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On the representation of the Southern Ocean in a finite-element coupled sea ice–ocean model

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A finite-element coupled sea ice–ocean model (FESOM) has been developed at the Alfred Wegener Institute for Polar and Marine Research. The sea-ice component is a dynamic-thermodynamic model with an elastic-viscous-plastic rheology. The ocean component is the primitive-equation Finite Element Ocean Model (FEOM). An eight-compartment model of the marine ecosystem, featuring nitrate and silicate cycles and considering possible iron limitation, has been implemented. The coupled model has been configured (1) in a circumpolar domain covering the Southern Ocean between the coast of Antarctica and 48S, and (2) on a global grid with 1.5° mean resolution. Multi-decadal simulations have been performed in both configurations using atmospheric forcing data from the NCEP reanalysis. The circumpolar model has also been integrated with atmospheric forcing from the ECHAM5-MPIOM coupled climate model. Results are analysed with regard to ice concentration and thickness, as well as ocean hydrography and circulation. All model setups yield stable integrations and give quite reasonable results. In simulations forced by NCEP reanalysis data, summer ice coverage in the western Weddell Sea is substantially underestimated. This deficiency is cured by using forcing from the ECHAM5-MPIOM simulations, which contain substantially lower temperatures and a different wind pattern in this area. This indicates that the underestimation of ice concentration and thickness in the northwestern Weddell Sea, which is typical to many models of the Southern Ocean, is not due to model deficiences but produced by a poor representation of the Antarctic Peninsula in the NCAR/NCEP reanalysis model. For winter conditions, however, especially outside the peninsula region, NCEP forcing data yield very good results. Results from a wide range of sensitivity studies confirm the crucial importance of a carefully chosen adaptive mixing scheme to parameterize vertical and horizontal mixing. Specifically, to

reproduce Southern Ocean hydrography and circulation at the same time, it turned out to be essential to use isopycnic (instead of horizontal) diffusion and to scale lateral diffusivities with the horizontal grid scale.