Response to referee # 2 Comments:

Barja and Antuña (Authors)

We are very grateful for the referee´s recommendations and comments. These help us to get better this paper. In addition to our point-by-point responses to the referee's comments provided below, we also added some details in each section of the revised paper.

Specifis remarks.

Abstract

1) The first few sentences of the abstract are too general and should be moved to the introduction, if their statement is not already there. The abstract should give a condensed summary of what is done and found in the paper, but not statements like "clouds are important". It might start at "We analyze ..." (line 7). Also the last sentence is too general and can easily be made more specific. In fact, I think that the time shift from noon of the forcing maximum is the most interesting finding in this paper and should get more attention in the abstract, as the general effects (sign of the forcing and heating rate and dominance of the NIR contribution) of the cirrus clouds are not very much surprising.

Response: We agree with Referee. It was already fixed in the text. We re-organize the abstract, deleted the first sentences and add few others in the text:

"The effect of optically thin cirrus clouds on solar radiation is analyzed by numerical simulation, using lidar measurements of cirrus conducted at Camagüey, Cuba. Nature and amplitude of the effect of cirrus clouds on solar radiation is evaluated. There is a relation between the solar zenith angle and solar cirrus cloud radiative forcing (SCRF) present in the diurnal cycle of the SCRF. Maximums of SCRF out of the noon located at the cirrus cloud base height are found for the thin and opaque cirrus clouds. The cirrus clouds optical depth (COD) threshold for having double SCRF maximum out of noon instead of a single one at noon was 0.083. In contrast, the heating rate shows a maximum at the noon in the location of cirrus clouds maximum extinction values. Cirrus clouds have a cooling effect in the solar spectrum at the Top of the Atmosphere (TOA) and at the surface (SFC). The daily mean value of SCRF has an average value of -9.1 W m^{-2} at TOA and -5.6 W m^{-2} at SFC. The cirrus clouds also have a local heating effect on the atmospheric layer where they are located. Cirrus clouds have mean daily values of heating rates of 0.63 K day^{-1} with a range between 0.35 K day^{-1} and 1.24 K day^{-1}. The principal effect is in the near infrared spectral band of the solar spectrum. There is a linear relation between SCRF and COD, with -30 W m^{-2} COD^{-1} and -26 W m^{-2} COD^{-1}, values for the slopes of the fits at the TOA and SFC, respectively in the broadband solar spectrum."

Introduction

2) Page 8779, lines 4-7: More recent information about global distribution of cirrus and its optical depth might be available from the space-borne lidar CALIPSO.

Response: We agree with Referee. It was already fixed in the text. More recently work (Nazaryan et al., 2008) shows frequency of occurrence of 70 % in the tropics. Global average of frequency of occurrence of cirrus clouds of 16.7 % (Sassen et al., 2008).

Nazaryan, H., M. P. McCormick, and W. P. Menzel (2008), Global characterization of cirrus clouds using CALIPSO data, J. Geophys. Res., 113, D16211, doi:10.1029/2007JD009481.

Sassen, K., Z. Wang, and D. Liu (2008), Global distribution of cirrus clouds from CloudSat/Cloud□Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) measurements , J. Geophys. Res. , 113 , D00A12, doi:10.1029/2008JD009972.

3) Lines 10-11: the last sentence is too general; shorten and merge it with the preceding

Response: We agree with Referee. It was already fixed in the text. We merge these sentences with preceding paragraph.
"Cirrus clouds climatologies based on remote sensing measurements reveal high occurrence of cirrus clouds, both optically thick and thin cirrus clouds. Several studies have demonstrated that the global average frequency of cirrus cloud occurrence is near 27%, reaching 70 % in the Tropics (Stubenrauch et al., 2006; Nazaryan et al., 2008; Sassen et al., 2008). The considerable coverage of cirrus clouds, their high altitude and their microphysical and radiative properties emphasizes them as a key factor controlling the vertical energy distribution in the upper troposphere and the total radiation budget of the earth system."

4) Last paragraph: This is a little messy, with some results already given here. You might want to just outline the steps taken in the different parts of the manuscript.
Response: We agree with Referee. The paragraph was rewritten.

Shortwave broadband cirrus cloud radiative forcing and heating rates profiles were calculated. In section 2 we discuss the data and radiative transfer code used in the study. Also a definition and explanation about magnitudes used in the work is given. In section 3 we discuss the results about diurnal cycle of the solar cirrus cloud radiative forcing (SCRF) and heating rate. Three days are analyzed representing the three categories of optically thin cirrus clouds. Also a discussion about daily mean values of upward and downward irradiances at TOA, SFC, cloud top and base is given in this section. Finally, in section 4 we highlight the important conclusions resulting from this study.

Data and methods

5) The dataset consists of 132 lidar profiles, but only three of them are shown and analyzed here. The number 132 is misleading. Did the authors actually calculate the radiative effects of all 132 cases? If yes, they should give a statement about the statistics and how representative the chosen three examples are. If no, mentioning 132 cases gives a false impression of a good statistic that actually contains only three samples.
Response: We agree with Referee. More explanation is needed. Yes, we use 132 profiles in calculations of the radiative effects, in both daily cycle and mean values. We select this three days for saving space in the text. These three days represent the three categories of thin cirrus clouds following Sassen and Cho, (1992) classification: opaque, thin and subvisible. The statistic about cirrus clouds is given in Antuña and Barja, (2006). Frequency of occurrence of different types of cirrus clouds are 8 %, 67 % and 25 % to opaque, thin and subvisible, respectively. Opaque cirrus case selected is the optically thickest cirrus clouds measured in Camagüey with lidar, with COD 2.74. Thin cirrus case selected has COD of 0.16, in the middle of the thin cirrus COD range (0.03 – 0.3). Subvisible cirrus cloud case selected has a COD value of 0.004, with one order of magnitude lower than the upper boundary of the subvisible COD (0.03). Determination of the threshold COD value of 0.083 for the occurrence of double maximums in SCRF out of the noon instead of one at the noon is possible because we calculate the diurnal cycle for the 132 lidar profiles. We add sentences to the last paragraph in section 2.

"The downward and upward irradiances, heating rates, and cloud forcing profiles were calculated for each hour of the cirrus measurements day. It was considered that the cirrus clouds measured were present at all hours of the day, with the same characteristics. In the night hours solar irradiances zero values were considered. Thus diurnal cycles of the SCRF and heating rate for 132 profiles were derived. Three cases of diurnal cycle of cirrus clouds were selected for discussion, representing different types of optically thin cirrus clouds following the classification of Sassen and Cho, (1992). Frequency of occurrence of three types of thin cirrus clouds in the 132 cases are 8 %, 67 % and 25 % for opaque, thin and subvisible cirrus clouds respectively (Antuña and Barja, 2006). Daily means values of upward and downward irradiance at the TOA, SFC, cloud base and top were calculated from 24 h of the day with the

132 lidar profiles. Also the mean values of SCRF at TOA and SFC were calculated for each 132 day simulations, three categories of cirrus clouds and all the 132 cirrus cases”

6) It is good that the authors mention that their dataset is biased. Cases from certain conditions were chosen. It would be highly interesting to know how often those conditions occur in Camagüey. 36 days in five years is not very often. Is that how rarely such cirrus clouds can be observed in Camagüey, or are there other reasons, such as technical reasons, that led to this sparsity of measurement nights?
Response: We agree with Referee. More explanation is needed. Lidar makes measurements once per week at night around the year. The principal goal of this lidar was the detection of stratospheric aerosols, with a clear sky to the naked eye in the night. But in some cases when the measurements were interrupted by the presence of optically subvisible cirrus clouds, which were invisible to the human eye, we made the cirrus clouds measurements. Thus, a total of 136 measurements days (stratospheric aerosols measurement days plus cirrus measurement days) were conducted from 1993 to 1998. Cirrus clouds measurement were carried out in 36 days. Thus, it is a 28.3 % of occurrence. So, the dataset is biased to thin cirrus cloud observations. We add this explanation in the first paragraph of section 2.

“The cirrus clouds dataset consists of 132 individual lidar extinction profiles in 36 days of measurements from 1993 to 1998 (Antuña and Barja, 2006). Lidar makes measurements once per week at night around the year. The purpose of this lidar was to determine stratospheric aerosols backscattering profiles. Because of that constraint the measurements were conducted in conditions of clear sky to the naked eye during night, when cirrus clouds were not apparent to the human eye. But, under those conditions when mainly optically thin cirrus clouds were present in some cases we made the cirrus clouds measurements. Thus, a total of 136 measurements days (stratospheric aerosols measurement days plus cirrus measurement days) were conducted from 1993 to 1998. Cirrus clouds measurement were carried out in 36 days, with 28.3 % of occurrence. So, cirrus dataset is biased to thin cirrus cloud observations. Only a few percent of the measurements were a thick cirrus clouds. The Lidar system used a doubled frequency Nd – YAG laser (532 nm, 50 Hz, 300mJ pulse−1) and the altitude resolution is 75 m. The receiving telescope has 34cm of diameter and the field of view is 3 mrad. The cirrus measurements average 1000 laser shots (Antuña and Barja, 2006).”

7) Page 8781, lines 18-19: Shift wording to ’The "adding" technique is used to obtain vertical profiles of flux densities and heating rates.’
Response: We agree with the suggestion.

8) Lines 19-21: I do not understand the last sentence. What is compared to what? What do you mean by accuracy?
Response: More explanation is needed. This sentence is about the accuracy of the code calculation of heating rates and atmospheric absorbed flux density, compared with reference calculations. This result is reported by Freidenreich and Ramaswamy, (1999).

“Freidenreich and Ramaswamy, (1999) compare results from the code with reference calculations without cloud or aerosol, line-by-line plus doubling-adding reference computations These comparisons give errors of 10 % for heating rates, and 2 % for atmospheric absorbed flux density.”

9) "surface albedo average value of 0.22": Is this a spectrally constant value? Valid for which spectral range? The value is pretty high; I’d suppose the site is on barren ground or concrete, this would be good to specify.
Response: We agree with Referee. It was already specified in the text. The value of surface albedo is used as a spectrally constant value. It is obtained from the broadband solar measurements, conducted at Camagüey Meteorological Center for more than 40 years.

Results and discussion

10)UTC and local time are mixed in this chapter; at least state the difference between both.
Response: We agree with Referee. It was already specified in the text.

11)Page 8783, line 11: "dominant": Absorption is certainly not dominant in a cirrus, especially in broadband considerations, but it's enough here to cause heating.
Response: We agree with Referee. It was already fixed in the text.

“Although for an atmosphere almost free of clouds the scattering of the solar radiation is the predominant process in radiative transfer. In the levels where cirrus clouds are present the solar absorption due cirrus clouds becomes an important process, enough to cause this heating (Ramaswamy and Ramanathan, 1989).”

12)Line 16: "Two maximum values...": The numbers are negative, so the extrema are minima, not maxima.
Response: We agree with Referee. More explanation is needed in the text. The negative sign in the SCRF mean a radiative cooling. So, we consider the absolute value.

“Two maximum values of the broadband SCRF, considering absolute values, -200.6 W m^{-2} and -201.7 W m^{-2} are clearly seen at 9 and 15 local time (LT: UTC −05:00)…”

13)Line 18: "local time", not "local hour"
Response: We agree with Referee. It was already fixed in the text.

14)Whenever you give the times of the strongest forcing, you should also give the corresponding solar zenith angle. The extrema are symmetric around noon, so the SZA should be the same in the morning case and the afternoon case.
Response: We agree with Referee. It was already fixed in the text. In the case of opaque cirrus case the maximum arise with a SZA near to 39 degrees. Thin cirrus cases SCRF diurnal cycle shows the maxima at a SZA near to 61 degrees.

15)Page 8784, line 5: I do not understand this sentence; rephrase it to make the grammatical references clear.
Response: We agree with Referee. It was already fixed in the text.
“The difference between these two profiles is in the order of magnitude of the extinction coefficient values.”

16)Line 12: "water vapor": how much?
Response: We agree with Referee. It was already added in the text. Code uses the vertical profile of water vapor mass mixing ratio. We use a vertical profile of water vapor mixing ratio obtained from the dataset of radio sounding of the atmosphere from 1981 to 1988 in Camagüey. This aspect is explained in section 2.
“In the troposphere for pressure below 300 hPa we have a water vapor mixing ratio (dimesionless (kg/kg)) range from 0.0014 at 300 hPa to 0.0154 at near of SFC.”

17)Line 15-16: divide part 1 of this sentence (line 15) from the second part (line 16) by a dash or colon; or re-phrase it
Response: We agree with Referee. It was already fixed in the text.

“The sign of the values is negative indicative of the radiative cooling of the atmosphere. This negative sign denote that more radiation escapes the top of the atmosphere in the presence of cirrus clouds.“

18) Line 18-19: 0800 and 1700 local time: which SZA?
Response: We agree with Referee. It was already fixed in the text.

“At these times the relative solar zenith angle was near to 61º.”

19) Page 8785, line 20: "The maximum values"
Response: We agree with Referee. It was already fixed in the text.

20) Line 24: "A possible explanation": the word "possible" is inappropriate here, as it implies guessing, whereas the authors to provide calculation results in the next paragraphs
Response: We agree with Referee. It was already fixed in the text. We eliminate the word possible.

“An explanation for such a feature…”

21) Page 8786, second paragraph: In determining the threshold, the model was used with which parameters? Which cloud structure, cirrus altitude, date, minimum SZA, atmospheric structure?
Response: We agree with Referee. More explanation is needed. In determining the COD threshold we calculate the diurnal cycle for the 132 lidar profiles. We use the calculation of SCRF with each cirrus profile, with characteristics for each cirrus case and mean profiles of the atmosphere as we explain in section 2.

22) Last paragraph: Did Khvorostyanov and Sassen use the same fixed parameters in modeling the the diurnal cycle as the authors in this manuscript? How does that affect the comparability?
Response: More explanation is needed. Khvorostyanov and Sassen did not use the same parameters as we use in our work. This aspect, affects the comparability. We only made a qualitatively comparison, it is impossible to make a quantitative comparison.

3.2

23) Page 8787, line 14: "dispersion": I think you mean scattering rather than dispersion (which means something like wavelength dependence of the speed)
Response: We agree with Referee. It was already fixed in the text.

24) "at the surface" and "at TOA", not "in"
Response: We agree with Referee. It was already fixed in the text.

25) Line 22: "have a similar behavior"
Response: We agree with Referee. It was already fixed in the text.

26) Page 8788, line 1: "Figure 4a shows ..."
Response: We agree with Referee. It was already fixed in the text.

27) The authors explain the difference in downward irradiance with water vapor in the lower layers. This would be much easier to see in a spectral calculation (with a few nm resolution) which should clearly show the water-vapor absorption bands. Also, Fnet(z) might be better suited to indicate absorption below z.
Response: We agree with Referee. It was already fixed in the text. We include a table with the values of downward irradiance at TOA, SFC, cloud base and top for the different spectral bands to show this asect.

28)Line 21: "linear": this is not obvious from the log plot. Maybe add a linear fit curve to the plot?
Response: We agree with Referee. It was already fixed in the text.

29)Lines 25-29: The concentration of the radiative effect in the near infrared is clear, that is where the spectral absorption bands are.
Response: We agree with Referee. It was already fixed in the text. We add the explanation in this paragraph

Table 1. Average, maximum and minimum values of upward and downward irradiance at TOA and SFC, respectively. In the broadband, Near infrared, visible and Ultraviolet bands.

	Irradiance (W/m^2)						Solar Irradiance at TOA Percent
	Upward Irradiance TOA			Downward Irradiance SFC			
	Mean	Max	Min	Mean	Max	Min	
Solar Broadband	91.1	166.6	60.2	322.2	356.2	212.8	100
Near Infrared	37.5	82.7	22.8	160.1	177.2	106.2	55.2
Visible	42.6	68.6	29.1	140.3	154.8	92.8	36.4
Ultraviolet	11.4	15.2	8.23	21.3	24.1	13.7	8.4
	Upward Irradiance cloud top			Downward Irradiance cloud base			
	Mean	Max	Min	Mean	Max	Min	
Solar Broadband	89.6	167.2	57.7	399.5	448.6	271.3	100
Near Infrared	37.0	83.0	22.7	222.8	252.2	152.7	55.2
Visible	41.8	69.1	27.6	149.7	165.9	100.9	36.4
Ultraviolet	10.8	15.1	7.2	26.9	30.6	17.8	8.4

30)Page 8789, line 11: "ice crystal distribution represented by droplets": droplets are liquid, do you mean "spheres"?
Response: We agree with Referee. It was already fixed in the text.

Conclusions

31)Again, 132 cases are mentioned although only 3 are shown here.
Response: We agree with Referee. It was already fixed in the text.

32)Page 8791, line 10: "probably": If your finding is so weak that you have to say "probably", you should do and show more calculations of SCRF vs. SZA for a number of COD cases.
Response: We agree with Referee. It was already fixed in the text. The word "probably" is inappropriate here.

33)Figures 3-5: Replace "Infrared Band" by "Near-infrared band", and "flux" by "irradiance" or "flux density"
Response: We agree with Referee. It was already introduced in the text.