

Dear Reviewer,

On behalf of the co-authors and myself we appreciate your thoughtful feedback. We submit the following responses for consideration. Your comments are italicized in gray and my responses are in black.

Best wishes,

Dr. Christian B. Lewis

This study lays the groundwork for the use of Southern Hemisphere tree-rings for studying changes in Southern Ocean upwelling and air-sea CO₂ flux. The authors demonstrate that trees from Chile and New Zealand from the 1980s to present accurately record atmospheric 14C (with a few exceptions) with a latitudinal gradient observed for New Zealand sites. Using HYSPLIT software they model back-trajectories for the air masses reaching the site and show that the New Zealand gradient is driven by Southern Ocean outgassing and atmospheric transport. The methods used are robust and the manuscript is generally well-written. Due to the importance of the Southern Ocean in global climate, this study will be critical for future work on constraining temporal changes in upwelling and air-sea gas exchange.

Minor comments: (strikethrough indicates completion/comment is resolved)

Line 30: Insert space after (Talley, 2013) Done

Line 33: Possibly insert 'content' after 'carbon' just to be clear that this doesn't refer to 14C (although probably fine). Done

Table 1: 'The final column references numbered locations on Figure 2a/b maps.' Note: The final column with location number is missing. Done

Line 163: 'using a FFT filter cut-off of 667' What are the units?

The value for f_c is specified in 'number of days'. Figure 4 shows the response function with cutoff values of 80 days for the short term filter and 667 days for the long term filter. <https://gml.noaa.gov/ccgg/mb/chrfit/chrfit.html>

Line 168: 'Data will be included in Supplementary Material' Is this yet to be done or will it be at 10.5281/zenodo.14532802?

I've simply removed this line because it may cause confusion. I will let readers find the Data Availability statement rather than bring it up piecemeal throughout the paper.

Figure 2: Perhaps change the label 'CCGCRV Trend Reference' to 'CCGCRV SHB Trend' for clarity

It may be clearer to simply remove the legend. An extra line was added in Figure caption to say the line has been smoothed.

Line 209: ‘The data was filtered for existing radiocarbon measurements ('G2c14')’ Please insert ‘ocean’ in front of radiocarbon.

Following text was edited:

The GLODAP Merged and Adjusted Data Product v2.2023 is used to add context to the discussion of our results (Key et al., 2004; Lauvset et al., 2023). The data was filtered for existing ocean dissolved inorganic carbon radiocarbon measurements ('G2c14') south of 5°S, shallower than 100m, and post-1980 to match our tree-ring temporal span.

Line 213: ‘on bottle latitude/longitudes’ Some readers may not be familiar with the use of bottles for ocean water collection- perhaps replace with ‘sample collection latitude/longitudes’

Fixed

Line 309: ‘(Prend et al., 2022) discovered a deep maximum mixed layer depth surrounding Campbell Island and westward in the ASZ (Prend 2022 Fig. 1c).’ The sentence should start with ‘Prend et al. (2022) discovered’ and presumably end with (Prend et al. 2022, Fig. 1c)

Fixed

Line 313: ‘Low $\Delta\Delta^{14}\text{CO}_2$ at Campbell Island may be linked air originating’. Insert ‘to’ after ‘linked’.

Fixed

Line 326: ‘local effects such as nearby obduction from deep mixed layer’ Doesn’t obduction refer to crustal movements?

Prend et al. (2022) define obduction as follows:

“We find that the interbasin variation in surface ocean pCO₂ is primarily driven by regional variability in wintertime entrainment of carbon-rich deep water from the permanent pycnocline (“obduction”).” (Prend et al., 2022).

We have removed this term to avoid further confusion.

Line 329: ‘This suggests that the influence of non-local fossil fuel and biospheric signals are small in the Southern Hemisphere.’ Does this apply to the entire Southern Hemisphere?

Yes. This response is in alignment with previous observational and modelling studies that show the latitudinal gradients of ¹⁴C from pole-to-pole suggests that fossil fuel emissions and biosphere signals are small in the Southern Hemisphere. ¹⁴C increases in the tropics due to lower fossil fuel emissions and biospheric signals, but decrease in the Southern Hemisphere due to Southern Ocean upwelling before increasing again

toward the pole due to stratospheric production of ^{14}C ((Graven et al., 2012; Levin et al., 2010; Randerson et al., 2002; Turnbull et al., 2009; Turnbull et al., 2017)).

The citations need to be carefully checked as many in the text are missing from the reference section or incomplete. I've found the following problems with citations but may have missed some: Fixed

Line 49: 'Levin et al.)' Is this Levin et al. 2010?

Line 110: Zondervan et al., 2016. This is given as 2015 in references

Line 200: Warner 2018 is not in references. Should this be Millissa & Warner 2018?

Line 490: 'Norris, M. W. (2015). Reconstruction of historic fossil CO₂ emissions using radiocarbon measurements from tree rings' This reference is incomplete.

Citations not in reference section:

Line 52: Turnbull et al. 2009

Line 58: Rend et al. 2022 (typo, should have been Prend et al., 2022).

Line 108: Baisden et al. 2013

Line 109 Turnbull et al. 2015

Line 110: Stuiver & Polach 1977

Line 161: Thoning et al. 1989

Line 182: Suess 1955

References

Graven, Heather D., Nicolas Gruber, Robert Key, Samar Khatiwala, and Xavier Giraud. "Changing controls on oceanic radiocarbon: New insights on shallow-to-deep ocean exchange and anthropogenic CO₂ uptake." *Journal of Geophysical Research: Oceans* 117, no. C10 (2012).

Key, Robert M., Alex Kozyr, Chris L. Sabine, Kitack Lee, Rik Wanninkhof, John L. Bullister, Richard A. Feely, Frank J. Millero, Calvin Mordy, and T-H. Peng. "A global ocean carbon climatology: Results from Global Data Analysis Project (GLODAP)." *Global biogeochemical cycles* 18, no. 4 (2004).

Lauvset, Siv K., Nico Lange, Toste Tanhua, Henry C. Bittig, Are Olsen, Alex Kozyr, Marta Álvarez et al. "The annual update GLODAPv2. 2023: the global interior ocean biogeochemical data product." *Earth System Science Data* 16, no. 4 (2024): 2047-2072.

Levin, Ingeborg, Tobias Naegler, Bernd Kromer, Moritz Diehl, Roger Francey, Angel Gomez-Pelaez, Paul Steele, Dietmar Wagenbach, Rolf Weller, and Douglas Worthy. "Observations and modelling of the global distribution and long-term trend of atmospheric $^{14}\text{CO}_2$." *Tellus B: Chemical and Physical Meteorology* 62, no. 1 (2010): 26-46.

Prend, Channing J., Alison R. Gray, Lynne D. Talley, Sarah T. Gille, F. Alexander Haumann, Kenneth S. Johnson, Stephen C. Riser, Isabella Rosso, Jade Sauvé, and Jorge L. Sarmiento. "Indo-Pacific sector dominates Southern Ocean carbon outgassing." *Global Biogeochemical Cycles* 36, no. 7 (2022): e2021GB007226.

Randerson, J. T., I. G. Enting, E. A. G. Schuur, K. Caldeira, and I. Y. Fung. "Seasonal and latitudinal variability of troposphere $\Delta^{14}\text{CO}_2$: Post bomb contributions from fossil fuels, oceans, the stratosphere, and the terrestrial biosphere." *Global Biogeochemical Cycles* 16, no. 4 (2002): 59-1.

Turnbull, Jocelyn C., Sara E. Mikaloff Fletcher, Gordon W. Brailsford, Rowena C. Moss, Margaret W. Norris, and Kay Steinkamp. "Sixty years of radiocarbon dioxide measurements at Wellington, New Zealand: 1954–2014." *Atmospheric Chemistry and Physics* 17, no. 23 (2017): 14771-14784.

Turnbull, Jocelyn, Peter Rayner, John Miller, Tobias Naegler, Philippe Ciais, and Anne Cozic. "On the use of $^{14}\text{CO}_2$ as a tracer for fossil fuel CO_2 : Quantifying uncertainties using an atmospheric transport model." *Journal of Geophysical Research: Atmospheres* 114, no. D22 (2009).