Answers to the Reviewers comments

Thank you for your comments! We copy your remarks and questions and answer to each point directly afterwards *in italics*.

1. Line 27-28: could be useful to add a reference to “Both processes intensify with increasing temperature”.

   We agree with the reviewer, but rather than being text-book knowledge or a well described phenomenon in the peer-reviewed literature, we suggest this as a hypothesis how to physically explain the observations. There are a lot of publications on firn and models (e.g. Arnaud et al., 2000, Goujon et al., 2003), and of course the Martinerie et al. papers 1992 and 1994, dealing with those processes and implying temperature dependence of the processes of creep. The second process (minimizing surface energy) is a thermodynamical principle. We slightly changed the text to make this more clear:

   “We suggest that air enclosure is primarily dependent on two competing processes during densification and bubble close-off. On the one hand increasing ice deformation (creep) with depth leads to expulsion of air and therefore a reduction of the pore space. On the other hand water vapor transport tries to minimize surface free energy of the pore surfaces enlarging pores and keeping the pore space open against the closure supported by creep. Both processes intensify with increasing temperature."

2. Line 46: Freitag, pers.com. Could you precise the site(s) where this observation has been made.
   and
3. Around line 50 and related to how surface snow structure might survive the recrystallization in the firn, please note that a pretty detailed discussion has been published in Lipenkov et al., 2011.

   We changed the section to:

   “Grain size in the uppermost 3 m is influenced (increased) by summer insolation (Measurements from the EPICA Dronning Maud Land drill site, Antarctica, J. Freitag pers. comm.), but also on daily weather events. Hutterli et al. (2009) state that the total temperature gradient metamorphism (tTGM) influences the physical properties of the snow pack. tTGM is not necessarily synchronous with insolation, leading to a lag between the orbital parameters and the proxies depending on snow structure. Lipenkov et al. (2011) suggest how the summer insolation signal in the firn at Vostok, Antarctica, a low accumulation area, might influence the TAC at bubble close-off. However, in the light of the observed faster densification of winter layers with higher Ca2+ concentrations in Greenland firn (Hörhold et al., 2012), it is unclear how surface

snow structure in Greenland (high accumulation sites) might survive the recrystallization process in the firn."

4. Line 195: "…we expect also no difference in pore volume Vc… True when Vc depends only on T and insolation. But it can also depend on other parameters, like wind, …

   We changed the sentence to:

   "Accordingly, assuming the temperature consistency did also not change in the past, the only factor influencing the TAC difference between the two sites is altitude (and possibly wind (Martinerie et al., 1994), which is neglected here)."

5. Section 4.3.1, relation to Ca2+/dust: should we conclude that dust concentration has a negligible influence on pore volume in the firn?

   So far there exists no physical understanding of Ca2+/dust (or any other impurity) effects on the densification, so we don't want to make a proposition on this subject. Also we cannot resolve seasonal signals in the TAC and therefore our resolution is not appropriate for a more definite statement on Ca2+/dust influence on the densification.

6. Lines 459 and below: As the authors mentioned, the artificial densification experiments (as referred as a personal communication of B. Stauffer) are not appropriate for simulating natural processes, mainly because these "sintering" experiments are made during a very short time compared to what happens in the nature. For that reason I suggest to delete this part, which I feel not to be necessary to the description of the transient firnification model experiment. Instead, I would discuss more the assumptions made, as assuming a constant duration to reach close-off.

   We think that the artificial densification is crucial to mention here, because it is the reason we came up with the modeling experiment by knowing that higher densification expulses air and leads to less time for the surface processes to happen. We slightly changed the section to, hopefully, improve our argument:

   "The reason for low TAC in artificially densified ice is most likely that, due to the extremely high densification rate, there is not enough time to form spherical cavities, which are a result of minimizing surface energy by slow mass re-deposition through vapor diffusion. At the beginning of a DO event, accumulation increases in a step-like fashion, causing (less drastically but analogous to the artificial densification experiments) additional pressure in the bubble close-off zone by the increasing load of snow. We therefore expect a pore volume reduction and expulsion of air from the firn, yielding to lower TAC compared to steady-state conditions."