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# Dealing with uncertainty I
## *concepts, tools, pitfalls*

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# Daily practice of dealing with uncertain science in policy making

Two dominant strategies: uncertainties are either

- **downplayed** to promote political decisions (enforced consensus), or
- **overemphasised** to prevent political action

- Both promote decision strategies that are **not fit for meeting the challenges** posed by the uncertainties and complexities faced.

- We need new ways to deal with uncertainty, scientific dissent & **plurality** in sustainability science.

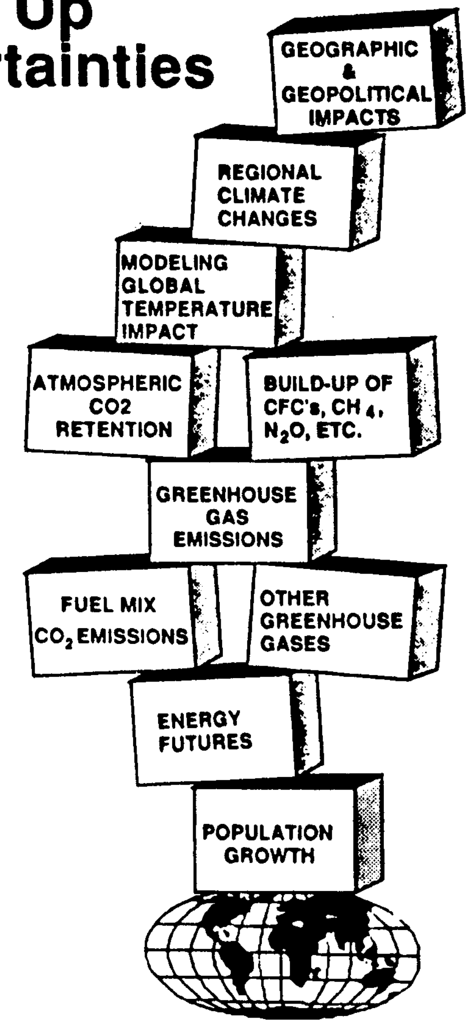
# Complex - *uncertain* - risks

Typical characteristics (Funtowicz & Ravetz):

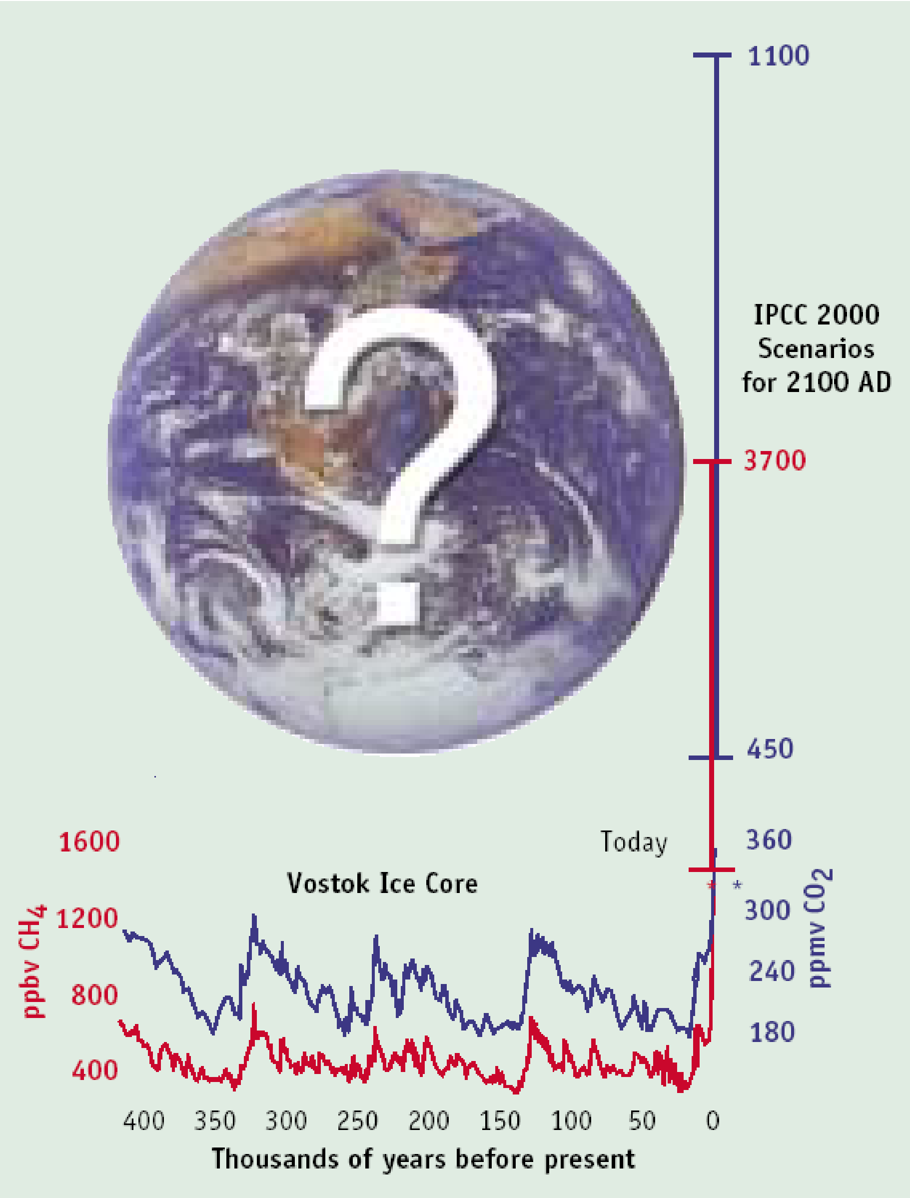
- Decisions needed **before conclusive scientific evidence** is available;
- Potential **impacts of ‘wrong’ decisions** can be huge
- **Values in dispute**
- Knowledge base characterized by large (partly irreducible, largely **unquantifiable**) uncertainties, multi-causality, knowledge gaps, and **imperfect understanding**
- More research ≠ less uncertainty; unforeseen complexities!
- Assessment dominated by **models**, scenarios, assumptions, extrapolations
- Many (hidden) **value loadings** reside in problem frames, indicators chosen, assumptions made

# GLOBAL CLIMATE CHANGE

## Piling Up Uncertainties




## Sailing into terra incognita?



*A practical problem:*

**Protecting a strategic fresh-water resource**

5 scientific consultants addressed same question:

*"which parts of this area are most vulnerable to nitrate pollution and need to be protected?"*

*(Refsgaard, Van der Sluijs et al, 2006)*

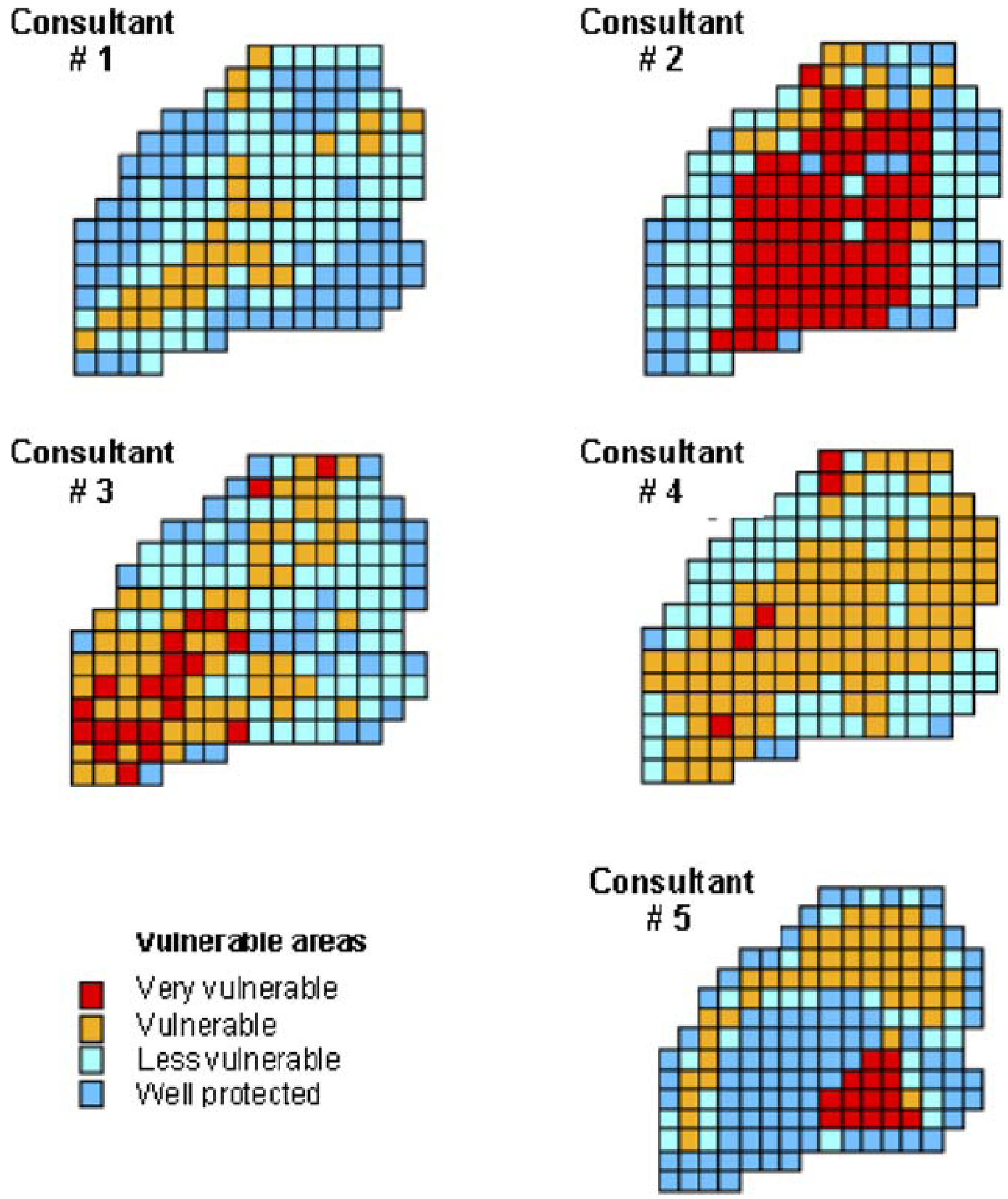



Fig. 1. Model predictions on aquifer vulnerability towards nitrate pollution for a 175 km$^2$ area west of Copenhagen [11].

# 3 framings of uncertainty

## 'deficit view'

- Uncertainty is provisional
- Reduce uncertainty, make ever more complex models
- *Tools:* quantification, Monte Carlo, Bayesian belief networks
  - ***Speaking truth to power***

## 'evidence evaluation view'

- Comparative evaluations of research results
- *Tools:* Scientific consensus building; multi disciplinary expert panels
- focus on robust findings
  - ***Speaking [consensus] to power***

## 'complex systems view / *post-normal* view'

- Uncertainty is intrinsic to complex systems
- Uncertainty can be result of production of knowledge
- Acknowledge that not all uncertainties can be quantified
- Openly deal with deeper dimensions of uncertainty
  (problem framing indeterminacy, ignorance, assumptions, value loadings, institutional dimensions)
- *Tools:* Knowledge Quality Assessment
  - ***Working deliberatively within imperfections***

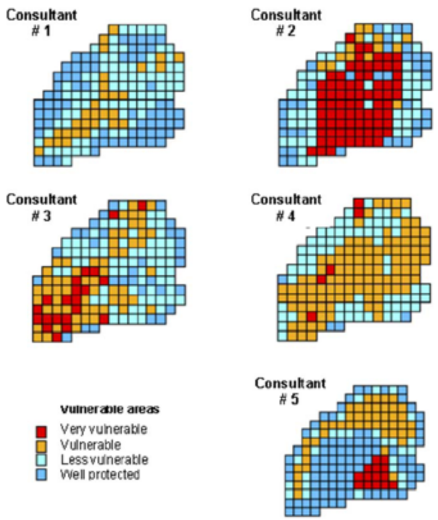



Fig. 1. Model predictions on aquifer vulnerability towards nitrate pollution for a 175 km² area west of Copenhagen [11].

# How to act upon such uncertainty?

- **Bayesian** approach: 5 priors. Average and update likelihood of each grid-cell being red with data (but oooops, there is no data and we need decisions now)
- IPCC approach: Lock the 5 consultants up in a room and don’t release them before they have **consensus**
- **Nihilist** approach: Dump the science and decide on an other basis
- **Precautionary** robustness approach: protect all grid-cells
- **Academic bureaucrat** approach: Weigh by citation index (or H-index) of consultant.
- Select the consultant that you **trust** most
- Real life approach: Select the consultant that best fits your **policy agenda**
- Post normal: explore the relevance of our ignorance: **working deliberatively within imperfections**

# Former chairman IPCC on objective to reduce climate uncertainties:

- "*We cannot be certain that this can be achieved easily and we do know it will take time. Since a fundamentally chaotic climate system is predictable only to a certain degree, our research achievements will always remain uncertain.* ***Exploring the significance and characteristics of this uncertainty is a fundamental challenge to the scientific community.***" (Bolin, 1994)

[Prof. Bert Bolin, 15 March 1925 – 30 December 2007]

# KQA tools

- Quantitative methods
  - SA/UA Monte Carlo
- Uncertainty typology (matrix)
- Quality assessment
  - Pedigree analysis (NUSAP)
  - Assumption analysis
  - Uncertainty Guidance
  - Extended Peer Review
  - Model Quality Checklist
  - Argumentative Discourse Analysis (ADA); Critical Discourse Analysis (CDA)
  - ....

Clark & Majone 1985

# Critical Appraisal of Scientific Inquiries with Policy Implications

1. Criticism by whom?

Critical roles

- Scientist
- Peer group
- Program Manager or Sponsor
- Policy maker
- Public interests groups

# Clark & Majone 1985

Criticism of what?

Critical modes:

- Input
  - data; methods, people, competence, (im)matureness of field
- Output
  - problem solved? hypothesis tested?
- Process
  - good scientific practice, procedures for review, documenting etc.

**Table 1.** Critical criteria. **(Clark & Majone, 1985)**

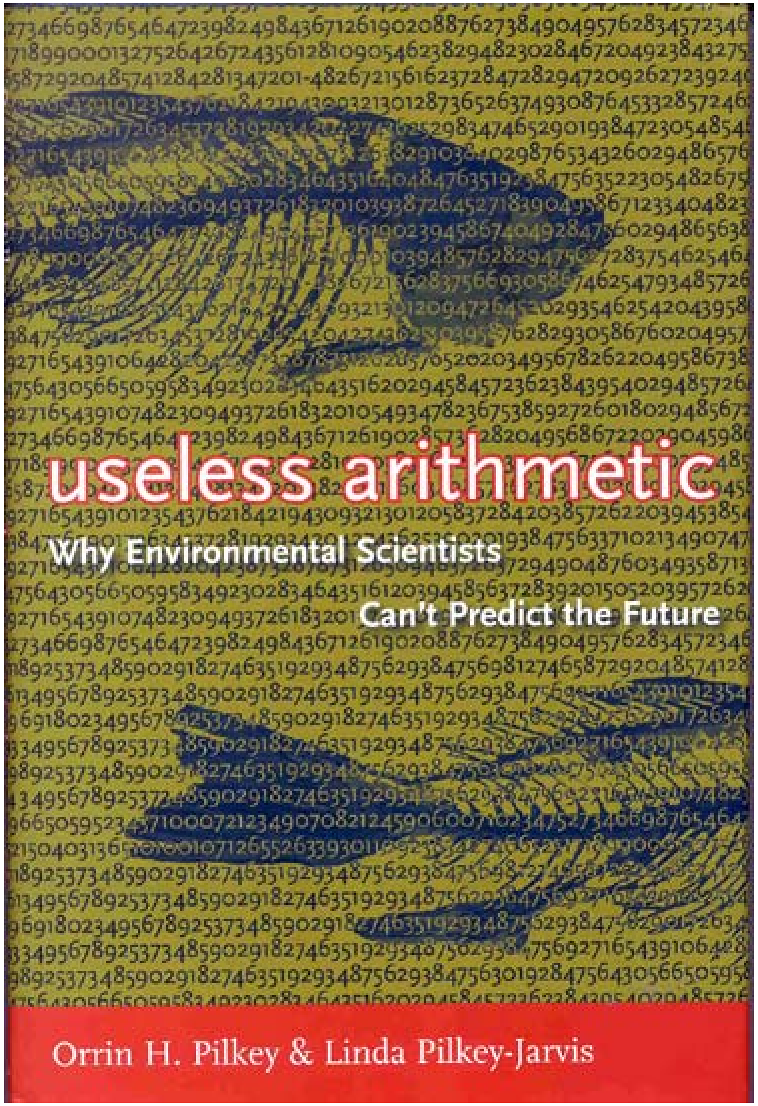
| Critical Role | Critical Mode<br>Input | Output | Process |
|---|---|---|---|
| Scientist | Resource and time constraints; available theory; institutional support; assumptions; quality of available data; state of the art. | Validation; sensitivity analyses; technical sophistication; degree of acceptance of conclusions; impact on policy debate; imitation; professional recognition. | Choice of methodology (e.g., estimation procedures); communication; implementation; promotion; degree of formalization of analytic activities within the organization. |
| Peer Group | Quality of data; model and/or theory used; adequacy of tools; problem formulation. Input variables well chosen? Measure of success specified in advance? | Purpose of the study. Are conclusions supported by evidence? Does model offend common sense? Robustness of conclusions; adequate coverage of issues. | Standards of scientific and professional practice; documentation; review of validation techniques; style; interdisciplinarity. |
| Program Manager or Sponsor | Cost; institutional support within user organization; quality of analytic team; type of financing (e.g., grant vs. contract). | Rate of use; type of use (general education, program evaluation, decisionmaking, etc.); contribution to methodology and state of the art; prestige. Can results be generalized, applied elsewhere? | Dissemination; collaboration with users. Has study been reviewed? |
| Policymaker | Quality of analysts; cost of study; technical tools used (hardware and software). Does problem formulation make sense? | Is output familiar and intelligible? Did study generate new ideas? Are policy indications conclusive? Are they consonant with accepted ethical standards? | Ease of use; documentation. Are analysts helping with implementation? Did they interact with agency personnel? With interest groups? |
| Public Interest Groups | Competence and intellectual integrity of analysts. Are value systems compatible? Problem formulation acceptable? Normative implications of technical choices (e.g., choices of data). | Nature of conclusions; equity. Is analysis used as rationalization or to postpone decision? All viewpoints taken into consideration? Value issues. | Participation; communication of data and other information; adherence to strict rules of procedure. |

# Clark & Majone 1985

Meta quality criteria:

- Adequacy
  - reliability, reproducibility, uncertainty analysis etc.
- Value
  - Internal: how well is the study carried out?
  - External: fitness for purpose, fitness for function
  - Personal: subjectivity, preferences, choicesd, assumptions, bias
- Effectiveness
  - Does it help to solve practical problems
- Legitimacy
  - numinous: natural authority, independance, credibility, competence
  - civil: agreed procedures

## Pilkey & Pilkey, 2007 book




## US-DOE's Total System Performance Assessment, TSPA Model pyramid

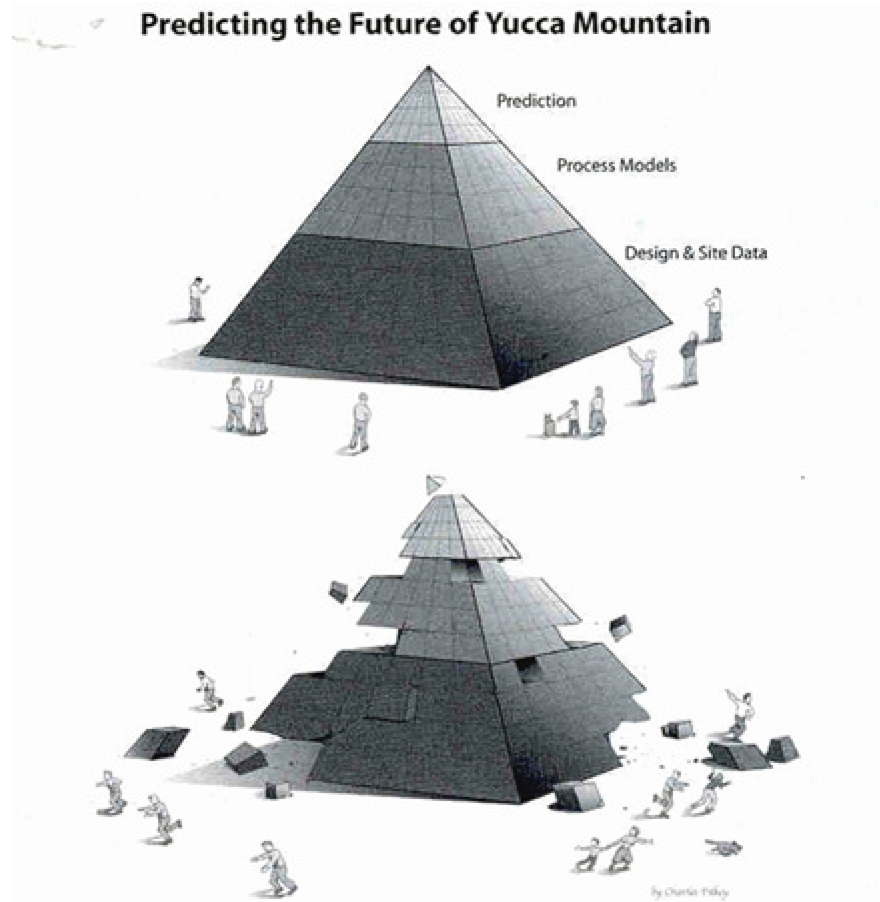



*Figure 3.5* The Department of Energy views the modeling effort at Yucca Mountain as a pyramid. At the bottom are field observations. In the second layer are the hundreds of mathematical models that predict how natural processes will work over very long periods of time. At the top are the models that put it all together to predict the behavior of the repository over a long period of time. But a pyramid founded on limited data and faulty models projecting far into the future can never survive! Drawing by Charles Pilkey.

# Yucca Mountain: bizarre mismatch

**Regulatory standard** implied need for scientific certainty for up to one million years

- **State of knowledge**
  - limitations of a quantitative modeling approach *(US-DOE's Total System Performance Assessment, TSPA)*
  - radical uncertainty and ignorance
  - uncontrolled conditions of very long term unknown and indeterminate future.

**Ignorance:**

Percolation flux: TSPA model assumed 0.5 mm per year (expert guess)

Elevated levels of Chlorine-36 isotope in faults uncovered by tunnel boring: percolation flux > 3000 mm per year over the past 50 yr…

# Uncertainty in knowledge based society: the problems

1984 Keepin & Wynne:

*“Despite the appearance of analytical rigour, IIASA’s widely acclaimed global energy projections are highly unstable and based on informal guesswork. This results from inadequate peer review and quality control, raising questions about political bias in scientific analysis.”*