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Using Muon Radiography to map the Bedrock Geometry underneath an active Glacier: A Case Study in the Central Swiss Alps

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In recent years, muon radiography has been successfully applied to tackle geological issues and has enjoyed an increasing interest, mainly because this methodology enriches the geophysical arsenal by another shallow subsurface imaging tool that may give independent constraints on material density. Muons that originate from the collision of cosmic particles with Earth's atmosphere are able to penetrate the material in question and can finally be recorded by a detector. The irradiation intensity can then be inverted to the density of the traversed material.

Various successful two-dimensional attempts have already been made to image e.g. magma chambers inside volcanoes (Lesparre et al., 2012; Nishiyama et al., 2014; Tanaka et al., 2005), but this method has yet to be applied for mapping the base of glaciers, where the density contrasts between ice and underlying bedrock are even greater than those between magma and host rock. While a high Alpine setup limits the possibilities to deploy traditional geophysical methods for surveying the base of glaciers (because of inaccessible terrain, poor infrastructure or the presence of water in the ice), muon radiography might prove to be a promising alternative.

The muon intensity data from stereo observation can be related to the three-dimensional geometry of the interface between the glacier and its bedrock. Given a suitable input model, this relation can be solved within the framework of geophysical inverse problems. The final model then gives geologists invaluable information on erosional mechanisms underneath active glaciers, as this has not yet been observed.

We test this methodology for a site within the Jungfrau region, situated in the central Swiss Alps. Our first goal is to demonstrate the feasibility of the method through a case study at the Eiger glacier, starting from a toy model in a first phase and continuing with real data in a second phase. For this purpose, we installed cosmic-ray detectors at two sites inside the Jungfrau railway tunnel that traverses the rock underneath our target glacier. In order to achieve a high angular resolution, emulsion film detectors will be used. Compared to scintillation detectors, we gain also the advantage that no in-situ power supply is needed.

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