Resolution of ice streams and outlet glaciers in large-scale simulations of the Greenland ice sheet

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Since the late 1970s, numerical modelling has become established as an important technique for the understanding of ice sheet dynamics. Ice sheet models are particularly relevant for predicting future changes of ice sheets, mass loss and resultant contribution to sea level rise in response to climate change. Mass transfer from the Greenland ice sheet to the ocean is to a large part through ice streams and outlet glaciers that have a higher velocity than the surrounding ice. Since they form in many cases due to the existence of subglacial troughs, bed topography plays an important role for properly modelling ice dynamics. However, these trough systems typically have a width of less than 10 km and are thus poorly resolved in large-scale simulations that employ coarser grids.

In this study, the ice sheet model SICOPOLIS (http://sicopolis.greveweb.net/) is applied to the Greenland ice sheet with resolutions from medium (20 km) to very high (5 km), thus resolving ice streams and outlet glaciers with different accuracy ranging from poor to reasonably good. The impact on the simulated surface velocity field of the present-day ice sheet is discussed, and the consequences for predictions of mass loss and contribution to sea level rise under several climate change scenarios for the next centuries is investigated.

Specifically, standard scenarios of the SeaRISE (Sea-level Response to Ice Sheet Evolution) community effort (http://tinyurl.com/srise-lanl, http://tinyurl.com/srise-umt) are carried out. The paleoclimatic spin-up over 125,000 years until the present is run with a surface temperature forcing derived from the GRIP oxygen isotope ($\delta^{18}O$) record (Dansgaard and others, 1993; Johnsen and others, 1997), and the topography is kept fixed over time in order to enforce a good fit between the simulated and observed present-day topographies. The bed topography is based on the 5-km DEM by Bamber et al. (2001) plus high-resolution data for four major outlet glacier systems (Jakobshavn, Helheim, Kangerdlussuaq, Petermann) by CReSIS, Univ. Kansas, integrated by a new algorithm (Herzfeld et al., submitted) that preserves shape, orientation and continuity of the outlet glacier systems on the 5-km scale. Results show that the simulated patterns of present-day fast flow depend strongly on the horizontal resolution, as it is illustrated in Fig. 1 for the Jakobshavn ice stream. SeaRISE future climate experiments are carried out 500 years into the future and comprise climatic, oceanic and basal lubrication forcings. Here only two scenarios out of this suite, namely the constant climate control run C1 and the constant climate/doubled basal sliding run S1, are considered. The results displayed in Fig. 2 show that simulated absolute ice volumes depend significantly on the horizontal resolution (the finer the resolution, the less ice volume), while the sensitivities (control minus 2 x sliding) are not so much affected, which is a somewhat surprising finding.

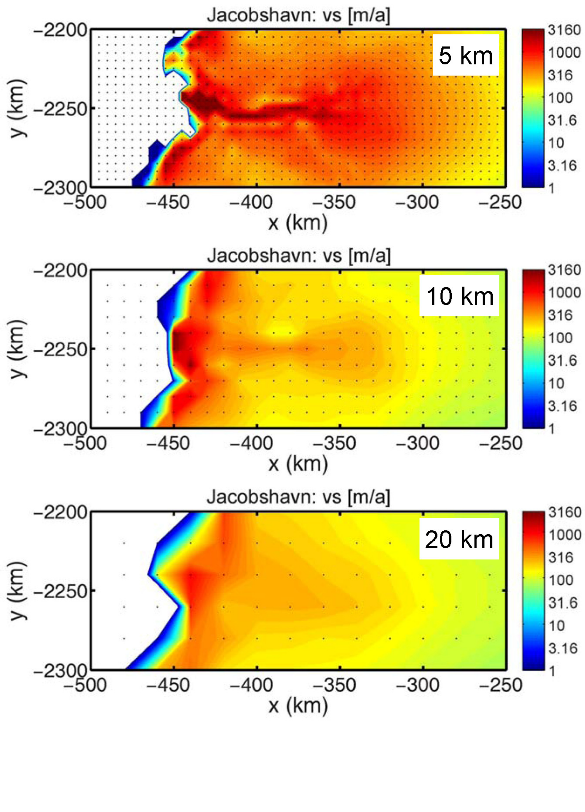

Figure 1. Simulated present-day surface velocities in the vicinity (250 x 100 km) of the Jacobshavn ice stream for horizontal resolutions of 5, 10 and 20 km.

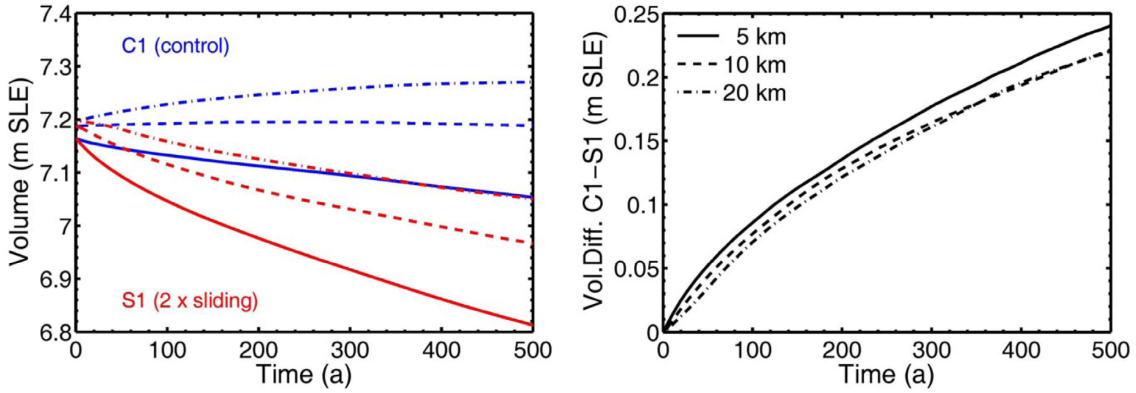

Figure 2. Left panel: Simulated ice volumes (in metres of sea level equivalent) 500 years into the future for the constant climate control run C1 (blue) and the constant climate/doubled basal sliding run S1 (red), carried out at horizontal resolutions of 5 (solid), 10 (dashed) and 20 km (dash-dotted). Right panel: Sensitivities (control minus 2 x sliding) for the three different resolutions.

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