Final response on "Climatic signals from 76 shallow firn cores in Dronning Maud Land, East Antarctica" by S. Altnau et. al

To Anonymous Referee #3

AC: We are very grateful to Referee # 3 for the thorough review and we especially appreciate the good structure of the review.

This paper is a valuable analysis of climatic data from Dronning Maud Land. Records of oxygen isotope and surface mass balance variations in firn cores have been collected from many different sources. By stacking groups of these records together, the authors have reduced the signal-to-noise ratio and derived new information from data previously analysed in isolation. The paper is certainly worth publication but could perhaps be improved by some re-balancing of the material. My personal feeling is that the first sections (1-4) are a bit too detailed, while the results and discussion sections (5 and 6) could do with a stronger structure. Since the sources of the data are acknowledged in Table A1 the authors could perhaps do without a separate Section 3;
where previous authors have made relevant deductions from their data these could be commented on in the Discussion section. I found it quite hard to recall which ideas presented by the authors had already been proposed by others because of the separation between sections 3 and 6.

AC: One of the questions to the reviewers is always, " Does the paper give adequate reference to related work"? Therefore we think that section 3 is necessary. Referee #2 wrote," The authors gave proper credit to related work and clearly indicated their own new/original contribution." We reformulated parts of section 3 to make this even clearer.

I think the number of figures could perhaps be reduced. Figures 5 and 7 do not seem to be essential.

AC: We think that Fig. 5 and 7 are useful to give the reader valuable information about SMB and stable isotope trends at first glance.

I agree with Referee 1 that the comparison with the SAM index is worthwhile reporting, whatever the result.

AC: We never wrote anything that contradicts this. If we did not think the comparison was worthwhile we would not have included it in the paper. On the contrary, we wrote that the lack of correlation between SAM index, air temperature and $\delta^{18}O$ is highly interesting. We think the comment of Referee 1 is not very objective and we do not understand why Ref. 1 should think/write that we are annoyed.

It is important to remind the non-specialist reader that Antarctic precipitation does not always increase with warming temperatures even if a clear explanation of what is happening in the coastal regions cannot be derived from the data available so far.

AC: That's what we wrote.

The English is generally excellent, although there are inevitably a few places where minor improvements can be made. I have suggested some possible changes in the detailed comments section below. There is a slight problem of wavering tenses which needs to be sorted out. My own preference is for past work to be described in the past tense but for the new work presented in the paper to be described in the present tense. However, it does not matter what convention is used so long as the authors are consistent.

AC: We fully agree to that and checked the tenses throughout the paper.

Detailed comments

(Suggestions for minor improvements in English are in italics)

p.5962 l.15 *has exhibited*
AC: Done

l.24 *not only is an increase in sea ice observed but also…*
AC: Done

l.26 *observed over the entire..*
AC: Done

p.5963 l.5 How about "This is important because an increase in precipitation, and hence increased surface mass balance (SMB), might mitigate sea level rise."

AC: Done

l.7 *Close monitoring…*

AC: Done

l.12 *are only available since…*

AC: We would like to stress here that they were not available earlier.

l.16 isotope ratio; annual mean SMB…

AC: Done

l.20 *as part of different national… In particular, the pre-site-survey..*

AC: Done

l.23 *hitherto poorly explored…*

AC: Done

l.25 *have been published*

AC: Done.

l.26 *In this study…*

AC: Done

l.27 At this point I would move into the present tense: "the spatial and temporal variations are investigated. Calculation of stacked records helps considerably to improve…
AC: see above. We investigated the spatial and temporal variations, that's done, and then we can show the results. So we prefer past tense here. We guess in this case it is a matter of taste.

p.5964 l.6 The area of the rectangle shown in Figure 1 is c. 960,000 km^2 according to the scale shown. So the area of the western part of DML under discussion must be less than this. Would it be more useful to give this area rather than that of the whole of DML?

AC: Since the borders of DML are not clearly defined, this is just some general information. The study area is not better defined, so we think this is also just a matter of taste.

l.6 *Our study is focused on…*

AC: Done

l.12 *with an area of 33000 km^2*

AC: Done

l.20 *After this DML was only visited sporadically……Systematic data acquisition…*

AC: Done

l.22 I cannot see Neumayer Station on the map

AC: Sorry, it got lost somewhere in the stage of submitting. The label for Neumayer Station was added to the map.

p.5965 l.4 The statement that the cores are not directly comparable is confusing for the reader at this stage since it is not clear whether you are going to include the data in your comparison or not.

AC: We added in the text, that, for the sake of completeness, we did not omit them from our study.
Page 5968 line 9:
(For the sake of completeness we did not omit them from our study.)

l.9 To make this sentence clear you could write " a positive correlation of the Ritscherflya stable isotope ration with the surface air temperature at Halley" .
AC: Done

l.10 This is all a bit confusing for the reader – what exactly is the point being made by this paragraph? Is there a connection between meterorological conditions at a coastal

station and in the inland region or not? Bear in mind that the reader does not know until p.5969 l.11 that you do not think Halley is representative of your coastal ice shelves because of the presence of the ice-covered Weddell Sea.

AC: We deleted the sentence about the connection between meteorological conditions at Halley and the ice core properties.

l.9-10: *…large spatial and temporal variability (Isaksson and Karlén, 1994a, b; Isaksson et al., 1996) .*

We delete the next two sentences (see marked-up manuscript version).

l.24 *when the SAM is…*
AC: Done

l.27 *as part of*
AC: Done

p.5966 l.5 *The area was found to be…*
AC: Done

l.24 *study by Frezzoti…*
AC: We rewrote this paragraph according to the comments of Ref. #2.

Frezotti (2013) provided a synthesis of Antarctic SMB during the last 800 years. They state that SMB over most of Antarctica do not exhibit an overall clear trend. However, they found a clear increase in SMB in coastal regions and over the highest part of the East Antarctic ice divide since the 1960s, which confirms the results of Fuijta et al. (2011) but contradicts those of Divine et al. (2009) and Kaczmarska et al. (2004).

l.27 East Antarctic Plateau
AC: Done

l.28 *but found that almost all sites*

AC: We rewrote the paragraph:

...SMB changes in ice cores retrieved during the above-mentioned traverse from Troll to South Pole but found that almost all sites...

p.5967 l.3 *ice cores obtained during…*
AC: Done

l.11 As a matter of interest what were the chemical species determined by the Continuous Flow Analysis?
AC: With the CFA e.g. Ammonium, Calcium, Sodium were determined. More information:

Sommer, S., Wagenbach, D., Mulvaney, R., and Fischer, H.: Glacio-chemical study spanning the past 2 kyr on the three ice cores from Dronning Maud Land, Antarctica, 2. Seasonally resolved chemical records, J. Geophys. Res., 105, 29423–29433, doi:10.1029/2000JD900450, 2000b. 5966

Röthlisberger, R., M. Bigler, M. Hutterli, S. Sommer, B. Staufer, H.G. Junghans, and D. Wagenbach: Technique for continuous high-resolution analysis of trace substances in firn and ice cores, Environ. Sci. Technol., 34, 338-342, 2000

We add this information on p. 5967 in line 13 :
Continuous flow analysis allowed fast analysis of ammonium, calcium, sodium along the ice core with an high spatial resolution (Röthlisberger et al., 2000a; Sommer et al., 2000b).

l.20 Do you mean "**annual** values of SMB are poorly correlated" ? If so you could write *Annual values of SMB….are poorly correlated even between cores from the same location….*

AC: Yes, we corrected this: *Annual values of SMB and mean annual* $\delta^{18}O$…

l.22 *due to the effects of wind….. values. Furthermore,….*

AC: Done

p.5968 l.16 *on Amundsenisen…*

AC: Done

l.27 *the percentage deviation from the mean*

AC: We rewrote this: *the relative deviation expressed as a percentage*

p.5969 l.4 *are available. An automatic weather station (AWS) was installed 1.5 km west of Kohnen Station in 1998 and moved to the Station in 2007. In coastal …*

AC: Done

l.11 *not representative of the climate*

AC: Done

l.14 "no homogenous time series"?

AC: Done

l.17 *thus the data can be used*

AC: Done

l.24 *a SAM index*

AC: This has to be **an** SAM index since S is pronounced "es" and thus starts with a vowel.

p.5970 l.10 I had to go back to the Johnsen et al (1997) paper to work out what was meant here. I suggest you repeat the wording of that paper which is quite precise:

One way of estimating the signal to noise (S/N) variance ratio is by comparing the variance of a stacked record (VARS) based on n overlapping records, with the mean of the variances (VARM) for the n individual records. The estimate of a single record S/N variance ratio then becomes…..

AC: We do not like to simply take exactly Johnson's words; this is not good style and reminds us of copy-paste methods some authors use, who cannot speak English very well. However, we reformulated the paragraph:

*The signal-to-noise variance ratio (SNVR) of a single record Fi can be estimated (Johnsen et al., 1997) by comparing the variance of a stacked record (VAR_C) **derived** from N individual records to the mean variance of the N individual records **(VAR_M)**:*

l.19 You do not explain here that $F_c = n F_i$ although this seems to be the case from Table 2. I wonder if you mean you are comparing F_c and F_i between areas rather than with each other, which is what you appear to be saying in the text?

AC: We reformulated this paragraph:

In Table 2, for each subgroup (Ice shelf cores, plateau cores, and 200-year series of the plateau cores) the SNVR of the single records (mean of all cores of one group) F_i compared to the corresponding composite record Fc is shown. F_c is determined by multiplying F_i with the number of individual cores contained in the composite record.

l.23 why do higher values of mean accumulation mean higher SNVR? Could you expand a little?

AC: We rewrote the paragraph from page 5970 line 22 to page 5971 line 2:

On the plateau, accumulation rates are considerably lower than in the coastal areas. At the same time, the effects of wind scouring and thus disturbance of the annual layers, are larger, which leads to higher variance in the plateau cores than in the coastal cores.

p.5971

l.3 Present tense here? *It turns out that*

AC: We keep past tense here since it describes something that was done (and finished) during our investigation.

l.12 *independent of short-term (interannual) variability. An ANOVA F-test is used to test whether these trends are statistically significant. The period 1950-2000…*

AC: We did not change this. Readers who are not familiar with the F-test won't know the abbreviation ANOVA either, and we think F-test is clear enough.

l.21 Have you said the same thing twice here? Is normalisation and detrending the same as converting into anomalies?

AC: yes, thank you, we deleted the sentence:
~~Prior to estimation of the correlation the series were converted into anomalies with respect to the common period.~~

p.5972 l.1 “The significance of the correlations…. using the standard t- test” is followed at line 6 by “Significance of the cross-correlations…… using Students t test” . This appears to be a duplication.

AC: Again, thanks, we deleted the sentence:
l.5: ~~Significance of the cross-correlations between the composite records was assessed using Students *t* test.~~

l.6 *cannot*
AC: Done

l.12 The font in Figure 2 is rather small and difficult to read without magnifying the figure. Would it be possible to use a larger font for the values?

AC: We put quite some effort into creating these figure. We agree that it is hard to read in the discussion paper. In the final paper, the figure is supposed to have full page-width, which makes it better readable. The number of cores is so high that a larger font size would not increase the clarity of the figure.

l.18 *related to geographical factors*

AC: Done

l.19 *The distance to the coast (continentality)…precipitation. Latitude and elevation effects are….*

AC: We rewrote this paragraph according to the comments of Ref. #2.

p. 5972 line 19: remove the word “latitude”
Further we removed the paragraph line 20-line 25.

p.5973 l.6 *In contrast to other studies… because of differences in moisture transport..*

AC: Done

l.14 *cannot be explained physically.*

AC: Done

l.15 But are the values from these cores shown as points on the graph? If so could they be indicated?

AC: They are not shown on the graph.

l.24 Earlier in the paper you use R^2 rather than write out “coefficient of determination” in full.

AC: We removed Figure 3b and the paragraph where we discuss Figure 3b according to a comment by Referee #2.

p.5974 l.1 *Both Schlosser et al. (2008)and Fujita et al. (2011) note that the main wind direction along ID1 is NE.*

AC: Done

l.7 *lower than on the windward side…… generally lower on the lee side…*

AC: Done

l.12 *however, not as strong (R^2=0.90) as between…*

AC: matter of taste

l.17 I am not quite sure how this diagram works. If the whiskers mark the extreme data points how can the "outliers" be outside the whiskers? Are these "outlier" points excluded from the statistical calculation? If so, maybe you could specify that the whiskers indicate the range of points included in the calculation, not the extreme data points.

AC: We rewrote this paragraph:
The red line indicates the median. The tops and bottoms of each box are the 25th and 75th percentiles; the distances between the tops and bottoms are the interquartile ranges. Whiskers are drawn from the ends of the interquartile ranges to the furthest observations within the whisker length, the latter corresponding to 1.5 times the interquartile range. Values beyond the whisker length are marked as outliers and plotted as red dots.

p.5975 l.4 *to Student's t test…*

AC: Done

l.9 *agrees well with…*

AC: Done

l.10 The stable isotope ratio is not almost constant year-to-year. The smoothed record (5-year running mean) shows little variation which is, I think, what you mean.

AC: We rewrote this paragraph:

For the last 20 years the smoothed record of $\delta^{18}O$ shows little variation.
The $\delta^{18}O$ of the plateau cores (Fig. 6e) behaves similar to the ice shelf cores, with the exception of slightly higher values around 1960.

p.5976 l.2 It is not clear here whether the previous work involved only some of the cores or only some sections of all of the cores.

AC: The previous work involved only some of the cores. We changed the formulation to *"…with only a subset of the cores"*

l.24 *on two different ice shelves.*

AC: Done

p.5977 l.3 r = 0.59 ? Previously you have used R^2

AC: The correlation coefficient r refers to a measure of the strength of association between two variables. The correlation coefficient is useful as an initial exploratory tool when several variables are being considered. The sign of r gives the direction of the association.

The coefficient of determination is a number that indicates how well data fit a statistical model i.e. a line. This is useful to check how much of the variability in the key response can be explained.

l.7 *A positive correlation between….. is expected because of….*

AC: We did not change this because we do not think this relationship is EXPECTED (at least we don't expect it anymore), but it is ASSUMED in ice core studies, particularly to estimate the accumulation rate using the stable isotope ratio as a temperature proxy. We did not add this explanation in the text since it deters from the topic we are talking about.

l.13 The notation implies that you are going to compare a ratio with the SAM index. I think you mean both $\delta^{18}O$ and SMB will be compared with SAM.

AC: We changed the title of the subsection to:

Possible influence of SAM on $\delta^{18}O$ and SMB

Further we rewrote l.13-1.14:

… as a first step, a possible influence of SAM on d18O and SMB was considered.

l.17 Figure 9 actually shows (a) $\delta^{18}O$, Neumayer temperature and SAM index and (b) SMB, Neumayer pressure and SAM index as a function of time. This allows a comparison to be made by eye, but is not in itself a comparison.

AC: We removed "compare to" and write "together with" in line 19.

p.5978 l.14 It is a matter of choice, but if you choose to use the present tense to describe the analysis in the paper then at this stage the analysis is completed. Therefore you would say… *have been analysed…. This has been the first comprehensive study… Thus it has been possible to analyse climatic trends…*

AC: As you say, the analysis is **completed**. Present perfect is used for something that started in the past and is still **ongoing**. Thus we cannot use present perfect here. (We had the same discussion with a native speaker in another review…)

p.5979 l.8 *The origin of precipitation…*

AC: Done

l.11 *In the 200-year records…*

AC: Done

l.12 *However, in this context…. should also be discussed*

AC: Done

l.19 *This suggests that winter accumulation has decreased even more strongly than…*

AC: matter of taste

l.25 Saying "to confirm the hypothesis" is probably better than saying "to prove" it

AC: We changed this:
Recent data alone are not sufficient to confirm this hypothesis.

p.5980 l.19 *for the data set presented here.*

AC: Done

l.25 *As well as firn cores and ….*

AC: matter of taste.

p.5981l.3 *ice core data from the ….*

AC: Done

p.5992 *The standard deviation of the slope is also given*

AC: Done

p.5993 Should the 1950-2000 Plateau trend be in bold type?

AC: This is correct. We changed this in Table A3.

p.6004 The diagram is a bit difficult to understand. Maybe you could separate plateau and ice shelf data i.e. have 4 panels?

AC: We prefer to have plateau and ice shelf cores in the same figure since this facilitates the comparison. It allows to detect immediately periods where SMB or $\delta^{18}O$ of ice shelf and plateau cores are in phase or not. For the final publication, Figure 8 should have full page width and be thus easier to read.