PRIMAVERA

PRocess-based climate sIMulation: AdVances in high-resolution modelling and European climate Risk Assessment

Uncertainty in climate projections

“Uncertainty” has a specific meaning in climate science. It arises in climate models from a number of sources and falls broadly into three categories, with their contributions to the total uncertainty varying over time. The categories covered in this fact sheet are natural variability, scenario uncertainty, climate model uncertainty; in the latter category there are significant improvements expected from the PRIMAVERA project and other similar initiatives. There can also be uncertainty in impact modelling, where climate projections are used to drive other models in order to understand a particular climate impact, and in the decision-making process itself.

Types or sources of uncertainty in climate science

Uncertainty is any departure from complete deterministic knowledge of the relevant system (Walker, 2003). In climate sciences, the term “uncertainty” has a different, and more precise meaning compared to the every-day usage of the word. Three different types of uncertainty are distinguished:

- Natural variability;
- Scenario uncertainty or spread;
- Model uncertainty or spread;

Generally, taking into account uncertainties will improve decision making related to natural climate variability and anthropogenic climate change. The respective contributions of the types of uncertainties to the total uncertainty varies over time (Fig. 1, on the right).

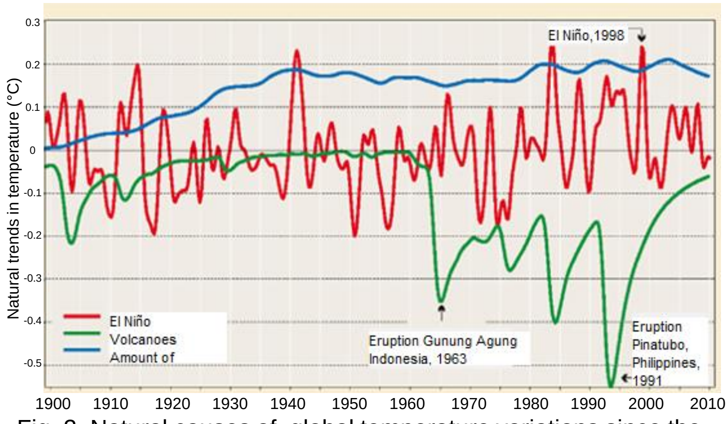

Fig. 2. Natural causes of global temperature variations since the beginning of the 20th century (Source: KNMI/Noordhoff, 2011)

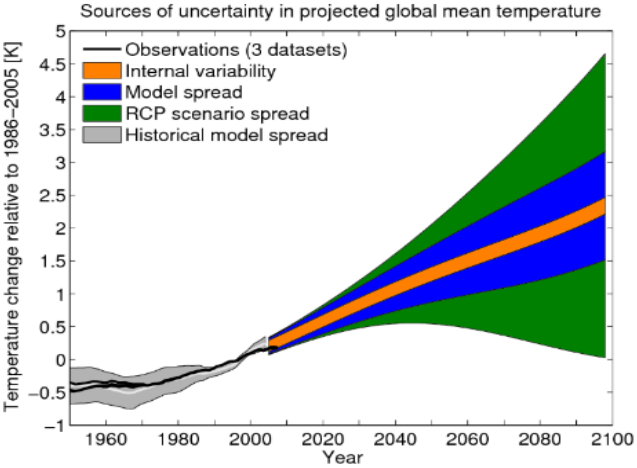

Fig. 1. Sources of uncertainty in CMIP5 projections, Ed Hawkins, 2013: https://www.climate-lab-book.ac.uk/2013/sources-of-uncertainty/

Natural variability

Natural variability (e.g. day-to-day variation, decade-to-decade variation) is the temporal variation of the atmosphere–ocean system around a mean state due to natural (not man-made) processes. Variability may be “internal” (due to natural internal processes within the climate system, e.g. El Niño), or “external” (due to variations in natural forcing outside the climate system, from e.g. solar activity or volcanoes). Examples of natural processes affecting climate are shown in Fig. 2. Natural variability is important for weather forecasting and for seasonal-to-decadal predictions. In future projections, other uncertainties change more with time, so that natural (internal) variability makes a proportionally smaller contribution overall (Fig. 1).

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Info

PRIMAVERA is a collaboration between 19 leading European research and technology organisations with complementary expertise in climate science, climate change modelling, and high performance computing.

The project is led by the Met Office and the University of Reading.

Media

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Scenario uncertainty

Scenario uncertainty arises because we do not know what the future will be like; and there are no physical laws that can be used to calculate it. Instead we have to assume different socio-economic developments. These assumptions are made to span the range of possible futures, not to predict them. This used to be described through the Special Report on Emissions Scenarios (SRES), and has been superseded by Representative Concentration Pathways (RCPs), which describe futures with different amounts of warming, ranging from an average approx. 1°C to approx. 4°C by the end of the 21st century (Fig. 3). In the second half of this century, scenario uncertainties cause the largest uncertainty (Fig. 1).

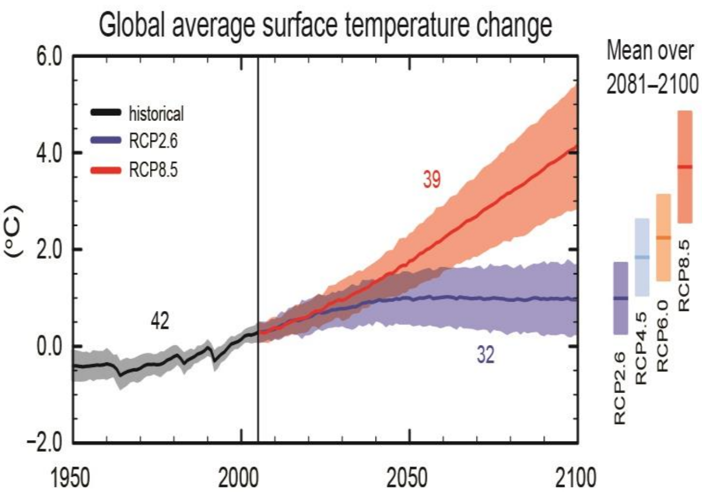

Fig. 3. Global temperature rise in IPCC models (IPCC, 2013). The figure shows the model and scenario uncertainty. The differences between the averages for the RCPs represent the scenario uncertainty, the bands around the averages per RCP show the model uncertainty. The 3 numbers inside the graph refer to the number of climate model simulations used.

Model uncertainty

Model uncertainty is the incomplete knowledge about the climate system, quantified with the help of a large number of climate models that simulate the future climate for the same emission scenario. Climate models describe atmospheric, land-, sea-based and other environmental processes with physical equations and through parametrisations. Although the physical processes simulated are the same, the parametrisations may differ somewhat between the various climate models, and also the datasets used for calibrating the models. This results in different projections for the various climate models with the same emission scenarios. For the coming decades, model uncertainties are the most important uncertainties (besides natural variability); see also Fig. 1 on the separate factsheet about ensembles of climate models.

Uncertainties in impact models and decision making

Climate model output is used as input into impact models and hence the existing uncertainties propagate further (Fig. 4). Uncertainties in impact model outputs are yet another important factor that decision makers need to consider, as they may be as significant as the uncertainties coming from climate models.

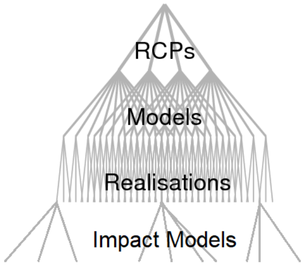

Fig. 4. Schematic cascade of uncertainty, from RCP scenarios, models and realisations to impact models. After Hawkins, www.climate-lab-book.ac.uk/2014/cascade-of-uncertainty/

References

Walker, W.E., et al. 2003. Defining uncertainty: a conceptual basis for uncertainty management in model-based decision support. Integrated Assessment, 4(1), pp.5-17.

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Partners