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Geomorphically Effective Energy Expenditure for Quantifying Channel Responses to Extreme Floods

William Amponsah (1,2), Margherita Righini (3), Ellen E. Wohl (4), Marco Borga (2), Lorenzo Marchi (1), Sara L. Rathburn (4), Nicola Surian (3), and Davide Zoccatelli (2)

(1) National Research Council of Italy, Research Institute for Geo-Hydrological Protection, Padova, Italy (william.amponsah@irpi.cnr.it), (2) Department of Land, Environment, Agriculture and Forestry, University of Padova, Italy, (3) Department of Geosciences, University of Padova, Italy, (4) Department of Geosciences, Colorado State University, USA

Flash floods are characterized by strong spatio-temporal rainfall variability and therefore show variations in energy expenditure and associated geomorphic impacts that depend on geological controls on channel geometry and sediment characteristics, as well as on variations in flood intensity. Geomorphic modification is expected to occur in river channels when driving forces (i.e. hydraulic and abrasive forces of water and sediment acting on the channel) exceed threshold of resisting forces (i.e. the ability of channel boundaries to remain unchanged by the passage of water and sediments). However, these forces that determine the capacity of floods to modify existing channel configuration are extremely difficult to quantify. Geomorphic impacts or hazards usually take the form of erosional and depositional modification of the pre-flood channel and valley geometry. A central question in hydrogeomorphology relates to why flash floods of similar magnitudes and intensities sometimes produce dissimilar geomorphic results? In fact, some less magnitude floods in terms of discharge per unit of drainage area have been found to produce major geomorphic damage than some high magnitude events. Furthermore, the use of peak instantaneous flow parameters such as discharge, velocity, shear stress and stream power to quantify geomorphic changes have often been non-deterministic and/or inconclusive. Investigations are therefore needed on how factors such as channel geometry, substrate, riparian vegetation, sediment supply, and flood magnitude and duration can interact and influence geomorphic effectiveness of high magnitude floods. The main objective of this study is to assess the coupled influence of flood-flow duration and total energy expenditure on geomorphic response to extreme flash floods, which is aimed at developing an index that combines flow duration, stream power per unit area and threshold for major channel erosion to be evaluated as a predictor of geomorphic adjustment to extreme floods. To achieve this, we carried out an integrated analysis of data from post-flood observations, remote sensing and hydrological modelling to simulate stream power hydrograph characteristics (i.e. magnitude and duration of flow energy expenditure) at 30 cross-sections for four major flash floods that occurred between 2011 and 2014 in Italy and downstream along 6 river channels that were impacted by the October 2011 extreme flash flood in the Magra River basin in Italy. Multiple regression models, which incorporate geomorphic variables such as topography, channel confinement and sediment supply areas, were also carried out to understand how these variables can interact with flow energy expenditure to influence channel modification at the channel-reach scale. Results show that the combined influence of flow duration and total energy expenditure can better predict channel response to extreme floods, relative to peak instantaneous stream power.