Understanding and improving AMOC forecasts in inter-annual to decadal climate predictions

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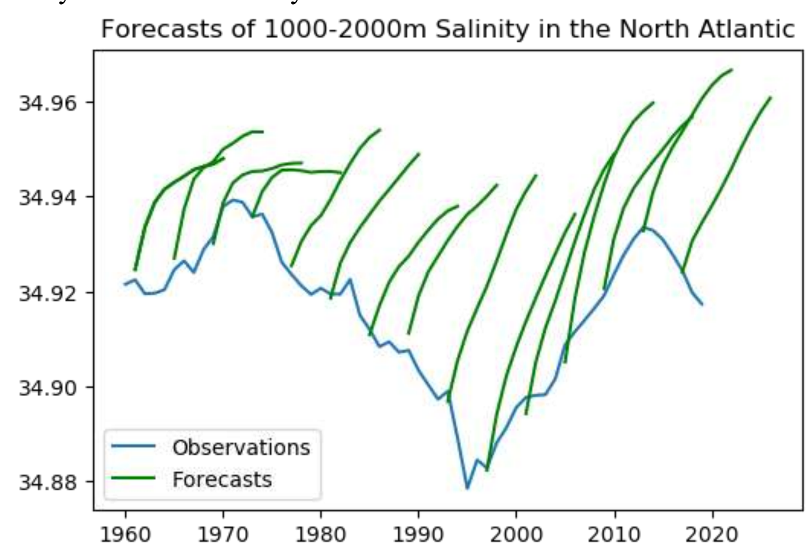
Decadal prediction is a rapidly growing field that forecasts the evolution of regional climate several years to decades ahead by using information from the current state of the climate. It is crucial in linking today's climate with that of climate projections and is important for many sectors, such as energy, agriculture, reinsurance and disaster risk reduction. On the timescales of several years, the ocean is thought to be much more predictable than the atmosphere and successful predictions should be possible from years to decades ahead. Therefore, by taking account of what the ocean has been doing, and by predicting how it will evolve over the coming decade, we hope to improve our predictions of regional and global climate. Indeed, these kind of climate predictions are now being routinely carried out at many climate centres around the world and the World Meteorological Organization considers them crucial for adapting to climate change and mitigating its worst effects.

The Atlantic Meridional Overturning circulation (AMOC) is a key ocean current in the North Atlantic which plays an important role in Earth's climate. For example, the AMOC – and its role in transporting heat – is the main cause of warm winters in the UK and Europe compared to other continents at similar latitudes. Changes in the strength of the AMOC have also been linked with changes in regional temperatures and shifting rainfall patterns over Europe and Africa, as well as extreme weather events such as hurricanes. Paleo-proxy evidence also suggests that the AMOC has been through rapid, large, and persistent changes in the past during periods of global climate change. Therefore, the ability to predict the AMOC from years-to-decades ahead would have many benefits for society.



Drifts in 10-year subsurface salinity forecasts in the Met Office decadal prediction system. Observed salinity shows strong decadal variability in the North Atlantic (blue line). The forecasts begin close to the observed values, but quickly become too saline (green lines). This behaviour increases the density at the depth of the southward branch of the AMOC, which in turn causes errors in the AMOC forecasts. The cause of this salinity drift is currently unknown. X-axes shows time in years, and y-axes shows salinity.

Unfortunately, AMOC predictions in many decadal prediction systems are hampered by poor performance and physically unrealistic behaviour such as large and substantial "drifts" (see figure). Given the AMOC's important role in transporting heat and freshwater, these drifts in AMOC impact other variables in the ocean and atmosphere (see figure). Therefore, this poor performance is limiting predictability of regional climate and are a serious barrier to providing useful climate forecasts. Improving the predictions of the AMOC is crucial to improve the quality of, and the confidence in, decadal climate predictions.

The causes of the AMOC drift are currently not known and improving the predictions will require better understanding of the processes controlling the AMOC to guide development of the next generation of climate prediction systems. The representation of the AMOC in decadal predictions is limited by the ability of models to reproduce important physical processes such as air-sea interactions driving the formation of deep dense water in the North Atlantic, which is a key component of the AMOC. Biases in surface heat and freshwater fluxes or sea surface properties of temperature, salinity, and sea ice lead to errors in dense water formation. Ocean mixing processes that modify these water masses – for example, at subsurface overflows or within ocean eddies – are also poorly represented and can lead to errors in circulation. Thus, both air-sea interactions and internal ocean processes can lead to significant errors in the distribution of sub-surface ocean properties that impact the AMOC.

Therefore, the overall aim of this project is to understand how the representation of key processes in ocean models can interfere with successful reproduction and prediction of the AMOC. The student will do this by first characterizing and understanding the evolution of the AMOC in a multi-model ensemble of predictions of past climate. Through detailed process-based analysis they will explore the reasons for poor performance of AMOC predictions and understand which oceanic and atmospheric processes are key for a successful multi-annual prediction. In particular, they will use a novel application of surface water mass transformation diagnostics to address the question of whether errors in air-sea interactions or internal ocean processes dominate the drifts in AMOC in model-based predictions.

After exploring the causes of poor model performance, the student will develop specific hypotheses that can be tested in new climate model simulations. To that end, the student will design and perform modelling experiments with the Met Office coupled climate model to test for improvements in AMOC prediction in a state-of-the-art Decadal Prediction System. One key outcome of the project will then be recommendations to the Met Office, which will lead to improved models and predictions of climate in the years ahead.

Training opportunities:
The student will benefit from extended visits to the Met Office CASE partner. They will have hands on training in how to run experiments with the Met Office state-of-the-art coupled climate models, and will gain experience of working in an operational organisation. At the University the student will join an active research group with access to a wide range of meetings for national and international research projects in related science areas and they will also be able to attend and present their work at focused collaborative workshops and international conferences. There will also be opportunities to attend relevant summer schools, such as the NCAS climate modelling summer school.

Student profile:
We seek a highly motivated student who has a keen interest in the physics of the natural world, especially the ocean's role in climate, and a good degree in physics, mathematics, computer science, or a closely related environmental or physical science.

Funding particulars:
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References:

Yeager, S. G. and Robson, J. I. (2017) *Recent progress in understanding and predicting Atlantic decadal climate variability.* Current Climate Change Reports, 3 (2). pp. 112-127. ISSN 2198-6061 doi: https://doi.org/10.1007/s40641-017-0064-z

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https://research.reading.ac.uk/scenario/