

# ***Interactive comment on “Contribution of Greenland ice sheet melting to sea level rise during the last interglacial period: an approach combining ice sheet modelling and proxy data” by A. Quiquet et al.***

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Review of Quiquet et al., Contribution of Greenland ice sheet melting to sea level rise during the last interglacial period: an approach combining ice sheet modelling and proxy data, Climate of the Past Discussions

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I was happy to see this new article by Aurelien Quiquet and colleagues, which uses ice sheet modeling to estimate the Greenland Ice Sheet’s contribution to sea level change

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during the Eemian warm period. As Quiquet et al. note, the Eemian provides an important analog to possible near-future conditions on Greenland, and investigation of this period may lead to better projections of future sea level change. Results from other studies using similar methods diverge widely; Alley et al. (2010, Quaternary Science Reviews) note a possible range of 1-5 m sea level equivalent, or about 15-70% of the ice sheet's present volume (~7.3 m sea level equivalent; Bamber et al., 2001, J. of Geophysical Research; Lemke et al., 2007, Fourth Assessment, IPCC Working Group 1, ch. 4). More work on this important question is clearly needed.

This study includes some important methodological advances over past work. In particular, Quiquet et al. use an ice sheet model with a relatively good treatment of ice streams and ice shelves. To my knowledge, only one previously published ice sheet modeling study that covers the Eemian period includes these advanced dynamics (Fyke et al., 2011, Geoscientific Model Development – please cite this paper). The paper also takes advantage of some new global climate model simulations of the Eemian, from two different climate models. The temperature anomaly curve in Figure 2 helps overcome the limitations of ice core records from Greenland (no published, continuous records extend into the pre-Eemian period, as needed for satisfying simulation of the Eemian itself). Although not quite new, the study also includes the tracer method from Lhomme et al. (2005, Quaternary Science Reviews; originally from Clarke and Marshall, 2002, Quaternary Science Reviews – Quiquet et al. need to cite this paper). The use of this tracer method allows comparison of model results to ice core data (and must have been a great deal of work to code!).

However, a critical-minded, but not very careful, reader might miss the advances in the paper, and I recommend extensive changes to help bring out the paper's good qualities. The authors should include descriptions in the abstract and introduction about what is new about the paper, explain more clearly how this study relates to earlier work (including Quiquet et al.'s earlier paper in *The Cryosphere*), and proofread the text carefully. I recommend "minor revisions" because I think the study does not need

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Interactive  
Comment

many new analyses to be complete; changes to the text should be largely sufficient.

I also need to say up front that I cannot reconcile Quiquet et al.'s estimates of contributions from the Greenland ice sheet to Eemian sea level rise with earlier work, particularly that of Kopp et al. (2009, *Nature*) and Lhomme et al. (2005). Kopp et al. used well-founded statistical methods and paleo-sea level data to estimate a 95% probability that Northern Hemisphere ice sheets (largely Greenland) contributed at least 2.5 m sea level equivalent to overall Eemian sea level change. This statement is a bit buried in the paper – check the left-hand column on their p. 866. Lhomme et al. came up with a range of 3.5–4.5 m for the Greenland contribution to Eemian sea level change. Quiquet et al. find an \*upper bound\* of 1.5 m for this quantity. In other words, Quiquet et al. fundamentally disagree with earlier studies on their key finding, including the study that is their nearest methodological predecessor (Lhomme et al., 2005). I didn't find any explanation of this disagreement in the paper – I would expect to see it in the Discussion. A satisfying explanation of this discrepancy is absolutely needed for the paper to be publishable. In particular, Quiquet et al. should please explain what methodological choices they made that are 1) different from those of Lhomme et al. and 2) tend to make their Eemian ice volume change estimate smaller than that of Lhomme et al. How robust are the assumptions underlying these choices? Could a reasonable person make different choices and obtain a larger estimate?

The authors' new temperature anomaly curve is clearly important; however, other studies have performed similar "blends" of Greenland and Antarctic paleoclimate records (Marshall and Cuffey, 2000, *Quaternary Science Reviews*; Huybrechts et al., 2002, *Quaternary Science Reviews*; Greve, 2005, *Annals of Glaciology*; Barker et al., 2011, *Science*). Quiquet et al. should explain why their spliced record is preferable to the others, and show a comparison of their reconstruction to that of Barker et al. (2011). Placing the Barker et al. curve in the background of Figures 1 and 2 would help a great deal.

The authors should proofread the revised manuscript carefully before resubmitting it,

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Interactive  
Comment

and they should also proofread future manuscripts \*before\* the initial submission. At least one of the reviewers on Quiquet et al.'s earlier paper in *The Cryosphere* also asked for more careful proofreading. To help catch mistakes, I recommend reading manuscripts out loud.

The paper includes a number of unsupported statements, some of which I will flag in my detailed comments below.

As far as I can determine, the GRISLI model is not publicly available. The Grenoble group should consider releasing the model code to guarantee that their papers are fully reproducible by other scientists. Other groups have released their codes on the Web (PISM, Glimmer-CISM, SICOPOLIS...). This practice has led to wider use of these models and an increase in publications for the scientists who wrote the models. Also, I have heard that the highest-impact journals (*Science*, *Nature*) will no longer accept papers based on closed-source models.

/— Detailed comments —/

**Title:** The title should emphasize what is really new about the paper. Many other studies "combin[e] ice sheet modeling and proxy data" with methods rather similar to those used here. Perhaps "Estimating the Greenland ice sheet contribution to sea level rise during the last interglacial period using an advanced ice sheet model" would more accurately reflect the advances made in this study.

### Abstract

Please begin the abstract with a one-sentence summary of the paper that explains what was done, how, and the significance of the results. Perhaps, "Long-term simulations of the Greenland Ice Sheet using an improved ice sheet model suggests a relatively low contribution to Last Interglacial Period sea level rise from Greenland melting."

Consider rewriting the abstract according to the *Nature* template.

4-5: Please remove all parenthetical citations from the abstract. You can just say, "...

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as pointed out in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change."

5: "warm up": odd word choice

9: "has survived": just "survived"

10: "...ice reduction during the LIG and its sea level rise contribution": partly redundant

12-14: "paleo data," "proxy data": what data do you mean? how did you do the confrontation?

13: "methodoly": spelling

15-16: how does your estimate compare to those from other studies?

Introduction

18-21: this paragraph contains an awkward first sentence and is somewhat underdeveloped; what methods or proxies did Vezina et al. and Kopp et al. use to arrive at these conclusions?

26: "is assumed to have been found": needlessly verbose; avoid using the passive voice

p. 3347

1: the evidence for ice cover at Dye-3 during the Eemian is much more equivocal than at the other sites; see Alley et al. (2010, Quaternary Science Reviews)

2-3: "Pollen and sediment studies..." Need references here, and some more explanation; how do these studies help?

1-6: you should mention the work of Born and Nisancioglu (2011, The Cryosphere Discussions), who point out that ice loss can happen in the north as well as the south – in that case, inferences of small sea level contribution from the extent of the southern part of the ice sheet (Colville et al., 2011) become much more equivocal

C1480

CPD

8, C1476–C1485, 2012

Interactive  
Comment

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Interactive Discussion

Discussion Paper



7: "few studies": I would say that a fair number of studies provide an estimate of this contribution, including some that are not in Table 1. Huybrechts (2002, Quaternary Science Reviews), Colville et al. (2011), and Alley et al. (2010) should perhaps be listed.

9: "is one of the major issues": unsupported statement; why is this the case? the next few sentences explain different methods of estimating surface mass balance, but say nothing about why this diversity is a problem

12: "amongst": just "among;" "amongst" is used almost exclusively in spoken language

20: replace "largely" with "considerably"

p. 3348

3: "improve on the classical index formulation": I'm not 100% sure, but I think the approach endorsed by Quiquet et al. is actually quite standard – please see Pollard and PMIP Participating Groups (2000, Global and Planetary Change), Kirchner et al. (2010, Quaternary Science Reviews) and Greve et al. (2005) for examples of earlier studies that use the same approach. If Quiquet et al. are doing something different, they should explain here how their methods differ from these studies.

5-8: please provide more description of Lhomme et al: what did they do and what were their key findings? please also acknowledge other studies that use the Lagrangian tracer approach, such as Clarke and Marshall (2002) and Tarasov and Peltier (2003)

20-25: "... facilitates the advance onto the continental shelf": unsupported statement; please demonstrate that this assertion is true, perhaps by rerunning one of your simulations in Figure 5 with the advanced ice dynamics turned off in the model – how do the results change?

26: "this": this what? always follow the word "this" or "these" with a noun that makes it clear what you mean – in this case, "this error in modeled marginal slopes"

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p. 3349

1-5: I realize this section is about the GRISLI ice sheet model, but a reader not familiar with the literature could get the impression that these are the only ice sheet modeling studies that have ever been done. Could you include another section before this that describes how ice sheet models in general work and lists some earlier, groundbreaking studies?

6: "largely discussed": just "described"

6-7: "previously mentioned": just "previous"

7: "we only describe here the most relevant features": we only describe the most relevant features here

8-20: Kirchner et al. (2011, Quaternary Science Reviews) provide an excellent description of the different flow regimes within ice sheets and ice shelves – please cite that paper here, and provide more explanation of the different flow regimes so that a non-glaciologist can more easily follow the paper

10: "heigh": spelling; do you mean thickness?

11-13: please show this map in the supplement

20: somewhere around here, please explain how GRISLI finds the grounding line position – this model design choice is notoriously problematic in ice sheet modeling; perhaps reference Hilmar Gudmundsson's work on this issue

p. 3350

1-8: this section contains many grammatical errors

2-3: "re-gridded to a stereographic projection...": too much information; delete

4-8: how does this geothermal heat map and procedure for adjusting it compare to Greve (2005)?

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Interactive Discussion

Discussion Paper



23-24: unsupported statement; what proxy data, and how do you know that they are a good representation of past climates?

p. 3351

1-3: how did you make this composite map?

2-3: "... in order to have good agreement...": unsupported statement; how do you know that the agreement is good? how did you evaluate this agreement? show a scatter plot with measured accumulation for the ice core sites on the x-axis and the modeled values on the y-axis; if the agreement really is good, the points should lie on a 1:1 line

10 and following: in your abbreviation for  $\delta^{18}O$ , the O should not be italicized

11: I don't think you mentioned your splicing of the Antarctic records to Greenland before this point

19: "profile": profiles

19: "This calibration is however ice model dependent": "This calibration is, however, ice sheet model-dependent"

19: unsupported statement; show us that the calibration depends on the model, or explain why it is

19-20: "of past evolution": on past evolution

24: monthly values of what? the lapse rate?

p. 3352

eqn. 3: how does this approach compare to other studies? many other Greenland ice sheet modeling studies include a change in precipitation with surface temperature anomaly; see review in van der Veen (2002, Global and Planetary Change)

12-13: "even the most sophisticated RCMs disagree": unsupported statement; can you provide a reference?

C1483

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Interactive Discussion

Discussion Paper





p. 3353

13: "more representative of the winter temperature": more representative of the local winter temperature

13: "while": use "whereas" instead

21: I don't think the Lemieux-Dudon time scale includes the ODP 980 core

23: "works": no s here

p. 3355

5-12: "as close as possible", "close to," "similar to," "close to": how did you evaluate the match between your results and the data sets you were trying to match? did you do the matching "by eye," or did you try to minimize the root mean square error, or what did you do?

18-19: "the ice extent is governed by... the ablation coefficients": this would be a good place to cite Greve (1997, Journal of Climate)

23 and following: this paragraph, which spills onto the next page, seems to reproduce material that appears earlier in the paper; delete or condense

p. 3358

18-19: the last sentence of this paragraph is ungrammatical

p. 3359

14: I couldn't find the reference to Members in the list of references

24: "approximatively": approximately

p. 3360

Acknowledgements: use the active voice as much as possible here ("We thank so and so", instead of "So and so are thanked"), and check for grammatical mistakes

C1484

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8, C1476–C1485, 2012

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Discussion Paper



## References

Each reference seems to end with one or more unnecessary four-digit numbers; delete these

Fig. 2 – is this the annual mean temperature? – "that +5 deg C": than – please show a comparison to Barker et al. (2011) here or on Fig. 1

Fig. 3 – isn't it circular reasoning to use NorthGRIP as both a forcing and a constraint?

Fig. 4 – the model domain includes the Canadian islands northwest of Greenland and Iceland, which most modeling groups cut away; does the inclusion of these islands explain some of the ice volume overestimate noted in the text? – you show the ice core data and results before you show us where the ice cores are located; switch Figs. 3 and 4 and show us where the ice cores are located on this figure – the caption needs some editing

Fig. 5 – please show this figure in terms of raw, undifferenced, simulated ice volume on the y-axes, instead of with the modern value subtracted out

Fig. 7 – "melt may potentially occur at...": I don't understand this statement; why is this significant? I think melt occurred at all of these sites during the 2012 ablation season – do you mean that your results are more likely to be correct because the model can produce melt at these sites?

Fig. 8 – "what is found in literature:" spelling, odd phrasing

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Interactive comment on Clim. Past Discuss., 8, 3345, 2012.

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