Response to reviewers

Geoscientific Model Development

ForEdgeClim v1.0: a 3D process-based microclimate model incorporating vertical and lateral radiative and thermal fluxes to simulate forest edge-to-core transitions

Authors: Emma Van de Walle[1,2], Félicien Meunier[1,3], Steven J. De Hertog[1], Louise Terryn[1], Pieter Sanczuk[4], Kim Calders[1], Francis wyffels[5], Pieter De Frenne[4], Michiel Stock[2], Hans Verbeeck[1]

[1]Q-ForestLab, Laboratory of Quantitative Forest Ecosystem Science, Department of Environment, Faculty of Bioscience Engineering, Ghent University, Ghent, Belgium
[2]Kermit, Department of Data Analysis and Mathematical Modelling, Faculty of Bioscience Engineering, Ghent University, Ghent, Belgium
[3]Department of Water and Climate, Vrije Universiteit Brussel, Brussels, Belgium
[4]Forest & Nature Lab, Department of Environment, Faculty of Bioscience Engineering, Ghent University, Gontrode, Belgium
[5]IDLab, Internet technology and Data science Lab, Ghent University-imec, Ghent, Belgium

Correspondence: Emma Van de Walle (egvdwall.vandewalle@ugent.be)

May 9, 2026

Letter to the Editor

Dear Topic Editor,

We sincerely thank you and the reviewers for the careful evaluation of our revised manuscript and for the constructive feedback provided throughout the review process.

We are pleased that the reviewers found the manuscript substantially improved and that the remaining comments are primarily focused on clarification and refinement of the model description and discussion. In this revised version, we have carefully addressed all remaining comments and revised the manuscript accordingly.

The main revisions include:

- clarification of the formulation and interpretation of canopy heat exchange processes, including a clearer definition of the exchange coefficient and the role of voxel density in regulating effective heat exchange;
- improved consistency between the textual descriptions and governing equations related to convection and sensible heat transfer;
- clearer discussion of the limitations of the current latent heat formulation, including the absence of explicit stomatal regulation;
- more precise wording throughout the manuscript to avoid overstatement regarding the representation of fully resolved 3D microclimate dynamics;
- additional clarification regarding the seasonal optical parameterisation and the limitations of the coupled vertical–lateral two-stream radiation framework;
- refinement of the discussion regarding the model's likely domain of applicability and transferability.

We believe that these revisions have improved the clarity and transparency of the manuscript and we thank the reviewers again for their thoughtful and constructive comments.

Sincerely,

Emma Van de Walle
on behalf of all co-authors

Contents

1 Reviewer 1: Ilya Maclean

Reviewer 1 Complete comment

The manuscript is much improved and now reads more clearly. However, while the presentation has been strengthened, the underlying model has not been substantially revised, and several of my previous comments have only been partially addressed.

For example, in relation to the iterative solution of the energy balance, the authors argue that this is required owing to non-linearities and the need to solve the balance per voxel. However, neither of these reasons is, in itself, prohibitive. Penman–Monteith-type formulations can be applied independently at the voxel level and are specifically designed to handle the relevant non-linearities. While the use of an iterative solution is not incorrect, the response does not fully engage with the original point, which was whether such an approach is necessary.

Similarly, for the ground heat flux, the dimensional inconsistency has been corrected, which resolves the specific error identified. However, the broader issue regarding the treatment of phase shifts is not fully addressed. Campbell and Norman (Chapter 8) provide a clear description of approaches that account for this, which was the point raised. That said, the errors arising from the current approach are likely to be small.

I am content to leave these points as they stand. However, there remains a more substantive issue that does require clarification, namely the treatment of canopy heat exchange.

Previously I noted that foliage density does not appear to influence the formulation, despite the fact that it should directly affect the magnitude of exchange. The authors state that canopy structure is represented through a voxel density term (ρ), but this term does not appear in the governing equations, so it is unclear how it is incorporated. This is further confused by the use of notation consistent with Campbell-style formulations, where ρ typically denotes air density.

The revised text states that heat exchange is parameterised through "effective exchange processes" representing turbulent mixing and small-scale air movement. However, the link between this description and the equations is not clear. A convection coefficient (g) is introduced, but how it is calculated is not specified. Moreover, in the later description of sensible heat flux, reference to convection has been removed, implying that convective exchange is not explicitly represented (consistent with the absence of wind speed in the formulation). However, neither here nor in the sensible heat section is it clear how g is calculated.

This is the point that needs to be properly addressed. The manuscript should:

(1) clearly specify how the exchange coefficient g is calculated;
(2) explicitly state how canopy structure (voxel density) influences heat exchange;
(3) ensure that the text is consistent with the equations (particularly regarding the role of convection).

Without this, it remains unclear how heat exchange within the canopy is actually represented.

Additionally, the revised wording: "Extending the evapotranspiration formulation to a Penman–Monteith framework would further enable explicit representation of canopy resistance and atmospheric demand..." misses the more substantive issue. The current Priestley–Taylor formulation is already closely related to Penman–Monteith, so framing this primarily as a change in formulation is somewhat misleading. The key limitation is that transpiration is not explicitly represented, particularly the role of stomatal regulation. This limitation in the treatment of latent heat flux would be better highlighted as a separate and more prominent point, explicitly acknowledging the absence of stomatal control and its response to environmental drivers.

Reviewer 1 Comment 1

For example, in relation to the iterative solution of the energy balance, the authors argue that this is required owing to non-linearities and the need to solve the balance per voxel. However, neither of these reasons is, in itself, prohibitive. Penman–Monteith-type formulations can be applied independently at the voxel level and are specifically designed to handle the relevant non-linearities. While the use of an iterative solution is not incorrect, the response does not fully engage with the original point, which was whether such an approach is necessary.

Response:
We agree that Penman–Monteith-type formulations can, in principle, also be applied independently at the voxel level and are capable of handling the relevant non-linearities. Our intention was not to suggest that iterative approaches are inherently required, but rather that an iterative framework provides a practical way to couple multiple interacting voxel-scale energy exchange processes within the 3D framework. We have revised the manuscript to clarify this point explicitly.

Section 2 Model description, Lines 107–113:

> Each component of the energy budget depends explicitly on the local forest surface temperature (K), defined here as an effective surface temperature representing leaf and woody elements, weighted by their local structural density, through non-linear physical relationships. These include longwave radiation emission (Stefan–Boltzmann law), sensible heat exchange, and latent heat flux, all of which depend on the unknown surface temperature. As a result, the energy balance forms a coupled non-linear system within the voxel-based framework which is solved iteratively until convergence to a steady-state solution is achieved for a single moment in time. The iterative solution strategy represents a practical numerical approach for coupling multiple interacting voxel-scale energy exchange processes within the 3D framework.

Reviewer 1 Comment 2

Similarly, for the ground heat flux, the dimensional inconsistency has been corrected, which resolves the specific error identified. However, the broader issue regarding the treatment of phase shifts is not fully addressed. Campbell and Norman (Chapter 8) provide a clear description of approaches that account for this, which was the point raised. That said, the errors arising from the current approach are likely to be small.

Response:

We agree that the current formulation does not explicitly represent temporal phase shifts associated with soil heat storage and delayed conductive heat transfer, as described by Campbell and Norman (Campbell and Norman, 2000). The present implementation was intended as a simplified first-order approximation suitable for instantaneous or quasi-steady-state simulations. We have now clarified this limitation more explicitly in the manuscript.

Section 2.2.3 Ground heat flux, Lines 269–271:

> Eq. (12) provides a simplified local closure of the surface energy balance and implicitly assumes that ground heat flux responds instantaneously to net radiation. As such, the formulation does not explicitly resolve temporal phase shifts associated with heat storage and delayed conductive heat transport within deeper soil layers.

Reviewer 1 Comment 3

Previously I noted that foliage density does not appear to influence the formulation, despite the fact that it should directly affect the magnitude of exchange. The authors state that canopy structure is represented through a voxel density term (ρ), but this term does not appear in the governing equations, so it is unclear how it is incorporated. This is further confused by the use of notation consistent with Campbell-style formulations, where ρ typically denotes air density.

Response:
In the current manuscript version, voxel vegetation density (ρ) already enters explicitly in several governing equations, including the formulations for sensible heat flux (Eq. 15), latent heat flux (Eq. 16), ground heat flux (Eq. 12), and radiative transfer attenuation within the RTM framework (Eqs. 6–11). Through these formulations, vegetation density directly modulates the magnitude of radiative absorption and surface–air energy exchange.

We agree, however, that this role was not explained sufficiently in the text, which may have caused ambiguity regarding the interpretation of ρ. We therefore revised the manuscript to clarify more explicitly that ρ refers to voxel vegetation density throughout the model formulation, whereas air density is separately denoted as ρ_{air}. Specifically, we added this clarification at the first introduction of ρ in the manuscript and revised the relevant heat exchange sections accordingly.

Section 2.2.3 Ground heat flux, Lines 261–268:

> **2.2.3 Ground heat flux**
>
> Ground heat flux (G) represents the transfer of energy between the ground surface and the underlying soil. It is modelled as a fixed proportion of the net radiation at the ground surface:
>
> $$G = p\,(1-\rho)\,R_{\mathrm{n}}\,, \tag{12}$$
>
> following the approach implemented in the *SCOPE 2.0* model (Yang et al., 2021). Here, p is the fraction of R_{n} that is absorbed by the soil surface and ρ is the forest structural density of the voxel layer directly above the soil (dimensionless). Ground heat flux is therefore reduced under dense vegetation cover, where less radiation reaches the soil surface. Throughout this manuscript, ρ refers to voxel vegetation density (dimensionless), whereas ρ_{air} denotes air density (kg m^{-3}).

Section 2.2.4 Sensible heat flux, Lines 274–285:

2.2.4 Sensible heat flux

Sensible heat flux (H) represents the transfer of thermal energy between forest surfaces and the surrounding air. In *ForEdgeClim*, this process is simulated in three dimensions and includes two components: (i) heat exchange between adjacent air voxels:

$$D = h\,A\,\frac{\Delta T_{\mathrm{air}}}{\Delta x}\,, \tag{13}$$

$$T_{\mathrm{air,new}} = T_{\mathrm{air,old}} - \frac{D}{c_{\mathrm{p}}\,\rho_{\mathrm{air}}\,V}\,, \tag{14}$$

and (ii) heat exchange between forest elements and the air:

$$H = \rho\,g_{\mathrm{f}}\,(T_{\mathrm{f}} - T_{\mathrm{air}})\,, \tag{15}$$

where h (W m^{-1} K^{-1}) is an effective heat transfer coefficient governing air–air exchange between adjacent voxels, and g_{f} (W m^{-2} K^{-1}) is a bulk forest–air sensible heat transfer coefficient. Here, ρ represents the voxel-scale vegetation density (dimensionless), such that sensible heat exchange increases proportionally with the amount of vegetated surface present within a voxel.

Section 2.2.5 Latent heat flux, Lines 303–311:

2.2.5 Latent heat flux

Latent heat flux (LE) represents the transfer of energy associated with phase changes of water, including both evaporation and transpiration (i.e., evapotranspiration) from forest surfaces to the atmosphere. In *ForEdgeClim*, LE is estimated using the empirical Priestley–Taylor method:

$$LE = \rho\,\alpha\,R_{\mathrm{n}}\,\frac{\mathrm{s}(T_{\mathrm{f}})}{\mathrm{s}(T_{\mathrm{f}}) + \gamma}\,, \tag{16}$$

which provides a simplified form of the Penman–Monteith equation by representing evapotranspiration as a function of available radiative energy (Lhomme, 1997). Here, ρ refers to voxel vegetation density (dimensionless), α (dimensionless) is the Priestley–Taylor coefficient, γ is the psychrometric constant (kPa K^{-1}), and $\mathrm{s}(T_{\mathrm{f}})$ is the slope of the saturation vapour pressure curve.

Reviewer 1 Comment 4

The revised text states that heat exchange is parameterised through "effective exchange processes" representing turbulent mixing and small-scale air movement. However, the link between this description and the equations is not clear. A convection coefficient (g) is introduced, but how it is calculated is not specified. Moreover, in the later description of sensible heat flux, reference to convection has been removed, implying that convective exchange is not explicitly represented (consistent with the absence of wind speed in the formulation). However, neither here nor in the sensible heat section is it clear how g is calculated.

This is the point that needs to be properly addressed. The manuscript should:

(1) clearly specify how the exchange coefficient g is calculated;
(2) explicitly state how canopy structure (voxel density) influences heat exchange;
(3) ensure that the text is consistent with the equations (particularly regarding the role of convection).

Without this, it remains unclear how heat exchange within the canopy is actually represented.

Response:
We agree that the previous manuscript version did not sufficiently clarify the physical interpretation of the effective heat exchange parameterisation and the respective roles of the exchange coefficients (g) and voxel vegetation density (ρ).

In the current model implementation, the coefficients (g) are prescribed model parameters and are not diagnostically calculated during the simulation. They are specified as spatially uniform semi-empirical bulk exchange coefficients prior to model execution and remain constant throughout a simulation run. The coefficients are therefore not dynamically linked to local wind speed, turbulence, or explicitly resolved airflow dynamics. Instead, they represent characteristic canopy-scale heat exchange efficiencies under typical forest conditions.

We additionally clarified that canopy structure influences heat exchange explicitly through the voxel vegetation density term (ρ), which scales the magnitude of sensible and latent heat exchange within the governing equations (see also our response to your previous comment paragraph). Voxels with higher vegetation density therefore exhibit proportionally stronger coupling between vegetation surfaces and surrounding air.

To improve consistency between the process descriptions and the governing equations, we revised the manuscript throughout to consistently describe the formulation as an effective parameterisation of unresolved turbulent and convective exchange processes, rather than explicit physically resolved convection.

Section 2.1.2 Air temperature, Lines 173–176 (repeated from previous manuscript version) and 187–194:

> In addition, vegetation density (ρ, dimensionless) directly scales the magnitude of surface–air energy exchange. In the model, ρ represents the effective fraction of vegetated surface within a voxel and enters explicitly in the formulations of sensible

> and latent heat fluxes (Eqs. 15 and 16). Voxels with higher density therefore exhibit stronger coupling between surface and air temperatures, whereas low-density voxels represent more open air space with reduced exchange.
>
> [. . .]
>
> The convection coefficients g and distances of influence i are prescribed model parameters treated as effective bulk exchange coefficients controlling the magnitude and spatial reach of heat exchange within the canopy. In the current model implementation, the coefficients g are prescribed as spatially uniform semi-empirical parameters and are not dynamically calculated from local wind speed, turbulence, or voxel-scale canopy structure. Instead, they represent characteristic canopy-scale exchange efficiencies under typical forest conditions. This effective parameterisation is commonly used in microclimate and canopy models where metre-scale turbulent transport and airflow dynamics cannot be explicitly resolved computationally (Campbell and Norman, 2000; Bonan, 2019). In this context, the coefficients g implicitly represent the combined effects of unresolved turbulent mixing, boundary-layer exchange, and small-scale convective heat transport within the canopy.

Section 2.2.4 Sensible heat flux, Lines 283–285 and 297–300:

> Here, ρ represents the voxel-scale vegetation density (dimensionless), such that sensible heat exchange increases proportionally with the amount of vegetated surface present within a voxel.
>
> [. . .]
>
> The coefficient g_{f} is treated as an effective bulk sensible heat exchange parameter representing the characteristic efficiency of heat transfer between vegetation surfaces and surrounding air under typical canopy conditions. It implicitly accounts for unresolved turbulent mixing, boundary-layer convection, and small-scale air movement within the canopy.

Reviewer 1 Comment 5

Additionally, the revised wording: "Extending the evapotranspiration formulation to a Penman–Monteith framework would further enable explicit representation of canopy resistance and atmospheric demand..." misses the more substantive issue. The current Priestley–Taylor formulation is already closely related to Penman–Monteith, so framing this primarily as a change in formulation is somewhat misleading. The key limitation is that transpiration is not explicitly represented, particularly the role of stomatal regulation. This limitation in the treatment of latent heat flux would be better highlighted as a separate and more prominent point, explicitly acknowledging the absence of stomatal control and its response to environmental drivers.

Response:

We agree that the key limitation of the current latent heat flux formulation is not primarily the absence of a Penman–Monteith formulation itself, but rather the absence of explicit stomatal regulation and dynamic canopy resistance responses.

In the current model implementation, evapotranspiration is represented as a bulk canopy flux using the Priestley–Taylor approach, in which stomatal regulation, canopy resistance, and atmospheric demand are not explicitly resolved. We agree that the previous wording overemphasised the distinction between Priestley–Taylor and Penman–Monteith formulations, whereas the more important limitation concerns the absence of mechanistic transpiration regulation.

We therefore revised the manuscript to more explicitly acknowledge that the current latent heat flux formulation does not represent dynamic stomatal responses to environmental drivers such as vapour pressure deficit, soil moisture limitation, or drought stress. This limitation is now stated more prominently in both the Latent heat flux subsection and the Discussion.

Section 2.2.5 Latent heat flux, Lines 315–318:

> Consequently, the current formulation does not explicitly represent dynamic stomatal responses to environmental drivers such as vapour pressure deficit, soil moisture limitation, or drought stress. The latent heat flux formulation should therefore be interpreted as a simplified first-order approximation of canopy evapotranspiration.

Section 6.5 Model limitations and future development roadmap (part of Sect. 6 Discussion), Lines 937–943:

> Future developments should additionally improve the representation of transpiration processes and canopy resistance. In the current formulation, evapotranspiration is represented as a bulk energy-limited flux using the Priestley–Taylor approach, without explicitly resolving stomatal regulation or dynamic canopy responses to environmental drivers such as vapour pressure deficit, soil moisture limitation, and drought stress. Incorporating more mechanistic transpiration formulations, including Penman–Monteith-type approaches, would enable more explicit representation of canopy resistance, atmospheric demand, and humidity-related state variables such as vapour pressure deficit and relative humidity.

2 Reviewer 3: Anonymous

Reviewer 3 Complete comment

I recommend acceptance subject to minor revisions. The remaining revisions are mainly clarifications rather than fundamental model changes.

First, the authors should ensure that the abstract, conclusion, and model description consistently avoid overclaiming that the model fully resolves 3D microclimate dynamics. The current formulation should be described as a 3D voxel-based radiative–thermal framework with wind-driven processes represented implicitly.

Second, the manuscript should clearly state that the new leaf-on/leaf-off optical parameterisation is a first-order seasonal treatment and does not yet represent continuous phenological transitions or explicit separation of foliage and woody components.

Third, the discussion of the two-stream radiative transfer scheme should remain explicit that the method represents the radiation field as coupled one-dimensional vertical and lateral transfer problems, with only partial representation of anisotropy.

Finally, the wind-speed residual analysis is a useful addition, but the text should clearly state the model's likely domain of applicability: the current parameterisation appears adequate for first-order edge temperature gradients under the tested temperate conditions, but may be less transferable to more open, windy, drought-stressed, or structurally different forest edges without further validation.

Reviewer 3 Comment 1

First, the authors should ensure that the abstract, conclusion, and model description consistently avoid overclaiming that the model fully resolves 3D microclimate dynamics. The current formulation should be described as a 3D voxel-based radiative–thermal framework with wind-driven processes represented implicitly.

Response:
We agree that the manuscript should avoid overstating the degree to which the current model formulation explicitly resolves all three-dimensional microclimate processes.

We therefore revised the abstract, model description, and conclusion to more consistently describe *ForEdgeClim* as a three-dimensional voxel-based radiative–thermal framework that explicitly represents vertical and lateral radiative and thermal exchanges, while parameterising wind-driven and turbulent transport processes implicitly through effective bulk exchange formulations.

In particular, we clarified throughout the manuscript that: (i) radiative transfer is represented through coupled one-dimensional vertical and lateral two-stream formulations rather than a fully angularly resolved 3D radiation field; (ii) turbulent mixing and airflow processes are not explicitly resolved dynamically, but represented through effective bulk exchange coefficients; and (iii) the model focuses on radiative and thermal energy exchange processes under quasi-steady-state conditions at the voxel scale.

Abstract, Lines 10–14:

> Building on this detailed structural representation, *ForEdgeClim* couples meteorological forcing with a physically based energy balance framework – including shortwave and longwave radiation, sensible and latent heat fluxes, and soil heat exchange – to simulate three-dimensional microclimate temperature patterns through a voxel-based radiative–thermal framework that explicitly represents vertical and lateral radiative and thermal exchanges, while representing wind-driven processes implicitly.

Section 2 Model description, Lines 96–98:

> The voxel-based 3D formulation enables the representation of vertical and lateral radiative and thermal energy fluxes, capturing key spatial interactions that characterise forest edge environments while parameterising turbulent and wind-driven processes implicitly.

Section 7 Conclusions, Lines 1017–1019:

> *ForEdgeClim* demonstrates that forest microclimate temperatures can be realistically simulated at high spatial resolution using a voxel-based radiative–thermal framework that explicitly represents vertical and lateral radiative and thermal exchanges, while parameterising turbulent and wind-driven processes implicitly.

Reviewer 3 Comment 2

Second, the manuscript should clearly state that the new leaf-on/leaf-off optical parameterisation is a first-order seasonal treatment and does not yet represent continuous phenological transitions or explicit separation of foliage and woody components.

Response:
We agree that the current representation of seasonal canopy optical properties should be more clearly framed as a simplified first-order treatment.

The current model implementation represents seasonal variability through separate leaf-on and leaf-off parameter sets, but does not explicitly resolve continuous phenological transitions or dynamically separate foliage and woody canopy components within voxels. We therefore revised the manuscript to clarify these limitations more explicitly in the discussion.

Section 6.5 Model limitations and future development roadmap (part of Sect. 6 Discussion), Lines 905–909 and 949–952:

> **Key limitations**
>
> [. . .]
>
> In addition, although seasonal variation in canopy density is partially represented through PAI scaling and separate leaf-on and leaf-off optical parameter sets, this currently represents only a first-order seasonal approximation. Continuous phenological transitions and explicit separation of foliage and woody canopy components are not yet represented within the voxel-based framework, which may limit the realism of seasonal radiative and evapotranspiration dynamics during transitional periods.

> [. . .]
>
> **Future development roadmap**
>
> [. . .]
>
> While seasonal variation in optical properties is already represented through separate leaf-on and leaf-off parameter sets, this currently represents a simplified first-order seasonal treatment. Future developments could enable explicit separation of foliage and woody canopy components together with a more continuous and mechanistic representation of phenological transitions within the voxel framework.

Reviewer 3 Comment 3

Third, the discussion of the two-stream radiative transfer scheme should remain explicit that the method represents the radiation field as coupled one-dimensional vertical and lateral transfer problems, with only partial representation of anisotropy.

Response:
We agree that the level of approximation associated with the current radiative transfer formulation should remain clearly stated throughout the manuscript.

The current formulation represents the radiation field as a set of coupled one-dimensional vertical and lateral radiative transfer problems, rather than a fully angularly resolved three-dimensional radiation field. As a result, radiative anisotropy is only partially represented through the separation of vertical and lateral fluxes and the dependence of direct radiation on solar elevation angle.

To further improve clarity and avoid overinterpretation, we revised both the Radiative transfer model subsection and the Future development roadmap discussion to more explicitly emphasise the approximate nature of the current two-stream radiative transfer formulation and its relationship to future extensions involving more complete angular radiation schemes.

Section 2.2.1 Radiative transfer model, Lines 238–244:

> This formulation represents the three-dimensional radiation field as a set of coupled one-dimensional vertical and lateral radiative transfer problems. While this introduces a simplified representation of the angular distribution of radiation, it enables the model to capture the dominant radiative gradients associated with vertical attenuation and lateral radiation penetration at forest edges in a computationally efficient manner. The radiative transfer scheme is therefore directionally resolved within the vertical and lateral domains, but does not explicitly discretise the full three-dimensional angular radiation field. Anisotropy is thus only partially represented through the separation of vertical and lateral fluxes and the dependence of direct radiation on solar elevation angle.

Section 6.5 Model limitations and future development roadmap (part of Sect. 6 Discussion), Lines 970–975:

> **Future development roadmap**
>
> [. . .]

> Finally, advances in radiative transfer modelling could be explored within the current framework by replacing or complementing the current coupled vertical–lateral two-stream approximation with more detailed angular radiation schemes, such as discrete ordinates methods (Stamnes et al., 1988), spherical harmonics expansions (Modest and Lei, 2012), or Monte Carlo ray tracing approaches (Disney et al., 2000), where computationally feasible. Such developments would allow a more explicit representation of the full three-dimensional angular radiation field and radiative anisotropy within heterogeneous forest canopies.

Reviewer 3 Comment 4

Finally, the wind-speed residual analysis is a useful addition, but the text should clearly state the model's likely domain of applicability: the current parameterisation appears adequate for first-order edge temperature gradients under the tested temperate conditions, but may be less transferable to more open, windy, drought-stressed, or structurally different forest edges without further validation.

Response:
We agree that the manuscript should more clearly define the likely domain of applicability of the current model formulation.

The residual analysis indicates that the present parameterisation is capable of reproducing first-order edge-to-core temperature gradients under the temperate forest conditions considered in this study, despite the absence of explicitly resolved wind dynamics. At the same time, increasing residuals under higher wind speeds and in structurally open conditions suggest that transferability may be more limited in environments characterised by stronger atmospheric coupling, such as open-canopy, windy, drought-stressed, or structurally contrasting forest edges.

We therefore revised the Results and Discussion sections to more explicitly frame the current model formulation as a first-order radiative–thermal approximation whose applicability has presently only been evaluated under the temperate forest conditions represented in this study.

Section 5.3.3 Influence of wind speed on model residuals (part of Sect. 5 Results), Lines 747–753:

> Overall, these results indicate that the use of fixed convection parameters and distances of influence is sufficient to represent first-order macroenvironmental exchange and edge-to-core temperature gradients under the temperate forest conditions considered in this study, but insufficient to capture the full spatial variability in wind-driven turbulence and mixing associated with canopy gaps and structurally complex forest interiors. At the same time, the relatively weak sensitivity of residuals to wind speed suggests that explicitly resolving wind processes would likely lead to only incremental improvements under the tested conditions. However, the transferability of the current parameterisation to more open, windy, drought-stressed, or structurally contrasting forest systems remains uncertain and would require additional validation.

Section 6.5 Model limitations and future development roadmap (part of Sect. 6 Discussion), Lines 899–901:

> **Key limitations**

[. . .]

Consequently, the current parameterisation is expected to be most applicable to temperate forest conditions characterised by moderate wind exposure and relatively closed canopy structure, similar to those represented in this study.

References

Bonan, G.: Climate change and terrestrial ecosystem modeling, Cambridge University Press, Cambridge, 1 edn., https://doi.org/10.1017/9781107339217, 2019.

Campbell, G. S. and Norman, J. M.: An introduction to environmental biophysics, Springer, New York, Heidelberg, Berlin, 2. ed., corr. 2. printing edn., ISBN 978-0-387-94937-6, 2000.

Disney, M., Lewis, P., and North, P.: Monte Carlo ray tracing in optical canopy reflectance modelling, Remote Sensing Reviews, 18, 163–196, https://doi.org/10.1080/02757250009532389, 2000.

Lhomme, J.-P.: A theoretical basis for the Priestley-Taylor coefficient, Boundary Layer Meteorol., 82, 179–191, https://doi.org/10.1023/A:1000281114105, 1997.

Modest, M. F. and Lei, S.: The simplified spherical harmonics method for radiative heat transfer, Journal of Physics: Conference Series, 369, 012 019, https://doi.org/10.1088/1742-6596/369/1/012019, 2012.

Stamnes, K., Tsay, S.-C., Wiscombe, W., and Jayaweera, K.: Numerically stable algorithm for discrete-ordinate-method radiative transfer in multiple scattering and emitting layered media, Appl. Opt., 27, 2502–2509, https://doi.org/10.1364/AO.27.002502, 1988.

Yang, P., Prikaziuk, E., Verhoef, W., and Van Der Tol, C.: SCOPE 2.0: a model to simulate vegetated land surface fluxes and satellite signals, Geosci. Model Dev., 14, 4697–4712, https://doi.org/10.5194/gmd-14-4697-2021, 2021.