Context

To better appraise the rheology of marine ice, lab-based deformation experiments have been performed on ice samples. We performed uniaxial compression experiments at constant load and under unconfined conditions. The aim of this work is to refine Glen's flow relation as a function of various ice parameters (temperature, salinity, debris content, grain size ...) in order to improve deformation laws used in ice shelf dynamic models, and therefore provide more accurate and / or realistic predictions on ice shelf stability in a changing climate.

Deformation experiments were made on marine ice samples at different temperatures and for different fabrics. These fabrics are evaluated using an automated fabric analyzer system (G50 LED-White) before and after deformation but, no microstructural data are recorded during the experiments.

Mark Peternell from the Institute of Geosciences, Tectonophysics, Johannes-Gutenberg-University, Mainz (Germany) worked on ice deformation in two-dimensions with a G50 RGB fabric analyser system. He refined a technique for a simultaneous recording of ice microstructures such as grain sizes, grain shapes and shape preferred orientations and crystal orientation during *in situ* deformation experiments, using an automated fabric analyzer. Such experiments consist of thousands of single microstructural analysis and therefore, automated procedure for grain and grain orientation analysis are needed.

The intersection of these two projects is the Fabric analyser G50, who gives output data pixel by pixel. The aim of this collaboration is to work from this output data and build automatic procedures to obtain microstructural data and statistics analysis. These scripts will be open source and will help to build a standard analysis platform for such large datasets. MTEX is an open source Matlab toolbox for quantitative texture analysis that can be used with the data from both fabric analyser systems (G50 LED-White and RGB). This procedure will be open source and be very useful for others researchers who want to check some microstructure (also in geology and metallurgy), more specifically for someone who uses a FA.

This exchange fits inside the MicroDice networking given the aim of our collaboration: to get a more accurate understanding of the ice microstructure. In this case, we would like to obtain automatically this microstructure (grain size, grains boundary, Eigen vectors …) during and after ice compression, respectively in 2D and 3D compression experiments. We would like to write some automated procedures compatible with the MTEX toolbox and the FA.

Work carried out during the visit

In a first step, we have rebuilt the fabric analyser and have compared the output file from the G50 RGB and the G50 LED-White. Moreover, we have deepened our knowledge of the output files with the designer, depending on the resolution, because the FA can take two different resolution measurements. So we began to work on these different files to obtain the same structure for input for the new scripts.
After that, we worked some days together to equilibrate our personal skills in Matlab and MTEX and plan our future work to build these open source scripts.
The planning was to obtain a valuable grain structure (by MTEX toolbox) and by this structure, determine some statistics, like preferential orientation, grain size histogram, median radius …
For all these scripts, we decided to apply filters, to work with less data, and to clean data by pixels quality (given by the FA). We decided too to delete very little grains, which are measurements artefacts, because of the FA resolution.

Main results obtained

At the end of this short collaboration, we obtain different automated scripts to begin with the output data of the FA. Each script produce output data, and become input data for the next script.
We decided to work in this way in this first version, because of the calculation time needed by the complete set of scripts (which depends of course on the computer onto which they are run).
The script structure is shown in the figure 1 of this document.
The first script, named *cis2mtex_import_file* work from the classical input file of the FA and generates a txt file. This is a pre-requisite to work properly with the MTEX toolbox. The conversion from Fabric Analyser dip direction dip data to Euler angles (needed by MTEX) is implemented from a script of David Mainprice, who we want to greatly acknowledge for sharing his data.
The second script, *import_file2mtex,* takes this output txt file as input and work with MTEX functions. The aim of this script is to build a MTEX structure.

The third script takes this MTEX structure as input. It creates grains boundaries from parameters like angle between two different grains, minimum acceptable grain size, etc... The function creating grains works from the Voronoï polygons (MTEX function). In this script, it is possible to determine if you want all of the pixels, or only pixels with good quality (geometric and retardation quality, from the FA cis file).
Finally, at the end of the script, a new structure in Polylx, a powerful Matlab toolbox for grain shape analysis, is created, to gain more capabilities like performing statistical analysis. This script generates figures of the grain map boundaries and the new polylx structure.

The aim of the fourth script is to obtain statistic data about the grain orientations and the grain sizes. The polylx structure is given as input file. The script generates a histogram comparing the diameter of each grain with the associated area, to know if the grain distribution corresponds to a unimodal or a bimodal distribution, or if we have two grain size groups or only one.
The script also generates figures with directional statistics, for each grain size group.
Finally, it plots a last figure that represents the interquartile range function of the median diameter.

All of these scripts can work with only one input file or in batch modus, with multiple files, for example in case of analysing a deformation experiment. This function is named *batch*. The only thing you need is to tell the script in which case you are: if you take a single input file or multiple (movie-like) inputs.

At this time, all the scripts work properly, but we continue the collaboration to improve the accuracy, for example in statistics (last script).

So, we can say than our objective is reached, because all of the scripts works and the results are very satisfactory. For an external user, it is very easy to use, because you just need to change some parameter (depending on the input data like material, grain size or orientation). This therefore allows already a more widespread distribution of the scripts.

Future collaboration with host institution

We would like to continue this collaboration, in a first time to improve scripts. Now, we can begin to analyse our respective personal data (for example, thin section before and after compression experiments in 3D) and find how we can improve the script. Moreover, in collaboration with colleagues from Europe, we would like to build up an open source microstructural analysis platform using MTEX. The aim of this platform would be that users using this new script could propose improvement or propose a new version of the script.
This platform would be the place where people can discuss about which parameter is better to take as a function of the material or the grain size.

Projected publications / articles resulting or to result from the grant

In the next weeks, we would like to submit a paper to the Journal of Structural Geology (special issue on microstructures in ice). The working topic will be "simultaneous determination of crystallographic preferred orientations and microstructures in ice during see through deformation experiments". The data for this work was analysed with these scripts, in particular to obtain the grain boundaries and the grain statistics.
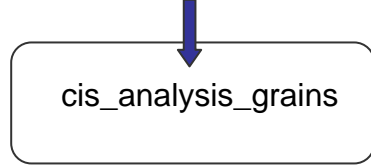
Input: cis file (from the FA)
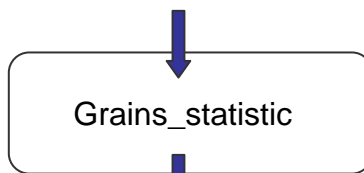
cis2mtex_import_file
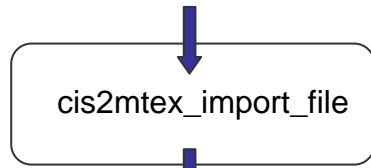
Output: txt file

Input

import_file2mtex

Output: mtex file

Input

cis_analysis_grains

Output

grain figure   Polylx grains

Input

Grains_statistic

Output: statistic data