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Predicting the Arctic Ocean Environment in the 21st century

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Recent environmental changes in the Arctic have clearly demonstrated that climate change is faster and more vigorously in the Polar Regions than anywhere else. Significantly, change in the Arctic Ocean (AO) environment presents a variety of impacts, from ecological to social-economic and political. Mitigation of this change and adaptation to it requires detailed and robust environmental predictions. Here we present a detailed projection of ocean circulation and sea ice from the present until 2099, based on an eddy-permitting high-resolution global simulation of the NEMO $\frac{1}{4}$ degree ocean model. The model is forced at the surface with HadGEM2-ES atmosphere model output from the UK Met. Office IPCC Assessment Report 5 (AR5) Representative Concentration Pathways 8.5 (RCP8.5) scenario. The HadGEM2-ES simulations span 1860-2099 and are one of an ensemble of runs performed for the Coupled Model Intercomparison Project 5 (CMIP5) and IPCC AR5. Between 2000-2009 and 2090-2099 the AO experiences a significant warming, with sea surface temperature increasing on average by about 4° C, particularly in the Barents and Kara Seas, and in the Greenland Sea and Hudson Bay. By the end of the simulation, Arctic sea ice has an average annual thickness of less than 10 cm in the central AO, and less than 0.5 m in the East-Siberian Sea and Canadian Archipelago, and disappears entirely during the Arctic summer. In summer, opening of large areas of the Arctic Ocean to the wind and surface waves leads to the Arctic pack ice cover evolving into the Marginal Ice Zone (MIZ). In winter, sea ice persists until the 2030s; then it sharply declines and disappears from the Central Arctic Ocean by the end of the 21st century, with MIZ provinces remaining in winter along the Siberian, Alaskan coasts and in the Canadian Arctic Archipelago. Analysis of the AO circulation reveals evidence of (i) the reversal of the Arctic boundary currents in the Canadian Basin, from a weak cyclonic current in 2040-2049 to a strong anti-cyclonic current in 2090-2099, and (ii) increased anti-cyclonic surface ocean circulation in the eastern part of the AO, while the surface circulation in the western Arctic becomes more cyclonic. We relate the shift in the circulation to changes in the winds and reduction of sea ice cover, which modify momentum transfer from atmosphere to the ocean. Our simulation suggests a potentially complex picture of future AO change, and highlights the importance of high resolution modelling in forecasting it.