Reviewer #1

Comment R1.1:

This study provides a new flexible irrigation and crop scheme, in which several parameters of irrigation and crop phenology could be modified by users. This is very important for detecting irrigation-induced impacts as it considers the spatial heterogeneity of agricultural activities. For the main idea of study, I have no further comments, but I still have some minor comments on the structure, language and some contents. I strongly recommend the authors to polish the full text, as there are some repititions, unclarity and even grammar errors.

Response R1.1:

Many thanks for your new inputs. We did our best to revise the English. In particular a number of typos you mentioned were corrected.

Comment R1.2:

gmd-2021-332-ATC1.pdf L50: after 'Affect non-irrigated areas' cite de Vrese paper: Asian irrigation, African rain: Remote impacts of irrigation :

Response R1.2:

This citation was added:
de Vrese, P., Hagemann, S. and Claussen, M.: Asian irrigation, African rain: Remote impacts of irrigation, Geophys. Res. Lett., 43, 3737-3745, https://doi.org/10.1002/2016GL068146, 2016.

Comment R1.3:

L71: after 'vegetation density' (add some citations here)

Response R1.3:

These two citations were added:
Perry, C.: Efficient irrigation; Inefficient communication; Flawed recommendations, Irrig. Drain., 56, 367–378, 2007.
Perry, C., Steduto, P., Allen, R. G., and Burt, C. M.: Increasing productivity in irrigated agriculture: Agronomic constraints and hydrological realities, Agr. Water Manage., 96, 1517–1524, 2009.

Comment R1.4:

L76: cite Jägermeyr paper 'Water savings potentials of irrigation systems: global simulation of processes and linkages'.

Response R1.4:

This citation was added:

Jägermeyr, J., Gerten, D., Heinke, J., Schaphoff, S., Kummu, M., and Lucht, W.: Water savings potentials of irrigation systems: global simulation of processes and linkages, Hydrol. Earth Syst. Sci., 19, 3073–3091, https://doi.org/10.5194/hess-19-3073-2015, 2015.

Comment R1.5:

L92: I would put the SURFEX and ISBA part to model description in Section2. Here you should briefly describe your objective, and the new features of the new irrigation scheme and what it could be used for.

Response R1.5:

These 10 lines were moved to new Section 2.1.

Comment R1.6:

L101: Also here the simulation part should be in simulations protocol.

Response R1.6:

These 4 lines were moved to new section 2.2.2.

Comment R1.7:

Sec 2: General comments: Section2.1 is called Model implementation and evaluation, actually you talk about study area and simulation settings. I would rename it experimental design or something else, then move it between the description of your new irrigation scheme and data.

Response R1.7:

This section was renamed and moved to new Section 2.3 (Experimental design).

Comment R1.8:

L123: I won't say implementation is made over this region, you could say the simulations and evaluation are conducted over this region.

Response R1.8:

"implementation" was replaced by "simulations".

Comment R1.9:

L130: You don't need to specify the forcing data here, as you should do it in Data. Here you can just say meteorological forcing data.

Response R1.9:

This sentence was reworded as:
"The ISBA LSM simulations are made at a spatial resolution of 0.25° × 0.25°, over a 40-year period from 1979 to 2018. "

Comment R1.10:

L138: 'nature types'? Aren't they crop types?

Response R1.10:

Yes. "C3" was replaced by "C3 crops"

Comment R1.11:

L146: Specify the reason why you only choose the area with more than 50%. I guess it is because this is off-line simulation, so there will be no non-local effects, right?

Response R1.11:

The reason why we choose areas with more than 50 % irrigated surfaces is because we use offline simulations and that we want to focus on local effects irrigation.

The following sentence was added in new Section 2.3:

"For the intercomparison of the simulations we select areas where the irrigation fractional coverage is larger than 50 % as determined from the irrigation map."

was replaced by

"For the intercomparison of the simulations we select areas where the irrigation fractional coverage is larger than 50 % as determined from the irrigation map, in order to better assess the local effects of irrigation in offline simulations."

Comment R1.12:

L159: give the formulas of Pearson's correlation and RMSD.

Response R1.12:

We added Eqs (2-4) at the end of new section 2.3.

Comment R1.13:

L219: 'In ISBA_ref simulations' Here I would avoid mentioning simulations, instead, I would say 'In the original crop scheme of the ISBA model'. Other information regarding the simulations could be moved to section experimental design mentioned in the general comments.

Response R1.13:

We now say : "In this tudy".

Comment R1.14:

L237: What do you mean 'based on', or you just want to express that you used SURFEX v8.1 to do the simulations?

Response R1.14:

This sentence was reworded as:
"The SURFEX v8.1 version (Le Moigne et al., 2018) was used to do the simulations"

Comment R1.15:

Section 2.3. It is very hard to compare your new scheme and the old scheme, as the old scheme is not presented in paper at all. I would add a brief description of the old scheme, including how irrigation is triggered and where the water is applied. I would split this section to two subsections: the original crop and irrigation scheme and the new one, which would be more clear for readers.

Response R1.15:

The "Irrigation processes" subsection was renamed as "New irrigation processes" and the description of pre-existing elements of the model was moved before this subsection.

Comment R1.16:

L261: How the values of these parameters are decided? By observation or by calibration. Please specify.

Response R1.16:

These values are based on past studies. This sentence was replaced by:
"Using these values allows the model to predict a realistic amount of irrigation water over irrigated corn in southern France (Bonnemort et al., 1996; Voirin-Morel, 2003; Calvet et al., 2008)."
and a new reference was added:
Bonnemort, C., Bouthier, A., Deumier, J.-M., and Specty, R.: Conduire l'irrigation avec Irritel ; intérêts et limites, La Météorologie, 14, 36-43, https://doi.org/10.4267/2042/51182, 1996.

"This irrigation strategy tends to limit water applications when the plant is able to extract water from the soil." was added to new section 2.2.

Comment R1.17:

L280-284: I would just say that the model provides the options to …

Response R1.17:

"This new crop and irrigation scheme is able to"
was replaced by
"The new crop and irrigation scheme provides the option to".

Comment R1.18:

L298: top layers? I would say total soil layers in root zone (if I understand correctly).

Response R1.18:

"the number of to soil layers containing roots"
was replaced by
"the total number of soil layers in the root zone".

Comment R1.19:

L301: Could you please specify the reason why this threshold decreases for new seasons?

Response R1.19:

The following sentence was added:
"This irrigation strategy tends to limit water applications when the plant is able to extract water from the soil. "

Comment R1.20:

L311: I would say 'the irrigation water can be intercepted by vegetation canopy.'

Response R1.20:

The following sentence was added:
"The irrigation water can be intercepted by vegetation canopy."

Comment R1.21:

L448: why did you choose these two weather stations, one in irrigated land and one in rainfed irrigated land? Is it on purpose or just based on the availability?

Response R1.21:

The sentence was reworded as: "The two weather stations are within 170 km of each other and correspond to contrasting environmental conditions."

Comment R1.22:

L493: the first paragraph is unnecessary.

Response R1.22:

Was deleted and 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 R1.23:

L512: I think taking no water availability into account could explain the slight overestimation.

Response R1.23:

Yes. These sentences were rephrased as:
"The mean simulated value of the yearly irrigation water amount used for irrigation (271±75 mm year^{-1}) slightly overestimates the observed one (264±65 mm year^{-1}), with a difference of +2.7%. This difference could be explained by the availability of the water resource, not accounted for by the model yet."

Comment R1.24:

L516: 'While … is realistic.' I don't think I understand this sentence. Satellite Lai observations are not realistic?

Response R1.24:

This sentence was reworded as:
"The data from Boedhram et al. (2001) show that the modelled LAI plateau in August at LAI values of about 3.5 m^{2}m^{-2} is realistic for irrigated corn. The satellite LAI observations are sensitive to both rainfed and irrigated vegetation. "

Comment R1.25:

L557: Based on my understanding, you want to say that surrounded rainfed vegetation affects the phenology? It is better to specify it.

Response R1.25:

This sentence was reworded as:
"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".

Comment R1.26:

L561: 'Positive …' I would move it to the caption of the figure.

Response R1.26:

Done.

Comment R1.27:

L646: I am wondering if it is possible to add more paramets related to phenology, like the growing period, peak dates, ect… I think this could be a good way of further improving the model performance.

Response R1.27:

The following sentence was added at the beginning of Section 4.1:
"The crop phenology model is very simple and adding more parameters related to phenology could be a way to further improve the model performance. Integrating satellite LAI observations using data assimilation could also be an option (Mucia et al., 2020)."

Comment R1.28:

L656: I would describe the poor representation of the cold season processes in ISBA and clarify why it could be the reason.

Response R1.28:

This sentence was reworded as:
"Moreover, the representation of the cold season processes is not perfect in ISBA (Decharme et al. 2019) and the model tends to underestimate snow depth and the length of the snow season."

Comment R1.29:

L685: What are the impacts of irrigation on atmospheric model simulations. I would go deeper how it may limit your study.

Response R1.29:

The following paragraph was added:

"Over Nebraska, Szilagyi and Franz (2020) show that the decadal increase in irrigated land tends to trigger a reduction in precipitation over the most densely irrigated areas, of about -10 mm per decade. The largest precipitation suppression is observed at Spring, in March, before the corn growing season, in relation to larger soil water content values. In our simulations, ISBA_pheno_irr presents larger soil moisture values than ISBA-ref in March (see Fig. S3.1), but this is mainly due to crop phenology."

Reference:

Szilagyi, J., Franz, T.E.: Anthropogenic hydrometeorological changes at a regional scale: observed irrigation–precipitation feedback (1979–2015) in Nebraska, USA, Sustain. Water Resour. Manag. 6, 10 pp., https://doi.org/10.1007/s40899-020-00368-w, 2020.

Comment R1.30:

Sec.5: You didn't really describe what this study really implies. I would talk more about the advantage of the new irrigation scheme and for what it could be used, and some implications of this study. Example1. This flexible crop and irrigation scheme could take the spatial heterogeneity of irrigation activities into account, thus it is a better tool to detect irrigation-induced impacts on earth system. Example2. Results show that phenology parameters could modify the seasonal pattern of LAI and other variables, and irrigation could affect the magnitude of the variables. This could provide the information for further development.

Response R1.30:

Many thanks for this suggestion. We added the following paragraph at the end of the Conclusion:

"This flexible crop phenology and irrigation scheme could take the spatial heterogeneity of irrigation activities into account, and detect irrigation-induced impacts on Earth system simulations. Our results show that crop phenology parameters could modify the seasonal pattern of the simulation of LAI, soil moisture, evapotranspiration and plant carbon uptake, and that irrigation could affect their magnitude. This could provide the basis for further development in offline and online applications of the ISBA model."

Comment R1.31:

Sup: Check the tense consistency you used in manuscript and supplements. Both present or past tense are ok but keep it consistent

Response R1.31:

Thanks for noting this. We moved all past tense sentences to present tense.

Reviewer #2

Many thanks for your comments. They are addressed below. Also, a number of typos you mentioned were corrected.

Comment R2.1:

Abstract L 24: "The ISBA simulations with and without irrigation scheme…" Is this conclusive as the comparisons are also made for simulations with/without crop phenology?

Response R2.1:

"The ISBA simulations with and without the irrigation scheme are compared to different satellite-based observations. "
was replaced by
"The ISBA simulations with and without the new crop phenology and irrigation scheme are compared to different satellite-based observations. "

Comment R2.2:

L105 – 110: may need to modify the description of the scope of this study as you also changed the title by including the role of crop phenology.

Response R2.2:

"Section 2 presents the observational datasets, the current version of the ISBA LSM, the description of the new crop and irrigation scheme, followed by a description of the validation protocol. Section 3 illustrates the impact of the new scheme when compared to a model run without irrigation. An evaluation of the performance of the model is made over Nebraska. Section 4 discusses the added value and the limits of the newly implemented irrigation scheme. Finally, section 5 presents the conclusions and future research directions."
was replaced by :
"Section 2 presents a description of the ISBA LSM, the new crop and irrigation scheme, the validation protocol, followed by a description of the observational datasets. Section 3 illustrates the impact of the new scheme when compared to simulations without crop phenology and without irrigation. An evaluation of the performance of the model is made over Nebraska. Section 4 discusses the added value and the limits of the newly implemented irrigation scheme. Finally, section 5 presents the conclusions and future research directions."

Comment R2.3:

Figure 1: Please add the latitude and longitude coordinates for the maps.

Response R2.3:

Thanks for noting this. Figure 1 was updated and coordinates are now more visible.

Comment R2.4:

L136: Why only mentioned the LAI comparison here?

Response R2.4:

The following sentence was added:
"In addition to LAI, other variables are considered: gross primary production, evapotranspiration and land surface temperature."

Comment R2.5:

What is the spatial resolution of the model simulations? Please clarify in section 2.

Response R2.5:

The sentence is now in Section 2.3 and was reworded as:
"The ISBA LSM simulations are made at a spatial resolution of 0.25° × 0.25°, over a 40-year period from 1979 to 2018. "

Comment R2.6:

L176: Is there any sensitivity analysis done regarding the magnitude of this parameter (30mm)? Similarly, any sensitivity test conducted for the choice of SWI threshold? How sensitive your result would be to these irrigation parameters? And how does this sensitivity transfer to vegetation conditions?

Response R2.6:

These values are based on past studies. Using these values allows the model to predict a realistic amount of irrigation water over irrigated maize in southern France (Bonnemort et al., 1996; Voirin-Morel, 2003; Calvet et al., 2008). This irrigation strategy tends to limit water applications when the plant is able to extract water from the soil.
This sentence was replaced by:
"Using these values allows the model to predict a realistic amount of irrigation water over irrigated corn in southern France (Bonnemort et al., 1996; Voirin-Morel, 2003; Calvet et al., 2008). "
and a new reference was added:
Bonnemort, C., Bouthier, A., Deumier, J.-M., and Specty, R.: Conduire l'irrigation avec Irritel ; intérêts et limites, La Météorologie, 14, 36-43, https://doi.org/10.4267/2042/51182, 1996.

Comment R2.7:

L197: "Irrigation can optionally be triggered without considering..." It is a bit hard to understand this as you mentioned earlier that the irrigation time window is based on the emergence and harvest dates.

Response R2.7:

This sentence was reworded as:
"Irrigation can optionally be triggered without considering any specific crop phenology parameter but this option was not considered in this study."

Comment R2.8:

Why don't the emergence and harvest dates differ among different vegetation types? Is this assumption reasonable? If mentioned as a limitation, could you populate the discussion on how this assumption may affect the states and fluxes?

Response R2.8:

This information is now given in the new 2.3 section "Experimental design", after the model has been presented, as well as the model parameters. In this study, the main irrigated vegetation type is corn. This is indicated now. The discussion of Section 4.1 was completed with the following senstence:
"The crop phenology model is very simple and adding more parameters related to phenology could be a way to further improve the model performance. Integrating satellite LAI observations in ISBA using sequential data assimilation is also an option (Mucia et al., 2020)."

Comment R2.9:

Line 300: Is the model simulation conducted at a resolution of 300m * 300m? It is not quite clear why the irrigation map needs to be transferred to 300m*300m if the model resolution is not at this scale.

Response R2.9:

We achnowledge that this is confusing. This sentence was moved to another part of the new section 2.2.

Comment R2.10:

L343-345: "It is available every 10 days…does not cover the whole simulation time period (1979 to 2018)" These sentences contain contradictory information, please clarify.

Response R2.10:

Thanks for noting this.
"It is available every 10 days for all simulation years. The LAI time series is available from 1999 onward. It does not cover the whole simulation time period (1979 to 2018)."
was replaced by
"It is available every 10 days from 1999 onward. It does not cover the whole simulation time period (1979 to 2018).".

Comment R2.11:

I don't think GLEAM ET is a good candidate reference datasets as the model does not explicitly include the irrigation signal. Please consider select other ET reference datasets that can detect the irrigation signal or include several widely used ET datasets for comparison besides GLEAM.

Response R2.11:

See Response R2.15.

Comment R2.12:

Figure 4: I would suggest converting the irrigation number to total irrigation amount in this figure. Your y-axis is irrigation number while some of the data shown are compared in terms of amount.

Response R2.12:

This is a very good point. Irrigation number was converted to Irrigation amount in Fig. 4.

Comment R2.13:

Section 3.1: Other than the averaged irrigation amount, could you comment on the model performance in simulating irrigation amount in wet/dry years? Even though it is not possible to evaluate the interannual variation as the data is only available every 5 years, it is possible to at least see how the model perform in wet/dry conditions.

Response R2.13:

Yes. We revised Fig. 4 in order to indicate the 2000 and 2005 dry years, and the 2010 wet year. The last paragraph of Section 3.1 was replaced by
"This difference could be explained by the availability of the water resource, not accounted for by the model yet. The large observed irrigation amounts in 2000 and 2005, larger than 300 mm year^{-1}, are relatively well represented by the model. On the other hand, the observed small irrigation amount for the 2010 wet year, is overestimated by about 110 mm year^{-1}."

Comment R2.14:

Figure 6&7: I would suggest including correlation and RMSD difference between ISBA_pheno and ISBA_ref and then discuss the major contributor for this improvement. It seems that irrigation only plays an additive role in improving the vegetation seasonal cycle as compared to the role of including crop phenology.

Response R2.14:

We checked this. Actually, ISBA_pheno correlation and RMSD differences with respect to ISBA_ref are nearly identical to those showed for ISBA_pheno_irr in Figs. 6-7.
The following sentence was added at the end of Section 3.3:
"The ISBA_pheno correlation and RMSD differences with respect to ISBA_ref are nearly identical to those showed for ISBA_pheno_irr in Figs. 6-7 (not shown)."
In Section 4.1,
"The results of our numerical experiments over Nebraska show that considering crop phenology and irrigation improves the consistency of the simulations with LAI and GPP observations. The corresponding correlation and RMSD scores are improved. Two new developments can explain this behaviour: (1) the crop phenology parameters used to force emergence and harvest dates reduce the length of the growing season, delay spring growth and avoid a regrowth in the autumn, and (2) the irrigation limits the water stress and enhances plant growth at summertime. Nevertheless they both have shortcomings and their performance could be limited by difficulties in simulating processes that are not directly related to irrigation."
was replaced by

"The results of our numerical experiments over Nebraska show that considering crop phenology improves the consistency of the simulations with LAI and GPP observations. The corresponding correlation and RMSD scores are improved. The crop phenology parameters used to force emergence and harvest dates reduce the length of the growing season, delay spring growth and avoid a regrowth in the autumn. It seems that irrigation only plays an additive role in improving the vegetation seasonal cycle as compared to the role of including crop phenology (Section 3.3). Both crop phenology and irrigation models have shortcomings and their performance could be limited by difficulties in simulating processes that are not directly related to irrigation."

Comment R2.15:

Figure 9: Degradation in R for ET for most of the months considered may be evidence that GLEAM is not suitable to be referred for irrigation impacted ET comparison. Please investigate other reference datasets. Besides, ET products are subject to uncertainties in magnitude and RMSD needs to be discussed under this context.

Response R2.15:

Yes. We added additional results in the Supplement (Table S3.1, Table S3.2, Figure S3.5). The following sentence was added at the end of Section 3.5:
"Degradation in r can be observed at some locations throughout the growing season. "
The following paragraph was added at the end of a new Section 4.2:
"Finally, degradation in r for evapotranspiration in Fig. 10 may be evidence that GLEAM may not be considered as a suitable reference for evapotranspiration comparisons in areas impacted by irrigation. The use of other datasets is investigated in Supplement 3. In particular, in situ observations over an irrigated corn field (Suyker and Verma, 2009) are used. Table S3.1 shows that GLEAM tends to underestimate evapotranspiration by 20 % during the growing season (from May to September). During the non-growing season, the ISBA_pheno_irr model overestimates evapotranspiration by 48 %. Table S3.2 and Fig. S3.5 show that the ISBA_pheno_irr evapotranspiration peak (in June) tends to happen too early. Mean values of near-surface wind speed are particularly large over Nebraska, especially at wintertime and springtime (Chen, 2020). This feature could exacerbate the impact of a misrepresentation of soil evaporation."

Reference:

Chen, L.: Impacts of climate change on wind resources over North America based on NA-CORDEX, Renewable Energy, 153, 1428-1438, https://doi.org/10.1016/j.renene.2020.02.090, 2020.

Comment R2.16:

For all the correlation related analysis, how the values are selected to mask out the grid cells with white color? It would be better to add a significance test and use the significance result to mask out the grid cells.

Response R2.16:

We tried to improve the readability (also for color-blind readers) of Figures 6 to 12 by simplifying the color bars and adding white plus symbols for areas presenting the largest improvements.

Comment R2.17:

L521: Is it possible to derive emergence and harvest dates based on the LAI observation so that it can represent the interannual variation? Please comment on this.

Response R2.17:

The following sentence was added in Section 4.1:
"Also, emergence and harvest dates could be derived from the LAI observation in order to better represent the interannual variation."

Comment R2.18:

Please make sure all the supplemental materials are mentioned in the main manuscript to support relevant statements.

Response R2.18:

We checked that and we added a few more citations to the supplemental materials.