The Aral Sea and Coastal Zone Degradation: Monitoring by Space Images

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Abstract – The Aral Sea degradation is one of the strongest nature and ecological catastrophes of XX century. Laboratory of aerospace methods of Moscow State University conducts the space monitoring of the Aral Sea and surrounded territories. The map of changes in coastal line position since 1957 to 2003 has been compiled by space images (Salut-4, MSU-SK/Resource-O, MODIS/Terra, etc.) and the areas of aquatory for 15 time cuts were determined. Seasonal fluctuations of the Sea area have been registered. They have strong connection with sea level fluctuations taken by radioaltimetry from TOPEX/Poseidon. Seasonal changes in landscapes of coastal zone have been analyzed and mapped.

Keywords: Aral Sea degradation, area changes, sea level, space images.

1. INTRODUCTION

Regular space surveys allow to watch changes of drying out the Aral Sea, formation it landscapes at a former sea bottom and their impact to surrounded area. Laboratory of aerospace methods of Moscow State University conducts the space monitoring of Aral and surrounded territories.Multitemporal space images have been used for compiling of maps of sea coast line retriet for the whole period of sea degradation. Due to regular MODIS observations during a year images taken in different seasons show seasonal changes in sea area which may be compare with radioaltimetry measurements. Mapping of seasonal landscapes changes may show the main factors of former sea bottom regime, salinity and humidity dynamics.

2. MULTIYEAR CHANGES OF ARAL SEA AREA

The map of changes in coastal line position since 1957 to 2003 has been compiled by space images and the areas of aquatory was determined for 15 time cuts (Fig. 1, Tab.1) [Kravtsova et al, 2002]. The follow materials were used for these purposes: the map of Aral Sea dynamics in 1961-1989, compiled by Kazach Aero-geodesy Department using space photos from Resource-F Satellites with resolution (R) 20-30 m; MSU-SK/Resource-O images (R=170 m) for 1989-1998; images taken from International Space Station (R=50 m) in 1999; MODIS/Terra images (R=250 m) for 2000-2004. All images were geocoded, transformed to Gauss-Kruger projection. The Aral Sea coast line was interpreted and drawn in vector format at each image and then combined at final map. Sea area for all 15 cuts were calculated. They are shown at tab.1 for Aral at whole and for its parts: western and eastern parts of Big (Bolshoe) Sea, not yet have been separated for 2004 and Small (Maloe) Sea, having been separated in 1989.

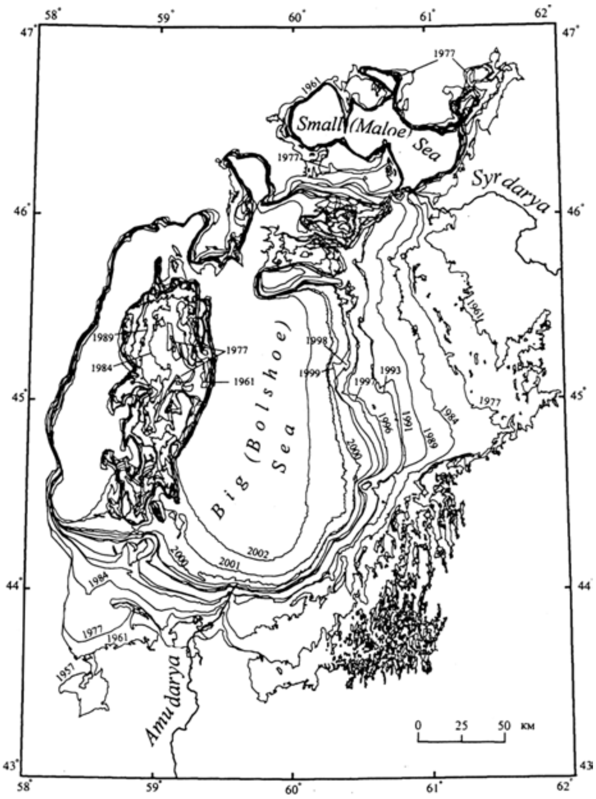

Figure.1. The map of Aral Sea coastal lines in 1957-2002.

The Aral Sea area in September 2003 was 19370 km^2, that is 29% from its area in 1961. Unknown water levels of the sea were calculated by the known sea area taking into account the dependencies between sea area and sea level received for the period when supervision were still carried out; basing on the water level volume of waters was calculated, which in turn was used for water salinity determination. By these calculations the volume of Big Aral sea water in 2001 was 279 km^3, the salinity was around 57% [Mikhailov et al, 2001]. Changes in landscapes of coastal zone have been analyzed by multitemporal space images [Kravtsova, 2001].

3. SEASONAL CHANGES OF SEA AREA AND SEA LEVEL

The opportunity to watch the Aral Sea changes during a year from opening ice to ice formation has appeared due to regular performance of space survey. The changes of the sea area and coastal line position within a year have been determined by multitemporal MODIS images. Fig.2 shows that coast line at

Table 1. CHANGES OF ARAL SEA AND ITS PARTS AREA FROM 1957 TO 2003 (km^2)

(areas of separated parts of the sea distinguished by bold)

A year	Aral Sea at whole	Big (Bolshoe) Sea			Small (Maloe) Sea
		At whole	Western part	Eastern part	
1957	**67 100**	61 200			5 900
1961	**66 400**	60 500			5 900
1977	**54 900**	50 600			4 300
1984	**47 400**	43 700			3 700
1989	41 500	**38 400**	9 400	29 000	**3 100**
1991	36 600	**33 800**	8 200	25 600	**2 800**
1993	36 000	**33 000**	7 900	25 100	**3 000**
1996	31 300	**28 600**	7 100	21 500	**2 700**
1997	31 200	**28 100**	7 000	21 100	**3 100**
1998	29 700	**26 500**	6 700	19 800	**3 000**
1999	29 300	**26 300**	6 500	19 800	**3 000**
2000	26 700	**23 900**	6 200	17 700	**2 800**
2001	24 200	**21 400**	5 700	15 700	**2 800**
2002	19 300	**16 500**	5 000	11 500	**2 800**
2003	19370	**16530**	5000	11530	**2840**

various time of a year changes its position in different directions and with various velocity. It is clear visible at shallow water eastern part of Big Sea, where spring, summer and autumn coast lines are shown. Accurate determination of sea area shows some growth of area in spring and the beginning of summer and very fast decreasing in autumn (Tab.2). Results of these measurements were compared with satellite radioaltimetry data from TOPEX/Poseidon and Jason satellites and shows good connection (Fig.3). The features of the reservoir regime, namely non-uniform falling of a level within a year: small rise in spring - early summer time and sharp falling in late summer - autumn are revealed. Such a stepped character of changes in a sea level proves to be true.

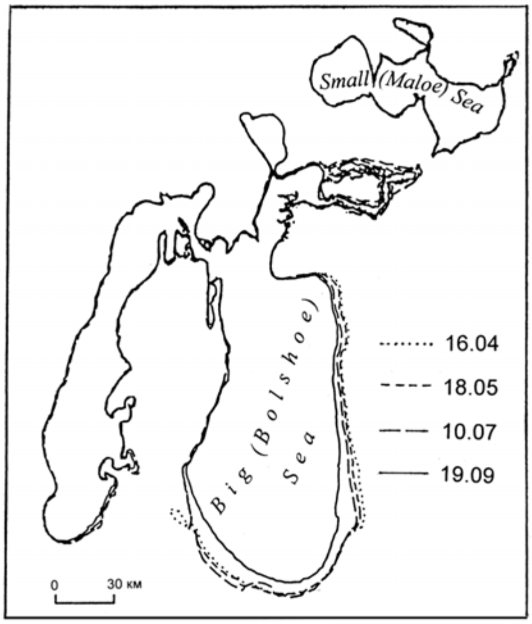

Figure.2. The Aral Sea coast line position in 2002 year. Changes in eastern part of Big Aral are evident.

Seasonal rhythm of sea level falling is explained by some reasons. In spring and early summer (March – the middle of July) the level is conserving and even small rise take place after melting of snow cover at surrounded plains and during melting of snow cover and glaciers in mountains, that stipulates the peaks of hydrographs for Amudarya and Syrdarya rivers, which give some small volume of discharge to Aral. In summer months, in spite of big evaporation, some compensation of water loss, stipulated by thermal widening, which explain the conserving of water level. At the end of summer and in autumn, when receipt of water is finishing and water is cooling, the fall of sea level is maximal. In winter months, when evaporation from aquatory covered with ice is minimal, coast line has no significant changes.

Table 2. CHANGES OF ARAL SEA AND ITS PARTS AREA DURING 2002 (km^2)

Date	Aral Sea (at whole)	Big (Bolshoe) Sea			Small (Maloe) Sea
		At whole	Western part	Eastern part	
16.04	21 700	18 900	5 200	13 700	2 800
18.05	21 600	18 700	5 100	13 600	2 900
10.07	21 900	19 000	5 200	13 800	2 900
19.09	19 300	16 500	5 000	11 500	2 800

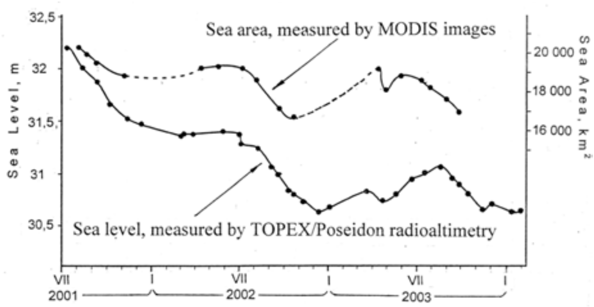

Figure.3. Connection of Big Aral area (measured by space images) and sea water level (by TOPEX/Poseidon radioaltimetry).

4. SEASONAL CHANGES OF COASTAL ZONE LANDSCAPES

For investigation of seasonal changes in the landscapes of a former sea bottom the map of natural complexes of coastal zone was compiled, where terraces of three levels are characterised, having been formed 1-2 years back, 5-6 years and to 30-40 years back. A series of maps of seasonal changes of natural complexes has been firstly compiled by images taken in April, May, July and September 2002. Seasonal changes of wetness and salinity in all wide stripe of a former sea bottom are precisely traced alongside with the changes connected to phenology of deserts vegetation, surrounding a hollow, and reed thickets of deltas.

The state of natural complexes varies here with drying of territory after winter-spring humidifying. The mode of ground salinity is closely connected to change of territory wetness. The wide stripe of terraces of the 1-st and 2-nd level is moistened in spring. The salt crust formed at the edge of these terraces owing to evaporation and perspiration; it borders the moist surface of terraces by a continues strip from 2 to 10 km in width.

As far as drying of territory, the crust dries up, being eroded by wind, becoming a source of salt storms, and gradually destroys. In 2-3 months it breaks up to separate fragments, and terraces of the 3-rd level behind them become covered by a raid of salts. By the end of summer the remains of this salt crust completely disappears. In parallel with destruction of the first salt crust (formed in spring, the thickest one) with drying of the 2-nd level terraces, at the edge of a narrowed strip of wet terraces, new strips of salt crusts are forming, moist in beginning and subsequently drying out and then destructed by deflationary processes. Salt storms and wind-inducing surges have been fixed by space images. Some time there are simultaneously two and even three strips of salt crusts, each of which is at a different stage in a cycle of formation on edge of the wet terrace, drying and then deflationary destruction. Thus, the basic processes of seasonal dynamics of territory of a former sea bottom are connected to a regime of moistening and salinization, drying of a ground and formation and then destruction of salt crusts on the edge of the narrowed humidified strips. These processes are shown at a series of maps (Fig. 4).

Colonisation of former sea bottom territory with vegetation (annual halophytes, then shrubs) is not seen on images due to rare vegetation cover. Occurrence of reed vegetation on the dried bottom is traced by a temporary run off (surface or underground); strips of a reed as though continue river channels. Incidental presence of water in southern branch of Syrdarya was observed on image taken on June 21 2002 due to humidifying of a ground in brunch continuation at terrace. An image of July 10 2002 fixed a fault of water in Amudarya delta into the sea from a wastewater basin with formation of alluvial cone, which was quickly destroyed by along-coast processes. Images shows the features of economic activities in Amudarya delta directed to preservation of extensive reservoirs here, filled at the end of summer with waste post-irrigation waters. Thus they are also objective witnesses of reasons of Aral collapse.

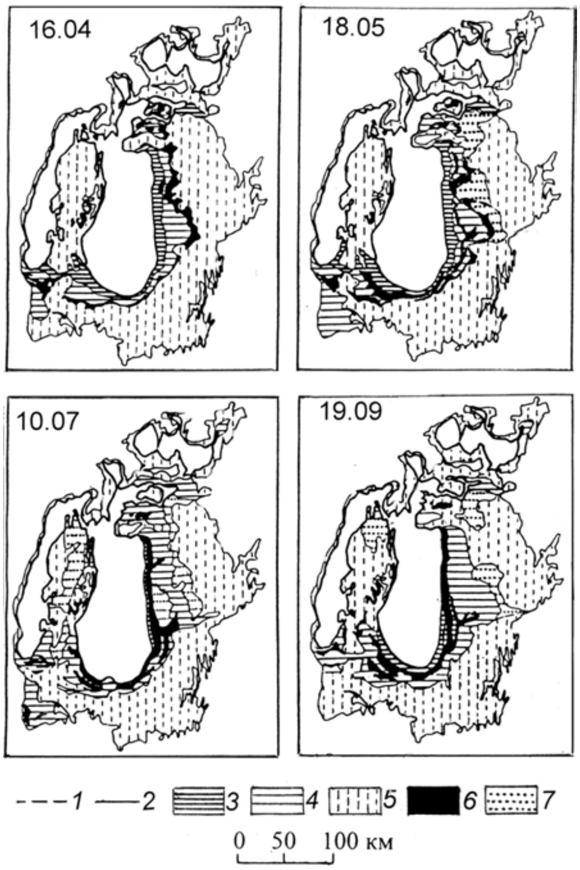

Figure.4. Seasonal changes of humidity and salinity at former sea bottom zone. Coast line: 1 – in 1961, 2 – in 2002. Parts of former sea bottom: 3 – strong wet, 4 – moderate wet, 5 – dry, 6 – salt crusts, 7 – plots with salt accumulation after salt crusts erosion by wind.

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REFERENCES

V.I. Kravtsova. “Analysing of Aral Sea coastal zone dynamics in 1975-1999” / Vodnye Resursy, 2001, vol.28, N6, pp.655-662 (in Russian)

V.I. Kravtsova, I.K. Lourie, T.M. Mudrya “Monitoring of Aral Sea degradation from space” / Geodesy and Cartography, 2002, N10, pp.46-53 (in Russian)

V.N Mikhailov., V.I Kravtsova., F.N Gurov, D.V Markov, M. Greguar “Estimation of Aral Sea recent state” / Vestnik Moskovskogo Universiteta, ser. 5 – Geography, 2001, N6, pp.14-21 (in Russian)