HIGH-RESOLUTION MULTI-MODEL SERVICE OF POLLUTANT DISPERSION IN THE MEDITERRANEAN SEA

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INTRODUCTION

The Mediterranean Sea is a vast and intricate ecosystem facing substantial environmental challenges due to the growing maritime traffic and resulting marine pollution (EUROSTAT, 2021; Polinov, et al., 2021). To address these concerns, the need for reliable and accurate monitoring service is increasingly important, particularly for predicting and mitigating the impact of pollutant spills on the environment.

This research aims to comprehensively understand the dynamics of oil spills in the Mediterranean region. The primary objective is to establish a robust framework for a user-friendly application that not only offers valuable insights into both historical events of oil spills and the complex interplay of various environmental factors but as a forecast tool for monitoring and planning uses.

METHODOLOGY

The study focuses on calculating the dispersion velocity of pollutants, considering three distinct contributions that influence the spill movement. Specifically, these contributions include the surface velocity of currents, the Stokes drift induced by waves, and the influence of wind within the first 10 meters above the sea surface. The latter two contributions are further mitigated through coefficients, a method that is employed in previous studies for similar purposes (Li, et al., 2022).

Incorporating these factors contributes to a more comprehensive understanding of pollutant dispersion mechanisms in the Mediterranean. In this investigation, we integrate data from three distinct oceanic models to assess surface current velocities, allowing us to analyze the uncertainties within the ensemble. More specifically, the models correspond to data provided by the Copernicus Marine Environmental Monitoring Service - CMEMS (Clementi, et al. 2021), the Naval Hydrographic and Oceanographic Service - SHOM (Shom, 2017), and the French Research Institute for the Exploitation of the Sea - IFREMER (Garnier, et al., 2014).

Regarding Stokes drift and wind data, two models with significantly different spatial resolutions are utilized. In the first case, ERA5 data, (ECMWF, Hersbach, et al., 2023) reanalysis data is used, which features a horizontal resolution of 55 km for waves and 25 km for the atmosphere. In the second case, the WaveWatchIII model (Mentaschi, et al., 2015), operational at the DICCA of the University of Genoa, with a grid resolution of 10 km across the entire Mediterranean basin, is employed. This approach allows us to evaluate the impact of data resolution on the accuracy of our dispersion modeling. The analysis encompasses the characterization of the temporal and spatial evolution of the oil slick. To simulate this dispersion, the OceanParcels (Van Sebille, et al., 2023) Lagrangian Particle Tracking Model (PTM) is employed. This approach allows us to tailor the dispersion modeling to the specific event being studied. For instance, it enables to determine parameters such as the number of particles to release, the release area, and the specific time at which the release occurs. Using this data, an empirical distribution of the released particles is calculated, enabling to track the spatial evolution of the particles that constitute the slick. This analysis helps to understand how the slick expands or contracts in various directions over time. Subsequently, to gain insights into how the particle cloud evolves, the centroids at each moment of an oil spill event are evaluated. This permits to estimate both the absolute D_{b0} and relative distances D_b of the particle clouds from the release point, providing a more detailed depiction of the trajectory of the oil slicks. The final step of the research involves a comparison of dispersion outputs with satellite imagery acquired via Synthetic Aperture Radar (SAR, Magrì et al., 2021). This information enhances the precision of the analyses. It not only confirms the real-world applicability of the model but also allows for a granular evaluation of which model best approximates the real scenario. This in-depth analysis contributes to improved accuracy in future assessments, ensuring that policy and decision-makers can rely on the most reliable data for environmental protection efforts.

RESULTS

To validate the methodology, a real case scenario is used, specifically a shipping accident that occurred the 7 October 2018 off the coast of Corsica, resulting in a spill of over 600 tons of hydrocarbons. The initial approach involves comparing only the outputs of sea surface currents from the three models, resulting in notably different trajectories of the centroids of the oil slicks that move over time (Figure 1).

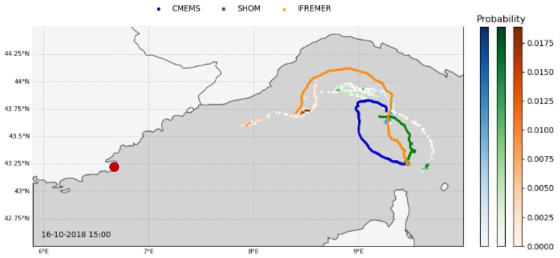

Figure 1 - *Simulation trajectories of the three models after 9 days, considering only sea surface currents and showing the evolution of the centroid trajectory and particle distribution in space and time. On the right the color bar showing the values of the particles' experimental distribution for the three ocean models.*

Subsequently, the two additional contributions, namely wind at 10m and stokes drift, are integrated into the analysis, mitigated by different empirically estimated coefficients. The selection of the correct coefficients is crucial in influencing the resulting outputs (Figure 2).

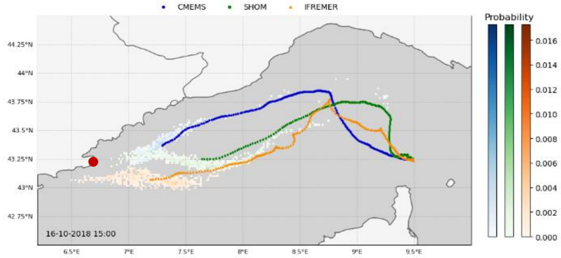

Figure 2 - *Simulated trajectories of the three models after 9 days, considering sea surface currents, wind at 10m and stokes drift, depicting the evolution of the centroid trajectory and particle distribution in space and time.*

In both figures, the trajectories of the centroids of the oil slicks at various time intervals are depicted. It is worth noting that the two figures exhibit differing outputs at the same timestamp, with Figure 2 showcasing an improved representation. The models in Figure 2 demonstrate a better alignment with reality. This is particularly evident when considering the detection of hydrocarbons in France on October 16th, marked by the red dot on the figures, signifying the models' enhanced predictive capabilities compared to the actual observed events.

To attain a more comprehensive characterization of oil spill movement, a graphical representation that depict the spatiotemporal evolution of the particle cloud in both the x (R_x^2) and y (R_y^2) directions is employed, as well as the distances traversed by three distinct models over the course of the simulation (Figure 3).

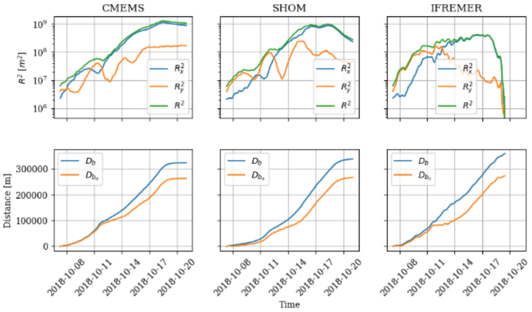

Figure 3 - *The graphs on top represent respectively the relative dispersion of the three models with bilogarithmic trend and dispersion in x and y directions. The graphs below show the relative distance D_b and the absolute distance D_{b0}.*

Finally, Figure 4 displays a comparative analysis of the satellite imagery SAR (white dots) and dispersion simulation of the three models, accentuating the disparities between the two approaches.

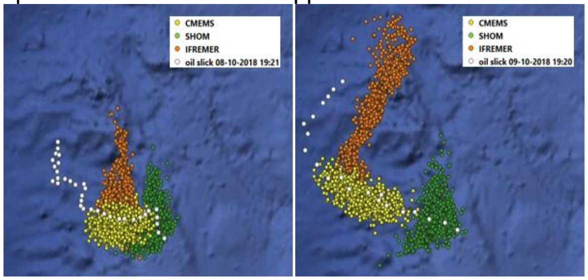

Figure 4 - *Representation of SAR images on the left 8th October 2018, and on the right 9th October 2018, compared with the simulated position of the models' dispersions.*

CONCLUSIONS

While significant progress is being achieved, the persisting uncertainties in climate services pose a formidable challenge in predicting and mitigating the impact of oil spills on the environment. Consequently, sustained investments in research and development for climate monitoring services are imperative to address these uncertainties and secure the long-term sustainability of our planet's delicate ecosystems. As we look to the future, the continued refinement of our models and their integration with high-resolution data sources holds the key to improving the accuracy of predictions and minimizing the environmental impact of pollutant spills in the Mediterranean.

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