PS The Use of Multi-Level Potential Field Data in Regional, Geophysical Modeling

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Abstract

Modeling of potential field data suffers from the ambiguity problem and constraining data are needed to minimize the uncertainty of forward and inverse models. Useful information which can limit the uncertainties is contained in the frequency content of the potential field data. Routinely, wavelength filtering and methods like power-spectrum estimates have been used in the past in interpretation of potential field data. However, shallow geological structures often are not limited to a certain wavelength and overlap in their characteristic wavelength with deeper-seated anomalies (e.g., cratonic basins).

The availability of data sets at different levels, e.g., ground data, ship borne data, airborne data and satellite data, allows nowadays modeling simultaneously potential fields from different heights, and overcomes therewith the necessity of wavelength-filtering. Models can be tested immediately against their response in multi-level data sets, which increases the uncertainty of the solutions. Especially, in inversion of potential field data the use of different observation levels minimizes the uncertainty in the analysis of sources superposed from different depth. We present key examples of multi-level modeling of the magnetic field and gravity field for the Oslo Graben, Barents Sea and mid-Norwegian margin, where multi-level data sets have been used to model crustal intrusives and crustal structure underlying sedimentary basins.

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Introduction

Modeling of potential field data suffers from the ambiguity problem and constraining data are needed to minimize the uncertainty of forward and inverse models. Useful information which can limit the uncertainties is contained in the frequency content of the potential field data. Routinely, wavelength filtering and methods like power-spectrum estimates have been used in the past in interpretation of potential field data. However, shallow geological structures often are not limited to a certain wavelength and overlap in their characteristic wavelength with deeper-seated anomalies (e.g., cratonic basins). The availability of data sets at different levels, e.g., ground data, ship-borne data, airborne data and satellite data, allows nowadays modeling simultaneously potential fields from different heights, and overcomes therewith the necessity of wavelength-filtering. Models can be tested immediately against their response in multi-level data sets, which increases the uncertainty of the solutions.

Oslo Graben

A low-altitude aeromagnetic survey was flown in 2003 as part of the GEOS project at NGU. For the area adjacent to the new high-resolution data set we merged our data with another, low-altitude, draped aeromagnetic survey flown in 1973, with a mean height above terrain of 150 m.

Already in 1970 a high-altitude aeromagnetic survey (at 3400 m above sea level) was flown as part of the Norwegian Geotraverse Project [Aalstad et al., 1977; Heier, 1977].

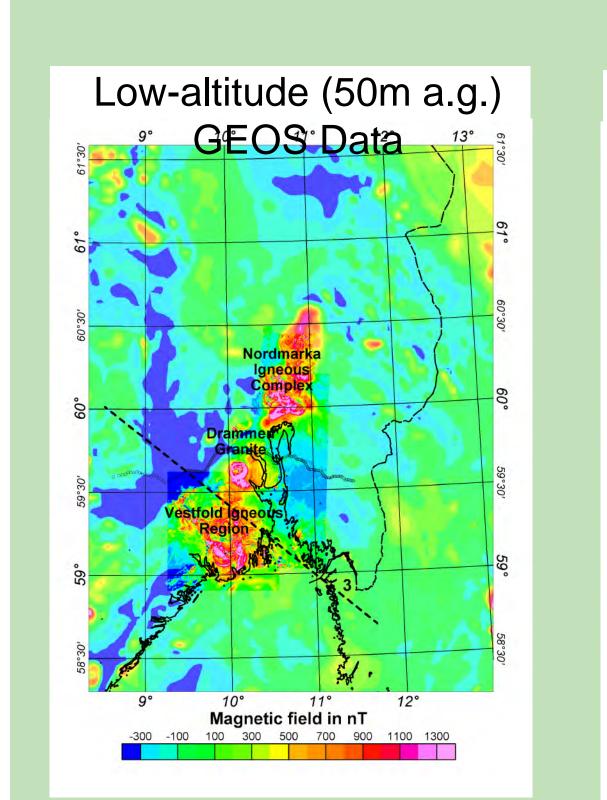
In the high-altitude data, the effects of the varying terrain are minimized and the major and deeper features are enhanced elatively to the effects of shallower features. See table for further specifications.

High-altitude (3400 a.s.l.)

Magnetics in nT
-300 -100 100 300 500 700 900 1100 1300

Upward continued (3400m)

Geotraverse Data

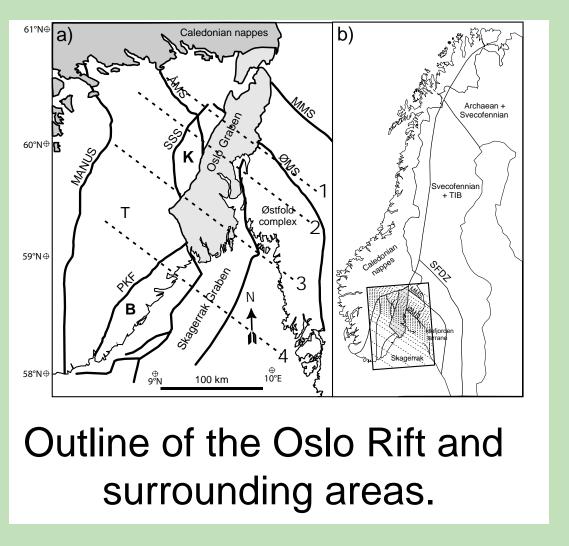


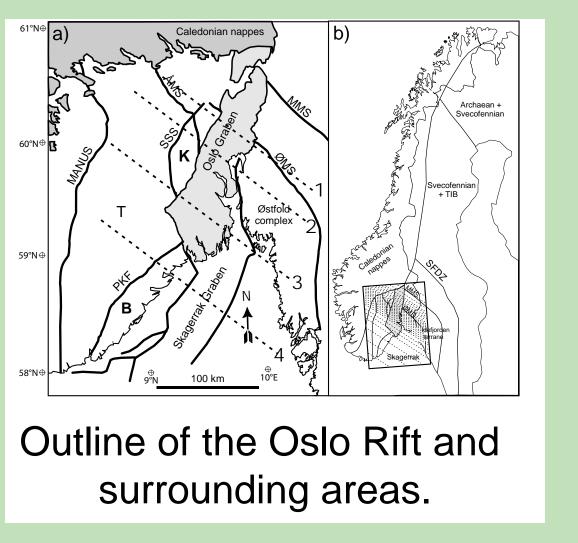
To right: Upward continued low-altitude data set into the level of the high-altitude data set of 3400 m.

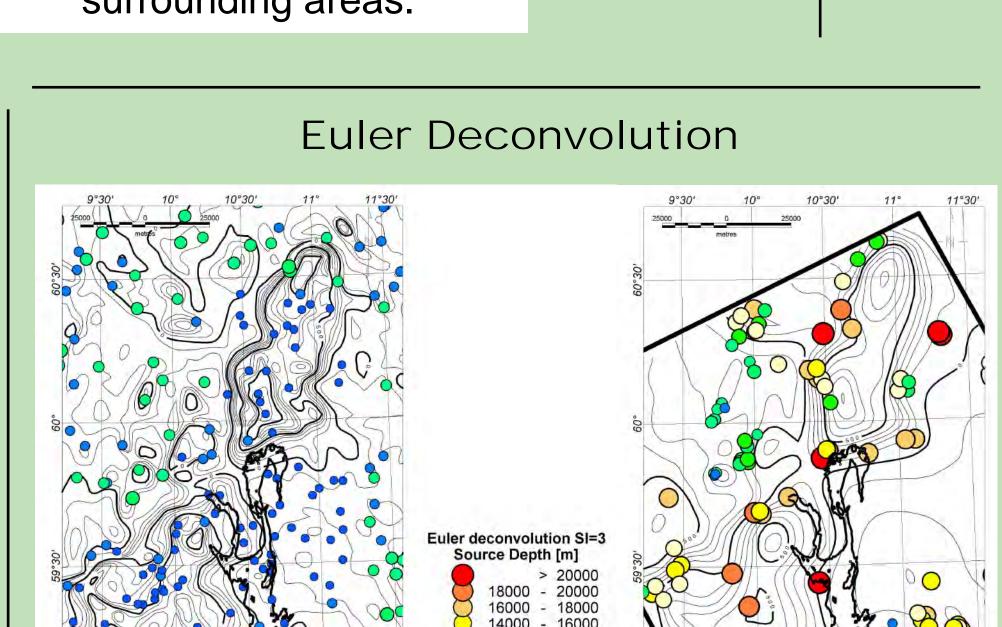
The upward continued data set is similar to the highaltitude data set outside the Graben area, but shows large differences for the Oslo Graben itself.

Survey specifications

Survey
NameFlight
yearAltitude
spacingLine
spacingNormal field
IDTo

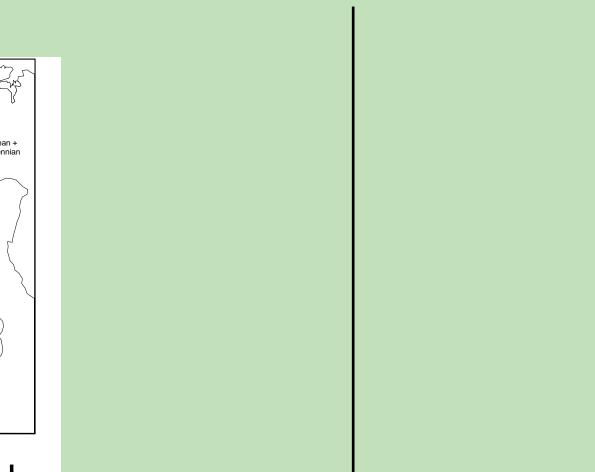




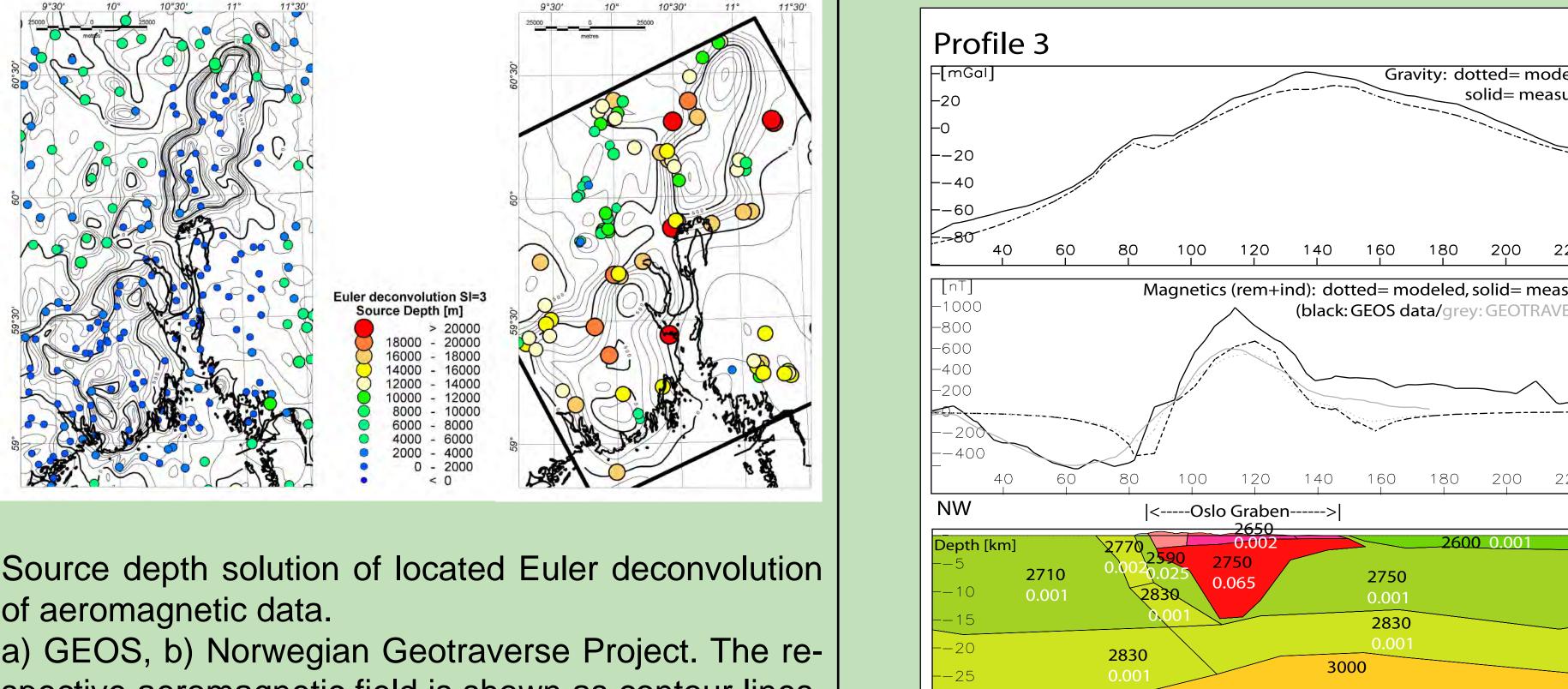


Source depth solution of located Euler deconvolution of aeromagnetic data.

a) GEOS, b) Norwegian Geotraverse Project. The respective aeromagnetic field is shown as contour lines. The large square in b) is indicating the area of available high-altitude data. Note: only solutions with depth uncertainty <10% are shown.



Geological map, location of petrophysical samples in the Oslo Graben region, and Bouguer anomaly. a) simplified geological map after Lutro and Nordgulen [2004], b) measured densities, c) magnetic susceptibilities. The gray area in b) and c) is indicating the surface expression of the Oslo Graben. d) Bouguer anomaly



Simultaneous forward modeling

Profile 3 crossing the southern Oslo Graben in the 3D crustal model. The upper panel shows observed and modeled Bouguer gravity, in the middle the observed and modeled magnetic anomaly for the GEOS (50 m a. ground) and Geotraverse (3400 m a.s.l.) data are shown. The lower panel shows the crustal density (black numbers in kg/m³) and magnetic (white numbers: susceptibility in SI) structure. The high-magnetic bodies are interpreted to represent the magmatic intrusions.

Simultaneous modeling of magnetic field at two altitudes especially helps to define the extent and thickness of the magmatic

(a) bottom of shallow (b) bottom of deep

magmatic intrusion.

Simultaneous modeling of aeromagnetic = datasets collected at two flight altitudes using susceptibility and remanence within a range of reasonable magneti properties suggests an underlying intru sion with a depth extent up to 15 kg

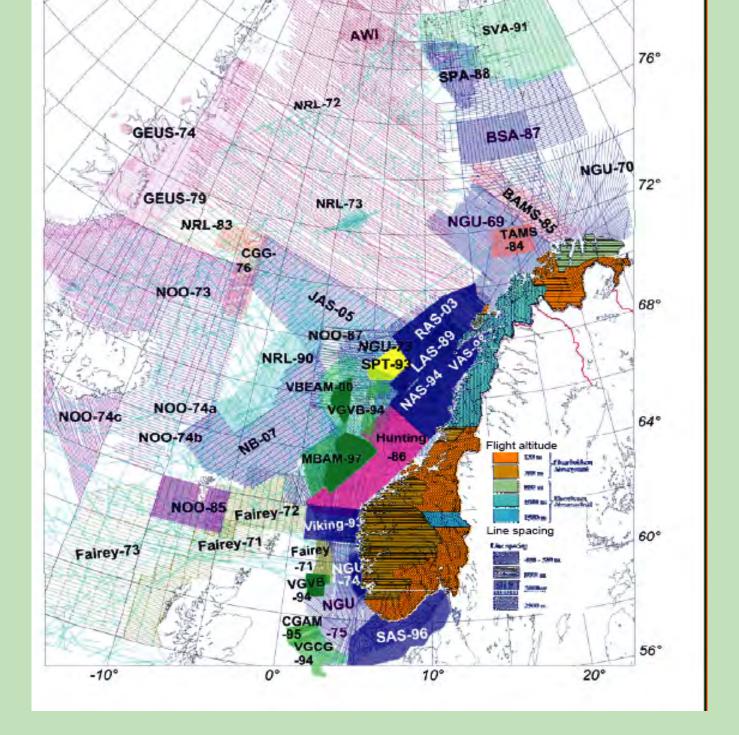
below the Oslo Graben. Only modeling of the magnetic fields ca esolve the nature of the deep intrusions The 3D model provides a new estimate the volume of magmatic material in th Oslo Graben system (~63,000 km³); th is only 2/3 of the values proposed earli

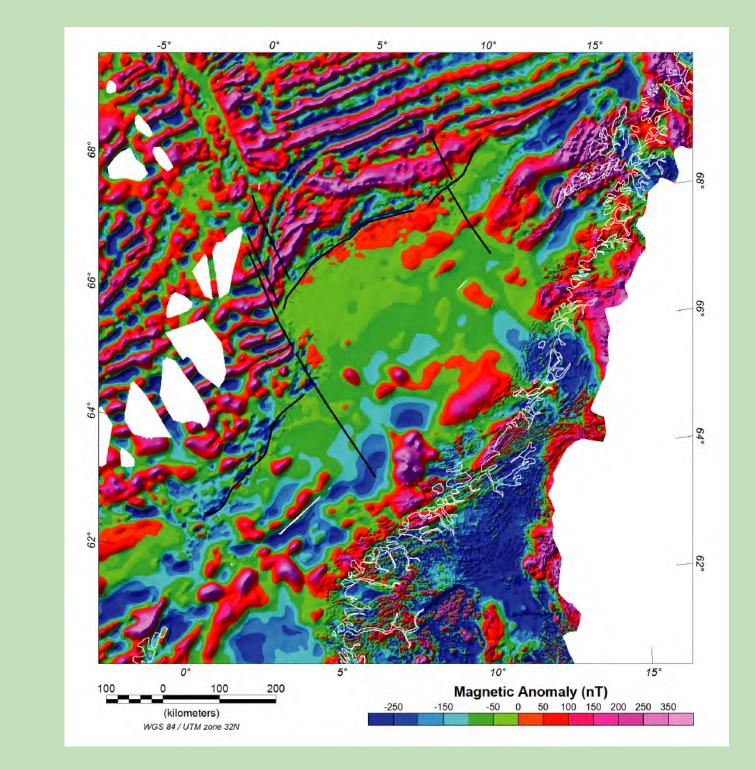
Basaltic lavas Rhomb-porphyry lavas Rhyolitic lavas	0.05 (0.0005-0.11) 0.011 (0.0001-0.058)	0.035	4.0 (1.6-24.8) 2.2	0.5	2950 (2700-3100) 2680	2900 2700	300 1,250	300 ~1,200
lavas	0.011	0.01	` ,	0.5	` ′	2700	1 250	1 200
lavas		0.01	2.2	l (J.,)				
	(0.0001-0.038)	4	(0.2-15.8)		(2480-2770)	2700	1,230	~1,200
Kilyonuc iavas	0.001	0.002-0.02	0.32	0.1-1	2645	2550	100	50 a)
•	0.001	0.002-0.02	(0.3-0.34)	0.1-1	2620-2670	2330	100	30
trusive rocks	0.001-0.002		(0.5-0.5+)		2020-2070			
	0.058	0.001-0.08	9	0.1-0.7	3040	3000	50	~5 a)
			(0.2-64)					
Larvikites	0.032	0.025-0.04		0.3-1	2700	2650	2,000	10,000
	(0.0001 - 0.109)		(0.04-48)		(2550-3090)		ŕ	ŕ
Syenites, granites,	0.016	0.015-0.035	1.6	0.1-1	2610	2600	7,600	14,045 a)
etc.	(0.0001 - 0.136)		(0.1-27.1)		(2490-2980)			
xposed magmatic							11,300	25,600
ense, subsurface								
Vestfold		0.045-0.065		0.4-1		2750	25,000	4,610 ^{a)}
Nordmarka		0.020-0.055		1-1.5		2780		
Magmatic rocks in		< 0.0001		0.5	2950-3100	3000	<9,000	65,000
the deep								
crust/upper mantle								
OTAL							~62,800	> 95,200
	Gabbroic rocks Larvikites Syenites, granites, etc. Aposed magmatic cks, total ense, subsurface odies Vestfold Nordmarka Magmatic rocks in the deep crust/upper mantle	Gabbroic rocks (0.0009-0.165) Larvikites 0.032 (0.0001-0.109) Syenites, granites, etc. (0.0001-0.136) Aposed magmatic cks, total ense, subsurface odies Vestfold Nordmarka Magmatic rocks in the deep crust/upper mantle	Gabbroic rocks (0.0009-0.165) Larvikites (0.0001-0.109) Syenites, granites, etc. (0.0001-0.136) Caposed magmatic cks, total ense, subsurface odies Vestfold Nordmarka Magmatic rocks in the deep crust/upper mantle	Gabbroic rocks	Gabbroic rocks 0.058 (0.0009-0.165) 0.001-0.08 (0.2-64) 9 (0.2-64) 0.1-0.7 (0.2-64) Larvikites 0.032 (0.0001-0.109) 0.025-0.04 (0.04-48) 4.2 (0.04-48) 0.3-1 (0.04-48) Syenites, granites, etc. 0.016 (0.0001-0.136) 0.015-0.035 (0.1-27.1) 1.6 (0.1-27.1) 0.1-1 (0.1-27.1) Apposed magmatic cks, total cks, total 0.045-0.065 0.4-1 0.020-0.055 Nordmarka 0.020-0.055 0.5 Magmatic rocks in the deep crust/upper mantle <0.0001	Gabbroic rocks	Gabbroic rocks 0.058 (0.001-0.08 9 (0.2-64) (2760-3300) 3000 (2760-3300) (2760	Gabbroic rocks 0.058 (0.001-0.08 9 (0.2-64) (2760-3300) 50 Larvikites 0.032 (0.001-0.109) (0.04-48) (2550-3090) (

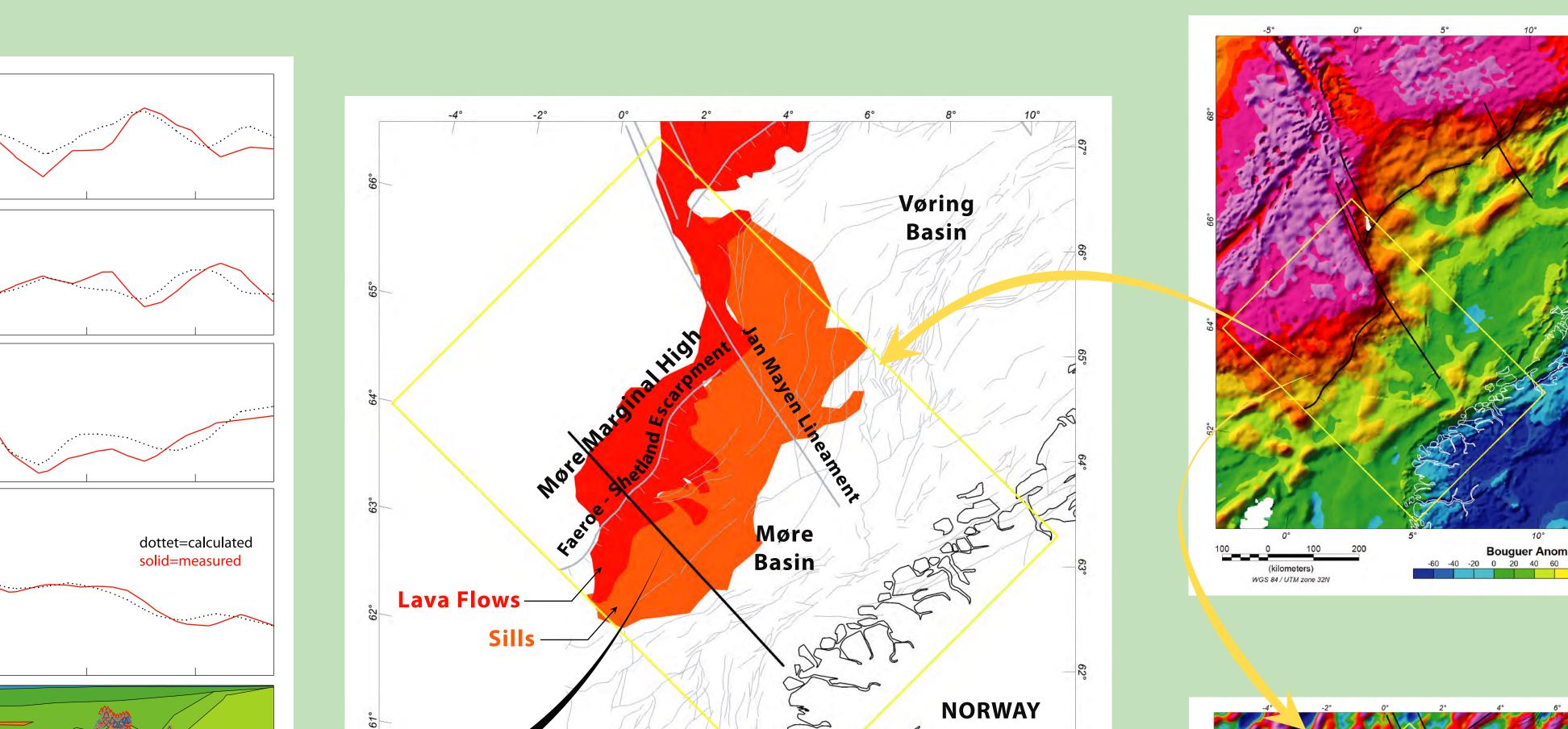
Mid-Norway

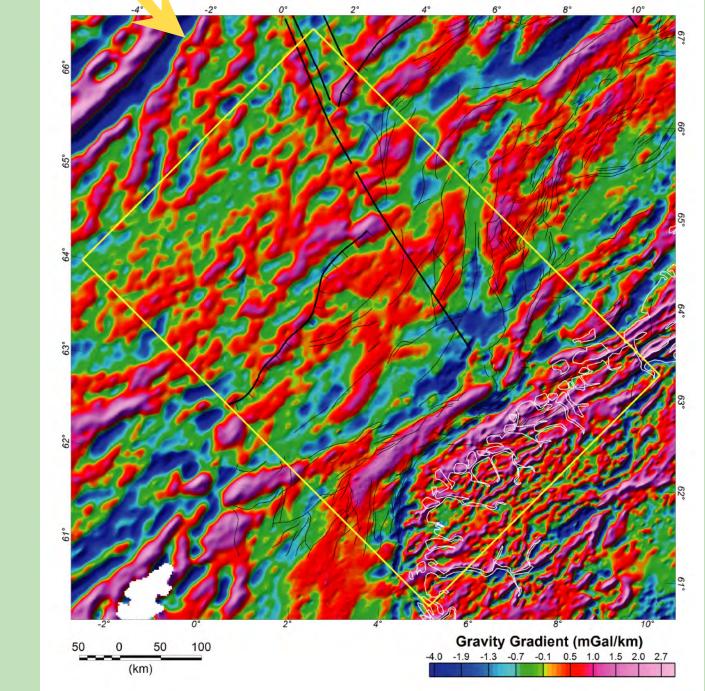
On the Norwegian margin, NGU has aquired a vast amount of aeromagnetic data sets (see overview of surveys), and is also maintaining the gravity data base for the margin and onshore Norway. Routinely, techniques like Euler deconvolution have been combined with seismics to study the crustal configuration of the margin in terms of top basement, crustal base and extent of intrusives.

Below we show an example from the Møre margin, where gravity and magnetic data have been integrated with seismic data to study the marginal architecture and the extent of volcanics, also using calculated horizontal gradients.









StatoilHydro

Sub-basaltic structures and basalt thickness estimates have been acquired on the Møre margin by integrating gravity, magnetic and seismic data but the estimates contain considerable uncertainty. Feasibility studies, tailored to the margin, indicate that a further integration with CSEM and MT methods would increase the confidence in the estimates.

References

Density Susc. Q

Water 2.20
Cenozoic 2.10 0.002 0.1
Cretaceous 2.40 0.0003 0.1
Pre-Cretaceous 2.55 0.0003 0.1
Cont. Basement 2.70 0.02 1
Cont. Lower Crust 2.85 0.02 1

Aalstad. I., K. Åm, H. Håbrekke, and O. Kihle (1977), Aeromagnetic investigations along the Norwegian Geotraverse, in The Norwegian Geotraverse Project: A Norwegian contribution to the international upper mantle project and the international geodynamics project, edited by K.S. Heier, pp. 77-98, Geological Survey of Norway (NGU), Trondheim. Heier, K.S. (1977), The Norwegian Geotraverse Project: A Norwegian contribution to the international upper mantle project and the international geodynamics project; Geological Survey of Norway (NGU), Trondheim

Neumann, E.-R. (1994), The Oslo Rift: P-T relations and lithospheric structure, Tectonophysics, 240, 159-172.

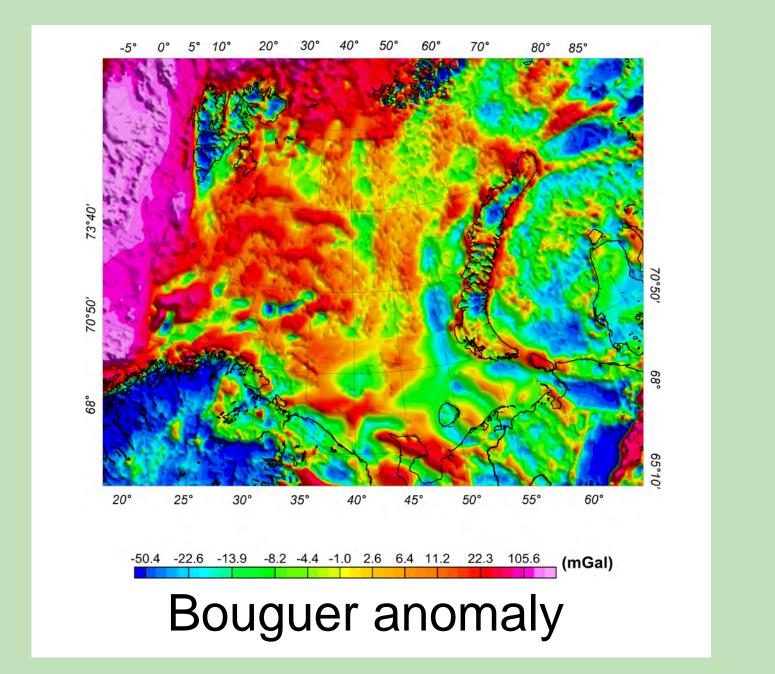
Acknowledgements

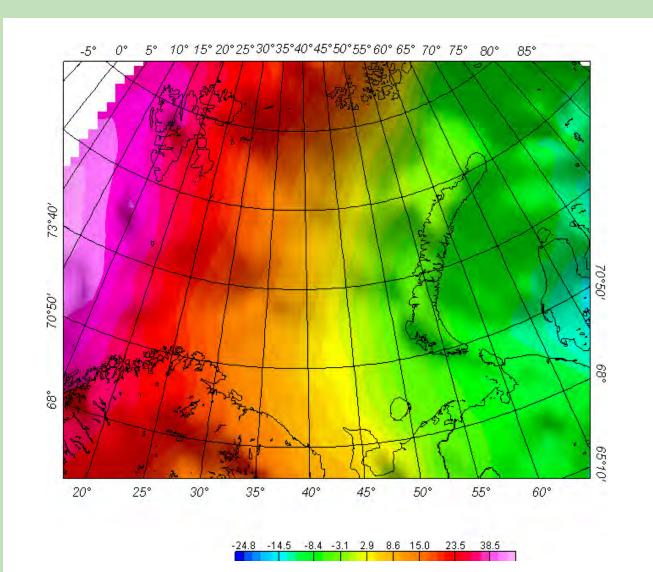
The presented examples are results from the GEOS project funded by NGU, and project focusing on the Møre margin and Barents Sea, funded by Shell and StatoilHydro and the Norwegioan Research Council.We achnowledge also the different sponsors for the individual surveys on the Norwegian continental margin.



Barents Sea

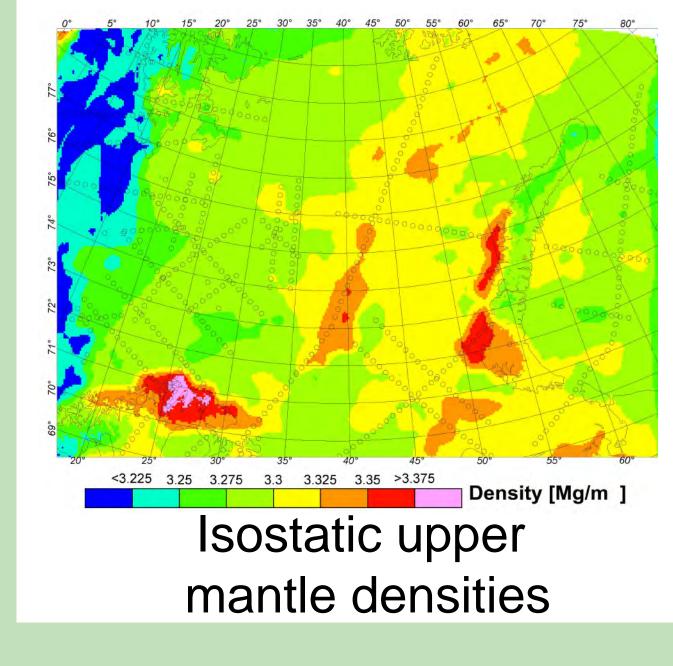
To understand large sedimentary basins, as in the Barents Sea, a combination of satellite derived fields and terrestrial or ship-borne data is helpful. Satellite data help both to level individual data sets from diferent territories, as well as as they give a better constraint on long-wavelength features in the lower crust or upper mantle mantle.





Geoid undulations

Simultaneous modeling of the gravity field and the geoid undulations allows analyzing the lower crust and upper mantle in great detail due to the different dependency to the source distance of the two fields. The figureto the right shows an upper mantle density distribution by this approach based on isostatic consider-



For more details see poster P6 "Satellite Gravity and Geoid Studies Reveal the Formations Underlying Large-Scale Basin Structures" and P31 "Insights into Basin Formation and Lithospheric Structure of the Barents Sea".

Conclusions

Combining different data sets at multiple altitudes and of different spectral information allows more precise forward modeling.

The case example shows the advantages of this approach in different geological scenarios.

Modern modeling software is overcoming the limitations of analysis of a single-data set.

Joint forward modeling is only the first step of a joint inversion of data sets, like gravity, gravity gradients, magnetics, and even EM and MT

