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Calibration of a rainfall-runoff hydrological model and flood simulation using data assimilation

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Rainfall-runoff models are crucial tools for long-term assessment of flash floods or real-time forecasting. However, their efficiency is limited by uncertainties on the rainfall and on the initial water content in the hydrosystems. Thus, these models must generally be calibrated. This work focuses on the calibration of a distributed parsimonious event-based rainfall-runoff model using data assimilation. The model combines a SCS-derived runoff model and a Lag and Route routing model for each cell of a regular grid mesh. The SCS-derived runoff model is parametrized by the initial water deficit, the discharge coefficient for the soil reservoir and a lagged discharge coefficient. The Lag and Route routing model is parametrized by the velocity of travel and the lag parameter. These parameters are assumed to be constant for a given catchment except for the initial water deficit and the velocity travel that are event-dependent (landuse, soil type and moisture initial conditions). In the present work, a BLUE filtering technique was used to calibrate the initial water deficit and the velocity travel for each flood event assimilating the first available discharge measurements at the catchment outlet. The advantages of the BLUE algorithm are its low computational cost and its convenient implementation, especially in the context of the calibration of a reduced number of parameters.

The assimilation algorithm was applied on two Mediterranean catchment areas of different size and dynamics: Gardon d'Anduze and Lez. The Lez catchment, of 114 km2 drainage area, is located upstream Montpellier. It is a karstic catchment mainly affected by floods in autumn during intense rainstorms (up to several hundred millimetres in 24h) with short lag-times and high discharge peaks (up to 480 m3.s-1 in September 2005). The Gardon d'Anduze catchment, mostly granite and schistose, of 545 km2 drainage area, lies over the departement of Lozère and Gard. It is often affected by flash and devasting floods as it is characterized by the highest rainfall intensities in France, shallow soils and steep slopes (up to 3000 m3.s-1 in September 2002).

The discharge observations at the beginning of the flood event are assimilated so that the BLUE algorithm provides optimal values for the initial water deficit and the velocity travel before the flood peak. These optimal values are used for a new simulation of the event in forecast mode (under the assumption of perfect rainfall). On both catchments, it was shown over a significant number of flood events, that the data assimilation procedure improves the flood peak forecast. The improvement is globally more important for the Gardon d'Anduze catchment where the flood events are stronger. The peak can be forecasted up to 36 hours head of time for some events. Such results are obtained assimilating very few observations (up to 4) during the rise of the water level. For multiple peaks events, the assimilation of the observations from the first peak leads to a significant improvement of the second peak simulation. It was also shown that the flood rise is often faster in reality than it is represented by the model. In this case and when the flood peak is under estimated in the simulation, the use of the first observations can be misleading for the data assimilation algorithm. The careful estimation of the observation and background error variances enabled the satisfying use of the data assimilation in these complex cases even though it does not allow the model error correction.