Response letter

Title: Design and trial implementation of a continental-scale, kilometre-resolution hourly precipitation analysis for Australia using satellite, radar and gauges

MS No.: egusphere-2026-666

Dear Editor and Reviewers,

Thank you again for your careful evaluation and constructive comments on our revised manuscript. We have carefully considered all comments and revised the manuscript accordingly. Our point-by-point responses are provided below, with the reviewer comments shown in **black**, our responses in **blue**, and the corresponding revisions to the manuscript in **purple** for clarity and ease of reference.

Reply to Editor

Dear Authors,

The revised paper takes into account all the reviewers' comments. It will be of great interest to the hydrologic community, as it presents the implementation of a continental-scale precipitation analysis for Australia.

Therefore, I recommend its publication in HESS after minor revision as proposed by the reviewers:

- Line 627-629: "However, the intensity-stratified bias results should be interpreted with caution, ..., which can contribute to a tendency towards negative conditional bias, particularly at high intensities." Why would observation-based intensity categories contribute to negative biases? Please elaborate. Could these results indicate the advantage of radars in capturing small scale severe storms? When merging with satellite, those high intensity features might have gotten smoothed by the coarser satellite estimates, thus the negative bias in BR-SRG (vs. R1)?

- Line 701-709, discussion of Fig.9: There is an area near the southwest corner of Australia with apparently lower CC and higher RMSE while the gauge density was high. What could be the cause of this relatively poor performance?

- I recommend that the paper be published after careful checking to avoid mismatches between the results and conclusions, to remove duplicate entries in the reference list, and to make some technical corrections to the figures.

Kind regards,

Roger Moussa

Response: We sincerely thank you for your efficient coordination of the review process. We also appreciate your positive assessment of our revised manuscript and your recommendation for publication in HESS.

We are grateful for the additional comments and suggestions. Below, we summarise the main revisions.

- **Interpretation of rainfall-intensity-dependent biases:** We have clarified how observation-based rainfall-intensity categorisation may contribute to negative biases at high rainfall intensities. We have also expanded the discussion of the relative roles of radar and satellite data in capturing intense rainfall and how blending may affect rainfall peaks.

- **Update of Fig. 9**. We have re-examined the spatial evaluation results and found that the previous Fig. 9 was generated using an earlier version of the results. We have corrected the figure using the final evaluation results, in which the previously observed lower correlation and higher RMSE in southwestern Australia are no longer evident. We have also included additional spatial evaluation maps based on independent hourly and daily gauges to provide further evidence of the robustness of the blended product.
- **Manuscript consistency checks and corrections.** We have carefully checked the entire manuscript to ensure consistency between the abstract, results, and conclusions. We have also reviewed the reference list and in-text citations, removed duplicate references, and made the necessary technical corrections to the figures.
- **Proofreading and editorial improvements.** We have carefully proofread the entire manuscript to correct grammatical errors, ensure consistency in verb tenses, refine the wording and descriptions, and check and correct cross-references to figures and tables throughout the manuscript.

Detailed point-by-point responses to all reviewer comments, together with the corresponding revisions made in the manuscript, are provided below. We sincerely appreciate the time and effort you and the reviewers have devoted to evaluating our work. Your constructive comments and suggestions have been invaluable in improving the clarity and quality of our manuscript.

Reply to Anonymous Referee #2

General Comments:

I recommend that the paper be published after careful checking to avoid mismatches between the results and conclusions, to remove duplicate entries in the reference list, and to make some technical corrections to the figures.

I appreciate the great work by the authors in this revised manuscript. The authors discussed the contributions and limitations more thoroughly. The comparison and validation of the BR-SRG dataset with other sources are also more reasonable than in the previous manuscript. I have some minor comments as follows:

Response: We sincerely thank you for your positive assessment of our revised manuscript and your recommendation for publication in HESS. We appreciate your recognition of the improvements made to the discussion, comparison, and validation of the BR-SRG product.

In response to your suggestions, we have carefully checked and revised the manuscript to ensure consistency between the results and conclusions, reviewed the reference list and in-text citations to remove duplicate entries and correct inconsistencies, and made the necessary technical corrections to the figures.

We also appreciate your additional comments, which we address individually below.

Minor comments

R2-M1

Abstract and conclusions:

Only two events were selected for the comparison with AGCD. For Cyclone Ellie, the authors explain the difference between BR-SRG and AGCD in lines 729–732. However, the statement in lines 902–903 ("The blended analyses also showed good agreement with the daily operational AGCD product") contradicts this explanation. I think this statement should be removed from the Conclusions section.

Response: Thank you for pointing out this inconsistency. We have therefore removed this statement and revised the conclusion to better reflect the findings of the cases and ensure consistency with the Abstract and Results

sections. Rather than emphasising agreement with AGCD, the revised conclusion highlights the additional spatial details captured by BR-SRG through the integration of satellite and radar information.

The revised conclusion (4) now reads:

"(4) The added value of the blended product is confirmed through comprehensive comparisons. BR-SRG generally showed better overall performance than the individual satellite and radar estimates and the simpler two-source blending configurations. Gauge availability also affected the performance of gauge-dependent estimation processes, with greater improvements generally found under higher gauge-density conditions. Comparisons with the gauge-based IDW reference and daily operational AGCD product in selected cases further illustrate the benefit of incorporating spatially continuous satellite and radar information. The blended analysis captures finer-scale rainfall structures and spatial variations in rainfall intensity that are not fully represented by these products."

R2-M2

Reference list: Please check the in-text citations and reference list. There are duplicate references.

Response: Thank you for pointing this out. We have carefully checked the in-text citations and reference list throughout the manuscript, removed duplicate references, and corrected inconsistencies to ensure that all citations and references are accurate and consistent.

R2-M3

Line 110: "grided" rainfall -> "gridded"

Response: Thank you. Corrected.

R2-M4

Line 171: There is a mismatch in the total number of daily gauges (within radar + outside= 3569, not 3659). Please check again.

Response: Thank you. Corrected.

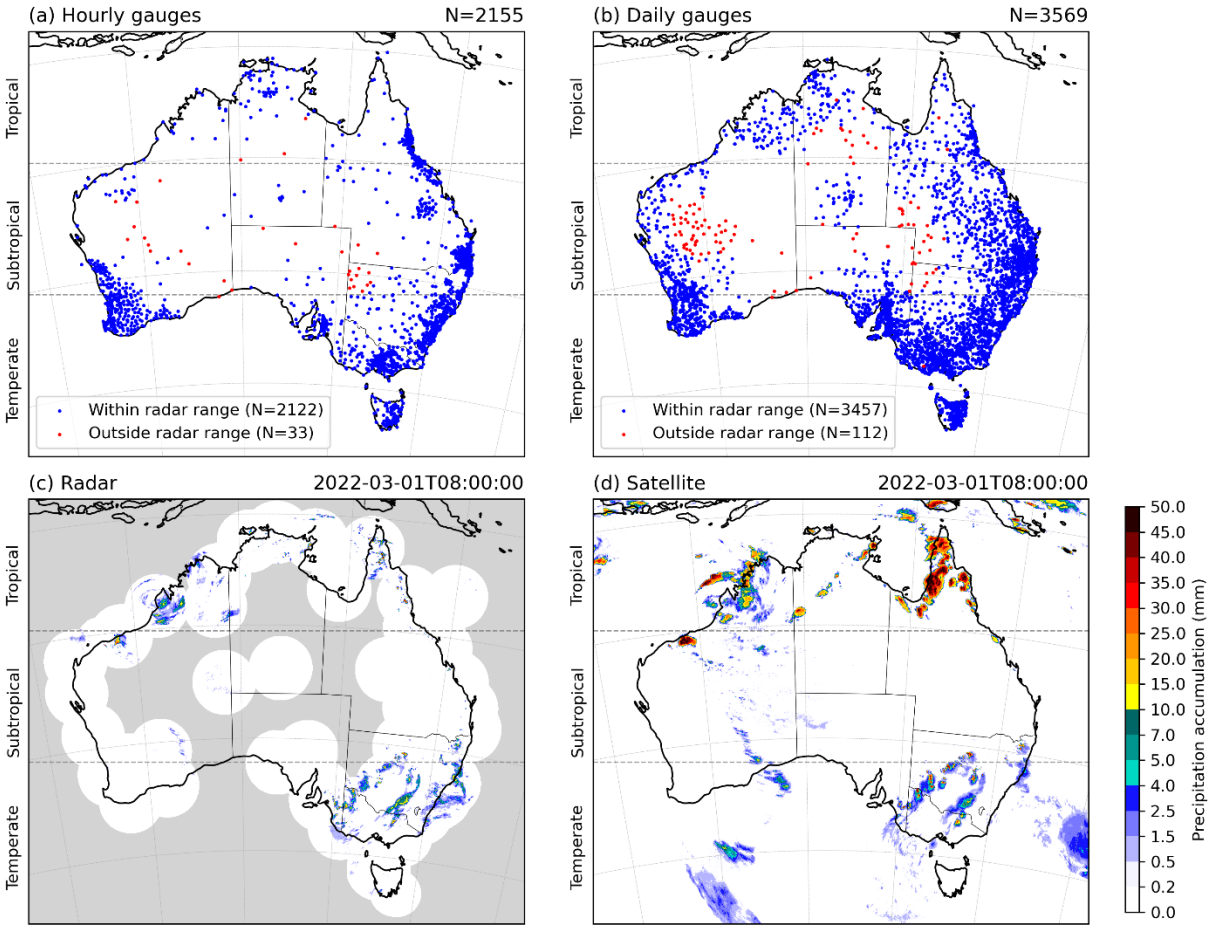


Figure 1. Spatial distribution and coverage of the data sources used in this study: (a) hourly gauges (aggregated from sub-daily observations; N = 2,155) categorised as within (N = 2,122, blue) or outside (N = 33, red) the maximum radar range, (b) daily gauges (N = 3,569) similarly categorised as within (N = 3,457, blue) or outside (N = 112, red) the maximum radar range, (c) radar-based hourly precipitation accumulation at 08:00 UTC on 1 March 2022, with a maximum radar range of approximately 300 km and a spatial resolution of 1 km, and (d) satellite-based precipitation (CRRPH) for the same time, with seamless spatial coverage at a 2-km resolution. The tropical, subtropical, and temperate subregions used in subsequent analyses are indicated by the horizontal dashed lines.

R2-M5

Line 228: increase -> increases

Response: Thank you. Corrected.

R2-M6

Line 245: background filed -> background field

Response: Thank you. Corrected.

R2-M7

Fig. 9 vs lines 701–708: The text says correlation is high "particularly where gauge density is higher" and RMSE is lower in well-observed areas. Fig. 9 shows the densely gauged SW Western Australia cluster with visibly lower correlation and higher RMSE. I think this should be pointed out in the text and explained further.

Response: Thank you for highlighting this inconsistency. We have carefully re-examined the spatial evaluation results and found that the previous Fig. 9 was generated using an earlier version of the evaluation results rather than the final version. The differences may partly be related to gauge data quality control, as observations from gauges with poor data quality can affect evaluation results, even in areas with relatively high gauge density. We have therefore corrected Fig. 9 using the final evaluation results, in which the previously observed lower correlation and higher RMSE in southwestern Australia are no longer evident. We have also reviewed the corresponding text to ensure consistency with the updated figure.

In addition, we have included spatial evaluation maps (Figs. S11 and S22) based on independent daily and hourly gauges in the Supplement to provide further evidence of the spatial performance and robustness of the blended product.

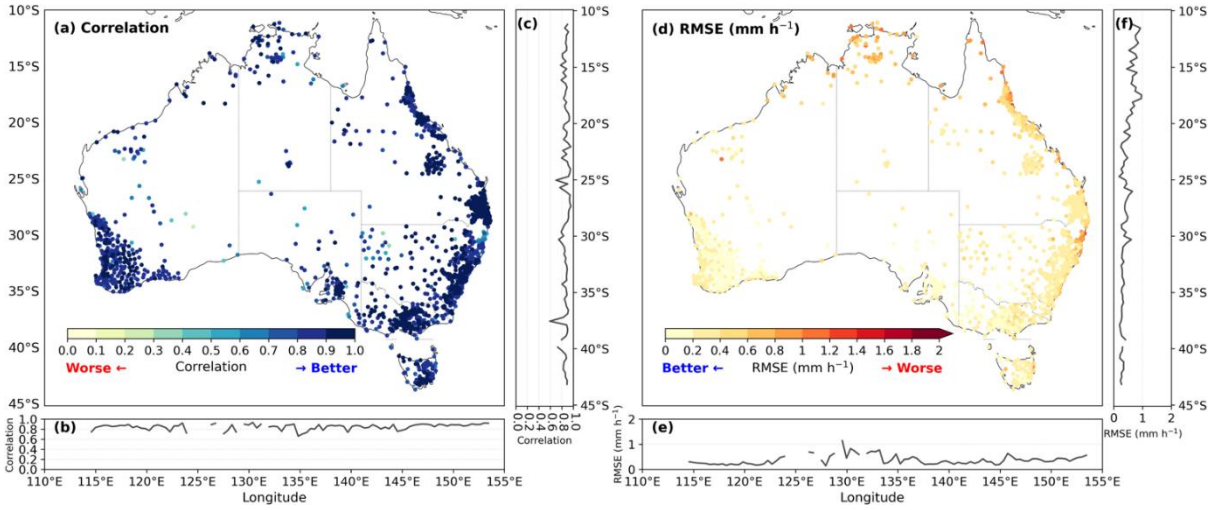


Figure 9. Spatial performance of the blended estimate (BR-SRG) evaluated against hourly gauge observations across Australia. Panels show the spatial distributions of (a) correlation and (d) RMSE (mm h-1), with higher correlation and lower RMSE indicating better performance. Panels (b, e) and (c, f) show the corresponding longitudinal and latitudinal variations, respectively, averaged across gauges.

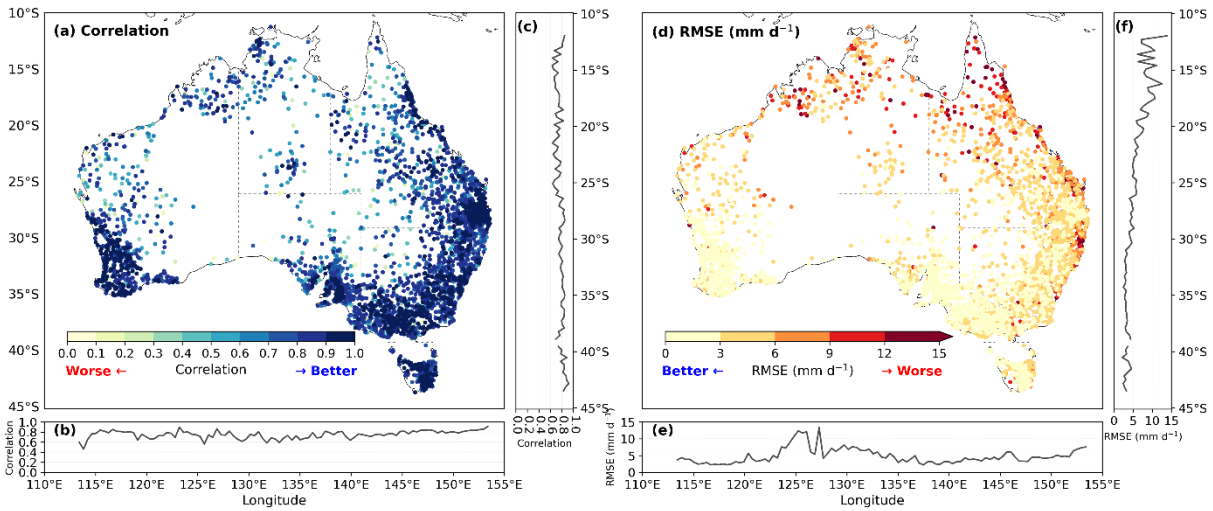


Figure S11. Spatial performance of the three-source blended rainfall estimate (BR-SRG) in the independent daily-gauge evaluation across Australia. Panels show the spatial distributions of (a) correlation and (d) RMSE between BR-SRG and daily gauge observations, with higher correlation and lower RMSE indicating better performance. Panels (b, e) and (c, f) show the corresponding longitudinal and latitudinal variations, respectively, averaged across gauges.

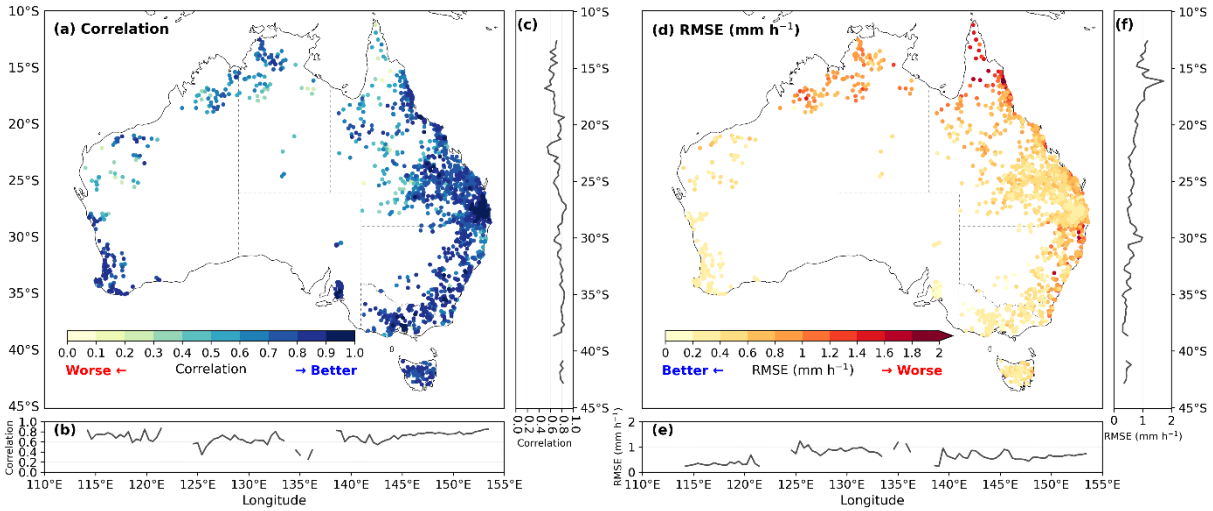


Figure S22. Spatial performance of the three-source blended rainfall estimate (BR-SRG) in the independent hourly-gauge evaluation across Australia. Panels show the spatial distributions of (a) correlation and (d) RMSE between BR-SRG and hourly gauge observations, with higher correlation and lower RMSE indicating better performance. Panels (b, e) and (c, f) show the corresponding longitudinal and latitudinal variations, respectively, averaged across gauges.

R2-M8

Line 780: Please write out the full word for ME in section 5.2, as I think it wasn't explained before line 780.

Response: Thank you for pointing this out. We have revised the sentence in Section 5.2 to explicitly define ME as mean error (or mean bias) at its first occurrence in this section.

5.2 Behaviour and sensitivity of gauge-based interpolation

The evaluation revealed two notable behaviours of IDW: its mean error (ME, or mean bias) remained consistently close to zero despite relatively large RMSE and lower correlation (Figs. 5 and S16), while its relative performance improved from hourly to daily evaluation, achieving a lower RMSE than BR-SRG at the daily timescale (Fig. 6), a pattern consistently observed across different subregions outside radar coverage (Fig. S2).

R2-M9

Lines 830 - 831: The figure for Cyclone Jasper was shown in Fig. 14b, not 14a. Similarly for Cyclone Ellie. Please check the text again.

Response: Thank you for pointing out these typos. The figure references for Cyclones Jasper and Ellie were reversed in the text. We have corrected them accordingly.

Reply to Anonymous Referee #3

General Comments:

The revised paper clarified the main questions I had in the 1st round of review. I only have two minor comments on the revised paper, which are listed below.

Response: We sincerely thank you for your positive assessment of our revised manuscript. We are pleased that the revisions have addressed your main concerns from the first round of review. We also appreciate your additional comments, which we address individually below.

R3-M1

1. Line 627-629: "However, the intensity-stratified bias results should be interpreted with caution, ..., which can contribute to a tendency towards negative conditional bias, particularly at high intensities." Why would observation-based intensity categories contribute to negative biases? Please elaborate. Could these results indicate the advantage of radars in capturing small scale severe storms? When merging with satellite, those high intensity features might have gotten smoothed by the coarser satellite estimates, thus the negative bias in BR-SRG (vs. R1)?

Response: Thank you for your helpful comment and suggestions. We have revised this section to clarify the interpretation of the negative biases at high rainfall intensities and further discuss the relative roles of radar and satellite data in the blending process.

First, we have expanded the explanation of how observation-based rainfall-intensity categorisation may contribute to negative conditional biases. Because rainfall-intensity categories are defined using gauge observations, cases where gauges record heavy rainfall but gridded estimates are lower are included in the high-intensity category. In contrast, cases where gridded estimates indicate heavy rainfall but gauges record lower intensities are assigned to lower-intensity categories. This conditional sampling effect may contribute to the negative biases observed at high rainfall intensities. We have also clarified that differences in spatial representativeness between point-based gauge observations and gridded rainfall estimates may contribute to these biases.

Second, we agree with your suggestion that radar may better capture localised intense rainfall, while incorporating satellite estimates may smooth rainfall peaks in some cases. We have added this explanation to discuss why BR-SRG shows a more negative bias than R1 at high rainfall intensities. We also note that the effects of blending can vary between rainfall events, as illustrated by the selected case studies in Section 5.3.

These explanations have been incorporated into the revised discussion of the rainfall-intensity-dependent performance.

Comparison with the radar estimates. The bias-corrected radar product (R1) showed strong overall performance within radar coverage. In the hourly-gauge cross-validation, R1 had slightly higher correlation and lower RMSE than BR-SRG, whereas BR-SRG showed a smaller absolute bias (Fig. 5). In contrast, BR-SRG generally showed higher correlation, lower RMSE, and smaller absolute bias than R1 in both the independent daily-gauge (Fig. 6) and independent hourly-gauge (Fig. S16) evaluations. The rainfall-intensity analysis provided further insight into these differences. BR-SRG generally performed better than R1 in terms of correlation and RMSE at low and moderate rainfall intensities, whereas R1 performed better at high rainfall intensities. For bias, however, R1 generally showed a less negative bias than BR-SRG across all rainfall-intensity categories, with the difference becoming more evident at high intensities (Figs. 7, S3 and S20).

The more negative bias of BR-SRG relative to R1 at high rainfall intensities may result from the blending process. Radar estimates can better capture localised intense rainfall, whereas incorporating satellite estimates may smooth rainfall peaks in some cases. However, the effects of blending vary between rainfall events, as further illustrated by the selected case studies in Section 5.3.

The negative biases observed for both R1 and BR-SRG at high rainfall intensities should also be interpreted with caution for two reasons. First, rainfall-intensity categories were defined using gauge observations, which may introduce conditional sampling bias. For example, cases where gauges record heavy rainfall but gridded estimates

are lower are included in the high-intensity category, whereas cases where gridded estimates indicate heavy rainfall but gauges record lower intensities are assigned to lower-intensity categories. This sampling effect may contribute to the negative biases observed at high observed rainfall intensities. Second, gauges provide point measurements, whereas R1 and BR-SRG represent gridded rainfall estimates. Differences in spatial representativeness may also contribute to the observed negative biases, particularly for highly localised rainfall events.

R3-M2

2. Line 701-709, discussion of Fig.9: There is an area near the southwest corner of Australia with apparently lower CC and higher RMSE while the gauge density was high. What could be the cause of this relatively poor performance?

Response: Thank you for highlighting this issue. We have carefully re-examined the spatial evaluation results and found that the previous Fig. 9 was generated using an earlier version of the evaluation results rather than the final version. The differences may partly be related to gauge data quality control, as observations from gauges with poor data quality can affect the evaluation results, even in areas with relatively high gauge density. We have therefore corrected Fig. 9 using the final evaluation results, in which the previously observed lower correlation and higher RMSE in southwestern Australia are no longer evident. We have also reviewed the corresponding discussion to ensure consistency with the updated figure.

We have also reviewed the corresponding discussion to ensure consistency with the updated figure. In addition, we have included spatial evaluation maps based on independent hourly and daily gauges in the Supplement to provide further evidence of the spatial performance and robustness of the blended product.

Please refer to our response to R2-M7 for the updated figures.