Recent past and projected future freshwater fluxes from Arctic land ice

ARCTIC PASSION

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1. Abstract

We have developed a freshwater flux (FWF) time series aimed at providing a benchmark data set for testing the sensitivity of ocean and coupled GCMs to realistic, plausible future FWF forcing alongside a 70 year reconstruction of past fluxes, building on previous work (Bamber et al., 2018). We combine ERA5 reanalyses, a regional climate model and satellite observations to reconstruct the FWF for all Arctic land ice from 1950-2021, partitioned into solid and liquid phases around the coastline of glaciated sectors of the Arctic. We then project the FWF forward until 2100 using estimates of Greenland Ice Sheet melt derived from a structured expert judgement assessment for two temperature scenarios that approximate business as usual and a Paris Agreement limit to warming (Bamber et al., 2019; Bamber et al., 2022).

We develop projections for both the median and 95th percentile melt estimates to provide FWF forcing that encompasses plausible future FWF anomalies. The geographic distribution of melt anomalies are scaled according to present-day anomalies in runoff and solid ice discharge from the ice sheet. For the high end case (business as usual, 95th percentile) this equates to a FWF anomaly from the Greenland Ice Sheet of about 0.15 Sv by mid century and ~0.25 Sv by 2100, representing an unlikely but plausible FWF entering, primarily, the sub-polar North Atlantic. This is comparable to values used in hosing experiments.

2. Approach

We broadly follow the approach in Bamber et al 2018 by combining observations of ice discharge from 1985-2021 (King et al, 2018) with modelled runoff data from the regional climate model MAR forced by ERA5 for the period 1950-2021. We extrapolate the discharge time series back to 1950 correlating pentad runoff with discharge (Fig 1) for the Greenland Ice Sheet resulting in the basin-average time series in Fig 2:

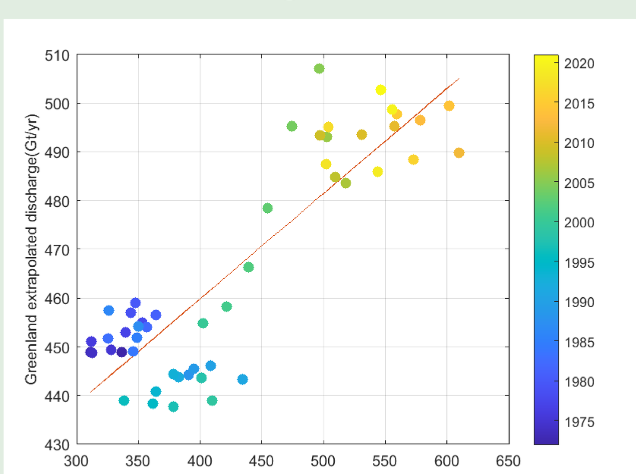


Fig 1. Previous 5-year mean runoff vs discharge for the whole of the ice sheet

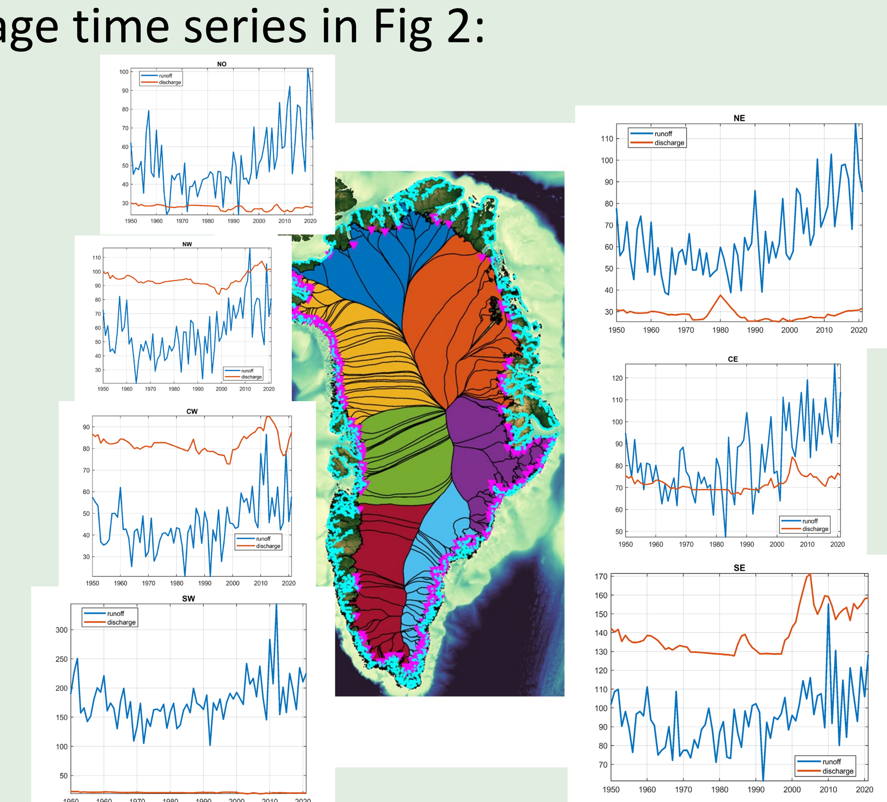


Fig 2. Runoff (blue) and discharge (red) for 7 basins over the ice sheet for 1950-2021

3. Results

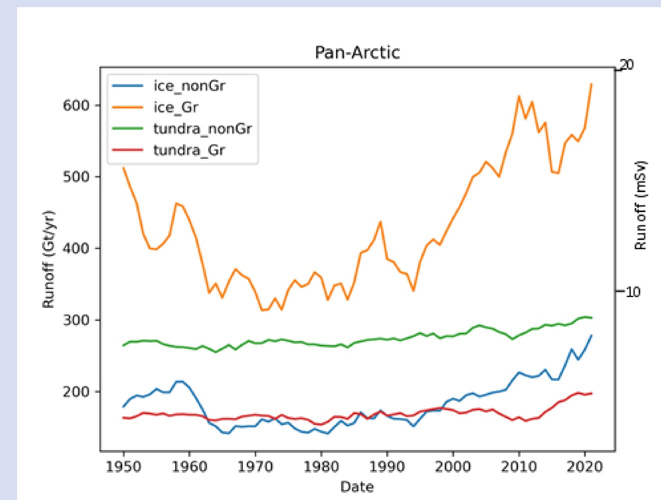


Fig 3. Runoff trend by land type, 1950-2021. Fig 2 shows the change by basin.

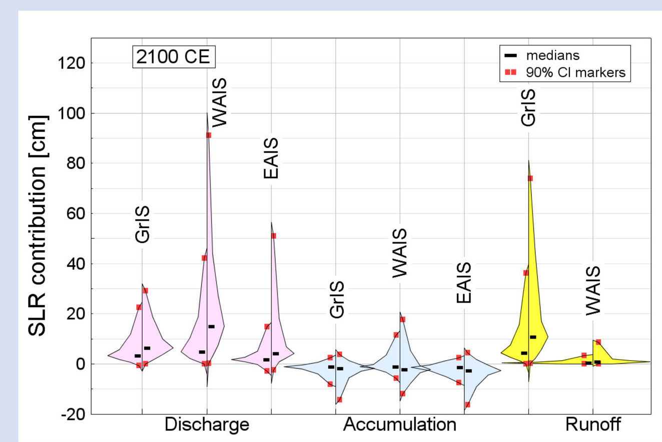


Fig 4. Data used in projecting discharge and runoff to 2100 from Bamber et al 2022. Violin plots (PDFs plotted vertically): LHS is 2° warming, RHS 5° by 2100. GrIS= Greenland Ice Sheet. Red bars are 90% credible ranges used in "worst case" reconstruction

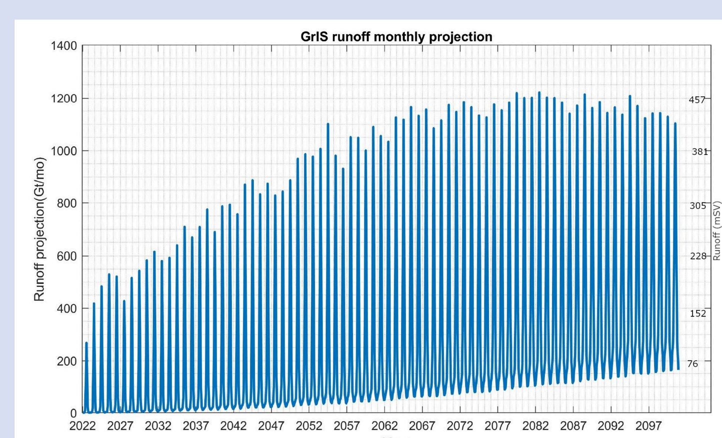
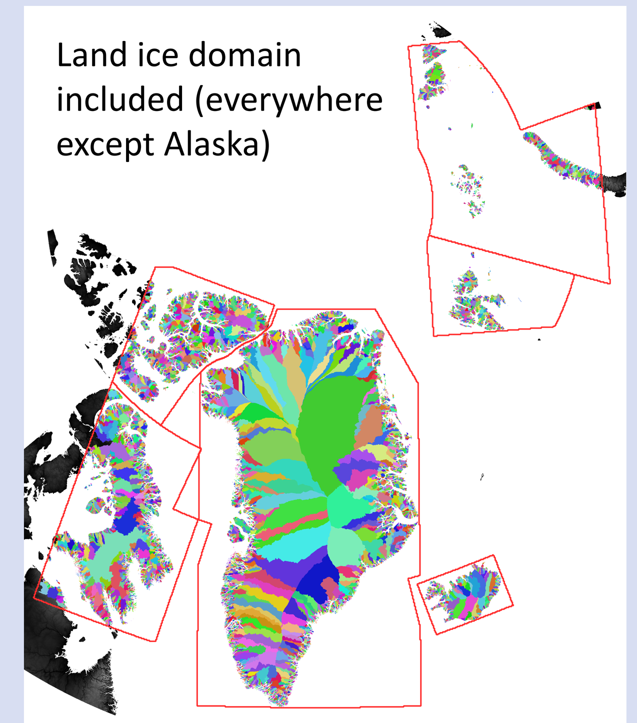


Fig 6. The projected runoff time series showing the seasonal cycle and max amplitude of the FWF of ~0.5 Sv during summer.



The runoff data set covers all Arctic land ice except Alaska for the period 1950-2021 and the goal is to make it near real time (Igneczi et al, in prep)

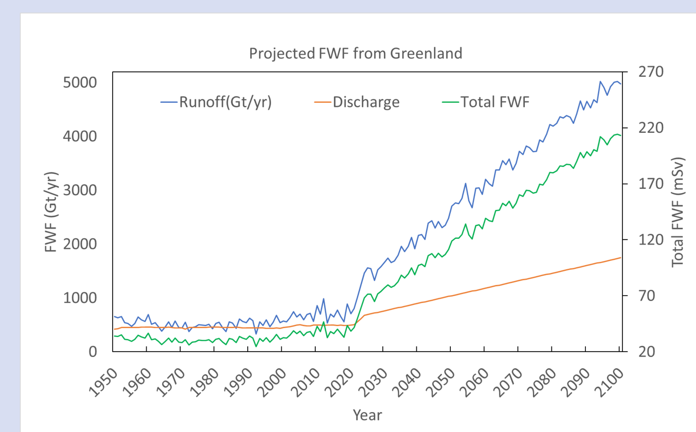


Fig 5. The preliminary past and future FWF time series for runoff and discharge (Gt/yr) and combined in mSv (RH axis) for the high temperature scenario (5degs) and 95th percentile probability (~1 m by 2100).

5. Discussion and Conclusions.

- In the previous study (Bamber et al 2018), the reconstruction started in 1958 and the FWF anomaly roughly increased monotonically from the mid 1990s to present. Extending the time series back captures the tail end of the warming in the late 1940s and the monotonic trend is less clear. Nonetheless, as before, the largest trends are seen in Labrador and GIN seas. In our projections, it is also southern Greenland that sees the largest response.
- By 2100 for the 95th percentile high temp. scenario the annual mean FWF reaches around 0.25 Sv by 2100 but with a large seasonal cycle such that summer anomalies are more than double this value (Fig 5).
- The median probability FW fluxes for the same temp. scenario (the most probable) results in a flux of 0.05 Sv by 2100 which is, in general, smaller than typical hosing expts and below the value that results in a substantial reduction in AMOC strength in AOGCM and ESM simulations.

Conclusion and Outlook

- The reconstructed FWF shows an approximately monotonic increase since the mid 1990s with Arctic GIC (particularly the Canadian Arctic) contributing significantly to the increase. Most of this anomaly enters the sub polar North Atlantic.
- We are in the process of running a suite of FW forcing experiments with a medium resolution GCM, HadCM3 with several FW forcing scenarios to investigate climate feedbacks and interactions.

References:

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