

Introduction

A method to estimate model predictive uncertainty using a split-sample approach is presented. The split-sample methodology has long been used in hydrology to assess the confidence that can be placed in a calibrated model. In this methodology a user calibrates a model with one time period of data and then evaluates that calibration with a second time period of data. If the second time period of data is predicted well then the calibration is deemed "successful". Here we present a methodology that relies on a split sample approach to estimate model predictive uncertainty.

Errors (Sources of Uncertainty) in Modeling (Singh, 1988)

Sources of Error	Size of Error	Statistical Analogy
Data	A	Measurement and Sampling Error
Calibration Period Comparison	A-B	Standard Error of the Estimate
Evaluation Period Comparison	A+C	Standard Error of the Prediction

Typical uncertainty analysis focuses on A-B
But evaluation period, A+C, has information about the level of trust (uncertainty) we should have in our models.

Figure 3 Existing uncertainty methods typically involve some subjective decision making on acceptability of simulations (e.g. GLUE). Or make overly strict assumptions about model and data correctness and thus have unreasonably small uncertainty bounds (e.g. BARE method and ParaSol method discussed below). Beven and Young (2003) advocate methods between these two extremes Singh's framework provides a way out. Use the evaluation period to determine model parameter set acceptability? But how? Here we present one option.

Model bias for the sediment loads (%)

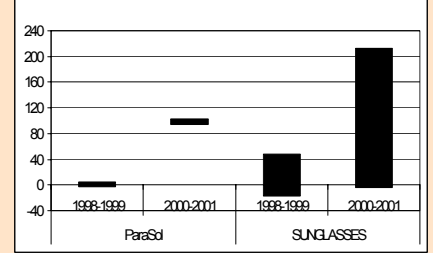


Figure 5 - Model Prediction Bias for Sediment Loads. The ParaSol uncertainty bounds do not include the zero bias case in either the prediction or evaluation period. The revised SUNGLASSES bounds of course do because this is the foundation of the method. Rationale for using bias is that for water quality application total mass flux is critical model prediction daily variations are less important from a management stand point. Other applications may have other benchmarks to use during the evaluation period that are suitable

River Basin System

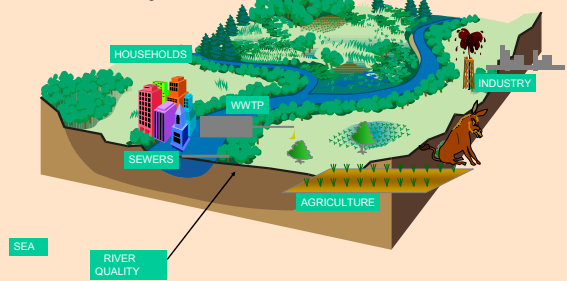


Figure 1 - Water Quality Modeling Problem. In simulating the water quality of a river basin there are many potential locations, activities and processes that can influence basin outlet water quality. In turn this means that these models have a large number of parameters and conversely water quality data is rarely as plentiful as hydrologic flow data. Hence the general practice of separate calibration of hydrologic and water quality portions of water quality models despite the known control that hydrologic processes have on water quality.

Methodology

Two methodologies are presented on this poster.

- 1) ParaSol - a statistically based parameter uncertainty method.
- 2) SUNGLASSES - A split sample model predictive uncertainty methodology which is the real focus of this poster.

The ParaSol method uses the SCE-UA sample population to then estimate a chi-squared or Bayesian uncertainty bounds

χ^2 -squared: Threshold = GOC MINIMUM $[1 + \chi_{p,0.95} * (\sigma^2)]$
Bayesian: Threshold ~ 95% cumulative probability for GOC
These bounds end up being very small (See Figure 6). This necessitated the development of an alternative method which we have called SUNGLASSES (Sources of Uncertainty Global Assessment using Split-Samples). This method determines membership in the behavioral set by revising the uncertainty bounds outward until some objective is met during an evaluation time period not used in calibration of the model. In our case with the sediment export component of SWAT we wanted to make sure the zero bias case was included in the model. Zero bias would mean the observed mass is included in model predictions.

Uncertainty ParaSol and SUNGLASSES

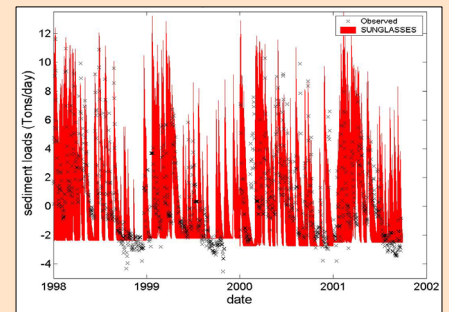
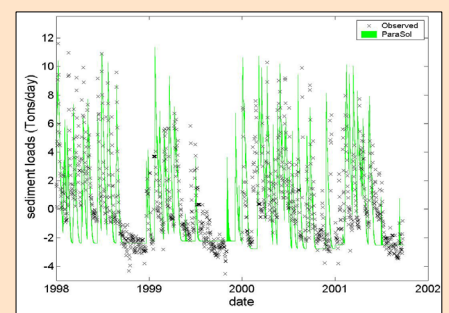


Figure 6. Uncertainty Bounds for ParaSol and SUNGLASSES on Sediments. Parasol bounds are overly restrictive. Revised SUNGLASSES bounds capture daily sediment data better during evaluation period and during the initial calibration period.

Ranked GOCs for all SCE-UA simulations

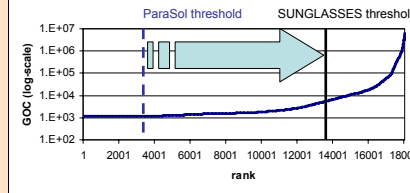


Figure 4- Revising Uncertainty Bounds. Based on results with ParaSol. Parameter uncertainty bounds were overly restrictive and did not bound observations (Figure 6) nor include the zero bias case during an evaluation time period.

Conclusions

Results indicate the SUNGLASSES method successfully revised uncertainty bounds outward. Revised bounds captured observations during an earlier calibration period without additional information beyond model bias predictions.

SUNGLASSES method shares many attributes of GLUE methodology in that it is not strictly statistical but determines model behavioral membership based on specific and easy to understand threshold criteria.

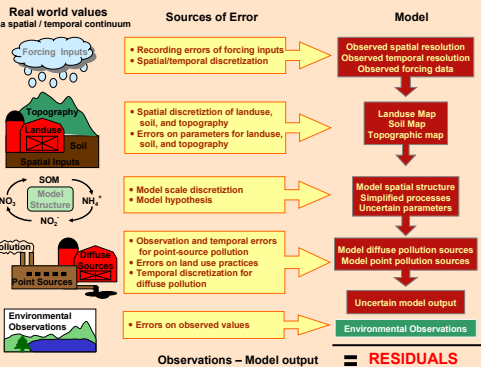


Figure 2 - Sources of Error in Water Quality Models.

The problem of water quality modeling is complex and the sources of error multiple: temporal variability (climate, seasons, weather, human activity), spatial variability (land use, river network). Computer models are used to help but many factors of the system are not or poorly known and all systems are different. As with many environmental modeling problem we are left with the classic questions. Do models describe reality? comparison to observations? Are model results confident? Must Calibrate models but also evaluate them in prediction mode.

References

Beven, K. and P. Young, Comment on "Bayesian recursive parameter estimation for hydrologic models" by M. Thieman, M. Torsset, H. Gupta, and S. Sorooshian, *Water. Resour. Res.*, 39(5):COM 1-1-COM 1-4, 2003.

Singh, V. P., *Hydrologic Systems- Rainfall-Runoff Modelling* Prentice Hall, Englewood Cliffs, NJ, 1988.

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