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# Expansion and contraction of the flowing stream network changes hillslope flowpath lengths and the travel time distribution

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The length of the stream network (here defined as streams with flowing water) can change substantially between seasons and in response to rainfall events. Expansion of the stream network can greatly increase the drainage density and significantly shorten the flow pathways to the stream. This is expected to alter the distribution of travel times to the stream, and likely also affect water quality. However, the effect of stream network expansion and contraction on the travel time distribution has not been assessed, and most transport models use a static stream network, often derived from maps that ignore temporary streams.

As a test case, we compared field-mapped stream networks for four different conditions (ranging from extremely dry to extremely wet), as well as the stream network from the topographic map, for a 12 ha headwater catchment in the Swiss pre-alps. For these stream networks, we used a LiDAR-based digital elevation model to determine the subsurface flow distance to the stream network and the surface flow distance through the flowing streams to the outlet, starting from each pixel in the catchment. We assumed average subsurface and surface velocities to estimate the travel time distribution based on these distances. The results show that the expansion of the stream network not only substantially shortened the mean travel time but also changed the shape of the travel time distribution, even with all other factors kept constant, because the expansion of the flowing stream network significantly shortened the hillslope travel distances. When the stream network was extended, the travel time distribution was strongly skewed, but as the network contracted, the distribution of the travel times became more uniform. Furthermore, the area of the catchment with travel times less than two days shrank from almost the entire catchment to a small area near the outlet, suggesting that stream network expansion and contraction affect the area of the catchment that can contribute to streamflow at the event time scale, thus altering the connectivity between hillslopes and the stream outlet. These results highlight the need to consider the dynamics of the flowing stream network when studying travel time distributions or using solute transport models.