Response to the comments of referee 2

Below, the referee comment marked by “RC2” is followed by our answer, marked by “AC2”and in italics. The proposed new text in the revised manuscript is written in bold.

RC2: The manuscript “Supporting climate change adaptation worldwide: A web application for exploring uncertain future changes in water resources” introduces the web application Climate Change Impact of Water Resources (CCIWR) Explorer. The web application is designed to support climate change adaptation in the water sector by communicating multi-model ensemble (MME) uncertainty in future water resources. The manuscripts reports on a pilot user survey evaluating CCIWR Explorer’s quality in use. Overall, the paper is relevant, with a clear applied focus and a commitment to transparency (open code and survey materials).

The paper introduces a web-based tool, the CCIWR Explorer. The purpose of the tool is to help users understand and utilize uncertain projections of future changes in water resources at global scale, with a particular focus on groundwater recharge and related variables. The tool displays map-based information and percentile plots for different time periods and scenarios, allowing users to explore the plausible range of future changes for their region of interest.

The documentation accompanying the Explorer explains the app’s purpose, applicability, content, and guidance on how to use its information for local climate change adaptation processes.

The authors explicitly position the tool within participatory climate change adaptation work, drawing on recent experiences in communicating uncertain climate hazards in participatory processes and on previous work on quantifying and communicating uncertain hazards. To evaluate the Explorer, the authors conduct an online pilot user survey (21 respondents) built around ISO/IEC 25019 quality-in-use criteria.

The authors address the practical need of how to communicate uncertain future changes in water resources in a way that supports adaptation decisions. The title and initial framing clearly state this application-oriented focus. The linkage to participatory climate change adaptation in the water sector is explicit with references to recent practical projects and experiences.

It is good to see the incorporation of pilot user feedback into both the documentation and the tool design. For instance, a user suggestion to add the survey tasks as documentation examples was directly implemented, turning well-designed survey tasks into a tutorial. The detailed response table shows which suggestions were implemented, partially implemented, or rejected with justification. This iterative design process—particularly the revision of the documentation to better guide users through interpretation of the outputs and to add a tutorial—enhances the credibility of the tool’s usability claims.

The authors provide the questionnaire, survey results, original and revised documentation, and the web application code as supplementary material, with a clear data availability statement and link.

The linkage to participatory climate change adaptation in the water sector is explicit and consistent throughout, with references to recent practical projects and experiences.

User satisfaction and intention to reuse the tool appear generally positive; only 3 out of 21 participants indicated they did not intend to consult the Explorer again. Participants provided detailed qualitative feedback on documentation, maps, and “Local Insights” plots, much of which the authors incorporated into a revised documentation and minor feature refinements.

The paper concludes that the CCIWR Explorer is a functioning, low-budget tool that can support local adaptation processes under uncertainty and underscores the value of carefully designed user surveys for evaluating climate data and decision-support web tools.

AC2: We thank the referee very much for the intensive reading, correct description, and positive evaluation of our manuscript.

RC2: I find the article worth to be published, if the following major concerns are addressed in a revised manuscript:

1. The pilot survey includes 21 participants recruited via professional and student mailing lists, LinkedIn, and personal contacts. While this is reasonable for an initial usability test, the authors claim about effectiveness, efficiency, and satisfaction would benefit from a more explicit discussion of limitations related to sample size and selection bias. For example, many participants appear to have pre-existing knowledge of percentiles and MME applications in climate studies. This may mean the evaluation over-represents technically literate users compared to typical stakeholders in adaptation processes (e.g., municipal planners, community representatives). Therefor, I recommend a) to add a short subsection explicitly discussing how the sampling strategy might affect generalizability of the findings to broader user groups (non-experts, practitioners with limited quantitative training), and b) to adjust any general conclusions about the tool's effectiveness beyond the user profile actually represented in the survey.

AC2: We thank the referee for this recommendation. We plan to add the following text as the last paragraph of section 4 Evaluation results:

The survey participants are more knowledgeable about evaluating uncertain climate change impacts than the typical stakeholders in climate change adaptation processes. Based also on the positive correlation between user satisfaction and expertise, we would expect the participation of typical stakeholders in the survey to lead to less positive evaluations of the CCIWR Explorer. Furthermore, the survey results suggest that typical stakeholders should not be encouraged to peruse the Explorer without guidance. Instead, experts, such as researchers and consultants, should use the CCIWR Explorer to access information that they can then communicate to non-expert stakeholders in an appropriate manner.

RC2:

2. For many practitioners, especially outside climate or hydrology research, explicit formulas and visual aids can reduce cognitive load and increase trust. I suggest: a) reconsider including at least simplified versions of key equations in an appendix or "advanced" section of the documentation, clearly linked to the verbal explanation, to bridge both audiences (non-experts and technically interested users) and b) consider adding examples (using concrete locations and variables) that walk through map interpretation and "Local Insights" percentile boxes, showing how to move from visual output to adaptation-relevant conclusions. This would reinforce the app's educational value and better support uptake in teaching (as exemplified by the hydrogeography class use case) and stakeholder workshops.

AC2: Regarding a), as also formulated in Table 2, we prefer not to include these (rather simple) equations for computing changes in the documentation, as the approach is well explained *verbally in the documentation. For experts, the equations are available in the provided app code. Regarding b), we included a tutorial in the documentation that was revised after the survey. This tutorial includes examples for the usage of the maps and the percentile boxes and is also available in an interactive format, with the link to it in the documentation. We experienced that this tutorial is enough for teaching university students.*

RC2:

3. The paper emphasizes that the Explorer is designed to help users "understand and embrace" uncertainty from MMEs and use this information for robust decisions. It also references prior work showing the usefulness of presenting distributions of potential future changes via percentile boxes. While this conceptual framing is fair, it would be interesting to explicitly address a) how different user groups interpret the percentile information (e.g., P10, P30, P70, P90) and whether misinterpretations were observed in the survey tasks; b) whether and how users were guided away from over-interpreting median values as "most likely" outcome, especially under deep uncertainty, and c) how the interface and documentation deal with potential confusion between statistical uncertainty, scenario uncertainty, and model uncertainty. If the revised manuscript includes such discussion elsewhere, it would be helpful to cross-reference it clearly from the evaluation section, since this is central to the app's core claim: supporting adaptation "under uncertainty" rather than despite or ignoring it.

AC2: Regarding a), we cannot offer experience with how different user groups interpret the percentile information. In the Discussion section on "Usage of information provided by the CCIWR Explorer in local participatory processes for climate change adaptation", we wrote about our experience in the KlimaRhön process: "All but one of the stakeholders advocated adapting to the worst-case scenario, guided by the precautionary principle. However, concerns were raised regarding costs and other issues (see Müller and Döll, 2024, for more details)." To clarify the relation to the percentile information, we plan to extend the text as follows:

All but one of the stakeholders advocated adapting to the worst-case scenario, **i.e., the decrease in water resources under the highest greenhouse gas emissions scenario as quantified by P10**, guided by the precautionary principle. However, concerns were raised **about the costs and trade-offs that would be involved in achieving such a target** (see Müller and Döll, 2024, for more details).

Regarding b), we plan to extend the description of what explanations were given in the KlimaRhön process as follows:

Already in the first workshop, which was preceded by interviews with stakeholder representatives, we, as hydrological researchers familiar with climate change impacts on water resources, communicated the potential changes of total water resources and groundwater resources by percentile boxes, after explaining what **greenhouse gas emissions scenarios and** MMEs are and how to read the percentile boxes (Müller and Döll, 2024). **We clearly stated that the percentiles do not represent probabilities but just the percentage of models that do not exceed a certain change under a given greenhouse gas emissions scenario. As described in detail in Müller and Döll (2024), the interpretation of percentile boxes was explained by showing first a generic percentile box and then the percentile boxes for the specific changes in water resources in the study area. For example, for the median P50, it was explained that 50% of the models compute a change in water resources that is below the**

value shown by the percentile box, and 50% a change that is higher. This was to prevent the stakeholders from believing that the median is the most likely future change.

Regarding c), we find it most suitable to include the following paragraph in the Introduction, to distinguish the treatment of deep uncertainty of the greenhouse gas emissions scenarios and the uncertainty due to the climate and hydrological modeling:

The development of the CCIWR Explorer was guided primarily by the question: How can information on potential future changes in water resources, derived from a GHM MME, be optimally provided on a web portal, with a focus on supporting local climate change adaptation processes worldwide? The focus was on how to best communicate the uncertainty of the quantitative estimates of future changes, i.e., the range of potential future changes. **In the Explorer, the deep epistemic uncertainty due to future greenhouse gas emissions (Döll and Romero-Lankao, 2017) is taken into account by the user being able to select between the MME output computed for three greenhouse gas emissions scenarios. The CCIWR Explorer is distinguished by the innovative way in which the low-to-medium epistemic uncertainty caused by 1) translating emissions scenarios into climate scenarios by global climate models and 2) translating climate scenarios into water resources scenarios by global hydrological models (Döll and Romero-Lankao, 2017), as quantified by the MMEs, is visualized. In the web app and documentation, we do not use the terms deep or low-to-medium uncertainty. MME results are always provided specifically for one of the three emissions scenarios, implicitly separating these two types of uncertainties. Statistical uncertainties are not mentioned at all; these are not quantified from the MME results for the CCIWR Explorer as they are beyond the scope of quantitative information input in the case of most participatory processes and rather difficult to grasp for most stakeholders (see visualization of changes in water resources in wet and dry years in Müller and Döll, 2024).**

RC2

4. While most participants were familiar with percentiles and MMEs, it will be useful to explicitly define "Local Insights" in the main text the first time it appears, and to briefly explain what each percentile line represents in practical terms (e.g., "10% of model simulations show changes more extreme than this line"). And importantly, please justify why you have chosen "local insights" on gridcell level? I wonder if this is useful for the users, at all. I question the usability for two reasons: a) the gridcells are very coarse 0.5 x 0.5 deg and b) users often operate on administrative or geographic scales such as county, city or catchment level.

AC2: *"Local Insights" is first mentioned in Section 2.2 Implementation of web application with Google Earth Engine. There, we write:*

"When a user clicks on the map, the application dynamically renders "Local Insights" with percentile boxes showing P10, P30, P50 (median), P70, and P90 values for the selected **0.5°** grid cell. The P10, for example, indicates the future percent change that is not exceeded by 10% of all ensemble members.

In the Discussion section on "Usage of information provided by the CCIWR Explorer in local participatory processes for climate change adaptation", we propose addressing the fact that some users may not consider the results for a 0.5 degree grid cell as local by adding the following text to the final paragraph that contains our recommendations:

Some stakeholders presented with the 'Local Insights' percentile boxes may consider the term 'local' to be inappropriate when referring to projected changes in 0.5° grid cells (covering approximately 1,500–3,000 km^2) and may wish to obtain information on the potential impacts of future climate change at a higher spatial resolution. In this case, the expert should explain that, mainly due to the limited spatial resolution of global climate models, uncertainties in projected climatic changes for smaller areas are so large that they cannot be used as a meaningful source of information for climate change adaptation measures.