ANNUAL CYCLE OF CLOUD RADIATIVE FORCING OVER SOUTH AMERICA: SIMULATIONS WITH CPTEC/COLA AGCM AND SRB DATA

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RESUMO

As comparações entre os fluxos de radiação solar na superfície simulados por alguns modelos de circulação geral europeus com os fluxos medidos na superfície na Europa e África indicam que os modelos tendem a superestimar os valores de fluxos de radiação solar incidente na superfície em condições de céu claro e céu nublado. Para entender melhor as variações sazonais de impacto de nuvens sobre a radiação solar, os ciclos anuais da forçante radiativa de nuvens simulados pelo modelo global do CPTEC/COLA no presente estudo foram comparados com os dados do projeto SRB baseados em medidas de satélites. As análises foram feitas considerando 4 latitudes sobre a América do Sul e calculando a média para cada latitude. Os resultados mostram que o modelo reproduz bem as variações sazonais da forçante radiativa de nuvens que é definida como a diferença entre o saldo dos fluxos de radiação solar na superfície com céu nublado e céu claro. Entretanto há divergências entre os valores simulados e fornecidos pelo SRB que são maiores nas regiões extra-tropicais. A analise mostra a necessidade de melhorar o esquema de cobertura de nuvens e o código de radiação solar utilizado no modelo.

ABSTRACT

Recent comparisons between the surface solar radiative fluxes simulated by some European atmospheric general circulation models and fluxes measured at the Earth’s surface in Europe and Africa indicate that the models tend to overestimate incoming solar radiation in both cloud-free and cloudy conditions. In order to better understand the seasonal variation of cloudiness impact on the solar irradiance, we compare the annual cycles of cloud radiative forcing and cloud radiative forcing ratio simulated by the CPTEC/COLA AGCM with those provided by the SRB project data base in 4 latitudes over South America. It was shown that the model reproduces the main features of seasonal variations related to cloud radiative forcing and cloud radiative forcing ratio. But there are quantitative discrepancies which increase in the extra-tropical latitudes. The analysis performed herein demonstrate the need of improvements in the cloud cover scheme employed by the model as well as in its radiative transfer code.

INTRODUCTION

Comparisons between the surface solar radiative fluxes simulated by some European atmospheric general circulation models (ECHAM3 and ECHAM4 of the Max Plank Institute for Meteorology, Hamburg; ARPEGE from Meteo-France, Toulouse, and HadAM2b from Hadley Center for Climate Prediction and Research, Bracknell) and fluxes measured at the Earth's surface in Europe and Africa indicate that models tend to overestimate incoming solar radiation in both cloud-free and cloudy conditions (Wild et al., 1995; Wild and Ohmura, 1999). Probably, it is explained by the underestimation of the solar radiation absorption by the water vapor, trace gases and aerosols in the broadband radiation codes employed by the models. The errors of solar irradiance measurements also can be responsible for the discrepancies.

The results of 11-year run of CPTEC/COLA spectral AGCM were analyzed by Tarasova and Cavalcanti (2000) by comparing its surface solar radiative fluxes obtained for July and January 1986-1988 (averaged over 3 years) with the fluxes available in the Surface Radiative Budget (SRB) project data base. The fluxes were also averaged over each latitude over South America. The use of the SRB data for comparisons was related to the scarcity of the ground based solar irradiance measurements in South America. It was shown that the model simulates well the variations with latitude of both clear-sky and all-sky fluxes. Nevertheless, the systematic overestimation of both fluxes was noticed. For the all-sky fluxes the difference is from 0 W/m2 to 100 W/m2 in January and from 0 W/m2 to 30 W/m2 in July depending on the latitude. For the clear-sky fluxes the overestimation is from 20 W/m2 to 40 W/m2 in January and from 10 W/m2 to 40 W/m2 in July.

In order to evaluate the cloudiness effect on the solar radiative flux, Tarasova and Cavalcanti (2000) also compared the modeled values of cloud radiative forcing (CRF) with SRB data as well as modeled values of cloud radiative forcing ratio (CRFR) with SRB data. By its definition, the CRF at the surface is the difference of the net surface fluxes in all-sky and clear-sky conditions. The CRFR is the ratio between surface incident fluxes in all-sky and clear-sky conditions. The comparisons demonstrate that the model also reproduces well the main features of variations with latitude of cloudiness impact on the incoming solar irradiance at the surface. Nevertheless, there are quantitative discrepancies. In the tropical region the effect of cloudiness is small in July (dry season) and it increases in January (wet season). On the contrary, in the extra-tropical region the effect of clouds is larger in July (S.H. winter) than in January (S.H. summer). In order to better understand seasonal variations of cloudiness impact on solar irradiance, in this study we compare the annual cycles of CRF (CRFR) simulated by the CPTEC/COLA model in different latitudes over South America with those provided by the SRB project data base.

11-YEAR RUN OF CPTEC/COLA AGCM

The CPTEC/COLA AGCM is a modified version of the Center for Ocean, Land and Atmosphere Studies (COLA) model (Kinter et al., 1997). It was run at T42L18 resolution with the Kuo convection scheme. The shortwave radiation code of the model is based on the method of Lacis and Hansen (1974) taking into account the Rayleigh scattering, water vapor and ozone absorption as well as scattering and absorption by cloudiness. The cloud cover scheme of the model uses the parameterizations of Slingo (1987) which differ for convective cloudiness and for clouds of high, middle and low-levels. The cloud cover for the convective clouds linearly depends on the time-averaged precipitation rate provided by the convection scheme. The cloud cover for other cloud types depends mainly on relative humidity. The model was integrated for 11 years, from September 1985 to December 1996, using NCEP initial conditions of 15 September 1985. Monthly observed Sea Surface Temperatures (SST) were used as forcing boundary conditions. Other boundary conditions as soil humidity and albedo were introduced as initial climatological conditions adjusted during the integration.

SURFACE RADIATIVE BUDGET (SRB) PROJECT DATA

The SRB project database provides surface solar radiative fluxes for the period from March 1985 to December 1988 (Whitlock et al., 1993). The surface fluxes were computed with the two radiative transfer codes using as inputs the upward fluxes at the top of the atmosphere provided by the International Satellite Cloud Climatology Project (ISCCP) and the Earth Radiation Budget Experiment (ERBE) dealing with satellite measurements. In this study, we utilize data obtained with the method of Pinker and Laszlo (1992), which is the physical radiative transfer model based on the delta-Eddington approximation. It takes into account ozone and water vapor absorption, Rayleigh scattering, modeled aerosol scattering and absorption, and cloudy scattering and absorption.

RESULTS OF THE COMPARISON

We compared the monthly mean values of cloud radiative forcing (CRF) and cloud radiative forcing ratio (CRFR) averaged over the three years from 1986 to 1988. The fluxes were also averaged over the 4 latitudes (46.25°S, 31.25°S, 16.25°S, 1.25°S) for the continental region of South America excluding coastal zones. Figures 1 and 2 show the result of the comparison of CRF values. In the latitude 31.25°S the model underestimates SRB data during the whole year. In the latitude 46.25°S the model simulates well the magnitude of CRF in the winter months (from May to September) and strongly underestimates cloudiness impact in the summer months (from October to March). As a consequence the modeled annual cycle of CRF is much smoother. On the contrary, in the tropical latitudes the model overestimates the SRB data: From January to May (16.25°S) and from April to

December (1.25°S). From May to October the model's behaviour at 16.25°S is quite good. Strong seasonal variations of CRF in this latitude is explained by the change of cloud amount over Central-Southern Brazil during the dry and wet seasons. Near the equator (1.25°S) seasonal variations of both cloud amount and CRF are weaker.

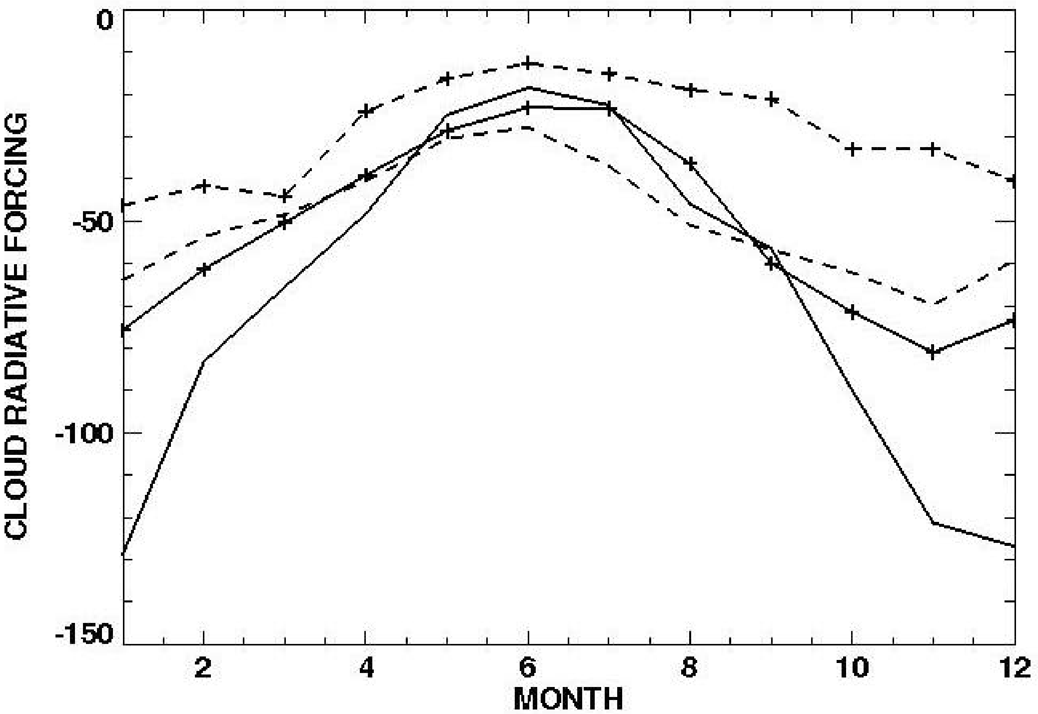

Figure 1. Annual cycle of monthly mean cloud radiative forcing at the surface averaged over the South America latitudes 46.25°S (solid) and 31.25°S (dashed) (3-year averages: 1986-1988). Plusses denote the model outputs, curves without marks show SRB data.

The magnitude of cloud radiative forcing depends not only on the cloud amount but also on such variables as solar zenith angle and surface albedo. Cloud radiative forcing ratio mainly presents the cloudiness effect on the solar irradiance. Figures 3 and 4 shows the monthly mean values of CRFR averaged over the same latitudes analyzed previously with CRF. There are similar discrepancies between the model results and SRB data. By comparing Figures 1 and 3, one can see that the strong seasonal variations of CRF in the latitude 46.25°S are related mainly to the annual cycle of the solar zenith angle while cloudiness impact presented by CRFR changes slightly during a year. On the contrary, annual cycle of CRF in the latitude 16.25°S is related to the change of cloudiness during a year (Figures 2 and 4).

CONCLUSIONS

Clouds significantly change the radiation budget of the atmosphere-surface system altering thermal conditions at the Earth's surface particularly in tropics. The representation of the monthly cloudiness impact on the solar radiation over South America in CPTEC/COLA AGCM was analyzed by comparing the simulated annual cycle of cloud radiative forcing with SRB data. The comparison of annual cycles was performed for 4 latitudes (2 in tropical region an 2 in extra-tropical one). It was shown that the model qualitatively reproduces well seasonal variations of cloud radiative forcing and cloud radiative forcing ratio. Nevertheless there are quantitative discrepancies which increase in extra-tropical latitudes. The analysis of the modeled and measured biases demonstrate the need of improvements in the cloud cover scheme of the model as well as in the radiative transfer code.

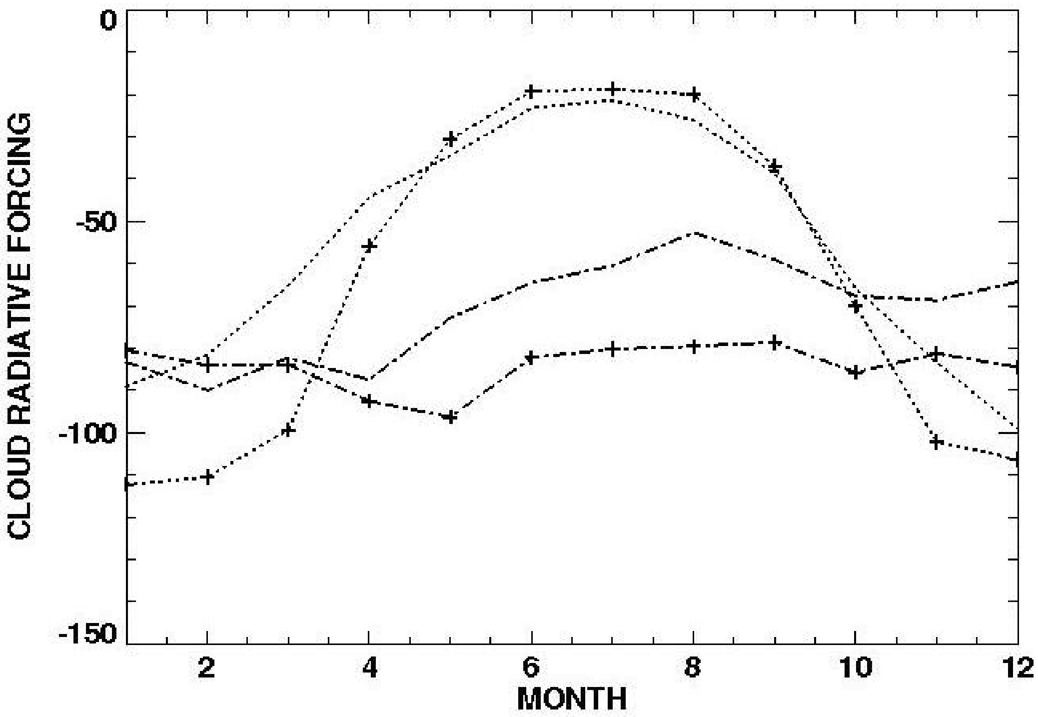

Figure 2. Annual cycle of monthly mean cloud radiative forcing at the surface averaged over the South America latitudes 16.25°S (dotted) and 1.25°S (dash dot) (3-year averages: 1986-1988). Plusses denote the model outputs, curves without marks show SRB data.

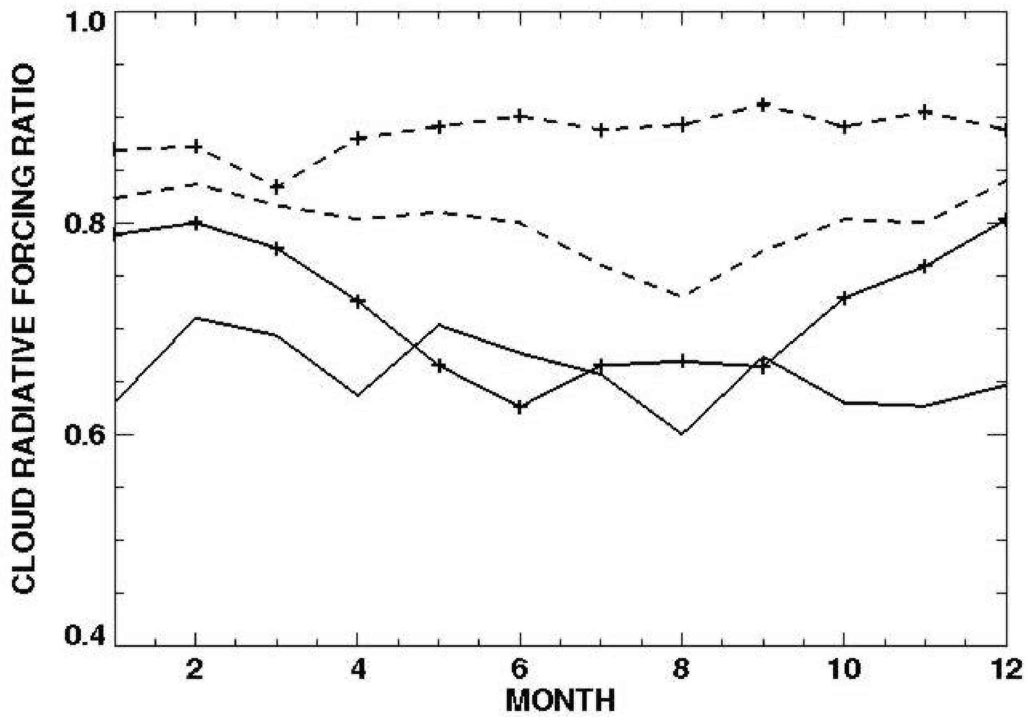

Figure 3. The same as in Figure 1 but for cloud radiative forcing ratio.

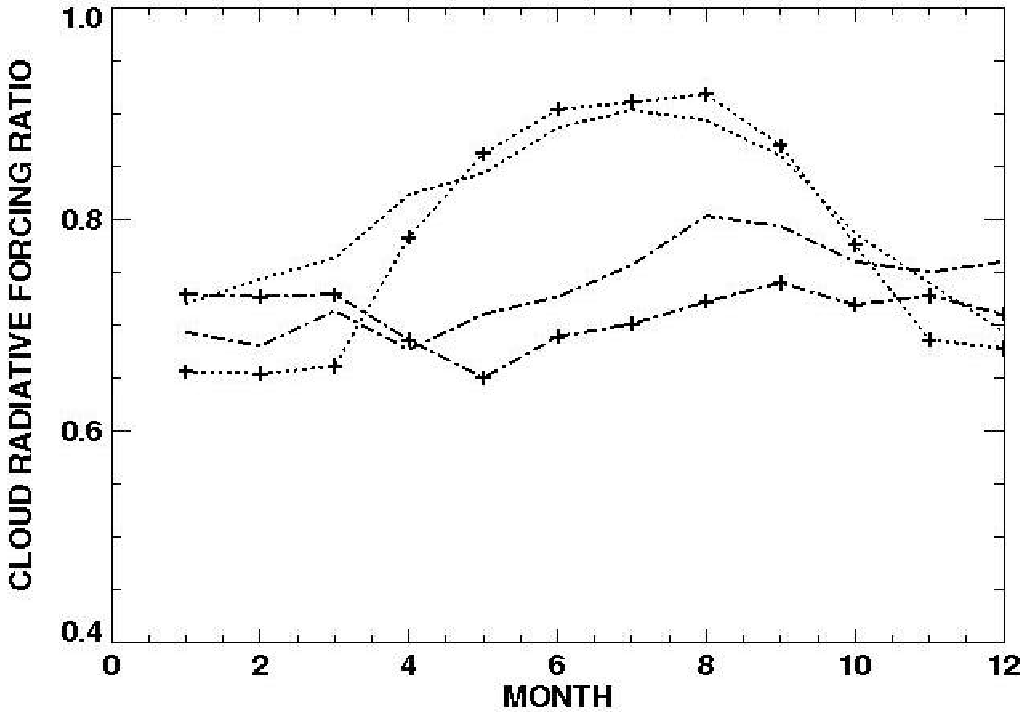

Figure 4.The same as in Figure 2 but for cloud radiative forcing ratio.

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