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SOFTWARE TOOL ARTICLE

REVISED WALIS dashboard: An online tool to explore a global paleo sea-level database

[version 2; peer review: 2 approved, 2 approved with reservations]

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Abstract

In this paper, we present WALIS Dashboard, an open-access interface to the World Atlas of Last Interglacial Shorelines (WALIS), which was developed and compiled thanks to funding from the European Research Council. WALIS is a database that includes thousands of samples (dated with different radiometric methods) and sea-level indicators formed during the Last Interglacial (~80 to 130 ka). The WALIS Dashboard was coded in R (shiny app), and allows querying a simplified version of WALIS by either geographic extent or by attributes. The user can then download the queried data and perform simple and reproducible data analysis. The WALIS Dashboard can be used both online and offline.

Plain language summary

Tide gauges and satellites provide reliable measurements of sea-level changes since the beginning of the 20th century. To estimate sea-level changes before this period, we rely on sea-level indicators, i.e., geological features that were formed in close connection with sea level in the past, such as fossil shallow-water coral reefs or cemented beach deposits. Similar to tide gauge and satellite data, data on sea-level indicators are collected and standardised in databases, which are then made available to the scientific community (and the public at large) for further analysis. In this work, we present an open-source application that allows exploring, analysing, and downloading sea-level indicators included in the World Atlas of Last Interglacial Shorelines (WALIS), a paleo sea-level database compiled thanks to funding from the European Research Council. The application aims to facilitate access to this information for researchers, students, and citizens by creating more interactive and intuitive ways to explore the scientific information contained in WALIS.

Open Peer Review

Approval Status ? ✓ ✓ ?

	1	2	3	4
version 2 (revision) 01 Mar 2024		✓ view	✓ view	? view
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Keywords
Past sea level change, Geological database, Last Interglacial, Data visualisation, Sea-level changes, Paleoclimate

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REVISED **Amendments from Version 1**

The article has been reorganised to address the comments by the reviewers. We included more information about the underlying database and the Merging SLIPs process. We modified the Use case to focus on evaluating a hypothesis using the dashboard and interpreted the results. This version includes a new set of figures to better adapt to the new document structure.

A new version of the dashboard was released. We modified the document to reflect the changes on the dashboard.

Any further responses from the reviewers can be found at the end of the article

Introduction

Geological indicators of past sea levels are fundamental to assessing how ice sheets melted in the past and provide fundamental benchmarks to define possible scenarios of ice sheets melting in a warmer future climate[1]. To be used as a sea level index point (SLIP, also called "relative sea-level indicator"), a geological feature must be assigned an elevation and geographic location, an age via radiometric dating or chronostratigraphic correlation, and must have a quantifiable relationship witha former sea level, called indicative meaning[2]. Knowing these three parameters, it is possible to reconstruct the relative sea level (RSL) at a point in time in the past. In turn, RSL corresponds to the sum of global mean sea level and post-depositional land motions caused by different processes (e.g., tectonics, glacial isostatic adjustment, sediment compaction[3]).

The advent of data digitalisation has provided paleo sea-level researchers with new opportunities to discover and access studies from different research groups. Among the tools facilitating the exchange of information, scientific articles and open-access repositories have opened the possibility to download, analyse and in some case visualize[4] sea-level data to anyone with internet access. However, access to new studies and data comes with additional challenges. A widespread issue is that the information related to sea-level indicators is communicated in multiple ways (e.g., graphs, tables, in-text explanations, supplementary information) that require readers to navigate among different styles and conventions. Sea level researchers often face additional challenges as a correct interpretation of data requires an understanding of several measurement and dating techniques, and requires in-depth knowledge of how the original information (e.g., the stratigraphic context of geological sea-level index points) was interpreted by the authors. Recent efforts among the sea-level research community have resulted in standardised formats designed to store and share information on sea-level indicators in a way that allows different researchers to understand the origin and details of their measurements and reproduce the process to extract their components[5,6].

The World Atlas of Last Interglacial Shorelines (WALIS) is a standardised database that includes data from thousands of studies published since the early 1900s. The focus is on sea-level indicators formed during the Last Interglacial (~80 to 130 ka), although the database includes some older data points[7]. The database includes 4545 sea-level proxies and 4110 dated samples standardised from 2130 references compiled by multiple research groups within a special issue of the Earth System Science Data journal. The structure of the database consists of multiple tables, that are openly available in Zenodo[8] in different export formats (e.g., CSV and geoJSON). In this work, we present a dashboard that allows exploring WALIS data, and can be used both offline and online. The basic use of the dashboard does not require downloading the database or extensive coding knowledge.

The WALIS Dashboard

The main purpose of the WALIS Dashboard is to provide an alternative entry point for end users to explore the information included in WALIS. We note that our use of WALIS falls within the license under which the database is shared (CC-BY 4.0). The WALIS Dashboard was originally coded in the framework of the master thesis of Sebastián Garzón[9]. The first version (ver. 1.0) of the WALIS Dashboard was released in 2021[10]. The second version (ver. 2.0) was released at the end of October 2022[11] and is briefly outlined within the WALIS database description paper[7]. For the peer-review of this manuscript, we prepared version 3.0, which includes bug fixes and improvements to the interface[12]. Post-review, we released version 3.1[13], which considers the reviewer's comments and proposes further improvements to the interface.

The WALIS Database

The WALIS Dashboard is based on a simplified, single-table version, of the WALIS database (called Summary Table), which is included (together with the code used to generate it) in the WALIS database repository (see *Underlying data*). This table is created from the "Summary sheet" included in WALIS, calculating percentiles of the probability distribution for paleo RSL and age (0.1,2.3,15.9,50,84.1,97.7 and 99.5 percentiles). The RSL percentiles for each SLIP are calculated by applying, to each index point, the following procedure:

1. If the SLIP is a "Single Coral", the percentiles are obtained from a gamma function interpolated considering the upper limit of living range inserted in the database as, respectively, the 2.3 and 97.7 percentiles of the distribution.

2. If the RSL Indicator is a "Sea Level Indicator" or "Single Speleothem": the percentiles on paleo RSL are calculated from the Gaussian distribution represented by the field "Paleo RSL (m)" and its associated uncertainty (1-sigma).

3. If the RSL Indicator is a "Terrestrial Limiting" or "Marine Limiting", the RSL percentiles are not calculated.

For which concerns age percentiles, for SLIPs with radiometric ages they are calculated from the Gaussian distribution of the mean age and its associated 2-sigma uncertainty. In case the age of the SLIP is present in WALIS only as a time period (e.g., the SLIP is attributed to Marine Isotopic Stage 5), the age range is treated as a uniform distribution, with upper and lower age limits matching those indicated by Lisiecky and Raymo (2005)[14] and Spratt and Lisiecky (2016)[15], that are already coded into WALIS (e.g., a MIS 5 age assignment corresponds to an age range between 71 and 130 ka).

Rationale and software description

WALIS is a complex database framework, as it includes several tables connected by several SQL relations (see Rovere *et al.*, 2023[7] for a detailed description of the database). Traditional access to WALIS for end-users would require them to directly download the full dataset from Zenodo or connect to the SQL server that hosts the database. Given the complexity required to standardize SLIPs, these tasks would require end users to familiarize themselves with the dataset structure and with either Python or SQL to explore, visualize, or perform data analysis on the database. While the WALIS distribution[8] includes Python scripts to perform simple queries on the data, end-users would still need a good proficiency level in Python to use and modify these scripts to their needs. Given the challenges described above, we created the WALIS Dashboard to allow for a quick exploration, query, and analysis of the SLIPs included in the database. The WALIS Dashboard software architecture is described hereafter and the software is available for open access (see *Software availability*).

The WALIS Dashboard is an interactive application developed using open-source R packages. The software was developed using R (RRID:SCR_001905) version 4.1.0[16]. The application is built using the R-Shiny package (RRID:SCR_001626)[17] that allows the integration of data visualization and analysis in an interactive web platform. The application includes individual data visualisations often used in the literature to provide context on SLIPs, such as maps, sea-level plots, and tables. Additionally, the application provides the end users an interface to apply a Monte Carlo method[9] to merge and summarise multiple SLIPs within the same geographic context.

The WALIS dashboard can be accessed both online and offline. The online version is available as a freely-hosted shiny app here (Last access January 30th, 2024). We coded the online application targeting end-users who want to explore the WALIS data set without installing any R package or manipulating code. Access to the online version only requires a stable internet connection. The dashboard can be also accessed in a local build after downloading the source code available on our GitHub repository or in the Zenodo repository[12]. The target for the offline version is researchers who want to contribute to expanding the capabilities of the dashboard, or who need to run more computationally intense data analyses. Contributions are welcome as new issues or pull requests in the main GitHub repository.

Main features

The application is divided into three tabs: "*Interactive map*", "*Summary table*", and "*Merge SLIPs*" (Figure 1). These are described hereafter one by one, but we remark that the operations (e.g., filtering) done on the data in one tab are propagated to the other ones.

Interactive map

The starting page of the WALIS Dashboard is divided into three main parts: a filtering application, a map, and a sea-level plot. The filtering application allows querying the data through age properties (age range with user-specified percentile bounds and dating technique, SLIP properties (elevation error, RSL uncertainty and associated percentiles, and type of RSL indicator), and geographic extent (either gathered from the map display or via a polygon drawn by the user). The map shows the location of the SLIPs included in WALIS. Clicking on one point in the map, a popup menu appears with general information about the selected record. As a default, when panning and zooming onto the map the sea-level plot is updated. The sea-level plot shows RSL on the Y-axis and Age (ka) on the X-Axis and is the main element of data visualisation in the "Interactive map" tab. Based on the filters applied to the data, the graph is updated in real time. In the graph, we implemented a symbology for the nine types of sea-level indicators and associated ages allowed by the WALIS database[7]. The sea-level plot can be downloaded in PNG format.

Summary table

The second tab in the WALIS dashboard is called "*Summary table*" and includes the data as filtered in the "*Interactive map*" tab. As a visual guide, on the top of the page, two insets show the current filters active on the data and a map that defines the area of interest. The table displayed on this page includes all the information available from the simplified version of WALIS described in the previous sections. In the upper right corner of this page, a button allows downloading the data in CSV format.

Merge SLIPs

The "*Merge SLIP*" tab allows the end-user to create a point cloud or density plot that represents a probability distribution of RSL vs age, using the SLIPs that were selected in the "*Interactive map*" tab. In this tab, the end-user can combine the different probability distributions of Age and RSL values of each sea-level index point (SLIP) into a single point cloud. Before merging the data, the user can further filter the dataset (by excluding selected index points) and determine the number of points to be sampled within each SLIP.

The merging method follows the methodology proposed by Garzón (2022)[9], which was adapted from the work of Bender *et al.* (2020)[18] (code available in Rovere *et al.*, 2020[19]). The method consists of a Monte Carlo sampling of RSL and Age for each SLIP within their probabilistic distributions (Figure 2). In the WALIS Dashboard, the end-user can select how many times per SLIP the workflow shown in Figure 2

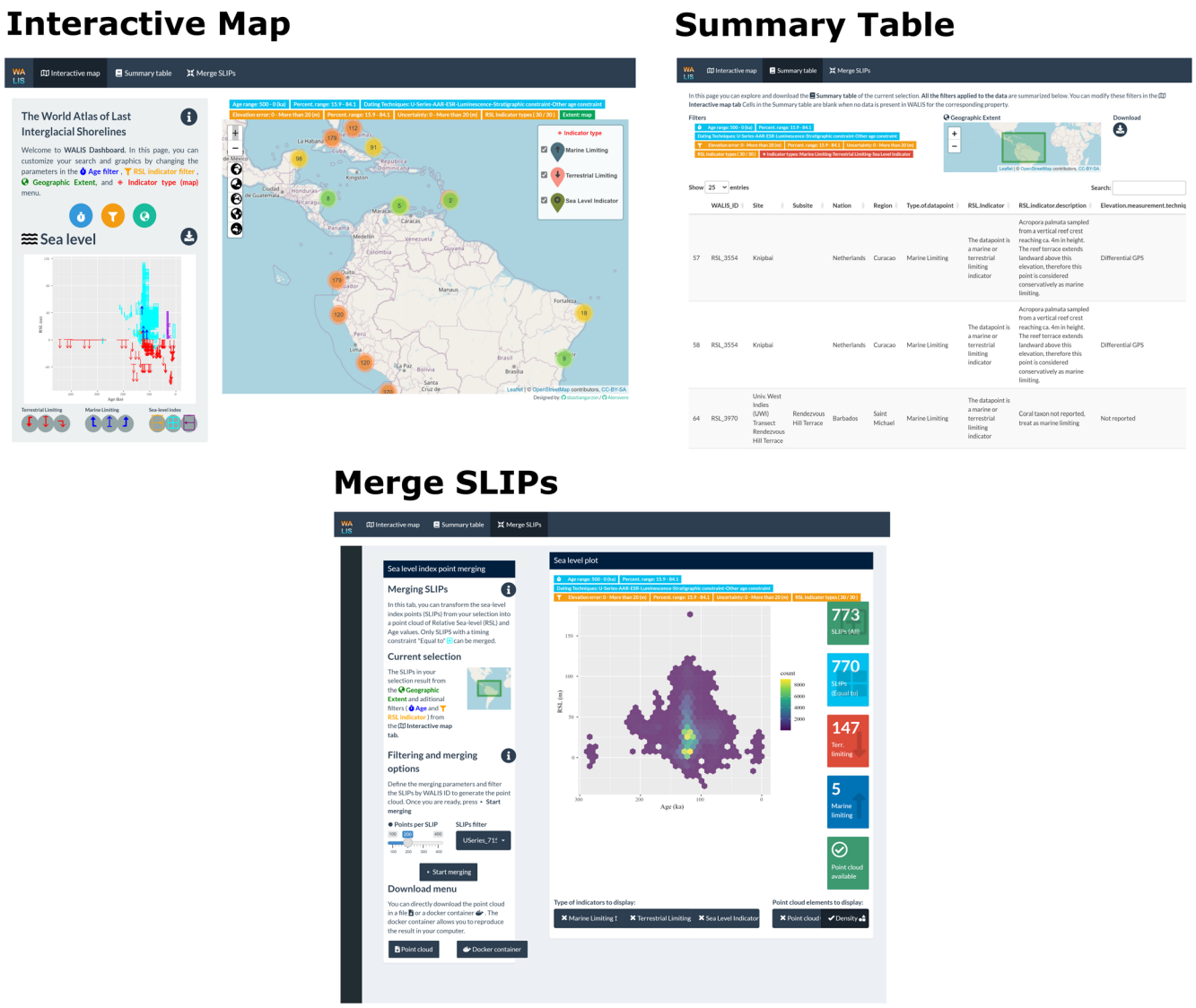

Figure 1. WALIS Dashboard interactive tabs.

is repeated. The WALIS Dashboard limits the number of points per SLIP depending on the number of SLIPs selected for the analysis. Analysis including a large number of samples can be performed by downloading a docker container from the "Download" menu after merging a selection of SLIPs.

After the SLIPs are merged, the user can explore the results in a RSL vs Age plot. The results can then be exported using two different strategies: "*Point cloud download*" or "*Docker container*". The first option exports the resulting point cloud into a CSV file accompanied by a geoJSON file with information about the filters used. The second option creates a docker image accompanied by the required data and code to fully reproduce the results of the data merging. In this way, the results obtained remotely in the Dashboard are fully reproducible on a local machine.

Operation

System requirements

The WALIS dashboard is available both online and offline. The online version only requires a stable internet connection to access the interactive web app. To guarantee the long-term availability of the application, here we explain two alternatives to deploy the application on a local machine.

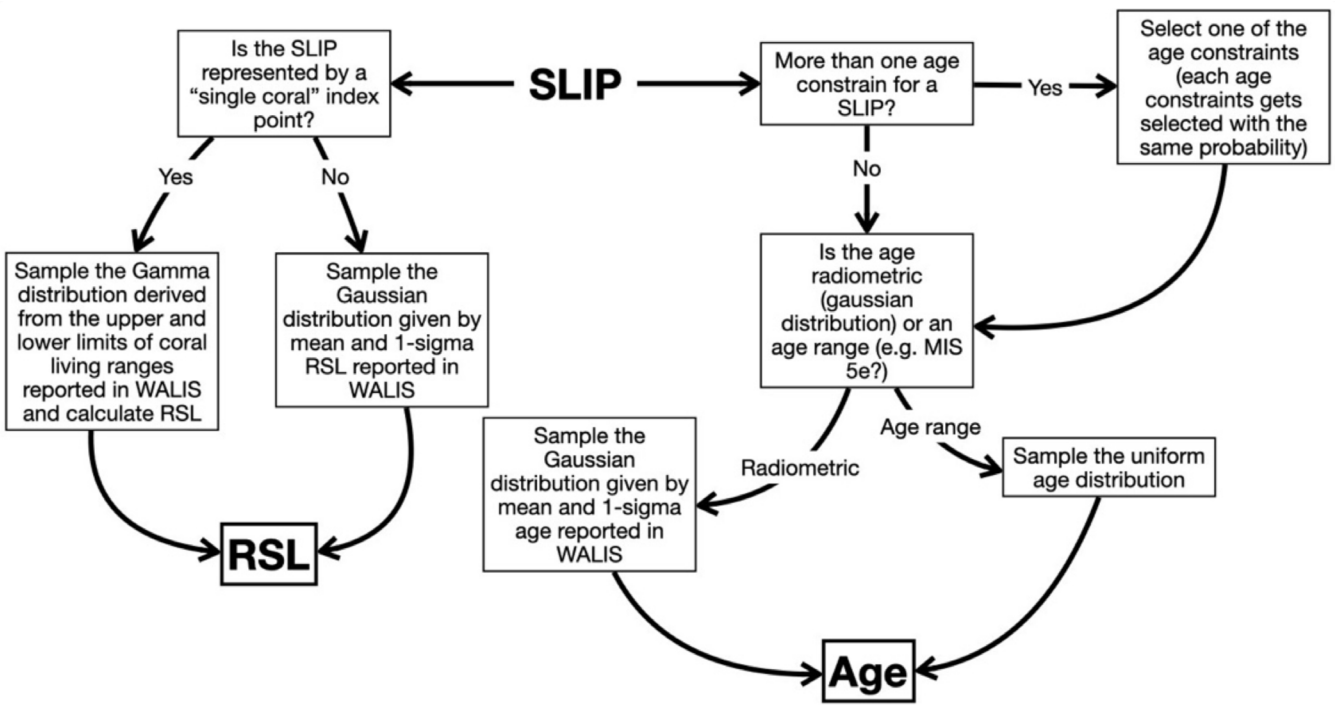

Figure 2. Overview of the processing done on each SLIP within the WALIS Dashboard at each run of the Monte Carlo processing.

Local shiny application

Users can deploy a local implementation of the shiny application using the {renv} package. This option provides the required files and R packages information. An R installation is a prerequisite for this option.

1. Download the WALIS dashboard from GitHub - see *Software availability*
2. Open R and install the *renv* package.
    - `install.package("renv")`
3. Open the R Project file (WALIS_Visualization.Rproj). This file should start the process of restoring the dependencies of the project using the Lockfile (renv.lock). You can manually restore the dependencies using the function restore() from the R package *renv*
    - `library("renv")`
    - `restore(renv.lock)`
4. Open the app.R file.
5. Run the App using the runApp() function from the Shiny R package.
    - `library("shiny")`
    - `runApp(your_path/to/app.R)`

Docker image

A Docker image to run the application is available as part of the application. This docker image allows the application to be fully reproducible as the instructions and computational requirements (e.g., operating system, R packages) to deploy the application inside a software container are automated. The only prerequisite is to have Docker () installed and running on the local machine.

Download and start-up instructions - Docker

1. Download the WALIS dashboard from GitHub - see *Software availability*
2. Open Docker to run in the background
3. Open a terminal and access the folder with the application
    - `cd WALIS_Visualization`
4. Create a Docker container using the Dockerfile image. This process could take hours the first time as it requires setting up all computational requirements.
    - `docker build -t 'walis-shiny'.`
5. Run the Docker container
    - `docker run -p 3838:3838 'walis-shiny'`
6. Open the application in a web browser at *http://localhost:3838*

Use case

In the following sections, we use the WALIS Dashboard to test a simple hypothesis using RSL data included in WALIS. We want to test the hypothesis that across the island of Curaçao

there is a long-term North-South tectonic tilting, similar to the one already suggested for the nearby island of Bonaire[20,21]. If present, such tilting should be evident from the paleo RSL record on Curaçao (that is, the local sea-level indicated by SLIPs across the island, uncorrected for any post-depositional displacement).

Step 1 – Data query

The first step is to verify that data is present for the island of Curaçao, in the Lesser Antilles. This is done by panning and zooming on the map to the island. From the WALIS Dashboard, we can verify that there is data across large parts of the island, mostly on its Northern, Central, and Central-Southern parts (Figure 3A). The data spans a large age range (~80-160 ka) and indicate that RSL could have attained elevations between 0 and 20 meters above present (Figure 3B). For our work, we want to limit the age of the SLIPs to Marine Isotope Stage 5e, i.e., 110-130 ka), and we want to discard marine limiting points (i.e., points that indicates that sea-level was above the measured feature, but for which no relation with the former sea-level is provided). We therefore filter our data using the "*Age filter*" menu to keep only the desired age range, and we turn off from the legend in the main map the "Marine Limiting" points.

Step 2 – Database Exploration

From the "*Summary Table*" page, we can explore the data and see what literature sources are present. The data in this area has been inserted in the WALIS database by two studies, Chutcharavan and Dutton (2021)[22] and Rubio-Sandoval *et al.* (2021)[23], who reviewed the works of Schellmann *et al.* (2004)[24] and Muhs *et al.* (2012)[25]. The full references to these studies are present in the full version of WALIS[8]. In total, in Curaçao, there are 26 SLIPs with ages between 130 and 110 ka, most of them concentrated in the North (n=18), the others in the Central (n=4) and Central-South (n=4) sub-areas (Figure 3A).

Step 3 – Merge SLIPs

We use the geographic filter option to select and export (via the "*Summary Table*" page) one CSV file for each sub-area shown in Figure 3A. For each sub-area, we then use the "*Merge SLIP*" function to create a point cloud describing the probability distribution of RSL and age in each sub-area. We use a sample of 10.000 points per SLIP in each area. For each sub-area, we download both the point cloud and the docker container. In the Central-South sub-area, we exclude from merging the index point labelled as "USeries_1764" (labelled in Figure 3B), which is characterized by very large error bars, and therefore may be unreliable.

We then use the exported point cloud within a graphic software to explore in detail the trends in the data (Figure 4A-C). From the histograms of RSL in each area (Figure 4D), we verify that there is an overlap between the RSL records in the North, Central, and Central-South areas. However, the first and third quantiles of the distribution show that, in the North, RSL is slightly higher (6.5-10.3 m) than in the Central (6.1-8.9 m) and Central-South (5.4-7.4 m) parts.

Therefore, the WALIS Dashboard allowed us to extract the data to test a simple hypothesis on the North-South tilting of the island of Curaçao. Standing the results, the hypothesis is rejected, as there is no significant difference between the probability distribution of RSL across the island. However, the data also suggests that there might be some differences (as per the quartiles shown in Figure 4D), therefore highlighting the need for more precise *in-situ* surveys across the island to gauge whether these differences might reflect

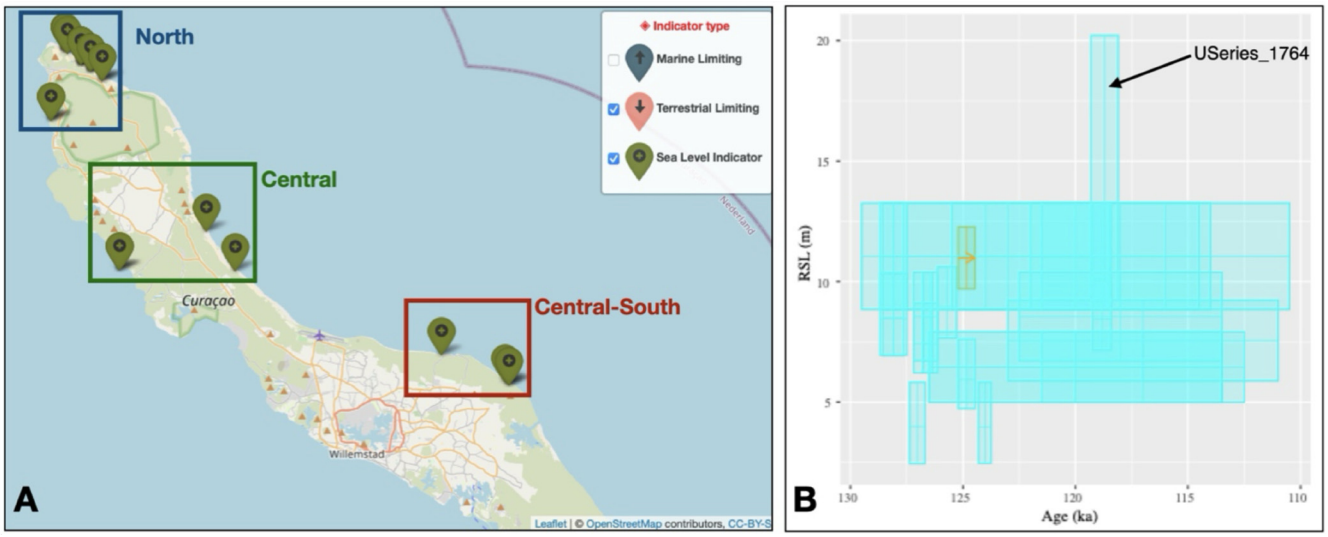

Figure 3. **A**) Map and **B**) RSL vs Age plot from the WALIS Dashboard for the island of Curaçao after the filtering described in the text. The datapoint labelled in **B**) has been excluded before merging the SLIPs, as described in the text.

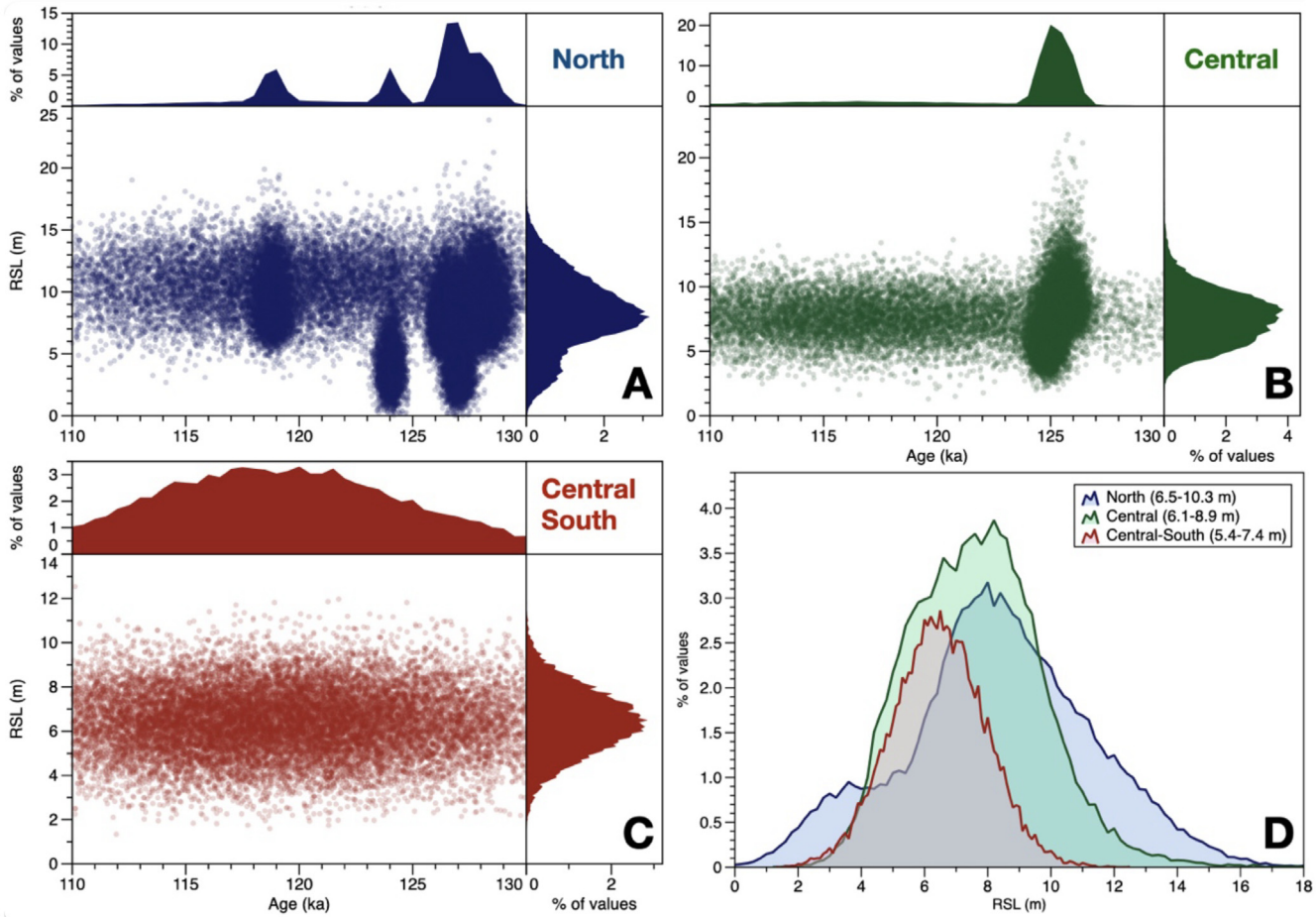

Figure 4. **A**-**C**) Plots showing the point clouds expoted from the WALIS Dashboard after the *"Merge SLIP"* processing. The upper and right panels show the histograms of, respectively, age and RSL derived from the point clouds. **D**) Histograms of RSL for each of the three areas. Within the legend, in parenthesis, are indicated the first and third quartile of each histogram.

a different post-depositional deformation signal across the island.

Conclusions

In this article, we presented an open-source online dashboard developed using R packages to explore the WALIS database. This dashboard is an example of how open-source tools can be used to simplify access to database information for research teams with limited software development or use capabilities. The interactive application consists of three tabs that summarise the database information for researchers to provide a user-friendly point of connection to the information. The application includes basic data processing methods that provide meaningful observations for researchers to start analysing the content of the database. Given the application design, end-users of the application should be able to easily explore the WALIS database before engaging in more complex and time-consuming tasks to understand the database structure. To promote further developments and guarantee the long-term and offline maintenance of the application, the software includes reproducibility strategies such as software containers and dependency management strategies. Similarly, the application is licensed under an MIT permissive free software license, to encourage researcher teams to implement similar interactive visualisation approaches for other databases.

Ethics and consent

Ethical approval and consent were not required.

Data availability

Underlying data

Zenodo: WALIS - The World Atlas of Last Interglacial Shorelines (Ver 1.0 final).

https://doi.org/10.5281/zenodo.7348242

This project contains the following underlying data:
Atlas_Versions/Ver_1/Ver_1_0_post_review/Output/DB_Structure/Summary_full.csv (CSV file containing the WALIS summary table).

Data are available under the terms of the Creative Commons Attribution 4.0 International Public License (CC BY 4.0).

Software availability

Software available from: https://warmcoasts.shinyapps.io/WALIS_Visualization/

Source code available from: https://github.com/Alerovere/WALIS_visualization

Archived source code at time of publication: https://doi.org/10.5281/zenodo.4943540

Licence: MIT

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Version 2

Reviewer Report 20 June 2024

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Selasi Yao Avornyo
University of Ghana, Accra, Greater Accra Region, Ghana

The WALIS Dashboard represents a significant advancement in the field of paleo sea-level research. By providing an intuitive, user-friendly interface to a vast database of sea-level indicators from the Last Interglacial, this tool facilitates greater accessibility and usability of data for researchers, students, and the general public. The open-access nature of the dashboard promotes transparency and encourages collaborative research efforts. The Dashboard's intuitive design and persistent filtering feature across all tabs greatly enhance user experience. The ability to use it both online and offline adds valuable flexibility, making it a highly effective tool. This dashboard demonstrates impressive functionality and ease of use, providing a powerful resource for users.

I have perused the earlier and current versions; the authors have been responsive to peer review comments, as evidenced by the amendments made from version 1 to version 2. However, peruse your document thoroughly. There are a few typographical and grammatical errors that require attention. I have listed a few below:

INTRODUCTION:...quantifiable relationship "**witha**" former sea level"...should be "**with a**".

THE WALIS DASHBOARD:...which considers the **reviewer's** comments and proposes further improvements to the interface, should be **reviewers'**.

Use Case, Step 1 – Data query:...points that **indicates** that sea-level was above the measured feature...should be "**indicate**".

Figure 4. A-C) Plots showing the point clouds **expoted** from...should be "**exported**".

Overall, the WALIS Dashboard is a well-conceived and effectively implemented tool that enhances access to and analysis of paleo sea-level data. The manuscript is thorough and presents the development, functionality, and significance of the dashboard. To ensure its continuous usage and improvement, consider the following as well:

1. Implement a feedback mechanism within the dashboard where users can suggest

improvements, report issues, and share how they are using the tool. This will help in continuous improvement and ensure the dashboard meets the evolving needs of the research community.

2. While the manuscript includes a general overview of the code and methods, additional details would enhance replicability. Provide more extensive documentation, including code snippets, setup instructions, and a comprehensive user manual.

Is the rationale for developing the new software tool clearly explained?

Yes

Is the description of the software tool technically sound?

Yes

Are sufficient details of the code, methods and analysis (if applicable) provided to allow replication of the software development and its use by others?

Yes

Is sufficient information provided to allow interpretation of the expected output datasets and any results generated using the tool?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Coastal Processes and Remoting Sensing

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 25 May 2024

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Stephen Chua
Earth Observatory of Singapore,, Nanyang Technological University, Singapore, Singapore

Dear authors,
I have completed a review of your programme and manuscript entitled: **'WALIS dashboard: An online tool to explore a global paleo sea-level database'**. This programme provides a powerful yet user-friendly open-access database with a graphic-user interface (GUI) to tap on the thousands of samples and sea-level indicators dated to the Last Interglacial and older. Previous reviewers have already provided excellent feedback and technical suggestions to the manuscript and

dashboard which have been well addressed in version 2. I am in good agreement with their points especially the clarification and substantiation of the Merge SLIPs function.

The intention of the authors for widespread utilisation of this tool as stated in the Plain language summary (i.e., used by researchers, students and citizens) is laudable. I will thus approach this review from a slightly different angle – that of a non-expert end-user.

Manuscript comments
To achieve this goal, this paper could perhaps expound more on key terms and concepts required by the end users to use the tool effectively. For example, there could be a sentence or two explaining the difference between global mean sea level (GMSL) and relative sea-level (RSL). This is fundamental information for non-experts to understand the premise of this tool in para 1 of the introduction.

Is sufficient information provided to allow interpretation of the expected output datasets and any results generated using the tool?
I answered 'partly' because the lone practice 'case study' is rather advanced and perhaps a simpler one is needed for non-technical users. I understand from other reviews that there used to be more case studies in version 1 which were removed in version 2. Unfortunately the hyperlink to version 1 is no longer working for me and thus I cannot comment on other case studies. From what I infer from reviewer 1's comments case study #1 seem to be a straightforward first-order collation of regional sea-level data for understanding RSL magnitude and timing at a region of interest. I think such a case study would aid greater adoption and usage amongst your target user groups.

Dashboard comments
For ease of understanding each sea-level data point, I hope that elevation values can also be provided when a sample is clicked. At the moment I can only view 'elevation error' when clicking on a sample point in the map view - I had to access the summary table to see both elevation and the elevation error. Also it would be very helpful if that particular data point gets highlighted in the synthesized sea-level plot on the left window when a sample is selected in the map view on the right window. For example, a site near Gaudulupe, South America has 4 samples RSL 3003 – 3006. It would thus be useful to know which sample refers to which SLIP in the sea-level plot especially when we cannot view elevation values.

I observed a strange occurrence in the summary table tab. When I minimized text size of the summary table the geographic extent in map view likewise got zoomed in and I lost the delineation of study region. I could not recover the original map extent in summary table view and had to redo in the interactive map view.

My final point has to do with data management - would the database be continually updated as new studies emerge in the future?

Overall, an impressive and valuable tool and excellent contribution to the sea-level community and anyone in relevant fields and interest.

Is the rationale for developing the new software tool clearly explained?

Yes

Is the description of the software tool technically sound?
Yes

Are sufficient details of the code, methods and analysis (if applicable) provided to allow replication of the software development and its use by others?
Yes

Is sufficient information provided to allow interpretation of the expected output datasets and any results generated using the tool?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: sea level, paleoenvironmental reconstruction, stratigraphy

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 05 April 2024

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Jennifer S. Walker
Rowan University, Glassboro, New Jersey, USA

I appreciate the authors' efforts in addressing my previous comments and find that the manuscript has been greatly improved through the revision process. I just have a few final comments below.

In the WALIS dashboard, on the interactive map page, under the RSL indicator filter, under "Select type of RSL indicator", when I click on an indicator, nothing happens. You can't retain any selection of an indicator, select multiple indicators etc. Therefore, this feature needs to be fixed.

There are still typos/grammatical errors in the text and in the WALIS dashboard, so they should go through a final editing. To name a few examples in the dashboard: 1) on the interactive map page, under RSL indicator filter, under the uncertainty description, it should read "This variable does not **apply**..."; 2) on the summary table page, there should be a period after 'You can modify these filters in the Interactive map tab'; 3) on the merge SLIPs page, under the Current selection description, 'additional' is spelled incorrectly

Is the rationale for developing the new software tool clearly explained?

Partly

Is the description of the software tool technically sound?
Partly

Are sufficient details of the code, methods and analysis (if applicable) provided to allow replication of the software development and its use by others?
Partly

Is sufficient information provided to allow interpretation of the expected output datasets and any results generated using the tool?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Paleo sea level reconstructions/modeling

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 14 September 2023

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This manuscript introduces and details the WALIS dashboard, which is a new interface to explore and interact with sea-level data contained in the World Atlas of Last Interglacial Shorelines paleo sea-level database which has been previously published. The dashboard allows users to quickly explore the available data through a map visualization, sea-level plots, and a series of filters such as the type of indicator, age, or uncertainty. The authors provide their motivation for creating the dashboard and describe how to use the various elements of the interface with detailed examples through three case studies.

An online open-access tool to investigate an extensive standardized sea-level database is very useful within the sea-level community and for anyone interested in simply exploring available sea-level data in an accessible, interactive way. Having such an interface is a great next step forward

from the standardized sea-level databases that have been created across different spatial and temporal scales. Overall I would approve this manuscript with reservations considering my comments below.

Comments

In the last paragraph of the introduction, it is not clear what is meant by 'one-to-one and many-to-many relationships.' Could the authors please explain this?

The interactive map and summary table are valuable tools to have and use case #1 clearly describes how to discover sea level indicators in a way that is simple to replicate. However, I am uncertain about the use of the Merge SLIP feature that is described in use case #2. The method is from a masters thesis that does not seem to be available online and is not fully described in this manuscript. I would suggest the methodology be fully presented in this paper to go through formal peer-review or that this feature is removed from the dashboard until the methodology for the Merge SLIP is published elsewhere and could be added to the dashboard at a later date. As written, it is unclear how the Merge SLIP results should be interpreted, it at all, or if this is just another method to simply view a particular dataset. The dashboard is still a valuable tool with the map, summary, and plotting features to access paleo sea-level data. Further, I was not able to replicate use case #2 because the dashboard crashes when I tried to produce the point cloud and density figures and then resets all of the filters.

Use case #3 describes how to reproduce the results, which is important by itself, but is not really an example of how to use the dashboard, which should require no coding experience as stated in the introduction. I did not try to replicate use case #3 so cannot comment on its reproducibility, but I might suggest moving this information to a supplemental file for those interested where perhaps an example could be included with how users would perform their own individual analyses.

Because the manuscript is focused on the accessibility and exploration of data, and I am not sure about the suitability or relevance of use cases #2 and #3, one suggestion might be to add a new use case #2 that is focused on the dashboard and its specific features. Use case #1 is about discovering sea level indicators, so perhaps the authors could have a use case that begins with more of an actual research question and explore how a user could use the dashboard to determine where data is available, what relevant information is available in the summary table, and how having access to the dashboard specifically contributes to advancing the paleo sea-level field.

While the manuscript is generally clearly written, there is some awkward wording throughout the text, including typos/misspelled words in the text and within the figures (ex. 'analyse' spelled incorrectly in Figure 1), the capitalization of words or terms from the dashboard is inconsistent (ex. sometimes only first word of a term is capitalized, other times all words are capitalized – see 'Age filter' and 'RSL Indicator filter' on page 4), and some unnecessary/repetitive wording or descriptions. Overall the text could be cleaner and would benefit from a readthrough to correct these mistakes and inconsistencies.

The interface itself is straightforward to use, but would benefit from final editing to fix typos and inconsistent capitalization of categories and terms throughout the various menus to improve the

clarity of the dashboard.

Another comment with the dashboard is that if you move to another window or other internet tab for a period of time, the dashboard will often 'disconnect from the server', so that when you go back to the dashboard, anything you were previously viewing has been reset and you would have to start over with finding data, setting filters, etc.

Answers to peer review form questions

Is the rationale for developing the new software tool clearly explained?
- Yes, the rationale is clearly explained in the introduction and its benefits to the scientific community are outlined in the intro and reiterated in the conclusions. Having this dashboard greatly simplifies accessing and visualizing available data as is described in the manuscript.

Is the description of the software tool technically sound?
- Yes, the descriptions of the software to use the dashboard and the offline version are clear and detailed. However, I did not access the offline version.

Are sufficient details of the code, methods and analysis (if applicable) provided to allow replication of the software development and its use by others?
- Partly; the code is available on Github and provides opportunities for replication, as well as through the offline version of the software. However, as stated above, I could not fully replicate use case #2 as the online dashboard kept crashing when I tried to produce the point cloud and density figures. Further, the methods for the Merge SLIP feature are not publicly available and should either be incorporated into this manuscript or the Merge SLIP feature should be removed from the dashboard.

Is sufficient information provided to allow interpretation of the expected output datasets and any results generated using the tool?
- Partly; the interactive map and summary table features produce expected results that can be easily interpreted and are the most valuable part of the dashboard. The manuscript does not provide sufficient information to interpret the Merge SLIP feature as the methods are not described fully or available elsewhere. In the current state of the manuscript and dashboard, the Merge SLIP feature could potentially result in misinterpretation of sea-level data from users since the methods and output are not fully explained.

Is the rationale for developing the new software tool clearly explained?

Yes

Is the description of the software tool technically sound?

Yes

Are sufficient details of the code, methods and analysis (if applicable) provided to allow replication of the software development and its use by others?

Partly

Is sufficient information provided to allow interpretation of the expected output datasets and any results generated using the tool?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Paleo sea level reconstructions/modeling

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 31 August 2023

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Jessica R. Creveling
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Summary of the Article's Contribution to the Scientific Community
In the article titled 'WALIS dashboard: An online tool to explore a global paleo sea-level database', authors Garzón and Rovere present a dashboard or 'graphical user interface' that enables users with little or no coding knowledge to query the World Atlas of Last Interglacial Shorelines (WALIS) (see Rovere *et al.*, *ESSD*, 2023). The authors present the rationale for this dashboard, a text description of the visualization (map view, table view), and describe research analysis capabilities within this dashboard using three case studies.

The following comments arise from two co-reviewers' (Creveling, Thompson) exploration of the online version of the WALIS dashboard; neither of us accessed the offline version through the downloads described in the Operation section and, hence, cannot speak to that functionality.

Creveling's Overarching Comments
I offer high praise of the interactive map and the summary table components of the WALIS Dashboard. The Interactive Map is a tremendous tool to achieve the goal of case study #1, to discover sea level indicators. The Summary table is a complementary companion to the map-view, and this table guides users into the underlying data/the scientific literature. Overall, the map and table are accessible and easy to navigate. While I offer minor critique on how to enhance these features in the dashboard functionality comments below, I feel that these contributions are ready to share with the community.

My broader criticisms relate to user case studies #2 and #3.

For case study #2, the user is guided towards creating a point-cloud of relative sea-level change based using the Merge SLIP tab, and from this encouraged to make research-relevant conclusions, such as “around 130 and 125 ka relative sea level in Bonaire and the northern part of Curaçao was around 12 and 5 m, with a decreasing tendency.” First, I have concerns that the MergeSLIP method does not appear to be peer reviewed––the reference for this is a Master’s thesis that was not accessible in my internet search. While I do not assume that the output is inaccurate, I simply note that it is not evaluable with the given information. I have reservations about the precedent of releasing an unevaluated output to a user community that may lack sea level expertise. Second, I ask that the authors provide a specific, nuanced definition of ‘relative sea level’ in the context of the underlying WALIS data. The example sea level conclusion presented by the authors, that relative sea level was around 12 and 5 m, will likely be perceived very differently based upon expertise. I illustrate this with an example from our own WALIS database entries. If one looked at the ‘relative sea level’ at Newport, Oregon, during MIS 5a (~80 ka), one sees a paleo-RSL of 22.11 m ± 23.04 m. Yet this does not mean that sea level fluctuated between -1 and 45 m at Newport, Oregon during MIS 5a––instead, this is a range that reflects the present-day terrace elevation from 22.5 m ± 22.74 m arising from tectonic warping of the marine terrace over space (the source publication reports this terrace between ~0 – 45 m modern elevation). This “relative sea level” takes no account of regional tectonic uplift. (Perhaps we erred in how we have input this data, leading to this confusion? If so, perhaps others have too?) So it’s from this perspective that when I read in Case study #1 that the authors state that “the sea level plot shows that the relative sea level during the Last Interglacial in this area fluctuated between 2.5 and 20 meters.” that I find myself in disagreement. Have the authors defined ‘relative sea level’ as how the height of the ocean (the geoid) rises relative to the land, and included in that definition land motion from tectonic deformation that accrued long after the indicator formed? The authors state in the Introduction paragraph that corrections for land motions are crucial for global mean sea level––yet I contend that they are crucial for local relative sea level too. Thus, defining “relative sea level” with respect to the WALIS input data is crucial to prevent non-experts from misinterpreting or over-interpret the output.

Case study #3 (Reproducing the results) shares with users how to reproduce the SLIP Merge analysis presented in case study #2, though this appears to require coding skills more advanced than ‘no coding knowledge’. Whether this remains in the manuscript will depend on the justification for the non-peer reviewed SLIPMerge method. Should it stay, I ask the authors to clarify the first paragraph of this subsection (page 8). I was left with ambiguity about whether this code simply reproduces the relative sea level point cloud in Figure 7 (case study #2) or whether it applies a GIA correction to this point cloud. Please clarify.

In summary I recommend that the article be revised to: (i) offer clear explanation for how to interpret “relative sea level”, the measure in the sea level plot, given the nature of the underlying WALIS data, and (ii) either eliminate the filtering/merging that generates the relative sea level point cloud or greatly expand the methodological description so that this analysis can be thoroughly peer reviewed. For request (ii) my strong preference would be to ask the authors to separate these two components into distinct publications (removing the point cloud from the Dashboard publication), and then to incorporate the relative sea level point cloud (all ‘analysis’ tools) into the Dashboard after peer review.

Thompson’s Overarching Comments

The problem of effectively accessing and utilizing paleo-shoreline data is well known to the

community, and the WALIS interface described in this publication is a strong step towards increasing data accessibility. The authors successfully introduce the issue at hand and present the WALIS dashboard as a solution to improve data accessibility.

My first broad comment is how the manuscript reports the span and utility of the database. The article abstract presents the contents of the database as “indicators formed during the Last Interglacial (125 ka)” while the database itself contains indicators ranging in age from up to ~450 kyr ago to near present day. Though the project presents itself as the “Atlas of Last Interglacial Shorelines”, the data contained in the database which falls outside of strict last interglacial (LIG) bounds is an important resource. Literature introducing the database to the public shouldn’t exclude components which may be important to those working outside of the LIG. A brief discussion of the scope of data included which falls outside of the LIG will help researchers interested in a wider temporal span utilize the database. Additionally, it is worth mentioning in the introduction that much of the shoreline data is applicable to fields outside of sea level research, such as active tectonics and archeology. Acknowledging a wider range of fields when introducing the database will help broaden the audience for this manuscript (and the database itself).

I also support the point made above in Creveling’s Overarching Comments that presenting paleo-shoreline elevations as “relative sea level” misses important nuance in interpreting relative sea level data. On many coastlines, especially those near active margins, tectonic movement may lead to significant displacement, sometimes shifting indicators upwards of ~100 m vertically during the interval between the LIG and present day. Interpreting relative sea level from these indicators requires careful correction to remove the tectonic signal, which can significantly obscure the record of sea level change. I appreciate the authors acknowledgement of the role of tectonics and GIA in interpreting global mean sea level from an indicator, but both of these factors also play a large role in interpreting local shoreline data.

Overall, the WALIS dashboard is a valuable contribution to the sea level community and I appreciate the authors efforts to give an overview in this manuscript. Revisions to address the scope of the data presented in the manuscript and careful reconsideration of the way case study #2 presents the interpretation of sea level data would improve the manuscript.

Response to Open Research Europe's guiding review questions

Is the rationale for developing the new software tool clearly explained?

The authors adequately lay out the importance of an interface for the WALIS database as an easy-to-use tool for researchers interested in utilizing (particularly a portion of) the compiled sea level data. As these reviewers are well familiar with, accessing sea level data through the primary publications can be a frustrating endeavor due to inconsistent reporting and standardization, and through the introduction, dashboard overview, and case study #1, the authors make a strong case for how their interactive interface will benefit the greater sea level community.

Is the description of the software tool technically sound?

The authors provide adequate detail of the technical base for the dashboard, supported by providing the full source code powering the dashboard through GitHub and an archived version on Zenodo. As neither reviewer accessed the offline versions of the database, we are not able to speak to the technical descriptions of the offline versions.

Are sufficient details of the code, methods and analysis (if applicable) provided to allow

replication of the software development and its use by others?
The base code powering the dashboard itself, being accessible through GitHub and an archived version on Zenodo provides the basis for replicability. The manuscript provides instructions for replicating the full software offline through R and Docker, though neither of us tested these cases. Case study #1 is mostly replicable in the online version, other than some inconsistencies in the parameters outlined in the text (see Line-Specific Comments below for details). Neither reviewer was able to fully replicate case study #2 as displayed in the manuscript instructions and guidance given in Figure 7. Attempting to complete the "merge" with 10,000 points (or a similarly high number) per SLIP as shown in Figure 7 resulted in the dashboard crashing. Other attempts to perform the analysis successfully ran during the initial "Start merging" but crashed when attempting to display the output as a density plot. Merging with the default 5,000 points per SLIP produced a similar but not identical density figure to that illustrated in Figure 7. For case study #3, it is appreciated that the authors provide a method to download the data and files needed to replicate the analysis.

The major issues that we see with replicability are that the method underlying the "Merge SLIP" analysis is not based on a peer-reviewed publication and that this thesis is not publicly available. While the results of the dashboard can be replicated using the code provided, there is no way to replicate the analysis independent of the underlying dashboard code.

Is sufficient information provided to allow interpretation of the expected output datasets and any results generated using the tool?
The dashboard 'filter' functionalities correctly filter the WALIS database (tested on our own inputs) and provide accessible summaries of the selected data in csv format (as described in use case #1). We feel that these are the most useful and robust outputs that the dashboard provides.

Importantly, we have concerns that the manuscript's suggested interpretation in use case #2 lacks important nuance for some users, including ambiguity about interpreting indicator elevations as "relative sea level". This may potentially mislead future researchers using the dashboard. Additionally, neither the dashboard nor the manuscript provide sufficient information to interpret the Merge SLIP point and density clouds. The lack of accessible, peer-reviewed literature supporting the Merge SLIP analysis prevents robust interpretation of the dashboard output, since the analysis itself has not been validated by the greater community and the literature needed for an individual researcher to closely examine the method is not publicly available.

Dashboard Functionality Comments
The aspect ratio of the world map on the 'Interactive map' tab does not allow the user to visualize the entire globe (viewed on both an iMac and laptop running Ubuntu), yet this is never specified. Both reviewers confused the 'extent:map' specification as meaning the entire globe. (This becomes clear to a user in the 'geographic extent' thumbnail in the Summary table tab. For example, at the maximum zoom out, to include all of North America in the default map almost none of South America can be included in the map). This matters because the corresponding 'sea level plot' then has an unspecified geographic filter. When we drag the map around––at the same zoom and with the filter saying 'extent:map' throughout––the 'sea level plot' updates with the map area, but at no point can we see the 'sea level plot' for the entire globe. It appears that a user can never view a sea level plot for the entire globe. We request that the default "Interactive map" be the full globe. We request that the 'extent:map' clarify whether the whole globe, or a subset of the globe is selected, and that any further sub-selection of the map area (by manual polygon versus zoom-in area) have

a more specific filter label.

We would appreciate a 'Reset' button to return all filters to default ranges.

For Summary Table, can you clarify the meaning of 'blank' entries for the user? This may be clear to those who have uploaded data, but perhaps not to those who are coming with fresh eyes.

For the filter such as age range and elevation error, it would be beneficial to add an option to manually enter in the desired numeric range. While the sliders work well in some scenarios, for ranges spanning large numeric intervals (such as those in the age range), selecting specific values solely with the slider may be difficult or inaccessible to some users.

The dashboard crashes at times when developing a density cloud, particularly when high Point per SLIP values are used in the merging options.

Line-specific Comments

- Would benefit from copy-editing; grammatical errors introduce some ambiguity about the dashboard's function.
- Please clarify what you mean by 'database consists of multiple tables with one-to-one or many-to-many relationships' (page 3).
- Please clarify what you mean in the sentence 'In our design … as proposed by 4'.
- The text states that the map visualization displays sea level indicators with pop-ups with additional metadata on elevation measurements and dating, etc.. (page 4), yet we find that this metadata only includes the indicator code (RSL_####) with no additional data as described. Please update the pop-up or this text accordingly.
- The authors state that the platform includes notes explaining the temporal and relative sea-level dimensions for each of the nine types of sea level indicators (page 5), though we could only find information on the temporal aspects when hovering our cursor over the nine symbols. Information about the sea-level meaning is missing.~
- The 'Merge SLIP' tab title (page 5) is jargon, please consider a phrase more understandable to the non-sea–level expert end user.
- Change 130.00 to 135.00 in restriction #2 of the numbered list in user case #1 (page 7).
- One page 7, the text for use case #1 reads "(e.g., 135 to 110 ka to include additional data)" when describing the age filter menu - please clarify whether this is a theoretical example or a part of the use case, as in order to replicate the sea level plot in figure 6, the age range had to be 135 - 110 kyr (as listed in the example filter diagram in figure 6), not the 130 - 115 kyr listed in item 2 of the restrictions for use case #2.
- For Figure 6a, you only specify the RSL filters 'elevation error' but not the 'percentile' and 'uncertainty'. Please specify the former to make this case study more easy to replicate.

- Please clarify what you mean by ‘relative sea-level indicators can have more than one constraint’ (page 8).
- Please clarify what you mean by ‘Uniform distribution’ in ‘For example, sea level indicators in which the age calculation comes from a Uniform distribution from a Marine Isotope Stage (MIS) assignment’ (page 8).
- Please clarify what you mean by ‘remove individual sea-level indicators by code’ (page 8).
- In Figure 1, please restructure elements of the figure to clarify the relationship between the WALIS database itself, the archived copy on Zenodo, the contributors, and the end users.
- We could not reproduce Figure 7 from the information in the text/figure. Please offer more information to replicate this case study.

Is the rationale for developing the new software tool clearly explained?
Yes

Is the description of the software tool technically sound?
Yes

Are sufficient details of the code, methods and analysis (if applicable) provided to allow replication of the software development and its use by others?
Partly

Is sufficient information provided to allow interpretation of the expected output datasets and any results generated using the tool?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Stratigraphy, sea level.

We confirm that we have read this submission and believe that we have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however we have significant reservations, as outlined above.