Spatio-temporal evolution of the Greenland ice sheet and associated deformation of the Earth

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Abstract: Here, we use variations of the Greenland ice-sheet (GIS) elevation derived from satellite altimetry (Icesat), from 2003 to 2009, displacements recorded at regional GNSS stations and time variable gravity measurements from a new GRACE solution where smaller wavelength signals are preserved, to improve our knowledge of the spatial and temporal evolution of the ice sheet. First, we assume an elastic Earth where all the deformation is due to recent melting. We estimate present-day ice variations by combining satellite altimetry and an empirical model of firn densification. To resolve short wavelengths load variations affecting the displacement of nearby GNSS stations, we decompose our ice variations estimates into spherical harmonics up to degree 2700 and predict horizontal and vertical crustal displacements assuming first elastic Earth properties. We show that vertical elastic predictions, while in good agreement with observations in some regions, cannot explain observations overall, and particularly in the Southeast and the North of Greenland. Those differences seem mainly due to viscoelastic deformation induced by glacial isostatic adjustment (GIA). Consequently, we use vertical GNSS residuals to infer potential ice variations in Greenland since the Last Glacial Maximum (LGM). We also investigate, potential viscoelastic deformation associated with short-term rheology of the asthenosphere induced by recent ice melting that could as well significantly affect the observed deformation. For that we use an ice history loading from 1900 to 2009 derived from both in situ and satellite altimetric measurements, and we compute current potential viscoelastic deformation observable. Both the GRACE gravity data and the horizontal component of the deformation add useful constraints on the relative amplitude of these viscoelastic deformations. The combination of altimetric, gravimetric and GNSS data is necessary first to separate the different deformation sources in the region (GIA, deformation induced by recent ice melting and recent viscoelastic deformation), then to constrain short-term (decadal) rheology of the mantle and finally, to improve our knowledge of the present-day ice mass budget over the GIS.

Keywords: Spatial geodesy, Geodynamics