Contrasting patterns in the decrease of spatial variability with increasing catchment area between stream discharge and water chemistry

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Understanding the relationships between spatial variability in hydrological and biogeochemical processes and spatial scale is required to obtain information about the spatial representativeness and potential of extrapolation of these processes and to improve our ability of predictions in poorly gauged or ungauged basins (PUB). One major approach was to determine the Representative Elementary Area (REA), which was defied as the minimum area where spatial variability in small catchments became sufficiently small to be ignored. Despite the large number of studies available, only a few have examined how spatial variability in stream discharge and water chemistry decreases with increasing catchment area, and how the size of REA is determined. Therefore, our purpose was to obtain a better understanding of how the spatial variability of stream discharge and water chemistry decreases with increasing catchment area in small headwater catchments. For this purpose the following questions were addressed.

1) How does the rate of decrease in spatial variability with increasing catchment area differ among catchments and for stream discharge and water chemistry?

2) What type of spatial structure causes different rates of decrease in spatial variability with increasing catchment area?

We observed stream discharge and water chemistry in multiple points within three forested headwater catchments and investigated differences in this decrease of variability with increasing catchment area among catchments, and among specific discharge (Q_s) and water chemistry parameters. We quantified the slope of the decrease in the variability with increasing catchment area as the rate of decrease in the standard deviation and coefficient of variation (δ_{SD} and δ_{CV}, respectively), both of which are −0.5 for the simple mixing of random variables (random mixing). Then, we defined two indices to evaluate the spatial structure of the parameters. One was "relative difference", which referred to the ratio (in percentage) of the parameters' mean values between low- and high-order streams. The other was "D_{200}", which indicated the dissimilarity of parameter values within sub-catchments.

All δ_{SD} and δ_{CV} values of Q_s were less than −0.5, while those of most water chemistry values were greater than −0.5, indicating that with increased catchment area the spatial variability of Q_s decreased more steeply than for random mixing, while for water chemistry they decreased less steeply. δ_{SD} and δ_{CV} had positive linear relationships with the relative difference and negative linear relationships with D_{200}. It suggested that differences in δ_{SD} or δ_{CV} for Q_s and water chemistry can be explained by the different spatial structures, where dissimilar values of Q_s and similar values of water chemistry, respectively, are located close together in space. Differences in δ_{SD} and δ_{CV} according to Q_s and water chemistry should significantly affect the determination of representative elementary area (REA), and therefore need to be considered when predicting REA from spatial variability of low-order streams.

Keywords: Spatial variability , Stream discharge , Stream water chemistry, Catchment area

