Geophysical Research Abstracts, Vol. 9, 01174, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-01174

Constraining climate models from observations

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A primary problem in testing climate models is that observed climate changes are not known with sufficient accuracy to allow one to constrain closely important properties of the climate system, such as the climate sensitivity. Furthermore there are multiple uncertainties which can offset each other, i.e., a given temperature increase might be explained equally well by a high climate sensitivity and strong aerosol cooling, or by a low climate sensitivity and weak aerosol cooling. Given these problems, one can at best use the available observations to calculate joint probability distributions for the uncertain parameters. In recent years a number of such analyses have been published, with the primary goal being to use the results to make probabilistic projections. Because of the large number of simulations required for probabilistic projections, simplified climate models that are more efficient than state-of-the-art coupled GCMs are required to make the projections (Webster et al., 2003). However the deduced probability distributions can nevertheless be used to test whether the properties of state-of-the-art models are reasonably consistent with observations. Such a test was carried out by Forest et al. (2006), using observed temperature changes in the 20th century, and the results indicated that coupled GCMs generally have equilibrium climate sensitivities that are consistent with the observed warming in the 20th century, but that the models generally overestimate how rapidly heat is being mixed into the oceans below the oceanic mixed layer.

We have updated the Forest et al. (2006) calculation of the joint probability distribution for the three major uncertainties affecting simulations of 20th century temperature changes, namely the climate sensitivity, the rate of mixing of heat into the deep oceans, and the strength of the aerosol forcing. The main changes compared to the earlier analysis are that the atmospheric model contains an improved representation of the land surface and that the effective climate sensitivity is used in place of the equilibrium sensitivity as one of the major uncertainties. We use these results to update the earlier assessment of coupled GCMs, and we also now include results for some of the AR4 models whose performance characteristics were not available at the time of the earlier study. The models' climate sensitivities (now the

effective sensitivities) are still generally consistent with the observed warming, and the models' rates of heat uptake in the deep ocean are still too strong, although not as excessive as found in the earlier comparison. In particular, the rate of heat uptake in all the models analyzed exceeds the median deduced from the observations, and all are far from the mode. These results imply that state-of-the-art models are generally underestimating how rapidly global warming will occur in the future.

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