

## Responses to RC #1:

This manuscript presents a comprehensive framework for developing a spatially and temporally continuous soil moisture dataset over China. The methodology is technically rigorous, well justified, and the resulting product is of clear relevance for drought monitoring and hydroclimatic research. The following comments are intended to clarify specific methodological aspects and improve the presentation and interpretability of the results.

**Reply:** Thank you for your thoughtful review and valuable feedback. We appreciate your positive acknowledgment of the potential significance of our study and your constructive comments, and we are grateful for the time and effort you've dedicated to this review. Your comments and good suggestions are very important for us to improve the quality of the manuscript. We have carefully addressed all the issues raised by you and the response is presented below.

### Comments:

1) Outlier/QC description is too vague (Page 4, lines 157–161). The authors state that outliers were excluded via “rigorous quality control,” but they do not specify the method (e.g., SD-based screening, median absolute deviation, percentile/IQR filtering, temporal consistency checks, etc.). Please explicitly describe the QC procedure and provide a citation.

**Reply:** Thank you for your valuable feedback. We fully agree with your suggestion and have revised it accordingly.

In our data quality control, we applied two specific steps:

(1) Time series anomaly detection – For each station, we first calculated the multi-year mean and standard deviation of soil moisture for each hour of the day over the entire study period (2003–2023). Any hourly observation that deviated from its corresponding hourly mean by more than 3 standard deviations was removed as a statistical outlier. Additionally, we examined the absolute difference between consecutive hourly records at the same station. If the difference exceeded  $0.15 \text{ m}^3 \text{ m}^{-3}$  (a threshold determined based on typical diurnal soil moisture variation in China), and the change could not be attributed to known meteorological events (e.g., heavy rainfall), the abnormal value was discarded. This combined approach effectively removes both long-term systematic anomalies and short-term instrumental spikes.

(2) Spatio-temporal consistency check – We identified meteorological stations that experienced location migration during the study period (2003–2023) and excluded all data from those stations. Only stations with a stable, non-relocated monitoring record were retained for further analysis.

We have revised the manuscript accordingly. We have replaced the original vague statement with a clear description of the above two steps in the validation paragraph and added appropriate citations. We appreciate your constructive suggestion.

2) Baseline datasets should be introduced earlier and motivated. The two benchmark soil moisture products (Zhang et al., 2023; Meng et al., 2021) are used for comparison, but the Introduction would benefit from a short description of what these datasets are, and why they may be insufficient for agricultural drought monitoring in China (e.g., continuity limitations, regional bias, coarse spatial resolution, limited temporal coverage). This is especially important for Meng et al. (2021), which is China-specific, because the novelty here appears to be extended temporal coverage and finer target resolution ( $0.25^\circ \rightarrow 0.05^\circ$ ).

**Reply:** We thank the reviewer for this insightful comment. We fully agree that the two benchmark soil moisture products should be introduced earlier in the manuscript, with their key limitations clearly articulated. Accordingly, we have added a brief description of these datasets in the Introduction section, immediately following the discussion of limitations in existing downscaling products and prior to presenting our proposed framework. In this addition, we emphasize the reasons why these benchmark products are insufficient to support accurate agricultural drought monitoring across China.

In addition, to demonstrate the advantage of our product, we estimated drought-affected areas across different regions of China based on three datasets: (1) our constructed  $0.05^\circ$  high-resolution SM data, (2) the coarse-resolution ( $0.25^\circ$ ) SM data, and (3) the  $0.05^\circ$  benchmark product from Meng et al. (2021). The estimated drought areas were compared against observed drought areas. The observed drought areas were derived by integrating multiple authoritative data sources, including: (i) government-published annual crop drought-affected area statistics (from the China Statistical Yearbook and China Flood and Drought Disaster Bulletin); (ii) the China Agricultural Meteorological Disaster Dataset compiled by the China Meteorological Administration (CMA), which contains disaster name, occurrence date, intensity, affected area, and damage percentage; and (iii) the daily agricultural drought comprehensive monitoring spatial distribution data from the Open Laboratory of the National Meteorological Center Forecast System. The results show that the drought-affected areas derived from our high-resolution data are considerably more consistent with the observed areas than those derived from the coarse-resolution data or the Meng et al. product (Fig.1), particularly in capturing local severe drought events. We have added a dedicated Discussion subsection that elaborates on the gains in drought area identification achieved by improved spatial resolution and accuracy of SM data. These revisions can be readily identified in the revised manuscript.

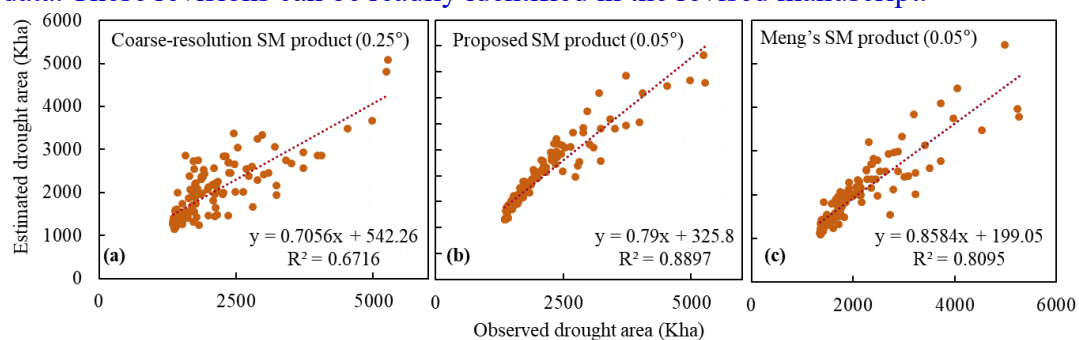


Fig.1 Validation of drought-affected area estimation using multi-source soil moisture products

3) DEM resampling + slope derivation need methodological clarity (Page 4, lines 181–183). The paper states that SRTM 1 km DEM was resampled to 0.05°, and slope was derived using a 3×3 neighborhood gradient algorithm, but the resampling method is not provided. Bilinear interpolation is often preferable to nearest-neighbor for continuous topography to avoid blocky artifacts at 0.05°. Also, please clarify whether slope was computed after resampling to 0.05° (recommended to reduce artifacts) or computed at 1 km and then resampled.

**Reply:** We thank the reviewer for this constructive and detailed guidance. Consistent with the reviewer’s suggestion, the SRTM 1 km DEM was resampled to 0.05° using bilinear interpolation in ArcGIS. Slope was then calculated from the resampled 0.05° DEM rather than the original 1 km product, thereby minimizing artificial discontinuities. We have clarified these methodological details in the revised manuscript.

4) Figure 2 readability/layout. Figure 2 is comprehensive but difficult to read at its current size and vertical arrangement. Consider using a layout that better leverages horizontal space (e.g., moving Steps 1 and 2 beside Step 3, or increasing font size and simplifying inset elements) to improve readability.

**Reply:** We thank the reviewer for this valuable suggestion. Based on your suggestion, we are currently re-optimizing the layout and design of Figure 2 to improve its readability, and the revised figure will be presented in the updated manuscript.

5) Figure 4 color convention + inset choice. Consider reversing the palette so that higher soil moisture is visually intuitive (commonly blue = wetter, red = drier). Also, the inset region shown does not strongly demonstrate “local-scale” improvements; choosing a more heterogeneous boundary/transition zone (e.g., shrubland–cropland or complex terrain/land cover) would better illustrate the benefit of the downscaled product.

**Reply:** We appreciate the reviewer’s thoughtful feedback on Figure 4. Based on your advice, we have reversed the color palette so that higher soil moisture appears in blue and lower values in red, following conventional hydrological visualization. Additionally, we selected three regions with diverse land cover types—Harbin (Heilongjiang Province), the junction of Lüliang, Taiyuan and Xinzhou (Shanxi Province), and the Aba Tibetan and Qiang Autonomous Prefecture (marked as I, II, and III in the figure, respectively)—to demonstrate the downscaling performance in detail. The land cover types are: Region I – agricultural land, forest, grassland, and residential land; Region II – residential land, agricultural land, and forest; Region III – forest and agricultural land. By comparing the spatial patterns before and after downscaling, the improved capability of our product in capturing local soil moisture heterogeneity is clearly visible. The revised Figure 4 has been included in the updated manuscript. Thank you again for your valuable suggestion.

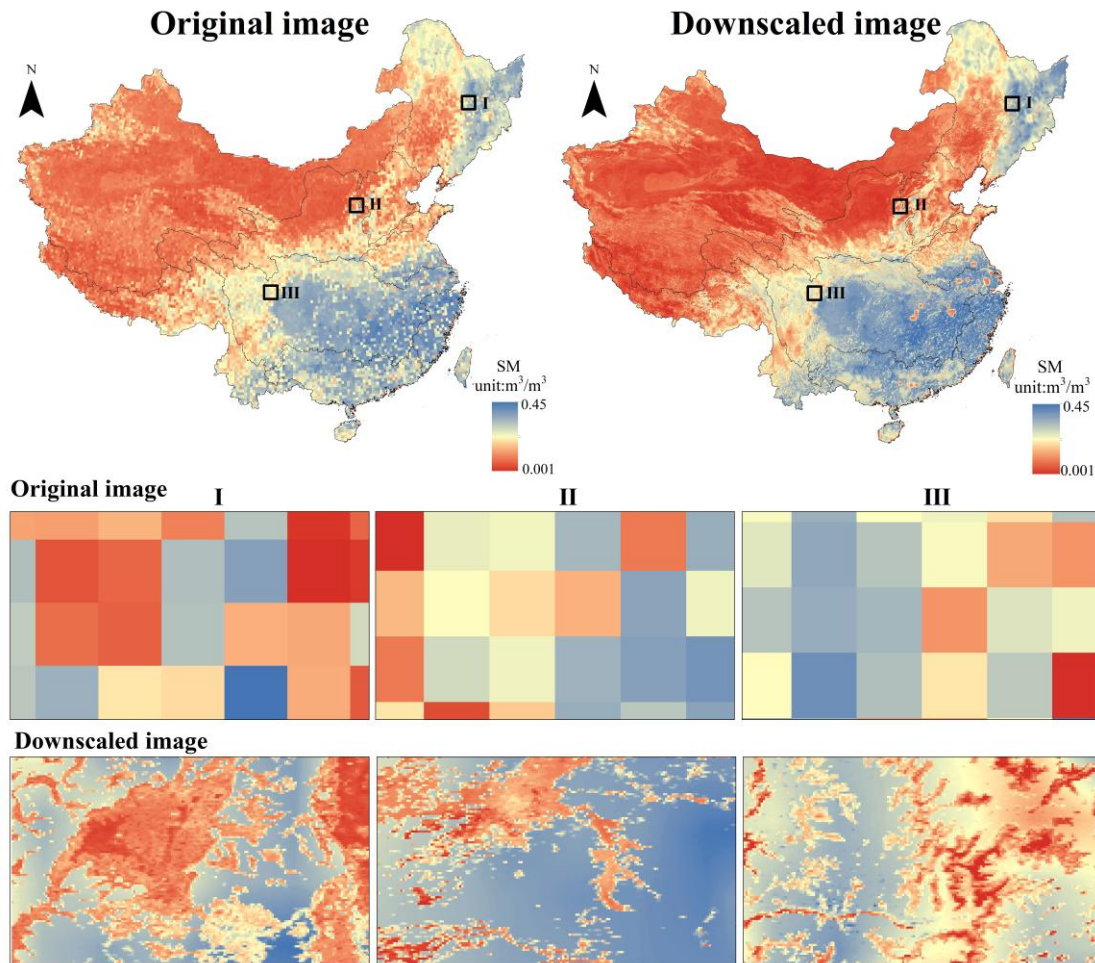


Fig.4 in the revised manuscript — Comparison of original images and downscaled SM images.

6) I am not sure what is meant by this sentence on Page 12, lines 403–405, "As shown in the zoomed-in area of Fig. 4, critical subgrid features that were previously obscured in passive microwave observations are now resolved with a precision of  $0.038 \text{ m}^3/\text{m}^3$ ". Please clarify what precision means here.

**Reply:** Thanks a lot for pointing this out. We are sorry for our unclear expression. What we intended to convey is that, for the zoomed-in area shown in Figure 4, we have a set of in-situ soil moisture measurements collected by our team. We compared the pre-downscaling (coarse) SM data and our downscaled ( $0.05^\circ$ ) data against these ground measurements. The downscaled product achieved a higher accuracy, with an error metric (root mean square error) of  $0.038 \text{ m}^3/\text{m}^3$  relative to the in-situ observations. Therefore, the term "precision" here actually refers to RMSE of the downscaled product validated against local measurements.

As suggested in your previous comment, we have replaced the original inset region in Figure 4 with three more representative regions. For these three regions, we compared the pre-downscaling (coarse) SM data and our downscaled ( $0.05^\circ$ ) data against the in-situ measurements. The downscaled product achieved higher accuracy, with RMSE values of  $0.029$ ,  $0.037$ , and  $0.039 \text{ m}^3/\text{m}^3$  for the three regions, respectively.

Again, we appreciate the reviewer's careful reading and valuable suggestion.

7) Pearson's R inconsistency (Page 15, lines, 449–450). The manuscript writes that there is significant "negative correlation" but the numbers reported are positive (Pearson's  $R=0.015$  to  $0.277$ ,  $p<0.05$ ).

**Reply:** We appreciate the reviewer's careful reading and valuable suggestion. What we intended to report was the coefficient of determination ( $R^2$ ), not the Pearson correlation coefficient ( $R$ ). The values ( $0.015$  to  $0.277$ ) presented in the manuscript are actually  $R^2$  values. We have revised the manuscript accordingly.

8) Expand the discussion on generalizability. The manuscript argues that the China-specific hydroclimatic drivers mitigate biases relative to generic global products (Page 13, lines 431–433). It would strengthen the Discussion to briefly frame how this workflow could be transferred to other drought-prone regions (and what region-specific drivers would likely be needed), which could broaden impact/citability.

**Reply:** Thank you for your thoughtful comment. Based on your advice, we have expanded the Discussion section to briefly address how our workflow could be transferred to other drought-prone regions, including the likely need for region-specific hydroclimatic drivers and retraining of the model. This addition will be presented in the revised manuscript. Again, we thank the reviewer for this valuable suggestion.

9) Their data availability statement lists input sources, but it's not clear (from the statement excerpt) whether the new seamless  $0.05^\circ$  SM dataset and processing code are archived somewhere persistent.

**Reply:** Thanks for your good suggestion. Based on your suggestion, we have uploaded our generated seamless  $0.05^\circ$  dataset and the associated processing code to the ZENODO platform for persistent archiving. The public download link will be provided in the revised data availability statement. Again, we thank the reviewer for this valuable advice.

**Additional remark:**

**Lines 758-759 in the revised manuscript:** "The authors are grateful to the editor, five reviewers, and one reader for their constructive comments and suggestions on this paper." has been added to Acknowledgments.

**Special thanks are extended to you for your valuable comments.**

We are doing our best to improve the manuscript and are making substantial changes to address the concerns raised.

We greatly appreciate your help and hope that the revisions will meet with approval once we submit the updated manuscript.

Once again, we would like to extend our sincere gratitude and appreciation for your valuable comments and suggestions.