

## ***Interactive comment on “On the recent contribution of the Greenland ice sheet to sea level change” by M. van den Broeke et al.***

### **Anonymous Referee #1**

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This is an interesting and useful up-to-date analysis of recent changes in the Greenland Ice Sheet mass balance, considering independent estimates of surface mass balance, solid ice discharge and total mass change from GRACE, that is set in a longer-term context of the last 58 years. The paper is generally well-written and -presented, and the underlying analysis seems proficient, although a few aspects (detailed below) need clarification. I'd be happy to recommend full publication in TC once the authors have addressed the following points.

page 1, line 11: change to "increased refreezing prevents runoff of meltwater FROM OCCURRING, at the expense of..."

p.4, l.26: How well do the ERA-40 and ERA-I climatologies agree for the overlap period (1979-2002)? If there is any mismatch, splicing or some other adjustment of the

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temperature and precipitation etc. fields may be required.

p.5, l.10: "typical uncertainties of 9% and 15% were found for ice-sheet wide integrated accumulation and ablation" - can you comment on regional-scale uncertainties, as these can be much greater and might be important in the context of this study?

p.5, l.21: who are "A. et al. (2013)"?

p.5, l.22 "The uncertainty in monthly GRACE values are..." - how are these uncertainties defined?

p.5, l.26 "we interpolated the GRACE data to the end of the month" - how? E.g. linear or sinusoidal interpolation?

p.6, l.4: change to "are usually assumed TO BE part of..."

p.6, l.19 "Until mid-1996, cumulative D represents a straight line, because its annual value is assumed constant at the 1996 value". How reasonable is this assumption and what difference does it make to your results? Rignot et al. (2008) suggest that anomalies in D since ~1960 are quite variable in time (their Fig. 3).

p.6, l.23 re. reference to ice sheet in "approximate balance" in the mid-1990s. How do you reconcile this with Krabill et al.'s (2004) finding of a GrIS mass balance of  $\sim 60 \pm 15 \text{ km}^3 \text{ yr}^{-1}$  from 1993/4-1998/9 based on ATM data? Krabill, W., Hanna, E., Huybrechts, P., Abdalati, W., Cappelien, J., Csatho, B., Frederick, E., Manizade, S., Martin, C., Sonntag, J., Swift, R., Thomas, R. and Yungel, J. (2004). Greenland Ice Sheet: increased coastal thinning. Geophysical Research Letters, 31, L24402, doi:10.1029/2004GL021533.

p.7, l.6: ", the real uncertainties in the trends.." - again, how are these defined? Also, comma at beginning of the words in (my above) parentheses should be a semicolon.

p.7, l.31: change to "preventing the surface meltwater FROM REACHING the deeper firn layers and USING the full retention potential".

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p.8, l.2 suggest modify/add text in CAPS as follows; "Remarkably, the summer of 2013 saw a return to near-normal melt conditions, with melt close to the 1961-1990 average, WHILE SUMMER 2015 SAW RECORD MELTING IN THE NORTHERN REACHES OF THE ICE SHEET (TEDESCO ET AL 2016). This exceptional interannual variability in the melt climate of the GrIS points towards important roles for large-scale atmospheric drivers (Fettweis et al. 2013, HANNA ET AL. 2013, 2014 & 2016, MCLEOD & MOTE 2016) and local feedback processes.

And add extra references:

Hanna, E., Jones, J. M., Cappelen, J., Mernild, S. H., Wood, L., Steffen, K. and Huybrechts, P. (2013), The influence of North Atlantic atmospheric and oceanic forcing effects on 1900–2010 Greenland summer climate and ice melt/runoff. *Int. J. Climatol.*, 33: 862–880. doi: 10.1002/joc.3475

Hanna, E., Fettweis, X., Mernild, S. H., Cappelen, J., Ribergaard, M. H., Shuman, C. A., Steffen, K., Wood, L. and Mote, T. L. (2014), Atmospheric and oceanic climate forcing of the exceptional Greenland ice sheet surface melt in summer 2012. *Int. J. Climatol.*, 34: 1022–1037. doi: 10.1002/joc.3743

Hanna, E., Cropper, T. E., Hall, R. J. and Cappelen, J. (2016), Greenland Blocking Index 1851–2015: a regional climate change signal. *Int. J. Climatol.* doi: 10.1002/joc.4673

McLeod, J. T. and Mote, T. L. (2016), Linking interannual variability in extreme Greenland blocking episodes to the recent increase in summer melting across the Greenland ice sheet. *Int. J. Climatol.*, 36: 1484–1499. doi: 10.1002/joc.4440

Tedesco, M., T. Mote, X. Fettweis, E. Hanna, J. Jeyaratnam, J.F. Booth, R. Datta, K. Briggs (2016) Arctic cutoff high drives the poleward shift of a new Greenland melting record. *Nature Climate Change*, in press.

p.8, l.6 Has year-to-year variability of annual precipitation decreased significantly for

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the whole period? The graph suggests there may have been a decrease and maybe an opposite trend (recently increased variability) for runoff - ?

p.9, l.13 "previous work reported little difference between discharge estimates from the early 1960s and the mid 1990s (Rignot et al. (2008) - this is strictly correct but Rignot et al. (2008, their Fig. 3) also suggest a 50-100 Gt yr<sup>-1</sup> change in discharge between these two periods and the intermediate mid-late 1970s and early 1980s period.

p.10, l.30 "use of...robust re-analysis products that cover the full 20th century" - add Hanna et al. (2011) reference to Lee & Biasutti (2014): Hanna, E., Huybrechts, P., Cappelen, J., Steffen, K., Bales, R.C., Burgess, E.W., McConnell, J.R., Steffensen, J. P., van den Broeke, M., Wake, L., Bigg, G.R., Griffiths, M. and Savas, D. (2011). Greenland Ice Sheet surface mass balance 1870 to 2010 based on Twentieth Century Reanalysis, and links with global climate forcing. *Journal of Geophysical Research - Atmospheres*, 116, D24121, doi:10.1029/2011JD016387.

p.11, l.14: add "impact of atmospheric circulation changes on Greenland melt" to "Other emerging research topics of GrIS melt climate.", and add the following references: Tedesco et al. 2013, Hanna et al. 2013, 2014 & 2016, McLeod & Mote 2015. See above for reference details except for: Tedesco, M., Fettweis, X., Mote, T., Wahr, J., Alexander, P., Box, J. E., and Wouters, B.: (2013) Evidence and analysis of 2012 Greenland records from spaceborne observations, a regional climate model and re-analysis data, *The Cryosphere*, 7, 615-630, doi:10.5194/tc-7-615-2013.

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Interactive comment on The Cryosphere Discuss., doi:10.5194/tc-2016-123, 2016.

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