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Scenario
DOCTORAL TRAINING PARTNERSHIP
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Impact of air-sea interactions on Mediterranean Cyclones

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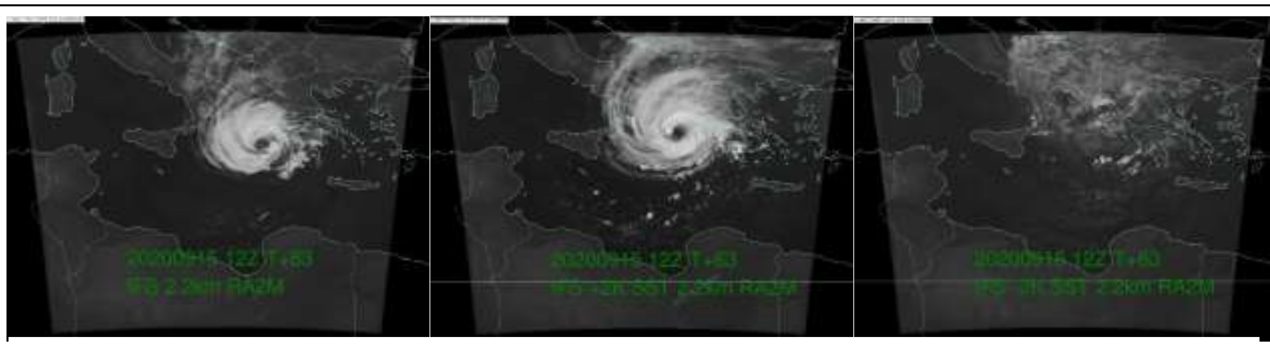
The Mediterranean basin is among the most cyclogenetic regions in the world and Mediterranean cyclones can lead to devastating socio-economic impacts for coastal communities. This region is also one of the major climate change “hot spots”, being highly sensitive to climate change. Some Mediterranean 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, see Figure) produced wind gusts exceeding 50 ms^{-1} (nearly 100 knots), precipitation accumulations exceeding 700 mm, and high waves on landfall on the Ionian islands; medicane Blas (November 2021) caused flooding, landslides and blackouts in the Balearic islands and a total of 9 fatalities.

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 streamers of air associated with upper-level jets. Modelling these cyclones is challenging and computationally costly. Convective-scale resolutions with model grid lengths of less than 10 km are needed to represent intensification via processes in deep convective clouds that are fuelled by heat and moisture fluxes, 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 simulating and studying medicanes challenging.
The overarching aim of this project is to quantify and characterize the importance of air-sea interactions and deep convection in Mediterranean cyclone evolution across spatial scales from the cyclone scale (cyclone track and intensity) to the scale of weather hazards (surface winds and precipitation).



Simulated infrared satellite imagery at 10.8 µm showing the extreme sensitivity of medicane Ianos to sea surface temperature (SST). Runs initialised 63 hr earlier with 2.2-km grid spacing.
Left: control SST; middle: SST+2K; Right: SST-2K.

Important questions to be addressed include:
1. How and through what mechanisms does the representation of convection (though a simplified approach called a parametrization scheme or explicitly represented) affect the development and associated hazards (rain and winds) of Mediterranean cyclones?
2. How do processes generating heat (ocean surface fluxes, convection, radiation) modify Mediterranean cyclones?
3. How sensitive are Mediterranean cyclones to typical uncertainties in sea surface temperatures and the locations of mid-latitude features such as streamers or cut-off lows that are critical for their cyclogenesis?
4. How important are interactions between the atmosphere and oceans, waves and dust to obtaining skilful forecasts?

You will run model simulations of Mediterranean cyclones, including medicane cases, using a new convective-scale resolution configuration of the Met Office's weather forecast model over the Mediterranean basin, alongside other configurations and resolutions. You will then analyse the output using novel diagnostics to evaluate the importance of deep convection and 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. 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 downstream effects of mispresenting the characteristics of deep convection through the simplified representations required in global-scale models, and even the limitations of km-scale resolution models which is important as operational systems move to even higher, sub-km scale models.

The proposed work 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. The work will also enable exploration of the behaviour of convective-scale model configurations in this new geographical location, where midlatitude shear-driven and subtropical convective (buoyancy-driven) processes can be equally important.

Training opportunities:
This project will provide opportunities to develop mathematical modelling and data analysis skills, particularly in numerical weather model prediction. You will also develop scientific insight into mid-latitude and tropical cyclones and their associated interactions with smaller and larger-scale weather features, including their associated hazards. It will offer opportunities to attend postgraduate MSc modules and summer schools. The student will have CASE support for an internship at the Met Office (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. The student will also have the opportunity to engage with an ongoing European networking and training initiative on Mediterranean cyclones.

Student profile:
This project would be best suited to a student with a strong physical sciences or mathematical background. The student will not need to have prior coding or data analysis expertise as full training and support will be given, but they should be keen to run complex weather forecast models and perform careful analysis work on the model output.

Funding particulars:
CASE support from the Met Office for this project is confirmed.

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