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The Cryosphere Discussions

Interactive comment on "Influence of the Tungurahua eruption on the ice core records of Chimborazo, Ecuador" *by* P. Ginot et al.

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Responses to comments of Anonymous Referee:

General Comments: Very good. This paper presents a valuable comparison study of shallow tropical ice cores to test the impact of volcanism on preservation of chemical stratigraphy. Such repeated ice core studies on tropical glaciers are rare and offer an important check on post-depositional processes. The merit of this paper is thus in providing empirical data to test the robustness of ice core records and the preservation of data used to interpret climate variability. The results apply more generally to any ice core location potentially impacted by volcanism. Moreover, there is reason to believe that volcanic deposition in the tropical latitudes is a particularly important impact given the more intense solar radiation regime, and resulting control over mass balance. The

analyses are largely qualitative in describing relative trends, and the inter-comparison of the cores requires some tuning so raw data are not shown. Likewise, interpretations of patterns are necessarily selective, and certain questions about processes are raised and not answered. Nevertheless, the dataset and demonstration of selective elution by volcano induced meltwater are worth publishing, and perhaps could inform future hypotheses to test. Specific Comments: The overall organization of text is somewhat confusing, as much inter-comparison and discussion of both cores and the adjustments made before Fig. 2 all in section 2.2. It might be best to have an observations section discussing both cores together, and then discuss the meaning/interpretation of the observations in the discussion section, that could include the ionic ratios. Also, a methods section before observations would help clarify by explaining the "adjustments" made to the core that are foundational to all interpretations. In the current form, we are only shown the post-adjusted depth trace of the isotopes and ions in Fig. 2. And it is not until describing Core B on P1348 we are told so or how. And even then, it appears the whole trace of core B was "stretchedshrinked" to do so. How?

⇒ For a better understanding, I add in figure 2 a first graph with raw depth data of core B. With that information, it is now simple to understand how the depth profiles were adjusted. Also in the text was added "As observed in figure 2, some shifts in the raw depth scale are present in the comparison of both δ18O records."

Were upper layers compressed differentially more to account for firn densification?

⇒ Not really

We're only told the entire length of record is compressed 10% as a result. With only depth recorded on the isotopes and ion traces (Fig. 2), it is not possible to verify the presence or absence of a "bimodal peak" referred to P1347,L18 but then heavily relied on subsequently as the explanatory factor for other ionic variations.

→ I've indicated in figure 2, with 4 arrows, the annual delimitation for 3 well defined bimodal shape contiguous years.

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This begs the question of how was the ice core record dated? Is it an assumption that there are 2 peaks in isotopes per year? Explain this clearer in text (not just by ref to Ginot et al. 2002) and/or include age/depth relationship.

⇒ As answered for previous referee: The following paragraph was inserted: “Because of the proximity to the equator the air temperatures measured in all meteorological stations are relatively constant throughout the year. Temperature therefore does not play a significant role in the seasonal pattern of stable isotopes in precipitaton; it is the amount of precipitation and the link to the passage of the ITCZ. In the Andean domain (Quito and Izobamba) the d18O values in precipitation range between -7‰ and -9‰ during the two dry seasons and between -10‰ and -16‰ during the rainy seasons. As mentioned, “Veranillo” is less pronounced and not always visible in the isotope record (Garcia et al., 1998 and the Global Network for Isotopes in Precipitation GNIP, IAEA, Vienna, http://nds121.iaea.org/wiser/). In the Chimborazo ice cores the d18O values range between -12‰ and -15‰ during the dry seasons and between -16‰ and -22‰ during the rainy seasons. In the 12 years time interval as recorded by the stable isotopes, three to four “Veranillos” can be identified by little negative dips interrupting the general positive d18O trend during the dry season (Fig. 2)”.

The isotopic records coincide after just over a meter depth. Yet the magnitude of lighter isotope is diminished significantly in the year between cores, so that the d18O value at 0.5 m in 1999 is the most negative of entire records from both years. This disappears by 2000. What happened? Is this resulting from fractionation as meltwater percolated?

⇒ The negative peak of -26 ‰ in 1999 was more or less totally soaked and mixed up by refreezing together with a part of the melting precipitation in 2000 during the volcanic activity. Only a little dip of -18‰ was left. Most of these post-depositional processes must have taken place under equilibrium conditions. We compared the first meter of cumulated firn in both cores in the ïĄď2H / ïĄď18O plot. From 1999 to 2000 the slope shifted only from 8.02 to 7.88. The mean deuterium excess (related to the slope of 8) shifted from 11.0 to 8.9 ‰Ḟurther down, the ïĄď-values of both cores were almost

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identical (fig.2).

How does this challenge (or not) the initial assumptions about the isotopes being least affected by surface melting (P1348), with percolation not subjected to refreezing?

⇒ At the firn/ice transition only deuterium data are available up to now and a check in the ïĄď2H / ïĄď18O plot is not possible. However, from the deuterium values no significant change in the record can be concluded. The remaining water must have been drained off through crevasses to the bedrock. ⇒ The way it is presented here, penitents (should this be spelled “penitents”? I think so) and hoarfrost are caused exclusively by volcanic ash. Yet this is a qualitative assessment by visible contrast of the ice cap surface in successive years (Fig. 1).

⇒ Hoarfrost is common for the glacier in this wet region. However, penitents are mostly related to preferential sublimation or melting associated with dust deposition. In that case, the volcanic ash deposits are associated to penitents.

Moreover, the authors use the net accum in w equiv to estimate a big deficit due to melt. There obs of a deep melt layer is fairly convincing, but are there any corroborating independent measurements of precipitation/accumulation?

⇒ On the drilling site, there are no precipitation/accumulation measurements data available. To deduce the 760mm mean accumulation for Core A, with count 12±1 annual cycles in the isotopic record.

Some discussion of species is selective, or features ignored, or else generically noted to feature “some discrepancies.” This is perhaps inevitable when no explanations are thought of, but it should be noted. For example, why is formate included? It is cursorily correlated to ammonium only in Core A, but there is no attempt to address the large peaks in Core A at 3 and 4 m depth that disappear in Core B.

⇒ Formate was included as an example of organic species. It appears in figure 2 that elution or other processes are different for this species that was not emitted by

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the volcanic activity. Formate can be associated with ammonium and results from anthropogenic emission, like observed in Core A. Concerning the changes observed in Core B, I have, for the moment, no unquestionable answer for that.

Other subtle contrasts in interpretation of presence/absence of seasonality. For example, the authors mention a lack of expected bimodal peaks in Na+ and K+, and this is certainly true for Core B, but there is better variability in Core A, comparable to the SO42- that the authors acknowledge as seasonally varying (P1350). This is unclear.

⇒ We were expecting in Core A, in correlation with the bimodal shape in the isotopic profile, that during the wet season with precipitation coming from Pacific Ocean, the sodium should be higher as during the wet season with precipitation from the East. For that other wet season, we were expecting more deposition of species related to biomass emission or organic species.

Technical corrections: P1345, L4: should be “the Chimborazo summit glacier”

→ Corrected

P1345, L6: Delete “The” before Chimborazo

→ Corrected

P1345, L22: change to “is far from trivial.”

→ Corrected

P1346, L15: is verano “summer” and “little summer” what the dry seasons are called?

→ Yes

P1346, L24: incorrect use of “analyzes”. Probably should be analyzed.

→ Corrected

P1356, L26: delete “pure”

→ Corrected

P1347, L1-2: citation for info on volcano emissions? How was this information determined?

→ Citation added “(Smithsonian Global Volcanic Program http://www.volcano.si.edu/)”

P1347, L9: change “form” to “from”

→ Corrected

P1347, L13: it is not clear what this means: “the definition of the adequate ionic ratio indicator related to the ice core evolution.” Explain this in clearer terms.

→ Changed with “the determination of some adequate ionic ratio as indicator to some processes”

P1347, L18: include “annual” precipitation

→ Corrected

P1347, L20, 21: precipitation is singular

→ Corrected

P1350, L21: edit: “persisting down to 3.3 m weq depth was completely removed”

→ Corrected

P1351, L1: aren’t the authors actually referring to Core B?

→ Yes, you are right. . .

P1351, L12: replace “than” with “to”

→ Done

P1351, L13: delete “already”

→ Done

P1351, L21: replace “than” with “as”

→ Corrected

P1352, first sentence of second paragraph is convoluted and needs re-written as two sentences.

→ Corrected

P1352, L13 and L19: “allover” is two words

→ Corrected 3 times

P1354, L2: change “much concentrated” to “highest concentration”

→ Corrected

P1354, L18: change “reports” to “features”

→ Corrected

P1354, L24: change to “reached” and “covered” (past tense)

→ Corrected

P1354, L25-27: edit to “: : :both ice cores permits an evaluation of: : :and an investigation of: : :” delete “involved” on L27.

→ Corrected

P1355, L1: change “from” to “of” and “isotopes” to “isotope”

→ Corrected

P1355: other grammatical roughness... Fig. 2: (a) any way time can be expressed? (b) the accumulated deposition flux is awkward, since it starts at surface (0-depth).

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Interactive comment on The Cryosphere Discuss., 4, 1343, 2010.