Response to Referee #1 Comment (RC1)

We would like to thank the referee for taking the time to review our manuscript and for providing constructive comments. Please see our responses to the comments below.

The paper is a long-standing pending issue in addressing the CO2 fluxes of this very important region. It deserves publication in Ocean Science. However, it has missed the following key elements, which need to be addressed.

Valsala et al., (2020) have done, for the first time, analysis of 60-year long record of sotheastern tropical Indian Ocean CO2 flux variability, pCO2 variability associated with the IOD. The study concluded that, “The IOD leads to a substantial sea-to-air CO2 flux variability in the southeastern tropical Indian Ocean over a broad region (70–105°E, 0–20°S), with more focus near the coast of Java-Sumatra due to the prevailing upwelling dynamics and associated westward propagating anomalies. The sea-to-air CO2 fluxes, surface ocean partial pressure of CO2 (pCO2), the concentration of dissolved inorganic carbon (DIC), and ocean alkalinity (ALK) range as much as ±1.0 mole m−2 year−1, ±20 μatm, ±35 μmole kg−1, and ±22 μmole kg−1 within 80–105°E, 0–10°S due to IOD. The DIC and ALK are significant drivers of pCO2 variability associated with IOD. The roles of temperature (T) and biology are found negligible. A relatively warm T and extremely high freshwater forcing make the southeastern tropical Indian Ocean carbon cycle variability submissive to DIC and ALK evolutions in contrast to the tropical eastern Pacific where changes in DIC and T dominate the pCO2 interannual variability. For the first time, this study provides a most comprehensive and extended analysis for the region while highlighting significant differences in carbon cycle variability of the eastern tropical Indian Ocean compared to that of the other parts of the global oceans.”

This is an important recent work and needs to be cross-discussed in this paper, especially due to the reason the IOD impacts are revisited in this manuscript, and the results have differences. It is always good to have various modelling comparisons so that the community is benefited from knowing how the model performs and differ from each other. Other papers missed addressing are also added below:

Valsala, V., M. G. Sreeush, and K. Chakraborty, (2020), IOD impacts on Indian the Ocean Carbon Cycle, Journal of Geophysical Research, https://doi.org/10.1029/2020JC016485

Chakraborty K., V. Valsala, T. Bhattacharya, J. Ghosh, (2021), Seasonal cycle of surface ocean pCO2 and pH in the northern Indian Ocean and their controlling factors, Progress in Oceanography, Vol.198, doi.org/10.1016/j.pocean.2021.102683

Valsala V., Sreeush M.G., Anju M., Sreenivas P., Tiwari Y.K., Chakraborty K., Sijikumar S., An observing system simulation experiment for Indian Ocean surface pCO2 measurements, Progress in Oceanography, 194: 102570, June 2021, DOI: 10.1016/j.pocean.2021.102570, 1-14

Sreeush, M. G., Valsala, V., Pentakota, S., Prasad, K. V. S. R., and Murtugudde, R (2018), Biological production in the Indian Ocean upwelling zones – Part 1: refined estimation via the use of a variable compensation depth in ocean carbon models, Biogeosciences, 15, 1895-1918, https://doi.org/10.5194/bg-15-1895-2018

**Response**: Thank you very much for your comment and for providing us with a recent study that is relevant to our manuscript. We will add some discussion, especially regarding the previous modeling results, in the revised manuscript. For a lively community discussion here, we will explain some key points we obtained from the articles provided by the referee.

Both our model and the study by Valsala et al. (2020) agree that a positive IOD (pIOD) corresponds with stronger-than-usual sea-air $CO_2$ flux in the southeastern tropical Indian Ocean (SETIO). The important role of DIC which outweigh the temperature influence on regulating the $pCO_2$ and further $CO_2$ flux in the area also highlighted from these modeling studies. However, we also noted some notable differences between this modeling study and the recent study by Valsala et al. (2020).

There is a difference regarding the center of IOD influence on sea-air $CO_2$ flux modulation suggested in Valsala et al. (2020) compared with our modeling results. Instead of concentrated IOD influence on the southwestern part of the Sumatra coast, study conducted by us suggested another strong $CO_2$ flux modulation signal on the south coast of Java, even with limited local wind modulation under the same climatic forcing. We suppose that this pattern is related to the influence of remote forcing, as indicated by Delman et al. (2016, 2018). They suggested that anomalous wind stress west of Sumatra or equatorially forced Kelvin Wave plays an important role in upwelling variabilities in South Java during pIOD events. Because the model utilized here was forced by high-temporal resolution atmospheric data (Three-hourly JRA55; Kobayashi et al., 2015) and all the tracers (physical and biogeochemical) were calculated online during model integration, it is likely that our model captured the intraseasonal variabilities during IOD development. The intraseasonal signal accumulated further and resulted in an interannual pattern, as shown in Figure 9 in the submitted manuscript.

To further prove that the regressed $pCO_2$ and $CO_2$ flux anomaly patterns in the submitted manuscript are related to the IOD-induced upwelling variabilities, we also regressed the wind speed anomalies, anomalies in the difference between sea surface $pCO_2$ and atmospheric $CO_2$ ($\delta pCO_2$), and SST anomalies against a one-standard deviation of the DMI, as shown in figure below. The regressed patterns of wind anomalies and SST anomalies were consistent with the study by Delman et al. (2016), who utilized satellite data. Therefore, it is very likely that the presented $pCO_2$ and $CO_2$ flux anomaly pattern related to the IOD is due to upwelling modulation, especially along the southern Sumatra-Java coast.

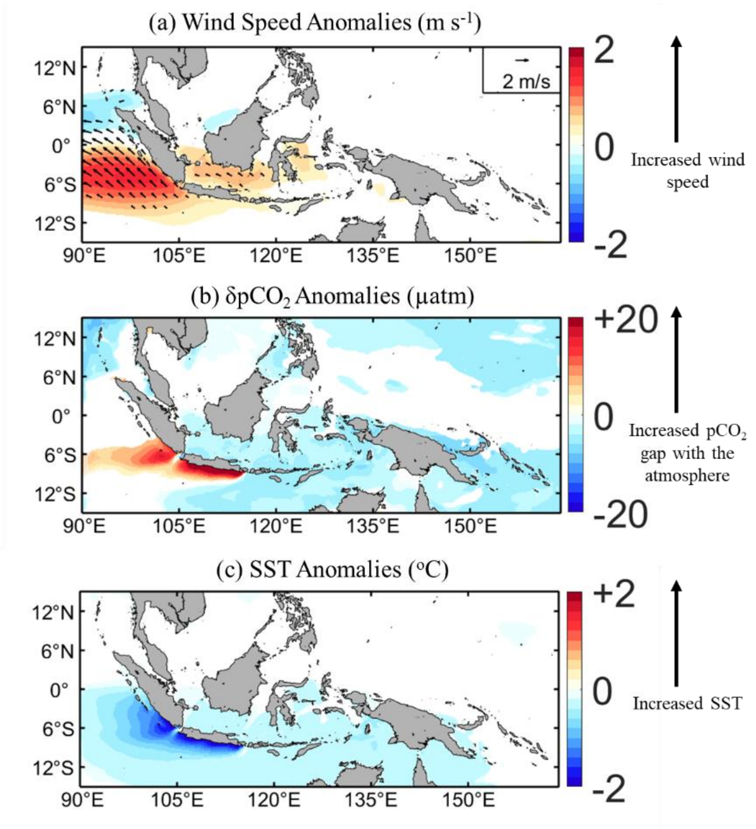


**Figure AR1. Regressed (a) wind speed (vector arrows) and magnitude (shaded color), all in m $s^{-1}$ units; (b) anomalies in the difference between sea surface $pCO_2$ and atmospheric $CO_2$ ($\delta pCO_2$, in μatm); and (c) SST anomalies (in ˚C) against a one-standard deviation of DMI ($+1\sigma_{DMI}$), representing typical positive IOD events according to the simulation results that use historical monthly atmospheric $CO_2$ concentrations. Plotted vector and shaded color were significant at *p* > 0.01**

Another point that should be noted is the possible effect of the horizontal resolution setting used in our model (i.e., $1/6^{o} \times 1/6^{o}$), which may limit the extent of IOD influence related to upwelling variabilities. A recent study by Kido et al. (2022) argued that low-resolution OGCM exaggerated the coastal-open ocean water exchange artificially, which is in line with the experiments conducted by Liu et al. (2019). Additionally, Delman et al. (2018) in their study also indicated that a relatively coarse resolution model product underestimated the advection effect (both horizontal and vertical) on South Java cooling during the development of the pIOD. This may explain the relatively smaller extent of IOD influence according to our simulation results relative to Valsala et al. (2020).

**Reference:**


Delman, A. S., McClean, J. L., Sprintall, J., Talley, L. D., and Bryan, F. O.: Process-Specific Contributions to Anomalous Java Mixed Layer Cooling During Positive IOD Events, J. Geophys. Res. Ocean., 123, 4153–4176, https://doi.org/10.1029/2017JC013749, 2018.

Delman, A. S., Sprintall, J., McClean, J. L., and Talley, L. D.: Anomalous Java cooling at the initiation of positive Indian Ocean Dipole events, J. Geophys. Res. Ocean., https://doi.org/10.1002/2016JC011635, 2016.

Kido, S., Nonaka, M., and Miyazawa, Y.: JCOPE-FGO: an eddy-resolving quasi-global ocean reanalysis product, Ocean Dyn., 72, 599–619, https://doi.org/10.1007/s10236-022-01521-z, 2022.

Liu, X., Dunne, J. P., Stock, C. A., Harrison, M. J., Adcroft, A., and Resplandy, L.: Simulating Water Residence Time in the Coastal Ocean: A Global Perspective, Geophys. Res. Lett., 46, 13910–13919, https://doi.org/10.1029/2019GL085097, 2019.

Kobayashi, S., Ota, Y., Harada, Y., Ebita, A., Moriya, M., Onoda, H., Onogi, K., Kamahori, H., Kobayashi, C., Endo, H., Miyaoka, K., and Kiyotoshi, T.: The JRA-55 reanalysis: General specifications and basic characteristics, J. Meteorol. Soc. Japan, 93, 5–48, https://doi.org/10.2151/jmsj.2015-001, 2015.

Valsala, V., Sreeush, M. G., and Chakraborty, K.: The IOD Impacts on the Indian Ocean Carbon Cycle, J. Geophys. Res. Ocean., 125, 1–18, https://doi.org/10.1029/2020JC016485, 2020.