Challenges in simulating sea ice: insights from HighResMIP runs

State-of-the-art coupled climate models face challenges in accurately simulating historical variability and trends of Arctic and Antarctic sea ice, which affects the reliability of their future projections. Enhancing horizontal resolution is expected to improve the representation of coupled atmosphere-ice-ocean processes, particularly at high latitudes. This study examines past and projected changes in sea ice properties using a set of climate models participating in the High-Resolution Model Intercomparison Project (HighResMIP) within the Coupled Model Intercomparison Project Phase 6 (CMIP6). Each experiment within HighResMIP, is conducted using both reference resolution configuration (typical of CMIP6 runs) and higher-resolution configurations. The role of horizontal grid resolution in both the atmosphere and the ocean model component in reproducing past and future changes in the sea ice cover is analysed. Model outputs from the coupled historical (hist-1950) and future (highres-future) runs are used to describe the multi-model, multi-resolution representation of sea ice and to evaluate the systematic differences (if any) caused by resolution enhancement. Our results indicate a limited relationship between the representation of sea ice cover and the ocean/atmosphere grids; the impact of horizontal resolution depends more on the sea ice characteristic examined and the model used. However, refining the ocean grid has a more significant effect than refining the atmospheric grid, with eddy-permitting ocean configurations generally providing more realistic representations of sea ice area and edges. In particular, in the Arctic all models project substantial sea ice shrinking, with nearly 95% of sea ice volume lost from 1950 to 2050. Along with the overall sea ice loss, changes in the spatial structure of the total sea ice and its partition in ice classes are noticed: the marginal ice zone (MIZ) is expected to dominate the ice cover by 2050, suggesting a shift to a new sea ice regime much akin to the current Antarctic sea ice conditions. Given the high computational cost of climate-scale simulations at high spatial resolution, we advocate prioritizing enhancements in sea-ice physics and the interactions among model components in coupled climate simulations.

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