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Hydrology and Earth System Sciences Discussions

Interactive comment on "The yearly amount and characteristics of deep-buried phreatic evaporation in hyper-arid areas" *by* H. Li et al.

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Note Response to Anonymous Referee #1

Hydrol. Earth Syst. Sci. Discuss., 12, C6197–C6200, 2016 www.hydrol-earth-syst-sci-discuss.net/12/C6197/2016/ © Author(s) 2016. This work is distributed under the Creative Commons Attribute 3.0 License. Interactive comment on "The yearly amount and characteristics of deep-buried phreatic evaporation in hyper-arid areas" by H. Li et al. Anonymous Referee #1 Received and published: 18 January 2016

General comments This paper describes and discusses the results of a long-term experiment carried out in a hyper-arid region of the Gobi Desert, with the aim of quantifying soil evaporation and identifying the main drivers of the process. Soil evaporation

was assessed through a greenhouse equipped with an air conditioner, while soil moisture, temperature and air humidity were recorded both inside and outside the greenhouse. The main results are quite obvious and show that evaporation is, as expected, very small (4.52 mm) and that the main drivers are temperature and solar radiation. The only original contribution of the study is the claim by the Authors that the water table, located on average at 200 m depth, is able to provide moisture to sustain evaporation. Thanks the reviewers' comments concerning our manuscript entitled "The yearly amount and characteristics of deep-buried phreatic evaporation in hyper-arid areas" (doi:10.5194/hessd-12-13123-2015, 2015).

In my opinion, the paper is not suitable for publication in HESS, as i) the main results are not new, ii) the fact that the deep aquifer contributes to soil evaporation is not demonstrated by the experimental observations, and iii) the methodology appears to be flawed. See the reviewer's comments we are very disappointed. This is an arbitrary decision. Firstly, the results are new in this paper; we do not know where you have seen a paper introduced the measurement and analysis of the yearly characteristics of deep-buried phreatic evaporation in hyper-arid areas? If so, why the Editor Initial Decision: Publish subject to minor revisions (Editor review) (13 Nov 2015) by Prof. Gregor Laaha Comments to the Author: "I have screened the paper and find it generally suitable for publication in HESSD"? I think a paper whether or not suitable for HESS is deferent the meet the publication requirements of HESS, they are different concepts. Or the HESS has a suspicion of cheating contributors deliberately. Secondly, you did not carefully read our paper, so made some misunderstand.

Specific comments 1. Page 13125, lines 4-11: I wonder what is the connection between deep groundwater availability and this study. Evaporation in hyper-arid zones is probably negligible, but this does not mean that deep aquifers cannot be exploited. In summary, I cannot understand what is the relevance of this research. Logical relationship is this: we would like to use the available water resources, phreatic water, owing to for a long time it was commonly believed that with an increase in depth-to-groundwater, there would, at some point, be no PW available; Also for a long time there is the concept of “extinction depth” or “maximum depth” – for a water table at a level below this extinction depth the phreatic evaporation (PE) would be zero. But we contend that PW vapor can penetrate through such thick soil layers and form evaporation, i.e. “evaporation in hyper-arid zones is probably negligible, but this does not mean that deep aquifers cannot be exploited”. That is completely as same as you understood. I hope you read carefully, spend some time, after all this is someone’s fruit which spend six years, working day and night.

2. Page 13125, lines 20-26: these statements are reported as results, still they are in the introduction and refer to papers already published. Rewrite the last part of the introduction to better explain what has been done in this study compared to the previous ones. At present, we are the only one tested the phreatic water by the air-conditioner greenhouse method; we introduced the experiment progress and yearly results in this paper firstly, not already published! In last part of the introduction, we insert that “this time tests PE for 6 years and monitoring annual soil temperature and humidity to a depth of 5.0 m”.

3. Pages13126-13127: soil water content must be either 1-1.5% or ranging from 2 to 9%. Which is correct? I think the referee should read carefully and read some we marked references. The soil water content of 1-1.5% refer to “Three observation holes, each deeper than 150 m, were dug to investigate the geological and water conditions near our research site during 2007−2008. No seepage water was detected, and the soil water content was only 1.0−1.5%. The top 50 cm of the soil has high salinity (4.4% on average), and mainly consists of Na2SO4 and NaCl. The water in the soil is mainly present as water of crystallization, e.g. Na2SO4âĂć10H2O. The soil water content lies in the range 2.0–9.0% and fluctuates with the daily temperature (Li et al., 2010a, 2014a). Therefore, it is clear, the range 2.0–9.0% refer to the top 50 cm, there no issue of “which is correct”, and in the references paper introduced more detailed, see Table 1 (Li et al., 2014a).

Here is Table 1.

4. Sections 2.2.2 and 2.2.3: I wonder if the sensors used in this study are suitable for measurements of temperature and humidity of the air phase in soils. I am not familiar with the humidity, but soil temperature typically requires the use of thermocouples or thermistors, while, as far as I understand, the device used in the study is suitable only for outdoor applications. We very understand your doubt. We want to monitoring air temperature and humidity of soil before 10 years ago, at that time found that soil temperature can be monitored by mostly instrument of thermocouples/thermistors way, but there no an instrument at the same time can measure air humidity in soil. At this point, we used miniature monitor HOBO monitoring air temperature and humidity of cave in Mogao Grottoes. After studied its structure (Fig.1), we found that its temperature and humidity sensor are installed into a protective shell, and closed with air permeable paper. It records the small space temperature and humidity automatically. We found that it can be very accurately monitoring temperature and humidity within the soil by the laboratory validation. So we innovated use it in soil.

Here is Fig.1.

5. Section 3.2: it is not possible to assess daily fluctuations of soil moisture from Figure3. I strongly recommend that the complete and continuous time series of soil moisture at different depths be reported. That a good idea! However, we try our best to monitor soil moisture in continuous time, but failed! And then cooperated with the specialized agencies of soil water content monitoring, also failed! The main reason is that the soil water content too low to test by resistivity method; and same time the resistivity monitor seriously is interfered by salts. Even the monitor displayed value contrary to the actual value. As a long-term result of phreatic evaporation, a large amount of salts has detained in the shallow soil layers forming a salt-rich stratum in 0–60 cm, and especially in 10–20 cm region. The crystallized water (mainly in the form Na2SO4âĂć10H2O) leads to the distribution in the soil moisture that matches the distribution of the salinity (Table 1). The water is relatively high, but the water potential

is low. Therefore, we searched all over the world did not find an ideal monitoring equipment to monitoring the extra-arid soil, now using the method of weighing and oven drying is the most reliable way. But the sampling would disturb the soil moisture and soil salt, can not be continued monitor. Therefore we invented use HOBO monitored RH, AH as a supplement way (see the Specific comment replies 4). If you can recommend an instrument can continuous time series to monitor soil moisture, we'll very glad!

6. Section 3.3: Comparison between the temperature and humidity data inside and outside the greenhouse shows that temperature, but most importantly humidity, is constantly lower inside than outside. This, combined with the fact that when it rains there is no infiltration under the greenhouse, make me suspect that the air conditioner in the greenhouse is extracting soil moisture laterally, as Figure 4 would suggest. Water vapor could be even recalled from the outside atmosphere through the shallowest layers of soil (but deeper than 30 cm), being the latter basically dry and thus prone to conduct gases. Therefore, the evaporation is likely to be overestimated and possibly related to the annual amount of rainfall in the area. As a matter of fact, I would like to see whether or not there is a significant correlation between annual rainfall and annual evaporation. Why is yearly rainfall from 2010 to 2015 not shown in the paper? Yes, the temperature and humidity is constantly lower inside than outside, there is a slight water vapor comes from outside. But not the air conditioner in the greenhouse is extracting soil moisture laterally. The reviewer maybe not read the conference papers (see "The daily evaporation characteristics of deeply buried phreatic water in an extremely arid region". J. Hydrol., 514 (6):172–179; and "Measurement of deep buried phreatic water evaporation in extremely arid area". Acta Ecol Sinica 30: 6798-6803) in Fig. 2, Table 2 and that context we detailed instructions this in that articles, because of shed-effect, soil temperature and humidity in the shed/greenhouse higher than the outside soil, there is no lateral water into the greenhouse. In the greenhouse we are measured a part of the PE, a small amount of PE through lateral flow in the outside world. Soil temperature and humidity in the whole process of the 45 d monitoring show that soil in greenhouse has been higher than the outside's (see Fig. 2, Table 2). Here is Fig. 2 Here is Table 2

In this time the average quantity of PE recorded (827 g d–1) is 25.9% larger than that recorded during the 45-day experiment in 2009 (Li et al., 2010b) for the same period (May 22 to July 5). This is because of the greater power of the new air-conditioner. Even if water came from outside, it will not more than 25.9%. See Table 3. The comparison of the average temperatures, RHs, and AHs inside and outside the greenhouse (2010):

Here is Table 3

At 30 cm under the ground, the inside values were again lowers than those outside (by 0.79 °C, 1.38%, and 1.57 g m–3, respectively). However, after the 48.8 mm rainfall (June 16, 2012), outside soil RH reached 100% in 30–140 cm, so outside RH high than inside more than 33% from 2012 to 2015, but in 2010, 2011, 2012, 2014, and 2015, the average PE was 614, 667, 553, 671, and 647 g d–1 for the same period (June 20 to October 26), respectively. Compared with this PE of 2010, the fluctuation amplitude was 8.7%, –9.9%, 9.3% and 5.4%, respectively in 2011, 2012, 2014, and 2015. This suggests that different soil RH values outside have very little influence on PE. There was almost no water vapor flowing horizontally into the greenhouse soil (Fig. 4b). The influence is less than the influence of confounding climate factors, such as, the yearly temperature (±1 °C), sunshine rate (±3%), etc. Even if we did not consider effect of the greater power of the new air-conditioner, the water vapor came from outside should not more than 9.3%. Owing to the yearly rainfall from 2010 to 2015 was in normal range and rainfall prevent by sheds, so we ignored it, now we add the precipitation of 25.63, 56.4, 32.52, 38.10, 28.50, 40.50 mm, respectively. 7. Page 13132 line 15 to page 13133 line 6: this paragraph is rather obscure. First of all, it is impossible to distinguish what has been done in the present paper from the work by Li et al. (2010a, 2013, 2014b). Second, the series of six soil moisture snapshots over 6 years is quite limited and show a distinctive profile, typical of an infiltration front. I wonder whether this makes any sense, given the very small and sparse rainfall events that characterize the area. The reviewer maybe is not familiar with soil water content in the hyper-arid areas. See the Specific comment replies 3, 4 and 5.

8. Section 3.4: this entire discussion is difficult to follow and it is not very clear to what extent the data shown in Figure 5 support these statements and conclusions. In order to confirm or confute the hypotheses, I suggest the use of a numerical model that can be calibrated and validated against the data. If not a simple 2D Richards equation coupled to heat transport (e.g., Hydrus 2D), a two-phase model of air and water flow would help to better understand the main driving mechanisms of water movement in this arid region. Other statements, such as the ones related to movement of film water, seem just speculations, as they are currently not supported by neither cited literature nor observed data. The reviewer suggested use of a numerical model, thought that a two-phase model of air and water flow would help to better understand the main driving mechanisms of water movement in this arid region. We also did a lot of try, such as used Darcy's law, Fickian formula or Richards equation. But, all of them can not reflect this experiment results. We found as same as the wikipedia (https://en.wikipedia.org/wiki/Richards_equation): Darcy's law was developed for saturated flow in porous media; to this Richards applied a continuity requirement suggested by Buckingham. The numerical solution of Richards equation has been criticized for being computationally expensive and unpredictable (Short, D., W.R. Dawes, and I. White, 1995. The practicability of using Richards' equation for general purpose soil-water dynamics models. Envir. Int'l. 21(5):723-730 because there is no guarantee that a solver will converge for a particular set of soil constitutive relations. This prevents use of the method in general applications where the risk of non-convergence is high. The method has also been criticized for over-emphasizing the role of capillarity(Jump up Tocci, M. D., C. T. Kelley, and C. T. Miller.1997. Accurate and economical solution of the pressure-head form of Richards' equation by the method of lines, Adv. Wat. Resour., 20(1), 1–14). Although the Richards' equation represents the movement of water in unsaturated soils, obviously, it is not suitable for the extra-arid soil. There no capillarity water in the extra-arid area, soil-combined water (i.e. hygroscopic, film, and crystallized water) is released in the form of vapor when temperature is rising, and

soil layer absorbs vapor as the temperature falls. The Darcy's law, Fickian formula or Richards equation are suited to more wet soil, at least there is some capillarity water. We believe that the soil moisture in the extremely arid zone is a new type which has not yet been fully researched, and need further exploration.

9. Section 4: the Discussion section should be rewritten according to the previous suggestions. At present, daily fluctuations of temperature and soil moisture are not shown; therefore it is difficult to follow discussions such as the one reported in Section 4.1. Similarly for Section 4.2, I am not able to see any connection between the data reported in Figure 3 and soil moisture hysteresis. Maybe the reviewer did not see our reference paper, Line 137-139: "Prior to this study, migration mechanisms were analyzed based mainly on the daily temperature and humidity of shallow soil at 0–60 cm (Li et al., 2010a; 2014a)", Li, H.S., Wang, W.F., Zhan, H.T, Qiu, F., and An. L.Z.: New Judgement on the source of soil water in extremely dry zone. Acta Ecologica Sinica, 30(1): 1–7, 2010a. Li, H.S., Wang, W.F., and Liu, B.L.: The daily evaporation characteristics of deeply buried phreatic water in an extremely arid region. J. Hydrol., 514 (6):172–179, 2014a. In these paper, the daily water content variation was shown as Fig. 3, the daily temperature and humidity was shown as Fig. 4.

Here is Fig. 3 Here is Fig. 4

We cannot insert all the figures in this one paper. If you have read our related research paper (as in the reference), we think the discussion part is clearly. About soil-water hysteresis we explain as below, Ssoil water content very more important for phreatic evaperation, especially at 10 to 20 cm depth. There are soil-water hysteresis effects to consider, i.e. the water-related characteristic curves of drying soil (basal water content is low) are different from those of soil that is wetter (basal water content is higher), as shown in Fig. 5.

Here is Fig. 5.

Generally, most of the studies on soil hysteresis have focused mainly on water contents and water potential, rather than evaporation of soil water. Presently, we have given much attention to the relationship between evaporation and water content. When the temperature is increasing (e.g. the secondary X-axis in Fig. 5), the soil is losing water and forming vapor (as on the secondary Y-axis in Fig. 5) and thus the WC is declining. The water lost from the soil is equal to the water evaporated. Curves corresponding to soil-water hysteresis are shown in Fig. 5. If the soil water content moves repeatedly along the line A–D–C (PDSC) for a long time. In this repetitive process, soil moisture is desorbed as temperatures increase during the daytime, and during the nighttime (i.e. temperature declining) the soil absorbs water vapor from the subsoil (Li et al., 2014a). During the cyclic diurnal process of soil absorption–desorption, PW vapor is transported through the surface soil and completes the process of PE. If the soil-water changes along the path A–B–C (PWSC), when the cyclic diurnal process of soil absorption–desorption repeats, the amount of water absorbed and desorbed is lower than that in PDSC because the basic water content in PWSC is lower than that in PDSC. Thus, the amount of PW transported and evaporated is lower than that in PDSC. Therefore, sodium sulphate is also an important material, its crystallized water increased water content, is conducive to increase PE. If we familiar with soil-water hysteresis phenomenon, this is simple and easy understand. The Discussion section is not the key part in this paper, we can delete or made a more detailed description.

10. Page 13139, lines 9-11: I agree that deep PW can be an important resource (not new though) in hyper-arid areas, but this is true regardless of the results and conclusions of this study. In fact, the main message seems to be that soil evaporation in such areas is extremely small; not only that, but given that it is probably overestimated, I expect it is practically negligible. We think that the measured PE quantity of 4.52 mm yr–1 in a typical hyper-arid area which is larger, relatively, compared with that required for the survival of drought-tolerant vegetation or water quantity of deterioration cultural. However, compared to PE supported by a continuous supply of capillary water, it can be ignored. The two amounts have entirely different orders of magnitude. The Mogao Grottoes is a valuable world's cultural heritage, with nearly 45,000 m2 wall paintings,

but the wall paintings have suffered deteriorating diseases, moisture is the main factor makes precious wall paintings deterioration. Therefore, it is not overestimated; you cannot expect it is practically negligible.

Technical corrections

Although the paper is mostly well-written, English language sometimes sounds awkward and does not help the comprehension of the discussed topics. Perhaps help from a native English speaker is required. This paper revised by a native English speaker, a professional translator in Services of Kyuwen. The English language maybe sometimes sounds awkward; we can revise better if you point out the details.

In summary, we think the reviewer did not familiar with the practical soil situation in the extra-arid areas, and also our related papers were not look carefully. However, we also thanks for your comments and good suggestions. We all urgent suggest that to re-review this paper by an exporter who familiar soil moisture in extremely arid zone. For our 6 years research sake!

Kind regards! Hongshou Li

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/12/C6296/2016/hessd-12-C6296-2016-supplement.pdf

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 13123, 2015.

Table 1. Salt and water content of soil in the study area.

Depth (cm)	Anions (g kg^{-1})			Cations (g kg^{-1})			Total ion content (g kg^{-1})	Water content (g kg^{-1})
	$Cl^{□}$	$NO_3^{□}$	$SO_4^{2□}$	Na^+	K^+	Mg^{2+}		
0	0.086	0.006	0.275	0.092	0.007	0.002	0.129	0.469
10	27.765	1.365	16.127	25.206	0.890	0.191	1.436	71.544
20	8.840	0.672	15.626	13.095	0.370	0.099	0.678	38.701
30	3.926	0.275	3.927	3.992	0.178	0.042	0.700	12.341
40	1.917	0.083	1.966	1.766	0.097	0.012	0.548	5.842
50	1.039	0.048	1.575	1.022	0.055	0.007	0.454	3.746
60	0.907	0.046	1.331	0.928	0.059	0.007	0.352	3.277

Fig. 1.

Table 2. Comparison of the average parameters recorded inside and outside of the greenhouse.

Depth (cm)	Temperature (℃)			Relative humidity (%)				Absolute humidity (g m$^{□3}$)			
	Inside	Outside	Δ	Inside	Outside	Δ	Ratio (%)	Inside	Outside	Δ	Ratio (%)
+50	27.8	24.3	3.6	29.0	19.5	9.5	67.2	7.1	3.9	3.2	54.9
□ 10	29.1	27.6	1.5	35.4	34.5	0.9	97.4	10.5	9.6	1.0	90.9
□ 20	26.8	25.5	1.3	49.9	49.4	0.5	99.0	12.8	11.8	1.0	92.0
□ 30	25.1	24.4	0.7	62.6	61.2	1.4	97.8	14.5	13.6	0.9	93.5
□ 40	23.8	23.0	0.8	74.5	69.4	5.1	93.2	16.1	14.3	1.8	88.7

Fig. 2.

Table 3. Comparison of the average temperatures, RHs, and AHs inside and outside the greenhouse (2010).

Position (cm)	Temperature (°C)		RH (%)		AH (g m^{-3})	
	Inside	Outside	Inside	Outside	Inside	Outside
+50	19.35	21.70	29.00	30.21	4.83	5.77
–30	22.95	23.74	66.4	70.78	13.61	15.18

Fig. 3.

Fig. 1

Fig. 1 The structure of HOBO.

Fig. 4.

Fig.2

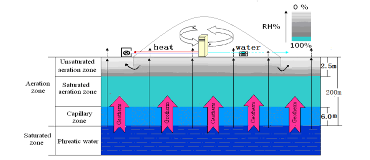


Fig. 2. Sketch map of the GSPAC water movement and condensation in the greenhouse (2009).

Fig. 5.

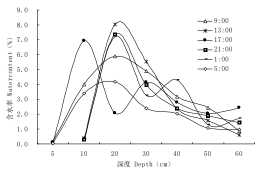


Fig.3. The daily change of soil water content in Gobi soil (2007-6-12).

Fig. 6.

Fig. 4.

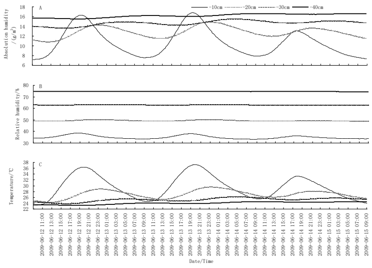
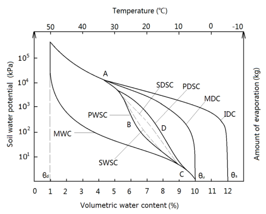


Fig. 4. Temperature and humidity at different soil depths in the greenhouse.

Fig. 7.



IDC — the initial drying curve;
MDC — the main drying curve;
PDSC — the primary drying scanning curve;
MWC — the main wetting cure;
PWSC — the primary wetting scanning curve;
SDSC — the second order drying scanning curve;
SWSC — the second order wetting scanning curve.

Fig. 5. Relationship between the soil-water hysteresis characteristic curves, desorption water and temperature.

Fig. 8.