

## Effect of meltwater refreeze on the Greenland ice sheet surface mass balance estimated by the regional climate model NHM-SMAP

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In the Greenland Ice Sheet (GrIS), a significant loss of ice mass has been occurring recently. Since around 2010, more than 80 % of the increase in the GrIS mass loss are attributed to increased surface meltwater runoff. In the GrIS margin, most of the meltwater are forced to runoff, because there are not sufficient firn pore space for water storage; however, in the interior GrIS, more water can be retained in firn and some of them are forced to refreeze. Once refreeze are occurred, firn can be warmed substantially due to the latent heating. The increased firn temperature can lead earlier onset of firn melting, which can result in enhanced surface mass loss. Although the above mentioned positive feedback mechanism are qualitatively probable, quantitative impacts by the latent heating in the GrIS are still unclear. Here we present estimated qualitative effect of latent heating on the GrIS surface mass balance (SMB) by utilizing the state of the art regional climate model NHM-SMAP (Niwano et al., 2018). In this study, we performed an off-line numerical sensitivity test with SMAP forced by the NHM-SMAP-calculated surface atmospheric conditions, where the released latent heat due to meltwater refreeze are always set to  $0 \text{ W m}^{-2}$ , and investigated resultant calculated GrIS SMB during the 2011-2014 mass balance years (September to August). NHM-SMAP has been evaluated from various aspects during the same period by using in-situ measurement data obtained in the GrIS, and shows good performance (Niwano et al., 2018). During the study period, no initialization of the GrIS snow/firn/ice physical conditions were performed in the sensitivity simulation. A comparison between simulated yearly-accumulated GrIS SMBs from the default simulation (Niwano et al., 2018) and the sensitivity test indicates that the latent heating aided to enhance the GrIS surface mass loss by 11.3, 5.6, and 5.6  $\text{Gt year}^{-1}$ , for the 2011-2012, 2012-2013, and 2013-2014 mass balance years, respectively. This result suggests that the impact of the latent heating on the surface mass loss is not accumulated year after year at least during the study period. In addition, the impact during the relatively warm year (2011-2012) is roughly doubled compared to other years. According to Niwano et al. (2018), the current default version of NHM-SMAP tends to simulate runoff from the very near-surface layer due to frequent formations of impermeable ice near the surface during the study period, which might cause the weak impacts of the latent heating on the GrIS SMB. Although the frequent formations of the near-surface ice layers simulated by NHM-SMAP are consistent with the in-situ measured conditions reported by Machguth et al. (2016), more field measurements focusing on this topic are necessary to assess the estimated effect of latent heating on the GrIS SMB and understand the rapidly changing GrIS physical conditions.

### References:

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Keywords: Greenland ice sheet, surface mass balance, meltwater refreeze, NHM-SMAP