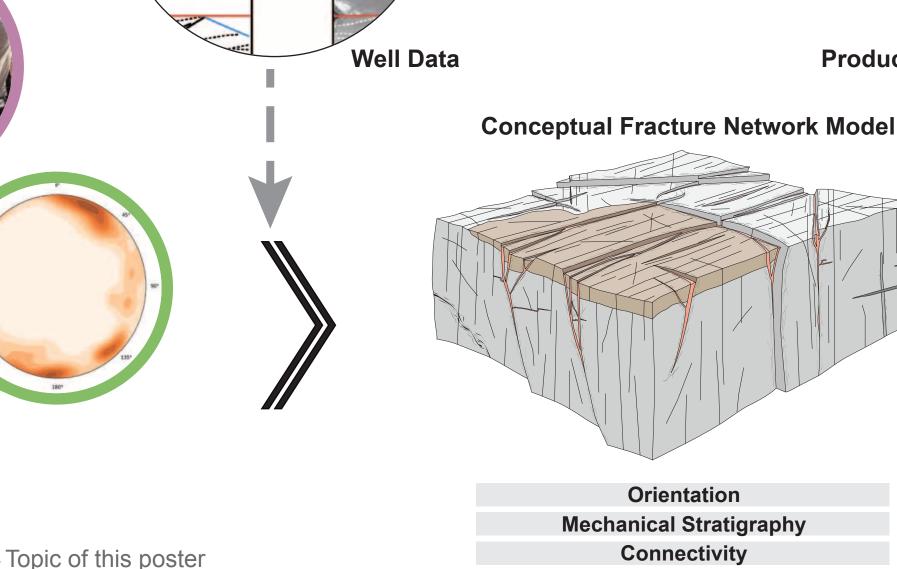
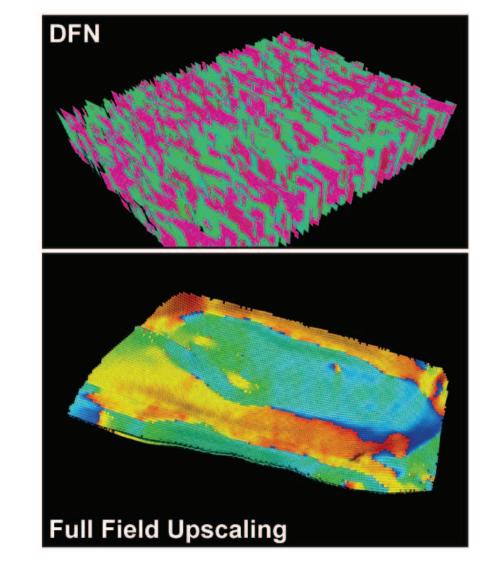


### Reducing Uncertainty in Fracture Modelling: Assessing User Bias in Interpretations from Satellite Imagery

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# 1. Introduction: The "Outcrop Analogue to Fracture Model" Workflow **Production Data**





Fracture models that inform development and production decisions

## in earth sciences?

studying and / or working you've studied for a qualification as an earth scientist?

5. Results: Questionnaire

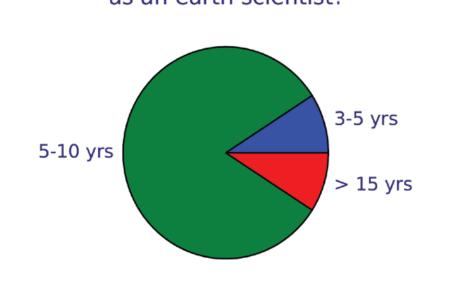
Have you ever systematical

measured fracture properties

Do you consider yourself to

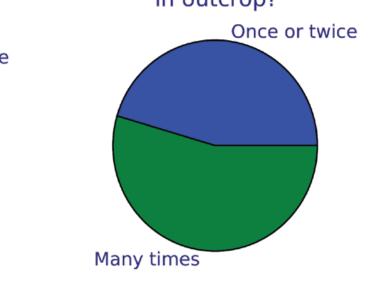
be a structural

Never

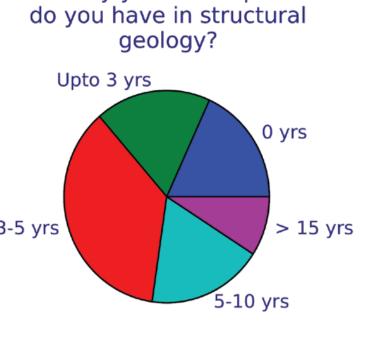


How many years have you spent

Have you ever systematically measured fracture properties in outcrop?



How many years of experience



In spite of the low sample size results from Levene's test show that there is a significant difference (p > 0.90) in variance of bulk intensity between the following groups of people:

- People who consider themselves structural geologists and those who
- People with > 3 years structural geology experience and those with
- People who have measured fractures in outcrop many times and those who have only done it once or twice
- People who previlusly have measured fractures in satellite data and those who haven't.

In summary, there is less variance within the experienced population; e.g. experienced people pick similar intensities of fractures, in contrast with inexperienced groups.

#### 6. Post-Processing

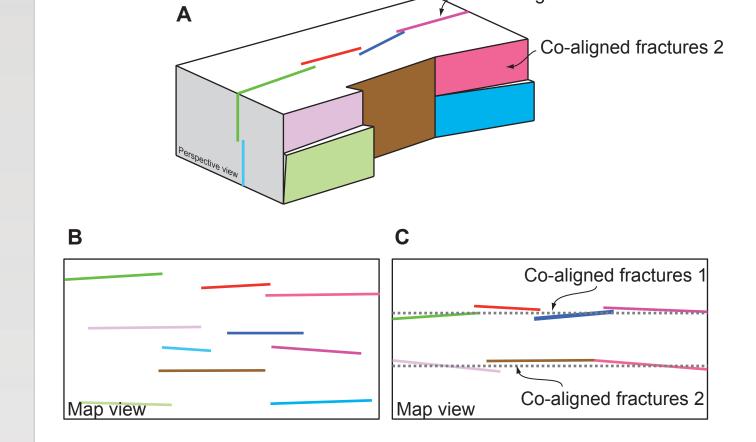


Fig. 5 Link Co-Aligned Fractures traces that were auto-linked to represent a single fracture array

 Post-processing of the fracture picks is done to try and reduce the variance in the sample and standardise the results.

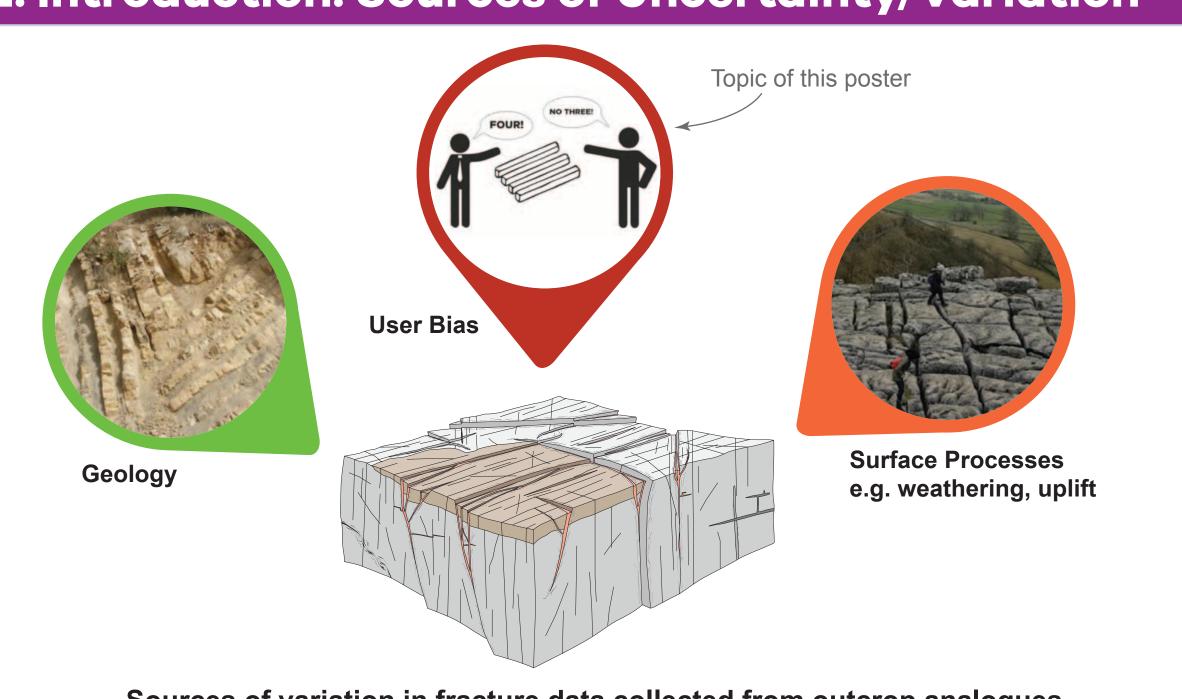
fracture. Ends of other fractures that fall in the buffer are considered to be terminating at that fracture. (B) At the end of each fracture search ellipses are used to locate other end-points. If the angular separation is within tolerance fractures are linked. If multiple end-points are found the one with the highest probability is used. (C) Example of linked fracture trace.

 Processing steps aim to improve geological representation of the natural fracture network within the modelled DFN (Fig. 6).

- 1. Topological uncertainty in the digitalisation of end-point connectivity is cleaned using a buffer size proportional to the resolution of the underlying satellite imagery (Fig. 6A).
- 2. The input parameters that define whether fractures are co-aligned are angular difference and proximity of end nodes to each other (Fig. 6B). An elliptical search is used to find nodes within a constant area (ellipse axes oriented parallel and normal to the fracture trace). When multiple valid end points are located, the linkage favours the creation of the longest most co-aligned fracture.

#### 2. Introduction: Sources of Uncertainty/Variation

**Quantitative Outcrop Analogue Characterisation** 



Sources of variation in fracture data collected from outcrop analogues The aim of this poster is to look at variations in fractures properties, used in DFN modelling, that result from different users interpreting the same satellite data. Other sources of variation are not considered. The interpretation of geological data almost invariably involves human input, which introduces

#### 3. Methodology

**Linked Size-Intensit** 

**Density Drivers** 

**Spatial Clustering** 

**Aperture and Fill** 

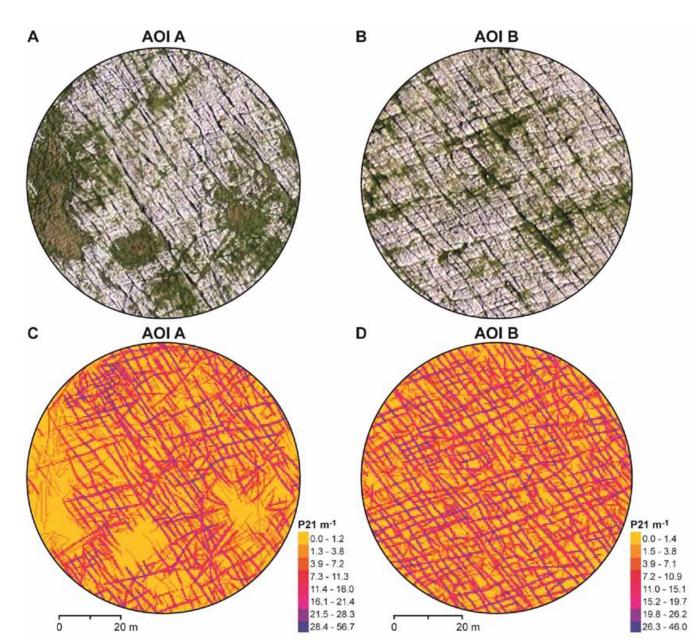
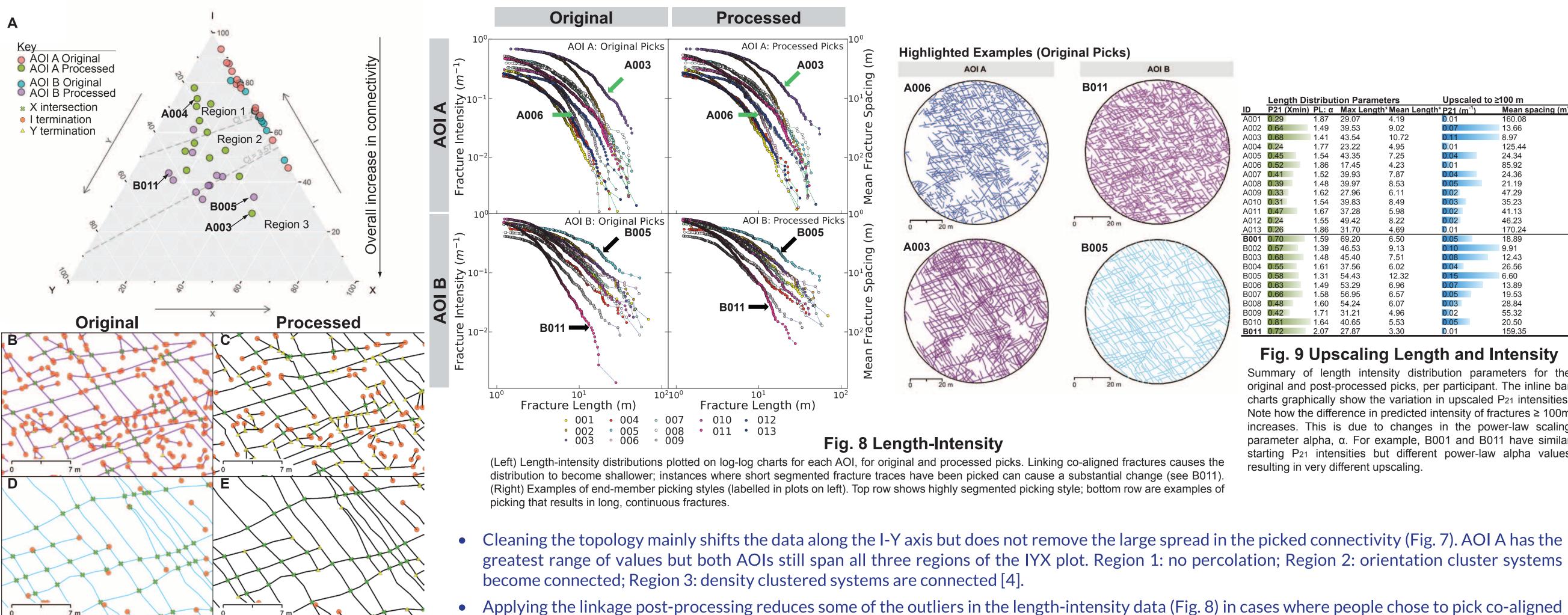
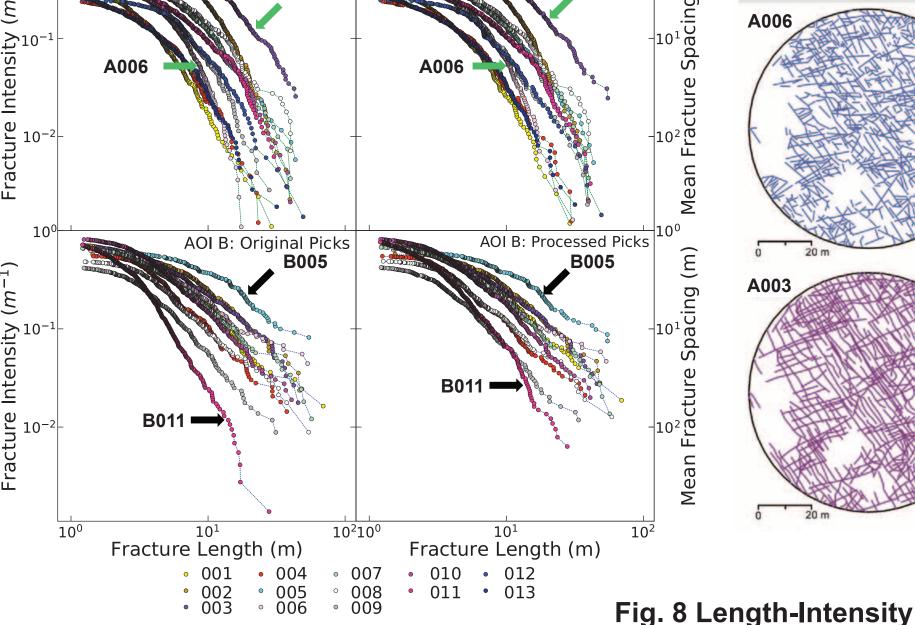


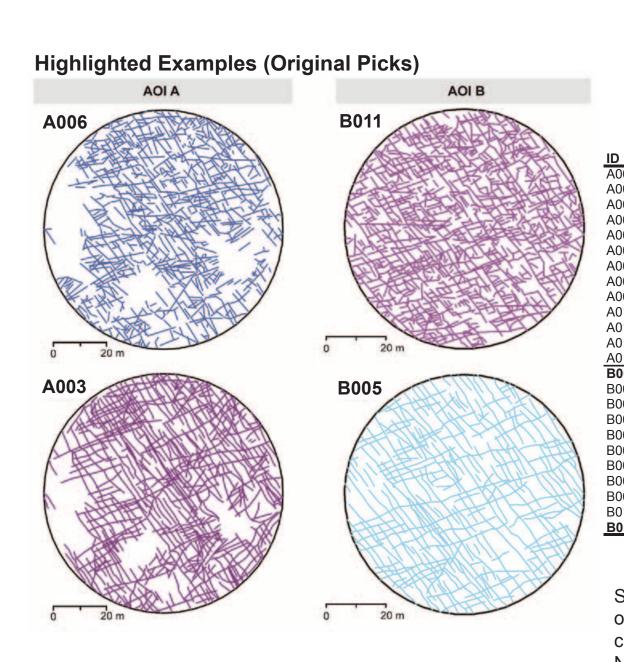
Fig. 1 Test Area Of Interest (AOI) (A and B) Satellite AOIs given to the participants for fracture picking. (C and D) Concurrence map for all participants, darker colours represent areas most commonly picked.

- Participants were asked to pick two circular AOIs with varying amounts of vegetation cover. (Fig. 1A,B)
- Images were interpreted at a fixed resolution in ArcMap using straight line polylines with no snapping.
- Participants also completed questionnaire (see box 5). This is a pilot study, and the statistical significance in correlation between answers and the observed variation in results may be
- We looked at variation in orientation. bulk intensity, connectivity and length-intensity scaling (see boxes
- The raw results and post-processed results were analysed to look for variation in fracture properties due to different users (see box 7).

#### 7. Comparison of Raw and Post-Processed Results

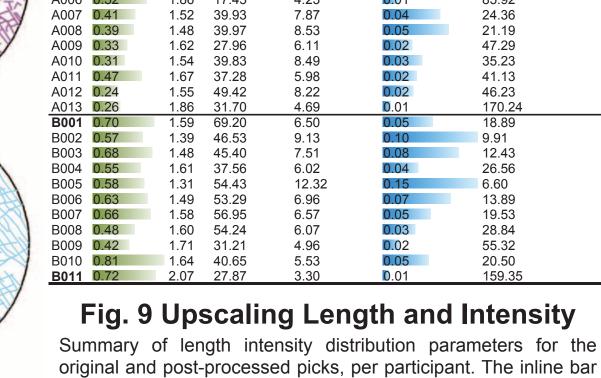






fractures as segmented traces. However a significant spread of inferred intensities and fitted power-law distributions (α) still remain after

• Note how the scaling distribution dominates the resultant upscaled values more than the intensity at small scales (Fig. 9: see B001 and B011).



Angular separation

Fig. 6 Linkage Criteria

#### charts graphically show the variation in upscaled P21 intensities. Note how the difference in predicted intensity of fractures ≥ 100m increases. This is due to changes in the power-law scaling parameter alpha, $\alpha$ . For example, B001 and B011 have similar starting P21 intensities but different power-law alpha values esulting in very different upscaling.

#### 4. Results: Variations in Orientation & Intensity

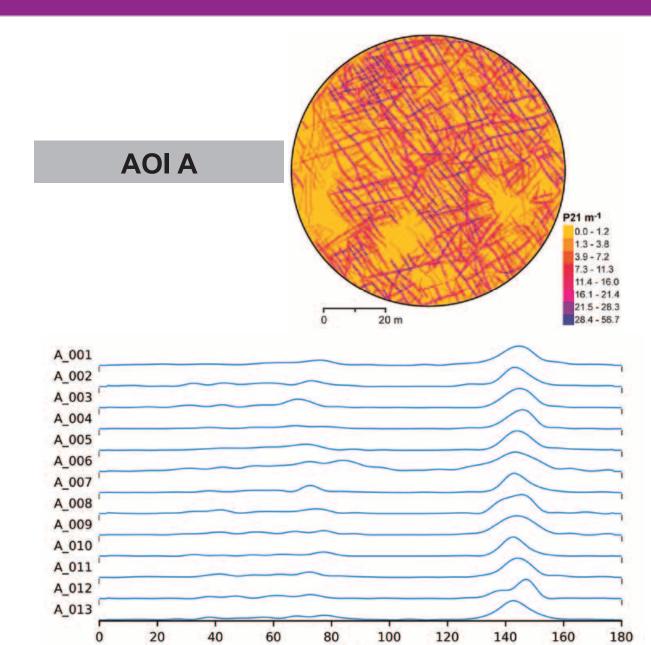
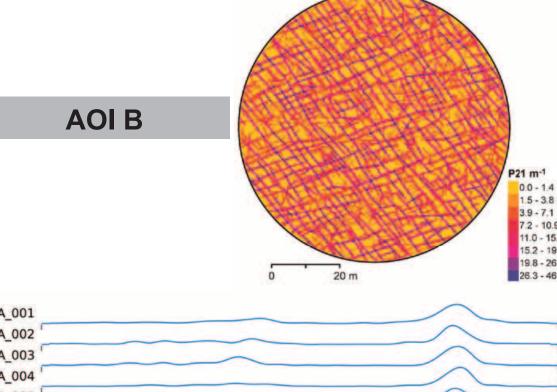


Fig. 2 Orientation of Picks for AOI A Thirteen participants completed AOI A.

 AOI A has a greater percentage of vegetation cover and there is also a greater variation in observed picks.



(see also Wednesday 3:50pm

Session 550, Room 214 B/C)

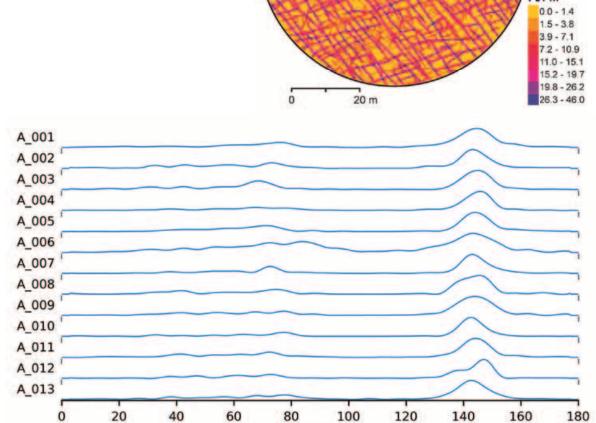


Fig. 3 Orientation of Picks for AOI B Eleven participants completed AOI B.

 Most people pick the same dominant orientation peaks, but when vegetation increases weaker sets are poorly identified.

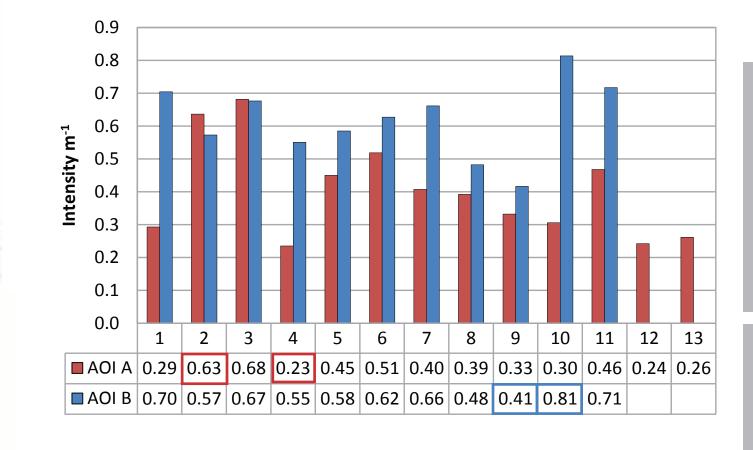
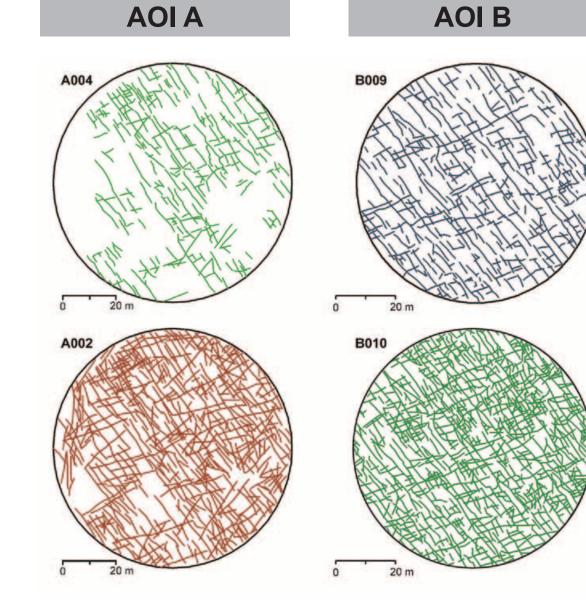


Fig. 4 Bulk Intensity Variations (Top) Bulk intensity for each participant, per AOI. (Right) Examples form each AOI showing the end member picking results (high and low cases), corresponding values are highlighted in the table above.

- AOI A: 2.9x difference between min and max bulk intensity (Fig. 4).
- AOI B: 2x difference between min and max bulk intensity (Fig. 4).



- With greater vegetation cover (ambiguity in signal to noise in AOIA) there is an increase in the variation of picked fracture traces.
- Orientation showed the least variation of all the fracture properties investigated.

Fig. 7 Connectivity

corrections. (B to E) Before and after examples of how the topology changes during the

the I-Y axis. Despite the post-processing there is still a significant spread in inferred

8. Conclusions

processing steps. (A) Applying the post-processing steps predominately shifts the data along

- Fracture networks are highly susceptible to user picking differences, which adds uncertainty to fracture modelling parameters, especially length, intensity, scaling and connectivity.
- Changes in outcrop/image quality within an AOI causes increase in variance within the measured fracture properties.
- Increasing the skill level of people interpreting fractures and applying post-processing corrections can help standardise results for DFN modelling.
- However, post-processing can only partially mitigate against the effects of under- or over-picking and consequent effect upon the derived length distributions within satellite datasets.

#### 9. References

post-processing. These differences are exaggerated when upscaled to modelling scale ranges (Fig. 9).

1] Bond, C.E., Gibbs, A.D., Shipton, Z.K. and Jones, S., 2007. What do you think this is? "Conceptual uncertainty" in geoscience interpretation. GSA today, 17(11), p.4.

P.] Bond, C.E., Shipton, Z.K., Jones, R.R., Butler, R.W.H. and Gibbs, A.D., 2007. Knowledge transfer in a digital world: Field data acquisition, uncertainty, visualization, and data management. Geosphere, 3(6),

network characterization. Journal of Structural Geology, 72, 55-66.

Therefore the way in which people pick fracture length is highly important (not just how many fractures they pick in total).

B] Watson, F., Long, J., Wilkinson, M. and Javis, Z., 2013, April. Variability in nterpretations when picking fractures from satellite images. In EGU General Assembly Conference Abstracts (Vol. 15). Sanderson, D.J. and Nixon, C.W., 2015. The use of topology in fractu

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