Title
Estimating volumes of supraglacial lakes on the AIS: Comparing satellite-based and model-based techniques for estimating water volume of supraglacial lakes on the Antarctic ice sheet

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Abstract
Disintegration of Antarctic ice shelves can induce devastated consequences for the environment and human infrastructure in the form of an increase of the global mean sea level. One of the causes of an ice shelf break down is hydrofracturing due to the mass load of supraglacial lakes. The top of the snowpack melts and the meltwater flows to a local depression where it accumulates and forms melting ponds. Detecting and quantifying the depth of these supraglacial lakes will increase the knowledge on the evolution of supraglacial lakes. Satellite remote sensing techniques are able to determine the volume of individual ponds. However, these methods have their limitations in calculating the depth and area per lake. Regional climate models are capable of estimating the total volume of meltwater within a certain area of interest, but have until now not been able to measure the depth and area of separate supraglacial lakes with certainty. This research study focused on highlighting the limitations of and developing possible improvements for three climate-based and satellite-based methods for comparing them to one another. The first method made use of Sentinel-2 scenes and a threshold-based classification to calculate the water extent and the water depth was calculated by use of band values and by knowing both the volume can be estimated. The second method made use of Sentinel-1 and Sentinel-2 images to classify areas containing water over a biweekly interval. A new method, denoted as the kernel method, was developed for measuring the depth of each detected lake with a lake mask and a digital elevation model. The volume is subsequently derived from the water extent and depth. Snowmelt, refreezing, precipitation and snowfall from a regional climate model, RACMO, was applied to estimate the total volume of meltwater within a catchment. With a digital elevation model a routing is determined to visualize where the calculated meltwater accumulates and subsequently the depth and area were computed. Based on comparing the water extents over the period of 2016-2021 on the Nivlisen Ice Shelf the following can be concluded: the climate model-based method cannot produce realistic water extents (the results were ten times larger than the satellite-based methods); the different classification methods have similar outcomes, the thresholds of the method using solely Sentinel-2 are preferred; The satellite methods are limited by clouds and frozen ice lids. The results of the water extents indicated unnatural large depths (average +30 m) and that the satellite remote sensing methods produce water extent in the same order of magnitude. In addition, the kernel method showed potential, since it can be executed without non-optical satellite data. However, in order for it to improve, the size of the kernel needs to be optimised. The total volumes are in the same magnitude range, but the climate data method overestimates (getal) due to the fact that the maximum value is chosen within the biweeks. In addition, this study's resulting volumes are close to the values computed by Van der Zalm (2020) and Dell et al (2020), which increases the confidence in the results. However, a problem that arose is the absence of a ground truth to accurately compare the results with and therefore it is recommended to possibly compare the data to that of an altimeter. Additional improvements can be made in kernel size optimization based on the middle line of the

lakes and developing a method to correctly locate and calculate the depth of water using a total runoff and a digital elevation model.