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APPLICATION OF COASTAL FORECASTING SYSTEM TO SIMULATE SPREAD OF POLLUTING SUBSTANCES IN THE GEORGIAN BLACK SEA COASTAL AREA

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Summary: *In this study some results of modeling dynamic fields and propegation of oil and other polluting substances in the Georgian Black Sea coastal zone are demonstrated. 2D and 3D impurity's dispersion numerical models based on transfer-diffusion equation for nonconservative admixture are components of the easternmost Black Sea coastal forecasting system. The nonstationary sea current field used in these models is provided from M. Nodia Institute of Geophysics high-resolution regional model of the Black Sea dynamics, which is a core of the forecasting system. This model is nested in the basin-scale model of the Black Sea dynamics of Marine Hydrophysical Institute (Sevastopol).The two cycle splitting method is used for solution of the transfer-diffusion equations.*

Keywords: *Numerical model, regional circulation, oil spill, forecasting system.*

Introduction. In recent decades an intensive pollution of several regions of the World ocean with different substances of anthropogenic origin takes place. In this regard a special place is held by inland bodies, which are more sensitive to anthropogenic loads due to their low water exchange with the World ocean. This fact primarily may be referred to the Black Sea, where the pollution of waters with different substances progresses significantly. It is well known that the Black Sea is one of the most contaminated basins of the World ocean due to intensive anthropogenic impact and specific hydrological features. Among different pollutants, for the Black Sea (as for other regions of the world ocean), oil and petroleum products are the most widespread and dangerous pollutants which are able to cause significant negative changes in hydrobiosphere and infringe natural exchange processes of energies and substantes between the sea and atmosphere.

The coastal and shelf zones are undergoing most great human pressure which creates a serious danger to the ecosystem of these areas. The Georgian coastal zone is not exception. Through the Georgian sector of the Black Sea passes the international transport corridor TRACECA (Transport Corridor Europe-Caucasus-Asia) and in the coming years more intensive transportation is expected. In the nearest future the construction of the Deep Sea Port of Anaklia begins, which will become the largest port not only in Georgia, but in the eastern Black Sea.The port of Anaklia will significantly increase the Black Sea transport function and, accordingly, an anthropogenic pressure on the Georgian sector of the Black Sea. It is obvious that this fact creates a serious danger to the sea ecosystem. In conditions of increasing anthropogenic load the development of the Black Sea monitoring and forecasting system is very relevant and important, which will enable to forecast circulation and contaminated areas in the Georgian Black Sea water zone in accidental situations.

In the present paper some results of simulation of dynamic fields and propegation of oil and other polluting substances in the Georgian Black Sea coastal zone are demonstrated.

Method of modeling and forecasting. With the purpose of modeling and forecast propagation of contamination of the Black Sea waters 2D and 3D impurity's dispersion numerical models are coupled with the M. Nodia Institute of Geophysics of I. Javakhishvili Tbilisi State University high-resolution regional model of the Black Sea dynamics. This model is a core of the easternmost Black Sea coastal (regional) forecasting system, which is a part of the Black Sea basin-scale Nowcasting/Forecasting System. The nonstationary sea current field used in the dispersion models is provided from the regional model of the sea dynamics.This regional model with 1 km space resolution is nested in the basin-scale model of sea dynamics of Marine Hydrophysical Institute (Sevastopol) with 5 km space resolution. The structure and scheme of functioning of the regioanal forecasting system is described in the previous papers of authors [1-3]. Some results of modeling of spreading contamination by oil and other substances in the Georgian water area are presented in [4-7].

The two-cycle splitting methods are used to solve the problems included in the regional forecasting system [8]. This method substantially simplifies the implementation of complex physical models and enables us to reduce solution of nonstationary problem to solution of more simple 2D and 1D problems.

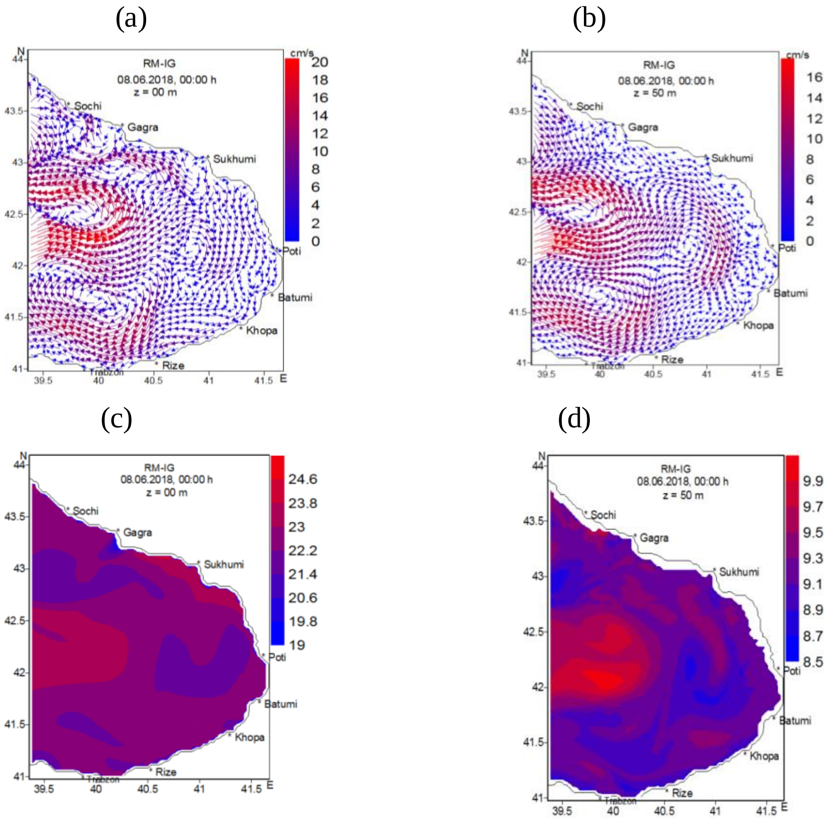

Fig.1. Forecasted current (a, b) and temperature fields (c, d) on the sea surface and on depth of 50 m at moment 00:00 GMT, 8 June 2018 (The forecasting period is 00:00 GMT, 6-9 June, 2018).

The software of the problems involved into the forecasting system is elaborated on the basis of the algorithmic language “Fortran” and consists of separate modules intended for different purposes (data entry, transferring data from a coarse grid to a fine one by interpolation,*etc.*). Some of the modules are designed for calculation of pollution zones and concentrations. To calculate forecast of pollution zones and concentrations input of the following parameters is required: the source coordinates, quantity of polluting substances entering into the sea environment, spill duration and the parameter describing the change of pollution concentrations due to physical and biochemical factors depending on the type of the polluting substance. The 2D version of the pollution transport module is applied to simulate oil spill transport on the Black Sea surface.

The numerical models are realized for the Georgian Black Sea coastal zone and adjoining water area bounded with the Caucasus and Turkish shorelines and the western liquid boundary coincident with a meridian 39.08^{0}E passing near Tuapse (Russia).

Input data. Numerical models involved in the coastal forecasting system (3D dynamics model, 2D and 3D pollution transport models) use a grid having on horizons 215x347points with 1 km spacing.

On a vertical the non-uniform grid with 30 calculated levels on depths: 2, 4, 6, 8, 12, 16, 26, 36, 56, 86, 136, 206, 306,…,2006 m are considered (for 3D models). The time step is equal to 0,5 h.

Validation of the coastal forecasting system. Correct simulation of the admixture dispersion processes in the sea environment significantly depends on adequate reproduction of dynamic fields - flow, temperature, salinity.

Validation of forecasted main hydrophysical fields in the easternmost part of the Black Sea was carried out in 2005, when pilot experiment on operational functioning of the Black Sea Nowcasting/Forecasting System has been carried out for the first time in the Black Sea region with participation of Oceanographic Centers of the Black Sea riparian countries during five days from 22 July till 26 July, 2005. The experiment has been developed in the framework of the EU project ARENA (A Regional Capacity Building and Networking Programme to Upgrade Monitoring and Forecasting Activity in the Black Sea Basin). A comparison between predicted and real fields made within the pilot experiment showed an ability of the regional model of the Black Sea dynamics of M. Nodia Institute of Geophysics to predict hydrophysical fields with sufficient accuracy.In [1] we were able to carry out a comparison of the forecasted sea surface temperature (SST) with SST satellite images derived from NOAA (http://dvs.net.ru/mp). In [7] forecasted surface flow field for December 31, 2012 in the easternmost water area was compared with the picture from [9], where cyclonic and anticyclonic eddies are identified on the basis of the array of surface geostrophic velocities obtained from satellite altimetry data.The analysis of the comparison showed good qualitative and quantitative agreement between the forecasted and measured fields.

Results of numerical experiments. Fig.1 illustrates forecasted fields of current and temperature on the sea surface and at depth of 50 m on 00:00 GMT, 8 June,2018. From Fig1a and 1b is well visible the main feature of the surface circulation in the easternmost water area – the triplet structura consisting from two anticyclonic and one cyclonic eddies. This structura is expressead more cleary on 50 m horizons. Current speed decreases from maximal value equal to 20 cm/s till 16 cm/s in the upper 50 m layer. Maxiamal value of temperature decreases from 24,6^{0}c to 9,9^{0}c in this layer.

(a) (b) (c)

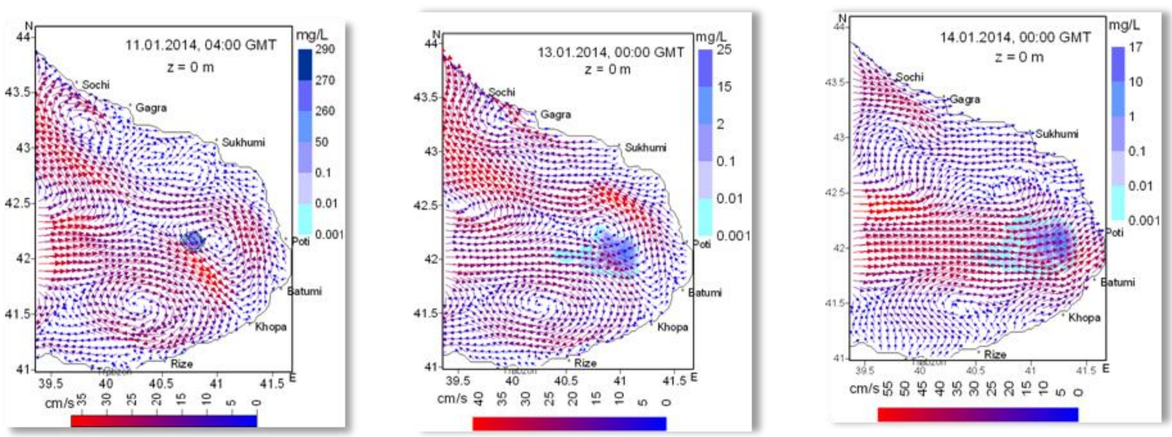

Fig. 2. Forecasted surface current field and oil spill transport at time moments (after oil flood): (a) – 4 h, (b) – 48h, (c) – 72 h. The forecasted interval is: 00:00 GMT, 11-14 January 2014 [7].

In fig.2 the forecasted surface current field and drifting of oil spill are shown on different time moments afrer hypothetical oil flood, when 50 t within two hours occurred on distance about 65 km from Poti shorline (Forecasting period: 00:00 GMT, 11-14 January 2014). Fig.2 shows that the surface circulation is essentially changeable for the forecasting period. Such circulating reorganization is essentially reflected on the oil spill transport. In the course of migration the oil slick gradually extends and deforms. Under the influence of sea current the oil spillage comes nearer to the coast of Georgia.

(a) (b) (c)

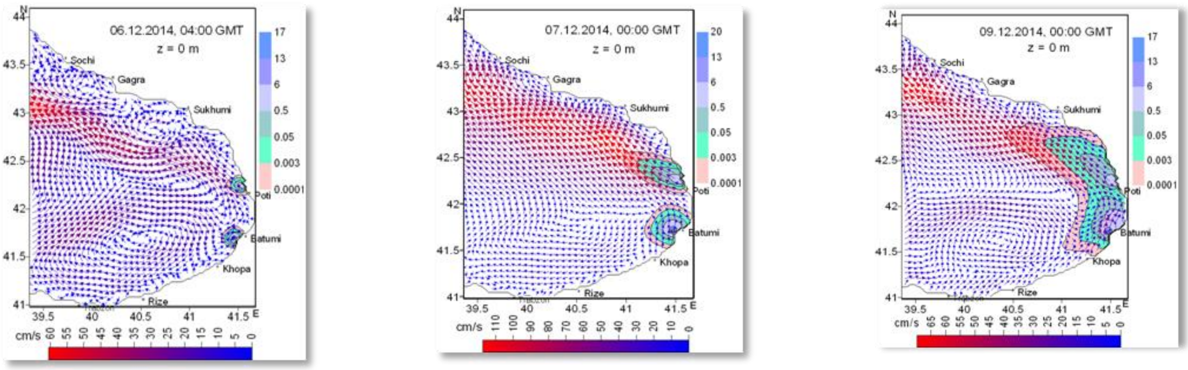

Fig. 3. Simulated surface current field and distribution of impurity at t = 4 (a), 24 (b) and 72 h (c) after start of getting impurity to the sea from rivers Chorokhi and Rioni. The forecasting period: 00:00 GMT, 6-9 December, 2014 [3].

Fig.3 illustrates distribution of the nonconservative hypothetical impurity discharged into the sea from the rivers Rioni and Chorokhi in the following amount per 1 sec.: from river Chorokhi – 100000 reference units, from Rioni – 10000 reference units, respectively.

Conclusion. The development of pollution forecasting methods for the coastal zones is one of the urgent problems of contemporary applied oceanology. A reliable operational forecast of pollution zones and concentrations in case of acidental situations will allow to optimize the effectiveness of performing measures in order to bring down to the minimum the possible negative consequences caused by pollution. In the present paper some examples of forecasting dynamic fields and impurity dispersion in case of hypothetical release in the Georgian Black Sea water area are showed.

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