Optimized Geoelectric Monitoring for 3D Arrays

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Capturing the relevant spatiotemporal geoelectric detail of a hydrogeological event relies on fast acquisition hardware, adequate electrode coverage, and acquiring the best subset of data from the combination of electrical current and voltage potential electrode pairs. The definition of best subset, however, will likely be considered from a combination of important factors such as 1) signal strength, 2) depth of penetration, 3) the ability to sweep through the subset rapidly, and 4) the resolving capability of the subset. The pole-pole (or 2-pole) array offers the best advantage for the first three factors but is significantly hampered by its low resolving power. The bipole-bipole (or 4-pole) array has the best resolving capability but may suffer from long acquisition times based on the large number of possible combinations, as well as low signal strength. Even a small survey with 168 electrodes will have $14x10^3$ 2-pole non-reciprocal combinations, but an excessive $96x10^6$ 4-pole combinations. While we realize not all 4-pole combinations are viable, choosing the best 4-pole subset may be computationally daunting or difficult without knowing first the makeup of the subsurface. Additionally, 4-pole subsets created ad hoc by either maximizing signal strength (i.e., by collecting only combinations with low geometric factors) or through expert judgment may still have low resolving capabilities or worse.

We propose that the advantages of both 2-pole and 4-pole arrays can be combined to obtain an optimized subset for imaging dynamic events. The combined process would include the acquisition of a complete 2-pole dataset to ensure high quality data and the largest number of snapshots within a given monitoring period. Then, an optimized 4-pole subset would be calculated from the 2-pole dataset based on maximizing the resolution matrix using the Compare R method. The reconstruction of any 4-pole combination, including both voltage and measurement error, is conducted by superposition of four measurements within the 2-pole dataset. Furthermore, by calculating the optimized subset after data acquisition is complete, we can ensure that the resolution is maximized for the entire series of snapshots.

To demonstrate the effectiveness of the combined process, we generated an optimized 3D, time lapsed, 4-pole dataset from a base 2-pole dataset during a surface infiltration study. The survey was composed of 168 electrodes over an area of 260 ft by 100 ft, with 14 snapshots acquired over a three day period. Figure 1 shows an example of the baseline conditions (prior to infiltration) as a slice through the middle of the inverted 3D domain. The figure confirms that both conductive and resistive targets are enhanced with greater detail for the optimized 4-pole dataset (Fig. 1C) compared to the original 2-pole dataset (Fig. 1A) and an ad hoc 4-pole dataset comprised solely of combinations with low geometric factors (Fig 1B). Additionally, the matrix resolution value at a depth of 20ft is 4.8 and 3.5 times greater for the optimized set compared to the 2-pole and ad hoc 4-pole sets, respectively. With these findings, it is possible to ensure that the best data will be acquired and that the most information can be extracted given a particular electrode arrangement.

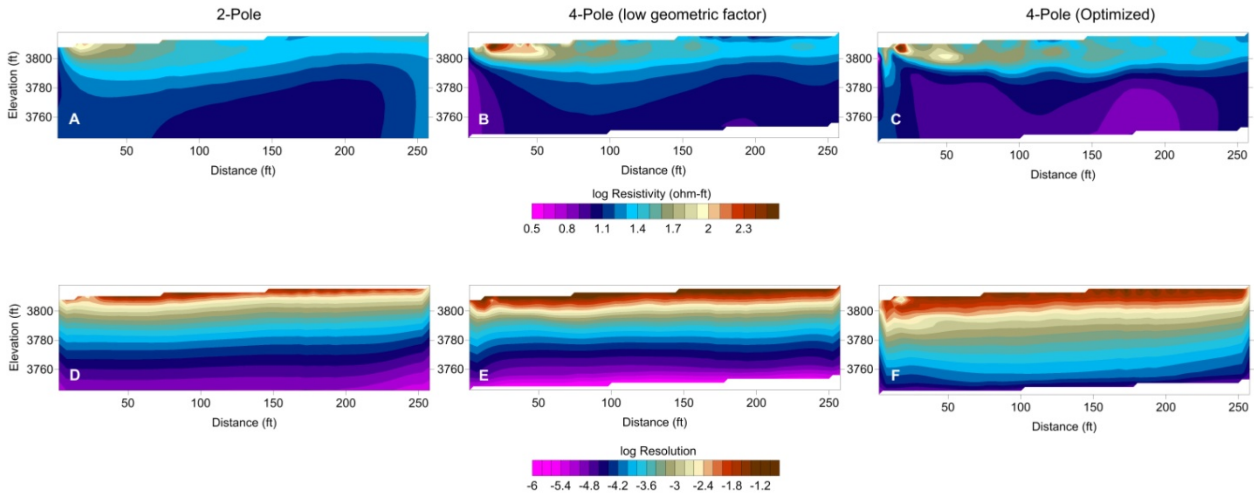

Figure 1. Inverse modeling results for a baseline survey conducted during infiltration, presented as a slice through the center of the 3D domain. A) resistivity of the original 2-pole dataset, B) resistivity of a 4-pole reconstructed dataset based on the lowest geometric factor, C) resistivity of an optimized 4-pole resistivity dataset, D) resolution of the 2-pole dataset, E) resolution of the ad hoc 4-pole dataset, F) resolution of the optimized 4-pole dataset.