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Observation of the transient meltwater accumulation in Greenland with GRACE satellite gravity data

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Transient meltwater accumulation in Greenland spans the entire ice layer, down to the ice bed. As such, this process may have a large impact on Greenland ice dynamics and on the future ice sheet evolution. GrIS subglacial hydrology is an area of active research. Unfortunately, it is difficult to validate and calibrate existing subglacial hydrology models because of intrinsic data limitations. Data collected in situ or from aircraft have a very limited spatial or/and temporal coverage, whereas space-borne electromagnetic sensors (both passive and active) are capable of observing only the near-surface part of the ice layer. With our study, we present the first direct observations of transient meltwater accumulation in Greenland with satellite gravimetry. We estimate total mass anomalies using GRACE satellite mission data and subtract from them the contributions associated with the Surface Mass Balance (SMB) and the Ice Discharge (ID). The SMB estimates are provided by the Regional Atmospheric Climate Model v. 2.3 (RACMO 2.3). The signal related to ID is approximated by a linear function fitting the "Total minus SMB" residuals in spring and autumn months. An analysis of seasonal variations in ice flow at 55 outlet glaciers in northwest and southeast Greenland shows that the deviations of ID-related mass anomalies from a linear trend are negligible. By taking the average of seasonal mass variations in 2003–2013, we observe substantial meltwater accumulation in Greenland during summer, with a peak value of 80-120 Gt in July. At the regional scale, the largest accumulation is observed in the southeast and northwest parts of Greenland: up to about 40 Gt in each region. The extracted signal is not altered substantially when using an alternative snow and firn model called SNOWPACK, which partitions meltwater into refreezing and runoff differently, as compared to RACMO 2.3. Furthermore, the meltwater accumulation signal is present in all of the considered GRACE data product variants and processing schemes, though with somewhat different magnitude and timing. Our study shows that GRACE data are capable of sensing transient meltwater accumulation not only at the scale of entire GrIS, but also at the scale of individual drainage systems. A continuation of research efforts is envisioned in order to further improve the accuracy of the obtained estimates.