Atmos. Meas. Tech. Discuss., 3, C2566–C2571, 2011
www.atmos-meas-tech-discuss.net/3/C2566/2011/

Atmospheric
Measurement
Techniques
Discussions

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

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Received and published: 31 January 2011

Reply to referee #1

The authors are grateful to this referee for his/her review and much appreciate for all comments elaborated. Our main replies and changes to be made to a revised manuscript are listed below.

General Comments Reply

We agree that the methodological part can substantially be enhanced as far as the page limit allows for. We will add also one unsegmented slice image for the graupel particle #1 (Figure 3 in AMTD version) as shown below. The English will be checked

by a native English speaking colleague.

Detailed Comments Reply

Units used: We will change all units on a cm-base

Tradition 2-D imaging: The paragraph on the limits of 2-D imaging by optical methods has been completely dropped as deemed not relevant for this paper.

Metamorphosis and annealing: both terms have been replaced consistently by the term "metamorphism" throughout all text. Please note, however, that the term metamorphosis is still valid if we speak of "metamorphosing graupel".

SEM imaging: The more recent literature by Si Chen et al. (2010) on cold stage scanning electron microscopy imaging will be considered as well in the introduction.

We agree that the temperature history of the different samples is somewhat scattered. This is because it became an important part of the improvement history of the related PhD thesis work and iteration towards the ultimate experimental demand which became evident during that work. We prefer to document the different adopted approaches which were common in the related community. Although the state-of-the-art approach is to keep samples in LN all the time which is simple in case the samples do not leave the laboratory. However, fixation of the sample in the synchrotron beam during spinning of the sample holder is mandatory for high-resolution XMT. For this we have experimented with alternative sample fixation by an organic fluid and related cooling approaches which turned out to work at the micrometer spatial resolution and hence were documented as well. This spatial resolution was possible at the time the work was performed only at synchrotron facilities, but is currently possible also with state-of-the-art lab machines which merits a report on the alternative cooling approaches used. Clearly, for sub-micrometer spatial resolutions currently available on synchrotron facilities these approaches might no more work as detailed in the paper.

More details on the segmentation technique will be provided. In fact, we didn't use automatic threshold segmentation, this was a misunderstanding in between writers of the different sections of the manuscript. The quality of raw data with a lot of artifacts was too poor for any automatic approach. We have applied 3D median, 3D Gaussian and edge-preserving smoothing filters to elaborate the locations of phase boundaries and to enable a better segmentation. The slice to be added as shown below also shows the significant edge enhancement effect as typical for synchrotron XMT. This effect, however, can favorably been exploited for the threshold segmentation before edge smoothing.

The Amira/Avizo software package does help to visualize the segmentation results during processing for a manual check as a kind of interactive segmentation process. Anisotropic diffusion filtering is definitely a highly useful technique but is not applicable with our raw data because of too much artifacts and an inhomogeneously distributed edge enhancement effect. The latter effect, in particular, is not closed around all features to be segmented (cf. the slice figure below).

The camera currently used at PSI/SLS TOMCAT beamline is in fact 16 bit recording (floats). For the experiments to be reported on the older X04SA beamline was 12-bit recording, but the dataset was rescaled to 8-bit for segmentation due to limited computer power at that time. Note that during our very first SLS measurement campaign, we gathered within 3 days 1 TB of data, while the whole storage capacity available at PSI at that time (5 years ago) was 1.5 TB only. Meanwhile this is no longer any limitation. Our "burning" algorithm has been described by Turek (1999) and was applied to volumes. Our approach is used commonly for fluid flow simulations in porous media.

We will work further on the visualization of the Figures, drafts are attached below. The main problem is to reproduce the ice-air contrast calculated by the software on a printed paper which is not a trivial task. It is not surprising for as that XMT figures of graupel internal porosity are yet virtually absent in literature.

References

Chen, S., and Baker, I., 2010: Evolution of individual snowflakes during metamorphism. J. Geophys. Res. 115, D21114.

Turek S., 1999: Efficient Solvers for Incompressible Flow Problems: An Algorithmic and Computational Approach. Springer, ISBN 3-540-65433-X.

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

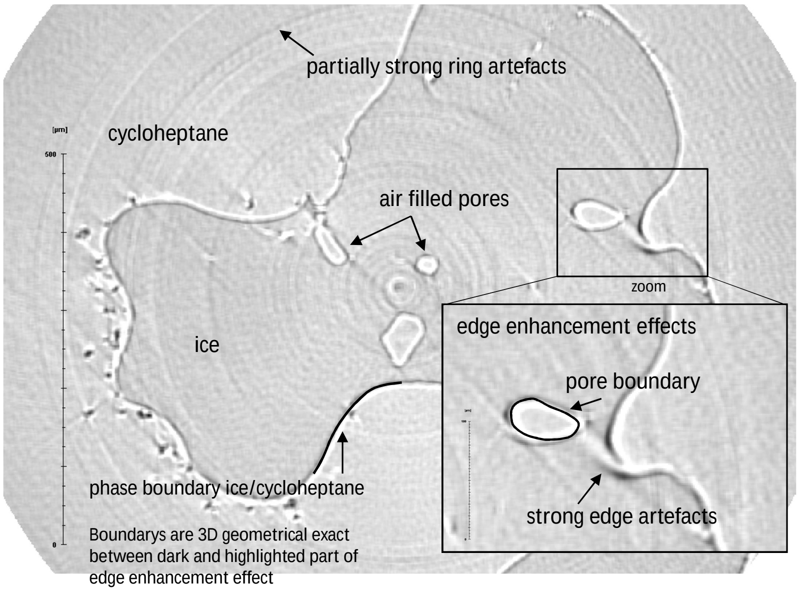

Fig. 1. 1: Unsegmented slice image for the graupel particle #1

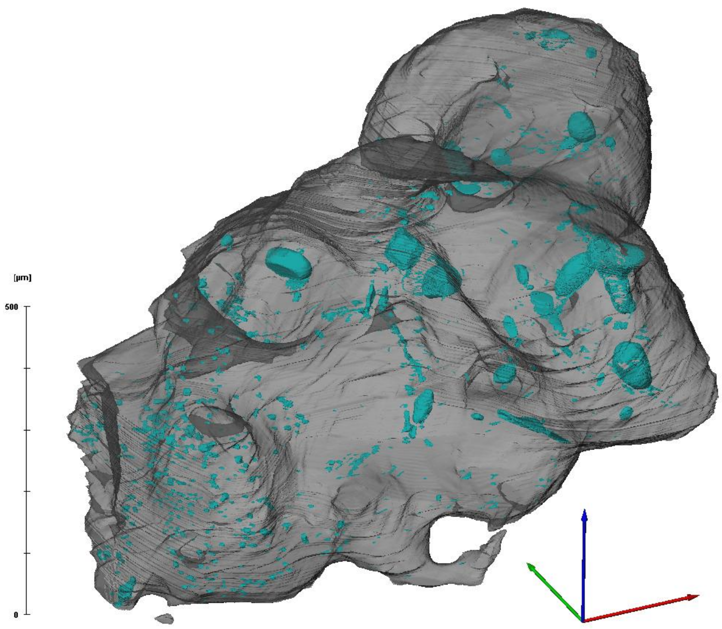

Fig. 2. 2: Ice particle #1 collected at the high alpine research observatory Jungfraujoch. This will replace the Figure 3a in the first manuscript draft.