Multi-platform experiments, numerical simulations and data science techniques for generation of new altimetric products: focus on mesoscale and sub-mesoscale variability (MANATEE – OSTST proposal)

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The general objective of the MANATEE project is to improve the characterization of oceanic mesoscale and sub-mesoscale features (e.g. fronts, meanders, eddies and filaments) through the combined use of in situ and satellite data in synergy with numerical models and innovative computational techniques.

The ultimate goal is to enhance our understanding of the impact of fine-scale processes. MANATEE has assessed our actual capability to map the SSH variability for a range of scales (15-100 km) traditionally not resolved by conventional altimeters through the development of a multidisciplinary expertise in physical oceanography and computational science.

In this presentation we review some of the results obtained in the framework of this project including those obtained from the synergy of in situ and satellite observations with supporting numerical simulations during dedicated multi-platform field experiments in the western Mediterranean Sea aimed at estimating fine-scale horizontal and vertical currents (e.g. Abacus, PRE-SWOT, Calypso2018 and Calypso2019).
Motivation

- Horizontal and vertical motions associated with fine-scale ocean processes play a critical role in the distribution and exchange of heat, fresh water and biogeochemical tracers.

- Modelling suggest that vertical exchange is enhanced at density fronts.

- The measurement of vertical velocities and horizontal currents at small scales are two key challenges in ocean observation.
A synergy among three programs

- Gain experience in multi-platform (two ships, gliders, drifters,...), multi-lateral campaign coordination.
- Area relatively sparsely sampled in previous oceanographic cruises
- Few modeling and remote sensing studies.
- Small Rossby radius, low tides, low internal waves
- Lagrangian and eulerian approaches
- Characteristic horizontal scale (Rossby radius of deformation) of 6 km
- Eddy radius ranging from 5 to 18 km
- Temporal variability of circulation and transport over timescales of weeks stronger than seasonal changes
Glider missions along altimetry tracks: ABACUS program

Sea Level Anomaly (color scale)
Geostrophic velocity anomalies (black arrows)

Blue lines show the glider track from 15th Sept to 20th Oct 2014. The glider sampled and eddy and followed a SARAL/AltiKa track.

Cotroneo et al. (2016)
Aulicino et al. (2018)
Cotroneo et al. (2020)
PRE-SWOT sampling strategy

- Mimic SWOT swath width and resolved scales
- Radiator grid covered 100% in 4.5 days
- All data QC and public (DOI)
Dynamic Height – Geostrophic Velocity

PRE-SWOT - Mimic ‘SWOT’

Optimal Interpolation

20 km Correlation scale
Illustration of SWOT potential

PRE-SWOT - Mimic ‘SWOT’

DUACS/AVISO
OSSE – impact of interpolation and lack of synopticity

- OSSE to evaluate the impact of the errors associated with the reconstruction of SSH field from CTDs.

- Model: free-run 400 meters simulation initialized from the WMOP forecast model (Juza et al. 2016) + assimilation of satellite altimetry, L4 gridded SST and temperature and salinity profiles from Argo floats and CTD casts.

E. Cutolo & B. Mourre
Non-synoptic CTD sampling, SSH errors associated with the interpolation + lack of synopticity are 20% for scales in the range of 20-40 km.
Chl subduction - glider

Subduction
Multi-platform experiment (ship, glider) during commissioning phase of Sentinel-3A. SAR mode improves SLRM.

New SAR instrument gives an improvement of 42% in the estimation of across-track surface velocities with respect to lower-resolution altimetry.

Decrease in percentage error between SARM and P-LRM product.

Heslop et al. GRL (2017)
Coherent Lagrangian Pathways from the Surface Ocean to Interior

Mahadevan, Pascual, Rudnick, Ruiz, Tintoré, D'Asaro, BAMS, 2020
CALYPSO dataset: uCTD 2019

Underway CTD 2019 – Phase 2 – Anticyclonic eddy, strong front
~5 days sampling
Optimal interpolation vs variational method (DIVA, Barth et al. 2014)*

Dynamic height and geostrophic velocity overimposed

Cutolo et al. in prep.
Vertical velocity – sensitivity to the method of interpolation

- QG-W max DIVA ~ 40 m/day
- QG-W max OI ~ 20 m/day
How reliable are w-QG and w-SG? – response from a model simulation

(Winter snapshot of PSOM from M. Freilich, 500 m resolution)
Can we learn how to best reconstruct surface dynamics from satellite data? Can we directly learn observation data?

An example for upcoming SWOT mission

Variational data assimilation & Neural Networks for the reconstruction of ocean dynamics

https://www.youtube.com/watch?v=fKIlVmeq9dk
Summary and outlook

• In complement with SWOT and other satellites, integrated multi-platform experiments (ship, gliders, drifters, floats, aircraft, saildrones, moorings), including direct measurements of vertical velocities and surface currents (e.g. HF radar) are needed.

• Efforts are already underway in the Western Mediterranean (e.g. MedSWOT/PRE-SWOT and also ONR CALYPSO DRI).

• Combination of satellite and in situ data opens doors in order to infer vertical velocities.

• SWOT fast sampling phase through the Adopt a Crossover Consortium offers an opportunity to the oceanographic community for international collaboration.
Summary and outlook

- New developments to measure and predict vertical velocities (CALYPSO - US ONR funded initiative).
- Autonomous and ship-based observing.
- Understand the implications. Vertical exchange of heat, gas, nutrients and biology.
- Machine learning and deep learning strategies to identify sampling strategies to reconstruct with.
- Need to observe and resolve a range of scales that will contribute to enhance our understanding of ocean currents associated with meso- and submesoscale features, with impacts on longer climatic scales.