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ABOUT THE EFFICIENCY OF ACTIVE INFLUENCES ON THE ATMOSPHERIC PROCESSES AIMING AT THE ARTIFICIAL INCREASE OF PRECIPITATION OVER THE CRIMEAN PENINSULA IN SEPTEMBER 2020

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The natural arid climatic conditions, unfavorable climate change, cessation of fresh water supplies from the mainland of Ukraine, as well as intensive water use, have caused a decrease in water content of reservoirs and freshwater shortage on the Crimean Peninsula [1,8]. Climate change in recent decades on the peninsula, especially in the steppe zone, has become more noticeable due to the increased frequency of abnormally high summer temperatures (above 30 °C), intensification of evaporation, decrease in precipitation, especially during warm season, and due to warm winters with the increased variability of weather conditions [1, 8].

The lack of fresh water on the peninsula, which has arisen not only due to natural reasons, was tried to be solved in several ways: brackish groundwater and seawater desalination; using groundwater resources from wells; artificial increase of the amount of atmospheric precipitation by active influence on the atmospheric processes, as well as, for example, water supply to Simferopol from the Taigansky reservoir, located in the Belogorsk region.

In order to solve the problem with a fresh water shortage and to fill the reservoirs on the peninsula, the active influences on atmospheric processes were applied on 29^{th}–30^{th} of September 2020, aimed at the artificially increase of atmospheric precipitation. The active influence on atmospheric processes may course the increase in the amount of atmospheric precipitation directly in the affected zone by 1.5–2.0 times, as well as the increase in seasonal amount of atmospheric precipitation in the affected zone by around of 15–30% [2].

The effectiveness of this work over the Simferopol region was analyzed based on literature sources, available observation data from meteorological stations in Simferopol and Dzhankoy (resource used [6, 8–10, 12]) and radar remote sensing data from Sentinel-1 (satellite imagery processing was conducted in Google Earth Engine, a web platform for cloud processing of remote sensing data) (resource used [3, 11]). Since 2014, the access to weather data from the peninsula is complicated.

Active influences on atmospheric processes in September 2020. The negative situation with the shortage of fresh water on the peninsula has become even more complicated in 2020. Major cities turned out to be the most vulnerable. Simferopol

city, with the required water consumption of about 160,000 m^3/day, was provided with only 100,000 m^3/day of fresh water. Therefore, the regime of scheduled hourly water supply was introduced in Simferopol and another 39 settlements of the Simferopol region due to the fresh water shortage in August 2020 and the reservoirs with drinking water were additionally installed on the streets of the city (resource used [4]).

The precipitation sum amount of 135–140 mm was recorded at the Simferopol meteorological station during three summer months from June to August 2020 (with a climatic norm of 149 ± 32 mm), and 115–120 mm at the Dzhankoy meteorological station over the same period (with a norm of 122±31 mm), which is only 7–9% below the norm. However, weather conditions, intensification of water intake for domestic, economic and military needs, as well as a low water level in reservoirs (due to depletion of fresh water reserves over the past years) further aggravated the situation with a shortage of fresh water on the peninsula.

Weather conditions in September-October 2020 in Crimea were characterized by warm and predominantly dry weather, but on September 29 – October 2, the peninsula was influenced by the Balkan cyclone and the associated cold front [10]. These weather conditions were used on September 30 to introduce the active influences on the atmospheric processes aimed at additional precipitation and filling of reservoirs (resource used [5]). Fig. 1 shows a satellite image of cloud cover acquired by Proba-V satellite during the passage of the Balkan cyclone and the associated cold front during on September 30, 2020.

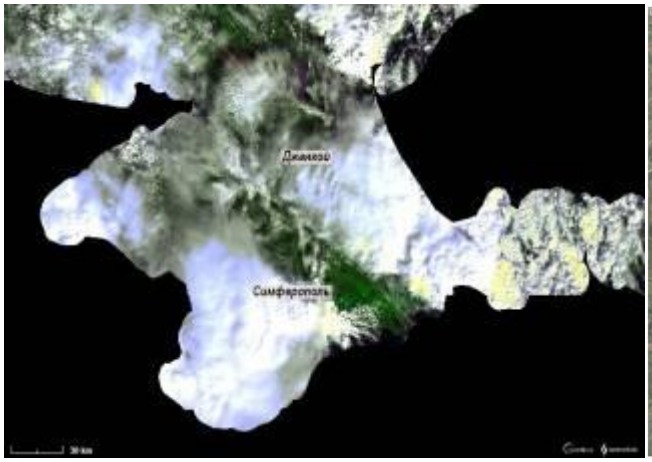

Fig. 1. Satellite images of cloud cover (Proba-V) during the passage of the Balkan cyclone and the associated cold front after its application on September 30, 2020

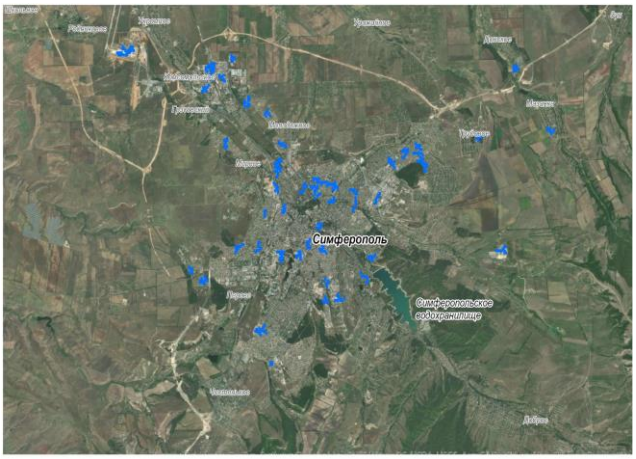

Fig. 2. Map of flooding zone (blue color) and areas of open water surfaces (dark green color) near Simferopol city after the application of artificial influence on the atmospheric processes on September 30, 2020.

In accordance with the data of ground observations at the Simferopol meteorological station for the period from September 28 to October 2, 2020, during the passage of the corresponding synoptic processes and as a result of active influences, an additional increase in cloudiness by 15–20% during 1–2 days was

recorded, as well as the increase in relative humidity up to 25–30% and the atmospheric precipitation amount of 46±7 mm (the monthly total atmospheric precipitation in September 2020 was about 51 mm/month) with a climatic norm of 37±23 mm/month for September in the period of 1961–90. Thus, as a result of active influence on the atmospheric processes over Simferopol, the precipitation of almost ~125% of the monthly norm of September was recorded.

At the same time, at the Dzhankoy meteorological station (~100 km north of Simferopol) for the period from October 28 to November 2, 2020, according to the recorded observations, a continuous cloud cover was noted and the precipitation amount of 63±8 mm was recorded (with a climatic norm of September 33±28 mm/month).

Fig. 3 shows the changes in meteorological parameters (cloud cover, precipitation and relative humidity) due to the certain synoptic processes and the active influences on the atmospheric processes in order to obtain the additional atmospheric precipitation during Balkan cyclone and the associated cold front at the weather stations Simferopol and Dzhankoy for the period from September 28 to October 2, 2020. The cloud cover thickness is presented as a percentage of the amount of all observed clouds or their absence.

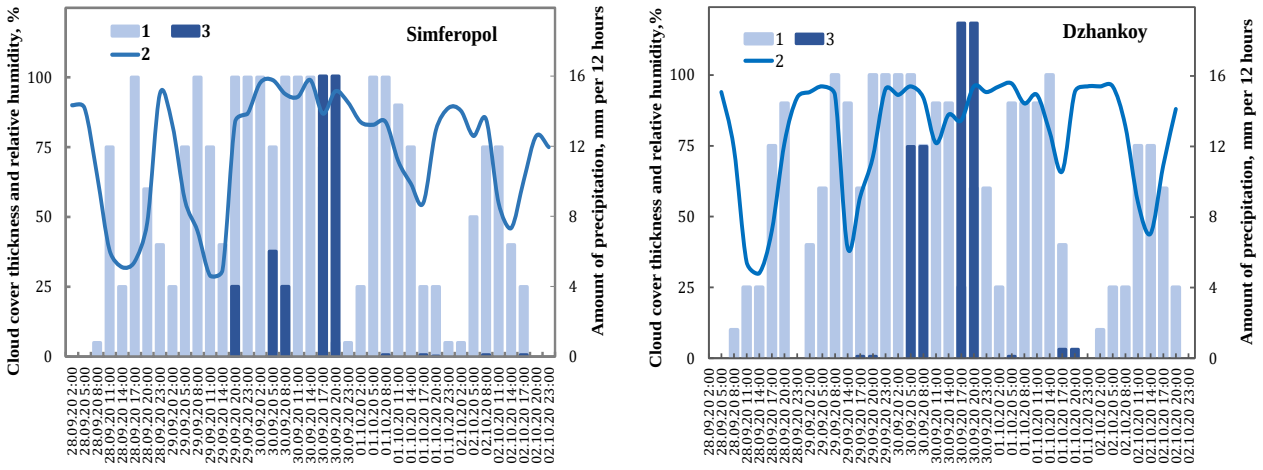

Fig. 3. The daily variation of the cloud cover thickness (1 – scale on the left), relative air humidity (2 – scale on the left) and the amount of precipitation (3 – scale on the right) at the Simferopol and Dzhankoi meteorological stations for the period from September 28 to October 2, 2020 during active influences on the atmospheric processes

Using the Sentinel-1 SAR images, the spatial distribution of atmospheric precipitation and cloud cover was analyzed before and after the application of active influence on atmospheric processes. The satellite data were compared for the period from 01.09 to 25.09.2020 and the period after active exposure on 30.09 to 05.10.2020 (resource used [3, 11]).

From satellite images in a given sector it can be seen that the precipitation occurred over Simferopol. As a result, flooding zones were recorded within the city, while an increase in the surface water in the Simferopol reservoir was not detected. The map shows the flooding areas marked in blue color, as the consequences of the

rainstorm, and the open surface water of the Simferopol reservoir marked in dark green (see Fig. 2).

It also became known from the media that Simferopol was hit by heavy rain on September 30, 2020, which caused large-scale flooding in the city (resource used [7]). Unfortunately, the work on active influence on atmospheric processes in favorable weather conditions this time did not affect the filling of the reservoirs. Note that the targeted precipitation in a certain location is a rather complex applied problem [2].

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