

Application of a distributed surface mass balance model to ice caps in northwestern Greenland

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Background

Ice caps and glaciers (GICs) existing along the coastal margin of Greenland are losing ice under the influence of recent atmospheric warming, resulting in significant contribution to sea level rise. Northwestern Greenland is one of the areas that experienced large amount of ice mass loss over the last decades. The surface ice loss has been accelerated in recent years (Khan et al., 2010). Bolch et al., (2013) estimated with satellite images of ICESat that surface mass balance of the coastal GICs in northwestern Greenland was -0.60 m a^{-1} and that of all coastal GICs was -0.45 m a^{-1} from 2003 to 2008. Saito et al., (submitted) examined the surface level change of some ice caps in northwestern Greenland more precisely with satellite images by ALOS (Advanced Land Observing Satellite) PRISM and found that the surface change of some ice caps in northwestern Greenland was -1.1 m a^{-1} . We have estimated annual mass balance of some ice caps in northwestern Greenland.

Study site

The studied area is near Qaanaaq ($77^{\circ}28'N$, $69^{\circ}13'W$). The studied five ice caps are the Qaanaaq Ice Cap (QIC), the Hurlbut Ice Cap (HIC), the Five Glacier Dal Ice Cap (FGDIC), the Kiatak Ice Cap (KIC) and Steensby Land Ice Cap (SLIC) in northwestern Greenland. The Equilibrium line altitude (ELA) of QIC was 819 - 864 m a.s.l. in 2012 - 2014 (Maruyama, 2015). Thule climate station ($77.2N$, $68.4W$, hereafter TCS), which is one of the long-term running climate stations in Greenland, situates about 100 km south to Qaanaaq. It is near the Qaanaaq air base and at the altitude of 59 m a.s.l.. The weather station, called sigma-b, was installed on QIC in 2012 (Aoki et al., 2014). The stakes observation was conducted on the outlet glacier of QIC during 2012 - 2015 (Sugiyama et al., 2014; Maruyama, 2015).

Climate of the region

Air temperature at TCS has been increasing gradually. The increasing rate of air temperature, obtained from linear approximation, is $+0.08 \text{ }^{\circ}\text{C a}^{-1}$ from 1980 to 2014. Mean air temperature at TCS during 1980 - 2014 was $-10.7 \text{ }^{\circ}\text{C}$. Air temperature lapse rate between TCS and sigma-b was -4.8 and $-4.9 \text{ }^{\circ}\text{C Km}^{-1}$ for summer 2012 and 2013, respectively.

Annual precipitation does not show a wide change since 1980. July and August are months of high precipitation revealed by the monthly precipitation from 2000 to 2014 at TCS. The mean annual precipitation at TCS during 1982 - 2014 was 163.7 mm a^{-1} .

Mass balance model

The mass balance was calculated with the mass balance model of Distributed Enhanced Temperature-Index Model (DeTIM) (Hock, 1999). The model is able to compute spatial variations of surface mass balance for the ice caps. We used a 500 m gridded digital elevation model and surface condition of snow or ice of the ice caps derived from Advanced Land Observing Satellite (ALOS) PRISM data (Saito et al., submitted). Air temperature with lapse rate and precipitation at TCS were used as input of the model. The model was tuned with in-situ stakes data obtained on the Qaanaaq ice cap in 2012-2015.

Result and discussion

Annual mass balance of QIC was consistently negative from 2000 to 2015. The mass balance for the whole area agreed with the satellite data (Saito et al., submitted) for QIC, FGDIC and HIC. However, the model calculation overestimated the satellite data for KIC and SLIC. The surface of KIC and SLIC are covered with fresh snow. Therefore, the surface albedo of KIC and SLIC are higher than other ice caps (Saito et al., submitted). Since KIC and SLIC exist near the coast, KIC and SLIC are probably under maritime climate more than QIC, FGDIC and HIC.

Conclusion

The mass balance of ice caps in northwestern Greenland was estimated with a mass balance model. The tuning factors for ablation require higher value than typical value, which shows that the ice cap experienced high ablation recently. The result of

the calculation shows similar spatial variation to the observed data with stakes. On the other hand, the model results show large variety among ice caps. The reason of difference between the ice caps is possibly due to albedo difference.

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