

Oasis montaj Gravity & Magnetic Exploration

Ralph R.B. von Frese

School of Earth Sciences
The Ohio State University Columbus, OH 43210, USA

CONTENTS

INTRODUCTION	3
PROTOCOLS FOR ACCESSING OASIS MONTAJ-BASED EXERCISES	4
TUTORIAL	4
MAGNETIC DATA PROCESSING	5
Start new project	6
Import magnetic data	7
Assign a coordinate system	9
Designate the cartesian coordinates	11
Profile display	11
Create a plan map	12
Gridding	13
Grid display	16
Colour adjustment	17
Map plot and annotation	18
Colour bar legend	18
Save the colour boundary file	20
Grid your data using a different (eg., a finer) sampling interval	20
Display the 100-m interval grid	20
Grid your data using another interpolation method	21
Compare outcomes of different sampling and interpolation methods	23
Measuring distances	25
Grid differences	26
Calculating Grid Attributes	28
IGRF calculations	29
FILTERING	30
A) Reduction-to-pole [rtp] filter	30
B) Derivative filtering	31
C) Directional filtering	32
D) Composite directional+wavelength filter	33
E) Continuation filters	35
F) Apparent susceptibility filter	35
GRAVITY DATA PROCESSING	37
Gravity data import	37
Designate the cartesian coordinates	37
Station location plot	38
Add legend	39
Gridding	40
SUPPLEMENTAL	41
TRANSMISSION OF FILES	41
CONCLUSIONS	41
REFERENCES	41

INTRODUCTION

Oasis montaj Gravity & Magnetic Exploration edition (OmGM) is the professional geophysical data processing suite of modules that supports professional-grade gravity and magnetic data analyses, including interactive data import, reduction, processing, interpretation, and graphics displays. OmGM is developed by Seequent Inc. and runs on the WINDOWS platform and WINDOWS emulators. A set of computational exercises based on OmGM has been developed to accompany the textbook entitled *Gravity and Magnetic Exploration: Principles, Practices, and Applications* [W.J. Hinze, R.R.B. von Frese, and A.H. Saad, 2013, Cambridge University Press, ISBN 9787-0-521-87101-3] by the authors in collaboration with Seequent (previously Geosoft Inc).

These exercises may be accessed at:

<https://www.seequent.com/exercises/cup/gravityandmagneticexploration>

A protocol has been established for the book's users to access and conduct the exercises while preserving the integrity and confidentiality of the software. This protocol limits access to only the software germane for specific exercises. For each user, the total time, calendar period of use, and the input dataset size are limited. The protocol is established both for the individual user and the group of students involved in a course under an instructor's direction. Restrictions established in the use of the software and data will not prevent interested users from the timely completion of the exercises.

The individual exercises together with access to the appropriate data and software for performing them are available on the Seequent landing page at the above URL. Only the specific software from the comprehensive suite of computational programs in OmGM will be available to the user. The nature and objective of each exercise is described briefly in the list of exercises so that the user can select the appropriate exercise.

Each exercise describes its objectives and data processing instructions, and questions related to the results of the processing as appropriate. The tutorial section below gives more details for using OmGM, and on the nature and size of the input data, and the prepared output products. Completion of the exercises will provide the user with experience in processing and interpretation of gravity/magnetic data, as well as insight into the principles of the methods, and the data processing and interpretation practices.

The authors of the text have prepared the exercises with the assistance of recognized individuals. Additional computational exercises are planned beyond those cited in the current release.

PROTOCOLS FOR ACCESSING OASIS MONTAJ-BASED EXERCISES

Users access these exercises either

1. as students of a course performing the exercises under the direction of an instructor, or
2. as an individual user.

For students enrolled in a course, the course instructor will submit a list of the students and their email addresses to Seequent who will provide the instructor with time-restricted subscriptions for each student and the instructor to access the software and exercises. The timed subscriptions issued to students are issued for a single 6-month period.

Subscriptions for instructors from official educational institutions can be extended multiple times.

On accessing the URL, students will be prompted for their email addresses. If registered by the instructor, students will download the installation software, the exercise, input data, and necessary OmGM components.

Each student will install OmGM on their computer and create a Seequent ID using their registered email address. This ID will have a defined lifetime not to exceed six months.

For the individual user, an ID must be obtained from Seequent through the Book's link above for a single 6-month period.

Individuals will have access to all exercises and the related OM modules using the ID. Applications are limited to the size of the exercises' input datasets.

TUTORIAL

The sections below describe the magnetic and gravity data processing operations utilized for the exercises. Here, the names of folders, files, menu options, and tools are marked in *italics*, whereas the headings are underlined, and the parameters are in bold. Right arrows → indicate submenu items selected with mouse clicks. At all times, the user can click on the help button. At the top-right of the OmGM window or dialog to view a definition of any item.

MAGNETIC DATA PROCESSING

This section illustrates OmGM's magnetic anomaly mapping, processing, and filtering operations using the total field data from the northeastern Minnesota study area 'A' shown in the micro-leveled aeromagnetic survey data in Figure 1. The magnetic anomaly data were primarily observed under the auspices of the Minnesota Geological Survey along north/south flight paths separated by 400 m at a mean terrain clearance of 150 m (Chandler, 1985, 1991, 1996; Chandler et al., 2007). The total magnetic intensity measurements were made with a proton precession magnetometer mounted in a tail-stinger at either 50 or 75 m, leveled with tie-line observations measured at either 2 or 4 km intervals, and processed for anomaly values using standard methodologies. Subsequently the magnetic data were micro-leveled using the commercial version of the *Oasis montaj* software.

The data of the 4 study areas displayed in Figure 1 are supplied. The exercises are conducted on the study area A. You are encouraged to run the same exercises on the other study areas.

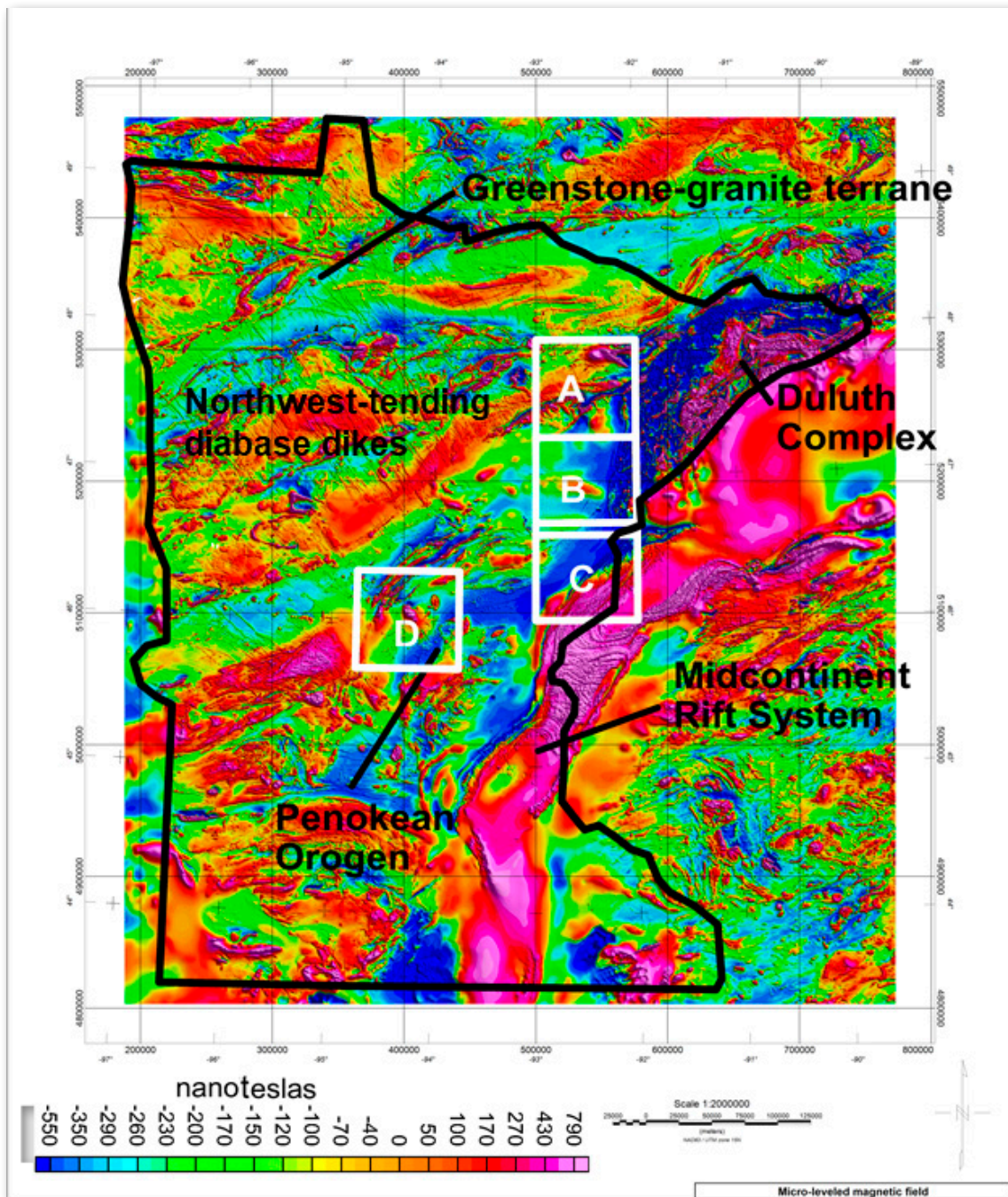


Figure 1: Minnesota micro-leveled total field aeromagnetic survey anomalies with the study areas outlined and adapted from Chandler 1991.

In the following exercises, you will import the magnetic and gravity data of study area A and visualize and process them.

Before running OmGM, copy the supplied data files to a working folder.

1. In *File explorer*, under the *Gravity and Magnetics Exploration* root folder, create a folder and name it *Minnesota*
2. Extract the content of the downloaded zip file in this folder

■ Start new project

The OmGM project is the application that keeps track of the processes, pointers to files used, and processing parameters. You will start by creating a new project.

1. Run OmGM
You are now in the OmGM application
2. Inside the application, click → *Create a new project*
This will initiate a blank project file (GPF) and pane (e.g., Fig. 2) that you are prompted to name
3. Navigate to *Gravity and Magnetics Exploration* root, then *Minnesota*
4. Name the project in *Minnesota*

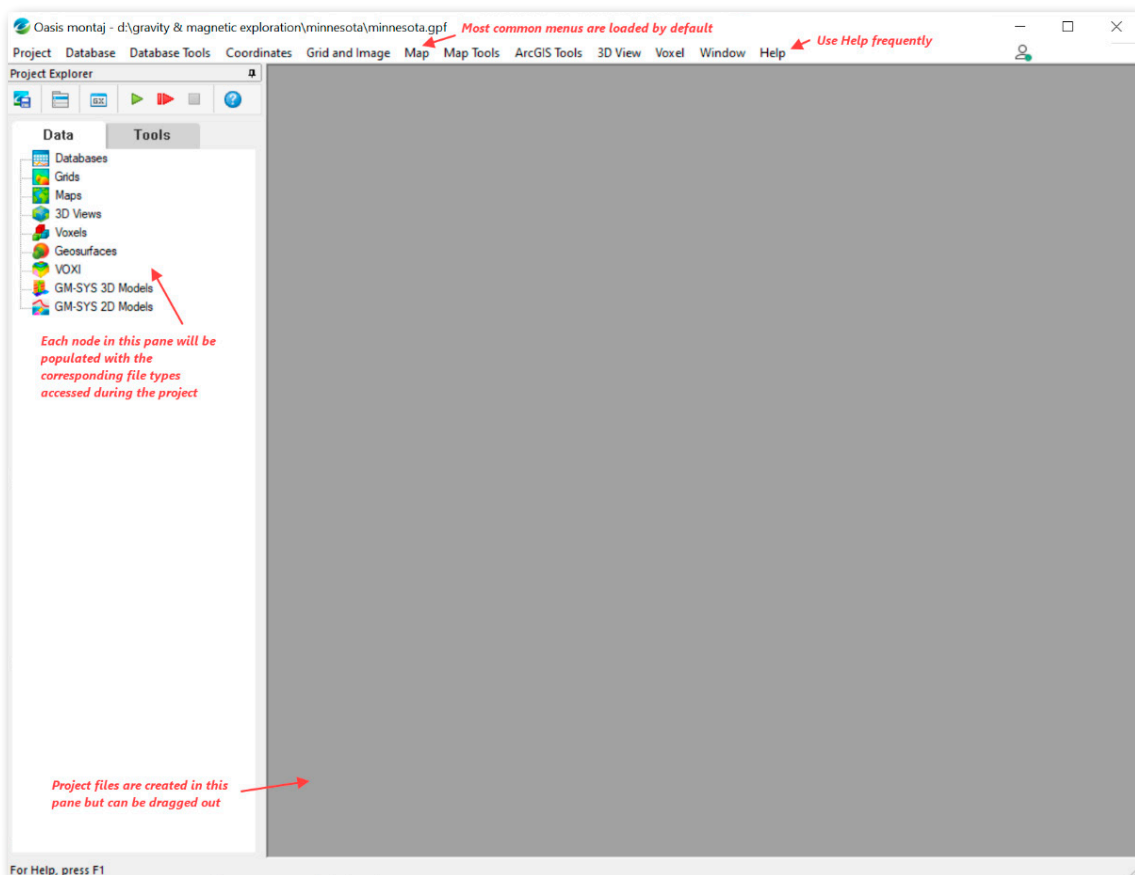


Figure 2: Oasis montaj project.


■ Import magnetic data

The fundamental format of *Oasis montaj* is the database format. All tools operating on survey data operate on Geosoft databases, consequently, external data should be first converted to this database format.

1. On the menu bar click → *Database* → *Import* → *Geosoft XYZ ...*
2. In the dialog that appears click → Create database
3. Name the database **MN_MagA**
4. Set Maximum lines/groups to **500**
5. Set Maximum channels/fields to **100**
6. Click → OK

A blank database is created.

- ① To see the description of each parameter, simply click on the *Help-* button on the top right of the Dialog

7. Select the search button  to the right of File(s) to import
8. Along the bottom right, ensure the filter is set to **XYZ Files (*.xyz)**
9. Navigate to the data subfolder Magnetics and select *MN_Mag_A.xyz*
10. Click → Open

This is the file that will be imported

11. Click → Create a template that defines the field to be imported
12. Define the template file parameters as indicated in Figure 3.
13. Click → OK and then again click → OK

The data are now imported into a Geosoft database.

- ① All fields that are imported into database channels are initially protected to maintain the integrity of the initial data. It is strongly recommended not to alter the content of these channels. When a channel is protected, a black triangle appears in the upper left corner of the channel label indicating that it cannot be modified. To unprotect a channel, right-click on the cell showing the label of the channel and toggle the protection off, or select → *Unprotect All*
- ① Make copies of the channels with contents that you would like to alter by running *Database Tools* → *Channel Tools* → *Copy Channel*
- ① The latitude and longitude channels are saved as double precision float values in the database. However, for display purposes, these values also can be viewed in degrees, minutes, and seconds.
- ① To change the display format, right-click on the intended channel header and select → *Edit* from the drop-down menu. Under Display Format select the desired format.
- ① Any occurrence of double asterisks ** in a database cell indicates that the cell is not wide enough to display the value in the assigned format. To correct this situation, widen the columns by clicking on the right side of a cell and dragging until the numbers appear.
- ① For easy access, the database is added to the Project Explorer pane. All files in this pane can be drag-dropped onto the main canvas.

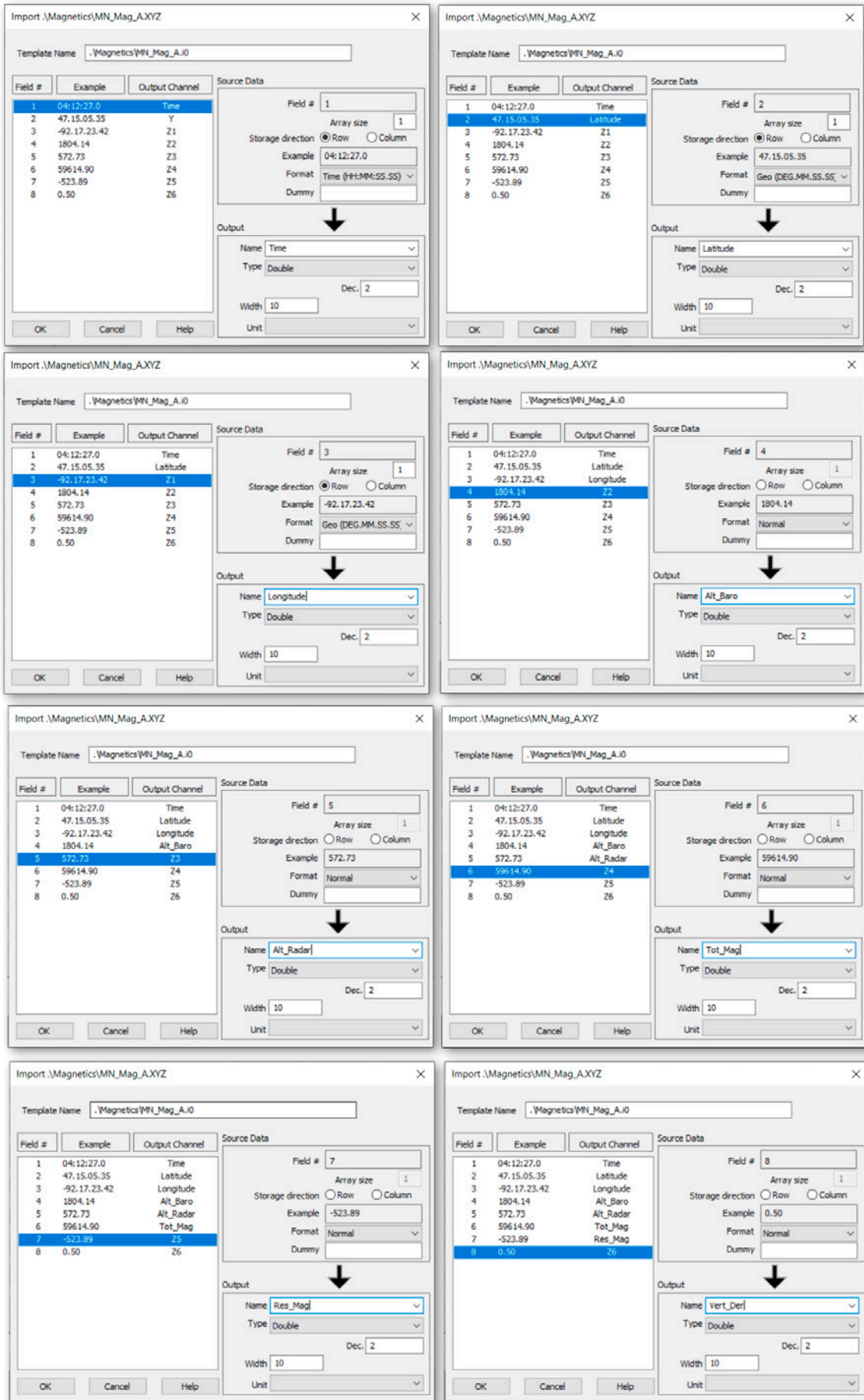


Figure 3: Create an import template once. For subsequent imports will use this template.

Assign a coordinate system

The data generally are recorded in geographic latitude and longitude coordinates. However, the data processing is mostly performed using ground coordinates. Often, the first course of action is to project the geographic coordinates to ground units. To convert the geographic coordinates of the imported data:

1. On the top menu bar, click → *Coordinates* → *New Projected Coordinate System...*
2. For the X/Longitude channel from the dropdown list of channels, select **Longitude**
3. For the Y/Latitude channel from the dropdown list of channels, select **Latitude**
4. Click → Next
 - ① For coordinate transformation into a Universal Transverse Mercator [UTM] projection [see Hinze et al. (2013), Appendix A.6.1]
5. In the dialog that appears, in the lower search window, select → Geographic Coordinate Systems
6. Just above it, in the Search box enter **WGS 84**
7. Expand the Search window, where now the content is filtered for WGS 84
8. Expand the node World and select → WGS 84

The database is now aware that these channels represent Longitudes & Latitudes
9. Click → Ok

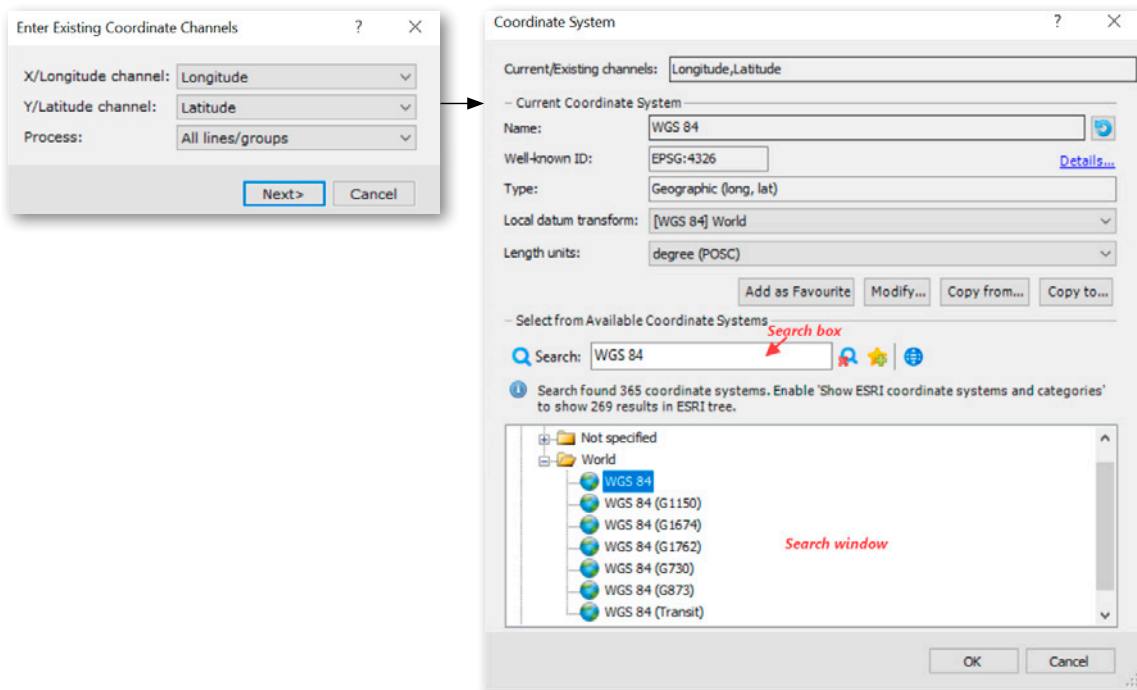


Figure 4: Assign the geographic coordinates.

Specify the names of the new ground coordinate channels:

10. Set X/Longitude channel to **UTME_N83**
11. Set Y/Latitude channel to **UTMN_N83**
12. Click → Next
13. This time in the search window, select → Projected Coordinate Systems
14. In the search box enter **Zone 15 N**
15. Expand the Search window, where the content now is filtered for Zone 15 N

16. Expand the node USA and then expand 96°W to 90°W
17. Select → **NAD83**
18. Click → **OK**

The corresponding ground coordinate system channels UTME_N83 and UTMN_N83 are now calculated and saved to the database

- ① If you get a warning regarding the coordinate systems, simply ignore and proceed
- ① To ensure that the calculated channels are committed to file storage, click while simultaneously depressing the Ctrl_and S keys.

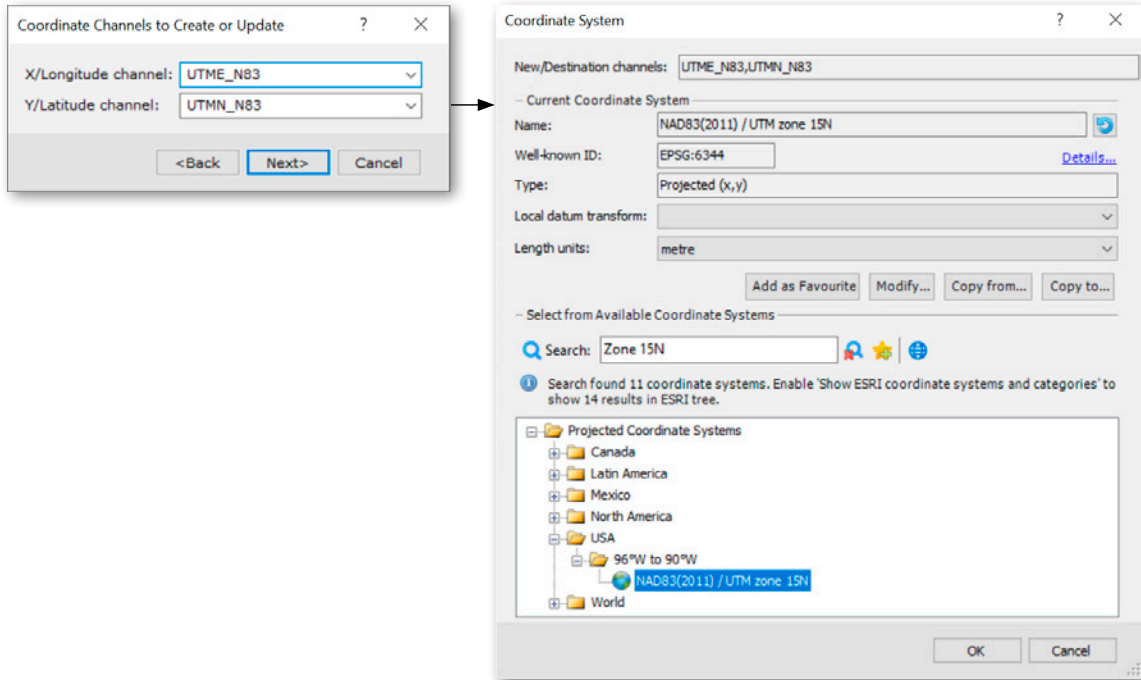


Figure 5: Assign the projected ground coordinates.

L1.1:0	Time	Latitude	Longitude	Alt Baro	Alt Radar	Tot Mag	Res Mag	Vert Der	UTME_N83	UTMN_N83
0.0	04:12:24.00	47.15.03.66	-92.17.23.40	1783.00	567.27	59613.90	-524.75	-0.03	553737.34	5233303.86
1.0	04:12:27.00	47.15.05.35	-92.17.23.42	1804.14	572.73	59614.90	-523.89	0.50	553736.44	5233356.02
2.0	04:12:30.00	47.15.07.03	-92.17.23.45	1804.14	569.09	59615.90	-523.04	0.65	553735.34	5233407.88
3.0	04:12:31.00	47.15.08.75	-92.17.23.47	1814.71	574.54	59616.40	-522.69	0.16	553734.44	5233460.97
4.0	04:12:32.00	47.15.10.44	-92.17.23.50	1814.71	570.91	59616.40	-522.84	-0.81	553733.33	5233513.14
5.0	04:12:35.00	47.15.12.12	-92.17.23.57	1825.29	572.73	59616.40	-522.99	-1.81	553731.39	5233564.98
6.0	04:12:38.00	47.15.13.81	-92.17.23.59	1814.71	576.36	59616.90	-522.63	-2.43	553730.49	5233617.15
7.0	04:12:40.00	47.15.15.49	-92.17.23.62	1825.29	572.73	59617.40	-522.28	-2.65	553729.39	5233669.00
8.0	04:12:41.00	47.15.17.17	-92.17.23.64	1835.86	567.27	59618.40	-521.43	-2.86	553728.50	5233720.86
9.0	04:12:43.00	47.15.18.86	-92.17.23.67	1835.86	561.82	59619.40	-520.58	-3.40	553727.39	5233773.02
10.0	04:12:46.00	47.15.20.54	-92.17.23.74	1835.86	552.73	59620.90	-519.23	-4.11	553725.45	5233824.87
11.0	04:12:48.00	47.15.22.23	-92.17.23.77	1825.29	543.64	59622.40	-517.87	-4.37	553724.35	5233877.04
12.0	04:12:49.00	47.15.23.91	-92.17.23.79	1804.14	558.18	59625.40	-515.02	-3.56	553723.45	5233928.89
13.0	04:12:52.00	47.15.25.60	-92.17.23.82	1835.86	550.91	59629.40	-511.17	-1.65	553722.35	5233981.06
14.0	04:12:55.00	47.15.27.28	-92.17.23.84	1804.14	552.73	59632.90	-507.82	0.62	553721.46	5234032.91
15.0	04:12:56.00	47.15.29.00	-92.17.23.91	1804.14	549.09	59636.40	-504.46	2.18	553719.50	5234086.00
16.0	04:12:57.00	47.15.30.68	-92.17.23.94	1825.29	550.91	59639.40	-501.61	2.37	553718.40	5234137.85
17.0	04:13:00.00	47.15.32.37	-92.17.23.96	1814.71	549.09	59641.40	-499.76	1.50	553717.50	5234190.02
18.0	04:13:03.00	47.15.34.05	-92.17.23.99	1825.29	540.00	59642.40	-498.91	0.59	553716.40	5234241.87
19.0	04:13:05.00	47.15.35.61	-92.17.24.01	1804.14	558.18	59644.90	-496.55	0.52	553715.54	5234290.03
20.0	04:13:06.00	47.15.37.20	-92.17.23.99	1804.14	558.18	59647.90	-493.68	1.44	553715.52	5234339.11
21.0	04:13:08.00	47.15.38.75	-92.17.24.02	1804.14	491.76	59649.90	-491.82	2.80	553714.45	5234386.96
22.0	04:13:11.00	47.15.40.34	-92.17.24.05	1825.29	485.88	59652.40	-489.46	3.91	553713.37	5234436.03
23.0	04:13:13.00	47.15.41.89	-92.17.24.03	1825.29	490.59	59653.90	-488.10	4.34	553713.36	5234483.88
24.0	04:13:14.00	47.15.43.48	-92.17.24.05	1814.71	490.59	59654.90	-487.23	3.97	553712.49	5234532.96
25.0	04:13:17.00	47.15.45.04	-92.17.24.03	1814.71	483.53	59654.90	-487.37	2.88	553712.47	5234581.12
26.0	04:13:20.00	47.15.46.62	-92.17.24.06	1814.71	483.53	59654.40	-488.01	1.39	553711.40	5234629.89
27.0	04:13:21.00	47.15.48.18	-92.17.24.08	1804.14	485.88	59653.90	-488.65	-0.11	553710.54	5234678.04
28.0	04:13:22.00	47.15.49.77	-92.17.24.06	1793.57	485.88	59653.40	-489.28	-1.32	553710.51	5234727.13
29.0	04:13:25.00	47.15.51.32	-92.17.24.09	1776.54	481.18	59653.90	-488.92	-2.07	553709.45	5234774.97

Figure 6: The calculated projected coordinates are added to the database.

■ Designate the cartesian coordinates

To proceed with processing, the data must be defined in cartesian coordinates. Defining the elevation channel is optional and subject to the type of processing. You can designate any pair of channels to hold henceforth the cartesian coordinates.

1. On the top menu bar click → *Coordinates* → *Set Current X Y Z...*
2. In the dialog that appears for Current X, select **UTME_N83** from the dropdown list
3. For the Current Y, select **UTMN_N83** from the dropdown list
4. For the Current Z, select **Alt_Baro** from the dropdown list
5. Click → **OK**
 - ① Upon completion, the supplied channels are now indicated with a blue X Y Z symbol.
 - From this point onwards, the project will not prompt you for the XYZ-channel names.

■ Profile display

Insights on the data often results from visualizing them in profiles. You can access up to 5 profile windows in the database, where each window can display multiple profiles – e.g.,

1. Inside the database, right-click → the *Tot_Mag* channel cell for a contextual menu
2. Click → *Show Profile*
3. Repeat with *Res_Mag*
4. Expand the second profile window along the bottom margin, click inside the empty window and display *Alt_Baro* in this profile window

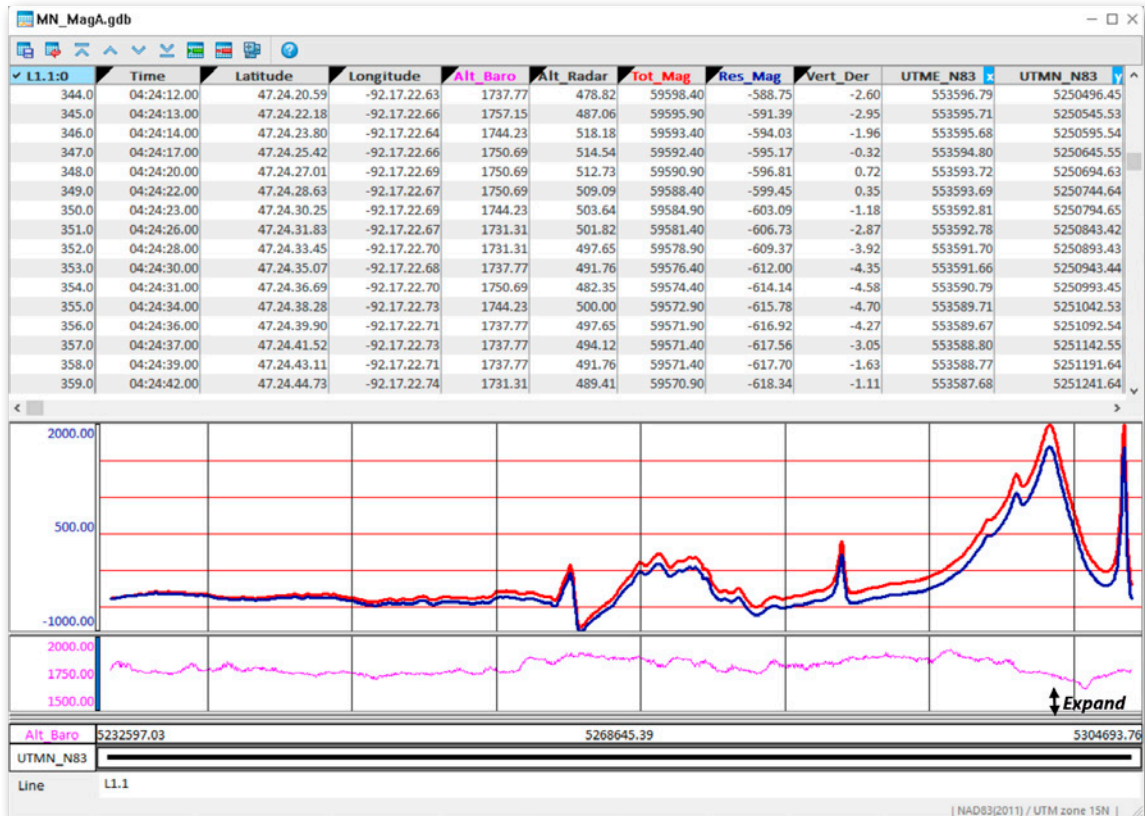


Figure 7: Display multiple profiles in multiple profile windows.

- ① All windows are resizable
- ① Right-mouse click in the profile window and explore the options.

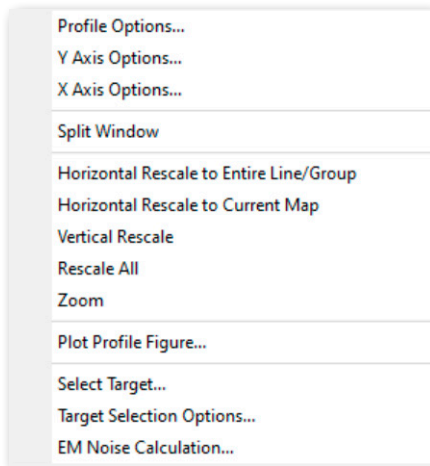


Figure 8: Profile window options

■ Create a plan map

To get a better understanding of the survey coverage, you can create a plan map to display the survey paths. First define the bounding rectangle of the study area and then plot the path - e.g., with the database open in the workspace:

1. On the menu bar, click → *Map Tools* → *New Map from* → *X,Y*
2. In the dialog that opens, click → Scan data
3. Click → Next
4. Name the map: **Plan_A**
5. Accept the defaults
 - ① The map recognizes the projection assigned to the database
6. Click → Finish
 - ① A blank geolocation map results with boundaries that accommodate the database
 - ① Move the mouse's cursor inside the blank map and note the commensurately updated geolocation coordinates along the status bar

To plot the path:

1. Click → *Map Tools* → *Line Path*
2. Set the label size: **0.75**
3. Accept the remaining defaults
4. Click → OK
 - ① Right-mouse click inside the map window and explore the options. You can zoom, pan, and measure distances and angles.

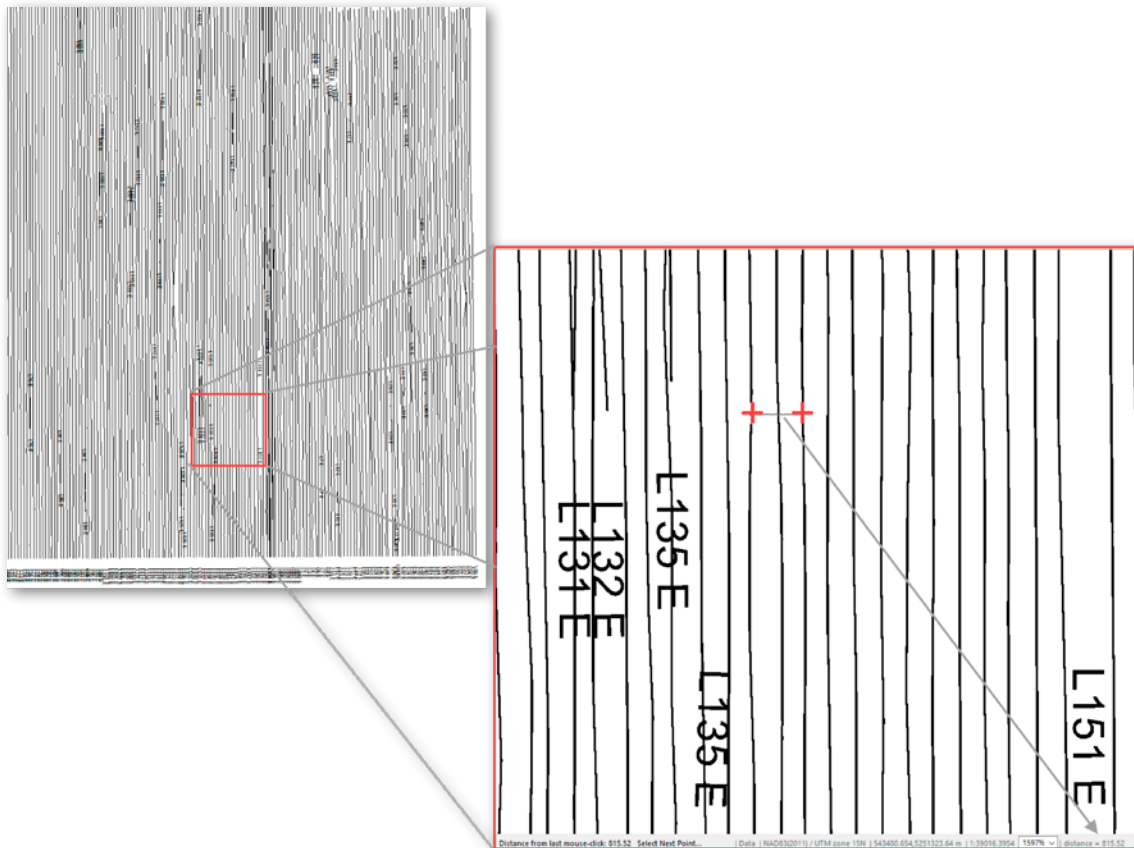


Figure 9: Zoom, pan, and measure distances. The status bar reports cursor location and the distance measured.

■ Gridding

The human eye has an affinity for pattern recognition, as a result the gridded form of the data is more comprehensible to the human interpreter. Gridded data sets can be produced from surveyed data and displayed using a colour ramp. Geophysical colour grids deliver a better understanding of a spatial distribution and of the nature of the data.

Gridded data files are compact and comprehensive for storage and archiving [see Hinze et al. (2013), Appendix A.6.2]. Oasis montaj offers numerous data gridding.

Bi-directional interpolation is commonly used to grid airborne data surveyed along quasi-parallel lines. This gridding approach interpolates the geophysical sensor data along the line at equal intervals then across the original survey direction, producing values for all equally spaced nodes.

Minimum Curvature interpolation is best suited for data of a more random spatial distribution and can be used with line-oriented data.

Multi-trend gridding honors the linear features in a dataset regardless of their azimuth angle.

To avoid data aliasing during the interpolation, the node spacing should be set to no less than $1/8$ and no more than $1/2$ of the line spacing. The supplied dataset MN_Mag_A is surveyed at a line spacing of 400 m. To grid the line-based data:

1. On the menu bar click → *Grid and Image* → *Gridding* → *Grid Data...*
2. In the window that opens select Channel to grid: **Res_Mag**
3. The Name of output grid file is defaulted, as a mnemonic for the applied process append it with **BG_200**
4. Select Gridding method : **Bi-directional**
5. Change the grid Cell size to **200**

6. Change the Maximum line separation to **1200** to avoid gaps in the output grid
 - ① The resizable preview window will display a desampled preview of the output grid produced with the current parameters

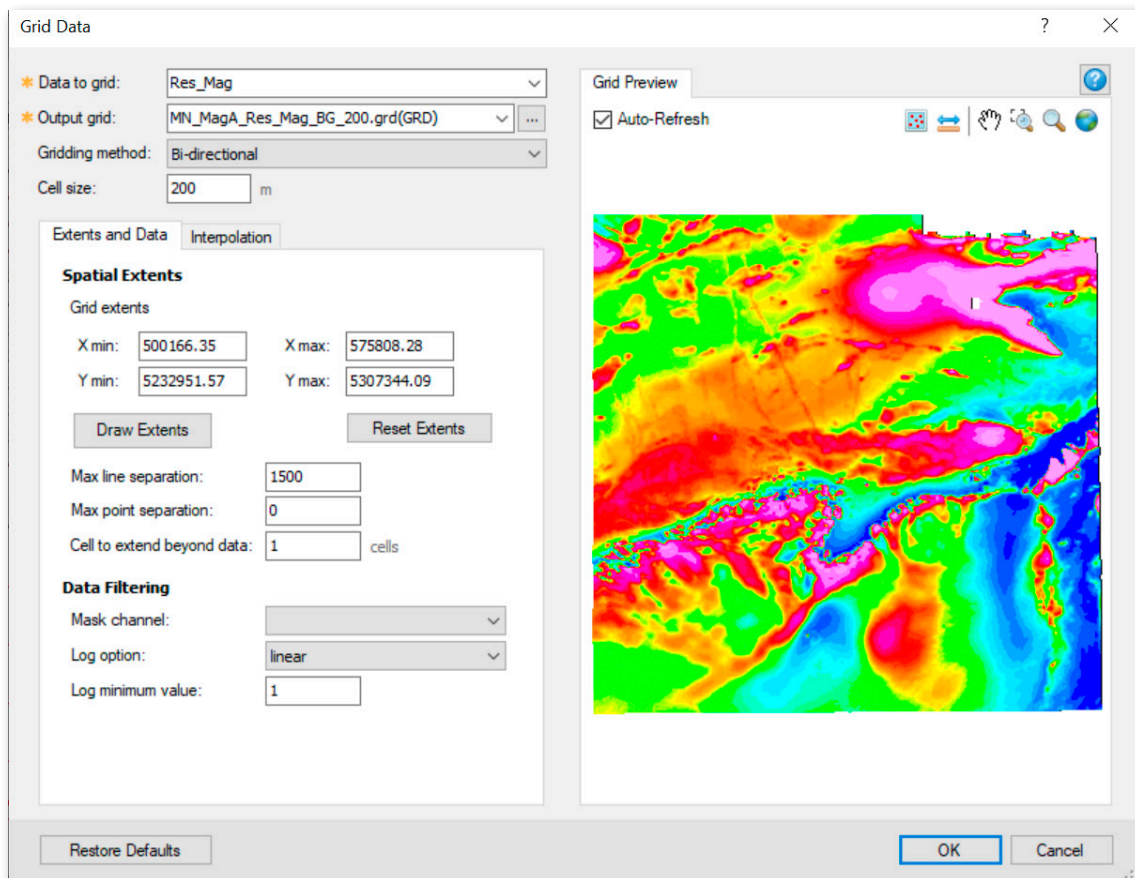


Figure 10: Gridding and preview dialog.

7. If you are satisfied with the preview, click → OK

The output grid will appear on the screen in a new window

 - ① For easy access, the grid is added to the Project Explorer pane

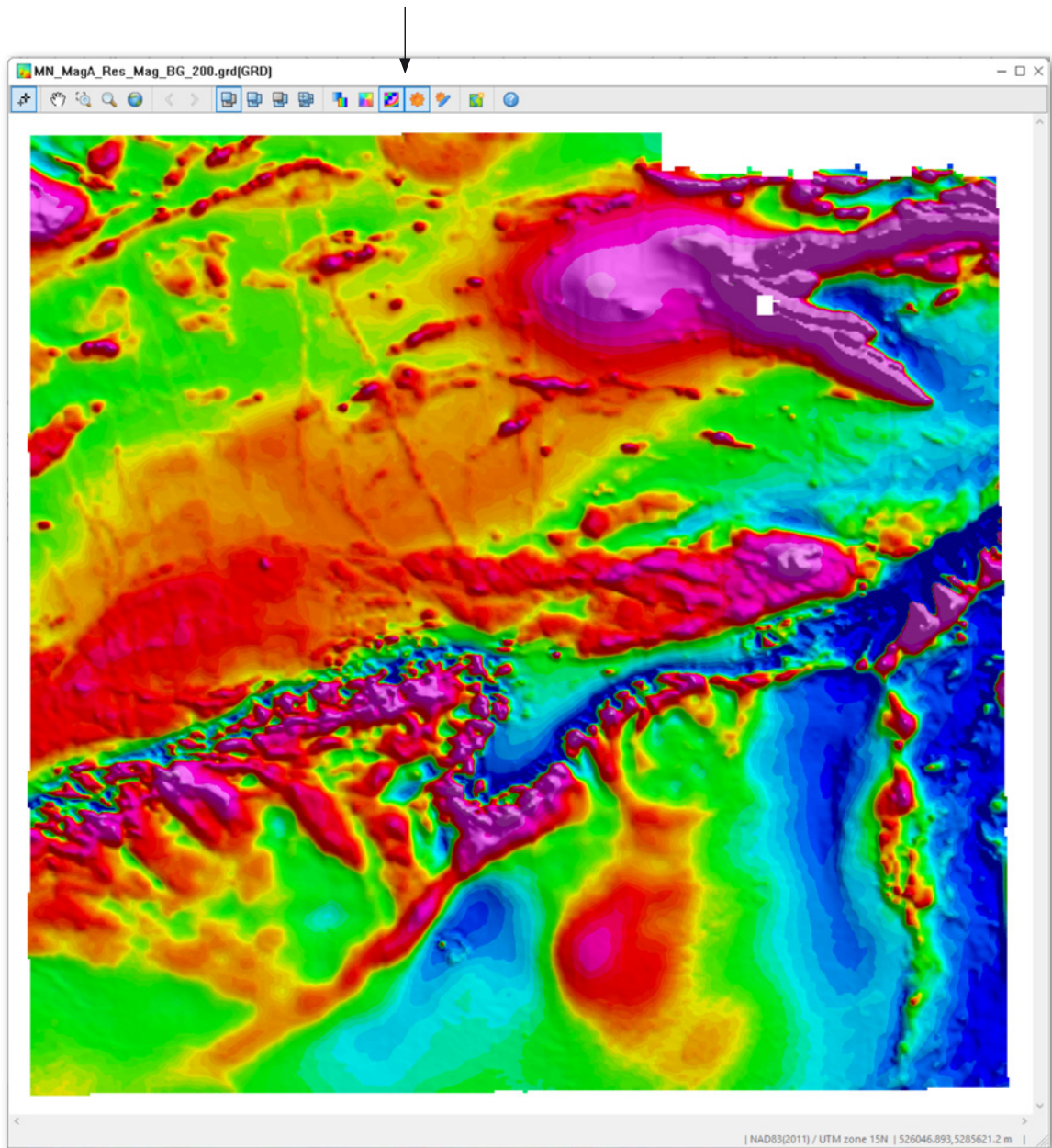




Figure 11: Area A displayed with a 45-degree shadow

It is generally more instructive to apply shadow to a colour grid because it emphasizes small features otherwise obscured by the colour distribution. To add the shadow:

8. On the grid tool bar click on the Sun 
 - ① You can modify the angle of the sun by clicking on 

Grid display

Generally, a multitude of data layers are overlaid on a geophysical map. To display the grid on a plan map:

1. Close the grid by clicking → X at the top right of the window
2. Drag and drop the grid MN_MagA_ResMag_BG_200 from the Project Explorer pane onto the plan map

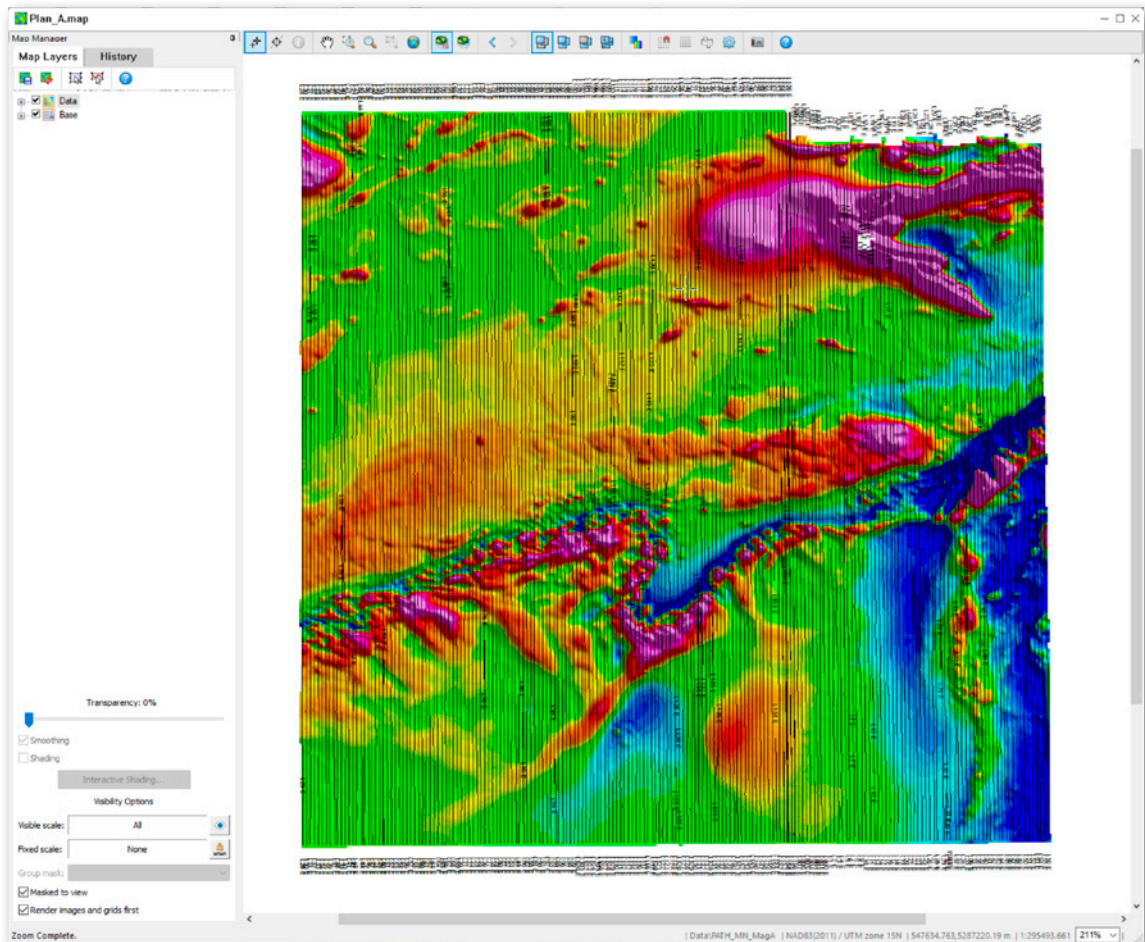


Figure 12: Plan map showing the colorized total field magnetic anomalies of Minnesota as gridded from the superimposed flight line coverage of the airborne survey.

■ Colour adjustment

To further emphasize the data's subtle features, the colour distribution can be adjusted without altering the data.


1. Expand the Map Manager tab along the left margin of the map
2. Expand the Data group
3. Uncheck the Path layer to better see the colour image
4. Click → the colour image layer AGG_MN_MagA_Res_MagBG_200
5. Click → the colour tool 
6. Modify the Distribution to **Normal distribution**
7. To stretch the colours around the mean of the data distribution, change the Expand parameter to **0.5**
8. Set the minimum Colour interval to **25** to force the colour breaks to occur on multiples of 25
9. Click → OK
10. Click → OK again



Figure 13: Expand the colour distribution.

Map plot and annotation

The plan map previously produced is not adequately annotated. To add the desired attributes consisting of the coordinate grid, geographic annotation and a title bar.

1. Click → Map Tools
2. Select → *Base Map* → *Draw Base Map*
3. Enter the parameters as shown on Figure 14
4. Click → Finish

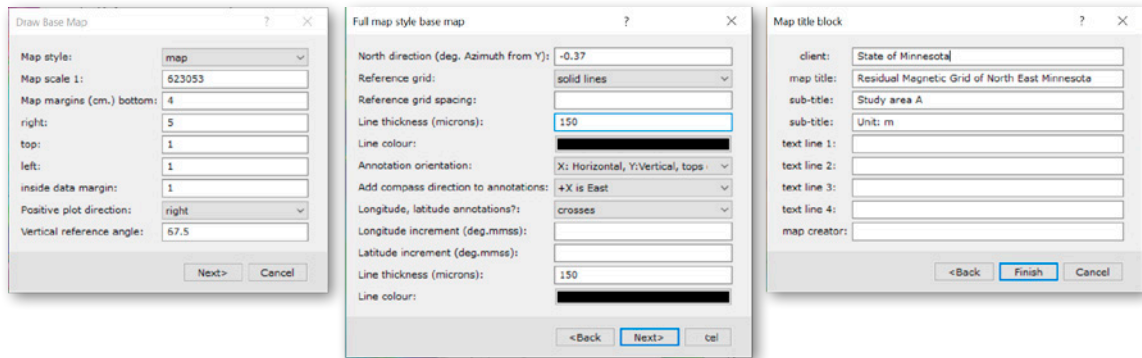


Figure 14: Set the Margins of the map, the geographic annotation, and the title bar.

The specified map features [North arrow, Scale bar, Title block, Annotated data border, etc.] will appear on the map as shown in Figure 15.

- ① Explore the options in the map's tool bar
- ① To move a layer click → the layer, the cursor will change, move the layer to the desired location
- ① To edit a layer, double click → the layer. When the edited layer is identified with a hashed rectangle you can edit its components. For example you can delete the unnecessary text Scale 1:623053 and only keep the actual scale bar

Colour bar legend

To add a colour bar legend to the map indicating the range of the colour bins. The legend's settings should honour the 25-minimum interval previously set:

1. Click → *Grid and Image*
2. Select → *Display on Map* → *Colour Legend Bar...*
3. For the Data layer select **MN_MagA_ResMagMN_BG_200** as the colour layer
4. For the Second layer select **MN_MagA_ResMagMN_BG_200_S** as the shadow layer
5. Provide a Title for the colour legend as **Residual Magnetics**
6. Set the Sub-title 1 to **nT**
7. Set X Location to **190**
8. Set Y Location to **40**
9. Expand More
10. Set Label text size to **2**
11. Set Maximum bar height to **100**
12. Click → Annotation Tab

13. Select **Ticks** for Division style
14. Select for Location to **Custom intervals**
15. Select for Coarse interval: **250**
16. Select for Fine interval to **25**
17. Click → OK
 - ① You can turn layers on an off or move them up and down in the map layer pane to change their order
 - ① Simultaneously depressing the Ctrl and_S keys saves the map

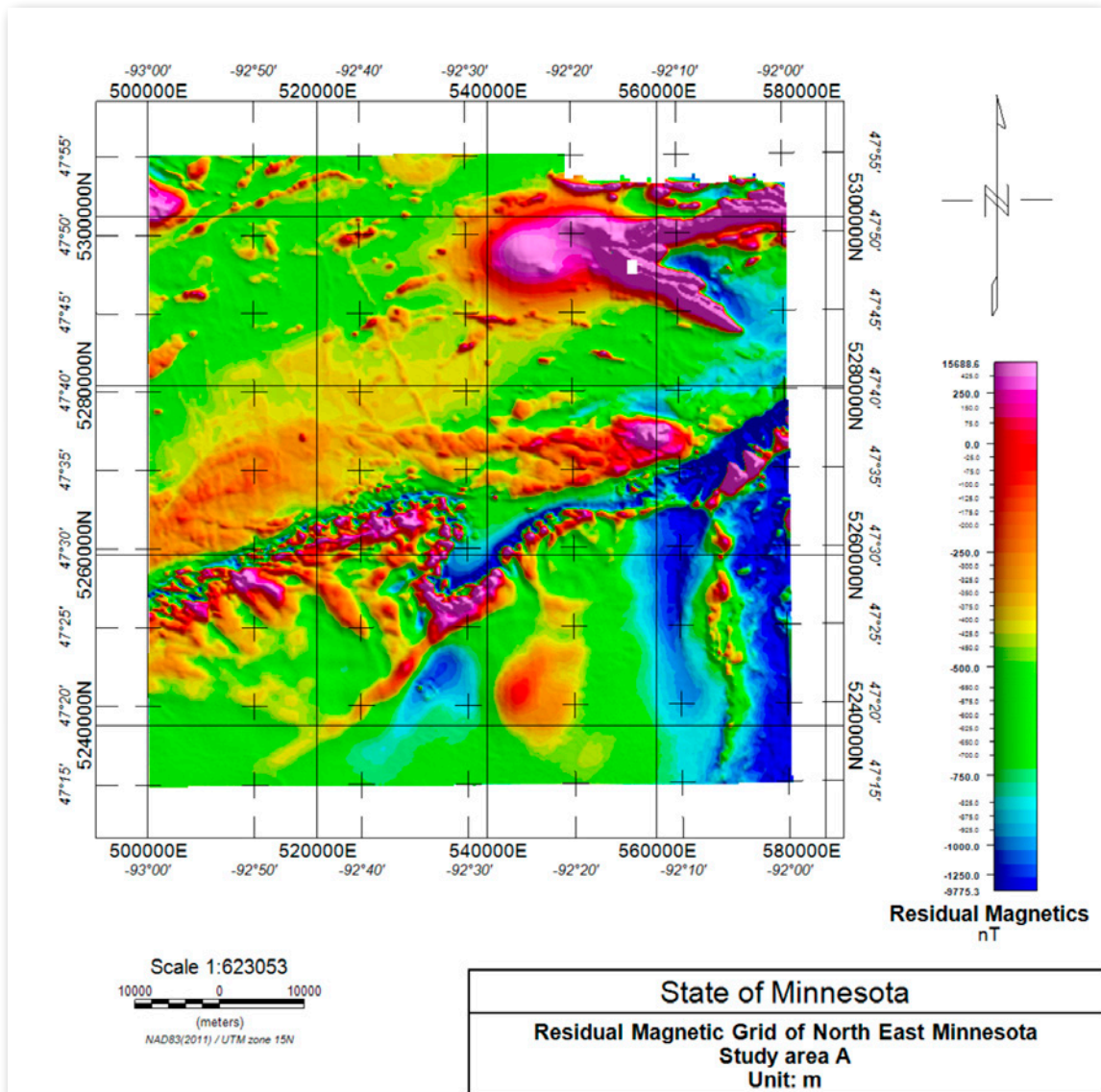



Figure 15: Annotated aeromagnetic anomaly map of study area A.

Save the colour boundary file

The plotted colour legend can be saved as a text file, both for inspection and to be used for loading additional grids with similar data coverage attributes.

1. On the colour map, select the layer MN_MagA_ResMagMN_BG_200.
2. Click → the colour tool 
3. Click → the Save icon  along the bottom
4. In the next window, click → Project Directory
Otherwise, the colour zone file is saved in the Geosoft tree
5. Click → Save
6. Click → OK

This file is saved in your working folder for future use.

Grid your data using a different (eg., a finer) sampling interval

Referring back to the Gridding section, regrid the data at the smaller sampling interval of 100 m.

1. On the menu bar, click → *Grid and Image* → *Gridding* → *Grid Data...*
2. In the window that opens, select *Channel* to grid: **Res_Mag**
3. The Name of output grid file is defaulted. Thus, as a mnemonic for the applied process, append it with **BG_100**
4. Select Gridding method: Bi-directional
5. Change the grid Cell size to **100**
6. Change the Maximum line separation to **1200** to avoid gaps in the output grid
7. Click → OK
 - ① The preview may not appear different than the 200-m interval result of previous Bigrid run. However, by zooming in, the difference that includes some aliasing is apparent.

Display the 100-m interval grid

Display the 100-m grid on the same map using the same zone file. The apparent differences result from the different cell sizes.

1. If the map is not already open, drag and drop *Plan_A.map* from the Project Explorer onto the Oasis montaj main pane
2. Click → *Grid and Image* → *Display on Map* → *Grid...*
3. From the dropdown list, select *Grid name*: **MN_MagA_ResMagMN_BG_100**
4. Click → inside the colour edit box to the right of *Colour*
5. Select *Category*: *Project directory*
6. Click → MN_Mag_Res_Mag_BG_200
7. Click → OK
8. Check *Shading*
9. Click → *Current map*
 - ① You can zoom then and check/uncheck the top layer to see the grid differences.

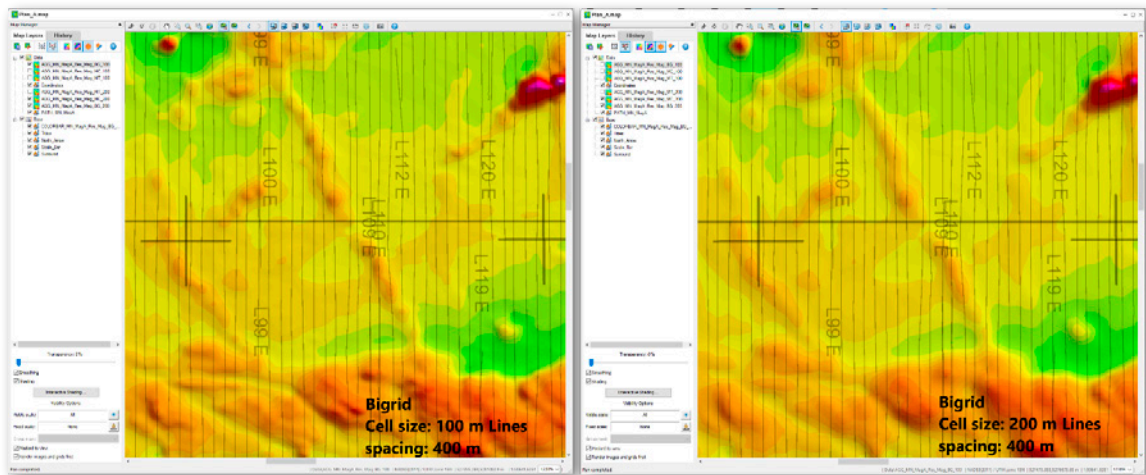


Figure 16: Bigrid estimates using intervals of 100 m (left) and 200 m (right).

Grid your data using another interpolation method

Refer to the Gridding section and grid your data at the same grid interval, using the Minimum Curvature and Multitrend gridding methods. Note that Multitrend gridding is a slower method, but it find and join linear features.

1. On the menu bar, click → *Grid and Image* → *Gridding* → *Grid Data...*
2. In the window that opens, select Channel to grid: **Res_Mag**
3. The Name of output grid file is defaulted. Thus, as a mnemonic for the applied process, append it with **MC_100**
4. Select *Gridding method*: **Minimum Curvature**
5. Change the grid Cell size to **100**
6. Change the Maximum line separation to **1200** to avoid gaps in the output grid
7. Click → **OK**
 - ① The preview may look like the result from running Bigrid, but a later investigation will further compare the differences

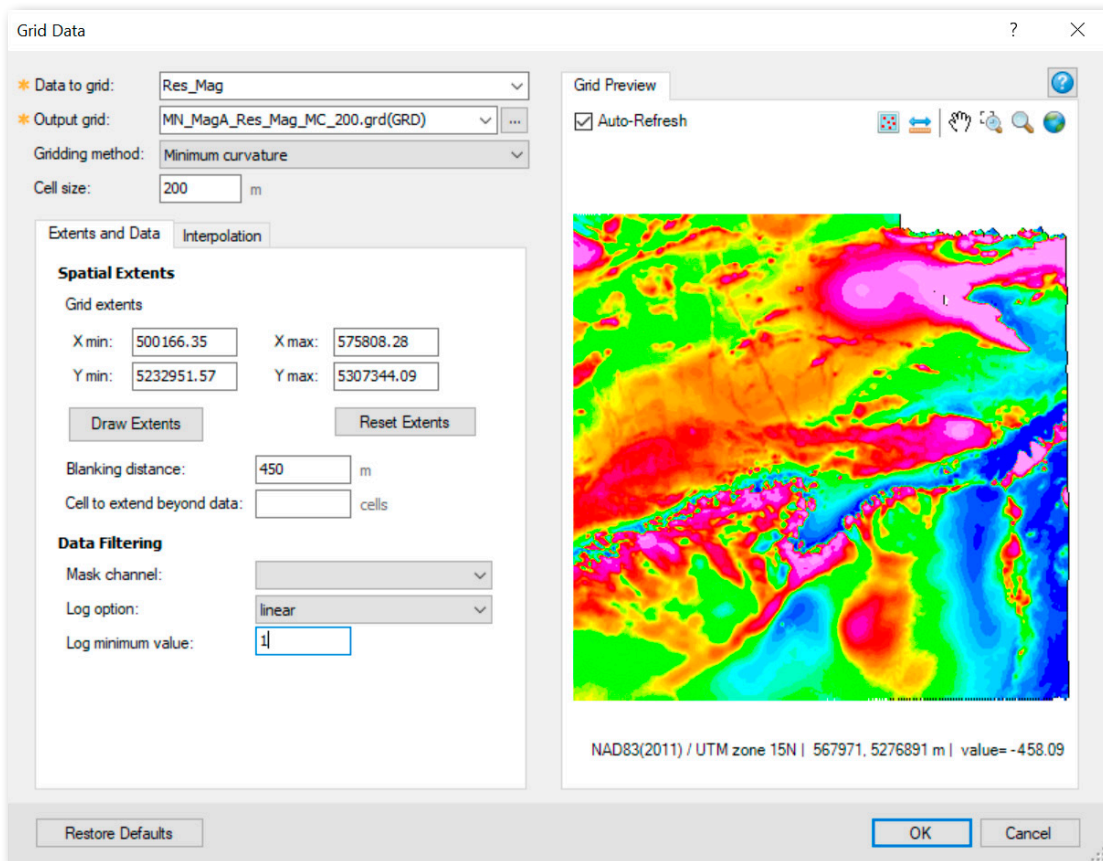


Figure 17: Minimum curvature gridding

- ① It is recommended to turn off the Grid Preview when running the Multitrend gridding because this method is slower and generating the preview consumes unnecessary time
- 8. Run the data gridding exercise using Multitrend gridding
- 9. Click → OK

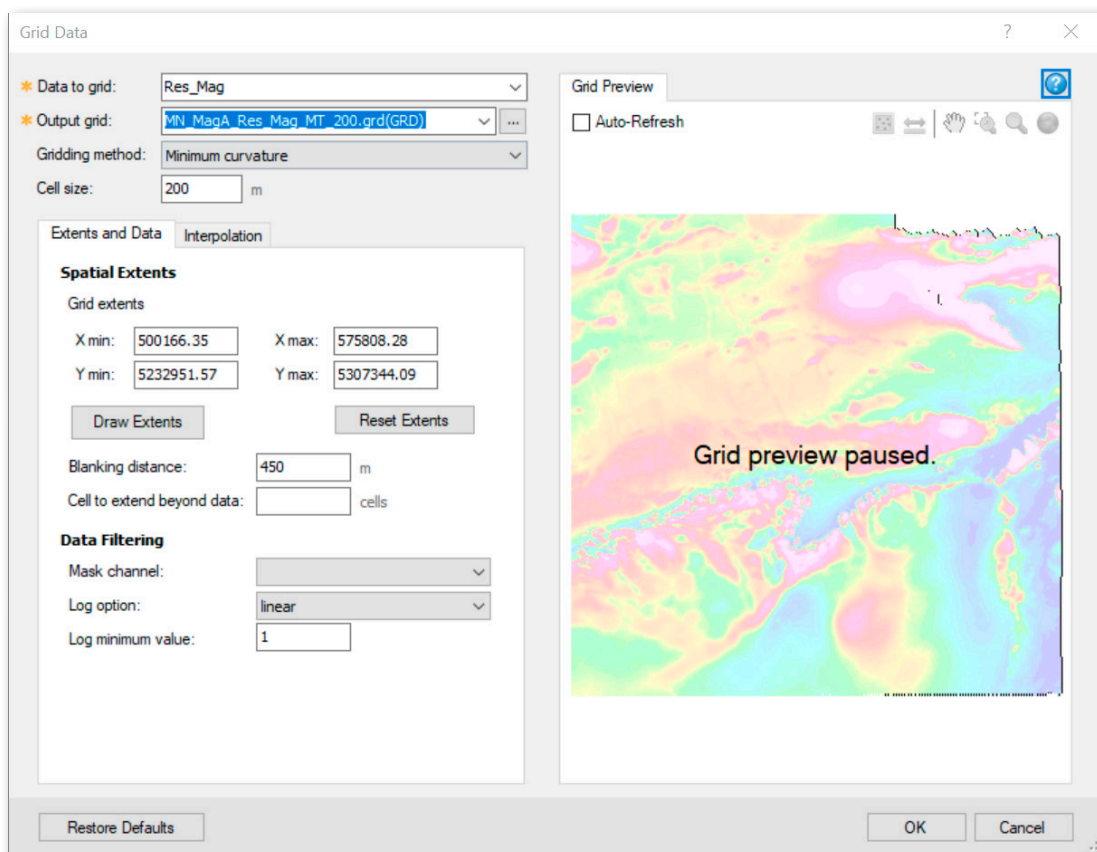


Figure 18: Multitrend gridding

Compare outcomes of different sampling and interpolation methods

Load the grids on the same map using the same colour zone file. The grid cell size being the same, the differences that you find are a result from using different methodologies.

1. If the map is not already open, drag and drop *Plan_A.map* from the Project Explorer onto the Oasis montaj main pane
2. Click → *Grid and Image*
3. Select → *Display on Map* → *Grid...*
4. From the dropdown list, select Grid name: **MN_MagA_ResMagMN_MC_100**
5. Click inside the colour edit box to the right of Colour
6. Select Category: **Project directory**
7. Click → MN_Mag_Res_Mag_BG_200
8. Click → OK
9. Check Shading
10. Click → Current map

Repeat the above steps to display the grid **MN_MagA_ResMagMN_MT_100**

- ① In the Map Layer pane, turn toggle the image layers off/on to view the differences. The data along the survey lines are honoured, but in between lines grid estimates are subject to the selected interpolation method.
- ① You can also zoom into a select window to see the differences better.
- ① Turn on the line path display to observe how closely the data along survey lines are honoured.

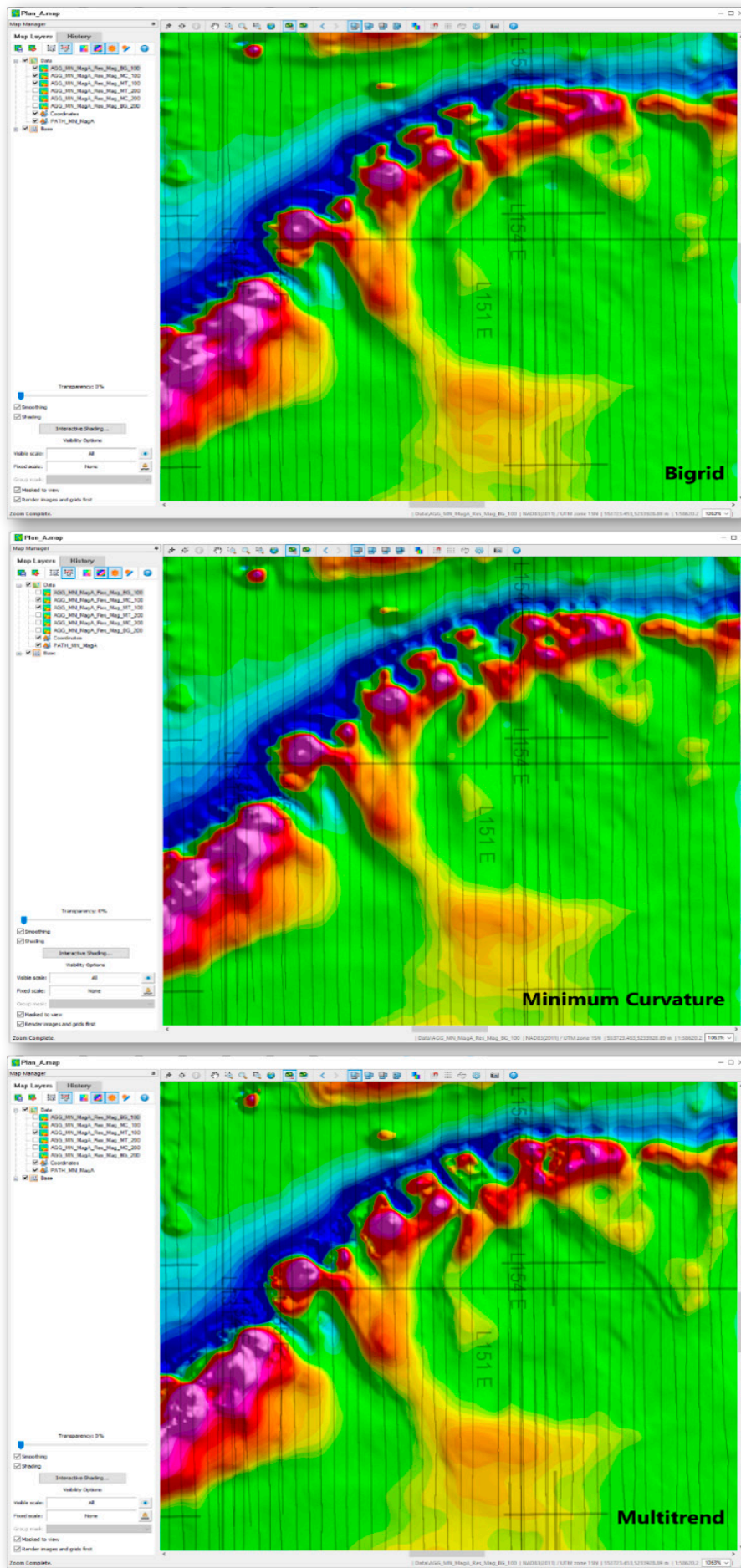


Figure 19: Comparing aeromagnetic anomaly estimates from the bigrid (top), minimum curvature (middle), and multitrend (bottom) gridding methods

■ Measuring distances

To measure the distance between any 2 points on the data view

1. Right-click → *Measure distance*
2. Left-click ← the first point in the map marking the beginning of the line segment
3. Move to the end point and left click ←
 - ① The distance appears in the View in the spatial units displayed at the right end of the status bar
4. Right-click → Done when finished

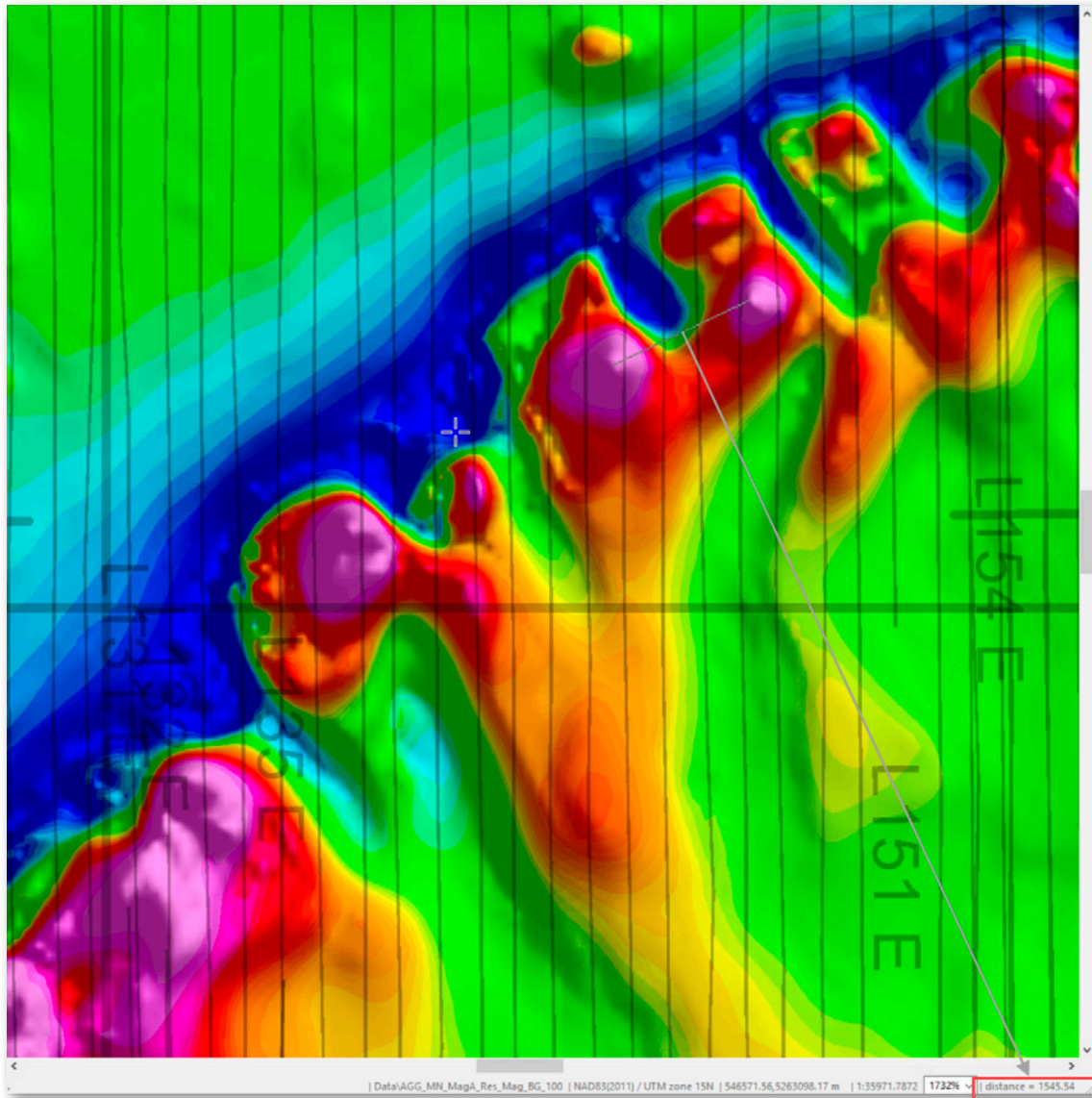


Figure 20: Displaying the ground distance between two aeromagnetic anomaly peaks.

■ Grid differences

Comparing grids is greatly facilitated by calculating and plotting the differences in the underlying data grids. Consider, for example, using the minimum curvature method [Hinze et al. (2013), Appendix A.6.2] to grid the Res_Mag channel at a 100-m interval for comparison with the bi-directionally gridded data in Figure 15.

To compare the effects of bi-directional versus minimum curvature gridding, the difference in the two grids can be taken using the Grid Math Expression Builder.

1. Click → *Grid and Image* → *Grid Math*
2. Set Expression: **G0 = G1 - G2**
3. Set Assign grids: G0 = **Diff_100_BG_MC**
4. Set Assign grids: G1 = **MN_MagA_Res_Mag_BG_100**
5. Set Assign grids: G2 = **MN_MagA_Res_Mag_MC_100**
6. Click → OK

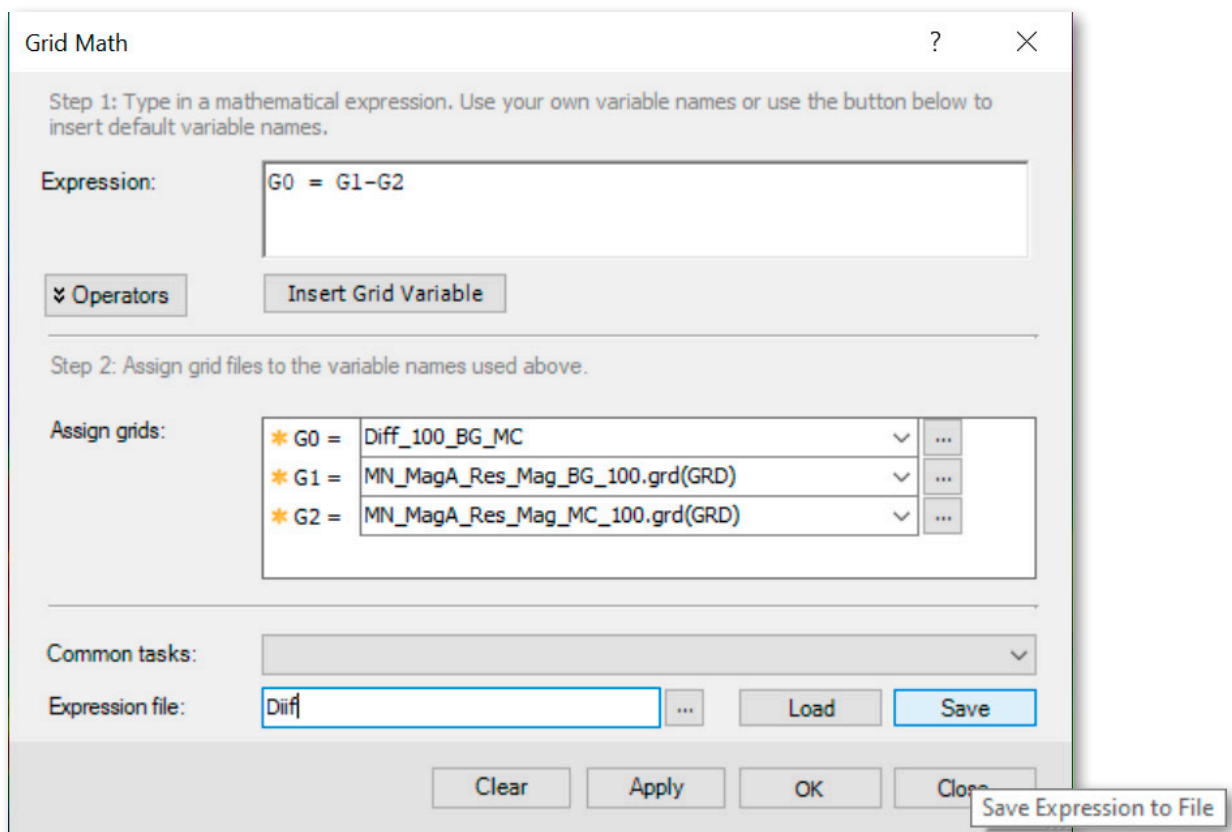


Figure 21: Grid math interface

The difference map in Figure 22 will appear

- ① You can save the expression you just build for future use or editing.
- ① Explore the Operators of the math expression.
- ① The database also offers math expressions.

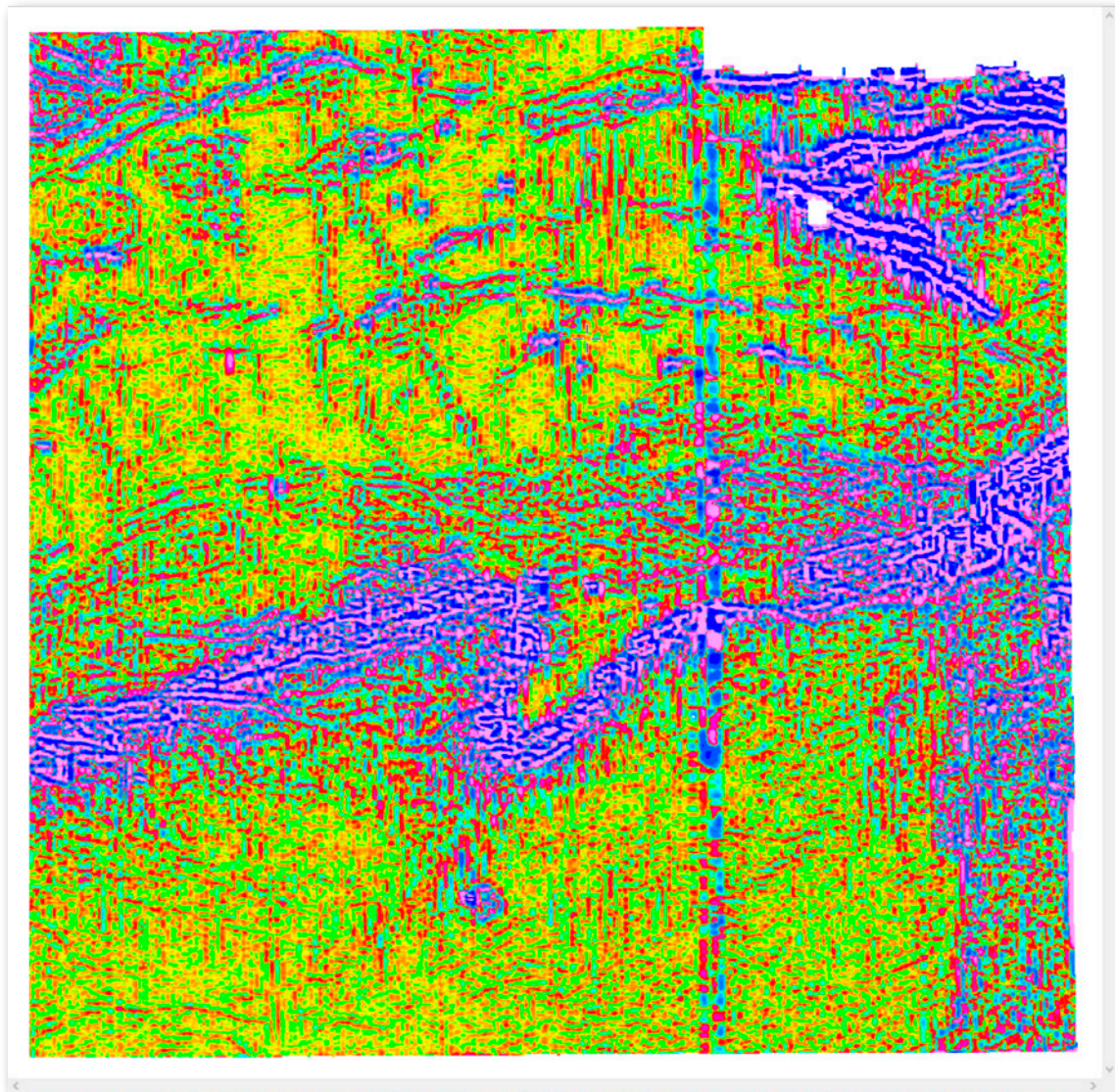


Figure 22: Difference between bi-directional and minimum curvature gridding at 100 m interval. The colour distribution is spread across the data's amplitude range.

■ Calculating Grid Attributes

The colour image (eg., Fig. 22) highlights the amplitude and geometric variations in the the bigrid and minimum curvature prediction differences. OmGM provides modules to estimate essential statistical attributes of the data to better understand them and assess effective graphical parameters (e.g., contour/ color intervals) for representing the data in profile, map, and isometric formats (e.g., Hinze et al., 2013, App. A)s. For example, to estimate the amplitude range, mean, and standard deviation of the difference grid that constrain the effective mapping parameters of the data:

1. In the Project Explorer pane, expand the Grids node
2. Right-click → the first input grid and select Properties

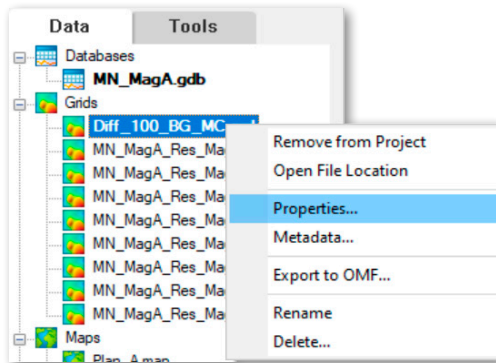


Figure 23: View grid properties.

3. Along the bottom Click → Stats
Repeat for the second input grid and the difference grid and compare the standard deviations

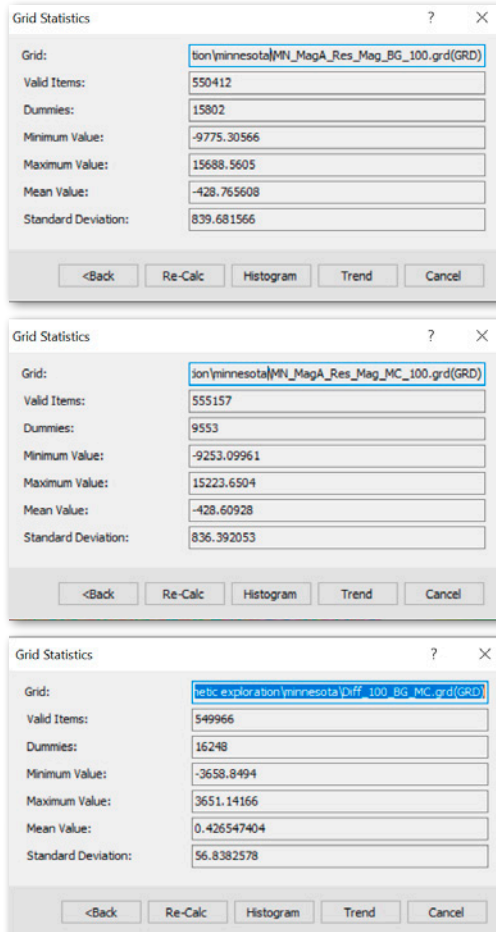


Figure 24: Statistics of the input grids and their differences.

IGRF calculations

The earth's magnetic field varies over amplitudes that range from about 30,000 to 60,000 nTs, respectively from the equator to the poles. These large amplitudes mask the typically much smaller magnetic anomalies of the subsurface. Thus, OmGM offers a module for computing accurate values of the *International Geomagnetic Reference Field (IGRF)* that may be subtracted from the anomaly observations to better reveal their subsurface attributes.

To load the *IGRF* module:

1. Click → *Project* → *Manage Menus*
2. Expand Extensions
3. Expand Geophysics
4. Select IGRE
5. Click → OK

The *IGRF* module is now added to the Menu bar

6. With the database open, Click → *IGRF* → *IGRF Channel*
7. Supply the parameters in Figure 25 to add the 3 new channels to the database
 - ① Display the profile of the total geomagnetic field in a profile window to check out the *IGRF*'s slow temporal and linear spatial trends
 - ① In general, the geomagnetic parameters within a study area that covers less than 2° show minimal variances
 - ① Right-mouse click → the channel Inclination, select edit, and increase the decimal field to 2 places

Compute GRF Channels

IGRF or DGRF: IGRF

IGRF Model year (ignored for DGRF): auto

Survey date: Single string YYYY/MM/DD or Channel name or Blank (to use line date): 2005/07/01

Input channels: -- Longitude: Longitude

-- Latitude: Latitude

Elevation (Channel name OR single value): Alt_Baro

Output channels: -- Total field: Tot_Field

-- Inclination: Inclination

-- Declination: Declination

OK Cancel

Figure 25: Setting parameters for IGRF calculations.

FILTERING

Data filtering is used extensively to isolate and enhance anomaly features of interest to interpretation. The applications and mathematical principles of magnetic anomaly filtering are outlined respectively in Chapter 12.4 and Appendix A.5 of Hinze et al. (2013). Examples of the numerous magnetic data filtering operations offered by OmGM are outlined below. To load the *2D Filtering* menu:

1. Click → *Project* → *Manage Menus*
2. Expand *Extensions*
3. Select *2D Filtering*
4. Click → *OK*

■ A) Reduction-to-pole [rtp] filter

Both the reduction-to-pole [RTP] filter, and the differential reduction-to-pole [DRTP] filter that is generally applicable to magnetic data covering 2° and greater regions are available. For example, to RTP-filter the minimum curvature grid file *MN_MagA_Res_Mag_MC_100.grd*.

1. Click → *2D Filtering* → *MAGMAP filtering...*
2. Set *Input grid*: **MN_MagA_Res_Mag_MC_100**
3. Set *Output grid*: **MN_MagA_Res_Mag_RTP**
4. Set *Filter file*: **RTP.com**
5. Click → *Edit filter*
to open the interactive window.

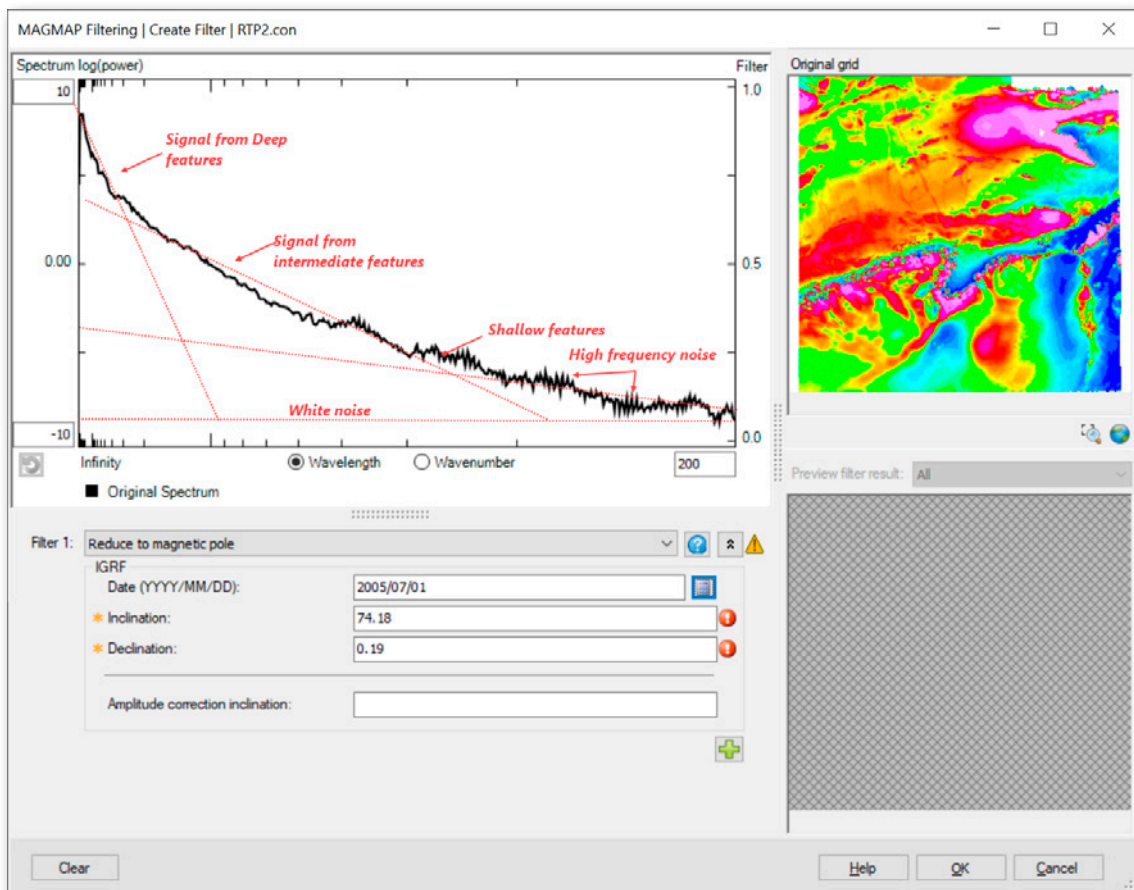


Figure 26: Magmap Interface. Panes are resizable. The power spectrum is displayed as a visual aid to select effective cutoff wavelengths.

6. From the dropdown list of Filter 1, select Reduce to magnetic pole
7. Set Date : **2005/07/01**
8. Click → Calculate button
to calculate the inclination and declination for the grid's geographic location at the supplied date
9. Click → OK
10. Click → OK again

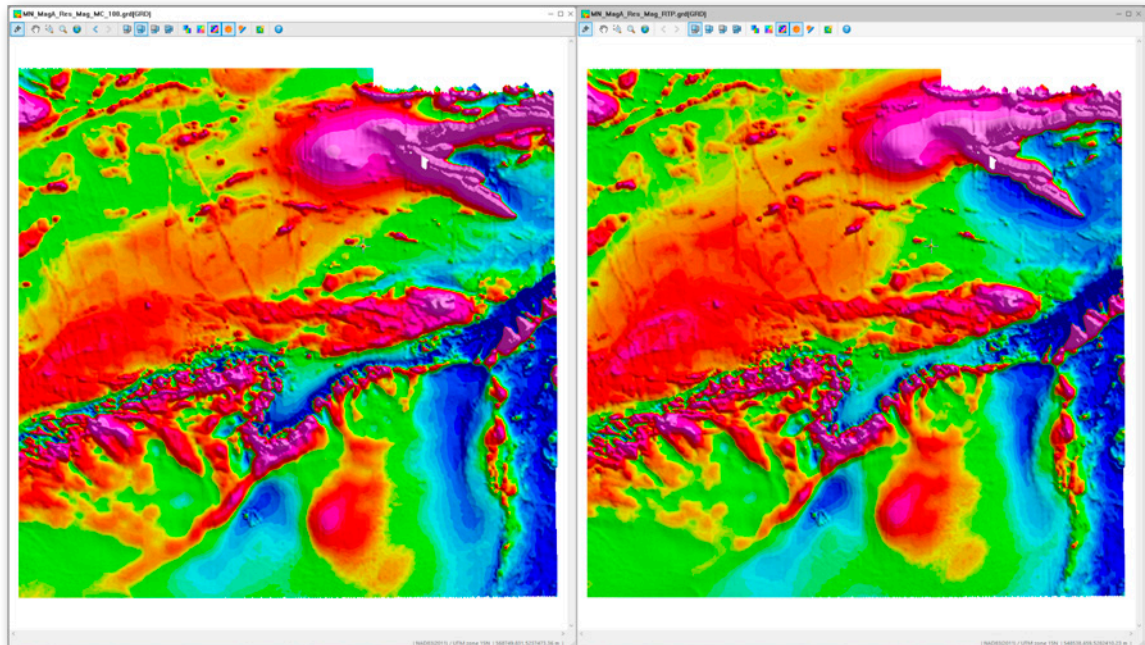



Figure 27: Comparing the Input anomaly grid (left) with the commensurate reduced-to-pole anomaly grid (right).

■ B) Derivative filtering

Vertical and horizontal derivative grids can be calculated in magmap. To calculate the first vertical derivative of the pole reduce grid:

1. Click → 2D Filtering → MAGMAP filtering...
2. Set Input grid: **MN_MagA_Res_Mag_RTP**
3. Set Output grid: **MN_MagA_Res_Mag_1VD**
4. Set Filter file: **VD.com**
5. Click → Edit filter
6. The interactive window to help setup the control file opens
7. From the dropdown list of Filter 1 select Derivative
8. Set Direction : Z
9. Set Order of differentiation: **1**
By nature derivation emphasizes noise as well as high frequency features. Add a second filter to subdue the noise
10. Click → 
11. From the dropdown list of Filter 2 select: Butterworth
12. Set Cutoff wavelength: **1000**
13. Set Filter order: **8**

14. Select: Lowpass
15. Click → OK
16. Click → OK again

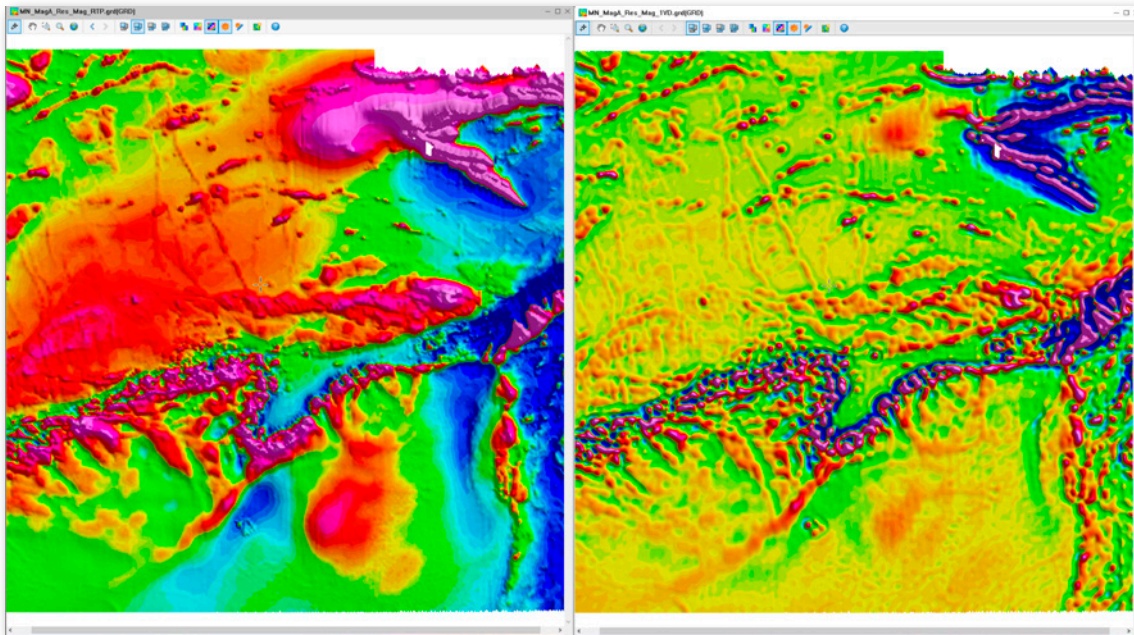


Figure 28: Pole reduced grid on the left, first vertical derivative grid on the right.

■ C) Directional filtering

To pass or reject strike-sensitive anomaly features in the gridded data, apply the directional cosine filter. Here, the filter wedge is constructed from the cosine function with smoothly tapering edges to better mitigate ringing and other Gibbs' errors in the output data. For an application to the minimum curvature grid:

1. Click → *2D Filtering* → *MAGMAP filtering...*
2. Set Input grid: **MN_MagA_Res_Mag_RTP**
3. Set Output grid: **MN_MagA_Res_Mag_DCOS**
4. Set Filter file: **DCOS.com**
5. Click → *Edit filter*
The interactive window to help setup the control file opens
6. From the dropdown list of Filter 1 select Directional cosine
7. Set Cutoff azimuth: **45**
8. Set Degree of cosine function: **8**
9. Reject

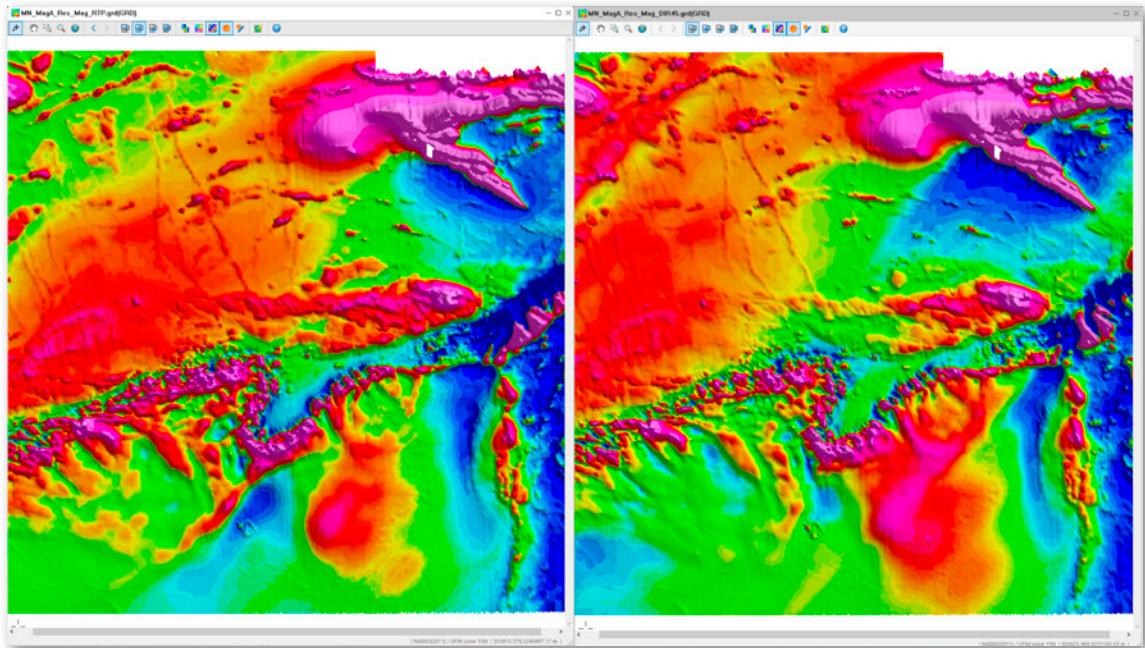


Figure 29: Pole reduce grid on the left, Directional filtered grid on the right

■ D) Composite directional+wavelength filter

Multiple filters may be specified together to achieve multiple filtering objectives. Filters are commutative and can be specified in any order. For example, to also enhance features with wavelengths roughly ≥ 1 km in the directionally filtered data:

1. Click \rightarrow *2D Filtering* \rightarrow *MAGMAP filtering...*
2. Set Input grid: **MN_MagA_Res_Mag_RTP**
3. Set Output grid: **MN_MagA_Res_Mag_DCOS**
4. Set Filter file: **DCOS.com**
5. Click \rightarrow *Edit filter*
The interactive window to help setup the control file opens
6. Add a second filter to this template
7. From the dropdown list of Filter 2 select Butterworth
8. Set Cutoff wavelength : 1000
9. Set Filter order: **8**
10. Low pass

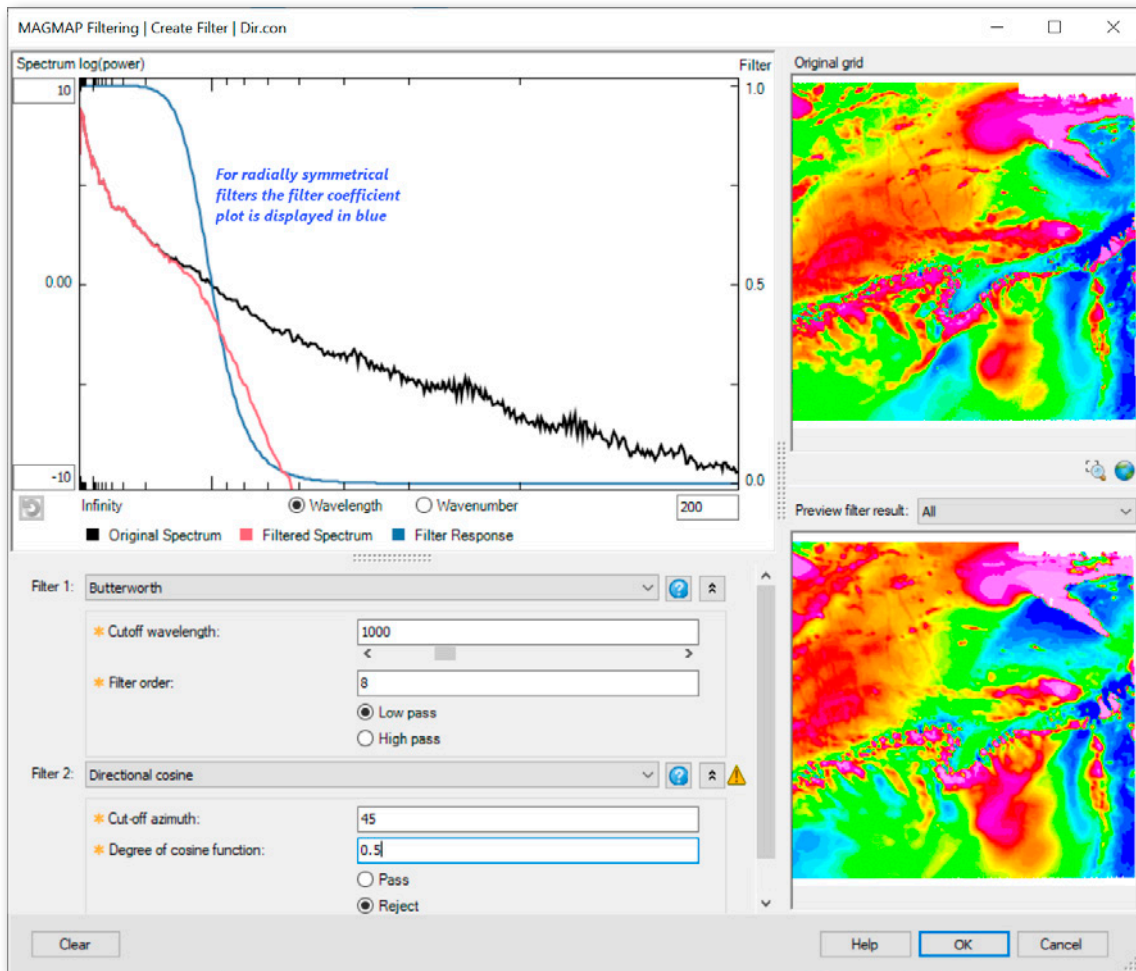


Figure 30: Composite filter. Coefficients of radial filters are displayed on the radial power spectrum.

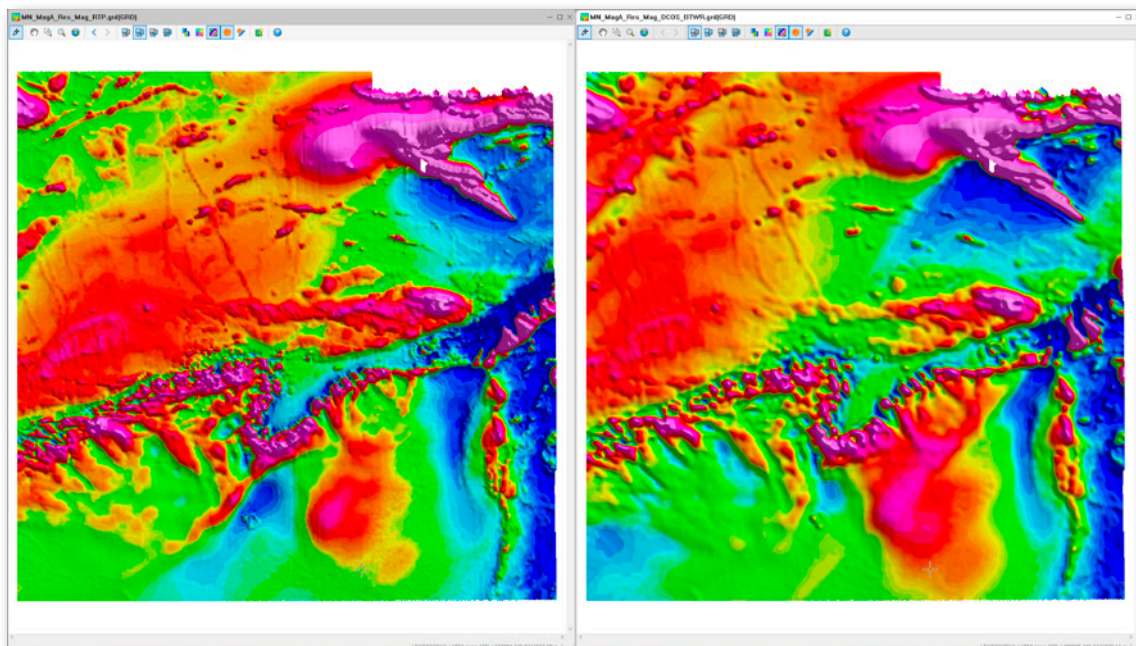


Figure 31: Composite directional and low pass Butterworth filter. Note the smoothness of the short wavelength feature.

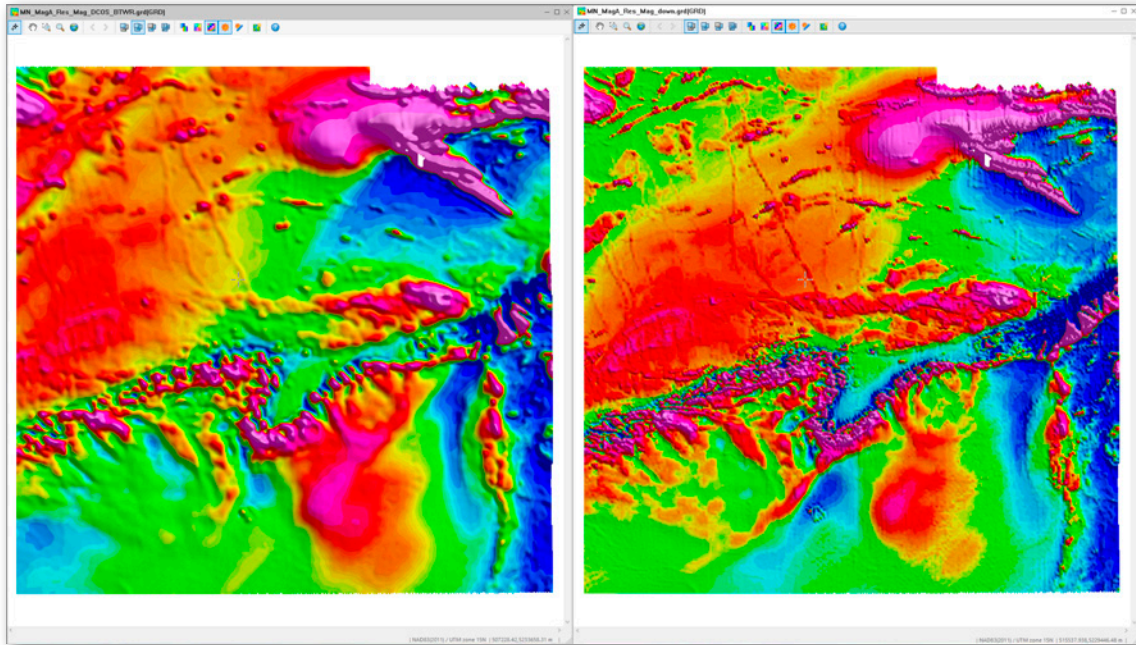


Figure 32: Upward continue grid to 1000 m on the left, downward continue grid with a 400 Butterworth low pass on the right.

■ F) Apparent susceptibility filter

Figure 33 shows the parameters for filtering the magnetic data grid for apparent susceptibility estimates at a depth of 120 m, assuming geomagnetic field strength [intensity], inclination, and declination values determined from the appropriate IGRF. Figure 34 shows the output grid.

You can also proceed to display all the processed grids on the same Plan_A.map and by turning them on and off compare the details that each reveals

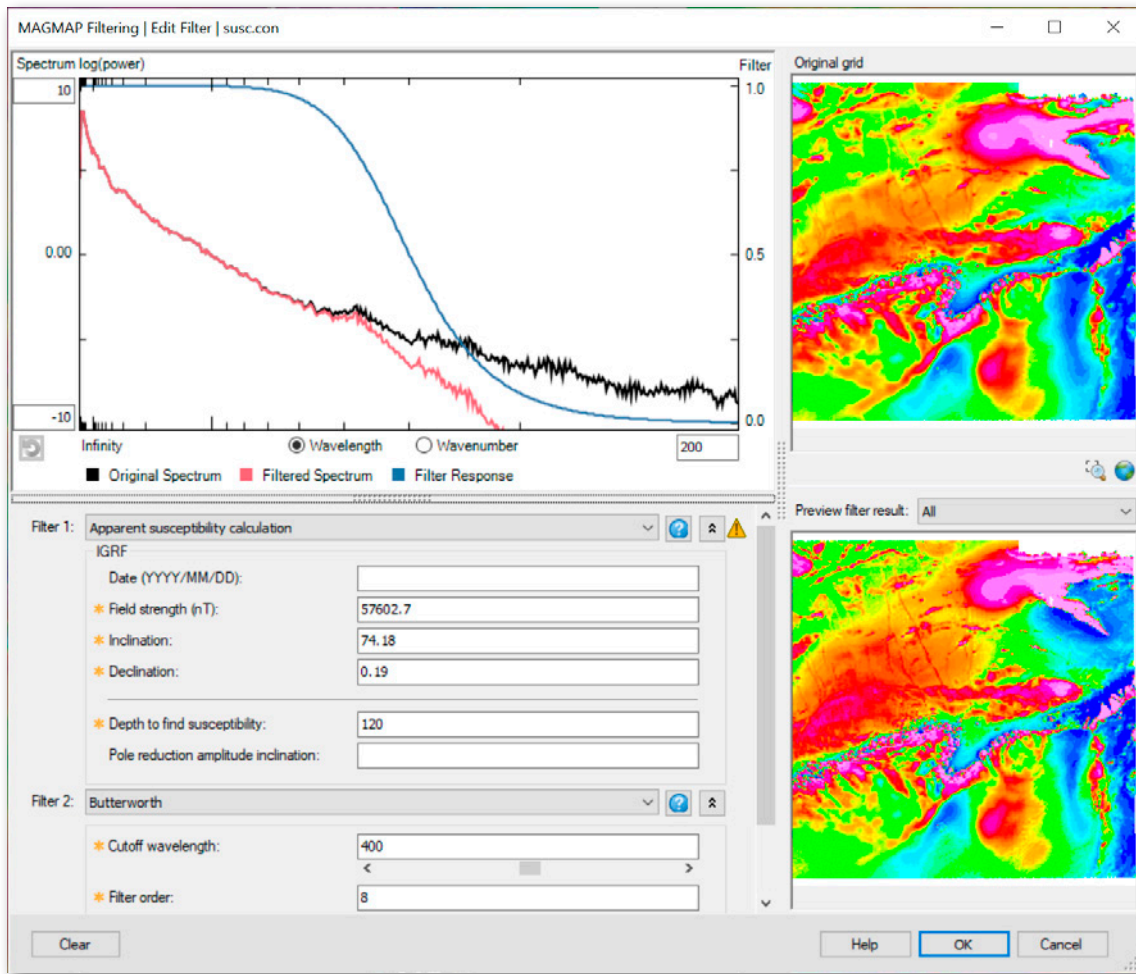


Figure 33: Apparent susceptibility parameters.

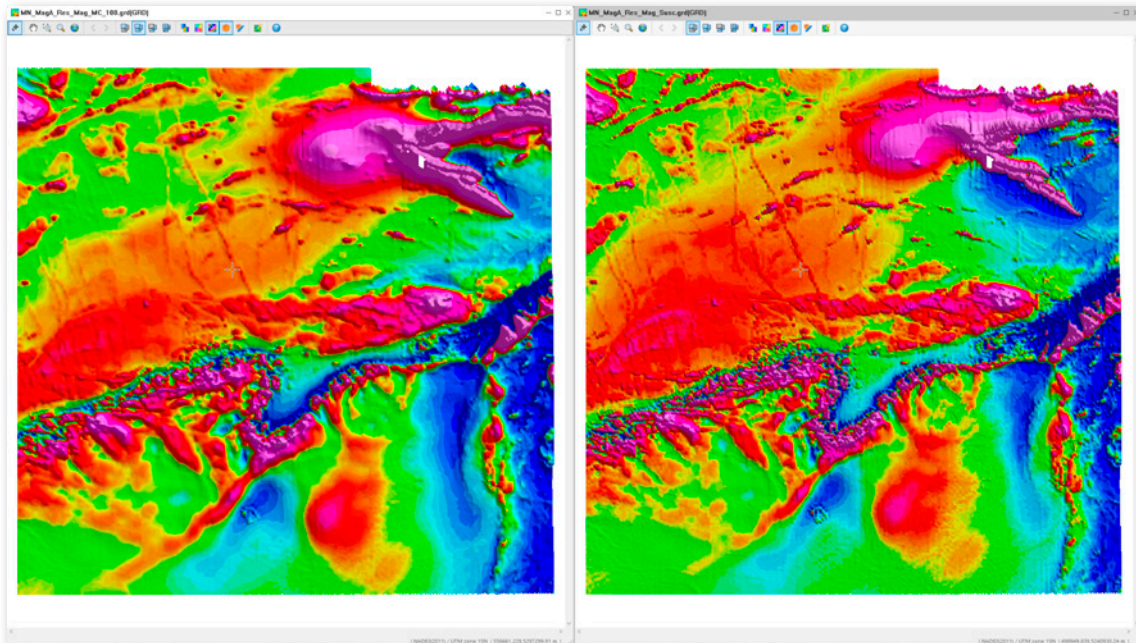


Figure 34: Apparent susceptibility

GRAVITY DATA PROCESSING

This section considers gravity observations that were reduced to simple Bouguer gravity anomalies using a density of 2,670 kg/m³ and standard procedures (Chandler, 1996; Chandler and Schaap, 1991). Observations were made at intervals ranging generally from 1.6 to 5 km, although the separation between observations may be as large as 10 km where ground access was limited.

Gravity data import

The fundamental format of OmGM is the database format. All tools operating on survey data operate on Geosoft databases, as a consequence, external data should be first converted to this database format.

1. On the menu bar click *Database* → *Import* → *ASCII ...*
2. In the dialog that appear click → Create database
3. Name the database **MN_GravA**
4. Click → OK
A blank database is created
5. Select the search button to the right of File(s) to import
6. Navigate to the data subfolder *Gravity* and select *MN_Grav_A.csv*
7. Click → Open
This is the file that will be imported
8. Select the search button to the right of Template
The Template file is provided
9. Select **Gravity\MN_Grav_A.i3**
10. Define the parameters as indicated in Figure 3.
11. Click → Open and then click → OK
The data is imported into a Geosoft database
 - ① Click Ctrl_S to commit the data to file.
 - ① To see the description of each parameter simply click on Help ? button on the top right of the Dialog

Designate the cartesian coordinates

To proceed with processing the data defining the cartesian coordinates is mandatory. You can designate any pair of channels to be henceforth the cartesian coordinates.

1. On the top menu bar click → *Coordinates* → *Set Current X Y Z...*
2. In the dialog that appears for Current X **select UTME_N83** from the dropdown list
3. For Current Y select **UTMN_N83** from the dropdown list
4. For Current Z select **Elev_Ft** from the dropdown list
5. Click → OK
 - ① It is recommended to go through the exercise of identifying the Geographic and projected coordinates. You can use the Set Coordinate System tool and then click on the Copy from option and copy the projection from the magnetic database.
 - ① Do the same for the Latitude/Longitude channels.
 - ① Edit the format of the latitude and Longitude channels and set the format to Geographic.

Station location plot

Since the gravity data belongs to the same area (A) as the magnetic data the gravity data can be plotted on the same map. In preparation to do so:

1. Open the map *Plan_A.map*
2. Turn off the magnetic processed layers
3. Turn off the colour bar
4. Move the north arrow to the lower margin

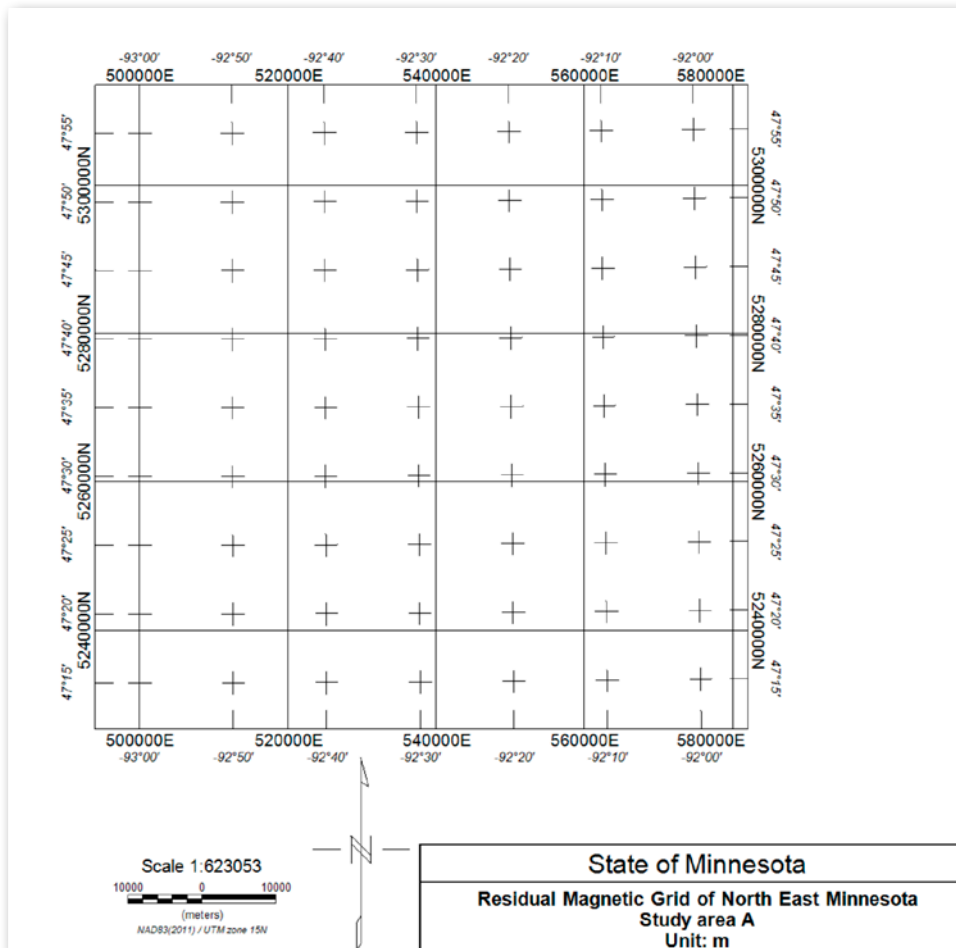


Figure 35: Map prepared for displaying gravity data.

While the gravity database is open run statistics on the *sBoug_mGal* channel. You will see that the data ranges from -81 to +21. This is important information that will be used to set the proportional size and colours:

1. Click → *Map Tools* → *Symbols* → *Colour Range and Proportional size...*
2. In the dialog that opens set *Colour channel*: ***sBoug_mGal***
3. *Number of ranges*: **12**
4. *Size channel*: ***sBoug_mGal***
5. *Zero level*: **-90**
6. *Scale factor*: **20**
7. Click → *Ranges*
8. Enter consecutively **-80, -70, -60,20**
9. Click → *OK*
10. Click → *Plot*

Add legend

1. Click → *Map Tools* → *Symbols* → *Colour Range Symbol Legend...*
2. In the dialog that opens set Title: **Bouguer Anomaly**
3. Title 2: Units: **mGal**
4. X position: **180**
5. Y position: **150**
 - ① You can also click on locate to set the location of the legend
6. Click → Plot

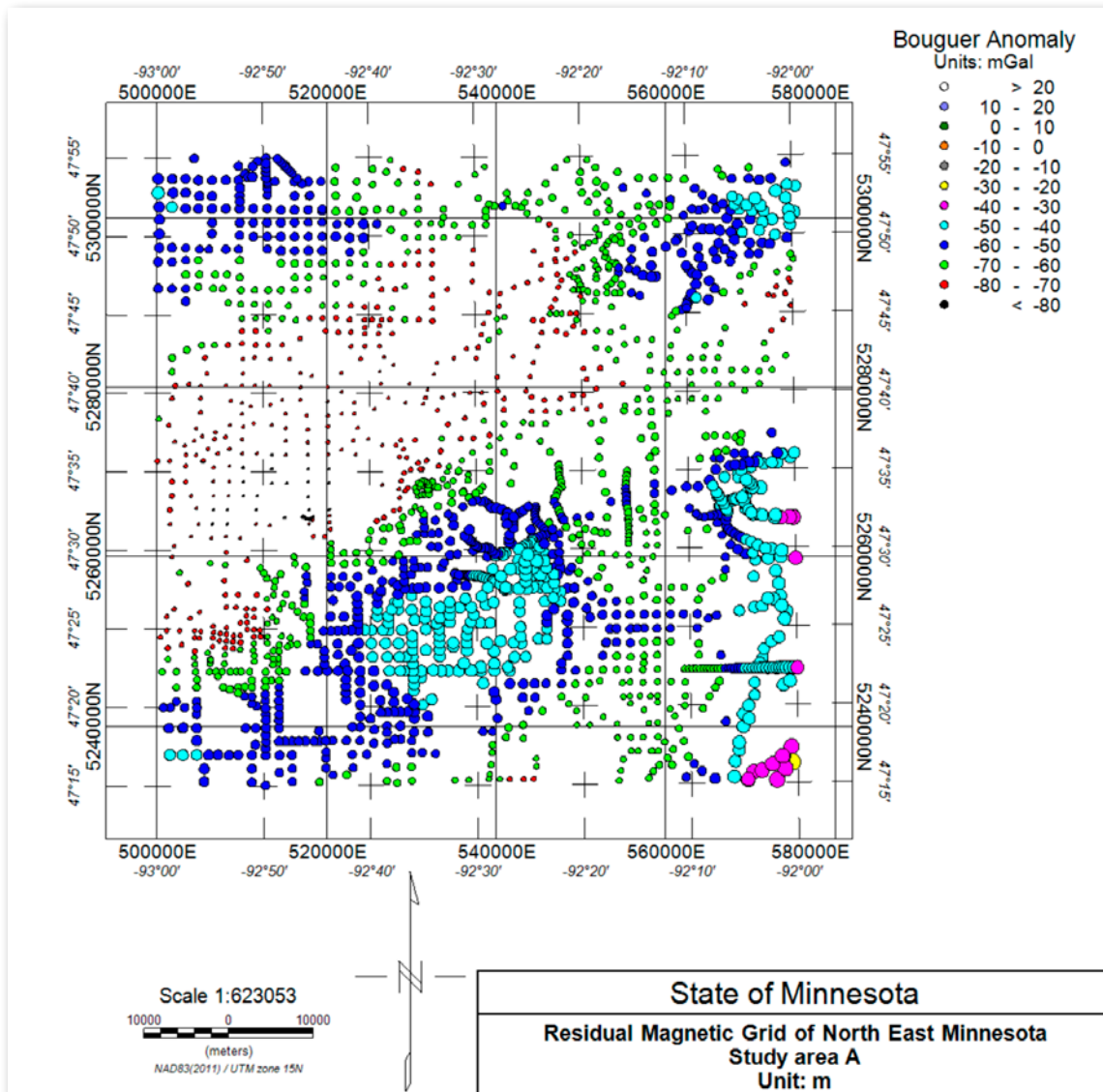


Figure 36: Proportional symbols of gravity stations.

Gridding

The gridding method applicable to randomly spaced data is minimum curvature.

To grid the line based data:

1. On the menu bar click → *Grid and Image* → *Gridding* → *Grid Data...*
2. In the window that opens select Channel to grid : **sBoug_mGal**
3. The Name of output grid file is defaulted, as a mnemonic for the applied process append it with **MC_300**
4. Select Gridding method : **Minimum urvature**
5. Change the grid Cell size to **300**
6. Change the Maximum line separation to **5000** to avoid gaps in the output grid
7. Click → **OK**

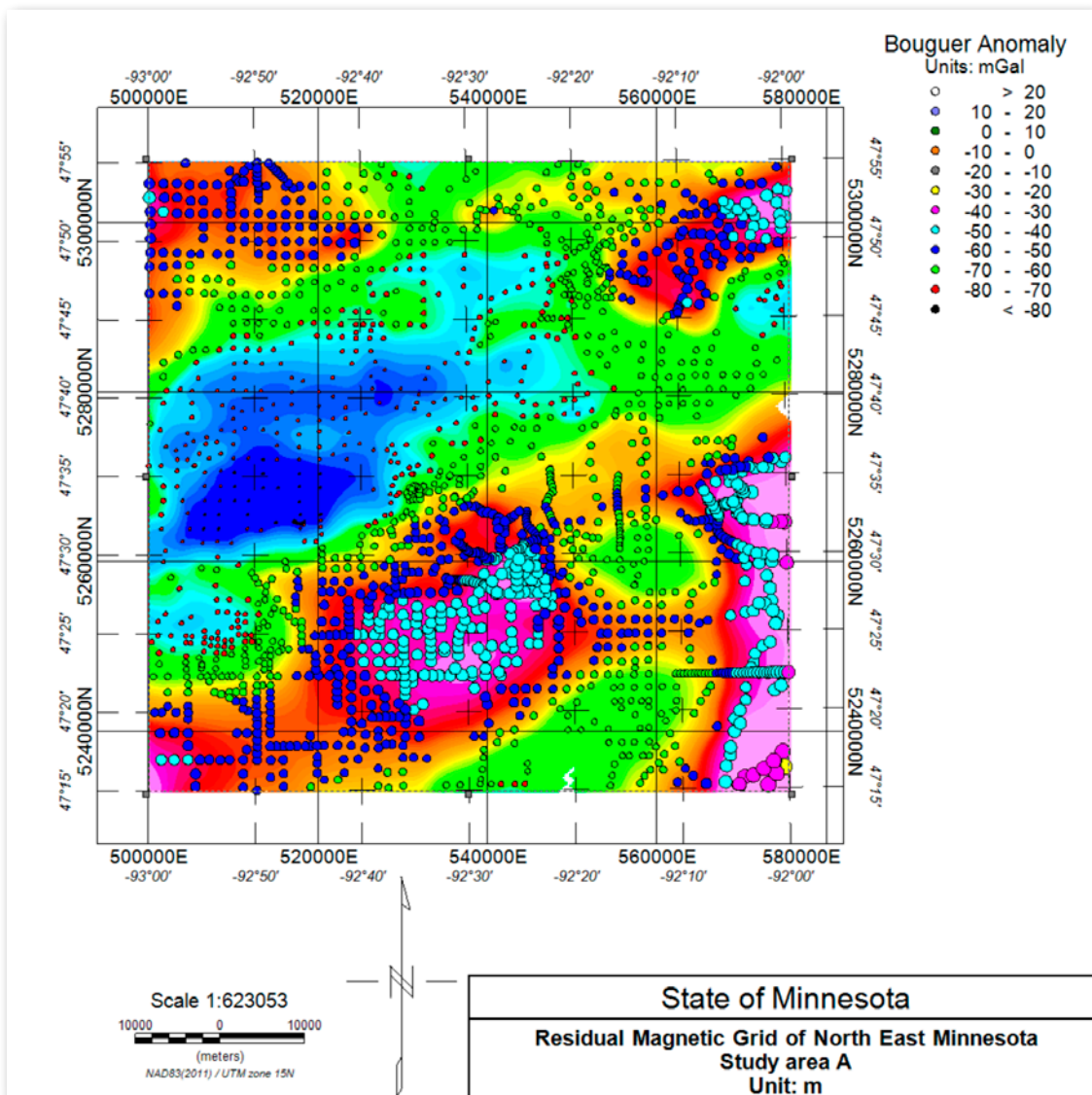


Figure 37: Bouguer anomaly grid

SUPPLEMENTAL

Study areas B,C & D have also been supplied to conduct the same exercises.

TRANSMISSION OF FILES

Geosoft files may be electronically sent to both license and non-license holders. For *Oasis montaj* license holders, pack the map by clicking → *Map* → *Pack Map Files...* so that all of the ancillary information transfers along with the map. However, this packing also can create very large file sizes.

For *Oasis montaj* non-license holders, Seequent provides a free *Oasis montaj* viewer that allows the sharing of databases and maps in their native formats.

Oasis montaj graphics may also be saved in standard graphical formats [e.g., jpg, tiff, geotiff, png, etc.] by clicking → *Map* → *Export...* and distributed to non-*Oasis montaj* users.

CONCLUSIONS

Oasis montaj offers an extensive package of data analysis and graphics programs for investigating the gravity and magnetic exploration topics in Hinze et al. (2013). The above sections offer only a cursory introduction to the package, and the reader is strongly encouraged to explore aggressively the many high-level capabilities of *Oasis montaj* to better appreciate its power in analyzing and interpreting potential field observations.

REFERENCES

- Chandler, V.W. 1985. Interpretation of Precambrian geology in Minnesota using low-altitude, high-resolution aeromagnetic data, in Hinze, W.J., (ed.), *The Utility of Regional Gravity and Magnetic Anomaly Maps*. Society of Exploration Geophysicists, Tulsa, OK.
- Chandler, V.W. 1991. Aeromagnetic map of Minnesota. Minnesota Geological Survey, State Map Series S-17, Scale 1:500,000.
- Chandler, V.W. 1996. Gravity and magnetic studies conducted recently, in Sims, P.K., (ed.), *Archean and Proterozoic geology of the Lake Superior region*
- U.S.A. U.S. Geological Survey Prof. Paper 1556.
- Chandler, V.W., and Schaap, B.D. 1991. Bouguer gravity anomaly map of Minnesota. Minnesota Geological Survey, State Map Series S-16, Scale 1:500,000.
- Chandler, V.W., Boerboom, T.J., and Jirsa, M.A. 2007. Penokean tectonics along a promontory-embayment margin in east-central Minnesota. *Precambrian Research*, v. 157.
- Hinze, W.J., von Frese, R.R.B., and Saad, A.H. 2013. *Gravity and Magnetic Exploration: Principles, Practices, and Applications*. Cambridge University Press, Cambridge.



A better understanding of the earth
creates a better world for all

[seequent.com](https://www.seequent.com)

Sequent, The Bentley Subsurface Company