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Crimea and Caucasus Accumulative Coasts Dynamics Estimation using Satellite Pictures

R.D. Kosyan[1,*], Yu.N. Goryachkin[2], V.V. Krylenko[1], V.V. Dolotov[2], M.V. Krylenko[1], E.A. Godin[2]

[1] Southern Branch of the P.P.Shirshov Institute of Oceanology RAS, 353467, Gelendzhik, Russia.
[2] Marine Hydrophysical Institute of NASU, 2, Kapitanskaya st. 99011, Sevastopol, Ukraine.

* Corresponding Author: Tel.: +7 86141 28281; Fax: +7 86141 28089;
E-mail: rkosyan@hotmail.com

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Abstract

The total length of Ukraine and Russia Black Sea coastal line makes almost half of Black Sea coast summarized extent. The policy of coastal zone development and management pursued by these states exerts an essential influence on the entire Black Sea. For the solution of the practical problems arising during economic development of the coast, frequently it is required to receive quickly the information on dynamics of coast, especially of the accumulative one. The data acquisition of the field instrumental observations requires the long expeditionary works and the time for the subsequent office treatment of results. The use of space pictures allows estimating dynamics of accumulative coastal forms of any scale and giving a complete picture of the area coast changes. The resorts Anapa (Russia) and Crimea (Ukraine) have been used as test areas.

Keywords: Monitoring, coast line, coast retreat, satellite observations.

Introduction

The total length of the Ukraine and Russia Black Sea coastal line makes almost half of Black Sea coast summarized extent. The solution of Black Sea coastal zone complex management problems is impossible without the full information of coasts current condition. The development of coastal natural systems is always accompanied by changes of coastal line planimetric position. Processes occurring at the coast essentially influence functioning of both Russia and Ukraine economic complexes. Prevention or minimization of coastal dynamics negative consequences for the economy is the important component of the sea coastal zone management. Therefore these countries pay the big attention to the monitoring of the coast modern condition and to the forecast of their development under the change of the climate and the anthropogenic impact.

Operative data about the coast changes and stability are often required for the solution of practical problems. Direct observations can give the exact information on current situation; short-term observations can specify certain tendencies of investigated processes development. However, natural processes are characterized by periodicity, non-uniformity, discrete behavior. In this situation it is necessary to involve data for as much as possible long term, and to have an opportunity to compare features of development of morphologically similar coasts, but in different regional conditions.

The most part of data about the Black Sea coastal line variability available to the present time was received by measuring the width of beaches on stationary section lines or, less often, by the comparative analysis of separate topographical and aerial mappings. However, field tool observation data acquisition demands long expeditionary works and time for the subsequent office processing of results. Traditional methods of topographical survey can not operatively reflect the coastal line change (Kravtsova, Mikhaylov, 2006; Shuvaev, 2006; Goryachkin and Dolotov, 2011). Use of space pictures allows receiving the periodic information for all studied territory, estimating dynamics of coastal forms of any scale and giving the complete picture of the area coast changes.

Materials and Methods

Authors of the paper have made the analysis of space series for made at different time pictures of Krasnodar territory (Russia) and Crimea (Ukraine) coasts for the long period. Coasts of resorts Anapa (Russia) and Evpatoria (Ukraine) have been chosen as test areas. While studying dynamics of Anapa bay-bar

coastal line for binding the remote sensing contemporary records, the coastal line GPS-tracks and GeoEye high resolution survey of the chosen area were used. It was possible to reference to GeoEye picture the II World War times Luftwaffe (Germany) air photographs and pictures of program CORONA (USA) 1966 (Krylenko, 2011). For the Crimea coast dynamics analysis the data of Landsat series artificial satellites for the period 1986-2009 were used. Position accuracy for aerial images is 1.5-2.0 m and 1.5 m for satellite images (resolution 0.6 m). Pictures were combined in software package ENVI, and then the deciphering was made in ERSI ArcGis (Goryachkin and Dolotov, 2011).

Results

Anapa Bay-Bar Coast Dynamics

Anapa bay-bar is an accumulative sandy body having the length of 47 km, located in a northwest part of the Black Sea Russian coast. Width of the bay-bar makes from 100 m in the northern part up to 1.5 km in the southern. The continuous strip of sandy beaches having the width of 50-200 m has huge recreational value (Figure 1).

The resort Anapa is located at southern end of Anapa bay-bar where the accumulative sandy body adjoins to the rocky Anapa cape. The projecting cape essentially complicates the hydrodynamic structure of the sea in this area. This part of the bay-bar is the final point of movement of the sediments moving from northwest. In the last some decades the recession of Anapa bay-bar coastal line has been noted repeatedly in the literature (Izmaylov, 2005, Artyuhin, Fedorova, 2010). Several hypotheses, about the reasons of reduction of beaches were put forward: hydraulic engineering constructions of port Anapa, groin and seawall at quay, withdrawal of sand from beaches. Some scientists assumed that the reason of beaches washout is the local bottom tectonic upraising at this given site. Meanwhile, on the map of 1828 it is well visible that almost 200 years ago the beach on the specified site of coast had the outlines close to the modern ones. Comparison of the available amateur photographs covering the period from about 1900th till our time also has shown that the beach on the considered site of coast remains stable while the scope of within- and interannual fluctuations water line position reaches 15-20 m.

The interesting information has been received at comparison of the aerial photographs made by the German secret service during II-WW, and satellite pictures for the period from 1966 till present time. It has been found, that at the length of 3 km of the bay-bar most southern part the coastal line has kept former position. The recession of coast is noticeable to the north; the size of this recession quickly increases to the north, reaching in area Dzhemete 70-80 m that coordinates with the data received by direct measurements (Figure 2). Comparison with CORONA pictures for 1966 has shown that from 1944 till 1966 the Anapa bay-bar coastal line was in rather stable condition; the recession of the coast has begun later.

The important feature is the change of zone of dunes sea border position (front dune bottom). On the greater part the front dune has receded with the coast recession speed, thus the width of the beach practically did not vary. We shall note that fluctuation of the water line noted after severe storms reaches 10-15 m. It is connected with fluctuations of the sea level and complex structure of the underwater slope. It is clear that tracing so fast changes of the coastal line by traditional methods is very difficult and expensive.

The analysis of the Anapka river near-the-mouth

Figure 1. Black Sea coast section from Taman peninsula to Anapa city.

zone changes also allows getting the information about proceeding hydro-lithodynamic processes. On the map of 1828 it is well visible, that in the mouth two differently directed blocking bars are available simultaneously with the more powerful northern one. The similar situation existed also in 1941; only later appears the artificially made and periodically updated channel crossing the beach under the right angle, the old channel remains in the form of dead channel. Thus on a new mouth also are formed blocking bars directed alternatively to the north and to the south. From these observations it is possible to draw a conclusion, that for this bay-bar site the unstable hydrodynamic mode defining frequent change of sediments movement direction (Figure 3) is characteristic. Nevertheless, the configuration of the Anapka river old channel confirms the resulting prevalence of sediments stream (Kosyan *et al*., 2011) directed to the south.

The important components of Anapa bay-bar lithodynamic balance are eolian processes. The intensity of eolian processes is substantially defined by the presence and by the condition of vegetation. The data describing the bay-bar vegetation condition for more than 100 years ago practically do not exist. On the photographs made in the beginning of XXth century it is visible that the wood vegetation in the bay-bar southern part was completely absent. On air photography made in 1941 the wood vegetation is available only on sites of high dunes in area Dzhemete. In 50th years of XX century large scale works on fastening dunes by landing of vegetation were carried out. The next years during construction of recreational objects the gardening of extended territory in the dune belt back part has been made. In opinion of some researchers it has led to the reduction of sand inflow from coast to the sea, to its accumulation in dunes, and could become one of the reasons of the coast recession.

Underwater bars are important elements of Anapa bay-bar lithodynamic system and they define the hydrodynamic mode of surfy zone. In the plan view the bars repeat outlines of the coastal line; on the studied site three underwater bars are traced. At storms the fall of the largest waves occurs above crests of underwater bars far from the coast and destructive energy of the wave is substantially extinguished. Thus, the question of underwater bars structure dynamics represents the big practical interest. During the severe storms considerably differing in a direction from the previous ones all system of bars is changed. Similar changes occur

Figure 2. Long-time changes of the water edge line position near Djemete (1941 – 2007).

Figure 3. The direction of the blocking bay-bar in the Anapka river mouth (1927, 2007, 2009).

quickly enough; therefore single bathymetric surveys despite of high accuracy do not allow defining the long-term stability of underwater bars system. Our researches including the analysis of space and aerial photographs for several years have shown that the entire system of bars has not changed from 1941 as a whole despite of the coast recession (Figure 4). Visible changes of bars configuration for this period are comparable by size with the interannual ones.

Crimea Northwest Coast Line Dynamics

The conducted analysis has shown that the Crimea coast northwest part (Figure5) is characterized by significant modern variability of the coastal line position (Goryachkin *et al*., 2009).

So, the distal part of Bakalskaya spit during 1986-2009 came forward in Karkinitsky gulf water area for 300 m (Figure 6). The reduction of bay-bar width in the area of the vent connecting the basic body of the bay-bar with distal part and its displacement to the east is traced. The bay-bar western coast up to 90th remained rather stable, after 2004 there was an activation of its washout. The thrust of the spit on Bakalskoye lake water area is well traced. For the considered period the bay-bar was displaced to 150 m; modern sea water line settles down on the former place of lagoon in 1986. Thus, the assumption made by Zenkovich (1955), that evolution of Bakalskaya spit will consist in its

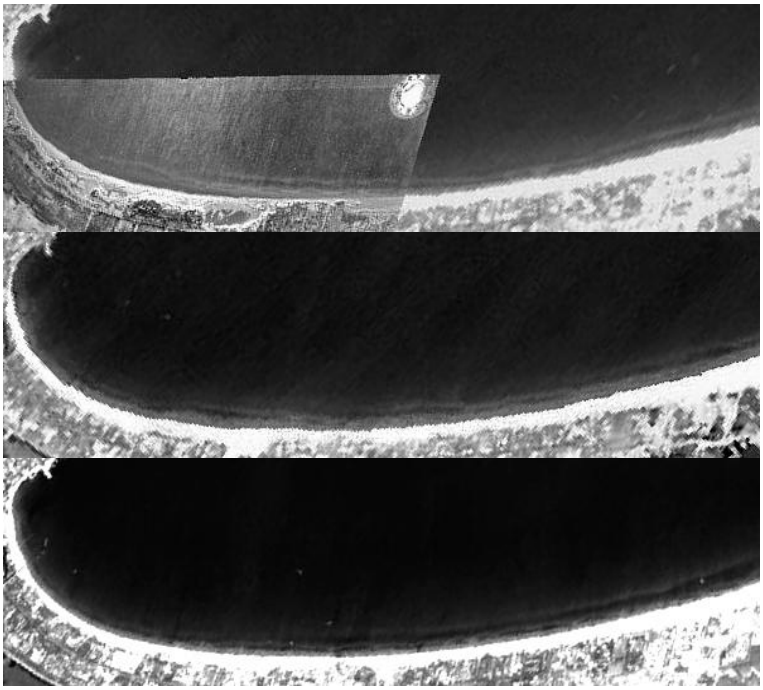

Figure 4. Anapa bay-bar southern part underwater bars dynamics (top-down 1941 (superposed with 2005), 1989, 2008).

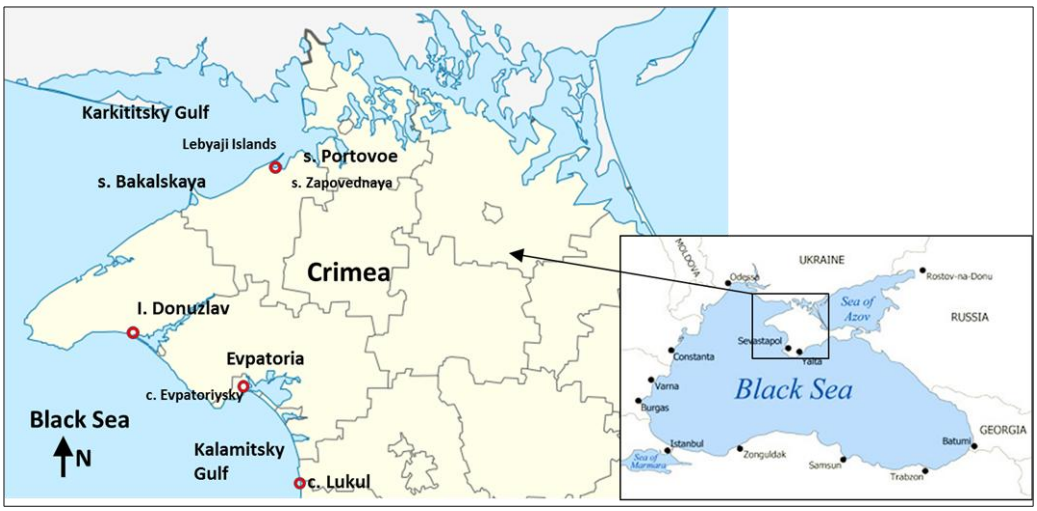

Figure 5. Crimea northwest coast line.

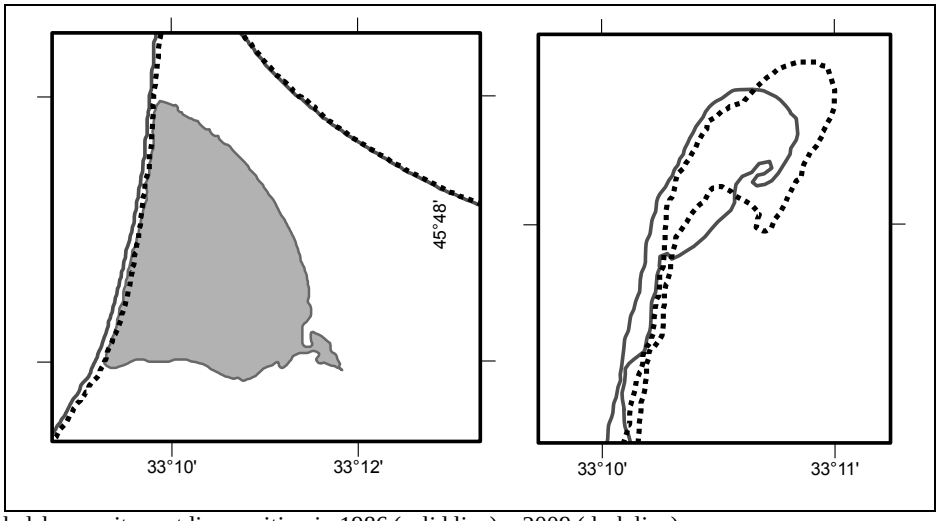

Figure 6. Bakalskaya spit coast line position in 1986 (solid line) и 2009 (dash line).

displacement in east direction, is true.

The most dynamical area is the coast adjoining to the item Portovoye. During 1986 - 2000 the growth of Zapovednaya bay-bar occurred in NW direction with average speed of 360 m/year. The greatest speeds have made about 680 m/years, thus the width of bay-bar adherent part made from 100 up to 150 m. In 1999 the bay-bar body was dismembered to some islands. The bay-bar distal part has formed island having the length of 1300 m and the width from 35 up to 100 m. The considered coast reacts to anthropogenic impact very quickly. The change of coast dynamics is traced on space pictures after construction in 1989 of coast protection structures i.e. rockfill blanket in item Portovoye area. Right after its constructions the coastal line came forward in the sea on the distance up to 60 m on all extent up to Andreevsky estuary. The same year the greatest growth of Zapovednaya bay-bar 2 times exceeding the rate of increase in the previous years was marked. In 1990 to the east from the rockfill blanket there was a strong washout of coast (30-70) which was traced down to distal part of 'Zapovednaya' bay-bar. Protrusion of the coast was observed up to 1999 then the coastal line was stabilized.

It is necessary to note, that for last 60 years the sea has absorbed here two settlements - Andreyevka and Sergeyevka. In the mouth of river Samarchik in 70th years of the last century there was a frontier post and children's holiday camp which now also are at the sea bottom. The islands Lebjazhi being ornithological reserve of the international value not only constantly change the outlines; their quantity varies also. Also for this site of coast the tendency of sea gulfs transformation in estuaries is characteristic. Sandy Kondzhalay islands existed still in middle of XX century now have turned in bay-bar separating estuary Andreevsky from the sea.

Contrary to the existing point of view that on the coast site from lake Donuzlav up to Evpatoria the coast everywhere recedes, the analysis of satellite data has shown, that on the piece from lake Donuzlav till cape Evpatoriysky on 75% of its length the coast is rather stable, 9% of coast accrue, its 16 % decrease. It is characteristic, that recession sites are connected to capes and sites of growth are connected to concavities of the coast. It is possible to assume that there is a natural process of coast alignment. The most problem site of coast is city boundary of Evpatoria (Figure 7). As a whole in city boundary (~15 km) on 68% of length the coastal line recedes, on 19% remains stable, on 13 % it is dressed in concrete. Average speed of coast recession makes about 1 m/year, and the area of beaches was reduced in 1986-2009 approximately for 130 000 m^2.

The coastal line on the site from Evpatoria till cape Lukull is characterized by alternation of coast recession and protrusion zones. Coast recedes on 30% of all the length; comes forward on 19%; on greater part (51%) it is rather stable. Zones of coast protrusion are connected mainly to the places where the coast protection structures perpendicular to the coast are constructed; intercepting the alongshore stream of sediments they create conditions for their accumulation. The most vivid example of such interception is the water intake constructed in 1981. For the considered period to the south of it the coast came forward on 30 m on the average (at length of 2.3 km); thus the area of the beach has increased for ~70000 m^2.

Conclusion

Chronological series of the high resolution satellite pictures is a reliable basis for monitoring fast changes of the coastal line and other elements of the coastal zone, especially on very dynamical accumulative coast. Their analysis has allowed to receive the detailed information about changes of Anapa bay-bar coastal zone and the resort Evpatoria for last decades and to connect them with natural and anthropogenic impact on the coastal zone.

Figure 7. Reduction of Evpatoria beaches width (1941 -2010). Coastline in 1941 (seaward edge of the white sector), coastline in 2010 (shoreward edge of the white sector). Black line is the coastline in 1967.

The conducted work has shown that space pictures application for studying the Black Sea coast of Russia and Ukraine is very perspective. The further researches will promote perfection of monitoring observations methods in the coastal zone of Russia and Ukraine in Black Sea.

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