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Hydrological unloading after Perito Moreno Glacier dam rupture: GNSS observation vs. modelling

Eric Marderwald (1,2), Juan Manuel Aragón Paz (1,2), Andreas Richter (1,2,3), Peter Busch (3), Gerardo Connon (4), Luciano Mendoza (1,2), Jose Luis Hormaechea (4), Martin Horwath (3), and Reinhard Dietrich (3)

(1) Laboratorio MAGGIA, Universidad Nacional de La Plata, Argentina, (2) Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina, (3) Institut für Planetare Geodäsie, Technische Universität Dresden, Germany, (4) Estación Astronómica Río Grande, Argentina

The Patagonian Icefields are subject to rapid uplift. GNSS observations revealed vertical crustal deformation rates at the Southern Patagonian Icefield (SPI) of up to 4 cm/a (Richter et al. 2016; Dietrich et al. 2010). Current regional models of glacial-isostatic adjustment (GIA) explain the observed uplift as a superposition of the visco-elastic response to ice-mass changes since the Little Ice Age and the elastic response to ongoing fast ice retreat (Lange et al. 2014; Ivins & James 2004). An elastic earth model is needed to infer the contribution of present-day ice unloading to the observed deformation rates and to separate it from the visco-elastic GIA signal. Glacial-isostatic relaxation, in turn, is unusually fast in Patagonia due to the peculiar tectonic-rheological setting characterized by the subduction of an oceanic ridge, the opening of the Patagonian slab window and the upwelling of low-viscosity mantle material.

Lake-tide observations in Lago Fagnano, some 500 km south of the SPI on Tierra del Fuego main island, have revealed an amplification of ocean tidal loading deformation (Richter et al. 2009). Tidal gravimetric observations on the island as well as in-situ ocean tide observations on the Fuegian Atlantic Shelf (Richter et al. 2012) lead to conclude regional elastic properties deviating from the predictions of conventional elastic earth models. The origin of this regional anomaly is at present not established and makes a validation of elastic earth models in the SPI region through a geodetic observation of the elastic response to a well-constrained surface load desirable.

Towards this aim, we make use of a natural experiment: the damming of Brazo Rico and Brazo Sur of Lago Argentino by the advancing Perito Moreno Glacier. During the last occurrence of this phenomenon in 2015-2016, the water level in these branches rose steadily by about 8 m until on 8 March 2016 a slow percolation set in and, two days later, the ice dam collapsed. We present the results of continuous GNSS observations at the eastern shore of Brazo Sur. The GNSS data were processed with the Bernese GNSS Software 5.2 (Dach et al. 2007) and yield time series of the 3D displacement throughout the sudden discharge of the water load. The observed vertical displacement is compared to a model of elastic vertical deformation due to the hydrological unloading. This model is based on a convolution of the Green's functions tabulated by Farrell 1972 for the Gutenberg-Bullen earth model with a load model describing the spatial distribution of the water mass. The load model was derived from a local kinematic GNSS survey in the vicinity of the GNSS site, tide gauge data from Brazo Rico and a digital elevation model. The comparison of the observed vs. modeled vertical displacement is discussed with regard to the validity of the global earth model in the SPI region, taking realistic accuracy estimates for the GNSS positioning, the long-term vertical deformation and the horizontal displacement components into account.