

## Reply to reviewer 1: Anonymous

*We marked all our replies to the comments of reviewer 1: Anonymous in blue.*

This paper deals with the relationship between the atmospheric warming and the englacial temperatures increase. This paper contains data coming from englacial temperature measurements performed in boreholes between 1982 and 2008 in the Monte Rosa area. The authors compare the 20 m deep temperature changes and conclude that there is a clear evidence of accelerated warming since 1991. They conclude also that the observed increase since 2000 is far beyond a modelled firn temperature increase based on the IPCC scenario. The paper is based on a comprehensive set of field data. These data are rare and valuable. Furthermore, the field measurements have been obtained in very hard conditions. However, I believe that the abstract and the conclusions are not relevant for the following reasons:

*We mainly followed the suggestions of the reviewers and have revised the whole paper, especially the abstract, results, discussion and conclusion sections. We believe now that the paper has been overall strongly improved.*

. First, the conclusion relative to a warming acceleration can be questioned: in most of the boreholes (Figures 5, 6, 8 and 9), it is not possible to compare the differences between 1991-1999-2008 because data are missing. We can make this comparison for measurements presented in Figures 4 and 7 only. In fact, Figure 7 shows a decelerated warming since 1991. It is not discussed in this paper. The warming acceleration is seen from Figure 4 only. This warming depends largely on the location (difference of 1.6 °C in 2008 for 2 sites 20 m apart...). Consequently, the analysis suffers from rigour. From these measurements, I conclude that temperature changes in firn can be very different according to depth and locations. I do not understand why the authors do not use the modelling tools they used previously (Suter, 2002) to interpret the temperature measurements profile. Moreover, the authors do not mention the effect of horizontal advection. Could the difference in temperatures between the boreholes B08-1 and B08-2 come from the horizontal flowlines? It is not discussed in the paper.

- a) *As the reviewer mentioned in his first paragraph, englacial temperature measurements are quite difficult to obtain in the harsh high alpine environment of over 4000 m a.s.l. This implies that these measurements are everywhere quite rare. As far as we know, there is no alpine site anywhere else in the world than on Colle Gnifetti, where measurements since 30 years exists. Therefore, questioning that there are not more measurements presented in this paper is in our opinion not appropriate.*
- b) *The reviewer mentions that the decelerated warming is not discussed. On page 2286 line 20, we describe the observed temperature change and on page 2287 line 9 we discuss the strong increase in temperature between 1991 and 1999, which we relate to a change in the firn facies zone. However, we added now in the paper an additional discussion to explain why the following temperature increase is not as high as in the first measurement period.*
- c) *We agree with the reviewer that the warming shows a strong spatial variability. However, we show this variability with our measurements in Figure 4 and we present the exact locations in Figure 2. We added now some sentences in the discussion section to make this variability more clear.*
- d) *We would like to focus in this paper only on the measurements and use already existing and published modelling results by Suter (2002), Lüthi (2000) and Lüthi and Funk (2001) for comparison. Performing new modelling is not the goal of this paper.*
- e) *In our view, horizontal advection has not much influence for the upper most 20 m of the cold firn in the saddle of Colle Gnifetti, which was already shown by several authors in the past (Wagner 1996, Lüthi 2000 and Schwerzmann 2006). However, we added a paragraph in the discussion section.*

. Secondly, heat flow modelling has not been carried out in this paper. The abstract is misleading. Modelling study has been performed in a previous study (Suter, 2002). The comparison between the results of this heat transfer model and the measurements is not discussed here (2 sentences in the conclusions). The modelling results (Suter, 2002, Figure 7.10) show that the calculated temperature is -12.7 °C in 2008 at Colle Gnifetti. The measured temperature is -10.4 at borehole B08-1 and -12.1 °C at borehole B08-2 (Figure 4). The uncertainties (relative to heat flow model, IPCC scenarios and measurements) are not discussed. Consequently, the conclusions "that the observed increase since

2000 is far beyond a modelled firn temperature increase based on the IPCC scenario" can be questioned. The analysis presented here remains qualitative.

- a) We have removed the sentence in the abstract and we have added in the discussion section some sentences comparing the results of Suter (2002) and Lüthi (2000) to the observed values presented in this study. We added some of the earlier modelling results to compare them directly with the measurements.
- b) We do not agree with the interpretation of the Reviewer, because the 0.6°C difference from the model to the 'colder' borehole is in our opinion quite a lot and a difference of 2.3°C is even a more pronounced change. However, we have included also a discussion about these effects.

. Thirdly, the paper is not well organised. Most of the data have been published elsewhere, except data of 2008, and I do not believe that all data presented here are needed. For instance, I do not understand why the authors show the figure 8. The figure 8 shows data from 2003 and 2004 measurements. This figure has been published in (Schwerzmann, 2006, p. 32). Here, data from this figure are not discussed (it seems that the measured temperatures profile was not very far from a steady state profile. Why ?) This figure is reproduced here without any change and without any reference in the caption.

- a) We improved the result, discussion and conclusion section and tried to make them more clear and not redundant.
- b) As already mentioned above, we believe that ALL the collected data since 2003 are worth to be published and therefore it is our strongest interest to publish and bring all available data to the whole research community.
- c) On page 2287 we also discuss figure 8 line 20 to 24, which is indicating that the observed warming can be clearly seen in the deep temperature profiles. We added now all older measured temperature profiles (some are already published by Lüthi (2000), who is now co-author of the paper) and added the second newer deep borehole CG05-1/07 (old number B07-2). The whole set of deep boreholes indicate without any doubt that all the profiles are influenced by the warming of the 20<sup>th</sup> century. In addition, we discuss the individual profiles and the corresponding temperature gradients in view of important influencing effects such as topography.
- d) We have the full agreement of Aurel Schwerzmann to use his data. In the text as well as in the acknowledgements we already have referenced his work and the data of Schwerzmann 2006. However, we will of course add the reference also at the caption of figure 8.

. Fourthly, the discussion suffers from vagueness and repetition. Moreover, many details should be corrected by the authors (the locations of boreholes of Grenzletscher on the map are missing. Figure number in p. 2283 is wrong. . .).

- a) We have revised the paper and tried to remove all repetitions, which we found.
- b) The location of the boreholes on Seserjoch and Grenzletscher are given both in figure 3 and is not missing.