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The combined effect of wind and rain storms on the hydrologic response

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Although rainfall is assumed to be spatially uniform in conventional hydrological modelling for rainfall–runoff simulations, moving storms have been shown to have a substantial influence on surface flow hydrographs since the spatial and temporal characteristics of rainfall are altered by wind. All the processes involved (e.g. rainfall, wind, runoff, soil erosion), which typically exhibit extreme variability, are germane for investigation at different scales. The importance of storm movement, under the combined effect of wind and rain, to surface flows at scales ranging from headwater scales to catchment basins has long been acknowledged. In countries like Portugal, whose Mediterranean type of climate means that intense rainfall events are common, this issue is becoming increasingly important in the context of a possible climate change scenario.

The main objective of this study is to quantify the hydrologic response in terms of discharges and soil loss caused by both non-moving and moving rainstorms. This subject is important to agriculture soil and water conservation, urban hydrology, water resources management and other fields.

This work reports the results from three case studies which involved the use of a physically based erosion model, laboratory rainfall simulations on soil flumes, and laboratory experiments using a physical scale model representing an urban area:
(1) A physically based distributed erosion model was used to evaluate the consequences of storm movement on runoff and erosion from the Alenquer basin in Portugal. The model was applied to storms moving both downstream and upstream along the basin's axis.
(2) Controlled flume laboratory experiments were carried out using several soil flumes and a movable sprinkling-type rainfall simulator. Moving rainstorms were simulated by moving the rainfall simulator upstream and downstream over the soil surface at different speeds. Overland flow and sediment transport were measured during runoff events in order to determine hydrographs and sediment production over time. The size distribution of the eroded material is governed by the capacity of the flowing water to transport it. Granulometric curves obtained through conventional hand sieving and optical spectrophotometry (material below 0.250 mm) were constructed.
(3) Laboratory tests were also carried out to simulate the response of an urban drainage system to static rainfall and rainstorms moving in diverse directions; building density was varied, and the existence or non-existence of wind was considered. A physical model (1:100 scale) was built in the laboratory to represent an impermeable city-centre urban area, with high rise buildings.

The laboratory soil flumes and physical scale-model experiments and the numerical model simulations all showed that the direction of storm movement, especially in case of extreme rainfall events, significantly affected the runoff and water erosion process. Downstream-moving storms caused significantly higher peak runoff and erosion than did upstream-moving storms. The hydrograph shapes were also different: for downstream-moving storms runoff started later and the rising limb was steeper, whereas for upstream moving storms runoff started earlier and the rising limb was less steep. The results also showed that storm movement has a marked influence on the granulometric characteristics of sediments transported by overland flow.