Seismic Near Surface Corrections in Sand Covered Areas by use of Airborne micro-TEM and Physics-Coupled Deep Learning

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Abstract

Accurate near-surface velocity modeling is essential for seismic imaging to avoid pitfalls during the interpretation of low-relief structures. Seismic tomography or full waveform inversions provide detailed and continuous velocity models but accuracy of these models at very shallow depths especially in complex arid regions still pose a significant challenge due to limited availability of short offsets, low first arrival quality and low velocity layers. The aeolian sand dunes cause extreme near surface velocity variations mostly due to compaction rather than mineralogy or saturation. Empirically derived sand curve functions obtained through high resolution field tests and laboratory measurements provides a reliable correction. Therefore, accurate definition of the buried unconformable base of sand surface is crucial for the robust near surface corrections. This surface is characterized by a highly resistive, dry and unconsolidated sand residing on a more compacted and lower resistivity substratum, called sabkha and forms a good target for airborne electromagnetics. A helicopter-borne micro transient electromagnetic (micro-TEM) survey was carried out to map the base of sand. The instrumentation, survey parameters and inversion strategies are tuned to the ultra-shallow depth of the target (2-20 m). Feasibility studies indicated requirement of sharp turn off and extremely early recordings of the decaying secondary magnetic fields. Therefore, entire recording happens within 0.35 μs to 40 μs hence the system is called micro-TEM. Nearly 1.2M micro-TEM soundings were acquired along 51 km long NS flight lines with 300 m line spacing. Acquired data were of good quality and nearly free of any cultural noise as the area is an inhabited remote location. Roll, pitch, yaw and position of the EM bird were monitored and loss of loop effective area due to system tilt was compensated. Final data were modeled by Physics-deep learning inversion (PhyDLI) approach where a hybrid approach of gradient based deterministic inversion combined with a pre-trained deep learning network model. PhyDLI allows machine learning network iteratively learn and adapt to field data gradually. The resistivity volume was calibrated by the available uphole data to associate a certain resistivity value to the base of sand. The results proved that custom-designed airborne EM technology integrated with machine learning can solve seismic sand correction problem in large and remote areas effectively.