EGU24-12651, updated on 24 Mar 2025
https://doi.org/10.5194/egusphere-egu24-12651
EGU General Assembly 2024

The influence of high Mediterranean Sea surface temperature on Storm Daniel intense rainfall

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In September 2023, Storm Daniel hit the central Mediterranean and became the deadliest storm in the recorded history of the region. The storm originated from a low-pressure system around 4th September, which genesis can be attributed to an omega block centred in southern Europe. Then, it evolved into a Mediterranean tropical-like cyclone (*medicane*), impacting both the northern and the southern Mediterranean shores before dissipating around 12th September.

The storm particularly impacted Greece and Libya and, although the casualties and other major consequences are closely linked to significant infrastructure failures in Libya, both countries registered record-breaking rainfall amounts. For example, Zagora (Greece) experienced 754 mm in just 18 hours and Al-Bayda (Libya) saw a record highest daily rainfall of 414 mm. These events require an extraordinary supply of water vapor to maintain such rainfall rates. In the complex interplay of factors contributing to the development and intensity of weather systems like Storm Daniel, the Sea Surface Temperature (SST) stands as a likely primary driver. High SSTs provide not only the necessary energy, but also the moisture required to fuel the cyclone.

Over the months preceding Storm Daniel, the Mediterranean SST has consistently reached anomalously high levels, which was potentially a key ingredient in shaping the storm characteristics. To quantify the influence of local SST on the storm intensity, we used five ensembles of convection-permitting simulations (2 km) with an atmospheric model, which each of the ensemble members were initialized at different times. The five ensembles vary on the atmospheric and SST boundary and initial conditions, which were generated using different approaches to create counterfactual scenarios, from a simple removal of the mean climatological difference to an innovative data-driven method, which removes the long-term climate change signal correlated to global warming from SST. Combining these different estimates of atmosphere and SST counterfactual scenarios, we could quantify the relative contribution of global warming through local high SSTs and remote factors to rainfall amounts by Storm Daniel. In addition, we used a back-tracking algorithm to determine the source of water vapor that precipitated over Greece and Libya to understand the differences between the two phases of the event and the role of local SSTs. Our results show that local SST was crucial on the Libyan phase of the storm, while the rainfall amounts registered in Greece were mainly driven by remote factors. Also, the comparison of the different ensembles showed that the effects of long-term trends in SST are

important in Libya, but the dominant contribution comes from the anomalous high SSTs that the region has recently experienced, which cannot be directly explained by mean climatological changes. In fact, these exception conditions are responsible for most of the record-breaking rainfall amounts observed during the second phase of the storm.