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How fast is the Greenland ice sheet melting?

The Greenland ice sheet (GrIS) is the world's second largest ice sheet, holding about ten percent of the Earth's total freshwater. Since the 1990s, the GrIS has experienced significant mass loss due to enhanced surface melt and accelerated ice discharge from marginal outlet glaciers. Brice Noël is a fourth year PhD student at the Institute for Marine and Atmospheric research at Utrecht University (IMAU), who graduated in 2013 as a polar climatologist at the Université de Liège in Belgium. His PhD research is the continuation of his master thesis that focused on the sensitivity of the GrIS climate to perturbations in sea surface temperature and sea ice cover, using a regional climate model.

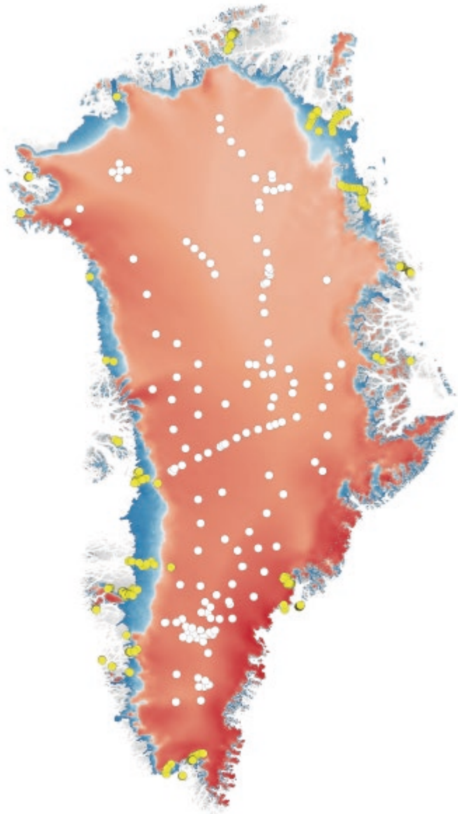
The GrIS and its surrounding peripheral ice caps are major contributors to ongoing sea level rise. If totally melted, the global sea level would rise by about 7.4 m. To better understand these changes and complement the sparse measurements available, I use the Regional Atmospheric Climate Model (RACMO2) to simulate the climate of Greenland. In particular, I model the surface mass balance of the GrIS, i.e. the difference between snowfall, sublimation and meltwater runoff. The polar version of RACMO2 is specifically adapted to simulate the surface mass balance of glaciated regions, including Greenland, Svalbard, Iceland, the Canadian Arctic and Antarctica.

Improving the model

Recently, the physics in RACMO2 have been updated. The first task in my PhD was to carry out a climate simulation at a resolution of 11 km for the period 1958–2015 to evaluate the updated model performance. Such climate simulations are computationally expensive and are performed using the supercomputers of the European Centre for Medium-Range Weather Forecasts (ECMWF) in Reading, UK.
Many processes have to be taken into account in the modelling. One of the improvements of the updated RACMO2 model is that it allows for super-saturation in ice clouds, which increases the maximum moisture-holding capacity of ice clouds at saturation. As a result, snowfall production is partly delayed to higher elevations in the ice sheet interior. These modifications improve the model performance by favoring snowfall at the expense of rainfall during relatively cold summers. As a result, highly reflective fresh snow cover can be formed over exposed dark bare ice at the GrIS surface, decreasing meltwater runoff during the melt season through locally increased surface reflectivity (albedo).

Higher resolution

To cover spatially extended glaciated regions while overcoming computational limitations, regional climate models are run at relatively coarse horizontal resolutions, typically 5 to 20 km. In RACMO2, the 11 km resolution does not resolve small ice bodies such as marginal outlet glaciers and surrounding peripheral ice caps. To address this issue, near-kilometer resolution is essential, but performing such simulations with RACMO2 remains computationally impossible at present.
Therefore, my second objective was to develop a new approach to statistically downscale the output of RACMO2 to a 1 km resolution. To that end, we developed a downscaling algorithm that corrects meltwater runoff for elevation and ice albedo biases in RACMO2 to provide a new state-of-the-art daily, 1 km resolution, surface mass balance product covering the whole ice sheet (see Noel et al., 2016).
Our study emphasizes the inability of the current climate models to accurately represent the large surface mass loss from Greenland's marginal glaciers, which are known to play an important role in the ongoing sea level rise. In this respect, the 1 km data set proves to be an overall improvement over the original RACMO2 product. It realistically resolves meltwater runoff in narrow ablation zones and over small outlet glaciers, showing a progressive mass loss increase towards



Surface mass balance of the Greenland ice sheet and surrounding ice caps downscaled to 1 km [1958-2015]. Greenland loses mass in the ablation zone at the ice sheet margins (blue) while it gains mass over the extensive accumulation zone in the interior (red). The white region separating both zones is called the equilibrium line, delineating the area where snowfall accumulation balances exactly the ablation from meltwater runoff. Regions in gray represent the tundra area fringing the ice sheet. Dots locate sites where surface mass balance is measured in both the ablation (yellow) and accumulation zone (white). Note how small marginal glaciers and ice caps are accurately resolved at 1 km resolution.

their glacial tongues. The downscaling technique was also successfully applied to Greenland's peripheral ice caps and more recently to the Canadian Arctic, highlighting the importance of an accurate representation of small glaciers in climate models in order to produce realistic mass loss.

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At the present rate of mass loss, it would still take about 10,000 years to melt the GrIS entirely. But at the same time, surface mass gains could become zero between 2023 and 2043. In the absence of other mass sources, this is sometimes regarded as a tipping point beyond which the ice sheet won't be able to recover.

At IMAU

Conducting a PhD at IMAU is a fantastic experience. The Ice and Climate group is very dynamic and offers excellent support for PhD students from numerous post-docs and professors working in various ice-related fields. Within this unique framework, I could tackle many challenges, collaborate with famous researchers and launch my scientific career through publications and inspiring travels abroad. For instance, I attended multiple international conferences such as EGU in Vienna or AGU in San Francisco, which are exceptional opportunities to promote my research and meet peer scientists. I will graduate in October 2017 and hope to pursue a career in academia as a postdoc at IMAU or abroad.

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De promotoren van Noël zijn Dr. Willem Jan van de Berg and Prof. Michiel van den Broeke van IMAU

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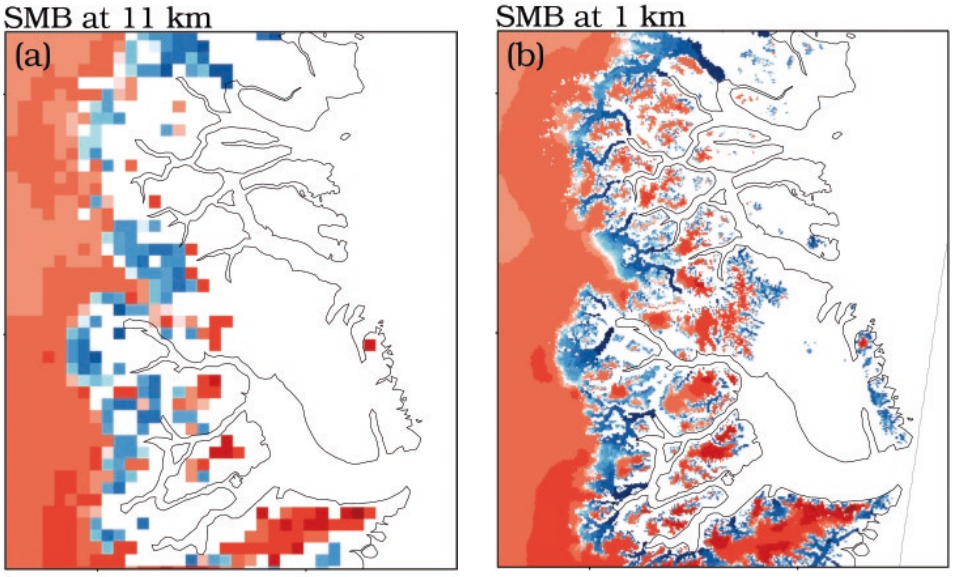
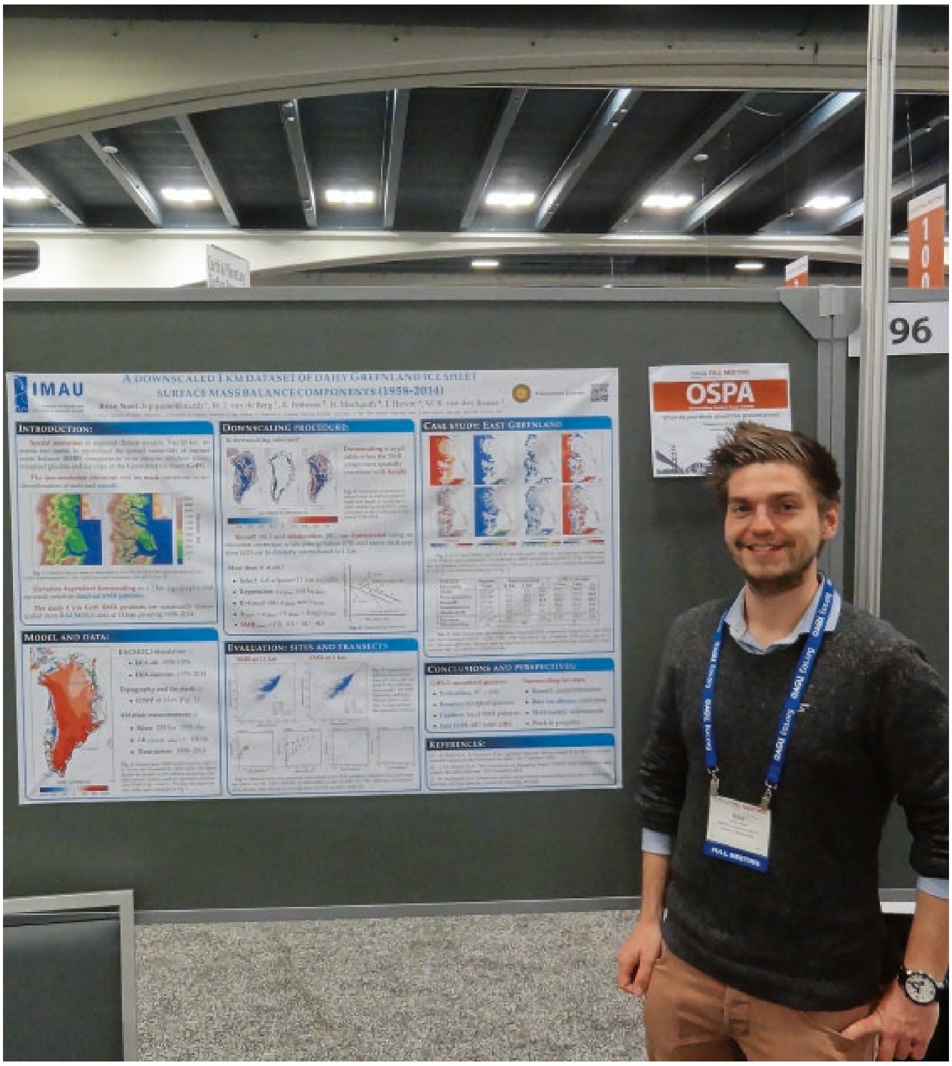


Surface mass balance of glaciers and ice caps in centre east Greenland modeled by RACMO2 at 11 km (a) and downscaled to 1 km (b) [1958-2015]. This figure highlights the inability of current regional climate models to represent small ice bodies at the ice sheet margins. Note how narrow ablation zones, glaciers and ice caps are realistically resolved at 1 km resolution, with a progressive increase in mass loss (dark blue) towards their glacial tongues.



Poster session at the American Geophysical Union (AGU). This conference took place in San Francisco in December 2015. There, I presented some preliminary results on the downscaling technique, which won me the Outstanding Student Presentation Award (OSPA).