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.

General comments:
Quality of long-term satellite record is quite important in climate studies using satellite data to detect/investigate variations of clouds, trace gases, the surface, and other atmospheric components. Estimation of the quality of calibrated radiances of an instrument becomes more difficult after launch. This article designs two indirect approaches, "stand-alone" and "relative", to estimate the bias, uncertainty, and trend of IIR observations. Very important conclusions are found by analyzing more than 9-year IIR data, together with collocated MODIS (and SEVIRI) IR observations and clear-sky model (4A/OP) simulations. The authors have developed two solid methods to analysis the long-term IIR data quality.

Some limitations can be found:
First, the analysis is limited to ocean. Considering that the land surface emissivity varies significantly with surface type and the land surface temperature has much stronger diurnal /seasonal variation than ocean, extend the current study to land surface is not an easy task. Do you have any plan to mitigate impacts from land surface in your future work? For example, how to estimate instant surface temperature from reanalysis data with 6-hour time interval? How to compare IIR with SEVIRI (or other instruments with different foot print sizes) if surface emissivity/temperature inhomogeneity cannot be ignored?
Response
Indeed, the analysis is limited to ocean, and we thank the reviewer for this important comment. The analysis over ocean allows a more robust assessment of the IIR calibration than over land. Even though limited to ocean, the analysis allows covering a wide range of brightness temperatures, at most latitudes and at any season, which is compatible with the aim of this study.

The current limitations are that the highest latitudes are not examined due to ice cover and that extreme temperatures found over land are not included. Analyses at the highest latitudes will necessarily be based on comparisons between IIR and MODIS. The highest latitudes are where IIR and MODIS viewing geometries are the closest, which is an important advantage. Analyses over hot surface such as deserts could be based on comparisons between IIR and MODIS or IIR and SEVIRI, but may be easier by using MODIS. For the stand-alone approach, a wrong estimate of the surface temperature from the reanalysis data will affect the absolute value of all the residuals, but should not prevent from comparing the residuals for each pair of companion channels. The difficulty will be, for instance, to assess the contribution of possible differences in surface emissivity within each pair of companion channels. Surface emissivity and temperatures could also be retrieved from IIR or MODIS (SEVIRI) observations using a split window/multi-channel technique (e.g. Chédin et al, J. Appl. Meteor. 21, n° 4, pp. 613-618, 1982, and also many other authors). This should lead to a better an accuracy and space/time coherence than using the reanalysis surface values. However, a remaining difficulty is that the emitting surface may be observed under different conditions, which is related to the difference in the pixel sizes as well as to the difference in the optical paths resulting from different viewing angles.

Changes in manuscript

At the beginning of Sect. 3.2, the manuscript will be revised as follows.

"In addition to the radiative coherence of the different pairs of channels, the quality of the comparisons performed for both the relative and the stand-alone approaches is based on the highest possible homogeneity of the observed surfaces and of the atmospheric optical paths. Differences in the spectral position and shape of the ISRFs can induce differences in surface emissivity. Furthermore, regardless of the perfection of the space-time collocation of the different instruments, the emitting surface may be observed under different conditions. This is inherently related to the difference in the pixel size of each instrument as well as to the difference in the optical paths resulting from different viewing angles. Handling these differences is more difficult over land where altitude and nature of the ground contribute to enhance the inhomogeneity of the observed scenes. We have chosen to minimize these issues by restricting our study to observations over ocean. It is worthwhile noticing that this choice allows a robust calibration assessment, in a wide range of brightness temperatures, at most latitudes and at any season, which is compatible with the aim of our study. Future work will include analyses at the highest latitudes, which are currently not examined because covered by ice, and analyses in extreme conditions of land surface temperatures."

Second, analysis of "relative" approach is break down into different BT ranges, for example, "200 _ 210 K" or "290 _ 300 K". Maybe cloud type is a more reasonable category. It is very interesting to see Figures 3-7 for different types of cloud. Is it possible to do that? If the authors believe the original BT range category is better or if the authors are planning to put cloud type analysis into further studies, please comment at appropriate place.

Response

Our first aim was to assess the calibration for different ranges in brightness temperatures measured by the instruments, whatever the underlying clear or cloudy scene. As for surface emissivity/temperature values (see comment above), it is very tempting – however out of scope of this present paper - to mix and match Level 1 and Level 2 data, including cloud type.

Changes in manuscript

It was indeed not clear in the introduction, where we write now:

"The two approaches are complementary: the inter-calibration approach studies the behaviour of one channel relative to its companion whatever the underlying clear or cloudy scene and therefore allows a wide range of brightness temperatures to be studied. "

Other minor comments:

This is a well-written and well-organized paper. The methods are solid and corresponding conclusions are important. Therefore, I recommend acceptance once the paper can be further clarified on several points listed below:

1. Abstract: The authors should put the important finding "IIR band2 may be biased high by 0.5-1 K at cold scenes" in the abstract.

Response

Sect. 5.2.2 has been revised after a comment by referee #2 (please see response to comment 5 below).

Changes in manuscript

The revised finding will be put in the abstract:

"For very cold scene temperatures (190-200 K) in the tropics, each IIR channel is warmer than its MODIS companion channel by 1.6 K on average".

2. Section 3.2.1: Please give the reference of "widely accepted mean value of 52 degree".

Response

i) In fact, the value used in our computations is 53 degrees and not 52 as formerly written in the manuscript. We are deeply sorry for this inaccurate value.
ii) Eventually, the attenuated reflected downward radiance has been here computed using a constant diffusivity factor. As suggested many years ago, this approximation avoids computing a large number of downward radiances (and above all the computation of a large number of transmittance functions) corresponding to a large number of incident angles as well as integrating over all these angles. Such a "mean" angle of 53 degrees has been used for instance in inter-comparisons of Line-by-Line models involved in radiances or fluxes simulations: ITRA (Spanküch 1984) or ICRCCM (Luther, F. M., R. G. Ellingson, Y. Fouquart, S. B. Fels, N. Scott, and W. J. Wiscombe, Intercomparison of radiation codes in climate models (ICRCCM): Longwave clear-sky results--A work-shop summary, Bull. Am. Meteorol. Soc., 69, 40-48, 1988.) or also in Feigelson et al. (JGR 1991).

Changes in the manuscript

"A widely accepted mean value of 52 degrees is taken for the computation of the downwelling reflected radiances."

Is replaced by:

"The attenuated reflected downward radiance has been here computed using a constant diffusivity factor. This approximation avoids computing a large number of downward radiances (and above all the computation of a large number of transmittance functions) corresponding to a large number of incident angles, as well as integrating over all these angles. Such an approximation for the integration over the angle is usual in radiative transfer calculations: it was suggested as early as 1942 by Elsasser. Later on, tests on the validity of this approximation have been presented by Rodgers and Walshaw (1966), Liu and Schmetz (1988), Turner (2004) and many others. A value of 53 degrees is taken here for the computation of the downwelling reflected radiances."

The following references will be added:

Rodgers, C. D. and Walshaw, C. D.: The computation of the infrared cooling rate in planetary atmospheres, Q. J. R. Meteorol. Soc., 92, 67–92, 1966.

Liu, Q. and Schmetz, J.: On the problem of an analytical solution to the diffusivity factor, Beitr. Phys. Atmos., 61, 23–29, 1988.

Turner, D. S.: Systematic errors inherent in the current modeling of the reflected downward flux term used by remote sensing models, Appl. Opt., 43, 2369-2383, 2004.

3. Section 5.1: Please change "5.10ˆ3" to "5x10ˆ3", and the same for other science notations.

Response

Will be changed in the revised manuscript.

4. Figures 3-7: In comparison with IIR-MODIS BTDs in the tropics at cold scenes (Fig 3 bottom panel), IIR-MODIS BTDs for mid- and high-latitude regions at cold scenes have much stronger daily variations (Figs. 4-7 bottom panels). Do you have any speculation about this?

Response

We believe that it is related to the smaller number of samples.

Changes in manuscript

The following sentence will be added in Sect. 5.1 of the revised manuscript:

"The large daily variability seen at mid- and high latitudes at the coldest temperatures is also attributed to the small number of samples (see Table 5)."

5. Figure 9: I suggest add MODIS Band29-Band31 and Band29-Band32 into this figure for comparison. Considering that this figure already includes a lot of symbols, please break it down into several panels for different latitudes.

Response

Sect. 5.2.2 about cold scenes has been revised after a comment by referee #2. IIR-MODIS BTDs for the cold scenes are now better quantified by examining the median value of the whole distributions. Previously, it was evaluated using the mean values of the distributions after removing the BTDs found outside the (TIGR_BTD ± 2.1 K) domain. We applied the same revision to the IIR inter-channel BTDs and added the MODIS inter-channel BTDs as suggested. Figure 9 (see below) includes now 2 panels: Fig. 9a shows the median IIR-MODIS BTDs against temperature and Fig. 9b shows IIR and MODIS inter-channel BTDs against temperature. The analysis has been carried out in the tropics, for representative months of the four seasons in 2008. Both IIR and MODIS inter-channel BTDs are close to zero at 190-200 K, the coldest range of temperature, showing internal consistency of the calibration within each instrument. On the other hand, IIR-MODIS BTD is about 1.6 K for the 3 pairs of channels at 190-200 K, indicating a warm bias of IIR with respect to MODIS.

Showing both IIR and MODIS inter-channel BTDs is important for the discussion, and we thank the reviewer for this excellent suggestion.

Changes in manuscript

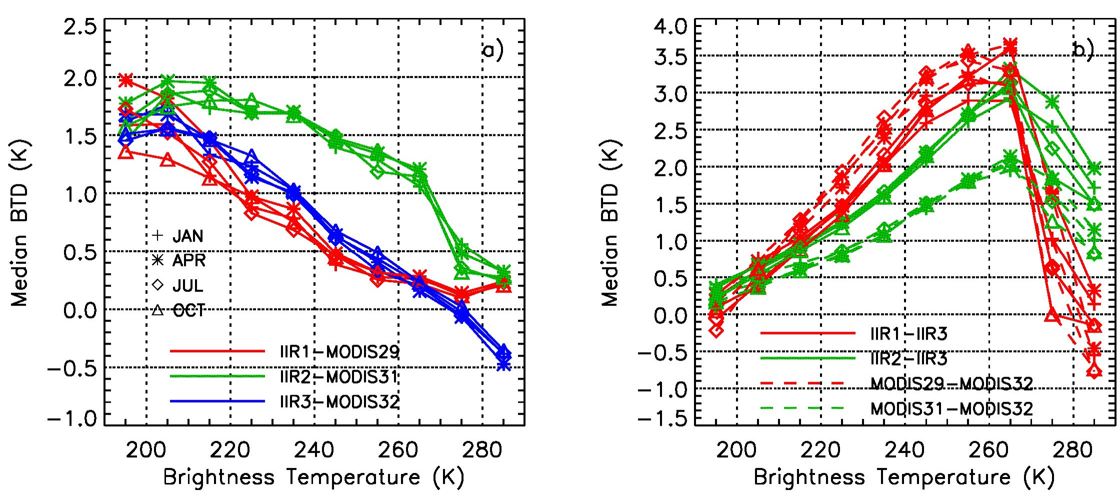

Figure 9: a) Median IIR1-MODIS29 (red), IIR2-MODIS31 (green), and IIR3-MODIS32 (blue) brightness temperature differences against brightness temperature. b) Median IIR1-IIR3 (red, solid), IIR2-IIR3 (green, solid), MODIS29-MODIS32 (red, dashed), and MODIS31-MODIS32 (green, dashed) brightness temperature differences against temperature. Plus sign: January 2008, star: April 2008, diamond: July 2008, triangle: October 2008. Latitude band: 30°S-30°N, ocean.