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SURFACE RADIATION BUDGET BY USING METEOROLOGICAL SATELLITES

Jaidete Monteiro de Souza[1] e Juan Carlos Ceballos[2]
[1]Fundação Cearense de Meteorologia e Recursos Hídricos – FUNCEME
Av. Rui Barbosa, 1246 Fortaleza - CE - CEP 60115-221
e-mail: jaidete@funceme.br

[2]Divisão de Satélites e Sistemas Ambientais – DSA, CPTEC/INPE
Rodovia Presidente Dutra, Km 40, SP-RJ 12630-000, Cachoeira Paulista, SP, Brasil
e-mail: ceballos@cptec.inpe.br

Abstract

The budget between incoming radiation surface and outgoing is called Surface Radiation Budget (SRB). For the parameterization of each one of the components of the BRS they had been used given generated for satellites NOAA-16 and GOES-8. The errors of estimate of this component are of the same order of precision of the 10%. Components OLA and OLD can be of the same even pyrgeometer, or either though bigger order of magnitude or of the one than the solar radiation; however, the balance of radiation of long wave is of inferior order. In consequence, the BRS approximately presents a linear relation with the incident solar radiation. Although the balance of radiation of long wave is of second order with relation to the one of short wave, it has influence in the coefficients of the linear relation during the daylight and is essential during the nocturnal period. Therefore, the accuracy estimates of OLA and OLD continue being important.

INTRODUCTION

The budget among the radiation that arrives and outgoing the surface is called from Budget of Radiation to the Surface (BRS). The estimates of the radiative budget to the surface starting from information of satellites are plenty complex due to the interactions of the radiation with the atmosphere.

An effort is observed, along several decades, of several groups and people of different countries to estimate the radiative components and the radiative budget in the top of the atmosphere and/or to the surface. In general the researchers have been using complex codes of radiative transfer (Zhang et al. 1995; Rossow and Zhang, 1995; Garratt and Silver, 1996; among other), as well as simplified physical models and empiric approaches to esteem the radiative components (Brunt, 1932; Idso and Jackson, 1969; Brutsaert, 1975; Ceballos et al. 2004; among other.), or they accomplish analyses starting from data obtained in field experiments (Azevedo et al. 1990; Calvet and Viswanadham, 1993; Pig, 1994; Galvão 1999, Belt, 2000, Silva, 2002).

Estimate efforts tend to combine surface data with satellite information, be to complement data of the radiative budget, be to establish empiric regressions among the radiation balance in the top of the atmosphere and to the surface. These efforts have the disadvantage of just presenting results with validity place or regional. However, the existence of great areas without surface data in the case of the first ones (place) and the space and temporary variability of the atmosphere and surface in the case of the last ones (regional), it limits the application of the results strongly. Therefore, it results advisable the integral use of data of satellites for estimates of the radiation balance in any circumstances. With the coming of the meteorological satellites and in the attempt of softening the problem of the lack of information on the surface and/or atmosphere, several researchers passed to use form united remote information (obtained by satellite) and conventional information (stations to the surface) to evaluate the radiative budget to the surface and/or the radiative components separately.

DATA AND METHODOLOGY

Surface data were used obtained starting from the platforms of collections of data (PCD´s) and data obtained during the experiment LBA campaign DRY-TO-WET AMC/LBA. Also images and products of the meteorological satellites were used GOES-8 and NOAA-16 (sensor AVHRR/3 and AMSU-A), atmospheric profiles obtained by the system Advanced TIROS-N Vertical Operational Sounder (ATOVS) and processed by ICI, these supplied by the Division of Environmental Satellites of INPE (DSA/INPE).

The methodology was defined to use and to develop estimates of the radiative budget to the surface, just basing on information obtained by satellites. Matter effort was devoted to the estimate of each one of the components of the budget. The incident solar radiation to the surface was determined starting from the model GL1.2 (Ceballos et al. 2004).

The radiation of wave long ascendancy of the surface (OLA) it was dear using the Law of Stefan-Boltzamm:

$$OLA = \sigma \varepsilon T_s^4 \quad (1)$$

where is the constant of Stefan-Boltzmann (5,67 x 10^{-8} $Wm^{-2}K^{-4}$); it is the emissivity of the surface; T_s is the temperature of the surface.

To component of radiation of descending long wave it was parametized starting from theoretical analyses done with the radiative code SBDART. Did we divide the spectrum among 4 μm and 50 μm in three areas: R1 - region 1 (4 μm to 7,5 μm); R2 - region 2 (7,5 μm to 14 μm), area of the "atmospheric window" and R3 - region 3 (14 μm to 50 μm).

The regions R1 and R3 presented the same temperature skin; so that OLD in these regions can be parameterization for a single expression, so much for conditions of clear sky as in conditions of cloudiness, so that OLD_R1 and OLD_R3 they depend on the equivalent medium temperature of the thickness executes of the atmosphere. In what refers to the region R2, the parameterization is in function of the amount of water precipitable in the layers that define the height executes of this region.

Adding the contribution of the three regions, OLD to the surface can be parameterization in the following:

$$OLD = \{1 - f_{(R2)}[1 - \varepsilon_{R2}(w)]\} * \sigma * T_m^4 \quad (2)$$

where f(R2) it is the fraction of the irradiance of black body with temperature T_m, and corresponding to the region 1 or 3; Tm is the average of the temperature of the first kilometers of the atmosphere, defined for each area, εR2(w) it is the atmospheric emissivity in function of the water precipitable in the area of the atmospheric window.

Finally, basing on the parameterization of each component of the radiative budget, we used the Equation 3.

$$R_n(\sup) = \left(R_S^{\downarrow} - R_S^{\uparrow}\right)_{\sup} + \left(R_L^{\downarrow} - R_L^{\uparrow}\right)_{\sup} = R_S + R_L \quad (3)$$

RESULTS

Analyzing the estimates of GL1.2, it was observed that the model evidences an annual cycle of the monthly medium error, overestimating the medium irradiance in the months of May to September, and underestimating it other months. The hypothesis of the error be associated to the presence of aerosols of burning can be judged more easily in the Figure 1. In agreement with this figure we can notice that as larger the number of focuses of burning in the larger area the error in the model GL1.2.

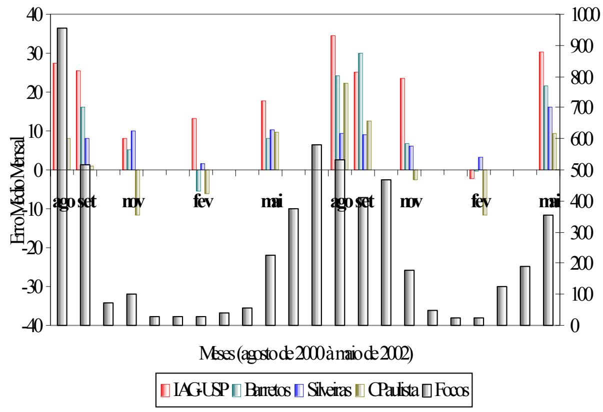

Figure 1 - Relationship between the monthly medium error and the total of burning for 4 stations of the State over Sao Paulo Brazil for August of 2002 and May of 2002.

For estimates of the radiation of ascending long wave, the Figure 2 shows comparisons among the estimates of radiation of ascending long wave obtained by satellite and the measure to the surface for September 04, 2002.

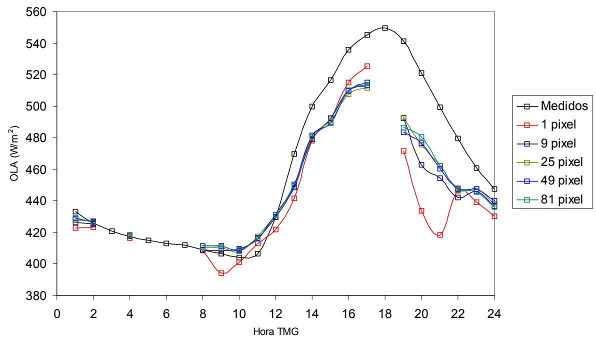

Figure 2 - Daily Cycle of the OLA. Comparisons between surface measures and satellite estimate, September 04, 2002, FNS.

The results show that the estimates are perfected during the night, and underestimated in the hour of larger heating. The balance of radiation of long wave is little variable for conditions of clear sky and cloudiness; it is waited this way that the error associated to the estimate of OLA they are compensated, or have a minimum influence. Although considered as critical procedure, there is possibility to obtain estimates of the radiation balance to the surface with acceptable levels of error. This allied factor to the difficulties of being to obtain data to validate the estimates, elimination of polluted "pixels" with clouds, among other, they represent the main limitation to the full operation of the estimate method of OLA starting from information of satellites.

The method proposed to esteem OLD using atmospheric explorations supplied by satellite presents smaller error than 20 Wm^{-2}

for conditions of clear sky and covered sky. This errors is of the same order that the radiosonde processed by satellites.

The Figure 3 illustrates the daily cycle of the dear radiative components by satellite information, in conditions of clear sky. To component OLD presents estimates just for two daily hour, that is due to the temporary resolution of the sonde generated starting from data of NOAA-16. The surface radiation budget, solar and of long wave, they are represents in the Figure 4.

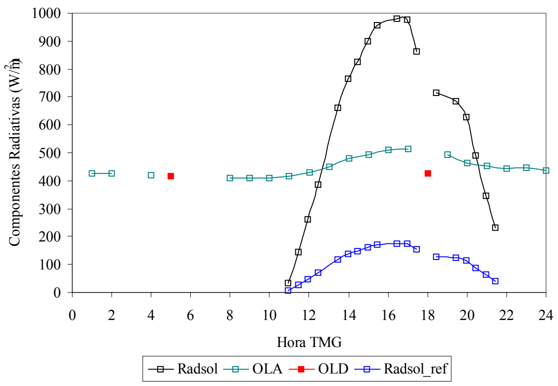

FIGURE 3 - Daily cycle of the dear radiative components for satellite for FNS, September 04, 2002, clear sky.

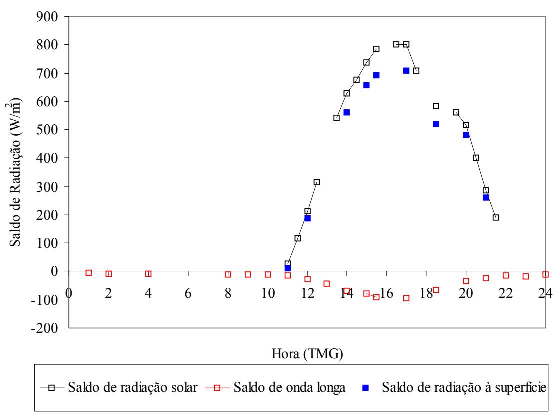

FIGURE 4 - Daily cycle of the radiation balance for satellite for FNS, September 04, 2002.

It is observed that the balance of radiation of long wave is of second order compared to the balance of solar radiation. As consequence, the radiation balance to the surface presents a relationship approximately lineal with the one of solar radiation, shown in the Figure 5. This figure was generated starting from surface measures obtained on FNS during the period of September 01 on November 05, 2002. During the period of the day the balance of long wave has influence in the coefficients of the lineal relationship, in the night period this is the only available information to determine the radiation balance to the surface. Therefore, it is important the estimate of OLA and OLD. The Figure 6 display the existent lineal relationship among the radiation balance to the surface and the solar radiation, using surface measures and estimates for satellite. The regression, in red, it was obtained starting from surface measures; in black we have the estimates for satellite. The difference among the two equation the overestimate of the model is owed GL1.2. Of this it sorts out the error associated to the radiation balance to the surface is of the same order of the error presented in GL1.2.

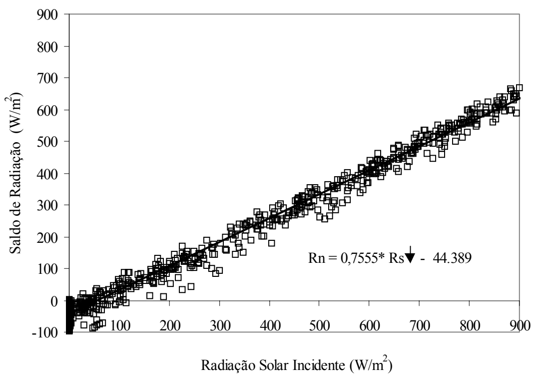

FIGURE 5 - Relationship between the radiation balance and the incident solar radiation to the

surface, September 01 on November 05, 2002, for FNS.

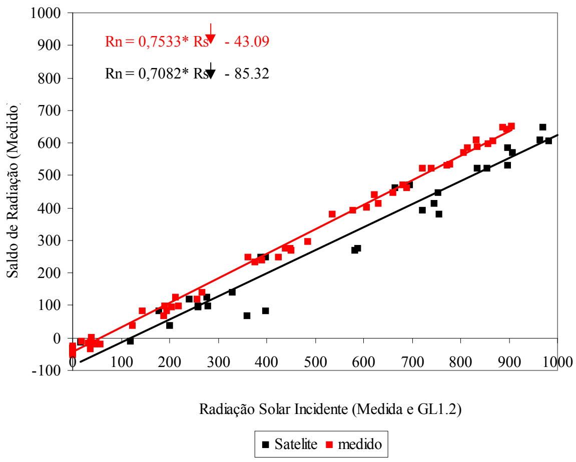

FIGURE 6 - Relationship between the radiation balance and the incident solar radiation to the surface measured and estimate for satellite.

CONCLUSION

The model GL1.2 in general supplies estimates of the daily irradiation with smaller medium error than 10 Wm^{-2} and smaller standard deviation than 25 Wm^{-2}, in atmosphere conditions with low optical thickness of the aerosols. In relation to component of radiation of ascending long wave (OLA) the surface measures indicate that this component is little variable front to variations of cloudiness (around 10 Wm^{-2} during the period of the day).

The balance of radiation of long wave varies on average among 0 to -100 Wm^{-2}, with maximum in the period of the afternoon. The clouds impede the local estimate of OLA with sensor infrared; however, when is considered the balance of radiation of long wave, effect is minimized, since the variation among to component of radiation of ascending long wave (OLA) for conditions of clear sky and with cloudiness it is of the order of 10 Wm^{-2}, and for OLD variation it is on average 30 Wm^{-2}. As a consequence of the order of greatness of the balance in long wave, the radiation balance to the surface (values corresponding to an average in half hour) it presents a relationship approximately lineal with the balance of incident solar radiation. Although the balance of radiation of long wave is of second order regarding the of wave tans, he has influence in the coefficients of the lineal relationship between the radiation balance and medium solar irradiance to the surface during the period of the day; for the night period it is the only available information to determine the radiation balance the surface. Therefore, the perfected estimates of OLAO and OLD continue being important.

In a general way we can affirm that the obtaining of radiative flows to the surface just using satellite information through simple parameterization is a viable alternative to outline the problem of the lack of direct measurements to the surface. Especially the use of satellites geostationary allows to obtain appropriate information with great temporary resolution.

However, the importance of the validation of methods should be emphasized by satellite that you/they are operational. The comparison with radiation data to the surface requests that these data are submitted to a quality control, due to the inherent difficulties of the pyranometer and pyrgeometer; the choice of the estimate method is crucial for the accurate of the results, and the filter of the clouds, when it is used sensor in the infrared. The full operational of these methods is possible, but the continuous validation is restricted due to the limitation of the surface data to validate the estimates for other periods.

BIBLIOGRAPHICAL REFERENCES

Brunt, D. Notices on Radiation in the Atmosphere. **Quarterly Journal of the Royal Meteorological Society**, v. 58, p. 389-420, 1932.

Ceballos, J. C.; Bottino, M. J.; Souza, J. M. Simple Physical Model goes Solar Assessing Radiation Over Brazil Using GOES-AND VILE Imagery. **Journal of Geophysical Research**, v. 109, No. D2, D02211, doi:10.1029/2003JD003531, 30 Jan. 2004.

Liou, K N. **An introduction to Atmospheric Radiation**. New York: Academic Press, 1980. 392p.

Ricchiazzi, P.; Yang, S.; Gautier, C.; Sowle, D. SBDART: The Research and Teaching Software Tool goes Glide-Parallel Radiative Transfer in the Earth's Atmosphere. **Bulletin of the American Meteorology Soci**ety, v. 79, n. 10, p. 2101-2114, Oct. 1998.

Souza, M. A. **Temperature of the Continental Surface: Estimate By Imagers GOES-8 and AVHRR/NOAA-14**. 2002. 117p. Dissertation (Master's degree in Meteorology) - National Institute of Space Researches, Sao José dos Campos, 2002.

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