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The Cryosphere Discussions

Interactive comment on "Estimating basal properties of glaciers from surface measurements: a non-linear Bayesian inversion approach" *by* M. J. Raymond and G. H. Gudmundsson

M. J. Raymond and G. H. Gudmundsson

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We would like to thank both of the reviewers for very detailed and careful reviews. We found the reviews very helpful and the manuscript has new been changed in accordance with those suggestions.

Referree Olaf Eisen

Major Issues

- We now use the term 'first order model derivative' rather than 'Frechet derivative'.
- 204.17. The expression for determining the a posteriori error covariance matrix

has been added in the text and this error estimate is now displayed graphically for some experiments.

- As suggested, the structure of section 5 has been changed and the experiments labelled such that the can be easily referenced in the tables. In the same section, attention was paid to mention only parameters which differ from those in previous experiments. The tables have been modified accordingly.
- Inversion vs. optimization procedure: The term iteration actually comprises the steps ii to iv of the inverse procedure. The first guess is the starting point of the iteration. This was not clearly defined in the text. 191.20 The analysis in Fourier space applies to the inverse step (Eq. 14). The term inversion has been removed to avoid confusion. 194.4 As the first guess is the starting point of the iteration, the sentence has been modified acoordingly.
- We claim to use the Gauss-Newton method, because in Eq.(13), the product of the second derivatives of the forward model with the vector ${C_D}^{-1}[\vec{d} - \vec{g}(\vec{m})]$ is small and can be ignored. Ignoring this term gives the Gauss-Newton method.
- Convergence 1: To test whether the inversion procedure converged to the correct answer (and not to a spurious minima, there might be several), we carried out standard Chi-Quadrat test to determine whether the difference between the retrieval and the measurement is statistically significant.
- Convergence 2: It should be emphasized that the additional forcing was applied stricly on the first guess (step i of the inverse procedure) and not on the iteration. In this paper, the first guess is defined as $m_{i=0} = m_{linear}$, but we could also have defined $m_{i=0} = m_{prior}$ with m_{prior} any realisitic prior basal perturbations. External forcing was applied on m_{linear} as for large basal perturbations the assumptions of the analytical theory are broken and hence the linear inversion cannot provide acceptable results. The external forcing could be avoided by using another $m_{i=0}$.

Minor issues

- Various typos and issues related to grammar and terminology have been corrected.
- The acronym MAP is now defined only once.
- The purpose of the paper in the introduction is now defined at a single location.
- The symbol for the forward function has been changed to f.
- Eq. (11). The second part of the derivative of each term of Eq. (11) can be transformed to the same form as the first part of the derivative (because the covariance matrix is symmetrical) and can be added to the first part.
- 191.3 It is the product of the second derivative of the forward model with the vector ${C_D}^{-1}[\vec{d} - \vec{g}(\vec{m})]$. This is now better explained in the text.
- Old section 5.2 is now called Non-dimensionalization
- 198.20. Actually, as explained in Section 4.4.inverse procedure, the iteration is continued until the stopping criterion (Eq. 20) is fullfilled. The sentence 198.20 was not correct and has been removed. Thank you for pointing out this problem.
- 199.21. and 203.10/13 The text has been modified and repetitions avoided.

Referee M. Morlighem

The proposed method has been applied along a flow line on Rutford Ice Stream, West Antarctica, and a corresponding publication is in preparation. This is the reason why no real case studies are presented in the paper.

- By applying the method to a flow line of Rutford Ice Stream lateral shear has to be considered. As our 2D model is plane strain, we parameterised side drag and introduced it in the model as a fictious body-force term.
- The iterative procedure solves for differences in basal properties. In each step the mean values of basal properties must be defined and those mean values enter the analytical expressions of the forward model derivatives. This poses no problem and does not represent an inherent limition of the model.
- Periodic boundary conditions are used in the particular case considerd in the manuscript. This is only done for convenience. Any other type of boundary conditions could be used, and the method is not limited to the case of periodic boundary conditions.
- The sliding law is a mixed boundary condition (Robin) relating velocities and stresses, and can not be implemented as von Neuman boundary condition. We have used this approach in a number of other papers and have compared results with anlytical solutions.
- In any given iteration the velocities at the base are defined using essential boundary conditions, which eliminates the zero mode.

Greetings

Melanie Raymond and G. Hilmar Gudmundsson

Interactive comment on The Cryosphere Discuss., 3, 181, 2009.