Glacial and erosional contributions to Late Quaternary uplift of the European Alps

Dirk Scherler (Freie Universität Berlin, GeoForschungsZentrum Potsdam)
Ricarda Winkelmann (Universität Potsdam, Potsdam Institut für Klimafolgenforschung)

The present-day velocity field of the Earth's surface holds valuable information about the spatial patterns and rates of tectonic activity. However, in the European Alps, which are uplifting at rates of up to ~2 mm/yr, no consensus exists on which processes drive the observed uplift (Figure 1). The processes suggested to account for uplift include isostatic response to tectonic shortening, the last deglaciation, long-term erosion, detachment of the Western Alpine slab, as well as lithospheric and surface deflection due to mantle convection. In this project, we want to test the hypothesis that spatiotemporal transients in glaciation and erosion have a significant influence on isostatic adjustments and that their quantification allows us to isolate the uplift related to tectonic and/or geodynamic processes.

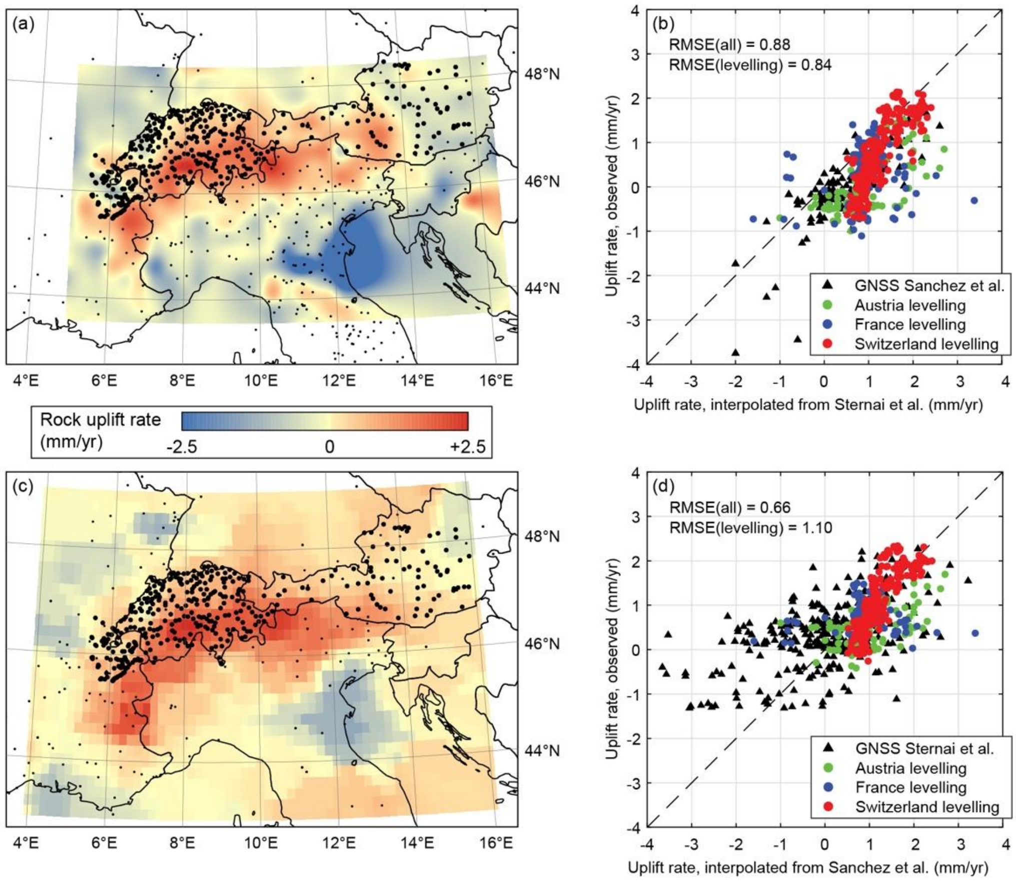

Figure 1: Observed present-day rock uplift rates in the greater Alpine region. (a) Interpolated map of rock uplift rates from Sternai et al. (2019), together with the used GNSS stations (small black dots) and the location of precise levelling data (big black dots). (b) Comparison of map values in (a), with precise levelling data (see main text for references) and GNSS station solutions from Sanchez et al. (2018). (c) Interpolated map of rock uplift rates from Sanchez et al. (2018), together with the used GNSS stations (small black dots) and the location of precise levelling data (big black dots). (d) Comparison of map values in (c), with precise levelling data (see main text for references) and GNSS station solutions from Sternai et al. (2018).

Field observations suggest rapid expansion and shrinkage of the Alpine ice cap during the last glacial cycle, and cast doubt on the validity of previously assumed isostatic equilibrium (Figure 2). Furthermore, trapping of sediments in overdeepened valleys of the Alps and in peripheral lake basins induces transients in the isostatic response to erosion. We will therefore employ transient numerical ice flow modeling during the last glacial cycle that includes erosion processes, calibrated to field observations, to estimate surface loading and unloading. We will use the model results in conjunction with new lithospheric models, derived from AlpArray data, to predict rock uplift rates due to surface processes. Comparison of modeled with observed rock uplift will clarify the role of glaciation and erosion in the present-day uplift of the Alps, and allow residual uplift to be linked to tectonic and/or geodynamic processes. Furthermore, we will upscale our results to longer periods, e.g., since the mid-Pleistocene transition, to estimate the integrated effect of Quaternary glacial erosion on rock uplift and exhumation in the Alps. Our modeling approach builds on results from the first phase of the SPP and will provide key constraints for linking spatial patterns of present-day to Quaternary rock uplift to deep-seated processes.

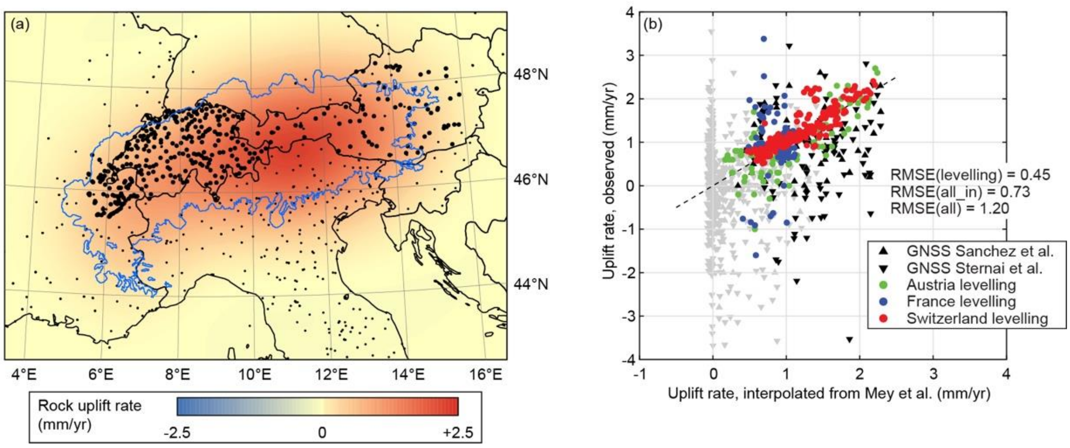

Figure 2: Rock uplift rates in the European Alps based on precise leveling and GNSS data and modeled by Mey et al. (2016). (a) Spatial distribution of observed and modeled rock uplift rates. Small black dots represent GNSS stations. Big black dots are places with precise levelling data. Blue line gives last glacial maximum ice extent. (b) Scatter plot of observed versus modelled rock uplift for all levelling data and GNSS stations within blue polygon in (a). GNSS stations outside blue polygon are shown in grey.

References

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