Performance of various radiation parameterizations in the climate version of the Eta regional model driven by reanalysis and HadAM3P

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Abstract. The climate version (Eta CCS) of the NCEP Eta model was run over South America for the period from 1979 to 1985. The two sets of boundary conditions, derived from reanalysis and from output of HadAM3P atmospheric global model, were used. The two convection schemes, three shortwave radiation schemes and two longwave radiation schemes are currently included in the model as options. The model runs were made with each optional radiation scheme. The model output fields are compared with the observational data of the CRU and GPCP projects. Here, the impact of change of shortwave radiation parameterizations on the precipitation rate is analyzed. Over the South American continent, the difference in precipitation rate associated with the change of shortwave radiation scheme is particularly noticeable over the regions of strong convective activity in austral summer. The magnitude of this difference is comparable with that related to the change of boundary conditions. In the winter months, the modeled precipitation rate is affected more by the change of boundary conditions than by the change of shortwave radiation scheme. The study demonstrates that more sophisticated radiation schemes implemented in a model not always improve model performance. The improvement can be achieved by adjustment of other physical parameterizations in the model in conjunction with its radiation schemes.

Keywords: climate downscaling, regional climate model, radiation codes for models
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INTRODUCTION

Climate dynamical downscaling [1] is a powerful method used to get small-scale climatological features from large-scale climate fields provided by coupled or atmospheric global models. The use of multiple models for the integration over the same domain allows to evaluate level of uncertainties in the simulation of climate, related to different dynamics and physics of regional models [2]. In [3] the authors present one more regional climate model Eta CCS developed for regional scale climate simulations and projections of future climate over South America (SA). To evaluate impact of different radiation schemes on the model performance is important tasks of climate model development. The impact of new solar radiation scheme on the simulation of summer climate with the Eta model running for 1.5 months was studied in [4]. The model with new shortwave radiation scheme simulates smaller monthly mean incident solar radiation at the surface due to the difference between the new and original radiation schemes. As a result of the decrease of incident solar radiation at the surface, the surface temperature decreases by $0.1-1^{\circ}$C and the precipitation rate decreases by 20-30% over most of the SA continent. In the South Atlantic convergence zone, the incident flux increases due to the decrease of cloudiness. In this study, we analyze impact of three shortwave radiation schemes on the Eta model outputs in the 5-year model runs.

ETA MODEL

The paper [5] gives detailed description of the NCEP Eta regional forecast model. The convective precipitation scheme is from [6] with modifications from [7]. Additional convective scheme [8] was implemented at the Science Operation Officer/Science and Training Resource Center (SOO/STRC) (http://strc.comet.ucar). The shortwave and longwave radiation schemes use the parameterizations [9] and [10], respectively.

In order to prepare climate version Eta CCS from the Eta forecast model, we made multiple modifications in the workstation (WS) Eta modeling package (version of 2003) developed at SOO/STRC. Our modifications include, for

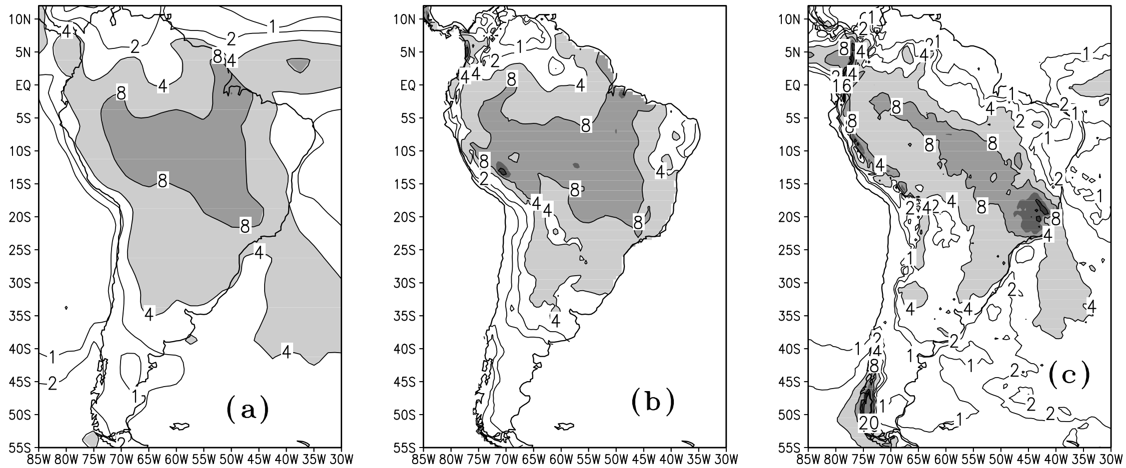

FIGURE 1. DJF mean precipitation (mm d^{-1}) averaged over 1980-1981 years: (a) GPCP, (b) CRU, (c) R2-Eta.

example, the new programs which convert the HadAM3P output data to the Eta model data format and the new restart programs. The full description of the modifications made in NCEP Eta is given in [3]. The paper also describes the results of the integration of the Eta CCS model for the current climate (1960-1990). The model runs have been also made for the future time period (2070-2100) (scenarios A and B). The outputs of these runs are currently analyzed. We implemented in the Eta CCS model (as options) the new shortwave radiation scheme (CLIRAD-SW-M) [11, 12], the shortwave radiation scheme CLIRAD(FC05)-SW [11, 13, 14] and the longwave radiation scheme [15].

INTEGRATION PROCEDURE

In the first experiment, the Eta CCS model was forced at its lateral and bottom boundary by the output of HadAM3P atmospheric global model with the original shortwave radiation code (Had-Eta), as well as with the CLIRAD-SW-M radiation code (Had-Eta(CLIRAD)) and with the CLIRAD(FC05)-SW radiation code (Had-Eta(CLIRAD-FC05)). In the second experiment (R2-Eta), the Eta CCS model was driven by the boundary conditions derived from the NCEP-DOE AMIP-II reanalysis (R2) dataset [16]. In this numerical experiment, only the original shortwave radiation code was used. The Eta CCS model updates lateral boundary conditions from the output of HadAM3P every 6 hours. Within this period a linear interpolation is used. The climate mean values of soil moisture and soil temperature were used as initial conditions. In each experiment, the Eta CCS model was run for the period from 1979 and 1985. The first year of the integration was considered as spin-up period and not considered in the analysis. The area of integration covers the territory of South American continent with adjacent oceans (55 S - 16 N, 89W - 29W). The model was integrated with the grid spacing of 37 km. The 38 eta vertical coordinate layers and the Betts-Miller cumulus convection parameterization scheme were used.

RESULTS

The output fields of the Eta CCS model are compared with the reanalysis and observational data sets. The data of Climatic Research Unit (CRU) of the University of East Anglia [17] is used for the evaluation of precipitation and surface temperature simulated by both regional and global models. The GPCP precipitation data set [18] based on the combination of satellite estimates and gauge observations are used for the evaluation of the model-generated precipitation.

First, we compared mean values averaged over 2 years (1980 and 1981) for observed and modeled precipitation for austral summer months from December to February (DJF). These months are characterized by strong precipitation in most South America (SA) east of the Andes. Figure 1 shows DJF mean precipitation from CRU and GPCP data sets and from the R2-Eta model run. Both CRU and GPCP data set reproduce precipitation maximum of 8

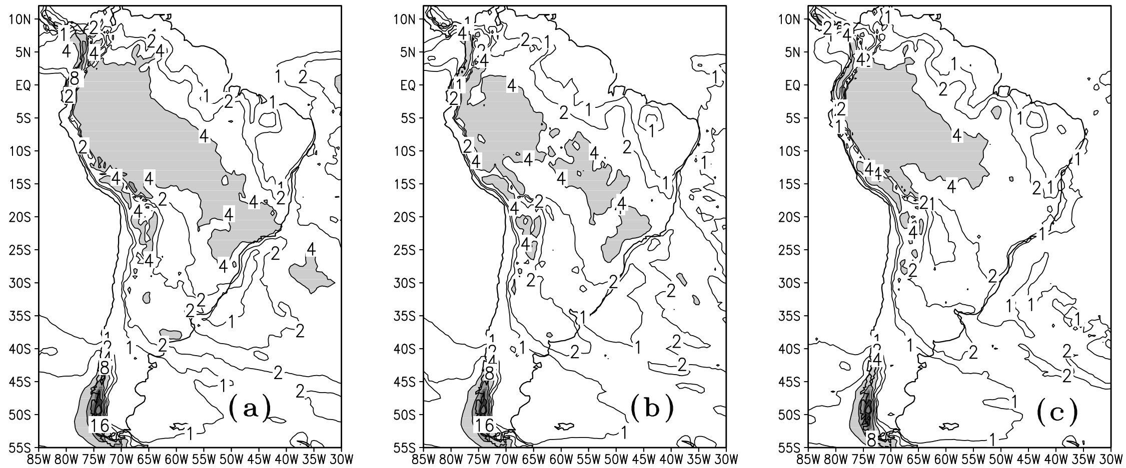

FIGURE 2. DJF mean precipitation (mm d^{-1}) averaged over 1980-1981 years: (a) Had-Eta, (b)Had-Eta(CLIRAD) , (c) Had-Eta(CLIRAD-FC05).

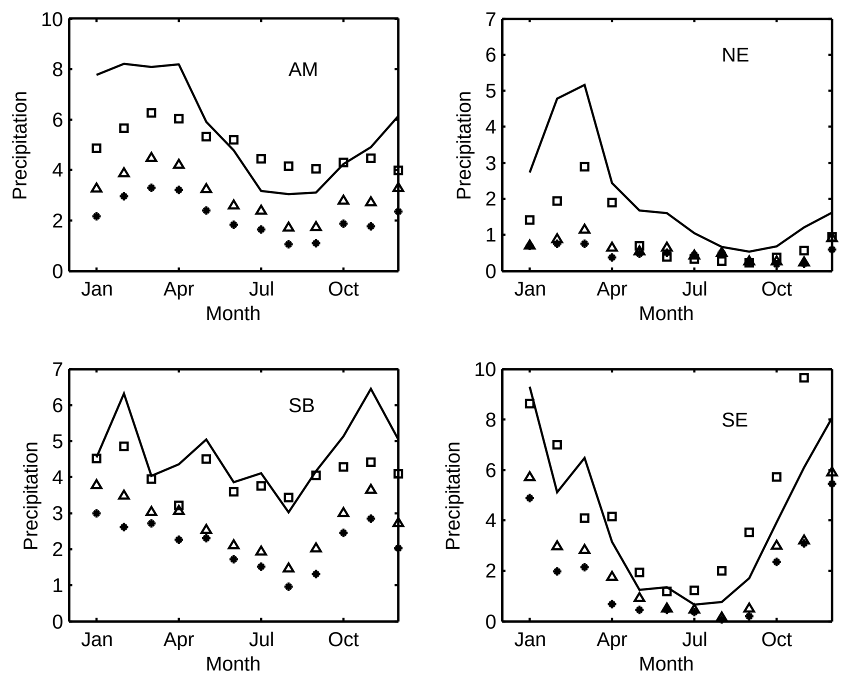

FIGURE 3. Annual cycle of monthly mean daily precipitation (mm d^{-1}) averaged over 1980-1983 years and 4 regions (Amazon (AM), North East Brazil (NE), South Brazil (SB), South East Brazil (SE)) from GPCP (solid), R2-Eta (square), Had-Eta (triangle), Had-Eta(CLIRAD) (filled circle),

mm d^{-1} associated with the South Atlantic Convergence Zone (SACZ). The R2-Eta model, which is driven by quasi-observational boundary conditions of Reanalysis II, captures this maximum over much smaller region. This model also underestimates precipitation value of 4 mm d^{-1} over northern part of the Amazon region and over central part of the SA continent. Due to the lack of cloudiness over these regions, the R2-Eta model overestimates near surface air temperature over them (not shown).

Figure 2 shows DJF mean precipitation (1980-1981) over SA simulated by Had-Eta, Had-Eta(CLIRAD), Had-Eta(CLIRAD-FC05). These models do not capture precipitation maximum of 8 $\mathrm{mm\,d^{-1}}$ and capture precipitation value of 4 $\mathrm{mm\,d^{-1}}$ over smaller region than that observed. This underestimation is related to the underestimation of precipitation rate by HadAM3P during summer months over SA (not shown). Cloudiness and precipitation over SACZ in summer has mainly convective origin. In [4], it was shown that CLIRAD-SW calculates larger absorption of solar radiation in the atmosphere and hence smaller incident solar radiation at the surface than the original code of the Eta model. As a result, convective processes are weaker in the Eta model with CLIRAD-SW (Fig. 2b) than in the Eta model with its original code (Fig. 2a). The CLIRAD(FC05)-SW calculates a little smaller incident solar radiation at the surface as compared with CLIRAD-SW [13]. Hence, convective precipitation rate is a little smaller in the simulation with Had-Eta(CLIRAd-FC05) (Fig. 2c) than with Had-Eta(CLIRAD) (Fig. 2b).

We also compared observed and model-simulated annual cycles of monthly mean precipitation rate averaged over four years (1980-1983) and over the selected regions: Amazon (AM) (12.5°S-5°N, 75°W-48.75°W), and North-East (NE) (15°S-2.5°S, 45°W-33.75°W), South (SB) (32.5°S-22.5°S, 60°W-48.75°W), South-East (SE) (22.5°S-15°S, 48.75°W-41.25°W) of Brazil. Figure 3 shows annual cycle of monthly mean precipitation rate obtained from the GPCP data set and modeled by R2-Eta, Had-Eta and Had-Eta(CLIRAD). One can see that the main features of precipitation annual cycle (for example, dry and wet seasons) are reproduced by the models. In the Amazon region, all models underestimate precipitation rate in the summer months. The difference between the precipitation rate values simulated by R2-Eta and Had-Eta (change of boundary conditions) is nearly similar to the difference between Had-Eta and Had-Eta(CLIRAD) (change of shortwave radiation code). During winter months the largest difference in precipitation values is related to the change of boundary conditions. The same is seen in the SE and SB regions. Small impact of the change of radiation scheme on the precipitation rate in the summer months in NE is probably related to the deficiencies of the convection parameterizations in this region.

We propose for use in the Eta model new shortwave radiation schemes (CLIRAD-SW and CLIRAD(FC05)-SW) that are more sophisticated than the original scheme of the Eta model. These schemes demonstrate higher accuracies than the original code of the Eta model in off line comparisons with line-by-line methods [4, 13]. The Eta model with CLIRAD-SW simulates incident solar radiation closer to observations [4]. Improvement of other meteorological variables simulated by the model depends on adjustment of other physical parameterizations in the model, such as convection scheme, land-surface scheme, etc, in conjunction with its radiation schemes.

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