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Spoilt for choice – A comparison of downscaling approaches for hydrological impact studies

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With the increasing number of available climate downscaling approaches, users are often faced with the luxury problem of which downscaling method to apply in a climate change impact assessment study. In Switzerland, for instance, the new generation of local scale climate scenarios CH2018 will be based on quantile mapping (QM), replacing the previous delta change (DC) method. Parallel to those two methods, a multi-site weather generator (WG) was developed to meet specific user needs. The question poses which downscaling method is the most suitable for a given application. Here, we analyze the differences of the three approaches in terms of hydro-meteorological responses in the Swiss pre-Alps in terms of mean values as well as indices of extremes.

The comparison of the three different approaches was carried out in the frame of a hydrological impact assessment study that focused on different runoff characteristics and their related meteorological indices in the meso-scale catchment of the river Thur ($\sim$1700 km2), Switzerland. For this purpose, we set up the hydrological model WaSiM-ETH under present (1980-2009) and under future conditions (2070-2099), assuming the SRES A1B emission scenario. Input to the three downscaling approaches were 10 GCM-RCM simulations of the ENSEMBLES project, while eight meteorological station observations served as the reference. All station data, observed and downscaled, were interpolated to obtain meteorological fields of temperature and precipitation required by the hydrological model. For the present-day reference period we evaluated the ability of each downscaling method to reproduce today's hydro-meteorological patterns. In the scenario runs, we focused on the comparison of change signals for each hydro-meteorological parameter generated by the three downscaling techniques.

The evaluation exercise reveals that QM and WG perform equally well in representing present day average conditions, but that QM outperforms WG in reproducing indices related to extreme conditions like the number of drought events or multi-day rain sums. In terms of mean monthly discharge changes, the three downscaling methods reveal notable differences: DC shows the strongest (in summer) and less pronounced (in winter) change signal. Regarding some extreme features of runoff like frequency of droughts and the low flow level, DC shows similar change signals compared to QM and WG. This was unexpected as DC is commonly reported to fail in terms of projecting extreme changes. In contrast, QM mostly shows the strongest change signals for the 10 different extreme related indices, due to its ability to pick up more features of the climate change signals from the RCM. This indicates that DC and also WG miss some aspects, especially for flood related indices. Hence, depending on the target variable of interest, DC and QM typically provide the full range of change signals, while WG mostly lies in between both method. However, it offers the great advantage of multiple realizations combined with inter-variable consistency.