Editor

This study describes a new irrigation parameterization for ISBA land surface model (LSM). Despite interesting subjective of this study, it is hard to read and to understand what the unique things in this study are. Please revise the manuscript carefully for better readability and provide clearly 1) how to parameterize irrigation processes in the model codes, 2) remove redundant sentences many places, 3) clarify the information on the data so that other people reproduce what this study did, and 4) rewrite fractured sentences. It is also important to organize sentences, paragraph, and figures to converge into clear goals and to support your conclusions. Here I put some comments on the manuscript, but I believe that overall structure of this manuscript should be reorganized and rewritten carefully.

Response:

Many thanks for your in-depth review of the manuscript and for your comments. We strived to highlight the novel aspects of this work and to improve the organization of the paper (see below and see responses to reviewers 1 and 2).

Comment E.1:

There is not enough information to reproduce the modeling results in this manuscript. Please provide more details on the irrigation parameterization especially for different kinds of irrigation methods. How do you deal with different irrigation types in the model?

Response E.1:

In this study, only sprinkling irrigation is considered. All the irrigation parameters needed to launch the simulation are listed in Table 2. The activation of a given irrigation method is described in Supplement 5, with two examples showing how to launch a simulation. In order to improve the reproducibility of our results we have included a doi reference pointing to the SURFEX initialization files and to the spatially resampled irrigation map (https://doi.org/10.5281/zenodo.6011618).

For sprinkling irrigation, water is added to the precipitation forcing. For drip and flood irrigation, the water flux is applied directly to the soil surface with no leaf interception as explained in section 2.3.1. Considering the static equipment used for drip irrigation, there is no irrigation interval (Δt_{Wn} = 0 day). This was indicated in the revised version of the manuscript, Section 2, and in Table 2:

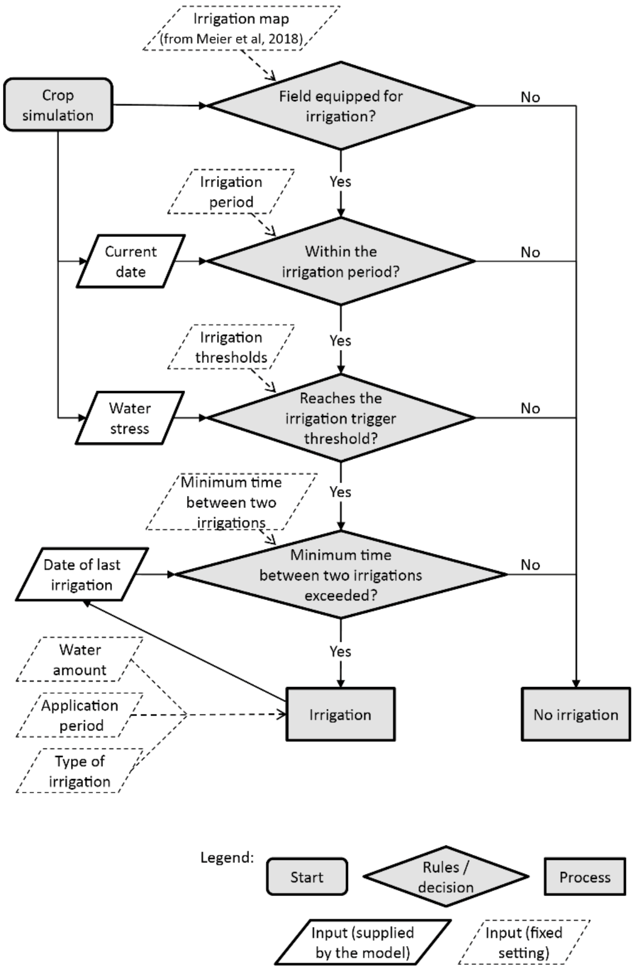
"In this study, only sprinkling irrigation is considered."

was replaced by

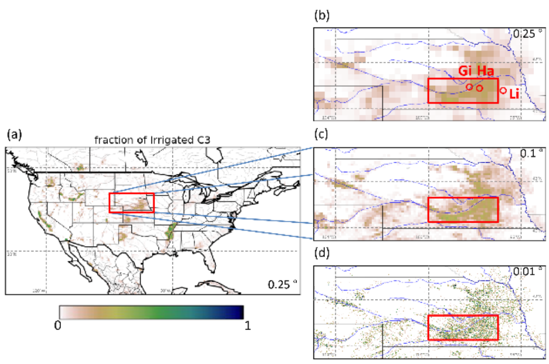
"In this study, only sprinkling irrigation is considered as this is the dominant irrigation type in Nebraska. Drip and flood irrigation will be evaluated in future works. The activation of a given irrigation method is described in Supplement 5. For sprinkling irrigation, water is added to the precipitation forcing. For drip and flood irrigation, the water flux is applied directly to the soil surface with no leaf interception as explained in

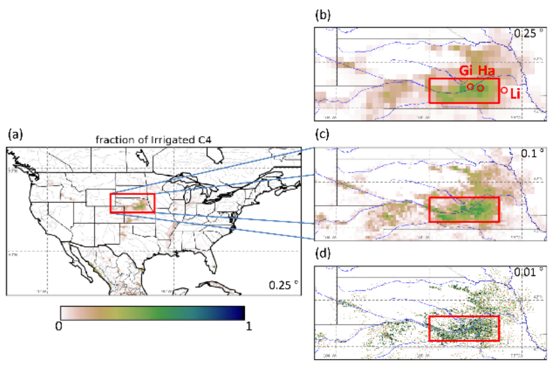
section 2.3.1. Considering the static equipment used for drip irrigation, there is no irrigation interval (Δt_{Wn} = 0 day).”

For the sake of clarity, the following decision tree Figure, valid for all irrigation types, was added to the manuscript:



For the sake of clarity, the following Figures showing the fraction of irrigated C3 and C4 crops were added to the Supplement:





Comment E.2:

Please provide specific information on water conservation and differences between different irrigation methods in the model.

Response E.2:

The present irrigation module in ISBA represents water demand for irrigation, only, and irrigation is not limited by the lack of water resources. This indeed has consequences on water conservation. However, water used for irrigation is usually withdrawn from aquifers, rivers or reservoirs. These compartments are not represented in ISBA. In the SURFEX platform, the ISBA model can be coupled to the CTRIP model (Decharme et al., 2019, Munier and Decharme, 2021) which is specifically designed to represent water dynamics within rivers and aquifers. In addition, a new module dedicated to dam/reservoirs is currently under development. Future work will focus on the coupling between the new irrigation module in ISBA and CTRIP, thus ensuring the water conservation.

In section 1,

"While the SURFEX framework allows the coupling of terrestrial processes with atmospheric and hydrological models, only offline ISBA simulations are considered in this study. The evaluation of the new irrigation scheme is made over the state of Nebraska (United States of America, USA). This area presents a high density of irrigated fields (Fig. 1) and large freely available observational datasets for evaluation."

was replaced by

"In the SURFEX platform, the ISBA model can be coupled to the CTRIP model (Decharme et al., 2019, Munier and Decharme, 2021) which is specifically designed to represent water dynamics within rivers and aquifers. The SURFEX framework allows the coupling of terrestrial processes with atmospheric models and hydrological models. For agricultural drought and water resource monitoring, SURFEX can also be operated offline, forced by a pre-existing dataset of atmospheric variables. Only offline ISBA simulations are considered in this study. The new irrigation module represents water demand for irrigation, only, and irrigation is not limited by the lack of water resources. This has consequences on water conservation. However, water used for irrigation is usually withdrawn from aquifers, rivers or reservoirs. These compartments are not re-presented in ISBA but a new module dedicated to dam/reservoirs is currently under development. The evaluation of the new irrigation scheme is made over the state of Nebraska (United States of America, USA). This area presents a high density of irrigated fields (Fig. 1) and large freely available observational datasets for evaluation."

References:

Decharme, B., Delire, C., Minvielle, M., Colin, J., Vergnes, J. P., Alias, A., ... & Voldoire, A. (2019). Recent changes in the ISBA-CTRIP land surface system for use in the CNRM-CM6 climate model and in global off-line hydrological applications. Journal of Advances in Modeling Earth Systems, 11(5), 1207-1252.

Munier, S., & Decharme, B. (2021). River network and hydro-geomorphology parametrization for global river routing modelling at 1/12° resolution. Earth System Science Data Discussions, 1-28.

Comment E.3:

Writing is important and this manuscript is not well organized. This manuscript is not easy to read and understand because of inconsistent and poorly organized sentences and redundant statements. More efforts are necessary to revise the manuscript carefully.

- Line 176: One example of redundant sentences in this manuscript (« Moreover, an updated land cover description was used: ECOCLIMAP-SG (see Supplement S1) »).

- Line 188: One example of redundant sentences in this manuscript (« The new irrigation scheme is operated using the ECOCLIMAP-SG land cover classification within SURFEX »).

- Line 254: One example of redundancy

- Line 304: One example of redundancy (« The ISBA LSM simulations (non-coupled with the atmosphere) are forced by the ERA-5 reanalysis »).

Response E.3:

We agree. We did our best to account for your remarks as well as remarks from Reviewers 1 and 2. You can find below the response to your specific comments.

On L. 176, « Moreover, an updated land cover description was used: ECOCLIMAP-SG (see Supplement S1) » was deleted.

On L. 188, « The new irrigation scheme is operated using the ECOCLIMAP-SG land cover classification within SURFEX » was replaced by « The new irrigation scheme is operated using the ECOCLIMAP-SG land cover classification within SURFEX (see Supplement S1). »

On L. 304, « non-coupled with the atmosphere » was deleted.

We were not able to find a redundancy on L. 254.

Comment E.4:

Fluxcom data by Jung et al. do not consider the irrigation process and I am not sure if these data are useful for the model evaluation.

Response E.4:

This is a very good point. We tend to believe that the FLUXCOM data are relevant over irrigated areas at low spatial resolution. Al-Yaari et al. 2021 showed that the FLUXCOM daily evapotranspiration product can be used as a benchmark over irrigated areas. They compared global evapotranspiration simulations of the ORCHIDEE land surface model with FLUXCOM without activating an irrigation module in ORCHIDEE. They found

that a negative model bias can be observed over irrigated areas while the model is virtually unbiased over rainfed areas. The negative bias increases as the irrigation fraction increases, suggesting that FLUXCOM is sensitive to irrigation. The information on irrigation could come from the remote sensing data incorporated into the FLUXCOM products. Since evapotranspiration and GPP fluxes are closely connected to each other, it can be assumed that the FLUXCOM GPP product is also sensitive to irrigation.

This will be indicated in the revised version of the manuscript.

Reference:

Al-Yaari, A., A. Ducharne, S. Tafasca, H. Mizuochi and F. Cheruy, "Influence of irrigation on the bias between ORCHIDEE and FLUXCOM evapotranspiration products," 2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS, 6552-6555, https://doi.org/10.1109/IGARSS47720.2021.9554734, 2021.

Comment E.5:

Irrigation process may change local climate around the irrigated lands and I am not sure if reanalysis data of coarse resolution is appropriate to simulate the irrigation effects or not. In-situ observation data instead of the reanalysis data and its related offline simulation is more useful in this respect.

Response E.5:

The ERA5 screen-level 2 m air temperature and relative humidity are analyzed together with soil moisture by assimilating in situ observations from ground weather stations (Hersbach et al. 2020). In large irrigated areas where weather stations are present, the assimilation should be able to represent the irrigation effect on these variables, even at coarse spatial resolution. A large-scale experiment involving ground and airborne measurements was recently performed in northeastern Spain to assess the impact of irrigation on atmospheric model simulations (Boone et al. 2021).

This will be indicated in the revised version of the manuscript.

References:

Boone, A., J. Bellvert, M. Best, J. Brooke, G. Canut-Rocafort, J. Cuxart, O. Hartogensis, P. Le Moigne, J. R. Miró, J. Polcher, J. Price, P. Quintana Seguí, M. Wooster, 2021: Updates on the international Land Surface Interactions with the Atmosphere over the Iberian Semi-Arid Environment (LIAISE) Field Campaign. GEWEX News, 31(4), 16-21, available on https://www.gewex.org/gewex-content/files_mf/1640101560Q42021.pdf, last access January 2022, 2021.

Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., Nicolas, J., Peubey, C., Radu, R., Schepers, D., Simmons, A., Soci, C., Abdalla, S., Abellan, X., Balsamo, G., Bechtold, P., Biavati, G., Bidlot, J., Bonavita, M., De Chiara, G., Dahlgren, P., Dee, D., Diamantakis, M., Dragani, R., Flemming, J., Forbes, R., Fuentes, M., Geer, A., Haimberger, L., Healy, S., Hogan, R. J., Hólm, E., Janisková, M., Keeley, S., Laloyaux, P., Lopez, P., Lupu, C., Radnoti, G., de Rosnay, P., Rozum, I., Vamborg, F., Villaume, S., and Thépaut, J.-N.: The ERA5 Global Reanalysis, Q. J. Roy. Meteor. Soc., 146, 730, 1999–2049, https://doi.org/10.1002/qj.3803, 2020.

Comment E.6:

Line 115: Rewrite this sentence for better readability. I cannot understand the method used in this study. It seems to me that this is not downscaling. This is just to assign the same value to 1 km grid.

Response E.6:

Yes, the wording was not accurate. “spatial rescaling” was replaced by “spatial resampling”. The 300 m × 300 m resampled irrigation map is now published on zenodo (https://doi.org/10.5281/zenodo.6011618).

Comment E.7:

Line 140: Is there any inconsistency between these data?

Response E.7:

The two weather stations are within 170 km of each other. While the Gi station is located within a densely irrigated area, the Li station is located at the Lincoln airport, which is surrounded by rainfed agricultural fields.

This will be indicated in the revised version of the manuscript.

Comment E.8:

Line 144: How to distribute the annual values and how to justify the process?

Response E.8:

The USGS datasets contains annual raw amount of water collected for irrigation, together with conveyance loss. These data are available only every 5-year. Conveyance loss data are not available for 1995. The result of our calculations is showed in Figure 3 as red dots. Figure 3 was revised in order to make these more visible (see below).

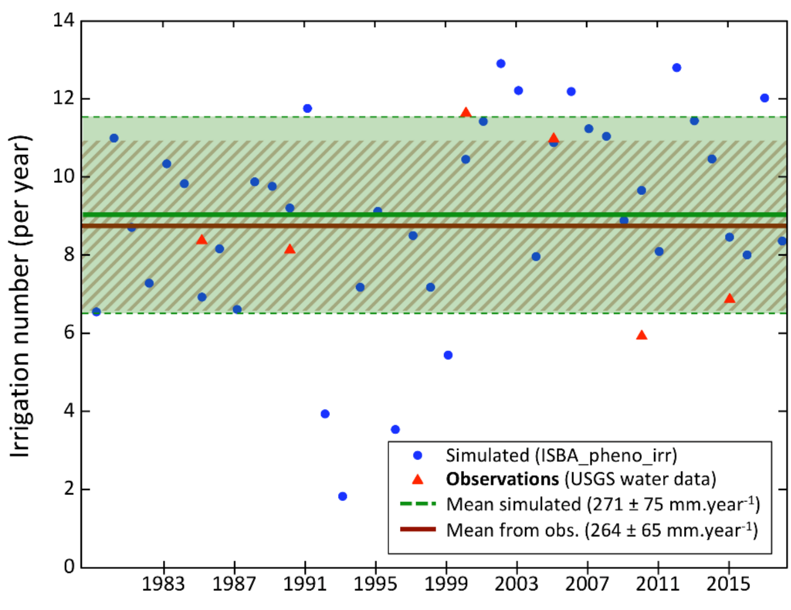


Figure 3 – Yearly cumulated number of irrigation events simulated by the model for the studied area in Nebraska from 1979 to 2018 (blue dots). The six yearly estimates from USGS for 1985, 1990, 2000, 2005, 2010, and 2015 are indicated (red triangles). The mean and standard deviation of the yearly values are shown for the model (green solid and dashed lines, respectively), and for the USGS water data from 1985 to 2015 (brown lines).

Comment E.9:

Line147: What kinds of inconsistencies? Any impacts on the results and conclusion?

Response E.9:

For 1995 conveyance loss data are not available.

"The USGS data we used cover the 1985-2019 time period. Because of inconsistencies in the record for 1995, this year was not taken into account."

was replaced by

"The USGS data we used cover the 1985-2015 time period. Because conveyance loss data are missing in the record for 1995, this year was not taken into account."

Comment E.10:

Line 149: What LAI values are used for the initial conditions?

Response E.10:

As explained on L. 305, a spin-up simulation was made. The same initial conditions are used for all the simulations, with and without crop and irrigation modeling. Section 2 was reorganized and model implementation is now described before describing validation datasets. Initial condition files are now published on zenodo (https://doi.org/10.5281/zenodo.6011618).

Comment E.11:

Line 154: Clarify how to process the data

Response E.11:

"The simulated GPP is compared to an upscaled estimate of GPP available at 0.25° from 1980 to 2013, from the FLUXCOM project (Jung et al., 2017)."

was replaced by

"The simulated GPP is compared to an upscaled estimate of GPP available at 0.5° from 1980 to 2013, from the FLUXCOM project (Jung et al., 2017). For the comparison, the FLUXCOM GPP data are interpolated to the model grid."

Comment E.12:

Line 155: I am not sure if there is any GPP observation by the eddy-covariance method in this study region.

Response E.12:

The FLUXCOM product is based on a global machine learning model that does not have to be locally trained. However, it seems that three flux stations in Nebraska were used in the training as their data are included in the La Thuile dataset used to build FLUXCOM (Tramontana et al. 2016). These stations are located at 45 km at the north-east of the Lincoln weather station, in a region where irrigation is present but not dominant.

This will be indicated in the revised version of the manuscript.

Reference:

Tramontana, G., Jung, M., Schwalm, C. R., Ichii, K., Camps-Valls, G., Ráduly, B., Reichstein, M., Arain, M. A., Cescatti, A., Kiely, G., Merbold, L., Serrano-Ortiz, P., Sickert, S., Wolf, S., and Papale, D.: Predicting carbon dioxide and energy fluxes across global FLUXNET sites with regression algorithms, Biogeosciences, 13, 4291–4313, https://doi.org/10.5194/bg-13-4291-2016, 2016.

Comment E.13:

Line 158: Clarify how to interpolate the data into the model grid.

Response E.13:

"The simulated evapotranspiration is compared to the GLEAM satellite-driven model estimates of land evapotranspiration available from 2003 to 2018 (version v3.2b, Martens et al., 2017) at a spatial resolution of 0.25° × 0.25°."

was replaced by

"The simulated evapotranspiration is compared to the GLEAM satellite-driven model estimates of land evapotranspiration available from 2003 to 2018 (version v3.2b, Martens et al., 2017). The GLEAM data come at the same 0.25° × 0.25° model's grid."

Comment E.14:

Line 169: what is for periods after "evaporation, sensible heat" . Absolutely, sensible heat is different from sensible heat fluxes.

Response E.14:

« (evaporation, sensible heat, …) » was replaced by

« (evaporation, sensible heat flux, ground heat flux, net ecosystem exchange of CO_2) »

Comment E.15:

Line 178: What kinds of technical development?

Response E.15:

« The simulations were based on the SURFEX v8.1 version, which is similar to the v8.0 version (Voldoire et al., 2017), but with new technical developments (Le Moigne et al., 2018). »
was replaced by
« The simulations were based on the SURFEX v8.1 version (Le Moigne et al., 2018). »

Comment E.16:

Line 182: I cannot figure out what were done to deal with heterogeneity.

Response E.16:

This is explained in Supplement 1 (see the first column of the patch aggregation rule diagram in Figure S1.1). We replaced

"To represent the global-scale heterogeneity of continental natural surfaces, twenty different surface types (hereafter referred to as "nature types") can be used in ECOCLIMAP-SG to represent the evolution of landscapes with low vegetation, with wooded vegetation, and without vegetation."
by

"To represent the global-scale diversity of continental natural surfaces, twenty different surface types (hereafter referred to as "nature types") can be used in ECOCLIMAP-SG to represent the evolution of landscapes with low vegetation, with wooded vegetation, and without vegetation (see Fig. S1.1 and Table S1.2)."

Comment E.17:

Line 197: I am not quite sure if this is realistic or not.

Response E.17:

"Table 2 lists the parameters and the values used by default in this study."

was replaced by

"Table 2 lists the parameters and the values used by default in this study. These values are based on results from previous studies (Voirin-Morel, 2003; Calvet et al., 2008)."

Comment E.18:

Line 202: I am not quite sure if other types of irrigation also need evaluation.

Line 210: This approach is valid only for sprinkler irrigation.

Response E.18:

"Three irrigation types are considered in Lawston et al. (2015): sprinkler irrigation, flood irrigation and drip irrigation. In the new version of ISBA the same irrigation types are represented but a different modelling approach is used. In this study, the sprinkler irrigation type is used."

was replaced by

“In Lawston et al. (2015), three irrigation types are considered: sprinkler irrigation, flood irrigation and drip irrigation. In the new version of ISBA the same irrigation types are represented but a different modelling approach is used. In this study, the sprinkler irrigation type is used and evaluated. Flood and drip irrigation will be considered in a future work.”

See also Response E.1.

Comment E.19:

Line 216: trough ?

Line 218: references.

Response E.19:

Thanks for noting this.

“The availability of resources (equipment or local water distribution) is taken into account trough a default minimum return time period between two irrigations. This default parameter value is a constant (7 days by default) but maps of this parameter could be used when available.”

was replaced by

“The availability of resources (equipment or local water distribution) is taken into account through a default minimum time gap between two successive irrigations (Zhang et al. 2019). This default irrigation interval parameter value is a constant (7 days by default) but maps of irrigation intervals could be used when available.”

Reference :

Zhang, G., D. Shen, B. Ming, R. Xie, X. Jin, C. Liu, P. Hou, J. Xue, J. Chen, W. Zhang, W. Liu, K. Wang, S. Li: Using irrigation intervals to optimize water-use efficiency and maize yield in Xinjiang, northwest China, The Crop J., 7, 322-334, https://doi.org/10.1016/j.cj.2018.10.008, 2019.

Comment E.20:

Line 234: I am not quite sure if the sum of this irrigated water is consistent with the USGS annual irrigation data.

Response E.20:

“The yearly sum of this irrigated water can be compared to the USGS data described in Section 2.1.3.” was added.

Comment E.21:

Line 238: how to consider water conservation?

Response E.21:

See Response E.2.

Comment E.22:

Line 249: What are nature types and how to decide it?

Response E.22:

"On the other hand, irrigation of all nature types is possible."

was replaced by

"On the other hand, irrigation of all the nature types listed in Table S1.2 is possible. By default, six vegetation types are considered (three crop and three woody vegetation types as shown in Fig. S1.1)."

Comment E.23:

Line 334: I cannot understand the meaning of this sentence. What kinds of code changes?

Response E.23:

Thanks for noting this.

"The comparison between the model without irrigation (ISBA_ref experiment) before and after the changes in the code structure (section 2.3) did not permit the detection of any impact on the model outputs (not shown). The results presented below are thus focused on the impacts of the crop phenology and irrigation implementation on the simulated land surface variables over Nebraska."

was replaced by

"The results presented below are focused on the impacts of the crop phenology and irrigation implementation on the simulated land surface variables over Nebraska."

Comment E.24:

Results: I am not sure if the new parameterization give improvement of important variables. For example, I don't believe that the new parameterization gives peak timing of LAI. Please check figures and numbers if they support the conclusion and results.

Response E.24:

We included new elements in Table 4 showing the added-value of crop and irrigation options on LAI simulation. See response R1.2 to Reviewer 1:

"Corn is the dominant crop type in the considered irrigated area in Nebraska (Zhang et al. 2020). While the satellite LAI observations present a peak at the end of July, the modelled LAI is plateauing in August (Fig. 4). Corn LAI observations at the field scale for various agricultural management conditions are showed in Boedhram et al. (2001). These data show that the modelled LAI plateau in August at LAI values of about 3.5 m2m-2 is realistic."

This will be added in Section 3.1.