Uncertainty in Environmental Models and Decision Making Under Uncertainty: Are We Communicating Effectively?

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CEEDS Seminar - Decision making under uncertainty:
Addressing trustworthiness of scientific evidence
in an uncertain world.

24 February, 2021

UK Centre for
Ecology & Hydrology

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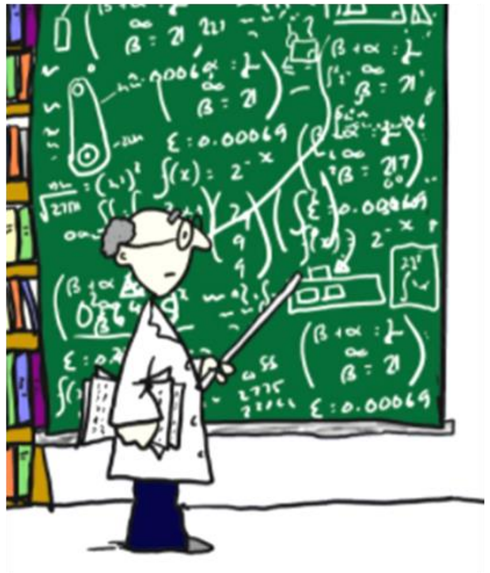
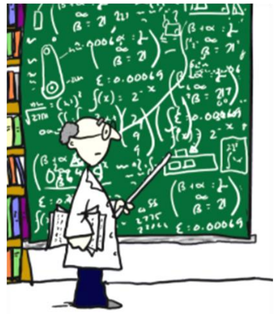


We're uncertain about your meaning of uncertainty….

Generating evidence of scientific reliability

We're uncertain about your use of uncertainty….

Evaluating evidence of scientific reliability



Environmental Modellers: Sources of Uncertainty

(generating evidence of scientific reliability)

- **Aleatory uncertainty -** also known as statistical uncertainty, is due to uncertainty in things that differ each time we run the model (e.g., parameter values, inputs, etc.).
- **Epistemic uncertainty** - due to things one could in principle know but do not in practice.
  - **System dynamics** - uncertainties arising from a lack of knowledge about how to represent the system in terms of both model structure and parameters.
  - **Forcing and response data** - uncertainties arising from lack of knowledge about the appropriate forcing data or the response data with which model outputs can be evaluated.
  - **Disinformation** - simplifications in either system representation or forcing data that are known to be inconsistent or wrong. Can result in biased or incorrect inference.
- **Semantic/linguistic uncertainty** - uncertainty about what statements or quantities in the relevant domain actually mean (e.g., in hydrology - storm runoff, baseflow, hydraulic conductivity, stationarity, etc.)
- **Ontological uncertainty –** uncertainty that results when assumptions don't fit nicely into existing mental models of how things work (e.g., whether formal probability assumptions are appropriate for representation of beliefs about model residuals).

Straightforward, yes?

Decision makers: Sources of Uncertainty
(evaluating evidence of scientific reliability)

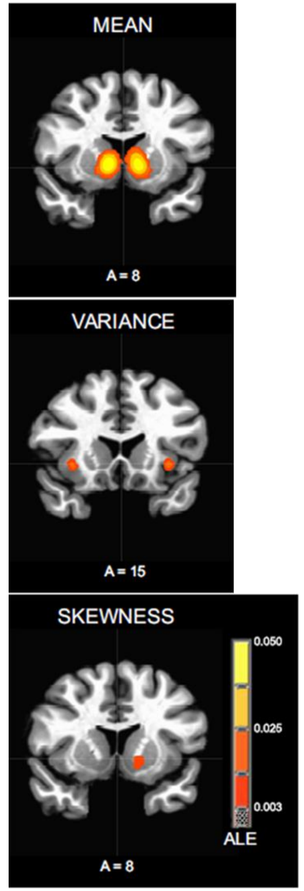
- **Missing information**. We can be uncertain because we are missing important information.
- **Unreliable information**. We can be uncertain because we aren’t able to trust the information, even if we have it
- **Conflicting information**. We may have the information and trust it, but it might be inconsistent with other information we have and trust.
- **Noisy information**. We may have to sift through a lot of irrelevant information but if we can’t be sure if it really is noise, we have to take it seriously and that adds to our uncertainty.
- **Confusing information**. We may have all the information we need, trust all of it, find that it is all consistent, find that it is all relevant, but we could still be uncertain if we cannot interpret it.

Confusing, no?

Decision maker's personal tolerance for ambiguity
(understanding human response to uncertainty)

The study of uncertainty in decision-making is receiving greater attention in the fields of **cognitive and computational neuroscience**

- Uncertainty is a common feature of many every day decisions
- Growing body of research exploring brain mechanisms which underlie our choices in conditions of uncertainty
- *Better understanding of how uncertainty is induced by variables in the decision-making environment*



Three forms of uncertainty:

- *Expected uncertainty* arises from the stochasticity inherent in the decision-making environment
  (i.e., known unreliability of predictive relationships within a stable familiar environment)
- *Unexpected uncertainty* arises from rare fundamental changes in the decision making environment
  (i.e., changes that invalidate prediction based on previous experience)
- *Volatility* arises from frequent fundamental changes in the decision-making environment

Comfort zones

Different varieties of uncertainty in human decision-making
Review Article: Frontiers in Neuroscience, 08 June, 2012, https://doi.org/10.3389/fnins.2012.00085

Decision making under uncertainty:
Addressing trustworthiness of scientific evidence in an uncertain world.

Conclusions (??)

Decision making always involves uncertainty

Decision making can be described as the *process of reducing uncertainty* about solution options by gaining sufficient knowledge of the options to allow a reasonable choice to be made

To be effective, the process should be a community effort involving scientists and decision makers at every stage.

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Knowledge is an unending adventure at the edge of uncertainty…..
Jacob Bronowski (1908-1974) mathematician and historian.

Engineering and Physical Sciences Research Council | Economic and Social Research Council | Natural Environment Research Council

Decision Making under Uncertainty Networks

M2D
Models to Decisions
Decision Making Under Uncertainty

The M2D Network will focus on model-informed decision making and defines itself as broad, inclusive and multidisciplinary. We welcome the active participation of members from a diverse range of academic research and public / private sector working backgrounds.

http://blogs.exeter.ac.uk/models2decisions/

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The CRUISSE network was set up by three UK research councils in “response to a demonstrable call” for support “from business and government” and funded by EPSRC for two years from January 2017.

2020 CRUISSE blog posts

‘Model Land’ and its phantasies threaten us all.

by Erica Thompson & Mark Fenton-O’Creevy

David Tuckett, Lenny Smith, Gerd Gigerenzer, and Jürgen Jost on making good decisions under uncertainty

http://cruisse.ac.uk/

Constructing a Digital Environment

Aim to develop the digitally enabled environment to benefit scientists, policymakers, businesses, communities and individuals.

https://digitalenvironment.org/cde-webinar-series/

Data for Decision Making Series

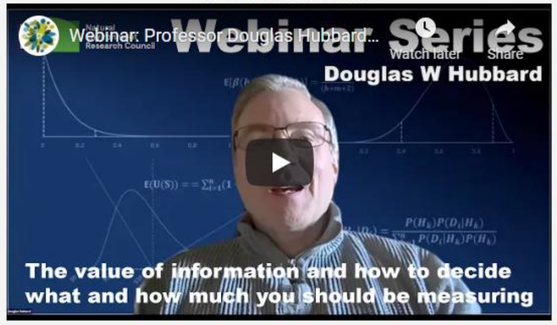
- **We most often collect the wrong data** – most resources are spent on measurements that have no value for the decisions they are meant to support
- **We often need less data than we think we need** – we only need enough to reduce uncertainties enough to make a clear decision
- **Everything can be quantified and applied to improving decisions**, however seemingly intangible.
- **The flaw of averages** – why we are nearly always behind schedule and over budget, and why relying only on averages is so dangerous and yet the norm
- **Why Big Data and AI are heading for disaster.** Expert knowledge is critical but often over-looked and under-utilised.
- **It is a fallacy that conveying uncertainty and its implications for a decision is too complicated for a general audience.**

Lessons from applying decision science in the public health sector

Professor Karl Claxton
14th January 2021

The value of information and how to decide what and how much you should be measuring

Douglas W Hubbard
12th November 2020



The Flaw of Averages and How to Cure It

Professor Sam L Savage
3rd December 2020

Why Big Data and AI machine learning will never work for critical problems of risk assessment – causal reasoning and knowledge to the rescue

Professor Norman Fenton
17th December 2020

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NERC’s £7m Probability, Uncertainty & Risk in the Environment (PURE) has helped UK Government and industries be better prepared for natural hazards

https://nerc.ukri.org/research/funded/programmes/pure/

Thank you

Any questions?