Outreach article on **"Regional Sea Level Changes for the Twentieth and the Twenty-First Centuries Induced by the Regional Variability in Greenland Ice Sheet Surface Mass Loss**

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Title: The spatial variability of the surface mass loss of the Greenland ice sheet affects the entire ocean !

Summary

Mass loss from the Greenland ice sheet - surface and basal melting of snow & ice, and iceberg discharge, consequence of the positive Earth's energy imbalance and its associated increase in surface temperature - is an important contributor to the current sea level rise, i.e. around 18% of the global mean sea level rise during the last two decades, and is expected to accelerate during the twenty-first century (Church et al., 2013). The mass loss at the surface – approximated by the difference between snowfall and snow melting, called surface mass balance (SMB) - is expected to dominate the entire mass loss of the Greenland ice sheet at the end of this century (Goelzer et al., 2013). The mass redistribution (transferred from Greenland ice sheet into ocean) associated with Greenland SMB generates changes in sea level through the influence on the Earth's gravitational field, the Earth rotation axis and the crust deformation. The 5th Intergovernmental Panel of Climate Change (IPCC) report projected sea level rise at global and regional scale associated with Greenland SMB over the 21st century. However, the last IPCC report did not take into account the regional variability in Greenland surface mass balance.

In a recent study, researchers from the Laboratoire d'Etudes en Géophysique et Océanographie Spatiale (LEGOS) and the Université of Liège , which are members of the international team of the International Space Science Institute (ISSI) on "Contemporary global and regional sea level rise" (http://www.issibern.ch/teams/climatemodels/), studied the regional sea level changes in response to the surface mass loss of the Greenland ice sheet. They showed that the Greenland SMB changes show a large regional variability due to different climatic conditions, snow & ice properties, and surface elevation & geometry over the Greenland basins (Figure 1 & 2). They found that the southern part of Greenland is more sensitive to climate warming, and thus that its surface mass balance will decrease sooner in the twenty-first century that the northern part (Figure 1 & 2). This regional variability in Greenland surface mass balance results in spatial

variability of sea level changes over the entire ocean, and has to be taken into account in sea level projections, especially along the United State East coast and the northern coast of Europe (Figure 3 & 4) where the effect is the most important.

Method

The regional sea level changes associated with Greenland SMB changes are obtained using the sea level equation that describes sea level changes induced by melting of ice sheets (Farrell and Clark, 1976). In order to derive several estimates of Greenland surface mass balance – and also to study its effect on regional sea level - for each 6 major drainage basins (Figure 1) during the twenty and twenty-first centuries, this study used a downscaling technique calibrated against the Modèle Atmosphérique Régional (MAR) and forced by 32 climate models (from the Coupled Model Intercomparison Project phase 5 – CMIP5) over the 1900-2100 time period. For the twentieth century, historical climate simulations are used, and for the twenty-first century scenario RCP8.5 simulations are used. Comparison for the end of the twentieth century with MAR forced by ERA-40 and ERA-Interim climate reanalysis – considered as reference – shows a good agreement at decadal and multidecadal time scales. Over the twentieth and twenty-first centuries, the ensemble of Greenland surface mass balance estimates shows a significant decrease in all basins as the climate warms - projected Greenland surface contribution to global mean sea level rise in 2081–2100 is around 20 centimeters.

Remarks

Due to the expensive computational time, it was not possible to perform 32 MAR simulations forced by the 32 climate models. Consequently, a downscaling calibration approach what developed using 4 reference MAR simulations that served to empirically calibrate snowfall and runoff of the climate models.

It's also important to note that "*the results are probably conservative because the effects of ice sheet dynamics, ice sheet topography changes, the routing of surface water, and freshwater inputs on the ocean circulation are not taken into account. To go a step further and take these effects into account, we would need to couple the MAR regional climate model with an ice sheet model and dynamics model as well as with an ocean model.*"

Main references

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Figures

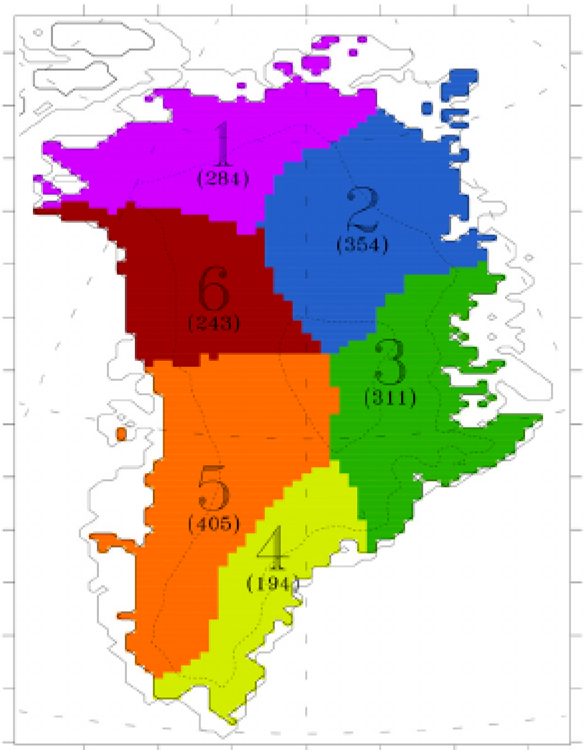

Figure 1. Map of the Greenland drainage basins.

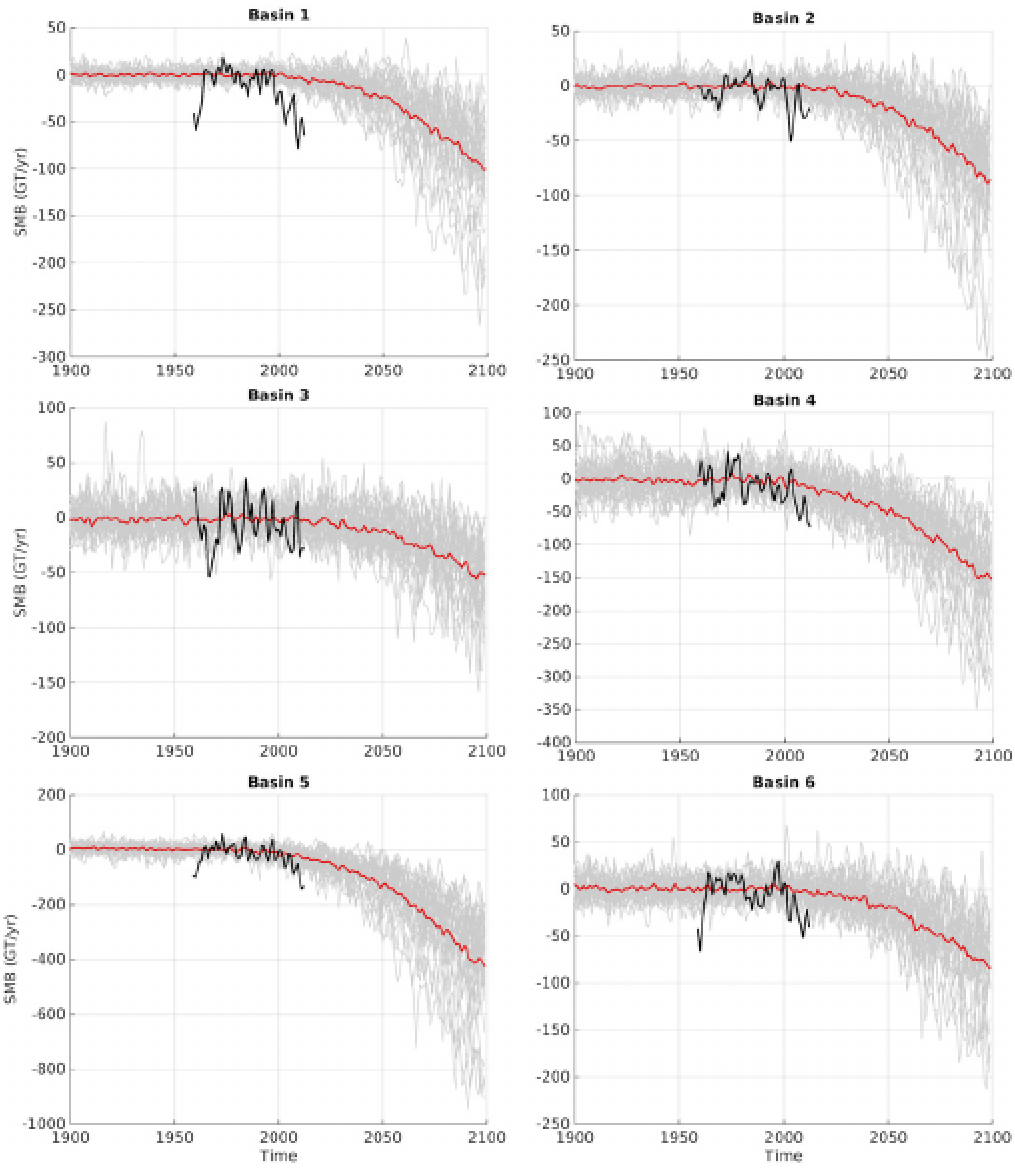

Figure 2. Annual surface mass balance anomalies (in Gt yr^{-1}, scaling with the 1970-89 period) calculated with the regional atmospheric model MAR, forced by 32 climate models using the downscaling approach (individual model simulations are in gray and the ensemble mean is the red line) and forced by ERA-40 & ERA-Interim reanalysis (black curve) for basins 1, 2, 3, 4, 5, and 6.

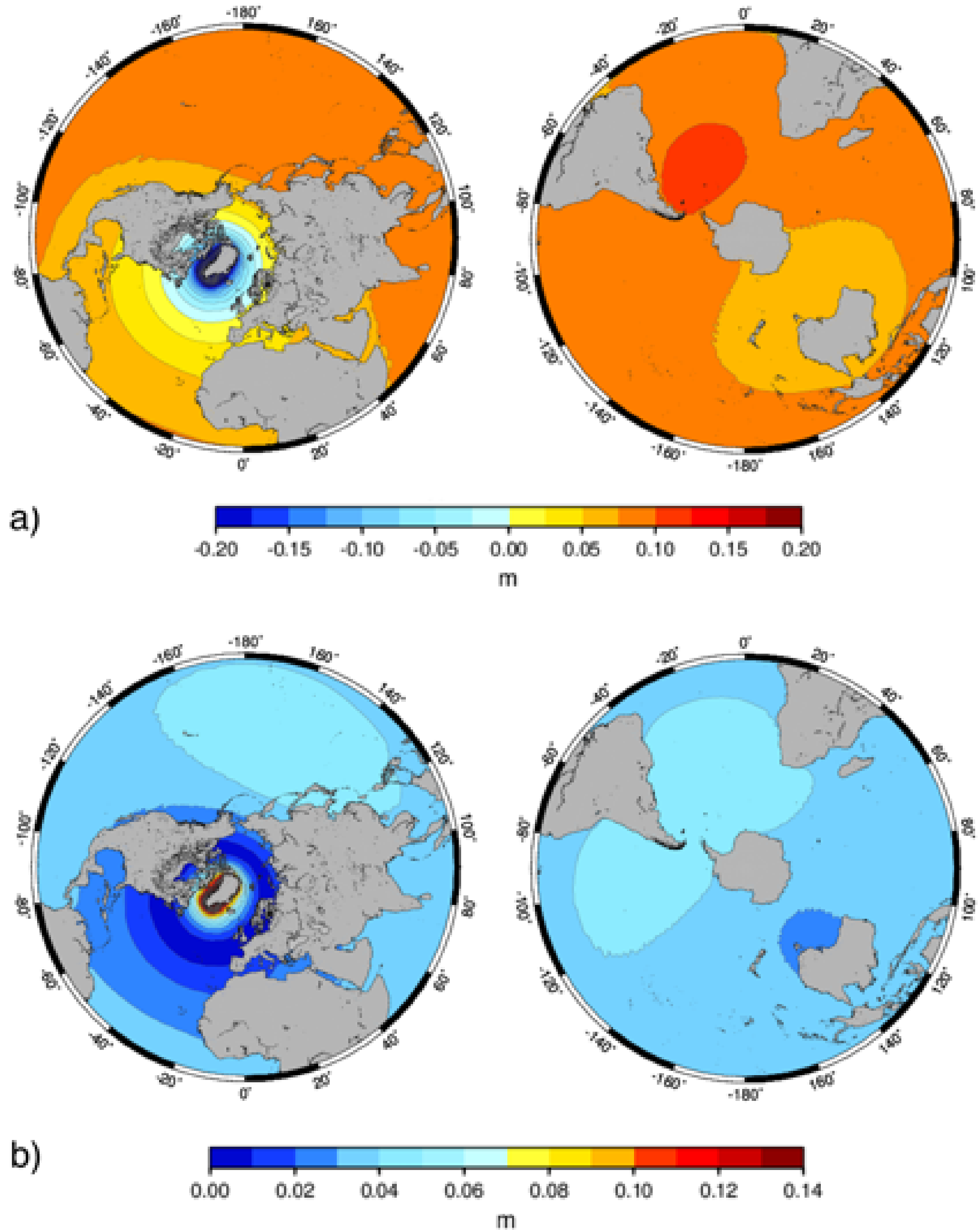

Figure 3. Ensemble mean (a) & standard deviation (b) of the regional relative sea level changes over 2080-2099 (with respect to 1900-1919) in response to Greenland SMB changes as estimated by the downscaling technique forced by global climate model outputs (see text). The regional sea level patterns of (a) & (b) include the effect of the regional variability in Greenland SMB changes.

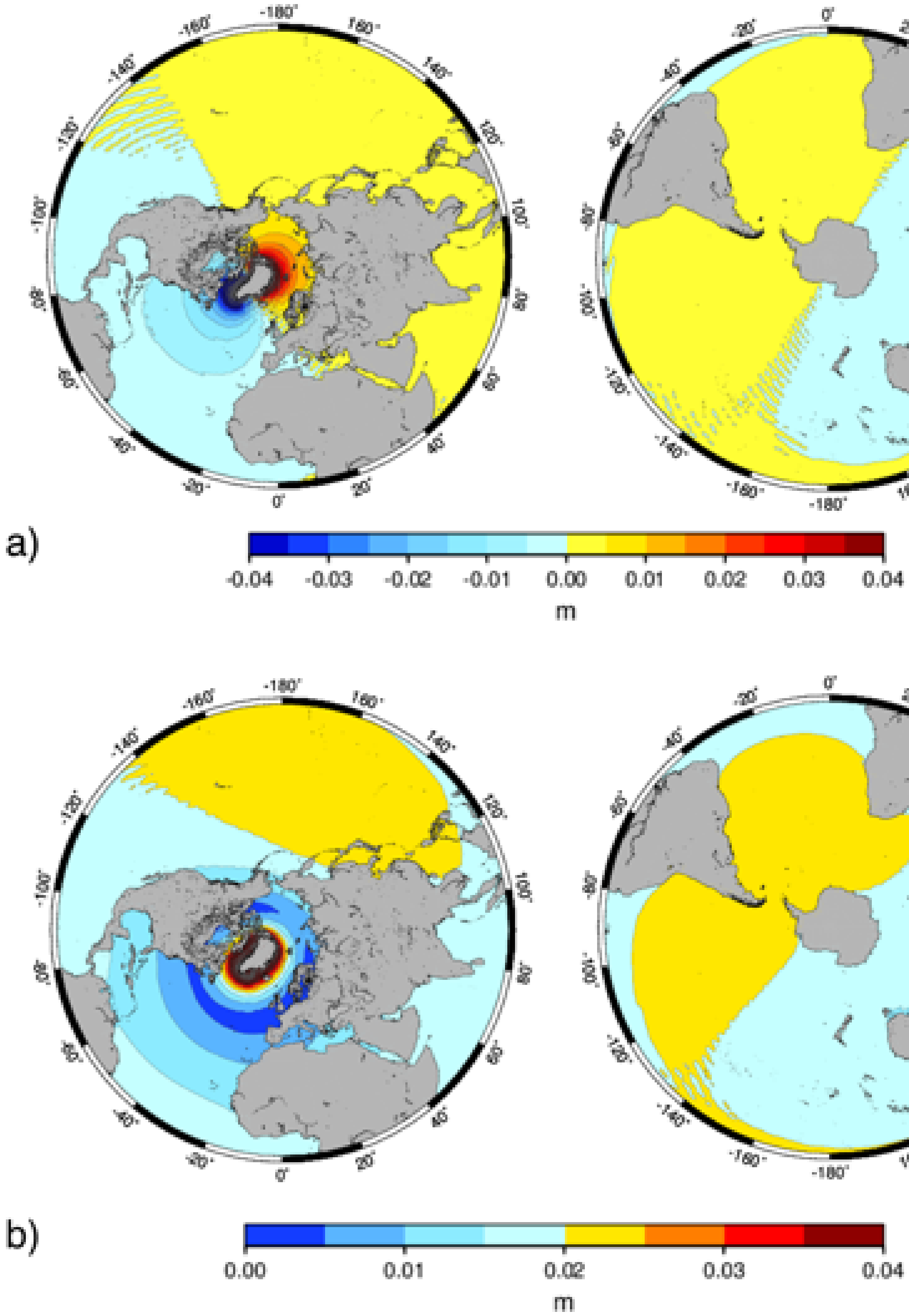

Figure 4. Ensemble mean (a) & standard deviation (b) of the regional relative sea level changes over 2080-2099 due to the regional variability in the Greenland SMB changes only.