Hydro-chemical detection of dead ice and permafrost degradation

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Abstract

Perennial and episodic springs well from the lateral moraine deposits in the proglacial area of the Kaunertal valley and potentially indicate dead ice and permafrost thawing. The water samples origin could be differentiated in pre and post nuclear ice or no ice waters using stable isotope signatures δ^2H and $\delta^{18}O$, and the long-lived anthropogenic radionuclide ^{129}I. Results hint dead ice lenses and permafrost in subsurface areas below 2300m. Geo-electric measurements validate the existence of the ice and ablation measurements gave first insights into the volume loss during summer days. The late melt out of dead ice and permafrost up to 70 years after glacial retreat has potential significance for slope stabilities, image based erosion measurements and possibly the future water balance in Alpine valleys.

Keywords: *Permafrost; stable isotopes; radionuclides; thermal erosion*

Introduction

In recent years, the global climate change raised average temperatures in Austria by 1.5°C causing an acceleration in glacier retreat in the Alps and exposing lateral moraine deposits on the steep valley flanks (Warburton, 1990; Carrivick & Rushmer, 2009; Carrivick *et al.*, 2013; APCC, 2014). These unconsolidated sediments are presently eroding with visible gully features and landslides along the slopes (Dusik *et al.*, 2014; Baewert und Morche, 2014). In the Kaunertal Valley perennial and episodic springs well from these lateral moraines. We hypothesize that the springs indicate the melt out of dead ice lenses or permafrost in areas below 2500m, causing a potential significant volume loss of the matrix due to the melt out of ice and the drainage of the water. This could lead to a potential decrease of slope stability in the proglacial long after glacial retreat.

In this study, we aim to identify the spring waters origin using hydro chemistry analysis, ERT measurements, and ablation stakes to validate the chemical findings and quantify the volume loss due to the melt out.

Methods

Sampling

From May until October 2015 around 240 water samples were monthly derived from the various springs in altitudes between 2100 and 2330m. Additionally, monthly averaged precipitation samples, and samples from the Gepatschferner glacier were collected. Waters were analyzed on site for their pH, EC, and temperature and locations recorded.

Fieldwork

ERT measurements were implemented on five transects and 17 ablation stakes inserted in areas were ice lenses were visible in lateral moraine deposits, measuring 72 ablation days in total.

Laboratory analysis

Samples were analyzed at the Helmholtz Centre for Environmental Research in Halle for their stable isotope signatures of δ^2H and $\delta^{18}O$ by means of the Cavity Ring-Down Spectroscopy (Picarro, Danta Clara, CA, USA) and referenced against the Vienna Standard Mean Ocean Water (V-SMOW).

At the Nuclear Physics Department of the University of Vienna the long-lived anthropogenic radionuclide ^{129}I concentrations were examined following an iodine extraction scheme for AMS measurements modified after Szidat *et al.* (2000) and supplemented with additional analysis steps from Jabbar *et al.* (2011).

Results

Stable isotope signatures showed that glacier samples of melted ice had a significantly lighter isotopic composition than precipitation and water samples with long time surface exposure, such as impounded water reservoirs. Springs could be differentiated in two groups using cluster and discriminant analysis with one group being characterized by significantly lower temperatures, lower EC values and a lighter isotope signature.

The ^{129}I results showed a similar pattern of statistical significant differences between glacier and precipitation samples with the latter showing several magnitudes higher concentration values. Springs plotted along the full concentration gradient.

Discussion

The lighter isotopic cluster group with colder waters and a lower EC was interpreted as being melt waters from ice. However, it was not clear from the stable isotope signature alone if these melt waters originate from (i) recent ice, (ii) dead ice from the glacier or (iii) the active or passive layer of permafrost thawing. Thus, the relative dating of the spring's water with ^{129}I was helpful to determine a potential pre or post nuclear surface exposure of the waters (older or younger than 1950), assuming that low concentration point to dead ice or the passive layer of permafrost thawing (Herod *et al.*, 2016).

The combined method was assessed on three samples, where the origin was known: the glacier samples (pre nuclear ice), the impounded water reservoirs (post nuclear and no ice), and the precipitation samples (post nuclear no ice). The hydro chemical results validate all of these origins.

All but two springs indicating ice show a reasonable spatial pattern with their location on north and northwest exposed slopes. Some of them depict a pre nuclear origin and many mixed waters, possibly caused by a recent atmospheric ^{129}I contamination of the ice due to observed partial ice exposure by off sliding sediments on the slopes.

ERT transects validate the existence of subsurface ice in two out of three chosen areas and ablation stakes gave a first insight into potential daily thawing volume in summer month of 2.5 ± 1.2cm.

Calculated on the area of the north exposed moraine this would amount to $850\pm407m^3$ matrix volume loss on one summer day.

Conclusions

Stable isotope signatures and ^{129}I concentrations can hint the origin of spring waters in the proglacial. First estimated volume loss due to the melt out of dead ice or permafrost points to a potential significant amount when deriving sediment erosion volumes in proglacial areas with imaged based technologies such as LIDAR, TLS or SfM technologies. Furthermore, it is speculated that areas with springs indicating pre nuclear ice origin might face higher slope instabilities in the future.

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