

Response to Interactive Comment on “Estimation of surface soil moisture and roughness from multi-angular ASAR imagery in the Watershed Allied Telemetry Experimental Research (WATER)” by S. G. Wang et al.

Dear Anonymous Referee #1:

First of all, we greatly appreciate your careful work and very useful suggestions. We will try to take advantage of your advice for improving the manuscript. For an easier comprehension, your comments are also reported. We respond below in blue to your comments item-by-item.

Referee #1: In abstract, please write out AIEM

Response: Thanks for your suggestion and the word ‘AIEM’ has been written out in the abstract section in the revised manuscript.

Referee #1: P. 3366, l.10: replace ‘connects’ with ‘relates’

Response: The word ‘connects’ has been replaced by ‘relates’ in the revised manuscript.

Referee #1: P. 3366, l.12: replace ‘form’ with ‘scheme’

Response: The word ‘form’ has been replaced by ‘scheme’ in the revised manuscript.

Referee #1: P. 3367, l.8: turn sentence with plural (radar systems)

Response: Thanks for your suggestion and this sentence has been turned with plural in the revised manuscript.

Referee #1: P. 3368, l.26: put ‘...surface roughness is an essential input...’

Response: This sentence has been modified with ‘...surface roughness is an essential input...’ in the revised manuscript.

Referee #1: P. 3370, l.8: replace When with After, put were instead of are

Response: The word ‘When’ has been replaced by ‘After’, the word ‘are’ has been replaced by ‘were’ in the revised manuscript.

Referee #1: P. 3372, l.22: put ‘... such as ASAR makes this possible.’

Response: This sentence has been modified with ‘... such as ASAR makes this possible.’ in the revised manuscript.

Referee #1: P. 3372, l.26: put ‘During the first step’

Response: Thanks for your suggestion, perhaps, it is in line 25. The word ‘During’ has been added into this sentence in the revised manuscript.

Referee #1: P. 3373, l.1: put ‘During the second step’

Response: The word ‘During’ has been added into this sentence in the revised manuscript.

Referee #1: P. 3375, l.10: please put actual incidence angle values here (18.4 and 43.9)

Response: Yes, the actual incidence angle values have been added into this sentence in the revised manuscript.

Referee #1: P. 3375, l.14: what do the authors mean by 'topography is flat'? How flat? Would it be possible to comment here on the implications of more heterogeneous topography on soil moisture retrieval? This is obviously important for a more world-wide application...

Response: Here, it means the terrain of this study area is fairly flat, since it locates in Zhangye oasis. On the contrary, if the terrain is rugged, such as high relief mountainous areas, topography may mask the signal variation in SAR caused by soil moisture, surface roughness and vegetation. Besides, it also affects the quality of image calibration and registration. As we were known, good quality calibration and registration are required for the use of SAR in the estimation of soil water content, especially for the multi-angular imagery method we proposed. Precise image-to-image co-registration is needed to obtain the backscatter difference for every SAR pixels in the domain of study area at different incidence angles. Thus, in this case study, both variations of incidence angle and SAR signals caused by topography are very small and can be neglected.

For more heterogeneous or high relief areas, although considerable efforts have been achieved in the field of geocoding and radiometric correction for SAR images (e.g., A. Loew and W. Mauser. "Generation of geometrically and radiometrically terrain corrected SAR image products," *Remote Sensing of Environment*, vol. 106, pp. P. 337-349, 2007), it is recognized that to precisely rectify the image distortions (i.e., layover, foreshortening and shadowing) is still a problem, and the variation of local incidence angle is complicated, both of them limit the usage of SAR observations to mountainous areas. Therefore, to use these images to retrieve soil moisture by multi-angular method is still an critical issue need to be further addressed, indeed for quantitative analysis.

Referee #1: P. 3376, l.5: replace ‘these two’ with ‘both’

Response: Thanks for your suggestion and the words ‘these two’ have been replaced by ‘both’ in the revised manuscript.

Referee #1: P. 3376, l.5: comment: would HH polarisation not result in an attenuation of vegetation effects? Maybe the authors could comment here on what could be expected with a HV or VH polarization for example

Response: The reason why the HH polarization observations were selected in this investigation is the AIEM model we used is a single scattering version, that is to say, it not includes multi-scattering components. By doing simulations, the cross-polarization component seems too small and not correct compared to lots of literatures and textbooks have been published, such as Ulaby et al., 1982, 1986; Fung, 1994, etc.. Thus, co-polarization mode in HH was employed.

As for the vegetation effect, both co-polarization and cross-polarization observations would definitely impacted by the presence of canopy towards soil moisture retrieval. The variables affecting the scattering process could be attributed to radar parameters, such as frequency, polarization and incidence angle, and target parameters, such as vegetation properties and underlying soil contributions. Hence to consider the vegetation effect sufficiently should taking plant cover categories, plant density, plant height, pattern and plant dielectric properties, etc. into account. Whatever co-polarization or cross-polarization observations were deployed, complex dependence of sigma naught on the above system and target variables makes it difficult at this stage to render a detailed description on HV or VH observations. However, general remarks can be made is the presence of vegetation layer would lead to more de-polarization phenomenon and the plant morphology plays a key role in the scattering phase and magnitude of cross-polarization component.

Referee #1: P. 3376, l.10: remove ‘better’

Response: Thanks for your suggestion and the word ‘better’ has been removed in the revised manuscript.

Referee #1: P. 3376, l.13: put ‘denotes’ instead of ‘means’

Response: The word ‘means’ has been replaced by ‘denotes’ in the revised manuscript.

Referee #1: P. 3376, l.14-15: write ‘...a coefficient of determination equal to...’

Response: This sentence has been modified with ‘...a coefficient of determination equal to...’ in the revised manuscript.

Referee #1: P. 3377, l.10: remove ‘was’

Response: Thanks for your suggestion and the word ‘was’ has been removed in the revised manuscript.

Referee #1: P. 3377, l.11: put ‘before’ instead of ‘ago’

Response: The word ‘ago’ has been replaced by ‘before’ in the revised manuscript.

Referee #1: P. 3377, l.12: put ‘considerably high’ instead of ‘very strong’

Response: Thanks for your suggestion and the words ‘very strong’ has been replaced by ‘considerably high’ in the revised manuscript.

Referee #1: P. 3377, l.21: put ‘...manifesting that the soil moisture is slightly underestimated.’

Response: This sentence has been modified with ‘...manifesting that the soil moisture is slightly underestimated.’

Referee #1: P. 3377, l.24: put ‘shown’ instead of ‘indicated’

Response: The word ‘indicated’ has been replaced by ‘shown’ in the revised manuscript.

Referee #1: P. 3377, l.25: put ‘...due to the fact that’

Response: Thanks for your suggestion and this sentence has been modified with ‘...due to the fact that...’

Referee #1: P. 3378, l.11: insert ‘these are’ between ‘but not’

Response: This sentence has been modified with ‘...but these are not...’

Referee #1: P. 3378, l.11: write ‘A sampling...did take place at site E.’

Response: Thanks for your suggestion and this sentence has been modified with ‘A sampling...did take place at site E.’

Referee #1: P. 3378, l.13: put ‘from the literature’

Response: Thanks for your suggestion and this sentence has been modified with ‘...from the literature...’

Referee #1: P. 3378, l.18: remove ‘both’

Response: The word ‘both’ has been removed in the revised manuscript.

Referee #1: P. 3378, l.26: put ‘verified’ instead of testified’

Response: The word ‘testified’ has been replaced by ‘verified’ in the revised manuscript.

Referee #1: P. 3379, l.20: put’..., it could still result in some uncertainties.’

Response: Thanks for your suggestion and this sentence has been modified with ‘..., it could still result in some uncertainties.’

Referee #1: P. 3380, l.6: put ‘seeking’

Response: The word ‘seek’ has been replaced by ‘seeking’ in the revised manuscript.

Referee #1: P. 3380, l.8: put ‘The investigation presented in this paper’

Response: This sentence has been modified with ‘The investigation presented in this paper...’

Referee #1: P. 3380, l.14: put ‘reliable’ instead of ‘feasible’

Response: The word ‘feasible’ has been replaced by ‘reliable’ in the revised manuscript.

Referee #1: P. 3380, l.18: remove the second ‘the’

Response: Thanks for your suggestion and the second ‘the’ has been removed in the

revised manuscript.

Referee #1: P. 3380, l.18-19: do the authors mean ‘the presence of remaining vegetation effects’, given that they corrected for these?

Response: Yes, we agree with the referee and this sentence has been modified with ‘...the presence of remaining vegetation effects...’

Referee #1: P. 3380, l.24: put ‘instead’ of instead of ‘in place’

Response: The words ‘in place’ has been replaced by ‘instead’ in the revised manuscript.

Referee #1: P. 3381, l.1: put ‘area’ instead of ‘aspect

Response: Thanks for your suggestion and the word ‘aspect’ has been replaced by ‘area’ in the revised manuscript.