Response to referee #1

We are thankful to the reviewer for his/her useful comments that will contribute to greatly improve the manuscript. In the following, the reviewer's comments are in black and our response is in red.

The paper "CALIPSO IIR Version 2 Level 1b calibrated radiances: analysis and reduction of residual biases in the Northern Hemisphere" presents and discusses the L1b calibrated radiances of the Imaging Infrared Radiometer (IIR) onboard CALIPSO and the improvements of the new Version (Version 2). Two calibration biases revealed in Version 1 initially are addressed: a striping effect of IIR inter-channel BTD and the seasonal warm biases nighttime IIR BT. These technical issues are of critical importance for the quality of the IIR since the biases systematic contaminate the IIR channels. The paper is not only limited to addressing the issue. The paper discusses the developed methodology, the developed semi-empirical approach to deal with the discussed biases and an extended to compare between the two versions, Version 1 and Version 2, is presented. The study falls within the scope of AMT. The authors have done a thorough job and have a rigorous approach. The manuscript is well-written/structured, the presentation clear, the language fluent and the quality of the figures high. The results support the conclusions. I recommend publication in AMT, however I recommend the following minor revisions before it can proceed to be published.

Comments:

1) Regarding references, a very brief list of references is provided. I would suggest the authors to expand the list of references in order to strengthen the manuscript and at the same in order to give credit to related work. For example in the very first paragraph, at the end of line 7 (page 2) and at line 12 (page 2) suitable references should be made.

Response

At the end of line 7 (page 2), we will repeat the reference to Winker et al. (2010). We will add a reference to Stephens et al. (2017) after the reference to Stephens et al. (2012) (line 6, page 2).

At line 12 (page 2), we will add references to Weinreb et al (1997) and EUMETSAT (2012a). The computation of the equivalent brightness temperatures will be detailed in a new Sect. 2.4 (following a comment by referee #3), where we will add another reference: EUMETSAT (2012b).

To summarize, the following references will be added:

EUMETSAT: Effective radiances and brightness temperature relation tables for Meteosat Second Generarion, Rep. EUM/OPS-MSG/TEN/08/0024, 631 pp., Darmstadt, Germany, 2012a.

EUMETSAT: The conversion from effective radiances to equivalent brightness temperatures, Rep. EUM/MET/TEN/11/0569, 49 pp., Darmstadt, Germany, 2012b.

Stephens, G., Winker, D., Pelon, J., Trepte, C., Vane, D., Yuhas, C., L'Ecuyer, T., and Lebsock, M.: CloudSat and CALIPSO within the A-Train: Ten years of actively observing the Earth system, B. Am. Meteorol. Soc., doi:10.1175/BAMS-D-16-0324.1, in press, 2017.

Weinreb, M.P., Jamieson, M., Fulton, N., Chen, Y., Johnson, J.X., Bremer, J., Smith, C., and Baucom, J.: Operational calibration of Geostationary Operational Environmental Satellite-8 and -9 imagers and sounders, Applied Optics, 36, 6895-6904, 1997.

2) Page 2, line 8: please provide a more detailed description of the wavelength bandwidths used in IIR1, IIR2 and IIR3.

Response

The IIR spectral response functions will be shown in a new Figure 1 which will be introduced in Sect. 2.1 where the IIR instrument is described. Below is this new figure:

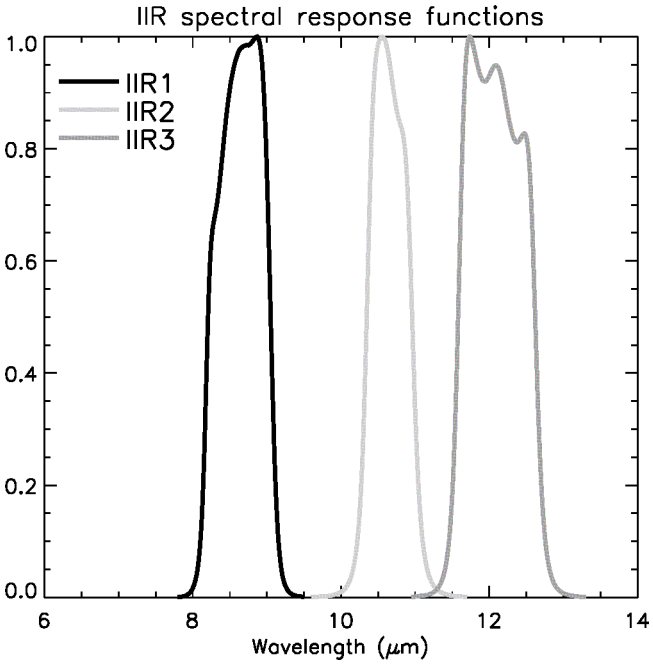

Figure 1: Spectral response functions in IIR channels IIR1 (black), IIR2 (light grey), and IIR3 (dark grey).

3) Page 2, line 23: At this point the striping effect is introduced for the first time the manuscript. Although the stripping effect is well established and properly explained and presented, this is done later on in the manuscript, leaving a reader to wonder in the early stages of the manuscript. In that case it would be beneficial for the manuscript to provide at least a brief description of this crucial problem at an earlier stage of the manuscript, maybe through simple referencing to Figure 1.

Response

We will add a brief description and referencing to Sect. 3.1 where the striping effect is presented and illustrated. The text will read as follows:

"Nevertheless, a striping effect was noticed soon after launch over homogeneous scenes (Trémas, 2006; Scott, 2009). The striping effect ***refers to the presence of stripes in images of IIR inter-channel brightness temperature differences (BTDs) as presented and illustrated in Sect. 3.1****."*

4) The biases of the IIR are revealed mainly in the geographical domain between 30o N and 60o N. Although the biases, the developed methodology and the improvements are extensively discusses it is not clear the geographical reasons why the IIR channels are contaminated in this domain. I wonder whether the authors can provide an explanation

regarding the underlying biases, the causes of the geographical preference in the biases.

Response

In the introduction, we will clarify that this study was motivated by the observation of biases only in the Northern Hemisphere and that we are searching for possible sources of biases in the Northern Hemisphere. Thus, the text at lines 4-6, page 3 will be:

"Both the striping effect and the warm biases in the nighttime IIR calibrated radiances were seen typically ***only*** *north of 30° N. These two issues have motivated a detailed examination of the IIR internal calibration procedure and the search for possible sources of biases* ***in the Northern Hemisphere****."*

In Sect.4, we find calibration biases that are functions of IIR cycle number, which is counted from elapsed time since night-to-day transition. The geographical areas corresponding to the affected IIR cycles result from the season-dependent relationships between IIR cycle number and latitude shown in Fig. 3 of the submitted manuscript (this figure will be Fig. 2 in the revised manuscript). This is discussed in Sect. 4.1 (lines 10-17, page 7), briefly in Sect. 4.2.1 (line 1, page 8), and more explanations will be added in Sect. 4.2.2 (see comment # 7 about the hysteresis effect).
In Sect. 5.3 about the Version 2 correction coefficients, we will add the following sentence after line 16 page 11:

"The Version 2 corrections are between cycles # 46 and #85, in season-dependent portions of the orbits (Fig. 2) that are always located in the Northern Hemisphere."

In the conclusion, we will clarify by modifying the text as follows around lines 6-8, page 14 :

"Because of the season-dependent relationship between cycle number and latitude (Fig. 2), these calibration errors ***were affecting season-dependent latitude ranges always located in the Northern Hemisphere. The calibration errors were detected in the summer months (June/July), because the impacted latitude range was such that they*** *induced a hysteresis effect in the IIR-MODIS BTDs in the Northern Hemisphere."*

5) Page 3, line 1: The authors state that "the analyses revealed that this phenomenon originates from IIR and is due to warm biases in Version 1 nighttime IIR brightness temperatures in this latitude range". Please provide some more information regarding the analysis and how did the authors reach the conclusion that it is due to the warm biases in V1.

Response

A reference to G17 will be added as suggested by referee #3, as well as a referencing to Sect. 3.2. The text will read :

"Analyses revealed that this phenomenon originates from IIR and is due to warm biases in Version 1 nighttime IIR brightness temperatures in this latitude range ***(G17). These analyses are summarized in Sect. 3.2****."*

6) Page 4, line 21: The authors state "by averaging digital counts from the eight or nine surrounding DS views". If it is possible provide a more detailed description when and why sometimes the number is 8 and when 9, along with references.

Response

We tried to clarify by changing the text to :

"The internal calibration consists in calibrating each pixel of each individual Earth view image by using surrounding DS and BB views (see Table 1). For each channel, and for each pixel in a row (i) and in a column (j) of an individual 64x64 Earth view image in a sequence s, the raw digital counts $X_E(i,j,s)$ are calibrated as follows. First, $X_E(i,j,s)$ is corrected for the offset measured during surrounding DS views. Then, the corrected raw digital counts are converted into calibrated radiances through the gain, $\overline{G}(i,j,s)$. Thus, the calibrated radiance R(i,j,s) in units of $W.m^{-2}.sr^{-1}.\mu m^{-1}$ is written as ***(Trémas, 2006)****:*

$$R(i,j,s) = \left(X_E(i,j,s) - offset\right) \times \frac{1}{\overline{G}(i,j,s)} \qquad (1)$$

The offset and the gain $\overline{G}(i,j,s)$ ***are derived after averaging several individual DS and BB views, respectively, as was established before launch and confirmed during the in-flight performances assessment (Trémas, 2006). Specifically, the offset is obtained by averaging digital counts from the DS view associated to the sequence, s, if any, and from the eight closest DS views.*** *The gain* $\overline{G}(i,j,s)$ *is obtained by averaging four individual gains associated to the four BB views surrounding the sequence s. An individual gain G(i,j,c) derived from the BB view in a cycle c is computed as:*

$$G(i,j,c) = \frac{X_{BB}(i,j,c) - offset_{BB}}{R_{BB}(c)} \qquad (2)$$

where $R_{BB}(c)$ is the blackbody radiance associated with its measured temperature $T_{BB}(c)$, $X_{BB}(i,j,c)$ are the digital counts in the BB view, and $offset_{BB}$ is the offset correction obtained by averaging the digital counts from the eight closest DS views."

We noted that Eq. (2) was giving $G^{-1}(i,j,c)$ and not G(i,j,c). We apologize for this mistake which will be corrected in the revised manuscript.

7) Page 8, line 31: The hysteresis effect is very interesting, though it needs further explanation.

Response

The following sentence will be added at line 32, page 8:

"Looking at the relationship between IIR cycle number and latitude in June (Fig. 2), the hysteresis effect indicates that the "global" bias appears after IIR cycle # 40 (35° N in the daytime ascent) and then increases up to cycle # 85 (35° N in the nighttime descent)."

8) Page 9, line 22: The authors state that XBB(i)-offsetBB always differ by less that 1.5%. Is the 1.5% a critical value used as boundary limit?

Response

The value of 1.5 % is not a critical value. We will add at the end of the sentence:

", which was deemed not significant."

9) Page 9, line 25: What do the authors mean through the term over-correction? Please quantify.

Response

The sentence will read:

"Initial attempts to apply the correction between cycles #36 and #85 showed an over-correction ***that led to a striping effect as in Version 1, but with anomalous BTDs of opposite sign of about +0.2 K.****"*

10) Page 10, line 22: What do the authors mean through the term "parasitic contribution"? Please quantify.

Response

We tried to clarify by modifying the sentence as:

The fact that the corrected gains ***between cycles #51 and #85*** *are found to* ***be larger and to*** *increase more rapidly than the gains derived after equalization correction (see Fig. 8) suggests* ***that they correct for*** *the presence of an additional parasitic contribution to the digital counts in the Earth view images* ***(see Eq. 1). This additional contribution represents about 1% of the digital counts in the worst case at cycle #85 in IIR2****.*

11) Page 13, line 5. The authors state that overall, the latitudinal variations of the differences between the IIR and MODIS residuals are reduced using IIR V2. Please quantify.

Response

This statement is indeed difficult to justify and to quantify without a detailed analysis of the remaining longitudinal variations, which is beyond the scope of this study. Therefore, we decided to delete the sentence.

12) Figure 1a and Figure 10a. The authors should consider to implement the CALIOP official backscatter colormap.

Response

These figures (which will be Figures 3a and Figure 11a in the revised manuscript) have been modified as suggested. The revised figures are shown below.

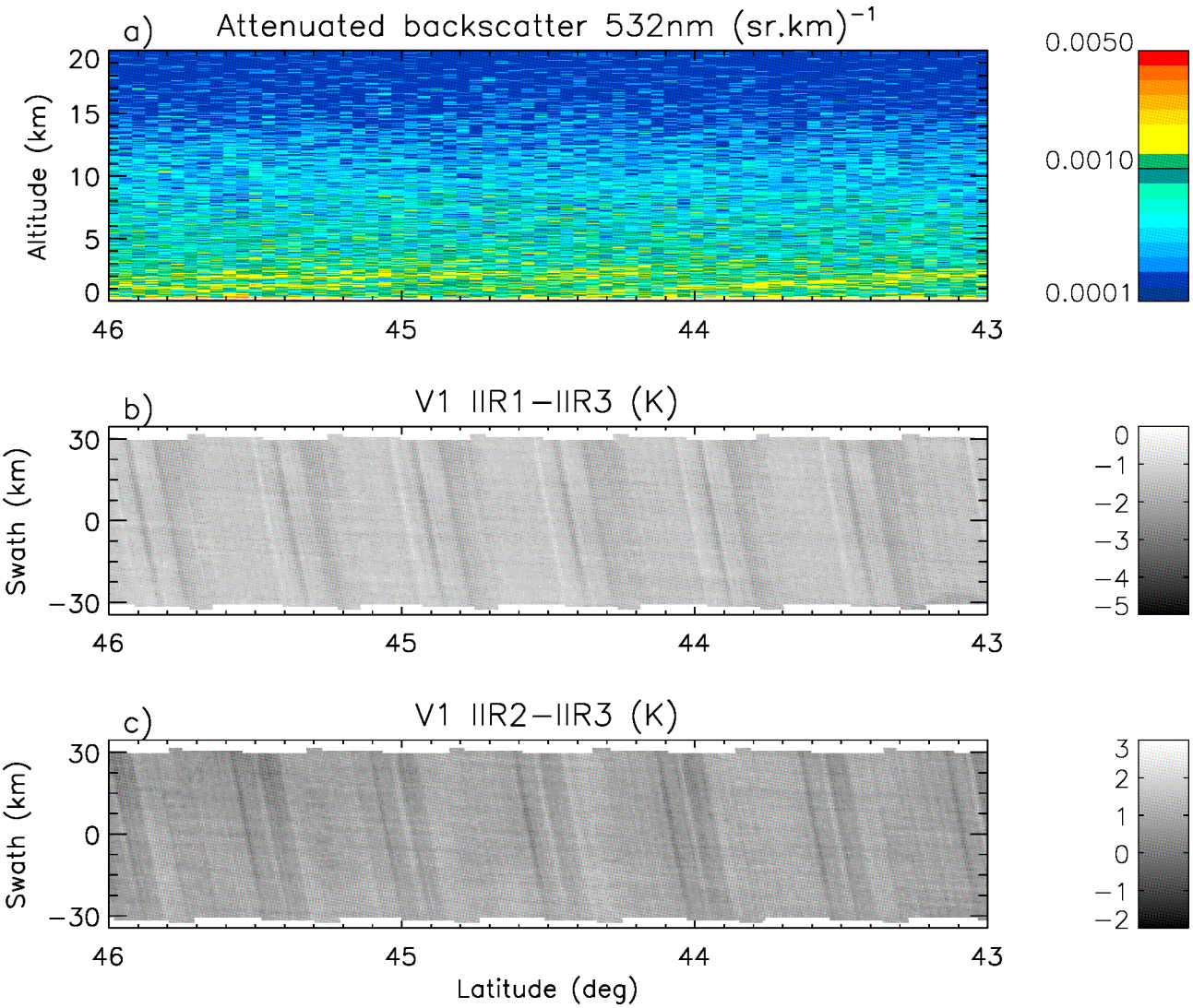

Figure 3: Example of striping effect seen in Version 1 IIR inter-channel BTDs for a cloud-free scene over water surface in the nighttime descending portion of an orbit between 46° N and 43° N on 25 June 2012; (a): CALIOP lidar attenuated backscatter; (b): IIR1-IIR3 BTD; (c): IIR2-IIR3 BTD.

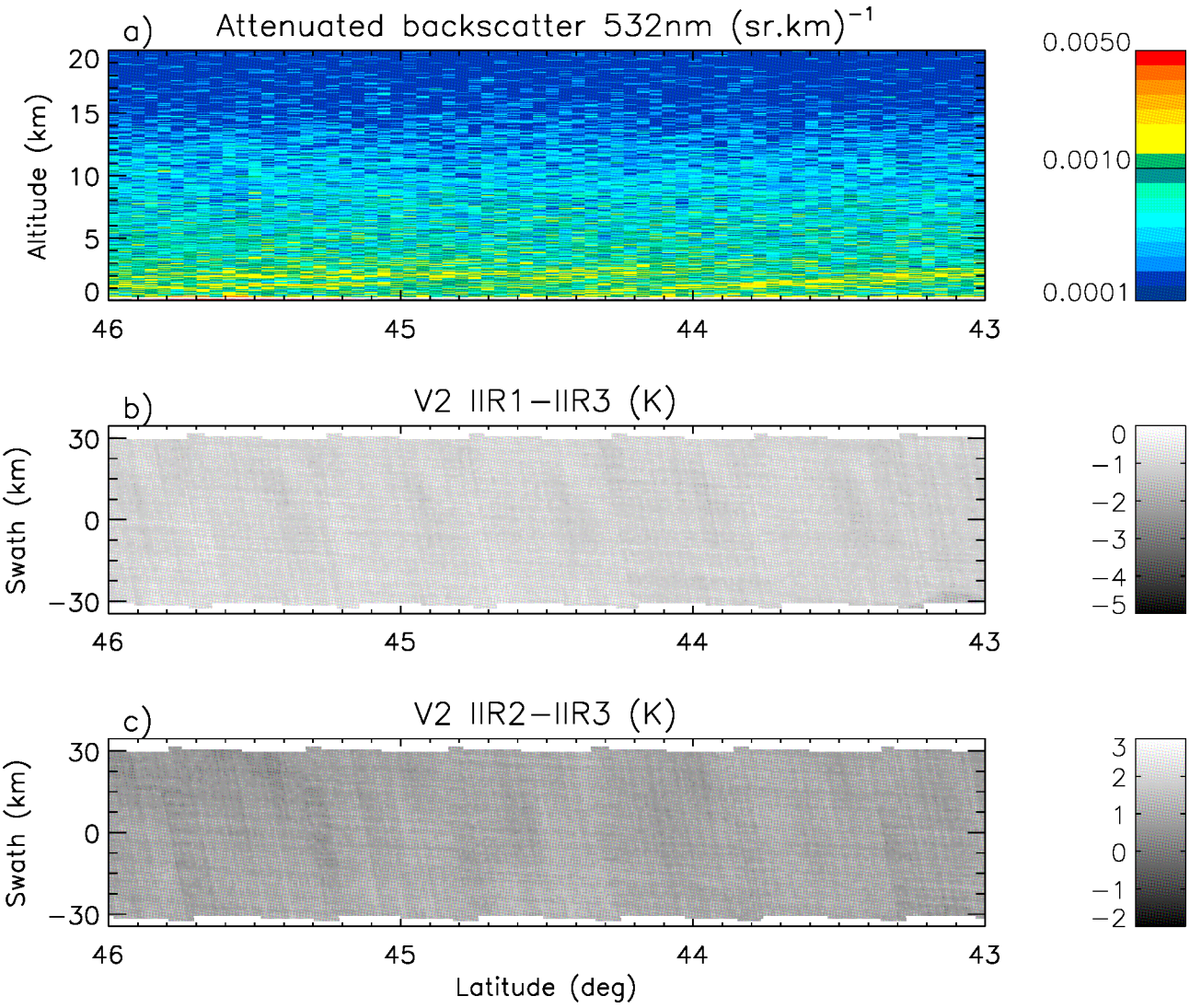

Figure 11: Version 2 IIR inter-channel BTDs in the same nighttime descending portion of the same orbit as in Fig. 3. (a): CALIOP lidar attenuated backscatter; (b): IIR1-IIR3 BTD; (c): IIR2-IIR3 BTD. The striping effect is significantly attenuated compared to Version 1.