2.8 GLOBAL LAND SURFACE RADIATION BUDGET AND ITS IMPACT ON WATER AND ENERGY CYCLES

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1. INTRODUCTION

The net radiation (combined shortwave and longwave) absorbed at the surface is the primary forcing of the surface water and energy cycles. However, it is one of the most misrepresented variables in general circulation models (GCMs), due to the inaccuracy in modeled cloud structure and its variation. In a GCM, errors in surface radiation budget can lead to inaccurate simulations in surface temperature, soil moisture, and surface heat fluxes. This has motivated the development of a Global Land Data Assimilation System (GLDAS) (Rodell et al., 2002), which is a joint project between the National Aeronautics and Space Administration's Goddard Space Flight Center (NASA/GSFC) and the National Oceanic and Atmospheric Administration's National Centers of Environmental Prediction (NOAA/NCEP). The concept of GLDAS is taking a GCM-constructed land-atmosphere environment, and using an un-coupled land surface scheme, forced by observations, to produce optimal fields of land surface states and fluxes.

A 1/4 degree resolution GLDAS has been implemented in near real time, using various new satellite- and ground-based observing systems. Within the GLDAS framework, two operational GCMs, namely, the NASA/GSFC GEOS (Pfaendtner et al., 1995) and the NOAA/NCEP GDAS (Derber et al., 1991), are available to provide the baseline land- atmosphere environment. Surface radiation from the GCM is then replaced by a observation-based radiation product to force GLDAS. The Air Force Weather Agency (AFWA) Real Time Neph-analysis (RTNEPH) is implemented, which is a global cloud analysis using geostationary and polar orbiting satellite observations. In RTNEPH, the observed cloud properties (cloud amount, type, and top and base heights) are reported every 3 hours globally at a 48 km resolution. Surface downward shortwave and longwave fluxes are estimated from the observed cloud properties using the radiation scheme of the AFWA AGRMET model (Shapiro, 1987). In this study we evaluate the surface radiation from the three models and investigate their impact on the consequent land surface simulation. The main purpose of this study is to understand the sources and feedbacks of the land surface water and energy cycles, thereby, contributing to the future development of land and atmosphere modeling and data assimilation systems.

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2. EVALUATION OF SURFACE SHORTWAVE FLUXES

The monthly mean, zonal averaged, land surface downward shortwave fluxes from the three models (AGRMET, GEOS, and GDAS), for July 2001, are shown in Figure 1. AGRMET and GEOS exhibit very similar patterns, except that GEOS is lower in the region between 10° S and 10° N, and is higher between 55° N and 70° N. The differences are within 10%. On the other hand, GDAS is about 10% lower than AGRMET in most of the southern hemisphere, and is about 25% lower in most of the northern hemisphere. Smaller spatial and temporal scale analysis indicates that the modeled fluxes are in agreement under clear-sky conditions. The differences in the fluxes are attributed to the differences in the modeled (GEOS and GDAS) and observed (AGRMET) cloud structures.

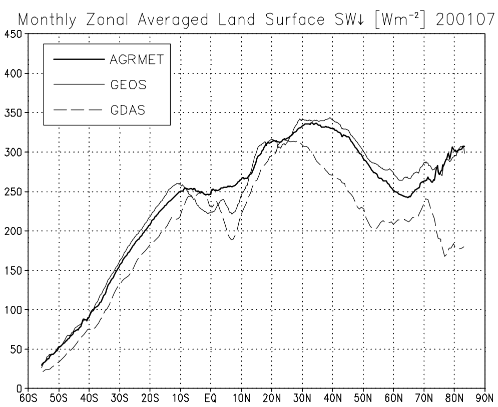

Figure 1. Monthly mean, zonal averaged, land surface downward shortwave fluxes for July 2001.

Monthly mean surface downward shortwave fluxes from the three models have been compared to the observations from the SURFRAD network. SURFRAD operates six ground stations over the continental United States to measure the surface radiation budget. The comparison results for July 2001 and January 2002 are summarized in Table 1 and Table 2, respectively. In general, AGRMET has an about 10% high bias in both summer and winter. The largest bias occurs at the site of Goodwin Creek, Mississippi (GWN), in January 2002. It is due to an underestimated fog effect, which has been improved in later experiments. Both GEOS and GDAS significantly overestimate surface shortwave fluxes in January 2002, suggesting that these two models underestimate the wintertime cloudiness.

Table 1. Comparison of modeled and observed surface downward shortwave fluxes at SURFRAD sites for (a) July 2001. Values are in Wm^{-2}.

SITE	SURFRAD	AGRMET	GEOS	GDAS
FPK	276	330	307	291
PSU	257	372	325	246
TBL	268	307	353	274
BON	275	313	269	274
DRA	340	346	362	331
GWN	257	273	256	260
BIAS		**10%**	**12%**	**0%**
RMS		**12%**	**17%**	**3%**

Table 2. Similar to Table 1, but for January 2002.

SITE	SURFRAD	AGRMET	GEOS	GDAS
FPK	55	58	77	72
PSU	74	78	102	83
TBL	104	99	133	121
BON	80	98	108	99
DRA	123	123	147	134
GWN	89	116	132	119
BIAS		**9%**	**33%**	**20%**
RMS		**15%**	**33%**	**20%**

3. LAND SURFACE SIMULATION EXPERIMENTS

To study the sensitivity of land surface processes to surface radiation, two GLDAS experiments are constructed. The first experiment is a baseline simulation, which uses the GEOS output for all the initial land-atmospheric conditions, and for all the land surface forcing. The MOSAIC model is used to calculate the land surface stats and fluxes from January 1 to March 31, 2001. The second experiment inherits all the land surface stats of March 1, 2001 from the baseline experiment. Then, the simulation continues from March 1 to March 31, 2001, using the AGRMET surface downward shortwave and longwave fluxes, while keeping the rest of the GEOS forcing.

Comparing the results from the two experiments, focusing on the continental United States, shows that the March 2001 monthly mean downward shortwave fluxes of AGRMET are about 30 Wm^{-2} lower than GEOS. The monthly mean downward longwave fluxes of AGRMET are about 25 Wm^{-2} higher than GEOS. It suggests that there are more clouds in AGRMET than in GEOS. The higher cloud amount in AGRMET reduces the downward shortwave fluxes by reflection, and increases the downward longwave fluxes by emission. The net effect during the daytime is negligible. At night, with the absence of solar energy, the higher AGRMET downward longwave fluxes show a warming effect to the surface. The differences in monthly mean surface temperature from the two experiments are of the order of $\pm$0.2 K for most of the continental United States. The largest difference appears in Idaho, where AGRMET is about 1 K warmer than GEOS. Figure 2 compares the surface temperature time series in Idaho from the two experiments. In the first half of March 2001, the daily maximum temperatures from the two experiments are about 273 K, since the surface is covered by snow. The nighttime minimum temperatures of AGRMET are about 4 K higher than GEOS, owing to the higher downward longwave fluxes. During the two-day period of March 19 and 20, the maximum temperatures of AGRMET are about 8 K higher than GEOS, indicating the difference in surface radiation leads to a different rate of snow melting.

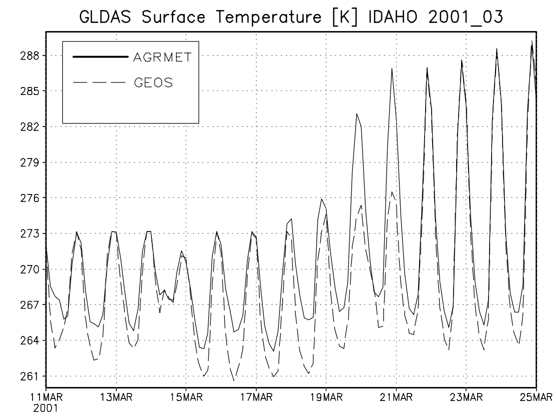

Figure 2. The comparison of surface temperature from the two GLDAS experiments over Idaho, for March 2001.

4. CONCLUSION

There is a large discrepancy between modeled land surface radiation budgets (up to 25%), due to the differences in modeled cloud structures. The impact of the different radiative forcing on the land surface water and energy cycles, namely, altering the surface heating, cooling, evaporating, and snow melting processes, can be identified from the GLDAS experiments.

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