

Review of: Simulating the seeder-feeder impacts on cloud ice and precipitation over the Alps

by Zane Dedekind, Ulrike Proske, Sylvaine Ferrachat, Ulrike Lohmann, and David Neubauer

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#### General comments

In this paper, the impact of so-called seeder-feeder events on cloud properties and surface precipitation are investigated in the frame of model sensitivity studies. From an upper seeder cloud ice particles fall out reaching the lower mixed-phase feeder cloud where they may change the cloud microphysics and, eventually, precipitation. To quantify these effects model simulations were performed with and without seeding effects and, additionally, with and without secondary ice formation, and with and without the assumption of spherical ice particles instead of snow aggregates or ice crystals. The simulations were performed with the 3D cloud model system COSMO combined with a two-moment microphysical scheme. From their results, the authors deduced the importance of seeder-feeder effects, not only on the microphysical properties of the feeder cloud such as liquid and ice water content, updraft and latent heat release, but also on in-cloud processes such as riming rate and depositional growth rate, and, finally, on the development of precipitation. Furthermore, they come out with suggestions for future model studies.

The paper represents a substantial contribution to the research in this field. The authors used a real case for their simulations that took place in Switzerland where the topography over the Alps favors frequent occurrence of natural cloud seeding. The scientific approach and the applied methods are valid, and the results are discussed in an appropriate way. The paper is very well written and well-structured.

To my opinion, the paper is worth publication after minor revisions.

#### Specific comments:

Page 2 line 39: What exactly do you mean by accretion? The deposition of water vapor? Please clarify in the text.

Page 3 line 56 and others: Describe explicitly that the seeder cloud is the upper cloud and the feeder cloud the lower one (as I understand it).

Page 4 line 99: Explain the terms cloud area fraction and the abbreviation CLC.

Page 7 lines 158 to 160 and Figure 3: How did you calculate these values of 48%, 10%, and 31%? Are they mean values over the entire time period? Please specify this in the text and add the range of the values.

Page 7 line 164: Instead of > 10%, give a more specified value.

Page 8, Figure 3: What exactly do you mean with “occurrence frequency of total cloud tops”? Occurrence of any clouds?

Page 12, title of section 3.2.4: I think the title is somehow misleading as not the effect of seeding on the ice particle shape is studied but the effect of the ice particle shape on the seeder-feeder process. I suggest to change the title accordingly.

Page 13 last paragraph: It is not completely clear to me at the end how breakup after ice-graupel collisions affects precipitation. First you discuss about riming, then about aggregates, finally about ice-ice collisions that are not included in your model. Please rework this paragraph to make your results and conclusions clearer to the reader.

Page 16 line 365: What do you mean by “cloud condensate difference”?

Page 17 line 373: I cannot not agree with this statement. Could you give a reference that growth via the deposition of water vapor is generally the dominant process and not riming? You write later that during

summer the enhanced liquid water fraction favors riming as the dominant growth process. Why not in winter? Please overwork these phrases.

Technical corrections:

Page 1 line 18: Please remove the reference in the Abstract.

Page 4 line 119: Maybe change “further distances” into “longer distances”.

Page 4 line 114: I think this must be Fig. 1b.

Page 5, caption of Figure 1: I think “... referred to as ... or (**b**) No-Int-SF ...” should be correct.

Page 7, caption of Figure 2: Reformulate the sentence “The large *domain* is the simulated *domain* ... ”

Page 7 line 158: Please correct the time from 13:00 to 13:30.

Page 7 line 165: please correct Figs. 3a and b, line 168: Fig. 3b.

Page 8, caption of Figure 3: I suggest to move the last sentence into the text where you describe the model setup.

Page 8, Figure 4b, title of x axis: change Layered into layered.

Page 8 line 174: I suggest to reformulate the sentence into: We note from Figs. 4a and b that there are rare cases in which ... that was more than 2.5 km below the seeder cloud.

Page 8 line 176: It is not clear which cases you mean by “some of these cases”. Please rewrite this sentence.

Page 8 line 183: ... blue histogram in Fig. 4a) ... (remove the point before the second bracket).

Page 9, caption of Figure 4: I suggest to move the sentences “The 230 km×235 km analysis domain at a 1.1 km×1.1 km horizontal resolution gives about 45 000 columns. 550 000 layered clouds and 55 000 seeder-feeder occurrences were observed during the time period.” into the text, see comment above.

Last sentence in figure caption: change into: “ ... against the vertical distance between clouds derived from Proske et al., 2021. (The other information is already given in the text.)

Page 11 line 232: please change “riming rate” into “riming”. A growth *process* is riming, not the riming rate.

Page 12 line 247: Figure 4b illustrates ...

Page 12 line 251: seeder\_feeder process

Page 13 line 274: change into: “... at slower velocities against the strong updraft.” (omit the last “velocities”).

Page 13 line 276: seeder\_feeder

Page 13 line 280: I would suggest to write here mixed-phase clouds instead of MPCs because for some readers this abbreviation is not well-known although it was explained some pages before.

Page 13 line 283 and 287: Figs. 6a and b

Page 13 line 286: I think the abbreviation of secondary ice production (SIP) is not explained in the text.

Page 14 line 305: Omit the word “percentage”.

Page 15 line 325: Please introduce the abbreviation of the Wegener-Bergeron-Findeisen process (WBF) because not every reader may be familiar with this, for example in the Introduction where you mention this process.

Page 16 line 341: Remove the comma after “glaciation”.

Page 16, section 4: I suggest to rename this section in “Summary and Conclusions” because the main part is a summary of your results.

Page 16 line 344: Remove the comma before “COSMO”.

Page 16 lines 351 and 359: I suggest to omit the time data because they are not relevant in this context.

Page 16 lines 355/356: I suggest to change: “ ... the high occurrence of short distances smaller than 0.9 km between multi-layered clouds.”

Page 16 line 357: I suggest to change: “ ... confirm that seeder-feeder events are frequent ...”

Page 16 lines 360/361: Please reformulate this sentence. Table 2 provides the changes of precipitation and so on, but not the changes of the sensitivity simulations. You could write “changes found in sensitivity simulations”. See comment below.

Page 16 lines 362-364: Please rework this phrase, there must be a mistake. Additionally, the statement “south of 46.25°N” should be omitted here.

Page 16 line 370: seeder-feeder

Page 17, Table 2: This table belongs into the section containing the results and not in the Conclusion section. I suggest to move the table together with the above commented phrase into section 3 where it is firstly mentioned.

Page 17, caption of Table 2: Please correct: “Average and maximum changes ( ... ) riming rate<sub>z</sub> and depositional growth rate (...) compared to the CNTL\_BR simulations...”

Page 17 line 372: mixed-phase clouds

Page 17 line 373: What is meant by “these clouds” – observed clouds or mixed-phase clouds? Please mention it clearly in the text. The formulation that the WBF process is the dominant precipitation process is not completely correct, the WBF process promotes precipitation formation. Please rewrite this phrase.

Page 17 line 377: I suggest to omit the time data.

Page 17 line 382: Omit “(Table 2)”.

Page 18 line 401: I suggest to start a new paragraph before you discuss the microphysical schemes.

Page 18 line 402: Please change into “ The two-moment scheme ...”

Figures S2 and S3, captions: I suggest to change “Cross-section of the growth rate of ice particles”.

“ ... for the ensemble means<sub>z</sub> respectively.”

It seems that Figure S3 is not mentioned in the paper.