Research Networking Programmes

Short Visit Grant or Exchange Visit Grant

(please tick the relevant box)

Scientific Report

The scientific report (WORD or PDF file – maximum of eight A4 pages) should be submitted online within one month of the event. It will be published on the ESF website.

Proposal Title:
Comparison of c-axes measurements of polar ice with “automatic fabric analyser” and “CIP”

Application Reference N°:

1) Purpose of the visit

The high anisotropy of the hexagonal ice Ih has impact on many properties of the material, from electrical to optical and mechanical behaviour. In modern glaciology the mechanical anisotropy is especially respected, as it has direct consequences on the deformability of ice in certain deformation regimes and settings, because polycrystalline ice in polar ice sheets develops a strong LPO with depth. Electrical anisotropy as well as elastic behaviour, for example, have consequences for integration of crystallographic data with geophysical methods and their interpretation. Optical anisotropy can be utilized to determine the principle crystallographic axis of the ice crystallites in a polycrystal applying the classical polarization microscopy. Computer-assisted methods to enable fast, but accurate results of optical c-axis determination have been developed, serving different needs of the Earth science community: a) computer-integrated polarization microscopy (CIP, Heilbronner & Barrett 2014), b) automatic fabric analyser (FA, Wilson, Russell-Head, Sim 2003).

Comparison of the two systems have been performed using quartz (Toy et al. 2014) and snow and firn (Leisinger et al. 2014, Calonne 2014), however giving contradicting results.

2) Description of the work carried out during the visit

In order to obtain solid knowledge of the measurement systems involved in this study, we repeated this study using solid polar ice, having full control of sample preparation quality and measurement quality; and making use of advanced processing tools available and applicable for both data types.

The visit took place August 13 to 18 2015.

-day 1-3: set-up of system

The CIP system was set up as follows: Macroscope (*Wild* M420), equipped with a Basel "home-made" sample stage with four tilting mechanisms, rotatable polarizer, analyser and lambda/4 plate and a bandpass filter. Images are taken with a digital camera Basler Ace 1600-20gm attached to the macroscope with an uncalibrated light source.

The FA system (G50) is set-up standardised in the AWI cold laboratory. The mapping function did unfortunately not work (damage of stage motor) during the time of the visit, however as CIP measures one field of sight the comparison could still be performed.

-day 2-4: sample selection and preparation

Samples from EDML (Antarctica) have been chosen: 656.90, 1375.80, 1555.80. Thin sections have been prepared according to standard procedures (ca. 130µm). One section could not be used as frost formation between glass plate and sample let the sample "buckle" forming fringes between crossed polarisers which disturb the measurements.

- days 3.-7: measurement of samples and concurrent processing of data

LASM (sublimation feature mapping) of the full samples was performed giving an overview of the samples as well as high spatial resolution of microstructural features to be expected in the sample. CIP measurements have been performed, with FA measurements of the same areas in similar resolutions. Quality of measurements was concurrently checked by inspection and preliminary processing tests of the data.

- days 6.-7: processing, discussion and embedding of topic into other lab activities. Visual inspection and general comparison of data was done on-line with the measurements. Advanced processing of data of both types especially with respect to angular resolution of the two systems was performed using MTEX (Ralf Hielscher: https://mtex-toolbox.github.io/); Mainprice et al., 2014).

3) Description of the main results obtained

Both measurement systems produce comparable results in terms of c-axis orientation. Due to the small field of view in macroscope used to obtain the CIP data and hence the small number of grains, CIP is limited to the approximation of c-axis inclination as it partly relies on the full spread of c-axis inclinations. This problem can be omitted by acquiring input of regions which are large enough to contain a representative spread of crystal orientations. For some grains, orientation differences exist in the determination of upper or lower hemisphere position between both methods. The manual acquisition of input images and manual processing makes CIP the more time consuming method. Because of the ad-hoc assemblage of the CIP system, the results suffer locally from artefacts which are due to produced by uneven lighting, dust and other optical imperfections of the system. These can be clearly eliminated. Artefacts present in both methods which cannot be overcome are related to section thickness and apparent orientation deviations along grain boundaries, due to light absorption and scattering. The FA is a fast system and produces relatively noise free data. While CIP orientation data is limited to integer numbers, FA data contains one decimal. However, the significance of this higher angular resolution remains to be determined. The manual processing of input in the CIP method gives a fine grained control on every step needed to obtain the orientation data and hence a good estimate on the quality of data, hence it is easier to recognise e.g. errors and artefacts.

Data of both input types have been imported to a common framework used for post-processing (clean-up, filtering), grain segmentation, advanced orientation mapping and analysis. In the following details will be given on the internal structure of grains. For this purpose a novel method is used to display small (< 1 ° c-axis misorientation) is used to visualise orientations differences (Fig. 1).

Figure 1 shows the a cropped region of sample edml656_90 in (a, b) CIP and FA derived c-axis orientation maps, (d,e) display the orientation maps with a highly stretched colour look-up table, to visualise small orientation differences in individual grains and (e,f) show the stretched orientation maps superposed to the LASM image. The stretched colour look-up table (Fig. 1 c-e) is calculated using the mean c-axis direction of each grain as the white centre and stretching colour values with a fraction of the orientation space around this centre. The colour look-up table is displayed in IPF coordinates, setting the third Euler angle to 0. Hence only differences in azimuth and inclination of the c-axis determine the colour value. A shortcoming of this visualisation method is that the colour-coding cannot be related to the global c-axis direction however it can be clearly seen how individual areas of grains possess slightly different orientations. The boundaries of these areas coincide with fine, linear sublimation features in the LASM images, interpreted as subgrain boundaries. Some of these areas are not as accurately defined in the CIP derived maps as in those obtained from FA data. This is most likely due optical artefacts introduced by dust on the polarisation filters.

Individual orientation changes across well-defined areas are comparable as can be seen in an example of an individual grain (Fig. 2). Small differences of the azimuth of the displayed grains are due to slightly different sample orientations in the setup; the azimuth is derived correctly in both sample reference frames. C-axis misorientation profiles (Fig. 3) are calculated from data of a 5 pixel wide profile. In Profile 3 obtained from FA data, individual spikes can be recognised separating plateau regions. These spikes represent artefacts introduced by surface irregularities due to differential sublimation.

The angular-spatial resolution across these subgrain boundaries of CIP and the FA is about 0.2-0.4° c-axis misorientation/pixel which is only slightly above the angular noise of around <0.1°/pixel of both methods. Hence downsampling of the orientation maps is a viable possibility to allow a better discrimination of orientation gradients.

One particular outcome of this visualisation method is that diametral orientation changes are recognised in the four sectors around flattened bubbles. Sectors are divided by the traces of the basal plane and its normal. The occurrence of these structures will be subject to further research.

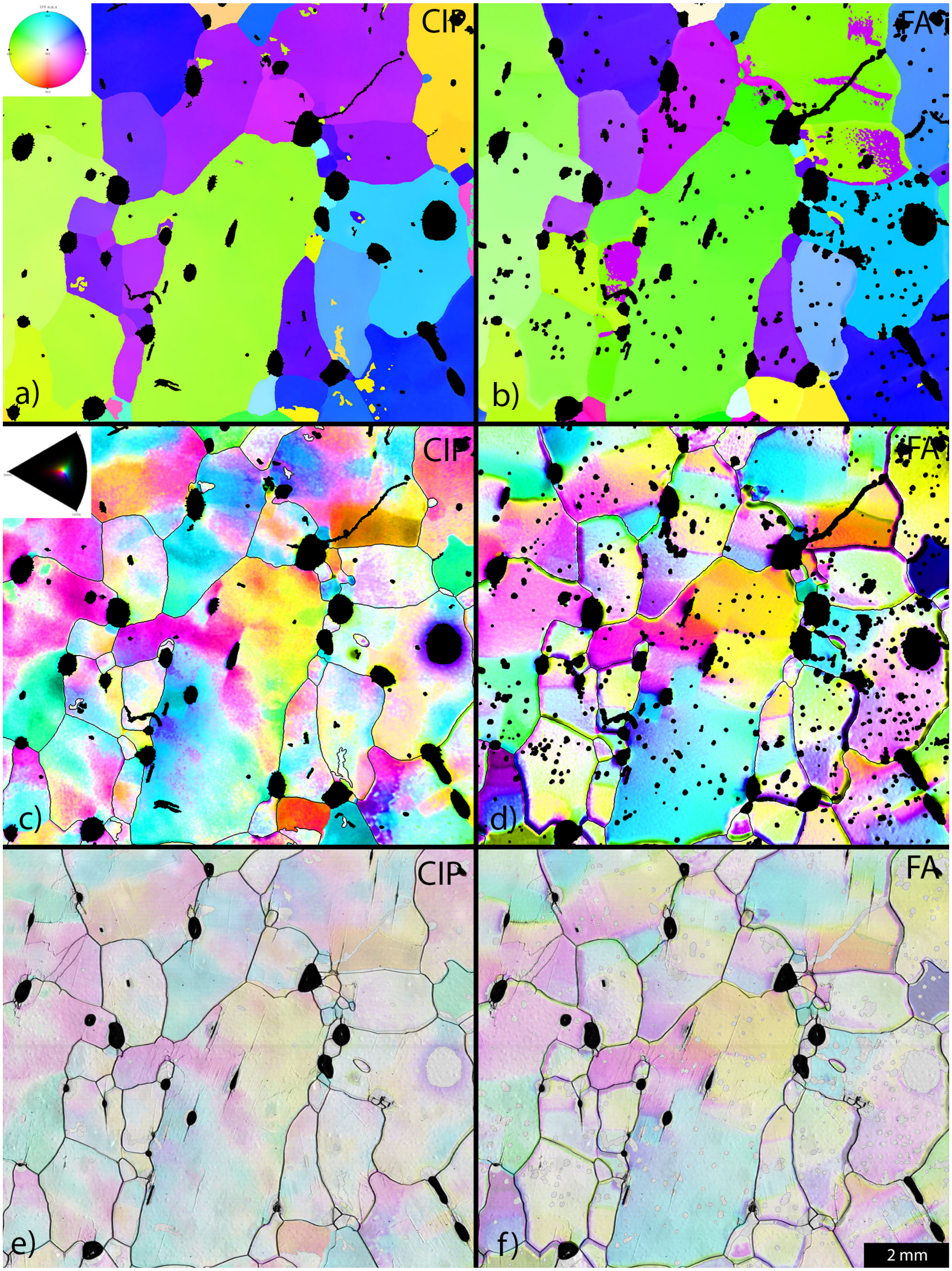

Figure 1: Orientation maps

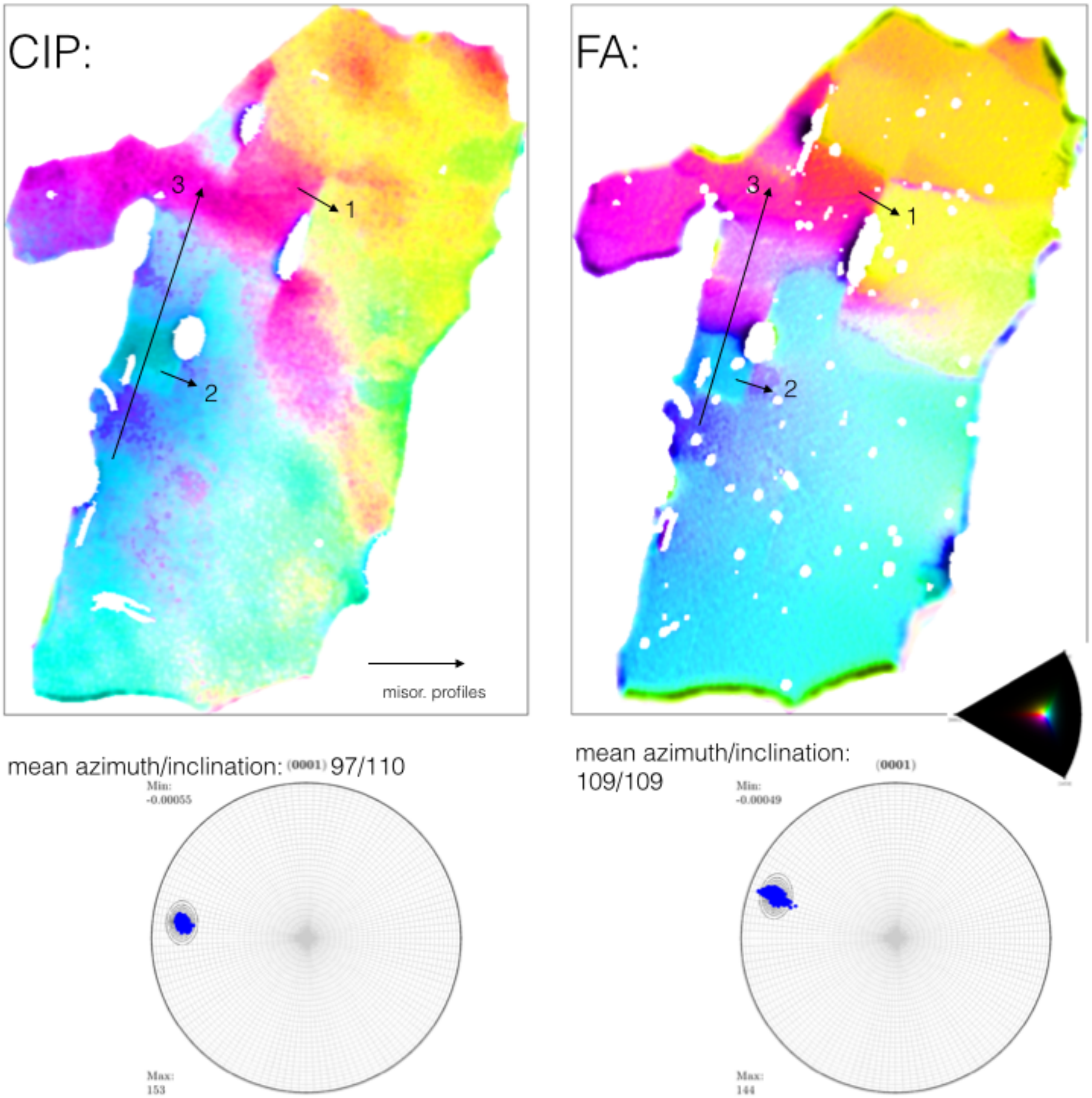

Figure 2: Comparison of two individual grains. Position of misorientation profiles (Fig. 3) are indicated.

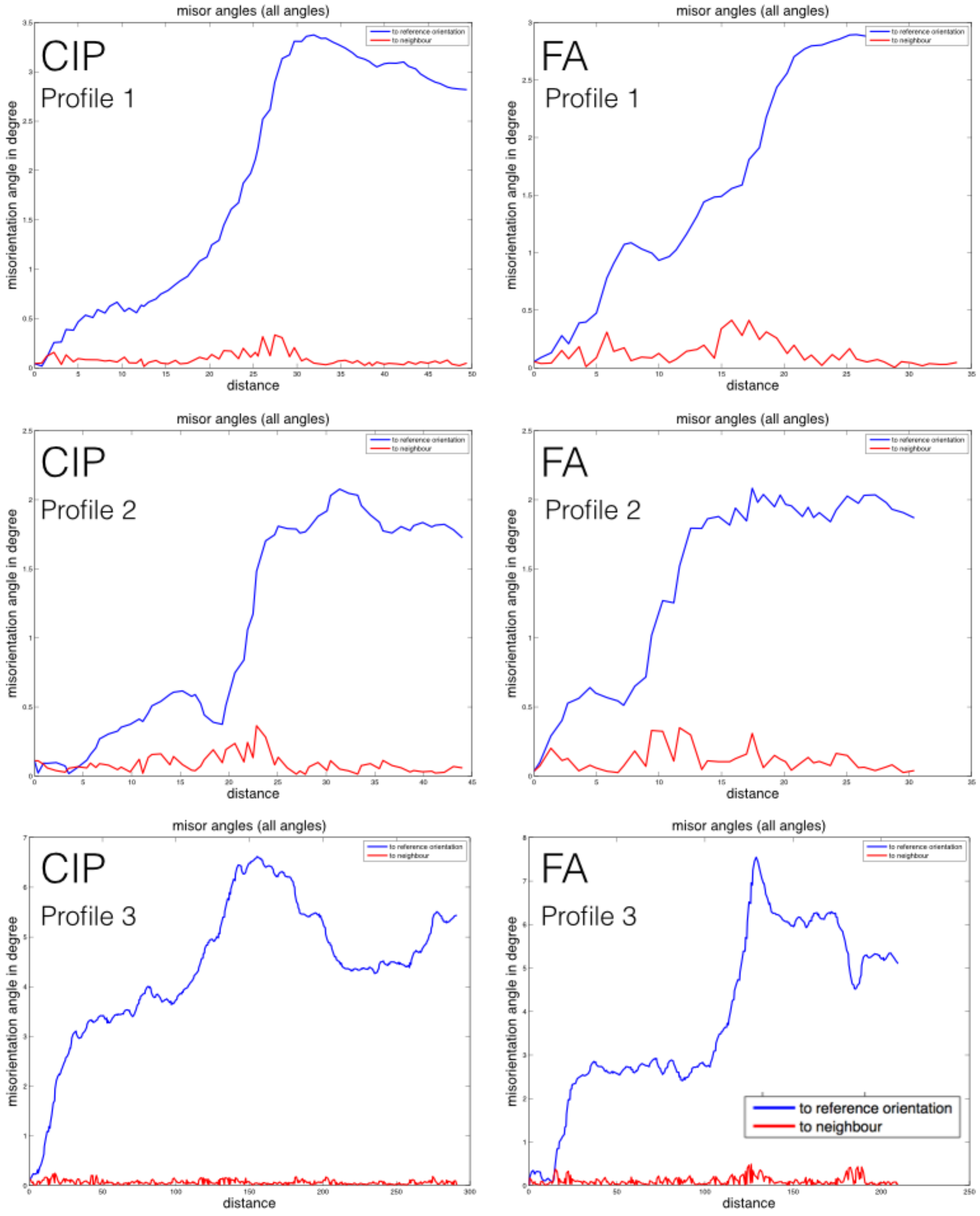

Figure 3: C-axis misorientation profiles. Red line is misorientation with respect to neighbour, blue line is misorientation with respect to origin.

4) Future collaboration with host institution (if applicable)

N/A

5) Projected publications / articles resulting or to result from the grant *(ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)*

In discussions, publications and collaborations directly resulting from this meeting MicroDICE will be fully acknowledged.

6) Other comments (if any)

None.

References

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