Observational constraints on future climate: distinguishing robust from model-dependent statements of uncertainty in climate forecasting

Contribution to the IPCC Workshop on Communicating Uncertainty and Risk, May, 2004

M. R. Allen[1], B. B. B. Booth[1,3], D. J. Frame[1], J. M. Gregory[2,3], J. A. Kettleborough[4], L. A. Smith[5], D. A. Stainforth[1] & P. A. Stott[3]
1. Department of Physics, University of Oxford, UK (Clarendon Laboratory, OX1 3PU, UK & myles.allen@physics.ox.ac.uk)
2. Department of Meteorology, University of Reading, UK
3. Hadley Centre for Climate Prediction and Research, The Met Office (Reading Unit), Reading, UK
4. Space Science and Technology Department, Rutherford Appleton Laboratory, UK
5. Department of Statistics, London School of Economics, UK

Background: The IPCC Third Assessment Report (TAR) was strongly criticised for failing to present its headline projections of 21 of system response uncertainty or model error

[3,4].

Sources of uncertainty in climate forecasting: AR4 will need to distinguish clearly between

1. Uncertainty in anthropogenic forcing due to different emission paths ("scenario uncertainty")
2. Uncertainty due to natural variability, encompassing internal chaotic climate variability and externally driven (e.g. solar, volcanic) natural climate change ("natural variability")
3. Uncertainty in the climate system's response to external forcing due to incomplete knowledge of feedbacks and timescales in the system ("response uncertainty")

These different sources of uncertainty need to be distinguished because they have very different policy implications. Scenario uncertainty is a special case because it is, to some degree, under policy control. Some uncertainties due to natural variability may be reduced by detailed observations of the current trajectory of the climate system, but typically on timescales of a few years, thereafter representing an irreducible lower bound on forecast skill even given complete knowledge of climate system behaviour. All aspects of response uncertainty are reducible in principle by the acquisition of new information, but it helps to distinguish between

- 3a Robust aspects (timescales, forecast variables) of response uncertainty that are unlikely to be revised substantially except on the timescale of climate change itself
- 3b Subjective aspects of response uncertainty that could be revised substantially with a change in expert opinion, the acquisition of new data or implementation of new models.

We will argue that the system may be sufficiently linear on anthropogenic climate change timescales for a useful distinction to be made, at least in principle, between these sources of uncertainty even though there are obvious interactions. For example, more sensitive uncertainties sum approximately in quadrature, so this presentation tends to exaggerate the role of scenario versus response uncertainty. The converse presentation showing response uncertainty as the inner plume (a single scenario forcing a range of models) suggests an almost negligible role for scenario uncertainty until the mid-21st-century, which is also potentially misleading. The use of an energy balance model suppresses the contribution of natural variability altogether. A more balanced presentation would be to show forecast plumes combining response uncertainty and natural variability for a (necessarily small) range of representative emissions scenarios, allowing the reader to visualise the impact of adopting different scenarios in the context of other sources of uncertainty in the forecast[6].

Confidence versus likelihood in the presentation of uncertainty: No consistent distinction was made in the TAR between statements of *confidence*, reflecting the degree of consensus across experts or modelling groups regarding the truth of a particular statement, and statements of *likelihood*, reflecting the assessed probability of a particular outcome or that a statement is true. This needs to be resolved in AR4, because we need to communicate the fact that we may have very different levels of confidence in various probabilistic statements. For example, we might wish to argue we have a much higher level of *confidence* in the statement

A: "anthropogenic warming is likely to lie in the range 0.1-0.2^{o}C per decade over the next few decades under the IS92a scenario" (TAR SPM)

than in the statement

B: "it is likely that warming associated with increasing greenhouse gas concentrations will cause an increase in Asian summer monsoon precipitation variability" (ibid.)

even though both can only be qualified by the same "better than two in three chance" *likelihood*. The first statement is based on the analysis of observed anthropogenic warming, the constraint of energy conservation and the assertion that no strongly non-linear global climate changes are anticipated in the coming decades. It is unlikely to change through the introduction of higher-resolution models, additional physical processes or changes in expert opinion. Although relatively weak in itself ("likely"), this statement of odds is reliable in the sense that the level of uncertainty is unlikely to be revised other than downwards as more data are acquired. In contrast, the second statement represents the current consensus across climate models, and the uncertainty estimate could be revised either up or down as the next generation of models and additional physical processes are considered. Hence, although both statements refer to the same level of probability, they have very different policy implications: there is little point in postponing policy decisions in case the scientific community changes its mind on the first statement, because it is unlikely do so, whereas new modelling results are much more likely to impact on the second.

Robust, observationally constrained, STAID probabilistic forecasts: Probabilistic statements that rely on constraints provided by observations, making use of climate models simply to identify robust relationships between observable and forecast quantities, have a very different status to statements based on model inter-comparison studies or surveys of expert opinion. Underlying statement A above, both basic theory and a range of results from climate models suggest near-linear re, busmelmm9(y)TJ2.5(y)0.31(getp7-31(getp7