EM wave velocity and porosity using 2D GPR borehole tomography

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Tomographic imaging has become popular amongst geophysicists as it provides high resolution images of the subsurface. Many approaches to this problem have been taken which may include anything from a simple straight ray traveltime analysis using a prior model to full-waveform inversion using coupled data sets. Often, extra steps need to be taken due to the non-uniqueness of solutions and sparseness of data. Before taking this leap to more complex processing algorithms, it is very important to first observe how simple models perform, as a means of justifying further analyses and developing an understanding of tomographic inversion.

Borehole to borehole and borehole to surface ground-penetrating radar (GPR) data were collected for a set of boreholes at the Boise Hydrogeophysical Research Site. The boreholes are spaced roughly 10m apart and have a slight elevation difference between the wellheads. In order to analyze the data set as individual channels averaged traces were added to the 73rd shot of the 12th, 26th, and 39th channel, as these traces were found to be absent. After the traces were added, the data matrix was divided into a 750 x 73 x 50 matrix and imaged observe the data.

Observing the data and corresponding shot array, it is clear that the surface based transmitters had some issues with high frequency noise. A large section of these traces is characterized by a window (>100ns) of high frequency noise in the data, which will likely need to be filtered with a bandpass filter.

To determine the slowness matrix, the subsurface was divided into 2500 pixels, through which the straight ray travel paths for each trace were calculated. A prior model of slowness values of the same size was generated using the water table depths from the given data: any cells above the water table were set to a slowness of 8.3 ns m^{-1} (v = 0.12m ns^{-1}) and cells below set to 14.3 ns m^{-1} (v = 0.07m ns^{-1}), corresponding with unsaturated and saturated conditions, respectively. The inversion algorithm used a simple Tikhonov regularization coupled with an *a priori* model with the regularization parameter (α) set to 1000. Implementing smoothness using the second spatial derivative in the *x* and *y* directions was also explored; and the inversion result was greatly improved. Uncertainties, however, still remain on the accuracy of this model due to the minimal information used for the inversion. The seismic data collected at this site may offer insight through a joint inversion, but may produce similar results as the same amount of prior information is known. Another approach may also be utilizing the full waveform, rather than the first arrival. Further, there may be some amount of error caused by the model as it uses straight rays to calculate distances. Straight rays are highly unlikely given that the water table interface will likely refract the GPR waves.

A more elaborate algorithm must be developed to enhance the accuracy of this inversion; however, this initial analysis provides motivation for more complex methods, which will involve a separate seismic inversion, more research about the site to build a stronger prior model, and a further analysis of the GPR data in hopes of identifying subsurface structure and quantifying porosity.