March, 12th, 2025

Dear Editor,

We thank you and the two reviewers for the very constructive and valuable comments on our manuscript [No. gmd-2024-212]. We have carefully addressed each comment and made comprehensive revisions to enhance the quality and clarity of our work. We are pleased to submit this revised manuscript for publication in *Geoscientific Model Development*. The main changes in this revised manuscript can be summarized as follows:

1. We provided all necessary code and valid data in compliant formats with details documented in the *Code and data availability* section.
2. We identified the primary factors driving the spatial variations in regulation potentials of all target variables by correlation analyses. Meanwhile, we extended relevant discussions in the *Results and discussion* and *Data and Methods* sections.
3. We presented the geographical distribution of observation sites along with corresponding environmental conditions.
4. We added a summary table to clarify variables and sources of model input data.
5. We made point-by-point minor revisions according to all the reviewer's specific comments.

We hope that this revised manuscript will be of sufficient quality to be considered for publication. Thank you again for your interest and time in reviewing our manuscript. We look forward to hearing from at your earliest convenience and are available to provide any additional information if required.

Yours sincerely,

Dr. Feng Zhou (on behalf of all co-authors)
Boya Distinguished Professor of Biogeochemistry
College of Urban and Environmental Sciences,
Peking University
Email: zhouf@pku.edu.cn
Tel: +86-13810171339
ORCID: 0000-0001-6122-0611

Response to Reviewers' comments (gmd-2024-212)

Editor's Comments

Dear authors,

Unfortunately, after checking your manuscript it has come to our attention that it does not comply with the "Code and Data policy" of our journal: https://www.geoscientific-model-development.net/policies/code_and_data_policy.html

First, the code that you provide for the model that you use contains binary files: .exe. This is not code, and we can not accept it. You must provide the code of the model, not compiled files. Therefore, you must reply to this comment with a new repository (including its DOI and link) that contains the full code of the model. Moreover, I would like to not that the FigShare repository that you have shared contains many .xls files. This format is not a fully compliant ISO format, and depends on proprietary software to assure compatibility when accessing the files. Instead of this format, we encourage you to share this content in the OpenDocument format, for example, .ods files.

Also, you provide part of your data with a link to a site that does not comply with our policy, and it is not a valid repository for scientific publication. I refer here to the land data in bnu.edu.cn. Moreover, the link is pointing to a main portal, not the exact data that you have used in your study, that is what is necessary to replicate your work. Therefore, you must store the land data that you use in your work in one of the repositories that we can accept according to our policy, and reply to this comment with the information about it (link and DOI).

I should note that the current situation with your manuscript is irregular due to this failures to comply with our policy, and therefore should have not been accepted in Discussions. Therefore, we are asking you to address this situation as soon as possible, without waiting for the end of the Discussions period. In the meantime, we can not continue with the review process for your manuscript until the mentioned issues are solved. Please, note that if you fail to comply with this request, we will have to reject your manuscript for publication in our journal.

Juan A. Añel

Geosci. Model Dev. Executive Editor

[RESPONSE] Thank you for your comments on our manuscript. We apologize for the initial submission not fully complying with the journal's code and data policy. We have addressed the issues raised.

First, we supplemented the full source code of the WHCNS model to the repository (https://figshare.com/s/139f3ad8a70faa99724d) (in the file named 'source code of the WHCNS model'). In the repository, we converted all the .xls files into the OpenDocument format (.ods) to ensure compatibility and compliance with open standards. Note that .xls files are necessary for running the model, so we provide both .xls and corresponding OpenDocument (.ods) files in the repository.

Second, we provided detailed links of the exact land database and other datasets we used in the *Code and data availability* section of the manuscript. We also provided our processed data for regional simulation to reproduce the results presented in the manuscript (named as 'Regional_weatherin_China' and 'Regional\input\China_soil' for the processed climate and soil data in the repository).

Last, we provided detailed explanations in the 'Readme' document for each file in the repository.

In the revision, we ensure that all the necessary code and data are now accessible and properly documented. We revised the *Code and data availability* section of the manuscript as below.

> "**[Lines 840-850]** Code and data availability
> The origin code of WHCNS model and required model input files are available at https://figshare.com/s/139f3ad8a70faa99724d. Spatial dataset of harvested area of irrigated rice is available from https://doi.org/10.7910/DVN/KAGRFI. Origin climate data is available from https://cds.climate.copernicus.eu/datasets/reanalysis-era5-single-levels?tab=download. Origin soil data is obtained from https://doi.org/10.1002/2013MS000293. Processed climate and soil data for running model are also provided in the figshare repository (see Readme for detailed explanations). Crop calendar data are available from https://zenodo.org/record/5062513. All other data that support the findings of this study are available in the main text or the Supplementary Information."

Reviewer #1:

[R1C1] General Comments

Simulating the complex relationships between water, crop yield, and greenhouse gases at a region scale based on process-based model is a challenge. To address this problem, this study proposes a novel framework that simulates regional rice yield, water use, and greenhouse gas emissions in response to various irrigation schemes. This framework integrates critical physiological processes, upscales model parameters, and employs multi-objective optimization. It has been carefully evaluated. Overall, the manuscript is well-structured and well-written. With a few enhancements, I believe this study would make a significant contribution to Geoscientific Model Development.

[RESPONSE] Thank you very much for reviewing our manuscript and for your encouragements. Below we responded to each comment and updated the results in revision accordingly.

[R1C2] The authors showed large spatial variabilities in regulation potentials while less explanations are provided. Understanding the driving factors behind these variations is essential for designing more targeted and effective irrigation schemes. A more detailed analysis of the spatial patterns and their underlying drivers would greatly benefit the readers' comprehension and application of the findings.

[RESPONSE] We totally agree with the reviewer that it is necessary to understand the drivers underlying spatial variabilities of the regulation potentials. To do so, we first performed correlation analyses between WHCNS-simulated regulation potentials for each target variable (ΔYield, ΔIRR, ΔCH_4, and ΔN_2O) and several independent variables. We selected climatic, soil and management-related factors as independent variables (e.g., T, P, ET, Clay, BD, SOC and fertilizer rate). Second, we conducted spatial correlation analyses using different moving windows (e.g., 3.5° by 3.5°, 2.5° by 2.5°) to reveal spatial patterns of dominant drivers. Third, we identified the dominant factors driving variations in regulation potentials at both national and grid scales.

In the revision, we extended relevant contents in the *Results* and *Method* section (section 3.3 and 2.5) together with three new figures (Fig. 5, S10 and S11).

> "**[Lines 442-452]** To identify the dominant factor driving spatial patterns of NCF effects, correlation analyses between simulated NCF effects and variables were performed following Cui et al. (2021). Climatic, soil and management-related factors were selected as independent variables, including T, P, ET, Clay, BD, SOC and fertilizer rate. The analyses were conducted respective for ΔYield, ΔIRR, ΔCH_4, and ΔN_2O using 3.5°-by-3.5° moving windows. The data resolution was 0.5° by 0.5°, meaning the surrounding 49 pixels were used for each grid. The correlation coefficient and its significance in each grid was first calculated, and the dominant

driver was then defined as the factor with the largest absolute correlation coefficient. To assess the robustness of the results, similar analyses were done with moving windows at higher spatial resolutions (e.g., 2.5° by 2.5°)."

and

"**[Lines 649-662]** To further understand the drivers shaping the spatial variations in NCF effects, correlation analyses were conducted for each target variable across varying lower irrigation threshold. Overall, climatic and edaphic variables were the most important drivers, while management-related variables were less important (Fig. 5). Exceptions occurred in the south double rice region (HND) for ΔYield and the southwest single rice region (XNS) for ΔN_2O, where higher fertilizer application rate was associated with larger yield increase but decreased N_2O reduction potentials (Fig. S10 and S11). For both ΔYield and ΔIRR, clay content was the most important driver at higher irrigation thresholds, while climate factors showed increasing importance with decreased irrigation thresholds (Fig. 5a and b). By contrast, reduction potentials for CH_4 and N_2O emissions were dominated by edaphic factors regardless of irrigation threshold (i.e., clay for CH_4 and bulk density for N_2O) (Fig. 5c and d). These findings highlight the complex interplay of factors influencing regulation potentials of rice production, irrigation water use and greenhouse gas emissions through NCF adoption."

and

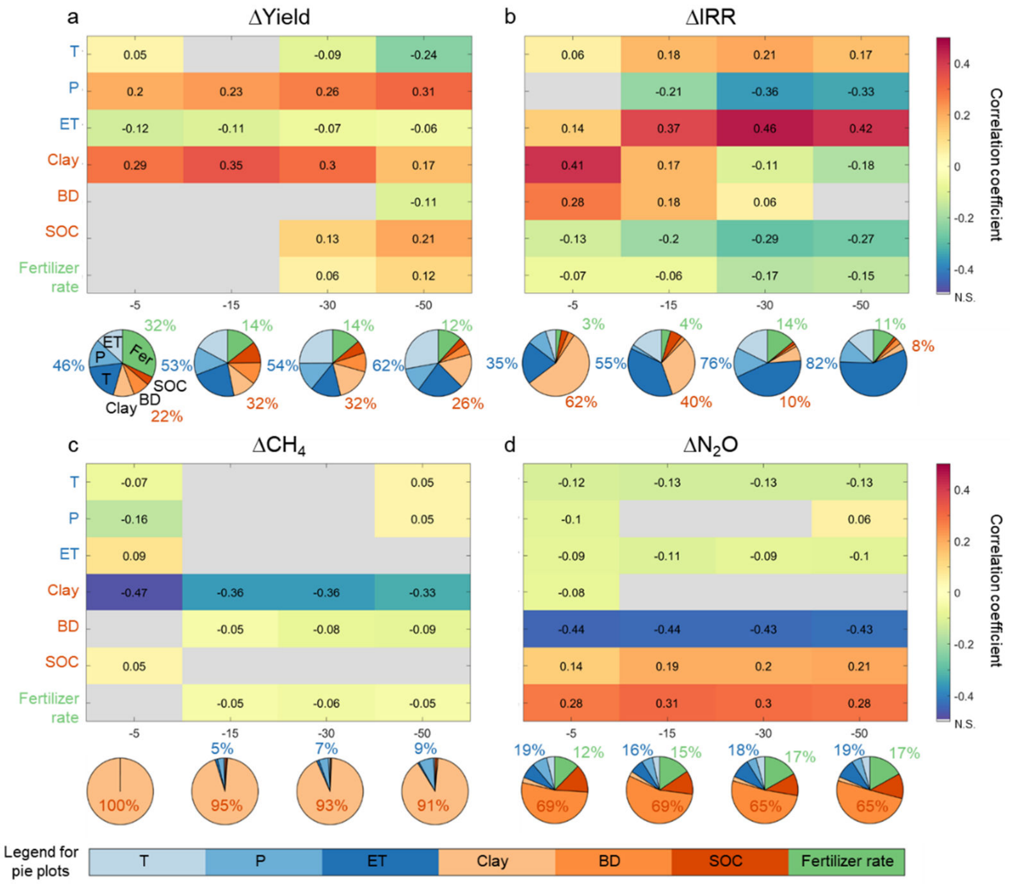

Figure 5 Drivers regulating spatial variations in relative changes in yield (a), IRR (b), CH_4 (c) and N_2O (d). The numbers and colors indicate correlation coefficients, with gray indicating non-significant correlations (N.S., $P > 0.05$). The pie plots represent the proportion of irrigated rice areas (%) for which relative changes variation is regulated by the dominant drivers. The dominant driver is defined as the factor with the largest absolute correlation coefficient in each grid cell, identified from 3.5°-by-3.5° moving windows. The numbers in blue, orange and green around the pie plots denote the area proportions dominated by climate (i.e., T + P + ET), soil (i.e., Clay + BD + SOC) and management-related (i.e., Fertilizer rate) factors under corresponding lower irrigation threshold. Spatial distributions of dominant drivers are shown in Fig. S10 and S11.

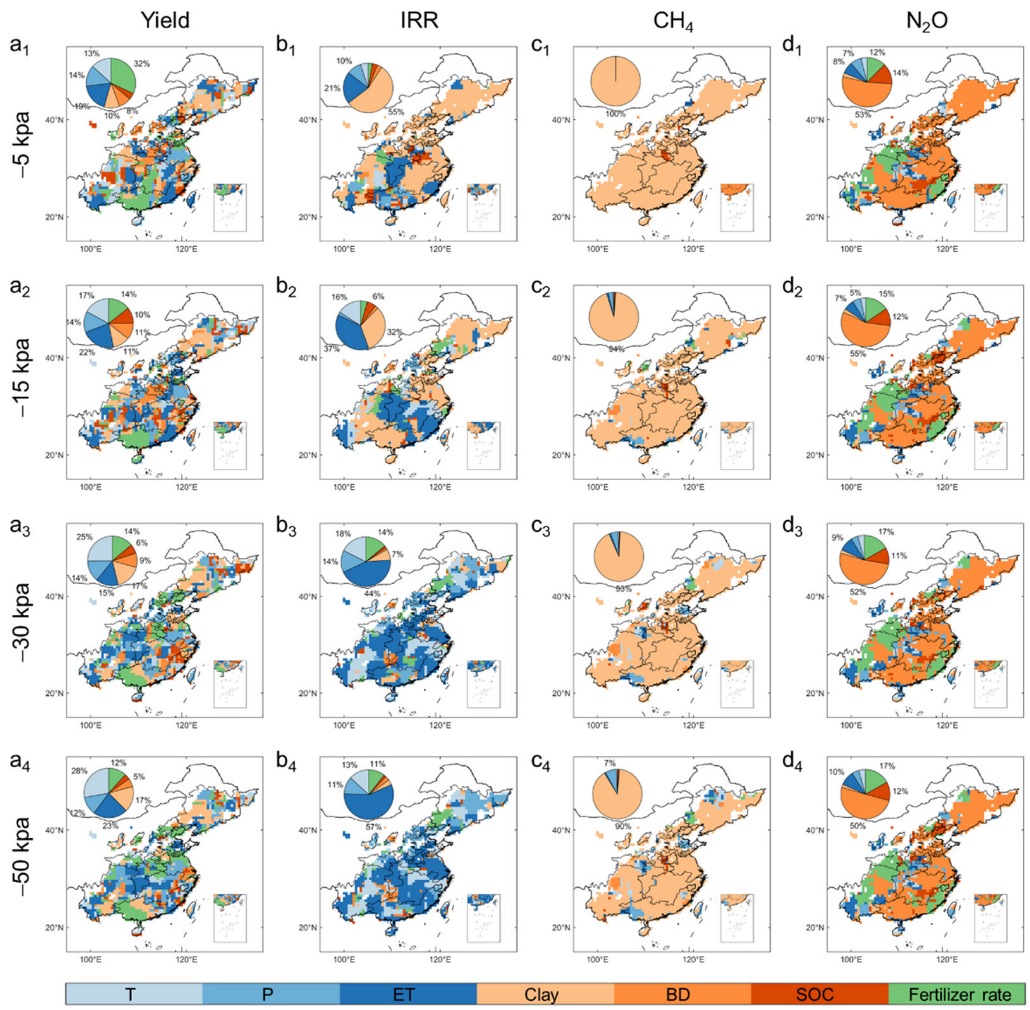

Figure S10 Distribution of dominant drivers regulating variation in relative changes of (a) Yield, (b) IRR, (c) CH_4, (d) N_2O. Each row represents results under lower irrigation threshold at −5, −15, −30 and −50 kpa. The inset pie plots represent the ratio (%) of irrigated rice areas for which relative changes variation is regulated by the dominant drivers. The dominant driver is defined as the factor with the largest absolute value of the correlation coefficient in each grid cell, identified from 3.5°-by-3.5° moving windows.

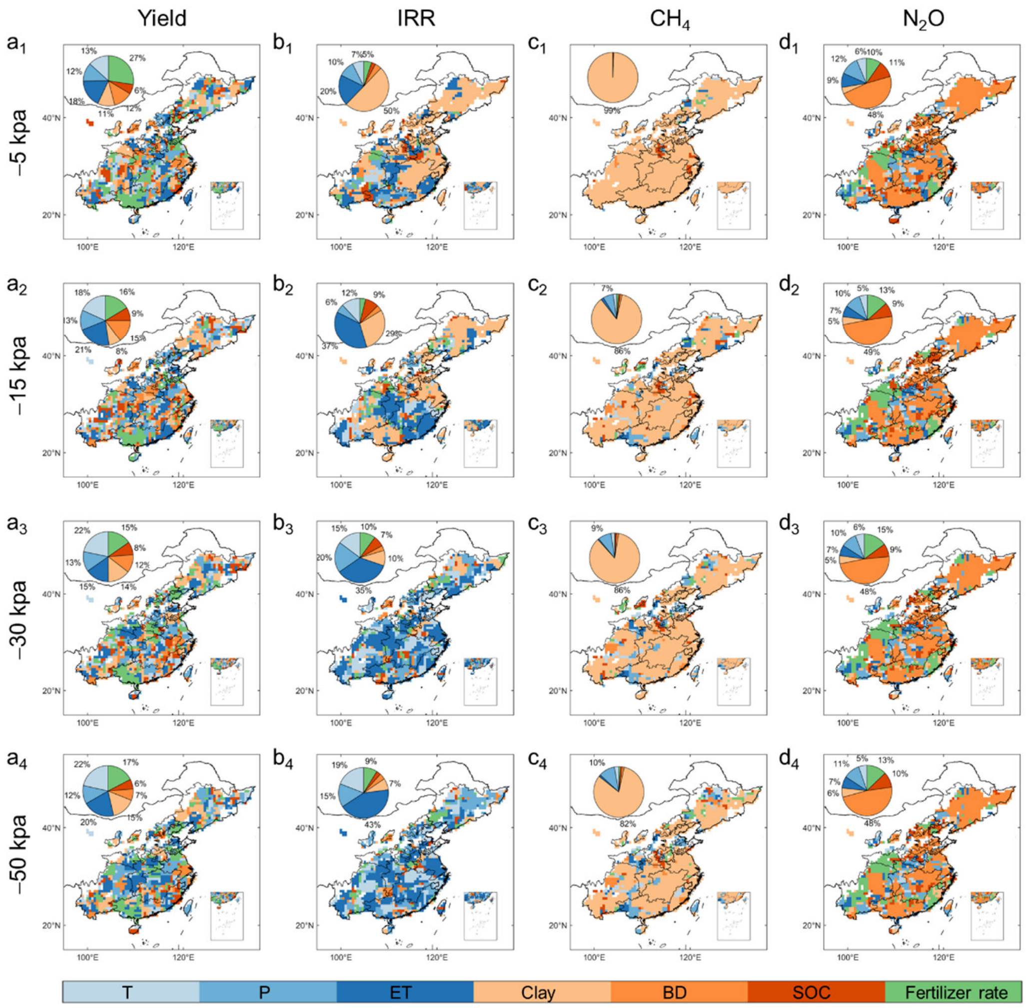

Figure S11 The same as Fig. S9 but for 2.5°-by-2.5° moving windows.

[R1C3] Experimental observations are important for improving and calibrating the WHCNS model in this study. The authors also discussed uncertainties associated with observation availability. However, the current description lacks clarity regarding the geographical distribution and environmental context of these observations (Lines 198-228). Detailed information on the observation sites, including their locations and conditions, is crucial for identifying areas for further research and for situating the study's findings within a broader geographical context.

[RESPONSE] Thanks for the reviewer's insightful suggestions. To address this important issue, we have taken the following steps. First, we provided a map to illustrate geographical distribution of observation sites. Detailed information on the numbers of experiments conducted at each site was also presented (Fig. S1a). Second, to assess how well the observations could represent China's rice area, we compared the probability density of climate and soil conditions between the observation dataset and China's rice areas (Fig. S1b). Third, we highlighted the necessity of conducting more extensive field experiments in underrepresented conditions.

"**[Lines 805-809]** To better constrain the PTFs and reduce extrapolation uncertainty, field experiments combined with incubation experiments across a broader range of climate conditions (e.g., colder and more humid areas) and soil properties (e.g., areas with higher SOC or lower bulk density) should be conducted (Fig. S1)."

and

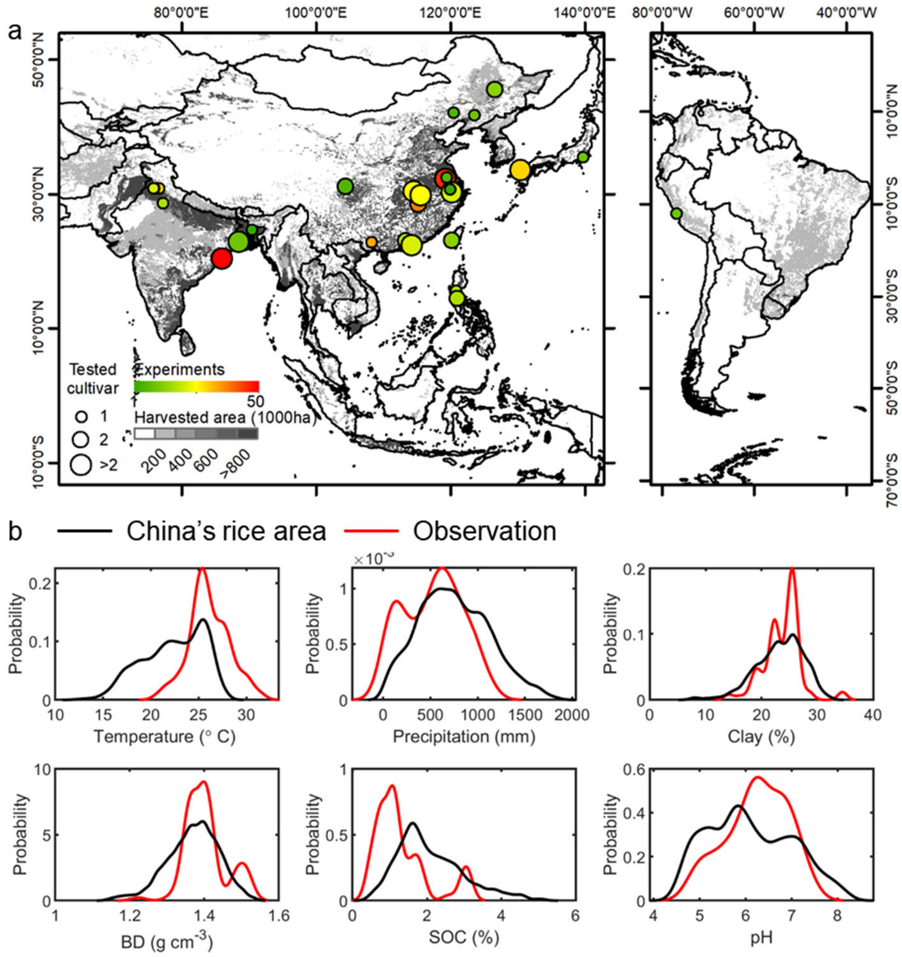

Figure S1 Observation dataset of water management effects and its representativeness. (a) Spatial distribution of observation sites. Dot color indicates the number of experiments, and dot size indicates the number of tested cultivars. The gray area represents irrigated rice areas. **(b)** Comparison of probability density of climate and soil factors between our observation dataset (red) and China's rice areas (black).

[R1C4] Specific Comments
Line 126, please provide full name of NSGA-II and related references.

[RESPONSE] Revised.

[R1C5] Line 168-194, the model running requires a lot of input data for both site and regional simulations, including variables related to climate, soil and management practices. Although the authors have already provided such information in the Method section, a separate summary table are helpful for clearer view.

[RESPONSE] Thanks for the reviewer's kind suggestion. In the revision, we have added a supplementary table for model input data as below.

Table S1 Summary table of model input data.

Category	**Variables**	**Spatial resolution and sources**
Climate (daily)	Mean air temperature, °C Maximum air temperature, °C Minimum air temperature, °C Wind speed, m s^{-1} Precipitation, mm Humidity, % Downward solar radiation, W m^{-2}	0.25 × 0.25° the fifth generation ECMWF reanalysis (ERA5) (Hersbach et al., 2018)
Soil (5, 15, 30, 60, 100, 200 cm depth)	Bulk density, g cm^{-3} Clay contents, % Saturated water content, cm^3 cm^{-3} Field water capacity, cm^3 cm^{-3} Wilting point, cm^3 cm^{-3} Saturated hydraulic conductivity, cm day^{-1}	10 × 10 km SoilGrids (Han et al., 2015)
Management	Planting date, year/month/day Harvest date, year/month/day	0.5 × 0.5° GGCMI Phase 3 (Jägermeyr et al., 2021)
	Fertilizer rate, kg N ha^{-1} Fertilizer timing, year/month/day	0.5 × 0.5° Simulated by the auto-fertilization component
	Upper irrigation threshold, mm Lower irrigation threshold, mm or kpa Maximum allowable field water level after rainfall, mm	Station Table A1 Chen et al. (2022)

[R1C6] Line 177, delete the spacing after the reference and please carefully check other formatting errors.

[RESPONSE] Revised.

[R1C7] Line 208-210, why only observations at the soil depth of 15-20 cm were included?

[RESPONSE] The 15-20-cm soil depth was chosen for two reasons. First, soil depth may affect hydraulic properties by controlling connectivity with root systems and through slowly evolving changes in soil morphology (Novick et al., 2022). We used measurements from 15-20-cm soil depth to make spatial analyses consistent. Second, the 15-20-cm soil depth represents root zone for most rice varieties and most measurements in our compiled were available for this depth.

Novick KA, et al. Confronting the water potential information gap. Nat Geosci 15, 158-164 (2022).

[R1C8] Line 590, please provide full name and related references of the DNDC and DLEM model.

[RESPONSE] Revised.

[R1C9] Line 701-704, only national results of the tradeoffs or synergies relationships between different variables were stated. Please discuss more about their spatial heterogeneity.

[RESPONSE] Thanks for the reviewer's comments. In the revision, we extended discussions about the spatial heterogeneity along with a supplementary figure as below.

> "**[Lines 749-756]** Spatially, over 90% of the reduction potentials for IRR and CH_4 could be achieved across 53% and 60% of the national rice areas, primarily in southern regions (Fig. 7 and S14). In these areas, N_2O increase was inevitable, but yield increase could be expected. By contrast, stronger tradeoffs occurred in the northern regions, where the reduction potentials of IRR and CH_4 were limited even with decreased yield and increased N_2O emissions. Therefore, NCF adoption should be prioritized in southern regions (e.g, XND, CJD, CJS) to achieve a national optimum balance among rice production, water use, and greenhouse gas emissions mitigation."

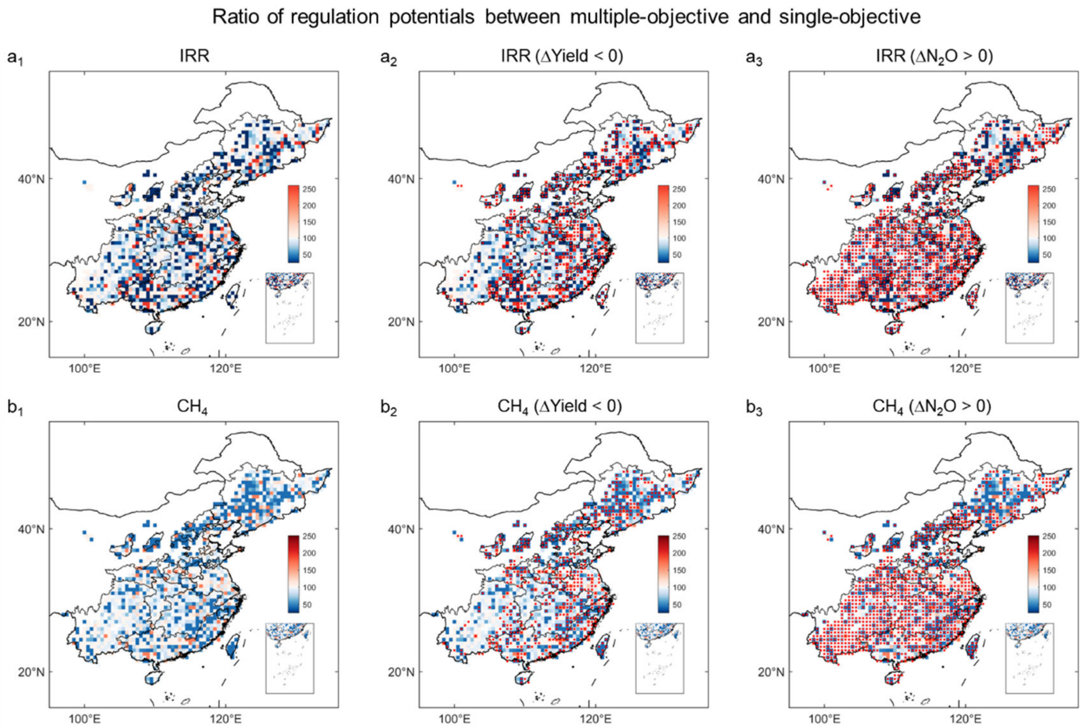

Figure S14 Tradeoffs between regulation potentials of different target variables. The plots show the ratio (%) of regulation potentials of IRR (a_1-a_3) and CH_4 (b_1-b_3) between multiple-objective and single-objective targets. The red dots indicate areas with decreased yield (a_2 and b_2) or increased N_2O emissions (a_3 and b_3) under multiple-objective target, highlighting regions with stronger tradeoffs between IRR (CH_4) reduction and yield increase or N_2O reduction.

Reviewer #2:
This study improves process-based modeling of the complex food-water-climate nexus under various water management schemes by incorporating the effects of three critical physiological stages and upscaling model parameters. It provides a practical tool for multi-objective optimization of water management, delivering co-benefits such as ensuring food production, conserving water, and reducing greenhouse gas emissions in rice fields.

In my opinion, the manuscript aligns well with the scope of the journal and contributes to the advancement of process-based modeling. The manuscript is well-structured and presents a comprehensive analysis. The selection of methods is well-supported by theoretical foundations, and all model parameters and assumptions are appropriately validated, ensuring the reliability of the results. The figures are accurate and effectively illustrate the findings. Additionally, the study's limitations have been thoroughly discussed. While the methods used are not entirely novel, they are effective and appropriate.

Therefore, I recommend acceptance without revision.

[RESPONSE] Thank you for reviewing our manuscript and for your positive feedback.