FIRST LOOK AT FAST-SAMPLING TOWED-RIG EM DATA COLLECTED ON LAND

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INTRODUCTION

Properly characterising the regolith is becoming increasingly important in our understanding of many deeper processes in the Earth. Accurate, high detail images of the top 10 to 20 metres of the earth's surface have the potential to provide insights that help us to understand, for example, the distribution of shallow salinity on floodplains or over areas affected by dryland salinity. This paper reviews the initial results from testing of an existing electromagnetic technique. This modified system is providing information about the top 10 metres with both good horizontal and vertical resolution, in a non-destructive, economically viable way.

EXISTING TECHNOLOGIES

Frequency domain geophysical instruments that take advantage of the Low Induction Number (LIN) approximation (McNeill, 1980) are the most commonly used tools for electrically mapping the near-surface. The Geonics EM31, EM-34 and EM-38 instruments (McNeill, 1980) are used a great deal in Australia to map, for example, the extent of salinity underlying a farm paddock. It is possible to invert data from these instruments into depth sections by taking data in both the vertical dipole as well as the horizontal dipole modes and using the fact that the two modes "see" to different depths. Nevertheless, it is most common to take data in the vertical dipole mode and produce a simple contour map of conductivity over an area of interest. Through careful, consistent data acquisition over the same area at different times it is possible to map changes in conductivity that can then be correlated to the progress of salinity over a floodplain or farm paddock. This information can be useful to land managers and scientists, but there are situations where the ability to produce more detailed depth sections and depth slices of an area is necessary for land planning.

DESCRIPTION OF MOVING RIG NANOTEM SYSTEM

This system is based on one of the standard geophysical techniques called Transient Electromagnetics (TEM), in this case used in the so-called "in-loop" configuration (see, for example, Parasnis (1986) for a description of this type of system). As most mineral and energy explorers are not particularly interested in the near surface and the collection of shallow data involves using very fast sampling rates and specialised transmitters, traditional TEM data has not been suitable for most shallow engineering and hydrogeological applications.

Recent advances in electronics have allowed for the development of systems suited to collecting shallow data for use in engineering and hydrological studies. The system used in this study is based around a "standard" Zonge Engineering NanoTEM system, consisting of a single channel receiver equipped with Zonge's NanoTEM analog card, and a separate NanoTEM transmitter. The analog card is able to collect a decay sample at 1.2 microsecond intervals, while the transmitter turns off in approximately 2 microseconds. These features make it possible to start collecting conductivity information from within one to two metres of the surface. The "standard" configuration for collecting data with this type of system uses a 20 m x 20 m single turn transmitting loop and a 5m x 5m single turn receiver loop. A two to three person crew can collect 50 or so stations of this type of data in a day (i.e. one line kilometre) often to depths of around 50 to 60 metres.

The moving rig constructed for the data acquisition described in this paper uses a much smaller 3m by 3m triple-turn transmitting loop and a 1m by 1m triple-turn receiving loop. The ability of a system like this to "see" to a given depth is related to a number of factors. These include the power output of the transmitter (more power equals deeper penetration), and the transmitting and receiving moments of the transmitting and receiving antennae. These moments are directly proportional to the areas of the transmitter and receiving antennae and the number of turns of wire used when building the antennae. The transmitting moment of the "standard" system is proportional to the area of that loop (i.e. 20m x 20m x 1 turn = 400 square metres). Likewise, the transmitting moment of the moving rig is proportional to 3m x 3m x 3 turns or 27 square metres. The receiver side of the system is similarly reduced for the moving rig (i.e. 25 square metres for the standard and 3 square metres for the rig). The implication is that the rig system should only be able to "see" 7 to 12 % as deep as the larger standard rig. At this time it appears that the moving rig is able to image to at least 10 metres, which is slightly deeper than expected. Figure 1 is a schematic diagram of the towed NanoTEM rig.

All of the data shown in this paper have been inverted using Zonge's STEMINV program (MacInnes, 2005). This program converts TEM decay data at a given station to resistivity and depth assuming a 1-dimensional earth. This assumption appears to be valid for most of the data encountered up to this time. All data are then displayed either as contoured depth sections with position along line on the horizontal axis and depth on the vertical. Resistivities are contoured with conductive values as reds, and resistive values blues.

Data are also presented here as depth slices. In this presentation the inverted data values are interpolated at desired depths from the surface and contour maps prepared at those depths. These maps have then been displayed on a GIS image of the area.

RESULTS

Figure 2 reviews results from the initial phase of a feasibility study conducted to verify whether the towed rig responds appropriately to differences in geology. The top two data sets (Figures 2a and 2b) were collected in February of 2006 at the bottom of a small sand hill near the Roseworthy campus of the University of Adelaide. They compare the geophysical responses of the "standard" 20 metre loop versus the rig sitting still at the same location. Data for Figures 2c and 2d were collected at the top of the hill, thereby comparing a thicker sequence of sand at the top of the hill with a thinner sequence at the bottom. In each case the plot on the left shows the "raw" decay curve for each configuration and location. We expect these to be quite different for the 20 metre and 3 metre loop data sets as the signal amplitude for the 20 metre data should be much larger, and the decays should then last longer. Each figure on the right shows the inverted results. For these plots we expect the two curves to be "reasonably" similar, with the expectation that the 20 metre loop data should "see" significantly deeper than the 3 metre loop.

Once the feasibility study was completed, a comparison of the standard NanoTEM and the moving rig was performed from the bottom of the same sand hill to the top. These data were collected in May 2006. In this case the "standard" NanoTEM setup used 10m x 10m transmitting loops and a 2.5m x 2.5m receiving loops. This was necessary as there was not enough space for the 20m x 20m loop over much of this particular paddock. That survey took two people approximately four hours to complete. Once that was completed the rig was built (assembly time of approximately one hour) and the same hill was run again. The first run took approximately five minutes to complete. Figure 3 shows a comparison of the results from the more standard configuration against the moving rig. The vertical red line on the left side of the Figure highlights a small resistive feature that is obvious in both sets of data. The vertical red line on the right side of the Figure highlights a small conductive feature deeper in the data. This is not resolved in the rig data at all. The horizontal red line at 15 metres suggests the depth limit for the rig in this type of moderately conductive regime. Resistive features in the top five metres of both sections also match each other quite well.

Figure 4 shows depth slices from the next round of data collected with the NanoTEM rig. These data were collected on Clark's Floodplain (near Berri, South Australia) in September of 2006 over the course of four to five hours. For this figure all of the data were inverted, depth slices prepared, and the slices displayed on a GIS image of the area. Only the depth slices at 2 metres, 6 metres and 10 metres depth are shown here. The bottom-of-river resistivity values from the 2004 Instream NanoTEM are displayed in the river for comparison (Telfer *et al.*, 2004). It is pleasing to note that the Instream NanoTEM results and the rig NanoTEM show similar resistivity contrasts over much of the survey area, most notably in the northern bend of the river. In this particularly conductive setting the depth penetration of the system appears to be less than 10 m, as the there are "holes" in the image where the inversion was unable to come up with results in the 10 metre depth slice.

Figure 5 presents a comparison of "normal" 20m x 20m loop NanoTEM data with data collected using the NanoTEM rig. The 20 metre loop line of data was surveyed in through thick scrub, while the rig data follows a nearby track. Only the top 10 metres of the inversion for the 20 metre loop data are shown here; the actual inversion extends to approximately 40 metres depth. In both sets of data the inversions clearly show the influence of the Murray River on the west ends of the sections.

FURTHER WORK

More work needs to be done to establish both the precision and accuracy of this technique. Further work to tie the data with drill logs over areas that have been run needs to be done, as well as comparison with detailed soil-water chloride content logs at selected sites. Further tests will be run over other types of terrain, especially over much more resistive ground to investigate the response of the setup in a significantly different environment.

CONCLUSIONS

The moving rig NanoTEM system has been tested over a limited number of areas. The results have been encouraging, suggesting that the technique is suitable for collecting detailed conductivity information in the top ten metres of the regolith in a non-invasive and economic manner.

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TELFER A. L., PALFREYMAN C., BERENS V. & HATCH M. 2004. Atlas of instream NanoTEM 2004: Blanchetown to Mallee Cliffs, pp. 30. Murray River Darling Basin Commission and Mallee Catchment Management Authority, Adelaide, SA.

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LIST OF FIGURES

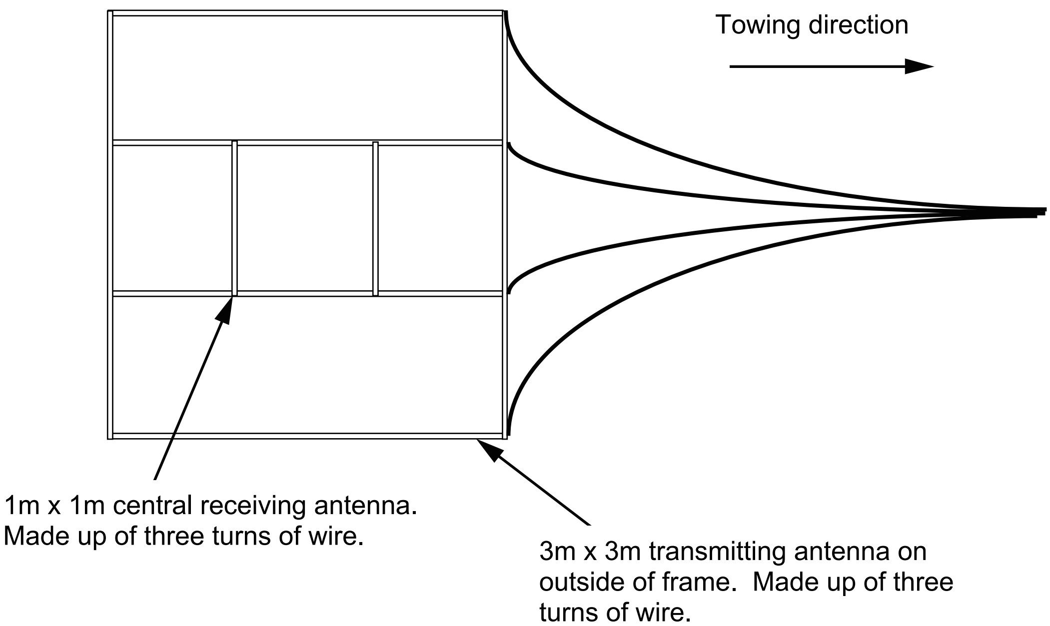

Figure 1: Schematic diagram of Towed NanoTEM rig. Data are collected at approximately 4 metre intervals at 4 km/hour.

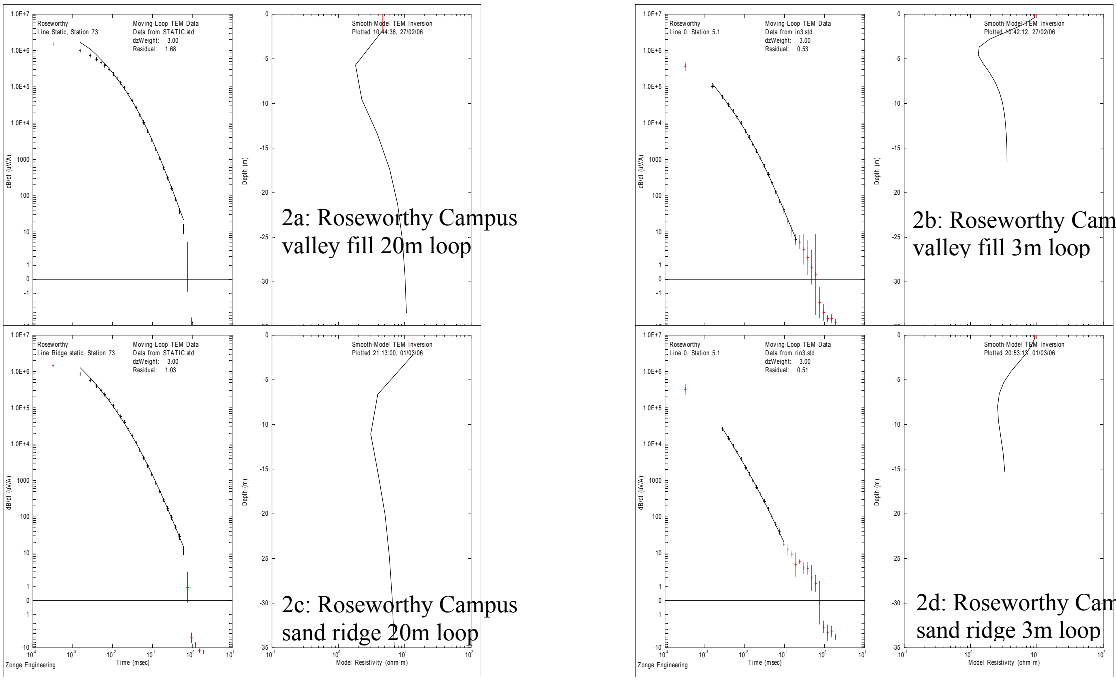

Figure 2a-d: Comparison of responses using static 10 m loop and static 3m loop at different locations on same line. The left side of each set of plots shows the TEM decay for each sounding. The right side of each set shows the inverted model results derived from that sounding. 2a and 2b were taken at the same location. 2c and 2d were taken at the same location.

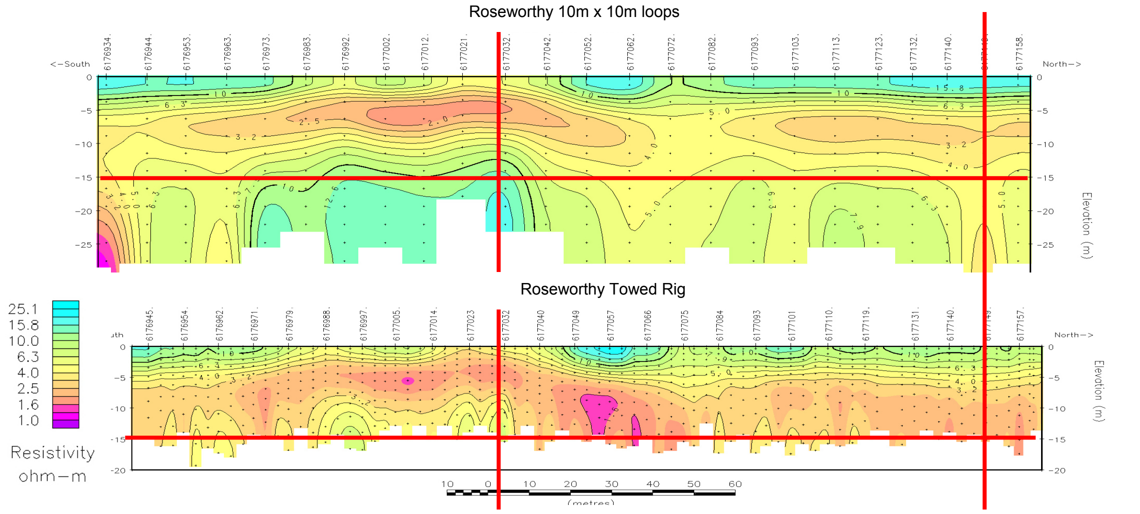

Figure 3: Comparison of inverted responses using 10 m loops and moving 3m loop. Top set of data took two people approximately 4 hours to collect. The bottom data set took approximately 5 minutes to collect. The vertical red line on the left side of the Figure highlights a small resistive feature that is obvious in both sets of data. The vertical red line on the right side of the Figure highlights a small conductive feature deeper in the data.

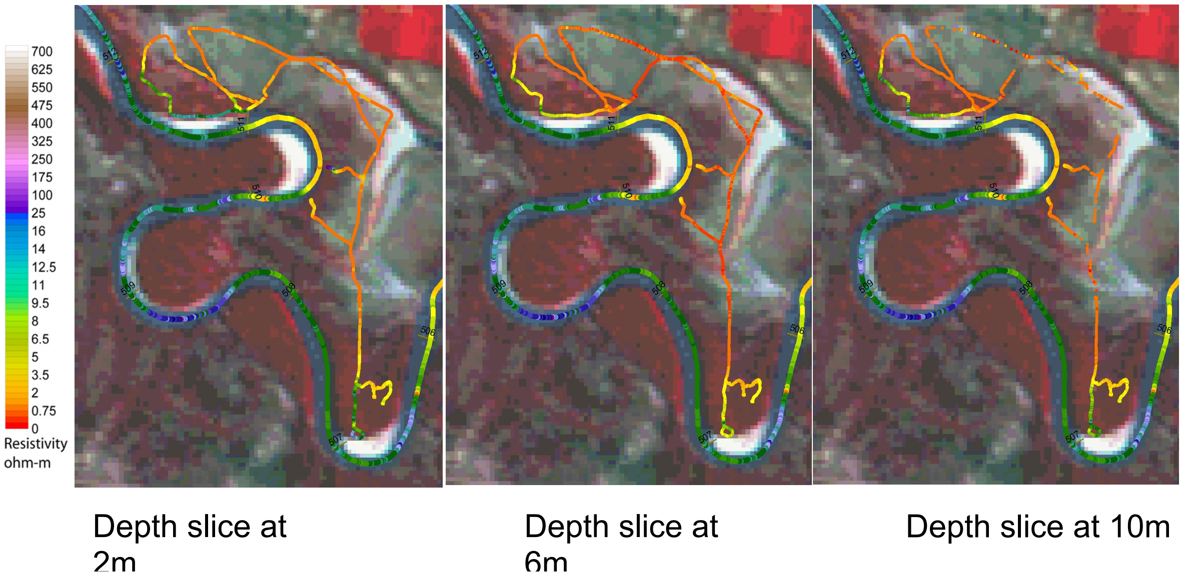

Figure 4: Depth slices of inverted towed rig NanoTEM data. Depths as indicated under each figure. Note that by 10m depth there are holes in inversion indicating that this is probably just past the depth limit of the system under these very conductive conditions.

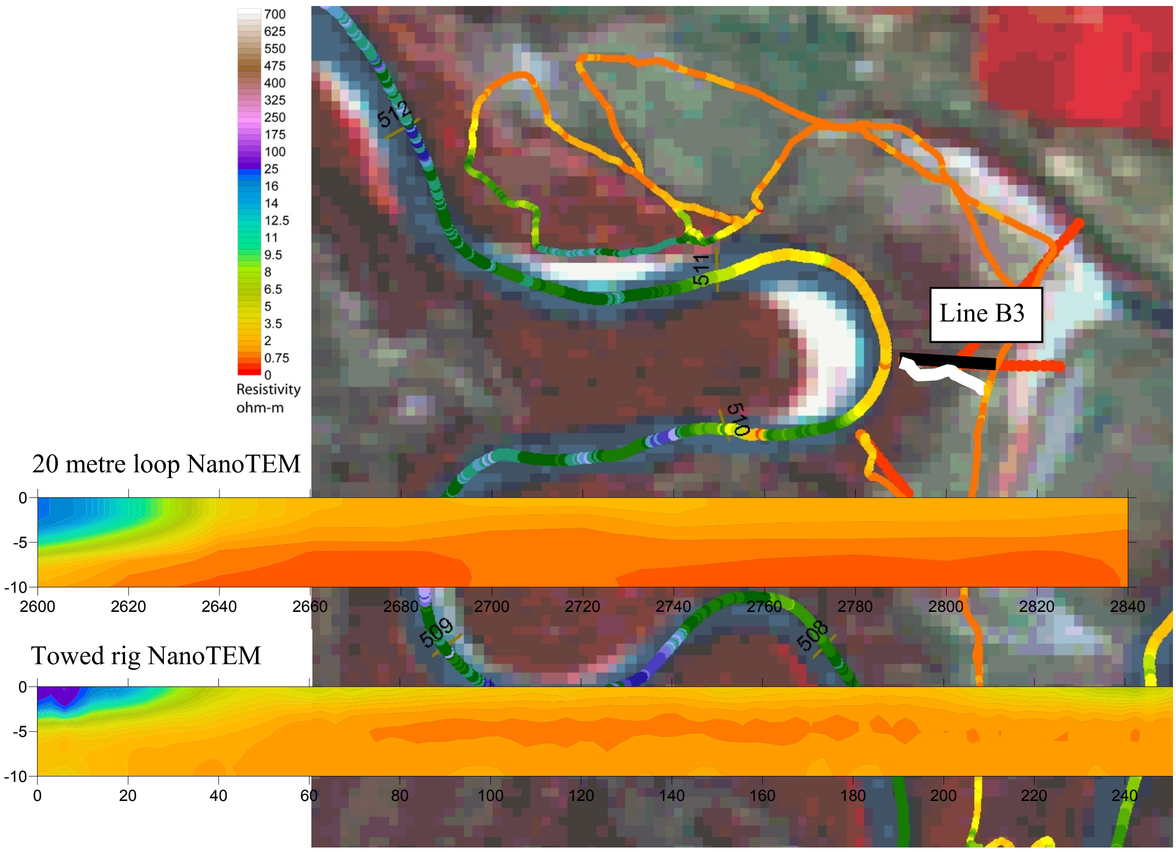

Figure 5: Comparison of "normal" 20m x 20m loop NanoTEM data with data collected using the NanoTEM rig. The 20m loop data is highlighted in black on the overview map, and was surveyed through thick scrub. The rig data (highlighted in white) follows an adjacent track. Only the top 10 metres of the inversion for the 20m loop data are shown here; the actual inversion extends to approximately 40 metres depth.