

We thank Referee #1 to support publication of our paper. In the following, we address the referee's comments in the order of appearance in the annotated manuscript.

Page 2, line 1 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text "(GHGs, including halocarbons)" of the following sentence in the manuscript "The three well-mixed atmospheric greenhouse gases (GHGs, including halocarbons) that contribute the most to current global warming are CO₂, CH₄ and N₂O." and has commented: "there is a contradiction here as the sentence refers to only three GHGs."

Author's response: The sentence refers to only three GHGs, as the referee correctly points out, because our study does not include another group of well-mixed GHGs that is halocarbons. We agree with the referee that the sentence could be misleading. We believe there is no need to mention these "synthetic greenhouse gases", as the radiative forcing of even the largest one, CFC-12, was below that of N₂O for all but 1984-2008. CO₂, CH₄ and N₂O are the long lived GHGs that contribute most to "current" global warming.

Author's changes in manuscript: We have changed the sentence at page 2 lines 1-2 to: "*The three well-mixed (long-lived) atmospheric greenhouse gases (GHGs) that contribute the most to current global warming are CO₂, CH₄ and N₂O.*"

Page 5, line 2 (of the manuscript with no track changes revisions)

Comment from referee: "This paragraph needs a map which depicts the different ice core sites, the accumulation distribution and the wind direction"

Author's response: We agree with the referee that a map would help the reader, so we have produced a map of Law Dome, which is now figure 1. The other figures numbers have been changed accordingly.

Author's changes in manuscript: A reference to Figure 1 has been added at page 5 line 8 "*The ice cores used in this study, referred to as DE08, DE08-2, DSS and DSS0506, were drilled at Law Dome, East Antarctica (Fig. 1).*" Also, the figure caption for figure 1 describes the map: "*Figure 1: Map of the Law Dome region, slightly modified from Smith et al. (2000), showing the location of the drilling sites DE08, DE08-2, DSS, DSS0506 and DSSW20K discussed in the text. Dotted lines are accumulation isopleths (kg m⁻² yr⁻¹) and unbroken lines are elevation contours (meters above sea level). The inset shows the location of the region in Antarctica*"

Page 5, line 8 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text "Re-working of the accumulated snow is minimal as high wind speeds are relatively infrequent and the snow surface is smooth." and has commented "I question this statement, there is always wind re-working. You could, however, say that the wind re-working is not able to erase annual layers"

Author's response: We agree with the referee that our sentence can be improved to describe wind conditions at Law Dome more accurately.

Author's changes in manuscript: We have modified the sentence at page 5 lines 11-13 to: "*Re-working of the accumulated snow is insufficient to erase annual layers as high wind speeds are relatively infrequent. The resulting annual layering is thick and regular and preserved for much of the ice thickness (van Ommen et al., 2005)*"

Page 6, line 5 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text “ice grown with no visible bubbles in it” and has commented “this is too vague, how exactly do you produce this ice?”

Author’s response: A detailed explanation of how BFI is produced has been provided in previously published article, such as Rubino et al. (2013). Here, we report a short explanation and introduce a reference to Rubino et al. (2013).

Author’s changes in manuscript: We have added a sentence at page 6 lines 12-17 to explain how BFI is produced: “BFI is grown in ICELAB by keeping a container filled with deionized water in thermal equilibrium, in order to grow ice as slowly as possible from the bottom to the top of the container. The container features Plexiglass sidewalls that are electrically heated. The water exchanges heat only through the metallic base and freezes from the bottom to the top. If the process is slow enough, the produced ice is free of visible bubbles. The results of the tests performed on ICELAB-BFI, as well as on other, externally grown BFI, have been extensively described by Rubino et al. (2013).”

Page 6, line 25 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text “condensable gases and to extract CO₂ (plus N₂O) from air. The residual CO₂ (and N₂O) is injected into the MAT252 ion source via” and has commented “you have to describe somewhere how you correct for the N₂O interference in the mass spec (chemical slope calibration)”

Author’s response: A detailed explanation of how the N₂O correction is performed has been provided in previously published article, such as Allison and Francey (2007). Here, we report a short explanation citing Allison and Francey (2007).

Author’s changes in manuscript: We have added a sentence at page 7 lines 4-7 to explain how the N₂O correction is performed: “Nitrous oxide (N₂O) has identical molecular masses to CO₂ and interferes with the isotopic analyses. To remove this interference, a correction is made to the IRMS output in GASLAB using the relative ionisation efficiency of N₂O and CO₂, the isotopic composition of N₂O and the measured N₂O and CO₂ concentration, as described in detail by Allison and Francey (2007).”

Page 8, lines 17-21 and page 11, lines 12-15 (of the manuscript with no track changes revisions)

Comment from referee: At page 8, line 17-21, the referee has highlighted the text: “Francey et al. (1999) estimated statistical and systematic $\delta^{13}\text{C-CO}_2$ biases between 0.025 and 0.07 ‰, and uncertainties of up to ± 0.05 ‰, but found an unexplained discrepancy of up to 0.2 ‰ (Trudinger, 2000, section 3.8) around 1900 AD from the South Pole $\delta^{13}\text{C-CO}_2$ firn record measured at NOAA-INSTAAR (National Oceanic and Atmospheric Administration-Institute of Arctic and Alpine Research, Boulder, Colorado).” and has commented “is it worrissome that the Bauska data agree better with the uncorrected Francey data than with the revised data by Rubino (see below)? Note that the Bauska data for the last glacial termination also agree within error limits with the data by Schmitt et al., 2012. This needs more discussion”. At page 11, line 12-15, the referee has highlighted the text: “It is important to resolve the difference between the Law Dome and the WAIS d13C-CO₂ records to establish a Pre-Industrial baseline and, thus, a Pre-Industrial-to-Industrial d13C-CO₂ difference, as well as a Pre-Industrial to Last Glacial Maximum $\delta^{13}\text{C-CO}_2$ difference. These could be useful values 15 for biogeochemical interpretation (Broecker and McGee, 2013; Krakauer et al., 2006).” and has added a comment which reminds to the comment at page 8, line 17-21: “see comment above on the offsets between different d13C records”.

Author's response: We completely agree with the referee that it is worrisome that the Bauska $\delta^{13}\text{C}$ data do not agree with the Rubino et al. $\delta^{13}\text{C}$ dataset, which has revised the Francey et al. $\delta^{13}\text{C}$ dataset and resolved the discrepancy between the Law Dome and South Pole $\delta^{13}\text{C}$ records. Because of the way we have decided to structure our paper (section 3.1 shows the old Law Dome datasets, whereas section 3.2 shows the new Law Dome records and how they compare with records from other sites), we believe it is more appropriate to add the discussion suggested by the referee in section 3.2 at page 11 lines 24-32.

Author's changes in manuscript: We have modified the discussion at page 11 line 33 – page 12 line 10 to address the referee's comment: *"The Bauska et al. (2015) record agrees within uncertainties with the Francey et al. (1999) dataset. However, Rubino et al. (2013) is the only record to show consistency with all firn records and direct atmospheric measurements (see Figs 3c and 5a). This would suggest that the Rubino et al. (2013) is currently the most accurate record and should be used to set a pre-industrial baseline. However, no definite conclusion can be drawn until a thorough intercomparison study is carried out between the labs that have produced the WAIS and the Law Dome $\delta^{13}\text{C}$ -CO₂ datasets (Oregon State University-University of Colorado-Institute of Arctic and Alpine Research, INSTAAR and CSIRO). It is important to resolve the difference between the Law Dome and the WAIS $\delta^{13}\text{C}$ -CO₂ records in order to establish a Pre-Industrial baseline and, thus, a Pre-Industrial-to-Industrial $\delta^{13}\text{C}$ -CO₂ difference. Setting a Pre-Industrial baseline could have consequences on the Last Glacial Maximum-to-Pre-Industrial $\delta^{13}\text{C}$ -CO₂ difference as well (Schmitt et al., 2012). These values are useful for biogeochemical interpretation (Broecker and McGee, 2013; Krakauer et al., 2006)."*

Page 9, line 1-2 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text: **"In doing so, they resolved the 0.2 ‰ discrepancy found between the Law Dome $\delta^{13}\text{C}$ -CO₂ record and the South Pole $\delta^{13}\text{C}$ -CO₂ firn record."** and has commented: **"these $\delta^{13}\text{C}$ offsets are the most important discrepancies, it may be worthwhile to show the South Pole data"**

Author's response: We agree with the referee that the $\delta^{13}\text{C}$ difference between the Law Dome ice core record and the South Pole firn record was the most important discrepancy found between datasets from different sites. However, we feel that this issue has been extensively discussed in the Rubino et al. (2013) paper. Also, showing the South Pole firn data in figure 2 (where the only other firn record is shown, now figure 3) would be out of context, as the figure only shows ice and firn data from Law Dome. Therefore, we have added an extra plot (figure 5) with the South Pole firn data and a reference to the Rubino et al. (2013) paper for further details.

Author's changes in manuscript: We have added a line at page 9, line 16-18: *"In doing so, they resolved the 0.2 ‰ discrepancy found between the Law Dome $\delta^{13}\text{C}$ -CO₂ record and the South Pole $\delta^{13}\text{C}$ -CO₂ firn record (the South Pole firn records have been reported in Fig 5, but see Rubino et al., 2013, for more details)"*

Page 9, lines 14-23 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text:

"- To investigate changes in Pre-Industrial sources of CH₄, Ferretti et al. (2005) produced a record of $\delta^{13}\text{C}$ -CH₄ in Law Dome ice covering the last 2000 years (not shown). They reported unexpected changes of the global CH₄ budget, mainly attributed to variations of biomass burning emissions during the Late Pre-Industrial Holocene (LPIH) through an atmospheric box model (Lassey et al.,

2000). The $\delta^{13}\text{C}-\text{CH}_4$ record from Ferretti et al. (2005) has not been included in ICEBASE because the air samples extracted in ICLAB were measured on a mass spectrometer not maintained by CSIRO-GASLAB. Therefore, the $\delta^{13}\text{C}-\text{CH}_4$ data are not on a CSIRO calibration scale.

- Park et al. (2012) measured oxygen and intramolecular nitrogen isotopic compositions of N_2O (not shown) covering 1940 to 2005 in Law Dome firn air and archived air samples from Cape Grim (Tasmania). In doing so, they confirmed that the rise in atmospheric N_2O levels is largely the result of an increased reliance on nitrogen-based fertilizers. These measurements are not included in ICEBASE either.” and has commented “as this data base summarizes all gas results from Law Dome, it is really a pity that the Mischler and Park data are not accessible via this tool as well. It is clear that these data cannot be updated constantly, as they come from other labs, but the status quo of the data sets as published could be included in the data collection”

Author’s response: It is tempting to include the $\delta^{13}\text{C}-\text{CH}_4$ and $\delta^{15}\text{N}-\text{N}_2\text{O}$ records in our database, but, as the referee has correctly points out, those data have not been produced in CSIRO GASLAB. Therefore, we have no control over them. We have written this paper to make the scientific community aware of the updates we have performed on our $\text{CO}_2/\delta^{13}\text{C}-\text{CO}_2$, CH_4 and N_2O dataset, and to explain how the dataset has been produced and revised. One of the main reasons to revise and publish these records was because our CO_2 , CH_4 and N_2O data were used in the Meinshausen et al. (2017) compilation and $\delta^{13}\text{C}-\text{CO}_2$ in the Graven et al compilation for CMIP6 (we say this in the Introduction), whereas we are not aware of CH_4 or N_2O isotopes being used in CMIP6. The risk of introducing records that are not treated in the same way as the CSIRO data is that we raise confusion among people using the datasets. The Ferretti (not Mischler as the referee writes) and Park data can be downloaded from different repositories and will always be available to the scientific community, independently from the updates of the Law Dome datasets we will release from time to time.

Page 10, line 11 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text: “Comparison with records from other cores show general agreement, but also a number of unexplained discrepancies.” and has commented “too vague”

Author’s response: This sentence is vague because it is just an introduction to the following list of bullet points. We has replaced it with a clearer sentence.

Author’s changes in manuscript: We have modified the sentence at page 10 line 27: “The following list compares the new Law Dome records with records from other sites and discusses the main differences:”

Page 10, lines 30-32 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text: “The difference is even more surprising when the tight agreement between the Law Dome CH_4 record and the WAIS CH_4 record (Mitchell et al., 2011) around this time is considered (compare red circles and grey squares in Fig. 3c).” and has commented “I don't really understand this argument. The CO_2 and CH_4 measurements are independent and in case of Mitchell even the gas extraction is separate from that of CO_2 ”

Author’s response: The CO_2 and CH_4 measurements are mostly independent from each other in terms of measurement technique, but their comparison allows us to test whether the two sites of Law Dome and WAIS are providing consistent records in terms of smoothing of the atmospheric signal. The fact that the CH_4 records are consistent, whereas the CO_2 records show significant

differences points towards a problem with CO₂, rather than issues related to poor understanding of the site (dating, firn smoothing, etc...). In other words, the consistency between the Law Dome and the WAIS CH₄ records is evidence of

1. Consistent dating (ice age and gas age)
2. Similar smoothing of the atmospheric signals at the two sites ([ice age-gas age and gas age distribution).

Therefore, the differences found in the CO₂ records are hard to explain with issues of dating uncertainty, as partly claimed by Ahn et al. (2012), or differences in smoothing of the atmospheric signals between the two sites. This support a chemical origin of the discrepancies (in-situ production), which is more likely to occur for CO₂ than for CH₄.

That said, the comment of the reviewer has alerted us that the way we have phrased our explanation is not very clear. Therefore, we have modified the text to make it easier to understand.

Author's changes in manuscript: We have modified the sentence a line at page 11 lines 16-18, by adding: *"The consistency between the Law Dome and the WAIS CH₄ record rules out dating issues or large differences in smoothing of the atmospheric signals between the two sites. This suggests a chemical origin (in-situ production) of the CO₂ discrepancies, which is more likely to occur for CO₂ than for CH₄."*

Page 11, lines 18-21 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text: **"Interestingly, the LIA CH₄ decrease measured at NEEM appears to start before the CH₄ decrease measured at Law Dome/WAIS, suggesting that the LIA event had an effect on the Northern Hemisphere CH₄ concentration first, and then propagated to the Southern Hemisphere."** and has commented **"Is such a multidecadal lag really possible from a CH₄ cycle/atmospheric mixing point of view? You could check this using a multi-box model. It looks more like an age scale issue as the Mitchell record is shifted to younger ages compared to Law Dome in this time interval."**

Author's response: We thank the referee for this important comment, which has compelled us to think about this issue carefully. We have updated the original NEEM CH₄ gas age scale published in Rhodes et al. (2013), with the new NEEM ice age scale published in Sigl et al. (2015) and the revised delta_age (gas age-ice age) after Buizert et al. (2014). The different timing is now partially resolved (15 years now, instead of 30 years). Having added the CH₄ GISP2 record (as suggested by reviewer 2), we have commented on how the Northern (GISP2) and Southern (WAIS) records have been synchronised by Mitchell et al. (2013) based on the reasoning that "The multidecadal events observed in both ice core records must have occurred simultaneously since the durations of the events were much larger than the atmospheric mixing time (~1 year)." There are multiple possible reasons, associated with the differences of the sites and/or the sampling resolution of the records, to explain the discrepancy found between Northern (NEEM) vs Southern (Law Dome/WAIS) Hemisphere CH₄ records, as discussed in the following:

- Age scale issues, as suggested by the referee. Usually, age scale issues are not very significant for the last centuries. Over such a short time scale, the age of the ice is established through annual layer counting. However, there can be significant uncertainty associated with the Δ age (ice age-gas age).
- Smoothing of the atmospheric signals due to air diffusion in the firn open porosity. As shown for the Law Dome CO₂ record smoothed through the gas age distribution of DML in Figure 2

of Rubino et al. (2016), the smoothing causes a shift in age of the max and min values of the LIA CO₂ decrease. For the Law Dome vs DML comparison, the shift amounts to a few years. NEEM has higher accumulation than DML, so firn smoothing should cause an even smaller shift.

- Inadequate sampling resolution. The NEEM CH₄ records plotted in figure 3 (now figure 4) is a 5 year average of the high resolution record published in Rhodes et al. (2013). The Law Dome CH₄ record has a lower sampling resolution (5 datapoint over a 30-year period of decreasing CH₄ concentration, so on average 1 datapoint every 6 years). By increasing the sampling resolution, it is possible that the time shift between the NEEM and the Law Dome CH₄ event decreases.

A thorough investigation of the cause of the differences in the LIA CH₄ event in the Northern (as recorded in NEEM) and the Southern (as recorded in Law Dome/WAIS) Hemisphere is out of the scope of our paper. However, in the future, this discrepancy should be resolved to obtain a precise synchronisation of all ice core records available over the LIA.

Author's changes in manuscript: We have modified the discussion at page 12 lines 18-27 (now page 12, lines 10-20): *"The age scale of the NEEM CH₄ record published in Rhodes et al. (2013) has been revised with the updated ice age scale published in Sigl et al. (2015) and the new estimate of Δ age provided by Buizert et al. (Buizert et al., 2014). Mitchell et al. (2013) have synchronised the GISP2 CH₄ record with the WAIS CH₄ record to investigate changes of the Inter Polar Difference in the Pre-Industrial based on the reasoning that "the multidecadal events observed in both ice core records must have occurred simultaneously since the durations of the events were much larger than the atmospheric mixing time (~1 year)" (Mitchell et al., 2013). The NEEM CH₄ record has not been synchronised with the others, and there are multiple possible reasons, including age scale issues, different smoothing of the atmospheric signals at the different sites and inadequate sampling resolution, to explain the discrepancy found between the NEEM and the GISP2/Law Dome/WAIS CH₄ records during the LIA. A thorough investigation is out of the scope of this paper, but, in the future, this discrepancy should be resolved to obtain a precise synchronisation of all ice core records available over the LIA."*

Page 12, lines 20-25 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text: **"Considering that:**

- All GHG records in ice cores are a smoothed representation of the real atmospheric history;
- DSS is the highest accumulation rate site ever sampled in Antarctica recording the LIA CO₂ event;
- There is the risk that the WAIS core is affected by in-situ production of CO₂;
- Accurate CO₂ record have not been derived from Greenland ice cores

we suggest that there is a need to sample a new, clean and deep ice core from Law Dome, to recover the real atmospheric LIA CO₂ decrease and other rapid changes in atmospheric composition during Pre-Industrial millennia." and has commented **"this would fit better into the conclusions"**

Author's response: We agree with the referee.

Author's changes in manuscript: We have moved the sentence from page 12 lines 20-25 to page 18 lines 16-23.

Page 13, lines 2-3 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text: “**processes removing GHGs from the atmosphere (sinks).**” and has commented “**typically we do not talk about sinks in the case of CO₂ as for the carbon cycle there is not really a destruction of the molecule but a constant exchange of carbon between different reservoirs**”

Author’s response: We agree with the referee that since there is no destruction of CO₂ in the atmosphere, then, strictly speaking, there is no “sink” in the case of CO₂. However, the general biogeochemical literature uses the word “sink” to signify a process removing GHGs, including CO₂, from the atmosphere (e.g. information from the Global Carbon Project <https://www.globalcarbonproject.org/>). Thus, we have decided to leave the sentence unaltered.

Page 13, line 29 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text: “**recent**” and has commented “**unclear**”

Author’s response: To clarify, the word “recent” here means over the last decades, as opposed to the records from ice cores covering the last centuries/millennia.

Author’s changes in manuscript: We have replace the word “recent” now at page 15 line 4 with “*over the last decades*”.

Page 14, lines 21-22 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text: “**tropospheric species [OH], oxidation by stratospheric species [OH, Cl and O(1D)], and oxidation in soils are the main sinks.**” and has commented “**marine boundary layer Cl sink**”

Author’s response: We thank the reviewer to have reminded us of this sink.

Author’s changes in manuscript: We have added the text “*and reactive chlorine in the marine boundary layer*” at page 15 line 33.

Page 14, line 33 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text: “**hypothesis of an early anthropogenic influence.**” and has commented “**the use of this expression is misleading here, as the "early anthropogenic influence hypothesis" by Ruddiman refers to a much earlier increase. Please change the wording.**”

Author’s response: Generally, the “early anthropogenic hypothesis” refers to the explanation of an influence on the changes of atmospheric CO₂ and CH₄ concentration during the Holocene, originally suggested by Ruddiman. In some of his papers, Ruddiman also discusses the influence of human activities on the atmospheric CO₂ and CH₄ concentration during the Little Ice Age. Therefore, the “early anthropogenic hypothesis” can also refer to any pre-industrial alteration of the atmospheric chemical composition caused by human activities. However, to avoid confusion, we follow the referee’s suggestion.

Author’s changes in manuscript: We have modified the text at page 16 line 11 to “*supporting the hypothesis of a pre-industrial anthropogenic influence on atmospheric CH₄*”.

Page 15, lines 9-10 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text: “As already mentioned, the Pre-Industrial inter-hemispheric N₂O difference is also poorly constrained.” and has commented “I doubt this can be resolved, as it is extremely small due to the long life-time of N₂O”

Author’s response: We agree with the referee that the Inter-hemispheric N₂O difference is small and we would need very high precision ice core measurements to resolve it. However, with the development of new analytical techniques, it could become feasible. Therefore, we have decided to leave the sentence unaltered

Page 16, lines 1-4 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text: “There are regional (Mann et al., 2008), continental (Pages2k, 2013) and hemispheric (Neukom et al., 2014) temperature reconstructions that can be used in Coupled Carbon Cycle-Climate Models to quantify the contribution from each region to the total CO₂ decrease (Fig. 4b).” and has commented “the wording is weird. It is not clear how the reconstructions could be “Used in Coupled Climate Models”, the provide a benchmark”

Author’s response: We are just suggesting that regional temperature reconstructions could be used as “forcing” for models describing the relationship between climate and carbon cycle to quantify the regional contribution to the total CO₂ change recorded through the LIA

Author’s changes in manuscript: We have modified the sentence at page 17 line 17: “There are regional (Mann et al., 2008), continental (Pages2k, 2013) and hemispheric (Neukom et al., 2014) temperature reconstructions that can be used to drive models describing the relationship between climate and carbon cycle to quantify the contribution from each region to the total CO₂ decrease”.

Page 16, lines 11-13 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text: “The consequences of the LIA climatic changes on contemporary societal development are important for understanding why different communities were more or less vulnerable, resilient or even adaptive (Degroot, 2018), and plan future choices accordingly.” and has commented “This is a little far fetched as all societies today have technical means that were not available during the LIA. So it can be questioned, whether we really learn something from the LIA about societal resilience.”

Author’s response: We agree with the referee that current societies have more advanced technical means than in the LIA. However, the ability of a society to adapt to climate change will not depend on technical means only. Political and socio-economic factors will influence how efficiently our society will adapt to future climate change. So, being able to quantify which regions have been more vulnerable to past climate change, also in terms of the response of the natural carbon cycle, could help plan future adaptation strategies.

Author’s changes in manuscript: To put our statement into perspective, we have modified the sentence at page 17 lines 29-31: “The consequences of the LIA climatic changes on societal development are important for understanding why different communities were more or less vulnerable, resilient or even adaptive (Degroot, 2018). Being able to quantify which regions have been more vulnerable to past climate change, also in terms of the response of the natural carbon cycle, could help plan future adaptation strategies”.

Page 16, lines 15-16 (of the manuscript with no track changes revisions)

Comment from referee: The referee has highlighted the text: “($\delta^{13}\text{C-CO}_2$, $\delta^{13}\text{C-CH}_4$, $\delta\text{D-CH}_4$, $\delta^{15}\text{N-N}_2\text{O}$, $\delta^{18}\text{O-N}_2\text{O}$)” and has commented “**here you refer to the isotopes of all greenhouse gases, but you only store $\delta^{13}\text{CO}_2$ in your data base (see comment above).**”

Author’s response: A few lines below (page 16, lines 17-18) we have clearly stated that, of all the isotopic records, only the $\delta^{13}\text{C-CO}_2$ is constantly being updated and revised. However, to avoid confusion, we have removed the records that are not stored in the database.

Author’s changes in manuscript: We have modified the sentence at page 18, lines 2-3: “*The records of GHG (CO_2 , CH_4 , N_2O) concentrations and the isotopic composition of CO_2 ($\delta^{13}\text{C-CO}_2$) from the Law Dome ice cores are one of the most important sources of information for models trying to predict the future behaviour of biogeochemical cycles and their influence on the climate system.*”

Supplement page 2

Comment from referee: The referee has highlighted the text: “**derive the gas-age from the ice-age-vs-gas-age difference for ice samples and gas-age vs depth for firn samples**” and has commented “**it is not clear how this is done (firn modeling). Please elaborate on this somewhere in the supplement**”

Author’s response: An extensive description of how gas age is attributed to ice and firn samples has been provided in past papers. For firn, the dating is based on the firn model, but for ice samples the gas-age – ice age is based on a number of factors, including firn modelling.

Author’s changes in the Supplement: We have added the following line to the text at page 2: “*For firn samples, the dating is based on the firn air diffusion model, whereas for ice samples it is based on a number of factors, including firn model (Trudinger et al., 2013).*”

Supplement page 4

Comment from referee: The referee has highlighted the text: “**The blank correction is quantified by the average deviation of replicated BFI/Blanks measured concentration and isotopic composition from the expected value (i.e.: the value associated with the reference gas used). A blank correction is calculated for each period when the conditions of preparation/storage/extraction are the same. In other words, a new blank correction is calculated each time any of the factors (operator, freezer, temperature of cold room, duration of extraction, etc...) that are believed to influence preparation/storage/extraction changes. The blank correction has an uncertainty associated with it, given by the standard deviations of differences from the expected value.**” and has commented: “**how large is this blank correction typically for the different measured species**”

Author’s response: We agree with the referee that it is useful for the reader to have an idea of the size of the blank correction, so we have added the best estimate for each species.

Author’s changes in the Supplement: We have added a sentence at page 4: “*The blank correction can vary significantly depending on the conditions of the extraction line and on how experienced the line operator is. Typical values are within the following ranges: 0.5-1.5 ppm (uncertainty 0.5-2 ppm, 1σ) for CO_2 , 3-10 ppb (uncertainty 3-15 ppb, 1σ) for CH_4 , 0.5-3 ppb (uncertainty 0.5-4 ppb, 1σ) for N_2O and 0.03-0.1 ‰ (uncertainty 0.04-0.13 ‰, 1σ) for $\delta^{13}\text{C-CO}_2$.*”

Supplement page 4

Comment from referee: The referee has highlighted the text: “**The gravity correction: Gravitational enrichment of heavier species in air in the firn open porosity (Craig et al., 1988; Schwander et al.,**

1988) has different effects depending on the difference between the mass of the measured species and the average mass of air: $[X]_{\text{corr}} = 10^{-3} \times d_{15N} \times (M_X - M_{\text{air}}) \times [X]_{\text{meas}}$, where X is the measured species (i.e.: CH₄, CO₂ and N₂O), "corr" and "meas" stands for corrected and measured respectively, and δ^{15N} is the isotopic ratio of molecular nitrogen (N₂) in firn. For δ^{13C} measurements, the gravity corrected δ^{13C} equals the sum of a correction factor (very close to the δ^{15N-N_2}) and the measured δ^{13C} (see Rubino et al., 2013 for details)." and has commented: **"how large is this gravity correction typically for the different species? Here you refer to δ^{15N_2} values. Where do they come from? Are these values also stored in the database (they should)? How do you correct if you do not have δ^{15N_2} values?"**

Author's response: The questions of the referee are all very relevant and we have included a few lines to answer them in the Supplement.

Author's changes in the Supplement: We have added a few lines at page 4: *"The values of δ^{15N} are often measured in firn to constrain the firn diffusion model. In case of missing δ^{15N} measurements, the firn model is constrained with other measurements and then used to simulate the δ^{15N} profile. Our database stores all measured and modelled δ^{15N} values for firn sites at Law Dome. The gravity correction is typically 1-1.5 ppm for CO₂, 2-6 ppb for CH₄, 1-1.4 ppb for N₂O and 0.25-0.3 ‰ for δ^{13C-CO_2} ."*

Supplement page 4

Comment from referee: The referee has highlighted the text: **"The diffusion correction (only for measurements of isotopic composition): For measurements of isotopic ratios in firn and ice air samples, a so-called diffusion correction is needed (Trudinger et al., 1997). This correction arises from the fact that an isotope ratio is the ratio of two isotopes with slightly different diffusion coefficients and therefore slightly different effective ages (Trudinger, 2000, section 3.6). For hypothetical species with constant isotopic ratio, but changing atmospheric concentrations, the isotopic ratio in the firn can be significantly different from the atmospheric ratio. For δ^{13C} , the diffusion correction is proportional to the rate of change of CO₂ concentration, which makes the δ^{13C} diffusion correction insignificant in the LHPI, and a very significant term in the Industrial Period."** and has commented **"how large is this correction typically? How do you do the correction (firn modeling)?this needs more detail"**

Author's response: The questions of the referee are all very relevant and we have included a few lines to answer them in the Supplement.

Author's changes in the Supplement: We have added a few lines at page 4: *"The diffusion correction is estimated using the CSIRO firn diffusion model and, at Law Dome, can range from around 0 in the Pre-Industrial to 0.13 ‰ in the Industrial Period."*