

Anonymous Referee #3, 01 Jun 2026

Report #3

Submitted on 01 Jun 2026
Anonymous referee #3

[Notes for the submission of interactive comments](#)

Anonymous: Yes No

Formal manuscript rating and recommendation to the editor

(visible to authors and reviewers only)

1) Scientific significance Does the manuscript represent a substantial contribution to modelling science within the scope of this journal (substantial new concepts, ideas, or methods)?	Excellent Good Fair Poor
2) Scientific quality Are the scientific approach and applied methods valid? Are the results discussed in an appropriate and balanced way (consideration of related work, including appropriate references)? Do the models, technical advances and/or experiments described have the potential to perform calculations leading to significant scientific results?	Excellent Good Fair Poor
3) Scientific reproducibility To what extent is the modelling science reproducible? Is the description sufficiently complete and precise to allow reproduction of the science by fellow scientists (traceability of results)?	Excellent Good Fair Poor
4) Presentation quality Are the scientific results and conclusions presented in a clear, concise, and well structured way (number and quality of figures/tables, appropriate use of English language)?	Excellent Good Fair Poor

For final publication, the manuscript should be

accepted as is
accepted subject to technical corrections
accepted subject to minor revisions
reconsidered after major revisions
rejected
Please note that this rating only refers to this version of the manuscript!

Were a revised manuscript to be sent for another round of reviews:

I would be willing to review the revised manuscript.

I would not be willing to review the revised manuscript.

Referee Comment: '[Comment on egusphere-2026-551](#)'

General Comments

Overall, this study provides a solid and well-organized description of a new one-tile “slab” urban module implemented in the ORCHIDEE v2.2 land surface model. The authors have done a commendable job situating their work within the broader context of urban land surface modeling and presenting the model evaluation in a coherent manner. The manuscript is generally well-written and the figures and tables are informative. However, I have several major concerns that I believe should be addressed before the manuscript is suitable for publication.

- Limited discussion of urban hydrology in the introduction. While the introduction dedicates space to the evolution of urban energy balance parameterizations, the treatment of urban hydrology is comparatively brief and could be strengthened. A more thorough review of how existing urban schemes represent urban hydrology, and what the key modeling gaps are, would help readers better appreciate the novelty of the approach proposed here. This concern is reinforced by specific issues throughout the manuscript: the definition of “imperviousness” itself (L271) is never made explicit—does it refer to the impervious surface fraction, a hydrological connectivity metric, or something else? The authors should clarify this early in the manuscript and use it consistently.

We thank the reviewer for this comment. We agree that the previous version of the introduction did not sufficiently describe how urban hydrology is represented in existing ULSMs, nor did it clearly define how the term “imperviousness” is used in our model. We have therefore expanded the introduction to better situate our approach within previous developments in urban hydrology parameterizations and clarified the definition of imperviousness in the model description.

In the revised introduction, we now discuss how urbanization modifies surface and subsurface hydrological pathways, including infiltration, runoff generation, soil water availability, groundwater recharge, and drainage-related processes. We also clarify that “imperviousness” is not uniquely defined in urban hydrology, as it may refer to the total impervious surface fraction, to the fraction effectively connected to the drainage network, or to an effective hydrological control on infiltration and runoff generation.

We then review how urban hydrology has been introduced in ULSMs through several modelling choices, including simplified impervious representations, pervious/impervious surface distinctions, water storage on artificial surfaces, infiltration through artificial surfaces, coupling with LSM soil hydrology, and more detailed approaches including urban subsoil processes, lateral water transfer, and sewer drainage. This expanded discussion better explains the context for our approach and highlights that runoff parameterization, storage dynamics, water-balance closure, and the lack of complete water-balance observations remain important challenges.

We also clarified the definition of imperviousness in the model description. In this study, imperviousness does not represent effective connected impervious area or hydrological connectivity to the drainage network, and it is not used to define separate pervious and impervious hydrological sub-tiles. Instead, it is used as an effective hydrological parameter that modifies saturated hydraulic conductivity as a function of depth, thereby affecting infiltration, runoff generation, soil water storage, and vertical water transfer within the ORCHIDEE soil hydrology.

Finally, we revised the novelty statement to clarify that our contribution is not a detailed urban drainage or multi-tile hydrological scheme, but a parsimonious, physically motivated representation of imperviousness designed to remain consistent with the one-tile structure and existing hydrology of ORCHIDEE.

We updated this part in the introduction:

“Similarly, urban hydrology has progressed from simplified impervious representations (Kusaka et al., 2001; Masson, 2000) to more complete schemes incorporating pervious/impervious distinctions, water reservoirs, irrigation, and subsurface routing (Chancibault et al., 2014; Lemonsu et al., 2007; Oleson et al., 2008; Wouters et al., 2015). Urban hydrology introduces additional challenges due to soil sealing, compaction, preferential flow pathways, and anthropogenic drainage infrastructure. Imperviousness affects both surface and subsurface processes and is not uniquely

defined; it may refer to sealed surfaces, hydrologically disconnected areas, or the effective fraction contributing to runoff (Saadi, 2020). These processes influence infiltration, soil moisture, and groundwater recharge, yet remain poorly understood (Bhaskar et al., 2016; Fletcher et al., 2013). This complexity highlights the need for parameterizations in Urban LSMs that explicitly link imperviousness to hydrological properties within the soil column.”

To:

“On top of vegetation, hydrology has also been shown as a key element to capture correctly latent heat fluxes. Urbanization also modifies surface and subsurface hydrological pathways by increasing soil sealing, compaction, changing preferential flow pathways, and through water use infrastructures (Fletcher et al., 2013; O’Driscoll et al., 2010; Bhaskar et al., 2016). These changes increase surface runoff and shorten hydrological response times, while their effects on soil moisture, groundwater recharge, low flows, and evapotranspiration depend on local soil properties, vegetation, water use, drainage connectivity, and sewer or stormwater networks (Fletcher et al., 2013; Bhaskar et al., 2016; Oudin et al., 2018; Saadi et al., 2020). This complexity is partly reflected in the use of the term “imperviousness”, which is not unique in urban hydrology. Depending on the modeling and spatial context, it can refer to the total impervious surface fraction, the fraction effectively connected to the drainage network, or an effective hydrological control on infiltration and runoff generation (Arnold and Gibbons, 1996; Shuster et al., 2005; Jacobson, 2011; Saadi et al., 2020). This distinction is important for ULSMs because urban hydrology influences not only runoff, but also soil water availability and evapotranspiration, which directly links the water and energy balances.

In ULSMs, urban hydrology has been introduced progressively through several modelling choices. Early urban canopy schemes primarily focused on radiative, thermal, and aerodynamic exchanges, while hydrological processes were absent or simplified, with artificial surfaces commonly represented as impervious and water exchange mainly limited to surface interception, evaporation from wet sealed surfaces, and runoff (Masson, 2000; Kusaka et al., 2001; Martilli et al., 2002). Later developments introduced more explicit hydrological distinctions between urban surface types. One direction was to distinguish hydrological behaviour between pervious and impervious urban fractions, for example through pervious and impervious canyon-floor fractions in CLM-U (Oleson et al., 2008). TEB-related developments add infiltration through artificial surfaces, and connected rainfall interception on roofs and roads toward a soil component (Lemonsu et al., 2007). Other schemes refined the representation of water stored on impervious surfaces and its evaporation after rainfall, as in TERRA-URB (Wouters et al., 2015). Hydro-microclimate approaches further extended urban hydrology to include subsoil beneath built surfaces, lateral water transfer between pervious and impervious tiles, sewer drainage, and irrigation, as in TEB-Hydro (Chancibault et al., 2014; Stavropoulos-Laffaille et al., 2018, 2021). Despite these advances, recent intercomparison work shows that

urban water-balance representation remains uncertain in ULSMs, especially regarding water-balance closure, storage dynamics, and runoff parameterization (Jongen et al., 2024). Progress is also constrained by observations, because urban sites providing turbulent fluxes do not provide all water-balance terms needed to evaluate runoff, irrigation, drainage, and storage changes consistently at the same spatial scale (Jongen et al., 2024)."

We also updated the following part:

"Second, we introduce a physically based representation of imperviousness that affects both surface and subsurface hydrological processes. Unlike most one-tile schemes that treat imperviousness as a surface-only property, we allow imperviousness to influence water storage and transfer throughout the soil column by modifying saturated hydraulic conductivity as a function of depth."

Into:

"Second, we introduce a parsimonious, physically motivated, representation of imperviousness. Rather than resolving separate water budgets for pervious and impervious urban sub-tiles, the proposed approach preserves the existing ORCHIDEE soil hydrology with an urban soil tile where imperviousness is represented through its effect on the hydraulic properties of the soil column. Specifically, imperviousness modifies saturated hydraulic conductivity as a function of depth, allowing it to influence infiltration, runoff generation, soil water storage, and vertical water transfer. This formulation is designed for one-tile, kilometer-scale and coarser LSM applications, where the objective is to represent their aggregate effect on the water budget and surface fluxes feedback to the atmosphere."

We modified Line 271: *"For the water budget, the key parameter is imperviousness, which controls both infiltration and runoff generation."*

Into:

"For the water budget, the key input parameter is the impervious surface fraction, ranging from 0 to 1. In this study, this fraction is not used to define separate pervious and impervious hydrological sub-tiles, nor does it represent the fraction directly connected to the drainage network. Instead, it is converted into an effective hydrological parameter that modifies saturated hydraulic conductivity as a function of depth, thereby affecting infiltration, runoff generation, soil-water storage, and vertical water transfer within the ORCHIDEE soil hydrology."

Finally in the discussion we added:

"Urban land surface models use a range of runoff strategies, from routing a fixed fraction of rainfall directly to runoff to more process-based formulations accounting for infiltration capacity, soil saturation, surface-water storage, and transfers between pervious and

impervious tiles. The simpler formulations may be insensitive to rainfall intensity, antecedent soil moisture, and site characteristics (Jongen et al., 2024). The present study introduces a novel physically based representation of imperviousness by linking it to saturated hydraulic conductivity, thereby affecting infiltration, subsurface water transfer, and runoff generation. This development directly addresses the weak sensitivity of runoff to imperviousness found in 7 of the 18 models evaluated by Jongen et al. (2026). Nevertheless, Jongen et al. (2026) also found that 10 models omitted at least one major runoff-generation mechanism. Future developments should therefore represent surface ponding and interception storage, irrigation, drainage connectivity, and water transfers between urban and vegetated tiles. These processes should ultimately be evaluated against hydrological observations, because the present sensitivity analysis alone cannot establish whether the simulated water partitioning is realistic. Importantly, advancing the hydrological realism of the model should not be guided by latent heat performance alone, but by a comprehensive evaluation of the full water balance (Jongen et al., 2024). However, such evaluation is currently limited by a lack of observational data for key hydrological variables (e.g., runoff and soil moisture) at the urban flux tower sites used in this study (Jongen et al., 2026, 2024). This underscores the need for coordinated efforts to collect hydrological data in urban environments to support model development and validation.”

- Equations require polishing for consistency and completeness. Several equations contain inconsistencies or missing terms that need to be corrected. First, Equations 1 and 2 are inconsistent: Equation 1 includes a heat storage term (dW/dt), but this term is absent from Equation 2. The authors should clarify whether these terms are explicitly resolved, implicit in other terms, or assumed negligible, and this justification should be provided in the text (see also specific comment at L162–163). Second, the same symbol K_s is used in both Equation 15 (saturated hydraulic conductivity for non-urban PFTs) and Equation 22 (for the urban PFT), creating ambiguity. A distinct notation should be adopted for the urban case to avoid confusion.

We thank the reviewer for this comment, which helped us improve the consistency and clarity of the model description. We agree that the previous presentation of the equations was ambiguous. Equation 1 was intended as a general surface energy-budget framework, whereas Equation 2 only defined the net radiation term used by ORCHIDEE. However, this distinction was not sufficiently clear in the text, and the use of a separate heat-storage term in Equation 1 could be confusing because ORCHIDEE does not diagnose an additional storage flux independently from the conductive ground heat flux.

We therefore revised Section 2.1.1, “Representation of the energy fluxes and surface energy budget”, to distinguish more clearly between the conceptual surface energy balance and the individual fluxes computed by ORCHIDEE. In the revised formulation, the surface energy balance is written as:

“

$$R_{net} = H + L_E + G$$

where R_{net} is the net radiation, representing the total balance between incoming shortwave (SW) and longwave (LW) radiation and their respective outgoing components, H is the sensible heat flux, L_E is the latent heat flux, and G is the ground heat flux. The heat stored and released by the soil or urban substrate is not neglected, but is represented through (G), which is used as the upper boundary condition of the one-dimensional heat diffusion equation for the soil temperature profile. Thus, no additional storage term is introduced in the surface energy budget.”

We further clarified in the manuscript how these terms are connected in the ORCHIDEE computation. At each time step, ORCHIDEE first uses the prescribed or computed surface properties, including albedo, emissivity, roughness length, and soil or substrate thermal properties. The model then computes net radiation from incoming shortwave and longwave radiation, surface albedo, emissivity, and surface temperature. This corresponds to the radiative term of the surface energy budget.

The turbulent fluxes are computed consistently with this same surface temperature. Sensible heat depends on the surface–air temperature gradient and on the aerodynamic exchange coefficient, which is affected by wind speed and surface roughness. Latent heat depends on the surface–air humidity gradient, the saturation humidity at the surface temperature, the same turbulent exchange coefficient, and the water-availability limitations imposed by the hydrological state of the soil and surface. Thus, Equations 2, 4, and 5 are linked through the surface temperature and through the turbulent exchange formulation: Equation 2 defines the net radiation term, while Equations 4 and 5 define the latent and sensible heat fluxes that appear in the surface energy budget.

The conductive ground heat flux is computed from the thermal gradient between the surface and the upper soil or substrate layer, together with the thermal conductivity and heat capacity. It provides the upper boundary condition for the one-dimensional heat diffusion equation, which updates the soil or substrate temperature profile. Heat storage and release are therefore represented through the prognostic evolution of this temperature profile, rather than through a separate diagnosed storage term. The updated surface and soil or substrate temperatures are then used as thermal state variables at the next time step.

Finally, the water budget is updated through precipitation partitioning, infiltration, surface runoff, drainage, soil water redistribution, and evapotranspiration. The updated soil moisture then feeds back on latent heat fluxes and on soil thermal properties at the following time steps. We added this clarification to make explicit that the radiative, turbulent, conductive, and hydrological terms are coupled in ORCHIDEE, even though they are introduced through separate equations in the model description.

We also revised the notation for saturated hydraulic conductivity to avoid ambiguity between the standard ORCHIDEE profile and the urban-modified profile. In the revised manuscript, $K_s(z)$ denotes the standard ORCHIDEE saturated hydraulic conductivity profile defined in Eq. (15), while $K_s^{urb}(z)$ denotes the saturated hydraulic conductivity profile used for the urban soil column. The urban profile is now described as :

$$K_s^{urb}(z) = K_s^{ref} F_K(z) F_{urb}$$

where F_{urb} is the dimensionless reduction factor, new notation of K_{fact}^{urban} . This notation clearly distinguishes the reference ORCHIDEE formulation from the imperviousness-modified urban formulation.

- The novelty of this urban scheme relative to existing one-tile schemes is insufficiently articulated. The manuscript describes the new ORCHIDEE urban scheme as a one-tile “slab” approach and positions it within the Lipson et al. (2023) classification, but it does not clearly delineate what distinguishes this scheme from other existing one-tile urban parameterizations in the literature. The authors highlight the physically based treatment of imperviousness through saturated hydraulic conductivity as a key novel contribution, but this is not placed in the context of other schemes’ imperviousness representations. A concise comparison, even qualitative, would help readers assess the incremental scientific contribution and appreciate what is genuinely new here.

We thank the reviewer for this comment. We agree that the previous version did not sufficiently articulate the novelty of the proposed ORCHIDEE urban scheme relative to existing one-tile and bulk urban parameterizations. We added in the manuscript:

“On top of vegetation, hydrology has also been shown as a key element to capture correctly latent heat fluxes. Urbanization modifies surface and subsurface hydrological pathways by increasing soil sealing, compaction, changing preferential flow pathways, and through water use infrastructures (Bhaskar et al., 2016; Fletcher et al., 2013). These changes generally increase surface runoff and shorten hydrological response times, while their effects on soil moisture, groundwater recharge, low flows, and evapotranspiration depend on local soil properties, vegetation, water use, drainage connectivity, and sewer or stormwater networks (Bhaskar et al., 2016; Fletcher et al., 2013; Oudin et al., 2018; Saadi et al., 2020). This complexity is partly reflected in the use of the term “imperviousness”, which is not unique in urban hydrology. Depending on the modeling and spatial context, it can refer to the total impervious surface fraction, the fraction effectively connected to the drainage network, or an effective hydrological control on infiltration and surface runoff generation (Jacobson, 2011; Saadi et al., 2020). This distinction is important for ULSMs because urban hydrology influences not only surface runoff, but also soil water availability and evapotranspiration, which directly links the water and energy budgets.

In ULSMs, urban hydrology has been introduced progressively through several modelling choices. Early urban canopy schemes primarily focused on radiative, thermal, and aerodynamic exchanges, while hydrological processes were absent or simplified, with artificial surfaces commonly represented as impervious and water exchange mainly limited to surface interception, evaporation from wet sealed surfaces, and runoff (Kusaka et al., 2001; Martilli et al., 2002; Masson, 2000). Later developments introduced more explicit hydrological distinctions between urban surface types. One direction was to distinguish hydrological behaviour between pervious and impervious urban fractions, for example through pervious and impervious canyon-floor fractions in CLM-U (Oleson et al., 2008). TEB-related developments add infiltration through artificial surfaces, and connected rainfall interception on roofs and roads toward a soil component (Lemonsu et al., 2007). Other schemes refined the representation of water stored on impervious surfaces and its evaporation after rainfall, as in TERRA-URB (Wouters et al., 2015). Hydro-microclimate approaches further extended urban hydrology to include subsoil beneath built surfaces, lateral water transfer between pervious and impervious tiles, sewer drainage, and irrigation, as in TEB-Hydro (Stavropoulos-Laffaille et al., 2021, 2018). Despite these advances, recent intercomparison work shows that urban water-balance representation remains uncertain in ULSMs, especially regarding water-balance closure, storage dynamics, and runoff parameterization (Jongen et al., 2024). Progress is also constrained by observations, because urban sites providing turbulent fluxes do not provide all water-balance terms needed to evaluate runoff, irrigation, drainage, and storage changes consistently at the same spatial scale (Jongen et al., 2024).”

And:

“Second, we introduce a parsimonious, physically motivated, representation of imperviousness. Rather than resolving separate water budgets for pervious and impervious urban sub-tiles, the proposed approach preserves the existing ORCHIDEE soil hydrology with an urban soil tile where imperviousness is represented through its effect on the hydraulic properties of the soil column. Specifically, imperviousness modifies saturated hydraulic conductivity as a function of depth, allowing it to influence infiltration, surface runoff generation, soil water storage, and vertical water transfer. This formulation is designed for one-tile, kilometer-scale and coarser LSM applications, where the objective is to represent their aggregate effect on the water budget and surface fluxes feedback to the atmosphere.”

And:

«A more refined representation of urban hydrology could also help address the above biases. Urban land surface models use a range of runoff strategies, from routing a fixed fraction of rainfall directly to runoff to more process-based formulations accounting for infiltration capacity, soil saturation, surface-water storage, and transfers between pervious and impervious tiles. The simpler formulations may be insensitive to rainfall intensity, antecedent soil moisture, and site characteristics (Jongen et al., 2024). The

present study introduces a novel physically based representation of imperviousness by linking it to saturated hydraulic conductivity, thereby affecting infiltration, subsurface water transfer, and runoff generation. This development directly addresses the weak sensitivity of runoff to imperviousness found in 7 of the 18 models evaluated by Jongen et al. (2026). Nevertheless, Jongen et al. (2026) also found that 10 models omitted at least one major runoff-generation mechanism. Future developments should therefore represent surface ponding and interception storage, irrigation, drainage connectivity, and water transfers between urban and vegetated tiles. These processes should ultimately be evaluated against hydrological observations, because the present sensitivity analysis alone cannot establish whether the simulated water partitioning is realistic. Importantly, advancing the hydrological realism of the model should not be guided by latent heat performance alone, but by a comprehensive evaluation of the full water balance (Jongen et al., 2024). However, such evaluation is currently limited by a lack of observational data for key hydrological variables (e.g., runoff and soil moisture) at the urban flux tower sites used in this study (Jongen et al., 2026, 2024). This underscores the need for coordinated efforts to collect hydrological data in urban environments to support model development and validation.»

- The term “drainage” should be replaced with “subsurface runoff” or other terms throughout. The manuscript uses “drainage” (e.g., L132, L245–247, L516–527) to refer to gravitational outflow at the bottom of the 2 m soil column. However, the term “drainage” in an urban hydrology context typically refers to engineered drainage infrastructure (sewers, storm drains), which is explicitly noted as absent from this model. This conflation of terms is potentially misleading, particularly for readers from the urban hydrology community and in the context of the stated objective of advancing urban hydrological representation in LSMs. The authors themselves use “subsurface runoff” as a synonym in places (e.g., L132). Please use “subsurface runoff” or other terms consistently throughout the manuscript to avoid ambiguity.

We thank the reviewer for this important clarification. We agree that “drainage” may be misleading in an urban hydrology context, as it can refer to engineered infrastructure. We have therefore replaced it with “subsurface runoff” throughout the manuscript.

Specific Comments

- L27–29: Would the authors provide some examples of which land surface models they were referring to?

Yes, we now include 3 examples for each:

“Historically, their development followed two pathways shaped by the application scale. GCM-oriented LSMs, such as ORCHIDEE, CLM, and JSBACH, operate on coarse grids (tens to hundreds of kilometers; e.g. Fisher and Koven, 2020) and focus on global water and carbon cycles (Krinner et al., 2005; Lawrence et al., 2019; Raddatz et al., 2007). By

contrast, LSMs used in mesoscale and limited-area models, such as Noah-MP, TERRA, and ISBA-SURFEX, have long used finer resolutions, favoring more accurate landscape representation and parameterizations relevant at kilometer scale over restricted domains or shorter periods (Doms et al., 2011; Masson et al., 2013; Niu et al., 2011), but neglecting groundwater processes (Barlage et al., 2021)."

- L57: What does "leading to significant advances" refer to here? Please clarify or provide specific references.

We meant improvement of fluxes simulation; we removed this last part of the sentence.

- L81: Please spell out "PFTs" at first use.

Done

- L83–100: This is a coherent paragraph, but the authors could be more explicit about which key surface properties they are referring to. Listing them explicitly (e.g., (1) albedo, (2) roughness, (3) thermal properties ...) would improve clarity, as the current prose is slightly convoluted.

We added: "(1) radiative properties, particularly albedo and longwave-radiation trapping; (2) aerodynamic properties, including surface roughness and urban geometry; (3) thermal properties, especially heat capacity and thermal conductivity; (4) vegetation cover, imperviousness, and water availability; and (5) anthropogenic heat emissions."

- L125–127: Do the authors mean "energy fluxes associated with radiative and aerodynamic parameters are aggregated for individual grid cells as PFT-weighted parameters"?

Yes, we modified as suggested.

- L128–133: This paragraph raises two points of confusion. First, what distinguishes the soil columns for bare soil versus high and low vegetation? Do they differ in soil properties, depth, or only rooting effects? Maybe this detail embedded in ORCHIDEE, but it is important for readers who are not familiar with ORCHIDEE. Second, the model has a 2 m hydrology column and an 18 m temperature column, both discretized into 12 layers—does this imply a mismatch in layer thicknesses between hydrological and thermal calculations? Please clarify.

Thank you for highlighting this issue, we added a new figure 1 to describe ORCHIDEE structure, and we modified the paragraph into:

"Each grid cell contains three soil columns, one for bare soil, one for high vegetation, and one for low vegetation. These columns have the same depth, vertical discretization, soil texture, and texture-dependent hydraulic properties. They differ in their vegetation-related processes: the high- and low-vegetation columns have distinct rooting profiles and root-water uptake, whereas the bare-soil column has no root extraction. Their soil-

moisture states and water budgets therefore evolve independently. Each soil column is vertically discretized (12 layers, down to a depth of 2 m for hydrology, and 18 m for soil temperature computation), allowing the model to simulate temperature and moisture transfer through the soil profile. For each soil column, ORCHIDEE calculates the surface runoff, and subsurface runoff, representing gravitational outflow at the bottom of the soil column.”

Later in the manuscript we also now specify:

“The hydrological and thermal discretizations share the upper 2 m of the soil column. Within this common domain, hydrological soil-moisture variables are transferred to the thermal grid, including interpolation of volumetric water content to the thermal-layer interfaces. Below 2 m, the saturation degree and volumetric water contents are held equal to those of the deepest hydrological layer, while the total water content is adjusted for the thickness of each thermal layer.”

- L140: Consider using the plural “theses” here, as multiple Ph.D. and HDR theses are cited.

Done

- L142–144: The text states that snow-covered conditions and floodplains are “not considered in this description.” Does ORCHIDEE represent them at all, and they are simply excluded from the description for brevity, or are they absent from the model? Please clarify.

We clarified that snow-covered conditions and floodplains are represented in ORCHIDEE but are omitted from this methodological description for brevity, as they are not directly relevant to the urban one-tile developments presented in this study:

“For clarity, snow-covered conditions and floodplain processes, although represented in ORCHIDEE, are omitted from the description below because they are not relevant to the urban one-tile developments presented here.”

- Equation 2: Where are the ground heat flux (G) and heat storage (dW/dt) terms? Does the model assume these are negligible, or are they resolved elsewhere? This should be explicitly stated, as they appear in Equation 1.

Thank you for highlighting this point. Equation (2) defines only the net-radiation component of the surface energy budget and is therefore not intended to include the turbulent or conductive fluxes. In ORCHIDEE, the sensible and latent heat fluxes are calculated separately in Eqs. (4) and (5), while the ground heat flux G is calculated from the temperature gradient between the surface and the upper substrate layer in Eq. (7). This flux provides the upper boundary condition for the one-dimensional heat-diffusion equation used to update the soil-temperature profile. Heat storage and release within the soil or urban substrate are therefore represented prognostically through G and the

evolution of the thermal profile; they are not neglected or introduced as an additional independent dW/dt term. We revised the text and Eq. (1) to clarify this formulation and avoid double counting heat storage.

- L162–163: The list of latent heat flux components appears incomplete. Evaporation from canopy interception is missing as in L250, ORCHIDEE does include evaporation from vegetation interception (canopy interception). Please double check.

Thank you. ORCHIDEE includes evaporation of water intercepted by the vegetation canopy, also referred to as interception loss. This component was inadvertently omitted from the list, although it was included later in the methodological description. We have revised the sentence to list all four components of the latent heat flux: bare-soil evaporation, plant transpiration, canopy-interception evaporation, and snow sublimation.

- L237–241 and L239: This paragraph is slightly confusing and could benefit from clearer structure. Also, please provide the unit for F_K max.

Thank you for this comment. We reorganized and simplified the paragraph to distinguish more clearly between the reference conductivity, its depth-dependent reduction, and the root-induced enhancement:

“In version 2.2 of ORCHIDEE, the vertical profile of saturated hydraulic conductivity $K_s(z)$ is prescribed as a function of depth. Its value at any depth z results from three components:

- (i) Reference saturated hydraulic conductivity (K_s^{ref}) at the depth $z_{lim} = 0.30\text{m}$, derived from the dominant USDA (U.S. Department of Agriculture) soil texture of the grid cell (12-class texture classification). Each grid cell's dominant soil texture influences soil transfer (Ducharne et al., 2018; Tafasca et al., 2020).
- (ii) An exponential decrease with depth, controlled by the dimensionless factor $F_K(z)$. This decrease applies from z_{lim} to the bottom of the soil column (2 m).
- (iii) A root-induced enhancement in the upper soil layers, represented by a factor $F_{Kroots}(z, c)$, where c denotes the soil-column index. This enhancement is applied only to vegetated soil columns, whereas $F_{Kroots}(z, c)$ is set to 1 for the bare soil column, which therefore retains a constant K_s over the first 30 cm (d'Orgeval et al., 2008; De Rosnay et al., 2002).

The resulting expression for the saturated hydraulic conductivity profile is:

$$K_s(z) = K_s^{ref} F_K(z) F_{Kroots}(z, c) \quad (15)$$

where $F_K(z)$ controls the exponential decrease with depth:

$$F_K(z) = \min\left(\max\left(\exp\left(-f(z - z_{lim})\right), \frac{1}{F_K^{max}}\right), 1\right) \quad (16)$$

Apart from the texture-dependent K_s^{ref} , the other three parameters (z_{lim} , f , F_K^{max}) are constants, i.e. they do not depend on the PFT, the soil tile, and the soil texture. The depth z_{lim} is set to 0.30 m, the decay factor f is set to 2 m^{-1} , and the dimensionless parameter F_K^{max} is set to 10. Therefore, $F_K(z)$ cannot be smaller than $1/F_K^{max}=0.1$.”

- L255: Please use “potential evapotranspiration”.

Done

- L271: The clear definition of “imperviousness” can be helpful here or when this terminology was first introduced. Does it refer to the impervious surface fraction (the interpretation implied by Eq. 24) or a more general hydrological concept?

Thank you for this comment. As detailed in our response to the first major comment, we now define imperviousness explicitly in both the introduction and the model description. In Eq. (24), imperviousness corresponds to the prescribed impervious surface fraction, ranging from 0 to 1. However, it is not used to partition the urban tile into separate pervious and impervious fractions, nor does it represent the fraction connected to the drainage network. Instead, it is translated into an effective hydrological control by scaling saturated hydraulic conductivity throughout the urban soil column. We have clarified this distinction at its first introduction and at Line 271.

- Equation 22: Please use a different notation for the saturated hydraulic conductivity of the urban PFT. The symbol K_s is already used in Equation 15 for non-urban PFTs, and reusing it creates unnecessary ambiguity.

Yes, thank you for this observation, we have change $K_s(z)$ to $K_s^{urb}(z)$.

- L320: According to He et al. (2023), the reference model is Noah-MP, not NOAH. Please verify and correct this throughout the manuscript.

Done

- L426: Since maximum daily sensible heat fluxes naturally take the largest absolute values, it is not surprising that they also show the largest absolute biases. It would be more informative to evaluate model performance in relative terms (e.g., normalized bias or percentage error) to allow fair comparison across variables.

We agree that absolute bias magnitudes should not be interpreted as a direct ranking of relative performance across flux variables, because their characteristic magnitudes differ. Figure 3 is intended primarily to compare model configurations within each flux

diagnostic while retaining the sign and physically interpretable magnitude of the biases. We have revised the text to clarify this scope and no longer interpret the larger absolute sensible heat biases as evidence of poorer relative performance than for the other fluxes.

We did not introduce normalized or percentage errors because a single normalization applicable to all diagnostics would not be robust. In particular, the observed nighttime minima frequently approach zero and may change sign, making normalization by the observed mean or individual values unstable or undefined. We have instead explicitly acknowledged that the small absolute biases in minimum latent heat flux do not necessarily indicate high relative accuracy, while their consistently positive sign provides evidence of systematic nocturnal overestimation:

"Because the characteristic magnitudes differ among fluxes and between daytime maxima and nighttime minima, the absolute bias magnitudes should not be interpreted as a direct ranking of relative model performance across panels. The comparisons below focus primarily on differences among model configurations within each diagnostic. "

- L451: Similarly, minimum daily latent heat flux values are inherently small, so small absolute biases here are expected. A relative comparison would be more meaningful.

We agree that the small absolute biases partly reflect the inherently small magnitude of nocturnal latent heat flux and should not, by themselves, be interpreted as indicating high relative accuracy. As explained in our response to the previous comment, we retained the absolute bias but clarified its interpretation in the revised manuscript.

- Figures 4 & 5: The text in the first x-axis tick label is cut off. Please fix.

We updated the figures 4 and 5 of the manuscript with a complete x-axis that is not cut off.