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Sensitivity of the Runoff Characteristics of Small Alpine Catchments to Climate Change

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Floods and debris flows in small torrent catchments (< 10 km^2) arise from a combination of critical antecedent system state conditions and mostly convective precipitation events with high precipitation intensities. Thus climate change may influence the magnitude-frequency-relationship of extreme events twofold, by a modification of the occurrence probabilities of critical system state conditions and by a change of precipitation characteristics. In order to study these effects, we investigated three small Alpine catchments in different altitudes (400 – 1100 m a.s.l.; 900 – 2000 m a.s.l.; 1900 – 3000 m a.s.l.) in Western Austria within the project SeRAC-CC (Sensitivity of the Runoff Characteristics of Small Alpine Catchments to Climate Change, funded by the Austrian Climate and Energy fund, Austrian Climate Research Programme). We used spatially and temporally downscaled and bias corrected climate projections (three A1B-scenarios) to drive a precipitation-runoff-model and to simulate future system state conditions and runoff behaviour of the study catchments. To ensure process-orientated parameter calibration, we conducted intensive field work, especially sprinkling experiments, in order to analyse runoff processes at different site characteristics and hydrological system state conditions.

Hydrological modelling showed that the number of days with critical antecedent soil moisture content will be significantly reduced to about 60% or even less in summer for all investigated catchments and climate scenarios. The other seasons show no clear trends and partly differing results between the three runs driven by the three climate scenarios used. Sprinkling experiments (rain intensity 100 mm/h) revealed different sensitivities to antecedent soil moisture content depending on land use:
a) sites showing a significantly higher level of surface runoff in case of wet conditions (here especially pastured sites),
b) sites, where surface runoff starts earlier at wet conditions, but reaches about the same level as at dry conditions (here especially hay meadows)
c) sites, whose surface runoff reaction is not sensitive to antecedent soil moisture content (here especially forests and sites with a priori high level runoff).
Thus, the reduction of days with wet conditions in summer will affect mainly catchments with a high percentage of sites of the first type, reducing surface runoff.

According to the analysis of the climate scenarios, the number of days with dried up litter layer will strongly increase by 8-11% in the two lower situated catchments. Thus catchments with a high percentage of area susceptible to hydrophobic effects (e.g. pastures with high proportion of mat grass Nardus stricta) may show increased surface runoff in case of precipitation events with high intensity after dry periods. The analyses of the maximum intensity of heavy precipitation events indicate a clear increase up to 10% till the end of the century. If one of these trends equalizes the other out resulting in unchanged occurrence probabilities of extreme runoff events, cannot be answered generally because of the local characteristics of relevant processes and uncertainties regarding the modelling chain. Regardless of the open question about its return period, peak runoff of extreme events may increase by approximately 25% comparing to current peak runoff due to the higher rain intensities.