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A test for the transferability of regionalized model parameters across calibration scales and locations

R. Kumar and L. Samaniego

Helmholtz Centre for Environmental Research-UFZ, Computational Environmental Systems, Leipzig, Germany
(rohini.kumar@ufz.de, 0049 341 235-1939)

Several recent studies have advocated on improving evaluation procedures for testing the reliability of distributed hydrologic models. The traditional approach of model evaluation in calibrated conditions against daily stream flow has proven to be inadequate in identifying a robust hydrologic model or a parametrization scheme among several competing ones, as noticed in several model inter-comparison studies (see e.g. DMIP-I & II; Reed et al. 2004, Smith et al., 2011).

In this study, we propose a model evaluation procedure aiming at testing the reliability of a distributed hydrologic model for predictions beyond the calibrated conditions. Specifically, our goal was to assess the effectiveness of the transferability of model parameters to scales and locations other than those used during calibration. For this case study, we used a grid based distributed mesoscale hydrologic model (mHM, Samaniego et al. 2010, WRR) and show the effectiveness of two parameterization methods: one based on hydrological response units (HRU) and the other based on the multiscale parameter regionalization (MPR) technique.

mHM with both parameterization methods was set-up in 45 southern German river basins covering a wide range of physiographical characteristics and drainage area (100 km^2 to 12 700 km^2). Model simulations were carried out at four spatial resolutions: (2, 4, 8, 16) km in the period from 1980 to 2008. At each scale, a set of free parameters of both methods were estimated using a dynamically dimensioned search algorithm (DDS).

Both parametrization methods provided nearly similar acceptable performances for daily discharge simulations at all four modeling scales as long as their free parameters were calibrated at each scale. A significant deterioration (up to 40%) in performance of the HRU method was, however, noticed when its free parameters calibrated at a given modeling scale were shifted to another scale. The MPR method, on the contrary, exhibited a quasi scale-invariant performance, meaning that the loss in the model performance while transferring the free parameter across scales was almost negligible (less than 2%).

The performance of both parametrization methods for daily discharge simulations in all investigated basins was nearly similar as long as their free parameters were calibrated for each basin at a given scale. The Nash-Sutcliffe efficiency during the evaluation period (1988-2008) varied between 0.62 to 0.92 across basins. However, the results of the cross validation test at interior locations and non-nested basins (i.e. both assumed ungauged for testing, also known as proxy basin test) corroborated the superiority of the MPR over HRU method.

These results, therefore, supported the research hypothesis that the traditional way of evaluating model performance at calibrated conditions will fail to identify a robust parametrization technique. Whereas the proposed evaluation method helped to identify the most reliable parametrization technique for mHM.