

The authors aim to analyze the influence of riverine input on the CO₂ system in the northwestern Pacific, and its implications for future climate change and coastal acidification. Their analysis focuses on four key parameters of the CO₂ system: total alkalinity (TA), dissolved inorganic carbon (DIC), calcite saturation state (Ω_{cal}), and fugacity of CO₂ (fCO₂).

The manuscript presents an interesting and relevant assessment of the effects of freshwater discharge from the eastern coast of Japan into the northwestern Pacific Ocean. The statistical approach is sound, and the manuscript is well-organized. It should be considered for publication, provided the discussion of acidification processes is further improved.

In the Introduction, the authors state that riverine input is the major carbon source for the oceans. However, this claim is not supported by current estimates. Rivers discharge approximately 0.9 to 1.3 Pg of carbon per year into the ocean, in both dissolved and particulate forms. A recent global assessment by Liu et al. (2024) estimates riverine carbon export at 1.02 ± 0.22 (2 σ) Pg C yr⁻¹, partitioned into 0.52 ± 0.17 Pg C yr⁻¹ of dissolved inorganic carbon, 0.30 ± 0.14 Pg C yr⁻¹ of dissolved organic carbon, 0.18 ± 0.04 Pg C yr⁻¹ of particulate organic carbon, and 0.03 ± 0.02 Pg C yr⁻¹ of particulate inorganic carbon. In contrast, the ocean's uptake of atmospheric CO₂ is estimated to be significantly higher—around 2.9 ± 0.4 Pg C yr⁻¹ (Friedlingstein et al., 2025). Therefore, on a global scale, atmospheric carbon uptake is a more substantial source of carbon to the ocean than riverine input. It should be noted, however, that earlier estimates, such as those by Bauer et al. (2013), suggested that in coastal regions specifically, riverine carbon inputs could exceed atmospheric contributions. This distinction between global ocean and coastal zone carbon budgets should be clarified in the manuscript.

The abstract addresses the issue of coastal acidification; however, this aspect is only indirectly considered in the manuscript, as the selected parameters do not include pH. Instead, the authors use the calcite saturation state (Ω_{cal}) as a proxy for acidification. While Ω is commonly used in ocean acidification (OA) studies, it is important to note that in the global surface ocean, pH and Ω often exhibit out-of-phase behavior in terms of both spatial distribution and seasonal variability (e.g., Xue et al., 2021; Kwiatkowski & Orr, 2018), which may seem counterintuitive. Although both pH and Ω are widely used as indicators of OA, their asynchronous variability complicates the choice of which parameter better represents the impact of carbonate chemistry on marine organisms (Jokiel, 2013; Waldbusser et al., 2014). This complexity arises from the interplay between long-term trends and short-term natural variability, which can obscure biological responses (Kwiatkowski & Orr, 2018; Landschützer et al., 2018).

Many of the biological effects of ocean acidification depend not only on carbonate ion concentration [CO₃²⁻] but also on hydrogen ion concentration [H⁺], i.e., pH, as well as on bicarbonate [HCO₃⁻] (Cyronak et al., 2015; Jokiel, 2013). If the authors intend to explore the impacts of acidification in depth, it is essential that they include and discuss pH data alongside the other CO₂ system parameters. Without pH, the discussion of acidification remains incomplete and indirect. Alternatively, if the focus is primarily on the carbonate saturation state, the manuscript should clearly state this and align the discussion accordingly.

Furthermore, the authors report Ω (omega) for calcite but do not include Ω for aragonite, which is more commonly used in ocean acidification studies. Aragonite is more soluble than calcite, and organisms that produce aragonitic shells or skeletons are generally more vulnerable to decreasing saturation states under acidified conditions. Therefore, aragonite saturation is typically the preferred indicator when assessing biological sensitivity to ocean acidification. The manuscript would benefit from a clearer justification for the choice of Ω_{calcite} over $\Omega_{\text{aragonite}}$, or, from the inclusion of both parameters to allow for a more comprehensive assessment.

Minor comments

L.21 The sentence should be revised: the affirmation that the riverine water is not the dominant cause of Dissolved Inorganic Carbon should be better formulated.

L. 23 The supply of by riverine water “: correct.

L371-374 and 380 and 398. The sentences referring to acidification should be revised for clarity and accuracy. As the authors do not include pH data in their analysis, they are not directly addressing the acidification process, which is fundamentally defined by changes in hydrogen ion concentration [H⁺]. Instead, their focus is on the carbonate saturation state (Ω), which is indeed affected by acidification but also depends on the buffering capacity of the system.

Given this, I suggest that the authors frame their discussion primarily in terms of the saturation state of the studied system, rather than acidification per se, unless they choose to explicitly include calculated or measured pH values. Including pH—either measured or derived from the available CO₂ system parameters—would allow for a more comprehensive and direct discussion of the acidification process.

L. 386-387 Regarding the statement that the DIC flow were more complex than the TA flow it is not very clear if the authors refer to the advection to the biologically related process, they should explain better how the flow is affected by a residual term -- which are the processes behind it?

L174-176. "Please add units to the colour bars in panels (b) and (c) of Figure 1 to ensure clarity and consistency. Additionally, the significance level (e.g., *p*-value) for the linear regression should be provided to assess the statistical robustness of the trend. The term 'approximate line' is ambiguous—please clarify its meaning. If it refers to a fitted trend line, specify the method used (e.g., least squares regression).

L. 237-240 in figure 4 b and e I suppose that the units should be $\mu\text{mol kg}^{-1} \text{ month}^{-1}$ not year^{-1}

L280-281 However, no regional difference in calcification rate of up to $10 \mu\text{mol kg}^{-1} \text{ year}^{-1}$ has not been reported... The are two negations which means an affirmation The sentence should be corrected.

L. 331 In figure 6a the units should be $\mu\text{mol kg}^{-1} \text{ month}^{-1}$ not year^{-1} . As the data represented are monthly averages.

L.345-347 Due to the wide offshore oceanic area with respect to the shallow coastal waters of I wonder if the role of submerged aquatic vegetation can be considered relevant. Could you provide more support to this affirmation.

L.369 Correct “air-sea CO₂ fluxes”.

Text S1 Vertical profile an advection

“They ranged from” : correct

Text S2 Riverine supply from mainland of Japan

It is not clear to me if the authors assumed the same flow rate for all the rivers or if they compute the total riverine flow considering a proportionality with the flow rate of each river. Could you explain better this part.

Could the authors provide a table similar to S1 comparing the characteristic of area A and B in order to show the different oceanographic characteristics

"The English throughout the manuscript should be revised by a native speaker or a professional language editor to improve clarity, and overall readability.

References

- Bauer, J. E., Cai, W. J., Raymond, P. A., Bianchi, T. S., Hopkinson, C. S., and Regnier, P. A. G.: The changing carbon cycle of the coastal ocean, *Nature*, 504, 61–70. <https://doi.org/10.1038/nature12857>, 2013.
- Cyronak, T., Schulz, K. G., Jokiela, P. L. 2015. The Omega myth: what really drives lower calcification rates in an acidifying ocean. *ICES Journal of Marine Science*, doi: 10.1093/icesjms/fsv075.
- Friedlingstein, P. et al. 2025. Global Carbon Budget 2024 *Earth Syst. Sci. Data*, 17, 965–1039.
- Jokiela, P. L. 2013. Coral reef calcification: Carbonate, bicarbonate and proton flux under conditions of increasing ocean acidification. *Proceedings of the Royal Society B: Biological Sciences*, 280(1764), 529–549. <https://doi.org/10.1098/rspb.2013.0031>
- Kwiatkowski, L., & Orr, J. C. (2018). Diverging seasonal extremes for ocean acidification during the twenty-first century. *Nature Climate Change*, 8(2), 141–145. <https://doi.org/10.1038/s41558-017-0054-0>
- Landschützer, P., Gruber, N., Bakker, D. C. E., Stemmler, I., & Six, K. D. (2018). Strengthening seasonal marine CO₂ variations due to increasing atmospheric CO₂. *Nature Climate Change*, 8(2), 146–150. <https://doi.org/10.1038/s41558-017-0057-x>
- Liu, M., Raymond, P. A., Lauerwald, R. et al. Global riverine land-to-ocean carbon export constrained by observations and multi-model assessment. *Nat. Geosci.* **17**, 896–904 (2024). <https://doi.org/10.1038/s41561-024-01524-z>
- Xue, L., Cai, W.-J., Jiang, L.-Q., Wei, Q. 2021. Why are surface ocean pH and CaCO₃ saturation state often out of phase in spatial patterns and seasonal cycles? *Global Biogeochemical Cycles*, 35, e2021GB006949. <https://doi.org/10.1029/2021GB006949>
- Waldbusser, G. G., Hales, B., Langdon, C. J., Haley, B. A., Schrader, P., Brunner, E. L., et al. 2014. Saturation-state sensitivity of marine bivalve larvae to ocean acidification. *Nature Climate Change*, 5, 273–280. <https://doi.org/10.1038/NCLIMATE2479>