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Atmospheric Measurement Techniques Discussions

Interactive comment on "Pore structure 3-D imaging by synchrotron micro-tomography of graupel grains" *by* F. Enzmann et al.

Anonymous Referee #2

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This paper describes what appears to be the first investigation of the structure of graupel grains by X-Ray microtomography. The authors describe in detail the sampling procedure, the method used to obtain the 3-D images. They then analyse their images to derive microphysical properties and in particular the shape and surface area of air bubbles. They then make preliminary suggestions as to the relevance of their results to growth processes.

While this paper doubtless has a significant interest, I found it very confusing and very difficult to read. The vocabulary is often not internally consistent, which largely contributes to the confusion, and the English is too often not very good. The introduction is confusing, as it does not clearly state the objectives of the paper. The impact of

air bubbles on ice particles optical properties is discussed at length, but no conclusion on this aspect is drawn from this study. My feeling is that the numerous senior authors may not have done their share of the work. This does not do a service to anyone, the main result being that in my recommendation I hesitate between rejection and complete rewriting with a second review. Given the potential merit of this paper, I will nevertheless try to provide helpful and constructive comments.

1- Quality of the writing

The first problem is vocabulary. What is graupel ? What is hail ? The authors should clearly define that at the very start. I think they misunderstand the difference. In their discussion, they refer to many previous studies, in particular to those of the Macklin group, which dealt with hail, not graupel, and use their conclusions to discuss what they call graupel. Now are the samples studied here graupel or hail ? If I understand the data clearly, the porosity of their samples is 0.5% or less. Their particles therefore have a density greater than that of the densest graupel particle mentioned in the literature.

There are a number of electron microscopy studies of graupel particles in the literature. For example Rango et al. (2003) Scanning, 25, 121; and Domine et al. (2001) Environ. Sci. Technol., 35, 771. The images therein show that probably most of the graupel particle volume is air, not ice, in sharp contradiction with the results of the authors. In typical graupel particles, most of the air volume is space between rime particles, not air bubbles formed within riming droplets, and that were trapped during the growth of ice. To sum up this point, the authors should either call their particles hail or explain that they have studied exceptionally atypical graupel particles.

Another vocabulary problem is annealing/metamorphosis/metamorphism. To my understanding, annealing is subjecting a solid to a higher temperature to induce physical changes. Metamorphism is one such physical change that happens to ice or snow during annealing. Metamorphosis is sometimes used instead of metamorphism, but much less often, and I do not recommend mixing up both terms in the same paper, unless

the authors explain that for them, both terms have different meanings.

Again regarding style, I recommend checking sentence construction. Many sentences are difficult to understand. The abstract is particularly hard to follow and should be completely rewritten. Isolated is used many times for insulated, etc. The style problems are just too numerous to mention, and they end up affecting the perception of the value of this paper.

2- Experimental protocol

I am just surprised to see all the stages of thermal cycling that the samples were subjected to. Why were the samples simply not kept in liquid nitrogen all the time ? This is what many authors who study snow and graupel do. Please look up for example Erbe et al. (2003) Microsc. Research Tech., 62, 19. Was the collection temperature of the Mainz samples really +9°C ? If this was the case, then the samples properties were obviously irremediably modified by melting and any mention of those samples should be deleted. In the same paragraph, could the author explain what they mean by “snowflake” ?

3- Results

This study really deserves the publication of higher quality images. In particular, given the 1 micrometer resolution, close up images are required. The authors mention that X-ray tomography could be used to determine the specific surface area (SSA) of snow, but they do not perform the exercise. By the way, although Kerbrat et al. concluded that gas adsorption and XMT could both be used to measure snow SSA, they studied samples where closed porosity was negligible. If most of the porosity is closed, as could be the case in hail particles, then the statement is not valid anymore.

4- Discussion

The authors do not discuss any implication regarding the optical properties of their particles, while this is expected from the introduction. By the way, many optical models

of ice particles just use the optical grain size, i.e. the SSA. The SSA of their samples, if properly defined (gas adsorption SSA or XMT SSA ?) could be easily derived from their data and used in optical models to obtain some optical properties of the particles. The implications of their finding for the understanding of the growth mechanism should be clearer and perhaps more detailed.

5- Recommendation

If the editor does not wish to reject this paper, I recommend extensive rewriting and clarification of numerous points, and first and foremost, is this graupel or hail ? Ideally, more experiments with typical graupel particles, avoiding unnecessary thermal cycling, would be highly desirable, but I realize this may not be possible. The objective of this paper should not be only to provide images, but to derive detailed implications for ice optical properties and hail (graupel ?) growth mechanism. If a thoroughly revised version is submitted, I strongly recommend that it be reviewed again.

Interactive comment on Atmos. Meas. Tech. Discuss., 3, 4761, 2010.