

ANALYZING DISPERSION IN THE PORT OF GENOVA: HYDRODYNAMIC AND LAGRANGIAN MODELS FOR METE-OCEAN SCENARIOS

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INTRODUCTION

Thanks to its strategic position in the upper Tyrrhenian coast, linking international cargo traffic and the European trade stage, the port of Genoa is one of the most important in Europe. In recent years, the volume of goods moved through the port has increased and is expected to increase even more, due to its expansion with a new breakwater (Port Authority, 2023). As commercial activities increase, so does the risk of accidents that can adversely affect the environment (Jungen, 2021). This study aims to understand the impact of the port traffic on the surrounding marine environment, by developing a numerical model for the simulation of the dispersion of substances released within the port. It is also planned to provide a tool able to support mitigation and recovery activities, allowing the user to efficiently and rapidly simulate a release and forecast its temporal and spatial evolution. The study is carried out using the hydrodynamic model Delft3D for the simulation of currents and the Lagrangian dispersion model OceanParcels (Van Sebille, 2023) for the dispersion analysis.

DATA

The first step consists in collect all the variables to use as boundary condition for a hydrodynamic model. The forcings to take in consideration are wind, waves, tides and regional currents. Current data are obtained from Copernicus Mediterranean reanalysis database (Escudier, 2021), tides are obtained through the OSU TPXO models (Egbert, 2002), wind and waves data come from the MeteOcean hindcast, which covers a period from 1979 to 2002 (Ferrari, 2019, Mentaschi, 2013). Due to the computational cost of the hydrodynamic model, a clustering procedure has been performed following the methodology by Cremonini, 2021. Then, this study focused on the simulation of 25 weekly scenarios of wind, waves, currents, and tides representative of the whole variability of the historical conditions, with hourly resolution.

HYDRODYNAMIC MODEL

Once the boundary forcing conditions are obtained, the Delft3D hydrodynamic model can be implemented to simulate the currents in the domain. It is done by coupling a high-resolution grid (250 meters offshore and 40 meters inside the port) with a bathymetry, taken from GEBCO (Weatherall, 2015) and the Naval Hydrographic Institute. The model solves the Navier-Stokes equations for an incompressible fluid, under the shallow water and the Boussinesq assumption. The wind time-series are uniformly distributed inside the domain, while waves, tides and regional currents are applied along the offshore boundary. In Figure 1, the surface velocity field averaged

over the week for a specific scenario and the corresponding wind and wave direction comparison, are reported. The time series plot shows that wind (blue line) and waves (orange line) have almost the same directions, suggesting the presence of local waves, moving to south during the first three days of simulation, and to north during the last four days, according to the nautical convention. Due to the variables' temporal behavior, we expect most of particles to stay inside the port during the first half of the dispersion simulation and subsequently to leave it.

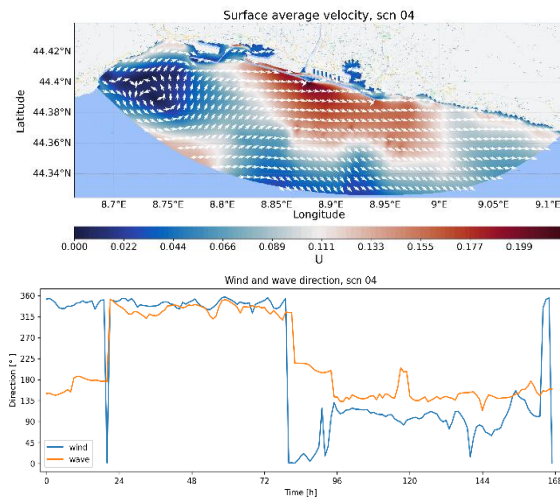


Figure 1 - Top panel: surface average velocity field, scenario number 4. Down panel: wind (blue line) and wave (orange line) direction for scenario number 4.

DISPERSION MODEL

Starting from a velocity field and the releasing positions, a Particle Tracking Model (PTM) allows to simulate a Lagrangian particles dispersion. The PTM solves the advection-diffusion equation for each particle, at each time step, giving back the particles' trajectories. About 20000 virtual particles have been released inside the harbor, with a distance of 40 meters between them. In Figure 2, the trajectories after a week of simulation are reported. Here, particles are pushed against the coast by wind, while few particles leave the port and move eastward. When particles reach the outer boundary of the domain, they are no longer considered in the simulation.

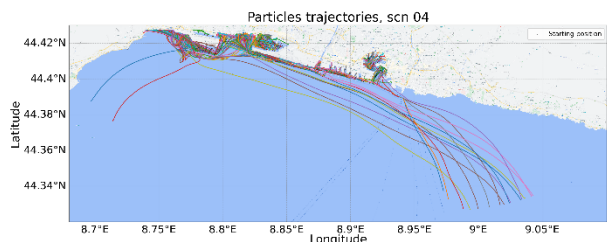


Figure 2 - Particles trajectories, scenario number 4.

MIXING PROPERTIES

The Lagrangian approach makes it possible to analyze the temporal evolution of an accidental release of particles. Various statistical analysis have been performed to understand the behavior of the release within the port and which will be presented during the conference. Firstly, we evaluated the number of particles leaving the port, through which outlet, and after how long with respect to the releasing time. The aforementioned analysis gives an idea of the areas potentially crossed by the particles, but not a lot of insight on how the cloud is evolving in time and space. To go further, the mixing properties are applied, to understand the spatial and temporal scale of the transport; these properties are statistical descriptors which helps characterize the dispersion phenomenon and understand the best defense strategy to adopt. There are descriptors aiming to reveal the temporal scale of the transport (as the absolute dispersion), meaning the time after which the cloud starts to move with a randomic behavior, or descriptors aiming to understand the spatial scale of the motion (as the relative diffusivity), meaning the size of the flow structures driving the transport.



Figure 3 - Drifter campaign with Libeccio wind.

VALIDATION AND CONCLUSIONS

The modelling chain is being validated with currents measurements from ADCPs, already installed in three different points inside the port, and by different drifter campaigns, allowing to validate the dispersion model within the harbor. In Figure 3, the drifters' trajectories of a mission are reported; in this case, Libeccio wind, blowing to north-east, moved the drifters to the shore. In conclusion, the project aims to reveal the potential impact of an accidental release occurring inside the water

port, in function of the mete-ocean condition, and to offer a support to mitigation and recovery activities, by describing the fate of the particles through statistical descriptors. In fact, the previous knowledge of the evolution of the cloud in time, as well as an estimation of the amount of particles leaving the ports and through which doors, could significantly decrease the impact of the release, both in terms of environmental damage and operational cost.

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