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Linking chemostatic behaviour of streams to storage dynamics and long tails in water age distributions

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The water storage and release dynamics at the catchment scale are still incompletely understood. This is in particular true when considering actual particle transport rather than only the hydraulic response. Environmental tracers are frequently instrumental in inferring transport process dynamics. Several recent research papers for example highlight the importance of difference time scales in transport dynamics. While on the short term, particle transport patterns can exhibit considerable variability, many catchments are characterized by near-chemostatic behaviour on the long term. In other words although the tracer response can show considerable fluctuations on the intra-annual scale, it remains surprisingly stable at the inter-annual scale. This suggests (1) that at the long term the composition of water can be largely independent of flow volumes and (2) that water as well as tracers/contaminants, once stored in a catchment can remain in the system for a very long time. Here we use long term (< 20 years) precipitation, flow and tracer (chloride) data of three contrasting upland catchments in the Scottish Highlands to inform integrated conceptual models investigating different mixing assumptions. Using the models as diagnostic tools in a functional comparison, water and tracer fluxes were then tracked with the objective of exploring the origin and pattern of near-chemostatic behaviour which manifests itself in long, power-law tails of water age distributions. The results highlight the potential importance of partial mixing processes in the generation of long tails in water age distributions. However, the degree to which partial mixing influences the generation of long tails is dependent on the hydrological functioning of a catchment. As second influential factor controlling the tailing behaviour of water age distributions was identified to be the interplay of flow path connectivity with the relative importance and timing of different flow paths. This understanding will allow classification of catchments according to their vulnerability to and the persistence of contamination, allowing for the development of more adequate, tailor-made contamination protection and mitigation strategies. In general this study highlights the potential of customized integrated conceptual models, based on multiple mixing assumptions, to infer system internal transport dynamics and their sensitivity to catchment wetness states.