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Residual and tidal circulation revealed by VHF radar surface current measurements in the southern Channel Isles region (English Channel)

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ABSTRACT

Two very high-frequency radars (VHFRs), operating in the southern Channel Isles region (English Channel) in February–March 2003, provided a continuous 27-day long dataset of surface currents at 2 km resolution over an area extending approximately 20 km offshore. The tidal range in the region of study is one of the highest in the world and the coastal circulation is completely dominated by tides. The radar data resolve two modes which account for 97% of the variability of the surface current velocities, with the major contribution of the first mode. This mode accounts for oscillating tidal currents whereas the second mode represents motions emerging from the interaction of tidal currents with capes and islands (eddy in the vicinity of the Point of Grouin and jet south of Chausey). A fortnightly modulation of the modal amplitudes causes the exceptional (more than 600%) variability of currents which is well captured by the VHFR observations. The radar data revealed that tidal circulation in the region is flood-dominated with a strong asymmetry of current velocity curve. Wind events and fortnightly variability affect the course of tidal cycle by modifying the magnitude and duration of ebb and flood. In addition to expected features of coastal circulation (tidally dominated flow, eddies) and high wind-current coupling, the residual currents revealed a strong cross-shore structure in the mean and a significant variability which has the same order of magnitude.

1. Introduction

In recent years, high-frequency (HF) Doppler radar systems have had stunning success in the mapping of surface currents. The ability to map surface circulation in coastal ocean areas has brought new insights to the complexities of physical processes in nearshore waters, and allowed significant advances in our understanding of circulation and oceanographic conditions in many coastal regions (e.g. Prandle, 1993; Shay et al., 1998; Marmorino et al., 1999; Haus et al., 2000; Breivik and Sætra, 2001; Kovacevic et al., 2004; Bassin et al., 2005; Kaplan et al., 2005; Kosro, 2005; Yoshikawa et al., 2007).

Very high-frequency radar (VHFR) system operated in the English Channel in spring 2003 on two different sites (southern part of the Channel Isles region and along the Opal coast in the Dover Strait), and has provided high resolution surface current maps which shed a light on small scale features and extreme variability of coastal water dynamics.

The circulation in the English Channel has been studied previously by many authors by means of numerical modeling (Pingree and Maddock, 1985a; Orbi and Salomon, 1988; Bailly du Bois and Dumas, 2005; Sentchev et al., 2006), remote sensing (Ménesguen and Gohin, 2006), field measurements (Lafite et al., 2000), and also radar observations of the currents. The earliest radar measurements of surface circulation in the English Channel have been performed at the beginning of eighties. Broche et al. (1987) reported the results of 3-day long VHFR measurements in the Bay of Seine. In 1990–1991, Prandle et al. (1993) conducted an intense nearly year-long HFR experiment in the Strait of Dover, which allowed to obtain relatively accurate estimates of the tidal flow into the North Sea. The water dynamics in the French sector of the Strait of Dover derived from radar measurements has been recently described by Sentchev and Yaremchuk (2007). It was shown that a discontinuity in current velocity field, observed approximately 10 km offshore, is caused by the reversal in the sign of rotation of surface current vectors due to bottom friction and stratification effects. This provides surface current convergence on ebb and divergence on flood. The line of convergence approximately follows the 30-m isobath.

In the present study we focus on physical processes governing the tidal and residual circulation in the southern Channel Isles

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region which will be referred hereafter as SCIR (Fig. 1). A unique combination of historical heritage, tourism, aquatic industry, makes this region of considerable commercial and ecological interest, and requires new concepts of ecologically sustainable development. Nevertheless, recent experimental or modeling studies of the marine environment in SCIR, are rather scanty. With the exception of earlier modeling studies of tidal and residual circulation in the SCIR performed by Pingree and Maddock (1985a), Orbi and Salomon (1988) and Le Hir et al. (1986), authors did not find any results relevant to a detailed description of the SCIR dynamics in literature. Small scale features of circulation, their magnitude and dependence on various forcing factors remain relatively uncertain. This shortcoming is primarily due to the difficulties in acquisition of long-term *in situ* data because of the extremely strong currents and severe meteorological conditions in this part of the Channel. In that respect, remote sensing of surface currents by VHF radars provides a unique opportunity to establish a monitoring system in the SCIR on a regular basis.

The first step in the description of fine scale circulation patterns derived from VHFR measurements in the eastern English Channel (EEC) has been done by Sentchev and Yaremchuk (2007). The present work can be considered as an extension of the above mentioned investigation. We report the results of 27-day long VHFR survey performed in the SCIR in February–March 2003 and compare our results with radar-derived circulation patterns along the Opal coast of France in the Dover Strait (Fig. 1).

The paper is organized as follows. In Section 2, we present the study site, environmental data recorded during the radar

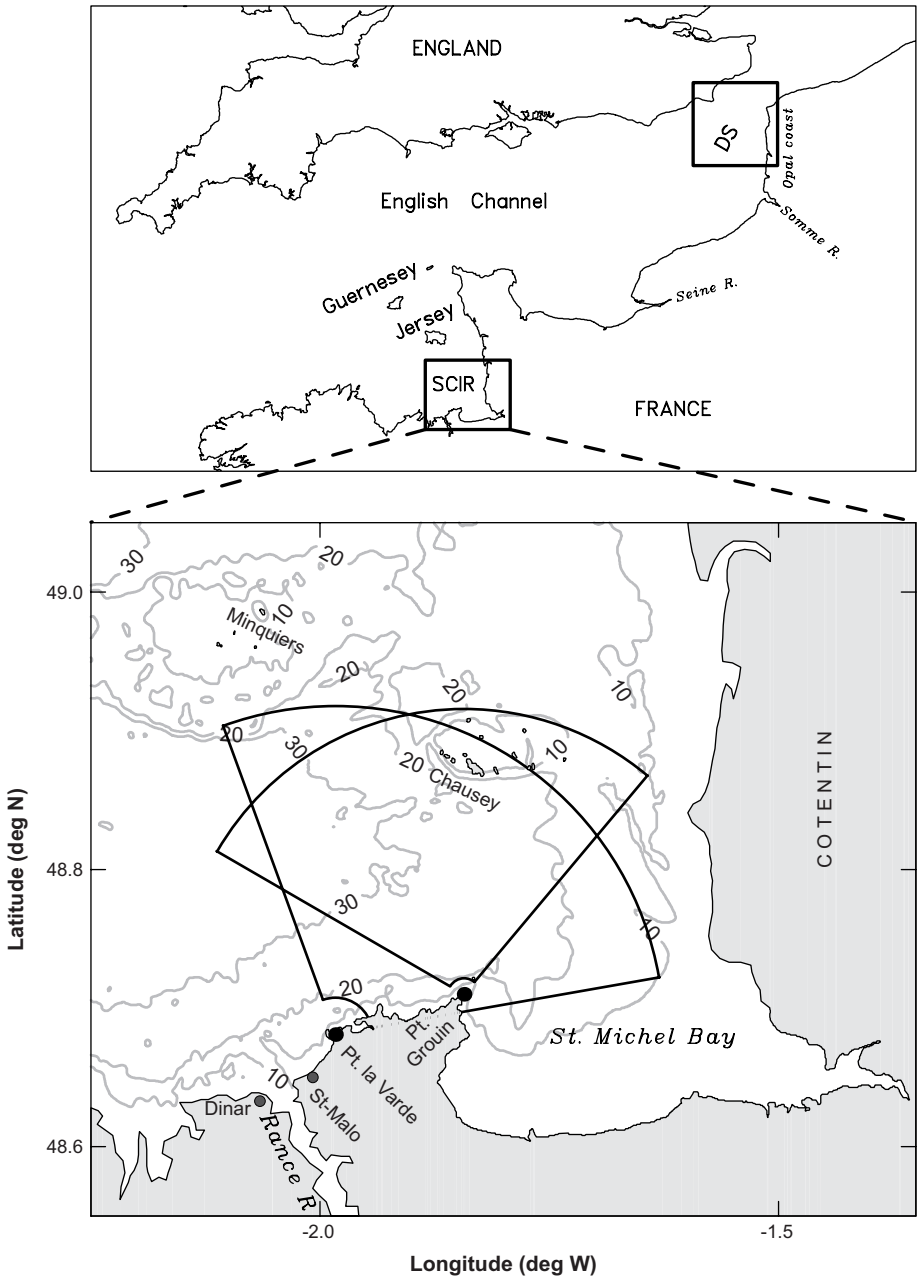

Fig. 1. Location of VHFR survey areas in the English Channel (upper panel). Experimental domain in the southern Channel Isles Region and radar coverage zone (lower panel). Radar sites are shown by black circles. Grey circles denote locations of geographic names used in the text. The Rance river contributing to the freshwater input, and bottom topography are also shown. Contour interval of bathymetry map is 10 m (grey solid lines).