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Southern Ocean warming and increased ice shelf basal melting in the 21st and 22nd centuries based on coupled ice-ocean finite-element modelling

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In the framework of the EU project Ice2sea we utilize a global finite element sea ice - ice shelf - ocean model (FESOM), focused on the Antarctic marginal seas, to assess projections of ice shelf basal melting in a warmer climate. Ice shelf - ocean interaction is described using a three-equation system with a diagnostic computation of temperature and salinity at the ice-ocean interface. A tetrahedral mesh with a minimum horizontal resolution of 4 minutes and hybrid vertical coordinates is used. Ice shelf draft, cavity geometry, and global ocean bathymetry have been derived from the RTopo-1 data set.

The model is forced with the atmospheric output from two climate models: (1) the Hadley Centre Climate Model (HadCM3) and (2) Max Planck Institute's ECHAM5/MPI-OM coupled climate model. Data from their 20th-century simulations are used to evaluate the modeled present-day ocean state. Sea-ice coverage is largely realistic in both simulations. Modeled ice shelf basal melt rates compare well with observations in both cases, but are consistently smaller for ECHAM5/MPI-OM.

Projections for future ice shelf basal melting are computed using atmospheric output for IPCC scenarios E1 and A1B. Trends in sea ice coverage depend on the scenario chosen but are largely consistent between the two forcing models. In contrast to this, variations of ocean heat content and ice shelf basal melting are only moderate in simulations forced with ECHAM5/MPI-OM data, while a substantial shift towards a warmer regime is found in experiments forced with HadCM3 output. A strong sensitivity to salinity distribution at the continental shelf break is found for the Weddell Sea, where in the HadCM3-A1B experiment warm water starts to pulse onto the southern continental shelf during the 21st century. As these pulses reach deep into the Filchner-Ronne Ice Shelf (FRIS) cavity, basal melting increases by a factor of three to six compared to the present value of about 100 Gt/yr. By the middle of the 22nd century, FRIS becomes the largest contributor to total ice shelf basal mass loss in this simulation.