Geophysical Research Abstracts
Vol. 15, EGU2013-8988, 2013
EGU General Assembly 2013

Adaptation of a fully-unstructured-mesh, finite-element ocean model to the simulation of ocean circulation in the presence of ice shelf

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There have been many efforts to explicitly represent ice shelf cavities in ocean models. These ocean models employ isopycnic, terrain-following, or z coordinates. We will explore an alternate method by using the finite-element ocean model, Fluidity-ICOM, to represent an ice shelf. The Fluidity-ICOM model simulates non-hydrostatic dynamics on meshes that can be unstructured in all three dimensions. This geometric flexibility offers several advantages over previous approaches. The model represents melting or freezing on ice-ocean interfaces oriented in any direction, treats the ice shelf topography as continuous rather than stepped, and does not require any smoothing of the ice topography or any additional parameterisations of the ocean mixed layer used in isopycnal or z-coordinate models. We will demonstrate these capabilities by investigating the response of ice shelf basal melting to 1) variations in ocean temperature on an idealized ice shelf and 2) variation in sub-glacial discharge on an idealized Fjord.

Melting near the grounding line of the ice shelf produces melt water that is lighter than the surrounding and therefore the meltwater ascends along the base. A band of melting area is concentrated at the Western region due to the Coriolis force in the Southern Hemisphere. As found in previous studies, the melt rate increases non-linearly as the temperature of the water forcing the cavity increases. However, the model is able to represent the dynamics of a meltwater plume that separates from the ice shelf when it reaches neutral buoyancy, unlike previous models with mixed-layer parameterisation. In the warmest case, the meltwater is lighter than the surrounding water, thereby warming the surface of the ocean. As the deep water temperature decreases, the meltwater is not light enough to penetrate to the surface, so it intrudes into the open ocean, cooling the deep water. In the case of the idealized Fjord, the discharged water ascends along the vertical ice base. As the water ascends, temperature and salinity of discharged water is modified by the meltwater. When the ascending water reaches the surface, a thin layer of relatively cool, fresh water is formed on top of the ambient ocean. This layer gets advected radially towards offshore as the discharge continues.

An application of the model to investigate physical processes at the ice-ocean interface is presented. This is in preparation for applying the model to more realistic ice shelf ocean cavity and vertical ice faces, for example in Greenland fjords.