Answer for the comments

Thank you for your insightful comments. Here is our detailed response:

Among the major comments from the reviewer, I would like to address the methodology and conclusion sections. The related comments are as follows:

1) The abstract lacks clarity and specificity regarding the major research findings.

a) For instance, the statement, “This study investigates the dynamics of evapotranspiration in a monsoon-dominated region of the Korean Peninsula, focusing on the challenges associated with measurement, identification, and prediction of potential and actual evapotranspiration,” does not align with the paper's content, as the discussion on these challenges are not evident throughout the whole document.

Answer) The complementary relationship hypothesis regarding evapotranspiration, first proposed by Bouchet (1963) and Budyko (1974), has played an important role in explaining the evapotranspiration process. Many researchers have demonstrated the validity of this hypothesis in various climatic environments. The basic logic of this hypothesis is simple and clear: Initially, when the surface is dry and the atmosphere is also dry, potential evapotranspiration is at its maximum and actual evapotranspiration does not occur. As moisture on the surface increases, actual evapotranspiration begins, increasing atmospheric humidity and reducing the moisture gradient between the surface and the atmosphere, which in turn decreases potential evapotranspiration. When the surface moisture continues to increase to near saturation, the atmosphere also approaches saturation, and potential evapotranspiration and actual evapotranspiration converge to maintain a constant value (wet-environment evapotranspiration). While the natural behavior of evapotranspiration is straightforward, proving the complementary relationship hypothesis with actual measured data is challenging. This is because the hypothesis assumes a local situation where the inflow or outflow of air masses with different humidity levels from the outside is blocked, which is difficult to find in natural conditions. If there have been lengthy and confusing descriptions in the process of explaining these conditions and limitations of application, as well as the different conditions under which various studies have been conducted, these should be corrected in future updates of the document.

b) Additionally, the claim, “This research confirms the existence of complementary relationship behavior in regions with strong correlations between soil moisture and air humidity, such as deserts and tropical areas,” is misleading because the study is exclusively focused on the Korean Peninsula only.

Answer) As previously explained, the environment most suitable for proving the complementary relationship hypothesis is one where there is a high correlation between soil moisture and atmospheric humidity. Cases where the soil is dry but the atmospheric humidity is high, or where the soil is wet but the atmosphere is dry, involve the inflow or outflow of air masses with different moisture contents due to lateral atmospheric motion (advection). While the local complementary relationship characteristics are inherent, they are mixed with external factors, making it difficult to distinguish them in the data. In the case of the Korean Peninsula, the synoptic-scale atmospheric motion is predominantly characterized by the inflow of warm and humid Pacific air masses into the inland areas. Although typhoons or localized rainfall can temporarily obscure these macro-scale atmospheric motions, the Pacific air mass generally dominates the monsoon climate in Korean peninsula. Therefore, during prolonged droughts, the atmosphere may be hot and humid while the soil remains dry, and during the rainy season, the soil may be wet while the atmosphere is dry, which hinders the CR appears clearly. This paper aims to assert that the complementary relationship may not be distinctly observed depending on the climate and that regions with strong seasonal advection are more likely to deviate from the complementary relationship.

2) The introduction is lengthy and detailed, obscuring the core reason for the paper's necessity.

Answer) This paper aims to assert that the complementary relationship may not be distinctly observed depending on the climate and that regions with strong seasonal advection are more likely to deviate from the complementary relationship. We agree with the comment that a concise edit focusing on the main argument is necessary.

3) The purpose of each figure in the article is unclear, and their contribution to the overall conclusion is not well-articulated. It appears that the author included all figures without considering their specific relevance or how they support the main conclusions.

Answer) We plan to revise the manuscript to effectively explain the connection between each figure and the main topic.

4) The text is unclear about the use of PET and WET. It appears that potential evapotranspiration (PET) was calculated using the Penman-Monteith method, and wet evapotranspiration (WET) was derived from the Priestley-Taylor (P-T) equation. However, the role of the pan evapotranspiration data collected at Jeonju is ambiguous, as it is only mentioned in the context of calculating the pan evaporation coefficient. A significant issue is the choice not to use pan evaporation (EPan) as the measure of PET, as done in studies like Ramirez et al. (2005), which is also referenced in this study. Using EPan as PET would establish it as the upper limit of evapotranspiration in the region. Currently, WET from the P-T method is acting as the maximum limit. While this might not be the major issue as we can still interpret the results, but the author needs to warrant all the rationale behind such selection and usage also highlighting how (if) it impacts the analysis.

Answer) WET stands for "Wet Environment Evapotranspiration". This term refers to the evapotranspiration that occurs under conditions where water for evapotranspiration is provided unlimitedly, essentially representing the maximum possible evapotranspiration given the available energy and environmental conditions. WET is commonly estimated by the Priestley-Taylor equation. Both PET and WET define the maximum limitation. However, PET is the maximum under given temperature and humidity and WET is the maximum under the unlimited moisture provision even when the air is fully saturated. PET can be estimated by FAO Penman-Montheith equation or directly by pan measurement. We used pan measurements from 3 national weather stations, one(Jangsu) inside the basin and 2(Jeonju and Geumsan) outside the basin. Even though Jeonju and Geomsan stations are outside the basin, they are located closest from the Yongdam dam site and the spatial variability of the pan evaporation was assumed not significant relatively. We used the FAO P-M for calibrating pan coefficient.

5) Regarding the main highlight of the paper, Figure 13, there are several concerns:

a) It appears that each dot represents a daily observation. Most studies on the complementary relationship of evapotranspiration (CRE) use annual scale observations for different basins. The choice to use a daily scale needs clarification. The introduction should specify whether the author intends to validate CRE on a daily scale.

Answer) As the reviewer indicated a number of CRAE paper have dealt with annual scale to capture synoptic scale behavior. However, recently there are comments on the needs for finer scale analysis. For example, Tu et al.(2023)* commented that their study acknowledged uncertainties in the estimation of Epa_max and the challenges of applying the CR model at shorter time scales and suggested further research is needed to test the model performance at daily or sub-daily scales.

* Tu, Z., Yang, Y., Roderick, M. L., & McVicar, T. R. (2023). Potential evaporation and the complementary relationship. Water Resources Research, 59, e2022WR033763. https://doi. org/10.1029/2022WR033763

b) Typically, the x-axis in the CRE hypothesis or Budyko framework reflects longterm water availability, as it represents climatic conditions and aids in predicting actual evapotranspiration (AET) based on the region's characteristics. This is usually represented by the ratio of long term mean annual precipitation (P) to PET (Budyko) or the potential humidity index (phi) as the ratio of annual precipitation to WET (Ramirez et al., 2005). The author, however, calculates the moisture availability index as the ratio of AET to PET (lines 186-187) in daily scale (as I understood). The rationale for this choice should be explained (also related to point a).

Answer) The rationale for using the moisture availability index as the ratio of Actual Evapotranspiration (AET) to Potential Evapotranspiration (PET) on the x-axis of the Complementary Relationship (CR) graph lies in its ability to represent the degree of water limitation and the evaporative environment's condition. The ratio AET/PET directly indicates the availability of water for evaporation in a given environment. When AET is close to PET, it suggests that the environment is not water-limited, and the surface has sufficient moisture for evaporation to occur at its potential rate. Conversely, when AET is much lower than PET, it indicates water scarcity, as the actual evaporation is limited by the lack of available moisture. AET is most relevant variable for representing the moisture availability regardless of temporal scales. However, Budyko and Ramirez et al. (2005) used annual precipitation instead of AET because AET measured by flux sensor was guessed so limited at that time and the actual annual precipitation was best available component as an alternative for the AET. The recent paper on the CR (used AET measured by the flux tower and used the moisture availability as the ratio of AET/PET (Tu et al., 2023).

c) To better understand how AET and PET change with moisture availability, it may be necessary to include at least one additional variable in computing moisture availability, rather than current formulation of moisture availability (MA) as the ratio of AET to PET. Relying solely on calculating MA from the ratio of AET to PET and trying to explain the dynamics of AET and PET based on that ratio might obscure the relationship between AET and moisture availability (MA). For instance:
(i) The blue line in the graph indicates that PET/WET (y axis) is nearly equal to 1 for all AET/PET values (moisture availability), which suggests that PET is approximately equal to WET across different moisture conditions.
(ii) The red line shows that AET/WET is almost linearly proportional to AET/PET (moisture availability), implying that PET is proportional to WET, unless the temporal scales of x-axis and y-axis are different (similar to (i)). This approach obscures how AET responds to moisture availability. Therefore, the x-axis could represent long-term moisture availability or catchment characteristics more effectively, and alternative methods of representation of moisture availability should be considered.

Answer) The reviewer indicates the PET/WET ratio appears nearly 1 which means PET is approximately equal to WET regardless of moisture availability. Accurately saying, the PET*(=PET/WET) is mainly and randomly distributed between 1 and 1.2~1.3 and lower limit seems clearly 1. PET* is distributed above 1.2~1.3 which occurs when air is dry (PET>>WET). Usually in Korean peninsula during the most summer monsoon season period, humidity rises up to over 90%. Because the AET* is defined as the ratio of AET/WET and MA is defined as AET/PET, AET* vs MA shows distribution nearly above 1:1 line by its definition.

d) Since the author utilizes AET from the flux tower as the measure of regional actual evapotranspiration, it is essential to highlight the potential fetch area of the flux tower, as it depends on the wind direction and speed. In the map, the flux tower appears to be located quite close to the dam. If the scales on the figure are accurate, it needs to be clarified whether the flux tower measures ET from the dam or the surrounding vegetation (forest) most of the time.

Answer) The flux tower data are very limited in general. There are only 2 flux towers installed in the Yongdam dam basin, one in the Mt. Deogyu and the other one near the Yongdam dam. However, Yongdam dam flux tower was installed in 2017 so the recorded data are relatively short, and the sensor is currently not available due to repair. Currently the data from the tower on the Mt. Deogyu are only available ones. As commented, we consider the effective coverage for a single flux tower and there will be uncertainties or biases in representing basin-wide areal measurements due to the spatial remoteness among individual measurements. Those aspects would be limitations of this work which should be improved as a lot more data will be accumulated.

We appreciate the opportunity to address these points and hope our response clarifies the rationale and methodology of our study.