MONITORING AS A TOOL FOR ASSESSING THE ECOLOGICAL STATE OF HIGHLY ANTHROPIZED COASTAL SITES

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KEY POINTS

- *Long term monitoring of physical and hydrodynamic parameters*
- *Correlations among turbidity, temperature, currents and tides*
- *Trend of target parameters in time and frequency domain could aid in supervising human impacting activities*

1 INTRODUCTION

In coastal regions, especially in heavily anthropized areas, monitoring key parameters over extended periods and providing high-quality data prove to be valuable tools for disclosing the main local physical processes, significantly contributing to their sustainable coastal planning and administration. This is even more necessary when specific operations are carried out, such as dredging operations, aimed at reclaiming land and facilitating access for larger ships to inland port basin or waterways, as they represent a significant source of disturbance. These activities can lead to adverse effects in coastal systems including habitat degradation, increased turbidity and suspended sediment levels, altered current dynamics, released pollutants and changes in water quality (*De Padova et al.*, 2020; *Kaizer & Neumann*, 2021). At the same time periodic maintenance dredging is necessary to maintain navigable depths (*Mirò et al.*, 2022)

This research focuses on analyzing annual time series data, particularly turbidity, temperature, tide, and current data, which are crucial for evaluating the ecological condition of a coastal areas affected by human activities and ensuring the sustainability of these endeavors (*Armenio et al*., 2017; *Schmidt et al*., 2019).

The procedure used here is illustrated through the examination of a specific site, i.e. the Bari Port coastal area, situated along the Adriatic Sea in Southern Italy (Figure 1).

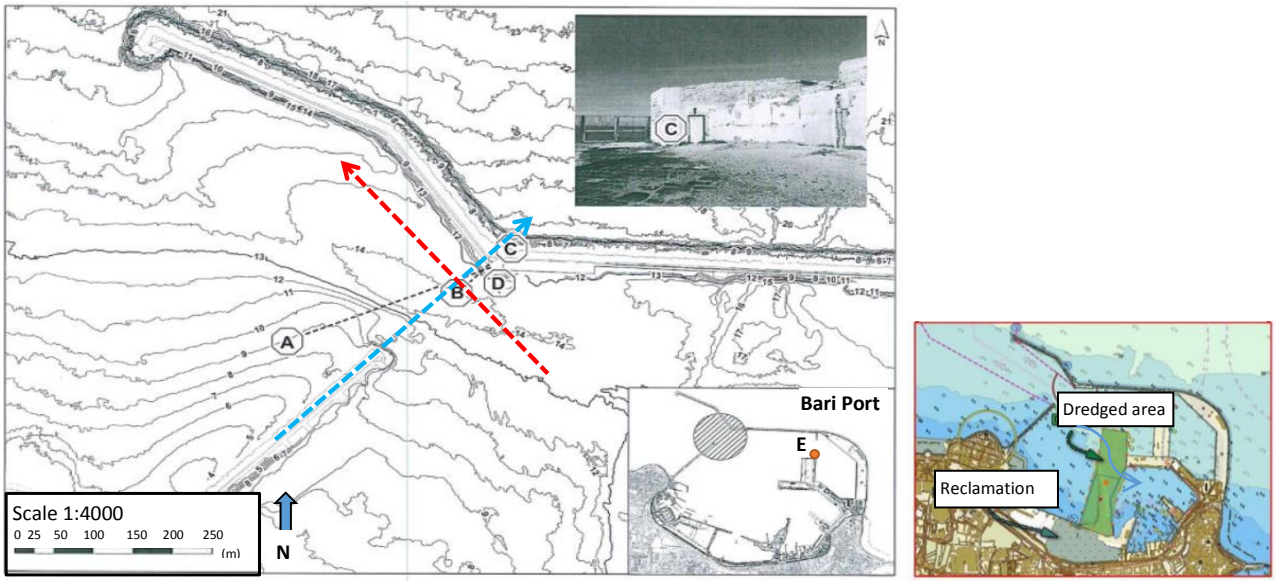

Figure 1. Left: Target site, with location of the instruments network. The ADCP and the wavemeter analyzed in the present case are labeled B and A, respectively. Longitudinal axis (red) and transversal axis (blue) of the port's mouth are shown. Geographic coordinates of point E in the subfigure are 41.140° N e 16.866° E. Right: Sketch indicating the dredged area and the reclamation area.

2 FIELD MEASUREMENTS

This choice has been made because some monitoring stations have been in place in the port of Bari since February 2019. Such monitoring network had been conceived to control the evolution of the basin status and identify its main hydrodynamics along with possible sediment spreading and transport. This is because the Port Authority had planned a heavy dredging operation, which was effectively carried out in 2022, starting on May 20 and ending four months later, with a dredged area of about 216000 m^2 for an average depth of 2.5 m (see Figure 1). Specifically, an Acoustic Doppler Current profiler (ADCP) equipped with a multidirectional wave array (station A), a second ADCP (station B), a CTD-fluorimeter-nephelometer probe (station D) were installed. Unfortunately, during spring and summer 2022, station A had some technical problems and provided no data. In this study we analyze current data recorded by the ADCP in station B, and temperature and turbidity data recorded by the multiparametric probe in D, acquired during the whole year 2022 (except for December months), to assess possible correlations about the main parameters involved and derive meaningful time and length scales governing the diffusive processes. Also tidal data are considered, being available from the ISPRA (Regional Environmental Protection Institute) station, which is located inside the basin (station E), providing averaged values every 10 minutes.

The multiparametric probe is fixed at a depth of 2m from the mean sea surface and provides, among others, hourly averaged values of water temperature and turbidity. The ADCP is bottom-mounted, upward-facing, and has a pressure sensor for measuring mean water depth. The transducer head is located 0.50 m above the seafloor, and the blanking distance is 1.0 m, so velocities are sampled along the water column with a 0.50 m vertical bin resolution, starting at 1.5 m from the seafloor up to the most superficial bin not biased by waves, namely up to 1.5 m from the sea surface. Mean current velocity profiles have been collected continuously at 1-hour intervals, with a sampling frequency of 0.1 Hz for the first 10 minutes of each hour, resulting in 60 measurements successively averaged. In this way, hourly averaged velocity components along the water column are provided. Specifically, only the current velocity components in the horizontal plane are addressed in this study.

3 RESULTS

Firstly, currents measured in station B have been processed, projecting at all the investigated depths the velocity in the horizontal plane along the longitudinal and the transversal axes of the port‘s mouth, thus obtaining respectively *uL* component and *uT* component (Figure 1). The *uL* velocities are considered positive when entering the port, while the *uT* velocity when anticlockwise directed. It is worth noting that the transversal components are quite halved concerning the longitudinal ones. Focusing on the *uL* velocities, they determine a double and opposite circulation through the mouth, with outflowing currents in the most superficial layers and inflowing currents closer to the bottom. The inversion occurs in the range z/h=0.4-0.6, being z the height from the sea bottom and h the local depth in station B, i.e. 13m on average. The inversion height is close to z/h=0.6 in autumn winter months, while close to z/h=0.4 in spring-summer season, thus seemingly influenced also by the thickness of the thermocline, greater in spring-summer. It is evident that starting from z/h>0.4 all the monthly averaged vertical profiles of *uL*, normalized by each *uL* maximum value (*maxuL*) have a logarithmic trend and tend to collapse in a single line, with a regression coefficient R^2=0.92, as displayed in Figure 2. In the range z/h=0.1-0.3 the normalized uL increases from the inversion point towards the bottom, meaning that the bottom boundary layer is for z/h<0.1.

Secondly, tide data and *uL* data, measured in the most superficial bin, have been analyzed in the frequency domain, by means of amplitude spectra of both signals. They both show two peaks at frequencies corresponding to 12 hours and 24 hours, thus showing that the tide is semidiurnal for this site and that a strong relation exists between tide and superficial current (Figure 3). Also, the annual time series of turbidity and temperature, measured both close to the surface by the CTD probe, have been examined. In time domain they appear correlated, so that when temperature increases, a reduction of turbidity is observed (Figure 4) Moreover, it is worth noting that in the dredging period (i.e. from May to August) apart from some local and temporary increased values of turbidity, generally it results quite low. This could be the direct consequence of all the precautions and preventive measures used during the dredging works, which have contained the spreading of fine sediments. As well it could also depend on the stratification typical of the summer period

which, opposite to mixing, could contribute to maintain low turbidity values. The spectra of both turbidity and temperature show frequency peaks at 12 and 24 hours, analogously to *uL* and tide spectra, even if less pronounced.

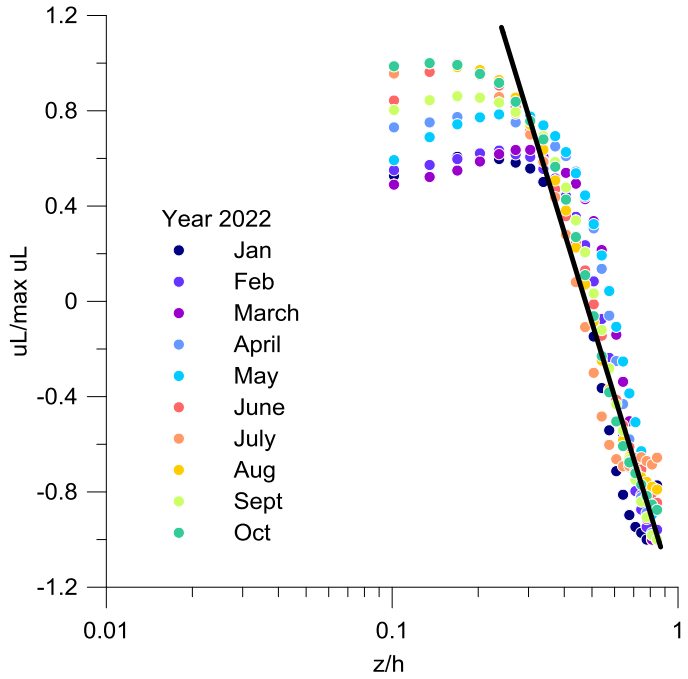

Figure 2. Normalized vertical profiles of monthly averaged longitudinal current in station B. Logarithmic interpolation fitting is shown.

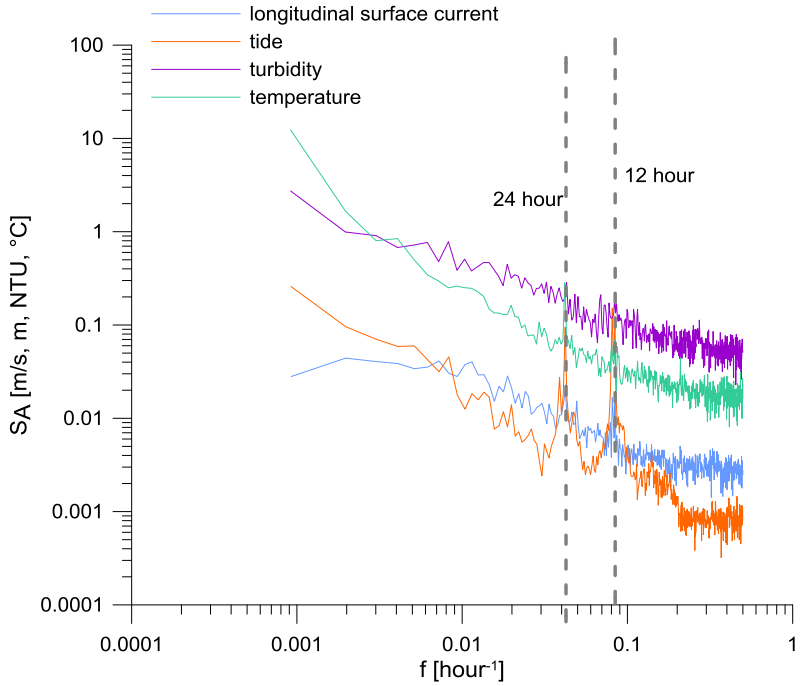

Figure 3. Amplitude spectra of annual data of: longitudinal current in the most superficial ADCP cell; tide amplitude; turbidity recorded by the nephelometer; temperature recorded by CTD probe at 2m below the sea surface.

Finally, the Eulerian diffusivity has been computed as the product of the integral time scale and the time

averaged velocity variance (*Di Bernardino et al.*, 2022). The integral time scale has been estimated as the integral of the autocorrelation function of the velocity until the first zero-crossing. This operation has been carried out for all the measuring points in station B, considering the whole available velocity time series *uL* and *uT*. A period of 90 days has been used for averaging the velocity variance, with the observation that longer periods do not significantly affect the variance. The obtained values of diffusivity, successively depth-averaged, have an order of magnitude $O(10^6)$ cm^2/s in the longitudinal direction and $O(10^5)$ cm^2/s in the transversal one. This information is essential for solving the advection-diffusion equation, governing the transport of a passive tracer.

In conclusion, it is evident that long-term monitoring characterized by high quality data can be greatly helpful in assessing the main physical features of a coastal basin and in controlling human activities. In fact, monitoring networks of this kind, still working, enable us to detect modifications to typical and recurring trends in hydrodynamics, physical parameters and water quality (if and when they occur). Thus they play a fundamental role in the surveillance and management of complex coastal sites.

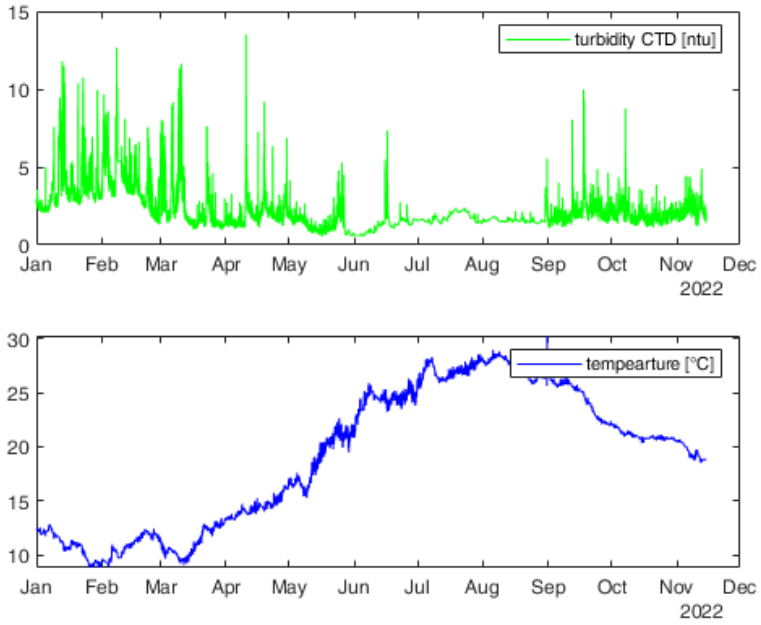

Figure 4. Annual time series of measured turbidity and temperature.

ACKNOWLEDGMENT

The measuring network has been funded by the Bari Port Authority. F. De Serio acknowledges the HUB - National Centre for HPC, Big Data, and Quantum Computing for partially supporting research activity.

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