ASEG 3D IP WORKSHOP

AUGUST 2016

Nigel Cantwell

Resource Potentials

Softwares Used

- **TQIPdB,** produced by Scientific Computing and Applications (John Paine), to edit the data and export it to UBC 3D format for inversion.

- **UBC 3DIP** inversion code.

- **3D Modeller – 3D Viewer** and Pitney Bowes Encom **Profile Analyst** for 3D visualisation of the results.

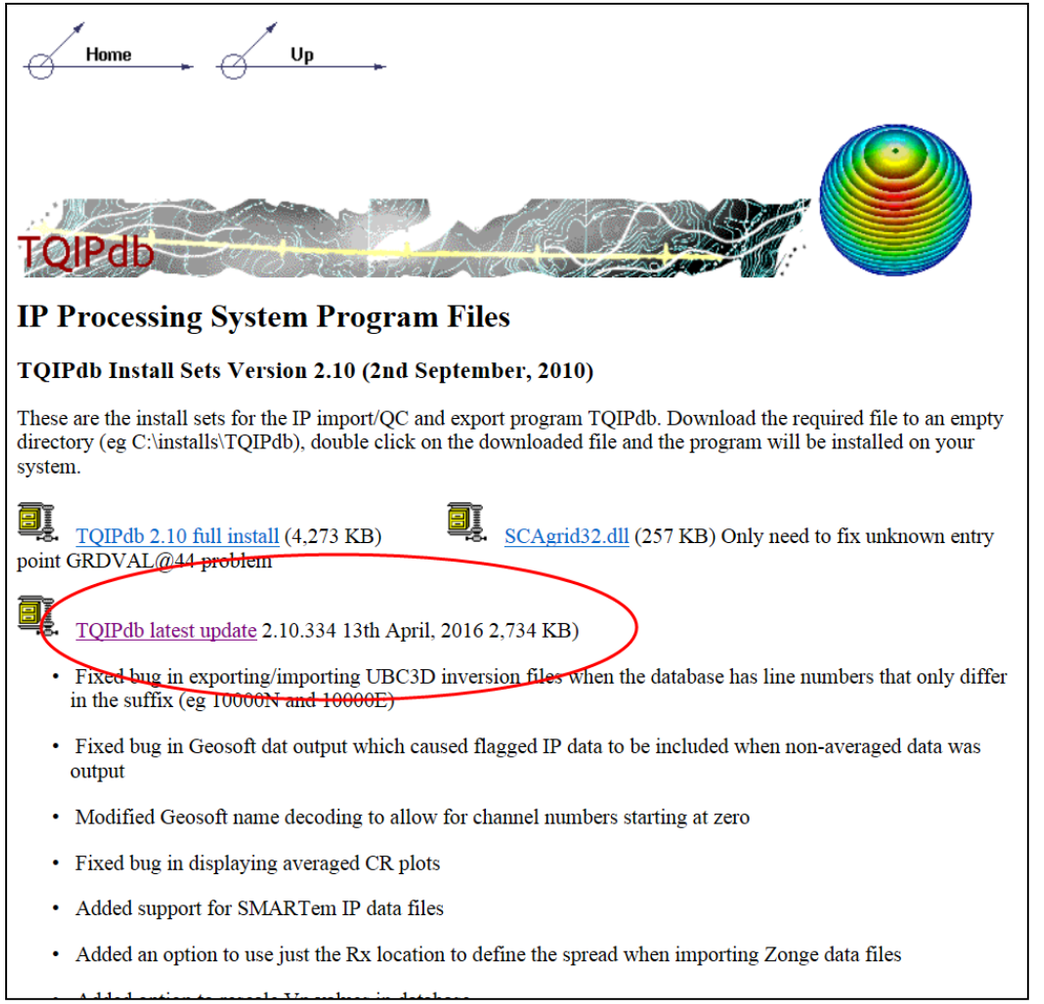
Installed the latest version of TQIPdB

The software is updated regularly, so you need to constantly check the website for updates.

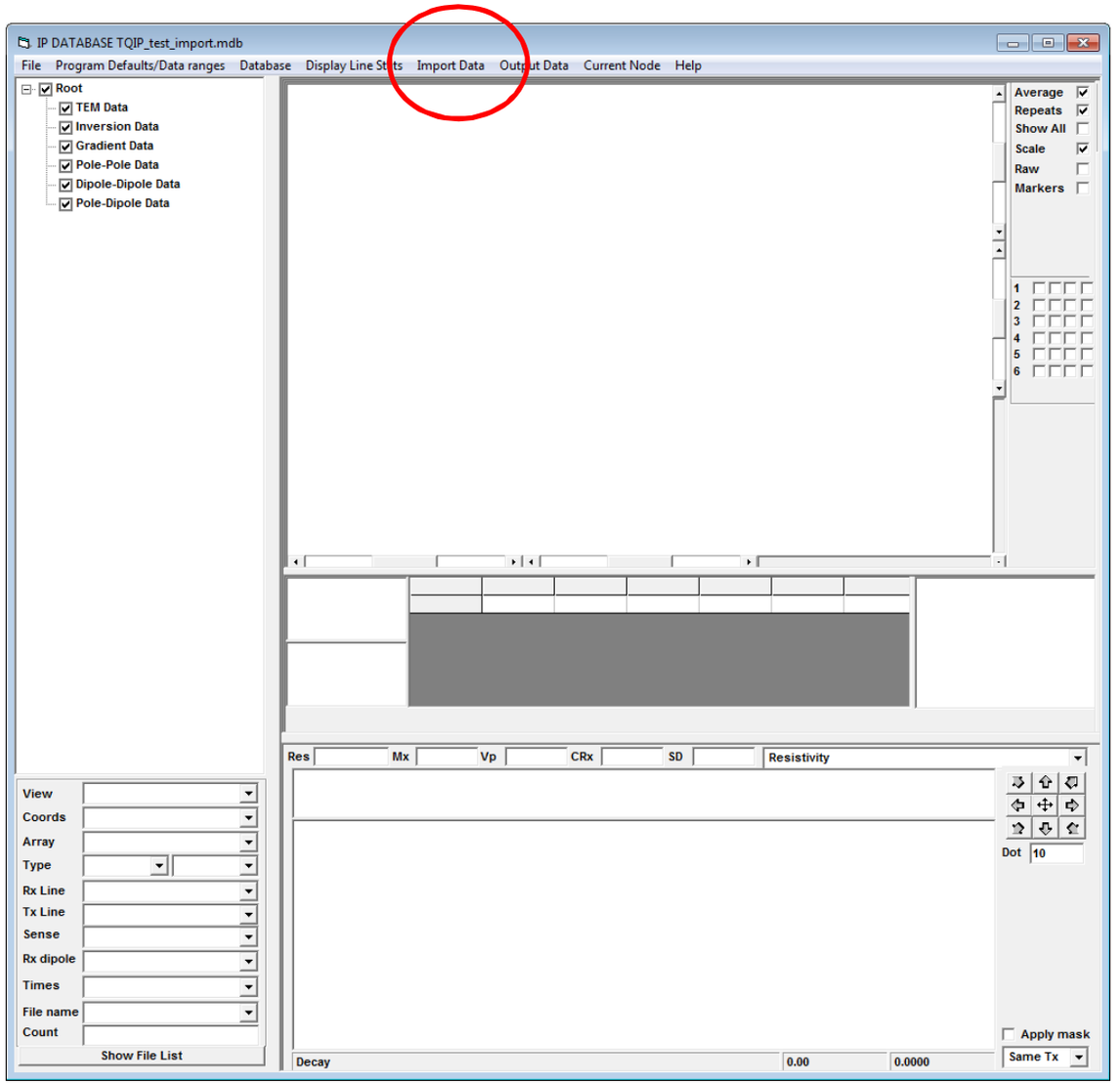
I check every time I start a job, and an update is usually available each time.

I really like this program, and that updates are made available soon after an issue is raised.

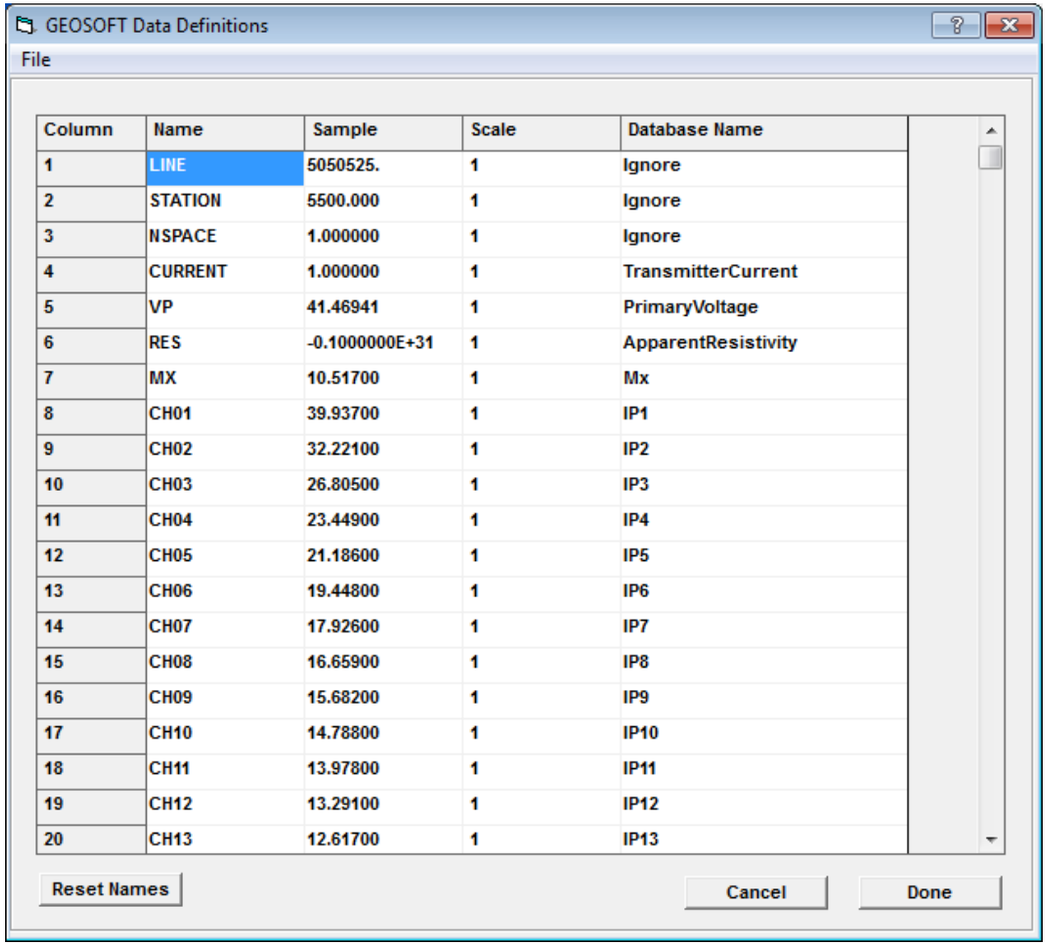
It was in about mid April that I first got a chance to have a look at the IP data.



Imported the DAT file provided into TQIPdB



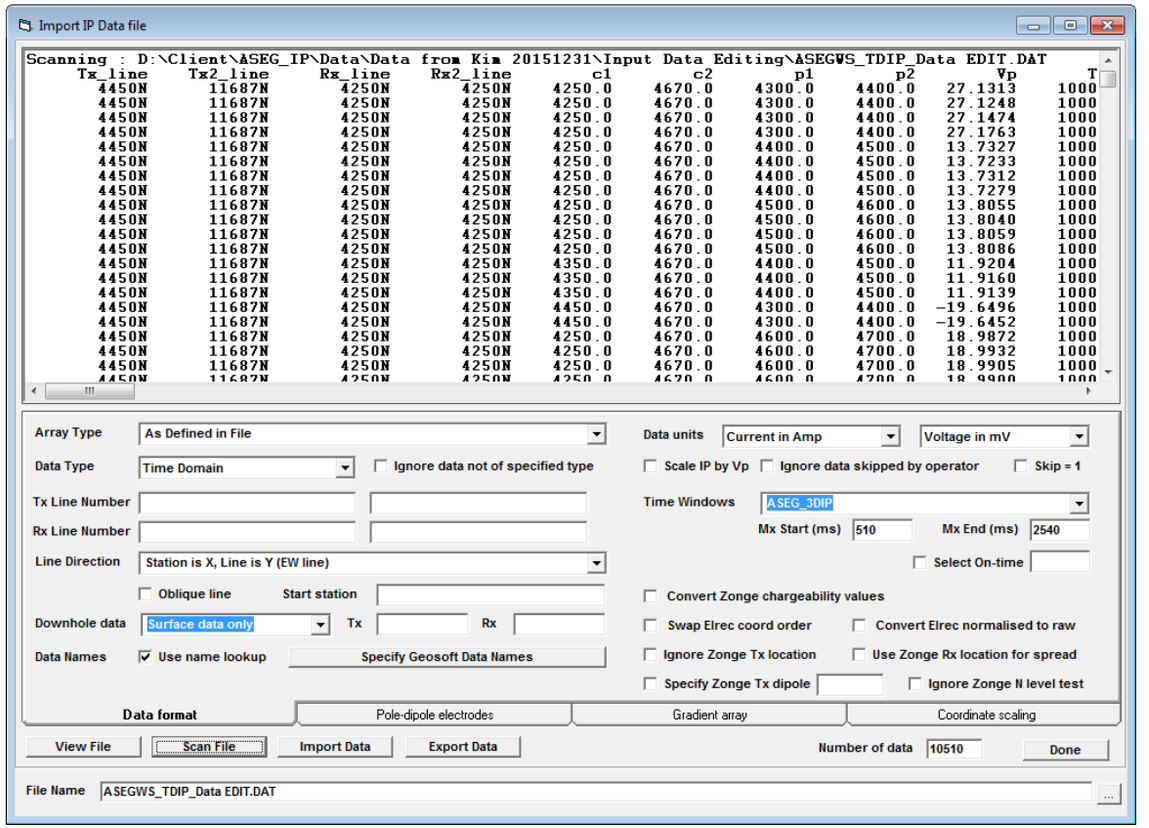
Set columns names on import so that TQIPdB can recognise them



There's often confusion on import due to the different data formats that get output from different IP receivers, and that are provided by the different contractors.

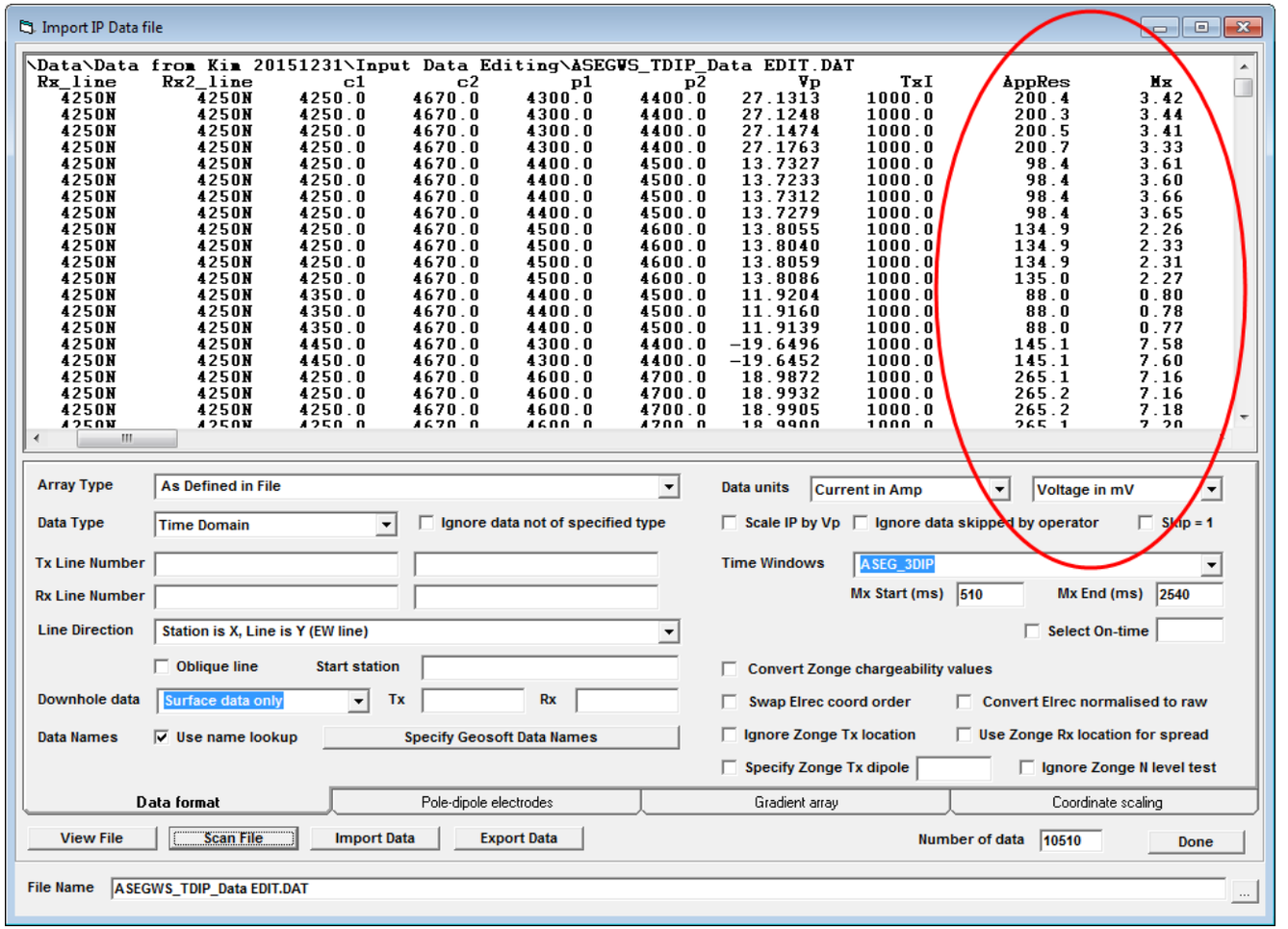
This problem is compounded as, more often than not, I am reviewing a 3D dataset where I didn't have much involvement in the survey design, data QC and monitoring.

Try to keep it simple on the import page – always a struggle



→ If in doubt, email John Paine and I usually do.

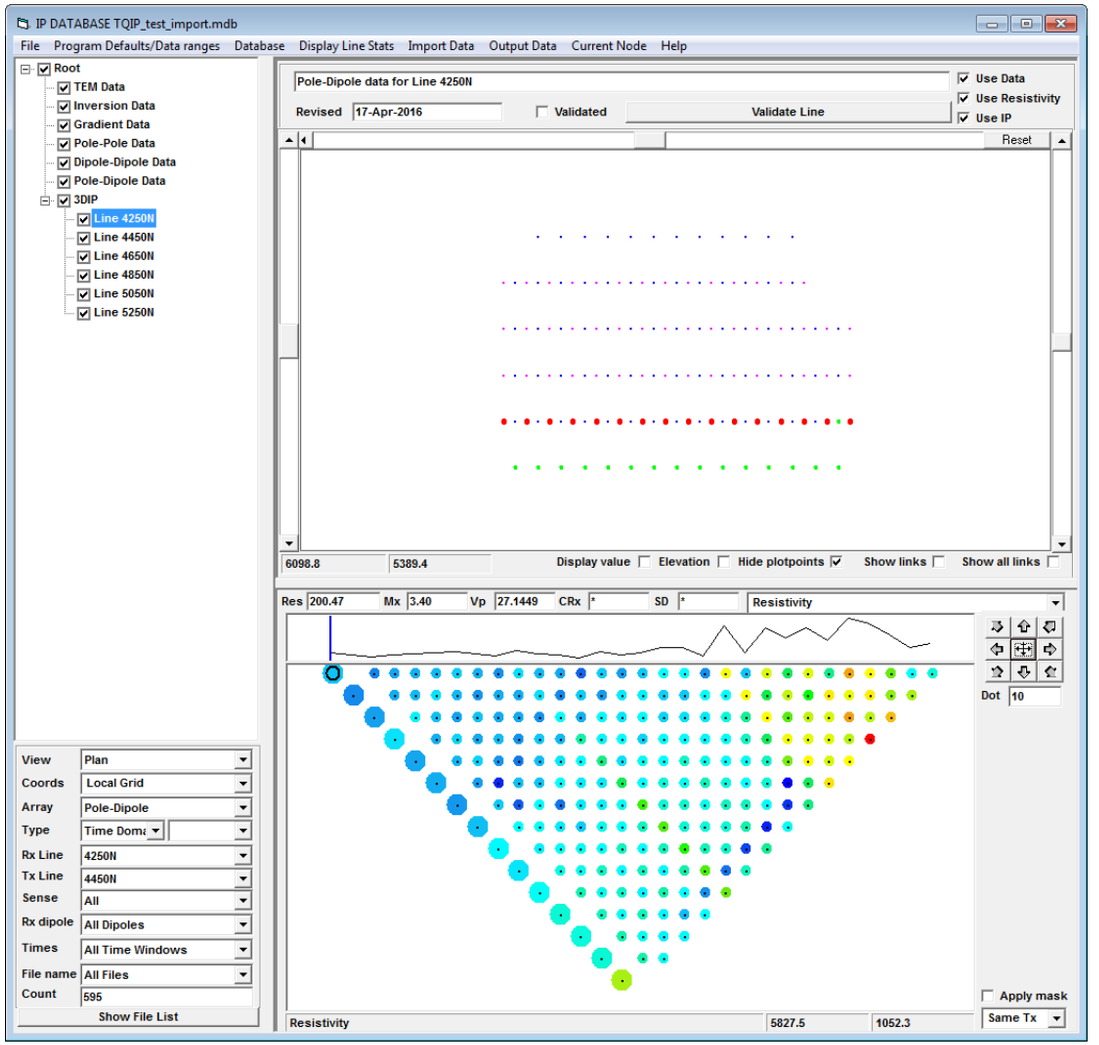
Check the calculated AppRes and Mx – compare to values in the raw data file



Checking the calculated AppRes and Mx, and making some preliminary observations of the raw data

- The imported resistivity and chargeability values seem OK compared to the raw data file.
- The resistivity ranges between about 40-50 ohm-m at shallow N-levels in the west, up to about 1,500 ohm-m in the east. This is a fairly significant range of resistivity.
- The western part of survey is generally more conductive and eastern part is generally more resistive.
- There doesn't appear to be a highly conductive cover, as the lowest resistivity values in the western part of the survey area seem typical of a weakly to moderately conductive regolith cover.
- There's generally elevated chargeability above 10 msec, and anomalous responses are generally 15-25 msec.
- I would call the background chargeability value about 5 msec, but we just don't see much of it because of the broad zone of elevated chargeability through the centre of the survey area.

Survey stations seem to be imported into TQIP OK

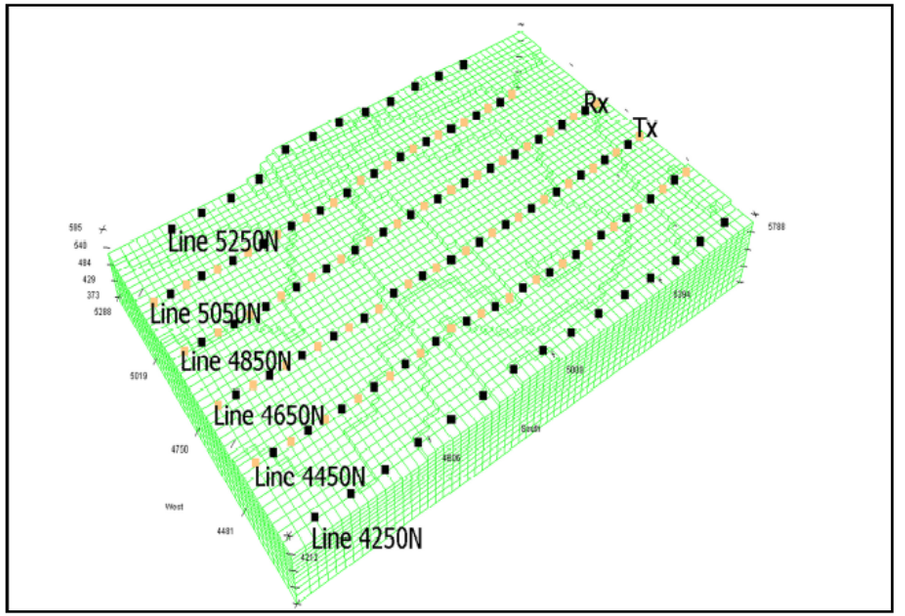


But it's difficult to be totally sure because it's difficult to know which station markers are transmitters or receivers.

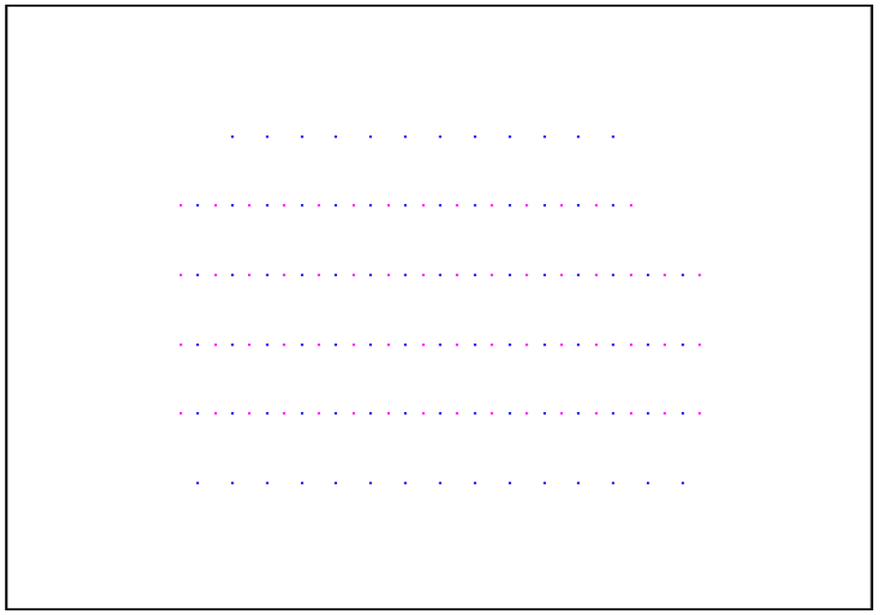
It just takes a bit of time to flick back and forth between the map view and data window to determine if the data has been imported OK.

Checking Tx-Rx Locations

Location map provided



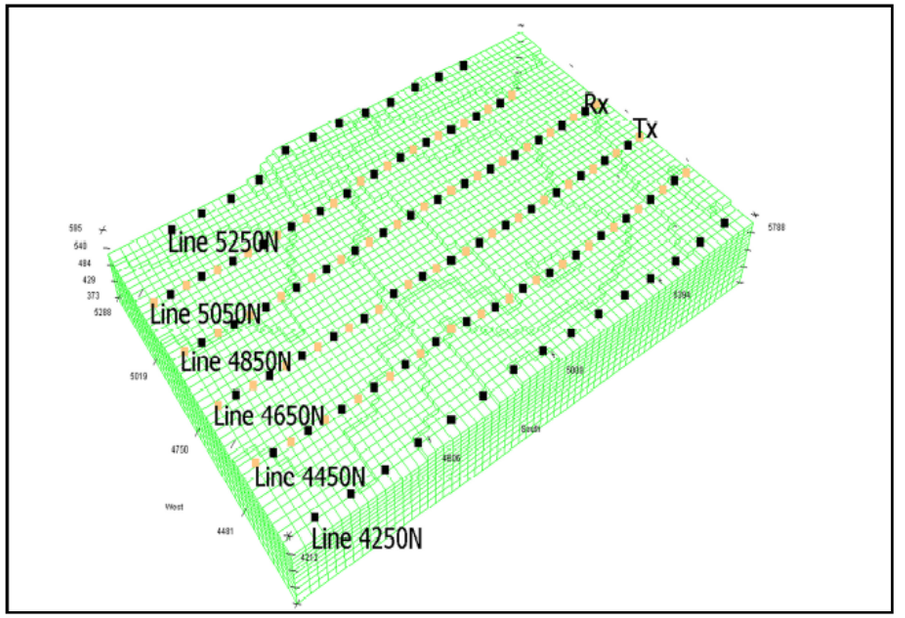
There is a similar pattern in TQIPdB



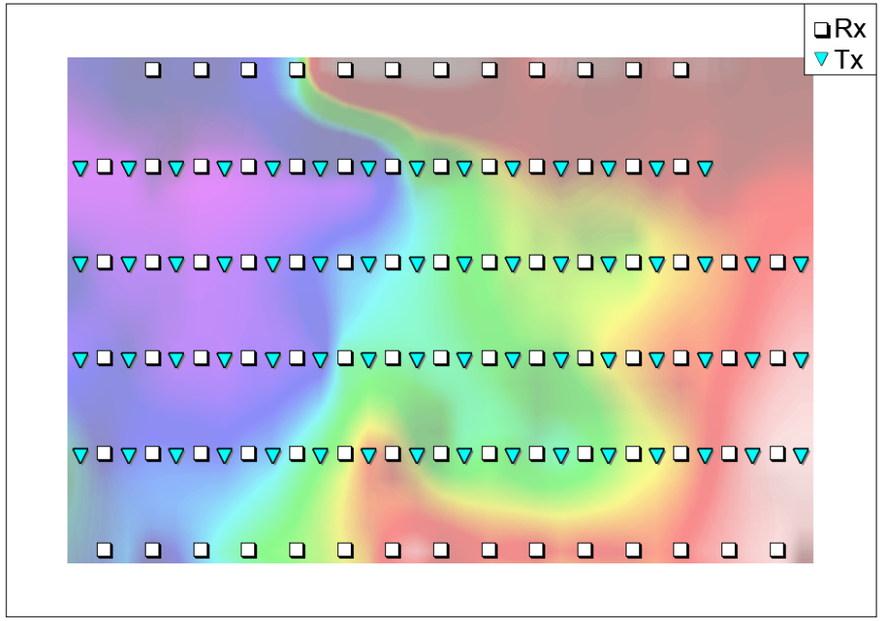
Tx = transmitter
Rx = receiver

Checking Tx-Rx Locations

Location map provided



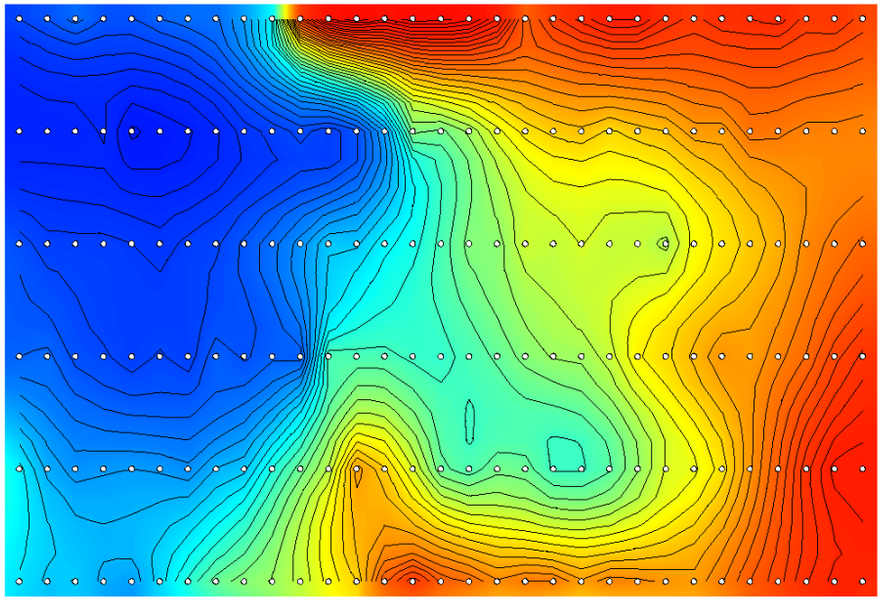
Locations exported from TQIPdB and then overlain on the topo grid

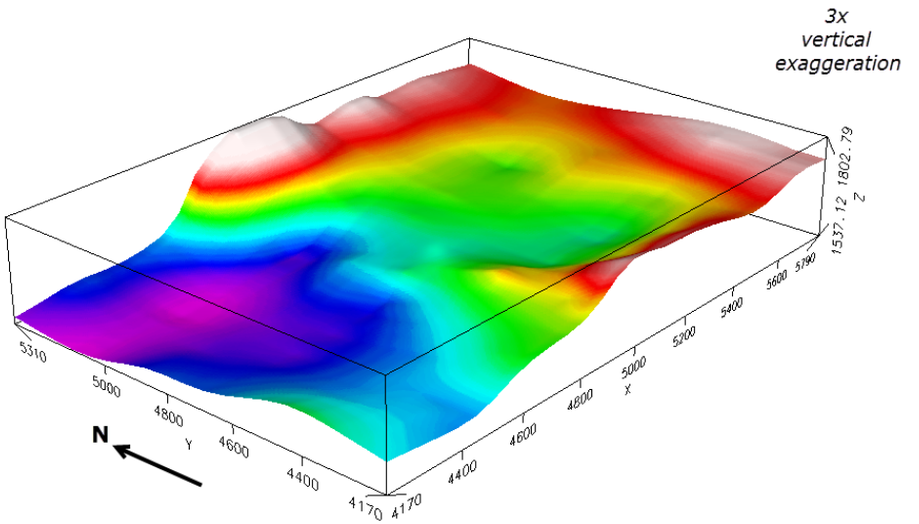


→ 6 receiver lines oriented E-W, with 200m line spacing and 100m station spacing.

→ Therefore, we might expect some generally N-S oriented model sources in the chargeability and resistivity inversion results.

Checking supplied topo grid - looks OK





- Topo ranges from 510m in the west, to 595m in the east, a range of 85m.
- The topographic variation is not too severe.
- Just wonder where it is (?)

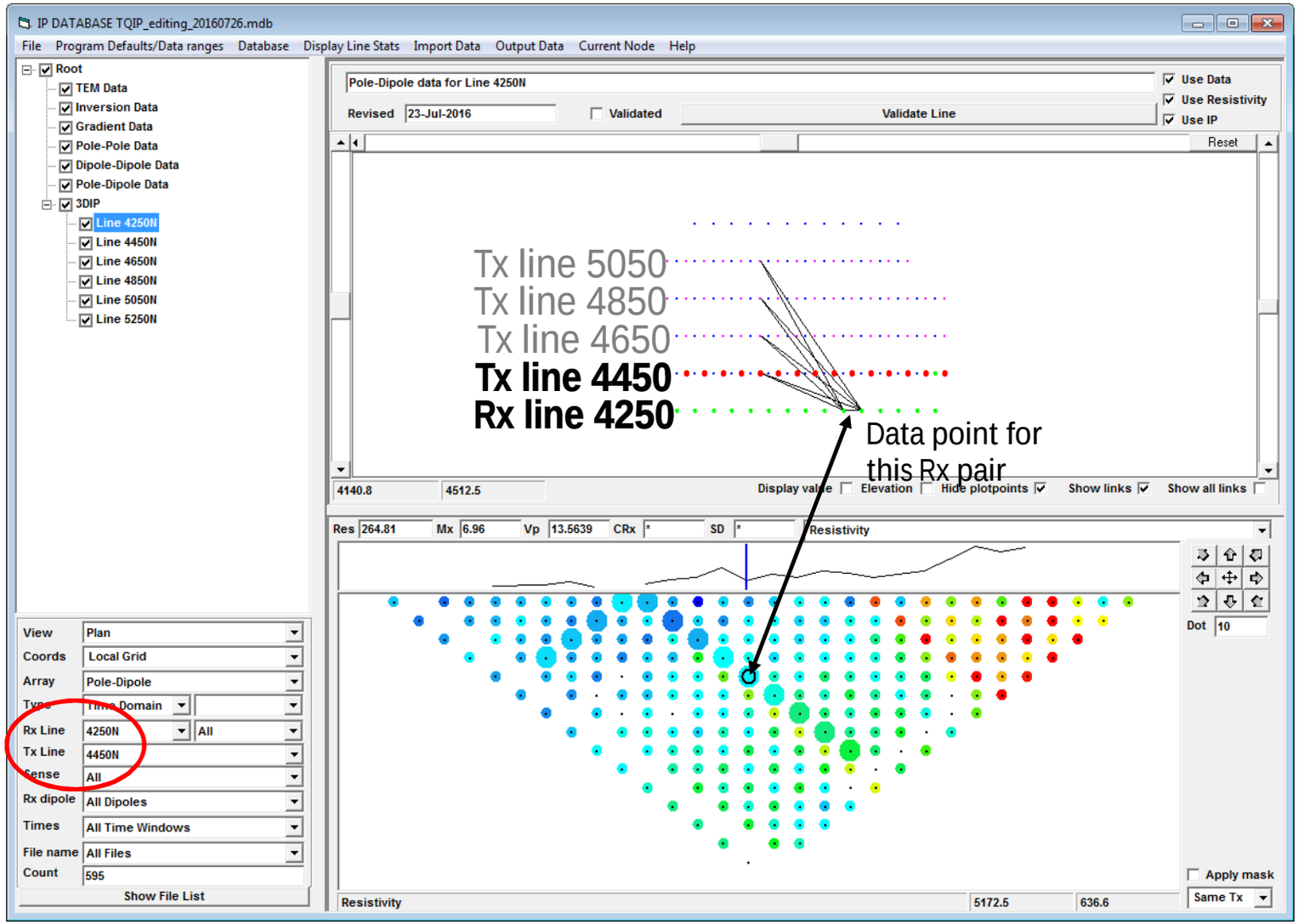
Survey Configuration

- 6 receiver lines oriented E-W, with 200m line spacing and 100m station spacing.

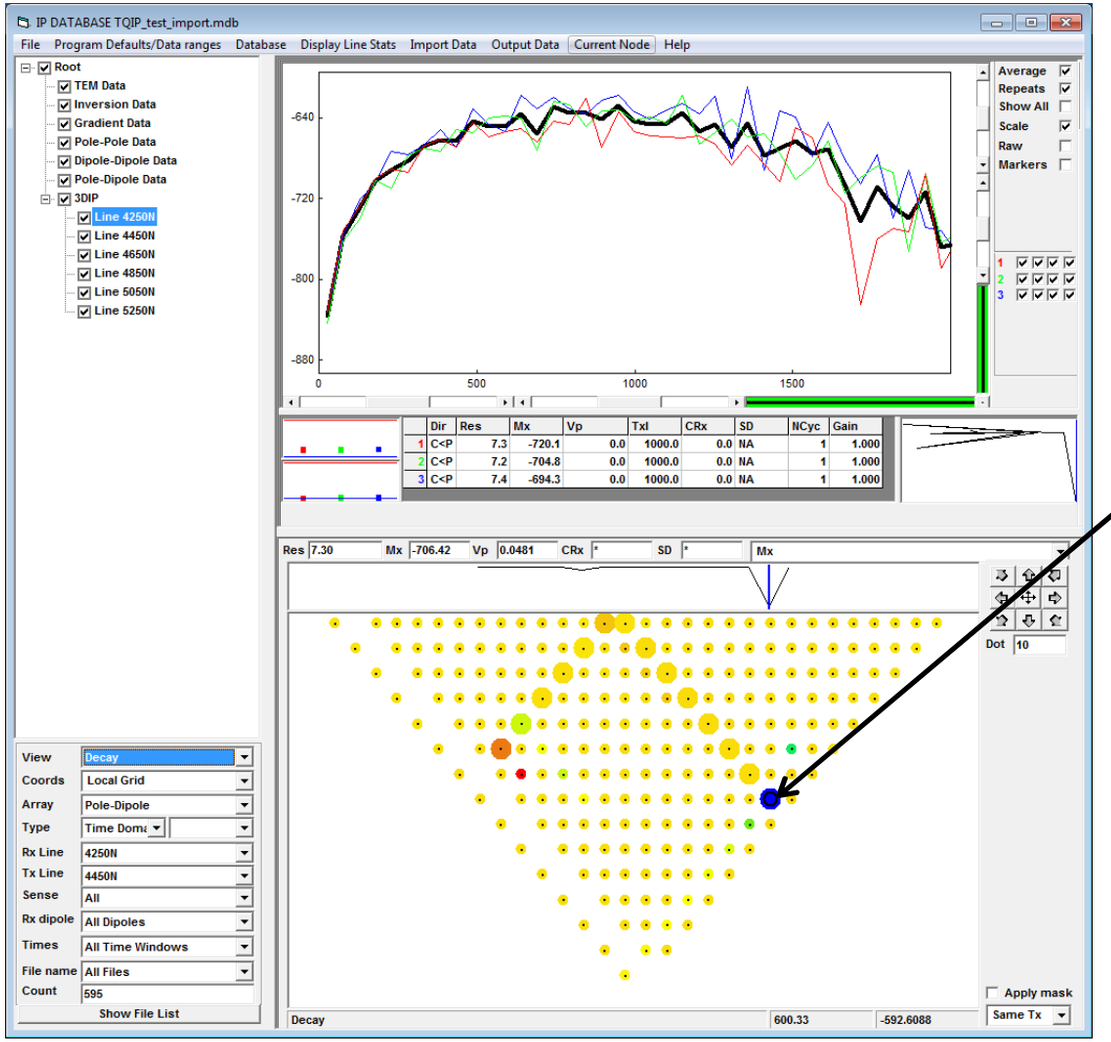
- Each receiver line has readings from 4 separate transmitter lines, so there are 24 different Tx-Rx line combinations, which can each be viewed in TQIPdB as a pseudosection of observed data points.

- For the four central Rx lines, there was a Tx line along the same local northing. So this data, with common Tx-Rx line, would be closer to a standard pole-dipole survey.

Survey Configuration



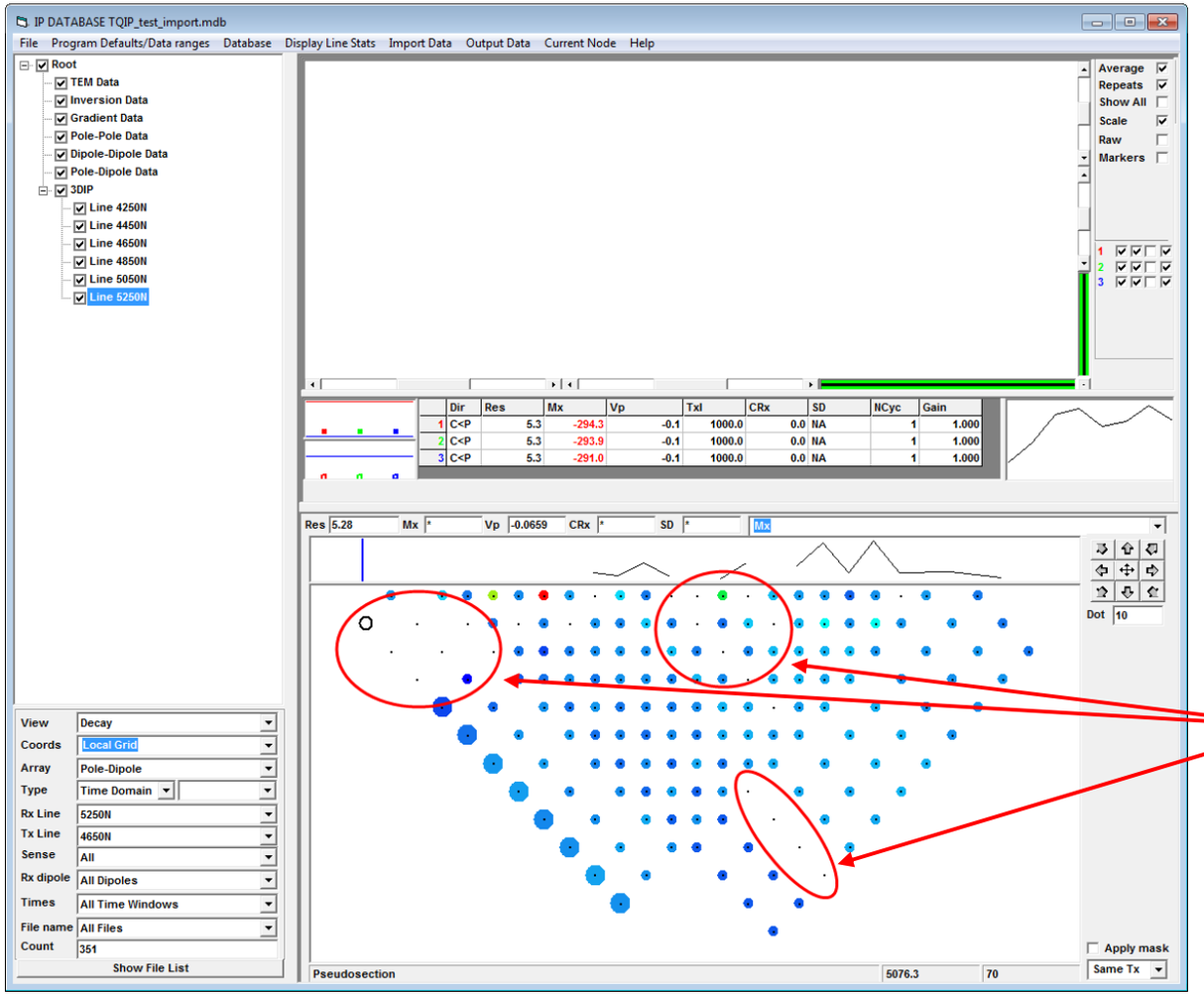
Data editing - started by going through the data, point by point, and line by line, to remove spurious readings



Null this data point for all 3 readings – Mx only.

Mx = -700 msec

Decided to apply a negative Mx threshold to data – normally wouldn't but I was short on spare time



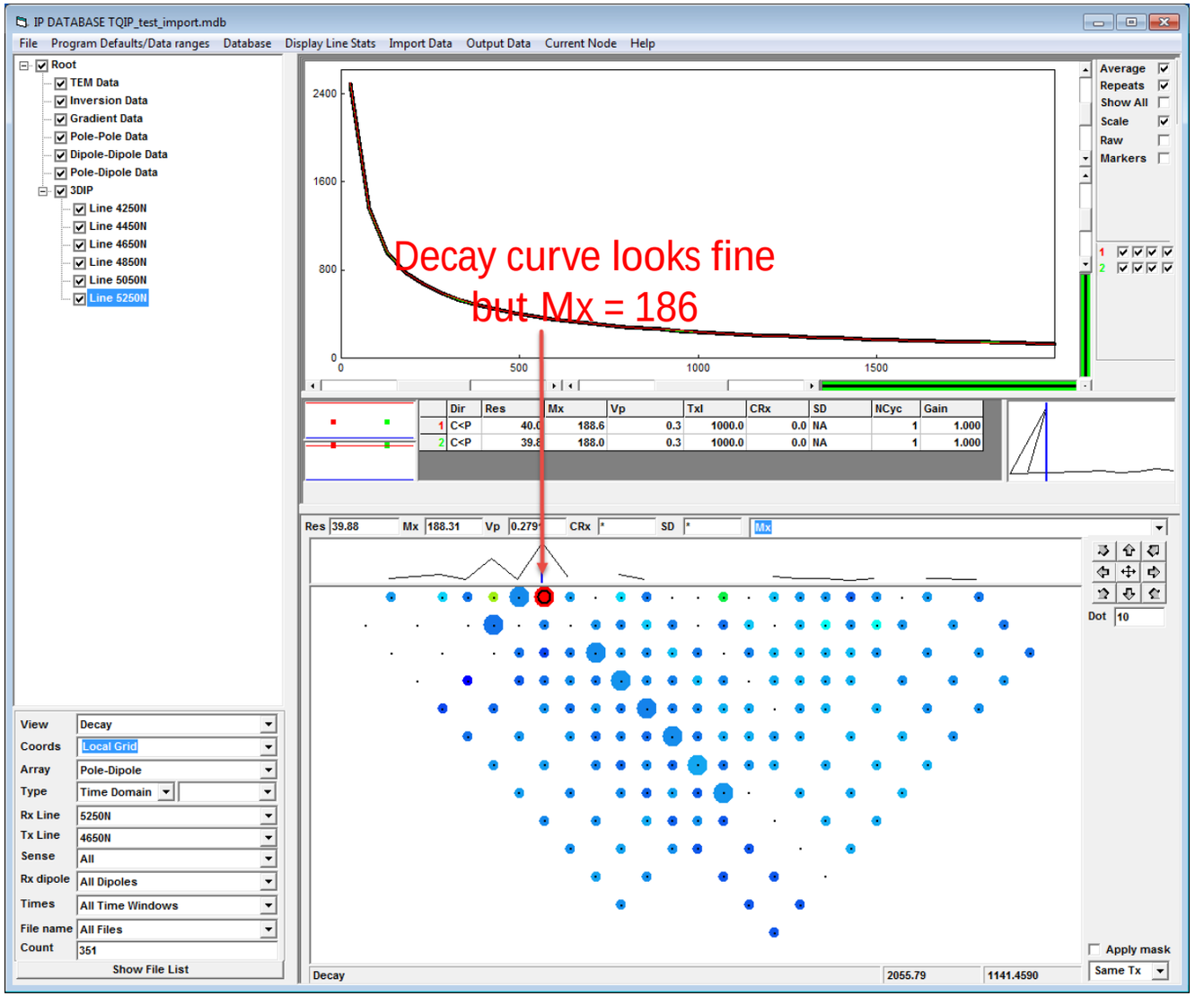
A fair amount of data is removed on some lines, but there is still adequate data points in section to resolve anomalies.

Do need to be careful not to remove too much data, such that the inversion process becomes unstable.

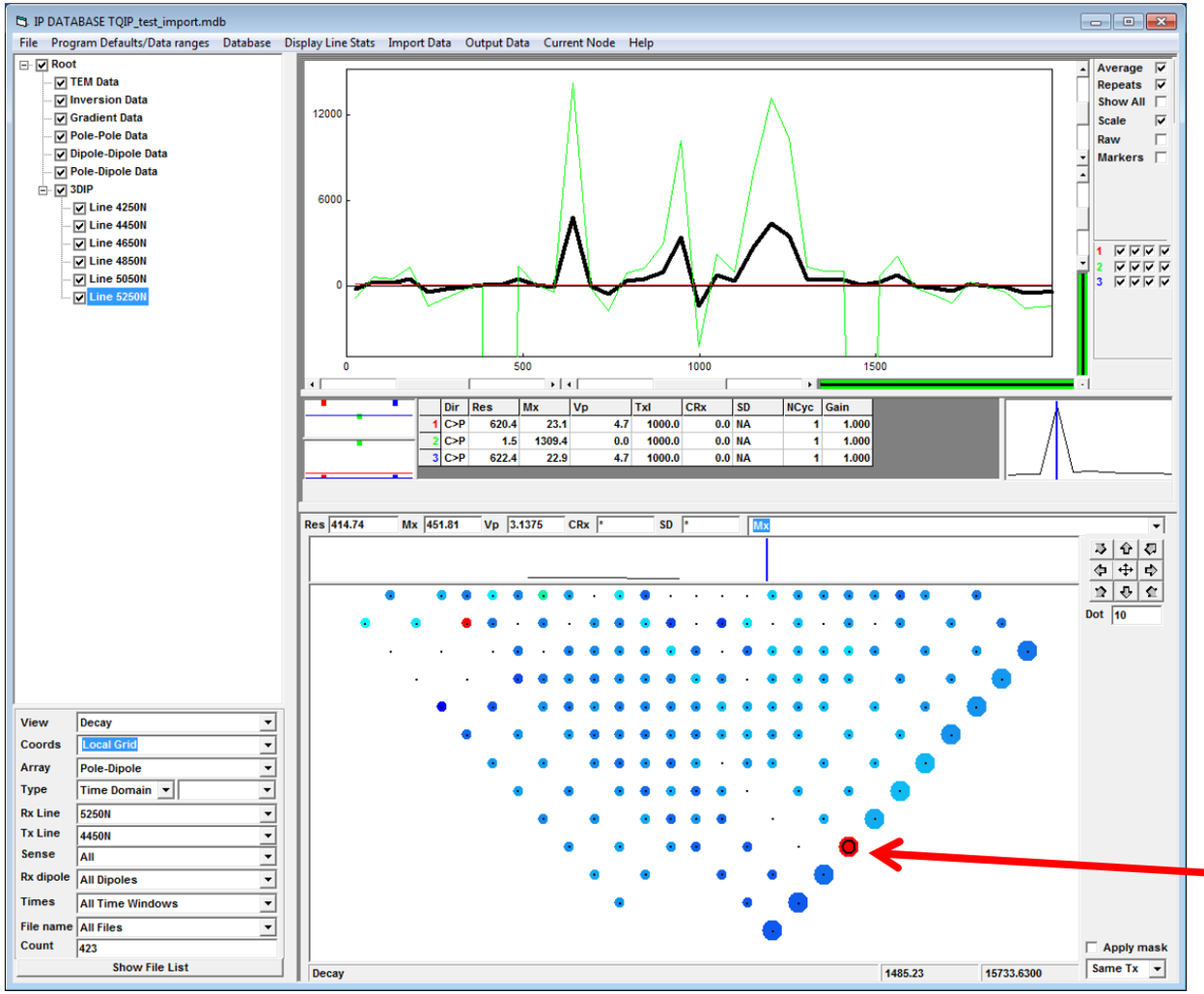
Areas with negative Mx values removed. These are mostly very low resistivity zones with very low Vp.

→ Most are considered likely to be isolated zones of EM coupling and weird responses from cultural features. Some may be real features e.g. fault zone?

Removed very high outlier Mx readings

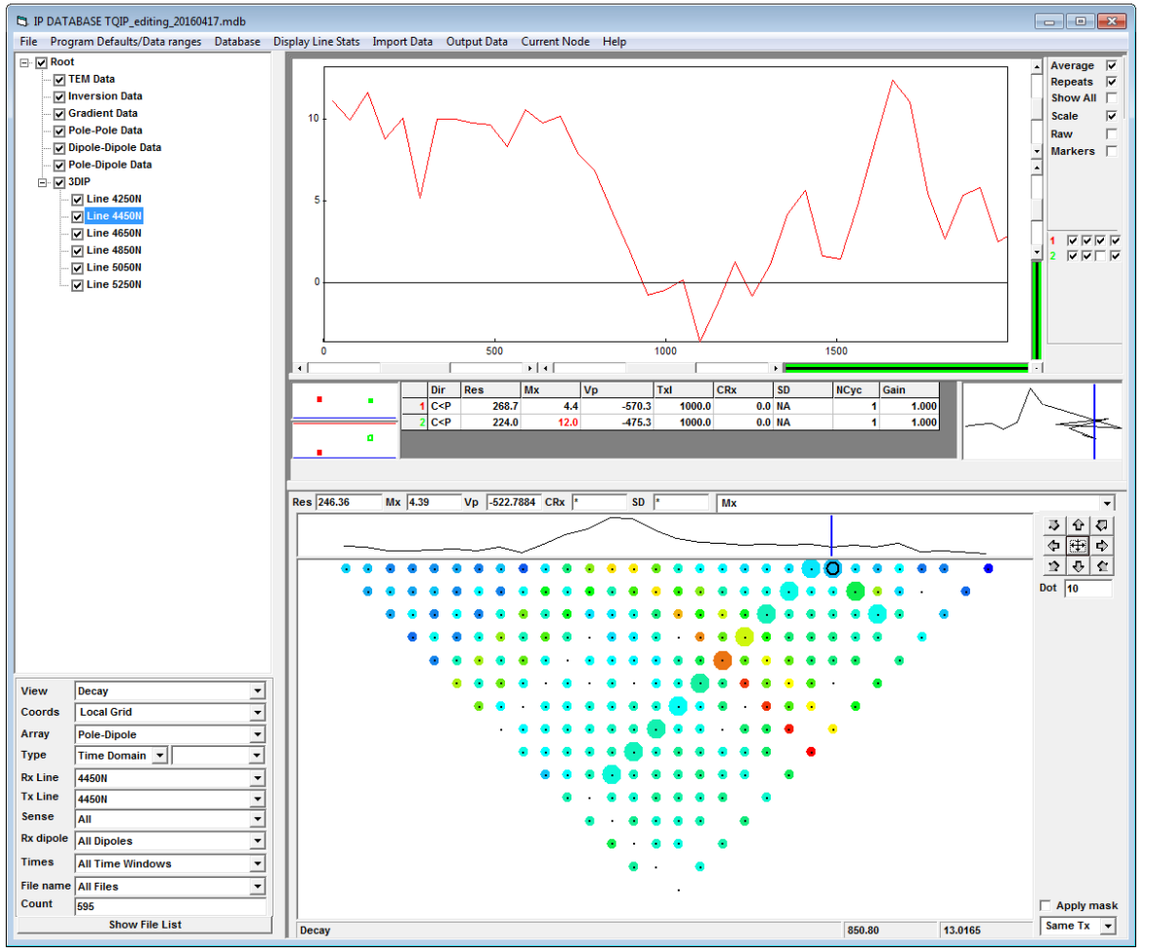


Removed very noisy decays causing outliers

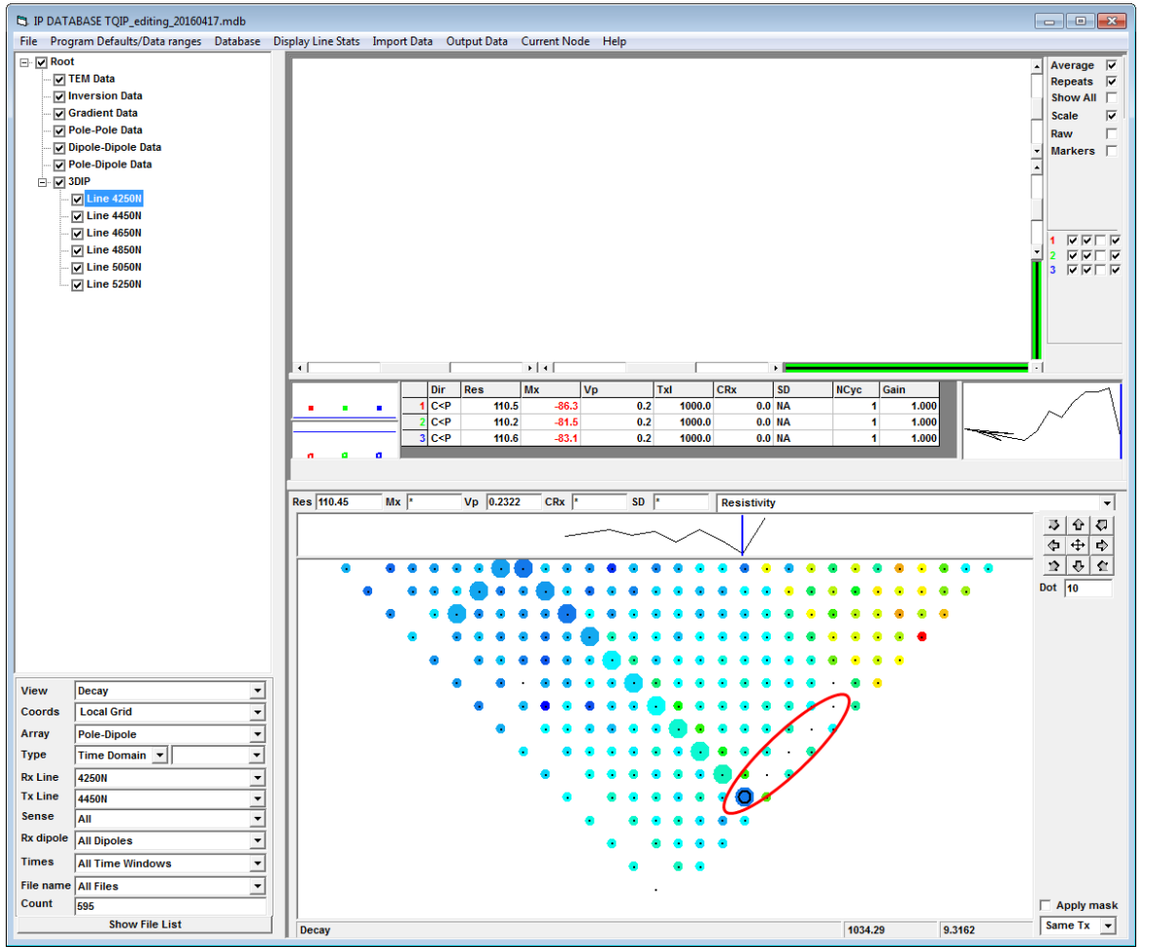


>1,000 msec

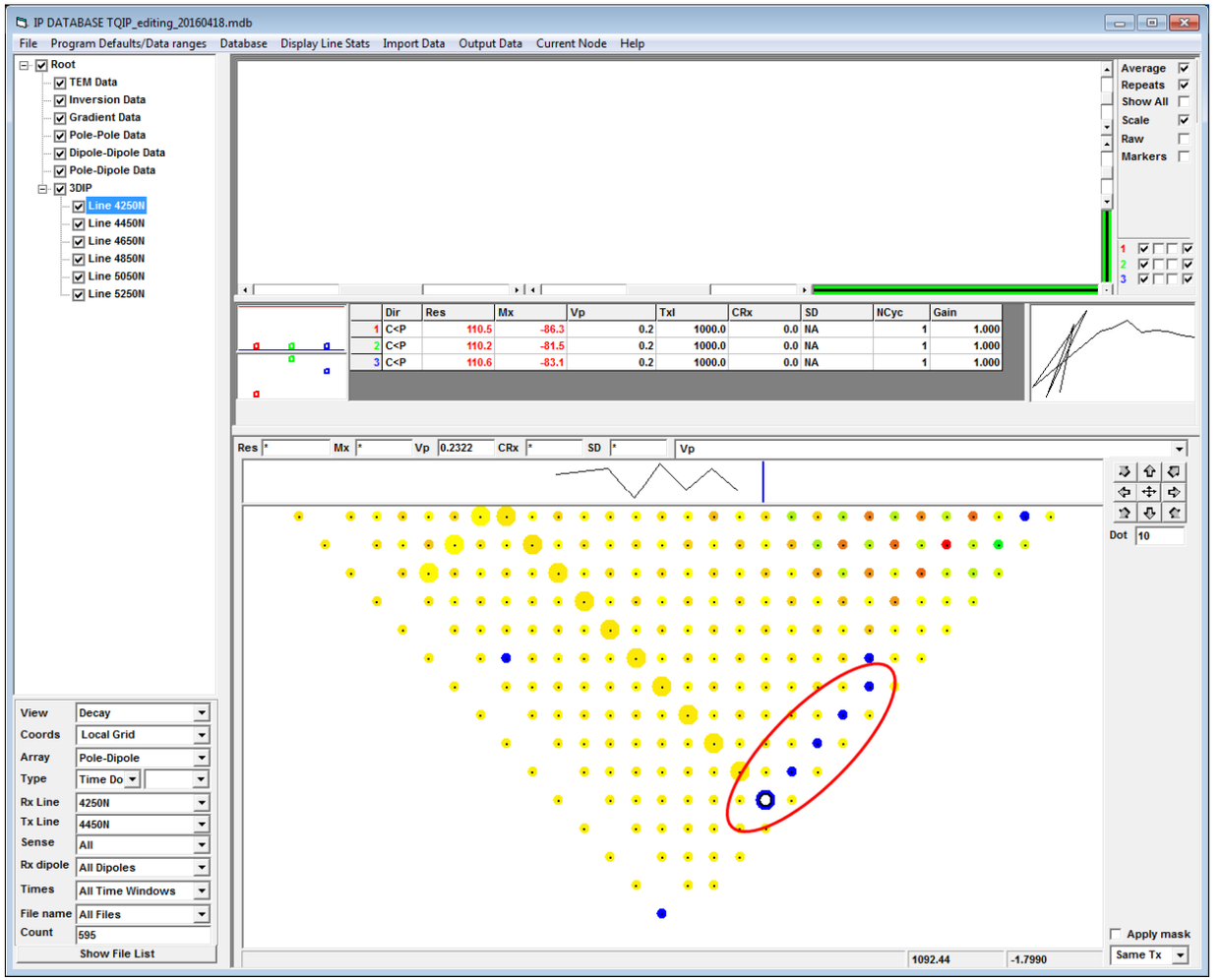
Sometimes leave poor data points in if they are not causing a drama – if the calculated resistivity and chargeability make sense compared to surrounding data points in section



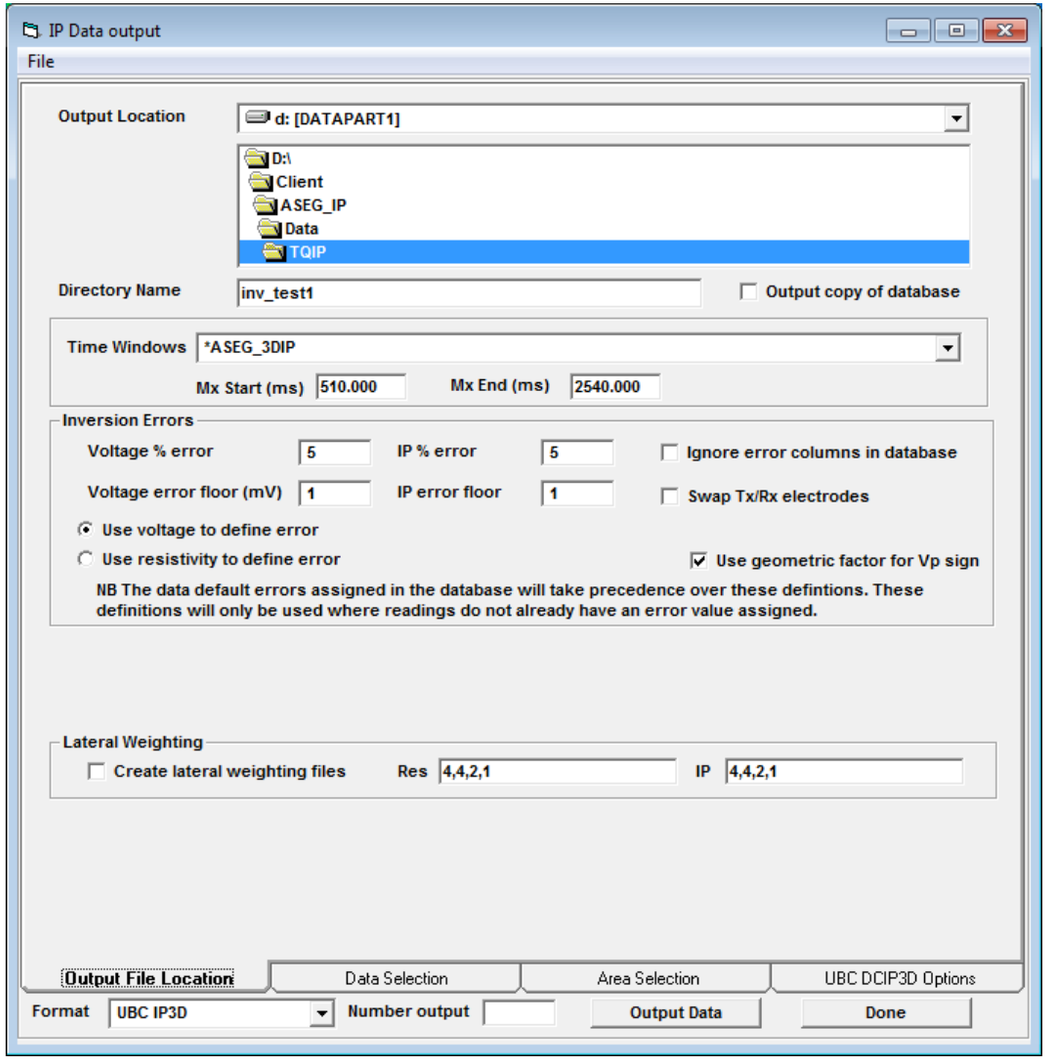
Removed outlier resistivity data points where low Vp e.g. <1 mV



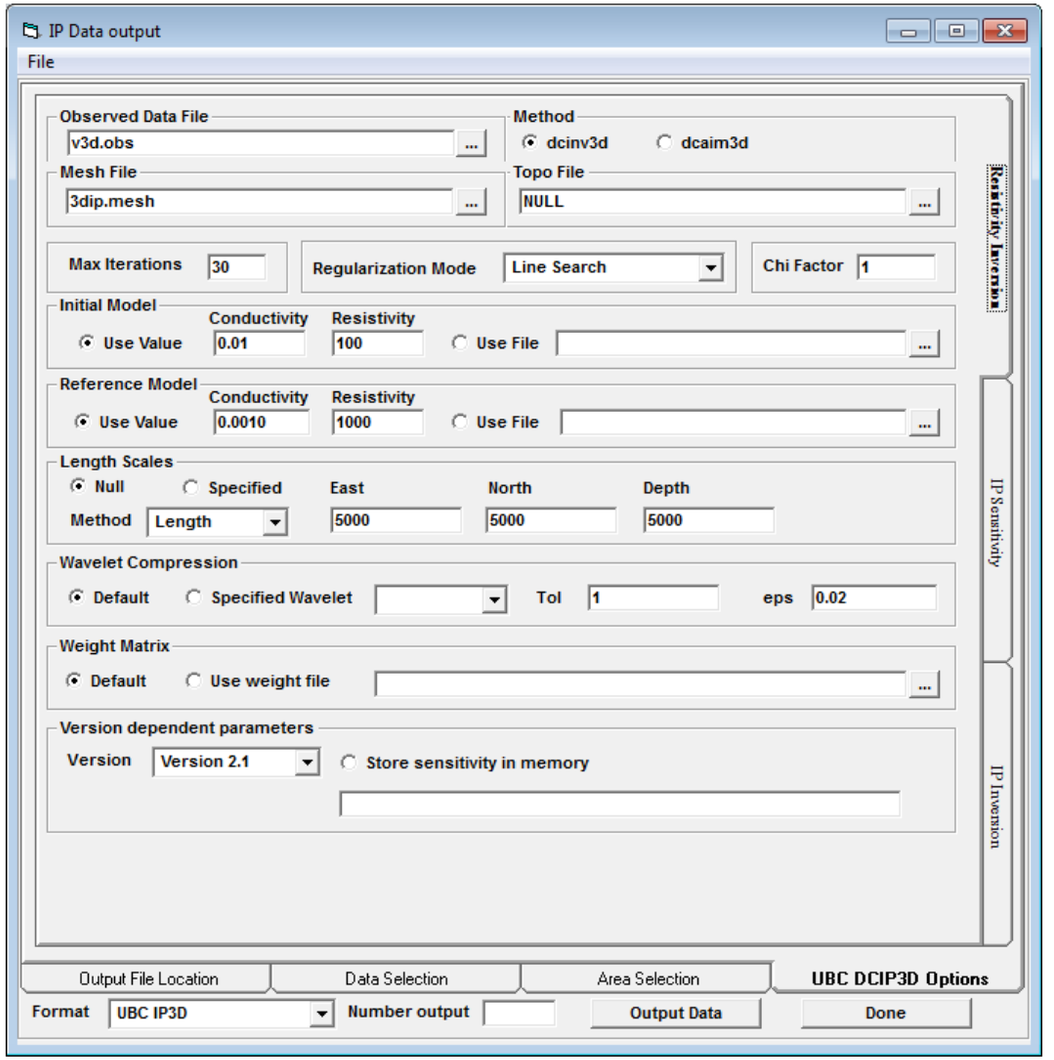
Check data again for poor readings where low Vp – all had already been removed by the Mx threshold



Early 2016 – Already getting anxious and needed to see some preliminary 3D models – output the inversion input files from TQIPdB



Setting default inversion parameters

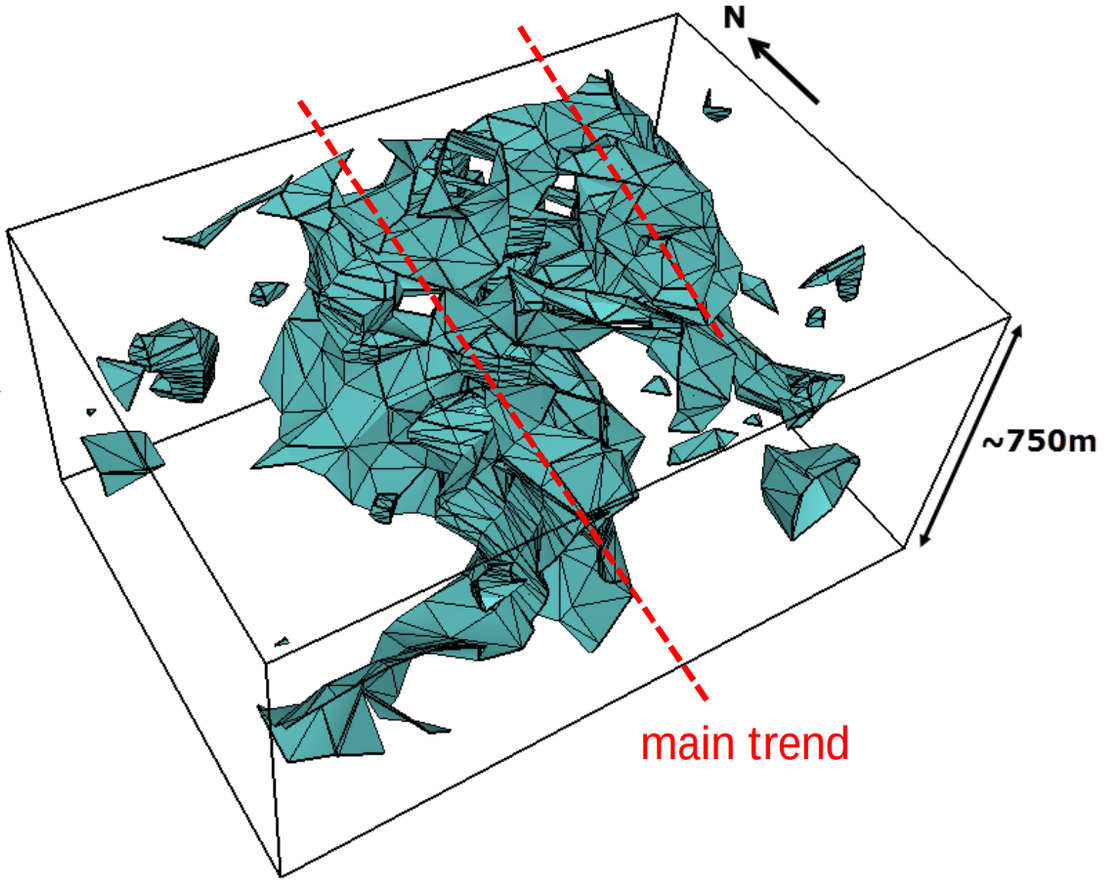


Setting inversion parameters

- Just let the UBC 3DIP batch file run with default parameters.
- Let the UBC DCIP3D conductivity inversion run to convergence, which occurred after 12 iterations.
- Used the resulting conductivity model in the running the sensitivity matrix calculation.
- Let the chargeability inversion run through.
- Had a quick look at results using 3D Modeller – 3D Viewer.

First trial default inversions – Chargeability 3D Model

20 msec chargeability model

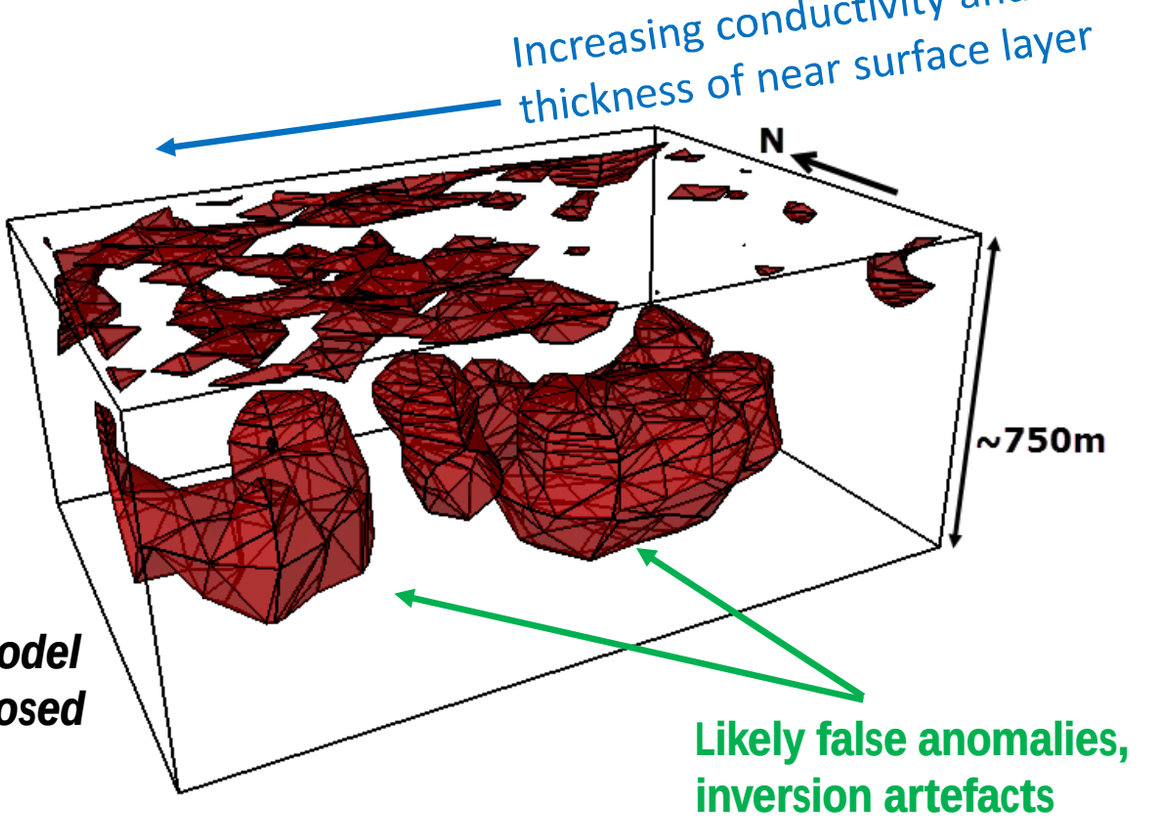


- Shikes!
- Early results were poor.
- There's something through the centre.
- And something through the east-northeast.
- I believe in these general trends, but the model results are scattered and extend too deep in some places e.g. a shallow and noisy chargeability response in the south and centre of the grid.

First trial default inversions – Conductivity 3D Model

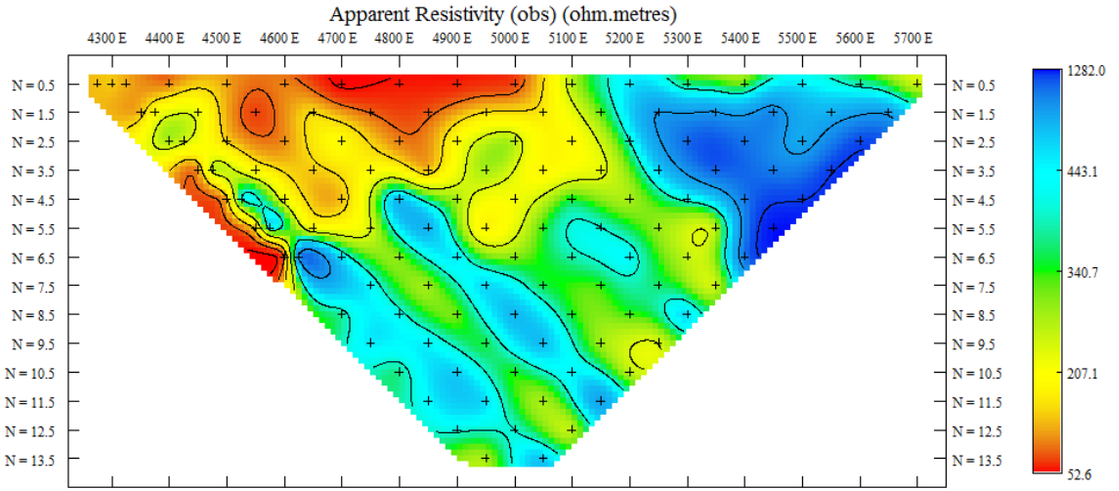
- The near surface layer increases in conductivity and thickness to the west, as expected, but the results in general are ugly.

- Likely false deeper conductivity model bodies → inversion artefacts resulting from errors in the raw data and poor inversion parameters that don't match the degree of error still present in the edited data.

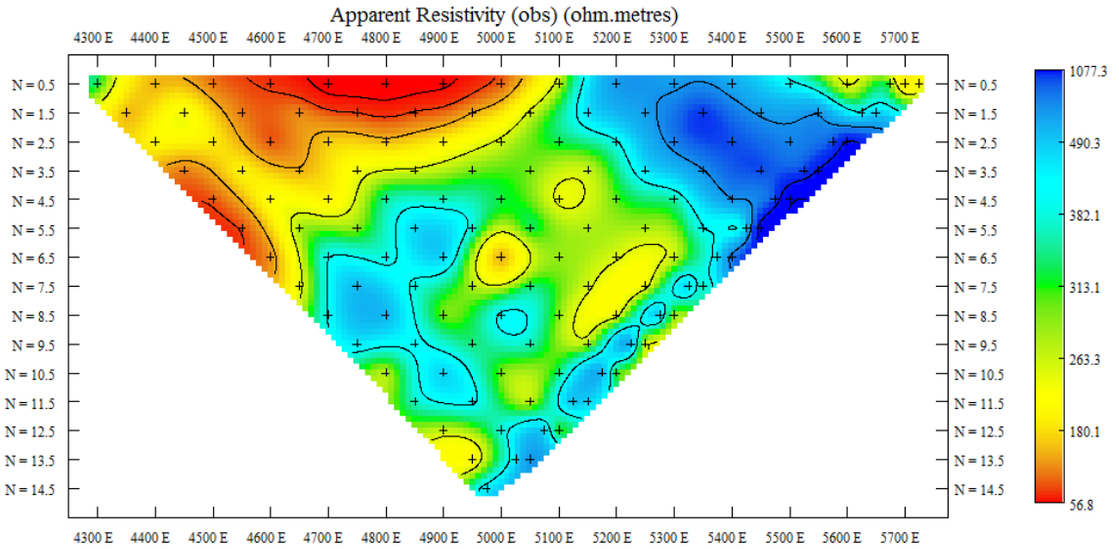


50 ohm-m model, where model values <50 ohm-m are enclosed by the isosurfaces

Check of the raw data to assess the preliminary conductivity inversion model results

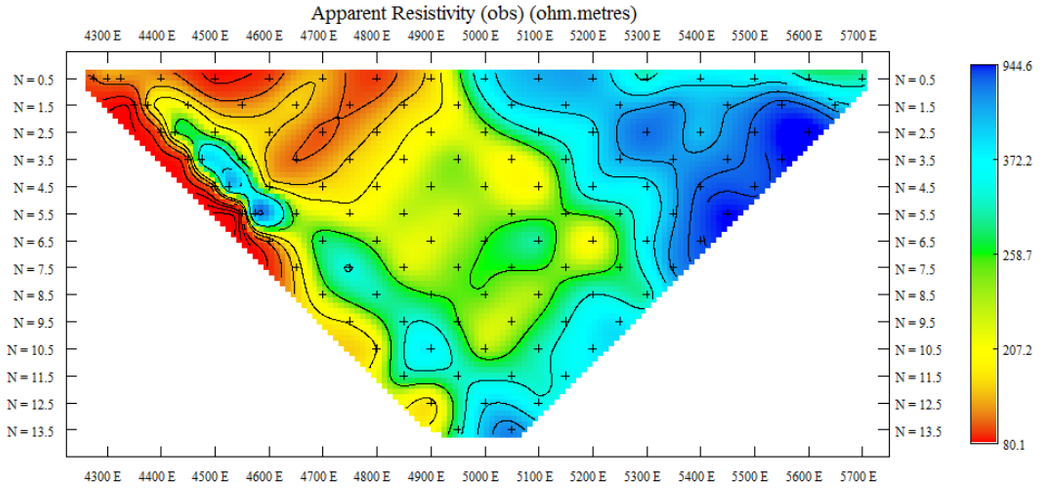


Tx 4450N and Rx 4450N

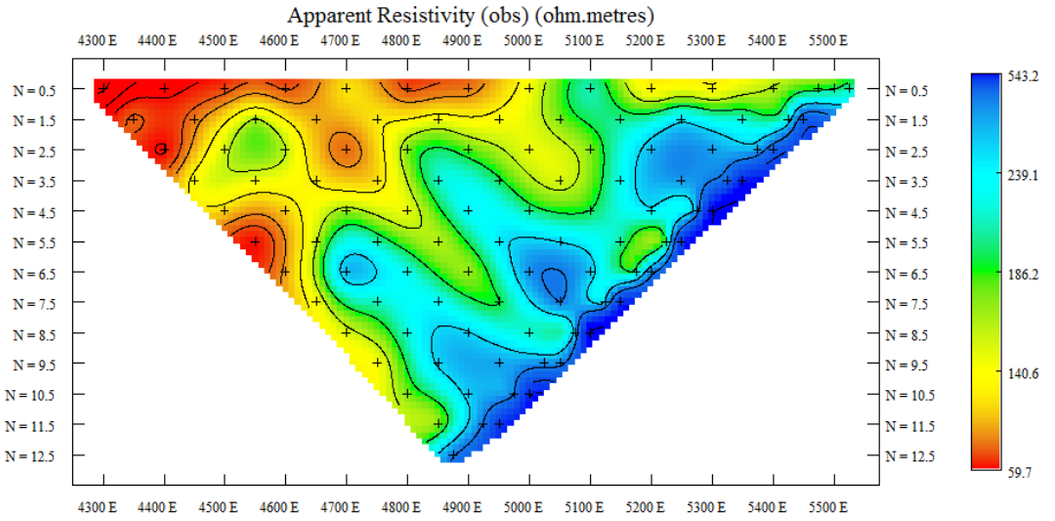


Tx 4650N and Rx 4650N

Check of the raw data to assess the preliminary conductivity inversion model results



Tx 4850N and Rx 4850N



Tx 5050N and Rx 5050N

Summary of raw data conductivity check

- There is nothing really standing out in the raw resistivity data to suggest that the deeper conductivity sources produced in the initial trial inversions are valid.
- Poor 3D model results have been produced from the trial inversions because of poor starting and reference models, and because there was still a lot of error present in the edited dataset.
- My simple understanding of the chi factor is that if we have a lot of error in the data, then we will likely need to increase the chi factor, so that the inversion doesn't work too hard to fit all of the smaller deviations in the dataset that are caused by error.
- Conversely, if we have a dataset with low error, then we can keep the chi factor low (1 or less).
- The edited dataset still has a fair amount of error/noise.

Outcomes of the work completed so far

- The inversion models don’t look very good at this stage, but there is clearly a chargeable source trending N-S through the centre of the area, possibly through the east to northeast as well.

- The conductivity inversion model is confirming a general near surface trend interpreted from the raw data, but the model results are ugly, and typical of an inversion process that is pushed too far and is over fitting the small deviations (error) in the raw data.

- I need to knuckle down, spend some time to re-edit the data, and focus on running some better inversions.

Revised trial inversion

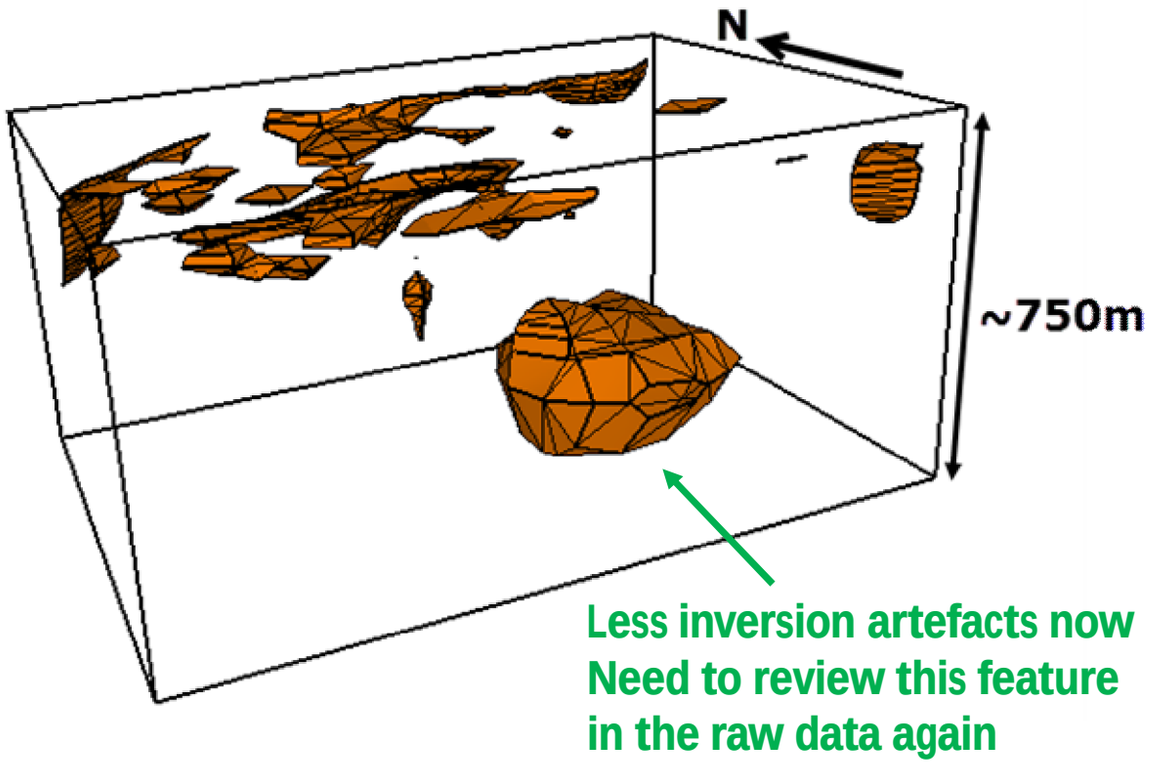
- I just re-ran the sensitivity matrix calculation again using an earlier iteration of the conductivity inversion model, where there is much less variation in the model, and then re-ran the chargeability inversion.

- So I used the conductivity inversion iteration number 6 out of 12, and then ran the sensitivity matrix and chargeability inversion based on the interim conductivity model.

- I have seen this work well on a couple of other projects.

Revised trial inversion - conductivity

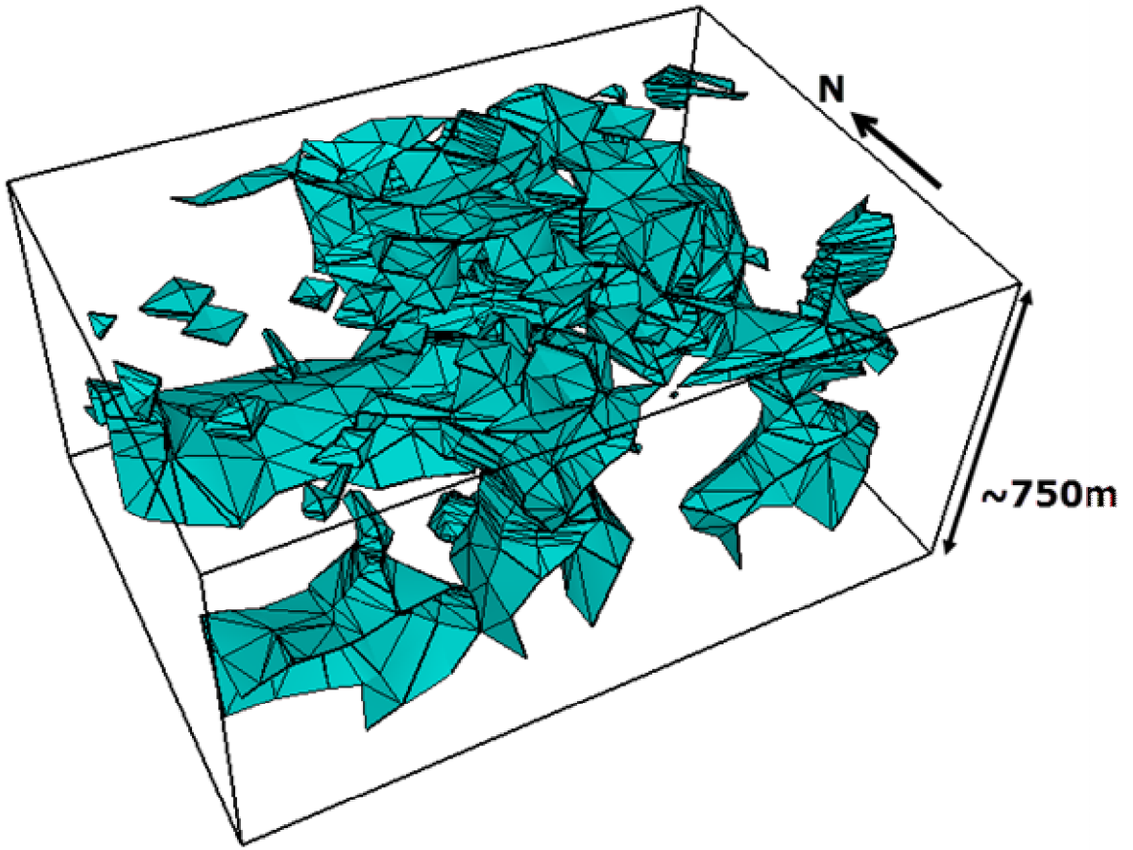
- The near surface layer is still behaving as expected, but the model results still look ugly.
- There are less inversion artefacts at depth in the revised trial inversion.



50 ohm-m resistivity model, where model values <50 ohm-m are enclosed by the isosurfaces

Revised trial inversion - chargeability

- The chargeability inversion model still doesn’t look very good.
- Back to the drawing board.



Final Inversions Late July

- Re-crunched the raw data to edit out quite a few more resistivity data points.
- Took the approach of working on getting a smoother conductivity inversion model first, calculating the sensitivity matrix from this model, and then changing various inversion model parameters for the chargeability inversion.
- Used better starting and reference models e.g. conductivity starting model 50 ohm-m and reference model 250 ohm-m, and chargeability starting model 5-15 msec and reference model 20-25 msec. Higher than normal starting and reference chargeability values were required to get the inversion model result to match expectations, based on anomalies observed in the raw data.
- A better conductivity inversion model was achieved by better starting and reference models, plus using a higher Chifact 5, so that the inversion didn't run for as long before it was happy with the misfit.
- Incorporated the topo grid.

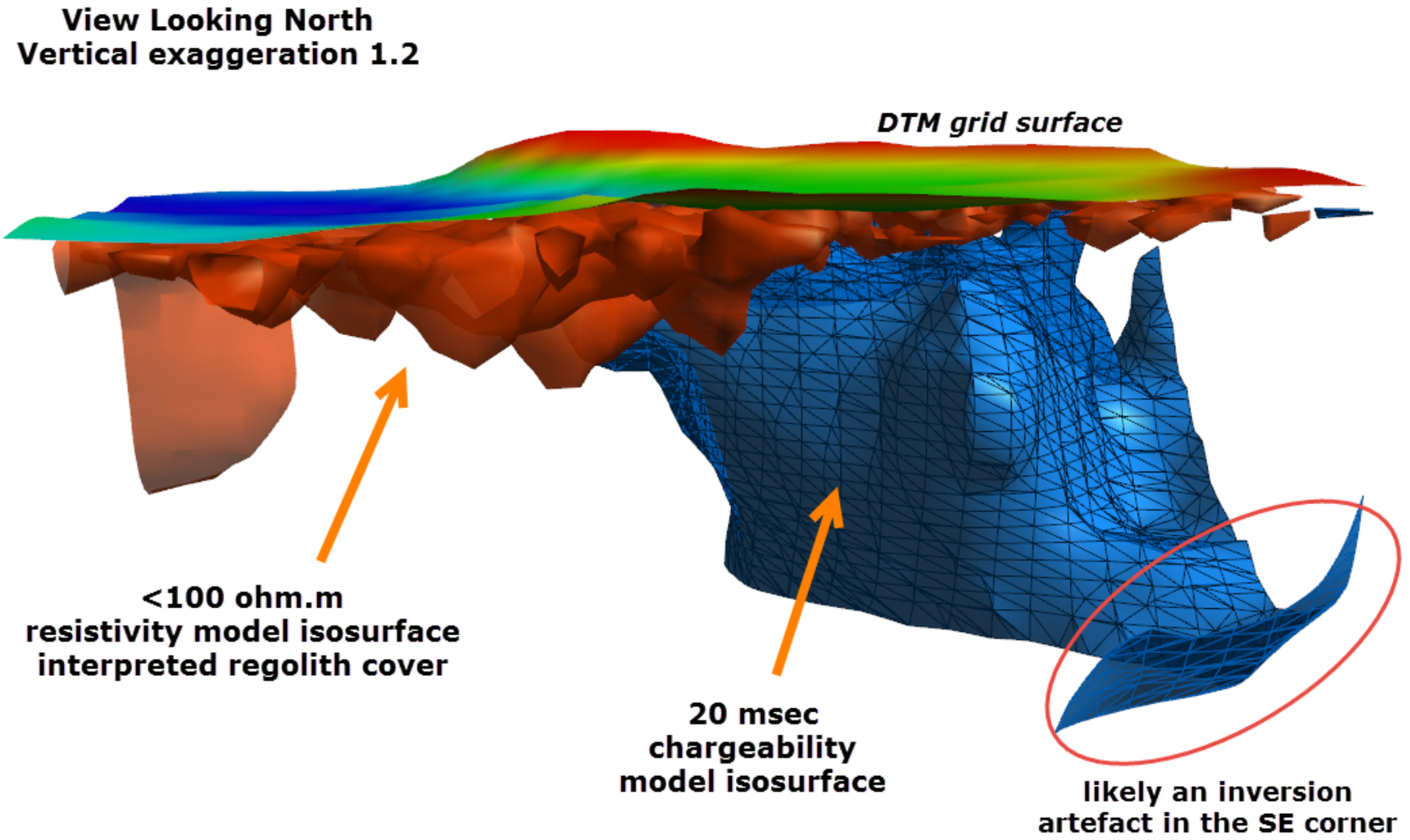
Inversion Processing

- Once set on a reasonable conductivity model, I trialed many alternative chargeability inversions using different variations of chi fact, starting and reference models, smoothing parameters/length scales → trying to remove likely model artefacts, add a bit of structure, and improve the relative amplitude of model features.
- An Excel spreadsheet was setup to record parameters used for each inversion. I worked through changing chi fact 1 – 2 - 5 – 10, then back to 5. Then changed the chargeability starting and reference models, with chi fact at 2. And so on.
- At least 20 new trial inversions were completed.

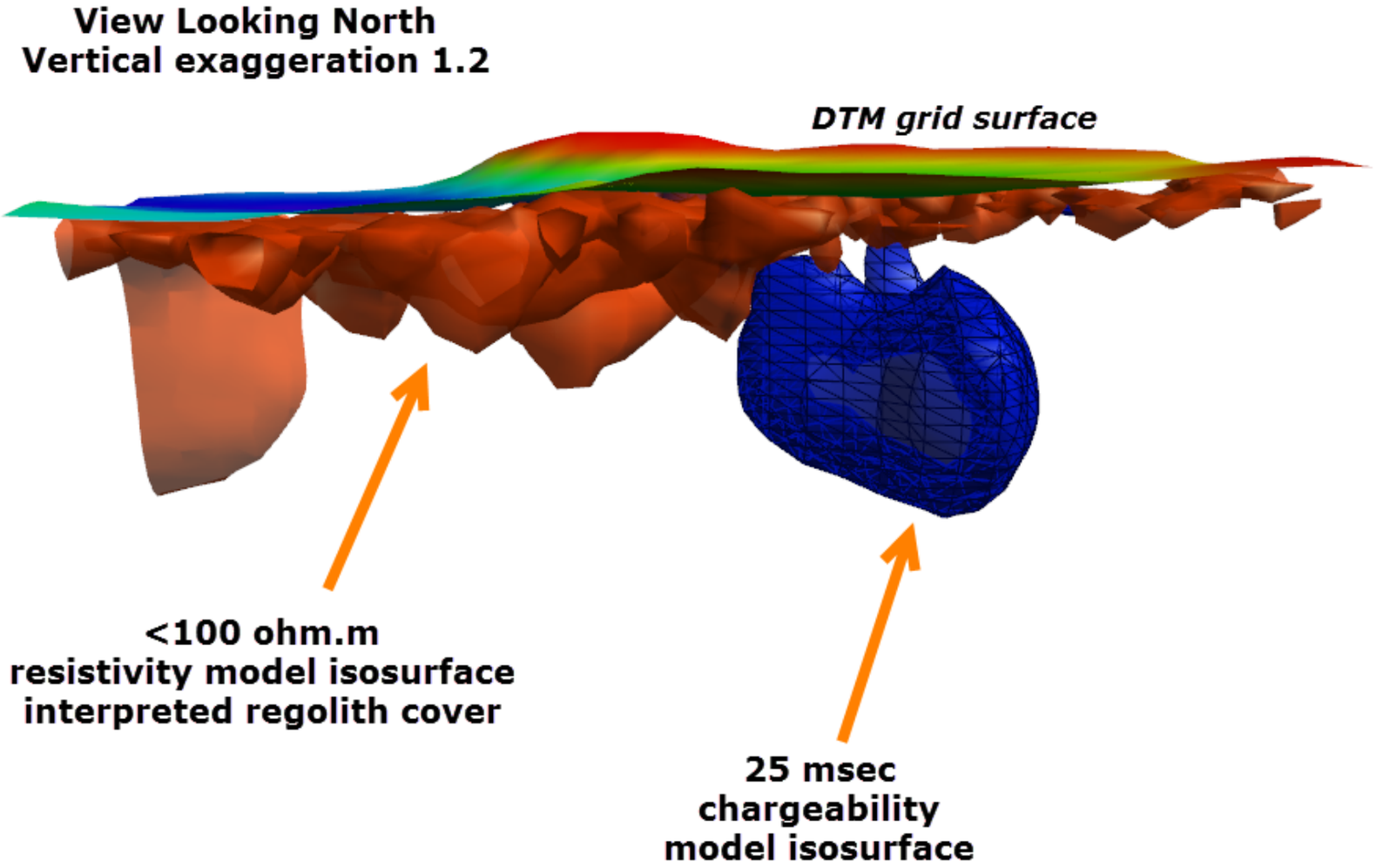
Chargeability Inversion Processing Summary

- Starting chargeability model 15 msec.
- Reference chargeability model 25 msec.
- Trying to push the inversion result to higher values, as in the raw data.
- Chi factor = 2, because chi factor = 5 was too smooth, and chi factor = 1 contained too many model artefacts.
- Favoured length scales 100m (E), 100m (N), 150-300m (Z) to force a bit more vertical structure.

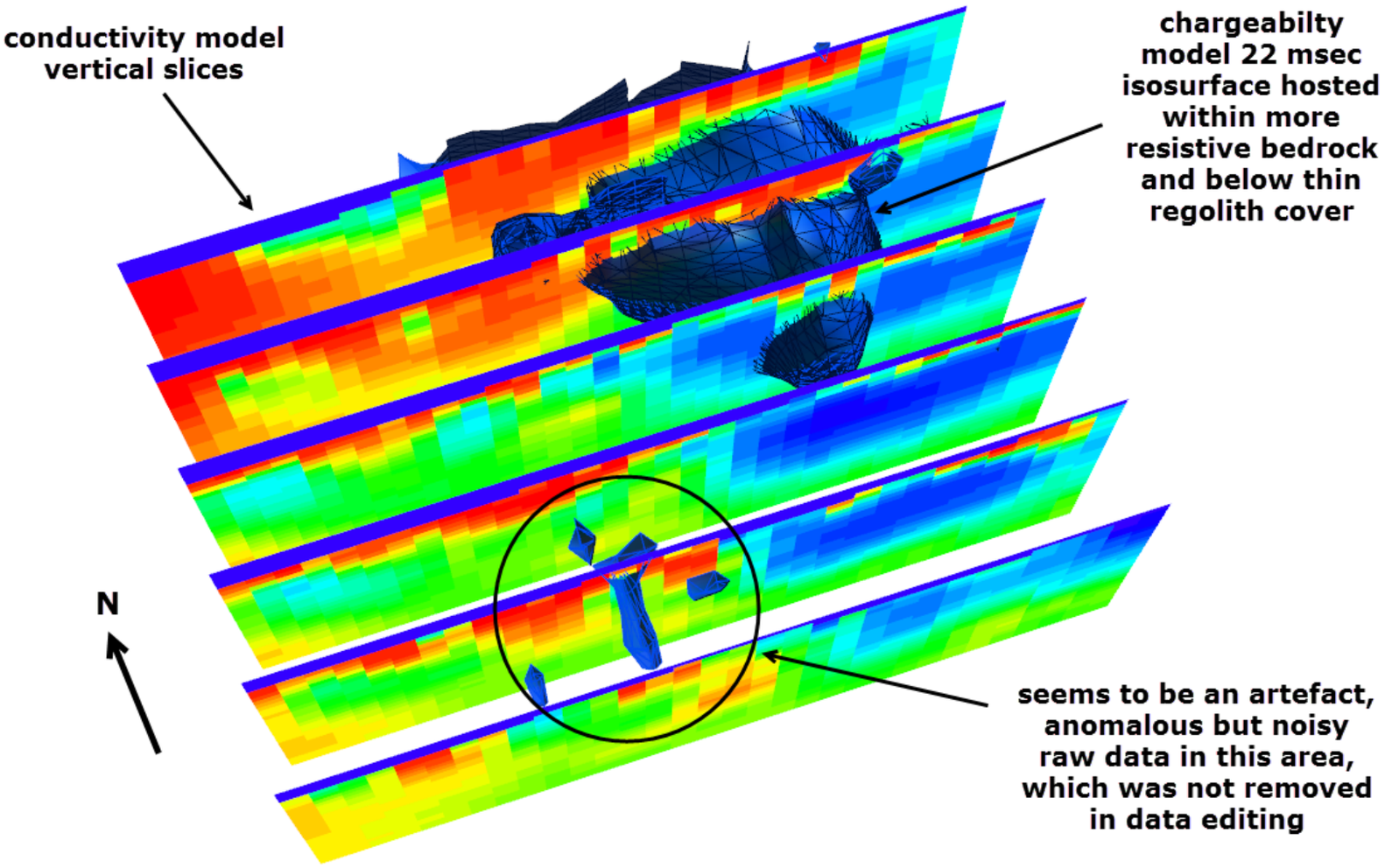
Latest Results



Latest Results



Latest Results



Checking the validity of the inversion models (without any geological data)

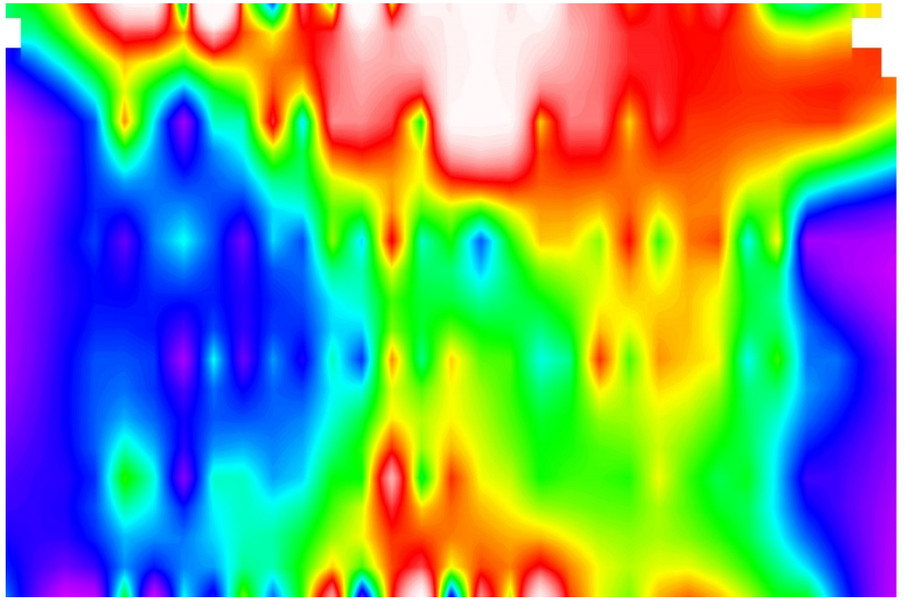
- Not something that I would normally do with 3D IP data. It's difficult, I don't yet understand how to do it properly, and I would prefer to use geological input, which is usually available.

- Initially tried gridding all N-level data → technically incorrect, as all data measured at a receiver pair were assumed to be all on the same receiver line, whereas in reality they would sit somewhere in between the Tx and Rx line, depending on which Tx electrode was being used for that reading.

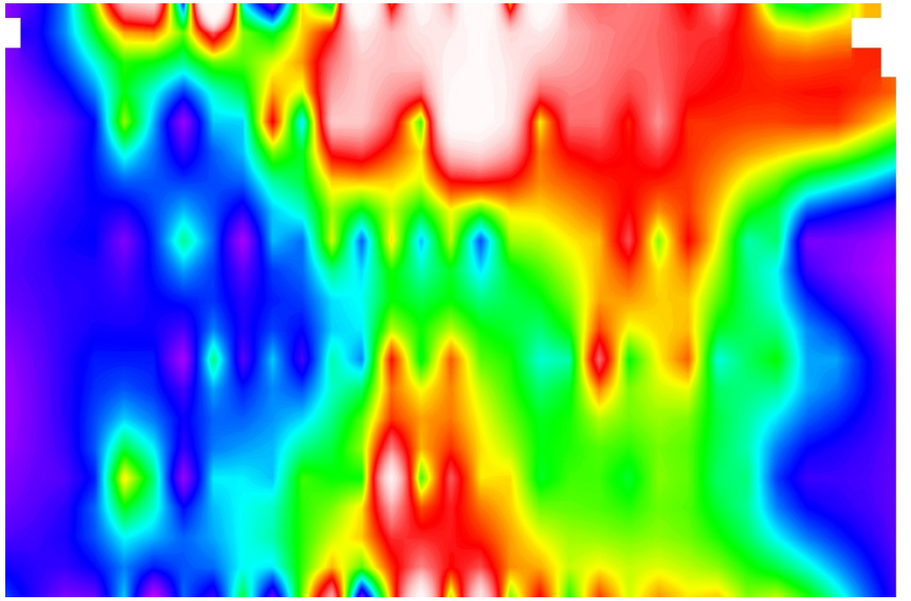
- So this gridding would be averaging data from near to far Tx offsets from the receiver line, so it's a very crude method of checking the data, but it's still worth looking at…

N-level comparisons
Chargeability N-Level 0.5

Observed

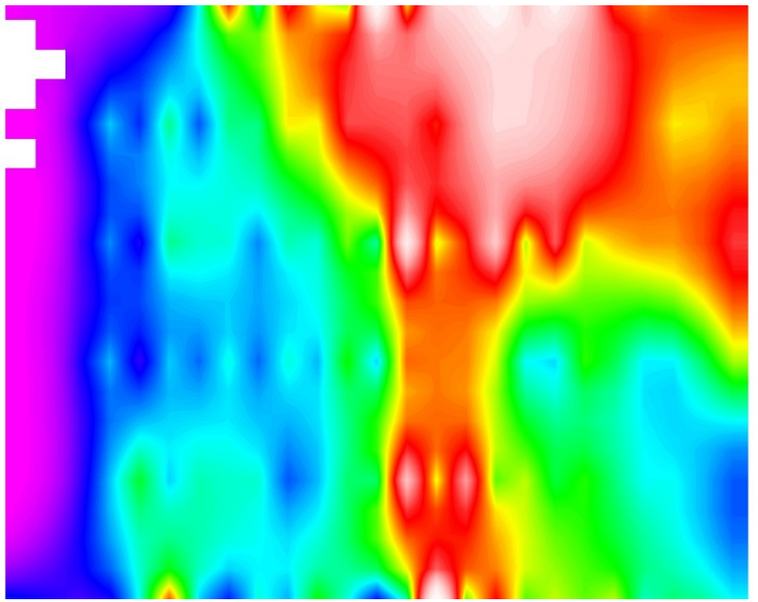


Modelled

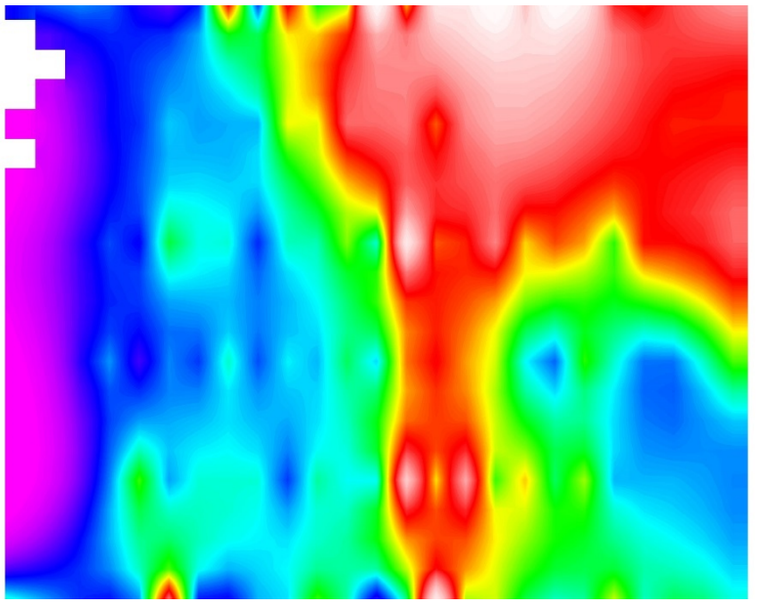


N-level comparisons
Chargeability N-Level 3.5

Observed

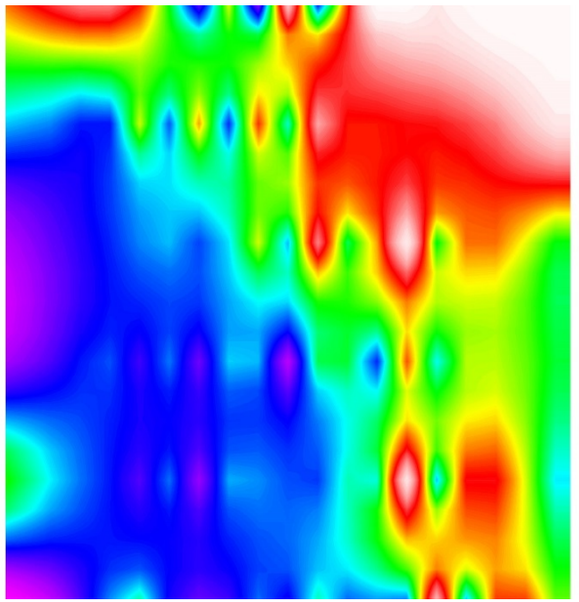


Modelled

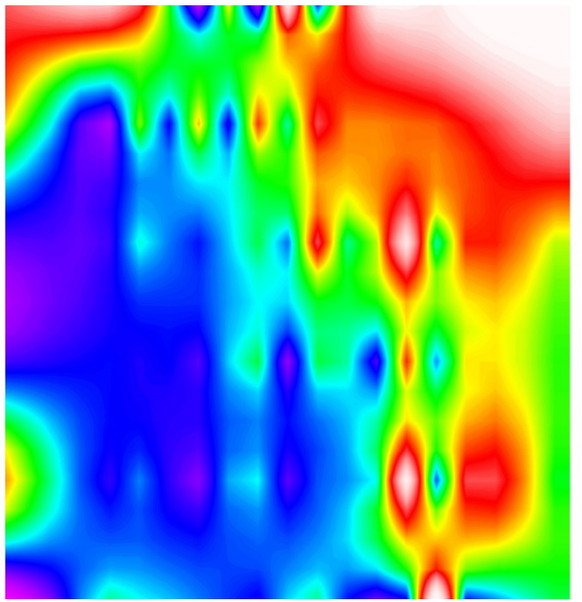


N-level comparisons
Chargeability N-Level 6.5

Observed



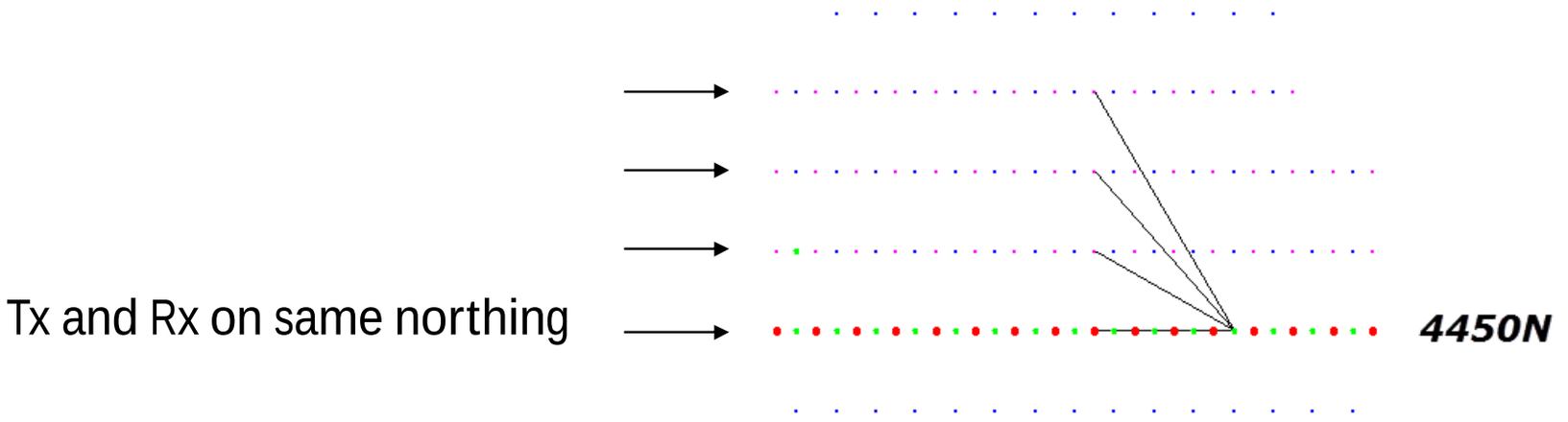
Modelled



Further N-level comparisons

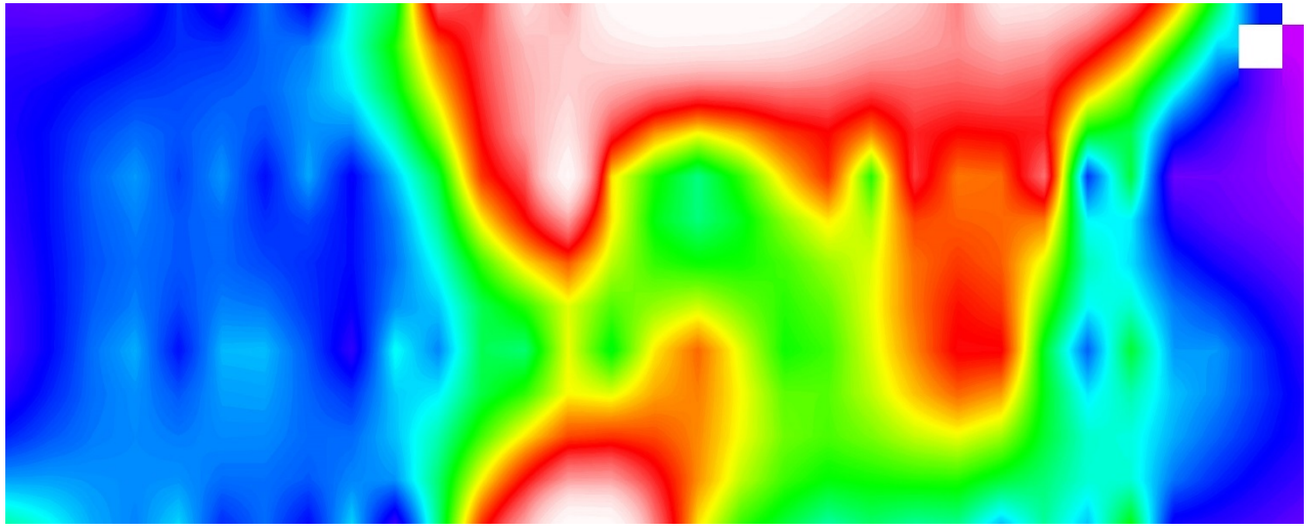
- The central survey lines: 4450, 4650, 4850 and 5050, each have data recorded with the Tx along the same line as the Rx.

- So I gridded the coincident Tx-Rx line N-level observed and modelled data for these survey lines only.

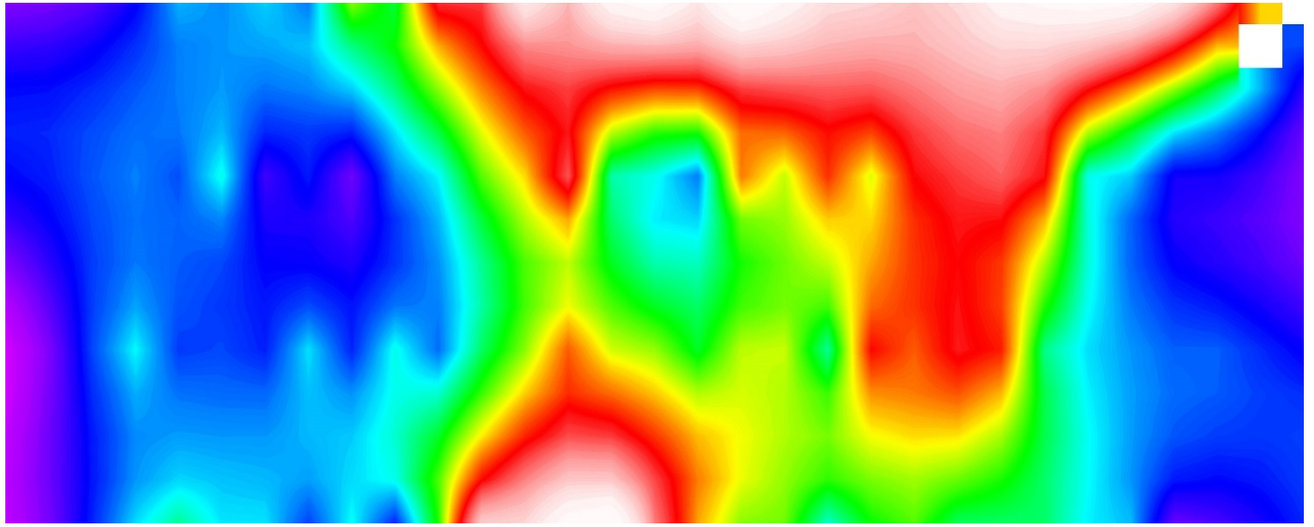


N-level comparisons for the 4 central Rx lines only
Chargeability N-Level 0.5

Observed

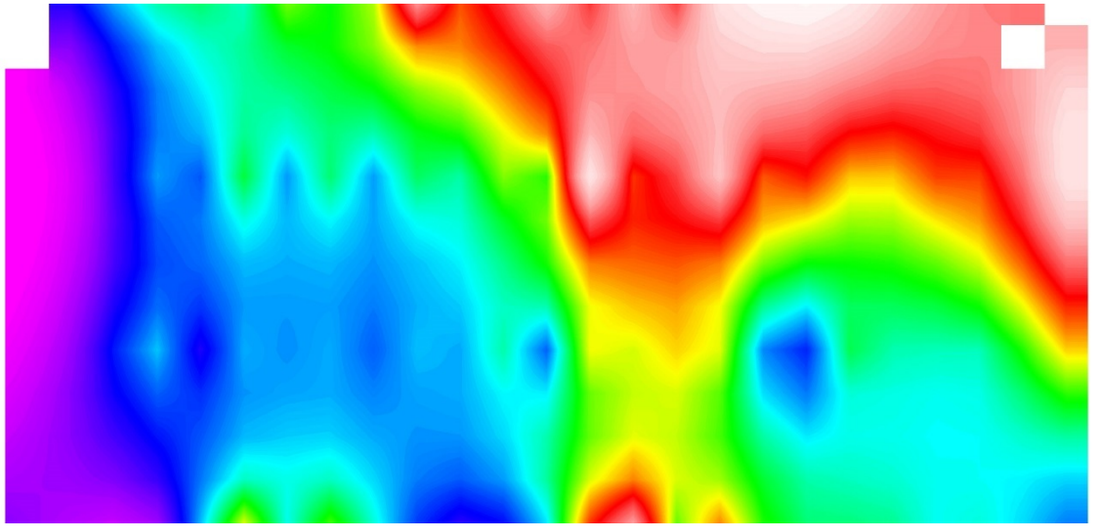


Modelled

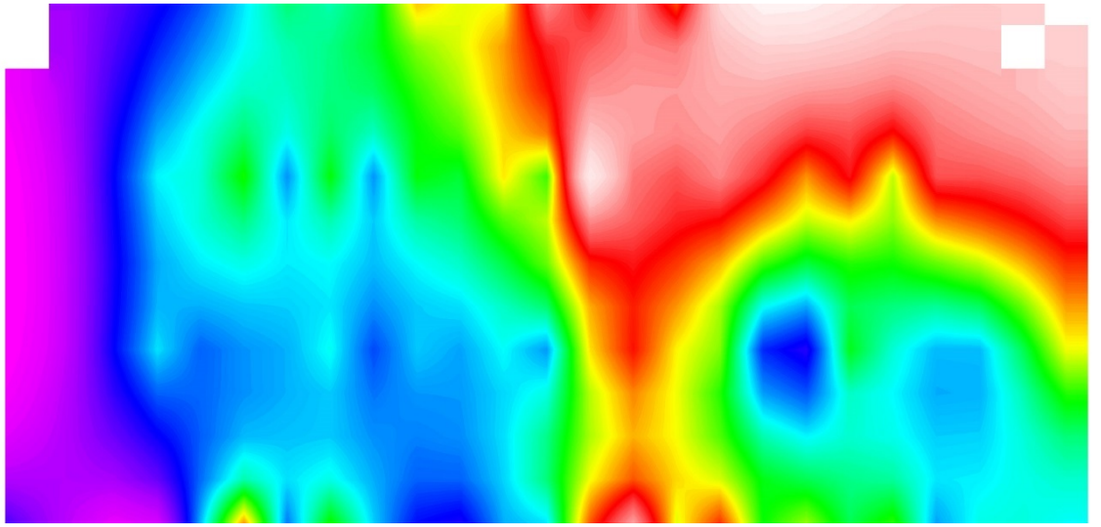


N-level comparisons for the 4 central Rx lines only
Chargeability N-Level 3.5

Observed

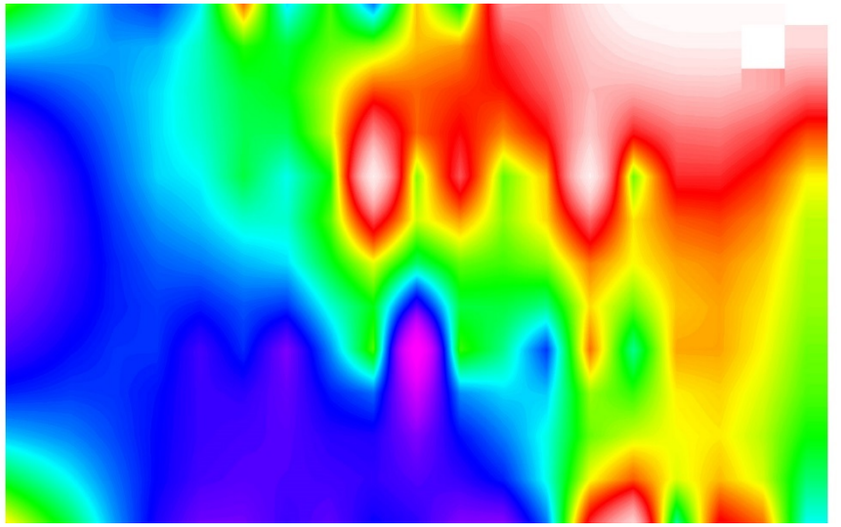


Modelled

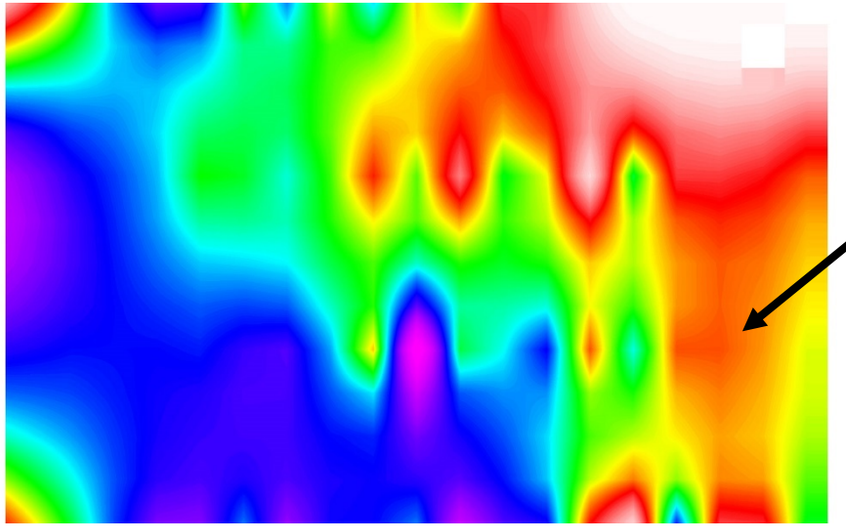


N-level comparisons for the 4 central Rx lines only
Chargeability N-Level 6.5

Observed



Modelled



The inversion model may be extending this anomaly too far to the south.

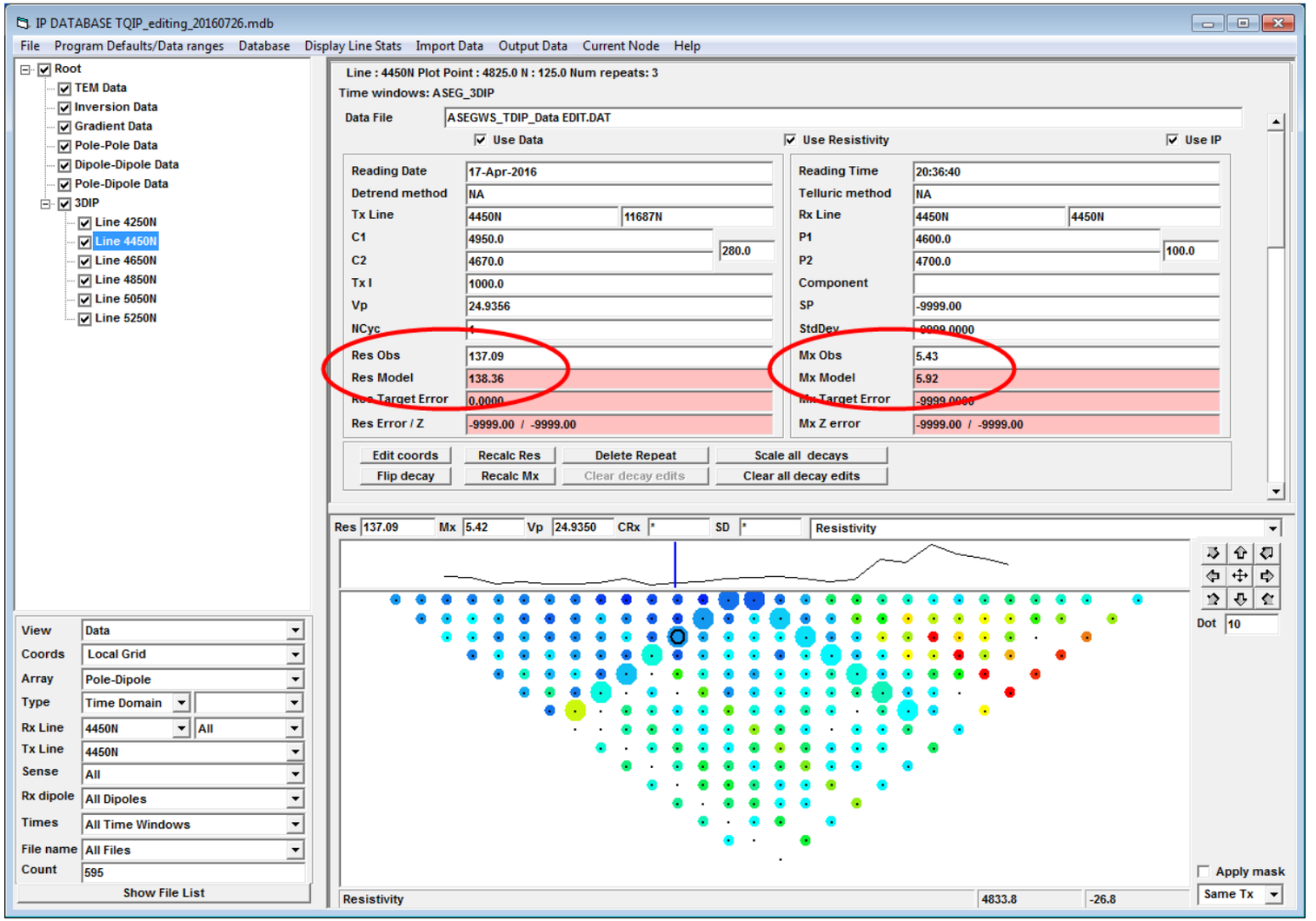
Summary of N-level Comparisons

- Crude N-level comparisons of the observed and modelled (back calculated) raw data have been shown here, but they're better than nothing and simple to understand.
- The inversion model may be over extending chargeability anomalies in some places e.g. eastern side.
- The central southern chargeability response looks to be strike limited and only shallow. I don't trust this anomaly based on the raw data, but am trying not to over edit the data.
- The stronger and bigger chargeability response is to the north and east of centre.
- It's very difficult to predict model sources from the raw data, unlike PDIP or DDIP.
- Geological input is necessary to validate and refine 3D IP inversions.

Importing forward model/predicted data back into TQIPdB

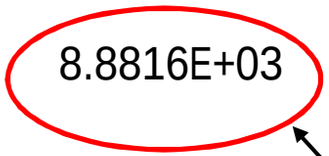
- I haven't known how to do this until recently → assistance from John Paine.
- I reviewed a few data points on each line and the observed and predicted data looks comparable. However, it's too slow to evaluate each point, and then it is difficult to know at which stage you would decide the data needs to be reprocessed i.e. 20 bad data point comparisons?
- I understand sections could be created for each Tx-Rx line, but then there are 24 sections that need to be reviewed, and once again it would be difficult to determine where to draw the line on what is a successful inversion or not.

Importing forward model/predicted data back into TQIPdB



Quick review of inversion misfit values

	Misfit	Model Norm	Multiplier
Initial default inversions	4.4988E+03	1.3914E+08	4.6573E-06
Revised inversion	4.4055E+03	3.0645E+08	1.7153E-06
Final inversion	8.8816E+03	4.1257E+07	2.3236E-04



Best inversion has the worst misfit!

My 3D IP data editing and inversion modelling approaches

- Up until now, I have preferred to null poor data and go without it, when editing 3D IP data, as I don’t yet have a good understanding of where the poor data comes from, and I don’t like to alter raw data too much e.g. correcting for EM coupling.

- I usually undertake 3D IP inversion processing with less attention to the inversion misfit results or error analysis, than what I would do with 2D IP inversion processing, as I think it is often more practical and more useful to compare 3D inversion model results with existing geological data, and then consider - is this inversion model valid or do I need to go back and re-crunch it?

My 3D IP data editing and inversion modelling approaches

- Each of the 3D IP survey datasets that I have dealt with have been for projects where there is already a lot of other project data that can be used to constrain the inversion process, or rather, adjust inversion parameters to get a better match to geology e.g. change inversion smoothing bias to force either horizontal or vertical model features.

- Having a fair bit of sulphide mineralisation already confirmed underground, and already having completed a few successful IP traverses (DDIP or PDIP) over it, actually seems to be a prerequisite for getting a client to consider approving the huge cost of a detailed 3DIP survey.

Final Comments

- Thanks!
- So far, I have really only dealt with a handful of **3D** IP datasets, and only one where our consulting group was involved in the survey planning – MIMDAS at the Bentley VMS deposit, South of Jaguar and Teutonic Bore, for Jabiru Metals Ltd.
- Other small consulting jobs undertaken have been either reviewing historical data or giving a 2nd opinion on a confusing dataset that didn't really match the geo's expectations.