Evolution of ocean freshwater forcing from antarctic ice shelves over the past 20 years

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1-Introduction

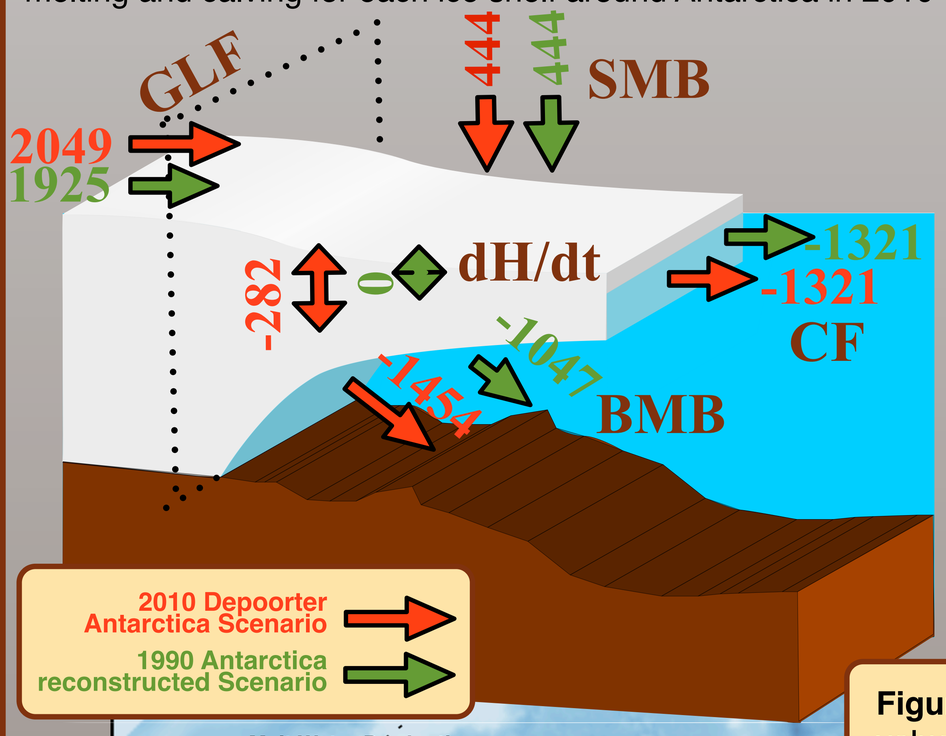
Freshwater run-off from Antarctica plays a crucial role in setting Southern Ocean properties and circulation. As a consequence, the observed speed-up of Antarctic outlet glaciers and associated increase of freshwater release may have a large influence on ocean dynamics and sea-ice formation. Increase in freshwater forcing is usually neglected or poorly considered by current ocean models but may contribute to explain the observed trends in the Southern Ocean. Starting from a recent estimation of calving and melting fluxes of each ice shelf around Antarctica in 2010, and taking into account mass balance of both grounded ice sheet and floating ice shelves, we propose a possible scenario of the spatial and temporal evolution of the freshwater run-off during the two last decades.

2-Methods

We consider the melting and calving rate study from *Depoorter et al. 2013 (1)*. Its results are based on a simple mass balance equation corresponding to a mean 2010 state

$$GLF + SMB + CF + BMB = dH/dt$$

where **GLF** is the grounding line flux, **SMB** the surface mass balance, **CF** the calving flux, **BMB** the basal mass balance and **dH/dt** the thickening rate. This equation is applied to each ice shelf greater than about 100km2, with an upscaling correction for each ocean sector accounting for the rest of ice shelves. This provides an estimation of melting and calving for each ice shelf around Antarctica in 2010



Here, we reconstruct each term of the equation in order to obtain a scenario of the BMB at the beginning of the 90s. We use the following assumptions:

GLF: *Shepherd et al. 2012 (2)* provides an estimation of each drainage basin mass loss over the 1992-2011 period. The origin of this imbalance is supposed to have a dynamical origin in West Antarctica, Antarctica Peninsula and Totem and Cook sectors in East Antarctica. Therefore, we linked this mass imbalance with a corresponding grounding line flux change in the ice shelves of those regions.

SMB: Depoorter results are based on a 32yr RACMO2 simulation. Besides, no significant trend (mostly lower than 10%) is observed in the ice shelves areas (*Monaghan et al. 2006 (3)*). We therefore consider there are no reason to modify the SMB provide in Depoorter study.

CF: Since no important change in the calving front has been observed during the last decades, we assume that there is no trend in calving flux over this period.

dH/dt: We start from the hypothesis of a stable ocean-Antarctica interaction at the beginning of the 90s. Even if we know that outlet glaciers like Pine Island were already thinning during the 80s, we assume that ice shelves were mostly well balanced before starting the observed Antarctica mass imbalance during the last two decades. That leads to consider **dH/dt=0**. At least should be a good general approach at continental scale at the beginning of that period.

Figure 1 shows a drawing of an ice shelf with the mass exchange budgets in Gt. In red we show the global value at Antarctica scale coming from Depoorter study. In green we show the values of our reconstructed scenario. Note the increase of almost 400 Gt of meltwater during the studied period. If our assumptions are reasonable, most of studies about Antarctica-Southern Ocean interaction are underestimating the increase of freshwater flux when only considering the Antarctica mass imbalance in the grounded ice sheet.

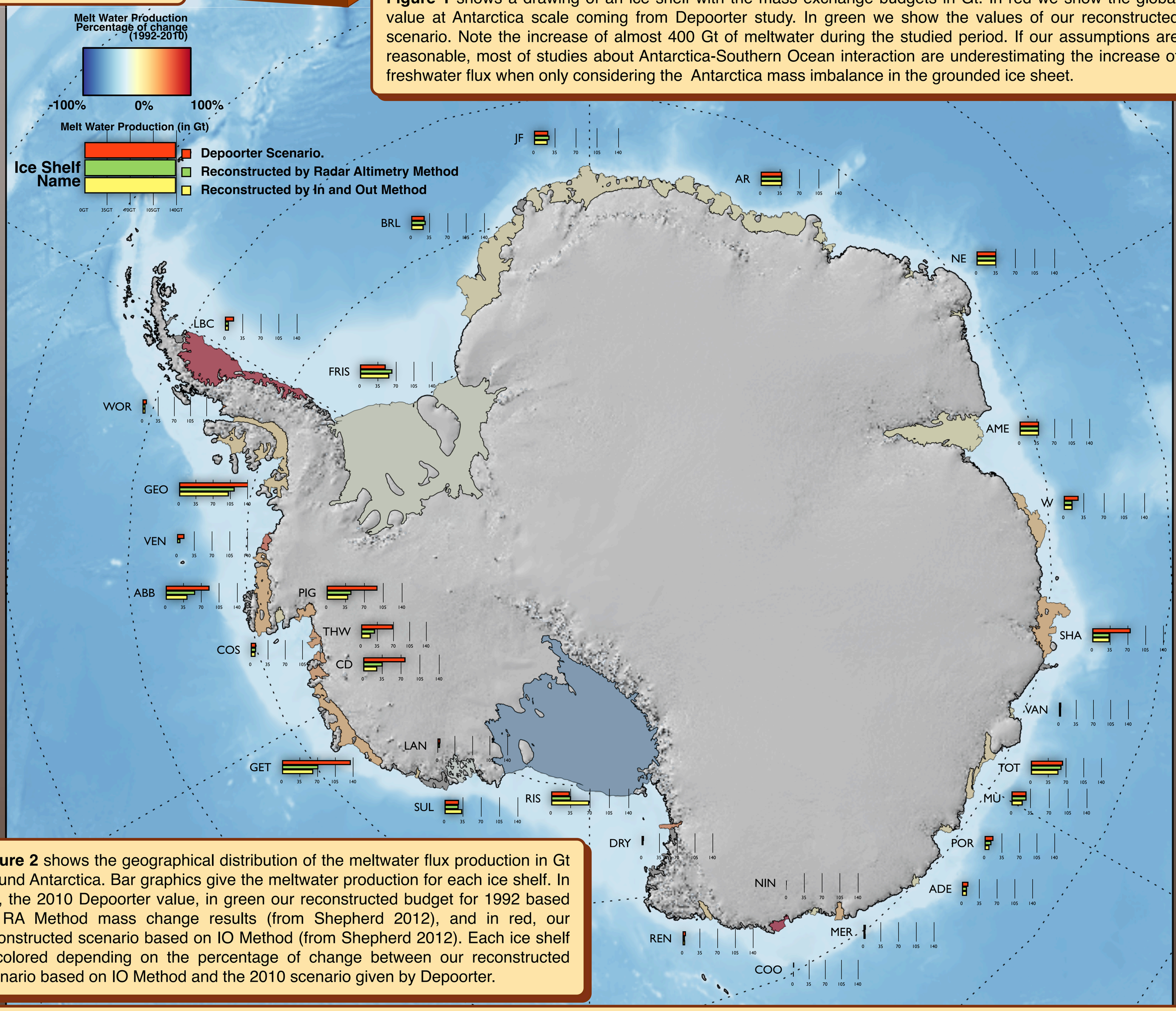


Figure 2 shows the geographical distribution of the meltwater flux production in Gt around Antarctica. Bar graphics give the meltwater production for each ice shelf. In red, the 2010 Depoorter value, in green our reconstructed budget for 1992 based on RA Method mass change results (from Shepherd 2012), and in red, our reconstructed scenario based on IO Method (from Shepherd 2012). Each ice shelf is colored depending on the percentage of change between our reconstructed scenario based on IO Method and the 2010 scenario given by Depoorter.

(1) Depoorter, M. A., et al. "Calving fluxes and basal melt rates of Antarctic ice shelves." *Nature* (2013).
(2) Shepherd, Andrew, et al. "A reconciled estimate of ice-sheet mass balance." *Science* 338.6111 (2012): 1183-1189.
(3) Monaghan, Andrew J., David H. Bromwich, and Sheng-Hung Wang. "Recent trends in Antarctic snow accumulation from Polar MM5 simulations." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 364.1844 (2006): 1683-1708.