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# Fundamental Mechanisms of Arctic Summer-time Cyclone Growth and Sea-ice Interaction

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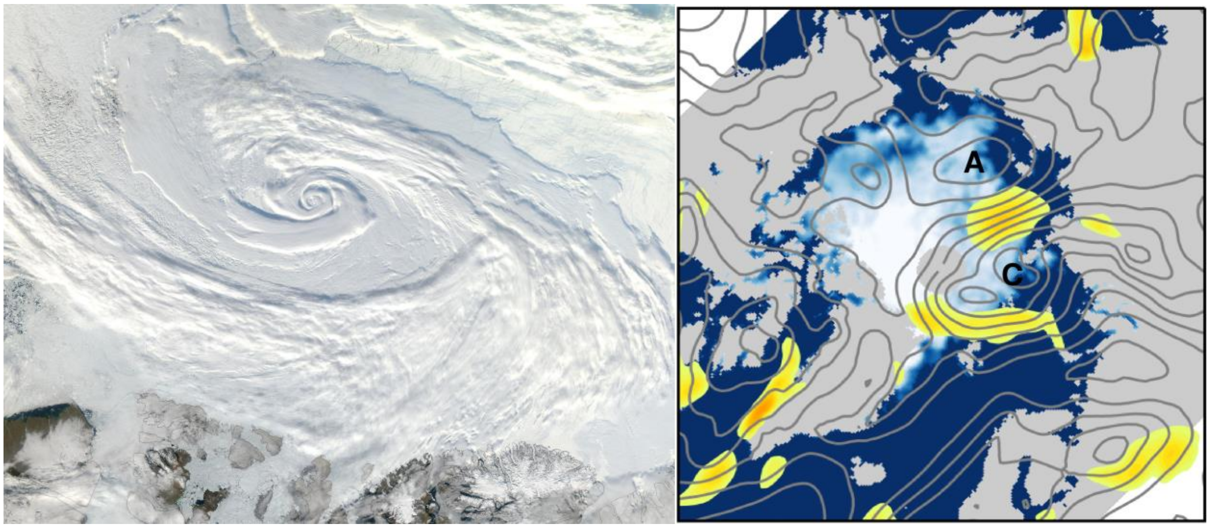
As the climate has warmed in response to increasing greenhouse gases, the September minimum in Arctic sea-ice extent has decreased dramatically and the drift speed of summer Arctic pack ice has increased, attributed to thinner ice. At the same time, human activity has expanded within the Arctic, with more residents and visitors making use of the reduced sea ice extent for shipping and offshore operations in summer. This has driven demand for forecasts of weather, ocean and sea-ice state across the Arctic on timescales needed to make decisions, typically ranging from hours to weeks. As we move to the “new Arctic”, where the marginal ice zone is projected to dominate the summer Arctic Ocean, we anticipate that surface drag will increase due to the ice floe edges and this may enhance surface interactions with Arctic weather systems. Unfortunately, current forecast skill is more variable in the Arctic than the northern mid-latitudes. The new frontier in prediction is to model this coupled system with fidelity and skill. Keeley and Mogensen (2018) demonstrated that forecast skill of the new ECMWF coupled system beats persistence for *sea ice predictions* and coupling has greatest effect in summer. However, improvements in Arctic weather system prediction have yet to be realized. Understanding of the physical processes is incomplete.



Left: Satellite image showing the cloud signature of an Arctic Cyclone spinning up north of Canada.
Right: Mean sea level pressure (contours) for a different Arctic Cyclone (C). Sea ice fraction (shading). Strong winds (yellow).
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Arctic cyclones are the dominant type of hazardous weather system affecting the Arctic environment in summer and can also have critical impacts on sea-ice movement. Cyclone growth is strong in summer because the temperature gradient across the Arctic Ocean shoreline (the “Arctic Frontal Zone”) *increases* as the land warms more than the neighbouring ocean and sea ice.

The aim of the project will be to isolate the mechanisms that distinguish Arctic cyclones from the much-studied mid-latitude cyclones and to determine whether these mechanisms render them less predictable, or whether the coupling with the dynamic sea ice surface beneath is responsible for the lower forecast skill. Different approaches will then be investigated to see if prediction can be improved.

The project brings together modelling and theoretical approaches to cyclone dynamics and coupling with sea-ice. We will use novel theoretically-based approaches to interrogate forecast models as they run and determine the mechanisms through which the surface properties alter cyclone growth. The primary tool will be the state-of-the-art ECMWF global atmospheric model with and without coupling to a sea ice model. The PhD project will evolve in 3 stages: 1) analysis of operational ECMWF forecasts archived with physical process tendencies for the extended YOPP period (3 years), 2) experiments using the comprehensive ECMWF model but in simplified configurations to examine sensitivity of cyclone development to varying environment and 3) re-forecasts in real cases varying the coupling with the sea ice through changes in the coupling physics and sea ice model itself.

**Training opportunities:**

The project will be based in the world-renowned Department of Meteorology, University of Reading and partner with the ECMWF and University of Oklahoma. The ECMWF global coupled earth system model (IFS) will be used for new experiments with support from ECMWF to run the model and use of ECMWF supercomputing resources. This will entail occasions working at the ECMWF.

In addition to the computer modelling, the project could involve a combination of the development of theory (building on existing theory for mid-latitude cyclones) and use of new observations, depending on your skill set and strengths and the direction you chose to take the project. You will receive masters-level training in the dynamics and physics of the atmosphere, global numerical modelling, as well as the ECWMF course on Numerical Weather Prediction.

The project links in with the THINICE international project which plans an aircraft experiment in summer 2021 aiming to observe Arctic cyclones and the evolving sea ice state below. The studentship funding will involve a research placement at the University of Oklahoma (USA), with the THINICE project team and their Arctic and Antarctic Research Group. If the aircraft field experiment is funded, you will have the opportunity to join the flight planning mission team in the Arctic.

**Student profile:**

The project would be suited to a student with a degree in physics, mathematics or science subject with a strong mathematical content. Some experience with computer programming would be good. Prior knowledge of atmospheric and environmental science is desirable, but not essential.

**Funding particulars:**

The NERC studentship funding includes payment of stipend, fees and research training and support grant. The University of Oklahoma will cover the accommodation costs of placement in Oklahoma. The ECMWF offer processing time on their supercomputing facility.

## References:

Keeley, S. and Mogensen, K. (2018). ECMWF Newsletter 156, 23-29.
https://www.ecmwf.int/en/elibrary/18874-dynamic-sea-ice-ifs
Simmonds, I. and Rudeva, I. (2012). *Geophys. Res. Lett.*, **39**, doi:10.1029/2012GL054259.
Yamagami, A., Matsueda, M. and Tanaka, H.L. (2017). *Atmos. Sci. Lett.*, **18**, 307-314.
Year of Polar Prediction (YOPP). https://www.polarprediction.net/

**http://www.reading.ac.uk/nercdtp**