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

PIs: Elco Luijendijk (University of Göttingen) and Christoph von Hagke (RWTH Aachen)
Postdoc: None
PhDs: None

Goals

The aim of this research project is to quantify deep fluid flow in the Alps, to quantify the impact of deep fluid flow on subsurface temperatures, and to quantify links between fluid flow and seismic activity and neotectonics. This is a relatively small research project with a total budget of 39,000 EUR and work conducted by student assistants & MSc. Students along with the two PIs.

New results and interpretations

We have constructed a new database of thermal springs that contains 506 thermal springs (Fig. 1). This is the first large-scale database of thermal springs outside North America, the first complete database of a mountain belt, and the first at this level of detail (including hydrochemistry, isotope data & geological setting).

In tandem with data compilation efforts we have improved and published an open source model code of heat flow and thermochronology around thermal springs and hydrothermal systems called Beo (Luijendijk, 2019). See Figure 2 for an example output of this model code. A manuscript that describes the model code is available at the journal Geoscientific Model Development, and the source code is available on Zenodo and GitHub.

The first results of this research project were presented at the EGU general assembly in April 2019 (Luijendijk et al., 2019). We are currently wrapping up a second publication on the contribution of thermal springs and deep fluid flow to the fluid and heat budget of the Alps. Our conclusions are that:

1. Thermal springs are exclusively fed by deep infiltration of meteoric water, other deep fluid sources such as magmatic volatiles or metamorphic dehydration appear to be insignificant.
2. The calculated circulation depths range up to 5 km, which suggests the presence of deep permeable faults and near-hydrostatic fluid pressures in large parts of the upper crust of the Alps.
3. The contribution of thermal springs and deep flow to the overall groundwater budget of the Alps is very small, ~0.1%.
4. However, the contribution of upward fluid flow towards the overall heat transport in the Alps is much higher, 2%. This is likely an underestimate of the overall contribution of deep flow because of springs are affected by mixing with shallow water sources and deep fluids also contribute to diffuse discharge instead of focused discharge in springs.

Relevance for research themes of the 4D-MB's first phase

Our research findings affect:

1) Subsurface temperature and heat flow data and their role in constraining geodynamic models of the Alps (activity F, research themes 1,2,3,4), and as additional controls on the structure of the crust and lithosphere (research theme 1).
2) The interpretation of thermochronology datasets and their key role in quantifying the surface response to deep processes in the Alps (research theme 2)
3) The role of fluid pressure in modulating seismic activity in the Alps (research theme 4)

Figures

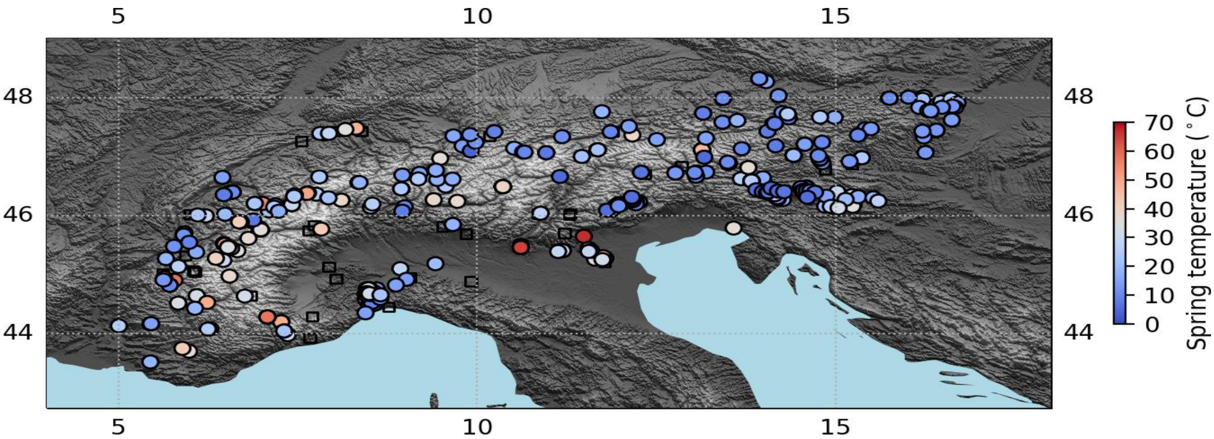

Figure 1: Discharge temperatures for 506 thermal springs in the newly compiled database of thermal springs in the Alps

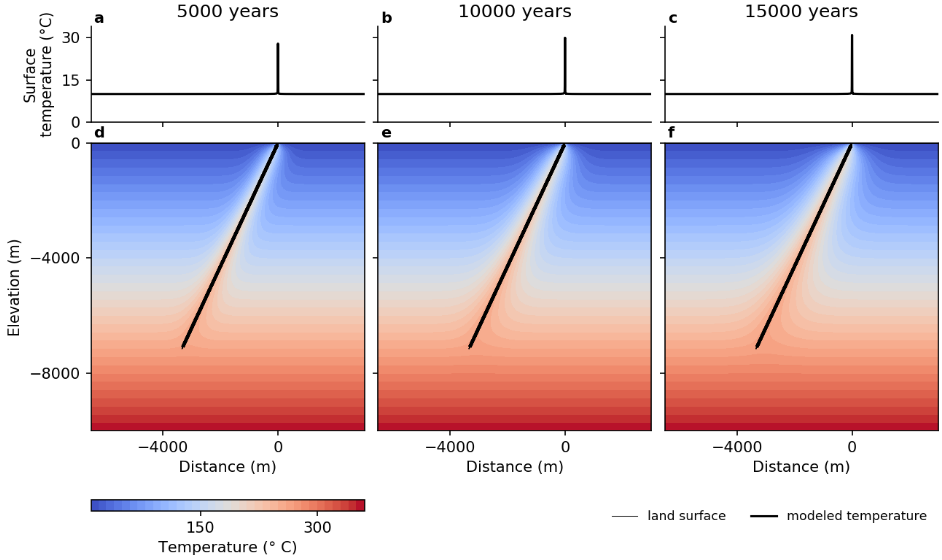

Figure 2: Example of modeled spring and subsurface temperatures over time in an active hot spring and hydrothermal system using the new open-source model code Beo that was improved and published in the framework of this research project (Luijendijk 2019).

Publication list

Luijendijk, E., 2019: Beo v1.0: Numerical model of heat flow and low-temperature thermochronology in hydrothermal systems, *Geosci. Model Dev. Discuss,* https://doi.org/10.5194/gmd-2018-341.

Luijendijk, E., von Hagke, C, Köhler, S, Winter, T, Ferguson, G., 2019, Using thermal springs to quantify deep fluid flow and its thermal footprint in the Alps. *Geophysical Research Abstracts* 21, EGU2019-14373, https://meetingorganizer.copernicus.org/EGU2019/EGU2019-14373.pdf