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Hydrology and Earth System Sciences Discussions

Interactive comment on "

Capillary rise quantification by field injection of artificial deuterium and laboratory soil characterization" *by* O. Grünberger et al.

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This document contains authors comments and actions to enhance the manuscript following the suggestions of the reviewers.

– Formatted answers (respecting units, table and figures) was downloaded in a *.pdf file as supplement and should be available with the proper link located at the end of

the tewt part.

– modified tables (4),figures (3) are visible after the end of text.

– References like (p5, lines33-23) refer to planed change to the manuscript.

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Authors answers to comments by referee # 1

General Comments

reviewer #1 : The article presents a method of quantification of the capillary rise flow based on the peak displacement 35 days after local injection of deuterium enriched solution at a depth of 50 cm below the soil surface. Results are compared to quantification based on integration of hydraulic functions depending on hydraulic conductivity and tension head. Results are also compared to other published study. Actually, the question of such a new method for local quantification of rise flow from shallow aquifer in arid zone C3679 area is within the scope of HESS. The aim is quite important with regard to the methodology and with regard to the aquifer budget in arid zones. In general, the text is clear and the language is fluent. However, in several different places, the text needs rewording. And also, in some places, assumptions are not clearly outlined or comments on published papers should be corrected. Precisions on these points are presented below. Moreover, some complement would be welcome.

Authors answers: We thanks the reviewer for his valuable comments and sound lecture

reviewer #1 As steady state is assumed, characterization of the conditions would have been important on this point.

Answer of the authors: Steady state is not required for the measurement of a capillary rise based on peak displacement of artificial deuterium; this is the main enhancement of this method in front of other methods used in this study. Displacement of the tracer during the 35 days measured a cumulative effect that can include some changes in

boundary conditions without any inconvenience. The central point of the work is to demonstrate that the measurement was possible at the field and make a first analyze of it. Measuring a value is not enough if no comparison is performed with other methods. That's why we confronted the rate measured to values estimated by other methods adapted to the context of a capillary rise in an arid climate from a shallow aquifer, with only a few soil monitoring data. We used a capillary rise estimates based on steady state assumption, this later method being currently applied. We agree with reviewers, about the fact that these later method (by integrations of K(ψ) functions and/or simulations with Hydrus) require this hypothesis to be effective (similarly to the natural isotopic profile method cited in bibliography). We did the possible to assess the validity of the steady state assumption with the available data and enhanced the manuscript with more detailed information. We would have expected peak displacement method to deliver higher rate value than rates computed with steady state assumption, thus the difference would have come from the unsteady or unachieved drying state of the profile at the time of the sampling and would have been easily explained. As the opposite situation was encountered we could not sustain this hypothesis. Nevertheless, it is good to recall, that estimate based on laboratory hydrodynamic characteristics are not accurate, thus, estimates are very sensitive to water contents: an under-estimation of soil water content of 1% (i.e. 0.0595 instead of 0.0495 at 50 cm depth) would have been enough to compute, steady state rates within the same range than the rates computed from the tracer peak displacement.

reviewer #1 : The simulations presented on this (7768, 12) are interesting. An isotopic vertical profile, before the injection and after the sampling 35 days after would have been usefull to get an estimation of the evaporation by such method and to check the stability of the upward flux from the aquifer.

Answer of the authors We agree and we think it would be a challenging next step for us. We would also like to get an independent and external evaporation flux measurement (eddy covariance continuous measurement between the injection and the samplings).

The authors consider this work as a preliminary (and risky!) intent to validate the possibility of making some field, in situ, measurements with lower requirements about steady state assumption, this later hypothesis being always difficult to prove.

reviewer #1 : Precisions on the rainfall are also not sufficient, as for example how far are the stations, what is the spatial gradient of rain, etc. As a conclusion, the study and the results are quite interesting, and need some corrections and additions. Answer of the authors : We agree and made our best to clarify the situation of the stations and what we can deduced from the previous studies. We added a table for relative humidity and some hydrus simulations about the effects of water content changes and depth saturation changes.

reviewer #1 : Discussion is needed on porosity – kinematic one with respect to the volumetric water content. Answer of the authors: Volumic water contents are based on the combination of 105 °c drying measurement and density measurement from undisturbed samples and also laboratory saturation measurement for Van Genutchen parameters. We agree, that for peak displacement method, kinetic porosity or effective porosity could have important effects in the case of quick movements of water in nearly saturated soils with bypassing effects by macro-pores. In the case of a very slow convection movement, in soils with water content lower than 10%. Tracer has all time to diffuse to every micro-pore. We assumed that there was homogeneity of tracer content in all pores and that diffusive exchange between transmitting pores and dead-end pores was quick in front of the convection. Our sampling include vacuum-drying, so all the water of the sample was analyzed, (situation that would have been different if water was extracted by suction cups). Moreover, the effect of "effective porosity" is partially included in the dispersivity coefficients (L and T) that arise from the 2D simulation with Hydrus.

Detailed questions Reviewer #1 : The title: it refers to elements of the work but does not account properly for the study. The "Capillary rise quantification" is not "by" field injection neither "by" laboratory soil characterization, it is based on the injection of

deuterium-enriched solution and subsequent evaluation of the peak displacement.

Authors answer: The title of the study was much debated between co-authors. We agree that “Capillary rise quantification based on the injection of deuterium enriched solution and subsequent evaluation of the peak displacement“ would have been more correct and precise but still, much too long. Moreover, it would not account for the comparison with estimates based on soil integration functions.

We will apply some changes in the title: “Capillary rise quantifications based on in situ artificial Deuterium peak displacement and laboratory soil hydrodynamic characterization.” (P1,lines 1-2)

Reviewer #1 Abstract: the word “observed” is not correct, a rate cannot be observed, it is estimated on the base of peak displacement and of porosity measurements.

Authors’ answer : We agree and changed to estimated (P1, Line 24)

Reviewer #1 “This value was higher, than other estimates based on natural diffusion with the same depth of aquifer” is not clearly outlined. A relationship between capillary rise and water depth established for arid area where steady state rise from the aquifer is established. This study gives a range: 28 z-1.8 à 205 z-1.6, hence the 3,7 cm y-1. For a water depth at 2.44 m, this range is 0.6 to 4.9 cm y-1 that is within the range.

Authors comments: We agree to the observation of the reviewer. In fact there is two relationships between evaporation and depth from Coudrain et al (1998) that we wanted to compared our results with : 1) Gathering 21 natural isotopic profiles lead to a relationship between evaporation and depth of the aquifer (E=71,9 z-1.49), from this relationship, the depth of 2.44 m would lead to an average estimate of E of 19.54 mm y-1. It is this value (1.9 cm y-1) which is a lower value than the 3.7 cm y-1 found in the present study. 2) Study gives also a range based on integration of soil permeability curves of a sandy and a loamy soil, that gives a range 28 z-1.8 < E < 205 z-1.6 and clearly the value founded in this study for a death of 2.44 m of the aquifer by peak

displacement is within this range [0.6-4.9 cm. y-1]

Changes applied: “This value was higher than the rate computed from the relationship between evaporation rates and water level depth based on natural isotopic profiles estimates, but lower to every estimates established using integration of van Genutchen closed-form functions for soil hydraulic conductivity and retention curve. (P1- Line 25-28)

Reviewer #1 p. 7758, line 22 “high suction values in soil (lower that -800 cm)”; suggestion : “low suction values in soil (lower than . . .)”

Authors: Yes, we agree to change (p2, line 9)

Reviewer #1 7759, 6 “to other contexts” explain which other contexts, where pseudo steady-stage mentioned before is not valid? Authors comment: The reviewer is right.

Change proposed to reflect this: “Conceived for very arid conditions in desert vadose zone, the method was progressively extended to semi-arid conditions with shorter profiles where “pseudo steady-stage of evaporation” was considered valid at the end of the dry season” (Liu B. et al. (1995); Yamanaka and Yonetani (1999); Grünberger et al (2008)) and modeling . . .... (p2 Lines 17-20)

Reviewer #1 7759, 9 : Shimojima not in references

Authors comments : Thanks , Reference will be added (P18-line 22-24) Shimojima E. , Curtis Alan A., Turner Jeffrey V. 1990. The mechanism of evaporation from sand columns with restricted and unrestricted water tables using deuterium under turbulent airflow conditions. Journal of Hydrology, Volume 117, Issues 1-4, September 1990, Pages 15-54.

Reviewer #1 7759, 19 : precise that it was for steady state C3680 here, then the following sentence would begin by “This” instead of “The” and “assumed to be constant” can be removed.

Authors : We agree with “this”, but kept “the assumed to be constant” to precise “along all the soil profile” Changes proposed: . . .average value. “Gardner (1958) was the first author to propose a relationship based on a specific integration of the Richards equation to determine rise rate by capillarity, assuming a steady state of the soil profile. This relationship linked depth of the saturated level, the soil hydrodynamic characteristics and an ascending rate assumed to be constant along all the profile.”(P2-Lines 31-32, P3 line 1-3)

Reviewer #1 7759, 23: Gardner Wr and Fireman M, not in references. Authors comment: Thanks, Yes we agree. Authors added reference: Gardner WR and Fireman M.: Laboratory Studies of Evaporation From Soil Columns in the Presence of A Water Table. Soil Science. May 1958 - Volume 85 - Issue 5 - pp 244-249 (P17-lines18)

Reviewer #1 7759, 23: And the sentence “Although . . .flux” does not refer clearly to previous studies: when steady state is established, vapor flux in the upper part equals the one below

Authors : Comments : Gardner did not acknowledge the presence of a vapor transfer layer in soil top layer. Existence of this layer and “a evaporative front” was clearly put in evidence by isotopic measurements in the late 70’s. Nevertheless, we agree that the conjunction of a steady state of evaporation and the existence of a vapor transfer layer lead to equality of vapor and liquid fluxes.

Changes proposed: “Although vapor fluxes were not considered separately from liquid fluxes, and that the expression could not account for layered soils, this method has been widely used to compute the relation between the depth of the water table and the stabilized evaporation flux. . . ...”. (P3 lines 6-7)

Reviewer #1 7759, 28: reference to Coudrain-Ribstein et al study is not correctly outlined. This study that application of Gardner method taking into account sufficient range of permeability and suction, up to to vapor conditions, leads to estimated rates ranging between two curves 28 z-1,8 and 205 z-1,6 ; that is between 0.6 and 4.9 cm y-1 for a

water depth at 2.44 m below soil surface.

Authors comment: we agree Sentence totally re-written: . . ...(1998).). Rates computed with natural isotopic profiles gathered in this later study led to an average relationship between evaporation (E in mm y-1) and depth of the aquifer (z in meters) where E=71,9 z-1.49. Application of Gardner equation taking into account sufficient range of permeability and suction, for sandy and loamy soils resulted in the rate interval [28 z-1,8, 205z-1,6] (P3-Line10-14)

Reviewer #1 7760, 1: not clear, what is the limiting rate of phreatic evaporation after the reference cited.

Authors comment: We agree, although the expression comes from the citation. . Expression will be changed to “Steady state capillary rise rate under evaporation.” (P3 line 16-17)

Reviewer #1 7760, 10: As Garcia et al is mentioned as the solely study of artificial tracer used to quantify field capillary rise, more information on this studies would be welcome as a comparison of present one on the method and on the results.

Authors’ comments: we agree. Artificial tracer is not commonly used to quantify field capillary rise and Garcia et al study stands from a very different global objective than for quantifying evaporation.

We have rewritten the sentence: “Then, to our knowledge, artificial tracing was never used to quantify field capillary rise. Recently, Garcia et al (2009) studied a Tritium release in the vadoze zone of a desert, but Tritium fluxes were approximated as simple products of Evapotranspiration fluxes (measured by the eddy covariance method) and Tritium concentrations in order to estimate the rate of the release in the environment from a low level radioactivity waste area facility.”. (P3- Lines 22-25)

Reviewer #1 7760, 23: precision on “some distance” is needed, and on local space gradient of rainfall amount

Authors' comment: We agree. We will shift to "at 2.6 km from the coast" (P 4-Line 9)

Reviewer #1 7760, 25: where were measures 86 mm of rain amount and for which period ? Authors' comment: All measurements including the study of Stoure & Agoumi, were based in the Agadir airport Meteo station.

Authors' comment: We will make it Clear in the text, (P4 lines 10-11)

Reviewer #1 7761, 1: Stour and Agoumi 2008 in text, 2009 in references Authors comments: Reviewer is right , Sorry, 2008 is the year of journal, (2009 is the year of the publication) We will apply the change in the reference (P18 line 29)

Reviewer #1 7761, 3: "nearest station", precision on the distance is needed

Authors' comment: Yes, we agree We inserted : Nearest meteorological station was located at Agadir International Airport, 14 km from the sampling site. At this station, the annual.... (P4 Line13)

PS: Reviewer #2 suggested rewriting of meteorological part, see Reviewer #2.

Reviewer #1 7761, 7: Need of table with depth and data range of relative humidity monitored during sampling day

Authors' comment: We agree. We will add a new table (Tab 1, P20 Line 1-8) showing soil profiles relative humidity at different time of the day in the soil top layer. 7761, 6 : We have rewritten totally the concerned sentence to "Relative humidity was monitored with a moisture capacity probe at the soil surface and at four depths during three days following the sampling days (Tab. 1). The values at the soil surface ranged from 31.0 % at midday to 82.6% early in the morning. The measurements were always greater than 80.2% at 31 cm depth." (P4 lines 30 -32, P5 Lines 1-2)

Table 1: Relative humidity (%), measured the 19th, 20th, 21th and 22th of June 2001, in the soil top layer on a side of the sampling pit. For 0 cm depth measurement, the capacitance probe was located on soil surface, for 7, 10, 20, 23 and 31 cm depths

probe was inserted in a 40 cm long PVC tube driven horizontally in the soil from the wall of the pit. Measurement was achieved after 5 min contact with soil moisture. (Avg = average, [Min-Max] = interval of extreme values, Nb = Number of measurements, σ = Standard deviation) Reviewer #1 7761, 17: precise that all the fifty injections were performed at a depth of 50 cm and precise how long it took.

Authors comments: We agree injections were performed at a depth of 100 cm and the time of injection was 1,5 hour. Changed performed: - at the end of the sentence in 7761,19,.... along a horizontal line on a side of the pit at 100 cm depth. - in sentence at 7761, 24. Immediately after excavation, a spray paint is used to seal pit wall surface in order to I) prevent drying during injection time (1,5 hour for the 50 points), ii).... (P5 Line 18-19)

Reviewer #1 7761, 21: "with water" precise nature of this water, the one of the aquifer ? same salinity?

Authors' comment: The water used was laboratory deionized water. Soil was calcareous and sandy and the injected amount very small. No dispersion effect due to the injection was expected. We will change "with water" to "with laboratory deionized water" (P5-line 16)

Reviewer #1 7762, 1: precise the number of samples collected (16 after fig. 3?), is "above" correct as fig 3 sho results below ? Precision on how were collected the samples would be appreciated.

Authors' comments: We agree. In fact 17 samples were analyzed for D, but some water content comes from other measurements (like density measurements). We added two sentences and corrected (Fig. 1 and 2) "Sampling for determination of laboratory soil hydrodynamic parameters (Fig. 1) included 5 undisturbed core samples (diameter 10 cm and length 8 cm). 5 cylinders of 98 cm3 were also sampled for water content measurements from (3 cm to 114 cm) (Fig. 2). (P 5 Line 5-7) Water extraction and deuterium analysis was performed on 17 samples between 113 and 43 cm depths.

(P5 Line 30-31)

Reviewer #1 7762, 2 The sentence “A steel . . . coating” is not clear.

Authors comments: we agree. We suggest to shift to the following sentence: “The sampling was located along a column (Fig 1) adjacent to the paint spray coating. Soil was progressively removed horizontally, slide by slide, following the spray coating that was used as a landmark. Samplings were performed with a rectangular steel frame of 0.15 m by 0.05m. For each sampling, the frame was oriented with the 0.15 m side along the paint coating line, in horizontal position and centered upon the 50 cm injection line. After sampling depth was measured, the frame was driven 0.5 cm inside the upper part of the soil column. Only the soil inside the frame was sampled..” (P5-Line24-30)

Reviewer #1 7762, 19: van Genutchen not in references

Authors comment : We don’t understand the reviewer point : van Genutchen reference is in 7773, 20 and in line p19-line 1-2

Reviewer #1 7762, 23: “Real saturated water contents were kept unchanged” : not clear

Authors comments: Yes, we agree.

Change suggested: “Saturated water content was not included in the set of parameters to adjust with the inversion process and was kept unchanged from laboratory measurement.” Results. . . (P6 Lines 22-23) - Reviewer #1 7763, 20: “When the soil saturation depth is known, the knowledge of another potential head at a different depth may lead to another estimate of evaporation.” Is not clear. In fact, E is assumed constant along the vertical profile. Hence, when values of K are known with respect to psi, the integration is made between two values. In the present study, the integration has been carried on between three couples of boundaries. In two cases, one boundary is the one of the saturation depth . . .

Authors’ comments: We agree Sentence is deleted and changed to: “Similarly, assum-

ing steady state, Eq.(5) may apply using particular field measured water contents at known depths as boundary conditions.” (P7 lines 13-14)

Reviewer #1 7763, 15: C3681 31% need to be in a table with other measured values

Authors : yes we agree and will insert a table (see upper)

Reviewer #1 7765, 21: “observed”: saturated hydraulic conductivity my not be observed, measurements lead to estimated values of Ks

Authors comment : yes we agree suggested change will be made (P9 line1)

Reviewer #1 7766, 5: range of fluxes in text is 0.59 to 3.46 when in table the range appears as from 0.58 to 3.74 (correct?).

Authors comment :yes, reviewer is right, correct value is 0.58 (mistakes comes probably from simplification and column shift error) Number will be corrected in the text, anyway as asked later by the reviewer #1 table 1 was split (Table 1 was split in tables 2,3,4) and so sentences are corrected to fit Sentence is corrected to : “The geometric means of estimates using integrations based on Eq.(5) with (i), (ii) and (iii) sets of boundary conditions (Tab. 3), ranged between 0.58 and 1.41 cm for 35 days, corresponding to the interval (89-146 mm y-1) with an overall arithmetic average of 1.27 cm for 35 days corresponding to 133 mm y-1. (P9, Lines 16-19)

Reviewer #1 7766, 6 : Precision on the “geometric means” is needed

Authors comments: we agree A sentence added in the text “Geometric mean is an appropriate averaging value in a soil profile with layered hydraulic conductivity in order to get an indicator of overall vertical transfer capability. Geometric mean of hydraulic conductivity is also appropriate in the case of assumed statistical log-normal distribution that is frequently encountered in experimental soil data (Jim Yeh and Harvey, 1990)..” (P9 Lines12-16) This reference will be added : Jim Yeh, T.-C., and D. J. Harvey (1990), Effective unsaturated hydraulic conductivity of layered sands, Water Resour. Res., 26(6), 1271–1279, doi:10.1029/WR026i006p01271. (P17 Line27-28)

Reviewer #1 7666, 7 from last line of table 1, values of average range from 0.47 to 1.71.

Authors' comment: We agree In table 1: Sentence was changed (see upper)

Reviewer #1 7766, 25: "the values computed from the laboratory measurements were 1.6 to 9.84 higher" is not clear, as far as the reviewer understand the values are those estimated by integration of equation 5 using lab measurements of hydraulic soil characteristics.

Authors' comment: yes, reviewer is right. Sentence will be changed : "The values computed using Eq.(5) and steady stage assumption based on Wind method laboratory measurements were 1.66 to 9.85 higher than the rate computed from peak displacement. "(P10 line 7-9)

Reviewer #1 7768, 20: Precision on why the evaporation front is assumed above 40 cm is needed.

Authors comment: We agree. These sentences will be added: "Indeed, deeper than 31 cm, as indicated in table 1, relative humidity was always higher than 80% and at 50 cm depth, potential head computed from the measured water contents (0.0495) and Eq. 2, lead to a maximum suction of -455.3 cm (Tab. 2). This range of potential head is clearly characteristic of dominant liquid transfer. Moreover, near steady stage, in the top layer of a dry soil, it was established that evaporation front depth was related to the inverse of the evaporation rate (Barnes et Allison, 1983). For instance, in similar conditions, in a sandy loam in Northeast Thailand at the end of dry season, Grunberger et al (2008) founded the evaporation front, to be located at 12 cm depth for a rate of evaporation of 82 mm y-1. Considering the range of evaporation rate measured in the present study (36 mm y-1), depth of the evaporation front would roughly be established around 27 cm depth." (P12, lines 7-17)

Reviewer #1: 7769, 5: sentence with "vapor flow processes may mitigate the evapo-

ration flux" should be reworded, at steady state flux above and below the evaporation front have same value when permanent conditions are achieved.

Authors' comment: We agree Sentence will be added:"Inside VTL, vapor flow processes may drive the evaporation flux, but quantifications based on water contents measured under the VTL should correspond to the same rate if the steady stage of evaporation is assumed." (P12-Lines27-29)

Reviewer #1: 7769, 26: sentence corresponding to point (i) is not clear ;

Authors comments : We agree This sentence will be changed to : i) Peak displacement measurement method, is not based on the stability of water regime in the soil between injection time and sampling time and therefore does not require steady stage assumption. Nevertheless, a strong limitation rises from the need to retrieve the tracer peak inside the soil, thus previous knowledge about expected range of displacement is compulsory. (P13-Line16-20)

Reviewer #1: 7769, 28: "density" or "porosity" ?

Authors comment: Only bulk soil density is required (to compute water content on a soil volume base).

Reviewer #1: 7770, 6: use the range proposed in Coudrain et al and then the value 3.7 cm y-1 fit into the range.

Authors : OK : added a sentence inside the end of discussion : "Nevertheless, experimental value (3.7 cm y-1) is included into the range defined by the same authors after high suction permeability measurements on loamy and sandy soils [6-49 mm y-1] ". [p13-Lines 9 –10]

Reviewer #1: 7774, Table 1: this important table should be separated into two tables; one should present results of experiments in laboratory that were performed to estimate the hydraulic soil characteristics. Another table would present the results of computation of E and be more precise on the condition of the integration of equation 5,

using the i; ii; iii of the three couples of boundaries described in

Authors' comment: yes we agree We will split in 3 tables : putting apart, As table 2: Van Genutchen laboratory measurements and value of potential head for 0.0495 water content. (p 20 Lines 9-15) As table 3: with Steady state results with integration of Eq 5 (P21 Line 10-18) A table 4: Hydrus simulation results, with consideration of change in Saturation depth and Water content. (P22 lines 1-8)

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Table 2. Van Genutchen hydrodynamic parameters measurements for 5 undisturbed soil samples. Measurements were performed using Wind methods with parameter adjustment by inversion using Hydrus (1.4) software. Resulting potential head (ψ) for a water content of 0.0495. (in bold: geometric mean).

Table 3: Steady state fluxes (cm) for 35 days computed using Eq. (5) and Eq. (3) with 3 different sets of boundary conditions and 5 soil data sets (Tab. 2). (in bold: geometric mean). Z1 is the depth of upper limit (cm), Z2 the depth of lower limit (cm). Θ1 and Θ2 are the water contents at depths Z1 and Z2. Θs is the saturated water content, and $\psi(\Theta 1)$, the potential head (cm) at the depth Z1. Sets i, ii and iii correspond to field measured conditions.

Table 4: Steady state capillary rise rate (cm) for 35 days based on Hydrus simulations for 5 van Genutchen data sets (Tab. 2) and 6 sets of boundary conditions. Boundary conditions sets ii and iii are similar to Tab. 3. (In bold: geometrical averages). Z1 is the depth of upper limit (cm), Z2 the depth of lower limit (cm). Θ1 and Θ2 are the water contents at depths Z1 and Z2. Θs is the saturated water content. Boundary conditions sets ii and iii correspond to field measured conditions.

Reviewer #1 7764. 7775. fig 1: precisions on the dimensions of samples in right part

Authors agree : Samples where taken with a PVC tube of 6 cm of diameter and 10 cm length. We will add this information inside figure 1. (see New Fig 1 and P5 Lines 5-6)

Reviewer #1 7776 Fig 2: need precision on the empty circles

Authors comments: We agree. nevertheless. the size of the empty circles was chosen to be greater than the estimated accuracy of the measurements. We will add in the caption: the following sentence: "Estimated accuracy for sampling point wass 0.5 cm in level and 0.5% in water content. (P23 line 10-11)

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1. Answers to comments by reviewer #2

General comments Reviewer #2 : Grunberger et al. present a field study on a tracer experiment to determine steadystate moisture fluxes from a shallow water table toward the landsurface due to evaporation. Results are juxtaposed with simple calculations of 1D steady-state Darcy- Buckingham equation using van Genuchten moisture-retention approximation. and numerical simulations.

Reviewer #2 : Application of the proposed tracer technique in conjunction with equation 1 hinges on the steady-state assumption or the assumption of some dynamic equilibrium over longer time periods.

Authors answers :

Eq. 1 (7762. 13) is the way to calculate the peak displacement of the tracer and precisely do not require steady state assumption. We understand that reviewer was confused by a erroneous presentation of the equation and we apologize. Still, peak measurement is cumulative and includes all the water movements that could have occurred between injection and sampling times. For instance, effects of night and day alternation, reasonable changes in the level of the aquifer and/or upper water contents would have been easily taken in account in the measurement. The manuscript induced this erroneous perception in the objectives of the paper (7760. 17) and this has have been corrected.

We agree that steady state assumption is required for methods using hydrodynamic

laboratory soil characterization. eq. 4 and 5. Also, simulations with Hydrus 1D software mimic steady state from invariance of boundary conditions and large time simulations. 1) We also agree that simulation with Hydrus 2D, was performed with a steady state assumption

We propose to clear up the objectives by insertion of the following sentence at the end of introduction paragraph: “Site and injection time were selected to present characteristics prone to approximate steady state drying conditions. These conditions would allow to compare the rate computed by tracer peak displacement to the range of steady state rates based on laboratory soil measurements in accordance to measured field boundary conditions.“ (P4 lines 3-6)"

Reviewer #2 It is not clear to me why the authors put this assumption in quotation marks throughout the manuscript and state that “no hypothesis around steady state water regime is compulsory” in the conclusion section.

Authors’ answers: We agree : quotation marks were there to emphasize that steady state is always a working hypothesis in natural ambient. We removed all the quotation marks except the one that emphasize a citation from Barnes and Allison (1983) that use a slightly different expression “pseudo steady-stage of evaporation”. Sentence in the conclusion dealing with the measurement with tracer peak displacement and has been changed (see answer to reviewer #1 and P13 corrections)

Reviewer #2: Clearly. equation 1 is based on the steady-state assumption. and any deviation from this assumption may lead to erroneous results.

Authors answers : Again. We differ from reviewer opinion 1) Eq. 1 relies on a tracer movement that is ideally miscible with soil solution. Value of the liquid flux can change in between injection and sampling time, and along the profile, but peak displacement will still represent a cumulative measurement including these changes. In our view, it is not possible to say that peak displacement method measurement of flux is based on steady-state assumption, (although the method is fully compatible with this ideal

situation). 2) Erroneous measurement would come from other difficulties than the compliance with non-steady state water regime. For instance: error on field water content, error on the field actual position of the peak, discrepancy from piston-flow-like transfer (for instance: bypassing fluxes with preferential flows on micro-pores). 3) Flux measurement by peak displacement was made on a small part of the profile (47mm). Comparison or assimilation to the whole profile requires steady state of the profile. We agree with the reviewer #2 that this needs to be recalled : We added in the conclusion paragraph: iv) The method does not require knowledge of soil characteristics under and above the sampling zone “but assimilation of peak displacement rate to the evaporation flux of the whole soil profile would require steady state assumption to be sustained”. (P13 lines 24-25)

Reviewer #2 The authors do not convince the reader that the system was at steady state over the course of the experiment nor do they provide an assessment of the impact on the results if the steady-state assumption was violated.

Authors answers : Steady state is a working hypothesis in an intent to obtain a range of rates from computation and simulation (using laboratory characterization of hydrodynamic parameters on undisturbed samples) that we would like to compare to peak displacement value obtained by the field experiment (that doesn’t require such hypothesis). With the presence of a shallow aquifer, dry soils in arid lands (like under South Moroccan climate) tend to reach the so call a steady state of evaporation at the end of dry season. Authors acknowledge that absolute steady state will never be totally reached in natural conditions (i.e. after an infinite lag time). Nevertheless, site and time were specially selected to near this ideal situation (Long dryness, sandy cover, unexploited aquifer). To convince the reader that our field conditions were the closer possible to this working hypothesis 1) We performed simulations with Hydrus using laboratory measured van Genutchen parameters sets : Assuming a. Initial condition of a saturated profile from 50 cm to 2.44 m. at the beginning of the year 2001. b. Lower boundary conditions of aquifer level at 2.44 m depth. c. Upper boundary value of

0.0495%. Water content at 50 cm depth. assuming ET and Rainfall events measured at Agadir Meteo station d. What ever was the soil parameter data set introduced in the model, permanent steady state is installed in no more than 50 days after saturation. (Injection is performed the 135th days of the year) (see following graph for illustration)

Figure 5: Simulation of the steady state establishment for 5 different van Genutchen soil parameters sets, assuming an initial saturation of soil profile from 0.50 m to 2.44 m at the beginning of the year 2001. Uprising fluxes computed with Hydrus 1D (right axis, cm d-1) and rain events (left axis, mm d-1). Boundary conditions reflecting: i) meteorological data (rain events and potential evaporation (5 mm d-1)) and maximum suction head corresponding to 0.0495 water content at the upper cell (0.5 m depth), ii) Lower boundary condition fixed to water saturation at 2.44 m depth. The top layer (0 to 0.5m depth) was not considered in the simulation.

2) We computed with hydrus the effects of what would be the effect of a change of water contents measurement at 50 cm (+/- 1% (i.e. 0.0595 and 0.0395 water contents) and a change of depths of the aquifer level (+/-10 cm (i.e. 2.34 and 2.54 m depths of free aquifer level)) See Table 4, in answer to reviewer #1. , (P 13 new manuscript or P10 this document) a. 10 cm drop down of aquifer level would lead to an insufficient decrease of the steady states computed rates to approximate the peak displacement value b. Higher water content at 50 cm, (0.0595 instead of 0.0495) would lead to a sufficient decrease in the steady state estimates to approximate peak displacement value.

3) If steady state is not assumed due to the absence of significant rain events since more than 100 days the only realistic water movement during the experiment is a drying movement with a lowering of the piezometric level. a. Evaporation should be greater than the rate computed with steady state assumption. b. if aquifer depth increase is related to evaporation, then decrease is very low. c. If aquifer depth increase is related to other cause we would have seen the effect on the piezometric level. 4) The result of the measurement with peak tracer displacement is lower than the measures assuming

steady state.

If the field steady state assumption was violated:

a) That would not change anything about peak displacement value that would have necessarily accounted for the cumulative effect of the changes observed between injection and sampling. Nevertheless, tracer needed to be recovered: son no strong infiltration, not too strong dispersion. b) In the case of non-steady state during drying : If we suppose a drying stage with slow changing rates, Peak tracer displacement should be higher than computed steady state fluxes values computed with Hydrus and/or integration of permeability function on the base on Wind laboratory method.

Reviewer #2 Additionally the impact of soil heterogeneity. which is not considered as I understand. is barely mentioned.

Authors answer : We disagree that soil heterogeneity is not mentioned in the study :

a) We systematically performed the calculations using the 5 data hydrodynamic data sets we had. This was done with the objective to maximize the effect of the heterogeneity we detected upon the rate ranges. Another choice would have been to combine measurement by layer in a profile to obtain an average rate. Thus, the ranges of rate values we obtained and discussed are representative of a range of heterogeneity. b) Inside a volume of 1 m3 of soil we performed a (5) samplings for undisturbed laboratory measurements of soil hydrodynamic characteristics. c) 17 samplings for peak displacement measurement were performed on a block of (15*5*80 cm)). d) Experimental site was chosen to be upon a eolian sandy material (supposed to be homogeneous from literature) e) We have no clear effects (on the concentration peak) of heterogeneity (with the probable exception of the deeper value).

Reviewer #2 Site description - The climatology is incomplete. The authors talk about the piezometric level of the free water table.

Authors answer : We will reconfigure the paragraph on rainfall data and add values for

the Potential Evapo-Transpiration data. As proposed by reviewer #1 we will add data on soil relative humidity and Evaporative demand and apply suggestion of the reviewer #2 about “piezometric level of free water table” and correct the expression. Nevertheless, the main fact is that only very small significant rain events occurred more than 100 days before the injection experiment.

Entire paragraph was rephrased. (P4, lines 17-20) “Nearest meteorological station was located at Agadir International Airport, 14 km from the sampling site. At this station, the annual rainfall was exceptionally low the year of the experiment with a value of 86 mm, whereas the average annual rainfall recorded for 1961-2004 period was 255 mm y-1 (Stour & Agoumi, 2008). The experiment started the 16th of May 2001 and concluded the 20th of June 2001. Experiment took place at the end of a 5 months pronounced dry period. Since the beginning of the year, a total precipitation amount of 12 mm was confronted to a high evaporative demand, characterized by an annual potential evaporation higher than 2000 mm y-1 (Bouchaou et al, 2008). Daily precipitations recorded at the station, since the beginning of the year 2001 were never higher than 4 mm. Recorded amounts were: 0.7 mm 25 days ago, 0.51 mm 70 days ago, 3.05 mm 75 days ago.”

Reviewer #2 : How was the water table measured exactly. with a piezometer screened at a certain aquifer depth or with an observation well screened across the free water table? It is stated that the water level was at a depth of 2.44m at the beginning and at the end of the experiment.

Authors answer : We agree: We will add this sentence for explanation: “Before excavation of the experimental pit, a 3 meters drilling with an helical hand auger allowed to encounter a water level around 2.5 m depth and to observe that the fine eolian sandy cover was thicker than 3 m in the selected site. Indeed, shallow free aquifer in sandy material was a requirement for this experiment. A 3m-long, 2” PVC tube, screened on 2 m length was used as a well-piezometer to measure the level of the free table. The tube was driven into the auger hole in order to get the first 50 cm of the screen inside

the water. Measurements of water levels were performed using an electrical flat tape water level meter. Values were corrected in reference to the soil surface level. Depth of water level was measured, one hour after the setting of the tube, a day after the filling of the injection pit and just before and after the tracer samplings (35 days later). All measurements delivered the same value (2.44m).” (P4, Line 22-32)

Reviewer #2 : Does that mean that the water level was exactly at 2.44m and did not change at all over the course of the experiment? It would be very satisfying in the assessment of the steady-state assumption and the Hydrus results to have a plot of the time series of water table depth over the course of the experiment.

Authors’ comment: Yes. The measurements were the same. Yes we expected very little changes in depth of aquifer free level as we located our experiment in time and space for this purpose: - upon a shallow free aquifer, -on a flat area, after a prolonged seasonal drying episode, under an arid climate. There is no drivers left for level change at this period: this shallow aquifer with brackish water is not used for pumping and we also located the experiment in this site because the level of water was known by local people to be around two meters depth in dry season. Functioning of the well-piezometer was confirmed by pumping a few liters and observing that the level was quickly stabilized at the same depth at the end of the experiment.

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Reviewer #2 : From analytical and/or numerical considerations it becomes obvious that even small changes in water table depth will have considerable transient impacts on the soil moisture profile over the time scale under consideration. This has also been shown in previous studies.

Authors answer : Yes we agree and we added some hydrus 1D simulations to take in account this aspect (Tab. 4). On one hand, computations show that steady state estimates are not so sensitive to water level depth (10 cm change would not explain differences between peak measurements and steady state rates). On the other hand,

steady state rates are very sensitive to changes on water content at 50 cm depth, particularly in the case of under-estimation (0.0595 % water content at 50 cm depth would allow steady state rates to be in the range of the peak displacement computed rate).

We will add this sentence: “The influence of an error on the field measured volumetric water content and a change of water level depth could be characterized on Hydrus simulation estimates (Tab. 4). An increase of 1% in water content at 50 cm (i.e 0.0595 instead of 0.0495) led to decreases of fluxes between 13% (37 cm data set) and 83% (112 cm data set). On the opposite, a decrease of 1% (i.e 0.0395 instead of 0.0495) resulted in rate increases between 6% (37 cm data set) and 37% (112 cm data set). Similarly, a 10 cm increase in depth water level (i.e 2.54 m instead of 2.44 m) led to rate decreases between 20% and 27%. Free aquifer level located 10 cm higher (2.34 m depth) led to increased rates by 21 %(37 cm data set) to 36% (53 cm data set).” (P10 Line 2-6)

Moreover, another sentence was inserted in discussion paragraph: Higher steady state rates than the value computed from peak displacement cannot be explained by smaller depths of free water level or lower water contents that would emphasize the difference. Effect of a 10 cm increase in depth (2.54m instead of 2.44m) would not be enough to account for the observed difference, but steady state rates for 35 days obtained by setting upper boundary condition to higher water content (0.0595 at 50 cm) resulted in a larger interval [0.14-3.27cm] (Tab 4.) This later range includes the value measured by peak displacement (0.351 cm for 35 days). (p11; lines 28-32)

- Reviewer #2 : Section 2.3 - The first paragraphs on the inversion are difficult to follow. What do the authors mean by observation nodes data. etc.? Definition of the coordinate system is missing that determines the sign in equation 4. The part on the integration can be omitted. since standard techniques are available today (I am not sure why the authors resorted to a spreadsheet application. which may be highly inaccurate).

Authors comments : We took the expression “Observation nodes” from the help manual inside Hydrus 1D software. But the reviewer is right the sentence will be changed to enhance understanding.

“The inversions were based on selected data extracted from the laboratory drying curves of saturated undisturbed soil samples. 8 couples of time and tension heads and 8 couples of times and water contents were selected. Initial van Genutchen parameters values were approximated by direct method in a spread sheet file and consistency was checked.” The next sentence was already modified from reviewer #1 suggestion.

- Reviewer #2 : Definition of the coordinate system is missing that determines the sign in equation 4.

Authors answer : Reviewer is right. Eq. 4 is to be understood as a 1D equation with a coordinate system referenced from the soil surface. z axis being vertical and positive with depth, Suction head being negative (when soil is dry), and so, resulting E being positive when evaporation flux takes place and negative in case infiltration takes place.

Indications will be added “Z =0 at the soil surface and Z>0 inside the soil” (P7 line 3)

Reviewer #2 : If the part on the integration is retained in the manuscript the comparison with the numerical solution using Hydrus needs to be shown.

Authors answer : It is the case and comparison as being performed with Hydrus1D simulations that showed good correlation but Hydrus estimates being higher than previous (Eq 5) rate, (and also, of course, higher than peak displacement measurements) . The splitting of the former table 1 allows to clearly confront Tab 3 (eq5 computations) to Tab 4. (Hydrus results).

Reviewer #2: Section 3.1 - This section is convoluted and difficult to read in my opinion.

Authors answer: Reviewer is right. we added some words to ease comprehension . We added: with depth p 8, line 29 Measured saturated p9 line 5

Reviewer #2 : Where are the results from Hydrus simulations for shallow depths (<50cm) in Figure 2?

Authors answer: We understand the surprise of the reviewer, but as explained in the introduction, in paragraph 2.1 (line 4-5) and in discussion, there is no soil data for suction lower than – 800 cm (limit of tension head measurements with ceramic cups). Then, simulation for upper layers of dryer soils with Hydrus, considering vapor transfer is not fully reliable. So we located our experiment in lower part of the profile where tension heads were higher than -500 cm.

We will introduce inside the figure 2 caption: As water contents were very low in the upper part of the profile (depth <50 cm), significant vapor transfer was suspected. Consequently, top layer of the profile was not considered in the simulation.(P23 line 8-9).

Reviewer #2 : Section 3.2 - Again. this section is convoluted and difficult to read in my opinion. Lines 5 to 6. where do I find the values 0.59 to 3.46 in Table 1? Looking at the values I see a range from 0.1 to 3.74. Also on line 7. where do I find the range 0.8 to 1.2? I believe I see a range of 0.47 to 1.71. although “Average” in Table 1 is not defined as the geometric average. Table 1 is difficult to understand and the caption is incomplete.

Authors’ answer : agree Changes were proposed in accordance with reviewer#1 - The paragraph has been totally reworded (see this document page 7 , P9 Line s 11-19) - Splitting the tables allow better distinction between v Genutchen parameters (tab .2) , Integration results (Tab 3) Hydrus simulation results (Tab 4) (see this document pages 8,9,10). -

Reviewer #2 : Section 3.3 - Extrapolating the flux estimates from a 35 day experiment to a yearly average is a stretch in my opinion.

Authors’ answer: As we understood the point of the reviewer, reviewer is delivering the

opinion that extrapolating to a yearly value should not been done. On one hand, we agree because the value is relevant of a particular period which was carefully selected (end of a long dry period with a particular ground water level). On the other hand, most of the authors used this kind of unit in the references cited. The obvious advantage is to facilitate comparison with elements of the hydrological cycle (Rain. ET. recharge. . .) and to give an immediate idea of the range of fluxes the study is dealing with. In this manuscript we used cm for 35 days for raw values of computations (Tab. 3 and 4) and mm Y-1 for comparison with literature.

Reviewer #2 : How was the best fit of Hydrus-2D obtained with the measurements? Did the authors simultaneously fit moisture content and 2H content?

Authors answer : No, best fit is obtained for “steady state” and inverse fit is only performed on 2H contents. Objective is to obtain a realistic shape of the plume for recovering calculation. Precision on this point will be done.

Sentence modified : “Steady state for water movement fluxes was assumed and soil water flow parameters used in the simulation were those measured for 53 cm depth (Tab. 1). Soil water content profile was set corresponding to the figure 2 water contents for 53 cm data set”. (P10 Lines 22-23)

Reviewer #2 : Section 4 - In the section. the authors introduce the term “stability” in the evaporation state as the major assumption in the calculation of the fluxes. Do they mean steadystate? If so. why to they put stead-state in quotation marks through the manuscript and introduce a new and ambiguous term here? In the following. the authors refer to a long-term Hydrus simulation without providing a reference or additional specifics and results.

Authors answer : Reviewer is right we should not use stability of the evaporation state, and still use steady state. “ - Quotation marks has been removed. - A figure 5 can be introduced (that is presented in general comments) - sentenced has been modified - “To check that this equilibrium was reached during the experiment we used hydrus 1D and

simulated the evolution of the soil profile from 0.5m to 2.44m, since the beginning of the year, for all the sets of laboratory hydrodynamic parameters. The upper boundary conditions were representative, in the upper part, of daily precipitation records from the nearest meteorological station and an evaporation demand fixed to 0.5 cm d-1. Maximum suction of upper cell was set to the potential head corresponding to a water content of 0.0495 (Tab 2). The lower boundary condition was soil water saturation at 2.44 m depth. Although, initial condition assumed the water saturation of the profile, all simulations indicated a steady-state evaporation regime between injection and sampling dates and the water regime was stabilized in less than 50 days (Fig. 5).

Reviewer #2 : This is unsatisfying for the reader and does not support the results and findings of the study. The language is sometimes convolute and often ambiguous in my opinion. Some sections are difficult to follow such as section 3.1 and 3.2. Therefore. I recommend careful restructuring. and language and grammar editing.

Authors' answer : We hope that the sound modifications proposed are enough to satisfy the reviewer #2. We think that most of the language was checked and sections 3.1 and 3.2 were deeply modified. We added 3 tables, Input new hydrus simulations and exposed better the assumptions and site characteristics.

Reviewer #2 :The figures are useful though the captions need to be expanded. In figure 2. a legend is missing.

Authors' answer : We agree and we input new captions in the legend in fig 2. (See new figure 2)

Reviewer #2 :Table 1 contains a lot of information that needs to be explained more clearly in the caption and in the text.

Authors' answer : We agree, this part has been changed with suggestions made by reviewer #1 (split of the tables).

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/7/C4374/2010/hessd-7-C4374-2010-supplement.pdf

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 7757, 2010.

Table 1: Relative humidity (%), measured the 19th, 20th, 21th and 22th of June 2001, in the soil top layer on a side of the sampling pit. **For 0 cm depth measurement, the capacitance probe was located on soil surface, for 7, 10, 20, 23 and 31 cm depths probe was inserted in a 40 cm long PVC tube driven horizontally in the soil from the wall of the pit. Measurement was achieved after 5 min contact with soil moisture. (Avg = average, [Min-Max] = interval of extreme values, Nb = Number of measurements, σ = Standard deviation)**

	Late Night (02h-06h)				Midday (10h-14h)				Early night (22h-02h)			
Depths	Avg	[Min–Max]	Nb	σ	Avg	[Min–Max]	Nb	σ	Avg	[Min–Max]	Nb	σ
0 cm	81.8	[81.6-82.6]	6	0.6	47.1	[31.0-62.6]	8	9.8	75.2	[73.4-78.7]	5	2.1
7 cm	77.1	[76.5-78.0]	6	0.5	57.0	[50.0-64.6]	8	4.9	73.6	[70.3-77.5]	5	3.0
10 cm	81.0	[79.7-81.6]	5	0.7	66.4	[62.7-70.2]	7	2.5	78.8	[77.2-81.4]	5	1.8
19 cm	82.1	[81.8-82.4]	5	0.2	73.6	[69.1-77.8]	7	3.3	79.4	[78.4-81.6]	6	1.3
23 cm	86.7	[85.8-88.2]	5	1.0	79.9	[76.5-84.5]	7	3.0	84,1	[83.3-85.6]	6	0.8
31 cm	87.8	[87.2-88.9]	5	0.7	84.7	[80.2-88.4]	7	2.9	84.9	[83.6-86.4]	6	1.2

Fig. 1. newtable 1

Table 2. Van Genutchen hydrodynamic parameters measurements for 5 undisturbed soil samples. Measurements were performed using Wind methods with parameter adjustment by inversion using Hydrus (1.4) software. Resulting potential head (ψ) for a water content of 0.0495. (in bold: geometric mean).

Sampling depths	Θ_r	Θ_s	α	n	K_s	$\psi(0.0495)$
cm	-	-	cm^{-1}	-	cm min^{-1}	cm
37	0.012	0.291	0.0289	1.7770	0.2478	-455.3
53	0.030	0.287	0.0304	2.2067	0.6615	-277.6
77	0.008	0.314	0.0565	1.6320	0.6045	-416.2
92	0.014	0.295	0.0413	1.8360	0.5996	-285.9
112	0.014	0.310	0.0378	1.9157	0.3639	-266.5
Average	0.0156	0.2994	0.0390	1.8735	**0.4645**	-340.3

Fig. 2. new table 2

Table 3: Steady state fluxes (cm) for 35 days computed using Eq. (5) and Eq. (3) with 3 different sets of boundary conditions and 5 soil data sets (Tab. 2). (in bold: geometric mean). Z_1 is the depth of upper limit (cm), Z_2 the depth of lower limit (cm). Θ_1 and Θ_2 are the water contents at depths Z_1 and Z_2. Θs is the saturated water content, and $\psi(\Theta_1)$, the potential head (cm) at the depth Z_1. Sets i, ii and iii correspond to field measured conditions.

	Boundary sets	i	ii	iii
	Upper boundary	$\psi(\Theta_1)$= - 1.64 10^6cm	Θ_1=0.0495	Θ_1=0.03546
		Z_1= 0 (soil surface)	Z_1 =50 cm	Z_1 =37 cm
Van Genutchen Data sets	Lower boundary	$\Theta_2=\Theta s$	$\Theta_2=\Theta s$	Θ_2=0.07623
		Z_2=244 cm	Z_2=244 cm	Z_2=100 cm
37 cm		1.56	3.46	1.17
53 cm		0.58	1.41	1.82
77 cm		0.59	1.09	0.75
92 cm		0.72	1.33	1.60
112 cm		1.20	0.77	1.03
Geometric mean		***0.86***	***1.40***	***1.21***

Fig. 3. new table 3

Table 4: Steady state capillary rise rate (cm) for 35 days based on Hydrus simulations for 5 van Genutchen data sets (Tab. 2) and 6 sets of boundary conditions. Boundary conditions sets ii and iii are similar to Tab. 3. (In bold: geometrical averages). Z_1 is the depth of upper limit (cm), Z_2 the depth of lower limit (cm). Θ_1 and Θ_2 are the water contents at depths Z_1 and Z_2. Θs is the saturated water content. Boundary conditions sets ii and iii correspond to field measured conditions.

		Boundary conditions sets ii and iii		Aquifer level depth change		Upper water content change	
		---	---	---	---	---	---
van Genutchen Data sets (Tab. 2)	Upper boundary	Θ_1=0.0495	Θ_1=0.0346	Θ_1=0.0495	Θ_1=0.0495	Θ_1=0.0595	Θ_1=0.0395
		Z_1 =50 cm	Z_1 =37 cm	Z_1 =50 cm	Z_1 =50 cm	Z_1 =50 cm	Z_1 =50 cm
	Lower Boundary	$\Theta_2=\Theta s$	Θ_2=0.07623	$\Theta_2=\Theta s$	$\Theta_2=\Theta s$	$\Theta_2=\Theta s$	$\Theta_2=\Theta s$
		Z_2=244 cm	Z_2=100 cm	Z_2=254 cm	Z_2=234 cm	Z_2=244 cm	Z_2=244 cm
37 cm		3.74	1.13	2.99	4.52	3.27	3.98
53 cm		1.62	2.15	1.19	2.21	0.17	2.04
77 cm		1.26	0.79	1.03	1.54	0.99	1.39
92 cm		1.34	1.87	1.02	1.75	0.42	1.74
112 cm		0.83	1.14	0.62	1.12	0.14	1.14
Geometric mean		***1.53***	***1.33***	***1.18***	***1.98***	***0.50***	***1.86***

Fig. 4. new table 4

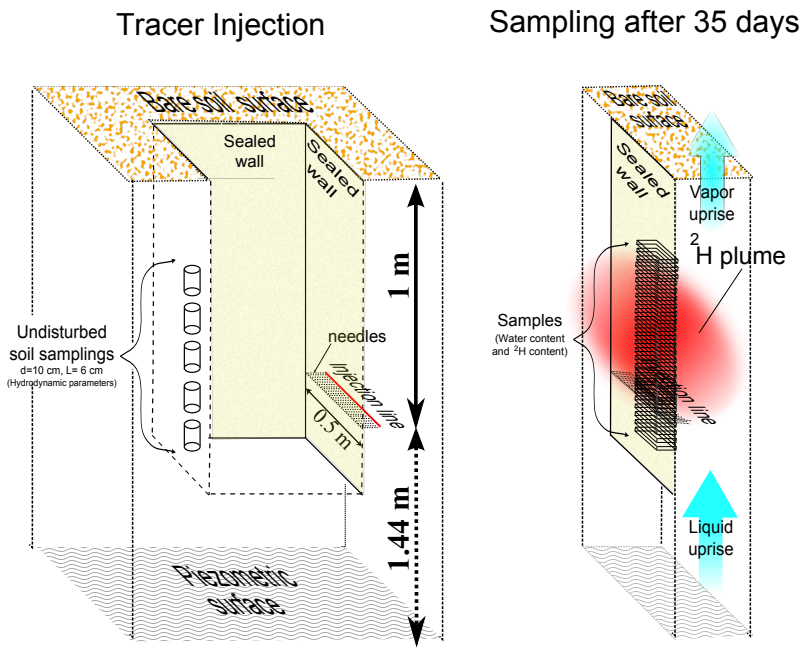

Fig. 5. corrected figure 1

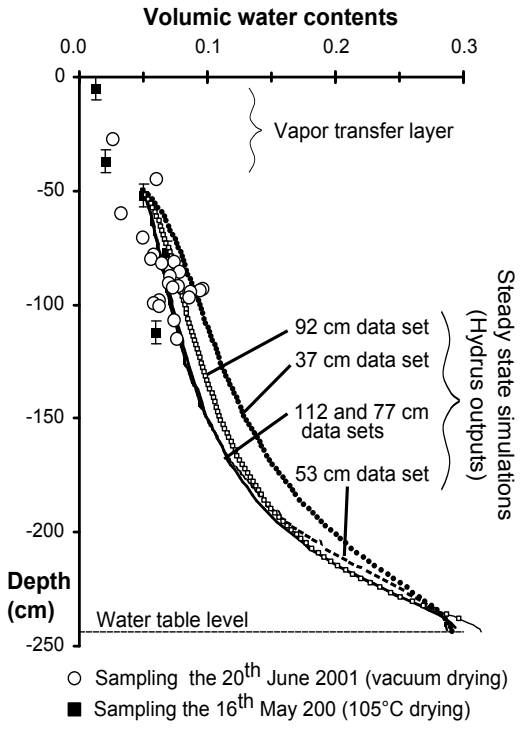

Fig. 6. corrected figure 2

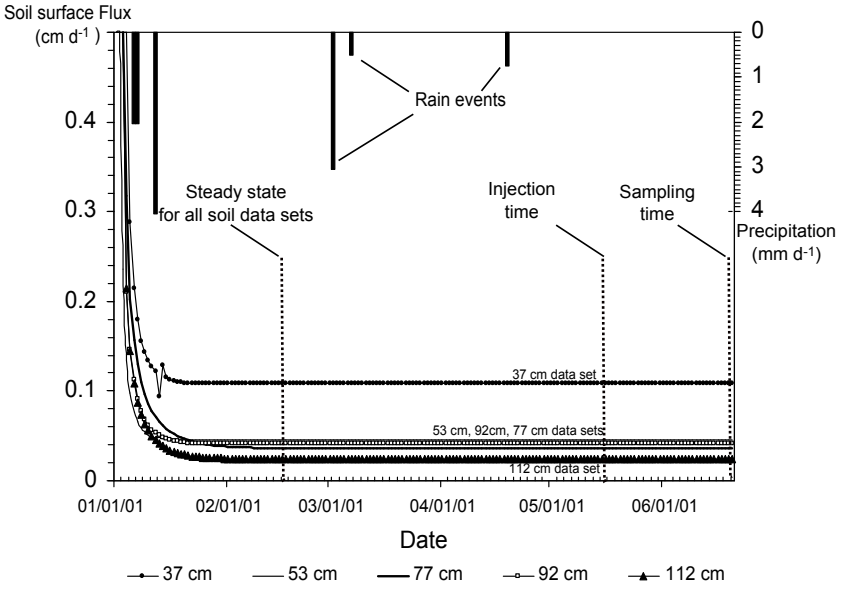

Fig. 7. new figure 5