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Keynote: Flash floods predictions and mitigation under change –challenges, models, perspectives

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Flash flood are among the most dangerous natural hazard - the flash flood series in 2016 caused about Euro2.5 bn of economic losses in Southern Germany alone. Flash floods occur in small catchments or on individual hillslopes within a span of minutes to hours in response to high-intensity convective rainstorms, resulting in strong infiltration excess and significant overland flow. Extreme overland flow often mobilizes large amounts of sediments, leading onsite to loss of fertile land, while their deposition in settlements and reservoirs is causing huge damages. Suspended particles may, furthermore, carry substantial amounts of contaminants, heavy metals, pathogens) and nutrients, impacting the quality of surface water bodies.

A warmer climate will due to Clausius-Clapeyron scaling likely lead to increasing frequencies of more intense rainstorms triggering more frequent flash flood and erosion events. This is worry-some because predictions of flash floods formation is due to the threshold nature of infiltration excess overland flow a great challenge to today's forecasting systems. Flash floods are, furthermore, rarely observed with conventional rain and stream gauge networks. The sample for statistical learning and training of AI-based models is thus small.

Here we will revisit the cascading processes and thresholds controlling coupled water and sediment fluxes during convective rainstorms, and elaborate on the related challenges for standard hydrological forecasting systems. We will in particular show that the current practice of separating hydrological and hydraulic simulations is largely inappropriate, as changes in the overland flow mass balance affect it's velocity and vice versa. We then provide evidence that gradient-resolving physics based models account for this strong coupling of the mass and momentum balance during successful predictions of historical flash floods. They are, furthermore, most helpful for quantifying the sensitivity of flash flood runoff to changes in precipitation intensity as well as soil and land use characteristics. We show that the latter is key for developing integrated flood safety concepts, combining distributed land use measures dampening infiltration excess runoff, with central flood defense reservoirs.

We finally show that physics based models can be used for operational flash flood warnings in head water catchments, using re-analysis products as input and the inverted mass balance of flood defense reservoirs as target. This opens opportunities for using data from several hundred of flood defense reservoirs for learning.

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