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The Cryosphere Discussions

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8, C129–C134, 2014

Interactive Comment

Interactive comment on "Drifting snow measurements on the Greenland Ice Sheet and their application for model evaluation" *by* J. T. M. Lenaerts et al.

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Summary: In this article, the authors report drifting snow fluxes measured on the Greenland Ice Sheet that are then used to evaluate a coupled regional climate model (RACMO2) and blowing snow routine. The measurements were conducted during a field campaign in the fall of 2012 and provide half-hourly records of meteorological variables and drifting snow particle counts 1 m above ground. The simulations capture well the evolution of wind speed, air temperature and relative humidity observed at the study site (station S10 that is part of the K-transect in west Greenland) including the passages of synoptic storms and katabatic wind events. The blowing snow

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routine captures the timing and frequency of blowing snow events but overestimates the typical size of drifting snow particles and the horizontal transport fluxes. This paper is generally well-written and provides some interesting results and much needed measurements of drifting snow. My detailed report on the paper follows:

We thank S. Déry for his valuable comments and positive review. Find the responses to his reported comments point-by-point below.

General Comments:

1) The field experiment lasted only from 7 September to 6 October 2012 due to instrument to failures. While it is particularly difficult to obtain extended time series of meteorological and drifting snow conditions on the Greenland Ice Sheet, are the measurements of sufficient length (one month) to assess the performance of the regional climate/drifting snow simulations? This is a concern as there are perhaps only 10 or so drifting snow episodes during the study period.

Unfortunately, we are restricted to this one month of data, and we are unable to retrieve additional data since the SPC's were malfunctioning from the beginning of October. Although we agree that we we have missed stronger, mid-winter events, we are confident that we have sufficient data of both events, i.e. the dry events and events with precipitation. We will indicate this in the revised manuscript: ***Although this implies that we have no data from the core winter, when we expect the strongest drifting events (Lenaerts et al., 2012b), we have detected around 15 drifting snow events in various weather conditions.***

2) It is interesting to note the discrepancies between the simulated and observed distributions of particles 1 m above ground as well as the local drifting snow fluxes. Perhaps further investigation is warranted here to establish the source of those discrepancies and sensitivity experiments with the numerical model should be attempted. For instance, the mean particle diameter, assumed to be 200 microns in PIEKTUK-B at a height z = 0.1 m above the snow surface, could be increased to verify if the model is

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then able to capture more accurately the observed drifting snow particle distribution at z = 1 m. In addition, PIEKTUK-B assumes the drifting snow particles are at the density of ice (917 kg m-3) and sensitivity to this value should be tested. Perhaps sensitivity tests should also be carried on the shape parameter ? of the gamma distribution (say values of 5 to 8 as reported in the present study). Finally, what is the lower range of detection (in terms of drifting snow particle diameter) of the Snow Particle Counter (SPC)? During both case studies, the SPC does not seem to capture drifting snow particles below a diameter of 60 microns – is that accurate?

This is a justified issue raised by the reviewer. To discuss the sensitivity of the drifting snow module to its input parameters, we have performed a sensitivity analysis, varying (a) drifting snow density (500,700,900 kg/m3), (b) mean saltation particle radius (100,200,400 micrometer), (c) shape parameter α (2,5,8), and (d) friction velocity (-10% and +10%). This sensitivity analysis clearly demonstrates that the drifting snow model is highly sensitive to the input parameters, in particular to (b) and (c) as the resulted flux can vary several orders of magnitude within the applied range of input. For this sensitivity analysis, it appears that the contribution of saltation to the simulated flux at 1 m height is overestimated in the model; if we suppress saltation by applying a larger particle radius, the resulting transport is largely decreased. If we increase the mean saltation particle diameter to 200 micrometer (default 100 micrometer) and alpha to 5, both of which are assumed to be more representative of the observed conditions, we get much more reliable (within one order of magnitude) simulated transport fluxes in both cases (24 and 26 September 2012); it appears that saltation in PIEKTUK is overestimated in the default case, leading to much too high fluxes. This is an important result, which will be presented in detail in a separate table and a detailed discussion. The minimum detectable snow particle diameter of the SPC is 50 micrometer. The omission of very small particles could lead to an underestimation of the observed transport, although we do not believe that this will greatly influence the results. We will add this comment in the revised manuscript.

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3) More information on the numerical simulations needs to be provided. How are the model simulations initialized and updated? Is there a model spin-up? What is the timestep for the integrations? What information is transferred back and forth from RACMO2 to the blowing snow routine?

The RACMO2 simulations analysed here are part of a much longer time integration of the the entire Greenland ice sheet and surroundings. We will refer to Lenaerts et al., 2013 and van Angelen et al., 2013 in the text of model setup. The physical schemes of RACMO2 are updated with respect to these papers, but the domain size, and drifting snow routine has been unchanged. The time step of the simulation is 2 minutes. Each time step, the meteorological variables of RACMO2 are passed on PIEKTUK, and the drifting snow output is passed back to RACMO2, see Lenaerts et al. (2012a) for details. We will add this information in the revised version.

Specific Comments: 1) P. 24, lines 18 and 21: Change to “three months” and “nine months”.

Will be changed in the revised version.

2) P. 25, line 18: This should be “917 kg m-3”.

Will be changed in the revised version.

3) P. 26, line 1: Rewrite as “an 8 m high”.

Will be changed in the revised version.

4) P. 26, line 7: Should this be: “H2O/CO2”?

Yes, thanks for pointing out! Will be changed in the revised version.

5) P. 26, line 18: How much of the experimental data are omitted in the present study?

This only applies to the humidity sensors, which can give erroneous data in very

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cold conditions.

6) P. 27, line 25: Is this relative humidity with respect to water or ice?

To ice, will be included in the revised version.

7) P. 28, line 13: Is there a reference for this assumed snow density of 300 kg m-3? **This is a first-order estimate of surface snow density. 300 kg/m3 for snow density is a typical value to the dry snow zone in Greenland, see e.g. Hawley et al., 2006 (GRL). This reference is added to the text.**

8) P. 30, line 26: Are the simulated drifting snow particle size distributions also for z = 1 m? **Yes, that is correct.**

9) P. 31, line 10: The simulated horizontal transport fluxes are highly sensitive to the simulated wind speed. How do the simulated and observed wind speeds compare during the two case studies presented here? Slight overestimations of the simulated wind speed could cause large overestimates of the simulated horizontal transport fluxes compared to observations. Another source of discrepancy may be the detection accuracy of the SPC.

We agree that sensitivity of the flux to wind speed is highly non-linear. However, we show in Figure 4b that the simulated friction velocity compares well with the observed friction velocity, although it somewhat underestimates the friction velocity peaks during storms (which would contribute to an underestimation of observed transport in the model, but the opposite is true). To test this sensitivity, we have added two extra simulation to the sensitivity analysis (see previously), varying the friction velocity between -10% and +10%.

10) P. 39, Table 1: Please use upper case letters for the titles of each column in the table.

Will be changed in the revised version.

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11) P. 47, Figure 8: Why are transport rates are expressed in kg m-2 s-1 elsewhere in the paper but here are presented in units of kg m-1?

Because this shows the vertically integrated snow transport, also integrated in time for each 6 hours shown. This will be clarified in the caption.

12) PP. 49 and 53, Figures 10/14: The captions should state: “1 m height”?

Will be changed in the revised version.

Interactive comment on The Cryosphere Discuss., 8, 21, 2014.