Dear reviewer:

Thank you very much for your great help on our manuscript. Many thanks are also to the Associate Editor and the reviewers for their constructive comments and suggestions. They are very important and useful to improve our work and brush up the manuscript. According to all the comments, the paper was thoroughly revised. Meanwhile, some errors and deficiencies have been also revised through our self-check process and proofread service. The key changes are marked with red color. The point-to-point responses to all comments and suggestions from the reviewer are listed in the following. We hope these revisions can satisfy your requirements and meet with your approval, and of course, we are more than happy to improve the paper again according to new comments and suggestions they might come.

Best regards,

Kunlong He and Wei Zhao

Corresponding author: Wei Zhao Prof. E-mail: zhaow@imde.ac.cn

1. Title: what are the capitals, SMPD, standing for? Please label them.

Ans.: Thanks a lot for your comment. SMPD stands for Soil Moisture-based Precipitation Downscaling method. We labeled it in this paper. See line 13 and 207.

2. Title: would it be possible for downscaling the IMERG at hourly or half-hourly scale? For this point, I would like to recommend you some references.

Ans.: Thanks a lot for your comment. In the proposed method, the key inputs of the downscaling process is surface soil moisture and precipitation data. Even on hourly or half-hourly scales, the soil moisture exhibits an instantaneous response to collocated precipitation. Then, as introduced in the method section, the soil moisture estimation method has achieved seamless downscaling for high-resolution soil moisture generation under cloudy conditions. Therefore, it would be able to obtain real-time soil moisture from microwave satellite observations combined with surface temperature and vegetation index derived from optical and thermal infrared remote sensing. Therefore, this approach would work well for rainfall data at hourly or half-hourly scale. We will be looking at this in future studies and adding this part to the discussion (see lines from 526 to 535 of section 5.2). Thank you very much for the recommended references, which we have read and referenced in this paper.

3. Introduction: this part demonstrates that the authors have not comprehensively known the key spatial downscaling investigations, and the writings is really not good. Please reorganize and rewrite it.

Ans.: Thanks a lot for your comment. We have read the literature you provided and added more methodological descriptions in the introduction section, and our research points are reorganized and rewrote 'Furthermore, suffering from an indirect physical connection between topographic and vegetation factors and precipitation at coarse temporal scale, a large amount of downscaling research has been conducted at monthly or annual scales. In addition, although daily high-resolution precipitation data have been produced by different statistical methods (Brocca et al., 2019a; Hong et al., 2021), the use of high-resolution SSM data to improve the spatial resolution of satellite precipitation products for generating daily-scale high-resolution precipitation data based on physical mechanisms is less studied. See lines from 90 to 95 of page 4.

4. Datasets-IMERG: Various investigations have been done to exploiting the potential errors in IMERG. If the authors point out some potential error sources of IMERG, it is much better.

Ans.: Thanks a lot for your comment. We added the potential error sources analysis of IMERG in the discussion section of the paper. 'At first, the IMERG-Final products are corrected on a monthly scale using the interpolated precipitation product Global Precipitation Climatology Centre (GPCC, 1.0°/Monthly) based on ground observations. However, there is no mature calibration algorithm for calibrating the daily satellite-based precipitation estimates (Ma et al., 2020b). Second, the a-priori databases of cloud cover and precipitation profiles for retrieving passive microwave-based satellite precipitation estimates are not sufficiently robust due to the lack of ground-based radar observations. In addition, since passive microwave remote sensing-based precipitation retrieval is the primary input to the IMERG-Final products, it may lead to poor performance of the satellite-based product in winter and high-latitude regions (Xu et al., 2022)'. Please see lines from 496 to 502 of page 23.

5. Datasets-SSM: how do you think that whether the too coarse spatial resolution of CCI SSM data, 0.25 deg, have negative efforts in downscaling IMERG at 0.1 deg or

not?

Ans.: Thanks a lot for your comment. The spatial resolution of surface soil moisture data of 25 km is very coarse and cannot meet the precipitation downscaling, while the surface soil moisture data are easily affected by clouds. Therefore, in this study, the 25-km European Space Agency (ESA) Climate Change Initiative (CCI) SSM product is used to derive 1-km SSM data based on the seamless downscaling method proposed by Zhao et al. (2021). Therefore, the 1 km precipitation data can mitigate the impact of the coarse resolution of GPM precipitation products. In addition, the uncertainty of SSM and the sensitivity relationship between SSM and precipitation under continuous rainfall conditions may introduce uncertainty in the downscaling precipitation results. First, the responses of SSM with different land cover conditions and vegetation coverages to precipitation are relatively different (Fan et al., 2021), and topographic factors such as depressions and slopes also affect the uncertainty of SSM. Second, although the relationship between SSM and precipitation has been well demonstrated in many previous studies, the sensitivity of SSM to precipitation will decrease when soil water storage becomes saturated after repeated precipitation. Therefore, it is necessary to further improve the relationship by considering the soil water threshold saturation in future studies. We investigated this limitation in the discussion section of the paper.

6. Datasets-NDVI: how do you think that whether the too coarse temporal resolution of CCI SSM data, 16-day, have negative efforts in downscaling IMERG at daily scale or not?

Ans.: Thanks a lot for your comment. Some studies stated that the precipitation–NDVI relationship was hardly time-delayed since vegetation could influence precipitation by adjusting temperature and air moisture during the growing seasons (Chen et al., 2020; Lu et al., 2022). The NDVI values within the 16-day scale remain largely constant and respond well to precipitation, while vegetation dissipates precipitation through leaf interception and evapotranspiration. Thus, we believe that the 16-day NDVI does not negatively affect the downscaling results.

7. Why did not using the POD index, which is a very common index evaluating precipitation datasets.

Ans.: Thanks a lot for your comment. We added the POD index results in the results section of the paper. Please see Fig.6, Fig.7 (j, k, and l), and Table. 2.

8. Results: The idea of Fig.3 is not very clear.

Ans.: Thanks a lot for your comment. We proposed the soil moisture-based precipitation estimation model based on equation 6. An important prerequisite is the assumption of spatial invariancy in the precipitation estimation model described in Eq. (6) at coarse and fine scales. Thus, we compare the precipitation results fitted by equation 7 with the original GPM products over the study area during the period of 2016-2018, which evaluate the performance of the soil moisture-based precipitation estimation model.

9. Results: the downscaled results on 20171210 in the central part seems have anomalies, why?

Ans.: Thanks a lot for your comment. These anomalies may be due to the uncertainty of SSM and the sensitivity relationship between SSM and precipitation under continuous rainfall conditions may introduce uncertainty in the downscaling precipitation results. First, the responses of SSM with different land cover conditions and vegetation coverages to precipitation are relatively different, and topographic factors such as depressions and slopes also affect the uncertainty of SSM. Second, although the relationship between SSM and precipitation has been well demonstrated in many

previous studies, the sensitivity of SSM to precipitation will decrease when soil water storage becomes saturated after repeated precipitation. Therefore, we re-changed the code in these regions, using either spatial proximity image element or temporal proximity image element values to fill the outliers.

10. Discussion: would it be possible to analyze the potential error sources of the downscaled results?

Ans.: Thanks a lot for your comment. We added the potential error sources of the downscaled results in section 5.2. Please see lines from 507 to 518 of page 23. 'In addition, the uncertainty of SSM and the sensitivity relationship between SSM and precipitation under continuous rainfall conditions may introduce uncertainty in the precipitation downscaling results. First, the responses of SSM with different land cover conditions and vegetation coverages to precipitation are relatively different (Fan et al., 2021), and topographic factors such as depressions and slopes also affect the uncertainty of SSM. Therefore, it is necessary to establish the relationship between SSM and precipitation for different land cover types or different terrain types. The establishment of a more reliable fitting relationship based on precipitation data with different land cover properties or topographic factors would be helpful to enhance the accuracy of the downscaling results (Chen et al., 2020; Senanayake et al., 2021; Zhao et al., 2021). Second, although the relationship between SSM and precipitation has been well demonstrated in many previous studies, the sensitivity of SSM to precipitation will decrease when soil water storage becomes saturated after repeated precipitation. Therefore, it is necessary to further improve the relationship by considering the soil water threshold saturation in future studies.'

11.The English writings are also greatly needed to be improved.

Ans.: Thanks a lot for your comment. We have carefully checked the language and rewritten some parts of the manuscript.

12.Last but most important one: would you like to use some traditional method as a comparison with your proposed method, SMPD?

Ans.: Thanks a lot for your comment. We collected the downscaling results evaluation metrics of existing studies on GPM precipitation products in Table 2 and indicated the superiority of SMPD method by comparing with various methods (e, g. GWR). Additionally, the comparison by bilinear interpolation method to interpolate the original GPM precipitation products to 0.01 resolution reveals that the SMPD method has a slight improvement compared to the interpolation method. The accuracy of interpolation precipitation based on rain gauge stations is limited by the density of gauge-based stations, and the GWR method is limited by the model window radius and the influence of the number of gauge-based stations. The SMPD method breaks the limitation caused by the rainfall gauge density and the model window radius, it has a broader application prospect to produce precipitation data with high resolution and high accuracy in the study area with heterogeneous terrain morphology and precipitation. Please see lines from 456 to 478 of page 20.

Chen, S., Xiong, L., Ma, Q., Kim, J.-S., Chen, J., and Xu, C.-Y.: Improving daily spatial precipitation estimates by merging gauge observation with multiple satellite-based precipitation products based on the geographically weighted ridge regression method, Journal of Hydrology, 589, 125156, 2020.

Lu, X.-y., Chen, Y.-y., Tang, G.-q., Wang, X.-q., Liu, Y., and Wei, M.: Quantitative estimation of

hourly precipitation in the Tianshan Mountains based on area-to-point kriging downscaling and satellite-gauge data merging, Journal of Mountain Science, 19, 58-72, 2022.
Zhao, W., Wen, F., Wang, Q., Sanchez, N., and Piles, M.: Seamless downscaling of the ESA CCI soil moisture data at the daily scale with MODIS land products, J. Hydrol., 603, 126930, https://doi.org/10.1016/j.jhydrol.2021.126930, 2021.