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Interactive comment on "Comparison of hybrid schemes for the combination of Shallow Approximations in numerical simulations of the Antarctic Ice Sheet" *by* Jorge Bernales et al.

Anonymous Referee #1

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General comments

This paper describes a study of 4 hybrid schemes, combining the Shallow Ice and Shelfy Ice approximations for Antarctic Ice Sheet simulations. The 4 schemes are implemented into the open source ice sheet model Sicopolis (Greve, 1997), and a number of simulations are made for the Antarctic Ice Sheet with each and the resulting basal sliding coefficients compared. Analysis of the calibrated sliding parameter is done and runs where average values from all 4 schemes is applied, as well as the results from other schemes (swapped). The paper is clear but the conclusions are not clearly specified and reader is left with wondering if authors have been able to conclude which scheme is preferred and how they will continue working with one, or all, of the

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schemes. A clearer message and conclusions from the study, as well as more concise analysis of the results (e.g. Figures 5 and 6) would improve the paper.

The structure of the paper could improve by adding a separate data section, before the Methods section, the text in lines 4-22 on page 8 would be better located in a separate Data section and a more detailed information about the data used for this modelling approach would be beneficial for the paper. Also lines 19-24 on page 9 would be better located in a data section.

The wording of the method used and the results is confusing, in this study a forward method is used to determine or rather calibrate Co , the basal sliding coefficient, and therefore it is confusing to call it inversion technique (e.g. line 23 page 8) or inversion (e.g. line 28, page 8), suggest to call it iterative technique or calibration, see further comments below (as in line 5 in the abstract: "the model is calibrated using an iterative technique . . .")

It is not clearly explained why authors are swapping the determined Co values between the calibrated models, why is this useful? Is the following ice sheet adjustment indicating model consistency? As stated in the paper, each method has its own way of combining the approximated term and not clear why swapping of the determined (or calibrated) Co values would give any insight in the model behavior or result. It is discussed that the different methods, and the results of Pollard and DeConto (2012) give qualitative similar results, with high/low values in same regions, but the numerical value of Co is method/model dependent and not clear what swapping of the results is useful for. The text on page 15 is not clear and the two figures 5 and 6 are not discussed in satisfying manner, what information about the schemes and the results can we draw from this analysis?

Specific comments:

The wording in abstract and introduction is confusing, the Shallow Ice approximation is a zeroth order approximation assuming the thickness of the ice is much smaller than

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the length scale and thereby horizontal stress gradients omitted. This approximation has no assumptions for the sliding law and a full system model would equally have to assume some sliding approximation, or shelfy ice solution to account for sliding. Line 2 in the abstract should be reworded (SIA is not applicable ... where basal sliding operates) and line 6 (minimal sliding) on page 2. Consider to rewrite also lines 2-5 on page 2, ("neglecting terms" and "simplest and most commonly used"): the Shallow Ice Approximation is a zeroth order approximation of the momentum balance equation assuming the H/L is very small.

The wording in the abstract in lines 9 and 11 is not clear and should be rewritten for clarity: "averaged and swapped" cannot be understood until reading the main text of the paper and therefore needs some clarification in the abstract. ".. this requirement for internal consistency" – is not clear in this context and needs more explanation.

I find missing an overview figure indicating the location of the areas that are named in the paper, such as Dronning Maud Land, Coats Land, Siple Coast etc., this would be useful for readers not familiar with place names in Antarctica and makes the paper easier to read.

Note that "Blatter-Pattyn models" were developed much before the asymptotic analysis by Schoof and Hindmarsh (2010) and therefore it would be appropriate to reference the earlier papers with these model developments.

Lines 27-29 on page 2 are not clear, more information and detailed explanation of what authors mean is needed here, why would it be necessary to look for further explanations when two models yield similar result under similar forcing?

Model resolution is very low, were any tests made to assess the sensitivity of the method to grid resolution? - or to potential errors/inaccuracies in the topographic data? How good is the observed topography?

The quality of English is generally good, but in many places the wording is strange and

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needs some editing, it would be beneficial for the paper to have a thorough editing of all the text. Below are a number of places indicated where rewriting/editing would improve the quality of the text.

Technical corrections:

Page 1, line 2, suggest to replace “ice dynamics” with “stress within the ice” Page 2, line 10, suggest to add “at the base” after “no friction” Page 2, line 21, suggest to rewrite, models do not “detect”, replace with something like “the algorithm used to identify . . .” Page 2, line 23, suggest to replace “versus” with “compared to” Page 2, line 25, suggest to replace “superposition” with “combination” Page 2, line 31, suggest to rewrite, replace “these result from ..” with “ these are . . .” Page 2, line 32-33 reword sentence: “Mechanical properties . . .. may serve as an example of . . . parameters” does not make sense. Page 2, line 34, something missing “widespread misfit” of what? Elevation? - do all models show this type of misfit? A reference to a study showing this would be useful here. Page 3 Line 11, missing information and reference, what observational data sets are used? Line 14, add “the” between by and different Line 19, see comment above, replace “inverse” with “iterative” Line 29, the model does not “consider” or is “keeping track” of temperature, the algorithm or post processing does, suggest to rewrite. Suggest to add “computed” after “ice is”

Page 5 Line 1, see comment above, “detect” seems a strange selection of word, suggest to replace with “determine” or “identify” Line 14, not clear wording “a consistent use of inverted distributions of Co” - (replace inverted with determined, or calibrated) Line 21, not clear wording: “enters the computation of SStA velocities” – suggest something like “and SStA velocities are computed for this point” Line 25, suggest to delete “which is assigned to the SStA” this is explained in next sentence (and add velocity after SStA)

Page 6, Line 2, suggest to add “SIA and SStA” before “Velocities are . . .” Line 16-17, unclear wording, suggest something like “It is rather used to determine. . .. . . the com-

puted SStA contribution should partly or completely replace sliding" Line 24, sentence is not clear, suggest to rewrite, something like "In the continental interior the modelled ice flow is dominated by the SIA solution Line 29 see comment above, replace "inversion" with "determination or calibration" Line 30, replace "infer" with "determine"

Page 7, Line 11, see comment above, "easier activation of the inversion procedure" suggest to rewrite to something like "more frequent computation of sliding velocity" - what does "slightly" mean here? Line 14, suggest to delete "similarly, and" Line 16, suggest to replace "speed" with "velocity", not clear what "local adjustment" means here, elevation, or Co? suggest to replace "keeps the inversion" with "prevents the method" Line 17 suggest to replace "over-adjustment of" with "over-adjusting", replace "speed" with "velocity" Line 18, suggest to delete "the" before "numerical" Line 20, replace "This" with "These" (plural of values) Section in lines 22-29 is not clear, and needs rewriting for clarification what is the time in the iterative method or calibration? Line 24, "time derivative of the ice thickness", do you mean observed or modelled? why suspend adjustment if previous time step reduced the difference? (line 24): What process? Line 26 replace "overshoot prevention" with "over-adjustment of Co" line 27, suggest to replace "lets" with "allows" and delete "to" before "influence" line 31, add "the" before "fringing"

Page 8 See comment above, move lines 6-18 to a Data description section Line 6, replace "which" with "that" Line 19 suggest to add "is used to" before "account", replace "changes" with "discrepancies" , replace "by" with "with" Line 23, see comment above, replace "inversion" with "iterative" or calibration Line 24, this is forward method, suggest to replace "inversion" with "iterative" Line 28, replace "inversion" with "calibration" see above Line 30, suggest to delete "one-to-one" Line 33, suggest to replace "not accounted for" with "is not included in the simulations"

Page 9 Line 1, see above, replace "inversion" with "calibration" Line 12, replace "simulations" with "calibration run" Line 13, see above, replace "inverse technique" with "iterative" or calibration Line 27 what do you mean by "glacier flux gate" do you mean

an outlet glacier? Line 21 not clear text “which overlap at their interface” needs clarification here

Page 10 Line 8, suggest to add “a” before “new” Line 12-13, this sentence is not clear and needs rewriting (what is internal operation of the hybrid schemes?) Line 17, what does “quasi-equilibrium” mean here? Line 19, what is “negligible” in this context? A percentage or some value would be useful here Line 24, suggest to replace “prevents” with “does not require”

Page 11 Line 9, the smallest error of 49.9m is according to the table using HS-1, is there an error in the table? If not then this section should be rewritten to reflect that. Line 21, replace “independently” with “independent” - here some discussion would be appropriate about if this is related to the common SMB forcing or geothermal heat flux? Line 22, add “simulated” before “frozen” Line 24, suggest to edit, change to something like: “far below the pressure melting point” and delete “the” before “white coloured” Line 25, edit the text, delete “on the other hand”, suggest to write “Areas where ice is underestimated . . .” – but what does “sparsely distributed” mean? Line 27 replace “inversion” with “determination” or “computation” Line 31, replace “inversion” with “iterative” or calibration

Page 12 Line 2, replace “inverted” with “applied” or “computed” Line 4-5, same comment, suggest to write “region where Co is not applied” Line 6, replace “inversion” with “calibration” Line 21, delete “also” Line 26, what do you mean here? What significant modification of Pollard and DeConto (2012) scheme would result in similar values of Co? suggest to replace “perturbation” with “distribution” or “pattern” and delete “inverted” Line 30 add “the” before hybrid Line 33 replace “small” with “low” and add “the” after “near” Line 35, what are “high velocity flanks”? suggest to add “sheet” before “margins” and at the end of line, after “ice”

Page 13 Line 2, strange wording, suggest to replace “contaminated by” with “characterized with” Line 6, add “the” before hybrid Line 7, suggest to replace “in” with “at” Line 8,

"flux gates" - not clear, is this a specific location? Line 11, delete "inferred" and delete "On the other hand" Line 14, delete "inferred" Line 19, delete "a" before slow ice motion, replace "flow speed" with "velocity" and "predicted" by "simulated" Line 21, delete "Arguably" Line 22, replace "stagnated" with "stagnant" Line 25, not clear wording "deviated to either side" - "pushed to merge" are you referring to modelled or observed velocity? – what side of what?, what is pushing what?, suggest to replace "deficiencies" with "errors" Line 28, according to the table, it is HS-1 that has the minimum misfit for the ice thickness Line 30, see above, replace "inversion" with "calibration" Line 31, suggest to delete "in the modelled surface velocities" Line 33, what do you mean by "opposite ends"? Line 34, suggest to replace "enabling" with "adding"

Page 14 Line 4, suggest to replace "imply" with "control" Line 5, what does "internal operation of the hybrid scheme" mean? Line 1, suggest to replace "the velocity field from the observational data set" with " the observed velocity" Line 12, suggest to replace "simple differentiation" with "transition" Line 17, reword, "tends to prevent" to "can prevent" and delete "s" in causes (and cause underestimation..) Line 24, what is a "cursory comparison" ? clarification is needed Line 29-30 suggest to rewrite (delete Here we attempt) and write: To isolate the influence .... we plot averaged errors ... Line 35, replace "inferred" with "resulting" or delete "inferred"

Page 15 Line 1 add "the" before different Lines 2-5 this sentence is not clear and does not explain the difference between the 3 figures in Fig.5 clarification is needed here Line 9, suggest to replace "looking" with "comparing" Line 19 delete "the" before "period" Line 26 – this line is not clear, what do you mean by "generalizing" – see comment above, it is not clear what information about the model can be drawn from Figures 5 and 6 Line 34, delete "On the other hand,"

Page 16 Line 2 suggest to add "distributions of Co from" before the HS-1 and HS-3 Lines 1-6, it is not clear from this text what this analysis gives for useful information about the different schemes used in the study Line 8, add "The" at beginning of line Line 11, rewrite: "allows us" is a strange wording here Line 23, what is the criteria

for selecting lower and upper limits for each scheme? Line 31, suggest to replace "decrease" with "get worse"

Page 17 Line 4, delete "by" before 2.5% Line 24, delete "," after "enables" Line 27-29 suggest to rewrite, something like "differ in the way ways the 1) relative contributions . . . are computed 2) areas where . . . is applied is determined, and 3) basal sliding is accounted for. Line 30, see above, replace "inverse" with "iterative" or "calibration" Line 31, delete "all" or add "the applied" after "all" Line 32, add "the" before "schemes", replace "below" with "less than" and add "the" before "total"

Page 18 Line 3, delete one "can" Line 5, add "the hybrid" after "all" Line 7, add "the" before hybrid Line 8, suggest to replace "develops" with "exists" Line 15 What particular scheme is discussed here? It is not clear Line 19 add "," after Here Line 27, what does "the neglect of paleoclimate signal" mean here – can applied geothermal heat flux, or applied SMB play a role here? Line 33, does the scheme affect the way the temperature is computed? Line 34, does the scheme allow determination of hard or soft bed? – it can only indicate high or low value for Co, or what?

Page 19 Line 3, suggest to replace "inferred" with "calibrated" - not clear how high variability can "provide an opportunity to quantify the effects of the uncertainty" – suggest to rewrite to clarify what is meant here. Line 8, see comments above, replace "inverse method" with "iterative technique" Line 9, what is meant with "internal consistency required to avoid misfit" suggest to rewrite to clarify. Suggest that the concluding sentence of the paper will state the main results of the study and how it can be useful for further modelling approaches.

Figures and tables

Table 2, suggest that the caption include some explanation, referring to text, what the different lines stand for (HS-1 etc). See comments above, the lines may have got mixed up, since the text states that the minimum difference for elevation is for HS-2, but 49.9 m is in line HS-1

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Figure 2, is this at the end of the simulation?

Figure 4, suggest to replace “grid cell” with “point” for the right hand column figures

Figure 5, the figure caption is not clear and needs editing. What does “quantify different ice flow regimes” mean here? The y-axis label is mean velocity ratio, but the text states Surface velocity error, clarify what is shown here. Suggest to replace “by” with “as” before ratios.

Figure 6, as discussed above it is not clear how this figure is useful. What information can be gained from this analysis? “retrieved distributions of basal sliding coefficients” is not clear, do you mean standard deviation of the determined values with each scheme in each grid point?

Figure 7, what does this figure tell us? What meaning does the median of the inferred distributions of Co have? Is this a useful quantity?

Figure 8, what do the bumps in the lines of HS-1 with r-thr=0.0 and HS-2b for v-ref=1000 m/yr shortly after 50 kyr mean? Is this instability in the simulations?

Figure 9 “throughout the simulations” – do you mean at the end of simulations?

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/tc-2016-117/tc-2016-117-RC1-supplement.pdf

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