Miniaturized drifting buoy platform for satellite calibration and validation

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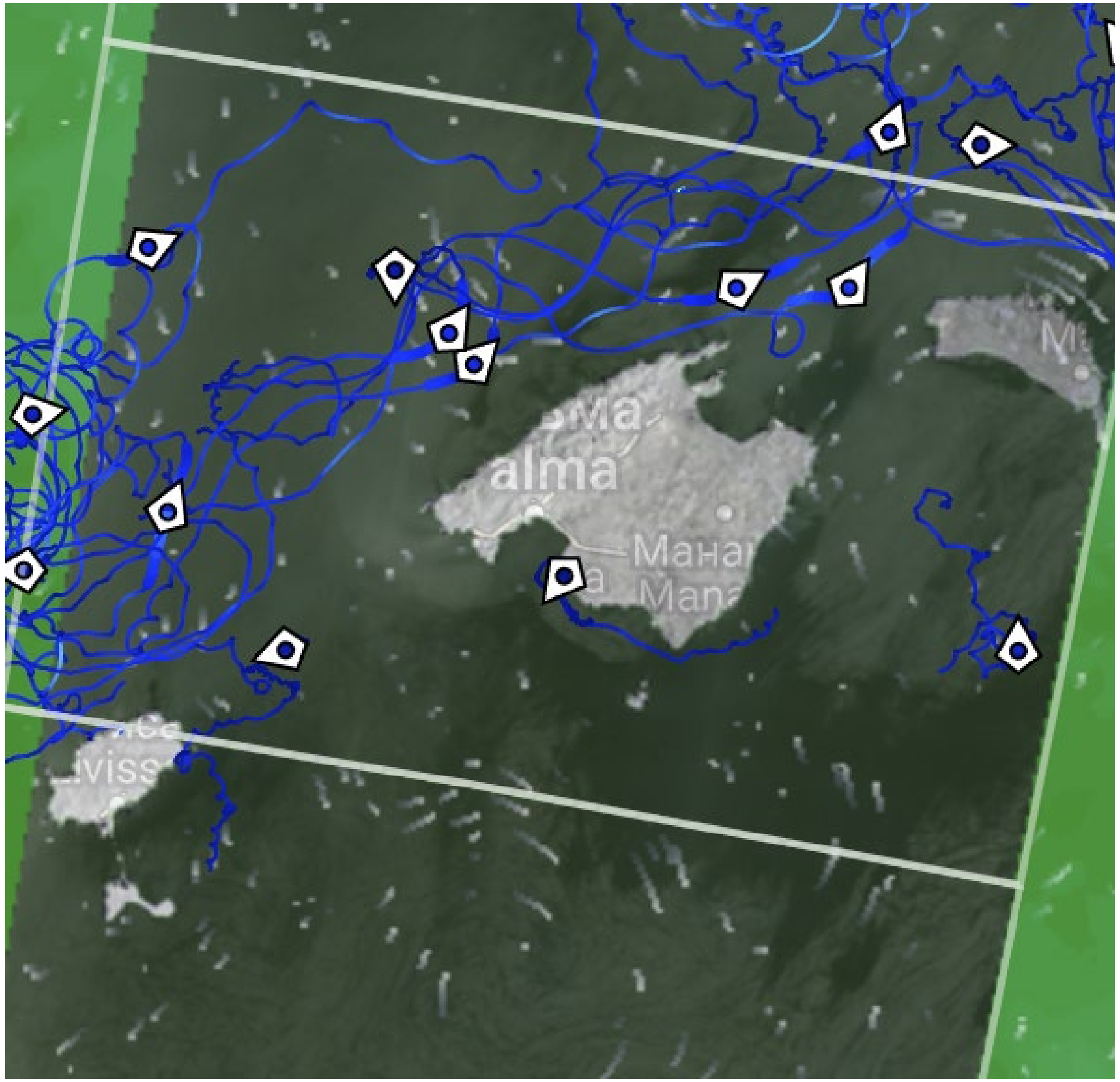
Introduction

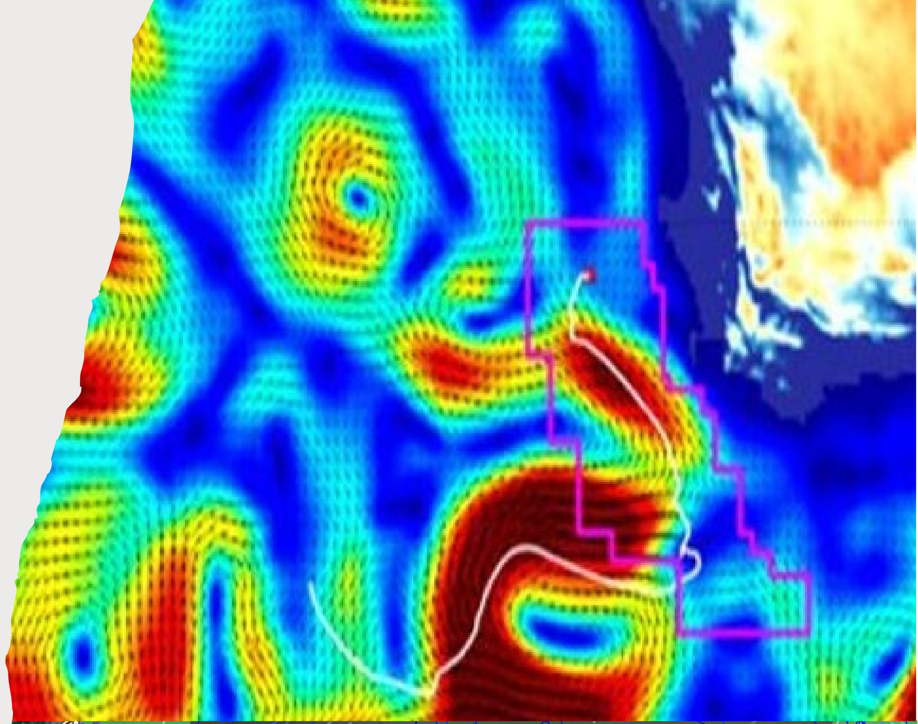
A satellite network offers a global, multiparametric view into the world's oceans. However, rigorous calibration and validation are essential to ensure the accuracy of satellite-derived geophysical data products.

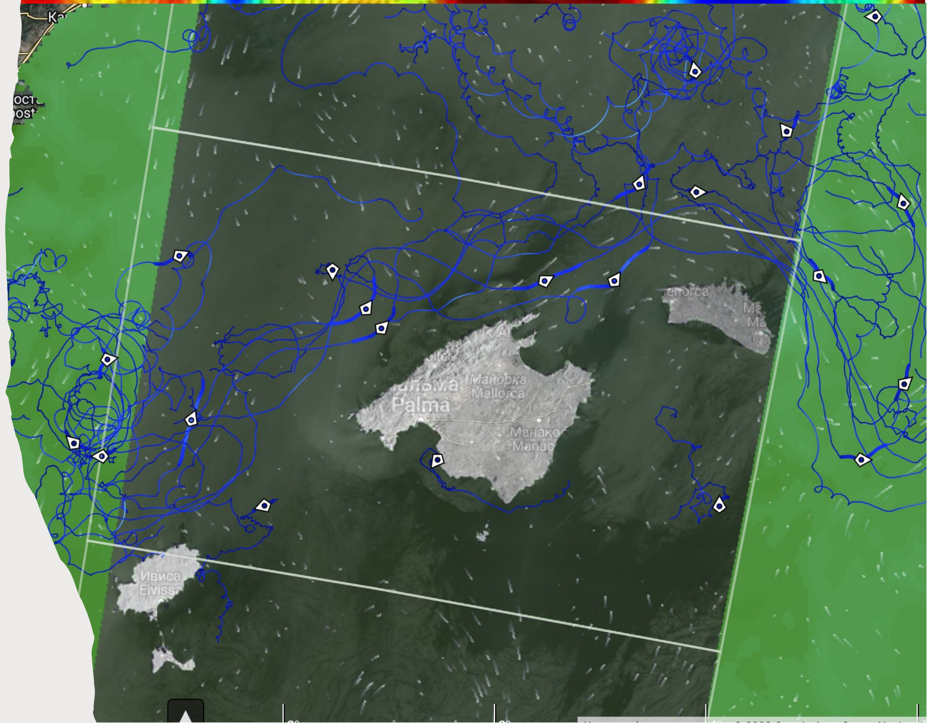
While various methods may be employed, ocean buoys provide continues ground truth validation for satellite remote sensing observations of the sea surface.



Motivation points

- 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
- Dedicated buoys needed to measure different key sea surface parameters: wave spectrum, current, temperature, color etc.
- Buoy network deployment is costly





MELODI project

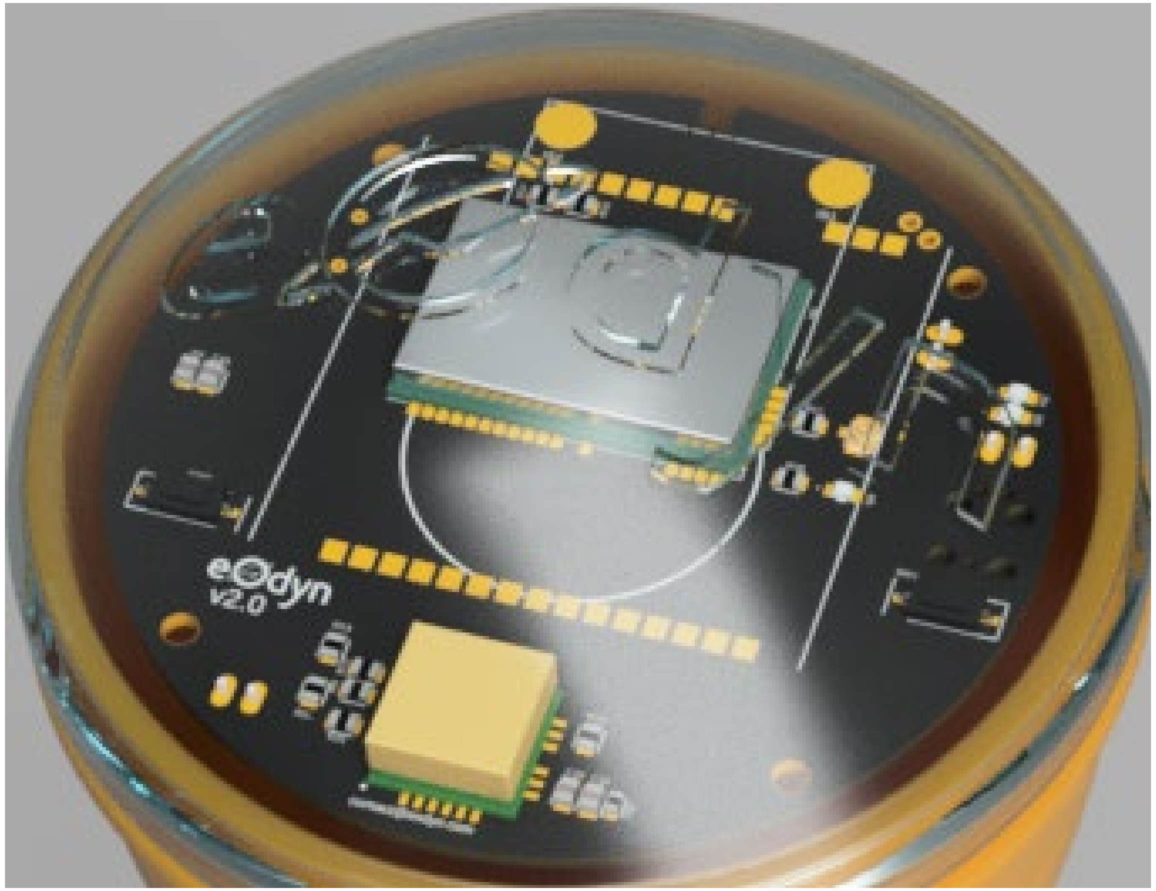
The Miniaturized Electronics Lagrangian Ocean Drifter project is aimed to propose a flexible polyvalent solution for undersatellite calibration/validation tasks and ocean monitoring problems.

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

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
- SD-card with full data available



Selection of buoy hull

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

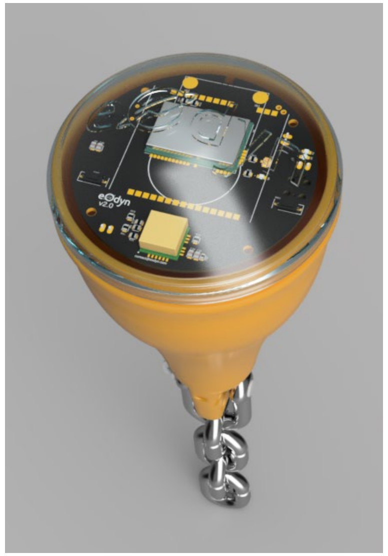
Every shape designed to fit a specific requirements of every problem

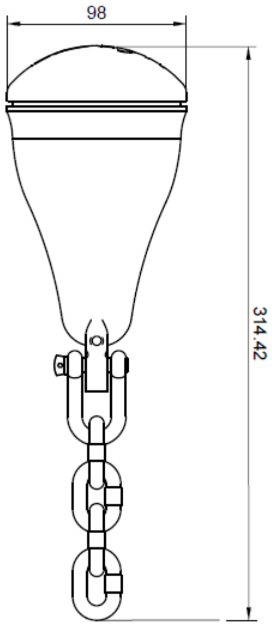
Main parameters:

Weight: 800 gr

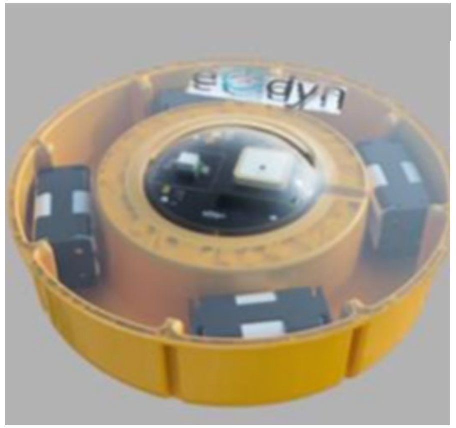
Size: ~10-20 cm

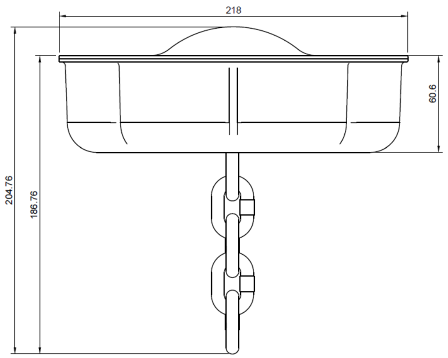
Wave spectrum version



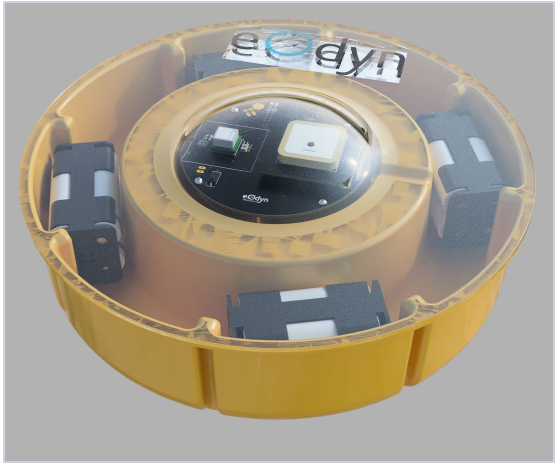


Surface drift version





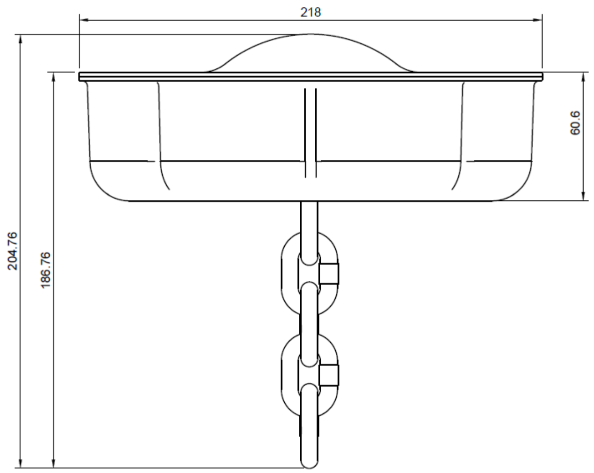
MELODI Drifters Technical Summary



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 profile with reduced wind drag
  - Real-time data visualization
  - Onboard full data log on SD card
  - Cost-effective conception
  - Biodegradable hull/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 (under validation)
  - Sea surface temperature
  - Atmospheric air pressure (under 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

Bio-SWOT buoy trajectories

Ifremer
SHOM L'océan en référence
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mio Institut Méditerranéen d'Océanologie
IPSL LOCEAN
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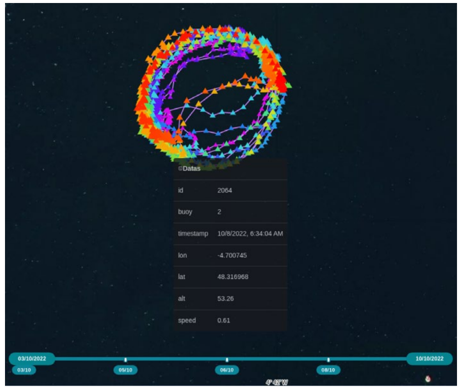
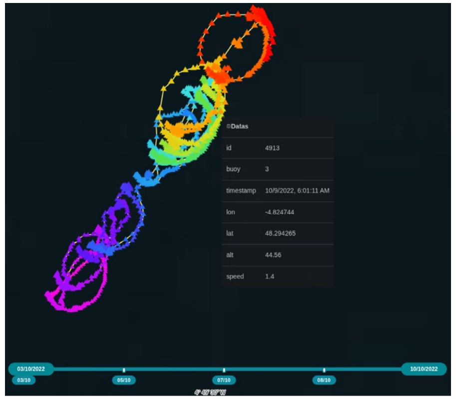
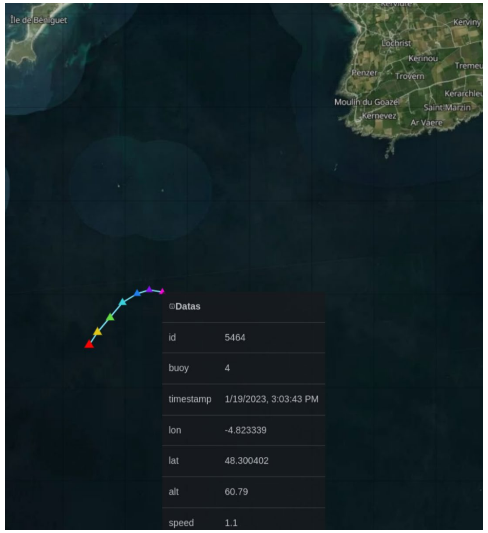
Validation: positioning and drifting properties

Moored buoy long observation series





Free floating drifting tests



Very low direct wind impact!

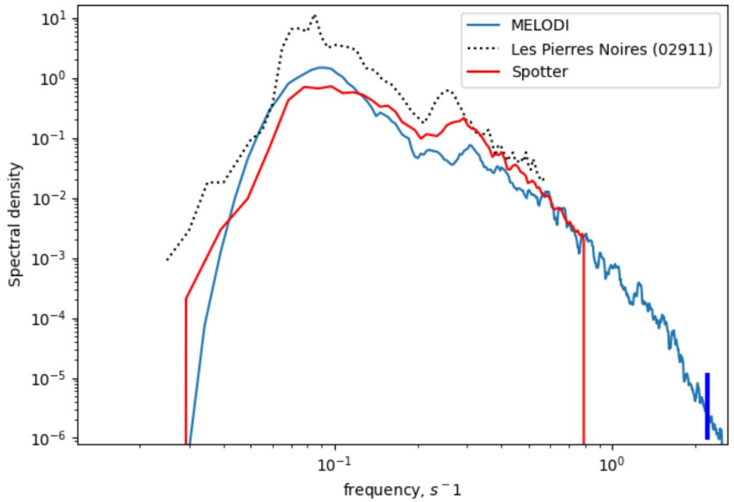
Validation: ocean wave state

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.

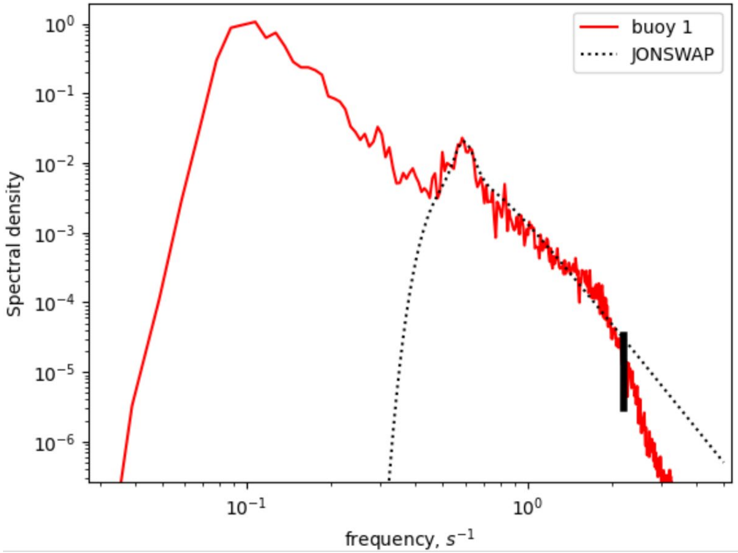
$$S(f) = C_{\zeta\zeta} = \frac{C_{zz}}{(2\pi f)^4}$$

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

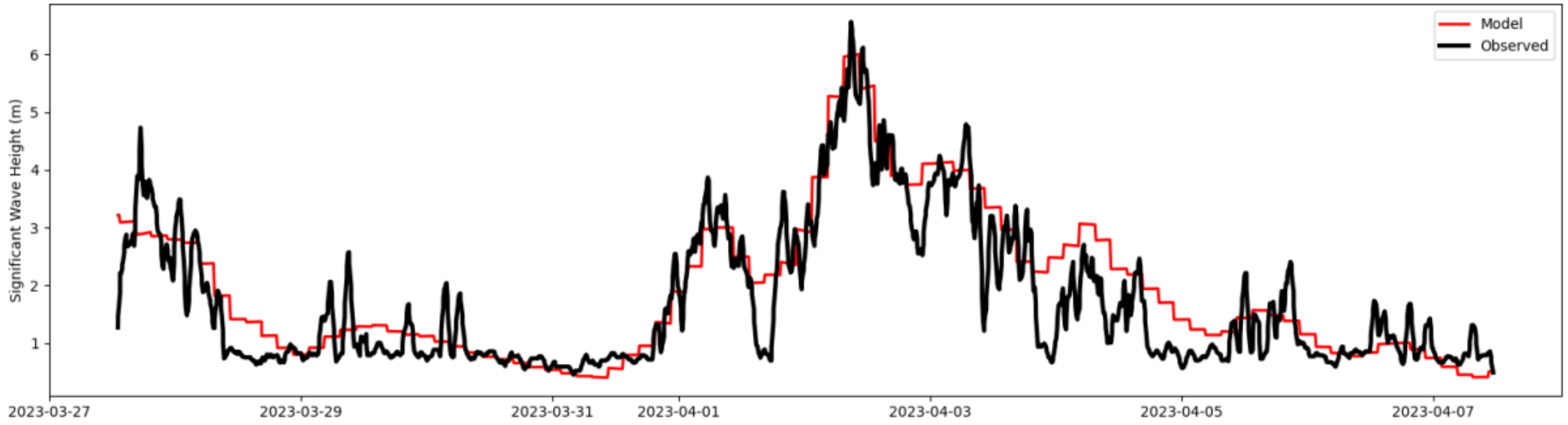
Wave spectrum cross-validation



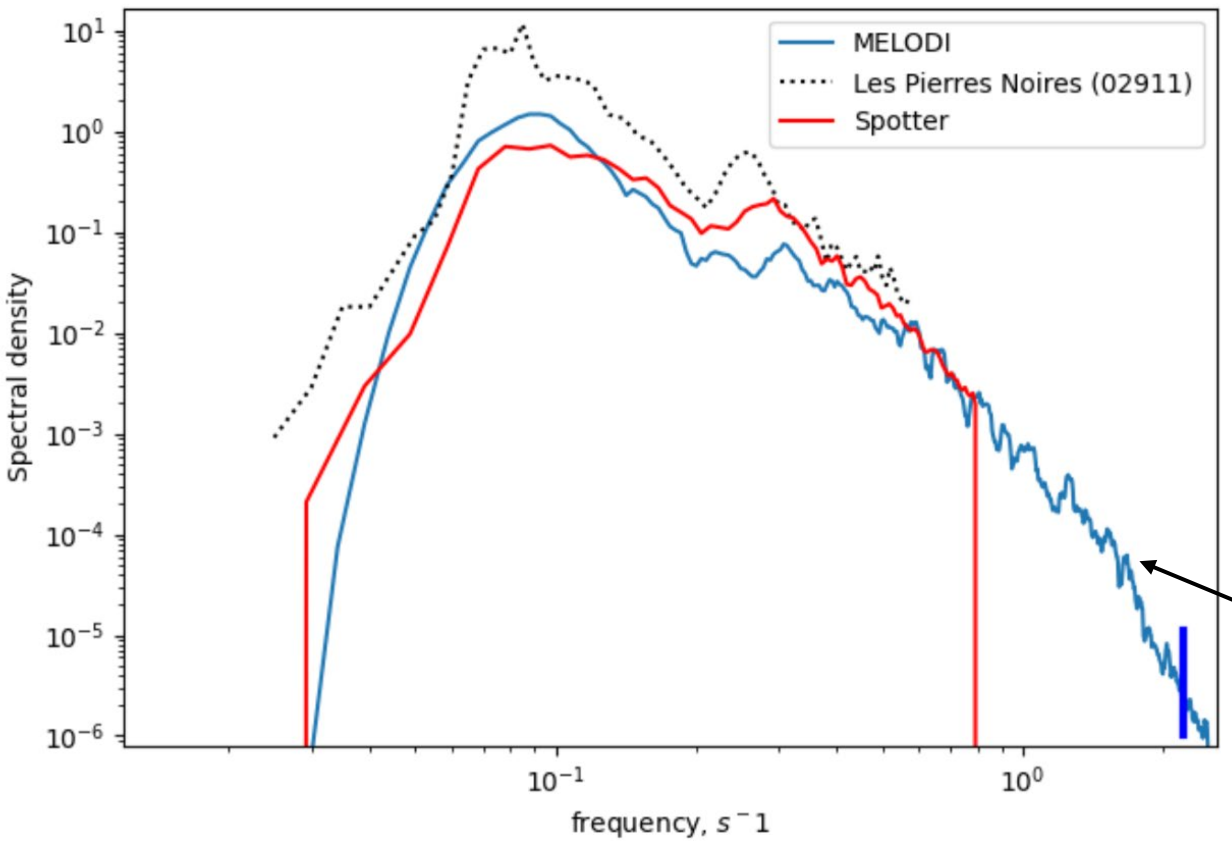
Wave spectrum and model cross-validation



Significant wave height against Wave Watch 3 model



High frequency wave measurements



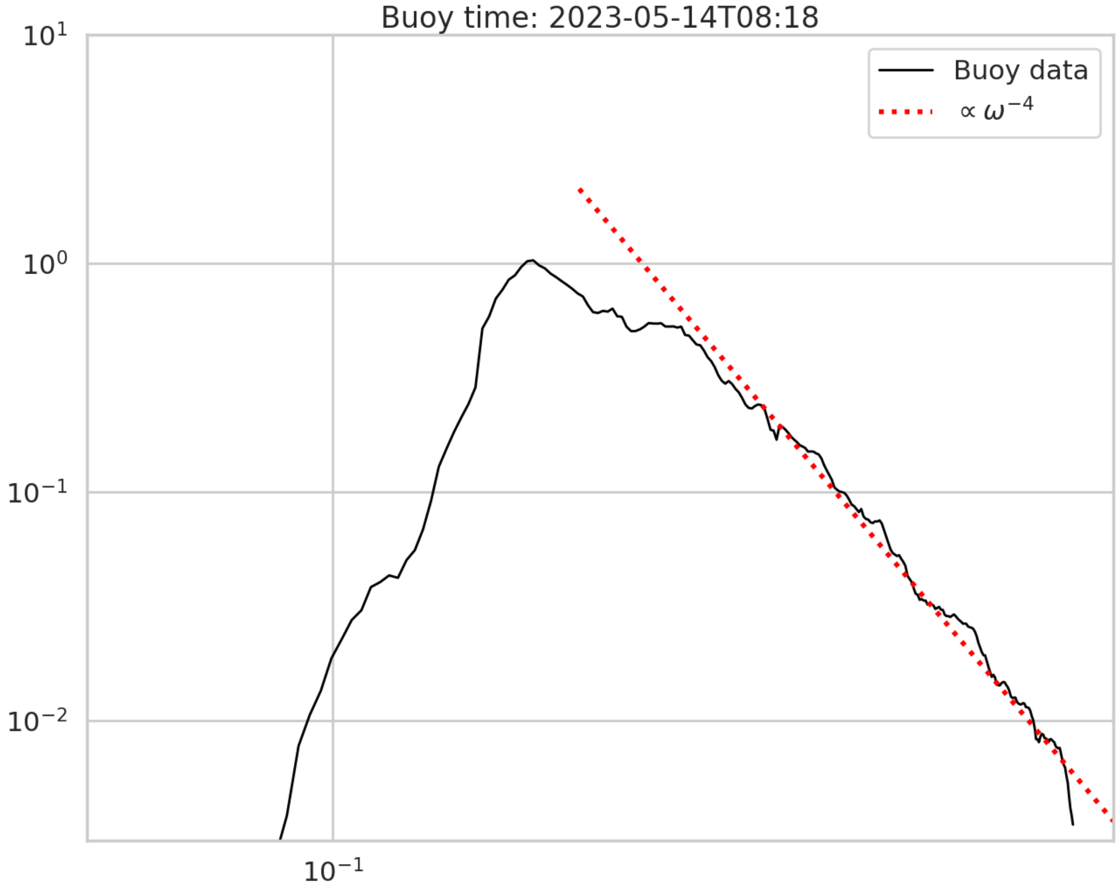
Small diameter of buoy hull and small size allows to perform precise high frequency wave measurements. This frequency part is particularly sensible to wind changes and contains a lot of information about wave-wind-sea surface current interactions.

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

High frequency spectrum part

Wind speed retrieval

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



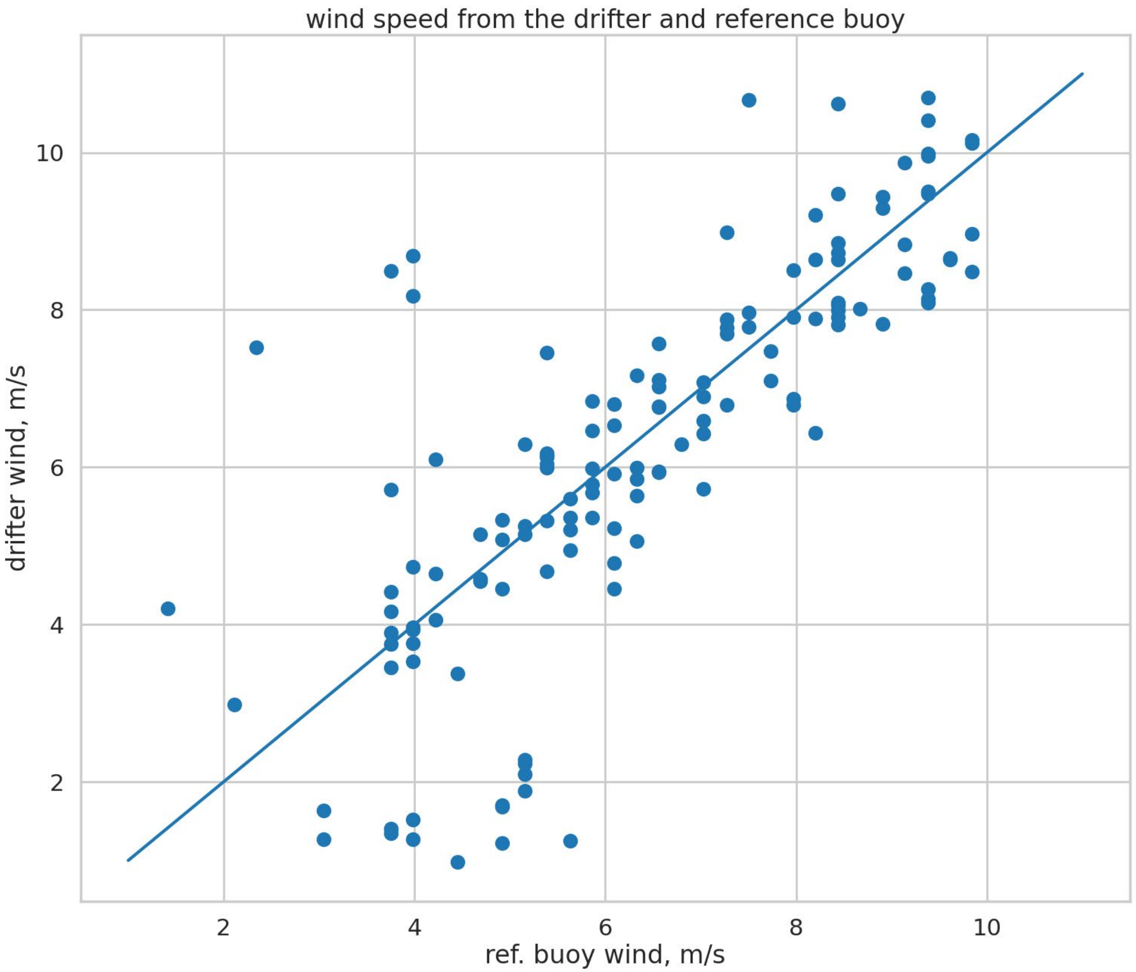
The tail of the spectrum responds relatively rapidly to changing wind conditions and takes the equilibrium shape:

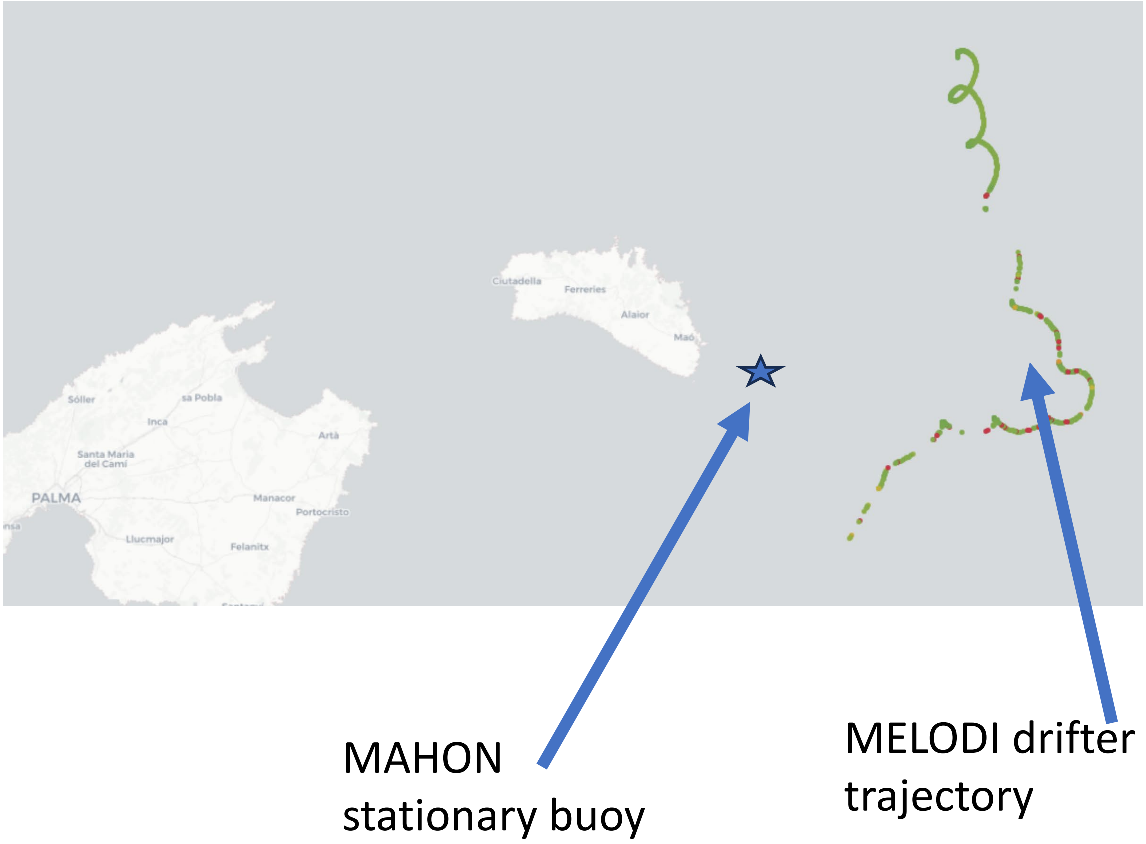
$$E(f) = \frac{4\beta I u_* g}{(2\pi)^3}, f > 1.3 f_p$$

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

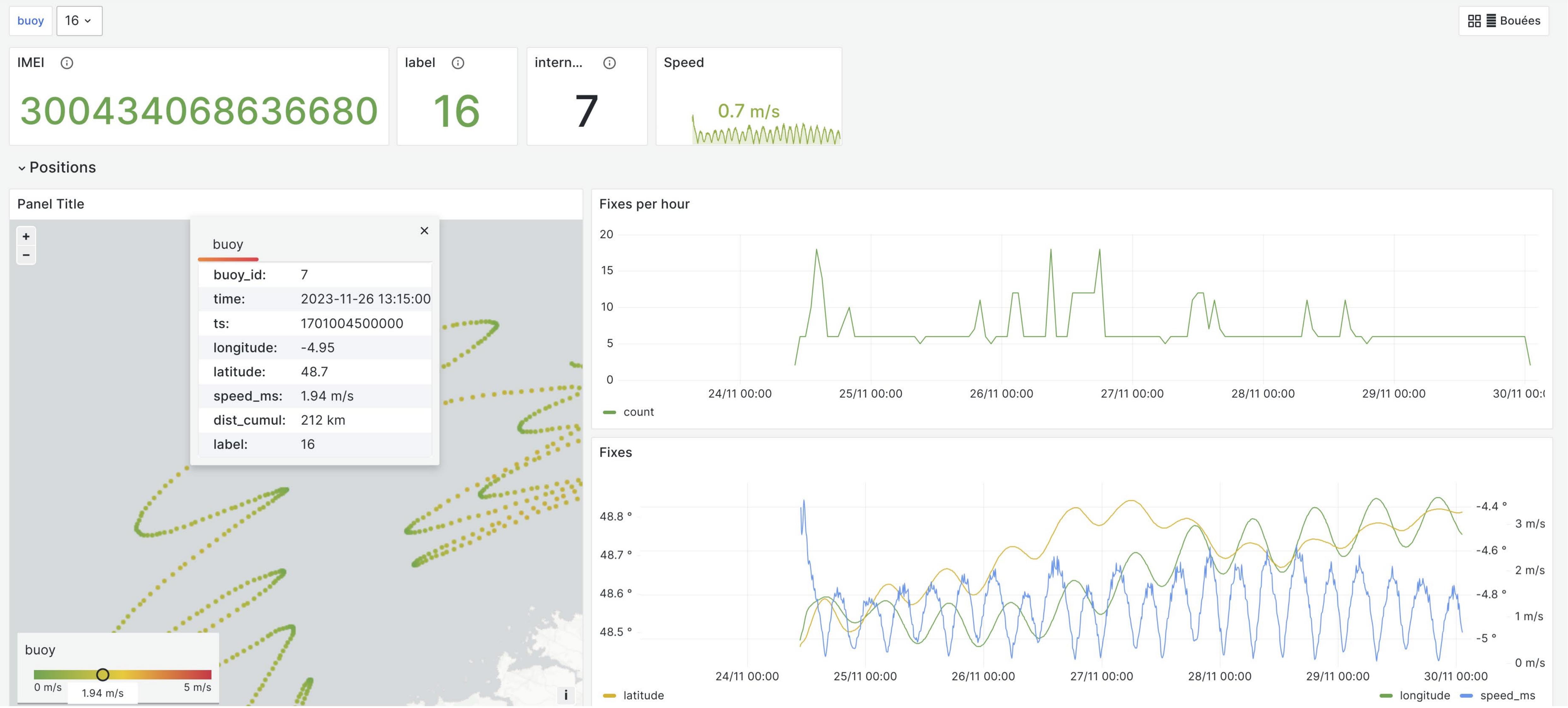




Buoy real-time data reporting

- The trajectory of the test buoy during this week

Buoy real-time control panel

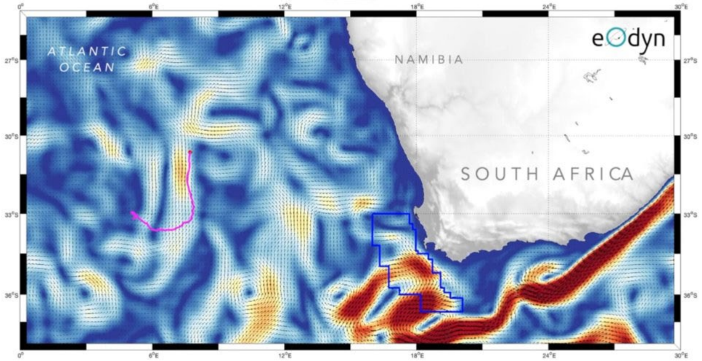


Further improvements (solution scaling)

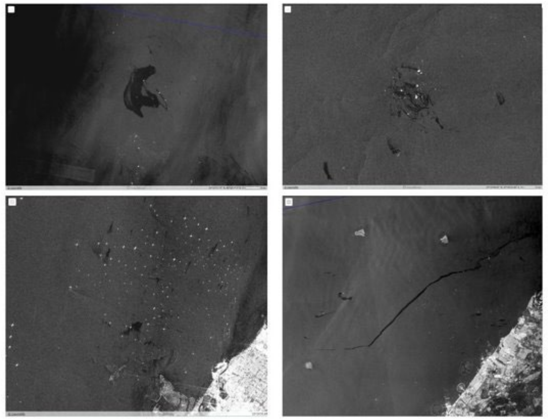
- EXTENDED AUTONOMY WITH SOLAR PANEL (UP TO 1 YEAR)
- DIRECTIONAL WAVE SPECTRUM
- REDUCED ENVIRONMENTAL IMPACT WITH BIODEGRADABLE BUOY HULL
- MORE SENSORS
- WIND SPEED MEASUREMENTS
- UAV AND AIRPLANE DROPPABLE DEPLOYMENT VARIANT

Usage Perspectives

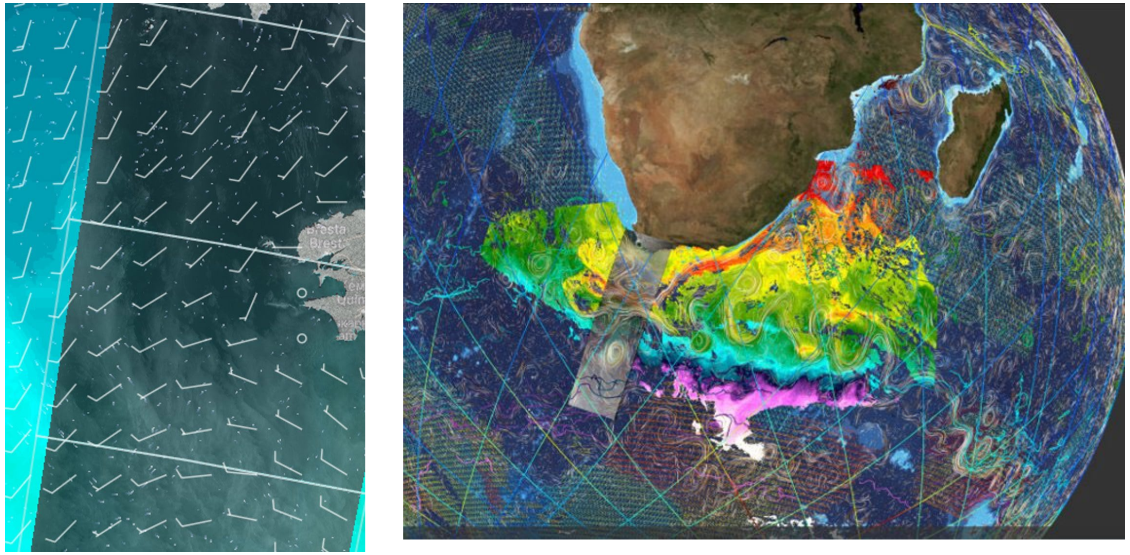
Model data assimilation



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 and precision of MELODI buoys across a range of ocean conditions.

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

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