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The Libya floods: a climate and infrastructure catastrophe » Yale Climate Connections

Africa's deadliest storm in recorded history struck eastern Libya on Sunday and Monday, leaving thousands dead and an already struggling society faced with a mammoth recovery effort. Storm Daniel's preliminary death toll of 5,300 in Libya as of Wednesday morning surpasses the 1927 floods in Algeria (3,000 killed) as the deadliest storm in Africa since 1900, according to statistics from EM-DAT, the international disaster database. Storm Daniel is also the deadliest storm globally since at least 2013 when Super Typhoon Haiyan killed 7,354 people in the Philippines.

The worst flooding from Storm Daniel was in the port city of Derna (population 90,000), where the failures of the nearby Derna and Abu Mansur dams, both about 50 years old, allowed a wall of water to rip through the heart of town along the Wadi Derna, which is a dry riverbed during much of the year. Carving a path some 100 meters (320 feet) wide, the floodwaters inundated some buildings and caused others to collapse.

Derna was still largely inaccessible on Wednesday, making it difficult to assess the flood's full impact. The eastern and western parts of Libya, riven by conflict, have operated largely apart from each other for more than a decade, which has complicated the effort to address the catastrophe.

Reuters cited the director of the Wahda Hospital in Derna as reporting 2,300 deaths on Tuesday. According to the Associated Press, a spokesperson for eastern Libya's interior ministry said later in the day that the death toll in Derna was more than 5,300, and the Libyan Red Crescent Society estimated that at least 10,000 people were missing. Flooding in other parts of northeast Libya led to dozens of other deaths.

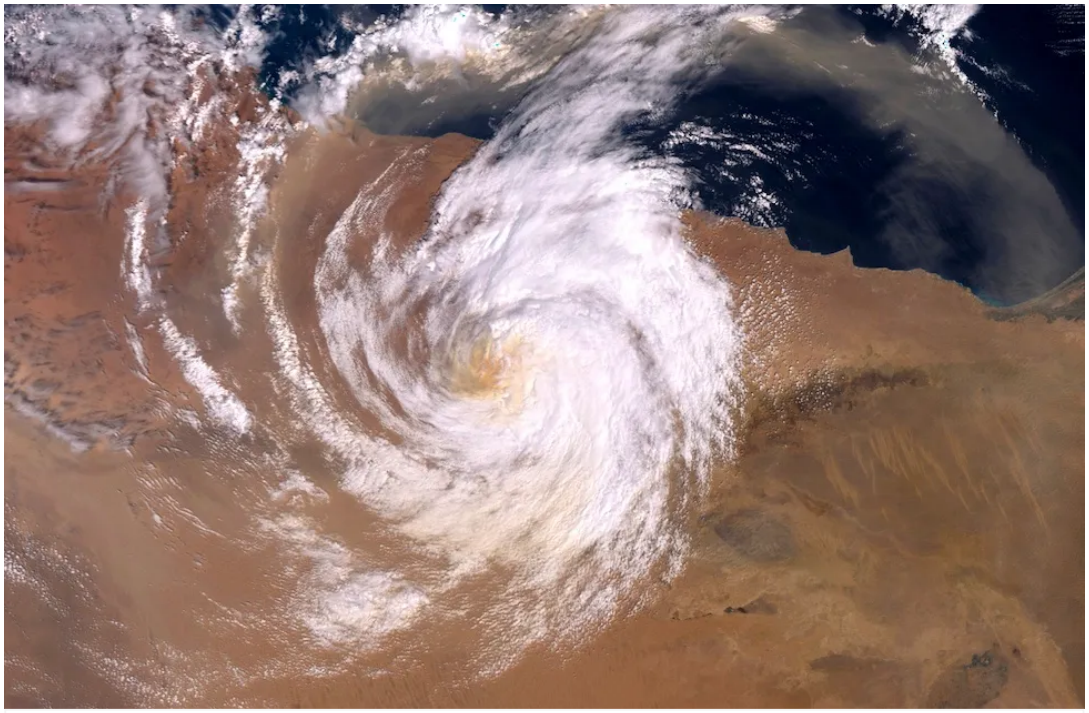

Figure 1. The circulation of former Medicane Daniel spinning over eastern Libya and western Egypt on September 11, 2023. (Image credit: Copernicus/Sentinel, via @kosmi)

Medicanes, Storm Daniel, and the Libya floods

The torrents that caused the Libya floods were delivered by Storm Daniel, a medicane (shorthand for Mediterranean tropical-like cyclone) that moved southward into Libya as an unusually well-formed system, with gale-force winds reported northwest of its center. It is already clear that Daniel will be by far the deadliest and costliest medicane ever recorded.

"Medicane" is a nickname for storms that develop tropical characteristics just off the coast of southern Europe. (There is no official definition of a medicane, although one group is working to develop one.) Medicanes are rarely full-fledged tropical systems with a warm core, since they typically evolve from cold-cored upper-level lows, and the waters of the Mediterranean aren't extensive or warm enough to sustain a true hurricane. And despite the implication embedded in the name, very few medicanes achieve sustained winds as strong as a Category 1 hurricane.

A typical medicane would be classified as a subtropical storm and given a name by the National Hurricane Center if it occurred outside of the Mediterranean, but there is no official agency responsible for naming

subtropical or tropical storms in the Mediterranean. Daniel was named by the meteorological service of Greece, as it brought deadly flooding to Greece and Turkey last week while it was morphing from a cold-core upper low into a medicane.

After the center of Daniel moved onto the Libya coast Sunday morning near Benghazi, about 100 miles west-southwest of Derna, analysis from the MIMIC-TPW2 system at the University of Wisconsin–Madison showed that precipitable water – the amount of moisture above a point at ground level – was in the range of 51-76 millimeters (2-3 inches) around the center of Daniel. Such moisture values would be impressive in late summer even along the U.S. Gulf Coast, which has a far wetter climate than coastal Libya.

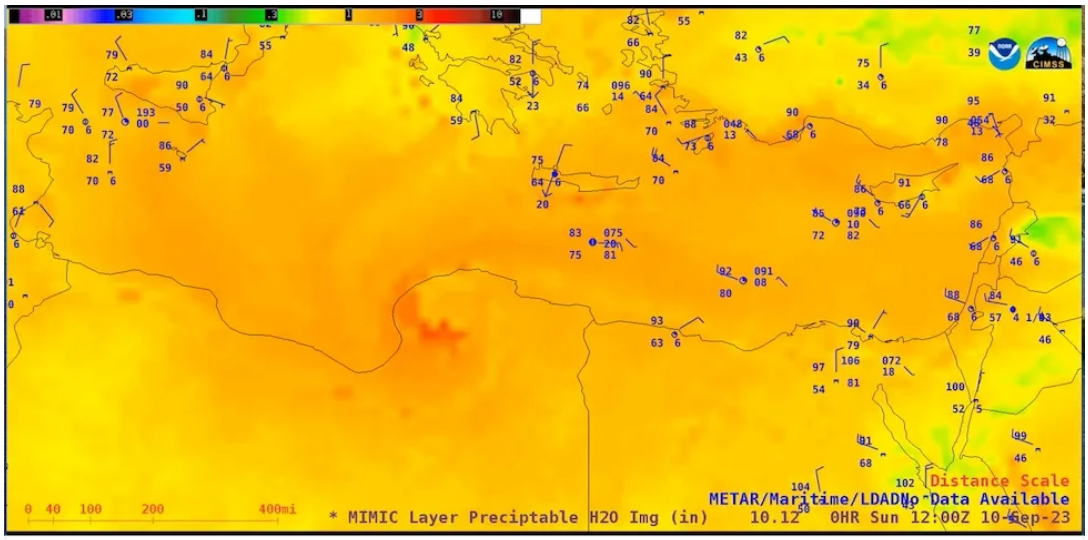

Figure 2. Extremely high values of precipitable water (in inches; see legend at upper left) pushed into northeast Libya at 12Z (8 a.m. EDT) Sunday, September 10, 2023, as the center of Storm Daniel pushed inland (see reddish swirl near the coast). (Image credit: Scott Bachmeier, University of Wisconsin–Madison.)

One or two medicanes typically form in the Mediterranean each year, but they rarely track toward Libya. Derna averages only 10.8 inches of rain a year, and more than 90% of that typically falls from cool-season storms in October through April. When the core of Daniel pushed ashore, an immense amount of rain was squeezed out as Daniel's moisture-laden winds were forced upward by striking the compact Jebel Akhdar plateau (Green Mountains). The plateau rises to as high as 900 meters (3,000 feet) above the Mediterranean coast.

Figure 3. Derna, Libya, as photographed from the highlands that rise just inland from the coastal city. (Image credit: Maher A. A. Abdussalam, via Wikimedia Commons)

The highest rainfall total recorded in Daniel from Libya's sparse observing network was in Bayda, where flooding took at least 50 lives. Bayda sits atop the Jebel Akhdar plateau about 40 miles west of Derna. The city recorded 414.1 millimeters (16.30 inches) from 8 a.m. local time Sunday to 8 a.m. Monday. This compares to Bayda's September average of 6 mm (0.24 inches) and its annual average of 540 mm (21.26 inches).

Medicanes projected to become fewer but stronger in a warming world

The Libya flood disaster was driven in part by the meteorological bad luck of Daniel coming ashore directly atop a compact zone of higher elevation. That's only part of the story, though. Human-induced climate change is loading the dice, enhancing the ability of tropical cyclones and similar storms to produce extreme rain as they draw more water vapor out of oceans into a warming atmosphere.

The Mediterranean Sea has warmed by an average of roughly 2 degrees Celsius (3.6°F) over the past 40 years. This summer the daily average sea surface temperatures of the Mediterranean hit new records for July (topping 28 degrees Celsius or 82°F for the first time in any month) as well as for August, according to the Spanish research center CEAM.

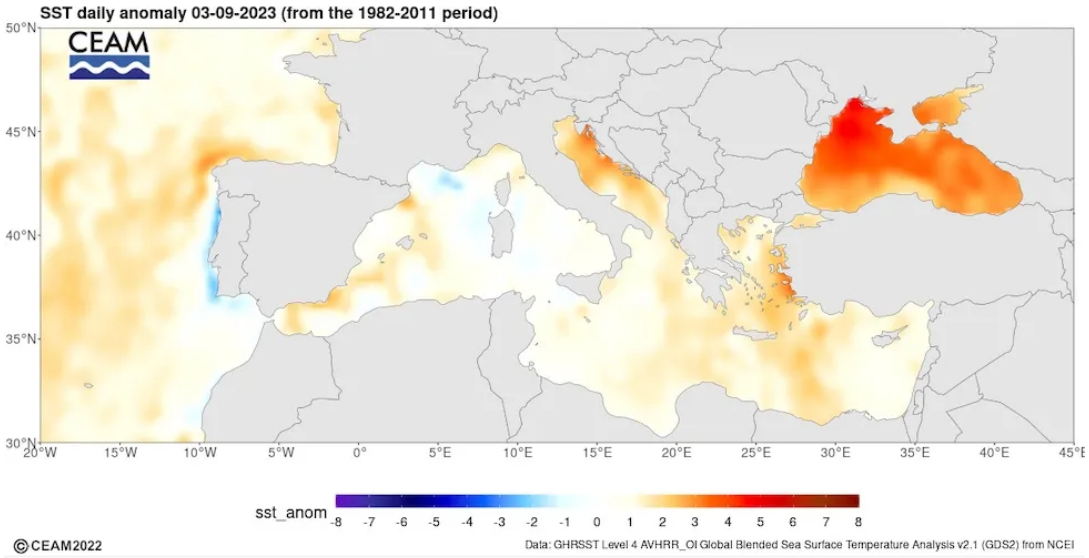

Figure 4. Surface temperatures across the eastern Mediterranean Sea were running 1-2 degrees Celsius (2-4 degrees Fahrenheit) above the seasonal norm on September 3, 2023, just before Storm Daniel began organizing near Greece. (Image credit: CEAM)

In its recent Sixth Assessment Report, the Intergovernmental Panel on Climate Change noted that the long-term outlook for medicanes is similar to that for tropical cyclones: fewer, but stronger on average. "A growing body of literature consistently found that the frequency of medicanes decreases under warming, while the strongest medicanes become stronger." Similarly, the IPCC added, "The frequency of Mediterranean wind storms reaching North Africa, including medicanes, is projected to decrease, but their intensities are projected to increase, by the mid-century and beyond."

As summarized by Dr. Liz Stephens, an associate professor in climate risks and resilience at the University of Reading, "Climate change is thought to be increasing the intensity of the strongest medicanes and we are confident that climate change is supercharging the rainfall associated with such storms."

Mid-latitude atmospheric blocking in the summertime, which led to Storm Daniel as well as record heat in central Europe and another cold-core low that brought flooding to Spain (see embedded tweet/post below from September 4), may also be influenced by climate change. Possible factors include the disproportionate warming toward the Arctic versus mid-latitude areas, although the possible effects of Arctic warming on "weather weirding" are still being studied and debated.

Compounding the catastrophes: an increase in vulnerability

Climate change doesn't occur in a social or ecological vacuum. Whether it be the proliferation of non-native grasses in Hawai'i or frenzied development along the Gulf or Atlantic coast, changes in ecosystems, housing patterns, and infrastructure can overlap in ways that exacerbate the risks posed by a changing climate by increasing our vulnerability to extreme weather events.

In the case of Libya, poor maintenance of the Derna-area dams may have further raised the risk of this week's catastrophe. As reported by Sky News, research published last year by civil engineer Abdelwanees A R Ashoor (Omar al Mukhtar University) warned that the city's naturally flood-prone landscape could lead to disaster if the local dams were not properly maintained.

Libya's meteorological agency issued warnings for Daniel three days in advance, and a state of emergency was declared for parts of eastern Libya, according to the World Meteorological Organization. It's unclear how much of a difference these warnings made, especially given the freakish nature of Storm Daniel and the rapid onset of floodwaters in Derna.

Deadliest Weather Disasters of Africa

YALE Climate Connections

Rank	Disaster	Location	Year	Deaths
1	Drought	Ethiopia, Sudan	1983-85	450,000
2	Drought	Ethiopia	1973-78	100,000
2	Drought	Mozambique	1981-85	100,000
4	Drought	Niger	1910-14	85,000
5	Drought	Somalia	2017-18	44,700
6	Drought	Somalia	2022-23	>43,000
7	Drought	Cabo Verde	1946	30,000
8	Drought	Cabo Verde	1920	24,000
9	Drought	Cabo Verde	1940-44	20,000
9	Drought	Somalia	2010-11	20,000
11	Drought	Somalia	1974-76	19,000
12	Drought	Cabo Verde	1900	11,000
13	Storm Daniel	Libya	2023	>5,300
14	Drought	Chad	1981-85	3,000
14	Flood	Algeria	1927	3,000
16	Drought	Uganda	2022	2,465
17	Flood	Somalia	1997	2,311
18	Drought	Ethiopia	1965	2,000
19	Cyclone Freddy	Malawi, Mozambique, Madagascar	2023	1,434
20	Cyclone Idai	Mozambique, Zimbabwe, Malawi, Madagascar	2019	1,294
21	Mudslide	Sierra Leone	2017	1,102
22	Flood	Algeria	1995	921
23	Flood	Nigeria, Niger, Benin, Chad, Mali, Cameroon	2022	876
24	Cyclone Eline	Mozambique, Madagascar, Zimbabwe	2000	800
25	Flood	Morocco	1995	730
26	Flood	DRC, Rwanda, Uganda, Kenya	2023	603
26	Flood	Egypt	1994	600
27	Drought	Somalia	1987	600
29	Flood	South Africa	2022	544
30	Flood	Tunisia	1969	540

Data from EM-DAT except Somalia 2022 (Watson and Checchi, 2023), Somalia 2017-18 (Warsame *et al.* 2023), and 2023 storms (Gallagher Re and Aon)

Figure 5. Deadliest weather-related disasters in Africa since 1900, according to the international disaster database EM-DAT (data for the 2023 storms is from insurance brokers Aon and Galagher Re; data for the 2022-23 drought in Somalia is from Warsame *et al.*, 2023).

Climate change is increasing the severity of African weather disasters

Despite recent improved weather forecasting technology and increased disaster awareness and preparation efforts, Africa has suffered an unprecedented number of deadly weather-related disasters over the past two years. The catastrophe in Libya is the seventh weather-related disaster to kill at least 500 Africans since 2022; an astonishing 23% of Africa's 30 deadliest weather-related disasters since 1900 have occurred in the past two years. This ominous figure could well be a harbinger of the future, as higher vulnerability, a growing population, and more extreme weather events from climate change cause an increase in deadly disasters.

Innovations in climate science have made it possible for scientists to study whether human-caused climate change influenced a specific disaster, a field known as attribution science. A human climate change influence has been found via scientific attribution studies in more than 20 African extreme weather events since 2000, including 13 droughts, seven floods, and two heat waves. As in other parts of the world, drought as well as extreme flood-producing rains in Africa have been associated with climate change in several analyses from the World Weather Attribution group (WWA).

Read: Keeping up with fast pace of attribution science

> In a study of the 2020-22 drought in East Africa, WWA concluded: "Climate change has made events like the current drought much stronger and more likely; a conservative estimate is that such droughts have become about 100 times more likely."
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> A May 2022 study from WWA on the South African floods of 2022 that killed 544 people concluded that "greenhouse gas and aerosol emissions are (at least in part) responsible for the observed increases [in rainfall]."
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> A separate WWA study for the summer 2022 floods in West Africa that killed 876 people concluded that human-caused climate change made the event "about 80 times more likely and approximately 20% more intense."
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> However, WWA's June 2023 study for the floods in Rwanda and the Democratic Republic of Congo that killed 603 people concluded, "the scarcity of data does not allow us to draw any conclusions on the role of climate change in the floods."

For more on Africa's vulnerability to weather disasters, including those exacerbated by climate change, see our May post, Five of Africa's top 30 deadliest weather disasters have occurred since 2022.

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