# Review of “Exploiting airborne far-infrared measurements to optimise an ice cloud retrieval” by Panditharatne et al.

## General comments

Retrievals using the far- and mid-infrared have been carried out using synthetic data (e.g. Saito et al. 2020). This study provides the first retrievals (to the knowledge of the authors and this reviewer) of ice cloud properties using an observation of coincident upwelling far- and mid-infrared radiances taken during the CIRCCREX campaign. Since the study is in the frame of the FORUM mission, the observed radiances are adapted to mimic what would be observed by FIS (Forum Sounding Instrument), the so called FORUM-aircraft observations.

This work aims to explore if adding the far-infrared benefits the retrievals, especially regarding the distinction of ice crystal habits, and to assess the limitations of two bulk cloud optical property models (Solid Column and General Habit Mix) on the retrievals. The authors perform simultaneous retrievals of cloud optical thickness, cloud effective radius, cloud top height, temperature and water vapor and compare the results to in-situ measurements.

The current study expands the work done in Panditharatne et al. 2025, which describes the method to create the FORUM-aircraft observations and the retrieval of temperature and water vapor. Comments regarding this methodology have been assessed by the reviewers of the mentioned paper.

In general, I find it an interesting article that is well structured, although there are a few points that get confusing (see comments below). I consider it can be published after assessing the following specific and technical comments:

## Specific comments

Line 126: what bimodal function has been fitted to the PSDs?

Line 127: is the habit of particles smaller than 50 um. assumed spherical? What is the range of sizes from the in-situ measurements?

Line 128: is the distribution of habits similar for each of the sampled altitudes or are there significant differences?

Line 150: how is the quality of the fit of the PSD evaluated?

Line 152: “some work suggesting that the smaller mode of the distribution is an artefact of the instrumentation” If the bimodality of the PSDs is real or an artefact is indeed still a matter of debate. There is a lot of work done to correct and avoid the shattering of ice particles to provide a database of PSDs of ice crystals where bimodality is not associated to shattering. I would suggest having a look at, e.g. Krämer et al., 2020 and references therein.

Line 154: can you explain why the uncertainty in CER is larger the closer to the bottom of the cloud?

Line 173: why were 6 scans chosen?

Line 184: "… the simulated FSI and FORUM-aircraft spectra produced similar results, suggesting a retrieval from an FORUM-aircraft observation is indicative of its FSI counterpart given a homogeneous scene". I would recommend to add a few sentences explaining why the selected cloud is homogeneous and therefore the method is applicable to the studied case.

Figure 7: any comments on the pick of the uncertainty at around 750 $cm^{-1}$ and the BT residual for 35 um being consistently lower than for the rest of CRE?

Line 325: "When the correct (GHM) bulk optical... ", what do you mean here by correct?

Line 335: "This is an incorrect result as the GHM model was used in the simulation". I don't understand this sentence.

Line 333-342: here it is discussed that the results using the GHM model are better, however, when looking at Table 3, MIR+FIR (SC) is the combination that delivers the closest results to the considered true state. I would suggest expand the discussion about GHM vs SC.

Line 357-360: I would add a few lines about why the observations exceed the uncertainty but not the simulation.

**Technical comments**

Line 79: this comment is a little bit picky, but what do you understand as a well characterized cirrus cloud?

Figure 1: what is the difference between the continuous blue line and the dashed blue lines? If the first line was changed to continuous because of overlapping with the cloud extent, I would suggest marking the extent of the cloud with a continuous line, so all the in-situ are dashed and picking two colors that contrast a little bit more than blue and purple.

Line 33: add reference to some of the studies.

Line 75: add reference to the website of CIRCCREX.

Figure 2: I would add in the caption the altitude of the dashed blue lines so it is faster to identify which line corresponds to the the altitudes specified in Table 1. "… have been characterised are shown in blue (6, 6.8, 7, 7.3, 7.5, 8., 8.3 km)"

Table 1: As a suggestion, I would add another column with the temperature.

Line 144: number distribution of sizes → size number distribution (?)

Line 147: I would recommend adding some references regarding the bimodality of cirrus clouds. For temperatures larger than approx. 210 K, bimodality starts playing a role. For lower temperatures, a fit to a monomodal PSD should be expected.

Line 179: for consistency, I would give the FOV of ARIES, TAFTS and FIS in the same units.

Line 180: although the acronyms of NEDT and ARA appear in the caption of Fig. 3, I would suggest to write ‘The apodised noise-equivalent-differential-temperature (NEDT) and target absolute radiometric accuracy (ARA)’.

Line 205: here is mentioned for the first time the “FORUM-aircraft simulation”, but it passes a little bit unnoticed. For the rest of the manuscript it gets a bit confusing what the FORUM-aircraft observation is and what the FORUM-aircraft simulation is. I would suggest to rephrase this line to make clearer what the differences between the two are. Also in the caption of Fig. 4 is written “FORUM-aircraft LBLDIS simulation”, is this the same as FORUM-aircraft simulation? Same for caption in Fig. 8 and caption in Table 3 and in line 310 where is written “LBLDIS GHM FORUM-aircraft simulation”.

Line 216: … and in the presence of cloud → … and in the presence of clouds (?)

Line 245: “the ice cloud is modelled as a Gaussian of 1 km thickness”. Is 1 km at full-width-half-maximum?

Line 247, eq. 7: isn’t a dz missing? And are the limits from 0 to z or from CBH to CTH? Since the ice crystal is much larger than the wavelength, is <Qe,vis> assumed to be 2?

Line 278: for convenience for the reader, I would add also here the five CER and the number for the fixed IWP.

Figure 7: in the caption I would specify again of what the black line is uncertainty of.

Line 372: “…, before Section 5.3 evaluates the …” → “… and Section 5.3…”

Line 379: verticle → vertical

Line 399: for those not familiar with the term, I would specify “DOFS (degrees of freedom)”.

Caption of Fig. 9, lines 2-3: I would specify Figure 8b. Also I would add “:” after “...as follows” and I would change the “.” for “,” in between SC(MIR): 0.33**.** GMH()...

Line 423: These have → It has (?)

Line 431: do you mean from 0.9 to 1?

Caption of Fig. 11, in line 4: ‘… or CER. The error bars The measurements of the cloud taken…’ → delete ‘The error bars’. In line 5: … from lidar measurements between from 09:48:09 to 09:49:09 → delete ‘between’ or delete ‘from’ and change ‘to’ for ‘and’.

Line 454: “… 1600 cm-1” → $cm^{-1}$

Line 484: https://doi.org/10.24381/cds.bd0915 doesn’t work.

Line 487: “The MODIS data is taken from” this sentence is not finished.

Line 528: https://doi.org/https://doi.org/10.1016/j.jqsrt.2022 – delete the first https://doi.org/

Line 530: ‘...Cycle Coopera-tive’ → ‘...Cycle Cooperative’

Line 548: https://doi.org/https://doi.org/10.1029/2022GL099394, e2022GL099394 2022GL099394, 2022 → https://doi.org/10.1029/2022GL099394, 2022

Line 564: I don’t find the technical report.

Line 601: https://doi.org/https://doi.org/10.1029/2021JD035733, e2021JD035733 2021JD035733, 2022 → https://doi.org/10.1029/2021JD035733, 2022

Line 631: add doi: https://doi.org/10.1175/JAMC-D-11-067.1

Line 638-639: Delete “ and add doi: https://doi.org/10.1175/JAS-D-12-039.1

## References

Krämer, M., Rolf, C., Spelten, N., Afchine, A., Fahey, D., Jensen, E., Khaykin, S., Kuhn, T., Lawson, P., Lykov, A., Pan, L. L., Riese, M., Rollins, A., Stroh, F., Thornberry, T., Wolf, V., Woods, S., Spichtinger, P., Quaas, J., and Sourdeval, O.: A microphysics guide to cirrus – Part 2: Climatologies of clouds and humidity from observations, Atmos. Chem. Phys., 20, 12569–12608, https://doi.org/10.5194/acp-20-12569-2020, 2020.

Panditharatne, S., Brindley, H., Cox, C., Siddans, R., Murray, J., Warwick, L., and Fox, S.: Retrievals of water vapour and temperature exploiting the far-infrared: application to aircraft observations in preparation for the FORUM mission, Atmos. Meas. Tech., 18, 717–735, https://doi.org/10.5194/amt-18-717-2025, 2025.

Saito, M., Yang, P., Huang, X., Brindley, H. E., Mlynczak, M. G., & Kahn, B. H. (2020). Spaceborne middle- and far-infrared observations improving nighttime ice cloud property retrievals. *Geophysical Research Letters*, 47, e2020GL087491. https://doi.org/10.1029/2020GL087491