A comparative analysis between daily cycles of shortwave radiation from CHUVA Experiments at Vale do Paraíba and Santa Maria

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The aim of this abstract is to spread the analysis of the typical daily cycle of the shortwave radiation (solar radiation) during dry and rainy days, for two campaigns. The analysis was performed using datasets from the CHUVA Experiments at Vale do Paraíba (2011) and Santa Maria (2012) sites. During those campaigns, the micrometeorological instruments for turbulent heat fluxes (sensible and latent) and the surface meteorological station (climate and shortwave radiation data) were placed, respectively, from 7 November to 22 December 2011 at Instituto de Estudos Avançados do Departamento de Ciência e Tecnologia Aeroespacial (IEAv/DCTA), located in São José dos Campos / SP; and from 7 November to 22 December 2012 at Universidade Federal de Santa Maria (UFSM), Santa Maria / RS.

For this analysis, one has considered incoming and reflected shortwave radiation data (with time resolution of 60 minutes) in order to characterize the daily radiation budget. These dataset have been collected from a micrometeorological tower, amongst air temperature, relative humidity, sea level pressure, and wind speed and wind direction data. Infrared satellite imagery (provided by INMET [Brazilian Official National Institute of Meteorology] and INPE [Brazilian National Institute for Space Research]) have aided in the identification of the meteorological conditions at the sites. All time series in the figures are in local time (LT) hours. Each day has been classified according to as follows: dry cases (rain absence; cases under conditions of clear sky or, eventually, some cloud covering), frontal cases (cases in which there is presence of frontal type rain) and also non-frontal convective cases (cases in which there was rain caused by free convection). The typical values of the radiative flux for the “dry”, “frontal” and “non-frontal convective” categories for each campaign were obtained using the function maximum value and then the average of the maximum values within each category. The actual dataset range considered in this analysis is from 07 November to 30 December 2011 (Vale do Paraíba); and from 07 November to 15 December 2012 (Santa Maria).

During the Vale do Paraíba campaign, one identified nine occurrences of rain, as follows: 11/11, 13–16/11, 22–23/11, 28/11, 01–02/12, 08-10/12, 14–15/12, 18/12 e 20/12. One then classified the days as follows: frontal cases (13-16/11, 01-02/12, 08-10/12), non-frontal convective cases (11/11, 22-23/11, 28/11, 14-15/12, 18/12, 20/12), dry cases (the remaining set). Either absence of rain and clouds or not necessarily affects the amplitude of the diurnal radiative cycle in many ways, above all in the incoming shortwave component, as one may see in Figures 1 e 2 for, respectively, November and December 2011. Figure 3 shows the precipitation time series during the 2011 campaign. The daily maximum values of shortwave radiation (incoming) – that occurs near 1200 LT in the totality of the categories – for non-frontal convective cases were approximately 650 W/m², whereas for frontal cases the values were of the order of 400 W/m², and for dry cases the typical values easily exceeded 1000 W/m². The reflected component of the shortwave radiation also has shown a decreasing tendency in the maximum values during rainy days when compared to dry cases. In rainy days, this reflected component has shown maximum values of approximately 85 W/m² for frontal cases (this quantity represents almost 21% of the incoming component value for frontal cases) and 150 W/m² for non-frontal convective cases (that is, 25% of the incoming shortwave radiation for non-frontal cases). For dry cases, the reflected component was of the order of 200 W/m² (approximately 20% of the maximum incoming quantity during dry cases). Excepting the nine rainy days formerly named, the remaining days (dry cases) has shown a typical daily radiative cycle for clear sky days, that is, maximum values of incoming shortwave radiation of the order of 1010 W/m² near 1200 HL. Eventually, slight and isolated decreases were observed along the daytime shortwave radiation cycle in response to the diurnal development of *Cumulus* clouds.

During the Santa Maria campaign, one also has identified nine occurrences of rain, as follows: 11-13/11, 19–20/11, 21/11, 23-24/11, 01/12, 04/12, 07/12, 11/12 e 12-13/12. The remarkable influence of these events of precipitation in the daily shortwave radiation cycle may be seen in Figures 4 e 5 for November and December 2012, respectively. Figure 6 shows the precipitation time series during the 2012 campaign. As in the 2011 campaign, one classified the 2012 experiment dataset as follows: frontal cases (11-13/11, 23-24/11, 07/12), non-frontal convective cases (19-20/11, 21/11, 01/12, 04/12, 11/12, 12-13/12), dry cases (the remaining set). The maximum values of the incoming shortwave radiation during non-frontal convective cases were – near 1200 HL – of the order of 400 W/m², and during the frontal cases the value were of the order of 200 W/m². Typically, such component along dry cases reached 1000 W/m² near the same time. Regarding the reflected component, its values for the dry cases were of the order of 150 W/m² (that is approximately 15% of the incoming component for such category). For frontal cases the reflected component has shown maximum values of the order of 50 W/m² (about 25% of the typical quantity of the incoming component for frontal cases), whilst for non-frontal convective cases the values were about 100 W/m² (that is almost 25% of the incoming component). Just as during the 2011 campaign, one also observed in Santa Maria some slight and isolated decreases along the diurnal cycle of the shortwave radiation during the dry cases, probably due to the presence of non-precipitating *Cumulus* clouds. One still highlights that the amplitude of both components, during non-frontal convective cases, may be strongly affected whether there was cloudiness or not since before the dawn up to the hour of maximum insolation, that occurs near 1200 HL. Such influence, observed in some cases (*e.g.*, day 12/12, Figure 5), tends to smooth the amplitude of the diurnal cycle of the shortwave radiative flux along that day. The maximum values during the frontal cases, in turn, may not be strongly affected by the cloudiness and by the rain if the main influence of the frontal system occurred after the hour of maximum insolation (that is, nighttime rain) and/or also during the advance of a weak frontal system. Such situation may be seen in the days 11-13/11 e 23-24/11 along the Vale do Paraíba campaign (shown in Figure 1).

Therefore, one may state that between the two campaigns, the rainy days have shown the lower values of maximum shortwave fluxes. And, regarding only the rainy days, the frontal cases have shown the lower quantities of incoming shortwave radiation. Such fact, as shown along the analysis, is related to the increased cloud cover – including to the multi-layer cloud distributions along the middle- and high-troposphere – and to the precipitation, since both characteristics are related to frontal systems. One still emphasize the difference between the two campaigns with respect to the maximum incoming shortwave radiation observed, in which values were lower during the Santa Maria experiment, owing to the geographic location of such site (Santa Maria is located in higher latitude than Vale do Paraíba). For dry cases, such difference was up to 25% for the reflected component and of approximately 1% for the incoming one. For the non-frontal convective cases, the difference was up to 33% for the reflected component and almost up to 38% for the incoming one. And finally, for the frontal cases, such difference was up to 41% for the reflected component and up to 50% for the incoming component.

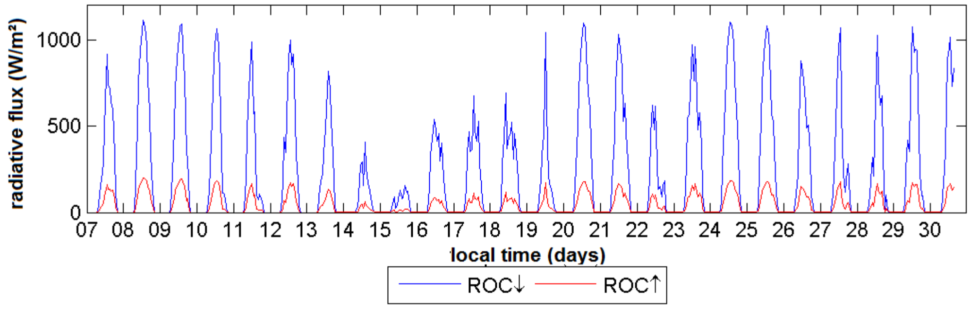

Figure 1. Shortwave radiation fluxes (W/m²) time series (ROC↓ incoming, ROC↑ reflected) from 07 to 30 November 2011, during the Vale do Paraíba campaign.

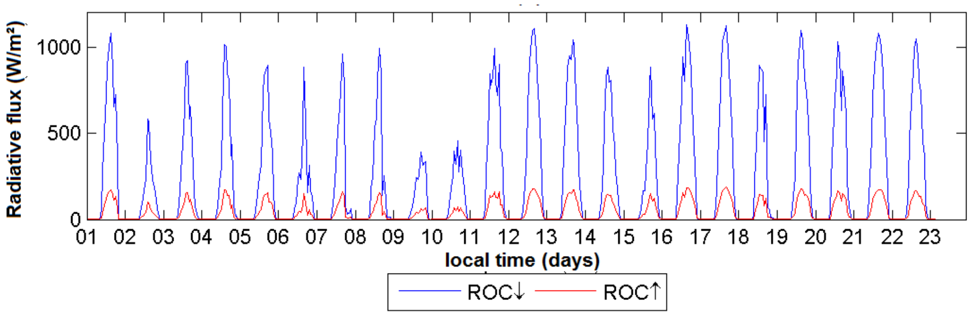

Figure 2. Shortwave radiation fluxes (W/m²) time series (ROC↓ incoming, ROC↑ reflected) from 01 to 22 December 2011, during the Vale do Paraíba campaign.

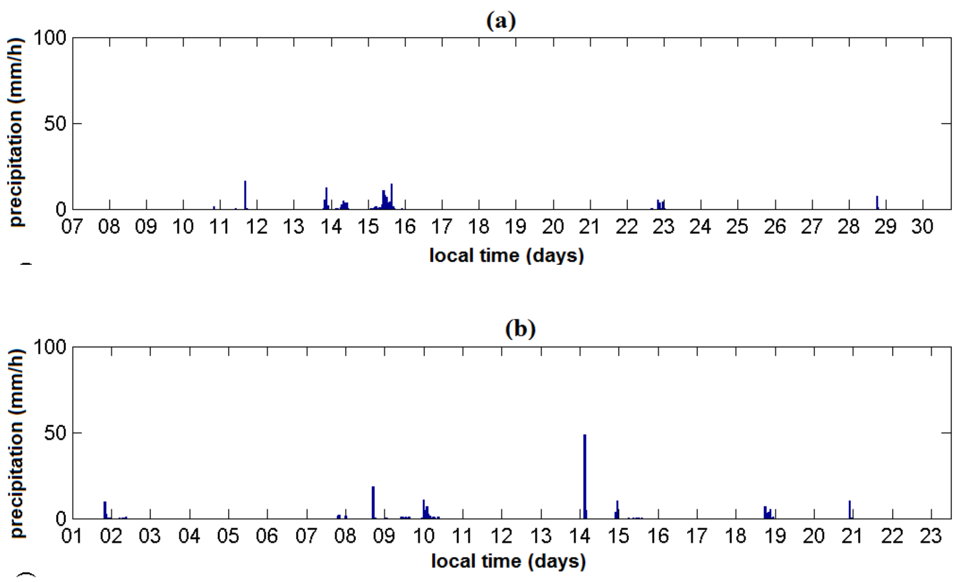

Figure 3. Precipitation (mm/h) time series (a) from 07 to 30 November 2011 and (b) from 01 to 22 December 2011, during the Vale do Paraíba campaign.

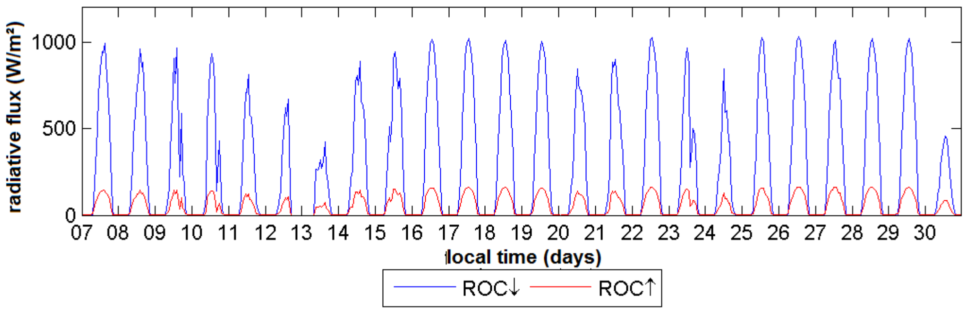

Figure 4. Shortwave radiation fluxes (W/m²) time series (ROC↓ incoming, ROC↑ reflected) from 07 to 30 Novembro 2012, during the Santa Maria campaign.

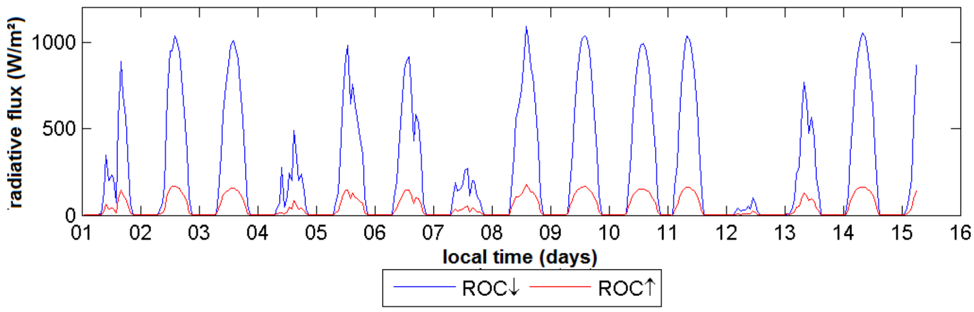

Figure 5. Shortwave radiation fluxes (W/m²) time series (ROC↓ incoming, ROC↑ reflected) from 01 to 15 November 2012, during the Santa Maria campaign.

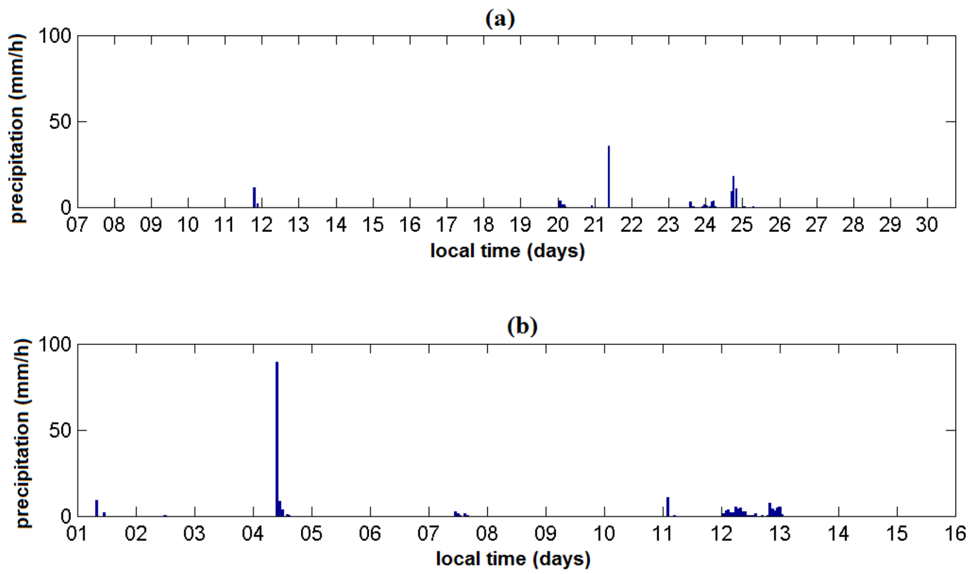

Figure 6. Precipitation (mm/h) time series (a) from 07 to 30 November 2012 and (b) from 01 to 15 December 2012, during the Santa Maria campaign.