

## ***Interactive comment on “EBSD in Antarctic and Greenland Ice” by Ilka Weikusat et al.***

### **Anonymous Referee #2**

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This manuscript gives original results on the EBSD observations of sub- (or small angle) grain boundaries (SGB's) in deep ice cores recovered from Antarctica (EPICA-DML) and Greenland (NEEM). Introducing a new tool (EBSD) to determine small changes in crystallographic orientations within crystal grains, a number of different SGB's were successfully analyzed, resulting in a higher reliability of the statistics. The statistical distribution of different types of SGB's shown in Tables 1 and 2 is the main result of this study.

Table 2 clearly shows that both N(a) (i.e., tilt SGB's normal to the basal plane with rotation axes parallel to the basal plane) and P(a) (i.e., tilt SGB's parallel to the basal plane with rotation axes parallel to the basal plane) are predominant over other types, with almost equal probability for N(a) and P(a). The authors claim that this result strongly suggests both the basal and non-basal slip systems work in deformation of ice in deep ice sheets because the SGB's of N(a) and P(a) types are composed of the dislocations

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with Burgers vector  $\langle a \rangle$  and  $\langle c \rangle$  (and/or  $\langle c+a \rangle$ ), respectively. Although the similar argument has been proposed in their previous papers, the present paper confirms the argument by highly reliable data obtained by the EBSD method. By this confirmation, the ice sheet flow modeling can be developed or improved on the basis of a reliable deformation mechanism of ice. Therefore, I recommend publication of this paper in Journal SE after some major and minor revisions by considering the following comments.

(1) Brush up the description in 'Abstract' by focusing on the main result. For example, there is a significant gap in author's argument in the description 'The finding that ....., is surprising. These findings are .... with respect sea-level evolution' (Line 13 to 16 on p.1), resulting in a confusion about the main topic of this paper.

(2) Line 12 on p.1: Is 'prism  $\langle a \rangle$  or prism  $\langle c+a \rangle$  slip' correct? Do you think no pyramidal slip is involved?

(3) The 'Introduction' seems to be too long with some redundant duplicates. Focus on introductory remarks (or reviews on closely related topics) required for understanding the arguments in the main text. For example, as far as I understand, the most important points that should be described in the introduction are (a) we have no direct evidence for the non-basal slips in glacier ice until now in spite of the shortage of independent slip systems to deform ice only by the basal slip system, (b) the evidence for non-basal slips can be obtained by finding SGB's which can be formed only when non-basal slips take place, and (c) a rapid SGB analysis becomes possible with the use of EBSD for the SGB analyses although number of data was not sufficient in previous studies because of the time-consuming method (x-ray Laue method). Other topics can be included in the introduction, but it should be concise as possible.

(4) Section 4.2 ; As the authors conclude the P(a) type SGB's are formed as a result of the non-basal slips in deformation of ice, the explanation for P(a) should be given more precisely. For example, the term 'non-basal edge dislocations' in line 22 includes

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an ambiguity in 'non-basal' because it does mean either an edge dislocation lying on non-basal planes or an edge dislocation with Burgers vector lying on non-basal planes. Of course, the authors mean the latter, but it becomes clearer if it is written 'an array of edge dislocations with Burgers vector  $\langle c \rangle$  or  $\langle c+a \rangle$ '. Then, readers can easily follow the argument.

(5) What does 'controlled' in the title of Section 4.2 mean? Is any other word(s) appropriate here?

(6) The discussion given in the paragraph from line 28 on p.11 to line 6 on p.12 seems to fail to explain the dislocation processes involved in formation of P(a) type SGB's. Reconsider the description here. For example, 'limited strain can result in the formation of N-type tilt wall made up of immobile [c] dislocations' (Line 1 to 2 on p.12) is not understandable. More careful explanation is needed here without a gap in the argument. In addition, the closely related arguments are also given in Section 4.4. These should be combined.

(7) Seven types of SGB's in some rock-forming minerals are briefly described in the next paragraph and Sections 4.3 and 4.4, but with no explanations on a relation of different types of SGB's between ice and the rock-forming minerals. Is it possible to describe the definition of the seven types in rock-forming minerals with respect to the four types of ice given in this paper?

(8) What is the purpose of Section 4.4? It includes a formation mechanism of P(a) type SGB's which must be the main topic of this paper. As suggested above, this part should be combined with the closely related part in Section 4.2.

(9) Line 1 on p.14. 'X-ray tomography' should be 'x-ray topography'.

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