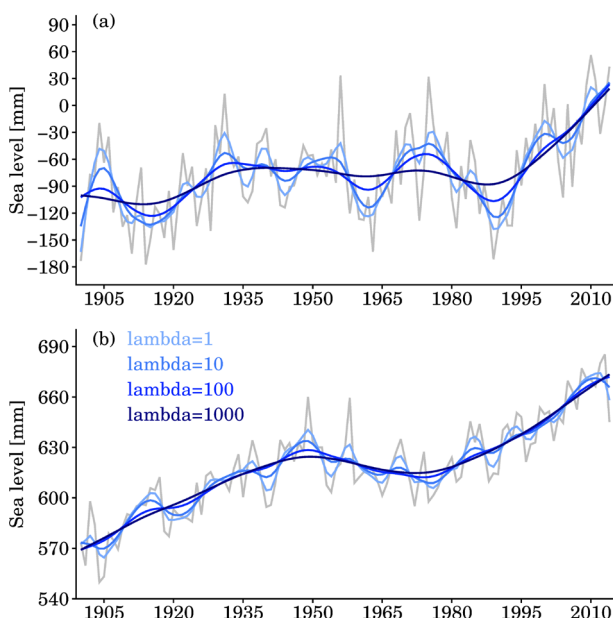


The paper reconstructed a century-scale sea level rise at tide gauges, using a data assimilation approach that has been proposed by previous studies, but I saw some modifications or improvements, e.g., introducing a random process. The data assimilation is indeed driven by physical mechanisms, and therefore the reconstruction, or essentially the interpolation or extrapolation are physically interpretable. Authors considered 35 CMIP6 model output and, consequently, they gave 35 reconstructions, this ensemble obviously offers some useful statistical assessments, and this is really convenient, users can compute a desirable uncertainty estimate. Authors compared their reconstructions to observations from satellite altimetry, and other sea level reconstructions that are widely accepted by the community. The comparisons were performed on both global and local scales, and the results seems promising, although some differences were still seen, especially at the sites of tide gauges. The new global mean sea level reconstruction can serve as an independent estimate, users can get a better ensemble for average and spread. Overall, I think the dataset can be potentially applied to sea level studies, and the community would benefit from it. However, I have several comments, and I hope authors can address them before I see the paper published.

Reply: thank you very much for these comments that summarize concisely our work, and we sincerely thank you for your suggestions that help to improve the paper. Below, we answer your questions and address your concerns.

(1) In the method section, authors used the HP filter to compute the instantaneous rate for SDSL changes. My question is how the authors determine the parameter lambda (i.e., equation 14)? As a filter, HP might be sensitive to the changes of lambda. Based on my own understanding, the filtered or smoothed SDSL is perhaps related to the smoothed sea level curves seen in, e.g., Figure 6. Another reason that might explain the smoothed curves is that authors used the Kalman filter and smoother for the sea level fingerprints, so the total sea level would be much smooth. Authors need to prove how the curves would vary with parameter lambda.

Reply: this is good question. It should be recognized that the time series smoothed by HP filter are indeed affected by the parameter lambda. To illustrate this effect, we select the SDSL time series from the ACCESS-CM2 model interpolated at tide gauges Den Helder (PSMSL ID 23) and Buenos Aires (PSMSL ID 157), then perform the HP filter with $\lambda = 1, 10, 100$, and 1000 , respectively. See the plot below.



The plot shows the HP filtered time series at (a) Den Helder (PSMSL ID 23) and (b) Buenos Aires (PSMSL ID 157), with different values of lambda, note that the gray lines are the raw SDSL time series from the ACCESS-CM2 model. We can observe that a large lambda produces a refined curve that suffers from less high-frequency variability or better represents the low-frequency variability. In our practice, we adopt the value of 10, as it already shows less peak-to-peak changes. We must admit that this choice is empirically determined. This smooth curve is then used to

compute the instantaneous rates that drives the data assimilation, and yes, it is a major reason that our reconstructed sea level curves are smooth. The other reason is the application of Kalman filter and smoother, as you pointed out. All these materials are included in the revision, thank you again.

(2) There might be confusing explanation in Table 3. Treu et al. (2024) used the low-frequency sea level reconstruction from Dangendorf et al. (2019), who employed a hybrid reconstruction. This hybrid reconstruction combined traditional EOF reconstruction and the data assimilation, the former provided sea level variability, the latter provided long-term trends. But why authors claimed that ‘Differences are possible between reconstructions and raw records’, is this because they observed apparent discrepancies in Figure 10 when they compared with Treu et al. (2024). If so, I think there might be another reason, that is Treu et al. (2024) considered different selection of tide gauges. Anyway, authors should add some more wording to clarify.

Reply: thank you for the concern. We clarify this difference with more words. Please let us explain a little bit here. First, the selection of tide gauges has direct effect on the sea level reconstruction, this is no doubt. Second, we need to explain how the EOF reconstruction works. An important data processing procedure is that the sites of tide gauges should be projected onto the altimetry grid, which is commonly regular, e.g., $1^{\circ} \times 1^{\circ}$, or $0.25^{\circ} \times 0.25^{\circ}$. To this purpose, we can search for the nearest altimetry grid point. Each site only has one nearest altimetry grid point, but, be careful, an altimetry grid point may be accompanied with two or even more sites. In such cases, we can merge these sites into one synthesized series of observations at the grid point. Anyway, the EOF reconstruction provides reconstructed sea levels on this regular grid, not at specific sites of tide gauges. So, even at a tide gauge that selected by both our study and Treu et al. (2024), there may be some differences.

(3) In Figure 9, authors compared many GMSL reconstructions to justify theirs. I saw some differences in the overall rates. Authors attributed the differences to reconstruction methods and selections of tide gauges, this is true, and I agree. But authors overlooked another fact, that is, the GMSL curves represent the relative sea level or absolute sea level? This is of course highly related to the reconstruction methods, but I think author should add some comments to this point, and the paper Dangendorf et al. (2017) might be helpful (<https://doi.org/10.1073/pnas.1616007114>).

Reply: Thank you very much for this concern, we reflected on it, and thank you for providing the nice paper by Dangendorf et al. (2017). There is a subtle difference among the reconstructed GMSL time series; some of them are absolute GMSL and others are relative GMSL; the paper by Dangendorf et al. (2017) helps us to clarify. We are sorry that we ignored this issue before. Now we look into it.

Essentially, the reconstructed sea level represents either relative sea level or absolute sea level, and it depends on the correction to tide gauges. There are two ways. First, some studies included the vertical land motion effect at the sites of tide gauges. By nature, tide gauges (relative sea level) + vertical land motion gives us the absolute sea level, which is consistent with the observations from satellite altimetry; so, it is preferable to do this way for EOF reconstruction. The vertical land motion is observed by, e.g., GNSS and InSAR, but those observations only span recent years or one or two decades, they are not available for long-term reconstruction. Given this, many studies consider the vertical land motion caused by GIA process, which only represent a portion of total vertical land motion. This is a limitation, but it is the best we can do for now.

Our strategy is to correct the tide gauges for relative sea level effect caused by GIA process. By doing this, we obtain contemporary relative sea level rise at the sites of tide gauges. Consequently, our reconstructed sea level is different from, e.g., C2011, R2011, and J2014; they all represent absolute sea level. We also highlight that the real difference between our reconstruction and C2011 or R2011 or J2014 can be illustrated by the following relation:

$$C2011 = \text{total absolute sea level} = \text{tide gauges} + \text{vertical land motion (assume that vertical land motion is only caused by GIA)} = \text{our reconstruction} + \text{GIA relative sea level} + \text{vertical land motion}.$$

If we also assume that vertical land motion is only related to GIA, then, $C2011 = \text{our reconstruction} + \text{GIA absolute sea level (or geoid)}$. Note that the GIA geoid changes are smooth over oceans, compared to the relative sea level

and vertical land motion, see Figure 1 in Tamisiea (2011; <https://doi.org/10.1111/j.1365-246X.2011.05116.x>). But we should be aware of a fact that, at local scale, vertical land motion is related to many processes, more than just GIA. On average, we should expect a smaller change in vertical land motion. Nevertheless, the difference in sea level reconstruction could be related to this issue.

All the discussion above is included in the revision.

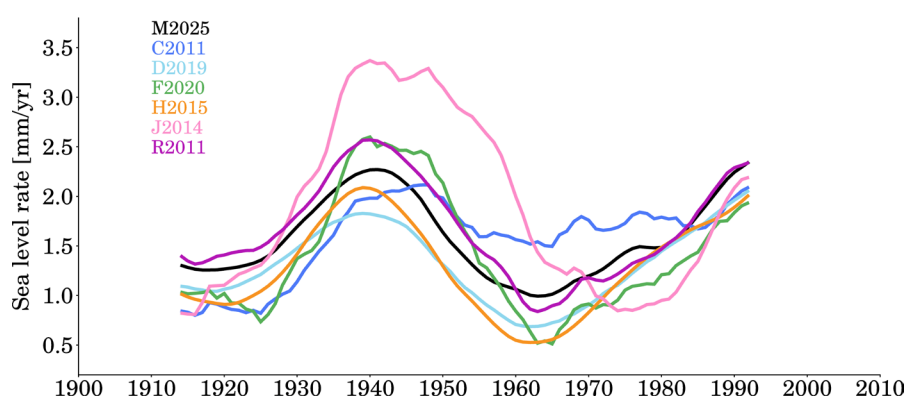
(4) In section 4, authors pointed out some limitations in their reconstructions, this is very important and useful. Authors claimed that some abrupt changes are not removed from the raw records, and those changes are induced by earthquakes, but have no significant effect on sea level reconstruction, this is understandable, as they account for only a small portion. I could agree to this. However, authors should elaborate a little bit more on the second limitation. The refined trends could be informative for long-term changes, despite we did not know how ‘long’ it is. The community usually employs a 30-year window for computing GMSL rise, so why not compare all the GMSL curves for the 30-year-rate curves, I would expect some differences, even significant ones, readers can glean some useful knowledge, and it would be better if authors add more wordings.

Reply: thank you for this good suggestion. We compute the curves of 30-year sea level rates, starting from 1915, and ending at 1993, as the reconstruction R2011 spans the period 1900-2007, see the plot below.

Our rate curve falls between those curves, except for the beginning period (1915-1928) and the ending period (1980-1993), over these two periods, our rate curve lies at the upper bound. The rate curve of J2014 is apparently distinct from other curves, especially since 1930, this distinction is of course directly connected with the fact that J2014 employed the largest number of tide gauges, which is about twice or even triple the numbers of tide gauges used by others.

The selection of tide gauges is indeed an important factor that affects reconstruction. This can be further confirmed by the difference between C2011 and R2011, especially over 1950-1980; both studies employed the EOF reconstruction, but they used very different distributions of tide gauges, R2011 used only 89 tide gauges, the lowest number for sea level reconstruction, to our knowledge. A major reason for this lowest number is that R2011 resolved the datum issue in PSMSL tide gauges. Every tide gauge requires a datum, but it’s unknown. R2011 modified the EOF reconstruction, so the approach permits for estimating the datums. We suspect that, to better resolve the datum, a smaller number of tide gauges is desirable.

We notice that the reconstruction methods also matter, which is demonstrated by the difference between C2015 and D2019, as they considered very similar distribution of tide gauges, D2019 adopted the trends from C2015, but D2019 reconstructed interannual variability with the EOF reconstruction. This difference also implies that the interannual variability has some noticeable effect on the 30-year rates. A very similar comparison is suggested by Wang et al. (2024; <https://doi.org/10.1175/JCLI-D-23-0410.1>, see their Figure 6), This paper is cited by our work. All the discussion above is included in the revision.



The figure shows the curves of 30-year running rates from different sea level reconstructions. This plotting is

included in the revision.

Minor suggestions:

Line 13, period over 1900 to 2022 -> period from 1900 to 2022

Reply: thank you, we change it to 'from'

Line 17, assessment -> assessments

Reply: we change it, thank you.

Line 18, GMSL rise -> GMSL rate

Reply: we change it to 'rate'

Line 22, observed sea level rise at -> observations from

Reply: we change the wordings, thank you.

Line 27, collection -> collected

Reply: we change it to 'collected'

Line 27, add the reference Holgate et al. (2013) after the website

Reply: we add this paper citation.

Lines 33 and 35, reference Calafat et al. (2022) was not shown in the reference list, correct it

Reply: it should be Calafat et al. (2022a) or Calafat et al. (2022b) and these two papers are included in the reference list, thank you.

Line 43, cause -> causes

Reply: we corrected it.

Line 62, at tide gauges -> at the sites of tide gauges

Reply: we add the words. Thank you.

Line 69, physical -> physically

Reply: we corrected it. Thank you.

Line 75, error in citation of Calafat et al. (2022) as shown before

Reply: we corrected it.

Line 76, Since -> since

Reply: we corrected it. Thank you.

Line 97, at tide gauges -> at the sites of tide gauges

Reply: we corrected it.

Line 113, raw tide gauge records -> raw records of tide gauges

Reply: we corrected it. Thank you.

Line 132, include -> includes

Reply: we corrected it.

Line 176, its -> their

Reply: we corrected it.

Line 189, Instantaneous -> instantaneous

Reply: we corrected it. Thank you.

Line 190, variation -> variations

Reply: we corrected it.

Line 215, sea-level -> sea level, you should be consistent about the writing

Reply: we use consistent wordings. Thank you.

Line 226, to address the 'a zero global mean', you add ocean mass increase, what about the global mean of thermosteric sea level, how you exactly treat this term?

Reply: the CMIP6 models used by this study provide estimates of global mean thermosteric sea level, in addition to

the gridded products, so we can remove the global mean of the gridded products, and add the global mean thermosteric sea level back to the gridded products.

Line 230, figure 3 was not even cited, you might want to add some more wordings to describe the changes shown in figure 3

Reply: good idea, we fix the citation, and add more wordings.

Line 235, error in caption of figure 4, e.g., panel (e) was missing

Reply: we corrected it. Thank you.

Line 240, rises -> rise

Reply: we corrected the typo.

Line 249, remove 'for this'

Reply: we removed it. Thank you.

Line 300, AVISO sea level observations -> AVISO sea level products

Reply: we corrected it.

Line 316, assessment -> assessments

Reply: we corrected it.

Line 333, influence of sea level observations in -> influence of sea level observations on

Reply: we corrected it. Thank you.

Line 355, ensemble of subset -> subsets

Reply: we corrected it.

Line 379, the GMSL -> the GMSL curves

Reply: we corrected it.

Line 401, The resulting GMSL curve with raw records exhibits -> The resulting GMSL curves with raw records exhibit

Reply: we corrected it. Thank you.

Line 425, figure 11, add a panel showing the difference between 95th and 5th percentiles

Reply: Good suggestion, thank you.

Line 429, sea level rate -> sea level rates

Reply: we corrected it.

Line 440, T2024 who provide -> T2024 who provided or provides

Reply: we corrected it.

Line 458, 3.3 Statistical assessment -> 3.3 Statistical assessments, this correction applies to others, e.g., line 459

Reply: we corrected it. Thank you.

Line 505, add a plot showing the 30-year rates for all GMSL reconstructions

Reply: Great suggestion; we add this plot, along with a few wordings.