# On the problem of parameterizing ice shelf - ocean interaction in global climate models

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## Introduction

Sensitivity studies for the Southern Ocean indicate that freshwater fluxes from various sources have a significant impact on the stability of the water column with consequences for sea ice and water mass characteristics [*Marsland and Wolff*, 2001; *Timmermann et al.*, 2001; *Hellmer*, 2004]. These sources are either atmospheric or result from ocean interaction with the base of Antarctic ice shelves and drifting icebergs [*Schodlok et al.*, 2004]. The resolution of global climate models does not allow for an adequate representation of the processes on polar continental shelves. Therefore, model deficits exist in terms of sea ice thickness, and water salinities and temperatures in regions important for the composition of the deep water participating in the global thermohaline circulation. In view of these deficits, *Beckmann and Goosse* [2003] parameterized the freshwater flux from major Antarctic ice shelf cavities in a global climate model (CLIO) calculating the net ocean-ice shelf heat flux as a combination of subsurface temperature at the continental shelf break and an effective basal area of melting. The latter was determined using the melt rates of the regional model BRIOS forced with two different atmospheric data sets. Due to consideration of the glacial freshwater, the model's sea ice thickened as a consequence of less vigorous convection which also prevented the deep water from cooling and freshening.

Although the results of the global model improved for the Southern Ocean, it remains questionable whether a general, circumpolar valid link exists between basal melting and ocean temperatures at the continental shelf break. At most, for a narrow continental shelf (e.g., East Antarctica) the sub-ice shelf freshwater flux might be correlated with the temperature of the nearby passing coastal current. On the broad continental shelves of Weddell and Ross Seas, however, the influence of the coastal current is minor and other coastal processes might maintain the density gradient for driving the thermohaline circulation beneath the vast ice shelves. Observations and model simulations confirm that High Salinity Shelf Water (HSSW) and its spatial distribution [*Nicholls and Østerhus*, 2004; *Timmermann et al.*, 2002b], and local wind forcing [*Assmann et al.*, 2003] control the sub-ice shelf circulation and, therefore, basal melting. A parameterization of the sub-ice freshwater flux in global climate models based on salinity is problematic due to a coastal current being unable to establish a strong cross-shelf density gradient because of its low salinities [*Gill*, 1973].

The following study, though preliminary, investigates the relation between heat and salt content of the continental shelf waters and the sub-ice shelf freshwater flux for the two major Antarctic cavities of Filchner-Ronne (FRIS) and Ross (RIS).

## Experiment

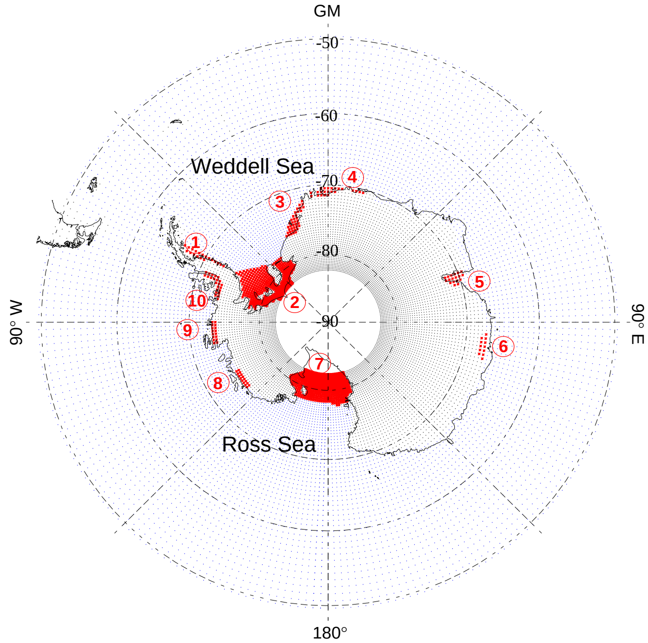


**Figure 1:** BRIOS-2.2 model grid for the Southern Ocean south of 50°S with the major Antarctic ice shelves considered (gray). (1) Larsen, (2) Filchner-Ronne, (3) Eastern Weddell, (4) Fimbulisen, (5) Amery, (6) Shackleton, (7) Ross, (8) Getz, (9) Abbot, (10) George VI.

The coupled ice-ocean model BRIOS-2.2 [*Timmermann et al.*, 2002a; *Assmann et al.*, 2003] which considers ten of the major Antarctic ice shelves (Fig. 1), representing 74% of the total floating ice body [*Fox and Cooper*, 1994], is used to determine shelf water characteristics and to quantify the monthly mean freshwater flux. The focus will be on Filchner-Ronne and Ross Ice shelves because here resolution (~25 km at the southern boundary (82°S)) and data coverage for ice thickness and sea floor depth are sufficient to provide a realistic estimate for basal melting. The model includes state-of-the-art representation of the processes of air-sea ice/ice shelf-ocean interaction, deep convection, and deep-water formation at the continental margin. This configuration was forced for 20 model years with a 20-year (1978–1997) climatology using NCEP 10-m winds, 2-m air temperature, specific humidity, cloudiness, and net precipitation [*Kalnay et al.*, 1996].

## Results

For the $20^{th}$ model year, the FRIS freshwater flux increases from the minimum of 3.1 mSv (1mSv = $1{\times}10^3 m^3 s^{-1}$) in March to the maximum of 4.3 mSv in August (Fig. 2). Compared with the total heat and salt content of the southwestern Weddell Sea continental shelf (depth $\leq$ 1000 m) the flux shows a strong positive (negative) correlation on the salt (heat) content. The maximum of the salt lags that of the freshwater by two months. The relation degrades (improves) for the salt (heat) content of the lower (200 m) water column which has direct access to the ice shelf cavity.

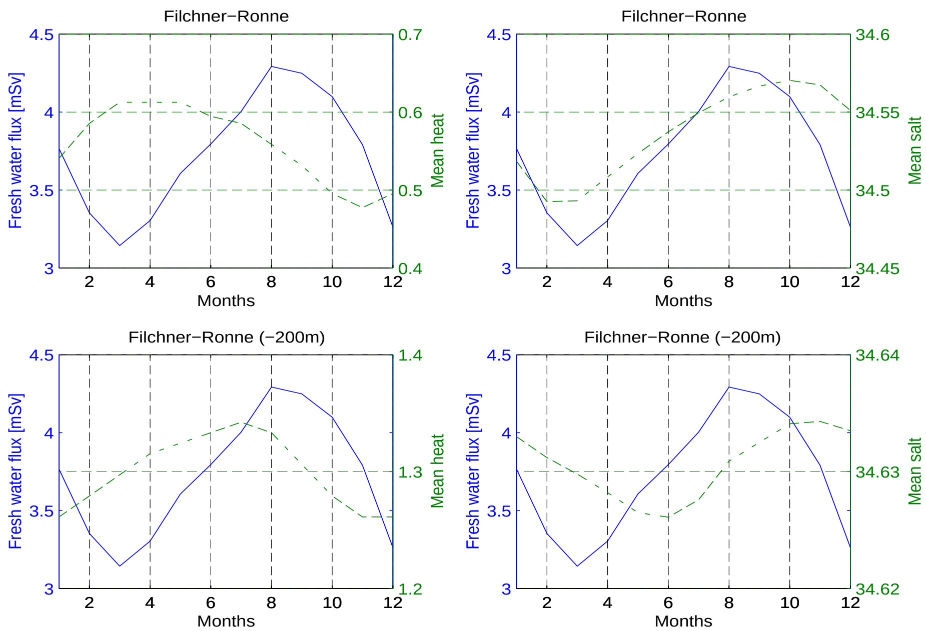


**Figure 2:** The total freshwater flux [mSv] from melting the base of Filchner-Ronne Ice Shelf (solid line) compared with the mean heat (left) and salt (right) content of the total (upper panels) and lower 200 m (lower panels) water column of the continental shelf of the southwestern Weddell Sea (dashed line). For a better visibility the scales for heat and salt differ with water column thickness.

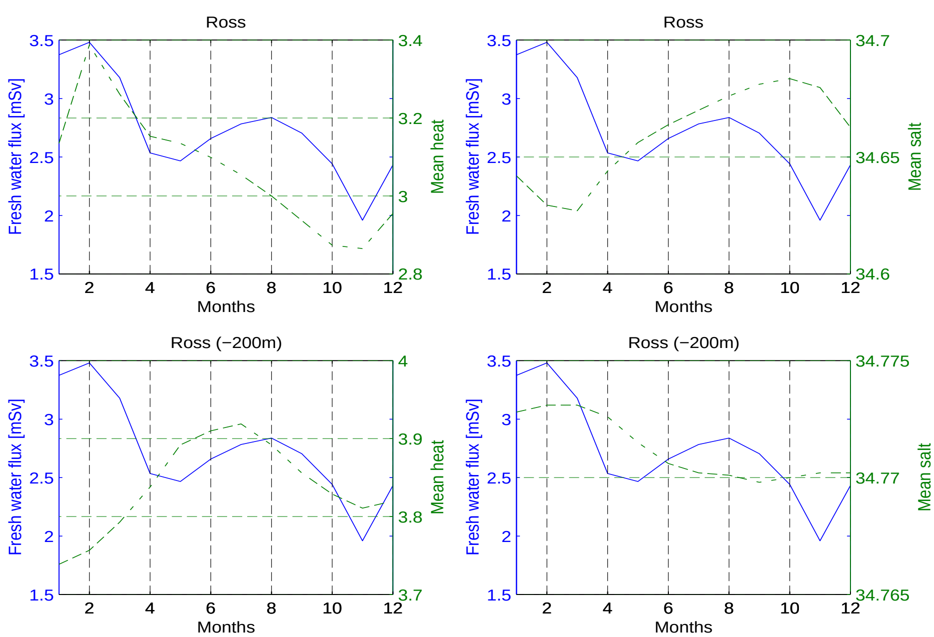


**Figure 3:** The total freshwater flux [mSv] from melting the base of Ross Ice Shelf (solid line) compared with the mean heat (left) and salt (right) content of the total (upper panels) and lower 200 m (lower panels) water column of the continental shelf of the Ross Sea (dashed line). For a better visibility the scales for heat and salt differ with water column thickness.

The relation is more complicated for the Ross Sea where the RIS freshwater flux shows two maxima; the first of 3.5 mSv in February and the second of 2.8 mSv in August (Fig. 3). Detailed studies of the Ross Sea [*Assmann et al.*, 2003] show that the first maximum is due to a wind-driven circulation which forces warm near-surface waters around Ross Island. As for the southwestern Weddell Sea, the second maximum corresponds to the increase of the density gradient due to the growth of the HSSW pool on the Ross Sea continental shelf. The relation changes sign for the lower 200 m of the water column, but the amplitudes of the variability decrease significantly especially for salt.

## Conclusions

This study shows that a parameterization of the sub-ice freshwater flux as proposed by *Beckmann and Goosse* [2003] is problematic because of the missing direct link to continental slope temperatures, major regional differences, and dependencies on the thickness of the shelf water column considered. Therefore, the only suitable way today might be prescribing the freshwater fluxes determined by regional coupled ice-ocean models (Fig. 4) at the southern boundary of large-scale global models corresponding to ice shelf fronts. Further studies are necessary for the Ross Sea to investigate whether the maximum sub-ice freshwater flux during the onset of the freezing season significantly impacts sea ice formation and shelf water characteristics.

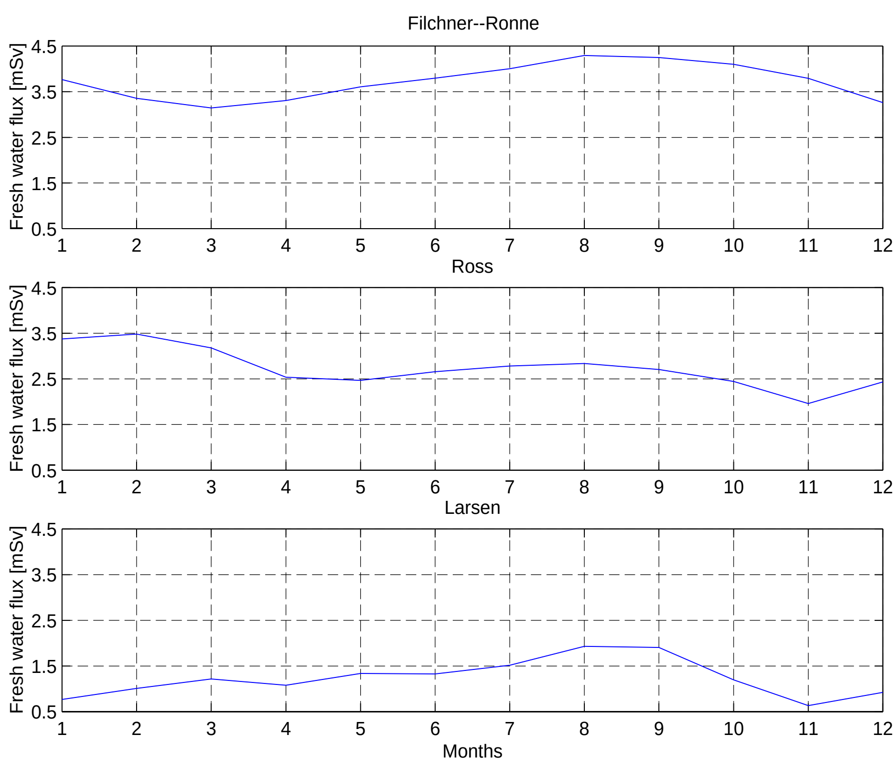


**Figure 4:** Total freshwater fluxes [mSv] from basal melting of Filchner-Ronne (upper), Ross (middle) and Larsen (lower) ice shelves.

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