Dear Editor,

Thank you for the opportunity to review the manuscript “Reconstructing sea level rise at global 945 tide gauges since 1900” by Mu et al. This study introduces a new dataset of reconstructed sea level time series at 945 global tide gauge sites covering the period 1900–2022. The authors employ a data assimilation approach that integrates outputs from 35 CMIP6 climate models, sea level fingerprints (SLF), glacial isostatic adjustment (GIA) corrections, and a random process to capture unresolved local variability. Each tide gauge location is associated with a 35-member ensemble, allowing for physical interpolation across data gaps and direct quantification of reconstruction uncertainty. The results are evaluated against previous global mean sea level (GMSL) reconstructions and compared locally with an independent product by Treu et al. (2024). Overall, the dataset aims to improve the spatial and temporal completeness of historical sea level records while preserving physical consistency and enabling robust statistical assessments.

This manuscript presents an ambitious and valuable contribution by reconstructing a long-term sea level dataset directly at tide gauge locations, using an ensemble-based data assimilation framework. It offers methodological advances by extending previous assimilation techniques, resolving sea level changes explicitly at gauge sites rather than interpolated grids, and enabling uncertainty quantification through a 35-member ensemble. However, the scientific motivation behind reconstructing sea level specifically at tide gauges—as opposed to existing gridded products—requires clearer articulation. While the technical execution is sound, the manuscript would benefit from improved clarity in its writing and structure, as well as a more critical discussion of key assumptions, particularly the use of coarse-resolution climate model outputs to inform local-scale variability.

1. Motivation of the Work

While the authors present a technically sound reconstruction effort, the manuscript lacks a compelling justification for why this new reconstruction is necessary—particularly at the exact locations of tide gauges. Existing products already provide gridded or interpolated sea level fields that span the 20th century, and the advantages of reconstructing sea level directly at the gauge sites, rather than relying on interpolation from existing reconstructions, are not fully explained. It remains unclear whether the primary purpose is to improve regional and coastal estimates, fill data gaps, validate climate models, or support impact studies. Furthermore, the distinctions between this dataset and other recent efforts, such as Treu et al. (2024), Dangendorf et al. (2024), or Frederikse et al. (2020), are only briefly addressed in a comparison table, without a deeper discussion of functional or practical differences. A clearer articulation of the scientific and applied motivation would significantly strengthen the manuscript.

2. Methodology

The central methodology relies heavily on outputs from CMIP6 climate models to estimate sterodynamic sea level (SDSL) changes, which are used to fill data gaps at the tide gauge sites. However, the coarse spatial resolution and limited representation of shelf dynamics, coastal processes, and tectonic settings in global climate models are not sufficiently acknowledged.

While the authors introduce a random term to account for local variability, it is unclear whether this compensates adequately for biases or structural mismatches between models and observations at local scales. The manuscript would benefit from a more explicit discussion of the limitations of applying global climate model output to local-scale reconstruction, and from a clearer justification of the confidence placed in these physically driven interpolations at individual tide gauges.

3. Validation

Although the authors validate their reconstructions at the global scale by comparing with satellite altimetry and other GMSL products, the evaluation at local scales remains limited. In particular, more rigorous assessments are needed in regions affected by vertical land motion, tectonics, or discontinuous observational records. While qualitative comparisons at selected sites are shown, these do not fully demonstrate the fidelity of the reconstructions. To improve confidence in the dataset, the authors should present additional quantitative validation—such as RMSE, correlation, or explained variance—between the reconstructed and raw records at long, continuous tide gauge sites. Ideally, the analysis would also identify regions where reconstructions are more or less reliable, based on observational completeness or environmental complexity.

4. Interpretation of Ensemble Spread

The use of a 35-member ensemble to express uncertainty is a valuable feature of the reconstruction, but the interpretation of this spread is not sufficiently clear. The ensemble is constructed from 35 climate model realizations, which likely reflect structural differences in the models and their simulation of large-scale processes. However, this ensemble does not appear to incorporate observational error, methodological uncertainty (e.g., parameter tuning), or other sources of reconstruction variability. Presenting the ensemble spread as a comprehensive uncertainty estimate may therefore be misleading. The authors should clarify what the ensemble spread represents—and, just as importantly, what it does not—and consider discussing additional sources of uncertainty that are not captured by this approach.

5. Data Usability

The caveats section correctly notes that some tide gauge records include abrupt jumps due to earthquakes or other geophysical events, which are then inherited by the reconstructions. However, the manuscript does not offer a systematic way for users to identify or handle these problematic records. For a dataset intended to support broad scientific and applied use, this raises concerns about usability and transparency. At minimum, the authors should consider flagging affected sites or events within the data files, and ideally provide guidance on how users might treat such anomalies (e.g., masking, correction, or exclusion). More generally, the caveats section would be more helpful if integrated earlier in the manuscript and more clearly linked to the limitations of the reconstruction method.

Minor Comments:

Title: Consider rewording for clarity, e.g., “Reconstructing global sea level rise from 945 tide gauges since 1900” is smoother.

Line 7: “Tide gauges record sea level changes along coast.” → "along the coasts" or "along coastlines"

Line 10: “sometime persistent” → should be “sometimes persistent”

Line 15: “offering complete and refined sea level time series” → “providing continuous and refined sea level time series” might read better.

Line 18: “agreements” → “agreement”

Line 19: “despite apparent rate differences at locations, it is suggested…” → This phrasing is awkward. Suggest: “Despite some rate differences at certain locations, the reconstructed trends closely follow the raw records…”

Line 22: “informing coastal adaptation strategies” – consider specifying how this is useful, even briefly.

Line 27: “Tide gauges sample relative sea level changes along coast.” → should be “along the coast” or “along coasts”

Line 40: “characterized with” → should be “characterized by”

Line 41: “only, (see Figure 1b)” → comma before parenthesis is awkward; rephrase as “e.g., only a few years (see Figure 1b).”

Line 47: “as well as spatial and temporal interpolation or extrapolation using neural networks…” – awkward phrasing. Suggest breaking into two sentences or removing “as well as”.

Line 59: “added it into the basic functions” → “added it to the basic functions”

Line 64: “some major climate variability such like the El Niño–Southern Oscillation” → “such as”

Line 79: “the neural networks” → “neural networks”

Line 89: “extrapolations on rates” → better: “extrapolations of rates”

Line 93: “examination for reginal sea level rise” → should be “regional”

Line 100: “distinguished literatures” → “seminal studies” or “notable publications”

Line 104: “use to reconstruct” → “use it to reconstruct”

2.1 Title: “Sea level reconstruction by data assimilation” → Consider: “Sea level reconstruction using data assimilation”

Line 110: “to facilitate understanding for readers” → redundant; delete or simplify: “to facilitate understanding”

Line 116: “physically orientated” → should be “physically oriented”

Line 120: “including Greenland ice melting…” → better as “including mass loss from the Greenland Ice Sheet…”

Line 124: “Those oceanic geometries are termed as sea level fingerprint” → “These oceanic patterns are termed sea level fingerprints”

Line 126: “A random process is further proposed…” → awkward. Try: “We also introduce a random process…”

Line 200: “clime model” → “climate model”

Line 215: “we do not exclude records with large jumps or high rates, as their impact… is negligible” → requires justification or citation.

2.6 GIA description: “mainly is an ongoing response…” → should be “is mainly an ongoing response…”

Line 254: “see section ‘Code and data availability’” → inconsistent with other section references; consider standardizing.

2.7: “Reconstruction from literatures” → should be “Reconstructions from previous studies” or “Existing reconstructions”

Line 265: “exerted broad influence” → more objective phrasing is “widely used”

Table 2 Caption: “Sea level reconstruction from literatures” → “Overview of sea level reconstruction studies”

2.8: “we average the weekly samples into annual time series…” → passive form might be clearer: “The weekly data were averaged to annual time series…”

2.9: “we select the nearest grid point from T2024 for each site of tide gauge” → “…for each tide gauge site”

Line 315: “committed to address” → “dedicated to addressing”

Line 318: “illustrate diverse reconstructions at tide gauges” → redundant phrasing. Better: “illustrate the diversity in reconstructions”

Line 323: “regardless their durations” → “regardless of their duration”

Line 324–326: Repetition of “physically” in “(physically) simulated sea level…” is awkward and unnecessary.

Line 332: “tend to converge over periods when raw records are available” → could be shortened: “converge when raw records are available”

Line 460: “rate differences are very minor” → better: “rate differences are generally small”

Line 470: “sea level rates are expected to be high over a short period” → maybe clarify: “rate estimates are more variable over short periods”

Line 477: “use of these data should be with cautions” → “should be used with caution”

Line 480: “anthropologic activities” → “anthropogenic activities”

Line 485: “not purely relevant to SDSL or SLF changes” → unclear. Better: “not directly attributable to SDSL or SLF mechanisms”

Line 490: “we did not remove those tide gauges… because, first, we intend to include…” → awkward. Suggest breaking into two sentences and rewriting as:

“We retained all gauges to maximize spatial coverage. Moreover, the impact of anomalous records is localized and does not significantly affect other stations.”

Line 504: “Sea level rates spanning period less than 30 years must be explained with cautions…” → “Sea level rates estimated over periods shorter than 30 years should be interpreted cautiously…”

Line 510: “offer an ensemble of complete, refined, and smooth time series” → could be shortened: “provide refined, continuous time series”

Line 514: “align with sea level observations and other sea level reconstructions…” → redundant use of “sea level”; remove one.

Line 517: “our reconstructions advocate the raw records of tide gauges” → “closely follow” or “are consistent with” is clearer than “advocate”

Line 519: “expected to contribute…” → “expected to support efforts to understand…”

Line 521: “It contains following variables” → “It contains the following variables:”

Line 530: “missing values are assigned with ‘NaN’.” → “missing values are denoted by ‘NaN’.”

Line 534: “contains the spread of sea level reconstructions···” → maybe clarify: “the ensemble spread (standard deviation) across models”

Line 539: “scripts are also available upon request to…” → better to specify whether code will be publicly released or must be requested; ESSD encourages transparency.