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Freshwater flux from ice sheet melting and iceberg calving in the Southern Ocean

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This dataset is a multiyear mean Southern Ocean freshwater flux field that uses recently compiled measurements of ice sheet melting, iceberg calving, iceberg tracking, and river runoff. It has a horizontal resolution of 1/6° and uses BEDMAP2 for identifying and placing individual ice sheets. The aim of this work is to improve the representation of Antarctic freshwater input in Southern Ocean models.

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Dataset

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Creator: Hammond, M. D. and D. C. Jones.
Title: Southern Ocean freshwater flux field
Publisher: British Oceanographic Data Centre
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Resource type: Dataset
Version: 1.0

Introduction

The circulation and stratification of the Southern Ocean is highly sensitive to the rate and distribution of freshwater input from the Antarctic continent, which is dominated by ice sheet melting and the melting of calved icebergs (Rignot *et al.*, 2013). Freshwater input from Antarctica helps to maintain the Southern Ocean's stable salinity stratification, in which a layer of colder, fresher water (i.e. Circumpolar Deep Water) sits on top of a layer of warmer, saltier water (i.e. Antarctic Bottom Water) (Kjellsson *et al.*, 2015). At present, ocean models that include the Southern Ocean use a variety of representations of Antarctic freshwater flux and display a wide range of stability and water mass properties (Heuzé *et al.*, 2013).

Here, we derive a mean freshwater input field for the Southern Ocean using recently compiled measurements of ice sheet melting, iceberg calving, iceberg tracking, and river runoff. This freshwater flux field can be used in ocean models and in climate data analysis. We use geolocated ice sheet outlines, iceberg tracks, and river mouths together with their runoff volumes to derive a more accurate freshwater flux field. Figures 1 and 2 show a previously available flux field and our new flux field respectively. The previous estimate is a uniform flux distribution along a gridded coastline, whereas our new field uses spatial and volume data for a more realistic representation of freshwater input. The longitudinal distribution of flux in the new field is markedly different from the previous estimate, as shown by the 18° bins around the edges of Figures 1 and 2. The total freshwater input is 45% higher in the new field, as it has been tuned to be in better agreement with observational estimates of the total freshwater flux due to basal melting and iceberg calving (Rignot *et al.*, 2013).

The British Oceanographic Data Centre (BODC) record contains our freshwater flux field on a 1/6° grid and a sample MATLAB script for reading and plotting the field. The flux file itself is in binary format and is thus universally readable. The input datasets used to produce the field, and MATLAB scripts that can be used to generate a new freshwater flux field with different input datasets are available on request from the authors in an extended dataset.

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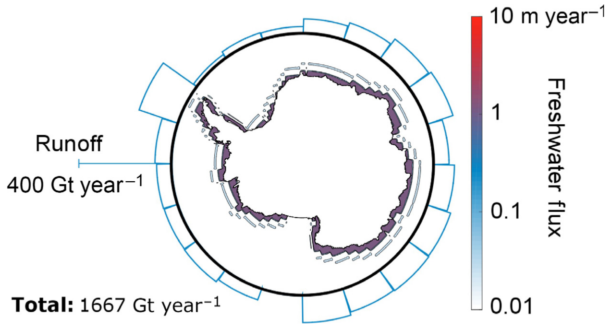

Figure 1. The freshwater input field used in the construction of the Southern Ocean State estimate (Mazloff *et al.*, 2010). The longitude bins are 18° wide.

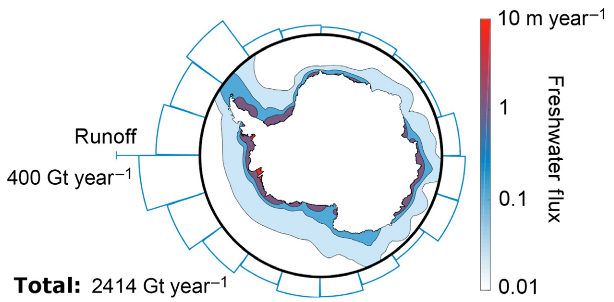

Figure 2. The updated freshwater input field. The flux includes contributions from iceberg calving and ice sheet melting. The longitude bins are 18° wide.

1. Data production methods

The main field in the dataset is a sum of fields from two sources of freshwater: (1) ice sheet melting and (2) iceberg calving and melting.

1.1. Ice sheet melting

We use the ice sheet position and shape data from the 'BEDMAP2 Toolbox for MATLAB' (Fretwell *et al.*, 2013) together with recently updated ice sheet melting data (table 1 in Rignot *et al.*, 2013) to distribute the freshwater flux due to each ice sheet along its coastal edge in the model grid. We then applied a Gaussian decay with decay length 100 km to each flux source to avoid overly large flux values in any grid cell. Each flux value was normalised and rescaled to its previous value to conserve the total amount of flux, so the chosen decay length does not affect the total flux.

Some ice sheets had directional masks applied to restrict their fluxes to certain ranges of angles. This was necessary for sheets with high fluxes on peninsulas to prevent their flux reaching the other side of the land feature. The angles used are listed in the extended dataset.

1.2. Iceberg calving and melting

We represent the flux from small (i.e. with scales of less than 1 km) icebergs as a Gaussian decaying flux away from the coastline, with a decay length of 500 km so that 95% of the total flux is below 60 °S (Holland *et al.*, 2014). We represent the flux from large (i.e. with scales greater than 1 km) icebergs via the approach of Silva *et al.*, (2006). We use iceberg tracks from the Antarctic Iceberg Tracking Database (Stuart and Long, 2011) (QSCAT data from 1999 to 2009) to produce a field representing the likelihood of finding a large, trackable iceberg in each grid cell. The total 'large iceberg' volume flux is distributed over this likelihood field.

The free variable in this field is the proportion of large iceberg flux (distributed over the field from the tracks) to small iceberg flux (distributed over the Gaussian decaying flux from the coastline). We selected 50% for the proportion as this roughly matched the amount of flux in various sectors (e.g. Weddell Sea) predicted by the total iceberg calving volume data of (Rignot *et al.*, 2013). Silva *et al.* (2006) used a more sophisticated approach which considered icebergs melting as they progressed along their paths.

2. Dataset location and format

The field itself is on a 2160 × 320 (1/6°) latitude–longitude grid with the freshwater flux calculated at each grid cell in units of m/year.

The BODC dataset contains the freshwater flux field in binary format, grid files in binary format, a PDF colourmap of the field, and a MATLAB script which reads and displays the field. The MATLAB script is included for convenience, but the freshwater input file and grid files are in binary format and are therefore universally readable.

The extended dataset (available on request from the authors) contains MATLAB scripts to generate a custom field using different data or on different grids. It also contains the raw ice sheet melting, iceberg calving, and iceberg tracking data used to generate the freshwater flux product.

3. Dataset use and reuse

We used our new freshwater flux dataset to improve the representation of Antarctic freshwater input in an eddy-permitting model of the Southern Ocean. The model setup (called BASSOON) is described in Jones *et al.* (2016). When forced with the previously available freshwater flux field, BASSOON developed large, open ocean polynyas associated with deep convection within 4–6 years in both the Weddell Sea and Ross Sea. When forced with our new freshwater input field, the Ross Sea stabilised such that polynya formation (and the associated runaway positive feedback loop of sea ice melt and vertical entrainment of warm water from the interior) was suppressed. Both (1) the increased total flux from the continent and (2) the newly estimated distribution of flux helped to stabilise the Southern Ocean against polynya formation and

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overly vigorous deep mixing. However, the Weddell Sea was still subject to polynya formation and instability, indicating that more freshwater input (perhaps from precipitation) is required to stabilise this region. The details of this stability experiment are beyond the scope of this paper, but a technical report is available on request from the authors.

Our dataset can be used (1) in ocean models to replace a more basic freshwater runoff flux field or (2) as part of a broader observational data analysis. The extended dataset (available on request) will allow the user to generate their own field using different raw data. The user can change the grid of the field, change the ice sheet data, or add more iceberg tracks. It also contains data for freshwater runoff from rivers into the Southern Ocean, which can be added to the flux field if required. This is explained in detail in the extended dataset and does not require familiarity with MATLAB. The ice sheet data is stored in an Excel spreadsheet, and new icebergs tracks can be downloaded to a folder and automatically added.

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