

# Using of Landsat space images to study the dynamic of coastline changes in the Black Sea north-western part in 1983-2013

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**Introduction.** The problem of destruction of marine coastal zones, which are the most densely populated and developed areas in the world, is in focus of attention of many researchers globally (e.g. Cherkez, 1996; Cherkez et al., 2006; Freiberg et al., 2012; Luijendijk et al., 2018; Tatui et al., 2019) whose efforts are concentrated on studies of natural and anthropogenic factors' influence on intensity of shore erosion, which is caused first of all by changing of sea level and coastline abrasion, as well as revealing of critical coastline areas with maximal intensity of coast destruction processes. Besides, in line with the EU Marine Strategy Framework Directive, coastal abrasion has been chosen one of impact indicators for coastal ecosystems of European seas, having special importance for the Black Sea. The main impact of coastal abrasion on the marine environment is big volumes due to large amount of suspended matter entering coastal waters thus decreasing transparency and causing siltation, which dramatically damages coastal algal and seagrass communities and completely destroys natural processes of their reproduction. There are abrasion and cumulative types of coasts, which differ in prevailing processes and forming of different relief forms, which are characteristic of each type (Cherkez, 1996; Freiberg et al., 2012). The problem of coasts erosion is especially important for shallow north-western part of the Black Sea (NWBS), where intensity of coast destruction varies within broad limits for different parts of the coast and different periods of observation (Atlas, 2006). According to the authors (Shuiskiy and Vikhovanets, 1989; Zelinskiy et al., 1993; Safranov et al., 2017), coastal abrasion is the main mechanism of coastline formation in the NWBS. It has been shown that intensity of coastline forming processes is different for separate NWBS areas and depends on lithological composition of sea cliffs rock, sea level, wave's direction and intensity, composition, direction and intensity of sediments flow, economic activities. Light and easily corrodible rocks dominate in the NWBS coasts. That is why more than 75% of sedimentary material is carried out from the coastal zone to the open sea driven by differentiation processes (Shuiskiy and Rotar, 1975; Zelinskiy et al., 1993). It has been established that qualitative characteristics of beach drifting in the NWBS are characterized by high spatiotemporal variability from -1.5 to +5 m/ year. This is true for all the NWBS areas but the Danube River delta part, where beach drifting could reach +180 m/ year (Atlas, 2006). At that it should be pointed out that instrumental studies have been brought down to a minimum in past decades due to economic reasons; the available sets of historical instrumental data are discontinued; observation points are located along the NWBS coast unevenly; local geological, hydrological, meteorological and economic conditions of the coast are very rarely taken into account. Therefore to study how the sea ecosystems are affected by intensity of shore (beach) drifting, currently remote sensing techniques (RST) are widely used (Cherkez et al., 2013; Gazyetov et al., 2015; Luijendijk et al., 2018; Tatui et al., 2019). Using RST we are able not only assess coastal destruction, but also perform quantitative estimation of coastal areas increase/ decrease, quantify suspended terrigenous matter, nutrients and toxicants carried into the open sea and then accumulated in other coastal areas and/ or in bottom sediments. Aim of the work has been to study different coast areas' growth/ reduction resulting from coastlines position dynamics changes under abrasion and accumulation processes in the North-Western Black Sea (NWBS) influenced by natural and anthropogenic factors over 1983-2013.

**Methods and materials.** Study area has been located in the NWBS region (see Cherkez, 1996; Kovalova et al., 2010; Medinets and Medinets, 2012) between Odessa bay and the Danube Delta (Figure 1). Region is exposed by high input of freshened waters (from Danube and Dniester Rivers) and atmospheric deposition with high content of organics and marine-origin ions (Medinets, 2014). LANDSAT space images of 1983-2013, as well as own and historical field measurement datasets have been used for this investigation (Shuiskiy and Rotar, 1975; Shuiskiy and Vikhovanets, 1989; Zelinskiy et al., 1993; Cherkez et al., 2013; ; Gazyetov et al., 2015; Safranov et al., 2017). Data processing has been done out using ArcGIS version 9.2 (ESRI Inc., USA).

**Results.** Using results of Landsat space images processing for 1983, 1993, 2003 and 2013, we have built maps of coastline positioning in the NWBS. Comparing them, we have revealed 5 areas of maximal changes (Figure 1). Next, to assess long-term dynamics of coastline position changes every 10 years, we have built maps of coastline position changes for 1983, 1993, 2003 and 2013. Figures 2-5 show the examples of coastline drifting during 1983-2013.

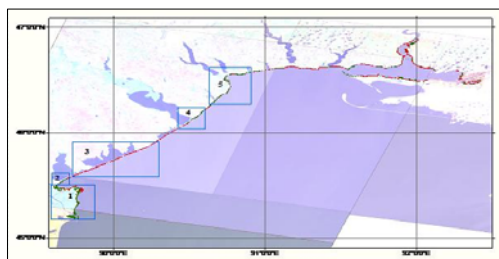


Figure 1 - Location of areas of the biggest coastline changes in the NWBS (red – decrease of land, green – increase of land). 1 - the Danube Delta, 2- the Sasyk Liman, 3 – from the Sasyk Liman to the Budakskiy Liman, 4- the Dniester Liman, 5 – Odessa city (from the Sukhoy Liman to the Dofinovskiy Liman).

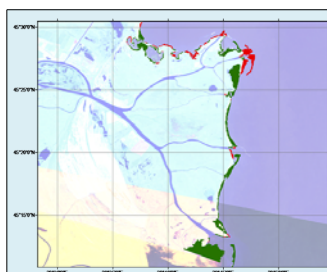


Figure 2 - Schematic map of coastline dynamics, 1983-2013, the Danube Delta area (No. 1) (red – decrease of land, green – increase of land)

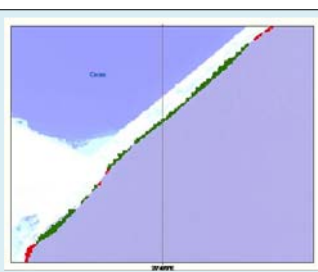


Figure 3 - Schematic map of coastline dynamics, 1983-2013, the Sasyk Liman area (No. 2) (red – decrease of land, green – increase of land)

We have shown that main areas with maximal changes of coastline location are the river deltas (Danube, Dniester, Dnipro), as well as bay-bars of practically all the Black Sea limans. Results of of coastal land areas' changes increase (+)/ decrease (-) of the areas are shown in Table 1. Analysis of coastal zone changes (increase / decrease) in the selected areas has shown that generally in the NWBS coastal zone area grew 11.312 km<sup>2</sup> in 1983-2013. At that during 1983-1993 decrease by 6.435 km<sup>2</sup> and then increase by 3.151 km<sup>2</sup> and 14.596 km<sup>2</sup> were registered in 1993-2003 and 2003-2013 respectively. The highest intensity of coastal zone area emerging was observed in the Area No. 1 (Figure 1; Table 1) – the Danube Delta (from + 0.361 km<sup>2</sup> in 1983-1993 to +5.123 km<sup>2</sup> and 9.133 km<sup>2</sup> in 1993-2003 and 2003-2013 respectively).

The decades 1983-1993 and 2003-2013 should be specially stressed as in all the studied areas increase in acreage was minimal in 1983-1993 and maximal in 2003-2013. Study of this phenomenon reasons is still to be performed. It could have been caused by global climatic changes, which affected aqueous run-off to the NWBS. Our results agree well with historical data for 1986-1997 (Atlas, 2006) and with data for 1984-2016 (Luijendijk et al., 2018; Tatui et al., 2019) related to establishing of the most critical coastline areas. Study of this phenomenon reasons is still to be performed. It could have been caused by global climatic changes, which affected aqueous run-off to the NWBS. Our results agree well with historical data for 1986-1997 (Atlas, 2006) and with data for 1984-2016 (Luijendijk et al., 2018; Tatui et al., 2019) related to establishing of the most critical coastline areas.

Table 1. Results of assessment of dry land areas increase (+)/decrease (-) in 1993, 2003 and 2013 for some of the most dynamic NWBS areas (from the Danube Delta to the Dnipro Delta) every 10 years and generally for the period 1983-2013

Area, km <sup>2</sup>	1983-1993	1993-2003	2003-2013	1983-2013
The Danube Delta area (1)	+0.361	+5.123	+9.133	+14.617
The Sasyk Liman area (2)	-0.014	+0.208	+0.261	+0.455
Area from the Sasyk to the Budakskiy Liman (3)	-1.257	-0.514	+0.137	-1.634
The Dniester Liman area (4)	+0.256	+0.536	+0.261	+1.053
Odessa city area (the Sukhoy Liman – the Dofinovskiy Liman) (5)	+0.466	+0.333	+0.899	+1.698
Altogether, areas Nos. 1-5	-0.188	+5.686	+10.691	+16.189
Other areas	-6.247	-2.535	+3.905	-4.877
Altogether in the NWBS	-6.435	+3.151	+14.596	+11.312

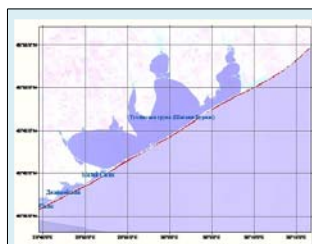


Figure 4 - Schematic map of coastline dynamics, 1983-2013, area (No. 3) from the Sasyk Liman to the Budakskiy Liman (red – decrease of land, green – increase of land)

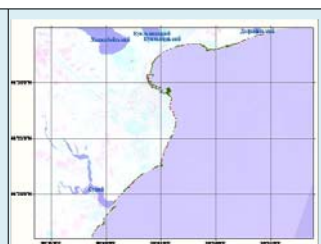


Figure 5 - Schematic map of coastline dynamics, 1983-2013, Odessa area (No. 5) (red – decrease of land, green – increase of land)

It is confirmed of the main conclusion that velocities of coastline retreat/ emerging as the result of abrasion/ accumulation processes are not uniform in different NWBS areas. It is important to underline that according to the benchmarking of long-term field observations and data derived from satellite images processing for the above mentioned periods of time, for the areas No. 1 (Figure 2; the Danube Delta) and No. 3 (Figure 4; coastline between the Sasyk and Budakskiy Limans) we received the values of coastline dynamics coinciding in direction of process (retreat/ emerging) and having similar rates. At that, data of coastal areas' acreage increase/ decrease calculation, for example, in area No. 5 (Figure 5; the Sukhoy Liman – the Dofinovskiy Liman), show contrastingly changing variability of beach drifting direction and intensity along the area as the result of high development (building in different years of protection facilities for access canal in Chernomorsk port, set of coastal protection and anti-landslide works in Sovinoh housing estate, Odessa city and Odessa Bay, Kryzhanovka village and Yuzhny port). To reveal the local processes and reasons of coastline moving, its retreat and emerging in different areas, we have to study in more details the geological structure and lithological composition of the material exposing on coastal cliffs, as well as changes of sea level, direction and intensity of waves; composition, direction and rate of sediments flow; and human economic activities. These matters are to be mandatory taken into account when planning economic activities in the coastal zone and developing Integrated Coastal Zone Management plans.

**Conclusion.** Maximal changes of coastline position in the North-Western part of the Black Sea were registered in the Danube Delta, areas of the Sasyk and Dniester Limans and Odessa Bay for the past 30 years. Land area in those locations grew more than 16 km<sup>2</sup>. In the other NWBS areas decrease of land terrain was observed, i.e. destruction of coasts, which made about 5 km<sup>2</sup>. At that, it should be noted that the biggest changes were taking place in the past decade.

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