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A theoretical framework for the interpretation of karst spring signals

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The changes in discharge, conductivity, and temperature observed at karst springs have long been used to derive information about karst aquifers. However, interpretation of these signals has sparked debate as to their true information content. Some researchers have hypothesized that the extent of variability at a spring is an indicator of the extent to which the aquifer is dominated by conduit or diffuse flow. Others have countered that the mode of recharge largely determines the variability of spring signals. Here we use analytical derivations for the propagation of conductivity and temperature signals to motivate a broader theoretical framework for the interpretation of spring signals. We show that the damping of these signals can be linearized on the scale of a single network element. This allows application of linear network analysis to the calculation of system response. Ultimately, our analysis suggests that spring response is determined by three factors: 1) the variability in input signals, 2) the ability of flow paths within the system to damp signals, and 3) the distribution of recharge among the available flow paths. The first factor is trivial, and the latter two factors can be expressed using a recharge distribution function, which can be used to mathematically express the relationship between recharge, network geometry, and spring responses. We apply the theoretical framework to a selection of field studies from the literature to demonstrate how it can aid in the interpretation of spring signals.