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A Diagnostic Study of Storm Daniel's Meteorological and Environmental Characteristics in Derna, Eastern Libya, 2023

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Keywords:
climate change
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ABSTRACT

Many climate change hotspots around the world are characterized by annual droughts, floods, and fires. In September 2023, the city of Derna became a significant hotspot that garnered global attention due to severe material and human losses caused by the semi-cyclonic Storm Daniel. This study examines the weather factors influencing this storm, including sea level pressure, precipitation, sea surface temperature, and wind speed, from the 8th to the 11th of September, with a focus on northeastern Libya, where the storm peaked on the 10th. The highest total precipitation recorded in Al-Marj was approximately 379.08 mm per day. Notable precipitation anomalies for September 2023 in northeastern Libya included daily anomalies of 10.91, 14.98, and 9.23 in Benghazi, Al-Marj, and Al-Bayda, respectively, with the highest anomaly recorded in Derna at approximately 16.44.

دراسة تشخيصية للخصائص المناخية والبيئية لعاصفة دانيال في درنة، شرق ليبيا، 2023

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قسم علوم الغلاف الجوي، كلية العلوم، جامعة طرابلس، ليبيا.

الكلمات المفتاحية:
التغير المناخي
درنة
الهطول
درجة حرارة سطح البحر
عاصفة دانيال.

الملخص

تتميز العديد من مناطق العالم الساخنة بالتغير المناخي بالجفاف والفيضانات والحرائق السنوية. في سبتمبر 2023، أصبحت مدينة درنة منطقة ساخنة بارزة اجتذبت الاهتمام العالمي بسبب الخسائر المادية والبشرية الكبيرة الناجمة عن العاصفة شبه الإعصارية دانيال. تتناول هذه الدراسة العوامل الجوية التي أثرت على هذه العاصفة، بما في ذلك ضغط مستوى سطح البحر، والهطول، ودرجة حرارة سطح البحر، وسرعة الرياح، في الفترة من 8 إلى 11 سبتمبر، مع التركيز على شمال شرق ليبيا، حيث بلغت العاصفة ذروتها في العاشر من الشهر. سُجل أعلى مجموع لهطول الأمطار في المرج بحوالي 379.08 ملم في اليوم. شملت حالات الشذوذ في الهطول لشهر سبتمبر 2023 في شمال شرق ليبيا شذوذات يومية بلغت 10.91 و14.98 و9.23 في بنغازي والمرج والبيضاء على التوالي، مع تسجيل أعلى شذوذ في درنة بحوالي 16.44.

1. Introduction

The Mediterranean Sea serves as a case study for dense water formation, basin-scale climate functioning, and how a body of water responds to environmental changes [1]. In the 20th century, the Mediterranean Sea experienced significant and swift transformations. In recent decades, there has been an acceleration in both temperature and salinity, reflecting the trend toward global warming [2]. As one of the most well-known and susceptible "hotspots" of climate change, the Mediterranean area reacts quickly to atmospheric changes. Consequently, numerous extreme weather events have occurred in the region, with more predicted in the future [3].

Libya has a Mediterranean climate along the thin coastal strip in the north and a desert climate in the interior, with coastal temperatures typical of the Mediterranean climate and very low precipitation levels [4]. Climate models suggest that extreme precipitation events will become more common in an anthropogenically warmed climate [5]. Changes in precipitation extremes are critical for human welfare and the ecosystem. Increased heavy precipitation can enhance surface runoff, leading to more severe floods and mudslides [6].

Over the Mediterranean Sea, extra-tropical cyclones undergo a tropical transition process, forming "medicanes." These storms, with

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their warm core, symmetric structure, and concentric convective clouds, resemble tropical cyclones [7]. Medicanes cause wind, flooding, and surge damages around the Mediterranean region [8]. The formation of these cyclones is influenced by the hot conditions on the African coast and the Sahara [9].

Those of tropical cyclones, which are caused by the intrusion of Arctic air over the Mediterranean basin, are tiny and do not only occur in the fall. The Channel of Sicily is the preferred location for medicanes to form; one of the most recent cyclones, Ianos (2020), has intensified quickly and moved northeast of the Gulf of Sirte, where it formed and on September 18, 2020, Ianos reached its peak intensity close to Greece, bringing with it winds of 120 km/h and heavy rains that resulted in flooding and considerable damage to agriculture [10].

2. Study objectives

1. The study aims to analyze data on weather factors during the occurrence of Storm Daniel, from its initial impact on the Mediterranean Sea to its effects in Libya, particularly in eastern Libya.
2. To explain the anomalies in rainfall amounts in the cities of eastern Libya, and the conclusion of the storm with the flood that occurred in the city of Derna

3. Data and Methodology

The data were downloaded from the Climate Data Store - Copernicus, originating from the ECMWF (European Centre for Medium-Range Weather Forecasts), with a horizontal resolution of 1° x 1° for the region of latitude 30-47N° and longitude -6W° to 37E° [11].

4. Analysis and Discussion

4.1 Mediterranean climate in September

By analyzing the data for the month of September over the Mediterranean Sea, it was revealed that a quasi-cyclonic storm was forming over Greece. As shown in Figure 1(b), the average pressure at sea level in September reached 1010-1013 mb. The average precipitation during September was about 8.340 mm/day, as shown in Figure 1(a). Additionally, sea surface temperatures increased from 20-29C°, as shown in Figure 1©, and wind speeds increased from 8-12 m/s, as shown in Figure 1(d).

Through this analysis, the anomaly of this storm in September was clarified, as shown in Figure 2. The pressure anomaly at sea level reached 4.2 mb, as shown in Figure 2(b). The precipitation anomaly was highest in Greece at about 20 mm/day, and in the central Mediterranean opposite northeastern Libya, it ranged from 5 to 17.85 mm/day, as shown in Figure 2(a). The sea temperature anomaly ranged between 0.2 to 0.9C°, as shown in Figure 2©, while the wind speed anomaly ranged between 2.4 to 5.1 m/s, as shown in Figure 2(d).

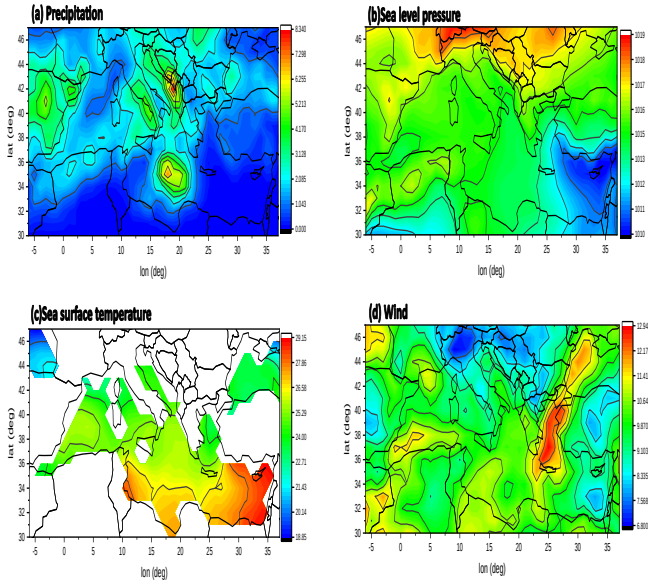

Fig .1: Monthly average for September 2023 for (a) precipitation, (b) sea level pressure, (c) sea surface temperature, (d) wind for the area 30-47 Nº, -6Wº-37 Eº.

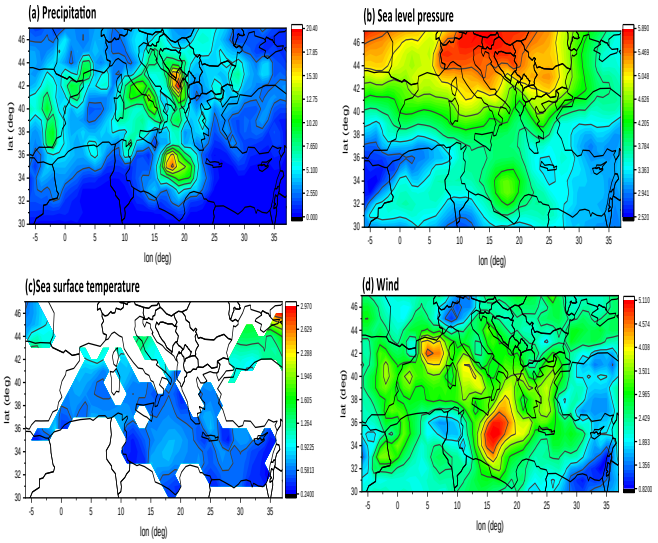

Fig. 2: Anomalies for September 2023 for (a) precipitation, (b) sea level pressure, (c) sea surface temperature, (d) wind for the area 30-47 Nº , -6Wº-37 Eº.

Daily analysis shows the concentration of Storm Daniel. One of the reasons for strengthening this storm into a semi- cyclone is the difference between temperatures between the land and the sea, as shown in Figure (3). It shows the difference between the land temperature for the area of northern Libya at lat: 30, 32.9 Nº , lon: 11 ,24.55 Eº, and the sea temperature. For space lat: 37.76 ,30.10 Nº ,lon:10 ,36.2Eº, , for temperatures from day 8 to 11 for every 6 hours, where the sea surface temperature reached at 06 hour about 27.47 C^0, at 12 hour about 27.69 Cº, at 18 hour about 27.68 Cº, and at 00 hour about 27.42 Cº. This is considered normal because of the heat capacity of the oceans, unlike the land. While on Earth, the temperature gained during the day and lost during the night ranges between 21.5-33.5 Cº, as shown in Figure (3).

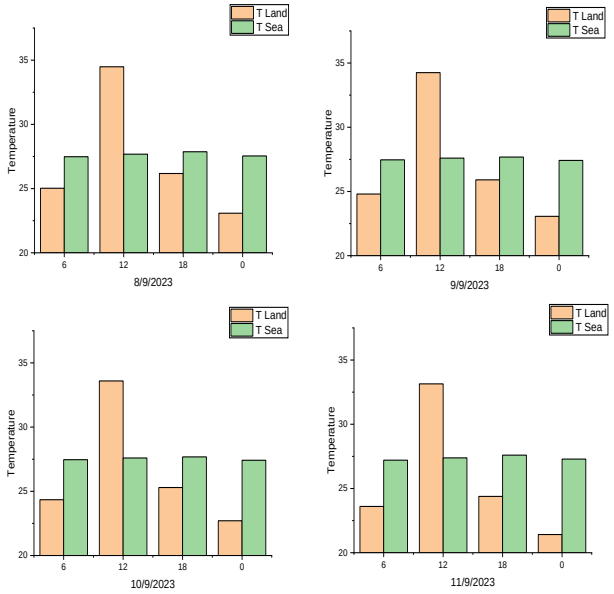

Fig.3: Land temperature (Cº) for the region 30-32.9 Nº, 11 -24.55 Eº, sea surface temperature (Cº) for the region 37.76 -30.10 Nº, 10 -36.2Eº for September 2023 for days 8-11 for every six hours.

On September 8, 2023, Storm Daniel approached the middle of the Mediterranean Sea of the Libyan coast, affecting the western are in Tripoli and Al-Khoms , as shown in Figure 4. The average pressure at sea level reached less than 1005 mb, and the average wind speed was high, reaching 20 m/s at the same time, as shown in Figure (5), while the average sea surface temperature reached 27.5 Cº in Figure (6), the total precipitation was about 1000 mm/day in day 8 on the central Mediterranean opposite north eastern Libya , as shown in Figure (7).

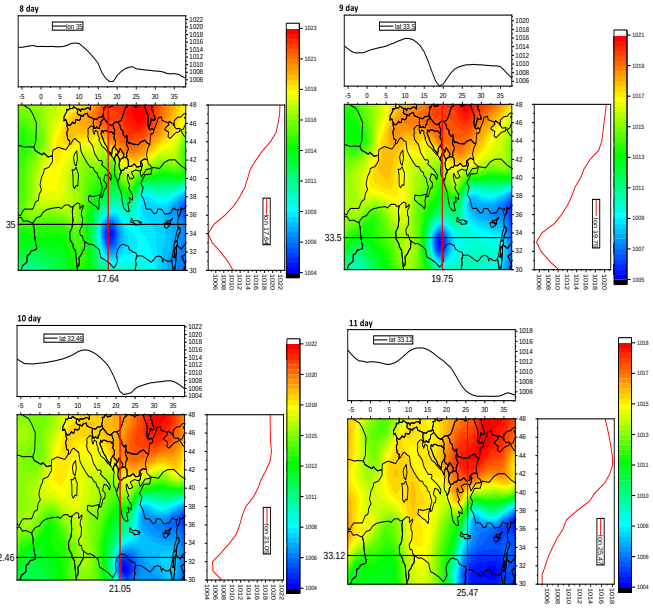

Fig.4: Average daily sea level pressure (mb) from September 8 -11, 2023.

While on day 9 the average pressure ~~at~~ sea level, it approaches the eastern Libyan coast and reaches 1004 and affects the western side, represented by the Gulf of Sirte, See figure (4). The average wind speed reaches 24 m/s, centered on Sirte and Misrata, and extending from west to east of the country, as shown in Figure (5), and in return the average temperature in the sea, is about 27.5, as in Figure (6), and increase in precipitation amounts reaching between 313.8 - 502, in the middle of the Mediterranean, extending to Sirte, less than the eastern region , which became clear with the arrival of the storm, as in Figure (7), which is strongly visible on the 10th day over the eastern region, and the center of Storm Daniel reaches the average wind speed between 15.65 - 28.40, and the amounts of precipitation reach between 190 - 380, affecting Benghazi, Marj, Al-Bayda, and Derna, as shown in Figures (7,9.a) ,and in the table. 1.

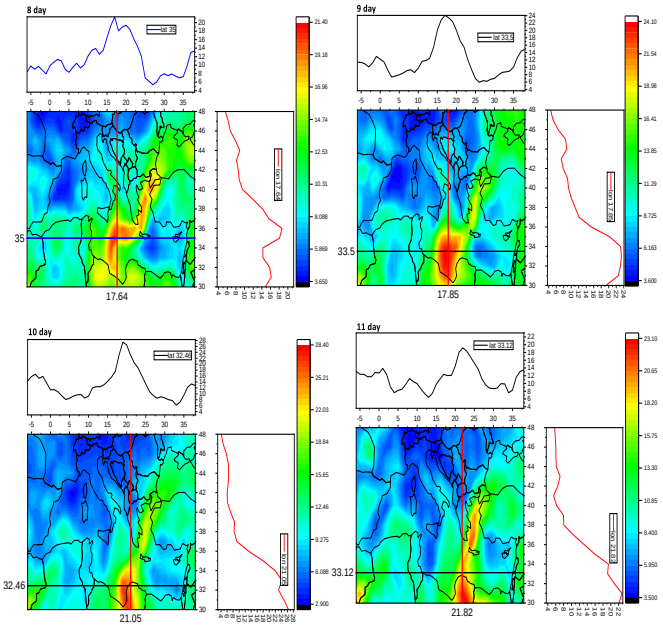

Fig. 5 : Average daily wind speed (m/s) from September 8-11, 2023

Table 1: Sum daily precipitation (mm/day) in September 2023

City	Sum Precipitation on day 9	Sum Precipitation on day 10
Benghazi	244.79	311.56
Marj	297.16	379.08
AL Bayda	278.60	318.48
Darna	243.25	246.47

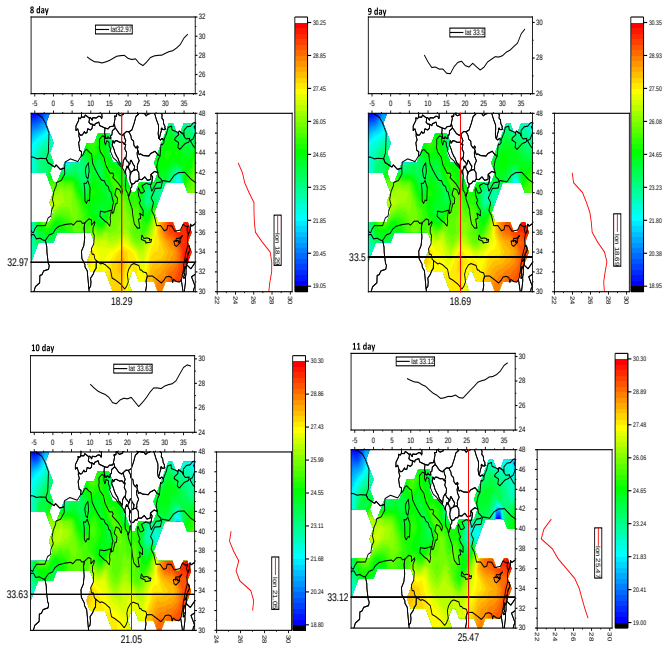

Fig. 6: Average daily sea surface temperature (C°) from September 8-11, 2023

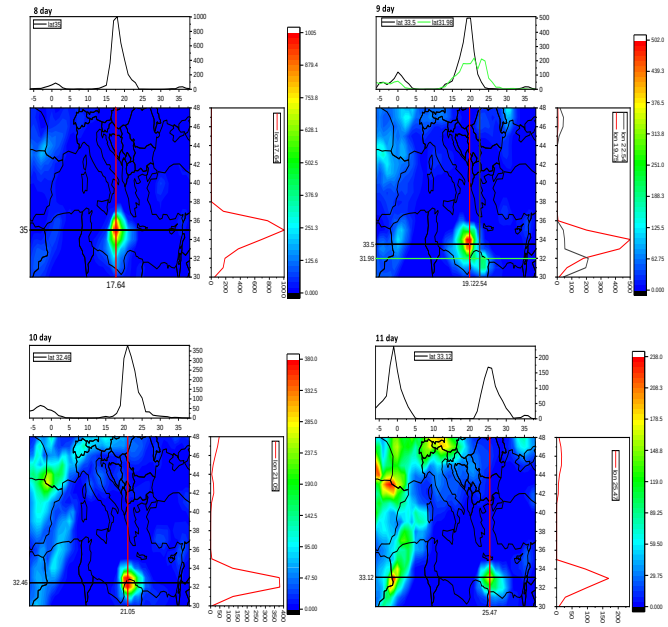

Fig. 7: Total daily precipitation (mm/day) from September 8-11, 2023

After the disaster caused by this storm occurred, it was almost a cyclone It resulted the flooding of Wadi Derna, and the talk of the world about the hot spot for climate changes above the average. It subsided on the 11th day, as shown in the figures, and Egypt was affected by the appearance of high waves on the beaches [12]. When analyzing the precipitation anomaly for the month of September over the Mediterranean region and its surrounding areas, it was found that the anomaly in the amount of precipitation over Benghazi was 2.45, while in Marj it was 1.39, and the highest in Al-Bayda was about 4.29, and over Derna it was 1.07. See Figure (2, C.9) as well as Table 2, when calculating the anomaly for days. From 8-15 of September, the highest anomalies were found in Benghazi, reaching 4.65, in Marj, 2.39, in Al-Bayda, about 1.08, and in Derna, 0.89. While on the stormy days, specifically from September 9-16, we found the highest anomalies in the city of Derna, reaching 16.44, as shown in Table 2 and the figure (8, 9b) And here the disaster occurred, flooding the valley and Libya losing many victims. It affected the Libyans and the entire world, and the anomaly began to decrease during the rest of the days. See Figure (8).

Table .2: Daily and monthly precipitation anomalies (mm/day) in September 2023.

City	Anomaly Precipitation on 8/9/2023 06:00-15/9/2023 06:00	Anomaly Precipitation on 9/9/2023 06:00-16/9/2023 06:00	Anomaly Precipitation in September
Benghazi	4.65	10.91	2.45
Marj	2.39	14.98	1.38
AL Bayda	1.08	9.23	4.29
Darna	0.89	16.44	1.07

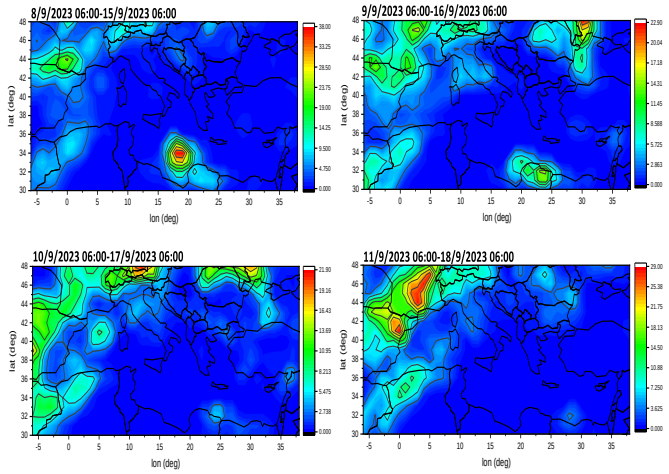

Fig 8: Daily precipitation anomalies (mm/day) for September 2023.

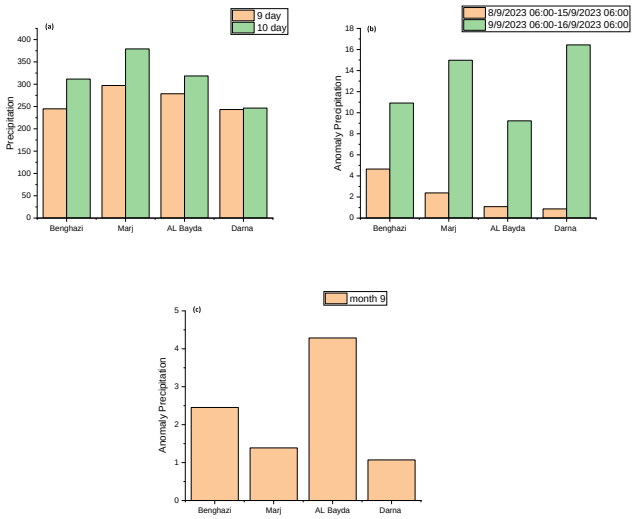

Fig. 9: Precipitation (mm/day) for September 2023 for four cities of Benghazi, Marj, Al-Bayda, and Derna. (a) Total precipitation, (b) Daily precipitation anomaly, (c) Precipitation anomaly.

5. Conclusion

Tropical cyclone activity typically occurs in the fall due to ocean heating [13]. This warming has extended to the Mediterranean Sea, leading to significant changes in its features in recent years. This was evident in the Daniel storm, which affected Greece and then Libya, particularly in the northeast. Data analysis showed that the average sea level pressure centered in the middle of the Mediterranean extended to the Libyan coast. The total precipitation reached 1000 mm/day in the middle of the Mediterranean, with wind speeds around 20 m/s and sea surface temperatures at 27.5°C.

On September 8th, the storm was centered in the middle of the Mediterranean. By September 9th, it extended towards eastern Libya, with precipitation amounts reaching approximately 297.16 mm/day in Marj, 278.60 mm/day in Al-Bayda, 244.79 mm/day in Benghazi, and 243.25 mm/day in Derna. On September 10th, the storm's intensity increased in eastern Libya, with rainfall amounts reaching 311.56 mm/day in Benghazi, 379.08 mm/day in Marj, 318.48 mm/day in Al-Bayda, and 246.47 mm/day in Derna.

The precipitation anomaly for September was significant in the eastern part of the country, reaching 4.29 in Al-Bayda and 1.07 in Derna. For a more accurate calculation, the anomaly from September 8-15 in Benghazi was 4.65, indicating the storm's approach. From September 9-16, Derna became a global hotspot with a precipitation anomaly of around 16.44. This marked the beginning of the valley dam's collapse, leading to severe flooding and significant loss of human lives.

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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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