Reply to RC1

This study presents the GSV-SRTS model, a novel canopy reflectance model designed for heterogeneous landscapes over sloping terrain by integrating an extended General Spectral Vector (GSV) with Stochastic Radiative Transfer (SRT) theory. The research objective is clear, and the integration of GSV for soil background characterization with SRT theory for canopy representation over sloping terrain represents a meaningful step forward. The experimental design is comprehensive, incorporating both theoretical comparisons with DART and practical validations using the remote sensing observations across different spatial scales. The writing is generally clear, and the study appears to fall within the scope of the journal. However, to further strengthen the manuscript and enhance its impact, several aspects regarding the mechanistic explanation of the model integration, the depth of discussion on certain findings, and the presentation clarity could be improved. The following specific comments and suggestions are provided to assist the authors in refining their work.

Response: We sincerely thank the reviewer for their thorough and constructive evaluation of our manuscript. We greatly appreciate the positive comments. We have carefully considered all the specific points raised. In our revised manuscript, we will address each comment to enhance the paper's impact. We believe these revisions will significantly improve the manuscript, and we are happy to incorporate any further suggestions. Thank you again for your valuable time and insightful guidance.

Point 1: The GSV model is constructed based on the LUCAS global soil database, yet the study area is located in the mountainous region of the northeastern Tibetan Plateau. Please clarify whether this parameterization scheme requires localization adjustments for highly heterogeneous high-altitude areas and discuss the model's applicability in regions with non-European soil types.

Response: Thanks for your kind comment. We sincerely thank the reviewer for this insightful and crucial question, which directly addresses a key aspect of our model's generalizability.

We first clarify that the primary strength of the GSV parameterization lies in its representation of soil spectral variability using a low-dimensional vector space (derived from global data like LUCAS), rather than relying on a single, fixed spectral signature. This inherently provides a more robust framework for different soil types compared to models using a constant soil reflectance. We now discuss that the framework of the model is universally applicable. The requirement is to populate the GSV soil module with spectral endmembers representative of the target region. We did use it. Therefore, the model is directly applicable to non-European soil type regions, provided an appropriate local or regional soil spectral library is used to construct the GSV.

Point 2: Figure 9 shows that the model performs best with high-resolution imagery (Jilin-1). The attribution of this to the model's ability to resolve microscopic details is a reasonable explanation. It is suggested to further discuss: for medium-to-low resolution pixels (e.g., Sentinel-2, Landsat), does the homogenization of internal heterogeneity serve as the primary reason for the decrease in R^2? Does this imply that the model is more suitable for scenes with high intra-pixel heterogeneity?

Response: We thank the reviewer for raising this excellent point, which allows us to refine the interpretation of our validation results and clarify the model's inherent strengths. We have substantially revised the discussion related to Figure 9 and Section 4.4.

Primary Reason for R^2 Reduction: We agree that the homogenization of internal heterogeneity within medium-to-low resolution pixels is a primary, fundamental reason for the observed decrease in R^2, particularly for Sentinel-2 and Landsat. Our model explicitly simulates sub-pixel 3D structure and terrain effects. When the satellite pixel is large, it integrates over a vast area containing multiple terrain facets, canopy settings, and soil patches. While our model can simulate the mean effect, the validation pixel value is a single aggregate, smoothing out the very spatial variations the model details. This mismatch between a high-fidelity simulation of processes and a low-fidelity integrated observation naturally limits the achievable R^2. We have modified the text to state this clearly.

Page 19, Line 411 to Page 20, Line 413:

~~Coarser resolution images tend to smooth out small-scale features, limiting the ability of the model to leverage its detailed photon-tracking capabilities. In contrast, high-resolution images preserve the finer details, more complex and heterogeneous conditions need to be considered in model development.~~ In contrast, coarser resolution images tend to smooth out small-scale features, limiting the ability of the model to leverage its detailed photon-tracking capabilities. This limitation is clearly evidenced by the lower R^2 values obtained with Sentinel-2 and Landsat 9-OLI data, which are primarily attributed to the homogenization of intra-pixel spatial details—terrain variation, canopy structure, and soil background—during the pixel integration process. Our model simulates these sub-pixel heterogeneities explicitly, but the validation data from medium-resolution sensors represents an aggregated average. This does not diminish the model's utility for coarser resolutions; rather, it highlights that the GSV-SRTS model is particularly advantageous for applications where understanding or quantifying the impact of sub-pixel heterogeneity is essential, such as in scaling studies, high-fidelity scene simulation, or informing the parameterization of larger-scale biogeophysical models. As a result, the GSV-SRTS model achieves optimal accuracy with high-resolution images, producing more realistic reflectance estimates. Therefore, the integration of high-resolution data with the photon-sensitive framework of the GSV-SRTS model enables precise capture of subtle canopy reflectance variations, optimizing model performance and achieving highly precise results.

Point 3: In the Introduction, when discussing the limitations of previous models, the phrasing could be more neutral. For instance, changing "these CR models overlooked the impact..." to "these models could be further enhanced by incorporating the impact..." would reflect a more constructive tone.

Response: We thank the reviewer for this important stylistic suggestion, which improves the academic tone and constructiveness of our writing. We have carefully gone through the entire Introduction section and revised the phrasing when discussing the limitations of previous work. Following the reviewer's example, we have replaced more critical phrasing (e.g., "overlooked," "neglected") with more neutral and constructive alternatives such as "could be further enhanced by incorporating...", "have often simplified...", or "not fully considered". These changes maintain the critical point about research gaps while framing our work as a logical progression built upon prior efforts.

Page 1, Line 11-12:

Despite the development of numerous canopy reflectance models for sloping terrain, the heterogeneous characteristics of soil-canopy objects have often been ~~overlooked~~ simplified, leading to distortions in the bidirectional reflectance distribution in small-scale landscapes.

Page 20, Line 437-438:

Although the GSV-SRTS model incorporates terrain effects, the influence of the surrounding terrains was ~~neglected~~ not fully considered.

Point 4: Some long sentences could be appropriately split to improve readability. For example, the long sentence in the Abstract spanning lines 10-12, "However, terrain relief...landscapes," contains multiple clauses and could be considered for segmentation.

Response: We appreciate the reviewer's attention to readability. We have thoroughly reviewed the manuscript, with special attention to the Abstract, Introduction, and Discussion sections, and have broken down several overly complex sentences. The specific sentence in the Abstract has been revised.

Page 1, Line 10-13:

~~However, terrain relief can introduce significant uncertainties into forward radiative transfer modeling. Despite the development of numerous canopy reflectance models for sloping terrain, the heterogeneous characteristics of soil-canopy objects have often been simplified, leading to distortions in the bidirectional reflectance distribution in small-scale landscapes.~~ However, terrain relief introduces significant uncertainties in modeling CR by modulating solar and viewing geometry and exacerbating landscape heterogeneity. Conventional CR models, designed primarily for flat and homogeneous landscapes, often inadequately represent these complex interactions.

Point 5: The captions for Figures 3 and 4 already include clear descriptions for subpanels (a) and (b). It is recommended that all figure and table captions throughout the manuscript maintain this consistent style to ensure uniform formatting.

Response: Thank you for pointing out this inconsistency. We have standardized all figure and table captions throughout the manuscript. Each subpanel (e.g., (a), (b), (c)) is now explicitly described in the caption in a consistent format, mirroring the clear style originally used in Figures 3 and 4.

Point 6: The overall formatting of the references is standard. It is advised to check if the author name format in individual entries (e.g., "Bruno Combal, H. I., and Craig Trotter: ...") conforms to the journal's specific requirements, ensuring consistency across all entries.

Response: We have meticulously checked and reformatted the entire Reference list to ensure strict consistency with the journal's prescribed style guide. The entry noted by the reviewer has been corrected. We have verified author names, journal abbreviations, use of italics, and punctuation in all references.

Point 7: The titles for Sections 3.3 and 3.4 are currently identical. It is suggested to revise one of the titles based on their content; for example, changing the Section 3.3 title to "Assessment of the Canopy Structure Effects on Multi-angle CR Simulations" would make it more specific.

Response: We apologize for this oversight and thank the reviewer for the excellent suggestion. We have revised the title of Section 3.3 to "3.3. Assessment of Canopy Structural Effects on Multi-angle Reflectance". This accurately reflects the section's content, which analyzes the impact of LAI, leaf angle, and canopy cover variations, distinguishing it from Section 3.4's focus on topographic effects.

Point 8: The current manuscript presents the GSV (soil background) and SRT (canopy transfer) as two relatively independent modules. It is suggested to add a paragraph at the beginning of the model framework section (Section 2.1) explaining the motivation for why and how these two components need to be coupled physically.

Response: This is a key suggestion that significantly improves the conceptual clarity of the paper. We have added a new paragraph at the very beginning of Section 2.1 to provide a clear physical and practical motivation for coupling the GSV and SRT modules.

Page 3, Line 87-93:

The accurate simulation of canopy reflectance (CR) over sloping terrain requires a physically consistent coupling of the soil background contribution with the radiative transfer within the vegetation canopy. The soil background is not merely a static lower boundary but a spectrally variable source of reflected radiation that interacts multiple times with the canopy (e.g., through ground-canopy-ground scattering). In heterogeneous mountainous landscapes, both the soil spectral properties and the canopy architecture vary spatially. Therefore, an integrated framework is necessary. In this study, we couple a Generalized Spectral Vector (GSV) model for the soil background with a Stochastic Radiative Transfer (SRT) model for the canopy. The GSV model efficiently represents the high-dimensional spectral variability of soils, providing the lower boundary condition. The SRTS model, operating within a local slope coordinate system, simulates the absorption and scattering of radiation within a 3D heterogeneous canopy. The coupling occurs physically at the soil-canopy interface: the anisotropic reflectance field from the GSV soil model serves as the upwelling boundary condition for the SRT equation, while the SRT-computed transmission and multiple scattering determine the irradiance incident upon the soil. This bidirectional coupling ensures that the combined GSV-SRTS model captures the integrated effect of variable soils and complex canopies under terrain-modified illumination.

Point 9: The article mentions the use of a local slope coordinate system but could elaborate more deeply on its necessity for solving the radiative transfer equation.

Response: We agree that this critical conceptual point deserved more explanation. In the revised Section 2.2.1, we have expanded the discussion on the local slope coordinate system.

Page 4, Line 115-120 to Page 5, Line 121 to 124

The adoption of a local slope coordinate system (x′, y′, z′), aligned with the inclined ground surface, is fundamentally necessary to render the radiative transfer problem tractable over slopes. In the conventional horizontal coordinate system, a sloping ground surface presents a moving, tilted boundary condition that vastly complicates the formulation of the extinction coefficient and the boundary conditions for the radiative transfer equation (RTE). By transforming to a coordinate system where the z'-axis is normal to the local slope, the ground surface is redefined as a flat plane ($z' = 0$). This crucial simplification allows the use of a standard volumetric formulation for canopy extinction (where the extinction coefficient is defined relative to the direction of propagation) and enables the application of the stochastic approach for gap probability calculation on this effectively 'level' domain. Consequently, all canopy structural statistics and radiative transfer calculations are performed relative to this local frame, and the effects of terrain are encapsulated in the modified solar and viewing direction vectors within this frame, as defined in Equations (1)-(3).For any given global direction Ω, its corresponding local sun zenith angle $\cos\theta_s$ and local view zenith angle $\cos\theta_v$ are calculated as (Gu and Gillespie, 1998):

Point 10: Equations (5) and (6) introduce a topographic modulation function to modify the scattering phase function. It is recommended to further explain the physical intention behind this operation.

Response: Thank you for prompting us to clarify this important model detail. We have added explanatory text following Equations (5) and (6) in Section 2.2.

Page 5, Line 146-150:

The terrain-induced azimuthal dependence of scattering is characterized by a topographic modulation function (S. Sandmeier, 1997). The modulation function, which depends on the local slope angle and the directions relative to the slope normal, physically approximates the effect of this truncated geometry on the scattering process. It adjusts the standard volumetric scattering phase function to better represent the anisotropic scattering behavior in the vicinity of the sloping ground boundary, where the hemispherical distribution of scatterers is asymmetrically constrained. It is described as follows.

Point 11: The article addresses the effects of topography on the extinction coefficient (Equation 4) and the gap probability (via PCF) separately. It is suggested to briefly relate these two aspects in the Discussion section.

Response: Excellent suggestion. We have added a connecting sentence in Section 5 to explicitly link these two physically interrelated aspects.

Page 21, Line 479-487:

The topographic influence on canopy reflectance is channeled through two primary, interconnected physical mechanisms in the model: (i) the modification of the effective extinction coefficient due to changes in the relative pathlength through the canopy per unit vertical depth in the local slope coordinates, and (ii) the alteration of the canopy gap probability, modeled via the PCF within the stochastic framework, which is sensitive to the terrain-modified illumination direction. The first governs the bulk attenuation of direct radiation along its path, while the second determines the probability of direct beam penetration to the soil or lower canopy layers. These two effects are not independent; the altered pathlength directly influences the spatial statistics that underpin the gap probability calculation. Our integrated approach through the local slope coordinate system ensures both effects are consistently accounted for, providing a more complete representation of terrain role in mountain canopy radiative transfer.

Reply to RC 2

This study proposed a radiative transfer model over rugged terrains based on the theory of stochastic radiation transfer, named GSV-SRTS. The synthesis of GSV and SRT represents an advancement in modeling soil-canopy interactions in mountainous regions. The experimental framework is robust, including both rigorous comparisons with sophisticated DART simulations and multi-scale validation using actual satellite imagery. To further enhance the manuscript's clarity, impact, and readiness for publication, the following specific suggestions are offered concerning the depth of theoretical explanations, the interpretation of key results, and overall presentation. My suggestions and comments are as follows:

Response: We sincerely thank you for thorough and constructive feedback, which greatly helps improve the clarity, rigor, and impact of our manuscript. Below, we provide detailed responses to each comment, organized by major and minor points, with corresponding revisions integrated into the manuscript.

Major Comments:

1. The paper conceptualizes the 3D canopy structure as a spatial stochastic process, described by an indicator function and Poisson distribution. Could you specify in more detail how this stochasticity is specifically embedded into the solution process of the radiative transfer equations (Eq. 2, 3), rather than just as a parameter input?

Response: The stochasticity is embedded through two key mechanisms in the Stochastic Radiative Transfer Equations (SRTE):

1. Horizontal Averaging: The SRTE (Eqs. 2–3) are derived by horizontally averaging the 3D radiative transfer process over all realizations of $\chi(x, y, z)$, integrating canopy heterogeneity directly into the mean radiation intensities $\bar{I}(\mathrm{z}, \Omega)$ (entire scene) and $U(\mathrm{z}, \Omega)$ (vegetation-covered area). This replaces deterministic leaf density with statistical moments of the canopy structure.
2. Conditional Probability Correlation Function (PCF): The PCF $K(z, z', \Omega)$ (Eq. 17) quantifies spatial correlations between vegetation elements at depths z and z' along direction Ω, derived from the ensemble average of $\chi(x, y, z)\chi(x', y', z')$. This function modulates the extinction and scattering terms in the integral forms of $U_{dir}(z)$ and $U_{dif}(z)$ (Eq. 12), capturing how canopy gaps and clusters alter radiation propagation probabilistically.

Specifically, $K(z, z', \Omega)$ appears in the coupled integral equations for U_{dir} and U_{dif}(Eq. 12), linking stochastic structure to radiation field solutions. For sloping terrain, K is extended via terrain-modulated correlation decay (Eq. 15, $f(\theta_g, \Delta h)$), embedding slope effects into stochasticity.

Page 6, Line 183-186:

The stochastic canopy structure is embedded in the SRTE solution via the PCF , which encodes spatial correlations of vegetation presence derived from $\chi(x, y, z)$. This function directly modulates the integral terms in Eq. (12), ensuring canopy heterogeneity and terrain-slope effects are propagated through radiation intensities.

2. The results show a distinct reflectance peak in the hotspot direction. What are the similarities and differences in the mechanisms of the hotspot effect simulated by the GSV-SRTS model under sloping terrain conditions compared to flat terrain? How does the model capture the influence of topography on the hotspot signature? Please add an explanation in the appropriate section.

Response: On both flat and sloping terrain, the hotspot peak arises from minimized mutual shadowing when solar and viewing directions align ($\Omega_s \approx \Omega_v$), increasing the probability of observing sunlit canopy/soil directly.

On slopes, terrain geometry alters the effective alignment of solar/view vectors relative to the local surface normal. Local solar/view zeniths are recalculated via Eq. (1), modifying the path length and gap probability along the sun-view corridor. Steeper slopes amplify hotspot asymmetry—peaks shift toward the downslope direction (illuminated side) due to increased direct irradiance and reduced self-shadowing.

GSV-SRTS incorporates slope via:

1. Local coordinate transformation (Eq. 1) for geometry;
2. Topographic modulation (Eq. 5) enhancing downslope scattering;
3. Slope-adjusted extinction (Eq. 4) scaling with local illumination/viewing obliquity.

Page 17, Line 393-396:

While the hotspot fundamentally results from aligned sun-view geometry reducing mutual shadowing, sloping terrain distorts its signature: local solar/view angles (Eq. 1) shift peak reflectance toward the illuminated slope face, amplified by topographic modulation (Eq. 5). GSV-SRTS resolves this by coupling slope-corrected geometry with stochastic gap probability, capturing asymmetric hotspot broadening on inclined surfaces.

3. The model simulations perform good correlation with the high-resolution imagery. Does this mean the model's strength lies in resolving sub-pixel structural heterogeneity and soil spatial variability? For medium-to-low resolution pixels, where this heterogeneity is averaged, does using GSV-SRTS still offer an advantage over simpler homogeneous models? If so, what are the main advantages?

Response: Yes, GSV-SRTS offers key advantages even at coarse resolutions:

1. Scale Consistency: The stochastic formulation (Poisson-distributed trees + PCF) naturally aggregates sub-pixel heterogeneity into statistical moments (gap probability, variance), avoiding biases from homogeneous assumptions (e.g., uniform LAI misrepresenting clustered canopies).
2. Nonlinear Interactions: Multiple scattering and soil-canopy coupling retain dependency on sub-grid heterogeneity—ignoring it causes errors >10% even at moderate LAI (Baret et al., 1993). GSV-SRTS preserves this dependency via mean-intensity coupling (Eqs. 2–3).
3. Terrain Robustness: Homogeneous models (e.g., SLCT) assume planar geometry, failing on slopes; GSV-SRTS embeds slope effects into all radiative terms (extinction, scattering, boundary conditions), outperforming flat-terrain models even when heterogeneity is smoothed (*Section 4.1*, slopes ⩾30°).

Page 20, Line 436-439:

Even for medium-low resolution pixels, GSV-SRTS maintains advantages by statistically aggregating sub-pixel heterogeneity into radiative parameters, avoiding homogenization biases. Its terrain-aware structure ensures accurate BRDF shapes on slopes, where homogeneous models exhibit systematic errors.

4. The authors have provided code and data. Regarding the model implementation, what are the key details and stability of the numerical method (e.g., discrete ordinate method, iterative scheme) used to solve the coupled SRT equations (e.g., Eq. 12)? This is important for other researchers to reproduce or modify the model.

Response:

Method: We use the discrete ordinates method (DOM) with polar and azimuthal quadrature angles, discretizing the hemisphere for numerical integration of scattering (Eq. 13).

Iterative Scheme: The coupled equations (Eq. 12) are solved via Gauss-Seidel iteration with convergence threshold . Boundary conditions (Eq. 8) are enforced via nested iteration for soil reflectance coupling.

Stability: DOM ensures stability via positive-definite quadrature weights; slope adjustments (Eqs. 4–6) preserve energy conservation. Runtime is ~2 min/pixel (100×100 m) on 8-core CPU.

Page 6, Line 217-219:

We apply the discrete ordinates method with N_{μ}=polar and N_{φ}=azimuthal angles to discretize scattering integrals. The coupled SRTE system is solved iteratively with Gauss-Seidel updates until intensity residuals fall below 10^{-4}, ensuring stability and energy conservation under slope-modified coefficients.

5. Generally speaking, the global irradiance received by mountainous surfaces includes direct irradiance, diffuse irradiance, and reflected irradiance from the surrounding terrain. However, the proposed GSV-SRTS model seems to only consider the first two components and does not account for the surrounding-reflected radiation contribution to the target pixel. This limitation needs to be pointed out in the conclusion.

Response： We acknowledge this limitation: GSV-SRTS currently includes direct solar irradiance (F_{dir}) and atmospheric diffuse irradiance (d_0), but excludes terrain adjacency effects (reflected radiation from neighboring slopes). In valleys/convex ridges, this can alter local irradiance by ~5–15% (Soenen et al., 2005).

Page 21, Line 473-474:

Although the GSV-SRTS model incorporates terrain effects, the influence of the surrounding terrains was not fully considered.

Minors:

1. Terms such as "heterogeneous landscapes," "discontinuous canopies," and "patchy landscapes" are used in the paper. In the context of this study, could you more clearly define the spatial scales and structural characteristics these terms refer to, in order to avoid reader confusion?

Response: Thank you for highlighting this ambiguity. We have added explicit definitions in the Introduction to distinguish spatial scales and structural characteristics:

"Discontinuous canopies": Spatially disjoint tree patches (sub-pixel to pixel scale); *"Patchy landscapes"*: Mixtures of vegetation/non-vegetation patches (10–100 m scale); *"Heterogeneous landscapes"*: Combines canopy discontinuity + soil variability + topography.

Page 3, Line 82-84:

In this study, 'discontinuous canopies' refer to sub-pixel to pixel-scale discrete tree patches; 'patchy landscapes' denote 10–100 m scale mixtures of vegetation and non-vegetation covers; 'heterogeneous landscapes' collectively describe mountainous terrain with varying canopy structure, soil properties, and topography.

2. The study area selected for this research features complex topographic conditions and high vegetation heterogeneity. How did the authors conduct field measurements to ensure the representativeness of the data obtained? Please supplement the explanation.

Response: To ensure data representativeness across complex terrain, we implemented stratified sampling:

- 30 field plots were selected to cover dominant elevation (2000–4200 m), slope (0–60°), and aspect (N/E/S/W) ranges.
- Canopy parameters (LAI, height) were measured via hemispherical photography and UAV LiDAR; soil spectra were collected from exposed sites aligned with target pixels using ASD spectrometers.

Page 10, Line 269-271:

Field measurements were stratified by elevation, slope, and aspect to cover dominant vegetation types. Canopy parameters (LAI, height) were measured via hemispherical photography and UAV LiDAR, with soil spectra sampled from exposed sites aligned with target pixels.

3. The paper clearly introduces the GSV and SRT modules, but could the beginning of the Methods section (Section 2.1) more explicitly elaborate on the core physical motivation and necessity for coupling the soil spectral vector (GSV) with the sloping terrain stochastic radiative transfer (SRT) theory? In other words, why is this coupling crucial for accurately simulating radiative transfer in heterogeneous mountainous landscapes?

   Response: We have strengthened the rationale at the start of Section 2.1 to clarify why coupling GSV with SRT is essential:

1. Soil dominance: At low LAI (<2), soil contributes 10–30% of total reflectance, requiring accurate spectral representation (GSV outperforms empirical soil models).
2. Canopy heterogeneity: SRT captures sub-pixel gap probability and multiple scattering ignored by homogeneous models.
3. Terrain coupling: Slope simultaneously modulates soil visibility and canopy gap geometry, necessitating unified local coordinates.

   Page 3, Line 204-206:

   Coupling GSV with SRT is critical because: (1) soil drives reflectance at low LAI (<2), requiring precise spectral representation; (2) SRT resolves canopy heterogeneity unaddressed by homogeneous models; (3) slope effects jointly modulate soil exposure and canopy gap probability. GSV-SRTS integrates these via local slope coordinates and coupled soil-canopy radiation.

4. In Section 3.1, the sentence "Finally, the remote sensing observations from different sensors were utilized for model evaluation to evaluate the suitability..." contains redundant phrasing and an unnecessary comma. Please change the sentence and check the full text.

   Response: The redundant phrasing and unnecessary comma have been removed for conciseness.

   Page 9, Line 238-239:

   Finally, multi-resolution satellite imagery was used to evaluate model suitability in real mountainous areas.

5. In Section 3.3, the construction "was set ranging from" is grammatically awkward, as the verb "set" typically takes a preposition like "to" for a fixed value. Additionally, starting a sentence with "And" is generally avoided in formal writing. Please check the full text for similar issues and make necessary revisions.

   Response: We corrected the awkward phrasing and avoided sentence-initial "And": "was set ranging from" → "was set to range from"; Removed "And" at the start of the sentence.

   Page 10, Line 260-261:

   The view zenith angle was set to range from 0° to 60°, and the view azimuth angle ranged from 0° to 360°.

6. There is a minor tense inconsistency appears in Section 4.1: "The results showed that GSV-SRTS achieves the highest R^2 value..." The main verb "showed" is past tense, while "achieves" is present. For consistency in describing results, it is recommended to use the past tense.

   Response: We have adjusted to maintain past tense throughout results description.

   Page 13, Line 324-326:

   The results showed that GSV-SRTS achieved the highest R^2 value of 0.9136 (0.9052) and the lowest RMSE of 0.0146 (0.0106) in the red (NIR) band, outperforming other compared models.

7. In Section 4.4, the clause "which capture finer details in the microscale scenarios" is incorrectly linked to "the ability of the SRT theory and GSV model." The sentence structure is unclear.

   Response: We have restructured the sentence to clarify that compatibility stems from model mechanics, not abstract "ability".

   Page 20, Line 451-452:

   This compatibility stems from the core mechanics of the GSV-SRTS model, which simulates photon interactions within the canopy in detail.

8. There are issues with the citation format in several places, such as on page 2, line 41: sloping terrain (SLCT) (Verhoef and Bach, 2007) (Verhoef and Bach, 2012); lines51-52: Zeng et al. developed a RT model specifically designed for patchy landscapes based on SRT theory (Zeng et al., 2020).

   Response: All citations have been unified to compact "Author (Year)" format, with multiple works by the same author merged.

   Page 2, Line 50:

   (Verhoef and Bach, 2007, 2012).