10.17 HYDROLOGICAL DISCHARGE OVER GREENLAND

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1 Introduction

The fresh water from melting sea ice and ice sheet over Greenland, transported into the North Atlantic, influences the deep water formation and the thermohaline circulation. Since only sparse or no runoff data exists over Greenland, especially from the inner regions, as an alternative, climate model simulations can be used to compute the lacking information. A routing scheme is developed here and applied over Greenland to determine the regional distribution of discharge of fresh water into adjoining ocean. Regional climate model (REMO) simulations will later provide the atmospheric forcing data, whereby the land surface scheme of the REMO model must first be extended to include represenatation of surface hydrology processes taking place in the ablation zone of the ice sheet. This scheme will then be directly implemented in the climate model in a following study.

2 Routing Scheme - Multiple Path Distributed Flow

A simple straightforward routing scheme is constructed with flow proportional to gradient towards all lower elevated direct neighbours. This implies that flow will disperse since it may occur in more than one direction for any arbitrary grid point. The "Multiple Path Distributed Flow" (MPDF) scheme first applied to flow over orography with simple geometry generates numerically accurate results within the assumptions of this approach. The discharge computed for normed runoff set to 1 from each grid point is distributed to the lower grid points

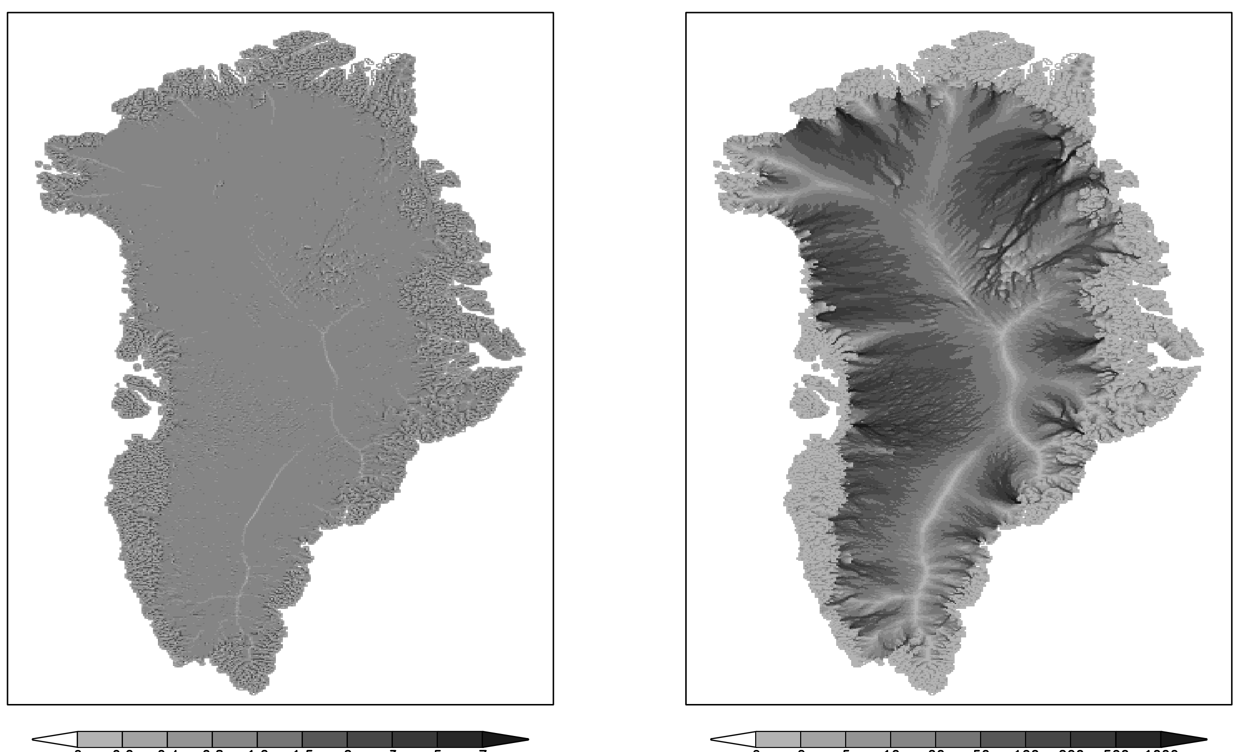

Figure 1: (a) Discharge over Greenland using MPDF scheme, (b) contributions of upspream catchment area

proportional to the gradient in each direction [1]. The flow pattern is calculated at suitable time interval for Greenland using 2.5 km digital elevation model constructed by Eckholm (1996). The flow pattern for a single time step presented in Fig. 1 (a) has resolution of 5 km in order to reduce the size of the figure. The bright shade demarcates the catchment area and higher elevations whereas the dark regions are lower lying regions from where the flow contributions are very small.

The inverse process of computing the upstream catchment contribution to the flow through a grid point is substantially more complicated. The flow through a grid point is a sum of flow over all paths consisting of connected grid points, where when starting from the grid point under consideration each grid point along a path must lie higher than the previous one. Since many paths cross, care must be taken in calculating the flow contribution of each path without multiple counts. A fast algorithm is constructed here, which in a simple test case was shown to be exactly mass conserving. The distribution of upstream catchment is shown in Fig. 1 (b) for Greenland. The dark regions towards the edge of the ice sheet have the largest catchments feeding the flow, indicating ice streams and regions where mass loss due to calving of the glaciers is expected to be the strongest.

3 Runoff over Greenland

The unsaturated flow in the REMO is the same in the ECHAM general circulation model. A fraction of rainfall over a grid point is allowed to infiltrate depending on the soil properties and saturation also accounting for sub-grid heterogeneity of the land surface. The results of a previous simulation study [2] with the regional climate model - REMO for one year (March 1996 to February 1997) at 0.5 ° resolution are used to construct annual (Fig 2 (a)) and summer (Fig 2 (b)) runoff from Greenland as currently represented in the land surface scheme of REMO and ECHAM 4. Most of the runoff occurs here in the summer season. This pattern is however not consistent with observations; for example, large discharges along the south-east coast are completely absent. Thus a better representation of melting ice sheet and higher resolution are essential for capturing the primary features of fresh water discharge.

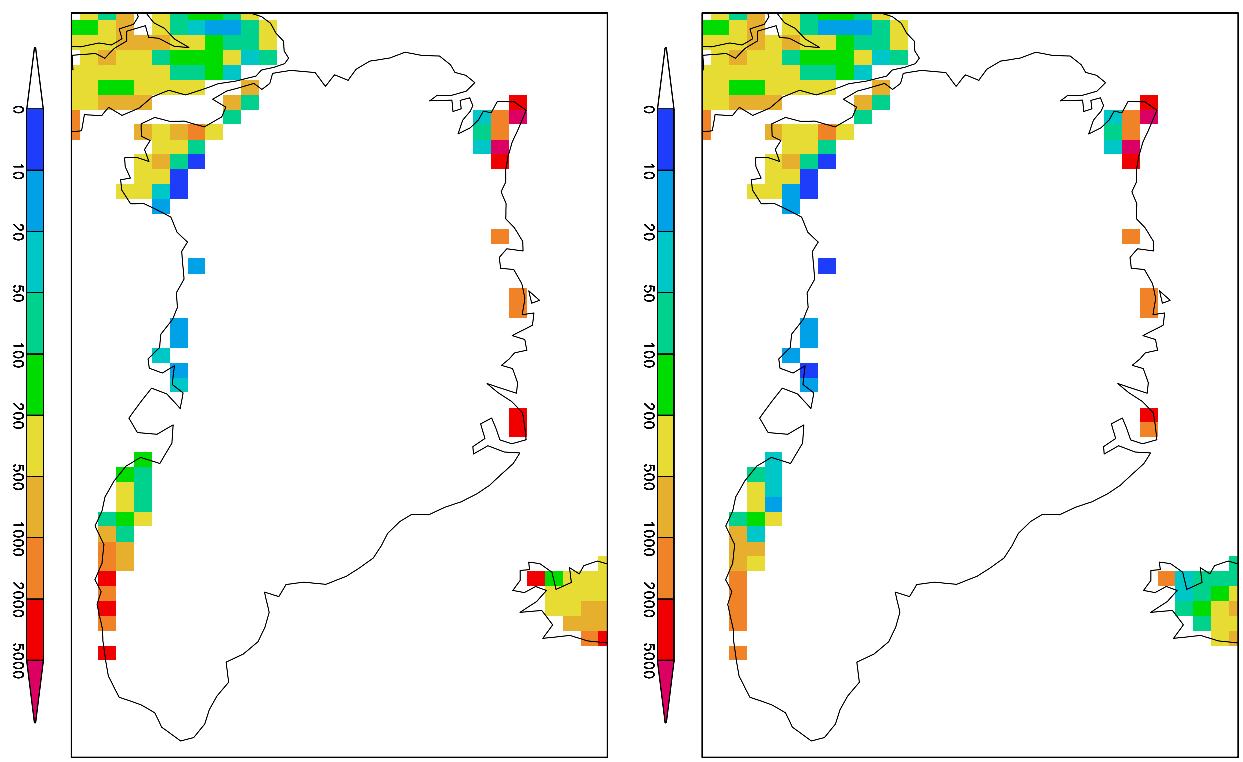

Figure 2: Surface runoff from Greenland: (a) Annual Mar 1996 - Feb 1997 and (b) Summer JJA 1996

4 Discussion

This is one of the first attempts to apply a runoff scheme for ice sheets directly to climate simulation studies. The main aim is to obtain an estimate of the discharge of fresh water and ice into the ocean from the ablation zone of the Greenland ice sheet. Since the extreme coastal orography strongly affects the atmospheric ciculation, high resolution studies become necessary. The resolution also limits the details of the processes which may resonable be represented in hydrological models or in land surface schemes of climate models [3]. Since over 80% of the total land surface of Greenland is covered by ice and the vegetation is sparse with a short growing season, the land use does not limit the resolution of the study. Regional climate models are now beginning to operate on resolution of 3 to 30 km, where some of the conceptual hydrology models may be applied based on simplified hydro- and thermodynamic equations. For the lateral transport and the MPDF scheme, the resolution must be suffiently high in order to capture the details of catchment orography which is necessary to simulate subcatchment scale flow.

Simulations with smaller grid size can better resolve the ablation zone since it may be narrow in certain regions. The MPDF scheme can then be used to transport the runoff to the coast and provide the ocean modellers with an improved estimate and distribution of the fresh water discharge from the ice sheet. Thus the land surface scheme must be extended to regions covered by ice allowing for processes such as melting, refreezing, infilteration, sublimation and calving to occur. A control run will then be compared with a simulation using the improved land surface scheme to assess the added value of new parameterisation and higher resolution. The implications on seasonal and annual time scales will also be considered. The results will be validated with the NASA study [4] on the observed thinning of ice sheet from 1992-1993 to 1998-1999.

References

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