Response to reviewer on the paper "Joint evolution of irrigation, the water cycle and water resources under a strong climate change scenario from 1950 to 2100 in the IPSL-CM6", in the Earth System Dynamics journal.

Thank you for the revised manuscript. The expanded explanation throughout is appreciated, particularly the inclusion of model choices, simplifications, and limitations. The revision represents a significant improvement. I am recommending minor revisions, with a focus on the following two points:

We thank the anonymous reviewers for this second round to comment on our paper. Below, we provide a point-by-point response to these comments. Sentences from the manuscript submitted after the first review round are presented in italic, while the proposition to respond to the observations are presented in bold. Lines correspond to the manuscript indicated, submitted manuscript or manuscript with changes tracking.

1. (1) Quantitative interpretation of results: Many sections, particularly in the results (Sections 3.1 - 3.5), still rely heavily on qualitative language (e.g., "important increase," "slightly decrease," "no major change"). These descriptions can be subjective and would be significantly strengthened by including quantitative data (e.g., % changes, mm/year, or °C ranges). Please incorporate numerical values or trend magnitudes directly into the text to help readers better assess the significance of the findings without relying solely on visual interpretation of the figures.

Please read response to observation 6, 7, 8 and 10

2. (2) Language clarity and conciseness: There are multiple areas in the manuscript that could benefit from improved clarity and conciseness. Some phrasing is either redundant, awkward, or overly verbose. Few suggestions are noted below.

Please read response to observation 3, 4, 5 and 9

3. Throughout the manuscript, please remove 'see' before the Figure references.

We removed 'see' before the figure references, so it is more concise.

4. Line 87: Please remove: "We briefly describe each component." This is redundant and unnecessary, given the content that follows.

We removed the sentence "we briefly describe each component", so the manuscript is more concise

5. Line 109: Remove: "Organising Carbon and Hydrology In Dynamic Ecosystems". ORCHIDEE is already defined earlier in the manuscript.

We note that line 109 corresponds to the version with change tracking. In the submitted version, a second mention to the full ORCHIDEE acronyme is set in line 83. We remove the second mention of the acronyme, so it is more concise.

6. Line 132: “Remark that this simplification may have an impact on the timing and volume of total water withdrawal ...”

Please clarify/revise this statement.

We note that line 132 corresponds to the version with change tracking. In the submitted version, it corresponds to line 99.

Here, we wanted to note that the representation of crops as grassland has an impact on irrigation, because the irrigation module is not able to represent local crop calendars, and because harvesting is not included.

We propose to include these two points to clarify the sentence:

“Remark that this simplification may have an impact on the timing and volume of total water withdrawal, by inducing an overestimation of water demand and ultimately water use. ***This is due to the lack of representation of the crop calendar, including the harvest stage, which keeps the leaf area index values high in the model.***

7. Line 209: The phrase “this scenario could be seen as the upper boundary of potential climate change impacts” is repeated thrice now. Please retain it at the first instance and expand on it in the Discussion, stating what is the implication of this choice for the model results.
   Please consider adding a concise justification for the use of SSP5–8.5 in the first instance, e.g., it was chosen to represent a high-end pathway of climate forcing, allowing the analysis of irrigation under extreme water stress and strong climate signals, etc.

We use “upper boundary of potential climate change impacts” in lines 156, 449 and 526 of the submitted manuscript. We follow the reviewer recommendation, and add a sentence in line 156 to justify the use of the SSP5-8.5 scenario:

The use of scenario SSP5-RCP8.5 could be seen as the upper boundary of potential climate change impacts and results in a strong global warming and important changes in precipitation. ***The use of this scenario allows for analysis of the interaction between irrigation and climate in a context of strong climate change signals and significant changes in irrigated land area****.*

And we add a sentence to explain the implications of this choice for model results, in line 449:

The use of SSP5-8.5 as a single radiative forcing scenario induces a strong warming and significant changes in precipitation. This scenario could be seen as the upper boundary of potential climate change impacts, but the magnitude and spatial distribution of these changes are uncertain (AR6, IPCC, 2021). ***The direct impact of climate change on irrigation could be affected by this uncertainty, especially with regard to changes in precipitation patterns.***

8. Lines 212, 217, 220: The repeated mention of “Historical and SSP5–8.5” can be streamlined to improve readability. Consider rephrasing to avoid redundancy and improve flow.

We note that lines 212, 217 and 220 of the tracking changes document correspond to lines 156, 162 and 164 of the submitted manuscript.

We understand the concern of the reviewer, we propose to change the sentence in line 164 of the submitted manuscript, so readability is improved:

Changes in land use include changes in cropland area (see Figs. S1 and S2 in the Supplementary Material). Each year of irrigated area per grid cell is also prescribed with LUHv2, using the same ***setup (historical and SSP5-8.5 scenario)****.*

9. Line 280: ‘processus’ might be a typographical error.

Indeed, it corresponds to ‘process’. This typo was already corrected.

10. Line 353 (and throughout Sections 3.1 - 3.5): Qualitative statements such as “Warming tends to be greater in northern latitudes” would be clearer if supported by specific values. For example, you can state that warming is more pronounced in northern latitudes, exceeding X°C in parts of Canada and Russia, compared to Y–Z°C in tropical regions.

We note that some of these qualitative statements are supported by quantitative results, shown in tables and figures. On the other hand, we understand that noting key values can further support the main ideas we are presenting. We propose then to add some key values in the manuscript, following the reviewer’s observation.

In line 240 of the submitted manuscript (line 320 of manuscript with changes tracking):

We observe that the influence of irrigation (i.e. the difference between the NoIrr and the Irr simulations) increases the average land values of ET, precipitation (P), runoff (R), and LAI ***(+4%, +1%, +2% and +3%, respectively)****, while it depletes water storage in irrigated areas, i.e., groundwater storage (GWS****, -7%****) and stream storage (Stream S****, -8%****), but increases water storage in non-irrigated zones* ***(+2% for GWS)****. The influence of irrigation on total water storage (TWS)* ***on average land values*** *is positive* ***(+0.7%)****, which is partially due to an increase in soil moisture (SM****, +1% over land****).*

In line 258 of the submitted manuscript (line 346 of manuscript with changes tracking):

In irrigated areas, precipitation may either increase due to climate change (e.g., China and southern India, ***with local extremes of more than +1 mm/day****) or decrease (Mediterranean area,* ***with local extremes in the Iberian Peninsula below -1 mm/day****), whereas warming occurs in all areas. These changes in climate can contribute to changes in irrigation: positive changes in precipitation can increase available water and water resources while decreasing the soil moisture deficit and water demand. Negative changes in precipitation increase water demand, which could increase irrigation if water resources are available. Warming tends to increase water demand, but it should be noted that warming tends to be greater in northern* *latitudes* ***(warming over 7 °C)*** *than in tropical and southern areas* ***(warming over 3 °C)*** *as a result of the land warming pattern, visible in non-irrigated areas (see Figure 3-b).*

Line 305 of the submitted manuscript (line 406 of manuscript with changes tracking):

Figure 6 shows the spatial distribution of the influence of irrigation (Irr-NoIrr) in the future for ET and P. In the future period, irrigation always increases ET in irrigated areas ***(with local extremes in the Indus river basin above +1 mm/d)****, and in many non-irrigated areas nearby (Figure 6-a, especially in central Asia and the African Sahelian band,* ***with values below +0.1 mm/d****).*

Line 312 of the submitted manuscript (line 416 of manuscript with changes tracking):

Like for ET, irrigation mostly increases P, over both irrigated and non-irrigated areas, but on smaller surfaces (Figure 6-b, ***with values below 0.5 mm/d****; the same figure including the oceans is shown in Fig. S3).*

Line 347 of the submitted manuscript (line 465 of manuscript with changes tracking):

The effects are mostly negative for both variables in irrigated areas, but in the case of Stream S, depletion is more important in the grid cells containing large rivers ***(with local extreme values under -50 mm in the Indus and Rio de la Plata rivers) …***

Line 368 of the submitted manuscript (line 493 of manuscript with changes tracking):

In these river basins, irrigation activities decrease discharge values throughout the year ***(decrease in the future due to irrigation ranges between -4 up to -51% of discharge)*** *under both historical and future climate conditions …*

Line 378 of submitted manuscript (line 509 of manuscript with changes tracking):

and a decrease of river discharge with climate change **(decrease due to climate change range from -1 up to -15% of discharge)***.*

And line 385 of submitted manuscript (line 519 of manuscript with changes tracking):

in both periods, but a slightly positive influence of irrigation on discharge ***(increase in the future due to irrigation ranges between +3 to +12%)****.*

11. In general, please consider revising phrases like "important differences," "slower increase," "no major change," "slightly higher", etc., by including corresponding numerical values (e.g., percentage increases in ET, mm/year changes in precipitation). This would allow a more objective assessment of the magnitude of change and make your interpretation more robust.

Following reviewer observations, we included numerical values so the assessment of the magnitude is more objective. Please see response to observation 10 above.

12. Line 522: Similarly, please quantify “slightly higher”. For example: “...discharge values were slightly higher (by ~X%) in the Irr simulation compared to the NoIrr simulation under historical climate conditions.”

Following the reviewer's observation, we included numerical values. Please see response to observation 10, the last correction corresponds to this part of the text.

13. Fig. 5 and 7: Different readers may interpret visual trends differently. Adding numerical summaries (e.g., trend magnitude) in the figure and the text would help standardize interpretation.

We included some numerical summaries in the text to standardize interpretation.

First, line 297 of the submitted manuscript (line 394 of manuscript with changes tracking):

For ET, the NoIrr simulation shows a decreasing trend in irrigated areas ***(from 1.81 mm/d during 1950-1975, to 1.79 mm/d during 1975-2000)*** *during the 1950-2025 period that is not present in the Irr simulation (Figure 5a, second row). Additionally, the changes in ET observed over land (Figure 5a, first row) are driven by changes in irrigated areas* ***(+0.15 mm/d in historical, +0.25 mm/d in future)****, as the ET values in non-irrigated areas are similar for both simulations (Figure 5a, third row). Finally, we observe that the increase in ET in irrigated areas after 2025 is faster in the Irr simulation than in the NoIrr simulation, even though irrigation expansion stops by 2040 (Figure 2-a). In the case of P, irrigation activities increase the yearly average values over land* ***around 0.04 mm/d*** *(Figure 5b, first row).*

And line 337 of the submitted manuscript (line 450 of manuscript with changes tracking):

The impact of climate change induces a positive trend in water storage (Figure 7-a and b, first row), whereas irrigation decreases the average GWS and Stream S in irrigated areas in around ***-14 and and -12% in the future, respectively*** *(Figure 7-a and b, second row) and slightly increases the GWS and Stream S in non-irrigated areas* ***around +2 and +0.02% in the future, respectively*** *(Figure 7-a and b, third row).*

14. Discussion: Thank you for stating both the sources of uncertainty and the limitations of the modeling framework. It will be helpful to briefly state the impacts of the uncertainties (604 - 625) on model findings similar to the simple explanations provided for ORCHIDEE limitations (Ln 629 647). Listing the uncertainties without offering context limits their usefulness to the reader.

We propose to add the following sentence in line 465 (line 626 of manuscript with changes tracking):

These uncertainties quantitatively influence the entire simulated water cycle, so that our results are model-specific and must be confirmed using other land-atmosphere models and available observations.

Finally, we changed the color bar of maps in the Supplementary, so colors are coherent with figures in the main manuscript. We also changed minor typos in the manuscript.