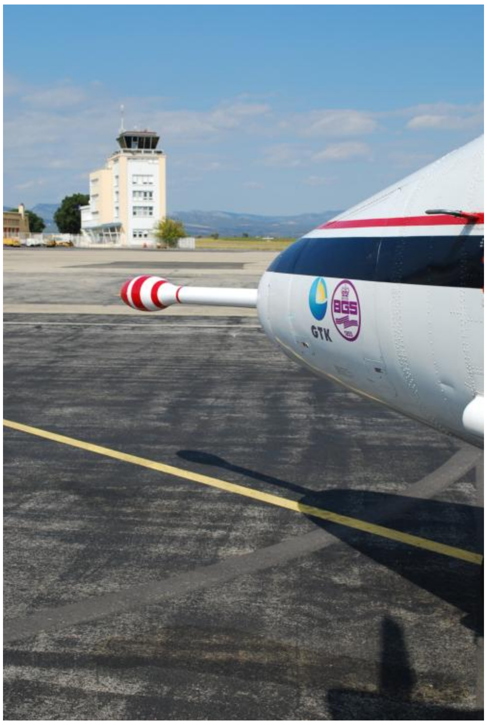
Perpignan Airborne Geophysical Survey

EUFAR projects: Aerosalt&Aerolit



Survey Logistics Report

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September 2008

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Summary

This report provides a summary of the logistics of the airborne geophysical survey conducted in September 2008 in the vicinity of the Gulf of Lyons, in southern France. The Joint Airborne-Geoscience Capability (JAC) established between the Geological Survey of Finland (GTK) and British Geological Survey (BGS), carried out the survey under contract to EUFAR. The projects supported by the survey are AEROSALT and AEROLIT experiments. The principal client for the experiments is the BRGM.

The survey was conducted at high resolution (a flight line spacing of 100 m) and at low altitude (50 m) across the coastal zone of the Roussillon aquifer. The three main data sets acquired are magnetic, radiometric (gamma ray spectrometry) and active frequency domain electromagnetic. The aim of the present report is to provide descriptions of the logistical and processing elements of the survey operations.

Perpignan, 25th September 2008	Perpignan, 25th September 2008
David Beamish	Robert Cuss
Project Manager	Project Geophysicist

1 Survey: Location and details

The EUFAR airborne geophysical survey in the vicinity of the Gulf of Lyons, east of Perpignan, was designed on the basis of the award of 30 hours survey time. Two joint experiments were awarded 10+10 = 20 hours (AEROSALT) and 10 hours (AEROLIT). The survey data for AEROSALT relates to increasing an understanding of the processes governing the saltwater spatial distribution in the Quaternary aquifers of Mediterranean coastal areas. The survey data for AEROLIT relates to an evaluation of airborne geophysical data in relation to coastal sedimentological studies.

The EUFAR awards for both experiments were in place towards the end of May 2008. The survey, in terms of line-km coverage, was designed using best-estimates of survey parameters to equate the 30 hours survey time to a high-resolution airborne survey design (e.g. a line separation of 100 m) for the two experiments.

Permitting of the survey via the French CAA and local authorities took until early August 2008. The authorities allowed a survey height of 50 m. A required condition was that the survey should not commence until after September 08, due to the potential for distraction of tourists by the survey.

1.1 SURVEY SCHEME

The maximum survey line lengths are 45 km. This line length can be regarded as both efficient and stable in terms of the EM measurements (Hauteneimi et al., 2005). The survey flight direction (N-S) was selected largely on the basis of survey efficiency. The survey plan is shown in Figure 1.

The idealised survey lines provided the parameters of the survey shown in Table 1.

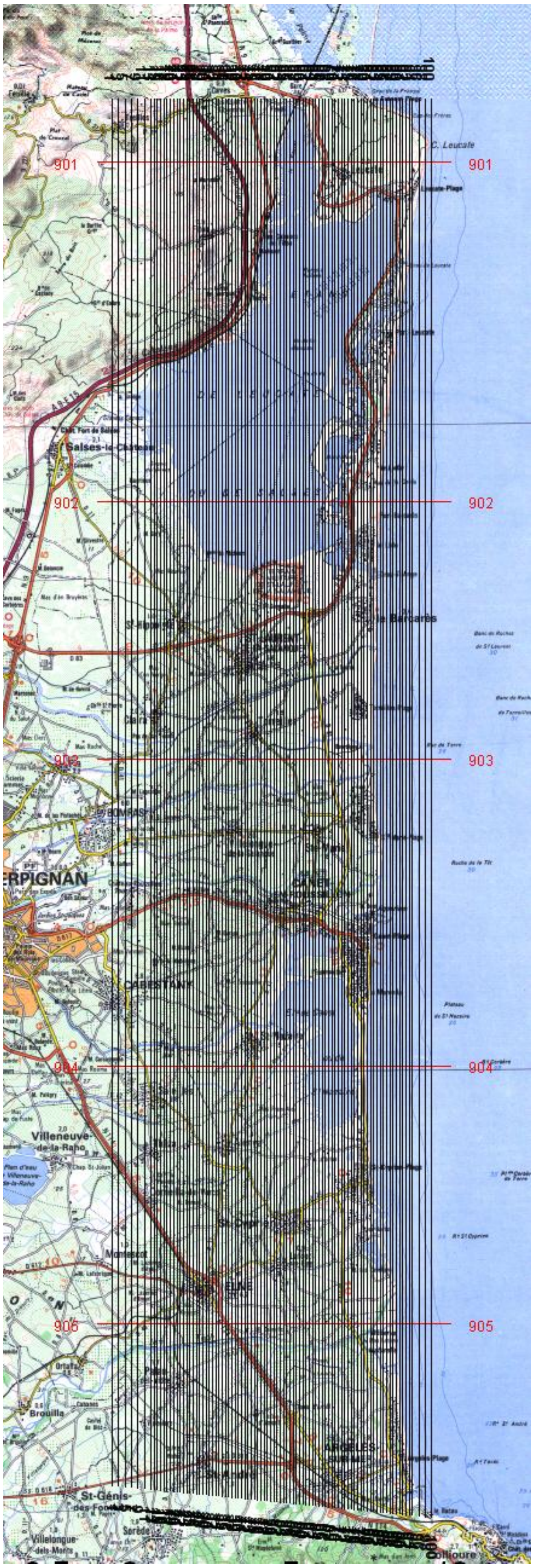
Table 1. Summary of planned and completed flight lines and survey line-km.

	Direction	***Line separation (m)***	***Number of lines***	***Line-km***
Plan, 2008	0/180	100	100	3,948
Cross-lines (7km)	90/270	8000-9000	5	35

During the survey, the flight plan was adjusted in relation to the target number of hours available. The original target of 91 (N-S) lines was increased to 100 at 100 m line-spacing.

The total (ideal) line-km for the survey is 3948.5 (N-S) line-km with an additional 35 (5 x7 km) line-km obtained from the cross-lines. The actual survey includes many excess line-km obtained from longer-than-ideal lines.

Figure 1. Flight line plan plotted over topographic map. The start (original) survey plan comprises 91 flight lines at 100 m spacing, except in the west and east. The final plan used 100 lines at a spacing of 100 m,



1.2 COORDINATE SYSTEM

The local geographical grid system used for the data collection is WGS84 UTM zone 31N.

1.3 REFLIGHT SPECIFICATIONS

Specific conditions for reflights due to technical reasons were according to the JAC internal Quality Manual. For this survey, the nominal reflight specifications applied were as follows:

i. Where ***flight line deviation*** is a maximum of 50 m or exceeds 30 m over a distance of 2 km. (except where ground conditions dictated otherwise, for example to avoid radio-masts etc).

ii. Where ***terrain clearance*** exceeds a maximum of 30 metres from the nominal survey height (50 m) or exceeds 15 m over a distance of 2 km.

iii. Where the ***sample separation*** exceeds 77 m i.e. an increase of 7m/s above the nominal maximum survey speed of 70 m/s.

The above conditions may be exceeded without a reflight where such constraints would breach air regulations, or in the opinion of the pilot, put the aircraft and crew at risk (e.g. wind farms). The first survey flight (139) experienced cross-winds in excess of 30 knots. The above conditions were relaxed in order to make progress with the survey. The crew have also commented that the coastal strip sometimes has a complex wind pattern, with changes of direction during the course of an individual flight line. High gradient topography may also cause the terrain clearance (altitude above ground level) to be exceeded due to the intrinsic climb-rate of the aircraft and subsequent safety considerations.

1.4 SURVEY OPERATIONS

1.4.1 Survey Duration

The survey data acquisition was conducted between 19th September and 25th October 2008. The survey base was Perpignan airport. Flight operations occupied a 5-day week. The operational chronology of data acquisition is provided in Table 3. The Table summarises the dates, the time duration and the number of lines accepted for each sortie. The survey comprised xx operational flights over 7 days with Flight/Material numbers from 138 to 146.

Operationally, a target of two 4-hour sorties each day was specified. The first flight crew departed on Saturday 20 September. The second flight crew began work on 22 September and continued on survey until 25 September.

Table 2. Survey duration.

Flight	Date	Julian day	Out (UTC)	In (UTC)	Flight time	Accepted lines	Cross-line
138	19/09/08	263	11:55	12:45	00:58	Compensation	0
139	19/09/08	263	13:38	17:36	03:58	16	0
140	20/09/08	264	06:36	10:55	04:19	18	0
141	22/09/08	265	15:07	17:27	02:20	7 (72 reflight)	0
142	23/09/08	267	06:55	10:02	04:07	15	905
143	23/09/08	267	13:10	17:11	04:01	15	905
144	24/09/08	268	06:23	10:23	03:49	15	905
145	24/09/08	268	12:24	16:00	03:36	14	905
146	25/09/08	269	08:23	10:53	02:30	14 (4 reflights)	901-905

1.4.2 Personnel

A list of personnel involved in the survey is provided in Table 3.

Table 3. List of project personnel.

Position	Name	Affiliation
Project Manager/ Geophysicist	Dr. David Beamish	BGS
Geophysicist/ Party Chief	Dr R Cuss	BGS
Electronics engineer/Operator	Mr Jouni Piispanen	GTK
Operator	Mr Ed Haslam	BGS
Captain	Capt Mika Raivonen	FAA
Captain	Capt Mika Kanto	FAA
Navigator	Mr Esa Tiainen	FAA
FAA a/c Engineer	Mr Marku Kosonen	FAA
Data Processing	Dr R Cuss	BGS
Flight Crew (22/08/2008 onwards)		
Captain	Capt Raimo Vartiainen	FAA
Pilot	Mr Esa Pirinen	FAA
Navigator	Mr Veikko Wetterstrand	FAA
FAA a/c Engineer	Mr Jussi Jarvinen	FAA

1.4.3 Flying instructions and restrictions

Permitting for the survey was conducted through the French CAA and local authorities. The authorities allowed a survey height of 50 m across the complete survey area. A required condition was that the survey should not commence until after September 08, due to the potential for distraction of tourists by the survey.

Two military areas in the vicinity of the Terrain Militaire de St-Laurent de la Salanque placed restrictions on the timing (the days) on which they could be overflown. These were obeyed.

1.4.4 Technical quality control

The in-field geophysicist carries out daily technical quality control and follows the specifications described in chapter 1.3. The main emphasis of the technical quality control is related to flight path deviation and flight elevation. Quite often these specifications are exceeded due to safety reasons and piloting decisions. In these cases re-flights are not issued. Table 5 summarises the statistical data of the technical parameters. The figures are calculated from the original data with 70,559 data points (the radiometric data sampled at 1 second).

Table 5. Statistics for technical parameters (radar altitude, distance from the nominal line and flying speed). Results are calculated using all the data including exceptions. Distance from nominal flight line is presented as a negative value if the true flight path has been on the left side of nominal line and positive if on the right side (according to flight direction).

	Mean	Standard deviation	Min	Max
Radar altitude (m)	50.16	7.74	25	173
Distance (m)	-1.08 (left)	16.5	-77 (left)	84 (right)
Speed (m/s)	62.82	3.8	48	75

2 Equipment

The airborne survey equipment used on the survey comprises a geophysically equipped De Havilland Twin-Otter aircraft (OH-KOG). The aircraft is owned by the NERC/BGS and the geophysical equipment is owned by the JAC/GTK. The BGS and GTK undertake airborne geophysical survey work in a partnership venture known as the Joint Airborne geoscience Capability (JAC). The aircraft is operated by the Finnish Aviation Academy (FAA) based in Pori, Finland.

A background to the development of the geophysical equipment used by the JAC is given by Hautaniemi et al., (2005). The main components of the geophysical measurement system are summarised in Table 6.

Table 6. Outline specification of the main geophysical systems.

Electromagnetic system	GTK AEM-05 four frequency
Aircraft Magnetometer	2 Scintrex CS-2 caesium vapour sensors, located at the left wingtip and nose stinger
Magnetic Compensator	RMS Instruments Automatic Aeromagnetic Digital Compensator (AADCII)
Gamma-ray spectrometer	Exploranium GR-820/3 gamma-ray spectrometer 256-channels, self-calibrating
Altimeter	Collins radar altimeter
Navigation/data location system	Real time DGPS based on Ashtech GG-24 GPS+GLONASS receiver, when RDS signal available
Data acquisition system	GTK proprietary: control unit including server, power unit, alarm box, Local Area Network

Standard ancillary equipment includes an external temperature sensor and barometric height sensor and a power-line (50/60 Hz) sensor (housed in the nose of the aircraft). Details of these devices are included in chapter 2.2.

Figure 10. Twin Otter in parked at Perpignan airport.

2.1 AIRCRAFT

The aircraft used in the survey is a fixed-wing, twin-engine DHC-6/300 Twin Otter (registration sign OH-KOG, registered in Finland).

Table 7. OH-KOG specifications.

Normal flight speed	210-220 km/h
Rate of climb	7.5 m/s
Total flight hours	About 16000 hours to date
Landings	About 8000 landings to date

This aircraft was built in Canada in 1979 and has been in use since 1980 for aerogeophysical measurements. During the manufacturing of the Twin Otter several modifications were made to its electrical systems in order to reduce the electrical noise levels. The aircraft offers several major advantages in terms of utility and cost, including excellent performance reserves, low-speed handling characteristics and operational flexibility allowing the use of unsupervised and unpaved air strips.

2.2 GEOPHYSICAL EQUIPMENT

Magnetics

- Two Scintrex CS-2 Caesium magnetometers, one at the left wingtip and one at the nose stinger

- Automatic compensation unit RMS AADCII
- Sampling rate of 10 Hz

Electromagnetic four-frequency unit

- Model AEM-05, vertical-coplanar coil configuration
- Frequencies in use: 912 Hz, 3005 Hz, 11962 Hz and 24510 Hz
- Coil separation of 21.4 meters
- Sampling rate of 4 Hz

Gamma-ray spectrometer

- Exploranium GR-820/3
- Two sets of NaI crystals, each containing four downward looking and one upward looking package
- Total volume 42 litres
- Sampling rate of 1 Hz

Navigation system:

- Ashtech GG24 (24-channel GPS + Glonass receiver)
- Accuracy 7 m / 16 m (50% / 95 %)
- Real time DGPS when differential signal available
- Sampling rate 1 Hz

Altitude

- Collins radar altimeter
- Resolution 0.1 m, accuracy 0.5 m
- Sampling rate of 10 Hz

Auxiliary equipment

- Digital camera
- Riegl laser altimeter
- Barometer, thermometer, accelerometer

Base station equipment

- Scintrex CS-2 sensor for magnetic recording
- Ashtech Ranger GPS receiver for DGPS correction
- Picodas MEP-7110 magnetometer

2.3 GROUND-BASED EQUIPMENT

Ground-based equipment comprises a base magnetometer and a GPS station. The primary base station records magnetic and GPS data prior to, during, and after each flight. The data from this station are used to post process the airborne data. The base magnetic data are used to correct diurnal variations of the airborne magnetic field records. The base GPS records are used to perform differential processing of the airborne GPS recordings.

The magnetic data are logged at 1-second intervals and displayed on a base station laptop that controls data acquisition. The continuous display of the base station data (rolling screen) provides a capability for monitoring the magnetic disturbance conditions that might lead to a reflight condition.

Figure 11. Base station. Magnetometer, GPS unit and control PC inside a tent. Magnetometer sensor, GPS sensor in the field. Photo: Kai Nyman.

2.3.1 Base station(s)

A particular feature of this survey was the difficulty experienced in establishing a magnetically low-noise site for the base magnetometer. Initial tests in the vicinity of Perpignan airport (flying club) proved fruitless due to the high noise levels. A second base station was established next to a vineyard several kilometres to the west of the airport. Long-term (~ 1 day) recording at this site established the nature of the high magnetic noise level. The figures below provide examples of the data/noise behaviour.

Figure 11. Base magnetic station 2 data recording overnight, showing noise reduction during night. Time is UT.

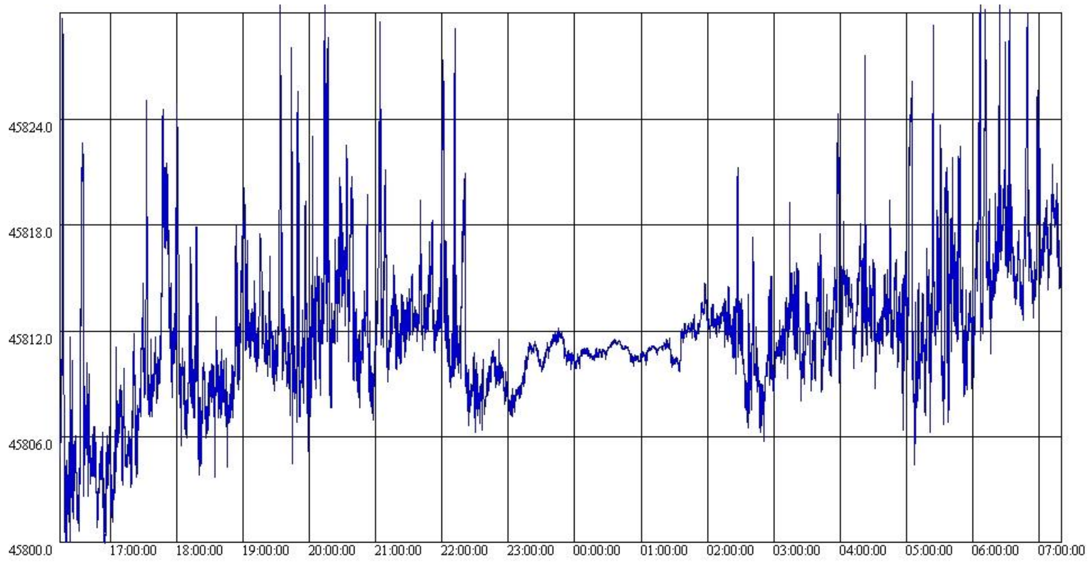
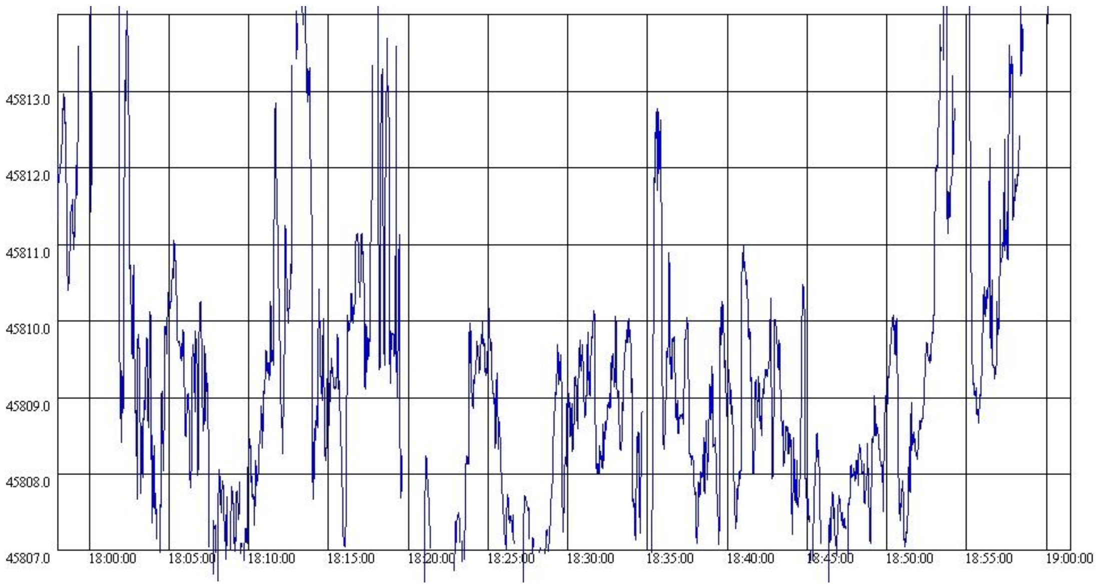


Figure 11. Base magnetic station 2 data recording for 1 hour. Time is UT.



Due to the excessive noise levels experienced, a portable Overhauser magnetometer was used to perform noise level checks across, and beyond, the survey area. The tests indicated that the noise levels were transmitted across a wide area, and that it was likely that the alluvial Quaternary soils were carrying electromagnetic noise across the basin. Further trials with the portable magnetometer resulted in a final base station being selected in the village of village of Chateau de Caladroy in the hills to the west of the survey area. The site is underlain by Paleozoic bedrock.

Complete base station operations and precise locations are summarised in Table 8. An example of the final magnetic base station data acquired during the survey is shown in Figure 13.

Table 8. Summary of primary base station used during the survey.

Primary Base Station	village of Chateau de Caladroy
Start Date (Julian Day)	19/09/2008 (263)
End date (Julian Day)	25/09/2008 (269)
Geographic Latitude	42:43:24.65243
Geographic Longitude	02:38:44.5735
Elevation (m)	394.61976

The precise coordinates of the GPS base station (given above) were determined using a differential correction with the Perpignan (PERP) station of the French GPS permanent reference station. Six hours of data from both PERP and the basestation (day 264) were used.

During field processing a magnetic base level of 46850 nT was applied to the magnetic data..

Figure 12. The base station tent and GPS receiver at their location in village of Chateau de Caladroy. The magnetic sensor was located among the bushes for protection against strong winds. Photo: Rob Cuss

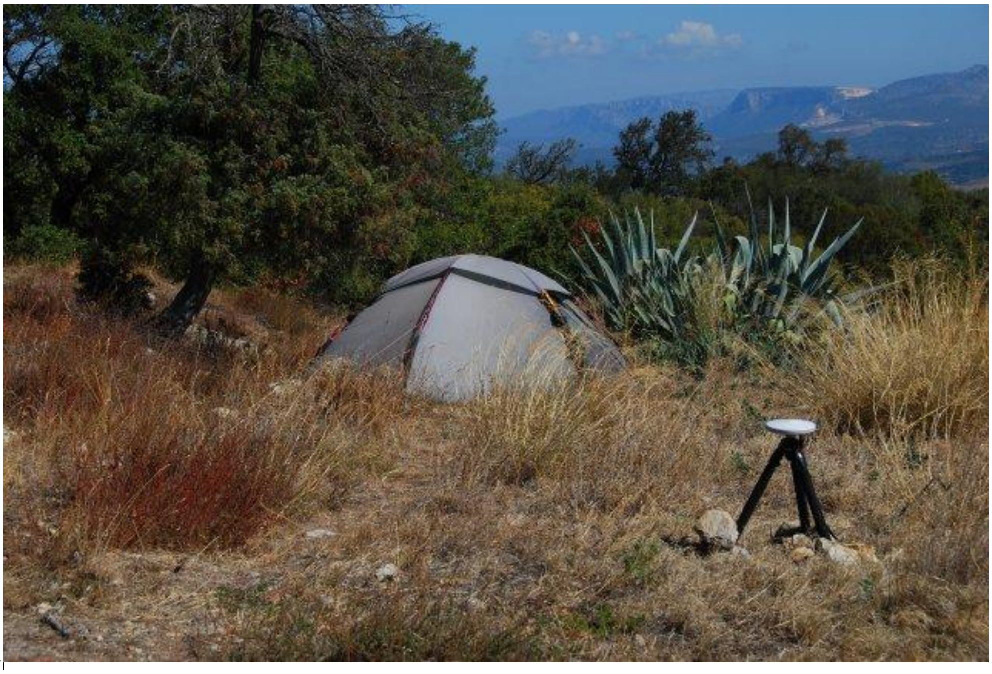
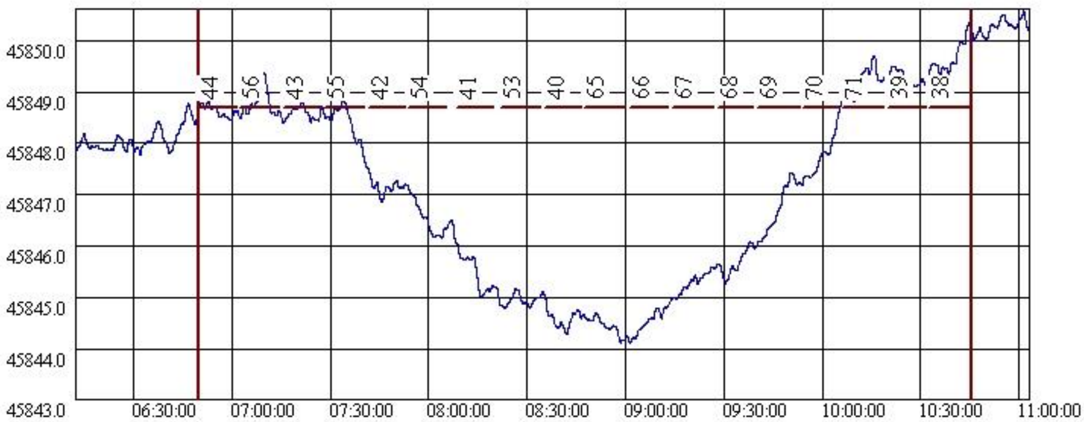


Figure 13. Example of magnetic base station recording (flight 140), showing flight line numbers and their durations. Time in UT.



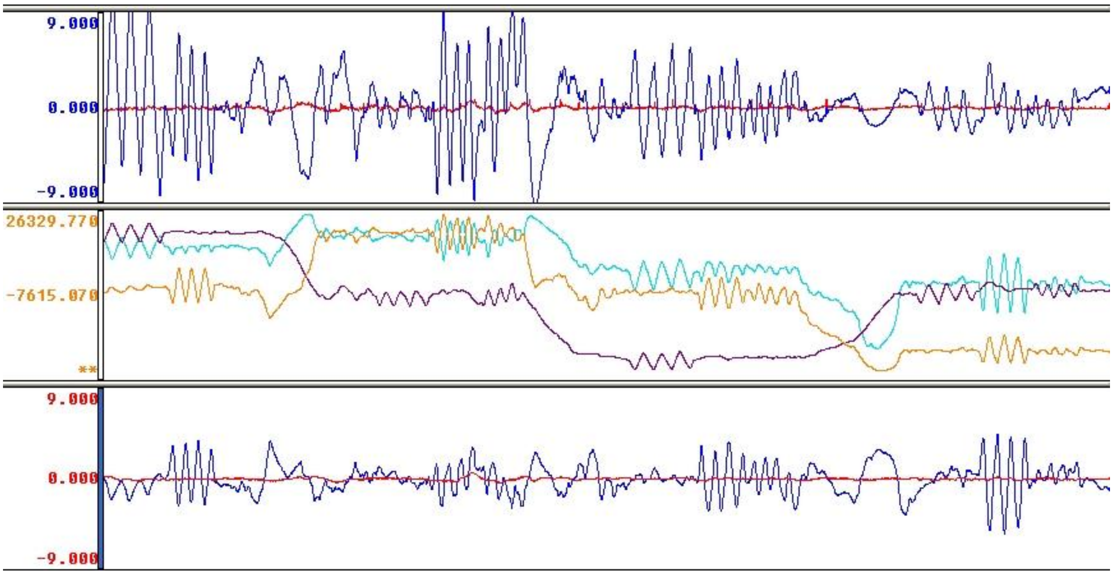
3 Calibration Data

3.1 MAGNETIC COMPENSATION

The effect caused by the movements of the aircraft is removed/diminished automatically during the flight by use of the compensation data. During the compensation flight the aircraft flies at 3 km altitude in the two flight line directions and the directions perpendicular to those and performs pitch (±5º), roll (±10º) and yaw (±5º) manoeuvres along each direction. After recording, the magnetic effects of all twelve movements, the AADCII compensator (RMS Instruments) computes the compensation coefficients, and stores the results to provide real-time corrections during the actual survey.

The effectiveness of the compensation is verified by a Figure-Of-Merit (FOM) survey immediately after the compensation during the same flight. The same movements are repeated and the new compensation parameter file is utilized. All three compensated movement effects are summarized in all four directions, and the FOM parameter is thus the sum of these 12 peak-to-peak anomaly values of the compensated magnetic field. The compensated FOM values are a judgement of the peak/trough amplitudes observed during each manoeuvre.

Figure 14. The profiles of magnetometer compensation data for the 4x3 =12 set of manoeuvres. Upper panel: Nose magnetometer data, uncompensated (blue) and compensated (red). Scale is in nT. Middle panel: Fluxgate magnetometer data. Lower panel: Left wing-tip magnetometer data, uncompensated (blue) and compensated (red).



The location of the compensation flight was just offshore from the survey area. The area was located on the basis of low magnetic gradient. The FOM parameters of each direction and each movement are summarised in Table 9.

Table 9. Figure of merit calculations for magnetic data (Flight 138)

Compensation 19th September 2008

Left sensor uncompensated					**Left sensor compensated**			
Dir	Pitch	Roll	Yaw	Total (FOM)	Pitch	Roll	Yaw	Total (FOM)
360	1.9	5.8	1.0	**8.7**	0.15	0.13	0.10	**0.38**
270	1.3	3.2	3.6	**8.1**	0.09	0.15	0.09	**0.33**
180	2.0	6.8	3.1	**11.9**	0.05	0.15	0.13	**0.33**
090	1.1	9.8	1.8	**12.7**	0.15	0.10	0.14	**0.39**
Total				**41.4**				**1.43**

Left sensor ratio (uncompensated/compensated) = 41.40/1.43 = 28.9

Compensation 19th September 2008

Nose sensor uncompensated					**Nose sensor compensated**			
Dir	Pitch	Roll	Yaw	Total (FOM)	Pitch	Roll	Yaw	Total (FOM)
360	17.9	10.8	2.7	31.4	0.15	0.15	0.20	0.50
270	3.0	13.0	12.6	28.6	0.12	0.24	0.20	0.56
180	8.9	6.9	5.4	21.2	0.12	0.15	0.14	0.41
090	4.0	4.7	2.8	11.5	0.22	0.20	0.15	0.57
Total				**92.7**				**2.04**

Nose sensor ratio (uncompensated/compensated) = 92.7/2.04 = 45.44

3.2 RADIOMETRIC CALIBRATION DATA

As noted previously the radiometric instrument employed is the Exploranium GR-820 with 256-channels. The commonly adopted standard in carrying out airborne gamma-ray measurements is to calibrate and process the data in a manner presented in AGSO and IEAE reference manuals (Grasty and Minty, 1995; IAEA, 1991). The radiometric system was calibrated prior to the survey using locations and calibration ranges in Finland that have been used for over 25 years. The following sections summarise the calibrations that were performed prior to this survey.

3.2.1 Cosmic and background coefficients

To determine the aircraft and cosmic background, a test flight was carried out over the sea near the base airport, at flight surfaces from 5000 to 10000 ft. Linear regression from the mean counts in each channel and equivalent cosmic channel count rate provide the constant and linear coefficients. The constant represents the background radiation from the aircraft and the linear coefficient is used to calculate the varying part of background radiation because of cosmic radiation.

The cosmic coefficients were found to be:

cos_tot	52.57 (0.870)	Total counts
cos_kal	6.05 (0.039)	Potassium
cos_ura	3.1 (0.031)	Uranium
cos_tho	0.0 (0.039)	Thorium
cos_Ur	0.33 (0.008)	Uranium upward

The numbers in parentheses are the linear coefficients.

3.2.2 Stripping ratios

The stripping ratios were determining using 4 transportable calibration pads (1m x 1m x 0.3m) prior to the survey season in Pori, Finland. Each pad was measured for 10 minutes and the stripping ratios were calculated using the Padwin program provided by the manufacturer of the pads. The calculated values are very close to the manufacturer's and IAEA's ideal values.

The results of the calibration are:

TH INTO U (ALPHA = A23/A33)	.2408 (.0629)
TH INTO K (BETA = A13/A33)	.4071 (.1330)
U INTO K (GAMMA = A12/A22)	.7327 (.1760)
U INTO TH (A = A32/A22)	.0453 (.0638)
K INTO TH (B = A31/A11)	-.0031 (.0342)
K INTO U (G = A21/A11)	.0032 (.0335)

The numbers in parentheses are estimated standard deviations.

3.2.3 Height attenuation

For determining height attenuation, a series of heights from 100 to 800 ft was used to take measurements near Porvoo, Finland. This test line has been used for more than 25 years. Background and stripping corrections were applied and the attenuation was calculated using the logarithmic values of corrected Tot, K, U and Th, and flight altitude.

The attenuation coefficients were calculated as:

K	0.008437
U	0.005381
Th	0.006920

Total counts	0.006774

3.2.4 Concentration coefficients

The same Porvoo test line was used to determine the system sensitivities. This same line has been measured for more than 25 years using the same aircraft (OH-KOG). The sensitivity parameters have been applied yearly to the radiometric data measured. Comparisons have been made also between different areas measured during different years to find out the possible variations. The variations are mostly due to different methods used earlier for sensitivity determining, e.g. pads, runaway. For the last few years the sensitivity parameters have been varied by just a few percent.

All the corrections were made to the radiometric test flight data and the concentrations were compared to earlier measurements and new sensitivity parameters were calculated as:

K	0.0082	%K/(pulses/s)
U	0.0700	ppm eU/(pulses/s)
Th	0.1221	ppm eTh/(pulses/s)

3.2.5 Resolution of the spectrometer

The Spectrometer resolution was measured with a Cs-137 source in Pori, Finland. Background was also measured and after a background correction, the Cs peak was measured and the FWHM determined. The FWHM is across 5.0 channels, each with an energy of 12.1 keV, which makes 60.5 keV. Thus we obtain a spectrometer resolution of

R = 100*60.5 keV/662 keV = 9.14 **%**

Individual crystals were measured at Helsinki-Vantaa airport. The downward looking spectra were stabilized using K-40 and the upward looking spectra with Cs-137. The results are given as Crystal Number with %Resolution in parentheses:

D1(7.4%), D2(11.0%), D3(7.5%), D4(6.1%), D5(5.3%), D6(5.9%), D7(5.9%), D8(5.4%), U13(9.5%), U14(7.9%)

D refers to downward and U to upward.

3.3 ELECTROMAGNETIC CALIBRATIONS

3.3.1 Coefficient Calibration

The calibration of the JAC AEM-05 system used in the survey is described by Hautaniemi et al. (2005) and Leväniemi et al., (2008).

The EM system was calibrated by flying a test line over the sea (Gulf of Finland) prior to the 2008 survey season, at different heights from 25 to 100 m. The conductivity of the sea was measured by a CTD sensor at 4 different points along the test line, from the surface to the sea bottom. The conductivity of the sea was estimated by a model, which contains layers with a different conductivity for each layer.

The theoretical responses of the airborne EM to the model described above were calculated using the Leroi-air program developed by AMIRA. Non-linear optimization was used to obtain a best fit to a complex, scalar coefficient. The coefficients obtained at each frequency enables measured units to be converted to coupling ratios (Hs/Hp, meaning secondary over primary) in ppm (parts per million)

An example of the coefficient calculation (3005 Hz) is shown in Figures 16 and 17.

Figure 16. EM optimisation results for the Real component calibration at 3005 Hz.

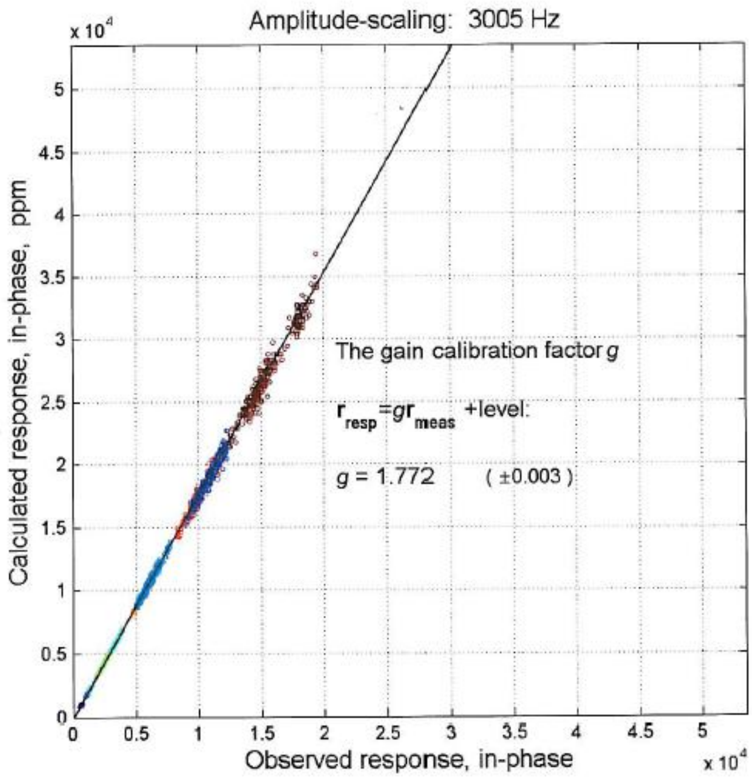
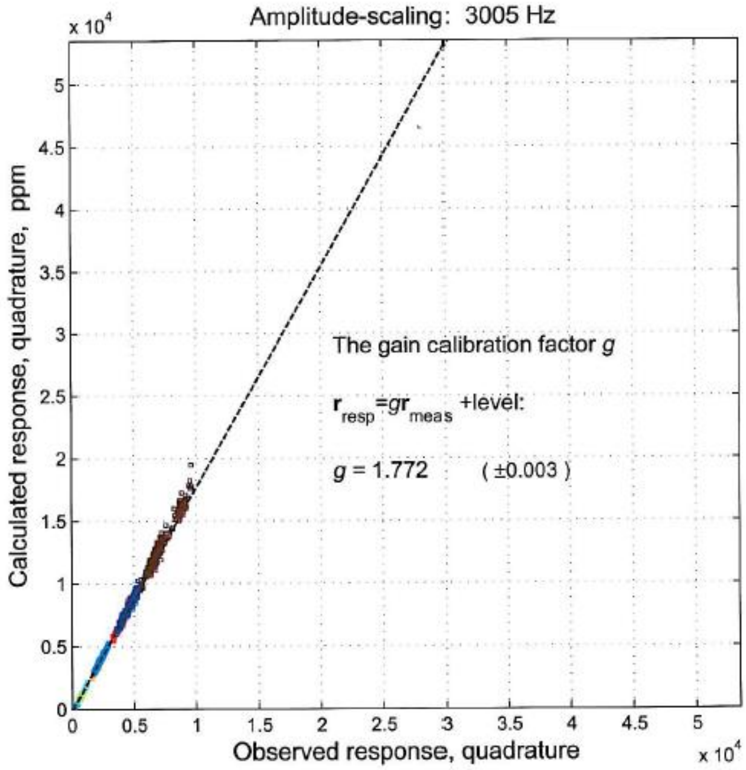


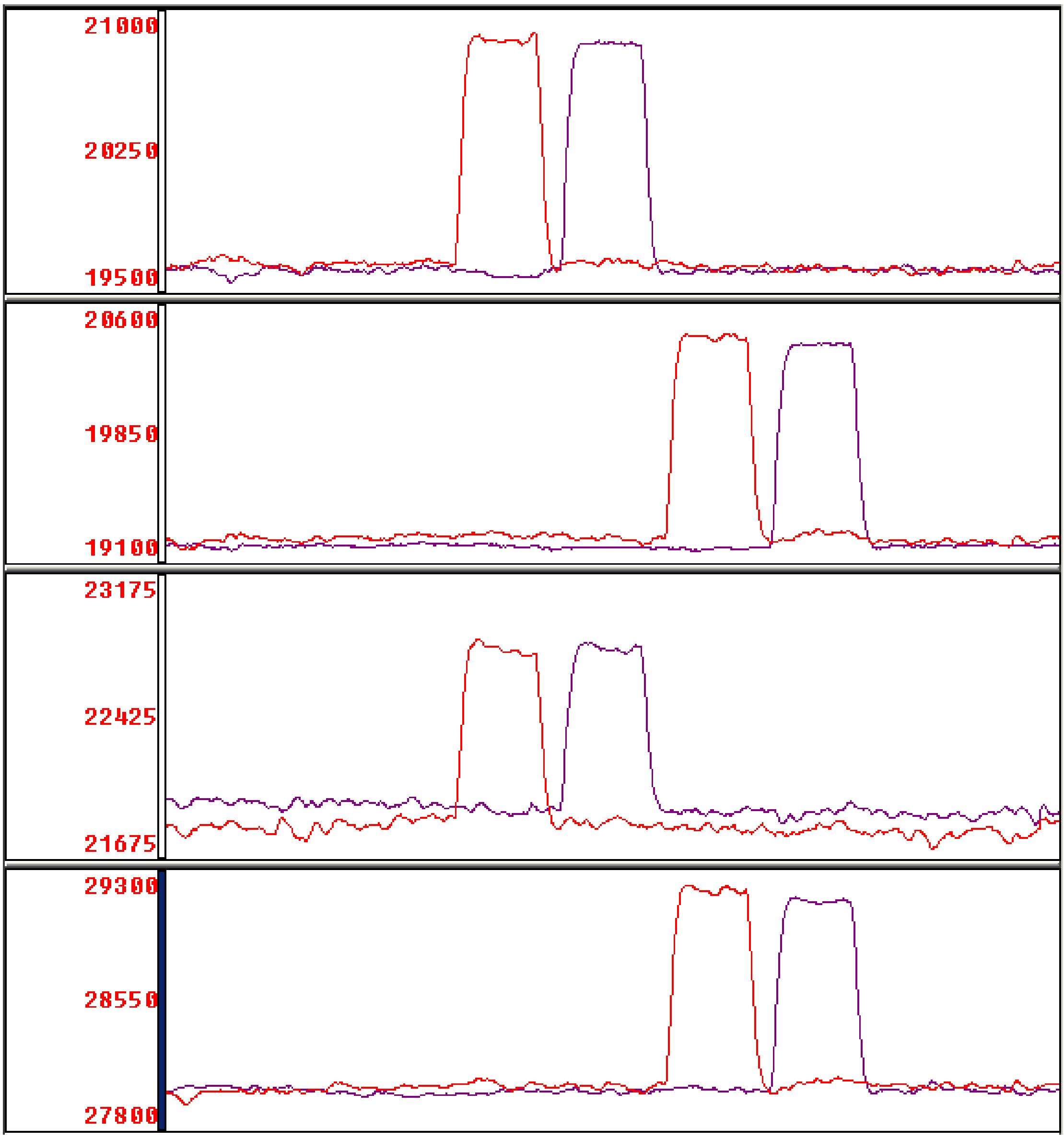
Figure 17. EM optimisation results for the Imaginary component calibration at 3005 Hz.



3.3.2 EM System orthogonality

The phase shift between in-phase (real) and quadrature (imaginary) components is checked and adjusted at the beginning and end of each survey flight. The test is undertaken at an 'out-of-ground-effect' elevation (e.g. >300 m) over the landmass (i.e. not over the sea). As the phase shift is 90 degrees, there should not be any trace in the quadrature component as an artificial signal is applied to in-phase component and vice versa. This procedure is done separately on each frequency to in-phase and quadrature components. At the end of each survey flight this same procedure is repeated to check for any possible phase drift during the flight. An example of the calibration pulses observed at the start of a flight is shown in Figure 18.

Figure 18. The orthogonality test for Real and Imaginary components of the Twin Otter EM configuration. Panels show the frequencies in increasing order from top to bottom with Real component in red and imaginary component in magenta.



4 Data handling, QC procedures and Processing

The data handling and QC procedures used by the JAC are fully described by Hautaniemi et al., (2005).

The geophysical and avionic data acquired during each flight is monitored by a geophysical operator as shown in Figure 19. The geophysical operator monitors all the instruments and the data being acquired using a laptop computer. Each instrument is connected to a dedicated microprocessor. The microprocessor controls data transfer to a Local Area Network (LAN). A GPS-based synchronisation pulse is provided through the LAN at a frequency of 40 Hz.

Figure 19. Geophysical operator and main instrument rack on OH-KOG.

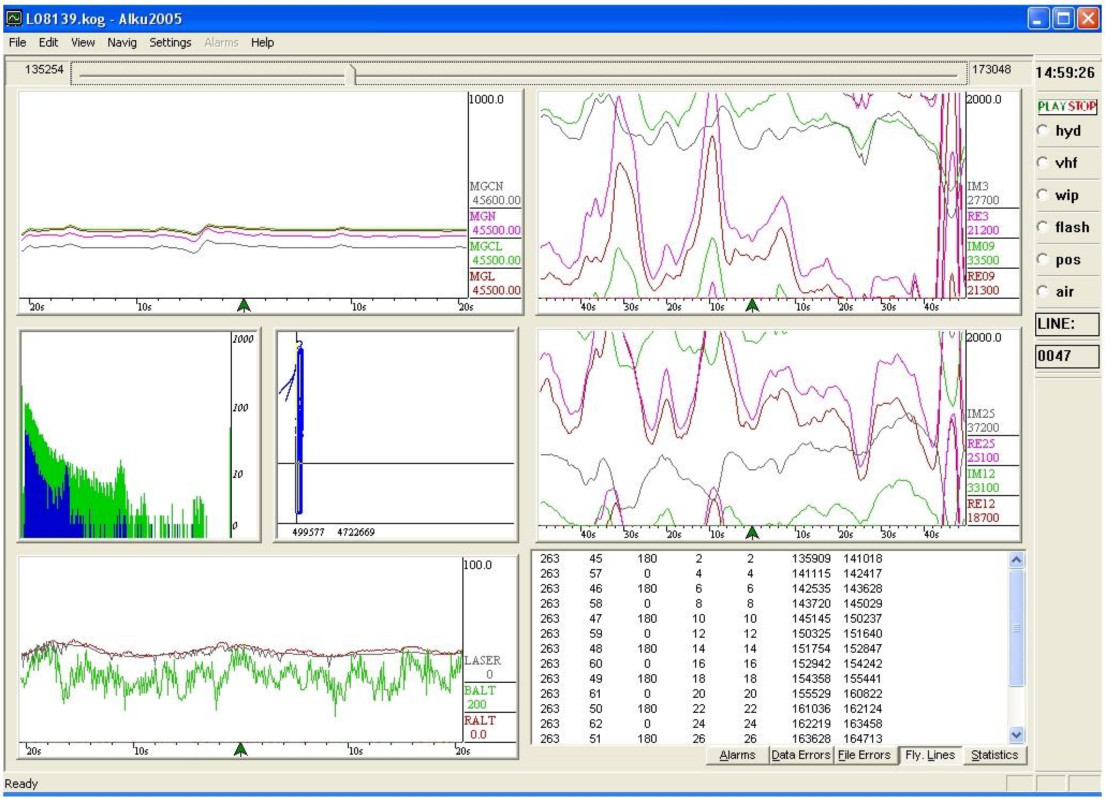
The operator is responsible for maintaining the flight logs, which summarise all the required parameters for each survey flight. An example log from Flight 140 of the survey is shown in Figure 20. Any noteworthy factors (e.g. urban fly-high conditions) and exceptions are digitally logged using a fixed-point (FP) number data channel that ties the operator’s notes to the recorded data stream. Fixed points also define on-line and off-line conditions.

4.1 QC AND FIELD PROCESSING

The basic processing of the recorded data is undertaken immediately after each flight and before the start of the next flight.

In the first stage the data is examined for any apparent errors such as file corruption or significant data errors. An example of this is shown in Figure 21. After this, the data profiles are examined more carefully. Standard processing and QC involves the use of fourth differences in the magnetic and electromagnetic channels. The appearance, quality and noise levels of all data components together with EM calibrations, drift levels and noise peaks are examined.

Figure 21. Example of the initial QC using ALKU2000 (Flight 139)



Base station magnetic and GPS data are also checked. For magnetic data this means comparing the recorded data against specification conditions for reflights. The GPS data are checked for any recording gaps or low-quality data.

Although the final levelling of the EM data is performed after the whole area has been surveyed, preliminary levelling is carried out at this phase. This initial levelling step, carried out in the field, is important in that it allows for a greater degree of QC on the EM coupling ratios acquired.

After all these processing steps, further programs are then applied for the calibration and the application of methodological corrections to the geophysical data. These procedures provide an initial, but still preliminary, set of text files (termed .xyz) for each flight and for each of the three geophysical data sets. These data sets are finally assembled into a Geosoft database for further QC assessments according to those required by the survey specifications.

The outcome of the application of the procedures mentioned above, together with the DGPS corrections, result in flight-line by flight-line xyz text files for each geophysical parameter. These are transferred to Geosoft databases where further QC control is applied. Altitude deviation is checked statistically and also by plotting colour profiles. The line paths are compared to the specified line paths and the flight path deviation is analysed. Sampling intervals and survey speed are also checked.

Average radiometric spectra and the main energy windows are plotted for each line. This allows an assessment of any spectral drift. Spectral stability and overall functioning of the spectrometer is controlled during the survey in real-time (geophysical operator), together with the initial QC and line-based spectral inspection.

Processed data for each successive flight are appended to the survey area databases. Geophysical parameters, errors and noise levels of all measurements are examined on a line-by-line basis. Geophysical parameters are also interpolated to grids and examined. All these grids are preliminary but they form useful updated summaries of the behaviour of the survey data.

Figure 22. Example QC processing of magnetic and radiometric data (Flight 141).

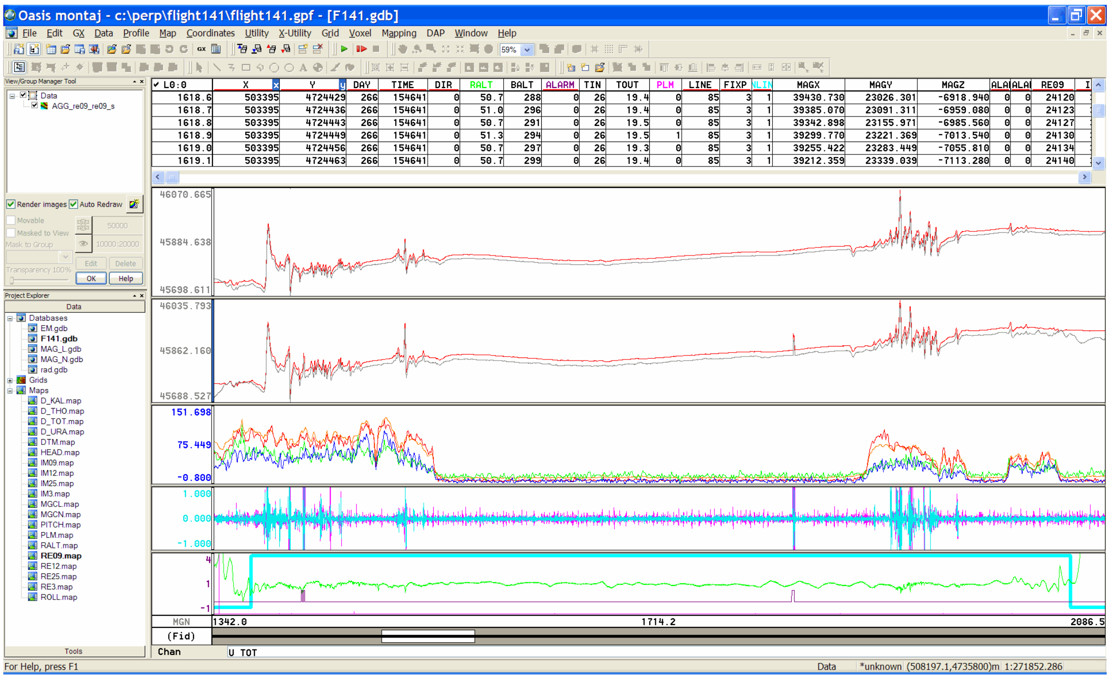


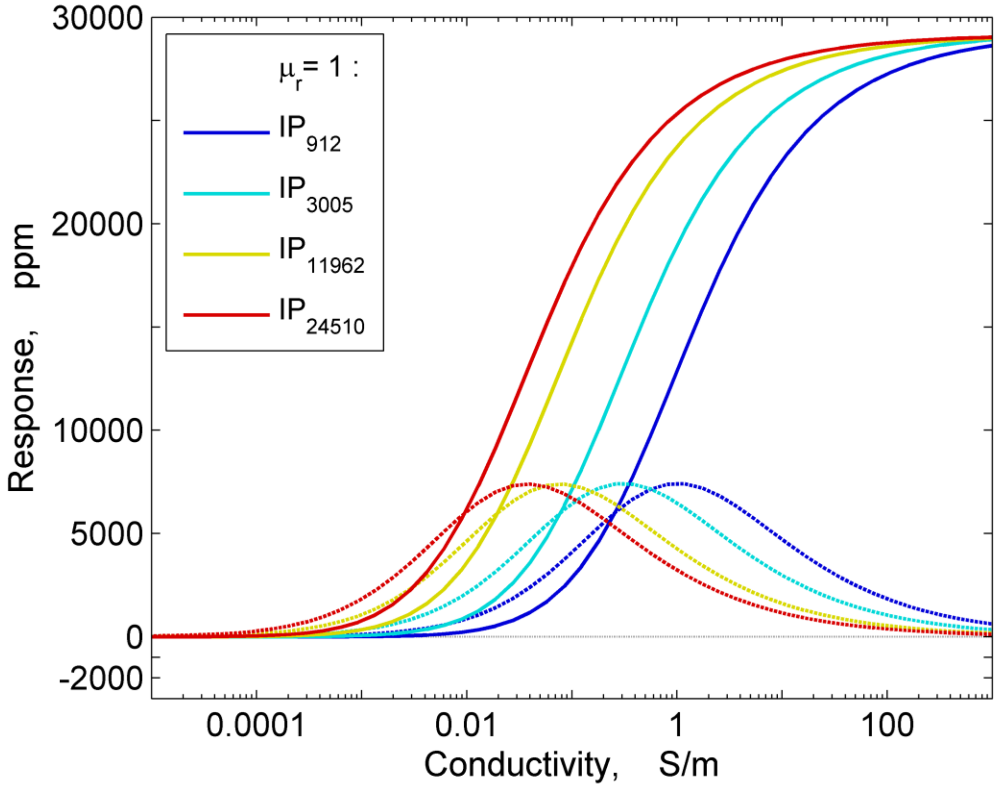
Figure 23. Example QC processing of electromagnetic data (Flight 141).

4.2 FINAL PROCESSING

Final processing of all the data is carried out only after all survey lines have been acquired and accepted. The procedures applied to the data are described by Hautaniemi et al. (2005).

The final levelled EM data are then used to calculate apparent resistivity and depth according to a half-space model (Hautaniemi et al., 2005, Leväniemi et al., 2008). The behaviour of the EM coupling ratios for a range of half-space resistivities is shown in Figure 24.

Figure 24. 4 frequency AEM-05 coupling ratios (in-phase=P, quadrature=Q) across a range of half-space resistivities, at an elevation of 30 m.



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