We want to thank anonymous reviewer #1 for his or her positive evaluation of our work, and for the constructive comments. Below we reproduce the reviewer comments in red, with our response in black.

1- The most important one is the link to the Hulu chronology. The new chronology for Hulu cave is not presented in this paper except for the short period between 58 and 60 ka BP. It does not seem to have been published elsewhere. As a consequence, it is not really possible to support the chronology of WAIS based on Hulu chronology if the latter is not shown / published.

Publication of the updated Hulu record has unfortunately been delayed. In the updated MS we now provide three references for the refined Hulu record. Two of them present the updated chronology, namely the IntCal13 manuscript [*Reimer et al.*, 2013] and Southon et al. [*Southon et al.*, 2012], where the same well-dated Hulu speleothems were used to generate atmospheric $\Delta^{14}C$ calibration curves. The third reference is Edwards et al. (in prep), which will present the $\delta^{18}O$ of calcite record that we used in determining the matchpoints:

Edwards, R. L., Cheng, H., Wang, Y. J., Yuan, D. X., Kelly, M. J., Severinghaus, J. P., Burnett, A., Wang, X. F., Smith, E., and Kong, X. G.: A Refined Hulu and Dongge Cave Climate Record and the Timing of Climate Change during the Last Glacial Cycle, Earth Planet. Sci. Lett., in preparation.

We sent a copy of the refined Hulu record to the editor that can be shared with the reviewers, which will allow them to verify the quality of the new record, and validate our selection of tie-points.

2- It is very difficult to understand how the link was done to the Hulu chronology. In the text, the authors explain that they use either warming or warming + cooling. When looking at Tables 1 and 2, it is clear that the link to Hulu has been made only through warming but cooling are linked to NorthGRIP chronology only. If the authors claim that there is a direct relationship between Hulu d18O and WAIS CH4 and/or NorthGRIP d18O for the warming, why should it not be valid for cooling ? Actually, when looking at figure 5, the shapes of events recorded in Hulu d18O does not always reflect shapes of CH4 and NorthGRIP d18O of the same events (e.g. shoulder at 59.5 ka BP in the Hulu record). This raises question on the correspondence between Hulu variations and CH4 and/or Greenland water d18O records. This correspondence should be much more discussed in this paper before giving this ice core chronology based on speleothem dating.

In all records of abrupt DO variability, the DO interstadial onset (associated with Greenland warming) is much a more pronounced and abrupt than the interstadial termination (associated with Greenland cooling). This is also true for the Hulu record. The age of the DO warming transitions can be pinpointed much more reliably than the age of the DO cooling transitions. As we note in the text, Hulu provides strong constraints on the absolute age of the events, but not

on their duration. Our strategy of uniformly stretching the GICC05 chronology by 0.63% ensures that we match the Hulu absolute age constraints in an average sense, while still retaining the timing structure of stadial and interstadial periods as given by GICC05.
In summary, evaluating the timing of the Hulu DO interstadial terminations would provide us with absolute age constraints that are less reliable than those already obtained for the DO interstadial onsets, and with (inter-)stadial durations that are less reliable than those already obtained from GICC05.

In response to this comment we have clarified the manuscript in 3 places.

At the end of the first paragraph of section 4.4 we now note:
"In the Hulu data, as in other records of DO variability, the interstadial onsets are more pronounced and abrupt than their terminations. We therefore only use the timing of the former as age constraints, as they can be established more reliably."

And further down in section 4.4:
"Note that the GICC05 x 1.0063 target chronology only respects the Hulu age constraints in an average sense; the age of individual events differs between Hulu and our target chronology by up to 180 years."

In section 4.5 we clarified:
"Because the duration of (inter-)stadial periods is well constrained in the layer-counted GICC05 chronology, using both the NH warming and NH cooling tie-points results in a more robust chronology. The duration of (inter-)stadial periods is 0.63% longer in WD2014 than in GICC05, which is well within the stated GICC05 counting error of 5.4% (31.2–60 ka interval)."

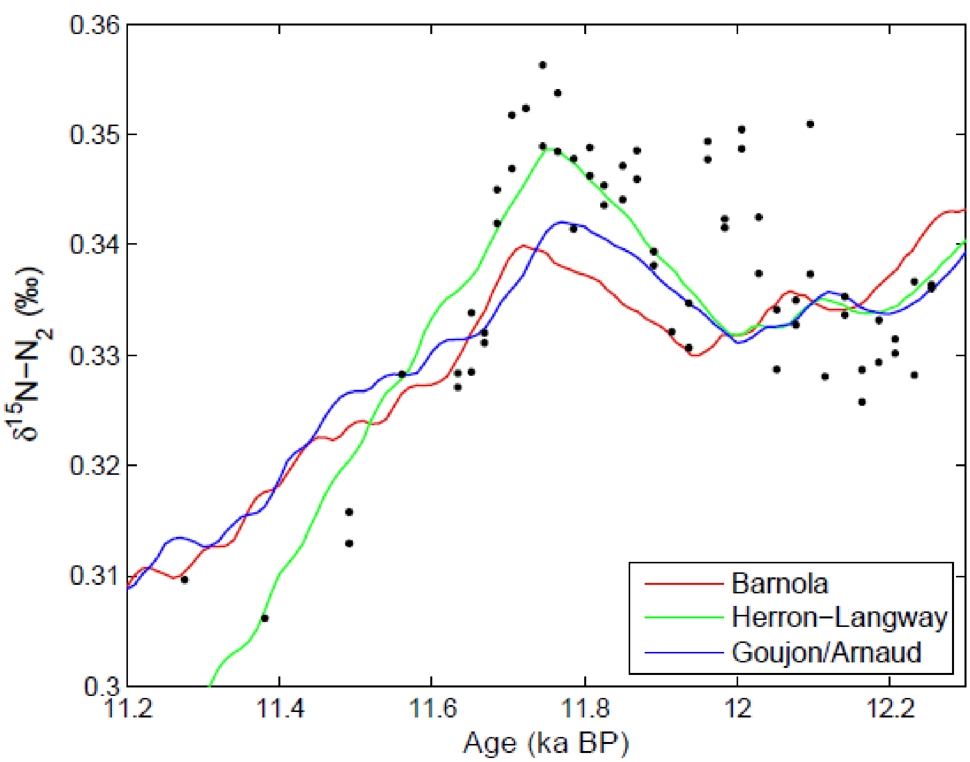
3- A wealth of firnification models have been developed over the last 30 years. Why then have the authors chosen to use the Herron and Langway model which is one of the oldest model with only empirical parameterization? The author states that they have compared this model with other firnification models but no comparison is shown which could have been useful to quantify the uncertainty in Dage calculation due to the use of a particular model.

In response to this reviewer comment, we have performed our inverse firn modeling approach using the firn densification physics from Arnaud et al. [*Arnaud et al.*, 2000], which is also the physics implemented in the commonly used densification model of Goujon et al. [*Goujon et al.*, 2003]. This model is based on a description of the physical processes of firn densification, rather than on an empirical parameterization, in line with the reviewer request. The alternative

Δage solution is shown in Fig 3 on top of the Δage solutions found in the (Herron and Langway-based) sensitivity study, and a brief description of the model is included in Appendix A.

On average, the Δage found with Arnaud et al. firn physics is 19 years smaller than that found using Herron-Langway firn physics (about 7 % of the modeled Δage). The Root Mean Square (RMS) difference between the two solutions is 35 years, which corresponds to 0.63 times the estimated 2σ uncertainty. We state this in the revised Manuscript.

The Herron-Langway model is preferred because the internally consistent solution for temperature, accumulation and ice flow associated with the H-L model provides a better fit to borehole temperature data than solutions associated with the Arnaud model. Furthermore, the Herron-Langway model is more successful in simulating the magnitude of the $\delta^{15}N$ signal that accompanies the 12ka accumulation anomaly at WD; this proved more problematic with both the Arnaud and Barnola firn densification models (see figure below this paragraph), suggesting the latter models are not sensitive enough to accumulation variability.



The high-resolution record of WD $\delta^{15}N$ is still a work in progress, and as such our conclusion regarding the superior performance of the H-L model is still tentative. We prefer not to include this preliminary figure in the peer-reviewed literature at this early stage.

4- The calculation of $\xi(t)$ at the bottom of p. 3545 and the top of p. 3546 and in figure 2 is unclear. Please rewrite more clearly how the accumulation rate scenarios are determined. I think that it may be useful to display the two A_{init} scenarios on Figure 2 in addition to the final $A(t)$ scenarios / or show the $\xi(t)$ functions.

Following the reviewer's suggestion we now also show the two A_{init} scenarios in figure 2, by adding an additional panel.

5- The discussion l. 7 – l. 23 on p. 3554 is difficult to follow without the Hulu data.

See our comments above regarding the publication status of the refined Hulu record. The manner in which the tie-points were derived is explained in detail in section 4.3. A plot of the midpoint evaluation process is shown in Figure 5, which directly shows a part of the Hulu data. All the tie-points used in the NGRIP-Hulu comparison are provided in Table 1. We believe that all the "ingredients" of the discussion on lines 7-23 are thus well explained.

In response to this reviewer comment we have further clarified the discussion on lines 7-23 in two places to better guide the reader:

"A plot of the Hulu-NGRIP age difference is shown in Fig. 6, where the error bars denote….."

was changed to:

"In both the NGRIP and Hulu $d^{18}O$ records we have determined the ages of the midpoints of the DO transitions (Fig. 5; Table 1); a plot of their difference (Hulu age minus NGRIP age) is shown in Fig. 6, where the error bars denote ……"

At the end of the discussion we added:

"Note that the GICC05 x 1.0063 target chronology only respects the Hulu age constraints in an average sense; the age of individual events differs between Hulu and our target chronology by up to 180 years."

6- p. 3555 : there are some inconsistencies in the text when you discuss the phasing between CH4 and Greenland temperature (in phase or not ? l. 10 and l. 17). Baumgartner et al. Have clearly identified lags of methane over Greenland temperature over DO 5, 9, 10, 11, 13, 15, 19 and 20.

When we wrote that Greenland $\delta^{18}O$ and CH_4 change "in phase", we meant that they are in phase on the millennial timescales of the DO oscillations – when one investigates this claim on the decadal time scales this is obviously untrue, as the reviewer notes. We agree that our use of the term "in phase" was sloppy. We removed "in phase" from line 10, which now reads:

"Moreover, CH_4 emission changes are near-synchronous with Greenland $\delta^{18}O$ variations, which they lag by only a few decades on average [*Baumgartner et al.*, 2014; *Huber et al.*, 2006; *Rosen* *et al.*, 2014]. Since CH_4 emissions are closely linked to tropical hydrology, this corroborates the notion that any time lags between NGRIP and Hulu are on decadal time scales."

The updated MS thus consistently notes the decadal lag of CH_4 behind Greenland $\delta^{18}O$.

7- The discussion is very disappointed. Indeed the authors suggest many applications but do not show any. At least one figure showing the seesaw relationship of WAIS vs NorthGRIP should be added since the new chronology is partly linked to the GICC05 chronology.

In the revised MS we elaborated on the discussion of the phasing of CO_2 and Antarctic climate. We now provide values for the deglacial onset of the CO2 and CH4 rise in the WD2014 chronology, based on the records published by Marcott et al. [*Marcott et al.*, 2014].

The seesaw relationship with NGRIP is an important result of the WAIS-Divide ice core. That result, and its climatic implications, is the subject of a separate manuscript aimed at a broad audience, authored by the WAIS-Divide community. We have chosen to present the technical aspects of the chronology and Δage reconstruction in this paper, which is aimed at specialists in ice core science. We have included a reference to the upcoming WAIS-Divide community paper discussing the bipolar seesaw timing, which is currently in revision.

References:

Arnaud, L., J. M. Barnola, and P. Duval (2000), Physical modeling of the densification of snow/firn and ice in the upper part of polar ice sheets, in *Physics of Ice Core Records*, edited by T. Hondoh, pp. 285-305.

Baumgartner, M., et al. (2014), NGRIP CH4 concentration from 120 to 10 kyr before present and its relation to a δ15N temperature reconstruction from the same ice core, *Clim. Past*, *10*(2), 903-920.

Goujon, C., J. M. Barnola, and C. Ritz (2003), Modeling the densification of polar firn including heat diffusion: Application to close-off characteristics and gas isotopic fractionation for Antarctica and Greenland sites, *J. Geophys. Res.*, *108*(D24), 18.

Huber, C., M. Leuenberger, R. Spahni, J. Fluckiger, J. Schwander, T. F. Stocker, S. Johnsen, A. Landals, and J. Jouzel (2006), Isotope calibrated Greenland temperature record over Marine Isotope Stage 3 and its relation to CH(4), *Earth Planet. Sci. Lett.*, *243*(3-4), 504-519.

Marcott, S. A., et al. (2014), Centennial-scale changes in the global carbon cycle during the last deglaciation, *Nature*, *514*(7524), 616-619.

Reimer, P. J., E. Bard, A. Bayliss, J. W. Beck, P. G. Blackwell, C. B. Ramsey, P. M. Grootes, T. P. Guilderson, H. Haflidason, and I. Hajdas (2013), IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP, *Radiocarbon*, *55*(4), 1869-1887.

Rosen, J. L., E. J. Brook, J. P. Severinghaus, T. Blunier, L. E. Mitchell, J. E. Lee, J. S. Edwards, and V. Gkinis (2014), An ice core record of near-synchronous global climate changes at the Bolling transition, *Nat. Geosci.*, *7*(6), 459-463.

Southon, J., A. L. Noronha, H. Cheng, R. L. Edwards, and Y. Wang (2012), A high-resolution record of atmospheric< sup> 14</sup> C based on Hulu Cave speleothem H82, *Quat. Sci. Rev.*, *33*, 32-41.