Anonymous Referee #2 Received and published: 26 September 2018

The authors present a new blanket peat record from Canopus Hill, Falkland Islands, to reconstruct changes in the in the Amundson Sea Low (ASL) and the Southern Annual Mode. The new record from Canopus Hill extend previously published results (Turney et al., 2016) to the mid-Holocene. The new record suggests a major shift of the ASL at around 2.5 kyr BP, as previously stated by Turney et al (2016). The main results presented in this study are therefore not really original and are therefore not a major advancement. The comparison of the Canopus Hill record with other records show some differences in the timing of this major change, which however are not really discussed in the manuscript. Overall, the manuscript require major revisions (see detailed comments below).

We thank the reviewer for their comments, which have helped clarify our manuscript. (Our responses in blue, reviewer comments in black). We suspect there may be some confusion regarding the Turney et al. (2016) paper, which presents a record only 2.5 kyr long, and therefore does not (and could not!) report a shift at 2.5 ka BP. We think this confusion may be a result of the sentence at line 125-127: "*Work at this site has previously recognised the input of exotic pollen and charcoal derived from South America (Turney et al., 2016a), with changes to westerly airflow over the past ~2.5 ka*." We appreciate that this sentence is confusing, and we sincerely apologise for this oversight. The sentence was only intended to convey the fact that exotic pollen has been previously identified at this site over the length of the Turney et al. (2016) record, which had only been analysed back to 2.5 kyr ago. It is an unfortunate and confusing coincidence that the changes we see in this manuscript occur at the limit of the Turney et al. (2016) study. We have changed this sentence to ensure that it does not promote confusion to "*Work at this site has previously recognised the input of exotic pollen and charcoal derived from South America but was limited to the last 2.5 kyr (Turney et al., 2016a).*"

Importantly, in terms of the originality of the manuscript, the South Atlantic is traditionally interpreted in terms of westerly wind strength changes. Here we report the first Atlantic record that recognises changes in the Amundsen Sea Low through the mid to late Holocene. We have ensured this finding is highlighted more clearly. Viewing the CPD metrics, the discussion paper has been viewed more than 377 times, demonstrating the interest in this topic. Both reviews have made excellent suggestions to improve the clarity and we believe the manuscript has been significantly improved.

1) The current age model and its uncertainties are not very well presented and it remains unclear why two radiocarbon ages at the base of the sequence were omitted. These ages are clearly not in stratigraphic order and the authors should provide plausible explanations for this mismatch. The 2-sigma age range should be also given in table 1 to allow readers to evaluate the chronological age uncertainties.

We have added more detail on the construction of the age model, and included the 2-sigma age range. However, the only radiocarbon ages that are not in stratigraphic order are the two basal ages that were excluded, though we agree that we should have explained in more detail why the two basal ages were removed. The sedimentation rate is internally more consistent when excluding these two basal ages; without them the sedimentation rate from the entire metre of sediment above does not change significantly (with a sedimentation rate for 141.5-156 cm of 38 yrs/cm compared to an average of 27 yrs/cm for the preceding metre of sediment), whereas including them increases the sedimentation rate over this depth range abruptly to 11.6 yrs/cm. We suspect these basal ages may comprise some intruded younger root material; a scenario not unusual in relatively slowly accumulating sedimentary sequences e.g. Brock et al. (2011, *Quaternary Geochronology*). However, we have run the age model again to include these basal ages, and have added a column in Table 1 include the mean calibrated 2 sigma age range. The calibrated age ranges are almost identical for both age models until 142 cm, from where it diverges. Importantly, our conclusions based on the changes observed in the Canopus Hill Record at ~2.5 ka BP are not at all affected by the choice of age model. The modified Table 1 is pasted below:

Depth, cm	**Wk lab number**	**Material**	**% Modern /^{14}C BP ± 1 σ**	**2σ cal. age range (years BP)**	**2σ cal. age range (years BP)**	**Mean cal. age (years BP)**
				With 2 basal ages	**Excluding 2 basal ages**	
8-9	34598	Fruits and leaves	117.0±0.4%M	-4 to -43	-4 to -44	-21
9		^{137}Cs		-6 to -42	-6 to -42	-19
11-12	32994	Fruits and leaves	107.8±0.4%M	-2 to -14	-1 to -14	-8
18-19	37007	Fruits and leaves	107.3±0.3%M	0 to -13	26 to -15	-3
25-26	35146	Fruits and leaves	95±25	250 to -1	249 to -1	86
35-36	37008	Fruits and leaves	647±25	652 to 547	652 to 547	603
39-40	33445	Fruits and leaves	761±25	719 to 570	719-570	661
57-58	32996	Fruits and leaves	1818±25	1804 to 1595	1801 to 1597	1682
70-71	32350	Fruits and leaves	2235±25	2315 to 2102	2314 to 2104	2215
97-98	32997	Fruits and leaves	2749±25	2866 to 2755	2865 to 2755	2810
107-108	32998	Fruits and leaves	2914±26	3140 to 2877	3139 to 2878	2997
120-121	41767	Fruits and leaves	3238±20	3476 to 3361	3471 to 3362	3416
141-142	32351	Fruits and leaves	3955±32	4430 to 4184	4511 to 4236	4352
148-149	41768	Fruits and leaves	4390±20	4515 to 4300	5027 to 4845	4908
153.5-154.5	42144	Fruits and leaves	4039±21	4521 to 4421		
156.5-157.5	42145	Fruits and leaves	4075±22	4567 to 4429		

Table 1. *Radiocarbon and modelled calibrated age ranges for the Canopus Hill peat sequences using the P_sequence and Outlier analysis option in OxCal 4.2 (Bronk Ramsey, 2008; Bronk Ramsey and Lee, 2013). The SHCal13 (Hogg et al., 2013) and Bomb04SH (Hua and Barbetti, 2004) calibration curves were used. Note: calibrated ages are relative to Before Present (BP) i.e. CE 1950.*

2) It I s not entirely clear how the SAL and the Southern Annual Mode (SAM) are dynamically linked! The authors should discuss this in greater detail in their manuscript.

We apologise that this was not clear in the manuscript. In fact the dynamical links between these two modes of variability are not well understood. While there have been suggested links between strong cyclone events in the Amundsen-Bellinghausen Sea region and the Southern Annular Mode e.g. Fogt et al. (2012), the main modulator is not clear. We have added some more information to the introduction about this, but also go into more detail in the discussion about the links between the SAM, ASL and ENSO (see response to comments 5 and 6).

3) Lines: 230-232: Explain the difference to previous publications (e.g., Turney et al., 2016a), in particular in the representation of Cyperaceae and the total accumulation of pollen centred at 2.5 ka BP. The core presented in Turney et al., 2016 was also collected from Canopus Hill.

We apologise that this was not clear in the manuscript. The data presented in Turney et al. (2016a) was indeed collected from the same site (Canopus Hill). However, this record was only 2.5 kyr long. We have removed the Turney et al. (2016) reference from line 230 as this does add confusion since the sentence does say through the mid- to late-Holocene, which the Turney et al. (2016) record does not infer.

4) Line 267-269: It would be interesting to see a detailed comparison between the charcoal records from Canopus Hill and Patagonia to support the statement that "The aeolian delivery of the charcoal to the Falkland Islands is supported by the close correspondence between the Canopus Hill and Lago Guanaco, Southwest Patagonia (Moreno et al., 2009) charcoal records". Such a comparison would strengthen the manuscript, and in particular the statement " Our results support the notion of pervasive westerly winds throughout the mid- to late-Holocene".

We apologise for the confusion. As intimated in the previous sentence, this observation was intended to convey that Lago Guanaco shows a consistent pattern of pervasive fire in the immediate area in Patagonia over the last 3000 years, with limited expression prior to this time. We have included the Moreno et al. charcoal record in Figure 4 to aid comparison. More importantly the presence of fire in the Patagonian landscape during the late Holocene provides a ready source of exotic material for aerial transport to the Falkland Islands as a result of westerly airflow. We have amended this sentence, and broadened the discussion of *Nothofagus*; the fact that *Nothofagus* is consistently represented throughout the Canopus Hill record indicates pervasive westerly winds throughout the mid to late-Holocene, but does not have sufficiently high concentrations to robustly assess changes.

5) The authors state that "These results compliment other studies from the broader South Atlantic region (Figure 4). " However, the change is ssNA in Simple Dome are rather smooth, especially when compared to the pollen record. This difference should be explained in more detail, e.g. are the Falkland Islands more sensitive to these changes than Simple Dome. A marked increase in ssNA at around 2.9 ka is hardly visible in the Simple Dome record and pre-dates the vegetation changes at 2.5 ka. What is the reason for the 400 year time lag. Adding the uncertainties of the age estimate of 2.5 kyr in the Canopus Hill record. Furthermore, the increase in the PALM2 record starts even later at around 2kyr BP. The authors should discuss the offsets more carefully and not simply state that a major change in the westerlies occurred at 2.5 kyr as this estimate is not supported by the current evidences. This discrepancy could be either related to dating uncertainties or may hold important information on the spatial-temporal impacts of the ASL/westerlies.

We acknowledge are there are differences in the timing within the records that we compare. These may be an artefact of the uncertainties in the individual age models, or represent real dynamic changes operating on multi-decadal to centennial timescales. Importantly, we now make clear we are not specifically suggesting that there is a 'regime shift' that affects the entire region concurrently. Indeed, the Siple Dome ssNA+ record shows a more long-term trend to a deepening of the ASL that may suggest an early expression in this part of the Antarctic (as shown in Figure 4). Identifying a particular time for a shift may be misleading, and we have removed any reference to a specific age. The uncertainties of the age estimates for the Canopus Hill record are already plotted in Figure 4, and show that there are relatively large uncertainties of between 100 and 300 years (though the calibrated 2-sigma age range is now clearer to see in Table 1).

However, there does seem to be some confusion regarding the changes at ~2.5 ka BP. We do not state that there is a change in westerlies at 2.5 ka BP, but rather that the changes in vegetation and westerly airflow at Canopus Hill are consistent with the deepening of the ASL. As suggested in point 2, we have added more detail on the dynamical link between the westerlies and the ASL, which provides more context to the discussion. In terms of comparisons to reconstructions of westerly airflow in published literature, there is a substantial incongruity between different proxy records over the Holocene. The Lamy et al. (2010) paper does seem to indicate stronger westerly airflow from ~2 ka BP, which may have been influenced by the ASL, however, the last age control point for this record is the start of the inflection, which is dated to 2570 ^{14}C BP, calibrated to 2410 cal yr BP (note however that no uncertainty or calibrated age range is given, nor is there a reported uncertainty for the marine reservoir correction of 200 years). This indicates that the age uncertainties between the changes observed in the Canopus Hill record and the PALM2 record may possibly overlap. We will include a significantly more detailed discussion on the timing of these changes.

Interestingly, the $\delta^{18}O_{diatom}$ record from Site 1099 in the Palmer Deep representing multi-centennial fluctuations in glacial discharge presented by Pike et al. (2013, *Nature Geoscience*), also shows an underlying decrease towards lower values, "particularly from ~2.5 kyr". Specifically, this increased glacial ice discharge is thought to have been driven by atmospheric warming (as a result of peak local summer insolation; now added to Figure 4), in addition to the maximum Holocene ENSO frequency from circa 2.2 kyr (suggested by Makou et al. (2010, Geology), likely representing increased La Niña intensity (Site 1228 Peru Margin core displays an increase in La Nina events, now plotted in Figure 4). We have added these important details to the discussion.

6) I would also suggest to include ENSO reconstructions (e.g., Moy et al., 2002 or Carre et al., 2014) in a separate figure

This is an excellent idea to include an ENSO reconstruction, although we think it is best to add to Figure 4 to enable better comparisons. Unfortunately, since this paper was submitted, the record of Moy et al. 2002 has been questioned as an El Nino record (Schneider, T., Hampel, H., Mosquera, P. V., Tylmann, W. and Grosjean, M.: Paleo-ENSO revisited: Ecuadorian Lake Pallcacocha does not reveal a conclusive El Niño signal, Glob. Planet. Change, 168(June), 54–66, doi:10.1016/j.gloplacha.2018.06.004, 2018.). This study states that ENSO may not be the major driver of precipitation at Lake Pallcacocha, and therefore may not be appropriate to cite in an ENSO context. While Carre et al. (2014) establish that modern ENSO conditions were established between 3 and 4.5 ka BP, this is based on discontinuous records; the record published by Makou et al. (2010 *Geology*) appears to present a more continuous record of ENSO over the time period of interest for this study, and we have included this record in Figure 4. We also significantly broaden our discussion of the potential influence of ENSO on the ASL: The El Nino Southern Oscillation circulation pattern is teleconnected to Southern Ocean and Antarctic climate, in particular the Amundsen Sea low-pressure region, via movements of the South Pacific Convergence Zone (Russel and McGregor et al. 2010, Climatic Change). Specifically, La Niña events are accompanied by a northerly shift in the South Pacific Convergence Zone and the production of cyclones in the region of the Amundsen Sea low. This then produces a warm, northerly airflow over Patagonia, the Western Antarctic Peninsula and the Falkland Islands. In addition, Fogt et al. (2011) found that when a La Niña event occurs with the positive phase of the SAM, ASL exhibits deeper pressure anomalies, suggesting that the SAM and the ASL may indeed modulate one another. Please see revised Figure 4 below:

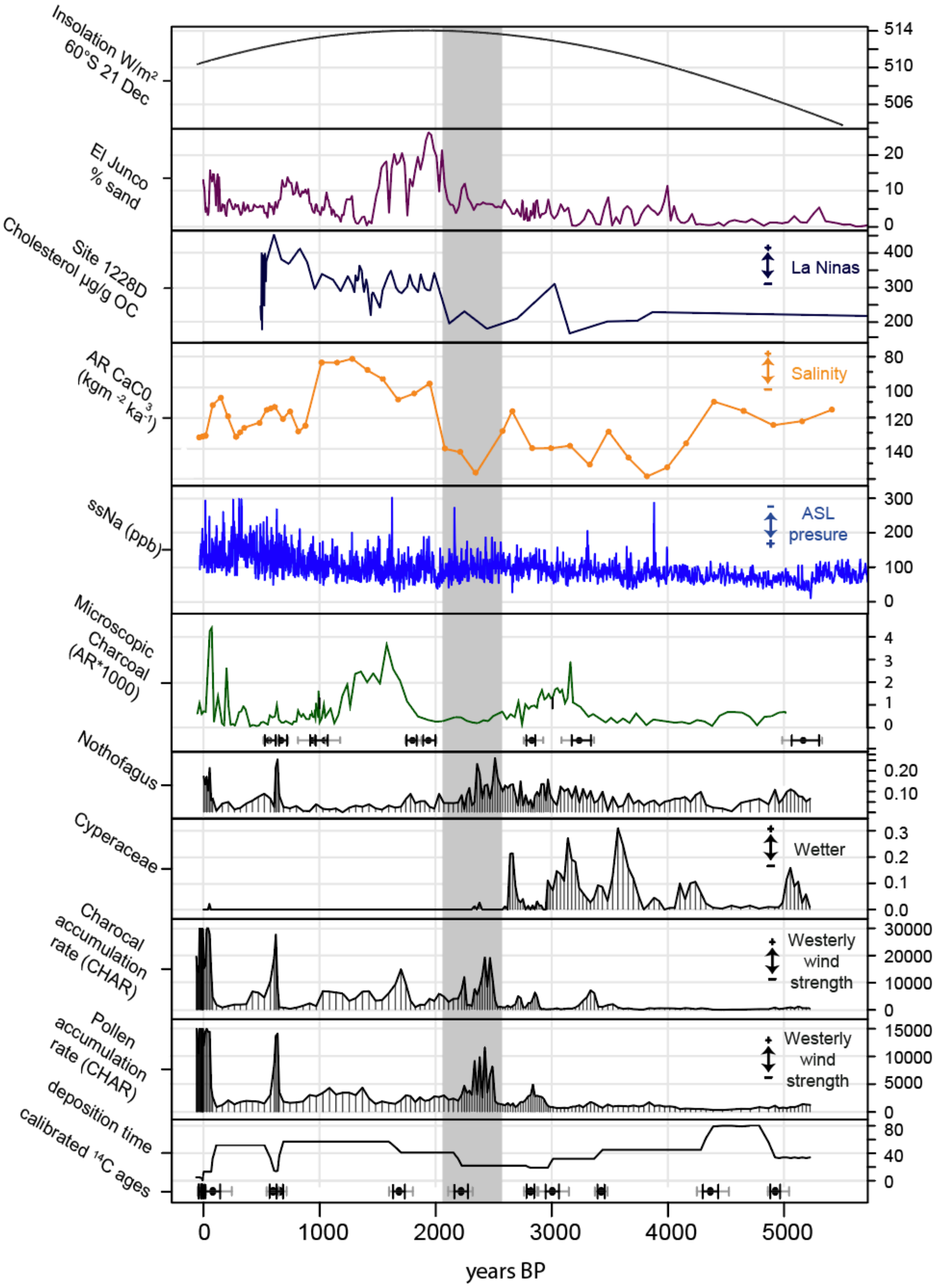

Figure 4: *Key data from the Canopus Hill sequence (Falkland Islands) and other South Atlantic records. From bottom to top: deposition time, total pollen accumulation rate (PAR), total charcoal accumulation rate (CHAR), Cyperaceae and Nothofagus re-expressed as accumulation rates, microscopic charcoal from Lago Guanaco (Moreno et al. 2009), ssNa⁺ from Siple Dome (Mayewski et al., 2013), salinity anomalies from PALM2 (Lamy et al., 2010), cholestrol abundance, ODP Site 1228, Peru margin (Makou et al. 2010), percentage of sand, El Junco Crater Lake, Galápogos (Convey et al. 2010) and summer (21 Dec) insolation (W/m²) at 60°S (Laskar et al. 2004). Calibrated radiocarbon ages and 1σ (black) and 2σ (grey) age ranges for Canopus Hill and Lago Guanaco are plotted at the base of the respective panel. Note that PAR and CHAR have both been capped at the modern end due to high accumulation rate. The grey boxed area marks the transition period during which the ASL strengthened over the South Atlantic.*