Response to Reviewer

We sincerely thank you for your careful review of our manuscript and for your valuable comments. Your suggestions have not only precisely identified areas that required clarification or improvement, but have also provided clear guidance for further strengthening the manuscript. We have carefully considered each comment and addressed them individually in the revised version. The primary changes in the manuscript are as follows:

(1) Following the reviewer's suggestion, the manuscript title has been revised to more clearly convey the main objective and contribution of the study. The new title is: *"Reconstructing Climate-Driven Global Terrestrial Water Storage (2002–2021) Using a Four-Parameter Linear Recursive Model."*

(2) To address concerns regarding the absence of CSR mascon products, we have incorporated CSR-based reconstruction results into the comparative analysis. The corresponding figures and analyses in the manuscript have been updated accordingly to provide a more complete assessment of reconstruction performance.

(3) To avoid ambiguity regarding temperature forcing datasets, we have added clarifications in the Methods section to explicitly distinguish GLDAS-2.2 temperature variables from ERA5-Land meteorological forcing data. In addition, new supplementary figures have been included to illustrate spatial

and temporal differences between these datasets.

Please find point-by-point responses on the following pages, where reviewers' comments are shown in black text and our responses are shown in blue text.

Sincerely,

Pu Xie and Shuang Yi

February 2026

Responses to Major Comments

Comment 1: The title could be improved to more accurately reflect the core contribution of the paper.

Response: We thank the reviewer for this helpful suggestion regarding the manuscript title. We fully agree that the title plays a critical role in accurately conveying the core contributions of the study. Following your suggestion, we have revised the title accordingly. The proposed new title is: *Reconstructing Climate-Driven Global Terrestrial Water Storage (2002–2021) Using a Four-Parameter Linear Recursive Model*

We believe that this revised title more clearly represents the main objectives and contributions of the study. We would be pleased to further refine the title should the reviewer or editor have additional suggestions.

Comment 2: The authors could provide the rationale for not using the CSR Mascon data product in this study.

Response: We thank the reviewer for raising this important and well-targeted question. We fully acknowledge the value of the CSR Mascon product in terrestrial water storage studies.

Specifically, we have added the reconstruction calibrated against the CSR Mascon product (hereafter CSR-REC) and calculated the NSE between CSR-REC and the CSR Mascon solution (CSRM), as shown in Fig. R1(c) of this response. The results indicate that the spatial distribution of NSE derived from CSR-REC is generally consistent with those obtained from JPL-REC and GSFC-REC. Most grid cells exhibit NSE values within the range of 0.5–0.8, with relatively high agreement in mid- and high-latitude regions where meteorological observations are denser. This consistency further demonstrates the robustness of the proposed reconstruction framework and suggests that it is not strongly sensitive to the choice of mascon product.

In the revised manuscript, we have incorporated CSR-REC into the overall analysis to provide a more comprehensive evaluation of the reconstruction performance. The original Fig. 3 in the manuscript has been updated to include the newly added CSR-REC results. Fig. R1 in this response letter replaces the original Fig. 3 and will be included as the updated version in the revised manuscript. In addition, we have inserted the following statement after line 333 in Section 4.1 of the revised manuscript:

To further evaluate the robustness of the reconstruction model, we also compared the reconstruction calibrated against the CSR Mascon product (CSR-REC) with the CSR Mascon solution (CSRM). The spatial distribution of NSE (Fig. 3c) is broadly consistent with those obtained for JPL-REC and GSFC-REC. The NSE distributions derived from the three mascon-based calibrations are largely consistent, indicating that the reconstruction approach exhibits limited sensitivity to the source of the mascon products, which is consistent with findings reported in previous studies ((Humphrey and Gudmundsson, 2019)).

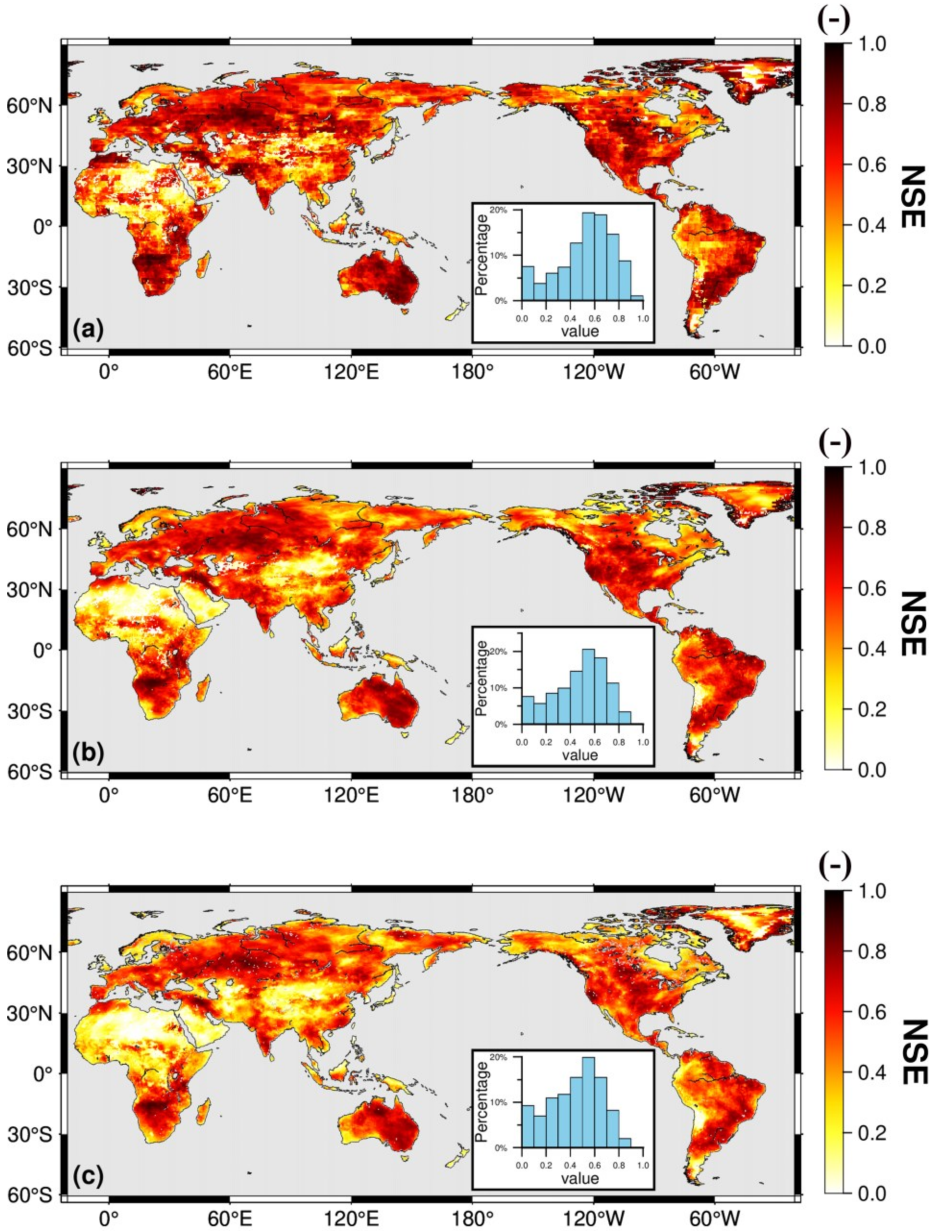


Figure R1: Spatial distribution of NSE (of de-seasonalized, de-trended anomalies) between our reconstruction and (a) JPLM, (b) GSFCM, and (c) CSRM for 2002–2021. Histograms show the distribution of NSE values across all global grid points.

Comment 3: The GLDAS-2.2 data is also forced with the meteorological analysis fields from the operational European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecasting System. Due to the data agreement with ECMWF, this GLDAS-2.2 daily product does not include the meteorological forcing fields. The GLDAS-2.2 data are archived and distributed in NetCDF format. Thus, the authors should explain the differences between the two temperature datasets.

Response: We sincerely thank the reviewer for this careful and highly professional comment. We fully agree that clarifying the origin and differences of the temperature datasets is essential for avoiding confusion regarding the model forcing variables, and we greatly appreciate the reviewer for pointing out this important issue.

First, we would like to emphasize that the two temperature datasets used in this study are indeed different. Fig. R2(a) presents the basin-scale root-mean-square (RMS) differences between ERA5-Land 2 m air temperature and GLDAS-2.2 surface temperature across 116 global river basins. Please note that we have removed the mean values from each dataset prior to comparison. The figure clearly shows that apparent differences exist between the two datasets at the basin scale. Fig. R2(b) shows one example in the Amazon basin derived from ERA5-Land and GLDAS-2.2. As shown, although the two datasets exhibit generally consistent seasonal variability, noticeable discrepancies at the daily scale are present.

Regarding the source of these differences, the official documentation further clarifies that ERA5-Land and GLDAS-2.2 are based on distinct atmospheric forcing systems and land surface models, as well as temporal resolution (Fig. R3 and Fig. R4). ERA5-Land is forced by meteorological variables from the ERA5. In contrast, GLDAS-2.2 is forced by the operational ECMWF Integrated Forecasting System (IFS) analysis fields. In addition, ERA5-Land employs the H-TESSEL land surface model, whereas GLDAS-2.2 uses the Catchment land surface model. Finally, ERA5-Land provides hourly temperature fields that retain sub-daily variability (with daily temperature in this study obtained through temporal aggregation), while GLDAS-2.2 provides temperature fields at a daily temporal resolution, further contributing to the observed discrepancies between the two datasets.

To address this issue and avoid ambiguity, we have added a clarification in the Methods section of the revised manuscript to explicitly distinguish between the temperature variables from GLDAS-2.2 and the meteorological forcing temperature provided by ERA5-Land. Specifically, Fig. R2 in this response has been incorporated into the Supplementary Materials of the revised manuscript as Fig. S6. Additionally, we plan to insert the following explanatory text after Line 155 in the original manuscript:

It should be noted that, due to the data usage agreement with the European Centre for Medium-Range Weather Forecasts (ECMWF), which prohibits redistribution of products from the Integrated Forecasting System (IFS), the GLDAS-2.2 daily product does not include the meteorological forcing fields. Instead, GLDAS-2.2 provides land surface variables simulated by the Catchment land surface model, which is forced by meteorological analysis fields from the operational ECMWF IFS.

Although both ERA5-Land and GLDAS-2.2 are ultimately based on meteorological information produced within the ECMWF framework, their temperature datasets exhibit a discrepancy of approximately 1–2 °C (Fig. S6) due to different data assimilating methods and models.

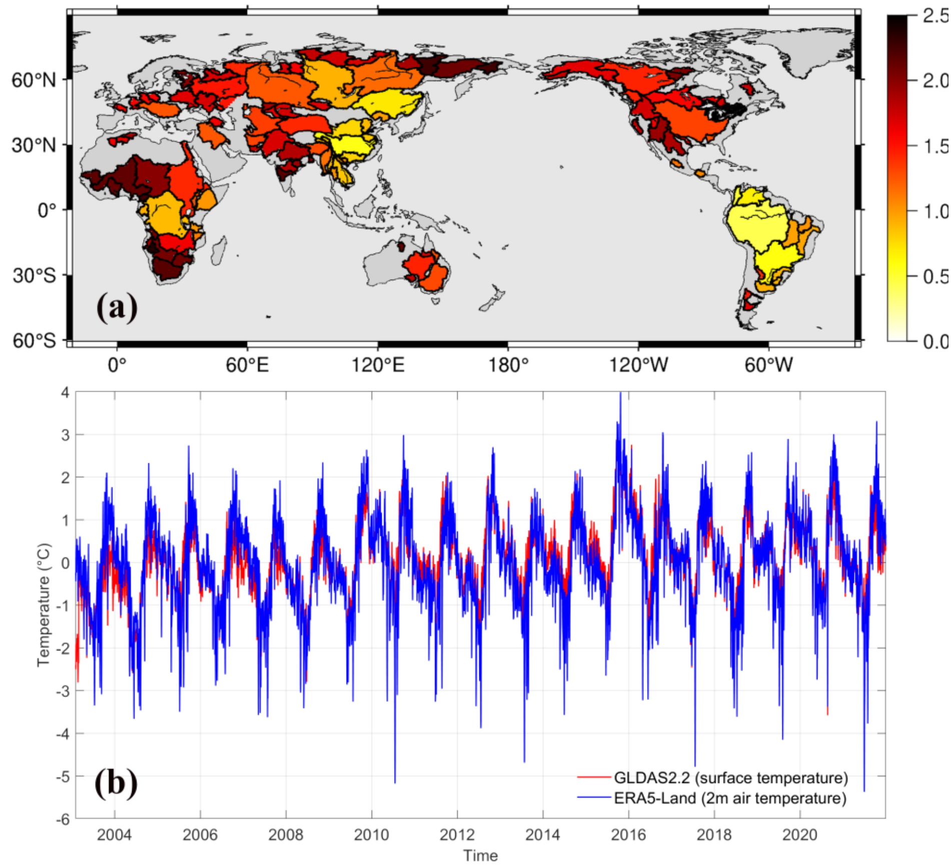
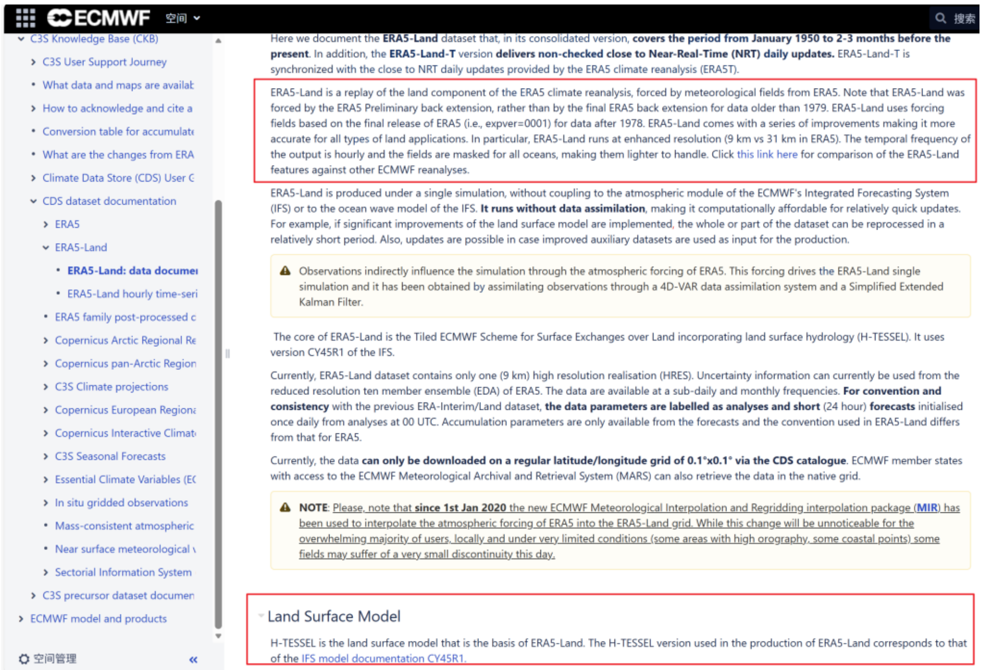


Figure R2: Spatial distribution of RMS differences between ERA5-Land 2 m air temperature and GLDAS-2.2 surface temperature over 116 global river basins (a). Comparison of daily ERA5-Land 2 m air temperature and GLDAS-2.2 surface temperature over the Amazon basin (b).



Here we document the **ERA5-Land** dataset that, in its consolidated version, **covers the period from January 1950 to 2-3 months before the present**. In addition, the **ERA5-Land-T** version **delivers non-checked close to Near-Real-Time (NRT) daily updates.** ERA5-Land-T is synchronized with the close to NRT daily updates provided by the ERA5 climate reanalysis (ERA5T).

ERA5-Land is a replay of the land component of the ERA5 climate reanalysis, forced by meteorological fields from ERA5. Note that ERA5-Land was forced by the ERA5 Preliminary back extension, rather than by the final ERA5 back extension for data older than 1979. ERA5-Land uses forcing fields based on the final release of ERA5 (i.e., expver=0001) for data after 1978. ERA5-Land comes with a series of improvements making it more accurate for all types of land applications. In particular, ERA5-Land runs at enhanced resolution (9 km vs 31 km in ERA5). The temporal frequency of the output is hourly and the fields are masked for all oceans, making them lighter to handle. Click this link here for comparison of the ERA5-Land features against other ECMWF reanalyses.

ERA5-Land is produced under a single simulation, without coupling to the atmospheric module of the ECMWF's Integrated Forecasting System (IFS) or to the ocean wave model of the IFS. **It runs without data assimilation**, making it computationally affordable for relatively quick updates. For example, if significant improvements of the land surface model are implemented, the whole or part of the dataset can be reprocessed in a relatively short period. Also, updates are possible in case improved auxiliary datasets are used as input for the production.

Observations indirectly influence the simulation through the atmospheric forcing of ERA5. This forcing drives the ERA5-Land single simulation and it has been obtained by assimilating observations through a 4D-VAR data assimilation system and a Simplified Extended Kalman Filter.

The core of ERA5-Land is the Tiled ECMWF Scheme for Surface Exchanges over Land incorporating land surface hydrology (H-TESSEL). It uses version CY45R1 of the IFS.

Currently, ERA5-Land dataset contains only one (9 km) high resolution realisation (HRES). Uncertainty information can currently be used from the reduced resolution ten member ensemble (EDA) of ERA5. The data are available at a sub-daily and monthly frequencies. **For convention and consistency** with the previous ERA-Interim/Land dataset, **the data parameters are labelled as analyses and short** (24 hour) **forecasts** initialised once daily from analyses at 00 UTC. Accumulation parameters are only available from the forecasts and the convention used in ERA5-Land differs from that for ERA5.

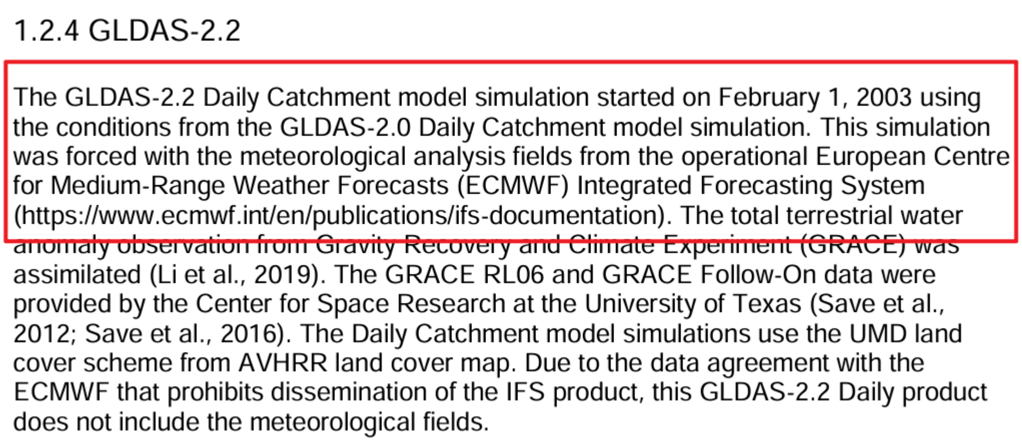
Currently, the data **can only be downloaded on a regular latitude/longitude grid of 0.1°x0.1° via the CDS catalogue**. ECMWF member states with access to the ECMWF Meteorological Archival and Retrieval System (MARS) can also retrieve the data in the native grid.

NOTE: Please, note that **since 1st Jan 2020** the new ECMWF Meteorological Interpolation and Regridding interpolation package (**MIR**) has been used to interpolate the atmospheric forcing of ERA5 into the ERA5-Land grid. While this change will be unnoticeable for the overwhelming majority of users, locally and under very limited conditions (some areas with high orography, some coastal points) some fields may suffer of a very small discontinuity this day.

Land Surface Model

H-TESSEL is the land surface model that is the basis of ERA5-Land. The H-TESSEL version used in the production of ERA5-Land corresponds to that of the IFS model documentation CY45R1.

Figure R3. Official documentation of ERA5-Land dataset from ECMWF. (Source: ERA5-Land: data documentation , accessed on 2026-01-22)



1.2.4 GLDAS-2.2

The GLDAS-2.2 Daily Catchment model simulation started on February 1, 2003 using the conditions from the GLDAS-2.0 Daily Catchment model simulation. This simulation was forced with the meteorological analysis fields from the operational European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecasting System (https://www.ecmwf.int/en/publications/ifs-documentation). The total terrestrial water anomaly observation from Gravity Recovery and Climate Experiment (GRACE) was assimilated (Li et al., 2019). The GRACE RL06 and GRACE Follow-On data were provided by the Center for Space Research at the University of Texas (Save et al., 2012; Save et al., 2016). The Daily Catchment model simulations use the UMD land cover scheme from AVHRR land cover map. Due to the data agreement with the ECMWF that prohibits dissemination of the IFS product, this GLDAS-2.2 Daily product does not include the meteorological fields.

Figure R4. Official NASA GLDAS Version 2 Data Products README provided by the GES DISC at NASA Goddard Space Flight Center. (Source: https://disc.gsfc.nasa.gov/datasets/, accessed on 2026-01-22)

Responses to Minor Comments

1) L50, Usage of 'Eq' is not defined before.

Response: Thank you for your advice. We have added add a definition at the first occurrence of "Eq" in the revised manuscript (Line 50): *"Eq is short for Equation."*

2) L135-136, the citation format '(Lan and Wenke, 2022)' is wrong. The same for '(Muñoz-Sabater et al., 2021; Muñoz Sabater, 2019)'.

Response: We appreciate the reviewer's careful attention to citation formatting. We have corrected these citation errors in accordance with the journal's style requirements.

3) L179 and L185, abbreviations with 'where' at the beginning of a sentence are unnecessary.

Response: Thank you for your advice. We have revised the sentences on Lines 179 and 185 to remove the redundant use of "where" at the beginning of definitions.

4) L680, 'In some other basins' to 'In other basins'.

Response: Thank you for your advice. We have revised "In some other basins" to the more standard expression "In other basins."

References

Humphrey, V. and Gudmundsson, L.: GRACE-REC: A reconstruction of climate-driven water storage changes over the last century, Earth Syst. Sci. Data, 11, 1153-1170, 2019.