Geophysical Research Abstracts,
Vol. 11, EGU2009-12748, 2009
EGU General Assembly 2009

Effects of scale and spatial process organisation in hydrology with implications for predictability

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One of the fascinating features of hydrological processes is their astounding spatial variability and spatial organisation at all scales. Organisation relates to the spatial arrangement of media characteristics and flow properties including continuity, zones with boundaries between them, the presence of preferential pathways, self-similar organisation and extremes or outliers that occur more often than would be expected based on standard statistical distributions. These organised patterns are linked to the processes that drive and modulate them. Conversely, this heterogeneity may introduce measurement biases and make it difficult to interpret and reconcile data collected at different scales.

In this paper I will discuss the concepts of process scales, sampling scales and model scales; and the concept of a scale triplet consisting of spacing, extent and support. This will provide a framework of scale effects in sampling and modelling. The effects will be demonstrated quantitatively for the example of spatially correlated random fields, i.e., when spatial continuity dominates the heterogeneity characteristics. Other types of organisation will also be reviewed and how their scale effects differ from the basic case of random fields.

The implications of these scale effects for sampling design will be discussed as will be the implications for modelling spatial flow processes in the subsurface. The degree of non-linearity in the flow processes is critically important for the extent to which data collected at different scales can be interpreted and reconciled. Predictability will be limited if threshold processes exist due to the limited level of detail at which data can be collected. I will emphasise the value of observed spatial patterns vis a vis the sampling of point data. Pattern information is particularly important if spatial organisation is present in the subsurface.