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The Cryosphere
Discussions

Interactive comment on "Challenges associated with the climatic interpretation of water stable isotope records from a highly resolved firn core from Adélie Land, coastal Antarctica" *by* Sentia Goursaud et al.

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Reply to the editor's comments

Summary In this study, the authors examine the accumulation, isotopic (δ18O and d-excess) and chemical records (MSA, nssSO4) from a shallow firn core (TA192A; 66.78°S; 139.56°E, 602 m a.s.l.) from Adélie Land, Antarctica. The 21.3 m core was retrieved at a coastal high-accumulation site. Local meteorological station data, accumulation stake data, an isotope-enabled GCM and back-trajectory analysis are utilized

to examine the signal that is captured in the core. These highly-resolved records only cover the last two decades, coinciding with Interdecadal Pacific Oscillation's recent negative phase, but provide a rare opportunity to examine climate dynamics from the East Antarctic sector. A sector that in general suffers from a death of observations and where historically recovered cores, in general, are from low accumulation (low resolution) sites from the East Antarctic plateau. I recommend that this study will be accepted but with major revisions. Dear Dr Emanuelsson, many thanks for reviewing and recommending the acceptation of our manuscript, and for all the comments you brought, which will undoubtedly help us to improve our work and make it more robust.

Comments to the authors Major comments:

The TA age scale There is a significant correlation between ECHAM5-wiso δ18O and DDU SAT, but the correlation between TA δ18O and DDU SAT is insignificant. As the lack of correlation consistently appears to be associated with the TA isotope records one can suspect that an error in the age scale introduces an offset between the TA isotopes and station data, and between the TA isotopes and the ECHAM5-wiso data. "No significant isotope [d18O or d-excess]-temperature relationship can be evidenced at any timescale, ruling out a simple interpretation of in terms of local temperature." (Abstract L.15). "ECHAM5-wiso produces a significant relationship between δ18O and temperature, a feature which is not identified in the TA record." (P22 L17). We made a mistake when writing that ECHAM5-wiso produces a significant relationship between δ18O and the temperature (p22), whereas we had written in the manuscript p21 l5: "Neither t2mECH – δ18OECH, nor SMBECH – d-excessECH, nor δ18OECH – d-excessECH relationships are identified in ECHAM5-wiso seasonal or annual outputs.". We thus removed this sentence and replaced it: "Similarly than in the TA firn core, ECHAM5-wiso simulates no δ18OECH – t2mECH correlation, but also no d-excessECH – δ18OECH."

I encourage, the authors to investigate if the lack of significant relationship for the TA isotope records with SAT station data, with ECHAM5-wiso SAT and with simulated isotopes can be due to an error in the TA age-scale. The age-scale can be susceptible towards this type of error as there appears to be a lack of age constrains for the core. If one annual layer count is missing this would result in isotopic data being assigned climate data that is one year or more too current. For example, looking at one single year, if a layer-count is missing, values that are truly 2011 would be assigned as 2012 and thus aligned with too contemporary climate data. These concerns prompted me to try to understand the TA isotopic data, that is, to check if there is an offset associated with the age scale. I created a new depth-age relationship, which includes one more annual count. You didn't include this layer, but you had flagged it as ambiguous (0.68 m depth, dashed black line in Fig. 3). In our previous paper related to the S1C1 firn core (Goursaud et al., 2017, see Figure 3 attached to this response), we had highlighted the difficulty to date a firn core from Adélie Land based on isotope data only, and thus the necessity of coupling isotope data to chemical species for an annual layer dating. 25 out of the 60 annual δ18O peaks were not identified when compared to chemical summer annual peaks. This absence of isotope annual peak can be due to deposition processes of snow, like drifting snow (e.g. Grazioli et al., 2017), and isotope post-deposition processes (e.g. Jones et al., 2017), for which deposited aerosols are not prone. Moreover, changes in seasonal precipitation and the origin of moisture can result in a different δ18O seasonal cycle than the classical one (displaying a summer peak), associated to distillation processes only. When investigating the ECHAM5-wiso model for the grid point corresponding to the S1C1 firn core (which also corresponds to the TA192A firn core), we noticed that simulated water stable isotopes displayed a high interannual variability of the seasonal cycle (Table S3, Goursaud et al., 2017). For the period 1998-2014, the ECHAM5-wiso model simulates 9 years with maximum values out of the summer time, with 2 in March and 2 in August (Table 1 in the Supplement attached to this response), suggesting that atmospheric dynamic processes are behind this high variability. We thus based our annual layer counting on nssSO4,summer (Table S3, Goursaud et al., 2017), supported by MSA. But as shown in Figure 3, there were 3 uncertain years. We had no absolute horizons for this firn core (neither nuclear

test, nor volcanic horizons). However, stake data measured by the French national observatory GLACIOCLIM were a tool to adjust our dating by comparing it with our reconstructed accumulation. These data were found to be very reliable, as punctual stake data recorded similar interannual variabilities than the mean of the 156 km line data with coefficient correlations equal or higher than 0.8. We initially had 4 uncertain summer layers, the three remaining shown by dashed vertical black line in Figure 3, and the layer we included associated to year 2008 in our resulting dating, that allowed us to obtain the best correlation between our reconstructed accumulation and the stake data. To support our dating, we tested here the three remaining uncertain layers that we numbered in Figure 1 (attached to this response). The layer you pointed, is numbered as "1" on the Figure, and the two deeper ones along the firn are numbered "2" and "3". None of these three layers fill the conditions to count it (Table 2 in the Supplementary attached to this response), that are (i) nssSO4,summer > 200 ppb, or (ii) 100 ppb < nssSO4,summer< 200 ppb and a peak for MSA. An uncertainty is highlighted when one of the condition is close to be filled, or when a peak in δ18O coincides with a peak in nssSO4,summer or MSA, or both. Note that nssSO4,summer peaks at a value of 76.2 ppb at layer "1", thus below the threshold we fixed to count it as an annual summer peak. Our first main constrain was to correlate the stake data which cover the period 2004-2014. Only layer "1" could make a change compared to our submitted dating, as other layers are at depths corresponding to a time before 2004. However, a new reconstruction including this layer gives no correlation with the stake data (r = 0.2 and p-value = 0.16 for the stake data "19.2", r = -0.02 and p-value = -0.06 for the 156 km stake line). We thus excluded it from our annual layer counting. Nevertheless, we simulated, out of curiosity, linear regressions with the ECHAM5-wiso model and find no correlation for the accumulation (r = 0.1 and p-value = 0.7), and a weak correlation for δ18O at the annual scale (r = 0.5 and p-value = 0.045) and at the monthly scale (using 12-points resampling for the firn core record, r = 0.18 and p-value = 0.008). The second method we proposed to refine our dating, was to adjust our dating to improve the correlations between our reconstruction and the simulations (accumulation and

δ18O). Table 3 and 4 in the Supplementary (attached to this response) display the results for the dating from the submitted version, and new tests including layers "2" ("test2"), "3" ("test3"), as well as both "2" and "3" ("test23"). For the accumulation, the simulated regressions widely differ, with correlation coefficients close to 0 for test2 and test23, increasing to 0.36 for test3 and to 0.45 for the original version. To the opposite, the simulated regressions for δ18O are very close with a mean correlation coefficient of 0.26 $\pm$ 0.07. As a result, the correlations between the different dating and the ECHAM5-wiso simulations advocate for our initial dating. At this stage, we thus decided that our initial dating was the most consistent. We added the results of these tests in the Supplementary Material of the manuscript and mentioned it p12 l18-21: "We note an uncertainty in layer counting of 3 years when comparing the outcome of layer counting using chemical records with δ18OTA peaks, which have nonetheless been excluded from our dating as they do not improve the correlations neither between the reconstructed SMB and the stake data, nor between our records and the ECHAM5-wiso simulations (Tables S2 to S4 in the Supplementary Material)." Although these new tests lead us to the conclusion that our dating is the most robust, we looked at the relationship between δ18O recorded in the TA192A firn core (δ18OTA192A) with the near-surface temperature measured at Dumont d'Urville (TDDU, Table 5 in the Supplement attached to this response), and with the 2-meter temperature simulated by the ECHAM5-wiso model (TECH, Table 6 in the Supplement attached to this response). These pieces of information do not have the purpose to call into question our dating, but to test the isotopic thermometer (e.g. the thermodynamic response of the δ18O). We notice that whatever the dating test, the δ18OTA192A-TDDU and δ18OTA192A-TECH remain insignificant (p-value $\geq$0.05), emphasizing our hypothesis that processes out of thermodynamic act on Adélie Land δ18O.

Correlation maps I correlated the TA isotopic data (δ18O and d-excess; estimated from Fig. 7) with ECMWF ERA-Interim (Dee et al. 2011) geopotential 500-hPa (z500), surface air temperature (SAT), and meridional (v850) and zonal (u850) winds, as well as with HadISST sea ice concentration (SIC) (Rayner et al. 2003). These correlations

were done both with the original and updated new depth-age relationship. I made plots where the up- per set of panels show the modified age scale and the lower panels shows the original (Figs. R1–6). Many thanks for making such a work, and suggesting the use of correlation maps with the reanalyses to help interpreting the data. Although we did not go for including the 0.54 m layer, and thus the interpretation you made out of this dating, we tried to use the correlation maps to make an interpretation of our Adélie Land isotopic data. We thus first introduced the use of ERAinterim outputs in this arm, completing its description in section 2.2 ("Datasets"), p9 l27: "We also extracted 2-meter temperature (2mT), 10-meter u and v wind components (u10 and v10), and the geopotential height at 500 hPa (z500) over the whole southern hemisphere (50 – 90 °S), in order to investigate potential linear relationships between our records and the large-scale climate variability." We then described the maps in the results section 3.5 ("Influence of synoptic weather on TA records: insights from ECHAM5-wiso simulation, ERA-interim reanalyses, back-trajectories and modes of variability"), adding the question this analysis allows us to answer beforehand, p20 l25: (iv) "Are there significant relationships between our isotopic records and the large-scale climatic variability?". Only maps depicting significant correlations were described in a proper paragraph, p22 l13: "Relationships with the large-scale climatic variability The ERA-interim outputs allow us to investigate whether the large-scale climatic variability influence the isotopic composition of Adélie Land precipitation recorded in the TA firn core. We looked at the simulated linear relationships between the TA isotopic records (δ18OTA and d-excessTA) with the ERA-interim outputs (2mT, u10, v10 and z500, Section 2.2). We here report only significant relationships with absolute correlation coefficients higher than 0.6. For δ18OTA, we found a correlation with 2m-T over the Antarctic plateau (Fig.12a), as well as a correlation with v10 (Fig. 12b) along the westerly wind belt, at $\sim$ (55 °S, 100 °E) and $\sim$ (55 °S, 130 °E) in the Indian Ocean, at $\sim$ (55 °S, 10-50 °E) in the Atlantic Ocean, and a very little area on coastal Dronning Maud Land at $\sim$ (60 °S, 30-40 °E). For d-excessTA, we found a correlation with 2m-T (Fig. 12c) toward the Lambert Glacier at $\sim$ (70-80 °S, 30-40 °E), and an anticorrelation in the south of the Peninsula at $\sim$ (55-65 °S, 250-300

°E). Finally, we noted a correlation between d-excessTA and u10 (Fig. 12d) at a very narrow area of Dronning Maud Land at ∼ (80 °S, 10-20 °E), and an anticorrelation on the westerly wind belt in the Atlantic Ocean at ∼ (55 °S, 40-50 °E). No correlation is found with z500, neither with δ18OTA nor d-excessTA." Finally, interpretations were proposed in the discussion part, first suggesting that the near-surface temperature of the plateau is linked to the δ18OTA (Section 4.2 The δ18O – temperature relationship in coastal Antarctic regions), hypothesis that we strengthened by the significant correlation δ18OTA and the near-surface temperature measured at Dome C over the period covered by the TA core (1998-2014). We used the significant correlation observed between δ18OTA and the 10-meter u wind component to suggest that dynamic processes partly drive the water isotopic composition of Adélie Land, p27 l5: "The δ18O measured in the ice of coastal Adélie Land may thus not allow to reconstruct surface temperatures of this region. However, correlations between δ18OTA and the 2m-temperature by ERA-interim over each grid point of Antarctica (Fig.12a) show significant relationships over the plateau, confirmed by a significant correlation between annual δ18OTA and the near-surface temperature measured at Dome C over the period 1998-2014 (slope of 0.70 ± 0.29 ‰ °C-1, r=0.53, p<0.05). These results support previous studies suggesting warm intrusions offshore Dumont d'Urville towards Dome C (Naithani et al., 2002). Finally, the significant linear relationships with the u10 wind component above the westerly wind belt and at some coastal Antarctic area (Fig 12b) stress the influence of other processes than thermodynamic drive the isotopic composition of Adélie Land precipitations." Second, we extended our interpretation, using correlations with the second order term, the d-excess, in the following paragraph (Section 4.2 Water stable isotope, a fingerprint of changes in air mass origins). Especially, the correlation maps between d-excessTA and ERA-interim 2-meter temperature and 10-meter u wind component came to support the conjecture that the d-excess signature analyzed in the TA firn core is particular when corresponding to air masses coming from the western sector of Antarctica, p28 l11: "Linear relationships between d-excessTA and ERA-interim outputs come to strengthen the link between the climate variability

of western Antarctic and associated southern oceans, as we note an anticorrelation between d-excessTA and the 2m-T in the south of the Peninsula, the Ellsworth region and the Bellingshausen sea (r>0.6); and an anticorrelation between d-excessTA and the u10 wind component over the coastal Ross sector, consistent with the suggestion of air coming from western Antarctica towards Adélie Land via the Ross sector."

Here is why I think the updated age-depth relationship, with the 0.68 m layer count, supersede the original age-scale. *The nssSO4 peak is in the 100 ppb range and the nssSO4 peak is associated with a well-defined δ18O peak. Please refer to our previous paragraph which shows the inconsistency of taking this peak into account for our dating.

*The correlation maps between δ18O and the monthly reanalysis fields display higher significance when the updated age-depth relationship is used (Figs. R1–6). (This is a somewhat circular argument, but it provides enough of an indication that the age- scale needs to be better constrained.) We agree that our age-scale would need to be better constrained, at least over the period prior to 2004. Notwithstanding, we have no other tools at our knowledge.

The higher significance for the updated age- depth relationship is particularly clear for sea ice (Fig. R3). Figure R3a indicate that a negative sea-ice anomaly towards the Southern Ocean in the 120âŮęE–150âŮęW sector and off the coast of Princes Elizabeth Land (65âŮęS, 75âŮęE) is associated with a positive δ18O anomaly. Note that no significance pattern appears in these sectors when the original age-scale is used (Fig. R3b). It is well-known that water isotope records from coastal locations are significantly influenced by regional sea ice conditions (Noone and Simmonds 2004; Küttel et al. 2012). Sea-ice advance and retreat are affected by (and interact with) large-scale atmospheric circulation modes. Indeed, Noone and Simmonds (2004) showed how changes in sea-ice, taken independently from other variables, can affect coastal δ18O, and in a more complex way the d-excess. However, this study does not account for the interplay between sea-ice changes and other climate variables, like e.g. katabatic winds, which also partly drive the atmospheric isotopic composition in Adélie Land, as shown by the recent vapor monitoring processed by Bréant et al. (submitted). In our submitted version, we used the sea-ice concentration averaged over specific longitudinal ranges. Also, we have been advised to rather consider the area where the sea ice concentration is higher than 15 %, what we took into account, as described in section 2.2, p9 l1: “D’Urville summer sea ice extent was estimated by extracting the number of grid points covering the area (50 – 90 °S, 135 – 145 °E) where the sea ice concentration is higher than 15 %, from December to January (included) for each year from 1998 to 2014.” We just considered the d’Urville summer sea ice extent, and rather used map correlations to look at the larger scale. We reported our findings in the results section (removing our prior results), first in section 3.3 (“Inter-annual variations”), p16 l25: “Significant increasing trends are detected in the annual values of d-excessTA (0.11 ‰ y-1, r=0.61 and p<0.05) as well as of d’Urville summer sea ice extent (r=0.77, p<0.05).” and p17 l15: “Our record depicts a significant anti-correlation between annual values of SMBTA and d-excessTA (r=-0.59 and p<0.05), as well as a significant correlation between d-excessTA and d’Urville summer sea ice extent (r=0.65 and p<0.05).” With our new results, we also obtain particular high values in 2011 (instead of year 2013), as specified p18 l11: “Year 2011: high MSA, d’Urville summer sea ice extent, and wind speed values.” The pattern of the mean seasonal cycle remains unchanged. We thus have changed our interpretation in the discussion part in section 4.3 (“Water stable isotope, a fingerprint of changes in air mass origins”), p28 l21: “Noone and Simmonds (2004) have shown, thanks to climate modelling, that water stable isotopes were conditioned by changes in sea ice extent (as a contraction in sea ice increases the local latent heat and temperature due to open water), but confirmed that a thorough understanding of main mechanisms controlling the d-excess was still needed. Also, earlier studies have suggested the use of the d-excess recorded in ice cores to reconstruct past sea ice extent (e.g. Sinclair et al., 2014). Although we find a significant correlation between the d-excessTA and the d’Urville summer sea ice extent (section 3.3), a correlation map between the annual d-excessTA and the summer sea ice concen-

tration (S16 in the Supplementary Material) show significant correlations with further sea ice areas (e.g. an anticorrelation in the Amundsen sea and correlations in the Belligshausen, Scotia and Lazarev seas).”

*The significant pattern with the updated relationship indicates a contemporaneous, in sync, relationship between δ18O and the monthly reanalysis fields. Positive δ18O anomalies tend to be associated with a low-pressure system (clockwise rotation) centered over Tasmania, Australia. The low appears to conduit wind and warm air south (Figs. R1a and R2a). Onshore meridional winds (negative v850) are associated with positive δ18O anomalies, see green shading close to the site. Vapor transport associated with this path tend to be linked with a positive δ18O anomaly as the air comes from a warm open water source region. This is a common correlation pattern for coastal Antarctic ice-core sites (Abram et al. 2011; Thomas et al. 2013). However, commonly with a larger significant region compared to the pattern shown in Fig. R2a. Note that the SAT pattern is significant just off the coast of the site (Fig. R1b), however, only over a limited extent. With our original dating (Figures R1c, R2c and R2d from your comments), no significant relationship appears between δ18O and z500, or winds (u850 and v850). We thus cannot conclude on schemes of transportation of water vapor at large scale, using the pressure and wind fields simulated by the reanalyses.

The v850-wind anomaly close to the site provides an indication that the age-scale and climate data is in sync as the anomaly occur in the atmosphere and thus isn’t associated with long memory effects (lead/lags), as can be the case for sea ice and SST. If onshore winds drive warm ocean air toward East Antarctica (positive TA δ18O anomaly) the warm air can potentially linger and cause SAT anomaly on the plateau the following year. Thus when the reanalysis data is misaligned with the isotope data, a significant positive SAT anomaly pattern can appear over the plateau (Fig. R1d). (Alternatively, if the original age scale is correct, you didn’t see this positive anomaly over the plateau as you used the DDU station SAT time series instead of reanalysis fields.) Although we do not observe correlations between δ18OTA and v850 for our initial dating, we observe a significant correlation between δ18OTA, and the 2m-temperature from the reanalyses over the plateau, confirmed by a significant correlation between δ18OTA and the near-surface temperature measured at Dome C (slope of 0.70 $\pm$ 0.29 ‰ °C-1, r=0.53, pvalue=0.03). This result comforts your idea that warm ocean air driven by winds offshore coastal Adélie Land towards the plateau, resulting in a significant SAT anomaly. This new result was added to the discussion part 4.2 ("δ18O – temperature relationship in coastal Antarctic regions"), supported by a replication of your Figure R1d, p25 l17: "The δ18O measured in the ice of coastal Adélie Land may thus not allow to reconstruct surface temperatures of this region. However, correlations between δ18OTA and the 2m-temperature by ERA-interim over each grid point of Antarctica (Fig.12a) show significant relationships over the plateau, confirmed by a significant correlation between annual δ18OTA and the near-surface temperature measured at Dome C over the period 1998-2014 (slope of 0.70 $\pm$ 0.29 ‰ °C-1, r=0.53, p<0.05). These results support previous studies suggesting warm intrusions offshore Dumont d'Urville towards Dome C (Naithani et al., 2002)."

The next set of figures shows d-excess correlation pattern with z500, 2mT, v850, u850 and SIC (Figs. R4–6). Positive d-excess anomalies is associated with anti-cyclone at 55âŮęS and 90âŮęE (Fig. R4a) this high force winds along the coast towards the site (Fig. R5b). There is a similar pattern of significant zonal easterly winds that approach the site from the Ross Sea side (Fig. R5b). These easterlies appear to be associated with a weak high over the Ross Ice Shelf and a low-pressure band to the north of the shelf. The easterlies appear to bring vapor to the site from the eastern Ross Sea polynya and sea-ice margin (Fig. R6a). With the original dating, the significant correlations you pointed disappear, especially with z500 at (55 °S; 90 °E), and the easterlies in the neighborhood of the Ross sector.

The westerlies associated with high off the polynya and sea-ice margin (Fig. R6a). The westerlies associated with high off the East Antarctic coast (65âŮęS, 90âŮęE) appears to provide a similar conduit of vapor from polynya region (Fig. R6a). The

d-excess signal originating from these regions can be anomalously positive as evaporation occur at a high-latitude low RH setting and the transport path towards the site can be associated with kinetic distillation processes as the air parcels are advected over ice, which further increase the positive d-excess anomaly. The cold atmospheric temperatures in combination with the long distance travelled by the air parcel over ice (without re-enrichment from an ocean source), can allow for a greater expression of the Rayleigh distillation and temperature dependence of kinetic effects, which is associated with higher d-excess values (Jouzel and Merlivat 1984; Risi et al. 2013). This is also consistent with your results, namely, the anti- correlation between d-excess and SMB; as the air is advected over ice shelf and sea- ice it will have experience "rainout" before reaching the site and thus the high d-excess values will be associated with relatively dry conditions. The setting with a positive SIC trend in the 110âŮęE–160âŮęW sector (Fig. R7) can also be important for the d-excess trend as it provide a setting with anomalously northerly sea-ice margin where air can be advected along the coast without contact with an ocean source. As aforementioned, we observe a significant correlation between the d-excessTA and the sea ice extent with our original dating, not only for the Ross Sea, but also the Bellingshausen, Scotia (in the North of Peninsula) and Lazarev seas (face to Dronning Maud Land). Nonetheless, we tested your hypothesis by fitting a linear relationship between the annual d-excessTA and the annual sea ice area where the concentration is lower than 15 % over the region (60 – 70 °S; 150 – 210 °E), as a surrogate for Ross Polynya. But we found no significant correlation. This was reported in the section 4.3 ("Water stable isotope, a fingerprint of changes in air mass origins"), after discussing the link between the d-excessTA and the sea ice extent, p29 l8: "As we suggested a particular d-excess signature in the TA firn core, associated with air masses coming from the western sector, we tested the possibility for the d-excessTA to imprint changes in the Ross polynya. We thus estimated it, by counting the annual sea ice concentration over the polygon (60 – 70 °S; 150 – 210 °E), lower than 15 %. But we find no significant correlation between this estimated Ross polynya and the d-excessTA over the period 1998-2014."

Note that both the eastern Ross Sea and the sea-ice region off the coast of East Antarctica (55âŮęS, 90âŮęE) have seen a significant negative sea-ice trend over the examined 1997–2014 period (Fig. R7). This is particularly clear for the eastern Ross Sea. The negative eastern Ross Sea sea-ice trend, therefore, provides a compelling explanation to the positive d-excess trend. Interestingly, we observe positive correlations between d-excessTA and the sea ice concentration for areas associated with positive trends in sea ice concentration over the period 1998-2014, while we observe negative correlations for areas with negative trends in in sea ice concentration over the period 1998-2014. This, indeed, provides an additional proof that the deuterium excess has a high potential for reconstituting the origin of air masses, as it seems very sensitive to sea ice conditions. However these differences in the sign of the correlation between d-excessTA and the sea ice concentration highlight by another mean, the need for more comprehensive studies about the processes driving this signal. We reported these results just after describing the correlation map between the d-excessTA and the the sea ice concentration, p29 l3: "We also noted a coincidence between the sign of the correlation of the relationship between the d-excessTA and the the sea ice concentration, and the sea ice extent trend over the period 1998-2014 (S17 in the Supplementary Material), especially positive correlations (negative) associated to positive sea ice concentration trends. These findings call for mechanistic studies to understand the different processes behind d-excess associated to each air mass origins."

I think it could be interesting if you could show whether these transport pathways exist. You can do this by showing the paths associated with the back-trajectories, perhaps as clusters. Hysplit provide a cluster analysis. However, daily back-trajectories over the period 1998-2014 are too many. We thus make a k-means clustering analysis over the last point of whole back-trajectories, and obtained two clusters, one above the Indian Ocean, and another one in coastal West Antarctic Ice Sheet, as reported in the result section 3.5 p23 l14 (""): "A k-mean clustering over the last points of the whole back-trajectories indicate two main origins, in the Indian Ocean (62.4 °S, 131.7 °E) and in the coastal West Antarctic Ice Sheet (73.4 °S, 227.5 °E)."

Note that air originating from these sea- ice regions doesn't necessarily have to have seen a significant increase, that is the transport path can always have been there it could be that the polynyas just recently became active. However, your findings that back-trajectories from the WAIS+Pacific region have increased is consistent with a positive d-excess trend, assuming that the air pass over Ross Sea sea ice or shelf prior to reaching the site. Our new results from this response show that the increase in d-excess would rather be linked to the increase of back-trajectories from the western sector than the Ross sea polynya. But a proper explanation remains to be investigated by other studies (as significant correlations between the d-excessTA and the sea ice concentrations are also to be noted).

The examined interval, 1997–2014, is short and almost exclusively coincide with the Interdecadal Pacific Oscillation's recent negative phase. Thus, it should be cautioned that your results and these correlation plots might look different if the examination period had been longer. This feature was added in the conclusion, p35 l13: "Ways forward include a better documentation of the spatio-temporal variability in SMB and water stable isotopes using a matrix of coastal firn core records spanning longer periods over the last decades (17 points being small to assess linear relationships, and record climate shifts, e.g. the IPO shift occurring in 1998 (Turner et al., 2016))"

I suggest that you show correlation maps similar to those that I introduced. Local conditions like those presented in Figure 6 in the paper does not necessarily show any influence on the isotopic record. For example correlation plot with reanalysis z500 fields can provide you with information about the pressure systems that are associated with air advection to the site and the isotopic signature. A pressure time series from a nearby station will not provide you with this information. Thus I suggest that you replace Figure 6 with correlation maps. We left Figure 6 that we think necessary to illustrate the inter-annual variability of the observations. We took into account your advice, selecting correlation maps (Figure 12), describing them and including them in our interpretation (see previous response).

Note that it can also be fruitful to correlate d-excess with SST and RH reanalysis fields, to check if any region stands out. I can share my Matlab analysis code for the correlation maps if that would be helpful? Contact the editor if you would like to get a copy. Many thanks for suggesting to share your code. However, we decided to keep this idea for a study focusing on the processes behind the d-excess signature.

The dating process of this core seems to be challenging. However, by not providing any reanalysis correlation maps or investigate the records relationship with standard indices (such as for ENSO and SAM), it feels like you have not exhausted the standard methods used to interpret the isotopic signature of an ice core. We tested potential linear relationships between the isotopic TA records and the modes of variability. We first introduced the used of specific indices in the methods, section 2.2 ("Datasets"), p11 l15: "Modes of variability We tested either the main modes of variability were imprinted in our recorded, especially: - the Southern Annual Mode (SAM) using the index defined by Marshall (2003), and archived on the National Center for Atmospheric Research website (Marshall, Gareth & National Center for Atmospheric Research Staff (Eds). Last modified 19 Mar 2018. "The Climate Data Guide: Marshall Southern Annular Mode (SAM) Index (Station-based)." Retrieved from https://climatedataguide.ucar.edu/climate-data/marshall-southern-annular-mode-sam-index-station-based.) - the El Niño Southern Oscillation (ENSO) using el Niño 3.4 index defined by the Climate Prediction Center of NOAA's National Centers for Environmental Prediction, and archived on their website (Trenberth, Kevin & National Center for Atmospheric Research Staff (Eds). Last modified 06 Sep 2018. "The Climate Data Guide: Nino SST Indices (Nino 1+2, 3, 3.4, 4; ONI and TNI)." Retrieved from https://climatedataguide.ucar.edu/climate-data/nino-sst-indices-nino-12-3-34-4-oni-and-tni.) - the Interdecadal Pacific Oscillation (IPO), using the IPO Tripole Index (TPI) defined by Henley et al. (2015) based on filtered HadISST and ERSSTv3b sea surface temperature data and archived on the internet (Accessed on 09 20 2018 at "https://www.esrl.noaa.gov/psd/data/timeseries/IPOTPI".). - the Amundsen Sea Low pressure center (ASL) archived one the National Center for Atmospheric Research

website (Hosking, Scott & National Center for Atmospheric Research Staff (Eds). Last modified 19 Mar 2018. "The Climate Data Guide: Amundsen Sea Low indices." Retrieved from https://climatedataguide.ucar.edu/climate-data/amundsen-sea-low-indices.)" We then reported the results of the linear relationships between our records and theses modes of variability in section 3.5 (retitled "Influence of synoptic weather on TA records: insights from ECHAM5-wiso simulation, ERA-interim reanalyses, back-trajectories and modes of variability"), p23 l19: "Note that no significant relationship is obtained between the TA records and any mode of variability."

Combining the correlation maps with the back-trajectory analysis can be a powerful approach to test the d-excess hypothesis and thus aid in addressing the goals of the study (P7 L7). I don't think it is justified to call the research challenging (referring to the article title) before you have tried additional analysis. The record you present here is interesting so it also deserves a more exciting title. We have followed your advices and nevertheless, still remain limited in our interpretation. We thus prefer keeping this title as the message we would like to emphasize is the current limitation of this isotopic interpretation, at least for Adélie Land.

The introduced update of the age-depth relationship, should not be viewed as a permanent update. Instead, it was meant to raise a concern. It would be good if you can find some age constrains for the core. Many thanks to have raised concerns about the age-depth profile. Unfortunately, we do not have more constrains.

The data for the closest stake needs to be included in Fig. 3 if it is central for the age-scale. SMB for the closest stake area is central for the age-scale, but not for the first step consisting in an annual layer counting, and illustrated by Fig.3. Its use comes to a second step consisting in comparing the reconstructed accumulation from the TA with the SMB from this stake area. This is illustrated by Fig. 4.

I like the age-scale section otherwise it has enough detail to ensure reproducibility. Are there any other chemical records from the core, any other shallow cores or pits (that can provide a historic snow surface), or can you use the Acoustic Depth Gauge (ADG) record of snow surface height from the D-10 station? We are very confident in the SMB data from the closest stake area which is highly correlated with the 156 km stake line data. It covers only the period 2004-2014. Unfortunately, no other shallow cores or pits have been drilled and analyzed in the surroundings. And we have no knowledge of Acoustic Depth Gauge record of surface height from the D10 station.

In your 2017 study, you used NH4 and Na, but they might not add any additional information? You couldn't match the isotopes with the S1C1 record, but is it possible with any other records? This might be helpful if the S1C1 age-scale is associated with less uncertainty. NH4 and Na are associated with more uncertainties than nssSO4 and MSA: NH4 depends not only on the population of penguins, but also on conditions enabling the degradation of urea (Legrand et al., 1998), while Na shows peaks during winter, a feature very specific to Adélie Land and not fully explained. The S1C1 firn core is associated with an uncertainty of 8 years, its accumulation is not correlated with the ECHAM simulation, and its variability is different from the Glacioclim stake data over the short period 2004-2007. Unfortunately, there are no other data.

In the future, can there be something to gain in terms of resolution to measure these cores on a continuous-flow analysis (CFA) setup or increase the sample resolution of the discrete samples? For water stable isotopes, a CFA setup is currently installed, so it is planned for the next months.

We were fortunate on the project that I worked on researchers had visited there in the 1970s and retrieved cores. From their pioneering research, we got additional age-constrains from their snow surface at the time, plus beta-counts and we were able to match our isotope record with theirs (Emanuelsson 2016; Winstrup et al. 2017). We looked at your work we were not aware of. Our interpretation regarding air masses coming the western sector is in line with what you suggested, leading us to complete section 4.3 ("Water stable isotope, a fingerprint of changes in air mass origins") p29 l20: "These dry air masses might origin from the Amundsen Bellingshausen sea (Winstrup

et al., 2017; Emanuelsson et al., 2018), but cannot be directly linked to the Amundsen sea cyclonic, as we obtain no significant relationship with the ASL center pressure indices."

Age-scale thresholds The introduced threshold for your annual counts does not capture the older/deeper part of the record. Note how the picks at 12.2 m, 11.2 m, and 10.5 m (currently assign for the year 1999, 2000, and 2001) does not exceed the 100 ppb nssSO4 threshold. There, of course, has to be layer counts for this section, but they are not strictly speaking captured by the introduced rules. You are true. Thanks for noticing this mistake. So our dating is reproducible, we changed the rules we had fixed, p13 l3" For depths lower than 10 m w.e., summer (December-January) peaks were identified (i) from nssSO4 values higher than 100 ppb, synchronous with MSA peaks (with no threshold), and (ii) for nssSO4 values higher than 200 ppb (with or without a simultaneous MSA peak). Double nssSO4 peaks were counted as one summer (e.g. 2012, 2003, and 2001). For depths higher than 10 m w.e., summer peaks were identified for nssSO4 values higher than 27 ppb."

Perhaps this can be linked to the low proportion of air parcels that come from the Indian sector at the beginning of the record? You could might thus get less of an ocean signature. There is no trend in the proportion of air parcels coming from this sector that would allow to make such a suggestion.

Please cite earlier studies that have successfully used nssSO4 and/or MSA for dating (e.g., Steig et al. 2005; Abram et al. 2013). This method has been used for decades (e.g. Wagenhach et al., 1994), and the seasonal cycles of these species depend on local observations of the seasonal cycles of associated aerosols. We thus prefer referring to our previous publication (as already done) which gives the appropriated citations (i.e. related to atmospheric observations at Dumont d'Urville).

Back-trajectories Show your results on maps too. Consider cluster analysis for the trajectories or it might suffice to show just the 5-day endpoints. The path can be important though, consider this case. The air is classified as WAIS+Pacific as the endpoint fall in this sector, but the air advected from this sector can be re-enriched from an ocean source or polynya on its way to the site. Please refer to prior answers.

I also suggest that you split up the Indian sector, it covers a too vast region. In my mind, the region from 0âŮę–90âŮęE is likely to be associated with a different signature compared to direct onshore moisture transport. Sticklers might also object to that the Indian and WAIS+Pacific sectors intrude into the Atlantic Ocean sector. Our arm was to discriminate different types of back-trajectories, especially continental vs maritime, and East vs West trajectories, which explains large defined zones: the plateau and the newly named eastern sector for the EAIS, the western sector for WAIS, and the Ross sea sector in between those two zones, with a particular climate still under debate regarding its association to EAIS or WAIS for recent past climate variability (Stenni et al., 2017). Narrower sectors might be defined in a new study focusing on processes.

Also, why do you leave a region south of New Zealand undefined? It was a mistake as we should have taken into account this region. We thus included in the eastern sector (previous "Indian Ocean"), changing the boundary of the regions in in the description (section 2.2 "dataset"), p10 l21: "(i) the eastern sector: (0 – 66 °S, 0 – 180 °E), (ii) the Plateau: (66 – 90 °S, 0 – 180 °E), (iii) the Ross sea sector: (0 – 75 °S, 180 – 240 °E), and finally (iv) the western sector: (0 – 75 °S, 180 – 240 °E), and (50 – 90 °S, 240 – 360 °E)." We also recalculated back-trajectories with end points in this region, as relationships with this amount. Quantitative results were modified, but note that it does not change the main results (ie trends and significant relationships).

Is it a concern that the start elevation of 1,000 m a.s.l. does not correspond to the elevation at the site (602 m a.s.l.). One of the findings in Goursaud et al. (2018a) was that the site elevation was important for the d18O-d-excess phase-lag. This is an important point we raised in a previous study, and that we cannot have answered until now, as current analysed ice cores were drilled at sites lower than 1 000 m asl. However, the new ASUMA ice core measured in water stable isotopes and under study

was drilled at a site above this threshold. We thus hope that its study will provide a step forward in the comprehension of the δ18O- d-excess phase lag.

"Finally, we associated each daily back-trajectory to daily precipitation δ18O and d-excess values simulated by ECHAM5-wiso in the precipitation, and classified the time series for each variables by back-trajectories sectors." (P22 L3). Did you report any of the results from the d-excess back-trajectory analysis? Yes, we reported these results p24 l14: "The d-excess mean seasonal cycles substantially differ by their amplitude: for air masses coming from the western sector, it is 11.8 ‰ with outstanding values in March and October (minima) and in May (higher than the mean plus two standard deviations), whereas it varies between 3.2 ‰ and 3.6 ‰ for the other sectors."

Is there a way to tag the back- trajectories with TA d-excess data? It would be neat, if you can tag the back-trajectories with monthly TA d-excess values and then show that high d-excess months tend to originate from (or pass over) the Ross Sea and the off the coast of East Antarctica (65âŮęS, 90âŮęE) negative sea ice trend zones. To pinpoint these area, you might need a finer sector resolution and to also look at the path not only the 5-day back-trajectory endpoints. We had already tagged monthly averaged back-trajectories with either δ18OTA or d-excessTA but unfortunately, nothing stand out. For Ross Sea, please refer to the test we made with our estimation of Ross polynya which brought no significant correlation with the TA isotopic records.

Post-depositional effects I think three years is a too short period. However, this number corresponds to the only peaks we have a (weak) doubt on.

Your argument, as you pointed out, is assuming that there is no natural interannual or inter-decadal variability. What ratio do you get if you just split the records in two parts (8 yrs in each)? Dividing the mean amplitude of the 8 first annual amplitudes by the mean of 8 next ones, we obtain a ratio of 1.06.

If you want look at intra-annual (seasonal or monthly) isotopic resolution I still think you would have to consider diffusion. Please refer to our calculations of diffusion lengths (in months) using the method of Küttel et al. (2012), we reported as an answer in the next lines.

However, I think your analysis and the correlation maps (Figs. R1–6) using annual values shows that you can also obtain interesting information from the annual records. We thank you once more for having pointed these tools to extent our analysis.

Note that one approach would be to forward-diffuse the isotope records (Vinther et al. 2010; Küttel et al. 2012). You can use the methodology in Küttel et al. (2012) and then compare the results from using the forward-diffused record and the untouched record to evaluate objectively if there is a difference. We applied this methodology and reported the results in the section 3.1 ("Firn core chronology"): P13 l19 "For the TA, we also estimated the diffusion length (Küttel et al., 2012), and found mean diffusion lengths of 1.4 $\pm$ 0.3 months for δ18OTA (with a maximum of 1.9 months in 2007), and 1.6 $\pm$ 0.5 months for d-excessTA (with a maximum of 2.4 months in 2007)."

ECHAM5-wiso Could the S1C1core's age-scale be better constrained than the TA core? Beta-counts were used for the S1C1age-scale, which can help to reduce the uncertainty. The significant correlations for the S1C1 with the model data would indicate that this could be the case and the lack thereof for TA could indicate that TA's age-depth relationship is not as well constrained. This provides another indication that an annual-layer count might be missing for the TA age scale. These cores are located only 14 km apart, so they will be exposed to similar climatic conditions. It thus seems to be a hasty conclusion to attribute the lack of similarities for the accumulation records of the two core solely to S1C1. "the absence of similarity between the TA and the S1C1 accumulation reflects the uncertainty in the S1C1 dating resulting from the large spatial variability and from more frequent erosion processes occurring at the S1C1 site" (P24, L1). Although the S1C1 firn core was dated with more constrains, it is associated with more uncertainty (8 years). Indeeed, it was really more difficult to date it. Also, people on the field can have attest of stastrugi and rugosity for the S1C1 drilling site contrary to the TA192A, evidence of wind drifting and scouring. It is also displayed by the cor-

relation coefficient of the closest stake from the S1C1 and TA192A data with the 156 km mean accumulation (added in the Supplementary Material of the manuscript, and in the Supplement attached to this response). Finally we are very confident with the match between the reconstructed accumulation and the stake data.

For the same reason, I would caution you against being too strong with your criticism against the model simulations here. The analysis that you perform requires that the age-depth is well constrained, that is, that the isotope data is aligned with the GCM data year by year. (The seasonal cycle comparison should not be as sensitive though.) We did not write that the model was wrong but listed the potential causes of model/data mismatch, p32 l2: "This could be related to (i) to post-deposition processes associated with wind scoring or snow metamorphism not resolved in ECHAM5-wiso, (ii) the key role of very local atmospheric circulation effects related to katabatic wind processes, not resolved in large-scale atmospheric reanalyses and simulations, (iii) or the difficulties of ECHAM5-wiso to resolve the processes associated with the ocean boundary vapour d-excess", that we develop within the paragraphs. Finally, the only solution to decipher wich of the model or the data is not a (realist) climate signal is to obtain more isotope data, as we can have concluded p32 l9: "and thus calls for more isotopic measurements (from ice cores, snow precipitation, and water vapour) in Adélie Land to reduce uncertainties."

SMB Are you using a sufficient number of points (stakes and cores) to get conclusive SMB results? There are 91 stake data on the 156 stake line from Dumont d'Urville towards Dome C (Agosta et al., 2012), with a field mean accumulation highly correlated with the three closest stake data from the TA192A drilling site (r): - the "18.3" stake point, 1 km from the TA192A drilling site, and r = 0.91; - the "19.2" stake point, 83 m from the TA192A drilling site, and r = 0.86; - the "20.3" stake point, 998 m from the TA192A drilling site, and r = 0.85; Correlation coefficients with the TA192A firn core given in fig. 4 argue for the robustness of our reconstruction (over the overlapping period 2004-2014). And that is one of the key messages of the section 4.1 ("SMB") we develop, defending here that our firn core thus imprinted a regional SMB signal. A second key message (l5 to l10) is that, over the period covered by the TA192A (1998-2014), we observe no trend. This is an important point, as shown by Thomas et al. (2017). Of course we are less confident out of the interval time from 2004 to 2014, but there is an absence of trend not only in the TA firn core but also in ECHAM.

Perhaps it would be wiser to leave the SMB part for a later publication? As drawn in our introduction, our arm through our current studies, is to infer SMB information from water stable isotopes. Consequently, this paragraph is important to remind it, and we made it clearer by adding the following paragraph p27 l6: “The anticorrelation between the d-excessTA and SMBTA shows the possibility to use water isotope firn core records from Adélie Land to complete the document of the SMB spatio-temporal variability. Dry air masses from the western sector may be associated with particular high d-excess values. The remaining uncertainty in the dating and the extraction of a pure signal limited our investigation.”.

For that study, you could include all the available stakes and cores. Unfortunately, there are no more stakes and cores.

I suggest that you home in on one or two novel ideas. I also suggest that you work on focusing and shortening the paper, clarify sections, and work on presenting some findings in figures instead of the text. (I can also become better at this). We have decided not to shorten the manuscript, because we did not find one prominent message about the interpretation of our water stable isotope records. Thus, at this stage, we think that all the pieces of information we can have extracted from this study might help to deepen the question.

I like your short summaries at the end of each section and they are written in a clear concise way. Strive towards getting this level of clarity throughout. Suggestions: focus on the δ18O and d-excess TA data, interpretation of the signal (explain the d-excess trend), the isotopes relationship with the ECHAM5-wiso model, and back-trajectories.

These findings seem novel, robust and interesting. Remove the snow surface sampling archive part, the SMB and the δ18O/d-excess signature analysis? You can still publish these findings elsewhere. Many thanks for these advices, but please take into consideration our point.

Specific comments: I suggest that you add a subscript to δ18O and d-excess when you refer to ECHAM5- wiso data. That way the reader doesn’t have to look back in the text to check if it is the simulated or TA data that you refer to. Done

Article title You can perhaps change the title. You have to show that this is true first, but here is my suggestion. “Recent positive trend in d-excess in an Adélie Land coastal ice core, Antarctica, is linked to the activation and increased distant advection from the eastern Ross Sea polynya”. The new tests we made do not argue in favor of this statement.

Abstract P1 L2. Provide the name of the core here too: Terre Adélie 192A (TA192A). Done.

P1 L5. It is not necessary to include “hereafter” when you introduce a new acronym. Writing “... reconstructed surface mass balance (SMB)” should suffice. Change this throughout. I removed it throughout the manuscript.

In the abstract you might even consider avoiding the acronyms altogether to be brief. We removed all acronyms in the abstract.

P1 L15. Remove the space so it says:”isotope-temperature relationship” Done.

P1 L20. Use another type of dash for intervals, that is, the en-dash: “135 âŮę–145 âŮęE” and “1998–2014”. Change throughout. Done.

Introduction P3 L22. Change this sentence so it reads? ...are thus essential to provide continuous local to regional sub-annual resolution climate information spanning the last decades. We modified the sentence to: “. . .are thus essential to provide continuous climate information spanning the last decades at sub-annual resolution, at local but also regional scales."

You would ultimately be more interested in information about past climate conditions, not just a couple of decades back. Recent data is important for the interpretation of the isotopic signal as there is an overlap between the observational records and proxy records. From a SMB point of view, it also allows to expand the documentation of the spatio-temporal variability and the comprehension of the underlying mechanisms.

P3 L24. The SMB acronym has already been introduced on line 11. Done.

P3 L27. The ITASE cores (Mayewski 2005; Steig et al. 2005) are not coastal (at least not all of them), unless you define everything that's not on the plateau as coastal. They are similar to coastal cores, however, in that they are exposed to synoptic conditions. We removed the citation, and did not replace it by another one, as those given in the following sentence illustrates this purpose: "in Dronning Maud Land (e.g. Isaksson and Karlén, 1994; Graf et al., 2002; Altnau et al., 2015) and the Weddell Sea Sector (Mulvaney et al., 2002). Fewer annually resolved water stable isotope records have been obtained from ice cores in other regions, such as the Ross Sea sector (Bertler et al., 2011), Law Dome (Morgan et al., 1997; Delmotte et al., 2000; Masson-Delmotte et al., 2003), Adélie Land (Yao et al., 1990; Ciais et al., 1995; Goursaud et al., 2017), and Princess Elizabeth region (Ekaykin et al., 2017)".

P4 L5. Change to "initiated" instead of "triggered"? Done.

P5 L3. I would remove "until now". Otherwise it sounds like you have resolved this issue here once and for all in this study. Done.

P5 L11. Under-documented, is not a common word (at least not according to google Ngram), replace? Can you say, "remains poorly documented and understood", instead? Done.

P7 L19. Stick to one convention for units, so write "3.9 m s-1" here instead. Done.

P6 L17. Remove "search" here and say something like, highlights the importance of

retrieval of more Done.

P6 L22. 139.56âŮęE not S. Done

P7 L6. I would say resolution instead of scale here. Done.

P7 L7. Remove ", and dated." And start a new sentence and say "these records were used to establish the age scale for the firn core. Done.

P7 L10. Section references can be shortened, e.g., Sect. 2. Material and method Done.

P7 L18. No need to write "(see Fig. x), (Fig. x) should be fine. Change throughout. Done.

P8 L4. You write ", respectively" here but it's not clear what it refers back to. Rewrite so this sentence becomes clear. We completed the sentence as follows: "Samples devoted to ionic concentration measurements were stored in the cold room until concentrations of sodium (Na+), sulfate (SO42-), and methane sulfonate (MSA) were analyzed by ion chromatography equipped with a CS12 and an AS11 separator column, for cations and anions respectively."

P8 L8. Write Picarro without all the caps. P8 L16. Use the DDU acronym. Done. P8 L18. When in 1959? March. We precised it in the text.

P8 L24. Change to "range" not "ridge". And change the dash symbol for the range. Done.

P9 L3. Change to ". . . km from the TA drill site" instead. Done.

P9 L10. Move Table 1 to the supporting material? We did not remove Table 1 to the supplementary material so references of all data we used are cited in the manuscript.

P9 L15. Change to "back-trajectories" to be consistent with the rest of the text Done.

P9 L19. Change to "DDU intra-annual precipitation variability." instead. Done.

P9 L20. If you use the 0.75âŮęx0.75âŮę grid data, wouldn't the grid point at 139.50âŮęE be the closest point to the drill site, not 140.25âŮęE? Note that you can choose even higher resolution when downloading the data. We made this mistake as we were thinking about observations at Dumont d'Urville (66.7 °S, 140.0 °E). We thus extracted the precipitation for the grid point 0.75 ° western (i.e. 139.5 °E). We did not substantial changes neither in the distribution of the precipitation along the year (see Table 7 in the Supplement attached to this response, and replaced in table S7 of the Supplementary Material of the manuscript), nor in the mean precipitation of 46.0 ± 26.9 cm w.e. y-1 (replaced p15 l14).

P9 L28. 1500 m a. s. l. not m. a. g. l.? Yes indeed. We changed it.

P10 L24. Change to "... same simulation as Goursaud et al. ...", instead of ". . .same simulation than Goursaud et al. . . .". Done.

P10 L26. Can you add one more year of ECHAM5-wiso output data to the analysis to match the analysis period of the core? Done. It did not change any results of our study.

P10 L27. End the sentence with a period. Did you rather mean a point?

Results

P11 L7. Change to "multi-year study"? Done.

P13 L5. "...obtain a ratio of 0.5 (see Section 3.3)". Did you want to reference the supplementary table again, Table S3? We meant the next supplementary material, so we replaced Section 3.3 by the corresponding supplementary table 6.

In the supplementary table, it also looks like the ratio for d-excess is 1.1, not 0.5. I think you are a bit too thorough when you write (in the Supplementary Material) for each entry. Write it one time and then after that Fig. S1 and Table S1 etc. should suffice. We made a mistake and corrected this ratio to 1.1 in the text.

P15 L5. You write nssSO4 in many different ways throughout the paper (and define the

acronym at several places). I assume they are the same? Stick to one. We checked that the same notation nssSO4 was used through all the manuscript and changed it when it was not the case.

P15 L24. You mean $p<0.05$, not >0.05. We changed it to $p<0.05$.

P15 L25. The significance level should be <0.001 than, if r=1? Be consistent with the significant levels throughout, that is, include the <0.001 level too. In the Material and methods section, we precised the significance level p11 l13: "Note also that linear relationships are considered significant when the p-value < 0.05."

P15 L27. Change to "... in Fig.6. In Figures 6 and 7,..". Done.

P16 L1. Change to "Figs. S5 and S6" instead. Done.

P16 L5. "The sea ice trend is the largest in summer, they disappear if we discard the value observed in 2013." This sentence seems ambiguous, as it can be interpreted as it is only the trend in summer that is lost if 2013 is omitted. Split the sentences into two parts. We changed the sentences to: "Significant increasing trends are detected in the annual values of TA d-excess (0.11 ‰ y-1, r=0.61 and p<0.05) as well as of local and Indian Ocean sea-ice concentrations (0.10 % y-1, r=0.53 and r=0.52 respectively, p<0.05) with the largest sea-ice trend in summer. The sea-ice disappear if we discard the value observed in 2013."

P16 L18. Delete the "at all" part of the sentence. Done.

P16 L17 It is not clear what ", respectively" refers back to here. We detailed "r=0.65 and r=0.55 for δ18O and d-excess respectively".

P16 L26. It is just one value. You can present the p-value here instead of providing the range. We gave the exact p-value of 0.08.

P16 L27. Is it anti-correlated or positively correlated? This is hard to follow. We resentenced: "Although we are cautious with the short DDU precipitation time series (with only 19 points, and p-values = 0.08, cell in italics in Table 5), it shows a positive relationship, similar to the one identified in the TA record. We conclude that the positive correlation observed in the TA records is specific to the coastal Adélie Land region, what is unusual in an Antarctic context."

P20 L4. "This relationship is valid for all seasons." Done.

P20 L7 "m.s-1" the period is not needed. We actually removed what was related to wind speed as we did not use it in the manuscript.

P20 L12. Correct figure reference, (Fig. S8). Done.

P20 L14. and L18. I understand why you have put the table and figure together. However, it is probably better to present them separately and refer to them as (Fig S#) and (Table S#) in the text. Done

P20 L14. Indeed there is a large spike on 7 May. Nevertheless, there are also other anomalously positive events during 2007 that contribute to the annual anomaly. It is the only so high value during the year (with a value of 43.3 per mille!). The second highest value is 27 per mille and all other values are below 20 per mille. As written previously, there are only 4 other so high d-excess values simulated over the period 1998-2014 (ie > 30 per mille, maximum d-excess mean + standard deviation simulated by ECHAM5-wiso over Antarctica at the monthly scale).

P20 L20. Please clarify this sentence. This is a case where I think a subscript can be handy and a table to refer to. As you have simulated and TA d-excess and DDU and wiso 2mT, it is hard to keep them apart. Especially in a long sentence like this. The sentence was rewritten as: "Neither t2mECH – δ18OECH, nor SMBECH – d-excessECH, nor δ18OECH – d-excessECH relationships are identified in ECHAM5-wiso seasonal or annual outputs."

P20 L24. Please provide a p-value. Rather than providing a p-value, we specified that the correlation is significant: "a systematic positive significant correlation. . ."

P21 L12. Change to "On average,". Done.

P21 first paragraph. You say that the calculation are based on the 1998–2014 period, on the 2nd line, that should be enough, so you can remove the "over the period 1998–2014" text from line 13, 13–14, and 15 as it is redundant. Done.

P22 L4. "and classified the time series for each variables by", Change to "variable" instead. Done.

Discussion

P23 L3. "slightly increasing but not significant trend". I'm afraid that you can't call it a trend if it is not significant. If it has some significance, p<0.1, you can perhaps call it weak. Given the additional 2014 year output from the ECHAM5-wiso and the lack of significant trend, we changed the sentence to: "For our study period (17 years for the TA record, and the ECHAM5-wiso simulation), we observe no significant trend."

P23 L18. I believe it is just called sastrugi when plural too. Done.

P24 L3. Are you referring to the wrong supplementary figure here? P24 L16. Is this p-value correct? Do you use too many zeros? We copied the data as given in the reference. However, we harmonized in our manuscript with our notation and thus replaced this value by 0.05. We specified this threshold for considering the relationships significant p11 l8: "Note also that linear relationships are considered significant when the p-value < 0.05."

P25 L3. The formatting of this header has been lost. Done.

P25. L27. Did you use 10 points (see Fig. 11) or 12 (see the referenced line) for the smoothing and running correlation? We used a 10-points running correlation. Many thanks for pointing this absent-mindedness.

P26 L13. "As a result, the δ18O-d-excess relationship may be a fingerprint of changes in air mass origins, and particularly of the occurrence of precipitation of air masses coming from the WAIS+Pacific sector". From visually inspecting Figure 7a (and from what you mention in the text) it seems like air originating from WAIS + Pacific and the Ross Sea sectors has increased. If your cite statement above would hold up, how would I see this in Figure 11? The frequency of occurrence of significant relationships (bold line) seems quite even throughout. 2007 and 2011 stand out as anomalies, but so does 1999, 2001, 2003. Or is 2007 more remarkable because it is a negative anomaly? Or do you mean that a spike in the slope signals an abrupt change in air origin, e.g. a sudden change from Indian to WAIS+Pacific? Are there any remarkable conditions associated with the year 1999, 2001 and 2003 too? We observe that anomalies in the δ18O-d-excess slope, i.e. values out of the range defined by mean $\pm$ 2 standard deviations ([-0.81;2.48] ‰ ‰1), are associated to years 2007 (-1.46 ‰ ‰1) and 2011 (6.9 ‰ ‰1), identified as particular from air mass back-trajectories. Checking, we realized that we had made a mistake for year 2002 which is actually within the range by mean $\pm$ 2 standard deviations. Slopes calculated for years 1999, 2001 and 2003 are also within this range. Although we note concomitant specificities in δ18O-d-excess slopes and air masses from the western sector, we could not explain processes behind these features. The origin of the air masses might not be the only condition to explain these particular isotopic signatures, but also specific moisture conditions at this location or along the trajectory. We were limited to investigate processes, as for this, we would need data allowing the identification of events (typically daily data).

P26 L17. ". . . respectively (consistently with what obtained within each year, see. . .). ". . .-1, respectively (this is consistent with the annual means, see. . .). Does this sound better? Done.

P27 L7. Change to "not only with stake data closest to the drill site". Done.

P27 L11. "However, we cannot draw any conclusion. . ." Done.

P27 L12. "(Unfortunately, there are no striking features during the records common period, which makes it challenging to match the isotope records)". Done.

P27 L18. "These findings suggest". Done.

P28 L2. "(from ice cores, snow precipitation, and water vapour)' Done.

P28 L5. "We compare the chemical concentrations recorded in the TA firn core with S1C1core, for their common period (1998–2006). The mean concentrations are slightly lower for the. . ." Done.

P28 L15. "Air originating from near the sea ice margin may contain relatively high d-excess". In general, I think to say just "air" is fine, that is, the "mass" or "masses" part is often not needed. We prefer to keep using "air masses" which is more rigorous physically as it characterizes an air parcel by its temperature and water vapor content.

P28 L17. "Such a configuration. . ." this sentence is confusing as it doesn't appear to correspond to the setting described above. The presiding sentence describes a low sea ice setting and the latter describes a positive sea ice scenario, so these sentences don't seem to correspond with one another. "Such a configuration should be associated with high sea-salt concentrations due to increased sea-salt emissions when the sea-ice concertation is low in summer." In this configuration, we meant that sea-salts concentrations should be high compared to air originating from ocean. We thus reworded: "Such a configuration should be associated to low sea-salt concentrations due to the presence of the sea ice, as shown by atmospheric studies (Legrand et al., 2016)."

P28 L25. Chang to "probably caused by marine air advection". Done.

P28 L26. It might be better to avoid starting sentences with a conjunction ("And" here) in formal writing, as some people might object to it. We removed it.

P29 L13. Change the highlighted parts of the sentence "...insure that small scale SMB random variability caused by presence of sastrugis, dunes and barchans is negligible. . ." to "ensure that small-scale SMB random variability caused by presence of sastrugi, dunes and barchans is negligible". Done.

P28 L19. “In contrast, vapour formed over the ocean. . .” Done.

P29 L1. Change to “To summarize,” or “In summary,” instead. Done.

Conclusions and perspectives P29 L11. Change to “The high estimated SMB rate of 74.1 $\pm$ 14.1 cm w.e. y-1 limits the effects of diffusion and ensures that records with sub-annual resolution are preserved.” Done.

Figures Change the figure texts so that not everything is in bold. Just keep the fig numbering (Fig. 1, etc) and the letter (a) indicators in bold. Change throughout this section. It is not necessary to write “in” when you specify units, e.g. (in ‰Ċhange throughout the document. Done.

Fig. 2. Remove the 45âŮęS boundary in the figure, otherwise, it looks like these regions have a northerly limit at this latitude. Done.

Defining sectors: *It is confusing that you use both signs (-, +) and letters to indicate the hemispheres. Stick to just letter. Done.

*I also suggest that you write the intervals as ranges as you do otherwise. That way you can skip the “lat”, “lon” text too, S/N and W/E provides you with this information. Example: Ross Sea sector: 0âŮę–75âŮęS, 180âŮę–240âŮęE. You write that you don’t have any equatorward boundary. Assuming that you don’t have any endpoint in the NH you can write this way. Done.

*Skip the dash in “Ross-Sea sector” as it is a name. I also don’t think you need all of the quotation marks when you introduce the names, see if you can write this in a clear way without them. We removed the dash in “Ross Sea sector”. However, we remained the quotation marks as it refers to the text in the figure.

*Note also, that you wouldn’t usually call a sector that extends so far into the Atlantic Ocean, Indian or WAIS+Pacific. We changed the names of the regions: “Indian” to “the eastern sector”, and “WAIS+Pacific to “the western sector.

*Apply this formatting guidance to where you define sectors elsewhere in the text too, e.g. P8 L25 and P10 L12. Done.

Fig. 3. The δ18O record seems to be shown both as regular value and a smoothed record, but you don’t tell the reader how the record has been smoothed. You reference Fig. 3 in the figure text, but this is Fig. 3. For clarity it would be better if you list what the figure show here and describe the methodology elsewhere. Smoothing of δ18O should have been removed, as we had made tests for dating, but finally did not use it. We thus replicated the figure without.

Fig 6. Local sea-ice extent with a % that is in the 124–134% range, this looks odd to me? Fig. S6 should be the same just with the standard deviation too. However, note here how the range of sea ice concertation is different. You write sea ice concentration in the figure text and sea ice extent on the figure axis, please clarify. All that said, I rather see that you scrap this figure and replace it with correlation maps. As mentioned before, we changed the definition used for the sea ice: whereas we looked at the mean concentration (which is, by the way, over 233 in the NSIDC data; so we forgot to divide the outputs by 233 for the figure), we defined the sea ice extent face to Dumont d’Urville as the number of grid point with a sea ice concentration higher than 15 % between 135 and 145 °E. The figure was changed with recalculated values, consistently with this last definition.

Fig. 7. Mention the panels in order, that is, accumulation occurs last, but is mentioned first in the text. Done.

Fig. 9. A letter is missing text inside the figure, it should say “Plateau”. Can you increase the length of the bars (a, b) so it will be easier to see differences between the regions? You could also consider splitting a, c and b, c into two separate figures and align a, c so that the years in the panels correspond to each other, that is so that 1998 and 2014 is aligned in a and c. And that the moths are aligned in a similar manner in b, d. Subplots a and b were removed to show only a sector diagram with mean

percentage of back-trajectories for each sector.

Fig. 11. Maybe start the sentence with "Ten" instead of 10. There is also one parenthesis bracket too many. Sentence 2. Change to "Significant results are indicated by thick lines ($p<0.05$)". It is confusing that the secondary axes exceed 1.0. Also, you might want to change so it's not using a comma for the axis text, (e.g.1.0 instead of 1,0). Done.

Supplementary material The CNRS affiliation is missing for Vincent Favier, Suzanne Preunkert, and Michel Legrand. Show figures and tables as separate items. Done.

Start by list the tables Table S1, S2, S3, . . ., then continue with the figures in a new section (Fig. S1). Done.

Table S7 ". . .and deuterium excess ("dxs") from. . .", change to ". . .and d-excess from. . ." to be consistent with the rest of the document.

Place the text associated with figures below the figures. Done.

The year 2014 seems to be missing in Fig. S8. Add one more year of ECHAM5-wiso output data to the analysis to match the analysis period. Done.

Article references Please, format the references list so that there is wider line space between individual article entries (like in the Reference list below). It is hard for the reader to identify where one entry start or ends otherwise. Done.

The Cavalieri et al. 1996 reference does not appear in the Reference list. We added it.

Figures attached to this response

Figure 1: Annual layer counting of the TA192A firn ice core with the numbering of the years of uncertainty tested for the dating. Figure 2: Correlation coefficient between the sea-ice concentration extracted from the Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) and Defense Meteorological Satellite Program Special Sensor Microwave/Imagers - Special Sensor Microwave Image/Sounder (DMSP SSM/I-SSMIS)

passive microwave data (http://nsidc.org/data/nsidc-0051) and stable water isotopes records from the TA192A ice core (using the original age-depth relationship), δ18O in (a), and d-excess in (b). Figure 3: First empirical orthogonal function of moisture uptake in the boundary layer and the upper troposphere simulated by the moisture source diagnostic Watersip at the monthly scale over the period 1998-2014 (Sodemann, H., and Stohl, A.: Asymmetries in the moisture origin of Antarctic precipitation, Geophysical research letters, 36, 1-5, 2009.)

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Author's changes in the manuscript We took into consideration your suggestion as well

as E. Thomas'. We also add a data availability paragraph referring to the PANGAEA data archive. Please find below the resulting revised manuscript. Abstract. A new 21.3 m firn core was drilled in 2015 at a coastal Antarctic high accumulation site in Adélie Land (66.78 °S; 139.56 °E, 602 m a.s.l.), named Terre Adélie 192A (TA192A). The core was dated by annual layers counting based on non-sea-salt sulfate and methane-sulfonate summer peaks, refined by a comparison between the reconstructed surface mass balance (hereafter, SMB) and the closest available stake data. The mean reconstructed surface mass balance SMB of 75.2 $\pm$ 15.0 cm w.e. y-1 is consistent with local stake data, and remarkably high for coastal East Antarctica. The resulting inter-annual and sub-annual variations in isotopic records (δ18O and deuterium excess, hereafter d-excess) are explored for 1998 – 2014 and are systematically compared with a couple of climatic time series: an updated database of Antarctic surface snow isotopic composition, surface mass balance SMB stake data, meteorological observations from Dumont d'Urville station, sea ice concentration based on passive microwave satellite data, precipitation outputs of atmospheric reanalyses, climate and water stable isotope outputs from the atmospheric general circulation model ECHAM5-wiso, as well as air mass origins diagnosed using 5-days back-trajectories. The mean isotopic values (-19.3 $\pm$ 3.1 ‰ for δ18O and 5.4 $\pm$ 2.2 ‰ for d-excessdeuterium excess) are consistent with other coastal Antarctic values. No significant isotope- temperature relationship can be evidenced at any timescale. This, rulesing out a simple interpretation of in terms of local temperature. An observed asymmetry in the δ18O seasonal cycle may be explained by the precipitation of air masses coming from the eastern Indian and Pacific/West Antarctic Ice Sheet western sectors in autumn and winter times, recorded in the d-excess signal showing outstanding values in austral spring versus autumn. Significant positive trends are observed in the annual d-excess record and local sea ice extent (135 °E—145 °E) over the period 1998-2014. However, processes studies focusing on resulting isotopic compositions and particularly the deuterium- excess- δ18O relationship, evidenced as a potential fingerprint of moisture origins, as well as the collection of more isotopic measurements in Adélie Land are needed for an accurate interpretation of our signals. âĂČ 1. Introduction Motivation for new coastal Antarctic firn cores Polar ice cores are exceptional archives of past climate variations. In Antarctica, many deep ice cores have been drilled and analyzed since the 1950s. For instance, Stenni et al. (2017) compiled water stable isotope data from 112 ice cores spanning at least part of the last 2000 years. Most deep ice cores were drilled in the central Antarctic plateau where low accumulation rates and ice thinning give access to long climate records. In today's context of rapid global climate change, it is of paramount importance to also document recent past climate variability around Antarctica. Many Antarctic regions still remain undocumented due to the lack of accumulation and water stable isotope records from shallow ice cores or pits (Masson-Delmotte et al., 2008; Jones et al., 2016). An accurate knowledge of changes in coastal Antarctic surface mass balance (hereafter, SMB), an evaluation of the ability of climate models to resolve the key processes affecting its variability, and thus an improved confidence in projections of future changes in coastal Antarctic surface mass balance is important to reduce uncertainties on the ice sheet mass balance and its contribution to sea level change (Church et al., 2013). Meteorological observations have been conducted since 1957 in manned and automatic stations (Nicolas and Bromwich, 2014), and considerable efforts have been deployed to compile and update the corresponding dataset (Turner et al., 2004). This network is marked by gaps in spatio-temporal coverage (Goursaud et al., 2017) as well as systematic biases of instruments such as thermistors (Genthon et al., 2011). Satellite remote sensing data have been available since 1979 and provide large-scale information for changes in Antarctic sea- ice and temperature (Comiso et al., 2017), but do not provide sufficient accuracy and homogeneity to resolve trends at local scales (Bouchard et al., 2010). Coastal shallow (20 – 50 m long) firn cores are thus essential to provide continuous local to regional climate information spanning the last decades at sub-annual resolution, at local but also regional scales. They complement stake area observations of spatio-temporal variability in surface mass balance (Favier et al., 2013), which also help assessing the representativeness of a single record. Since the 1990s, efforts have been made to retrieve shallow ice cores in coastal Antarctic areas .Most

of these efforts have been focused on the Atlantic sector, in Dronning Maud Land (e.g. Isaksson and Karlén, 1994; Graf et al., 2002; Altnau et al., 2015) and the Weddell Sea Sector (Mulvaney et al., 2002). Fewer annually resolved water stable isotope records have been obtained from ice cores in other regions, such as the Peninsula (Fernandoy et al., 2018), the Ross sSea sector (Bertler et al., 2011), Law Dome (Morgan et al., 1997; Delmotte et al., 2000; Masson-Delmotte et al., 2003), Adélie Land (Yao et al., 1990; Ciais et al., 1995; Goursaud et al., 2017), and Princess Elizabeth region (Ekaykin et al., 2017). However, the recent 2k temperature and SMB reconstructions for Antarctic (Stenni et al., 2017; Thomas et al., 2017) highlighted the need for more coastal records. In this line, Nnew coastal drilling efforts have recently been triggered initiated in the context of the ASUMA project (improving the Accuracy of SUrface Mass balance of Antarctica) from the French Agence Nationale de la Recherche, which aims to assess spatio-temporal variability and change in SMB over the transition zone from coastal Adélie Land to the central East Antarctic Plateau (towards Dome C).

Climatic interpretation of water stable isotope records Water stable isotope (δ18O, δD) records from central Antarctic ice cores have classically been used to infer past temperature changes (e.g. Jouzel et al., 1987). The isotope-temperature relationship was nevertheless shown not to be stationary and to vary in space (Jouzel et al., 1997), calling for site-specific calibrations relevant for various timescales (Stenni et al., 2017). In coastal regions, several studies showed no temporal isotope-temperature relationship at all between water stable isotope records in firn cores covering the last decades and near-surface air temperature measured at the closest station. This is for instance the case in Dronning Maud Land, near the Neumayer station (three firn cores, for which the longest covered period is 1958-2012, Vega et al., 2016), in the Ross Sea sector (one snow pit covering the period 1964-2000, Bertler et al., 2011), and in Adélie Land, close to DDU (one firn core covering the period 1946-2006, Goursaud et al., 2017). While several three-dimensional atmospheric modelling studies have suggested a dominant role of large-scale atmospheric circulation on the variability of coastal Antarctic snow δ18O (e.g. Noone and Simmonds, 2002; Noone, 2008), understanding the drivers of coastal Antarctic δ18O variability remains challenging (e.g. Schlosser et al., 2004; Dittmann et al., 2016; Bertler et al., 2018; Fernandoy et al., 2018). While distillation processes are expected theoretically to relate condensation temperature with precipitation isotopic composition, a number of deposition processes can distort this relationship: changes in moisture sources (Stenni et al., 2016), intermittency or seasonality of precipitation (Sime et al., 2008), boundary layer processes affecting the links between condensation and surface air temperature (Krinner et al., 2008), as well as several post-deposition processes, such as the effects of winds (Eisen et al., 2008), snow-air exchanges (Casado et al., 2016; Ritter et al., 2016), and diffusion processes in snow and ice (e.g. Johnsen, 1977). Nevertheless, all these processes remain poorly quantified until now. As a result, comparisons between firn core records with precipitation records or simulations have to be performed carefully. Changes in the atmospheric water cycle can also be investigated using a second order parameter, deuterium excess (hereafter, d-excess). The definition given by Dansgaard (1964) as d-excess = δD – 8 x δ18O aims to remove the effect of equilibrium fractionation processes to identify differences in kinetic fractionation between the isotopes of hydrogen and oxygen. In Antarctica, spatial variations of d-excess have been documented through data syntheses, showing an increase from the coast to the plateau (Masson-Delmotte et al., 2008; Touzeau et al., 2016), but temporal variations of d-excess (seasonal cycle, inter-annual variations) remain under-documented and poorly documented and understood. Theoretical isotopic modeling studies show that d-excess depends on evaporation conditions, mainly through the impacts of relative humidity (hereafter RH), and sea surface temperature (hereafter SST) on kinetic fractionation at the moisture source (Merlivat and Jouzel, 1979; Petit et al., 1991; Ciais et al., 1995), and the preservation of the initial vapor signal during transportation towards polar regions (e.g. Jouzel et al., 2013; Bonne et al., 2015). The effect of wind speed on kinetic fractionation is secondary and thus has been neglected in climatic interpretations of d-excess. Some studies usually privileged one variable (RH or SST). For instance, glacial – interglacial d-excess have classically been interpreted to reflect past changes in moisture source SST, neglect-

ing RH effects or assuming co-variations of RH and SST (Vimeux et al., 1999; Stenni et al., 2001; Vimeux et al., 2001). Recent measurements of d-excess in water vapor from ships have evidenced a close relationship between d-excess and oceanic surface conditions, especially RH, at sub-monthly scales (Uemura et al., 2008; Pfahl and Sodemann, 2014; Kurita et al., 2016). Other recent studies have suggested that evaporation at sea ice margins may be associated with a high d-excess value due to low RH effects, a process which may not be well captured in atmospheric general circulation models (e.g. Kurita, GRL, 2011; Steen-Larsen et al, 2017). Several authors have thus identified the potential to identify changes in moisture sources using d-excess (Ciais et al., 1995; Delmotte et al., 2000; Sodemann and Stohl, 2009). The comparison between multi-year isotopic precipitation datasets with the identification of air mass origins using back-trajectories showed however a complex picture, with no trivial relationship between the latitudinal air mass origin and d-excess (Schlosser et al., 2008; Dittmann et al., 2016). A few studies have also explored sub-annual d-excess variations, and suggested that seasonal d-excess signals cannot be explained without accounting for seasonal changes in moisture transport (e.g. Delmotte et al., 2000). These features have been explored through the identification of back-trajectory clusters and their relationship with δ18O—d-excess relationships, including phase lags (Markle et al., 2012; Caiazzo et al., 2016; Schlosser et al., 2017). Most of these d-excess studies have been performed using firn records and not precipitation samples. We stress that the impact of post-deposition processes on d-excess remain poorly documented and understood. While relationships between moisture origin and d-excess should in principle be conducted on vapour measurements to circumvent the uncertainties associated with deposition and post-deposition processes, the available vapour water stable isotope records from Antarctica only cover one or two summer months (Casado et al., 2016; Ritter et al., 2016) and do not yet allow to explore the relationships between moisture transport and seasonal or inter-annual isotopic variations. Also, state-of-the-art atmospheric general circulation models equipped with water stable isotopes such as ECHAM5-wiso can capture d-excess spatial patterns in Antarctic snow, but they fail to correctly reproduce its seasonal variations (Goursaud et al., 2017). Finally, the understanding of the climatic signals preserved in d-excess is limited by the available observations. This motivates the search importance of retrieval of morefor highly resolved d-excess records from coastal Antarctic firn cores.

This study In this study, we focus on the first highly resolved firn core drilled in coastal Adélie Land, at the TA192A site (66.78 ° S;, 139.56 ° ES;, 602 m a.s.l., hereafter named "TA"). Only two ice cores and one snow pit were previously studied for water stable isotopes in this region, without any d-excess record: the S1C1 ice core (14 km from the TA, 279 m a.s.l., Goursaud et al., 2017), the D47 highly resolved pit (78 km from the TA, 1550 m a.s.l., Ciais et al., 1995) and the Caroline ice core (Yao et al., 1990). The climate of coastal Adélie Land is greatly influenced by katabatic winds (resulting in a very high spatial variability of accumulation), and by the presence of sea ice (Périard and Pettré, 1993; KönigâĂŘLanglo et al., 1998), including the episodic formation of winter polynya (Adolphs and Wendler, 1995), which lead to nearby open water during winter time. The regional climate is well documented since March 1957 at the meteorological station of Dumont d'Urville, where multi-year atmospheric aerosol monitoring has also been performed (e.g. Jourdain and Legrand, 2001). The spatio-temporal variability of regional SMB has also been monitored at annual time scale since 2004 through stake height and snow density measurement over a 156-km stake-line (91 stakes) (Agosta et al., 2012; Favier et al., 2013). The TA firn core was analysed at sub-annual scale resolution for water isotopes (δ18O and δD) and chemistry (Na, SO42-, and MSA), and dated. These records were used to establish the age scale for the firn core. Using these records, we explore: (i) the links between the TA isotopic signals, local climate and atmospheric transport, (ii) the possibility to extract a sub-annual signal from such a highly-resolved core, and (iii) how to interpret the d-excess signal of coastal Antarctic ice cores. In this manuscript, we first present our material and methods (Sect.ion 2), then describe our results (Sect.ion 3) and compare them with other Antarctic records and the outputs of the ECHAM5-wiso model in our discussion (Sect.ion 4), before summarizing our key

findings and formulating suggestions for future studies (Sect.ion 5). 2. Material and method 2.1 Field work and laboratory analyses We present here the results of one firn core drilled at the TA site (66.78 ° S;, 139.56 ° S;, 602 m a.s.l.), located at 25 km from Dumont d'Urville station (hereafter, DDU) and at 14 km from the S1C1 ice core (Goursaud et al., 2017; Fig. 1). The 21.3 m long firn core was drilled on the 29th of January in 2015, when the daily surface air temperature and wind speed were -8.5°C and 3.9 m/.s-1 respectively, at the D17 station (9 km from the drilling site). The FELICS (Fast Electrochemical lightweight Ice Coring System) drill system was used (Ginot et al., 2002; Verfaillie et al., 2012). Firn core pieces were then sealed in polyethylene bags, stapled and stored in clean isothermal boxes. At the end of the field campaign, the boxes were transported in a frozen state to the cold-room facilities of the Institute of Environmental Geoscience (IGE, Grenoble, France). Every core piece was weighted and its length measured in order to produce a density profile. The cores were sampled at 4 cm resolution, leading to a total of 533 samples for oxygen isotopic ratio and ionic concentrations following the method described in Goursaud et al. (2017). Samples devoted to ionic concentration measurements were stored in the cold room until concentrations of sodium (hereafter Na+), sulfate (hereafter SO42-), and methane sulfonate (hereafter MSA) were analyzed by ion chromatography equipped with a CS12 and an AS11 separator column, for cations and anions respectively. Samples devoted to oxygen isotopic ratio were sent to LSCE (Gif-sur-Yvette, France) and analyzed following two methods. First, δ18O was measured by the CO2/H2O equilibration method on a Finnigan MAT252, using two standards calibrated to SMOW/SLAP international scales, with an accuracy of 0.05 ‰Ṡecond, δ18O and δD were also measured using a laser cavity ring-down spectroscopy (CRDS) PicarroICARRO analyzer, using the same standards, leading to an accuracy of 0.2 ‰ and 0.7 ‰ for δ18O and δD respectively. The resulting accuracy of d-excess, calculating using a quadratic approach, is 1.7 ‰2̇.2 Datasets Instrumental data To assess potential climate signals archived in our firn core records, we extracted meteorological data to explore regional climate signals, and outputs of atmospheric models to explore synoptic scale climate signals. The regional climate is well documented since 1957 thanks to the continuous meteorological monitoring at Dumont d'UrvilleDDU station (https://donneespubliques.meteofrance.fr/?fond=produit&id_produit=90&id_rubrique=32), with one gap between March 1959 and January 1960. We extracted near-surface temperature, humidity, surface pressure, wind speed and wind direction data computed monthly and annual averages over the periods 1957—2014 and 1998—2014. The monthly average sea ice concentration was extracted from the Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) and Defense Meteorological Satellite Program Special Sensor Microwave/Imagers - Special Sensor Microwave Image/Sounder (DMSP SSM/I-SSMIS) passive microwave data (http://nsidc.org/data/nsidc-0051), over the 50 – -90 °S latitudinal rangeridge at a 25 km x 25 km grid resolution (Cavalieri et al., 1996). D'Urville summer sea ice extent was estimated by extracting the number of grid pointssurface covering the area (50 – 90 °S, 135 – 145 °E) where the sea ice concentration is higher than 15 %, from December to January (included) for each year from 1998 to 2014. We then averaged sea- ice concentration data over four longitudinal sectors: (i) "local" (135°E – 145°E), (ii) "Indian" (100°E – 145°E), (iii) "Amundsen" (160°E – 205°E) and (iv) "regional" (100°E – 205°E). SMB measurements from stake point data were obtained from the Glacioclim observatory (https://glacioclim.osug.fr/). We extracted data from the three stakes closest to the TA drilling site, namely "18.3" (66.77 °S, 139.57 °E; 1.04 km from the TA drilling TA site), "19.2" (66.77 °S, 139.56 °E; 83 m from the drilling TA site), and "20.3" (66.78 °S, 139.55 °E; 1.00 km from the drilling TA site), all spanning the period 2004—2014.

Database of surface snow isotopic composition In order to compare the d-excess record from the TA firn core with available Antarctic values, we have updated the database of Masson-Delmotte et al. (2008), by adding 26 new data points from precipitation and firn core measurements provided with d-excess (see Table 1). This includes data from five ice cores from the database constituted by the Antarctica2k group (Stenni et al., 2017). Altogether, the updated database includes 777 locations. This includes 64 coastal sites at an elevation lower than 1000 m a.s.l., (with 19 new datasets).

These data were extracted from our updated isotope database (Goursaud et al., 2018) archived on the PANGAEA data library (https://doi.org/10.1594/PANGAEA.891279).

Atmospheric reanalyses and back-trajectories Unfortunately, because of the katabatic winds around DDU, no instrumental method allows reliable measurements of precipitation (Grazioli et al., 2017). We use outputs from ERA-interim reanalyses (Dee et al., 2011), which were shown to be relevant for Antarctic surface mass balance (Bromwich et al., 2011), to provide information on DDU intra-annual precipitation intra-annual variability. We extracted these outputs from the grid point (0.75 ° x 0.75 °, $\sim$ 80 km x 80 km, point centered at 66.75 °S and 13940.25 °E) closest to the TA drilling site over the period 1998—2014, at a 12-hours resolution, and calculated daily, monthly and annual average values. We also extracted 2-meter temperature (2mT), 10-meter u and v wind components (u10 and v10), and the geopotential height at 500 hPa (z500) over the whole southern hemisphere (50 °S – 90 °S), in order to investigate potential linear relationships between our records and the large-scale climate variability. In order to identify the origin of air masses, back-trajectories were computed using the HySPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) model. It is an atmospheric transport and dispersion model developed by the National Oceanic and Atmospheric Administration's (NOAA) Air Research Laboratory (Draxler and Hess, 1998), based on a mixing between Lagrangian and Eulerian approaches (Stein et al., 2015). We set the arrival point at the coordinates of the TA drilling site, at an initial height of 1500 m a.sg.l., and used the NCEP/NCAR Global Reanalysis ARL archived data for forcing the meteorological conditions, as the ERA-interim reanalyses are not available in the required extension. Earlier studies (e.g. Sinclair et al., 2010; Markle et al., 2012) highlighted good performances of NCEP outputs when compared with Antarctic station data after 1979. For instance, previous studies showed that the mean sea level pressure simulated at DDU and averaged on a 5 year running window, was well captured in NCEP reanalyses after 1986 (correlation coefficient > 0.8, bias < 4 hPa and RMSE < 5 hPa) (Bromwich and Fogt, 2004; Bromwich et al., 2007). Also, Simmons et al. (2004) showed quasi-equal twelve months running mean of 2-meter temperatures for the Southern Hemisphere between the European Re-Analyses ERA-40, the NCEP/NCAR and the Climatic Research Unit CRUTEM2v products. We thus run daily five-days back-trajectories from January 1998 to December 2014. Each back-trajectory was analyzed for the geographical position of the last simulated point (the estimated start of the trajectory, 5 days prior arrival at DDU), and classified into one of the following four regions, represented on Figure 2 and defined by their longitude (hereafter, lon) and latitude (hereafter, lat) as follows : (i) the eastern sector"Indian": (0 – 66 °S, 0 °E –<lon < 1680 °E, 0 °S – and lat > -66 °S), (ii) the "Plateau": (66 – 90 °S, 0 °E –< lon < 180 °E, and lat<-66 °S – 90 °S), (iii) "the Ross- sSea sSector": (0 – 75 °S, 180 °E – <lon< 240 ° E, and lat > -0°S – 75 °), and finally (iv) "the Wwestern sectorAIS + Pacific": (0 – 75 °S, 180 °E <lon< – 240 °E, lat<-0 °S – 75 °S), and (50 – 90 °S, 240 °E –<lon< 360 °E). (no condition for the latitude).

Atmospheric general circulation and water stable isotope modeling: ECHAM5-wiso The potential relationships between large-scale climate variability and regional precipitation isotopic composition was also investigated through outputs of a nudged simulation performed with the atmospheric general circulation model ECHAM5-wiso (Roeckner et al., 2003), equipped with stable-water isotopes (Werner et al., 2011). We chose this model due to demonstrated skills to reproduce spatial and temporal patterns of water stable isotopes in Antarctica (Masson-Delmotte et al., 2008; Werner et al., 2011; Goursaud et al., 2017; SteenâĂŘLarsen et al., 2017), and in Greenland (Steen-Larsen et al, 2017). In this study, we use the same simulation asthan Goursaud et al. (2017), in which the large-scale circulation (winds) and air temperature were nudged to outputs of the ERA interim reanalyses (Dee et al., 2011). The skills of the model were assessed over Antarctica for the period 1979—20143. The model was run in a T106 resolution (i.e. ∼ 110 km x 110 km horizontal grid size),. In the following, we used the subscripts "ECH", "TA", and "S1C1" to differ ECHAM5-wiso outputs from the TA and S1C1 firn cores records respectively (e.g. δ18OTA and δ18OECH). Note also that linear relationships are considered significant when the p-value < 0.05.

Modes of variability We tested either the main modes of variability were imprinted in our recorded, especially: - the Southern Annual Mode (SAM) using the index defined by Marshall (2003), and archived on the National Center for Atmospheric Research website (Marshall, Gareth & National Center for Atmospheric Research Staff (Eds). Last modified 19 Mar 2018. "The Climate Data Guide: Marshall Southern Annular Mode (SAM) Index (Station-based)." Retrieved from https://climatedataguide.ucar.edu/climate-data/marshall-southern-annular-mode-sam-index-station-based.) - the El Niño Southern Oscillation (ENSO) using el Niño 3.4 index defined by the Climate Prediction Center of NOAA's National Centers for Environmental Prediction, and archived on their website (Trenberth, Kevin & National Center for Atmospheric Research Staff (Eds). Last modified 06 Sep 2018. "The Climate Data Guide: Nino SST Indices (Nino 1+2, 3, 3.4, 4; ONI and TNI)." Retrieved from https://climatedataguide.ucar.edu/climate-data/nino-sst-indices-nino-12-3-34-4-oni-and-tni.) - the Interdecadal Pacific Oscillation (IPO), using the IPO Tripole Index (TPI) defined by Henley et al. (2015) based on filtered HadISST and ERSSTv3b sea surface temperature data and archived on the internet (Accessed on 09 20 2018 at "https://www.esrl.noaa.gov/psd/data/timeseries/IPOTPI".). - the Amundsen Sea Low pressure center (ASL) archived one the National Center for Atmospheric Research website (Hosking, Scott & National Center for Atmospheric Research Staff (Eds). Last modified 19 Mar 2018. "The Climate Data Guide: Amundsen Sea Low indices." Retrieved from https://climatedataguide.ucar.edu/climate-data/amundsen-sea-low-indices.) 3. Results 3.1 Firn core chronology Ice core dating The firn core was dated using an annual layer counting method (Fig. 3). As in Goursaud et al. (2017), we used concentrations in MSA and non-sea-salt (nss) SO42- (hereafter nssSO42-). We have explored the validity of an approach using a definition of nssSO42- based on a sulfate to sodium mass ratio of 0.25 inferred from summer observations only. The multi-ple year study of size-segregated aerosol composition conducted at the coast of TA (the DDU station) has demonstrated that sea-salt aerosol is depleted in sulfate with respect to sodium in winter, with a sulfate to sodium mass ratio of 0.13 from May to October instead of 0.25 (i.e. the sea-water composition) in summer (Jourdain and Legrand, 2002). Even at the high plateau station of Concordia, Legrand et al. (2017a) showed that sea-salt aerosol is depleted in sulfate in winter (sulfate to sodium ratio of 0.13 from May to October). We resampled the sulfate time series recorded in the TA with 12 points per year and inferred seasonal average values from averages over the corresponding subsets of points, as previously done for isotopic records (see Section 3.2). We then calculated nssSO4 (hereafter noted as nssSO4*) using a sulfate to sodium ratio of 0.25 for points associated to months from November to February and 0.13 for points associated from months from March to September. Note that when ignoring the change in sulfate to sodium ratio in winter, (i.e. applying a sulfate to sodium ratio of 0.25 for all the points of the year), the mean nssSO4 value is lower by 18.2 %, decreasing from 36.5 $\pm$ 12.3 ppb to 43.1 $\pm$ 11.8 ppb for nssSO4* (see Figure S1 in the Supplementary Material). We thus applied a calculation of nssSO4 for all points of our firn core, only using the sulfate to sodium ratio obtained from summer observations, as [nssSO42-] = [SO42-] – 0.25 [Na+]. For depths lower than 10 m w.e., Ssummer (December-January) peaks were identified (i) from nssSO4 values higher than 100 ppb, synchronous with MSA peaks (with no threshold), and (ii) for nssSO4 values higher than 200 ppb (with or without a simultaneous MSA peak). Double nssSO4 peaks were counted as one summer (e.g. 2012, 2003, and 2001). For depths higher than 10 m w.e., summer peaks were identified for nssSO4 values higher than 27 ppb. The outcome of layer counting allowed us to estimate annual layer thickness, which, combined with the density profile, allowed us to estimate annual SMB in the firn core. This estimated SMB was then compared with stake area data. The three stake data closest to the TA firn core ("18.3", "19.2" and "20.3", not shown) depict the same inter-annual variability (pairwise coefficient correlations, r>0.93 and p-values, p<0.0501), giving confidence in the use of these measurements to characterize the inter-annual variability of local SMB. The comparison with the stake data shows that our initial layer counted chronology results in a mismatch in the measured versus estimated SMB for year 2008 (See Fig. 4a). This mismatch can be resolved by identifying one more sum-

mer peak in the chemical records (thin green line, Fig. 3). The revised firn core SMB record from this revised chronology shows correlation coefficients between the stake data and the TA firn core varying from 0.64 for the "20.3" to 0.83 for the "19.2" (p<0.05), with coherent inter-annual variability (See Fig. 4b). Peaks in δ18OTA or d-excessTA were not used in our layer counting, so that our age scale is independent of a climatic interpretation of water stable isotopes (e.g. assumption of synchronicity between temperature seasonal cycles and water stable isotope records). We note an uncertainty in layer counting of 3 years when comparing the outcome of layer counting using chemical records with δ18OTA peaks, which have nonetheless been excluded from our dating, as they do not improve the correlations, neither between the reconstructed SMB and the stake data, nor between our records and the ECHAM5-wiso simulations (Tables S1 to S34 in the Ssupplementary Mmaterial). As a result, we consider that the "best guess" chronology results from the annual layer counting based on nssSO4 and MSA refined with the comparison with stake data, giving a total of 18 summer peaks (green vertical lines, Fig. 3). In the following, we thus use the dated firn core records covering the complete period 1998—2014. We note that our chronology is more robust for the period 2004—2014, for which stake area SMB data are available.

Potential post-deposition effects In order to test whether the available d-excessTA records are not affected by post-deposition effects, one may apply calculations of diffusion (e.g. Johnsen et al., 2000; van der Wel et al., 2015; Jones et al., 2017). However, many records are not available as depth profiles, and annual accumulation rate data are missing, precluding a systematic approach. We thus applied a simple approach to quantify how the seasonal δ18OTA and d-excessTA amplitudes vary through time in firn records, as an indicator of potential post-diffusion effects. For this purpose, we calculate the ratio between the mean amplitude of the most recent three complete seasonal cycles (2011—2014 for TA) and the average seasonal amplitude for the whole record (1998—2014 for TA). If seasonal cycles are stable through time, and if there is no significant smoothing due to post-deposition effects, we should obtain a ratio of 1. However, it is expected to be above 1 in the case of large post-deposition smoothing.

We obtain a ratio of 0.5 for TA δ18OTA data, possibly reflecting the inter-annual variability of the δ18O seasonal amplitude. We repeated the same exercise with all the 8 other sub-annual δ18O records from our database (see Table S452 in the Supplementary Material.). Discarding an outlier (NUS 08-7), all ratios are between 1.0 and 2.9. Ratios based on d-excess amplitudes are similar to those found for δ18O (see Table S563 in the Supplementary Material). For the TA firn core, we again obtain a ratio of 1.10.5 for d-excessTA (see Section 3.3). We also note high ratios for d-excess data in the NUS 08-7. Except for the ratios calculated in the WDC06A, which notably differs for d-excess (1.1) compared to δ18O (2.9), other ratios for d-excess data vary between 1.0 and 1.4, with 20 % maximum difference compared to the corresponding ratio for δ18O data. For the TA, we also estimated the diffusion length (Küttel et al., 2012), and found mean diffusion lengths of 1.4 $\pm$ 0.3 months for δ18OTA (with a maximum of 1.9 months in 2007), and 1.6 $\pm$ 0.5 months for d-excessTA (with a maximum of 2.4 months in 2007). These results suggest that (i) potential post-deposition effects in the TA can be neglected. Notwithstanding, a potential loss of seasonal amplitude in the other average time series compared to the most recent seasonal cycles cannot be discarded, and has to be considered in the comparison of seasonal amplitudes, from one core to the other, in the comparison with the seasonal amplitude of precipitation δ18O time series, and with ECHAM5-wiso outputs. 3.2 Mean values Mean climate from instrumental data Before reporting the mean values from TA records, we describe the available meteorological data. A time-averaged statistical description of the available meteorological data measured at DDU, the station closest to the drilling site, is given in Table 2 for the whole available measurement period prior to 2015 (1957—2014), and over the period covered by our TA records, 1998-2014. For all the considered parameters (near-surface temperature, wind direction, wind speed, humidity, and surface pressure), the time-averaged values differ by less than 8% (the maximum deviation being for the wind direction) over the period 1998-2014 compared to the whole available period. Standard deviations calculated over these two time periods also differ by less than one respective standard deviation unit, except for wind direction which shows

much less variability over the recent period. We conclude that the local climate of the period 1998—2014 is representative of the multi-decadal climate state since 1957. In ERA-interim, the average precipitation is 46.053.7 $\pm$ 26.97.6 cm w.e. y-1 and the average SMB (calculated as precipitation minus evaporation or sublimation) is 40.5 $\pm$ 8.3 cm w.e. y-1 over the period 1998—2014. Finally, we compare the statistical description of the sea ice concentration for the four aforementioned regions (see Section 2.2) over the available period 1979—2014, with the period covered by the TA firn core 1998-2014 (see Table 3). We note that the mean difference between the two periods is maximum for the local sea ice concentration (135 °E – 145 °E), with 8.9 % difference, whereas it is remains below 1.5 % for the other sectors. The extrema (minimum and maximum values) varies of 0.5 % on average (all regions included) from one sector to another, with a maximum difference of 2.9 %. As a result, the mean sea ice concentrations of the period 1998—2014 are also representative for the last decades over large sectors from Amundsen to Indian Ocean.

Mean values recorded in the TA firn core Time-averaged values calculated from TA records are reported in Table 4. The average SMBTA is 75.2 $\pm$ 15.0 cm w.e. y-1. Stake data points from Glacioclim show that this site of high accumulation is located in an area of large spatial variability. This features is confirmed by the values given by (i) the stake data closest to the TA site (“19.2”, 100 m for the TA site and associated to a 76.6 $\pm$ 25.8 cm w.e. y-1 mean accumulation rate) compared to further stake data (“18.2”, 1.04 km from the TA site and associated to a 47.7 $\pm$ 15.7 cm w.e. y-1 mean accumulation rate), (ii) our mean SMB reconstruction from the S1C1 ice core almost four times lower than for the TA (21.8 $\pm$ 6.9 cm w.e. y-1 (Goursaud et al., 2017)) (iii) and meso-scale fingerprints such as the SMB estimated for coastal Adélie Land by Pettré et al. (1986), based on measurements at stakes located from 500 m to 5 km from the coast and the estimated SMB simulated by ERA-interim 85.7 % lower than for the TA (see Table 2). The TA average δ18OTA value is -19.3 $\pm$ 3.1 ‰ close to the average S1C1 δ18OS1C1 of -18.9 $\pm$ 1.7 ‰ and the average TA d-excessTA is 5.4 $\pm$ 2.2 ‰Compared to the 64 points located at an elevation lower than 1000 m a.s.l.

from our database, the TA δ18OTA and d-excessTA average values are slightly higher than the average low-elevation records (-22.7 ± 8.8 ‰ and 4.8 ± 2.3 ‰ for δ18O and d-excess respectively, see Fig. 5). Finally, the average TA concentrations in Na+, MSA and nssSO4 are of 126.0 ± 276.5 ppb, 4.5 ± 5.6 ppb and 36.5 ± 44.2 ppb respectively. Note that the Na+ average concentration value is affected by strong peaks in 2003 and 2004 with annual values of 369.4 and 388.5 ppb. Excluding these two peaks, the average Na+ concentration is reduced to 93.2 ppb (with a standard deviation of 38.6 ppb). These concentrations will be discussed later in Section 4.4.

To summarize our findings, the TA records encompass a period (1998—2014) representative of multi-decadal mean climatic conditions. The isotopic mean values appear lower than the average of other Antarctic low elevation records (as shown in Fig. 4). The local SMB is remarkably high for East Antarctica, consistent with stake measurements performed close to the TA site. 3.3 Inter-annual variations In the following, we refer to seasons as follows: summer (December to February), autumn (March to May), winter from (June to September) and spring (October and November). This cutting was defined based on the mean seasonal cycle of temperature, showing the highest values from December to February, and a plateau of low values from May to September (see Fig. 8a). In the TA records, resampled with 12 points per year, we identified seasonal average values by calculating averages over the corresponding subsets of points (e.g. for autumn, we select from the 3rd to the 5th points out of the 12 resampled points within the year). We are fully aware that this is a simplistic approach, assuming a regular distribution of precipitation year round, and that our chronology is more accurate for summer than for other seasons, due to the layer counting method. We nevertheless checked that the distribution of precipitation simulated by ERA-interim within each year is rather homogeneous (see Table S674 in the Supplementary Material).

Trends in time-series We report here the analysis of potential trends from 1998 to 2014, and the identification of remarkable years. Figure 6 and 7 display the time series of meteorological variables, d'Urville summer sea -ice concentration extent and TA

records over 1998—2014. Sea ice concentrations from all selected sectors in this study (see Section 2.2) are correlated (r>0.56 and p>0.05), particularly the “local” and the “Indian” sea ice concentrations (r=1.0 and p<0.05), “local” sector being part of the “Indian” sector. As a consequence, although we explored sea ice records from all sectors described in Section 2.3, we thus only depict the local sea ice concentration (i.e. in the 135 —145 °E sector) on Fig. 6. IOn Figures 6 and 7, we chose not to display standard deviations for readability, but they are reported in the Supplementary Material (see Fig. S285 and S3965). Significant increasing trends are detected in the annual values of TA d-excessTA (0.11 ‰ y-1, r=0.61 and p<0.05) as well as of local and Indian Ocean d'Urville summer sea ice concentrationsextent (0.10 % y-1, r=0.7753 and r=0.52 respectively, p<0.05). The sea ice trend is the largest in summer, they trendsdisappear if we discard the value observed in 2013.

Pairwise linear regressions between variables We performed pairwise linear regressions for all records (meteorological and firn core records), using on one side, annual averages and on the other side, monthly or seasonal values. As previously observed by Comiso et al. (2017), we report a significant anti-correlation between annual regional sea ice concentration (i.e. 100 – 205 °E, but not with other sectors) and DDU near-surface air temperature (r=-0.56 and p<0.05). This relationship is strongest in autumn (r = -0.75 and p<0.05), where it holds for sea- ice in all sectors, and disappears in spring or summer. Confirming earlier studies (Minikin et al., 1998), we observe a close correlation between annual concentrations of MSA and nssSO4 (r=0.76, p<0.05). Statistically significant linear relationships appear between the isotopic signals (δ18OTA and d-excessTA) and nssSO4 in spring (r=0.65 and r=0.55 for δ18OTA and d-excessTA respectively, p<0.05), and only between d-excessTA and nssSO4 in autumn (r=0.65 and p<0.05). We find no relationship between δ18OTA and the DDU near-surface temperature at all. Our record depicts a significant anti-correlation between annual values of TA SMBTA and d-excessTA (r=-0.59 and p<0.05), as well as a significant correlation between d-excessTA and d'Urville summer sea ice extent (r=0.65 and p<0.05). Finally, aA systematic positive significant correlation is identified between d-excessTA and δ18OTA, except in summer. It is the strongest in austral spring, with a correlation coefficient of 0.75 (with a slope of 0.61 ‰ ‰1). In order to understand the specificities of the TA record, we explored the temporal correlation between δ18O and d-excess from all available Antarctic records (see Table 5, cells in bold for significant relationships), using all data points (in order to be able to exploit non-dated depth profiles) as well as inter-annual variations, when available. When focusing on significant results, we note that most precipitation datasets depict an anti-correlation between d-excess and δ18O (3 out of 9 precipitation records). Although we are cautious with the short DDU precipitation time series (with only 19 points, and 0.05<p-values = 0.08<0.10, cell in italics in Table 5), it shows a positive relationship, similar to the one identified in the TA record. At the inter-annual scale, significant results correspond to anti-correlations between d-excess and δ18O for 3 out of 9 precipitation records. We conclude that the positive correlation observed in the TA records is specific to the coastal Adélie Land region, what is unusual in an Antarctic context.

Remarkable years Using only annual SMB, water stable isotope and chemistry TA records, we finally searched for remarkable years, defined here as deviating from the 1998—2014 mean value by at least 2 standard deviations. We highlight three remarkable years (red-shaded for high values and blue-shaded for low values, Fig. 6 and 7): ïĆő Year 2007: very low SMBTA in in TA data. ïĆő Year 2009: remarkably high δ18OTA values. ïĆő Year 2011: high MSA, d'Urville summer sea ice extent, and wind speed values. We had previously noted that years 2003 and 2004 are associated with very high Na+ values and add that year 1999 experienced low nssSO4 values. and year 2013 high local sea ice concentration. The remarkable large sea ice concentration was also observed at a larger scale by Reid et al. (2015).

To summarizeIn summary, we identify increasing trends in d-excessTA and sea -ice concentration, no significant correlation between TA δ18OTA and DDU near-surface temperature, and an anti-correlation between d-excessTA and SMBTA. We also note 2 remarkable years in SMBTA ("dry" 2007) and δ18OTA ("high" 2009). Finally, no sys-

tematic relationships are identified between chemistry and water stable isotope signals (e.g. parallel trends, inter-annual correlation, and remarkable years). 3.4 Intra-annual scale Mean cycles The high resolution of the TA record allows us to describe the mean seasonal cycles (see Fig. 8), as well asand to explore the inter-annual variability of the seasonal cycleall seasonal cycles to explore how they vary from year to year. Among the meteorological variables, only near-surface temperature, relative humidity and sea level pressure show a clear seasonal cycle. Temperature (Fig. 8a) is minimum in July and maximum in January, while relative humidity and pressure (Fig. 8b and 8c respectively) are minimum in spring (in November and October respectively), and a maximum in winter (in August and June respectively), as reported in earlier studies (Pettré and Périard, 1996). The average seasonal cycles of wind speed and wind direction are flat but marked by large inter-annual variations (Fig. 8d and 8e). Finally, the local sea ice concentration shows a rapid advance from March to June, a plateauing from June to October and a rapid retreat from October to November, with a minimum in February (see Fig. 8c), as previously reported by Massom et al. (2013). In the TA firn core, Na, nssSO4, and MSA show symmetric cycles with minima in winter and maxima in summer (by construction of our time scale) (see Fig8 g-i), consistent with previous studies of aerosols and ice core signals (e.g. Preunkert et al., 2008). The δ18OTA seasonal cycle is surprisingly asymmetric (Fig. 8j), with a maximum in December and a minimum in April, thus not in phase with the seasonal cycles of local sea- ice concentration (Fig. 8f) nor DDU temperature (Fig. 8a). The mean d-excessTA seasonal cycle (Fig. 8k) is marked by a maximum in February, two months after the δ18OTA maximum, and a minimum in October, six months after the δ18OTA minimum. We then calculated the mean of the isotopic seasonal amplitudes, preferentially to the amplitude of the mean seasonal cycle, due to the different timing of peaks from one year to another. The mean δ18OTA seasonal amplitude is 8.6 $\pm$ 2.1 ‰ more than three times higher than found in the S1C1 ice core, and close to the DSSA mean δ18O seasonal cycle of 8.0 $\pm$ 2.8 ‰Ṫhe mean d-excessTA seasonal amplitude is 6.5 $\pm$ 2.8 ‰ close to the DSSA value of 5.3 $\pm$ 1.0 ‰Ċompared with other precipitation and firn/ice core isotopic data from other regions of Antarctica (see Table S7107 in the Supplementary Material), the average seasonal amplitude obtained from TA δ18O is closest to the one obtained at KM, BI sites in Dronning Maud Land, and Vernadsky or Rothera in Peninsula, but is much larger than identified from NUS 08-7 or WDC06A, and significantly smaller than at Halley (by a factor of almost 2), Neumayer (a factor of 2.3), Dome C or Dome F (a factor of $\sim$4). In addition to DSSA, the average seasonal amplitude obtained from TA d-excess is also comparable to the one obtained in the KM, BI, and the IND25B5 firn cores in Dronning Maud Land, but is systematically higher (by a factor higher than 3) than in precipitation datasets. This calls for systematic comparisons of d-excess seasonal amplitudes in precipitation and snow data. Due to their common symmetric aspect, significant positive linear relationships emerge from the mean seasonal cycles of (i) temperature, nssSO4 and MSA (r>0.93 and p<0.05), (ii) nssSO4 and MSA (r=0.97 and p<0.05), (iii) nssSO4 and Na+ (r=0.93 and p<0.05) and finally (iv) δ18O with nssSO4 (r=0.75 and p<0.05). Due to the asymmetry of water stable isotope seasonal cycles, no linear relationship is detected between the seasonal cycles of DDU near-surface temperature, δ18OTA, and d-excessTA. Finally, the seasonal cycle of d-excessTA is clearly anti-correlated with all sea -ice concentration indices (local, Indian, Amundsen and regional), with correlation coefficients varying between -0.83 and -0.80.

Inter-annual variability of peaks Over the whole period covered by the TA firn core (1998—2014), the seasonal cycle of δ18OTA shows a large inter-annual variability (see Table 6). δ18OTA maximum values occur primarily in summer (41 % of the time) and winter (41 %), and more rarely in spring (12 %) and in autumn (6%). The same feature is observable for d-excessTA, which most of the time has its maximum in summer (38 %) and winter (43 %), and more scarcely in spring (6%) and in autumn (13%).

In summary, the TA water stable isotope seasonal cycles displays an asymmetry, with higher isotopic values in austral spring than in austral autumn. The TA d-excessTA seasonal cycle is anti-correlated with the reconstructed SMBlocal sea ice concentration. Finally, the TA isotopic seasonal cycles show a high inter-annual variability from one

seasonal cycle to another one, with no recurrent pattern between those of δ18OTA and d-excessTA. 3.5 Influence of synoptic weather on TA records: insights from ECHAM5-wiso simulation, ERA-interim reanalyses, and back-trajectories and modes of variability In order to explore the influence of the synoptic scale weather on TA records, we explore outputs of ECHAM5-wiso and back-trajectory calculations, driven by atmospheric reanalyses. None of the associated atmospheric simulations does resolve local processes such as katabatic winds or sea breeze. We used the ECHAM5-wiso model outputs to explore the following questions: (i) Do ECHAM5-wiso outputs show similarities with the corresponding observed variables for their inter-annual variability, trends and remarkable years? (ii) What are the simulated seasonal cycles for δ18O and d-excess? (iii) What are the simulated relationships between local near-surface air temperature and δ18O, and δ18O and d-excess at the seasonal and inter-annual scales? (iv) Are there significant relationships between our isotopic records and the large-scale climatic variability?

ECHAM5-wiso similarities with the corresponding observed variables For inter-annual variations, the annual means of DDU near-surface temperature measured at DDU and the simulated 2-meter temperature (hereafter 2m-TECH) are significantly correlated (slope of 0.850 $\pm$ 0.149, r=0.767 and p<0.05). This relationship holds when selecting any seasonis valid for all seasons. It is the strongest in winter (slope of 1.13 $\pm$ 0.1 °C °C-1, r=0.936 and p<0.05), and the weakest in summer (slope of 0.986 $\pm$ 0.3 °C °C-1, r=0.69 and p<0.05). The simulated wind speed is only significantly related to the observed wind speed during spring and summer (slope of 0.36 $\pm$ 0.15 m.s-1 (m.s-1)-1 and 0.21 $\pm$ 0.08 m.s-1 (m.s-1)-1 respectively, r=0.54 with p<0.05 for both relationships). For δ18O, model outputs are only correlated with the TA record in winter (slope of 0.25 $\pm$ 0.11 ‰ ‰1, r=0.53 with p<0.05), and no correlation is identified for d-excess.There are no significant correlation between water stable isotope records from the TA and simulated by the ECHAM5-wiso, neither for δ18O, nor for d-excess. Finally, wWe found no significant trend in any model output over 1998—20143. In terms of remarkable years, ECHAM5-wiso shows a low δ18OECH mean value in 1998 and a high d-excessECH mean valuelevel in 2007 (see Fig. S4118 in the Supplementary Material). Only year 2007 is remarkable in both the data (low reconstructed SMB) and the model. We thus explored more deeply the model. The highest d-excess value was simulated the 7th of May (see Table S8129a in the Supplementary Material). When comparing from the 6th to the 8th of May in 2007, with daily averages over the period 1979-20143, the model simulates similar near-surface temperature, but particularly low precipitation, and wind components (zonal and meridional). Despite the small precipitation amount, the daily isotopic anomaly is sufficiently large to drive the annual anomaly (see Fig. S5912b in the Supplementary Material). D-excess values higher than 30 ‰ (threshold chosen as it corresponds to the maximum d-excess mean + standard deviation simulated by ECHAM5-wiso over Antarctica at the monthly scale, see Fig. S613 in the Supplementary Material) occur only 4 other timer over 1998—2014. We nevertheless remain cautious with theseis values which could be due to a numerical artefact. Neither δ18Ot2mECH – δ18OECHtemperature, nor SMBECHd-excess – d-excessECH - SMB, nor δ18OECH – d-excessECH relationships are identified in ECHAM5-wiso seasonal or annual outputs for precipitation and d-excess. Likewise, no significant relationship could be identified between d-excessTA and SMB simulated by ERA using both annual and seasonal values. A systematic positive correlation is identified between d-excess and δ18O, except in summer. It is the strongest in austral spring, with a correlation coefficient of 0.75 (with a slope of 0.61 ‰ ‰1).

Simulated seasonal cycles for δ18O and d-excess We now explore the simulated seasonal variations in δ18OECH and d-excessECH over the period of simulation (1998-20143, see Table 6). The peaks in the simulated δ18OECH predominantly occur in spring and summer (25 % and 63 % respectively), while it only happens 12 % of the time in winter and never in autumn. The simulated d-excessECH peaks most often in autumn (69 %) and secondarily in winter (31 %), but never during the other seasons. As a result, the model simulates more regular isotopic seasonal cycles with δ18O maxima during spring to summer seasons, and d-excess maxima during autumn to winter seasons, than identified in the TA record.

Relationships with the large-scale climatic variability The ERA-interim outputs allow us to investigate whether the large-scale climatic variability influence the isotopic composition of Adélie Land precipitation recorded in the TA firn core. We looked at the simulated linear relationships between the TA isotopic records (δ18OTA and d-excessTA) with the ERA-interim outputs (2mT, u10, v10 and z500, Section 2.2). We here report only significant relationships with absolute correlation coefficients higher than 0.6. For δ18OTA, we found a correlation with 2m-T over the Antarctic plateau (Fig.12a), as well as a correlation with v10 (Fig. 12b) along the westerly wind belt, at $\sim$ (55 °S, ; 100 °E) and $\sim$ (55 °S, ; 130 °E) in the Indian Ocean, and at $\sim$ (55 °S, ; 10-50 °E) in the Atlantic Ocean, and a very little area on coastal Dronning Maud Land at $\sim$ (60 °S ,; 30-40 °E). For d-excessTA, we found a correlation with 2m-T (Fig. 12c) toward the Lambert Glacier at $\sim$ (70-80 °S ,; 30-40 °E), and an anticorrelation in the south of the Peninsulat at $\sim$ (55-65 °S,; 250-300 °E). Finally, we noted a correlation between d-excessTA and u10 (Fig. 12d) at a very narrow area of Dronning Maud Land at $\sim$ (80 °S,; 10-20 °E), and an anticorrelation on the westerly wind belt in the Atlantic Ocean at $\sim$ (55 °S,; 40-50 °E). No correlation is found with z500, neither with δ18OTA nor d-excessTA. Note that no significant relationship is obtained between the TA records and any mode of variability.

Origin of air masses Finally, we used the HYSPLIT back-trajectory model to count the proportion (in percentage) of air mass back-trajectories, based on daily calculations over the period 1998-2014, and averaged at the annual and seasonal scale, from four different regions (see Section 2.3): the plateau, the eastern Atlantic Ocean and th Indian Ocean (eastern sector), the Ross Sea sector (hereafter RSS), and the West Antarctic Ice Sheet with the Pacific Ocean and the western Atlantic Ocean (hereafter WAIS+Pacificwestern sector), as displayed on Fig. 92. IOn average, the highest annual proportion of air masses comes from the eastern sectorIndian Ocean (49.854.1 $\pm$ 6.48.3 % over the period 1998-2014) and the East Antarctic plateau (32.54.3 $\pm$ 4.93.8 % over the period 1998-2014), while a small proportion of air masses come from the WAIS and the Pacific Oceanwestern sectors (9.76 $\pm$ 3.76 % over the period 1998-

2014), and from the RSS (3.66.3 ± 2.41.3 % over the period 1998-2014). A k-mean clustering over the last points of the whole back-trajectories indicate two main origins, in the Indian Ocean (62.4 °S, 131.7 °E) and in the coastal West Antarctic Ice Sheet (73.4 °S, 227.5 °E). Inter-annual variations in back trajectories (Fig. 9ba and 9b) reveal a positive trend for the fraction of air masses coming from western sector WAIS+Pacific (slope of 0.416.5 ± 0.162.1 % y-1, r=0.5563 and p<0.05), and remarkable years: 1999, which was identified as a remarkable high δ18O value and low nssSO4 in our TA records, is here associated with a minimum of back-trajectories from the Plateau, and year 2011 which was associated with particular high MSA in our TA record, shows a minimum particular low proportion of air massesback-trajectories coming from the Indian regionestern sector and maxima ofwhile particular high proportion of air masses back-trajectories coming from the Ross and the western sectorsWAIS+Pacific regions. The seasonal cycles of back-trajectories per region is shown on Figures 9c and 9d. The percentage of back-trajectories coming from the Plateau display peaks in autumn and spring (March and November), those from the Ross Sea sector in winter and summer (January and June), those from the Indian Oceaneastern sector in autumn and winter (May and August), and finally those from the WAIS+Pacificwestern sector region in spring (November). We note a significant linear correlation between the seasonal cycles of the percentage of δ18O and back-trajectories coming from the Ross sea sector (r=0.68 and p<0.05), and from the WAIS+Pacific regionwestern sector (r=0.59 and p<0.05), and between the seasonal cycles of d-excess and the percentage of back-trajectories coming from the WAIS+Pacific regionwestern sector (r=-0.678 and p<0.05). Finally, we associated each daily back-trajectory to daily precipitation δ18O and d-excess values simulated by ECHAM5-wiso in the precipitation, and classified the time series for each variables by back-trajectories sectors. We then computed the corresponding seasonal cycles (see Fig. 10). The mean δ18OECH value is slightly higher for air masses coming from the easternIndian sector (-20.6 ‰ compared to -21.9± 0.2 for the other sectors). The asymmetry in δ18OECH is particularly well marked for air masses coming from the Ross sea and western WAIS+Pacific sectorsregions, with

peaks in August and September respectively (resulting in a winter amplitude more than twice higher compared to the Indian eastern and Plateau sectors), and correspond to higher precipitation amounts during these months during the winter season. The d-excess mean seasonal cycles substantially differ by their amplitude: for air masses coming from WAIS+Pacificthe western sector, it is 11.8 ‰ with outstanding values in March and October (minima) and in May (higher than the mean plus two standard deviations), whereas it varies between 3.2 ‰ and 3.6 ‰ for the other sectors. The back-trajectory of the 7th of May in 2007 (shown to be remarkable of simulated d-excess by ECHAM5-wiso) was identified as coming from the western sectorWAIS+Pacific, but those associated with the 4 other remarkable simulated d-excess (i.e. > 30 ‰ indicate air masses coming the three other regions, and sometimes varying with the hour of the day (S613 in the Supplementary Material). To summarizeIn summary, we found a mismatch between ECHAM5-wiso outputs and the TA data for d-excess variations. There are no similarities for trends, for seasonal cycles, or for inter-annual isotopic variations. ECHAM5-wiso produces a significant relationship between δ18O and temperature, a feature which is not identified in the TA record. However, bSimilarly than in the TA firn core, ECHAM5-wiso simulates no δ18OECH – t2mECH correlation, but no d-excessECH – δ18OECH. Both TA records and ECHAM5-wiso depict an unusual feature in 2007, with dry conditions and high d-excess values. The comparison between TA records and air mass back trajectories suggests that the asymmetry in the δ18O seasonal cycle is due to the precipitation of air masses coming from the the western sectorWAIS+Pacific region, and that an increased occurrence of (rare) air masses coming from the the western sectorWAIS+Pacific region is associated with high d-excess values. 4. Discussion 4.1 SMB The estimated SMB of East Antarctica does not show a clear trend since 1900 (Favier et al., 2017). Recent studies (Altnau et al., 2015; Vega et al., 2016; Ekaykin et al., 2017) report negative SMB trends in coastal areas contrary to positive trends for the plateau. Especially, Thomas et al. (2017) report an unprecedented negative trend observed in Victoria Land for the last 50 years (1961-2010). For our study period (17 years for the TA record, and16 years for the ECHAM5-wiso simulation), we observe noa slightly increasing but not significant trend (Agosta et al., 2012), the TA firn core, the ERA or ECHAM5-wiso data. In Adélie Land, a quality controlled SMB dataset has been developed (Favier et al., 2013), but the drivers of SMB spatio-temporal variability remain unexplored (Favier et al., 2017). This is related to the challenges in monitoring 1) precipitation in windy areas 2) sublimation of precipitating snow flakessnowflakes (Grazioli et al., 2017) in the katabatic flow, 3) and the amounts of surface erosion or deposition according to surface wind convergence or divergence, of drifting snow fluxes, and of sublimation of the drifting snow particles (Gallée et al., 2013; Amory et al., 2016; Amory et al., 2017). The low correlation (over 1998-2006) between TA192A annual accumulation and from the first shallow ice core ("S1C1" (Goursaud et al., 2017)), collected 14 km from TA192A site, demonstrates this complexity, even though this mismatch may be explained by age scale uncertainties. The S1C1 reconstructed accumulation was also weakly correlated with stake data and model outputs, reflecting the random snow accumulation amounts due to the presence or absence of sastrugis, and the potential occurrence of annual erosion at S1C1 site (Fig. S7 in the Supplementary Material). Here, the TA accumulation record is highly correlated not only with the closest stake data, but also with the ECHAM5-wiso model output over the period 2004—2014, showing the robustness of our reconstruction for this period. The fact that the TA record, the ECHAM5-wiso output for the corresponding grid point, and the "156 km" stake area data are pairwise correlated ($0.79 \leq r \leq 0.90$ and $p<0.05$), indicates that the TA firn core captures a 100 km- scale regional signal. The differences between the local and regional SMB signal are (see Fig.3b): (i) a higher local SMB average compared to the regional SMB, and (ii) the shift of minimum peak of 2007 in the local signal (i.e. the TA firn core and the "19.2" stake data) to 2008 in the regional signal (see the 2007—2008 plateau in the "156 km" network and the 2008 minimum value simulated by the ECHAM5-wiso model in Fig. 3b). The anticorrelation between the d-excessTA and SMBTA shows the possibility to use water isotope firn core records from Adélie Land to complete the document of the SMB spatio-temporal variability. Dry air masses from the western sector may be associated

with particular high d-excess values. The remaining uncertainty in the dating and the extraction of a pure signal limited our investigation. As a conclusion, the absence of similarity between the TA and the S1C1 accumulation reflects the uncertainty in the S1C1 dating resulting from the large spatial variability and from more frequent erosion processes occurring at the S1C1 site (see Fig. S10 in the Supplementary Material). More ice core records within a 100 km area will allow reducing uncertainties in the interpretation of ice core signals, in particular on the link with the atmospheric variability. 4.2 The δ18O – temperature relationship in coastal Antarctic regions Several studies have shown that the annual δ18O – temperature relationship is weak in coastal regions. As an example, over Dronning Maud Land, Isaksson and Karlén (1994) found a weaker correlation between δ18O records and Halley temperature for coastal ice cores, i.e. for sites below 1000 m a.s.l., with a correlation coefficient of 0.56 compared to a correlation coefficient of 0.91 for site above 1000 a.s.l. More recently, Abram et al. (2013) reported a coefficient correlation of 0.52 for the relationship between δ18O recorded in the James Ross Island ice core (at a high of 1524 m a.s.l., with a mean reconstructed SMB of 63 cm w.e. y-1), and the near-surface temperature measured at Esperanza station (n=56 and p<0.05001,). In coastal West Antarctica, Thomas et al. (2013) also reported a significant but weak correlation between the the δ18O recorded in an ice core drilled on the Bryan coast and the near-surface temperature simulated by ERA-interim, over the period 1979-2009. Closer to Adélie Land, in Victoria Land, Bertler et al. (2011) found a correlation coefficient of 0.35 between the δ18O recorded in the Victoria Lower Glacier ice core (at a high of 626 m a.s.l.) and the summer near-surface temperature measured in Scott Base station (n=30 and p<0.0005). In this study, we find no relationship between the DDU near-surface temperature from DDU and the δ18OTA recorded in the TA firn core, based on annual averages. Similarly, no relationship had been identified in the S1C1 core (Goursaud et al., 2017), and was here not simulated by the ECHAM5-wiso model.. The ECHAM5-wiso model, over the period 1979-2013, selecting the grid point corresponding to the location of DDU (as well as the TA and S1C1 drilling sites), produces however a significant but weak relationship between the 2m-T and precipitation-weighted δ18O, with a slope of 0.27 ‰ (°C)-1 and a correlation coefficient of 0.35 ($p<0.05$). Our study shows that changes in air mass trajectories (dynamics) may dominate over thermodynamical controls (condensation temperature) on coastal Adélie Land δ18O signal, as shown by the asymmetry of the δ18O seasonal cycle recorded in the TA firn core (see Section 3.4 and Fig. 8). The coupling of calculations of air masses back-trajectory and ECHAM5-wiso outputs suggests that δ18O outstanding high values occurring during winter time would be brought by air masses coming from the WAIS+Pacificwestern sector (see Section 3.5 and Fig. 10). The δ18O measured in the ice of coastal Adélie Land may thus not allow to reconstruct surface temperatures of this region. However, correlations between δ18OTA and the 2m-temperature by ERA-interim over each grid point of Antarctica (Fig.12a) show significant relationships over the plateau, confirmed by a significant correlation between annual δ18OTA and the near-surface temperature measured at Dome C over the period 1998-2014 (slope of 0.70 $\pm$ 0.29 ‰ °C-1, r=0.53, p<0.05value=0.03). These results support previous studies suggesting warm intrusions offshore Dumont d'Urville towards Dome C (Naithani et al., 2002). Finally, the significant linear relationships with the u10 wind component above the westerly wind belt and at some coastal Antarctic area (Fig 12b) stress the influence of other processes than thermodynamic drive the isotopic composition of Adélie Land precipitations. 4.3 Water stable isotope, a fingerprint of changes in air mass origins In the TA firn core, tThe mean d-excessTA is 5.4 $\pm$ 1.0 ‰ close to the 4.7 $\pm$ 0.4 ‰ value simulated by the ECHAM5-wiso model for the "coastal Indian" region defined in Goursaud et al. (2017, different definition than in this study), and the 5.2 $\pm$ 0.6 ‰ value for the grid point corresponding to the TA drilling site. Inter-annual variations of TA d-excessTA (see Fig. 7) are anti-correlated with TA reconstructed SMB, a feature not depicted by ECHAM5-wiso.

Main trajectories imprinted in the TA isotopic records We suggest that air masses associated with small/large precipitation amounts are associated with different trajectories and moisture sources:, with main mass air mass origins from the Indian Ocean. These maritime air masses, isotopically enriched may transport water vapor , that for some,

persue their trajectories, to the plateau, as shown by the significant relationship between δ18OTA and the near-surface temperature of the plateau, especially in winter.; and rRare dry air masses may also comeing from the western sector, and that thiswith a signal is preserved in d-excess., These different cases we propose here are illustrated by Figure XX. Last pointa is leadled by the following hints: (i) the positive trends both for the TA d-excess and the percentage of air masses coming from the western sectorWAIS+Pacific region (ii) an anti-correlation between the seasonal cycles of the TA d-excess and percentages of air masses coming from the western sectorWAIS+Pacific region (iii) the high simulated d-excess amplitude simulated by ECHAM5-wiso for air masses coming from the western sectorWAIS+Pacific sector, reflecting outstanding values occurring in autumn and winter times (iv) The particular case of the 7th of May in 2007 with very high d-excess values simulated by ECHAM5-wiso, corresponding to an air mass trajectory from the western sectorWAIS+Pacific sector As pointed discussed earlier, the last item should be consideredis however to take with cautionus as the four other remarkable d-excess values (i.e. higher than 30 ‰ simulated by the ECHAM5-wiso are associated to air masses coming from other regions (S613 in the Supplementary Material), and also to the fact that such high values it could be due to potential a numerical artefacts. Linear relationships between d-excessTA and ERA-interim outputs come to strengthen the link between the climate variability of western Antarctic and associated southern oceans, as we note an anticorrelation between d-excessTA and the 2m-T in the south of the Peninsula, the Ellsworth region and the Bellingshausen sea (r>0.6); and an anticorrelation between d-excessTA and the u10 wind component over the coastal Ross sector, consistent with the suggestion of air masses trajectories coming from western Antarctica towards Adélie Land via the Ross sea sector. These dry air masses might origin from the Amundsen Bellingshausen sea (Winstrup et al., 2017; Emanuelsson et al., 2018), but cannot be directly linked to the Amundsen sea cyclonic, as we obtain no significant relationship with the ASL center pressure indices.

Potential interaction with sea ice Noone and Simmonds (2004) have shown, thanks to climate modelling, that water stable isotopes were conditioned by changes in sea ice extent (as a contraction in sea ice increases the local latent heat and temperature due to open water), but confirmed that a thorough understanding of main mechanisms controlling the d-excess was still needed. Also, earlier studies have suggested the use of the d-excess ice core recordsed in ice cores to reconstruct past sea ice extent (e.g. Sinclair et al., 2014). Although we find a significant correlation between the d-excessTA and the d'Urville summer sea ice extent (section 3.3), a correlation map between the annual d-excessTA and the summer sea ice concentration (S814 in the Supplementary Material) show significant correlations with further sea ice areas (e.g. an anticorrelation in the Amundsen sea and correlations in the Belligshausen, Scotia and Lazarev seas). We also noted a coincidence between the sign of the correlation of the relationship between the d-excessTA and the the sea ice concentration, and the sea ice extent trend over the period 1998-2014 (S915 in the Supplementary Material), especially positive correlations (negative) associated to positive sea ice concentration trends. These findings call for mechanistic studies to understand the different processes behind d-excess associated to each air mass origins. As we suggested a particular d-excess signature in the TA firn core, associated with air masses coming from the western sector, we tested the possibility for the d-excessTA to imprint changes in the Ross polynya. We thus estimated it, by counting the annual sea ice concentration over the polygon (60 – 70 °S; 150 – 210 °E), lower than 15 %. But we find no significant correlation between this estimated Ross polynya and the d-excessTA over the period 1998-2014.

The δ18O – δD relationship Earlier studies showed empirically that the relationship between d-excess and δ18O, and mainly the phase lag between signals within the seasonal cycle may indicate variations of the origin of the moisture source. This phage lag was shown to be of $\sim$ 3—4 months over coastal regions such as Law Dome (Masson-Delmotte et al., 2003), Dronning Maud Land (Vega et al., 2016) and in the Ross Sea sector (Sinclair et al., 2014). By contrast, most studies identified an anti-phase over the East Antarctic plateau (e.g. Ciais et al., 1995; Landais et al., 2012), and at D47, situated close to the TA drilling site (Ciais et al., 1995). We thus focus on the outcome

of the running linear regression between d-excessTA and δ18OTA over 102 points all along the core (see Fig. 11). We focus on the periods (53.3%) when a significant linear relationship is identified (i.e. p<0.05). The time-averaged correlation coefficient is 0.71 $\pm$ 0.45, which is consistent with the results obtained from the annual averages (varying from 0.51 in autumn to 0.75 in spring, see Section 3.3). The time-averaged slope is 0.83 $\pm$ 0.83 ‰ ‰1. These positive values prevail for 91.5 % of the significant linear regressions. However, we observe remarkable deviations from this overall relationship. Particularly, linear regressions within years 2002 and 2007 show slopes lower than the time-averaged minus two standard deviations (with a minimum value of -1.46 ‰ ‰1 in 2007), and others within year 2011 show surprisingly very high slopes up to 6.9 ‰ ‰1. The years 2007 and 2011 were also previously noticed: the mean d-excessECH simulated by ECHAM5-wiso for the year 2007 was shown to be driven by the high value occurring the 7th of May, associated to air masses coming from the WAIS+Pacificwestern sector; and year 2011 is associated with a minimum of annual back-trajectories percentage from the Indian regioneastern sector and maxima of back-trajectories from the Ross and the western sectorWAIS+Pacific regions. As a result, the δ18O-d-excess relationship may be a fingerprint of changes in air mass origins, and particularly of the occurrence of precipitation of air masses coming from the WAIS+Pacificwestern sector. We undertook the same exercise with outputs of the ECHAM5-wiso model (see Fig. S10711 in the Supplementary Material), where only 19.2 % of the simulated linear regressions are significant (i.e. p<0.05). All significant relationships have negative correlation coefficients and slopes of time-averaged values -0.72 $\pm$ 0.25 ‰ ‰1 and -0.39 $\pm$ 0.23 ‰ ‰1 respectively (this is consistently with the annual meanswhat obtained within each year, see Section 3.4). Moreover, these significant relationships do not occur during the remarkable years 2002, 2007 and 2011 identified in the TA firn core. As a result, we propose that remarkable anomalies in d-excess / δ18O running linear relationships provide an isotopic fingerprint associated with changes in dominant air mass trajectories. But a more comprehensive mechanistic study would be necessary to quantify the fractionation processes associated with different moisture source and transport characteristics. 4.3 4.4 Limits associated with model-data isotopic comparisons We note a mismatch between ECHAM5-wiso outputs and the data (see Section 3.5 and Fig. S4118 in the Supplementary Material). This could be related to (i) to post-deposition processes associated with wind scoring or snow metamorphism not resolved in ECHAM5-wiso, (ii) the key role of very local atmospheric circulation effects related to katabatic wind processes, not resolved in large-scale atmospheric reanalyses and simulations, (iii) or the difficulties of ECHAM5-wiso to resolve the processes associated with the ocean boundary vapour d-excess, a mismatch already identified in the Arctic (SteenâĂŘLarsen et al., 2017). The first issue is related with the robustness of records from a single coastal firn core. Several studies have evidenced signal to noise limits (e.g. Graf et al., 2002; Mulvaney et al., 2002). Given the high SMB estimated from TA, diffusion effects can be ignored (Frezzotti et al., 2007), and the estimated inter-annual variations in TA SMB are closely correlated not only with the stake data the closest to the drilling site, but also with the 156 km network stake data and to precipitation from the corresponding grid point of ECHAM5-wiso within a 100 x 100 km area. This finding supports an interpretation of the TA record to be representative of a regional SBM signal (100 km scale). However, we cannot draw have any conclusion of the signal to noise aspects of the water stable isotope records, given the lack of coherency between the inter-annual variability in the TA and S1C1 δ18O records for the few years of overlap (Unfortunately, there are no striking features during the records common period, which makes it challenging to match the isotope recordswith unfortunately no remarkable year in this period), and the lack of any other d-excess record within hundreds of kilometers. The second source of uncertainty lies in the mismatch between inter-annual variations from coastal Adélie Land meteorological observations and the TA records, with ECHAM5-wiso outputs. For instance, we only see high correlation for the surface air temperature inter-annual variations for winter, and weak correlation for wind speed in spring and summer. These itemfindings suggest limitations in the skills of either atmospheric reanalyses or the ECHAM5-wiso model to correctly capture the processes responsible for local climate variability. We

had previously reported the capability of ECHAM5-wiso to correctly simulate observed large-scale features of water stable isotopes and SMB across Antarctica, for spatio-temporal patterns identified from datasets spanning the last decades such as mean values, amplitudes and phases of mean seasonal cycles, amplitude of inter-annual variance, strength of isotope-temperature relationships, d-excess versus δ18O relationships) (Goursaud et al., 2017). We thus highlight here specific challenges related to the Antarctic coastline, where local processes associated with katabatic winds, open water (e.g. polynya), and local boundary layer processes (e.g. snow drift) may affect isotopic records without being resolved at the resolution of reanalyses and ECHAM5-wiso simulation. Our study therefore depicts limited understanding of the drivers of seasonal and inter-annual variability in coastal Adélie Land hydrological cycle, and thus calls for more isotopic measurements (from ice cores, snow precipitation, and water vapouralong ice cores, in precipitation and in vapour) in Adélie Land to reduce uncertainties. 4.4 4.5 Chemistry We compare the chemical concentrations recorded in the TA firn core with S1C1core (Goursaud et al., 2017), for their common period (1998–2006). The mean concentrations are slightly lower for theWe now compare the chemical concentrations recorded in the TA firn core compared to the costal S1C1 firn core (Goursaud et al., 2017a). On the common covered period (1998-2006), we observe that mean chemical concentrations are slightly lower in the TA than the S1C1 firn core from 30 % for Na+, to 50 % for MSA (see Table S1941 in the Supplementary Material). This decrease with the increasing distance from the coast (or elevation above sea level) is consistent with atmospheric studies showing a decrease of levels from the coast to the plateau for sea-salt (Legrand et al., 2017) and sulfur aerosols (Legrand et al., 2017). No significant linear regression emerges from any chemical species, highlighting a high spatial variability and/or the uncertainty in the dating of the S1C1 firn core. Finally, we initially processed chemical measurements in our firn core, to support the isotopic records not only for dating, but also to identify air mass origins, making the hypothesis of three possible cases: (i) Air masses formed near the sea- ice margin may be associated with relatively high d-excess and δ18O values, due to respectively a high kinetic fractionation due to evaporation under low humidity levels, and limited distillation effects. Such a configuration should be associated to low sea-salt concentrations due to reduced sea-salt emissions when summerthe presence of the sea ice, is present at the site as shown by atmospheric studies (Legrand et al., 2016). (ii) In contrast, vapour formed over the oceanBy contrast, air masses formed over the Ocean in the absence of sea ice may be associated with high δ18O values, low d-excess and high sea-salt concentrations. (iii) Finally, air masses from central Antarctica may be associated with depleted δ18O values and high d-excess, while air masses from ocean regions may lead to intermediate δ18O and d-excess values, due to distillation effects, and evaporation under relatively humid conditions, but with low sea-salt concentrations. The period from December 2003 to February 2004, associated with Na+ values higher than the mean plus five standard deviations, probably caused by marine advections, is not distinguishable in the isotopic records. And nNone of the three aforementioned cases was systematically observed. To make it short, taking into account the definition of summer observations only does not alter our results. The sea-salt and sulfur concentrations measured along the TA records are slightly lower compared to the S1C1 firn core, consistently with the coast-to-plateau depletion previously observed in atmospheric measurement. Unfortunately, we could not use the sea-salt measurements to support our hypotheses regarding the air mass origins associated with isotopic compositions. 5. Conclusions and perspectives In this study, we report the analysis of the first highly resolved firn core drilled in Adélie Land covering the very recent period 1998—2014, with a sub-annual resolution. The chronology was based on chemical tracers (Na, nssSO4 and MSA) and adjusted by one year based on stake area information. Three δ18O peaks found no counterparts in the chemical records. The high estimated SMB rate of 74.1 $\pm$ 14.1 cm w.e. y-1 limits the effects of diffusion and ensures that records with sub-annual resolution are preservedThe high estimated SMB rate of 74.1 $\pm$ 14.1 cm w.e. y-1 gives access to sub-annual records and limits the effects of diffusion (e.g. Johnsen, 1977). The good consistency of the estimated annual SMB variations with observations on stakes reflects that high accumulation amounts

are needed to ensure that small-scale SMB random variability caused by presence of sastrugi, dunes and barchans is negligibleinsure that small scale SMB random variability caused by presence of sastrugis, dunes and barchans is negligible when compared to the mean accumulation value. This condition allows avoiding the erosion of seasonal or annual layers, which would lead to removal of the annual cycle of the recorded signal. For this reason, getting long term observations on distributed stake networks around a drilling site, or ground penetrating radar data is crucial to accurately select a drilling site, by retrieving the location of mesoscale accumulation maxima, and by rejecting zones with potential erosion. Using an updated database of Antarctic surface snow isotopes, we showed that not only δ18OTA but also d-excessTA mean TA values are in line with the range of coastal values in other locations. Neither in the TA – DDU dataset, nor in the ECHAM5-wiso output do we see any significant relationship between inter-annual variations in δ18O and local surface air temperature. The anti-correlation between annual reconstructed SMBTA and TA d-excessTA leads us to suggest that changes in large-scale atmospheric transport could lead to an explanation for this feature. Particularly back-trajectory simulations from HYSPLIT and atmospheric outputs from ECHAM5-wiso at the seasonal cycle show the occurrence of air masses coming from the WAIS+Pacificwestern sector during autumn and winter times, corresponding to high simulated d-excess values. Also, the identification of remarkable years both in back-trajectory percentages and in the relationships between d-excess and δ18O also lead us to evidence a potential in the d-excess — δ18O to identify remarkable features in moisture transport. We cannot explain at this stage the observed positive trends in the TA d-excessTA and local sea ice extent over the period 1998-2014. We suggest that an improved understanding of the drivers of moisture transport towards coastal Adélie Land can benefit from the interpretation of water stable isotope tracers, especially d-excess, through mechanistic studies and the exploration of global atmospheric models. Ways forward include a better documentation of the spatio-temporal variability in SMB and water stable isotopes using a matrix of coastal firn core records spanning longer periods over the last decades (17 points being small to assess linear relationships, and record climate shifts, e.g. the IPO shift occurring in 1998 (Turner et al., 2016))the last decades; a better documentation of the relationships between precipitation and ice core records through the monitoring of the isotopic composition of surface vapour, and precipitation snow and firn (Casado et al., 2016; Ritter et al., 2016); and the implementation of water stable isotopes in regional models resolving the key missing processes linked for instance with katabatic winds, boundary layer processes, wind drift (Gallée et al., 2013). Data availability The TA192A isotope and chemical firn core records were archived on the PANGAEA data library at . Acknowledgements This study has been supported by the ASUMA project supported by the ANR (Agence Nationale de la Recherche, Project n°: ANR-14-CE01-0001), which funded the PhD grant of Sentia Goursaud and the publication costs of this manuscript.

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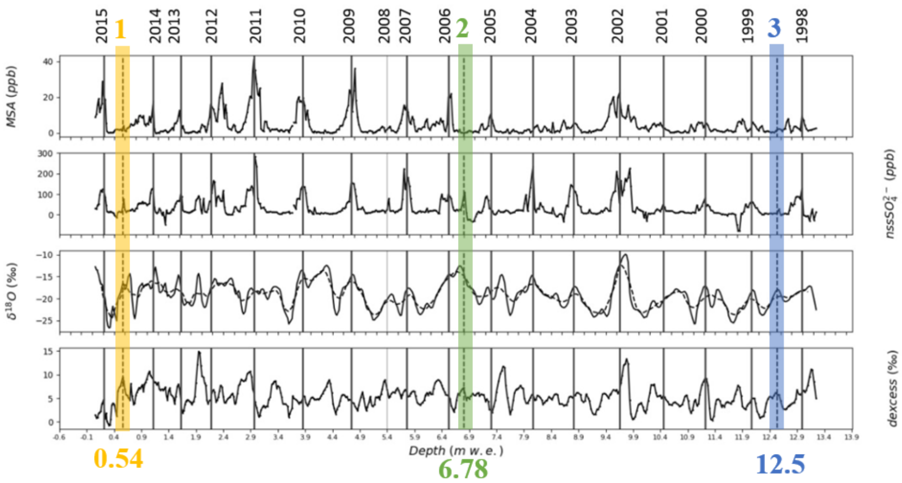

Fig. 1. Figure 1: Annual layer counting of the TA192A firn ice core with the numbering of the years of uncertainty tested for the dating

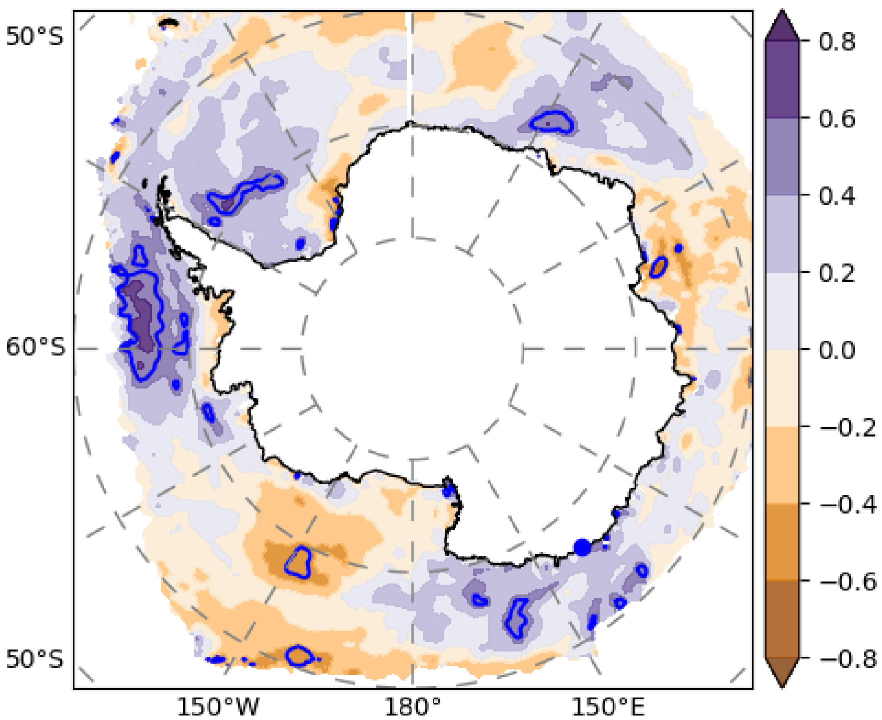

Fig. 2. Figure 2a: Correlation coefficient between the sea-ice concentration and TA δ18O

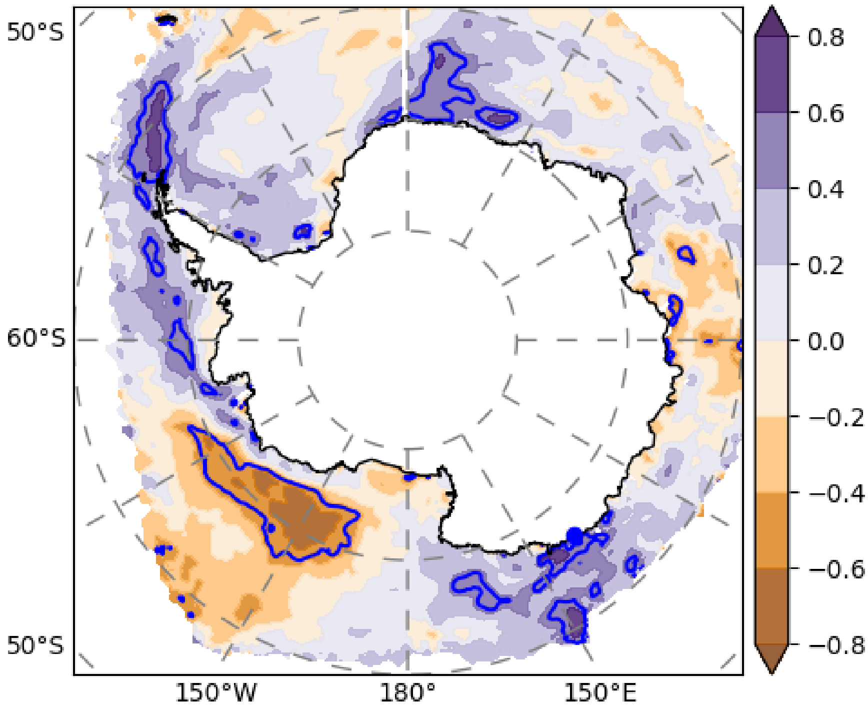

Fig. 3. Figure 2b: Correlation coefficient between the sea-ice concentration and TA dexcess

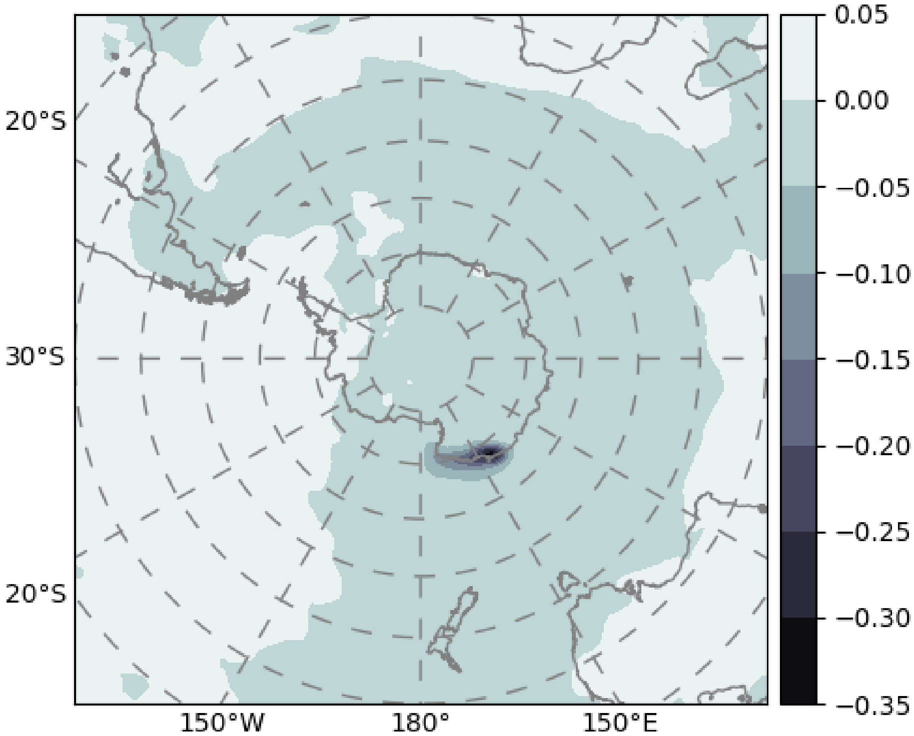

Fig. 4. Figure 3: First empirical orthogonal function of moisture uptake in the boundary layer and the upper troposphere simulated by Watersip