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Evaluation of the role of dispersion mechanisms at different basin scales

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The geomorphologic instantaneous unit hydrograph has been often employed in the literature in order to quantify the role of the different mechanisms contributing to the variance of the travel time. Specific dispersion coefficients have been introduced, each one accounting for a dispersive effect. The Geomorphological Dispersion D_G (Rinaldo et al., 1991) quantifies the fraction of spreading of the arrival times deriving from the difference of path lengths. The Hydrodynamic Dispersion D_L measures the portion of variance induced by non identical travel times of particles injected simultaneously at the upstream origin of an individual reach. Moreover, recent works of Saco and Kumar (2002a; 2002b) proposed an analytical approach taking into account (i) the spatial variations of velocity within the channels, thus defining this dispersive effect given by the spatial heterogeneity of convective processes as Channel Kinematic Dispersion D_{Kc}, and (ii) the effect given by different velocities u_h and u_c assigned respectively to hillslopes and channels (Saco and Kumar, 2004) thus introducing the so called Hillslope Kinematic Dispersion D_{Kh}. Relative roles of D_G and D_L were established by Rinaldo et al. (1991) showing that within the range of acceptable Peclet numbers for natural basins, the effect of D_L appears to be negligible. Additionally, Botter and Rinaldo (2003) found that even for quite unrealistic changes in u_c, the effects of D_{Kc} appear of less relevance.

The actual impact of D_{Kh} appears instead crucial, since as u_h becomes smaller enough if compared with u_c, the variance, duration and peak discharge of the generated hydrograph are strongly affected by the hillslope processes. Nevertheless the relative roles of $D_G$and $D_{Kh}$for different basin sizes, has never been fully established.

In this work, following the width function approach , the role of D_G and D_{Kh} is examined for a set of 13 basins located in central Italy, their size ranging from 200 to 4000 km^2. Geomorphological characteristics of each basin have been derived through standard terrain analysis applied to a digital terrain model. This allows to quantify directly D_G by sampling all the individual flow paths. Data shows that D_G depends on the contributing area of the catchment according to a power law. The same result has been analytically derived starting from geomorphological laws formally similar to the Hack's law.

The behaviour of $D_{Kh}$is then studied defining its sign as a function of the ratio between u_c and u_h. Velocities were estimated comparing the moments of both rainfall and discharge data and assessing the lag time and variance of the IUH for each basin.

Since velocities appear to depend from basin geology, in addition to other morphologic features, D_{Kh} cannot be computed directly from the size of the basin. However, the general behaviour of D_{Kh} shows to decrease with basins size, thus counteracting, for large basins, the increase of Geomorphological Dispersion.

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