Geophysical Software Update

1 January 2020

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NOTE : Routines modified since the last update are indicated in Italics

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GENERAL

Report all errors to me as **I can't fix what I don't know about!**. The best way to do this is to first check that you did not stuff up, then capture the error message and paste it to an email to me along with a brief description of what you were doing at the time. Depending on the error message I may need your input files as well. Each executable is compiled in two versions, one with production settings for speed and another with debug setting for assistance when you don't understand why something is not working. If you have problems and if the debug version is available , it may help if you run it as you may get more useful error statements. Note however that the debug versions can produce errors that may have nothing to do with your problem because of underflow, I can get around this but it slows the normal program down considerably. The full debug versions can be up to 10 times slower depending on the programming sequence. You will get more traceback information, which will help me isolate the problem, if you start the program from a command line (DOS box in Windows, Terminal in Linux)

All variables in the binary database are stored as 4 byte reals. This means you only have **7** digits of precision. If you need more (eg gravity data 9?????.?X mGal or UTM Northing ???????.XX) you will have to split the number **before** you bring it into the database. Once it is read in the precision is lost.

The database has a header and this is used for some survey types for storing important survey information. It may seem a nuisance to you but it is worthwhile filling in as completely as possible, time spent here will save time later. If you don't know what should go in a particular box find out as it is bound to come in handy later on.

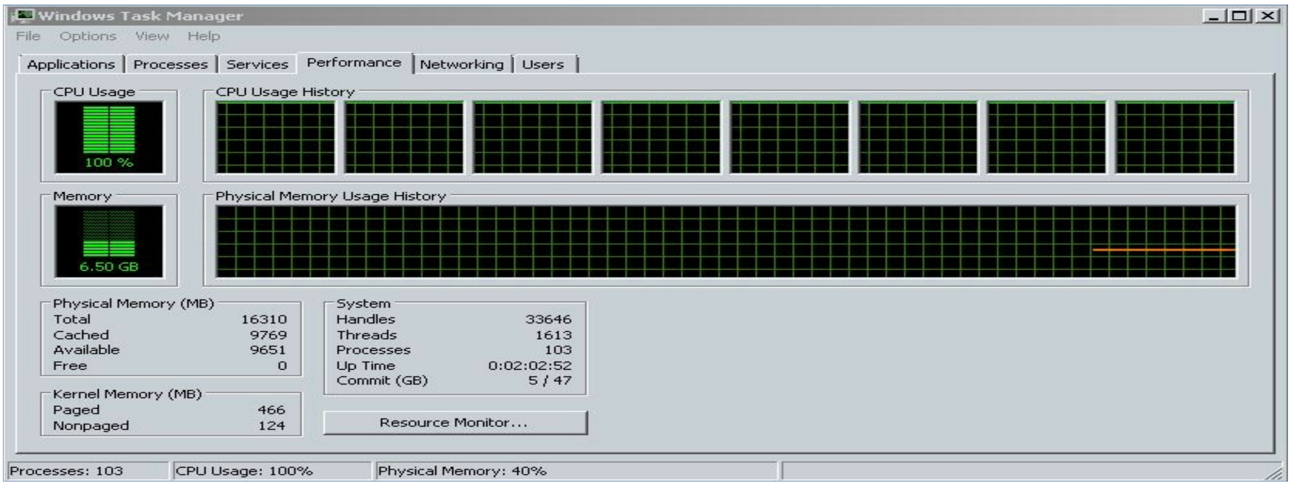
Each program generates an input file (*.inp) and a print file (*.prt) on execution. They will have the same name as the executable and be written to the current directory. The input file stores all the values you have put into the input dialogues. The print file stores a log of who did what and when. It stores important statistics and problem reports as well as survey information etc. It is often a good place to go looking when you get an error message that does not fit or if your inversion looks a bit odd! For this reason you should run these programs so that your current directory is the directory with the data in it, that way the data and the log files are all together.

Since 2017 the code has been compiled for both Linux (Ubuntu) and Windows. Although the geoproc binaries run the same on both systems the setup and external behaviour is a little different so the two operating systems will be discussed separately.

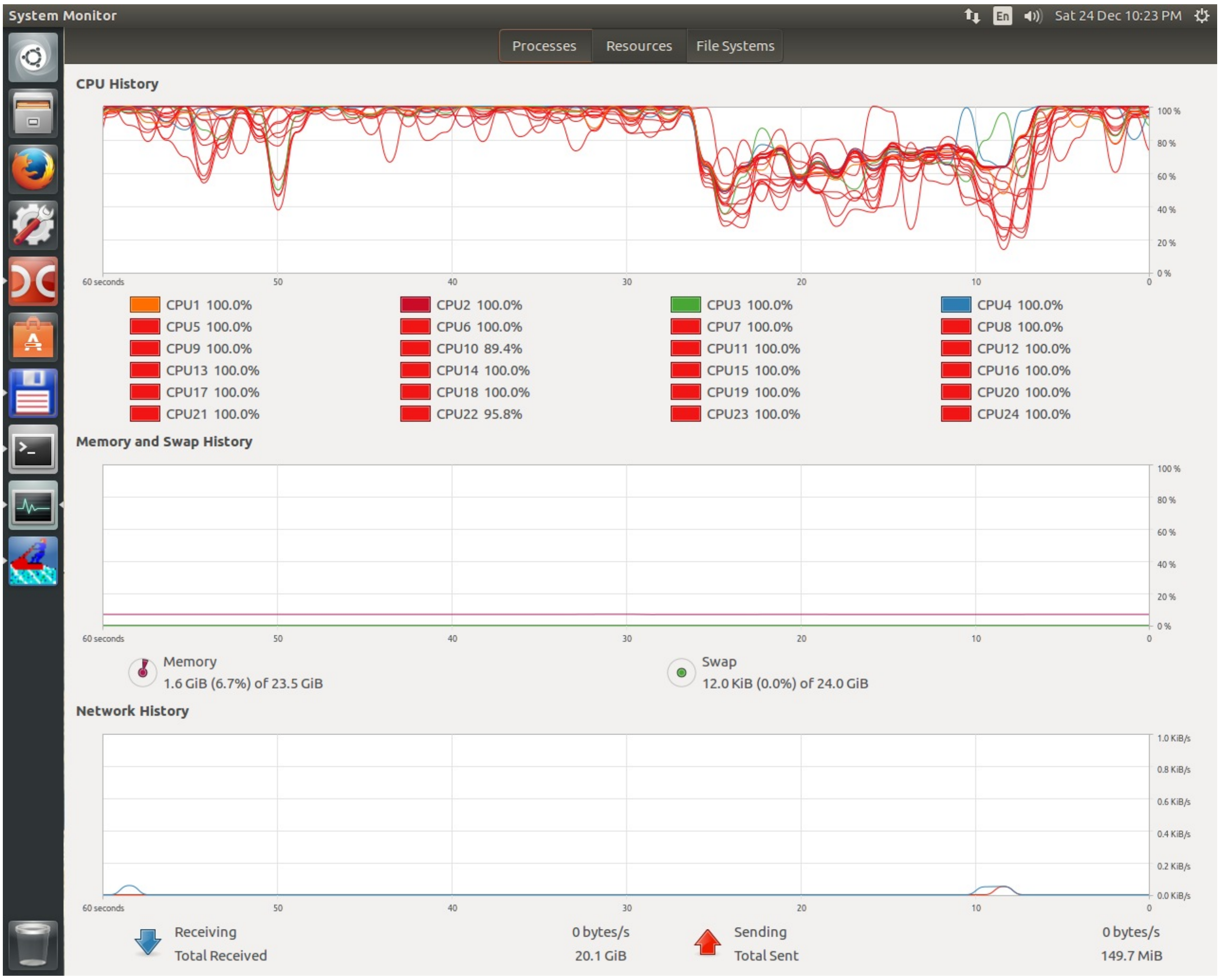
The dialogues of some of the routines in this suite prompt you for a label name for an output field. If you leave this blank the existing label will be retained. If this is not what you want or there is no existing label then ensure you enter a meaningful label.

All routines automatically add fields to the output database if you specify an output field greater than the current database. There is therefore no need to add spare fields to a database for later use as these can be added as needed.

All routines are 64 bit and multi threaded. Where possible the code will use all available processors and can create very large databases and grids.



Windows task manager showing the multithreading at work.



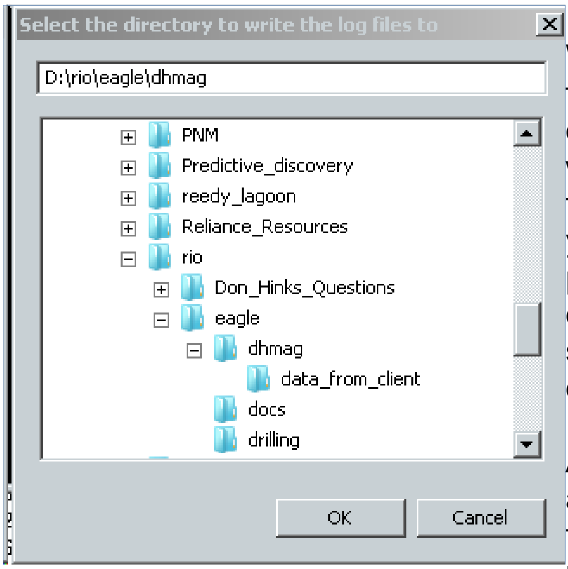
Ubuntu system monitor showing multithreading at work with GSGrid

Windows:

Note that the following works on Windows versions up to Win 7. I have not used Win 10 so can not confirm that they work but no one has complained so far so I assume they do.

Because of the way operating systems handle the current directory, starting the programs in the data directory is difficult to achieve unless you use a file manager shell like Total Commander which gives you a command line in your current directory as you move about. It also provides 1 button viewing, editing, copying and moving as well as built in zip/unzip and a file rename facility which allows for search and replace on multiple files. It has hundreds of other useful features.

To make it easier for those who want to run the programs from the Windows File manager or Start button, each executable starts with a select directory dialogue which allows you to select the directory to write the log files to. This should be the same directory as the data are stored in. You can create a new directory by typing its path into the Path bar at the top of the dialogue.



In order to run the executables directly from the Windows file manager you will have to turn on the folders panel in Windows Explorer (View/Folders) or My Computer (View/Explorer Bar/Folders) If, when installing the software you opted to be able to run the software from Windows Explorer, when you right mouse click on a folder in the folder panel you will be able to run the software from the drop down menu and the input and prt files will be stored in that folder. Note that the same thing does not happen if you try doing it in the file panel.

Any of the Geoproc suite of programs compiled after 2014 have multithreading enabled to allow the program to run in parallel where possible. This requires an additional dynamic library at run time. The Intel library is called **libiomp5md.dll** and should be copied to the same directory as the executables

Running Geoproc code from the Command Line.

In order for this to work the executables need to be either on your path or be pathed to. Because the DOS shells within windows have a 255 character limit to the command line and several commonly used packages add to the path it is possible to push the end of the path variable beyond 255 characters. You could copy the executables into the working directory each time you wanted to use them or you could copy them to the windows or home directory which is always on your path however these are messy solutions to the problem. A better solution is to place the executables in their own folder in C:\Program Files, in a subdirectory called geoproc or something that works for you. Then path the call to the executable on the command line using a batch file. To do this, using the above example directory name, you would create a batch file with a text editor, lets call it g.bat. It would have one line;

c:\progra~1\geoproc\%1

progra~1 is the 8 character equivalent of Program Files and gets around the problem of having a space in the line. You could use the full abbreviated path and enclose it in double quotes instead if you wanted. %1 is the first variable on the command line. Save g.bat to

the windows directory (c:\winnt or c:\windows) and then from the directory containing your data get a command line and type in
g *exename*
Your program exename should now run.

Running Geoproc code from the Windows file manager.

If you want to run the software direct from the Windows File Manager without Total Commander, you can tell the program at installation and it will load the necessary registry keys. If you said no at installation and change your mind later you will need to add a key to the registry. If you said yes jump to the next section. Note that you need to have local admin rights to write to the registry.

To do this open Notepad (note other editors such as Textpad may not work as they do not add the correct binary start bit unfortunately)

Cut and paste the lines below into Notepad

Windows Registry Editor Version 5.00

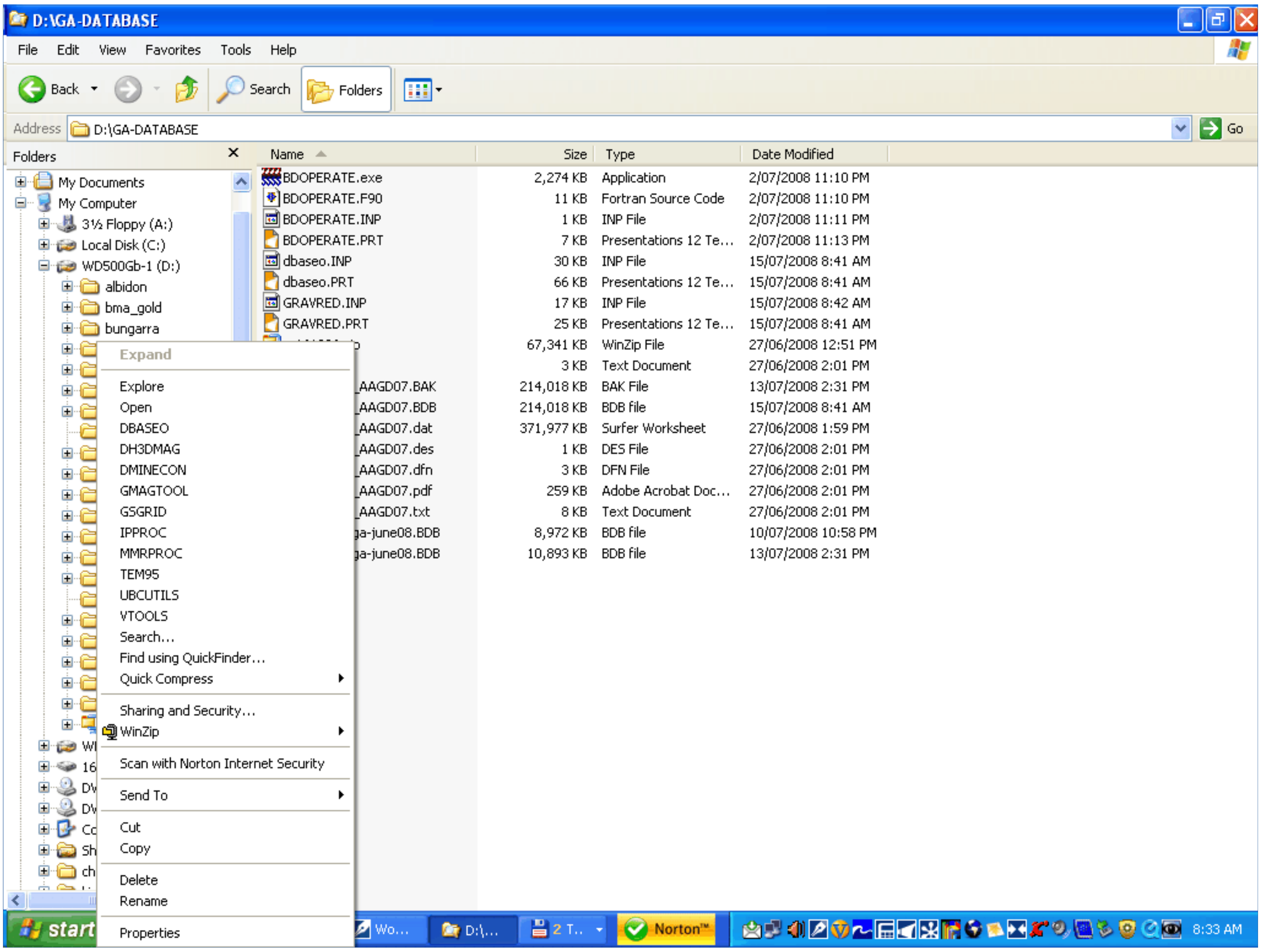
[HKEY_CLASSES_ROOT\Folder\shell\GSGRID]

[HKEY_CLASSES_ROOT\Folder\shell\GSGRID\command]
@="C:\\program files\\geoproc\\gsgrid.exe"

Replace the red GSGRID with the name of the executable you want to run and the blue path with the path to the place you stored the executable - note the double \\ in the file name wherever the real path has a \. Also note that the path is enclosed in double quotes.

Save the file as geoproc.reg (the reg extension is critical).

Double click on the file and it should load the registry and you should now have added options in your drop down menu. If it all becomes to hard for you, ask me to send you a ready made .reg file



Once loaded, use Windows Explorer set up to display a folder view in the left hand tab, go to the folder with the data in it and right click on that folder from the folder tab, as below. Note that in order to have the log files automatically stored in the folder with the data you must have the folder view enabled and click on the folder within this view, not folders displayed in the file panel on the right.

Running Geoproc code from the Start Button.

Go to C:\Documents and Settings\All Users\Start Menu\Programs if using Win XP or C:\Users\All Users\Start Menu\Programs if using Win 7 and later versions although if you are using these you might as well reformat and downgrade to Win 7 or supergrade to linux.

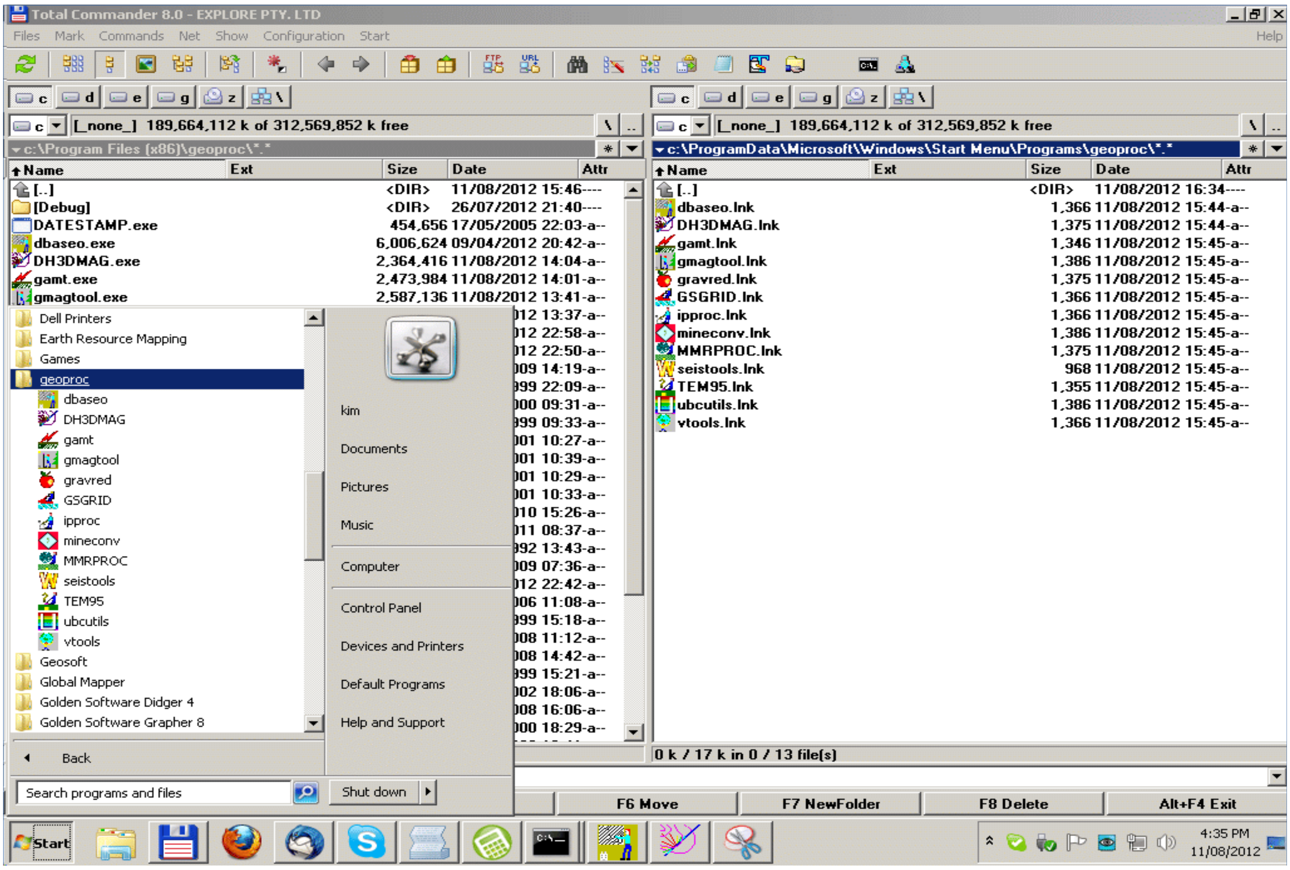
Create a directory to store the shortcuts to the software in, I'll call it Geoproc for this example.

Go to the directory where you have stored the executables, presumably in a folder called Geoproc under C:\program Files. For each executable right click in the Windows explorer and create a shortcut.

Move the shortcuts you have created to C:\Users\Public\Start Menu\Programs\geoproc or C:\Documents and Settings\All Users\Start Menu\Programs\geoproc on older systems.

You should then be able to access the programs by clicking on the start button, click on All

programs, scroll down to the geoproc directory open it and double click on the file you want to run.



If you want to further tidy it up you can rename the shortcut files from *Shortcut to exename* to *exename.lnk*. e.g DBaseO.lnk. It will then just show up as DBaseO in the start menu.

Linux:

Before trying to run the software in Ubuntu you will need to install Motif as this is not part of the standard Ubuntu install package, You'll also need the Motif fonts for the GUI. From a terminal type….

```
sudo apt install libmotif-dev libxmu-dev xfonts-75dpi
```

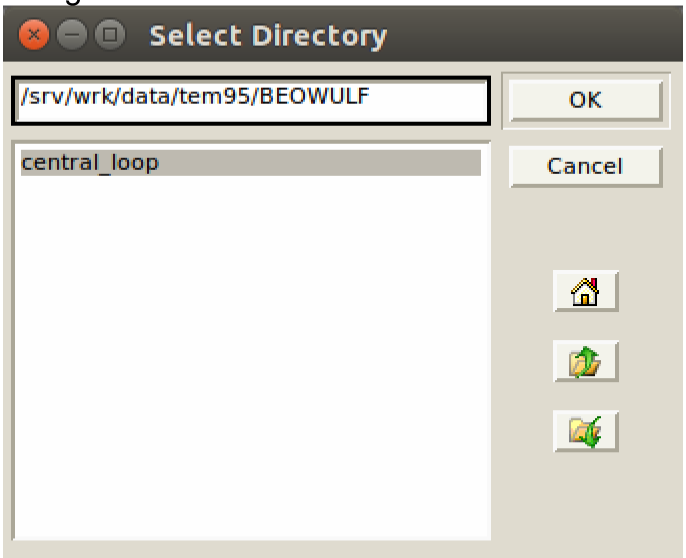
Note that xfonts-100dpi can be installed instead, if preferred. Either resolution is OK, but you need the core X fonts. Ubuntu doesn't install these by default. If using older versions of Ubuntu replace the reference above to the aptitude wrapper apt with apt-get

If you also want sound i.e. the finishing bell, then you'll also need to install the ALSA library

```
sudo apt install libasound2-dev
```

Because of the way operating systems handle the current directory, starting the programs in the data directory is difficult to achieve unless you use a file manager shell like Double Commander or Krusader which give you a command line prompt in your current directory as you move about. These managers also provides 1 button viewing, editing, copying and moving as well as built in zip/unzip and a file rename facility which allows for search and replace on multiple files. They have hundreds of other useful features. You could of course also open a terminal in the current directory direct from Nautilus.

To make it easier for those who want to run the programs from the Launch Bar or Dash, each executable starts with a select directory dialogue which allows you to select the directory to write the log files to. This should be the same directory as the data are stored in. You can create a new directory by typing its path into the Path bar at the top of the dialogue.



All the Geoproc suite of programs have multithreading enabled to allow the program to run in parallel where possible. This requires an additional dynamic library at run time. The Intel library is called **libiomp5.so**. Copy the library to /usr/lib/ then run ldconfig from a terminal, you'll need to either sudo or be super user for both these operations.

Running Geoproc code from the Command Line.

In order for this to work the executables need to be either on your path or be pathed to. You could add the path to your environment by adding it to the end of .bashrc or you could copy the executables into the working directory each time you wanted to use them or you could copy them to the root of your home directory or /usr/bin which is always on your path however these are potentially messy solutions to the problem. Although logically, placing the executables in /usr/bin would fit best with the linux structure it would require root privileges to update the files each time there is a software update as updates are not handled by aptitude. It would also make life tricky in a multiuser environment where the executables are on a file server so that all users get updates at the same time. A way around this is to place the executables in their own folder in your home directory, say in a subdirectory called geoproc or something that works for you. Then path the call to the executable on the command line using a bash shell file. To do this using the above example directory name you would create a bash shell with a text editor, lets call it g. It would start with shebang bin bash and then the path to the binaries.
e.g.

```
#!/bin/bash
~/geoproc/"$1"
```

If you are running the files from a central network location then either specify the network path explicitly on line two above or mount the network drive locally and point to the mounted path.

Set the executable flag and save the file to /usr/bin/ and then from the directory with your

data get a command line and type in g *exename*
Your program exename should now run.

Copy and paste to and from the Geoproc suite to external programs may not work as expected, depending on the implementation of Xorg on your machine. If copy and paste between geoproc and 3rd part codes does not work as expected then try editing .bashrc in your home directory and add the following line.

export WINTCLIPBOARD=0

DATABASE SOFTWARE

DBASEO: Current Version: 1.0.1.67 - database generation and manipulation program - 64 bit, multithread -- current features include;

- Create a database from a Geosoft XYZ file. Displays labels from the XYZ file allowing the order of the fields to be rearranged. Note that the field labels should **not** be edited as these are used to assign the correct XYZ fields to the corresponding BDB field. An XYZ field can only be read into **one** BDB field. Dates, times and Lat/Long in DDD:MM:SS.S format and three character month strings in the XYZ are converted to digital degrees or YYMMDD/HHMMSS.S format in the BDB. Note that dates are expected in Australian/UK format as YYYY/MM/DD or DD/MM/YYYY not US format. Geosoft arrays can optionally be read in with a new record for each element of the array.
- Create a database from a fixed format ASCII file. You have to specify a standard Fortran format specifier and the fields go into the database in the same order as the input file. Any lines that the routine has trouble reading and parsing will be written to an error file. You may start parsing part way through the file. Use this to skip over headers, bad data sections or to read a particular part the file.
- Create a database from a free format ASCII file. The order of the output can be re-arranged relative to the input. No alpha characters are allowed in the data being read to the database. Any lines that the routine has trouble reading and parsing will be written to an error file. You can start parsing part way through the file. Use this to skip over headers, bad data sections or to read a particular part the file.
- Create a database from an ASEG GDF2 format file. The read format specifier can be modified to allow a single input field to be written to multiple database fields. These will be labelled InputLabel1, InputLabel2 etc. e.g observed gravity may have 9 significant digits, 7 before the decimal point and 2 after. A 4 byte real only has 7 digits of precision so if the format spec in the GDF file was F17.2 it could be read in using F3.0,2(F7.0) to create three database fields, the first would be empty and so if you know that there are only 9 digits in the observed gravity the F3.0 could be replaced by X3 to skip 3 spaces, the next field will have the first thee digits from the observed gravity and the final field will have the last 6 and decimal point. *Modified to allow an array to be read in as multiple records – if used the format spec for the array can not be modified.*
- Create a database from a CSV file. The order of the fields can be re-arranged on input, however a CSV field can only be read into **one** BDB field. Note that the field labels should not be edited as these are used to assign the correct CSV fields to the corresponding BDB field. Only numeric values can be loaded into the BDB and any non conforming values are set to null. Dates, times and Lat/Long in DDD:MM:SS.S formats can be read and converted to be read. Note that dates are expected in Australian/UK format as YYYY/MM/DD or DD/MM/YYYY not US format. Modified to allow for colon delimited file and three character month strings
- Create a database from a mesh of points - user inputs X and Y limits and interval and a database of X Y couplets is produced. Useful when planning surveys. The resulting database can be masked by a BLN file to the survey area shape and output as an ASCII file for delivery to a contractor.
- Create a database from a Surfer BLN file. The BLN file can be simple 2D, XY or 3D, XYZ. Each string or polygon in the BLN file is assigned a unique identifier in

the BDB and the type of masking (inside or out) is also transferred to the database. This routine can be used to convert a 2D BLN file from Surfer to a 3D format suitable for Voxler by loading elevations to the database from a grid.

- Create a database from a Newmont Random file (.RND) format. The current Newmont RND format supports field labels and database description. This was not supported in the early format and I have not bothered implementing it here. If you view the RND file and go to the end of the file you will find the field labels which you can manually enter in to the database. If someone gets a big mob of modern RNDs to reformat I'll look at implementing a label converter.
- Line based spatial filters - modified to allow azimuths flipping from 360 to 0 to be filtered by decomposing the angle into two components and filtering each then recombining.
    - AGC
    - Fraser
    - Butterworth
    - Median
    - Moving Average
    - Absolute value - handy for converting horizontal difference to slope
    - Simple Despike then Moving Average - improved
    - Despike a noisy profile based on an iterative spline, depending on your choice of threshold and number of iterations this can remove single spikes or apply a heavy duty hammer to the data
    - Compute the Average/Median/Minimum or Maximum for a whole line and write to the database. Handy for levelling badly collected ground mag surveys.
    - 1st Horizontal difference
    - 2nd Horizontal difference
    - 4th Horizontal difference
    - nth order horizontal gradient or slope. Horizontal difference does not take the distance between points into account horizontal gradient does
    - compute window maxima
    - compute window minima
    - compute window absolute maxima
    - compute window absolute minima
    - Non linear filter, based on approach of Naudy. Recommend you use with a small kernel
    - Calculate the standard deviation over a window
    - Nested spline smoothing - generates a series (user selected number) of resampled subsets of the data each with a spacing of something close to the filter distance, splines each subsample back to the original station spacing and then takes a tapered average of the results for each station, rejecting outliers. The more subsets created the better but there is no point in having more than filter_distance/number_of_subsets > original sample spacing.
- Line based Frequency domain filters. Remember that these operations are performed on line data which may not be appropriate, depending on the data. The program will do it however it is up to you to use it wisely. - supports;
    - Lancoz and Hanning Low pass filters
    - RTP
    - Upward & Downward Continuation
    - Vertical and horizontal derivatives and integrals

    - band pass and notch filtering
    - Hilbert transform
    - pseudogravity and pseudomag transforms.
    - *Added an option to save the Fourier coefficients to a separate BDB for analysis*
- Append up to 21 data bases together. The number of fields, labels and header will be inherited from the master database, all others will be re-shaped to suite.
- *Append database fields. The two databases must have the same number of records and be in the same logical order as this routine simply copies the values from fields in the donor database to a new field in the master database on a record by record basis. If the databases are not or can not be sorted alike then use the lookup tool instead.*
- Compute the distance between readings on a line or cumulative distance and write to specified column
- Convert between UTM and Lat/Long for selected projections (currently supports AGD66, AGD84, GDA94, WGS84, WGS72, Everest)
- Convert between GDA/WGS/MGA and AGD/AMG using a 7 point similarity transform. This is the most accurate method to transform between these data.
- Cross correlate two databases. This routine can be used to scan a set of field data for a particular signature, eg. in Kimberlite detection or for quickly picking cultural noise once you have identified a “type” curve to act as the model to correlate against.
- Edit a database using a spreadsheet like editor. The editor includes;
    - Save and exit
    - Save and continue
    - Fast move to start or end of database
    - delete row/cols
    - insert row/cols
    - compute simple arithmetic on columns in the database extended to include log, ln, abs, mod, int, nint and sqrt
    - swap 2 columns
    - find a value or condition (e.g Max of field 2 or number < 200 in field 3). Modified to search for NULL and allowed the user to enter NULL rather than -1.0E30
    - Search and Replace based on either a value or condition (e.g. find all numbers >497.4 in field 4 and replace with null) Modified to search or replace NULL and allowed the user to enter NULL rather than -1.0E30
    - go to a particular row and column
    - edit the field labels
    - Plot a graph of up to 8 fields using 2 independent scales. Graphs can be line, symbol, both or classed post coloured by the value of any other field. Graphs can be sent to any windows printer or saved as a metafile (.wmf, .emf or clipboard). The input can be masked on up to three conditions to further restrict what is plotted. Added scale locking and scroll features to graphs
    - Plot a histogram of the data in a selected field. Optionally generate a Goldensoft *or QGIS* colour file of the field being plotted by clicking on the colour bar button. This can be used for colouring scatter plots in Voxler *or QGIS*
    - Allow user to sort the database without exiting
- Attempt to generate line numbers based on a user specified reading distance

gap. Use this to break up a database supplied simply as XYZ values into lines for filtering and bidirectional gridding.

- Interpolate over nulls for any field in a database - useful for assigning co-ordinates to every point in a line when you only have occasional GPS fixes
- Load fields in the database using a lookup table. Lookup table can be either ASCII or another BDB.
- Mask a single field in a database using a Surfer BLN file
- *Apply a parallax correction to data to shift a sensor position to the GPS position.*
- Sort a database based on the values of 4 of the fields. This is not recommended for use on an EM or IP database, use the sort routines in TEM95 and IPPROC for these data
- Compute the speed and heading. The time used to compute the speed should be a decimal value not HHMMSS format. If this is not available the record number can be used instead. If the sample frequency is known the speed computed using the record number can then by divided by the frequency to recover speed in m/s.
- Calculate the difference between a database field and a Surfer Grid at all points in the database. If no datum field is specified then the interpolated grid value at that database point is written to database.
- Sympathetically level the Uranium channel of a radiometric data base based on the Potassium or Thorium values. Assumes line busts are due to atmospheric radon variations which are not present in Potassium or Thorium
- rotation of axes based on either two common points or one common point and a rotation angle and scale factor - X,Y in x,y out
- extract part of database to another, based either on Surfer BLN file or a user defined criteria. Criteria can be based on Inclusion or Exclusion
- Write a database to an ASCII file
- Write the database to an ASEG GDF2 format file suite
- Write a database to a Geosoft XYZ file. For IP and gravity databases use the routine in IPPROC and Gravred as these also exports the header information.
- Write a database with array data stored as consecutive records out to a Geosoft compatible XYZ array file suitable for Geosoft or Profile Analyst.
- Generate a second database with all repeat readings averaged or replaced by their median. Based on a repeat having similar values in 2 fields only and therefore not suitable for EM or IP data. Use purpose built subroutines in TEM95 and IPPROC for these data
- Output lines in BLN format for Surfer. The output BLN can be 2D, XY or 3D, XYZ. Includes horizontal skip option to stop plotting over gaps. *Added minimum segment length so reduce output file size for close spaced data.*
- *Output lines as BNA file for QGis or Surfer.*
- Generate a DXF suitable for Surfer/Mapinfo/QGIS of the flight/survey lines. Lines can be drawn straight between end points, between recovered fids or between every n^{th} fid. User can specify the horizontal skip distance to create a line break in areas of no data. *Fids now posted as arrows to indicate the flight direction*
- Generate a DXF suitable for Surfer/Mapinfo/QGIS of stacked profiles or flight lines with no fids plotted and line gaps missing. The database should be sorted first as the positive X axis is in the direction of travel. ie if the database is not sorted you may end up with profiles plotting with positive down or right. Added an option to subsample the database to reduce the output DXF file size

- Generate an equispaced database from an irregular one by splining or linear interpolation. The splining routine uses Akima's spline under tension which reduces the over/under shoot as sharp discontinuities. Linear interpolation between known points may be more appropriate than splining on some datasets. Modified to allow the user to leave in the original points - handy when linear interpolating straight line segments at right angles to retain their shape.
- Report line statistics and total survey length to PRT file. Reports the max and min station spacing as well as median.
- Generate a Surfer grid using bi-directional splines. For most aeromag data this will produce a better grid than minimum curvature, however if the data are noisy minimum curvature will do a better job. Bi-directional splines are only suitable if the flight line direction is parallel to rows or columns! You will have to rotate your database to a local grid parallel co-ordinate system if this is not the case. The resulting grid will then have to be rotated and shifted back to its true location using GSGrid. The routine uses a spline under tension with the amount of tension controlled by the user. A value of zero equates to a standard bicubic spline whereas a high value (e.g. 50) equates to a polygonal line. The higher the value the more overshoot is encountered over large gaps. A value of around 0.1 appears to be a good compromise. Added option to convert data to a log before gridding then convert grid back to real space after creation. This reduces the amount of gridding overshoot on data with log normal distribution but requires that all of the data to be gridded are > 0. Clamped output to 3 x the range of the input data to avoid overshoot from noise.
- Generate a Surfer grid using bi-directional splines and transverse gradiometer data to improve the between line resolution. The way the transverse gradiometer data is provided by the contractor needs to be understood and the correct notation used in the gridding. Because of acquisition artefacts simply subtracting one wingtip sensor from the other will not provide a good enhancement. The difference will have to be levelled first to remove heading errors. Note that the comments above regarding bi-directional splines apply to this routine as well. Clamped output to 3 x the range of the input data to avoid overshoot from noise.
- Generate a Surfer grid from the database - using minimum curvature. Note that a more aesthetically pleasing grid will result if the iteration accuracy is set to reflect the accuracy of the values in the input data set. Increased maximum grid size again by a factor of 4. Added option to convert data to a log before gridding then convert grid back to real space after creation. This reduces the amount of gridding overshoot on data with log normal distribution but requires that all of the data to be gridded are > 0

BDOPERATE: User written operations on a database - allows you to do almost anything so long as you can code it up. The coding is simple. The windows version of this library used the Lahey compiler which limited it to 32 bit. *The Linux version can either use the Intel or gfortran compiler. For Intel the Winteracter library should be present but for gfortran these calls have been replaced by a gtkfortran GUI. This will in time be extended to Windows.* If you don't have the source code ask for a copy. Copy the code directory to your machine and edit bdoperate.f90. The bit you need to work on is the very last subroutine BDOPNS. The data is read in one record at a time into an array ZDATA which is defined to be a vector of dimension 100. As an

example, in order to multiply field 3 by 3.67 add it to field 4, divide the result by field 6 and output that to field 8 the code would be;

```
ZDATA(8)=(ZDATA(3)*3.67 + ZDATA(4))/ZDATA(6)
```

Once you have edited the code, run the batch file go.bat and you should get an executable, if not, look for errors in the file output.lst which is just the screen redirected to a file.

This is obviously a pretty simplistic example and the possibilities with BDOPERATE are almost limitless. Don't edit the code directly from the distribution package, copy the whole subdirectory to your machine and edit there. That way your mistakes will not carry onto others!!!

BDOPERATE2: User written operations on 2 databases - allows comparison, mixing, IF A and B then C etc. See notes for BDOPERATE

BDLDATA: User modified routines to read in LDT and output to a database. Most DOS formatted LDT's can be read in using DBASEO but if you have a UNIX format or a corrupted LDT (very common with the old ones) and need to hand craft an input routine this is where you do it. You will need to edit the lines containing the format statement, the record length and the relationship between variables and the read statement. See notes for BDOPERATE

GRID BASED SOFTWARE

GSGRID: Current Version: 1.0.0.51 - Program to operate on Surfer Grids - 64 bit and multithreaded - currently supports the following;

- Colour files for all grids now generated for both QGis and Surfer.
- *Convert an ASEG GXF file to Surfer grid.*
- Convert ER Mapper to Surfer grid. Allows for on the fly rotation of the input ER-Mapper grid if rotation is specified in the ERS file.
- Convert Geosolutions to Surfer grid
- Convert a 24 bit BMP file to RED, GREEN, and BLUE grids. Use with scans to manipulate them and then register with other data
- Create a grid filled with a user defined constant (NULL if you want)
- Convert a Newmont Grid to a Surfer Grid
- 2D spatial filters
    - Butterworth filter
    - De-corrugate a grid
    - Calculate integer order horizontal derivative either dX , dY or Slope
    - Weighted Moving Average
    - Median
    - maximum
    - minimum
    - standard deviation
    - range of the data
- Frequency Domain operations. Multiple operations can be conducted in one pass e.g. 1st VD of RTP. If you use it more than once without a change to the input data then click the use existing button for the frequency grid as this will save the step of calculating a forward FFT. Pseudomag can be computed at points other than the north pole. operators include;
    - Lancoz or Hanning smoothing
    - RTP and *RTE*
    - directional filter
    - Upward and downward continuation
    - Vertical derivative or integral
    - bandpass filter
    - notch filter
    - pseudo-gravity transform
    - pseudo-mag transform
    - Hilbert transform
    - non integer horizontal derivatives
- Insert one grid into another. Modified to allow user to chose the way the output limits are calculated. First input grid can be the same as output grid
- Insert a grid into another and feather the edges with a weighted average.
- Mesh two grids using minimum curvature across the join. This routine applies a shift to one grid so that the average values in the overlap area are the same. If your grids have tilts or different dynamic ranges these will have to be corrected first. Plot a scatter plot or histogram to determine the parameters you should use if in doubt.
- Patch up to 21 grids either vertically or horizontally, aligning either by common co-ordinates or justifying one edge
- Basic grid operations (Grid1 [+-*/] constant*Grid2=Grid3 or Grid1 [+-*/] constant = Grid3)

- Search and replace. Search for a value meeting a criteria and replace with either a constant or a value from another grid.
- Mask one grid based on non-NULL values in another. Reverse Mask a grid based on another, i.e if Grid2 is nun-null output will be null - use for iterative gridding of irregularly spaced data
- Clean up a worm grid by removing isolated non-null values
- Cross correlate two grids to produce a grid of coefficients. Input grids need not be same size so this can be used to compare mag and gravity over the same area or to find anomalies of a particular signature (Keating's technique)
- Extract a sub-grid from a larger grid
- Pad a grid to fill all null values
- Linear Interpolate grid interval, can be used to reduce the grid size or do a non-smoothed in fill.
- Linear Interpolate grid interval with automatic smoothing - do not use this to decrease the size of a grid (i.e. increase the pixel size)! Routine does a linear interpolation then follows with a Butterworth filter with a kernel twice the original grid size. In theory you should not lose or gain any information this way. However because it uses a Butterworth there is a limit to how much you can interpolate in 1 operation. Depending on the input data this limit is usually between 1/10 and 1/20 of the original grid size. If your grid has artefacts from smoothing try doing the interpolation in stages.
- Rotate a grid to any angle, uses bicubic interpolation to calculate values between grid nodes
- Calculate a Tiltangle grid. Tiltangle, also known as Instantaneous Phase, is the arctan of the VD/Slope. You can use any order VD. The HD should be calculated as slope in the spatial domain rather than one of the HD's calculated in the frequency domain. The generic formula for Tilt is as follows; $Tilt^n = ATAN((dT/dz)^n/((dT/dz)^{(n-1)})/dxy)$
- Terrace a grid as per Cordell and McCafferty and modified by Phillips
- Create an Analytic Signal Grid. Analytic signal is the amplitude of the sum of the 3 directional derivatives and can be calculated using the VD and slope grids. Use the spatially derived slope rather than the frequency domain version. The generic formula for analytic signal is as follows; $AS^n = \sqrt{}(dT/dz)^n * ((dT/dz)^{(n-1)})/dxy)$
- Compute the Vector of Residual Magnetic Intensity (VRMI) also known as the T-Modulus. Automatically outputs the three component grids as well
- Create a cross plot of 2 grids - handy when you have to merge two grids which need more than a DC shift to get them to fit. If you want you can write the data from the crossplot to a dat file for Grapher and use Grapher to calculate a best fit line which you can use to adjust your grid. *File names now written as headers to .dat file.*
- Histogram normalise a grid - useful for displaying a grid in Surfer when it has a very narrow histogram. This routine alters the data values so **DO NOT** use the resulting grid in any of your processing unless that is what you intended.
- Recalculate the statistics of the grid - allows you to set artificial max/mins. The histogram of the grid can optionally be saved for later use in bitmap creation using a global colour scheme
- Export grid to XYZ or BDB *optionally* skipping NULLS - better than Surfer's which includes null values. *Modified to also export null values so that the data can be exported as a structured mesh for Paraview.*
- Read or Write the header of and ECW file. An improvement on the ERMapper

version in that is retains your previous entry which makes it is easy to set the headers of multiple ECWs if they are over the same area.

- Convert to an ER Mapper grid
- Calculate local maxima and write to a database and a grid - cheap Worms. This will normally be run on the slope grid of either gravity or pseudogravity data. Some datasets may need VD’s taken as well before worming. Useful worms can also be got directly from the analytic signal or from the wavenumber = slope of tiltangle. See clean worm grid above
- Generate a bit map from one or two grids with one grid draping the other - optional sun angle or grey scale. Grids must cover same are but can have different areas NULL - ie can overlay IP or EM on mag. Can optionally generate a Mapinfo TAB file at the same time. Automatically creates an Arcview world file. A global look up table for colour stretch can optionally be applied which allows multiple images to use the same colour stretch so than adjoining map sheets can fit together seamlessly. *Added ARC60 datum*
- Generate a Ternary Bitmap from 3 or 4 grids with optional sun angle or greyscale for radiometrics or for taking 3 grids created from a bitmap and sticking another under them. Thus you can scan a geology map, convert it to the 3 rgb grids and then create a bitmap with the mag under it as relief. Can optionally generate a Mapinfo TAB file at the same time. Automatically creates an Arcview world file
- Generate a ternary sun angle bitmap using 3 different horizontal gradients. Can optionally generate a Mapinfo TAB file at the same time. Automatically creates an Arcview world file.

GSGRID will read all 3 types of Surfer Grid but can not perform all operations on all grids, particularly the ASCII version. For the best reliability you are advised to use the binary formats also known as Surfer 6 or GS Binary and Surfer 7 binary. The GS Binary format is limited to 32767 rows or columns (uses 2 byte integers to store these in the header) If the output grid has more than this threshold it will automatically be converted to a Surfer 7 grid.

Gridding Irregular data.

1. Make a 3 field subset of your database containing only East, North and the value you want to grid. *Real_data.bdb*
2. Compute the limits for the grid at the minimum grid cell size and round these out to make them integer multiples of the limits for the coarsest grid cell size likely so that all grids can use the same limits. While not critical this step will save you time later on.
3. Starting at the smallest grid cell size desired, grid the data using a small search radius so that the non-null part of the grid is largely due to real data rather than interpolation. *##m_??????.grd where ?????? is the property you are gridding and ##m is the cell size in metres e.g. 25m_BA2p67* Increase the number of points in the search radius so that there are no non-null pixels between data points while the pixel containing the data point is null. Repeat the process increasing the pixel size in somewhere between 2x and 5x steps, remembering to make the pixel size an even multiple of the grid limits you selected in step 2. Because we will be using smooth interpolation do not increase your pixel size

by less than 2 times. Continue this process until you have a grid of the entire area with no null values.

4. Starting with your coarsest grid, smoothly interpolate it down to the pixel size of the next most coarse grid. *##m_??????_##ms.grd*
5. Using a Reverse Mask in GSGRID compare the interpolated coarse grid with the next most coarse grid to generate a grid which has null values where the finer grid is non-null. i.e. a grid of the gaps in the finer grid *##m_mask.grd*
6. Write the resulting grid to a database using GSGrid eg *##m_mask.bdb*
7. Append the extracted database from step 6 to the 3 field database created in step 1 to create a new database *gridding_data.bdb*
8. Grid this using the cell size of the fine grid in step 4 and a large search radius with only 1 point. This should result in a grid containing no nulls. *##m_??????_it.grd*
9. Using the grid from step 8 go to step 4 and repeat until you get down to the finest pixel size.

Because this is a labour intensive process it is easy to make mistakes and use the wrong grid at some point. As a check against this calculate a 1VD at each stage - this will quickly highlight any problems in the data.

The iterative gridding process is described in detail in ExploreGeo Tech Note #7 which can be downloaded from the website . http://exploregeo.com.au/download_docs/Technical_Note_7_iterative_gridding.pdf

GDOPERATE: User modified routine to operate on a grid and make any changes needed. Same concept as BDOPERATE so see notes for BDOPERATE regarding compiling

GDOPN2: User modified routine to operate on two grids and output the result to a third. See above.

ELECTROMAGNETICS

NB: TEM database programs expect to see a database in a particular format, thus not all database programs are applicable to them. All times are now specified in mSec, previously the ramp time was in μSec

TEM95: Current Version: 1.0.1.9 - 64 bit and multithreaded.

- Create a database from a Smartem DAT file. Modified for use for dumps up to SmarTEM 24. Checks for and reports change of units in the file.
- Create a database from an AMIRA TEM file.
- Create a database from an ASEG ESF format file
- Create a database from an ASEG GDF2 format file
- Integrate Smartem dB/dt Stack data to create a database of B field data. Modified to accept S24 format stack files
- Create a database from a Crone PEM or RAW file
- Create a database from a Geonics Protem/EM37/EM42/EM58 dump file
- Create a database from a Zonge RAW file
- Create a database from a Timmins Geophysics/WGC TEM format file
- Create a database from a WMC TEM format file
- *Create a database from a smartem RAW file. Note that this is not an EM database, it is a time series database and can be viewed in DBaseO.*
- Create a database from a Tesla10 SGC error file
- Create a dummy database using plan and section limits
- Create a database from an EMO file output from EM1DINV used by HGG's excellent free EMMA 1D EM modelling program.
- Create a database from a Sirotem II cassette file
- Create a database from a Sirotem III dump file
- Adjust window amplitudes and gain if an attenuator has been used on one of the Smartem inputs.
- Downward continue AEM data to ground level - nothing fancy, just an empirical power law fit to some real data Obs_dB/dt = (Ground_dB/dt)/(Ht**x) where x = 0.395
- Take the average or median of repeat readings within a database. Database must be sorted first using TEM95's sort.
- Edit and view a database using a spreadsheet like editor. The Editor is a special purpose version of the one used in DBASEO and has added to it the ability to plot decays for each record as you move through the database. The function key on the tool bar allows simple maths to be applied to all EM windows simultaneously. Decays can be flipped for those operators that can not get their polarity right. Optionally plot decays for repeat readings in the one frame and allow the user to selectively delete them. The decay plot has a properties button to allow it to be changed from log-log to log-linear or liner format and to overlay either a median or average decay on the plot, the linear section of the log plt can also be changed. Also optionally plots profiles fo a line/component of data with user control over log, linear or ASINH display, scale and window range. Includes error bars if repeat readings exist. An SPM/IP button is included in the decay plot so that the user can apply a variable amount of SPM or IP correction to the decay to remove these effects. The same can be done with exponential and power law fits. See example in Fig 3. Large databases (e.g airborne EM databases) can slow down the editor so to get around this you are offered the opportunity to load one line at a time into the spreadsheet. Note that

the whole database is loaded to memory and the multiplot graph and math function will still operate on all the data, all that is masked is the spreadsheet and profile view. You can switch between lines using the line selector button on the tool bar or jump to the next lines using the forward or back controls on the profile window. The profile window has an Anomaly button which allows interactive anomaly picking on profiles. When first clicked you will be prompted to add or specify existing fields in the database to write the anomaly code, dip, confidence and depth to. Future clicks will prompt you to enter a numeric code for the anomaly e.g. you might use 1=surficial, 2=weak bedrock conductor, 3 = strong bedrock conductor etc. These codes can then be written to an ASCII file enabling you to created an anomaly map (squashed fly map) in Surfer or QGis. Up and down arrows added to profile plot to enable scrolling at larger scales. If the database needs to be sorted this will now be done without leaving the editor. *The multiplot graph can now be locked to the profile display so that as you scroll through the database the multiplot updates in line with the profiles. For this to work you must select Field 2 (station or fid) as your X axis and tick the box to lock to the profiles. The yellow marker line showing the active record on the profile displays and anomaly lines also show on the multiplot graph.*

- Compute the total field if three components have been measured. This generates a new database of total field readings and sets the component to 10 to differentiate it from the normal 1, 2 and 3 used to represent X, Y and Z or u, v and a.
- Compute the time constant for either a Power Law or Exponential decay or using Richard Smith's inphase approximation (not published).
- Run spatial filters on every window in the database. Useful for smoothing noisy data but needs to be highly sampled, eg. AEM or TinyTEM
  - Fraser
  - Median
  - Moving average
  - Moving average after simple despike
  - 1st Horizontal Difference
  - 2nd Horizontal Difference
  - 4th Horizontal Difference)
- Filter decays in time space. Filters available include;
  - Despike
  - Median
  - Non_linear
- Compute the Inphase response using Smith & Baulch's approach
- Compute max/mins for each window/component - helps set scales of graphs created using Grapher.
- From a set of depths, azimuths and dips calculate down hole co-ords. Uses standard Micromine collar and survey files with some quick edits
- Set the elevation field to a constant value for later CDI output
- Set or edit header
- Set window times based on a channel file
- Switch two components - if operator used a different notation to you
- Merge multiple readings collected at different gains
- Shift the window times by a constant
- Plot Smartem stack data along with equivalent binned reading. Arrow navigation controls and zoom features. Clicking on the plot returns the time and amplitude at that point. - see example in Fig 2. Modified to accept S24 format stack files.

Further mods for new Smartem 24 format

- Resample a decay to a new set of window times in order to merge datasets with different time bases.
- Re-window a Smartem data file using a user supplied channel file. Channel files are of the SmarTEM format (.STW) not the Encom (.CHN) format at the moment.
- Sort a database based on line, station and component
- Calculate CDI for Fixed loop data - Peter Fulgar's algorithm
- Calculate CDI for Slingram data - Peter Fulgar's algorithm - *abandoned.* Better to use the Fast CDI below
- Calculate CDI for In-Loop, coincident loop, slingram dB/dt or B field data or TEMPEST B field data. uses a modification of Nekut's algorithm (published by Davis, MacNae and me). Can be used effectively for helicopter AEM data using In-loop style systems, including Skytem and even HeliTEM although that is not strictly in-loop. The routine outputs four conductivities, expressed as logs to enable smooth gridding, COND0, COND1 and COND2 are the zero order, first order and second order conductivities defines by Nekut in his original paper. CONDB is a Bostic transformed version of COND0 and sometimes does a better job of enhancing thin layers than the Nekut derivatives do.
- Calculate CDI for In-Loop or coincident loop data - Richard Smith's Spiker algorithm
- Compute the primary field for a given loop configuration, requires loop details to be set in the header first.
- Rectangular Filament model of Colin Barnett - modified to allow current channelling. Individual filaments can be saved for re-use, give each a label, export to BLN as well as *either an IV file for Voxler or a vtk file for Paraview*. Assign a colour to each filament for the IV file. *Fixed loops can be read from the database header if aligned EW and NS or from a separate 3D BLN file if complex or at an angle to the grid.* Plot profiles of the model data along with a user selected channel. Allowance made for thick plates as well as Total field EM systems.
- 1D modelling and inversion using AMIRA P223 code Beowulf
- Output data to an AMIRA format file
- Output data to an ASEG ESF format file with support files
- Output to a DAT and BLN file for Surfer to plot plan or section vector plots
- Output a DAT file for Grapher to plot decays
- Output to DAT files for Grapher to plot stacked profiles. *Added option to specify a different output directory for the DAT files.*
- *Output DAT files and python control files for Matplotlib to plot stacked profiles.*
- Grid a single EM channel, optionally using a Log fiddle which allows you to calculate logs of negative values. The central linear section is 0.1 units high. Minimum curvature and bidirectional splining algorithms are available.
- Create a DXF file of Stacked decays for Surfer
- Create a DXF file of profiled decays for Surfer or Grapher
- Create a DXF file of a single EM channel profile optionally using a Log fiddle
- Export a CDI database in a format suitable for Profile Analyst
- Break into compass components for output to Voxler, Windisp or Potent

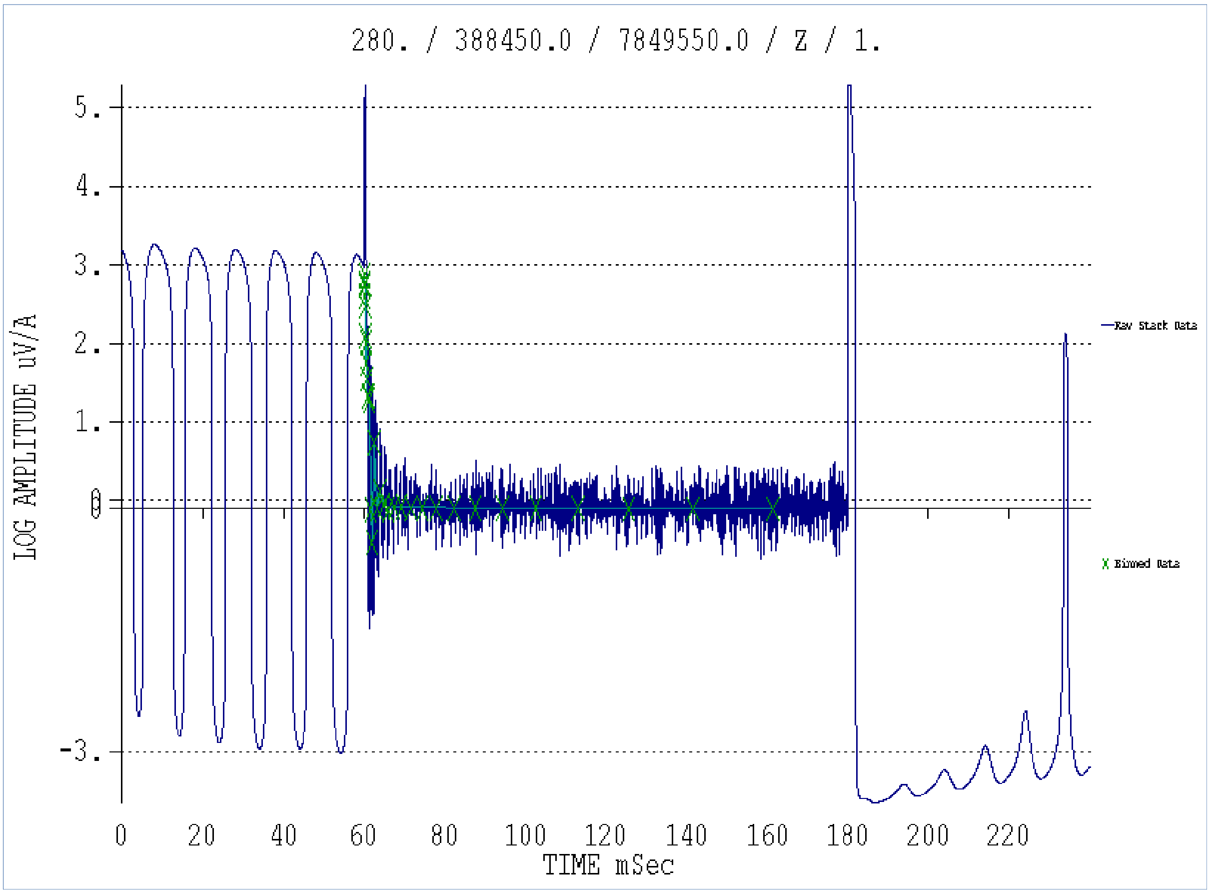


Figure 2: Example of a Smartem Stack file display with the stack data in blue and binned data in green

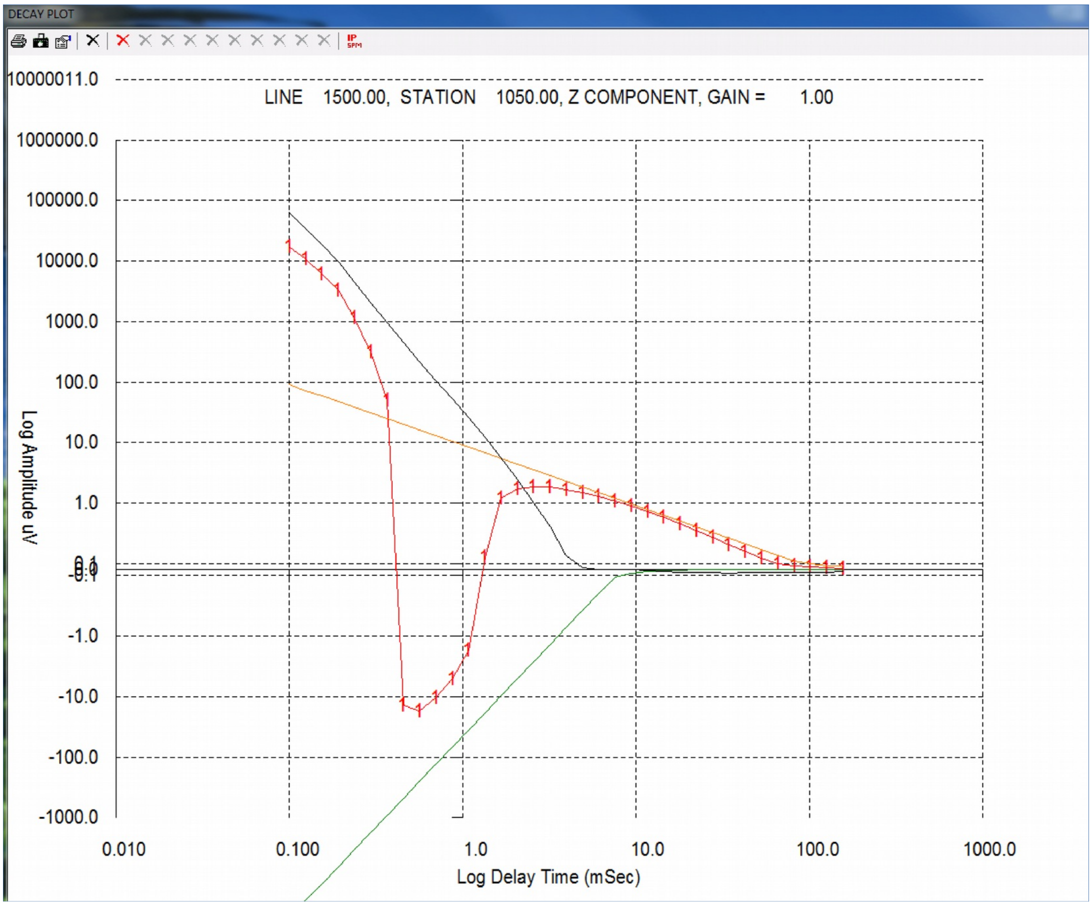


Figure 3: Example decay plot (red) showing IP (green) and SPM (orange) decays and resulting residual decay in black

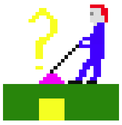
Process to load and process an airborne EM survey:

Assuming the start point is either an ASEG-GDF2 format file or a Geosoft XYZ format file. This example uses Tempest data but it could equally be any AEM system. The icon at the left top of each paragraph refers to the program used to perform that step, either DbaseO or TEM95

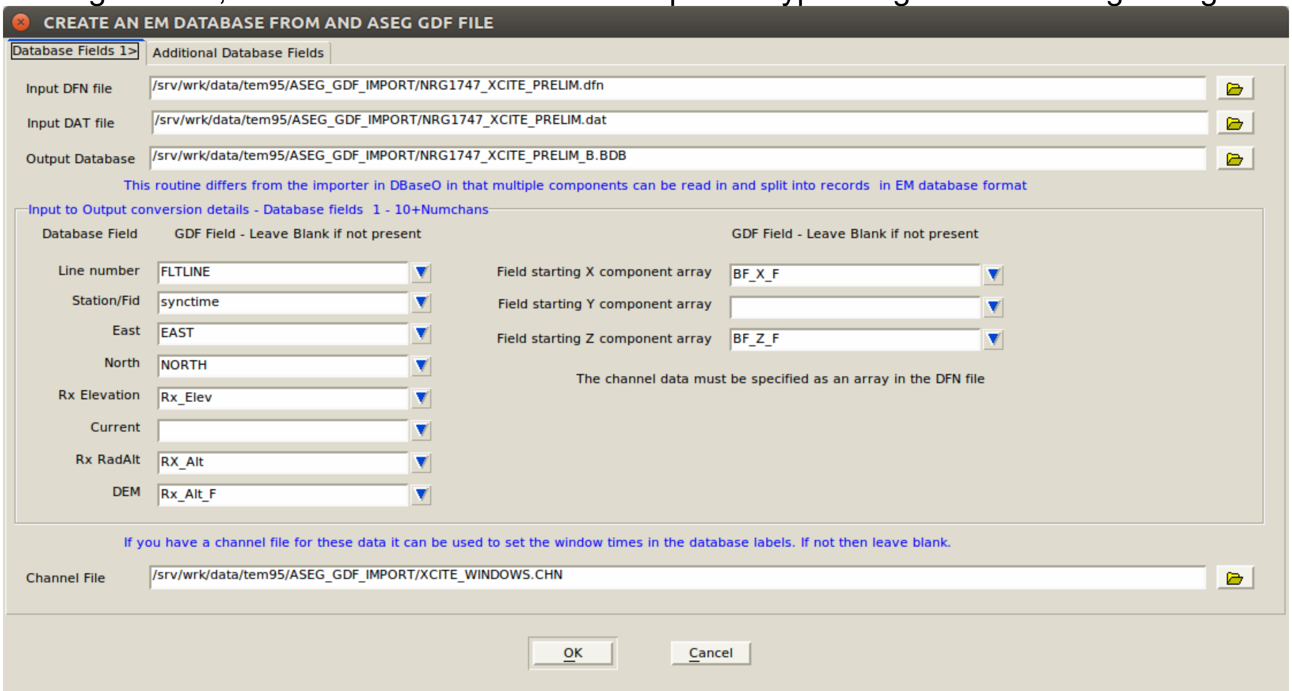
You can now use either DBaseO or TEM95 to import the data to a database. In most cases you should use TEM95 as this will set up the database structure correctly. An exception would be where you have numbers with more than 7 digits of precision which will be rounded if read in as a 4 byte real. The GDF parser in DBaseO allows you to edit the format specifier to split the input field into multiple output fields. This feature is not present in the TEM95 version of the parser. On the other hand for an EM database we want a single record to only contain the information for one component while typically a record of the GDF file will contain all components. The TEM95 parser handles this automatically whereas if you use the DBaseO parser you will have to create a separate database for each component and then append them. You can of course use both, TEM95 to load the EM and survey data and DBaseO to load the log fields (eg. GPS time for fast sampling systems). If you copy and append the DBaseO created database to itself to match the number of components and sort it by record number so that it is in the same sort order and has the same number of records as the TEM95 database then you can use DBaseO to append fields from the DBaseO database to the TEM95 database. If you used DBaseO then ensure that the single component databases have identical formats and remember that TEM95 expects to see an EM database with a set format.

FIELD	LABEL	
---------	------------	
1	LINE_NUMBER	
2	STATION	
3	EAST	
4	NORTH	
5	ELEVATION	
6	HOLEANGLE	◂Azimuth*1000+dip - ignore for AEM data
7	COMPONENT	◂1=x,u 2=y,v 3=z,a
8	CURRENT	
9	SPARE	◂You can use these two fields for what ever you
10	SPARE	want
11	CH01-0.01000	◂Window label must start with CH followed by the window number a hyphen and the window centre time in mSec. **Time zero is at the top of the ramp.**
12	....	◂Windows repeat till last window or window 90

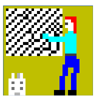
If using TEM95 you can select a channel file at input time to load the window times otherwise don't worry about the window times yet, we'll fix those later. Ensure however that you have the first EM window in field 11. You could read the fields into the database in any order and then re-arrange them in DBaseO's editor but for a large database that is time consuming so I'd suggest you order them as they are read in, as below.



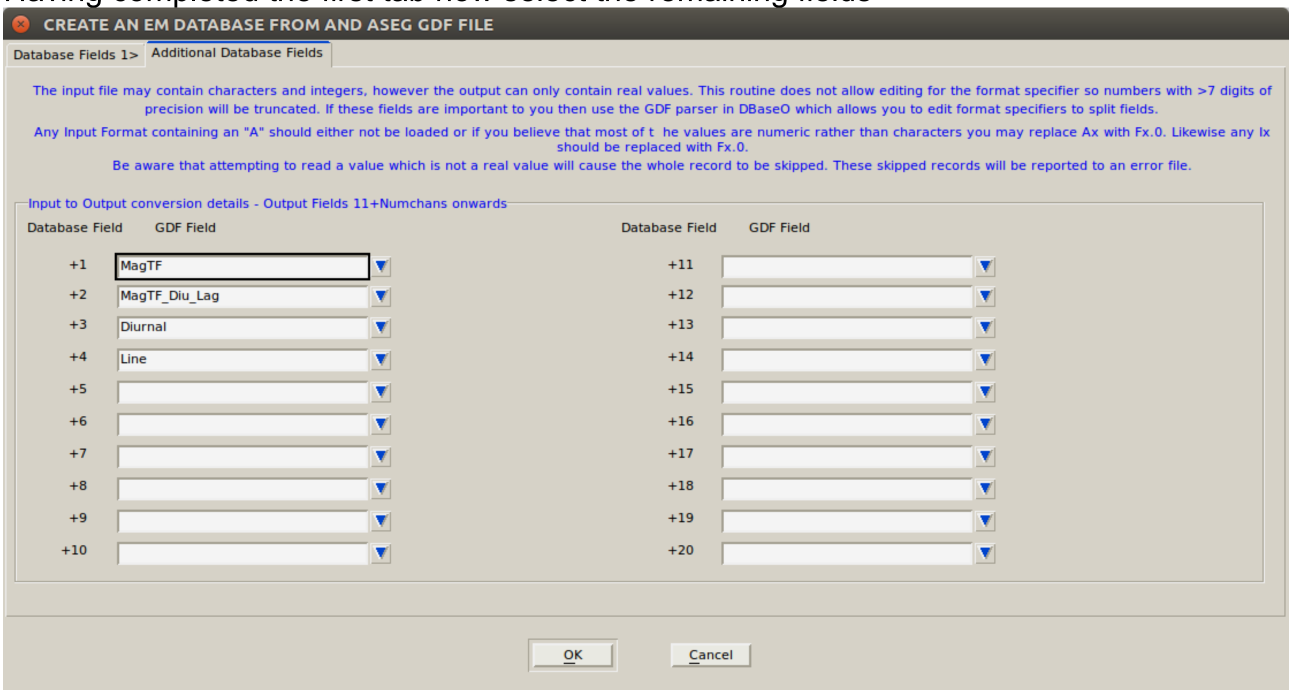
If using TEM95, select ASEG GDF2 from the input file types to get the following dialogue.



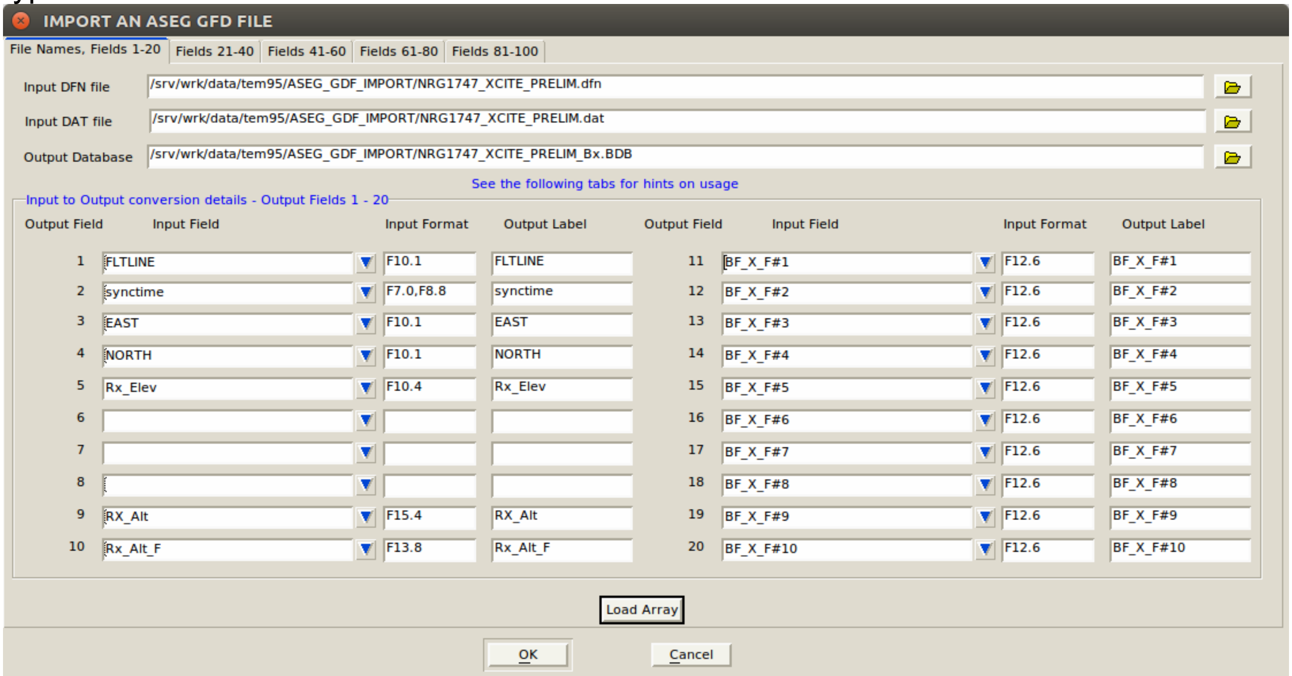
Enter in the names of the definition and data files as well as the output database. The fields on the left hand side of the dialogue have special meaning in an EM database so select the appropriate input field if it exists. You can then select the first field containing each component in the input file. Note that this routine requires that the channel data are written as an array and sorted from the earliest channel to the latest. Arrays only take up one line in the definition file. If your data are not in array format you will have to use the parser in DBaseO. If you have a standard AMIRA or ASEG ESF channel file you can point to that as well.



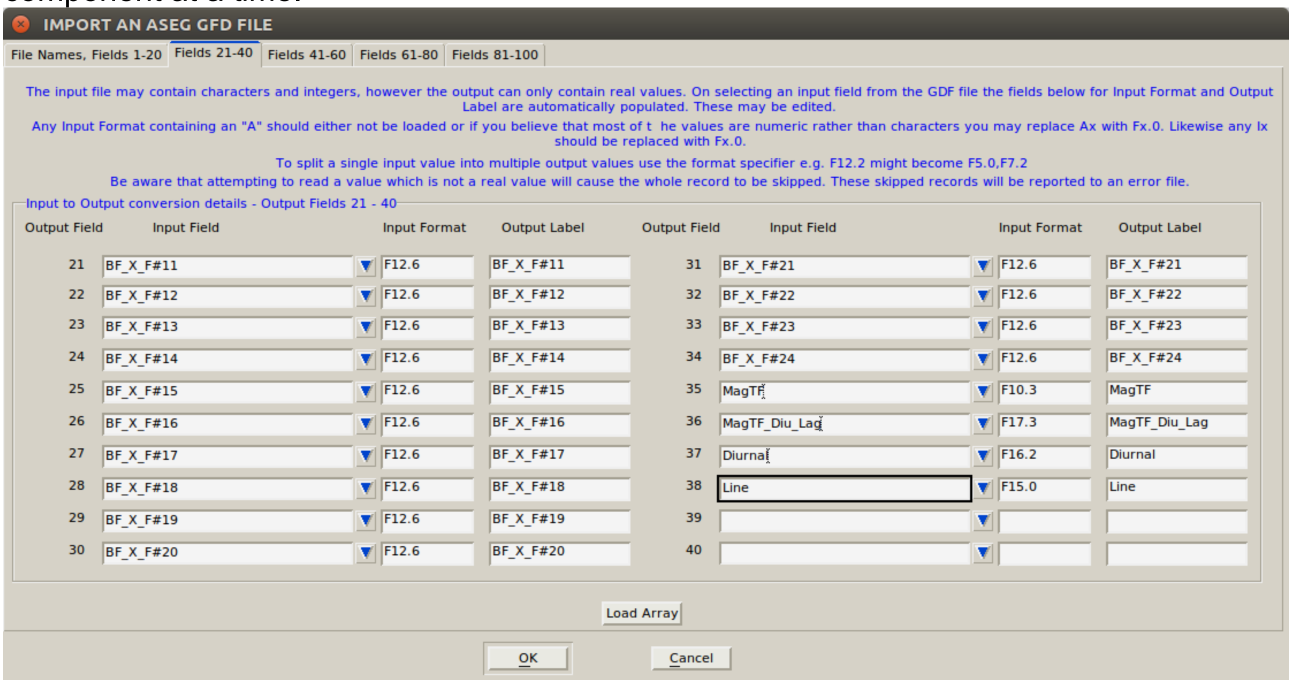
Having completed the first tab now select the remaining fields



Note that an input field can only be read in once so ensure that you do not double up!
If you are using DBaseO the process is similar. Select ASEG GDF2 from the input file types

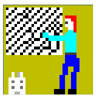


Note that the Elevation I have used for field 5 is the Rx elevation not the Rad Alt and that fields 6 to 8 are currently empty. If the input file has the channel data stored in array format you can load the first element of the array into field 11 and click on the Load Array button. This will automatically load all other elements of the array. Note also that the synctime in field 2 has been split into two output fields in order to retain precision. Move to the next available Tab and add in the remaining fields Remember we are only bringing in one component at a time.

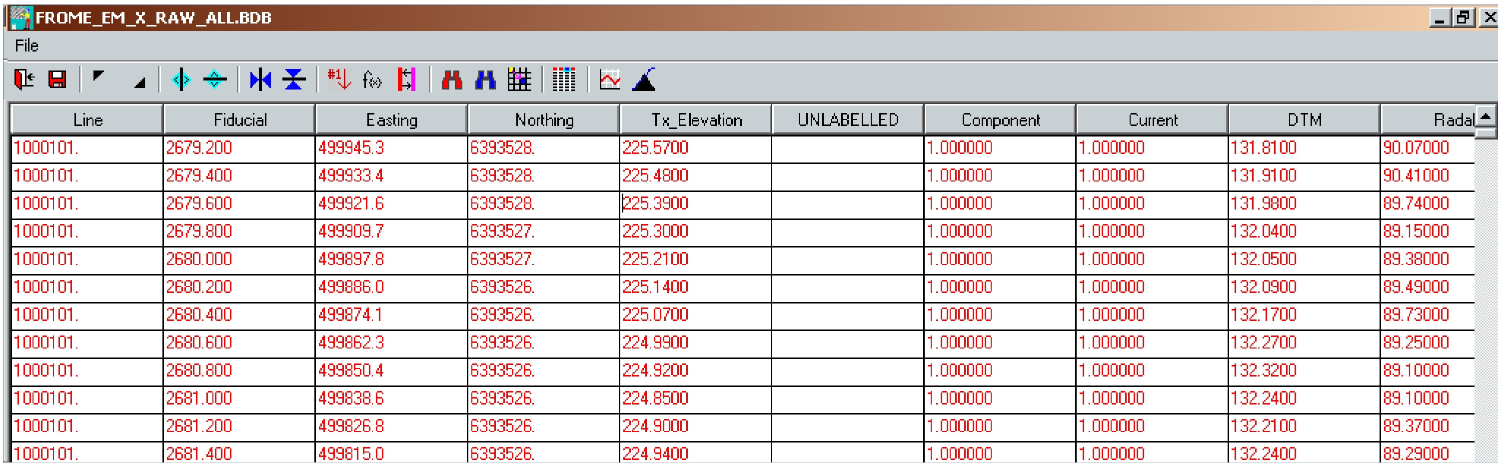


Repeat the import for the Z component so you now have two BDBs, one with X and one with Z component. Ensure that fields are in the same order so that when the databases

are appended things match up as they should.

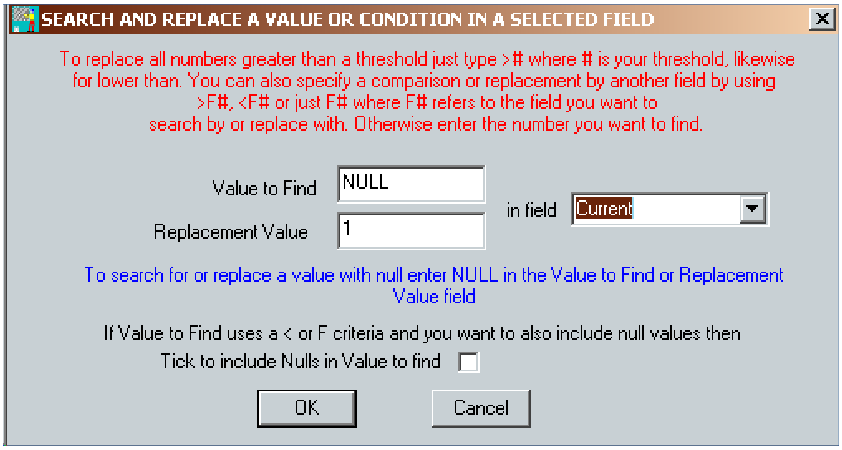


Using DBaseO's editor open one component at a time and set the three empty field labels.



Line	Fiducial	Easting	Northing	Tx_Elevation	UNLABELLED	Component	Current	DTM	Radal
1000101.	2679.200	499945.3	6393528.	225.5700		1.000000	1.000000	131.8100	90.07000
1000101.	2679.400	499933.4	6393528.	225.4800		1.000000	1.000000	131.9100	90.41000
1000101.	2679.600	499921.6	6393528.	225.3900		1.000000	1.000000	131.9800	89.74000
1000101.	2679.800	499909.7	6393527.	225.3000		1.000000	1.000000	132.0400	89.15000
1000101.	2680.000	499897.8	6393527.	225.2100		1.000000	1.000000	132.0500	89.38000
1000101.	2680.200	499886.0	6393526.	225.1400		1.000000	1.000000	132.0900	89.49000
1000101.	2680.400	499874.1	6393526.	225.0700		1.000000	1.000000	132.1700	89.73000
1000101.	2680.600	499862.3	6393526.	224.9900		1.000000	1.000000	132.2700	89.25000
1000101.	2680.800	499850.4	6393526.	224.9200		1.000000	1.000000	132.3200	89.10000
1000101.	2681.000	499838.6	6393526.	224.8500		1.000000	1.000000	132.2400	89.10000
1000101.	2681.200	499826.8	6393526.	224.9000		1.000000	1.000000	132.2100	89.37000
1000101.	2681.400	499815.0	6393526.	224.9400		1.000000	1.000000	132.2400	89.29000

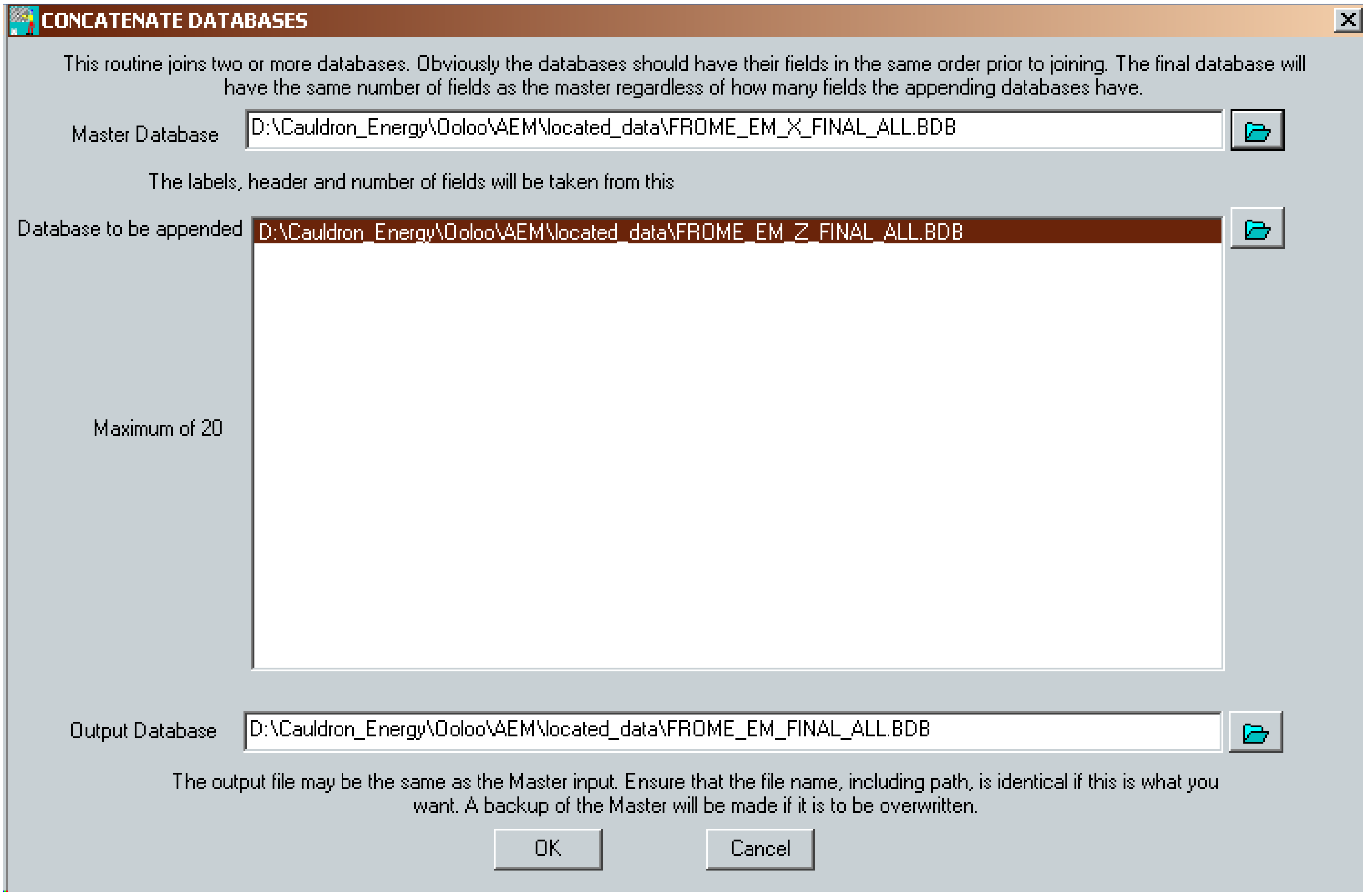
Use the search and replace button to set the current and component (X=1, Y=2, Z=3) by replacing all instances of NULL with the value you want.



Note that for Tempest B Field the data has been processed so that the effective current is 1A and the transmitter loop size is $1m^2$

Do the same for your Z component database.

Use DBaseO to append the two databases to a single EM database



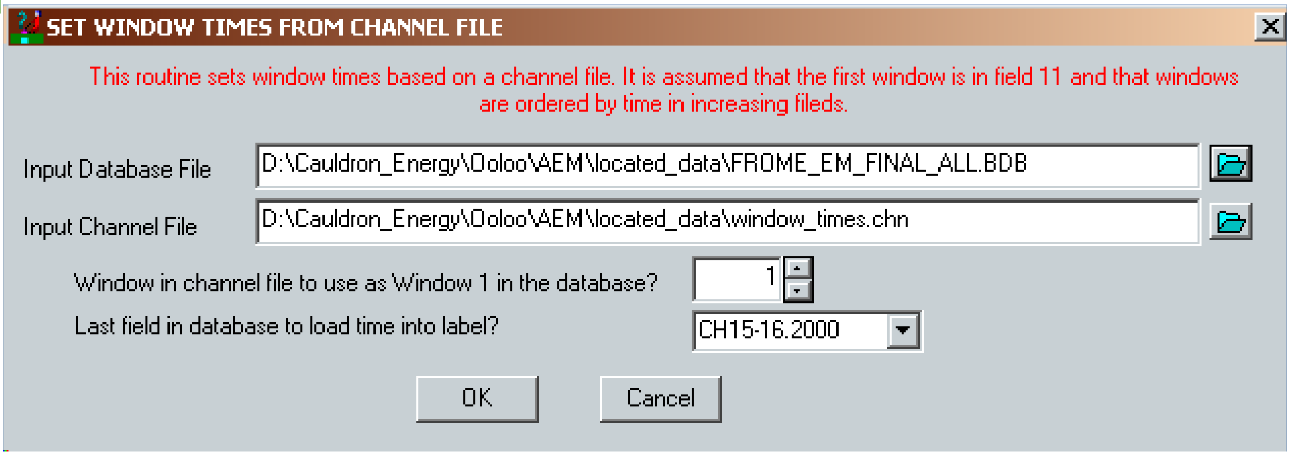
Now we need to set the window times and database header.

To set the window times you'll need to create a standard AMIRA or ASEG-ESF format channel file. See http://www.aseg.org.au/Standards/ASEG-ESF-Ver001.pdf for format details.

Your channel file should look something like this or the alternate format with the TIMESSTART and TIMESEND keywords;

```
FROME EM WINDOW TIMES
NUMTIMES=15
DELAY   WIDTH
0.013   0.013
0.040   0.014
0.067   0.013
0.107   0.04
0.173   0.067
0.280   0.12
0.453   0.2
0.720   0.306
1.120   0.466
1.733   0.733
2.693   1.16
4.200   1.826
6.560   2.866
```

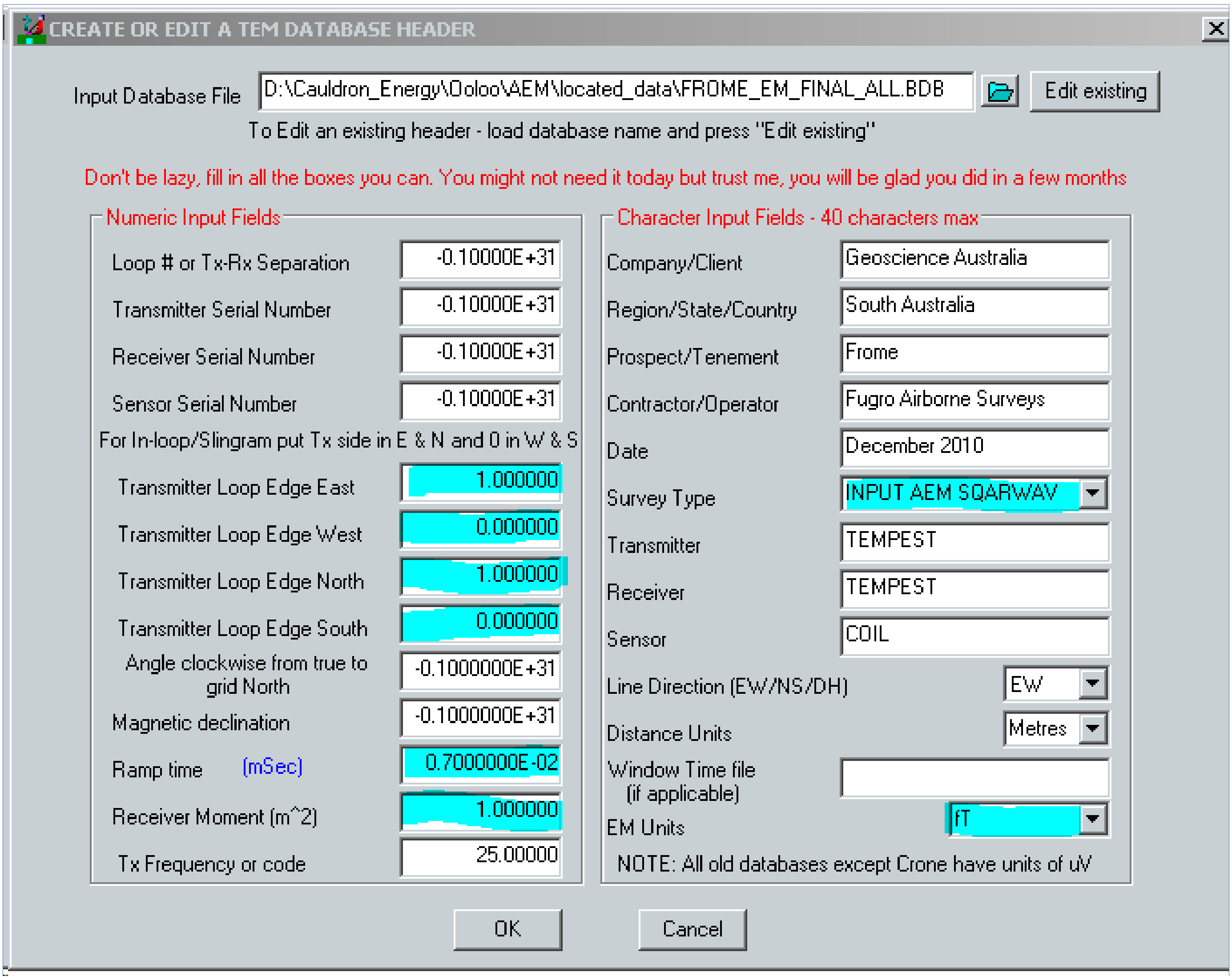
10.200 4.386
16.200 7.586
Using TEM95 load the window times into the database labels.



Your last field label will probably be different to CH15-16.200 above. That is showing up because this process has been run before on this database.

You can set up a generic channel file with time zero at the base of the ramp, load the window times into the database and then offset the window times by the ramp time in TEM95 using Utilities|Offset Window Times

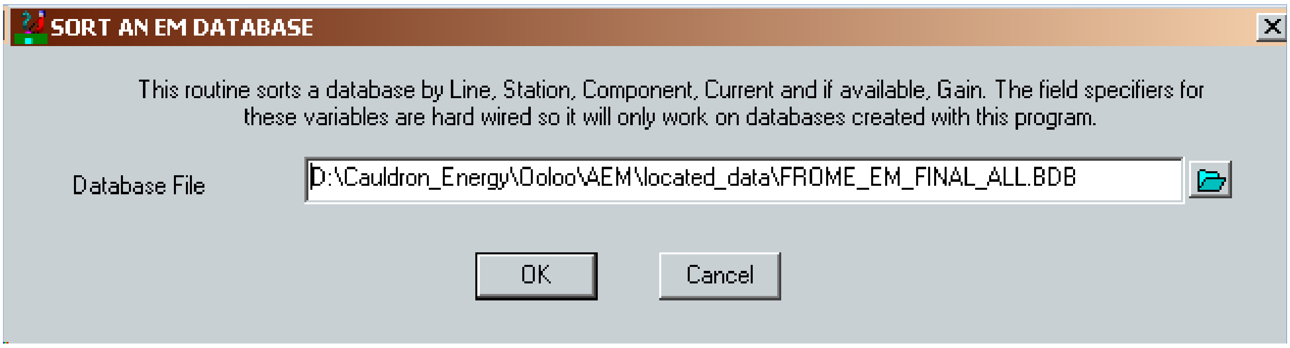
Now set the header. The important fields for a CDI are highlighted



Because of the way the Tempest data have been processed the final data assumes a 100% duty cycle square wave with a near instantaneous polarity change. The ramp time should be equal to or smaller than the first window time which for this survey started at 7 μS. VTEM on the other hand should have a long ramp time of around 1.4 msec

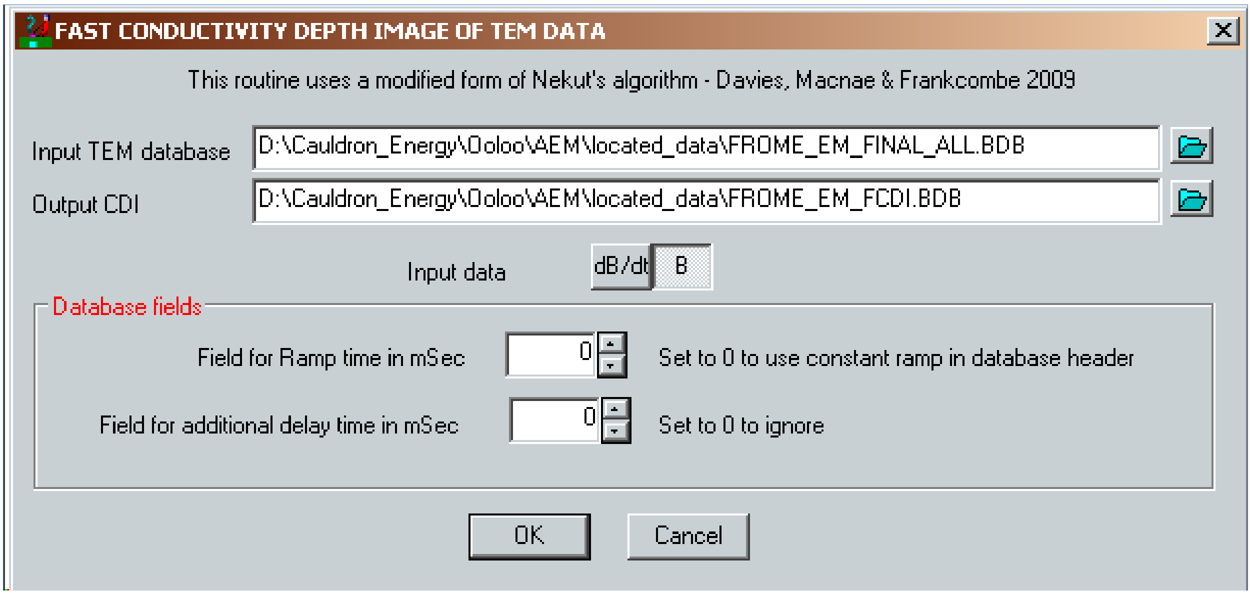
Your database currently has all the X readings followed by all the Z component readings. However in order to use them the two components for each reading need to be consecutive records in the database. The database therefore needs to be sorted.

Use TEM95 to sort the database rather than DBaseO because it is expecting to see a particular database structure and sorts on Line, Station, Component and optionally gain and current. The latter two are not required for AEM data as they are constant.

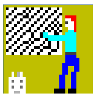


You are now ready to create CDIs.

Run the FastCDI remembering to specify that this is dB/dt or B Field data depending on the system. The fields for ramp and delay time are not needed as these are considered constant for AEM systems.

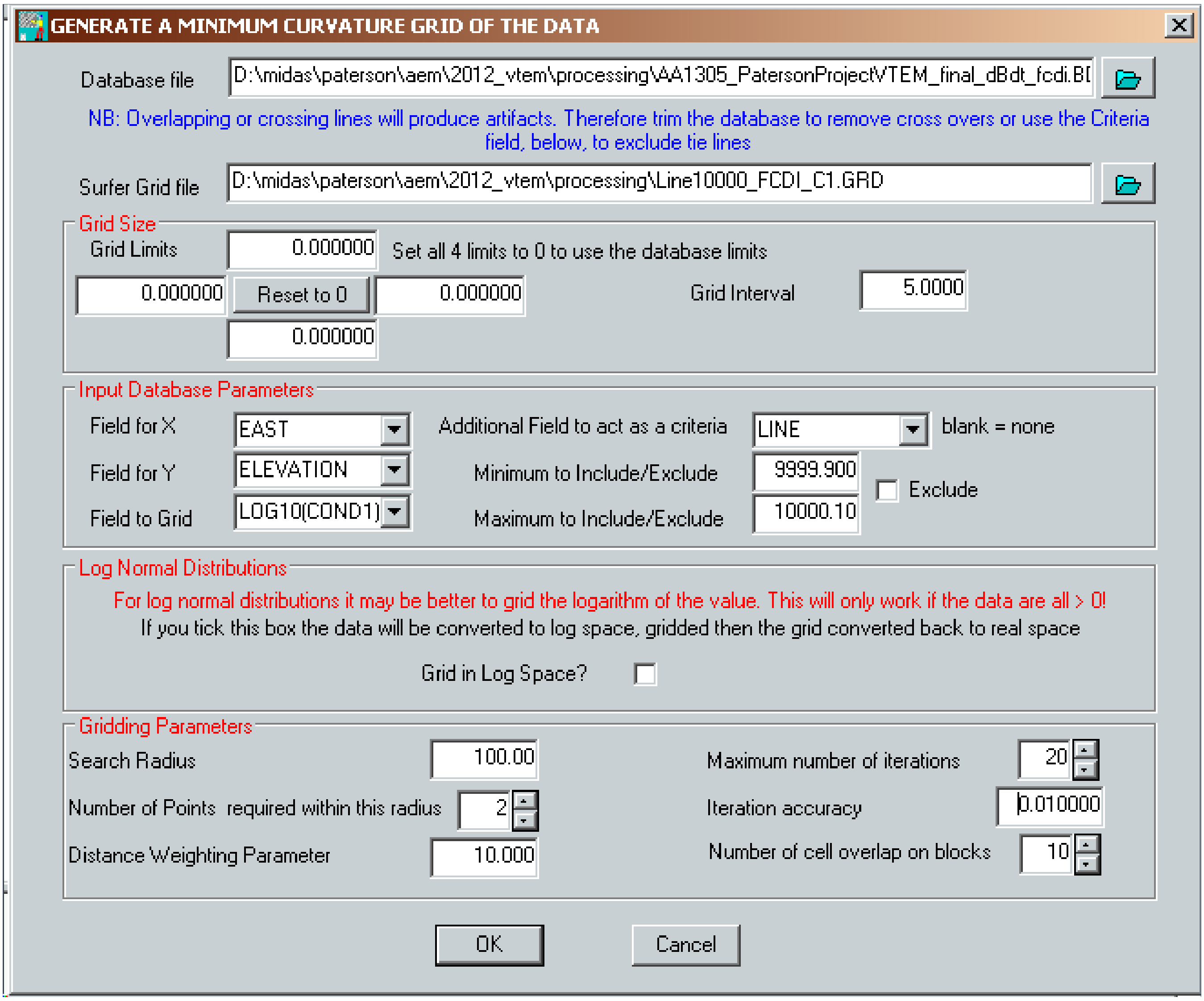


That should generate a database of conductivity depth pairs which can be gridded as line based sections, depth or RL based plans or exported to an ASCII format for manipulation with other software.



To generate sections based on a line number

Use DBaseO’s minimum curvature gridding algorithm and mask on the line number. You can use either the easting (in the case of EW lines) the northing or the station as the X axis. Note that the elevation here assumes you used the Tx_Elevation in Field 5 of the EM

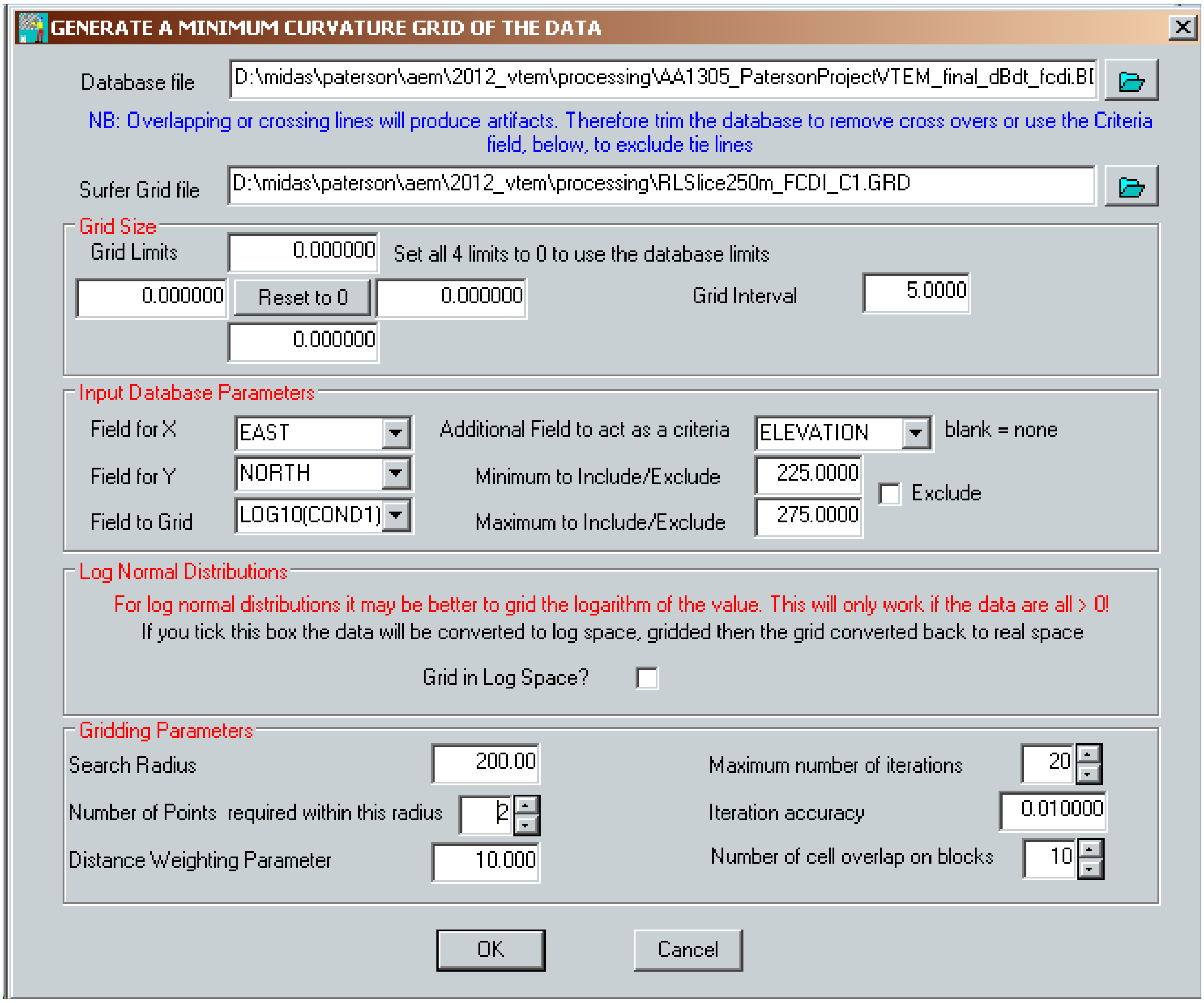


database. The CDI database includes Elevation (Field 6) and Depth (Field 7). Elevation uses the same datum as the Elevation in Field 5 of the EM database and increases upwards. Depth is depth below the transmitter and increases down, so should be >~120m for fixed wing systems and > ~40m for helicopter systems.

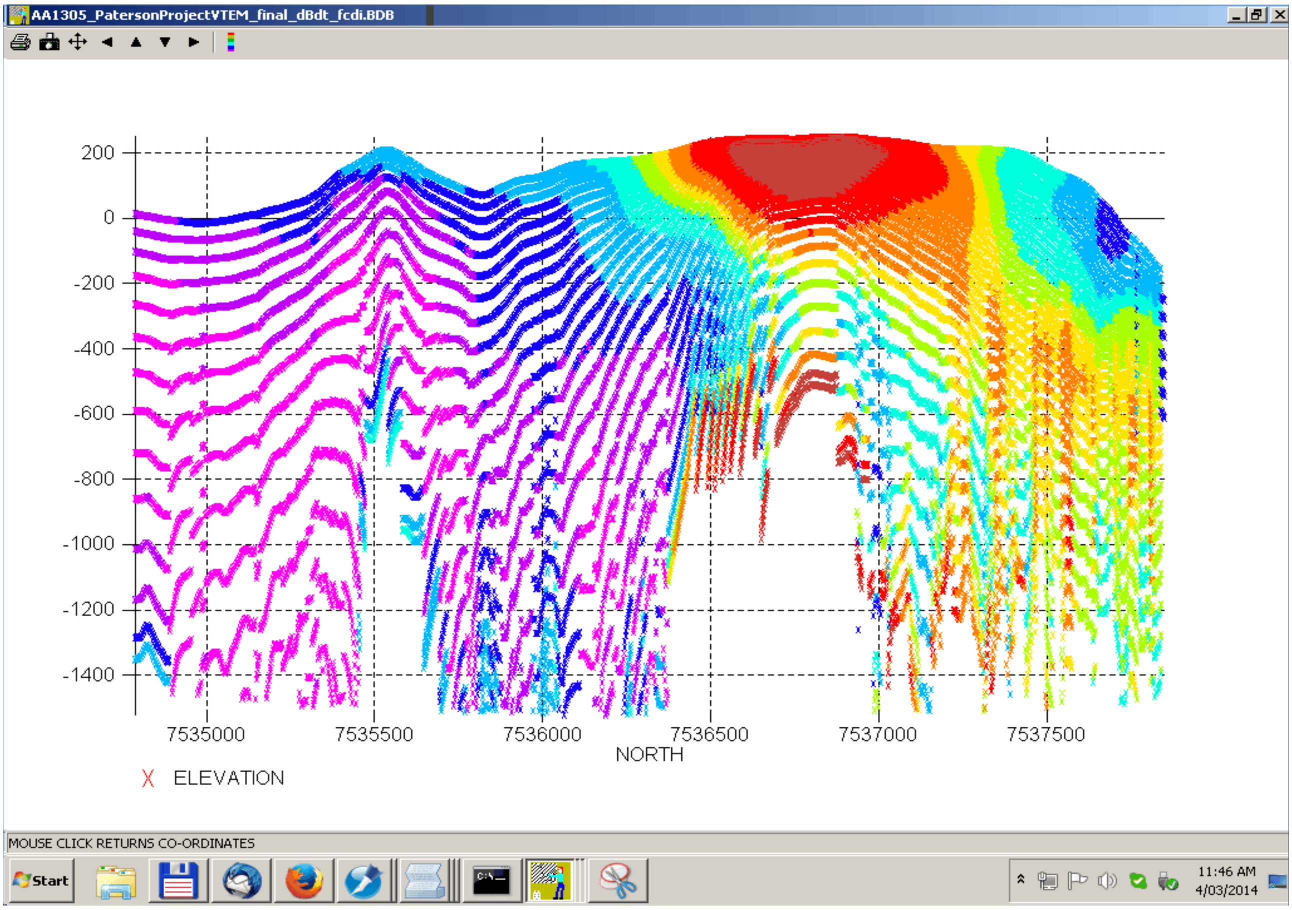
Leaving the grid limits at 0 will result in the limits from the whole database being used. This is handy if you want all your grids to be the same size or if all your lines have the same extents, however, if you have a staggered survey grid and don’t want a lot of white space in your grid you can manually specify these limits for each grid. If you specify one limit you must specify all four cardinal points as the default setting looks for 0 in all 4 limits.

To generate RL or depth slices

Use DBaseO’s minimum curvature gridding algorithm and mask on either an elevation range or a depth range.



Because each reading will have different elevations and depths you’ll need to use a range to obtain a slice. You can determine what a sensible search radius is by looking at the data in the DBaseO editor and plotting station against elevation or depth and colouring by conductivity.



These data would require a search radius of around 250m to fill the left hand side of the grid.

GRAVITY

GRAVRED - Current Version: 1.0.0.28 Gravity processing and reduction - 64 bit multithreaded - *several bug fixes, speed and performance improvements*

- Import a Scintrex CG3 dump file
- Import a Scintrex CG5 TXT file
- Import a CSV file. This is a special CSV importer which unlike the version in DBASEO subtracts a constant from the observed gravity in order to retain precision. It also unscrambles most of the contractors date and time formats as well as their Lat/Long values. It attempts to load the data into a BDB in the correct format for gravity reduction. Modified to allow the date to include a 3 character month string.
- Set the extended header of a database to include survey parameters
- Import a Geosoft XYZ format file. This is a special XYZ importer which unlike the version in DBASEO subtracts a constant from the observed gravity in order to retain precision. It also unscrambles most of the contractors date and time formats as well as their Lat/Long values. It attempts to load the data into a BDB in the correct format for gravity reduction. Modified to allow the date to include a 3 character month string.
- Convert Lacoste and Romberg dial readings to mGal equivalents
- Convert day or time from three separate fields to standard YYMMDD, HHMMSS format
- Compute the tidal correction using Longman's formula. *The position was entered into the dialogue as a constant for the database. Now read from the database to allow for large regional surveys*
- Compute a drift correction based on repeat readings
- Convert date and time to decimal day of year
- Compute Free Air and multiple Bouguer gravity using a selection of formula
- Change betweeen Potsdam 1930, GRS67 and GRS80 isogals
- Compute the Observed gravity from a file with only Bouguer anomaly, latitude and height. You have to make some assumptions about which gravity formula the original file used but if they have computed two Bouguer densities this can be resolved
- Having computed at least one Bouguer anomaly analyse the elevation and Bouguer anomaly to compute the best density to use. Note that the "best" density is scale dependant so as your study area reduces in size so usually does the best density. Therefore, run this routine with a database cropped to your study area. If you get a ridiculous high number your survey area is probably flat and the choice of bouguer density become irrelevant.
- Plot the meter drift over time. *Repeat stations will be identified by different colours.*
- Remove duplicate readings based on a user specified search radius. Report duplicate statistics to the PRT file and to a text file in a format suitable for plotting. *Added the standard deviation to the output text file statistics.*
- Compute a full Bouguer anomaly including the terrain correction. This currently uses the slab formula for stations outside of the topography grid. The correction for up to 10 densities can be computed at once. The size of the inner zone was expanded by a factor of three. The zone boundaries are determined by the DEM grid cell size and ideally the grid cell size should be smaller than the closest gravity station spacing.

- Switch between mGal and μm/s^2 - note this only applies to the Observed gravity any Bouguer or Free Air values will have to be recomputed
- Given a grid of upper surface, density and lower surface compute the gravity response in the frequency domain.
- Output a gravity data base to a Geosoft XYZ including all the header information as comments

Gravity reduction Formulae:

Gravred gives you a number of choices in the way you reduce the gravity data ranging from simple approximations to more detailed polynomial expansions. Constants in the following formulae are for units of milliGal, Gravred will read the units from the database header and scale accordingly.

The first choice you have is in how to compute the Free Air Gravity. There are two options.

First order approximation

$FA = 0.3086 * h$

where h = station height

Second order formula from Heiskanen and Moritz (1969) – preferred for modern reduction

$FA=(2*G_e/a)(1+f+m+((5/2)*m-3*f)\sin^2\varphi)*h+(3*G_e*h^2)/(a^2)$

where a = semimajor axis of the ellipsoid

f= flattening of the ellipsoid

G_e = Normal gravity at the equator

φ = latitude

$m=\omega^2*a^2*b/GM$, b=semiminor axis,

ω = angular velocity

GM = geocentric gravitational constant

Assuming you have a value for the latitude you then have to choose a formula for the theoretical gravity. Again there are two choices.

2nd Chebychev approximation - accurate to 0.1 mGal

$\lambda=G_e(1 + f_g*\sin^2\varphi - (1/4)f_4*\sin^2 2\varphi)$

where $f_g= (G_p-G_e)/G_e$ = gravity flattening

G_p = Normal gravity at the pole

$f_4=(-1/2)f^2 + (5/2)f*m$

Somigliana's formula – preferred for modern reduction

$\lambda=G_e(1+k*\sin^2\varphi)/(\sqrt{(1-(e^2)*\sin^2\varphi)})$

where $k = b*G_p/(a*G_e)-1$

$e = \sqrt{((a^2-b^2)/a^2)}$

You can optionally also compute the atmospheric correction

$\delta g_{atm}=8.74-0.00099*h + 0.0000000356*h^2$

Finally you have a choice of formula for the Bouguer gravity calculation.

Simple Slab formula

$B_g=2*\pi*G*\rho*h$

where G = Gravitational constant

ρ = density

Bullard B correction for a spherical cap of radius 166.735 km – preferred for modern reduction

$B_g = 2*\pi*G*\rho*(h + (\mu*h - \chi R))$

where $\mu = (1/3)\eta^2 - \eta$

$\eta = h/R$, $R = R_0 + h$, R_0 = Radius of earth to datum

$$\chi = 1/3*((d + f_b*\delta + \delta^2)*\sqrt{((f_b - \delta)^2 + k_b)} + p + m_b* \log(n/(f_b - \delta + \sqrt{((f_b - \delta)^2 + k_b)})))$$

where $d = 3*\cos^2\alpha - 2$, $\alpha = S/R_0$, S = Bullard B surface radius

$f_b = \cos\alpha$, $\delta = R_0/R$, $k_b = \sin^2\alpha$, $p = -6*\cos^2\alpha*\sin(\alpha/2) + 4*\sin^3(\alpha/2)$

$m_b = -3*\sin^2\alpha*\cos\alpha$, $n = 2*(\sin(\alpha/2) - \sin^2(\alpha/2))$

For each formula you have a choice of geoid models ranging from Airy 1930 through to GRS80 which is close to WGS84. Modern reduction uses GRS80.

In addition you have a choice of height datum. Historically gravity data has been reduced to the datum at sea level (AHD in Australia). This is approximates the geoid. With the increased use of GPS and some blurring between geodesy and exploration geophysics the ellipsoid has been adopted as the reduction datum. This is the GPS height and it differs from the geoid height by a value n (not the n value of the Bullard B correction above).

For a detailed description you should read;

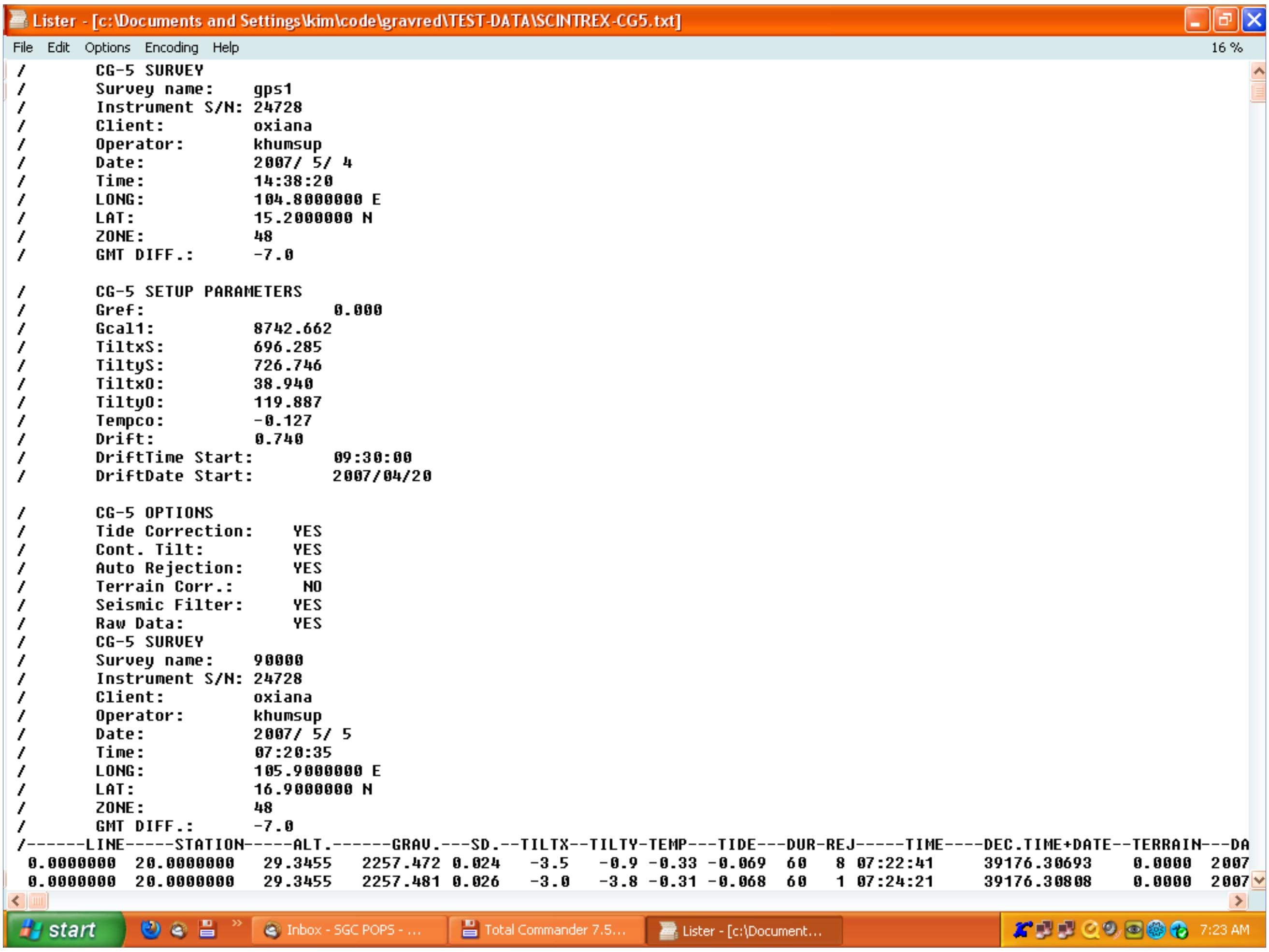
LaFehr T. 1991. An exact solution for the gravity curvature (Bullard B) correction. Geophysics 56, pp1179 -1184

Li, X. & Götze, H.-J., 2001. Ellipsoid, geoid, gravity, geodesy and geophysics. Geophysics 66, pp1660 - 1668.

Recommended Standards and Format for the North American Gravity Database 2003

Processing Gravity Data - a CG5 example;

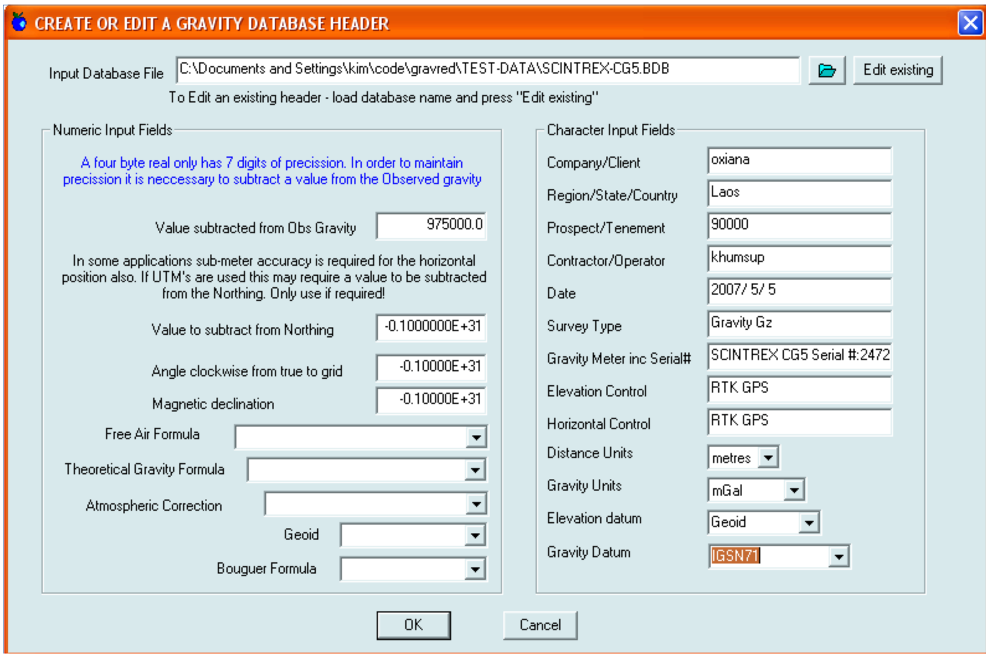
You should be starting with a CG5 dump file which should look like this.


Lister - [c:\Documents and Settings\kim\code\gravred\TEST-DATA\SCINTREX-CG5.txt]

```
/       CG-5 SURVEY
/       Survey name:     gps1
/       Instrument S/N: 24728
/       Client:          oxiana
/       Operator:        khumsup
/       Date:            2007/ 5/ 4
/       Time:            14:38:20
/       LONG:            104.8000000 E
/       LAT:             15.2000000 N
/       ZONE:            48
/       GMT DIFF.:       -7.0

/       CG-5 SETUP PARAMETERS
/       Gref:                    0.000
/       Gcal1:           8742.662
/       TiltxS:          696.285
/       TiltyS:          726.746
/       Tiltx0:          38.940
/       Tilty0:          119.887
/       Tempco:          -0.127
/       Drift:           0.740
/       DriftTime Start:         09:30:00
/       DriftDate Start:         2007/04/20

/       CG-5 OPTIONS
/       Tide Correction:     YES
/       Cont. Tilt:          YES
/       Auto Rejection:      YES
/       Terrain Corr.:        NO
/       Seismic Filter:      YES
/       Raw Data:            YES
/       CG-5 SURVEY
/       Survey name:     90000
/       Instrument S/N: 24728
/       Client:          oxiana
/       Operator:        khumsup
/       Date:            2007/ 5/ 5
/       Time:            07:20:35
/       LONG:            105.9000000 E
/       LAT:             16.9000000 N
/       ZONE:            48
/       GMT DIFF.:       -7.0
/------LINE-----STATION----ALT.------GRAV.---SD.--TILTX--TILTY-TEMP---TIDE---DUR-REJ-----TIME----DEC.TIME+DATE--TERRAIN---DA
  0.0000000  20.0000000   29.3455   2257.472 0.024   -3.5   -0.9 -0.33 -0.069  60   8 07:22:41     39176.30693   0.0000  2007
  0.0000000  20.0000000   29.3455   2257.481 0.026   -3.0   -3.8 -0.31 -0.068  60   1 07:24:21     39176.30808   0.0000  2007
```

Using Gravred Import the CG5 file - Import\Import a Scintrex CG5

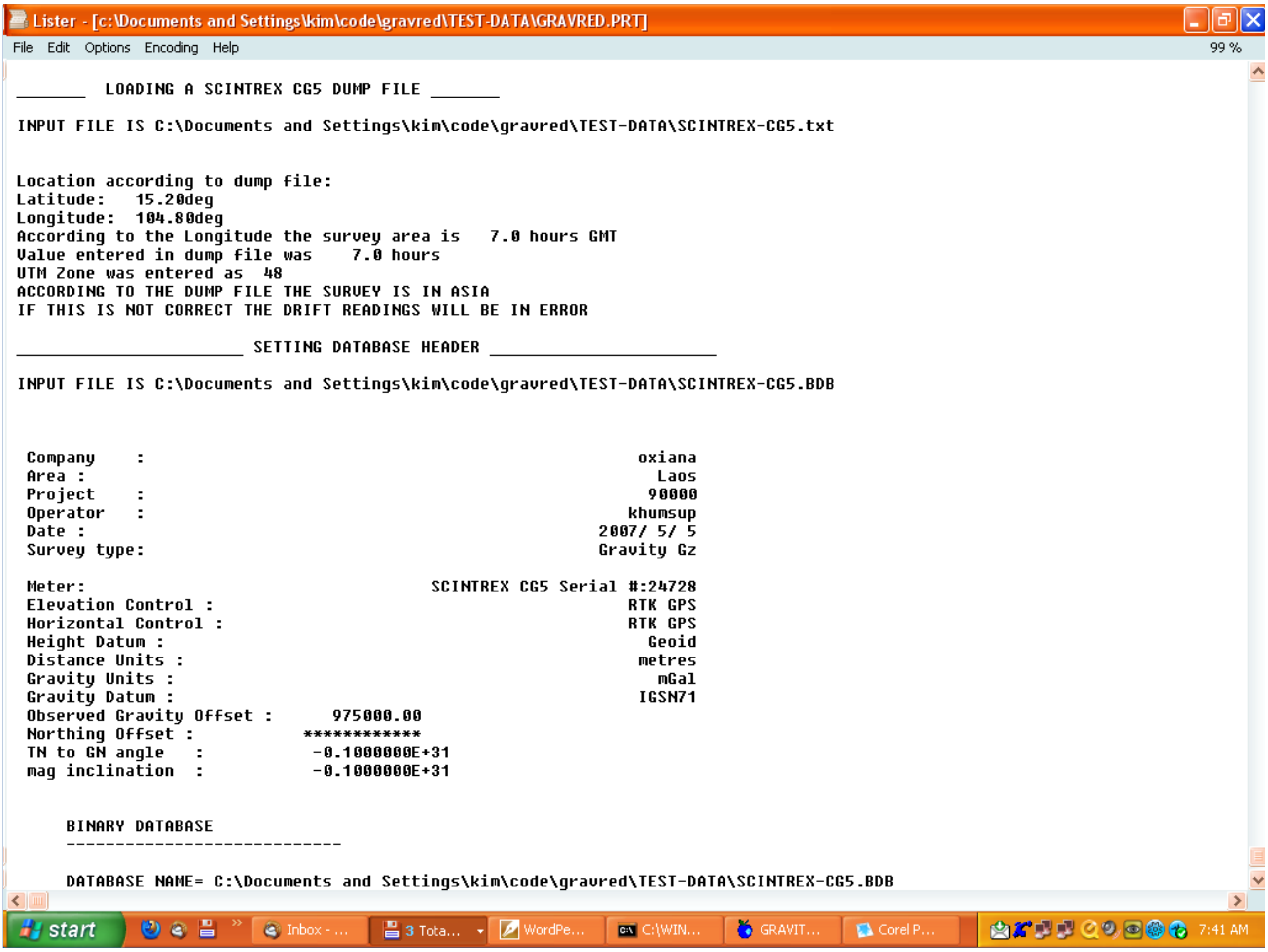
Unless there are problems with the file (eg Mac format dump file with line feed , carriage return at the ends of lines instead of the PC format carriage return, line feed - hex 0D0A) Gravred should read the file and give you a dialogue box to enter header details. These are important and worth sorting out.



The first four character input fields should be completed or the default values from the read from the CG5 file checked and edited if need be. You will also need to select a height and gravity datum from the drop

down lists although these can be set later when you tie the data to positions and gravity isogal. If you know the gravity datum you should enter both it and the Ellipsoidal model used to generate it (Note that Australian Isogal 84 gravity datum uses the GRS67 ellipsoid) The value to be subtracted from the Observed gravity, likewise can be entered when you have an isogal tie.

Press OK and check the PRT file to ensure the file has read in correctly.


Lister - [c:\Documents and Settings\kim\code\gravred\TEST-DATA\GRAVRED.PRT]

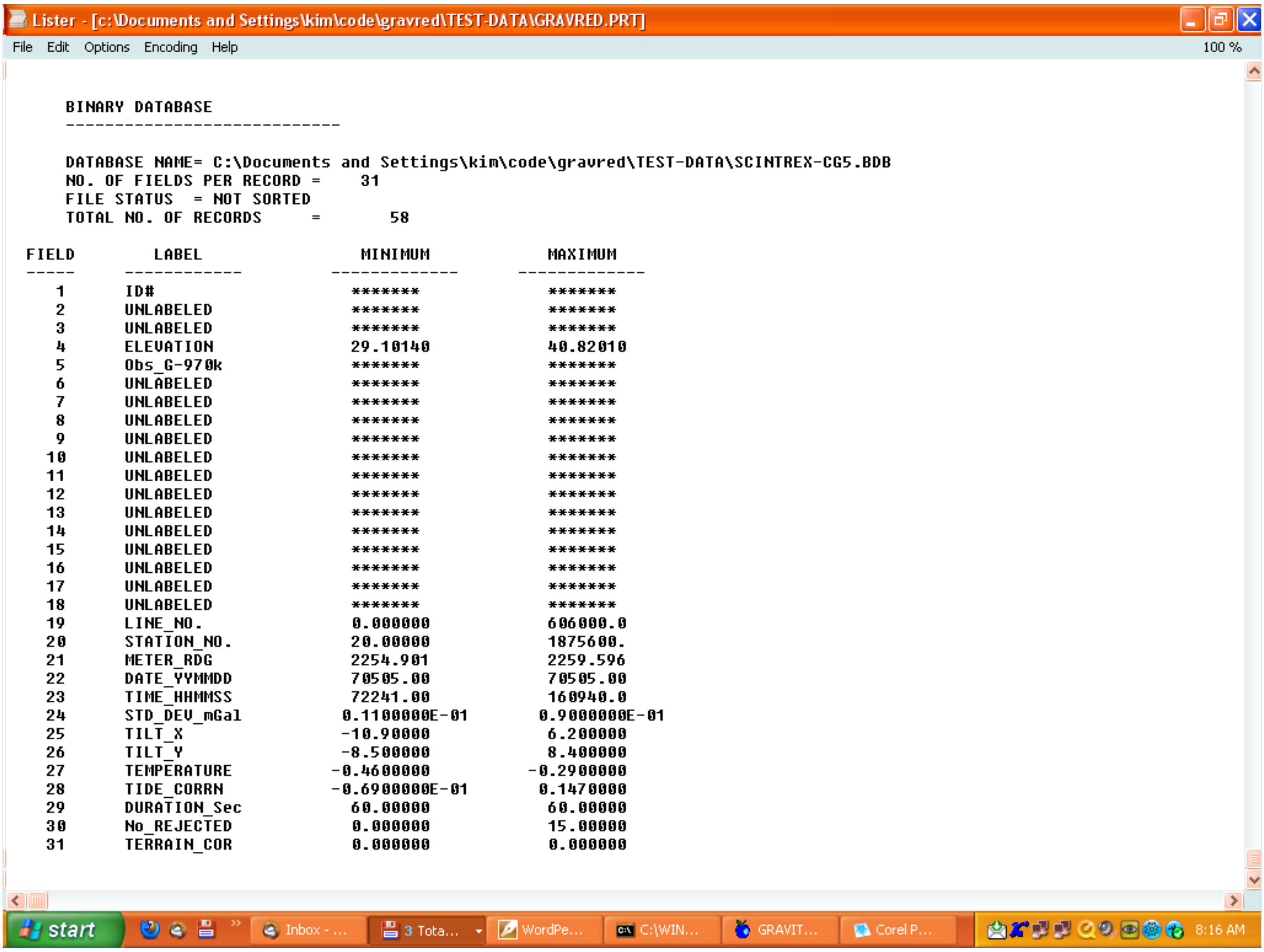
File Edit Options Encoding Help 99 %

```
_______ LOADING A SCINTREX CG5 DUMP FILE _______

INPUT FILE IS C:\Documents and Settings\kim\code\gravred\TEST-DATA\SCINTREX-CG5.txt


Location according to dump file:
Latitude:   15.20deg
Longitude:  104.80deg
According to the Longitude the survey area is   7.0 hours GMT
Value entered in dump file was    7.0 hours
UTM Zone was entered as  48
ACCORDING TO THE DUMP FILE THE SURVEY IS IN ASIA
IF THIS IS NOT CORRECT THE DRIFT READINGS WILL BE IN ERROR

_______________________ SETTING DATABASE HEADER _______________________

INPUT FILE IS C:\Documents and Settings\kim\code\gravred\TEST-DATA\SCINTREX-CG5.BDB



 Company    :                                                  oxiana
 Area :                                                          Laos
 Project    :                                                   90000
 Operator   :                                                 khumsup
 Date :                                                    2007/ 5/ 5
 Survey type:                                              Gravity Gz

 Meter:                                    SCINTREX CG5 Serial #:24728
 Elevation Control :                                          RTK GPS
 Horizontal Control :                                         RTK GPS
 Height Datum :                                                 Geoid
 Distance Units :                                              metres
 Gravity Units :                                                 mGal
 Gravity Datum :                                               IGSN71
 Observed Gravity Offset :      975000.00
 Northing Offset :           ************
 TN to GN angle   :           -0.1000000E+31
 mag inclination  :           -0.1000000E+31


      BINARY DATABASE
      ----------------------------

      DATABASE NAME= C:\Documents and Settings\kim\code\gravred\TEST-DATA\SCINTREX-CG5.BDB
```

start | Inbox - ... | 3 Tota... | WordPe... | C:\WIN... | GRAVIT... | Corel P... | 7:41 AM

Take note of the position checks at the start of the report. This is done as a check to ensure the operator has entered the time offset and lat/long information correctly to enable the CG5 to do a tidal correction. If these are wrong then the tidal correction will also be wrong and will need to be computed manually in Gravred. This was a particular issue with the CG3 which assumed longitude positive west of Greenwich resulting in many users setting the instrument up for 180 degrees away from their true location.

Now check the data part of the report. Note that the first 18 fields of the gravity database have special significance to Gravred and have thus largely been left blank.


Lister - [c:\Documents and Settings\kim\code\gravred\TEST-DATA\GRAVRED.PRT]

BINARY DATABASE

DATABASE NAME= C:\Documents and Settings\kim\code\gravred\TEST-DATA\SCINTREX-CG5.BDB
NO. OF FIELDS PER RECORD = 31
FILE STATUS = NOT SORTED
TOTAL NO. OF RECORDS = 58

FIELD	LABEL	MINIMUM	MAXIMUM
1	ID#	*******	*******
2	UNLABELED	*******	*******
3	UNLABELED	*******	*******
4	ELEVATION	29.10140	40.82010
5	Obs_G-970k	*******	*******
6	UNLABELED	*******	*******
7	UNLABELED	*******	*******
8	UNLABELED	*******	*******
9	UNLABELED	*******	*******
10	UNLABELED	*******	*******
11	UNLABELED	*******	*******
12	UNLABELED	*******	*******
13	UNLABELED	*******	*******
14	UNLABELED	*******	*******
15	UNLABELED	*******	*******
16	UNLABELED	*******	*******
17	UNLABELED	*******	*******
18	UNLABELED	*******	*******
19	LINE_NO.	0.000000	606000.0
20	STATION_NO.	20.00000	1875600.
21	METER_RDG	2254.901	2259.596
22	DATE_YYMMDD	70505.00	70505.00
23	TIME_HHMMSS	72241.00	160940.0
24	STD_DEV_mGal	0.1100000E-01	0.9000000E-01
25	TILT_X	-10.90000	6.200000
26	TILT_Y	-8.500000	8.400000
27	TEMPERATURE	-0.4600000	-0.2900000
28	TIDE_CORRN	-0.6900000E-01	0.1470000
29	DURATION_Sec	60.00000	60.00000
30	No_REJECTED	0.000000	15.00000
31	TERRAIN_COR	0.000000	0.000000

At this point you should check repeat readings (using the line and station values from the CG5) and see how well the ties repeat. If they don't there may be a problem with the tidal or drift correction done by the CG5 in which case these will need to be re-done manually using Gravred and DBASEO

If not already provided by the contractor you will need to generate a unique station ID for each station. This could be a combination of the line and station number or some other survey specific variation remembering that you only have 7 digits to work with. This computation can be done using the function feature in DBASEO's editor. You should also have enough information now to shift the data to the isogal remembering that the observed gravity needs to be reduced in size in order to retain two decimal places of precision. This is done by subtracting a base value (normally 975000 mGal) from the isogal tie value before shifting the local survey data to it. Ensure that the gravity datum set in the gravity database header reflects the datum of the isogal tie you used - File|Set database header.

The next step is to load the location information in from the GPS or what ever was used to obtain survey control. Bring the survey data into its own database using the appropriate parser from DBASEO. In order to load the survey data via a lookup you need to have two fields common to both the survey and gravity database. If using a GPS this will generally be date and time although it could equally be line and station. Obviously in order for the lookup to work the numbers need to be in the same format and refer to the same point.

You could load either Lat/Long/Elevation or East/North/Elevation or both depending on what you have. If loading Lat/Longs they will need to be expressed in decimal degrees. This may require that readings initially loaded in DDD MMM SSS.SS format are converted to decimal degrees first. Gravred has a tool to do this - Process|Convert 3 field time/place to 1.

The lookup can be done easily in DBASEO using Operations|Load database fields using Lookup table|Binary lookup table and the common fields mentioned above. Ensure that the height datum set in the gravity database header reflects the datum of the survey data you loaded - File|set database header.

If you loaded lat/Longs in the lookup you now need to compute the UTM co-ordinates, or if you loaded UTM the Lat/Long co-ords. This is done in DBASEO using Operations|Convert between UTM and Latlong if staying to the same datum or if switching datum you will need to use Operations|Convert between AGD and GDA/WGS. It is a good idea to use the field labels to indicate the datum as this is not stored in the header e.g. East_MGA or Lat_WGS84.

You should now have fields 1 through to 7 populated, 8 through to 18 blank and 19 through to 31 containing the CG5 data or your own edits. You can either go ahead and reduce the data to Bouguer Gravity at this stage or merge this gravity data with other data sets you have e.g. regional GA data or surveys from other days.

To reduce to Bouguer gravity use Gravred - Process|Compute free air and Bouguer gravity and select the appropriate reduction formulae for your data set. If simply QCing a data set you may want to use Gravred's tool to remove duplicate readings to get a report on the repeats. Use Process|Remove Duplicates and output the result to a temp or junk database, unless this is the final clean up. Then view the PRT file for information on the variation of repeat readings.

To merge with other data use DBASEO's append database feature - Operations|Append database. Note that when appending databases the header, number of fields and field labels are inherited from the Master database. You will need to ensure that all databases have the same constant removed from the observed gravity, use the same height and location datum and that the master has sufficient fields in order to retain all the information you consider important. Any wanted information in fields 19 onward should be in the same field in each database. This may require that fields are reordered. This can be done using DBASEO's editor and either rearranging or inserting or deleting fields from any database you want to conform to the master. Following a merge it is always a good idea to re-run the Bouguer and Freeair calculation even if this has been done before. This will highlight any mismatches between the data sets and ensures you have everything at the same datum.

Once processed you can grid using DBASEO, plot daily loop plots from DBASEO - Output\ Plot Flight Lines using the day as the line number and time as fid (after sorting by Date and Time) or simply plot up the data in the editor.

Drift correcting gravity data

There are three major components to drift in gravity readings; the tidal variation, normal instrument drift and tares. The tidal variation is caused by the gravitational influence on the

earth from bodies in space, the principal of these being the sun and the moon. Although there is a quantifiable effect from other planets in our solar system these have historically been ignored. As gravity instrumentation becomes more sensitive and surveys measure down below the nm/s^2 level these will have to be taken into account however for the moment tidal variations are corrected using a formula published by Longman (1959) which only uses the sun and moon.

The Scintrex autolevelling and modern Lacoste and Romberg meters compute the tidal variation using Longman’s formula and remove this from the reading. This however requires that the operator enter in the location and time correctly, something that was particularly easy for novices to get wrong using the CG3 as it referenced latitude to Canada so west of Greenwich was positive latitude rather than negative! Time, likewise was referenced in reverse. This idiosyncrasy was fixed in the CG5 which uses conventional notation. This is why Gravred has a check on reading a CG3 or CG5 dump file and reports where in the world the operator thought they were surveying as a cross check. If the wrong location or time difference to UMT were used the tidal correction will be wrong and will need to be removed and redone manually.

All gravimeters drift. The rate and linearity of this drift will depend on temperature stability and how well the meter is handled. Drift for a well maintained and cared for meter should be slow and linear. The Scintrex auto levelling gravity meters CG3 and CG5 have the option for the operator to enter the rate of drift as determined in controlled tests and have this removed from the reading. Again if the operator enters the wrong parameters this drift correction will be in error. I generally request that operators turn off this feature.

The final component to drift are tares. These are caused by misuse of the meter, either by giving it a sever knock or allowing it to lose temperature stabilisation. Again the CG3 and 5 and modern Lacoste and Robmerg meters report the temperature at each reading and when reading instrument dump files, Gravred will report if the temperature moves outside of the meter’s range while surveying. If the meter has a temperature shock during a non-reading interval (e.g. overnight) this will not be recorded by the instrument but will be evident in the data as is clear from the drift plot in Figure 4. In the example shown in Figure 4 the cause of the problem was a year end bug in the CG5 firmware which caused problems when the meter was used on both Dec 31 and Jan 1. This has now been fixed.

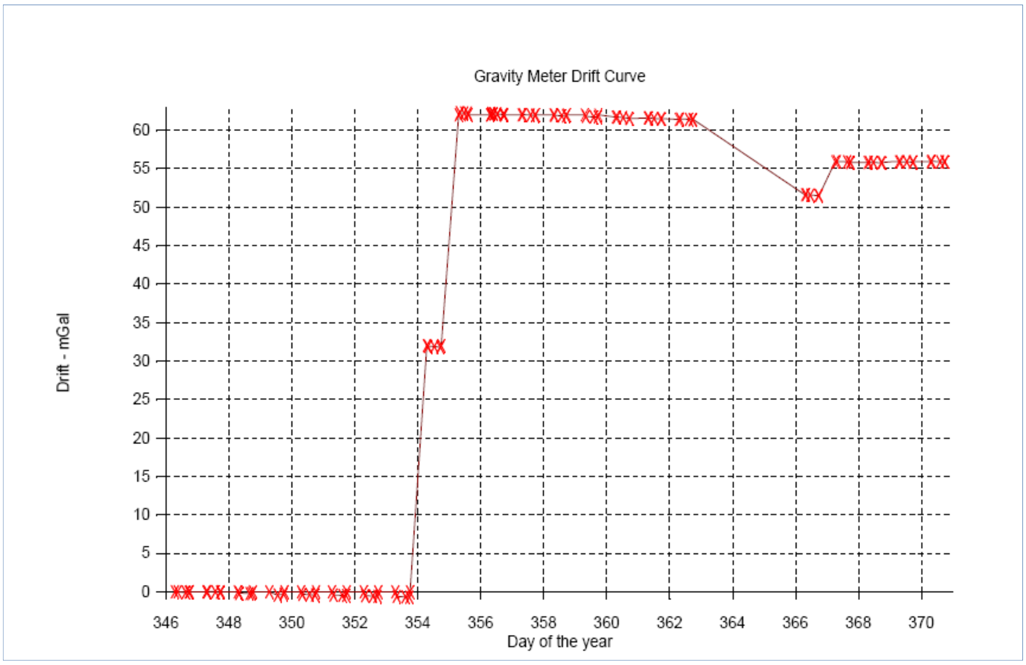


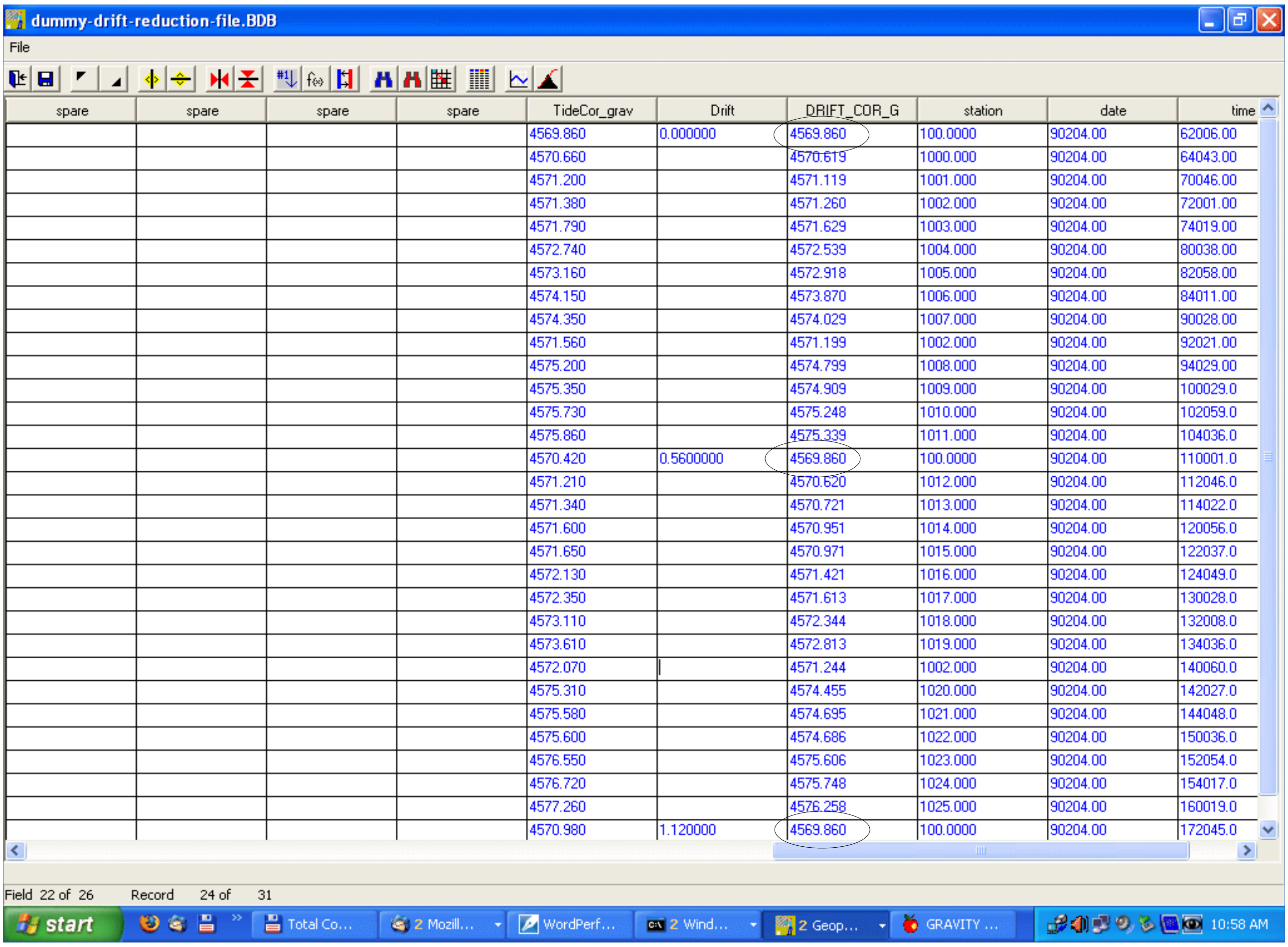
Figure 4: Drift curve from a survey over the new year period showing a bug in the CG5 firmware

On the nights of days 354 and 355 the firmware bug produced 32 mGal offsets (tares) in the drift. Prior to and for a period after this the drift was stable and relatively linear with a gentle negative slope. On day 364 the crew took a couple of days off after New Year. The firmware bug resulted in a tare to day 366 followed by another small jump the following day. The same thing could happen if the meter were allowed to go off temperature. Temperature stabilised meters should always be kept on temperature unless it is impossible to do otherwise e.g. over long shipments. If they have come off temperature for any reason they should be allowed to quietly stabilise for several days prior to use. A drift curve such as that in Figure 4 should point to equipment and or operator problems and this may be reflected in the overall data quality.

If you are working with older quartz spring meters (Worden, Sodin, old Scintrex) or Lacoste and Romberg G or D series meters or if the operator of a self compensating meter has not entered the parameters into the meter properly you will have to apply all the drift corrections yourself. Here, in order, are the steps you will need to follow in order to drift correct the data.

1. If using a L&R meter convert the dial reading to gravity units using the meter's calibration chart. If using a self compensating meter remove any meter applied drift from the observed gravity to re-produce a raw gravity value
2. Compute the tidal correction and remove that from the raw gravity
3. Drift correct repeat stations to remove instrument drift
4. Inspect the drift curve and see if it looks reasonable, rapid changes in slope point to a tare.
5. Compute Free air and Bouguer gravity from the drift corrected gravity and generate check plots to see if there are any acquisition artefacts due to drift or tare problems.
6. Repeat steps 3 to 5 until you have a data set free of drift.

Some software packages use an iterative least squares minimisation to automatically reduce the differences on all repeat readings however in Gravred the instrument drift correction is a manual process and uses both Gravred and DBASEO. Start by sorting the gravity database on date and time using DBASEO (ensure these are in YYMMDD and HHMMSS format). Then in DBASEO's editor create two empty fields beside the tide corrected gravity field, label the first DRIFT. Place a copy of the Station_ID in an adjacent field so you can see both it and the observed gravity field in the editor. Now work through the database and beside each repeat of the base station put in the drift required to make this value a constant once corrected. Once you have done this, plot the drift using the Gravred tool and ensure it looks sensible. Then run the drift correction in Gravred and write the drift corrected values to the second spare field you created earlier. If you have done this step properly all repeats at the base should have the same drift corrected value as in figure 5. *Note that the drift in this example is excessive and if encountered in real data would point to a problem, it is used here only as an example.* A drift plot at this stage should be close to a straight line after allowing for reading errors. Are there any other repeats? Repeats from previous days can have the drift corrected value from the previous day subtracted from the observed reading to provide an initial drift value. Two repeats taken within the one loop should have their drift corrected difference computed, halved, offset by the difference between the first reading at the repeat station and its initial drift corrected value and applied equally to each reading with a reverse sign on the first reading. In this way the drift corrections will plot on the overall drift curve for that loop. See Fig 6. Now you need to check the drift curve and confirm that the additional drift values you have entered sit on the curve properly and do not add excessive noise. (See Fig 7) If necessary manually iterate the adjustments until the drift curve is smoothly linear and the



dummy-drift-reduction-file.BDB

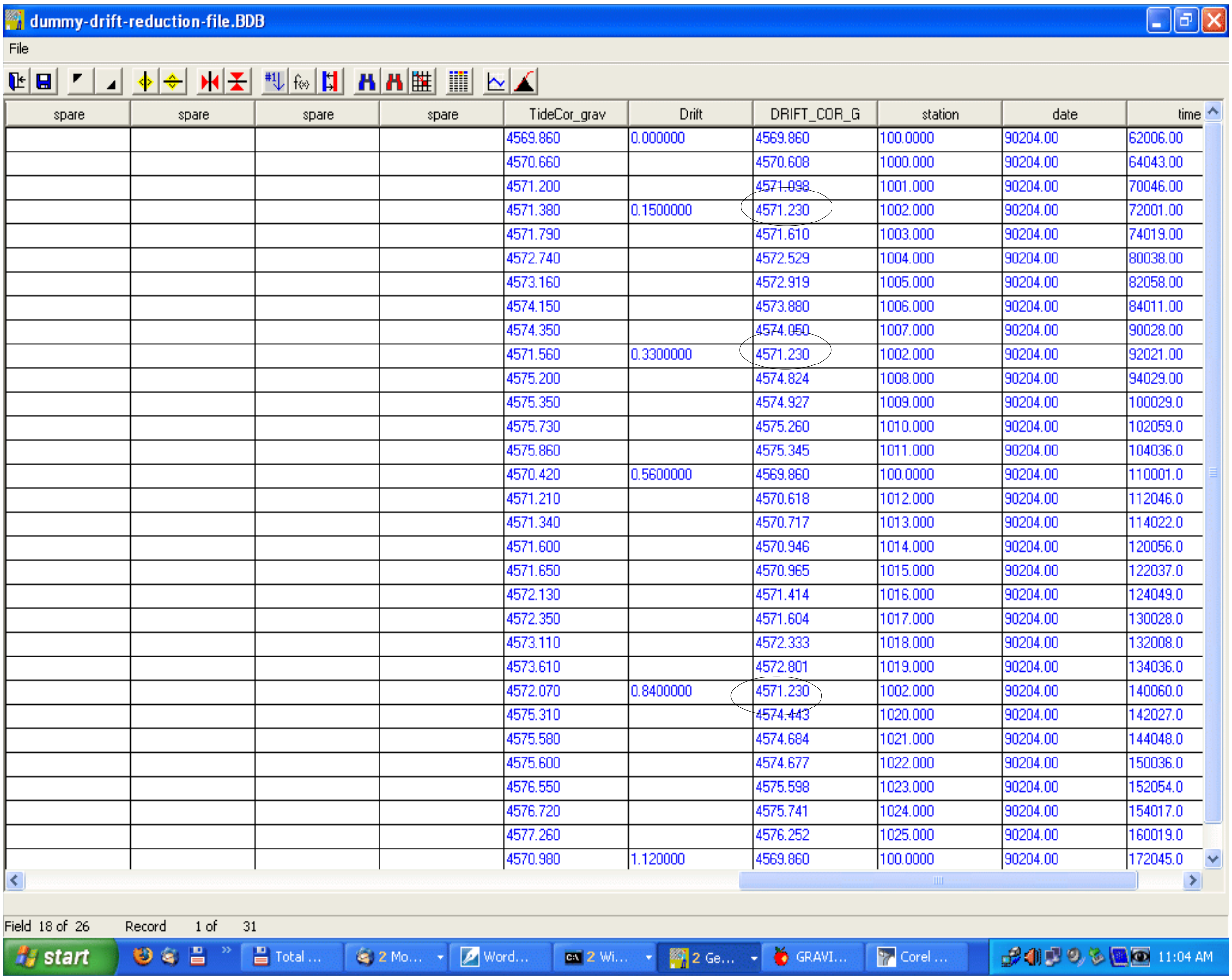
File

spare	spare	spare	spare	TideCor_grav	Drift	DRIFT_COR_G	station	date	time
				4569.860	0.000000	4569.860	100.0000	90204.00	62006.00
				4570.660		4570.619	1000.000	90204.00	64043.00
				4571.200		4571.119	1001.000	90204.00	70046.00
				4571.380		4571.260	1002.000	90204.00	72001.00
				4571.790		4571.629	1003.000	90204.00	74019.00
				4572.740		4572.539	1004.000	90204.00	80038.00
				4573.160		4572.918	1005.000	90204.00	82058.00
				4574.150		4573.870	1006.000	90204.00	84011.00
				4574.350		4574.029	1007.000	90204.00	90028.00
				4571.560		4571.199	1002.000	90204.00	92021.00
				4575.200		4574.799	1008.000	90204.00	94029.00
				4575.350		4574.909	1009.000	90204.00	100029.0
				4575.730		4575.248	1010.000	90204.00	102059.0
				4575.860		4575.339	1011.000	90204.00	104036.0
				4570.420	0.5600000	4569.860	100.0000	90204.00	110001.0
				4571.210		4570.620	1012.000	90204.00	112046.0
				4571.340		4570.721	1013.000	90204.00	114022.0
				4571.600		4570.951	1014.000	90204.00	120056.0
				4571.650		4570.971	1015.000	90204.00	122037.0
				4572.130		4571.421	1016.000	90204.00	124049.0
				4572.350		4571.613	1017.000	90204.00	130028.0
				4573.110		4572.344	1018.000	90204.00	132008.0
				4573.610		4572.813	1019.000	90204.00	134036.0
				4572.070		4571.244	1002.000	90204.00	140060.0
				4575.310		4574.455	1020.000	90204.00	142027.0
				4575.580		4574.695	1021.000	90204.00	144048.0
				4575.600		4574.686	1022.000	90204.00	150036.0
				4576.550		4575.606	1023.000	90204.00	152054.0
				4576.720		4575.748	1024.000	90204.00	154017.0
				4577.260		4576.258	1025.000	90204.00	160019.0
				4570.980	1.120000	4569.860	100.0000	90204.00	172045.0

Field 22 of 26 Record 24 of 31

Figure 5: Drift corrected data showing exact repeats at the base station as expected.

differences on repeats are minimised.



spare	spare	spare	spare	TideCor_grav	Drift	DRIFT_COR_G	station	date	time
				4569.860	0.000000	4569.860	100.0000	90204.00	62006.00
				4570.660		4570.608	1000.000	90204.00	64043.00
				4571.200		4571.098	1001.000	90204.00	70046.00
				4571.380	0.1500000	4571.230	1002.000	90204.00	72001.00
				4571.790		4571.610	1003.000	90204.00	74019.00
				4572.740		4572.529	1004.000	90204.00	80038.00
				4573.160		4572.919	1005.000	90204.00	82058.00
				4574.150		4573.880	1006.000	90204.00	84011.00
				4574.350		4574.050	1007.000	90204.00	90028.00
				4571.560	0.3300000	4571.230	1002.000	90204.00	92021.00
				4575.200		4574.824	1008.000	90204.00	94029.00
				4575.350		4574.927	1009.000	90204.00	100029.0
				4575.730		4575.260	1010.000	90204.00	102059.0
				4575.860		4575.345	1011.000	90204.00	104036.0
				4570.420	0.5600000	4569.860	100.0000	90204.00	110001.0
				4571.210		4570.618	1012.000	90204.00	112046.0
				4571.340		4570.717	1013.000	90204.00	114022.0
				4571.600		4570.946	1014.000	90204.00	120056.0
				4571.650		4570.965	1015.000	90204.00	122037.0
				4572.130		4571.414	1016.000	90204.00	124049.0
				4572.350		4571.604	1017.000	90204.00	130028.0
				4573.110		4572.333	1018.000	90204.00	132008.0
				4573.610		4572.801	1019.000	90204.00	134036.0
				4572.070	0.8400000	4571.230	1002.000	90204.00	140060.0
				4575.310		4574.443	1020.000	90204.00	142027.0
				4575.580		4574.684	1021.000	90204.00	144048.0
				4575.600		4574.677	1022.000	90204.00	150036.0
				4576.550		4575.598	1023.000	90204.00	152054.0
				4576.720		4575.741	1024.000	90204.00	154017.0
				4577.260		4576.252	1025.000	90204.00	160019.0
				4570.980	1.120000	4569.860	100.0000	90204.00	172045.0

Figure 6: Correcting non base station repeats

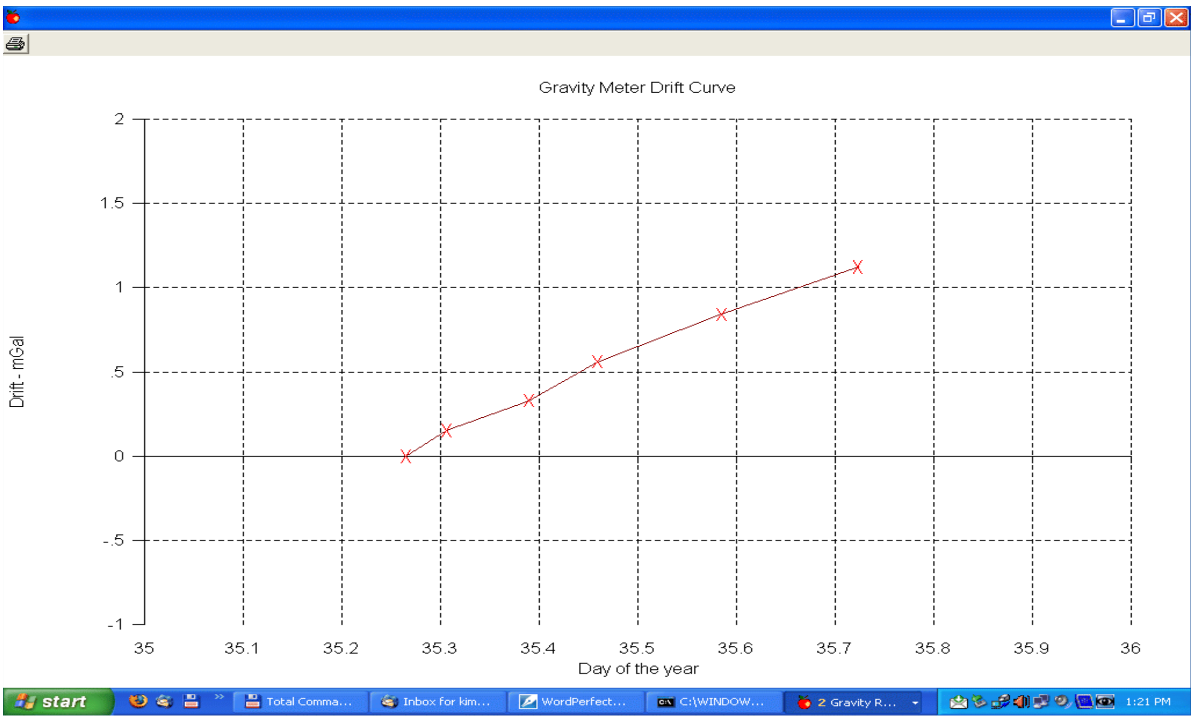


Figure 7: Drift curve from the above data

References;

Longman, I.M., Formulas for Computing the Tidal Acceleration Due to the Moon and the Sun., J. Geoph. Res., 1959, No. 64, pp. 2351-2355.

Tares:

On a tight grid a good operator will pick up tares as they happen and immediately go back and repeat the last couple of stations to resolve it properly. On regional surveys or with less experienced operators, the tare can go unnoticed until the data are processed, removal then becomes a more subjective process. The first hint that a tare exists should be in the base station drift curve, if this has departed from a relatively straight line then it is likely that a problem exists, either a tare or just noisy, low quality data. This will be confirmed when a check plot of the data is inspected. The check plot may need to be a vertical derivative of the bouguer gravity to highlight problems in the data. By overlaying a loop path plot on the image the station first effected by the tare can be identified. Artificial drift values then have to be inserted either side of the tare to re-drift the data.

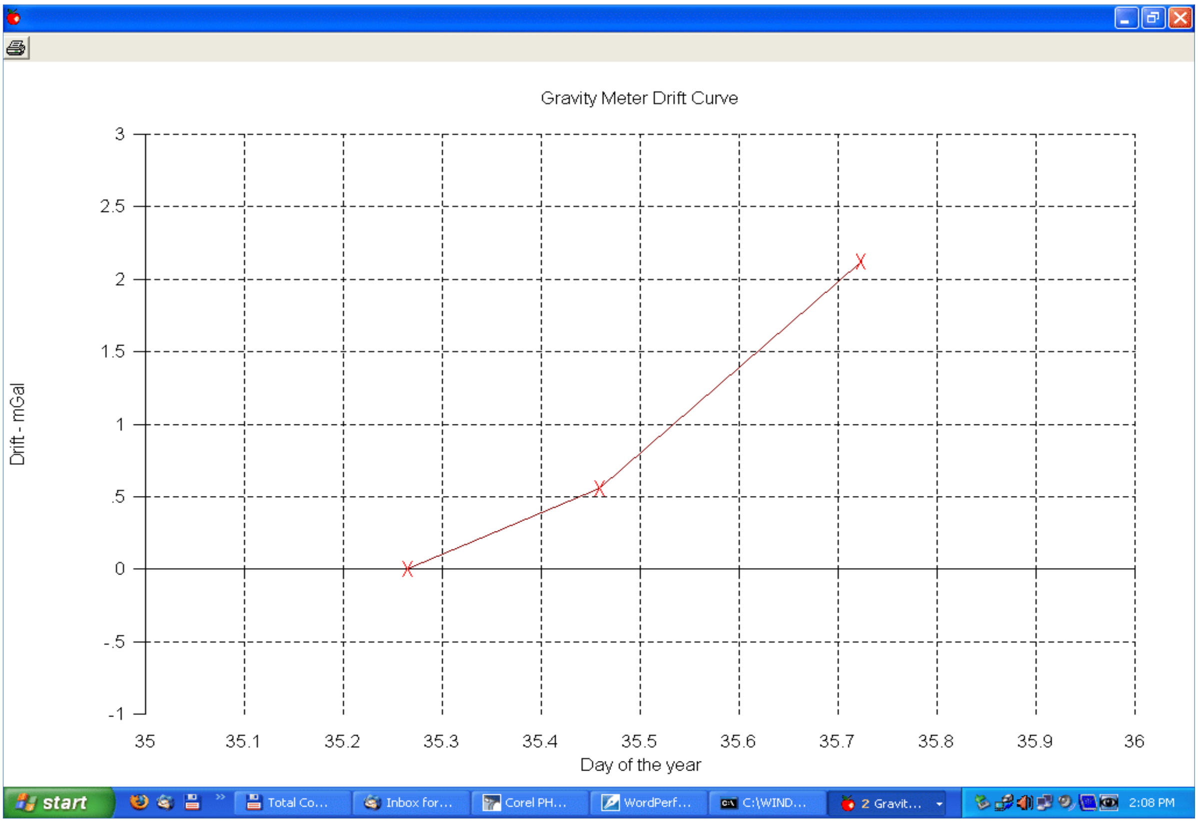


Figure 8: Example drift curve showing a tare

In the example of Figure 8 a tare has occurred at some time after the mid day tie. When viewed relative to other survey days the afternoon drift rate should be seen as anomalous. What we need to do here is to break the drift curve into two curves, parallel to each other, showing the normal instrument drift as we saw in Figure 6.

Say that after referring back to the check plot and loop path diagram we have decided that the tare occurred between stations 1021 and 1022. Scaling from the blue lines in Figure 9 we need to enter an end of drift value prior to the tare followed by a new start drift value after the tare as in figure 10.

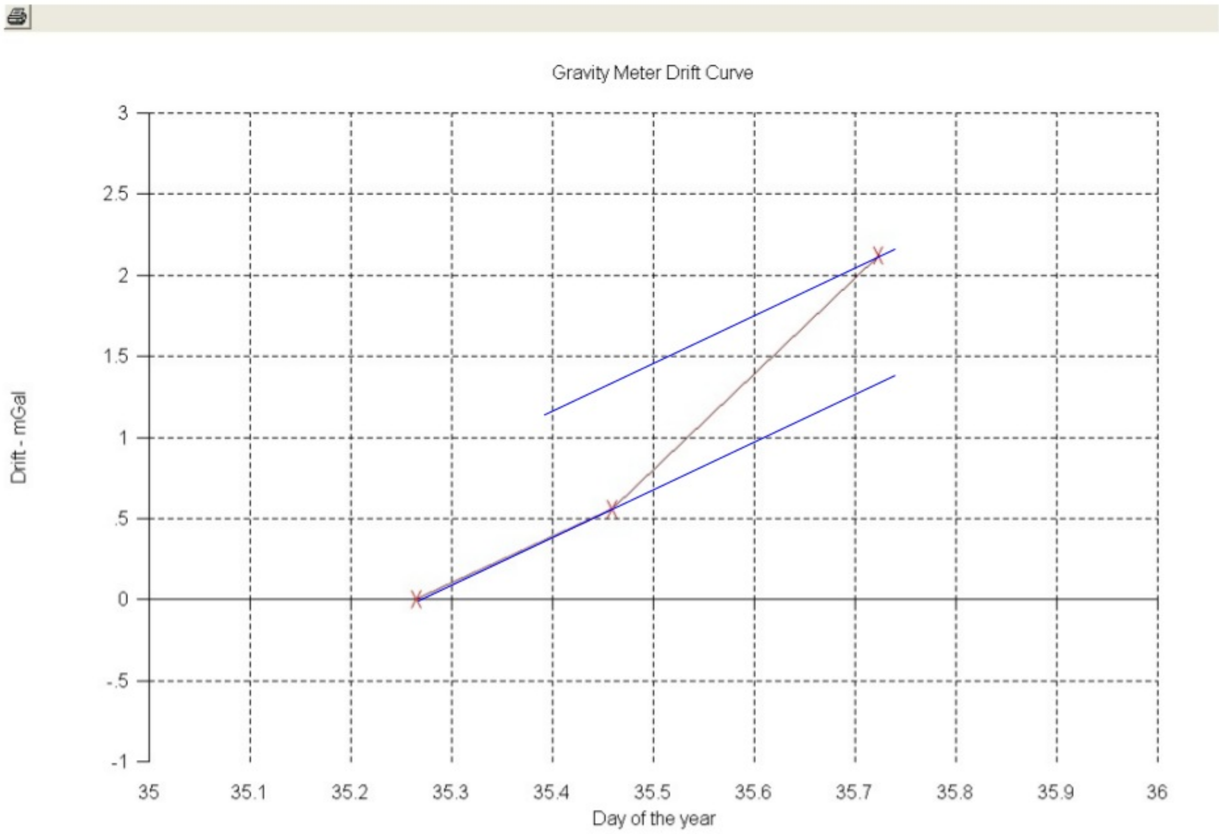
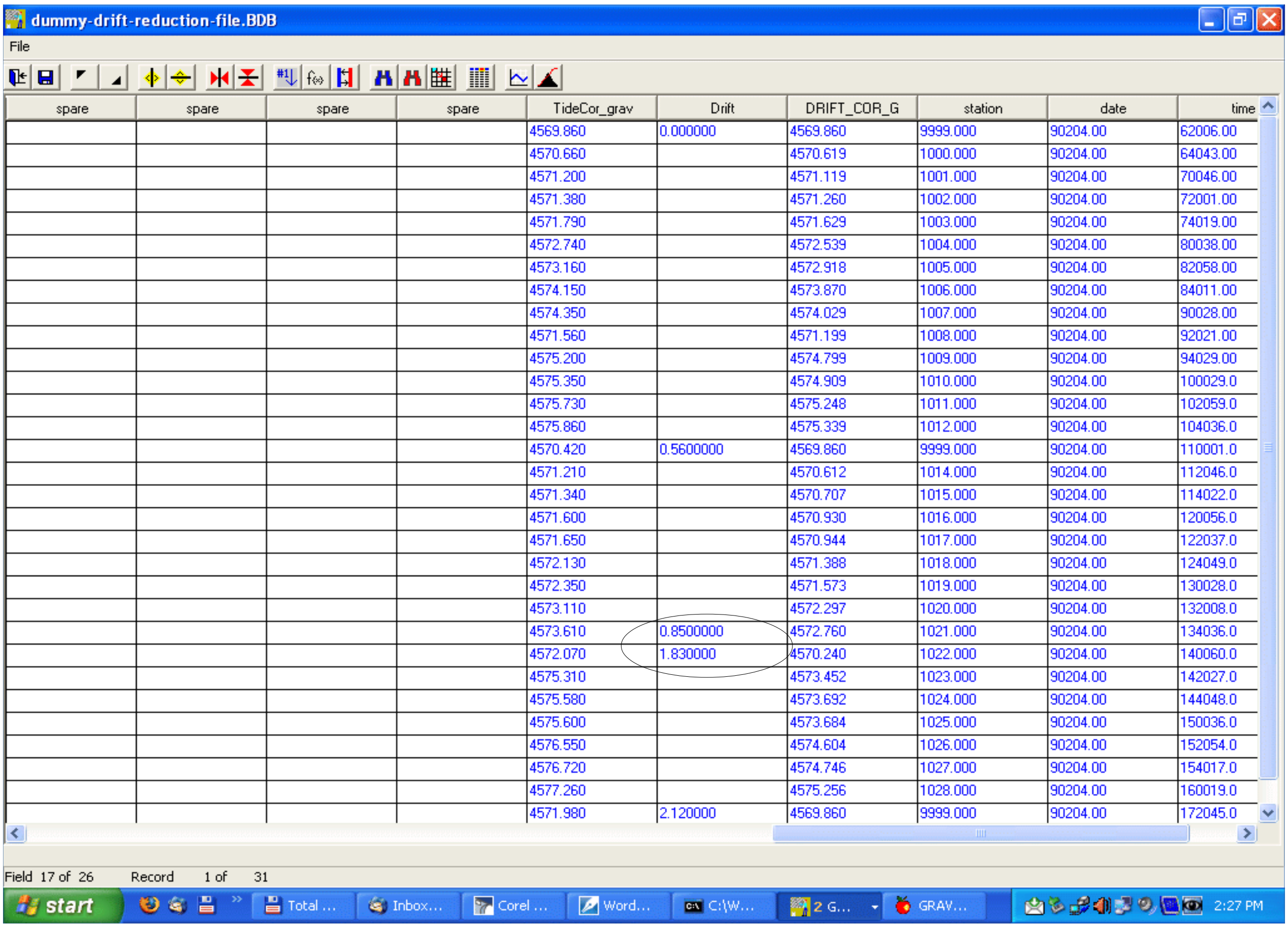


Figure 9: Field drift curve in red overlain with inferred true drift with tare (blue)



spare	spare	spare	spare	TideCor_grav	Drift	DRIFT_COR_G	station	date	time
				4569.860	0.000000	4569.860	9999.000	90204.00	62006.00
				4570.660		4570.619	1000.000	90204.00	64043.00
				4571.200		4571.119	1001.000	90204.00	70046.00
				4571.380		4571.260	1002.000	90204.00	72001.00
				4571.790		4571.629	1003.000	90204.00	74019.00
				4572.740		4572.539	1004.000	90204.00	80038.00
				4573.160		4572.918	1005.000	90204.00	82058.00
				4574.150		4573.870	1006.000	90204.00	84011.00
				4574.350		4574.029	1007.000	90204.00	90028.00
				4571.560		4571.199	1008.000	90204.00	92021.00
				4575.200		4574.799	1009.000	90204.00	94029.00
				4575.350		4574.909	1010.000	90204.00	100029.0
				4575.730		4575.248	1011.000	90204.00	102059.0
				4575.860		4575.339	1012.000	90204.00	104036.0
				4570.420	0.5600000	4569.860	9999.000	90204.00	110001.0
				4571.210		4570.612	1014.000	90204.00	112046.0
				4571.340		4570.707	1015.000	90204.00	114022.0
				4571.600		4570.930	1016.000	90204.00	120056.0
				4571.650		4570.944	1017.000	90204.00	122037.0
				4572.130		4571.388	1018.000	90204.00	124049.0
				4572.350		4571.573	1019.000	90204.00	130028.0
				4573.110		4572.297	1020.000	90204.00	132008.0
				4573.610	0.8500000	4572.760	1021.000	90204.00	134036.0
				4572.070	1.830000	4570.240	1022.000	90204.00	140060.0
				4575.310		4573.452	1023.000	90204.00	142027.0
				4575.580		4573.692	1024.000	90204.00	144048.0
				4575.600		4573.684	1025.000	90204.00	150036.0
				4576.550		4574.604	1026.000	90204.00	152054.0
				4576.720		4574.746	1027.000	90204.00	154017.0
				4577.260		4575.256	1028.000	90204.00	160019.0
				4571.980	2.120000	4569.860	9999.000	90204.00	172045.0

Figure 10: Adjustments made to stations either side of the tare

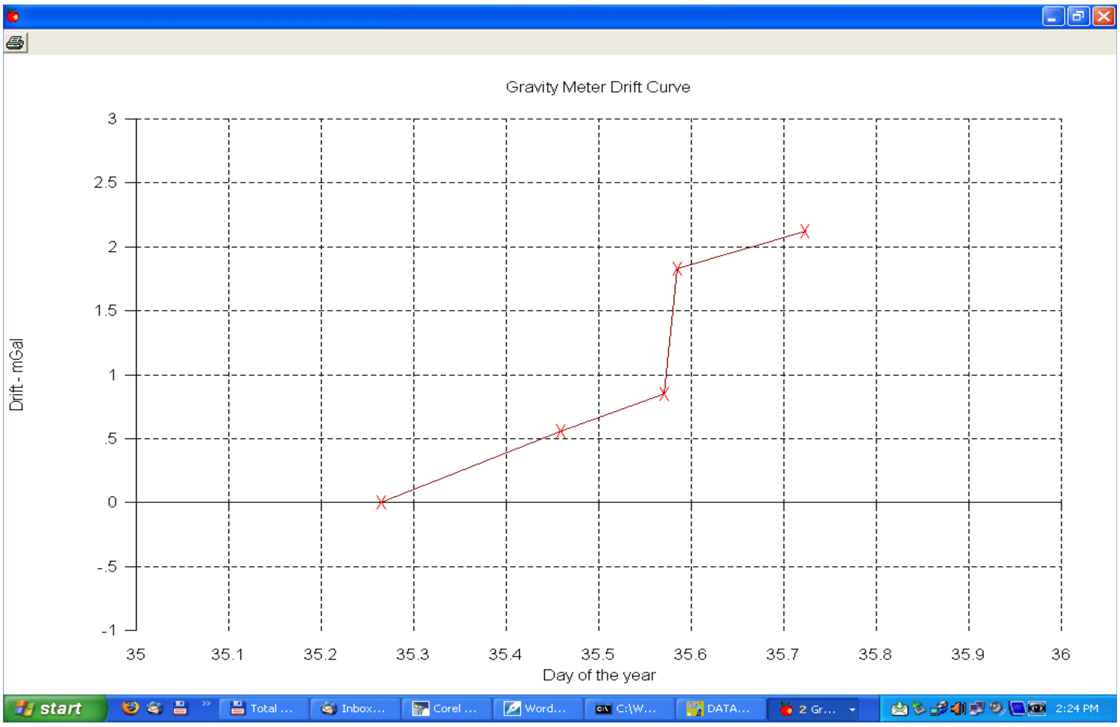


Figure 11: Drift curve after correcting for the tare

The drift curve should now look like Figure 11.

GROUND MAGNETICS

GMAGTOOL - Current Version: 1.0.0.12 Ground magnetics processing and reduction - 64 bit with multithreading - *several bug fixes, speed and performance improvements since last update.*

- Import a SatisGeo PMG-1 dump file
- Import a Scintrex Envimag dump file into a database *Extended to include more dump formats*
- Import a Geometrics G856 magnetometer dump file into a database
- Import a Geometrics G857 magnetometer dump file into a database
- Set the database header with field information
- Load and remove a diurnal field from a field reading based on a day and time lookup.
- Convert time or Lat/Long between HHMMSS format and a decimal
- Convert time or date from a three field entry to a single field

INDUCED POLARISATION

NB: IP database programs expect to see a database in a particular format, thus not all database programs are applicable to them

IPPROC: Current Version: 1.0.0.82 - 64 bit with multithreading

- Create a database from an ABEM Terrameter dump file. *Improvements to IP decoding and reading survey data information.*
- Create a database from an ASEG ESF format file
- Create a database from an Elrec 6 dump file, mods for early Elrec mode settings
- Create a database from an Iris BIN file, now extract data and time if included
- Create a database from a Geosoft IP format data file - **use for modern Search Exploration data and GDD DAT file dumps**
- Create a database from a Geoterrex format Huntec dump
- Create a database from a GDD16/32 or SCIP dump file
- Create a database from a GDD full waveform file. Note that this is not an IP database but can be edited with DBaseO
- Create a database from a Phoenix full waveform file. Note that this is not an IP database but can be edited with DBaseO. *Survey data now read from the .TBL file.*
- Create a database from a Scintrex IPR11 dump file
- Create a database from a Scintrex IPR12 dump file
- Create a database from a Scintrex IPR12 LST file
- Create a database from a Zonge RAW file
- Create a database from a Search Exploration DAT file
- Create a database from a Search full waveform file. Note that this is not an IP database but can be edited with DbaseO
- Create a database from a Smartem 24 TDIP .DAT file
- Sort a database based on line, station and n value
- Take the average or median of repeat readings, database must be sorted first using IPPROC. The user can select the percentile for the median and optionally ignore any negative readings when averaging noisy decays.
- Edit and view an IP database using a spreadsheet like editor. The editor is a stripped down version of the DbaseO editor but has a plot window added which plots decays for time domain data and phasor diagrams for frequency domain data The function button in DbaseO operates on a field at a time, in IPProc is works on all time windows for TDIP or all magnitudes or phases for CR data. This allows you to adjust all IP windows simultaneously to change units or apply an offset if needed. Added a flip decay button for reverse polarity decays or reverse phase phasors. Multiple decays or phasors can optionally be plotted if you have repeat readings and individual readings can then be deleted. The decay plot has a properties button to select between the default Log-log presentation and Log-linear or linear plots. Either a median or average can be overlain on the plot. Optionally plot a pseudo spectral section for a line and move a box around as you edit, this requires that the database is sorted. Deleting a reading no longer removes the reading from the database, rather it adds a flag to say do not use this reading. This allows you to un-delete readings if you later change your mind. The median or average decay plot can be set to use a non central median and ignore negative noisy values in computing the median or average. From the decay/phasor window or spectral pseudosection

plot all decays/phasors for the selected station can be flipped at once or deleted. The flip decay button on the spreadsheet toolbar only flips the decay or phasor for the reading the cursor is on. Spectral pseudosection can now be coloured by any field in the database. Added an electrode plot window to plot all the electrodes in the database and highlight those being used for the current reading(s). If you have stuffed up the plot point calculation and have two different electrode layouts producing the same plot point you will have more than 4 electrodes highlighted when displaying all repeats for a particular reading. Button added to compute a master decay curve shape which can be added to the decay plot window while the shape difference for each reading is written to the database.

- From the line, station, n value and survey parameters in the header compute the electrode positions. This is required for the 2D inversion so that multiple arrays can be inverted simultaneously
- From the electrode positions compute the line number, plot point and n value. *Extended to allow for the rolling gradient array used in ERI surveys.*
- Load all four electrode elevations using the X, Y coordinates in the database and a Surfer grid of elevations.
- Re-calculate the apparent resistivity and output the geometric factor
- EM decouple a CR data set using a choice of published 3 point formulae or your own 5 point coefficients
- Create a dummy n value for gridding as a pseudosection
- Assign down hole co-ordinates to a database from survey and collar files. Uses standard Micromine collar and survey files with some quick edits
- Fraser filter a dipole-dipole or pole-dipole data set with a user designed weighting.
- Resample a decay to a new set of window times in order to merge datasets with different time bases.
- Set survey details in extended database header
- Compute Swift's L/M decay shape parameter. Can be useful where decays are inverted and negative chargeabilities have been recorded as a result
- Compute the theoretical primary voltage anywhere in or on a halfspace. Useful for understanding data from downhole electrodes
- Compute a new chargeability from a user selected window range for Time Domain data.
- Re-order electrode positions. In order to compute apparent resistivities the inversion algorithms assume that current electrode C1 is closest to the potential dipole while potential electrode P1 is closest to C1. Failure to observe this will result in rubbish apparent resistivities - probably negative.
- Calculate a Newmont Geosection for dipole-dipole data
- Invert dipole-dipole data using the SGC inversion routine - no longer used
- Invert any array using a 2D model. This algorithm allows for electrodes any where in the plane of the inversion so it can accommodate topography and down hole data. This is 2D so you can only one line per database!
- Output the electrode positions to a .dat file suitable for class posting in Surfer. This is handy for plotting plans of double offset pole-dipole arrays
- Take a pole or dipole database and combine readings to generate a dipole database at deeper n spacings
- Output the data to ASEG ESF format file
- Output the data to a Geosoft XYZ file including all the survey information stored in the header as comments.

- Generate a pseudo-tomographic grid from a cross-hole survey
- Output the database in a format suitable for Loke's Res2dinv or Res3dinv. The 3D output has the option of outputting a trapezoidal mesh where you will have to use the graphic editor in IPProc insert dummy electrodes to fill the mesh or using the non-uniform mesh which does not require that electrodes to not sit on nodes. The non-uniform mesh can be handy when you have multiple vintages of data of different grids or where the line cutters have had too much to drink. However not that unless your electrodes are close to nodes the results are likely to be in error. Added visual indication of the electrode being moved and rainbow background graticule to help line electrodes up. Highlight the first malformed row on trying to exit the dot painting screen. *Added buttons to the trapezoidal dot painter to draw lines along rows or columns to help with large complex meshes. Optionally load all elevations from a grid rather than interpolate the dummy elevations from the true elevations.*
- Generate a DXF plot file of stacked decays for Time Domain data or phasors for Frequency Domain data. Decays can be Linear, Log/Linear or Log and plot in the normal plot point ie Pseudosection for dipole/pole data or plan for gradient data. Spectra can be coloured based on the value of a user selected field or on the basis of reading number.

Typical IP processing sequence

See also a detailed explanation of the workflow for a particular data set presented at the IP workshop held at the ASEG conference in Adelaide in 2016.
http://exploregeo.com.au/download_docs/Processing_IP_Data.pdf

1. Hopefully data will come in from the field as an instrument dump with some operator notes in a separate file. This is generally the best format to work with as it represents all the available data and should have had minimal opportunity for operator finger problems. Save these files to a "data-from-field" directory before you touch them.

2. Copy these files to your working directory. Note: we do not work on the files in data-from-field as it is important these stay pristine so you have something to go back to if you stuff up or if future versions of the software extract more information than the current version. Using IPProc and the appropriate instrument parser read the dump files into a BDB. On reading the dump file you will be presented with a header dialogue - fill it in! Some fields are read and loaded from the dump file, check that they concur with the values planned for the survey. You don't have a survey plan? Get one!

3. Unfortunately few dump file formats have valid information for the X and Y co-ordinates of all four electrodes, particularly with 3D arrays and so you will generally have to load these in, you may well have to also recalculate n values and dummy depths for pseudosection plotting outside of IPProc. This is particularly true if you are using offset arrays as few receivers yet support these as a standard. Most situations can be handled by the plot point computer in IPProc. However if that is inadequate the easiest way to do this and at the same time, leave a record for yourself and others of how you dealt with the data is to use BDOperate to re-organise the fields if necessary, populate those that are blank and recompute wrong values. An example from a double offset dipole-dipole survey is given below;

```
!re-arrange ELECTRODE fields FOR N-S LINES
ZDATA(41)=ZDATA(40)        !load C1Y from C1X
ZDATA(44)=ZDATA(43)        !load C2Y from C2X
ZDATA(47)=ZDATA(46)        !load P1Y from P1X
ZDATA(50)=ZDATA(49)        !load P2Y from P2X
ZDATA(40)=366700.0         !TX LINE NUMBER TO C1X
ZDATA(43)=366700.0         !TX LINE NUMBER TO C2X
ZDATA(46)=ZDATA(1)         !LOAD P1X FROM LINE NUMBER
ZDATA(49)=ZDATA(1)         !LOAD P2X FROM LINE NUMBER
ZDATA(2)=(ZDATA(41)+ZDATA(44)+ZDATA(47)+ZDATA(50))/4.0          !DIPOLE-
DIPOLE
ZDATA(6)=(((ZDATA(41)+ZDATA(44))/2.0-(ZDATA(47)+ZDATA(50))/2.0)-
HARR(12)/2.0)/HARR(12)
                           !CALCULATE THE N VALUE FOR DIPOLE-DIPOLE
ZDATA(57)=-(ZDATA(6)/2.0)*HARR(12)                     ! CALCULATE THE
DUMMY DEPTH FOR ALL ARRAYS
```

4. The field numbers in your database may be different so expect to edit these! HARR(12) above has the dipole size in it which you set in the header. Additional lines could be added to calculate a unique line number for offset arrays in cases where the instrument does not handle this step well.

5. Sort the data using IPProc rather than DbaseO as the sorting is done on the basis of Line, Station and N value.
6. You can now open the database in the editor and plot a spectral pseudosection. Initially set the colour field to blank otherwise the result will be messy if you have repeat readings. Assess the noise level in the data. You should also consider at this point whether the default chargeability window is appropriate or whether you should be recalculating it. Also plot the electrodes and ensure they look sensible or at least what you expect them to look like. If you are happy you have all the data in and there are no typo's in station numbers or similar problems with the database then make a copy of the database and add the extension _clean to the filename. This will become the database you use for editing and removing bad readings. It is likely that you will have no further need for the original database but keep it in case you make a mistake or if the whole data set is needed at some stage in the future. If you think the chargeability needs re-binning do it now on the _clean database. Rebinning should include as many windows as possible to maximise the noise reducing effect of the integration but narrow enough so that you are working in a relatively noise and EM coupling free part of the decay. If you are living in the past you can even compute a Newmont chargeability or more correctly a Newmont like chargeability. See presentations by Kingman for an explanation of why this is not a good idea.

7. Using IPProc's editor, edit the data, display all repeat reading decays or phasors along with the median or average (generally the median works best). Note that while in the editor you should refrain from using your mouse wheel, instead use the keyboard arrows or vertical scroll bars. There is an undocumented feature in the editor which causes it to lose its current record number if the mouse wheel is used often. This will cause it to crash and you'll

lose any edits you made! If time domain data then set the threshold alarms for excess secondary voltage and low primary. These alarms change the colour of the grid lines if breached by any one of the readings and provide a quick visual alert that there is a problem. It is difficult to see how the secondary voltage could ever be more than the primary voltage which is why the default for the over voltage alarm is set to the same as the primary i.e. 1000 mV/V. In reality, chargeabilities much above 100 mV/V in standard exploration data may indicate a problem. Each instrument has a sensitivity floor, with respect to input voltage, below which the readings are suspect. You should set the low primary voltage warning to a level appropriate for your instrument , that is not to say readings with Vp below this threshold should always be deleted but they should be treated with care.

Resolutions for some receivers are given in the table below.

Receiver	**Manufacturer claim**	**Practical limit**
Scintrex IPR12	0.01 mV	0.5 mV
Zonge GDP32II	0.00004 mV	
Elrec Pro		0.2 mV on a good day
Elrec 6 or EDA IP6	0.1 mV	0.2 mV on a good day
Search Fiberbyte Rx		0.2 mV
MIMDAS		
Smartem/IP	0.0002 mV	
GGD 16/32		0.1 mV on a very good day

8. The gaps will be filled in as they are determined. If there is a strong correlation between high chargeabilities or phases and low primary voltage you probably need to raise your Vp threshold.

9. Edit out bad readings, either individually or as a group of repeats. Taking time to undertake careful editing at this time will pay dividends when it comes to inverting the data. So although a typical double offset array consists of around 4000 readings which can take anywhere between one hour and 6 hours to edit depending on the quality of the data, this is time well spent. Don’t look for shortcuts! Shortcut experts have looked before you and have failed.

10. Some guidelines for editing.
    1. Decays should decay! Phasors should grow to the left with increasing frequency.
    2. For offset arrays readings with n=0 may be rubbish if the ground is homogenous and the potential electrodes lie on equi-potentials. If so, they should be deleted, readings for n=1 and n= -1 may also be affected, particularly if the current dipole is twice the size of the potential electrode.
    3. The only numbers that go into the inversion are chargeability or phase and apparent resistivity so for time domain data you may be able to accept a relatively noisy decay if the time region you are integrating chargeability from is well behaved.
    4. Although negative chargeabilities are physically possible (e.g. on sharp contacts), common inversion routines can not handle them so if you put

negative IP values into the inversion they will be ignored and in the case of Res3Dinv the inversion will run the resistivity and IP sequentially rather than together.

10. Once you have been through the database, regenerate a spectral pseudosection with a linear colour range for chargeability and scan it to see that you that you have not missed any clangers. If it appears OK then average repeat readings. Add the extension _MAV or _AVE, depending on your choice of averaging algorithm, to the filename. Rebin the chargeability as the median or average of the chargeabilities may not be the same as the chargeability of the median or average decay. Plot a spectral pseudosection of the averaged data using a linear colour range based on your chargeability (Field 10). If the resulting plot is largely purple then you probably have to do some more editing. Check the histogram of chargeability from the averaged database in DBaseO see if deleting a couple of high outliers fixes the problem. Repeat until you either have a pseudosection with most of the rainbow in it or if you plot up a non-linear version you can see why you should not have a rainbow and highs line up along current or potential legs on the psedosection. If you have not already done so, generate a Dummy N value and grid the chargeability for each line in the database with DBaseO using a cell size of half a dipole spacing. Overlay contours of these grids on your spectral pseudosections in Surfer or QGis and check for bullseyes. Save the raw all, edited and merged non-linear psedosections as a Surfer or QGis project for later reference.

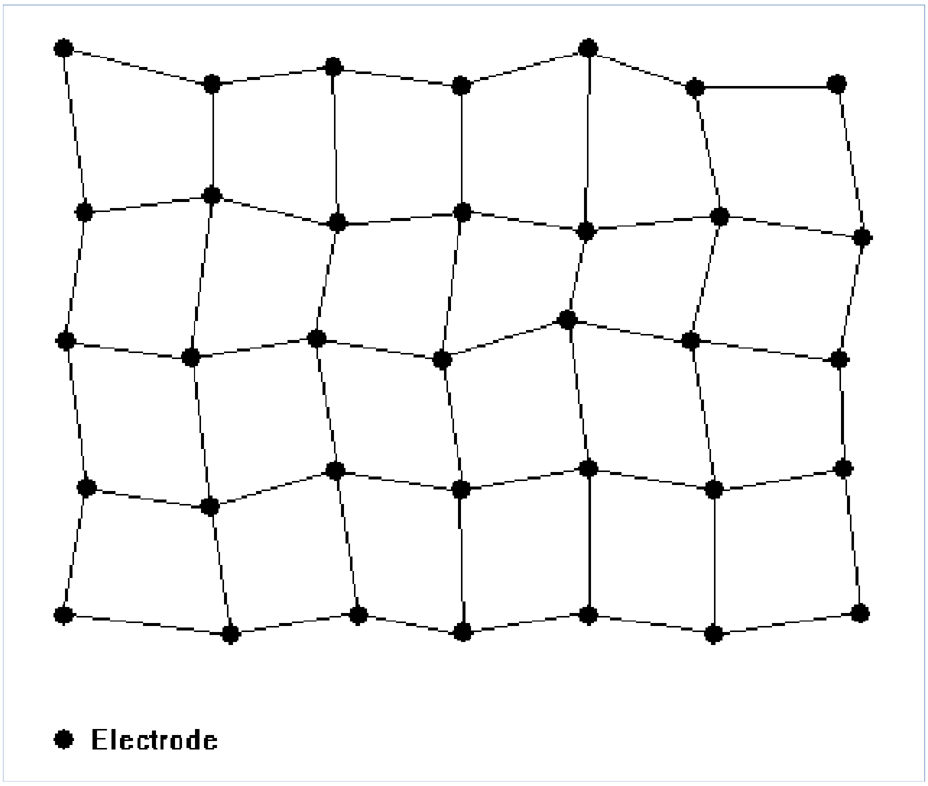
11. You should now re-order your electrodes in IPProc (Utilities|Reorder Electrode Positions) so that C1 is the closest current electrode to the potential electrodes and P1 is the closest potential electrode to the current electrodes and recompute the apparent resistivity. If you are dealing with an offset array no receiver can calculate apparent resistivities properly so you must do this. However, it is always good practice regardless of the array.

12. You now need to load the electrode elevations. Generally this is done using a lookup to an SRTM DEM grid in IPProc but if you have better elevation information you should use that so long as all electrodes have their elevations set. If you are working in a local grid and have an elevation source in another you will have to either do a grid rotation or a look up in DBASEO and compute a second set of electrode coordinates which you should store deeper in the database rather than generating yet another database - keep both sets of coordinates. You probably only need to have one set of elevations though.

13. From IPProc create a file of electrode positions (Output|Export electrode positions to Surfer/QGis) using whichever coordinate set you plan to display the data in. Check that it plots where you expect and looks right! You are now ready to export the data to Loke for inversion. Ideally you should use whichever coordinate set has lines running N-S or E-W as creating a finite element mesh on angled lines will be time consuming and result in a bigger inversion problem than needed. Because of the way Res3Dinv stores the mesh, IPProc prefers to see EW lines but it will tell you if it encounters a N-S line direction in the header however you can chose to ignore this message. Detailed instructions on how to proceed from here are included below.

Exporting data to Loke's software for inversion

14. For 2D, IPPROC and Res2dinv give similar results. Res2dinv has some advantages with noisy data but these could probably be addressed by changing the damping factor in IPPROC (see Loke's notes on this). Res2Dinv also returns sensitivity and resolution information which IPProc does not currently do.
15. The 3D export is more likely to be used however. Res3dinv has the option to work with trapezoidal meshes and non uniform meshes. Previously, the finite element mesh had to have rectangular cells so data collected on meandering lines with GPS pickup required a fine mesh in order to have electrodes on the cell nodes (a requirement of the finite element approach). This meant that the size of the mesh required to fit the electrodes to a mesh was relatively large which impacted on the amount of data that could be inverted at one time. The trapezoidal mesh removes this hurdle and should allow most 3D surveys to be inverted in one run. It also allows the remote current electrode to be included in the mesh rather than assuming it is too far away to matter (usually a false assumption). Below is shown an example 7 x 5 trapezoidal mesh.



16. The mesh must have an identical number of electrodes on each row and column. However, although electrodes must be defined for all nodes, readings do not have to involve all electrodes i.e you can create dummy electrodes to fill the mesh. IPPROC's 3D Loke export helps you do this. The subroutine optionally starts by gridding the topography from all electrodes so than any dummy points can have a semi-realistic elevation assigned to them. It can also load all the elevations in directly from a grid. This is the preffered approach, particularly in mountainous areas. It then displays the actual locations of the electrodes used in your survey. These are superimposed on a mesh of cell size selected by you but small enough so that only one electrode lies in any mesh

rectangle. The actual electrode location is indicated by a red dot while the cell it belongs to is shown by an green rectangle. Initially these overlap. Think of this mesh as a matrix storing the indices of the electrodes for the trapezoidal mesh i.e. not all cells need to be filled but all rows containing data must have the same number of data points. If your survey lines run north-south exchange rows for columns in the above and following discussion. Figure 12 shows the initial output from IPPROC.

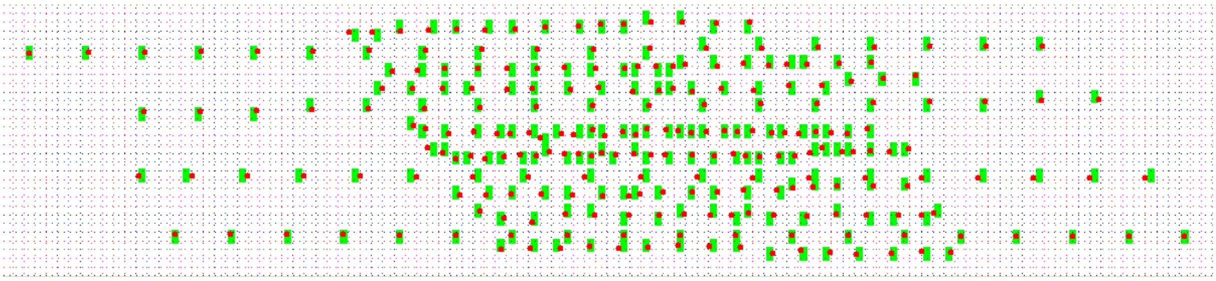


Figure 12: Initial output from IPPROC. Red dots = real electrodes, green rectangles = cell that electrode belongs to in the mesh matrix. Cell size is 40 x 40m

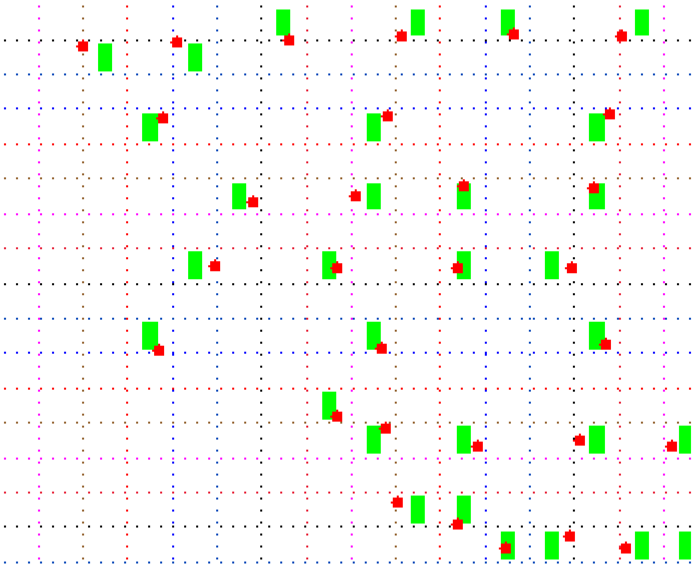


Figure 13: Close-up of initial output from IPPROC. Red dots = real electrodes, green rectangles = cell that electrode belongs to in the mesh matrix. Cell size is 40 x 40m

17. The first step is to re-assign electrodes to nodes on common lines. Note we are not moving electrodes here. All we are doing is generating a matrix with an equal number of non-null points on any non-null line. To do this use the Move button on the toolbar, click on the green node you want to re-assign then the node you want it assigned to. The southern most survey line in Figure 12 consists of 16 electrodes which are currently assigned to two rows in the mesh matrix. To complete this line the nine northern electrode nodes will have to be moved south, or the seven southern electrode nodes will have to be moved north. After this, dummy electrodes will have to be added to both ends of the line since the real electrodes do not extend as far west or east as some of the lines to the north (this is covered in point 18). After re-assigning an electrode position the display will be re-drawn and the new node coloured after each paired mouse click. To assist in tight electrode patterns the

electrode you are re-assigning will be highlighted while the move tool is active. Figure 14 shows the result when this process has been completed.

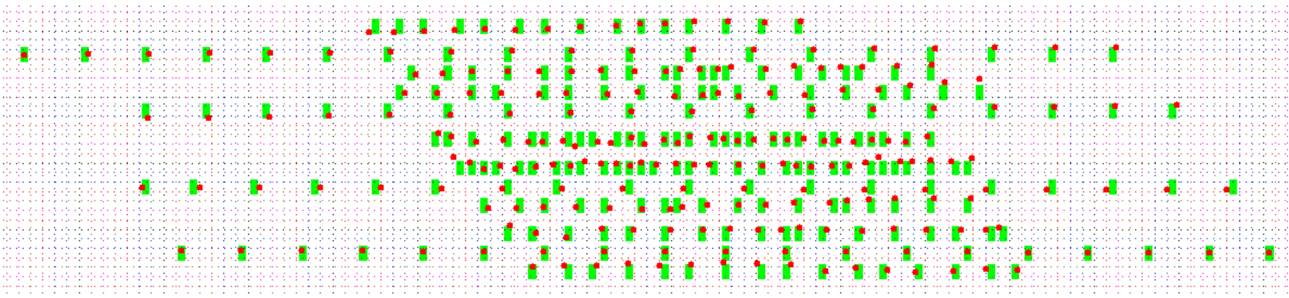


Figure 14: Output with electrodes re-assigned to appropriate cells

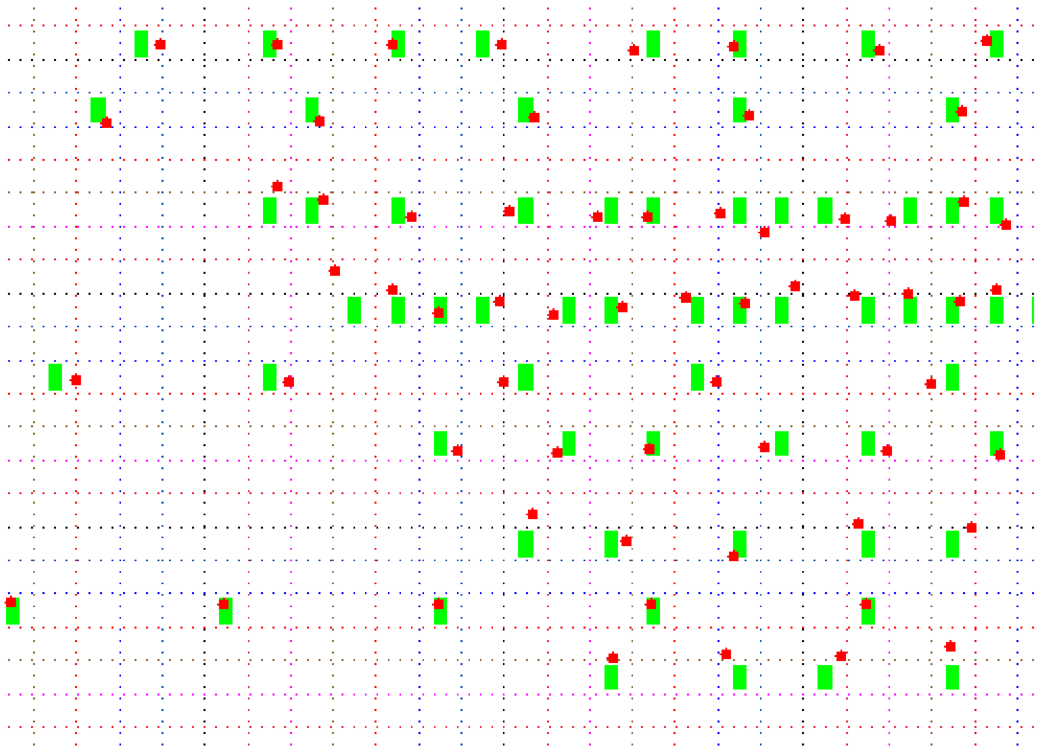


Figure 15: Close-up of IPPROC output with electrodes re-assigned to appropriate cells

18. The next step is to generate dummy electrodes to meet the requirement that each non-null row must have the same number of points. To do this cancel the MOVE mode by clicking again on the now depressed MOVE button. You should now have a cross hair cursor and each click will result in a blue diamond being placed where you click. If you make a mistake click on the delete button and delete that dummy electrode. Note you can not delete actual electrodes, only dummies. If you activate the delete button by mistake or want to finish deleting just click on it again to cancel delete mode.

19. Note that the position ascribed to the dummy electrode is the position of your cross hair when you clicked. In order to not distort the trapezoids too much you may need to put a dummy electrode in the wrong row of the matrix then use the move button the re-assign it to the correct row in the matrix. This can be seen clearly in Figure 17 on the third and forth lines from the bottom.

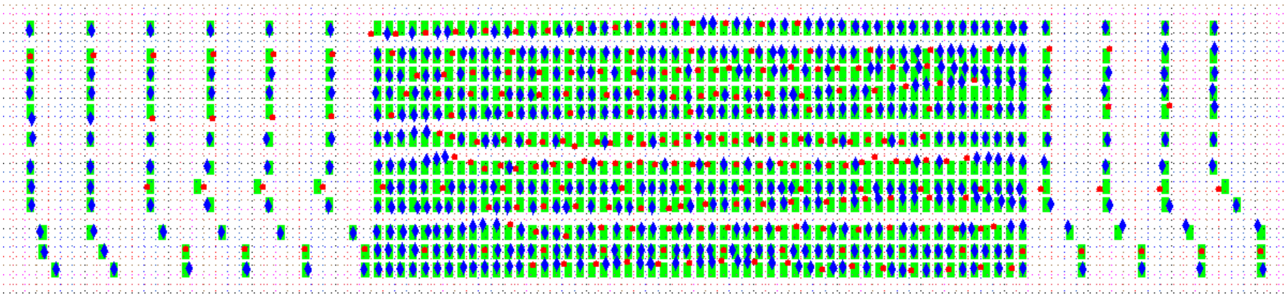


Figure 16: Output complete with dummy electrodes (blue diamonds)

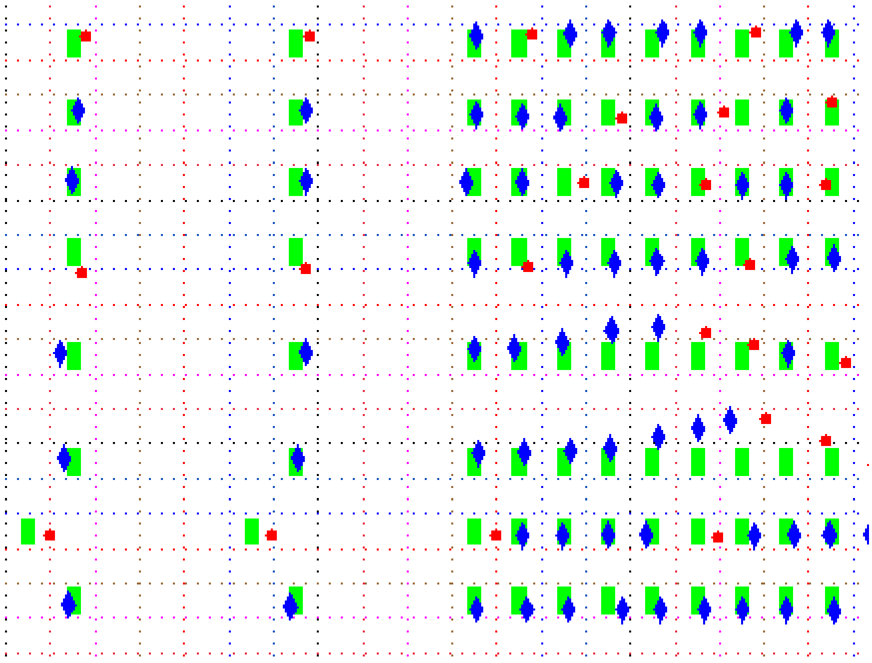


Figure 17: Close-up of output complete with dummy electrodes (blue diamonds)

20. Some things to note about mesh design;
    - The aspect ratio of a single cell should not exceed 4:1
    - Adjacent mesh voxels should not have more than a factor of two difference in size
    - Cells should be as rectangular as possible. Avoid angles of less than 30°

21. When you are happy you have an equal number of electrodes on each line click on the save and exit button. The routine will then check that you have in fact got your configuration correct and then either plot up a picture of your mesh and then write the Res3dinv file or report an error and drop you back in the display screen to fix your mistake.

22. Remember you are not moving electrodes, only the way the computer stores them. If someone finds code or an algorithm to automatically generate a trapezoidal mesh from an incomplete random data set let me know.

Cleaning up IP data prior to inversion

The quality of the inversion will depend to a large extent on the quality of the input data. Rubbish in = rubbish out!

Frequency Domain:

For CR data the 3 point decoupling algorithm assumes that over the frequency range collected (~1 decade for standard CR) the IP response of the ground is a constant while EM coupling is related to frequency by a polynomial. Laboratory tests on rocks indicate that over 1 decade of frequency the variation in phase is low but can vary by as much as 50%. Unless the data are very seriously effected you will probably not be able to tell from conventional pseudosections that you have a problem. You should start by plotting a spectral pseudosection of that data and remove any noisy phasors using the editor in IPPROC. Next work your way through the data one reading at a time in IPPROC's editor. For co-linear dipoles, EM coupling acts to increase the phase, this will not be true for off line dipoles (e.g. gradient array) which may show a mix of positive and negative coupling depending on the dipole axis offset. Orthogonal dipoles have little or no coupling. Looking at the phasor plots ensure that the decoupling has moved the phase in the correct direction and also that it has not over-corrected and made a positive phase, negative. Delete readings that have incorrect decoupled phase. The phasor plots have contours of phase across them to help calibrate the response. If your data plots with a contour interval greater than 4 mRad it is likely that you have more than just the ground's IP response in your data. The following are some example phasors saved to clipboard from the phasor plot in IPPROC using the metafile/clipboard button. The blue dot in these figures is Zonge's standard 3 point decoupled phase value. Phasors are normalised to the fundamental frequency and thus always start with a real value of 1 for the fundamental. Some examples of good and bad phasors are shown in the following figures.

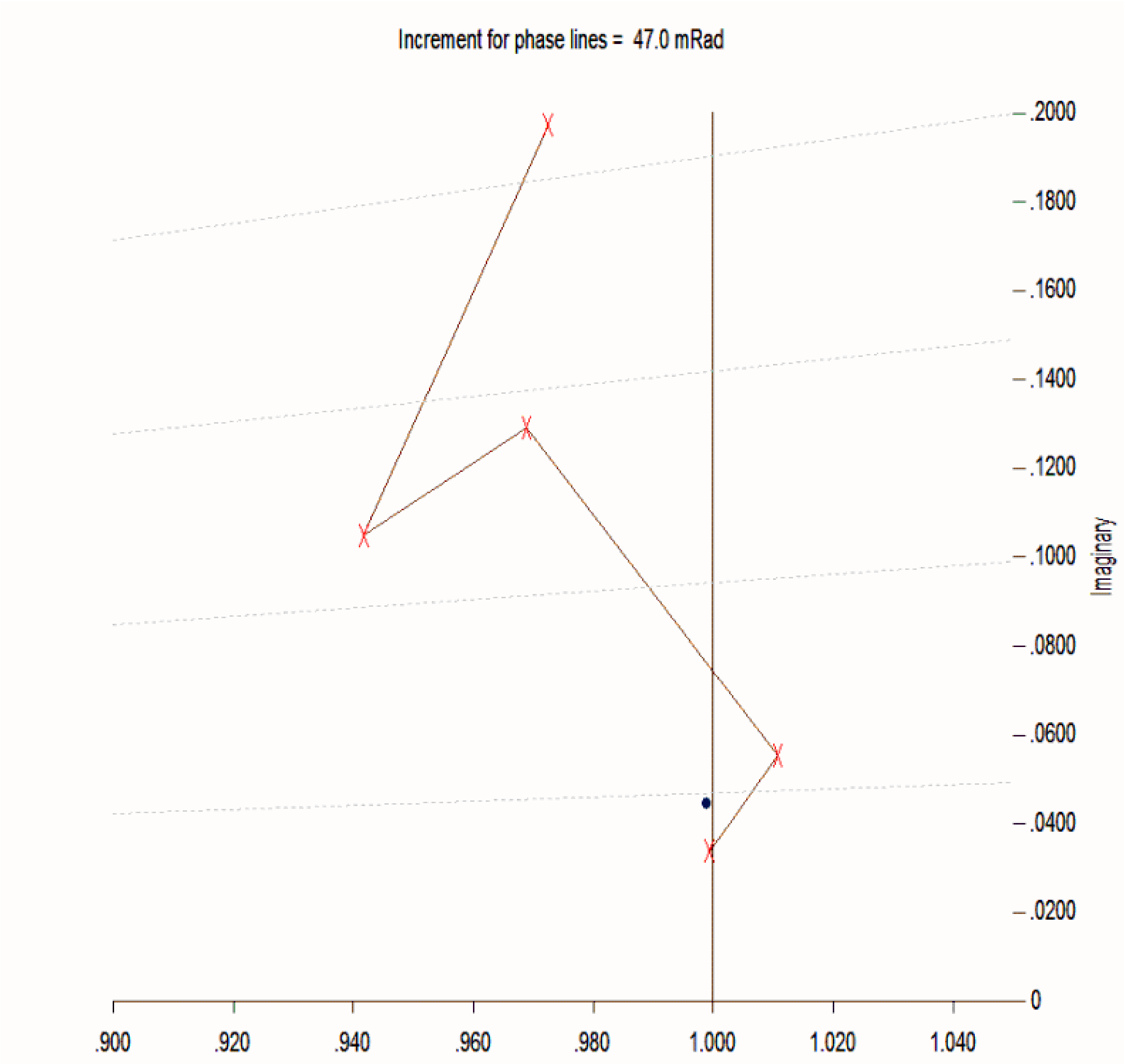


Figure18: 3 point decoupling not working here due to noise. The blue dot is the decoupled phase

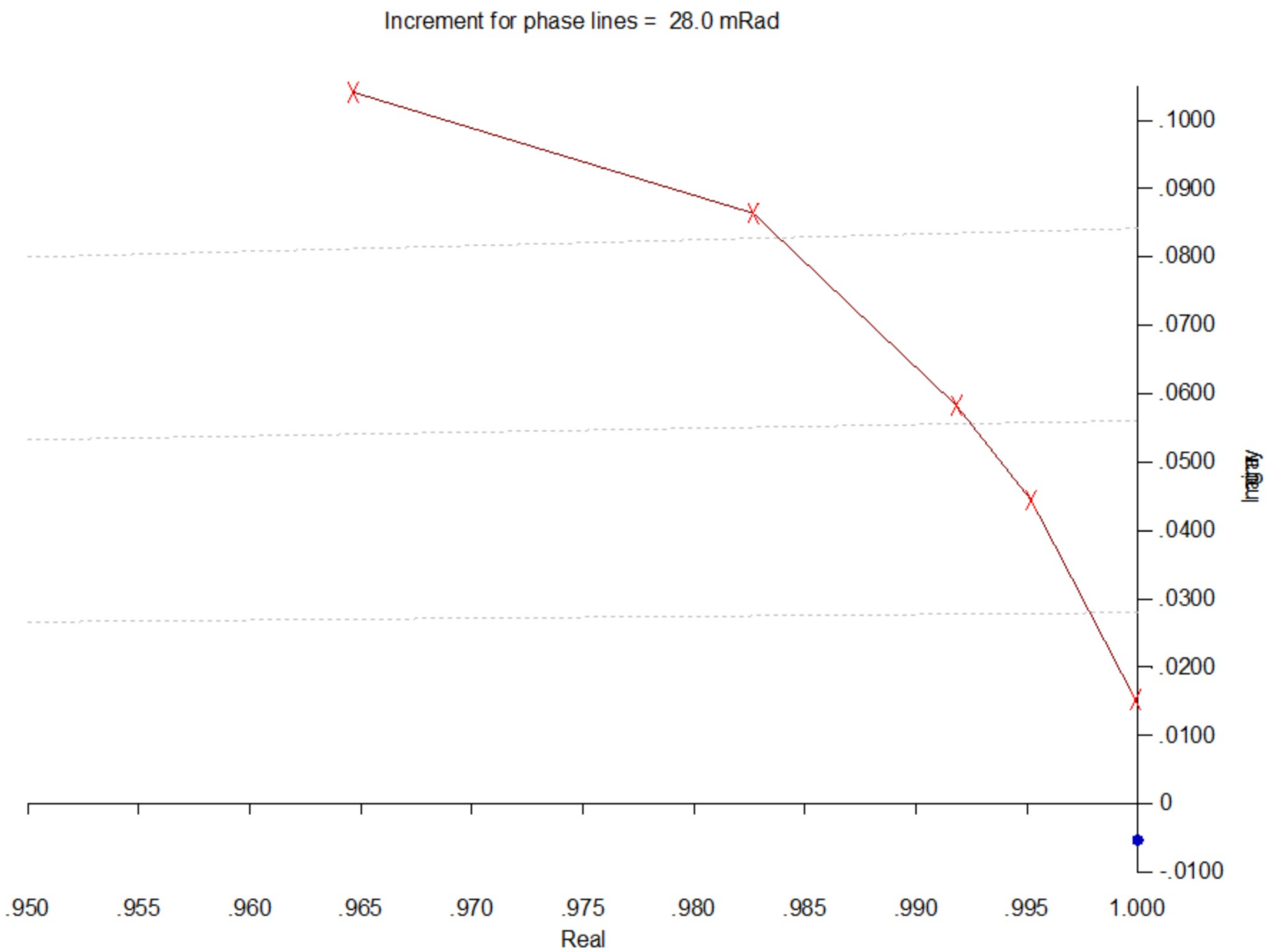


Figure 19: Serious EM coupling has been over corrected by the standard Zonge 3 pt decoupling. It may be salvageable using another decoupling approach

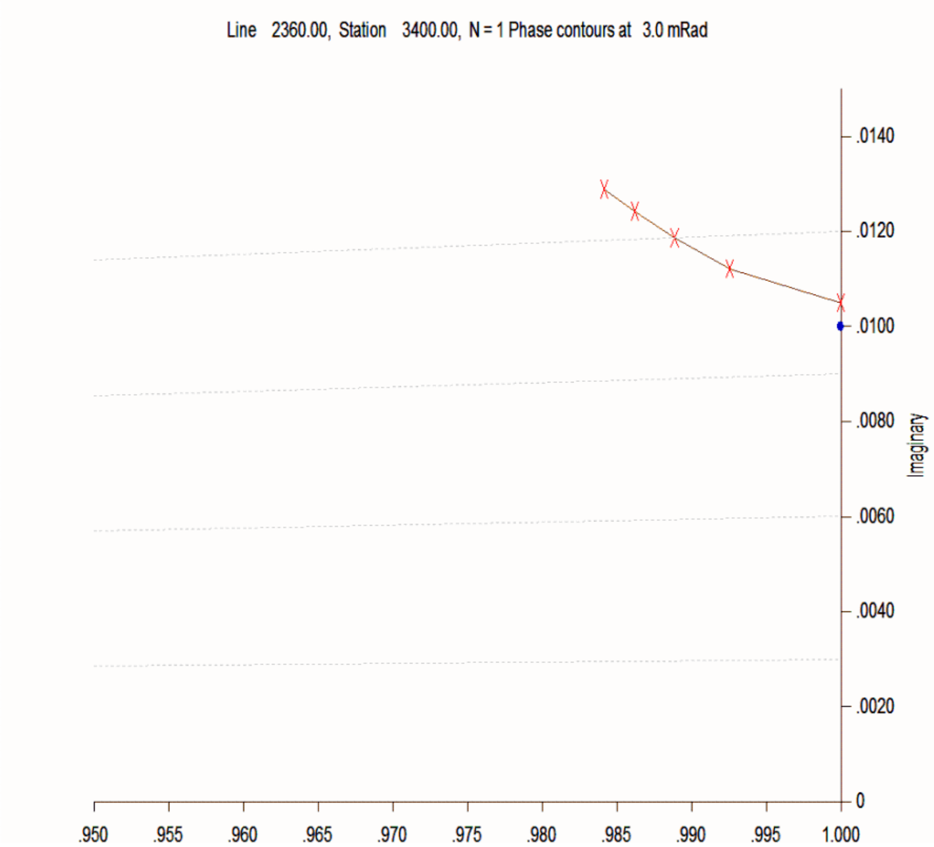


Figure 20: Phasor looks to be essentially free of EM coupling. Note that phase varies by <30% and magnitudes are nearly constant

Time Domain:

A similar process needs to be followed with Time domain data. Start by plotting a spectral pseudosection or plan of the data. The most obvious stations requiring editing will be those that plot upside down (see fig 21). This can happen when the electrode wires have been plugged into the receiver back to front or where the receiver has synchronised to the transmitter 180° out of phase or more commonly where the current is flowing backwards relative to what it would do in a half space. It is particularly common in down hole data, especially when both the transmitter and receiver are below ground. It can also happen in areas of extrem topography where the current electrodes are on one side of a hill and the voltage pots on the other, the shortest current path is not always along the ground surface over the crest of the hill. Another source of reversed decays is severe negative EM coupling and negatively polarised materials. These upside down decays may be “fixed” by pressing the flip decay button in IPPROC’s editor. In practice you are best to delete these decays but if you are chronically short of valid data and the flipped chargeability value looks about right relative to its neighbours, you can fudge it. So long as you remember that the anomaly will have different properties than implied by the inversion and that you are really only interested in its shape and location then this approximation is forgivable as the other option would be to remove them from the data and have nothing to invert. Sign flipping is fairly straightforward, noisy decays are more of a problem.

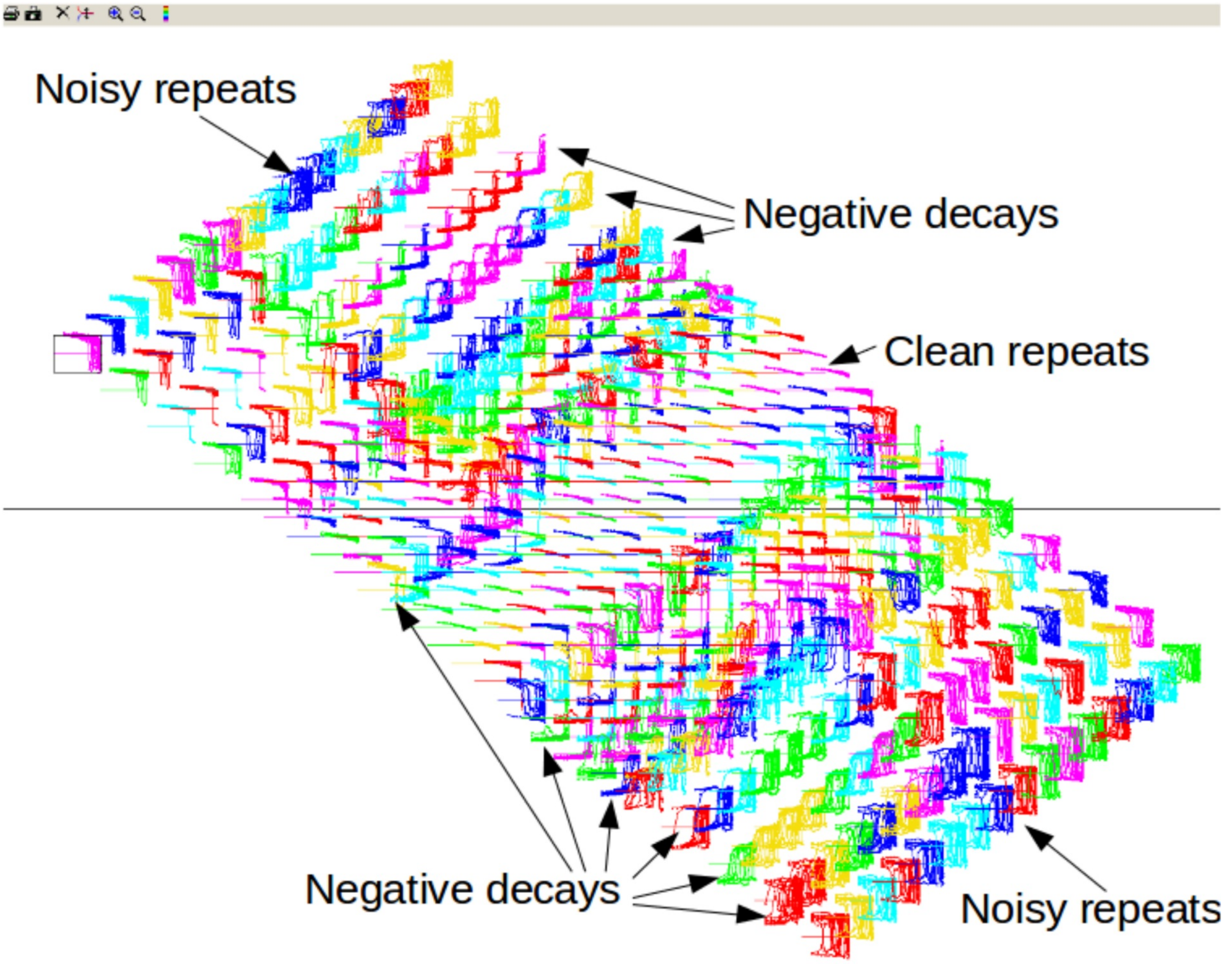


Figure 21: A spectral pseudosection showing decays for all readings, coloured by reading

You will have to judge how much noise is too much. Remember that when averaging repeat readings in IPPROC you have the option to take the median value rather than the average. This obviously only works for stations with more than 2 repeats. Taking the median may clean the data up enough to save you having to edit single bad readings out. Another thing to bear in mind is to keep enough repeats if you are relying on the median filter to do the work of cleaning the database.

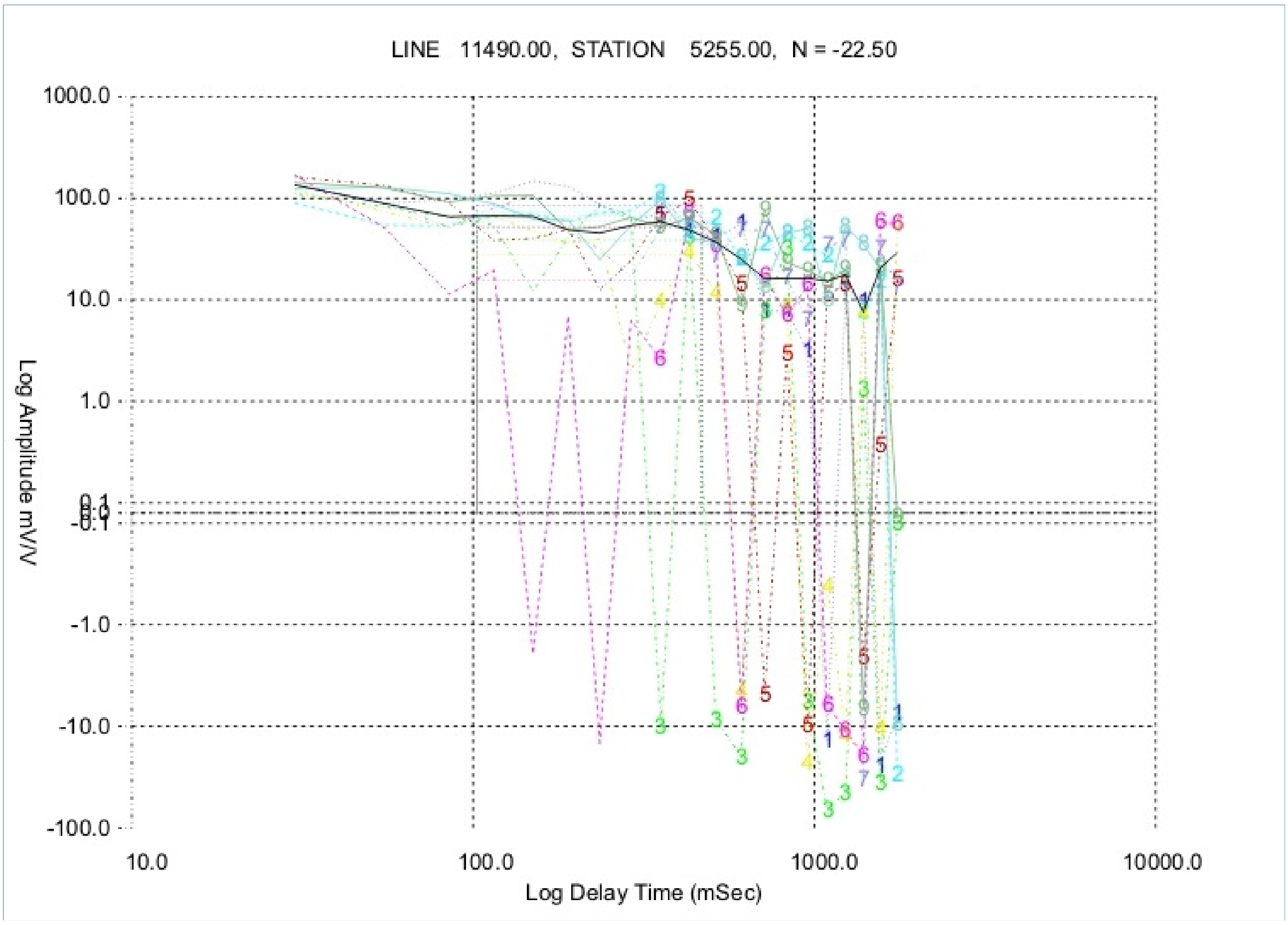


Figure 22: Example of noisy repeat readings salvaged by a median (black line)

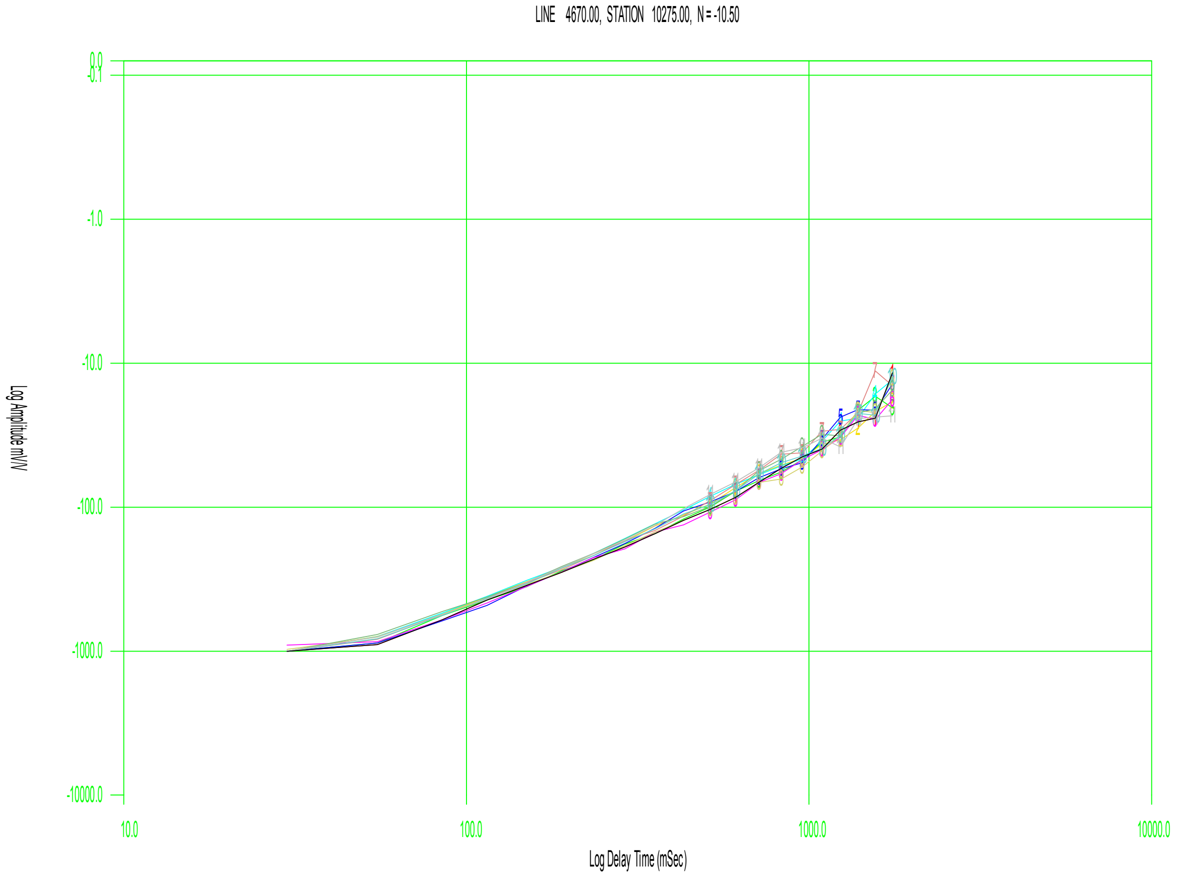


Figure 23: More than 10 repeat readings with good repeatability but negative chargeabilities. Note the green axis flag indicating excessive secondary voltages so these should all be discarded rather than flipped - just remember if flipped it is unlikely to be real so the IP anomaly recovered by the inversion will have meaningless parameters, just use its shape and position.

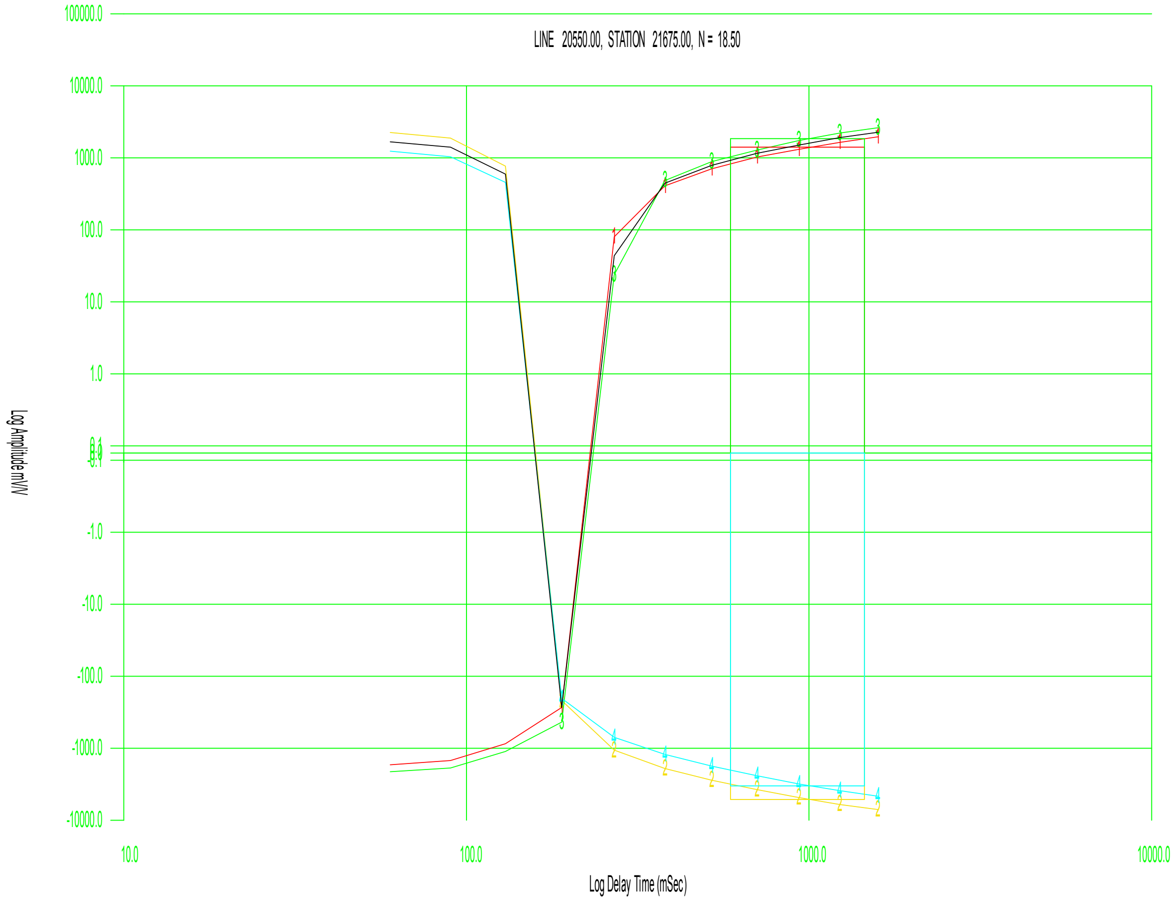


Figure 24: Mirrored S shape decays from the same station. Note the green grid indicating high secondary voltages. Delete these as they are probably due to very poor signal.

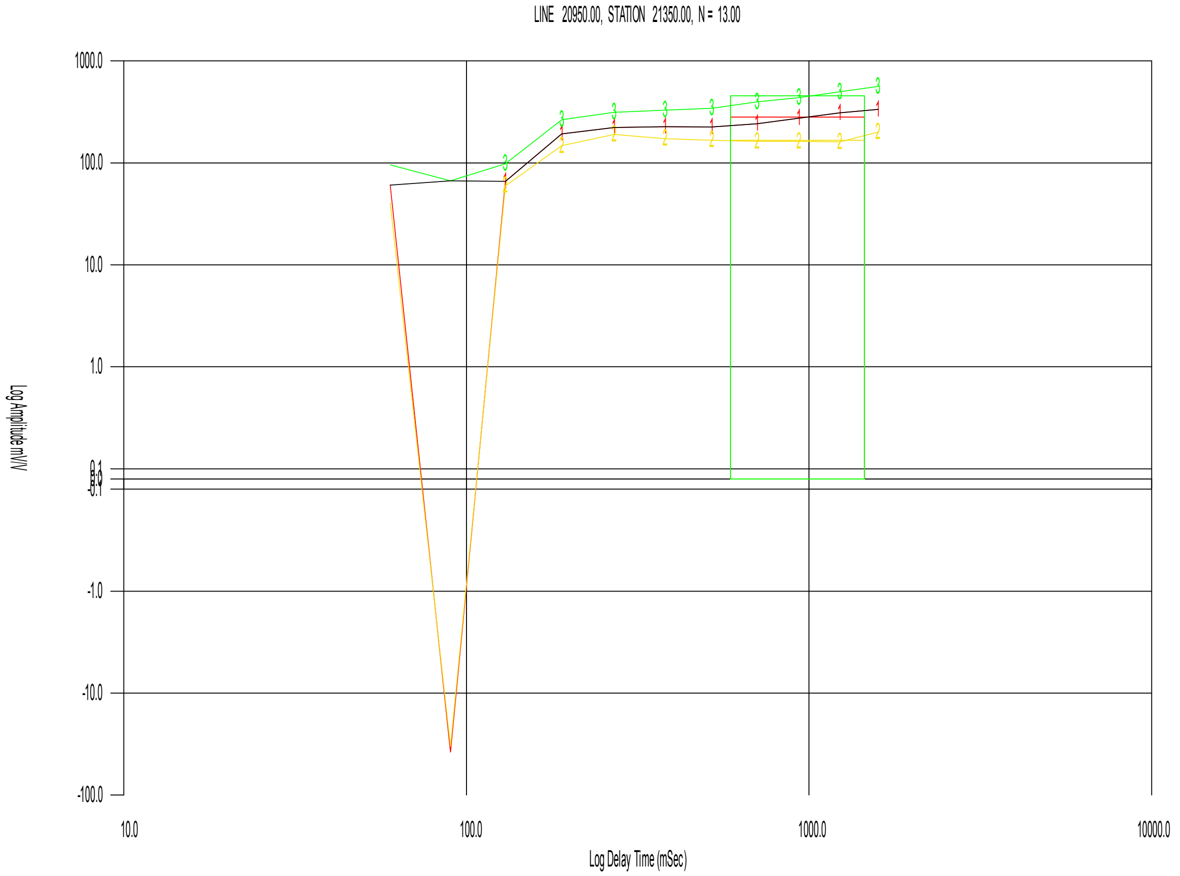


Figure 25: Decay does not decay - delete

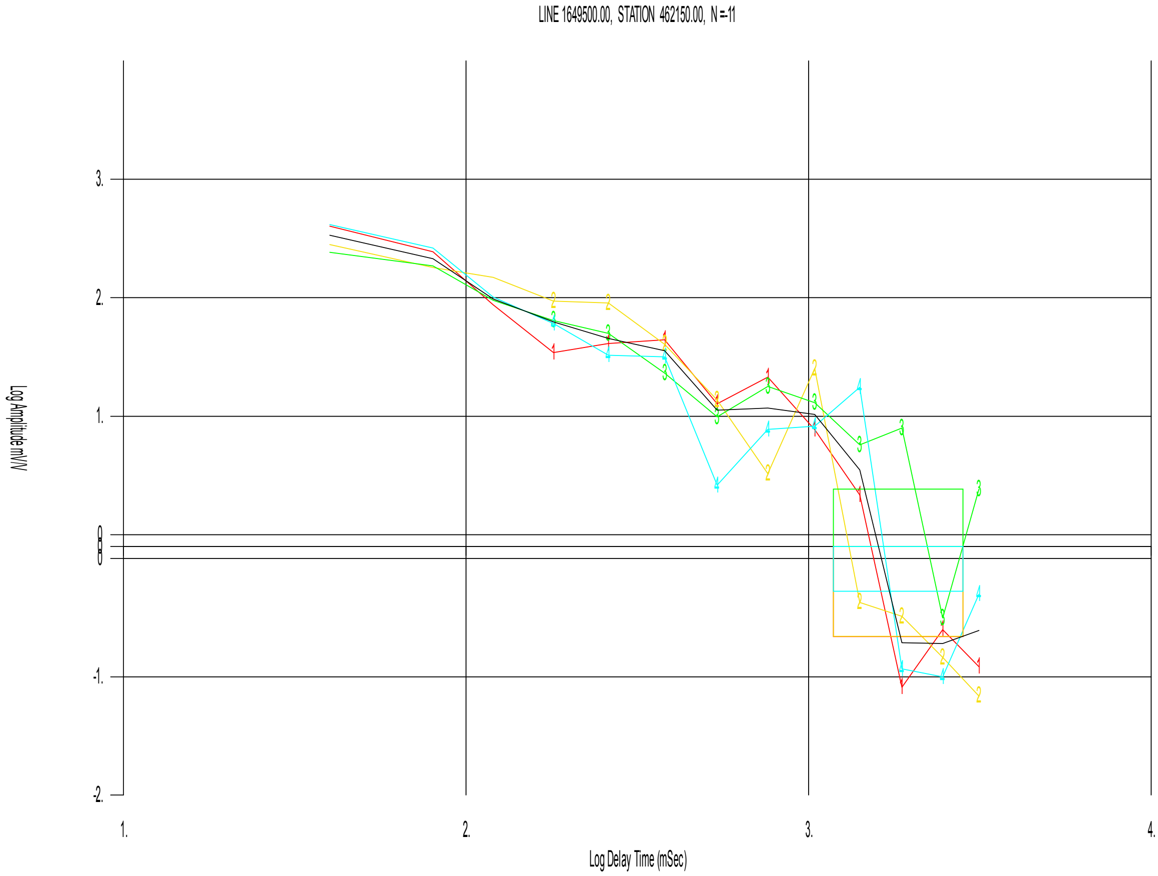


Figure 26: Using the Mx integration window shown this reading would be deleted. It may be usable if an earlier integration window were selected.

Notes on Inversion

The 2D inversion routine built into IPPROC allows electrodes to be anywhere in space in the X and Z plane but assumes they are all contained within the Y plane you are inverting across. You must start with a standard IP database with all header details set. The database should be sorted and have repeats averaged using IPPROC. **There should only be one survey line of data per database**. You can mix arrays within the one database but must then set the dipole size in the header to the smallest dipole used and must explicitly set all electrode positions within the database. You should not mix IP data from Time and Frequency domain surveys unless you just want an answer for resistivity.

As you can see from the screen dump in Figure 27 you will need to specify the fields containing the current and potential electrode X and Z locations (Z is positive up). Where you have fixed remote electrode(s) such as in Gradient array or Pole-dipole ensure the electrode location is specified correctly in the header and enter 0 for the field number for the fixed electrodes X and Z location. Databases with conventional arrays can have their electrode positions calculated using IPPROC while the Z co-ordinate can be added using a lookup table and DBASEO.

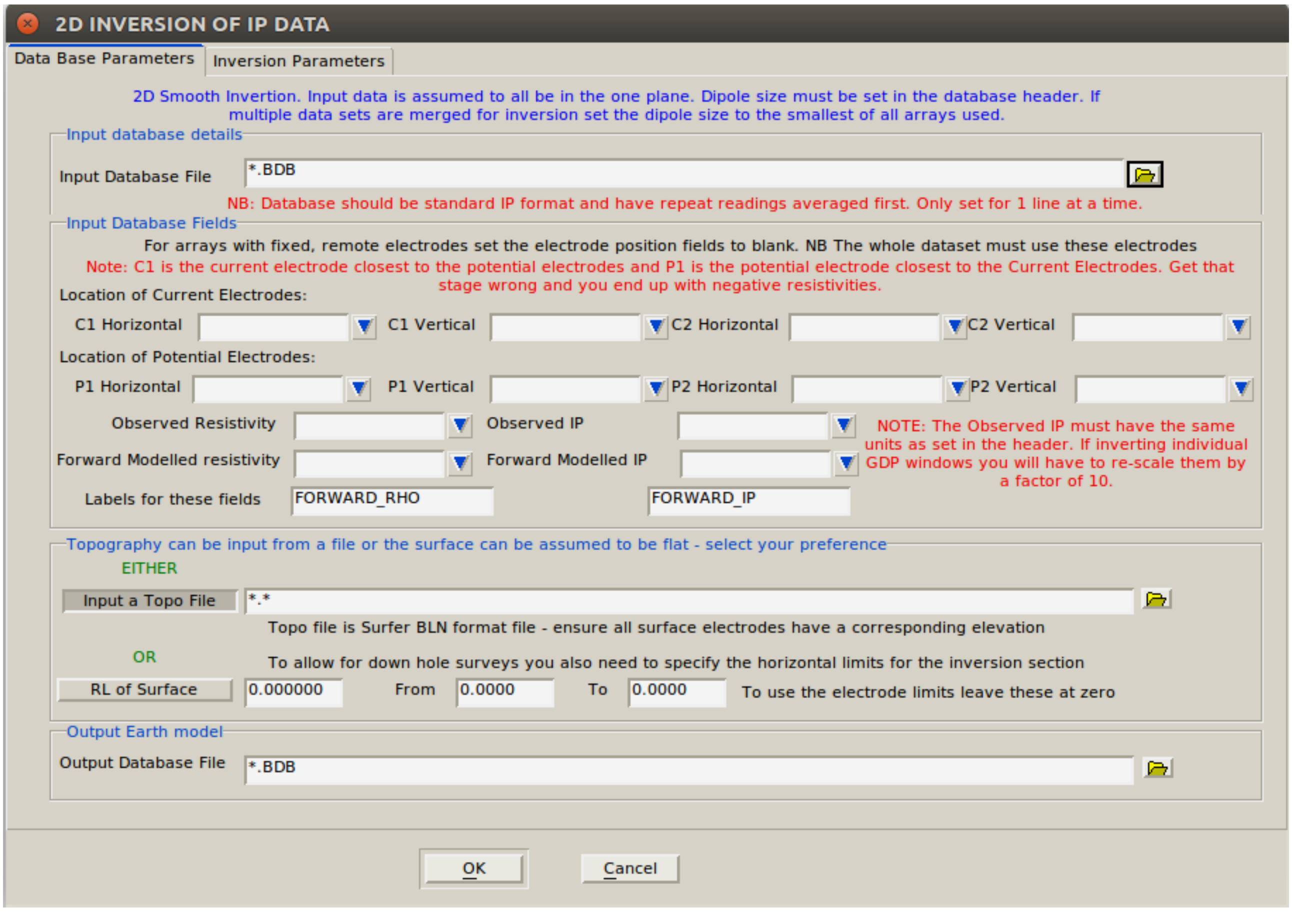


Figure 27: Database parameter dialogue for 2D IP inversion

You can invert using a topography file or a flat surface. If using a topo file the format is a surfer BLN file and you must ensure that every dipole has an elevation. This means that if your survey has a station missing or mixes data from two different sized dipoles you will have to dummy up a topo file using the minimum dipole length as a horizontal separator. DBASEO can spline a set of data to any spacing required.

The horizontal limits of the inversion are taken from the maximum limits of the topography data and IP data. This means that if all you have to invert is down hole data you should extend your topo data horizontally 50m or so either side of the hole. Otherwise you will only invert a narrow band containing the drill hole(s). This is why the flat surface option includes horizontal limits.

In general the default inversion parameters should be OK. The only numbers you may need to change will be the number of rows of blocks and the number of cells vertically in each block. The inversion mesh is broken up into blocks (each with a resistivity and IP), each block in turn is broken up into cells. The cells within a block all have the same resistivity and IP except where the cells cross the land, air interface. The blocks should be one dipole wide but can be less than 1 dipole deep. The mesh starts from the highest point on the survey line so in areas of extreme topography the default mesh may leave you with very little resolution in the low points. In these cases simply add more blocks 1 or 2 cells deep at the top. The number of rows of blocks should equal the number of comma separated cell heights you specify in the following box.

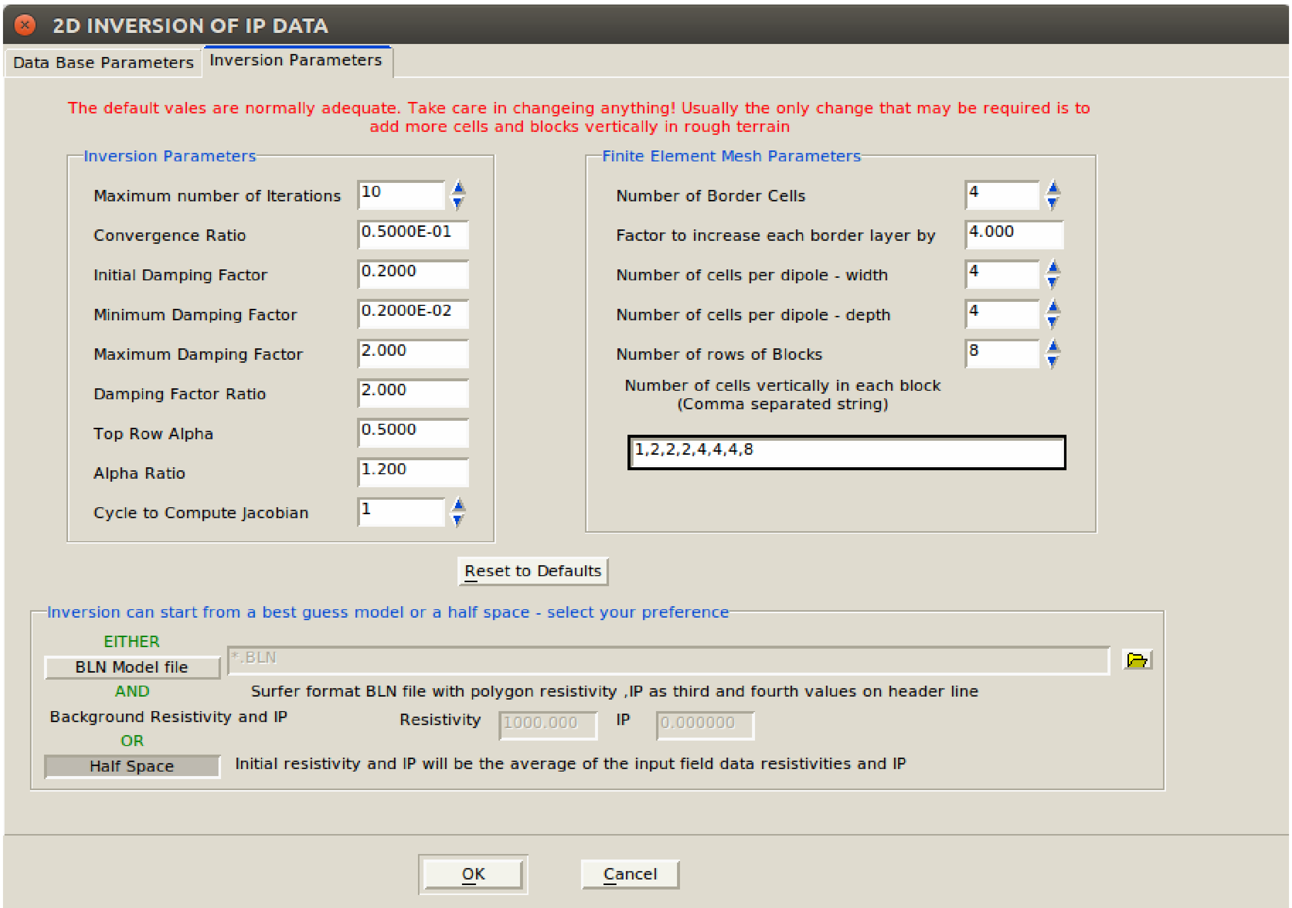


Figure 28: Inversion parameter dialogue for 2D IP Inversion

Once the inversion has run check the PRT file for information on how it went. The RMS error is reported at the end of every iteration. If the error has increased the iteration number will not be incremented and the damping factor will change. If the inversion starts to blow out the results will be clipped and you will see messages to this effect in the PRT file. e.g. *Block 1 Decomposition returned a ridiculous LN(resistivity) of 202.62 Reset to 10.0. You may need to increase your Z node density or range.* This has not been written to the PRT file just to take up space! If you have a few of them try doing what it suggests and increasing the z node density i.e. add more thin nodes to the surface in your mesh. If you are getting a lot of them, than chances are the inversion has lost the plot and headed off in the wrong direction. If you get a lot of them and the inversion is hunting unsuccessfully for a suitable damping factor you will find the inverted results are rubbish. They might look OK but trust me they are not! If that happens see where the inversion got to before it fell of the tracks, reset the maximum number of inversions to that number and re-run.

The following plots show an example of an inversion that successfully finished but produced a rubbish result after 7 iterations.

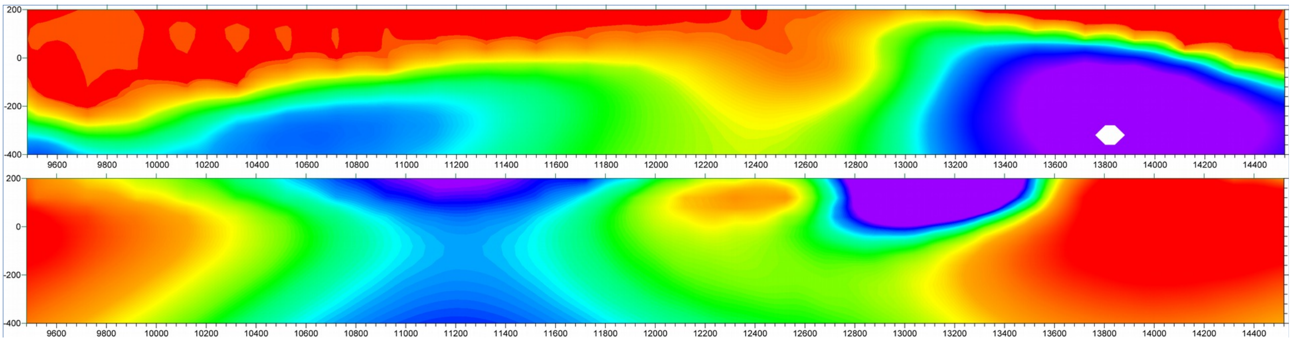


Figure 29: Example of an inversion which completed but failed to reach convergence. Resistivity, top. IP, bottom.

The same data set was then re-inverted using only 3 iterations with the following result.

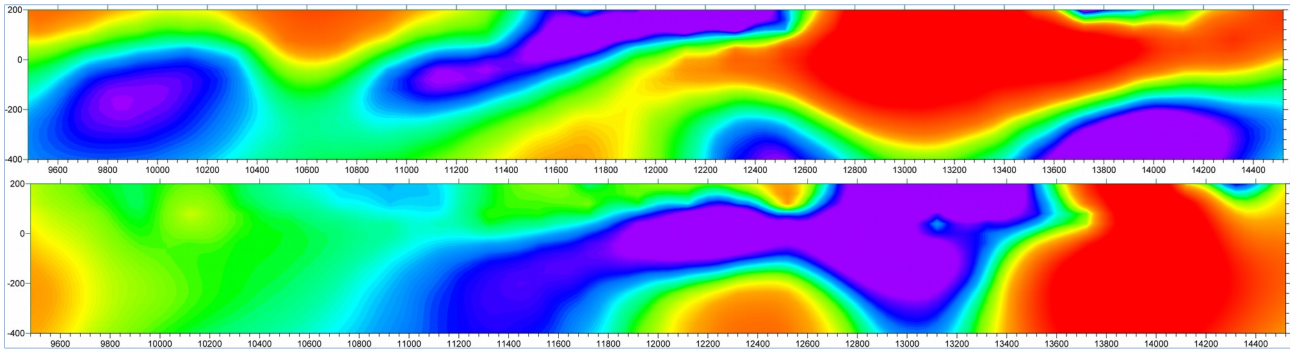


Figure 30: The same data set as used to generate the images in the previous figure run with half as many iterations

Which is right? Who knows, but the first example is less likely to be the answer than the re-run. **Moral:** Just because the inversion completes does not mean it is happy to be there - always check the PRT file for statistics.

Depending on your mesh size the inversion will return results from huge depths, these are nonsense. Trim the inversion to at least twice the deepest Edwards' depth as the Edwards' depth is the depth in a half space at which half the response comes from above and half from below.

For an explanation of the theory and maths behind the forward model and inversion see;

Sasaki, Y., 1989, Two-dimensional joint inversion of magnetotelluric and dipole-dipole resistivity data : Geophysics, Soc. of Expl. Geophys., 54, 254-262. (* Discussion in GEO-54-9-1212-1212 with reply by author)

Loke, M. H. and Barker, R. D., 1994, Rapid least-squares inversion of apparent resistivity pseudosections, 56th Mtg.: Eur. Assn. of Expl. Geophys., Session:I002.

Loke, M. H. and Barker, R. D., 1995, Least-squares deconvolution of apparent resistivity pseudosection: Geophysics, Soc. of Expl. Geophys., 60, 1682-1690. (* Errata in GEO-61-2-621)

Also see Loke's manuals and course notes for Res2dinv as this used the same algorithm as IPPROC although IPPROC does not have a finite difference option and by default computes the Jacobian on every iteration. I have experimented with variations on the

Jacobian cycle with disappointing results.

MAGNETOTELLURICS

GAMT: Current Version: 1.0.0.7 - 64 bit - *several bug fixes, speed and performance improvements since last update.*

- Import a Zonge Raw file from a CSAMT or Harmonic CSAMT survey. *Many updates for newer file formats and greater flexibility*
- *Load a bdb from a SEG EDI file.*
- *Load a raw time series bdb from a Phoenix TS# file.*
- Set the database header
- Sort the database

1D and 2D inversion code to be added.

DOWN HOLE MAGNETOMETRIC RESISTIVITY

NB: MMR database programs expect to see a database in a particular format, thus not all database programs are applicable to them

Processing MMR data requires a bit of thought so do not treat these routines as spaghetti machines - think things through!

MMRPROC: Current Version: 1.0.0.14 - 64 bit and multithreaded

- Create a database from an Agent 99 or Maxwell export
- Create a database from a Smartem MMR file
- Create a database from a Zonge MMR3C output
- Generate a dummy database using plan and section limits
- Reverse order of Tx wire vertices in the header
- From a set of depths, azimuths and dips calculate down hole co-ords. Uses standard Micromine collar and survey files with some quick edits
- Set or edit header
- Average/Median repeat readings - required that database is first sorted
- convert from dB/dt to B
- Convert between Magnitude/Phase and Real/Imaginary
- Sort a database - sorts on Line, Station and component
- Calculate and correct for the Tx wire field
- 2D Finite difference forward modelling
- Output to a DAT and BLN file for Surfer to plot plan or section vector plots
- Output to DAT file for Grapher to plot profiles
- Break into compass components for output to Voxler, Windisp or Potent

Notes:

MMR data can be collected by EM coils or fluxgates and the sensor used determines the first processing step which is to convert dB/dt data to B field. This is obviously not required for fluxgate or magnetometer data. For coil data you will need to know the coil effective area in order to convert from voltage to magnetic flux density using the following relationship for 100% duty cycle frequency domain data.

$$B(Tesla/A) = dB/dt(Volts/A)/(2 \times \pi \times Freq \times Coil\_area(m^2))$$

This clearly requires that the frequency and coil areas are set in the database header as coil calibration factors.

The next step is to convert the magnitude/phase data to Real/Imaginary space. Use the fundamental data rather than the harmonics for this. In general you will find that most of your data are real. If you see anomalously high imaginary values check the phases to make sure there has not been a pi flip.

Now we are ready to remove the field due to the transmitter wire but before we do we need to make sure the readings are located in the same reference co-ordinate system as the wire. For drill hole data this will involve setting the down hole co-ordinates using a collar and survey file, for surface data you will have to have the easting in Field 3, northing in Field 4 and elevation in Field 5. If the surface components were collected with the same north reference as the Tx wire co-ords Field 6 should be set to 0.0 and the two angles in

the header set to 0.0. However if the surface components have a different north reference than the Tx wire co-ords you will have to either change field 6 to have azimuth and inclination in the format Azimuth*1000+dip, where you would expect dip to be 0 or a better solution is to set field 6 to 0 and put the grid rotation into the header. As with all this code MMPPROC uses a right hand rule X=east, Y=North, Z=Up to describe the 3 components. Calculate the field due to the Tx wire and remove it from the Real part of the Observed field. The result should reduce your Real component in amplitude significantly.

Now comes the interesting bit. What is left is the field due to the earth. Because of the limited tools I have available I break this into two parts, a 2D geological component and a 3D anomalous field. The 2D part can be modelled in MMRPROC using a routine described by Nigel Edwards (1983). At the moment you have to ensure your reference frame is set so Y is the strike and X the dip direction. This may mean you have to rotate your database, note you will also have to rotate the transmitter wire co-ords stored in the header. One day I'll get the program to do it on the fly but for the moment it is manual.

Start with a half space - The 2D routine uses modified surfer BLN files to describe the polygons as described in the dialogue so start with a big rectangle extending well out from your data in both X directions. You may have to modify the top of the box to allow for any topography you have. You can then complicate this simple picture by adding as many 2D shapes as you want to your BLN file. The easiest way to do this is to draw your shapes in Surfer or QGis and export them as BLNs (BNA or Geojason for QGis – then convert to BLN) with scaling inherited from the base section. Then just edit the header of each polygon to add the resistivity. The direction (clockwise/anti-clockwise) of your polygons is not important. The similarity between your polygons and the resulting 2D model will be controlled by the cell size you select for your mesh, a coarse mesh results in slopes becoming steps etc. The 2D model is written to a Surfer grid file so you can see what you have ended up with. Once you are happy you have removed all the 2D effects all that is left is the 3D part which you can model using current channelling in TEM95.

References

Pai, D.M and Edwards, R. N. MMR2DFD: A programme for Magnetometric Resistivity 2D Modelling by the Finite Difference Method. 1983 Dept of Physics Univ of Toronto.

DHOLE MAG

NB: DHmag database programs expect to see a database in a particular format, thus not all database programs are applicable to them

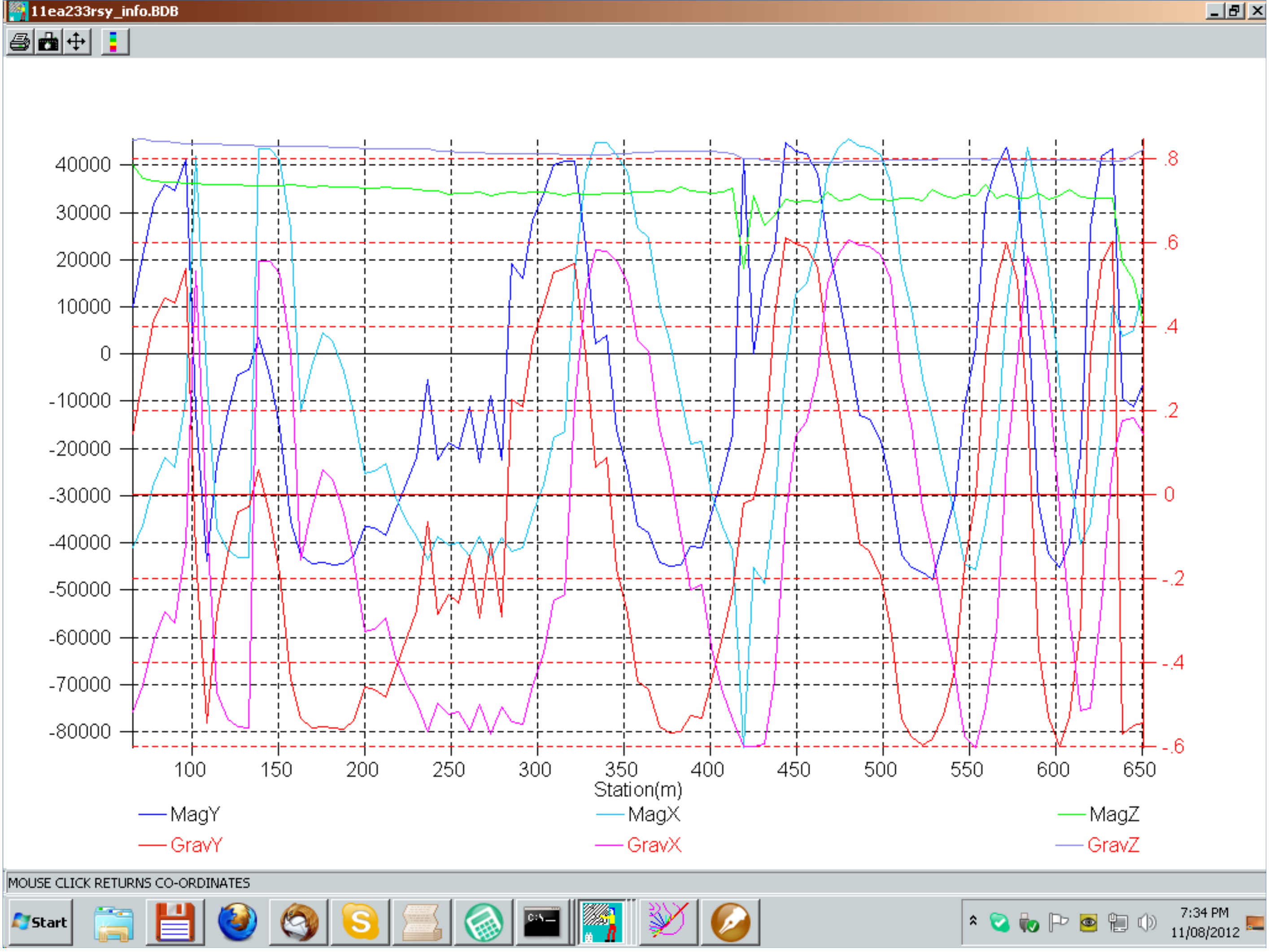
When asking the contractors for data specify that you want raw data for the 3 fluxgates and 3 accelerometers as well as their calculated azimuth and dip. There is no standard with regard to sensor orientation so each tool must be calculated manually to derive the orientations prior to running the software. The contractors do not generally know which way their sensors are facing so do not rely on being able to ask them. Program now outputs both the amplitude of the residual field vector |Bt| and the amplitude in the direction of the earth's field Bt_ITDOTEF

DH3DMAG: Current Version: 1.0.0.13 - note that database structure changed at version 1.0.0.6 - 64 bit - *several bug fixes, speed and performance improvements since last update.*

- Create a database from
  - a Flexit RSY file
  - a Smartem Atlantis ATL file - analogue tool only
  - a Smartem DAT file - use for digiAtlantis
  - a Surtron CHAMP DAT file
  - a Scintrex/AUSlog LAS file
  - a Surtron LV1-LV2 file
  - a TBS .MRG file
- Convert the triaxial response to compass point based readings - allows for a user specified constant regional magnetic field for the database of a variable magnetic field from a filed in the database .
- Convert UVA response from Smartem Atlantis to compass point based readings - allows for a user specified constant regional magnetic field for the database of a variable magnetic field from a filed in the database .
- Calculate down hole co-ordinates
- Compute components from a tool which only outputs total field and magnetic inclination - allows for a user specified constant regional magnetic field for the database of a variable magnetic field from a filed in the database .
- Remove the background regional field from a partially reduced data set. Use with data which comes supplied as Hh and Hv rather than the 3 fluxgate and 3 accelerometer components
- Set survey parameters in the database header
- Output to a DAT and BLN file for Surfer to plot plan or section vector plots. Added |Bt| to output

Processing down hole mag data.
See also an explanation of the maths in an article written for Preview.
http://exploregeo.com.au/download_docs/PVv2015n177p38.pdf

There are four possible input data types allowed by DH3DMag; principal data from the three fluxgates and three accelerometers, Tool software reduced Mag V and Mag H or TMI and MagInc and reduced Mag u, Mag v and Mag A, typically from EM probes like Atlantis.



The latter three data types must also include dip information and in the case of the Mag V and Mag H or TMI and Mag Inc files, azimuth as well. Although the steps taken vary between the data sets the aim is to take the provided data and reduce it to the three component residual magnetic field, referenced to compass co-ords.

3 Fluxgates and 3 accelerometers:

The ideal format includes the principal facts from the six sensors as well as dip and azimuth. Having the contractor or tool supplied dip and azimuth in this case allows you to check you have the sensors oriented correctly. Start by loading the data from the format supplied into a database using the format specified at the end of these notes. If you have been supplied with the values for anything beyond field 9 of the database format then shift them out to start at field 28 to act as a reference as DH3DMag will recalculate these for you. In the help tab of DH3DMag are some sign conventions for various tools and contractors, swap components and rescale as suggested. Look at the values for the three fluxgates and three accelerometers. For a hole steeper than 45 degrees dip Gz should be positive and have the largest amplitude the three accelerometers. In the southern hemisphere Mz should be negative and in the opposite in the north. Now plot depth against the three mag components and three accelerometers for one hole at a time in DbaseO. If you have the sensors matched properly and the hole at an angle to the earths field then the magnetic and gravity components should be mirror images of each other for the southern hemisphere or match for the northern hemisphere.
The data above are from a Reflex tool so the X and Y components have been switched but the labels retained as original so that I know I have done it.

These sensor values are rolling around the drill hole and of little interpretive use in their

current format. We can now use DH3DMag to compute azimuth and dip, total field, magnetic inclination, the horizontal and vertical magnetic fields and the residual north and vertical fields by using Operations|Convert Triaxial Response to Field. Plot depth against Total mag and Mag_Inc for each hole in the database and determine a constant background value for each. Write these to two new fields in the database, call Reg_Field and Reg_Inc to save confusion. You can use the IGRF values for the regional field and inclination as a start but that assumes the tool is well calibrated, clear of the drill stem and away from all mag anomalies. If you have a tool or contractor supplied azimuth and dip compare them with those you have just computed. They should match. If the Dip does but azimuth doesn't then it is likely that your X and Y components are reversed. If the dip disagrees then there is a problem with the field you have selected for Gz or its sign

Now plot the Total Field and Magnetic Inclination and see how they compare with the values you used. If they are different re-run the previous steps using different regional values. If you have done this step correctly then the residual north, vertical and Bt_ITDOTEF components in fields 21, 23 and 24 should have a background value of zero. If they don't then either your regional field is wrong or you have a very anomalous hole. If you have a multihole database you may find different holes require different background values in which case you can specify the Field and Inclination in two fields in the database. Once you have residual magnetic values you are happy with you are ready to move to the generic part of the process which applies to all input data types.

First the other two input types though.

A data set with Mag V and Mag H or TMI and Mag Inc as well as Azimuth and Dip from the same mag tool:

Read the data into a database and move the fields around so that Hole number, depth, dip, azimuth, Mag V and Mag H or TMI and Mag Inc are in the correct fields and anything else is out beyond field 26 or 28 if you have used 26 and 27 to store your regional values, as per the structure at the end of this document. For tools outputting V and H now using Operations|Remove IGRF compute the Total Field, Magnetic Inclination and residual components. As with the full sensor data set start with the IGRF values unless you know better then refine your values based on the background values you have calculated for Total Field and Magnetic Inclination. Again if you have done this correctly the residual magnetic field should be based on zero.

The Atlantis tool comes in two flavours; the old analogue tool and the digital tool. Both consist of three magnetic sensors and four accelerometers. The two axial accelerometers are fitted facing away from each other so output similar numbers but with opposite signs. While the .ATL file contains all six sensors these are currently only usable for the older analogue tool. When I get time I may be able to correct the digital tool but at the moment is is a low priority. For the Digi-Atlantis you will have to use the calculated the U, V and A components and dip in the .DAT file. Put Mag U, V and A into the fields normally used for Mag X, Y and Z and label them with U V and A so you are reminded that these are rotated. You may need to multiply the A component by -1 depending on the vintage of the file you are using.

Now use Operations|Convert UVA to field. As above, unless you know better use the IGRF values for Field strength and Inclination in the first pass. This should compute the Azimuth, magnetic field and inclination, Horizontal and Vertical magnetic fields and residual

components. Compare the background value for Field strength and Inclination against those you used and modify and re-run as necessary until your residual field has a background of zero.

From here on all three input data types get the same treatment.

At this point the east component of the magnetic field is zero because the apparent magnetic azimuth is the same as the “true” azimuth. There are two ways to generate a true azimuth: (a) assume that all long wavelength variations are due to hole deviation and short variations are due to magnetic bodies and use standard filtering techniques to separate the two or (b) use the azimuth from a non-magnetic tool such as a gyro or maxibore. The second method is preferable but not always an option. The “true“ azimuth is written to field 12 immediately after the apparent azimuth. It can either be created by filtering the apparent azimuth in DBaseO or by a lookup to the gyro data, remember however that the gyro azimuth is usually referenced to grid north rather than magnetic north so will have to have the magnetic declination removed from it. You will then need a collar file in the format HoleID East North RL and depth down hole for the collar. The last field allows for daughters to be logged from the wedge point only. Then using Operations|Calculate Hole Co-ords and 3D mag you will compute the hole deviation and the residual east component. You now have located 3 component mag which can be brought into 3D display packages or magnetic modelling packages. As with all mag data the residual can be filtered to remove high frequency noise or intersection spikes.

UBC MODELLING UTILITIES

UBCUTILS: Current Version: 1.0.0.20 - 64 Bit - *several bug fixes, speed and performance improvements since last update.*

- Create inversion files for UBC from Surfer Grids only or a mix of grids and a database - similar to John Paine's approach but gives a different (maybe better) solution for topo data. Modified to allow for 3 component down hole magnetic data to be output.
- Create a bounds file from a mesh and a database of values. Modified to create two bounds files rather than a single as required by version 5 of the Mag code.
- Create a mesh
- Create a forward modelling file using a topographic surface and a constant susceptibility.
- Create inversion files for UBC from a residual observations file created by subtracting a forward model from the observed data. Used in panelling when done using John Paine's approach. Also computes %error
- Create a database from a forward model and an observations file add fields subtracting the two and showing % error for later gridding. *Extended to allow mag3Dfor output as input.*
- Create UBC format model and mesh files from a Loke 3d forward model input file
- Convert a UBC 2D model and mesh to a BDB - use for GRS MT inversions
- Convert a UBC inversion log file to a BDB to allow rapid review of its progress and plots for the inversion report. Automatically computes the log of the misfit, model norm, total objective norm and barrier norm to make them easier to plot. Now accepts partial log files in the event of a crash or wanting to check the progress of an inversion
- Convert a UBC model and mesh to a BDB
- Convert a UBC model and mesh to a Micromine block model
- Read a version 5 .OUT file and write to a database
- Read a forward model or observation file and write to a database
- Apply simple maths to a model file or use a second model file to selectively alter the value in the first file based on the vale in the second. Good for masking to sensitivity.
- Slice a block model to output a grid This will slice in any direction and along non-straight line profiles
- Subset a model based on a user supplied mesh. This is similar in principle to John Paine's UBCExtract but the output mesh need not be the same dimensions as the input. Padding cells can thus be added. This is useful if you do a regional model and then want to take part of it as a starting point for a more detailed inversion. Does not try and interpolate just takes the average of all valid input blocks covered by the output block. The resulting model may therefore look a bit blocky if you have decreased the cell size but Windisp can smooth this for you and if you want to use it as a starting model for another inversion there will be no problem
- Cut a hole in a model - used as a starting point for forward modelling for panelling using John Paine's approach.
- Drape a model calculated on a flat surface under a topographic surface. The mesh is extended up to the top of the topographic grid and each pillar

from the block model is shifted vertically so that it sits just under the topographic surface. This is handy again if you do a regional inversion using a coarse data set and assume a flat earth and then want to use this as a starting model for a more detailed survey which takes topography into account. Should also be used if you have inverted a gravity data set after pseudomag transform, if you invert Bouguer anomaly this should always be on a flat surface which you may want to drape after inversion. Free air can be modelled using topo

- Insert a model into a larger mesh - used to reconstruct a complete inversion from a series of panels. Allowed user to decide if non-null values should be overwritten by nulls
- Fill a model top using the uppermost non-null value. After draping a flat model under topography there will be partial cells lying across the ground surface which are null. If these are input into UBC it will object. Therefore, pad all upper null vales first, UBC automatically nulls any values it finds above the topography. Better to do it this way than mess about trying to end up with the same topographic surface as UBC get with triangulation
- Mask a UBC model to the footprint of the observed data
- all I/O routines modified to accept Windisp's binary format UBC files and modify the expected null value based on the extension of the model file (e.g. .SUS, .DEN, .CHG etc.)

VOXLER SUPPORT UTILITIES

VTOOLS: Current Version: 1.0.0.18 - 64 bit - *several bug fixes, speed and performance improvements since last update.*

- From a BDB with Line or Hole number, X Y and Z values, create an Inventor .IV *or Paraview .vtk* file.
- Convert a CSV format drill hole database to a 3D assay point file for posting as scattered points. This works in a similar way to Windisp and requires a collar, survey and assay file. Added an output of hole traces *(in .IV or vtk format)* and hole labels which can be plotted independently of the assays. A CLR file is generated to colour the posted points. If your point file contains null values you will have to manually specify the limits for the colouring. These limits are reported in the PRT file. Modified to output up to 20 fields to the one output file.
- Generate an inventor .IV *or Paraview .vtk* file from a 3D BLN file
- Convert a Loke Res3Dmod file to an Explorer LAT file
- Convert a Micromine 3D model triangle file to an IV *or Paraview .vtk* file, includes on the fly rotation from one reference system to another. Modifications to allow for Micromine mixed Binary/ASCII format dat files.
- Convert a Surpac DTM file to an Explorer LAT *or Paraview .vtk* file, includes on the fly rotation from one reference system to another Added vertical shift and scaling to transform
- Convert a Surpac STR file to an Explorer LAT *or Paraview .vtk* file with optional on the fly rotation from one reference system to another Added vertical shift and scaling to transform
- Convert a UBC mesh to an Inventor IV *or Paraview .vtk* file
- Convert a UBC 3D model or bounds and mesh to an Explorer LAT file. User can decide whether to make null value high or low. Mods to accept John Paine's mesh format.
- Drape a coloured grid over a DEM to create a LAT file for importing into Voxler. Attach a height surface to this object and set its scale to 0. A CLR file is generated to colour the surface. If your coloured surface has null values you will have to manually specify the limits for the colouring and set the colour model to a ramp with a low cut a small value above the colour minimum. These limits are reported in the PRT file.
- Generate a 3D mesh of lines to help position yourself in the 3D model
- Export an Inventor IV file from Voxler *or vtk file from Paraview* (eg an isosurface) to Micromine
- Export an Inventor IV file from Voxler *or Paraview .vtk* (eg an isosurface) to Surpac

MINING SOFTWARE SUPPORT UTILITIES

MINECONV: Current Version: 1.0.0.5. - 64 bit with multithreading - *several bug fixes, speed and performance improvements since last update.*

- Convert a Datamine .DM file to a CSV format file
- Convert a Micromine .DAT file to a CSV including the new mixed ASCII Binary .DAT format
- Convert between a Surpac String (.STR) file and *a* Surfer BLN format

SEISMIC PROCESSING TOOLS

SEISTOOLS: Current Version: 1.0.0.1

- Convert a SEG1 format file from an OYO seismograph to a Seispac format file.

UTILITY PROGRAMS

REFONDOS: Reformats UNIX or other non-DOS ASCII files to insert CR, LF every n characters. Optionally strips trailing blanks from lines. Useful for reformatting header file on LDT so that it can be printed. Could use to reformat the whole LDT file so it could be read by DBASEO if you were too lazy to get BDLDATA working properly.

FILE FORMATS

General

The BDB format is not one we are locked into, it has just been handy and nothing better has come along to replace it. When a suitable replacement is found things have been set up so that changeover should be fairly simple, hopefully!

The BDB is a binary file with a 4096 byte header which can be used for storing method specific survey information along with the field labels and max/mins for each field. It has no limit to the number of records but is currently limited to ***100*** fields and 32 bit Windows imposed a 2 Gb file size limitation which is why all routines are now 64 bit. Each field is stored as a 4 byte real which means you only have 7 digits of precision. Thus UTM northings are only good to the nearest metre and UTM eastings to the nearest 0.1 metre and gravity values have to have a number such as 975000 mGal subtracted from them. If loss of precision in large numbers is an issue for a particular job either break the number into two parts and store in two fields or remove an average value from the number, **prior** to bringing into the BDB.

The null value is set to -1.0E30.

Field labels have a maximum of 12 characters. Avoid spaces as this can cause problems for other (3rd party) programs if the labels are exported to ASCII, especially Geosoft XYZ format and Excel. Use an underscore instead.

As projection and datum information are not stored in the database header, a good habit to get into is to write the datum into the label (e.g. EAST-AMG84 or LAT-GDA94)

Some programs expect to see a database with fields in certain order, this is detailed below.

TEM

Use of TEM95 to generate the BDB should result in the correct database structure, however if you are having to reformat a file created by DBASEO you will need to configure it as follows:

FIELD	LABEL	
1	LINE_NUMBER	
2	STATION	
3	EAST	
4	NORTH	
5	ELEVATION	
6	HOLEANGLE	Azimuth*1000+dip
7	COMPONENT	1=x,u 2=y,v 3=z,a
8	CURRENT	
9	SPARE	
10	SPARE	
11	CH01_0.01000	Window label must start with CH followed by the window number an underscore and the window centre time in mSec. **Time zero is at the top of the ramp.**

12	....	Windows repeat till last window or window 90

TEM95 computes the number of windows and their times by reading the database labels, starting at field 11. If the first two characters of the label are CH (or in the case of field 11 PP to allow for Crone data) the field will be considered a window and the time will be read from the last 7 characters in the label. The check loop stops when it reaches the first label which does not begin with CH. If you use field labels which are not window times but which start with CH this can cause grief if they follow on directly from the windows.

Note that many of the TEM95 routines require information from the survey header, it is worthwhile setting this information properly the first time as once it is stored into the INP file you will not have to enter it again.

Gravity

As previously mentioned the observed gravity if reduced to the Isogal, will have to have a constant removed from it in order to maintain precision. For Normandy databases this was 970000 mGal while for Newcrest and Newmont it was 975000 mGal. The constant that is subtracted is now allowed to vary and is stored in the survey header of the database. You should stick to a constant as you will run into grief if you append two databases together with different offsets. Ensure that this offset is set before running any of the reduction or modelling programs. A value of 975000mGal or 9750000 $\mu m/s^2$ is recommended.

The minimum requirements for a gravity database are Latitude, elevation and observed gravity but the format is usually extended as follows:

FIELD	LABEL	
1	ID	
2	LATITUDE	
3	LONGITUDE	
4	ELEVATION	
5	OBS_GRAV	
6	UTM_EAST	
7	UTM_NORTH	
8	FREE_AIR	
9	BA_.....	1 to 91 Bouguer densities

Note also that many of the GRAVRED routines require information from the survey header, it is worthwhile setting this information properly the first time as once it is stored into the INP file you will not have to enter it again.

IP

Use of IPPROC to generate the BDB should result in the correct database structure, however if you are having to reformat a file created by DBASEO you will need to configure it as follows:

	TIME DOMAIN	FREQUENCY DOMAIN
FIELD	LABEL	LABEL
--------	------------	------------
1	LINE_NO.	LINE_NO.
2	STATION_NO.	STATION_NO.
3	EASTING	EASTING
4	NORTHING	NORTHING
5	ELEVATION	ELEVATION
6	N_VALUE	N_VALUE
7	CURRENT_Amps	CURRENT_Amps
8	VOLTAGE_mV	VOLTAGE_mV
9	RHO_ohm-m	RHO_ohm-m
10	CHARGE_mV/V	3PTDCPHASEmR
11	CH01-50.0000	H1_MAGNT_mV
12	CH02-80.0000	H1_PHASEmRad
13	CH03-120.000	H3_MAGNT_mV
14	CH04-180.000	H3_PHASEmRad
15	CH05-260.000	H5_MAGNT_mV
16	CH06-380.000	H5_PHASEmRad
17	CH07-540.000	H7_MAGNT_mV
18	CH08-760.000	H7_PHASEmRad
19	CH09-1040.00	H9_MAGNT_mV
20	CH10-1410.00	H9_PHASEmRad
21	CH11-1870.00	

Window label must start with CH (note case) followed by window number a hyphen and the window centre time in mSec - will depend on base frequency of Tx and receiver used

Windows repeat till last window or window 90

For Gradient array and arrays with fixed remote electrodes the current electrode information can be stored in the survey header. for other arrays use fields > 21 to store potential and current electrode positions in 3D if necessary for use in later inversion.

Time domain IP routines computes the number of windows and their times by reading the database labels, starting at field 11. If the first two characters of the label are CH the field will be considered a window and the time will be read from the last 7 characters in the label. The check loop stops when it reaches the first label which does not begin with CH. If you use field labels which are not window times but which start with CH this can cause grief if they follow on directly from the windows.

Note also that many of the IPPROC routines require information from the survey header, it is worthwhile setting this information properly the first time as once it is stored into the INP file you will not have to enter it again.

DHMMR

Use of MMRPROC to generate the BDB should result in the correct database structure, however if you are having to reformat a file created by DBASEO you will need to configure it as follows:

FIELD	LABEL	
1	LINE	
2	STATION	
3	EAST	
4	NORTH	
5	ELEVATION	
6	HOLEANGLE	Azimuth*1000+dip
7	COMPONENT	1=x,u 2=y,v 3=z,a
8	CURRENT	
9	SPARE	
10	OBS-B	

plus another 10 to 20 fields for modelling

Note also that many of the MMRPROC routines require information from the survey header, it is worthwhile setting this information properly the first time as once it is stored into the INP file you will not have to enter it again.

DHMAG

Use of DH3DMAG to generate the BDB should result in the correct database structure, however if you are having to reformat a file created by DBASEO you will need to configure it as follows:

NB: - the label for field 1 should have uppercase HOLE as part of the label to tell the software that this is the new format. If this label is not detected DH3DMag will offer to reformat from old format to new. If you are certain you do not have the old format then say no to the format change request.

Fields 10 to 24 are computed by DH3DMag. If you have an instrument derived version then put it out beyond field 26 as a check.

FIELD	LABEL	
1	HOLE_NUMBER	
2	DEPTH	
3	Hx	
4	Hy	
5	Hz	
6	Gx	
7	Gy	
8	Gz	
9	TEMPERATURE	Not used in processing but supplied for QC
10	HOLE_INCLIN	

11	APP_MAG_AZIM	Unsmoothed or edited
12	FILT_MAG_AZ	Smoothed/filtered or Gyro derived
13	TOTAL_FIELD	
14	MAGNETIC_INC	
15	ANOM_INCLIN	
16	NORTH_MAG	
17	VERT_MAG	
18	EASTING	
19	NORTHING	
20	RL	
21	Bn	
22	Be	
23	Bv	
24	Bt	Total field in the direction of the Earths Field
25	|Bt|	Modulus of Total Field
26	SHOT_NO	

26 onwards - any additional data supplied by the tool or from another source e.g. Gyro

Note also that many of the DH3DMAG routines require information from the survey header, it is worthwhile setting this information properly the first time as once it is stored into the INP file you will not have to enter it again.

The data base structure was changed in version 1.0.0.6. Prior to that it used the historical structure. If the code does not see uppercase HOLE in the label for field 1 it assumes the old structure and asks if you want to rearrange the fields to create a new structure. If you have already done this then tell the program to skip this step.

Historical Structure;

FIELD	LABEL	
-------	------------	
1	SHOT_NO.	
2	DEPTH	
3	INSTR_INCLIN	
4	INSTR_MAG_AZ	
5	Hx	
6	Hy	
7	Hz	
8	Gx	
9	Gy	
10	Gz	
11	TEMPERATURE	Not used in processing but supplied for QC
12	HOLE_NUMBER	
13	HOLE_INCLIN	
14	APP_MAG_AZIM	
15	TOTAL_FIELD	
16	MAGNETIC_INC	
17	ANOM_INCLIN	
18	NORTH_MAG	

19	VERT_MAG
20	EASTING
21	NORTHING
22	RL
23	Bn
24	Be
25	Bv
26	Bt
27	SPARE
28	SPARE
29	SPARE
30	ORIGINAL_AZ