Geophysical Research Abstracts
Vol. 16, EGU2014-1970-1, 2014
EGU General Assembly 2014


# Unifying distance-based goodness-of-fit indicators for hydrologic model assessment

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The goodness-of-fit indicator, i.e. efficiency criterion, is very important for model calibration. However, recently the knowledge about the goodness-of-fit indicators is all empirical and lacks a theoretical support. Based on the likelihood theory, a unified distance-based goodness-of-fit indicator termed BC-GED model is proposed, which uses the Box-Cox (BC) transformation to remove the heteroscedasticity of model errors and the generalized error distribution (GED) with zero-mean to fit the distribution of model errors after BC. The BC-GED model can unify all recent distance-based goodness-of-fit indicators, and reveals the mean square error (MSE) and the mean absolute error (MAE) that are widely used goodness-of-fit indicators imply statistic assumptions that the model errors follow the Gaussian distribution and the Laplace distribution with zero-mean, respectively. The empirical knowledge about goodness-of-fit indicators can be also easily interpreted by BC-GED model, e.g. the sensitivity to high flow of the goodness-of-fit indicators with large power of model errors results from the low probability of large model error in the assumed distribution of these indicators.

In order to assess the effect of the parameters (i.e. the BC transformation parameter $\lambda$ and the GED kurtosis coefficient $\beta$ also termed the power of model errors) of BC-GED model on hydrologic model calibration, six cases of BC-GED model were applied in Baocun watershed (East China) with SWAT-WB-VSA model. Comparison of the inferred model parameters and model simulation results among the six indicators demonstrates these indicators can be clearly separated two classes by the GED kurtosis $\beta$: $\beta$ >1 and $\beta \leq 1$. SWAT-WB-VSA calibrated by the class $\beta$ >1 of distance-based goodness-of-fit indicators captures high flow very well and mimics the baseflow very badly, but it calibrated by the class $\beta \leq 1$ mimics the baseflow very well, because first the larger value of $\beta$, the greater emphasis is put on high flow and second the derivative of GED probability density function at zero is zero as $\beta$ >1, but discontinuous as $\beta \leq 1$, and even infinity as $\beta$ < 1 with which the maximum likelihood estimation can guarantee the model errors approach zero as well as possible. The BC-GED that estimates the parameters (i.e. $\lambda$ and $\beta$) of BC-GED model as well as hydrologic model parameters is the best distance-based goodness-of-fit indicator because not only the model validation using groundwater levels is very good, but also the model errors fulfill the statistic assumption best. However, in some cases of model calibration with a few observations e.g. calibration of single-event model, for avoiding estimation of the parameters of BC-GED model the MAE i.e. the boundary indicator ($\beta$ = 1) of the two classes, can replace the BC-GED, because the model validation of MAE is best.