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Comment

Interactive comment on “The imbalance of glaciers after disintegration of Larsen B ice shelf, Antarctic Peninsula” by H. Rott et al.

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We want to thank Nicholas Barrand for his positive response to the manuscript and his suggestions for improvement. We are taking into account his comments for the revised version of the manuscript as explained below.

1609.28: Figure 1. An inset with the location of Larsen A and B at the Antarctic Peninsula is added.

1611.7: We mapped ice motion of Larsen-A and Larsen-B glaciers also using TerraSAR-X images of 2007 (examples shown in Rott et al., 2008). In 2007 other swathes (with different viewing geometry) were acquired than in 2008 and 2009, extending over different parts of the glaciers (e.g. in Crane glacier only the lowest part of

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the terminus). For the analysis of ice fluxes reported in this paper we decided to use 2008 and 2009 data of the same swath. In the text we will add some numbers on ice velocities retrieved from TerraSAR-X data of 26 June, 7 July, 18 July 2007.

1611.8: HH is defined in the revision.

1611.9/10: Regarding the number of decimal places, we would not like to modify data coming from distinct sources. In this case the numerical values 3.3 m and 1.2 m are exactly as specified by Breit et al. (2010). The value for 35 deg incidence angle (2.09 m) is deduced from that. The pixel size (at 2 decimal places) is from the TerraSAR-X header of the data we used.

1611.13.-15: We believe this technical information is useful for people carrying out motion retrievals with repeat pass image data. If it is not of general interest, we can leave it out, or include a very short statement (just window size).

1611.19: The basis for DEM used is cited in the references (Jezek et al.). We make this clearer in the text. For terrain corrected geocoding of SAR data we use our in house SAR processing software.

1611.23: Wording changed.

1611.27: Using now m a-1 throughout.

1612.15: We use now H1 and G1 both in Table and Figure. The gate for Punchbowl (PU1) is plotted now in the lower left corner of Figure 2.

1612.17: We explain in the revised text how the drainage basins were delineated (geocoded high resolution satellite images and DEM). Because Figure 2 and 3 show only the frontal part of the basins, we add a new figure (Landsat image) showing the full extent and boundaries of the basins above Larsen B. (Would be too small in Figure 1).

1613.22: We rearrange the order of letters (now alphabetically according to date) in

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Figure 4, 5, 7)

Figure 5 and 7 captions: We explain the velocity profile labels also in these captions.

1614.3: Wording changed.

1614.1: The velocity increase in Aril 2009 is significant only 3 to 4 km upstream of the front. Beyond that (up to about km 7) it is a very small change. We will discuss this in some more detail.

1614.15-20: We believe that these images are interesting, as they show the typical conditions in the frontal bays of the glaciers at Larsen A and Larsen B. This is just one example out of many. We have an archive of > 200 SAR images (ERS, Envisat ASAR, TerraSAR-X) from Larsen A and B since 1995 showing this typical change of conditions from winter and spring to summer. Further explanation on this is added in the text. By the way, these seasonal changes in the state of the ocean surface were also of relevance for the timing and sequence of the disintegration events on Larsen-A and Larsen-B (see Rott et al., 1996; Rack and Rott, 2004).

1614.15-20: Wording changed.

1615.8: cm d-1 now used throughout

1616.7: No problem to reduce the number of decimal places to 2, but I am not sure if it is reasonable, because then the numbers for the smaller glaciers in Table 2 would be truncated to only 1 or 2 digits. The number of decimal places should be consistent for all glaciers.

1616.10: Uncertainty in gate cross-sectional area: In the meanwhile ice sounding data on a profile along the central flowline of Crane Glacier have been made available online by the Center for Remote Sensing of Ice Sheets (CReSIS), University of Kansas. These data from an airborne radar sounding survey on 4 November 2009 show an ice thickness of 772 m in the center of our profile C1. This is remarkably similar to our estimate of 760 m (for end of 2008) based on extrapolation from very limited data. As-

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suming thinning of about 20 m between the two dates, the ice thickness in late 2008 was about 790 m. On the other hand, the bathymetric data in front of the fjord (Zgur et al.) suggest that the lower base of the cross profile is slightly narrower than we assumed, which would compensate for the greater thickness. In any case, the new data show that our error estimate for the gate cross-sectional area was conservative and can be reduced.

16.16.14-17: Microwave radiometry: I am rather familiar with microwave radiometry over ice sheets and land surfaces, starting to work with such data in 1978 with SMMR, and performing microwave emission measurements on an Antarctic inland traverse, etc. There is no way to obtain any reasonable estimate of snow accumulation from satellite-borne microwave radiometer measurements along the mountain chain of the Antarctic Peninsula (API). Arthern et al. (2006) use the polarization ratio (PR) of the 6.9 GHz AMSR channel, which has an elliptic IFOV of 74 km x 43 km. They estimate the spatial resolution of their map being 100 km. So even if the method would work in mountains with high accumulation rates and in the percolation zone, the resolution is much too coarse. Geostatistical methods are applied, combining the MW data with in situ accumulation measurements which need to be representative for the area of at least one single AMSR IFOV. This means the quality and representativeness of the in situ data are essential. The method works only in the dry snow zone, as the PR is related to the sequence and properties of the internal interfaces (depth hoar layers are important). The method is not applicable in the percolation zone, because the sequence of annual depth hoar layers is spoiled after melting, and the main parts of the Larsen glacier basins belong to the percolation zone.

Regional climate model output van de Berg et al. (2006): The conclusion on the applicability of these data for the API mountain chain is similar as for MW radiometry. The authors use many surface mass balance measurements (1900 points) to constrain the results of their model computations. They state “support or falsification of this result can only be found in new SMB observations from poorly covered high accumulation

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regions in coastal Antarctica”. API is one of these. The steep topography and high local gradients of accumulation question the applicability of this model in the northern API region at the present stage.

Interesting to compare the numbers of the two papers on Antarctic snow accumulation: van de Berg et al. obtain a number of the surface mass balance integrated over the grounded ice sheet of 171 ± 3 mm/a. Arthern et al. “obtain a value of 143 ± 4 kg/(m² a) for the average rate of snow accumulation upon the grounded ice sheet”. And then, observations at single stations show significantly higher error bars, depending on the method (e.g. Takahashi and Komeda, J. Glaciology, 2007).

1616.28: Automated phase unwrapping was done along a path from ice-free surfaces a few kilometres upstream because the phase in the shear zone on the margins of this profile is partly noisy. The automated phase unwrapper in our software is set to choose the path of minimum noise. We reprocessed the interferograms at higher spatial resolution making it possible to distinguish individual fringes also in this zone and performed manual unwrapping, which results in a minor change of velocity in the marginal zone. Explanation on this is provided in the revision.

1617.5: For our response regarding 2 decimal places see 1616.7. Error bounds are now included in the Table 2.

1617.20: Explanation on length of the profile covered by TerraSAR-X is added.

1618.17-18: A new figure covering the whole drainage basins with boundaries is added. (see response to 1612.17).

1649.11: Information on the derivation of mass budget errors is already included in the present version of the text, but we will point this out clearer in the revision. Uncertainties will be included in Table 2.

1619.13: As described in the text, the estimate of the cross sectional area of those glaciers is based on the assumption that the glaciers were approximately in equilibrium

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at the time when ice motion was retrieved using ERS interferometric data in 1995 and 1999. The mass flux through a glacier gate in those years is computed using the estimated accumulation rate. The mass fluxes are the basis for estimating the cross section of the gate for these glaciers. Further details are described in the paper. A similar procedure was applied by Rignot et al. (2004, 2008) for estimating the mass fluxes for these glaciers.

1620.25: We believe that the comment on PCG and Larsen-A glaciers (trend of significantly lower mass fluxes in our results compared to published data) is useful as starting point and to motivate further work in this region. This statement should stay with the conclusions. We may also mention that ESA is planning an airborne ice-sounding campaign along the API (including the Larsen A glaciers) in early 2011 which will be important for reducing the uncertainty in calving fluxes.

Interactive comment on The Cryosphere Discuss., 4, 1607, 2010.

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