

Review of  
**Global Sea Level Budget 1993 – Present** by  
WCRP Global Sea Level Budget Group

This manuscript presents a review of the latest sea-level estimates, as well as of the single contributions (ocean thermal expansion, mass change from glaciers and ice sheets, land water, glacial isostatic adjustment). Bringing all the various data sets together, it assesses the sea-level budget over two periods with varying observational coverage of total mean sea level as well as sea-level contributions, namely the altimetry period (1993-present) and the GRACE/Argo period (2005-present). It is concluded that the sea-level budget is closed over the latter period when combining the contributions of thermal expansion (from Argo buoys) and ocean mass (from GRACE). However, larger discrepancies occur when the ocean mass contributions (glaciers, ice sheet, land water) are considered separately. The contribution of land water is identified as a major uncertainty over both periods considered.

The manuscript contains a wealth of information, an extensive review over the latest literature and estimates of sea level, its contributions and the respective uncertainties over the periods of interest. Thus, it is very informative and provides a good overview over the state of the art. I have no major criticisms on the contents. However, as it is usually the case with a paper of so many authors, I found it at times hard to read with many slips of the pen, typos and inconsistencies (see specific comments). I propose the authors (or one or two of them) go carefully through the manuscript and improve the readability.

### **General comments**

In general sea level is used without hyphen in the text, but not always. After my understanding, there is no hyphen if used as stand alone, but when it is used as compound adjective, e.g. sea-level budget, sea-level rise, sea-level change etc, there should be a hyphen. In any case, make sure you use it consistently.

Sometimes you give sea-level rates in mm/yr and sometimes in  $\text{mm}\cdot\text{yr}^{-1}$  – please choose one and stick to it.

Many abbreviations are used in this papers, sometimes without an explanation. As this study is quite interdisciplinary, not everybody is familiar with all the acronyms. I suggest you add a list at the end of the paper with all the acronyms and their explanation.

Also, make sure you use all you abbreviations consistently (GMSL, SLE, etc).

### **Specific comments**

#### 1. Introduction

Line 67: What do you mean with “constant evolution”?

Line 82-83: To me, it is not clear how contributions from marginal seas, shelf areas and polar regions can be inferred from the sea-level budget.

#### 2. Methods and Data

##### 2.2 Altimetry-based global mean sea level over 1993-present

Line 184: Replace “>” with “poleward of”.

Line 190: “the ocean response to atmospheric dynamics”: could you be more specific? Why does that need to be corrected for? Surely, we are interested in the sea level response to some of these processes.

Figure 1: there is still space to make the legend a little bigger.

Line 204: are the time series centred with zero mean in 1993? It does not look like it from the figure?

Line 205: subtracted *from* each data set.

Line 258: Removing the (*moving?*) *linear* trend... Is there a figure to show this? If not, I suggest you add a “not shown”, as I was expecting a figure, particularly as you highlighted the differences between the various detrended GMSL curves at the end of the paragraph, but could not find it.

Figure 3: are the accelerations give in the legend from the publications or from fitting a linear trend to the curves shown in the figure?

## 2.3 Steric sea level

Line 332: “referred to as...”

Line 342: “But sum of ...” there is something wrong with this sentence. Please re-write it.

Line 366: *insight* instead of *inside*?

Line 368-370: You are talking about *virtually global* and *quasi global coverage* here. What do you mean? How is *global* defined?

Table 2: the “\*” that appears in the third (Period) column is not explained. Also, the caption should be a bit more informative.

Line 463: *calculation*

Figure 6, Line 508-510: I don't really understand what you mean with *relative to 1993-2016/2005-2016*?

Line 512: I guess it should be *1993* instead of *1996*.

## 2.4 Glaciers

Line 552-553: in the parentheses either change to *provides a review of these different methods* or remove *of*.

Line 570-571: what do you mean by *long-term observations*? Is there a minimum number of years, or so?

Line 581: for better readability, skip the “(” before *e.g.* and only have the reference (Marzeion) in parentheses.

Line 608: ... and *are* distributed...

Figure 8: Also here, I think, the caption could be more informative in order to understand the figure. For example, state that the different estimates stem from different publications and are based on different methods.

## 2.5 Greenland

Line 687: ...*25-30% of*...

Line 695-697: Are there other uncertainties except for GIA that are large in Antarctica compared to Greenland? If not, I would suggest to skip the “for example”.

Line 702: Remove the parentheses around the reference.

Line 704: *mass rates* instead of just *rates*?

Line 730: So, does that mean that the weights used to compute the mean mass change change every year? How does the final time series differ from the ordinary mean?

Figure 9, Line 740: Do you mean the weighted mean mass *change* instead of *trend* as shown in the figure? Also, shown in the figure are the values tabulated in Table 5 (in Gt/yr as opposed to Gt in the figure)? Do you have to show the values in the Table or could the data just be provided as a supplement (except for the last 4 rows of the Table).

Line 759: Too many parentheses around the references.

## 2.6 Antarctica

There is a recent publication from the IMBIE Team that could be mentioned in this section: <https://www.nature.com/articles/s41586-018-0179-y>

Line 775: *to* instead of *with*.

Table 6: In the caption, please mention that the Table refers to Antarctica.

Line 826: put the references in parentheses.

Line 826 and Table 6 (third row): the reference should read Forsberg, and “r” is missing.

Line 827: I think, at this point, it could be useful to very briefly explain what a mascon solution is.

Line 843: “We ?? a single...” - a verb is missing. And what is OIB?

Line 845: But in Table 7, only GRACE and IOM estimates are shown, no altimetry estimates.

Line 849: *the annual mass change* instead of *to annual mass change*?

Figure 10: Why don't you show the mass change as in Figure 9 for Greenland. It would be more consistent. Also, just as for Figure 9 and Table 5, is it necessary to show the values plotted in Figure 10 again in Table 6 (with a reversed sign)?

Line 894: Too many parentheses around the references.

Line 897: I'm not sure if you use the abbreviation ASE again in the text. If not, just remove it.

## 2.7 Terrestrial Water Storage

Line 923: The year is missing in the reference of Döll et al.

Line 990: What is PCR-GLOBWB?

Line 991: Over what period was this number computed. What would be the sea level equivalent?

Line 1014: I really think it would be useful to explain all these abbreviations in a list at the end of the text.

Line 1110: I'm not sure but I think the figure shows mm not mm/yr. At least that's what the label on the y-axis says.

Figure 13: What do the green lines in the left panel show?

Line 1147: *panel*

Line 1149: “Tropical regions *show...*” instead of *are*.

Line 1165: Put the references in parentheses.

Line 1172: shows

## 2.8 Glacial Isostatic Adjustment

Line 1208: Maybe you could add a “glacial” or so before ice sheet, such that it is clear that you are not talking about the present day ice sheets.

Line 1214: Remove “in”?

Line 1222-1223: “the variance of  $N_{gia}$  over the surface of the oceans is much reduced”: what do you mean by that? Reduced compared to what?

Line 1227: “Since...” - this sentence does not make sense.

Line 1233-1234: Well,  $n$  is small compared to the global mean sea-level rise, but not compared to its uncertainty.

Line 1235: Table 9a.

Line 1238: How has  $n$  been weighted?

Line 1271: Table 9b.

Line 1272: weighted. How were the weights computed?

Line 1278: I would rather say *ice sheets* instead of *ice caps*.

Line 1281: Please spend a few more sentences on describing and interpreting Figure 14!

Line 1302: Table 9d. Also, since the GIA correction to TWS is discussed before the GIA correction to GRACE-based ice-sheet mass balance, consider swapping the according parts of Table 9.

Line 1306: Add a space between *an* and *accuracy*.

Line 1322: *them* instead of *tham*.

Line 1322: Table 9c.

Table 9: The format of Table 9 should be adapted to the format of the other tables.

## 2.9 Ocean mass change from GRACE

Line 1383: *constraint*

Line 1386-1393: This is a very long sentence. Consider splitting it in several sentences or us i), ii) and so on to list the major error sources.

Line 1395: Remove *on*.

Table 10, first row: please be more accurate with the column titles (also check all the other Tables) – the first column should be “source” or “publication” and the last one “ocean mass trend SLE (mm/yr)” or so.

Table 10, Line 1398: ocean *mass trend*

Line 1402-1404: I think this sentence should be moved to the end of the next paragraph (Line 1413). It seems a bit lost here.

Line 1409: Remove *to*.

Line 1431: What is  $\Delta C20$ ?

Table 11: same comment as for Table 10 – be more accurate with the titles of the columns. E.g. first column should be “GRACE data product” or so, and second “linear trend (mm/yr)” or so.

Line 1481-1482: As far as I understood, it was launched in March 2018, wasn't it? (Instead of “is scheduled to be launched”)

## 3. Sea Level Budget results

Line 1532: Don't you mean Table 13 instead of 12?

Section 3.2.2: A very short section. I think, even though you discuss it in the Discussion, in this section you should at least comment on the large discrepancy between Row 7 and 8 in Table 13, and how it relates to the large uncertainty in TWS.

Line 1549-1551: Be more accurate: the table provides annual mean values for the ensemble mean GMSL and the *sum of components* (GRACE-based ocean mass and Argo-based thermosteric component).

Line 1567: Is the residual trend statistically significant?

## 5. Concluding Remarks

Line 1728: for *example*

Line 1730: Remove the long term for NASA to a list of abbreviations at the end of the text.