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Topographical scaling of surface water-groundwater interaction

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Landscape topography controls the surface water exchange with groundwaters from mountain ranges to the smallest hills. The groundwater surface tends to follow topography in humid climates and this boundary drives groundwater circulation. This interplay between surface water and groundwater is crucial for the water balance in watersheds, as well as solute transport from the continents to the oceans. Separating the topography in a Fourier spectrum both represents the fractal ground surface topography in fluvial and glacial landscapes and provides an exact solution for the three-dimensional groundwater flows including the surface water interaction.

The fractal topography implies that all landscape features have a significant impact on the surface–subsurface water interaction. However, because of the decaying permeability with depth there is a clear tendency that the interfacial flux tends to be dominated by small-scale features, while the flux through deeper subsurface flow paths tends to be controlled by larger-scale features. In the order of 10 percents of the precipitation in Scandinavia infiltrates the ground, but only about 1 permille of the groundwater recharge reaches deeper than 400 m.

The fractal nature of surface-subsurface water fluxes yields a scale-independent distribution of surface fluxes and subsurface water residence times that can be formally implemented in surface hydrological models on the catchment scale. This new approach is expected to provide a better understanding of the overall water balance in watersheds as well as the renewal rate of deep groundwater. The spectral representation of topography over the entire continent has far-reaching implications for the

long-term management of water resources. The improved understanding of the exchange processes in the hyporheic zone and its interaction with biogeochemistry and colloids is of utmost importance for understanding recent environmental problems like eutrophication from nitrogen and phosphorus and spreading of toxic substances like heavy metals.