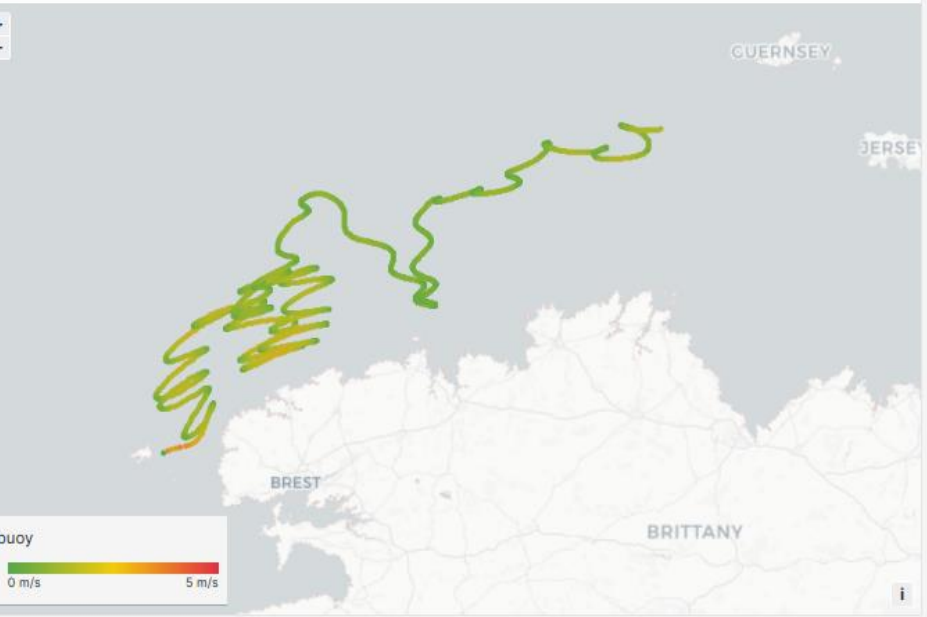


# Buoy real-time control panel

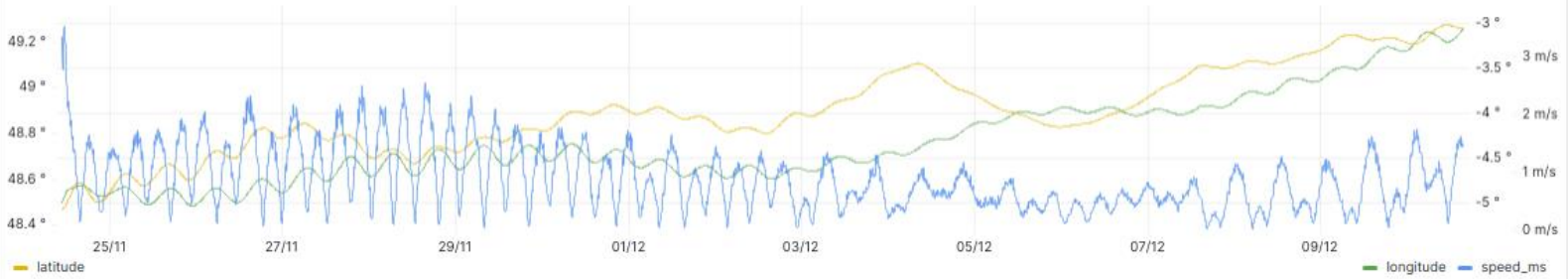
Positions

anel Title




Fixes per hour


Fixes




Battery

Battery Level


Battery Level

# The advantages of mini-buoys

New measurement opportunities

# Further improvements (solution scaling)

EXTENDED AUTONOMY WITH SOLAR PANEL (UP TO 1 YEAR)

DIRECTIONAL WAVE SPECTRUM

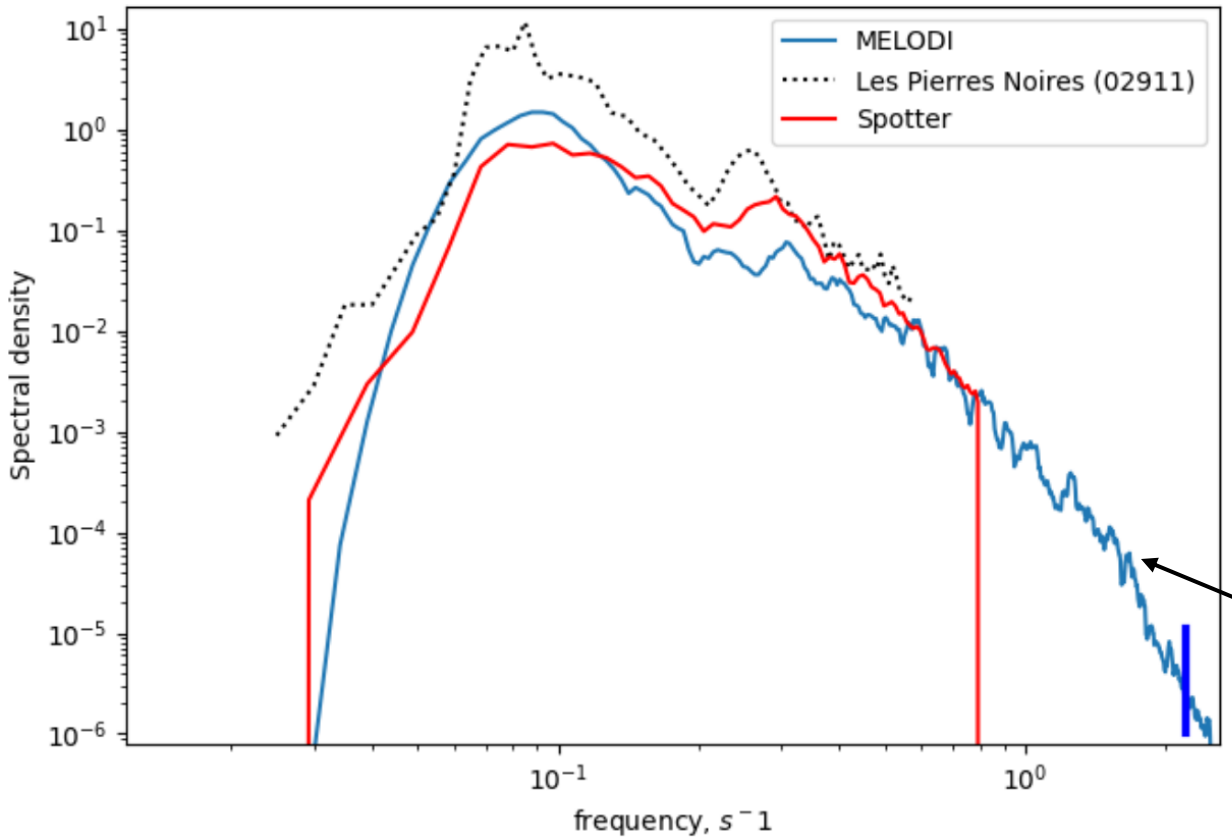
REDUCED ENVIRONMENTAL IMPACT WITH BIODEGRADABLE BUOY HULL

MORE SENSORS

WIND SPEED MEASUREMENTS

UAV AND AIRPLANE DROPPABLE DEPLOYMENT VARIANT

# High frequency wave measurements



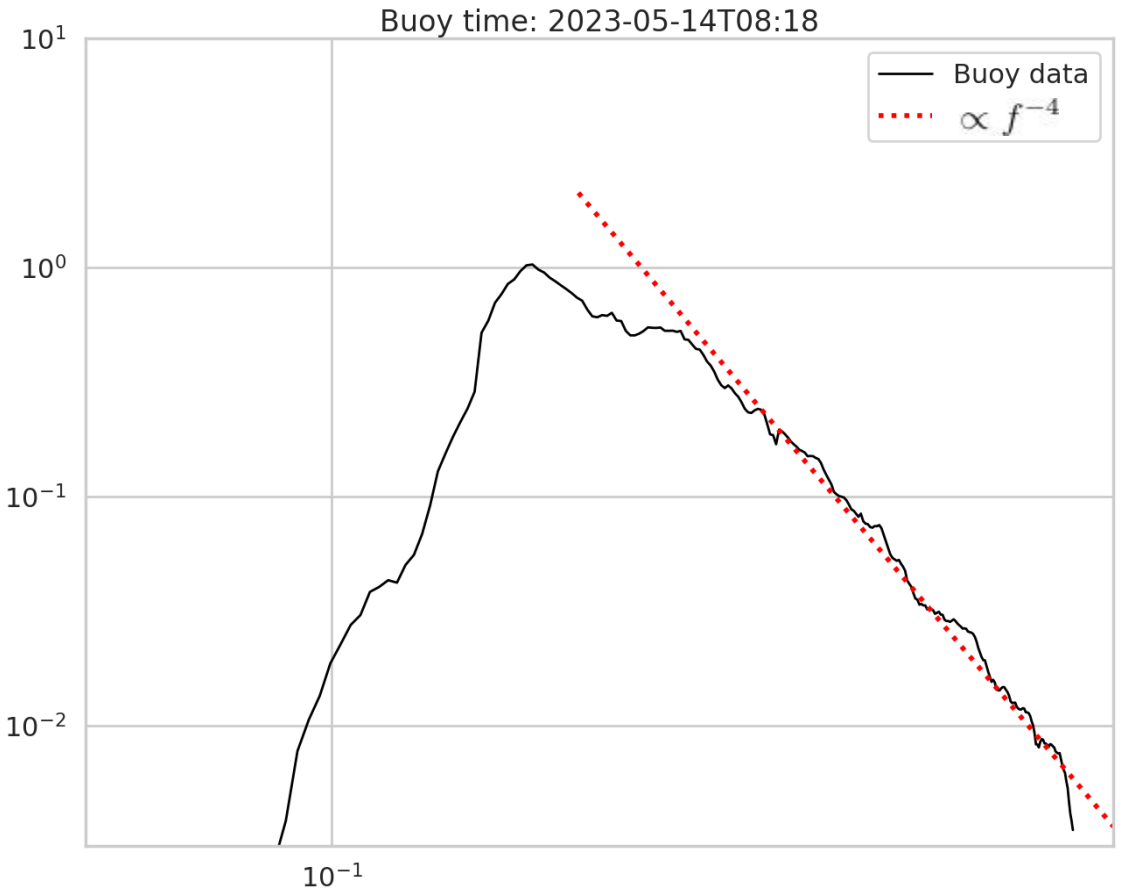

Small diameter of buoy hull and small size allows to perform precise high frequency wave measurements. This frequency part is particularly sensible to wind changes and contains a lot of information about wave-wind-sea surface current interactions.

As well high frequency measurements more related to sea surface roughness which is observed by radar.

**High frequency spectrum part**

# Wind speed retrieval from wave spectrum level

Wave field is intrinsically coupled to the wind field. Wave measurements can serve as a proxy observation of ocean surface winds.



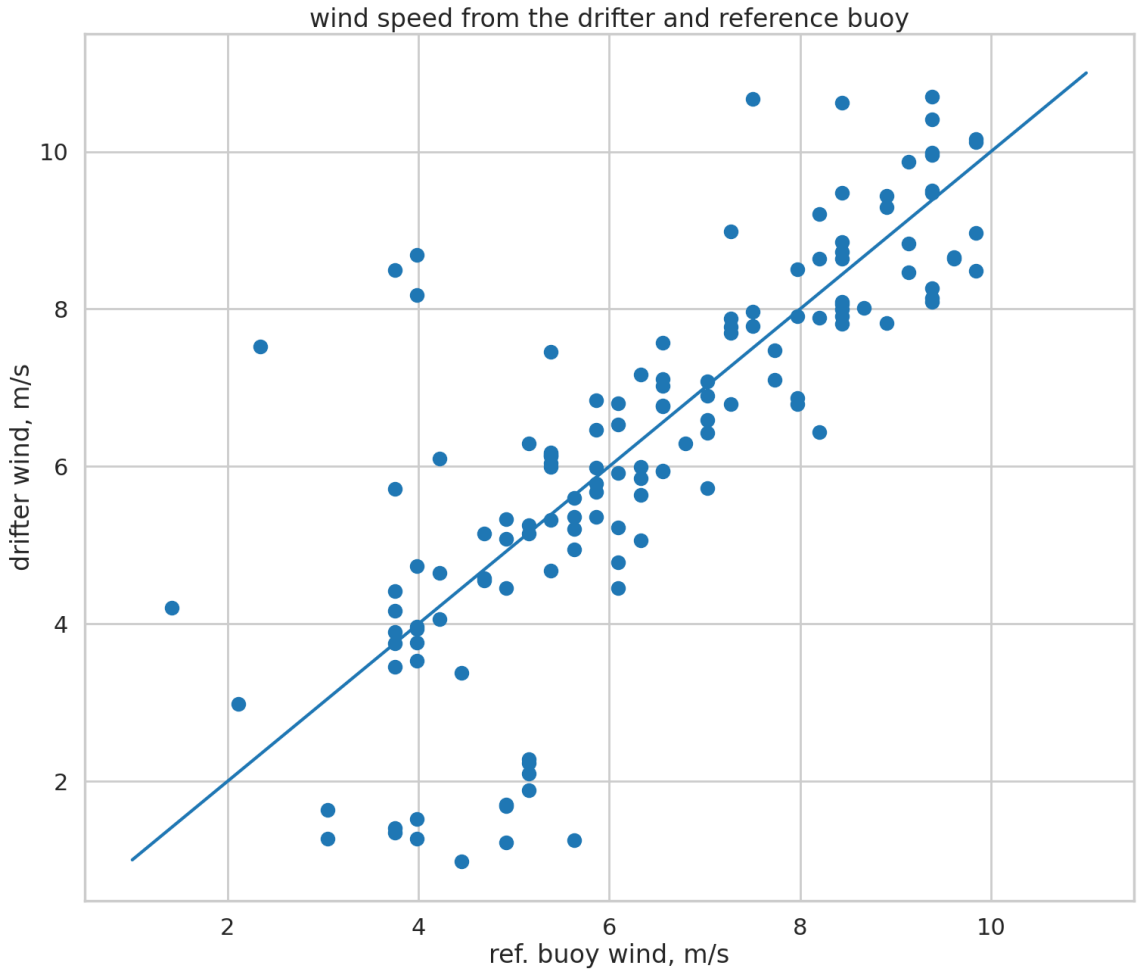

The tail of the spectrum responds relatively rapidly to changing wind conditions and takes the equilibrium shape:

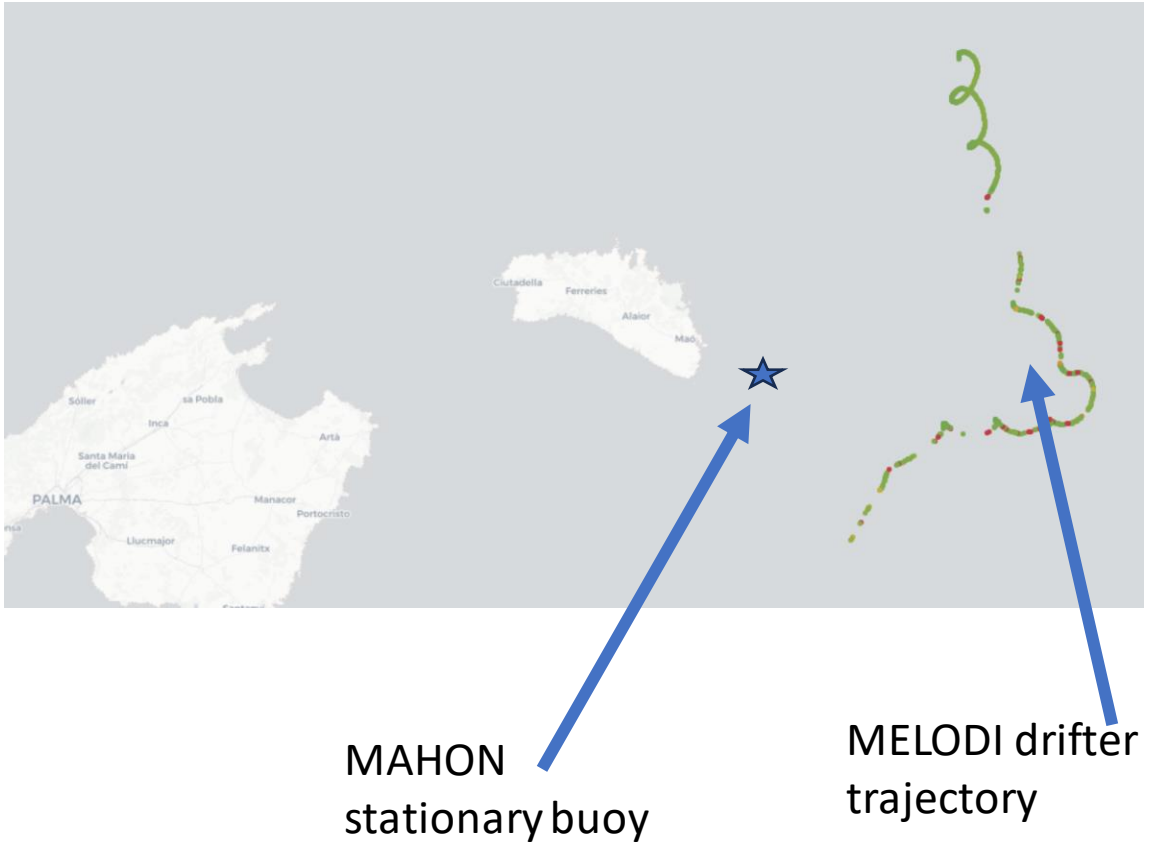
$$E(f) = \frac{4\beta u_* g}{(2\pi)^3 f^4}, f > 1.3 f_p$$

The friction velocity $u_*$ relates to wind speed assuming logarithmic wind profile

$$U(z) = \frac{u_*}{\kappa} \ln\left(\frac{z}{z_0}\right)$$

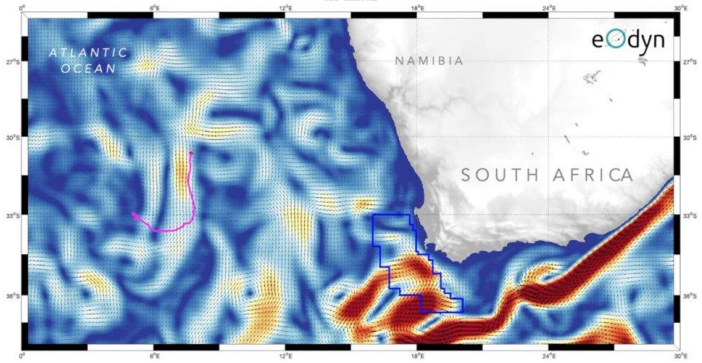
# Validation: wind speed retrieval (first results)



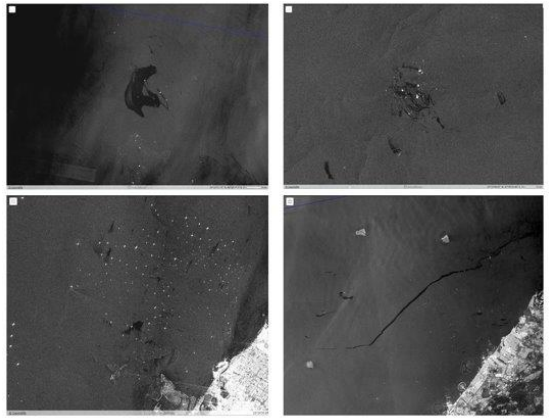



# Possible applications

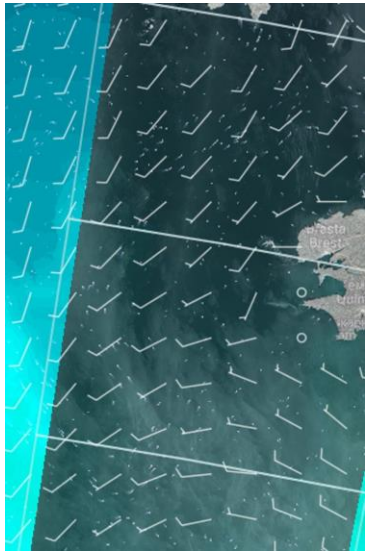
**Model validation and assimilation**

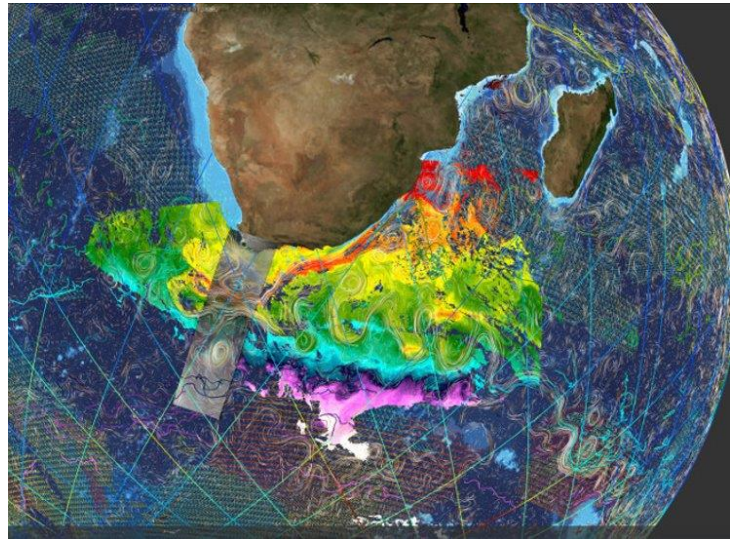



**Marine pollution tracking**



**Multi-instrument measurements**





# Summary

MELODI provides an affordable solution for developing customized drifting buoys tailored to specific ocean monitoring tasks.

Extensive field experiments have proven the reliability of MELODI buoys across a range of ocean conditions.

MELODI presents a scalable approach for constructing integrated ocean observing networks, including satellite cal/val.

Proposed ocean observation platform is supposed to be another key component of future multi-platform ocean observing systems.