Quantifying crustal fluid flow and its role in the thermal structure of the Alps

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Crustal fluid flow is a key process that affects temperatures and fluid pressures in mountain belts. In addition, fluid flow and its associated thermal effects influence thermochronological methods that provide crucial information on the evolution of mountain belts over time. We will quantify the importance of fluid flow for the thermal structure of orogens by quantifying the thermal effects of the most visible outcrop of deep fluid flow: thermal springs. We aim to compile thermal spring data in the Alps and use numerical models to quantify the thermal impact of the fluid flow systems that are associated with these springs. We will combine models with independent data on geological structure, changes in recharge, ice cover and topography to quantify the persistence of hydrothermal systems over geological timescales. The results will provide the first image of deep fluid flow and its effect on the thermal field at the scale of an entire orogen. In addition, our results will provide new constraints on fluid pressures and permeability of the crust.

To quantify the importance of thermal springs and crustal fluid flow in the Alps we aim to answer four research questions:

1) What is the overall contribution of thermal springs to the present-day heat budget and fluid budget of the Alps?
2) What is the effect of the hydrothermal systems that feed thermal springs on the heat budget and thermal structure of the crust?
3) What are the driving forces of thermal springs in the Alps?
4) How persistent are thermal springs over geological timescales?

These research questions will be addressed by combining compilations of thermal spring data (discharge, temperature, chemistry and structural setting) with thermal models of the hydrothermal systems that drive these springs. And example of the type of model that we will use is shown in Fig. 1. In addition to the relatively simple advective-conductive heat flow model shown in Fig. 1, we will run more complex coupled density-driven fluid and heat flow models on a selected number of springs to model the driving forces of these hydrothermal systems and changes of hydrothermal activity on geological timescales.

The project is designed to train four MSc. students, three of which will be based at Göttingen University, and one of which will be based at RWTH Aachen. In addition, this research project will be supported by prof. Grant Ferguson of the University of Saskatchewan, who is leading parallel research efforts on thermal springs in North America.

This project is part of SPP MB-4D research theme 2 (Surface response to changes in deep structure on different time scales) where it will provide data on the thermal structure that is crucial to interpret uplift and erosion of the Alps. The project has additional links research theme 4 (Motion and seismicity from the present backwards in time) and will provide data to evaluate the role of fluid flow and pressures in fault movement and seismic activity. This study will provide crucial input data for activity field E (Integrated structural, petrological, geochronological and surface studies
) and F (4D-Modelling). We will work closely with project INTEGRATE by Scheck-Wenderoth and co-workers to combine lithospheric thermal models with subsurface temperature and heat flow data and the project "Stress transfer and Quaternary faulting in the northern Alpine foreland" by Reicherter and Ritter to link recent fault activity and hydrothermal activity.

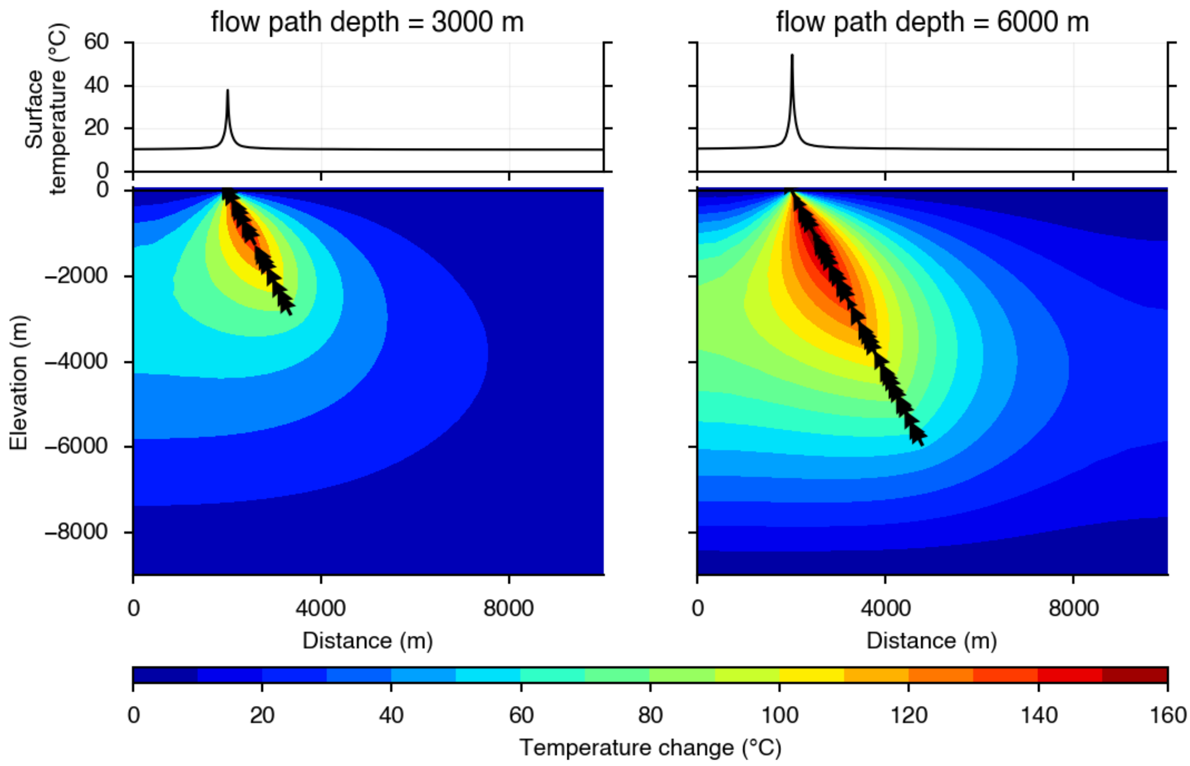

Figure 1: Example of a simplified advective-conductive thermal model of a hot spring. The hot spring is fed by upward groundwater flow along a fault that reaches a depth of 3 km (left) and 6 km (right) with a flow rate of 8 m/s, which is modelled after the Baden hot spring in the northern foreland basin of the Alps. These different flow depths lead to different predictions of spring temperature and subsurface temperatures. The colours show the temperature change due to hydrothermal activity compared to a background temperature field with a geothermal gradient of 0.03 °C/m.