Atmos. Chem. Phys. Discuss., 11, C676–C684, 2011
www.atmos-chem-phys-discuss.net/11/C676/2011/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Ancient versus modern mineral dust transported to high-altitude alpine glaciers evidences saharan sources and atmospheric circulation changes" *by* F. Thevenon et al.

F. Thevenon et al.

florian.thevenon@unige.ch

Received and published: 9 March 2011

General comment: The authors offer an interesting set of analysis of ice core and aerosols samples collected in the Western Alps. They conclude that the Saharan region was and still is an important source of dust for the Alps during the last few centuries. While data presented are certainly interesting and the conclusions reached are relevant and well within the scope of ACP, their data analysis and especially their presentation and discussion are not accurate and can be very much improved as well as the English. This might imply a very general revision of the text that goes well beyond

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

the suggestions provided below that, in most cases have just to be taken as examples of how the manuscript might be improved.

Reply: We followed the constructive comments and discussed the examples.

Specific comments: It seems that a significant contribution of local dust is ruled out by the authors. While this is possible, it is not demonstrated in the paper and no discussion about the local geomorphology and geochemistry is presented to support this idea.

Reply: We did not definitively rule out a possible contribution of local dust, when we wrote on p.9: "occasional contributions of local bedrock might occur. This may be the case, for instance, of the great abundance of mica accompanying paragonite (a mineral present in the Southern Alps but rare to absent in North Africa), within the end of the largest Saharan dust event dated about 1790". However, given the very high altitude of both remote sites, surrounded by permanent glaciers, the mineral dust air concentration is known as very low (e.g., 1 ug/m3 for the Colle Gnifetti glacier; Wagenbach and Geiss, 1989). Important interruptions of this background situation mostly occur by the advection of air-masses Saharan dust (e.g. Collaud Coen, et al., 2004 and Sodemann et al., 2006 for the Jungfraujoch glacier).

In addition to the Saharan dust input to CG and Jungfraujoch, the authors suggest that intercontinental transport of background dust has a secondary role, at least in this part of the Alps. Also this idea should be better supported. For instance, a background like this, should be not only characterized by a very fine particulate size but its composition may resemble the mean crustal one. In addition, this general background should significantly differ from the Saharan dust composition. This needs to be convincingly demonstrated.

Reply: To our knowledge, there is a lack of mineralogical and isotopic data on such a so-called background dust, except from polar ice cores which are representative of the long-range transport pattern of mineral aerosols. Based on our results and on Groenland and Antarctica ice cores data, we hypothesis that 1) the long-range dust

ACPD

11, C676–C684, 2011

composition resemble to the main dust sources (Patagonia, Gobi, China, Sahara), 2) dilution and low accumulation time may explain the depleted geochemical values (e.g. Sr) in depleted dust core-sections of CG and in short-time deposited samples at JGF research station, respectively.

A very interesting aspect of this work is the largest Saharan dust event occurred around 1790. This event might be discussed in a broader context as it apparently shows up also in the Dasuopu ice core in the Himalaya, as indicator of an exceptional monsoon failure (Thompson et al. Science Vol. 289 no. 5486 pp. 1916-1919).

Reply: This topic has been discussed in term of large-scale climate dynamic and possible teleconnection pattern in my precedent manuscript (Thevenon et al., 2009). This paper was cited in the first sentence of the introduction.

Here a reference is necessary. “Moreover, despite the striking increase of mineral dust transported over Europe during the last decades”.

Reply: Changed to: “Although the long-range transported mineral dust and sea salt are the most important sources contributing to aerosol loading in Europe (altering the atmospheric circulation and the global radiative forcing; IPCC 2007), there is a paucity of ice-core data about mid-latitude dust characteristics covering the preindustrial period”.

The structure of the introduction is somewhat confusing. The sentence “In order to link dust sources... and potential source areas” is a kind of conclusive for an introduction while it is unexpectedly placed right in the middle.

Reply: Changed to “In order to reconstruct the long-range mineral dust sources and the associated circulation patterns”

This sentence is not clear. “The CG ice-core dust samples were extracted from cellulose membrane filters mounted on smear slides using Canada balsam, previously analyzed for total aerosols and mineral grain size by image analysis, using the procedure as described in Thevenon et al. (2009).”

ACPD
11, C676–C684, 2011

Reply: The samples analyzed in this study have been already analyzed by the image analysis method described in (Thevenon et al., 2009). That is the reason why these samples were pasted on microscopic smear slides.

Filtering the samples might imply a fractionation of trace elements. The authors should discuss very carefully and eventually take into consideration this important analytical detail, providing also adequate references.

Reply: Although we cannot exclude a fractionation of trace elements, we were obliged to filter (0.22 μm pore size) the insoluble material, which allows to remove the sea-salt aerosols (soluble minerals). The only way to take in consideration a possible fractionation would have been to separate the coarse fraction, but this was not possible given the small amount of ice available and the multi proxy approach. However, Delmonte et al., 2010 demonstrate that the average isotopic ratios from ice core bulk samples (>0.4 μm) were roughly similar to those obtained from the fine (<8 μm) fraction of dust.

The description of trace element determination is not precise and lacks very important aspects. First, among the trace elements determined, only La is a REE. Details about blanks, accuracy, precision and how spectral interferences were circumvented during the analysis should be offered and adequate references presented. The equations used to estimate the percentages of clays should be referenced.

Reply: We removed the term REE, and add details on the ICPMS procedure, and reference for the calculation of clays content.

Paragraph 4 “Results and discussion” should be structured (4.1, 4.2 etc.).

Reply: We followed this constructive comment and structured the part 4.

A table summarizing the statistics of concentrations and crustal enrichment factors should be provided. It is not clear why the authors chose different crustal references (Sc, Ta, Hf, Th): this makes the discussion somewhat confusing and/or redundant (please, see also my comment on Fig. 2)

ACPD

11, C676–C684, 2011

Reply: Since we do not know the initial weight of ice, the results cannot be expressed in concentrations. That is the reason why 1) the results are presented as elemental ratios (and enrichment factors), which in fact depend of the surface of aerosols (Fig. 2), 2) by opposition to the isotopic data (Table 1), the elemental ratios values are not useful for other studies, so that a table is not provided.

"EFs were very low (EF<2) for Ti, Ba, and La, thereby excluding important anthropogenic-induced fluxes of crustal elements (i.e. enhanced dust due to deforestation and agricultural activities)." This is a strange argument: I'm not sure how one would distinguish changes in dust emission caused by natural or anthropogenic factors.

Reply: We agree and this sentence has been removed.

"The Sr and Nd isotopic similarity between CG ice core data ....is remarkable, demonstrating the overall Saharan origin for the paleodust reaching the Alps (Fig. 3)". The authors make too much from their two close sampling sites. This situation is likely to occur in the Western Alps but has still to be demonstrated to take place in the Central and in the Eastern Alps.

Reply: We agree and added "Western" Alps.

The authors may want to check the statement that maximum Pb emissions in Europe occurred not only in 1970s but also around 1910 and 1935. Are they referring to relative maximum? In addition, the presumed correlation between changes in Sr isotopes ratios and Pb should be evidenced quantitatively.

Reply: We are referring to relative maximum (anthropogenic Pb deposition = Pb/conservative element Sc). We added a correlation diagram on Figure 6 showing the negative correlation (r2 = 0.4) between changes in Sr isotopes ratios and EFPb after 1910.

"Such features may also explain the fact that the JFJ samples are relatively depleted in radiogenic Sr with respect to CG samples (Fig. 3), since the accumulation time is very

ACPD
11, C676–C684, 2011

low." This sentence is not clear. Reply: The accumulation time is very low at the high altitude research station, by comparison to the ice core samples (24h versus few years to decades, respectively).

"CG isotopic data furthermore suggest that intercontinental Saharan dust sources might contaminate glacial ice at summit Greenland and that Asian dust (e.g., Gobi desert) might reach the Alpine summits after long-range intercontinental transport within northwesterly winds (Burton et al., 2006; Svensson et al., 2000)". CG data might just be consistent with a long transport of Saharan and Asian dust to the Alps and Greenland. However, the fallout of Asian dust to the Alps remains extremely speculative and not at all well constrained.

Reply: "It is meaningful to note that a dusty layer recently deposited over CG glacier carries the isotopic signature of the Gobi desert (Fig. 3)". Although this pattern is rare, the fallout of Asian dust to the Alps has been already evidenced (e.g., Grousset et al., 2003).

"Weaker summer southwesterlies trade winds inferred from CG dust record during the latter part of the LIA, are consistent with the synchronous decline of the meridional overturning circulation (MOC)". In this sentence the word "consistent" seems inappropriate. The authors may want to check and reformulate their point.

Reply: "could be associated with" instead of consistent

Also this sentence is not clear. "Post-1850 increase in carbonaceous residues of combustion, or black carbon (BC), and in trace elements content, likely highlighted additional human impact on recent insoluble pollutant emissions".

Reply: Changed to "highlighted the anthropogenic atmospheric pollutant emissions since the European Industrial Revolution".

The conclusions might be reformulated according to the previous suggestions while the last two sentences of this paragraph might just be cut.

ACPD

11, C676–C684, 2011

Reply: The end of conclusion has been modified.

Figure 2 seems too busy while some important variations are not very well evidenced (e.g. 1780-1790 dust event). The concomitant use of EF and trace elements ratios (e.g. EF_Pb and Pb/Sc) seems redundant. Together with EF, it would be much more informative to display concentrations or fluxes. Finally, remarkable differences recorded at CG and Jungfraujoch for Ba, Ti and especially mean mineral size are not discussed within the text.

Reply: - A shaded area now highlights the largest Saharan dust event. - The trace elements ratios are shown instead of the concentrations, because we do not know the initial sample masses. Fluxes cannot be calculated in glacier ice cores, because of thinning of annual layers occurring with depth. - Large difference in the accumulation time (24h for JFJ versus few years to decades for CG) could explain the significant differences observed in some trace element enrichment (e.g., Ba and Ti, Fig. 2) and grain-size, as a result of the dilution of some mineral phases in the dust-depleted sections of CG ice core, and by the coarser Saharan dust collected on a single dust event at the JFJ.

Figures 3 and 5: Adding the composition of the local rocks would help to rule out a significant local dust contribution.

Reply: To our knowledge, there is no exhaustive data about the local geochemistry and mineralogy, which highly differ upon the local and complex geology. We did some Xray analyses from samples collected along the Grenz glacier (Fig. 1) that excluded this potential source, but we did not do Sr/Nd analysis that are time consuming and expensive. However, as already demonstrated, although a local contribution cannot be definitively ruled out (e.g. during thunderstorms), it is known that the bulk impurity content of the Colle gnifetti glacier is largely dominated by Saharan mineral dust (e.g Wagenbach and Geis, 1989), as well as for JFJ and Mont Blanc glaciers (and related snow/ice cores).

ACPD
11, C676–C684, 2011

Technical corrections: The following is an example of how the text is lacking accuracy and how it might be improved. “Polar ice core studies document enhanced atmospheric crustal dust transport during glacial/interglacial colder climates” might be changed in “Polar ice core studies document enhanced atmospheric crustal dust deposition at a glacial/interglacial time scale”

Reply: Changed to: “enhanced atmospheric crustal dust transport during cold glacial periods”. These studies concern the mineral dust transported to polar ice cores during glacial periods (and not over glacial/interglacial cycles).

“By contrast, Pb, and to a lesser extent Cs and U presented higher EFs (EF>10), suggesting the impact of atmospheric emissions of trace elements from anthropogenic sources (e.g. mining and open pit operations, smelting, nuclear tests)”. This is just another example where the authors might be more precise and accurate: speaking about nuclear sources, do they refer to Ce and to the period 1950-1960? Is the Ce enrichment compatible with what was found in other studies? Also the other sources should be discussed (mining and smelting, for Pb? when? references? Comparison with other studies?).

Reply: We agree and this sentence has been removed.

“Variations in crustal element abundances are primarily influenced by total and mineral dust inputs (Fig. 2)”. The authors probably refer to variations in concentrations and not changes in dust composition as discussed in Fig. 2. When they mention “depleted heavy elements”, they probably refer to concentrations and not changes in compositions.

Reply: We refer to variations in crustal element ratios (and enrichment), since we do not have the concentrations, and added precisions in the text.

“In order to evaluate European preindustrial atmospheric dust emissions” maybe the authors mean “In order to evaluate European preindustrial atmospheric dust concen-

ACPD
11, C676–C684, 2011

trations" R eply: Changed to: "In order to evaluate the atmospheric dust transported over Europe during preindustrial times".

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 859, 2011.

ACPD

11, C676–C684, 2011