DYNAMIC PHENOMENA IN THE COASTAL WATERS OF THE NORTH-EASTERN BLACK SEA RETRIEVED FROM SATELLITE DATA

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1. INTRODUCTION

The results of multi-sensor observations of the north-eastern part of the Black Sea are discussed. The study is based on remote sensing satellite data obtained by ERS-2 SAR, Envisat ASAR, Terra and Aqua MODIS, and NOAA AVHRR instruments. The data from the different sensors were co-located and analyzed jointly to investigate coastal water circulation, in particular the occurrence, evolution and drift of vortical structures. Special focus is on internal waves generated by breaking of eddy structures.

Investigation of eddies and mesoscale features in coastal zones is important for understanding local mechanisms of mixing and circulation processes. To a large extent, these mechanisms determine ecological, hydrodynamic and meteorological state of a coastal zone, constant monitoring of which is of vital necessity for densely populated regions. It is of interest to demonstrate the possibility to detect, observe and explore mesoscale features, in particular vortical structures in coastal zones and indicate applicable methods and instruments.

2. BYOGENIC SLICKS AS INDICATORS OF SEA DYNAMICS IN RADAR IMAGES

Regular SAR observations have demonstrated that biogenic films can be found virtually everywhere on the vast sea surface, mostly in warm seasons. Biogenic films are the result of life activity of marine organisms and seaweeds, primarily phytoplankton and zooplankton, as well as bacteria. Biogenic films are very sensitive to surface currents and, as a rule, reproduce the shape of local circulation pattern. Water dynamics forces biogenic films to accumulate along the flow lines of surface currents and in this way emphasize vortex structures, fronts, ship wakes, etc. Since the films influence the backscattering of microwaves, these structures become visible in SAR imagery [1]. This allows to monitor sea dynamics processes via their surface manifestations. Taking advantage of this two-stage process, we are able to improve and extend the information that can be inferred from satellite imagery of coastal zones by analysing signatures of marine surface films [2].

In particular, due to the presence of surfactant films, SARs are capable of registering eddy structures. Surfactant films get entrained in an eddy motion and, under low to moderate wind conditions, the structure becomes outlined in a radar image [3].

3. SMALL-SCALE EDDIES IN COASTAL WATERS

The circulation in the Black Sea is characterized by a strong basin-wide current along the shore in the cyclonic direction - the Rim Current. The current embraces the whole of the sea along its periphery and is characterized by high hydrodynamic instability [4]. The observed mesoscale eddy variability is presented by meanders, anticyclonic and cyclonic eddies, vortex dipoles, filaments and jets. Satellite observations of vortical activity in the eastern part of the Black Sea have been usually carried out with the help of IR or optical sensors. Spatial resolution of such images makes it possible to study eddy structures of more then 30 km. These eddies are mostly anti-cyclonic and referred to as Near-Shore Anti-cyclonic eddies. Observations of vortex structures of smaller sizes (less than 30 km) at short time scales can be supplemented by SAR imagery of higher spatial resolution [5].

This work was partly supported by INTAS project 06-1000025-9091, Black Sea Scientific Network (Contract # 022868) and RFBR grant # 08-05-00831. SAR data were obtained under ESA project AO Bear 2775.
The use of SAR data allowed us to find out an intense small-scale vortex activity in the test area which researchers were unaware of before. Our observations showed that many small vortices with dimensions of 10 km and less appear when the Rim Current slackens. The cumulative contribution of these small vortices into the transport of pollutants and water cleaning is comparable to that of the Rim Current and large anti-cyclonic eddies. Small-scale eddies have diameters of several kilometers, while peripheral ones may be even smaller. As a rule, such eddies are spiral in shape.

A seasonal variability of vortex structures in the coastal zone is established. In warm seasons, mostly small-scale (2-6 km in diameter) solitary eddies are observed. Predominantly cyclonic and quasi two-dimensional structures, they are located in the immediate vicinity of the coastline and have short life-times.

In cold seasons, eddies are found to accumulate in clusters with individual sizes of 4-30 km. These clusters are located at about 30 km off the coastline, at the bounds of the Rim Current. Both cyclonic and anti-cyclonic eddies are observed, they have longer life-times and perform horizontal as well as vertical mixing of water.

4. EDDY DIPOLES

There is a particular interest in the so-called mushroom flows (dipolar or quasi-dipolar eddies). These are spatial quasi-symmetric structures combining a narrow jet with a pair of vortices of opposite signs at the end. In remote sensing images, mushroom structures are visible when there is a natural tracer of some kind on the surface or a temperature contrast. In radar images, they are manifested due to surface roughness contrasts that are best pronounced at the edges. Using SAR data has considerably extended the possibilities of remote sensing detection and examination of such structures and, coupled with data from other sensors, raised the reliability of data interpretation and retrieval of coastal circulation patterns [6]. Particular attention is devoted to the evolution of eddy dipoles retrieved from the co-location of radar, thermal and optical data. Dynamic vortex structures of this kind are regularly observed in the north-eastern part of the Black Sea. They induce both horizontal and vertical mixing of water and contribute to hydrodynamic instability of the alongshore current and intensify coastal water transport to the open sea.

A reconstruction of the local velocity field and a retrieval of drift parameters of biogenic films driven by an eddy dipole are performed on the basis of radar data obtained over two consequent days.

5. CONCLUSIONS

Operational satellite monitoring has delivered further evidence of the complex near-surface circulation in the test area. Assimilation of satellite synthetic aperture radar data gives new possibilities to study the highly variable dynamic phenomena in the coastal waters of the north-eastern Black Sea. We expect long term regular regional satellite monitoring to provide grounds for the determination and analysis of small-scale eddies generation, persistence and recurrence in space and time. The combination of active and passive remote sensing techniques at different electromagnetic wavelengths leads to a considerable improvement in monitoring of these coastal dynamic features.

6. REFERENCES


