

Dr. Stenni

Thank you for the opportunity to revise our manuscript, “Trends in South Pole Particle Concentration Imply Holocene Westerly Wind Strengthening.” We appreciate your comments, time, and effort as it allowed us to improve the paper. The following responses address each comment and/or question based on the previous submission. Our responses are given below with your comments in italics. Our responses as the authors are given in regular font, and **revised text from the paper is provided in blue font**. Please note that our Line Numbers listed below are based on the edited document rather than the cleaned version.

Line Comments

In the abstract, line 38, the word “said”, seems not useful. Please, rephrase the sentence.

Line 38: We replace “...said atmospheric...” with **wind**.

Introduction:

Line 75-77: The sentence starting with “Nevertheless (by the way, why nevertheless?) and the sentence (line 88-90) starting with “We build....” Should be merged and improved and stay at the end of this section. Perhaps, you want to anticipate a bit on what you are elaborating in this study.

Line 75 – 77: We remove the sentence starting with “Nevertheless...”.

Line 90 – 91: We add “...**concentration and CPP**...” and “...**to better constrain Holocene SHWW dynamics within the context of early Holocene to modern climate dynamics**.” To the end of the paragraph so the final sentence now reads, “We build upon instrumental-era South Pole particle research to investigate Holocene particle variability on centennial to millennial scales throughout the Holocene using microparticle **concentration and CPP** data from the new SPC14 intermediate-depth ice core **to better constrain Holocene SHWW dynamics within the context of early Holocene to modern climate dynamics**.”

Line 78: the sentence: The South Pole is well situated for what? Improve the sentence here.

Line 78: We add “...for Southern Hemisphere atmospheric reconstructions...” so that the sentence now reads, “The South Pole is well-situated **for Southern Hemisphere atmospheric reconstructions** because 1) the symmetric position with respect to the annular SHWW belt favors interpretation of the hemispheric, rather than regional, SHWW system, 2) the relatively high snow accumulation rate (8 cm w.e. a⁻¹) relative to other sites in East Antarctica provides strong constraints on the ice core chronology and high temporal resolution and 3) aerosol and meteorological studies have been conducted at this location over the past 60 years, which provides context for paleo-interpretations (Lazzara et al., 2012; Sheridan et al., 2016; Clem et al., 2020; Casey et al., 2014).”

Methods:

Line 96: delete “and”.

Line 97: We remove the use of “and”.

From line 98 to 110: all this part is confused, and you repeat several times the same concepts. Please restructure all this part to ensure clarity!

Line 100 – 113: We remove repeated information in the paragraph, rephrase sentences, and make this section a standalone paragraph. The following paragraph now states, “To facilitate a comparison with other ice core records, we assume a spherical particle shape, rather than the measured prolate particle shapes (Chesler et al., 2023), use a density of 2.6 g cm^{-3} (following Koffman et al., 2014) to estimate particle mass flux, and, when possible, restrict particle flux to similar size ranges ($1.1 - 5.1 \text{ }\mu\text{m}$; Figure 1e and Figure 2). South Pole particle shape metrics (i.e., mass and flux) are unconstrained for the Holocene because of limited data (i.e., Chesler et al., 2023). In previously published ice core dust records using solely laser particle measurement techniques, the particle shape has been assumed to be spherical (Chesler et al., 2023; Simonsen et al., 2018; Potenza et al., 2016). Studies concerned with the absolute magnitude of dust flux at the South Pole should use prolate particle shapes to calculate flux (Chesler et al., 2023; data at USAP-DC, DOI: 10.15784/601553). We restrict particle metrics to number concentration and CPP because the particle shape assumption (i.e., particle flux and mass concentration), can artificially increase particle metric concentrations by 25 – 44%. While this produces higher-than-realistic particle flux values, it mitigates discrepancies from comparing records with dissimilar metrics.

Line 112: add the word “ice” between the words Antarctic and core.

Line 116: We add “ice” so that the sentence now reads, “East Antarctic ice core records”.

Results:

Lines 140-143: this short “chapeau” is a bit poor, as it is. Perhaps you could anticipate what you are showing in the subsections below? You can elaborate a bit more.

Line 142 – 149 We add to the chapeau of Chapter 3 so that it now reads, “South Pole dust concentration decreases during the mid-Holocene ($\sim 7000 - 3000$ years BP) compared to the relatively stable early Holocene ($11300 - 7000$ years BP), and a moderate decrease in the late Holocene ($3000 - 250$ years BP). The rate of the concentration decrease during the mid-Holocene is double that of the late Holocene and coincides with an increase in the CFR and CPP (Figure 1a – c). South Pole particle flux and NOAA HYSPLIT analysis suggests that trends in the South Pole particle flux are similar to those in other Antarctic records (Figure 2a and b) and broadly reflects synoptic scale Antarctic climate (Figure 3a and b). Therefore, we suggest the South Pole particle trends are reflective of Holocene mid-high latitude synoptic climate variability.

Line 141: after “CFR” add in parenthesis (not shown).

Line 116 – 119: We defined CFR in original Lines 114 – 115.

Line 141: after CPP add Figure 1a, b and c.

Line 145: We add “Figure 1a – c” after CPP. The sentence now reads, “The rate of the concentration decrease during the mid-Holocene is double that of the early Holocene and coincides with an increase in the CFR and CPP (Figure 1a – c).”

Line 151: The decrease in the early Holocene, is not visible at all from your figure, I cannot understand...Are you sure about this? This aspect was also raised by the referee 2. Moreover, in the figure 1a and 1b you report the values of the decrease for the early Holocene (in my opinion not visible at all) but not for the Middle Holocene where it is very clear.

Line 156 – 159: We correct our paper to report the moderate decrease of ~ 24 particles kyr^{-1} occurs in the late Holocene rather than the early Holocene. We correct the paragraph and statements in the paragraph to reflect this difference. The sentence now reads, “During the early Holocene, dust concentration remained relatively stable (~ -1.7 particles $\text{mL}^{-1} \text{kyr}^{-1}$ followed by a significant decrease (~ 50 particles $\text{mL}^{-1} \text{kyr}^{-1}$) until the Late Holocene where particle concentrations continued to decrease but at half the rate of the mid-Holocene (~ 24 particles $\text{mL}^{-1} \text{yr}^{-1}$; Table S1).”

Line 156: after coarse particles add (Figure 1b) and after total particles add (Figure 1a).

Line 164 – 165: We add the figure references so that they sentence now states, “The number concentration of coarse particles (Figure 1b) has a decrease similar to the total particle concentration (Figure 1a),...”

Line 182: the sentence starting with “Following....” should be another paragraph.

Line 191: The sentence that starts with “Following...” is now the start of a new paragraph.

Line 183: after d18O, add “a proxy for local atmospheric air temperature”.

Line 192 – 193: We update the sentence so that it now reads, “Following Albani et al. (2012), we compare our Holocene dust flux record against $\delta^{18}\text{O}$, a proxy for local atmospheric air temperature, to assess whether there are primarily remote or mixed dust source (Steig et al., 2021).”

Discussion:

Line 225: perhaps here you could make a short "chapeau", as done before for the section Results.

Line 236 – 241: We add a short chapeau to the beginning of our discussion section. The chapeau now reads, “We interpret the opposing South Pole particle trends and metrics to reflect strengthening and southward migration of the SHWW throughout the Holocene. We reach these conclusions based on a predominantly southern South American and Antarctic dust source regions through terrestrial and oceanographic paleoproxy records and PMIP4-CMIP6 atmospheric modelling analyses. Our interpretations suggest that insolation-like southern

hemisphere warming throughout the Holocene led to increasing wind strength and southward migration. Based on our interpretations, our data suggests that the early Holocene may not be a climatically comparable period. “

In general, avoid repetitions in the Discussion section to ensure clarity and check if all the profiles reported in Figure 5 are properly cited and referred in the text.

We check and update areas within the discussion so that Figure 5 is properly cited in the text. We also revise the discussion section so that repeated sentences, paragraphs, and ideas are removed for clarity.

Lines 266 – 288: We move this paragraph to Lines 299 – 311.

Lines 283 – 289: We rephrase this section, which now states, “In southern South America, Moreno et al. (2010) also suggested a progressive southward shift in the SHWW, which they interpreted from precipitation dynamics via plant community changes beginning ~7800 years BP (Figure 5e; Lago Guanaco and Lago Condorito; 51° [Figure 5e] and 41°S, respectively, ~72°W). We discuss the impact of precipitation changes in Section 4.3.

Line 336 – 337: We add the following sentence for clarity, “Reduced dust entrainment in the mid-latitudes may be a result of either increases in vegetation and/or a southward shift in the SHWW.”

Line 244: here I suppose you wanted to say lower latitudes instead than >51°S?

Line 260: We correct the sentence to say, “The weakening of the SHWW over lower latitudes <~51°S is consistent...”

Line 337: after total particle concentration add (figure 1a and 1b).

Line: 370: We add “...(Figure 1a and b) ...” after total particle concentration.

Line 339: after Holocene add (Figure 1c).

Line 372: We add”... (Figure 1c)...” after Holocene.

Line 355. Add “.” After SPC14 and make a new sentence after.... However,....

Line 389: We place a period after SPC14 and start the next sentence with “However, ...”.

Lines 359-362: this sentence is not clear, please, explain better.

Line 392 – 394: We rephrase the sentence to state, “Furthermore, the timing of surface elevation decrease around Antarctica corresponds to the SPC14 CPP increase, a southward shift in the Atlantic ITCZ, increasing rainfall in southern South America (Lago Guanaco), all of which can

be explained by a southward shift in the SHWW due to increasing Southern Hemisphere temperatures (Figure 5a, c, and e; Haug et al., 2001; Moreno et al., 2010; respectively)."

Line 369: insert "is", after "this".

Line 405: The sentence now states, "However, based on our data, this is outside the scope of this paper."

Data availability: Please, report in this section where the data that you used in this manuscript can be found. Not only dust, also $d18O$ for example....

Line 430: We update our Data Availability section to the following, "Dust datasets and water isotope data used in this paper are available at the U.S. Antarctic Program Data Center (<https://doi.org/10.15784/601553> and <https://doi.org/10.15784/601239>, respectively)."

Figure captions:

In general, I found the figure captions a bit too long and complex to read.

We edit Figures 1 and 2's captions. We have reviewed Figures 3 – 5's captions and are willing to remove additional text if you believe further edits are necessary.

Figure 1: add a short title... and add that the Holocene has been divided into 3 sections .. and explain the different panels in sequence ... 1a .., 1 b., 1 c and so on. The sentence "Note the bimodal distribution....." should be moved in the relative text.

Line 178: We add "South Pole Dust Trends" as the short title to the Figure and update the figure with the mid-Holocene slope values (see below).

Line: 161 – 163: We move the sentence that starts with from the figure caption and place in Line 161 - 163, "Note the bimodal distribution..." to the text. It now reads, "During the mid-Holocene, there is a bimodal distribution highlighting the transition from early to late Holocene (Figure 1d). During the early and late Holocene, the dust concentration is more normally distributed."

Line 178: We remove an additional sentence in after our descriptions of each panel. Our revised figure caption now states, "Figure 1a – e: 1a) 50-year median resampled SPC14 total dust concentration ($1.1 - 5.1 \mu\text{m}$ # particles mL^{-1} ; blue line), 1b) 50-year median resampled coarse particles concentration ($3.2 - 5.1 \mu\text{m}$ # particles mL^{-1} ; grey line), 1c) 50-year median resampled CPP (light red) and CPP 11-point rolling gaussian mean (2σ ; red dashed line), 1d) total dust # particles mL^{-1} concentration distributions during the early, middle, and late Holocene, and 1e) total dust # particles mL^{-1} size distributions by time period. Mid-Holocene slopes values are reported in # particles $\text{mL}^{-1} \text{kyr}^{-1}$. Average median absolute deviation (MAD) for the particle concentration is ~ 84 (Figure S1). Mid-Holocene slopes values are reported in # particles $\text{mL}^{-1} \text{kyr}^{-1}$."

Figure 2: line 197, delete "shows" and put "and". Line 198 "particle flux" is repeated, delete.

Line 207 – 208: We remove “...shows the...”, add an “and”, and remove the use of “particle flux”. The sentence now reads, “2b) ~~shows the~~ South Pole (SPC14) [and](#) $\delta^{18}\text{O}$ (Steig et al., 2021) resolved to 50-year resolution shows available Holocene flux records from Talos Dome fine (0.6 – 5 $\mu\text{m mg m}^{-2} \text{ yr}^{-1}$; Albani et al., 2012), Vostok (Petit et al., 1990), EPICA Dome C (EDC; Lambert et al., 2012).”

Lines 202 and 203: the words “calculated” perhaps are not the proper ones, better, measured?

Line 212 – 213: We replace both instances of “calculated” and replace them with “[measured](#)”

Figures:

Figure 1: please, add the average slope for the Middle Holocene in the Figures 1a and b and check the values for the early Holocene.

Line 178: We replace the Holocene average slope value with the mid-Holocene slope value in Figure 1a and b. See below for updated Figure.

South Pole Dust Trends

