Maximilian Söchting
Institute for Earth System Science and Remote Sensing
Leipzig University
Talstr. 35, 04103 Leipzig
Germany
E-mail: maximilian.soechting@uni-leipzig.de

To the Editors and Reviewers of *Earth System Dynamics*

Leipzig, 17.03.2026

**Response to Reviewers Letter**

Dear Reviewers and Editors of Earth System Dynamics:

Thank you very much for your reviews and helpful comments on how to further improve the quality of the paper. This is highly appreciated!

Regarding Figure 3: after the initial remark by the editorial team and already visible in the published preprint, we have modified Figure 3 to only show identifiable persons on subfigure (b), which is a photograph published on the ESA website under the ESA Standard License, which explicitly allows use in scientific publications without separate authorization.

Please find below a response point-by-point to the reviewers' comments:

Author comment #1

The authors introduce a tangible interface for interacting with spatiotemporal Earth system data, consisting of a physical cube where the faces represent the intrinsic dimensions of analysis-ready data cubes, i.e., latitude, longitude, and time. As a Perspective, they successfully identify the challenge non-experts face when exploring increasingly complex and high-dimensional Earth system datasets. Their approach aligns well with the scope of Earth System Dynamics, particularly regarding novel tools and interdisciplinary communication.
The physical data cube is a novel and appealing concept that will be of significant interest to the community. I recommend the manuscript for publication, subject to minor revisions. The authors should focus on providing sufficient technical detail to foster community adoption,

strengthen the conceptual arguments regarding the benefits of spatiotemporal reasoning, and critically reflect on the potential/limitations of the physical data cube.

- Thank you very much for your positive review and helpful comments on how to further improve the quality of the paper. This is highly appreciated.

1) The current hardware description is high-level. More details can be provided to ensure the tool is reproducible. Could you explain the technical connection between the overview monitor and the cube more comprehensively? Please also include a technical section or appendix with basic specifications (e.g., screen resolution, CPU/GPU requirements for low latency, etc.) to facilitate readers in assessing the feasibility of deploying this solution in institutions such as research centers and schools.

- 1) Thank you for bringing up reproducibility. Due to its position as a perspective paper, we have chosen to omit some technical details to keep the paper brief. However, you make a good point in the case of reproducibility. We have added a brief description of hardware requirements as an appendix (lines 137-146) as well as a description of the connection of the overview monitor (lines 65-67).

2) The authors argue that current 2D visualizations constrain "spatiotemporal reasoning and intuitive understanding". Could you complete the discussion based on the cited literature on data physicalization (e.g., Jansen et al., 2015) to motivate why the physical cube aids scientific discovery?

- 2) Thank you for this point. We have added additional discussion on why we believe current 2D visualizations are limited in understanding spatiotemporal patterns and how the physical shape may be beneficial (lines 26-33, 41-46).

3) Given the educational context, why can manipulating a cube of data be better for learning dynamics than spinning a globe? What could help users to mentally map the transition from the front face (map) to the side face (Hovmöller diagram)? Explicitly contrasting the "geometry-first" approach of a globe with the "data-first" approach of the cube would strengthen the educational argument.

- 3) Thank you for the comment. We added some further discussion on the geometry-first vs. data-first approach at the end of chapter 1 (lines 47-55). In practice, we found the most effective way of communicating the side faces being Hovmöller diagrams and grasp the data cube visualization is to show an animation of precipitation data, as the high-variance patterns on the front face effectively "draw their way through time" on the side faces (like here: https://www.lexcube.org/?!esdc-3.0.2/precipitation_era5 and press the “Play” button in the top right to start the animation).

4) While true for the data structure (array), geographically, the Earth is not a cube. Projecting a continuous sphere onto a cube creates discontinuities at the edges. Could you add a brief discussion on this and other limitations/constraints of the proposed tool?

- 4) Thank you for this comment. We added a discussion on the limitations of the cube shape (distortions, overrepresenting poles, alternative projections - lines 117-121) as well as other limitations of our tool (not being suited for sparse, vector or non-gridded data - lines 121-125).

5) The validation of the tool reported in the manuscript is anecdotal ("we personally interacted with approximately 150 attendees at the cube over the week"). Could you report some specific qualitative assessments of feedback? For example, did users comment specifically on the speed of interaction or the clarity of the temporal dimension, among other aspects?

- 5) Thank you for your concern on the user feedback. Yes, it is anecdotal and has not been systematically collected or quantified. However, from our interactions, users specifically noted the speed of the interaction (being built on Lexcube, it is virtually the same or even faster as https://www.lexcube.org as no network is involved in the physical cube - fractions of seconds as benchmarked in our previous publication: https://ieeexplore.ieee.org/document/10274107). Users also liked the spatiotemporal side faces, once understood. This way, one user found a new spatiotemporal pattern in data they have already worked with in the past. We revised the relevant paragraph in the manuscript to better reflect this (lines 94-97).

Author Comment #2

Overall quality of the preprint:

This is a preprint that is worth of publication. It is well written and clearly describes a novel new technology.

This paper introduces an interesting tool for the display of multidimensional data, allowing user to interact with the data in three dimensions. The rightly observe that these kinds of interactions have become more critical as the size and complexity of datasets has increased. They build upon the developments in Lexcube (a 2-D visualization of datacubes) to crate a fully three dimensional physical data cube. The physical cube is novel and fit for purpose. While the paper focuses on the describing the details of the cube, they also describe the responses of users when they took the cube to a scientific meeting and touch briefly upon

preliminary discoveries supported by the cube. The level of detail is appropriate for a short communication.

- Thank you very much for your positive review of our manuscript! Your comments have been very helpful in improving the paper, which we highly appreciate.

Specific comments:

In a longer presentation of the cube a number of questions could be addressed:

1. What are the specifications for the supporting PC, monitors etc. of the cube?

- 1) Thank you for mentioning hardware specifications. After reviewer #1 also brought up a similar point, we have included a short appendix detailing the hardware specifications of the physical cube (lines 138-146).

2. What are the specifics of the size and complexity of datasets that could be visualized?

- 2) Thank you for this comment. For the demo at the LPS conference, we ingested the same data sets as currently available on Lexcube.org and detailed in Table 1 in our previous publication on Lexcube (https://ieeexplore.ieee.org/document/10274107), i.e., in the order of magnitude of hundreds of gigabytes with dozens of parameters per data set. Even larger data sets would also most likely be supported, but testing this has not been the focus of this project. We added a short note in the manuscript to reflect the datasets the cube has been tested with (lines 86-87)

3. Are there ways to output the slices being visualized to allow for analysis beyond the visual analysis enabled by the cube?

- 3) Thank you for the comment. Right now, no further analysis is possible and the physical cube is a visual-only tool. We foresee various potential extensions for analytical use beyond visualization. We added a remark in the manuscript to reflect these plans (lines 114-116).

4. While the strengths of the cube for education and outreach are clear, how might it be further developed to support scientific analyses?

- 4) Thank you for the remark. We believe that analytical tools such as proposed in the above point 3) as well as deeper integration into scientific workflows, e.g., to easily allow exploration of in-progress data sets from a running computation or compute statistical measures, will further strengthen the scientific use cases (lines 114-116).

We look forward to your reply and thank you for reviewing the manuscript.

Sincerely,

Maximilian Söchting

and on behalf of co-author M. D. Mahecha