Responses to the comments of Anonymous Referee #1

It's my pleasure to review hess-2017-292 "Depth scaling of soil moisture content from surface to profile: multi-station testing of observation operators" by Gao et al. The authors try to use Cumulative Distribution Frequency (CDF) matching method to build the observation operators and adopt this method to predict profile soil moisture from surface measurements. This is a re-submitted manuscript with previous ID "hess-2016-617". The authors do not provide a response to previous reviewer's comments to indicate what has been changed in comparison to previous version, and I find that the results presented in the two versions are significantly different while the data and method are identical. In addition, I'm curious about the transferability of the proposed method, for example, how can the authors apply their method to satellite products? According to these, I suggest to reject this paper. My concerns are as follows.

>> Thanks a lot for your comments. Yes, this is a resubmitted manuscript based on the previous rejected paper hess-2016-617. We had addressed every single comment of the two reviewers of the paper hess-2016-617 whereas failed to upload the responses before the due time because of a number of reasons. But we emailed our responses to the two reviewers (Prof. Wolfgang Wagner and Prof. Na Li) before the resubmission and they generally agree with our responses. The resubmitted paper hess-2017-292 is a thoroughly revised manuscript according to the reviewer's comments. We have made recalculations for all stations in question because there is something wrong with the original procedure of the CDF matching. We have also redrawn all figures. This is why the results in the hess-2017-292 are clearly different with the former one. During the resubmission procedure, we were not sure whether we should upload the responses and thus we only upload the revised paper. And this time we have added the responses to the comments of previous reviewers as a supplement by posing a short comment. In this manner, the responses can be more visible to other referees and readers.

For the transferability, every method, including the data assimilation and analytical methods, in fact need prior soil moisture data to improve and test its robustness. In this paper, we mean that if the observation operators (polynomial) derived by the CDF matching is tested robust, we can use remote sensing soil moisture (generally shallower than 5 cm) as inputs to predict profile soil moisture *via* these simple operators.

Major Concern

1. The results presented in current version are significantly different from the previous version while the adopted data and method are identical, for example, Table 2 vs. Table 2 in hess-2016-617, Figure 3 vs. Figure 5 in hess-2016-617, why?

>> In fact, there was some wrong with the procedure of the CDF matching method in the hess-2016-617 and thus produced unbelievable results. According to the comments of Prof. Wagner, we corrected this procedure, made recalculations and redrew these figures. Therefore, the Table 2, Figures and also texts in hess-2017-292 significantly different with the former paper.

2. It's suggested to provide a response to previous reviewer's comments to indicate what has been changed.

>> We agree. We have uploaded the responses to previous reviewer's comments as a supplement

by posing a short comment. In this manner, the responses can be more visible to other referees and readers.

3. A fifth-order polynomial fit is adopted, but I do not see any fit parameters for the selected stations. In addition, I'm wonder the transferability of these fit parameters, for example, can these fit parameters applicable for the similar climate condition without further calibration?
>> Thanks for the comments. We did not indicate these parameters in the paper and did not test the spatial transferability of observation operators in a given climate. This is interesting, and we would do this work and show the results if we have a chance to revise our paper.

4. The authors mention the prediction of profile soil moisture from satellite based surface measurements in the Introduction part, I'm thus curious about how can the authors apply their method to satellite products?
>> In this paper, we mean that if the observation operators (polynomial) derived by the CDF matching is tested robust, we can use remote sensing soil moisture (shallower than 5 cm) as inputs to predict profile soil moisture *via* these simple operators.

5. In the Introduction part, the authors also argue that "continuous and accurate measurement of profile soil moisture, however, is difficult because of expensive field measurements", but they also indicate in the Abstract that "the findings here have the potential to be applied in profile soil moisture prediction from surface measurements at a range of environments if the target site has long enough (two years) soil moisture observations even with coarse temporal resolutions", then I'm wonder how their methods address the drawback of in situ profile soil moisture measurements, since the methods depend on the calibration that also needs the profile soil moisture measurements.
>> To our knowledge, every method, including the data assimilation and analytical methods, in fact need prior surface and profile soil moisture data to calibrate the parameters and validate its feasibility and robustness. Here we mean that if robust observation operators are built we only need surface measurements to obtain profile soil moisture.

6. The Title of the manuscript is confusing, for example, what do you mean by "depth scaling", and what's the meaning of "observation operators".
>> Depth scaling means scale surface observations to profile soil moisture. Observation operators is first introduced by Reichle and Koster (2014) and it denotes the polynomial built by the CDF matching method.

Reichle, R.H., and Koster, R.D.: Bias reduction in short records of satellite soil moisture, Geophys. Res. Lett., 31 (19), 2004.

Minor Concern
1. Page 2, Line 4, can the cosmic-ray probes measure surface soil moisture directly?
>> We have not used the cosmic-ray probe to measure soil moisture. We got this knowledge from the literature, for example, Peterson et al. (2016) where they defined surface soil as the top 20 cm.

Peterson, A.M., Helgason, W.D., and Ireson, A.M.: Estimating field-scale root zone soil moisture using the cosmic-ray neutron probe. Hydrol. Earth Syst. Sci., 20, 1373-1385, 2016.

2. Page 3, Line 29, "A total of 12 stations were chosen for analyses according to the objectives of this study". This sentence is not clear. I still do not understand why the authors only select 12 stations out of the more than 200 SCAN stations. In the previous version, the authors mentioned that 31 stations were selected, why the numbers are changed?
>> In fact, we also used 12 stations in the hess-2016-617. The text that 31 stations were used was a careless mistake. Please also see our explanations in the responses to previous reviewer's comments in the supplements. In this paper, we used three stations as three replicates for each of three climate regions and three other stations to test the effects of data lengths on the performance of observation operators. We only used 12 stations but not all of the SCAN stations for two primary reasons. On the one hand, we argue that three replicates are generally enough to test the feasibility of the observation operators. On the other hand, a lot of SCAN stations lacked considerable data at one or several depths especially in the humid continental and humid subtropical climates. We selected these stations because they have only a few miss in the data.

3. Page 4, equation (1), I do not understand why the authors use this equation to calculate profile soil moisture, please provide corresponding reference.
>> This equation considered the weight of soil thickness since the thickness of different depth intervals was not identical. It can be referred to Hu and Si (2014).

Hu, W., and Si, B.C.: Can soil water measurements at a certain depth be used to estimate mean soil water content of a soil profile at a point or at a hillslope scale. J. Hydrol., 516, 67-75, 2014.

4. Page 6, Line 6, "Specifically, soil moisture from the years of 2010, 2011, 2014, and 2015 was used to establish the observation operators for data lengths DL1, DL2 and DL3 (calibration), and data from 2012 and 2013 were used for validation", what is the reason for such a division, for example, why don't you use 2014 and 2015 for validation, and other years for calibration? What can be the impact?
>> Initially, the maximum data length was set as two years when analyze the effects of data length on observation operators. The data in the 2010 and 2011 were used for calibration and that in 2012 and 2013 for validation. Afterwards, we extended the maximum data length to four years and the data in 2014 and 2015 were used. In our opinion, this arrangement of data for calibration and validation has little impact on the results because there is no scientific rule to our knowledge that calibration should use earlier data than validation.