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Interactive comment on "High-resolution palaeovalley classification from airborne electromagnetic imaging and deep neural network training using digital elevation model data" *by* Zhenjiao Jiang et al.

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We highly appreciate your time in reviewing our manuscript for publication in HESS. The relevant comments have improved the quality of the manuscript. We now revised the manuscript accordingly. The detail responses are listed below. The modifications in the article are marked in the annotated manuscript (in the supplement).

Q1. . . . It remains a difficult issue to evaluate results of the analysis of large spatial datasets (like airborne EM) with individual boreholes, and I would suggest that the

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evaluation of the method focusses some more on the geological plausibility of the results.

Re: We now enhanced the description of geological background of palaeovalley system in both “Study area” (Line 71-85 in annotated manuscript) and “training data generation” (Line 144-166), to provide a more detail geological background to support the predicted palaeovalley system.

Q2. Line 32: Both (x,y) and z?

Re: It here means x-y plane, which is now clarified in Line 32.

Q3. Line 52: Gunnink and Siemomn, 2015 did not use ANN to classify AEM

Re: This is now deleted.

Q4. Line 82: Is 15m arbitrary chosen? Are there no clays in the alluvial setting to be expected?

Re: The value of 15m is the observed maximum thickness of eolian sediments (now Line 79). Because it is difficult to differentiate from the borehole logs the eolian from the alluvial sands, sediments with less than 15 m of sands are classified as transition between alluvium and Aeolian sands. Analysis of the borehole logs shows that clays present in the alluvial deposits. In our analysis of borehole logs, alluvium is defined on the basis of the relative thickness of coarse to fine-grained sediments within the borehole. If coarse sediments represent more than 50% of the total depth, then the entire borehole depth is considered as alluvium. If, on the other hand, coarse sediments exist in less than 50% of the borehole, the entire borehole depth is considered as transition between alluvium, Aeolian and bedrock. We now rephrased Line 90-94.

Q5. Line 94: Justify the dimensions of the spatial resolution.

Re: The constraint on the lateral resolution of the AEM data is determined by the line spacing of the survey. In the case of the APY lands survey with a survey line spacing of 2 km, it was gridded to a cell size of one fifth of the line spacing – hence the 400m value, to maintain a high fidelity. This is a common approach taken in geophysics. The depth interval defined is somewhat arbitrary, but is commonly between 5-10 m increasing exponentially with depth (Because AEM is a diffusive technology). In the APY lands a vertical interval starting at 10 m is selected and remains unchanged in the first 100 m depth, to avoid generating too many interval conductivity slices (Now Line 103-109).

Q6. Line 95: From this I conclude that the analysis will basically be 2D, per slice. If so, that should be mentioned here explicitly.

Re: This is now clarified in Line 107-109.

Q7. Figure1 caption: what does dS mean?

Re: dS or deciSiemens is a unit of electrical conductivity and often used in groundwater science. But it seems not necessary in this article and is now deleted.

Q8. Line 104: supply reference.

Re: References are now added in Line 119.

Q9. Line 106: You should also mention the EC differences between clay / shales and sands / sandstone. It is not just groundwater that controls EC!

Re: Indeed. This is now mentioned in Line 119. Since both Archie's Equation and the weighted average method applied to calculate bulk EC in this study considered the EC in both water and matrix (solids), we now deleted the sentence in Line 121 to avoid confusion.

Q10. Line 110: What about the spatial variability of EC in the paleo-valley itself, as mentioned on page 4: "variable water quality from upper reaches (lower salinity) to down-valley (higher salinity)"

Re: The description in page 4 is rather a general trend in palaeovalleys across entire

Australia (this statement is now deleted). In this specific study area, we found only a limited number of water salinity measurements, from which an approximate EC range in palaeovalleys was obtained. These measurements didn't show a particular trend of EC variation within the palaeovalley. We assume a uniform distribution of EC in both palaeovalleys and non-valley areas (now Line 190-191), respectively, without considering the spatial variation of EC in palaeovalleys.

Q11. Line 114: These changes might also be due to salinity changes in the groundwater in the paleo valley.

Re: Agree. This is now added in Line 129.

Q12. Line 129-130: This is a rather strong statement. Although in general true, you need to elaborate more on the validity in this specific case. E.g. what about larger discharges in the past that might have caused larger dimensions? Or a much lower erosional base, causing deeper incisions instead of broad valleys? Can climatic and geomorphological arguments help in justifying this statement? Line 132: Are the current "topographical lows" oversized, given the current river discharges? If so, this might be an additional argument for the statement that the current river valley network is an analogue for the paleo-system.

Re: We have rewritten this paragraph to accommodate these comments (see Line 144-166).

Q13. Line 136: why 80km x 80 km; any special reason?

Re: There is no special reason. It was mainly selected on the basis of the AEM-survey data availability.

Q14. Line 137: How was the DEM downscaled from 30x30 to 100x100; averging, min, max, moving window?

Re: The downscaling here is completed by a bicubic interpolation, which is mentioned now in Line 158-160.

Q15. Why was cropping to 50x50 necessary?

Re: The large training image represents a rather specific feature of the valley system. However, if we crop it into small training images and rotate by different angles, the combination of these small images allows to create more valley patterns. In this manner, the training image pool can be more representative. This is now described in Line 164-166.

Q16. Line 164: Was a statistical distribution of the EC values assumed or was the random sampling from a uniform distribution?

Re: They were assumed to follow the uniform distribution (now Line 190-191).

Q17. it was stated before that the bulk EC in the non-valley was < 2.5 mS/m.

Re: This is now explained in Line 192-197. We added the overlap in EC values between valley and non-valley in two sequential steps: first step is to enlarge the EC range in bedrocks, and then to enhance the overlap by downscaling and interpolation. The first step is to add noise relating to several uncertainties (e.g. land cover, local weathering of bed rocks, etc.) in AEM survey and interpretation, while the subsequent smoothing is to address the spreading of this noise. The noise added in training images would enhance the prediction capability of the neural network, as the neural network has the opportunity to learn to identify these noises. But if too much noise is added in training image, the neural network may overestimate the noise and make the palaeovalley disconnected. The selection of the size of the overlap and its influence on the output is discussed in Appendix A1 in Line 490-531.

Q18. Line 169: I assume that the size of the images is the same, only the pixels get larger (smaller number of pixels with same image size leads to larger pixels). If so, I do not understand how nearest neighbor interpolation leads to blurred images. In my experience, nearest neighbor creates more crisp images, because gradients in the original images are not expressed in the nearest neighbor images.

Re: We now rephrased this sentence in Line 198-202. The downscaling was operated by the nearest neighbour method, while the downscaled images were interpolated back to their original size by bicubic interpolation.

Q19. Line 173: Why using pre-interpolation images?

Re: We try to make the training images representative of multiple degrees of smoothing.

Q20. Line 201: Is this a probability?

Re: It is not a true probability, although a probability distribution function is created from the values 0-1. It is an index indicating presence of a palaeovalley when the value approaches 1.0 and non-valley when values approaches 0.0. This is now added in Line 232-234.

Q21. Eq. 6 What does e mean?

Re: It represents an exponential function, we now modified this equation.

Q22. Line 205: How are these filter sizes determined and how do they influence the results? Line 207: Finally, spatial correlation is mentioned! It should have been mentioned before and taken into account in the generation of the training images. How is the spatial correlation length determined?

Re: We now rephrased Line 239-248 to address these two issues. The filter size is originally selected according to the classical SRCNN structure proposed by Dong et al 2016, and then adjusted by trial-and-error test as explained in Appendix A3 (Line 555-588), and also the training image size as discussed in Appendix A2 (Line 532-553). The spatial correlation length is an unknown, and is not explicitly calculated in the convolution neural network. We use a large filter to guarantee that the spatial correlation in the images can be accounted for and the accuracy of resulting binary palaeovalley is sufficiently high. A two-layer example is used in Line 242-246 to demonstrate the relationship between filter size and correlation scale incorporated in the neural network.

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Q23. Line 211: What is meant by "width"?

Re: It is the number of images contained in each layer (now line 239).

Q24. Line 267: what is the exact value? How does the choice of this value influence the results?

Re: A threshold value of 0.5 is used here. As the palaeovalley index follows a bi-modal distribution with values grouped near 1.0 and 0.0, the selection of a threshold value in the range 0.2 to 0.8 doesn't really affect the classification of the palaeovalley significantly (Now Line 302-305).

Q25. Fig. 5: It seems from histogram (e) that the number of pixels with value > 0.8 is much smaller than number of pixels between 0 and 0.2. But, Figure (d) and (f) suggests otherwise....

Re: The histograms represent statistics of all 4000 images (now in caption of Fig.5), and many images have a very narrow palaeovalley.

Q26. Line 287 This seems a small overlap. What happens when the overlap is larger, as is often the case in "real life"?

Re: We here arbitrarily use an overlap of 2.5% to test if the trained neural network can identify the palaeovalley pattern properly. After smoothing, the overlapping size could exceed 2.5%. For example, in the training images, the artificial overlap size is given as 5%, but after smoothing, as shown in the histogram of Fig. 2d, the EC value in non-valley areas in training images can even reach 40 mS/m and in the valley zone can reach 1 mS/m. The maximum overlapping size addressed in training images can reach 50%. We discuss the influence of overlapping size used in training and test images on the output in Appendix A1 in Line 490-531.

Q27. Fig. 8c Here again, it seems that the proportion < and > 0.5 is not visible in the map; From (a) to (b) seems an increase in Ec value, is that correct and if so, is that what you want?

Re: The threshold value of 0.5 is now marked in Fig. 8c. There is a normalization operation from EC values ranging from 1 to 80 mS/m (a) to values in 0 to 1.0 (b).

Q28. Line 338: this implies that there is no trend in depth. Is that reasonable to assume? Re: We now rephrased this sentence in Line 374-376.

As the training images were generated from a DEM, training, validation and prediction of the neural network in this study were based on 2D images, and the trained neural network is employed layer by layer to generate a quasi-3D image of the palaeovalley. Since training images include palaeovalleys with varying geometries (e.g. width, curviness, length…), the palaeovalley pattern with varying geometry in each layer can be generated, determined by the EC values. However, one limitation is that the vertical relationship between EC and palaeovalley pattern cannot be addressed in such 2D image-based neural network. This is now mentioned in Line 474-480, and also future works that potentially overcome this problem.

Q29. Fig. 9. There seems to be quite a lot of paleo valleys. Is that realistic?

Re: The palaeodrainage system in arid zone of Australia is very developed. The more detail geological background on the formation of these palaeovalleys are now described in Line 71-85.

Please also note the supplement to this comment:
https://www.hydrol-earth-syst-sci-discuss.net/hess-2019-16/hess-2019-16-AC1-supplement.pdf

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