Review 2

Review of the manuscript entitled “Implementation of a dry surface layer soil resistance in two contrasting semiarid sites with SURFEX-ISBA V9.0” by Belen Marti et al.
This manuscript develops a new dry surface layer (DSL) resistance for the ISBA LSM to simulate more realistically evapotranspiration processes in rural areas. Two observational sites located in the north-eastern of Spain are used to validate the performance of the model. Three simulations (offline) are performed with the LSM in each site, one run does not use a soil resistance parameterization (hereafter NON simulation), one experiment uses the DSL approach (henceforward DSL simulation), and finally, the third simulation considers the soil resistance parameterization developed by Sellers et al. (1992b and 1996), hereafter S92 simulation. Modeled sensible, latent, and net radiative heat fluxes are compared against observations and common statistical errors are calculated for each experiment and site. This manuscript is interesting but considerable changes are needed before it can be accepted for publication.

We thank you for your positive review. We write this response in the past tense for clarity reasons. The modifications you suggest have been implemented as described in this response, the suggestions by the other reviewers have also been taken into account. The main text has been considerably reduced by moving the vegetation model description to an appendix, but other reviewer comments have asked for some additional text, although mostly minor. The main changes that the revised manuscript has following reviewer’s comments are:
-Part of section 2.3.1 has been moved to the introduction by another review’s suggestion
-Reduction on the number of equations, moving the larger part of the vegetation model description to an Appendix
-Tables that can be omitted from the main text have been moved to the appendices.
-Addition of a glossary (symbols, units: as suggested by the review process)
-Vegetation parameter discussion is moved to an appendix and only parameter value decision is left on the main text due to the extension of the main text.
-Small modifications to the figures as per the review process
-A section to prepare the reader for the sensitivity analysis has been added
-A table of sensors of the surface energy stations has been added and together with further citations of available related measurements
-The description of the measurements available has been clarified

1. Abstract, line 4. Before “models” add “land surface”.

It has been replaced in the revised manuscript

2. Page 3, line 75. “Both parametrizations are tested”, what parametrizations? The only parametrization described until now is the dry surface layer (DSL).

The citation of each parameterization has been added in the previous paragraphs and the line reads as: “Both the Sellers et al. (1992) and the Swenson and Lawrence (2014) parametrizations”

3. Section 2 should be reduced considerably. If you think all equations are important add them in an appendix or as a supplementary document.
This section is interlinked with the vegetation parameterization of the alfalfa, which has been moved to an appendix and reduced to a specification of the parameter values in the main text. Consequently, section 2.1 has conserved the latent heat decomposition and the vegetation decomposition has been moved to the appendix together with all of section 2.2.

4. Section 3.1. All the observational data collected in both sites and used for validating the simulations should be clearly explained.

A paragraph has been added indicating existing measurements and where to find further description at the end of section 3.1:
*Two surface stations were installed at la Cendrosa, the longer series was taken Canut 2022a). Measurements of temperature, humidity and wind at different levels depending on sensor availability and high frequency measurements were available 3 m, 10 m, 25 m and 50 m for the two sites (see Boone et al. (2025) and Brooke et al. (2023) for more details).*

The type of data used was already explained in sections 3.2 and 3.3.  Clarification on the surface energy budget terms has been added as indicated in the following comment.

5. Section 3.2. How were the SEB terms calculated/observed, especially the ground heat flux (G)? In general, the ground heat flux is calculated as the residual term of the SEB equation, that is, G = Rn – H – LE. However, in this study/experiment is not the case. Please, clarify.

A four component radiometer and an eddy covariance measurements with a gas analyser were used for Rn, H and LE respectively. A table of the sensors has been added to the appendix and is cited in the text. A buried flux plate measures the soil temperature and the soil temperature measurements allow the use of the calorimetric method to correct for the storage and adapt the flux to represent the flux of energy into the soil at the surface.
The following text has been added to add this information:
*They consisted in eddy-covariance systems equipped with a gas analyser to measure the turbulent fluxes and buried sensors including buried temperature sensors and flux plates, allowing the measurement of the ground flux directly and correction of its measurement to the surface (see Table E1) with the calorimetric method (de Silans et al. 1997).*

**Table E1.** Instruments at the selected SEB stations (N.A. represents non-applicable). CSAT3, EC150 and Krypton are Campbell Scientific (CS) Instruments; LI stands for LI-COR, HS-50 and R3-50 are Gill models, CNR1, CNR4, CRg4 and CM21 are Kipp & Zonen devices, the flux plates are made by Hukseflux. There were two SEB stations at La Cendrosa from the CNRM and from WUR.

| Site | Sonic and gas analyzer height (m) | Net radiation, height (m) | Flux plate depth (cm) | Soil temperature: depths (cm) | soil moisture depths(cm) |
|---|---|---|---|---|---|
| La Cendrosa | Gill R3-50, LI7550, 3.0 | CNR4, 1.0 | 3 | Generic Pt100, 5, 10, 30 | Delta T Thetaprobe ML3, 5, 10, 30 |
| La Cendrosa | IRGASON, LiCor7500, 1.0 | CM11 & CG2 | 5 | Generic Pt100, 2, 10 | N.A. |
| Els Plans | HS-50, Krypton, 2.0 | CRg4/ CM21, 1.0 | 2 | Delta T ST2 1, 4, 10, 17, 35, 50 | Delta T ML3, 10, 20, 30, 40 |

6. Section 3.3, line 288. The fact that the albedo is lower in El Plans than in La Cendrosa cannot explain the lower value for the Rn. Low albedos increase net radiative heat fluxes.

You are right, and furthermore the albedo is quite variable at this site, so depending on the period, it is lower or higher, which it is explained later in its own section. We now comment on the time difference. The sentence has been changed to:

"The Els Plans site is a rainfed, relatively dry area with natural grass that was drying during the LOP. The parcel is located within a special protection area for steppe birds, and it is not cultivated. The energy budget of a short dry-down period near the end of the LOP (Fig. 3) *with two small rain contributions of 2 mm and 0.8 mm on the eve of 2 September*. The Rn difference is due to the because the contribution of the net long wavelength radiation is lower and time difference between the two periods which can account up to 100 W m-2."

The additional rain sentence is due to another reviewer's comment.

7. Section 4.1, line 305. "The wind speed was filled with the 3 m data at the same site", It is the first time that observations are reported at this height in the manuscript. Was the wind speed recorded at 10 m or 3 m above ground? or at both heights?

It was measured at both heights. The text now reads as:
"The wind speed was filled with an additional wind measurement at 3 m at the same site, corrected by adjusting the wind speed to that which was already measured at 10 m above the surface assuming a logarithmic profile at neutral conditions."

8. Section 4.2.1. Is this large section needed? A summary with a table showing the values used in the runs should be sufficient. Results section starts at page 17!!!

The section has been reduced to a parameter value selection and its full version is sent to an appendix. While we agree with this reviewer (about removal of this text from the main body), we believe it is important to maintain it in the document as its contents are not reported in recent literature and fill a gap in knowledge that helps setting up simulations of this kind.

9. Section 5.1. Why do you think the ground heat flux is not improved with the new dry surface layer approach?

The heat is not being transferred to the atmosphere but to the soil. The roughness length can be increased to reduce the effect but the value of LE is then significantly reduced. A choice of configuration has been made for the purpose of this article. Some clarification has been added: "After irrigation, the NON simulation better reproduces the soil temperature diurnal pattern, the DSL simulation increases the temperature at 5 cm up to 5ºC in response to the increase in G due to the decrease in LE. *The interaction between the atmosphere and the ground is insufficient and heat is stored instead of being transformed into sensible heat. While the roughness length could be increased to reduce this effect, the characterization of LE would be impacted negatively*"
The subsection 'Parameter selection' justifies the choice of roughness length, which is taken within the tabulated values in the literature.
How is this term calculated in the LSM?

This term is extracted by the residual energy not spent in LE and H. It is presented as the ground flux at the surface.
A brief description of its calculation has been added to an appendix. The text reads as:
*The energy budget equation on the SURFEX model can be written as:*

$$Rn - H - LE - G' - S = 0$$

*where S is the energy storage term given by the transfer of energy and G' the ground flux given a particular ground level. G is given then by G' - S and it is defined at the surface.*

We refer to it in section 2.1 with the sentence:
*For completion, the G flux is also described in Appendix C1.*

10. Section 5.1, line 476. I was not able to find in Table 6 the daily RMSE reported for the ground heat flux in the manuscript (i.e., 57 W/m2).

The value should be 70 W m-2, it was erroneously taken as the value of La Cendrosa. It has been modified in the revised manuscript. The correlation values in the following text have been also corrected.

11. Figs 4-5. The period analyzed in these figures should be included in the captions.

The caption has been modified as follows. Figure 4 caption now reads as:

Scatterplots of the simulated terms of the energy budget against the observation for La Cendrosa site for the NON simulation (NON, a-d) and the DSL simulation (DSL,e-h). From left to right, Rn (a,e), H (b,f), LE (c,g), and G (d,h). *The simulation period is from July 1 at 00 UTC to August 1 at 00 UTC.*

Figure 5 caption now reads as:

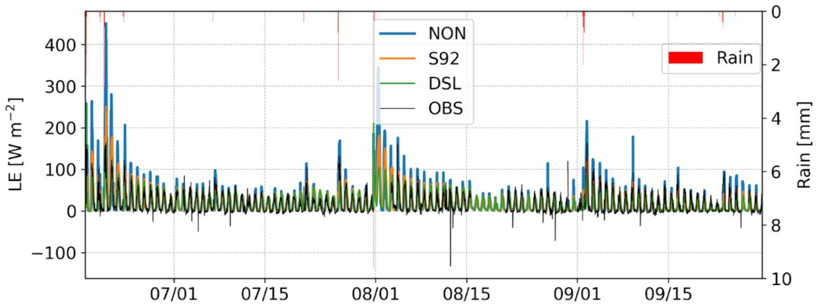
Scatterplots of the simulated terms of the energy budget against the observation for Els Plans site for the simulation with no resistance (NON, a-d) and simulation with the DSL approach (DSL,e-h). From left to right, Rn (a,e), H (b,f), LE (c,g), and G (d,h). *The simulation period is from June 17 10UTC to September 29 at 9UTC.*

12. Figs. 6, 7, and 8. The format of the days simulated (DD/MM) is not adequate.

It has been changed to MM/DD as in Figure 2 and 3.

13. Fig. 7b. Why does Fig. 7b show results for three months and Fig. 6b only shows results for 15 days for the Els Plans site?

Length of the series has been decided for viewing purposes, to better identify LE changes. VWC can be easily seen for a long period but flux series (see below) need shorter periods to be able to identify the processes.




14. Section 5.2.1. The resistance values shown in Fig. 7 are very different between S92 and DSL simulations, why do you think these significant differences are not producing substantial latent heat fluxes disparities?

Because there is not sufficient water. At some point no more evaporation is happening. We have added the sentence in italics to the text:

The resistance values estimated for Els Plans are similar to those found in Swenson and Lawrence (2014), while those of La Cendrosa are higher, due to the difference in soil properties. The increase in resistance starts earlier than observed in laboratory studies (Zhang et al. 2015). Their values were closer to the S92 simulation, but slightly higher and remained lower than those shown for the DSL simulation. *These differences result in limited change in LE as there's little water available in the soil, since the VWC is much lower than the field capacity.* In addition, Balugani et al. (2023) found that a DSL observed under natural conditions can be larger than that measured in a lysimeter, whether in laboratory or field conditions. The higher values for resistance compared to the ones by Zhang et al. (2015) may be explained by the exposition to the atmospheric conditions which will affect ET, soil moisture and soil temperature profile (Balugani et al. 2023). To explore this further, a sensitivity analysis is carried out in the following section to test the optimal parameter configuration.

15. Section 5.3.1. Is this section needed?

Yes, we believe that showing the variability of albedo due to the vegetation change for la Cendrosa and due to soil humidity in Els Plans so they can be seen explicitly is important, providing the full picture. Additionally, the setup of the simulation is reflected within this section.

16. Section 5.3.2, Fig. 10a. It seems to me (based on Fig. 10a) that the VWC is better captured by the NON simulation than by the DSL run, especially after the ~ 11th and before the ~ 24th of July, could you explain why?

The difference in VWC values for this period is due to whether the water is either being used by LE or being kept in the soil. The NON simulation overestimates LE signaling a too large loss of water. This explains why the decline in soil moisture is stronger for the non-DSL than for the DSL. Taking into account the tendency of the observations, the 'desired' behaviour is for the water to be evaporated.

While the absolute value is better in the NON simulation for this period it does not describe the processes better. The DSL simulation follows the tendency of the observations better, without crossing the observation, and final loss of water only differs by 1 mm. While being capable of doing both would be preferable, the good modeling of the tendency is prioritary as it is directly related to the evaporation flux. The absolute value is determined in part by the values of the soil field capacity and the saturation value. The problem for both simulations is that field capacity is much larger in the observations than that computed from the pedotransfer equations. As a consequence, infiltration is not sufficient to characterize better the VWC (this is already mentioned in the text). If field capacity is lowered, LE is not well captured.

In summary, we have added the italics text, for clarification, so that the text now reads as :

' ….The simulation has a positive bias of 5\% during *irrigation* flood events caused by a lack of drainage, but the model is able to capture the tendency of the VWC for the DSL simulation. Note that for the NON simulation, this tendency is underestimated. *Although the absolute value is closer to observation for the period before July 24, the rate of loss of water has to be correct for proper LE estimation, and it is thus prioritized over absolute value, which is driven by the field capacity value and which has been calculated with soil samples with CH78 pedotransfer functions. Furthermore, the values of VWC probes can be subject to biases due to the type of probe and manufacturing (Jäckish et al., 2020). The rapid response of the water content at all three* *observation depths following the flood irrigation event probably indicates that some of the water is being transferred to deeper soil levels via preferential flow pathways in macropores (Nimmo et al., 2025). Implementing a dual permeability approach, as described by Gerke and van Genuchten (1993), could improve the simulation of water flow using the Richards equation in fractures (macropores) and the matrix (micropores) in the future but such changes still face challenges for the implementation at larger scales.'*

For more context, the linkages between surface fluxes and soil properties still has to progress, which is similar to results from Aouade et al (2020). We chose to address the VWC but other studies are working on the pedotransfer improvement (Sobaga et al. 2023) and may be later implemented. A larger issue is that the suitability of pedotransfer functions at different scales is not assured (Weber, et al. 2024). In our case for individual sites, problems can arise from parent material, vegetation and land use. To better capture soil water retention curve, there would be the need to use in addition pressure head observation to capture not only the single time series, but also the pF-curve which was not within the scope of this study.

17. Section 5.3.2, Fig. 10. The format of the days simulated (DD/MM) is not adequate.

We have changed the time format to MM/DD

18. Section 5.3.2, Fig. 10b. Again, the VWC seems better simulated by the NON experiment than by the DSL simulation, could you explain why?

Here, the results of the DSL for latent heat flux were positive but more moderate as the resistance was too strong, and they were dependent on the period. This is observed also here (Fig. 10b) and it is one of the reasons why we later do a sensitivity test to improve the DSL simulation. The loss of water is still better characterized in the DSL simulation, particularly in the two first periods, as Figure 8b indicates with the final accumulated water difference of 1mm. As mentioned previously, parameterisation of soil hydraulic properties, high stone content, sensor bias in absolute values, and macropore existence (see image below) may lead to significant deviations from observations in simulated soil water content when using the NON or DSL approach. Such properties and defects are not readily available on large scales and have not yet become a priority in land surface modelling and are out of scope of the current article.

The text is modified (in italics) as follows:

For Els Plans (Fig. 10b), the same bias is observed in terms of the trend. *The absolute value of the NON simulation being closer to observation for 5 and 10 cm, but deviates significantly from the observation for 30 cm. Here, the DSL appears to capture the redistribution of water following a rainfall event more accurately than the NON, as too much water is used in this approach for soil evaporation. The tendency is larger for the NON simulation than for the observation. For the DSL the tendency is too strong on the wetting events, following what was observed for LE, and giving further necessity for a sensitivity test of the resistance.* The difference between the simulations becomes increasingly larger for each soil water content layer, which decreases after rain events.

19. Section 5.3.3. Fig. 11a shows that the NON simulation reproduces considerably better the maximum soil temperature at 5 cm (below the ground surface) than the DSL simulation for an approximately a 10-day period in the middle of the month (July), could you explain why? Also, the DD/MM format is not adequate here.

A sentence has been added in italics for clarification:

" After irrigation, the NON simulation better reproduces the soil temperature diurnal pattern, and the DSL simulation increases the temperature at 5 cm up to 5ºC in response to the increase in G due to the decrease in LE. *Interaction between the atmosphere and the ground is insufficient and heat is stored instead of being transformed into sensible heat. While the roughness length could be increased to reduce this effect, the characterization of LE would be impacted negatively.*"

We have changed the time format to MM/DD.

20. Section 5.4, line 661. How were the RMSE values of 4 and 2 W m-2 reported here calculated?

Each simulation pertaining to the sensitivity analysis has a RMSE value shown in the colorbar of figure 12a and b. We make the difference against the RMSE value of the DSL simulation of the previous sections for each site compared to the optimal one proposed in the text. The sentence has been extended to:
The RMSE value which compares the default DSL simulation shown in the previous section to the optimal value is very low, between 4 W m-2 for La Cendrosa and 2 W m-2 for Els Plans.

Bibliography

Aouade, G., Jarlan, L., Ezzahar, J., Er-Raki, S., Napoly, A., Benkaddour, A., Khabba, S., Boulet, G., Garrigues, S., Chehbouni, A., et al.: Evapotranspiration partition using the multiple energy balance version of the ISBA-Ag s land surface model over two irrigated crops in a semi-arid Mediterranean region (Marrakech, Morocco), Hydrology and Earth System Sciences, 24, 3789–3814, 2020.

Balugani, E., Lubczynski, M., and Metselaar, K.: Lysimeter and in situ field experiments to study soil evaporation through a dry soil layer under semi-arid climate, Water Resources Research, 59, e2022WR033 878, 2023

Boone, A., Bellvert, J., Best, M., Brooke, J. K., Canut-Rocafort, G., Cuxart, J., Hartogensis, O., Le Moigne, P., Miró, J. R., Polcher, J., Price, J., Quintana Seguí, P., Bech, J., Bezombes, Y., Branch, O., Cristóbal, J., Dassas, K., Fanise, P., Gibert, F., Goulas, Y., Groh, J., Hanus, J., Hmimina, G., Jarlan, L., Kim, E., Le Dantec, V., Le Page, M., Lohou, F., Lothon, M., Mangan, M. R., Martí, B., Martínez-Villagrasa, D., McGregor, J., Kerr-Munslow, A., Ouaadi, N., Philibert, A., Quiros-Vargas, J., Rascher, U., Siegmann, B., Udina, M., Vial, A., Wrenger, B., Wulfmeyer, V., and Zribi, M.: The Land Surface Interactions with the Atmosphere over the Iberian Semi-Arid Environment (LIAISE) Field Campaign, Journal of the European Meteorological Society, 2, 100 007, 2025.

Brooke, J., Best, M., Lock, A., Osborne, S., Price, J., Cuxart, J., Boone, A., Canut-Rocafort, G., Hartogensis, O., and Roy, A.: Irrigation875

contrasts through the morning transition, Quarterly Journal of the Royal Meteorological Society, 2023.

Canut, G.: LIAISE_LA-CENDROSA_CNRM_MTO-FLUX-30MINL2[Dataset]Aeris, https://doi.org/10.25326/320, 2022a.

Gerke, H. H., & Van Genuchten, M. T. (1993). A dual-porosity model for simulating the preferential movement of water and solutes in structured porous media. *Water resources research*, *29*(2), 305-319.

Nimmo, J. R., Wiekenkamp, I., Araki, R., Groh, J., Singh, N. K., Crompton, O., ... & Sprenger, M. (2025). Identifying preferential flow from soil moisture time series: Review of methodologies. *Vadose Zone Journal*, *24*(2), e70017.

Sobaga, A., Decharme, B., Habets, F., Delire, C., Enjelvin, N., Redon, P.-O., Faure-Catteloin, P., and Le Moigne, P.: Assessment of the interactions between soil–biosphere–atmosphere (ISBA) land surface model soil hydrology, using four closed-form soil water relationships and several lysimeters, Hydrology and Earth System Sciences, 27, 2437–2461, 2023.

Swenson, S. and Lawrence, D.: Assessing a dry surface layer-based soil resistance parameterization for the Community Land Model using GRACE and FLUXNET-MTE data, Journal of Geophysical Research: Atmospheres, 119, 10–299, 2014.

Weber, T. K. D., Weihermüller, L., Nemes, A., Bechtold, M., Degré, A., Diamantopoulos, E., Fatichi, S., Filipović, V., Gupta, S., Hohenbrink, T. L., Hirmas, D. R., Jackisch, C., de Jong van Lier, Q., Koestel, J., Lehmann, P., Marthews, T. R., Minasny, B., Pagel, H., van der Ploeg, M., Shojaeezadeh, S. A., Svane, S. F., Szabó, B., Vereecken, H., Verhoef, A., Young, M., Zeng, Y., Zhang, Y., and Bonetti, S.: Hydro-pedotransfer functions: a roadmap for future development, Hydrol. Earth Syst. Sci., 28, 3391–3433, https://doi.org/10.5194/hess-28-3391-2024, 2024.

Jackisch, C., Germer, K., Graeff, T., Andrä, I., Schulz, K., Schiedung, M., Haller-Jans, J., Schneider, J., Jaquemotte, J., Helmer, P., Lotz, L., Bauer, A., Hahn, I., Šanda, M., Kumpan, M., Dorner, J., de Rooij, G., Wessel-Bothe, S., Kottmann, L., Schittenhelm, S., and Durner, W.: Soil moisture and matric potential – an open field comparison of sensor systems, Earth Syst. Sci. Data, 12, 683–697, https://doi.org/10.5194/essd-12-683-2020, 2020.

de Silans, A. P., Monteny, B. A., and Lhomme, J. P.: The correction of soil heat flux measurements to derive an accurate surface energy balance
by the Bowen ratio method, Journal of Hydrology, 188, 453–465, 1997.

Zhang, C., Li, L., and Lockington, D.: A physically based surface resistance model for evaporation from bare soils, Water Resources Research,
51, 1084–1111, 2015