Validation of climate models

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Climate models are complex pieces of software combining dynamics, which are relatively well understood, with parameterisation of sub-grid processes such as convection which are less well understood. In this extended abstract I briefly describe some approaches to validation used within the Met Office and Hadley Centre. I also highlight how a climate quality reanalysis could be used to validate climate models.

1. Validation

At the Met. Office model components are tested in a variety of ways. The climate and numerical weather prediction models share many components as part of the "Unified Model" framework (Davies et al., 2005) which allows changes developed for NWP to be used in the climate model or vice versa. Individual parameterisation schemes are tested by comparison with data from field campaigns (for example Xie et al. (2002)) or, carefully, with data from cloud resolving models. Schemes have also been tested within the climate model by examining the rate of error growth(Martin et al., 2006) by starting from analysis initial conditions taken from the ERA-40 re-analysis (Uppala et al., 2005).

Climatologies estimated from the ERA-40 reanalysis were also used to evaluate the model climatology (Martin et al., 2006). This then lead to the development of a model skill index which was used to make a objective assessment of the coupled model's skill (Johns et al., 2006). However, from consideration of a multi-model ensemble of 21st century simulations (Fig. 1) having a good climatology does not seem to provide a very strong constraint on future climate change.

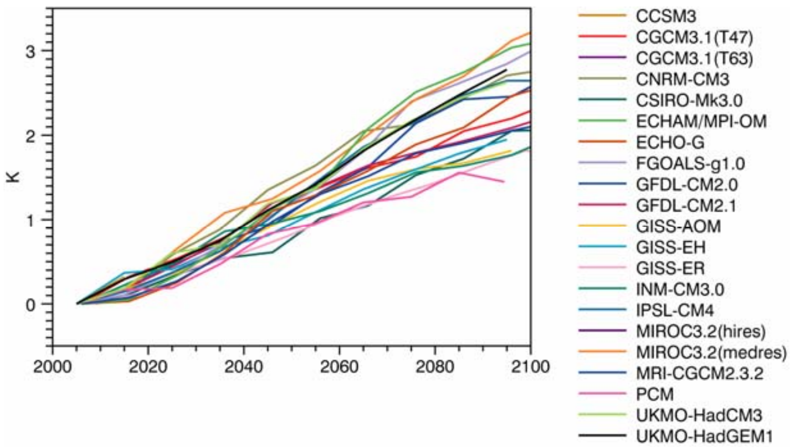

Figure 1 Future change from multi-model ensemble Simulated change from IPCC multi-model ensemble.

Another approach to model validation is to compare simulated historical climate change against actual historical change. This has the advantage of validating one of the principle purposes of the model. However, doing this requires taking account of three major sources of uncertainty:

Observational Uncertainty

Climate datasets are constructing by blending a variety of observations made for other purposes. These other purposes did not require long-term homogeneity so, without some further work, simply blending the data does not lead to a record which represents climate change and variability. As data needs adjustments and these adjustments are uncertain this leads to uncertainties in the records. See Rayner et al. (2006) for an example of this.

Climate Variability

The climate system has variability that is essentially unpredictable. When validating climate models, depending on what is being validated, good experimental design can reduce this effect. For example coupled ocean/atmosphere models have larger variability than atmosphere only models (Tett and Thorne, 2004).

Forcing Uncertainty

On decadal timescales both natural and anthropogenic forcings are important drivers of climate variability(Tett et al., 2006) of which there are considerable uncertainties in historical forcings (Ramaswamy et al., 2001). Very few studies have taken this into account.

To date no single study has considered all three of these uncertainties. Many studies (for example Stott et al. (2000)) have considered chaotic variability. Validating the response to greenhouse gases is most important as it is this which will largely determine climate change this century. Current techniques assume that the total response is the linear sum of the response to individual forcings. Then using regression techniques the magnitude of the individual simulated responses is sperarately estimated in the observed record (Allen and Tett, 1999; Tett et al., 2002). Gillett et al. (2004) found no evidence of non-linearity in the response to greenhouse gases and aerosols in a climate model. Stott and Kettleborough (2002) used a combination of near-surface temperatures, model simulations, unbiased statistical methods and assuming linearity found that future uncertainties were relatively small. However, they did not explicitly consider forcing and observational uncertainty.

2. How could reanalysis help

Current use of re-analysis to validate models is to provide initial conditions to examine error growth and provide climatologies. Both of which have been vary valuable for evaluating models. Regional models have been driven using data from reanalysis as boundary conditions (Noguer et al., 1998) though, not yet, at the Met. Office, with data from ERA-40. This approach has provided an important test-bed to examine problems with the regional model simulation and understand some of the reasons for model errors.

Current reanalysis has not been focused on delivering products suitable for studying climate change and multi-annual climate variability. For example trends in atmospheric temperature from ERA-40 are somewhat suspect (Fig. 2). To use such datasets for climate change also requires some estimates of uncertainty or at least of subjective quality for such purposes.

A climate quality reanalysis would also be an invaluable tool for monitoring climate change and variability in near-real-time as it would allow events to be placed in the context of a long historical record. It would also allow a detailed analysis of such events and exploration of the principle mechanisms that were responsible for them.

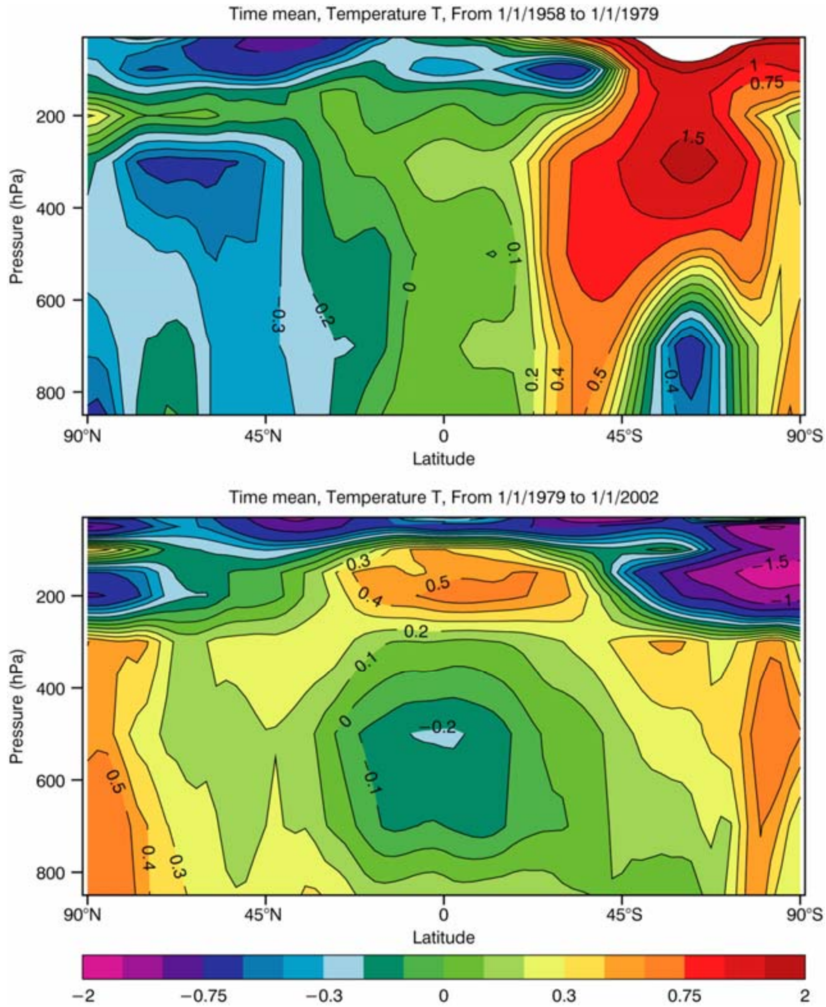

Figure 2 ECMWF temperature trends Temperature trends (K/decade) from ERA-40 reanalysis. Shown are trends from 1958 to 1978 and 1979 to 2002.

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