Miniaturized, Multi-purpose Drifter For Sea Surface State Monitoring

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5TH WORKSHOP ON WAVES AND WAVE-COUPLED PROCESSES, ECMWF | READING | 10-12 APRIL 2024

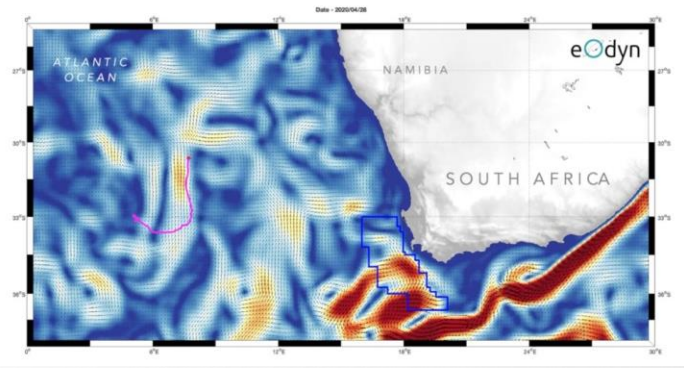
INTRODUCTION

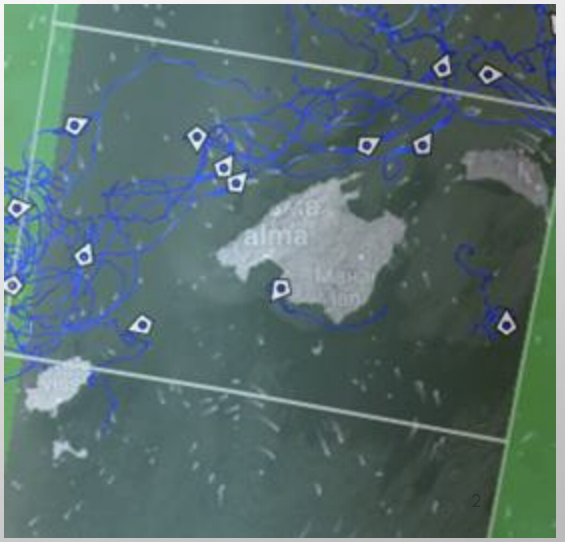
Many tasks on ocean upper-layer modelling, understanding of wave coupling mechanisms and understanding of the manifestation of sea surface physical processes at remote sensing data require time and spatial in-situ measurements as a ground truth.

Increasing resolution of the model and remote sensing data applies specific requirements on in-situ measured variables (time and spatial properties)

The volume of required measurements drastically increases for data-driven, ML and assimilation-based approaches.

Many in-situ measurements are concentrated in coastal areas and a limited number of geographical regions and provide a limited set of variables.





MOTIVATION AND OBJECTIVES

- Need an affordable buoy for rapid and/or mass deployment in any ocean area.
- Need for flexible custom sampling rates and averaging schemas (e.g. for subsatellite measurements, model validations)
- One of the challenges we face is that buoy measurements are not always collocated in time and space with other measurements, such as satellite swath.
- There is a need for a more affordable solution to measure different key sea surface parameters, such as the wave spectrum, current, temperature, and color.
- High-resolution applications need more dense measurements to reveal small dimensions of ocean upper-layer dynamics.
- Many approaches need significantly more measurements worldwide; however, developing an appropriate buoy network is costly.

OBJECTIVES

- Polyvalent solution for sea surface dynamics measurements: sea surface current, wave spectrum, SST, …
- Scientific quality measured data
- Cost-effective and easily deployable buoy
- Flexible measurement modes, customized sampling
- Eco-friendly solution enabling mass deployments
- Crowd/Citizen science applications. Provide elements for building of multi-actor buoy measurement network

MELODI DRIFTING BUOY PROJECT

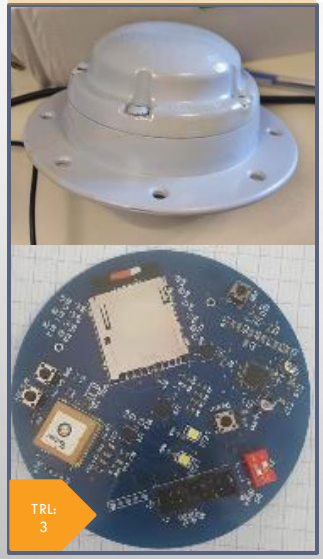
The miniaturized electronics Lagrangian ocean drifter (MELODI) project aims to propose a flexible polyvalent solution for undersatellite calibration/validation tasks, ocean monitoring and measurement problems.

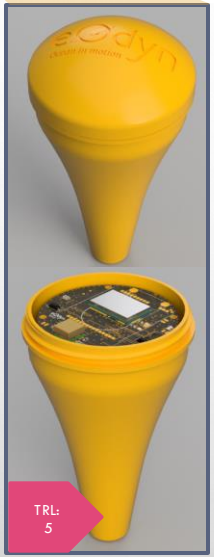
DEVELOPMENT STAGES

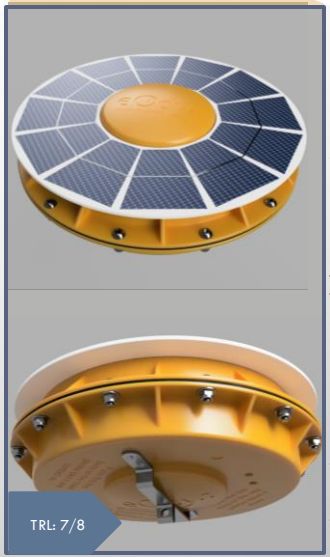
2022 2023

Tests 1 Tests 2 Tests 3 Tests 4 C-SWOT Tests 5 BioSWOT

M-01 M-02 M-03 M-04 M-05 M-06







TRL Level

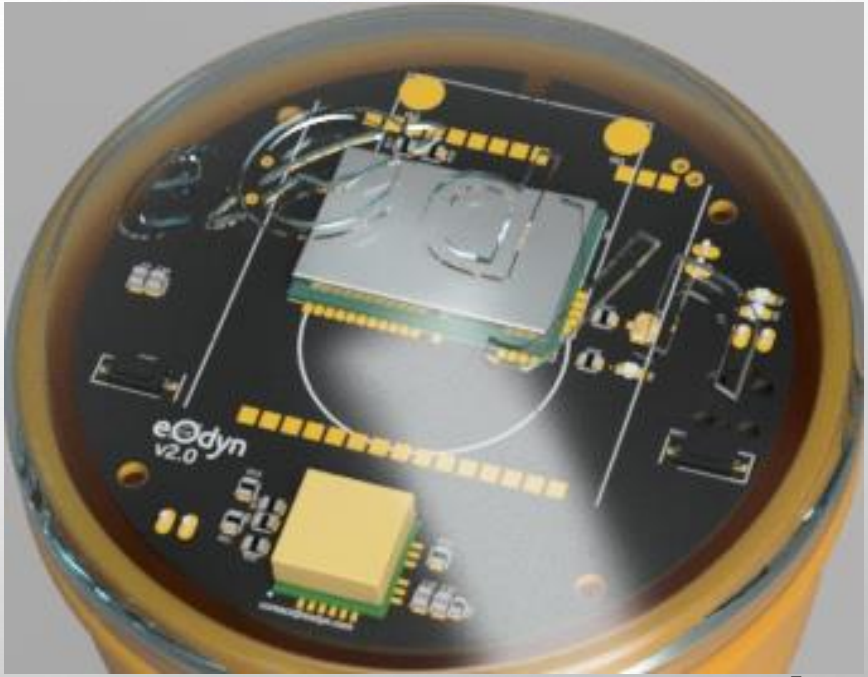
Idea: 0 1 2 3
Prototype: 4 5
Validation: 6 7
Industrial: 8 9

- Ø 10 cm
  H 19 cm
  300 g

- Ø 25 cm
  H 10 cm
  1kg

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
- Solar panel-powered



SELECTION OF BUOY HULL

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

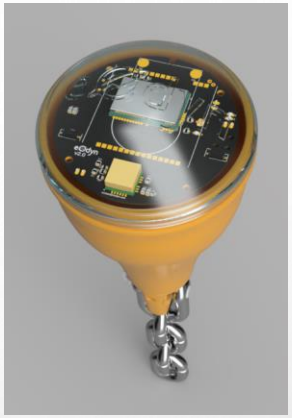
Every shape is designed to fit the specific requirements of every problem

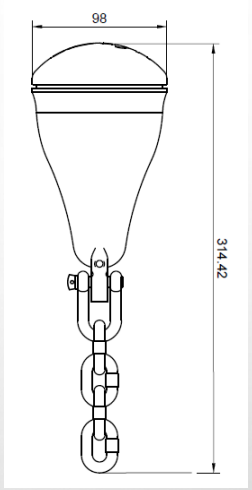
Main parameters:

Weight: 800 gr

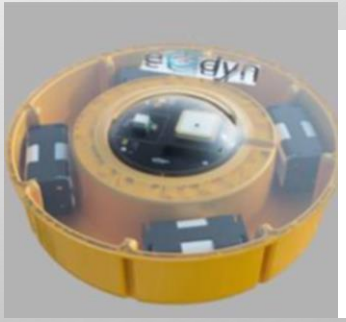
Size: ~10-20 cm

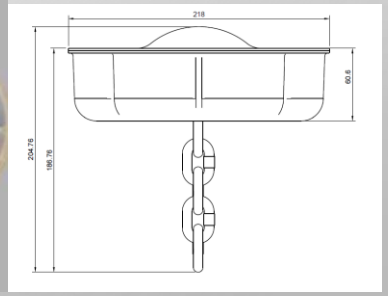
Wave spectrum version





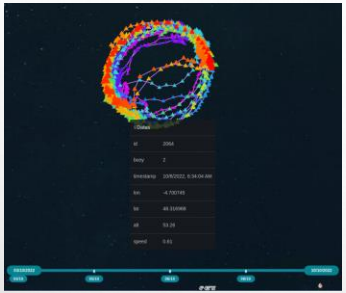
Surface drift version

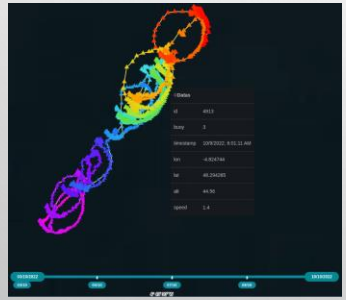




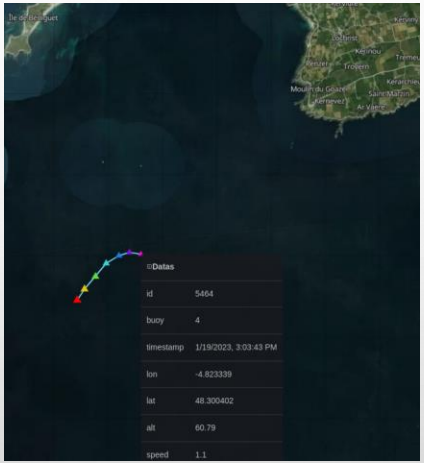
VALIDATION: POSITIONING AND DRIFTING PROPERTIES

Moored buoy long observation series





Free-floating drifting tests



Very low direct wind impact!

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

The experimental dataset is available publicly

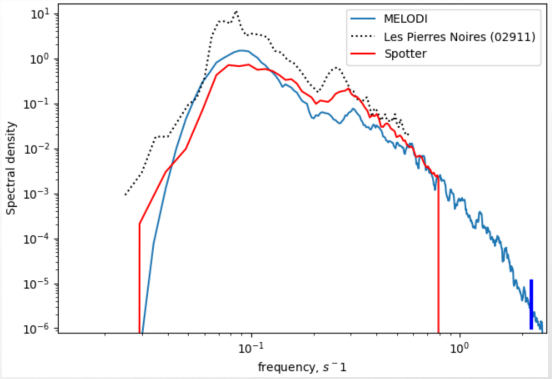
VALIDATION: OCEAN WAVE STATE

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.

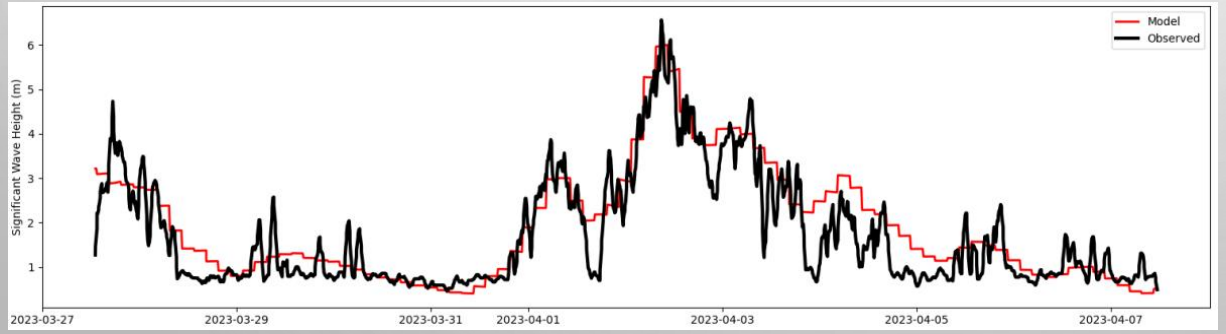
$$S(f) = C_{\zeta\zeta} = \frac{C_{zz}}{(2\pi f)^4}$$

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

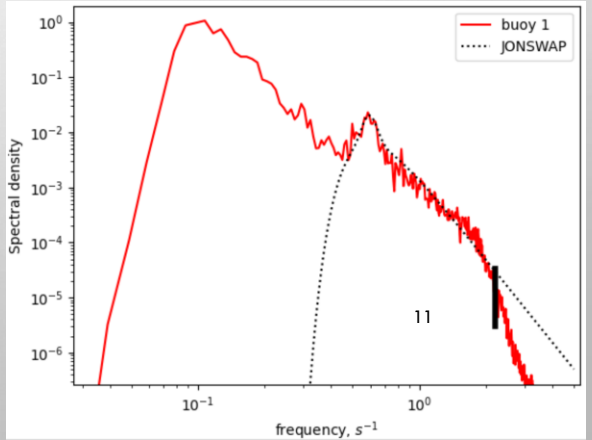
Wave spectrum cross-validation



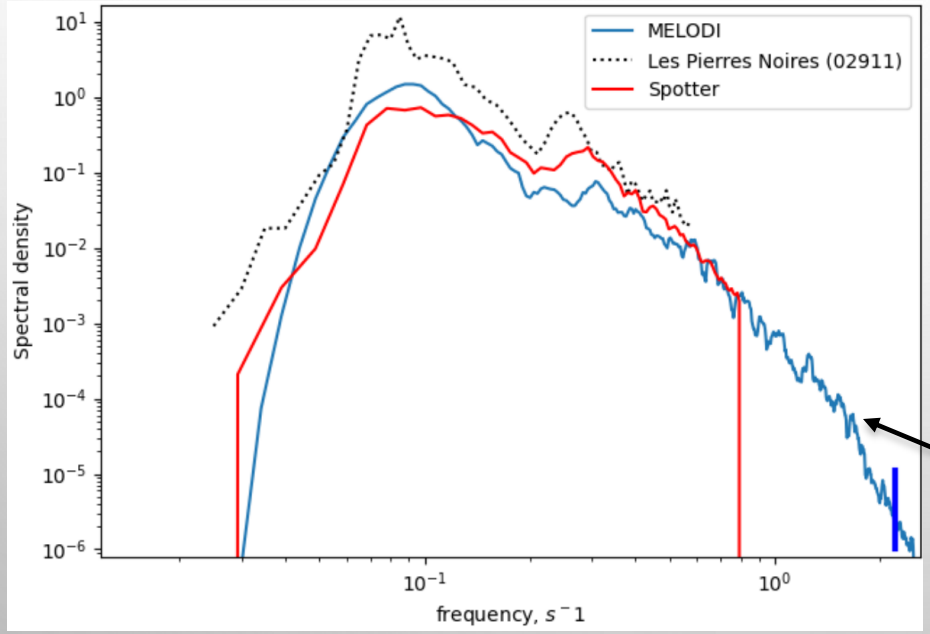
Significant wave height against Wave Watch 3 model



Wave spectrum and model cross-validation



HIGH FREQUENCY WAVE MEASUREMENTS



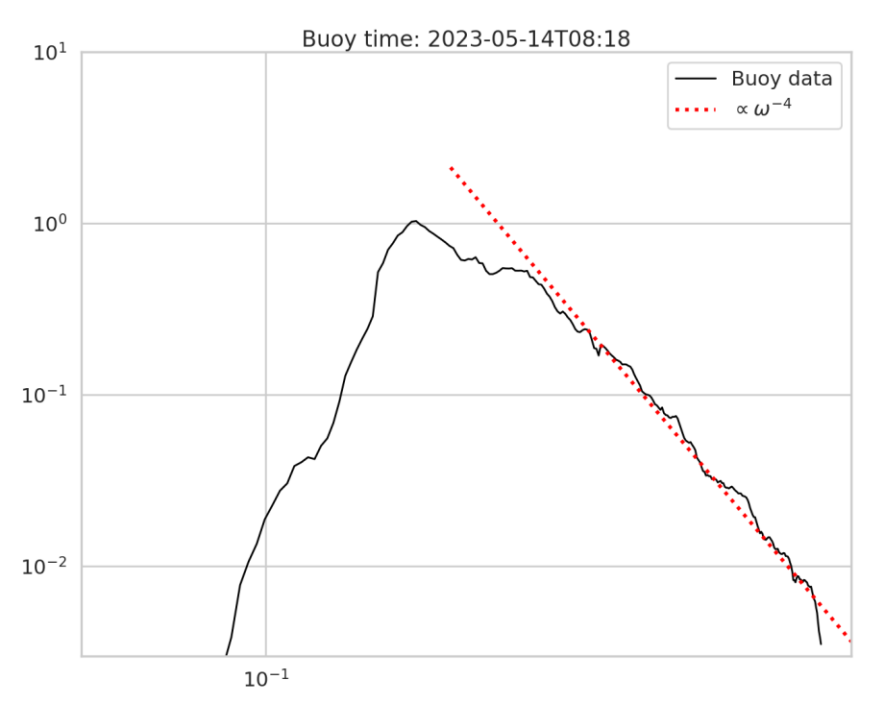
Small diameter of buoy hull and small size allows to perform precise high frequency wave measurements. This frequency part is particularly sensible to wind changes and contains a lot of information about wave-wind-sea surface current interactions.

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.



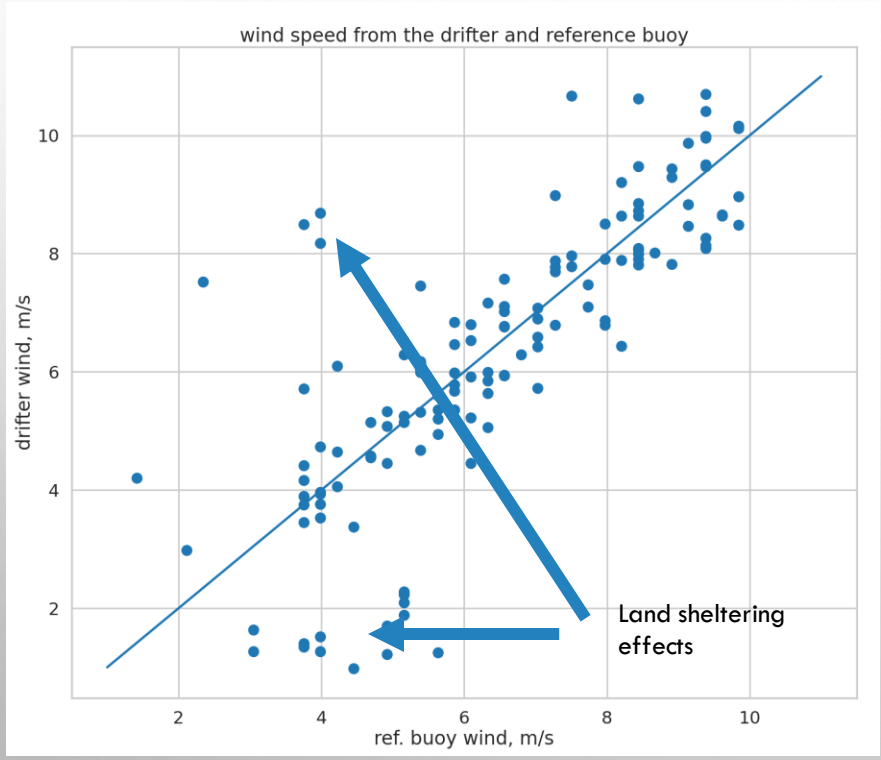
The tail of the spectrum responds relatively rapidly to changing wind conditions and takes the equilibrium shape:

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

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

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

Validation: wind speed retrieval



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
- Biodegradable hull

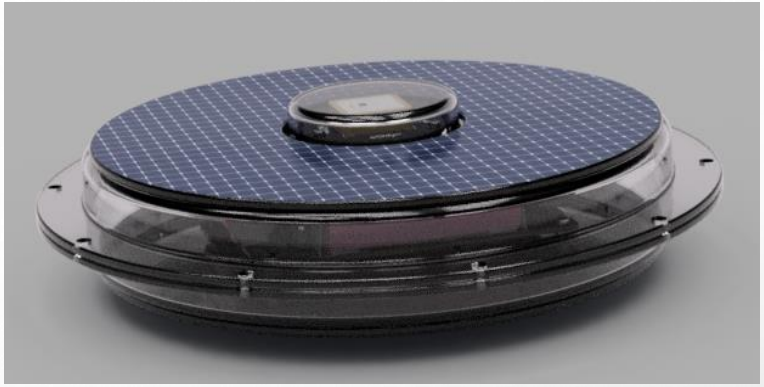
Measured parameters

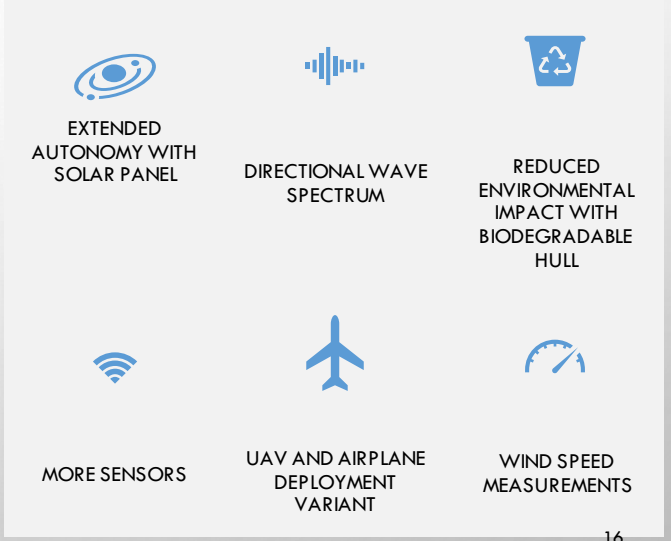
- Wave data sampling 3Hz
- GPS displacements every 10 min
- Significant wave height every 30 min
- Omnidirectional wave spectrum (0.02-0.8 Hz) every 1h
- Sea surface temperature
- Wind speed/friction velocity (under validation)
- Atmospheric air pressure (under validation)

BUOY REAL-TIME CONTROL PANEL

FURTHER IMPROVEMENTS, SCALING, OPEN-SOURCE VERSION

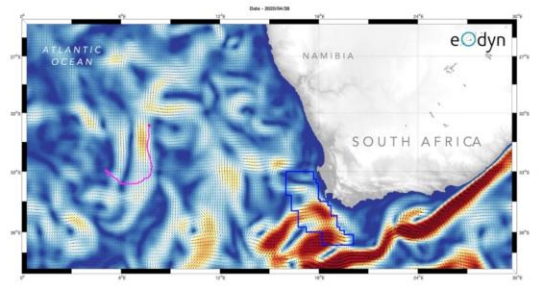
- Reducing the size of the floater
- Adding more complex onboard processing
- More indirect variables
- Open-source solution for customized versions
- Community driven development
- Common control interface, publicly available data
- Flexible data-sharing model



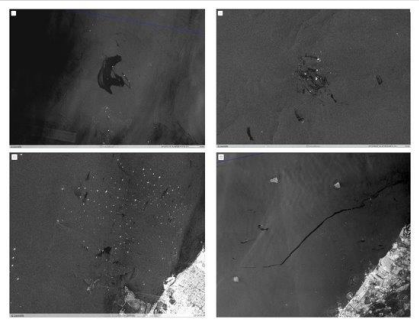


USAGE AREAS

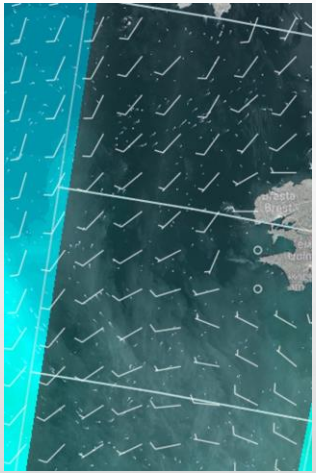
Model data assimilation

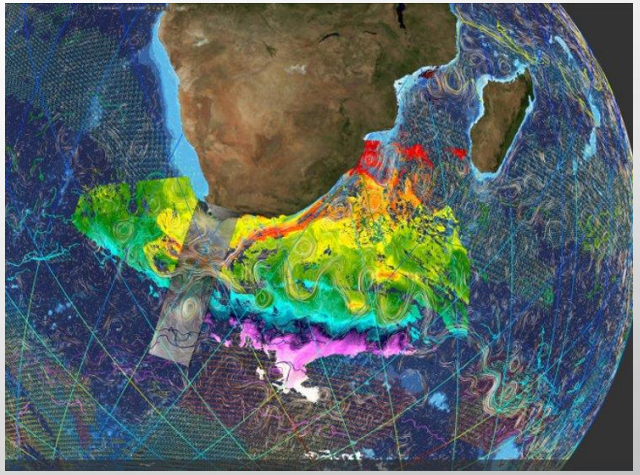


Marine pollution tracking



Multi-instrument measurements





SUMMARY

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

Field validation experiments have proven the reliability and precision of MELODI buoys across a range of ocean conditions.

MELODI buoys present a scalable approach for constructing integrated ocean observing networks, including models and satellite cal/val.

MELODI buoy is supposed to be another key component of future in-situ ocean observing networks.