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Biogeosciences Discussions

# *Interactive comment on* "The carbon budget of the North Sea" *by* H. Thomas et al.

**Anonymous Referee #2**

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Thomas et produce a carbon budget for the N. Sea, which has an imbalance. This they attribute to an unassessed term - air-sea exchange and conclude that the N. Sea imports, and is a sink, for atmospheric CO2.

All I wish to do at this stage of the review is to ask that we are given the wherewithal to establish the statistical reliability of the imbalance, thus the significance purported of the air-exchange term.

1) The imbalance is small - 0.724 Tmol/a, derived as the difference of numbers of the order 120 Tmol/a, i.e. the imbalance is about 0.6%. It will be subject to an array of random and systematic errors and it is surprising that no attempt is made to assess these. What I aim to do at this stage in the review process is to indicate where they may lay.

2) As far as the random element is concerned if we assume the confident limits that one works to of 95%, (2xSD), the input and export totals must be assessed with a coefficient of variance (% standard deviation) of 0.2% or better. This is derived as sqrt((CV, input)ˆ2+(CV, output)ˆ2))<0.6%/2

3) Each term is a product of a water flux term and concentration terms and each will contain random and systematic errors: the combined random error is derived in the manner given in 2) above. The authors appear to make the tacit assumption that in the water budget the water volume is conservative, i.e. evaporation and precipitation balance one another. This being the case, the important error terms are restricted to the carbon concentration terms.

4) The total carbon concentration is approximately 2,150 mmol C/m3, for the difference term (air sea exchange) to be significant, the error in assessing these concentrations must the $<$0.2% of 2,150, i.e. better than 4 mmol C/m3.

5) These are 12 sources of error: i) random and systematic errors of the analytical methods, ii) random and systematic errors associated with deriving a single value from the temporal and spatial variability for each of DIC, DOC and POC. As the chemical analyses come from a single and highly competent chemical laboratory we may presume careful monitoring of the accuracy of the chemical measurements, this we are left with three error terms in each of the three sets of measurements.

6) One can make a scaling calculation of the random errors associated with the laboratory measurements. If, on a routine basis, the DOC analysis is taken to have standard deviation of say 1-2mmol/m3 (1-2 micromolar) and the DIC a SD of say 0.5-1 mmol/m3, then the combined error would be 1 to 2.2 mmol/m3. POC measurements are generally less precise and have a greater sampling variance, but their lower concentrations tend to offset this - I cannot assess these. The chemists at NIOZ will have the exact values for the three analytical methods, but the point to note is that they may not be insignificant when compared with maximum allowed 4 mmol C/m3.

7) The temporal and spatial errors are likely to be more difficult to assess and probably to be the larger term. It is the DIC and DOC+POC estimates for the major flux terms (Shetland Channel and the Norwegian Trench) are the critical ones. Given that they are contributors to the overall variance [i.e. they combine with 6) above], they need to



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have a standard deviation better than about 3.5 mmol/m3 - if my estimates in 6) above are reasonable.

8) The budget acknowledges that there are spatial variations in DIC, but there is no estimate of the variance of the individual numbers used in the balance sheet - they are presumably some form of mean.

9) A single, and highly precise (76.8 mmol/m3), value is used for all the northern DOC+POC inputs. These properties are known to be spatially and temporally highly variable and I would be surprised if a single exact value was an accurate representation of the 50,000 km3 of water entering annually from the N. Atlantic. Oddly enough the authors (p.372, l. 23-5) refer to high resolution DOC data set. The point to note is the major terms need only to be wrong by 3 mmol/m3 (or have a variance of this size) to render the difference (the calculated air-sea exchange term) insignificant and the conclusion from the budget that the N. Sea is a sink, unsustainable.

10) DOC and POC show strong seasonal variability - each of the order of 20 mmol C/m3, further there will be differences in phasing of the DOC+POC cycles in the N. Sea and the N. Atlantic. There are I understand seasonal changes in the exchange of water, so compiling an organic budget with any precision is a daunting task.

11) As a reviewer I was frustrated that there was no description how these concentrations were derived and how the spatial and temporal variations were dealt with. Oddly enough the only description of the form of data processing is given for the river input, which is the least significant term in the whole budget. I searched the NIOZ website for the referenced source of the cruise data so I could get some feeling for its spatial and temporal cover; it may be there but was not able to locate it. There seemed to be a version lodged with the journal Science, but I was barred access. This should be remedied and I would suggest immediately (and the address provided), as other readers may need to see the data. I would recommend it was placed on a NIOZ website -indeed I was surprised not to find it there.



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12) The values used for the English Channel have no reference and as rounded off values they look suspiciously like best guesses. Although they are minor contributors to the budget, the estimate nonetheless needs to be accurate (in this case accuracy is the issue, as they appear to be an estimate) to much better than 40 mmol/m3.

13) Thus, there are a whole set of error terms, which sum up (their squares sum to give the overall variance term in the case of random errors) and the small difference (0.6%) upon which one of their major conclusions is based puts severe demands upon the precision of the values used in the budget. No consideration is given to this in the text as far as I can see and if they want to conclude anything from the budget deficit then it is something that needs very thorough discussion.

14) The authors claim some measure of support for their budget from an independent estimate of air-sea CO2 exchange. I note this also is reported with no confidence limits, without this any comparison is weak and open to criticism.

15) Finally, some small presentational details: i) Table 1, surely it should be Outflow “from” not “to”, ii) sedimentation rates should be given in the same units as the rest of the budget sheet (i.e. 10ˆ6 mol C, not kt C), iii) it is good practice that the number of significant digits in the reported numbers in a general way reflect their precision, please not six significant digits, iv) it would be nicer for the reader to not have a mixture of km3 and litres - why not give all the volumes as m3 - it makes the maths more straightforward and less prone to error, v) one has to guess the significance of the percentages in parenthesis in the Table - guesswork should be necessary - their significance should be made clear in the legend.

My view is that the authors will need to add to the MS a section dedicated to the consideration of errors - it would help the assessing of the paper if the authors post this so that we can pass to the second stage: the assessment of the budget itself.

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