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*Professor Hilmar Gudmundsson
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The Cryosphere*

Re: Manuscript No tc-2011-102

"A new glacier inventory for 2009 reveals spatial and temporal variability in glacier response to atmospheric warming in the northern Antarctic Peninsula, 1988-2009".

Dear Professor Gudmundsson,

We would like to thank Marinsek for his thoughtful comments, and reply to these comments below. We appreciate their local knowledge and expertise, which has been valuable in guiding our study.

In summary, we have changed the manuscript to account for the difference in glacier numbers between Skvarca et al 1995 (39 glaciers) and Rau et al 2004 (58 glaciers) and our study (104 glaciers on James Ross Island). We have also added more information on the SPIRIT DEM used in our study. We have also removed references to Glaciar Bahia Diablo throughout the manuscript as GIV09 and GBD are not comparable, and do not compare our ELA estimate to the published ELA estimate in Skvarca et al. 2004.

We have, as a result of this comment, also corrected the coastline around Vega Island, which was partly incorrect around GIV09.

However, we have not remapped the ice divides on Vega Island, for reasons provided in detail below. In this reply we have supplied two figures demonstrating the differences between ice-divide mapping in this study and in the Skvarca et al (2004) study to aid comparisons.

Below we have responded more directly to each point raised below (italic font).

Yours sincerely,

Bethan Davies

The study presents an extensive inventory over the Northern Antarctic Peninsula, updating several of the glaciers previously inventoried and including other glaciers. It is valuable that all data was uploaded to the GLIMS database.

Glaciology Division from Instituto Antártico Argentino has been working in field campaigns on Vega Island for more than thirty years. We are carrying out mass balance studies on Glaciar Bahía del Diablo since 1999 and detailed data has been published in the World Glacier Monitoring Service (WGMS) Glacier Mass Balance Bulletins (GMBB) and Fluctuation of Glaciers (WGMS 2008). We have

also carried out mass balance measurements on another glacier, also in Vega Island, in the period 1999-2003. These results remains unpublished.

Specific comments and suggestions:

From WGMS bulletins and from Skvarca et al. (2004) it is clear that GIV09 and Glaciar Bahía del Diablo (GBD) are not the same glacier. GBD is a land-terminating glacier with an area of 14.3 Km². GBD data is published in GMBB with WGMS ID, area, location, classification, state and other fluctuation data (WGMS 2008). GIV09 boundary is not correct and include GBD and parts from others neighbouring glaciers, a marine-terminating section belonging to GIV10 and a section belonging to GIV26. These two sections account the rest of the GIV09 derived area (4 Km² approx.). GBD drainage area and boundary were derived from field surveys over the whole glacier by means of differential GPS.

By processing SPIRIT DEM with hydrological tools we also could derive similar glacier basins, confirming that they are different glaciers with different catchments areas.

GIV24 presents a similar issue. From our differential GPS surveys carried out within the mass balance measurements in the period 1999-2003, this glacier is also composed by two separated glaciers. The glacier we have studied had an area of 3.3 Km² in 2002, half of the 6.6 Km² of the GIV24 in 2001.

Thank you for this comment, and we appreciate your local expertise. However, we note that there are many different ways of defining ice divides. We used glaciological mapping, and analysis of aspect, slope and elevation (Figure 1 below), as this can be applied quickly across large areas, such as the Antarctic Peninsula. Interpretation of DEM properties, even using models of aspect and slope and hydrographical tools, are ultimately subjective and require user interpretation. At the resolution at which we analysed all the ice divides, we were not able to separate GIV09 into two or more glaciers; the DEM clearly shows high points dividing GIV09 and GIV10, with different aspect and slope, and no reason to divide the glacier further – please see Figure 1 below. GIV24 is similar, and our glaciological mapping and analysis of the DEM presents no suggestion that this should be further divided.

Changing the settings and sensitivity means that what makes a good ice-divide at a high resolution on one glacier does not work on the wider region. Without large scale surveys, it is impossible to accurately delineate ice divides, which we have identified as the largest source of uncertainty in our study. The method used by Skvarca et al (2004) is equally applicable, but relies upon high resolution, detailed field surveys, which is not possible across the entire study area. Rather than changing the divides on Vega Island to fit their local knowledge, we prefer to use a regional technique for consistency across the whole study region. This is not to say that either method may be more accurate across a smaller local area, we do not have the ability to apply it across our entire study region. Please note that even if we did recalculate the ice divides to conform with those proposed by Marinsek, this would affect only 2 out of 194 glaciers in our study, so the main conclusions and all the tables would remain unaffected. Finally, it is not appropriate to amend our method to correct for two glaciers, resulting in different ice-divide mapping techniques across the study region.

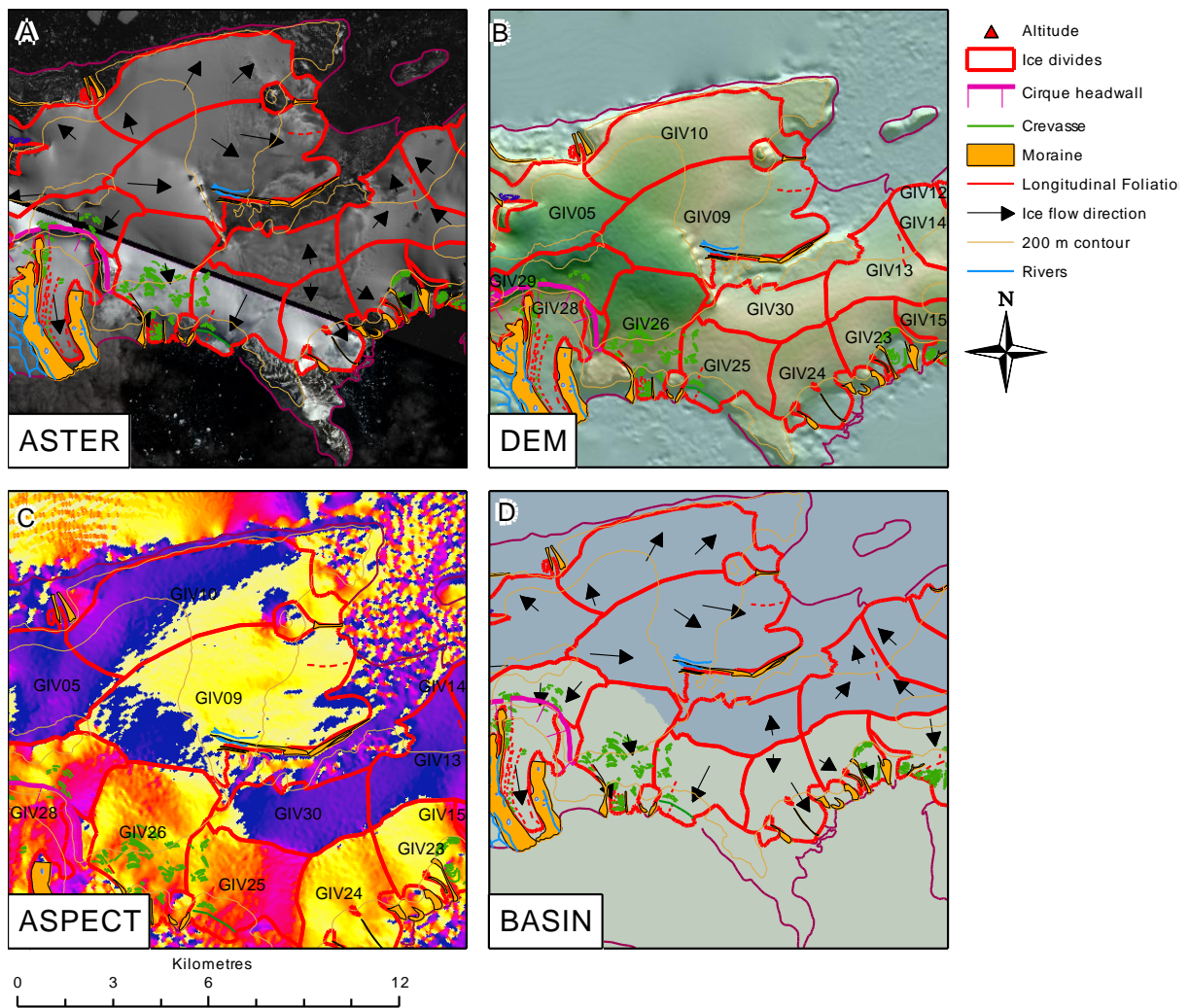


Figure 1. Analysis of ASTER imagery and the SPIRIT DEM on Vega Island, showing how we have interpreted our ice divides

Please see, for comparison, the ice divides mapped by Skvarca et al. (2004) below (Figure 2). Based on our mapping, we see no reason to divide GIV09 into two or more glaciers, as Skvarca et al. (2004) have done below.

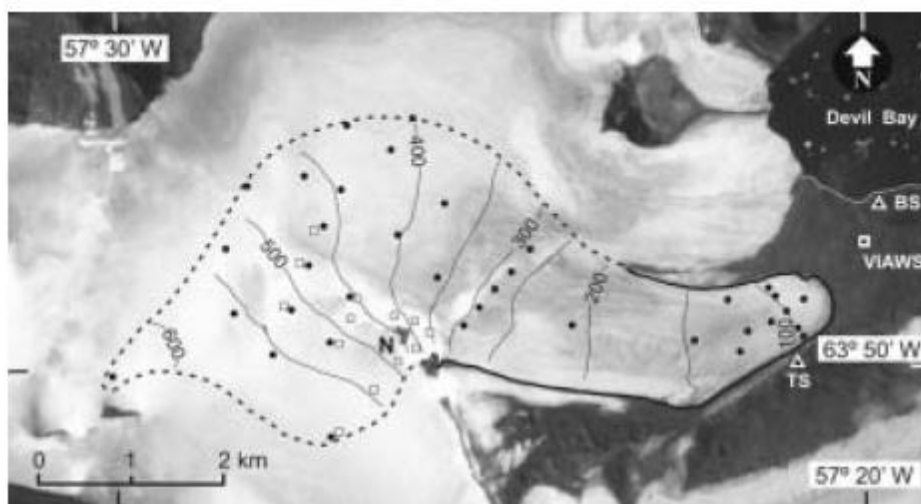


Fig. 2. Topographic map of GBD, superimposed over a section of Landsat 7 ETM+ image of 21 February 2000. Contour lines are in meters. Circles indicate positions of stakes, and squares the locations of snow pits. The glacier drainage area is delineated by a dashed line. N: nunatak; TS: triangulation station; VIAWS: Vega Island automatic weather station; BS: location of GPS base station.

Figure 2. Figure 2 from Skvarca et al. (2004), showing Glaciar Bahía del Diablo (our GIV09) and their mapped ice divides.

P3555: GBD is not experiencing frontal retreat (WGMS 2009, 2011). Mentioned GIV09 retreat corresponds to the neighbouring glacier marine-terminated GIV10. *Ok, this observed difference in recession is due to different ice divides being drawn. However please note that we were unable to map ice front retreat in 2001 because of unclear satellite imagery; we note clear retreat in the marine-terminating part of this glacier between 1988 and 2009 but duly note that the land-terminating portion has remained stationary throughout the study period. We have acknowledged this in section 5.2, adding:*

“However, the land-terminating part of GIV09, which corresponds with Glaciar Bahía del Diablo in previous studies, has remained stationary from 1988-2009, which agrees with previous workers (Skvarca et al., 2004).”

Equilibrium line altitude (ELA) found by Skvarca et al. (2004) and others ELAs published in GMBB are from GBD and not from GIV09. GMBB No. 11 includes the graph ELA versus specific mass balance for a 10 year observation period, confirming the ELAMEAN is higher than the remotely mapped. *We have removed comparisons between our remotely mapped ELA and the ELA mapped by Skvarca et al 2004, instead observing only that different ice divides means that they are not comparable. We have not referred to GBD as they are not comparable.*

P3558: The amount of land-terminating glaciers on Vega Island should be updated, as there are more than seven. *Only 7 are mapped in our study – GIV09 is only partly land terminating in our study.*

P3559: GBD must be removed from the section 5.3 as it is not a marine-terminating glacier and moved to section 5.2. The mentioned continued shrinkage of GIV09 is because of the GIV10 marine-terminating terminus retreat, which is not part of GBD. GBD is in stable state and has not sown area

change since the mass balance measurements started. *We have removed the reference to GBD and the comparison to Skvarca and Angelis 2003 in section 5.3 because of the different ice divides used.*

P3562: Rates of retreat mentioned of $22.3 \text{ km}^2 \text{ a}^{-1}$ in the period 1988-2001 and $15.1 \text{ km}^2 \text{ a}^{-1}$ in the period 2001-2009 can not be compared with results from Skvarca et al. (1995) and Rau et al. (2004) because the studied glaciers to measure the changes are different. Our results for the mentioned period indicate retreats of $2.9 \text{ km}^2 \text{ a}^{-1}$ in the period 1988-2001 and $2.6 \text{ km}^2 \text{ a}^{-1}$ in the period 2001-2009, which were measured over the same 39 glaciers studied in the period 1975-1988 by Skvarca et al. (1995). However these results also confirm an increased rate of recession in both periods compared with the observed retreat of $1.8 \text{ km}^2 \text{ a}^{-1}$ in the first period. *We have noted that previous studies observed only 39 glaciers while our study observed all the glaciers (104) on James Ross Island.*

Because of the issues mentioned in drainage areas delineation, ice divides should be improved on Vega Island in order to avoid mix of basins of different glaciers in only one. Also tables and figures should be updated. *As we note above, we have not changed the Vega Island ice divides, to account for this local knowledge. Please note that this only affects two out of 194 glaciers, and changing the ice divides would not affect any of the tables, regional trends or conclusions.*

There are two SPIRIT DEMs covering Vega and James Ross islands. Versions used in each processing also should be mentioned and if correlations coefficients or other information were used to mask the unreliable data. *This information has been added to the Data Sources section*