# Acquisition and Processing Helicopter Aeromagnetic Survey Mt. Spurr, Alaska

Performed for:

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Performed by:

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**August 2010**

# Acquisition and Processing
# Helicopter Aeromagnetic Survey
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## EDCON-PRJ, Inc.

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## Introduction:

During the period July 1 to August 3, 2010 a helicopter aeromagnetic survey was performed by EDCON-PRJ over a160 sq-km area south of the Mt. Spurr volcano approximately 80 miles west of Anchorage, Alaska. The project required nine field days to complete, but was spread over 34 calendar days as a result of both weather and helicopter availability delays. One thousand six hundred and seventy-five (1,675) line-kms of data were acquired and processed by EDCON-PRJ. Data were acquired on a 150-m by 750-m grid.The survey area location relative to Anchorage is shown in ***Figure 1***.

A Pico Envirotec AGIS-XP helicopter-magnetometer system with a GeoMetrics towed-bird cesium-vapor magnetometer was used. Navigation and positioning were accomplished using Global Positioning System equipment and methods. A Robinson R44 Raven II helicopter was used. The project was flown from Merrill Field, Anchorage, Alaska. These data were acquired and processed under EDCON-PRJ Job Number 21014.

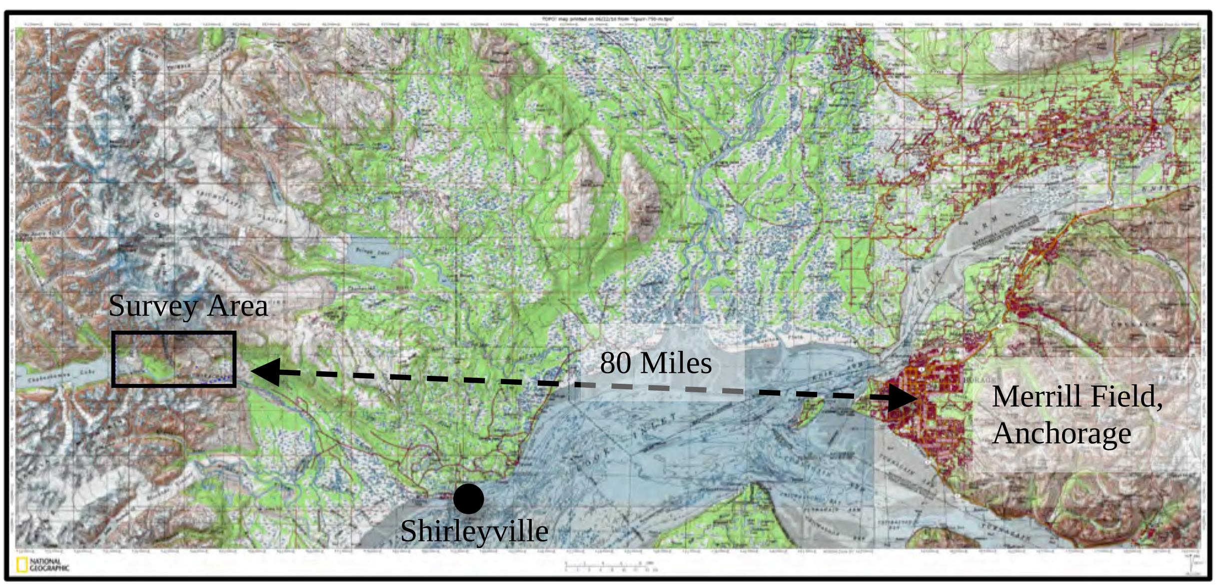


**Figure 1: Mt Spurr Survey Area Relative to Anchorage Alaska**

## Flight Grid:

The survey area in on the south flank of Mt. Spurr over the Chakachamna River as shown in ***Figure 2***. The area has 9,000 ft of relief. The completed survey is a 150-m north-south by 750-m east-west grid of helicopter flight lines.The survey plan was to fly a nominal controlled drape survey at 250 meters above the terrain. The survey yielded the flight line coverage shown in ***Figure 3***. The small area of missing data, shown in ***Figure 3***, is in a high and rugged topographic area which was difficult to survey due to cloud cover obstructing the terrain. The client decided to accept the data without the planned coverage over this small area instead of accepting weather standby and cost.

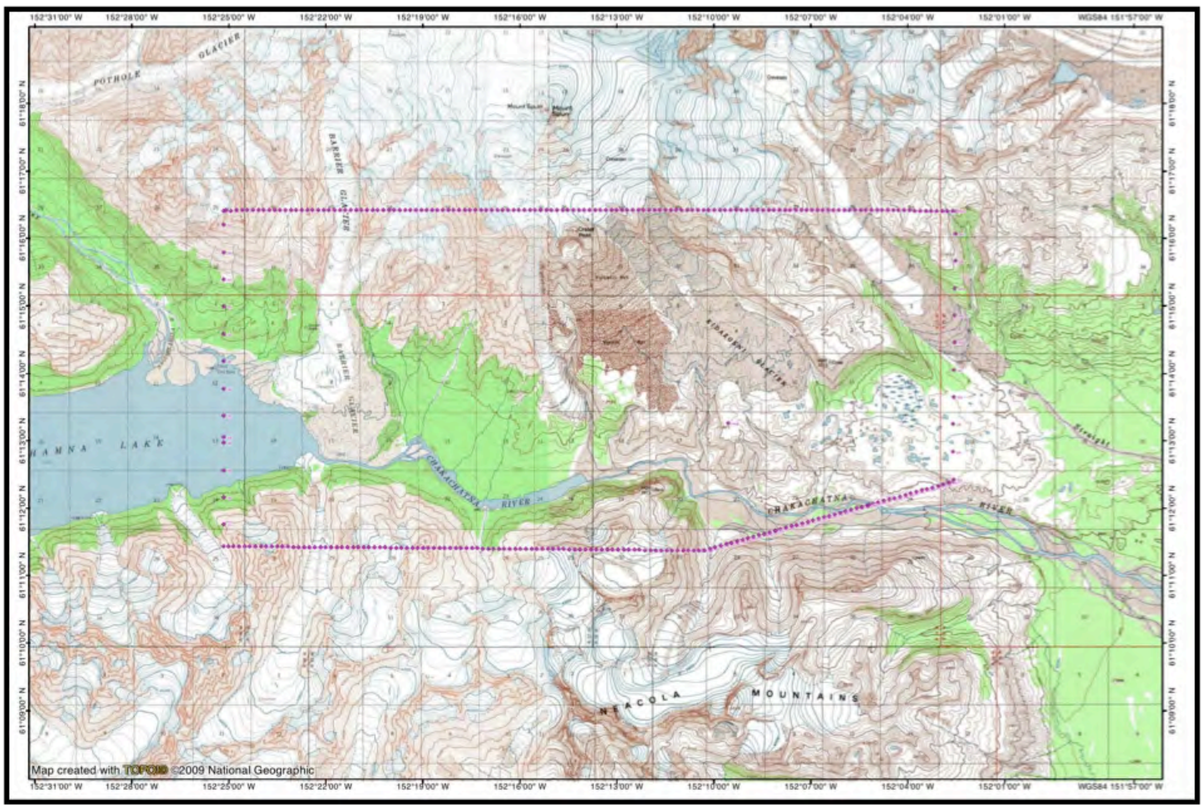


**Figure 2: Mt. Spurr Heli-mag Survey Area**

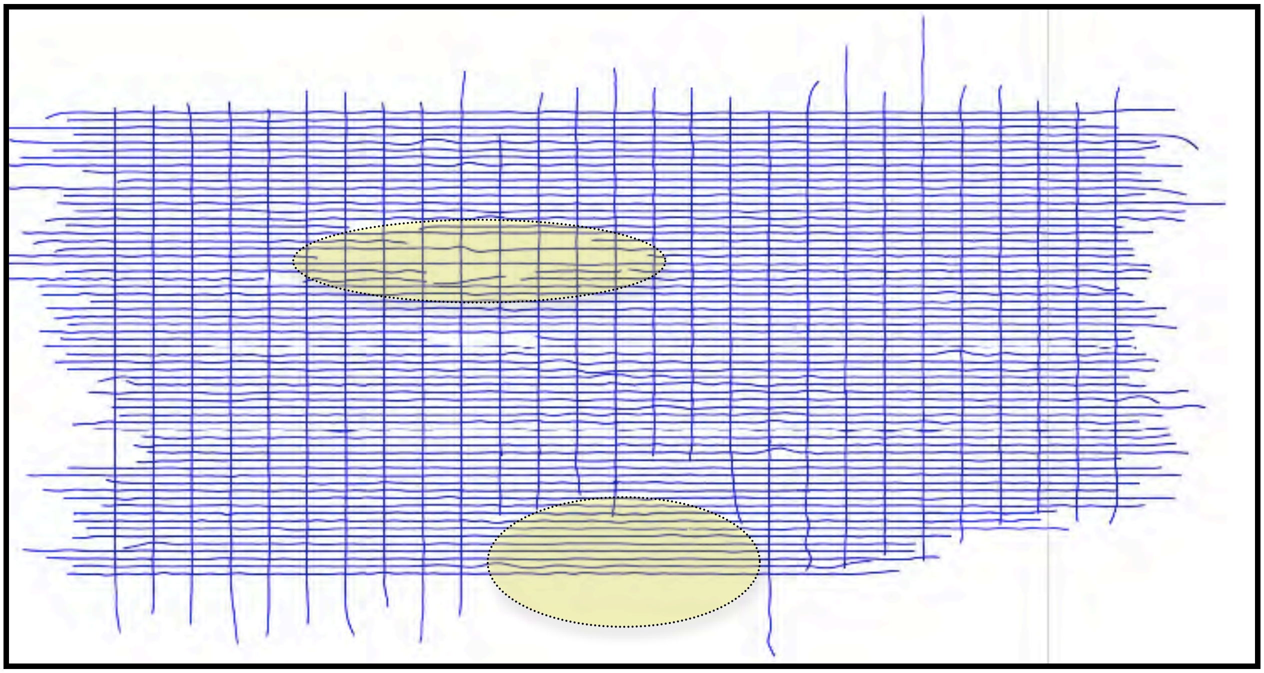

**Figure 3: Completed Flight Path (marked areas missing coverage due to weather)**

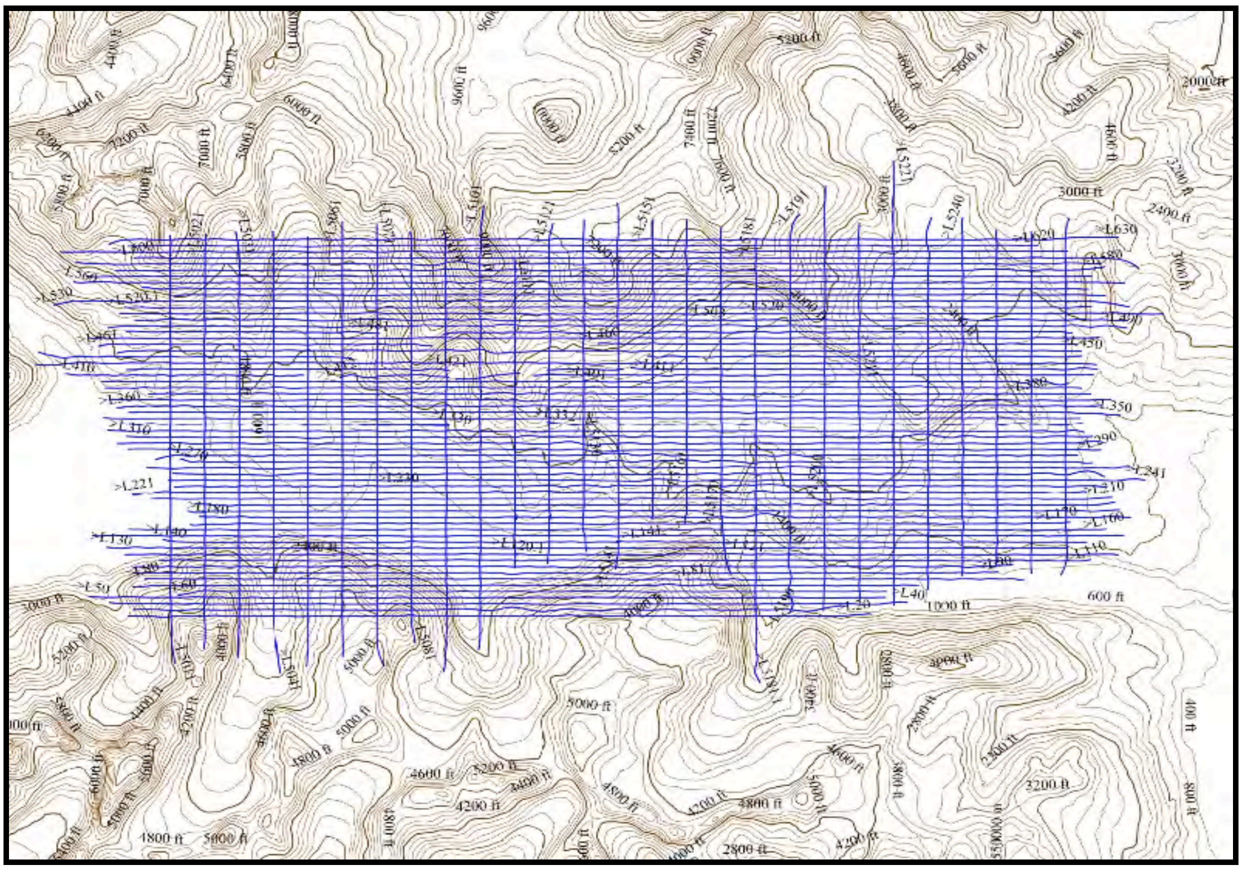

**Figure 4: Flight Paths on Terrain Base**

## Flight Elevation:

The survey has 9,000 ft (2,750 m) of relief. The survey plan was to fly a nominal controlled drape survey at 250 meters above the terrain. Poor visibility and helicopter performance resulted in segments of the survey that were flown well above the planned 250 meter drape surface. The northern 13 flight lines (lines 510 to 630) were flown at a high elevation with minimal drape over the terrain. From line 510 south, the survey lines generally do a better job of maintaining the planned 250 meter height above terrain. A map of the survey helicopter GPS elevation along the survey lines is shown in ***Figure 5***. This map shows the clear dividing point between the lines north of line 510 and south of line 510.

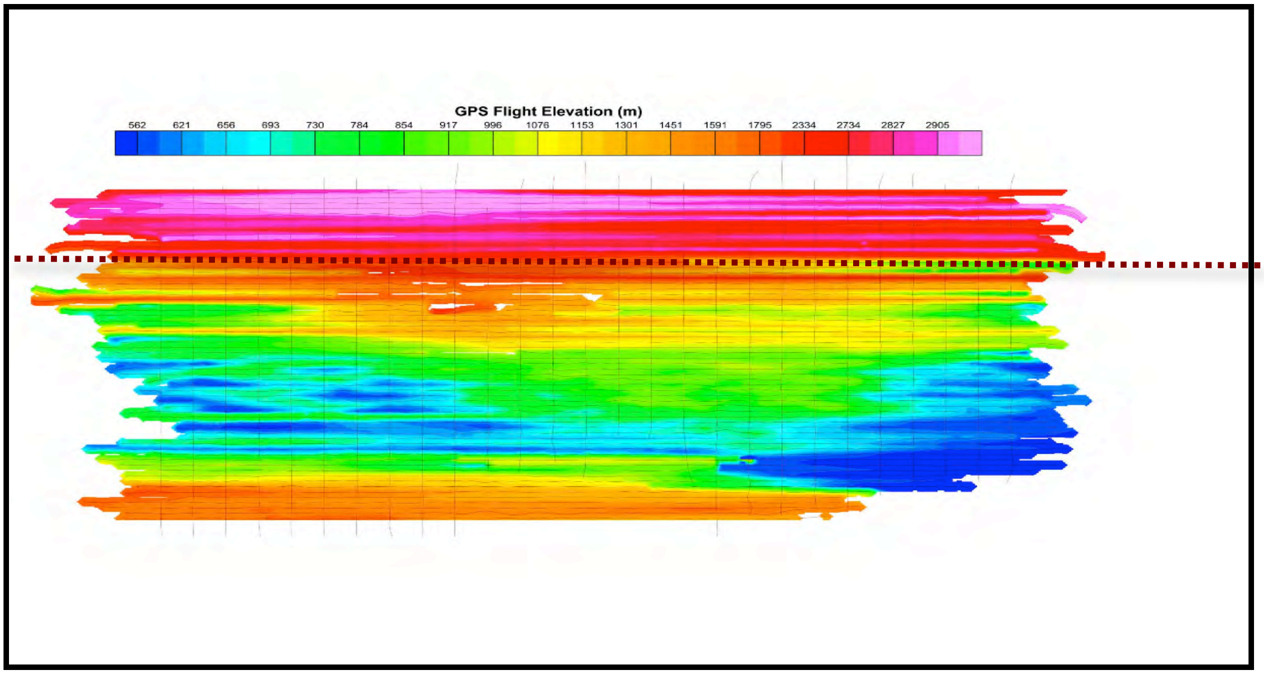


**Figure 5: Helicopter GPS Flight Elevation (dashed line is Line 510)**

The result of this difference in flight elevation is that the magnetic data north of line 510 generally has less high frequency signal than the magnetic data south of line 510. The difference in high frequency component is clearly shown on the survey maps.

## Survey Equipment:

The following survey equipment and personnel were used for this project.

## Helicopters:

Three different Robinson R44 Raven II helicopters were used, N74868, N4261A and N74713. The project was flown from Merrill, Field, Anchorage, Alaska. Field refueling was done at the Shirleyville airstrip using a Cessna 207 fixed-wing aircraft to transport drummed AvGas.

## Airborne Geophysical Equipment:

- Pico Envirotec AGIS-XP Airborne Geophysical Information System s/n 0910234 set to sample magnetic data at 20 Hz
- WAAS-enabled Hemisphere R-220 GPS s/n 0910400 with Antcom dual-frequency GPS antenna set to log GPS data at 10 Hz
- Pilot navigation display unit and operator iTech display unit
- FreeFlight radar altimeter and display, s/n 8472331 and s/n 8263174
- GeoMetrics cesium magnetometer s/n C-2087 and interface s/n 823206
- Fiberglass magnetometer bird and 30-m tow cable

## Ground-based Geophysical Equipment:

- GeoMetrics G-858 Base Station Magnetometer set to log magnetic data at 1 Hz and synchronized to UTC time using a hand-held Garmin 76CSx GPS receiver. The base station magnetometer was operated at Mt. Spurr airstrip at location:

  Latitude: 61° 13.317’ North,<br>
  Longitude: 152° 9.566’ West,<br>
  Elevation: 600 m<br>
  Average base magnetometer reading: approximately 56,000 nT

## Global Positioning System Surveying:

The survey positions and elevations are from a WAAS-enabled Hemisphere R-220 dual-frequency high-precision GPS receiver. The Federal Aviation Administration Wide Area Augmentation System (WAAS) is a system of earth stations and satellites that improves the tracking accuracy of the GPS navigation system. The earth stations track the GPS satellites and send correction signals to the WAAS satellites which then transmit them to WAAS-enabled receivers. The nearest reference station to the survey area is in Anchorage, Alaska. The FAA WAAS specification require position accuracy of 7.6 meters. Numerous tests of actual performance measurements of the system at specific locations have shown it typically provides 1.0 meter horizontally and 1.5 vertical accuracy.

The GPS antenna was mounted on the overhead bubble window on the R44 helicopter. The offset from the GPS antenna to the magnetometer sensor is shown in ***Figure 13***, and is 30 m vertical and 8 meters horizontal.

## Personnel and Base of Operations:

These data were acquired by John Seibert. The helicopters were chartered by JayHawk Air and piloted by two different pilots:

- Mark Barker
- Ryan Lehman

Flight operations were based at Merrill Field, Anchorage, Alaska.

Preliminary data analysis was performed in the field. The field-checked data were posted on the secure EDCON-PRJ ftp site for additional analysis and processing. Final data processing and analysis were performed by EDCON-PRJ in Denver, Colorado.

## Survey Flight Operations:

Survey Operations were conducted from July 1 through August 3, 2010. A total of 50.2 helicopter flight hours were utilized. Flight restrictions were in effect around Merrill Field on July 31 and August 1 and additional helicopter flight time (one hour each day) was required to comply with these restrictions.

## Weather:

The weather in July over the project area (and over much of Alaska) was unusually rainy and cloudy. There were nine days that flight operations were planned but were not initiated due to unacceptably poor weather over the project area. On July 11 and July 17 the survey helicopter was flown to the project area but survey operations could not be attempted due to poor visibility caused by cloud covering the topography. On several other days, survey operations were cut short due to weather.

There is a Alaska Volcano Observatory (http://www.avo.alaska.edu/ )Volcano Web Cam which looks out at Mt. Spurr and Crater Peak at GPS Station CKT at an elevation of approximately 3,200 ft. This web cam was used to access weather conditions at Mt. Spurr and used to decide if flight operations would be undertaken. The "Clear Day" view from the Volcano Cam is shown in ***Figure 6***. Sample views from the Volcano Cam during the surveyare shown in photos in ***Figure 8***. The lowering clouds and rain on the last day of the survey flying up the Chakachamna River are shown in ***Figure 7***.


**Figure 6: Spurr CKT "Volcano Cam" Clear Day Image**

**Figure 7: Flying up the Chakachamna River on August 3**

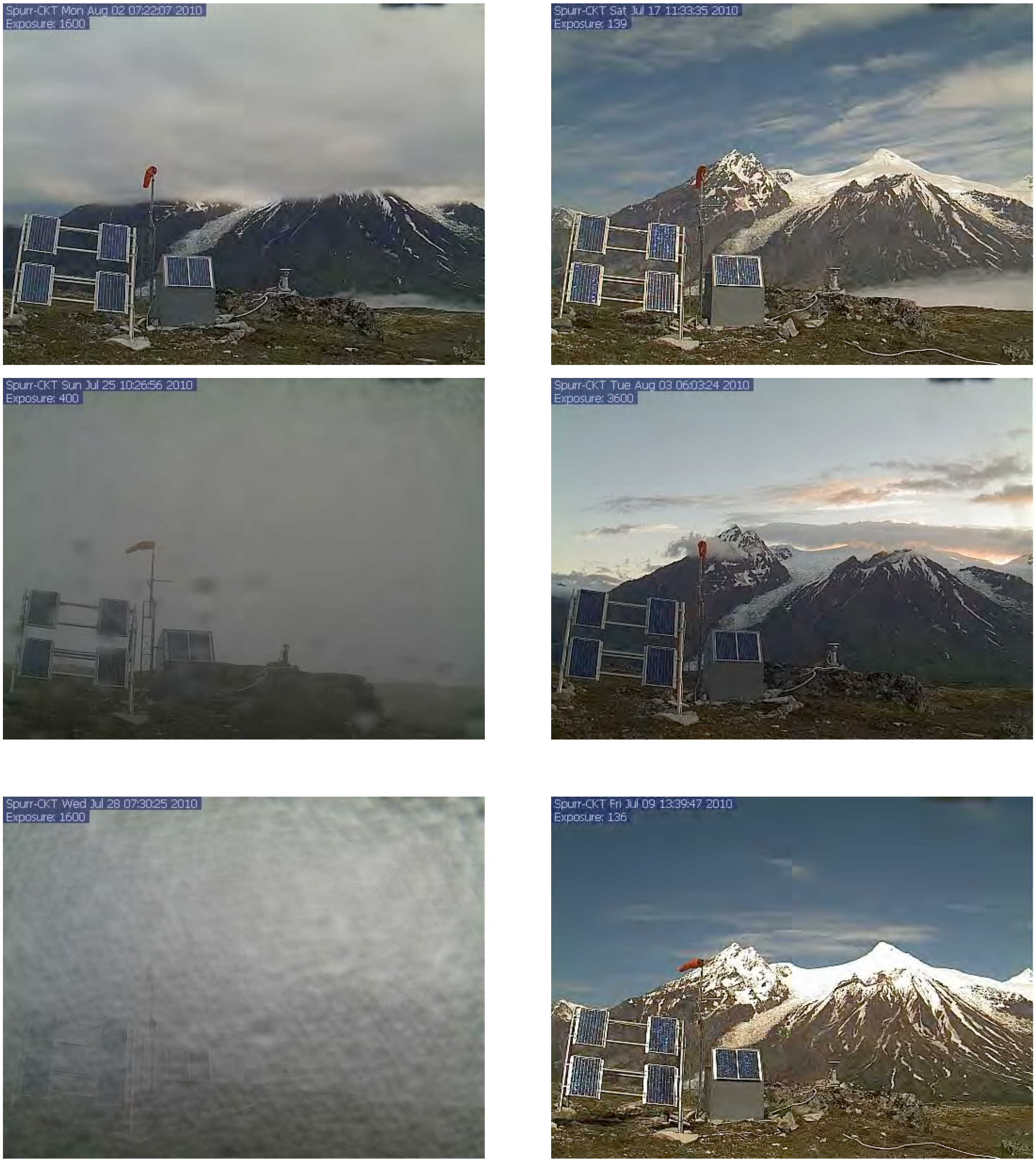


**Figure 8: Six Representative Volcano Cam Photos During the Survey Period**

## Survey Operations:

| Date 2010 | Helicopter Hours | Activity / Raw Data File Name | Helicopter Weather / ATC Hrs. | Crew Standby Days |
|---|---|---|---|---|
| 1-Jul | 3.9 | Flight 1, Data file B0070200.P03 | | |
| 2-Jul | 5.9 | Flight 2,<br>Data files B0070220.P14 and B007023.P28 | | |
| 3-Jul | | weather, no fly | | 1 |
| 4-Jul | | weather, no fly | | 1 |
| 5-Jul | | weather, no fly | | 1 |
| 6-Jul | 6.9 | Flight 3, Data file P0070618.P44 | | |
| 7-Jul | | Geophysical Crew not available | | |
| 8-Jul | | Geophysical Crew not available | | |
| 9-Jul | | Geophysical Crew not available | | |
| 10-Jul | | weather, no fly | | 1 |
| 11-Jul | 2.3 | Flight 4, wx, no survey data,<br>Data file B0071122.P14 | 2.3 | 1 |
| 12-Jul | 6.9 | Flight 5,<br>Data files B0071218.P23 and B0071221.P20 | | |
| 13-Jul | | weather, no fly | | 1 |
| 14-Jul | 5.3 | Flight 6,<br>file B0071419.P43 and B0071422.P42 | | |
| 15-Jul | | weather, no fly | | 1 |
| 16-Jul | 6.3 | Flight 7,<br>Data files B0071618.P27 and B0071621.P16 | | |
| 17-Jul | 2.0 | fly to area, unsafe high winds | 2 | 1 |
| 18-Jul | | weather no fly | | 1 |
| 19-Jul | | helicopter not available | | |
| 20-Jul | | helicopter not available | | |
| 21-Jul | | helicopter not available | | |
| 22-Jul | | helicopter not available | | |
| 23-Jul | | helicopter not available | | |
| 24-Jul | | helicopter not available | | |
| 25-Jul | | helicopter not available | | |
| 26-Jul | | helicopter not available | | |
| 27-Jul | | helicopter not available | | |
| 28-Jul | | helicopter not available | | |
| 29-Jul | | helicopter not available | | |
| 30-Jul | | weather, no fly | | 1 |
| 31-Jul | 5.0 | Flight 8, flight restrictions at Merrill,<br>Data file B0073020.P31 | 1 | |
| 1-Aug | 4.7 | Flight 9, flight restrictions at Merrill, Data file B0080117.P50 | 1 | |
| 2-Aug | | weather, no fly | | 1 |
| 3-Aug | 3.4 | Flight 10,<br>Flight 10, Data file B0080318.P00 | | |

## Equipment Photographs:


**Figure 9: Robinson R44 Helicopter N4261A with Magnetometer Bird**

The survey magnetometer bird was carried on the Robinson R44 side rack to and from the project area. The helicopter would land at the Mt. Spurr Airstrip, the base magnetometer would be deployed, the survey bird connected to the helicopter hook and the survey work would commence. When the helicopter needed refueling, the magnetometer bird would be temporarily left at the Spurr Airstrip and the helicopter flown the 15 minutes to the Shirleyville Airstrip. Fuel at the Shirleyville airstrip was positioned using four different flights from Merrill Field using a Cessna 207 fixed-wing aircraft.


**Figure 10: Magnetometer Survey Bird**

**Figure 11: Magnetometer Sensor in Nose of Survey Bird**

The GeoMetrics G-823 magnetometer sensor is mounted in the nose of the magnetometer bird and aligned to the proper orientation based on the magnetic inclination and declination of the magnetic field at the survey area. The GeoMetrics interface is mounted in the rear of the magnetometer bird. Power to the magnetometer and the Larmor Frequency from the magnetometer travel along a coax cable inside the magnetometer tow cable. The Larmor Frequency is converted to the magnetic field reading by the electronics in the helicopter and recorded at a 20Hz sample interval.


**Figure 12: Pilot Navigation Display**

The Pilot Navigation display provides the pilot with navigation information to allow the helicopter to be flown along each pre-determined survey flight line. The display shows the aircraft's position along each survey line and the position left or right of the survey lines. This information is displayed both graphically and digitally. The display shows the aircraft elevation relative to the digital terrain model as an aid to flying the planned controlled drape survey.

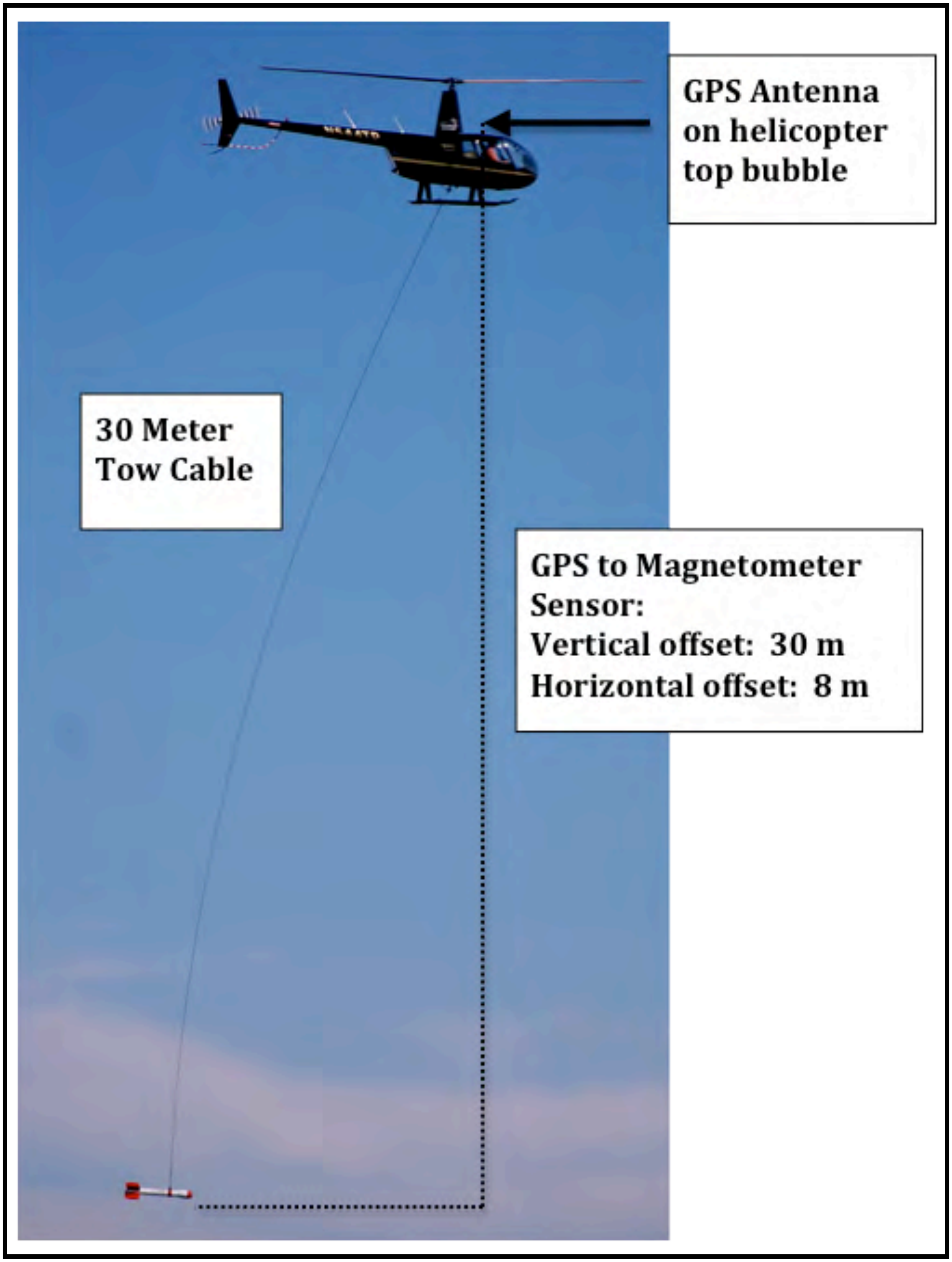


**Figure 13: Magnetometer Sensor - GPS Antenna Offset**


**Figure 14: GeoMetrics G-858 Base Station Magnetometer at Spurr Airstrip**

The GeoMetrics G-858 base station magnetometer was set up at the start of each survey day at the Mt. Spurr Airstrip. The base station clock was synchronized to UTC time using a hand-held Garmin GPS receiver. The G-858 recorded diurnal changes in the Earth's magnetic field and provided information about any excessive magnetic storm activity during the survey. For this survey, the diurnal magnetic activity was acceptably quiet and no survey lines needed to be re-acquired due to excessive diurnal or magnetic storm activity.

## Data Processing

The data were processed and mapped using the following steps:

## Field Data Processing:

Following each flight, the binary field “B” files were converted to ASCII files and loaded into GeoSoft on a flight-by-flight basis. The base station magnetometer files were downloaded and loaded into GeoSoft. The base station magnetometer values were correlated with the field data on a one-second basis. Field plots were generated of the flight path and used for survey completion analysis and next-day flight planning. Preliminary unadjusted maps were generated and provided to the client along with daily operations reports. Once checked and verified for data accuracy and completeness, the data were uploaded to the EDCON-PRJ ftp site.

## Mapping Parameters:

The GPS vertical and horizontal coordinate outputs were recorded as latitude, longitude, x, y and ellipsoid height using the WGS84 geographic coordinate system. Mapping parameters for processed digital and mapped data are:

| | |
|---|---|
| Projection: | UTM, Zone 5N |
| Datum: | WGS84 |

## Magnetic Data:

Digital magnetic data from the airborne acquisition systems were received by ftp.

Data editing was performed using the following steps:

- Profile plots of the magnetic data for each line were inspected for noisy or missing data.
- The data quality was considered good, and no filters were applied.
- No deculturing of the data was performed.

## I.G.R.F.:

The International Geomagnetic Reference Field (IGRF 2010), updated to the dates of the survey, was calculated and applied to the dataset.

## Diurnal Correction:

The base magnetometer data were inspected and compared with the observed magnetic data trace. The observed diurnal, corrected for the I.G.R.F. values for the location of the base station, were hi-cut filtered to remove noise and subtracted from the observed magnetic data.

## Leveling:

Mis-ties at line intersections were calculated and adjusted to minimize mis-tie errors. Initial leveling adjustments were completed using a DC level adjustment to compensate for long wavelength diurnal effects. The average intersection mis-tie before DC adjustment was 171.16 nT; after DC adjustment, the average mis-tie was 103.73 nT. After final leveling the average mis-tie was 5.48 nT. Elevation discrepancies between flight and tie lines caused major leveling issues. The tie lines were flown much higher than the flight lines, causing the tie-line to loose detailed magnetic signature seen in the flight lines. The lack of magnetic correlation between the flight and tie lines made leveling impossible, thus the tie-lines were removed from leveling and the flight lines were adjusted by plotting the flight line data and calculating line adjustments manually. The manually-adjusted data were then strike-filtered to remove any remaining line-oriented anomalies. This grid was then used in a micro-leveling procedure, producing the final leveled data.

## Micro-leveling:

After standard leveling is applied to magnetic data (e.g., DC least squares adjustment using misties between profile and tie lines), some corrugation is usually evident in the grid made from the data. This corrugation is due to small mismatches between adjacent lines arising from residual heading errors, small differences in flight elevation, and horizontal positioning errors. The corrugation can be removed from the grid by splitting the gridded data into matching low-pass and high-pass components, applying tuned strike-suppression filters along the profile and tie line directions to the high-pass component, and reassembling the result with the low-pass component. This eliminates short-wavelength geological anomalies oriented along the flight and tie line directions, but these are generally unrecoverable anyway in the presence of corrugation. Variations of this procedure are standard in the industry, and are known generally as decorrugation.

The remaining problem is to transfer this correction back to the profile data. Simply extracting the profiles from the gridded data yields a result which lacks the short-wavelength content of the original data. The idea is to retain the shorter wavelength components in the profile data, while using the longer wavelength components of the data extracted from the decorrugated grid.

The procedure used is as follows. The spectrum of the difference between the profile data and the extracted profiles is analyzed to design a low-pass filter that reflects the long-wavelength part of the difference, and the filter is applied to the difference. The low-pass difference is then subtracted from the profile data, which is equivalent to replacing the long-wavelength component of the profile data with that of the profile extracted from the grid. This is a variation of the procedure known as microlevelling.

The differences between the profile data before and after microlevelling are quite small, generally less than 1 nT except for DC shifts. However, the final data now interpolates to a grid which is essentially free of corrugation.

## Reduction to the Pole:

Reduction to the Pole calculates the field which would be observed if the survey area were located at the north magnetic pole. This transformation shifts the magnetic anomalies more nearly over the causative bodies. The Reduced-to-the-Pole grid used an inclination of 73.79 degrees and a declination of 18.50 degrees.

## Deliverables:

The following are the deliverable products of this project:

- Mt_spurr_tmi.pdf: Total Magnetic Intensity map in pdf format
- Mt_spurr_rtp.pdf: Reduced to Pole map in pdf format
- Mt_spurr_hg.pdf: Horizontal Gradient of the Reduced to Pole Magnetics map in pdf format
- Mt_spurr_tilt.pdf: Tilt Derivative of the Reduced to Pole Magnetics map in pdf format.
- Mt_spurr_hgtilt.pdf: Horizontal Gradient of the Tilt Derivative map in pdf format.

- Mt_spurr_tmi.xyz: Total Magnetic Intensity grid in ASCII XYZ format
- Mt_spurr_rtp.xyz: Reduced to Pole grid in ASCII XYZ format
- Mt_spurr_hg.xyz: Horizontal Gradient of the Reduced to Pole Magnetics grid in ASCII XYZ format
- Mt_spurr_tilt.xyz: Tilt Derivative of the Reduced to Pole Magnetics grid in ASCII XYZ format.

- Mt_spurr_hgtilt.xyz: Horizontal Gradient of the Tilt Derivative grid in ASII XYZ format.
- Mt_spurr.dat: Survey line data in Geosoft XYZ format
- 21014_Mt_Spurr_Heli-mag_Report.pdf: This report in pdf format

Survey Line Data Format is shown below:

| Columns | Format | Description | Units |
|---|---|---|---|
| 1-8 | A8 | Line Name | Alpha |
| 9-20 | F12.5 | Latitude (WGS 84) | Decimal Degrees |
| 21-32 | F12.5 | Longitude (WGS 84) | Decimal Degrees |
| 33-43 | F11.1 | UTM X | Meters (zone 58s) |
| 44-54 | F11.1 | UTM Y | Meters (zone 58s) |
| 55-63 | F9.1 | GPS Time | Seconds of the week |
| 64-70 | F7.1 | Radar Altimeter | Meters |
| 71-78 | F8.1 | GPS Elevation | Meters |
| 79-87 | F9.2 | Raw Magnetics | nT |
| 88-96 | F9.2 | Final Magnetics | nT |
| 97-105 | F9.2 | Diurnal Magnetics | nT |

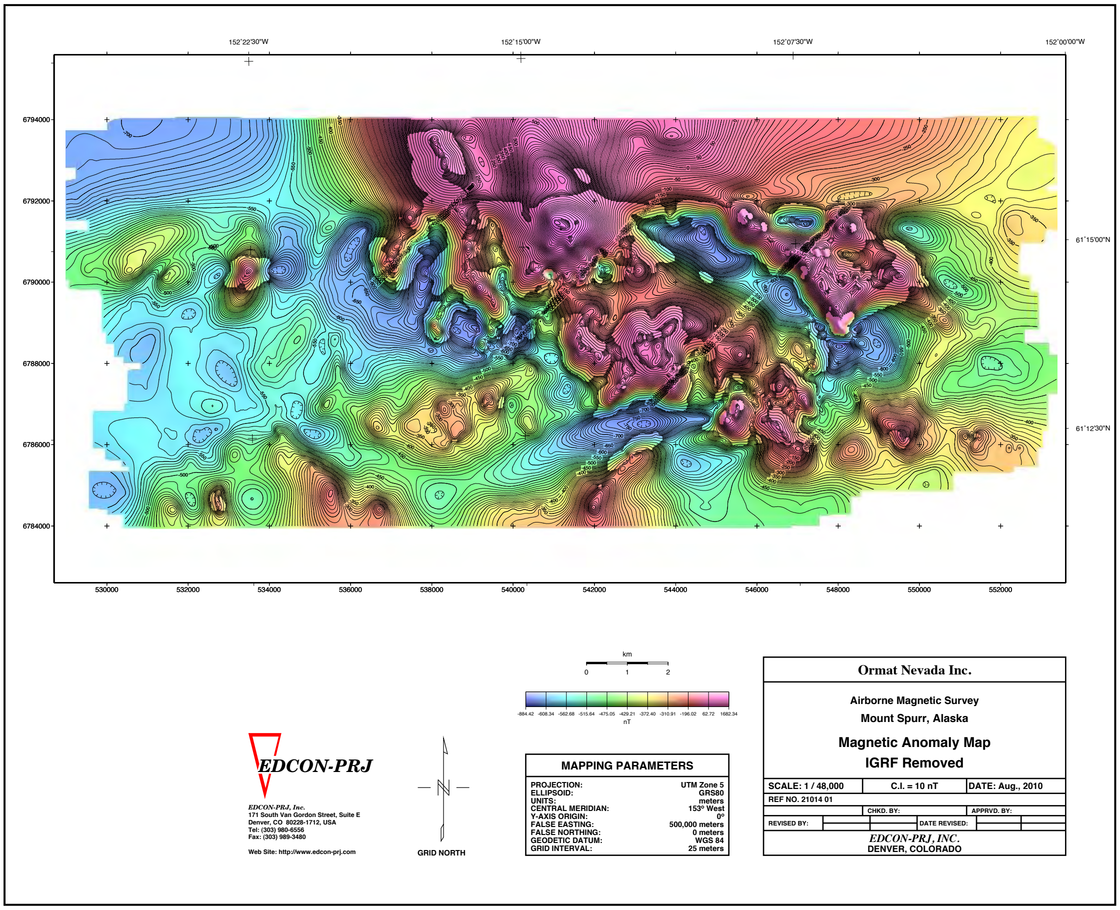


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**Figure 15: Total Magnetic Intensity Map**

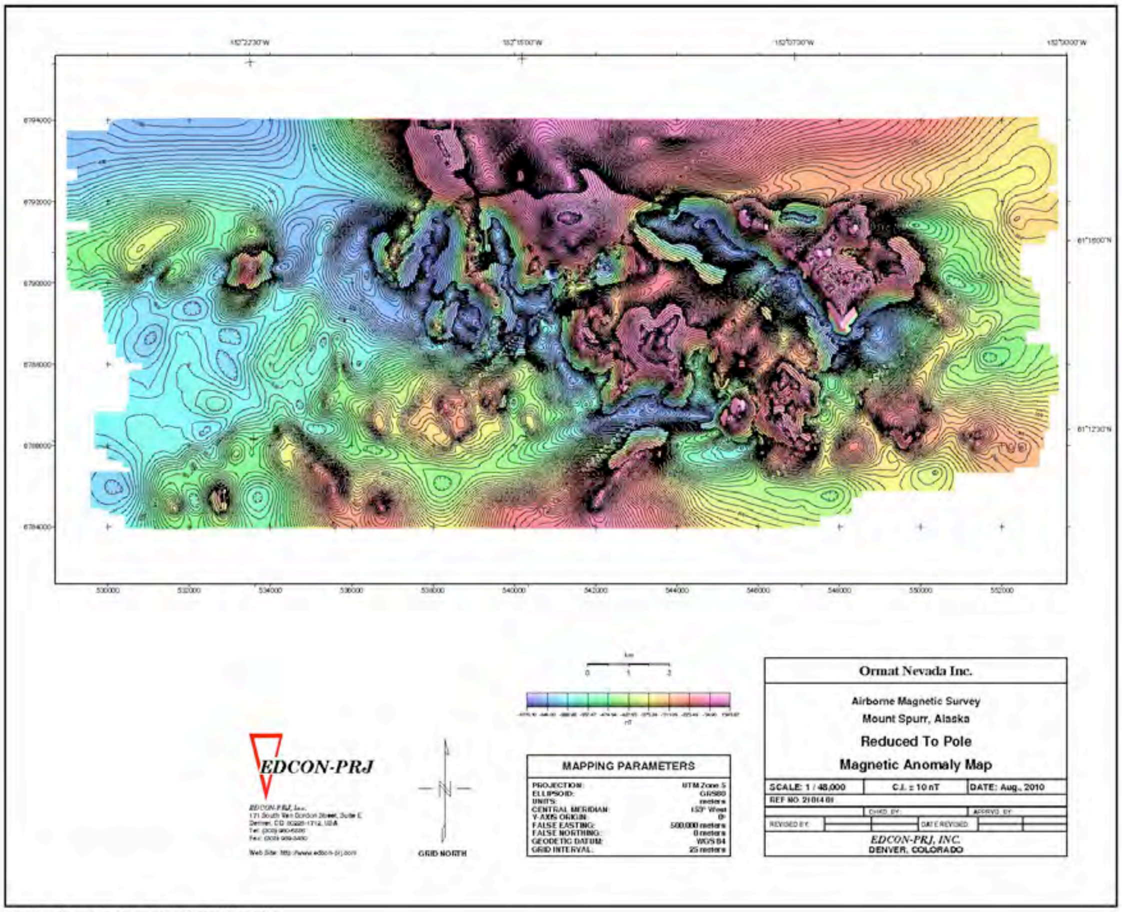


**Figure 16: Reduced-to-Pole Map**

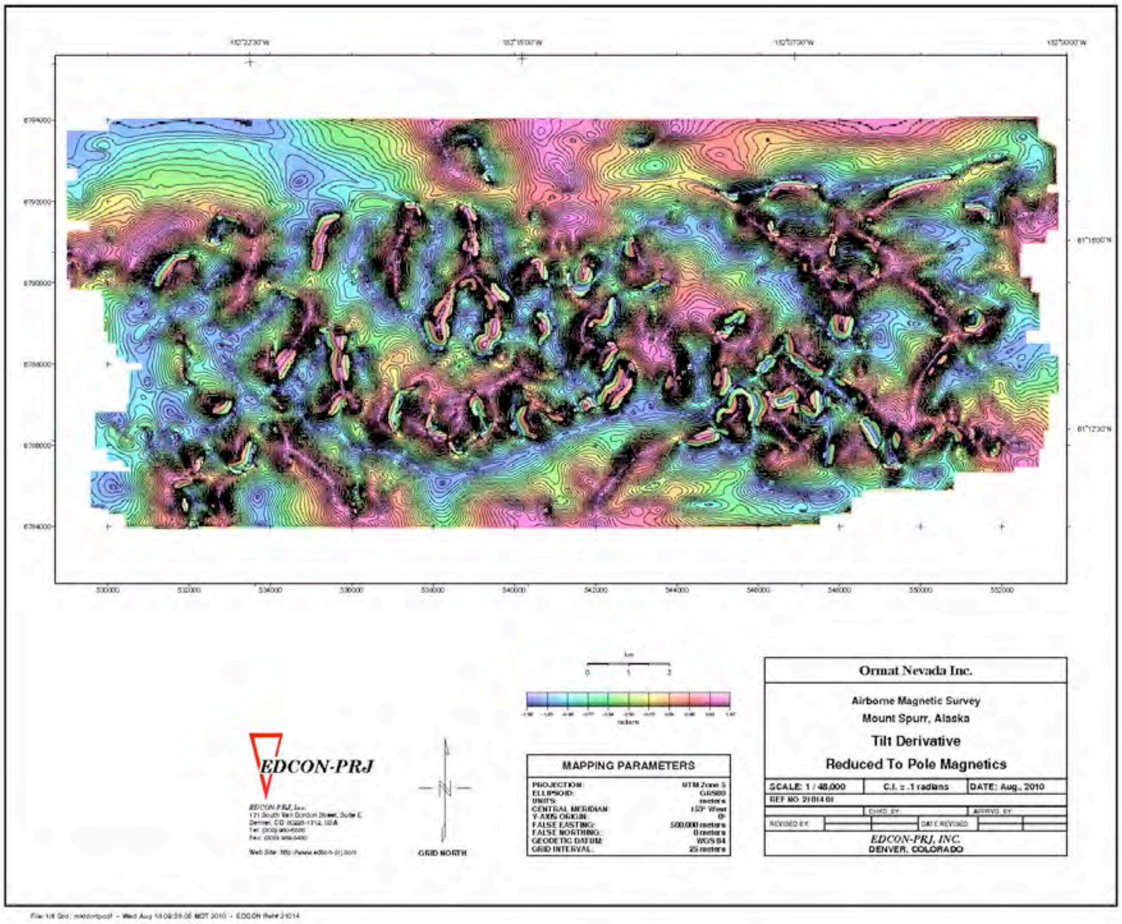


**Figure 17: Tilt Derivative Map**

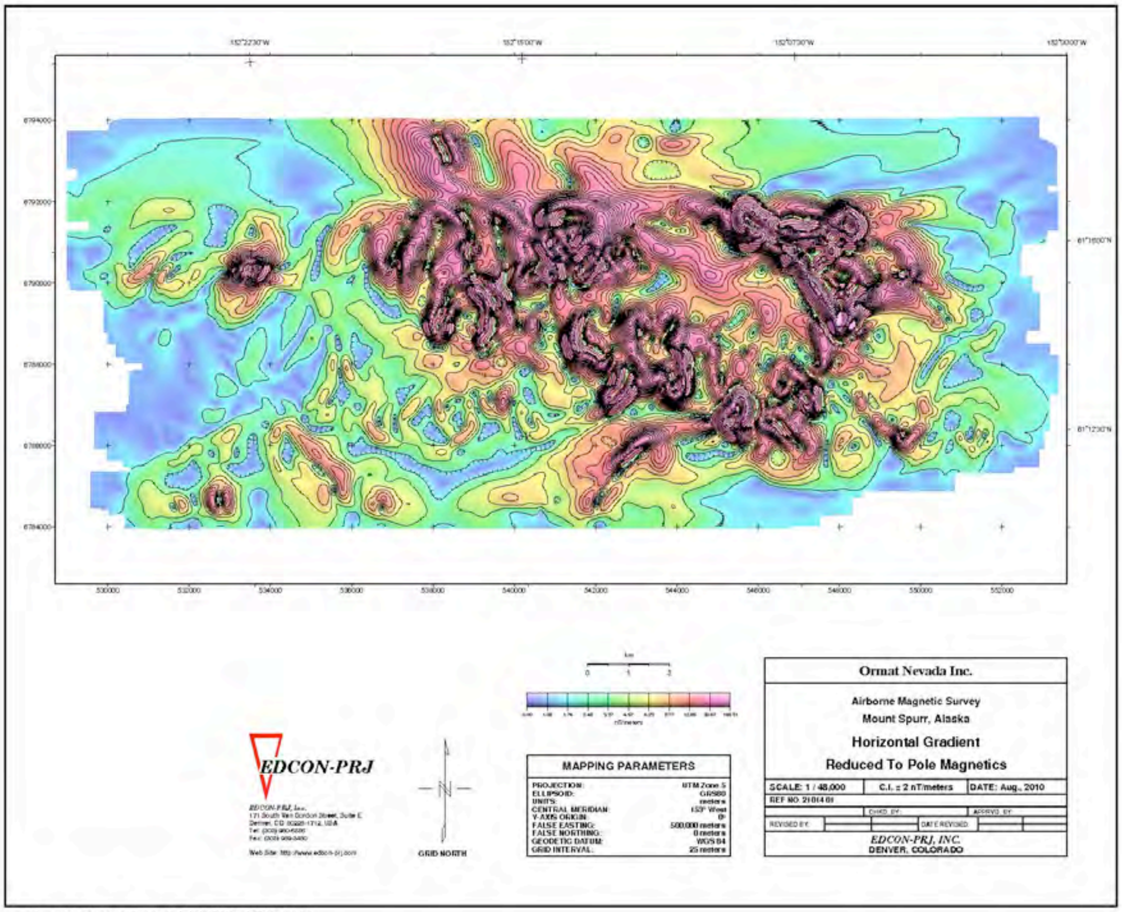


**Figure 18: Horizontal Gradient Map**

## Summary:

The survey was completed with several weather-related flight path deviations and delayed by weather on many days. The survey was further delayed by helicopter scheduling conflicts. The extreme terrain of the project area made flying a controlled drape surface difficult. There were no equipment or helicopter problems during the survey. No health, safety or environmental incidents occurred during the survey.

The geophysical product is of high quality and provides a tool to further understand the geology of the project area.

This project was completed under EDCON-PRJ job number 21014.

Sincerely,

EDCON-PRJ, Inc.

John E. Seibert

Nick Anderson