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The Cryosphere Discussions

Interactive comment on "Age of the Mt. Ortles ice cores, the Tyrolean Iceman and glaciation of the highest summit of South Tyrol since the Northern Hemisphere Climatic Optimum" *by* P. Gabrielli et al.

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Authors: Thank you very much for your review and your comments.

Referee #1: The manuscript (MS) presents an age scale of three âĹij75m deep ice cores drilled from near the summit of Alto dell'Ortles glacier in the Italian Alps. The MS is generally well written and argues convincingly for the suggested age scale that is based on radio- metric ages and nuclear fallout products. The deepest meters of the ice cores contain ice that is more than 1000 years old, and the MS argues that the glacier was formed during the Northern Hemisphere Climatic Optimum (NHCO). I

have a few suggestions for the authors to consider: In Figure 5, the orientation of the coordinate system is unclear to me. Are the X and ï£ijY directions following the GPR lines in Figure 1c or are they respectively along and perpendicular to the ice flow as stated in the main text? The best would probably be to show the orientation of the X-profiles and Y-profiles in a map. Are the units on the abscissas of Figure 5 meters?

Authors: The orientations of the X-profiles and Y-profiles follow the GPS lines and are now displayed in Fig. 6. The main text has been corrected accordingly. The units on the abscissas of Figure 5 are meters (added).

Referee #1: In section 6.2, the authors argue that the only way the obtained age profile can come about is if the glacier flow pattern has recently changed significantly. I have difficulties following the argumentation of this section as not many details are given. A simple model is applied, but no results are presented.

Authors: We now report the simple model results in a new figure.

Referee #1: There is one observation in Figure 5 that seems important to me in this context. The inclination of the 45 m deep melt layer seen in the GPR profile and in the cores is very steep. This isochrone suggests that the oldest ice of the glacier probably is to be found in right hand side of figures 5 (X-profiles), which is under the ice divide, if I got the geometry right. Alternatively, it suggests that the oldest ice is to be found in higher depth resolution below the ice divide. I'm uncertain if the authors take this observation into account, but to me the steep inclination of the melt layer suggests a significant increase in snow accumulation the further one gets away from the ice divide. Could it be that snow is blown away from the ice ridge and (re-)deposited further down the slope (on the lee side?). An increasing accumulation away from the ice ridge would probably lead to strong inclination of the deeper layers of the glacier and possibly explain why old ice is preserved close to the ice ridge where accumulation may be very low?

Authors: Referee #1 is correct. We observed modern snow accumulation at 3830 m,

$\sim$30 m below the drilling site (3859 m) and we determined a value of $\sim$ 1000 mm w.e. (Festi et al. 2015), which is $\sim$ 200 mm w.e. more than at the drilling site (3859 m). The point made by Referee #1 is now reported within the text.

Festi, D., Kofler, W., Bucher, E., Mair, V., Gabrielli, P., Carturan, L., and Oeggl, K.: A novel pollen-based method to detect seasonality in ice cores: a case study from the Ortles Glacier (South Tyrol, Italy, J. Glaciol., 61, 815-824, 2015.

Referee #1: In section 3, it is mentioned that limestone rock particles and pebbles are observed in the lowest meter of the ice cores. At the same time, the oldest ice is found in stratigraphic order in the same lowest meter of the cores. Indeed, the proposed age scale does look convincing based on the obtained C-14 ages, but still I am wondering how those pebbles got entrained in the ice if the ice is not disturbed (folded)?

Authors: Referee #1 is correct as the basal layers appear in stratigraphic order. In addition, the three stables isotopes profiles from the different cores match remarkably well down to the deepest ice layers (Fig. 10). One possibility is that, as already mentioned within the text, given the close rock outcrops near the Mt. Ortles summit, some relatively large pebbles were not entrained in the ice from the bedrock but from the glacier surface.

Referee #1: In section 2.2.2 it is suggested that the glacier bed could be lubricated by summer meltwater. This scenario seems rather implausible to me. If the ice is -2.8 C at 75 m depth, it seems highly unlikely that there is summer melt. There is no seasonal temperature variability possible at this depth.

Authors: The Mt. Ortles ice cores and the instrumental temperature record provide evidence of extensive surface melting on the Alto dell'Ortles summit during recent summers. Melt water percolation through the intersections of the glacier surface and bedrock, fractures and terminal crevasses, can thus lubricate the interface between basal ice and bedrock. There are several evidences in Svalbard and Greenland that seasonal meltwater can reach bedrock and change the ice velocity of cold-based ice

caps and ice sheets (e.g. Dunse et al. The Cryosphere 2015; Bartholomew et al. Nature Geosc. 2010). We have added this note to the text.

Bartholomew, I., Nienow, P., Mair, D., Hubbard, A., King, M. A., and Sole, A.: Seasonal evolution of subglacial drainage and acceleration in a Greenland outlet glacier, Nature Geosci., 3, 408-411, 2010.

Dunse, T., Schellenberger, T., Hagen, J. O., Kääb, A., Schuler, T. V., and Reijmer, C. H.: Glacier-surge mechanisms promoted by a hydro-thermodynamic feedback to summer melt, The Cryosphere, 9, 197-215, 10.5194/tc-9-197-2015, 2015.

Referee #1: In section 2.3 it is mentioned about the bedrock step that 'this feature does not completely enclose the drilling site in every direction'. In fact, the bump is only to one side of the cores, so I would suggest a reformulation.

Authors: Done. We now report that this feature is only on one side of the drilling site.

Referee #1: In Figure 3 it is hard to see details around the drilling sites in the main image. There is a white spot right below what appears to be BH3 and BH4. Is this a col, or does the spot indicate something else?

Authors: As mentioned in the caption of Fig. 3, the contour lines of the drilling dome are visible as the surface topography of the drill site was obtained from a LiDAR survey conducted exactly during the 2011 drilling campaign.

Referee #1: The authors argue that the ice started to form during the Holocene climatic optimum and that this same optimum is observed in the isotopic signature of nearby stalagmites. Is the NHCO seen in the isotopic signature of the deepest ice core ice? If the high frequency signal is removed? I cannot judge this from Figure 10.

Authors: Yes. Except the modern most enriched values, the lowest part of the ice core records, corresponding the NHCO, shows the most isotopically enriched values during the early-mid Holocene. This is one of the topics of another manuscript in preparation.

Referee #1: In Tables 2 and 3 it is difficult to see which samples correspond to each other as depth is transferred between the cores. Would it be possible to assign a unique name to each sample, so the reader can trace them from one table to the other?

Authors: We have improved Tables 2 and 3 in order to facilitate tracing of the same samples.

The conclusion seems to state the main findings in a bit disorganized way.

Authors: We have now subdivided this paragraph in two sections linked to the paleoclimatological and glaciological conclusions, respectively.

In point 6) is says the accumulation at the drilling site is 850 m/year. Probably this should be 850 mm/year?

Authors: corrected. Many thanks.

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