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West Adriatic coastal water excursions into the East Adriatic

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ABSTRACT

A pool of less saline surface waters was observed in late June 2006 at the northern edge of the South Adriatic Pit (SAP). Three possible sources were considered: (1) Albanian rivers, (2) local Croatian rivers, or (3) relatively fresh West Adriatic Current (WAC) waters. Available CTD and ADCP data, together with satellite images indicate that WAC waters are the most likely source. This requires an excursion of WAC water across the width of the Adriatic and is especially surprising as low winds and stable atmospheric conditions prevailed in mid/late June. However, quite strong NNW winds occurred during the first 12 days of June, with peak winds close to the western shore. These winds were the result of the translation of the Azorean high to the British Isles, producing strong pressure gradients over the Adriatic. The winds enhanced the WAC during early June 2006, preconditioning a cross-basin eddy circulation that appeared during the wind relaxation and calm conditions. As the unusually calm conditions persisted for more than two weeks, the WAC eddies and filaments grew freely and had enough time to reach middle east Adriatic waters. Navy Coastal Ocean Model (NCOM) simulations, using high-resolution Adriatic bathymetry and realistic atmospheric forcing show that such excursions are plausible and can occur when eddies and instabilities push WAC waters across the hyperbolic flow point separating the WAC and Eastern Adriatic Currents near the Palagruža Sill. During the latter half of June 2006, NCOM simulations show that the hyperbolic point was particularly well formed as an anticyclonic WAC, a cyclonic SAP rim flow, an anticyclonic cell southeast of Lastovo Island, and a cyclonic cell over the centre of the Palagruža Sill all bordered on each other. A simplified channel model suggests that the presence of the escarpment is a critical factor for producing cross-basin exchange of the coastal current following the relaxation of strong winds with a cyclonic wind-stress curl. However, the introduction of the Gargano Peninsula in the simulations was critical to the production of mesoscale eddies in the exchange flow, and such eddies qualitatively agree with the convoluted structures observed in satellite images.

1. Introduction

Riverine buoyant inputs to coastal seas often form currents that are bound to the coast and shelf, and propagate along the coast in the direction of a coastally trapped wave (Burrage et al., 2008). This is the case for the Po River plume of the Adriatic as fresh water is trapped along the western (Italian) coastline as a major part of the West Adriatic Current (WAC), a coastal boundary current that extends from the Po River Delta southeastward to the southern Adriatic (Hopkins et al., 1999). Such trapping can be broken by other dynamics and the plume can be advected across the basin as is the case in the northern Adriatic under the influence of strong bora storm winds (Mauri and Poulain, 2001; Kuzmić et al., 2006). However, in general, the Po and WAC influence on the eastern side of the Adriatic is mainly supposed to be indirect through basin-wide thermohaline controls and water mass modification. Therefore, when a large pool of low-salinity water was observed along the eastern edge of the South Adriatic Pit on 26 June 2006, which was seemingly unrelated to river plumes from the eastern coast of the Adriatic, the event motivated this study of cross-basin excursions of fresh waters that are normally coastally trapped. While the observations presented in this paper can only show that the origin of the low-salinity pool is very likely from the WAC, our study of these dynamics in this case study do reveal new insights for mechanisms of cross-basic exchange applicable to the Adriatic and other systems.

The Adriatic Sea is the northernmost Mediterranean embayment, having a shallow (at most 100-m deep) northern part, two depressions (the Jabuka Pit and South Adriatic Pit, SAP, of depths 280 m and 1200 m, respectively), and two sills: the Palagruža Sill separating the

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SAP and the Jabuka Pit, and Otranto Strait between the SAP and the Ionian Sea. A prominent feature of the Adriatic circulation is the cyclonic surface flow, with the East Adriatic Current (EAC) bringing warmer and saline waters from the Ionian Sea and Levantine basin and compensating the volume flux from the fresher WAC waters along the western shelf (Zore, 1956). More specifically, pronounced freshwater inflows that usually occur in spring support development of estuarine-like circulations, with enhanced outflow from the Adriatic in the surface layer being accompanied by increased inflow from the East Mediterranean in the deeper layers (Orlić et al., 2007). On the other hand, wintertime surface cooling of the Adriatic in contrast to warmer conditions over the East Mediterranean result in anti-estuarine circulations, characterized by an intensification of outflow from the Adriatic in the bottom layer and an increase of inflow from the East Mediterranean in the shallower layers (Orlić et al., 2007). The wintertime processes are also characterized by dense-water generation in the northern Adriatic and SAP (Beg Paklar et al., 2001; Vilibić and Orlić, 2001, 2002). The two dense-water masses formed, North Adriatic Dense Water (NAdDW, Vilibić, 2003; Vilibić and Supić, 2005) and South Adriatic Deep Water (SAdDW, Zore-Armanda, 1963; Gačić et al., 2002; Civitarese et al., 2005), impact the entire, deep, Eastern Mediterranean (Malanotte-Rizzoli et al., 1997); yet, they also strongly affect the circulation at Adriatic topographic constraints such as the Palagruža Sill (Vilibić et al., 2004).

As the WAC flows along the western shelf, it may be concentrated in a strong coastal jet or turn offshore during some situations at coastal topographical barriers such as the small Monte Conero Cape, located a few kilometres south of Ancona (Artegiani, 1980; Artegiani et al., 1999). However in mean surface flow maps derived from 9 years of drifter data, Poulain (2001) did not observe WAC cross-basin exchange from west to east anywhere south of the Po River input point, except at Monte Conero Cape during spring and summer. Also, the WAC as defined in that study included both buoyant Po-derived waters and waters that are off the Italian slope but still flowing southeastward, and therefore an offshore excursion of the WAC does not necessarily imply an offshore excursion of the most buoyant riverine waters. During the summertime, the WAC core is usually detached 5–10 km from the coastline, enabling the growth of instabilities and even reversal of currents very close to the shore (Metallo, 1965; Zavatarelli et al., 2002).

By using a numerical model with climatological forcing, Zavatarelli et al. (2002) concluded that the WAC exhibits a strong seasonal change, having more laminar flow during wintertime and meandering around baroclinic gyres on its way to the south Adriatic during summertime. The same has been concluded by Cushman-Roisin et al. (2007) who used a model with fine enough resolution to reproduce baroclinic instabilities (the grid resolution was a few times smaller than the internal Rossby deformation radius). In addition, their results showed that eddies travelling along a smooth shoreline with an

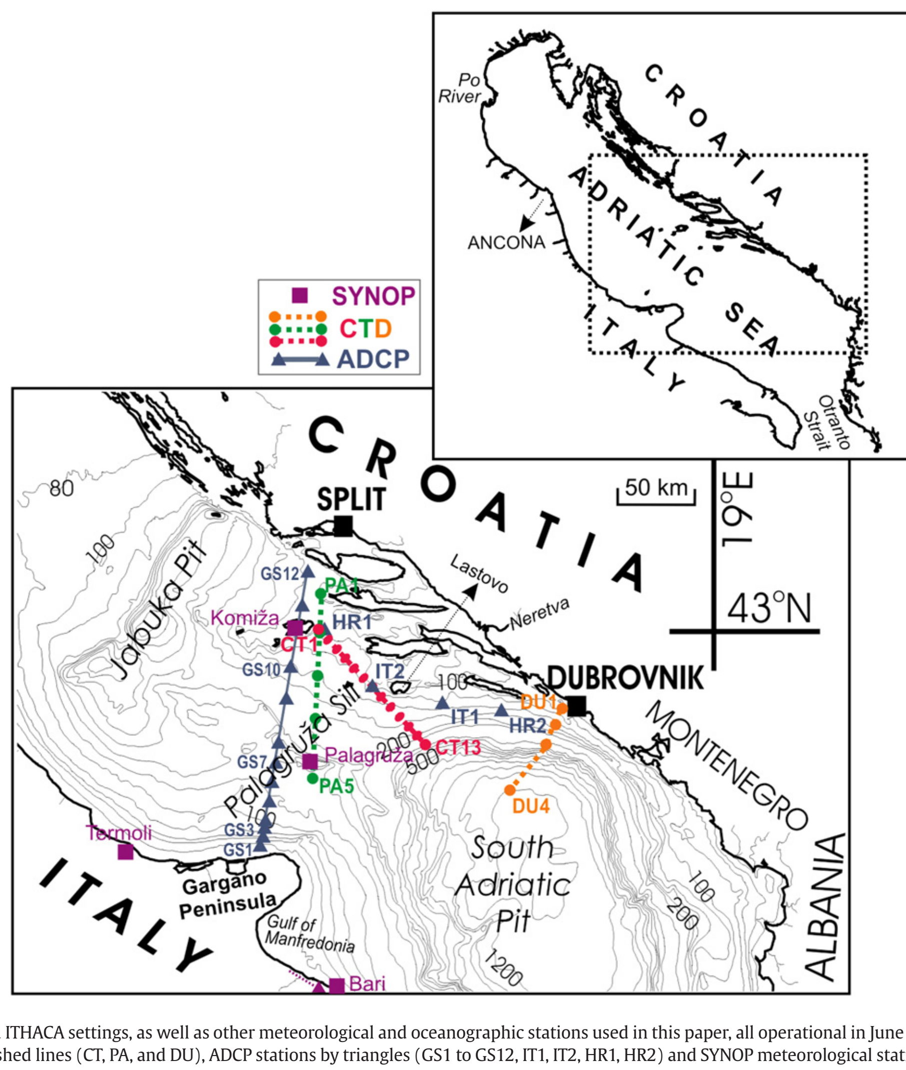

Fig. 1. Experimental DART and ITHACA settings, as well as other meteorological and oceanographic stations used in this paper, all operational in June 2006 in the middle-Adriatic Sea. CTD transects are given by dashed lines (CT, PA, and DU), ADCP stations by triangles (GS1 to GS12, IT1, IT2, HR1, HR2) and SYNOP meteorological stations by rectangles (Termoli, Bari, Palagruža, and Komiža).