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ORIGINAL RESEARCH ARTICLE

Current observations from a looking down vertical V-ADCP: interaction with winds and tide? The case of Giglio Island (Tyrrhenian Sea, Italy)

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Summary In the context of the environmental monitoring of the Concordia wreck removal project, measurements of currents, winds and sea level height were made along the eastern coast of the Giglio Island, Tyrrhenian Sea (Italy), during 2012—2013. The aim of the study was to investigate the effect of atmospheric forcing and periodic sea-level changes on the coastal currents. Normalised Cross-Correlation Function analysis allowed us to correlate these observations. A marked inter-seasonal variability was found in both current and local wind velocity observations but a significant level of correlation between the data was only found during strong wind events. Current and wind directions appeared to be uncorrelated and current measurements showed a predominant NW—SE direction, presumably linked to the shape and orientation of Giglio Island itself. During strong winds from the SSE, current flow was towards the NNW but it suddenly switched from the NNW to the SE at the end of wind events. The results show that, at Giglio Island, currents are principally dominated by the general cyclonic Tyrrhenian circulation, and, secondly, by strong wind events. The sea level had no effects on the current regime.

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1. Introduction

Sea and ocean circulation is generally characterised by the interactions of tidal currents, bathymetric constraints, wind forcing, and density gradients induced by river input and heat and mass (evaporation and rain) exchange. In this complex scenario, wind has been found to be the main forcing factor inducing currents, while tidal and baroclinic motions are of secondary importance (Bolaños et al., 2014). The barotropic component of the coastal circulation is mainly driven by local winds, but is also highly dependent on the topography of the marine basin, composed of sub-basin scale gyres that can be seasonally variable and recurrent (Molcard et al., 2002; Pierini and Simioli, 1998).

The periodic vertical motions produced by tides close to the coast induce (horizontal) currents with alternating floods and ebbs. In these water movements, tides can have local or regional and short-range or long-range influences (Naranjo et al., 2014). Close to the coast, sea level depends primarily on the periodic change of lunar and solar attraction (astronomic influences), but also on the local atmospheric pressure and wave and wind changes (atmospheric events) that induce non-periodic signals of varying strength (amplitude) and duration (low-frequency) which influence the daily periodic oscillations (Halverson, 2014; Tsimplis et al., 2011). Moreover, the magnitude of the sea level variation is site dependent. In fact, in areas characterised by very small tidal ranges, such as the Mediterranean Sea, the atmospheric effects may have greater amplitude than the normal tide and can partially or completely obscure the astronomic tide oscillations. These atmospheric effects vary, for example, with the direction, strength and duration of the wind and are also dependent on the morphology of the area and the depth of the body of water (Halverson, 2014).

In the context of the environmental monitoring of the Concordia wreck removal project, measurements of currents, winds and sea level were made during 2012—2013 along the eastern coast of the Giglio Island in the Tyrrhenian Sea (Italy) (Fig. 1). In order to study the general trend of the currents, and their daily and seasonal variations in relation to atmospheric forcing (winds) and periodic sea level changes (tides), a vertical Acoustic Doppler Current Profiler (V-ADCP) was deployed under a buoy from the 29th August 2012 to the 7th July 2013. The results of the cross-correlation analysis of the continuous data collected by the V-ADCP and the meteorological (wind velocity and direction) and sea level observations recorded at the permanent weather station of Giglio Porto are reported in this paper.

2. Study area

2.1. Geological and climatic characteristics of Giglio Island

Giglio Island (21.2 km^2) lies in the northern part of the Tyrrhenian Sea in front of the Argentario headland, 14-km off the Tuscany coast (Fig. 1). The small town and the harbour of Giglio Porto are on the eastern side of the island (Fig. 1). The island is 90% composed of a monzogranitic pluton resulting from crystallisation of magma within the earth's crust and raised to the surface as a result of a tectonic extensional phase subsequent to the collision between the Adriatic and Corsica-Sardinia plates (Rossetti et al., 1999). The island's shape is roughly elliptical, 8.5 km long and 4.5 km wide, with its major axis oriented NNW-SSE. Its coasts are predominantly high and rocky with numerous small bays and inlets. The sea bottom off the Giglio Porto coast is characterised by a steep rocky slope that slopes quickly to a 100-m depth at a distance of about 350 m from the coast. Sea bottom, beneath 50-m depth, consists of more than 60% clay (Frezza and Carboni, 2009).

The island's climate is typically Mediterranean, with rare rainfall between May and October (almost completely absent

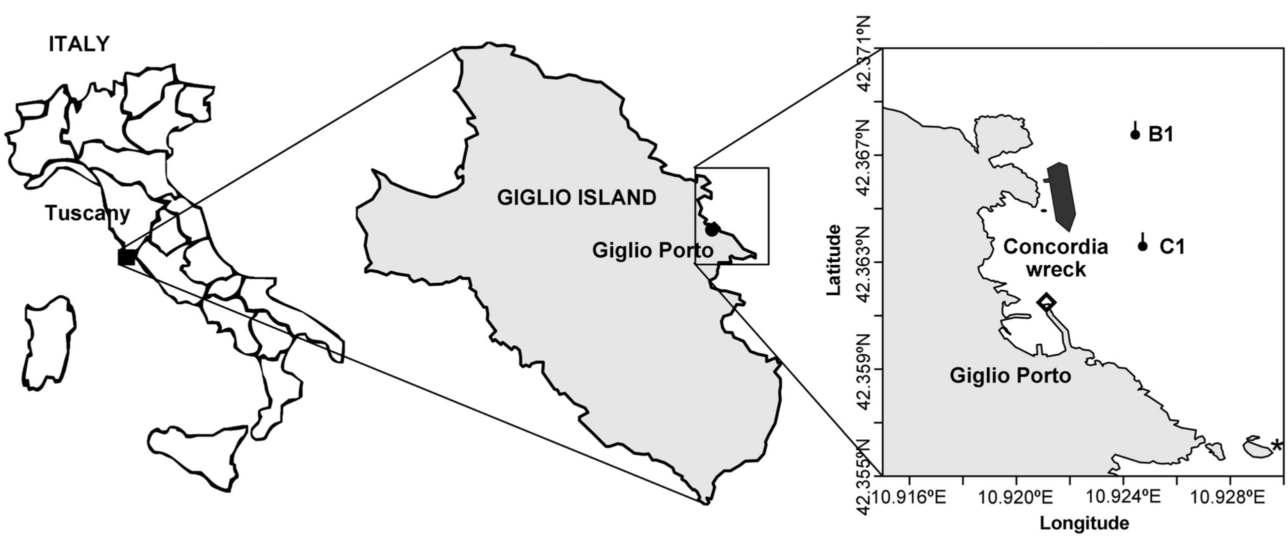

Figure 1 Location of the study area (Giglio Island, Italy). B1 and C1 are the buoys under which the V-ADCP was installed for the continuous monitoring of the currents; Concordia wreck black profile highlights the position of the vessel near the coast off Giglio Porto; the black rhombus shows the position of the weather station of the LaMMA Consortium (Environmental Modelling and Monitoring Laboratory for Sustainable Development) of the Tuscany Region; the black asterisk shows the collision point of the cruise vessel on the rocks.