Using GPS and absolute gravity observations to separate the effects of present-day and Pleistocene ice-mass changes in South East Greenland

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Abstract

Measurements of vertical crustal uplift from bedrock sites around the edge of the Greenland ice sheet (GrIS) can be used to constrain present day mass loss. Interpreting any observed crustal displacement around the GrIS in terms of present day changes in ice is complicated, however, by the glacial isostatic adjustment (GIA) signal. With GPS observations alone, it is impossible to separate the uplift driven by present day mass changes from that due to ice mass changes in the past. Wahr et al. (1995)demonstrated that viscoelastic surface displacements were related to the viscoelastic gravity changes through a proportionality constant that is nearly independent of the choice of Earth viscosity or ice history model. Thus, by making measurements of both gravity and surface motion at a bedrock site, the viscoelastic effects could be removed from the observations and we would be able to constrain present day ice mass changes. Alternatively, we could use the same observations of surface displacements and gravity to determine the GIA signal. In this paper, we extend the theory of Wahr et al. (1995)by introducing a constant, Z, that represents the ratio between the elastic changes in gravity and elastic uplift at a particular site due to present day mass changes. Further, we combine 20 yrs of GPS observations of uplift with eight absolute gravity observations over the same period to determine the GIA signal near Kulusuk, a site on the southeastern side of the GrIS, to experimentally demonstrate the theory. We estimate that the GIA signal in the region is 4.49 ± 1.44 mm/yr and is inconsistent with most previously reported model predictions that demonstrate that the GIA signal here is negative. However, as there is very little in situ data to constrain the GIA rate in this part of Greenland, the Earth model or the ice history reconstructions could be inaccurate (Khan et al., 2016). Improving the estimate of GIA in this region of Greenland will allow us to better determine the present day changes in ice mass in the region, e.g. from GRACE.

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