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ANALYSIS OF DROUGHT CONDITIONS IN ARMENIA  
IN JUNE 2021 USING OBSERVATIONAL AND SATELLITE DATA

H. H. AZIZYAN<sup>1,2\*</sup>, H. S. PANYAN<sup>1,2\*\*</sup>, A. M. GEVORGYAN<sup>1,2\*\*\*</sup>,  
Ye. S. KHALATYAN<sup>1,2\*\*\*\*</sup>, S. H. GIZHLARYAN<sup>1\*\*\*\*\*</sup>, H. V. ASTSATRYAN<sup>2\*\*\*\*\*</sup>,  
V. G. SAHAKYAN<sup>2\*\*\*\*\*</sup>, L. V. AZIZYAN<sup>1\*\*\*\*\*</sup>

<sup>1</sup> “Hydrometeorology and Monitoring Center” SNCO, Armenia

<sup>2</sup> Institute for Informatics and Automation Problems of the NAS of the RA

In June 2021, the RA experienced an unprecedented high temperature for 1961–1990 – 4.2°C above normal (13.4°C). The recorded rainfall (71 mm) was significantly below normal (27%).

The article presents maps of precipitation distribution in the territory of the Republic of Armenia in June, a comparison of satellite data and station data, as well as maps that show drought conditions.

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**Keywords:** temperature, moistening of the territory, atmospheric precipitations, climate change, drought, drought index.

**Introduction.** As a mountainous country with arid climatic conditions, Armenia is considered to be highly susceptible to climate change across its entire territory and vulnerable ecosystems. In recent years, along with the increase in air temperature and decrease in precipitation, there has also been a significant increase in the frequency and intensity of extreme weather events. These encompass a range of challenges, from droughts, heat waves, frost, and hail to forceful winds and diverse precipitation patterns. Additionally, a discernible uptick in natural disasters, including floods, inundations, and forest fires, negatively impacts ecosystems, economic stability, human well-being, and public health [1].

The global temperature for June 2021 was the fifth highest for June in the 142-year NOAA record, which dates back to 1880 [2]. The global land-only surface temperature for June 2021 was 1.42°C above average and the highest June land-only surface temperature on record. This was mainly driven by the very warm Northern Hemisphere land, which also had its highest June temperature at 1.69°C above average. Temperatures were much warmer than average across parts of North

\* E-mail: [shaykuhi86@yandex.ru](mailto:shaykuhi86@yandex.ru)

\*\* E-mail: [hasmik1292@gmail.com](mailto:hasmik1292@gmail.com)

\*\*\* E-mail: [agm86@yandex.ru](mailto:agm86@yandex.ru)

\*\*\*\* E-mail: [yelenakhalatyan@gmail.com](mailto:yelenakhalatyan@gmail.com)

\*\*\*\*\* E-mail: [sir1989arpi@gmail.com](mailto:sir1989arpi@gmail.com)

\*\*\*\*\* E-mail: [hrach@sci.am](mailto:hrach@sci.am)

\*\*\*\*\* E-mail: [svlad@sci.am](mailto:svlad@sci.am)

\*\*\*\*\* E-mail: [levon\\_azizyan@yahoo.com](mailto:levon_azizyan@yahoo.com)

America, northern South America, Europe, Africa and across parts of Asia, the Pacific, the Atlantic and the Indian oceans. North America had its warmest June on record. During the last week of June, a hazardous and unprecedented heat wave affected much of the northwestern contiguous U.S. and western Canada, with maximum (daytime) temperatures surpassing 38.0°C not typical for the region. Africa's June 2021 temperature was the highest for June, reaching the second-warmest June observed in 2020. The last three Junes (2019, 2020 and 2021) are the three warmest Junes on record. Europe and Asia (tied with 2010) recorded their second-warmest June [2].

The climatic conditions of June 2021 were studied, as it was considered the hottest and driest June in Armenia for 1935–2022. The temperature in June 2021 was 4.2°C higher than the norm of 1961–1990 (13.4°C), and precipitation was 27% of the norm (71 mm).

The average temperature in June in Yerevan was 27 degrees, the norm is 22.6°C, and the deviation from the norm was +4.4°C. Extremely hot and dry days were observed in June. The maximum temperature was observed on June 24 and was 41.1°C, which exceeds the absolute maximum ever recorded (39.8°C in 2018). Furthermore, the observed maximum daily temperatures exceeded the historical records for ten days (16–17, 19–21 and 23–27 June). Only 1.3–2.8 mm of rain was observed in June in Yerevan on 10<sup>th</sup> June, which is about 9% of the monthly norm. Daily minimum relative humidities at Yerevan-Agro station located in lower parts of the city were below 30 % during June and mainly varied between 10 and 20 %.

In Armenia, the decrease of precipitation and humidity is added to droughts the risks. In the Ararat Valley and other low-lying regions with high temperatures, the number of days with hot winds is 120 to 160 days per year, making them more vulnerable (World Bank, 2009). Poverty in drought-prone regions is above average, for example, Shirak (77.3%), Lori (16.7%), and Aragatsotn (57 %).

Droughts cause significant damage to Armenia's economy. The frequency and intensity of droughts varies. So, in the most arid regions, 10 severe droughts occur once or twice a year. Droughts negatively affect natural ecosystems, deepening desertification processes and contributing to secondary salinization. About 80% of the lands of Armenia are subject to varying degrees of desertification risk (and more than half are more high degree of desertification).

**Materials and Methods.** Data sourced from the “Hydrometeorology and Monitoring Center State Non-Commercial Organization” (HMC SNCO), along with satellite data from reputable platforms such as Global Precipitation Measurement (GPM) and Climate Hazards Group InfraRed Precipitation with Station data [3], has been employed in this study. ERA5 reanalysis was used to analyse the synoptic conditions and regional temperature anomalies over the study region [4]. The cartographic representations were generated using the ArcGIS software package, utilizing information gathered from the 43 meteorological stations operated by the HMC SNCO.

**Results and Discussion.** Fig. 1 shows the temperature anomaly of June 2021. An extremely hot temperature anomaly was observed in the entire territory of the republic. The maps were created using the data of the meteorological stations. Studying the precipitation map (Fig. 2), we notice that a significant area of the

republic was dry and very dry. In June 2021, below-normal precipitation values were observed in the entire territory of the republic with the following distribution: dry conditions were observed in the Ararat Valley, in the North-Eastern part of the republic and to the South-West, and very dry conditions were observed in the Central and South-Eastern Regions, extreme conditions were observed in the Southern coastal areas of Sevan.

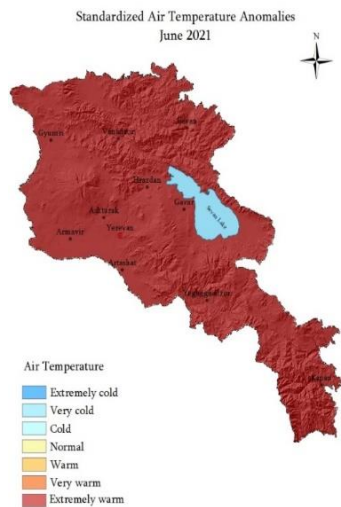


Fig. 1. Standardized air temperature anomalies June 2021.

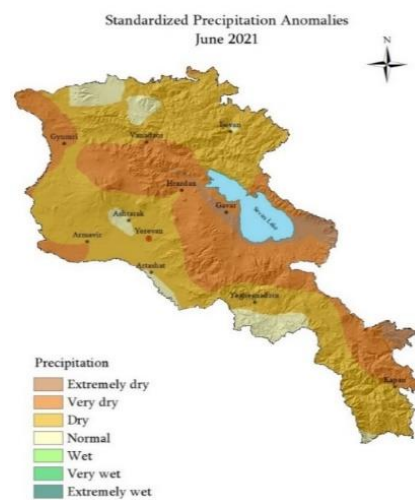


Fig. 2. Standardized precipitation anomalies June 2021.



Fig. 3. Monthly precipitation anomalies June 2021.

Fig. 3 shows the June 2021 rainfall anomaly in percent. Compared to the 1961–1990 norms, 20–40% of normal precipitation was observed in almost the entire territory of the republic, except for the northern and northeastern regions.

Furthermore, precipitation observations received from different satellites were compared with the observations of meteorological stations. In particular, the GPM satellite data was used, which provides global observations of precipitation: rain and snow.

GPM IMERG satellite data have a spatial resolution of  $0.1^\circ \times 0.1^\circ$  (or approximately  $10 \text{ km} \times 10 \text{ km}$ ), available at a 30 min time frequency. The other satellite data used is Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), which has more than 35 years of global precipitation data at a 5 km spatial resolution. Precipitation data from satellite and meteorological stations

Station data (CHIRPS), which has more than 35 years of global precipitation data at a 5 km spatial resolution. Precipitation data from satellite and meteorological stations

were analyzed and compared using the tools of the ArcGIS software package for the territory of Armenia, which is shown in Fig. 4.

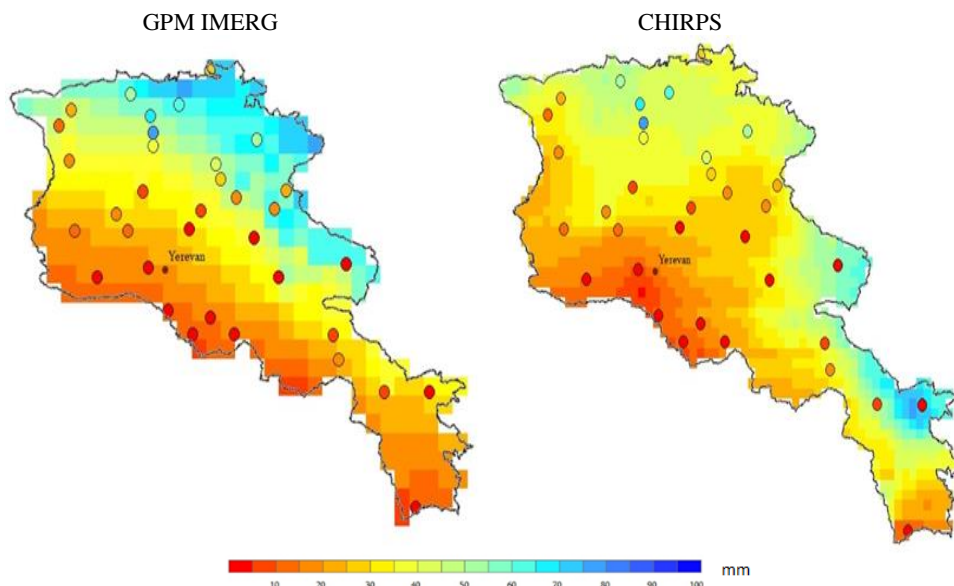


Fig. 4. Monthly precipitation for June 2021 derived from GPM IMERG (left) and CHIRPS (right) with satellite data and actual weather station data increased by dots.

Monthly temperature anomalies(deg.K) South Caucasus  
June2021 (1981-2010 base period)

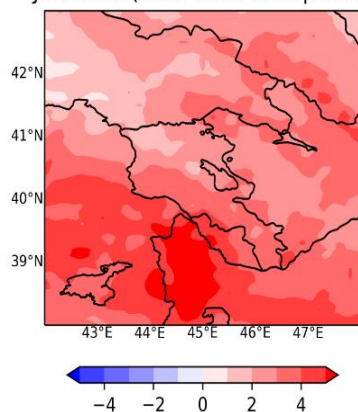


Fig. 5. Monthly temperature anomalies ( $^{\circ}\text{C}$ ) over South Caucasus in June, 2021 (1981–2010 base period) from ERA5-land reanalysis.

According to ERA5-land reanalysis data, the mean geopotential fields at 500 and 700  $hPa$  levels in June, 2021 showed that an upper anticyclone was formed over northern Africa and an upper cyclone was located to the north of the Black Sea. The southern Caucasus was under the influence of southwesterly and southerly mid-tropospheric winds advecting hot and dry air masses over South Caucasus Region [4].

Fig. 5 shows, that monthly temperatures were significantly warmer than the norms (by 3–4 $^{\circ}\text{C}$ ) over the entire South Caucasus Region in June 2021.

Drought intensity was evaluated based on the Standardized Precipitation Index (SPI) as well. SPI is a statistical indicator, which calculates and compares the observed precipitation amount in a given month to long-term climatological precipitation distribution for the same period. SPI was calculated for monthly (SPI1) periods.

The calculation was carried out with the R-Studio software package. Monthly precipitation values starting from 1970 were used to calculate the SP index [5].

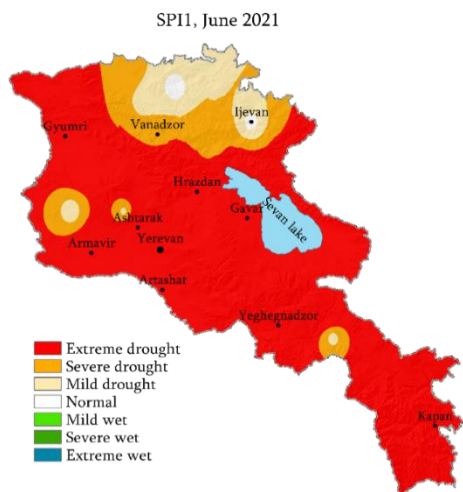


Fig. 6. SPI1 June 2021.

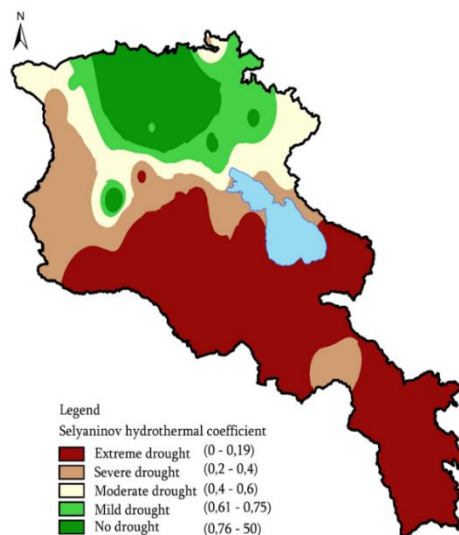


Fig. 7. Selyaninov hydrothermal coefficient, June 2021.

The map illustrates that SPI1 very clearly reflects very strong drought conditions in the territory of the entire republic.

To the north, the intensity of the drought decreases a little, which is due to relatively abundant precipitation in those regions. It can be seen by comparing Figs. 3 and 6.

Selyaninov’s hydrothermal coefficient (HTC) was used to estimate atmospheric drought [6].

$$HTC = \frac{\sum R(i + (i - 1) + (i - 2))}{0.1 \sum T \geq 10^{\circ}C(i + (i - 1) + (i - 2))}$$

where  $i$  is the number of the evaluated decade,  $(i-1)$  is the previous number of the evaluated ten-day period,  $(i-2)$  is the number of the 2 ten-day periods preceding the estimated ten-day period,  $\sum R$  is the amount of precipitation,  $\sum T \geq 10^{\circ}C$  is the sum of temperatures greater than or equal to  $10^{\circ}C$ .

Fig. 7 shows the drought conditions of the 3<sup>rd</sup> ten days of June 2021 according to Selyaninov’s hydrothermal coefficient. Here, almost the entire territory of the republic, except for the northern regions, is in extreme drought conditions.

**Conclusion.**

- Like worldwide, an unprecedentedly high temperature was recorded in Armenia. An extremely hot temperature anomaly was observed in the entire territory of the Republic. The temperature in June 2021 was  $4.2^{\circ}C$  higher than the norm.
- Precipitation was well below the norm, especially in the Central and Southern regions of the republic, and precipitation was 27% of the norm (71 mm) for the entire territory.

- According to GPM IMERG (Fig. 4), the precipitation is gradually increasing towards the northeast, and according to CHIRPS (Fig. 4), the maximum precipitation was recorded in the South-Eastern part of the country.

- In June 2021, there were extreme drought conditions in almost the entire territory of RA, except for the Northern regions, according to various drought indices calculated in this study.

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Հ. Հ. ԱՉԻՉՅԱՆ, Հ. Ս. ՓԱՆՅԱՆ, Ա. Ս. ԳԵՎՈՐԳՅԱՆ, Ե. Ս. ԽԱԼԱԹՅԱՆ,  
Ս. Հ. ԳԻԺԼԱՐՅԱՆ, Հ. Վ. ԱՍՑԱՏՐՅԱՆ, Վ. Գ. ՍԱՀԱԿՅԱՆ, Լ. Վ. ԱՉԻՉՅԱՆ

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#### Ա մ փ ո փ ու մ

2021 թ.-նի հունիսին ՀՀ-ում դիտվել է աննախադեպ բարձր ջերմաստիճան, որը 1961–1990 թթ. նորմայից (13.4°C) 4.2°C-ով բարձր է: Գրանցված տեղումները (71 մմ) եղել են նորմայից բավականին ցածր (27%):

Հոդվածում ներկայացված են քարտեզներ հունիս ամսին ՀՀ տարածքում տեղումների բաշխվածության, արբանյակային տվյալների և կայանների տվյալների համեմատության և երաշտային պայմանների վերաբերյալ:

А.О. АЗИЗЯН, А. С. ПАНЯН, А. М. ГЕВОРГЯН, Е. С. ХАЛАТЯН,  
С. А. ГИЖЛАРЯН, Г. В. АСЦАТРЯН, В. Г. СААКЯН, Л. В. АЗИЗЯН

### АНАЛИЗ УСЛОВИЙ ЗАСУХИ В АРМЕНИИ В ИЮНЕ 2021 ГОДА С ИСПОЛЬЗОВАНИЕМ ДАННЫХ НАБЛЮДЕНИЙ И СПУТНИКОВ

#### Резюме

В июне 2021 г. в РА наблюдалась беспрецедентно высокая температура за 1961–1990 гг. – на 4,2°C выше нормы (13,4°C). Зарегистрированное количество осадков (71 мм) было значительно ниже нормы (27%).

В статье представлены карты распределения осадков на территории РА в июне, сравнение спутниковых данных и данных станций, а также карты, которые показывают условия засухи.