

## ***Interactive comment on “Recent acceleration of ice loss in the Northern Patagonia Icefield based on an updated decennial evolution” by P. López and G. Casassa***

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Received and published: 16 January 2012

### **General Comments**

This study calculates and interprets geometrical changes (elevation changes, length changes and area changes) of the Northern Patagonia Icefield (NPI). The time period analyzed is mainly based upon the time of each individual DEM (1975-2000-2005), though is slightly different for the analysis of area and length (1979-2001-2011). Despite the varying temporal characteristics of the study, it documents an enhanced thinning (only below an average ELA, though) as well as a variation in length and area

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changes, mostly enhanced. The study is a useful addition and update to the previous elevation change studies of the NPI.

However, the manuscript requires some revision before full acceptance and publication. The major weaknesses revolve around the presentation of results and discussion. In particular, the elevation change measurements lack associated error estimates from which to confidently claim "acceleration of ice loss" in the title. More discussion is required about the lack of accumulation area data which has the potential to change glacier wide estimates. The discussion mainly revolves around area and length changes. I suggest to re-focus the discussion to include a comparison of elevation changes as well, in order to confidently claim "acceleration of thinning" below the ELA. Also, how do the area and length changes compare to the elevation changes? Last, the amount of tables and figures is over-whelming and there is plenty of room to cut and combine some of them. I hope my suggestions below will help the authors revise this contribution into a clear, concise manuscript.

### **Specific Comments**

- Abstract: Shorten. All specific glacier details are not required in the abstract.
- Section 3.1.2: I do not agree that C-band radar does NOT penetrate into snow (see again Berthier et al., 2006; Rignot et al., 2001). For your study, it may have little implications as elevation changes are mainly measured in the approximate ablation area (ice)...
- Section 4.2.1: Did you also estimate the  $c$  parameter of eq.1, and consequently correct for the mean bias between each DEM? According to Table 4, I can not see that this is done. Unless "Dh" is the mean difference over non-glacierized terrain? If yes, did you correct for this?

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The mean elevation bias (between the DEMs) may be a correction just as important as the horizontal co-registration. You may estimate the mean bias either using the  $c$  parameter of Equation 1 and dividing it by the tangent of the mean slope used to solve for the  $a$ ,  $b$  and  $c$  parameters (i.e. the second part of your equation 1), or by simply taking the mean of non-glacierized terrain after co-registration only in the horizontal. In particular, this will have large impacts on the ice elevation change estimates!

- Section 4.2.2 AND Section 5.1: Did you find any **significant** elevational biases? Figure 6 is not very convincing. Also, did you use ICESat for this, or did you use directly the DEM v. DEM comparison?

Also, when fitting a polynomial, not only the interval of elevation (Pg. 3334, Ln4) can be solved, but every elevation pixel can be corrected...

Granted that Fig. 6 is not very convincing, how does this adjustment effect your elevation change estimates of Table 8?

- Section 5.1 (Pg 3335, Ln17-22) & Table 6: Care needs to be taken here due to the lack of high elevation (i.e. accumulation area) data in the 1975 DEM (Fig. 2). One option is to use only pixels available in all three DEMs for calculating the means. In that way, at least you are at least sampling the same areas/elevations. However, this will not conserve mass, and therefore interpretation of melt etc. is not possible.

In addition, I suggest to combine table 6 with table 8 by showing a total average of all pixels (as described above) at the end of table 8. This will additionally save space and reduce the amount of tables.

- Section 5.1 (Pg 3336, Ln6-15): Can your estimates be directly compared with Rignot et al. (2003)? Your estimates are below the average ELA, but what about Rignot et al. (2003)? Please elaborate more on this.

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Also, to be consistent with your last statement of the paragraph, the validation of your results require error bars on your estimates (and their estimates) to determine whether the differences between previous studies are not statistically significant...

- Section 5.1.2 and Figure 8: Consider changing this plot to elevation change rates ( $\text{m a}^{-1}$ ) and show the two to three time epochs 1975-2000, 2000-2005 (and potentially 1975-2005). As of now, this section provides little value to the study, besides suggesting thickening above 1300m. By showing the rates, the figure will more confidently prove the "accelerating" trend...

In addition, I suggest to expand Fig. 8 with individual glacier centerline (or elevation bin average) elevation change rates for some of the larger glaciers in the NPI, and maybe for those of varying aspects... This will provide the reader with even more concrete information about the individual glacier elevation changes. This will also aid to the results of the maximum thinning rates described in the previous sections (and it could be worthwhile, then, to combine the sections).

- Section 5.2 and Section 5.3. Since I assume that most of the area changes are occurring at the fronts of glaciers, then area change and length change are saying pretty much the same thing. These sections and figures described may be considerably shortened and possibly combined.

In Section 5.2, All numbers that are present in tables are not required to repeat in the text. It makes the section un-interesting and difficult to find the interesting aspects. Instead, focus on the retreat rates, those glaciers that have accelerated, decelerated retreat. How do these numbers compare to the elevation change rates?

In Section 5.3, Similar to above, not all numbers are required to repeat in the main text. Focus on the important, interesting details. Also, maybe it would be interesting to see percent retreat per year in Fig. 11.

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- Pg3341, Ln5: How did you calculate the 81% of ice loss? Is this your measured ice elevation changes between 2000-2005?
- Pg 3345, Ln10-12: Any hypothesis why the west facing glaciers are wasting more?
- Table and Figures: All captions are not very helpful. Please fill in the captions with important information that helps the reader interpret your tables and figures. See below for more specific details and suggestions.
  - Combine Table 1 and 2?
  - Combine Table 6 and 7?
  - Combine Table 9 and 10?
  - Combine Fig. 1 and 3?
  - Is Fig. 4 necessary?, maybe it is enough with just a reference?
  - Fig. 7: This is **Mean** elevation changes, correct? Also, are the same exact pixels used for calculating the means in both time periods? If not, maybe they should be.
  - Fig. 8: As stated above, I suggest to show this figure using elevation change rates for all three time periods you have. Also, expand this figure to also show changes of the individual glaciers used in the results and discussion.
  - Fig. 10 and 13: Maybe these figures could be more helpful if you use annual change rates rather than absolute change magnitudes?
  - Fig. 12 and 14. I would remove Fig 12, or have it as an inset in Fig. 14. For Fig 14, would it be more interesting to see the percent change per year?

### Technical Corrections

Note to Author: Underlined words are deletions. Bold **words** are insertions.

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- Paragraphs should, in general, contain 3 sentences or more. Combine paragraphs containing less than three:
  - Pg3325, Ln14 - 24: Combine the first two paragraphs, and the third and fourth paragraphs.
  - Pg3327, Ln3-5
  - Pg3328, Ln19-21: Combine with the proceeding paragraph.
  - Pg3329, Ln8-14, 17-20
  - Pg3330, Ln4-8 (Section 3.1.3 can be 1 paragraph...)
  - Pg3331, Ln 12-15 (Section 3.2.1 can be 1 paragraph...)
  - Pg3334, Ln8-11
  - Pg3335, Ln3-8
  - Pg3336, Ln6-10
  - Pg3338, Ln3-14
  - Pg3339, Ln11-16
  - Pg3340, Ln1-3, 11-15, 23-26
  - Pg3341, Ln12-28
  - Pg3342-3, Entire Section 6.2...
- Pg3326, Ln19: "changes inside **of** the icefield"
- Pg3326, Ln26: remove " $\pm 1$ "
- Pg3327, Ln22: "the big **large** size"
- Pg3327, Ln23: "**Also**, prevailing cloud cover as well hampers the regular..."
- Pg3328, Ln19: "As mentioned before, the Ice elevation..."

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- Pg3328, Ln21: "...by every **each** DEM"
- Section 3.1.1: Add a short sentence how the contour lines were converted into a DEM (i.e. which interpolation?).
- Pg3330, Ln12: Remove entire sentence (Does not really add any information to the description of ICESat).
- Pg3331, Ln17: "From a general point of view, **Every** ..."
- Pg3331, Ln19: "Furthermore on, different **various** methods ,described in this sections, have been applied **to generate** the surface **area**, glacier length and ice elevation change estimations **are described in this section.**"
- Pg3331, Ln22: "have been taking into account **used**..."
- Pg3332, Ln19: "it is expected **assumed** that no matching errors **related to DEM mis-registration** exist."
- Pg3332, Ln25-27++: Use quotes when *directly* quoting from another source.
- Pg3333, Ln7-8: "calculated on **using** the non glacierized area **terrain** since there **assuming** no change on elevation must be expected **this terrain does not change** over time
- Pg3334, Ln3: "is fixed **fit**."
- Pg3334, Ln12: "The horizontal shift and coregistration of **Every** DEM was done related **co-registered** to ICESat data."
- Pg3334, Ln13: What about the linear vertical bias or shift (see Specific Comments)

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- Pg3334, Ln15-17: "... observed over time, a **potential vertical** bias..."
- Pg3334, Ln20: "... every DEM **pixel** to ICESat ..."
- Pg3334, Ln25: "For every DEM a bias of dh **horizontal mis-registration** has been..."
- Pg3335, Ln10: "... elevation was verified **checked**"
- Pg3335, Ln23-25: "**Average** ice elevation changes have **also been** calculated ... glacier **using all pixels below** the overall ELA ... Rivera et. al.(2007). has been taken into account.
- Pg3336, Ln2, "... **sparsely** cover merely the accumulation areas ..."
- Pg3336, Ln10, "...the **an** ASTER DEM.."
- Pg3336, Ln23: Missing a parenthesis.
- Pg3345, Ln9: "retreated and **lossed** surface **area** between..."
- Table 1: "Surface below 1150" not 11150...
- Table 4: "comparison of every DEM **pixel** with.."
  - I guess these statistics are over non-glacier terrain?
  - What is "Dh" ?
  - Where is the c parameter? is this "Dh"?
  - I am a little surprised about the rather large standard deviations, especially with the SPOT5 DEM... Have you removed the largest outliers before making this calculation?
- Table 6: Consider replacing "thinning" with "elevation change". It may be confusing with negative thinning rates. Also replace "Records" with "pixels"

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(Same for Table 7).

- Table 8: "comparison of elevation changes **rates** ..."
- Table 10: "Surface **area** changes"

## References

- Berthier, E., Arnaud, Y., Vincent, C., and Rémy, F.: Biases of SRTM in high-mountain areas: Implications for the monitoring of glacier volume changes, *Geophysical Research Letters*, 33, L08 502, <http://dx.doi.org/10.1029/2006GL025862>, 2006.
- Rignot, E., Echelmeyer, K., and Krabill, W.: Penetration depth of interferometric synthetic-aperture radar signals in snow and ice, *Geophysical Research Letters*, 28, 3501–3504, <http://dx.doi.org/10.1029/2000GL012484>, 2001.
- Rignot, E., Rivera, A., and Casassa, G.: Contribution of the Patagonia Icefields of South America to sea level rise, *Science*, 302, 434–437, <http://dx.doi.org/10.1126/science.1087393>, 2003.

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Interactive comment on *The Cryosphere Discuss.*, 5, 3323, 2011.