Response to reviewers: Understanding snow bedform formation by adding sintering to a cellular automata model

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Response to Kelly Kochanski's Short Comment

We thank Kelly Kochanski for taking the time to go through our manuscript and make important comments on the both the technical and scientific side of our work.

Kelly Kochanski has extensive field experience in studying snow bedforms in Colorado and her previous published work in The Cryosphere (https://www.the-cryosphere.net/13/1267/2019/) is an impressive collection of data and analysis. This makes her insight and critique of our work even more pertinent. Furthermore, she too is developing a snow specific version of ReSCAL (https://github.com/kellykochanski/rescal-snow) which is quite an exciting development.

We shall attempt to answer and clarify some of the issues she has touched upon below but her initial vote of confidence gives us further hope for continuing to explore the ReSCAL tool.

- It is quite heartening to note that you have observed sintered patches of snow trailing a mobile barchan dune. We must look into your datasets in more detail in the coming weeks.
- The main purpose of the cone experiments was to identify the M.S.L and not really to reflect reality. Our main thesis is that without sintering and with adequate supply of snow, snow barchans can grow like sand barchans. We turned on sintering abruptly to see whether a barchan of a particular size can even remain mobile for a given wind speed. A barchan that cannot remain mobile can in reality never grow to reach that size. We shall come back to this point further on.
- We realized that our sintering implementation is not clear in the submitted manuscript and we have made an attempt to make it clearer in the revised version. Since you are also a ReSCAL developer, I feel comfortable in being a bit more specific in responding to your question. The GR cells in ReSCAL come with an additional variable called CELL_TIME attached (see cells.h). This capability needs to be activated in defs.h. Whenever a cell transitions to GR, the CELL_TIME variable is updated to the current time-step value. We used this variable to keep a track of the "age" of the cell, i.e., how long as the cell been in place. You are perhaps using this variable in a similar way as well for your own sintering implementation.

  Next, we started blocking transitions of these GR cells in a stochastic fashion, similar to how the erosion transition is implemented in ReSCAL. For example, the probability of an erosion transition to occur for a particular GR cell is 0 if the age of the cell is greater than a chosen time, say 24 hours and the probability is 1 if the cell is subject to sufficient stress at the surface and it is freshly deposited, i.e., the age is 0 hrs. For cells with ages in between, we use a linearly decreasing probability.

- You are indeed correct about the sensitivity of the model with respect to the length and time scales chosen. It was one of the biggest challenges for us, particularly since we wanted to impose "realistic" sintering timescales. It was imperative for us to get a good handle on length and time scales. The air density we chose is indeed low and we could present a more extensive sensitivity analysis in the future. With regards to ice density, we are bit more confident about this number. Note that the threshold friction velocity and the flux formulations that are used to derive the length and time scales are based on density of drifting and blowing snow particles and not the bulk density of the granular bed, as far as my understand of Bagnold's book goes, or for that matter, drifting and blowing snow as described by Nishimura and Hunt, JFM 2000. The density of snow particles in aeolian transport should not be that far from that of solid ice. I am more concerned about the particle diameter which is likely to be larger than that in reality.

  With regards to our 1.6 meters high barchans - these were conical pile experiments without sintering activated. In a hypothetical scenario, with a huge conical pile of snow and sufficient wind speed, there is no reason why there should not be a huge barchan that scales with the size of the initial conical pile - As long as there is no sintering. As soon as sintering was activated, the large barchans immediately ceased moving - another way of showing that in fact, such barchans can never even be formed.

  A more realistic picture is perhaps found in Fig. 9. Here we begin a flat, 1.3 meter layer of snow that evolves into a complex dune field under the action of a (very!) strong wind. The resultant dune field, after 50 days, is shown in Fig. 9b. While we have not presented numbers about the geometry of the dunes formed, most of the dunes are less than 1 m high. The largest dune is approaching 1.1 meters. The situation simulated however is unlikely to ever occur in reality - 20 m/s continuous wind at 1 m above the surface for 50 days - but data from Antarctica always manages to surprise us about how extreme it can get - may be it does in reality - but surely there is no data for snow bedforms for such a scenario.

- Many apologies for the sloppiness in citing your work. It has been corrected.