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Statistical and numerical methods to improve the transient divided bar method

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A key element in studying subsurface heat transfer processes is accurate knowledge of the thermal properties. These properties include thermal conductivity, thermal diffusivity and heat capacity.

The divided bar method is a commonly used method to estimate thermal conductivity of rock samples. In the method's simplest form, a fixed temperature difference is imposed on a stack consisting of the rock sample and a standard material with known thermal conductivity. Temperature measurements along the stack are used to estimate the temperature gradients and the thermal conductivity of the sample can then be found by Fourier's law.

We present several improvements to this method that allows for simultaneous measurements of both thermal conductivity and thermal diffusivity. The divided bar setup is run in a transient mode, and a time-dependent temperature profile is measured at four points along the stack: on either side of the sample and at the top and bottom of the stack. To induce a thermal signal, a time-varying temperature is imposed at one end of the stack during measurements. Using the measured temperatures at both ends as Dirichlet boundary conditions, a finite element procedure is used to model the temperature profile. This procedure is used as the forward model.

A Markov Chain Monte Carlo Metropolis Hastings algorithm is used for the inversion modelling. The unknown parameters are thermal conductivity and volumetric heat capacity of the sample and the contact resistances between the elements in the stack. The contact resistances are not resolved and must be made as small as possible by careful sample preparation and stack assembly. Histograms of the unknown parameters are produced. The ratio of thermal conductivity and volumetric heat capacity yields a histogram of thermal diffusivity. Since density can be measured independently, the specific heat capacity is also obtained.

The main improvement with this method is that not only are we able to measure thermal conductivity, robust and accurate measurements of thermal diffusivity and heat capacity are also provided.