Deriving strong rain hazard risk maps from geo-mophology

EARSeL Cyprus 2022
Abstract
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Keywords (5): strong rain, hazard-risk-maps, digital surface models, climate-change

The challenge (max. 1000 characters space incl.)

In the last summer a long time stationary rain event struck parts of western Germany leading to massive floodings especially in the Ahr valley. Such long-term stationary weather conditions get actually more and more frequent and can lead to long extreme heat or massive continuous rainfall as shown in a study of the Potsdam-Institut für Klimafolgenforschung (PIK) last year (Rousi, E., Selten, F., Rahmstorf, S., Coumou, D. (2021): Changes in North Atlantic atmospheric circulation in a warmer climate favor winter flooding and summer drought over Europe. - Journal of Climate, 34, 6, 2277-2295. https://doi.org/10.1175/JCLI-D-20-0311.1).

The flood of the Ahr revealed that the existing modelling for flood probabilities is not sufficient. Possible causes may be the comparatively short observation period of the underlying measurements, missing historical data or the dynamics of climate change are not taken into account. For this reason, our approach is based on simulations of individually adapted worst case scenarios to derive possible effects of heavy rainfall more generally and over a wide area just based on satellite data and digital elevation models. So it's a simplified model which can be adapted and applied fast to regions all over the world – especially regions with only sparse available data.

Methodology (max. 1500 characters space incl.)

In the last years we developed a methodology for classification of strong rain dangers depending only on the terrain. It is based on 10 years events of a German insurance company and digital elevation models (DEMs) in resolutions starting from 2.5 m derived from the Indian Cartosat satellite up to 90 m (SRTM). The final method is based on the terrain positioning index with parameters, resolution and type of DEM calibrated using the available insurance data.

These strong rain danger maps estimate a worst case scenario by not taking into account local drains since those are mostly blocked by leaves and branches at such sudden events. But these maps are only based on the local situation and do not consider water coming from other areas. So we developed an additional component including water-run-off from up-stream areas.

In the presented study we calculate the maximum run-off for each point of a whole water catchment area (see fig. 1) assuming a massive strong rain event and the following flash flood. For each position in the run-off-map a local height profile perpendicular to the flow direction is calculated and filled up with the maximum estimated water volume at this position. This is depicted in fig. 2, right. There a blue "wall" is shown across the river profile representing the volume covered by the calculated run-off volume at this point of the river. These cross sections along the river in a valley gives the water levels for the maximum possible run-off for a given strong rain event.

Results (max. 1500 characters space incl.)

The result of the presented method is a map containing the flood outlines depending on the assumed rainfall (see fig. 2, left). But since some part of the rain will drain away and not contribute to the run-off this is also a worst case estimation. The results are compared to aerial imagery acquired on 2021-07-16 – two days after the flooding struck the Ahr valley –, flood-masks derived from Sentinel-1 imagery and Copernicus damage assessment maps. Based on this reference imagery, measurements and estimations of water gauge levels the effective flood level of the catchment was calculated and the simulation was calibrated and adapted to the observed water levels which led to a reasonable prediction of the flood extends.

A second result of the presented method is a color coded danger map (see fig. 2, right). The colors represent areas which will be covered by 10 cm or higher water level depending on the rain-fall over the up-stream catchment of each point.

Outlook for the future (max. 1000 characters space incl.)

The presented method will be operationalized and cross-checked with other observed strong-rain events all over the world to generate a system for a danger classification due to strong rain all over the world.

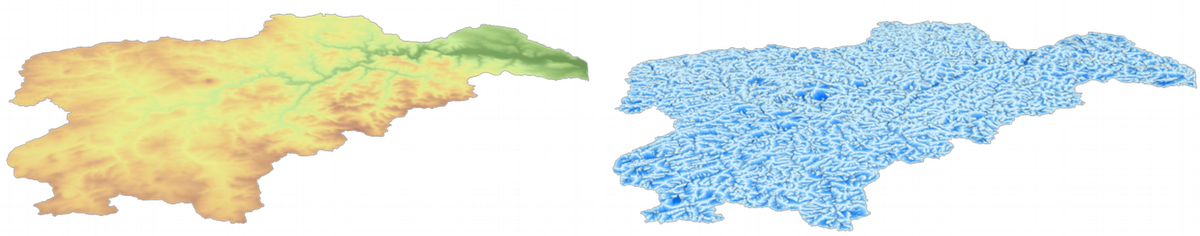

Figure 1 left: 3D view of calculated catchment of river Ahr, right: derived maximum run-off based only on a digital surface model (DSM, darker blue is higher run-off volume)

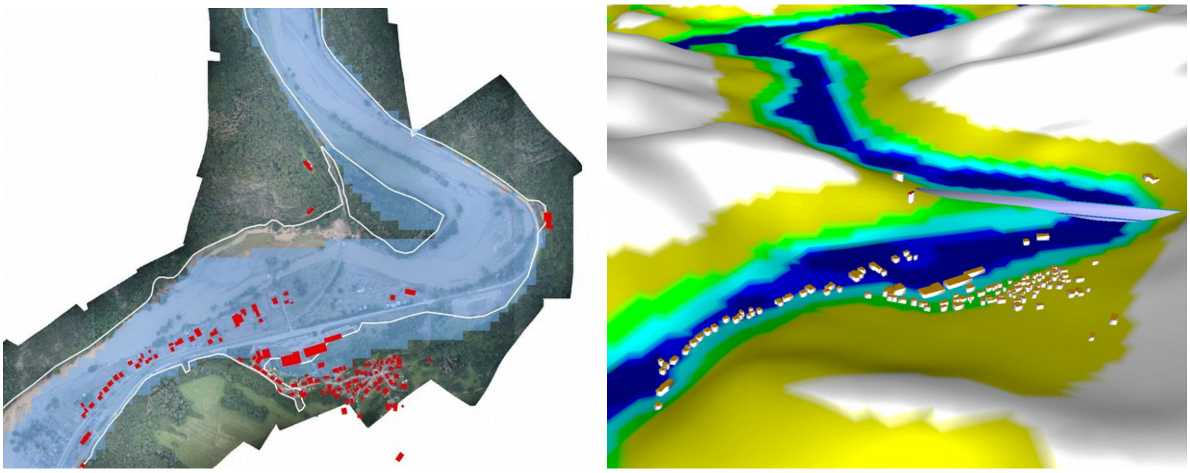

Figure 2 left: aerial image of Ahrbrück, manually derived maximum water level of flood event as overlayed outline, simulated water-level for estimated rain-fall of 125 mm/m² over catchment as blue pixel-mask, right: 3D view of DSM, same area including buildings, colors denoting flood-risk danger from dark-blue (water level 10 cm or higher at rainfall of 5 mm/m² over catchment) over middle blue (25 mm/m²), light blue (125 mm/m²), green (500 mm/m²) to brown (2500 mm/m²), light blue profile “wall”: lower section profile for 150 mm/m², top section profile for 1500 mm/m²