GCM Simulations of Clear-sky TOA Shortwave Fluxes Compared to Satellite Observations

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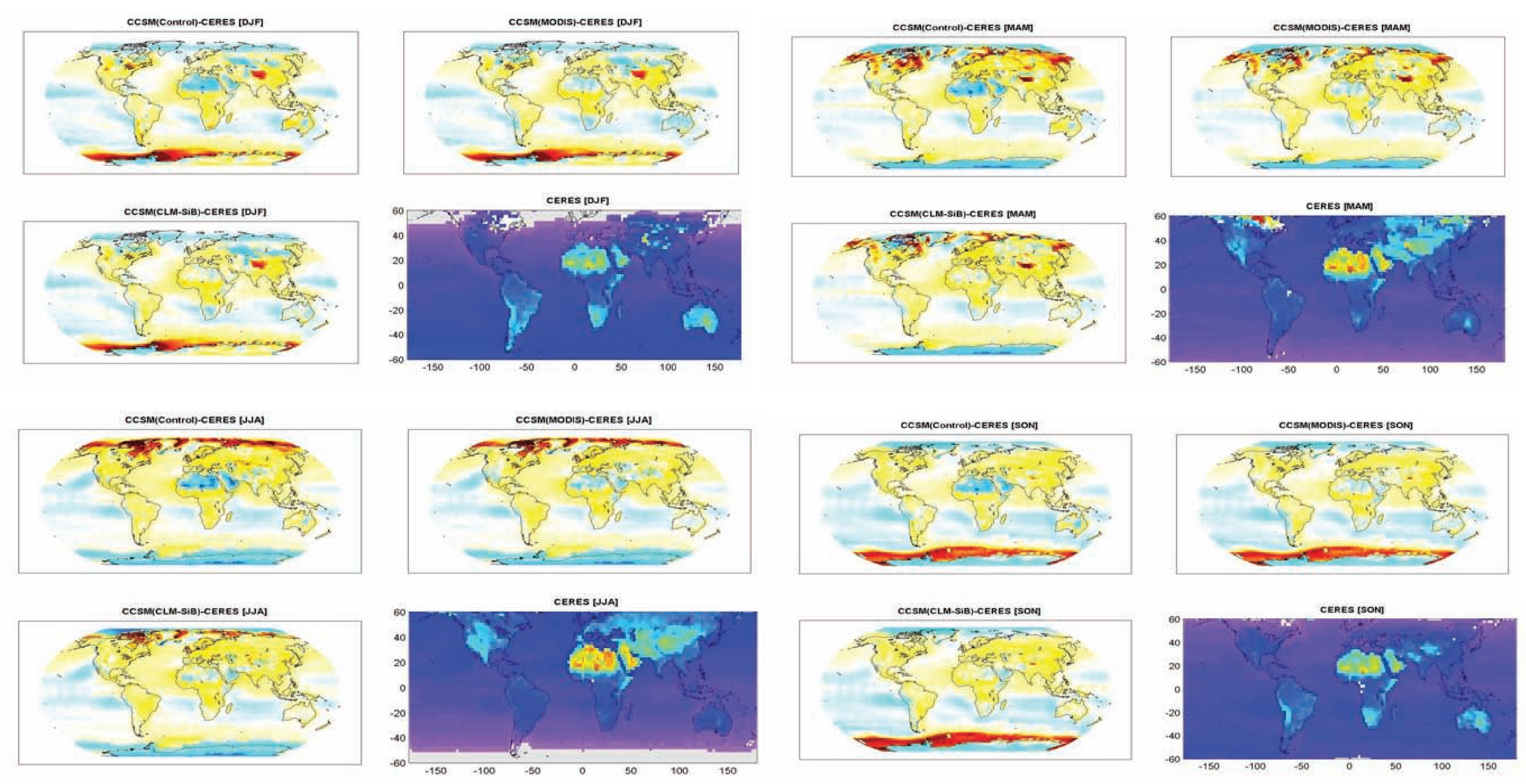
Introduction

Many of the Global Climate Models (GCM) have a positive bias in incoming and outgoing shortwave solar radiation, under both clear as well as cloudy conditions. We have examined and compared the climatology of clear-sky, upwelling shortwave fluxes at the top-of-the-atmosphere (TOA-SWF), from a suite of GCM experiments simulated using the Community Climate System Model 3 (CCSM3), against the monthly climatologies derived from Clouds and Earth's Radiant Energy System (CERES) observations. The CCSM3 (which really is CAM3 + CLM3 with climatological SST and sea ice) experiments considered include a set of three ten year climate simulations: (1) using CLM3 without any modification (CONTRL); (2) the default CLM3 land surface parameters substituted using land surface characteristics derived from MODIS observations (CLM-MODIS); and (3) CLM-MODIS in combination with SiB hydrological model (CLM-SiB).

An error model has been developed to determine the systematic biases in the model. This methodology uses in-situ measurements in conjunction with model simulations of column radiation to quantify the monthly mean error for a given location. Systematic biases in CAM3 radiative transfer parameterization are examined using observations from two ARM sites - the Southern Great Plains - Central Facility and the Niami/Niger Mobile Facility.

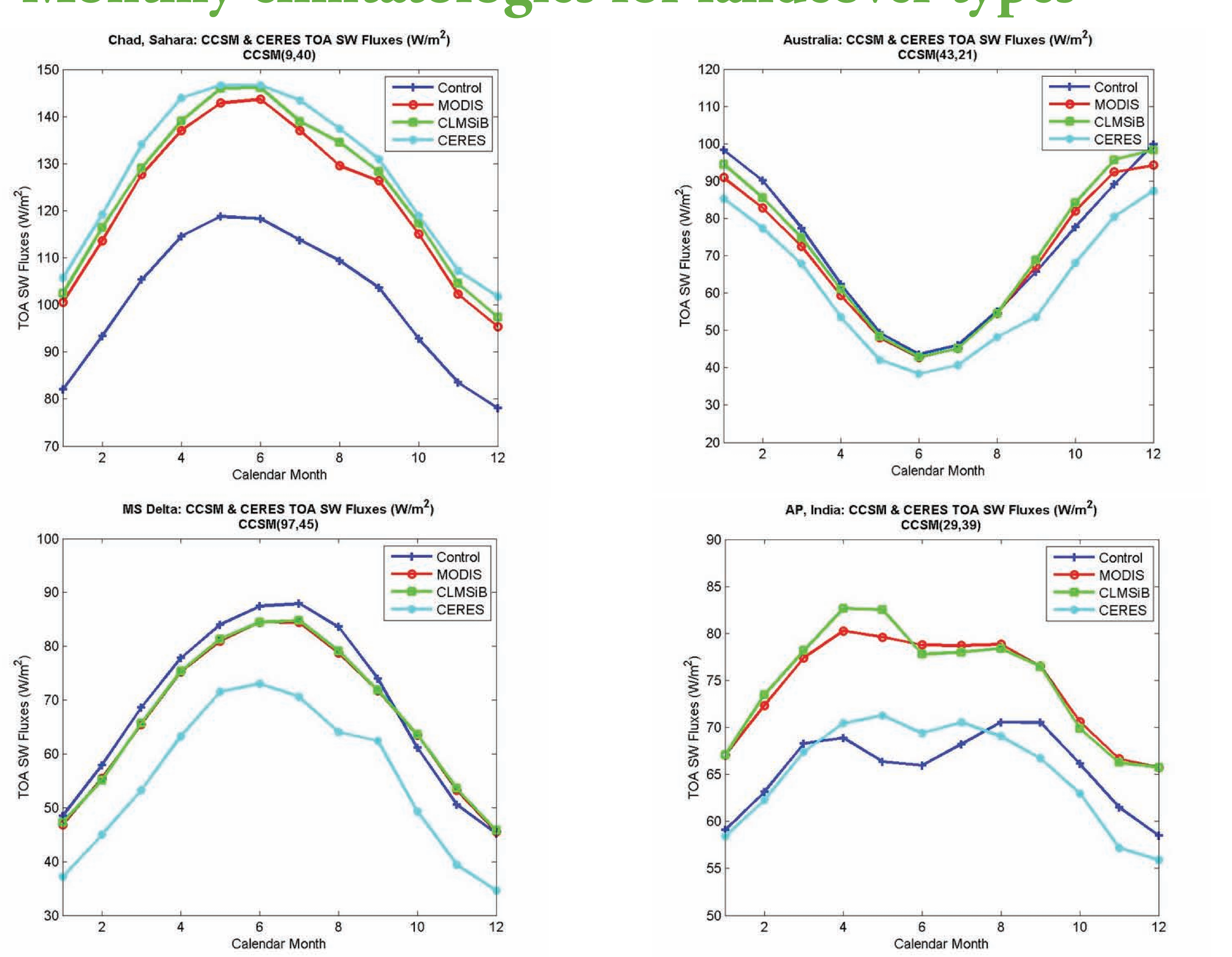
The bias correction is helpful in interpreting the results of comparing the GCM simulations against CERES observations of TOA clear-sky shortwave fluxes.

Clearsky TOA SW Fluxes



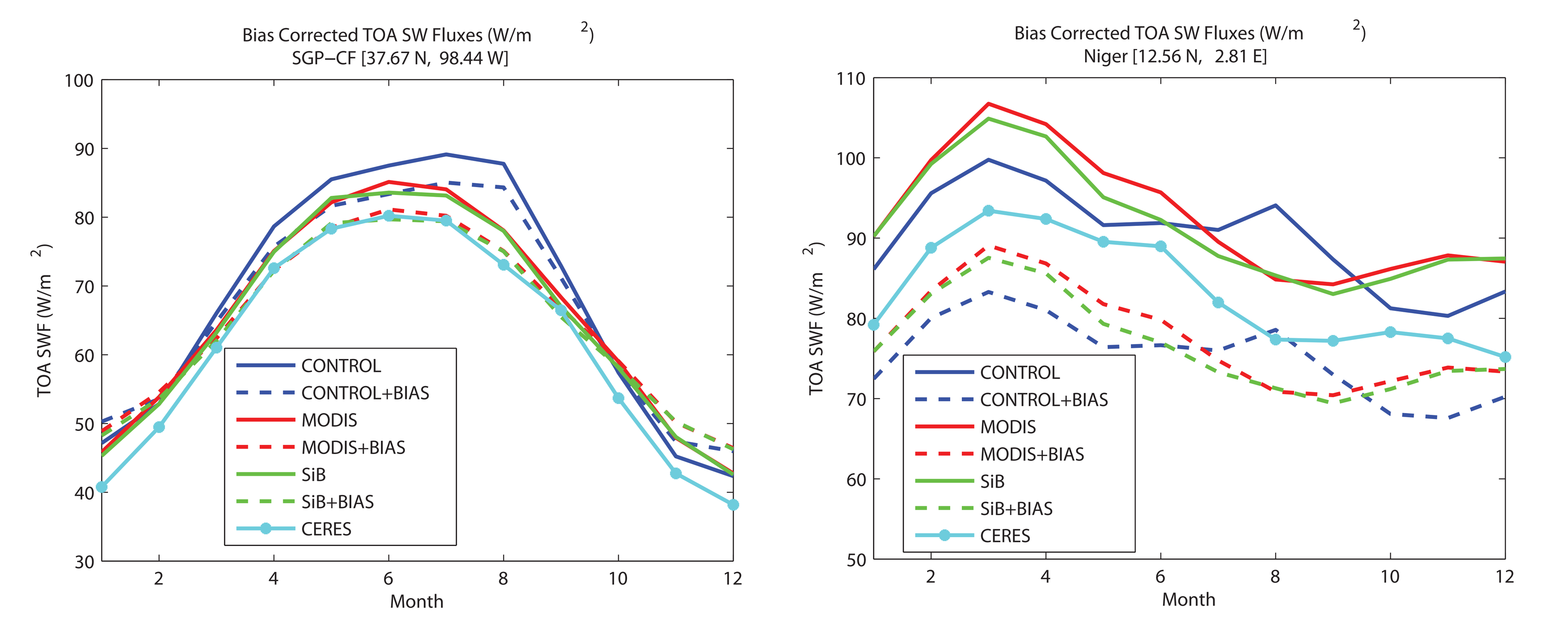
Seasonal variation of CERES observations and the differences in global averages of TOA upwelling SW flux between CCSM and CERES for current land use CONTROL, CLM-MODIS, CLM-SiB; and seasonal CERES estimates.

Monthly climtatologies for landcover types

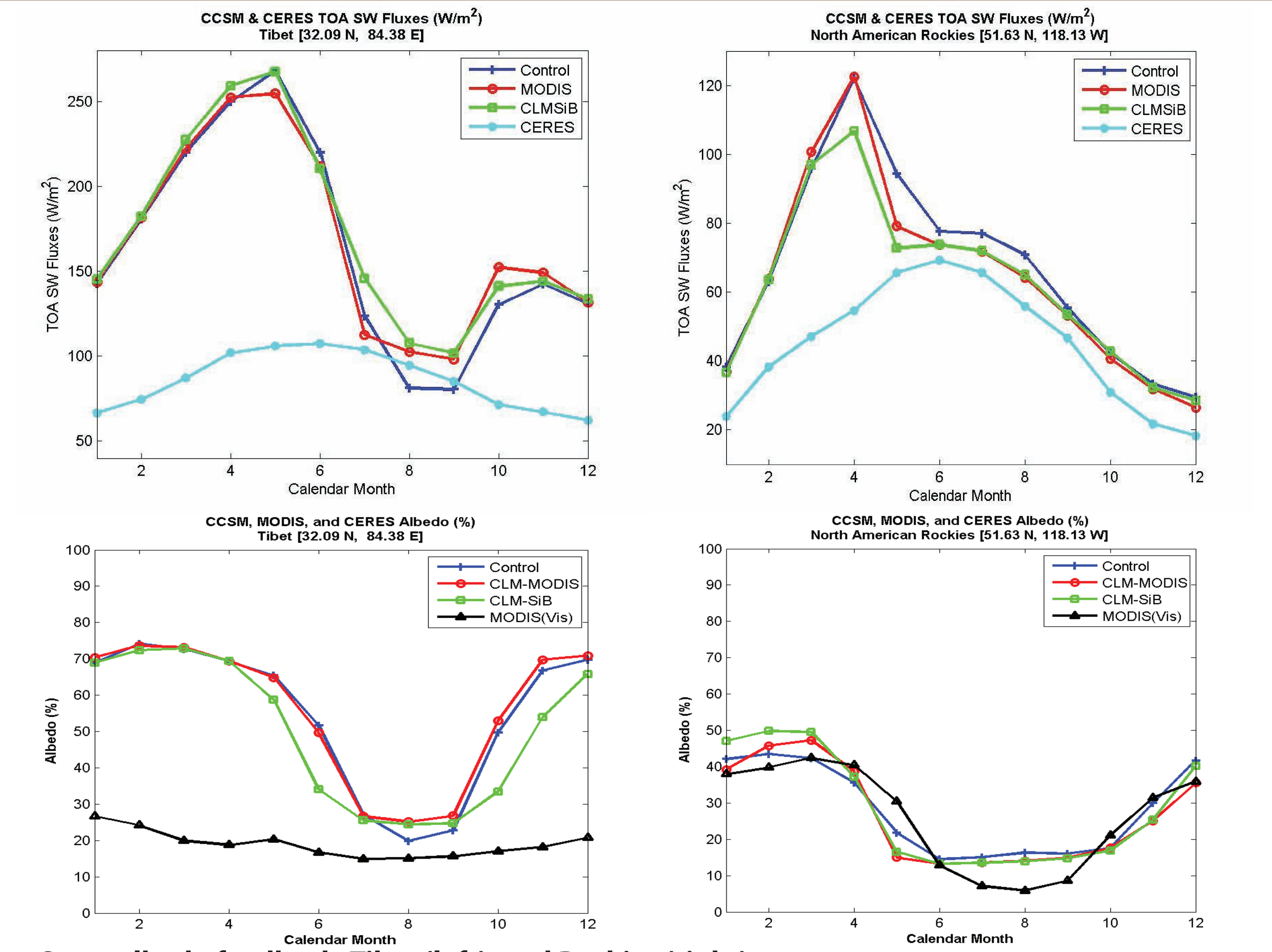


Landcover Types: Desert (Sahara) - top-left; and agriculture - top-right and bottom.

Bias corrrection using in-situ measurements



Bias corrected for systematic model errors. SGP-CF (left); and Niger/Niami (right)



Snow albedo feedback: Tibet (left); and Rockies (right)

Summary

The TOA shortwave radiation budget in GCM (specifically in CLM) can be improved through the use of MODIS-derived land surface albedo.

In comparison to CERES observations, on a global and annual average basis, all three CCSM3 experiments overestimate TOA-SWF over land and ocean areas. Regionally, CCSM3 overestimates TOA-SWF over some land and ocean areas while underestimating it over others.

Substantial differences exist between CERES observations and CCSM3 over global agricultural areas. CCSM3 significantly underestimates TOA-SWF over the Saharan and Arabian Deserts; and utilization of MODIS-derived land surface albedo to constrain CCSM3 simulation improves simulation of TOA-SWF over these regions. The seasonal impact of utilizing MODIS albedo observations can be substantial on a global average basis. Regionally the impact of utilizing MODIS albedo can be significant both on seasonal and annual time scales.

The inability of coarse resolution CCSM3 simulation to resolve spatial heterogeneity of snowfall over high altitude sites such as the US Rockies and the Tibetan Plateau causes overestimation of TOA-SWF in these areas. Use of MODIS-derived albedo does not help improve simulation of TOA-SWF at these high altitude sites.

Quantifying the systematic errors in the CCSM3 shortwave radiative transfer computations is also needed to fully analyze the impacts of the use of MODIS-derived albedo. Comparison of model simulated TOA-SWF to in-situ observations is difficult due to systematic biases that vary geographically in CCSM3.

Acknowledgments

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