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# Towards accurate quantification of ground ice content in permafrost of the Central Andes: geophysics-based estimates from three different regions

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Continued climate change is projected to cause significant temperature increase, yielding substantial water shortage especially in the semi-arid mountain regions of the Central Andes. The role of permafrost occurrences for the hydrological cycle in the Central Andes is currently discussed in a controversial way. On the one hand, permafrost in general, and especially rock glaciers are considered key stores of frozen water in view of the recession of glaciers, and degrading permafrost is expected to partly compensate the decreasing glacial discharge in future. On the other hand, the methodology to quantify ground ice resources in Andean permafrost regions as well as the time scales involved for significant discharge from permafrost bodies are currently disputed.

Comprehensive and quantitative field-based data on the local variability of internal structure, ground ice content and the hydrological contribution of different permafrost landforms are mostly lacking, and the current debate mostly focuses on rock glaciers as the prominent ice-rich permafrost landforms, as they can easily be identified by remote sensing.

To ameliorate this lack of ground truth data, we present a quantitative analysis of > 50 Electrical Resistivity Tomography and > 20 Refraction Seismic Tomography profiles from several permafrost sites in different geomorphologic settings, including ice-rich and ice-poor permafrost occurrences. The surveys were conducted between 2016 and 2019 in three different regions of the Central Andes of Chile and Argentina (28 - 32° S) in the framework of several Baseline studies in mining environments. For some sites borehole and test pit data are available and used to validate the quantitative estimates of ground ice contents by the 4-phase model (Hauck et al. 2011).

We demonstrate the value of geophysical surveys to detect ice-rich permafrost in various landforms (also beyond rock glaciers), and to estimate ground ice volumes in permafrost regions. Our data show, that remote-sensing based approaches tend to significantly overestimate ice volumes of rock glaciers, and on the other hand, that ice-rich permafrost is not restricted to rock glaciers, but also observed in non-rock-glacier permafrost slopes in the form of interstitial ice and layers with excess ice. In regions with widespread occurrence of such permafrost slopes, even relatively thin ice-rich layers can sum up to substantial total ground ice contents, which can be

close to the volumes observed in rock glaciers. Consequently, non-rock-glacier permafrost terrain, whose role for local hydrology is basically neglected in remote-sensing based approaches, may be of equal hydrological significance regarding stored ground ice volumes on the catchment scale in some cases, and shall not be ignored.

The presented data may therefore serve as one of the first available field-based and validated data sets regarding the presence and total quantities of ground ice, and as input for modelling studies about the relative contributions of rock glacier and non-rock glacier permafrost to runoff in the Central Andes.

References

Hauck C, Böttcher M and Maurer H 2011. A new model for estimating subsurface ice content based on combined electrical and seismic data sets. The Cryosphere 5(2): 453-468.