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Modelling iceberg trajectories and melting in the NEMO Global Ocean Model

V.O. Ivchenko (1), R. Marsh (1), S. Alderson (2), G. Bigg (3), G. Madec (4,2), and Ye. Aksenov (2)

(1) Southampton University, National Oceanography Centre, United Kingdom (voi@noc.soton.ac.uk), (2) National Oceanography Centre, United Kingdom, (3) University of Sheffield, United Kingdom, (4) Institut Pierre et Simon Laplace, Paris, France

Fresh water fluxes from the terrestrial cryosphere comprise liquid runoff and calved icebergs. This partitioning of freshwater fluxes is believed to be significant for freshwater distribution in the oceans. Runoff freshens the ocean locally near the coast, while individual icebergs represent pathways for continuous and increasingly remote freshwater influence on the open ocean (Bigg *et al.* (1996, 1997)). Furthermore, the distribution of icebergs at any time is principally due to a combination of the calving rate/location and prevailing oceanographic conditions (both thermodynamic and dynamic). The observational record at 48°N off Newfoundland shows that, through the twentieth century, the annual iceberg count was highly variable. The relative influence of variable calving and oceanographic conditions on the iceberg count is not yet well established. To address the role of icebergs in the ocean, and to distinguish how different processes - such as calving, heat exchange with the atmospheric and ocean, and ocean dynamics - affect iceberg distributions in the North Atlantic, an iceberg model is coupled to the global NEMO ocean model (Madec, 2008). The iceberg module is based on an original model of Bigg *et al.* (1997), as recently adapted for coupling to the CM2G climate model by Martin and Adcroft (2010). Icebergs are treated as Lagrangian particles, with the distribution of icebergs by size derived from observations. The momentum balance for icebergs comprises the Coriolis force, air and water form drags, the horizontal pressure gradient force, the wave radiation force, and interaction with sea ice. The mass balance for an individual iceberg is governed by bottom melting, buoyant convection at the side walls and wave erosion. The iceberg model is here implemented in a version of NEMO at 2° resolution. Iceberg calving is specified from climatology, with the annual-mean calving around Antarctica being $3.6*10^7$ kg/s, which comprises about 2/3 of total freshwater flux in the Southern Ocean ($5.4*10^7$ kg/s). The mean calving rate in the Northern Hemisphere is considerably smaller, at around $5.8*10^6$ kg/s. In the Southern Ocean, the icebergs are concentrated along most of the Antarctic coast, except for three regions of relatively high iceberg concentration at mid-high latitudes in the Southern Ocean. These three regions are in the north part of the Weddell Gyre (east of the Antarctic peninsula to about 20°E), in the Indian Ocean sector (45°E-100°E), and south of Australia (140°E-150°W). In these three regions, icebergs have drifted northwards and are melting rapidly. In the Northern Hemisphere, Greenland is the principal site of calving, with the highest iceberg concentrations located to the west and south-west of Greenland. The majority of the icebergs follow the Labrador Current and are fully melted within the vicinity of the Grand Banks.