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A manifesto for the equifinality thesis

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Abstract

This essay discusses some of the issues involved in the identification and predictions of hydrological models given some calibration data. The reasons for the incompleteness of traditional calibration methods are discussed. The argument is made that the potential for multiple acceptable models as representations of hydrological and other environmental systems (the equifinality thesis) should be given more serious consideration than hitherto. It proposes some techniques for an extended GLUE methodology to make it more rigorous and outlines some of the research issues still to be resolved.

Keywords: Equifinality; GLUE; Hydrological models; Observation error; Fuzzy measures; Uncertainty

1. Background

In a series of papers from Beven (1993) on, I have made the case and examined the causes for an approach to hydrological modelling based on a concept of equifinality of models and parameter sets in providing acceptable fits to observational data. The Generalised Likelihood Uncertainty Estimation (GLUE) methodology of Beven and Binley (1992) which was developed out of the Hornberger–Spear–Young (HSY) method of sensitivity analysis (Whitehead and Young, 1979; Hornberger and Spear, 1981; Young, 1983), has provided a means of model evaluation and uncertainty estimation from this perspective (see Beven et al., 2000; Beven and Freer, 2001; Beven, 2001a for summaries of this approach). In part, the origins of this concept lie in purely empirical studies that have found many models giving good fits to data (e.g. Fig. 1; for other recent examples in different areas of environmental modelling, see Zak et al., 1999; Brazier et al., 2000; Beven and Freer, 2001a,b; Feyen et al., 2001; Mwakalila, 2001; Blazkova et al., 2002; Blazkova and Beven, 2002; Christiaens and Feyen, 2002; Freer and K, 2002; Martinez-Vilalta et al., 2002; Schulz and Beven, 2003; Cameron et al., 2000; Romanowicz and Beven, 1998; Schulz et al., 1999). An independent example is provided by the results of Duan et al. (1992) from the University of Arizona group, although they have always rejected an approach based on equifinality in favour of finding better ways to find 'optimal' models, most recently in a Pareto or Bayesian sense (e.g. Yapo et al., 1998; Gupta, 1998; Thiemann et al., 2001; Vrugt et al., 2003). Despite this empirical evidence, however, many modellers are reluctant to adopt the idea of equifinality in hydrological modelling (and it can, indeed, always be avoided by concentrating on

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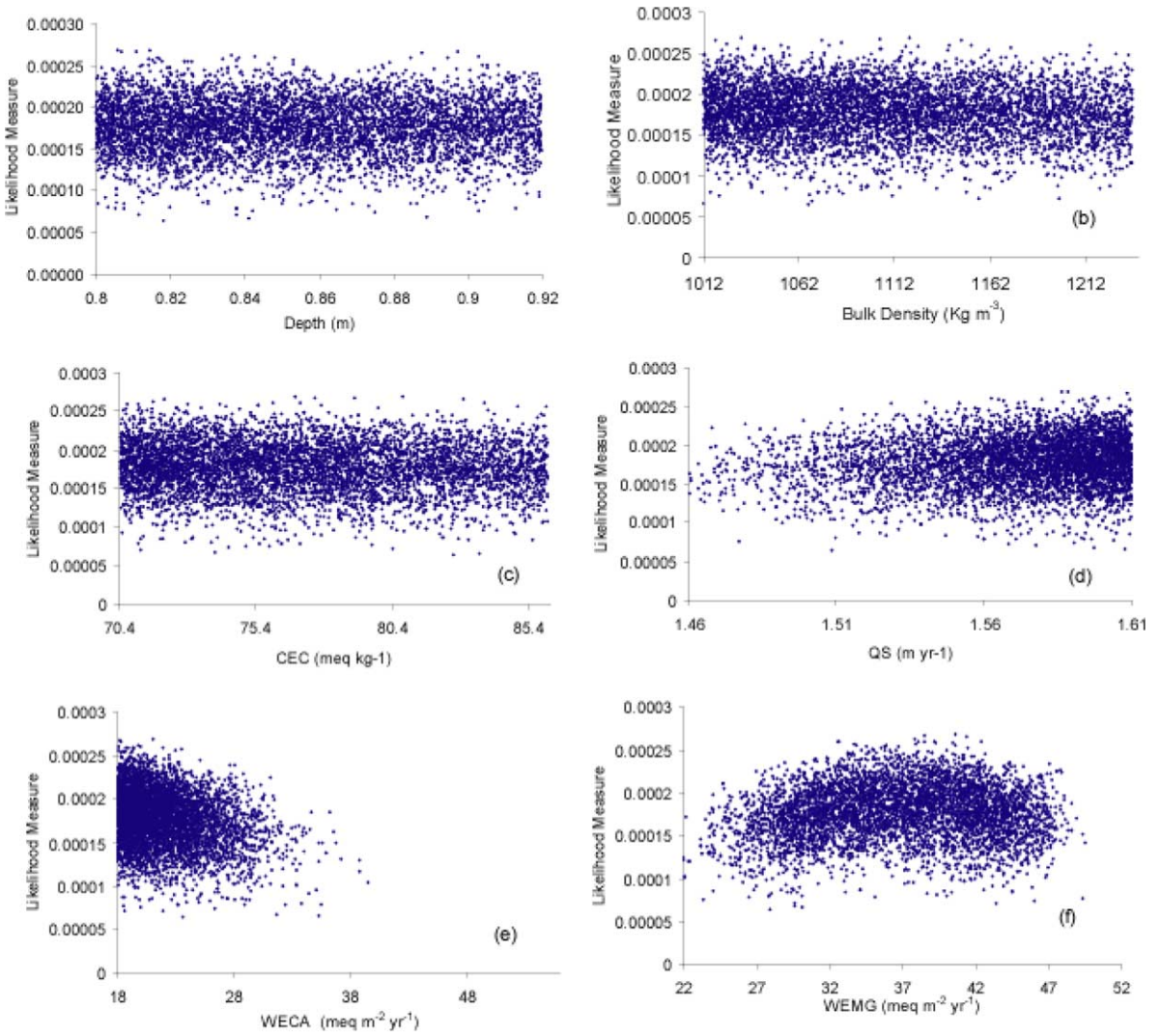

Fig. 1. Dotty plots (projections of points on a likelihood surface onto a single parameter axis) resulting from Monte Carlo realisations of parameter sets for the MAGIC Long Term Soil Acidification and Water Quality Model (after Page et al., 2003). Only six out of 12 parameters varied shown. Model evaluation based on joint fuzzy membership function as to whether modelled concentrations fall within acceptable limits for several specific points in time.

the search for an 'optimum' but at the risk of avoiding important issues of model acceptability and uncertainty). This manifesto is an attempt to provide a convincing case as to why it should be embraced in future.

There is a very important issue of modelling philosophy involved that might explain some of the reluctance to accept the thesis. Science, including hydrological science, is supposed to be an attempt to work towards a single correct description of reality. It is not supposed to conclude that there must be multiple feasible descriptions of reality. The users of research also do not (yet) expect such a conclusion and might then interpret the resulting ambiguity of predictions as a failure (or at least an undermining) of the science. This issue has been addressed directly by Beven (2002a) who shows that equifinality of representations is not incompatible with a scientific