CONFIDENCE IN MODELLING FUTURE CLIMATE:
A SOUTHERN HEMISPHERE PERSPECTIVE

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Abstract. Climate models are essentially surrogates for the real system, in which experiments can be carried out. When these experiments attempt to simulate future climate, the results cannot be compared with the real atmosphere because they involve changes unique in recorded human history. Confidence indicators include model comparison with the real atmosphere for current climate representation and model intercomparison for future climate representation.

From a Southern Hemisphere perspective general circulation models (GCMs) reveal some inadequacies in their representation of climate and differ significantly from each other in their response to a CO₂ doubling. Representation of drought as a response to sea surface temperature anomaly is shown to be successful but strongly dependent on correct parameterization of land surface exchange processes. More attention to Southern Hemisphere representation is required, particularly because of the likely strong role of the oceans.

1. Introduction

When considering the effect on climate of the current changes in atmospheric composition, we are concerned with a situation unique in recorded human history. Evidence exists which suggests that a similar situation may have occurred in prehistoric times, for example, ice core data show a correlation between surface temperature and carbon dioxide concentration extending several tens of thousands of years into the past. But even if the causal mechanisms are assumed to be similar, it is difficult to make useful inferences from prehistory about our likely future climate because so little can be deduced about the details of the relevant prehistoric climate pattern. Accordingly, the most feasible approach to estimating regional climate change due to increasing ‘greenhouse gases’ and/or to changing land-use patterns is via numerical climate models: general circulation models (GCMs) into which changing gas compositions or changing land surface processes can be inserted and which then simulate the dynamical and thermal atmospheric response.

The use of such surrogates poses the problem of how to assess the confidence which can be given to the results. Possible confidence indicators are the ability of these models to simulate current climate when given current conditions, the similarity of results for changed conditions between different models (or at least the convergence of results as models are improved), and the emergence of a climate-change signal from the real atmosphere that conforms to model predictions.

Aspects of the first two of these indicators are discussed below from a Southern Hemisphere perspective.
2. Equilibrium and Transient Experiments

The process of simulating changed or changing atmospheric composition can be undertaken by two types of modelling experiment: the equilibrium type and the transient type. In the former, a GCM 'control run' is performed for a given period using current gas concentrations and is later followed with an 'experiment run' with concentrations assumed to prevail in, say, 50 years time. In both cases the run must be long enough for the model to have recovered from any possible start-up imbalances and to have achieved a statistically stationary performance. The computed statistics for the model's control climate are then compared with the observed statistics for the real atmosphere's climate. Any inadequacies are a qualitative measure of the confidence to be given to the assumption that the computed experimental climate is an analogy to the future real climate under similar conditions.

The transient type of experiment involves a very long GCM run. Typically the model may be started up with gas concentrations as they are believed to have been, say, in 1850, representing immediate pre-industrial times. The run may be continued for 200 model years, to 2050, with gas concentrations being continually updated during this time on the basis of information provided from studies of atmospheric chemistry. This type of experiment is much more demanding of computer time and also of adequate representation of ocean-atmosphere interaction because of the time-lagged response of the oceans. However, it gives more scope for comparing the surrogate with reality because, over the period of adequate observational record, the transient behaviour of the model can be compared with the transient behaviour of the real atmosphere. It has yet to be shown whether a transient experiment gives results for future climate that are different from those of an equilibrium experiment when exactly the same model is used for both. Only one set of transient experiments (Hansen et al., 1988) has so far been published.

3. Model Verisimilitude

All climate model results to date have been undertaken by groups based in the Northern Hemisphere, and the socio-economic centre of gravity of the globe lies well to the north of the Equator. It is understandable, therefore, that the focus of attention for assessing model performance has generally been the Northern Hemisphere circulation patterns. However, this is not exclusively the case. Pitcher et al. (1983) show that a GCM which performs well for the Northern Hemisphere exhibits significant deficiencies in its simulation of the Southern Hemisphere flow pattern. This is demonstrated in Figure 1: the Northern Hemisphere west wind maxima at 300 hPa are well represented in both position and magnitude, but the Southern Hemisphere subtropical west wind maximum is located upstream (west) of Australia in the model whereas in the real atmosphere it is downstream (east). The model also does not simulate the band of west wind south of Australia.

Subsequently, aspects of model verisimilitude in the Southern Hemisphere have