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Minimum distance – A new performance measure for hydrological timeseries

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Most hydrological models include to a larger or lesser degree parameters that cannot be inferred directly from observations. As a consequence, model building includes iterative parameter optimization by minimizing an objective function, which expresses the agreement between model output and an equivalent observed quantity (often discharge). Thereby, the definition of 'agreement' (and with it the appropriate formulation of the objective function) is strongly dependent on the intended use of the model.
For this purpose, a multitude of metrics have been developed (Gupta et al. 1998, Dawson et al. 2007), among which the Root Mean Square Error (RMSE) and the Nash-Sutcliffe Efficiency are arguably the most widely used. Most of these measures compare observed and modeled quantities at the same timestep, which provides good results in cases where errors in magnitude dominate but fail when time-dependent errors occur. For example, in the rising or falling limb of a flood, even small timing errors lead to large values of RMSE which is not in accordance with intuition.
In addition to objective measures, visual comparison is also often applied, which is a multi-criteria, user-specific evaluation. However, the visual impression of agreement of two series with respect to the principal forms of errors (magnitude and timing) strongly depends on extend and scaling of the plot, which is often not considered explicitly.

From this, we suggest that a good performance metric should simultaneously account for errors in both magnitude and timing and explicitly allow user-specific relative weighting of the two. In this study, we present a new metric termed 'Minimum distance' which meets those requirements.

It comprises the following steps: Firstly, a relation between errors in magnitude and time is formulated in the form "a 10% error in magnitude is as bad as a time offset of 1 hour". This allows a) an explicit, user-specific weighting of the two errors and b) eliminates the problem of unit-mixing (both magnitude and time become dimensionless). The observed timeseries is then scaled according to this relation. Secondly, for each point in the modeled timeseries, the minimum distance (MD) vector to the scaled observation timeseries, represented by a polygon line, is calculated. Each MD vector is described by its direction and magnitude: The direction contains information about the nature of the error (e.g. whether advance or lag, over- or underestimation occurs), the magnitude contains information on the overall (dis-) agreement of the two series. Finally the individual distances, summed and averaged over the entire timeseries, yield the overall Minimum Distance. In addition to the single-valued Minimum Distance, rose plots of all distance vectors can also be plotted, which give a more detailed insight in the nature of the model errors.

The proposed method was applied to a set of simulated timeseries containing various types of errors. Ranking them based on the Minimum Distance was mostly well in accordance with intuition. Ranking according to standard 'vertical' metrics such as RMSE was often against intuition, especially in the presence of timing errors.

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