Cover Letter

Dear Editor,

We have further revised our manuscript according to the reviewer's detailed suggestions. We are pleased to resubmit the revised version of our manuscript titled "*Global evaluation of the dry gets drier and wet gets wetter paradigm from terrestrial water storage changes perspective"* (#ID: **hess-2022-190**).

All the comments are addressed in the new version of the manuscript to further improve the study. Please find below the attached point-by-point explanation of our correspondence for each suggestion by the reviewers. All the additional and changed parts of the text (except some minor language corrections) are marked in BLUE for easy review.

We sincerely hope you will find the revised version of the manuscript more comprehensive. All the authors have reviewed the manuscript and agree to the submission of the manuscript. We look forward to hearing from you.

Thank you for your time and efforts on our manuscript again.

Yours sincerely,

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Reply to Reviewers' comments (Reviewer#1)

Legend

Reviewers' comments

Authors' responses

Direct quotes from the revised manuscript

We thank the reviewer for his/her time in reading our manuscript and detailed comments on our manuscript. Point-by-point replies to the comments made can be found below.

Reviewer #1: The authors perform a global examination for the dry gets dryer wet gets wetter paradigm from water storage change perspective using GRACE and various land surface/climate models. The method has limitations in glacier-covered regions, but it has the advantages of taking into account the effects of reservoir construction and water movement in the soil, etc. The authors have improved this study significantly. Most of my concerns are generally well resolved and explained. There are still some places that need to be modified.

Response: We thank the reviewer for his/her time in reviewing our manuscript with informative suggestions and recognizing the potential of the manuscript. Both implications and limitations of our study have been clearly claimed as suggested. Please find the subsequent minor modifications in the new version as follows.

1. Line 9: "...is still unexplored from the perspective of terrestrial water storage anomaly (TWSA)". Please add a "systematically" or "comprehensively".

Response: Added "comprehensively" as suggested.

2. Line 17-18: "...while the varying significance levels (0.01-0.1) have subtle influences on the evaluation results of the DDWW paradigm." It doesn't make sense to show this result

Response: As suggested, we have removed this sentence from the Abstract.

3. Line 72-73: "However, there is no study to examine the global variability and validity of DDWW paradigm in the past and future in terms of TWS changes ". This sentence is not very accurate.

Response: As suggested in *Comment #1*, we have added "comprehensively" for conveying the meaning better.

4. Line 91: An explanation on why a regional case study of QTP is needed here.

Response: We have clarified the reasons for choosing the QTP as a case study in the revised version as follows (Line 91-94):
One of the global hotspots with significant changes in hydroclimatological conditions (e.g., precipitation and air temperature) (Liu et al., 2006; Zhang et al., 2017), i.e., the Qinghai-Tibetan Plateau (QTP), is selected as a typical region for regional analysis because it experienced alarming TWS losses in recent decades and shows continuing declines under future scenarios (Meng et al., 2019; Li et al., 2022).

5. Line 284: "access" --> assess.

Response: Changed.

6. Line 307-310: "On the contrary...On the contrary". The logic of these sentences need have a revision.

Response: We have removed the repeating phrase "On the contrary" to make these sentences smoother.

7. Line 584-592: At the beginning of this paragraph the author should explain what the purpose of conducting the following experiment is. Some of the expressions should be simplified.

Response: We have added explanations for the reason to conduct the experiment and also refine this paragraph as follows (Lines 589-597):

This study performs a global examination for the dry gets dryer wet gets wetter paradigm from terrestrial water storage perspective in the past and future. The historical TWS-DSI monthly time series over global land during 1985-2014 is calculated from two GHMs (VIC and WGHM), two LSMs (Noah and CLSM), and one GRACE reconstruction. In addition, future projections of TWS-DSI from 2071 to 2100 under SSP126, SSP245, and SSP585 scenarios are derived from the average of eight selected CMIP6 GCMs after bias-correction using GRACE observations. Further, the DDWW paradigm has been evaluated with a significance level of 0.05 from the perspective of terrestrial water storage change. We also establish the metric P-E-R based on multiple observational products and from the same models as the TWS-DSI for comparison. The uncertainty sourced from different choices of models, methods, and confidence levels has been discussed systematically. The new findings are summarised as follows.

8. Line 607-616: These are experimental results or research procedures used for testing, and I don't think these are new findings and should not be taken as a conclusion. Line 617-620: I think these insights can be the third conclusion.

Response: We have removed these research procedures and reorganize the third

conclusion as follows:

(3) Sensitivity analysis on different choices of significance levels from 0.01 to 0.1 for the long-term trends indicates similar patterns, in which the maximum decrease (increase) in the DDWW-validated regions reaches –7.4% (4.47% historically under the 0.01 (0.1) level, respectively. Such consistency is also evidenced by the projected TWS-DSI in the future under various scenarios. Moreover, independent experiments based on the individual TWSA datasets suggest that the divergent data sources might lead to model-variable biases for both the DDWW-agreed and DDWW-opposed patterns. The use of distinctive GCMs also suggests slightly overrated (e.g., GFDL-ESM4) and underrated (e.g., CanESM5) percentages of such patterns in the future under multiple emission scenarios.

9. Line 620-622: Expressions about regional studies on the Qinghai-Tibet Plateau are not necessarily included in the conclusions.

Response: As suggested, we have shortened and reorganized results about the regional study of QTP in the conclusions as follows:

(2) A total of 11.01% (VIC) to 40.84% (GRACE reconstruction) of the global land area shows the DDWW paradigm valid, in which the drying and wetting area account for 6.47% (VIC)-20.17% (GRACE reconstruction) and 4.54% (VIC)-20.67% (GRACE reconstruction), respectively during the period 1985-2014. However, the area showing the opposite patterns, like “dry gets wetter” (DW) or “wet gets drier” (WD), account for the 10.21% (WGHM)-35.43% (GRACE reconstruction) of the global land, respectively. The proportion of areas supporting (opposing) the DDWW paradigm is 14.66% (16.76%), 14.26% (18.72%), and 17.08% (26.64%) under SSP126, SSP245, and SSP585 scenarios, respectively. Regional assessment for the QTP reveals the drying trends of the land mass primarily attributable to the sublimation/ablation of glaciers and ice caps, together with a continued tendency in future warming climates until the end of the 21st century.

10. Table S2: Are there references or standards for this classification (TWS-DSI)?

Response: We have added the references for the classification as Zhao et al. (2017).

Reference:
Zhao, M., Geruo, A., Velicogna, I., Kimball, J.S., 2017. Satellite Observations of Regional Drought Severity in the Continental United States Using GRACE-Based Terrestrial Water Storage Changes. J. Clim. 30, 6297–6308. https://doi.org/10.1175/JCLI-D-16-0458.1

11. The language still needs to be polished in the result analysis and the conclusion section.

Response: We have further polished our presentations in the new version.

Reply to Reviewers' comments (Reviewer#2)

Legend

Reviewers' comments

Authors' responses

Direct quotes from the revised manuscript

We thank the reviewer for his time in reading our manuscript. We hope the new changes could put the manuscript in a more robust way.

Reviewer #2: I would like to thank the authors for considering my comments and putting so much effort to address them convincingly. I have no further remarks.

Response: We thank the reviewer again for the enlightening suggestions and comments on our manuscript in previous reviews.

Reply to Reviewers' comments (Reviewer#3)

Legend

Reviewers' comments

Authors' responses

Direct quotes from the revised manuscript

We thank the reviewer for his/her time in reading our manuscript and for detailed comments on our manuscript. Point-by-point replies to the comments or suggestions made can be found below. Overall, we have made the following minor changes to the manuscript:

Reviewer #3: This is my third review of the manuscript.

The authors present a re-examination of the dry gets drier, and wet gets wetter paradigm over global land, based on terrestrial water storage estimates from different sources. They make use of GRACE reconstructions, global hydrological models, and land surface models, as well as CMIP6 models for the future perspective. They conclude that the DDWW paradigm is challenged both in the historical period but also in the future. In addition to the TWSA-based analysis, the revised version of the paper now also includes an analysis based on the water balance (P-E-R).

Overall, the authors considered my points previously made and the manuscript considerably improved.

As such, I'm happy with the changes made. A few remaining specific comments are listed in the following.

Response: We thank the reviewer for his/her informative and detailed suggestions and comments on our manuscript. Please find our changes for the remaining specific comments below.

Specific comments:

(1) Line 13: "with a 0.05 significance level" Specify that this significance level relates to the long-term trends. Similar on line 18.

Response: Changed as suggested.

(2) Line 217: "long-term trends using (Figure S1) the linear regression method". Reference to Figure S1 should be in the next sentence.

Response: Thank you. We have changed it as suggested.

(3) Line 237: "The DDWW paradigm is evaluated at a 5% significance level" Would be helpful to remind the reader that the significance level refers to the long-term trends.

Response: As suggested in *Comment #1 above,* we have specified the significance is associated to the trend estimates as follows (Line 238-239):
The DDWW paradigm is evaluated at a 5% significance level (trend estimates) in this study, combined with the standard AI-derived climate classifications.

(4) Line 255: "from different datasets" Here and at other locations in the text: why not explicitly stating what you look at? I.e., "GHMs and LSMs" instead of "different datasets".

Response: We have specified the datasets used for comparison here with the figure reference in the new version as follows (Lines 259-260):
A temporal comparison of global average TWSA derived from GHMs, LSMs, GRACE reconstruction, and CMIP6 and GRACE during 2002-2014 is shown in Figure S5.

(5) Line 257: "GRACE TWSA ranges … with relatively higher uncertainty in the dry season than that in the wet season." Figure S5 does not show the uncertainty for GRACE TWSA anymore, it's only displayed for the GCMs. Please adjust the figure or the text.

Response: The adjusted text is as below (Line 260-261):
The GRACE TWSA ranges from roughly −20 to 20 mm and shows obvious seasonal characteristics.

(6) Line 266: Figure S8 and S9 needs information in the caption on the content of the individual panels a-i.

Response: We have added panel information in the captions of Figures S8 and S9.

(7) Line 272: "present a strong correlation with the observational products before and after bias correction" What is the "observational products" here? The observed P-ET-R? Please provide more details in the figure caption and in general use a consistent naming of the different estimates throughout the text.

Response: Yes, it indicates the observed P-E-R here. We have revised the sentence and added more details in the caption of Figure S11. Moreover, we have added this information in the Table 1.

(8) Line 324: "magnitude of the changes in the water storage, i.e., TWSC, in a region are minimal compared to the actual TWSA trends" You could apply a temporal integration to convert TWSC into TWSA to omit this fact? Also, precipitation undercatch can influence the observation-based P-ET-R.

Response: Performing the temporal integration for TWSC can ideally provide useful information for the TWSA changes, however, the uncertainties sourced from various datasets like P, E, and R can make the true signals of long-term trends elusive. In the case, we did not calculate the TWSA from TWSC data and directly carry out the comparisons between them. So it is not surprising that there exist relatively huge differences between the TWSA and TWSC results. Lastly, we agree that biases in P (and E and R) can impact the evaluations of metric P-E-R, but the impacts are limited on our major outcomes since the metric is only used for comparison with our developed TWS-DSI results.

(9) Line 436: "As reported in Table R3, …" I guess this should be Table S3?

Response: Yes, and we have corrected it.

(10) Line 508: Figure 5 caption needs more information about the content of the panels a-f.

Response: We have added descriptions for the panels a-f in the caption of Figure 5.

(11) Line 607: Point 3 of your conclusions should be more explicit given the large differences between the TWSA-based analysis and the one from P-E-R. What are the main take-home messages here?

Response: According to *Comment #8* from **Reviewer #1**, we have removed these descriptions for research procedures from the conclusion in the new version.