Reviewer #4 (anonymous)

Comment R1.1:

Thanks for the hard work, The manuscript has been substantially improved. And all my comments are well addressed by the authors. The innovation of this study and associated evidence are elegantly presented. However, I find two tiny issues that may be helpful. Thus I recommend considering publication on GMD after a minor revision.

Response R1.1:

Many thanks for these positive comments.

Comment R1.2:

Line 211-212: It will be great if the algorithm can be briefly introduced in one or two sentences.

Response R1.2:

"In order to limit the computing time, vegetation types can (optionally) be gathered. In this case vegetation "patches" are created (see Supplement S1 and Fig. S1.4)."

was replaced by

"In order to limit the computing time, vegetation types can (optionally) be gathered. In this case vegetation "patches" are created (see Supplement S1 and Fig. S4). Firstly, irrigated nature types are duplicated in order to ensure the distinction of irrigated and rainfed soil water budgets. Patch aggregation rules are then used to merge the nature types. Finally, model parameter values are computed following the new patch fraction map."

Comment R1.3:

I assume that supplementary documents are used to support related statements. Thus I suggest citing them rather than introducing them (e.g., Line 537-539 and 542-543).

Response R1.3:

Thanks for this suggestion. We rephrased all the sentences that were directly referring to Supplement Figures. Note that numbers of Supplement Figures and Tables were changed.

Reviewer #5 (Fabian Stenzel)

Comment R2.1:

The present study ("Implementation of a new crop phenology and irrigation scheme in the ISBA land surface model using SURFEX_v8.1") introduces a new phenology and irrigation scheme for the ISBA LSM and evaluates its performance against observational data from a densely irrigated region of Nebraska (USA). It becomes clear that the main improvement for better performance regarding LAI and GPP stems from the improved phenology with prescribed emergence and harvest dates. The irrigation scheme does not add much with respect to the aforementioned variables, but provides reasonable water use values with respect to observations. I have been only involved now where the manuscript is already in round 3 of revisions. Therefore I interpret my main responsibility is to judge whether the present version of the manuscript is fit for publication and the authors have taken care of all points raised by the two previous reviewers. This is the case. The only thing missing in terms of reproducibility of the study is a step-by-step explanation of how to use the data in the ZENODO archive(s) together with the SURFEX code to redo the simulations and any potential postprocessing scripts. I suggest to add a README file to the ZENODO archive containing this information. The manuscript itself is written very clearly and I enjoyed reading it. However, since I read the article for the first time and with fresh eyes, I noticed some minor things that could still be improved and I ask the authors to include them in the final version of their manuscript. I apologize for this, because I know that for authors, introducing new reviewers late in the review process is annoying, but at the same time I hope that they seize the opportunity to further increase the quality of their (already good) manuscript by including my remarks. I am looking forward to read about future work on the global evaluation of the phenology and irrigation schemes in ISBA.

Response R2.1:

Many thanks for these positive comments. We did our best to further revise the manuscript.

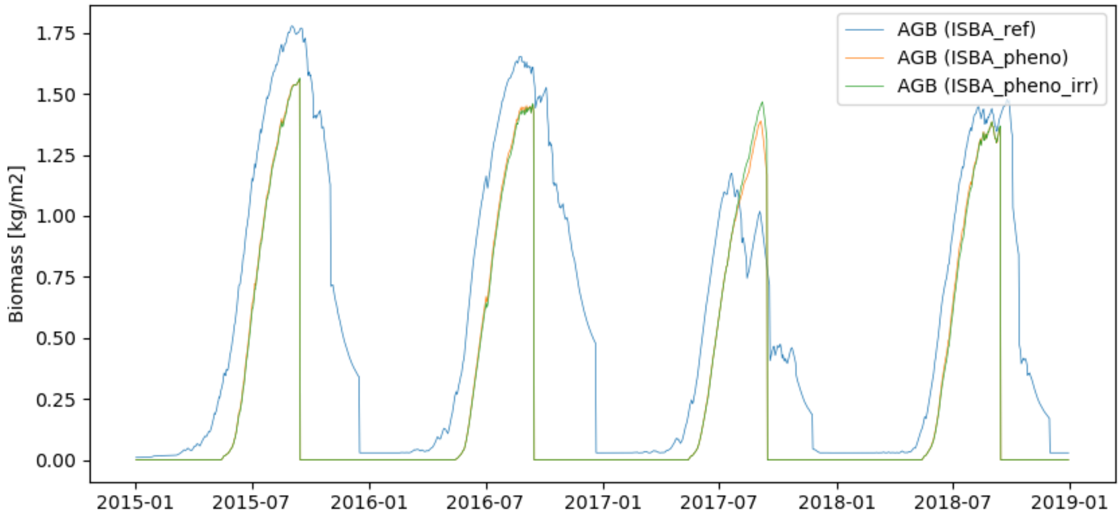
Concerning the reproducibility of simulations from the ZENODO data, we have enhanced the explanation of how to install the specific version of the ISBA model, to download different forcing files. We added a specific configuration file for each simulation and the script used to launch them. We strived to make it more readable. As suggested, we added in the ZENODO archive a step by step explanation in a README.txt (https://doi.org/10.5281/zenodo.7221291). It is nevertheless important, as mentioned in the readme file, to note that ISBA is a complex land surface model able to work at a global scale within the SURFEX modeling platform. Some training is needed for new users of SURFEX. We included contact points for technical support.

Comment R2.2:

What purpose is the model generally used for? One main purpose of crop models is to provide harvest amounts. Therefore I was wondering, why (additional to the irrigation water amount, LAI and GPP) you did not look at how harvests compared between the 3 model versions? I would suspect that here you might see a stronger difference between ISBA_pheno and ISBA_pheno_irr, suggesting that including irrigation is worthwhile.

Response R2.2:

ISBA is not a crop model (see Response 2.3). However, ISBA is able to simulate the green above-ground biomass (AGB) and this quantity can be compared with grain yield after model calibration or after the assimilation of satellite-derived LAI products (Calvet et al. 2012, Dewaele et al. 2017).
A new subfigure was added to Fig. S9 (Fig. S9d):



The main difference between annual AGB peak values simulated by ISBA_pheno_irr and ISBA_pheno are observed in 2017, which is a relatively dry year in the ERA5 reanalysis. Growing season (May-September) accumulated precipitation amounts in ERA5 are equal to 520, 499, 339, and 578 mm from 2015 to 2018, respectively. Irrigation increases the peak AGB value by 6 % in 2017.

References:

Calvet, J.-C., Lafont, S., Cloppet, E., Souverain, F., Badeau, V., Le Bas, C., "Use of agricultural statistics to verify the interannual variability in land surface models: a case study over France with ISBA-A-gs", Geosci. Model Dev., 5, 37-54, https://doi.org/10.5194/gmd-5-37-2012, 2012.

Dewaele, H., Munier, S., Albergel, C., Planque, C., Laanaia, N., Carrer, D., and Calvet, J.-C.: Parameter optimisation for a better representation of drought by LSMs: inverse modelling vs. sequential data assimilation, Hydrol. Earth Syst. Sci., 21, 4861–4878, https://doi.org/10.5194/hess-21-4861-2017, 2017.

Comment R2.3:

Lines 58-72: It it great that you implement irrigation into ISBA. However your are making it sound like just very few other models have implemented irrigation. I don't think that is a fair point, as basically all crop models have implemented it. Many of them can (depending on your definition) be regarded as a LSM.

Response R2.3:

Many thanks for this comment. We completed the definition of a LSM and made clear that LSMs are not crop models.

'Land surface models (LSMs) represent land surface biophysical processes and variables, including soil moisture and vegetation biomass, in a way that is fully consistent with the representation of carbon, water and energy fluxes.'

was replaced by

'Land surface models (LSMs) provide lower boundary conditions to climate and weather forecast atmospheric models. The new generation of LSMs is able to represent land surface biophysical processes and variables, including soil moisture and vegetation biomass, in a way that is fully consistent with the representation of carbon, water and energy fluxes. LSMs differ from crop models in the sense that they do not explicitly represent all the agricultural practices, nor crop yields. While most crop models have implemented irrigation, irrigation is not represented by all LSMs.'

Comment R2.4:

Lines 129-134: Your argument for having decreasing SWI thresholds for subsequent irrigation events is weak. The root fraction is already part of SWIroot_zone. Additionally: If the irrigation water amount is still 30mm for subsequent irrigation events triggered at lower SWI, you would need more water to fill the soil again, right?

Response R2.4:

Yes, we tried to consolidate the argumentation. The idea behind this approach is that irrigation does not completely refill the soil, especially at the end of the growing season. Mechanical harvest requires relatively dry conditions to avoid soil compaction. The crop is allowed to use rainwater together with the initial available water content of the soil. Results presented in Section 3.1 show that this hypothesis is realistic for Nebraska.

'This irrigation strategy allows the optimization of water withdrawal according to plant water extracting abilities at different crop growing stages.'

was replaced by

'The use of these values was validated by Bonnemort et al. (1996), Voirin-Morel (2003) and Calvet et al. (2008). The idea behind this approach is that irrigation does not completely refill the soil, especially at the end of the growing season. Mechanical harvest requires relatively dry conditions to avoid soil compaction. The crop is allowed to use rainwater together with the initial available water content of the soil. This irrigation strategy allows the optimization of water withdrawal according to plant water extracting abilities at different crop growing stages.'

Comment R2.5:

Lines 149-152: Please add that this first part describes sprinkler irrigation settings. Drip/flood description only starts in line 171.

Response R2.5:

'The irrigation water flux is evenly distributed over a period of time of 8 hours ...'

was replaced by

'For sprinkler irrigation settings, the irrigation water flux is evenly distributed over a period of time of 8 hours ...'

Comment R2.6:

Line 193: 20 non-irrigated + 20 irrigated * 3 types is 80

Response R2.6:

Thanks for noting this. It was corrected.

Comment R2.7:

Line 240: The random picking of harvest/emergence date seems to complicate things and you did not mention it previously. However it is relevant, because irrigation would not be allowed, if emergence is happening later or harvest earlier than the default date.

Response R2.7:

We agree.

Comment R2.8:

Lines 313-314: I suggest to change "simulated number of yearly irrigation events" to "simulated irrigation water amount". Events cannot be compared to amounts and you explain how the conversion is done in the next sentence.

Response R2.8:

We agree. This sentence was rephrased accordingly.

Comment R2.9:

Lines 360-364: Explain how you calculate the precipitation bias in Fig S4.6, either here in the text or in the figure caption. I assume it is ERA5 data minus weather station data for that pixel, right? You are arguing that the bias in ERA5 is the reason for too high simulated irrigation. But the absolute bias is also high in 2000 and 2005. If you want to take the relative change (2010 was a wetter year than 2005 and 2000) into account, I would think that this could be best seen in precipitation bias in [%] with respect to absolute precipitation. This should show higher deviations for 2010 than 2000 and 2005 and serve your point.

Response R2.9:

Caption of Fig. S18 (ERA5 minus in situ observations) was changed accordingly. We tried to consider the percentage precipitation bias but this did not change the conclusions.

'In 2010, the ERA5 precipitation bias in July and August triggers a cumulated precipitation gap of 150 mm. The model responds to this water deficit by triggering irrigation, especially in August (Fig. S4.6c).'

was replaced by

'In 2010, the ERA5 precipitation bias from July to September triggers a cumulated precipitation gap of 103 mm (Fig. S18a). The model responds to this water deficit by triggering irrigation at the end of the growing season, especially in August (Fig. S4.6c). On the other hand, ERA5 is unbiased at the beginning of the growing period (May-June 2010).'

Comment R2.10:

Lines 369-371: Where do I see this Boedhram data?

Response R2.10:

'The data from Boedhram et al. (2001) show that…'

was replaced by

'Figure 2 in Boedhram et al. (2001) shows that…'.

Comment R2.11:

Line 371: You could mention here that you will do a comparison across all "nature types" in the next section.

Response R2.11:

'The satellite LAI observations are sensitive to both rainfed and irrigated vegetation.'

was replaced by

'The satellite LAI observations are sensitive to both rainfed and irrigated vegetation. A comparison across all vegetation types is presented in Section 3.3.'

Comment R2.12:

Line 380: I assume you meant to say "without phenology (and without irrigation)" instead of "without irrigation" – the main difference here is the phenology, not the irrigation.

Response R2.12:

Thanks for noting this. "without crop phenology" was added.

Comment R2.13:

Lines 409-410: I would argue that the wider distributions are due to the effect of not having imposed emergence and harvest dates for natural vegetation.

Response R2.13:

Yes.

'Compared to crop simulations, the experiments with crop phenology (ISBA_pheno and ISBA_pheno_irr) present earlier peak LAI dates, because rainfed vegetation affects the phenology.'

was replaced by

'Compared to irrigated crop simulations, the experiments with crop phenology (ISBA_pheno and ISBA_pheno_irr) present earlier peak LAI dates, because they include rainfed crops and natural vegetation. Emergence dates are not imposed to rainfed crops and to natural vegetation. This allows earlier leaf onset.'

Comment R2.14:

Line 489: I would say, that rather than "empirical" it is "random".

Response R2.14:

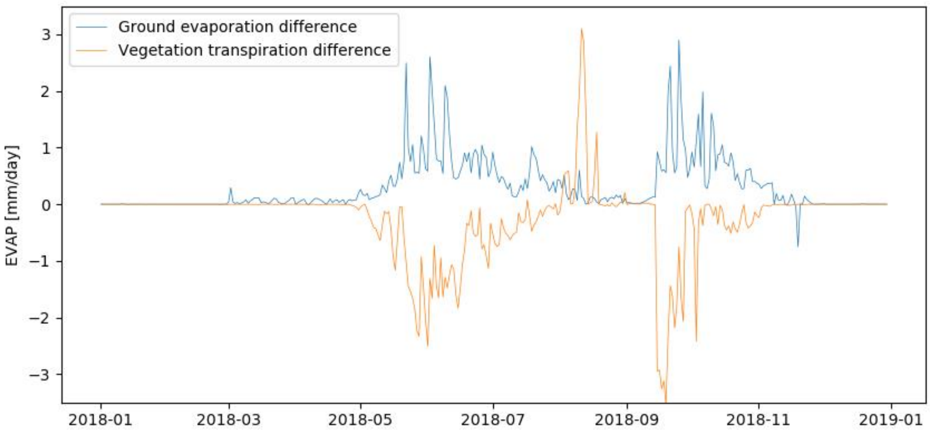
We agree. This sentence was rephrased accordingly.

Comment R2.15:

Line 539: It is really hard to see the difference, please add a third panel with the difference to this figure.

Response R2.15:

Yes. A new subfigure was added to Fig. S9 (Fig. S9c):



Comment R2.16:

Table 1: List all possible values as well, not only the default. Irrigated “nature“ type, I understand that the surface type is called this way in ISBA, but to call a crop “nature” sounds wrong to me. How about (at least in the paper), you rename it to “vegetation”, or what it is: “land surface type”. An irrigation water “turn” could be called “event”. Explain the abbrv. “SWI” in the caption. I believe a “time lapse” is sth. else, how about “time interval”/”lapse of time”/”time span”?

Response R2.16:

We revised Table 1 accordingly (see below).

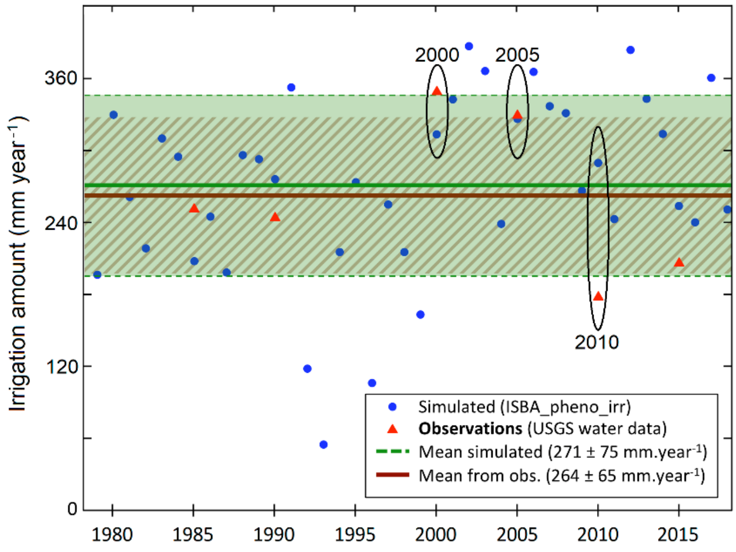
Symbol	Definition	Range	Default value (this study)
I_T	Irrigation type	Sprinkler, flood, and drip irrigation	sprinkler
I_{NT}	Irrigated land surface type	All 20 land surface types (Fig. S1)	C3 crops, C4 crops, shrubs
I_W	Water amount per irrigation event	0 mm or more	30 mm
I_D	Irrigation event duration	0.25 hour or more	8 hours
SWI_1	Soil wetness index threshold for triggering the first irrigation event	0 to 1	0.70
SWI_2	Soil wetness index threshold for triggering the second irrigation event	0 to 1	0.55
SWI_3	Soil wetness index threshold for triggering the third irrigation event	0 to 1	0.40
SWI_{4+i}	Soil wetness index threshold for triggering the following irrigation events (i, integer > 0)	0 to 1	0.25
Δt_{Wn}	Minimum time interval between two irrigation events (irrigation interval)	0 days (e.g. drip irrigation) or more	7 days
Δt_{WH}	Minimum time interval between the last irrigation event and the harvest	0 to 365 days	15 days
t_E	Emergence date	1 January to 31 December	15 May (± 15 days)
t_H	Harvest date	1 January to 31 December After emergence date	15 September (± 15 days)

Comment R2.17:

Figure 3: I suggest to use 5-year steps for the x-axis starting 1985.

Response R2.17:

We revised this Figure accordingly:



Comment R2.18:

Figure 7: This figure is never mentioned in the text.

Response R2.18:

Figure 7 is mentioned in Section 3.3 ("A month by month analysis of the scores (Fig. 7) shows a significant improvement of *r* values in June and September").