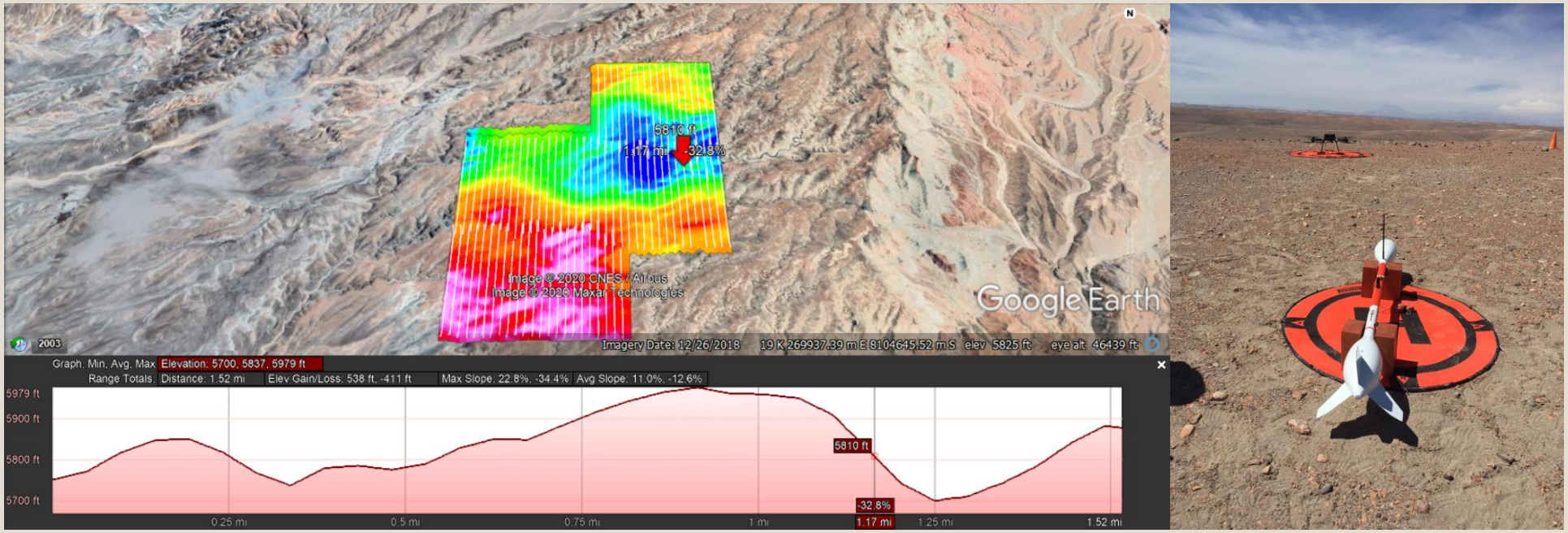


Aeromagnetic Surveying with a Multi Rotor Unmanned Aircraft System

A Case Study of comparing Heli-Mag and UAV-Mag Data in Greenfield Exploration

Telma Aisengart
Jose Arce
Carlos Cifuentes

Date: October 8th, 2020

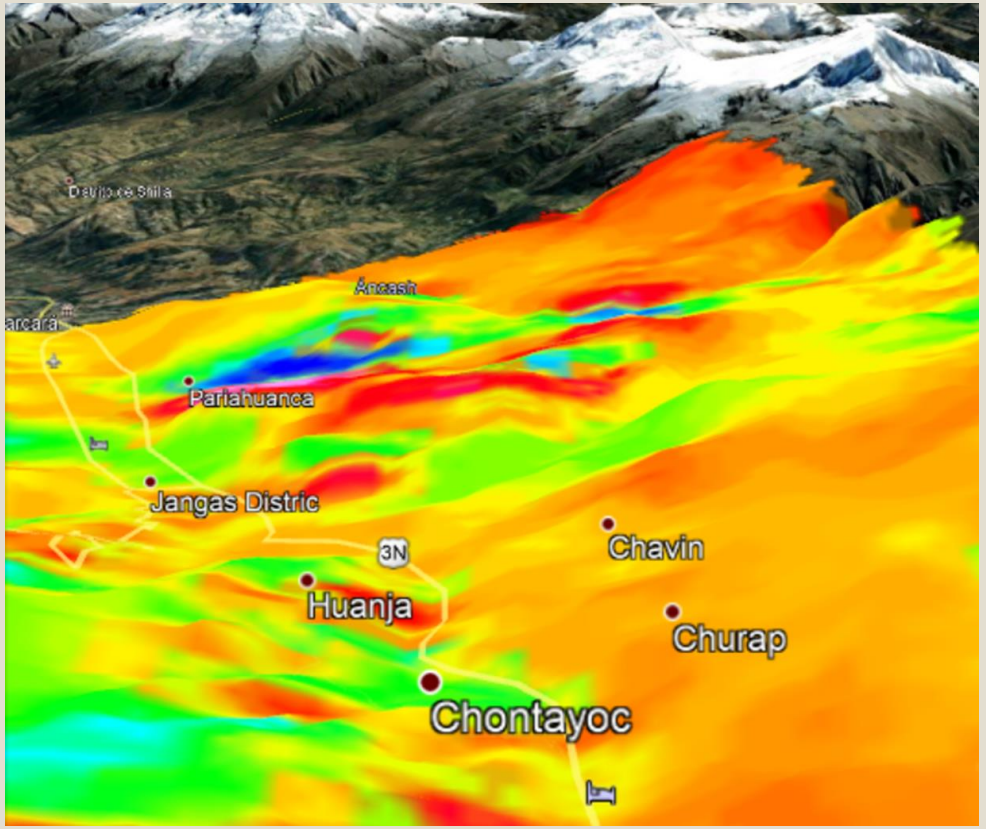
Agenda

1. UAV Mag Surveys for Mineral Exploration
2. Magnetometers used for commercial Surveys
3. UAV Mag Surveys Field Data Acquisition, Quality Control and Processing
4. Tambo Sur UAV Mag and Helicopter data analysis
5. Conclusions

1

UAV Mag Surveys for Mineral Exploration

UAV Mag Surveys for Mineral Exploration



Within the past decade, the development of UAV Mag Systems has been possible due to the following:

- Cost effective commercially available UAV platforms
- Development of low weight Magnetic sensors
- Software development for UAV flight path planning and data processing

UAV Mag Surveys for Mineral Exploration

UAV Mag System

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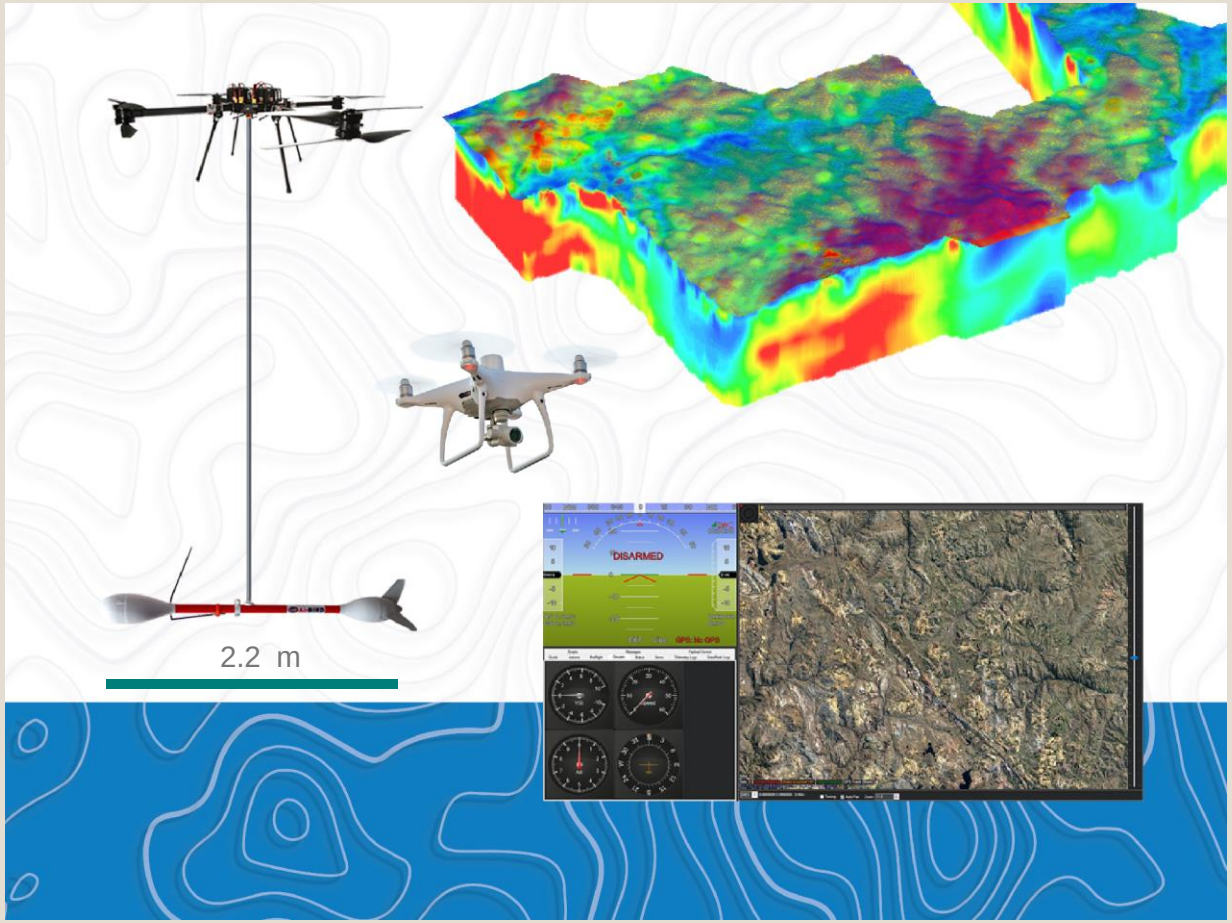

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* Source: https://www.gemsys.ca/uav-magnetometers/
** Source: http://www.geofisicos.com/es/servicio/prospeccion-mineral/magnetometria-en-uav

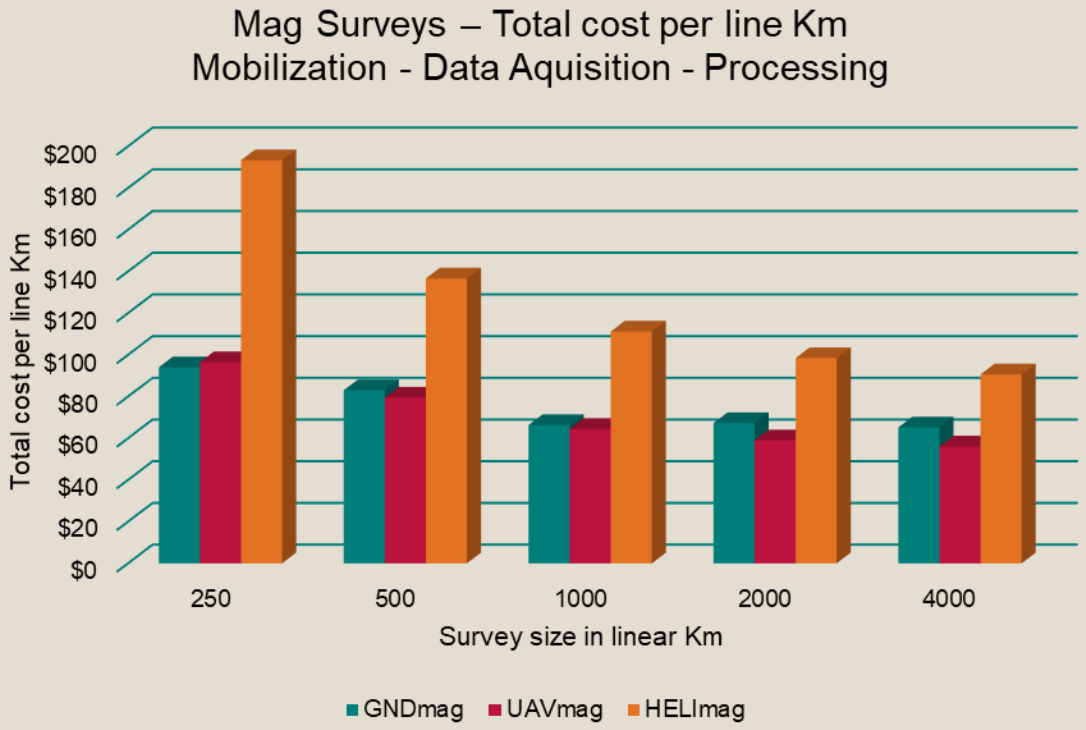
UAV Mag Surveys for Mineral Exploration

UAV Mag Advantages

UAV Mag Surveys for Mineral Exploration

UAV Mag advantages

- The mobilization and logistics is less complicated and less expensive than other aerial systems
- It is more cost-effective and requires fewer maintenance and operation personnel, compared to conventional airborne geophysical platforms (fixed wing or helicopters)

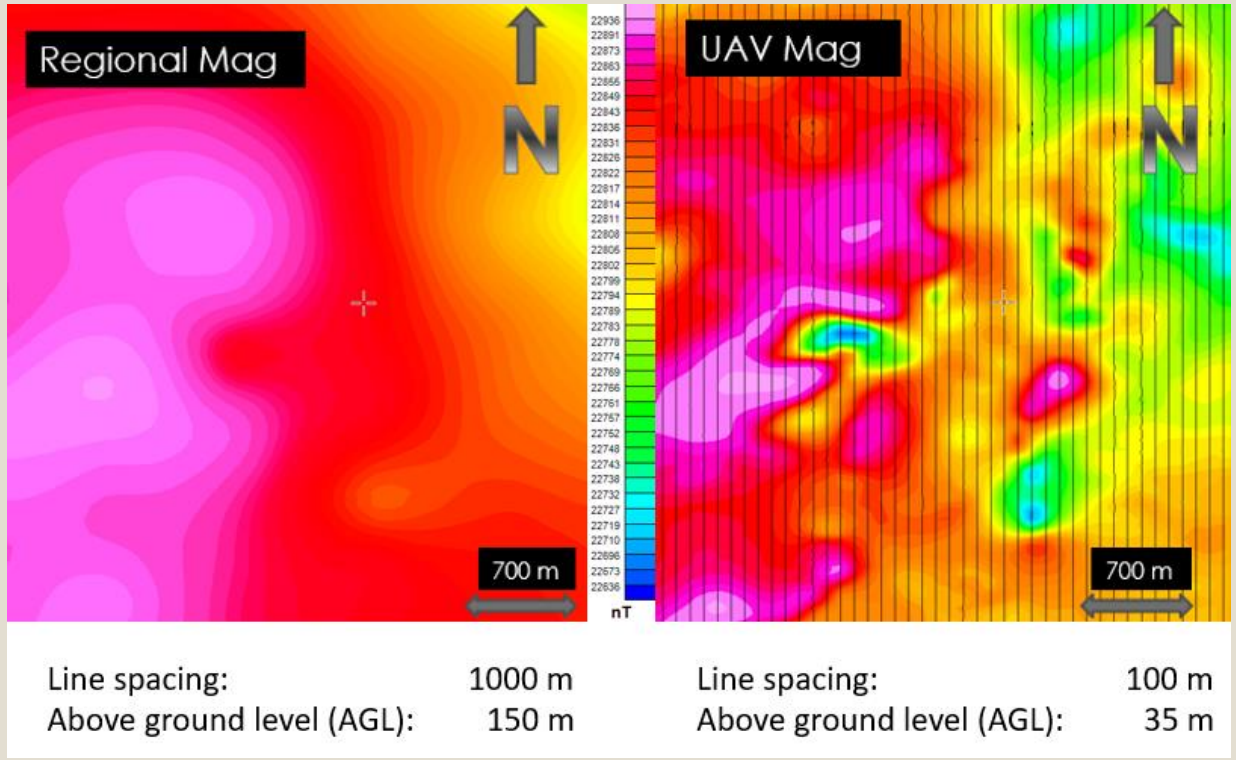


Average mobilization cost to Chiles II – Región	
GNDmag	$3,000
UAVmag	$5,000
Helimag	$18,000

Average acquisition cost per line km	
GNDmag	$60
UAVmag	$50
Helimag	$80

UAV Mag Surveys for Mineral Exploration

UAV Mag advantages

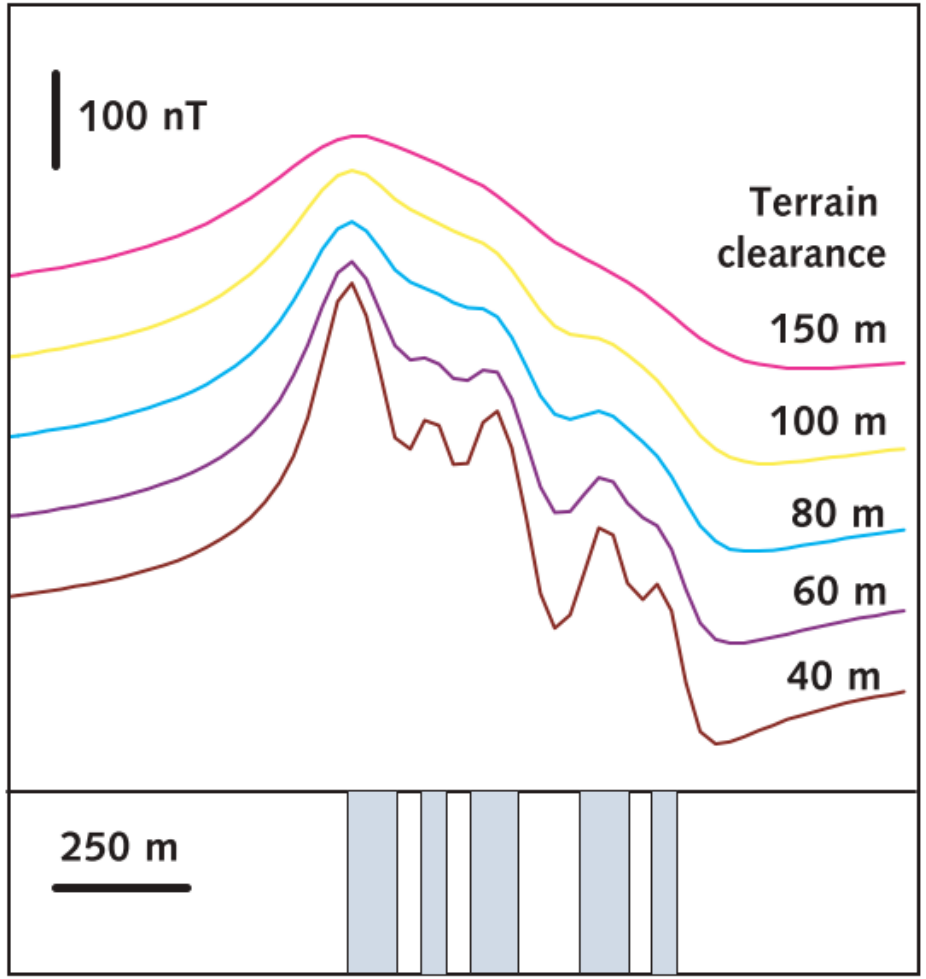


- In steep topography the UAV systems are capable to fly closer to the surface, compared to the helicopter or fixed-wing platforms
- Increasing flight height and line spacing greatly reduces the resolution of magnetic survey

UAV Mag Surveys for Mineral Exploration

UAV Mag advantages

- The magnetic signal is inversely proportional to the square of the distance from the source.
- In this case a Magnetic Survey flown at 150m AGL would be able to register the sum of the individual anomalies. A UAV Mag Survey flown at 40 m is capable to register the individual response of the anomalies.



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* Airborne Geophysics: Old Methods New Images, Reeves, C.V., Reford, S.W. and Milligan, P.R., 1997

2

Magnetometers used for commercial Mag Surveys

Magnetometers used for commercial Mag Surveys

There are two basic types of magnetometer measurement:

Fluxgate magnetometers

- Measure the vector components of a magnetic field. Typically the fluxgate are used for airborne flight orientation instead of magnetic field surveying
- Resolution of 0.1 nT
- The directional effect is very high
- Thermal drift of 0.6 nT / C and Offset when it is turned on and off of 50 nT
- They are extremely sensitive to very minor variations in sensor tilt

Total field magnetometers

- Measure the magnitude of the vector magnetic field. The total field magnetometers more commonly used are Proton Precession, Potassium, Cesium and Overhauser
- Resolution of 0.001 nT
- The directional effect is very low
- No temperature drift
- Standard magnetometers for commercial Mag Surveys

Magnetometers used for commercial Mag Surveys

There are two basic types of magnetometer measurement:

Fluxgate magnetometers

Total field magnetometers

Magnetometers used for commercial Mag Surveys

Technical Specifications and Mag Sensors available in the market

Mag Sensor Technical Specifications

Sensitivity	0.01 nT
Absolute Accuracy	±10 nT
Noise Envelope	0.10 nT
Ambient Range	20,000 to 100,000 nT
Sampling Interval	0.1 second
Heading Effect	< 2.0 nT

*

Industry standard for Mag Airborne Surveys

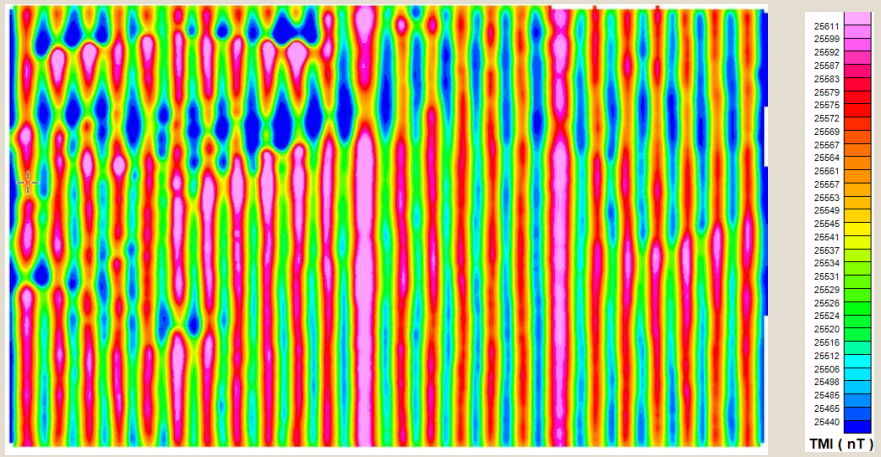
Company	Airborne Mag	UAV Mag
GEM SYSTEMS	GMP-35A Potassium Magnetometer	Airbird GMP-35U Potassium Magnetometer
SCINTREX A DIVISION OF LRS	CB-3 Cs Magnetometer Sensor	CS-VL Cesium Magnetometer
GEOMETRICS Simplify your search	G-823A Cesium Magnetometer	MagArrow Laser Pumped Cesium Vapor

* Source: Geological Survey of Canada aeromagnetic surveys: design, quality assurance, and data dissemination, M. Coyle, R. Dumont, P. Keating, F. Kiss, and W. Miles, 2014

Magnetometers used for commercial Mag Surveys

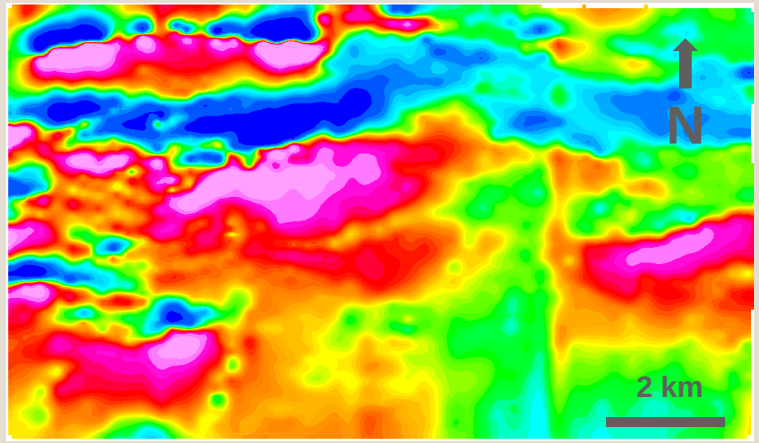
Raw data from an airborne mag survey

Fluxgate magnetometer



Directional effect of the Fluxgate magnetometer (stripes on the raw data)

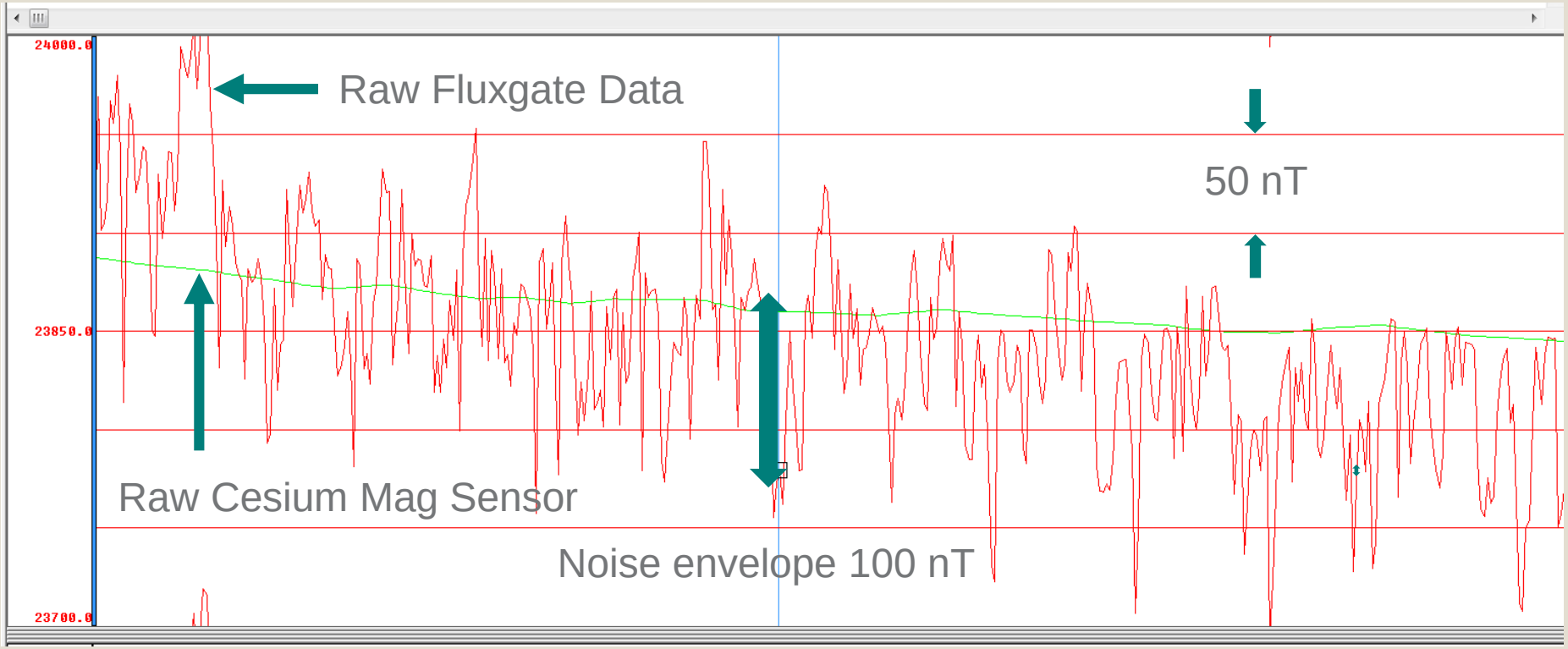
Total field magnetometer



Fix wing survey
Line spacing 250m
Flight Altitude 100 m

Magnetometers used for commercial Mag Surveys

Raw data from airborne mag survey



Raw Fluxgate Data

Raw Cesium Mag Sensor

UAV Mag Surveys Field Data Acquisition, Quality Control and Processing

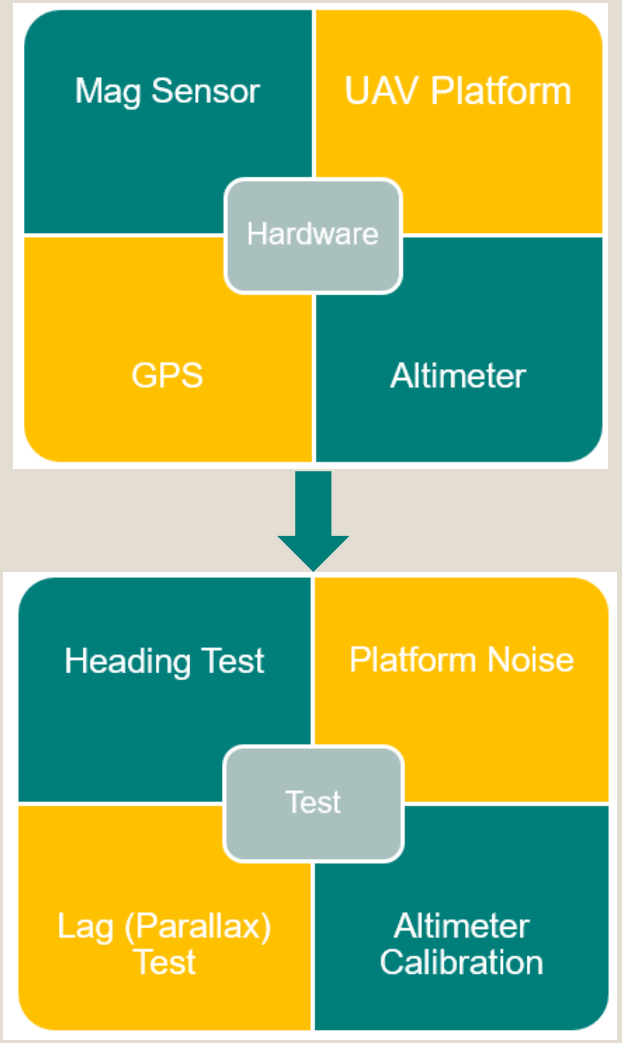
UAV Mag Surveys Field Data Acquisition, Quality Control and Processing

Equipment used in Data Acquisition

UAV Mag Surveys Field Data Acquisition, Quality Control and Processing

Quality Control of Aeromagnetic Surveys

- Inspection of airborne platform, geophysical equipment and personnel experience
- Airborne platform tests and calibrations
- Inspection of data compliance
  - Data integrity, noise and gaps
  - Flight path deviation
  - Flight line spacing
- Data processing procedures

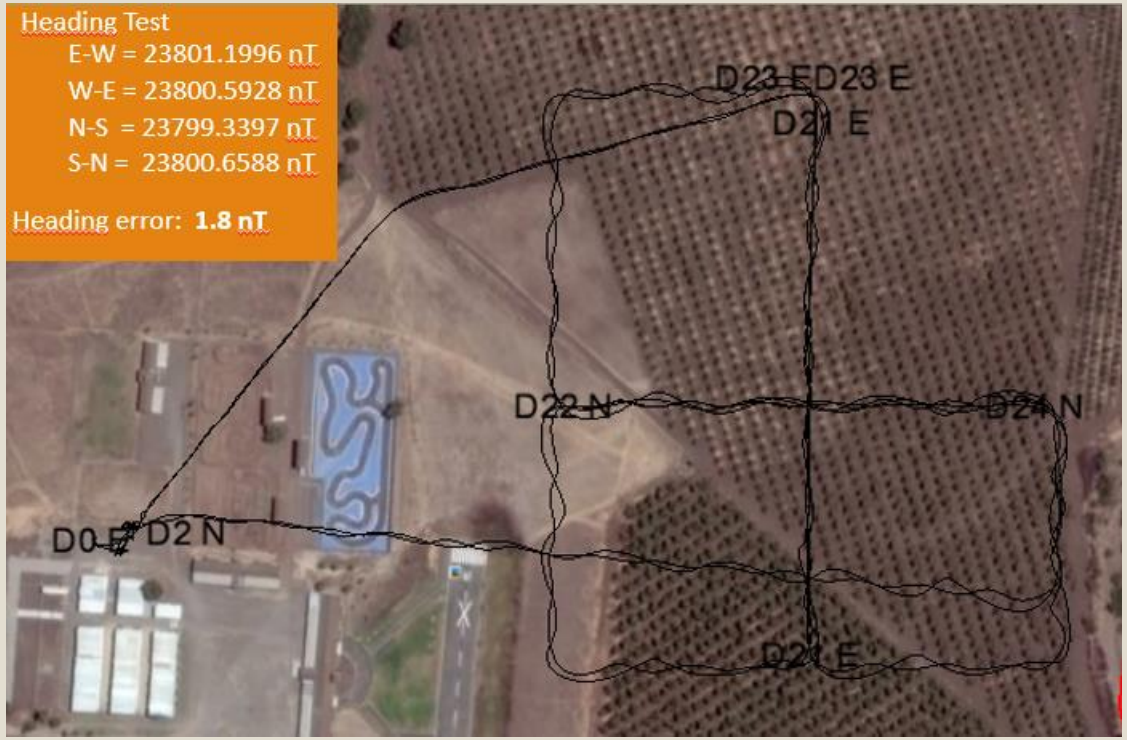


* Source: Geological Survey of Canada aeromagnetic surveys: design, quality assurance, and data dissemination, M. Coyle, R. Dumont, P. Keating, F. Kiss, and W. Miles, 2014

UAV Mag Surveys Field Data Acquisition, Quality Control and Processing

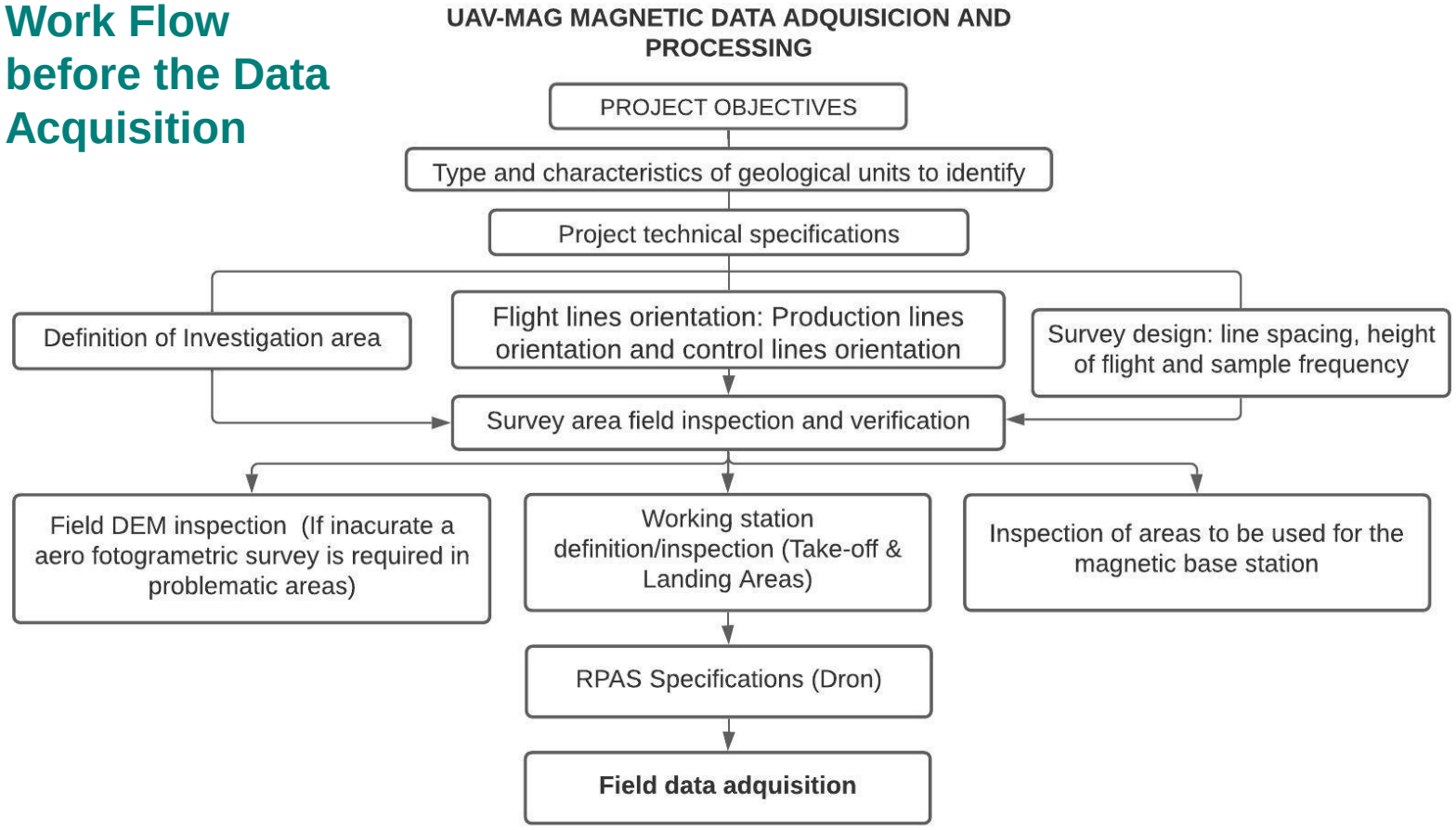
Examples of Calibrations

The Heading Test is designed to demonstrate that the flight platform and the data acquisition system do not have a significant heading effect, that is, that the same magnetic field value will be recorded at the same location, regardless of the heading in which the waypoint is flown.



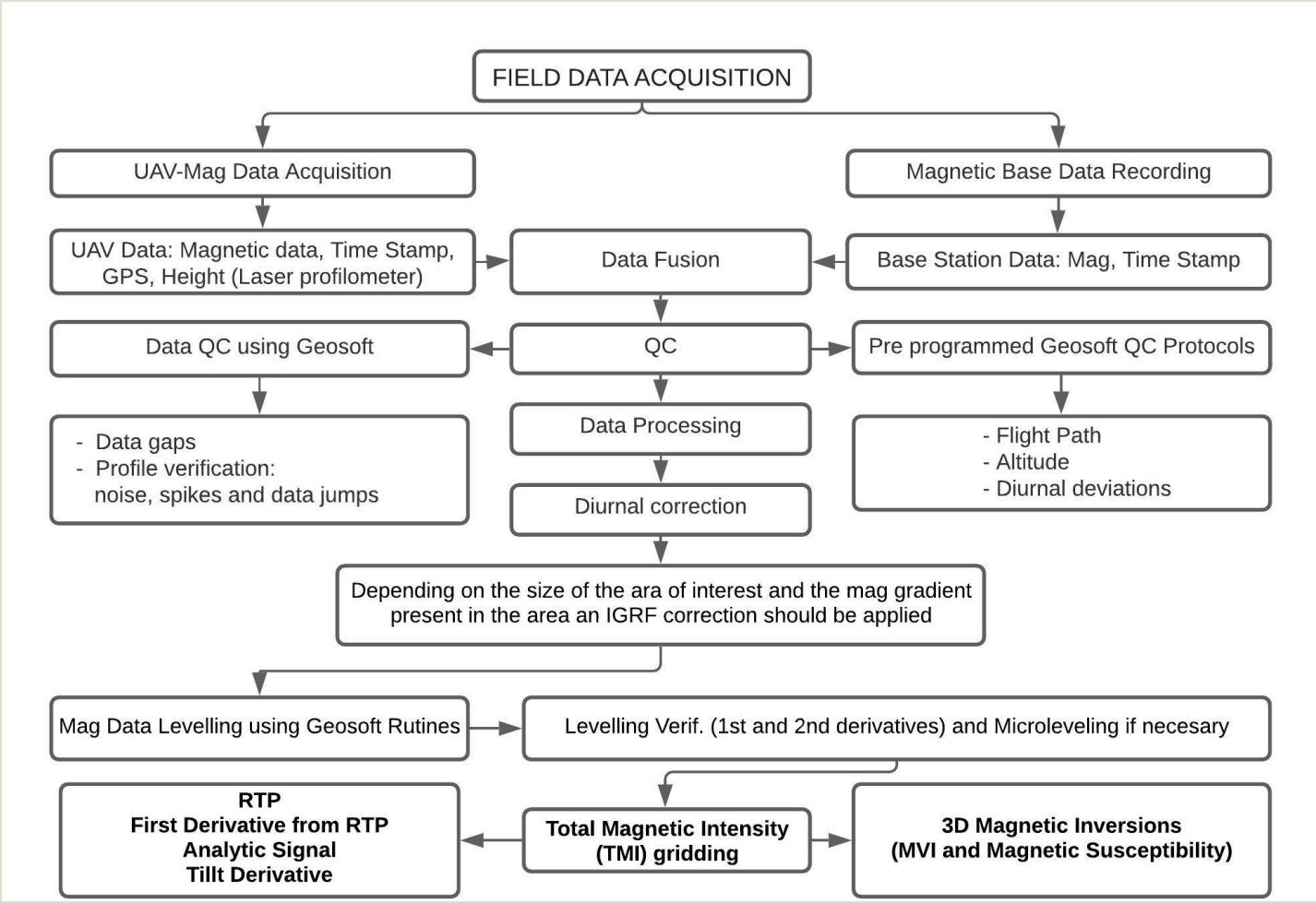
UAV Mag Surveys Field Data Acquisition, Quality Control and Processing

Work Flow before the Data Acquisition



UAV Mag Surveys Field Data Acquisition, Quality Control and Processing

Work Flow after the Data Acquisition



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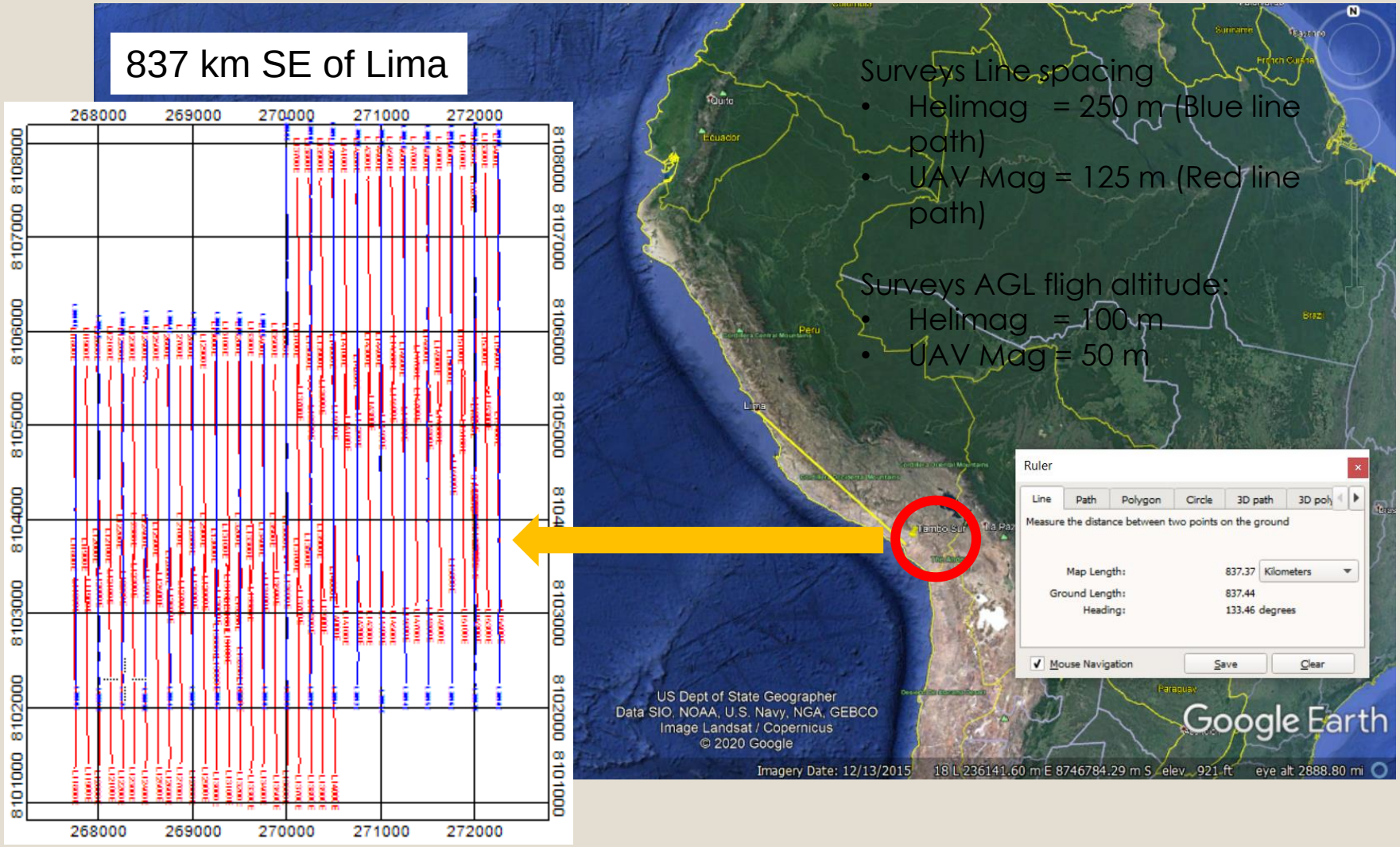
Tambo Sur UAV Mag and Helicopter data analysis

Tambo Sur UAV Mag and Helicopter data analysis

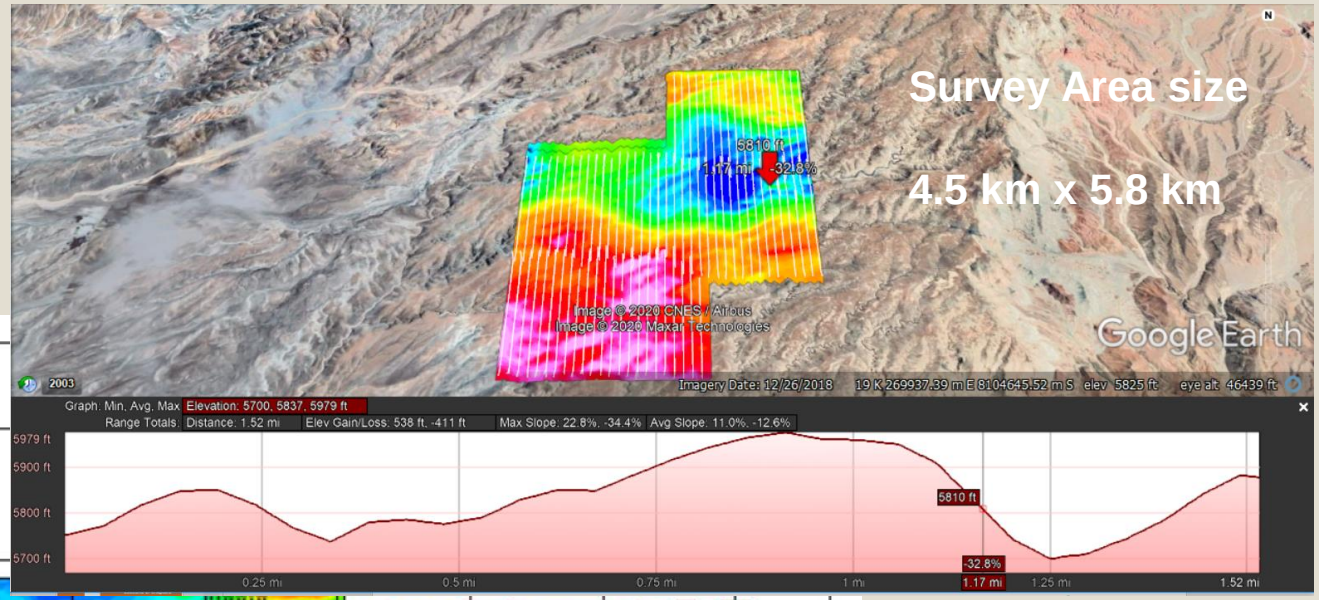
Survey Location

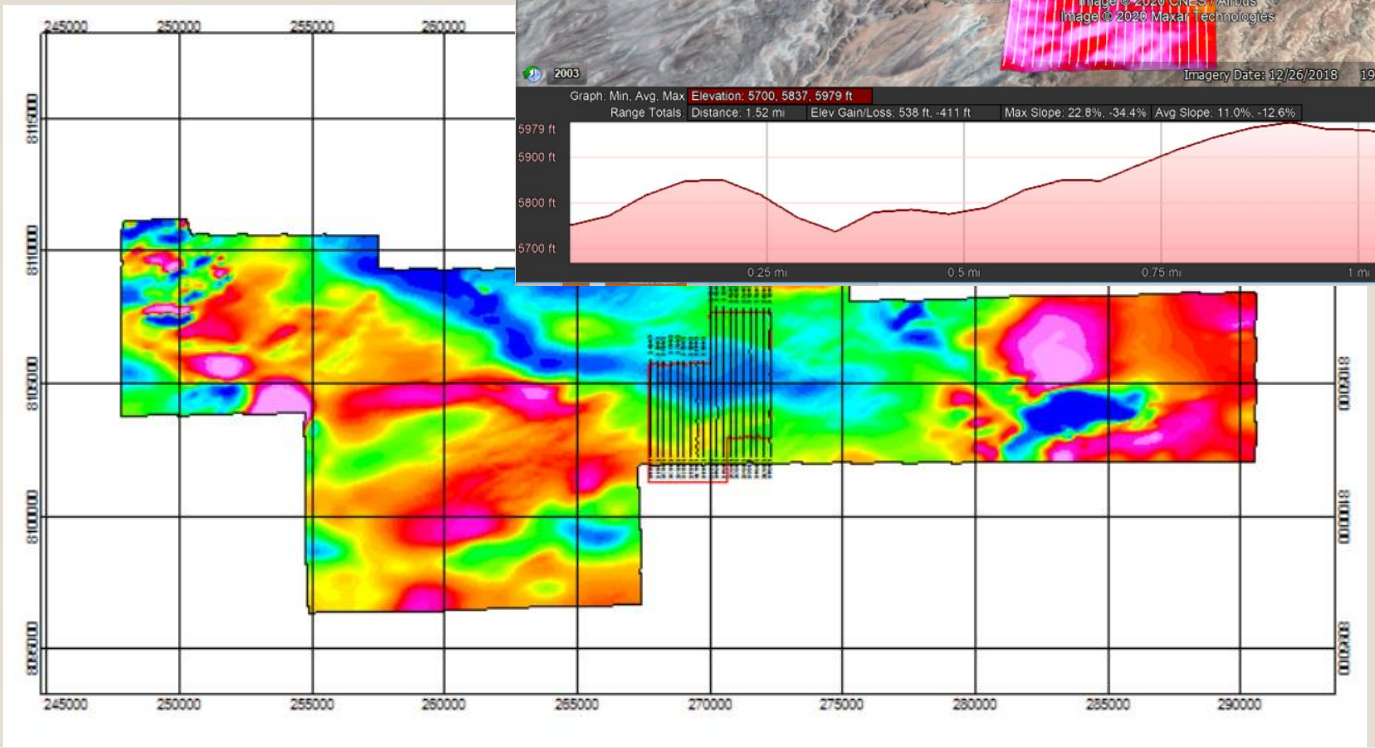


Tambo Sur UAV Mag and Helicopter data analysis

UAV Magnetic Survey Specifications

Line direction: N000
Total lines: 37
Line km: 181 km





Tambo Sur UAV Mag and Helicopter data analysis

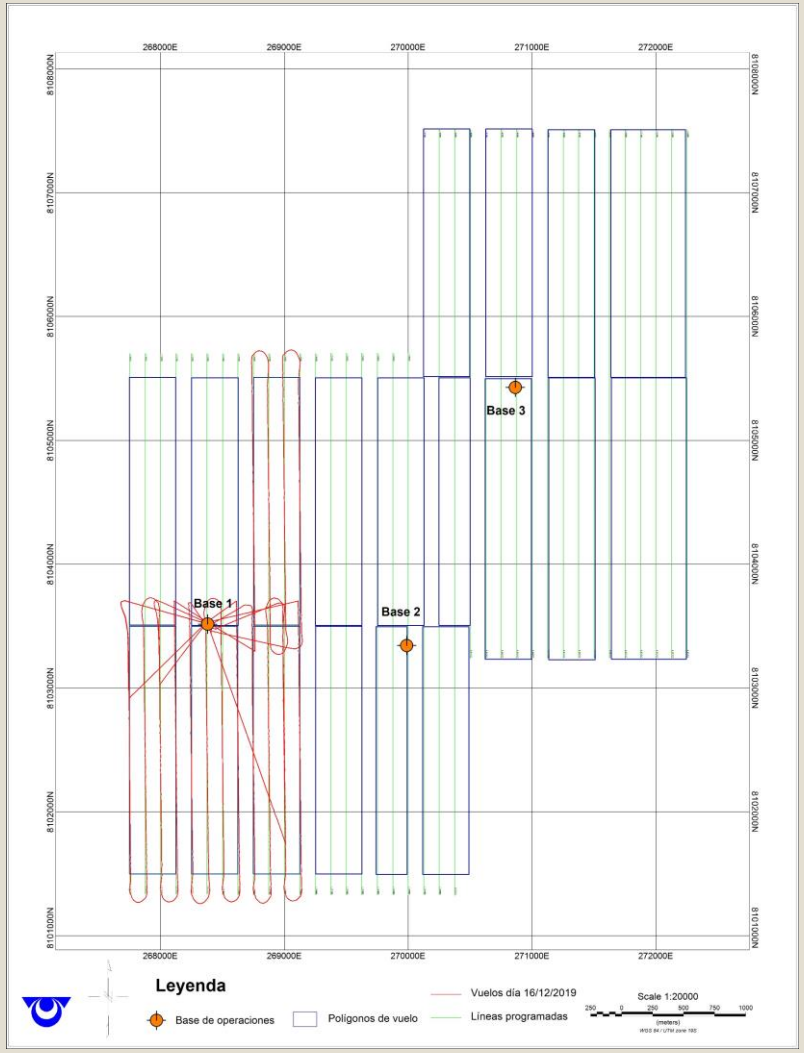
Survey Equipment

UAV Platform: BFD Systems HSE8
Number of motors: 8
Batteries: 4 of 22000 mA/h each

Mag system: GEM Airbird
Sensor: Potassium GSMP-35U
Resolution: 0.0001 nT
Absolute Accuracy: +/- 0.1 nT
Heading Error: + / – 0.05 nT

Tambo Sur UAV Mag and Helicopter data analysis

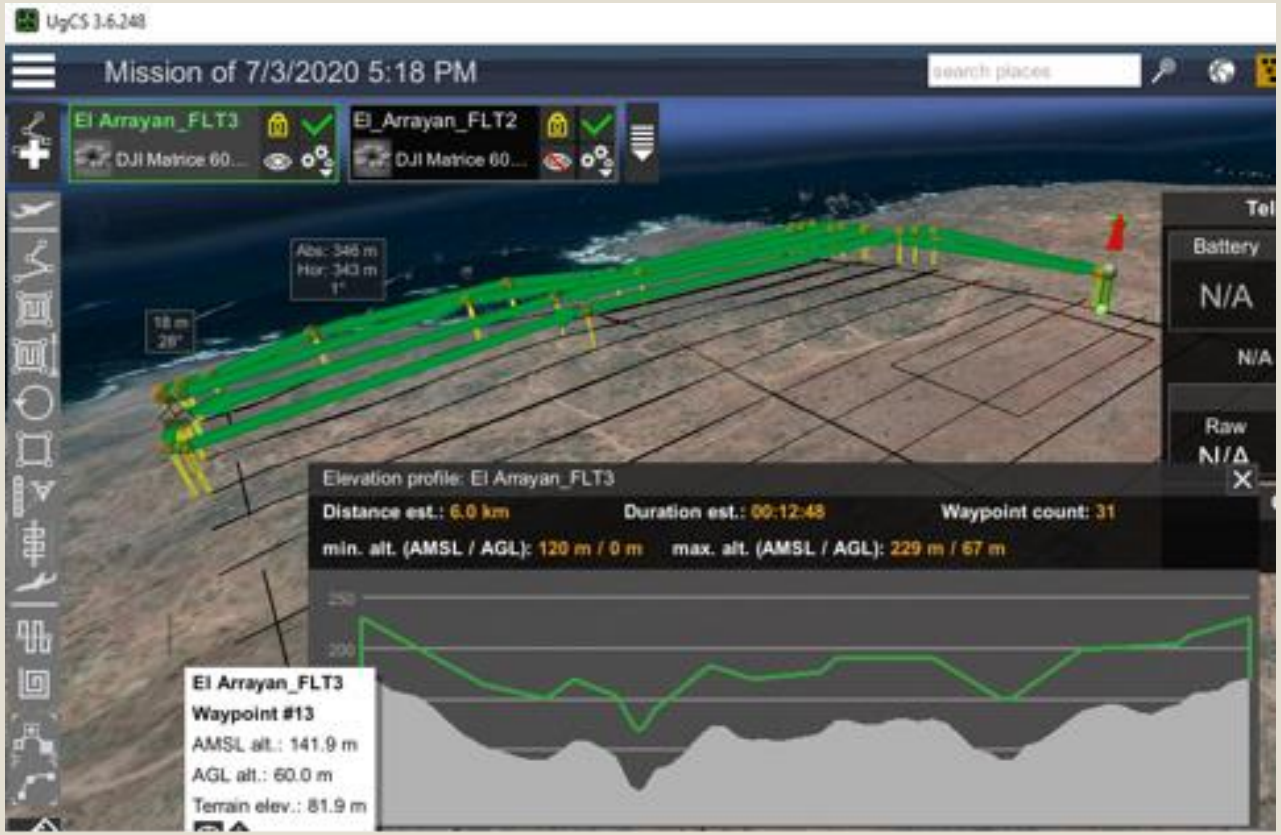
Data Acquisition



- In total three take-off/landing sites were used to cover the entire area
- The location of take-off/landing sites and the daily flight plan were programmed considering the topography, autonomy of the UAV, wind conditions and ferry time
- In normal conditions the UAV BFD model SE-8 has a flight autonomy of 25 minutes, however due to the complex topography and wind conditions during the present survey the flight time was reduced to a maximum to 16 minutes

Tambo Sur UAV Mag and Helicopter data analysis

UgCS UAV Mission Planner

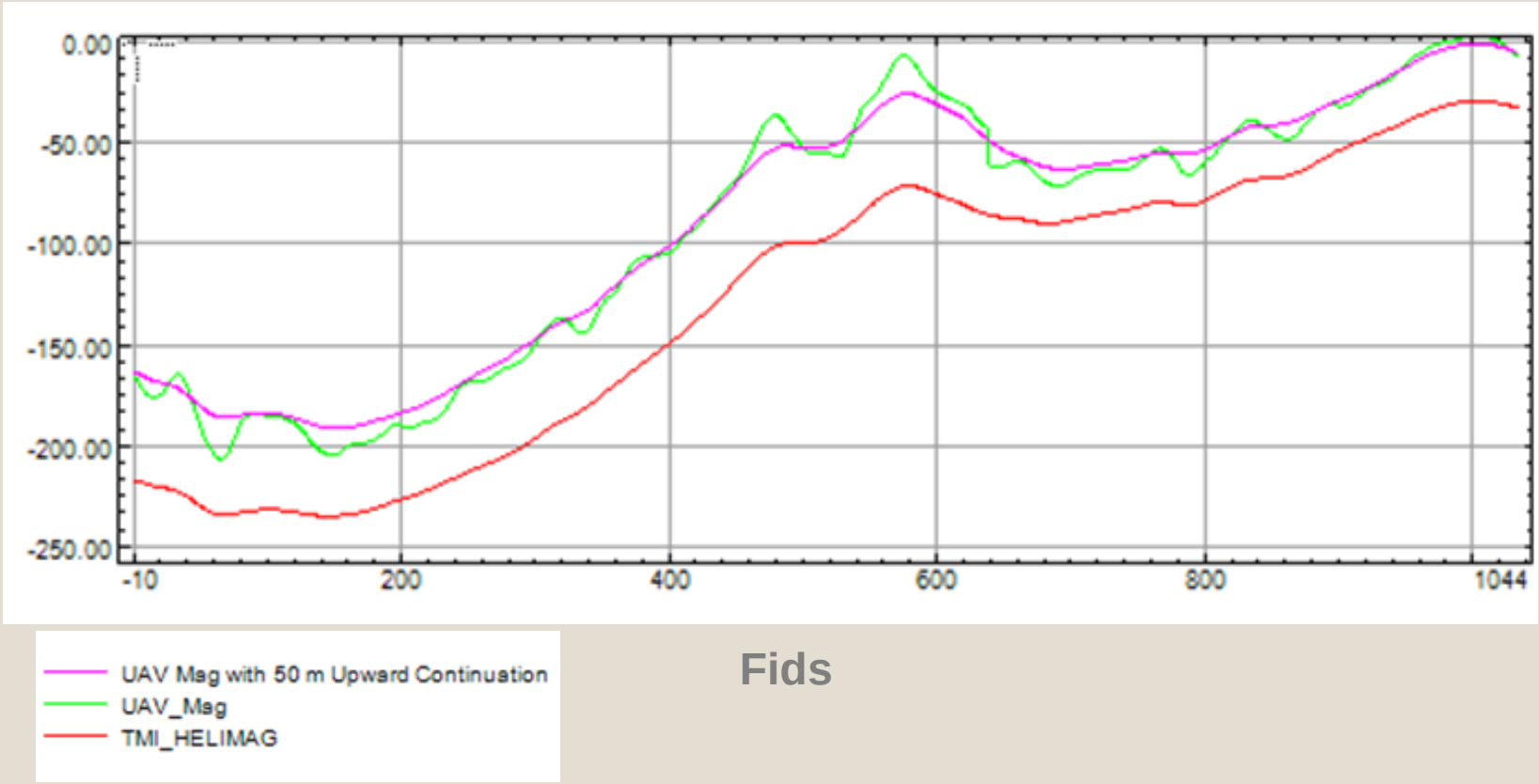


- The UAV Flight Plan software uses a DEM to plan the surface flight path
- It is recommend to use a high resolution DEM to plan an appropriate drape surface to avoid UAV collisions with the ground

Tambo Sur UAV Mag and Helicopter data analysis

Line Data

Direct Line Data Comparison between Helimag Data (L3082 – Red),
UAV Mag Data (L12200 – Geen) and
Upward continued 50m UAV Mag Data (L12200 – Magenta)

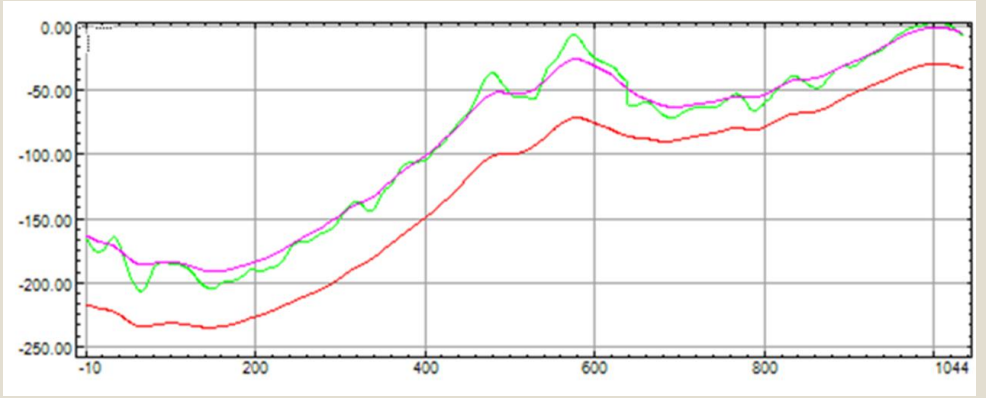


Tambo Sur UAV Mag and Helicopter data analysis

Line Data

- The Mag UAV on line data presents the same magnetic trend and response as the on line Helimag data
- The Mag UAV lines registered a more detailed magnetic response due to the flight height
- The details of anomalies ranging from 30m to 100m in amplitude observed in the UAV Mag survey cannot be observed in the Helimag data
- The 50m upward continued UAV Mag data have a good correlation with the Helimag data

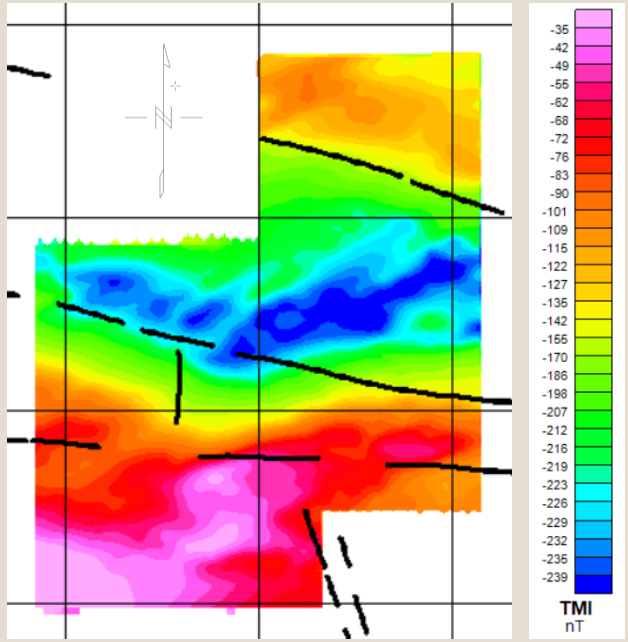
Direct Line Data Comparison between Helimag Data (L3082 – Red),
UAV Mag Data (L12200 – Geen) and
Upward continued 50m UAV Mag Data (L12200 – Magenta)

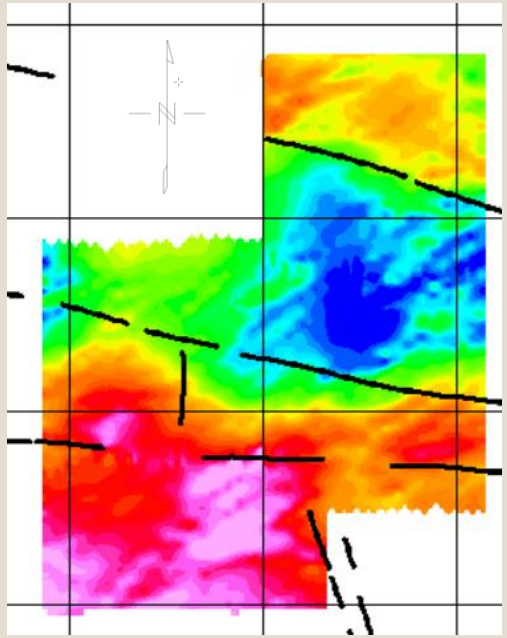


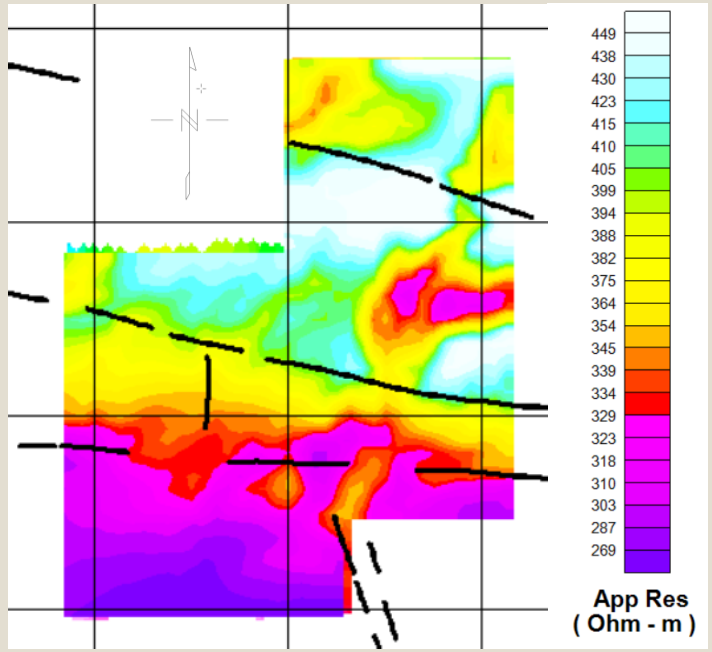
Tambo Sur UAV Mag and Helicopter data analysis

Grid Data

Helimag Grid at 250 m line spacing and 100 m AGL, UAV Mag Grid at 125m line spacing and 50 m AGL and App. Resistivity @ 500m from a ZTEM survey



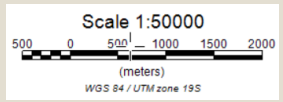




Helimag TMI

UAV Mag TMI

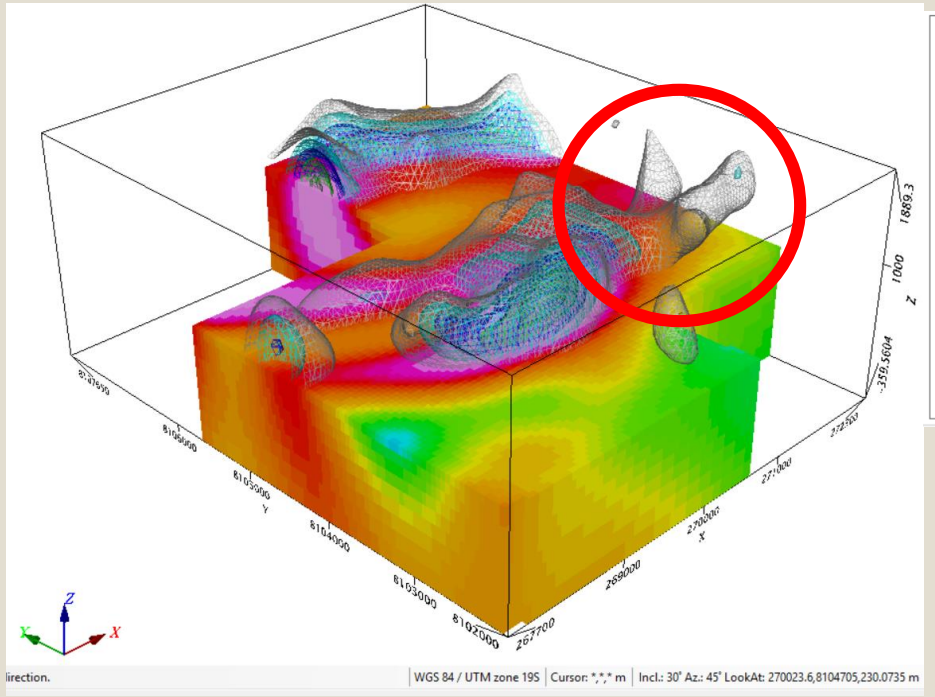
App. Resistivity @ 500m



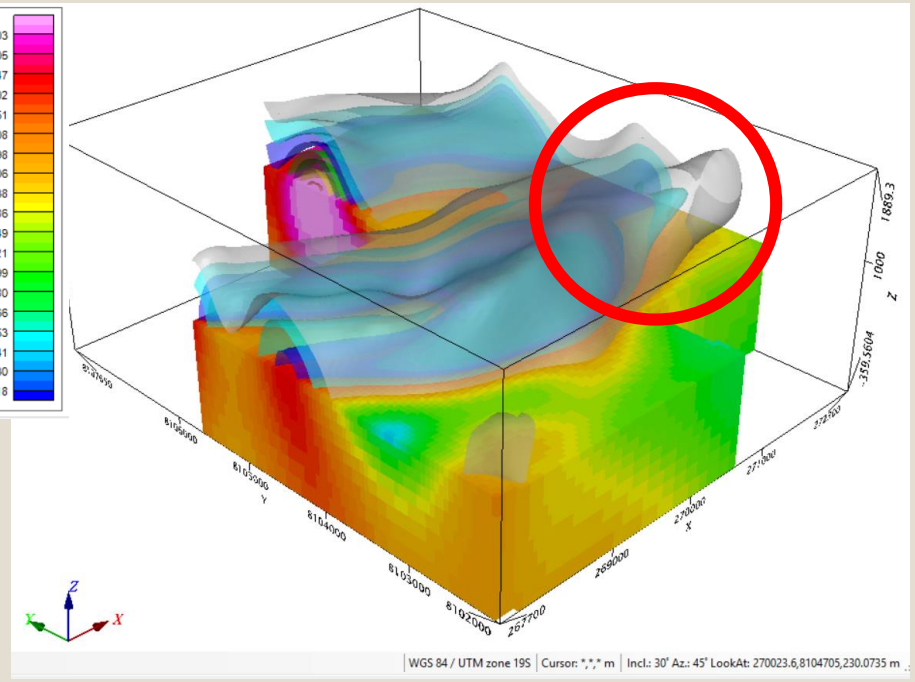
Tambo Sur UAV Mag and Helicopter data analysis

3D MVI Data

N045 View with inclination 30 of the Heli Mag Amplitude Magnetization Voxel and isosurfaces of the Heli Mag and UAV Mag MVI invertions



UAV Mag 3D MVI Data



Heli Mag 3D MVI Data

Tambo Sur UAV Mag and Helicopter data analysis

3D MVI Data

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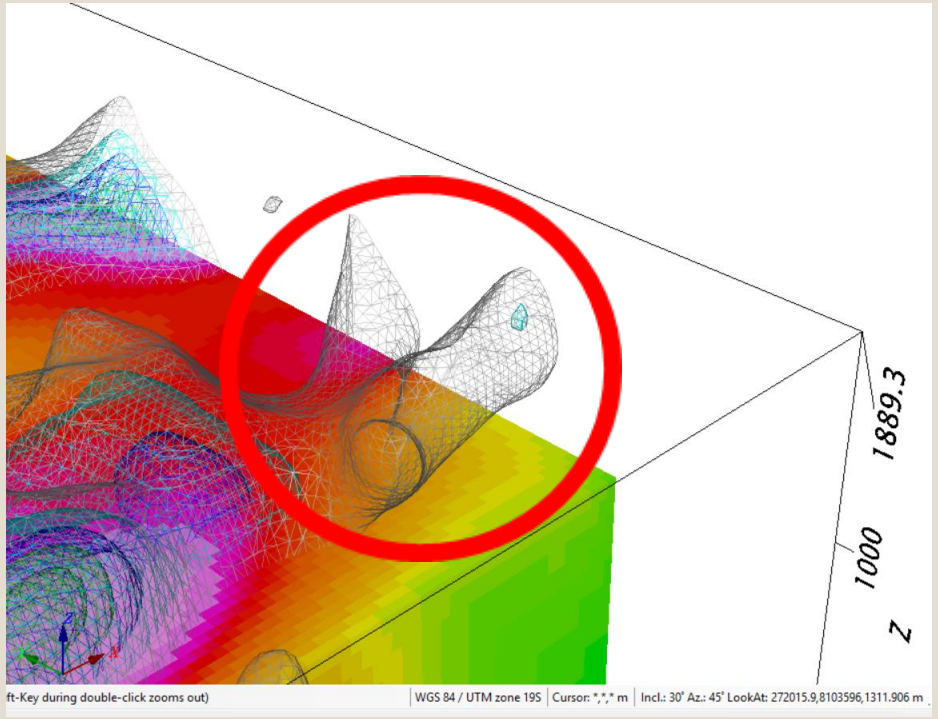
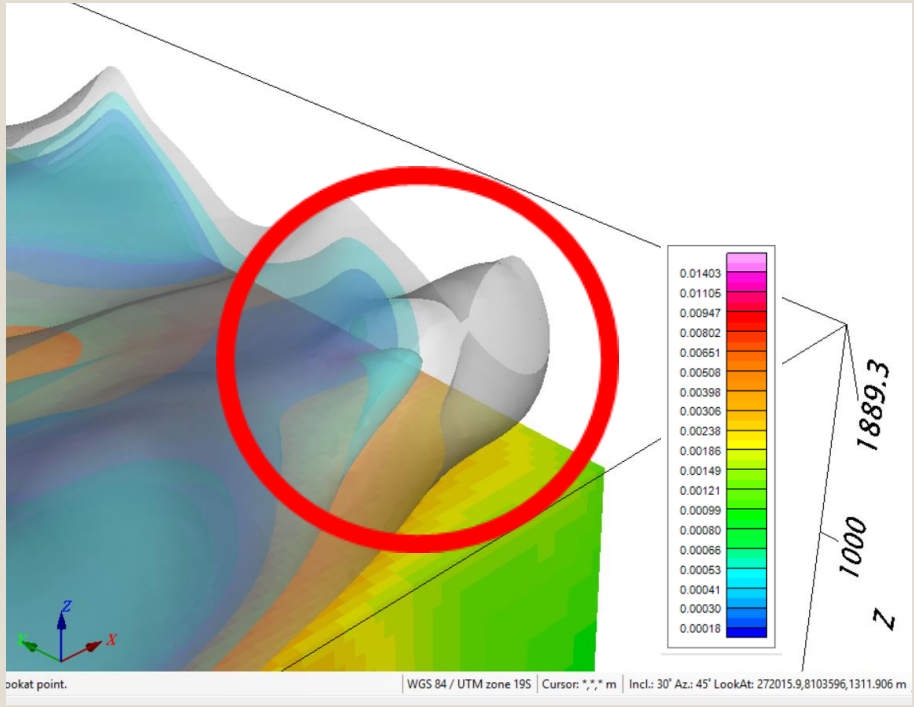


UAV Mag 3D MVI Data



Heli Mag 3D MVI Data

Conclusions

Conclusion

- Within the past decade, the development of UAV platforms and magnetic sensors has permitted to integrate UAV aeromagnetic platforms that can register magnetic data with similar characteristics to Airborne Mag Surveys
- For Mining Exploration a UAV Mag System should comply with similar technical specifications required in standard aeromagnetic platforms
- The UAV Mag Surveys have the advantage to have a lower total cost compared with Heli Mag Surveys and is competitive with Ground Mag Surveys.
- The UAV Mag Systems can fly close to the ground, specially in rough terrain, permitting a closer line spacing in order to obtain High Resolution Magnetic Surveys.

Conclusion

- The limitations of the UAV Mag Systems are the short time of the batteries, high survey altitude, the road access and the high wind gusts
- The line to line comparison shows that both data sets registered the same magnetic trend
- The UAV Mag data registered a higher resolution and more detailed magnetic response.
- The MVI inversion of the UAV Mag data shows higher resolution and more details
- The UAV Mag Test Survey flown in a Greenfield Exploration Environment demonstrated that the UAV Mag platform can be used to do High Resolution Magnetic Surveys

References

- Airborne Geophysics: Old Methods New Images, Reeves, C.V., Reford, S.W. and Milligan, P.R., 1997
- Geological Survey of Canada aeromagnetic surveys: design, quality assurance, and data dissemination, M. Coyle, R. Dumont, P. Keating, F. Kiss, and W. Miles, 2014
- https://www.gemsys.ca/uav-magnetometers/
- https://www.geometrics.com/magnetometers/
- https://scintrexltd.com/product-category/airborne/
- http://www.geofisicos.com/es/servicio/prospeccion-mineral/magnetometria-en-uav

Thanks ....

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