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Hydrologic forecasting of extreme rainfall events using hydraulic models at different spatial scales

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Hydraulic engineering calculations depend on the water discharge predicted with an hydrologic model. Hydrologic predictions have a high degree of uncertainty which emerges from both, the hydrologic model itself, which very often relies on aggregated empirical formulae, and the model parameters, which must be adjusted from the watershed physical properties and/or from experimental calibration in the cases in which adequate field data is available.

Using physically based models can improve the representation of hydrologic mechanisms and processes. A hydrologic model which includes the characterization of physical process might lead to more accurate discharge predictions, to a better understanding of catchment hydrology, and to identify which hydrologic processes are more relevant in the watershed.

In this paper we analyse the possibility of using physically based hydraulic models based on the two-dimensional shallow water equations in order to forecast the runoff generated by extreme and short rainfall events, in which the base groundwater flow is of minor importance in the generation of surface runoff. Surface runoff is a very shallow flow and should be well represented by a hydraulic model which includes the appropriate hydrologic processes involved in rainfall runoff transformation. The model used considers the effects of bed friction, watershed topography, precipitation and infiltration, all of them with a spatially distributed definition.

We analyse the accuracy and uncertainty in the model results, and the sensitivity to input parameters. Different rainfall events in watersheds of different spatial extension are analysed, including a laboratory rainfall simulator of 5m2, an industrial catchment of 100.000m2, a 5Km2 vegetated watershed, and a 25Km2 semi-arid watershed. In all the cases the model predictions are compared against experimental field data.

At the smaller scales we investigate the parameterization of surface roughness in very shallow flows, and the accuracy of model predictions in problems in which the watershed characteristics are defined with a high degree of accuracy and detail. In those cases the uncertainty in input data is reduced to a minimum. As the extension of the watershed increases, the accuracy and resolution of the input data decreases, and model predictions are expected to deteriorate due to uncertainty in model input data.

At the larger scales, we study the influence that the spatial extension of the model, and the spatial resolution of the input data (topography, infiltration parameters, surface roughness) and numerical model (spatial discretisation) have on the accuracy and uncertainty of the model predictions, as well as on the calibration of the input parameters. In general, a low spatial resolution implies a filtering of the small scale physical features and processes. In that cases the input parameters will have to account for that loss of information in the model, losing in such a way their physical meaning. The effects of small scale microtopography, which is not resolved by the model, must be included in the calibration parameters. On the other hand, with a high spatial resolution the hydrologic processes can be represented in the model in more detail and thus, the input parameters are expected to be more related to the physical properties of the watershed.

In ungauged watersheds models relying on physically based parameters are preferable, since calibration with field data is not possible and the input parameters need to be adjusted according to the physical properties of the watershed. On the other hand, in gauged basins where model calibration is possible, it is not clear that the computational effort and information required by a high resolution model is worth compared to a low resolution model.