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Analysis of the Shoaling of the Aral Sea by Effective Albedo

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Abstract. This article discusses the current situation in the shoaled areas of the Aral Sea based on the photos made from Terra and Aqua satellites.

Key Words and Phrases: satellite data, optical parameters, effective albedo, desertification

2000 Mathematics Subject Classifications: 97K80, 62M15

1. Introduction

The availability of scientific methods for exploring the shoaled and flooded areas with the use of special measurement systems installed on geophysical satellites is of great importance today. The data provided by the satellites at different times is playing an important role in controlling the dynamics of river course changes.

First studies of water-level in the Aral Sea date back to the 19th Century. Until the mid-20th Century, there were almost no dramatic changes in the water-level in the Aral Sea. At those times, the Aral Sea was one of the four largest lakes in the world with an area of 68,000 square kilometres. With a length of 426 km and a width of 284 km, it had a maximal depth of 68 m. Amu Darya and Syr Darya were the rivers that fed it. Since the mid-20th Century, those rivers have been used for the irrigation of cotton and rice plantations in Central Asia, and this significantly reduced the water volume of the Aral Sea. The total volume of precipitation in this region is incomparably less than the amount of vaporizable water. At the end, the Aral's sea level started to drop since 1961.

In this work, we analyze the situation around the shoaled areas of the Aral Sea using spectrometric data provided by the satellites over the past years. Our approach is based on the calculation of digital values of the spectral effective albedo of the atmosphere-underlying surface system which is the main optical parameter used in the exploration of Earth surface via satellite.

2. Methodology and The Analysis of Obtained Results

Photographing the Earth's surface from the space is closely related to the two-dimensional distributions of the flux of radiation reflected by the atmosphere-underlying surface system. The main optical parameter that characterizes the radiation properties of the environment (or the object) is effective albedo. On the upper boundary of the atmosphere, the albedo is defined by

$$\bar{A}(z=\infty)=\frac{F^{\uparrow}(z=\infty)}{\pi F_0\cos\theta_0},$$

where $\bar{A}(z=\infty)$ is the relationship between the extra-atmospheric stream of sunlight $\pi F_0\cos\theta_0$ and the energy reflected by the Earth surface. Spectral albedo is determined by the reflected part of the flux of spectral radiation. Photometric data related to the Earth surface is usually more comprehensive on the visible part of spectre. The maximal value of albedo is reached on the solar wave of length λ=0,55 mkm. The range of albedo on the surface strongly depends on the humidity of that surface.

Photographs taken by satellite make the exploration of Earth surface more comprehensive and more reliable. A lot of special applications have been designed for the processing of digital images. Image Processor is one of them.

Figure 1 is a collection of photographs of the Aral Sea taken at different times. All those photos are made by Terra and Aqua satellites equipped with MODIS technology. Figure 1 reveals the shoaling dynamics in the Aral Sea. Space observations of the last 10 years testifies to the significant growth of shoaled areas.

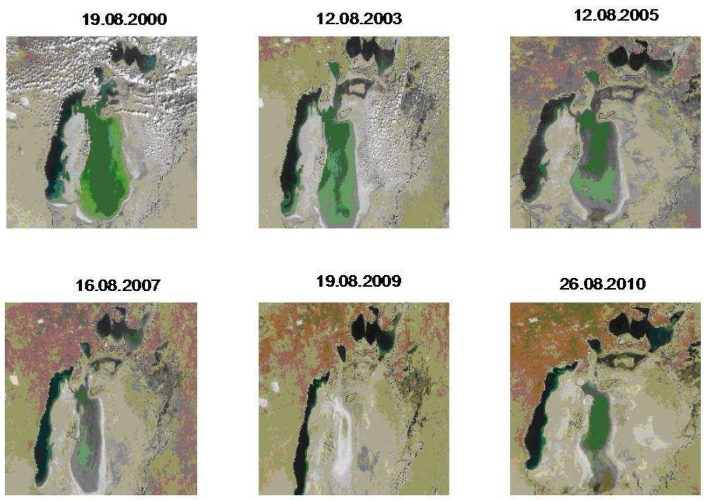

Figure 1. Surroundings of the Aral Sea as photographed from satellite

Since 1989, the Aral Sea has splitted into two different water basins – the North Aral Sea and the South Aral Sea. In 2003, the South Aral Sea, in turn, splitted into the western and eastern basins as a result of shoaling. Also, water level decline was the reason the Vozrozhdenie island turned into a peninsula in 2001. From 1960 to 2003, the surface area and the water volume of the Aral Sea shrinked to 25% and 10% of their original sizes, respectively, as a result of shoaling.

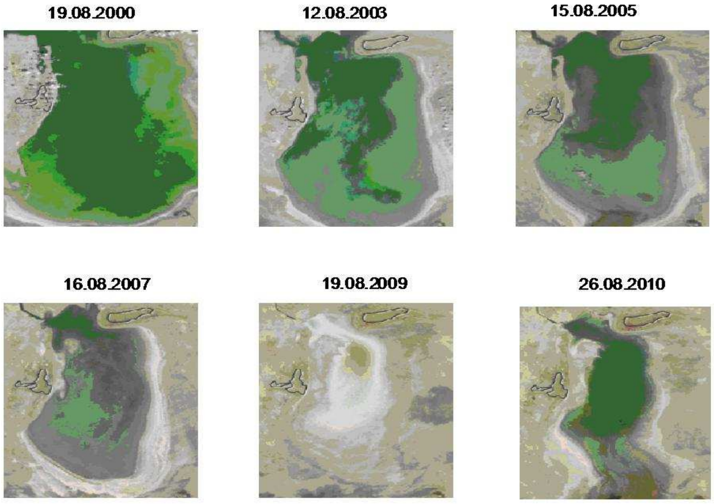

Figure 2. The Eastern Aral Sea as photographed from satellite

Figure 3 shows the two-dimensional distributions of the effective albedo of the eastern parts of the Large and Small Aral Seas. To get the images in this figure, distributions of reflected luminous flux have been estimated using Image Processor, with the upward luminous flux and the inclination of luminous flux taken in accordance with the solar constant and the upper culmination of the Sun, respectively, at the height of the aerial photography.

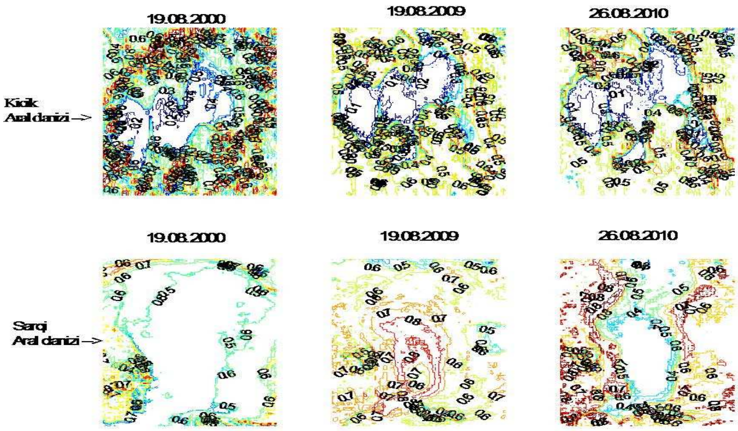

Figure 3.Distribution of the Isolines of Effective Albedo in Surroundings of the Aral Sea

Table 1 shows the variations of water surface area of the Aral Sea between 1960 and 2010. We can see that the surface area of the Aral Sea has drastically shrinked over the past 50 years. The variations of effective avbedo of some part of the surface are closely related to the characteristics (humidity, shoaling) of that part. Figure 3 shows the distribution of the isolines of effective albedo in different parts of the Aral Sea based on the satellite-made photos taken at different times. We can also see that the variations of albedo in the Small Aral Sea are less dynamic than those in the Eastern Aral Sea. As a result of shoaling, the percentage of the parts of the Eastern Aral Sea with albedo varying between 0.5≤ A ≤0.85 has sharply grown in 2000-2010, while the percentage of those with albedo varying between 0.2≤ A ≤0.35 has sharply reduced during the same period.

Table 1. Aral Sea's water resources

	1960	1990	2003	2004	2007	2008	2009	2010
Water level , m	53,40	38,24	31,0					
Water volume, km	1083	323	112,8		75			
Water surface area, thousand km	68,90	36,8	18,24	17,2	14,183.	10,579	11,8[]	13,9

3. Conclusion

Two-dimensional distributions of the effective albedo of the shoaled areas of the Aral Sea are determined in this work using satellite-made images. The following results are obtained:

1. shoaling process in the Eastern Aral Sea is more dynamic than in the North and Western Aral Seas;
2. effective albedo of the shoaled areas varies between 0.5≤ A ≤0.85.

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