Title: Hazardous Mediterranean Cyclones in the Current and Future Climate

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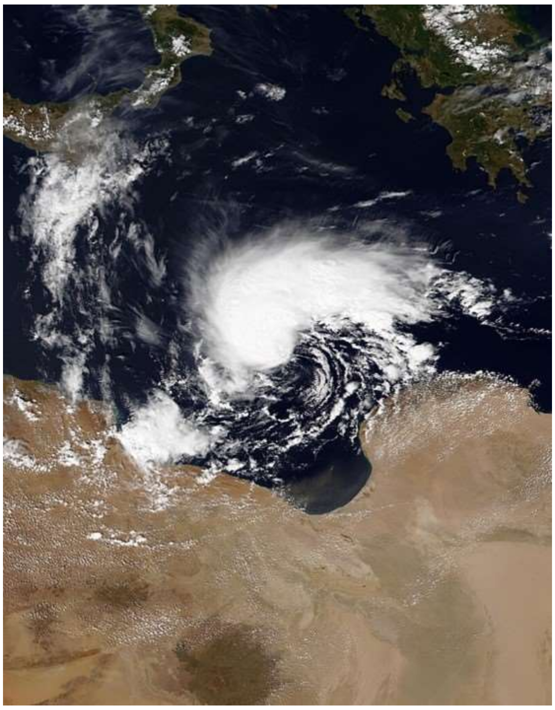
The Mediterranean basin is among the most cyclogenetic regions in the world and Mediterranean cyclones can lead to devastating socio-economic impacts for coastal communities. This region is also one of the major climate change "hot spots", being highly sensitive to climate change. Some Mediterranean cyclones, known as medicanes ("Mediterranean hurricanes"), can develop tropical-like features, such as a cloud-less eye, and these are usually the most hazardous. For example, medicane Ianos (September 2020) produced wind gusts exceeding 50 ms^{-1} (nearly 100 knots), precipitation accumulations exceeding 700 mm, and high waves on landfall on the Ionian islands. Storm Daniel, which caused extreme flooding in parts of the central and eastern Mediterranean in 2023, also had medicane characteristics prior to its devastating landfall over Libya. As the climate warms, most studies indicate that there will likely be fewer medicanes, but that these may be more hazardous.



Mediterranean storm Daniel to the north of Libya on 9th September 2023 (VIIRS Imagery from the NOAA-20 Satellite)

Mediterranean cyclones are far less understood than cyclones that form over the major ocean basins such as the North Atlantic, and which bring wet and windy weather to the UK in the autumn and winter. Their cyclogenesis and intensification are complex processes that combine tropical drivers, such as sea-surface fluxes from the warm sea, with those occurring in the mid-latitudes through interaction with southwards streamers of air associated with upper-level jets. Modelling these cyclones is challenging and computationally costly. Weather prediction models need to have grid lengths of less than about 6 km to resolve convective storms and so represent intensification via processes in deep convective clouds, whereas large model domains are needed to capture the evolution of steamers and the interaction of the cyclone with the background flow. Additionally, further complexity via coupling of a weather prediction model with other models such as those representing ocean, waves or dust is likely to be important for the skilful forecasting of cyclone development and their hazards. Both the range of spatial scales and interaction of processes make studying Mediterranean cyclones challenging.

The overarching aim of this project is to quantify and characterize the importance of air-sea

interactions and deep convection in the development of hazardous Mediterranean cyclones in both the current and future climate.

Important questions include:

1. How do processes generating heat (ocean surface fluxes, convective clouds, atmospheric radiation) modify Mediterranean cyclones and their associated hazards (winds and rain)?
2. How sensitive are Mediterranean cyclones to typical uncertainties in sea surface temperatures and the locations of mid-latitude features that are critical for their cyclogenesis?
3. How important are interactions between the atmosphere and oceans, waves and dust to obtaining skilful forecasts?
4. How do the answers to the above questions change in a future warmer climate?

You will run model simulations of Mediterranean cyclones, including medicane cases, using a new convective-storm resolving configuration of the Met Office's weather forecast model over the Mediterranean basin. You will then analyse the output using novel diagnostics to evaluate the importance of deep convection and sea-surface fluxes to cyclone development. This analysis will enable you to develop new conceptual understanding of moist and frictional processes in these cyclones and how they control the cyclone development and hazards. Sensitivity studies will enable you to explore the importance of uncertainties in sea surface temperatures to skilful model forecasts and convective-storm resolving model simulations initiated from climate model integrations will enable you to apply your knowledge to possible "worst-case" future cases. Other research avenues you could pursue include exploring the impact of coupling the atmospheric model to models of the ocean and waves, the role of dust and aerosols (e.g. dust from the nearby Sahara), the effects of misrepresenting the characteristics of deep convection through the simplified representations required in global-scale models, and even the limitations of the convective-storm resolving models. These limitations are important to characterise because these models are currently run by weather centres over several localised regions and also global models are moving towards these resolutions as computational power increases.

This research will support the Met Office strategy of developing the next generation of very high resolution regional environmental prediction systems by exploring the importance of coupling to the ocean in the Mediterranean basin. It will also exploit new climate model outputs generated by the UK science community.

Training opportunities:

This project will provide opportunities to develop mathematical modelling and data analysis skills, particularly in numerical weather model prediction and climate projections. You will also develop scientific insight in weather systems, including their associated hazards and how they will change with the warming climate. The project offers opportunities to attend postgraduate MSc modules and summer schools. You will have CASE support for an internship at the Met Office (in Exeter), where one of the co-supervisors is based. This internship will provide experience of models used operationally for atmospheric forecasting and an industrial research environment.

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