Review 1

Implementation of a dry surface layer soil resistance in two contrasting semi-arid sites with

SURFEX-ISBA V9.0

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Comments to the author.

This paper explores how adding a dry surface layer (DSL) soil resistance parametrization to the ISBA land surface model (LSM) within the SURFEX V9.0 within the MEB scheme improves the simulation of evapotranspiration (ET) in semi-arid environments. The study focuses on two contrasting field sites from the LIAISE campaign in Spain. The study addresses a longstanding error found in several land surface models, namely an overestimation of evapotranspiration in semi-arid environments, and is an important advance in SURFEX-ISBA parametrization development. A comprehensive evaluation of the DSL scheme is presented with encouraging and interesting results demonstrated. The commentary is well written, succinct (although it is a lengthy manuscript) and meets the objectives laid out in the study.

I recommend this article for publication after addressing a few minor points which are detailed below.

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)

-The vegetation parameter discussion has been moved to an appendix and only the description of parameter value choices is left on the main text due to the extension of the main text.

-Small modifications to the figures as per the review

-A section to better 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

Minor Revisions

1. The author has a significant number of parameters which are defined in Section 2. The author could consider a table of parameter lists (including symbol, units, parameter name, and equation number) either in Section 2 or as an Appendix. I feel this would be a useful reference/look-up to help with interpretability of this section.

An Appendix including the list of parameters, in the form of a glossary, has been added. It has been cited in 2.1.

2. Line 257-259 The SEB stations and associated data are contributions from a number of research groups. The one reference here (Price 2023) is not sufficient. Please add more references for the datasets.

The other citations available in the Aeris platform that houses the LIAISE database have been added in the following way:

"The field experiment took place in the north-eastern region of the Iberian Peninsula from April 2021 to the end of September 2021 (the Long Observational Period, LOP). Surface energy budget stations were installed over alfalfa (Canut 2022a; Mangan 2022), maize (Martínez-Villagrasa 2022), irrigated grass (Miró 2021), vineyard, apple orchard, almond orchard (Canut 2022b) and natural rainfed grass (Price 2023). "

3. Line 286-287 'energy budget of a short dry-down period near the end of the LOP shows a lower Rn compared to La Cendrosa' Would shortwave differences between July & September not also be a factor in the differences in RN between the sites?

Yes, it is a relevant factor. The downwelling shortwave radiation at Els Plans decreases from a diurnal peak of almost 1000 W m-2 to 800 W m-2 between July and September. La Cendrosa downwelling shortwave radiation is around 950 W m-2 during the period of growth shown. To reflect this, the text in italics below has been modified, this paragraph is also affected by comment 4 below. The text reads as:

"The energy budget of a short dry-down period near the end of the LOP (Fig. 3) shows a lower Rn compared to La Cendrosa *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 contribution of the net long wavelength radiation being lower and the time difference between the two periods which can account for up to 100* W m-2."

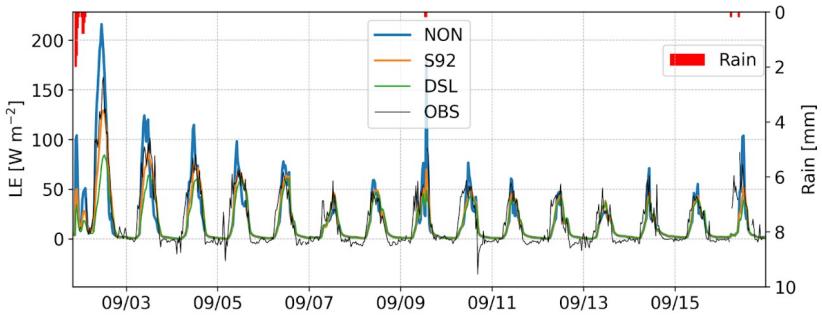
4. Line 286 'Short dry-down' Could you add a line about the rainfall event timing that causes this dry-down.

We have added to the revised manuscript the text in italics to the following paragraph:

"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 is shown (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 contribution of the net long wavelength radiation being lower and the time difference between the two periods which can account up to 100* W m-2."

When I get to Fig 6, it looks like there is 1 mm rainfall on 02/09, is this sufficient to be termed a dry-down?

According to McColl et al. (2017) and Akbar et al. (2018), a dry-down is defined as follows: it starts after the last rainfall event, with no rainfall on the first day, and rainfall on subsequent days should not exceed 1 mm per day. During the dry-down, soil moisture should decline, and it should last at least 5 days. The previous choice of time axis did not show the full precipitation. We have now modified it so it is visible. The precipitation range has also been modified in this figure at the request of another reviewer. Although a precipitation event occurred the night of September 9 it is smaller than 1mm, and it wasn't the intended target of the discussion. The increase of VWC for the following 5 days is also less than 1%. Thus, the period after the rainfall event on 02/09 the period shown in the figure can be defined as dry-down.



5. Section 4.2 What are the lengths of the two simulations (i.e. start/end date) or are they the same as the plots? For clarity, please add a sentence to explain.

The simulation of la cendrosa starts 1 July at 00:00 UTC and finishes 1 August at 00:00 UTC. The simulation of Els plans 17 June 10:00 UTC to 29 September at 09:00 UTC. Some plots have a reduced time length due to the variable characteristics. The text in italics has been added to the reviewed document:

"The simulations of La Cendrosa and Els Plans are performed offline (i.e. driven by observations as input). *They comprise the periods from 1 July at 00:00 UTC to 1 August at 00:00 UTC and from 17 June 10:00 UTC to 29 September at 09:00 UTC respectively.* The associated atmospheric variables are the incident short and longwave radiation fluxes, wind speed, temperature, specific humidity, pressure, atmospheric CO2 concentration, and rainfall rate at a 30 minute time step."

6. Figures. There is inconsistency between the date formatting on plots e.g. Fig2/Fig 6 have 07/05 and 05/07.

We have corrected formatting so it is consistent between the plots you mention and the following plots. We keep the format MM/DD. Thank you for the detailed revision.

Please could all plots have same start/end wherever possible, this makes it easier to line up harvest dates/irrigation dates and see the impact of these events on various parameters.

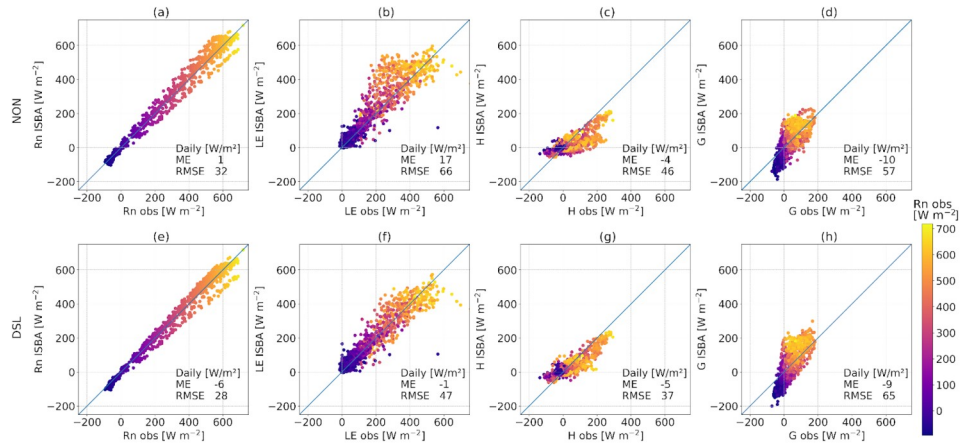
The simulation of La Cendrosa covers only the month of July and the simulation of els Plans is much longer at almost 4 months. Due to the electrical problems affecting the measurements at Els Plans, however, very few dry-down periods were captured. The current choice of limits needs to be maintained as is for the indicated previous reasons.

Please could the lines for harvest/irrigation be added to all relevant plots e.g., Fig 9 and Fig 11.

They have been added to Figures 9 and 11. In Figure 10, the irrigation lines have been added in the background so they don't cover the VWC, as the increase of this variable coincides with the irrigation event. The rest of the figures have the pertinent lines.

7. Table 5/6. I think a lot of the statistics displayed in the tables could be included within captions in subplots on Fig4/5. This would make it easier to move between the text and figures and not also have to refer to the tables. The tables could again be moved into an Appendix.

The ME, RMSE for all fluxes for the daily values are included within the figure frame as shown for Fig. 4. Since we cite within the text the daily values, the daytime values and the night values it is preferred to keep the tables on the main text.



The following text is added to the captions:

Daily mean error and root mean square error are included in the figure frame.

8. Table 5/6 It is not clear which parameter the 'Corr' relates to - it could be H/LE/G from the way the table is laid out. I have assumed it is H and LE, but it is not clear.

The caption has been clarified in the revised manuscript, for example for Els Plans:

"Mean Error (ME) and Root Mean Square Error (RMSE) in W m-2 for the net radiation (Rn), the sensible heat flux (H), the latent heat flux (LE), and the ground heat flux (G) for Els Plans site. *The correlation (Corr) between the simulations and the observations has been included for H and LE.* The values taking into account the residual using the Bowen ratio method are indicated in brackets."

The header of the tables indicates the variable the correlation to which it corresponds.

9. Line 451 'low/high vegetation' I think this is the first time you use this – could you add a line to explain what is meant by this.

It has been clarified as:

In order to describe the parameter selection methodology, we provide a description of the low vegetation scheme in ISBA (Calvet 2000), *which is used to represent crops and herbaceous types as opposed to high vegetation that considers woody types. The main difference is in the relationship between the mesophilic conductance and the maximum humidity deficit.*

10. Line 463 ‘Cendrosa (56Wm−2) and Els Plans (50Wm−2)’ I struggled to see where these numbers came from in Table 5/6. Could you please check.

These values are an additional calculation, not a comparison between simulation and observation, as they correspond to the residue and not the fluxes. We have added the values of the fluxes statistics to reduce confusion and changed the verb from ‘observed’ to ‘calculated here’ in order to clarify they are not in the table.

“The improvement of the statistics is also present for H, *with* the underestimation *being* reduced*, and the RMSE reducing to 37 W m-2 for La Cendrosa and 45 W m-2 for Els Plans These values are* within the values of the standard deviation observed *calculated here* for the residue for La Cendrosa (56 W m-2) and Els Plans (50 W m-2).”

11. Line 474 ‘except for an improvement from 0.81 to 0.88 in the overall correlation’ I could be wrong, but are these not the correlations for La Cendrosa, whilst the Els Plans correlations are 0.87-0.89?

You are right, the values are not those of Els Plans, they have been corrected in the revised manuscript.

12. Line 476 The value of 57 Wm-2 isn’t in Table 6 for the G parameter. Please check and consistency within text.

It should be 70 W m-2: the value was read erroneously from the table of la Cendrosa instead of Els Plans, indeed it is a typo. It has been corrected in the revised manuscript. We thank you for the fact check. We have revised the text for similar errors.

13. Line 486 Please add the date of the two irrigation events in brackets.

This has been done in the revised manuscript, see next comment.

14. Line 485-490 Please could you add a short explanation as to why the LE differences are so different after the two irrigation events. This is presumably due to the high/low vegetation differences, but it would be good to make this clear to readers.

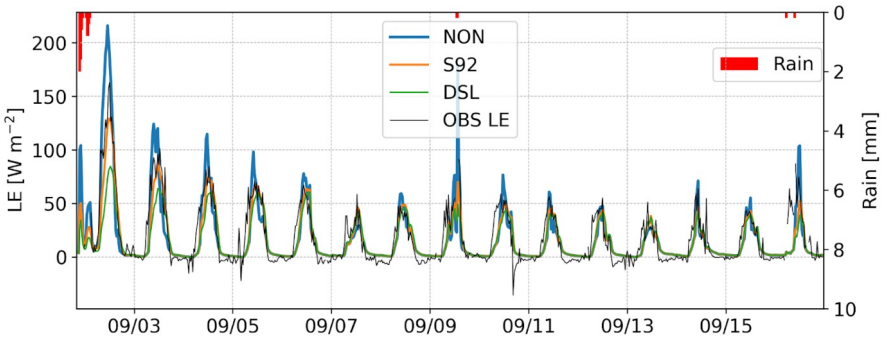
We have added the sentence in italics:

The observed LE is shown for the aforementioned simulations in Fig. 6a together with a top to bottom barplot with rain and irrigation. The largest change between simulations is after the first irrigation event *[July 11]*. The increase of observed LE is overestimated with the NON option, mainly due to the large contribution from soil evaporation, as in Lohou et al. (2014), whereas the LE in the DSL simulation is reduced more rapidly, which matches more accurately the observations in this period. The *second* irrigation event *[July 24]* and small rain events result in small increases

in LE that decrease during the ensuing hours since the soil is still near saturation. *The difference in the maximum LE between irrigation events is due to the change in transpiration. The first event occurs during very low vegetation whereas the second corresponds to fully grown alfalfa.*

15. Fig 6 The very low precipitation is quite difficult to see, particular in (b). Can the second plot axis be changed to make the precip clearer.

We have changed the axis for figure b, from 0 to 10. See the new graphic below.

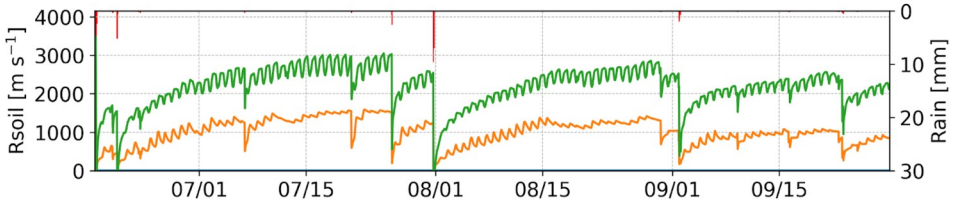


16. Fig 6 Please add the precipitation into the legend (red) obs precip (black) obs LE.

This change has been made in the revised manuscript. See comment 15.

17. Fig 7 Please consider having the same scale for Rsoil for (a) and (b) as this will highlight the different magnitudes of the resistance between the two sights.

Figure 7b has been modified to have the same Rsoil axis as Figure 7a.



18. Fig 9 Either in the manuscript text or in the Figure caption, please could you provide a line or two what the standard deviation is from the simulation? Is this the standard deviation of the three simulations? Or is this one simulation (if so, which)?

It corresponds to the standard deviation of the 30 minute time series of the observed and simulated albedo. It comes from the NON simulation but all three coincide as albedo is imposed and the LAI and vegetation height which could modify it also coincide.

The following sentence in italics has been added:

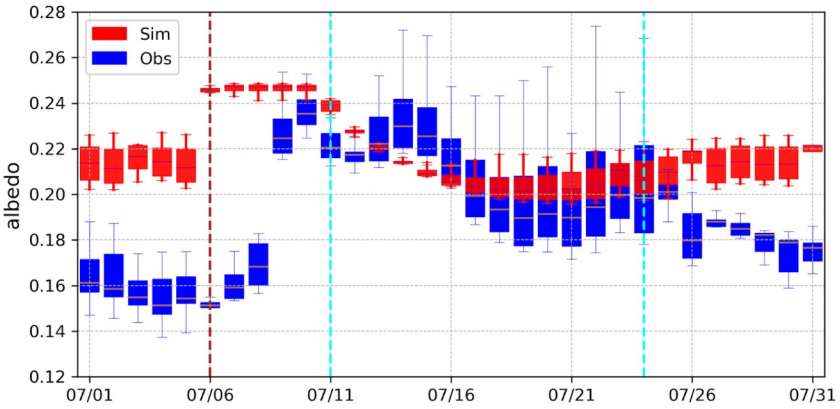
The observed daily variability of albedo and its model counterpart are shown for La Cendrosa in Fig. 9a. *The standard deviation shown is from the 30 minute time series of the observations and the simulation.*

Additionally, the caption in the revised manuscripts now:

“Figure 9: Observed (blue) and simulated (red) albedo for La Cendrosa (a) and Els Plans sites (b) for the NON simulation. Each boxplot measurement shows a central line with the median value. The size of the boxes correspond to the quartiles of albedo observations within the day and the error bars represent the variability of the albedo within the day.”

19. Fig 9 Please could you include additional date ticks on panel (a).

This has been done in the revised manuscript. Vertical lines have also been added.



Technical and typographical corrections

Line 54-56 Unclear sentence, please consider revising.

The sentence has been split and modified as:

“ Transpiration is modeled using a resistance analogue together with the humidity gradient. The resistance represents the canopy biophysical and turbulent processes. One of the configurations includes the assimilation of carbon, which allows the specification of species-dependent plant parameters.”

Line 83 Please define SEB
It has been replaced in the revised manuscript.

Line 121 ‘where f indicates the proportionality of internal CO2 and inside the leaf boundary layer’ remove and?
It has been replaced in the revised manuscript

Line 216 Reference formatting incorrect.

The format has been revised for this reference and all others

Line 256 Change ‘part’ to ‘region’
It has been replaced in the revised manuscript

Fig 2/ Fig 3 – Spacing needed between theRes.

It has been replaced in the revised manuscript

Line 369 Typo
It has been replaced in the revised manuscript

Line 443 Typo? – residual

Intentional to have residue

Line 478 Typo? Solids > Soils?

It is solids, such as quartz. The sentence is clarified adding ‘in the soil’, see comment below.

Line 477–480 Check sentence structure

The sentence has been split into two. It has been written as:

“A sensitivity test indicated that reducing the thermal conductivity of solids in the soil by 25% could reduce this error by reducing the G flux up to 20W m^-2, while increasing the error in the H proportionally. This value is within the range of different soil types reviewed from observations by Zhang et al. (2017)”

Line 489 Please change ‘other irrigation event’ to ‘second irrigation event’, and please include the date of the event in brackets
It has been replaced in the revised manuscript

Line 541-542 Date formatting: 29 July

Modified, two other dates have been changed too
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Bibliography

Akbar, R., Short Gianotti, D. J., McColl, K. A., Haghighi, E., Salvucci, G. D., & Entekhabi, D. (2018). Estimation of landscape soil water losses from satellite observations of soil moisture. *Journal of Hydrometeorology*, *19*(5), 871-889.

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.

Calvet, J.-C.: Investigating soil and atmospheric plant water stress using physiological and micrometeorological data, Agricultural and Forest Meteorology, 103, 229–247, 2000.

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

Canut, G.: LIAISE_PREIXANA_CNRM_MTO-FLUX-30MINL2[Dataset]Aeris, https://doi.org/10.25326/361, 2022b.

Mangan, M., Hartogensis, O., Branch, O., Martinez Villagrasa, D., Boone, A., Canut, G., Cuxart, J., de Boar, H., Le Page, M., Miro, J., Price, J., and Vila Guerau de Arellano, J.: LIAISE_UNIFIEDEC_WUR_10MIN_L1 [Dataset] Aeris, https://doi.org/10.25326/389, 2022

Martínez-Villagrasa, D., M., B., Cuxart, J., and Wrenger, B.: LIAISE_IRTA-CORN_UIB_SEB-10MIN_L2 [Dataset] Aeris, https://doi.org/10.25326/344, 2022

McColl, K. A., Wang, W., Peng, B., Akbar, R., Short Gianotti, D. J., Lu, H., ... & Entekhabi, D. (2017). Global characterization of surface soil moisture drydowns. *Geophysical Research Letters*, *44*(8), 3682-3690.

Miró, J. R.: LIAISE_IRTA-ET0_SMC_SEB-10MN_L1 [Dataset] Aeris, https://liaise.aeris-data.fr/page-catalogue/?uuid=10007f83e709-4ed4-49f1-b26f-c45d0519e4cf, 2021

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.

Price, J.: LIAISE_ELS-PLANS_UKMO_MTO-30MINL2[Dataset]Aeris, https://doi.org/10.25326/430, 2023

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.

Zhang, N. and Wang, Z.: Review of soil thermal conductivity and predictive models, International Journal of Thermal Sciences, 117, 172–183,
2017.