SYMPOSIUM OP'24 ADVANCING OCEAN PREDICTION SCIENCE FOR SOCIETAL BENEFITS

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Theme #7: User applications and societal benefits

Estimating trajectories of floating objects using the new ICATMAR high-frequency radar network

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I. Abstract

ICATMAR is a cooperative body between the Institute of Marine Sciences (ICM-CSIC) and the Catalan Government aiming to provide scientific advice for the maritime governance and blue economy development. Since early 2023, a new high-frequency radar (HFR) network is being implemented by ICTAMAR along the Catalan Coast (Northwestern Mediterranean Sea). By the end of 2024, the HFR network will consist of 7 CODAR antennas, 5 of which are already operating. The array of antennas provides surface radial velocities and waves measurements between the coastline and about 80 km offshore covering, once completed, around 300 km of the coastline. Here, we show first preliminary results on the consistency between sea surface currents observed by the HFR, measurements from meteo-ocean buoys and numerical models. Secondly, we analyze the ability to reproduce Largrangian trajectories of drifting objects deployed during a search and rescue (SAR) testing exercise within the area covered by the HFR network.

II. Introduction

The HFR network deployed by ICATMAR is being implemented in several phases (see Figure 1). As a first approach, the radial velocity measurements obtained by the single antennas are combined using a (unweighted) least-squares fitting method to build hourly maps of total velocity fields having a spatial resolution of about 3 km available through ICATMAR's website (https://www.icatmar.cat/visors/xarxa-observacional/). For data validation, a 1-year long time series of HFR-derived total velocity currents from the northern sector of the Catalan Coast has been compared with Eulerian velocity measurements from buoy sensors and ocean modelling systems spanning the same time interval.

Figure 1

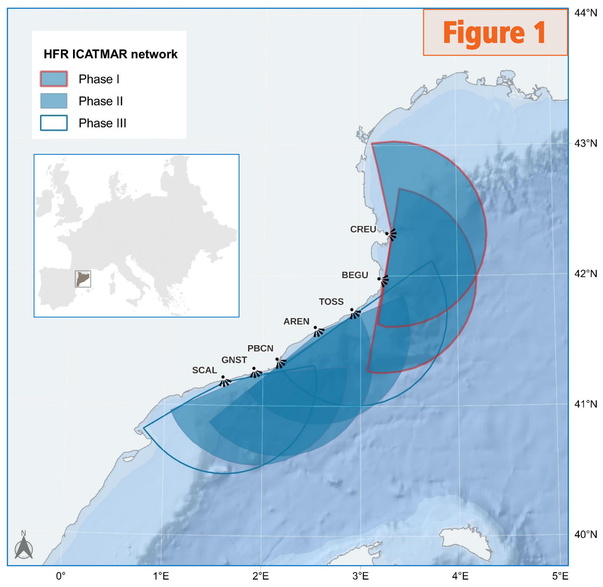

Figure 1: Location of the ICATMAR HFR stations along the Catalan coast and their coverage. For this study, 1-year measurements performed by stations CREU and BEGUR (coverage highlighted in red) have been used. Antennas are being installed in three phases: Phase I, from December 2022 to February 2023, Phase II, during December 2023, and Phase IV, during December 2024. Embedded map shows the Catalan coast location within Europe.

III. Validation results

- 1-year time series of sea surface velocities measured by HFR were compared with: a) currents measured by the Begur buoy of Puertos del Estado (location: yellow star in Figure 2), and b) with currents estimated by the CMEMS MED-Currents model [1] (represented by the 2D histograms in Figure 3).
- For the November 2023 period, current velocities derived from HFR, Begur buoy and CMEMS model were also compared with three high-resolution oceanographic models of the ICATMAR forecasting system developed for the Catalan sea (see Figure 4): CROCO, MITgcm and MITgcm-OP.
- In Figure 4, currents time series measured by HFR and Begur buoy show a higher frequency variability than those simulated by CMEMS, CROCO, MITgcm and MITgcm-OP models; nonetheless, all of them seem to roughly follow similar variation patterns of change in velocity and direction of the current.
- Figures 3 and 4 highlight the fact that HFR currents are more similar to those measured by the Begur buoy, while currents estimated by the models are more similar to each other (which is expected as CMEMS model has been used as the parent model for CROCO, MITgcm and MITgcm-OP models).

Figure 2

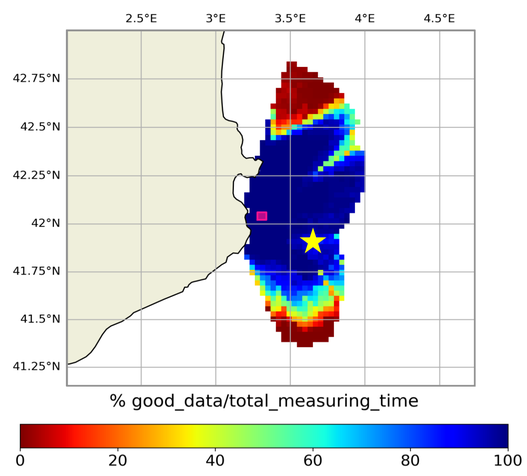

Figure 2: Current velocity data measured by the ICATMAR HFRs is filtered by quality control procedures [2]. The 1-year time series analysed here spans from 01/05/2023 to 30/04/2024. This map shows the percentage of data passing the quality controls (flagged as "good data") over the analysed period. Yellow star indicates the location of Begur buoy and pink square indicates the location (i.e. bounding box) of the SAR exercise performed on the 09/11/2023 by SASEMAR.

Figure 3

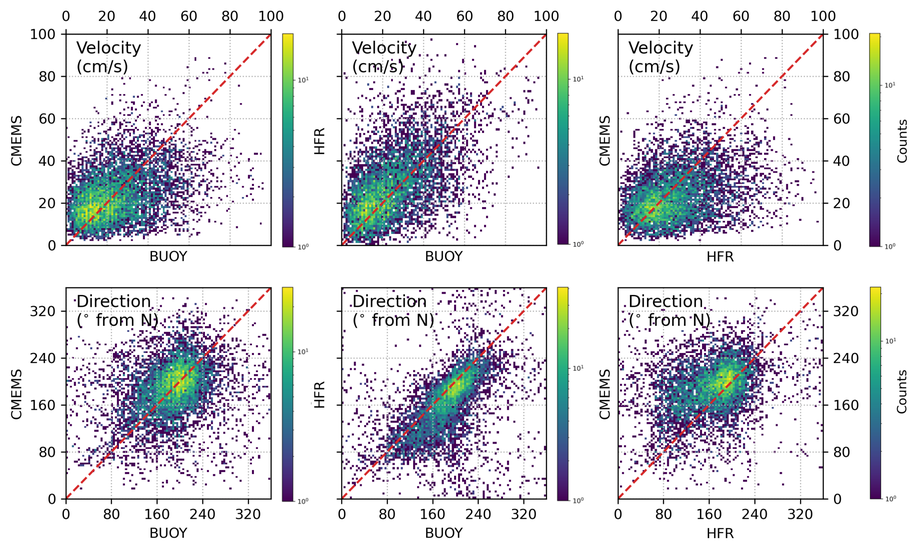

Figure 3: 2D histograms showing comparisons between 1-year time series of current velocities (three top panels) and directions (three bottom panels) from the Begur buoy, HFR and CMEMS model. For HFR and CMEMS-model data, currents measured at the location of Begur buoy (41.92°N, 3.67°E) were selected. In red, a 1:1 reference line is plotted.

Figure 4

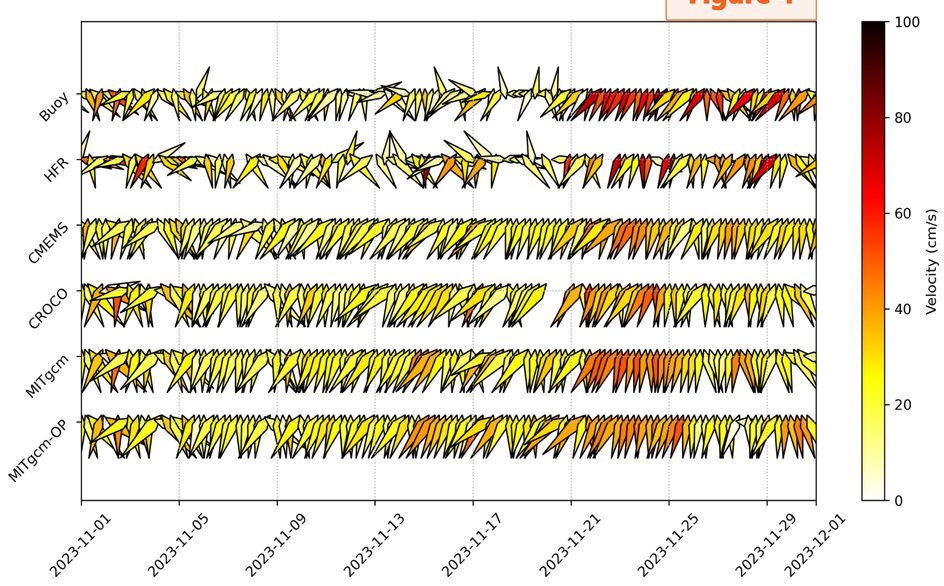

Figure 4: Current velocity and direction time series for November 2023 from Begur buoy, HFRs, CMEMS, CROCO, MITgcm and MITgcm-OP models. Each arrow symbol displays the 6h-average of represented parameters. For HFRs, CMEMS, CROCO, MITgcm and MITgcm-OP data, currents measured at the location of Begur buoy (41.92°N, 3.67°E) were selected.

IV. Lagrangian trajectories of drifting objects

Figure 5

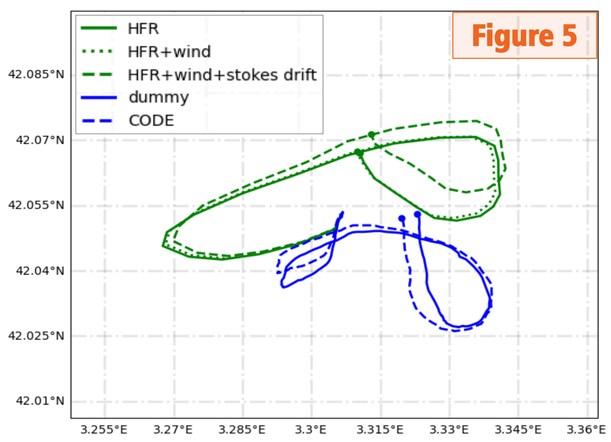

Figure 5: Trajectories of a dummy and a CODE buoy released during a SAR exercise on 09/11/2023. These are compared with Lagrangian trajectories simulated with OpenDrift based on ICATMAR HFR sea surface currents measured on the same date, both taking and not taking into account the effect of wind and stokes drift. Location of this SAR exercise is also indicated in Figure 2 with a pink bounding box.

- On November 9th of 2023, a search and rescue (SAR) exercise was organised within the ICATMAR HFR coverage area (see pink marker in Figure 2). A dummy configured vertically and a CODE buoy were released and recovered after 26 h, both following very close trajectories.
- In order to test the assessment of HFR products for SAR operations, the time series of HFR sea surface currents since November 9th 2023 were used to model Lagrangian trajectories (simulated with OpenDrift). Computed trajectories are compared with real trajectories of the dummy and CODE buoy (Figure 5).
- The addition of wind and stokes drift effects on the Lagrangian simulations did not show much difference in the resulting drift trajectories (max. 800 m distance difference; see dotted and dashed green trajectories in Figure 5).
- Sea surface currents for the same period from CROCO, MITgcm and MITgcm-OP models were also used on the Lagrangian simulations (Figure 6). Trajectories predicted for MITgcm and MITgcm-OP seam to show stronger agreement with the HFR case and with the real dummy and CODE buoy trajectories.
- The Lagrangian trajectories derived from the HFR are the closest to the observed ones. The separation between the real and simulated final positions is less than 2 km. The high frequency variability seen in Figure 4 may indicate that the HFR is able to detect small-scale dynamic structures, which are not reproduced by the models.

Figure 6

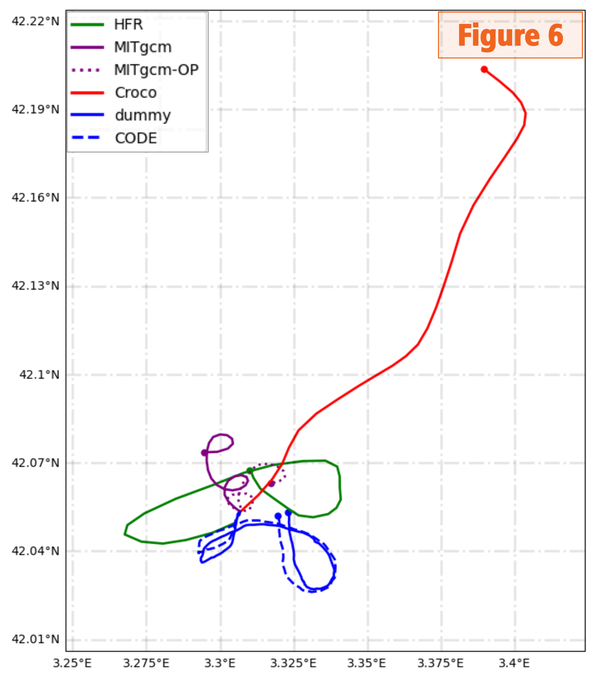

Figure 6: Trajectories comparison of the dummy and CODE buoy released during the 09/11/2023 SAR exercise with those simulated with the Lagrangian model using sea surface currents for the same date derived from HFR, CROCO, MITgcm and MITgcm-OP models.

V. Conclusions

The results of this study serve to highlight the relevance of HFR systems in providing operational products for marine safety, search and rescue operations, plastics and other kind of pollutants' drift. Future improvements are expected through data assimilation of HFR velocity fields into the ICATMAR forecasting system.

References:

[1] Clementi, E., Aydogdu, A., Goglio, A. C., Pistoia, J., Escudier, R., Drudi, M., Grandi, A., Mariani, A., Lyubartsev, V., Lecci, R., Cretí, S., Coppini, G., Masina, S., & Pinardi, N. (2021). *Mediterranean Sea Physical Analysis and Forecast (CMEMS MED-Currents, EAS6 system) (Version 1)* [Data set]. Copernicus Monitoring Environment Marine Service (CMEMS).

[2] Quirós-Collazos et al., 2024. *Level 3 velocity products from ICATMAR High-Frequency Radar network.* ICATMAR Technical Report, number 3, pp:27.

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