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The impact of climate change on the hydrology of the western region of Libya

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ABSTRACT

Extreme climate phenomena have become evident at the global and regional levels, its impact on the hydrological cycle. In this methodology, which was in the western region of Libya, it was found that the surface runoff for the year 2023 for the month of February from the 21st to the 24th is very weak compared to the year 2024, which was noticeable and reached 2-4 kg m^{-2} during the days 21 and 22 and the beginning of the day 23, and this change is shown in the difference between the two years, and then decreases on the days 23 and 24, and also when taking the average and the maximum and minimum values and the anomaly, it was found that there is no change in the year 2023 and that the change in 2024, where the quantities are higher, and it results in the river discharge and was evident on the days 22 and 23 and reached 390.3, 422 $m^3 s^{-1}$, and an increase in soil moisture at the three levels and reached 0.15-0.35 m^3. m^{-3}.

Keywords: Climate change , Libya ,River discharge ,Runoff water, Soil moisture.

1. Introduction

Global warming and its subsequent effects on climate change are two examples of the irreversible harm caused by humans to the environment[1], when it comes to the influence of climate change, attaining the sustainable development objectives for watersheds and basins is the main priority of Integrated water resources management IWRM[2].The predicted increases in precipitation and temperature over the next century may significantly alter the hydrological for rivers[3], these changes will in turn affect water availability and runoff and thus may affect the discharge regime of rivers[4].

Since water is the fundamental component of the planet's life support system, it is critical to comprehend how current and future climate change will affect water availability and supplies. Based on the available data, it is clear that there is global warming [5], Increased cloud cover and latent heat fluxes are two ways that global warming might modify the hydrological cycle and cause more intense and frequent extreme precipitation events (such as floods, storms, and droughts)[6] , and the availability of moisture will be impacted by projected climatic changes in several ways over the next few decades. These effects could include lake growth in hydrothermal limestone areas with streams, changes in the timing and volume of stream flow, and reduced water levels in numerous wetlands [7], and Water quality in both inland and coastal regions is predicted to be impacted by climate change. More often occurrences of high-intensity rainfall events are anticipated, which will lead to greater runoff and erosion from the precipitation. This means that streams and groundwater systems will get more silt and chemical runoff, which will lower the quality of the water, decreases in water supply could lead to a concentration of pollutants and nutrients, further lowering the quality of the water [8].

The need for more water extraction to support the agricultural, urban, industrial, and environmental sectors has increased due to the growing global population . Therefore, for successful adaptation to climate change and its implications, an understanding of the hydrological processes connected with land surface under current and future climate variability is essential[9].

In order to better optimize water usage across several water-demanding sectors, Integrated Water Resources Management, or IWRM, was launched in the 1980s. However, since its introduction, changes in the global water cycle brought on by climate change have made water systems more complex[10]. And with this the water issue is the main effect of climate change. The effects are felt by us in the form of droughts, wildfires, decreasing ice fields, increasing sea levels, and increased floods[11].

2. Objectives of the study

1. Studying the quantities of surface runoff on the west coast from climate models and their impact on river discharge and soil moisture.

2.Determining the locations of surface runoff accumulation and their future impact on the environment.

3. Source of data

In this study use, and data is the Runoff water equivalent (surface plus subsurface) kg m^{-2} for the period from 01/01/2023 to 30/06/2023, the Runoff water equivalent (surface plus subsurface) kg m^{-2} for the period 01/01/2024-02/07/2024, River discharge for the period 01/01/2024-02/07/2024, Volumetric soil moisture m^3. M^{-3} for the period from 01/01/2024 to 31/03/2024 for each 6 hours. The data were downloaded from Climate Data Store - Copernicus [12].

4. Area of Study

The study is located in the western region in western Libya, between longitudes 11.95-16.74 E° and latitudes 28.17-32.95 N°.

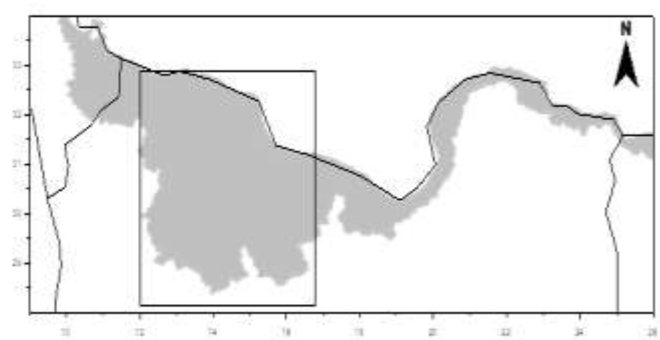


Fig.1. Area study

5. Analysis of Data

Severe changes in precipitation greatly affect environment [13], and through analyzing the total precipitation for the year 2024 for the month of February, it is noted that the amount of precipitation increases starting from the 21st at 00 hours, and in 18 hours it reaches 0.00309 m and increases more in day

22 at 00 hours by about 0.00352 m, and decreases until the 23nd and 24th, see Figure (2, a), this results in the change in the hydrological cycle was clearly evident through the analysis of the data Runoff water equivalent (surface plus subsurface) kg m^{-2}, from January until the end of June 2023 and 2024, shown in Figure (2). It was noted that during the period, the Runoff water equivalent amounts were very low and reached 0.04798 kg m^{-2} on the 21st of February at 6 pm in 2023, see Figure (2.b).

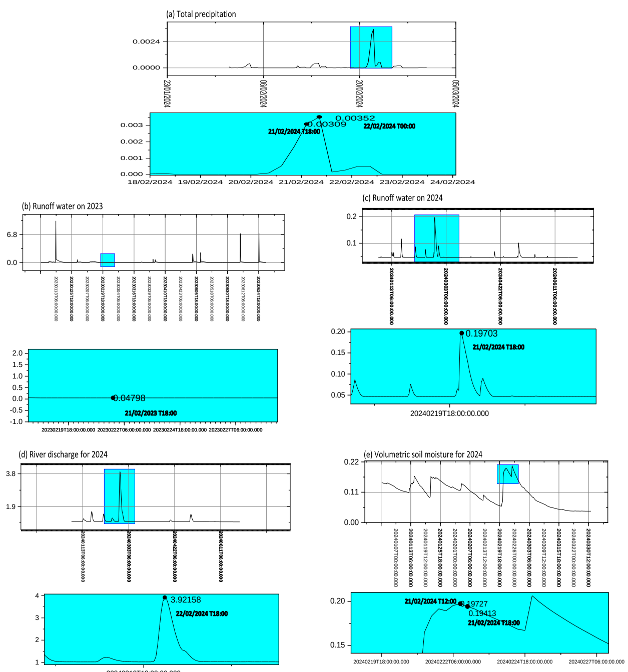


Fig.2. Analysis :(a) Total precipitation (m) for the period 01/02/2024-29/02/2024 ,(b) Runoff water equivalent (surface plus subsurface) (kg m^{-2})for the period 01/01/2023- 30/06/2023 ,(c) Runoff water equivalent (surface plus subsurface) (kg m^{-2}) for the period 01/01/2024-02/07/2024, (d) River discharge(m^3 s-1)for the period 01/01/2024-02/07/2024, (e) Volumetric soil moisture (m^3. m^{-3}) for the period 01/01/2024-31/03/2024 for western region.

Compared to Figure (2.c) for 2024, the amount was higher on the same day and hour by about 0.19703. In contrast, the water in River discharge was high in 2024 on the 21st of February at 6 pm and reached 3.92 m^3 s^{-1}, as shown in Figure (2.d), while the soil moisture in the three soil levels reached the highest value at the same time by about 0.194 m^3. m^{-3}, as shown in Figure (2.e). The analysis showed that the highest value starts from 21-02 to 24-02, so the focus was on these days for 6 hours per day. Figure (3) shows the difference in runoff water equivalent (surface plus subsurface) kg m^{-2} quantities between the years 2024 and 2023. It became clear that there was a change in the hydrology of the western region. In 2024, the surface runoff was greater than in 2023, resulting in higher quantities of water in the valleys and from there to the moisture in soil levels

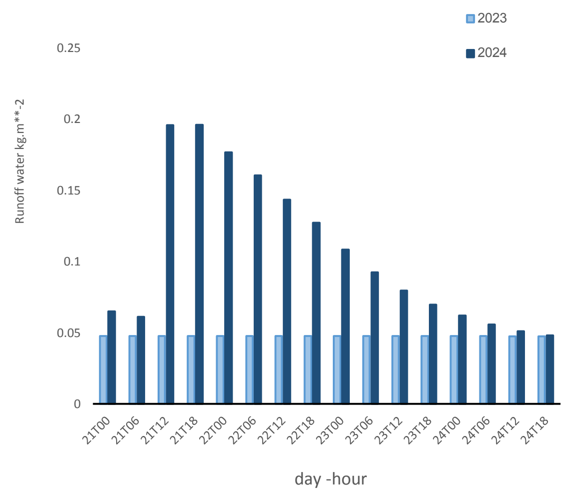
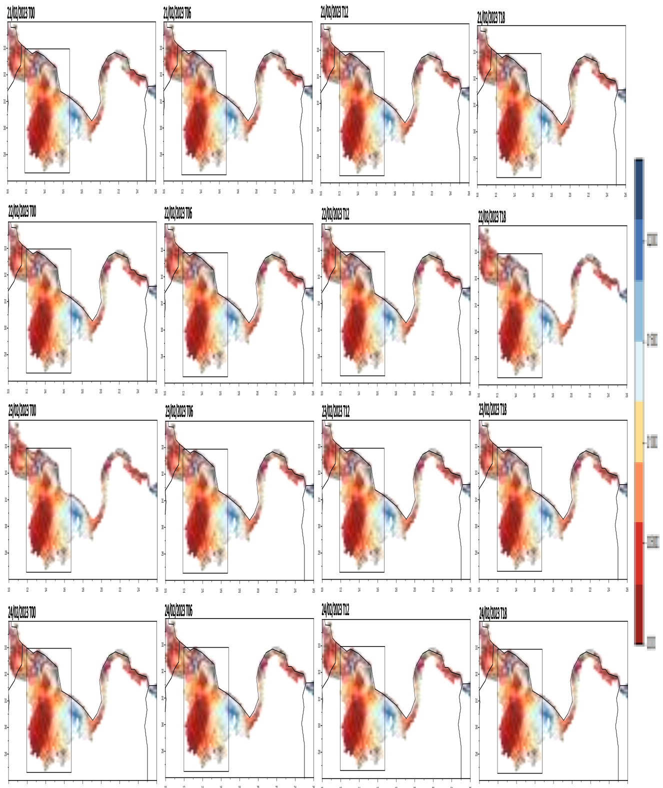


Fig.3. Runoff water equivalent (surface plus subsurface) kg m^{-2} for the 21th at 00 hour to the 24th at 18 hour at each of the years 2023 and 2024 for western region

6. Results and discussion

The effects of climate change and human activity on the hydrological cycle are significant, especially at the regional level [14], this study investigated Runoff water equivalent (surface plus subsurface) and recharging mechanisms during periods of intense precipitation this is shown analyzing the data from February 21 to 24, 2023, it was found that the surface runoff quantities are very weak, ranging between 0.15-0.04794 kg m-2, as shown in Figure (4), and that the density function for days for the surface runoff is the same, as shown in Figure (4, b), while Figure (4, a) shows the density function for hours, that the surface runoff quantities are very close to each other. In Figure (5) it shows the average quantities of surface water runoff from the 21st to the 24th, as well as the highest and lowest values, and the calculation of the anomaly showed us that there is no change in the year 2023.



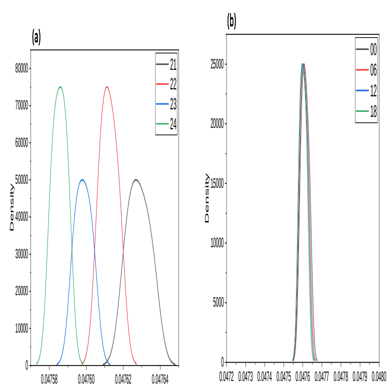


Fig.4. Runoff water equivalent (surface plus subsurface) kg m^{-2}, for the 21th at 00 hour to the 24th at 18 hour at 2023

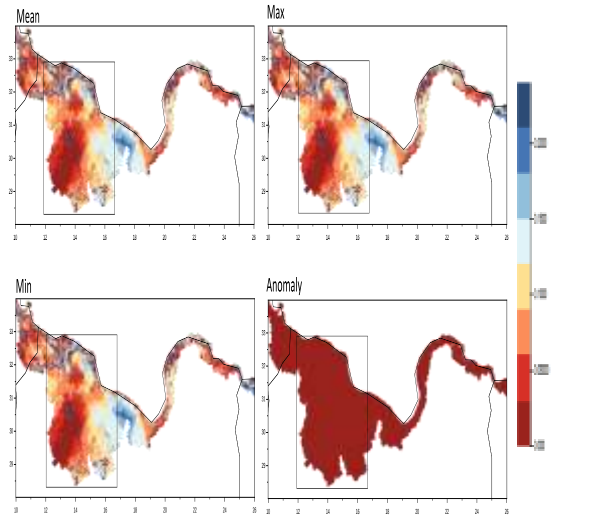


Fig.5.Runoff water equivalent (surface plus subsurface) kg m^{-2}, Mean, Max, Min, Anomaly , for the 21th at 00 hour to the 24th at 18 hour at 2023

When analyzing the data for the year 2024 to compare with the year 2023, it showed a disparity in the quantities of surface water runoff from Starting from day 21 to the 24th of February. It showed a gradual increase in the surface water runoff starting from the 21st at 00 hours by about 2-3 kg m^{-2} centered in Gharyan and extending to Mizdah. At 06 hours, it extended to the north towards the south of Misurata, Zliten and Tripoli by about 2 kg m^{-2}, and it gradually increases during the hours of 12 and 18 and reaches 4 kg m^{-2}, and the increase continues until the 22 nd at 00 hours, and begins to decrease in the remaining hours. On the 23 day, the decrease became noticeable and gradually decreased until the end of the 24th day, as shown in the density function for days in Figure (6, a), while for the density for hours, the quantities were observed at 00 hours, as shown in Figure (6, b). Figure (7) shows the average surface water flow from the 21st to the 24th day, and the quantity ranges around 2-4 kg m^{-2} in Mizdah and 2-3 kg m^{-2} in southern Misurata, Zliten and Tripoli. Also, when taking the highest value, see Figure (7, b). When taking the smallest value, the areas with the most water were shown, which are in southern Zliten and then southern Misurata. When calculating the anomaly to know the areas, it was shown in Mizdah, southern Zliten and Misurata, see Figure (7, d).

When taking the difference between the years 2024 and 2023, the areas where the increase in surface water runoff begins on the 21st at 00 hours and reaches 1.85-2.35 kg m^{-2} and increases at 06 hours to reach 2.35-2.85 kg m^{-2} and increases until the 22nd at 18 hours and reaches above 3.358 kg m^{-2} and then decreases until the 24th at 18 hours. See Figure (8) as shown by the density function in two figures (8, a, b) and also regarding the average and the highest value and the lowest value shown in Figure (9, a, b, d), while the highest value of the anomaly was in the study area. See Figure (9, c).

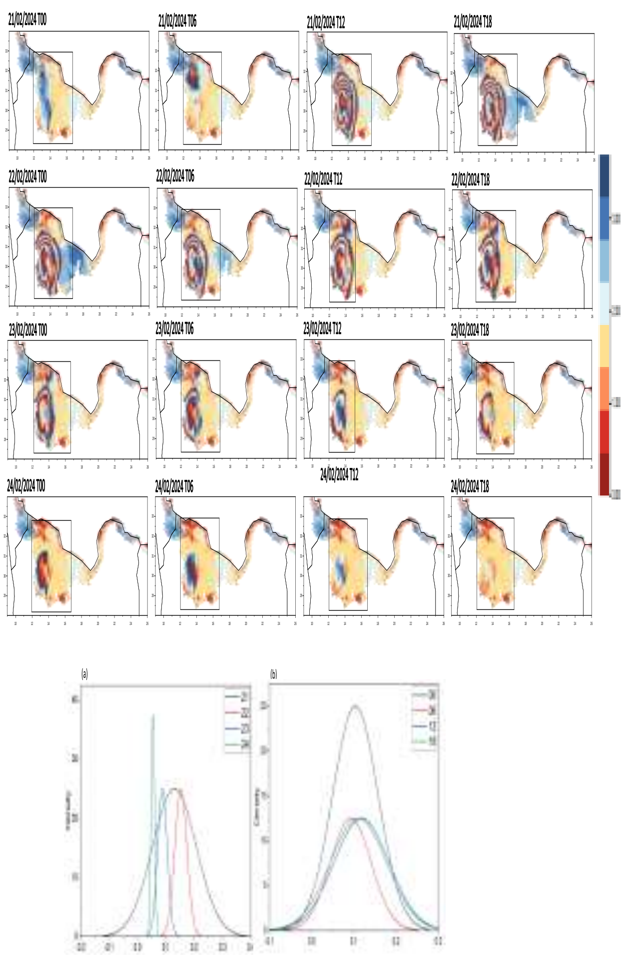


Fig.6. Runoff water equivalent (surface plus subsurface) kg m^{-2}, for the 21th at 00 hour to the 24th at 18 hour at 2024

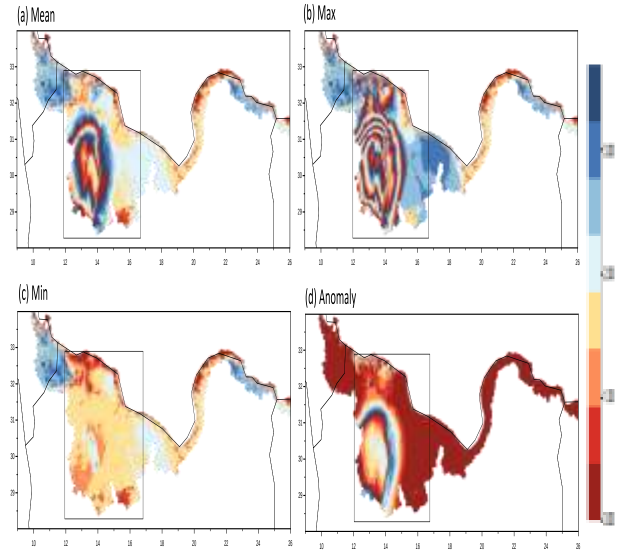


Fig.7. Runoff water equivalent (surface plus subsurface) kg m^{-2}, Mean, Max, Min, Anomaly, for the 21th at 00 hour to the 24th at 18 hour at 2024

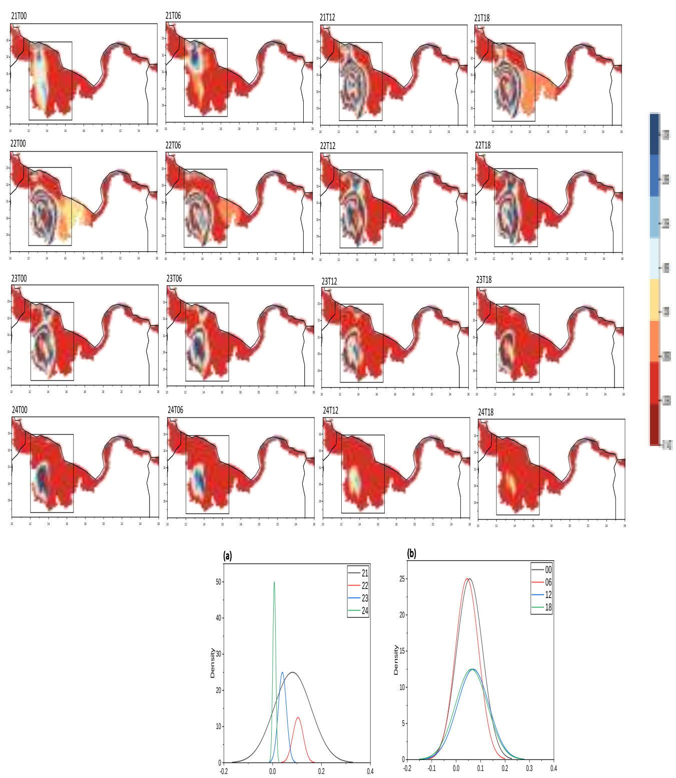


Fig.8. The difference in Runoff water equivalent (surface plus subsurface) between the year 2024 and the year 2023 for the 21th at 00 hour to the 24th at 18 hour

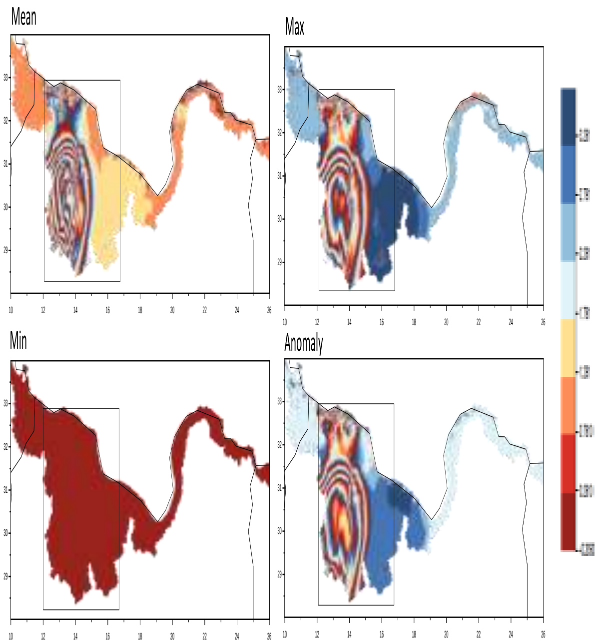


Fig.9. The difference Runoff water equivalent (surface plus subsurface) between the year 2024 and the year 2023, Mean, Max, Min, Anomaly for the 21th at 00 hour to the 24th at 18 hour

When analyzing the river discharge shown for the rivers Raml, Zamzam and Suf al-Jin in Figure (10), it increases gradually from the 21st day at 00 hours until 18 hours from 16.97-237.6 m^3 s^{-1}, while at the beginning of the next day, the 22nd, at 06 hours, the amount of water in the Zamzam Valley reaches about 339.4 m^3 s^{-1} and also increases at 12 and 18 hours by about 390.3, 422 m^3 s^{-1}, respectively. While at 18 hours it increases in Wadi Al-Raml by about 390.3 m^3 s^{-1}, and increases until the next day at 23 at 00 hours and in Wadi Zamzam it begins to decrease at the end of the 23 and 24th day as well as in Wadi Al-Raml as shown in Figure (10, a, b) for the density function, and regarding the total average of river discharge it is clear in Figure (11), and the highest value reaches in Wadi Zamzam and Al-Raml and reaches about 422 m^3 s^{-1} and also regarding the anomaly it is clear in Figure (11, d). In Figure (12) which shows the moisture level in the three soil levels it is clear that on the 21st at 00 hours there is no moisture in the soil and it gradually begins on the 21st at 06 hours in Mizdah and Gharyan and also at 12 hours it increases more and reaches 0.05-0.3 m^3. m^{-3} and at 18 hours it increases and reaches 0.15-0.35 m^3. m-3 and then on day 22 there is an increase but it starts to decrease until the end of day 24 as shown in the density function in figure (12,a,b).

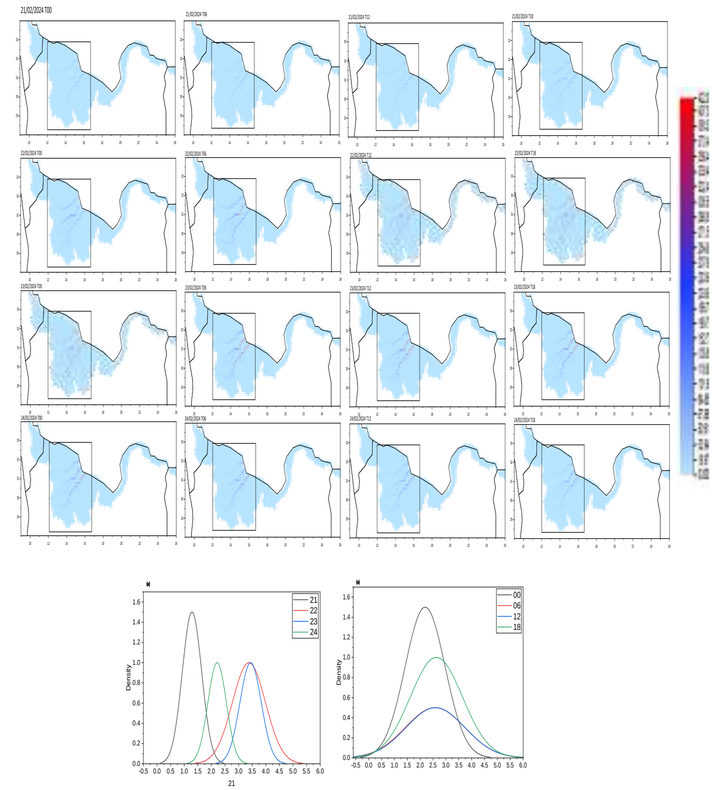


Fig.10. River discharge m^3 s^{-1}, for the 21th at 00 hour to the 24th at 18 hour at 2024

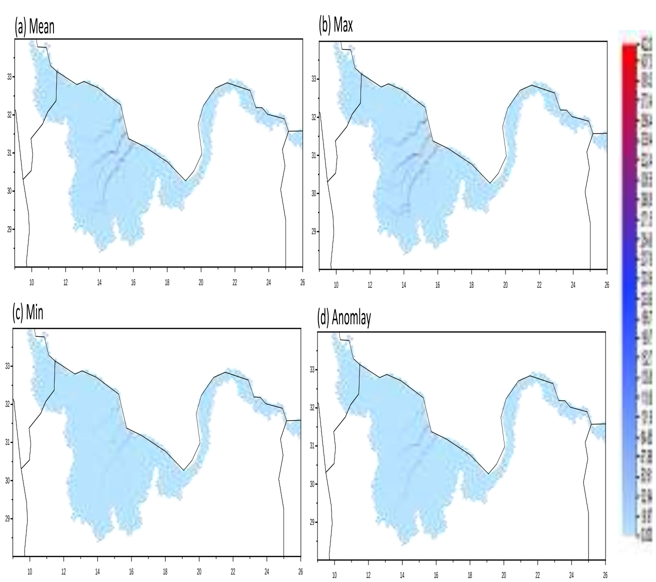


Fig.11. River discharge m^3 s^{-1} , Mean, Max, Min, Anomaly, for the 21th at 00 hour to the 24th at 18 hour at 2024

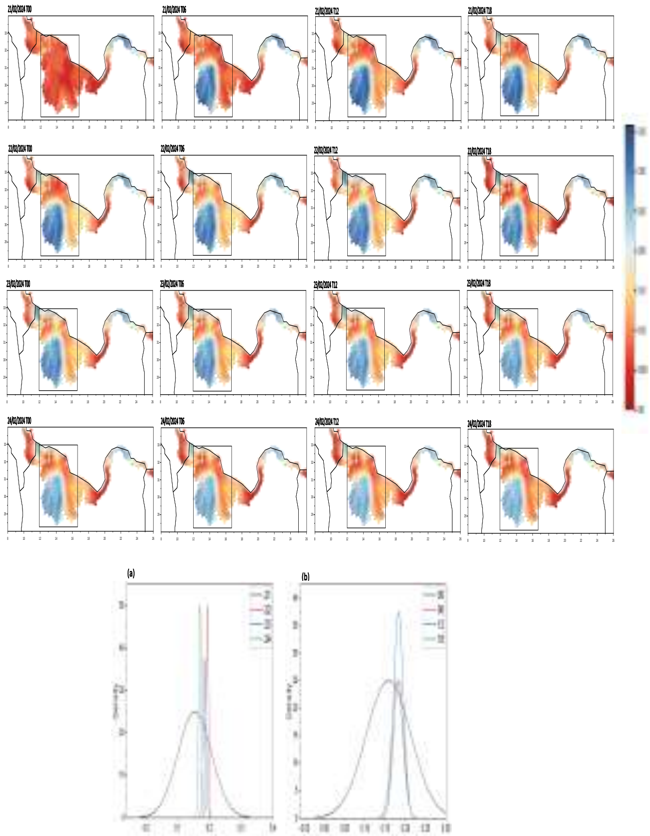


Fig .12. Volumetric soil moisture m^3. m^{-3}, for the 21th at 00 hour to the 24th at 18 hour at 2024

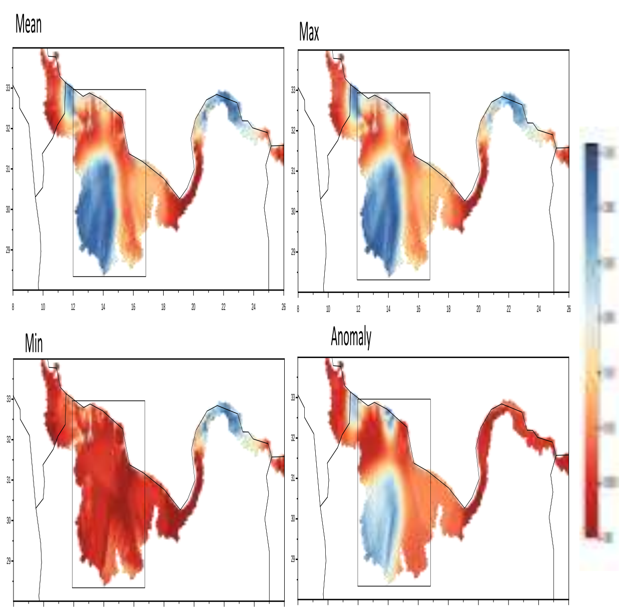


Fig.13.Volumetric soil moisture m^3. m^{-3}, Mean, Max, Min, Anomaly, for the 21th at 00 hour to the 24th at 18 hour at 2024

7. Conclusion

The impact of extreme precipitation and recharge mechanisms during periods of heavy precipitation is illustrated for the year 2024 for the month of February, where it is noted that the amount of rainfall increases starting from the 21st at 00, and at 18 hours it reaches 0.00309 m and increases further on the 22nd at 00 hours by about 0.00352 m. This results in an increase in the Runoff water equivalent (surface plus subsurface) starting from the 21st at 00 hours by about 2-3 kg m^{-2} centered in Gharyan and extending to Mizdah, and at 06 hours it extended to the north towards the south of Misurata, Zliten and Tripoli by about 2 kg m^{-2} and gradually increases during the hours 12 and 18 and reaches 4 kg m^{-2} and the rise continues until the 22nd at 00 hours, and begins to decrease on the 23 and 24th, unlike the decrease noticeable in the year 2023. As a result of the water supply, the discharge of rivers gradually increases from the 21st at 00 to 18th hour from 16.97 to 237.6 m^3 s^{-1}, while at the beginning of the next day, the 22nd at 06, the amount of water in Wadi Zamzam reaches about 339.4 m^3 s^{-1}, and also increases at 12 and 18 hours by about 390.3, 422 m^3 s^{-1}, respectively. While at 18 hours, it increases in Wadi Raml by about 390.3 m^3 s^{-1}, and increases until the next day, the 23 at 00 hours, and in Wadi Zamzam it begins to decrease at the end of the 23rd and 24th days, as well as in Wadi Raml, which increases the soil moisture at the three levels. On the 21st at 00 hours, there is no soil moisture, and it gradually begins on the 21st at 06 hours in Mizdah and Gharyan, and at 12 hours it increases more and reaches 0.05-0.3 m3. m-3 and at 18 o'clock it increases and reaches 0.15-0.35 m^3. m^{-3} and then on the 22nd there is an increase but it begins to decrease until the end of the 24th day.

8. Recommendations

1.The state's interest in spreading awareness among citizens about the consumption of groundwater in agricultural projects and limiting the conversion of agricultural land into housing, which negatively affects the entire climate.

2. Repeated warnings from scientists to the state in the event of an increase in these water bodies due to the extreme rainfall that the world is currently witnessing due to climate change, which results in coastal cities being eroded in the event of lack of attention.

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Data Availability Statement: The climatic data used in this research paper were obtained from Copernicus Climate Data Store.

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