SPEAKERS

Ranges of uncertainty in polar climate over the past and coming decades

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Estimates of past and future climate are inherently uncertain for a number of reasons, some of which are most acute in the polar regions. This paper presents a discussion of estimates of the uncertainties in our estimates of past and future climate. This discussion is centred around computer models of the climate system, which are an essential tool for these estimates. The concentration is on temperature, partly because it is a very relevant measure of polar climate, and partly because it is the most studied quantity; uncertainties in estimates of changes in other variables tend to be considerably larger. Uncertainties in Arctic climate do not appear to be large enough to mask a recent and future warming, while the situation is more ambiguous over the Antarctic where observational coverage is very sparse.

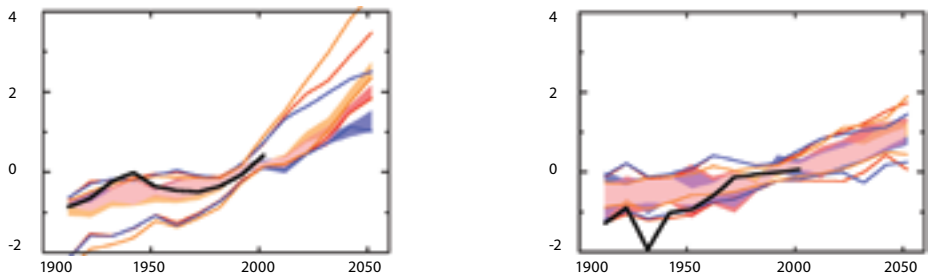
OBSERVING CLIMATE

What we have been observing over the past century is not the climate but rather the weather, i.e. the particular trajectory our world has taken in the past and current climate space (Allen, 2003). Time averaging can reduce the noise if we are concerned about long term mean climate change but not if we are concerned about more rapid changes, after a volcanic eruption, for instance, or about variability.
Additionally, our past observations are incomplete, especially over the polar regions. For instance, only about 20 meteorological stations have been recording temperatures south of 60°S since 1960 (Brohan et al., 2006). This issue is illustrated in Figure 1. The red lines show an estimate of the climate from model simulations if data is taken from the simulations only when and where observations exist, while the yellow lines show the estimate if all data is taken. This not only produces uncertainty in our knowledge of observed past climate change, but also in our projection of future change because our current point of reference is not clear. By the 2050s the difference between these two definitions affects warming estimates in the Arctic by 0.5-1.0°C.

MODEL FORMULATION

We must use numerical models of the climate system both to project future climate changes and to understand past changes. These models solve equations representing physical (and increasingly chemical and ecological) processes of the atmosphere, ocean, sea ice, land ice, land surface, and vegetation on a global spatial grid at consecutive moments in time. Some processes are not fully understood, while other processes cannot be fully resolved by models using current computing resources; thus, they must be represented in a simplified way. Some uncertainty in the use of such simplifications is captured in the differences between the simplifications

Figure 1: Time series of decadal average temperatures over the Arctic (left, north of 60°N) and Antarctic (right, south of 60°S) over the 1907-2056 period. Anomalies in °C from the 1977-2006 average are shown. The black line denotes observed values (from the HadCRUT3 dataset of Brohan et al., 2006, http://www.hadobs.org). The pairs of coloured lines denote the approximate 5th-95th percentile ranges of 21 simulations from 8 models (from the WCRP CMIP3 multi-model database, https://esg.llnl.gov:8443/index.jsp). The red and yellow lines show data from historical and SRES A1B scenario simulations, with data used for the red lines being masked according to the availability of observations in the HadCRUT3 dataset (with perpetual 2006 coverage into the future) while the data used for the yellow lines is not masked. The blue lines show data from historical and SRES B1 scenario simulations masked according to the observations. Shaded bands are identical to the line pairs except that data is restricted to 5 simulations from the MRI-CGCM2.3.2 model.



used by the various models around the world. Unfortunately though, we have no rigorous way of knowing if the range of simplifications spanned by current models truly encapsulates these uncertainties. Fortunately, large- scale spatial and temporal patterns of temperature changes appear quite robust across models, allowing the application of observational constraints on the less robust amplitudes (Stott et al., 2006); how far this extends to smaller spatial scales and other variables is actively being investigated.

The issue of model formulation is particularly important for the polar climates because processes important for the evolution of ice and its role in climate, such as leads, crevasses, and melt puddles, are only metres across. Such features can dramatically alter the radiative, energy, and moisture properties of the surface. We can see this importance in Figure 1. The coloured bands represent the range of 5 simulations from one particular climate model only, identical otherwise to the ranges marked with like-coloured line pairs. Over the Arctic, the bands from the single model cover only a small portion of the ranges covered by all of the models.

EXTERNAL FORCING

A number of factors have been and will be affecting global and local climates. Uncertainties in some of these, such as historical changes in atmospheric concentrations of greenhouse gases, are well constrained (Ramaswamy et al., 2001). Others are not so well known, however. Because various modelling groups use various reconstructions of these past external forcings, some of the uncertainty is represented in the ranges shown in Figure 1. The selection has not been coordinated across modelling groups though, so the sampling is probably biased.

In the future, how political, economic, and technological advances will translate into emissions is poorly understood. Figure 1 shows the spread of climate model simulations following two popular 'business as usual' scenarios of future greenhouse gas and sulphate emissions. Differences in the warming do not become substantial for another few decades. None of these simulations include the effects of sporadic volcanic eruptions, leading to an underestimate in the width of the future climate plume.

INTERPRETATION

Finally, there is the question of how to interpret the output from climate models. The useful output has a course spatial resolution. Nesting a higher resolution regional model inside the global model alleviates the problem, but still questions remain for instance on how a model's interpretation of precipitation compares with a station's interpretation. Statistical downscaling is another option, but it depends on remaining within the confines of past climate.

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