P2.21

IMPACT OF UKMO'S SHORTWAVE SCHEME ON CPTEC'S GLOBAL MODEL

Júlio C. S. Chagas⋆ and Henrique M. J. Barbosa
Centro de Previsão de Tempo e Estudos Climáticos, Cachoeira Paulista, SP, Brazil

1. Introduction

The parameterization of radiative transfer in the AGCM run at CPTEC/INPE (Center for Weather Forecast and Climate Studies/National Institute for Space Research, hereafter CPTEC) since early nineties is based on the work of Harshvardhan et al. (1987). The original implementation, made at COLA (Center for Ocean-Land-Atmosphere Studies), replaced the eight-exponential-term formulation of Lacis and Hansen (1974) for shortwave water vapor absorption with the five-exponential-term formulation of Davies (1982). This reduced costs and kept column-integrated fluxes, but gave origin to non-realistic oscillations on the heating rate profiles, and the main disadvantage of this old shortwave scheme was the underestimation of the solar radiation absorbed by the atmosphere in comparison to line-by-line reference calculations (Plana-Fattori et al., 1997; Souza et al., 1997).

The climatic characteristics of CPTEC's AGCM were analyzed by Cavalcanti et al. (2002), who confirmed its deficiencies in simulating the observed radiative fluxes and highlighted the need for improvement on the radiation and cloud parameterizations. Moreover, Tarasova and Cavalcanti (2002) showed that the model systematically overestimates surface solar fluxes if compared to satellite-derived estimates.

Overestimation of solar radiation reaching the surface has been a problem for most GCMs worldwide and improvement is being gradually achieved during recent decades (Wild et al., 2006). At CPTEC, an improvement was achieved in 2004 when the eleven-exponential-term formulation of Ramaswamy and Freidenreich (1992) for water vapor shortwave absorption became operational, replacing Davies's formulation. In parallel, efforts are being made to implement and test modern radiative transfer schemes inside CPTEC's AGCM (Barbosa and Tarasova, 2006).

This paper describes some impacts of the implementation of the UK Met Office's shortwave radiation scheme (Edwards and Slingo, 1996), hereafter UKMO code, on the climatic characteristics of CPTEC's AGCM. Section 2 highlights some aspects of UKMO's code implementation. Section 3 presents results of comparisons of current (Harshvardhan et al., 1987; Ramaswamy and Freidenreich, 1992) CPTEC's shortwave radiation scheme, hereafter CPTEC code, with UKMO code and line-by-line calculations for typical atmospheric columns. Section 4 presents results of two long-term ensemble integrations of CPTEC's AGCM, one with CPTEC code and other with UKMO code, and conclusions are presented in Section 5.

⋆ *Corresponding author address*: Júlio C. S. Chagas, CPTEC/INPE, Rod. Pres. Dutra km 39, Cachoeira Paulista, SP, Brazil; e-mail: julio@cptec.inpe.br

2. UKMO code at CPTEC

The radiative transfer scheme described by Edwards and Slingo (1996) was implemented at CPTEC for shortwave calculations. A so called spectral file defines limits of spectral bands, active gases and aerosols in each band and necessary parameters for the calculation of each extinction process. The spectral file used divides the solar region in five bands weighted by the Kurucz (1995) solar spectrum.

As for gaseous absorption, the main differences between the UKMO code and CPTEC code are the use of spectroscopic data from HITRAN2000 (Rothman et al., 2003), augmented by theoretical weak water vapor lines (Zhong et al., 2001), and the introduction of atmospheric extinction due to O_2 and CO_2. Also, UKMO code includes the version 2.4 of the CKD continuum (Clough et al., 1989) while no water vapor continuum is considered in CPTEC code. Other important diferences are the inclusion of aerosol extinction and the parameterization of cloud microphysics properties.

The aerosols introduced in the model are a simplified climatology as in Cusack et al. (1998). Five types of constituents are combined to describe the two profiles of aerosols used (WMO, 1982, 1983). Aerosol profile named CONT-I is used in all columns over land and profile named MAR-I is used in all columns over oceans and ice. Each profile is composed of stratospheric, free tropospheric and boundary layer components. Table 1 shows the total amount of each aerosol type in boundary layer (over ocean and continent), troposphere and stratosphere.

The cloud microphysics properties diagnosed in the model are cloud liquid water path, cloud drops and ice cristals effective radius and in-cloud water/ice fraction. The parameterizations follows CCM3 (CCM3, 2004) and, in this way, four different types of clouds are considered: stratiform (water and ice) and convective (water and ice).

Table 1. Types of aerosols contributing to extinction in each region of an atmospheric column. BL-L: boundary layer over land; BL-O: boundary layer over ocean; Fr-Trop: free troposphere; Strat: stratosphere. Figures are approximate values of the total column aerosol in $\mathrm{kg\,m^{-2}}$.

	BL-L	BL-O	Fr-Trop	Strat
water	2.776e-5	1.075e-5	3.470e-6	0.0
dust	6.700e-5	0.0	8.375e-6	0.0
oceanic	0.0	2.043e-4	0.0	0.0
soot	9.572e-7	0.0	1.196e-7	0.0
sulfur	0.0	0.0	0.0	1.866e-6

3. Tests in one column

Before being inserted into CPTEC's global model, UKMO code was implemented in an off-line version of its radiation parameterization. The framework of Fouquart et al. (1991) was used for comparisons with the off-line version of CPTEC code, taking the results of line-by-line calculations by Fomin and Gershanov (1996) as a reference. Table 2 shows the differences in the incident solar radiation at the surface and in the solar radiation absorbed by atmosphere from reference calculations for a group of cases with scattering and absorption by H_2O, O_2, O_3 and CO_2 for different combinations of atmospheric profiles (mid-latitude summer, tropical and sub-arctic winter), solar zenith angles (30 and 75 degrees) and surface albedos (0.2 and 0.8). Recall that shortwave absorption by O_2 and CO_2 are not included in CPTEC code. It can be seen that UKMO code implementation brings CPTEC results much closer to reference values.

4. Long time ensemble integrations

Two four-member-ensemble integrations of current CPTEC AGCM at T62L28 resolution were performed for ten years (1982 to 1991), one with CPTEC code and other with UKMO code. Table 3 shows the annual global mean solar radiation absorbed at the top of atmosphere and is partition between atmosphere and surface for the two integrations. Also shown are climatological values for the old CPTEC code taken from Cavalcanti et al. (2002), mean observed values of SRB/GEWEX (Whitlock et al., 1993) for the same period, and multimodel means and standard deviations taken from Wild (2005) and Wild et al. (2006). Even though the results of Wild (2005) and Wild et al. (2006) refer to a different period of model integrations, it is instructive to take their values as representative of models' climatology worldwide.

Inspection on the figures of Table 3 reveals the successive improvements on the global mean solar radiation budgets when the old (prior to 2004) CPTEC code (Davies, 1982) was modified to the new CPTEC code (Ramaswamy and Freidenreich, 1992) and when this last one was replaced by UKMO code (Edwards and Slingo, 1996).

Figures 1 and 2 clearly show how the annual mean of the clear-sky and all-sky incident shortwave at surface are much better represented by the CPTEC's AGCM with UKMO code than with current CPTEC code. As for all-sky, there are still big differences in some regions of the globe when UKMO is used, which are smaller but follow the same pattern as in CPTEC code. A detailed investigation will be done but the differences are probably related to the

Table 2. Differences in incident solar radiation at the surface (IncSurf, $\mathrm{W\,m^{-2}}$) and solar radiation absorbed by atmosphere (AbsAtm, $\mathrm{W\,m^{-2}}$) from line-by-line reference calculations (Fomin and Gershanov, 1996) obtained with CPTEC and UKMO codes. Cases are described in Fouquart et al. (1991).

	IncSurf		AbsAtm	
Case	CPTEC	UKMO	CPTEC	UKMO
31	28.8	10.7	-23.9	-4.1
32	24.8	-7.4	-29.7	-0.9
33	11.0	7.6	-9.7	-2.2
34	14.8	7.8	-10.6	-2.1
35	34.0	12.2	-29.9	-6.6
36	29.9	-5.6	-37.4	-5.0
37	13.2	8.4	-12.5	-3.6
38	13.1	4.7	-13.4	-3.2
39	19.9	12.0	-14.9	-6.3
40	15.3	-5.3	-19.2	-4.0
41	8.0	8.3	-6.6	-3.4
42	7.6	4.6	-7.4	-3.7

Table 3. Global mean solar radiation budgets (in $\mathrm{Wm^{-2}}$) for CPTEC AGCM. Old: original model with Davies (1982) formulation; New: current operational model with Ramaswamy and Freidenreich (1992) formulation; UKMO: current model with Edwards and Slingo (1996) shortwave code; Wild05 and Wild06: figures taken from Wild (2005) and Wild et al. (2006); Obs: SRB dataset (Whitlock et al., 1993).

	Clear-sky				
	Old	New	UKMO	Wild06	Obs
TOA	296	298	290	288(2.4)	288
Atm	57	62	74	69(6.7)	70
Surf	239	236	216	219(6.2)	218
	All-sky				
	Old	New	UKMO	Wild05	Obs
TOA	249	244	243	236(6.5)	241
Atm	58	63	75	74(7.3)	74
Surf	191	181	168	162(8.4)	167

cumulus convection and cloud schemes, as pointed out by Barbosa and Tarasova (2006).

5. Conclusions

It was shown that the climatic values of shortwave fluxes for clear-sky are much better represented by the CPTEC AGCM when the current shortwave code is replaced by the code of Edwards and Slingo (1996). For all-sky, global means are greatly improved but the spatial pattern of differences from observed values remains, although less intense. As pointed out by Barbosa and Tarasova (2006), those patterns may be related to the cumulus convection and cloud schemes which have been object of investigation at CPTEC (Figueroa et al., 2006).

References

Barbosa, H. M. J. and T. A. Tarasova, 2006: New solar radiation parameterization in CPTEC/COLA GCM. *Proceedings of 8 ICSHMO*, INPE, Foz do Iguaçu, Brazil, 493–494.

Cavalcanti, I. F. A. et al., 2002: Global climatological features in a simulation using the CPTEC-COLA AGCM. *J.Climate*, **15**, 2965–2988.

CCM3, 2004: TN-420 description of the NCAR Community Climate Model. *http://www.cgd.ucar.edu/cms/ccm3/TN-420/*.

Clough, S. A. et al., 1989: Line shape and the water vapor continuum. *Atmos.Res.*, **23**, 229–241.

Cusack, S. et al., 1998: The radiative impact of a simple aerosol climatology on the Hadley Centre atmospheric GCM. *Quart.J.Roy.Metorol.Soc.*, **124**, 2517–2526.

Davies, R., 1982: *Documentation of the Solar Radiation Parametrization in the GLAS Climate Model*. Goddard Space Flight Center, NASA-TM-83961.

Edwards, J. M. and A. Slingo, 1996: Studies with a flexible new radiation code. I: Choosing a configuration for a large-scale model. *Q. J. Roy. Meteorol. Soc.*, **122**, 689–719.

Figueroa, S. N. et al., 2006: The impact of cumulus and radiation parameterization schemes on Southern Hemisphere summer climate simulated by CPTEC Atmospheric General Circulation Model. *Proceedings of 8 ICSHMO*, INPE, Foz do Iguaçu, Brazil, 1037–1040.

Fomin, B. and Y. Gershanov, 1996: Tables of the benchmark calculations of atmospheric fluxes for the ICRCCM test cases, Part II: Short-wave results. Russian Research Center “Kurchatov Institute”, Moscow, Russia, volume IAE-5990/1, 42pp.

Fouquart, Y. et al., 1991: Intercomparing shortwave radiation codes for climate studies. *J.Geophys.Res.*, **96**, 8955–8968.

Harshvardhan et al., 1987: A fast radiation parameterization for general circulation models. *J.Geophys.Res.*, **92**, 1009–1016.

Kurucz, R. L., 1995: CD-ROM 23. *Harvard Smithsonian Center for Astrophysics*.

Lacis, A. A. and J. E. Hansen, 1974: A parameterization for the absorption of solar radiation in the earth's atmosphere. *J.Atm.Sci.*, **31**, 118–33.

Plana-Fattori, A. et al., 1997: Absorption of solar radiation by water vapor in the atmosphere. Part I: A comparison between selected parameterizations and reference results. *Brazilian Journal of Geophysics*, **15**, 275–290.

Ramaswamy, V. and S. M. Freidenreich, 1992: A study of broadband parameterizations of the solar radiative interactions with water vapor and water drops. *J.Geophys.Res.*, **97**, 11487–11512.

Rothman, L. S. et al., 2003: The HITRAN molecular spectroscopic database: edition of 2000 including updates through 2001. *J.Quant.Spec.Radiat.Transf.*, **82**, 5–44.

Souza, E. P. et al., 1997: Absorption of solar radiation by water vapor in the atmosphere. Part II: Sensitivity tests with a general circulation model. *Brazilian Journal of Geophysics*, **15**, 291–305.

Tarasova, T. and I. Cavalcanti, 2002: Monthly mean solar radiative fluxes and cloud forcing over South America in the period of 1986-88: GCM results and satellite-derived data. *J.Appl.Met.*, **41**, 863–71.

Whitlock, C. H. et al., 1993: WCRP surface radiation budget shortwave data product description - version 1.1. Technical report, NASA, TM-1993-107747, 28 pp.

Wild, M., 2005: Solar radiation budgets in atmospheric model intercomparisons from a surface perspective. *Geophys.Res.Lett.*, **32**, L07704.

Wild, M. et al., 2006: Evaluation of clear-sky solar fluxes in GCMs participating in AMIP and IPCC-AR4 from a surface perspective. *J.Geophys.Res.*, **111**, D01104.

WMO, 1982: Report of the meeting of JSC experts on aerosol and climate. Technical report, World Meteorological Organization, WCP-12.

— 1983: Report of the experts meeting on aerosol and their climatic efects. Technical report, World Meteorological Organization, WCP-55.

Zhong, W. et al., 2001: The impact of new water vapour spectral line parameters on the calculation of atmospheric absorption. *Quart.J.Roy.Metorol.Soc.*, **127**, 1615–1626.

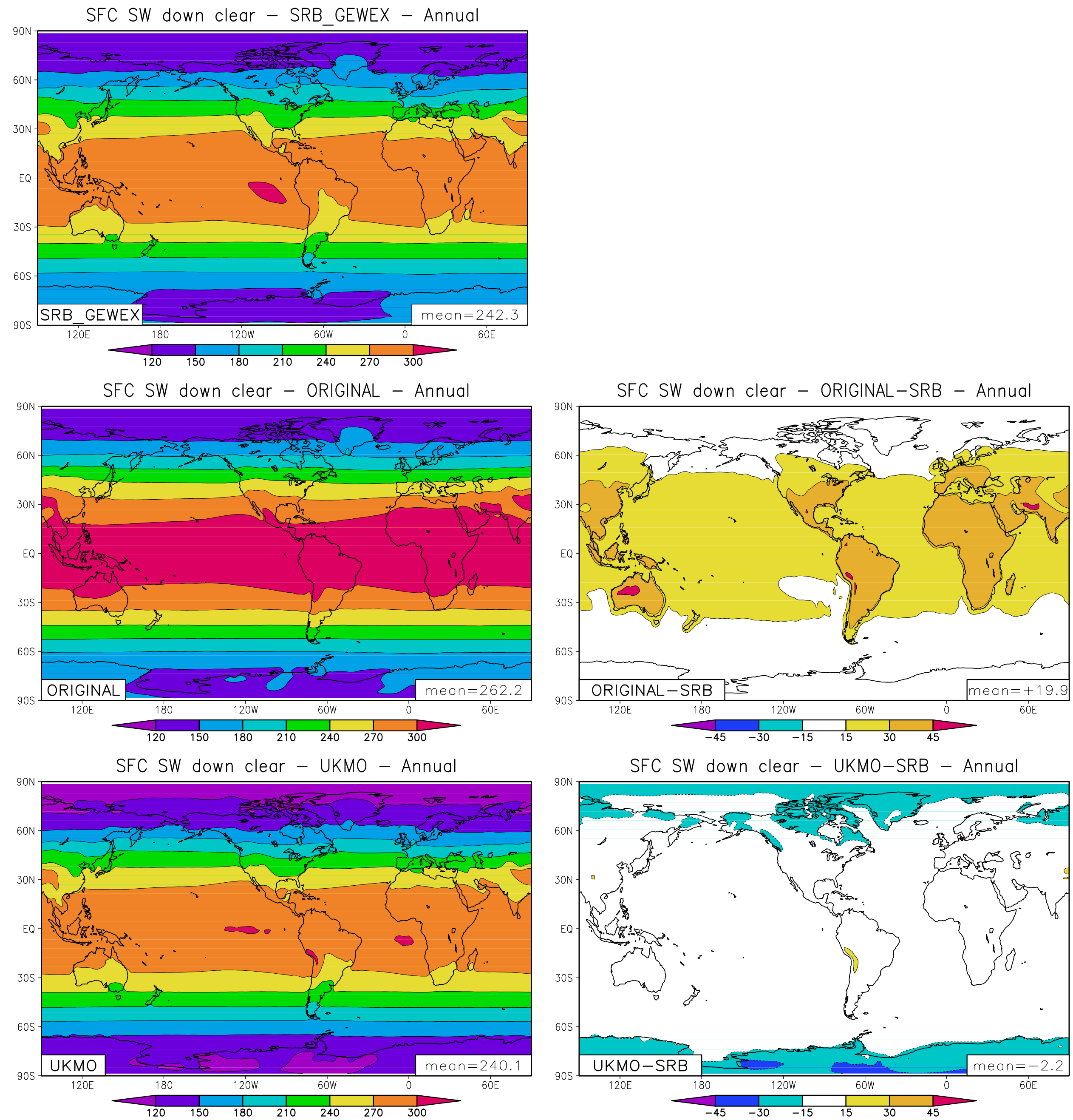

Figure 1. Annual mean of the clear-sky incident shortwave at the surface (Wm^{-2}). Top: measured by SRB/GEWEX; middle: calculated by current CPTEC AGCM and difference from SRB/GEWEX; bottom: calculated by CPTEC AGCM with UKMO short wave code and difference from SRB/GEWEX.

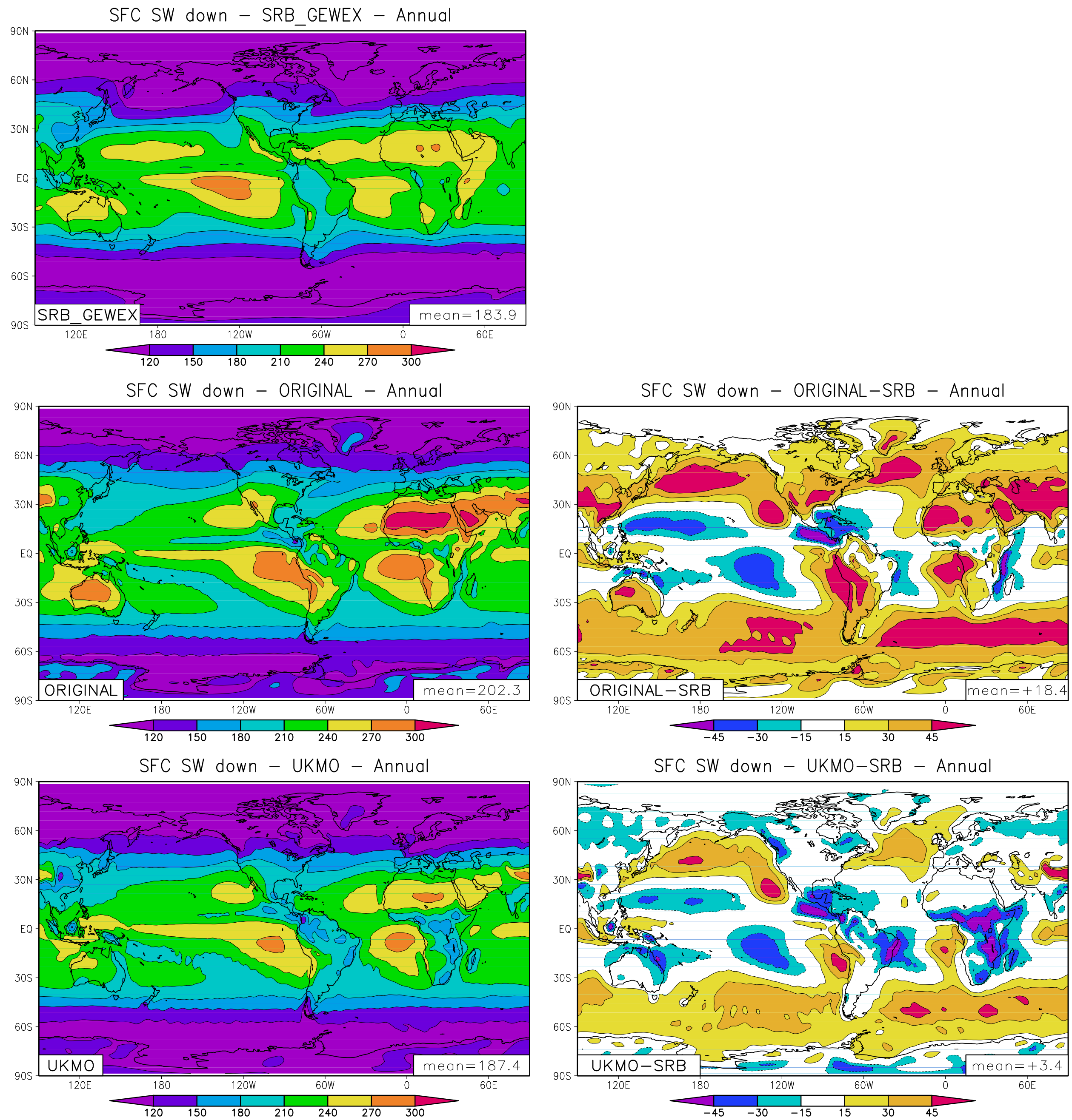

Figure 2. Annual mean of the all-sky incident shortwave at the surface (Wm^{-2}). Top: measured by SRB/GEWEX; middle: calculated by current CPTEC AGCM and difference from SRB/GEWEX; bottom: calculated by CPTEC AGCM with UKMO short wave code and difference from SRB/GEWEX.