Flash flood formation in pre-alpine landscape – impact of the spatial distribution of storm events

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INTRODUCTION

The general paradigm shift from hazard to risk and an increasing number of damaging flood events, especially within the last two decades, result in a strengthened commitment of the scientific community, engineers and policy-maker in the analysis, assessment, and management of flood risk. While hazard and risk analysis in the field of river flooding is widely established and standardized, appropriate methods for overland flow leading to flash floods in settled areas are still subject to research. These flash floods arise usually by short-term, small-scale heavy convective cells with extreme intensity and occur primarily in small watersheds with fast response times. For extreme precipitation events, there is a strong local link between damage occurrence and the intensity of rainfall as shown in Einfalt et al. (2012).

METHODOLOGY

The selected project area was facing flash floods caused by extreme precipitation events in recent years. It is a scattered settlement area located in the pre-alpine landscape whose agricultural areas are highly vulnerable to water erosion. For design purposes it is unrealistic that the whole catchment is affected by extreme intensities. In view of this, the spatial extension of the artificial design storm cell was limited to an area of 1km². By evaluating past events the precipitation intensity and track velocity of the artificial convective cell were selected. The remaining catchment was subjected to a design rainfall with a recurrence interval of 5 years and the duration of 2 hours. Numerous sets of storm tracks were simulated to assess the effect of the spatial distribution of convective events on flash flood formation.

The idea behind is, that risk assessment and design approach bear a considerable uncertainty with regard to simulated flood extends and water levels, depending on the rainfall scenario used. Where intensities and durations of rainfall events are categorized, the specific spatial-temporal distribution is not.

Assessing local flooding and pathways of flood requires a detailed hydraulic simulation of the surface runoff, especially when dealing with flash flood situations. The flood formation as a key process during local flash floods is considered by applying direct rainfall runoff modelling. For the hydraulic simulation an extension of Hydro_AS-2D (Klar et. al. 2014) was developed and applied. In extend to common setups, the model was prepared to accept spatially distributed rainfall by modifying water levels at discrete time steps. Distributed rainfall for varying intensities and durations is introduced via rainfall zones representing pooled model nodes. Thus, the approach allows the simulation of convective events with varying cell tracks. The loss models implemented consider initial and continuous losses as well as soil state based approach for different zones separated as hydrologic response units (HRU´s). Therefor soil conditions and surface runoff is simulated simultaneous.

RESULTS

The results were evaluated by assessing the flood levels at selected locations. The simulation results were presented in an exemplary manner for two storm tracks shown in figure 1. The top two illustrations show the effective precipitation for the watershed. In the upper left figure the convective cell was moved from the upper left to the right edge, in the right figure from the bottom left to the top right edge. The results of the simulations are shown below. Therein the maximum water level at the selected building (red dot) varies from 1.1 m in the left simulation to 0.65 m in the right figure.

At the selected location, the flood area in the left simulation is further extended and the maximum water levels are considerably higher.

CONCLUSION

The aim of this work was to evaluate the effects of spatially distributed convective cells on flash flood formation. The simulation results showed a significant impact of convective cell track onto the maximum water level. Similarly the extension of the flood prone area is triggered by cell pathways. Considering the maximum water level as the main indicator to flood damages, the spatial distribution of extreme precipitation events must be given greater consideration for future design tasks.

REFERENCES

- Einfalt T., Hatzfeld F., Wagner A., Seltmann J., Castro D., Frerichs, S. (2009). URBAS: forecasting and management of flash floods in urban areas. Urban Water Journal,6:5,369 — 374.
- Klar R., Achleitner S., Lumassegger S., Aufleger M., Hofer M. (2014). Extension and testing of a 2D hydrodynamic model for direct rainfall runoff simulation. HIC 2014 - 11th International Conference on Hydroinformatics New York, USA; 17 - 21 August 2014

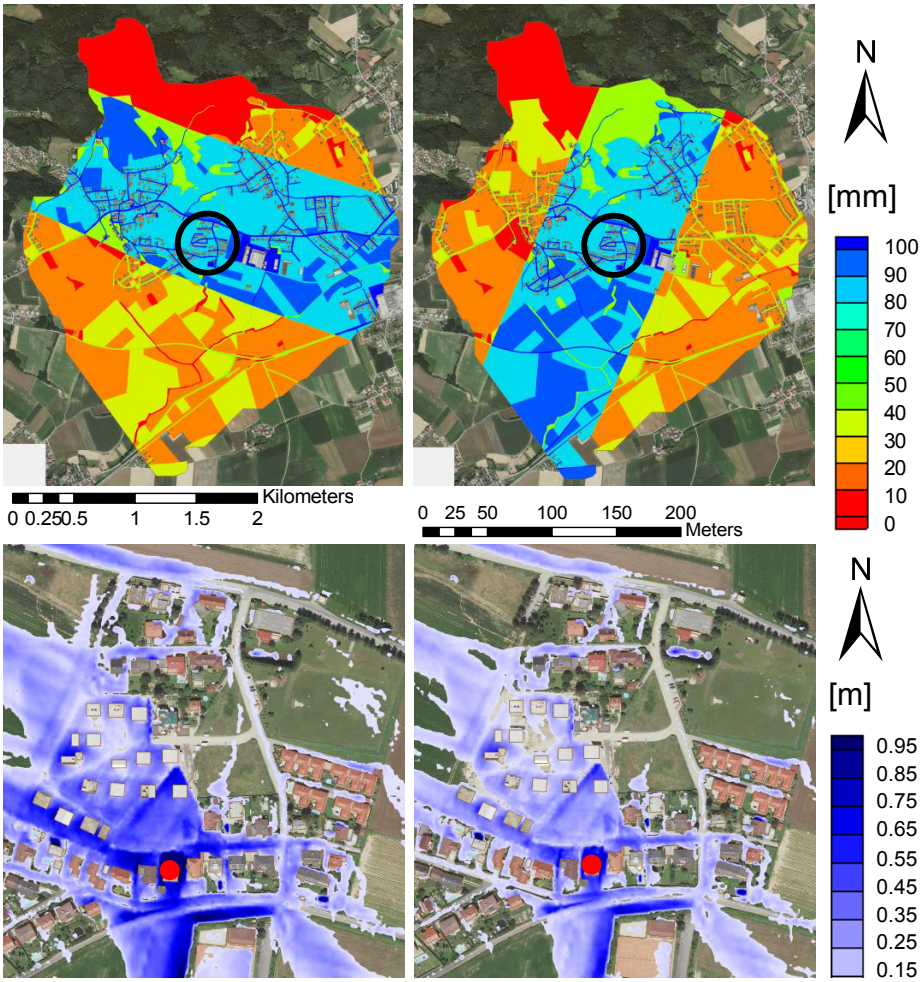

Figure 1. Spatial distribution of effective rainfall (top picture) and local snapshot of flood water levels (lower picture)

KEYWORDS

flash floods; direct rainfall runoff simulation;spatially distributed extreme precipitation; thunderstorm tracks

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