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Tracking surface and subsurface lakes on the Greenland Ice Sheet using Sentinel-1 SAR and Landsat-8 OLI imagery

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Supraglacial lakes (SGLs) on the Greenland Ice Sheet (GrIS) are an important component of the ice sheet's mass balance and hydrology, with their drainage affecting ice dynamics. This study uses imagery from the recently launched Sentinel-1A Synthetic Aperture Radar (SAR) to investigate SGLs in West Greenland. SAR can image through cloud and in darkness, overcoming some of the limitations of commonly used optical sensors. A semi automated algorithm is developed to detect surface lakes from Sentinel images during the 2015 summer. It generally detects water in all locations where a Landsat-8 NDWI classification (with a relatively high threshold value) detects water. A combined set of images from Landsat-8 and Sentinel-1 is used to track lake behaviour at a comparable temporal resolution to that which is possible with MODIS, but at a higher spatial resolution.

A fully automated lake drainage detection algorithm is used to investigate both rapid and slow drainages for both small and large lakes through the summer. Our combined Landsat–Sentinel dataset, with a temporal resolution of three days, could track smaller lakes (mean 0.089 km2) than are resolvable in MODIS (minimum 0.125 km2). Small lake drainage events (lakes smaller than can be detected using MODIS) were found to occur at lower elevations (∼200 m) and slightly earlier in the melt season than larger events, as were slow lake drainage events compared to rapid events. The Sentinel imagery allows the analysis to be extended manually into the early winter to calculate the dates and elevations of lake freeze-through more precisely than is possible with optical imagery (mean 30 August, 1270 m mean elevation). Finally, the Sentinel imagery allows subsurface lakes (which are invisible to optical sensors) to be detected, and, for the first time, their dates of appearance and freeze-through to be calculated (mean 9 August and 7 October, respectively). These subsurface lakes occur at higher elevations than the surface lakes detected in this study (1593 m mean elevation). Sentinel imagery therefore provides great potential for tracking melting, water movement and freezing within the firn zone of the GrIS.