The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2019-204-AC1, 2020

The Cryosphere Discussions

Interactive comment on "Brief communication: Sampling c-axes distributions from the eigenvalues of ice fabric orientation tensors" *by* Martin Rongen

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Received and published: 27 February 2020

Dear Wataru Shigeyama,

Thank you for your timely and detailed review. Please find the responses to the issues raised in-line with your review comments below:

This brief communication describes a method to generate arbitrary c-axis orientations from eigenvalues of ice fabric orientation tensors. I understood that the novelty of this study is to combine girdle and unimodal Watson distributions to generate the arbitrary c-axis orientations. Although there is a limitation in a specific case, the method can produce c-axis orientation distributions similar to those with input eigenvalues. However, the author should rewrite or reconsider the manuscript for the publication of The Cryosphere. The main reasons are the following.

1. There have been several methods for describing arbitrary c-axis orientation distribution of ice (e.g., Seddik et al., 2008; Gagliardini et al., 2009). The author should write appropriate research backgrounds and point out current problems. This could better convey the importance of the study, namely, combining two Watson distributions to sample c-axis orientations.

   While this brief communication article was intended as a minimalistic method description, I appreciate that some context about previous work in the field is needed. Based also on additional comments from the other referee, the following section shall be added to the introduction:

   "Probability density distribution functions (PDFs) previously used to sample c-axes have for example been summarized in Gagliardini et al. (2009). These include most prominently the Fisher distribution and its restricted form as proposed for use in glaciology by Lliboutry (1993). Both distributions are only applicable when describing a single maximum and can not be used for axially symmetric girdle fabrics. A single Watson distribution, to describe either a girdle or a unimodal fabric, has already been successfully used for example by Kennedy et al. (2013). Gillet-Chaulet et al. (2005) presented a conjugate gradient method which, starting from an arbitrary c-axis distribution, in-time converges to a distribution that can describe any orthotropic fabric. While generally applicable, the conjugate gradient method is computationally inefficient and as such undesirable for the intended purpose. As a result, we present a method based on sampling the combination of a vertical girdle and a single maximum Watson distribution, which is computationally efficient and can reproduce arbitrary eigenvalues of the second order orientation tensor."

In addition the introduction of the Watson distribution in section 3, page 3 shall be extended to:

"Of the presented PDFs the Watson (1965) distribution, as also for example used by Kennedy et al. (2013), seems most applicable for our case as ..."

2. Following the references the author cited in the manuscript (Fisher et al., 1987 and Best and Fisher, 1986), the distribution is bipolar (unimodal) if the parameter κ(kappa) is positive, while the distribution is girdle if the kappa parameter is negative. The kappa parameter in the manuscript is k in equation (2). The relationship between k and the distributions (unimodal and girdle), described in page 4 line 1 and in Figure 2, is opposite to what is written in the references (Fisher et al., 1987 and Best and Fisher,1986). Why are they different? I have to suspect that the estimation of k is appropriate because the estimation is based on a study of Best and Fisher (1986).

   Thank you for pointing out this inconsistency! The source code I have been using defined the Watson distribution with an $\ldots \exp(-k \cdot$ ..., in contrast to the original references and equation (1). The manuscript has been updated for consistency (so that negative values result in a girdle distribution).

In answering this question, I also realized that the uses of κ for the Woodcock shape parameter and k for the Watson distribution are inconsistent with most of the previous literature. To avoid potential confusion the use will be changed so that κ is the parameter of the Watson distribution and the capital K is the Woodcock shape parameter.

Minor comments and corrections:

(a) Do the words “sampling c-axes distribution” (e.g., in the title, page 5 - line 20) express what the author would like to? One would usually say “sampling c-axes (or c-axis orientations)” and then obtaining those distributions which he or she assumes the population of c-axis orientations. If this comment is not appropriate, please ignore it.

Changing the title to "Sampling c-axes from the eigenvalues of ice fabric orientation tensors" makes the title more concise and will be adopted for the revised manuscript.

(b) The author could write about the examples of c-axis orientation sampling (Section 4) in the Abstract. Some spaces remain there.

This is a nice suggestion and will be added to the manuscript: "... This paper describes a sampling technique based on the combination of a vertical girdle and a single maximum Watson distribution. A number of application examples is provided."

(c) “N” should be written with italic style as it is variable (page 2 - line 2).

This will changed to the referee’s recommendation.

(d) The author could consider replacing “&” with “and” as use of “&” is not official in some cases (e.g., page 2 - line 7; page 3 - figure caption 1; page 5 - line 1, - line 2, - line 20).

This will changed to the referee’s recommendation.

(e) “In” should be written with block style as it is not variable (page 2-line17, -line18,line21; page 5-line20).

This will changed to the referee’s recommendation.

(f) The citation of Donald E., Voigt (2017) may not be a very appropriate example because Donald E., Voigt (2017) does not show scatter plots of the fabric data in the Woodcock’s coordinate system. The author could consider adding a more appropriate reference.

The SP14 reference was chosen here, as the presented method was developed to describe fabrics akin to the once found in SP14. A reference to the WAIS Divide Ice Core (DOI: 10.3189/2014JoG14J100) will be added, which contains both a Woodcock diagram and fabrics which can be described by the described method.

(g) The author should explain the variables in equation (2) briefly (page 3 - line 7), maybe together with a coordinate system, and show the coordinate system (axes) in Figure 2 and 3.

The unmentioned variables θ, ϕ are the polar (colatitude) and azimuth angle of the standard spherical coordinate system. This will be mentioned in the revised manuscript: "In its standardized form the PDF, evaluated on a spherical coordinate system with the polar angle θ and the azimuth angle ϕ, has only one free parameter .... with the normalization constant C_w ..."

(h) “exp” in equation (2) should be written with block style as it is not variable (page 3 - line 7).

This will be changed to the referee’s recommendation.

(i) The third term in the second equation in equation (3) may be mistyping (page 5 - line 3).

Please elaborate. I double-checked the equation with the Best & Fisher publication and my source code and it seems fine.

(j) The author should consider showing the derivation of equation (7) briefly (page 5 - line 14). It would be more reader-friendly.

Going from equation (6) to equation (7) simply requires solving an equation system with two equations and two unknowns. To highlight this, the implication that the assumption $S_{2g} = S_{2u}$ also means $S_{2g} = S_{2u} = S_{1g}$ will be added to the manuscript.

(k) “BMBF” should be spelled out, or its meaning should be translated to English (page 6 - line 12).

This will changed to the referee’s recommendation. It’s the "Bundesministerium für Bildung und Forschung" or "Federal Ministry of Education and Research".

References Seddik, H., Greve, R., Placidi, L., Hamann, I., and Gagliardini, O. (2008). Application of a continuum-mechanical model for the flow of anisotropic polar ice to the EDML core, Antarctica. Journal of Glaciology, 54(187), 631-642.

Gagliardini, O.,Gillet-Chaulet, F., Montagnat, M., and Hondoh, T. (2009). A Review of Anisotropic Polar lee Models: from Crystal to Ice-Sheet Flow Models in “Physics of ice core records II (ed. Hondoh, T.)”, 149-166.