Interactive comment on "Water resources in the Badain Jaran Desert, China: New insight from isotopes" *by* Xiujie Wu et al.

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Reviewer 1ïïjŽ General comments Since water resources are the main topic/title and there were plans to use these resources for a large water diversion project (Chen et al., 2004) in a very sensitive (arid) environment, a better description of hydrological components and an overall balance would be helpful. Would it be possible to calculate the recharge area that has to feed an evaporation loss of the lakes given? It would be interesting for the readers to get a better description of the hydrogeology and aquifer characteristics in the area (unconfined aquifer, page 11, line 3). Reply: We agree. According to the comment, two points are highlighted in the revised manuscript: (1) An analysis of the mean annual water balance is performed in Section 5.3. (see Page 10; Line 26-32 & Page 11; Line 1-13) (2) The characteristics of the aquifer system in the BJD are described in the second paragraph of Section 2. (see Page 3, Line 11-23) Are

the evaporation experiments and especially the pan size that were used representative for real evaporation processes? How were the pans constructed and installed? - Metal rings – e.g., in comparison to "class-A-evaporation pan" recommendations. Reply: The evaporation experiments were performed using plastic pans with relatively small size. We did not use the class-A-evaporation pan which is specially applied to measure the potential evaporation rate in weather stations, because the objective of this experiment is limited to check the varying isotope components of open water during evaporating. We have revised the text to clarify this issue (see Page 5, Line 6,7) The given evaporation lines should be directly compared and values discussed with those of other studies (e.g., Wu et al. 2014, Chen et al., 2004). Because a main argument for source water relies on an extrapolated value of the LMWL it would be necessary to provide best evidence for this value. Reply: Accept. We compare the evaporation lines in our study with previous studies in the discussion part of Section 5.2. (see Page 8, Line 28-33& Page 9, Line 1-3) The method section lacks precise description and detailed information (e.g., on conducted 14C corrections, gas preparation methods for stable isotopes). Would it be possible to correct for the described carbonate contribution based on measured values? Would it be possible to use DOC for 14C-dating or other dating approaches? Was hydrochemistry data evaluated from the collected samples as well? Reply: Additional information is presented in Section 3.3. (see Page 5, Line 32& Page 6, 1-13) We make a correction of the carbonate contribution for the groundwater age. (see Page 11, Line 26-33; Page 12, Line 1-13) The DIC of groundwater is likely composed of two sources: soil CO_2 in the recharge area and carbonates in the aquifer. The $\delta13C$ of DIC derived from dissolution of soil CO_2 in the recharge zone can be estimated using equilibrium isotope fractionation factors for carbonate-water system (Deines et al., 1974). The desert is sparsely vegetated with shrubs and grasses. Although one C4 grass (Agriophyllum squarrosum) and two C4 shrubs (Haloxylon ammodendron and Calligonum alaschanicum) have been found the desert, the biomass in the region is dominated by C3 plants including Caragana korshinskii (C3), Pugionium cornutum and Psammochloa villosa (Yan et al., 2001; Wang et al., 2007; Ramawat,

2009). The shrubs are distributed on the dunes, but the lowland areas near the lakes are covered by grasses. The δ13C of soil CO2 in soils hosting dense C3 vegetation is about −23‰ (Cerling et al., 1991). In soils with <60% vegetation cover, δ13C of soil CO2 is > −21‰ due to mixing with atmospheric CO2 resulting from low soil respiration rates (Cerling et al., 1991; Quade et al., 1989). Assuming that the δ13C of soil CO2 is −20‰ the pH of the infiltration water in the soil zone in the recharge area is 5.3 and carbonates in aquifer have a δ13C value +2‰ Ẇe can calculate the fraction (F) of soil CO2-derived DIC in groundwater from the measured DIC- δ13C value using the following mass balance relationship: F=(δˆ13 C-δˆ13 C_carb)/(δˆ13 C_(DIC-ãĂŰCOãĂŮ_2 (soil))-ãĂŰ δãĂŮˆ13 C_carb) (5) where the δ13Ccarb is δ13C of DIC derived from dissolution of carbonates in the aquifer, and δˆ13 C_(DIC-ãĂŰCOãĂŮ_2 (soil)) represents δ13C of DIC derived from soil CO2 in the recharge zone. For example, the calculated F value for sample WS-1 is 58%. This suggests that ∼58% of the DIC in this sample was derived from soil CO2 , and the radiocarbon age (8250 yr B.P.) of this sample could be a result of 42% dilution by DIC derived from dissolution of 20000 year old carbonates in the aquifer (Table 3). That demonstrates that just a small amount of DIC from the dissolution of old carbonates can yield an erroneous DIC radiocarbon age that could be several thousand years (or more) too old. Various types of carbonate have been found in the lake area including tufa deposits, lacustrine carbonates and calcareous cementation (Yang et al., 2003). These carbonates provide possible sources of old DIC in groundwater. Unfortunately we were unable to do the 14C-dating using DOC or any other dating approaches, do not have other hydrochemistry data for the collected samples.

Specific comments

Title: Use "Groundwater studies . . ." instead of "Water resources . . .", otherwise your work should focus more on hydrological budget quantification and hydrogeological aspects. Reply: We revise the title to "Origin of water . . ." because this study is focused to reveal the origination of water in the BJD. (see Page 1, Line 1) Introduction: Page 2,

lines 31-33: This sentence is summarizing results and would fit better into the conclusion or abstract section. Reply: Accept. I find this sentence in the conclusion part, so I delete this sentence here. Methods: You mention the GNIP station Zhangye. Please add the distance in km to the study site and further information on time sampled, number of samples used for LMWL. Reply: Accept. Zhangye is the nearest IAEA-GNIP (International Atomic Energy Agency Global Network of Isotopes in Precipitation) station, approximately 170 km to the site-B in the BJD (Fig. 1A) at the altitude of ∼1400 m, with available data of IAEA/WMO for the period from 1986 to 2003. (see Page 4, Line 28, 29) IAEA/WMO, the internet link should be given as a reference in the references section. See also recommendations for referencing to GNIP data on the WISER database at IAEA. Reply: Accept. (see Page 15, Line 11) Page 5, line 6: ". . .artificial rainfall with 250 mL in 6 min . . ." It would be more informative to provide irrigation intensities in mm/min for 6 min. Reply: Accept. The mean "rainfall" intensity is 0.167 mm/min (see Page 5, Line 20) Page 5, line 13: I would recommend "Isotope analyses" or "Laboratory methods" instead of chemical analyses, because hydrochemistry is not discussed and isotope methods are no chemical methods. Reply: Accept. (see Page 5, Line 25) Page 5, line 17: ". . .Five groundwater samples . . ." In Table 3 seven ages are given for groundwater!? Reply: Sorry for the mistake. It should be 7 samples. (see Page 5, Line 29) Page 5, line 24. For the stable isotope analysis please give the specific gas preparation methods that were used, e.g., Gasbench, H-device, or TCEA? Reply: This information is presented in the revised manuscript. The gas preparation was performed with a Finnigan MAT Gas Bench. (see Page 6, Line 5)

Page 5, line 26. Please use appropriate definition of delta values. RSA/RST and not RVSMOW. This is especially important because you also give d13C values in Table 3. These are not defined against V-SMOW but VPDB I guess! Reply: The presentation is revised. The stable isotopic results are reported in the standard notation as δD, δ18O and δ13C values Eq. (1): δ=(R_SA/R_STD -1)×1000‰ (1) where δ is the isotopic concentration of a sample, RSA is the isotope atom ratio D/H, 18O/16O or 13C/12C, RSTD is the corresponding isotope atom ratio of the international standard V-SMOW

for hydrogen and oxygen and VPDB for carbon. (see Page 6; Line 7-13)

Your precision is given as 1‰ and 0.1‰ for d2H and d18O respectively. Your d-excess results therefore should not be given with commas (see values in Tables as well). Reply: Accept.

What is the precision for your d13C values? What are the precision of your 3H values? Did you test any post corrections for 14C DIC? Reply: The analytical precision is $\pm$0.3‰ for δ13C and ïĆś0.4 TU to ïĆś0.7 TU for 3H.The 14C dating correction method is described in Section 5.3. (see Page 11, Line 26-33; Page 12, Line 1-13)

Results and discussions Page 6, line 10-14: Please give d-excess values without digits. Reply: Accept.

Page 6, line 11: Why did you distinguish between groundwater and lake water? Please discuss results! Reply: That is because the difference in salinity between groundwater and lake water is significant (see the EC results in Table 2). The salinity of water would affect the stable isotope fractionation during evaporating. (see Page 6, Line 24, 25)

Page 6, line 22: You show that d-excess values are negatively correlated with d18O values (Figures 4b, 6b). Please discuss what this exactly means in your case. Usually these plots are used to argue for water vapor origin. Reply: Accept. (see Page 8, Line 8-11) Although the d-excess values are often used to infer atmospheric vapor sources, the evaporation experiments show that the d-excess values of water in the study area are primarily controlled by evaporation and decrease significantly but systematically with the extent of evaporation, providing another fingerprint for tracing the locally recharged water.

Page 6, line 27: "... as Fraction Modern (Fmdn)..." Usually given in percent modern carbon as pMC. See also Table 3. Reply: Accept. It is revised using pMC in the manuscript. (see Page 7, Line 12)

Page 8, line 10: "... from nearby IAEA GNIP ..." Please provide information on distance

and elevation of the station. Reply: Accept. (see Page 4, Line 28, 29)

You do not describe and discuss field parameters EC given in Table 2. Reply: The information of the EC given in Table 2 is presented in Section 4.1. (see Page 6, Line 24, 25)

The discussion on 14C free carbonate contribution to DIC is vague. Figure 9 is difficult to understand. Reply: This figure is not necessary after we made the correction of groundwater ages, so we delete the Figure 9. References: Please point out all Chinese references (in Chinese) for the international readers that do not understand Chinese language. Reply: Accept.

Figures and Tables: Figure 1. Please include location of GNIP station Zhanye in Fig. 1A) Reply: Accept. (see Page 18)

Figures 2 and 3 could be merged together Reply: Accept. (see Page 19)

Figure 6: The two diamond dots are not clearly visible, not visible in 6b. "Land water" should be rephrased! Soil water? Reply: Accept. We use two larger diamonds than the other ones to make the error bar of the dots more clearly. (see Page 22) It is explained in the figure caption. (see Page 22, Line 8-10) land water including groundwater (Li et al., 2016), rivers (average for each river) (Chen et al., 2012; Li et al., 2016), glacier snow melt water and frozen soil melt water (Li et al., 2016)

Figure 7: E – fluxes are misleading! Evaporation from groundwater to lake water fluxes could be better placed at boxes. Reply: Accept. (see Page 23) Table 1: d-excess values without digit. Reply: Accept. Table 2: Category should be rephrased into type. EC is given in mS not Ms! d18O and d2H measured against VSMOW. d-excess values without digit. Reply: Accept. Table 3: Temperature without digits or consistently. d13C against VPDB. Reply: Accept.

Technical corrections

Page 1, line 11: "(d2H-d18O) instead of (=d2H...) Reply: Accept. Page 1, line 25: "...

are scarce in arid regions, due . . ." Please delete "in arid regions" Reply: Accept. Page 2, line 5: progress instead of progresses. Reply: Accept. Page 3, line 3:". . . to104° . . ." Space is missing. Reply: Accept. Page 5, line 20. Beta instead of Bata. Reply: Accept. Page 5, line 20. Beta Analytic Inc. (Miami, Florida, USA). Reply: Accept. Page 6, line 22: " . . . and that it is negatively . . ." instead of ". . .and strongly and negatively .." Reply: Accept.

Figures and Tables: Table 2. Table caption should include all columns. Location, date and EC is not mentioned. Reply: Accept. (see Page 26)

Table. 2 The EC, δ18O and δD values of water samples from lakes, wells and spring in the BJD.

Figure caption Figure 5: delete space between d18 and O. Reply: Accept. Figure caption Figure 6: Please correct figure caption (e.g., d18O). Reply: Accept.
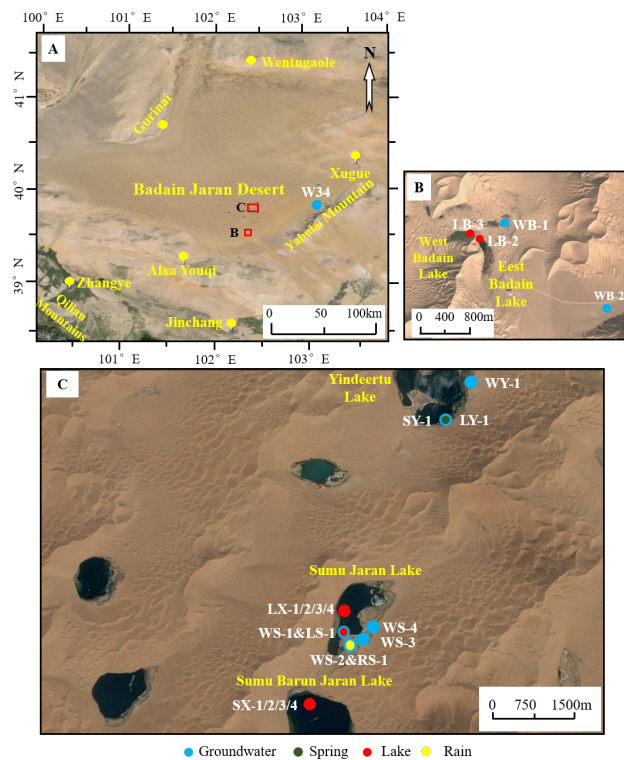
Fig. 1. Figure 1: Maps showing location of the Badain Jaran Desert (A), the Badain lake sampling area (B) and the Sumu Jaran lake sampling area (C). W34 in (A) is sampling site of Gates et al. (2008a).
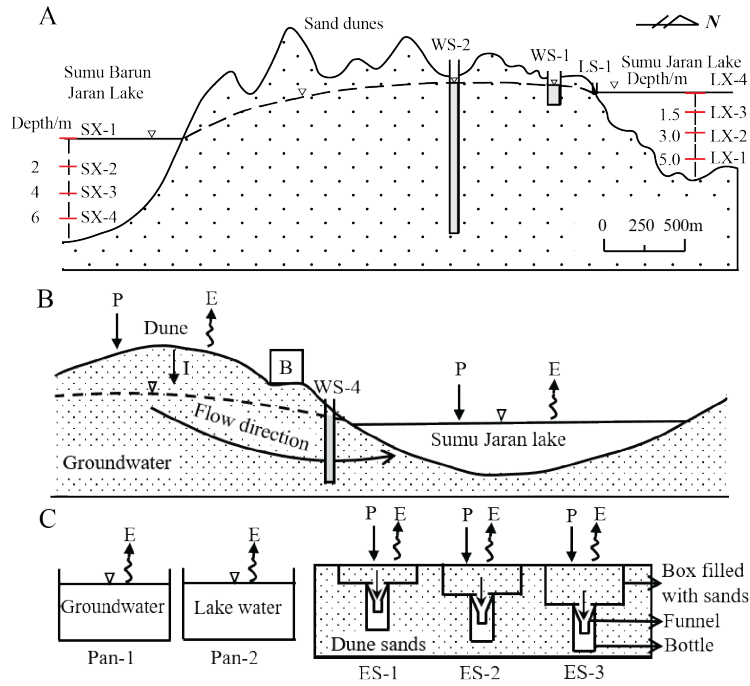
Fig. 2. Figure 2: Schematic diagram showing the cross-section profile between the Sumu Jaran Lake and the Sumu Baran Jaran Lake as well as the water sampling points (A) and the groundwater flow direction (B)
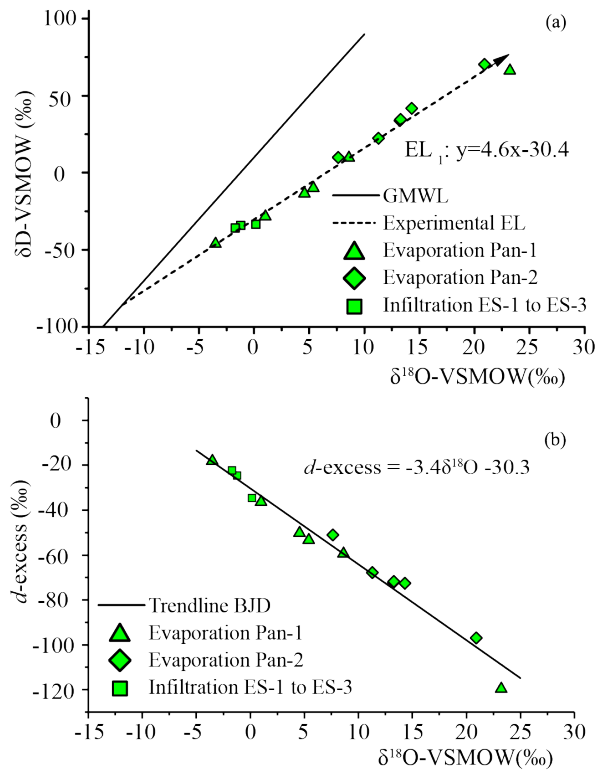
C9

Fig. 3. Figure 3: The relationship between δD and δ18O (a) and between d-excess and δ18O (b) of water samples from evaporation experiments.
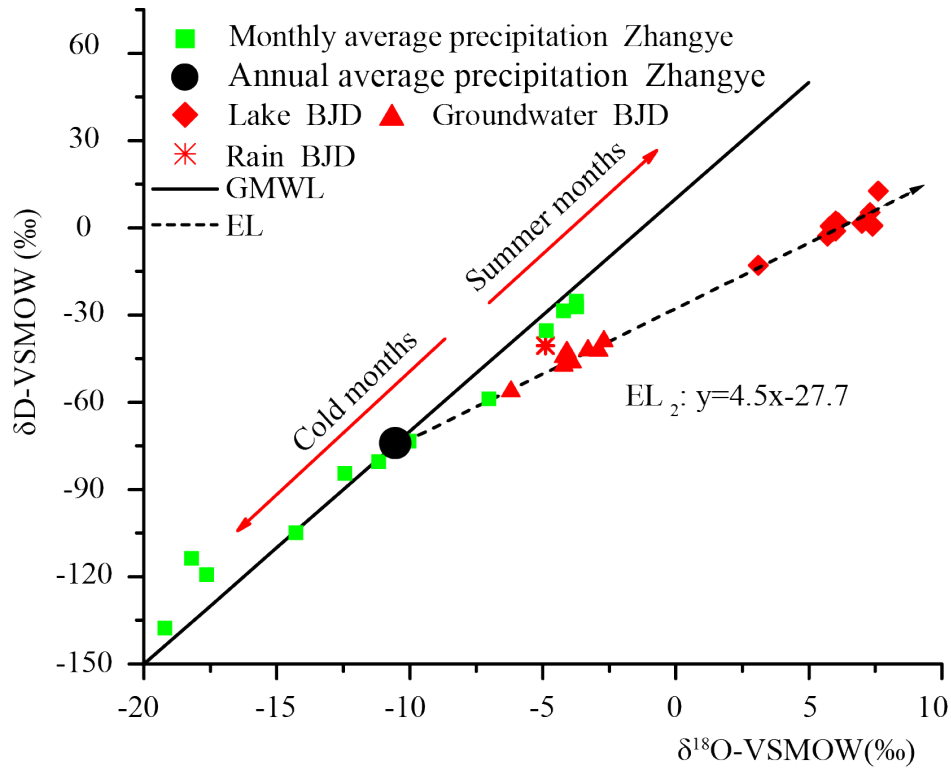
Fig. 4. Figure 4: The δD vs. δ18O plot of natural groundwater, lake water, and precipitation in the desert. Also shown are weighted monthly average and weighted annually average isotope ratios of precipitat
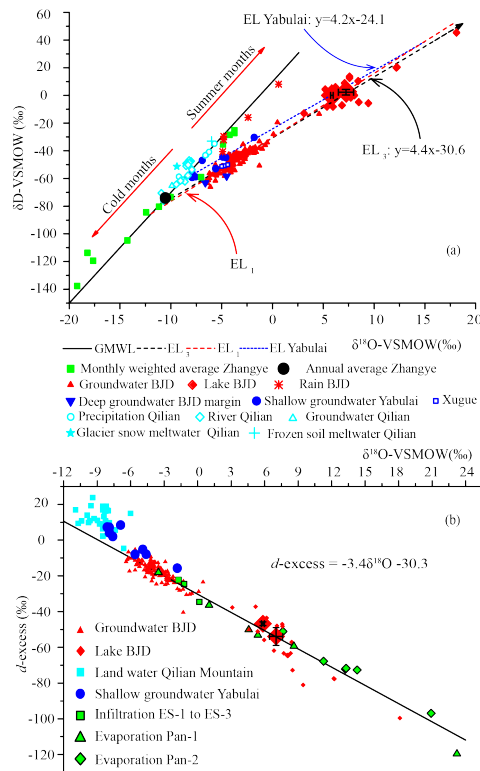
C11

Fig. 5. Figure 5: The plot of δD vs δ18O values (a) and d-excess vs δ18O values (b) of groundwater and lake water samples from the BJD (red symbols), including new data from his study and previously published
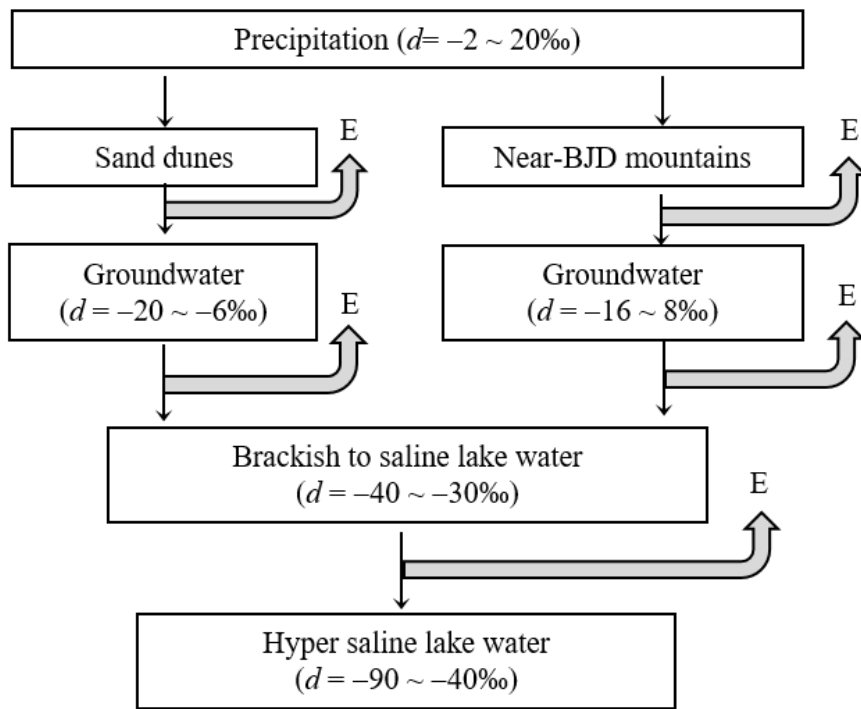
C12

Fig. 6. Figure 6: The conceptual model of the d-excess changing routines in the BJD. E represents evaporation.
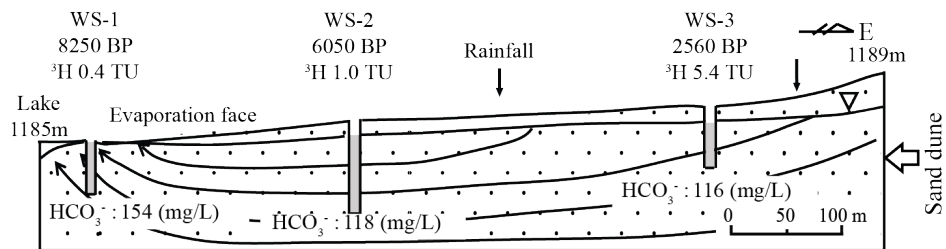
C13

Fig. 7. Figure 7: The flow model of groundwater near the Sumu Jaran Lake. The HCO3- concentrations of each wells are shown in the figure.