Evaluation of Climate Sensitivity Related to Different Cloud Feedbacks in Global Climate Models

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1. Background and objectives

For the current generation of climate models, climate response varies from model to model even when the radiative forcing used to drive the models is similar. This difference in the climate models' response is mainly the result of differing climate sensitivities. According to the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report, the climate sensitivity is likely to be in the range of 1.5 to 4.5°C. This estimate is unchanged from the first IPCC Assessment Report in 1990 and the Second Assessment Report (IPCC, 2001).

The range in estimated climate sensitivity of 1.5 to 4.5°C for a CO_2 doubling arises mainly from uncertainties in the climate models and their internal feedbacks, particularly those related to clouds and related processes.

Clouds can both reflect solar radiation (thereby cooling the surface) and absorb and emit long-wave radiation (thereby warming the surface). The potential complexity of the response of clouds to climate change makes clouds a dominant source of uncertainty. Although there have been a number of improvements in the simulation of both the cloud distribution and in the radiative properties of clouds, the uncertainty range associated with cloud feedbacks has no apparent narrowing in current climate change simulations (IPCC, 2001). Studies show a wide range of apparent effects of cloudiness on climate (e.g., Cess et al. 1990, 1996) and large discrepancies among different models when comparing observational data with model output (e.g., Senior and Mitchell, 2000).

The purpose of the present study is to explore the relationships between (1) the range of climate sensitivity and (2) the adequacy of cloud description in global climate models. Through comparing the nontraditional climatology of cloudiness between global climate model outputs and observational data, such as the relationship of cloud cover to temperature and humidity under clear sky or overcast conditions on different timescales, the models that can properly reproduce the contemporary climate related to cloudiness can be tested. Groisman et al. (1996) suggested that this statistical method (the construction of nontraditional climatology) may test the GCMs' abilities and distinguish more reliable models. In addition, through the comparison of ranges of estimated climate sensitivity between those models that can and cannot properly reproduce the above internal relationships, it may be possible to explore whether the range of climate sensitivity can be reduced in those models with reasonable cloud descriptions. At the same time, the physical designs of cloud schemes in the models may be compared to investigate the possible reason leading to different simulations of contemporary climate. On the basis of these comparisons, it may be possible to examine a more reasonable design of cloud scheme in the models and its relationship to the climate sensitivity.

2. Technical Approach

(1) Comparison of model outputs and observation

Groisman et al. (2000) suggested the method using nontraditional climatology to estimate cloud effects. We may follow this approach to compare cloud effects between models and observation. We will possibly test the effects of clouds in different heights and different regions and will use other data, such as satellite data, for comparison. We will also explore other ways to check the adequacy of cloud physical description in the models.

(2) Climate sensitivity analysis

It has been suggested there are several ways to evaluate climate sensitivity (e.g., Senior and Mitchell, 2000). On the basis of these approaches, we will also explore the other way to evaluate climate sensitivity related to cloud feedback in the models.

(3) Comparison of different cloud schemes

The quantitative analyses of effects of different cloud schemes will depend on the sensitivity experiment of cloud in the models. Therefore, different cloud schemes under comparison will be loaded into the same model in order to investigate their role in the difference of climate sensitivity. Community Climate System Model of National Center for Atmosphere Research (NCAR/CCSM) may be used to realize this objective.

3. Data requirement

CMIP2+: model outputs in details, daily and monthly average

4. References

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