Replies to reviewer #2

"Benchmarking convection-permitting climate simulations for hydrological applications: A comparative study of WRF-SAAG and observation-based products"

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We thank the reviewer for his/her time, revision and suggestions to our paper. We provide responses to each individual point below, and how we will address the main comments of the reviewer. For clarity, comments are given in black italics, and our responses are given in plain blue text.

General Comment:

This study presents a comprehensive evaluation of the high-resolution, long-term WRF-SAAG climate simulation (2000-2021) against station observations and two gridded meteorological products (CR2MET and RF-MEP) over Chile. The subsequent use of WRF-SAAG outputs to drive a hydrological model (TUW) successfully demonstrates the dataset's utility for hydrological applications. The paper highlights the good performance of WRF-SAAG in capturing precipitation and temperature, particularly in complex mountainous terrain where observational records are sparse. This is a valuable contribution to the regional climate modeling and hydrology communities.

The manuscript is well-structured and the analysis is thorough. However, I have several suggestions for improvement that I believe will enhance the clarity, presentation, and overall impact of the paper. My main suggestions focus on making the writing more concise, improving the presentation of results and data, and expanding the discussion to better guide potential users of these datasets.

Specific Comment:

Abstract

- *The abstract, and the paper in general, could be more concise. Please review for opportunities to shorten sentences and state the main findings more directly.*

  We will revise the abstract and the rest of the manuscript to shorten the text and advocate for conciseness.

- *The sentence on L9-21 is very long and difficult to parse. Please break this down into two or more sentences for clarity.*

  With the modifications proposed for the paper, we are going to restructure the abstract, summarizing the main results and clarifying the writing.

- *In that same sentence, it is unclear which "precipitation products" are being referred to. Please be specific.*

We referred to the three precipitation datasets. We have modified the text to reflect that change:

"We found that, although the three precipitation datasets (i.e., WRF-SAAG, CR2MET and RF-MEP) …"

Introduction

- *L62: The sentence beginning "As a result, high-resolution atmospheric models…" feels out of place. The preceding text introduces various observational and reanalysis datasets, but there has been no proper introduction to the concept of using high-resolution models as a data source. I suggest moving this sentence to a more logical position, perhaps after L91, where the rationale for using such models is better established.*

  We agree with this reviewer that the alluded text was out of place. Hence, we have moved it to the sixth paragraph of the introduction:

  "During the last decade, convection-permitting climate models (CPCMs) have become increasingly popular (Lucas-Picher et al., 2021) because they offer an enhanced representation of precipitation (e.g., Fosser et al., 2020) with the potential to outperform gridded observational products in capturing total precipitation over complex terrain (Lundquist et al., 2019). Additionally, CPCMs do not rely on cumulus parameterizations – detected as an important source of errors in regional climate modeling –, improving land-atmosphere interactions (Prein et al., 2015). CPCMs also offer the opportunity to advance hydrometeorological understanding at kilometer-scale resolution, and have been used for a myriad of purposes, including snowpack analysis (Ikeda et al., 2021), cloud band detection(Zilli et al., 2024), and flood studies (Li et al., 2022) over continental domains (e.g., Liu et al., 2025). In particular, CPCMs offer a physically consistent and spatially continuous representation of precipitation, making them a viable alternative for process-based hydrological modeling applications."

- *L75: The text discusses a "high disagreement among CR2MET, RF-MEP, and ERA5," but the RF-MEP dataset has not been properly introduced at this point. Please ensure all datasets are introduced before they are compared or discussed.*

  In the revised manuscript, we have introduced RF-MEP:

  "For example, Boisier et al. (2018) created the gridded meteorological product CR2MET based on the combination of in-situ observations and ERA5 (Hersbach et al., 2020) reanalysis outputs, whereas Baez-Villanueva et al. (2020) developed the Random Forest based MErging Procedure (RF-MEP) for precipitation estimation, which consists of the combination of observational data, meteorological products (e.g., ERA5 reanalysis) and topographic covariates."

- *L105: This paragraph should more clearly and explicitly state the aims of the study. Currently, it seems the primary goal is to assess WRF-SAAG, but much of the paper also focuses on the inter-comparison of the three gridded products. Clarifying the primary and secondary objectives here would help frame the paper for the reader.*

  The paragraph has been revised to clearly and explicitly state the study objectives, distinguishing the primary aim. We have explicitly stated the general scientific questions and the secondary objectives in the revised version of the manuscript.

  "The general objective of this study is to evaluate the ability of the WRF-SAAG simulations to represent daily precipitation and maximum and minimum temperatures over continental Chile, and to assess their potential as a meteorological forcing dataset for simulating hydrological signatures, by comparing them with observation-based meteorological products. To achieve this, four specific objectives are addressed: (i) to evaluate the performance of daily meteorological series from WRF-SAAG and observation-based meteorological products for precipitation, maximum temperature, and minimum temperature, against meteorological station observations; (ii) to assess the ability of the precipitation datasets to replicate daily precipitation events of different magnitudes at meteorological stations; (iii) to identify the regions and climatic conditions where the main differences among the three meteorological datasets are observed; and (iv) to analyze the ability of the meteorological datasets to reproduce hydrological signatures associated with mean flow and extreme runoff events in catchments across Chile, using a conceptual hydrological model."

Study Domain

- *Figure 1b-c: The colormap used for temperature could be improved. The minimum temperature values around 10°C are close to white, making them difficult to distinguish. Please consider using a different colormap that provides better contrast across the full range of values.*

  In the revised version of the manuscript, we will update the colormap to one that provides better contrast across the full range of temperature values, ensuring that both low and high temperatures are clearly distinguishable in Figures 1b–c.

Hydrometeorological Datasets

- *This section introduces four different datasets. To improve clarity and provide an easy reference, I strongly recommend summarizing their key attributes (e.g., spatial resolution, temporal coverage, variables, post-processing methods) in a table.*

  In the revised version of the manuscript, we will incorporate a summary table with meteorological data sets:

Table 1: Meteorological datasets.

Data set	Spatial resolution	temporal resolution	Period	Variable	Reference
WRF-SAAG	4 km	hourly	2000-2021	Precipitation; Temperature	Dominguez et al. (2024)
CR2MET (v2.5)	0.5° × 0.5	daily	1960-2021	Precipitation; Minimum and maximum temperature	Boisier et al. (2018)
RF-MEP (v2)	0.5° × 0.5	daily	1983–2018	Precipitation	Baez-Villanueva et al. (2020, 2021)

Results

- *Figure 2a: The y-axis scale (currently showing 0.0-1.0) makes the results difficult to read, as all the data points are clustered at the very top of the plots. Please adjust the y-axis scale to a more appropriate range (e.g., 0.5-1.0) to better visualize the differences.*

  We agree that the current y-axis scale (0.0–1.0) compresses the data points at the top of the plots, making it difficult to distinguish differences. In the revised version, we will add a zoomed view of the first column of Figure 2a, adjusting the y-axis scale (0.5–1.0) to better visualize the variations among data points.

- *Figure 3: The caption appears to be missing the "WRF-SAAG" label.*

  In the original submission, the caption included "WRG-SAAG" instead of "WRF-SAAG", and we have corrected the text accordingly. Thanks for catching this!

- *Evaluation of Gridded Products: Since CR2MET and RF-MEP both incorporate ground station data using different statistical methods (regression vs. random forest), a brief discussion on the potential sources of uncertainty and discrepancies between these two products would be valuable. Is the disagreement due to the selection of different stations, or the uncertainties inherent in the respective post-processing procedures?*

  We agree that a discussion of the potential sources of uncertainty and discrepancies between CR2MET and RF-MEP would add value to the manuscript. In the revised version, we will include a brief discussion in the Discussion section addressing how differences in station selection and the statistical methods used for post-processing (regression vs. random forest) can contribute to differences between the two gridded products.

- *Beyond Abstract Metrics: Figures 2 and 3 provide a good statistical summary, but the information is quite abstract. To give readers a more intuitive understanding of* *model performance, please supplement the KGE and contingency table metrics with an evaluation of the raw precipitation and temperature fields. For example, providing maps or summary statistics of the seasonal or annual mean biases (e.g., wet/dry bias, warm/cold bias) would be extremely helpful.*

In the revised version of the manuscript, we will add maps comparing the gridded precipitation and temperature fields at seasonal and annual scales, together with differences among the three datasets. Additionally, we will include a summary of performance metrics—either in tables or new figures, such as a Taylor diagram—to provide a more intuitive assessment of model performance. These additions will be presented in the Supplementary Material to complement the main statistical analyses.

Discussion

- *L452: This paragraph provides a good summary of limitations and future work. To increase the impact of the paper, please also provide some specific insights and examples of how the WRF-SAAG and the two observational datasets could be used in practical application studies (e.g., water resource management, agricultural planning, climate change impact assessments). This would provide valuable guidance to other researchers and stakeholders in the region.*

  In response to this comment and with the aim to improve the organization of the ideas, we have divided the Discussion section into subsections, including one entitled "Limitations and future work". We have added the following text within that subsection:

  "Future comparative assessments between WRF-SAAG and other gridded products could incorporate the effects of parameter equifinality on hydrological model simulations (e.g., Muñoz-Castro et al., 2023), examine model structural uncertainty (e.g., Saavedra et al., 2022), compare parameter regionalization results for streamflow prediction in ungauged basins (e.g., Baez-Villanueva et al., 2021), and conduct drought propagation analyses (e.g., Lema et al., 2025). Finally, the WRF-SAAG dataset could serve as a baseline for future climate change impact assessments aligned with the efforts of the SAAG community. Recenty, Liu et al. (in preparation) conducted a climate perturbation experiment with the WRF model using the Pseudo Global Warming (PGW) approach (Hara et al., 2008; Kawase et al., 2009; Schär et al., 1996), which applies climate perturbations derived from global climate model projections to adjust the reanalysis-based initial and boundary forcings used in the baseline historical regional climate simulations. Since the method assumes that the storm tracks and frequency entering the domain remain the same in both control and future simulations, these could be used to examine changes in hydrologic processes because of shift in thermodynamic conditions."

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