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The Cryosphere Discussions

Interactive comment on "Changes of Wilkins Ice Shelf over the past 15 years and inferences on its stability" *by* M. Braun et al.

M. Braun et al.

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Braun and others, (2008) provide a thorough review of Wilkins Ice Shelf (WIS) historic behavior. They further provide an important analysis of the changing physical characteristics of the ice shelf. We are early in the process of examining ice shelf collapse mechanisms and an analysis such as this paper and Glasser and Scambos (2008), are of critical importance in extending our understanding. This paper using multiple remote sensing products provides an important baseline for continued observation and understanding of the ongoing collapse of Wilkins Ice Shelf. I also congratulate the authors on their proofreading, which has left very few minor errors. I recommend the paper be published, after the following points are addressed that will strengthen the paper. The most compelling evidence offered by the authors is the nature of the expansion and extension of rifts and the rifted zone of the ice shelf leading to mechanical failure of

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sections of the ice shelf. This line evidence should be emphasized even more. The difference between tensile stress related and buoyancy stress related rift development needs to be emphasized throughout, to better illustrate that buoyancy stress is the key. In addition the paper relies on ice surface elevation data determined largely from ICESat data. The general ice shelf thicknesses and surface elevation noted in Figure 3 seem well corroborated by the radio echo sounding data; however, the correlation between the two data sets needs to be specifically stated.

ANSWER: In Section 3.4 on page 350, line 23ff, we state that the computed and measured ice thickness agree well and that this statement is limited by the uncertainty in the mean ice density.

The derivation of ICESat GLAS data for Figure 6 and Figure 7 needs to be better explained in section 3.5.3 before the reader can have confidence in the observations. As has been noted by H. Fricker it is not clear exactly how this data was processed to deal with either the cloud or tide effects. On page 356 a number of points are made regarding relatively modest changes in ice surface elevation, less than 1 meter, which raises the question of the accuracy of elevations from the repeat profile comparison of ICESat. This accuracy is possible given the instrument accuracy of approximately 0.1 m, if it is properly adjusted. Without proper reporting of how this data was processed and the resulting error bars, section 3.5.3, Figure 6 and 7 are not yet ready for inclusion in this paper.

ANSWER: In order to tighten the manuscript we decided to delete Fig.7. Although Fig.6 shows larger variations, the documentation of the data processing indeed requires more care. We used ICESat GLAS data from release 28. We did not apply the tidal correction. Only data with gain lower 50 and energy larger 4000aJ has been used and thus cloudy spots are eliminated. We revised the description of the data editing.

A map based figure more fully illustrating the structural characteristics of the ice shelf similar to those used by Glasser and Scambos (2008) would be quite useful at least in

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the Charcot and Latady Island area. In the conclusion more of a contrast-comparison with Larsen B conclusions from Glasser and Scambos (2008) should be made.

ANSWER: We now include a map of entire WIS showing the structural characteristics derived from the satellite image time series. The old Figure 5 has been replaced by this map. The map follows where possible the terminology of Glasser & Scambos (2008). The text has been expanded with a description of the mapped features. We also refer now in this section to the work of Glasser & Scambos (2008). Additionally, we improved the conclusions and also worked out the differences to the observations by Glasser & Scambos (2008)

This paper comments on the weak connection between Lataday and Charcot Island, and discuss its likely demise in the conclusion. Given the ensuing developments in May-July on the Wilkins Ice Shelf the authors should make a brief comment on the further collapse as it relates to the observed rift developments noted in this paper and add the appropriate ENVISAT image to Figure 4. I look forward to continued work by the authors on this ice shelf.

ANSWER: Yes, we agree; this is the problem when compiling material for a fast changing area. In Figure 4g, we have now included a TerraSAR-X image of the area showing the situation after the June/July 08 break-up. We now also briefly comment on the recent developments in the section “Fate of WIS”. Additionally we refer to a published note in the Journal of Glaciology describing and illustrating this point and the June/July08 event in more detail.

Specific Comments: 345-12. ...This coincides with... What is this referring to? A jump in ice shelf elevation is also noted in this sentence. Is there any corroborating evidence for this statement? Jumps in elevation of the surface of an ice shelf other than around an ice rise or island pinning point are not typical. Does the surface elevation change commensurate with shelf thickening coincide with a line from Dorsey Island to Petrie Ice Rise to Burgess Ice Rise?

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ANSWER: Reviewer #2 also refers to this point. Indeed our text is here ambiguous and we worked on a clearer description. Beside in the vicinity of ice rises ice shelves show changes or clear jumps in surface elevations, where two formerly distinct ice masses join. Cross-sections parallel to ice shelf grounding lines show areas were thick ice streams are flowing into the ice shelf and join thinner ice masses flowing into the ice shelf. This is not unusual. In order to improve the illustration of the ice thickness gradients, we have changes the color bar in Fig. 3 and included it as well in the map of structural characteristics, the new Figure 5.

45-22. Explain connection of pore closure to brine infiltration.

ANSWER: Pore closure means that the ice matrix contains single air bubbles which are not connected with each other. Thus, the material is to some extend porous, but the void space cannot be filled, if the material is pushed under the water surface.

346-20. Where was this breakup?

ANSWER: We state now that these events occurred on the northern ice front.

353-22. After defining crack types, it is important to consistently identify rifts as either tensile or shear stress induced based on orientation. This will aid the reader in developing a sense of the relative importance of each crack type, for example when fractures are discussed on 354-14-25.

ANSWER: We have worked through the entire manuscript to keep this consistent.

355-5. ...Crack propagation toward the ice front s...,is this in general or in reference to a specific crack? Are the associate cracks in this paragraph tensile or shear in origin?

ANSWER: This refers to this specific crack. The paragraphs according to the discussion of the open water at 'H' has been revised entirely.

358-17. It is noted that ice rises have been viewed as key pinning points in the past, and not key zones of weakness development. There is a fine line separating these two

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differing roles. Whether this is correct or incorrect this logical reasoning sequence for ice rises becoming a locus of failure needs to be completed. The authors may in fact be saying this in the sentence, ...Hence, ice rises are, in the absence of a compressive stress zone that hinders rift propagation, a destabilising factor...

ANSWER: We think that here a misunderstanding has taken place and we ask the editor for advice. The discussion of the role of ice rises goes over several paragraphs and ends with the sentence the reviewer refers to. The stabilising role and the evolution of failure zones in the vicinity of ice rises have been discussed in detail from our point of view.

359-9. ...drastic rift extension in coherence with break-up events...,Can this observation be quantified in some fashion?

ANSWER: We now include in this section quantitative values for exemplary fracture evolution. The new Figure 5 illustrates this partially, as rifts are shown color-coded according the years of first appearance. We have to admit, that the database of images prior to the 2008 break-up events has been enlarged since the manuscript has been submitted and analysis (which postponed the submission of the revised manuscript) of those images revealed, that the link that drastic rift extension occurs immediately after or together with the break-up was drawn erroneously. Nevertheless, the nature of the rift evolution is as described – large fractures formed on dynamic time scales and not on quasi-static time scales – but load alteration as cause for this cannot be excluded.

361-9. The conclusion that bending stresses and changing buoyancy forces are a cause for break-up needs to better explained.

ANSWER: We added some sentences explaining where and why the bending stresses arise and which assumptions need to be made in order to calculate their magnitude, as well as their relation to the 'ordinary' creep stress.

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365-7. The buoyant stress is indicated as the min cause for breakup, what would a tensile stress related breakup look like, needs to be stated here or on 361-9.

ANSWER: 'Tensile' and 'shear' are terms that refer to the direction of the stress and not to the cause of the load. The bending stress and the creep stress are both tensile stresses. We have included 'tensile mode' in 365-7, while 361-9 remains unchanged as bending stresses do by definition not cause shear mode rifts.

Figure 3. What is the correlation coefficient between the ICEsat GLAS data and the radio echo sounding data? It looks to be good.

ANSWER: The reviewer likely refers to the computed ice thickness rather than the ICE-Sat GLAS data itself. At the end of Sect. 3.4 we say that the computed and measured ice thickness (with about 30 years difference) agree to a reasonable extend and the uncertainty in this statement due to the unknown mean ice density. Furthermore, there are only few locations where the ICESat tracks and RES flight lines cross, so there would be a very poor statistics for a correlation coefficient. Both arguments show, that (even a high) correlation coefficient would be meaningless.

Figure 4. Indicate extent of rifted zone on ice shelf with line similar to ice front position.

ANSWER: Figure 4 now includes two lines – a line indicating the fracture extend by September 2008 and one line indicating the worst case scenario that we would expect WIS might retreat. The line is discussed in section 4.4 “Fate of WIS”. The graphic with retreat area (Fig.4h) has also been updates with an image showing the situation after the July event. The rift development and extent can now also be clearly seen in the new figure 5.

Figure 5. In panel 5d indicate extent of melt features on WIS as a whole.

ANSWER: This figure has been replaced by a structural map of Wilkins Ice Shelf. The map follows roughly the terminology and layout of Glasser & Scambos (2008) for Larsen-B Ice Shelf.

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Figure 6. Without further data explanation 3.5.3 this figure should be removed.

ANSWER: We have improved the description of the ICESat data analysis. We also updated the ICESat tracks with the revised dataset for the EGM96 geoid.

Figure 7. Without further data explanation 3.5.3 this figure should be removed.

ANSWER: The figure has been removed.

Figure 9. Identify type of crack formation of rifts.

ANSWER: Has been done. This is now numbered as Fig. 8.

Provide rift length!

Done in revised manuscript.

Interactive comment on The Cryosphere Discuss., 2, 341, 2008.