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Interactive comment on "Fabric measurement along the NEEM ice core, Greenland, and comparison with GRIP and NGRIP ice cores" *by* M. Montagnat et al.

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Dear Referee

As the answers to comments from the three referees are linked, I will provide them all in the following text.

First of all, I would like to thank all the referees who provided very helpful comments in order to improve the manuscript. In the following, I will answer to the 3 referees one by one.

- Answer to comments from Anonymous Referee #1 :

1- First of all, the title was modified as suggested, and the first general comments have been taken into account. 2- Most of the short comments (like the ones on L7, p310 L24, p311 L1, p315 L10 L16 L19 . . .) were taken into account and the text was modified accordingly.

3- Concerning the relative weight of the discussion about the jump at the Holocene to Wisconsin transition between abstract and rest of the text, we have strongly re-organized our discussion relative this transition, in relation with the strain-rate estimations of part 3.2, which will give it more weight in the text. The abstract has also been modified in this direction.

4- We agree on the comment about strain determining the fabric, text was modified accordingly.

5- Section 2 (Fabric measurements) has been lightened using more references to previous work, as suggested

6- Section 3 : the reason why we show fabric with “delta” values (Figure 2) is explained in section 2. The main objective is to show that the measurement errors are very small, except for the one associated with the limited number of grains on one thin section. Nevertheless, we found it interesting to integrate this “error bar” on the Figure as it shows that this “error” remains within the range of the natural variability of the data. We precise it in the text.

7- Concerning section 3.3 : we have decided to remove this part from the paper in order to remain focused on the global fabric signal. It will be treated in more details somewhere else.

8 – Figure 3 aims at providing an overview of the microstructure evolution, together with a more “traditional” representation of the fabric (horizontal pole figures). To have an idea of the microstructure shape and size is always interesting when trying to compare ice cores.

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9 – Section 3.2 : we have worked a lot on this section, and on its impact on our comparison of the 3 cores. In fact, we tried to make clearer the fact that although there exist many similarities between the cores (age, depth of climatic transitions...), the fabric are quite different, and the strain history could explain most of the differences. This part also aims at showing, by comparing NEEM and NGRIP, the fact that the difference in viscosity due to climatic changes (whether it is related to fabric at the time of deposition or dust content) is not sufficient to explain abrupt variation in fabric trend such as the one observed along NEEM. A strong impact of shear strain is also required. Furthermore, we need to provide the necessary data and descriptions which make this section long.

10 – We will try to make figures 4 and 5 clearer...

11- About L14, p315: Indeed “actual” means nothing for estimated strain rates, it has been changed by “present”; this is an usual translation error from french.

12- About L5, p316: Reference to Cuffey and Paterson has been changed to reference to Glen 1955.

13- Figure 1 was improved following your comments. 14- See comments #6 about error bars in Figure 2 15- Figures 3, 4 and 5 were modified. 16- Figure 6: we kept the “depth” on the x axis to remain coherent with the other figures. 17- Figure 8: Color map is associated with the microstructure figures. For pole figure, the color range stands for intensity of c-axis concentration (number of pixels). The size of the pole figures has been slightly increased.

- Answers to comments from C. Martin

The general comments were followed as much as possible as we had the feeling that they could really help us being more precise in our demonstration. In particular : We tried to be more precise about the term “viscosity” by which we mean “any changes in a layer that can explain a different answer to a similar stress”. Therefore it includes

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both change in fabric at the time of deposition and modification of dust content for instance. It could also include recrystallization mechanisms, but, as you noticed, this is not the subject in this paper (the transition we are interested in is not concerned by this mechanism, although we mention it for the bottom folding).

Section 3.2 has been reformulated to highlight the aim of this section which is to estimate strain rates in the 3 cores as our hypothesis is that differences in observed fabric results from different strain-rates histories and conditions, especially the transition from a state dominated by vertical compression to a state dominated by vertical shear. For clarity, we plot only one profile of vertical strain rate in Fig. 6 (with uncertainties) as the estimates for the three core are similar. This has been clarified in the text. We don't discuss here the two other components of the longitudinal strain rates (horizontal components) as they are difficult to estimate from topographic considerations. The discussion about the "girdle" fabrics has been clarified to highlight that they are the results of an asymmetry between these horizontal components.

Concerning the suggestion to provide the comparison based on the fabric vs age. Considering that strain is responsible for the fabric development, thinning would be the appropriate parameter to consider rather than age that also takes into account the variations in accumulation with time. As we can not have an easy access to the thinning data (owing to the way of estimating the age scale for these Greenland cores), we will not be able to provide such a comparison. We also estimate that, considering that the accumulation, the thickness and the transition depth are very close between the 3 sites, our comparison represent most of the information we needed.

Specific comments : 1- p309 L10-12 : Yes, we were referring to the same "positive feedback" as the one mentioned by Durand et al. 2007. We will reword this sentence to make it clearer

2- p309 L14, p310 L3-6 and L8-9 : we followed your suggestions

3- Please see answer #9 to first referee. Very similar comment.

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4- p313 eq 5: the “girdle fabric” described here is the “real” girdle, with c-axis mostly in one plane (horizontal here) and isotropy in this plane. The “girdle type” fabrics that are measured along NGRIP and NEEM are only very slightly “girdle” and remain mostly “single max”, with an asymmetry in the plane.

5- Concerning section 3.2 (p315 L14-25), please read answer #9 to first referee. Thanks to your comments, we will be able to precise the aim of these estimations and what we wanted them to tell about fabric and the comparison between the 3 cores. In particular, as noted just above, we will separate more clearly the role of shear and the role of the lateral extension asymmetry. Concerning the estimated vertical strain rate: we chose to give only one curve for clarity purpose on the figure, as there are only slight differences between the 3 curves, although thicknesses are different.

6- As mentioned before, we will remove section 3.3 as it will be treated with more details in future works.

7- p319 L28... : Very good suggestion, the paragraph has been moved to the introduction.

8- p320 L23-25: About the cause of folding. When reading papers by Alley et al 1997 for instance, it appears that the main causes of folding are the increasing impact of shear close to the bed, associated with some perturbation in fabric or microstructure at a small scale (stripes). This perturbation, that he relates to some local viscosity difference, induces the folding once the shear strain component is enough. Later, Wilson et al (2003) pointed out the probable impact of dynamic recrystallization to enhance local folding. Our fabric analyses of the bottom part of NEEM are very coherent with both previous works, we will give more details about it.

Figures will be modified as suggested.

- Answers to comments from Referee #3

We hope that, by taking into account comments from the two other referees, some

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of your suggestions were considered, and that the paper got improved in the good direction.

Interactive comment on The Cryosphere Discuss., 8, 307, 2014.