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Circulation processes in the easternmost part of the Black Sea in 2010-2012: Results of simulation and forecast

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Abstract

Results of forecasts of the basic hydrophysical fields for 2010-2012 in the easternmost part of the Black Sea became the basis for studying of some features of inner-annual variability of regional circulating processes in this part of the sea basin. The forecast of a hydrological mode is carried out on the basis of the regional forecasting system developed at M. Nodia Institute of Geophysics in cooperation with oceanographic Centers of Black Sea riparian countries within the framework of EU international scientific - technical projects ARENA and ECOOP. The analysis of the data shows, that the easternmost water area of the Black Sea represents dynamically very active zone, where different circulating processes significantly distinguished from each other continuously develop.

1. Introduction

Since June 2010 3- days forecasts of a hydrological mode of the easternmost part of the Black Sea on a basis of the regional forecasting system are regularly carried out at M. Nodia Institute of Geophysics. The regional forecasting system is one of the parts of the basin-scale Black Sea Nowcasting/Forecasting system [1, 2] and enables to forecast 3-D fields of current, temperature and salinity with 1 km spacing in the regional area, which is limited to the Caucasian and Turkish coastal lines and the western liquid boundary coinciding with a meridian 39.08^0E. A core of the regional forecasting system is the regional mathematical model of Black Sea dynamics of M. Nodia Institute of Geophysics (RM-IG), which is nested in the Basin-scale model of Black Sea dynamics of Marine Hydrophysical Institute (MHI) of the National Academy of Sciences of Ukraine (Sevastopol). All input data required for calculation of marine forecasts are received in operative mode from MHI via Internet. The basic principles of functioning of the regional forecasting system and some results of forecast of hydrological fields for the easternmost part of the Black Sea are described in [3-5].

Nowadays a significant database is created by us, which contains results of modeling and 3-days forecasts of dynamic processes developed for 2010-2012 in the easternmost part of the Black Sea. The analysis of this material promotes to the best understanding of mechanisms of formation and evolution of hydro and thermodynamic processes in one of dynamically active regions of the Black Sea and enrichment ours knowledge about these processes.

The main goal of the present paper is the research of some features of inner-annual variability of regional dynamic processes for 2010-2012 in the easternmost part of the Black Sea.

2. Results of simulation and forecast of circulation processes

In numerical experiments, the results of which are showed below, a grid having 215 x 347 points on horizons with 1 km spacing were used. 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 were considered. The time step was equal to 0.5 h.

Regular calculations of the regional forecasts for 2010-2012 show, that the easternmost part of the Black Sea including the Georgian water area, represents a dynamically active zone. Circulating processes here develop which are characterized by significant inner-annual variability.

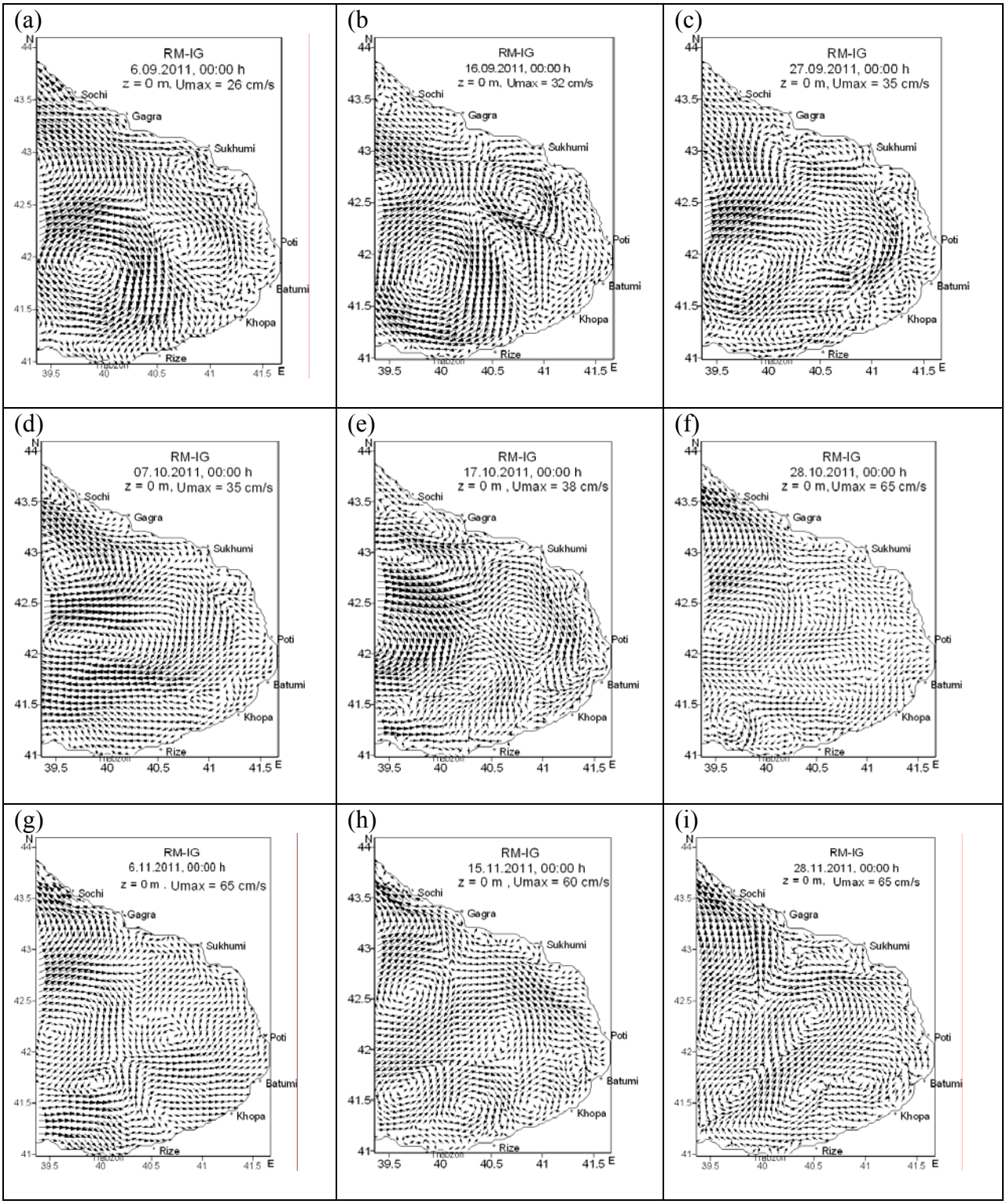

Fig.1. Simulated surface current fields in autumn 2011. (a) – 6 September , (b) – 16 September, (c) –27 September, (d) – 7 October, (e) – 17 October, (f) - 28 October, (g) – 6 November, (h) – 15 November, (i) – 28 November.

In Figs. 1-4 the calculated fields of surface currents for period since September 2011 till August 2012 are shown. Herewith for each month three circulation patterns are chosen which are more characteristic for the appropriate month.

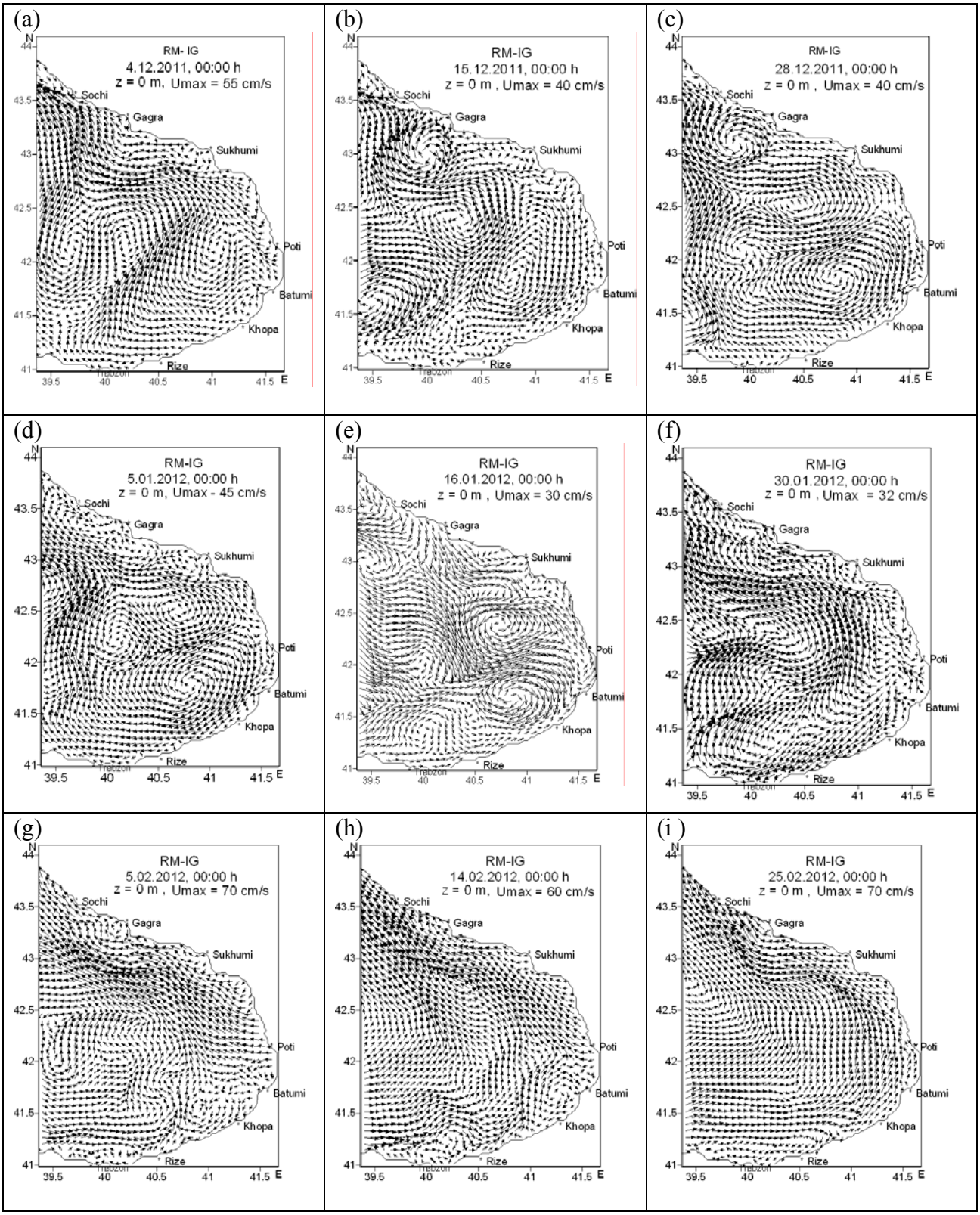

Fig.2. Simulated surface current fields in winter 2011-2012. (a) – 4 December 2011, (b) – 15 December 2011, (c) – 28 December 2011, (d) – 5 January 2012, (e) – 16 January 2012, (f) – 30 January 2012, (g) – 5 February 2012, (h) – 14 February 2012, (i) – 25 February 2012.

The main element of September circulation in 2011 is anticyclonic eddy with diameter about of 100-120 km (called the Batumi eddy), which is formed in the southwest part of the considered area.

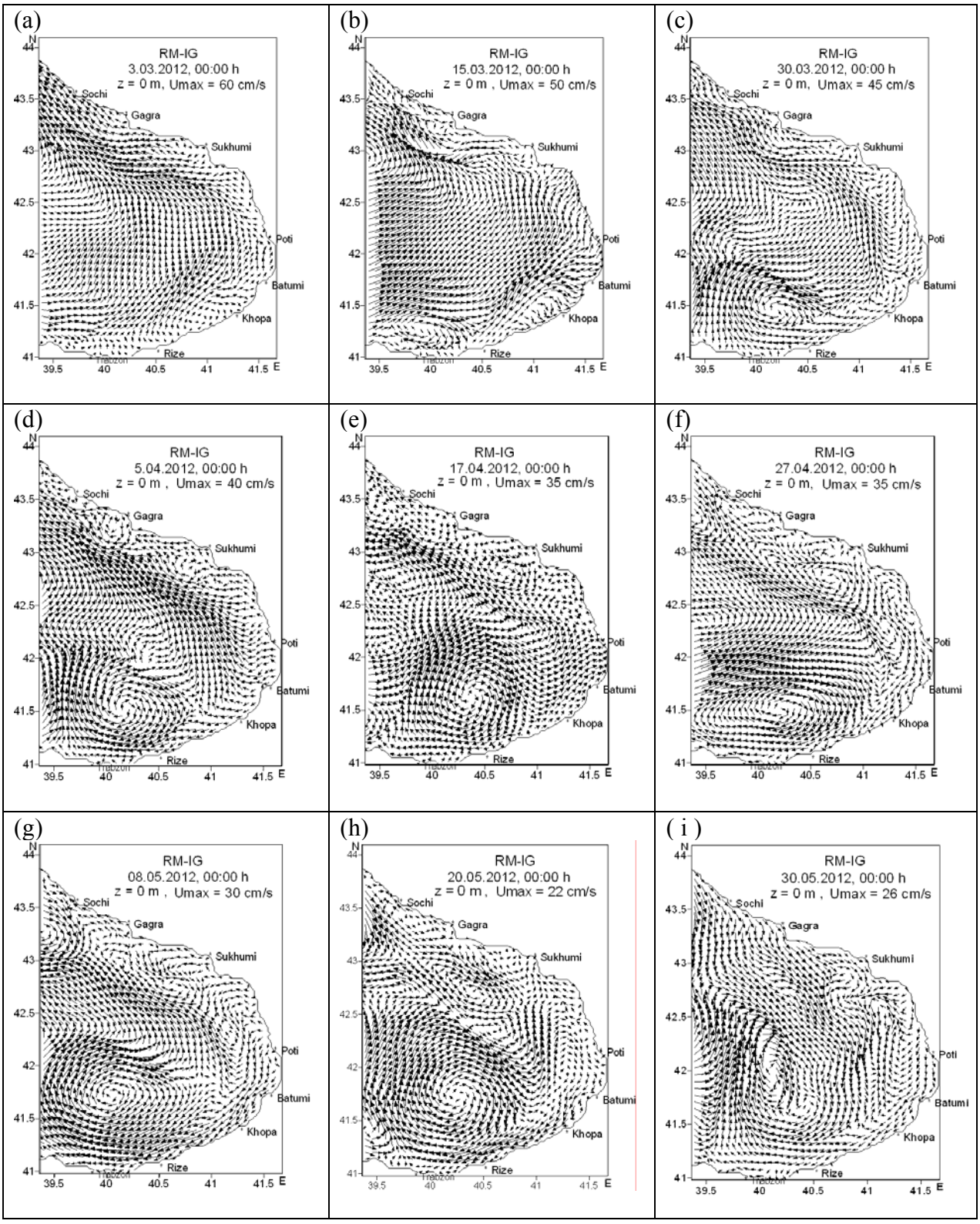

Fig.3. Simulated surface current fields in Spring 2012. (a) – 3 March , (b) – 15 March, (c) – 30 March, (d) – 5 April, (e) – 17 April, (f) - 27 April, (g) – 8 May, (h) – 20 May, (i) – 30 May.

The structure of this eddy undergoes some changes and by the end of the month substantially decreases in the sizes. from middle of September it is possible to observe also formation of the second anticyclonic eddy with rather smaller sizes, which is exposed to the certain changes. Along the Caucasian coast the narrow zone with width about of 20-25 km is formed which is characterized by intensive formation of small coastal unstable eddies, existence time of which are a few days. It should be noted that such coastal eddies of small sizes in coastal zones of the Black Sea are often observed [6-8]

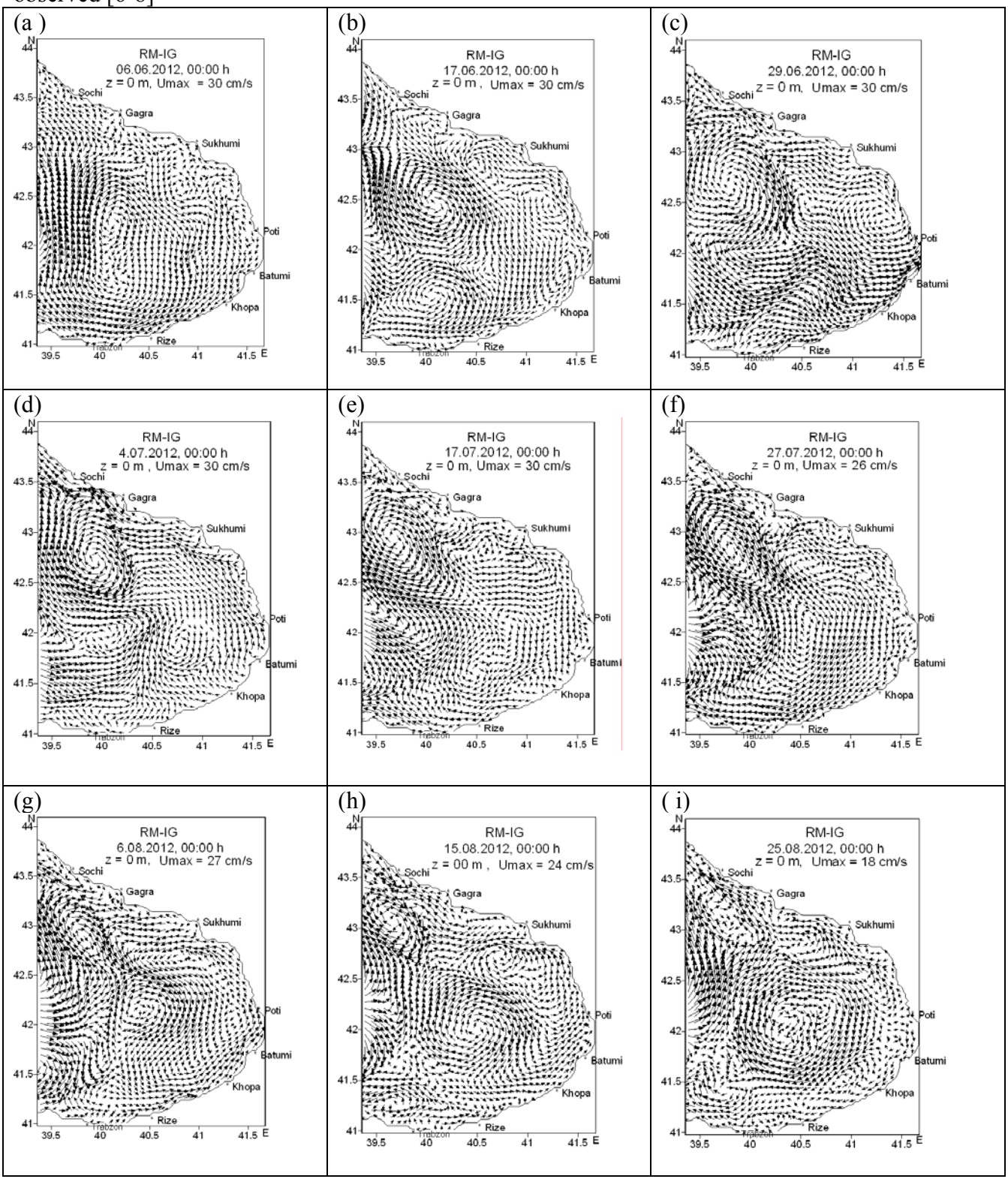

Fig. 4. Simulated surface current fields in Summer 2012. (a) – 6 June , (b) – 17 June, (c) – 29 June, (d) – 4 July, (e) – 17 July, (f) - 27 July, (g) – 6 August, (h) – 15 August, (i) – 25 August.

The transformation of a circulating mode proceeds within October. By the end of October the absence of a dominant direction and presence of several small anticyclonic and cyclonic eddies is characteristic for a circulating mode. The similar character of circulation takes place within November and here current speeds reach 60 cm/s.

The circulating mode in December 2011 differs from a mode of the previous month and is basically characterized by presence of the cascade of sharply expressed anticyclonic eddies. The January circulation in 2012 in the first half of month is similar in the certain degree with December circulation and the main elements of a circulating mode are obviously expressed cyclonic and anticyclonic eddies with characteristic diameter about of 30-40 km. East branch of the Rim Current is present at the majority of pictures of February circulation with the maximal speeds 60-70 m/c on its core. In general, Circulating mode of February 2012 is characterized by weak vorticity that is possible to explain by action of strong atmospheric winds, which develop in this period. An intense atmospheric circulation has smoothing influence on surface sea currents and promote disappearance of vortical formations [4].

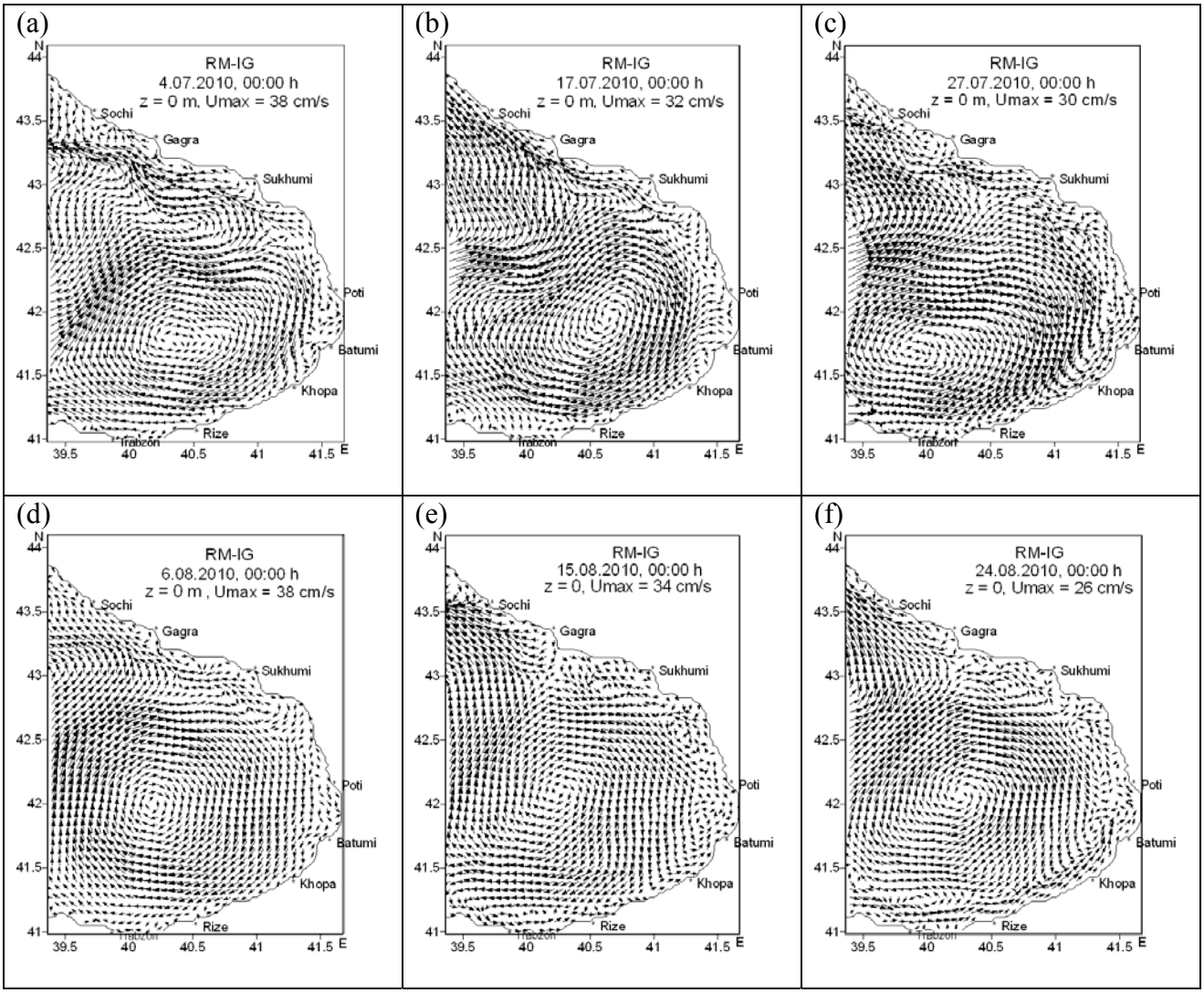

Fig.7. Simulated surface fields in Summer 2010. (a) – 4 July , (b) – 17 July, (c) – 27 July, (d) – 6 August, (e) – 15 August, (f) - 25 August.

The circulating mode of first half of March 2012 was characterized also basically by free-vortex movement (except for formation some coastal small eddies), but by the end of the month generation of anticyclonic vortical formation in the southwest part of the considered area is

observed. In April anticyclonic vortex grows in the sizes and it is present within all month. The narrow zone along the Caucasian coast is a zone of intensive vortex formation, where small coastal cyclonic and anticyclonic eddies are generated and transformed.

In middle of May the anticyclonic eddies amplifies, and by the end it weakens. The speeds of current decrease.

In the beginning of summer the anticyclonic eddy is stretched along a meridian and as a result in middle of June two anticyclonic eddies are formed. In June a zone of vortex formation along the Caucasian coast is well observed too. In local water area between Sukhumi and Poti the anticyclonic vortex with diameter about of 25 km is especially well observed.

In the beginning of July formation of the anticyclonic vortex in the northwest part of considered area is observed. This vortex by the end of July extends in the southern direction. In August formation of anticyclonic eddy takes place at the centre of the considered regional area and then gradually extends and covers the area with a diameter about of 80-90 km.

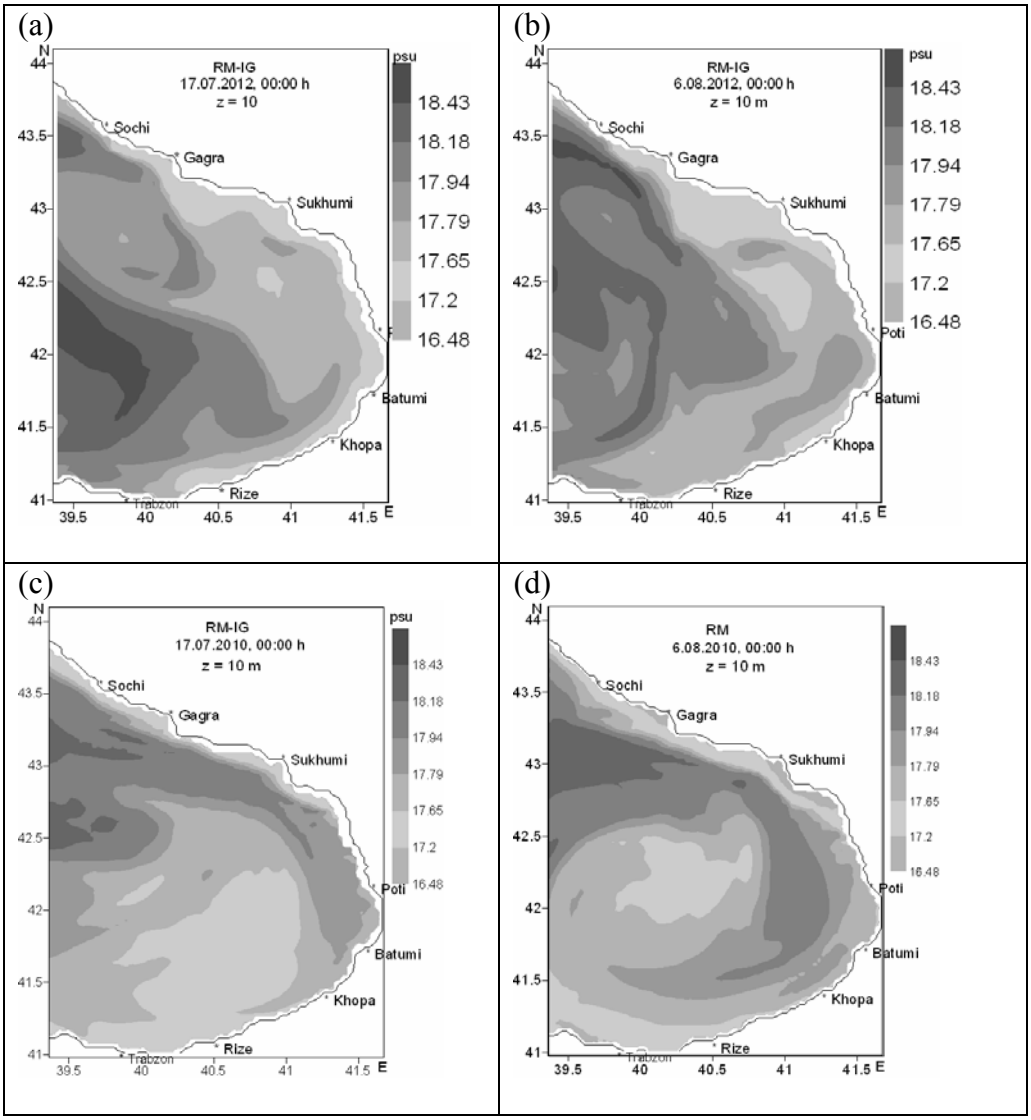

Fig.8. Simulated salinity fields on z = 10 m. (a) – 17 July 2012, (b) – 6 August 2012, (c) – 17 July 2010, (d) – 6 August 2010.

The analysis of the data of circulating modes for 2010-2012 shows that the circulating modes of the same season in the considered easternmost part of the Black Sea can considerably differ from each other per different years. There seems different meteorological conditions which are formed above the regional water area of the Black Sea promote this phenomenon. In confirmation of this

fact the comparison of summer circulating modes of 2010 (Fig. 7) and 2012 (Fig. 6) serves. The summer circulation in 2010, which significantly differs from summer circulation in 2012, was characterized by sharply distinguished features. The main feature of the regional circulation of 2010 was the existence of the Batumi anticyclonic eddy practically within all summer period. It was rather steady formation, which reached the maximal intensity in August and covered the significant part of the considered regional area. It is interesting to note, that under the information of synoptic-meteorologists the summer of 2010 in Georgia was abnormal hot for last decades. Temperature of air quite often reached and passed 40°C, and coastal waters of the sea were heated up more than 30°C. The abnormal temperature mode, obviously, has affected a mode of evaporation and precipitation and at the end thermochaline conditions of coastal waters have appeared favorable for formation intensive anticyclonic vortical formation.

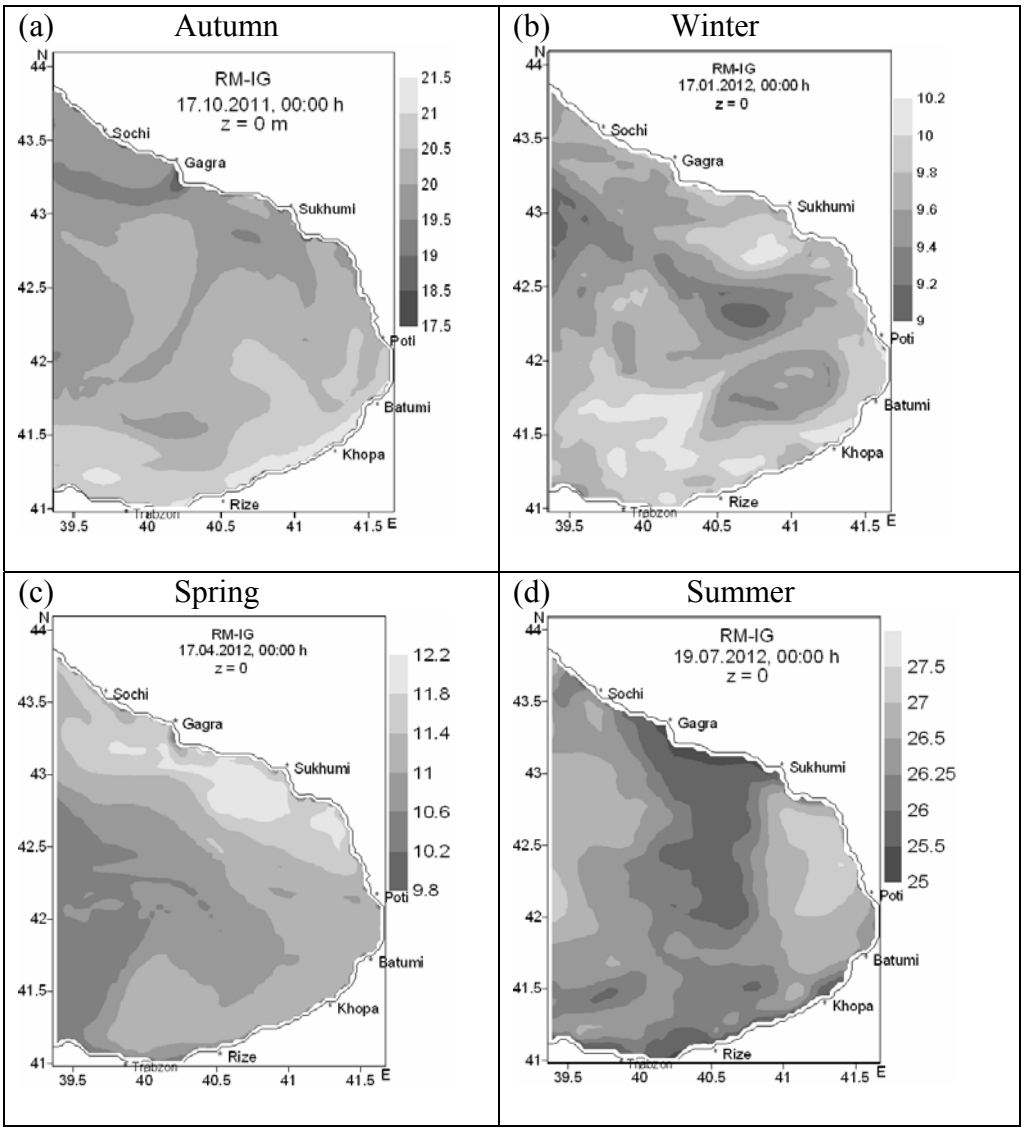

Fig. 9. Simulated surface temperature fields, corresponding to different seasons 2011-2012. (a) – 17 October 2011, (b) – 17 January 2012, (c) – 17 April 2012, (d) – 19 July 2012.

The analysis of the data for 2010-2012 shows that the distribution of the salinity field in the considered regional area underwent certain inner-annual changes. The general character of variability of the salinity field within one year depends both on inner-annual change of balance in system evaporation – precipitation, rivers' inflow and on the circulating characteristics. The analysis of our data confirms the known fact, that the salinity field well correlates with the field of circulation. General law is that anticyclonic eddies promote formation of waters with low salinity in

its central art, and cyclonic eddies - on the contrary. The ascending flows at the centre of a cyclone promote carry of more salty waters from deep layers in the upper layers, and the descending flows in the central part of anticyclonic eddy transfer less salt waters from upper layers downwards. Thus, the circulating mode in the greater degree determines structure of the salinity field in the easternmost regional area. This fact is especially precisely shown by comparison of pictures of salinity, corresponding to summer 2010 and 2012, when the circulating modes sharply differed from each other. From Fig. 8, where the calculated fields of salinity on horizon z = 10 м, corresponding to summer season 2010 and 2012 are shown, it is clearly visible that intensive Batumi anticyclonic eddy observable in the summer of 2010 has considerably affected a mode of salinity in the easternmost part of the basin. Here was observed rather lowered salinity on the significant central area of the Batumi eddy, and the peripheral current of the eddy promoted penetration of more salty waters from open area of the sea in the easternmost water area.

The certain impression about seasonal evolution of a surface temperature field gives Fig.9, where the distributions of the Black Sea surface temperature for four seasons are given. The temperature field undergoes both significant qualitative and quantitative seasonal changes and the character of its change in the upper layer is basically determined by heat exchange between the sea and atmosphere.

3. Summary

Summarizing the researches carried out in this work on the base of analysis of simulated hydrological fields for 2010-2012 it is possible to formulate briefly the basic features of inner-annual variability of dynamic processes in the easternmost water area of the Black Sea. During all seasons in the easternmost part of the Black Sea generation, deformation and disappearance of anticyclonic and cyclonic vortex formations continuously takes place. The analysis of calculated current fields again confirms the fact known from the Black Sea oceanographic literature [9], that the most intensive vortical formation is the Batumi anticyclonic eddy, which exists in the warm period of year. In most cases a narrow zone along the Caucasian coast with width about of 20-30 km is formed, where intensive vortex formation takes place. In this zone generation of small unstable eddies with diameters from 5 up to 20 km is observed. Vortex formation weakens in February when the atmospheric winds amplify having smoothing effect on sea current. In that case, when the Batumi eddy is intensive and occupies a significant part of considered water area, it forms the certain mode of salinity: salinity of waters considerably decreases in the central part of the Batumi eddy, but the peripheral current of the eddy promotes penetration of more salty waters from an open part of the Black Sea in the considered regional area.

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Циркуляционные процессы в восточной части Чёрного моря: Результаты моделирования и прогноза

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Резюме

Накопленные за 2010-2012 гг. результаты прогноза основных гидрофизических полей в крайне восточной части Чёрного моря явились основой для исследования особенностей внутригодовой изменчивости региональных циркуляционных процессов в этой части бассейна. Прогноз гидрологического режима производится на основе региональной прогностической системы, разработанной в Институте геофизики им. М. Нодиа в сотрудничестве с океанографическими центрами причерноморских стран в рамках международных научно-течнических проектов Евросоюза ARENA и ECOOP. Анализ материала, накопленного за отмеченный период, показывает, что крайне восточная акватория Чёрного моря представляет собой динамически довольно активной зоной, где в течение года непрерывно развиваются разные циркуляционные процессы, резко отличающиеся друг от друга.

ცირკულაციური პროცესები შავი ზღვის აღმოსავლეთ ნაწილში 2010-2012 წწ-ში: მოდელირების და პროგნოზის შედეგები

ავთანდილ კორძაძე, დემური დემეტრაშვილი, ვეფხია კუხალაშვილი

რეზიუმე

2010-2012 წლებში დაგროვილი ძირითადი ჰიდროფიზიკური ველების პროგნოზის შედეგები შავი ზღვის უკიდურესი აღმოსავლეთ ნაწილისათვის წარმოადგენენ საფუძველს რეგიონალური ცირკულაციური პროცესების შიდა წლიური ცვალებადობის თავისებურებათა გამოკვლევებისათვის ზღვის აუზის ამ ნაწილში.

ჰიდროლოგიური რეჟიმის პროგნოზი ხორციელდება რეგიონალური პროგნოზული სისტემის საფუძველზე, რომელიც შემუშავებულია მ. ნოდიას გეოფიზიკის ინსტიტუტში შავიზღვისპირა ქვეყნების ოკეანოგრაფიულ ცენტრებთან თანამშრომლობით ევროკავშირის სამეცნიერო-ტექნიკურ პროექტების ARENA და ECOOP ფარგლებში. აღნიშნულ პერიოდში არსებული მასალის ანალიზი გვიჩვენებს, რომ შავი ზღვის უკიდურესი აღმოსავლეთ აკვატორია წარმოადგენს დინამიკურად საკმაოდ აქტიურ ზონას, სადაც წლის განმავლობაში უწყვეტად ვითარდებიან ერთმანეთისაგან მკვეთრად განსხვავებული სხვადასხვა ცირკულაციური პროცესები.