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A compilation of sea surface temperature anomalies from the Southwest Atlantic during the Common Era: challenges and opportunities to support future research

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Abstract.
Here, we present a compilation of sea surface temperature (SST) anomalies from the Southwest Atlantic during the Common Era. We aim to highlight the challenges and opportunities in advancing our understanding of regional ocean variability and allow to understand the reasons behind the notable scarcity of such records and explore how we can improve mechanisms to prevent misinterpretation and ensure that these efforts effectively support future research. About 24 records indicated that SST anomalies fluctuated throughout the entire Common Era, with values between (-5.84 to 0.62). The limited availability of high-resolution SST records constrains our ability to fully grasp regional climate dynamics and their broader implications for the global climate system. To address this, it is essential to prioritize acquiring records that minimize coastal influences, thereby providing clearer insights into large-scale oceanic and climatic patterns. Enhancing the representation of currently under-sampled regions is crucial for constructing a more comprehensive picture of Earth's climate history. However, addressing these gaps involves more than data collection alone. It requires a concerted effort to produce and disseminate SST reconstructions spanning the Common Era, while also raising awareness of their value to the scientific community. Ultimately, such initiatives will enhance our ability to anticipate and respond to future climate change, equipping policymakers and communities with the knowledge necessary to build resilience and adapt to an increasingly dynamic climate system.

1 Introduction

The Common Era, spanning the last two thousand years, represents a critical period for investigating climate variability. This timeframe offers a unique opportunity to distinguish between natural climate fluctuations from anthropogenic influences (Neukom and Gergis, 2012). Reconstructions of sea surface temperature (SST) during this period are particularly informative, as they enhance our understanding of recent warming trends, the energy balance of the climate system, and multidecadal temperature variability (Neukom et al., 2019). The ocean plays a central role in regulating climate by functioning as a heat reservoir that stores, retains, and distributes heat, thereby regulating energy exchange between the ocean-atmosphere system (Rhein et al., 2013). It becomes possible to assess climate sensitivity and regional responses to climate variations

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through paleo-SST reconstructions, ultimately contributing to a more comprehensive global view of temperature changes over time (Abram et al., 2016). These insights ultimately improve our understanding of past climate dynamics and enhance the accuracy of future climate projections (Neukom et al., 2019).

The study of the Common Era faces challenges related to data scarcity and temporal coverage and resolution, particularly in the Southern Hemisphere, the tropics, and the ocean (Anchukaitis and Smerdon 2022; PAGES2k Consortium, 2017; Fig. 1a). These lead to an inter-hemispheric imbalance in both terrestrial and marine records, which tend to concentrate in the Northern Hemisphere (Neukom and Gergis 2012).

In the PAGES Ocean 2K working group database (PAGES2k Consortium, 2017), the Southern Hemisphere accounts for only 16% of the records. This highlights the deficit of SST records from this region, which affects the accuracy of global temperature estimates for the Common Era. Moreover, this data gap limits our ability to reconstruct and understand regional climate conditions (e.g., temperature and precipitation) and their variability. These are particularly important given the Southern Hemisphere's key role in driving and modulating global ocean and atmospheric circulation patterns (Neukom and Gergis, 2012). Therefore, addressing this gap in SST records and ensuring optimal efficiency in efforts to do this is crucial.

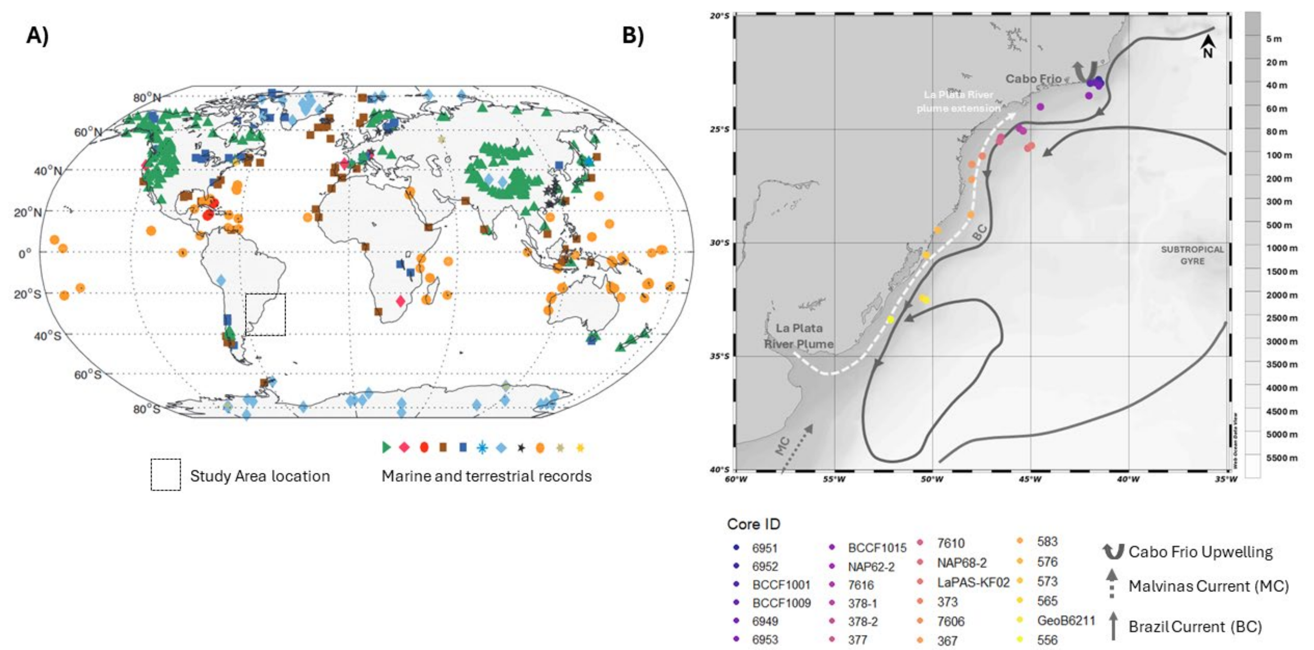

Figure 1: (A) Global records from PAGES 2k databases (from PAGES2k Consortium, 2017) and (B) location of the records on the SW Atlantic gathered by this study and regional hydrodynamic patterns, more information on Supplementary Table 1.

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2 Data

2.1 Insights from the SW Atlantic

To date, the available (i.e., deposited in open databases, supplementary material of published papers, or publicly shared) Common Era SST data from the SW Atlantic includes 24 marine sedimentary records (Supplementary Table 1). Based on three proxy types, MAT (Modern Analogue Technique), UK'37 based in alkenones and Mg/Ca using planktonic foraminifera (Supplementary Figure 1). These records span latitudinal ranges from 23ºS to 33.4ºS and depths ranging from 60 to 1393 meters, influenced by diverse oceanographic conditions (Fig. 1b). Most of these records except one (Nascimento, 2024) derive from studies that are not focused on the Common Era and cover only part of this period. Additionally, none of these records meet the quality criteria for the Common Era SST reconstructions established by the PAGES Ocean 2K (PAGES2k Consortium, 2017), which requires a minimum of 20 samples within the 1850–2000 interval and an average temporal resolution of at least one data point every 200 years. Although the SW Atlantic records do not fully meet these criteria, they may still provide valuable insights into regional climate variability when considered in relation to broader global trends.

Given the limited availability of SST records for the SW Atlantic (Supplementary Figure 1), here we present an exploratory visualization of SST anomalies (Fig. 2) for this region over the last two millennia. For this we obtained the anomalies from the SST data available for each core and generated a SST anomaly stack curve. The anomalies were calculated relative to the reference period 1961–1990 (summer), obtained from NOAA Optimal Interpolation (OI) SST V2, with resolution 1°x1° (Supplementary Figure). By normalizing SST data, the SST anomaly better represent description of climate variation and allows frequent comparisons between different areas significantly (NOAA, 2022). The SST anomalies were evaluated considering their distribution across the pre-industrial cold and warm epochs of the Common Era in order to identify patterns and fluctuations specific to SW Atlantic. We then compared the obtained stack curve of SST anomalies from the SW Atlantic with the tropical global SST anomalies presented by Abram et al. (2016) (Figure 3). These observations are not intended to replace comprehensive quantitative reconstructions, but rather to contextualize regional changes within the framework of hemispheric and global climate evolution. This perspective helps underscore both the importance of filling existing data gaps and the value of preliminary analyses for guiding future research directions.

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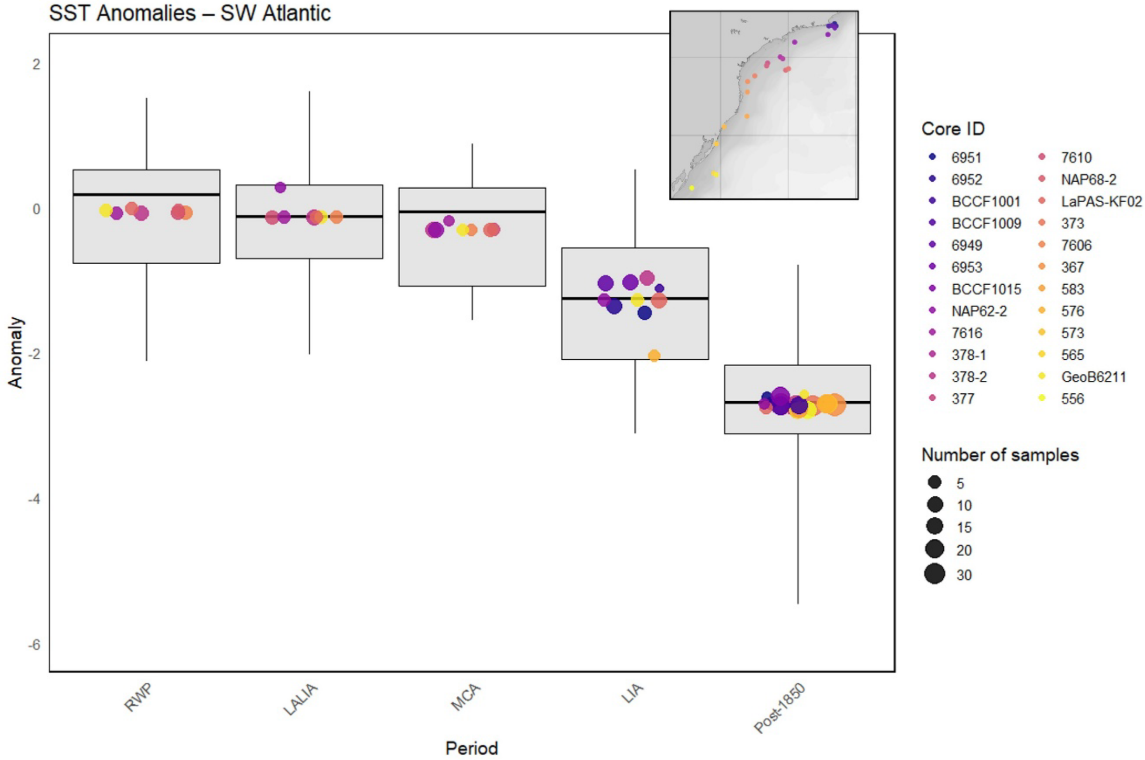

Figure 2: Sea Surface Temperature (SST) anomalies relative to the reference period (1961 - 1990) obtained from NOAA Optimal Interpolation (OI) SST V2 (NOAA, 2022) in the Southwest Atlantic across major historical climate periods. The boxplots show the distribution of annual SST anomalies (2.5th percentile, 25th percentile, median, 75th percentile, and 97.5th percentile) for each period: Roman Warm Period (RWP, 0-400 CE), Late Antique Little Ice Age (LALIA, 400-800 CE), Medieval Climate Anomaly (MCA, 800-1200 CE), Little Ice Age (LIA, 1300-1850 CE), and Post-1850 CE (Mann et al., 2009; Neukom et al., 2019). Coloured points represent mean SST anomalies from individual sediment cores within each climatic period, with point size scaled by the number of samples available for each core within that period.

SW Atlantic SST anomalies (Fig. 2) during the Roman Warm Period (RWP, 0 – 400 CE) ranged from negative (-1.56 ºC) to positive (2.49 ºC) values, while during the Late Antique Little Ice Age (LALIA, 400 – 800 CE), the anomalies exhibited a slightly broader range (-2.78 to 2.19ºC), including colder extremes. For the Medieval Climate Anomaly (MCA, 800 – 1200 CE), the range of SST anomalies was broader (-4.30 to 2.20ºC) than in previous periods, with both colder and warmer deviations. During the Little Ice Age (LIA, 1300 – 1850 CE), the SST anomalies exhibited a more pronounced range, with colder values dominating (-5.00 and 1.69ºC). For the post-industrial period, spanning from 1850 to 2020, SST anomalies exhibited a higher variability compared to the other periods (-6.82 to 1.56ºC) with the colder SST anomalies recorded. Although, we do not have evidence of coherent cold and warm epochs over the past two millennia (Neukom et al. 2019), the cooling trend from 1 to 1800 CE observed in SW Atlantic agrees with the Ocean2k SST synthesis (McGregor et al. 2015). During RWP, the Ocean2k synthesis shows that SST anomalies ranged from -1.85 ºC to 2.35 °C, LALIA from -2.0 to 1.9°C, MCA from -1.4 to 1,6 °C, and LIA from -2.1 to 1.7 °C. The strongest cooling observed during LIA suggested a global ocean cooling signal during this time (McGregor et al., 2015; Fig. 4) and is also recorded by the SW Atlantic SST anomalies.

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However, for the period from 1800 to 2000 CE, the Ocean2k SST synthesis shows a significant warming trend, marking a change from the long-term cooling of the previous centuries and featuring the greatest variability in SST anomalies values, ranging from -2.6 to 2.4°C (McGregor et al. 2015). Overall, unlike the global trend of rising SSTs observed in several studies, especially highlighting the marked post-industrial warming (e.g., Neukom et al. 2019), the SW Atlantic shows an opposite pattern with a cooling trend from 1850 to 2020 (Fig. 2).

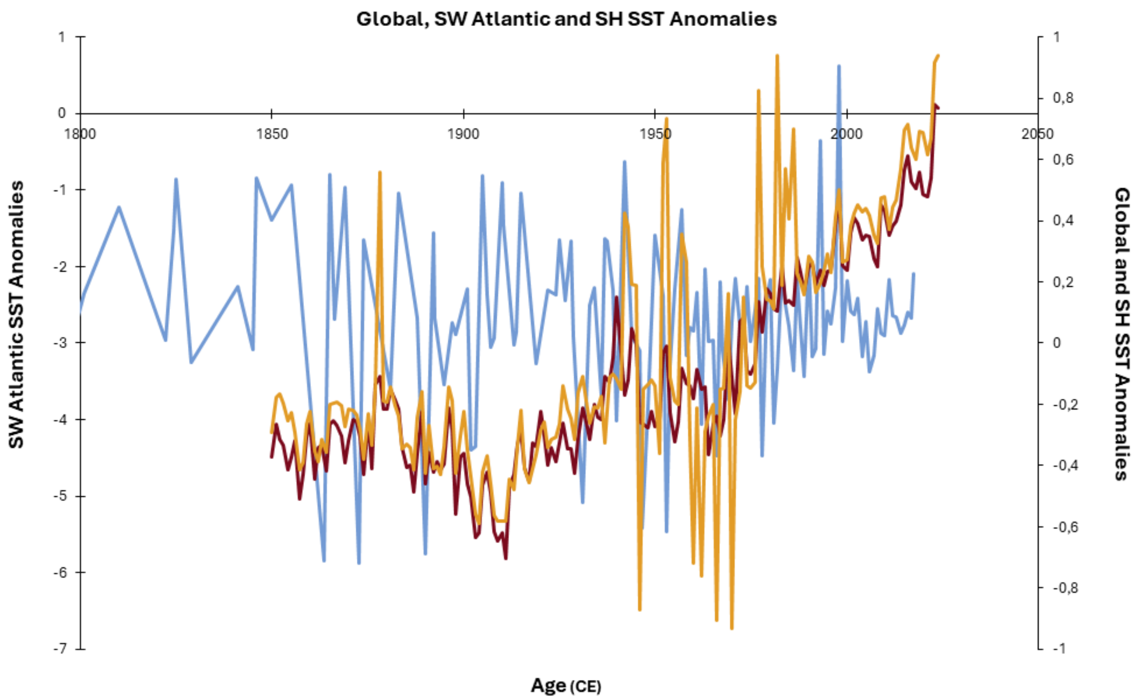

Figure 3: Southern Hemisphere (red line), Global (orange line) average SST anomalies for the full gridded dataset 1850-present, relative to the 1961-1990 (Kennedy et al., 2019) and SW Atlantic average SST anomalies (light blue line).

This reconstruction represents an interpretation based on available proxy records, this approach is essential for advancing our understanding of regional climate variability and its role within the broader climate system. These records are primarily located in regions influenced by three key oceanographic features: the Brazil Current, the La Plata River Plume, and upwelling zones (Fig. 1) (e.g., Pivel et al. 2013; Chiessi et al. 2014; Cordeiro et al. 2014; Lourenço et al. 2017; Nagai et al. 2020; Bícego et al. 2022). The Brazil Current is a warm western boundary current that transports heat poleward along the Southeastern American margin, shaping regional SST (Bou-Haya and Sato 2022). Variations in its strength and position can lead to significant changes in heat uptake and transport, which can also impact regional climate (Sen Gupta et al. 2021; Bou-Haya and Sato 2022). The La Plata River Plume, formed by the freshwater discharge from the Río de la Plata, results in cooling

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of the surface waters in response to wind patterns (Möller et al. 2008). The plume latitudinal extension follows the seasonal wind regime, extending as far as 25.5ºS (Bonifatto et al.2024; Marta-Almeida et al. 2021; Fig. 1b). Notably, the sedimentary records north of 25°S span 778–2010 CE and are influenced by the Cabo Frio coastal upwelling system, which may amplify the regional SST cooling signal from the LIA to the present (Fig. 5). Thus, the apparent cooling trend observed from ~800 CE onward may partly reflect the restricted spatial coverage of these records, whereas the full regional dataset covering 0–2010 CE incorporates sites that are more broadly distributed.

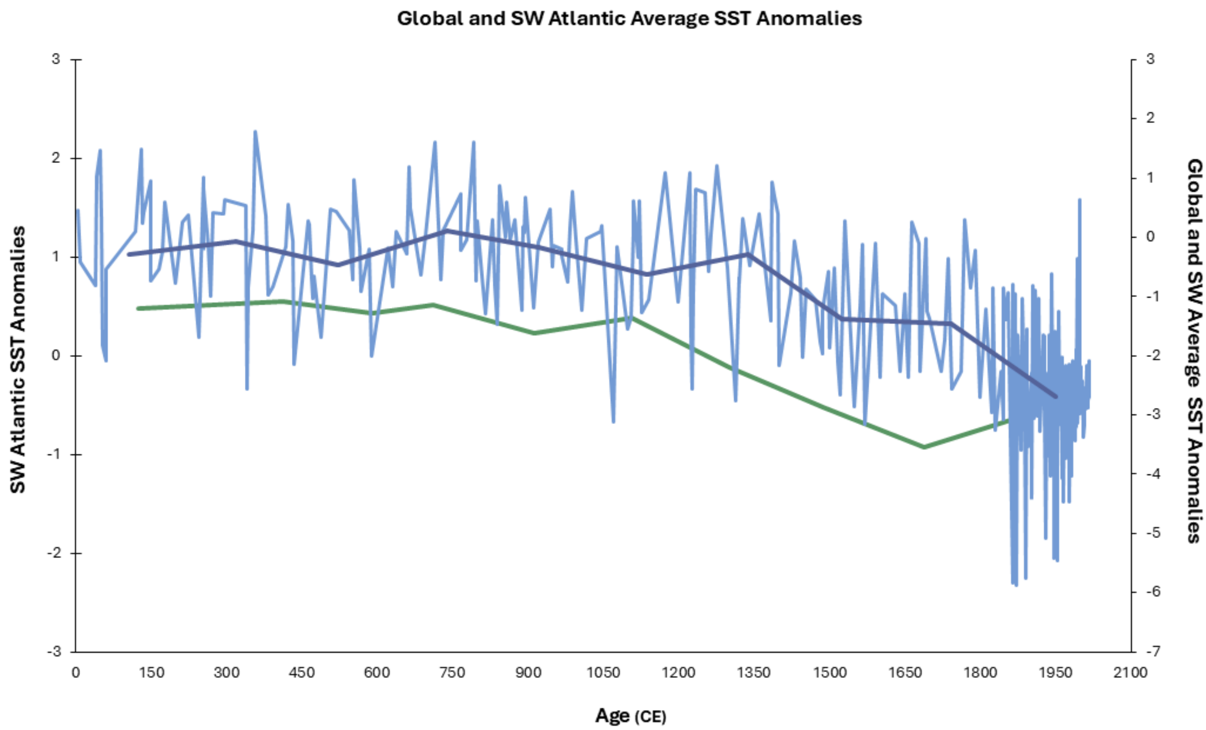

Figure 4: Global SST average anomalies from 57 records around the globe (McGregor et al., 2015; green line), SW Atlantic SST average anomalies (light blue line) and 200-yrs average (dark blue line).

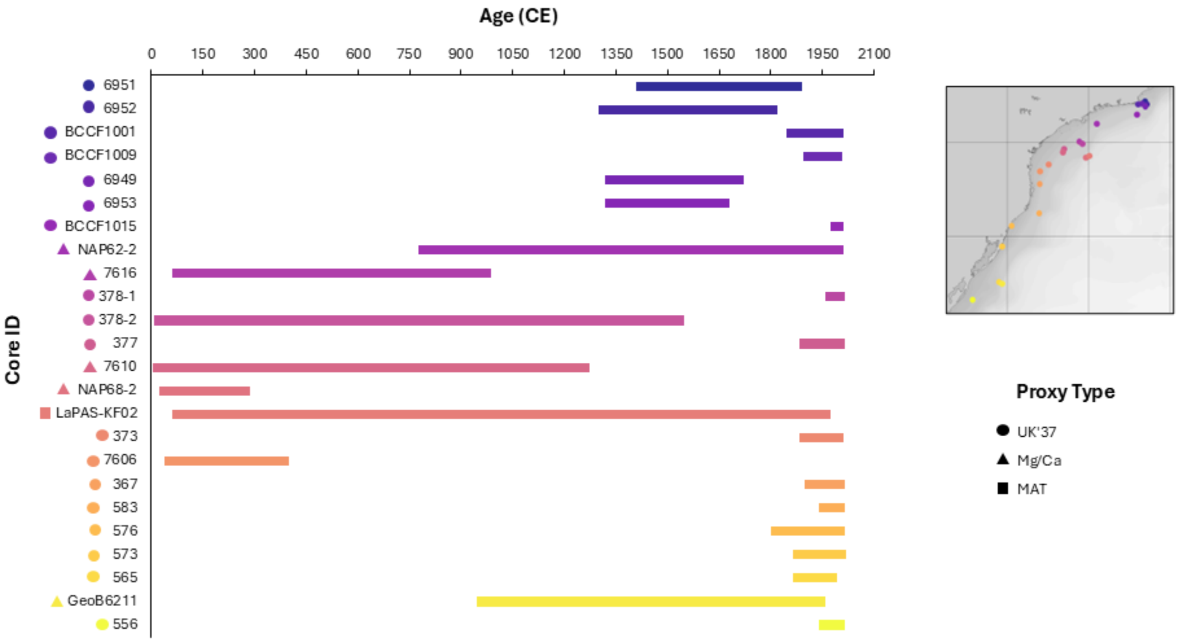

Figure 5: Temporal range and Proxy Type of all records compiled in this study.

These findings demonstrate that the SW Atlantic lacks adequate records to represent Common Era SST anomaly changes, as the available records have been retrieved from locations where local hydrodynamics control SST patterns. Therefore, future efforts should prioritize the collection of records from offshore locations that better reflect regional and/or global hydrodynamic influences, allowing for proper assessment of the regional response to climate change. Nonetheless, it is also noteworthy that understanding local oceanographic process variations during the Common Era may be crucial to improve future climatic change impacts on people's lives.

3. Summary and conclusions

The current scarcity of climate records from underrepresented regions, particularly in the Southern Hemisphere and the tropics, limits our ability to accurately reconstruct global and regional climate patterns. These gaps hinder our understanding of how different areas of the planet have responded to climate change throughout history. The SW Atlantic SST paleorecords highlight the importance of regional oceanographic features on SST reconstructions, which is why the SST anomalies (relative to the 1961–1990 reference period) differ from global signals. Elucidating regional paleo-SST records, considering their unique characteristics, in light of global climate fluctuations, is crucial for recognizing how these influences create signals in the data, which then become part of global reconstructions. Additionally, it is essential to carefully account for and clearly report the impact of regional oceanographic factors to avoid misinterpretation of records and to accurately understand the response of this ocean basin to climate change.

To minimize the impact of local oceanographic factors on Common Era SST reconstructions of the SW Atlantic, prioritizing offshore sampling in studies is crucial. Doing so will help build a more comprehensive understanding of Earth's climate history and highlight the significance of data from currently underrepresented regions. However, overcoming these limitations requires more than simply collecting data. The scientific community must intensify efforts to produce and share SST reconstructions spanning the Common Era. Open-access platforms such as PANGAEA and PAGES2k play a critical role in addressing this challenge by making data freely available. This accelerates research, reduces duplication of efforts, and ensures that the global scientific community benefits from a shared repository of knowledge. Progress in this area is gradual, but ongoing efforts focus not only on generating new records but also on raising awareness of the importance of investing in these reconstructions to advance climate science. Ultimately, this will enhance our ability to predict and respond to future climate changes, providing policymakers and communities with the tools they need to build resilience and adapt to a rapidly changing world. The time to act is now. By prioritizing these efforts, we can unlock the full potential of SST reconstructions and ensure a more sustainable future for all.

Data availability

The compilation of sea surface temperature (SST) anomalies generated in this study is available at Zenodo (https://doi.org/10.5281/zenodo.18392297; dos Reis de França et al., 2026).

Author contributions

JRF, AG, and RHN developed the study conceptualization. JRF, AG and RHN managed the data curation and formal analysis. JRF, AG and RHN prepared the manuscript with contributions from all co-authors.

Competing interests

The authors declare that they have no conflict of interest.

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