

Interactive comment on “True colors – changing perceptions of hydrological processes at a hillslope prone to slide” by P. Schneider et al.

P. Schneider et al.

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We thank the referee for the detailed comments and suggestions. Please find our response to the comments below.

Referee #1

1. Part of the title – “changing perceptions” of hydrological processes at the hillslope is misleading.

-> Reply: We see the point of the referee concerning the title and we will change the title accordingly to “True colors – experimental identification of hydrological processes at a hillslope prone to slide”. Just to clarify our previous title: we meant that OUR

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perceptions were changing during the experiments.

2. TDR calibration in clay soils (G horizon): is it factory (Topp curve) or locally performed?

-> Reply: Our TDR's were not locally calibrated, thus we applied the manufactures calibration (Topp curve). Text will be added to reflect this information.

3. NaCl experiment may impair TDR measurements (different calibration in saline soils on top of clay itself).

-> This comment is answered together with point 4.

4. NaCl could promote shrinking in clays and increase hydraulic conductivity as compared to distilled water (clay swelling).

-> Reply: In arid climates these two points (3+4) are an important issue, especially in the context of irrigation and thus have been addressed by many researchers. However, at the Rufiberg the climate is humid and the deeper soil horizons stay permanently saturated (Gr) or near saturation (Go) throughout the year, which is reflected in the vegetation by a dominance of hydrophilic plants (e.g. *Juncus effusus*, *Juncus inflexus*, *Ranunculus*, and *Pimpinella* indicate that the test site is permanently wet; see Brönnimann et al., 2013). Before applying NaCl (diluted in approx. 100 L irrigation water) we irrigated the plot with rather large amounts of rainfall (exp. I: 40 mm/2h, exp. II 25 mm/1h). These applied rain volumes had most probably filled the available pore space in the Go horizon entirely (exp. I) or at least to a large extent (exp. II). If highly concentrated NaCl enriched water would have entered the soil matrix in the Go or Gr horizons in the vicinity of the TDR sensors, the TDR signal would have changed significantly, which was not the case. Even if the NaCl solution would have infiltrated into macropores, NaCl would most probably have not entered the soil matrix, as it was already saturated (Gr) or saturated during an early phase of the irrigation (Go). As the exchange between macropores and matrix is limited (see brilliant blue experiments),

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the chances for NaCl induced clay swelling is low. Moreover, such NaCl induced clay swelling needs time, therefore it is unlikely that this process has influenced the porosity during our experiments. Furthermore, after the NaCl application we continued to sprinkle the soil for another two hours (exp. I), or another hour (exp. II), so that most of the salt solution probably was flushed out already during the experiments. In light of this information the TDR's measurements were not likely impaired and clay swelling did not influence the data of our sprinkling experiments.

5. As suggestion for future experiments at this instrumented plot: last two comments would not apply if stable isotopes are applied instead of NaCl and fluorescein (both also prone to adsorption on soil matrix), stable isotope analyzer is available at the workplace of the authors and would support this experiment without any questions posed. Natural water from Lake Zug could be a good tracer itself, if not, certainly enriched with affordable amount of deuterium.

-> Reply: We applied artificially enriched stable isotopes in the 2nd experiment in October 2011. We added 1 kg 70 ± 1 at% Deuterium to the sprinkling water from Lake Zug. However, the mixing of the added enriched Deuterium with the lake water was incomplete in the water tank (thus no constant input throughout the sprinkling). This was identified when analyzing the samples of our on-site rain collectors at the irrigation plot. We measured highly positive (!) Deuterium values $\delta\text{-}2\text{H} > +100\text{‰}$ (V-SMOW) in the surface-flow collector and both drainages. As the input due to the incomplete mixing in the sprinkling water reservoir unfortunately varied over time, we did not include these data in the paper.

6. On 8239 authors refer to nonexistent model of Campbell CR100 logger (correct to: Campbell Scientific CR1000).

-> Reply: We will correct this typo to "Campbell Scientific CR1000".

7. For fig. 4 and 5 - unify the date format 03.08.2011 and 6 October 2011 in the caption.

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-> Reply: We will change 6 October 2011 into 06.10.2011.

8. On 8271 - fig. 5 - 3rd graph - sensor W1 exhibits abrupt dropdown and it can be observed as a gentle dip on sensor W5 and W6 as well, that does not seem a natural behavior of groundwater table, could you explain?

-> Reply: We sampled the groundwater wells W1, W2, W5 and W6 at this time (approx. 1:50 h after the end of the sprinkling). We will add a sentence to explain this in the text.

9. Those two experiments (3.8.11 and 6.10.11) are performed in similar manner in terms of similar rainfall/sprinkling intensity (nearly the same) but quite different response in terms of overland flow - by one order, antecedent moisture is nearly the same, groundwater table is different in "opposite manner", higher overland flow is observed when initial groundwater is lower but rising quicker in October according to figures. -> Reply: As a consequence of the findings of the 1st sprinkling experiment, where we observed overland flow when rainfall intensity was higher than 20 mm/h, we designed the 2nd experiment to gain more information about the onset of overland flow. The 2nd experiment produced significantly more overland flow, after the H horizon (and partially the Go horizon) was saturated (or near saturation) and the sprinkling intensity was beyond the drainage capacity of the H-horizon. This explains the much higher overland flow volume in the 2nd experiment.

10. (10a) The second experiment in October (in slightly drier topsoil) is the one with slower rise of moisture (or groundwater table)-according to the text 8243/15 (which seem not to be true if confronted with fig.4 and 5), earlier NaCl application in latter experiment (August after 2hrs, October after 1 hrs, that might support the comment of change of hydraulic conductivity of G horizons and changing pattern of overland flow.

-> Reply: We state in the text 8243/17ff, that in the 2nd experiment the rise of GW levels and soil moisture are "delayed" (time off-set) but not necessarily slower (rate of change). Thus, we do not see a mismatch between text and figures.

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(10b) Some of NaCl might be in the profile in October from experiment performed in August) Nevertheless 10x higher overland flow intensity seems to hard to believe (check either data for the unit conversion error first).

-> Reply: This is not a unit conversion error. More details are given in the reply to point (10c).

(10c) Is this explainable by the 20 mm/h precipitation threshold?

-> Reply: The rainfall between the two experiments was about 254 mm (rain data from Zugerberg, ca. 6.5 km N of Rufiberg), this together with the initial electrical conductivities in the 2nd experiment make it possible to assume that there was no significant amount of NaCl from the 1st experiment left. As overland flow is a threshold process, it is possible that this varies by orders of magnitude even if rainfall input did not vary that much. The simple explanation is that we have been just at the threshold rainfall rate for overland flow generation. However, we can't clearly attribute this significantly higher (one order of magnitude) overland in the 2nd experiment to the "SOF threshold" alone. In the 1st experiment, sprinkling water quickly infiltrated and started to drain as organic layer interflow (a form of SSF) after at least parts of the H horizon were saturated. Only after increasing the rainfall intensity, "return flow" and/or SOF occurred. [interpretation A] One interpretation, why the SOF is significantly higher in the 2nd experiment, is that due to the high initial rainfall intensity the entire H horizon is saturated "up-to-the-top" (no infiltration excess = hortonian overland flow (HOF) in the beginning of the sprinkling indicates the high infiltration capacity of the soil) before the activation of organic layer interflow (after the matrix is saturated), resulting in a significantly higher fraction of SOF and return flow ("pseudo-overland flow" e.g. via mole-micro-tunnels) into the surface flow collector. In short, the 'perched' water level in the H horizon might be significantly higher during the 2nd experiment than in the 1st experiment. [interpretation B] As later mentioned by Referee #1, another explanation could be a significant increase of air-entrapment in the organic topsoil result in increased saturation of the uppermost zone of the H horizon paralleled by a reduced drainage by organic layer interflow. How-

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ever, these interpretations are quite speculative, as we unfortunately have neither soil moisture nor water level measurements in the H horizon.

(10d) (Paper suggest saturated hydraulic conductivity of G horizons (soil matrix) as 10^{-9} to 10^{-10} m/s ie 0.0036-0.00036 mm/h), completely of the range of suggested threshold, therefore topsoil and preferential flow in G horizons are the environment/mechanism responsible for the outflow dynamics) as mentioned in the caption on the fig.8. This seems to be crucial mechanism, but no topsoil hydraulic conductivity, porosity and thickness of the topsoil horizon is given in the paper (indirectly and insufficiently mentioned in 8251/5), please provide such information.

-> Reply: A table will be added to the manuscript to provide data about total porosity and saturated hydraulic conductivity of the Rufiberg's gleysol based on experiments performed by Maries (2011, data shown in table 2 in Brönnimann et al., 2013). Unfortunately the saturated hydraulic conductivity k_{sat} in the topmost layer (7-16 cm) could not be determined with the applied method (Oedometer measurements to determine soil properties of undisturbed soil samples in the lab). The quality of the topsoil sample in 7-16 cm depth – specifically in terms of root-holes and organic content – made it impossible to produce meaningful data.

11. One possible effect in October experiment is topsoil air entrapment which would attribute to higher overland flow.

-> Reply: Yes, this could also contribute to the significantly higher overland flow in the 2nd experiment. However, our data from both experiments support the interpretation that rainfall intensities > 20mm/h are beyond the drainage capacity of the topsoil (saturation overland flow), and not infiltration excess overland flow (hortonian overland flow = HOF), as the onset of overland flow in the 2nd sprinkling experiment starts after approx. 50 minutes (figure 5). This is a clear indication that the runoff response is not dominated by infiltration excess. Also in the first sprinkling, overland flow occurred when the intensity was beyond 20 mm/h for a longer period.

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12. Could authors make a summary of total flows-volumes of SSF/SOF and total masses NaCl (conductivity converted) and fluorescein applied and retrieved at the downslope collectors (or observation points presented on fig. 4 and 5) related to total mass applied (absolute or relative numbers) as complementary table to fig. 4 and 5?

-> Reply: We will add such a table the manuscript illustrating the mass of the applied tracers and their recovery for both experiments.

13. How much natural/artificial precipitation- "soil profile flush" occurred in between the experiments to flush out the August-NaCl/fluorescein prior to October experiment?

-> Reply: In the two months after the 1st sprinkling experiment approximately 254 mm rainfall fell at the Rufiberg. Total rainfall estimates for the Rufiberg are deduced from the nearby MeteoSwiss rain gauge at Zugerberg (920 m), 6.5 km N of the Rufiberg.

14. Final dye experiment (imaging) contradicts the findings of sprinkling (NaCl/fluorescein) experiment, according to authors at 8245/20-25, suggesting no intensive lateral flow in the subsoil (G horizons) (thus vertical only) flow. Flow at G horizons as suggested from NaCl/fluorescein experiments is present in the form of preferential flow in the clay cracks (small volume, but high water/mass transfer rate in such channels), with minor color staining. I do not see any contradiction here. Based on the images on fig.3 (8267) deeper horizons show non-negligible staining (preferential flow can conduct masses in single percents of the volume/area, smaller than seen in this experiment)

-> Reply: The stained structures in the G horizons are vertically oriented. When digging out the profiles (1-5 days after the dye application), earthworm burrows were still filled with liquid dye. The earthworm burrows are typically vertically oriented and aerate the Go-horizon. When we dug out the drainages (this was the starting point for the excavation of the soil profiles), we could clearly identify how the dye-colored water was 'laterally bridging' flowing the 3 m towards the drainages in the H horizon (organic layer interflow) and then infiltrating into the deeper soil horizons along the trench walls

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originating from the excavation pit when installing the drainage pipes (0.25 m and 1 m depth). We started excavating profiles at drainage pipes to a depth of 1.3 m, but we could not identify a single stained soil pipe in the G horizons over the entire 10 m width of the drainage pipes. Additionally, G-horizons outside the dye irrigation area were only stained, if the H-Horizons above these areas were stained too. Together, these are clear indications that lateral-downward flow towards (parallel to the slope's gradient and the soil surface/horizons) the drainage pipes is limited to the H horizon, whereas in the G horizons vertical macropores were stained "dead-ends", which were not connected laterally in the soil. In case the macropores are connecting to the bedrock (e.g. at shallow soil covered bedrock outcrops), a lateral connection parallel in the bedrock is possible, as data from the deep boreholes suggest by their reaction to the sprinkling experiments (Brönnimann et al., 2013). In our paper we focused on the soil and preferential flow in the soil, whereas the Brönnimann paper focuses more on water movement in the underlying bedrock.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 8233, 2013.

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