Response to M. Pelto

(Original comments are in bold, our replies are in standard font.)

Wagnon et al (2013) provide and excellent summation of mass balance work in the region and of the detailed mass balance and volume flux work on Mera Glacier and mass balance work on Pokalde Glacier. This paper will make a valuable contribution to our understanding of mass balance in the region, particularly since the work on Mera Glacier is expected to continue. Mera Glacier does provide an excellent opportunity for flux studies and also transects a larger altitude range, and due its slope and lack of debris cover, makes it an ideal glacier to focus upon. Below are a few minor suggestions and two recommendations. The first recommendation is that the 2011-12 Ba be reevaluated. The second is for a better error analysis for Mera Glacier, given the number of measurements actually made, this should provide a lower error than stated.

Thanks a lot for your suggestions and recommendations that we followed. See below for the detailed answer.

3340-23: Why mention Kadota et al (2000) when this is not an actual glacier mass balance?

Because in this introductory paragraph, we are not focusing only on mass balance data, which are very sparse actually. Actually we refer to every significant work conducted so far dealing with volume change of Nepalese glaciers. Kodata et al (2000) detected surface lowering of the debris-covered part of Khumbu Glacier by means of ground surveying between 1978 and 1995. We do think that this work is worth being cited in this review paragraph and we even included their estimates for the lowering rates as requested by C. Mayer.

3343-23: Redundant wetter climate statement unless you add quantities.

Unfortunately, we cannot quantify it. The sentence has been removed.

3345-15: How patchy is the transient snow line-ELA? This is an indicator of how consistent mass balance change is with elevation across the glacier.

To study the transient snow line-ELA, analyzing images acquired at the end of the ablation season (i.e. end of September or beginning of October) is required, but unfortunately, we have not analyzed such images so far. Indeed, the snow line was not visible on the Pleiades images acquired on 25 November 2012 because a snow fall had already covered the whole glacier surface (as observed in the field), preventing us from retrieving the snow line. Consequently, we cannot know how patchy the transient snow line-ELA is. We are planning to conduct such study in the future.

3345-25: Zemp et al (2009) have a good discussion with references to a number of other studies examining mass balance error, given the number of measurement sites used Mera Glacier could have a lower error.

The error range has been reevaluated following Thibert et al. (2008) methodology and the whole paragraph has been re-written. The result is now ±0.28 m w.e. yr^{-1} for the error range of the glacier-wide mass balance:

"Accuracy of this overall specific annual mass balance depends on various factors related to (i) the measurements themselves (such as the errors in stake readings or density measurements), and to (ii) the density and representativeness of stakes or accumulation measurement sites (i.e. the sampling error). As in Thibert et al. (2008), on Mera Glacier, we conducted an uncertainty analysis separating the error related to the measurements (standard deviation of 0.08 m w.e. yr^{-1}) and the sampling error (standard deviation ranging from 0.21 to 0.29 m w.e. yr^{-1}, according to the number of measurement sites from 31 (2008-2009) to 17 (2011-2012), respectively). Averaging those errors over the glacier surface and over the studied period, we obtained a mean overall uncertainty of ±0.28 m w.e. yr^{-1} for the glacier-wide mass balance. Zemp et al. (2009) provided also an interesting discussion examining the mass balance error, and concluded that the confidence interval for the global mass-balance dataset is in the magnitude of two standard errors of the reported annual mass-balance data, i.e. between 0.25 to 0.5 m w.e. As recommended by Thibert et al. (2008) or Zemp et al. (2013), to check the representativeness of our stake network and detect potential systematic biases, in the future, we will validate mass balances derived from annual field observations with decadal volume changes assessed from geodetic methods. Despite the relatively large error bars, year-to-year relative differences are instructive for climatic purposes because annual values refer to the same map, to the same area-elevation distribution function and to the same measurement network."

Details of the calculations are given below:

2 sources of errors: 1°) point mass-balance error to be spatially averaged and 2°) sampling error.

1°) point mass-balance error**:**

- Ablation stakes: σ_{b-}=0.14 m w.e. yr^{-1}

- Accumulation sites (Eqn 12 of Thibert et al. (2008)): σ_{b+}=0.21 m w.e. yr^{-1}

- Spatial average considering a minimum of 17 point mass balance measurements in 2011-12 ($n-$=14 stakes ($b-$) each of them representative of an area of s_- and $n+$=3 pits (b+) each of them representative of an area of s_+ over the whole glacier area S) and a maximum of 31 in 2008-09 (27 + 4) :

Spatial average between ablation stakes and accumulation pits:

$$b = \frac{1}{S}\sum s_- * b- + \frac{1}{S}\sum s_+ * b+$$

Thus the standard deviation is:

$$\sigma_b = \sqrt{\frac{1}{S^2}\sum s_-^2 * \sigma_{b-}^2 + \frac{1}{S^2}\sum s_+^2 * \sigma_{b+}^2}$$

Leading to

σ_b = 0.08 m w.e. yr^{-1} when (n- ;n+)=(14 ;3) and 0.07 m w.e. yr^{-1} when (n- ;n+)= (27 ;4)

2°) Sampling error (Eqn 13 of Thibert et al. (2008))

Obtained from the spatial variability observed in the data (Fig 5 of the revised MS): σ_{sp} = 1.2 m w.e. yr^{-1}

Giving with (eq. 13) : σ_{sp} = 0.29 m w.e. yr^{-1} in 2011-12 (17 measurements) and σ_{sp} = 0.21 m w.e. yr^{-1} in 2008-09 (31 measurements).

Summing those errors assuming that they are uncorrelated, the glacier-wide mass balance error ranges between 0.24 and 0.32 m w.e. yr^{-1} depending on the number of measurements. We therefore assume a mean error for every year of 0.28 m w.e. yr^{-1}. The same error range has been assumed for Pokalde Glacier.

3348-15: 2011-12 the Mera Glacier has an AAR of 0.10. The resulting mass balance -0.77 m is higher than any I have noticed for a non-arctic alpine glacier at that AAR value. A quick look through the AAR-Ba relationships in the MBB of WGMS confirms this. I suggest that the 2011-2012 Ba be reevaluated. For the other four years the transition between the two linear segments of the balance gradient occurs well above the ELA. In 2011-2012 the balance gradient transition is at _-1 m. The upper balance gradient line in 2011-12 also has a much shallower slope than for the other four years. Typically the balance gradient does not change that dramatically from year to year in its shape. In fact that argument is stated to be the case for Mera Glacier later in this paper. In this case the fit to just three data points does not provide a robust reason for altering the gradient dramatically from the other years. The slope of the balance gradient is likely a more robust measure than the actual elevation of the transition point.

> We agree that it was not correct to use negative point mass balance data measured at 5670 and 5790 m a.s.l. in 2011-12 to derive the regression line of the accumulation area, and then to calculate the glacier-wide mass balance. Consequently, both point mass balance data have been used to derive the linear regression line over the ablation area, the upper regression line being chosen equal to the mean vertical mass balance gradient obtained over the four previous years in the accumulation area, i.e. 0.06 m w.e. $(100\ m)^{-1}$. The resulting 2011-12 glacier-wide mass balance is now -0.67 m w.e. (instead of -0.77 m w.e.), the new ELA is 5800 m a.s.l. (instead of 6055 m a.s.l.) with AAR = 0.29 (instead of 0.10). This is really more consistent, with no gradients altered dramatically in both areas. The whole manuscript has been corrected accordingly and details of the method are now described in the Fig. 5 (Fig. 3 in the original MS) caption where a sentence has been added:
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> "In 2011-2012, point mass balance data measured at 5790 and 5670 m a.s.l. were exceptionally negative and thus used to derive the linear regression line over the ablation area, the upper regression line being chosen equal to the mean vertical mass balance gradient obtained over the four previous years in the accumulation area, i.e. 0.06 m w.e. $(100\ m)^{-1}$."
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> Accounting for this new calculation of the glacier-wide 2011-12 mass balance, the correlation coefficient r^2 between annual glacier-wide mass balance, and ELA has increased from 0.90 to 0.97 (n = 5 years), showing again that this new calculation is more consistent.

What this argues for going forward on Mera Glacier is at least in a few years much more detailed accumulation zone observations to better constrain the actual slope and its inter annual variability and identify the representativeness of the network. This is likely not sustainable, but as Fountain and Vecchia(1999) noted a few detailed measurement years better defining the overall pattern reduces the errors. Pelto (2000) noted that Ba errors improved moving from 10 to 20 measurements but not that much above 20 points. Pokalde Glacier also needs a more detailed survey in at least two years, to verify the representativeness of the network.

Thank you for these recommendations, we will try our best in the future, but already performing twice a year accurate accumulation measurements at 5800 and 6350 m a.s.l. is challenging. A new sentence has been added in section 4.1: Mass balance / methodology:

"As recommended by Thibert et al. (2008) or Zemp et al. (2013), to check the representativeness of our stake network and detect potential systematic biases, in the future, we will validate mass balances derived from annual field observations with decadal volume changes assessed from geodetic methods."

3350-26: That the mass balance gradient is consistent is not borne out by the upper gradient line on Mera Glacier in 2011-12.

Now corrected taking into account the new gradients in 2011-12 (See the revised Fig. 5 (= Fig. 3 of the original MS), 5^{th} panel 2011-12).

Figure 1: The images of the glaciers should be their own figure, this will allow better resolution. The Pokalde image needs to be brightened.

We followed this recommendation, images of the glaciers now shown as Fig. 2 and Fig. 3.