

Response from authors for RC2 for manuscript “Evidence of radionuclide fractionation due to meltwater percolation in a temperate glacier”

To our knowledge, the shift between the  $^3\text{H}$  and  $^{137}\text{Cs}$  1963 peak has been reported in a single study from Pinglot et al. (2003), more than 20 years ago and in a completely different context from the Alps. Our study is the first documentation of this phenomenon for an Alpine mountain glacier presenting fully temperate conditions. We think that despite the early single study, it is important to acknowledge the discrepancies we found between the radioactivity profile of the two considered radionuclides. It is common to find in literature chronological markers related to  $^{137}\text{Cs}$  or  $^3\text{H}$ , without really discussing the profiles or comparing them. The ice core community that works on mountain glaciers always assumes that those proxies are perfectly preserved in glacier ice, but, as we highlight, this is not the case, in particular at the time of climate change and global warming. Those signals can no longer be considered as fully reliable. We believe that this is an important message to share with glaciological community and we also believe that the scopes of this journal perfectly align with this.

Regarding the established timescale we understand that additional comments may be needed and will add a paragraph to text as follows:

*“The established timescale may be slightly inaccurate regarding the layer counting between the 1986 and 1963 tie points, as it heavily relies on the implication that the  $^{137}\text{Cs}$  peak corresponded to the 1963 unaltered signal. The inaccuracy would introduce an additional error of 1 /2 years as the downward migration of the  $^{137}\text{Cs}$  signal is of only a couple of meters.”*

We will also provide in the text an additional paragraph on the suitability of this glacier as paleoarchive by adding a summary of all glaciochemical published data available for this ice core, as pointed out by the reviewer:

*“In Festi et al (2021) it is observed that peaks in pollen concentration and black carbon concentration with exceptional high values may represent multiple years condensed in one single layer as a result of negative mass balance years and enrichment of the impurities at the exposed surface. This poses an issue for annual layer counting. Despite this, due to the alignment of many palynomorphs and BC peaks, the seasonality of the signal seems to be preserved. On the contrary, in Festi et al (2021) the  $^{210}\text{Pb}$  profile did not show a clear exponential decrease in activity concentrations with increasing depth, as it is typically observed in glacier ice.  $^{210}\text{Pb}$  concentrations have shown in literature large fluctuations connected with dirt horizons (Gaggeler et al 1983) indicating that  $^{210}\text{Pb}$  may be transported with water, thus preventing a meaningful dating of temperate glaciers with this nuclide.  $^{210}\text{Pb}$  thus shows a behaviour in ice similar to what observed for cesium: these highly insoluble elements remain bound to particulate matter and are prone to relocation and loss of signal when meltwater is present. Looking at  $^{137}\text{Cs}$ , by taking into account the highest  $^{137}\text{Cs}$  peak and comparing it to activity levels attributed to 1963 found at Colle Gnifetti (Eichler et al 2000), we found a loss of expected signal of more than 50%. On the other hand, looking at tritium the record seems to be mostly preserved at least for the period post 1960s (as the 1954 and 1958 peaks were not detected in this ice core), because the shape of the tritium profile matches the tritium precipitation record and because comparing the total inventory, no loss in tritium activity is found; this is further confirmation about the better preservation of tritium compared to  $^{137}\text{Cs}$ . We thus believe that Adamello glacier can still function as a paleoclimate archive but to correctly interpret the information thereby contained, it is necessary to consider melting and disturbances processes affecting the climatic signals”.*

Regarding the discussion about the misalignment between the peaks, the two tritium profiles (high and low resolution) have a difference of 1.5m but looking at activity values in the different samples between 29 and 31m it can be seen that they are well within the error bars; thus we can only say with no doubt that the 1963 deposition lies in this interval but we cannot pinpoint it without additional markers. Considering this, the displacement of  $^3\text{H}$  and  $^{137}\text{Cs}$  peaks lies in a range between 1.5 and 3 meters. Considering that the dating reported in Festi et al (2021) heavily relies on the implication that the  $^{137}\text{Cs}$  peak corresponds to 1963, it is difficult to say if the layer rich in mineral dust actually corresponds to 1959-1960, as the error on the dating would be much larger extending the possible dating range to the early 1950s. It is true that the Adamello ice core does not display radioactivity peaks that could be attributed to the pre 1963 era such as the 1954 and the 1958 peaks often reported in literature; the possibility of removal by percolation, especially since activities were much lower than 1963 and that additional time has passed (and therefore decay), leading to a much more faint signal which could easily be lost in presence of massive meltwater.

In regards to why the  $^{137}\text{Cs}$  was not at least partly accumulated in the dust-rich layer, this is a problem we cannot solve definitely with current data. Nonetheless we think that the key information contained in our data series is that in glaciers where heavy amount of melting is expected under current climate conditions, the  $^{137}\text{Cs}$  data is not to be considered as reliable as it always has been up to now in the ice core dating community. We will add some text to the article to further clarify this point:

*“Dislocation of cesium particles inside the ice cores has undoubtedly happened, and the fact that a dust-rich layer with no cesium was found just below the cesium peak may be an indication that even a small amount of particulate (small enough to not be identified as a dust layer in the stratigraphy) can lead to a high cesium peak. On the other hand, a signal such as the tritium one which is a matrix signal, is more likely to either be conserved or be lost to melting, but we do not expect to observe relocation of the peak, and therefore we wish to recommend tritium analysis rather than cesium when a strong tie point is needed for datation.”*