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Interactive comment on "Inferring the basal sliding coefficient field for the Stokes ice sheet model under rheological uncertainty" *by* Olalekan Babaniyi et al.

Anonymous Referee #2

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The paper "Inferring the basal sliding coefficient field for the Stokes ice sheet model under rheological uncertaint" by Babaniyi and co-authors, addresses the challenging topic of accounting for modeling errors when estimating the basal sliding coefficient β from surface velocity observations. In particular, the paper considers uncertainty in the rehology and demonstrate how it can be properly accounted for using the Bayesian Approximation Error approach. Several numerical results on simplified ISMIP-HOM like problems demonstrate the effectiveness of their approach and the failure of the traditional approach. I think the paper is well written and it represent a significant contribution to the ice sheet community. Before recommending it for publication, I would like the authors to address the following concerns:

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Discussion paper

1. While I am convinced of the effectiveness and usefulness of the proposed approach, I am wondering whether the difference between the proposed approach and the traditional one has been a overemphasized by taking a regularization (prior) for β that is too small. In fact, it seems to me that the data are over-fitted when using the traditional approach (REF/CEM). It would be interesting to see what happens when γ_β and δ_β are increased (one could do that using the the L-curve rule, for the deterministic inversion to compute the MAP point). In general, I think that the parameters used for all the priors should be motivated.

2. In real applications, the flow factor is not considered uniform, but it is a function of the temperature. Of course, because of modeling errors, the rheology will still be affected by uncertainty. I'm wondering how your approach and results would change if the parameter a^* were spatially variable.

3. I think it would be better if the true value of the parameter a_{true} were not sampled from the same distribution used for computing the statistics for the approximation error, but from another distribution (e.g. non Gaussian/with different mean/variance)? As a matter of fact, we don't know the distribution for a.

4. The authors make the point that the (offline) computation of the statistics for the approximation error requires a "fairly small number of samples". This is true for the numerical results reported in the paper. However, I would argue that in real applications, with complex geometries and real data, that won't necessarily be the case. As a different but related example, the number of eigenvalues needed to accurately approximate the prior-preconditioned Hessian for beta, in the examples reported in this paper, is about two order of magnitude smaller than that needed for the Antarctic ice sheet (Isaac et al. SISC, 2015).

Minor comments:

abstract: I would specify, both in the abstract and in the introduction that the paper is targeting synthetic/manufactured geometries and data.

p. 8, l. 24: Please motivate the assumption of Gaussianity of the unknown parameters. I think there is little evidence to suggest that the distribution of these parameters is Gaussian, and anyway in general we do not know parameters such γ and δ. Is the Gaussianity required by the Bayesian Approximation Error theory?

p. 8, l. 28 : Can you please explicitly write (not necessarily here) how the samples are computed using the covariance matrix? think the readers of this journal could benefit from that.

Table 1: Report units of δ and γ. Also, in my understanding $\sqrt{\frac{\gamma}{\delta}}$ is a correlation length for the samples. It might be worth pointing that out.

sect. 5.1: In each of the 3 examples, I would remind the reader that a_{true} is chosen as previously shown in Figures 3 and 4.

p. 27, l. 17: I would rephrase this sentence“The rheology parameters of the ice, in particular the flow rate factor and the Glen’s flow law exponent, were treated as unknown random fields, which is often the case in reality." In real application the rehology is computed out of the temperature based on physical models.

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