



Mediterranean Cyclone Daniel, 3 – 11 September 2023

Preliminary report – 15 September 2023

Summary

This report provides an overview and assessment of the high-impact weather event, Storm Daniel, which occurred from September 3 to September 11, 2023 in the eastern Mediterranean. Storm Daniel was a powerful and destructive Mediterranean cyclone that impacted several countries, mainly Greece, Bulgaria, Turkey, and Libya. More than 11,300 casualties have been reported in Libya, 15 in Greece, and 10 in Bulgaria and Turkey.

Storm Daniel seems to be an exceptionally rare event and has been characterized by some sources as a Medicane (“Mediterranean hurricane”), although this categorization will need a detailed meteorological analysis. Its formation is attributed to climate variability and the unseasonable undulation of the jet stream, the causes of which have yet to be thoroughly investigated. Preliminary results based on weather analogues, show that human-induced climate change has increased the intensity of such storms in recent years.

This report covers the event's timeline, meteorological characteristics, and impacts.

Event Timeline

- **Formation:** Storm Daniel originated as a Mediterranean depression in the Ionian Sea on Monday 4 September 2023. An omega-blocking pattern was in place over Europe, when a cut-off low formed in central Europe, along the eastern flank of the high-pressure system. This occurred through Rossby wave breaking (the irreversible undulation of the jet stream) and the cut-off low subsequently entered the Mediterranean, promoting cyclogenesis.
- **Floods in Greece, Turkey, and Bulgaria:** On Tuesday 5 September 2023, the position and the slow southward movement of the cyclone in the Ionian Sea, established a persistent easterly/northeasterly flow of warm and moist air masses over the Black and Aegean Seas, where several convergence zones created long-lasting training convection. High accumulations of rainfall were recorded in Greece by the network of National Observatory of Greece/meteo.gr, where more than 750 mm of daily rainfall

were recorded, and up to 1096 mm within 3 days. In Bulgaria, about 311 mm of rainfall were recorded within 14 hours.

- **Intensification:** Severe weather events gradually faded in Greece during the night on Thursday 6 September 2023. The surface cyclone was in phase with the mid/upper-tropospheric low, while frontal activity started to be less pronounced. In the following 3 days, Storm Daniel intensified over the warm Mediterranean Sea in terms of wind speed close to the centre, with sustained winds up to 40 kts (74 km/h) based on satellite data. Also, deep moist convection started to be more active close to the cyclone centre. The cyclone progressively evolved from a baroclinic to a barotropic system while slowly moving southward.
- **Landfall:** Storm Daniel made landfall in the northeastern coasts of Libya during the night on Saturday 9 September 2023. In Bayda, about 414 mm of rainfall were recorded within less than 24 hours, an amount that is equal to 80 % of the city's mean annually accumulated precipitation. Before landfall, based on satellite and numerical data, it seems that Storm Daniel was a warm-air seclusion, depicting a structure similar to subtropical cyclones in other oceanic basins. This similarity has motivated the characterization of the cyclone as Medicane by some sources.
- **Dissipation:** Storm Daniel resulted in severe flash floods in northern Libya and dissipated fast over the Sahara desert when it reached Egypt on Monday 11 September 2023, since it was not fed anymore by the warm sea surface. Ancient salt lakes in the Sahara Desert were also flooded.

Impacts

Human Impacts:

- Storm Daniel caused at least 11,325 fatalities and about 4,000 people have been injured (until 15 September 2023).
- Evacuation orders were issued, leading to the displacement of 9,047 residents in Central Greece.
- Significant power outages affected millions of people.
- Remaining swamp muddy areas pose concerns for water quality and other health related conditions.

Infrastructure and Property Damage:

- Widespread structural damage to homes, businesses, and public buildings. About 50 buildings have collapsed in Greece and more than 1,000 in Libya.
- Flooding damaged roads, bridges, and other critical infrastructure.
- Coastal communities experienced erosion and marine submersion.

Agricultural and livestock Impact:

- Crop damage, particularly to cotton, corn, and apples, was extensive.
- The storm disrupted fishing and aquaculture operations.
- More than 200,000 animals in Greece used as livestock, have been declared dead.

Economic Impact:

Estimated economic losses from Storm Daniel exceeded \$4 billion, including insured and uninsured losses.

Conclusion

Storm Daniel was a high-impact weather event that caused significant damage and disruption along Mediterranean countries. The numerous casualties and widespread destruction in Greece, Bulgaria, and Turkey stressed out systematic problems in preparedness and response strategies by the governments. In the case of Libya, according to WMO, the National Meteorological Center even though issued a warning for heavy rain and flood, did not address the risk posed by the ageing dams that collapsed and the government failed to evacuate flooded areas in advance. This lack of preparedness resulted in one of the deadliest weather-related events in recent history.

Governments should invest in infrastructure improvements to mitigate storm-related damage, such as reinforcing levees and flood defenses, and conduct outreach programs to educate residents about storm preparedness and evacuation procedures. Moreover, significant improvements in coordination between federal, state, and local agencies are needed, to streamline disaster response efforts.

Recognizing, now more than ever, the scientific evidence that the intensity of Mediterranean storms is increasing, developing adaptation measures in response to the impacts and establishing long-term climate change mitigation strategies are vital steps of utmost importance for sustaining a viable environment for the Mediterranean. To this direction, the European Cooperation in Science and Technology (COST) Action MedCyclones (<https://medcyclones.eu/>) promotes networking between scientists and stakeholders to advance our understanding on Mediterranean cyclones and to effectively exploit fundamental research outputs for the benefit of the society.