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A general methodology for estimating spatially-distributed source-specific travel times of solute through a catchment

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Quantifying the time it takes for water and non-reactive solute to travel along the diverse flow pathways from a solute source within a catchment to a recipient is essential for predicting the transport and fate of solutes. Quantification through direct observation or inverse modeling is difficult both in terms of collecting the appropriate data and in terms of interpretation. This is especially true in regions with limited available information, such as in arctic and sub-arctic catchments. There is need for practical and easily applicable methods to estimate spatially distributed travel times in the landscape, which are still process oriented and physically based so that the estimated travel times have real physical meaning and can be consistently used in the modeling of transport-transformation processes of different solutes. Such methods also need to be generally applicable and adaptable to solute transport from different and multiple surface and subsurface sources of various locations and extents within a catchment to the stream network or the outlet of the catchment. In this study, we present a general methodology for estimating spatially-distributed travel times at the catchment scale. We apply the methodology to a data-limited, sub-arctic catchment located in northern Sweden and exemplify its flexibility and possible use in a wide variety of solute transport-transformation applications, under different climatic scenarios, and at locations with limited data-availability. This lays the groundwork for modeling physico-chemical relevant travel times for specific sources of different solutes.