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NEW SOLAR RADIATION PARAMETERIZATION IN CPTEC/COLA GCM

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1. INTRODUCTION

The fundamental energy source causing atmospheric motions is the solar radiation absorbed at the Earth's surface and in the atmosphere. Hence, an accurate treatment of radiation processes in general circulation models (GCM) is fundamental for long-range weather and climate forecasts.

The CPTEC/COLA GCM (Cavalcanti et al., 2002) is currently used for weather and climate forecast at the Brazilian Center for Weather Prediction and Climate Studies (CPTEC). In a previous work, Tarasova and Cavalcanti (2002) have shown that our GCM underestimates solar radiation absorption and consequently overestimates the incident solar radiation at the surface. The solar radiation scheme used follows the parameterization of Lacis and Hansen (1974). Absorption by water vapor is computed with the broadband absorption function of Yamamoto (1962) that underestimates absorption when compared with the HITRAN-96 (Rothman et al., 1998). This scheme, referenced latter as L&H, lacks atmospheric extinction due to O_2, CO_2, aerosols and water vapor continuum.

This work describes the implementation of a new shortwave radiation scheme (CLIRAD-SW-M) developed by Chou and Suarez (1999) and modified by Tarasova and Fomin (2000). This scheme, referenced latter as CLIRAD, considers the fine effects of gaseous absorption and particle scattering which are not considered in the L&H scheme.

2. THE NEW RADIATION SCHEME

A special feature of CLIRAD scheme is the inclusion of absorption due to minor absorption bands of H_2O, O_3, O_2 and CO_2. The magnitude of the absorption in these minor bands is small, but the total effect is large (about 10% of the column atmospheric heating). Absorption lines of gases are taken from the HITRAN-96 database. The scheme also accounts for the absorption and scattering of aerosol and cloud particles. The code has 8 spectral bands in the ultraviolet and visible regions and 3 bands in the near infrared. The solar radiative transfer is calculated with delta-Eddington and two-stream adding approximations. The modified code also takes into account the water vapor continuum absorption model proposed by Clough et al. (1989). This was done by changing the water vapor k-distribution functions in the 3 near-infrared bands for those proposed by Tarasova and Fomin (2000). The magnitude of the continuum absorption is about 6% of the water vapor line absorption.

Aerosol optical properties are specified as inputs to the scheme. As our GCM lacks prognostic aerosols amounts and size distributions, we introduced background aerosol following the World Meteorological Organization (WMO, 1986). At each grid point we choose from two aerosol profiles: CONT-I has a column optical depth of .22 and is chosen over all land points; and MAR-I has a column optical depth of .08 and is chosen over ocean and sea ice. This prescription has rough spatial and temporal resolutions, but allows for first-order effects of aerosols to be considered.

3. OFFLINE PERFORMANCE

The first step in the validation of the new scheme was an offline comparison with the original scheme using as reference the LBL of Fomin and Gershanov (1996). This LBL method is very accurate due to the use of a fine wavenumber grid of 1/256 cm^{-1} and of Monte-Carlo technique in the radiative transfer calculations. The grid is fine enough to resolve any spectral line.

We selected some of the standard ICRCCM cases described by Fouquart and Bonnel (1991). Two clear-sky cases were chosen that include gaseous absorption of H_2O, O_3, O_2 and CO_2 and molecular scattering. Case 33 corresponds to a mid-latitude summer (MLS) atmosphere and solar zenith angle of 30^o, and case 35 to a tropical atmosphere (TRA) and solar zenith angle of 75^o. For the cloudy atmosphere we used test cases 43 and 45, describing stratocumulus with top located at altitudes of 13 and 2 km, respectively. Both have the same optical depth of 2.8 and effective particle size of 5.25μ. For all cases surface albedo is 0.2.

Table 1 shows that the bias in the surface fluxes and atmospheric absorption values computed with the CLIRAD scheme are much smaller than those computed with the L&H scheme in both clear-sky and cloudy conditions. For the same clear-sky cases, but with CONT-I aerosol loading, the bias in incident solar radiation of the new scheme is about 1-2 W/m^2, while it is about 55-80 W/m^2 for the old scheme.

Table 1. Bias in incident solar radiation at the surface Q (W/m^2) and atmospheric absorption A (W/m^2) from L&H and CLIRAD schemes.

			Q/A	
Case	**ATM**	**SZA**	**L&H-LBL**	**CLIRAD-LBL**
33	MLS	75^o	+18/-15	0/0
35	TRA	30^o	+44/-45	+1/-1
43	MLS	30^o	+57/-36	+6/-5
45	MLS	30^o	+54/-43	+6/-8

4. GCM CLIMATOLOGY × OBSERVATIONS

The climatology was obtained by running the model for 10 years, from 1982 to 1991. Two sets of model integrations were performed, one with L&H (old) and another with the CLIRAD (new) radiation scheme. The model resolution used for the simulations was T62L28. Initial conditions are derived from NCEP-NCAR analysis. Monthly observed sea surface temperature from NOAA OI.v2 dataset (Reynolds et al. 2002) was used as boundary conditions. Albedo is predicted by the SSIB (Xue et al. 1991) over the land and is a function of solar zenith angle over the ocean. The Surface Radiation Budget (SRB) datasets (Whitlock et al., 1993) were used as reference.

Table 2 shows that the fluxes of the new model are more accurate than the old one, for both clear and all-sky conditions. Notice that while the all-sky shortwave radiation bias at the surface decreased from +26 to +7W/m^2, for the clear-sky it decreased from +20 to -2W/m^2. This is largely related to inclusion of absorption by weak water vapor lines, water vapor continuum, O_2, CO_2, and aerosols.

Table 2. Energy budget from observations (SRB) and GCM with old (L&H) and new (CLIRAD) shortwave schemes. All fluxes are in W/m^2.

	OBS	***OLD***	***NEW***
TOA SW up	102	92	96
TOA SW NET	241	249	245
SFC SW down	189	215	196
SFC SW NET	167	191	176
TOA clear SW up	55	45	47
TOA clear SW NET	288	296	294
SFC clear SW down	247	267	245
SFC clear SW NET	218	239	221

Figure 1 shows the bias between the clear-sky and cloudy solar radiation surface fluxes simulated with the new model and that provided by SRB. The clear-sky biases are less than 10 W/m^2, which is smaller than the error of clear-sky shortwave flux derivation from satellite irradiance measurements. The all-sky flux biases are about 20-40 W/m^2 and are mainly related to cloudiness.

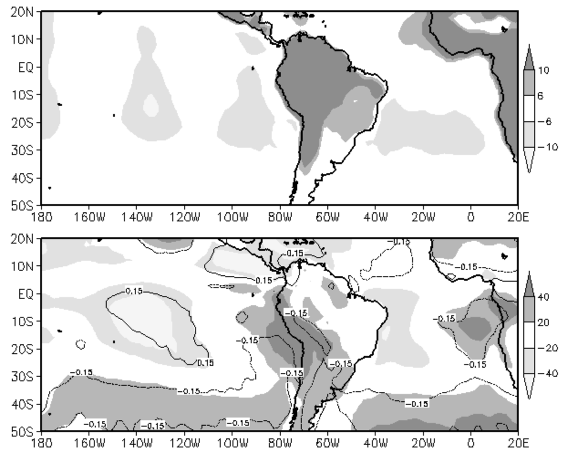

Figure 1. The bias between model (CLIRAD) and satellite-derived (SRB) fluxes, averaged from Jan84 to Dec91. Top: clear sky surface flux (W/m^2). Bottom: all-sky surface fluxes (W/m^2, shaded) and cloud cover ([0-1], contour).

The global impact on precipitation was not large, since the global average decreased from 3.5mm/day to 3.4mm/day, while GPCP satellite derived observations gives 2.7mm/day. However, there were impacts on the skill of seasonal forecasts (see Fig. 2). A larger improvement was found for the dry season and no change was found for DJF or JFM, when the excessive (lack of) precipitation over SACS (Amazon) due to the KUO convection scheme is significant.

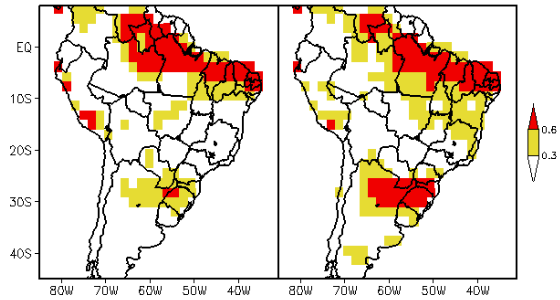

Figure 2. Skill for seasonal forecast of precipitation over South America during NDJ is shown. Old (left) and new (right) GCM results are shown.

5. CONCLUSIONS

We have shown that the CLIRAD scheme gives much better fluxes and atmospheric absorption than the L&H scheme. However, even with this new scheme, there are still biases in surface fluxes of the CPTEC/COLA GCM. This is due to the simplified representation of aerosols, poor cloud scheme and systematic errors of the convection scheme. Therefore, for further improvement of the GCM performance, a new convection and cloud schemes must be considered.

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