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e-mail: nicole.delpeche@gmail.com**STUDYING UPWELLING PHASES IN THE KAZAKHSTAN
PART OF THE CASPIAN SEA**

Abstract. The process of upwelling is the rise of cold water masses to the surface of the reservoir and is the subject of study around the world, because this process affects many water parameters. Upwelling increases biological productivity and provides nutrients to marine fauna, partially causes changes in the mass of coastal waters, and the influx of cold water can affect local changes in the climate cycle.

In open and closed reservoirs, the process occurs in different ways. The Caspian Sea is a closed reservoir where the upwelling process is observed in the summer. In the article, based on satellite data of sea surface temperature, as well as local data on wind speed and direction, the phases of upwelling in the Kazakh part of the Caspian Sea, which occurred in the period from June 5 to August 22, 2017, are determined. The influence of constant North and North-East winds on the stages of upwelling development is shown, the spatial and temporal scales of the process development are determined.

Key words: process of upwelling, mass of coastal waters, satellite data, Ekman transfer, SNAP program.

Introduction

The upwelling process is the lifting of nutrient-rich colder waters from the depth to the upper layers [1]. The process occurs in coastal and open areas of the oceans and seas [2, 3, 4].

A strong constant horizontal wind creates tension in the surface layer of the reservoir, which is transmitted to the lower layers. A surface force occurs, is balanced by the Coriolis force of the next layer, and an Ekman spiral is formed, along which water masses are transferred from the depth to the surface. This effect was first physically explained by the Swedish oceanographer Vagn Walfrid Ekman and is called Ekman transfer [5].

The upwelling process can consist of two phases: the active phase and the relaxation phase. In the active phase, there is a strong constant horizontal wind, which causes the transfer of Ekman. The relaxation phase occurs when the wind force decreases, while the Ekman transfer is also observed, strong temperature changes persist, but the process gradually fades. According to [6], these phases can be divided into three stages depending on the wind speed: the first stage reflects the active phase with Ekman transfer, the second stage describes an intermediate state covering

the end of the active phase and the beginning of the relaxation phase, and the third stage characterizes the end of the upwelling process.

There are generally accepted classifications of the following types of upwelling: Equatorial, coastal, neoceanic, artificial, etc.

The largest Equatorial upwelling of the open ocean is located near the equator in the Eastern Pacific ocean [2].

Coastal upwelling have been well studied off the North-West coast of Africa near the Canary Islands, in the southern regions of the African coast at latitudes 5-30°, in the Gulf of Guinea, on the Pacific coast of South America in the area of the Peruvian current, etc. In General, stable coastal upwelling are observed mainly at the Eastern edges of the oceans and seas.

The process of coastal upwelling occurs differently in open and closed reservoirs. Coastal upwelling in the Eastern part of the Baltic Sea regularly affects the Gulf of Finland, which is about 400 km long and 100 km wide [7]. A group of Estonian scientists is actively working on the problems of wave dynamics of closed reservoirs. They regularly conduct measurements to track currents in the upper water layer at a test site located near the southern coast of the Gulf of Finland and the Baltic Sea. They have obtained interesting

results that can be used in the study of similar processes in the Caspian Sea, similar in type to the Baltic Sea.

In the Caspian Sea in the summer, wind-induced upwelling results in a noticeable decrease in temperature and an increase in biomass in the upper layer of the Eastern part of the reservoir [8, 9, 10, 11, 12]. A number of Russian scientists have studied and recorded changes in the surface temperature of the Northern part of the Caspian Sea using a very high resolution radiometer (AVHRR). In addition to instrumental measurements of water flow velocity, the dynamics of the Caspian Sea can be studied with high accuracy using remote sensing data from space (satellite altimetry) [13, 14, 15, 16, 17]. Iranian scientists are exploring the southern part of the Caspian Sea using the optical flow (OF) method, or the so-called Horn-Shunk method. This method makes it possible to study small-scale processes in small regions, providing information about the intensity of movements in each pixel with high spatial resolution [18]. But the disadvantage of this method is that the optical flow looks smooth on all images, and to determine the temperature difference, you need to enter parameters for the size of the smoothness, which must be selected accordingly, which is quite a time-consuming task [19].

Mesoscale dynamics of the Caspian Sea is also analyzed using SET satellite data to record fast submesoscale currents. Thus, in [20] to better understand the process of mixing and transport at mesoscales, the seasonal circulation of the Caspian Sea caused by wind was studied.

Statement of the problem

The Caspian Sea is characterized by the phenomenon of upwelling, which is most clearly expressed near the coast of the Middle Caspian. The main cause of the process is constant North and North-easterly winds. The process of upwelling in June-August 2017 is investigated. SST data from the Earth observation satellite system (EOS) is used to obtain moderate resolution images (MODIS Aqua level 2 (MODIS heat bands 31 (11 μ) and 32 (12 μ)) from the NASA OceanColor open access website (<http://oceancolor.gsfc.nasa.gov/>).

Adequate information on wind data is needed to account for atmospheric impacts. For this purpose, we use local data on sea wind measured at the Fort Shevchenko station. Station Fort Shevchenko is located on the Eastern shore of the Caspian Sea in Bucinskas Bay, which is part of the Tyub-Karagan

Bay, and is located on the sandy Tyub-Karagan spit that separates the Bay from the sea. The zero mark of the post is 28.00 m BS (Baltic system). Coordinates of the post: latitude 44°33', longitude 50°15'. Since there was no reliable information about the stability of the air flow during the study interval, a constant correction factor of 0.85 was applied. This coefficient was chosen because it was calculated for similar conditions of a closed reservoir [12].

Results

SST maps do not allow you to determine the start of the upwelling process when cold water has not yet reached the sea surface. According to SST, upwelling becomes apparent when cold water reaches the surface layer. The data was processed in the SNAP (Sentinel Application Platform) program developed by the European space Agency (ESA). The program allows you to quickly create images taking into account atmospheric phenomena and displaying error areas, and determine the location of an object with convenient graphical processing (GPF). Advanced level management allows you to add and process new overlays, such as images from other bands, images from WMS servers, or ESRI shapefiles. ESA toolboxes support the scientific operation of ERS-ENVISAT and Sentinels 1/2/3 missions.

The obtained research results are shown in figures 1-3. Figure 1 shows the results of processing SST data in the SNAP program. Figure 2 shows a graph of wind speed and direction using local data, and figure 3 shows a calculation of temperature propagation depending on the distance from the coast using satellite data. Figure 2 and figure 3 were obtained using the MatLab program.

The SST maps (Fig.1) show that upwelling was caused by constant North and North-westerly winds that blew from 1-4 June 2017 at an average speed of 4.25 m/s (Fig. 2). According to satellite data, since June 5, 2017, the SST has decreased from 18° C to 15° C (Fig.1, a). By mid-June 2017, cold water filled a 300 km long coastal zone along the Eastern coast of Kazakhstan (Fig.1, b-d). This water soon formed jets (Fig.1, e-g), which reached a distance of 50 -55 km from the coast, as shown in Fig.3. The legend indicates the month / date. At the last stage 3 of upwelling, starting from July 28, the average wind speed fell below 5 m/s (Fig.2).

For consistency, the daily rate of temperature change was calculated from SST data. During the first phase of the rise of colder water to the surface layer (stage 1), the temperature dropped by about 1° C per day.

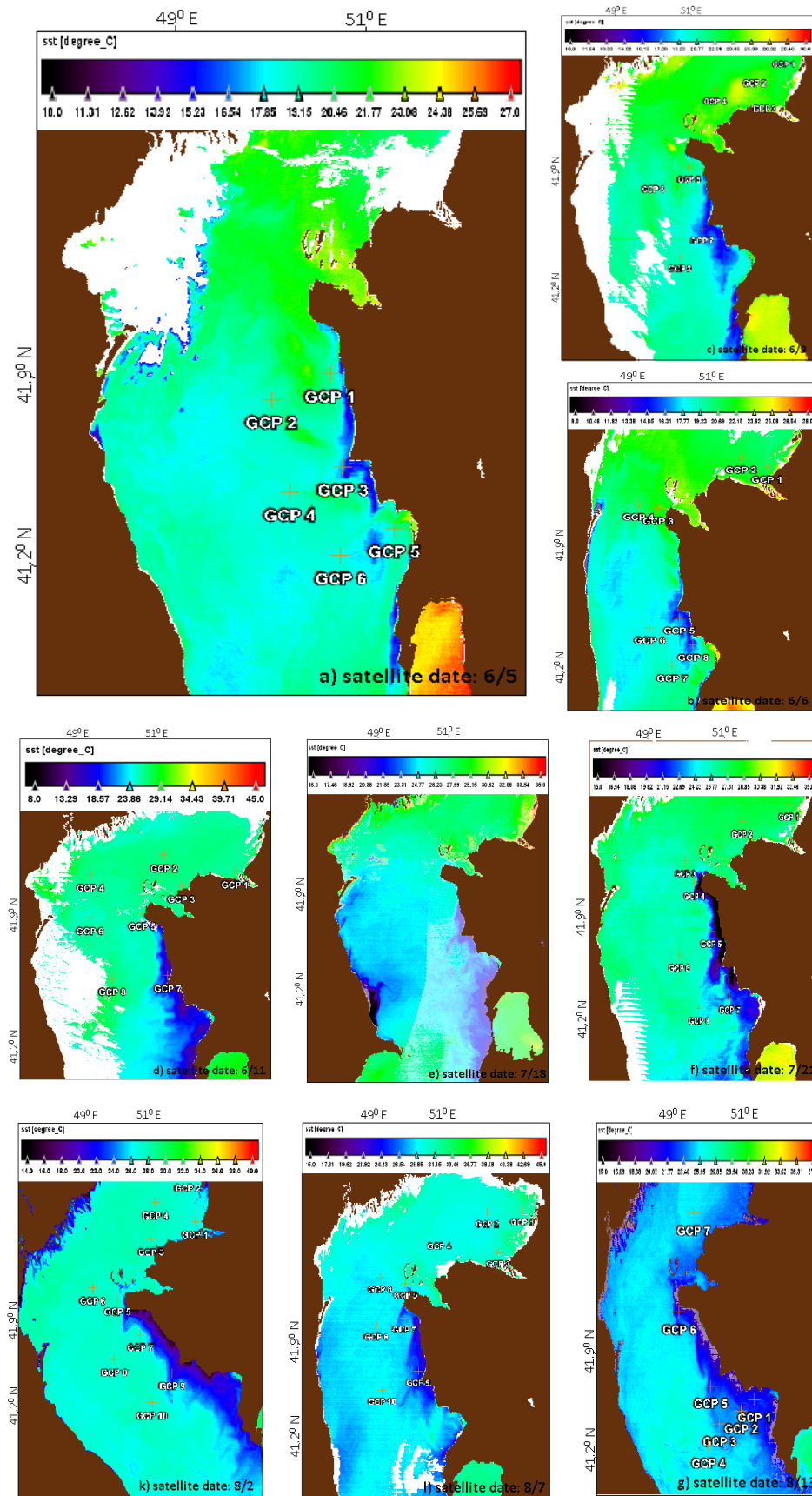


Figure 1 – SST maps of the Caspian Sea, cold-water distribution on the surface

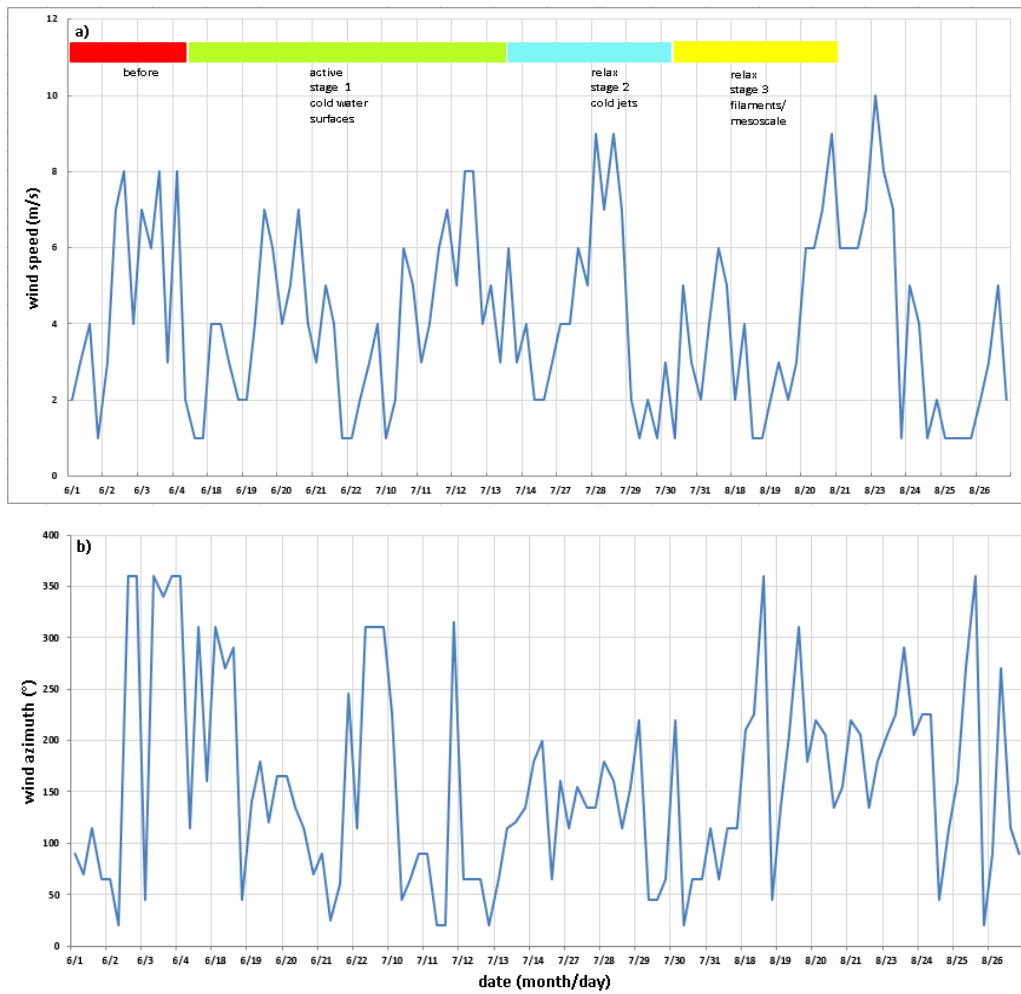


Figure 2. Values of wind speed (a) and wind azimuth (b) according to the Fort Shevchenko station at various stages of upwelling

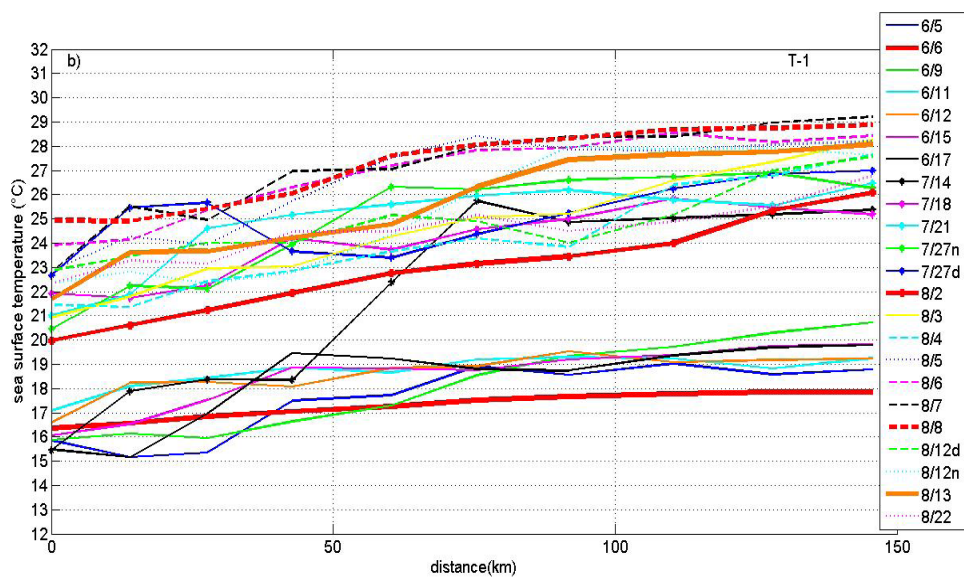


Figure 3 – Graph of temperature changes depending on the distance from the coast

This decrease was most intense at a distance of 50 km from the coastline and was significantly less away from the coast. During the next period of relatively strong winds (stage 2), the SST gradually increased, on average, by about 0.5°C per day. The subsequent relaxation phase (stage 3, June 11-15) was characterized by a decrease in wind speed. A much faster increase in SST (by 0.5-1°C per day) indicates the presence of intense mixing, which is most noticeable at a distance of 50-100 km from the coast.

Upwelling begins in June, but it reaches its highest intensity in July and August. As a result, there is a decrease in temperature on the water surface (by 13-15 C°). SST data at the time of their explicit presentation on June 5-August 22 as clearly distinguishable sections of colder water on the surface of the sea allowed us to determine its spatial and temporal scales and study the spatial distribution of waters.

Thus, on SST maps, the upwelling process is clearly visible in the Eastern part of the Caspian Sea. Using local wind data and SST data, the temperature changes relative to the distance from the coast were calculated and the upwelling phases were determined, when cold water reaches the sea surface, forms water jets with low mixing intensity, and then the water jets mix intensively in weak winds.

Conclusion

The phases of the upwelling process that took place in the Middle part of the Caspian Sea in the period from June 5 to August 22, 2017, as well as the spatial and temporal scales of the process development were Determined.

It was found that the nature of movements in the surface layer of the sea strongly depends on the wind speed. For moderate (6-10 m / s) and strong (>10 m / s) winds, the Ekman transfer is formed. For a weak wind (<5 m/s), intensive mixing of different temperature waters occurs, which leads to the last stage of the process.

In the areas under consideration, upwelling reaches its highest intensity in July-August, with a temperature drop of 13-15 C° observed on the water surface.

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