WESTERN BLACK SEA CURRENTS BY THE SHIP AND SATELLITE DATA

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Abstract

In spring-time of 1993,94 both CTD, ADCP and satellite infrared measurements were carried out in the framework of CoMSBlack international program. Geostrophic flow field, ADCP current vectors and thermal structures at the sea surface displayed good agreement. Satellite data essentially assist in the interpretation of ADCP currents data and explain several peculiarities in vectors distribution as manifestations of meso-scale dynamic features. The results reflect the effect of the Black Sea flow field transformation from winter type to summer one. These seasonal changes are superimposed over the strong inter-annual variability of the water dynamics.

Key-words: Circulation, Hydrography, Mesoscale phenomena, Remote sensing

Introduction

In spring time of 1993,94, both CTD, ADCP and satellite infrared measurements were carried out in the framework of CoMSBlack and NATO TU-Black Sea international programs to study the water circulation and bio-chemical processes in the western Black Sea. The aim of this paper is to present some results concerning the integration of different kinds of information (satellite images, measured currents and geostrophic flow fields) for the description of water circulation within the upper 100m layer of the sea, including the meso-scale dynamical features. The same approach is often used for other regional studies (*e.g.*, [1]) , but there was no opportunity before to obtain more or less full set of quasi-synchronous high-quality data covering the most part of the Black Sea. General structure of the Black Sea surface water circulation has been recently described on the base of geostrophic currents calculations and qualitative analysis of satellite images [2]. The cyclonic meandering Rim Current (RC) follows along the continental slope around the sea. The flow field between the RC and shelf break consists of meso-scale anticyclonic eddies to the right of meandering jet. Some of them are quasipermanent and other meso-scale features are unstable and variable on a short-time scale (*e.g.*, upwellings and cold jets, mushroom-like structures, RC instabilities) [3]. Seasonal (spring) changes in external forcing (wind weakening, surface layer heating and riverine runoff) lead to the current pattern transformation towards the less intensive and more meandering Rim Current. Sometimes the systems of meso-scale eddies are observed instead of continuous jet stream.

Data and methods

CTD data obtained during international experiments in the framework of CoMSBlack and TU-Black Sea programs (2-27 April, 1993 and 25 April - 14 May, 1994) were used for geostrophic circulation calculations. Observational stations grid had a spacing no more than 10 n.miles along meridian and 20 n.miles along parallel. Within the frontal and dynamically complex regions, stations have been sampled more frequently (steps were 2.5- 5 miles). Resulting grid covered deep-water, slope and shelf areas (in 1993, exception was the Bulgarian economic zone). The maps of geostrophic current vectors as well as the dynamical topography were produced. Dynamic heights were interpolated by means of Kriging procedure on the regular grid spaced by 0.20° in longitude and 0.12° in latitude, then geostrophic current components were revealed on the same grid from the horizontal gradients of dynamic heights. Also, CDT data were used to estimate the density of available potential energy (APE) distribution through the displacement of isopycnal surfaces regarding to their average levels for each survey.

ADCP current measurements were performed on board of R/V Bilim within the areas of CTD surveys, but without the Ukrainian economic zone in 1994. Data processing procedures were used for the ADCP information, such as: computing of absolute currents by means of the precise navigation data; error control and median filtration; statistical analysis for each level; producing of horizontal vector maps and vertical sections of currents. In present paper the vectors at 10 m level were analysed together with the satellite thermal images as the nearest to the sea surface valid ADCP data. Some statistical parameters for the 10 m depth are presented in Table 1. They give the first impression about general currents intensity and variability in the subsurface layer for the both surveys. Next steps of the data analysis were: (i) qualitative comparison of the vector current patterns with CTDderived dynamical topography and (ii) estimation of correlation between ADCP-measured and geostrophic velocities. The second procedure based on the data set for those points of dynamical topography regular grid where the ADCP measurements were made. Measured current components were obtained as the mean values for all ADCP-vectors within the half-step limits around the geostrophic vector nodes. Figure 1 presents the maps of dynamical topography calculated referring to the 500 m level, where the mean ADCP vectors used for the correlation calculations are shown as well. Finally, these current vectors were also used for the density of kinetic energy (KE) estimation. Table 2 presents the correlation coefficients derived for the different levels within the upper 100 m layer of the sea and Table 3 contains the results of basin-averaged APE and KE calculations for the same levels as well as the integrated values for 10-100 m layer.

Satellite images obtained from NOAA AVHRR in HRPT mode on MHI receiving station are used in the present work. Software developed in MHI is used for the pre-processing, geographical positioning and geometrical transformation of images to the rectangular projection maps. Second stage of processing gives the digital radiation temperature maps for the infrared channel 4.

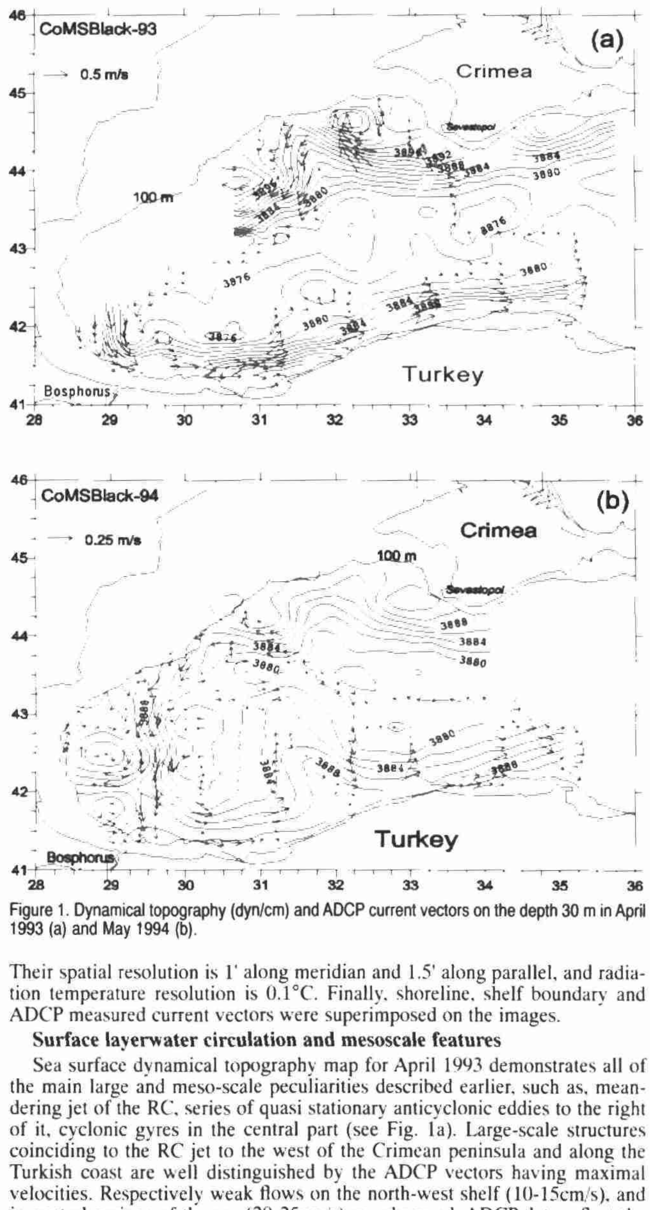

Figure 1. Dynamical topography (dyn/cm) and ADCP current vectors on the depth 30 m in April 1993 (a) and May 1994 (b).

Their spatial resolution is 1' along meridian and 1.5' along parallel, and radiation temperature resolution is 0.1°C. Finally, shoreline, shelf boundary and ADCP measured current vectors were superimposed on the images.

Surface layerwater circulation and mesoscale features

Sea surface dynamical topography map for April 1993 demonstrates all of the main large and meso-scale peculiarities described earlier, such as, meandering jet of the RC, series of quasi stationary anticyclonic eddies to the right of it, cyclonic gyres in the central part (see Fig. 1a). Large-scale structures coinciding to the RC jet to the west of the Crimean peninsula and along the Turkish coast are well distinguished by the ADCP vectors having maximal velocities. Respectively weak flows on the north-west shelf (10-15cm/s), and in central regions of the sea (20-25cm/s) are observed. ADCP data reflect the complex meso-scale current picture. This makes them more preferable for the comparison with high resolution satellite thermal images, especially in higher spatial variability zones (RC's meanders and frontal regions of eddies). The comparison of current vector distributions at the 6 - 20 m levels allows to infer the vertical homogeneity of upper layer circulation and thus is a good base for the interpretation of sea surface satellite imagery.

Considering the distribution of ADCP current vectors and thermal patterns together, we can note a good agreement between the measured flows and thermal structures at the sea surface in April 19, 1993 for those areas where the ship tracks passed. The velocity maxima coincide with the temperature gradient locations of the RC and the vector directions correspond to the satellite