Stakeholders and experts: a wide perspective on expertise in hydrological modelling

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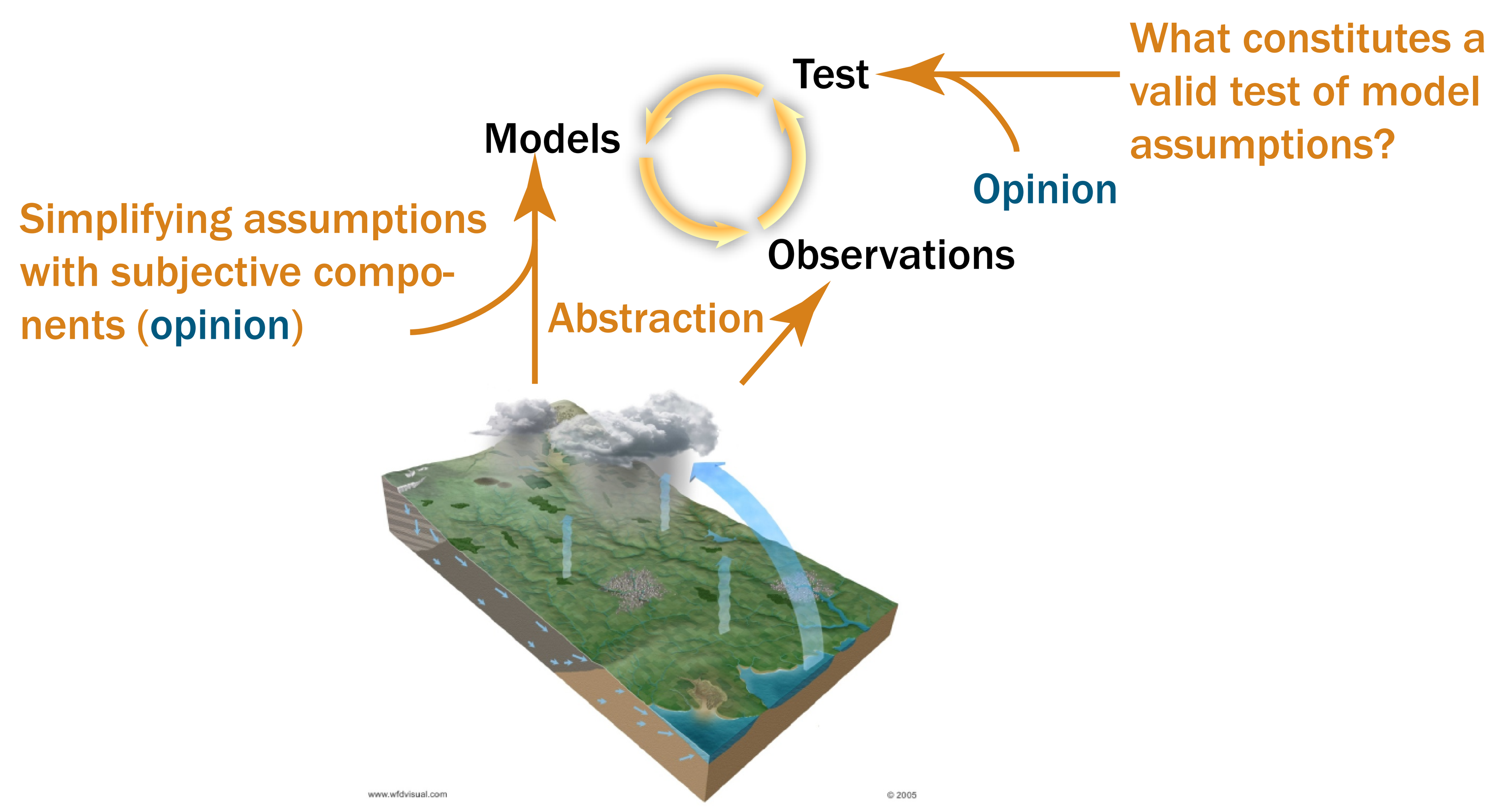
Models, knowledge & opinion

- Evolutionary nature of propositional knowledge (e.g. Ayyub, 2010)

- Evolutionary nature of models (= formalisation of knowledge about environmental systems behaviour)



Who is an expert?

- For us an expert can be "anyone with the right kind of experience" (Collins and Evans, 2007, p. 114), i.e. professionals such as scientists as well as experienced members of the public. This definition has advocates also in the ecological and statistical literature.
- Demonstrating that someone has the right kind of experience is challenging, and requires a definition of what is the right kind of experience in a specific context which may be contentious. But this is the discourse we should engage in instead of a superficial distinction of experts and non-experts which potentially discounts valuable knowledge.

Definitions of "expert".

Definitions prevailing in the modelling literature	Experience-based definition of Collins and Evans (2007)	More restrictive definitions (e.g. Ayyub, 2001)	Expanded definition of Lele and Allen (2006)
An expert is someone having specialist knowledge acquired through practice (also called training), study (also called education) or experience (e.g. Booker and McNamara, 2004; Kangas and Leskinen, 2005; O'Leary et al., 2009; Kuhnert et al., 2010)	Training and education credentials are dismissed as reliable qualifiers if these are not accompanied by the right kind of experience	Emphasise training as the prerequisite of expertise	Including computer models, but this seems counter-productive given the role of opinion in constructing models in the first place

- Experts are frequently distinguished from the public (also called laypersons), i.e. people not in possession of the knowledge of experts (implying some inferior knowledge base) or possessing a different form of knowledge: "everyday knowledge" or "folk knowledge"; "local knowledge"; "contextual knowledge" ; "indigenous knowledge" or "traditional knowledge".
- This superficial distinction between experts and the public is in conflict with experiential knowledge definitions of experts (e.g. Fazey et al., 2006) and findings that local knowledge can challenge scientific knowledge (e.g. Wynne, 1996; Ravetz, 2006, p. 276).

Informal use of expert opinion in modelling

Model structures

- Translation of a **perceptual** model into a **formal** model and subsequently a **procedural** model which has a specific time and space discretisation.
- Besides some level of perceptual ignorance, the **perceptual** and **formal** models draw on scientific knowledge from disparate temporal and spatial scales which do not connect unambiguously.
- The **formal** and **procedural** models rely on further assumptions to simplify calculations and on choices of numerical techniques to solve equations, which are to some extent arbitrary and hence have subjective components.
- When testing the predictions of a model structure against observations of system behaviour it is not clear, unless all elements of expert opinion are made explicit, exactly which set of knowledge and opinion is being assessed.

Model parameterisations

- Estimation of parameter values by drawing on scientific experience and previous studies from different temporal and spatial scales.
- Formal parameter inference from prior information and observed system responses relies on choices of error characteristics and numerical methods.
- Numerical methods can be justified by analysing convergence, but error assumptions eventually require independent data for justification. As these data have usually limited availability, subjective simplifications and choices are inevitable, yet should be made explicit to allow peer review.

Model boundary conditions

- Translation of data sources to the scale of model discretisation and estimation of future conditions. Scaling involves interpolation or disaggregation while future conditions may be estimated on a continuous scale from extrapolation to imagination.

Formal use of expert opinion in modelling

- Expert opinion is increasingly being used to assess which evidence is limited or inconclusive, to make explicit published and unpublished knowledge and the wisdom of experts, to provide a temporary summary of limited available knowledge, to inform policy before conclusive scientific evidence becomes available, and to serve as a basis for action when problems are too urgent or stakes too high to postpone measures until more complete knowledge is available (Kangas and Leskinen, 2005; Knol et al., 2010).

Examples of models and locations where expert opinion is found in the hydrological modelling literature.

Location	Use of expert opinion	Type of model	Topic (references)
Construction of conceptual model	Weighting importance of model components	Expert system	Faecal Indicator Organisms risk (Fish *et al.*, 2009; Oliver *et al.*, 2010)
	Rule derivation	Qualitative expert system	Land management (van Lanen and Wopereis, 1992; Wandahwa and van Ranst, 1996); Resource utility (Bello-Pineda *et al.*, 2006); Soil erosion (de la Rosa *et al.*, 1999)
Construction of conceptual model / parameterisation	Rule derivation / quantification	Fuzzy expert system	Climate change impact (Eierdanz *et al.*, 2008); Ecological quality (Kampichler *et al.*, 2010); Eutrophication (Taheriyoun *et al.*, 2010); Land management (Joss *et al.*, 2008); Sediment transfer (Nguyen *et al.*, 2007); Groundwater contamination (Uricchio *et al.*, 2004)
	Graph / probability tables	Probabilistic network	Estuarine response to nutrient loads (Borsuk *et al.*, 2001); Eutrophication (Borsuk *et al.*, 2003; Borsuk *et al.*, 2004); Drinking water treatment (Pike, 2004); Resource management (Cain *et al.*, 1999); Irrigation (Batchelor and Cain, 1999); Groundwater contamination (Stiber *et al.*, 1999; Stiber *et al.*, 2004; Henriksen *et al.*, 2007)
Parameterisation	Probability tables	Probabilistic network	Climate change impact (Varis and Kuikka, 1999); Salinisation (Ghabayen *et al.*, 2006)
	Prior parameter distributions	Statistical model	Landslide occurrence (Milheiro-Oliveira, 2007)
	Prior parameter distributions	Mechanistic model	Septic tanks (Montangero and Belevi, 2007)
	Parameterisation (incl. uncertainty)	Mechanistic model	Groundwater flow (Ross *et al.*, 2008)
	Uncertainty assessment (parameter distributions)	Mechanistic model	Nitrogen/phosphorous transfer (Bijlsma *et al.*, 2007); Modelling in general (Refsgaard *et al.*, 2007)
Provision of boundary conditions	Response data for learning fuzzy expert system	Fuzzy expert system	Water quality (Kawano *et al.*, 2005)
	Response data for regression	Statistical model	Soil erosion (Sonneveld and Albersen, 1999)
	Geomorphic indices as training data for Artificial Neural Network	Statistical model	Stream-morphological change (Besaw *et al.*, 2009)
Evaluation	Post-hoc uncertainty assessment	Mechanistic model	Water quality (Brouwer and De Blois, 2008)
	2nd order uncertainty about spatial parameter variation	Mechanistic model	Groundwater flow (Ross *et al.*, 2009; Mathon *et al.*, 2010)

Opportunities for participatory modelling

- By tapping into previously neglected knowledge from non-professional as well as professional domains information becomes accessible for which there is no measured data equivalent. This source allows building, parameterising and driving models in situations that are notoriously data scarce, yet of acute policy relevance, such as diffuse pollution.
- Expert data also allow the evaluation of model predictions as these are becoming increasingly local. We see expert data as one of many data sources, all with specific uncertainties that should be accounted for in modelling and decision making. The result is a broadening of the knowledge base which we expect will enhance the scientific enquiry and models, not least through creative conflict between scientific and non-scientific knowledge (Funtowicz and Ravetz, 1993).

Experts & stakeholders

- Not all stakeholders will classify as experts, but it can be argued that all experts are stakeholders in the sense that they can affect the outcomes of models and thus the outcomes of using models (such as policy and management decisions).
- There may also be experts that have a more tangible stake in that they are affected by the outcomes of using models.
- It follows that no expert will give a strictly impartial opinion. Adherence to rational consensus arguments for expert accountability and against expert anonymity will further increase the expert's stake in the use of their opinion and bias the elicitation process.
- We thus suggest that expert accountability necessitates a process in which expert critics are equally accountable, that is open and transparent, and that embraces the evolutionary nature of knowledge.

Enhanced function of expert opinion & future research programme

- We encourage a move away from the traditional ideal of unbiased and impartial experts towards an unbiased process of expert contestation (Munnichs, 2004) and a plurality of expertise.
- Where multiple legitimate perspectives on the behaviour of environmental systems exist, these should be reflected in a plurality of models.
- In the same way that knowledge is continuously tested and used, so should models.
- It is important that expert opinion enters models in an explicit, structured and documented way, i.e. formally, to allow scientific and extended peer review. Due to the complexity of models which cannot be laid out fully in scientific articles, effective peer review can only be achieved if source codes are in the public domain (e.g. Harvey and Han, 2002).
- The formalisation of expert opinion itself presents future research challenges, including: the selection of representative experts and the demonstration that they have the right kind of experience for the task at hand; the calibration of experts and the weighting of their responses; the quantification of different types of individual and collective uncertainty; and cost effective and robust means of expert elicitation.
- The processes as well as the outcomes of this research programme hold rewards for scientists, stakeholders and society at large.

For an extended version with full references look out for our forthcoming paper: Krueger, T., T. Page, K. Hubacek and K. Hiscock (in review). "The role of expert opinion in environmental modelling." Environmental Modelling & Software.

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