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## ***Interactive comment on “Gravity effect of glacial ablation in the Eastern Alps – observation and modeling” by P. Arneitz et al.***

### **Anonymous Referee #1**

Received and published: 25 January 2013

This paper estimates the gravity effect of glacial ablation in the Eastern Alps by comparing an observed absolute gravity time series with the modeled gravitational effect of changes to glacier mass. This is an interesting use of these datasets, and it will continue to have impact as the gravity and glacier data sets continue over time. I am not very familiar with this region of the Alps, so this likely contributes to my expressed confusion. But the work performed seems well done and the methods are appropriate. This paper is appropriate for publication in The Cryosphere.

I have several suggestions that will hopefully improve the clarity and impact of this work after revision. My main concern with this work is that many places in the text are unclear because they are too brief. The paper would be more clear if more detail/explanation was added. I felt I needed several reads through the paper before I

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understood the differences between the regions and glacier datasets. I have tried to note in my comments below where I was confused and think more detail is needed. Since the paper is on the shorter side, space should not be a concern when adding more detail. Hopefully this will make the paper more accessible to a wider audience. I think these changes are important to the paper, however they should also be easy to address. So I would say they are "moderate" revisions.

Main comments:

p4979 line 18: "This is quite surprising. . ." I found this statement confusing. First, uplift could mean several things when I think the authors mean 'rise of mean elevations'. Just say that instead. Second, it would help if there was a phrase like "a negative absolute gravity trend is expected, due mainly to the rise in elevation at the station." Often the GIA literature shows positive gravity trends from rebound because they have been corrected for elevation change, but you are looking at absolute gravity so you don't do that. Noting that difference would be more clear.

p4979 line 3: This paper cites several non-English references which I cannot read. It would be very helpful if when you cite these papers in the text there could be more detail on what the paper shows. For example on this line, I was wondering what technique do these two citations use to measure the uplift at the station?

Figure 1: These figures were modified from the Wikimedia Commons, and are not really the quality I would expect for a journal article. I would expect the authors to produce these maps themselves from the topo data using some freely available software (such as Generic Mapping Tools). Also, the Creative Commons license for the figures requires derivative figures to be "shared alike" with the same license. I will guess that this conflicts with the journal policy since they have their own license and copyright permissions cannot be transferred.

Section 3: You need to be more clear in this section that you will discuss 3 main areas and that they have different datasets. For example, p4981 line 15-18 about the

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photogrammetry and lidar. Does this statement apply to all 3 regions, because later in p4982 line 16-18 you make the same statement for just the Stubai Alps? Continuing in the first paragraph of sec 3, you next discuss volume change in p4981 line 19-22. Where is this volume change from? Is it just the Otztal area, like the Abermann (2009) citation suggests, or is it all three areas? You should start with a paragraph that says what is common to all regions. (e.g. We have 3 years, all same months, all 2006 data is lidar, we determine boundaries from roughness, etc. etc.) Then have a paragraph for each region that describes that specific dataset. (e.g. Otztal is 5m resolution. Ubeltalferner is 20m resolution.) Is the Ubeltalferner DEM also from lidar?

Section 4: This section is better because the 3 regions are more clearly separated. It could use a small starting paragraph saying: we have the glacier outlines and the elevation changes, and since we have small resolution in general we use this prism approach to calculate the gravity. Then the specifics of each region would have more context.

p4983 line 5-10: Does this mean that you are interpolating the DEMs onto uniform grids? If so, then say that. Why does the later time period (97-06) have a larger grid size than the earlier period, when the later data has a smaller resolution?

p4983 line 16-23: I do not understand this paragraph. You said earlier that the data from the Stubai Alps is from both photogrammetry and lidar. So are you describing what Seiser (2010) did to make the DEMs of the glacier models? OR are you describing what you did because this data is not in DEM form? Did you just get glacier outlines and volume changes? When you say you calculated mean elevation changes, does that mean you divided the volume estimate numbers by the areas? It is not clear a) if this is unique to the Stubai data and b) why that is the case.

p4984 line 1: Is this back to Stubai data? If so, then move it up after the class 4 Stubai paragraph.

Section 5 p4985 line 4-15: This is the first mention of the melting scenarios and the

description is quite abrupt. There should be a sentence or two explaining why you are using these different scenarios. For example starting p4984 line 26: "Calculating the gravity effect from digital glacier models at three dates (1969, 1997, 2006) gives the total estimated change in absolute gravity between these years. Table 1 summarizes the gravity effect caused by ice loss during the two evaluation periods and clearly shows the dominant influence of the Otztal glaciers. In order to compare the totals to the measured time series at Obergurgl we must decide how much of this melt occurred prior to 1985 and we therefore investigate 3 possibilities on how the ice melting rate changed over time. As shown in Figs. 2 and 3 . . . . ."

p 4985 line 10: This directly compares with the trend from p4981 of  $14 \text{ nm s}^{-2} \text{ yr}^{-1}$ , correct? So you can say the glacier correction explains 59% of the observations (8.2/14)?

p4985 line 24: Where does this 75% number come from? Also where does the 70% number come from on p4986 line 9? Then how is the 2/3rd value gotten on p4987 line 4? They all seem to be the glacier correction, which I think is 59% above?

p4986 line 21: In the introduction you mention that one of the gravity stations has uplift of 1 mm/yr. Was this for a different station, and the uplift at Obergurgl is unknown?

Minor notes:

p4979 line 21: This last sentence is passive voice and should be changed. The paragraph could end with something like "Here we calculate the associated gravity response of these nearby ice mass losses to explain the observed gravity trend."

p4979 line 25: "under best control" Do you mean well constrained?

p4981 line 23: Should be ". . . decrease of -9.5 m and -8.2 m, respectively."

p4981 line 26: ". . .glaciers in the surrounding area of Obergurgl. . ."

p4982 line 25: What is the meaning of this value of -7441 mm w. e.? Is that per square

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meter, so that it is an average value of the glacier mass loss? Otherwise how is it mass if you just have a length (mm) times a density (water equivalent)?

Figure 2: Same as last comment. The axis on the right hand side, is this the mean surface density for each glacier? m water equivalent is a surface density unit.

Figure 4: Do these changes in ice thickness correspond to the glacier areas in Table 1? Could the regions be labeled Otztal, Stubai, etc., be labeled on this map? Also, do the eastings and northings belong to a certain UTM zone? If so, the caption should mention that.

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Interactive comment on The Cryosphere Discuss., 6, 4977, 2012.

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