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The importance of water transit time and mineral dissolution kinetics for the flux of weathering products

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Soil mineral weathering is one of the major sources of base cations (BC), which play a dual role for a forest ecosystem; they function both as plant nutrients, and for buffering against acidification of catchment runoff. On a long-term basis, the soil weathering rates will determine the highest sustainable forest productivity without causing acidification. It is believed that the hydrologic residence time play a key role in determining weathering rates on a landscape scale. In this study, we investigate the significance of the water transit residence time (WTT) distribution for the transport of base cations to catchment runoff.

By modelling hillslope flowpaths with different transit times, using the geochemical computing code PHREEQC, we demonstrate how in-stream dynamics as exemplified by elemental ratios can be explained by mineral dissolution kinetics and equilibria. Specifically, we hypothesize that equilibrium of plagioclase regulates the delivery of base cations and silica to catchment runoff. These patters can be seen in field data from 10 years of sampling from a nested-catchment, where the Na+/BC and the Si/BC-ratios vary systematically with WTT on both a temporal and a spatial scale.

This behavior has implications for the total transport of products from mineral dissolution to catchment runoff. As the water entering the stream is a mixture of water with different transit times, the composition of stream water will not only be dependent on the average WTT, but also on the shape of the WTT distribution. For the base cations associated with minerals that becomes supersaturated or with precipitating secondary phases within the range of WTT, i.e. Na+ and K+, the tails of “old water” of the WRT-distribution will not contribute to any extra transport of these elements.

Finally, we use the derived relationships to estimate the transport of weathering products from a forested hillslope, given the modelled WRT distribution.