Reviewer – 2:

This study compiled the data of carbon dynamics in the estuaries of India and overviewed the regulating factors of carbon dynamics and the contribution of Indian estuaries on global carbon budgets. This approach is helpful to understand the role of continental estuaries on global carbon cycling. However, this version of manuscript contains major concerns which the authors have to improve before publication. In particular, I think the analytical approach and the interpretation of data should be revised substantially.

Response: *Thank you for the encouraging comments on the manuscript. We have addressed the concerns raised by both reviewers, which has substantially improved the manuscript.*

First, the authors discussed the mechanism of regulating factors of carbon dynamics mainly based on correlation between carbon and other physicochemical parameters but the results of these analysis were not shown in main Figures. If these analyses are substantially used in discussion section, the main text figures and tables should be restructured according to the main agenda.

Response: *As we had around 20 figures presenting the relationship between variables in the original draft of our manuscript, we decided to present many of the figures showing correlations as supplementary figures. As suggested by the reviewer, we have restructured the figures and tables so as to support the findings and arguments in the discussion section. We also kept numerous figures in the supplement because the visualization of correlations is not essential to the story; rather, we provide the supplemental figures in case a reader is interested to dive deeper into a particular set of parameters.*

In addition, the statistical analysis must pay attention to the multicollinearity of multivariate variables. For example, there is a correlation between river flow and population density, which may have a combined effect on carbon concentrations. I think the author should try some analytical methods such as principal component analysis. Although they mention various regulating factors, it is very difficult to understand from the manuscript what is the key controlling factor. I suggest analysis be extracted and discussed based on the statistical results of the above multivariate analyses.

Response: *Yes, we agree with the reviewer. We have performed PCA test to find out the major controlling factors for estuarine C biogeochemistry in India and the findings are given below and accordingly we revised the manuscript.*

Principal component analysis (PCA) was performed in order to identify major controlling factors for dissolved and particulate C as well as the variability of trace gases (CO_2 and CH_4) in the major estuaries of India. The PCA was performed for 7 parameters (DIC and its isotopic composition, DOC, POC and its isotopic compositions, pCO_2, and CH_4 concentration) based on the availability of other parameters (no of dams, population density, precipitation, estuarine area, discharge, catchment area, salinity, %DO, and pH). Moreover, due to the scarcity of data during the dry season, the PCA analysis is restricted only during the wet season. The principal component (PC) with eigenvalues >1 was considered for further analysis and only two factors were identified in this case as given below:

Table: Results for the Principal Component Analysis of estuarine carbon biogeochemistry of India.

	BB estuaries		AS estuaries	
Eigen value	2.90	2.07	4.40	1.65
Explained variance (%)	41.48	29.65	62.83	23.58
Cumulative	41.48	71.11	62.63	86.41
Variable	**PC1**	**PC2**	**PC1**	**PC2**
DIC	0.89	0.14	0.92	0.21
$\delta^{13}C_{DIC}$	0.73	0.27	-0.65	0.67
DOC	0.40	0.55	0.58	0.72
POC	-0.76	0.46	0.76	-0.61
$\delta^{13}C_{POC}$	-0.82	-0.35	0.92	-0.21
pCO_2	-0.35	0.80	0.87	0.46
CH_4	-0.23	0.84	0.78	0.12

The PC1 accounts for ~41.48% and 62.63% variability for the BB and AS estuaries with strong factor loadings of DIC, $\delta^{13}C_{DIC}$, POC, and $\delta^{13}C_{POC}$ for BB estuaries and DIC, $\delta^{13}C_{DIC}$, DOC, POC, $\delta^{13}C_{POC}$, pCO_2 and CH_4 for the AS estuaries. For the BB estuaries, the factor loading might be linked with the biological productivity; however, for the AS estuaries, the factor loading might be due to POC and DOC decomposition and its associated productions of CO_2 and CH_4. The oxygenated estuary supports aerobic degradation of organic matter producing CO_2 and considered to be restrained by anaerobic degradation. However, it should also be noted that CH_4 production in the isolated anoxic microhabitats of sinking particulate organic matter, in the well-oxygenated water column, has been observed in the open ocean (see Reeburgh, 2007). The PC2 represents 71.11% and 86.41% of the total variance for the BB and AS estuaries with relatively strong factor loading for DOC, pCO_2, and CH_4 for the BB estuaries and $\delta^{13}C_{DIC}$, DOC, and POC for the AS estuaries. The former might be associated with aerobic and anaerobic degradations of DOC; however, the latter might be linked with the aerobic decomposition of DOC and POC and their impact on the variability of $\delta^{13}C_{DIC}$.

Thereafter, Pearson correlation analysis was performed for the factor loadings of the estuarine data with the number of dams, estuarine area, population density, mean annual discharge, catchment area, salinity, pH and %DO. The Pearson correlation matrix for the BB estuaries suggests PC1 is strongly controlled by the area of the estuary while PC2 is controlled by the cumulative interactions between salinity, pH as well as catchment area. For the AS estuaries, despite the PC1 being controlled by the number of dams, catchment area, salinity, and %DO but the PCA analysis failed to highlight any controlling factor for the PC2.

Correlation Matrix (Pearson) for the BB estuaries:

Variables	Dams	Population (/km2)	Area	Discharge	Precipitation	Catchment area (x 103 km2)	Salinity	%DO	pH	PC1	PC2
Dams	**1**	-0.373	**0.805**	**0.934**	-0.052	0.318	-0.368	-0.272	**-0.675**	-0.420	0.528
Population(/km2)	-0.373	**1**	-0.373	-0.362	-0.083	0.155	0.490	0.161	0.293	0.108	-0.209
Area	**0.805**	-0.373	**1**	**0.766**	0.128	0.282	-0.370	-0.439	**-0.675**	**-0.605**	0.596
Discharge	**0.934**	-0.362	**0.766**	**1**	0.169	0.194	-0.496	-0.464	**-0.743**	-0.570	0.541
Precipitation	-0.052	-0.083	0.128	0.169	**1**	-0.402	-0.376	-0.429	-0.135	-0.547	0.047
Catchment area (x 10^3 km2)	0.318	0.155	0.282	0.194	-0.402	**1**	-0.181	0.030	-0.273	0.465	**0.720**
Salinity	-0.368	0.490	-0.370	-0.496	-0.376	-0.181	**1**	**0.680**	**0.748**	0.175	**-0.657**
%DO	-0.272	0.161	-0.439	-0.464	-0.429	0.030	**0.680**	**1**	**0.848**	0.516	-0.539
pH	**-0.675**	0.293	**-0.675**	**-0.743**	-0.135	-0.273	**0.748**	**0.848**	**1**	0.412	**-0.741**
PC1	-0.420	0.108	**-0.605**	-0.570	-0.547	0.465	0.175	0.516	0.412	**1**	0.000
PC2	0.528	-0.209	0.596	0.541	0.047	**0.720**	**-0.657**	-0.539	**-0.741**	0.000	**1**

Values in bolded digits are statistically significant at alpha = 0.05

Correlation Matrix (Pearson) for the AS estuaries:

Variables	Dams	Population (/km2)	Area	Discharge	Catchment area (x 103 km2)	Salinity	%DO	pH	PC1	PC2
Dams	**1**	-0.092	0.518	0.686	-0.713	-0.554	**-0.890**	0.550	**0.821**	0.224
Population (/km2)	-0.092	**1**	0.253	-0.202	-0.550	-0.376	-0.271	0.184	0.457	-0.509
Area	0.518	0.253	**1**	**0.828**	-0.502	-0.491	-0.569	0.560	0.490	-0.552
Discharge	0.686	-0.202	**0.828**	**1**	-0.455	-0.380	-0.645	0.696	0.412	-0.353
Catchment area (x 103 km2)	-0.713	-0.550	-0.502	-0.455	**1**	0.729	**0.938**	-0.699	**-0.940**	0.265
Salinity	-0.554	-0.376	-0.491	-0.380	0.729	**1**	0.687	-0.319	**-0.777**	0.177
%DO	**-0.890**	-0.271	-0.569	-0.645	**0.938**	0.687	**1**	-0.685	**-0.935**	0.100
pH	0.550	0.184	0.560	0.696	-0.699	-0.319	-0.685	**1**	0.501	-0.531
PC1	**0.821**	0.457	0.490	0.412	**-0.940**	**-0.777**	**-0.935**	0.501	**1**	0.000
PC2	0.224	-0.509	-0.552	-0.353	0.265	0.177	0.100	-0.531	0.000	**1**

Values in bolded digits are statistically significant alpha = 0.05

The analysis with outliers removed is also very arbitrary. I think the variability of freshwater endmember would cause such outliers. My recommendation is to analyze the effects of mixing and biogeochemical processes in estuaries separately from the determinants of the river endmember values.

Response: *Yes, we understand the application of the mixing model is a good approach to separate the effects of mixing and biogeochemical processes. However, in our case, we are constrained by the lack of seasonal data for end members of each river which prevents us from applying the mixing model.*

Line comment

203) I think the compiled dataset is very useful for further studies. Don't you open this via any repository?

Response: *All data used in the manuscript has been compiled and the data shall be made available either via a repository or will be presented as supplementary material for further use.*

208) What kind of statistical analyses did you use? You have to explain the approach.

Response: *In the original manuscript we used simple regression analysis to test dependency between variables. Based on the suggestions by the reviewers, we have performed 't' test and PCA test (for the wet season only when suitable data is available) and the same is included in the revised manuscript (results of 't' test are given below and results of PCA is detailed in the earlier comments). The Material and Method section was updated accordingly in the revised manuscript.*

Table – Results for statistical 't' test analysis between the mean of available data. The analysis is performed at 95% confidence level.

	Inter-seasonal comparison		*Inter-BB & AS comparison*	
Parameters	***BB estuaries***	***AS estuaries***	***Wet Season***	***Dry Season***
Salinity	*p = 0.55*	*p <0.0001***	*p = 0.003***	*p = 0.84*
%DO	*p = 0.60*	*p = 0.31*	*p = 0.07*	*p = 0.001***
pH	*p = 0.10*	*p = 0.006***	*p <0.0001***	*p = 0.012***
DIC	*p = 0.59*	*NA*	*p = 0.008***	*NA*
$\delta^{13}C_{DIC}$	*p = 0.69*	*NA*	*p = 0.000***	*NA*
DOC	*p = 0.32*	*NA*	*p = 0.45*	*NA*
POC	*p = 0.02***	*p = 0.02***	*p = 0.17*	*p = 0.06*
$\delta^{13}C_{POC}$	*p = 0.04***	*NA*	*p = 0.21*	*NA*
pCO_2	*p = 0.07*	*NA*	*p = 0.10*	*NA*
FCO_2	*p = 0.41*	*NA*	*p = 0.29*	*NA*
CH_4	*p = 0.39*	*p = 0.38*	*p = 0.03***	*p = 0.11*
FCH_4	*p = 0.05***	*p = 0.27*	*p = 0.13*	*p = 0.16*

**Statistically significant at α = 0.05.

224) You often indicate in this manuscript how large or small by %, is this comparison only rivers for which you have data for both wet and dry seasons? If you are compiling all data, you will have a bias due to the different rivers you are averaging.

Response: *Yes, the comparison is based on the seasonal variation among BB and AS estuaries. While calculating the average, we have considered all estuaries mixing with Bay of Bengal under the BB estuaries category and all estuaries mixing with the Arabian Sea under AS estuaries category.*

Fig. 2-6) This value is average in each estuary? At least, you should show error bars. Is possible, you should show whisker plots.

Response: *Yes, for the graphical presentation we have used an average value where multiple values are available. As in most cases, multiple data for a particular C parameter are not* *available to show whisker plot. The challenge with presenting data in such a manner is that most studies we cite do not include enough data points to visualize in box plots, for example.*

In result section) You used "higher" or "lower" terms. These are based on statistical analysis? All comparisons should be based on statistical analyses.

Response: *No, it is not based on statistical analysis. The term "higher" and "lower" are simply decided based on the magnitude of the data. However, as suggested by the reviewer, we have performed the 't' test to check if the data of two seasons/estuaries is significantly different or not and the details of the 't' test results are given earlier, and the same will be included in the revised manuscript.*

245) Basically, outliers should not be arbitrarily removed. It would be interesting to discuss the factors that cause freshwater endmembers to vary.

Response: *We have performed PCA (results shown earlier) now in place of simple regression analysis. We have added it to the revised manuscript. Sufficient information and values are not available on freshwater end members of respective rivers.*

253, 266) Is the average also higher than in estuaries around the world?

Response: *The mean DIC and DOC concentrations of the Indian estuaries were calculated as 1780 and 379 µmol L^{-1}, respectively. If we compare the mean values with global estuarine DIC and DOC (table 2 & 3), the values for the Indian estuaries are intermediate between low and high values reported for the global estuaries. We have modified the content in the revised manuscript to avoid any ambiguity in the paper.*

256) Here, "peak" may not be suitable. Higher-lower or heavier-lighter are often used.

Response: *Thanks for the suggestion, we have modified it in the revised manuscript.*

265) for dry season?

Response: *Yes, it is during the dry season. We have clarified it in the revised manuscript.*

290) unit

Response: *The unit "nM" is included in the revised manuscript.*

327) Rainfall dilute riverine DIC?

Response: *Yes, Krishna et al. (2019) showed the same for the Indian estuaries.*

331) These values are averages with the broad salinity range? It is difficult to differentiate the mixing effect from the freshwater endmember variability.

Response: *Regarding Indian estuaries, although two end-member mixing model was previously applied for some of the estuaries like the Godavari, Hooghly by Bouillon et al. (2003), Samanta et al. (2015) and Dutta et al. (2019, 2021) to differentiate mixing effect from the biogeochemical and anthropogenic impacts. We have included some of the major findings* *from the mixing model study by them in the revised manuscript. But, despite the availability of marine end member data (the Arabian Sea and the Bay of Bengal), seasonal freshwater end member data for most of the estuaries are not available to date which restricts us to use the mixing model to differentiate mixing effect from other effects.*

332) BB and AS use different fitting curves, but aren't they just different ranges of precipitation? I think it would be more general if the same relationship equation could be used to explain the difference.

Response: *We have performed PCA (results shown earlier) now in place of simple regression analysis. The PCA showed no significant correlation with precipitation. We have added it in the revised manuscript.*

392) Also degassing of CO_2?

Response: *Yes, we agree. CO_2 outgassing is also responsible for DIC removal depending upon gas transfer velocity and air-water partial pressure gradient. This has been clarified it in the revised manuscript.*

402) Rivers with large population densities may have large dilution of river flow. Multivariate analysis may be effective.

Response: *We have performed a PCA to test the same and it has added to the revised manuscript.*

420) The relationship between precipitation and DIC should also be discussed comprehensively. DIC supply due to carbonate weathering may dominate in rivers with low precipitation.

Response: *We have performed PCA (results shown earlier) that showed no significant correlation with precipitation. We have updated it in the revised manuscript.*

468) This paragraph is redundant because it is a general statement.

Response: *We have removed it from the revised manuscript.*

492) Fig. 12?

Response: *It is a typographical error. We have corrected it in the revised manuscript.*

496) p=0.06 is not significant

Response: *We have corrected it in the revised manuscript.*

521) There may be a combined effect of river discharge and population density.

Response: *Yes true. To test the same PCA analysis was added in the revised the manuscript.*

536) This may also be an effect of multicollinearity.

Response: *Agree. To test the same PCA analysis was added in the revised the manuscript.*

578) Splitting a fitting line is arbitrary if there is no meaning in 6800 µatm. The influence of other variables should be considered.

Response: *We have performed PCA (results shown earlier) now in place of the simple regression analysis that used in the pre-revised manuscript. We have added it to the revised manuscript.*

595) Without an OM source mixing model (using more than 2 variables), it is difficult to discuss the contribution of each carbon source. For example, d13C value of -24~-19‰ can be explained by the mixing between C3 and C4 without marine origin.

Response: *Yes, it's true that the OM source mixing model needs to solve to discuss the contribution of individual POC sources. We mentioned only about possible POC sources here.*

630) I think the quantity and quality of POC cause the decomposition and O2 consumption rather than isotopic fractionation. Isotope fractionation doesn't happen that often with degradation (if it did, POC would be noticeably reduced).

Response: *Thank you for the information. We have removed it from the revised manuscript. In the revised manuscript we have used PCA to find out the major controlling factors.*

653) Why? It is interesting.
Response: *We have performed PCA (results shown earlier) now in place of simple regression analysis. The PCA clearly indicates no potential impact of discharge in both BB and AS estuaries during the wet season. We have added the following interpretation of why this relationship is not significant: "...perhaps due to a complex interplay between nutrient inputs, primary productivity, and microbial respiration that complicate conservative mixing of* CO_2*."*

Citation: https://doi.org/10.5194/bg-2022-200-RC2