Gravity effect of glacial ablation in the Eastern Alps - observation and modeling

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Observation

Absolute gravity observations in Obergurgl (Austria) indicate a gravity increase of 300 nms^{-2} during the recent two decades (Fig.1). Newtonian effect of glacial ablation is the most probable explanation. Three glacier inventories (Abermann et al. 2009) performed in 1969, 1997 and 2006 allow for quantification of glacier ablation in the Ötztal Alps region (Fig. 2) .

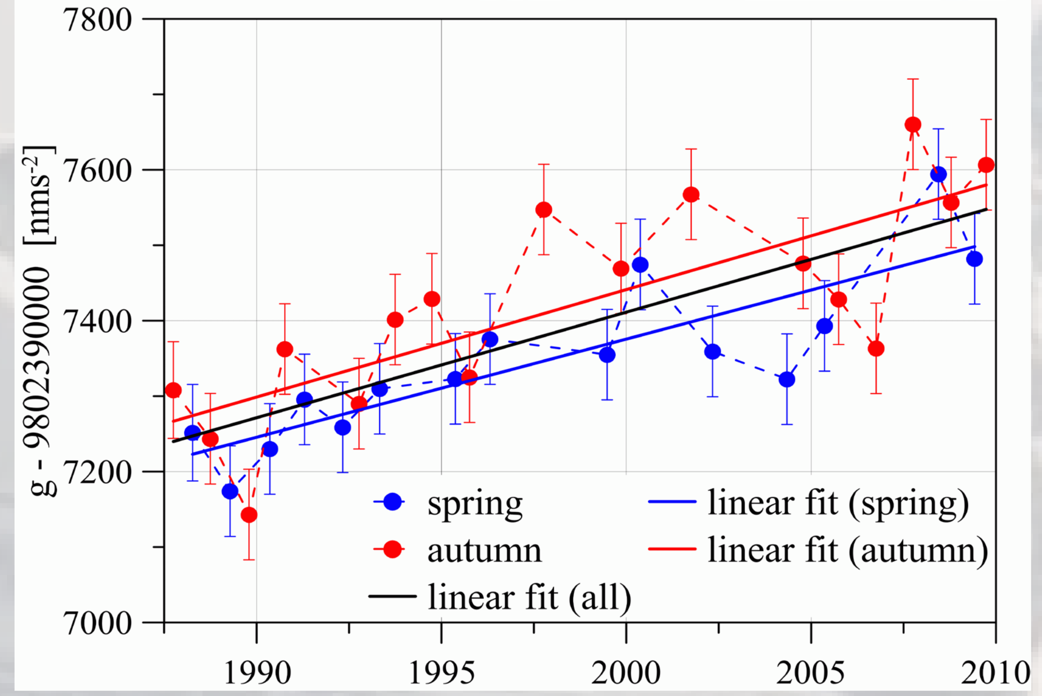

Fig. 1: Gravity variation at Obergurgl observed by the JILAg-6 absolute gravimeter (Ruess, Ullrich, BEV).

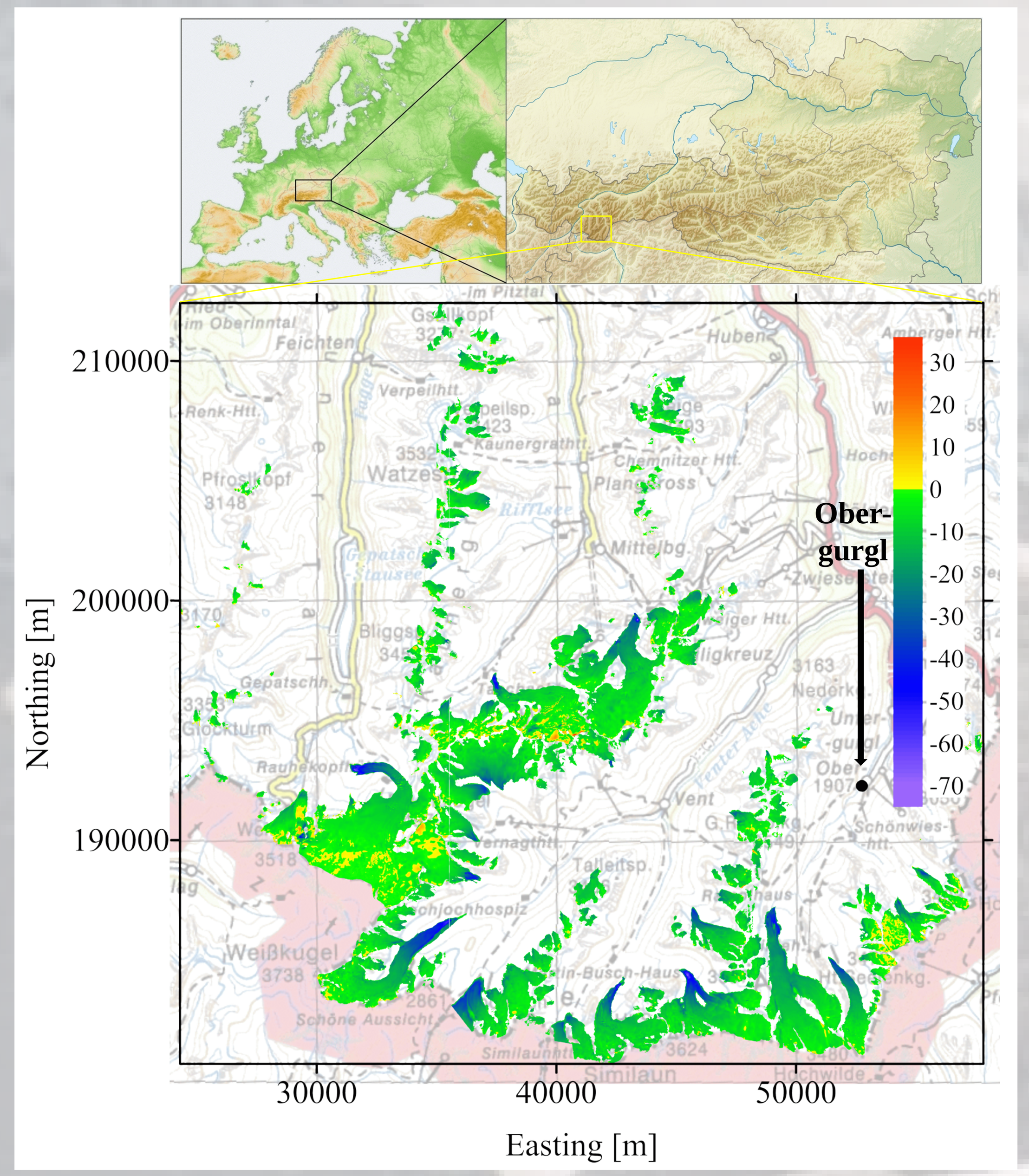

Fig. 2: Ice thickness variation during the period between 1997 and 2006 within the Ötztal Alps derived from glacier inventories (Abermann et al. 2009).

Modeling

Glacier ablation was modeled by very small (8 m × 8 m) flat topped vertical prisms. Based on mass balance estimates (Fig. 3) for specific glaciers (Fischer and Markl 2009; Kuhn et al. 1999) different ice loss rate scenarios are conceivable. Scenarios 2 and 3 (Fig. 4) are reasonable assumptions.

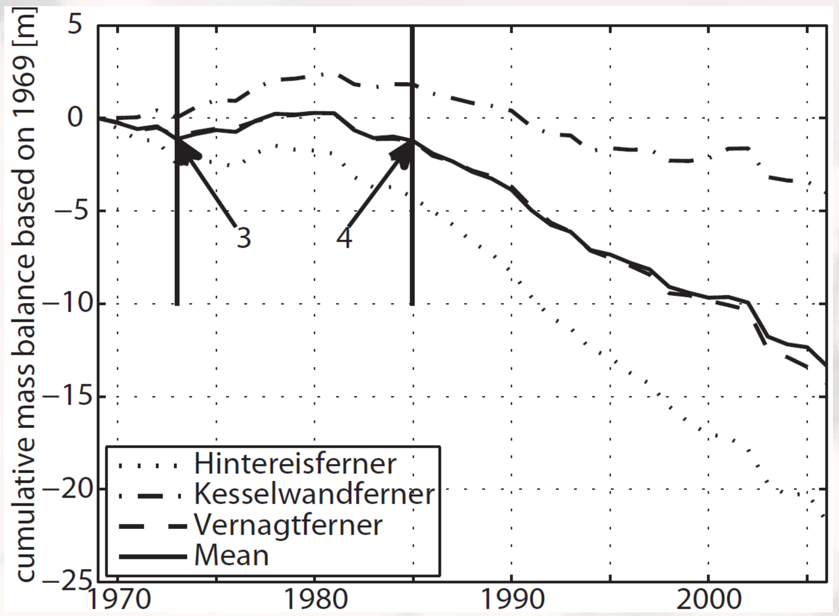

Fig. 3: Mass balance for some specific glaciers of the Ötztal region (Abermann et al. 2009). Estimates indicate, that ice loss is zero on average from 1973 to 1985.

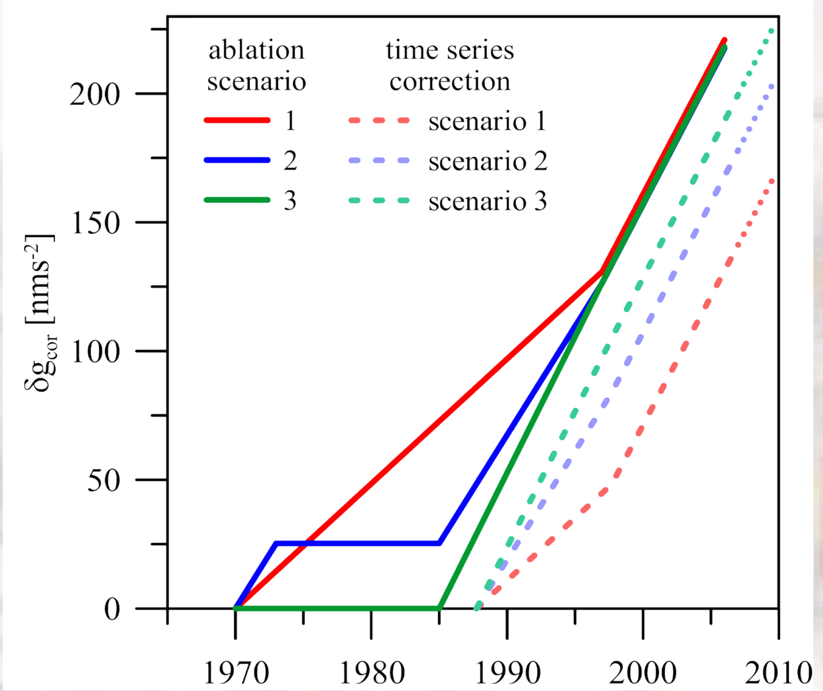

Fig. 4: Gravity effect of glacial ablation based on different ice loss rate scenarios. Solid lines indicate the gravity effect of the glacial ablation model during the entire inventory period, while the dashed lines show the corresponding correction applied on the observed gravity time series.

Results

The gravity time series presented in Fig. 1 was corrected for the gravitational effect of glacier ablation based on ice loss rates derived from scenario 2 and 3 respectively (Figs. 5 and 6). Man-made gravity changes due to reconstruction work in the station surroundings have been taken into account, too.

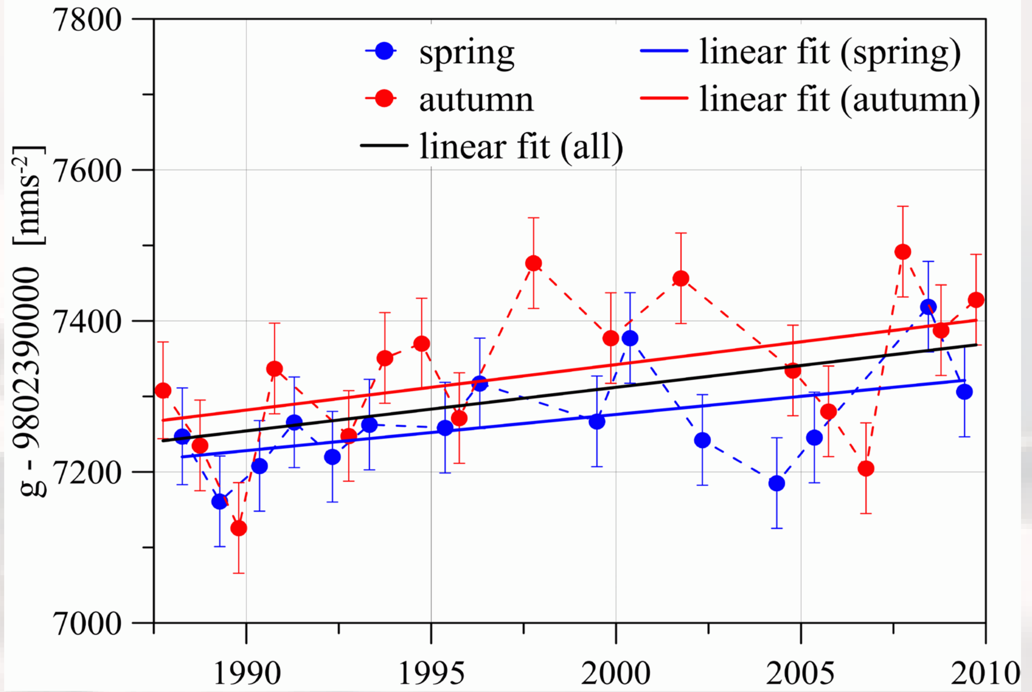

Fig. 5: Gravity variation at Obergurgl corrected for the effect of glacial ablation based on the scenario 2.

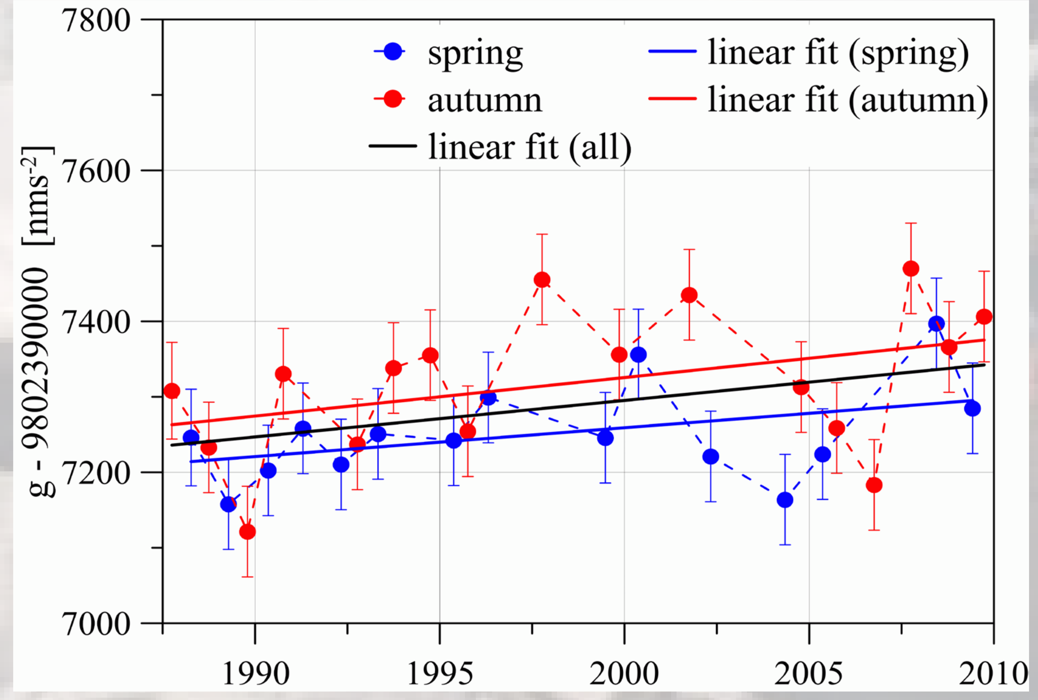

Fig. 6: Gravity variation at Obergurgl corrected for the effect of glacial ablation based on the scenario 3 representing the maximum possible gravity increase due to ice loss.

Interpretation

- About 70% of the gravity increase shown in Fig. 1 can be explained by the Newtonian effect of ice loss during the observation period.
- The remaining trend visible in Figs. 5 and 6 is only weakly significant.
- Barletta et al. (2006) estimated the rebound effect due to glacier shrinkage (Fig. 7). Based on this estimate, a gravity decrease of about -15 to -20 nms^{-2} is expected including local effects as modeled by Mémin et al. (2009).
- The rebound effect cannot be detected by the corrected observations. Provided its estimate is true, it is masked by still unexplained processes like local hydrology, erosion, denudation etc.
- Snow cover results to an average offset of 64 nms^{-2} of the spring w.r.t. the autumn observations.

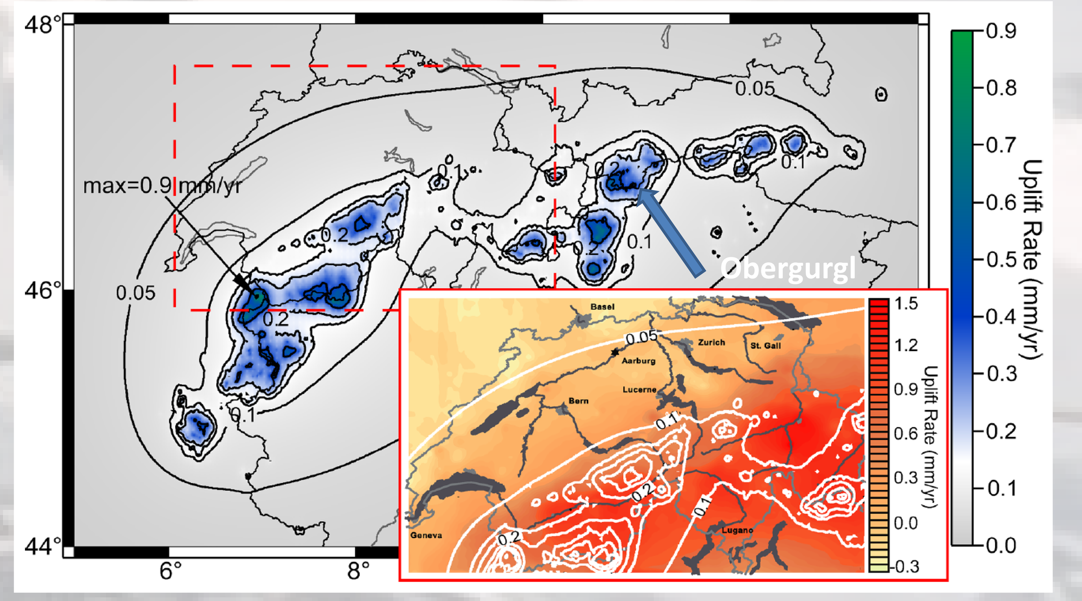

Fig. 7: Elastic response to ice mass loss in the Alps derived by Barletta et al. (2007). At Obergurgl, a vertical uplift of 0.2 to 0.3 mm/yr can be estimated.

References:

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