Comparing test line inversion results from different helicopterborne transient instruments with regard to hydrogeological mapping

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SUMMARY

The selection of an appropriate instrument for the data collection is one of the most important issues to address in survey design. Both theoretical analyses of the resolution capabilities of the candidate systems and field tests should be part of a selection process. It is also quite clear that any comparison must be performed based on the specific criteria of the survey. In this presentation we will concentrate on the field test aspects of the system selection process and compare the results of inverting data from three different helicopterborne systems: the VTEM system, the SkyTEM312 system, and the SkyTEM312FAST, that were flown over the same test lines. The bench marks of the comparison were mainly the near-surface resolution capabilities, both vertically and horizontally, and the resolution at depth. The results of our study show that in certain parts of the test lines both SkyTEM systems have a better near-surface vertical and horizontal resolution than the VTEM system, but that in other parts of the test lines differences are small. The depth penetration seems to be approximately the same for all three systems. The differences between the SkyTem312 and the SkyTem312FAST are almost imperceptible.

Key words: AEM system comparison, inversion, hydrogeophysical studies.

INTRODUCTION

A crucial part of a successful airborne survey is the pre-survey design, and one of the most important issues to address is the selection of an appropriate instrument for the data collection, and in recently years, this field has attracted more attention in the AEM community. Preferably, both theoretical analyses of the resolution capabilities of the candidate systems and field tests should be part of a selection process, and obviously any comparison must be performed based on the specific criteria of the survey: the demands on the instrumentation are not necessarily the same for mineral prospecting, hydrogeophysical investigations, and geotechnical surveys.

Christensen and Lawrie (2012) present a comparative analyses between two different methodologies of theoretical analysis of the resolution capability of AEM instrumentation and applies an inversion-based approach to comparing TEMPEST and SkyTEM systems, (Smiarowski and Mulé, 2014; Christensen and Lawrie, 2014). Equally important is the choice of an appropriate inversion method and program. Ley-Cooper et al. (2014) present a study in the dimensionality of inversion programs, and Hodges and Chen (2014) explore the possibility of using a common physical analogy approach to the comparison of AEM instruments.

In this abstract, we will concentrate on the field test aspects of the system selection process and compare the results of inverting the data from three different helicopterborne systems: the VTEM system, the SkyTEM312 system, and the SkyTEM312FAST, that were flown over the same test lines. Similar issues were addressed in Bedrosian et al. (2015) who compare both frequency and time domain systems with ground based measurements. To provide an even playing ground for our comparison, all data sets are inverted with the same inversion program using the final data delivered by the contractors and with equal inversion settings. The bench marks of the comparison were mainly the near-surface resolution capabilities, both vertically and horizontally, and the resolution at depth.

DESCRIPTION OF THE AEM SYSTEMS

The SkyTem312 systems belong to the latest developments at SkyTEM (Sørensen et al., 2004). They are both helicopterborne transient systems with a dual moment transmitter (Tx) and zero-coupled receiver (Rx) coils for both z- and x-component data. The only difference between the systems is that while the SkyTEM312 system is flown a survey speeds of 60-80 kph, the 312FASTsystem is aerodynamically engineered to remain stable at survey speeds up to 150 km/h. The system was calibrated at the National Danish Test Site before data acquisition. Tx height and attitude are determined based on three lasers and a double set of inclinometers all placed on the Tx frame. To what extent the lower lateral sampling rate and the slightly lower signal to noise ratio of the 312FASTsystem affects the near-surface lateral resolution capability is one of the objectives of this study. The system parameters for the test line flights are seen in Table 1, valid for the z-component data used in the study.

The VTEM system is a helicopterborne transient system with a central loop configuration including a bucking coil. Internal calibration of the voltage and current measuring systems are performed with the system on the ground. Further calibration on the ground is done by introducing an aluminium plate at different orientations close to the Tx-Rx systems. The system response is determined through measurements at 1000 m height. During acquisition, voltage and current data are collected with a sampling frequency of 192 kHz. The varying waveforms of the individual decays are post-flight deconvolved to a 'Common Waveform' for all soundings. The EM Tx-Rx loop height above ground is inferred from data from the radar altimeter located on the helicopter, and data from the laser altimeter and gyroscopic inclinometer located on the front of the magnetic gradiometer loop (not the EM Tx frame), and knowledge of the tow cable lengths. The system parameters for the test line flights are seen in Table 1, valid for the z-component data used in the study. VTEM data can be collected with both a long and a short pulse width; however, the lines that were coincident with SkyTEM lines were flown only with the long pulse system, so our comparisons are limited to those.

	SkyTEM Low Moment	SkyTEM High Moment	VTEM Long Pulse	VTEM Short Pulse
Tx area	337 m2	337 m2	531 m2	531 m2
Tx turns	2	12	4	4
Tx current	5.9 A	122 A	191 A	257 A
Tx moments	~4 kAm2	~500 kAm2	~406 kAm2	~546 kAm2
Base frequency	275 Hz	25 Hz	25 Hz	25 Hz
Tx waveform	linear rise linear ramp-off	trapezoid linear ramp-off	bipolar trapezoid	bipolar trapezoid
Tx ontime	0.8 ms	5.0 ms	7.33 ms	4.5 ms
Tx offtime	1 ms	15 ms	12.5 ms	15.5 ms
Tx turnoff time	~18 us	~320 us	~1.4 ms	~1.1 ms
Rx coil effective area	105 m2	105 m2	113 m2	113 m2
Rx coil low-pass cutoff	210 kHz	210 kHz	no info	no info
Amplifier low-pass cutoff	300 kHz	300 kHz	no info	no info
Nominal frame height	35 m	50 m	43 m	43 m
Acquisition speed	75-85 kph (312) 100-160 kph (FAST)	75-85 kph (312) 100-160 kph (FAST)	~87 kph	~87 kph
Gate delay time interval	20-880us	400-13,700us	21-10,667us	21-10,667us

Table 1: System parameters for the SkyTEM312, SkyTem312FAST and the VTEM systems.

THE INVERSION CODE

The inversions were carried out using a new inversion algorithm developed at Geoscience Australia called GALEIALLATONCE (Brodie, R.C., 2016 personal communication). Rather than inverting each sounding independently, GALEIALLATONCE inverts a complete line/survey of AEM data all at once. In addition to the conventional vertical roughness and reference model constraints, this allows horizontal roughness and borehole conductivity log constraints to be imposed in the inversion to improve non-uniqueness and thus along-line and across-line coherency of the results. For this system comparison work (in which a different number of lines were flown with each system) the inversion was carried out on each flight line separately so that the comparisons were as fair as possible. Similarly, borehole conductivity logs constraints were not used to ensure that it was the system resolution that was tested, and not the influence of the constraints. Furthermore the same layer thicknesses, reference model (0.050 S/m) and horizontal and vertical regularization settings were used for each system.

TEST LINE RESULTS

Among the lines flown in the Darling River area, Australia, there were four coincident lines flown with all three systems. In this abstract, we present results from only two of the lines. In Figure 1, model sections for the three systems are plotted to 200m depth. On first inspection, the models sections seem quite similar, but looking closer at the line distance interval 10,000-20,000, as well as around 2,000m, it is seen that the SkyTEM systems have a better resolution in the top 30m, providing a better definition of the well conducting layer at 20-30m depth. Moreover, looking closer, it is seen that the SkyTEM systems agree on a very near-surface well conducting layer separated from the one at 20-30m depth by a more resistive zone throughout the profile. This resolution is not seen in the VTEM profile. At depth, there is very good agreement between the three systems, and throughout the profile, there is hardly any difference between the two SkyTEM systems.

In Figure 2, model sections from second comparison are shown, now plotted to a depth of (at least) 50m. In these plots, there are only small differences to be seen between the three systems except that around profile coordinate 25,000, both SkyTEM systems show a coherent very near-surface conductor separated from one at ~10m depth. This feature appears not to be resolved by the VTEM system.

CONCLUSIONS

The results of our study show that over large parts of the test lines, both SkyTEM systems have better near-surface resolution than the VTEM system, although this is not always the case. The resolution at depth appears to be approximately the same for all three systems down to the 200m relevant for this conductivity setting . The differences between the SkyTem312 and the SkyTem312FAST are almost imperceptible, suggesting that, between the two systems, the more field efficient SkyTem312FAST may be preferred.

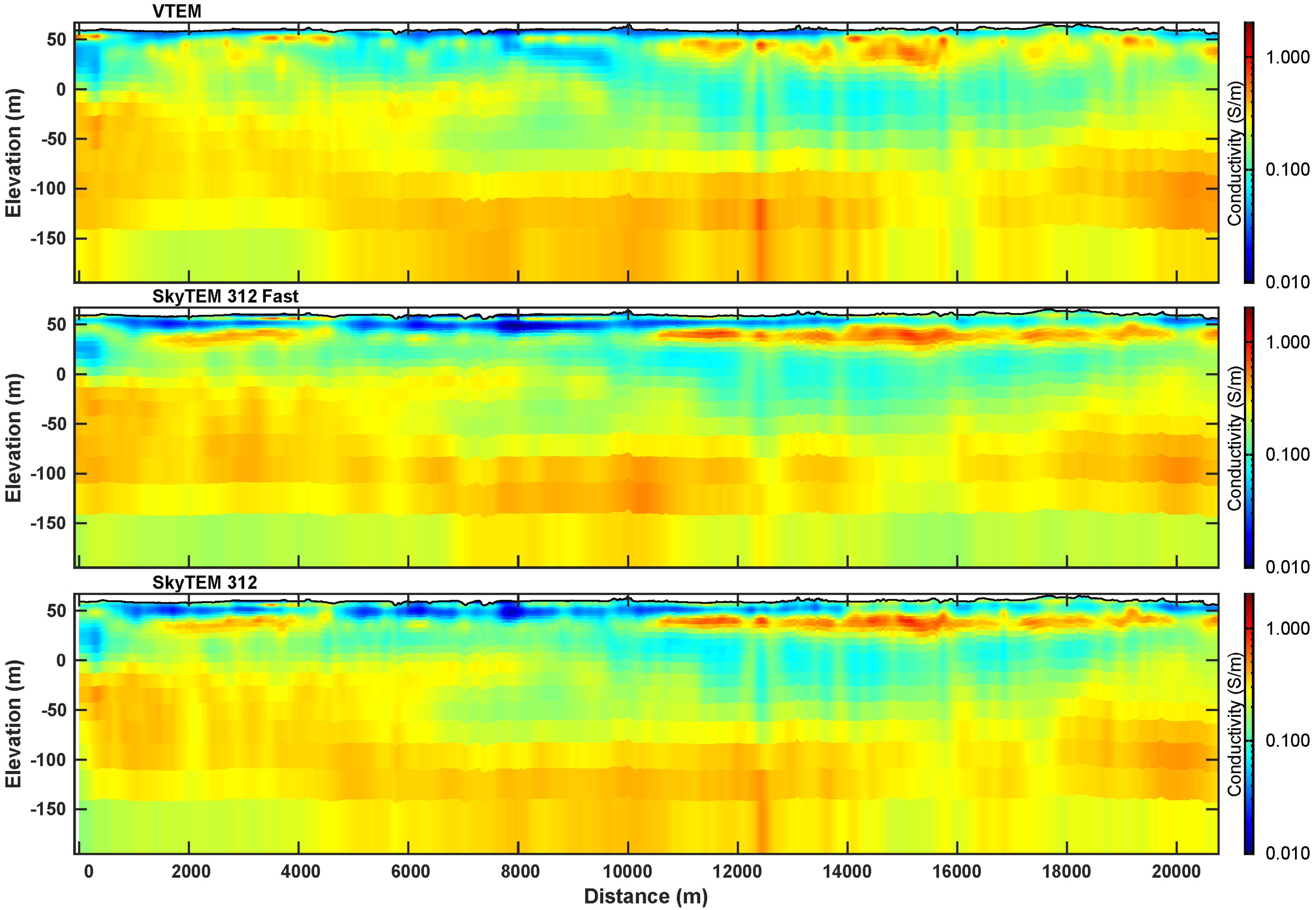

Figure 1: Model sections for the three systems plotted to 200m depth for the first line of the comparison.

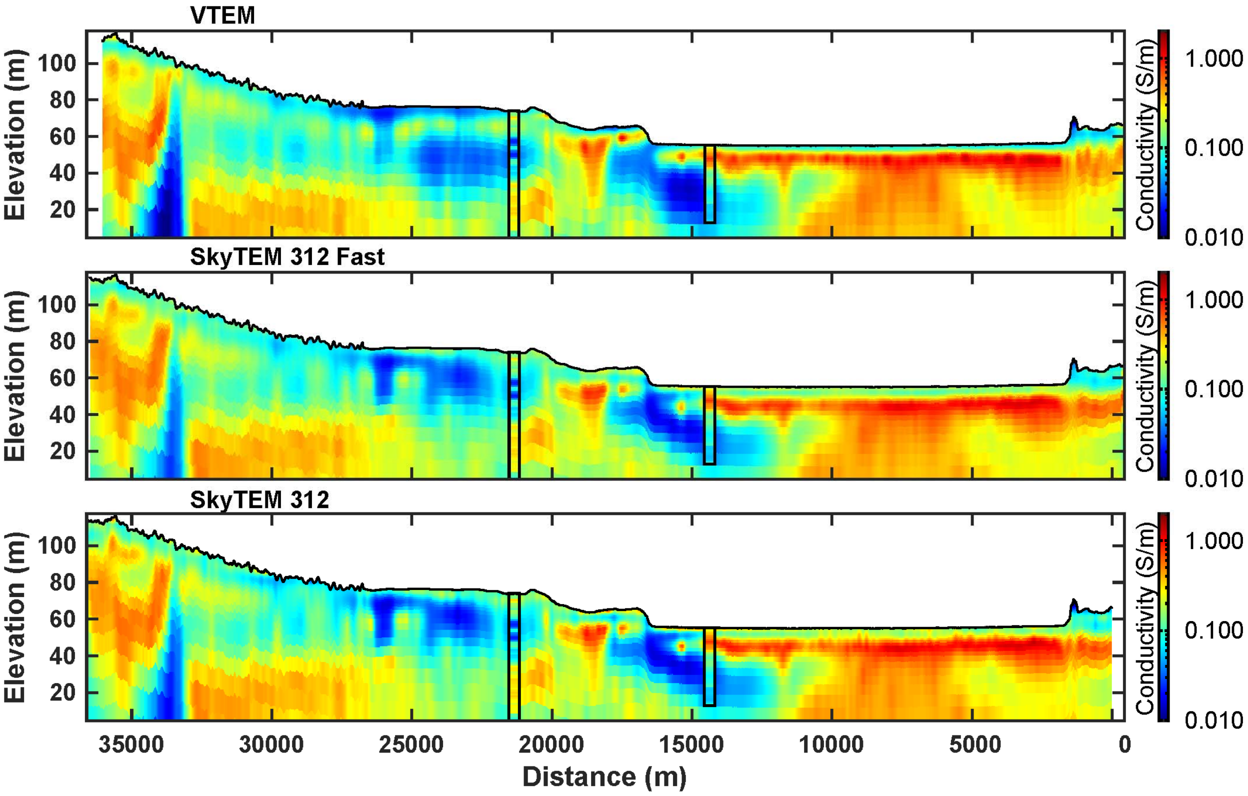

Figure 2: Model sections for the three systems plotted to 50m depth for the second line of the comparison.

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