Detrital Ground-Airborne Analyses

The ground data in the Detrital basin offers an excellent opportunity to compare the structural resistivity interpretation from ground and airborne data.

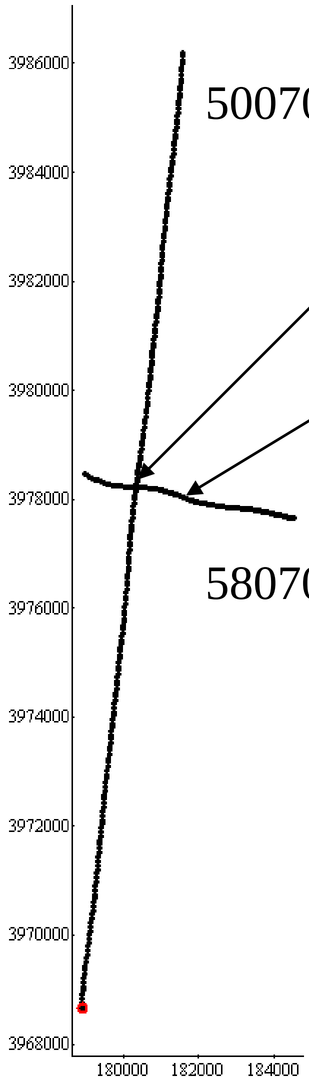
The first case examined here, (Loop 2), is at the intersection of the Geotem lines – 50070 and 58070. For the airborne case we have not only the two approximately perpendicular flights which intersect very close the Loop location but also we have 2 data components – the vertical, Hz and the horizontal Hx data.

The ground data was collected with a square loop with a size 150m on an edge at a base frequency of 8Hz with 28 data channels. The ground data was collected at 9 stations – one at the centre of the loop and 4 at 150m from the centre of the loops towards each cardinal direction and 4 at 300m from the centre of the loop again in each cardinal direction.

There were several purposes to collecting the ground data in this manner. Firstly, collecting the data in 4 directions at at 3 different offsets from the loop centre would indicate to what extent the ground was one-dimensional. Our intention to determine resistivity-depth structure was to use several one-dimensional inversion strategies. Secondly, if the structure was reasonably one-dimensional, then stacking (averaging) the data for a given offset would reduce both geological and system noise. For the 150m and 300m offsets, we also have the ability to delete bad data prior to stacking. Finally, our intent is to provide one model that fits the stacked data at all offsets. A model which fits only the inloop measurement is not adequate as the wider offset data provides more depth resolution for the model.

The airborne data was collected by Fugro Airborne using the GeoTem instrumentation at a basefrequency of 30Hz with 20 data channels. The 4 “on-time” channels are not suitable for our purpose and the 5th channel is partially sampled in the off and partially channelled in the on. Thus, we have chosen to use the last 15 channels for our interpretation.

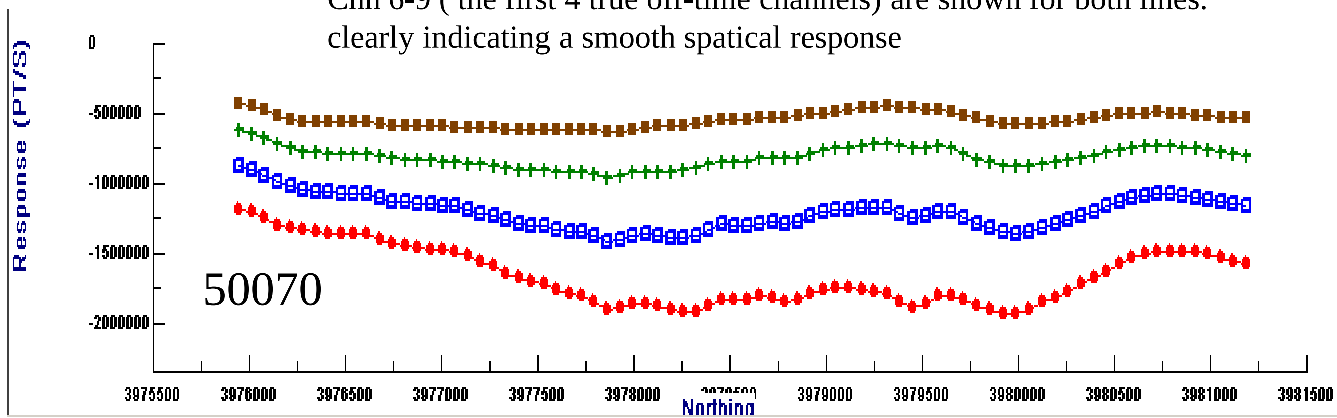
Loop 2/3 - 1

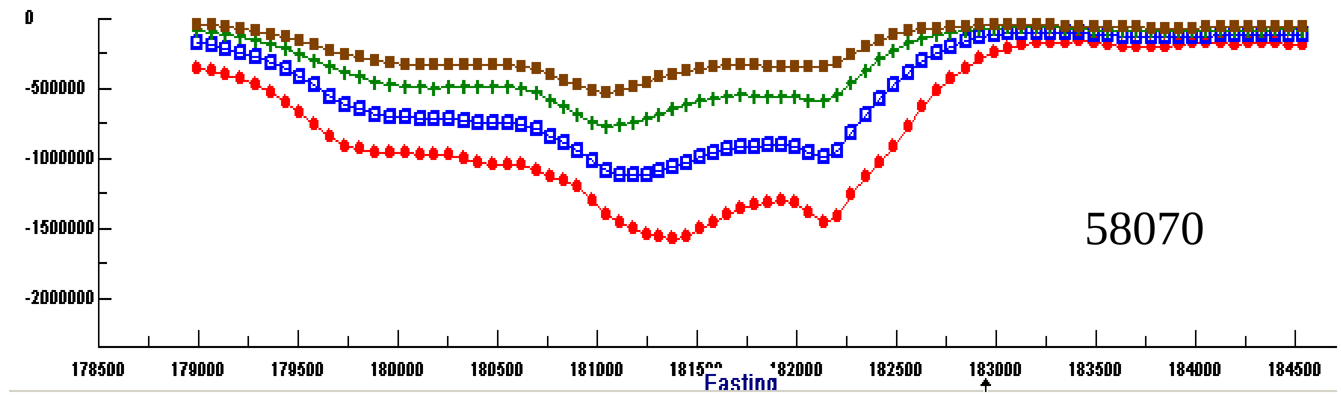


Loop 2: 180373, 3978221

Loop 3: 181319, 3978108

Chn 6-9 (the first 4 true off-time channels) are shown for both lines. clearly indicating a smooth spatical response

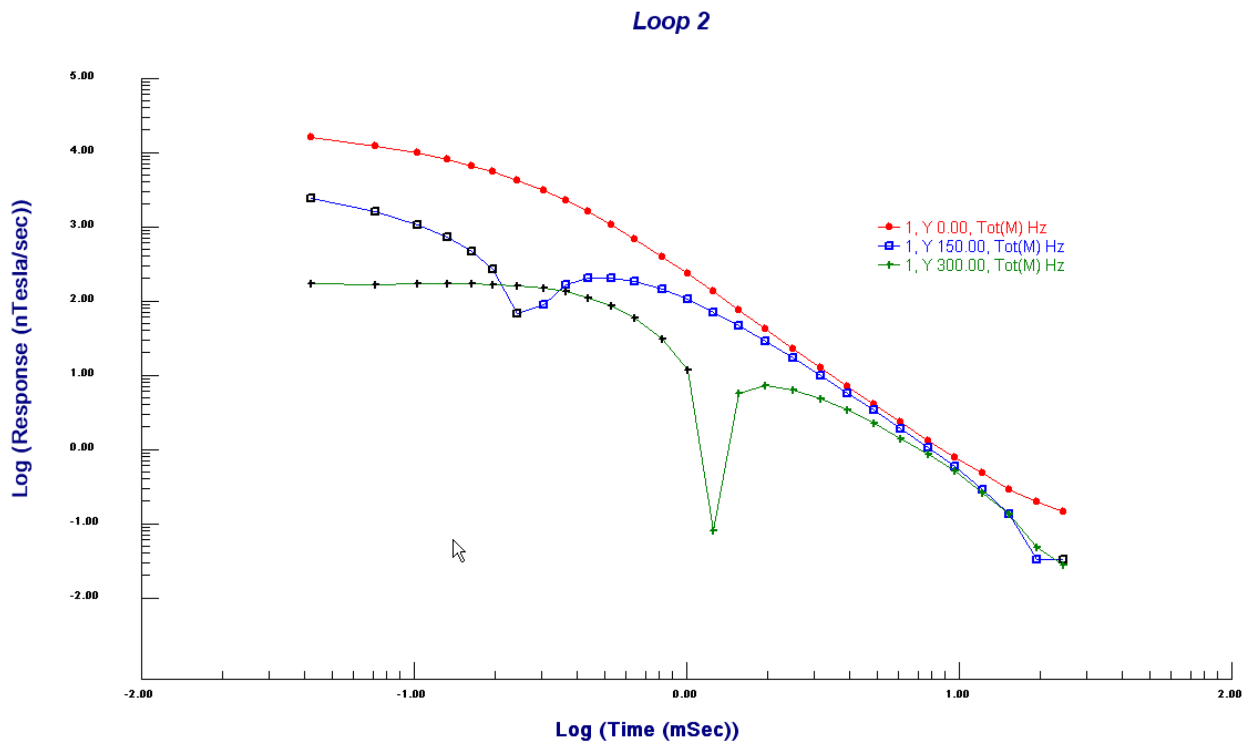




Loop 2 - 2

Loop 2 – Ground Zonge TEM

Loop 2 was measured at 9 stations 8 inside and 1 inside for the 8Hz basefrequency only.



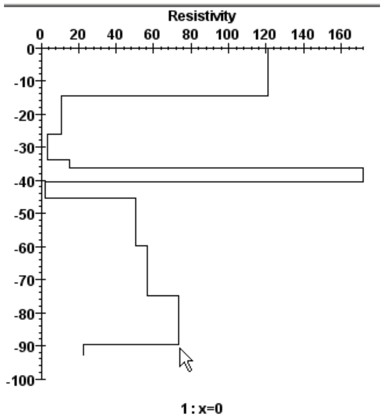
Stacked inloop measurements

simple examination indicates a moderately resistive cover underlain with a shallow conducting zone and then a modestly conducting zone beneath.

Loop 2 - 3

Loop 2

Loop 2 was measured at 9 stations 8 inside and 1 inside for the 8Hz basefrequency only.



Smooth 10-layer occam model

Simple modeling followed by a 10 layer occam inverse gave the model to the left. The other stations indicate roughly the same model.

layer	thickness	resistivity
1	14.5	121
2	12	11
3	7.5	3.2
4	6.8	15
5	4.8	1.9
6	29	50
7	15	75
8		15

Best fit for all 3 stations

A single layered model does fit the 3 stacked stations quite well. The repeatability of the data at a given distance from the loop centre indicated good quality data both from a system and acquisition perspective but also from the perspective of lack of high order dimensionality effects in the data.

The model was as expected indicating a moderately resistive top material underlain relatively shallowly by a conducting zone and then a a modest resistivity below.
Two points are of interest. First, the conductive zone interbedded with a more resistive zone at a depth of 33m and finally whether the conducting material as the basement can be resolved.

The issue of the interbedding was not examined but the it is clear from modeling that the conducting material in the basement must be present to explain the data.

Loop 2

Loop 2 - 4

Loop 2 was measured at 9 stations 8 inside and 1 inside for the 8Hz basefrequency only.

layer	thickness	resistivity
1	14.5	121
2	12	11
3	7.5	3.2
4	6.8	15
5	4.8	1.9
6	29	50
7	15	75
8		15

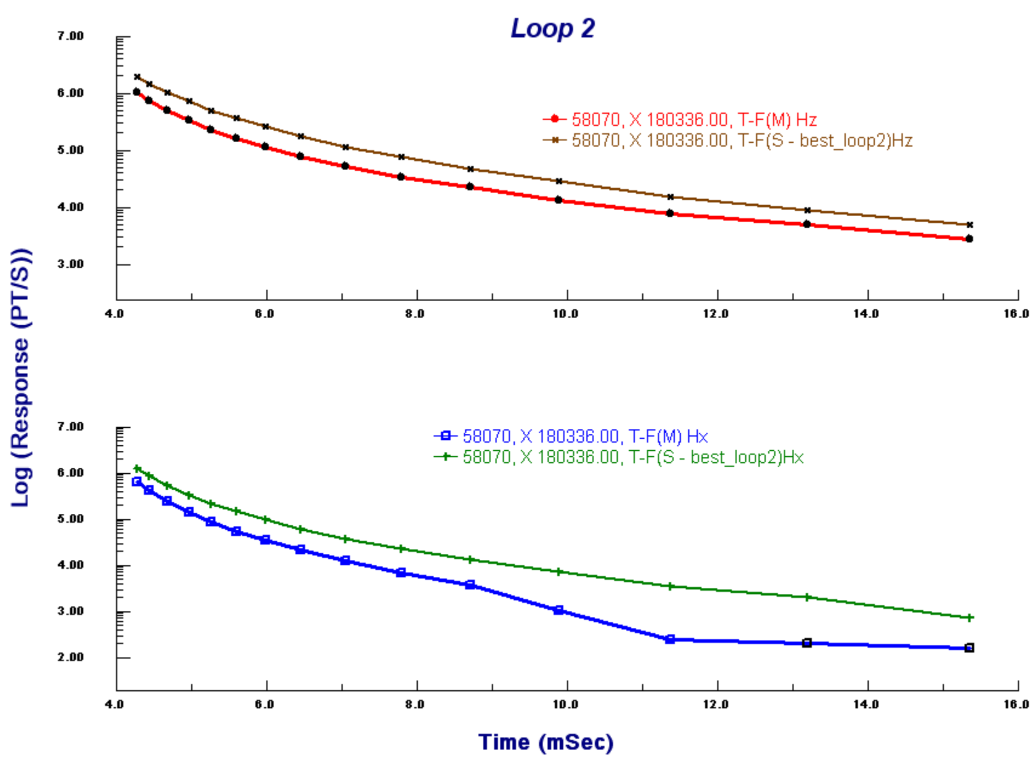
Best fit for all 3 stations

Given the clarity of the ground data and the fit of a model to the ground data, it seems now necessary to determine if the airborne data is consistent with this model. For loop 2, we have 2 flights passing overhead and in addition we have 2 data components – Hz, Hx.

Fit of Geotem data to ground model

A quick look at the airborne data reveals a strong indication that the airborne data does not "see" the shallow conducting layers. Modeling the airborne data to the ground model makes this obvious. The figure to the left indicates the response to both Hz and Hx to the model (Blue, Brown) is too large.

Here the airborne data has been spatially averaged to a inline sampling closer to 50m. This is the type of process undertaken in the original processing but we have increased the essentially stracking to improve late time signal to noise.



Line 58070

Loop 2

Loop 2 - 5

Loop 2 was measured at 9 stations 8 inside and 1 inside for the 8Hz basefrequency only.

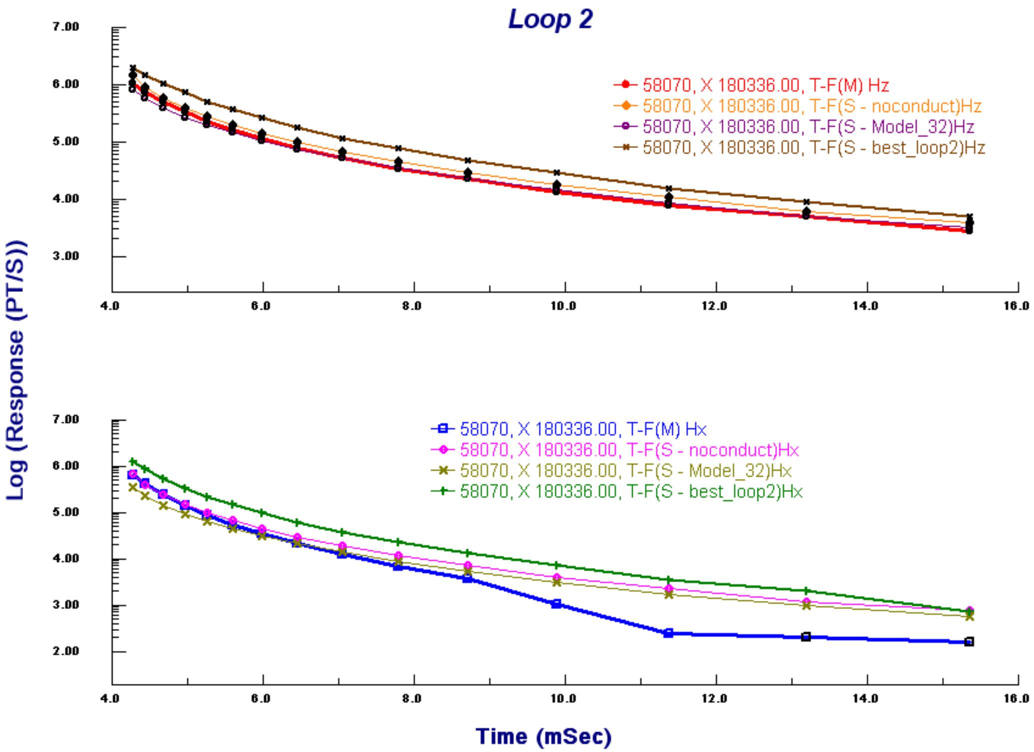
layer	thickness	resistivity
1	14.5	121
2	12	11
3	7.5	3.2
4	6.8	15
5	4.8	1.9
6	29	50
7	15	75
8		15

Best fit for all 3 stations

Given the clarity of the ground data and the fit of a model to the ground data, it seems now necessary to determine if the airborne data is consistent with this model. For loop 2, we have 2 flights passing overhead and in addition we have 2 data components – Hz, Hx.

Fit of Geotem data to ground model

As illustration, two other models were run. a) noconduct: in which the 2 most conducting layers were simply removed (Lay3,Lay5) b) Model_32: in which the all 5 tops layers were simply set to 121 Ohm_m. The results of this model indicate clearly that the airborne data does not see the shallow conductors?.



Line 58070

Loop2 - 6

Loop 2

Loop 2 was measured at 9 stations 8 inside and 1 inside for the 8Hz basefrequency only.

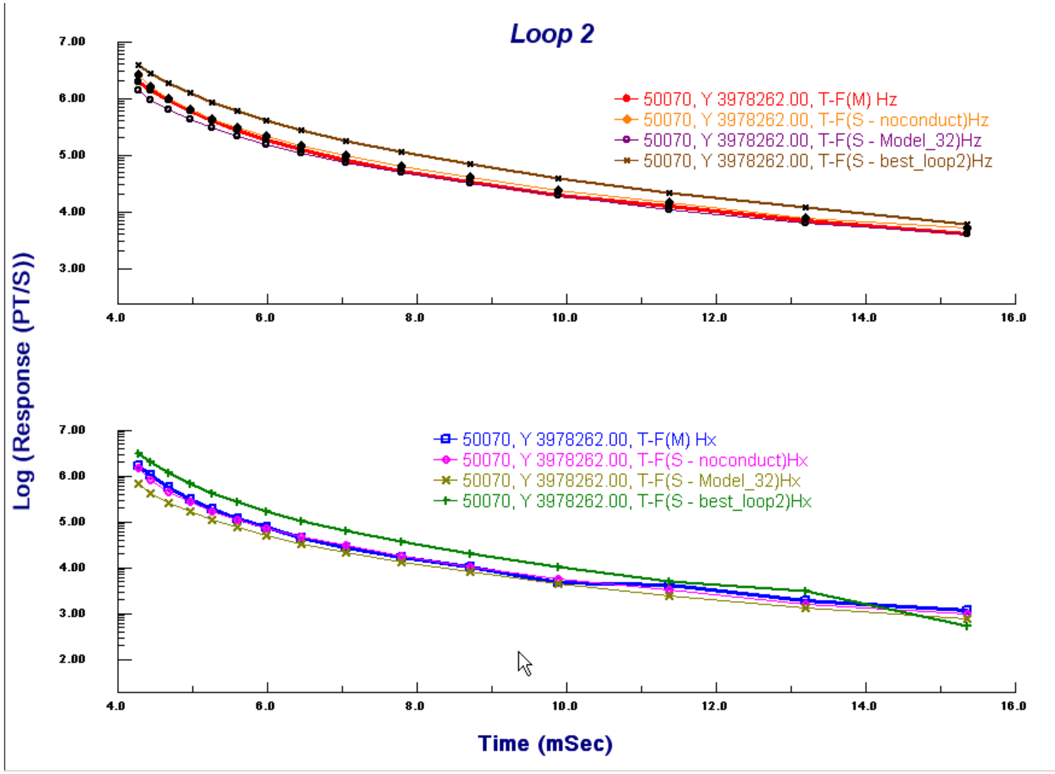
layer	thickness	resistivity
1	14.5	121
2	12	11
3	7.5	3.2
4	6.8	15
5	4.8	1.9
6	29	50
7	15	75
8		15

Best fit for all 3 stations

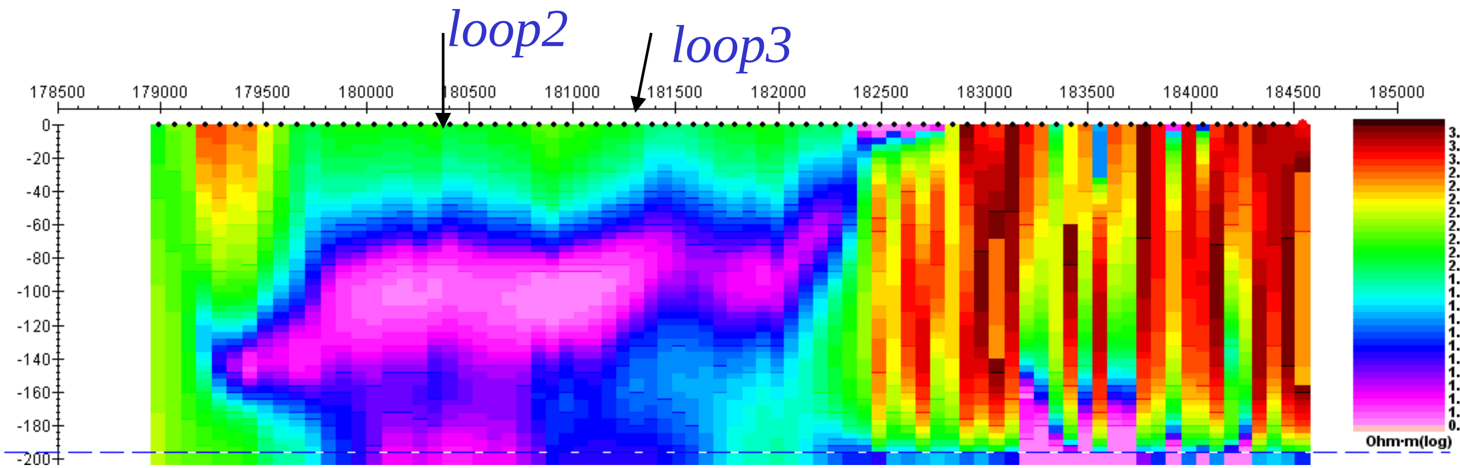
Given the clarity of the ground data and the fit of a model to the ground data, it seems now necessary to determine if the airborne data is consistent with this model. For loop 2, we have 2 flights passing overhead and in addition we have 2 data components – Hz, Hx.

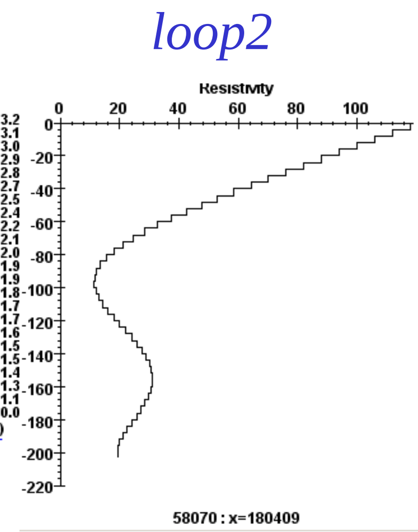
Fit of Geotem data to ground model

As illustration, two other models were run. a) noconduct: in which the 2 most conducting layers were simply removed (Lay3,Lay5) b) Model_32: in which the all 5 tops layers were simply set to 121 Ohm_m. The results of this model indicate clearly that the airborne data does not see the shallow conductors?.

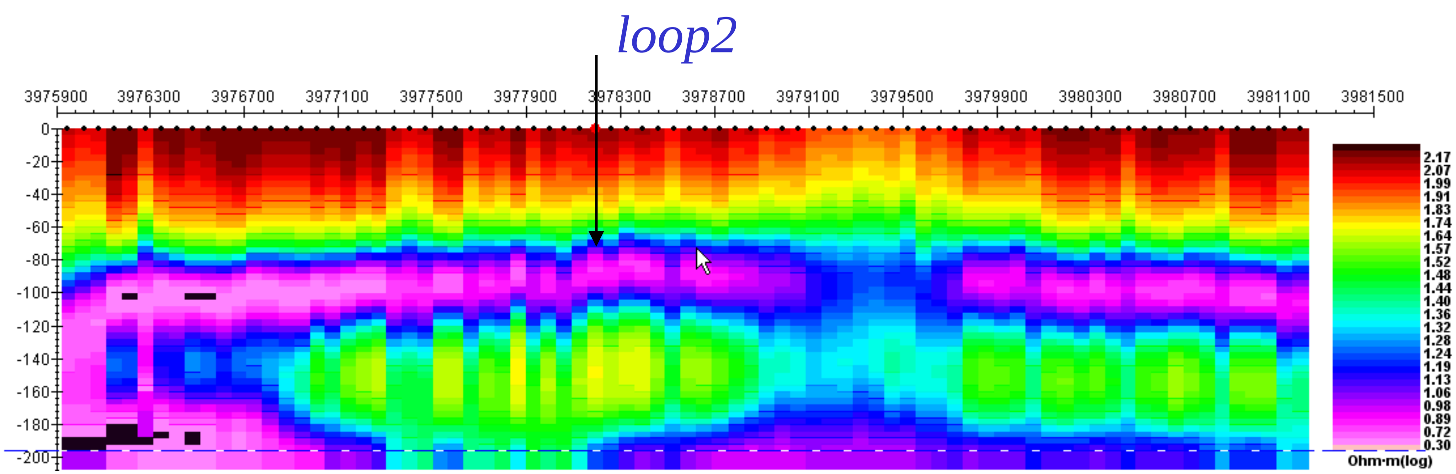


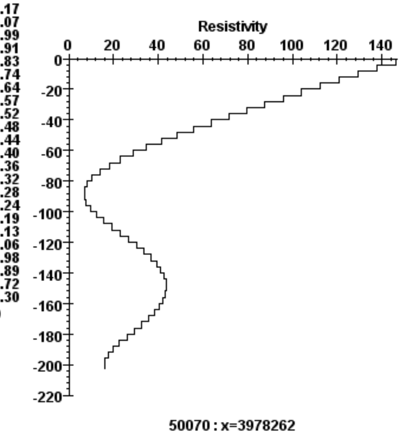
Line 50070





line 58070 - EW

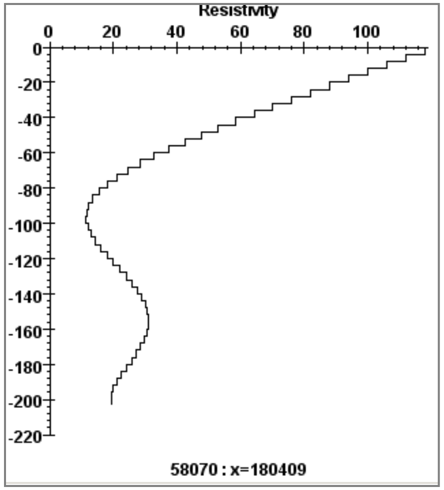




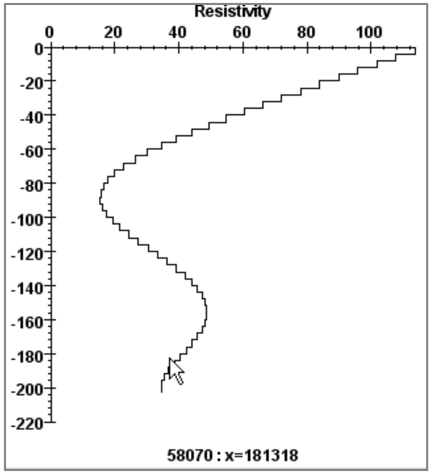
line 50070 - NS

Loop2 -7

loop2



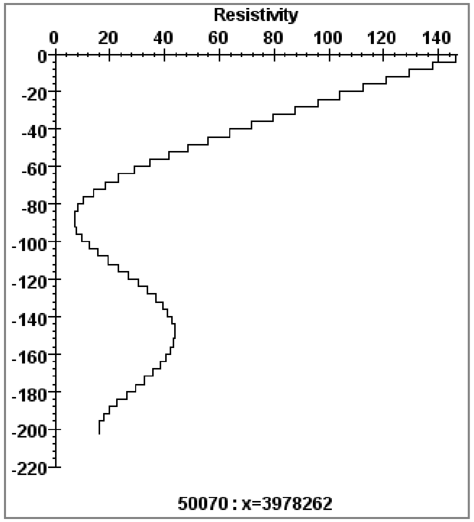
loop3



line 58070 - EW

AEM models

loop2



Loop2 -8

line 50070 - NS

Comments:

The model from the stations closest to Loop 2 is extracted from Line 58070 . This model was computed for both Hz and Hz for stations near Loop 2 on both NS and EW flight lines. The Hz component fits well for both flight lines but the Hx component while fitting well through mid and late times was a little too small in the early off channels for both flight directions. When compared to the ground model without the shallow conducting layers, it fit Hz better and fit mid to late times in Hx better while fitting early Hx channels not as well. These results confirm directly that the airborne data does not "see" any shallow layers.

Finally, we then computed the response to the ground survey to the airborne model for the area around Loop 2. As expected, the results do not even roughly approximate the ground data.

Conclusion from Loop 2

Modeling and inversion results from ground and airborne data over the region of loop 2 indicate strongly significant non-correlations between airborne and ground data.

Loop 2 offers an excellent example as we have the ground data at 9 positions and crossing airborne lines. The ground data is consistent at all 9 Rx locations which makes the possibility of instrument malfunction or poor data collection very slight. There remains the possibility the data was collected at another position but even if the GPS was malfunctioning badly the whole area around Loop 2 is relatively uniform from the airborne data perspective. Loop 2 and Loop 3 appear, however, out of order along line 58070 since as we travel east from Loop 3, we arrive at Loop 1 and then Loop 4. This possibility we will return to later.

The airborne data is consistent laterally and on the crosslines and generally consistent between Hx and Hz. This is not always the case for all of the data collected in this survey over the 6 basins. This seems to rule out this possibility. We will now explore the other ground data at the other loops with these issues in mind

Loop 3

Loop 3 -1

Loop 3 was measured at 9 stations 8 inside and 1 inside for the 8Hz and 16hz basefrequency

layer	thickness	resistivity
1	16.5	75
2	45	6.5
3	15	486
4	94	4000
5		5.2

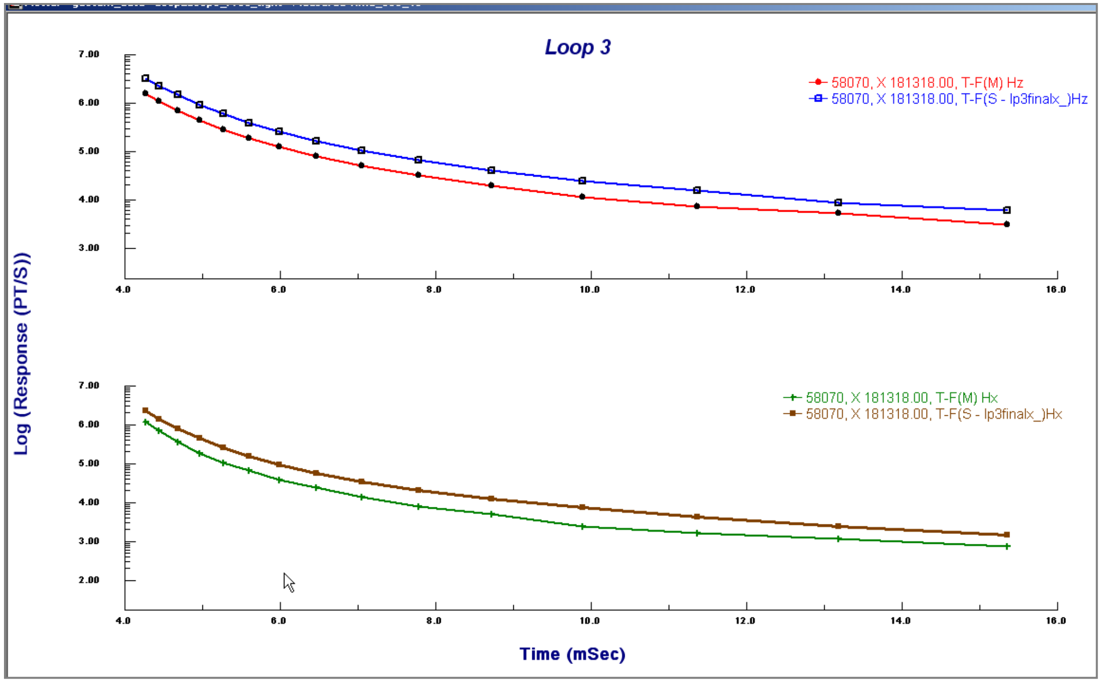
Best fit for all 3 stations

The model to the left fits all stacked stations for both 8hz and 16hz ground data. The individual stations prior to stacking were reasonably close.

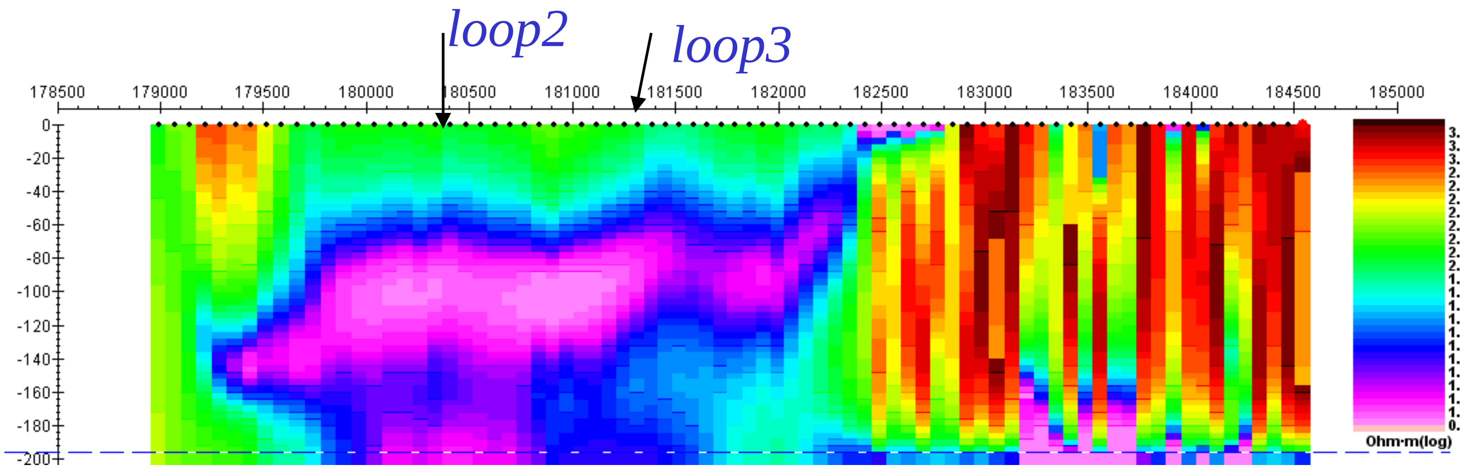
Fit of Geotem data to ground model

A quick look at the airborne data reveals a strong indication that the airborne data does not "see" the shallow conducting layers. Modeling the airborne data to the ground model makes this obvious. The figure to the left indicates the response to both Hz and Hx to the model (Blue, Brown) is too large.

Here the airborne data has been spatially averaged to a inline sampling closer to 50m. This is the type of process undertaken in the original processing but we have increased the essentially stracking to improve late time signal to noise.

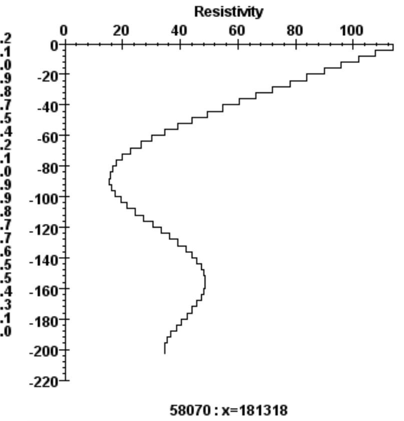


Line 58070



line 58070 - EW

loop3



AEM model

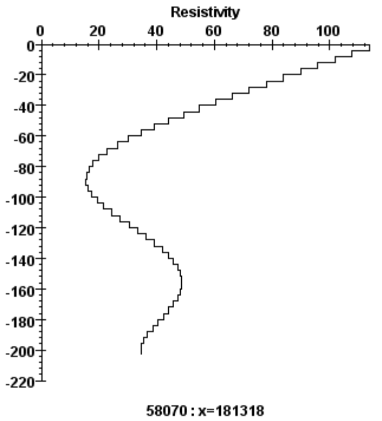
layer	thickness	resistivity
1	16.5	75
2	45	6.5
3	15	486
4	94	4000
5		5.2

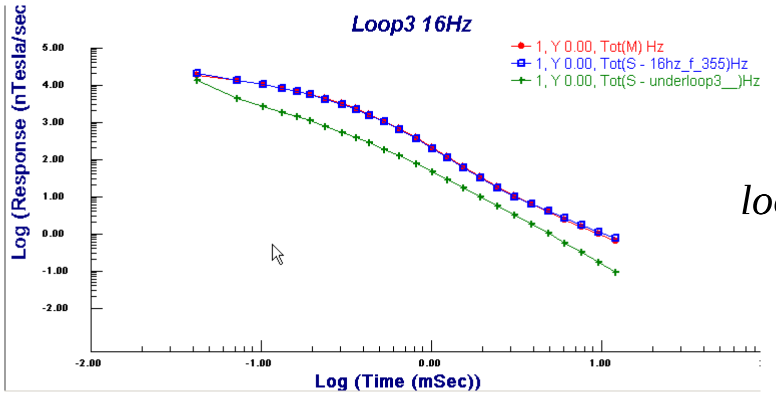
ground model

On the following pages, we will compare the ground response at both 8Hz and 16Hz at all 3 distances from the centre with the response to the airborne model.

Loop 3 -2

16Hz ground response to airborne mode





Loop 3 -3

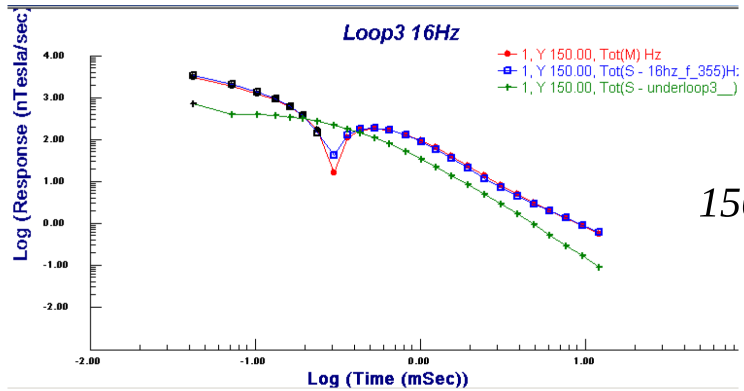
loop centre

line 58070 - EW

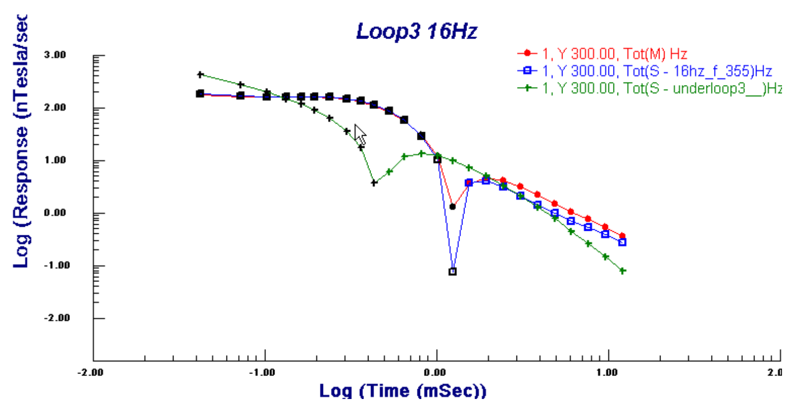
loop3

layer	thickness	resistivity
1	16.5	75
2	45	6.5
3	15	486
4	94	4000
5		5.2

ground model



150m outside

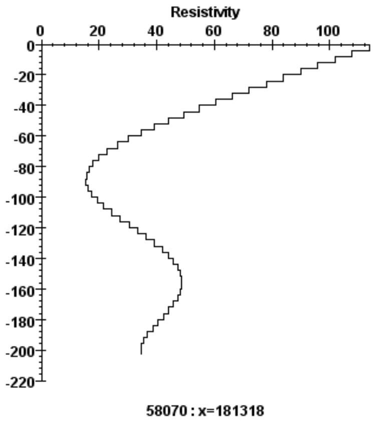


300m outside

data
ground model
AEM model

8Hz ground response to airborne mode

Loop 3 -3

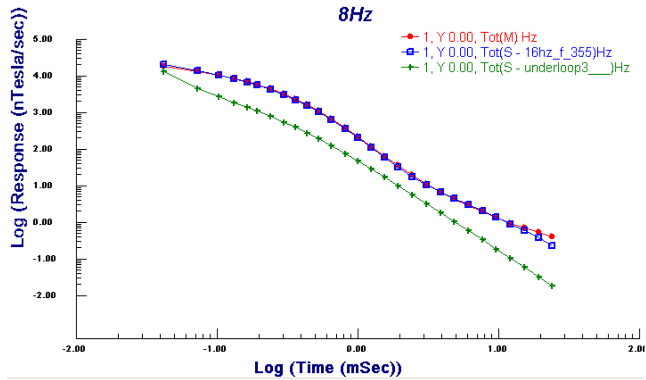


line 58070 - EW

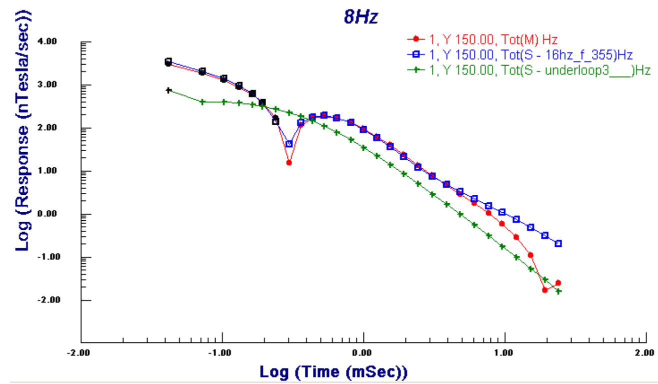
loop3

layer	thickness	resistivity
1	16.5	75
2	45	6.5
3	15	486
4	94	4000
5		5.2

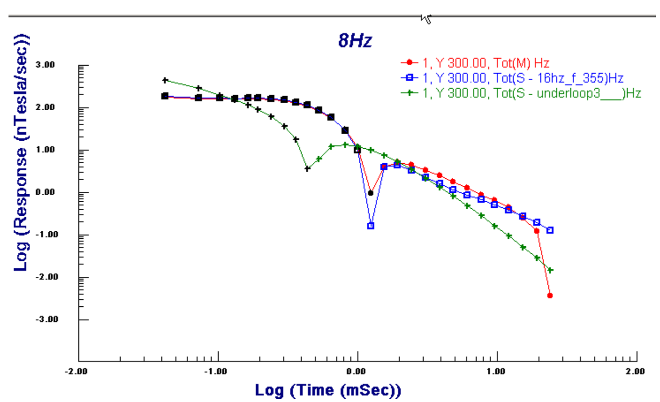
ground model



loop centre



150m outside



300m outside

data
ground model
AEM model

conclusions

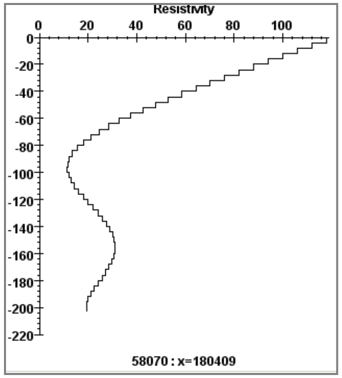
loop2

layer	thickness	resistivity
1	14.5	121
2	12	11
3	7.5	3.2
4	6.8	15
5	4.8	1.9
6	29	50
7	15	75
8		15

<u>ground model</u>

loop3

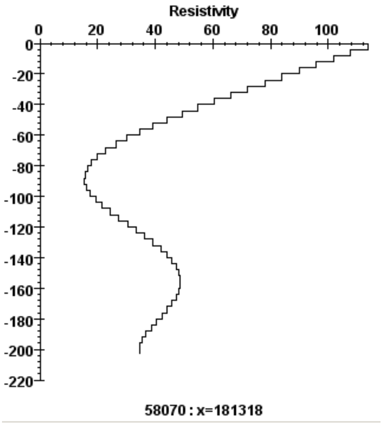
layer	thickness	resistivity
1	16.5	75
2	45	6.5
3	15	486
4	94	4000
5		5.2



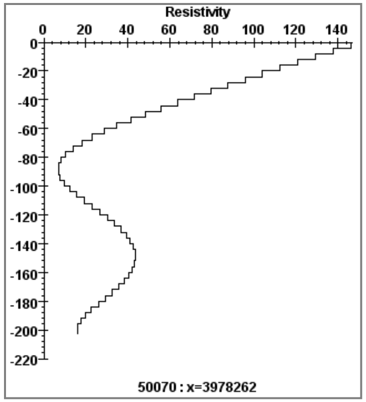
58070 : x=180409

line 58070 - EW

<u>airborne model</u>



58070 : x=181318



50070 : x=3978262

50070 - NS

conclusions

There is a consistency in the airborne models laterally and there is a consistency between the ground models but there is a dramatic inconsistency between the ground and airborne models.

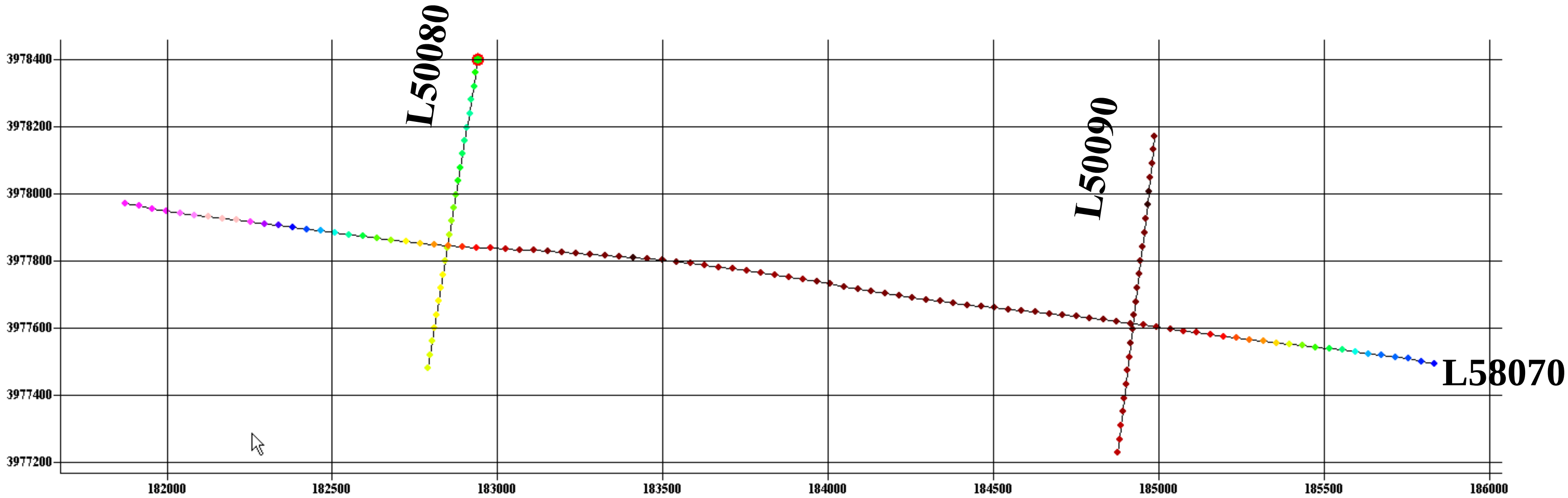
Under no circumstances could the ground data explain the airborne data and vice versa!

For this author, only 2 possibilities can be seen:

a) for some reason, the shallow ground is significantly different in resistivity between the time of the airborne data collection and the time of the ground data collection. For example, is there greater moisture content in the shallow ground during the ground survey.

b) equipment or processing failures: one or both instruments do not measure correctly. As this is highly unlikely since both systems are highly respected and greatly used. The other possibility is that there is a leveling procedure done with the airborne data. As the decays of the airborne data to the ground model match but there is a DC shift all through the time gates then this is a strong possibility.

Loop 4 -1



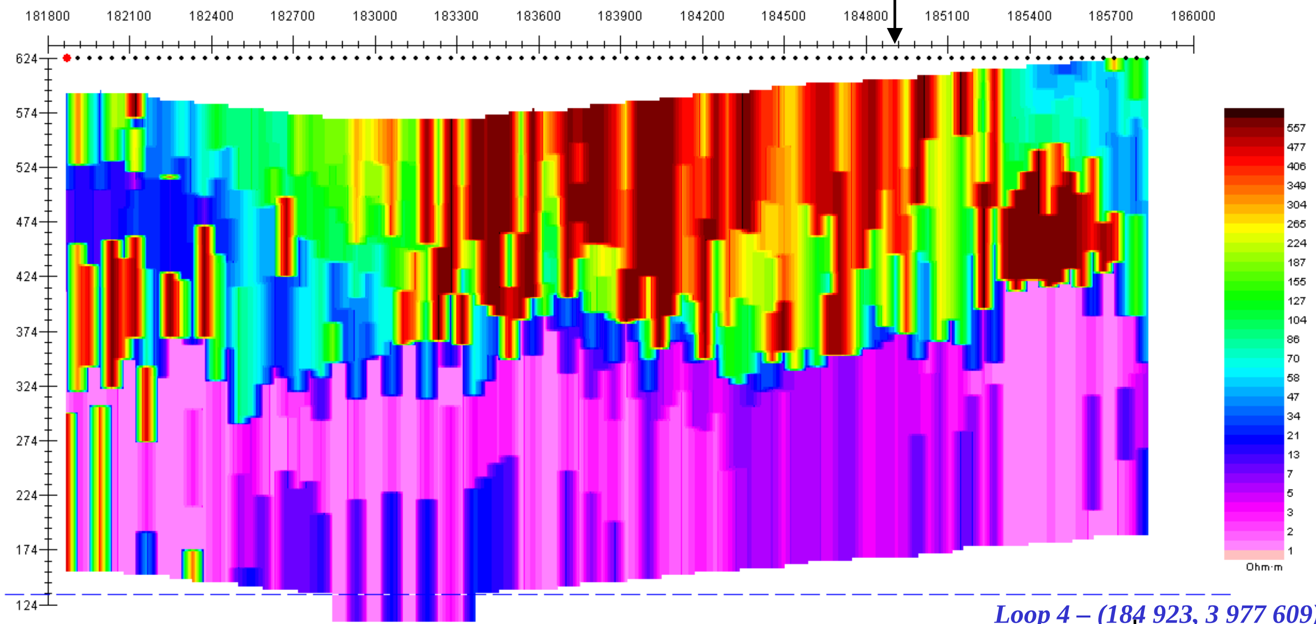
Loop 1 – (182 849, 3 977 845)

Loop 4 – (184 923, 3 977 609)

Loop4 and Loop 1 are extremely close to the intersection of flight lines

L58070 *Loop 4 – (184 923, 3 977 609)*

Loop 4 -2



EW inverson model from Hz

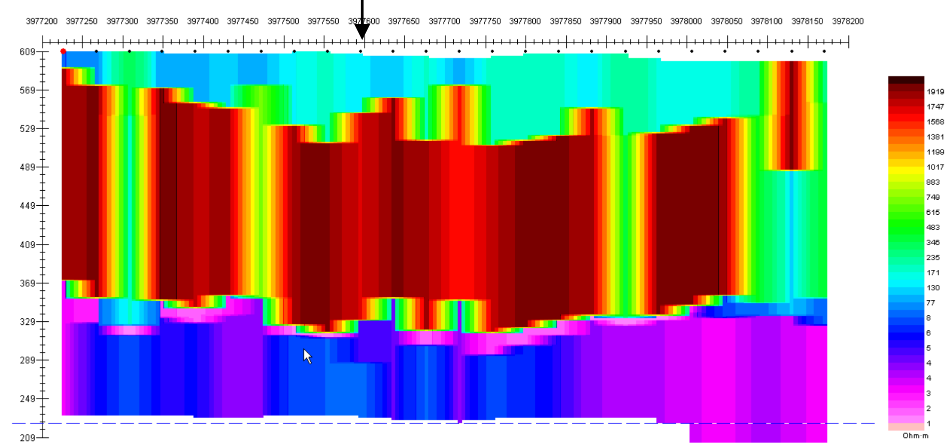
420♠m	**162m**
60♠m	**70m**
4♠m	

Loop 4 – (184 923, 3 977 609)

NS inverson model from Hz

137♠m	**57m**
1722♠m	**195m**
4.6♠m	**39m**
8♠m	

L50090



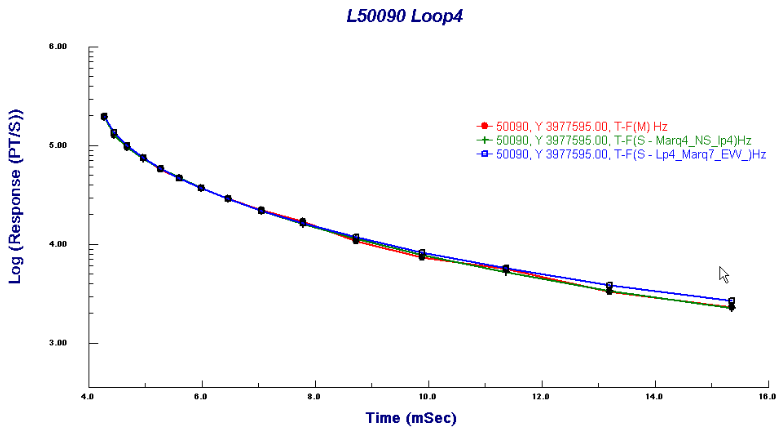
Inversion sections through Loop 4 show consistent sections for NS and EW lines
Depth to conductive layer is 232m (EW) and 252m (NS)

Model Consistency

Loop 4 -3

Loop 4 – (184 923, 3 977 609)

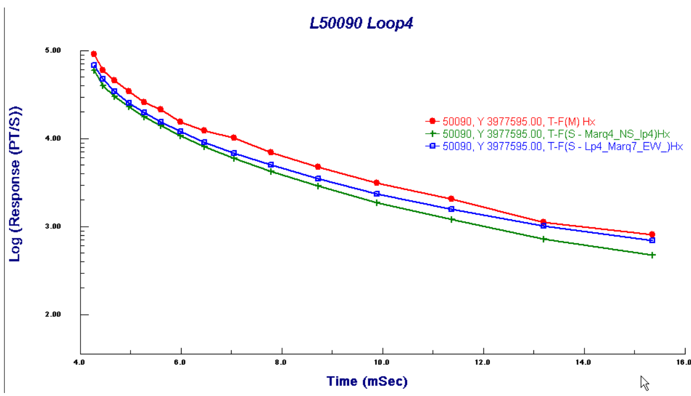
NS data Hz



data
fit to NS model
fit to EW model

Hz, Hx data are shown for Loop 4 for the NS line (50090). Fit of data to the inversion model derived from Hz is shown in top figure for Hz component and in bottom figure for Hx component. Green: from NS model, Blue: from EW model

NS data Hx



data
fit to NS model
fit to EW model

The top figure indicates the consistency of the 2 models. The EW inversion is slightly too high in late time but this model does not have the 8ohm-m basement as in the NS model.

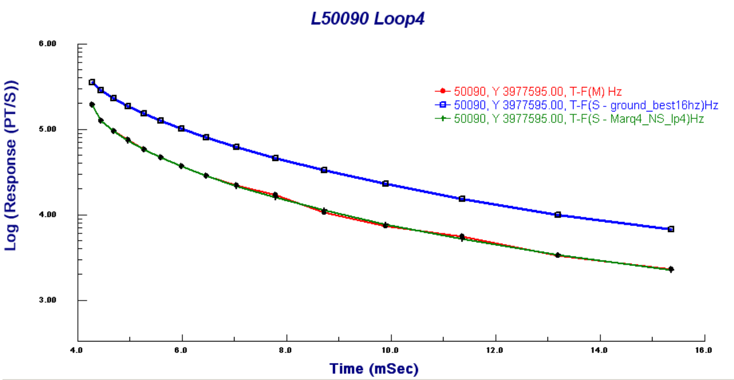
The bottom figure shows that the 2 models are consistent except in late time. There is a slight shift in amplitude below the actual data. This shift could be seen as a DC shift.

Model Consistency

Loop 4 -4

Loop 4 – (184 923, 3 977 609)

NS data Hz



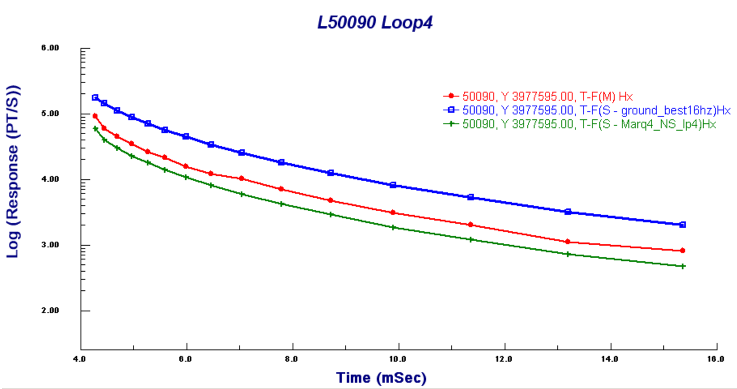
data
fit to NS model
fit ground model

ground model – Loop4

Loop4	layer	thickness	resistivity
finallp4	1	5.5	17
	2	145	550
	3	13	1
	4		4.6

Hz, Hx data are shown for Loop 4 for the NS line (50090). Fit of data to the inversion model derived from Hz is shown in top figure for Hz component and in bottom figure for Hx component. Green: from NS model, Blue: from ground model

NS data Hx



data
fit to NS model
fit ground model

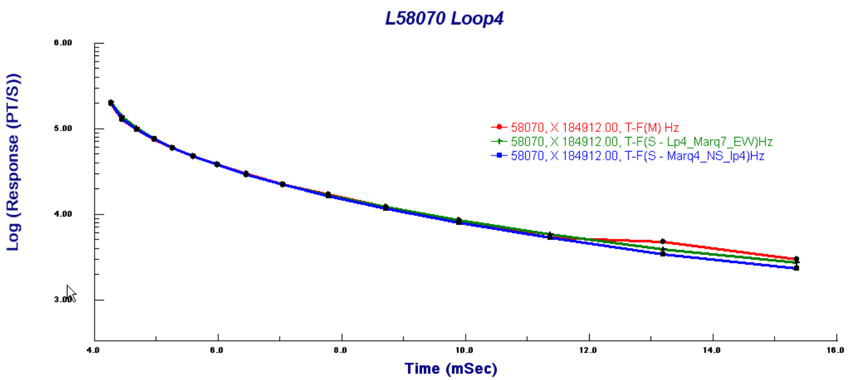
Although, we can see a clear amplitude difference between the response of the airborne system and the model for the ground data, it can also be seen clearly (especially in the Hz data) that there is an early time faster decay in the airborne data than would be seen were the ground resistivity to be explained by the ground model.

Model Consistency

Loop 4 -5

Loop 4 – (184 923, 3 977 609)

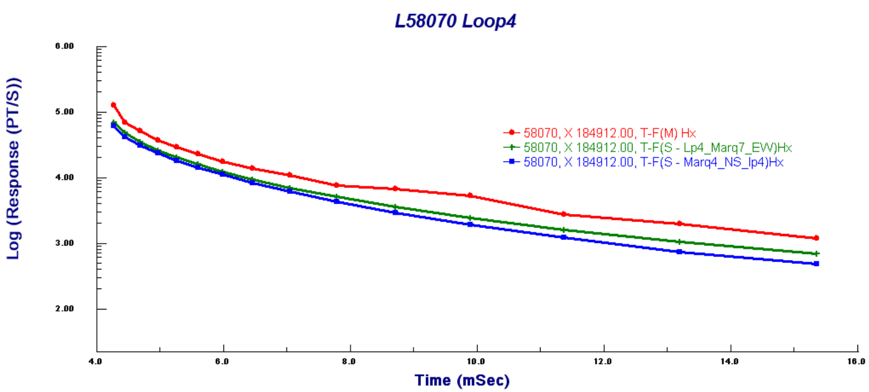
EW data Hz



data
fit to EW model
fit to NS model

Hz, Hx data are shown for Loop 4 for the EW line (58070). Fit of data to the inversion model derived from Hz is shown in top figure for Hz component and in bottom figure for Hx component. Green: from EW model, Blue: from NS model

EW data Hx



data
fit to EW model
fit to NS model

The top figure indicates the consistency of the 2 models. Here we can now see the reason for the differences in the EW and NS model. The obviously noisy data in late time has caused the EW model to have a more conductive lower region.

The bottom figure shows that the 2 models are consistent except in late time. There is a slight shift in amplitude below the actual data. This shift could be seen as a DC shift. This is similar to the results for the NS line, indicating a possible leveling problem.

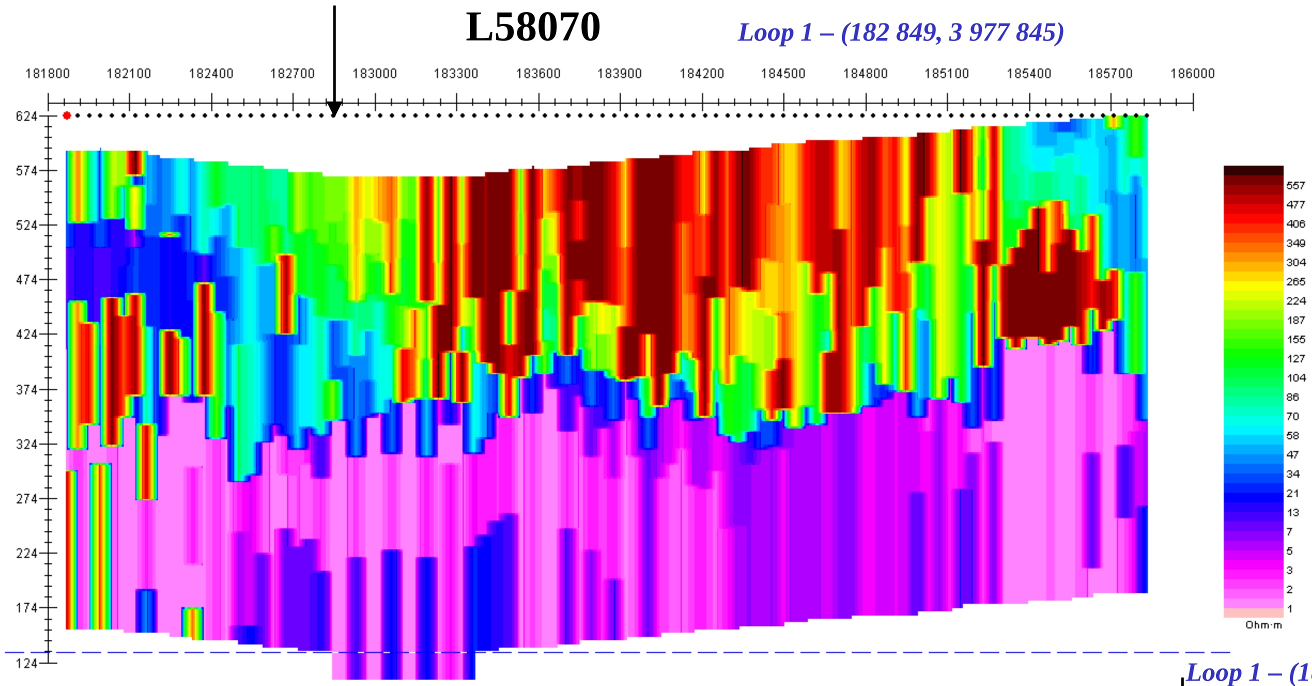
Model Consistency

Loop 4 -6

Loop 4 – (184 923, 3 977 609)

The results for the ground model are not shown as it is obvious that the airborne data for the EW line is too low to explain the ground model. This is so for both the Hz and Hx data components.

Loop 1-1

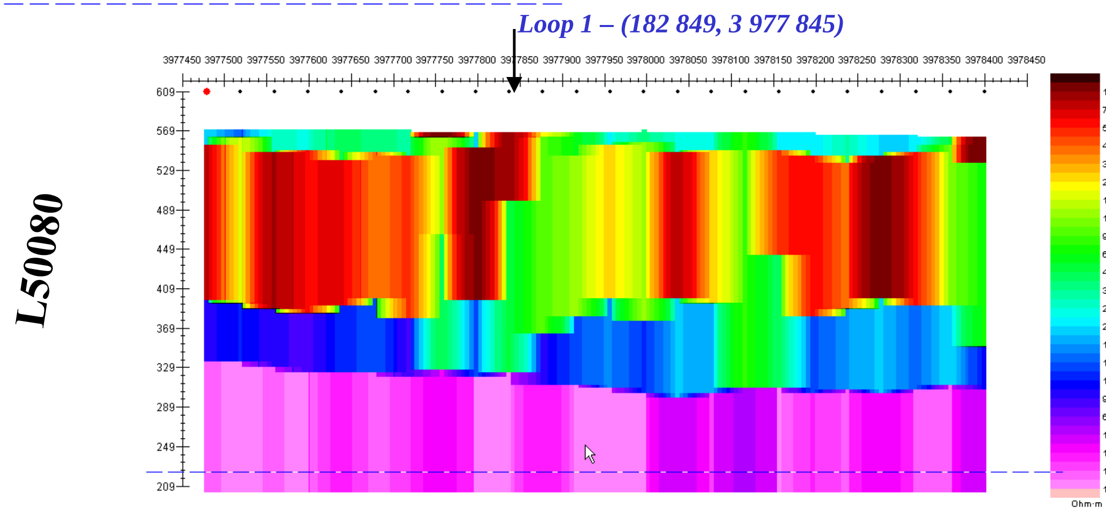


EW inverson model from Hz

180Ωm	42m
150Ωm	42m
96Ωm	48m
32Ωm	54m
172Ωm	34m
1 Ωm	

NS inverson model from Hz

1110Ωm	62m
147Ωm	158m
1Ωm	



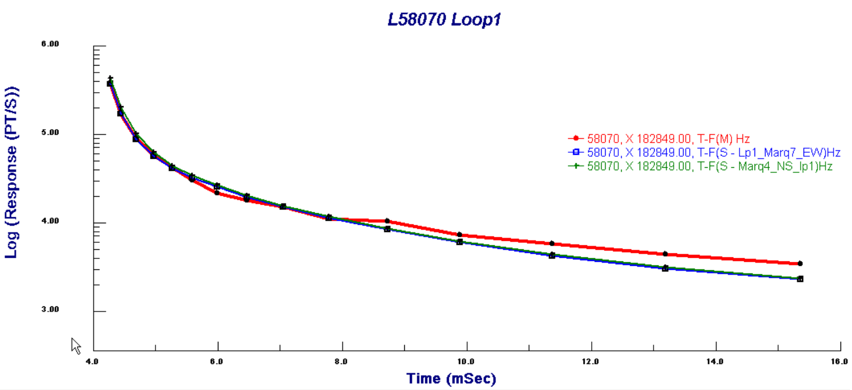
Inversion sections through Loop 1 show consistent sections for NS and EW lines
Depth to conductive layer is 224m (EW) and 221m (NS)

Model Consistency

Loop 1 -2

Loop 1 – (182 849, 3 977 845)

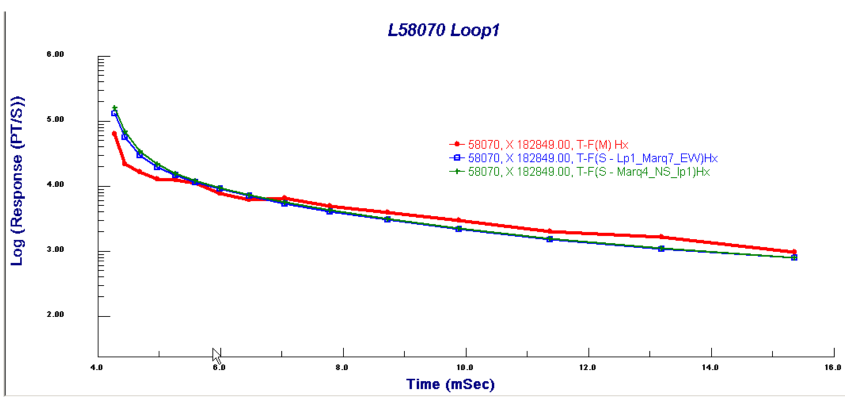
EW data Hz



data
fit to NS model
fit to EW model

Hz, Hx data are shown for Loop 1 for the NS line (58090). Fit of data to the inversion model derived from Hz is shown in top figure for Hz component and in bottom figure for Hx component. Green: from NS model, Blue: from EW model

EW data Hx



data
fit to NS model
fit to EW model

The top figure indicates the consistency of the 2 models.

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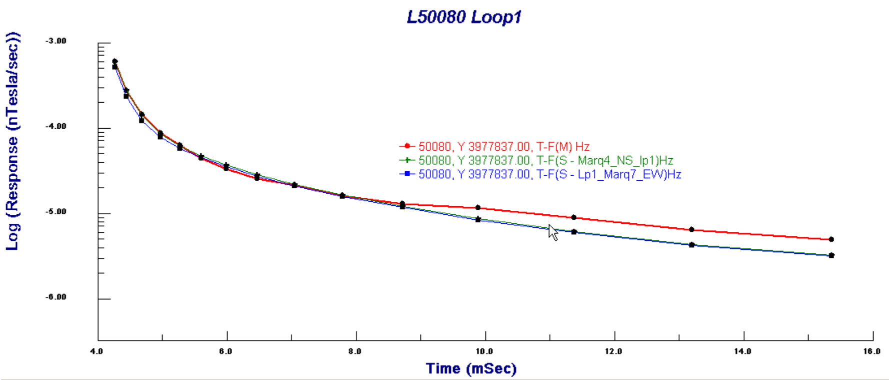
The bottom figure shows that the 2 models are consistent. The Hx data is not particularly good here.

Model Consistency

Loop 1 -3

Loop 1 – (182 849, 3 977 845)

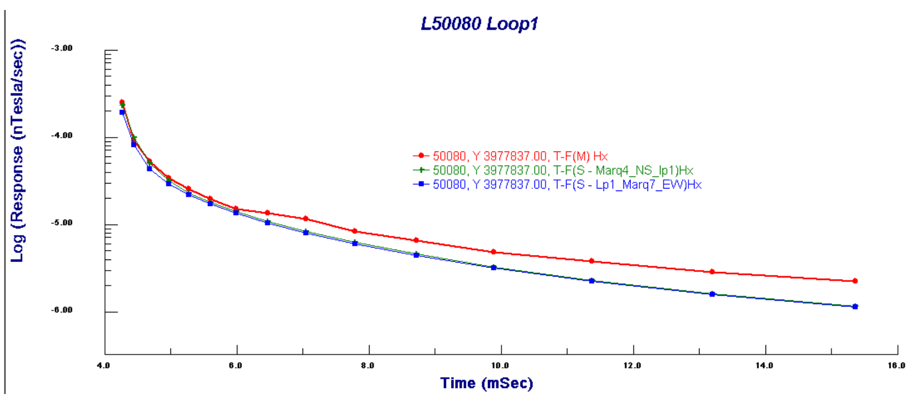
NS data Hz



data
fit to NS model
fit to EW model

Hz, Hx data are shown for Loop 4 for the NS line (50080). Fit of data to the inversion model derived from Hz is shown in top figure for Hz component and in bottom figure for Hx component. Green: from NS model, Blue: from EW model

NS data Hx



data
fit to NS model
fit to EW model

The top figure indicates the consistency of the 2 models.

The bottom figure shows that the 2 models are consistent except. Here the models also fit the Hx in the early off channels prior to the data turning upwards before decaying normally. Both Hz and Hx data show odd behaviour before the late time.

Model Consistency

Loop 1 -4

Loop 4 – (184 923, 3 977 609)

ground model – Loop1

Loop1	layer	thickness	resistivity
finallp1	1	128	86
	2	43	27
	3	141	3.2
	4		841

The ground data was collected at 2 basefrequencies – 8Hz and 16Hz. The 16Hz data was collected only at the centre of the loop while the 8Hz was collected at 9 positions – 1 inside and 8 outside and the centre was collected twice. Two of the outside loop measurements were clearly problematics. The others were stacked to create three measurements – 1 inside, 1 – 150m from cenre and 1- 300m from centre.

The central station at 16hz was first inverted. The primary result was the presence of a very thick conductive layer at a depth of more than 150m with a resistive structure below. This model was used to check against the 8Hz data. The model had an amplitude shift for the centre measurement but was a reasonably close fit to both the 150m and 300m stations. Adjustment of this model, led to the model above which fits the 150m and 300m stations but not the centre data. The final model when applied to the 16Hz data was found to fit as well as the best fit inversion directly from the 16hz data.

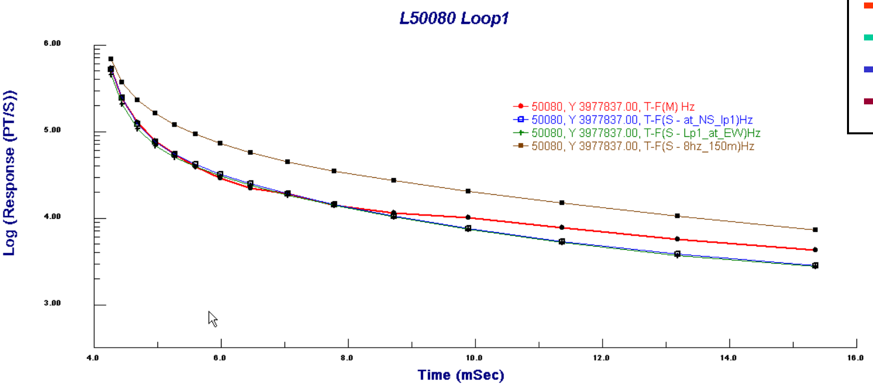
However, in all cases the presence of the a think conducting zone at a depth below 120m was consistent.

Model Consistency

Loop 1 -5

Loop 4 – (184 923, 3 977 609)

NS data Hz



data
fit to EW model
fit to NS model
fit to ground model

Loop1	layer	thickness	resistivity
finallp1	1	128	86
	2	43	27
	3	141	3.2
	4		841

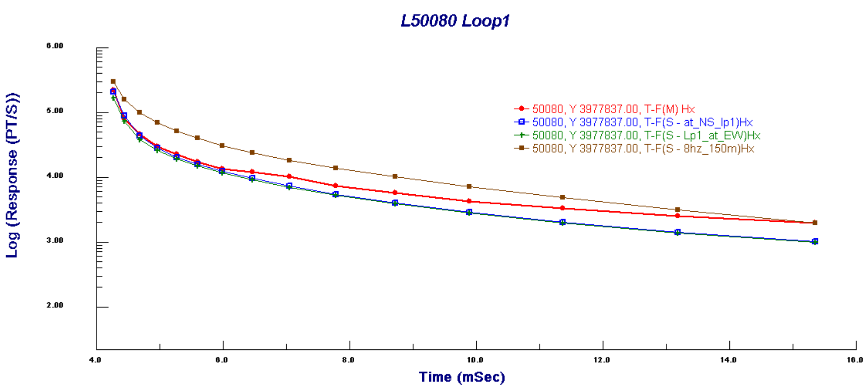
ground model – Loop1

1110Ω m	62m
147Ωm	158m
1Ωm	

air model – Loop1

Hz, Hx data are shown for Loop 1 for the NS line (50080). Fit of data to the inversion model derived from Hz is shown in top figure for Hz component and in bottom figure for Hx component. Green: from EW model, Blue: from NS model and Brown: for the best fitting ground model.

NS data Hx



data
fit to EW model
fit to NS model
fit to ground model

Both ground and airborne data (EW & NS) show a good conductive layer. In the case of the ground data this is indicated as at a depth of about 170m while for the airborne it is indicated at 220m depth. It is interesting to note that if the top very resistive layer were removed from the airborne model then the model would be reasonably close to the ground model. This is also seen to the left in the model comparisons. The time to strong conductor is definetely several channels later than one would expect from the ground model.

Comments:

One simple explanation for these difficulties, could be that the aircraft was flying such that the vertical offset was much less than 50m and thus the lateral offset was also more than the reported 125m offset. (Note: the report indicates 130m while the reference waveforms all indicate 125m offset).

However, taking the most extreme error that the offset was only 30m and taking the length of cable from the report and correcting for the reduced offset made a lateral offset of at most 136m.
In general, this must move the airborne model closer to the ground model as this change in geometry would reduce the data response.

However, trying this adjusted configuration on the data over Loop1 brought the early time amplitude closer but still did not address the fact that the airborne data shows a longer quick decay than the ground data.

In conclusion, the author does not feel this issue can explain the amplitude differences.