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Solid Earth Discussions

Interactive comment on "Vertical seismic profiling with distributed acoustic sensing images the Rotliegend geothermal reservoir in the North German Basin down to 4.2 km depth" *by* Jan Henninges et al.

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Dear authors,

I've had the chance to read manuscript SE-2020-0169, entitled "Vertical seismic profiling with distributed acoustic sensing images the Rotliegend geothermal reservoir in the North German Basin down to 4.2 km depth". I think it shows an exciting practical application that merits to be published. Nonetheless, I have several comments and suggestions, which I detail in the next paragraphs, and hope you will find useful. I'd be very happy to give the manuscript a second reading for minor fixes after you have addressed these issues.

First of all, I think the focus of the paper could be better. What is fundamentally new in your study is not the VSP processing, which is relatively standard, but the deep deployment of a vertical wireline DAS cable that yields excellent data. This example can have significant implications as old wells in which the fiber was not cemented/tubed will become available for different purposes. The fact that the deployment is in a hot area makes DAS even more attractive. Therefore, I'd suggest a change to the title and to possibly further emphasize this aspect in the text.

Another novel point, which is especially relevant to the DAS community, is the publication of a dataset acquired with the Schlumberger interrogator. One of the main benefits of the hDVS, if I correctly understood the company's claims, is that multiple gauge lengths are acquired during the acquisition step and can later be adjusted during data processing. I suppose there are limitations in what you can show, but it would be nice to see records of different GLs. In addition, you have pronounced changes in velocity, especially at <1500m. In the spirit of your GL optimization, would it be better to use a shorter GL (maybe the 20 m) for the shallower section if the processing workflow allows for it? Besides, the useful Dean et al. (2016) derivation is correct for vertically propagating wavefronts to follow up on that point. In your case, especially for the far offsets, it seems like the apparent slowness is significantly faster, thus commanding longer GL. Would it make sense to have a GL that is offset-dependent as well? I think it is important to discuss the variable GL, because using an average velocity to optimize GL is what one expects for more "standard" interrogators.

There is also a big gap between the acquisition/deployment efforts and the analysis reported here. In the Introduction and Survey design, you set the stage towards 3-D velocity model building/imaging. However, the eventual processing is much more modest – a 1-D velocity analysis with corridor stacks (if I understood correctly). This comment is not a criticism of the work, but I think it would be much better to set reasonable expectations early on in the paper. Also, I found the velocity model building/processing sections very opaque. Did you use all shots, or just the zero-offset ones, for velocity model building? What is the meaning of a corridor stack for non-zero offsets (the reflection point would be away from the well)? Assuming the 3-D analysis isn't ready, can you show gathers (common-receiver in VSP + direct downgoing travel time correction) to illustrate the azimuthal velocity variations and motivate future 3-D work?

On a related note, the estimated 1-D velocity model has a much lower resolution than the sonic logs, and I think it merits a discussion. The most obvious example is that the high-velocity zone in the top salt (interesting!) around 2500 m, almost 80 m high, only weakly shows in the estimated velocity model. I can understand why it happens to a certain extent. However, looking at the narrower sweep's signatures, it seems to me that you probably have $\sim$100 Hz with reasonable SNR down to the bottom of the well for most of the survey. So, you have a more than a wavelength that can fit inside the high-velocity zone that I mentioned. I suspect that the low-resolution in the velocity comes from mixing shots in different azimuths and averaging a 3-D structure into the best possible 1-D approximation, but it is only a guess.

Minor technical comments:

1. Sorry for referring to my work, but there have been a few recent deployments of downhole DAS in EGS projects. You can see the studies by Junzo Kasahara (mostly abstracts) and myself (Lellouch et al., 2020, SRL, and another one currently on arXiv). These studies have recognized the benefits of DAS in geothermal reservoirs, and I think they can strengthen your introduction and, eventually, conclusions.

2. It would also be interesting to mention if you picked up any earthquakes during the recording – downhole DAS is much more sensitive than surface arrays.

3. I think Figures 5 and 6 can be combined into one.

4. DAS/geophone comparison - the fact that downhole geophones are actually ac-

celerometers is highly confusing (not your fault...). It would be better to clearly state this fact and that the DAS comparison is to the vertical axis of the geophone. By the way, if you follow Egorov 2018 for unit conversions, you can scale each point in the F-K domain by ωˆ2/k and do it all in one pass.

5. Can you show the synthetic (predicted) trace for the logged section? It would be easier to compare with the corridor stacks and see which events are spurious.

6. For non-expert readers, it would be useful to mention why aren't the sonic logs sufficient for your final interpretation. This is not uniquely related to DAS, but to standard VSP as well.

Stay safe and all the best,

Ariel Lellouch, Stanford U.

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