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Hydrology and Earth System Sciences Discussions

Interactive comment on "Water storage change estimation from in situ shrinkage measurements of clay soils" *by* B. te Brake et al.

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We thank the reviewer, R. Stewart, for his helpful comments on our manuscript. Below we reply on the comments from the reviewer. For readability, the major parts of the reviewer's comments most relevant for discussion are quoted (indicated by GC or SC for general or specific comments), followed by the author's response (AR). In some cases the response to multiple comments is combined.

General Comments

GC1: "The authors assume constant, isotropic shrinkage throughout the moisture range. This is clearly not the case, based both on other studies and the data pre-

sented in this study (as in the slopes greater than 1 in Table 2 and Figure 5). If the geometric factor, r_s, is less than 3, then the volume loss could be less than the water loss and the slope of the shrinkage curve would be less than unity. r_s must be independently measured to accurately relate ΔV and ΔW based on the methodology of this study."

AR: We agree with reviewer that the slopes larger than 1 in Table 2 and Figure 5 indicate that r_s should be smaller than 3 in dry conditions in the upper soil layers. We will extend our analysis of in-situ shrinkage measurements to better assess the soil moisture dependency of the r_s factor, whereas we only did so tentatively in the current manuscript (P.31, l.24 through p.32, l.19.). We seek an approach to estimate the soil water balance from easily measurable soil surface elevation variations. This should ideally be attempted with a minimum of additional data requirements. The assumptions of isotropic and normal shrinkage are attractive for such purposes, and have been demonstrated to be valid under favourable circumstances (Bronswijk, 1990, 1991a; Bronswijk and Evers-Vermeer, 1990). But we agree with the reviewers these assumptions need to be examined critically and will revise the paper to reflect this. We will clarify our goal and identify assumptions early in the paper to improve the coherence of the manuscript. Based on the soil moisture dependency of the r_s factor we are planning to indicate a range of realistic volume and water storage changes and assess the potential water balance errors.

GC2: "The corrections used to account for the effect of changing layer thickness on water content (Equations [5] and [6]) are problematic, as it appears that as a result ΔV and ΔW may be inherently linked. For example, Figure 5 shows that the ΔW values are increasing beyond 60 cm, even though the deepest CS616 probe (at 80 cm) reports no appreciable change once at field capacity. This leads me to believe the plotted changes in ΔW are due only to the measured change in layer thickness. Of course in that case the shrinkage for those layers would appear to be normal. In reality, this only works if the shrinkage is indeed isotropic, but again r_s would need to be independently measured to verify this assumption."

AR: With Equation [5] and [6] we assign a section of the soil profile to each soil moisture sensor based on their actual position, not their original position at the time of installation. We do so to ensure we multiply each soil moisture content measurement with the correct depth interval for which this measurement is representative (that is, assigning each depth to the closest soil moisture sensor). The inherent link between the soil layer thickness measurements and independent soil moisture measurements is not problematic, but necessary: a soil layer thickness change necessarily induces a change in the volume of water stored in that volume and the total amount of water in the soil has to be corrected for volume change.

The references to Figure 5 and Table 2 in this comment do not seem to be correct: Figure 5 shows relationships between changes in storage and volume of soil slabs reaching from the soil surface down to the indicated depths, cumulative over the measurement period. The main difference in maximum (eventual) soil water storage change between the thickest layers (0-60, 0-100 and 0-150 cm) originates from a difference in water loss in the structural shrinkage phase, which is directly related to the total layer depth under consideration (see Table 2). Water loss from these thick layers outside the structural shrinkage phase ranges from 72 to 78.05 mm based on CS616 sensors and 58.85 to 65.57 mm based on EC5 sensors. For the thickest layer the soil water storage change is larger due to a very slight change in the deepest soil moisture sensors (multiplied by a depth interval of 700 mm), compounded by storage changed due to lowering groundwater level and the consequent increase in the depth of the capillary fringe.

Also, the comment suggests that only isotropic shrinkage can be normal - if the total loss of volume during anisotropic shrinkage equals the loss of water, shrinkage would still be considered normal.

The data from two consecutive years are not linked so closely that they need to be

presented chronologically. The line of thought of the paper benefited from presenting the 2011 data before those of 2010 - the rainfall regime in 2011 resulted in a much more prolonged and monotonic drying stage than 2010, and thus could be more easily interpreted. 2010 data for Field A where not available due to datalogger failures in the field campaign.

Based on the soil moisture dependency of the r_s factor we are planning to indicate a range of realistic volume and water storage changes. We are also planning to include an additional figure, illustrating the errors made by estimation of water storage change of the entire unsaturated zone by the approximations made in our manuscript (by using Bronswijk's approach to calculate volume change) and use this to discuss the usefulness of Bronswijk's assumptions for calculating the water balance of a soil profile.

Specific Comments

SC1: "p. 18 l. 19 – This is neither shown nor proven in this paper, and instead relies only on observations from other works. As such it seems out of place in the abstract."

AR: Agreed. Will be adapted.

SC2: "p. 19 l. 18 – I don't see how wireless sensors give any greater spatial coverage than wired sensors, except for requiring fewer dataloggers."

AR: Wireless sensors as such will not give any greater spatial coverage, but wireless networks of sensors allow monitoring of soil water content in space and time over larger areas than would be feasible with individual sensors (e.g Bogena et al., 2010).

SC3: "p. 20 l. 6 – This would be improved with a brief statement about why these measurements were only "partly successful"."

AR: The text will be improved, but some of the reasons were mentioned on p19 l.27 – p. 20 l. 4.

SC4: "p. 22 l. 15-17 – This may be true for certain layers or elementary volumes, but not for the whole profile. Volume loss cannot exceed water loss unless solid material is also being lost from the profile."

AR: We understand that the reviewer is right here. Change in aggregate or soil particle configuration (leading to a 'denser' soil) will result in specific volume (e.g. grams per cm3) increase of this part and simultaneous be counteracted by macropore/crack specific volume decrease due to the compressed configuration. This will therefore not influence the shrinkage curve slope of the total profile if expressed in specific volumes. Slopes larger than 1 could be an artefact if crack volume and vertical deformation are not independently measured, but this should then result in a change of r_s factor. We will adapt the text here and clarify the conditions to which this statement applies.

AR to SC5 and SC6: Agreed, the equation with r_s as a variable, and a description of sensor installation procedure will both be included.

SC7: "p. 27 l. 4-7 – Have the authors examined if the changing bulk density of a shrink-swell soil affects the calibration?"

AR: No, we examined the paper by Fransesca et al. (2010) for EC5 and the subtle differences between the calculated changes in water storage based on the different calibration equations and parameter sets supplied by Campbell Scientific for the CS616. We concluded from these sources that the effects were too small to warrant a calibration for different soil densities.

SC8: "p. 28 l. 24 – p. 29 l. 4 –Were the readings between the disdrometer and the weather station consistent for the overlapping ranges? If not, could a correction be applied for the weather station data used to fill in the disdrometer data."

AR: Yes, apart from expected (non-systematic) differences due to spatial variation of precipitation, records in the overlapping range were found to be consistent.

SC10: "p. 31 l. 11-13 – As in comment 1 above, without having actual laboratory data

for the shrinkage behavior of individual aggregates, any comparison remains conjecture. While I appreciate that this is not the main point of the study, there are multiple references to how these specific soils will behave differently at the field and laboratory scales, without any data to show this."

AR: We understand that the shrinkage curve of individual clay aggregates and the ΔV-ΔW relationship measured in the field can not be compared as done here. We will rephrase the text accordingly and point towards references showing the differences (by improving and extending p. 21 l. 21 – p. 22 l. 22. with appropriate references, such as Chertkov, 2007).

SC11: "p. 32 l. 2-5 – This sentence is not very clear, nor is it evident to what the sentence is referencing. I suspect these data are captured within Figure 5, but there is no way to link dates with data points. Instead, this may be more straightforward if the authors reference the ΔV and ΔW ranges within Figure 5."

AR: We will improve these references.

SC12: "p. 34 l. 13 – This perceived shrinkage of the lowest layer while everything else is swelling is surprising. Do the authors have a theory about why this might be, or is it possibly measurement error?"

AR: A possible explanation for this is given in p. 37 l. 3-5. We will rephrase to indicate this section relates to p. 34 l. 13. We do not believe swelling in the lower layer is underestimated as a result of a measurement error, since measurements of layer thickness change of the deepest layer deviate from the other layers in two consecutive intervals. Besides, the layer thickness of the deepest layer is restored at the end of the measurement period.

SC13: "p. 35 l. 12-26 – This paragraph is not very clear, particularly as to which data are being described. I suspect that the scatter in the EC-5 data may be due to contact issues with the probes in a shrink-swell soil. It has been my experience that some sensors may either cause or be located near a crack, which can cause non-linear, hysteretic-like data. Are the authors certain that the sensors are maintaining good contact throughout the study?"

AR: We will clarify the references to data. We will consider including a figure showing EC5 data, since the soil moisture content per sensor is quite stable (indicating contact loss was probably not an issue) and can therefore probably not be used as an explanation for the scatter observed in Figure 7.

SC14: "p. 37 l. 3-5 – As the EC-5 data are not shown directly, it is hard to assess the validity of the authors' hypothesis of sugar beet roots causing the decrease of moisture at 100 cm. Could a crack have developed near that sensor?"

AR: In field B, cracks at 100 cm depth are unlikely (the percentage of clay at that depth is only 3.4%). Furthermore, the sensors above the sensor that recorded the water loss at that depth showed no indication of the presence of a crack. We cannot confidently certify that the sugar beet roots were responsible for the water loss at 1 m depth, but all data considered it seems a plausible option.

SC15: "p. 37 l. 16-17 – If much of the water loss is from structural shrinkage, then surface elevation measurements can not accurately be related to soil water content until the soil has entered a normal shrinkage regime (ie. the measurement will be insensitive at the wetter end of the moisture curve). This should be discussed."

AR: Agreed. We will include a discussion of applicability of the relation between water storage change and soil volume change in the case of profound water loss in the structural shrinkage phase.

Authors response to Technical comments:

TC1-3 and 5: agreed

TC4: No, we mean to say that EC5 sensors measure within aggregates, so on a scale that includes aggregates and intra-aggregate pores, but not the pores between

aggregates.

References

Bogena, H. R., Herbst, M., Huisman, J. A., Rosenbaum, U., Weuthen, A., and Vereecken, H.: Potential of Wireless Sensor Networks for Measuring Soil Water Content Variability, Vadose Zone J., 9, 1002–1013, doi:10.2136/vzj2009.0173, 2010.

Bronswijk, J. J. B.: Shrinkage geometry of a heavy clay soil at various stresses, Soil Sci. Soc. Am. J., 54, 1500–1502, 1990.

Bronswijk, J. J. B.: Drying, cracking, and subsidence of a clay soil in a lysimeter, Soil Sci., 152, 92–99, 1991a.

Bronswijk, J. J. B. and Evers-Vermeer, J. J.: Shrinkage of Dutch clay soil aggregates, Neth. J. Agr. Sci., 38, 175–194, 1990.

Chertkov, V.Y. The reference shrinkage curve at higher than critical soil clay content, Soil Sci. Soc. Am. J. 71, 641-655, 2007.

Francesca, V., Osvaldo, F., Stefano, P., and Paola, R. P.: Soil Moisture Measurements: Comparison of Instrumentation Performances, J. Irrig. Drain. E-ASCE, 136, 81–89, 2010.

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