The comparison of the Greenland Ice Sheet surface melt extent between multi-spaceborne sensors and regional climate model in 2018 and 2019

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Surface melt on the Greenland Ice Sheet in recent years

Recent mass loss of the Greenland Ice Sheet had been affected by the expand of melt period for snow albedo reduction. Surface melt is not only a direct signal of the warming but the cause the enhancement of the snow metamorphism because of the snow grain size gaining and expansion of the bare ice and dark ice extent caused by glacial microbe cultivation acceleration. In previous studies, satellite observation has been widely used for ice sheet surface melt monitoring (Abdalati and Steffen, 1997, Mote, 2014 and Fig. 1). On the other hand, the polar regional climate model focused on the polar ice sheet has been developed and the surface melt estimated from the ice sheet surface temperature and snow water content has been calculated with the same accuracy as the long-term analysis by satellite observation (Niwano et al., 2018). However, environmental monitoring based on satellite observations still plays an important role, and it is necessary to improve the accuracy for detecting surface melt and mutual understanding between satellite observations and model calculations.

In this study, we have developed surface melt detection system using optical, thermal infrared and microwave observations. And we investigate the validity of this method by comparing the melt area retrieved by multi-spaceborne sensors and by a regional climate model for the period from April to August in 2018 and 2019.

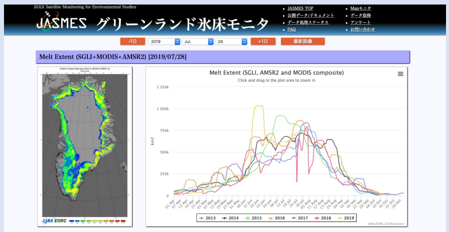


Fig. 1 Melt extent variations by JASMES Greenland Monitor.

Surface melt detection method

Surface melt detection system was based on combination of microwave, optical, and thermal infrared observations (Fig. 2). GCOM-W/AMSR2 was used for microwave observations, and MODIS onboard Terra and Aqua and SGLI onboard GCOM-C were used for optical and thermal infrared observations.

For microwave melt detection, we used the XPGR method (Abdalati and Steffen, 1997) and modified XPGR method (revXPGR). For thermal infrared detection, snow and ice surface temperature was used (Hall et al., 2013). For optical detection, the relationship between visible and near-infrared reflectance was used (Chylek et al., 2007). These methods were integrated by the weighted majority algorithm based on each melt detection accuracies as weights validated by the surface melt observation by AWS.

The NHM-SMAP calculation results were used as polar regional climate model. The NHM-SMAP model is a polar climate model developed for the Greenland ice sheet, and is capable of estimating surface melting from ice sheet surface temperature and snow water content (Niwano et al., 2018).

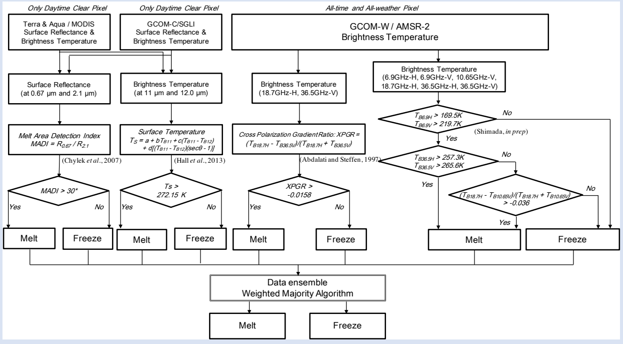


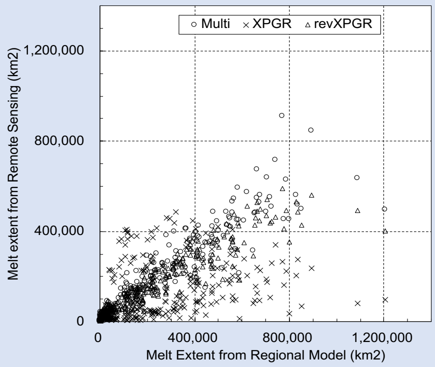
Fig. 2 Melt detection algorithm of the Greenland Ice Sheet melt area monitoring system.

Melt area extent comparison between multi-spaceborne sensors and regional climate model

Greenland Ice Sheet surface melt extent obtained by multi-satellite data showed similar variations with the model calculation (Fig. 3 to 5). The integrated method showed a relative error of 29% and the bias was 23,304 km^2 (Fig. 3). The traditional XPGR method using microwave, the relative error was 63%, while the improved revXPGR method had a relative error of 33%. Although the revXPGR method has the strongest correlation coefficient, the integrated method has the smallest relative error and bias, indicating that the integrated method with optical and thermal infrared information provides more reasonable melting area variation than single microwave method. In particular, the thermal infrared method detects surface melt based on the snow and ice surface temperature, which is the same principle as the model-based estimation method. Although the optical and thermal infrared observations are often deficient due to cloud cover, the integration of the observable regions suggests that it is possible to detect surface melt with higher accuracy than using microwave observation singly.

Time series comparisons in 2018 and 2019 showed that satellite observations underestimated the summer peak compared with the model outputs (Fig. 4 and 5). The difference was larger in 2018, which indicates that the microwave brightness temperature characteristics changed due to refreezing of meltwater in relatively cold condition. In 2019, when widespread melting occurred, showed that the peak of relatively small-scale melt in early summer could be detected by the integrated method and the revXPGR method.

It suggests that the traditional XPGR method may not be able to detect the melt sufficiently in 2018 and 2019, because the Greenland ice sheet has experienced multiple melting events in recent years compared to the XPGR method developed era. It is possible that the brightness temperature characteristics had been changed in recent years. Therefore, it is necessary to develop updated melt detection methods, such as the revXPGR method, as well as to further understand and improve the radiative transfer model by linking it with climate models in addition to the integrated method presented here.



	Multi	XPGR	revXPGR
Cor.	0.926	0.386	0.941
rel.Err	29%	63%	32%
bias	23304.6	65317.6	29577.9

Fig. 3 Melt area extent comparison.

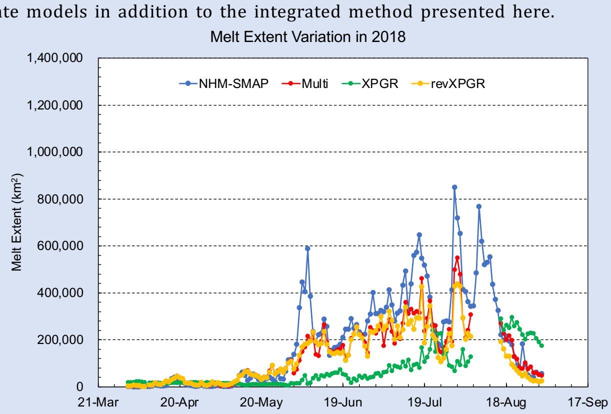


Fig. 4 Comparison between satellites and NHM-SMAP in 2018.

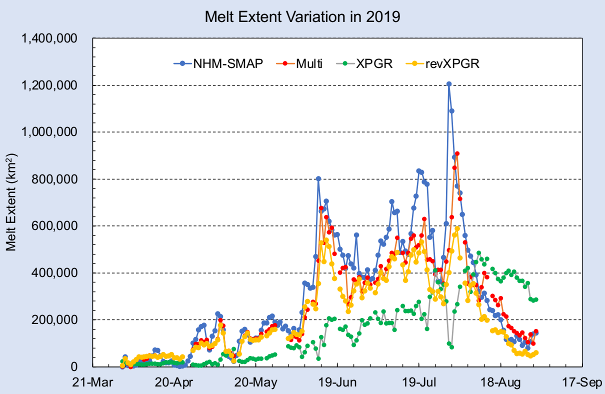


Fig. 5 Comparison between satellites and NHM-SMAP in 2019.

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