Automation of quality control procedures for high volume, high-quality airborne magnetic data at the State of Alaska

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DGGS Geophysics Program



Logan Fusso



Eric Petersen

- Produces geophysical datasets to:
  - Aid geologic mapping activities at DGGS
    - Mineral systems
    - Hydrology, permafrost, hazards
  - Provide the public with district & regional-scale data to help de-risk mineral exploration work



Photo: New Resolution Geophysics (NRG)

Contractors

AK State Constitution, Article 8, Section 2:

The legislature shall provide for the utilization, development, and conservation of all natural resources belonging to the State, including land and waters, for the maximum benefit of its people.

Geophysical surveying…

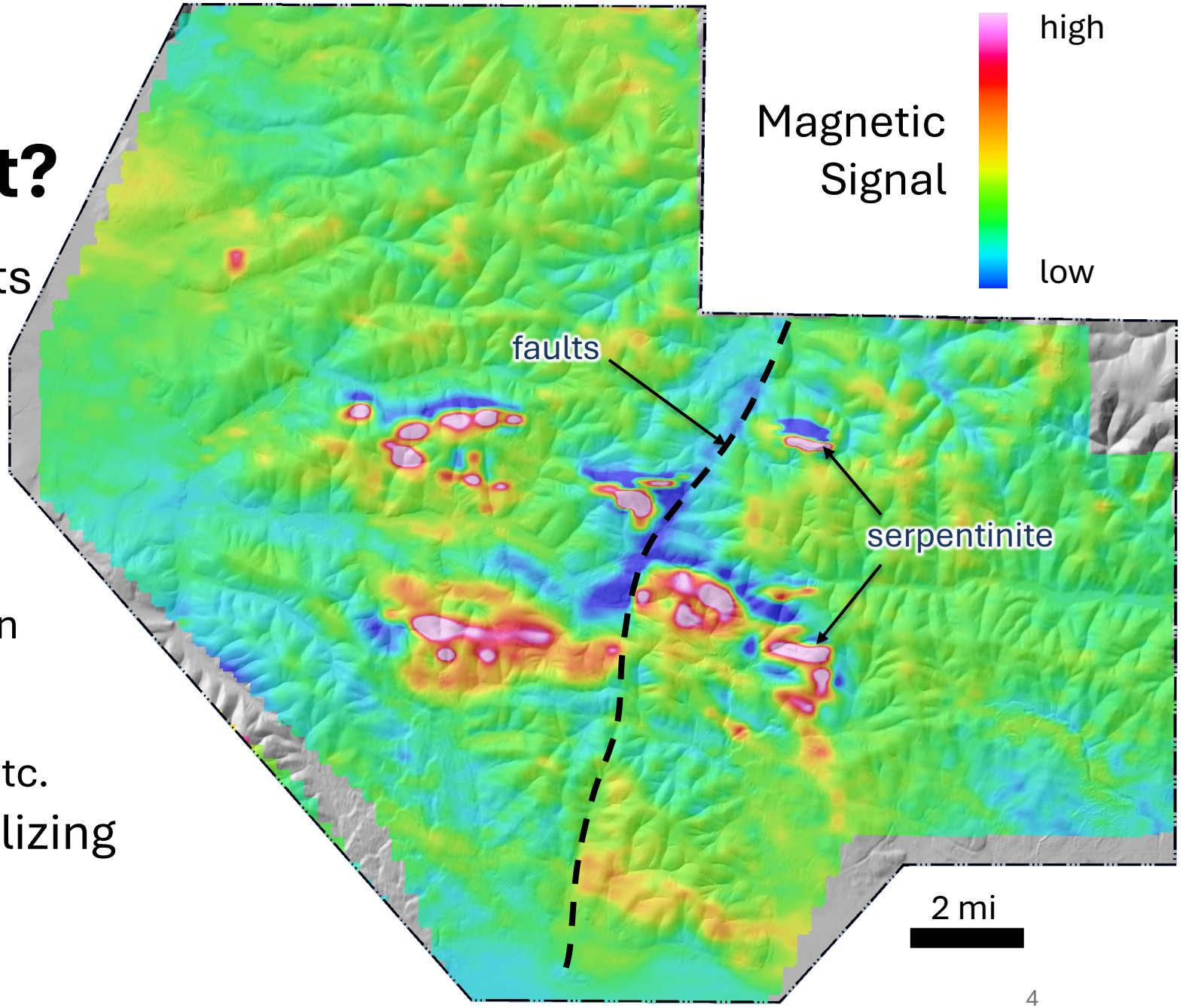
…tells us what's going on under cover





What does geophysics depict?

- Maps geology based on its physical properties
  - Magnetic properties
  - Conductivity
  - Radioactivity
  - Density
- See the subsurface
  - Sensing depth depends on many factors
- May directly detect ore
  - If magnetic, conductive, etc.
- Detect geology of mineralizing systems



East Richardson geophysical survey (Burns and others, 2006)

EarthMRI Program

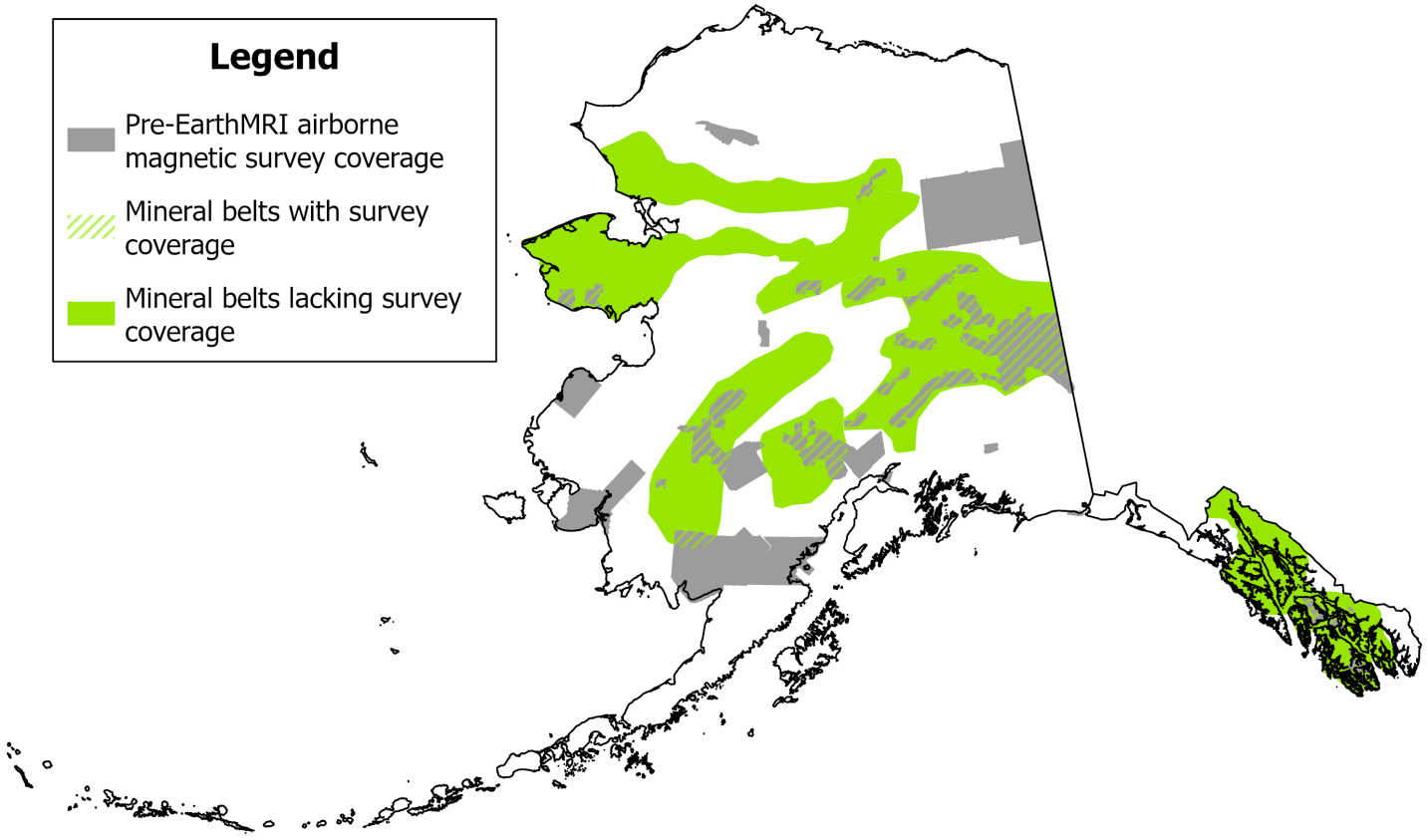
- Earth Mapping Resources Initiative (EarthMRI)
  - USGS partnership with state surveys
  - Critical minerals focus
  - Geologic mapping & geophysics
- EarthMRI geophysics goal:
  - Push towards comprehensive coverage of mineral belts in best possible airborne magnetic data
- Boosted funding through Bipartisan Infrastructure Law
- Surveys boosted with state match



Photo: New Resolution Geophysics (NRG)

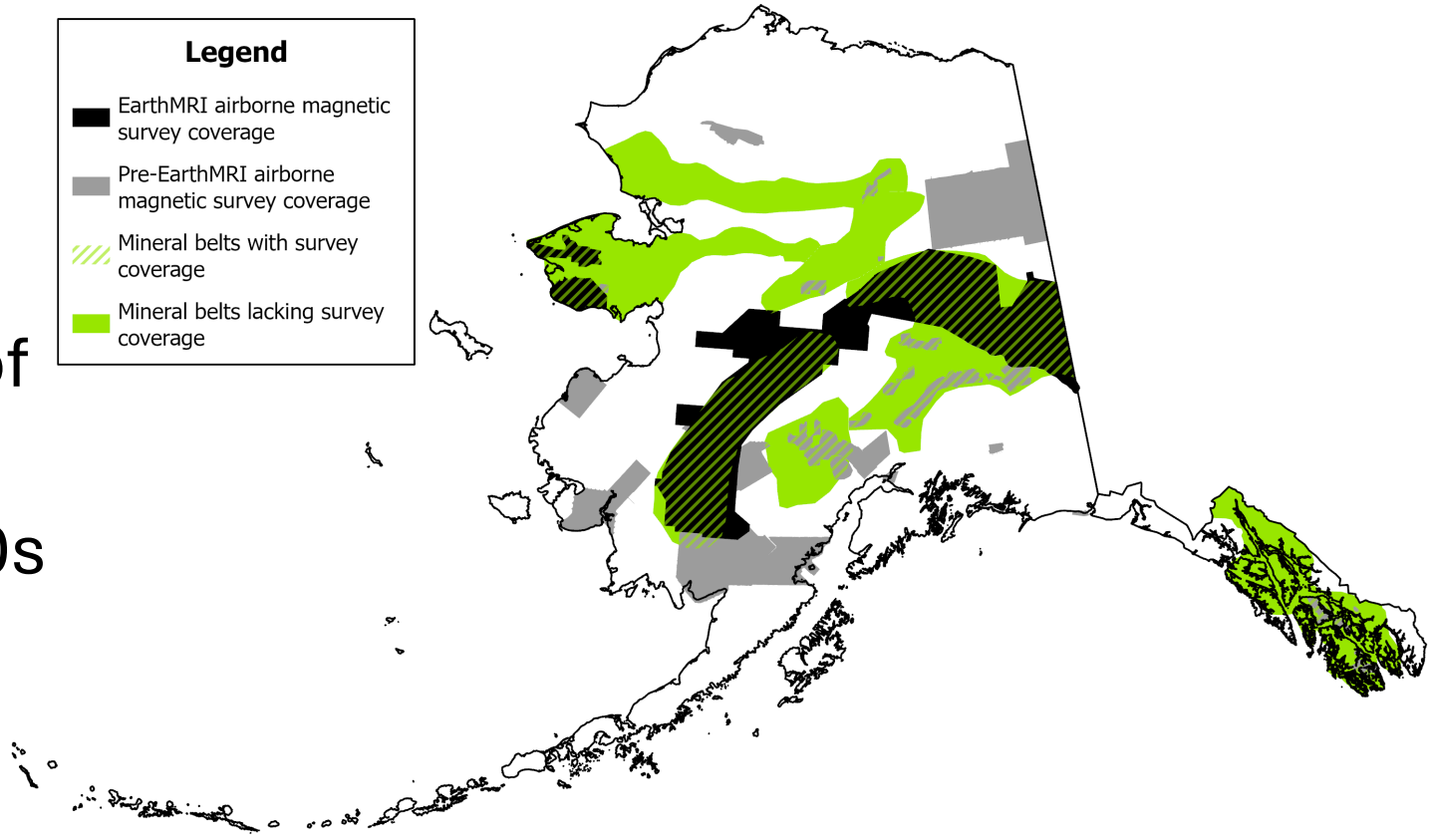
DGGS Geophysics Program before EarthMRI

- ~15,000 line km flown each year
- A few hours each week of QA/QC for active surveys
- Typically smaller, “postage stamp” survey sizes
- Some historical data acquired from other agencies



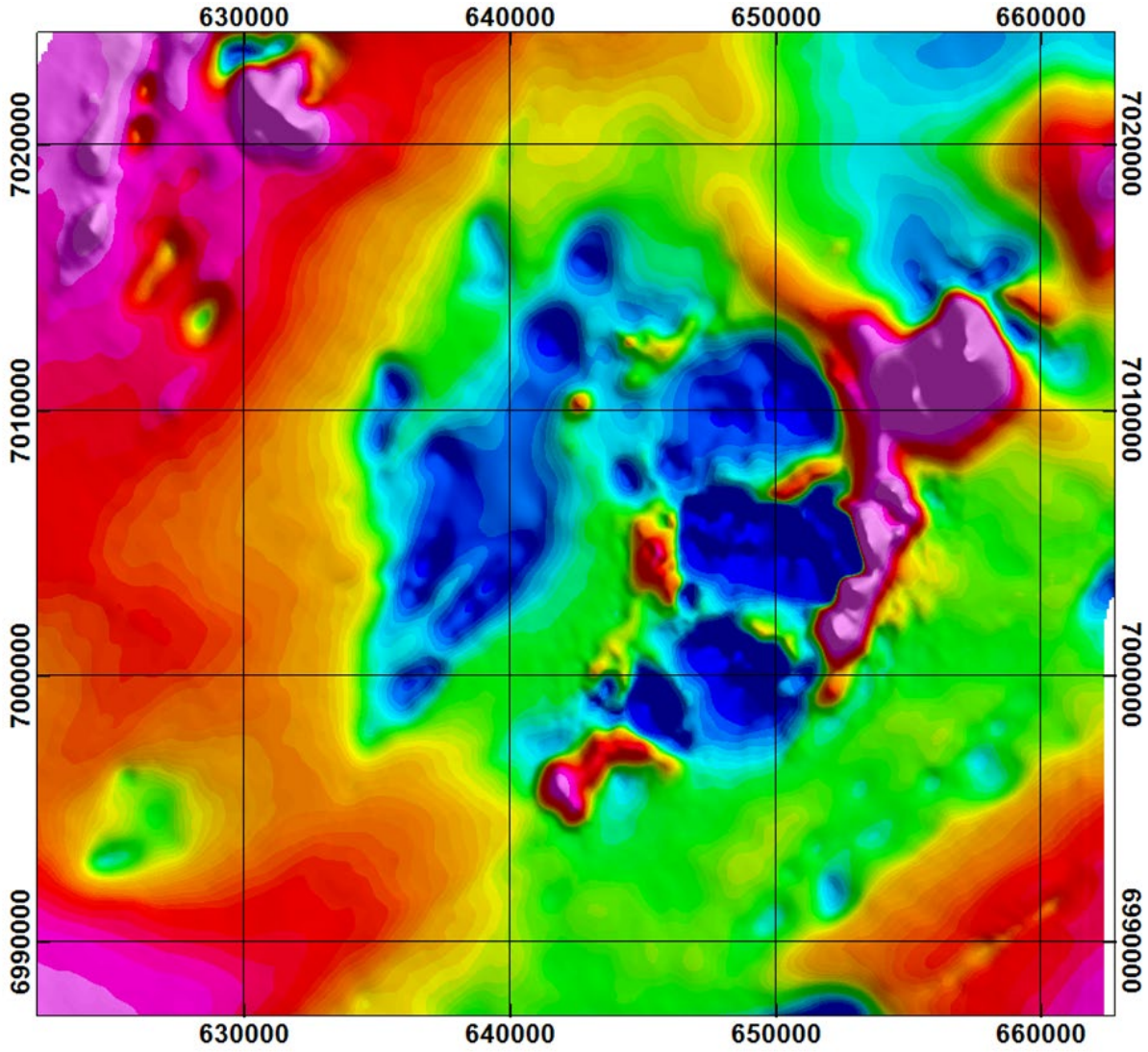
DGGS Geophysics Program through EarthMRI

- ~100,000 line-km flown each year, back-to-back
- >6x the previous rate!
- Each year double the rate of the busiest pre-EMRI year
- QA/QC often takes up to 10s of hours work per week of production



Flight height impacts magnetic data quality

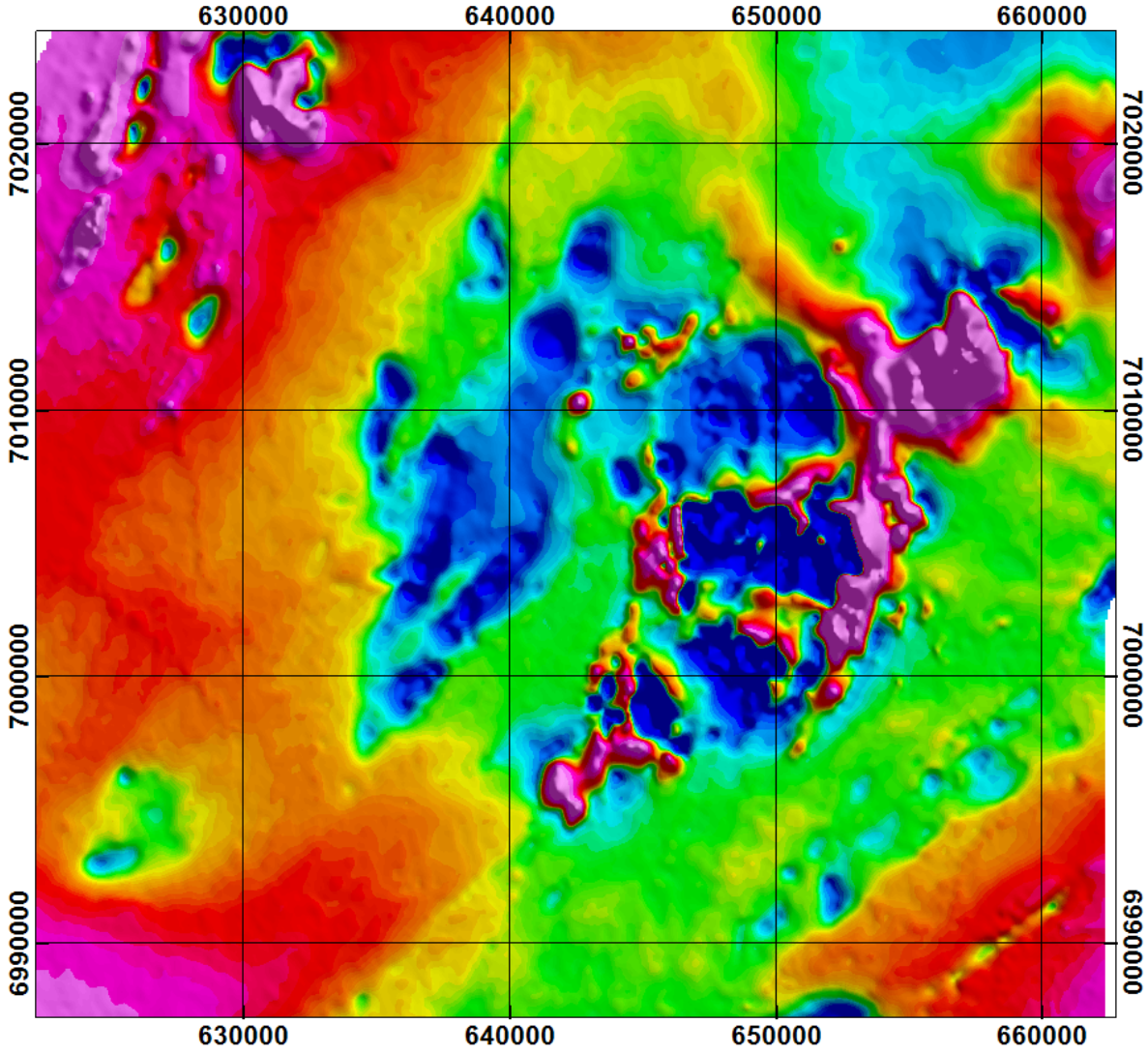
- Greater distance from the magnetic source = lose high frequency signal—important for detailed mapping!



400 m terrain clearance

Flight height impacts magnetic data quality

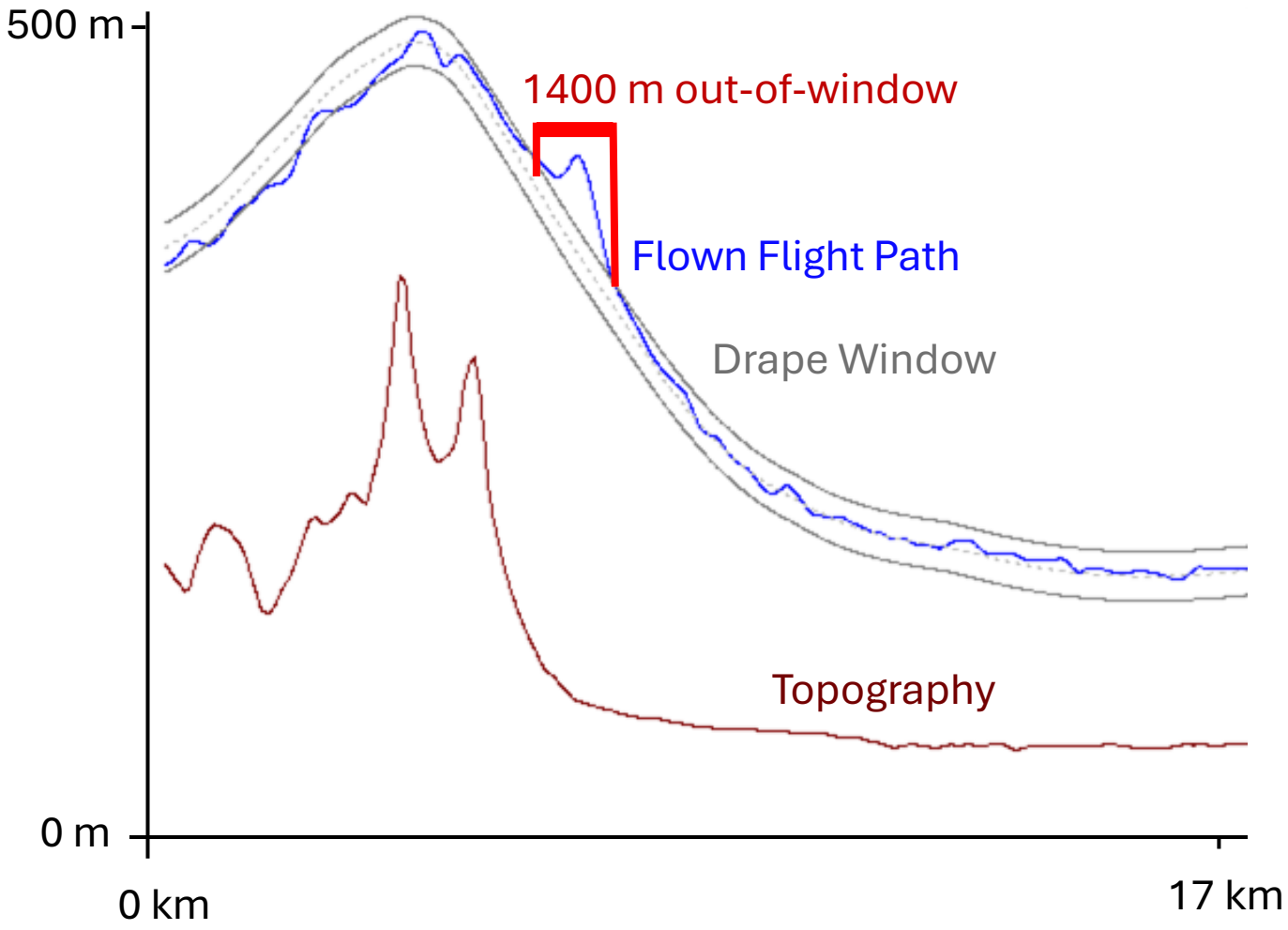
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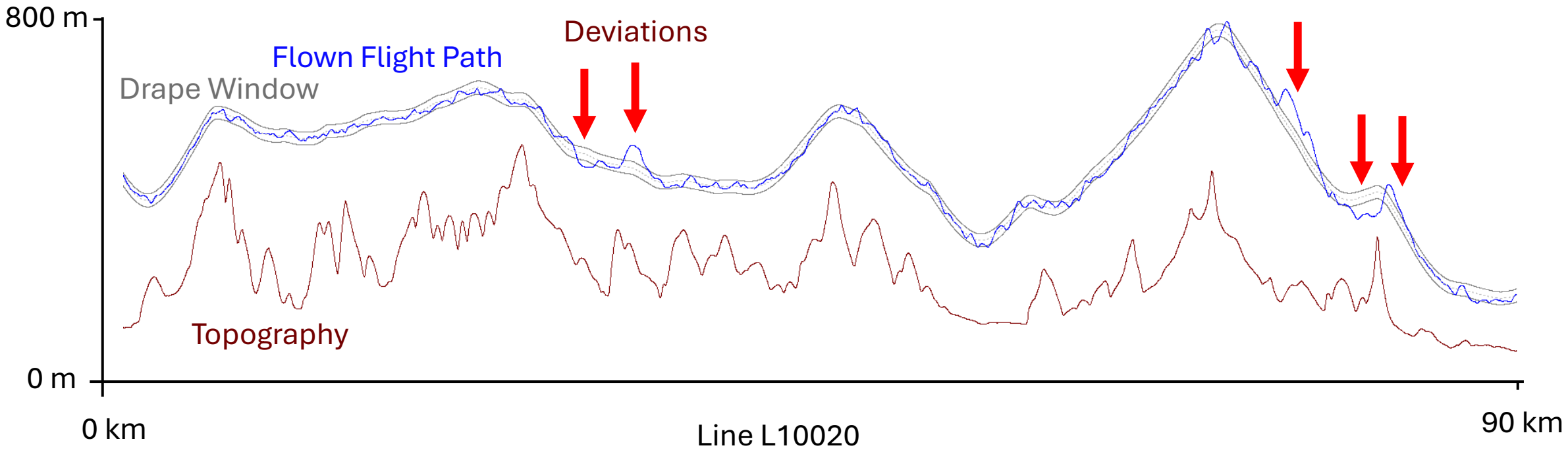
134 m terrain clearance

“Drape:” getting the aircraft as low as possible

- Drape = topography + ideal flight height tailored to aircraft performance
- Keep flights within ±15 m of drape
- No deviations >800 m long from that drape window
- These are used as contractual obligations



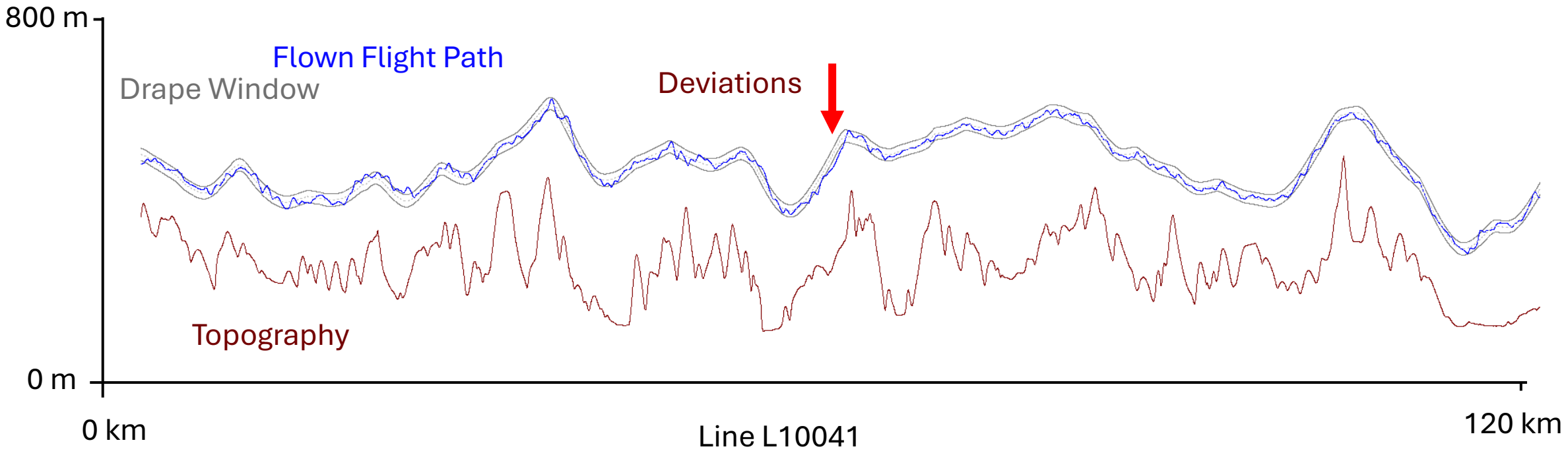
Standard QC procedure (adopted from NRCAN): manual inspection of drape deviations



Oasis montaj

Software for managing geophysical databases & reviewing data

Standard QC procedure (adopted from NRCAN): manual inspection of drape deviations



- After manual QA/QC review of all production flights, deviations from specification are prioritized for re-flight

The problems with manual QA/QC

- Very cumbersome and time-consuming
- Especially so with high data volumes associated with EarthMRI
  - 10s hrs QA/QC work each week of production!
- Easy to miss deviations (human error)
- Not strictly quantitative
- Not repeatable

DGGS QA/QC automation script

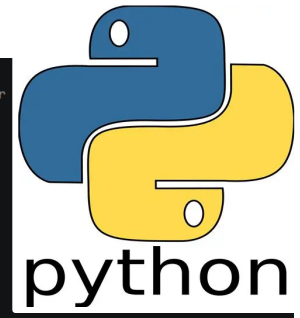
- Geosoft developer: write tools in python for Oasis montaj
- Reads in Oasis database
- Automatically identifies drape deviations
- Prepares reports for review and parameters for further analyses
- Ran as a menu item from Oasis

```python
# Calculate drape deviations and define out-of-spec (OOS) records
OOS_drape = ((drape_deviance > ztol) | (drape_deviance < -ztol)) #index for flight over or under
OOS_drape_mask = OOS_drape.astype('int8') # OOS drape mask to prep for saving in channel

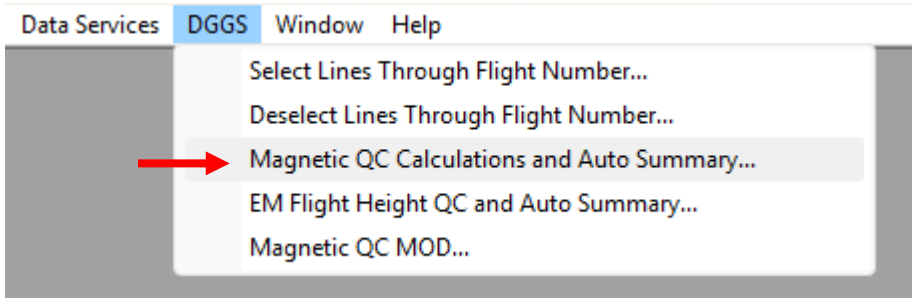
#gxapi.GXSYS.display_message("Debugging.... OOS_drape_mask", "{}".format(OOS_drape_mask))

# Find starts and ends to continuous segments of OOS_drape:
d = np.diff(OOS_drape.astype(int))
seg_starts = np.where(d==1)[0] + 1 # +1 because diff shifts by 1
seg_ends = np.where(d==-1)[0] + 1
# Edge case: starts at beginning
if OOS_drape[0]:
    seg_starts = np.r_[0, seg_starts]
# Edge case: ends at end
if OOS_drape[-1]:
    seg_ends = np.r_[seg_ends, len(OOS_drape)-1]

# Go through each segment:
num_segs = 0 # counter for number of segments recorded out of spec
for seg_start, seg_end in zip(seg_starts, seg_ends):
    seg_distance = np.nansum(step_dist[seg_start:seg_end]) # calculate total distance along segment
    if seg_distance < dtol: # disregard if segment is shorter than dtol (default 800 m)
        OOS_drape_mask[seg_start:seg_end] = 0 # OOS drape mask to prep for saving in channel; remove the segment if < 800 m
        continue
    else:
        num_segs += 1 # Keep count number of OOS segments
        # Extreme value (max for positive, min for negative)
        if np.sign(drape_deviance[seg_start]) == 1:
            extrema = np.nanmax(drape_deviance[seg_start:seg_end])
        elif np.sign(drape_deviance[seg_start]) == -1:
            extrema = np.nanmin(drape_deviance[seg_start:seg_end])
            OOS_drape_mask[seg_start:seg_end] = -1
        # Record results
```

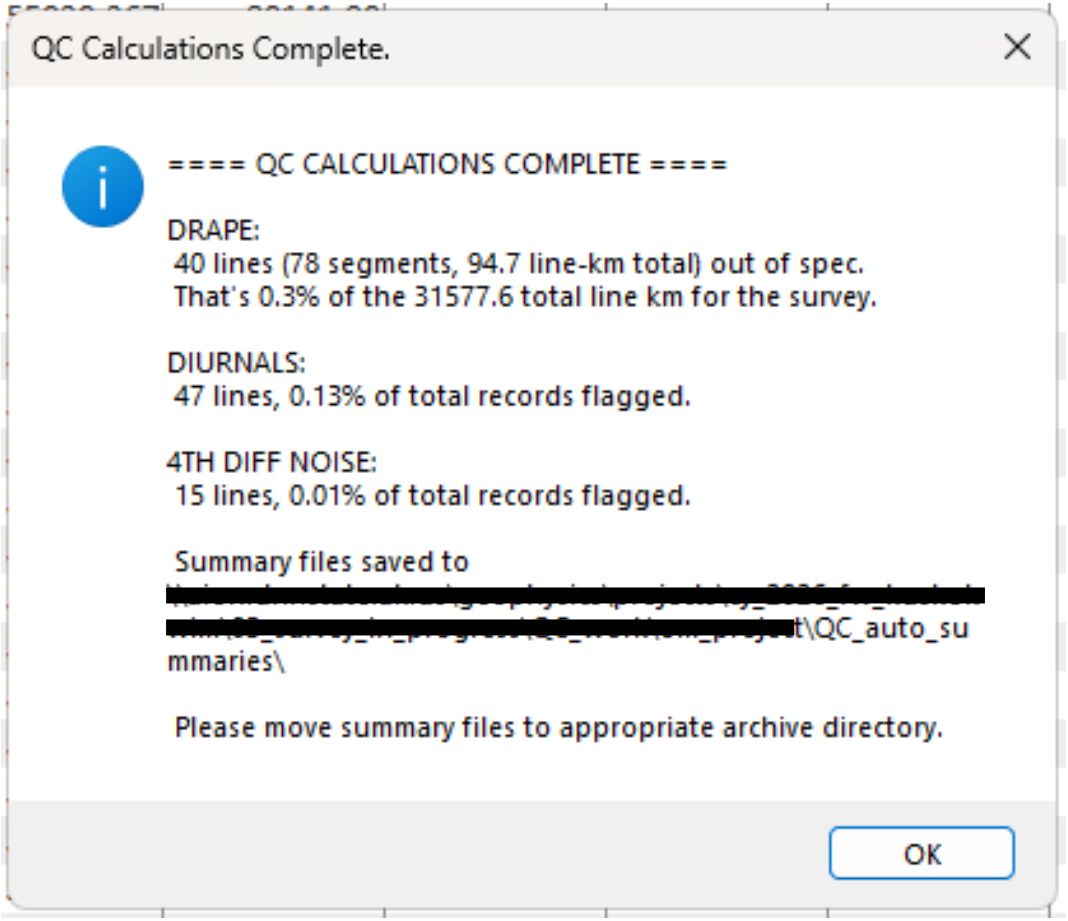


Oasis montaj



Link to GitHub

Quantifiable, repeatable results



- Upon running the tool, a high-level summary of auto-QA/QC results are first presented

- Detailed information is saved to csv files for further review

Summary for each “out-of-spec” (OOS) line

- Data can be sorted by total length or percentage of line out-of-specification
- Can differentiate between “over” and “under” drape to help with prioritization

Flight	Line	Line_length	OOS_length_overdrape	OOS_length_underdrape	OOS_total_length	OOS_length_overdrape_percent	OOS_length_underdrape_percent	OOS_total_percent
202	L10020	151864	5789	9584	15373	4	6	10
202	L10010	150425	974	8697	9671	1	6	6
202	L10041	144575	3843	3971	7813	3	3	5
203	L10080	149880	1817	3250	5067	1	2	3
202	T61130	44210	3915	1072	4987	9	2	11
205	L10160	149566	0	4064	4064	0	3	3
203	L10070	149585	842	3203	4045	1	2	3
202	L10030	150376	3448	0	3448	2	0	2
222	L10400	151830	0	3343	3343	0	2	2
204	L10140	150001	0	3231	3231	0	2	2
204	L10090	150047	2828	0	2828	2	0	2
223	L10350	149539	1854	937	2791	1	1	2
202	L10040	8525	2330	0	2330	27	0	27
205	L10170	149705	0	2050	2050	0	1	1
204	L10110	150567	1143	851	1995	1	1	1
203	L10061	77920	1957	0	1957	3	0	3
203	L10060	77202	0	1895	1895	0	2	2
204	L10100	121450	1731	0	1731	1	0	1
216	L10260	149563	1677	0	1677	1	0	1
212	L20930	34817	1429	0	1429	4	0	4
205	T61160	40977	0	1236	1236	0	3	3
223	T61220	40492	0	1205	1205	0	3	3

Detailed information on “out-of-spec” segments

- More detailed output gives info on how extreme the drape deviations are
- Aids in prioritizing further manual review and re-flight planning

Detailed info for L10020, one row for each time period the plane is outside the drape window:

Flight	Line	Fid_start	Fid_end	Length_OOS	Max_drape_dev	Avg_drape_dev	Avg_speed
202	L10020	82798	82812	960	-28	-20	72
202	L10020	82882	82906	1629	-31	-26	66
202	L10020	82946	82968	1227	-36	-28	57
202	L10020	83062	83084	1371	-39	-29	62
202	L10020	83121	83135	896	-35	-28	64
202	L10020	83699	83716	1224	-30	-26	72
202	L10020	83744	83768	1707	54	39	70
202	L10020	84379	84419	2711	79	54	68
202	L10020	84447	84480	2278	-55	-42	68
202	L10020	84483	84502	1371	45	32	70

NOTE: we missed a few segments in our test “manual review” earlier!

QA/QC report is sent to contractor weekly through survey season with action items

Flight	Line	Line_length	OOS_length_overdrap	OOS_length_underdrape	OOS_total_length	OOS_length_overdrape_percent	OOS_length_underdrape_percent	OOS_total_percent	Action:
202	L10020	151864	5789	9584	15373	4	6	10	Reflight for westernmost portion
202	T61130	44210	3915	1072	4987	9	2	11	Reflight
215	L10220	150355	0	1047	1047	0	1	1	No reflight requested

QA/QC as contractor evaluation tool

- Ensures we receive quality data as well as a good price
- Incentivizes contractor performance going forward
- Is made possible with our new quantitative QA/QC tool

Language in Task Order Solicitations:

B. Past Performance Metrics (25 points**)**
Delivered data was to specification in regard to drape, noise, and diurnals

a. Project data were to perfect or near-perfect specification (≤0.5% out-of-spec in all categories) (25 pts).

b. Project data were maximum 0.5-1% out-of-spec (20 pts).

c. Never had an awarded task order under Master Agreement (20 pts).

d. Project data were maximum 1-2% out-of-spec (15 pts).

e. Project data were maximum 2-4% out-of-spec (10 pts).

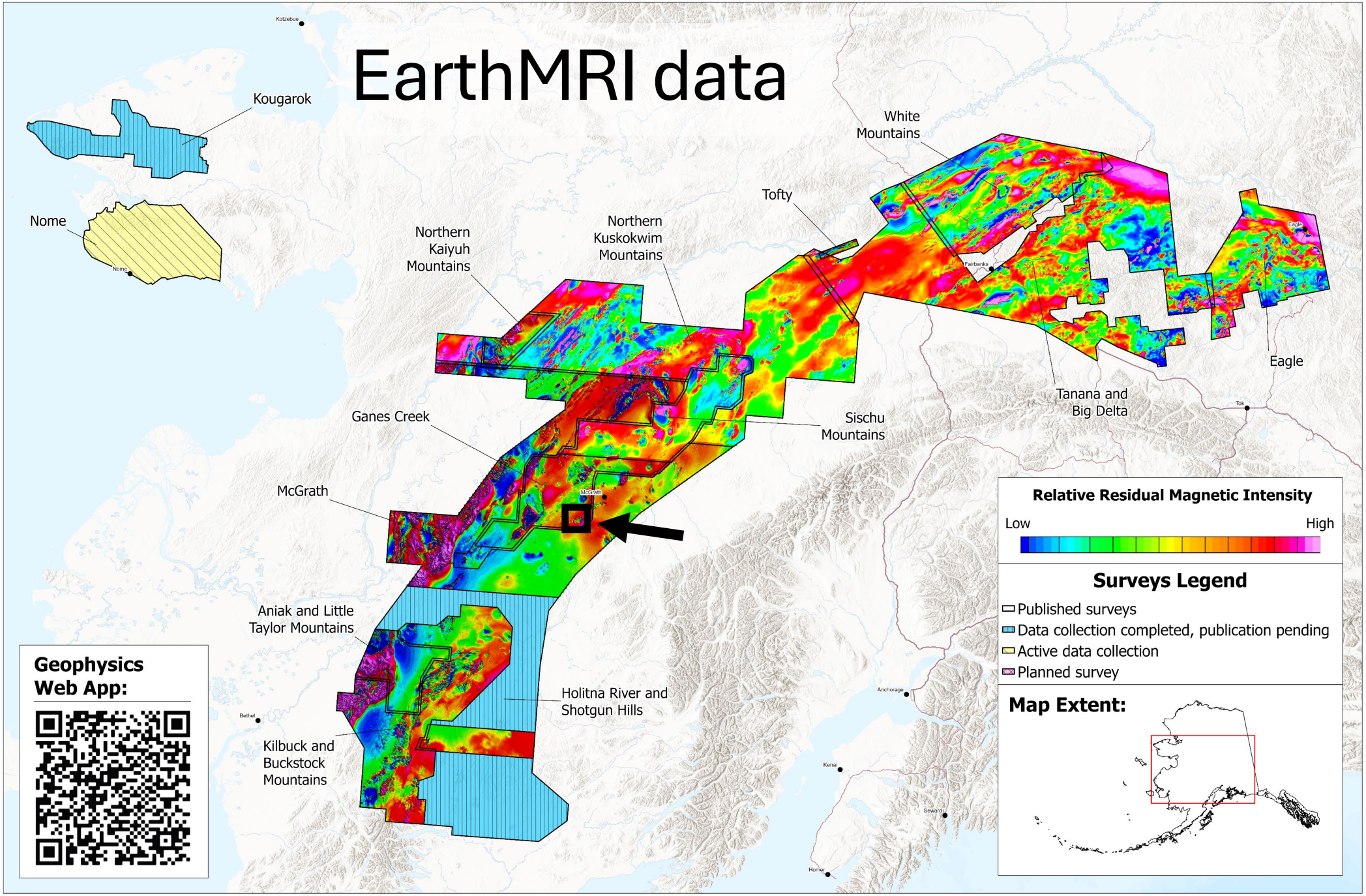
f. Project data were maximum 4-8% out-of-spec (5 pts).

g. Project data were >8% out-of-spec (0 pts).

Broader impacts…

- Easier to ensure quality data
- Measurable reduction in effort (up to 10+ hours per week during survey season)
- Ability to do more with our time

EarthMRI data



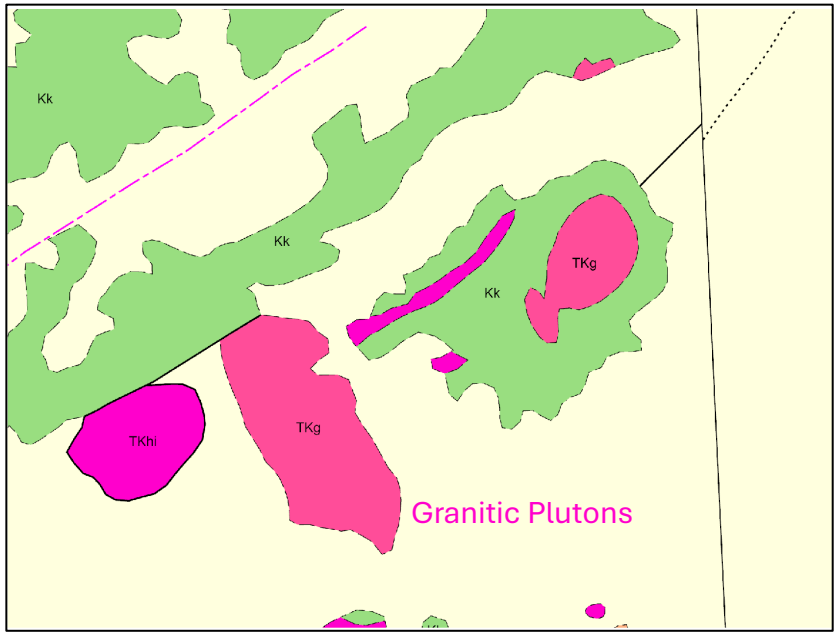
Data improvement at deposit scale

Magnetic Signal

high

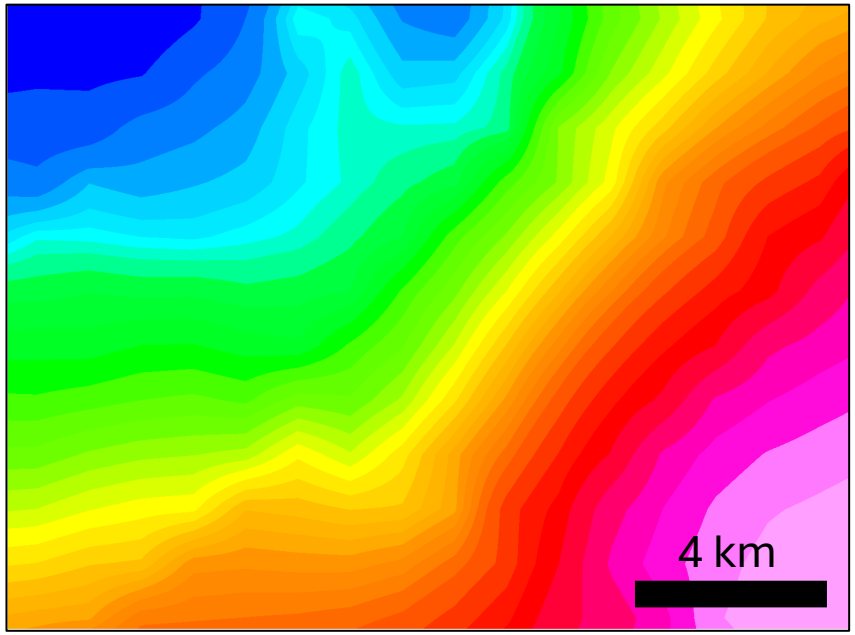
low

Geologic Map:



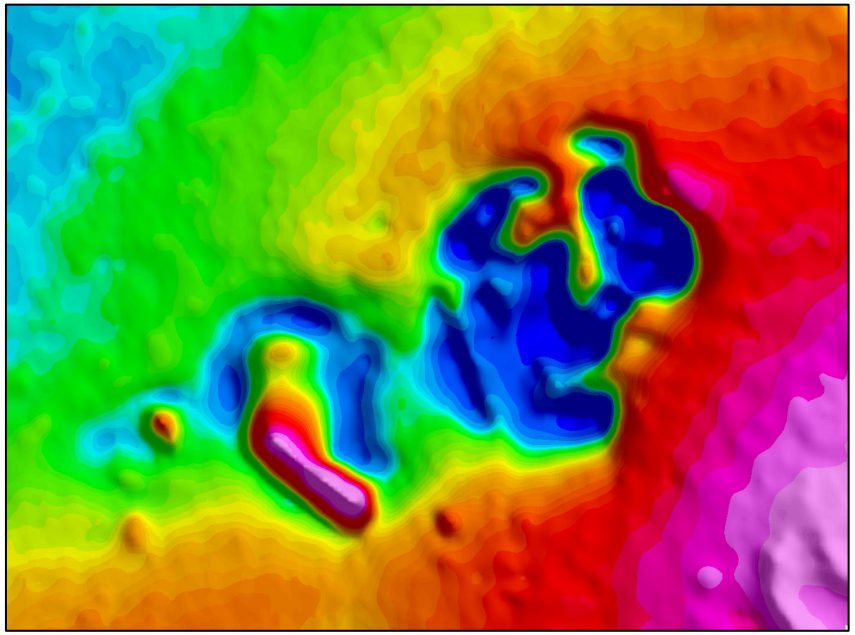
Wilson and others (2016)

Aeromag, Pre-EarthMRI:



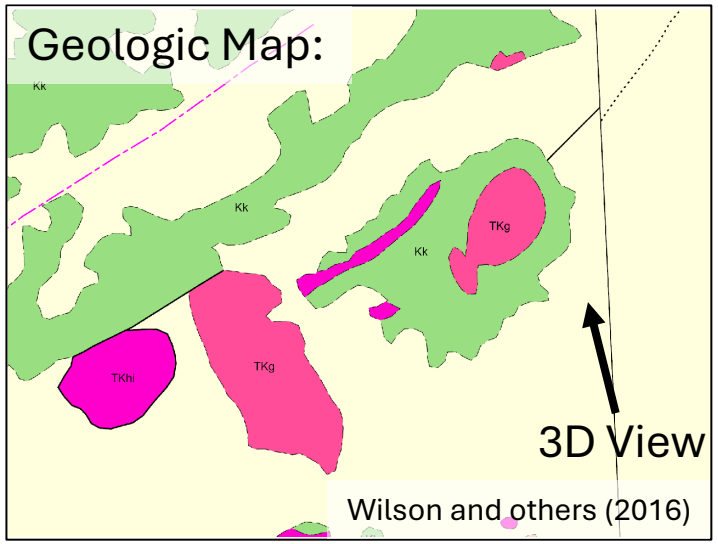
Connard and others (1999)

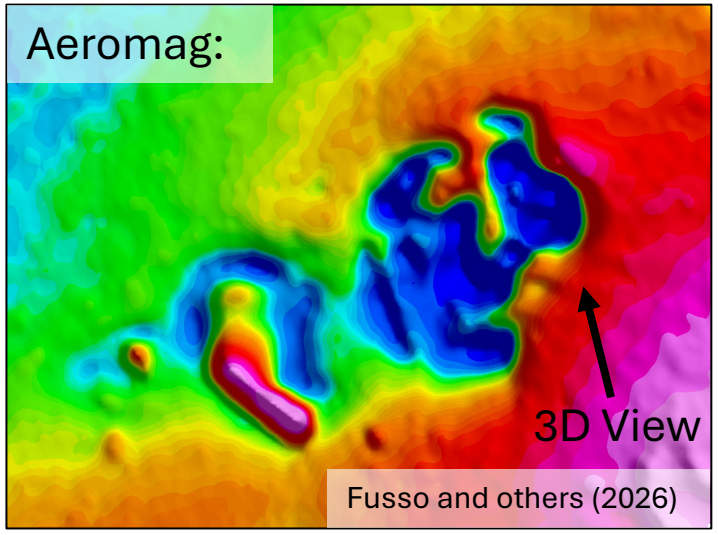
Aeromag, EarthMRI (2026):



Fusso and others (2026)

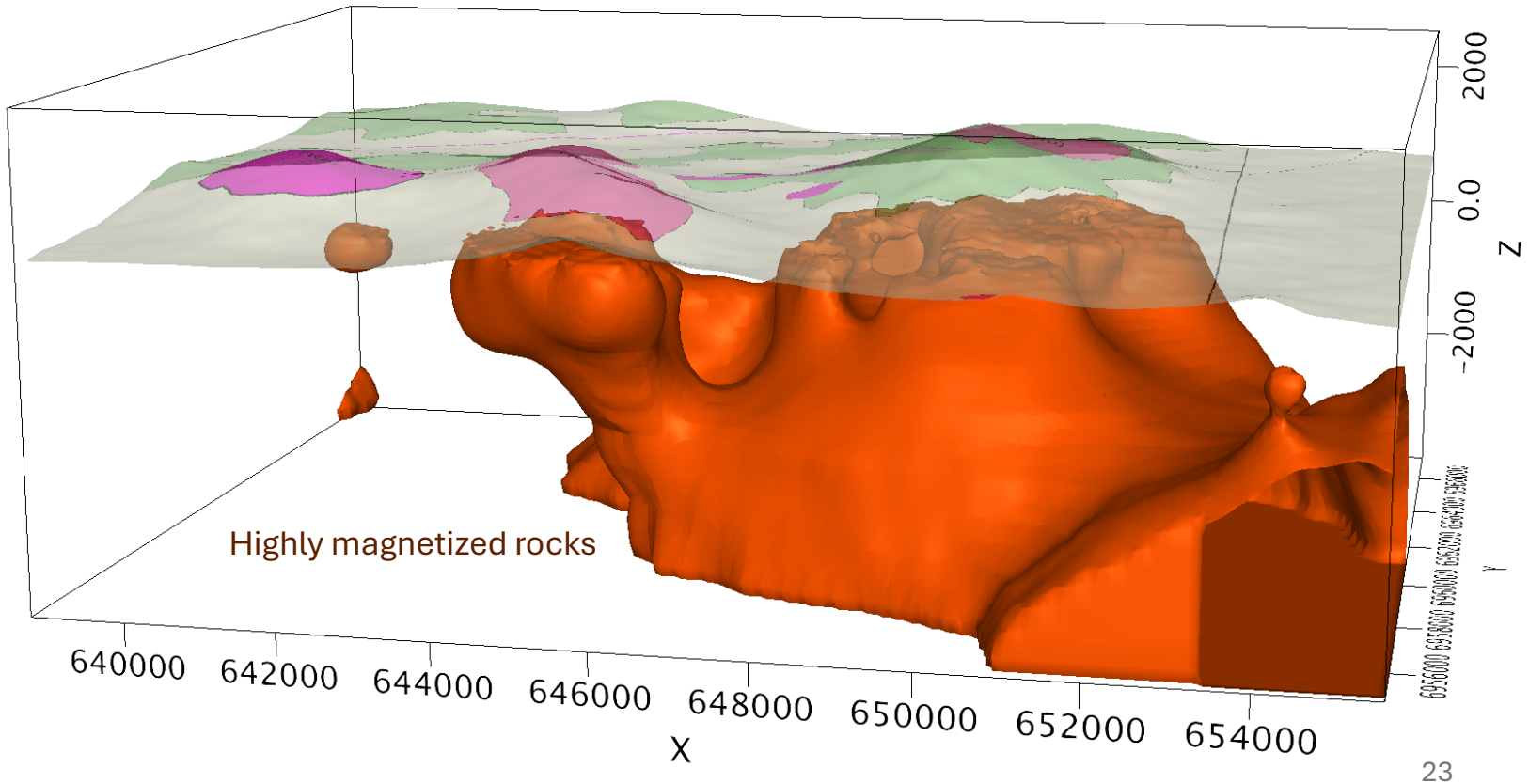
Data interpretation & models: using our re-gained time





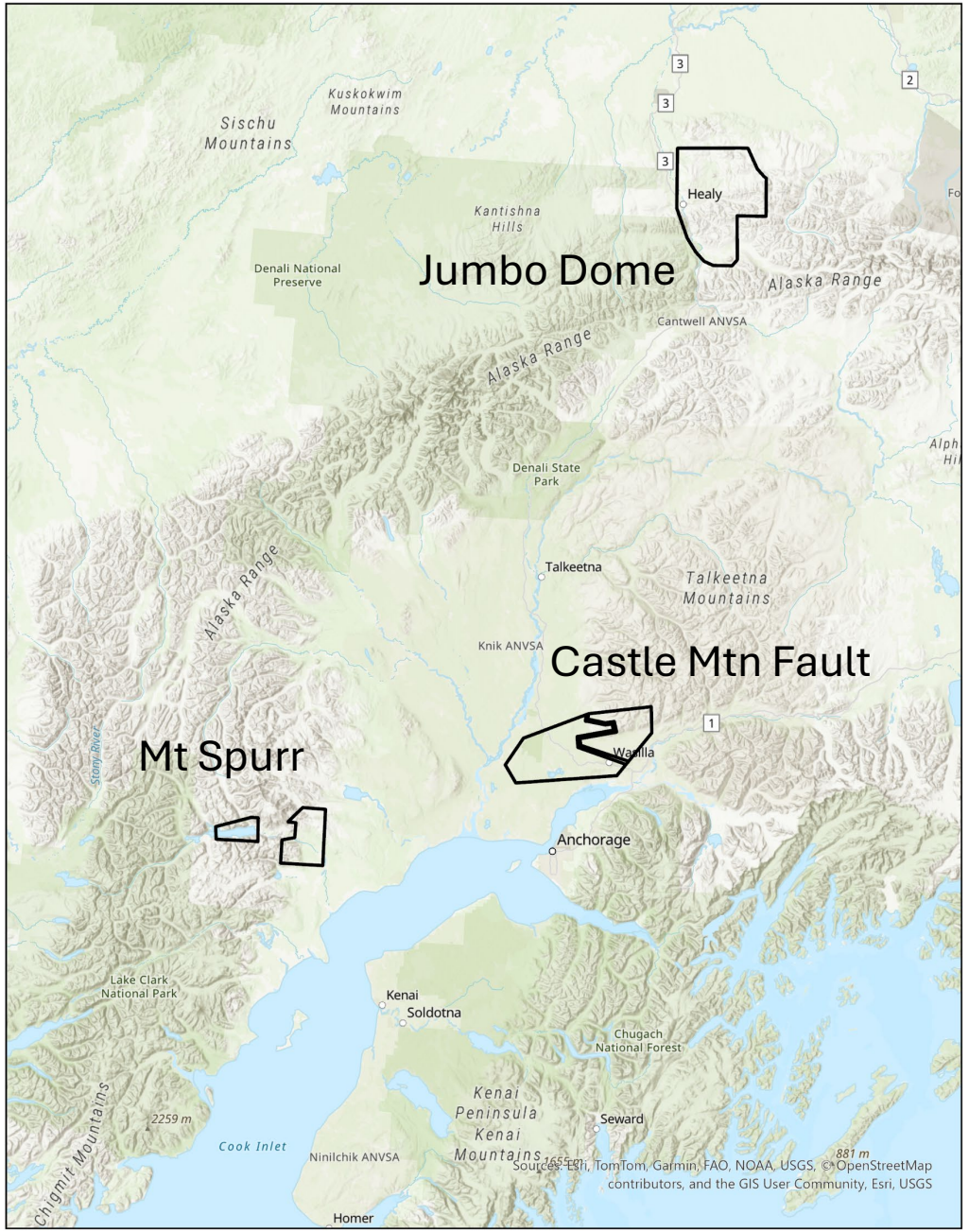
Magnetic Vector Inversion, preliminary results from DGGS:

- We can image igneous intrusions at depth
- Aid geologic mappers in developing their interpretations



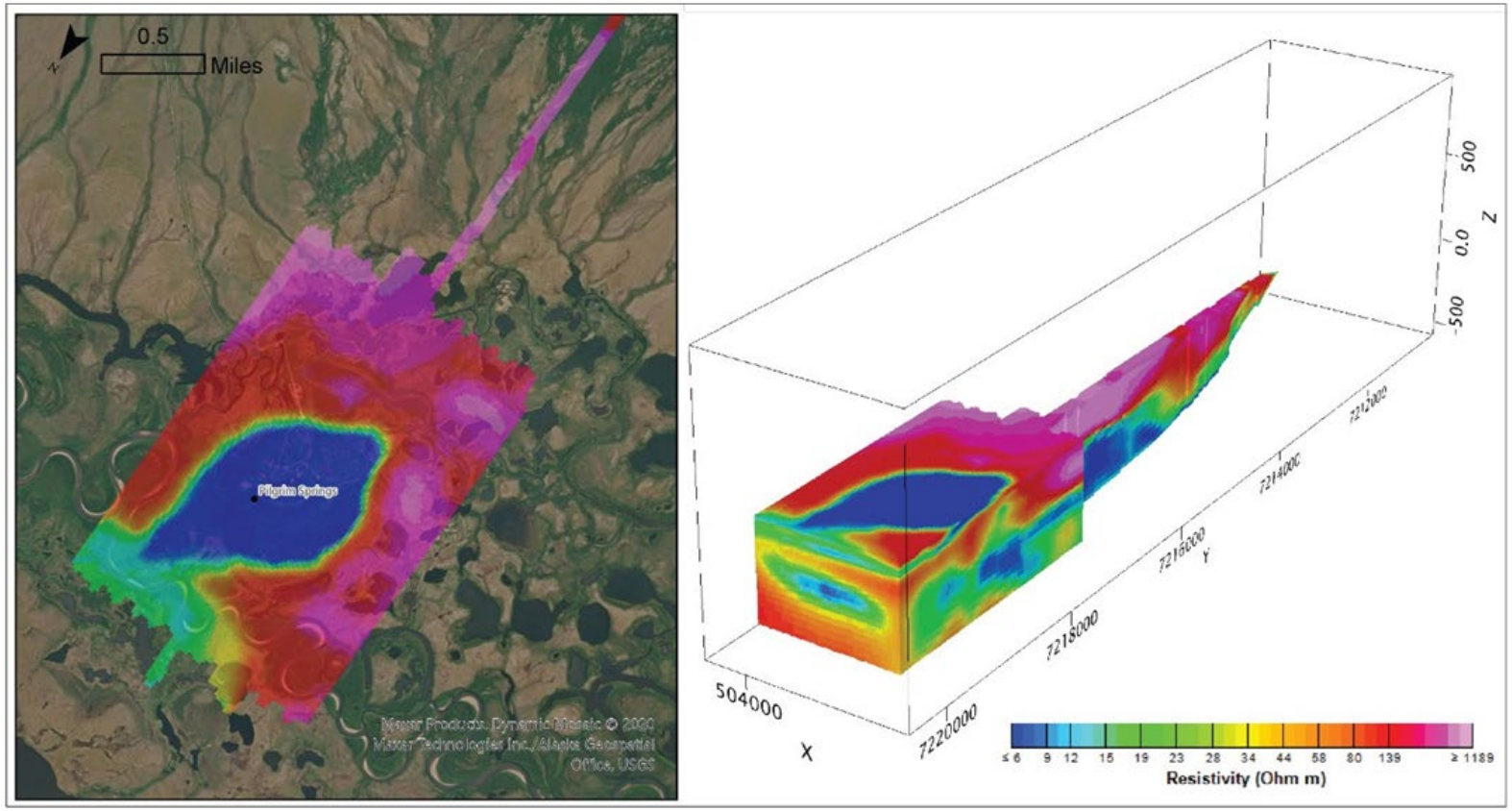
Geothermal geophysics at DGGS

- Exploration of sites for potential enhanced geothermal systems
- Aeromagnetic surveys to aid in mapping
- Recent DOE funding supporting DGGS through partnerships with:
  - Alaska Renewables
  - University of Alaska Anchorage



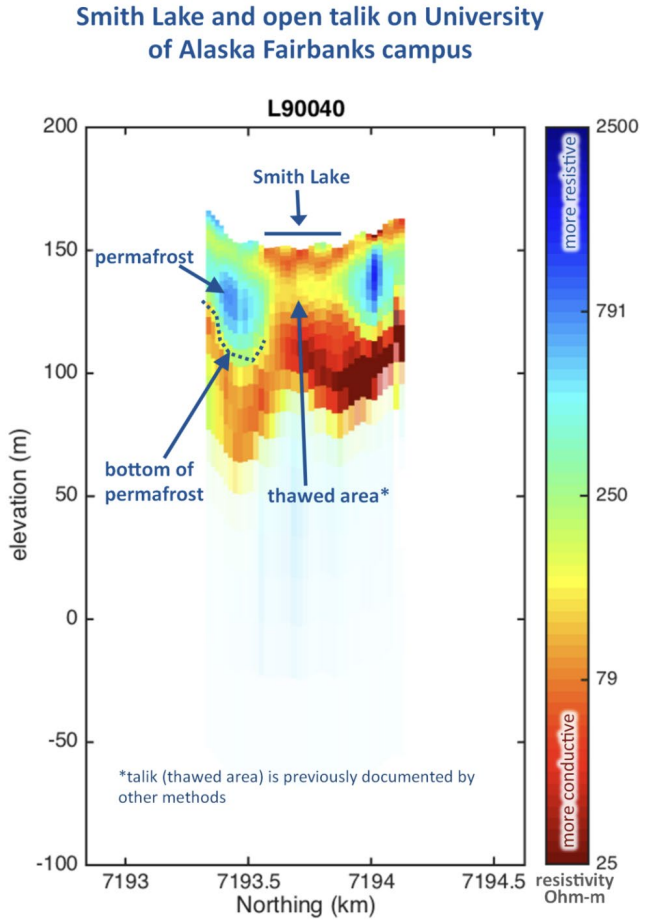
Airborne electromagnetic

Geothermal fluid pathways at Pilgrim Hot Springs:



Petersen and others (2025)

Permafrost assessment, Goldstream Valley:



Emond and others (2016)

Conclusions

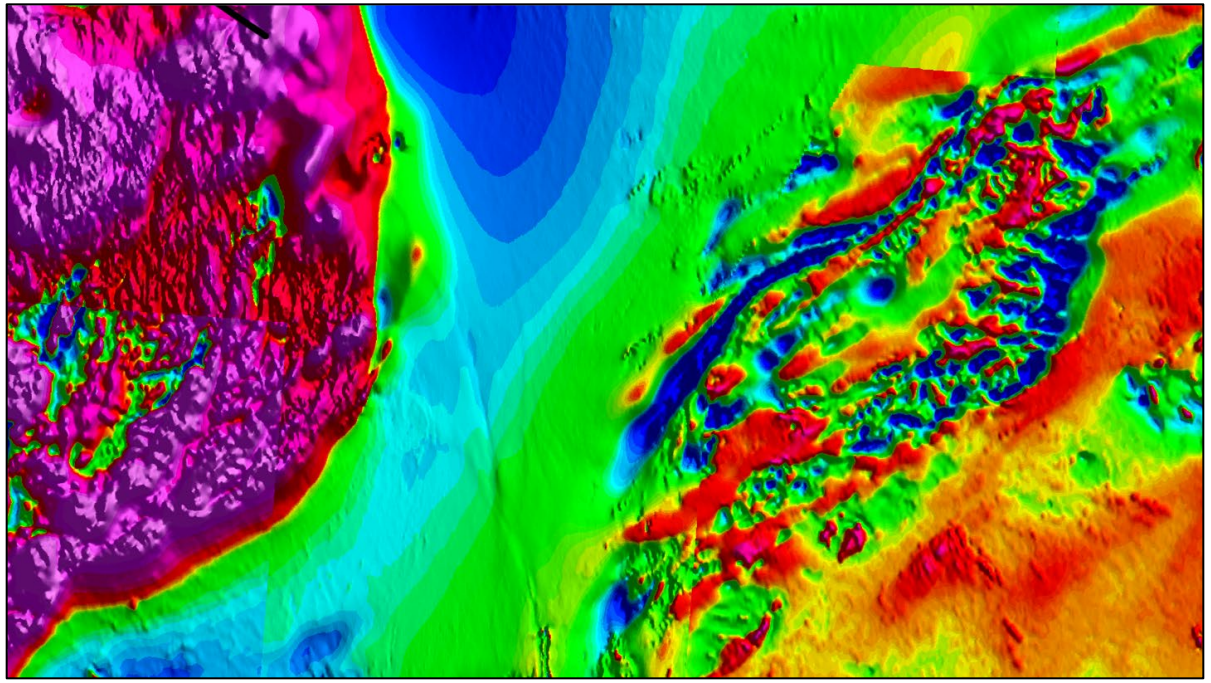
- Through the EarthMRI program, we are producing the highest quality regional-scale magnetic data for the public

- We used automation to speed up and improve our airborne QA/QC processes

- Our program is beginning to produce modeled and interpretive products (catch Logan Fusso's lightning talk!)



DGGS geophysics web portal



References

Burns, L.E., Graham, G.R.C., Barefoot, J.D., Fugro Airborne Surveys Corp., and Stevens Exploration Management Corp., 2019, East Richardson electromagnetic and magnetic airborne geophysical survey data compilation: Alaska Division of Geological & Geophysical Surveys Geophysical Report 2018-1, 12 p. https://doi.org/10.14509/29754.

Connard, G.G., Saltus, R.W., Hill, P.L., Carlson, L., and Milicevic, B., 1999, Alaska digital aeromagnetic database description: U.S. Geological Survey Open-File Report 99-503.

Emond, A.M., Daanen, R.P., Graham, G.R.C., Walter Anthony, Katey, Liljedahl, A.K., Minsley, B.J., Barnes, D.L., Romanovsky, V.E., and CGG Canada Services Ltd., 2018, Airborne electromagnetic and magnetic survey, Goldstream Creek watershed, interior Alaska: Alaska Division of Geological & Geophysical Surveys Geophysical Report 2016-5, 14 p. https://doi.org/10.14509/29681.

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Petersen, E.I., Fusso, L.A., Emond, A.M., SkyTEM Canada Incorporated, Aqua Geo Frameworks LLC, and Eichelberger, J.C., 2025, Pilgrim Hot Springs airborne electromagnetic survey, Seward Peninsula, Alaska: Alaska Division of Geological & Geophysical Surveys Geophysical Report 2025-1, 7 p. https://doi.org/10.14509/31452.

Wilson, F.H., Hults, C.P., Mull, C.G., and Karl, S.M., 2015, Geologic map of Alaska: U.S. Geological Survey Scientific Investigations Map 3340, 196 p., 2 sheets, scale 1:1,584,000, https://alaska.usgs.gov/science/geology/state_map/interactive_map/AKgeologic_map.html.