Geophysical Research Abstracts, Vol. 9, 08667, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-08667

Analyzing hydrological model performance in the wavelet spectral domain

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Discharge is the result of a joint action of different hydrological processes, the dominance of which varies through time. This interplay can be supposed to be imprinted in the temporal evolution of the frequency content of the observed discharge. Quantifying how well a simulated time series reproduces this temporal evolution can therefore give interesting insights into the model performance. Continuous wavelet transform yields a time - scale ($\sim$1/frequency) representation of an observed time series and is, therefore, the method of choice to estimate this non-stationary frequency content.

We have developed a method for rainfall-runoff model calibration in the wavelet spectral domain. The underlying wavelet spectrum-based performance criterion deals with the problem that the wavelet transform corresponds to an expansion from a 1-D (time) representation to a 2-D (time-scale) representation of the observed time series, which introduces some numerical artefacts. Using synthetic and real-world case studies, we show why and how the use of a wavelet spectrum-based performance measure can contribute to model diagnosis and improve the calibration of hydrological models. The obtained results show that hydrological models can be calibrated in the wavelet spectral domain and that the obtained results capture the dynamics of the observed time series better than models calibrated only in the time domain.

The strength of model performance analysis in the wavelet domain also lies in the gained insights into the model's ability to reproduce the observed frequencies. An application to discharge modelling from a highly glacierized catchment from the Swiss Alps clearly showed that the used model is not able to reproduce the temporal evolution of certain frequency bands - a hint that the model has a considerable structural problem.

Wavelet spectra have enough discriminant power to distinguish between apparently

very similar time series; based on these results we believe that wavelet spectral analysis has the potential to help to detect process-induced differences between simulated and observed discharge time series that cannot be seen in the original data and that ultimately, this will enable us to develop new model diagnosis tools that capture and explain the similarity (or dissimilarity) between observed and simulated discharge time series.