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TESTING THE IMPACT OF CLOUDS ON THE RADIATION BUDGETS OF 19 AMIP MODELS

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INTRODUCTION

We compare cloud-radiative forcing (CRF) at the top-of-the atmosphere from 19 atmospheric general circulation models, for simulations with prescribed sea-surface temperatures, to observations from the Earth Radiation Budget Experiment (ERBE). The atmospheric GCMs used in the present study are summarized in Table 1, and the simulations are from the Atmospheric Model Intercomparison Project (AMIP) II. With respect to 60^{O}N to 60^{O}S, as is demonstrated in Figures 1 and 2, a surprising result is that many of the 19 models produce unusually large biases in Net CRF that are all of the same sign (negative), meaning that many of the models significantly overestimate cloud radiative cooling. The primary focus of this study, however, is to demonstrate a diagnostic procedure, using ERBE data, to test if a model might produce, for a given region, reasonable CRF as a consequence of compensating errors caused either by unrealistic cloud vertical structure or cloud optical depth. For this purpose we have chosen two regions, one in the western tropical Pacific characterized by high clouds spanning the range from thin cirrus to deep convective clouds, and the other in the southeastern Pacific characterized by trade cumulus. For a subset of eight models, it is found that most typically produce more realistic regionally-averaged CRF (and its longwave and shortwave components) for the southeastern region as opposed to the western region. But when the diagnostic procedure for investigating cloud vertical structure and cloud optical depth is imposed, this somewhat better agreement in the southeastern region is found to be the result of compensating errors in either cloud vertical structure or cloud optical depth.

The optical depths, fractions and altitudes of a GCM's clouds can all contribute to errors in the model's CRF. And since CRF is referenced to the TOA clear-sky fluxes, then these clear-sky fluxes are also potential error sources for CRF. For this reason, we have compared clear-sky fluxes for 18 of the models (GISS did not supply clear fluxes) to those measured by ERBE. Biases, relative to ERBE, in the clear-sky SW reflection are summarized in Figure 3a. That NCAR has minimal biases is consistent with several studies which have compared that model's SW column radiation code to both surface and satellite radiometric measurements. For several of the models, however, the biases are disturbingly large. Similar comparisons are summarized in Figure 3b for the clear-sky outgoing LW radiation (OLR), and here the situation is somewhat more complicated than in Figure 3a. This is because the clear-sky OLR depends not only on a model's LW radiation code, but also upon the vertical temperature and humidity profiles that a model produces. For example, it has been suggested that the negative OLR bias for GFDL is consistent with that model having a cold bias in the tropical free troposphere plus excessive upper tropospheric humidity. On the other hand, for NCAR the modest positive biases are consistent with comparisons of that model's LW column radiation code with observed clear-sky OLR, for which observed temperature and humidity profiles were used as input to the column model. As with the SW biases, there are some substantial OLR biases shown in Figure 3b.

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Table 1. Summary of the 19 Atmospheric GCMs

Acronym	Group	Location
BMRC	Bureau of Meteorology Research Center	Melborne, Australia
CCCMA	CCCMA Canadian Centre for Climate Modelling and Analysis	Victoria, Canada
CCSR	Center for Climate System Research	Tokyo, Japan
CNRM	Centre Natianal de Recherches Meteorologiques	Toulouse, France
COLA	Center for Ocean-Land-Atmospheres Studies	Calverton, Maryland
ECMWF	European Centre for Medium-Range Weather Forecasts	Reading, England
GFDL	Geophysical Fluid Dynamics Laboratory Princeton	Princeton, New Jersey
GISS	Goddard Institute for Space Studies New York	New York, New York
GLA	Goddard Laboratory for Atmospheres	Greenbelt, Maryland
JMA	Japan Meteorological Agency	Tokyo, Japan
MGO	MGO Main Geophysical Observatory	St. Petersburg, Russia
MPI	Max-Planck-Institut fur Meteorologie	Hamburg, Germany
MRI	Meteorological Research Institute	Ibaraki-ken, Japan
NCAR	National Center for Atmospheric Research	Boulder, Colorado
NCEP	National Centers for Environmental Prediction	Suitland, Maryland
SUNYA	State University of New York at Albany	Albany, New York
UGAMP	The UK Universities' Global Atmospheric Modelling Programme	Reading, England
UIUC	University of Illinois at Urbana-Champaign	Urbana, Illinois
UKMO	United Kingdom Meteorological Office	Exeter, UK

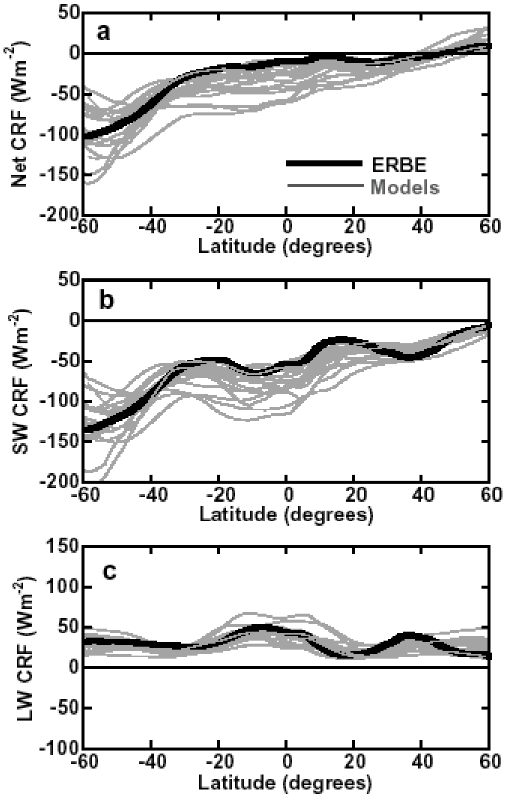

Figure 1. (a) Zonal mean Net (SW +LW) CRF for the19 GCMs compared with that for ERBE. These are for DJF and averaged over the five ERBE years (1985-1989). (b) The same as (a) but for SW CRF. (c) The same as (a) but for LW CRF

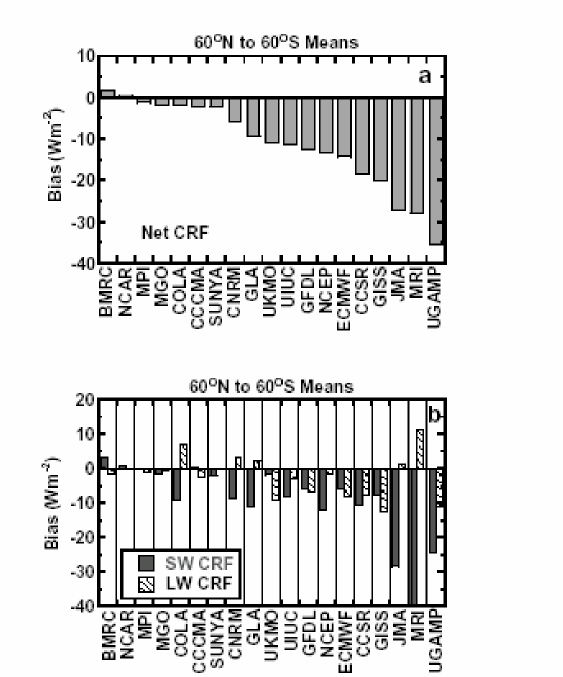

Figure 2. (a) The Net CRF biases, relative to ERBE and averaged from 60OS to 60ON, for each of the 19 GCMs. (b) The same as (a) but for SW and LW CRF.

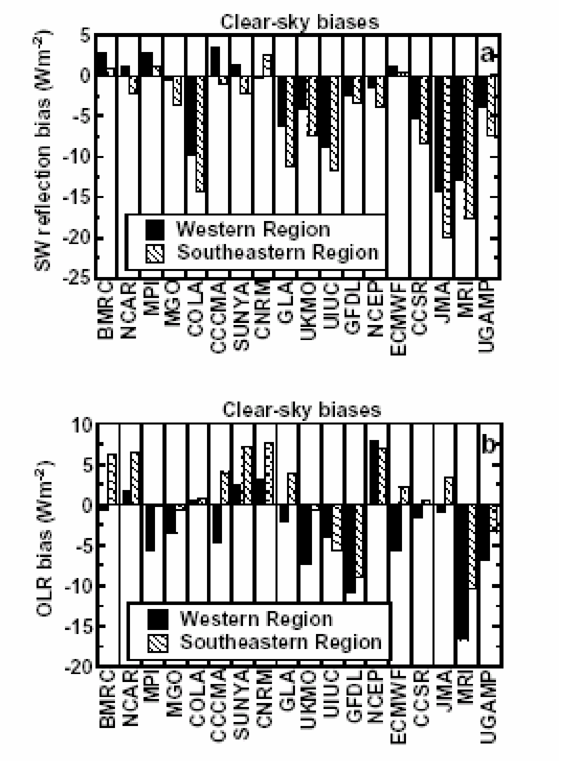

Figure 3. (a) Biases in the TOA reflected SW radiation for clear skies, relative to ERBE, for 18 GCMs. (b) The same as (a) but for the clear-sky OLR.