MicroDICE short term visit

Sönke Maus (University Bergen, Norway) visiting the WSL Institute for Snow and Avalanche Research SLF (Davos, Switzerland)

Experiment: *Micro-tomography of sea ice*

Time period: 29.01.-13.02.2012

1) Purpose of visit

The purpose of the 15 days visit by the author (*Sönke Maus*) at the Institute for Snow and Avalanche Research (SLF) of the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in Davos, Switzerland, was to perform 3-dimensional micro-tomographic imaging of natural sea ice samples, using the X-ray computed tomography setup in the SLF laboratory. Specific targets of this study were to

- Perform high-resolution micro-tomography on natural sea ice
- Obtain vertical profiles of the pore space and connectity
- Obtain information of the temperature dependence of the pore space geometry
- Evaluate the results in terms of percolation thresholds of permeability and connectivity

To date only very few 3-dimensional observations of sea ice microstructure exist, and those are based on laboratory-grown sea ice with relatively coarse resolution (e.g. Golden et al., 2007; Pringle et al., 2009). The proposed observations of natural sea ice with micrometer resolution have the potential to substantially improve our understanding of the physical properties of sea ice.

2) Work carried out

The visit lasted from 29.01.2012 (arrival) to 13.02.2012 (departure). Imaging of sea ice samples and first image postprocessing was performed at the SLF in Davos from 30.01. to 13.02.2012.

3) Main results of experiment

The sea ice samples to be imaged were obtained during field work in spring 2011 during field work on Svalbard fjords, from sea ice that had reached thicknesses between 30 and 70 cm. In the present analysys we focus on (i) the vertical profile as well as (ii) the temperature dependence of the microstructure of 35 cm thick ice. We applied our (Maus et al., 2011) previously successful procedure (i) ice coring and rapid cutting into subsamples, (ii) temperature-controlled sample transport to the nearby laboratory, (iii) centrifuging samples at *in situ* temperatures, (iv) storage in a low temperature (-80 ℃) freezer or on dry ice, until imaging.

The imaging was very successful and produced high quality tomographic images of natural sea ice. After 2 days of test scans, to find a suitable CT configuration, measurements were performed on two CTs from the firma Scanco, a μCT40 and a μCT80 instrument. In total, 5 cores of 35 cm thick sea ice were scanned with 10 μm voxel size, corresponding to more than 45 three-dimensional images of 20-40 mm height and 33-35 mm diameter. In addition a small set of images from old, 150 cm thick sea ice, was obtained. We thus were able to obtain almost two times as much images than planned, due to the strong experience at the SLF with tomographic imaging of snow (e.g., Schneebeli and Sokratov, 2004; Kaempfer et al., 2005; Kerbrat et al., 2008; Heggli et al., 2011) and the well calibrated X-ray computer tomographs from Scanco.

With the resolution corresponding to 10μm voxels, each image obtained corresponds to approximately 30-40 Gigabytes of data. The large files are a consequence of a combination of the requirements to resolve the relevant pore structure, yet obtain sufficiently large images that also include larger pore features and complete pore networks systems. These file sizes yielded an overall data volume larger than 2 TB. The postprocessing of raw absorption radiography images includes (i) reconstruction of 3-d tomography images, (ii) filtering and segmentation into ice, air and solid salts, and (iii) image analysis and interpretation. Due to the large amount of data obtained, and the large files sizes, the reconstruction (i) of the raw files lasted until 3 weeks after the measurements and was performed on the server of the SLF. The filtering and segmentation (ii) is still ongoing.

Figure 1 shows two slices of the reconstructed images obtained prior to segmentation. A preliminary image evaluation indicates that the dataset will allow a proper statistical analysis of sea ice microstructure. In particular, the dataset yields information about sea ice microstructure and percolation, and its dependence on temperature and vertical position. We thus have, for the first time, obtained such information for natural sea ice samples.

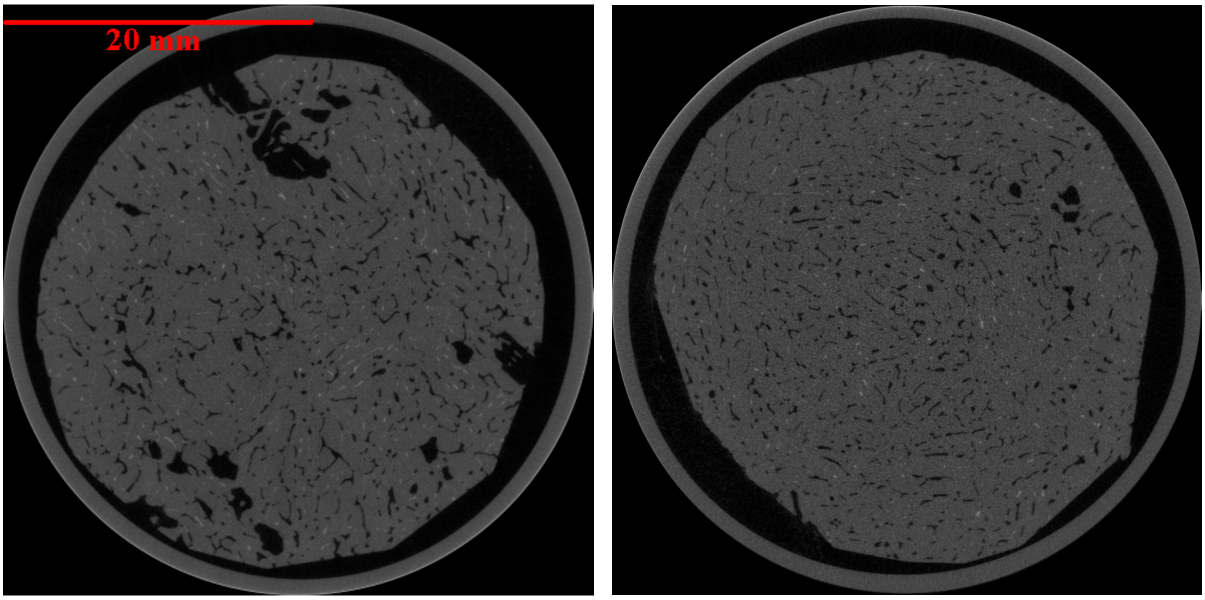

Figure 1: Horizontal X-ray tomography slices of sea ice obtained during CT imaging. Ice appears grey, centrifuged brine (now air) as dark, and salt crystals as bright. Left: sample centrifuged at -2.6 ℃; right: sample centrifuged at -8.0 ℃, containing more (white) salt crystals as well as finer pores.

4) Future collaboration

We have successfully obtained a large dataset of three-dimensional X-ray tomography images of natural sea ice and the postprocessing is still ongoing. It is mostly performed by the author, remotely on the server of the SLF, and is expected to take approximately one more month of time. After this the statistical data analysis of segmentated images will be performed, including pore size distributions and percolation properties of the samples. The most important future collaboration is the publication of the results of this analysis.

5) Projected publications

First results of the ongoing image analysis will be presented at the 'Conference of seasonal snow and ice', 28.05.-01.06.2012, Lahti, Finland, where the presentation 'An X-ray microtomographic study of sea ice percolation' has been accepted as an oral contribution. A follow-up publication in form of an article will we prepared soon.

References

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