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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Variations in water storage in China over recent decade from GRACE Observations and GLDAS" *by* X. Mo et al.

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Dear editors & reviewers, Thanks for your efforts and advices. We have substantially revised our manuscript after reading the comments provided by the two reviewers.

All the revisions are firstly traced based on page and line in NHESS Discussion Documentary. Places with revision are marked on both revised manuscript and NHESSD.

Answers to reviewers: Reviewer #1: NHESSD, Pg. 3252. Line 26. Precipitation is not a component of TWS. Answer: This is our mistake. Precipitation is one part in the water balance which determines final TWS changes. In the manuscript, We corrected this as 'these technologies primarily provide only variation information for single factor related to TWS, such as . . .'

NHESSD, Pg. 3253. Line 1. Should be groundwater level. Answer: Here we misused 'water level' and we originally mean 'river level', as we mentioned altimetry at the beginning of the sentence. In the manuscript, We corrected this as 'such as precipitation estimates, surface soil moisture, snow cover, and river level.'

NHESSD, Pg. 3256. Line 6. Gobi cannot be a land cover type. Answer: Thanks for pointing out the mistake. Gobi is Mongolian word for 'desert'. In the manuscript, We corrected this as 'Desert is the dominant land cover in northwestern China,'

NHESSD, Pg. 3257. Line 10. In Equations (1) what is i and j? This needs to be clearly stated in the text Answer: We clarified this in manuscript as 'which is set to 300 for measurement error and 100 for leakage error, number i and j mean the value in the ith column and jth row of the grid data.'

NHESSD, Pg. 3257. Line 11. It is not clear what is the difference between Errorregion and Errortotal ? Clear explanation is required in the text. Answer: We made adjustment in the manuscript and added explanation. The revised text is as follows: 'Because of spatial correlation among neighboring grids, covariance was considered in the calculation of regional scale error Error_region (Landerer et al., 2012; Eq. (1)). The dist in Eq. (1) is the geometric distance between any two grids in the basin (unit: km), n is the number of valid grids in a specific basin, β is the de-correlation length, which is set to 300 for measurement error and 100 for leakage error, number i and j mean the value in the ith column and jth row of the grid data. And the regional scale total error Error_total included both regional scale measurement error Error_measure and regional scale leakage error Error_leakage(Eq. (2)).'

NHESSD, Pg. 3260. The entire paragraph starting from line no. 9 till 19 has to be rewritten. The text here is very confusing and it is not clear what the authors are trying to convey. Answer: Original text: In Fig. 2, spatial difference in the RMS of TWS from scaled GRACE data have been expanded from approximately 6 cm to approximately 12 cm, and the highly left-skewed empirical PDF curve is quite similar to those from

the model simulations with for the RMS of the TWS from the unscaled GRACE data, the empirical PDF curve has a different relative peak position around with RMS value of 3 cm. The right boundary of RMS represents a strong TWS amplitude in space, and they are distinct among TWS model estimates' and GRACE observations because differences in the model mechanisms are amplified in TWS active regions. The TWS from the scaled GRACE data, the MOSAIC, VIC, CLM and GLDAS ensemble mean all have a left boundary of RMS close to 0 cm. Spatially, this corresponds to northwest China, which is an arid climate zone with vast deserts (Figs. 1, 3b and c).

In the manuscript, Pg. 8. revised text: 'The RMS value of TWS time series in a specific grid is an indicator for the amplitude of local TWS. And the empirical probability density distribution (empirical PDF) curve for RMS values in research region described the statistical distribution of TWS amplitude within the area. In Fig.2, empirical PDF curves based on TWS data from modeled TWS data (MOSAIC, VIC, CLM, NOAH and GLDAS ensemble mean) and observation TWS data (scaled and unscaled GRACE data) were compared. Empirical PDF curves based on scaled GRACE data and modeled data (except CLM) all showed larger RMS value range in x-axis than that based on unscaled GRACE data. This means the range of TWS amplitude within research area has been stretched after scaling. In addition, empirical PDF curves based on scaled GRACE data and most modeled data showed RMS values concentrated in the relative low value range, with lowest values close to 0 cm. Spatially, areas with low RMS values corresponds to northwest China, which is an arid climate zone with vast deserts (Figs. 1, 3b and c).'

NHESSD, The statement made on Pg. 3262 line no. 24, (i.e. "Disagreement between. . .. . .. in this basin) is not supported by the results and the conclusion seems to be far fetched. Answer: The original statement 'Disagreement between GRACE TWS, the TWS estimates and water resources records also revealed that there was an impact of human activities on the TWS variations in this basin.' is too brief. According to Figs. 4, 5, 6, in Yellow River Basin, there are different changing processes between

the GRACE TWS, gross water resource and precipitation. In research period, GRACE TWS was generally decreasing. Meanwhile, gross water resource and precipitation showed v-shaped processes (decreased at first and then kept rising). However, Fig. 7 showed that areas with large decreasing trends mainly located in midstream of yellow river basin, Shanxi and Shaanxi provinces, places famous for coal mining. But we still don't have data to identify the causes for the decreasing of TWS. In the manuscript, Pg. 10. we revised the statement as: 'Similar to Hai River basin, the TWS from scaled GRACE data in Yellow River basin followed a nearly linear decreasing trend (-0.73 cmyr-1) during 2004–2011, and it changed more slowly (-0.13 cmyr-1) after 2007. 'The basin averaged TWS, gross water resource and precipitation also showed different processes in the latter half of research period. But Fig.7 revealed that areas with large long term decreasing trends mainly located in midstream of Yellow River basin(Shanxi and Shaanxi Provinces), where is famous for coal mining. To identify the exact causes for decreasing TWS, more local statistical data and groundwater level records should be collected.'

NHESSD, Pg. 3263. Line 25. - Pg. 3264. Line 4. The first paragraph of Section 3.3 is mostly one single sentence. Such long sentences are confusing and should be avoided. Answer: Thanks for this suggestion. In the manuscript, Pg. 11. we revised the first paragraph of Section 3.3: 'When focusing on differences between large regions, spatial patterns of linear trends calculated from scaled and unscaled GRACE TWS are consistent (Figs. 7a and c). But at local scale, results from scaled GRACE TWS are better corresponding to natural features of the TWS intensity distribution. Areas around river networks usually have large quantity of TWS, thus present big absolute values of trends. From 2003 to 2013, four main regions were identified with intensive and significant long-term trends in TWS. Results also revealed that seasons in a year made different contributions to these trends (Fig. 8).'

NHESSD, Pg. 3264. Line 14. The sentence ". . ... where is intensively equipped with irrigation. . .." Does not make any sense. Please rewrite. Answer: Original text:

The groundwater is a major source to water consumptions in Huang-Huai-Hai plain, where is intensively equipped with irrigation facility to withdraw freshwater from deep wells (Foster et al., 2004, Kendy et al., 2004). In the manuscript, Pg. 11. we revised the sentence as: 'The groundwater is a major source to water consumptions in Huang-Huai-Hai plain, agricultural irrigation consumed large amounts of freshwater pumped from deep wells every year (Foster et al., 2004, Kendy et al., 2004).'

NHESSD, Pg. 3266. Line 9-11: A very confusing closing statement. Unfortunately there are many like this and has to be meticulously corrected. Answer: NHESSD, Pg. 3261. Line 5-7: In the manuscript, Pg. 9. 'Generally, basins with large areas are less affected by leakage errors and have slopes close to 1, but geographical location and hydrological cycle characteristics will contribute to this effect, as well.' was revised as 'Generally, basins with large areas are less affected by leakage errors and have slopes close to 1.'

NHESSD, Pg. 3261. Line 18-20: In the manuscript, Pg. 9, delete 'This process may be controlled by changes in some large-scale climate processes, which need to be further analyzed in the future.'

NHESSD, Pg. 3262. Line 1-2: In the manuscript, Pg. 9. delete 'Reservoir regulations may be one of the factors that alter the TWS signal.'

NHESSD, Pg. 3264. Line 4-6: In the manuscript, Pg. 11. 'According to the analysis in previous section, we inferred that human activities rather than climate parameters are responsible for the significant TWS depletion in North China,' revised as 'According to the analysis in previous section, we inferred that human activities rather than climate parameters could be responsible for the significant TWS depletion in North China,'

NHESSD, Pg. 3266. Line 9-11: In the manuscript, Pg. 13. , delete 'sy'

11) NHESSD, Pg. 3267. Line 1-4. In the Summary and Conclusion section the statement of attributing the TWS trends in certain basins to the overexploitation of deep

aquifers is an assumption that is not supported by the results presented here. Answer: We noticed this problem. We decided to just focus on what we really found in analyses. Original text: The TWS variations generally followed the variations in annual precipitation, but depletion in deep aquifers caused by overexploitation played a significant role in these trends until 2012 in the Hai River basin and Yellow River basin. In the manuscript, Pg. 14. we revised as 'The TWS variations generally followed the variations in annual precipitation at basin scale, but they showed inverse changes in 2007-2013 in both Hai River basin and Yellow River basin.'

In addition to the revisions based on reviewers' comments, we also revised some minor mistakes in the manuscript: NHESSD, Pg. 3252. Line 11, In the manuscript, Pg. 1. Line 19-20: Changes in soil moisture storage contributed over 50% in of variance in TWS in most basins. Revised as 'Changes in soil moisture storage contributed over 50% of variance in TWS in most basins.'

NHESSD, Pg. 3261. Line 10, In the manuscript, Pg. 9. Line 6: 'but different processes also exist in certain basins or over certain periods because of the influence of other factors' was revised as 'but distinct processes also exist in certain basins or over certain periods because of the influence of other factors'

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