

Generalised Likelihood Uncertainty Estimation (GLUE) - K.J. Beven

PUB-IAHS Workshop
 Uncertainty Analysis in
 Environmental Modelling
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a) Introduction:

GLUE (Generalised Likelihood Uncertainty Estimation) is a methodology based on Monte Carlo simulation for estimating the predictive uncertainty associated with environmental models. It rejects the idea of model optimisation in favour of retaining a set of *behavioural* or acceptable models. In this situation it is only possible to evaluate the relative likelihood of a given model and parameter set in reproducing the data available to test the models. In particular, those models that are deemed unacceptable or non-behavioural may be rejected by being given a likelihood of zero. Different model structures can be considered within this framework if they can be evaluated in the same way. The predictions of the set of behavioural models are weighted according to a likelihood weight associated with each behavioural parameter set in forming a CDF of predicted variables. These may be based on traditional likelihood functions (where the associated assumptions about the nature of the errors can be justified) or other forms of model evaluation (fuzzy measures, binary measures, ...). In the latter case, errors in the modelling process are treated implicitly by assuming that the nature of the errors in prediction will be "similar" to that in the conditioning period. Prior likelihood weights for each parameter set can be specified if necessary and likelihood weights can be updated as new data become available. Prediction CDFs are always conditional on the models chosen, parameter ranges sampled, measurement errors etc.

A new extended GLUE methodology is based on model acceptability being defined relative to a prior estimation of an "effective observation error" (see Manifesto paper).

b) Advantages

- Rejects the concept of an optimal model
- Treats parameters as sets of values that provide behavioural or non-behavioural simulations
- Allows many different ways of evaluating models (including traditional likelihood measures, fuzzy measures, binary measures)
- Allows updating of likelihood weights (using Bayes or other methods) as new data become available for model evaluation
- Allows that behavioural models may be scattered throughout the parameter space
- Allows multiple model structures to be considered within a consistent framework
- Does not require an explicit model of the errors – but each run of the model is associated implicitly with an error series.
- Allows all models to be rejected if results are not behavioural

c) Disadvantages

- Dependent on obtaining a sufficient sample of Model Runs to characterise the parameter sets giving behavioural simulations, especially where dimensionality of model space is high.
- Uniform sampling in the parameter space can be inefficient for simple response surface cases.
- Provides only prediction uncertainties, conditional on assumptions about models, evaluation measures, observation errors, ranges of parameters etc.

d) Assumptions

Likelihood measure associated with each parameter set should be positive, should increase monotonically with increasing model performance and should be zero for non-behavioural models
 Error series associated with each behavioural model should have similar characteristics in prediction as in the evaluation period

e) Most appropriate application areas

All environmental modelling problems

f) Reading list

- Beven, K J and Freer, J, 2001 Equifinality, data assimilation, and uncertainty estimation in mechanistic modelling of complex environmental systems, *J. Hydrology*, 249, 11-29.
- Freer, J. E., K. J. Beven, and N. E. Peters. 2003, Multivariate seasonal period model rejection within the generalised likelihood uncertainty estimation procedure. in *Calibration of Watershed Models*, edited by Q. Duan, H. Gupta, S. Soroshian, A. N. Rousseau, and R. Turcotte, AGU Books, Washington, 69-87.
- Beven, K. J., 2004, A manifesto for the equifinality thesis, *J. Hydrology*, in press.

g) Software availability

A demonstration program can be downloaded from www.es.lancs.ac.uk/hfdg/glue.html accepts a file of Monte Carlo simulation results (up to 6 parameters, 6 likelihood measures, simulations with up to 1000 parameter sets and 10 output variables) and allows the user to plot the results, examine the sensitivity of individual parameters, transform and combine likelihood measures in various ways and plot the resulting distributions of results. A Matlab version, with no constraints on runs or variables is also in preparation at Lancaster.

A Matlab version produced by Marco Ratto, is also available as part of the JRC Ispra, Generalised Sensitivity Analysis package (see <http://www.jrc.ec.eu.int/uasa/pri-glue-soft.asp>).

h) Web links or other information

<http://www.es.lancs.ac.uk/hfdg/glue.html>

i) Figures

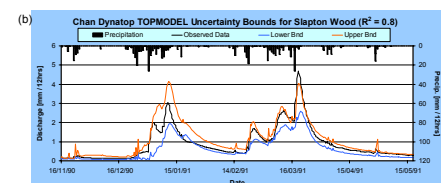
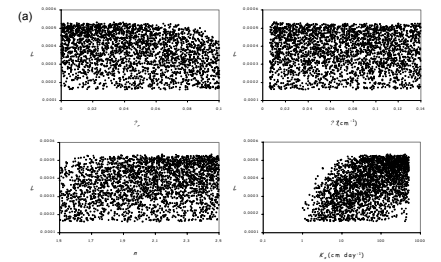
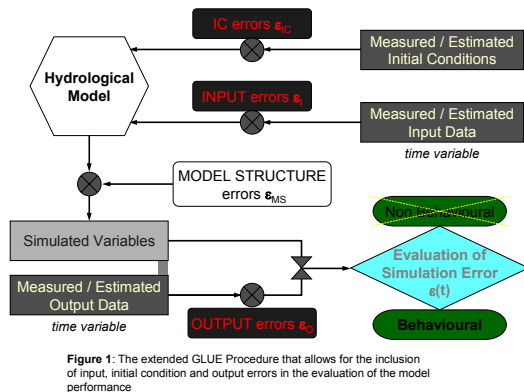


Figure 2: Some example GLUE results a) Dotty plots from Fitting van Genuchten parameters in modelling recharge after Binley and Beven, *Groundwater*, 2003, b) Prediction bounds for a selected hydrograph period from behavioural simulations using Dynamic TOPMODEL.

j) Delegates Comments (please add !!)