The Cryosphere Discuss., 4, C1608–C1611, 2011
www.the-cryosphere-discuss.net/4/C1608/2011/

The Cryosphere Discussions

Interactive comment on "Photogrammetric determination of spatio-temporal velocity fields at Glaciar San Rafael in the Northern Patagonian Icefield" *by* H.-G. Maas et al.

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Received and published: 3 February 2011

We acknowledge the potential importance of ice flow acceleration to thinning, as has been reported for glaciers in the Arctic (e.g. Dietrich et al., 2007; O'Neel et al., 2005) and the Antarctic (e.g. Rignot et al., 2004). However, in the case of San Rafael Glacier, the maximum thinning rate of 3.5 m/y reported by Rignot et al. (2003) for the frontal portion is typical for the outlet glaciers of the Patagonian icefields, and might be explained only by mass loss due to recent warming and associated feedback mechanisms as indicated by Raymond et al. (2005). Other glaciers in Patagonia, such as Jorge Montt and HPS 12, are thinning at a rate of over 15 m/y (18 m/y and 28 m/y respectively),

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which definitely cannot be explained by climate and feedback mechanisms alone. In this regard Rignot et al. (1996b) analyzed glacier velocities at the front of 4 glaciers in the Northern Patagonia Icefield, including San Rafael and 3 other lakewater calving glaciers, concluding that only San Rafael exhibited strong flow acceleration at the front, reaching a maximum of 0.005/d, similar to strain rate values reported by Naruse (1985, 1987), which are about half of the longitudinal strain rate of 0.012/d reported by us. The large frontal acceleration at San Rafael might be due to a narrowing of the glacier valley in the last 10 km near the front, as indicated by Rignot et al. (1996b). We realize that the simple consideration of ice mass continuity based on incompressible ice would lead to enormously large (2 m/d) thinning rates at the front, but since the real thinning observed of 3.5 m/y is much smaller, this suggests that other factors such as glacier narrowing and ice density decrease at the front due to widespread crevassing might explain the strong ice flow acceleration. The above ideas will be added in the corrected text.

As for the other comments, we will make the corresponding changes. According to the general comments of the reviewer we will modify the text in the following sections:

2416 line 17. Acknowledging that we cannot discard the role of ice thinning we have changed the text to "... showing that the conditions at the glacier front have been stable in at least the last 25 years, with a clear mass balance disequilibrium which has resulted in a thinning of 3.5 m/y. This thinning is similar in magnitude to that of other neighboring glaciers which show longitudinal compression near the front, suggesting that it may be explained by a regional signal of atmospheric warming, although in the case of San Rafael this thinning might also be linked to the strong longitudinal acceleration near the front."

2417. Line 24. Naruse (1985, 1987) Line 28. Rignot et al. (1996a, 1996b)

2418 Line 9. Before "Thomas" add the sentence "Koppes et al. (2010) measured in 2006 maximum water depths of slighly over 200 m near the glacier front."

2423 Line 16. Before "As a by-product" add "In fact this is supported by the measurements of Koppes et al. (2010), who found maximum water depths of the order of 200 m near the glacier front. Line 21. Naruse, 1985, 1987. Line 22. Rignot et al. 1996a, 1996b. Lines 22-26. Substitute sentence with: The stability of the velocity field over time suggests that at least in Glaciar San Rafael no significant acceleration/deceleration has taken place during the last 25 years. The frontal thinning of 3.5 m/y at Glaciar San Rafael is similar to other neighboring lakewater calving glaciers (Rignot et al., 2003) which show velocity deceleration and compression near the front. Our velocity measurements show a strong acceleration at the front of Glaciar San Rafael, with longitudinal strain rates of 0.012/d, which are not excessively larger than the strain rates of 0.005/d found by Naruse (1985, 1987) and by Rignot et al. (1996a, 1996b). The fact that Glaciar San Rafael shows thinning comparable to other neighboring glaciers suggests that regional warming is indeed the driver of the glacier wastage, as reported by Rasmussen et al. (2007). As for the very large longitudinal strain rates at the front of Glaciar San Rafael, assuming simple mass continuity with incompressible ice suggests that very large dynamic thinning (up to 2 m/d) could occurr. The narrowing of the glacier valley, as suggested by Rignot et al. (1996b), and the reduction of bulk ice density near the front as widesread crevassing occurs might reduce the dynamic thinning effect.

2424 Line 9. After "tidewater glacier" change to "Considering that neighboring lakewater calving glaciers are thinning at similar thinning rates of 3.5 m/y measured at the front of Glaciar San Rafael, this suggests that regional atmospheric warming is driving the glacier wastage." Final sentence remains the same. Line 20. Add "The support of a Research Award from the Humboldt Foundation to GC is acknowledged".

We are currently not able to produce the requested figure 7.

EXTRA REFERENCES

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Interactive comment on The Cryosphere Discuss., 4, 2415, 2010.