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The relative importance of heat exchange mechanisms in karst conduits

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Variations in discharge, conductivity, and temperature are often observed at karst springs in order to gain information about the flow system within the aquifer. A variety of models have been proposed to simulate heat exchange in karst conduits; however, many of the assumptions of these models have not been validated using field data or examined in detail using heat transport theory. Notably, some models incorporate conductive heat transport in the rock surrounding conduits while others assume constant temperature rock walls. Additionally, models typically assume a planar symmetry for heat conduction in the rock, whereas in many cases a cylindrical geometry may be more appropriate. We examine the conditions necessary for the validity of each of these assumptions, and determine the mechanisms that control heat exchange under a variety of conditions. To explore these questions we employ analytical solutions, record stream temperatures in multiple locations along cave streams in Tyson Spring Cave, Minnesota, USA and Postojna Cave, Slovenia, and simulate the observed temperatures with a numerical model using realistic geometrical parameters for the conduits. We conclude that, in most cases, conductive heat transport limits overall heat exchange rates, and therefore cannot be neglected. However, radiative exchange and convective exchange through the air can also play a role in conduits with open channels.