Response to reviewer #2

The reviewer's comments are in black and our answers are in red.
Modifications of the manuscript are reported in bold and italic.
The pages and lines reported here correspond to the original pdf.

This paper describes the first field application of a far IR radiometer operated on-board the Polar 6 aircraft over Arctic regions during the NETCARE campaign. The paper shows the importance to measure the far IR spectral region and how much these measurements, acquired in all-sky conditions, can improve the sensitivity to specific humidity and the cooling rate of thin ice clouds.

General comment:
The paper is well written, clear in the description of the field campaign, and convincing in showing the importance to cover this observational gap in the spectral range of the IR emission. The data analysis is limited to few cases with few general implications for atmospheric science. However, considering that it belongs to the NETCARE special issue, I think that the paper is worth to be published in ACP and of general interest for the Earth radiation budget community.

Some changes are required to improve the figures and the description as indicated here below.

• Introduction. Some more references about the available measurements in Arctic should be added, e.g from ICECAPS experiment or the CANDAC network, in order to better stress the contribution of these new measurements.

The projects ICECAPS (at Summit) and CANDAC (at Eureka) are now mentioned, to insist that NETCARE contribution is mostly in terms of airborne measurements.

p3 l.4 : "***These scientific flights offered the possibility to probe the atmosphere in situ, thus providing a valuable complement to the extensive ground observations performed at well instrumented sites such as Summit (e.g. ICECAPS project, Shupe el al., 2013) and Eureka (e.g. CANDAC network, Mariani et al., 2012). Altogether, these initiatives aim at refining our understanding of the radiative budget of the Arctic and the critical role clouds play in it, in the continuity of the seminal Surface Heat Budget of the Arctic Ocean (SHEBA) program (e.g. Shupe et al., 2006)***."

• page 5 line 1. Does the same radiometric resolution apply to all the spectral bands ? If not, I would put the numbers in Tab.1 otherwise please clarify the text. Furthermore, is the radiometric resolution limited by the detector noise or by other reasons ? I would add some more information about the noise on the different channels and the related radiometric resolution, even if this is characterized in laboratory conditions.

The Table 1 has been removed and was replaced by a figure showing the spectral transmittances of each channel. The radiometric resolution is very similar from one band to another, because the absorptivity of the detector is spectrally flat (due to the gold black coating) and all filters have maximum transmittance around 80%. The resolution is a bit less, though, for the 22.5-27.5 and 30-50 channels which have slightly lower transmittances of the filter and of the package window, respectively. This is now detailed in the text. Regarding the resolution, in laboratory it is essentially limited by the detector noise.

p5 l.1 : "In this configuration, the radiometric resolution of the FIRR in laboratory conditions ***is***

essentially limited by detector noise and is about 0.015 W m^{-2} sr^{-1}***. This corresponds to noise equivalent temperature differences of 0.1 – 0.35 K for the range of temperatures investigated in this study. The resolution is nearly constant for the 7 bands ranging from 7.9 to 22.5 µm because the absorptivity of the gold black coating is spectrally uniform and the filters all have similar maximum transmittances. It is approximately 30% less for the filters 22.5 – 27.5 µm and 30 – 50 µm, because of limited filter transmittance for the band 22.5 – 27.5 µm and reduced package window transmittance for the band 30 - 50µm***."

• page 6 line 2-4. It would be interesting to describe with more details the refinement introduced to better account for quick temperature variations. Otherwise this sentence is too general and not useful.

In Libois et al. (2016) the background radiance is assumed linear in time, and the rate is deduced using three measurements (ABB, HBB, next ABB). Here, another equation is added to the system, namely the next HBB measurement, so that we have 4 equations to retrieve 3 variables instead of 3 equations (eqs. 7 of Libois et al., 2016). Since it is a very technical detail and since the explanation would need too much reference to Libois et al. (2016), we decided to remove this detail.

p6 l.2 : "For previous flights, the calibration procedure detailed in Libois et al. (2016), that takes advantage of non illuminated pixels of the detector to remove the background signal, ensured good quality data for all bands except the 30 – 50 *µm*."

• page 6 line 17-18. It is not clear whether the images were used or not. If not I would avoid to cite this probe.

The probe indicated the presence of large particles, which is used in the analysis, but the exact shape and size were not used because they were not reliable. It has been clarified.

P6 l.17 : "A PMS 2D-C imaging probe ***was supposed*** to detect larger particles, ***but*** the images were obscured due to a problem with the true air speed used in the image re-construction, preventing accurate retrieval of particle size distribution. ***Practically, this sensor was mostly used to assess the presence of large cloud particles, but did not provide quantitative information about particle shape or size.***"

• page 7 line 2. 5 cases are too few cases to provide a real overview of the Arctic conditions, they are an example of different conditions. Please rephrase the sentence.

"Overview" was replaced by "***samples***"

• page 8 sect. 3. Since this paper is published in ACP, even if it is mainly an instrumental paper, I would try to introduce since here the general scientific results expected in the framework of the NETCARE campaign in order to give more evidence to the peculiar results of this work within the general scientific problem of the special issue.

To present our results in the more general context of the NETCARE campaign, the objectives of the campaign are now presented in more details in Section 2.1. The general context was also recalled in the conclusion. However, we do not dwell too much on the original objectives, because due to the deficiencies in the cloud probe and to the lack of cloud cases, it is hard to derive from this campaign general conclusions regarding the physics of ice clouds in the Arctic.

p4 l.7 : "***One of the objectives was to characterize at the same time the microphysical and the radiative properties of ice clouds, along with the nature of the aerosols, in order to further explore the conditions in which optically thin ice clouds form and how their microphysics depend on background aerosols.***."

p23 l.10 : "The first airborne campaign of the FIRR took place in the Arctic ***in the framework of the NETCARE aircraft campaign***. It was a great opportunity to study the ***radiative*** properties of the early spring Arctic atmosphere, ***and highlighted the importance of water vapor and ice clouds in this remote environment***."

• page 8 line 18. Please clarify whether the value of 0.015 W m-2 sr-1 applies to all the bands.

See above.

• page 8 line 25. This sentence is not completely clear because the calibration is not described. Furthermore, Sect 3.1 addresses the radiometric performance in terms of temperature resolution. It would be also interesting to have an idea of the absolute error of the measurement.

This sentenced has been removed because it was confusing. At the same time the description of the BB in Section 2.2.1 has been further detailed. The absolute error is about 0.02 W m^{-2} sr^{-1} according to laboratory experiments.

p4 l.1.25 : "***These correspond to BB nominal temperatures in flight but some experiments were performed with different BB temperatures depending on the environmental constraints, , which is not problematic since the instrument's response is linear in this range of temperature***."

p8 l.17 : "The FIRR performances were investigated based on laboratory and ground-based experiments by Libois et al. (2016). ***They estimated a radiometric resolution around 0.015 W m-2 sr-1 and an absolute error of 0.02 W m-2 sr-1, again slightly dependent on the channel considered***.

• page 11 line 6. I would say a "close agreement" above 2 km, below the difference is always more than 0.6 W m-2.

Done. 0.6 W m-2 is now 0.35 W m-2.

• page 12 line 3-4. If the peak is not present on the way down, please show this case in the figure.

This has been added to the figure. Since the descent shows a peak in the opposite direction, it has been mentioned in the manuscript and strenghtens the temperature adjustment hypothesis.

p12 l.3 : "This hypothesis is supported by the fact that data taken on the way down just before starting the ascent ***show a peak in the opposite direction***."

• page 11 fig. 4. In panel (b) the x-axis label should be Brightness temperature. I would also remove the temperature curve which is also shown in panel (a). Same for Fig. 6 panel (b) and (d).

Done, as well as for other figures showing vertical profiles of brightness temperature.

• page 13 line 10. Do you have some information about these clouds from CALIPSO ?

CALIPSO does not show any cloud above the aircraft altitude.

• page 13 line 17. In the comparison with simulation you should estimate the noise on measurements due to scene variations. Besides the aircraft movement considered here, please add some more considerations at least about the roll of the platform.

Scene variations do not result in an easily identifiable constant noise. Instead, it is mostly visible when strong variations occur, such as peaks seen on some vertical profiles. The roll of the platform is already meantione p11 l.2, but it is now converted in terms of distance.

p13 l.16 : "a single measurement of 0.8 s spanned 60 m at the surface. ***Similarly, a typical roll of 10° during the spiral corresponds to 1 km deviation at the surface when flying at 6 km.*** This could generate noise if the surface was not homogeneous at this scale, which was the case at the interface between the sea ice and open water."

• page 13 line 26-27. The sentence "They are of little interest ..." is too general. This spectral range can be of great interest for satellite observations because you can see high altitude clouds.

This point has been detailed.

p13 l.25 : For this reason, the data in the 30 – 50 µm band are not reliable ***and are not shown in the rest of the paper. This is not critical in this study because at the flying altitude this band essentially probes local temperature. On the contrary it is expected to be very valuable from a satellite view, where it should provide information about water vapor and clouds at the very top of the troposphere.***"

• page 16 fig.8. As said before, I would use Brightness temperature for x-axis in panel (b) and show the temperature profile only in panel (a). Same for Fig.9.

Done.

• page 19 line 6. Since resolution was used for the radiometric measurement, the sentence is not clear. I would say: ... temperature variations of 0.2 K are detectable with a vertical resolution of ...

p19 l.6 : "***Given the radiometric resolution of the FIRR is about 0.2 K, temperature variations of 0.2 K are detectable with a vertical resolution of 100 to 200 hPa in FIR bands.***"

• General comment on figures. The font size of labels and scales in most of the figures should be enlarged to be clearer.

Done for all concerned figures

New references:

Shupe, M. D., Matrosov, S. Y., & Uttal, T. (2006). Arctic mixed-phase cloud properties derived from surface-based sensors at SHEBA. *Journal of the atmospheric sciences*, *63*(2), 697-711.

Shupe, M. D., Turner, D. D., Walden, V. P., Bennartz, R., Cadeddu, M. P., Castellani, B. B., ... & Neely

III, R. R. (2013). High and dry: New observations of tropospheric and cloud properties above the Greenland Ice Sheet. *Bulletin of the American Meteorological Society*, *94*(2), 169-186.