We thank Reviewer #3 for the constructive comments and suggestions, which greatly help us to improve the quality of our manuscript. We have made revisions and replied to all the comments. Our responses are shown in "Blue" color and the changes in the manuscript are shown in "Red" color.

Response to the comments from Reviewer #3

Comment#1:
L1: In the title you write “land weakly coupled data assimilation”, while in the abstract you write “weakly coupled land data assimilation (WCLDA)” please be consistent.

Response:
Thank you for pointing out the inconsistency. We have revised both the title and the abstract to consistently use the term "weakly coupled land data assimilation (WCLDA)" throughout the manuscript.

Comment#2:
L18: Skip “initial” in “With an initial..”

Response:
We have removed "initial" to streamline our text and improve readability (L18).

Comment#3:
L59: Rephrase to skip “and so on”

Response:
We have revised this sentence to eliminate the vague reference "and so on" and provide a more explicit list of the coupled model components (L42-43).

L42-43: These models couple various components, such as models of the atmosphere, ocean, sea ice, land and river.

Comment#4:
L59: Skip “much higher”

Response:
Done

Comment#5:
L61: Skip “dedicated”

Response:
Done

Comment#6:
L61-63 Please rephrase, this is not what you are doing since you assimilate model data. This is what DA is used for in e.g. NWP.

Response:
Thank you for your valuable suggestion. We have revised this sentence (L45-46) to further emphasize the application of data assimilation in our study. Specifically, we now highlight our method of initializing climate models by assimilating reanalysis data, rather than actual observations.

L45-46: The application of DA methods is essential to incorporate reanalysis data into the components of coupled model and produce the optimal ICs to improve DCPs.

Comment#7:
L63: Add “uses both uncoupled DA...”?

Response:
Done.

Comment#8:
L82: Not “observational information” in your case.

Response:
We have revised this sentence to replace "observational information" with "reanalysis information" at Line 65.

Comment#9:
L104: Please revise what is done in Laloyaux et al., 2016, it is not a 3D-VAR for the whole system.

Response:
Thank you for pointing out the discrepancy in our initial reference to the 3DVar methodology employed in Laloyaux et al., 2016. We recognize that Laloyaux et al. (2016) implemented a 4DVar approach for the atmospheric increment and 3DVar method for the ocean increment. For accuracy, we have replaced the citation of Laloyaux et al. (2016) with Fujii et al. (2009) at Line 87, which employs a 3DVar method more aligned with the context of our discussion.

L86-87: such as the three-dimensional variational data assimilation (3DVar) (Fujii et al., 2009; Yao et al., 2021)

Comment#10:
L123: Why not refer to these studies?

Response:

Thank you for pointing out the need for specific references. We have revised this sentence to include pertinent references (He et al., 2017; Li et al., 2021; Kimmritz et al., 2018) to support our statement at Line 106.

L106: (He et al., 2017; Li et al., 2021; Kimmritz et al., 2018)

Comment#11:
L124: "..or land reanalysis data"

Response:
Done.

Comment#12:
L265: Skip "major" in "..major conclusions"

Response:
Done.

Comment#13:
L305: "ELMv2" as defined earlier in the text

Response:
Done.

Comment#14:
L332: What do you mean here with "independence between y' samples"

Response:
This term "independence" implies that each y' sample is selected without being influenced by the other samples in the ensemble. We have revised this sentence as "ensuring that each y' sample is selected independently of the other samples in the ensemble" at Lines 205-206.

Comment#15:
L335: The localization methodology should be explained in more detail. Do you mean vertically or horizontally? I assume that there is no need for horizontal localization since you assimilate a model derived product which has values everywhere your model has values? Please elaborate on this.

Response:
We implement both horizontal and vertical localization in our data assimilation process. Despite assimilating a model-derived product that provides global coverage, we have found it necessary to implement horizontal localization to reduce sampling errors due to the finite ensemble size and to alleviate the spurious remote influence from distant grid points. Our approach to horizontal localization is to apply a distance-dependent weighting function to the

background error covariance. We employ vertical localization to limit the influence of reanalysis information on specific soil layers. More detailed descriptions of the localization methodology in our study can be found in Wang et al. (2018).

According to your comment, we have revised our manuscript to provide more detailed explanations of the localization methodology (L208-213).

L208-213: We implement both horizontal and vertical localization to reduce sampling errors due to the finite ensemble size and to alleviate the spurious remote influence from distant grid points. Our approach to horizontal localization is to apply a distance-dependent weighting function to the background error covariance. The vertical localization is employed to limit the influence of reanalysis information on specific soil layers. Please refer to Wang et al. (2018) for more detailed descriptions of the localization methodology in our study.

Comment#16:
L424: Perhaps use “constraints”?

Response:
Done.

Comment#17:
L432-437: Should perhaps be put in Sect 2. when presenting the GLDAS product you assimilate?

Response:
We have moved these sentences to the "2.2 Datasets" subsection (L159-165) of Section 2, where the GLDAS product is introduced.

Comment#18:
L456-57: This is already mentioned, please remove

Response:
Done.

Comment#19:
L463: Remove “to”

Response:
Done.

Comment#20:
To the best of my knowledge, I don’t think you have specified the value you use for the observation error covariance matrix R throughout this manuscript?

Response:
Thank you for your attentive review. We have revised our manuscript to include the description of the observation error covariance (L318-319).

L318-319: The observation error covariance matrix R can be determined statistically by estimating the variance and covariance of the GLDAS data.

Comment#21:
L503: Do you here use the first guess from the Assim experiment or the analysis value?

Response:
We refer to the analysis value obtained from the Assim experiment. We have revised our manuscript to explicitly state that the analysis value from Assim is used at Line 325.

Comment#22:
L549: You need to introduce the MODIS data you use for validation, please do so in Sect 2.

Response:
According to this comment, we have revised Section 2 of our manuscript to include the introduction to the MODIS data (L171-176).

L171-176: (2) MODIS is an essential instrument onboard the Terra and Aqua satellite platforms (Remer et al., 2005). The MODIS datasets provide comprehensive global observations describing atmospheric, terrestrial and oceanic conditions, including land surface temperature, vegetation indices and cloud properties (Justice et al., 2002). The MODIS products are extensively utilized for monitoring environmental changes and supporting climate change research (Gao et al., 2015; Mertes et al., 2015).

Comment#23:
L701-2: Please rephrase as you are not assimilating observations but model data.

Response:
We have revised this sentence to replace "observed anomalies" to "reanalysis anomalies" at Line 178. This terminology change underscores the use of reanalysis data rather than direct observations in our study.

Comment#24:
L726: Please rephrase “the system is conducted...”

Response:
We have revised this sentence to "Monthly mean anomalies of soil moisture and temperature from the GLDAS reanalysis are assimilated from 1980 to 2016 through the WCLDA system" for clarity (L449-450).

Comment#25:

L776-80: Please rephrase. There are globally gridded surface soil moisture products that could have been assimilated as easily as the land product you used.

Response:

Thank you for your comment. We have revised these sentences (L460-463) to emphasize our future focus on assimilating satellite-based datasets.

L460-463: Future enhancements of our WCLDA system will explore the assimilation of additional land products, particularly those derived from satellite observations. The incorporation of such satellite-based datasets is expected to further improve the performance of the WCLDA system.

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