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From catchment organization to dynamic functional similarity

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At a very general level most surface and subsurface hydrologist would surely agree that their systems usually exhibit an enormous spatial heterogeneity. Jim Dooge was probably one of the first hydrologists who distinguished different types of heterogeneity namely stochastic and structured variability and to reflect about how these affect predictability of hydrological dynamics. He concluded that most hydrological systems drop into Weinberg's category of organized complexity – they are too heterogeneous for a purely deterministic handling, but they exhibit too much organization for a pure statistical treatment.

A straightforward way for defining spatial organization of a system is through its deviation from the state of maximum entropy, where all gradients are depleted. In this light the persistence of a smooth topography is probably the most obvious form of landscape organization; and catchment systems reflect the interplay of tectonic uplift and the amount of work water and biota have performed to weather and erode solid materials, to form soils and create flow paths. Despite of the fact these processes are strongly dissipative and produce entropy, they nevertheless leave signatures of self-organization in catchment systems. These are for instance manifested through the soil a catena and even stronger through all kinds of preferential flow paths veining the subsurface, to rill and river networks connecting across multiple scales. These networks exhibit similar topological characteristics and they commonly increase the efficiency in transporting water, chemicals, sediments/ colloids and energy across driving gradients across scales and compartments.

In line with these thoughts, joint research within the CAOS project has been guided by the postulate that self-organization in catchments leads to hydrological similarity and simplicity. This was deemed to manifest through the existence of a hierarchy of functional units, which act similarly either with respect to the controls of land-surface-atmosphere energy exchange and evaporation during radiation driven conditions or with respect to the controls of rainfall driven stream flow generation and water driven transport . This study will present model and experimental evidence from multiple catchments that functional units for stream flow generation exist and that the complexity of catchment functioning is indeed changing at its own pulse. The key to define these functional units is to acknowledge that runoff is jointly controlled by driving potential energy differences and dissipative losses along the flow paths and that a similar

combination of both will create cause runoff generation. While potential energy differences largely relate to catchment topography, dissipative losses increase with flow path length and the length specific energy loss. The latter is on one hand controlled by local textural properties, depending on either surface roughness or subsurface hydraulic conductivity and wetness, while on the other hand either rills or subsurface preferential flow paths reduce dissipative losses. Based on this evidence we suggest functional units exist, that they allow a simplification of hydrological models without loosing the physical basis and without loosing predict performance. If catchments are spatially organised, we expect that their dynamic functioning is less than the sum of their elements.