# Response to Reviewer #1

The reviewer's comments are shown in black. Our responses are shown in blue, and the revised text from the manuscript is highlighted in orange.

The authors provide an important and relevant analysis regarding the climatic conditions, particularly temperature and solar radiation, that influence mangrove growth in East Asia. The manuscript utilizes a set of excellent methodologies consisting of remote sensing data (NDVI), climate data from the ERA5 model, and projected data from CMIP6. The authors' attention to not only examine the current dynamics but also project future habitat suitability based on the selected climatic conditions in the regions divided by latitudinal zones complements the significance of their manuscript in the realm of mangrove ecologies and climate solutions. The manuscript is well-organized with proper written content. The techniques are excellent, and the conclusion has been well-formulated based on the results. There are some points that need to be clarified with adequate discussions in order to increase the significance of the MS. The comments are mentioned below for the authors' consideration in publishing the MS.

We sincerely appreciate the reviewer's thoughtful and encouraging evaluation of our manuscript. We are particularly grateful for the recognition of the significance of our study, the robustness of ethe methodologies employed, and the clarity of the presentation. At the same time, we highly value the reviewer's constructive suggestions, which have helped us to further strengthen the manuscript, particularly in clarifying key aspects and enhancing the depth of discussion. In response, we have carefully revised the manuscript to address all comments in detail. Our point-to-point responses to the comments are provided below.

**GENERAL COMMENTS**

The manuscript presents a strong case regarding the explanatory value of solar radiation, which has been, to a certain extent, underestimated in mangrove-related studies. This is certainly one of the main strong points of this manuscript. Nevertheless, the story could be improved by stressing the interaction between solar radiation or solar irradiance and temperatures, specifically on topics like confounding factors.

We sincerely appreciate this insightful comment and the suggestion to further examine the interaction between solar radiation and temperature, as well as potential confounding effects. Indeed, temperature and solar radiation may have the interacted impact on mangroves. In response, we tested the interaction between solar radiation and temperature, as illustrated in the **Fig. A** below. The statistical analysis did not reveal a significant interaction effect. This result suggests that the influences of temperature and solar radiation on mangrove growth may operate largely independently in our study region. One possible explanation is that potential interactions may occur under extreme environmental conditions or at finer temporal scales, which may not be fully captured by the monthly averaged data used in this study. Besides, the bootstrapping results also suggest limited interaction between mean temperature and solar radiation in this study.

Nevertheless, we fully agree that potential interactions and confounding factors deserve more detailed discussion. Accordingly, a paragraph discussing the limitations of this study has been added at the *Discussion* section, where potential interactions among relevant factors are also acknowledged.

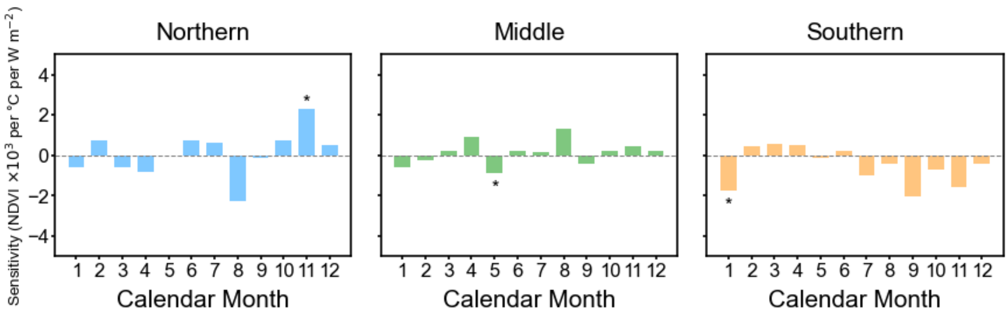


**Figure A.** Interaction effect between mean temperature and solar radiation on mangrove growth.

<u>**Lines 430-432:**</u> Second, the interaction between temperature and solar radiation was not examined in detail. Although the results from linear regression and bootstrapping suggested that their interaction was limited, this relationship warrants further investigation in future studies.

The use of the term "mangrove health" can be considered equivalent to the use of the term NDVI. Though NDVI can be considered a good proxy measure for vegetation greenness, it doesn't measure health per se. The authors can be more precise with their word choice throughout the text by perhaps using "canopy greenness," "photosynthetic activity," or "vegetation dynamics."

Thank you for the suggestions. We agree that the term mangrove health may be too broad when compared with the proxy NDVI. Since NDVI is derived from the spectral reflection of vegetation greenness, we have revised the wording to canopy greenness, which we believe more accurately reflects the measure used in our study.

The exclusion of precipitation as a main variable has been explained (Lines 78–81), but no mention has been made of the possible interaction between precipitation and solar radiation and temperature. For instance, when solar radiation is low, it might be expected that the conditions are associated with high cloudiness and precipitation. Can the correlations with solar radiation possibly be affected by water availability or salinity due to rainfall?

We appreciate the reviewer's insightful comments regarding the possible interactions between precipitation, solar radiation, and temperature. As with most vegetation, water availability is indeed an important factor influencing mangrove growth. However, in intertidal areas, mangrove water availability is affected not only by precipitation but also by tidal dynamics and water uptake capacity. For this reason, precipitation was not included as a main variable in our analysis.

We acknowledge that low solar radiation events could be associated with high precipitation, and such potential interactions were not explicitly tested in this study. Nevertheless, previous studies generally suggest a positive relationship between precipitation and mangrove growth (Feher et al., 2017; Ruan et al., 2022; Simard et al., 2019), as rainfall typically provides water and reduces salinity, which are favorable for mangrove growth. However, discussing the effects of precipitation and salinity inevitably involves the salt tolerance of different species, making it more complex (Luo and Chui, 2020). While high precipitation typically reduces salinity and increases water availability, which are generally favorable for mangrove growth, such conditions are often accompanied by low solar radiation due to increased cloudiness. In our results, solar radiation shows a positive relationship with mangrove growth, suggesting that the adverse impacts of reduced solar radiation may partially offset the positive effects of precipitation and lower salinity, thereby indicating that solar radiation is the primary driver of the observed canopy greenness patterns.


- Feher, L. C., Osland, M. J., Griffith, K. T., Grace, J. B., Howard, R. J., Stagg, C. L., Enwright, N. M., Krauss, K. W., Gabler, C. A., Day, R. H., and Rogers, K.: Linear and nonlinear effects of temperature and precipitation on ecosystem properties in tidal saline wetlands, Ecosphere, 8, e01956, https://doi.org/10.1002/ecs2.1956, 2017.

- Ruan, L., Yan, M., Zhang, L., Fan, X., and Yang, H.: Spatial-temporal NDVI pattern of global mangroves: A growing trend during 2000–2018, Science of The Total Environment, 844, 157075, https://doi.org/10.1016/j.scitotenv.2022.157075, 2022.

- Simard, M., Fatoyinbo, L., Smetanka, C., Rivera-Monroy, V. H., Castañeda-Moya, E., Thomas, N., and Van der Stocken, T.: Mangrove canopy height globally related to precipitation, temperature and cyclone frequency, Nature Geosci, 12, 40–45, https://doi.org/10.1038/s41561-018-0279-1, 2019.

- Luo, S. and Chui, T. F. M.: Annual variations in regional mangrove cover in southern China and potential macro- climatic and hydrological indicators, Ecological Indicators, 110, 105927, https://doi.org/10.1016/j.ecolind.2019.105927, 2020.


The difference between the three regions along the latitudinal range (Northern, Middle, Southern) is an essential part of the MS. This explanation is supported because it is related to climate factors as well as species. It would have been beneficial if there were more specific climatic factors regarding average winter temperatures and precipitation levels cited regarding each of these regions.

We are grateful for this suggestion. The climatology of temperature and solar radiation has been included in the supplementary materials, see Fig. S1. Our classification for the three zones was based on climatic conditions and dominant species composition. Following the reviewer's suggestion, we have also included the average winter (DJF) temperature for each zone, as temperature is one of the most important factors distinguishing these three zones and plays a key role in shaping mangrove species distribution. This information has been added in the revised manuscript (Lines 79-83).

**Lines 79-83:** Based on climatic conditions and dominant species composition across the natural latitudinal range of mangroves in this region (Zhao et al., 2024a) **(**Table S2), mangrove habitats were further classified into three distinct zones (northern, middle, and southern) for comparison**.** These zones exhibit clear thermal gradients, with mean winter temperatures of approximately 14.5°C, 16.6°C, and 19.1°C in the northern, middle, and southern zones, respectively.

The title is good, but perhaps a small adjustment can be made. "Climate extremes" is employed, yet the work examines mostly the lagged and anomalous aspects rather than extreme ones (such as the lowest 10%). One wonders if maybe the title "Climatic Controls and Extreme Events." would not be more universally descriptive. just my suggestion, not too tied to it.

We sincerely thank the reviewer for the thoughtful suggestion regarding the title. We agree that our analyses focus more on lagged responses and anomalous fluctuations (based on ±1 standard deviation) rather than extreme cases such as the lowest decile. At the same time, we feel that the current title appropriately reflects the scope and emphasis of the manuscript. With this consideration, we would respectfully prefer to retain the original title.

**Abstract**

The phrase "positive relations with temperature and solar radiation, particularly in cumulative anomalies on seasonal time scales" is a bit vague. It would be stronger to write the key finding more precisely, e.g., "mangrove growth is strongly influenced by preceding winter temperatures and seasonal solar radiation, with distinct lagged responses across latitudinal zones."

The mention of "low solar radiation events associated with aerosol emissions" is a key conclusion. It would be beneficial to briefly state the scenario under which this is most pronounced (i.e., the high-emission SSP3-7.0 scenario) to add specificity and highlight the policy relevance.

The final sentence is good but could be more direct. For example: "This study highlights that both temperature-driven opportunities and solar radiation constraints must be integrated into practical planning for mangrove-based climate solutions. The abstract fails to point out the innovative approach to methodology presented in the study, which uses bootstrapping to investigate the lagged effects, as well as unique events. This represents an area of significant methodological strength, which should at least be referred to in the abstract to draw the reader's attention to the statistical aspect.

The abstract focused on East Asia, which is actually accurate. Nevertheless, it does not contain information regarding the regional specification of East Asia that was considered in the MS (southern Japan and southern China), which helps give additional context.

We appreciate the reviewer's detailed and constructive suggestions regarding the abstract. These comments have significantly enhanced the clarity and effectiveness of the abstract, which serves as a concise summary of the study and plays a critical role in communicating its key contributions to the reader**.** We fully agree that it is important to convey our key findings clearly and directly, to point out the innovation, and to emphasize the broader significance of our research. Specifically, we have made detailed revisions in response to the reviewer's valuable suggestion:

(1) Included a statement highlighting the methodological innovation of using bootstrapping to investigate extreme events and lag effect.

**Lines 17-18:** A bootstrapping-based statistical framework was applied to identify vegetation responses associated with extreme climate events and quantify lagged climatic effects.

(2) Rephrased the description of the relationships with temperature and solar radiation to make the findings more explicit.

**Lines 18-20:** We found East Asian mangrove growth was strongly influenced by preceding winter temperature and seasonal solar radiation, with distinct lagged responses on seasonal time scales across latitudinal zones.

(3) Specified the regional focus to provide clearer context.

**Lines 20-22:** These findings were extrapolated to future projections by the Earth system modelling to explore not only existing mangroves but also potential habitats in East Asia, particularly China, South Korea and Japan.

(4) Slightly added details on the scenario under which low solar radiation events associated with aerosol emissions are most pronounced.

**Lines 22-24:** While shifts in wintertime isotherms indicate northward expansion of mangroves under global warming, low solar radiation events associated with aerosol emissions under the high-emission SSP3-7.0 scenario could remain as a limiting factor for their growth.

(5) Revised the concluding sentence to be more direct and policy-relevant.

**Lines 24-26:** This study highlights that both temperature-driven opportunities and solar radiation constraints should be integrated into practical planning for future conservation, restoration, and migration as nature-based climate solutions.

**Methods**

The reference to Table S2 for the list of CMIP6 models appears to be a typo; the list is in Table S1. Please correct this. (The text says Table S2, but the supplementary file has the list in Table S1).

We appreciate the reviewer's careful observation. The reference to Table S2 for the list of CMIP6 models was indeed a typographical error. We sincerely apologize for it. This has now been corrected to Table S1 in the revised manuscript to ensure consistency with the supplementary materials. We have also carefully checked all the table and figure reference throughout the manuscript to avoid similar mistakes.

**Major Point:** The selection criteria for mangrove pixels (≥60% canopy coverage from 1996–2020) is crucial. Why was the period 1996-2020 chosen for canopy stability when the primary analysis period is 2001-2022? Please clarify the rationale for this specific timeframe and the use of the MCD12Q1 product for a coverage threshold, as it is a land cover classification product, not a direct canopy density product.

We thank the reviewer for raising this important point. The mangrove distribution data was obtained from Global Mangrove Watch 3.0 (https://zenodo.org/records/6894273), which provides mangrove maps for the years 1996, 2007–2010, and 2015–2020. Due to these temporal limitations, we defined the intersection of mangrove presence between 1996 and 2020 as the "stable mangrove region" to be used in our analysis covering 2001–2022. This approach ensures that only areas consistently identified as mangroves across the available dataset are included, thereby minimizing potential misclassification or short-term fluctuations, although the analysis remains constrained by the temporal coverage of the dataset. We have revised our manuscript to clarify this point in Lines 106-107.

**Lines 106-107:** This period was selected based on the temporal coverage of the mangrove dataset, and to provide a sufficiently long baseline overlapping with the study period.

Regarding the ≥60% threshold, this criterion is based on the MCD12Q1 land cover classification product, which assigns a dominant land cover type to each cell when it occupies more than 60% of the area (See Page 7 of the user guide of MCD12Q1 at https://lpdaac.usgs.gov/documents/101/MCD12_User_Guide_V6.pdf). In our study, we applied this rule to MOD13Q1 cells: if mangroves accounted for more than 60% of a cell, we assumed that the NDVI signal was representative of mangrove vegetation and included the cell in the analysis. Cells with less than 60% mangrove coverage were excluded to avoid contamination from other land cover types. We have clarified this point in our manuscript (Lines 107-108).

**Lines 107-108:** The coverage criterion aligns with protocols from previous related research (Zhang et al., 2024), with the 60% coverage threshold consistent with the classification scheme of the MODIS Land Cover Type Yearly Global product (MCD12Q1) (Sulla-Menashe and Friedl, 2018).

**Major Points:** There is a major concern regarding the methodology because of the discrepancy in spatial resolutions. While NDVI has a spatial resolution of 250m x 250m, the spatial resolution of the climate variables provided in the ERA5 dataset is 0.25° x 0.25° (approx. 27.75 km x 27.75 km). There may be thousands of vegetation index pixels within a climate cell encompassing a diverse range of vegetation categories (water bodies, urban landscapes, agricultural lands). Fetching climate information for a 'mangrove formation' without the need for any index calculation may add noise and might reduce the precision of the resulting relationship. Kindly provide a thorough explanation of this choice and the implications of spatial mismatch between variables.

We thank the reviewer for raising this important point. We acknowledge the reviewer's concern regarding the spatial resolution mismatch between NDVI and ERA5 climate variables, which is indeed a methodological challenge and may introduce some uncertainties into our analysis.

We evaluated the feasibility of using higher-resolution climate datasets, including ERA5-Land, WorldClim, TerraClimate, and CHELSA. While these datasets offer finer spatial resolution, their application in coastal environments is not straightforward. For example, ERA5-Land is limited to land surface conditions and does not fully capture variability at the land–sea interface, where many mangrove systems are located. Other datasets, such as WorldClim, TerraClimate, and CHELSA, are largely based on statistical interpolation or downscaling, which may introduce additional uncertainties in representing consistent atmospheric conditions.

In this context, ERA5 provides a balanced dataset with globally consistent, spatially continuous, and temporally coherent climate information, making it well suited for large-scale analyses of climate–vegetation relationships. While its relatively coarse spatial resolution may smooth local variability, this reflects an inherent trade-off in macro-scale ecological studies, where spatial detail and data completeness must be carefully balanced.

To better reflect this consideration, we have expanded the discussion in the revised manuscript to explicitly address the implications of this spatial mismatch (Lines 424–428).

**Lines 426-430:** Despite these findings, several limitations should be acknowledged.

First, because mangroves are typically distributed in narrow and fragmented coastal zones, the mismatch in spatial resolution between the NDVI and climate datasets may introduce uncertainties. As a result, the climate data may not fully capture the local climatic conditions experienced by mangroves at the pixel level. Nevertheless, given the currently available global climate datasets, ERA5 provides a reasonable balance between spatial coverage, temporal consistency, and data reliability.

For the forest extraction, a 2 km buffer around undisturbed mangroves was used. What is the justification for this specific buffer distance? How sensitive are the comparative results to the choice of this buffer size?

We sincerely appreciate the reviewer’s thoughtful and constructive comment regarding the choice of buffer distance. This is an important point that helped us clarify the rationale behind our methodological design.

The choice of the length of buffer was based on following considerations. Our primary objective was to select a buffer size that would produce a forest reference region comparable in spatial scale to the mangrove region. Mangrove stands in China are generally small in spatial extent, with even the larger patches typically spanning only a few kilometers in width (considering that mangroves primarily grow along coastal zones, we only considered the width of mangrove communities in the land–sea direction). For example, Jia et al. (2018) provides detailed spatial distributions of mangroves in several nature reserves in China, which represent the largest mangrove habitats in the country. Most reserves have widths smaller than approximately 2 km, except for the Zhanjiang Nature Reserve—the largest in China—where the width may reach up to 5 km (see **Fig. B**). Thus, a 2 km buffer provides a reasonable reference distance that captures adjacent forest areas comparable to the scale of mangrove communities.

As the reviewer noted, the choice of buffer size may influence the results, and we agree that evaluating this sensitivity would be valuable. However, given the relatively small spatial extent of mangrove patches in China, the plausible range of buffer sizes is inherently limited. In addition, the climate variables used in this study were derived from ERA5 with a spatial resolution of 0.25° (approximately 27.75 km). At this spatial scale, variations in buffer size within a few kilometers would likely fall within the same climate grid cell, making it difficult to obtain meaningful differences in a sensitivity test. Therefore, in the current study we did not conduct a formal sensitivity analysis of buffer size due to these limitations. Nevertheless, such an analysis would be worthwhile to explore in future studies using higher-resolution climate datasets.

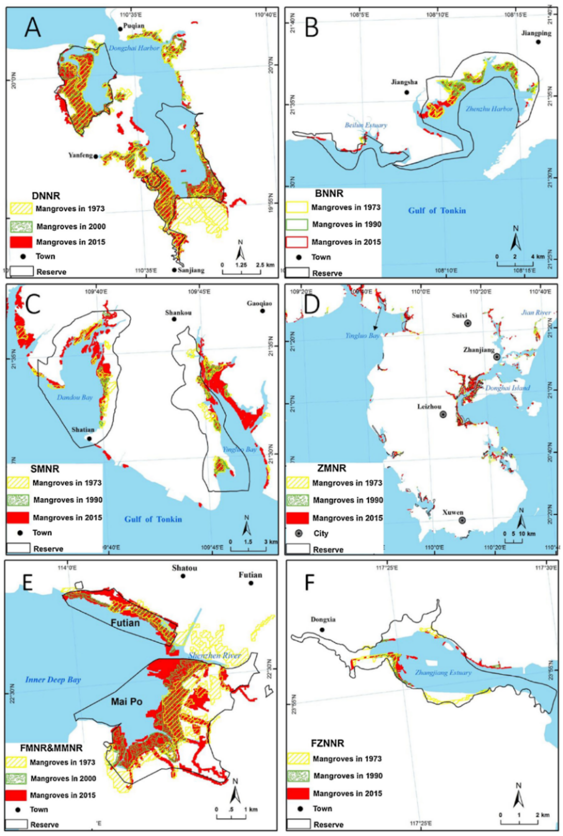


**Figure B.** Dynamics of mangrove forests along the coast of national nature reserves in the different years in China (Jia et al., 2018).

- Jia, M., Wang, Z., Zhang, Y., Mao, D., and Wang, C.: Monitoring loss and recovery of mangrove forests during 42 years: The achievements of mangrove conservation in China, International Journal of Applied Earth Observation and Geoinformation, 73, 535–545, https://doi.org/10.1016/j.jag.2018.07.025, 2018.

The analysis uses "monthly detrended anomalies." Please specify the method used for detrending (e.g., linear regression, polynomial fit) and how the anomalies were calculated (e.g., deviation from the monthly long-term mean).

We thank the reviewer for raising this point and sincerely apologize for the lack of clarity in the description of the detrending method in the original manuscript. The detrending was performed using a linear regression approach. Monthly anomalies were then calculated as deviations from the corresponding long-term monthly mean, based on the period 2001–2022. The description of this method has been clarified in the revised manuscript (Lines 121–123).

**Lines 121-123:** The monthly anomalies, calculated as deviations from the corresponding long-term monthly mean for 2001–2022, were detrended using a linear regression approach.

The moving windows in the lag-effect test are specified, such as "MAM NDVI vs. FMA climate factors" when referring to a 1-month lag. This is clear. However, it is also stated that "boreal seasonal composites" are used in the analysis. Could this be further clarified by stating whether the climate data were first averaged into 3-month blocks, for example FMA, and correlated with the seasonal NDVI, MAM, or if the analysis has used monthly data with lagged months?

We appreciate the reviewer for this clarification request. In our analysis, the climate data were first averaged into three-month seasonal composites (e.g., FMA, MAM), and these seasonal blocks were then correlated with the corresponding seasonal NDVI values. Thus, the lag-effect tests were conducted using seasonally aggregated climate variables rather than monthly data. We have revised the manuscript to clarify this methodological detail (Lines 138–139).

**Lines 138-139:** In all cases, both NDVI and climate variables were firstly averaged into the three-month seasonal composites.

The critical temperature threshold of 10°C in DJF is adopted from a study in Fujian Province (Wang et al., 2022). While this is a reasonable starting point, this threshold may vary by species and latitude. Please discuss the potential limitations of applying a single threshold derived from one part of the study region (the northern edge) to project expansion across all of East Asia, including Japan and South Korea, which may have different local conditions and species assemblages.

We are deeply grateful for this valuable suggestion. We acknowledge that using a single temperature threshold has its limitations. While temperature is the primary factor controlling mangrove distribution globally, other factors can also influence their presence. Our projections therefore represent only the potential habitat from a temperature perspective—i.e., areas where temperatures are suitable for mangrove survival. Actual migration and establishment, however, also depend on local conditions such as rainfall, tidal dynamics, topography, and hydrological regimes (Duke et al., 1998; Raw et al., 2019, 2023).

Indeed, applying a single threshold derived from one region may have limitations, as local conditions and species assemblages may vary across East Asia. Mangrove species are highly sensitive to temperature, and their diversity has been shown to decrease with increasing latitude in southern China (Yang et al., 2017). In our study, we adopted the critical winter threshold of 10 °C (DJF) from Wang et al. (2022), based on the cold tolerance of *Kandelia obovata*. This species represents the northernmost edge of mangrove distribution in East Asia and is the only true mangrove that persists in the edge of the northern zone due to its relatively high cold tolerance (Chen et al., 2017; Zhao et al., 2024b). *K. obovata* is also one of the dominant mangrove species in Japan (Analuddin et al., 2015; Khan and Kabir, 2017), and previous research has suggested that it is likely to be the first species to establish along the southern coast of South Korea once mean winter surface temperatures reach approximately 10.4 °C (Nam et al., 2024). Therefore, our projections are based on thresholds derived from the northern edge of the current distribution, reflecting the ecological limits of *K. obovata* as the most cold-tolerant true mangrove species in the region.

We have revised in our manuscript to discuss the potential limitations in the *Discussion* section (Lines 360-369).

**Lines 360-369:** Our projections suggest the potential for poleward expansion of mangroves, consistent with previous studies. Among mangrove species, *K. obovata*, which exhibits the highest cold tolerance, is a dominant species at the northern distribution limits of mangroves in both China and Japan (Analuddin et al., 2015; Chen et al., 2017; Khan and Kabir, 2017), and thus could serve as a representative indicator species for range expansion. In southeastern China, the natural northern limits of mangroves in Fujian Province have been projected to shift northward under future climate scenarios (Wang et al., 2022). Previous studies have further suggested that *K. obovata* could potentially establish along the southern coast of South Korea when the mean surface temperatures reach 10.4˚C in winter (Nam et al., 2024). It should be noted, however, that using a single winter temperature threshold represents only a simplified estimate of potential mangrove expansion. Successful establishment also depends on other local conditions, such as rainfall, tidal dynamics, topography, and hydrological conditions (Duke et al., 1998; Raw et al., 2019, 2023).


- Duke, N., Ball, M., and Ellison, J.: Factors influencing biodiversity and distributional gradients in mangroves, Global Ecology & Biogeography Letters, 7, 27–47, https://doi.org/10.1111/j.1466-8238.1998.00269.x, 1998.

- Raw, J. L., Godbold, J. A., van Niekerk, L., and Adams, J. B.: Drivers of mangrove distribution at the high-energy, wave-dominated, southern African range limit, Estuarine, Coastal and Shelf Science, 226, 106296, https://doi.org/10.1016/j.ecss.2019.106296, 2019.

- Raw, J. L., Van der Stocken, T., Carroll, D., Harris, L. R., Rajkaran, A., Van Niekerk, L., and Adams, J. B.: Dispersal and coastal geomorphology limit potential for mangrove range expansion under climate change, Journal of Ecology, 111, 139–155, https://doi.org/10.1111/1365-2745.14020, 2023.

- Wang, Y., Dong, P., Hu, W., Chen, G., Zhang, D., Chen, B., and Lei, G.: Modeling the Climate Suitability of Northernmost Mangroves in China under Climate Change Scenarios, Forests, 13, 64, https://doi.org/10.3390/f13010064, 2022.

- Chen, L., Wang, W., Li, Q. Q., Zhang, Y., Yang, S., Osland, M. J., Huang, J., and Peng, C.: Mangrove species’ responses to winter air temperature extremes in China, Ecosphere, 8, e01865, https://doi.org/10.1002/ecs2.1865, 2017.

- Zhao, C., Jia, M., Zhang, R., Wang, Z., Ren, C., Mao, D., and Wang, Y.: Mangrove species mapping in coastal China using synthesized Sentinel-2 high-separability images, Remote Sensing of Environment, 307, 114151, https://doi.org/10.1016/j.rse.2024.114151, 2024b.

- Analuddin, K., Septiana, A., Sharma, S., and Hagihara, A.: Phenological Traits of Mangrove Kandelia obovata Grown in Manko Wetland, Okinawa Island, Japan, International Journal of Sustainable Tropical Agricultural Sciences, 2, 89–96, 2015.

- Bunting, P., Rosenqvist, A., Hilarides, L., Lucas, R., Thomas, N., Tadono, T., Worthington, T., Spalding, M., Murray, N., and Rebelo, L.-M.: Global Mangrove Watch (1996 - 2020) Version 3.0 Dataset (3.0), https://doi.org/10.5281/zenodo.6894273, 2022.

- Khan, M. N. and Kabir, M.: Ecology of Kandelia obovata (S., L.) Yong: A Fast-Growing Mangrove in Okinawa, Japan, 287–301, https://doi.org/10.1007/978-4-431-56481-2_18, 2017.


Low solar radiation events are defined as values below -1 standard deviation of the long-term mean. This is a standard approach. However, is this based on the mean of the entire historical period (1940-2014) or a moving baseline? Clarifying this is important for interpreting the trend analysis in Figure 4.

> Thank you for this question. The definition of low solar radiation events was based on the mean and standard deviation calculated from the observational period 2001–2022, rather than from the entire historical record or a moving baseline. These results were then used as a reference in the trend analysis presented in Figure 4. We have modified in our revised manuscript to clarity this point (Lines 151-153).
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> **Lines 151-153:** We then calculated the number of low solar radiation events in that season at the monthly scale, defining events as values exceeding –1 SD of the long-term mean (based on the period of 2001-2022), and expressed the frequency as rates per decade.

In projecting future potential habitats, the method identifies "current non-mangrove shorelines." Please provide more detail on how these shorelines were defined and extracted. Was a specific coastal dataset used? What criteria (e.g., elevation, slope, proximity to the sea) were applied to ensure these are potentially viable areas for mangrove colonization, beyond just meeting the temperature threshold?

> We thank the reviewer for this insightful comment. In our analysis, “current non-mangrove shorelines” were identified by first screening areas where the mean DJF temperature during the observational period (2001–2022) was below 10 °C, but where future projections under SSP1-2.6 and SSP3-7.0 indicate values exceeding

10 °C. This ensured that only locations currently unsuitable due to low winter temperatures, but potentially viable under future warming, were considered. We further overlapped the national boundary datasets of China, Japan, and South Korea to delineate the potential region. This dataset is from Resource and Environmental Science Data Platform (https://www.resdc.cn/data.aspx?DATAID=205). Within these boundaries, shorelines were approximated based on proximity to the coast, without applying additional geomorphological criteria such as elevation, slope, or tidal influence.

We acknowledge that this approach may introduce limitations, as it does not incorporate high-resolution coastline data or local environmental factors that could affect mangrove colonization. Nevertheless, given the relatively coarse resolution of the climate dataset, the use of national boundaries provides sufficient accuracy for regional-scale projections across East Asia. Future work could refine this approach by integrating dedicated coastal datasets and geomorphological variables to improve the spatial precision of identifying potentially viable mangrove habitats.

**Results**

The linear regression analysis (Fig. 2a) shows no consistent NDVI response to temperature. This is a surprising but interesting result. The authors should discuss this more. Does this suggest that over the interannual scale, temperature variations within the established thermal niche are not a primary driver of productivity, whereas extreme temperature events (analyzed later) are? This distinction is important.

We thank the reviewer for raising this highly insightful point that has helped us better interpret and contextualize this result. Indeed, the result of linear regression was unexpected. Since mangrove distribution is largely dependent on temperature, it would be reasonable to anticipate a strong linear relationship. However, our analysis did not reveal such a pattern. This indicates that temperature variations within the normal fluctuation range do not significantly affect mangrove greenness, whereas extreme conditions and deviations beyond the typical variability (±1 SD) appear to exert a notable influence. This finding is consistent with previous studies, which suggest that the proportion of hot days is a key factor influencing mangrove area (Luo and Chui, 2020). We note that NDVI (greenness) is related to, but not equivalent to, productivity. In light of the reviewer's valuable suggestion, we have carefully revised and expanded the discussion in the manuscript to better clarify this distinction and its implications (see Lines 356–358).

**Lines 356-358:** Overall, our results suggest that temperature variations within the normal thermal niche have limited influence on mangrove greenness, whereas extreme temperature events may exert more pronounced effects. This finding is consistent with previous studies suggesting that the proportion of hot days is a key factor influencing mangrove area (Luo and Chui, 2020).

The finding of a "predominantly positive NDVI responses to solar radiation in the middle and southern zones" (Fig. 2b) is a central result. The authors should highlight the novelty of this finding more strongly, as they correctly state that solar radiation is often considered secondary in mangrove studies.

We sincerely appreciate the reviewer's insightful and constructive comment. We are grateful for the suggestion to more clearly highlight the novelty of this result. We agree that the finding of predominantly positive NDVI responses to solar radiation in the middle and southern zones is a central and novel result, particularly given that solar radiation has often been considered secondary in mangrove studies. Following the reviewer's suggestion, we have revised the manuscript to emphasize the novelty and importance of this finding more strongly (see Lines 197–198), and have expanded the Discussion to further elaborate on the role of solar radiation (see 4.2 Solar radiation as a key regulator of mangrove greenness).

**Lines 197-198:** In contrast, a predominantly positive NDVI response to solar radiation emerges as a notable and consistent pattern in the middle and southern zones (Fig. 2b).

The results show that high MAM NDVI in the northern zone is linked to warmer preceding winter temperatures (Fig. 3a). This is a clear and well-supported finding. The authors should emphasize this as strong evidence for the legacy effect of winter conditions on the spring growth of temperate-zone mangroves.

We are grateful for this specific comment. We agree that the finding of high MAM NDVI in the northern zone linked to warmer preceding winter temperatures provides strong evidence for the legacy effect. We have revised the manuscript to emphasize this point more clearly (see Lines 222–226).

**Lines 222-226:** Our results indicate that NDVI during MAM tends to strongly depend on preceding winter temperatures (Fig. 3a, c), providing clear evidence for a legacy effect of winter thermal conditions on subsequent spring mangrove growth. This pattern is particularly evident in the northern zone, where high MAM NDVI cases are significantly associated with temperature anomalies occurring simultaneously and 1–3 months prior (Fig. 3a). In contrast, low MAM NDVI cases in the middle and southern zones also demonstrate lagged temperature effects (Fig. 3c).

The results show an increasing trend of low-radiation events under SSP3-7.0, despite other studies showing a general increase in solar radiation in the region. This is a very interesting paradox. The authors should elaborate on this. Does it imply an increase in the "variability" of solar radiation, with more frequent extreme low events even if the mean increases? This would be a significant finding for ecosystem resilience.

We deeply appreciate for this important comment. We realize that our previous wording may have caused confusion regarding the projected changes in solar radiation. Under SSP3-7.0, the overall solar radiation across China is projected to decrease. However, there are clear regional differences: larger areas in the north and west show a decreasing trend, while Southeast China exhibits a significant increase, and some coastal areas in the southeast display only weak increases or even slight decreases. This indicates that the overall trend may differ from local patterns, highlighting the importance of considering regional variations in the model outputs, as they have implications for future mangrove planting and conservation.

We also appreciate the reviewer's thought-provoking comment regarding potential changes in the variability of solar radiation. We agree that this may indicate an increase in variability of solar radiation under SSP3-7.0 conditions, with more frequent low-radiation events despite changes in the mean state. We are grateful for this valuable interpretation, which highlights an important implication for ecosystem resilience. Accordingly, we have added a brief discussion to further elaborate on these aspects in the revised manuscript (see Lines 368–373).

**Lines 371-376:** This is particularly notable given previous studies reporting a general increase in surface solar radiation over southeastern China under the same scenario (Niu et al., 2023). However, such increasing trend is not uniform across all regions; in some localized areas, this signal is weak or even reversed. This highlights the importance of considering local variations in solar radiation in addition to large-scale trends. Furthermore, our results may indicate an increase in variability of solar radiation under SSP3-7.0 conditions. Such changes, beyond shifts in the mean state, may pose challenges for ecosystem resilience.

The analysis in Figure 5 suggests that in potential expansion zones, temperature thresholds will be frequently exceeded, while extreme low-radiation events will be limited, even under SSP3-7.0. This seems to slightly contradict the earlier finding that low-radiation events will be an increasing risk. Please clarify this. Does this mean the risk is primarily for "existing" mangrove zones, but not for the "newly suitable" northern zones? This distinction needs to be made explicit.

We thank the reviewer for this important comment. We agree that the apparent discrepancy requires clarification. Our results indicate that under SSP3-7.0, the increasing risk of low-radiation events is mainly relevant for the existing mangrove zones, where such events are projected to become more frequent. In contrast, in the potential expansion zones, low-radiation events remain limited, with no apparent shift in their distribution evident in the histogram analysis. We have revised the manuscript to make this distinction explicit (see Lines 391–394).

**Lines 394-397:** Notably, the increasing risk of low-solar-radiation events appears to be concentrated within existing mangrove regions rather than the newly suitable northern expansion zones. Consequently, under the SSP3-7.0 scenario, the projected rise in temperature is likely to support mangrove range expansion and enhance overall growth potential, although sporadic low solar radiation events may still constrain productivity in some areas.

## Response to Reviewer #2

The reviewer's comments are shown in black. Our responses are shown in blue, and the revised text from the manuscript is highlighted in orange. Deleted and newly added text are indicated in purple.

The overall novelty of this manuscript is limited. The writing is repetitive and wordy, and the structure is not well organized. The functions of the Results, Discussion, and Conclusion sections are not clearly separated. Their content overlaps, and material often appears in inappropriate sections, which weakens the logical flow and readability of the manuscript. Many paragraphs are too long and include several main points without clear topic sentences or structure. This makes it difficult for readers to identify the key information. Therefore, substantial revision is necessary before the manuscript can be considered for acceptance.

Regarding the reviewer's overarching concern about the limited novelty of the manuscript, we are deeply grateful to the reviewer for raising this critical point. We realize that our initial manuscript failed to adequately foreground our unique scientific contributions, which understandably led to this impression. We completely agree that a manuscript must offer clear advancements to the field. Prompted by your stringent critique, we have explicitly sharpened the articulation of our novelty in the revised *Introduction* and *Discussion* sections.

Specifically, our study provides three novel contributions to the realm of mangrove ecology and climate responses:

**1. Quantitative Elevation of Solar Radiation:** While existing literature predominantly fixates on temperature as the primary driver, our empirical findings quantitatively elevate the role of solar radiation—a dynamic frequently underestimated—as a persistent and critical driver of mangrove canopy greenness across latitudinal zones.

**2. Methodological Framework:** We introduce a robust bootstrapping-based statistical framework that moves beyond mean-state correlations to specifically identify vegetation responses to extreme climate anomalies and quantify delayed (lagged) climatic effects on seasonal time scales.

**3. Identifying a Future Ecological Paradox:** By integrating our empirical thresholds with CMIP6 projections, we identify a unique ecological trade-off under the high-emission SSP3-7.0 scenario: while warming temperatures may facilitate poleward expansion, increased aerosol emissions will lead to low solar radiation events, creating a new, critical limiting factor for future mangrove habitats.

We believe that by making these scientific contributions explicit, the revised manuscript now possesses the required academic depth and novelty. We thank the reviewer for pushing us to clarify the core value of our research.

We also appreciate the reviewer for the thorough and critical evaluation of our writing, which provides us the opportunity to improve the presentation of our work. The comments have prompted us to critically reflect on the structure, clarity, and overall presentation of our work.

Following the excellent structural guidance, we have fundamentally overhauled the manuscript. Specifically, we have:

**1. Fundamentally reorganized the manuscript structure** to clearly distinguish between *Results*, *Discussion*, and *Conclusion* sections, thereby reducing overlap and ensuring that each section fulfills its intended function.

**2. Systematically reviewed and extensively revised paragraphs** throughout the manuscript to reduce length, simplify complex sentences, and ensure that each paragraph conveys a single main point with a clear topic sentence.

**3. Carefully eliminated redundant expressions and repetitive content**, especially those highlighted by the reviewer, to improve conciseness and enhance readability.

**4. Substantially enhanced the logical flow**, particularly in the *Introduction* and *Discussion* sections, to ensure that the progression of ideas is coherent, the research rationale is clear, and the conclusions are well supported by the results.

**5. Undertaken a rigorous, line-by-line language refinement**, improving academic precision, clarity, and consistency in terminology and scientific expressions throughout the manuscript.

We believe that these revisions have improved the readability, logical structure, and overall presentation of the manuscript, addressing the reviewer's concerns regarding clarity, organization, and novelty. We have carefully updated the manuscript accordingly and provide detailed point-by-point responses to each comment below.

1. The overall logic of the Introduction is unclear. It is lengthy and lacks focus. For example, the first paragraph contains too much information. It should be divided into several shorter paragraphs, with each paragraph focusing on one main point, rather than combining multiple research backgrounds and motivations in one block of text.

We are grateful for this constructive suggestion, which has immensely clarified the narrative trajectory of our manuscript. In response, we have substantially refined the *Introduction* by reorganizing it into shorter, more focused paragraphs, each centered on a single main idea. This revision results in a more coherent progression and allows the overall storyline to unfold more clearly and naturally. Please see the revised manuscript for the *Introduction* section.

2. The explanation given in Line 65 is not sufficient to justify the exclusion of precipitation as an explanatory variable. Since mangroves are typical coastal ecosystems, the authors should also consider whether marine-related climate variables, such as sea surface temperature, may influence mangrove NDVI.

We appreciate this important comment and agree with the reviewer's opinions that hydrological factors, including precipitation, can play a role in shaping mangrove dynamics. We acknowledge that our previous explanation was not sufficiently clear and have revised the manuscript accordingly.

In many terrestrial ecosystems, precipitation is commonly used as a proxy for water availability. However, this assumption is less applicable to mangrove ecosystems. Mangroves typically occur in water-abundant intertidal environments where water is readily available but largely saline, and freshwater availability is strongly influenced by additional hydrological processes such as tidal exchange and surface runoff. Moreover, mangroves possess specialized freshwater acquisition mechanisms, including root uptake from saline environments and foliar water absorption. Consequently, precipitation alone may not adequately represent the actual water availability experienced by mangroves. Therefore, this study focuses on temperature and solar radiation as the primary climatic variables influencing mangrove vegetation dynamics. The relevant explanation has been revised in the manuscript (Lines 61–68).

**Lines 61-68:** In many terrestrial ecosystems, precipitation is commonly used as a proxy for water availability. However, it is not included as an explanatory variable in this study for the following reasons. Compared with most terrestrial ecosystems, mangroves typically occur in water-abundant intertidal environments where water is readily available but largely saline. Under such conditions, the availability of usable freshwater for mangroves is regulated by complex hydrological and physiological processes rather than precipitation alone. Mangroves therefore rely on specialized freshwater acquisition mechanisms, including root uptake from a saline environment and foliar water absorption (Reef and Lovelock, 2015), which means that precipitation alone may not adequately represent water availability for mangroves. Therefore, this study focuses on temperature and solar radiation as the primary climatic variables influencing mangrove vegetation dynamics.

We thank for the reviewer's insightful comment and agree with the reviewer's astute observation that mangrove ecosystems can be influenced by a range of marine-related environmental variables, including sea surface temperature, sea surface salinity, and other oceanographic conditions. Incorporating these factors would indeed provide a more comprehensive understanding of mangrove dynamics. In this study, we intentionally focus on temperature and solar radiation, as these are commonly used to explain vegetation dynamics in terrestrial forest ecosystems and allow for a more direct comparison between terrestrial forests and intertidal mangroves. Marine-related variables, while potentially important, are therefore not explicitly considered in the current framework. We have acknowledged it as a limitation for our study in the *Limitations* subsection (Lines 430–435).

**Lines 432-438:** Third, mangrove growth may also be influenced by additional climatic and environmental factors, such as precipitation, sea surface temperature, sea surface salinity, local topographic conditions, and tidal dynamics. In this study, however, we focused on temperature and solar radiation as fundamental climatic drivers that are applicable to both terrestrial forest ecosystems and intertidal mangrove systems. This does not imply that other factors are unimportant; instead, incorporating these additional environmental variables may provide a more comprehensive understanding of the drivers of mangrove vegetation dynamics and should be explored in future research.

3. The Methods section should clearly state the unified spatial resolution of the datasets and describe the processing steps. This information is currently not clear.

We appreciate the reviewer for pointing out this critical oversight, which affected the clarity and reproducibility of our methodology. We acknowledge that the spatial resolution used in the analyses was not clearly stated in the previous manuscript, therefore we made modification based on the reviewer's comment.

In the observational analyses, which involved NDVI and ERA5 data, the analysis was conducted at the spatial resolution of the NDVI dataset (250 m). ERA5 variables were interpolated to this resolution to match the NDVI data at the mangrove pixel level. For the future projections, the analysis was conducted at a spatial resolution of 0.25°×0.25°. This coarser resolution was adopted because the projections were intended to capture climatic conditions at a broader spatial scale rather than match the mangrove pixel level.

To address this issue, we have revised the manuscript accordingly, and the information of the datasets and processing steps is now fully documented in Section 2.2 (Lines 99–102).

**Lines 99-102:** To ensure spatial consistency for observational analyses, ERA5 climate variables were interpolated to match the spatial resolution of the NDVI dataset (250 m). Future climate projections from CMIP6 were analyzed at a spatial resolution of 0.25°×0.25°, consistent with the native resolution of the reanalysis data, as the projections were used to capture climatic conditions at a broader spatial scale rather than mangrove pixel level.

4. Lines 130 to 140 read more like results rather than methods and should be moved to the Results section.

We deeply appreciate this comment, which helped clarify the distinction between the *Methods* and *Results* sections. We agreed that the original text contained result-oriented description and explanatory statements, which are not appropriate for the *Methods* section. We have therefore revised the text accordingly and moved the explanatory content to the *Results* section (see Lines 150–153, Lines 248–252 and Lines 258-261).

**Lines 150-153 in *Methods* section:** We identified the season during which solar radiation exerted the strongest influence on mangroves for each zone, based on the results of the time-lagged analysis (Fig. 3d). ~~The DJF 10 °C isotherm is shown in Fig. 4a–b, comparing the historical baseline (2001–2022) with the late 21st century (2081–2100) under SSP3-7.0 and SSP1-2.6. The panels also illustrate differences in DJF temperature and solar radiation composites between the two scenarios. Low-temperature constraints are unlikely to remain a major limitation under future warming, while, in contrast, solar radiation is projected to decrease, motivating an assessment of how the frequency of low solar radiation events may change.~~ We then calculated the number of low solar radiation events in that season at the monthly scale, defining events as values exceeding –1 SD of the long-term mean (based on the period of 2001-2022), and expressed the frequency as rates per decade.

**Lines 248-252 in *Results* section:** In Fujian Province, the critical biological threshold for mangrove survival is approximately 10˚C during winter (Wang et al., 2022). The spatial distribution of this critical isotherm is shown in Fig. 4a–b, comparing the historical baseline (2001–2022) with projections for the late 21st century (2081–2100) under SSP3-7.0 and SSP1-2.6. Under both scenarios, 10 °C winter isotherm shifts poleward relative to the historical period, with the shift being more pronounced under SSP3-7.0.

**Lines 258-261 in *Results* section:** The results show that, although SSP3-7.0 projects winter (DJF) temperatures approximately 1.5°C higher than those under SSP1-2.6, this warming is accompanied by reduced solar radiation availability during critical growth periods. This pattern suggests that, while low-temperature constraints are unlikely to remain a major limitation under future warming, solar radiation may become a more important limiting factor.

5. The subtitle in Line 150 should be revised to “Results and Discussion.” In the current version, the results and discussion are strongly mixed, but the section is titled only “Results,” which is not appropriate. If the authors prefer to keep the title as “Results,” then a separate Discussion section should be added to ensure a clear structure.

We thank the reviewer for this important and constructive suggestion, which has significantly improved the clarity and structure of this manuscript. We agree that the results and their interpretation were closely integrated in the original version, leading to a lack of clear structural distinction. In response, we have undertaken a substantial restructuring of the manuscript by fully separating the *Results* and *Discussion* into two distinct sections. Specifically, the *Results* section has been refined to focus on the presentation of findings, while interpretative and explanatory content from the original *Results* and *Conclusion* sections (as mentioned in the following comments) has been carefully reorganized and integrated into a newly developed *Discussion* section (See the *Results*, *Discussion* and *Conclusion* sections). We believe this restructuring ensures a clear separation between results and discussion and substantially improves the logical flow and overall readability of our manuscript.

6. In Line 155, the full name of NDVI should be given at its first appearance, and the abbreviation can be used afterward. More importantly, the content of this sentence seems to belong to the background or methods rather than the results. It should be moved to the Introduction or Methods section.

We are grateful for your detailed observation. We realized that NDVI had already been defined earlier in the manuscript; this was not its first appearance, and it was unnecessary to restate the full name here. We apologize for this oversight. Upon reviewing this based on your feedback, we realized the sentence was awkwardly placed since NDVI was already defined in Section 2.2. To respect your observation and streamline the text, we simply deleted the sentence.

In addition, to prevent similar issues, we carefully reviewed the entire manuscript, including the use of abbreviations and the misplacement of statements. As also suggested in the reviewer's general comments, we have revised the manuscript to reduce repetitive descriptions where necessary.

7. Section 3.1 contains very long paragraphs with weak organization. The writing mainly lists findings without clear structure or emphasis. It is recommended to divide the long paragraph into several shorter paragraphs, with each paragraph focusing on one key result. This will improve clarity and readability.

We appreciate this insightful comment, which has helped clarify the narrative trajectory of the *Results* section. We agree that the original paragraph in Section 3.1 was overly long and lacked clear organization. Following the reviewer's recommendation, we have restructured this section into shorter and more focused paragraphs to improve clarity and readability. The corresponding discussions have been moved to the *Discussion* section to improve the structure. These revisions can be found in Lines 169-184.

**Lines 169–184:** Mangroves along the South China Sea were divided into three zones (Fig. 1a), and the seasonal cycle of NDVI reveals clear phenological differences among them (Fig. 1b). This pattern is consistent with previous studies indicating that, despite being evergreen, mangrove forests exhibit notable seasonal and spatial variability (Pastor-Guzman et al., 2018). The northern zone has generally lower values, and the amplitude of NDVI fluctuation decreases progressively from north to south. While both the northern and southern zones exhibited synchronized timing of NDVI maxima and minima—typically with minimum values in winter and maximum values in summer, reflecting the seasonal cycle of temperature—the middle zone demonstrated a markedly different phenological pattern. Specifically, in the middle zone, NDVI minima occurred in April and maxima in October, indicating a shift in the seasonal cycle relative to the other zones. This divergence suggests that, whereas NDVI dynamics in the northern and southern zones are more aligned with temperature seasonality with a potential lag, in the middle zone, NDVI variations are more strongly synchronized with fluctuations in sunshine hours rather than temperature (Fig. S1).

Annual NDVI distribution further reveals strong latitudinal dependencies, with higher and more clustered NDVI values observed at lower latitudes, reflecting more favourable conditions (especially temperature) for mangrove growth (Fig. 1c) (Chen et al., 2017). In the middle zone, the distribution of mean NDVI is relatively symmetric, while the maximum shows right skewness; in the southern zone, both mean and maximum are right-skewed. By contrast, the northern zone shows a more symmetric NDVI distribution.

Building on this suggestion, we have gone a step further by introducing a dedicated "Study Area" subsection in the Method section, which provides a clear information for the study area and improves the overall organization of the manuscript. These revisions can be found in Lines 76–84.

**Lines 76–84 in *Methods* section:**

**2.1 Study area**

The study focuses on mangroves distributed along the South China Sea, and the results provides a basis for assessing the expansion and growth potential of mangroves across East Asia. Mangrove distribution data were obtained from the Global Mangrove Watch (Bunting et al., 2022), which provides long-term observations that covers the study period. Based on climatic conditions and dominant species composition across the natural latitudinal range of mangroves in this region (Zhao et al., 2024a) (Table S2), mangrove habitats were further classified into three distinct zones (northern, middle, and southern) for comparison. These zones exhibit clear thermal gradients, with mean winter temperatures of approximately 14.5°C, 16.6°C, and 19.1°C in the northern, middle, and southern zones, respectively.

8. In Section 3.2, the authors need to explain clearly how the 250 m NDVI data were matched with the 0.25 degree climate data. Because of the large difference in spatial resolution, the potential errors introduced during the matching process should be explained. It is also necessary to clarify whether these errors were quantified. If higher resolution climate data are available, the authors should explain why they were not used.

We thank the reviewer for this important comment regarding the spatial resolution mismatch between the NDVI (250 m) and ERA5 climate data (0.25°).

In our analysis, ERA5 variables were interpolated to 250 m to ensure spatial alignment with the NDVI dataset, allowing climate conditions to be consistently assigned to mangrove pixels. We acknowledge that this approach does not increase the intrinsic resolution of the climate data; rather, it serves as a practical step to enable pixel-level comparison between vegetation and atmospheric variables. We have documented the process in the revised manuscript, see Lines 99-102.

**Lines 99-102:** To ensure spatial consistency for observational analyses, ERA5 climate variables were interpolated to match the spatial resolution of the NDVI dataset (250 m). Future climate projections from CMIP6 were analysed at a spatial resolution of 0.25°×0.25°, consistent with the native resolution of the reanalysis data, as the projections were used to capture climatic conditions at a broader spatial scale rather than mangrove pixel level.

We also explored the use of higher-resolution climate datasets (e.g., ERA5-Land, CHELSA, WorldClim, and TerraClimate), but their application in coastal regions introduced substantial challenges. In particular, datasets such as ERA5-Land, which are limited to land surfaces, resulted in extensive “NoData” gaps over coastal land-sea interfaces, where mangroves are primarily located. Similarly, other high-resolution products, often derived from statistical downscaling, may lack the spatial consistency and completeness required for coastal analyses. In contrast, ERA5 provides spatially continuous and internally consistent climate factors across both land and ocean, making it more suitable for large-scale analysis of intertidal ecosystems. We therefore adopted ERA5 as a pragmatic choice, balancing spatial resolution and data completeness.

We acknowledge that the potential errors associated with the spatial mismatch were not explicitly quantified in the study, as they arise from differences in spatial representativeness rather than a directly measurable statistical uncertainty. This uncertainty reflects an inherent trade-off in macro-scale ecological analyses and has been transparently addressed in our revised manuscript (see Lines 424-428).

**Lines 426-430:** Despite these findings, several limitations should be acknowledged. First, because mangroves are typically distributed in narrow and fragmented coastal zones, the mismatch in spatial resolution between the NDVI and climate datasets may introduce uncertainties. As a result, the climate data may not fully capture the local climatic conditions experienced by mangroves at the pixel level. Nevertheless, among the currently available global climate datasets, ERA5 provides a reasonable balance between spatial coverage, temporal consistency, and data reliability.

9. In Section 3.4, the authors should justify the use of 0.25 degree spatial resolution data. Mangroves are distributed in narrow coastal zones and are highly fragmented. A 0.25 degree grid cell usually contains large areas that are not mangroves. This may greatly dilute the climate response signal of mangroves. The possible influence of this issue on the reliability of the results should be carefully discussed.

Thank you for this valuable comment. This concern is closely related to our response to Comment 8, where we provide a detailed justification for the use of the 0.25° climate dataset.

We acknowledge that mangroves are typically distributed in narrow and fragmented coastal zones, and therefore a 0.25° grid cell may include non-mangrove areas. This spatial mismatch may dilute the climate signal associated with mangrove ecosystems. Despite this, as discussed above, ERA5 offers a practical compromise between spatial resolution and data completeness for large-scale analyses of coastal ecosystems. We have clarified this point in the revised manuscript by further discussing the implications of this spatial mismatch and its potential influence on the results (Lines 424–428, see the response to Comment 8).

10. The Conclusion needs to be rewritten. A conclusion should clearly summarize the main findings and contributions of the study. It should not repeat the Introduction or present new discussion. For example, in the current version, Lines 349 to 354 read like part of the Introduction, while Lines 355 to 370 and 374 to 395 read like Discussion. The authors should reorganize this section and clearly present the main conclusions of the study.

We appreciate the reviewer for the valuable suggestion. In the original manuscript, we attempted to include several broader implications in the *Conclusion* section; however, this resulted in an overly long section that diluted the main findings and blurred the distinction between *Results*, *Discussion*, and *Conclusion*.

Following the reviewer's suggestion, we have undertaken a substantial restructuring of the manuscript as we mentioned in the response to Comment 5. The *Conclusion* section has been rewritten to focus on summarizing the main findings and highlighting the contributions of our work (Lines 445–456). We believe these changes improve both the clarity and overall structure of the manuscript.

**Lines 448-459:** This study investigated the climate drivers of mangrove growth along the South China Sea and projected the potential changes in mangrove dynamics across East Asia under future climate scenarios. Our results show that solar radiation, rather than temperature, exerts a more consistent control on mangrove NDVI variability across latitudinal zones, while extreme reductions in NDVI are associated with climatic anomalies exhibiting seasonal dependence. We further identified pronounced lagged effects of climatic drivers, with preceding winter temperatures influencing spring growth and solar radiation exerting seasonally dependent lagged controls, particularly during transitional periods of the growing season. Future projections suggest that continued warming is likely to facilitate poleward expansion of mangroves in East Asia by alleviating winter temperature constraints; however, an increased frequency of low solar radiation events under high-emission scenarios may partially offset these benefits by limiting mangrove growth. These findings highlight the importance of considering both solar radiation and lagged climatic effects when assessing the future dynamics and resilience of mangrove ecosystems under climate change. Incorporating these climatic controls may inform climate-resilient mangrove conservation and restoration in East Asia.

11. Many sentences and expressions throughout the manuscript sound formulaic and unnatural. The authors are encouraged to carefully revise the language, improve clarity, and ensure that the writing is precise and academically appropriate.

We are deeply grateful for this constructive recommendation. In response, we have undertaken a rigorous, line-by-line stylistic overhaul of the entire manuscript to improve clarity, readability and academic precision. Specifically, we have carefully restructured complex and overly long sentences, eliminated formulaic and unnatural expressions, and refined the wording throughout to ensure a more natural and precise scientific tone. In addition, extensive proofreading has been conducted to improve consistency, grammar, and overall language quality.