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Using water isotopes for assessing catchment water mean residence time. An analysis of the impact of mixing assumptions.

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One of the main applications of stable water isotopes (Oxygen-18 and Deuterium) is the estimation of catchment water mean residence time (Tmr). This estimation is often performed through lumped parameter models based on convolution and sinewave functions. These traditional models are based on simplistic assumptions that are often known to be unrealistic, in particular, steady flow conditions, linearity, complete mixing, and others. However, the effect of these assumptions on Tmr estimation is seldom evaluated. In this paper, we build a conceptual model that overcomes several assumptions made in traditional mixing models. Using data from the experimental Maimai catchment (New Zealand), we compare a complete-mixing model, where rainfall water is assumed to mix completely and instantaneously with the total catchment storage, with a partial-mixing model, where the tracer input is divided between an 'active' and a 'dead' storage compartment. We show that the inferred distribution of Tmr is strongly dependent on the treatment of mixing processes and flow pathways. The complete-mixing model returns estimates of Tmr that are well-identifiable and in general agreement with previous studies of the Maimai catchment. On the other hand, the partial mixing model – motivated by a priori catchment insights – provides Tmr estimates that appear exceedingly large and highly uncertain. This suggests that water isotope composition measurements in rainfall and discharge alone may be insufficient for inferring Tmr. Given our model hypothesis, we also analyzed the effect of different controls on Tmr. It was found that Tmr is controlled primarily by the storage properties of the catchment, rather than by the speed of streamflow response. This provides guidance on the type of information necessary to improve Tmr estimation.