

## ***Interactive comment on “Basal crevasses in Larsen C Ice Shelf and implications for their global abundance” by A. Luckman et al.***

**Anonymous Referee #2**

Received and published: 2 November 2011

Page numbers (Page 2037 etc.) refer to the online layout, i.e.  
2035 = online pdf page 1,  
2036 = online pdf page 2  
e.g. 3.20 refers to online pdf page 3 line 20 etc.

### **General remarks**

In this paper Luckmann et al. investigate the origin and properties of linear features commonly observed in imaging satellite remote sensing on the Larsen C ice shelf. In the first part, using a combination of GPR, GPS and MODIS data, they deduce that these features are the surface expression of basal crevasses. The dimensions of the crevasses (along-flow extension at the surface and base and penetration height) is deduced from the GPS and GPR data. The resolution of available imaging remote sensing data lets them conclude that the majority of linear features observed in satellite images cannot be attributed to the

C1200

presence of surface crevasses, but that they are either surface troughs caused by basal crevasses or rifts.

In the second part, the authors employ a linear elastic fracture mechanics (LEFM) approach to model the penetration height of the basal crevasses into the ice. Although this model generally underestimates the penetration height, the results are decent given the number of assumptions for the shelf's stress regime etc.

Based on their findings they suggest that the presence of crevasses changes the overall rheological properties of the ice shelf and the thermodynamic exchange with the ocean considerably enough so that they should be considered in ice-shelf models.

The paper is well written, data analysis is thorough in general and the structure requires little change. However, most importantly, I miss a more quantitative discussion of the implications of the authors' findings. At several instances they stress that their findings has important implications as "deep faults within ice shelves have implications for both their thermodynamic and structural properties. By increasing the area of interface between ice and water, they may enhance heat exchange with the ocean deep inside the shelf where the ice would otherwise be well insulated from external sources of heat" (Page: 2050:16.12). I would expect at some point in the paper an estimate of the true increase of ice area in contact to water for a representative region compared to the case without considering basal crevasses at all (e.g. given as a normalized estimate). Likewise, the reduction of the effective cross section of the shelf in the presence of a large basal crevasses should be provided as an order of magnitude estimate to illustrate how important the crevasses really are rheologically. Having established the depth and width of the crevasses, with their length taken from the satellite images, both could be easily manageable. Such an estimate could be i) performed for the actual "crevasse area flow lines", that is, the flow width covered by the crevasses and ii) for the complete areas of Fig.2a and b. In this sense the title's promise "implications for their global abundance" is only very tentatively fulfilled.

### **Analysis of near-surface layers**

The authors use a the mean wave speed of  $v_{mean} = 0.175 \text{ m ns}^{-1}$  to convert travelttime to depth. For the deeper features this is fine. However, this is not appropriate for the analysis of the near-surface layers and tentative conclusions drawn on their influence on differential accumulation within the troughs. Any estimate on surface density/firn column density–depth function would do a better job. The justified error of 5% attributed to the crevasse height seems to be implicitly assumed for the surface layers as well. The statement on p.2041:8.1 "would predict surface trough depths approximately 1.5 times as deep as we measure" illustrates that this is not a neglectable issue, as the density distribution of the firn layer

C1201

influences the stress regime.

Other specific examples where this is important:

5.4: Based on which diffractions? How large would be the effect of velocity pull-up because of different density distribution in the surface depressions? Seems not justified to apply this velocity for uppermost layers (as for instance done in Fig3), which is important to see how the surface structure changes with depths. A higher velocity in the surface depression because of more snow will deepen the trough further in the radar data.

6.8 "follows approximately": this seems to be the case because  $v_{mean}$  has been used. However, in troughs more snow accumulates, so the density-depth fct. would be different and the shallow internal reflector needs not necessarily to be parallel to the surface but could deviate from it. This is likely most clearly illustrated with a radargram without static correction in the time domain.

7.17 This can only be illustrated with a time-depth conversion, that takes the different density-depth structure into account. Deeper (older) layers may show more deformation than the surface layers because more recent layers are likely to be subject to uneven accumulation which would tend to favour the trough.

## Figures and space considerations

At two instances they authors argue that because of "space considerations" they choose not to show further illustration. In both cases I think it is necessary to show these figures, e.g. as a supplement if indeed not appropriate for the paper.

## Minor remarks

### Crevasse dimensions

At several instances I was puzzled what is meant with crevasse width in contrast to crevasse length. This should be defined once in the beginning in respect to along- and across-flow directions to avoid ambiguities. Some instances where this causes an unclear context:

4.8 "10 km long"

6.11 "widths of these surface troughs"

C1202

7.10 Do you really mean "width" in terms of the along-flow dimension? The reader could only verify this by looking at migrated radargrams. The unmigrated sections in Fig.3/4 cannot be used to reliably support this statement.

### Other comments

Having introduced the nomenclature S1, S2, etc., the authors should keep on using it throughout the text. At several instances they switch back to e.g. writing "series 1". Using "series S1" seems more consistent.

Page: 2037

3.20 global positioning system (GPS)

3.22 MOA already contains mosaic: MODIS Mosaic of Antarctica (MOA) Image Map

Page: 2038

4.9 flow speeds: which are? Reference needed.

4.12 long: length of crevasse or spacing?

14.12 10 ... of series S1

4.17 equivalent to a creation every 14 years at a flow speed of ...

4.26 trace spacing of 4.3 m: Uncertainty? GPS position for every trace recorded or interpolated? Where was the GPS base station? (baseline length?)

Page: 2039

5.5 Indicate on map! How near is nearby? What is the error in the velocity based on this diffraction analysis? I'd prefer to see such a radar image anyway.

5.9 Figures 3 and 4: need labels on axes

5.18 "Assuming": If you know the GPR track and the crevasse position from RS, you know the angle.

C1203

Clarify.

Page: 2040

6.8 remove ",,"

6.16 Rewrite sentence, awkward: "Having established that the features visible in MODIS data (Fig. 1), illustrated using Landsat data (Fig. 2) and investigated using GPR (Figs. 3 and 4) are basal crevasses,..."

Page: 2042

8.18 I cannot see that this is a valid assumption, as the water is missing in the surface crevasse and gravity works the other way, so conditions ARE different. Please extend justification of the statement: "If we make the reasonable assumption that basal and surface crevasses have similar width-to-depth 20 aspect ratios,..."

Page: 2045

11.11 Example required. "We choose not to show them here for considerations of space"

11.21 The criticism raised here requires to show other data that clearly indicate, that the features cannot be crevasses, neither surface nor basal (see 11.11).

11.26 "be either the surface expressions of basal crevasses," Simply calling them crevasses in previous papers is all right in my opinion, as long as no distinction has been made between surface and basal crevasses.

Page: 2046

12.23 LEFM: explain acronym again, has only been done in the intro, 12 pages away.

C1204

Page: 2047

13.16 to adapt

13.22 What about the lateral stresses/boundary conditions to calculate the effective stress?

Page: 2048

14.22 Likely not if they all form at the same place for the same reason and are then advected downstream.

Page: 2049

15.15 This is why the introduction of the physical setting for the LEFM approach (13.22) requires more details on which assumption have been made. Would be good to provide an order-of-magnitude estimate on the effect of shear stresses on the crevasse formation.

---

Interactive comment on The Cryosphere Discuss., 5, 2035, 2011.

C1205