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 CO2 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)
**C-SWOT / WENSWOT**
- Date: 21/03 to 18/04/23
- 2 buoys deployed

**BioSWOT-Med**
- Date: 21/04 to 15/05/23
- 15 buoys deployed
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.

\[ S(f) = C_{\xi z} = \frac{C_{zz}}{(2\pi f)^4} \]

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

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

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

![Graph showing wind speed retrieval comparison between a stationary buoy and a MELODI drifter trajectory.](image)
Buoy real-time data reporting

- The trajectory of the test buoy during this week
Buoy real-time control panel

IMEI: 300434068636680
label: 16
internal: 7
Speed: 0.7 m/s

Panel Title

buoy_id: 7

- time: 2023-11-26 13:15:00
- ts: 17010045000000
- longitude: -4.95
- latitude: 48.7
- speed_ms: 1.94 m/s
- dist_cumul: 212 km
- label: 16

Fixes per hour

Fixes
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
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.