

Review of “Mineral dust concentration controlling convective cirrus structure and persistence: a large-eddy simulation study with observational constraints” by Juurikkala et al. (2026)

General comments

The work presented in this article offers a deep insight into dusty cirrus clouds by performing large-eddy simulations of one case study. The authors are able to study the evolution of dusty cirrus, the involved microphysical mechanisms and the associated convective dynamics.

The results are compared with different satellite products, ground based cloud radar data as well as with in-situ measurements corresponding to the same simulated period. It is a detailed study including sensitivity tests to different initial dust concentrations, different large-scale vertical forcing scenarios and daytime and nighttime simulations.

It also compares three schemes for heterogeneous ice nucleation currently available in many models and highlights the need to keep improving this aspect of models.

I find it is an interesting study adding valuable information on the nature of dusty cirrus. In general it is well structured, however some paragraphs and figure locations would benefit from a slight reorganization to make the text easier to follow. Some sections could also be improved by adding numerical values that support the conclusions reached with the interpretation of the figures.

I consider it is suitable for publication after assessing the following specific and technical comments:

Specific comments

Since ERA5 is used, I would suggest to add a brief description of the dataset in Section 2 and the following reference:

Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., Nicolas, J., Peubey, C., Radu, R., Schepers, D., Simmons, A., Soci, C., Abdalla, S., Abellan, X., Balsamo, G., Bechtold, P., Biavati, G., Bidlot, J., Bonavita, M., De Chiara, G., Dahlgren, P., Dee, D., Diamantakis, M., Dragani, R., Flemming, J., Forbes, R., Fuentes, M., Geer, A., Haimberger, L., Healy, S., Hogan, R. J., Hólm, E. A., Janisková, M., Keeley, S., Laloyaux, P., Lopez, P., Radnoti, G., Rosnay, P. D., Rozum, I., Vamborg, F., Villaume, S., and Thépaut, J.-N.: The ERA5 global reanalysis, Q. J. Roy. Meteorol. Soc., 146, 1999–2049, <https://doi.org/10.1002/qj.3803>, 2020.

Line 56: which hydrometeors are included in SALSA?

Line 61: which SIP are included in SALSA?

Line 79: under which conditions do the authors consider it would be important to include the sedimentation and coagulation of aerosols?

Line 86: although it is later shown in Fig. 4a that $T > 210$ K, it could be good to add a sentence after “...temperatures above 210 K.” mentioning that this is exactly the case for the presented results.

Line 122: which version of the DARDAR data is being used?

Section 2.4: I personally found this section a little bit messy. Fig 1d is not explicitly mentioned until much later (Section 3.1), Fig. 4 is described before Fig. 3 and Fig. 3 is just mentioned, there is barely no explanation associated with it. Some suggestions are:

- in line 159: "... under large scale lifting as shown in Fig.1." Specify in which panel (panel d?)
- Line 158 – 161: I would suggest rewriting this part to make clear that the sounding profiles in Fig. 4a correspond to T and θ and not to θ_e and that θ_e and its gradient are computed but not shown.
- Line 161: specify where do we find the horizontal wind velocity profile (Fig. 4c?)
- I think Fig. 3a is not used. I would suggest merging Fig. 3a with Fig. 3b by having the color code of w and IWC contours on top to identify the cloud.
- If the authors believe it would improve the readability, perhaps Fig. 4 could be placed before Fig. 3.
- Caption of Fig. 4: I would suggest explicitly describe what is seen in each panel, as it is done in the rest of figures.

Line 179: the model top is at 14 km, out of curiosity, how thick is and at what altitude does the sponge layer start in the used set-ups?

Line 186: what humidity profile is modified? The sounding? Can the authors explain a bit more how the modifications were done, which decisions were taken?

Line 191: to which line in Fig. 4b corresponds the integrated RH_i profile? Is it the solid blue line?

Line 239: the authors specify that the BASE and sensitivity runs are simulated using H14. Is this also the case for BASE-MIXED?

Line 258: "recycled ice crystals" what do the authors mean by this term?

Figure 9 is presented in Section 3.1 but is barely explained. If the authors agree, Fig. 9 and the paragraph from line 297-300 could be moved to Section 3.2.1

Section 3.1.1 could benefit of the addition of numerical values in the explanations, especially for IWC. For example, in how many order of magnitudes the values differ, means, variability, etc.

Line 344: it is mentioned that the differences between the ICNC produced by the different DIN schemes come from differences in the T and RH_i dependencies of the parameterizations at $T < 210$ K. However, it seems that for the studied dusty cirrus $T > 210$ K for most of the layer. Could the authors elaborate on this?

Line 403: could the authors expand on the behavior of IWC to N_D as it was done for ICNC?

Line 411-426: I think the flow in Section 3.2.1 would be improved if these paragraphs are moved after line 403, since there is continuation in the analysis of the ICNC.

In Section 3.2.2, Fig. 18 is discussed before Fig. 17. I would suggest either rearranging the figures or the paragraph order.

Technical comments

Please, review the format of the dates and choose one for consistency. In some cases it is written April 3th or April 4rd and in others 4 April.

Please, review the use of articles and the punctuation.

Line 111: there is an extra space in “(35...”

Line 142 - 143: “... over northern Sahara around Atlas Mountains and Moroccan-Algeria border...” -- “...over the northern Sahara around the Atlas Mountains and the Moroccan-Algerian border...”

Line 143: “... by WCB to higher in troposphere...” – “... by the WCB higher into the troposphere”

Line 144: “..satellite imagery (not shown) on April 3rd reveal...” -- “...satellite imagery (not shown) on April 3rd reveals...”

Line 146: “..was identifiable as large shield...” – “...was identifiable as a large shield...”

Figure 1:

- at the bottom, between panels c) and d) it is written “HALO measurements”. Is this suppose to be there?
- there is a grey line right of panel d)
- it could be useful to add in the caption that the color lines in panel a) and b) correspond to the HALO flight track with color code altitude in km.

Line 152: “.” missing at the end of the sentence.

Line 155: “Sounding profile measured...” -- “The sounding profile measured...”

Line 158: “Vertical gradient of...” -- “The vertical gradient of...”

Line 158-159: “...leads to new development...” -- “leads to the new development”

Line 160: “... find potentially unstable layer ...” -- “... find a potentially unstable layer...”

Line 165: “...early hours of April 4 (Fig. 3)” -- “...early hours of April 4 (Fig. 3b)” (If suggestion of merging panel a and b is not followed).

Line 166 and line 170: I think it was meant “as shown in Fig. 4 panels a and b” instead of Fig. 3

Figure 2:

- Caption: "... marked with black vertical line..." -- "... marked with a black vertical line"
- I think in the legend the dashed-dot line should be dashed to match the plot.

Line 182-184: "the model domain follows solar diurnal cycle at latitude 47.5° and therefore experiences both nighttime conditions in the initial 2.5 hours and daytime conditions for the latter half of the simulation time." -- "the model domain follows the solar diurnal cycle at latitude 47.5° and therefore experiences both nighttime conditions during the initial 2.5 hours and daytime conditions during the latter half of the simulation time."

Line 186: "The sounding profile is used..." -- "The sounding profile (Fig. 4a, also b?) is used..."

Line 188: "between 8.5 and 10.8 km (as shown in Fig. 4)" -- "between 8.5 and 10.8 km (as shown in Fig. 4b)"

Line 188-189: "... profile line in Fig. 4..." -- "... profile line in Fig. 4b"

Line 192: "... the model input potential profile between..." -- "... the model input potential temperature between ..." ?

Line 192: "... is set at fixed gradient..." -- "... is set at a fixed gradient..."

Line 203: please, explain what w_{LS} is.

Line 206: "...in altitude compared to sounding RH_i 6 hours prior (Fig. 4)." -- "...in altitude compared to the sounding of RH_i 6 hours prior (Fig. 4b)."

Line 207: "Satellite imagery (Fig. 1) shows that the cirrus..." -- "Satellite imagery (Fig. 1a, b) shows that the cirrus..."

Figure 5: would it be possible to plot the total fit in front of the red line? It is difficult to see.

Line 226: "... PSD which makes this extrapolation justified." -- "... PSD which justifies this extrapolation."

Line 228: N_D was already defined in line 45 as "mineral dust number concentration".

Line 229: "was extended up to 11 km." -- "was extended up to 11 km (Fig. 4d)."

Line 235: "...for upper troposphere Minikin et al. (2003)." -- "... for upper troposphere by Minikin et al. (2003)" ?

Line 249: "using H14, U17 and P13 are used to assess sensitivity of ice nucleation pathways..." -- "... using H14, U17 and P13 to assess the sensitivity of ice nucleation pathways..."

Caption Fig. 6: please specify that the contours in the upper panels correspond to RH_i.

Line 268-270: “ Towards the end of the simulation, SW radiation interrupts the LW cooling effect increasingly as the solar angle increases, the SW radiation flux increases, however, not enough to result in neutral heating”. Is punctuation missing? I find this sentence a little bit difficult to understand.

Line 273: “...over wider layer and...” -- “ ... over a wider layer and ...”

Line 274: “... in the Fig. 7.” -- “... in Fig. 7.”

Line 279: “At 10.5 km level, in the middle vertically of the CONV layer...” -- “At 10.5 km level, in the middle of the CONV layer” ?

Line 290: “ in the Fig. 8” -- “ in Fig. 8”

Line 302: “We compare here the...” -- “We compare the...”

Line 303: “measured dusty cirrus layer” – “measured the dusty cirrus layer”

Line 316: “SEDI layer...” -- “the SEDI layer”.

Line 316: “ice production in temperature range...” -- “ice production in the temperature range...”

Line 320: “... roughly same for total ICNC.” -- “... roughly the same for total ICNC”.

Figure 10:

- in panel b, there is a red dashed line that according to the legend correspond to the OCP measurements. Shouldn't it be a solid red line corresponding to NIXE-CAPS instead?
- Since it is mentioned in the discussion, it could be helpful to add also in the panels (or at least in one panel) the lines corresponding to CONV and SEDI.
- Please review this caption as it mentions “Model ICNC” when it should be IWC and the description of some of the lines does not match the legend.

Line 326: if the authors agree, instead of adding the abbreviation ISD in the text, “ice PSD” could be kept and in the caption of Fig. 11 add the meaning of ISD as it is done with INS and SOL.

Line 332: “The large number of ice below 30 μm ” -- “The large number of ice below 30 μm in Fig. 11a”

Line 336: “For the Fig. 11,” -- “For Fig. 11,”

Figure 11:

- for clarity, or in the title of each panel or in the caption, it would be helpful to add which panel correspond to which N_D .
- Please, review the legend in panel a. Some of the lines have the wrong description.

Line 348-350: “ with ICNC only exceeding 10–2 cm^{-3} but with substantially weaker nucleation activity.” I think the use of “but” can confuse the reader.

Figure 13:

- I think it is a bit difficult to differentiate the ICNC contours. If it looks better, I would suggest a change to a lighter color.
- Please, specify or in the panel titles or in the caption which N_D corresponds to which panel.

Line 389: the author refer to Fig. 13 (color code RHi) when the text is explaining LW cooling. Is this correct?

Line 400: “ICNC increases...” -- “ICNC (Fig. 14a) increases...”

Line 402: “The IWC on...” -- “The IWC (Fig. 14e) on...”

Line 405: “gradient $d\theta_e/dz$...” -- “gradient $d\theta_e/dz$... (Fig. 14b)”

Line 408: “the Fig. 9” -- “Fig. 9”

Line 409: “The smaller the value of $\partial\theta_e/\partial z$ that seems to be below 0” seems?

Line 410: “Fig. 14” -- “Fig. 14f”

Line 420: “When expressed in terms of mass concentration rather than number concentration N_D (Fig. 14)” -- “When expressed in terms of mass concentration rather than number concentration N_D as was shown in Fig. 14,”

Figure 14:

- Y label of panel d): radiative cooling/heating rate
- In the caption: “c) Radiative...” .. “c) radiative ...”
- Do the up triangles and down triangles in panel c) mean anything in particular?
- “RHi is shown with with...” one “with” too much.
- For consistency, I would suggest using also circles in panel e).
- In line 399 is mentioned that Fig. 14 shows the relationships between the N_D and bulk cirrus properties at the end of the simulations. In the caption it is written “The N_D corresponds to initial concentration at the beginning of simulations between 8.5 and 11 km altitude”. Could the authors clarify what is shown in the x-axis?

Line 431: “(Fig 14)” – “(Fig 14d)”. If the authors consider it convenient, it could be also mentioned that in the supplement are figures for the LW, SW and net radiative rates.

Line 432-433: “RHi also exhibits a dependence on N_D , where the RHi variability within the CONV decreases as N_D is increased, meaning that RHi is suppressed by frequent DIN events”. I would suggest moving this line to the discussion about RHi initiated in line 416.

Figure 15: missing in the caption the explanation of the black line.

Line 440: “Two simulations representing nighttime and daytime simulations...” -- “Two simulations representing nighttime and daytime...”

Figure 16: since it is mentioned in the discussion of this figure, I would suggest to add again in one of the plots the lines for CONV and SEDI.

Line 471-472: “ DARDAR-ice observations at 12 UTC show maintained high ICNC and IWC (corresponding to hour 10 in LES time (Fig. 10))” I would suggest rewriting this sentence, perhaps: “ As shown in Fig. 10, DARDAR-ice observations at 12 UTC show maintained high ICNC and IWC (corresponding to hour 10 in LES time (Fig. 16))”

Figure 17: if it looks clearer, I would suggest also here change the color of the contour lines.

Figure 19: it could help the reader to see the CONV lines also in one of these plots.

Data availability: shouldn't be also mentioned in this section where to find the DARDAR data?

Line 563: instead of “<https://github.com/UCLALES-SALSA/> UCLALES-SALSA under release tag dustycirrus.” I would suggest to write <https://github.com/UCLALES-SALSA/> (without / at the end) so the link works (without /) or directly:

<https://github.com/UCLALES-SALSA/UCLALES-SALSA/tree/dustycirrus>

Line 598: instead of introducing the term AIDA in line 626, I would recommend to introduce it here.

Figure B1:

- Title of the middle panel should be “Ulricht et al. (2017)”
- I personally find the size of the labels a bit smaller. I would recommend making them larger.

Line 645: $n_{\text{INP}, X}$ instead of n_X ?

Figure B2: same comment as for Fig. B1 regarding the size of the labels.