Specific Comments.

LL 6 and also LL 103-104. Please note that not all hydroclimatological events listed here will lead to “compound events”. “Compound events” is used a bit loosely in the manuscript.

We acknowledge that not all hydroclimatological events listed will necessarily result in compound events. We will revise the manuscript to ensure that the term "compound events" is used more precisely and appropriately with the definition.

We will revise the manuscript:

As our understanding deepens and the urgency to address future climate disasters grows, it becomes clear that hydrological disasters—such as floods, droughts, urban heat island, and more frequent heat waves- cannot be considered in isolation. These disasters can occur simultaneously or successively, creating compound events (Wehner, 2023; Zscheischler et al., 2020). Evaluating the compound impact of these interconnected disasters is crucial, as it provides a more comprehensive understanding than considering each disaster in isolation.

LL 63. “…small scale heterogeneity” is also characteristic of many natural systems not only urban.

We will revise the sentence in the manuscript as below:

Cities are characterized by dense populations and intense socio-economic activity, leading to intensive landscape modifications. Meteorology is notably intricate and heterogeneous in urban areas, and the hydrological processes differ significantly from those found in the natural environment. While small-scale heterogeneity is also characteristic of many natural systems, urban areas exhibit unique patterns and scales of heterogeneity due to human activities.

LL 72. At this stage is not clear what a distinction between a “urban meteorology tool” and “urban land surface model” is. A U-LSMs to be an urban meteorology tool needs to be coupled with a mesoscale weather model, otherwise at the best it can explore “micrometeorology” in the canyon, not the overall city meteorology.

We will revise the phrase and the sentence to be more rigorous. To avoid ambiguity, we re-wrote these sentences in lines 72 – 73:

To adequately simulate urban climate dynamics, several land surface parameterization schemes for urban areas have been developed in recent years, sometimes including urban land-atmosphere exchange. Urban land surface models (ULSMs) have been intensely applied to simulate urban thermal conditions in the past decades.

LL 82-82. It might be worth referring to Jongen et al 2024, which is looking to "hydrological aspects" of these U-LSMs, already at this stage and move the later text here.

We will move the text "*Recently, Jongen et al. (2024) evaluated the water balance in 19 ULSMs from the Urban-PLUMBER project (Lipson et al., 2024), concluding that the water balance appears unclosed in 43% of the model runs. The interactions between the urban water cycle and the energy budget may not be comprehensively captured by the existing models*." to the second paragraph of the Introduction.

And in the fifth paragraph of the Introduction section, we will revise the sentences: *Current process-based simulation tools, such as ULSMs and UHMs, have evolved independently, each driven by distinct considerations and applications. This divergence has resulted in limited overlap and interaction between the two. Consequently, accurately simulating urban hydrological and near-surface meteorological conditions—collectively referred to as hydro-meteorological conditions—simultaneously remains challenging. This makes it difficult to assess the risk of extreme events, particularly compound events, and to develop diverse strategies to address future climate change.*

LL 89-90. I think this sentence is not clear, I would suggest rephrasing it.

We will change the sentence into:

Regarding hydrological processes in urban areas, there is no universally accepted definition of the urban water cycle. However, many texts have previously agreed on dividing the system into two main networks: modified natural pathways and supply-sewerage pathways (Lerner, 2002; Dwarakish and Ganasri, 2015).

LL 163-164. While it is true that they represent all urban facets, many CFD approaches prescribe surface temperature of urban facets or of a subset of urban facets, which means they are not solving for energy budget (or at least not fully solving for it).

We will revise the description of the Building-resolving models to be accurate.

LL 172-173. I would suggest rewriting this sentence, it reads awkwardly.

We will rewrite the sentence into: *Studies using CFD models to explore microscale urban climate, energy balance, and wind environment are common, but rarely focus on water balance processes (Lipson et al., 2024).*

Table 1. For UT&C please see also Meili et al 2025, with further model developments.

We will incorporate this study to our review and add it into Table 1.

LL 221. How are lateral water flows solved in SUEWS?

We will add a description on how and to what extent SUEWS addresses the lateral water flow among different types.

Based on literature, in SUEWS, the surface water lateral flow within the grid cell, but among the different land use types, is simulated by the following steps:

Each surface calculates its drainage based on the water balance equations. The water distribution matrix, which specifies how water is redistributed among different surface types, will be used for the surface lateral flow process. For example, water drained from a paved surface might be partially redirected to nearby grass or soil surfaces. When the infiltration capacity is exceeded, excess water becomes surface runoff. The model calculates potential runoff for each surface type and redistributes it according to the water distribution matrix.

Besides, SUEWS accounts for both above-ground (surface runoff) and below-ground (subsurface flow) water movements. This ensures a comprehensive simulation of lateral water flow. We will include this part in section 5.4.1 and Table 7.

LL 255. Please note that a main advancement of UT&C is the capability to consider physiological and biophysical properties of vegetation, and thus being able to consider different vegetation types – at least in principle - which was not the case in any of the other models except partially VTUF-3D

Thank you for your valuable insight on the model UT&C. We will add the mentioned main advancement of the UT&C in the manuscript.

LL 261. They take "wind speed" too as input. I suggest having the complete list of six environmental variables. Pr, Ta, RH, Ws, Rsw, Ldw, some models need atmospheric pressure too.

Indeed, some models take wind speed as input forcing. We will revise the sentences and the Figure 2.

LL 276. The second acronym should be TUF-3D, without "V".

We will revise this, thank you for checking.

LL 313 and below. Maybe using "grid cell" rather than "square" would be more aligned with the previous literature. Overall, I think this part can be shortened.

We will modify the manuscript using the "grid cell".

LL320-333. I find all this part a bit convoluted and not very clear, please consider rewriting and probably shortening, as it might not be so essential.

The paragraph is shortened and more concise:

Figures 3c and d show the structures of the coupled mode in climate models, which simulate the entire study area in one go. These models use square grid cells of uniform size. SUEWS, similar to a complete land surface model, includes impervious land. Recently, WRF-SUEWS (Sun et al., 2023) was developed as a land surface scheme. The main difference between standalone and coupled SUEWS is the interaction of atmospheric conditions with the land surface. The coupled mode uses Urban Canopy Models (UCMs) for impervious areas, with the fraction set manually based on urbanization or land use data. The land surface model handles other landscapes like grass or bare land. Interactions between impervious and other land areas occur indirectly through air exchange. Coupled mode simulations resolve grid-to-grid atmospheric differences but limit grid-to-grid interactions. Coupled mode 2D UCMs focus on impervious land, while standalone UCMs integrate various urban canyon processes (Ryu et al., 2016; Wang, 2014; Lemonsu et al., 2012). Thus, standalone models are usually more advanced and comprehensive for urban process (Krayenhoff et al., 2020; Meyer et al., 2020).

LL346-347. Please note that “urban block scale” and “neighborhood area” are quite vague and actually they might largely overlap, a clarification about scale might be helpful here.

We acknowledge that the terms "urban block scale" and "neighborhood area" have a significant overlap. We will change the description enhancing the precision and clarity.

Consequently, UCM models are more widely utilized for studying regional impacts at the hundred-meter scale, and high-resolution CFD models are primarily used for detailed research at the meter scale.

LL 350. “present” rather than “utilise”

We will revise this.

LL 402-403. Please note that data availability might be an issue when defining branching and drainage structures in many urban environments, as sewage system locations are often poorly known in old cities or not available in modern cities. This can also be discussed later.

Indeed, we totally agree that the availability of data is an essential issue. We will include this in the challenge and future development section of the manuscript.

In Section 6 we have a discussion on this:

However, both 3D ULSMs and URBS hydrological models require high-resolution input data, such as urban morphology, topography, and sewer systems. This need for detailed urban data limits the application of URBS compared to models like SWMM. As data *collection and measurement methods for urban morphology and infrastructure improve, high-resolution simulations of urban microclimates and hydrological processes at the neighborhood scale may become feasible, enabling comprehensive thermal and hydro-hydraulic interactions.*

LL 435. Are you referring to water surface as "urban lakes" or "ponding water in various surfaces" the latter is likely solved in most U-LSMs.

We are referring to urban water surfaces, including urban lakes. We will revise the sentence to be clearer. Our review indicates that most Urban Land Surface Models (U-LSMs) do not incorporate these urban water surfaces. Specifically, only the SUEWS, TARGET, and Solene-Microclimat models resolve the energy balance above water surfaces. In most Urban Canopy Models (UCMs), only canyon elements (streets and buildings) and canyon vegetation are represented, meaning water surfaces are not addressed within an urban grid. In coupled models, where ULSMs are integrated with regional climate models, all water surfaces are simulated solely by the Land Surface Model (LSM). Our study highlights the need to consider how urban water surfaces, which can differ significantly from natural landscapes, influence the urban micro-mesoscale climate.

LL 458. Please note that the shortwave and longwave radiation budget is different and not only sky view factors but view factors among different urban facets are required, at least for longwave exchange, it is also not true that all U-LSMs do not compute multiple reflections.

We will adjust the sentence.

LL 459. "radiosity method" is unclear.

Thanks for your comment. The phrase "radiosity method" is directly adopted from the literature on the Solene-Microclimat model. We have an explanation of how this method works: "*This method involves two critical aspects: 1) geometric form factors between all facets of the built surface and the sky vault are calculated using the contour integral technique; 2) radiative properties (reflection, transmission, and absorption) are considered for all surfaces within the scene*." We will revise this part of the manuscript and make the description of this method clearer.

Table 5. Maybe it could be interesting subdividing between models using a multi-layer vs two- or three-layers approach for solving the urban canyon, as more than one layer is not lumped anymore.

We agree that more than one layer is not lumped. In Table 5, if the model can solve more than one layer value within the canyon, we marked it as P (profile). We double-checked all the models to what extent they solve the hydro-meteorological conditions and distinguish the lumped (single layer), two layers and multi-layer (three and above) models. There are only single and multi-layer models in our selected models. Thus, we keep the Lump (L) and Profile (P) for the table.

LL 495. “area” rather than “ares”.

We will correct this.

LL 537. Urban Hydrological Models not “Urban Heat Models”, which does not mean anything.

We will revised this, thank you for checking.

LL 598. Applying the 1d Richards equation allows for the solution of infiltration, but it is much more than an infiltration method, as it allows the solution of variably saturated flow in multiple soil layers.

Indeed, we agree with the comment. In Section 5.4.1, we mentioned that the vertical moisture transport in multiple soil layers is solved by the 1D Richards equation in SLUCM, TEB, UT&C and VUCM.

LL 604-605. The description of the “Horton method” is wrong. It is the other way around, infiltration decreases exponentially up to an asymptotic constant value at large times, which is typically the saturated hydraulic conductivity.

We double-checked the Horton method, and we agree with your comments. We will revise the manuscript:

The Horton method is an empirical model. It assumes that infiltration decreases exponentially over time until it reaches a constant value, typically the saturated hydraulic conductivity.

LL 615. Please note that on most impervious surfaces (e.g., roofs, paved streets), the saturated hydraulic conductivity will be fundamentally zero, so why one should compute infiltration? This is not clear to me.

You are correct that infiltration over impervious surfaces is negligible, which is consistent with the approach taken by most ULSMs. Our intention is not to suggest that models should compute infiltration over impervious land. Rather, we are highlighting that some models set a constant rate for infiltration over impervious surfaces, while others do not. This is a summary statement. We will make it clearer in the manuscript and propose the following sentences:

Generally, if a model includes the water balance, it considers depression storage and infiltration. Based on the above summary, depression storage over impervious land areas *can be solved relatively easily. The infiltration process over impervious land is not taken into consideration because the saturated hydraulic conductivity of these surfaces (e.g., roofs, paved streets) is fundamentally zero.*

LL623. Do you mean Table 7?

Yes, we will revise it.

LL 638. In VTUF-3D and UT&C transpiration is indeed simulated using an explicit solution of stomatal conductance, which is a function of photosynthesis, so plant photosynthesis needs to be solved.

Thanks for your comment. We will expand our description of the process of solving the transpiration in VTUF-3D and UT&C.

LL646-656. I think here, there is a bit of confusion around Penman-Monteith equation method. If a model solves the energy budget (i.e., latent heat) by solving for surface temperature/s, there is no need to use Penman-Monteith equation, which is actually a simplification of the overall energy budget and it does not guarantee energy budget closure. I think which models use Penman-Monteith and which aren't should be better described and specified.

We will summarise this and will make it clear in the manuscript. The paragraph starts from LL 646 and will be revised.

There are several groups of methods to calculate the evaporation:

1) SUEWS (Ward et al., 2016) and WEP (Jia et al., 2001): calculated based on the Penman-Monteith equation. The models first obtains the net radiation, equal to the sum of the heat fluxes, including sensible, latent and ground heat fluxes. The storage heat flux and anthropogenic heat flux will be calculated, and then the latent heat flux will be calculated based on the Penman-Monteith equation. The energy balance closure will be solved by setting the residual as the sensible heat flux.
2) VUCM, ASLUCM, TEB, UT&C, VCWG (Lee, 2011; Meili et al., 2020; Masson, 1999; Wang et al., 2013): solve the evaporation using the resistance method. This method directly calculates the moisture heat flux based on the saturation value of specific humidity at a given surface temperature. These models directly solve the energy balance and the surface temperature.
3) URB (Berthier et al., 2004): The evaporation flux is assumed to be proportional to the potential evapotranspiration and water storage, while the potential evapotranspiration is the model's input forcing.
4) SWMM (Rossman,2017): three simplified ways, including setting as a single constant value, getting from the input data, and computing the daily values from the daily temperatures in an external climate file

LL 692-694. Does this refer to canopy or ground vegetation? This is not clear.

We double-checked the literature Lee and Park, 2008. The vegetation referred to in the study is canopy vegetation. We will make it clear in the manuscript.

LL723. The end of the sentence is not clear, which empirical models? Which calibration?

We will revise this part of the manuscript with more details as follow:

Soil conductivity and saturated soil conductivity in urban hydrological models are consistent with those represented in most Urban Land Surface Models (ULSMs). These parameters can be calibrated in the field using infiltrometers and laboratory measurements, such as the constant head and falling head methods (Gupta et al., 2021). Additionally, they can be estimated using empirical models based on soil type, moisture content, and temperature, such as Pedotransfer Functions (Van Looy et al., 2017). The accuracy of these estimates can be further enhanced through machine learning techniques, including artificial neural networks and random forests (Jian et al., 2021).

LL770-772. I am not sure I understand the question here and especially why it is formulated as a question. It is mostly a parameterization issue how to deal with these processes.

Reply to the comments LL 770 – 772: We will revise the sentence:

As stand-alone ULSMs increasingly incorporate natural land surfaces and interaction processes, it becomes imperative for regional atmosphere-land models and ULSMs to systematically address the radiation, aerodynamic, and dynamic interactions between natural landscapes and anthropogenically influenced landscapes, particularly water surfaces and built-up areas.

LL 778. I am not sure I understand why ones would like to have two-ways feedback from the hydraulic part to the atmosphere, being the flood response mostly a very fast process and occurring largely in impermeable channels and drains.

We understand your perspective on the rapid nature of flood response and the role of impermeable channels and drains. Indeed, the atmospheric simulation output can be the input for the urban flooding forecast. However, we believe there are several reasons why linking atmospheric models, land surface models, and hydrological-hydraulic models can be beneficial: 1) Two-way feedback allows for more precise monitoring and control of hydraulic systems, which can improve the accuracy of flood predictions and responses. Currently, the hydraulic model takes a single grid precipitation data as the input. However, with a deeper understanding of the urban impact on precipitation events, the spatial variability can be quite large, even within a catchment, depending on its size. Thus, higher-resolution input data for hydraulic systems can provide better performance. 2) Two-way feedback can help manage waterlogging more effectively by providing real-time data on soil saturation and atmospheric conditions. This can lead to better predictions and responses to waterlogging events. 3) Two-way feedback can improve the simulation of the urban micro-climate during and after extreme precipitation events that may lead to urban flooding. This can also optimize drainage and reduce the negative impacts on local urban ecosystems.

To be clearer, more accurate and specific, as also suggested by reviewer 3, we will revise our manuscript for Section 6, Challenges and future developments, to include a more detailed explanation of the necessary model coupling. The revised Section 6 explicitly frames future developments around specific urban hydroclimate challenges, including urban thermal environment adaptation, urban flood forecasting, and compound extreme event analysis. The necessity and significance of model coupling strategies and modelling approaches are addressed for each specific topic.

LL 875. As the authors know, total evaporation and latent heat flux is the same thing, just different units, the sentence is awkward.

Yes, we will revise the sentence:

The surface water balance in ULSMs integrates evaporation, which is expressed as latent heat flux, thereby linking the water and energy balances. Conversely, UHMs may neglect or aggregate evaporation processes. ULSMs typically include multiple subsurface soil layers with vertical water transfer, predominantly within the unsaturated zone. However, their description of the saturated zone is often limited.

References

Meili, N., Zheng, X., Takane, Y., Nakajima, K., Yamaguchi, K., Chi, D., Zhu, Y., Wang, J., Qiu, Y., Paschalis, A. and Manoli, G., 2025. Modeling the effect of trees on energy demand for indoor cooling and dehumidification across cities and climates. Journal of Advances in Modeling Earth Systems, 17(3), p.e2024MS004590.