Review of Parrenin et al "Delta Depth in EDC…."

This is an important, useful paper that summarizes four different approaches to the difficult problem of constructing accurate gas chronologies, owing to the inherent problem of the gas age-ice age difference in Antarctic ice core records. The authors compare a classical approach of modeling with three observation-based methods. In brief, they find that the modeling approach has some shortcomings. This result will be important for the ice core community and should be published with some major revisions.

There seems to be a mistake in the formula used for the $\delta^{15}N$ approach (see below), and the authors have neglected the crucial effect of thermal fractionation in the firn on $\delta^{15}N$. Both of these issues could, and likely do, have substantial impacts on the conclusions and so must be rectified in any revised version.

Also, it seems highly unlikely that the authors' assumption can be correct there was no convective zone in the glacial periods, based on findings elsewhere in Antarctica. For example, at Taylor Dome the d15N went to near zero during the last glacial period. The fact that the authors have neglected the possible role of convection constitutes a major issue that must be resolved.

Finally, the authors state that "it has never been demonstrated" that d40Ar is a gas phase temperature proxy. This is not quite accurate – Severinghaus et al., 2003 GCA, Severinghaus and Brook, 1999, and Severinghaus et al. 1998 did show that d40Ar responds to temperature. However, it also responds to gravitational settling so the interpretation of d40Ar in terms of temperature change is not straightforward. Caillon et al (2003) did explain this clearly, I believe. Goujon et al. (2003) did show that part of the Vostok d40Ar signal at Terminations is due to temperature, although it is difficult to say whether it constitutes half or two-thirds of the amplitude.

Detailed comments:

P 1097
1. Gravitational acceleration should be 9.825 for Antarctica, not 9.81

p 1098
2. equation 15 has a mistake, I think:
$\delta^{15}N$ can be expressed as the sum of two terms, the gravitational and thermal components:

$$\delta^{15}\mathrm{N} = \frac{\Delta m g 1000}{RT} h_{diff} + \Omega(T) G h_{diff}$$

where

$$G = \frac{\Delta T}{h_{diff}}$$

Rearranging,

$$h_{diff} = \delta^{15}\mathrm{N}\left(\frac{\Delta mg1000}{RT} + \Omega(T)G\right)^{-1}$$

and

$$h = h_{conv} + \delta^{15}\mathrm{N}\left(\frac{\Delta mg1000}{RT} + \Omega(T)G\right)^{-1}$$

3. line 13 is confusing – perhaps you meant to say "Note that we have evidence for a large convective zone at present at some sites "?

4. line 14 – this assumption, of a constant ΔT, seems unnecessary. Goujon et al (2003) calculated ΔT, at Vostok, through glacial cycles. Why not do it at EDC?
They found it to be rather larger during the glacials, when a lower accumulation rate plus the transient cooling at the surface created a very substantial ΔT, with negative sign. They found up to -4 C at 25 ka, the neglect of which would create an error of 0.05 per mil in the gravitational signal, corresponding to a 10 m error in inferred firn depth.
This effect would make your δ^{15}N-based Δdepth systematically larger during glacials, if accounted for. So it is a bias, not just a source of uncertainty.

5. line 21 – this gradient uncertainty, of <0.003 K m^{-1}, corresponds to a value of 0.3 K for a diffusive column 100 m thick. This seems much too small given the above.
P 1104
6. line 6 "antiphase" not anthiphase

p 1105
7. line 15 – "come from" not comes from

p 1106
8. line 1 – "is the existence of non-laminar flow effects."
9. line 5 – "past variation of ice thickness"
10. line 22 "…firn densification model correctly estimated Δage at Vostok during Termination III."

p 1107
11. line 2 – Termination II (upper case when it is a specific one)
12. line 9 – "as is the case"

p 1109
13. line 23 – "can help improve the EDC…"