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Drone-based geophysical surveys - Magnetic XYZ data and 3D inversion

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Measuring devices

- Puffin VTOL drone of Radai Oy.
- Wingspan 2.16 m
- Endurance < 1.5 hours
- Pixhawk 4 autopilot (ArduPilot)
- Fluxgate magnetometer is in tail about 1.4 m away from the flight engine
- The black cylinders are GNSS antennas and the white rod is GSM antenna.

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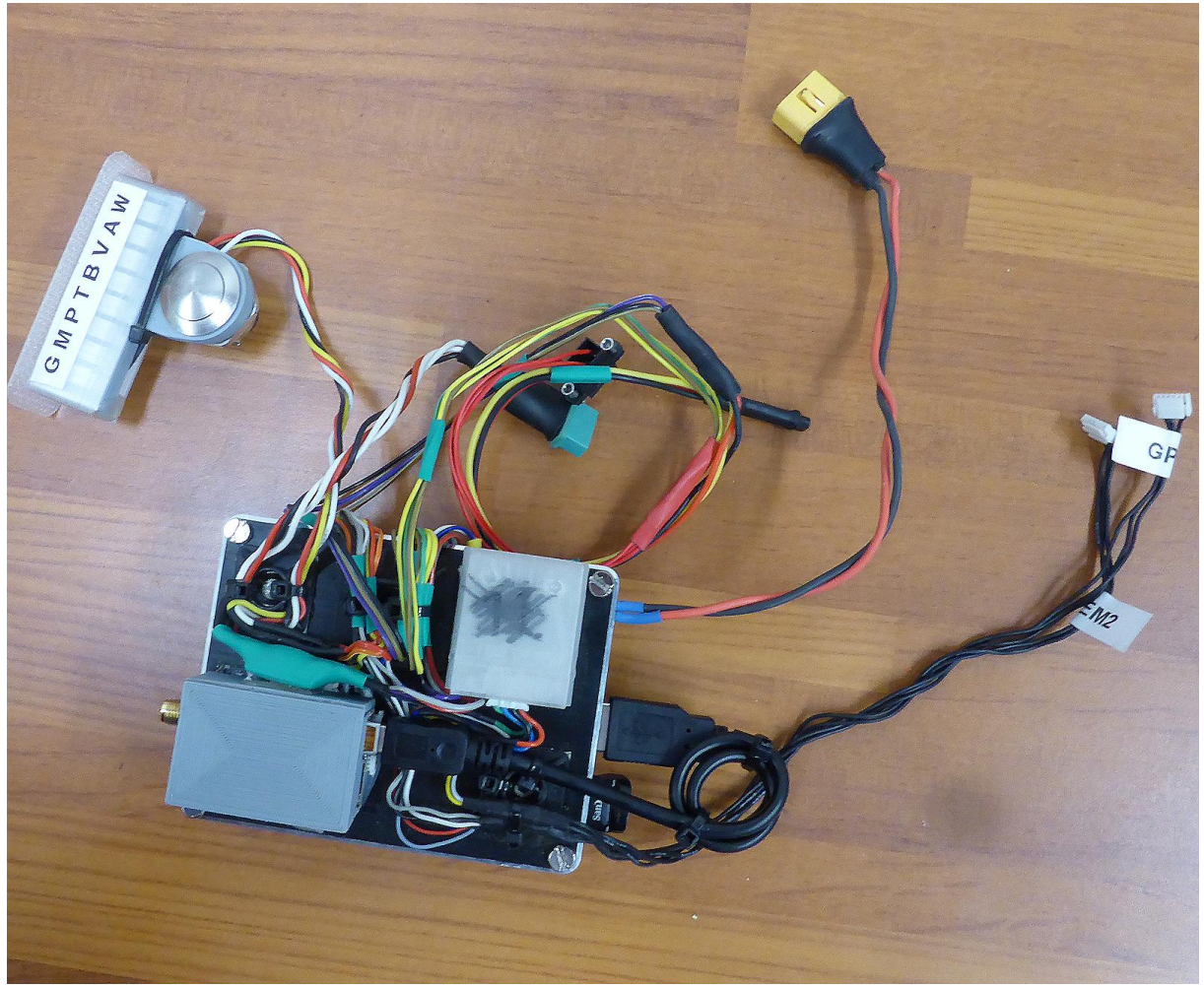
Measuring devices

- Radai's multipurpose datalogger - Build on Raspberry Pi4 mini-PC
- Records multiple digital sensors
- Fluxgate magnetometer (135 Hz)
- Zed9 GNSS (GPS, Glonass, Beidou, Galileo) (10 Hz), horiz. accuracy < 0.5 m
- Barometric pressure & temperature (10 Hz)
- IMU orientation (200-100 Hz) (optional)
- Synchronized by GNSS and Pi4 processor time
- Data transfer via Wifi (Lan, 3G/4G) or USB
- Upload to a Google Drive
- Pre-processing and QC made remotely in Oulu



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3D inversion

- Geomagnetic inversion seeks models of the Earth's physical properties: bedrock susceptibility (scalar) or magnetization (vector) which is the source of the magnetic field we measure
- There are an infinite number of models that can fit the measured data (i.e. the problem is nonunique). Additional information (constraints in the inversion) is essential for a unique solution.
- Susceptibility inversion assumes that the magnetization is aligned in the Earth's main field direction
- Magnetization inversion can reveal remanence field in the source: Does not require the magnetization direction to be aligned with the Earth's main field
- Traditional inversion of magnetic data is computed using (TMI) total magnetic field data (e.g. Oasis Montaj Geosoft software)
- In Radai's inversion algorithm, we can use TMI or vector Bx, By, Bz measurements as input
  - Cons: XYZ requires ~3 times more computing time and RAM of a computer compared to total field inversion.
  - Pros: XYZ gives 3 time more information of the source yielding better 3D inversion results

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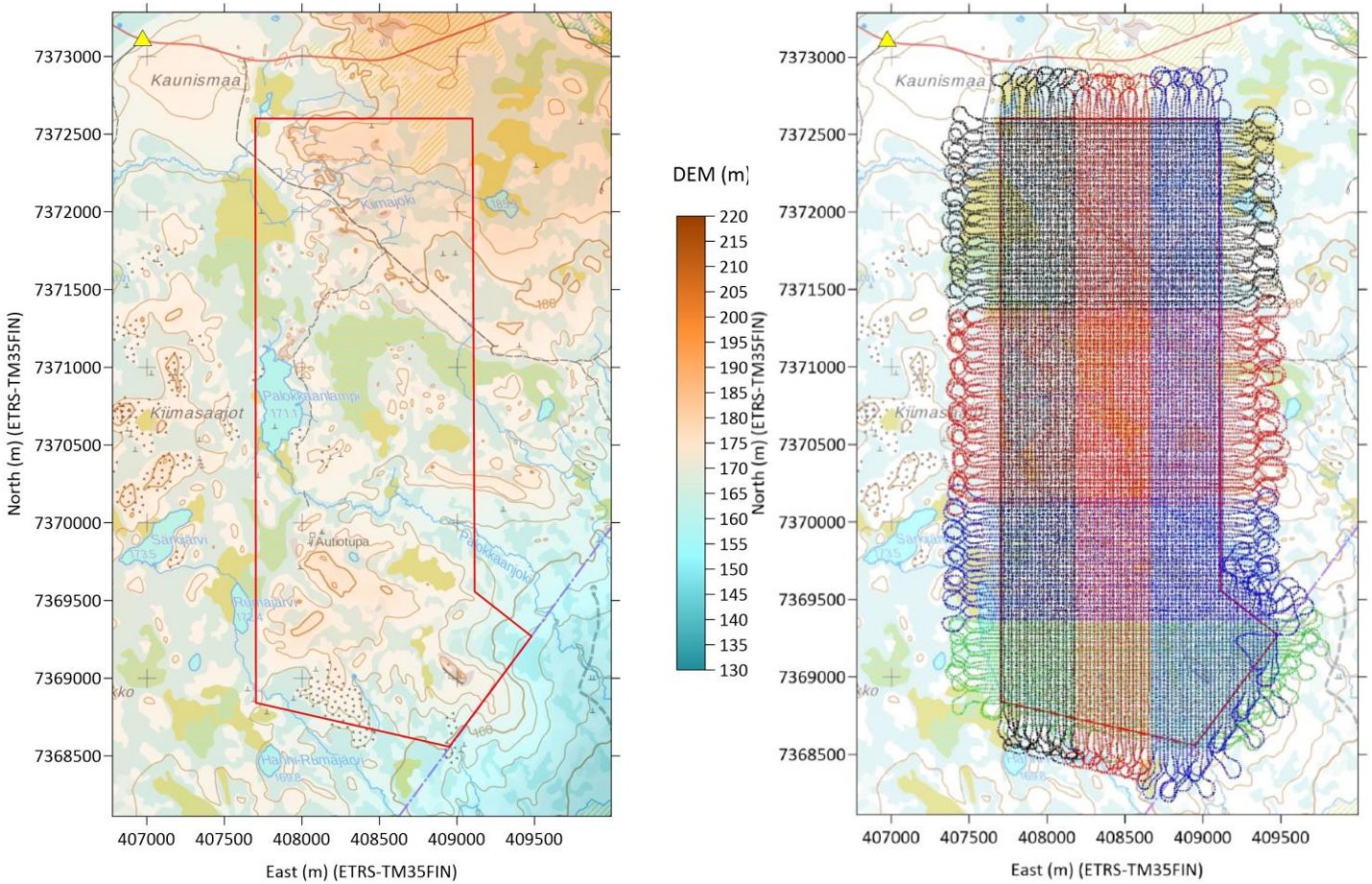
Palokkaanlampi survey

- Radai Oy airborne magnetic survey in Palokkaanlampi site
- Location in northern Finland about 35 km west of Rovaniemi
- Area about 6 km^2, About 460 km flight lines at 35 m altitude (25 m line separation)
- (Left) Topographic map of the Palokkaanlampi survey area outlined by the red polygon.
- (Right) Realized flight paths for Palokkaanlampi survey



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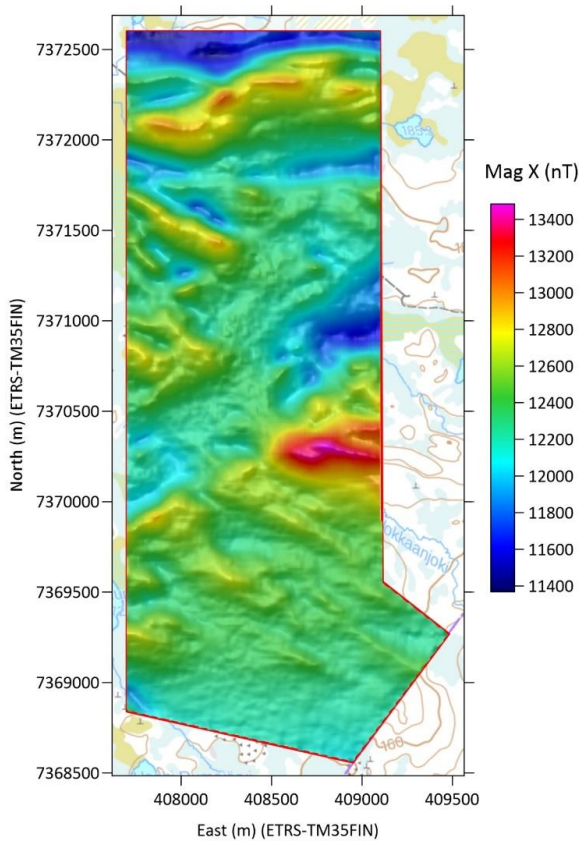
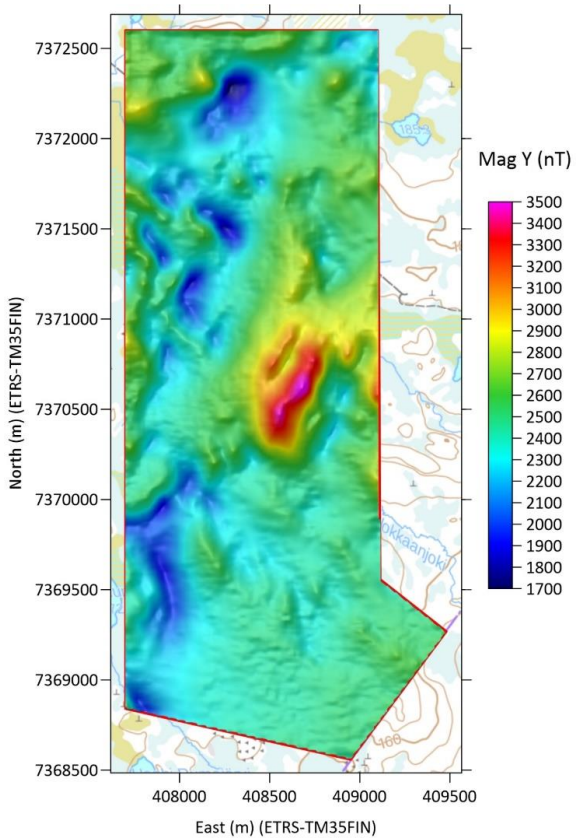
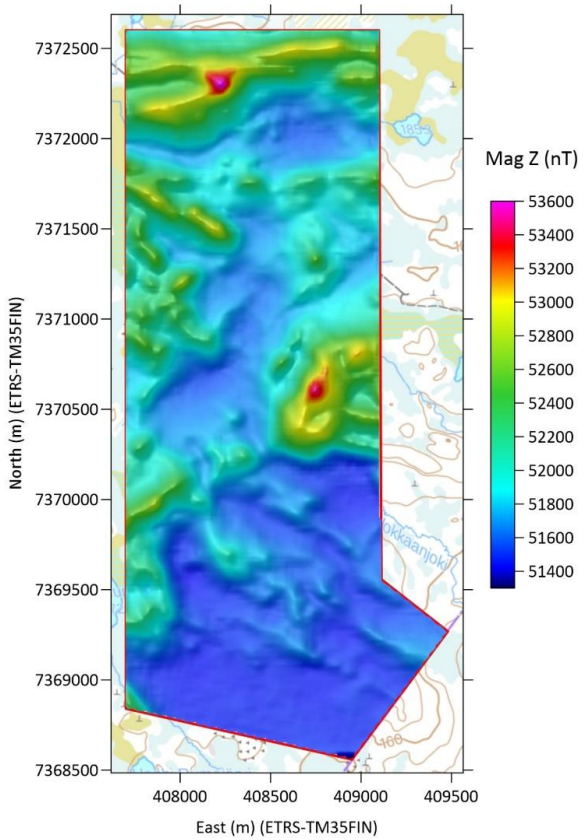
Palokkaanlampi survey

- Magnetic field **B** is a vector quantity (TMI, total magnetic intensity)
- **B** = B_x**i**+B_y**j**+B_z**k**, where **i,j,k** are the unit vectors along XYZ axes and *Bx, By, Bz* the magnitudes in these directions
- Utilizing the IMU (orientation sensor) it is possible to compute the components (Bx, By, Bz) from the fluxgate magnetometer data







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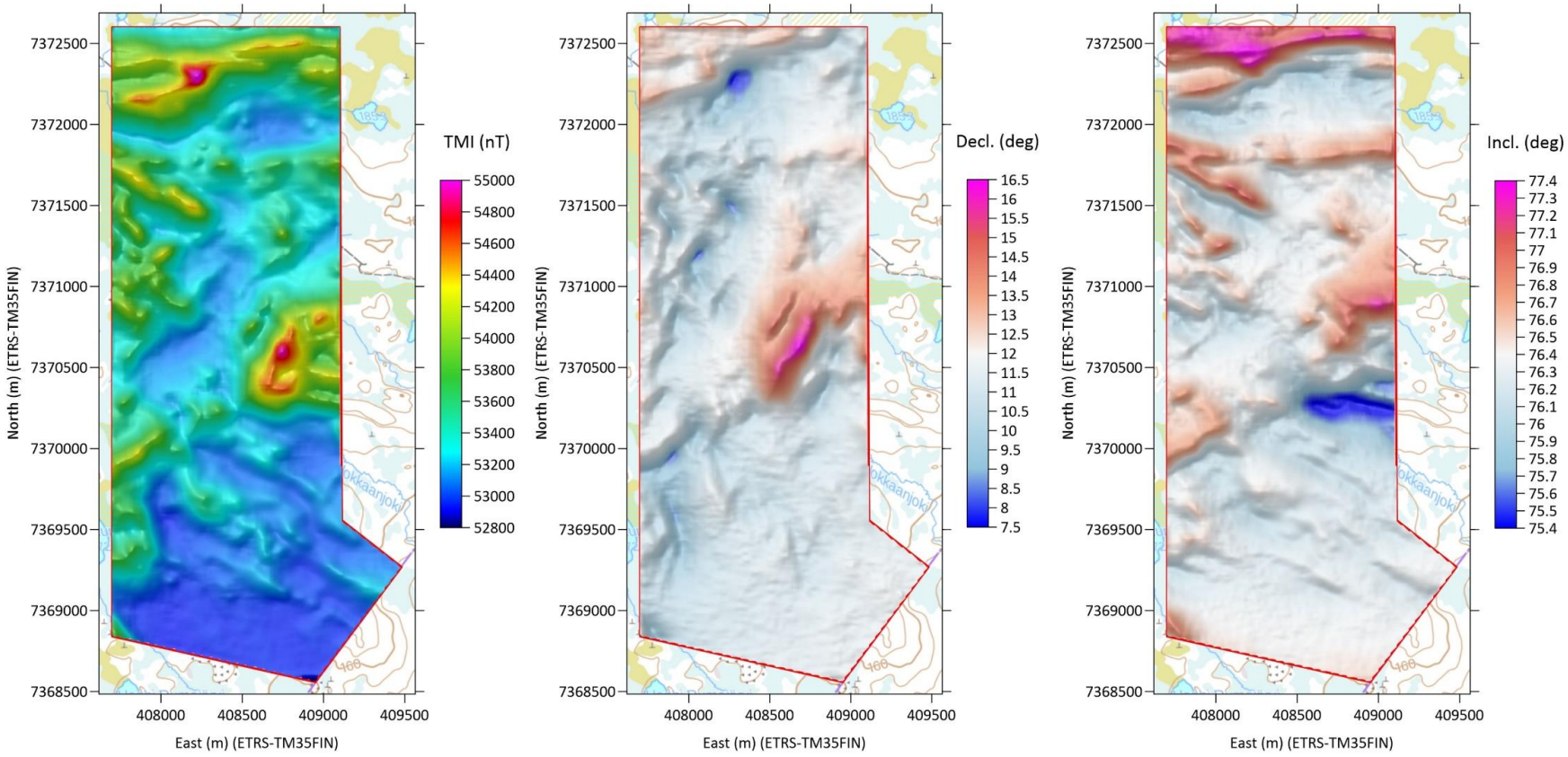
Palokkaanlampi survey

- Total field (TMI). Note, that this scalar value is traditionally the only measured quantity
- Declination: the angle between the magnetic north of the compass and the true north
- Inclination: the angle between the Earth's surface and the magnetic field lines
- Measuring Bx, By, Bz gives all possible information of the magnetic field



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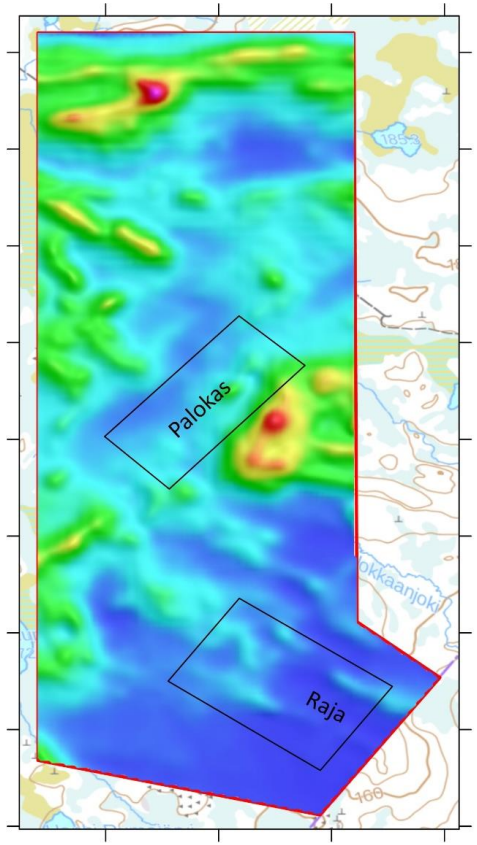
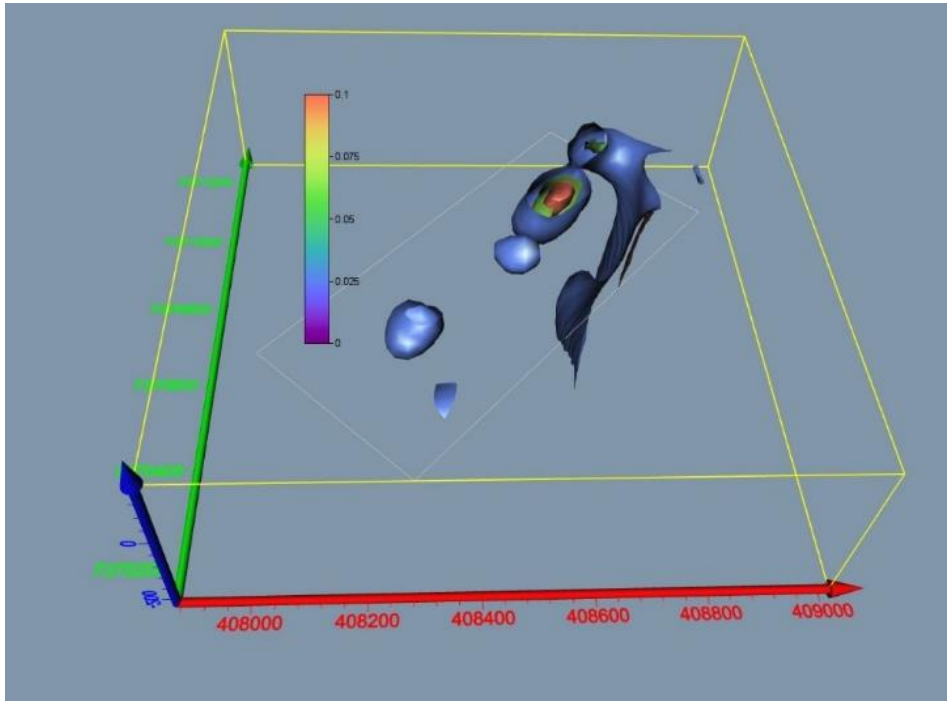
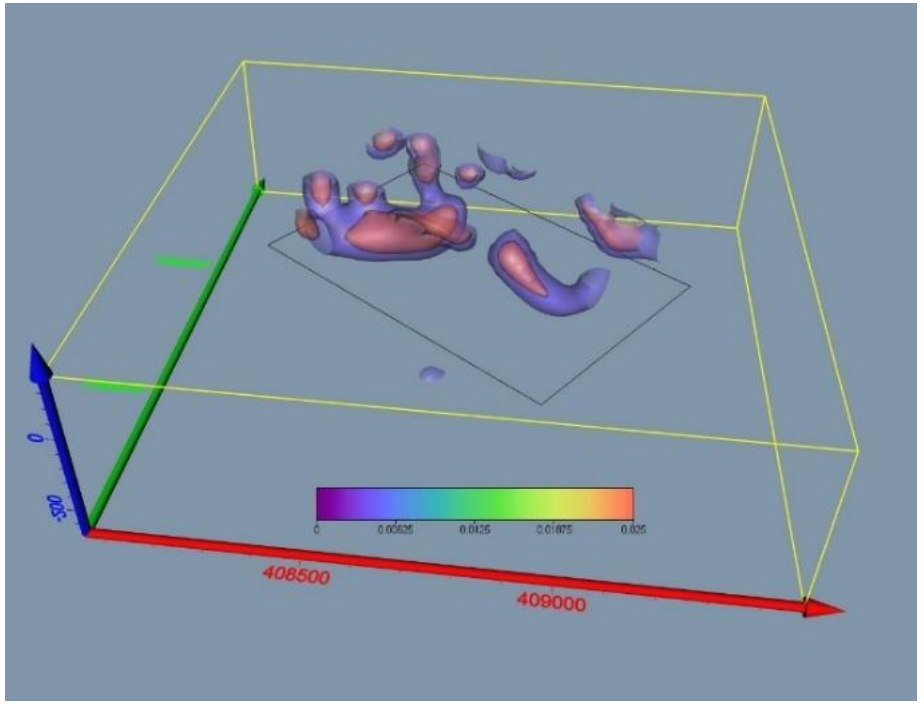
Palokkaanlampi Survey - 3D susceptibility inversion







- 3D susceptibility inversion of Palokas and Raja area. 3D inversion isosurface colors shows 0.005 SI and 0.025 SI.

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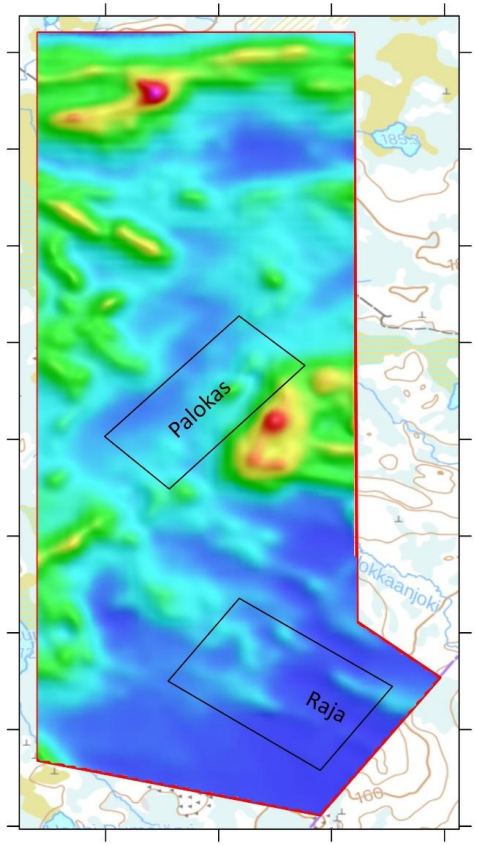
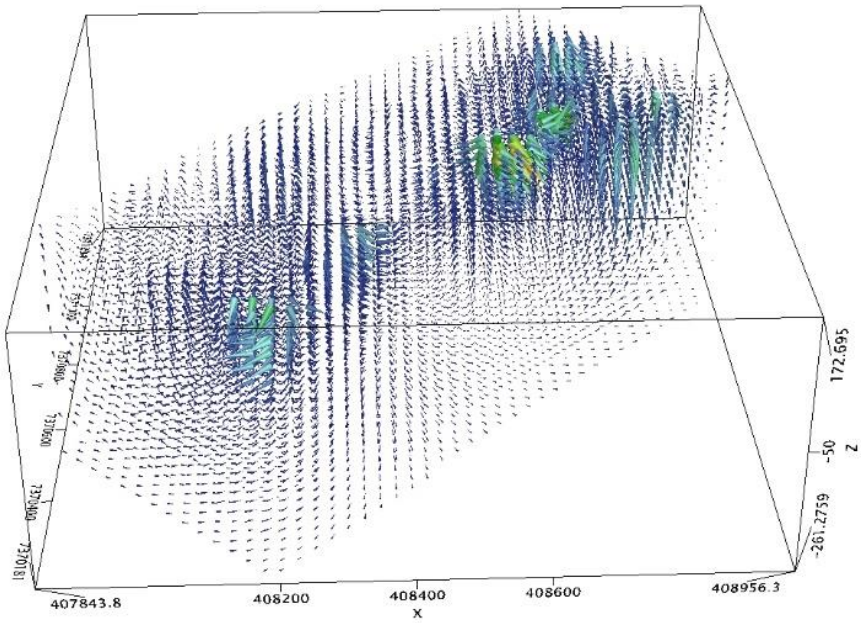
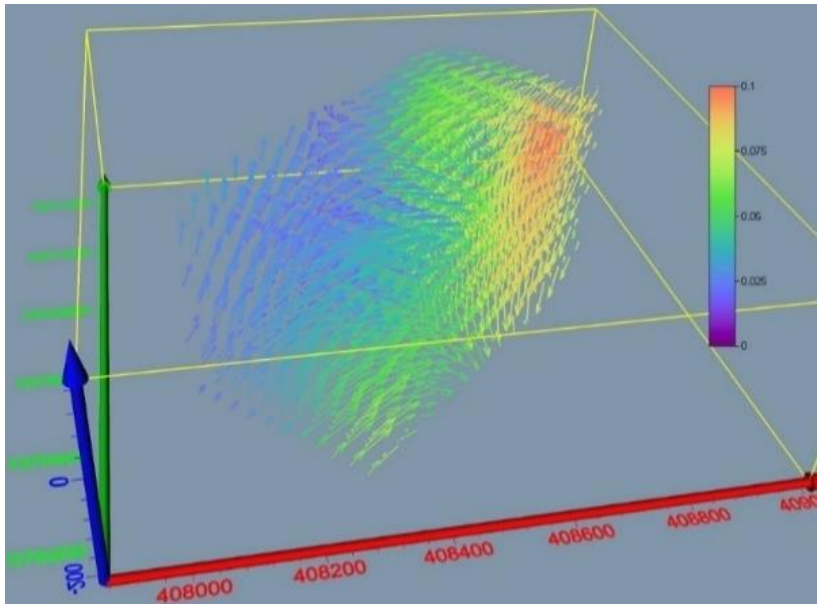
Palokkaanlampi Survey - 3D magnetization inversion





Oasis Montaj Geosoft VOXI 3D Modelling using total magnetic intensity
Radai inversion using XYZ measurements

- 3D magnetization inversion for Palokas area.
- Logarithmic scaling of vectors helps
- Magnetization unit is A/m



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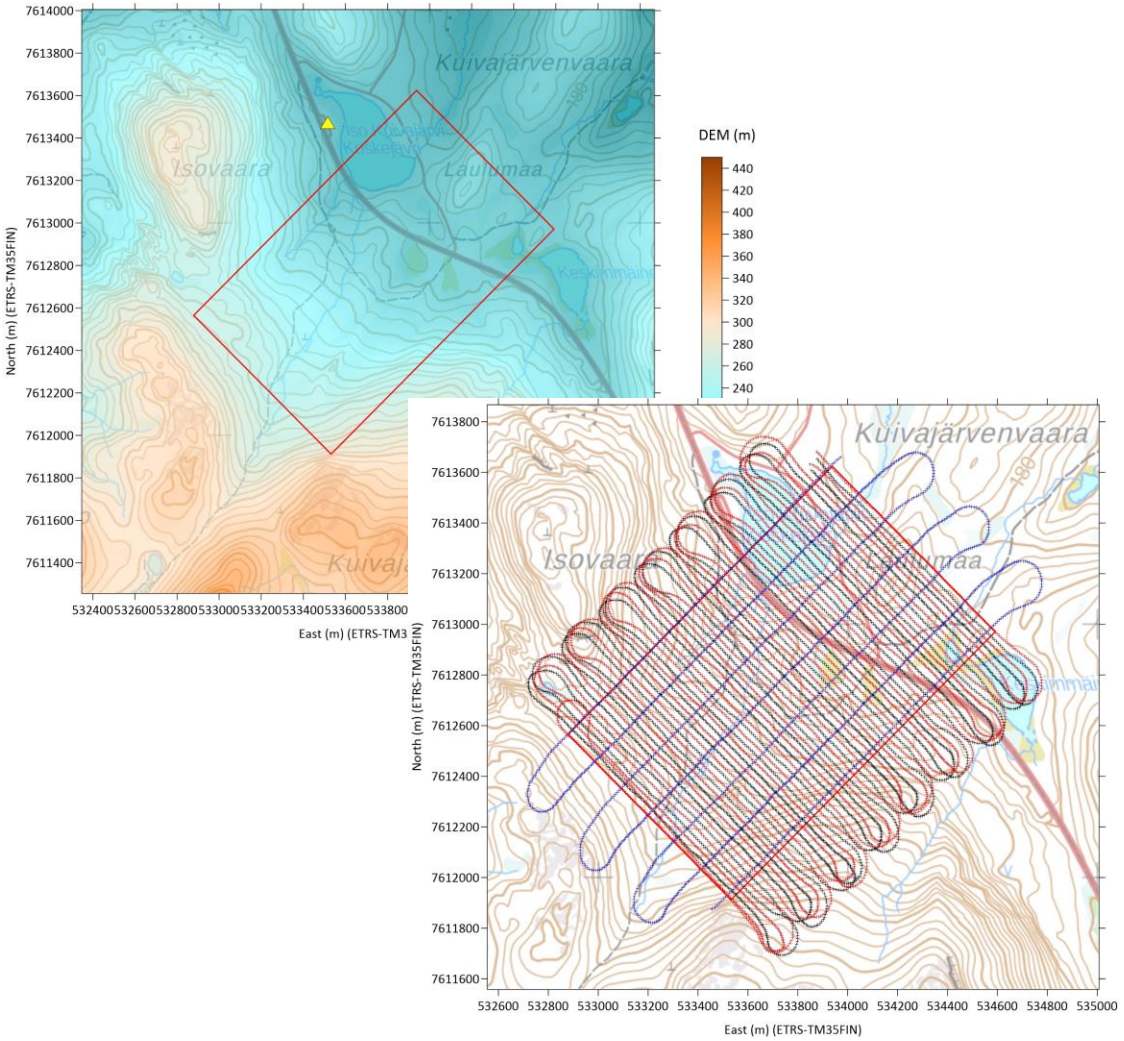
Kuivajärvi Survey

- Radai Oy airborne magnetic survey in Kuivajärvi site
- Location in northern Finland about 15 km east from Ivalo
- Area about 1.4 km2, ~ 268 km flight lines at 35 m altitude (25 m line separation)
- (Left) Topographic map of the Kuivajärvi survey area outlined by the red polygon.
- (Right) Realized flight paths for Kuivajärvi survey



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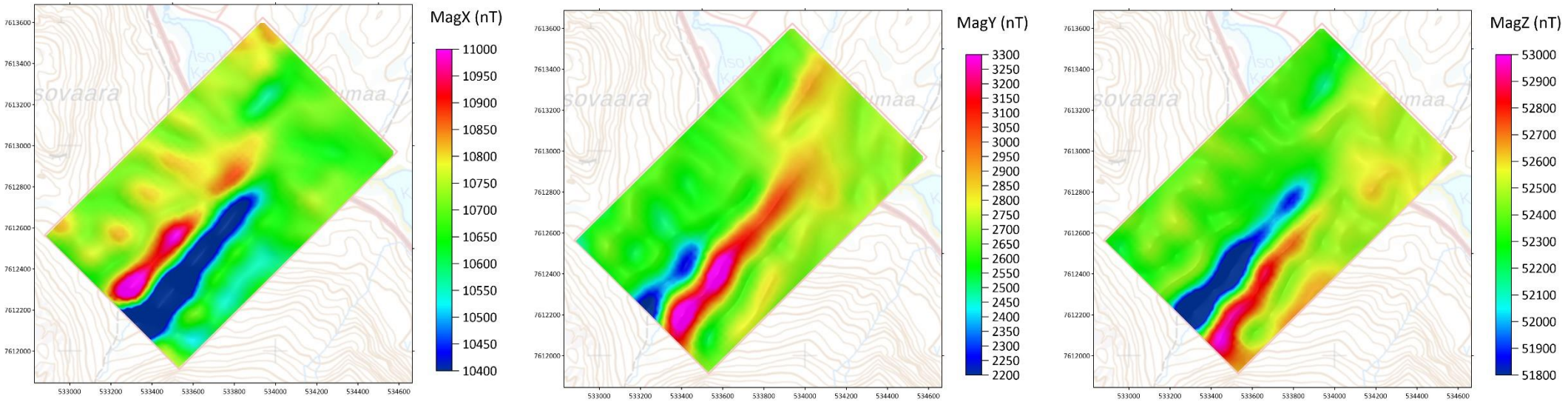
Kuivajärvi Survey

- The survey area was selected to investigate a known diabase vein of ilmenomagnetite with strong component of remanent magnetization
- A priori information: Remanent magnetization is opposite to the Earth's main field direction



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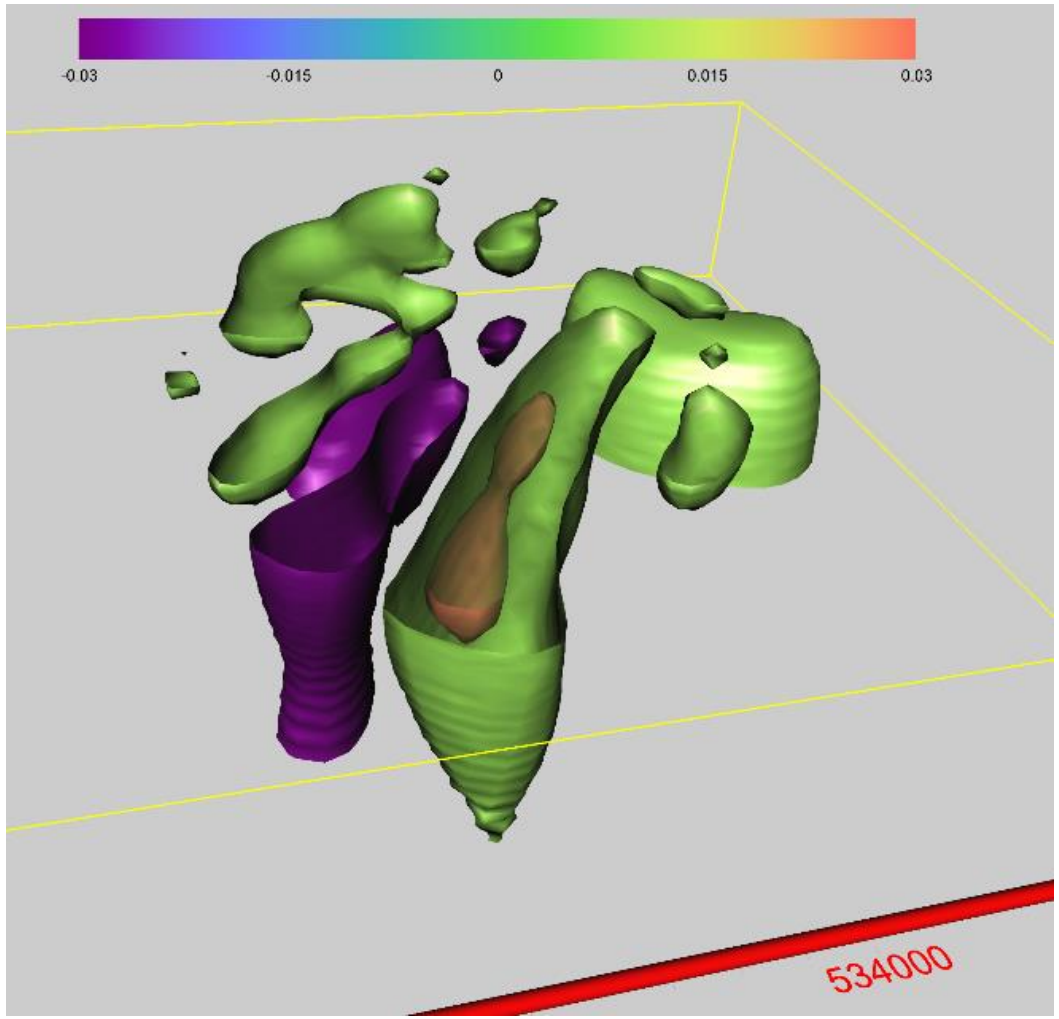
Kuivajärvi Survey

- 3D susceptibility inversion
- XYZ data as input
- Remanent magnetization is seen as negative susceptibilities (magnetization upwards)
- Induced magnetization as positive susceptibility (magnetization downwards)
- Accordingly, in this inversion case the susceptibility values were constrained to -0.25 – 0.25 SI



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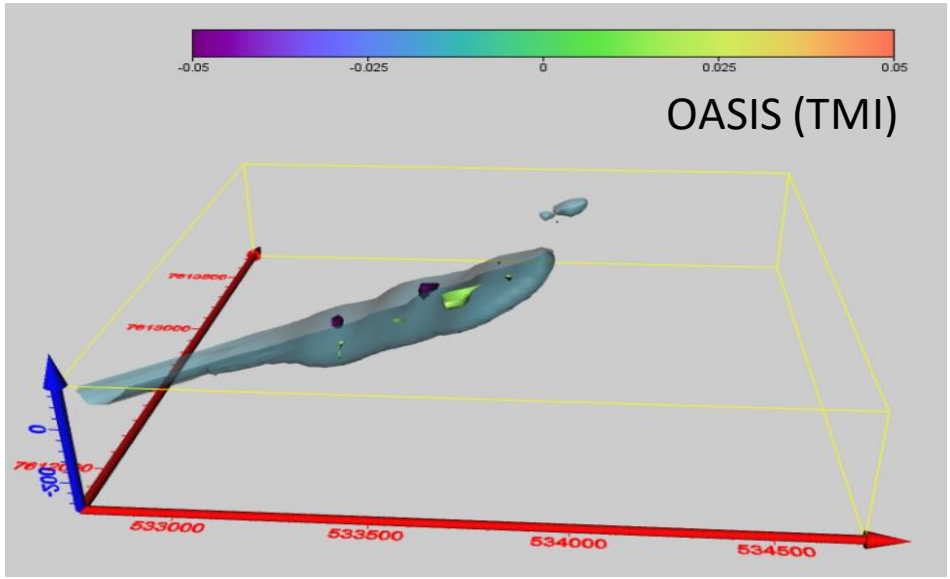
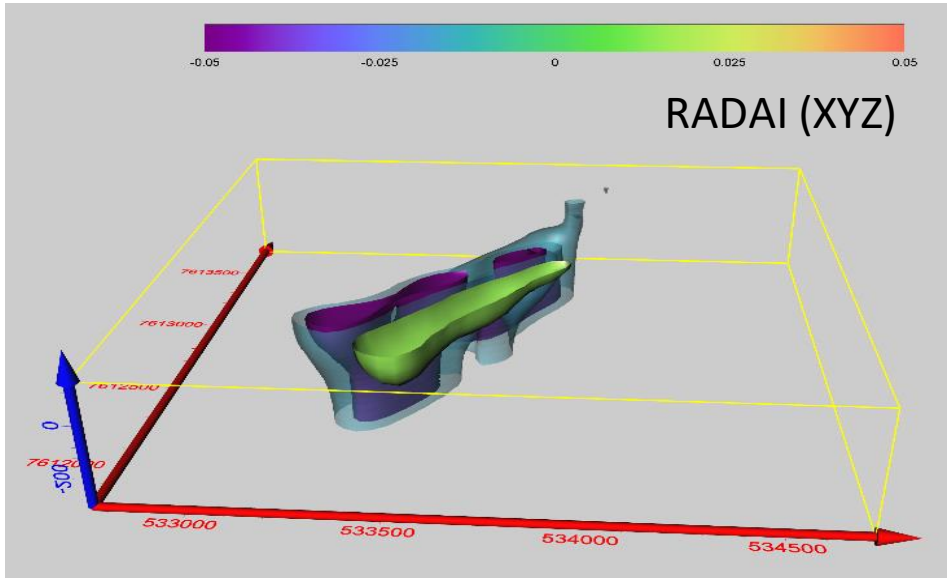
Comparison of software

- Kuivajärvi survey measurements
- Difference of 3D susceptibility inversion results from two different software: Radai algorithm vs. Oasis Montaj Geosoft VOXI 3D Modelling
- Both results were computed by constraining the susceptibility to -0.25 – 0.25 SI
- Oasis uses the total magnetic intensity (TMI) as its input data while Radai's inversion algorithm utilizes full magnetic field vector (XYZ)





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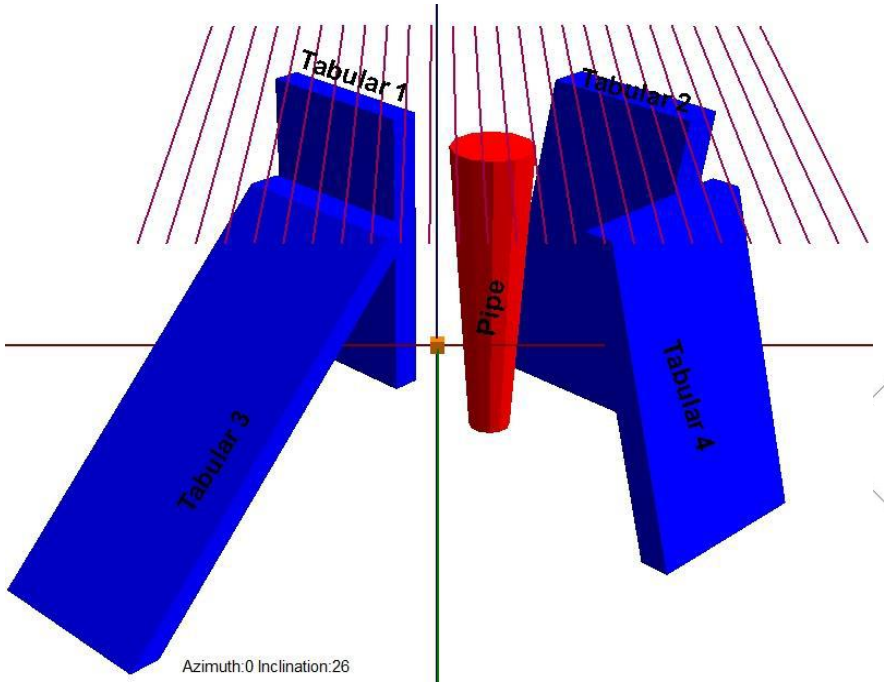
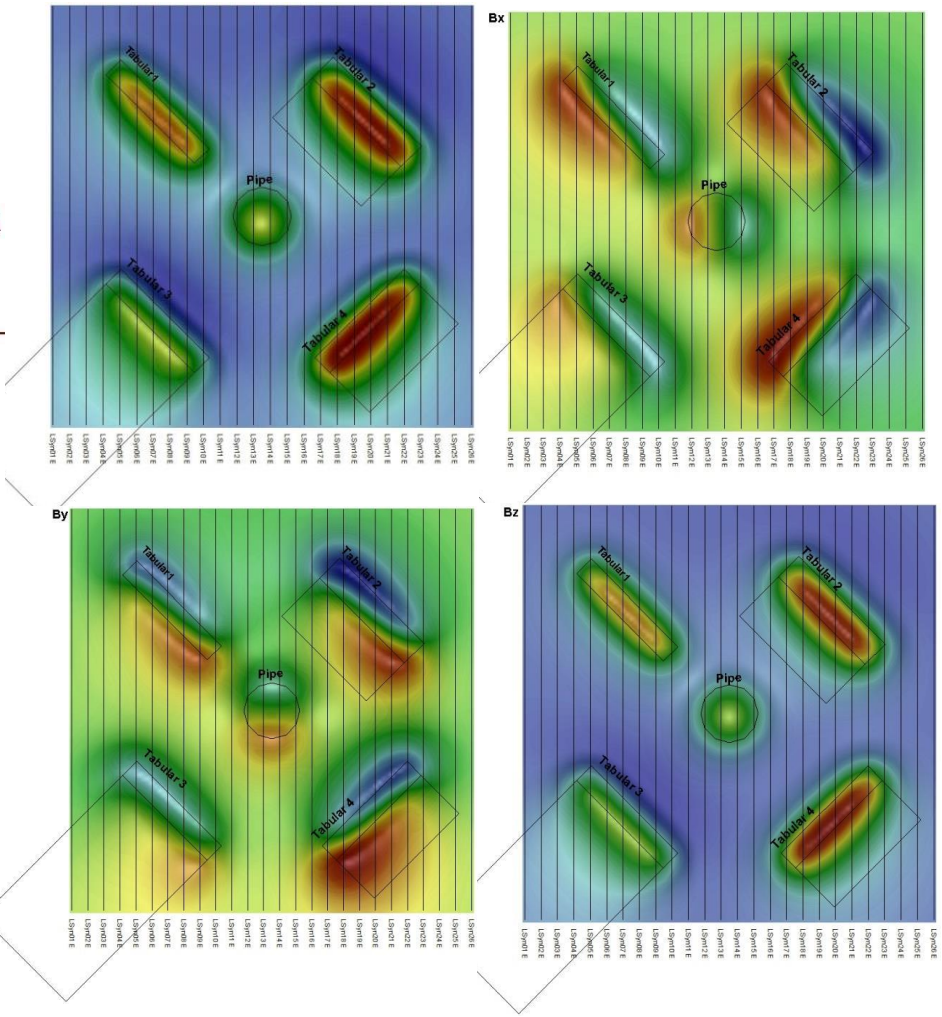
Synthetic source

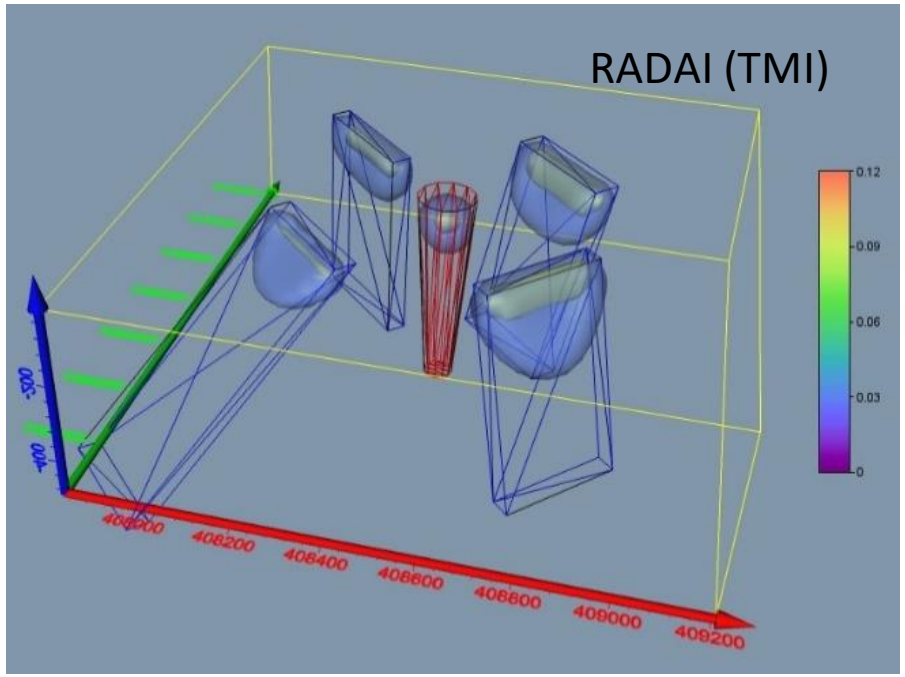
- Comparison of TMI and XYZ data as input in 3D inversion
- Schematic presentation of modelled magnetic bodies in the calculation.
- TMI, and XYZ data in the right panels

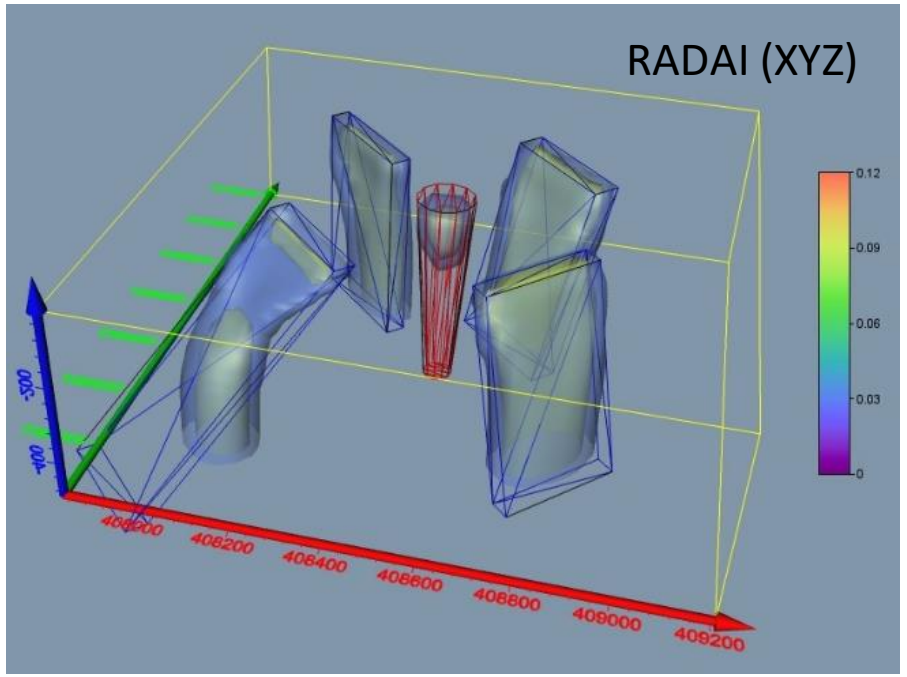




Body	X	Y	Z	Suscept (SI)	Thickness (m)	Strikelength (m)	DepthExt (m)	Dip(°)	Azim (°)
Tabular_1	408250	7369751	5	0.1	50	300	500	90	135
Tabular_2	408750	7369750	5	0.1	70	300	500	75	135
Tabular_3	408250	7369250	5	0.1	50	300	500	45	135
Tabular_4	408750	7369250	10	0.15	50	300	500	75	45
Pipe	408500	7369500	5	0.05		radius= 70/35 m	500	0	0

Synthetic source





- TMI vs XYZ 3D inversion results
- Both results used Radai's inversion algorithm
- XYZ gives more depth information of the source compared to using TMI

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Summary

- Magnetic vector data (XYZ) gives more information about the structure and composition of the Earth.
- It is possible to derive, e.g., declination and inclination from XYZ.
- The use of vector data (XYZ) instead of TMI gives more information and better 3D inversion results.

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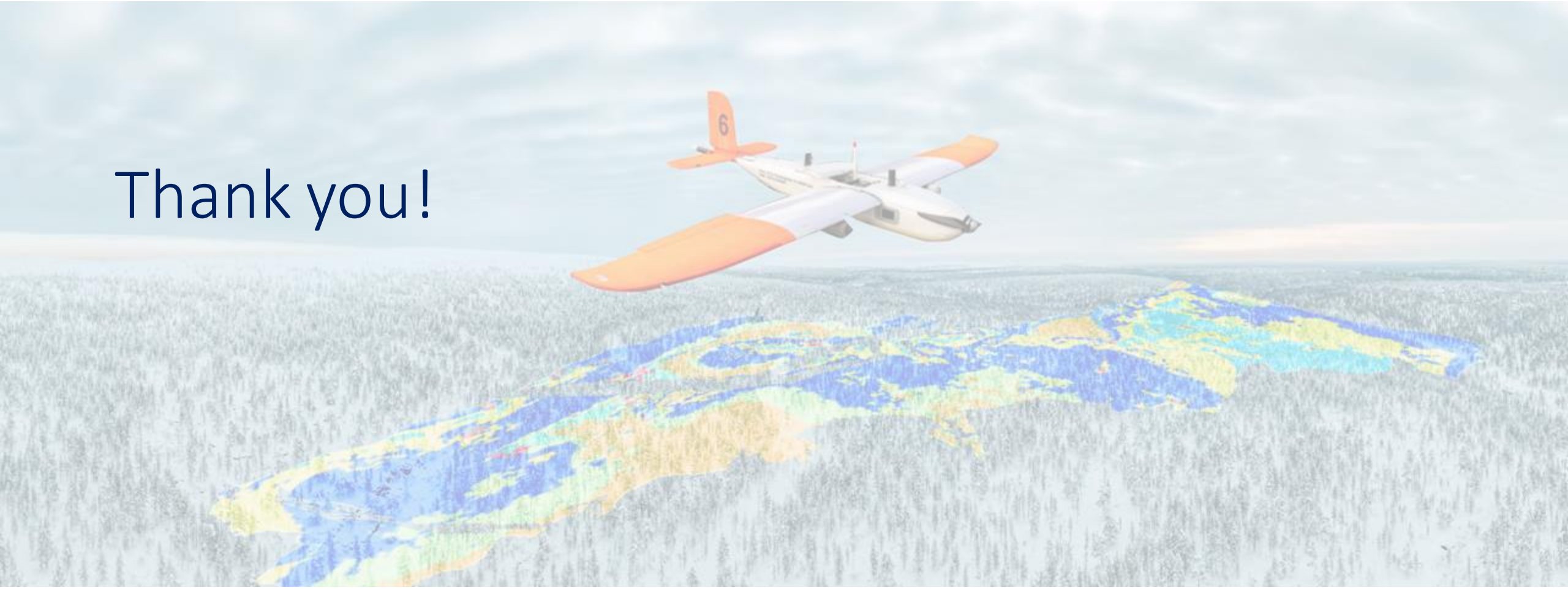

Thank you!

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