ANALYSIS OF THE BLACK SEA SURFACE CURRENTS RETRIEVED FROM SPACE IMAGERY

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Abstract
Variational assimilation of space imagery observations into a transport-diffusion model is applied to the study of surface currents in the Black Sea basin. The processing of NOAA-AVHRR observations allows retrieving surface currents with a spatial scale of one kilometer in areas of few hundred kilometers. The examples presented here show that surface currents induced by mesoscale features with typical spatial scale up to few kilometers are very intense. The current speed obtained by processing satellite imagery sometimes exceeds twice that retrieved from altimetry measurements, which assumes at least ten km spatial averaging.
Keywords : Black Sea, Mesoscale Phenomena, Remote Sensing, Inverse Methods, Currents.

In the last couple of decades many space missions launched a set of visible and infrared (IR) sensors. They have spatial resolutions of few hundred meters to one km and are able to resolve the manifestation of the mesoscale ocean dynamics in the sea surface. The analysis of space imagery shows that a significant part of these phenomena have typical spatial scales about one-two kilometers and are not resolved by a global marine observing system based on the altimetry data, profiling floats, or ships of opportunity. The quantitative formalisation of space imagery analysis is capable of improving ten times the resolution of the marine observing system, and make possible much more accurate mesoscale nowcasts and forecasts by models of marine dynamics.

Contrasts on the IR or visible band space images due to mesoscale eddies, jets, filaments or mushroom-like structures are transported by currents. Therefore surface velocity is an important state variable of the marine system that could be retrieved from the set of space images. There have been many attempts to retrieve velocity information from satellite images [see, for example 1 ,2 , 3, 4, 5]. However, they are based on the application of different kinds of formal regularisations that introduce uncontrolled uncertainties in the final product.

We are using here a variational assimilation method [6] that allows retrieving the sea surface velocity from a set of NOAA-AVHRR images with 1 km spatial resolution. Our method is also based on the assumption that the evolution of image contrasts is described by a transport - diffusion model [7]. We are assuming also that the surface velocity field varies much slower than the temperature field observed by space imagery. This is the real case for marine processes, as mesoscale eddies, that have typical temporal variability scale of about 10 days, whereas space images obtained even within one day interval show transport of contrasts.

A set of images of the Black Sea surface is processed to analyse surface current scales and intensity. Geographic and radiation correction of images were carried out by the Remote Sensing Department of the Ukranian Marine Hydrophysical Institute (NASU). The final files contain 11 μm radiation temperature in 1.1 x1.1 km pixels.

The analysis is based on space observations of fine scale meandering of the Rim Current Jet, fine structure of mesoscale eddy currents, and detachment of wind-induced coastal upwelling.

The first set of images used to retrieve surface velocity shows a patch of cold water detached from the coast and transported by currents to open sea. The current field obtained from image processing is compared with the velocity distribution obtained by assimilation of space altimetry in a circulation model with 5 km grid mesh. The velocity field structure from image processing corresponds in general to that retrieved from altimetry. However, surface currents are much stronger. The maximal velocity reaches 0.52 m/s, whereas altimetry assimilation shows a broad jet with current speed about 0.1-0.15 m/s.

The next example concerns a mesoscale eddy situated South from the Crimea peninsula. The eddy is about 120 km along the meridian and 100 km in zonal direction. The general anticyclonic circulation is contaminated by smaller scale features situated along the periphery of the main eddy. It is possible to identify an anticyclonic eddy on the western side of the plot with diameter about 20 km, and a set of meanders of the anticyclonic jet that belts the main eddy. This anticyclonic jet is rather intense; its average speed is about 0.35 m/s, while its maximum value reaches 0.44 m/s. The intensity of currents induced by the eddy well corresponds to the general concept of oceanic mesoscale variability.

The next area of interest is the Rim Current structure above the convexity of the Anatolian coast. The Black Sea Rim Current jet is rather narrow and subject to strong meandering. The most intense meanders induce the formation of cyclonic and anticyclonic eddies to the left and to the right of the jet. The current speed of the jet is up to 0.45 m/s that fits with the few direct measurements available in the Black Sea. Comparison with independent measurements of surface currents by drifters indicates good quality of the estimated velocity field.

The presented examples show that surface currents induced by mesoscale features, with typical spatial scale up to few kilometers, are very intense. The current speed obtained by image processing sometimes exceeds twice that retrieved from altimetry measurements, which assumes at least ten km spatial averaging.

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