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

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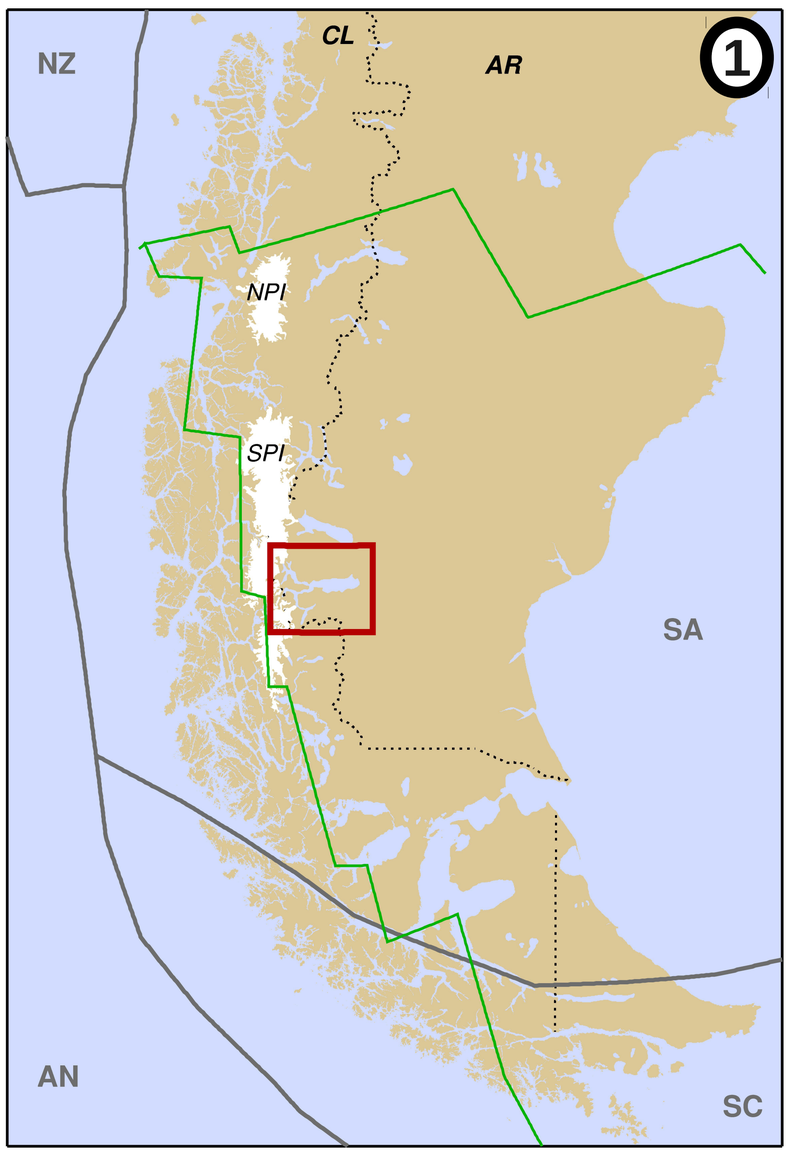
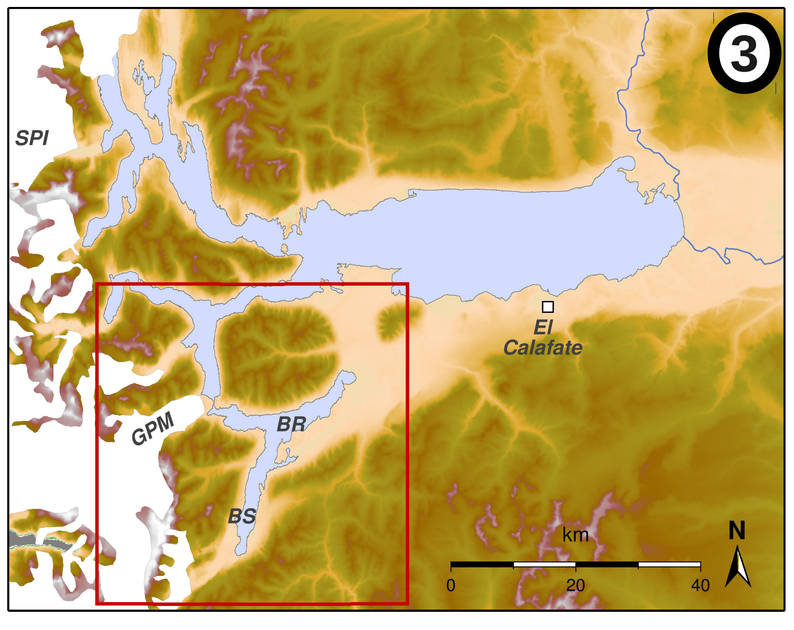


RATIONALE

The Patagonian Icefields (1) are subject to rapid uplift reaching rates of 4 cm/a *[Richter et al. 2016; Dietrich et al. 2010]*. Glacial-isostatic adjustment (GIA) models 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 separate the contribution of present-day ice unloading from the visco-elastic GIA signal.

Lake-tide observations in Lago Fagnano (Tierra del Fuego, 500 km south of the SPI) reveal 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 (BRS) of Lago Argentino by the advancing Perito Moreno Glacier (2) in 2016 (3).

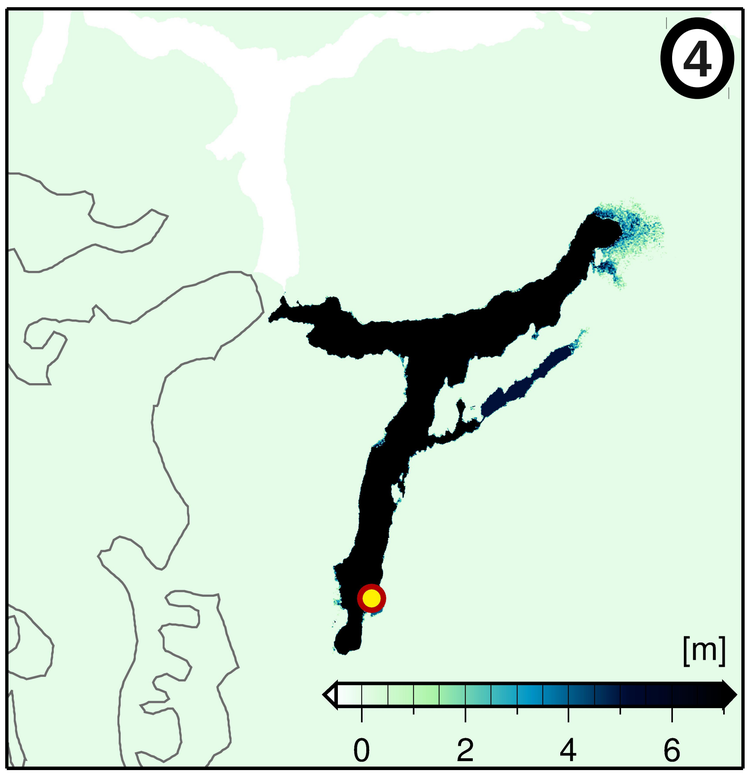


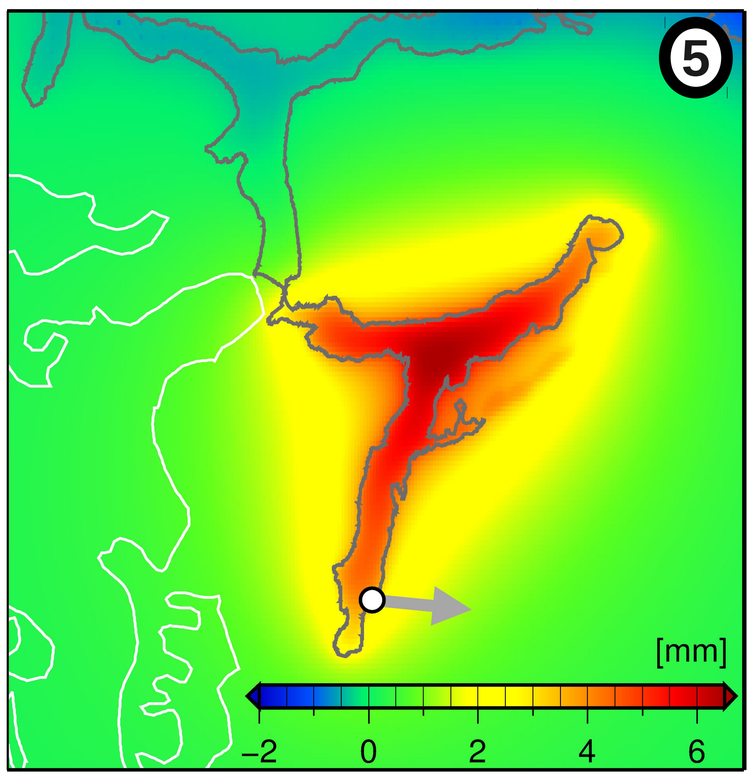
DATA & METHODS

During the ice dam rupture and discharge on March 8-12, 2016 (6), lake level in BRS dropped by 7.04 m according to tide gauge data in Brazo Rico *[Comisso 2017]*. In the same time, lake level in Lago Argentino rose by 0.74 m *[BDHI 2017]*.

The elastic vertical deformation due to hydrological unloading is derived from a convolution of the Green's functions tabulated by *Farrell 1972* for the Gutenberg-Bullen earth model with a load model that describes the spatial distribution of the change in water mass. The load model (4) is based on a local kinematic GNSS survey in the vicinity of the GNSS site, tide gauge data and a digital elevation model.

Continuous GNSS observations were recorded on bedrock at the eastern shore of Brazo Sur (7). The GNSS data were processed in differential mode with the Bernese GNSS Software 5.2 *[Dach et al. 2007]* and yield time series of daily 3D position coordinates. The bedrock displacement is derived from mean coordinates before (20 days) and after (27 days) the discharge of the water load.





RESULTS

- Pattern of vertical surface deformation (5) with maximum uplift of 6.6 mm.
- Change in UP component at the GNSS site before vs. after discharge:
  - Model: +3.3 mm
  - Observation: +3.6 ± 2.5 mm (i.e., 107%)
- Change in horizontal position: 1.8 mm ESE (grey vector in 5, i.e. qualitatively consistent with unloading in BRS).

CONCLUSIONS

- Consistency is found between observed and modelled vertical deformation.
- For the studied event, the magnitude of the hydrological load and resulting deformation is too small for robust conclusions on the regional validity of the applied elastic earth model.
- Perito Moreno glacier has dammed in previous events >20 m water load, thus in future reoccurrences our observational experiment might give further insights.
- Hydrological loading degrades GIA uplift rates derived from GNSS observations in the vicinity to BRS if not accounted for.

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