



EGUsphere, referee comment RC1
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Comment on egusphere-2022-168

Andrew Moy (Referee)

Referee comment on "Sub-millennial climate variability from high-resolution water isotopes in the EPICA Dome C ice core" by Antoine Grisart et al., EGU sphere, <https://doi.org/10.5194/egusphere-2022-168-RC1>, 2022

Title: Sub-millennial climate variability from high resolution water isotopes in the EDC ice core

Author(s): Antoine Grisart et al.

The manuscript entitled 'Sub-millennial climate variability from high resolution water isotopes in the EDC ice core' by Antoine Grisart et al. presents a compilation of the EDC water isotope ($\delta^{18}O$ and δD) that uses new (and previously presented) data at a higher sampler resolution (e.g. 11 cm sample resolution). The authors demonstrate that repeat water isotope measurements on the EDC ice core using different analytical methods on the same samples from different depth intervals are comparable within analytical uncertainty. The authors produce a multi-resolution analysis - wavelet analysis - to examine the variability of the water isotopic signal at EDC over at different depth intervals and glacial-interglacial periods over different time intervals over the 800 kyrs. The compilation of the EDC water isotope records at 11 cm sample resolution demonstrates that isotopic variability during glacial periods at multi decadal to multi centennial timescale is higher than the variability of the Holocene, and diffusion studies indicate that the water isotope diffusion is not influencing the observed isotopic variability.

The manuscript is well written but I would suggest there are many areas and sections that can be improved. Please see the below 'Detailed comments' for suggested changes to consider which will likely improve the reading and flow of the manuscript. Other queries and suggestions on the data comparison, analysis, etc. can be found in the 'detailed comments' - which once addressed - will vastly improve the manuscript.

Detailed comments, suggestions, edits, etc.

Page 1, Line 14: Suggest changing '800 000 years' to '800,000 years'

Page 1, Line 15; The mentioning diffusion here, also requires the mentioning of water isotopes (d18O, dD).

Consider changing this sentence to 'The high resolution (11 cm) water isotopic record (d18O and dD) is available for the EDC ice core and accounting for water isotopic diffusion provides a unique opportunity to investigate decadal to millennial variability during past glacial and interglacial periods'.

Page 1, Line 15: Change 'provide' to 'provides'

Page 1, Line 16: The use of the wording 'high resolution' can be sometimes be ambiguous to some depending on the site (e.g. inland or coastal site) and also depending on the accumulation rate. Also, the 11cm is reference to the sample resolution, and something like sample resolution for CFA - at millimetre resolution is also considered 'high resolution'? Suggest changing 'We present here a compilation of high resolution (11 cm) water isotopic records...' TO 'We present a continuous compilation of the EDC water isotopic record at a sample resolution of 11 cm that composed of 27,000 d18O and 7,920 dD measurements.....'

Page 1, Line 19; Consider changing 'We show that overlapping homogeneous data set.' TO something like 'Here, we demonstrate that repeat water isotope measurements on the EDC ice core using different analytical methods on the same samples from different depth intervals are comparable within analytical uncertainty. From this comparison we combine EDC water isotope measurements to generate a high resolution (11 cm) data set over the past 800 kyrs.'

Page 1, Line 27-29: The sentence 'Along air mass transportation, distillation.....' needs to be explained better as you are trying to explain the use of 'water stable isotopes' in polar regions in a single sentence. E.g. - the loss of heavy isotopes - is some ways it would be good to mention what is a heavy or light isotope OR the oxygen and hydrogen isotope ratios?

Page 1, line 27; 'Water isotopes' are not actually a 'tool to reconstruct past temperatures in polar regions'. Water stable isotopes (d18O, dD) are proxy records that can be used to reconstruct past temperatures'. Consider changing 'Water isotopes in ice cores (d18O, dD) are valuable tools to reconstruct past temperatures in polar regions' TO 'Water stable isotopes (oxygen, d18O; and hydrogen, dD) in ice cores are valuable proxy records that can be used to reconstruct past temperatures in polar regions'.

Page 1, Line 27; Consider changing 'Water isotopes in ice cores (d18O, dD)' TO 'Water isotopes in ice cores (oxygen, d18O; hydrogen, dD)'

Page 2, Line 36; Please be consistent with using 'kyrs' and 'ka'. For example - 'kyrs' is used here and at Page 2, Line 43-44, 'ka' is used.

Page 2, Line 37; Suggest changing 'displayed' to 'measured at ~4 m resolution detailing dD variations over 8 glacial - interglacial cycles (EPICA Community members, 2004)'.'

Page 2, Line 39; It might be a good idea to provide more info on 55cm? Are the bag samples composed of 55cm pieces of EDC or are the samples taken at 55cm intervals?

Page 2, Line 39; Delete 'systematic'.

Page 2; Line 40; The sentence 'In the following years, some studies ... climate variability.' as this is repeated in the next sentence.

Page 2, Line 47; 'affecting the signal'? What is meant by the signal?

Page 2, Line 60; delete 'while we know the'

Page 2, Line 61; Consider changing 'we lack documentation' TO 'there is limited evidence in high resolution climate variability.....'

Page 3, Line 69; Change '3147 - 3190 m' TO '3,147 - 3,190 m'

Page 3, Line 70; Consider changing 'because' TO 'due'

Page 3, Line 84; Change '3 233 m' to '3,233 m'

Page 3, Line 85; Consider changing 'around' to 'ca.'

Page 3, Line 85-86; change 'water equivalent.yr-1' to 'water equivalent yr-1'

Page 3, Line 87; Suggest re-wording 'on the Dome C where the ice was supposed to be the less deformed' and providing a reference?

Page 3, Line 88; Suggest re-writing 'The drilling project was conducted' to 'The EDC drilling project started in 1996 and was completed in 2004. In 1999, a second ice core (EDC2) was drilled from the surface due to the drill for EDC1 being stuck at depth of 788 m. Bedrock was reached in 2004 at a depth of 3,190 m. From here onwards, we refer to EDC1 and EDC2 as the EDC ice core'

'After drilling and core logging, the EDC ice core was cut into 55 cm long sections and each section was further cut longitudinally on site for several measurements (e.g. water isotopes, physical properties, ^{10}Be , chemistry, and gas analysis). The archival piece (~ one quarter of the section) was stored in polystyrene boxes in the EPICA snow-cave at the Concordia station at -50°C .'

Page 3, line 97; I am assuming 'EDC' here means the 'EDC2' ice core? Although, please see the earlier comment 'from here onwards, we refer to EDC1 and EDC2 as the EDC ice core' as this should cover this off now?

Page 3, Line 97; I suggest changing 'continuous' to 'contiguous'? Using 'continuous' might be taken as 'continuous flow analysis (CFA)'. Even though the EDC analysis is on samples at 55cm - it isn't really 'continuous' in terms of the meaning around CFA?

Page 3, line 98; consider changing 'Another section (stick with $2 \times 1\text{cm}$ cross section)... TO 'The second was a 55cm length stick with a 2 cm^2 cross section that was cut into 11cm length samples. Each sample was placed in a sealed plastic bag and stored at -20°C

prior to being melted and transferred into plastic bottles that were kept at -20°C .'

Also - are the plastic bags 'whirlpak' or similar that are tightly sealed?

Page 4, Line 102; Considering writing this section to read something like 'Several analytical techniques have been used to measure $d_{18}\text{O}$ and $d\text{D}$ on the EDC1 and EDC2 ice cores (Tables 1 and 2). Initial analytical techniques included uranium reduction method for

dD (Vaughn et al., 1988); CO₂ - H₂O equilibrium method for d₁₈O (Myer et al., 2000); with the most recent method to determine d₁₈O and dD on the EDC2 ice core using cavity ring down spectroscopy (CRDS) (Kerstel and Gianfrani, 2008; Busch and Busch, 1999). The analytical precision for each method are comparable where 2σ values range between 1 and 1.4 ‰ for dD and between 0.1 and 0.4 ‰ for d₁₈O (Table 2).

Page 4, Line 9; Page 5, Line 130, and Page 6, Line 165 - Please clarify the 'subheadings' used at 2.3, 2.4, and 3. as they are all 'The EPICA ice core'.

Suggest changing:

'2.3 The EPICA ice core' to '2.3 Discrete wavelet analysis' OR 'Multi resolution analysis (MRA)'?

'2.4 The EPICA ice core' to '2.4 Isotopic diffusion'

'3. The EPICA ice core' to '3. Coherency of different analytical measurements'?

Page 4, Line 111; 'Delete 'With thus aim' and consider 'We produced a multi resolution analysis (MRA)....wavelet filter.'

Page 4, Line 117; Consider changing 'The wavelet analysis needs to be applied on time intervals with a uniform resolution. Because we aim to keep....' TO 'The wavelet analysis needs to be applied on time intervals with a uniform sample resolution, and here we divide the EDC isotopic record on the AICC2012 age scale (add reference here) into six intervals. These include the youngest interval between 0 and 56 ka; where 11 cm corresponds to a 10 yr resolution; to the bottom of the core where the oldest interval between 651 and 800 ka; where 11 cm corresponds to a 320 yr resolution on the AICC2012 age scale (Table 3).'

Again - please use 'kyr' or 'ka'

Please reference the AICC2012 age scale.

Page 5, Line 130; Consider changing '2.4 The EPICA ice core' TO 'Isotopic Diffusion'

Page 5, Line 131; Consider changing 'To calculate the effect of isotopic diffusion....' TO 'The effect of isotopic diffusion with depth is convolved using a function $G(z)$ of associated diffusion length σ_z (Gkinis, 2011; Laepple, 2018; Gkinis et al., 2021):'

Page 5, Line 157; Consider changing 'could then be' TO 'is'

Page 6, Line 161; Again, please better define the numbers with 'comma'. Suggest changing '3255 m' TO '3,255 m'.

Page 6, Line 162; Please change '3000 m' to '3,000 m'

Page 6, Line 165; Consider changing '3. The EPICA ice core' to '3. Coherency of different analytical measurements'?

Page 6, Line 166; Consider changing 'Because d18O and dD measurements.....' TO 'Different analytical instruments and techniques have been used to determine d18O and dD in the EDC1 and EDC2 ice cores at different laboratories (Table 1). To determine the coherency of the different datasets, two different comparisons are made; (1) comparison of the isotopic values from the same samples measured by different analytical techniques; and (2) comparison of the 55 cm sample resolution data with the 11 cm sample resolution data using a 5 point average'.

Also - is the 5 point average a 'moving average'?

Page 6, Line 170; Consider changing 'First, we used the new CRDS technique.....' TO start off with a new subheading '3.1 Comparison of isotopic data using different analytical techniques: The CRDS analysis in 2019-2020 measured previously analysed samples from 2004-2010; uranium reduction for δD on MIS 5.5 (1670-1693 m) and by H₂O-CO₂ equilibration for $\delta^{18}O$ (1,670-1,793 m).'

dD comparison:

And consider also having sub heading for the dD comparison and d18O comparison? This consideration would make reading this section of the manuscript easier. Understanding any difference and the explanation for this difference will be critical for the manuscript.

Page 6, Line 172; Consider changing 'Additional comparisons of new vs old data....' TO 'Additional comparisons of isotopic data measured by different analytical techniques on the same samples are also presented in the'

Page 6, Line 173; Consider not using 'The difference between the old and the new'. Considering changing 'The difference between the old and the new' TO 'The difference between analytical techniques (Figure 2)

Page 6, Line 177; Consider changing 'home water standards' TO 'internal laboratory water standards'?

Page 6, Line 178; Can the isotopic difference be due to storage issues? For example - once samples were initially analysed, were they re-frozen immediately after analysis? And did they stay refrozen to ensure minimal evaporation?

Also - have repeat measurements using uranium reduction method for δD in 2004-2010 been repeated in 2019-2020 OR is this analytical capability not available or viable now?

Page 6, Line 180; Change 'N=1000' TO 'N = 1,000'

Page 6, Line 182; The use of the wording 'first, new and old' can get somewhat confusing. Maybe considering upfront when the use of 'first, new and old' is used to actually define them? Or maybe this could be done in the Figure captions for Tables 1 and 2.

Page 6, Line 185; Consider changing '1000' to '1,000'

Page 6, Line 188; Just wondering how you can 'conclude that both dD series are comparable' with the dD difference between these repeat measurements that at 1 to 3 months apart? If the 2-sigma difference 1.4 permille? Which is substantially larger than 2-sigma of 0.8 permille for the difference between first (chromium reduction) and the new (CRDS) measurements of the same samples for dD?

The 2-sigma difference of 1.4 permille for repeat CRDS measurements is similar to the Gaussian dist. of the difference between first (chromium reduction) and the new (CRDS) measurements of the same samples for dD?

Page 6, Line 188; Has anyone considered completing repeat sample measurements for dD of the first (chromium reduction) with chromium reduction method today? This may not be in the scope of the manuscript - but if it has been completed - please mention something; or if there is a totally valid reason why it has not be completed - e.g. Cr method and mass spec no longer available?

Page 6, Line 189; What is actually meant by 'no dependence'? Do you mean there is 'no significant statistical difference between d18O measurements completed using the CO2-equilibrium and CRDS method?

Page 7, Line 196; 'Consider changing 'N=1000' TO 'N=1,000'

Page 7, Line 197; What is meant by 'gathering'? Do you mean that you have calculated the isotopic average of five 11cm samples that overlap with the same sample depth as the 55cm samples?

Page 7, Line 203; Consider changing 'The two comparisons performed.....' TO 'The two comparisons performed above suggest there is no signification statistical difference in the d18O and dD in the datasets compiled here (Figure 1).'

Page 7, Line 204; Consider deleting the sentence 'It is thus reasonable to merge all datasets....'.

Page 7, Line 209; Consider changing 'The compiled high resolution.....' TO ' The compiled high resolution EDC water isotope record in present in Figure 1.'

Page 7, Line 209; The following sentences could be captured in the Figure 1 caption and hence probably don't need to be repeated here 'For δD , 5 interglacial periods have been analyzed at high resolution. For $\delta^{18}O$, we have a profile almost complete except MIS 7 and part of MIS 11. We use these times series to study the multi-decadal to millennial variability over the last 800 kyrs, extending the results of Pol et al., (2011, 2014), which focused on the evolution of the multi-decadal and multi-centennial variability during the Holocene, MIS 5 and MIS 11.

Page 7, Line 215; Change '800 000 years' TO '800,000 years'

Page 7, Line 221-222; Change '1280 and 2560 yr' TO '1,280 and 2,560 yr'

Page 8, Line 223; Change '2560 yr' TO '2,560 yr'

Page 8, Line 224; Consider changing 'can be' TO 'is'

Page 8, Line 226; Is it actual old ages? Or is it towards 'larger time intervals'?

Page 8, Line 228; Deep depth? Or do you mean with 'increasing depth'?

Page 8, Line 236; Maybe need to add a figure or table reference at the end of the sentence 'Diffusion has the expected effect to decrease the amplitude of the variability of the isotopic signal for older and deeper ice core sections (Figure or table?).'

Page 8, Line 242; Considering changing 'bottom part' TO 'deepest' or 'oldest' sections (e.g. xxx depth or older the 600 ka)'

Page 8; Line 246; The subtitle '4.2 The climatic variability at different timescales over the last 800 kyrs' is not correct. This section is looking at the 'climate variability at different time intervals over the last 800 kyrs'. E.g. decadal, etc.

Page 8, Line 252; Consider changing 'is not affecting much variability' TO 'diffusion has minimal affect on the variability..... (Jones et al., 2017)'.
(Note: 'affect' is misspelled as 'affect' in the original text)

Page 8, Line 254; What is meant by 'increase'? Do you mean 'The increase water isotopic variability.....' (maybe consider citing a reference to support this claim?).'

Page 9, Line 255; It might be a good idea to consider clarifying what is actually meant by 'the calculated diffused variability...'. I am assuming you mean 'the calculated water isotopic diffused variability....'.

Page 9, Line 263; Consider deleting 'hence'

Page 9, Line 263; Consider adding a reference to a figure at the end of this sentence?

Page 9, Line 22; Delete 'much'

Page 9, Line 270; Consider re-writing this sentence to something like 'A previous studies focused on the warm phase of MIS 5 (115.5 to 132 ka), where the wavelet analysis of the 11cm resolution δD record showed there were three different isotopic phases with different levels of variability (Pol et al., 2014).'

Page 10; Line 295; Consider changing 'We presented' TO 'Here, we compiled and presented a EDC ice core water isotopic record ($d_{18}O$ and dD) using new and previously published 11 cm data spanning the last 800 kyrs.....'

Page 10, Line 297; 'Coherent calibrations'? Not sure what this actually means?

Consider this 'Our compilation and comparison work showed that water isotopic data measured by different laboratories and techniques over the last 20 years on the same samples show no significant statistical difference and are within analytical uncertainty. As a result, the EDC water isotope data is combined to produce a contiguous high resolution data set at mostly 11 cm sample resolution'.

Page 10, Line 299; Consider changing '2560 years' to '2,60 years'

Page 15, Line 440; Consider changing figure caption as Figure 1 contains more than just the water isotopic record from EDC, and other features (precession and obliquity). Consider changing to 'EDC ice core, other palaeoclimate records and variations in Milankovitch cycles over the past 800 kyrs'

For Tables 1 and 2 - consider adding a 'comma' for the depths (e.g. consider changing '1489-1756' TO '1,489 - 1,756' and so on for the other depths.

Figure 2 - what is meant by 'evolution with depth'? Do you mean 'EDC dD measurements versus depth (m) over Termination 2, where measured completed in 2010 at LSCE (Uranium reduction method; Pol et al., 2014) (blue) and δD measurements completed in 2019 at LSCE (CRDS method) (red).

Figure 3 - please see the suggested comments on Figure 2 as these are similar.

References:

The following reference is listed in the reference section but it could not be found in the manuscript: Fisher D. A., Reeh, N., Clausen, H.B.: Stratigraphic noise in time series derived from ice cores. *Annals of glaciology* 7, 1985.