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Interactive comment on "Widespread Decline in Terrestrial Water Storage and Its Link to Teleconnections across Asia and Eastern Europe" *by* Xianfeng Liu et al.

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We would like to thank the reviewers for their professional, detailed and constructive comments, which improved our manuscript considerably. We have carefully revised the manuscript following their comments point by point. Our revisions and explanations have been inserted in blue, and all amendments are also highlighted in the version of revised manuscript. Additionally, the writing of our revised manuscript are also under carefully editing by English native speaker with specialized in hydrology. Anonymous Referee #2 The manuscript titled "Widespread decline in terrestrial water storage and its link to teleconnections across Asia and Eastern Europe" by Liu et al., has identified

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an interesting research gap of analyzing the linkage between teleconnections (TCs) with terrestrial water storage (TWS) in Asia and Eastern Europe. They have utilized comprehensive set of TCs for the study. The TWS has been abstracted from GRACE observations. The TWS is partitioned using GLDAS to generate surface water (SW), soil moisture (SM) and groundwater. The TWS components are then de-seasonalized. This is followed by spatiotemporal trend analysis, comparison analysis with TCs and dissection of each TWS component's contribution to TWS. Although the manuscript embeds a promising research topic, the level of write up lags far behind the study done which in turn lags behind the research gap stated. The manuscript lacks crisp, clear messages. Most of the time this is due to poor sentence structure and grammar. The reader has to infer what the authors are trying to state or sometimes even conclude. I would not recommend to accept the manuscript in its current form and structure. I would suggest the following major revisions to the authors, if the editor decides to move the process forward. Response: Thank you very much for your thoughtful and careful comments, which have significantly improved our manuscript. We have substantially revised our manuscript point by point based on reviewers' comments in our revised manuscript. Major Comments (1) It is mentioned that the lead author wrote the manuscript with contributions from all others. However, there are significant improvements required in the sentences, paragraphs and information sequence structure. This shows the manuscript was not sufficiently revised before submission. In its current form, the manuscript doesn't facilitate an uninterrupted flow. Response: Thank you for your comment. We feel sorry for the confusion and inconvenience we have caused to you. We have carefully modified the structure, paragraph and sentence of the manuscript. (2) Tabulation of data information and a flow diagram of data processing are necessary in the section "Data". It might be a better idea to make an overall methodology flow diagram that includes this. Response: Thank you for your constructive comment. We have added a table with data information (Table 1, see attached supplement, hereafter), and we also supplemented the flow diagram of overall methodology in our revised manuscript (Figure 2, marked by the figure number in the revised manuscript and attached supplement, hereafter). (3) There is no background on TCs and subject matter of the manuscript in regards to the study area in the section "study area". Response: Thank you for your comment. We have added the background on TCs and subject matter of our manuscript in the section of "study area" as follows. The Asian and Eastern European regions, a total of 54% of the area is arid and semiarid, are located between latitudes 6°S and 56°N and longitudes 4°E and 109°E (Figure 1a). These regions are the most densely populated regions in the world, sustaining nearly half of the global population and contain some of the largest and most intensively irrigated lands of the world (Figure 1b). The freshwater availability in these water-limit regions are essential to food and water security and hence sustainable economics. Notably, surface freshwater is critically limited in these regions (Wang, 2018). The amount of available freshwater in these regions are highly dependent on precipitation and temperature, which are influenced intensively by the Northern Hemisphere atmospheric circulation patterns and the coupled ocean-atmosphere patterns (i.e., teleconnections). The spatial explicit analysis of the impact of teleconnections on freshwater availability in these regions can be studied to provide a simple framework for understanding the complex response of freshwater availability to global climate change. (4) Although the subtopic headings of results section are clear, the content is very poorly structured and sequenced. Smooth reading flow is missing. Response: Thank you for your comment. We have substantially revised the sentences and structure of our manuscript according to the comments in our revised manuscript. (5) Although the subtopic headings of discussion section are clear, the content is very poorly structured and sequenced. For an instance, in section "4.2 Possible mechanisms of TC influence on TWS variability", only the dominant TC and their role in the regions are mentioned. However, the result from this study and discussion on "possible linkage" with these "roles" are missing. Response: Thank you for your thoughtful comment. We have reorganized the content of this section in our revised manuscript. (6) The figures and tables of the supplementary section are directly and heavily referred to in the manuscript. This needs to be ratified. The grouping of figures is also not optimal. Response: Thank you for your comment. We have moved the heavily referred supplementary figures to main body in our revised manuscript. (7) The preparation of figures and tables is poor and needs significant revising. This includes axes labeling, color combination, color code, headers, data source declaration in the captions. Response: Thank you for your comment. We have reproduced all the figures and tables in our revised manuscript according to the useful comment. We also attached the revised figures at the end of this response. Specific Comments (in order of sections of the draft) 1 Introduction (1) Line 38: May be the gap is mainly in Asia. There are existing studies for Europe. E.g. Rakovec et al. (2016) have already analyzed the TWS anomaly using GRACE in 400 European river basins. Response: Thank you for your comment. We have carefully read this paper in the revision of the introduction section in our revised manuscript. (2) Line 42: "...are undergoing intensive..." Response: Thank you for your comment. We have revised the grammar mistake, and we also carefully check the revised manuscript. (3) Line 44: mm/y vs mm yr-1 (in abstract). Inconsistent usage of unit format. Response: Thank you for your careful comment. We have corrected the mistake in our revised manuscript. (4) Line 63-64: "...and the remainder of the TWS time series..." It's not clear for the reader what this is referring to. Response: Thank you for your comment. We have paraphrased this sentences to "we use detrended and deseasonalized TWS time series" in our revised manuscript. 2.1 Study Area (5) Figure 1a: Source/ citation is missing. Color representation for Semi-arid and dry subhumid regions don't have sufficient contrast. Response: Thank you for your comment. We have reproduced the figure 1. Panel (a) is the spatial distribution of arid and semiarid areas based on averaged aridity index during 2002-2017. The aridity index is calculated based on the ERA-Interim dataset downloaded from European Centre for Medium-Range Weather Forecasts. Panel (b) is the percentage area of irrigated land across the study area. The percentage area of irrigated land dataset is derived from Food and Agriculture Organization of the United Nations. (6) Line 72: Mount Kilimanjaro is in Africa, not the study area. Response: Thank you for your comment. We have corrected the mistake in our revised manuscript. (7) Line 73: The URL link doesn't have public access. And its mentioning here is also not clear. Response: Thank you for your comment. We have replaced the URL link of data source citation in our revised manuscript. (8) Line 75: I couldn't grasp the usage of "...in this area". Did you mean to say "More importantly, the Asian and Eastern European regions are the most densely populated regions in the world, sustaining nearly half of the global population and contain some of the largest and most intensively irrigated lands of the world"? If so, kindly cite the source. Response: Thank you very much for your comment. We have revised the sentences according to your useful suggestions and also added the source. (9) Figure 1b: Source is missing. Response: Thank you for your comment. We have added the source of Figure 1b in Figure 1 caption as follow in our revised manuscript. The percentage area of irrigated land dataset is derived from Food and Agriculture Organization of the United Nations. (10) Line 75-77: Split long sentence to two. Also kindly include the source. Response: Thank you for your kindly comment. We have rewritten this paragraph and deleted this sentence in our revise manuscript. (11) Line 69-77: The research gap of comprehensive TWS-TC correlation would need some background on TCs in the study area. This is missing and should be discussed in more detail in this section. If the manuscript space permits, additional map/s depicting the TCs and their role in the regions would improve the clarity of the topic to the readers. Response: Thank you for the constructive comment. We have added the background on TCs and subject matter in the of "study area" section of our revised manuscript. 2.2 Data (12) Line 79-110: Tabulating the dataset information would be a more efficient way of presenting than the current form. E.g. Line 91 mentions the exact same thing mentioned in previous sentence just adding additional spatial information. This is followed by the web URL for the dataset. Tabulation of info would be the perfect solution here. Response: Thank you for your constructive comment. We have added the dataset table in our revised manuscript. (13) Line 92: Avoid using direct URLs for data reference. There are better ways to cite datasets. Response: Thank you for your comment. We have replaced the URLs of datasets citation in our revised manuscript. (14) Line 93: Bicubic interpolation doesn't preserve the mass while resampling. Mass conservative remapping is advised (e.g. remapcon operator of CDO) Response: Thank you for your comment. We have attempted different resampling methods in revision process, i.e. nearest neighbor and bilinear interpolation. We adopted the nearest neighbor interpolation method in our revised manuscript in order to preserve the original data values. Thank you for your advice. The climate data operators (CDO) is a powerful tool in time series data set. (15) Line 94-97: This sentence has 62 words! This doesn't help readability of the manuscript. Kindly break into shorter sentences. One message per sentence. Response: Thank you for your comment. We have rewritten this paragraph and split this long sentence into short sentences in our revised manuscript. (16) Line 98: The x-axis header for Figure S1 is missing. Moreover, the x-axis is not uniform across figures S1, S2, S3, S6. Response: Thank you for your comment. We have reproduced all figures in our revised manuscript and supporting information. We have attached these figures at the end of this response. (17) Line 101: "... by deducting..." Response: Thank you for your comment. We have revised the grammar mistake in our revised manuscript, and we also carefully checked the revised manuscript. (18) Line 79-110: Apart from tabulating the dataset information, the data assimilation approach would be much easier presented as flow diagram. Response: Thank you for your constructive comment. We have provided the methodology flow diagram of the detail data processing and analysis in our revised manuscript. (19) Line 105-110: This can go into the data table. However, some elaboration of these 12 TCs in regards to the study area is missing. I would suggest to switch the position of 2.1 and 2.2. With this new sequence, the authors can provide further insight on TCs from view point of study area in the section "Study Area". Response: Thank you for your comment. We have supplemented briefly elaboration of these 12 TCs in data section of the revised manuscript as follows. The term teleconnection may refer to patterns arising from the internal variability of the atmosphere only also from the coupling between the air and the ocean. In this study, we analyze the TCs that dominate climate variability in the Northern Hemisphere, namely, Arctic Oscillation (AO), North Atlantic Oscillation (NAO), East Atlantic (EA), East Atlantic/Western Russia (EAWR), Scandinavia (SCAND), Polar/Eurasia (polarEA), West Pacific (WP), Pacific/North America (PNA), and four important atmosphere-ocean coupled variability patterns that influence global climate, the Indian Ocean Dipole (IOD), the Atlantic Multidecadal Oscillation (AMO), the Pacific Decadal Oscillation (PDO), and ENSO (Zhu et al., 2017). The 8 first indices refer to Northern Hemisphere atmospheric circulation patterns. These 8 first indices were calculated for region 20°N- 90°N using a rotated principal component analysis (RPCA) of monthly mean standardized 500-mb height anomalies fields (Barnston and Livezey, 1987). The IOD is defined by the difference in sea surface temperature between two areas – a western pole in the western India Ocean (50∼ 70° E, 10° S∼ 10° N) and an eastern pole in the eastern Indian Ocean (90∼110° E, 10° S∼ EQ). The IOD affects the climate of Asia, and is a significant contributor to rainfall variability in this region (Saji et al., 1999). The AMO and PDO index are defined as the leading principal component of the North Atlantic Ocean (0-65°N, 80°W-0°E) and the North Pacific Ocean (poleward to 20°N) monthly sea temperature variability, respectively (Enfield, 2001; Bond, 2000). ENSO is the most important coupled ocean-atmosphere phenomenon driving global climate variability. We adopted the monthly Multivariate ENSO Index (MEI) in this study, which takes into consideration variability both in the atmosphere and in the ocean (Wolter and Timlin, 2011). 2.3 Methods 2.3.1 Time series decomposition (20) Line 113: The first sentence here is out of subject. The current subject is decomposition and this sentence is about trend analysis (belongs to section 2.3.2?) Response: Thank you for your comment. We have moved this sentence to section 2.3.2 in our revised manuscript. (21) Line 113-124: Revise the order of the sentences and info. Not in optimum order. Response: Thank you for your comment. We have revised the paragraph in our revised manuscript. (22) Line 118: STL is a robust method? Then cite the papers who have proven this method to be robust. Response: Thank you for your comment. We have added the citations in our revised manuscript. (23) Line 118: "for detecting non-linear time series in trend estimates". What do you mean? The sentence doesn't make sense to me. Response: Thank you for your comment. We have paraphrased this sentence in our revised manuscript. (24) Line 123-124: Refer to previous publication of this journal to

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understand how to cite in such situation. Response: Thank you for your comment. We have modified the citation in our revised manuscript. 2.3.2 Theil-Sen trend analysis (25) Line 126: "..the linear trend of .... and precipitation for the ..." Response: Thank you for your comment. We have revised this sentence based on the useful comment in our revised manuscript. (26) Line 126: Trend analysis on the deseasonalized time series? or the residuals? I am guessing the first sentence of section 2.3.1 belongs here [??] Response: Thank you for your comment. Trend analysis in this study is based on the deseasonalized time series. We have revised this sentence in our revised manuscript. (27) Line 126-127: Break the long sentence into two. Move the second part to the end of the section. In this way flow of read regarding Theil-Sen trend analysis is maintained. Response: Thank you for your comment. We have modified this section based on the useful comment in our revised manuscript. (28) Line 128: "... of the Theil-Sen trend analysis is ..." Response: Thank you for your comment. We have added “analysis” in our revised manuscript. (29) Line 130: Remove "non-robust". And cite the literature proving this statement. Response: Thank you for your comment. We have revised this sentence and added citation in our revised manuscript. (30) Line 130: "The TWS trend, ß, for a ...” Response: Thank you for your comment. We have revised this sentence based on your comment in our revised manuscript. 2.3.3 Cross-correlation analysis (31) Line 136: TWS or TWS residual? Response: Thank you for your comment. We have replace TWS of TWS residual, and reorganized this section in our revised manuscript. (32) Line 139: Move the "," to the end of the equation. At the moment its on the denominator. Response: Thank you for your comment. We have revised this mistake in our revised manuscript. (33) Line 139: What is the meaning of the symbol Tau here? Is it the lag? Response: Thank you for your comment. The symbol Tau is the time lag, and we have added the explanation in our revised manuscript. (34) Line 140-141: "auto-covariace"? Response: Thank you for your comment. We have revised this word in our revised manuscript. (35) Line 142: Why between 0 and 24? Reason, in brief, required. Moreover, can cross correlation have value greater than 1? Response: Thank you for your comment. The value of cross correlation coefficient lies between

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-1 and +1. We have corrected the statement in our revised manuscript. Additionally, the multiple TCs could reflect different influence of atmosphere and ocean variability on TWS from short-term to long-term. For example, the impact of AO and NAO have a relatively high-frequency variability on TWS. Therefore, we adopt the lag of 0-24 month in current study in order to address the different time scale responses of TCs on TWS. (36) Line 143-146: Break the sentence to get one message per sentence. Response: Thank you for the comment. We have broken this long sentence into short sentences in our revised manuscript. 3 Results 3.1 Spatiotemporal changes in TWS (37) Line 149: Mention that both JPL-M and CSR-M showed similar spatiotemporal pattern to begin with. Then let the reader know that the values will be referred to JPL-M. Response: Thank you for your comment. We have supplemented these sentences in first of section 3.1 in our revised manuscript. (38) Line 152: The 5 hotspots are clearly shown in Figure 2a. This should be included in the reference illustrations. Response: Thank you for your comment. We have added the reference illustration in our revised manuscript. (39) Line 152: Figure 2f doesn't have color code. Unit of time is missing. Time axis with years as axis tick labels would enhance clarity. Response: Thank you for your comment. Since this figure mainly presented the TWS trend for five hotspots, which is similar to the figure 5. Therefore, we have deleted this figure in our revised manuscript. (40) Line 153: Figure S6 doesn't have color code. Response: Thank you for your comment. We have reproduced the figure in our revised manuscript. (41) Line 154: Precipitation is in figure 2b, not 2c. Response: Thank you for your comment. We have corrected this mistake in our revised manuscript. (42) Line 157: Precipitation is in figure 2b, not 2c. Response: Thank you for your comment. We have corrected this mistake in our revised manuscript. (43) Line 158: How is this "within" Rodell's findings? The estimates are completely contrasting each other. Plus, the reasoning is not convincing and/or explained properly. Response: Thank you for your comment. We have rewritten this sentence in our revised manuscript. (44) Line 162: -73.2 mm y-1 is out of range for figure 2a. Response: Thank you for your comment. The trend in Figure 2a (Figure 3a in revised manuscript) is the changes in terrestrial water storage over the study area (equivalent water depth), whereas the trend of -73.2 mm y-1 is the water level variation of the Caspian Sea. 3.2 Influence of TC indices on TWS variability (45) Line 174: Which section of the multi-plot Figure 2? Revise the header and legend header of figure S5 to something more explicit. In caption of Figure S5, replace "phase shift" by "lag". Usage of same terminology maintains the flow of reading. And what are the symbol alpha and "n" in the caption? Response: Thank you for your comment. We have reproduced these figures, and added clarifications in figure captions. (46) Line 175: "... and NAO have a significant area of influence on TWS variability." Response: Thank you for your comment. We have revised the sentence according to you suggestion in our revised manuscript. (47) Line 181: Resolve the structural error. Two sentences or one? Response: Thank you for your comment. We have revised the structural error in our revised manuscript. (48) Line 189: "Proportions of time .... Figure 2d". This sentence should be the starting sentence of this paragraph. Response: Thank you for your comment. We have revised this sentence according to you useful suggestion in our revised manuscript. (49) Line 190: Tibetan plateau and Mongolia have more pixels of longer lags than SE Asia. Response: Thank you for your comment. We have rewritten this sentence in our revised manuscript. 3.3 Contributions of water storage components to TWS (50) Line 194: The first sentence is concluding findings. Thus, it is more suitable to be placed towards the end of the section. Response: Thank you for your comment. We have moved the first sentence to the end of the section in our revised manuscript. (51) Line 195: The hotspots have been well established in the manuscript and doesn't need the reference to Figure 2a every time. Response: Thank you for your comment. We have deleted the reference of hotspots in our revised manuscript. (52) Line 195: "Groundwater depletion dominates the contribution to TWS loss in region 1..." Response: Thank you for your comment. We have revised this sentence in our revised manuscript. (53) Line 197: "Similar results were observed in northwest..." Response: Thank you for your comment. We have revised this sentence in our revised manuscript. (54) Line 210: The term "sea level" could be confused with the world mean sea level. Suggested rephrasing: "...Caspian Sea with a decrease in its water level elevation by -73.2 mm y-1..." Response: Thank you for your comment. We have rephrased this sentence according to your useful suggestion in our revised manuscript. 3.4 Divergent response of water storage components to TCs (55) Line 217: The first sentence is concluding findings. Thus, it is more suitable to be placed towards the end of the section. Response: Thank you for your comment. We have moved the first sentence to the end of the section in our revised manuscript. (56) Line 222: "...is a synthesis signal i.e. its trend ...". "... different ways. Furthermore, the groundwater ..." Response: Thank you for your comment. We have revised this sentence in our revised manuscript. (57) Line 223: "...which indicates lower correlation..." Response: Thank you for your comment. We have replaced the word “less” of “lower” in this sentence in our revised manuscript. (58) Line 225: Reference to a figure or table missing Response: Thank you for your comment. We have added the reference in this sentence in our revised manuscript. 4 Discussion 4.1 Comparison of our results to previous studies (59) Line 235-257: Please be clear about which region are you talking about. If you start with "Region 1 shows ..." then its clear that the information corresponding to that region (1, 3 and 4) else its hard to follow (regions 2 and 4). Response: Thank you for your comment. We have rewritten this section in our revised manuscript as follows. We investigate the spatiotemporal trend of TWS and its components over Asia and Eastern Europe region during 2002-2017. The spatial pattern and trend of TWS over the study area are consistent with those of previous studies (Humphrey et al., 2016; Scanlon et al., 2016). Our estimate trend of TWS in region 1 is within that of previous studies in this region (22±3 mm yr-1 during 2003-2010) (Feng et al., 2013). Due to a long-term warm and dry climate and intensive anthropogenic activities (agriculture, industry, and urbanization), the groundwater in region 1 has been overexploited since the 1970s, and more than 70% of the groundwater exploitation is used for regional irrigation (Wang et al., 2007). The rate of groundwater loss was also reported by a previous study in region 3 (approximately 40±10 mm yr-1 from August 2002 to October 2008) (Rodell et al., 2009). As Indian agriculture leads the world in total irrigated land by consuming ∼85% of the utilizable water resources

(Panda et al., 2016; Salmon et al., 2015), a concluding consensus has been reached that the dramatic decline in TWS is mainly due to the overexploitation (extraction exceeding recharge) of groundwater for irrigation (Shamsudduha et al., 2019). Although precipitation in region 3 shows an increasing trend during the GRACE period, the rapid depletion of TWS in northwest India induced by unsustainable consumption of groundwater for irrigation and other anthropogenic uses has attracted worldwide attention because it is a major threat to India's sustainability (Panda et al., 2016; Rodell et al., 2009). Region 4 in our study is also heavily irrigated (Figure 1), so intensive irrigation is likely to induce groundwater decline. The increase in SW induced by melt water from mountains (Brun et al., 2017) was offset by the decrease in soil water that may be related to the decrease in precipitation (Figure 2b). For region 2, the rapidly melt of the glaciers of Tien Shan Mountain accelerate an increase in the loss of water resources, since the glacial meltwater will provide additional water that was lost to rivers or evaporation (Jacob et al., 2012). The negative trend in TWS indicates that water demand is larger than supply in region 2, which can be attributed to both continuous withdrawal of groundwater and extensive evaporation in the endorheic basin (Rodell et al., 2018). However, the increase in precipitation is expected to offset a certain portion of water losses in region 2. Previous studies documented that the widespread decline in TWS in region 5 is also attributed to the overreliance on groundwater for domestic and agricultural needs due to human-made dams in addition to the sharply surface water loss (Joodaki et al., 2014; Rodell et al., 2018; Voss et al., 2013), these reports are consistent with our results. (60) Line 258-260: Break the sentence to get one message per sentence. Response: Thank you for your comment. We have reorganized this paragraph in our revised manuscript. (61) Line 260-263: Break the sentence to get one message per sentence. Response: Thank you for your comment. We have reorganized this paragraph in our revised manuscript. (62) Line 263-264: Revise the sentence for clarity. The concluding sentence should be clear. Response: Thank you for your comment. We have revised this sentence for clarity in our revised manuscript. 4.2 Possible mechanisms of TC influence on TWS variability (63) Section 4.2: This is probably the most interesting subtopic of the paper. The writing style should have followed this pattern: 1) result observation at each hotspot, 2) literature on the dominant TC for the hotspot, 3) linking "possible mechanism" between the literature and the results. Currently the section is filled with only 2. There is no linking going on. Response: Thank you for your constructive comment. We have reorganized section 4.2 according to your comment in our revised manuscript. 4.3 Implications for future hydrological studies (64) Line 288: "... could explain the variability in TWS in most of the remote and ..." Response: Thank you for your comment. We have revised this sentence in our revised manuscript. (65) Line 290: "... variability interacts with human..." Response: Thank you for your comment. We have revised this sentence in our revised manuscript. (66) Line 297: "claim" is a very strong word. Moreover, it doesn't make sense especially as the paper hasn't included any prediction or scenario analysis of droughts and heatwaves. Response: Thank you for your comment. We have replaced the word "claim" of "infer" in our revised manuscript. (67) Line 300-314: Usage of "First, Second, Third" in paragraph structure requires different approach of writing. Instead, bullet style enumeration of the three recommendations would suit the current sequence and structure of writing i.e. start first bullet with "Withdrawal of ...", and so on. Response: Thank you for your comment. We have revised the usage of "First, Second, Third" by using bullet style enumeration in our revised manuscript. 5 Conclusions (68) Line 321: "...component vary from region to region. The ..." Response: Thank you for your comment. We have revised this sentence in our revised manuscript. (69) Line 323: "...and regions. This highlights the importance ...." Response: Thank you for your comment. We have revised this sentence in our revised manuscript. References: RAKOVEC, O., KUMAR, R., MAI, J., CUNTZ, M., THOBER, S., ZINK, M., ATTINGER, S., SCHÄFER, D., SCHRÖN, M. and SAMANIEGO, L.: Multiscale and Multivariate Evaluation of Water Fluxes and States over European River Basins, J. Hydrometeorol., 17, 287–307, doi:10.1175/JHM-D-15-0054.1, 2016. Response: Thank you very much for all the comments. âĂČ References Barnston, A. G., and Livezey, R.E.: Classification, seasonality and persistence of low-frequency atmospheric circu-

lation patterns. Mon. Weather Rev., 115: 1083-1126, 1987. Brun, F., Berthier, E., and Wagnon, P.: A spatially resolved estimate of High Mountain Asia glacier mass balances from 2000 to 2016. Nat. Geosci., 10(9): 668-673, doi:10.1038/ngeo2999, 2017. Crétaux, J. F., Jelinski, W., and Calmant, S.: SOLS: A lake database to monitor in the Near Real Time water level and storage variations from remote sensing data. Adv. Space Res., 47(9): 1497-1507, doi.org/10.1016/j.asr.2011.01.004, 2011. Enfield, D.B., Mestas-Nunez, A. M., and Trimble P. J.: The Atlantic multidecadal oscillation rainfall and river flows in the continental and its relation U.S. Geophys Res Lett, 28(10): 2077-2080, 2001. Feng, W., Zhong, M., and Lemoine, J. M.: Evaluation of groundwater depletion in North China using the Gravity Recovery and Climate Experiment (GRACE) data and ground-based measurements. Water Resour. Res., 49(4): 2110-2118, doi: 10.1002/wrcr.20192, 2013. Humphrey, V., Gudmundsson, L., and Seneviratne, S. I.: Assessing Global Water Storage Variability from GRACE: Trends, Seasonal Cycle, Subseasonal Anomalies and Extremes. Surv. Geophys., 37(2): 357-395, doi: 10.1007/s10712-016-9367-1, 2016. Jacob, T., Wahr, J., and Pfeffer, W.: Recent contributions of glaciers and ice caps to sea level rise. Nature, 482: 514-518, doi: 10.1038/nature10847, 2012. Joodaki, G., Wahr, J., and Swenson, S.: Estimating the human contribution to groundwater depletion in the Middle East, from GRACE data, land surface models, and well observations. Water Resour. Res., 50(3): 2679-2692, doi: 10.1002/2013wr014633, 2014. Landerer, F. W., and Swenson, S. C.: Accuracy of scaled GRACE terrestrial water storage estimates. Water Resour Res, 48: w04531, doi:10.1029/2011WR011453, 2012. Panda, D. K. and Wahr, J.: Spatiotemporal evolution of water storage changes in India from the updated GRACE-derived gravity records. Water Resour. Res., 52(1): 135-149, doi: 10.1002/2015wr017797, 2016. Rodell, M., Famiglietti, J. 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Y.: The effects of teleconnections on carbon fluxes of global terrestrial ecosystems. Geophys. Res. Lett., 44(7): 3209-3218, doi: 10.1002/2016GL071743, 2017. âĂČ Revised figures (see attached supplement)

Figure 1: Boundary of the Asian and Eastern European regions. Panel (a) is the spatial distribution of arid and semiarid areas based on averaged aridity index during 2002-2017. The aridity index is calculated based on the ERA-Interim dataset downloaded from European Centre for Medium-Range Weather Forecasts. Panel (b) is the percentage area of irrigated land across the study area. The percentage area of irrigated land dataset is derived from Food and Agriculture Organization of the United Nations.

Figure 2: Methodology flow diagram of data processing in this study.

Figure 3: Spatiotemporal changes in TWS as obtained from GRACE (a) and precipitation as obtained from CRU (b) across the Asian and Eastern European regions during 2002-2017. The trend is obtained from the removed seasonal cycle time series.

Figure 4: Spatial distribution of cross correlation analysis between TWS and teleconnection indices. (a) Spatial pattern of maximum correlation coefficients between TWS and teleconnection indices. (b) Spatial pattern of teleconnections that can best represent TWS variations. (c) Spatial pattern of teleconnection lag time. (d) Proportion of the area dominated by each teleconnection and its corresponding time lags. The maximum lag in the correlation analysis was limited to 0$\sim$24 months (significance threshold: $|r| > \sim 0.15$ given a significant level = 0.05 and numbers of time series = 183).

Figure 5: Contributions of different hydrological storages to TWS changes in five hotspots. Uncertainties represent the 95% confidence intervals.

Figure 6: The residual time series of spring soil moisture and associated ENSO in region 3 during 2002-2017.

Please also note the supplement to this comment:
https://www.hydrol-earth-syst-sci-discuss.net/hess-2019-281/hess-2019-281-AC2-supplement.pdf

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