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The Cryosphere Discussions

Interactive comment on "Increasing runoff from the Greenland Ice Sheet at Kangerlussuaq (Søndre Strømfjord) in a 30-year perspective, 1979–2008" *by* S. H. Mernild et al.

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Comments from Anonymous Referee #1: General Issues related to uncertainties are more clearly stated in the manuscript (see Chapter 3.3).

3.3 SnowModel calibration, verification, and uncertainty To assess the general performance of SnowModel simulated values were tested against independent observations. SnowModel/MicroMet-distributed meteorological data: air temperature, wind speed, precipitation, and relative humidity have been compared against independent Greenland meteorological station data both on and outside the GrIS, indicating respectable representations of meteorological conditions: Air temperature (87–99% variance), wind

speed (55–98%), precipitation (49–98%), and relative humidity (48–96%) (for further information, see Mernild et al., 2008; Mernild and Liston, 2010). SnowModel accumulation and ablation routines were tested both qualitatively and quantitatively using independent in situ field observations on snow pit depths; glacier winter, summer, and net mass-balances; depletion curves; photographic time lapses; and satellite images from in and outside the GrIS (for an overview of the different tests and maximum differences, see Table 3 in Mernild et al. 2009 and Mernild and Liston 2010): A comparison performed between simulated and observed values indicated good agreement, and an approximately 10–25% maximum difference between modeled and observed observations based on statistical analysis from previous SnowModel studies. Therefore, it is expected that the results – the accumulation and ablation processes, including runoff estimates, presented in this study are affected with the same level of uncertainty of 10–25%, as shown in previous studies. To assess the winter and summer model performance for this Kangerlussuaq study, the end-of-winter (31 May; recognized as the end of the accumulation period) simulated snow depth was compared with Station S5, S6, and S9 observed snow depths, and the simulated cumulative summer (June through August) runoff was compared with observed catchment outlet runoff entering directly into Kangerlussuaq Fjord. The snow depths were measured at 31 May (Table 3), and used to verify and adjust the SnowModel-simulated snow depth. Using Station K precipitation, the simulated snow depth was on average overestimated by up to $\sim$50% (400 mm w.eq.) (2003/04–2006/07) for Station S9. Therefore, the iterative precipitation-adjustment and convergence scheme following Liston and Hiemstra (2008) was implemented, yielding a simulated Station S9 snow depth on 31 May that was within 1% of the observed snow depth (Table 3). As a test, Station S5 and S6 simulated end-of-winter snow depths were within $\sim$10% of the observed end-of-winter snow depths. Catchment outlet runoff was observed for the 2007 and 2008 runoff seasons (Mernild and Hasholt, 2009), and both years were used for verification. The observed runoff had an accuracy of 10–15% (Mernild and Hasholt, 2009). Furthermore, independent glacier net mass-balance observations along the K-transect were used for verification of the simulated net mass-balance (van de Wal et al. (2005) (for further information see Chapter 4; Fig. 2). Simulated ELA was further validated against independent ELA studies from Zwally and Giovinetto (2001) and Fettweis (2007). It is important to keep in mind the limitations of these SnowModel results since uncertainties are associated with model inputs and unrepresented or poorly-represented processes in SnowModel. For example, glacier dynamic and sliding routines for simulating changes in GrIS area, size, and surface elevation are not yet represented within the modeling system. In addition, runoff from geothermal heating/melting was not included in the calculations. It is also noted that changes in GrIS storage based on supraglacial, englacial, subglacial, and proglacial storage, internal meltwater routing, and evolution of the internal runoff drainage system are not calculated in SnowModel; these neglected processes are unlikely to be significant unless there are long term, secular changes in glacier geometry and drainage system structure.

Abstract & Summary: We agree with the reviewer. Due to the uncertainties in the simulations, we decided to erase that statement from the abstract and from the summary. The text is erased and re-written (Chapter 4) where we are discussing the 10% decrease of catchment outlet runoff explained by runoff from the ice sheet.

p.323, l.22: Is done.

p.323, l.25: Is done.

p.328, l.20: Is done.

*p.330 (bottom)-p.331 (top): Is clarified. We divided the runoff amount into runoff originating from the GrIS alone (based on snow and ice melt, and liquid precipitation), and runoff originating from the area outside the GrIS, from the proglacial landscape (based on snowmelt and liquid precipitation).To get the runoff contribution from the proglacier landscape it is: catchment outlet runoff minus GrIS runoff.

p.331, l.18: Is fixed.

p.331, l.22: The 2-3 weeks period of time lag seems not to be significant, and the amount of water running in the first 2-3 weeks of the of runoff season is less than 5-8 m3 s-1, and less than 1% of the cumulative annual runoff. The retention part in SnowPack, a subprogram in SnowModel, has been tested previously indicating less than 1-2 days of time lag for example at the Mittivakkat Glacier, SE Greenland.

p.332:, l.14: Is added to the manuscript

Fig. 1: Contour lines (100-m interval) are added to Figure 1b for the core part of the simulation domain (a scale bare will not be included since contour lines are added to the figure). The divide is marked with a bold line to make it clearer.

Fig. 2(b): The figure caption has been rewritten to make in clearer.

Interactive comment on The Cryosphere Discuss., 4, 321, 2010.

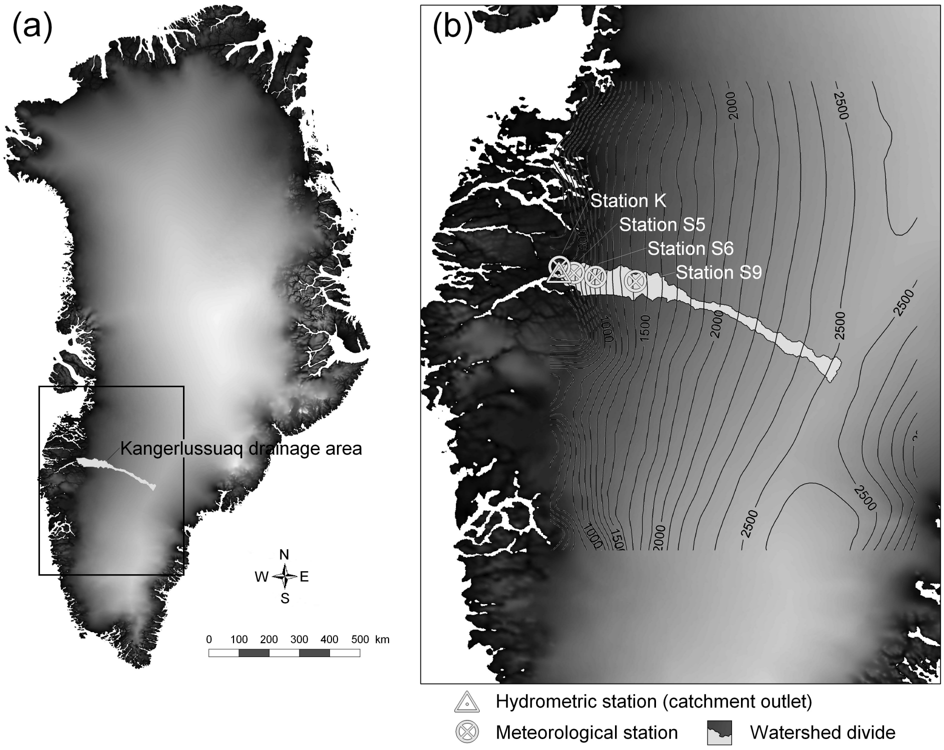

Fig. 1. Figure 1