LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN
GEOPHYSICS
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Collecting and calibrating magnetic data from surveys with Uncrewed Aerial Systems (UAS) and an approach for regions with strong magnetic gradients

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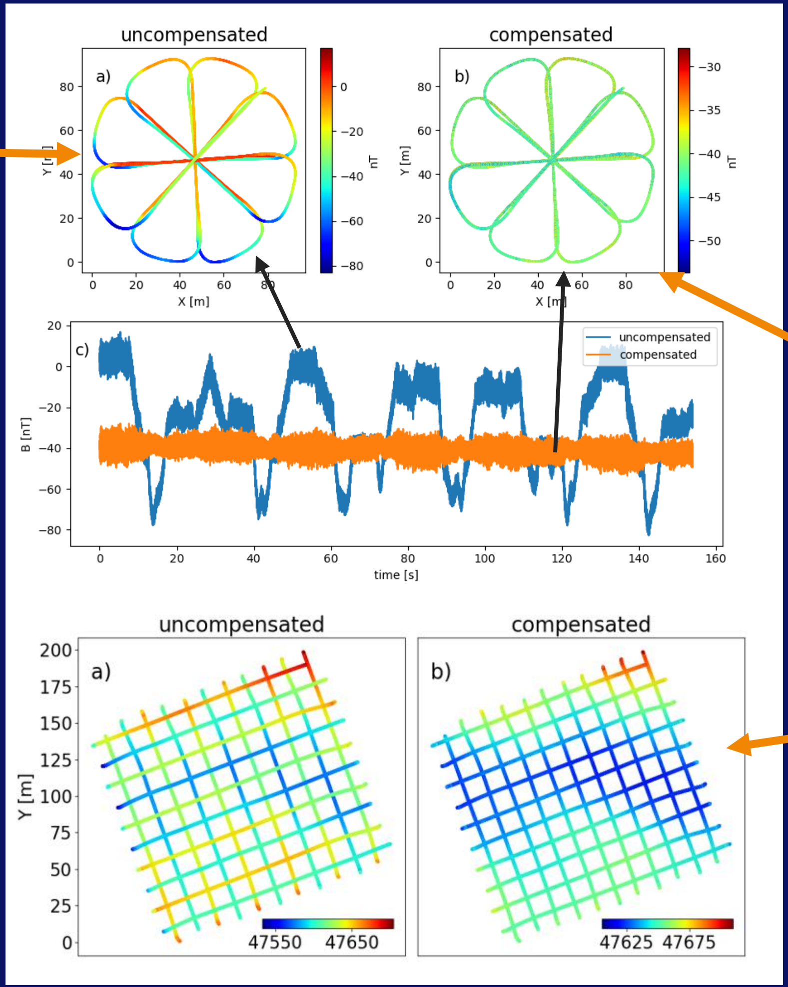
USGS science for a changing world

Sensors on a rigid frame + magnetic compensation

Scalar magneto-meter

Vector magneto-meter

1. Calibration flight in a **magnetically low-gradient area**

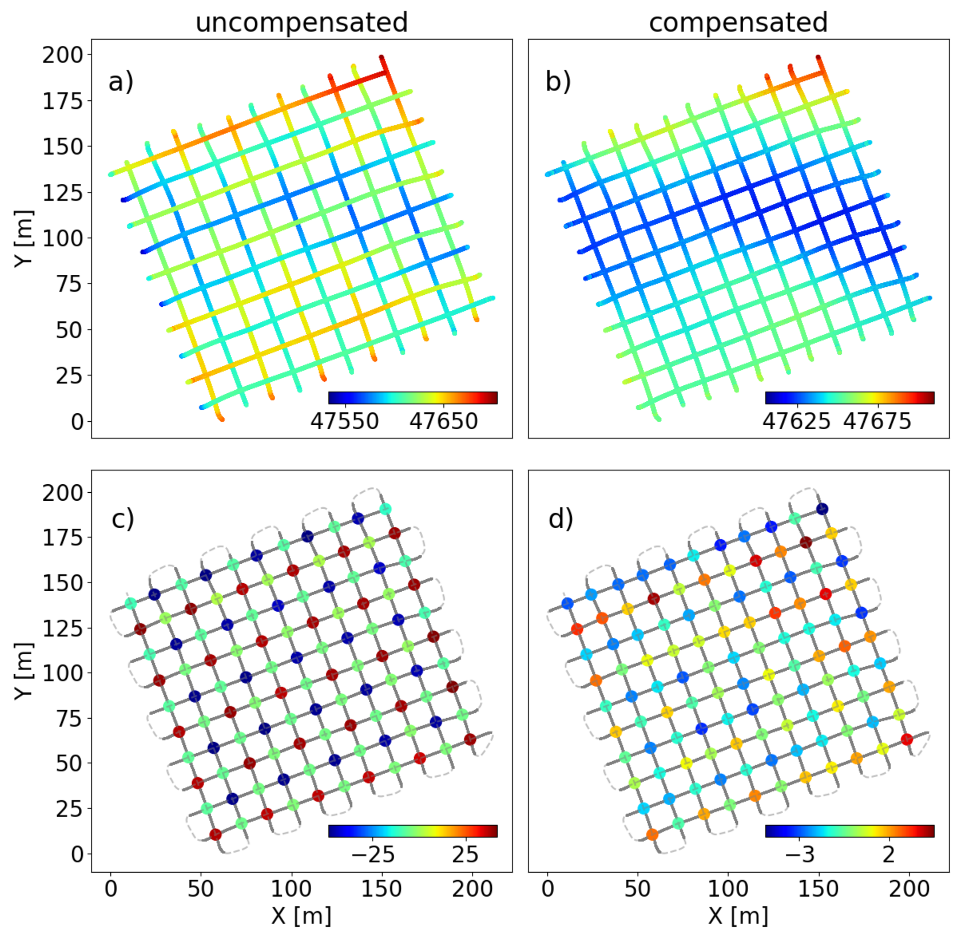


2. Compute best fitting model coefficients for the calibration data

3. Use model coefficients on survey data

Model for scalar magnetometers based on Leliak (1961)
Model for vector magnetometers based on Olsen et al. (2003) and Munschy et al. (2007)

Python code available online: MagComPy https://zenodo.org/record/5749446



Example of magnetic field intensity data (in nT) and cross-over differences (in nT) from sensor 2 of the Vector Magnetometer attached to the frame setup (from Kaub et al. 2021).

Comparing the accuracy of different sensor systems, suspension designs and compensation methods

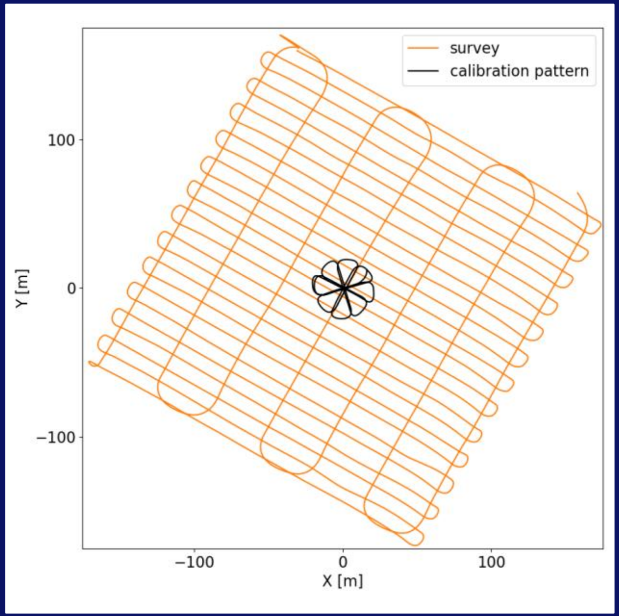
RMS of cross-over differences

Magnetometer	Suspension	Sensor	Uncompen-sated [nT]	Compen-sated [nT]
Scalar	tethers*		5.2	*
Scalar	landing gear		66.0	5.1
Scalar	frame		58.1	3.3
Vector	frame	1	58.9	2.2
Vector	frame	2	30.2	2.1
Vector	landing gear	1	84.5	6.6
Vector	landing gear	2	43.3	6.5

*signals from scalar magnetometer on tethers were not compensated

Best results with frame setup and magnetic compensation

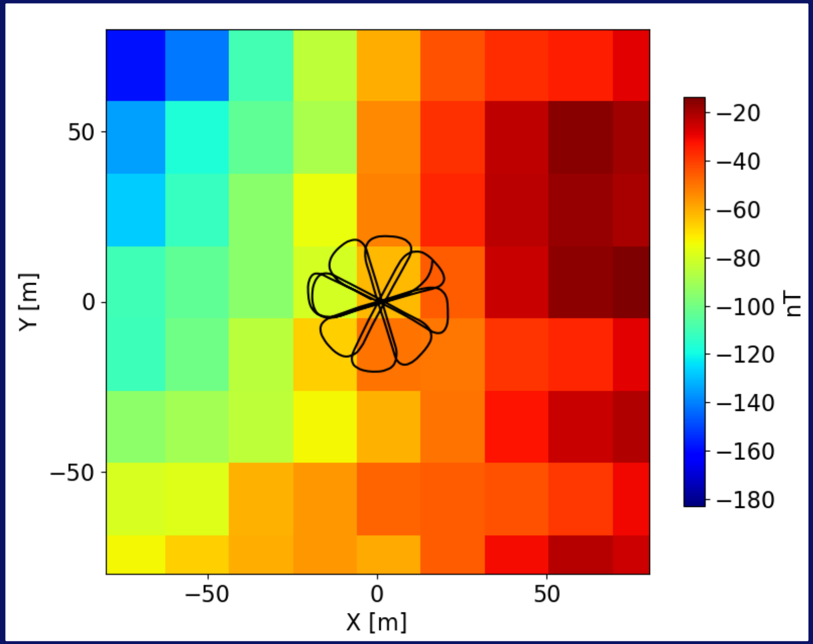
Strong magnetic gradients at the calibration site are problematic!



1st compensation:

- Collect additional data at the calibration site
- Compensate this data the normal way

→ Assumes a constant field at the calibration site



2nd compensation:

- Create a grid from the compensated data
- Interpolate the grid and resample along calibration flight
- Use this resampled data for a second compensation

→ Takes local magnetic gradients at the calibration site into account

Based on a similar approach by Mercier de Lépinay, J. (2019) for the compensation of a boat-born magnetic survey.

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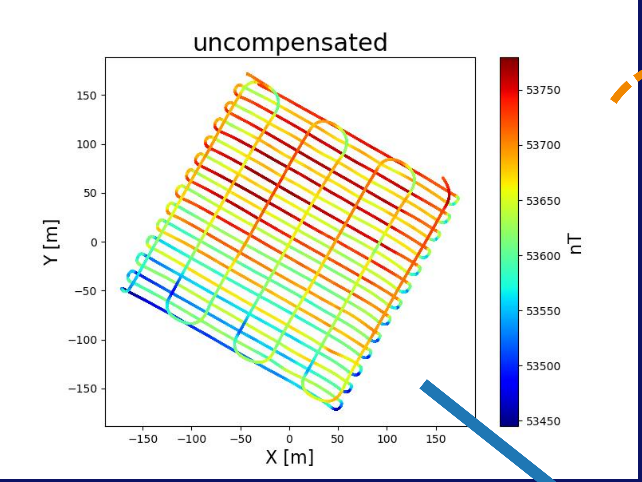
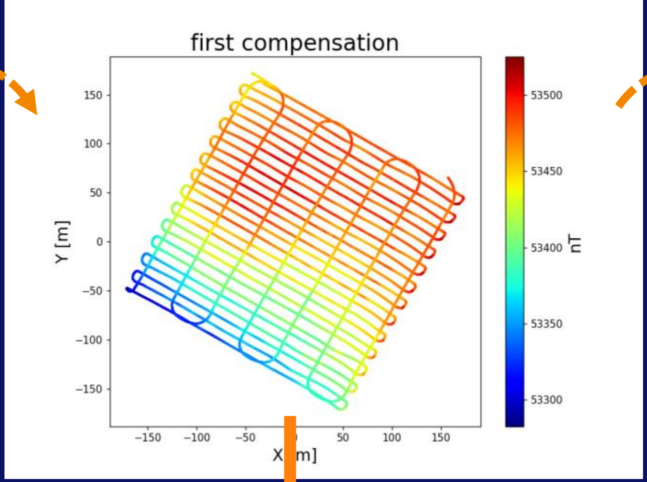
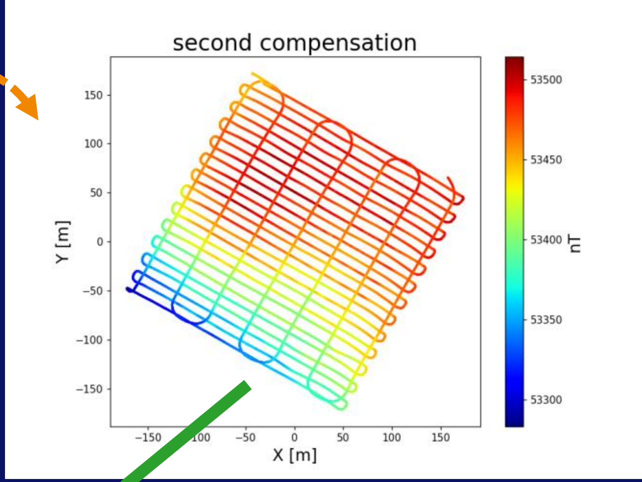
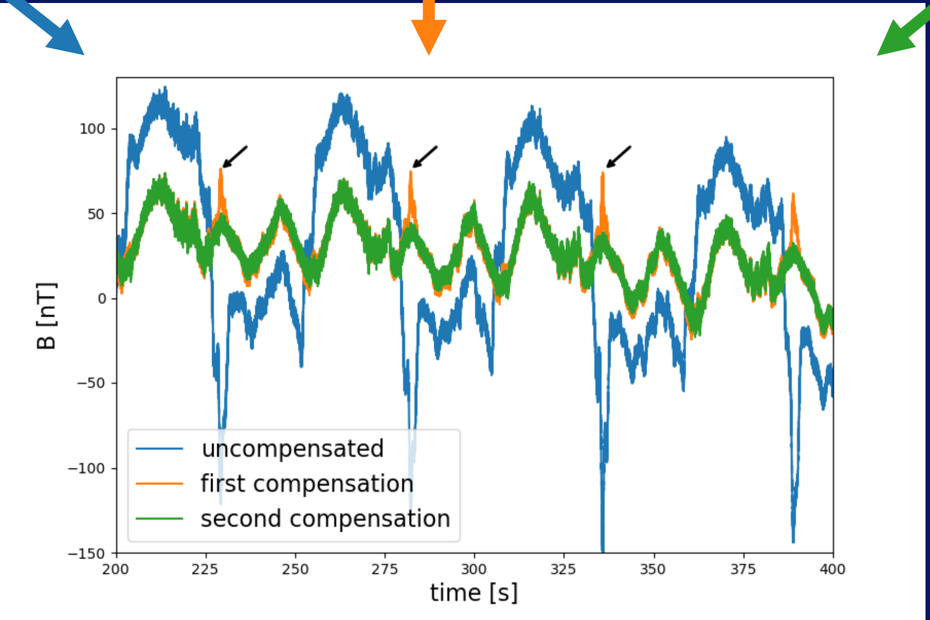
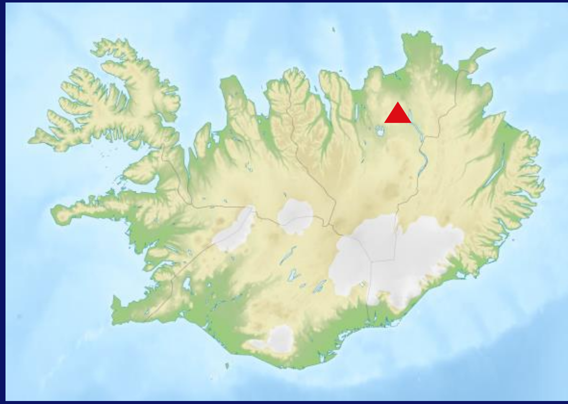
Krafla in Northern Iceland: a perfect place to test the double compensation











Iceland_location_map.svg: NordNordWestderivative work: Виктор В, CC BY-SA 3.0 via Wikimedia Commons

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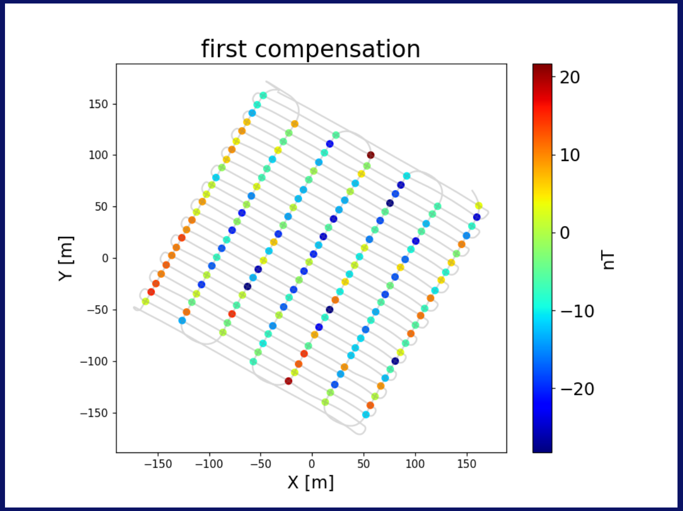
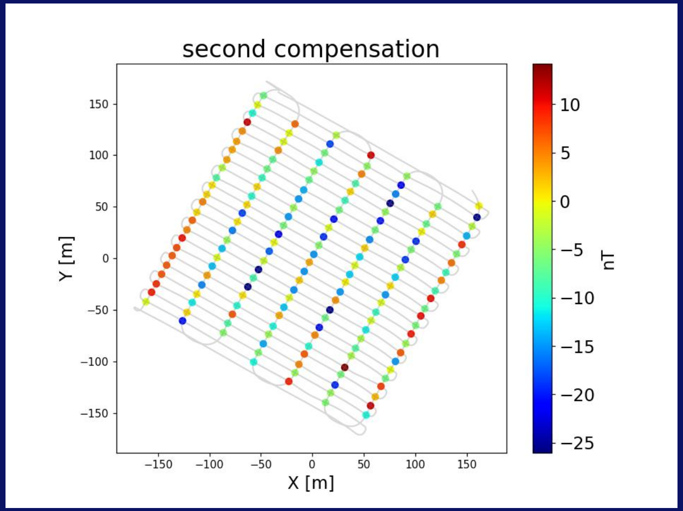
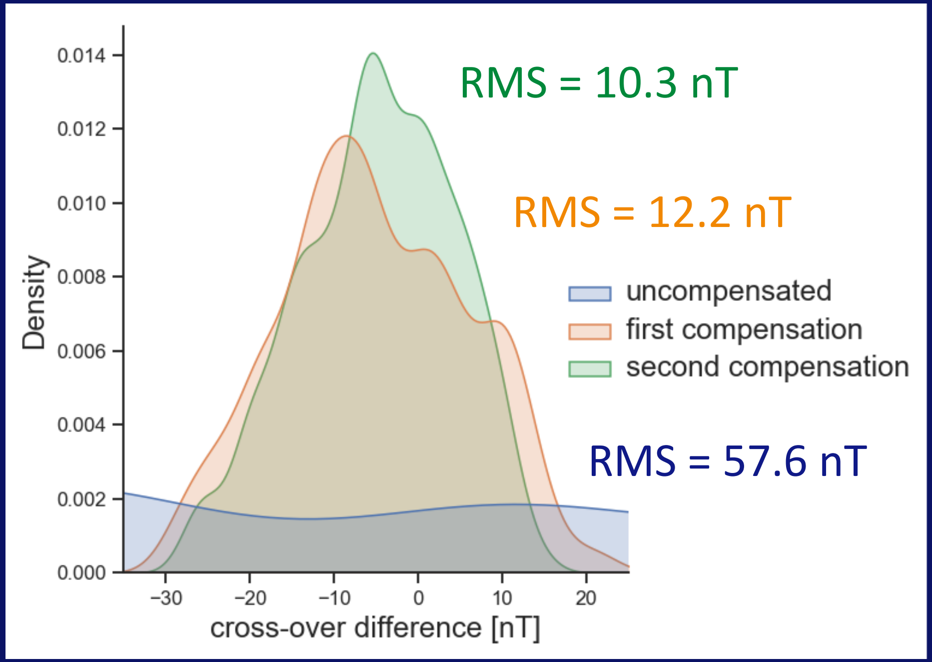
Cross-over differences of double compensated data





Comparing cross-over differences after first and second compensation:

- Narrower distribution
- Better centered around 0
- Lower RMS



RMS of cross-over differences in nT:

Sensor	Uncompensated	First	Second
1	57.6	12.2	10.3
2	28.1	10.5	9.5

Summary

- Aeromagnetic surveys with Uncrewed Aerial Systems can reach 2 – 3 nT accuracies under good conditions
- A frame setup comes with great stability allowing autonomous flights
- Requires calibration flights and data processing (→ magnetic compensation)
- Areas with strong magnetic gradients are problematic for magnetic compensation
- In such areas, a double compensation can improve data accuracy

Thank you for your attention!

- Kaub, L., Keller, G., Bouligand, C., & Glen, J. M. (2021). Magnetic surveys with Unmanned Aerial Systems: Software for assessing and comparing the accuracy of different sensor systems, suspension designs and compensation methods. Geochemistry, Geophysics, Geosystems, 22(7), e2021GC009745. https://doi.org/10.1029/2021GC009745.
- Leliak, P. (1961). Identification and evaluation of magnetic-field sources of magnetic airborne detector equipped aircraft. *IRE Transactions on Aerospace and Navigational Electronics*, (3), 95-105.
- Mercier de Lépinay, J. (2019). *Acquisitions et interprétations magnétiques pour l'exploration géothermique en Guadeloupe, Petites Antilles* (Doctoral dissertation, Strasbourg)
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- Olsen, N., Clausen, L. T., Sabaka, T. J., Brauer, P., Merayo, J. M., Jørgensen, J. L., ... & Risbo, T. (2003). Calibration of the Ørsted vector magnetometer. *Earth, planets and space*, 55(1), 11-18.