Dear Editor and Reviewer,

We sincerely thank the Reviewer for the constructive comments. Your recommendations are valuable and helped enhance the analysis and sharpen the argumentation in the manuscript. In this reply, we begin by addressing the three interrelated comments, followed by a point-by-point reply to the remaining suggestions. The reviewers' comments are presented in black, with our replies **in blue**.

Overview of the paper

This manuscript presents an enhanced hydrological simulation using a resolution-refined climate model coupled with a more comprehensive hydrological framework. The improvements achieved through convection-permitting WRF simulations and the integration of lake and reservoir modeling are evident, particularly in addressing biases in peak flow and dry-season flow during discharge simulations. These findings emphasize the enhanced capability of hydrological simulations when using refined climate models and lake-integrated approaches.

The study focuses on two key topics: the added value of convection-permitting models and the integration of hydrological models with lake systems. This work holds great value in addressing challenges related to unreliable hydrological simulations, especially over Eastern Africa. It provides critical benchmarks for optimizing hydrological modeling, contributing to improved flood and drought forecasting and loss reduction in water management applications.

In my opinion, this paper gives an incremental advancement in the hydrological modelling field more than novelty, considering the convection-permitting modelling and lake-integrated hydrological simulation. The paper is well written, and quite comprehensive and well-structured. The topic is of interest and fits the journal scope, I suggest a few major revisions and some minor before publication in HESS. I believe a minor revision is needed and the revised manuscript will be much better. My comments are listed below.

Both Major comments 1 and 2, as well as the minor comment Line154, are related to the time span for model simulation or evaluation.

Reply: While we acknowledge that conducting WRF simulations over a longer period (preferably more than 10 years, instead of the 5 years from 2010 to 2014) would be ideal, we are constrained by the fact that WRF/WRF-Hydro simulations are highly time-consuming and resource-intensive. Given that the project has recently ended, additional computational resources or time to perform these extensive simulations are no longer available. Consequently, our study is based on the existing WRF simulation timeframe.

Moreover, previous studies have shown that WRF/WRF-Hydro simulations are acceptable for regions like Africa, even with timeframes shorter than five years. Zhang et al. (2024) conducted WRF/WRF-Hydro simulation over 2015-2018 to assess how soil hydrophysical properties influence regional land-atmosphere coupling and the water cycle (involving precipitation) over the southern Africa region. Quenum et al. (2022) employed WRF/WRF-Hydro Modeling over 2008-2010 to explore the abilities of the fully coupled WRF-Hydro modeling system to simulate discharge and precipitation in the Ouémé River in West Africa.

Given the limited length of WRF simulation, the paper conducts precipitation evaluation and analysis based on data from January 2010 to December 2014. Typically, WRF simulations require a spin-up period of about one month (Minor comment Line 154), and the first month (January 2010) should be excluded from the evaluation of precipitation simulations. However, the evaluation period remains constrained, and the subsequent analysis focuses primarily on the rainy seasons (MAM and OND) and extreme events. Therefore, we employed simulated precipitation data from January 2010 to December 2014, without eliminating January 2010.

For the hydrological simulation based on the WRF-Hydro modelling, driven by the WRF output for 2010-2014, a spin-up time of at least one year is necessary (Figure 5). Therefore, our study WRF-Hydro simulations cover 2011-2014, with 2010 as the spin-up.

In future work, if time and resources permit, longer-term WRF simulations, along with WRF-Hydro simulations and data analysis, will be considered to reduce uncertainties.

References:

1. Zhang, Z. et al. Sensitivity of joint atmospheric-terrestrial water balance simulations to soil representation: Convection-permitting coupled WRF-Hydro simulations for southern Africa. Agricultural and Forest Meteorology 355, (2024).

2. Quenum, G. M. L. D. et al. Potential of the Coupled WRF/WRF-Hydro Modeling System for Flood Forecasting in the Ouémé River (West Africa). Water (Switzerland) 14, (2022).

Major comments

1. The data for precipitation evaluation is from 2010 to 2014, while the data for discharge is from 2011 to 2014. I suggested using the same time series (i.e. 2010-2014) for precipitation and discharge evaluation.

Reply: Thanks for your suggestion. While we should use the same time series for precipitation and discharge analysis, different spin-up times could be acceptable due to the limited length of the simulation. For precipitation with a limited time length, we should include 2010 and thus conduct precipitation analysis based on the data over 2010-2014. However, WRF-Hydro requires a full year of spin-up, so discharge evaluation excludes the first year, and thus is based on 2011-2014. While we acknowledge this mismatch, we believe that different spin-up times could be acceptable. We have added the clarification in the revised manuscript (Line 295-297). Please see our detailed explanation at the beginning of the replies.

2. If it is possible, longer time period of data for precipitation evaluation is necessary. Using data over 2010-2014 to calculate the monthly precipitation is not enough, which is usually more than 10 years.

Reply: We appreciate the comment. Please see our answer at the beginning of the replies.

3. It is not easy to understand how to calculate the attribution of discharge changes from WRF-refined precipitation and lake-integrated WRF-Hydro model in Sect. 4.3. Please add it to the method section.

Reply: Thank you for the comment. We have added it in Sect. 3.5 of the methodology in the revised manuscript. Please see below.

"3.5 Attribution of hydrological model improvement to convection-permitting WRF simulation and lake/reservoir module

To assess the contributions of CPWRF simulations and the lake/reservoir module, we compared three models: (1) the calibrated WRF-Hydro model without the lake/reservoir module, driven by CPWRF output (LakeNan), (2) the well-calibrated WRF-Hydro model integrated with the lake/reservoir module, also driven by CPWRF output (LakeCal), and (3) the well-calibrated WRF-Hydro simulation with the lake/reservoir module, driven by ERA5 (LakeCal-ERA5). We calculated the NSE value of simulated discharge against observed data for each model. Next, we computed the NSE increment between LakeCal relative to LakeNan representing improvements due to CPWRF precipitation, and the increment between LakeCal and LakeCal-ERA5 reflecting the influence of the lake/reservoir module. The ratio of CPWRF precipitation-induced or lake/reservoir module-induced NSE increment to the total increment is provided as the attribution of hydrological simulation improvements to the CPWRF simulations or the lake/reservoir module."

4. The Sect. 4.3 should be put at the front of the Discussion, since it explains why the hydrological simulation improves.

Reply: Thank you for the suggestion. We have now moved Section 4.3 to the Discussion, renumbering it as Section 5.1.

Minor comments

Line17: “limitations in modelling skills” in the abstract might be the defects or imperfections in the model algorithm, such as not involving lake processing. But the term “limitations in modelling skills” also covers the content of the forcing. So I suggest change ”limitations in modelling skill” to “limitations in model capacity”

Reply: Thanks for the suggestion. We have revised it.

Line34: Change “limitations of hydrological modelling” to “limited capacity of hydrological model”.

Reply: Thanks and done.

Line57: Change “realistic regional detail” to “the realistic regional detail”

Reply: Thanks and done.

Line58: Change “realistic regional details” to “refined-scale features”

Reply: Thanks and done.

Line67: Change “coarse resolution” to “the coarse resolution”

Reply: Thanks and done.

Line86: Change “suggesting” to “which suggests”

Reply: Thanks and done.

Line107-108: Please add references to the sentence “However, the region faces increasing risks of drought and flood, which are likely exacerbated by climate change. ”

Reply: We agree with the reviewer on this point. We have added the reference and revised the sentence as “However, the region is observed to be at risk of drought and flood, which are likely exacerbated by climate change (Kenya Climate Change Case

Study, 2024).”

Line118-119: Change “The research is to improve hydrological models for better water resource management and risk mitigation, supporting sustainable practices in regions vulnerable to water-related damages.” to “The research aims to improve hydrological models, which helps to better water resource management and risk mitigation, and supports sustainable practices in regions vulnerable to water-related damages.”

Reply: Thanks for the considerable suggestions and done.

Line129: Please keep the hyphen consistent in “S 1.25°~N 0.50°, E 36.50°-E 39.75°”.

Reply: Thanks for pointing out our carelessness. We have fixed it.

Line131-132: Before “We classified the terrain into mountainous regions above 1,600 meters and plains below 1,600 meters.”, please add “To analyze and evaluate the spatial distribution of precipitation related to the topography,”

Reply: Thanks and revised. Very helpful suggestion.

Line133-135: Change “There are five reservoirs in the basin and along the Tana River (Table 1, Fig. 1 c). It is worth noting that the Garissa station is downstream Rukanga and the lakes between them are Masinga, Kamburu, Gitaru, Kindaruma, and Kiambere from the upstream to downstream. While the lakes don’t affect the streamflow at Rukanga, they do impact the discharge at Garissa.” to “There are five reservoirs in the basin and along the Tana River (Table 1, Fig. 1 c), including Masinga, Kamburu, Gitaru, Kindaruma, and Kiambere from the upstream to downstream. The five lakes are between Garissa station upstream and Rukanga downstream. It is worth noting that the lakes don’t affect the streamflow at Rukanga while they do impact the discharge at Garissa.”

Reply: Thanks and done.

Line143: Change “boundaries” to “boundary”

Reply: Thanks and revised as “boundary”.

Line154: If one year is used as the spin-up year, the subsequent analysis in the results should be based on the simulated precipitation from 2011 to 2014 (which is 2010-2014 in the paper). However, I think the analysis in the results covering 2010 to 2014 is acceptable due to three reasons: 1) one month of spin-up is typically sufficient for WRF downscaling, 2) the time span of the precipitation data used is rather limited, 3) the precipitation analysis or evaluation focus on the MAM and OND, or the extremes. If you can extend the WRF downscaling (for example, from 2001 to 2014), it would be better.

Reply: Thanks for pointing it out. We delete “with the first year of spin-up.” Sect. 3.1 has been changed to as follows.

“To obtain convection-permitting modeling precipitation, we used the Advanced Research WRF (WRF-ARW) model of version 4.4 (Skamarock et al., 2019) with the designed domain of 5 km spatial resolution (Fig. 1). The lateral boundaries were forced with the 6-hourly ERA5 reanalysis with a spatial resolution of 0.25 degrees (Hersbach et al., 2020). The model was set with 50 vertical levels up to 10hPa. The convection parameterization was turned off for the WRF simulation, the Mellor-Yamada Nakanishi Niino Level 2.5 (MYNN2.5) Scheme (Nakanishi and Niino, 2006) for the planetary boundary layer, the RRTM scheme for longwave radiation (Mlawer et al., 1997), and the Dudhia Shortwave scheme for shortwave radiation (Jimy Dudhia, 1989). The Noah-MP Land Surface model (‘Noah-MP LSM’, Yang et al., 2011) was used for the land surface scheme.

The model runs from 1 January 2010 to 31 December 2014. Typically, WRF simulations require a spin-up of about one month, which should ideally be excluded from precipitation evaluation. However, given the limited length of simulated precipitation, the subsequent analysis is based on full precipitation simulation from January 2010 to December 2014.”

Line367: Change “GIS pre-41.processing” to “GIS pre-processing”

Reply: Thanks for the careful review. We have fixed it.

Line376: Change “ in the evolution of discharge ” to “ based on the discharge ”

Reply: Thanks and done.

Line378: There are two things related to the term “peak-flow”. One is the largest simulated daily flow on the date when the largest daily flow occurs based on the observations. Another is the peaks shown in the discharge-date curve. Please distinguish between the two.

Reply: Thanks for your helpful suggestion. We have changed the first term “peak-flow” to “Peak-Flow”. The term “Peak-Flow” has been clearly defined in Set. 3.3. In the whole text, the term related to “peak-flow” has been changed to “Peak-Flow”.

Line408: Change “demonstrate” to “demonstrates”

Reply: Thanks and done.

Line411: Please add references (i.e. figures) for “The water levels of the five lakes show the same spin-up time.”

Reply: Thanks and done.

Line411-412: Change “However, a larger lake seems to require more time to reach equilibrium. The lakes are interconnected, so the initialization time is determined by the longest spin-up. Therefore, despite the disparate sizes, the initialization times of the five lakes are the same.” to “Usually, a larger lake seems to require more time to reach equilibrium. Since the lakes are interconnected, the initialization time is determined by the longest spin-up. This results in the same initialization times of the five lakes despite of the dramatically disparate sizes”.

Reply: Thanks for the suggestion. After combining this suggestion with the comments of the Reviewer 2, we revised the related paragraph as follows.

"The water levels from the lake/reservoir-integrated model show a consistent spin-up period of 4 years across nearly all five lakes for the entire period, as well as during both the rainy and dry seasons (Fig. S2). Although KIAMBERE (one of the five lakes) exhibits a spin-up period of 3 years during the rainy season (Fig. S2 e), it can be considered nearly 4 years due to the uncertainty in determining the spin-up time required for the stabilization of specific variables. Since the lakes are interconnected, the stabilization time is governed by the longest spin-up period. This may result in nearly the same initialization time for all five lakes (Table 1)."

Line413-415： Please delete " The bias from the LakeRaw simulation is considerable (> 80 %). This is due to that the parameters used in the LakeRaw are from the primarily calibrated LakeNan Model or GIS pre-processing (Methodology), which needs further calibration for the WRF-Hydro system." Because there is no relationship between this part and the preceding text.

Reply: Thanks and done.

Line492: Please delete "still".

Reply: Thanks and done.

Line499: Please double-check the figure "-53".

Reply: Thanks and revised.

Line527: Change "under estimation" to "underestimation"

Reply: Thanks and revised.

Line532: The label in Fig. 10 is a bit confusing. Please label them more clearly.

Reply: Thanks for the useful suggestion and revised.

Line551: Change “Hydrological modelling improvement from convection-permitting WRF-simulated precipitation” to “Hydrological modelling improvement from lake/reservoir module”

Reply: Thanks for pointing out our carelessness and revised.

Line554: Delete “. Factors”.

Reply: Thanks and done.

We sincerely appreciate your valuable feedback and careful review of our manuscript. Your suggestions have helped us improve the clarity and depth of our work. Thank you for your time and effort in reviewing our paper!