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Invariant morphometric properties of headwater subcatchments

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The headwater catchment scale has emerged as a hydrological and environmental priority through control of human impacts on surface water as recommended by the European Union Water Framework Directive. Similarity indices are often used as metrics and indicators for catchment comparison and regionalization on ungauged basins. When modelling surface runoff processes, the transfer function can be characterized by indicators such as the global shape of the hydrograph, the peak and the time to peak, which can be related to the channel network topology and the spatial properties of the basin. The width function captures the essential features of the catchment's transfer function such as the Geomorphologic Instantaneous Unit Hydrograph (GIUH) response. This paper is an investigation into these areas and aims to characterize morphometric properties of headwater catchments and then to identify which morphometric properties of the channel networks' control the width function, and assess whether these indicators can be used as metrics for catchment comparison.

First, we present some newly found invariance properties of headwater subcatchments and shows that the invariant morphometric properties characterize only natural channel networks verifying Optimal Channel Networks (OCN) properties, but are not verified for non-OCN (Moussa, Colin, Rabotin, Water Resources Research; under revision). A heuristic approach was conducted, and a new empirical model based on self-affine properties was developed in order to calculate the number N and the total headwater area H as a function of the cutoff area S used to extract the channel network from DEM ($0.5 < S < 5$ km^2). For 18 French catchments between 43 and 116450 km^2, results show that H(S) / S0 (S0 being the catchment area) is independent from S and seems constant (0.29 +/- 0.03) for various shapes and sizes of channel networks, and consequently can be considered as invariant general descriptor of natural channel networks. On the contrary, this is not the case when the approach is applied on 6 virtual non-OCN.

Second, results show that the knowledge of six morphometric indices enable to calculate both functions N(S) and H(S) for all values of $S < S0$ and a new deterministic iterative model of the width function is proposed on the basis of a conceptualization of the topology of the channel network (Moussa, 2008, Water Resources Research, W08456). These indices can be considered as geometric and topological properties of headwater subcatchments, and are useful for studying the effects of cutoffs on self-affine river networks or as similarity indices for channel network comparison.

Automated classification of the width function offers a large number of advantages such as rapidity, objectivity and reproducibility. In hydrologic applications, the classification of the descriptors of the width function can be used to guide the hydrologist in defining the transfer function for lumped modeling approach, in comparing ungauged catchments for regionalization, in establishing experimental designs (choice of monitoring location) and for catchment subdivision in hydrological distributed modeling.