EGU22-11967
https://doi.org/10.5194/egusphere-egu22-11967
EGU General Assembly 2022

Development of persistent Southern Ocean biases in HadGEM-GC3.1-MM and implications for modelled ocean-ice interaction in West Antarctica

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The ice shelves of the Amundsen Sea are rapidly thinning, and this can be largely explained by basal melting driven by the ocean. However, sparse observational data and poorly known bathymetry contribute to the difficulty of quantifying the key ocean mechanisms that transport warm water onto the Amundsen Sea continental shelf and their variability. These processes should be represented in coupled climate models such as those used for CMIP6. Previously, we leveraged recent observational campaigns and gains in process understanding to assess how well four models, UKESM1 and the HadGEM-GC3.1 family of models, represent the ocean processes forcing warm water onto the Amundsen Sea continental shelf. We identified the medium resolution (1/4°) HadGEM-GC3.1-MM model's inability to represent warm water intrusion on the continental shelf, revealing substantial biases in sea ice, SST, salinity and circulation in the Southern Ocean. It is important to understand the processes that are driving these biases, to guide the improvement of this and similar models. Here, we study model behaviour during the spin-up, control and historical runs, to identify what is causing this unrealistic behaviour. A key result is the rapid development of biases in temperature and salinity on the Amundsen's Sea continental shelf, after only 15 years in the spin-up run, entering a state which persists throughout the following runs. By calculating the differences in sea ice concentration between years 0-5 and 10-15 of the spin up-run, we found significant changes across multiple regions of the Southern Ocean and continental shelf, with most of the East Antarctic sector and Bellingshausen Sea showing a considerable decline that exceeds 20% in some places. The differences between years 0-5 and 10-15 Notable freshening takes place in the whole West Antarctic sector and a strong westward slope current appears, which encircles Antarctica. While strong biases in sea ice and salinity develop later in the Weddell Sea, during the first 15 years the largest biases occur in Drake Passage and the west Antarctic sector. We analyse tendencies and the freshwater budget from the spin-up run to quantify the key processes that drive the development of these biases in selected regions.