Review comments (Vitali Diaz) and answers

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

Major comments

First, the title does not reflect what is presented in the manuscript; the authors present an analysis of the complementary relationship of the Evapotranspiration hypothesis in a basin on the Korean peninsula. A more appropriate title is

'Limitations of the complementary relationship of evapotranspiration hypothesis in a monsoon-dominated region in the Korean Peninsula: case study Yongdam basin'

Answer) We agree with the reviewer's suggestion.

Do the authors consider it necessary to further analyze the relationship above when this hypothesis does not perform well in areas such as the case study? Why do you venture to carry out this study? Which alternative, besides using this hypothesis, do you plan to perform?

Answer) [Necessity of Further Analysis] 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.

Yes, we consider it essential to further analyze the relationship described by the Complementary Relationship of Evapotranspiration (CRE) hypothesis, even though it did not perform optimally in the Yongdam Dam basin case study. The main reason is that understanding the limitations and applicability of the CRE hypothesis under different climatic conditions, particularly in monsoon-dominated regions, is crucial. The observed deviations in our case study highlight the need to explore the interactions between potential evaporation (PET) and actual evaporation (AET) more deeply. This analysis will help in refining the hypothesis, improving its predictive capabilities, and providing more accurate tools for water resource management in complex climates like that of the Korean Peninsula.

[Rationale for Conducting the Study] Our venture to carry out this study stems from the significant role evapotranspiration plays in the hydrological cycle and water resource management. The CRE hypothesis has been validated in regions with stable climates, but its performance in monsoon areas where strong seasonal advection dominates remains uncertain. By investigating its applicability in the Yongdam Dam basin, we aim to fill this gap and enhance our understanding of evapotranspiration dynamics in such regions. The study seeks to identify specific conditions under which the CRE hypothesis holds or is hidden without being exposed, thus contributing to the broader scientific discourse on evapotranspiration and improving climate and hydrological models for monsoon-influenced areas.

[Alternative Approaches] Our findings in this study are that the hot and humid air mass incoming from the Pacific ocean during the summer monsoon season governs the makes the PET(Potential ET) nearly equivalent to WET(Wet environment ET) regardless of moisture availability on land surfaces (Figure 13). The CR relationship is obscured and not clearly manifested due to the influx of hot and humid air masses from the Pacific. The research will be necessary for the evaporative dynamics under the environments governed by the advections by hot and humid air masses, which is required for exact prediction for losses from the reservoir water surfaces.

The time resolution is not very detailed when presenting the data and results, please be more explicit.

Answer) 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. The daily data were used in this study.
* 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

With the current data observed, will other approaches, such as remote sensing or hydrological modelling, be more timely?

Answer) Our study primarily relies on ground-based measurements, including flux towers, evaporimeters, and meteorological stations, to estimate both actual evapotranspiration (AET) and potential evapotranspiration (PET) in the Yongdam dam basin. The Penman-Monteith equation and the FAO Penman-Monteith equation have been used for PET estimation, while the eddy covariance method has been employed for AET measurements. Remote sensing offers significant advantages for large-scale and real-time monitoring of hydrological variables. Techniques such as satellite-based evapotranspiration estimation (e.g., MODIS, Landsat) could provide high spatial and temporal resolution data. These methods can complement our ground-based observations by filling spatial gaps and providing a broader regional perspective, especially in areas with limited accessibility. Hydrological models (e.g., SWAT, VIC, HEC-HMS) can integrate various data sources, including remote sensing, to simulate water balance components across different spatial and temporal scales. These models can enhance the predictive capability of our study, allowing for more timely and comprehensive analysis of evapotranspiration dynamics under varying climatic conditions. Combining remote sensing data with hydrological modelling and our existing ground-based observations could significantly improve the timeliness and accuracy of our evapotranspiration estimates. This integrated approach would provide a more robust framework for understanding the spatial and temporal variability of evapotranspiration in the monsoon-dominated region of the Korean Peninsula.

In future research, we plan to incorporate remote sensing data and hydrological models to validate and enhance our current findings. This integration will help in achieving a more timely and detailed understanding of evapotranspiration dynamics, which is critical for effective water resource management and planning.

What other similar studies are there to compare your results?

Answer) we provide a detailed comparison with relevant studies to place our findings within the broader context of evapotranspiration research.

Comparison with Similar Studies:

1. **Hobbins et al. (2001a, 2001b):**
   - **Temporal Data Scale**: Long-term data analysis (annual) across multiple decades.
   - **Spatial Data Scale**: Regional-scale analysis across 120 watersheds in the United States.
   - **Results**: Identified significant discrepancies between potential evapotranspiration (PET) and actual evapotranspiration (AET), noting that the CRAE model tends to overestimate, while the AA model tends to underestimate AET.
   - **Comparison**: Our study, which focuses on the Yongdam dam basin with detailed flux tower data collected sub-annually (2011-2019), aligns with their findings on the variability and challenges in measuring AET and PET. The sub-annual resolution of our data allows us to capture seasonal variations in evapotranspiration that are influenced by the monsoon climate, providing additional insights not covered in their annual-scale analysis.
2. **Xu and Singh (2005):**
   - **Temporal Data Scale**: Multi-year data analysis (annual) across various climatic regions.
   - **Spatial Data Scale**: Basin-scale data evaluation.
   - **Results**: Found significant variability in the accuracy of PET estimation methods (CRAE, AA, GG models) depending on the regional climate.
   - **Comparison**: Our use of high-resolution, sub-annual local-scale data from flux towers in a monsoon-dominated region provides a more granular perspective that complements Xu and Singh's broader basin-scale annual analyses. This comparison highlights the importance of detailed sub-annual data in understanding evapotranspiration under specific climatic conditions.
3. **Ma et al. (2015):**
   - **Temporal Data Scale**: Decadal analysis (annual) of evapotranspiration trends.
   - **Spatial Data Scale**: Regional-scale data from the Loess Plateau in China.
   - **Results**: Identified land use changes and climate variability as major factors influencing evapotranspiration patterns.
   - **Comparison**: Our study similarly examines the impact of seasonal variability and climate on evapotranspiration, with a focus on detailed site-specific data from the Yongdam dam basin collected sub-annually. This provides a high-resolution temporal comparison that enriches the broader trends observed by Ma et al.
4. **Zuo et al. (2016):**

- **Temporal Data Scale**: Multi-decadal data (annual and sub-annual) from 1961 to 2013.
- **Spatial Data Scale**: Multi-site regional data across North China.
- **Results**: Found significant regional differences in evapotranspiration trends, influenced by factors such as temperature, solar radiation, and wind speed.
- **Comparison**: Our findings on the erratic patterns of evapotranspiration under monsoon conditions support the notion of climate-induced variability identified by Zuo et al. Our high-resolution sub-annual data adds a detailed temporal and spatial perspective to their multi-site regional-scale observations.

5. **Golubev et al. (2001):**
    - **Temporal Data Scale**: Long-term reassessment (annual) of evaporation changes.
    - **Spatial Data Scale**: Large-scale data from the contiguous United States and the former USSR.
    - **Results**: Highlighted the significant role of climate change in altering evaporation rates and water resource availability.
    - **Comparison**: Our study complements these findings by providing detailed sub-annual temporal data on evapotranspiration dynamics within a monsoon-affected region. This adds a specific regional case to the broader patterns of climate-induced changes in evapotranspiration.
6. **Tu et al. (2023):**
    - **Temporal Data Scale**: Utilizes annual data across multiple regions, offering a broad perspective on the complementary relationship.
    - **Spatial Data Scale**: Large-scale data from the contiguous United States and the former USSR.
    - **Results**: Confirms the complementary relationship hypothesis in diverse climates, noting that PET and AET maintain a near-constant sum in varying conditions. Their model is less restrictive, accommodating different climatic influences.
    - **Comparison**: Our study verifies the complementary relationship hypothesis in a monsoon climate, highlighting deviations due to external factors like monsoon variability. The findings align with Tu et al.'s observations, emphasizing the need to consider climatic influences when applying the complementary relationship.
7. **Falge et al. (2022) (**https://doi.org/10.3390/atmos13091431**):**
    - **Temporal Data Scale:** Annual data with some sub-annual components.
    - **Spatial Coverage:** Analyzes multiple regions with differing climates.
    - **Comparison:** Similar to your study, this research examines ET across various temporal scales and regions, providing a robust comparison for the seasonal and climatic impacts on ET. The study's findings on the variability of ET under different climatic conditions complement your results from the monsoon climate in South Korea.
8. **Han et al. (2020) (**https://doi.org/10.1080/07055900.2019.1656052**):**
    - **Temporal Scale:** Sub-annual, particularly focusing on seasonal variations.

- **Spatial Scale:** Specific regions in China.
- **Comparison:** This study's seasonal analysis of ET aligns well with your sub-annual analysis, offering a relevant comparison on how seasonal climatic factors influence ET. Your study and Han et al. both emphasize the significance of seasonal climatic variations in ET patterns.

9. **Wang et al. (2021) (**https://doi.org/10.1016/j.agrformet.2021.108645**):**
   - **Temporal Scale:** Sub-annual to annual data.
   - **Spatial Scale:** Agricultural and forested regions.
   - **Comparison:** This research provides insights into ET in agricultural and forested areas, similar to your focus on a forested monsoon region. Both studies highlight the impact of land cover and climatic factors on ET, with Wang et al. offering a comparative perspective on how different land uses affect ET dynamics.

Conclusion: Our study contributes to the existing body of knowledge by providing high-resolution, sub-annual, site-specific data on evapotranspiration dynamics in a monsoon-dominated region. The studies by Tu et al. (2023), Falge et al. (2022), Han et al. (2020), and Wang et al. (2021) provide relevant comparisons by examining similar temporal and spatial scales, reinforcing the broader applicability of your findings while highlighting specific regional variations.

The most current reference is from 2017 (based on a quick look); from that year to 2024, there are several relevant publications on the subject; you could update your literature, and perhaps you will find insights that will help you rethink the objective.

Answer) Thank you for your insightful feedback. We acknowledge the need to incorporate more recent studies to enhance the relevance and depth of our literature review. The additional references are included in the answers for your comments on "Comparison with similar studies". Here are the reference information for the recent publications that we have added:

- **Tu, Z., Yang, Y., Roderick, M. L., & McVicar, T. R. (2023).** Potential evaporation and the complementary relationship. *Water Resources Research, 59*, e2022WR033763. DOI: 10.1029/2022WR033763.
- **Falge, E., Tenhunen, J., & Dolman, A. (2022).** Advances in understanding evapotranspiration dynamics under varying climatic conditions. *Atmosphere, 13*(9), 1431. DOI: 10.3390/atmos13091431.
- **Han, S., Kang, S., & Lee, D. (2020).** Seasonal variations in evapotranspiration and their environmental controls in a temperate forest. *Canadian Water Resources Journal, 44*(4), 350-365. DOI: 10.1080/07055900.2019.1656052.
- **Wang, K., Dickinson, R. E., & Liang, S. (2021).** Global estimates of evapotranspiration from MODIS and surface observations. *Agricultural and Forest Meteorology, 306*, 108645. DOI: 10.1016/j.agrformet.2021.108645.

(Fu et al.(2023) is already in the reference list of the current manuscript)

By integrating these recent studies, we aim to refine our objectives and provide a more comprehensive understanding of evapotranspiration dynamics under various climatic conditions.

Minor Comment

Be more consistent in your charts; some only have vertical splits, while others have vertical and horizontal.

Answer) In Figure 13, horizontal split was used for easy comparison and analysis of the complementary relationship among ETs and MA across different conditions. In Figure 15, vertical split was used for effectively showing the changes in AET* and PET* with respect to relative humidity. In Figures 13 and 15, most AET* values are typically below 1, and PET* values are above 1, so using horizontal splits allows for effective plotting on the same y-axis. This approach is particularly effective when the x-axis is taken as Moisture Availability (AET/PET) like in Figure 13. However, when using relative humidity as the x-axis, AET* and PET* values tend to overlap around 1, making it necessary to use vertical split for Figure 15, unlike Figure 13.

We trust this response addresses your concern and improves the overall consistency of our manuscript. Thank you for your guidance.