

Author Response to *Interactive comment on “Reflection tomography of time-lapse GPR data for studying dynamic unsaturated flow phenomena” by Adam R. Mangel et al.*

This response is directed toward the comments left by Anonymous Referee #1, posted to the Hydrology and Earth Systems Sciences (HESS) discussion board for manuscript [hess-2018-230](#) on August 5, 2018.

First and foremost, the authors would like to thank Anonymous Referee #1 (AR1) for devoting time to reviewing our manuscript and for providing a critical review of the content. Below, the authors have outlined responses to individual comments made by the reviewer.

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**ARI:** *Yet, I have found it to a large extent disappointing that the authors seem to give too much credit to their own past work, and neglect a large body of literature considering multi-offset GPR processing, that dates back at least a couple of decades.*

**Author Response:** The authors have added additional references for processing of multi-offset GPR data as suggested by the reviewer.

**ARI:** *Even more serious, is the lack of proper reference to wave migration methods that are state of the art in industrial seismic processing, and are yet presented herewith as if they are novel, or at least rediscovered by the authors.*

**Author Response:** The authors have added additional references for wave migration methods as suggested by the reviewer. The authors do not claim to have ‘rediscovered’ the methods used but are simply the first to apply them to time-lapse GPR data for imaging dynamic hydrologic conditions, which is novel.

**ARI:** *From a technical viewpoint, I am a bit puzzled by the error estimates for water content estimates that is 5-10% in vol/vol (is it saturation or moisture content?) – as compared to 5-15% from soil moisture probes (again, same question). I feel this error is too high to make the estimates useful (if it is moisture content as I read it!). Note that in cross-hole GPR usually 2-3% error in volumetric moisture content is generally accepted as realistic.*

**Author Response:** All soil moisture data is reported as volumetric water content. Errors calculated in the manuscript are absolute errors in volumetric water content between the soil moisture probe data and the values derived from analysis of the GPR data.

Errors in the estimation of volumetric water content from the simulated and measured GPR data vary over space and time. The authors offer explanations for these errors which will be the focus of later research, e.g. evidence of non-uniform wetting of the sand from soil moisture probe data and migration artifacts present in the Kirchoff migration. The authors do not recommend directly comparing results of this method to those of cross-hole GPR given increased data coverage using cross-hole GPR methods. The appeal of this method is partially because boreholes are not required to image the subsurface.

**ARI:** *Finally, as much as I like GPR, it should be clearly stated in the introduction that GPR can only be used in relatively resistive soil conditions. This is generally omitted when presenting GPR applications, yet in many practical situations the soil conductivity is high enough to force us to shift to ERT or EMI for soil moisture content estimates.*

**Author Response:** The authors have added a statement to the introduction that describes the limitations of GPR in conductive media.