Uncertainties in radiation protection

Simon French

simon.french@warwick.ac.uk

Uncertainties in radiation protection … and in other contexts too!

Simon French

simon.french@warwick.ac.uk

What is uncertainty?

▶ The opposite of knowledge

Process models
– as all models –
encode knowledge
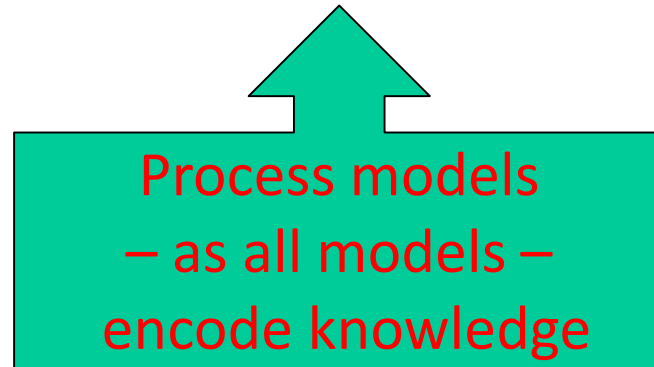
Uncertainty is not a negative thing …

… it describes our knowledge

What is uncertainty?

- ▶ The opposite of knowledge
- ▶ But there are other definitions
  - – Many other definitions and approaches
- ▶ Spiegelhalter (2017), following much of statistics, discusses 3 types of uncertainty

Spiegelhalter, D. J. (2017). "Risk and uncertainty communication." *Annual Review of Statistics and its Applications* ***4(1): 31-60.***

– Aleatory or stochastic, i.e. randomness	External
– Epistemological, i.e. lack of knowledge	
– Ambiguity, i.e. lack of clarity	Internal

But is that the whole story of uncertainty?

▶ One *...stions* relat...

▶ Decis...ublic often...e types of ur...

▶ CON...
D 9.2...cy exer...

Tanja Pe...(VUJE); Nadja
Zeleznik...N)

Uncertainties articulated by emergency managers, stakeholders, experts

- What is the origin of the first information?
- Is the information exchange sufficient?
- Which tools of information exchange are reliable?
- How to deal with time pressure?
- Which factors impact information exchange?
- How is information understood by different stakeholders?
- Is information consistent?
- Are all emergency actors informed timely?
- How to communicate negligible impacts?
- Is Information Communication Technology reliable?
- Which information is public and which information should be restricted to the emergency management?
- How public communication/information needs will be addressed effectively?
- Which areas will be affected?
- How serious is the accident?
- How to decide on protective actions?
- Which protective actions to apply?
- How to implement protective action?
- Will people follow the instructions or recommendations given?
- How to deal with long-term consequences?
- When is the time of the beginning of the release?
- How to deal with technical aspects (e.g. source term) during the early phase of the emergency?
- Is radiological assessment consistent?
- How to interpret dispersion models maps?
- How to coordinate cross-border aspects?
- How coordination and collaboration among emergency response actors will be achieved?
- Is there a gap between legislation (including plans) and reality ?
- Are the preconditions of the functioning systems taken into account?
- Are all emergency response actors familiar with their roles, procedures and plans?
- Are the available resources adequate?
- Are the emergency actors familiar and trained to use equipment?
- Are social and ethical considerations taken into account?
- What comes first: Safety or security?

A few types of uncertainty

- ▶ Stochastic or Aleatory (physical randomness)
- ▶ Actor (behaviour of others)
- ▶ Epistemological (lack of knowledge)

- ▶ Judgemental (what to include in models and analyses)
- ▶ Computational (inaccurate calculations – and mistakes)
- ▶ Modelling error (imperfect fit of the real world)

- ▶ Ambiguities (ill-defined meaning, e.g. choice of attributes)
- ▶ Value, Social and Ethical (legal, governance, representational)
- ▶ Depth of Modelling (Is the analysis requisite for its purpose)

A few types of uncertainty

- Stochastic or Aleatory (physical randomness)
- Actor (behaviour of others)
- Epistemological (lack of knowledge)

- Judgemental (what ... models and analyses)
- Computational (... calculations – and mistakes)
- Modelling (... fect fit of the real world)

- ...ities (ill-defined meaning, e.g. choice of attributes)
- ...lue, Social and Ethical (legal, governance, representational)
- Depth of Modelling (Is the analysis requisite for its purpose)

These are only some types of uncertainties!

A few types of uncertainty

- Stochastic or Aleatory (physical randomness)
- Actor (behaviour of others)
- Epistemological (lack of knowledge)

Knowledge of External World

- Judgemental (what to include in models and analyses)
- Computational (inaccurate calculations – and mistakes)
- Modelling error (imperfect fit of the real world)

Modelling and Analysis Errors

- Ambiguities (ill-defined meaning, e.g. choice of attributes)
- Value, Social and Ethical (legal, governance, representational)
- Depth of Modelling (Is the analysis requisite for its purpose)

Internal Uncertainties about Ourselves

A few types of uncertainty

Scientific Uncertainty

- Stochastic or Aleatory (physical randomness)
- Actor (behaviour of others)
- Epistemological (lack of knowledge)

Knowledge of External World

Usually ignored

- Judgem... ...e in models and analyses)
- Computati... ...te calculations – and mistakes)
- Modelling error (imperfect fit of the real world)

Modelling and Analysis Errors

Needs to be resolved by deliberation

- ...e.g. choice of attributes)
- ...al (legal, governance, representational)
- Depth of Modelling (Is the analysis requisite for its purpose)

Internal Uncertainties about Ourselves

A few types of uncertainty

- ▶ Stochastic or Aleatory (physical randomness)
- ▶ Actor (behaviour of others)
- ▶ Epistemological (lack of knowledge)

Knowledge of External World

- ▶ Judgemental (what to include in models and analyses)
- ▶ Computational (inaccurate calculations – and mistakes)
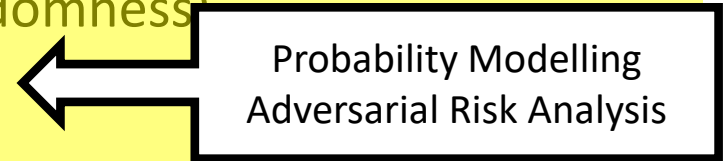- ▶ Modelling error (imperfect fit of the real world)

Modelling and Analysis Errors

- ▶ Ambiguities (ill-defined meaning, e.g. choice of attributes)
- ▶ Value, Social and Ethical (legal, governance, representational)
- ▶ Depth of Modelling (Is the analysis requisite for its purpose)

Internal Uncertainties about Ourselves

A few types of uncertainty

▶ Stochastic or Aleatory (physical randomness)

▶ Actor (behaviour of others)

▶ Epistemological (lack of knowledge)

| Probability Modelling |
| Adversarial Risk Analysis |

Knowledge of External World

▶ Judgemental (what to include in models and analyses)

▶ Computational (inaccurate calculations – and mistakes)

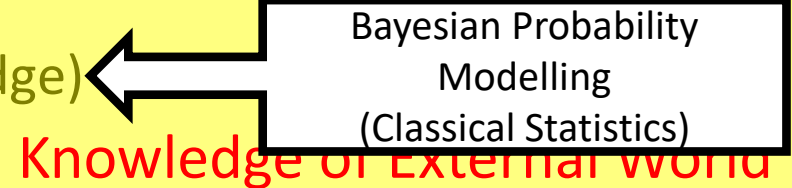▶ Modelling error (imperfect fit of the real world)

Modelling and Analysis Errors

▶ Ambiguities (ill-defined meaning, e.g. choice of attributes)

▶ Value, Social and Ethical (legal, governance, representational)

▶ Depth of Modelling (Is the analysis requisite for its purpose)

Internal Uncertainties about Ourselves

A few types of uncertainty

▶ Stochastic or Aleatory (physical randomness)

▶ Actor (behaviour of others)

▶ Epistemological (lack of knowledge)

Bayesian Probability
Modelling
(Classical Statistics)

Knowledge of External World

▶ Judgemental (what to include in models and analyses)

▶ Computational (inaccurate calculations – and mistakes)

▶ Modelling error (imperfect fit of the real world)

Modelling and Analysis Errors

▶ Ambiguities (ill-defined meaning, e.g. choice of attributes)

▶ Value, Social and Ethical (legal, governance, representational)

▶ Depth of Modelling (Is the analysis requisite for its purpose)

Internal Uncertainties about Ourselves

A few types of uncertainty

- Stochastic or Aleatory (physical randomness)
- Actor (behaviour of others)
- Epistemological (lack of knowledge)

Knowledge of External World

- Judgemental (what to include in mode...
- Computational (inaccurate calculations – and ...
- Modelling error (imperfect fit of the real world)

Expertise & Experience
Sensitivity & Robustness
Analysis

Modelling and Analysis Errors

- Ambiguities (ill-defined meaning, e.g. choice of attributes)
- Value, Social and Ethical (legal, governance, representational)
- Depth of Modelling (Is the analysis requisite for its purpose)

Internal Uncertainties about Ourselves

A few types of uncertainty

- ▶ Stochastic or Aleatory (physical randomness)
- ▶ Actor (behaviour of others)
- ▶ Epistemological (lack of knowledge)

Knowledge of External World

- ▶ Judgemental (what to include in models and analyses)
- ▶ Computational (inaccurate calculatio
- ▶ Modelling error (imperfect fit of the real world)

Numerical Analysis
Emulation Studies

Modelling and Analysis Errors

- ▶ Ambiguities (ill-defined meaning, e.g. choice of attributes)
- ▶ Value, Social and Ethical (legal, governance, representational)
- ▶ Depth of Modelling (Is the analysis requisite for its purpose)

Internal Uncertainties about Ourselves

A few types of uncertainty

- ▶ Stochastic or Aleatory (physical randomness)
- ▶ Actor (behaviour of others)
- ▶ Epistemological (lack of knowledge)

Knowledge of External World

- ▶ Judgemental (what to include in models and analyses)
- ▶ Computational (inaccurate calculations – and mistakes)
- ▶ Modelling error (imperfect fit of the

Very Difficult.
Expertise and Judgement

Modelling and Analysis Errors

- ▶ Ambiguities (ill-defined meaning, e.g. choice of attributes)
- ▶ Value, Social and Ethical (legal, governance, representational)
- ▶ Depth of Modelling (Is the analysis requisite for its purpose)

Internal Uncertainties about Ourselves

A few types of uncertainty

- ▶ Stochastic or Aleatory (physical randomness)
- ▶ Actor (behaviour of others)
- ▶ Epistemological (lack of knowledge)

Knowledge of External World

- ▶ Judgemental (what to include in models and analyses)
- ▶ Computational (inaccurate calculations – and mistakes)
- ▶ Modelling error (imperfect fit of the real world)

Modelling and Analysis Errors

- ▶ Ambiguities (ill-defined meaning, e.g.

Deliberation

- ▶ Value, Social and Ethical (legal, governance, representational)
- ▶ Depth of Modelling (Is the analysis requisite for its purpose)

Internal Uncertainties about Ourselves

A few types of uncertainty

- ▶ Stochastic or Aleatory (physical randomness)
- ▶ Actor (behaviour of others)
- ▶ Epistemological (lack of knowledge)

Knowledge of External World

- ▶ Judgemental (what to include in models and analyses)
- ▶ Computational (inaccurate calculations – and mistakes)
- ▶ Modelling error (imperfect fit of the real world)

Modelling and Analysis Errors

- ▶ Ambiguities (ill-defined meaning, e.g. choice of attributes)
- ▶ Value, Social and Ethical (legal, governance)
- ▶ Depth of Modelling (Is the analysis requisite for its purpose)

Internal Uncertainties about Ourselves

Deliberation

A few types of uncertainty

- ▶ Stochastic or Aleatory (physical randomness)
- ▶ Actor (behaviour of others)
- ▶ Epistemological (lack of knowledge)

Knowledge of External World

- ▶ Judgemental (what to include in models and analyses)
- ▶ Computational (inaccurate calculations – and mistakes)
- ▶ Modelling error (imperfect fit of the real world)

Modelling and Analysis Errors

- ▶ Ambiguities (ill-defined meaning, e.g. choice of attributes)
- ▶ Value, Social and Ethical (legal, governance, representational)
- ▶ Depth of Modelling (Is the analysis r...

Judgement

Internal Uncertainties about Ourselves

How is this relevant to process models in food chains?

For our topic, we should concentrate on issues relating to the first two groups:

▶ Stochastic or Aleatory (physical randomness)

▶ Actor (behaviour of others)

▶ Epistemological (lack of knowledge)

Knowledge of External World

▶ Judgemental (what to include in models and analyses)

▶ Computational (inaccurate calculations – and mistakes)

▶ Modelling error (imperfect fit of the real world)

Modelling and Analysis Errors

- Stochastic or Aleatory (physical randomness)
- Actor (behaviour of others)
- Epistemological (lack of knowledge)

Knowledge of External World

- Need to allow for biological & physical variations in
    - Soils and topography
    - Flora and fauna, crops
    - Food sampling 'at farm gate'
    - Food processing
    - Storage
    - Cooking
    - Consumers
    - etc

- ▶ Stochastic or Aleatory (physical randomness)
- ▶ Actor (behaviour of others)
- ▶ Epistemological (lack of knowledge)

Knowledge of External World

Variation, particularly local variation, in
- dietary preferences including styles of cooking
- Availability of different food types, especially to different social groups
- Particular food bans may have unexpected consequences (Chernobyl mushrooms)

- ▶ Stochastic or Aleatory (physical randomness)
- ▶ Actor (behaviour of others)
- ▶ Epistemological (lack of knowledge)

Knowledge of External World

- Need to remember that over time knowledge captured in handbooks, databases/GIS, surveys, etc. *decays*.
- So even if uncertainty bounds (confidence intervals, s.d.) were given, they will not apply a couple of years later

► Judgemental (what to include in models and analyses)
► Computational (inaccurate calculations – and mistakes)
► Modelling error (imperfect fit of the real world)

Modelling and Analysis Errors

- Are all Process-based models the same? Doubt it! So how do you choose which to use?
- Over what ranges, timescales are the models valid
- Which parameter values? Databases? …
- Etc.

▶ Judgemental (what to include in models and analyses)

▶ Computational (inaccurate calculations – and mistakes)

▶ Modelling error (imperfect fit of the real world)

Modelling and Analysis Errors

- What approximations? Iteration, convergence parameters?
- Linearity?
- Was the model designed for this purpose?
  - Very conservative models are used for normal risk analysis
  - Too conservative for recovery scenario?

▶ Judgemental (what to include in models and analyses)

▶ Computational (inaccurate calculations – and mistakes)

▶ Modelling error (imperfect fit of the real world)

Modelling and Analysis Errors
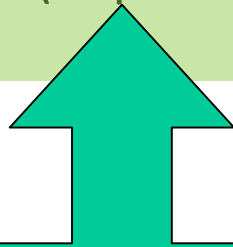
"All models are wrong; some are useful"

George Box

• So how do we test whether these process-based models are useful?

• And if they are, where/when they are useful?

And when all that is done ….

… how do we communicate the results
to the decision makers

and to the public?

Thank you

Deep or Knightian Uncertainty

▶ Knight (1921) distinguished:

  – **Risk**: probabilities known and available

  – **(Strict) Uncertainty** , now often called deep uncertainty: probabilities unknown or unavailable and no relevant data available (within time constraints)

▶ What happens when some uncertainties are **so deep** that while any expert might express his or her uncertainties as probabilities, the range of these probabilities over a group of experts is effective 0-1?

▶ Sensitivity analysis will give almost anything as possible.

▶ Some uncertainties are **too great** to build a **'useful' model**.