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Hydrological Modelling: on questions of ’robustness’ and ’graceful degradation’

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Hydrological modelling requires consistent measures of merit and trust. Hillel (1986: p42) advocated that hydrological modelling solutions should be: ’parsimonious’ - each model should contain a minimum number of parameters that can be measured in the field; ’modest’ - the scope and purpose to which a specific model can be applied must not be overstated; ’accurate’ - the correctness of the forecast or prediction need not be better than the correctness of the input measurements; and ’testable’ - the limits within which the model outputs are valid can be defined. This paper argues that other qualities and issues are also important with respect to practical operational implementations and considers the properties of ’robustness’ and ’graceful degradation’. To provide a robust solution each model must exhibit a constant or stable behaviour and be insensitive to potential uncertainties in the construction and parameterisation process e.g. problems related to measurements that cannot be obtained with sufficient accuracies or are not constant over long(er) periods. To be reliable and trusted an operational model must also exhibit the properties of ’graceful degradation’; a gradual and progressive reduction in overall performance such that the model continues to operate and function in a normal manner, but provides a reduced level of service, as opposed to taking incorrect actions or suffering a total collapse in processing activities.

It has been suggested in recent studies that multiple linear regression models and artificial neural network solutions can under certain circumstances offer similar hydrological forecasting accuracies. It is accepted that multiple linear regression solutions are appropriate for linear or near-linear modelling operations but if the process to be modelled is of a non-linear character then it is axiomatic that a non-linear model should be applied. However, several biological publications have recognized that robust behaviour is achieved in nature through the use of complex structures, and so the simpler and more parsimonious statistical multiple linear regression model might also be the poorer of the two options for operational situations in which marked uncertainties exist. The parallel processing structure of a neural network solution offers strong potential to develop a robust solution that can cope with difficult circumstances but the nature and extent of such strengths within a hydrological modelling context still need to be tested. SNNS is a popular neural network package for hydrological modelling purposes and trained solutions can be exported as source code and afterwards coupled to a random number generator. In the reported experiments this method is used to discover and compare the responsiveness of neural network solutions to their equivalent multiple linear regression counterparts and to provide a benchmark demonstration that the computed response functions related to multiple linear regression and neural network solutions are altogether quite different. This is equivalent to performing an investigation of input-output sensitivities but not in a limited manner that uses small variations in input variables to produce differing degrees of correct responses in the model outputs. Large scale disruptions are instead used to degrade the performance of the model and thus test for internal robustness in terms of progressive deterioration and the level of disruption that is required to produce it. Two hydrological modelling scenarios are investigated: CS1 [River Marne] comprises a linear hydrological modelling exercise in which past upstream and past downstream discharge records are used to forecast current discharge at the downstream gauging station; CS2 [Le Sauzay] comprises a non-linear hydrological modelling exercise in which past river discharge measurements and past local meteorological records (precipitation and evaporation) are used to forecast current discharge at the gauging station.

Hillel, D. 1986. "Modeling in soil physics: A critical review". In: Future Developments in Soil Science Research. Madison, Wis.: Soil Society of America. 35-42.