

Dear Dr. Erin McClymont,

On behalf of all co-authors, I would like to thank you for your careful reading of our manuscript and for the constructive comments and suggestions. We have revised the manuscript accordingly and provide a detailed point-by-point reply to all editorial comments and remaining reviewer concerns.

In particular, we have:

- Corrected the wording and minor editorial issues.
- Expanded and clarified the rationale for selecting planktic foraminifera over benthic foraminifera for radiocarbon dating, emphasizing the reduced influence of stratification and ventilation on surface waters.
- Substantially elaborated the explanation for using the SHCal20 atmospheric calibration curve combined with locally derived reservoir ages, including a clearer description of the procedure for incorporating reservoir ages, justification for this approach in the context of Chilean margin conditions, and explicit references to the relevant datasets and tables.
- Revised the text in Section 3.2 and related sections to make these points transparent and to highlight the steps and data sources used for the BACON age–depth modelling.

All changes performed are reported point by point below.

We believe these changes improve the clarity and robustness of the manuscript and address all remaining concerns.

Thank you again for your time and constructive feedback. We look forward to your evaluation of the revised version.

Sincerely,

On behalf of the authors,

Charlotte Läuchli

Point by point answer to the comments of the editor. Note that the editor's comments are shown in italic fonts.

(1) page 6 of the reply document: "...eastward-blowing westerly winds". In this context the text does not need to state "easterly-blowing"

"easterly-blowing" was deleted from the manuscript.

(2) Page 7: new text in new Section 2.3 "...highly heterogenous vegetation with vegetation ranging..." (remove "with vegetation"); also edit the final sentence to the following: "...found in Luebert and Plischoff (2022)."

"with vegetation" was removed and the final sentence was edited to the following: "...found in Luebert and Plischoff (2022)."

(3) Page 8: the answer to the reviewers question about why the ages were preferred still lacks the information on why the planktic foraminifera were the preferred choice. Please clarify if this is due with more direct ocean-atmosphere exchange, higher resolution of sampling....?

We thank the editor for highlighting this lack of precision. The manuscript was modified as follows (Section 3.2):

OLD (Section 3.2)	NEW
Note that we preferentially selected previously published ages acquired on planktic foraminifera samples over benthic foraminifera samples for core sections with a high density of radiocarbon age measurements (Table 1 reported in L��uchli et al., 2025, see Data availability).	Note that we preferentially selected previously published ages acquired on planktic foraminifera samples over benthic foraminifera samples for core sections with a high density of radiocarbon age measurements (Table 1 reported in L��uchli et al., 2025, see Data availability) as surface waters, in which planktic foraminifera live, are less affected by stratification and ventilation than deeper water masses (e.g., Siani et al., 2013).

(4A) In reply to Reviewer 2 the authors reiterate the use of the two radiocarbon calibration scenarios, and the comparison between them but choose SHCal20 (which is also outlined in the main manuscript). I'm still unclear about the choice of an atmospheric calibration curve to a suite of marine samples, especially as in the main text the authors note that they "combine reservoir ages" with the SHCal20 curve because there are marine reservoir affects. What is this process, and why is this better justified than using the recommended MARINE20 curve? If the authors continue to use the SHCAL20 curve then I recommend that they insert a line into this section to be clear that they are choosing to use acknowledge an atmospheric calibration.

Due to the inaccuracy of the Marine20 calibration curve in polar regions – caused by increased ventilation variability (Heaton et al., 2020)– and as similar conditions are found along the Chilean active margin since the Last Glacial Maximum (De Pol-Holz et al., 2010; Haddam et al., 2018; Siani et al., 2013), we decided to use the SHCal20 curve combined with previously published reservoir ages inferred along the Chilean active margin. This approach allows more accurate calibration of radiocarbon ages in the study area. The manuscript was modified as follows to make this point clearer:

Old (Section 4.1)	New
New age-depth models were established for cores GeoB7139-2 (30°S), GeoB3304-5 (33°S) and 22SL (36°S) using previously published and	New age-depth models were established for cores GeoB7139-2 (30°S), GeoB3304-5 (33°S) and 22SL (36°S) using previously published and

newly acquired radiocarbon ages (Table 1 in Lauchli et al., 2025, see Data availability). As past changes in the deep ocean stratification are complex along Chile (De Pol-Holz et al., 2010; Haddam et al., 2018; Siani et al., 2013) and water masses with different reservoir ages likely influenced the study area (Martınez Fontaine et al., 2019), we consider two scenarios.	newly acquired radiocarbon ages (Table 1 in Lauchli et al., 2025, see Data availability). Similar to polar regions, the Chilean active margin is characterized by complex changes in ocean stratification (De Pol-Holz et al., 2010; Haddam et al., 2018; Siani et al., 2013) and the influence of water masses with different reservoir ages (Martınez Fontaine et al., 2019). Under these conditions, the use of the Marine20 calibration curve is not recommended (Heaton et al., 2020). We therefore consider two scenarios. In the first, we apply previously constrained reservoir ages from offshore Chile combined with the atmospheric SHCal20 calibration curve (Hogg et al., 2020) to account for the complex ventilation variability since the Last Glacial Maximum. In the second, used for comparison, we apply the Marine20 calibration curve with local reservoir corrections (see below), acknowledging that this approach does not fully represent the complex stratification and mixing along the Chilean margin.
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(4B) They also need to explain what the steps are to incorporating the reservoir ages in this process, which are currently not transparent, and MARINE20 is the recommended marine calibration method.

We thank the editor for giving us the opportunity to clarify this point.

We consider that most of the steps regarding the incorporation of reservoir ages are already included in the manuscript (see text below including discussion regarding the water masses influencing the study areas, the uncertainties associated with considering the SAAW as the main water source and the references to the studies from which reservoir ages were derived). We however acknowledge that a line was missing specifying where reservoir ages selected can be found. The following line (in bold) was therefore added to the manuscript:

Section 4.1 In the first scenario, the sites are considered influenced predominantly by Subantarctic Water (SAAW) following scenario 1 of Martınez Fontaine et al. (2019). This is supported by the modern occurrence of SAAW at 28°S (Silva et al., 2009) and evidence for a predominant influence of the SAAW at 31°S before ca. 15.5 ka BP (Martınez Fontaine et al., 2019). After around 15.5 ka BP, evidence suggests a mixing of the SAAW, the Equatorial Subsurface Water (ESSW) and the Antarctic Intermediate Water (AAIW) at the studied sites (Martınez Fontaine et al., 2019). However, we followed a conservative approach and attributed the reservoir ages of the SAAW to the entire time-span investigated here as the proportion of the different water masses occurring at each site remains unknown. Furthermore, better constraints exist for the reservoir ages of the SAAW compared to the ESSW near the studied sites. The reservoir ages of the SAAW were determined at 47°S (Haddam et al., 2018; Siani et al., 2013), while the reservoir ages of the ESSW were constrained further away at the equator (Umling and Thunell, 2017). A modification of the reservoir age of the ESSW is also anticipated during its transport south due to potential mixing with Antarctic Intermediate Water (AAIW). A comparison of the reservoir ages of the ESSW and the SAAW suggests a difference of less than ca. 400 years for
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most of the periods where reservoir ages are available for both water masses since 20 ka BP. An exception occurred at around 14.4 ka BP during which a difference of about 1,200 years, caused by the relatively small reservoir ages reconstructed at the equator (Umling and Thunell, 2017), was observed between the reservoir ages of the ESSW and the SAAW. In scenario 1, uncertainties of less than about 400 yr are therefore implied for the reservoir ages over the last 20 kyr, with potentially higher uncertainties between 13.8 and 14.8 ka BP. For the first scenario, we thus combined the reservoir ages characterizing the SAAW water mass, as published in Haddam et al. (2018) and Siani et al. (2013), with the SHCal20 calibration curve (Hogg et al., 2020) to reconstruct age-depth models. **For each sample, the reservoir age corresponding to the nearest radiocarbon age (^{14}C age) was selected. The reservoir ages derived and used in the BACON v3.2.0 algorithm (Blaauw and Christen, 2011), as well as their references, are reported in Table 1 reported in Lauchli et al. (2025).**

We consider that further details regarding the use of the BACON v3.2.0 algorithm – found in Blaauw and Christen (2011) - is beyond the scope of this study.

The additional reformulations were also performed on the Summary and the conclusion sections of the manuscript for greater clarity.

Summary:

OLD	New
Large-scale atmospheric pathways connecting climate across latitudes are poorly documented in the past. Here, we report a high resolution spatial and temporal reconstruction of the evolution of the Southern Hemisphere Westerlies since the Last Glacial Maximum, which, compared with the past evolution of the Intertropical Convergence Zone, allows identifying the dominant atmospheric pathways acting on past climate in South America.	Large-scale atmospheric pathways connecting climate across latitudes are poorly documented in the past. Using a high-resolution spatial and temporal reconstruction of the evolution of the Southern Hemisphere Westerlies since the Last Glacial Maximum and comparing it with the evolution of the Intertropical Convergence Zone, we identified the dominant atmospheric pathways that shaped past South American climate.

Conclusion

OLD	NEW
Our reconstruction, combined with past reconstructions of the ITCZ, allow identifying two dominant atmospheric pathways modulating the climate of the west coast of South America since the LGM. Atmospheric pathways driven by large interhemispheric temperature contrasts and changes in the strength of Hadley cells likely prevailed during the last deglaciation period, while, atmospheric pathways resembling those associated with modern ENSO events likely dominated during the Holocene, except between 7.5 and 5.5 ka BP. These shifts correspond to changing dominance of major forcings: Atlantic Meridional Overturning Circulation (AMOC) and hemispheric temperature contrasts during the deglaciation period, and orbital insolation forcing (precession) during most of the Holocene. This work highlights the value of $\delta^2\text{H}_{\text{wax}}$ records for unravelling complex hydroclimate patterns. Furthermore, it underscores the need for further constraints on large-scale atmospheric pathways to deconvolve past Earth's climate and predict future climate. This is particularly relevant to predict the future impact of large-scale circulation regimes on regional climate in the context of an increase in the interhemispheric temperature gradient (Friedman et al., 2013).	Our reconstruction, combined with past reconstructions of the ITCZ, reveals two dominant atmospheric pathways modulating the climate of the South American west coast since the LGM. During the deglaciation period , atmospheric pathways driven by large interhemispheric temperature contrasts and variations in the Hadley cell strength likely prevailed, whereas during the Holocene – except between 7.5 and 5.5 ky BP – circulation patterns resembling modern ENSO dynamics were the primary influence. These shifts reflect changing dominant climate drivers: Atlantic Meridional Overturning Circulation (AMOC) and interhemispheric temperature contrasts during the deglaciation period, and orbital insolation forcing (precession) during most of the Holocene. Our results demonstrate the power of $\delta^2\text{H}_{\text{wax}}$ records to resolve complex hydroclimate patterns and highlight the critical need to better constrain large-scale atmospheric pathways to fully unravel past climate variability. Strengthening such constraints is essential for improving predictions of how evolving circulation regimes – amplified by a growing interhemispheric temperature gradient (Friedman et al., 2013) – will shape regional climates in the future.