Depth sensitivity of GOCE gravity gradients for lithospheric modelling

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GOCE Solid Earth workshop
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GOCE satellite data for lithospheric modelling

Data sets from the GOCE mission have two main advantages compared with earlier global gravity models:

(1) The GOCE gravity model has higher resolution in the transitional wavelength between earlier satellite and terrestrial gravity data.

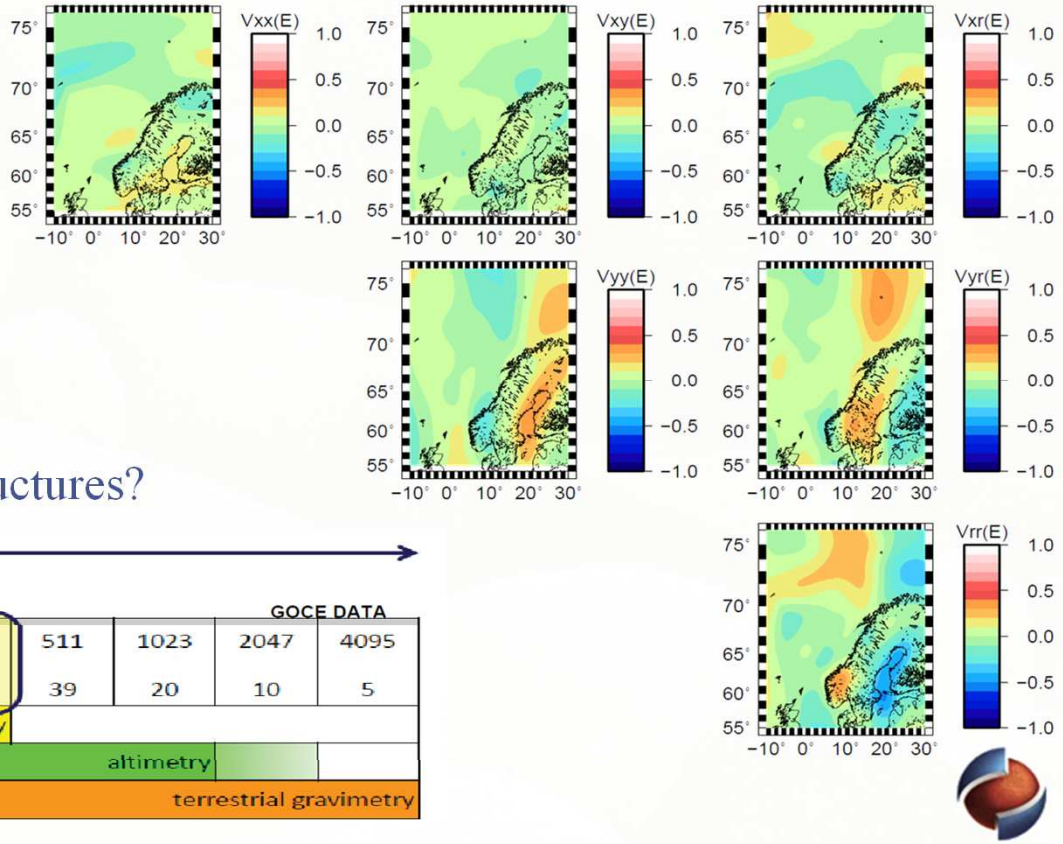
(2) The second and more revolutionary novelty is that GOCE measures gravity gradients.

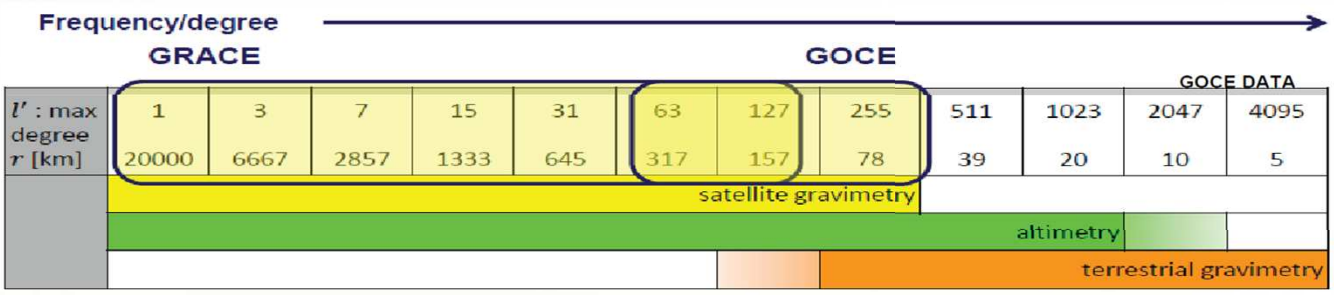
How useful for geophysical research and exploration?

⇒ What is the error if we calculate planar and not spherical?

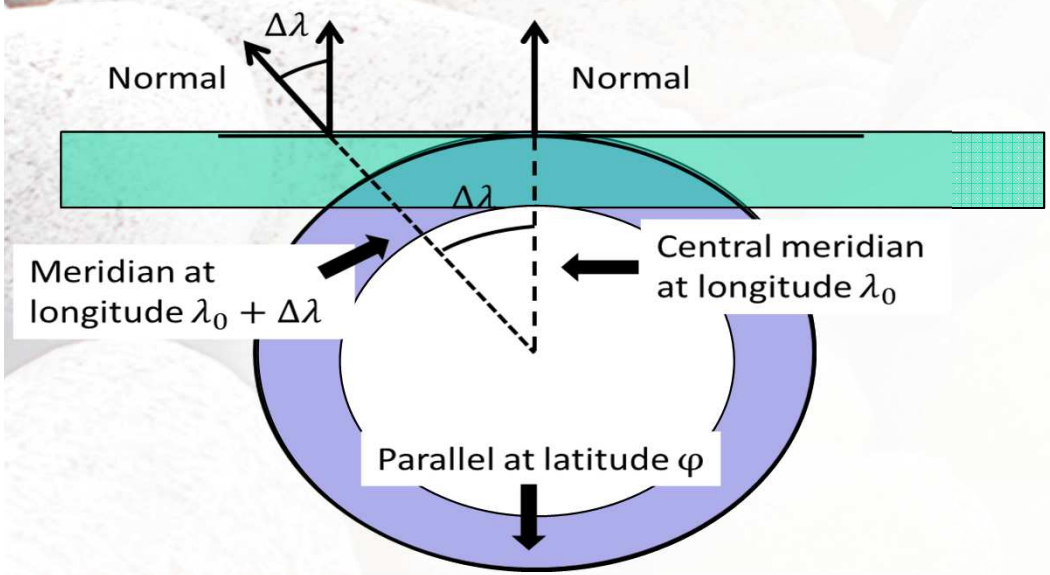
⇒ What is the depth extent visible in gradient data?

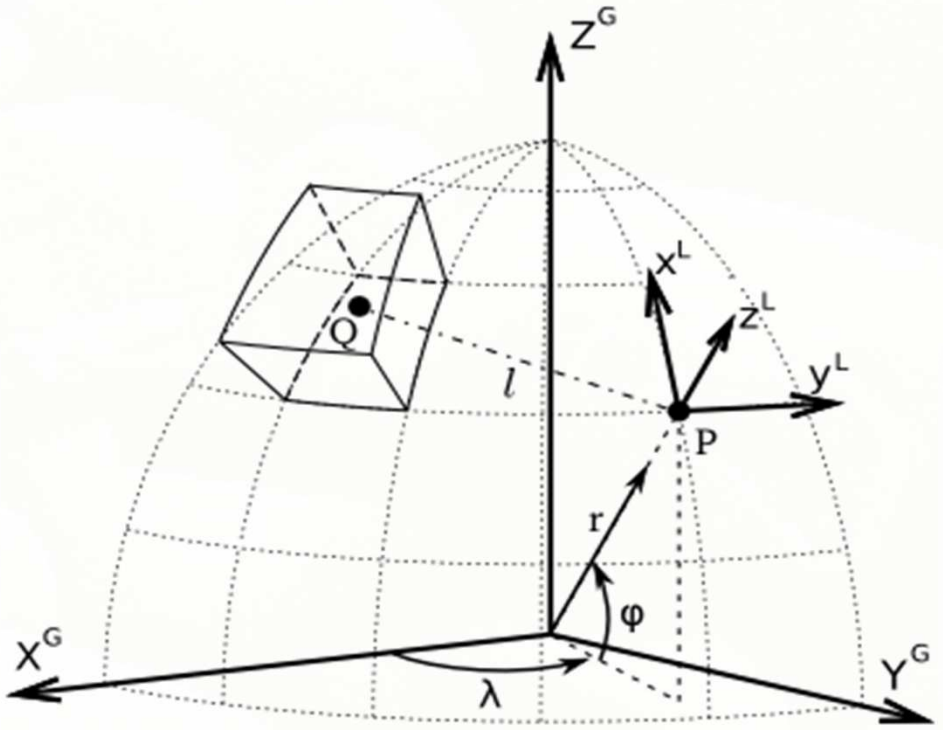
⇒ How can we combine gradients with gravity and geoid to model upper mantle structures?



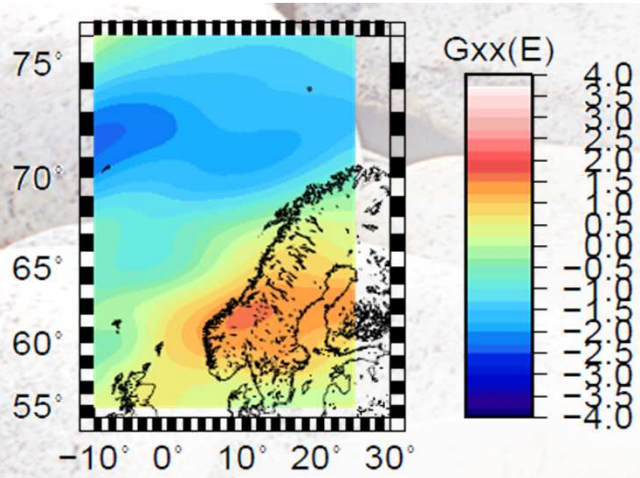


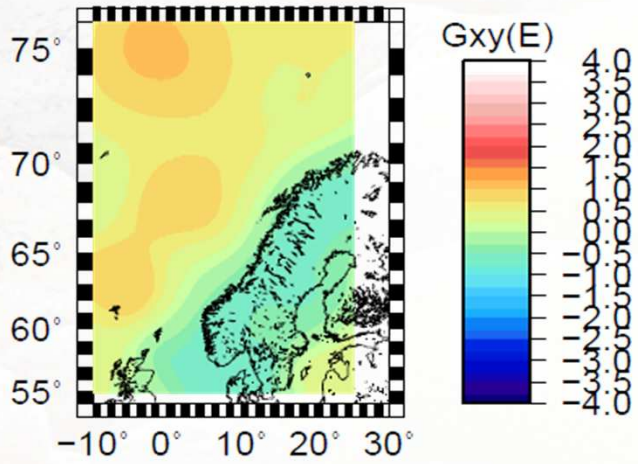
Flat Earth vs. Spherical calculations

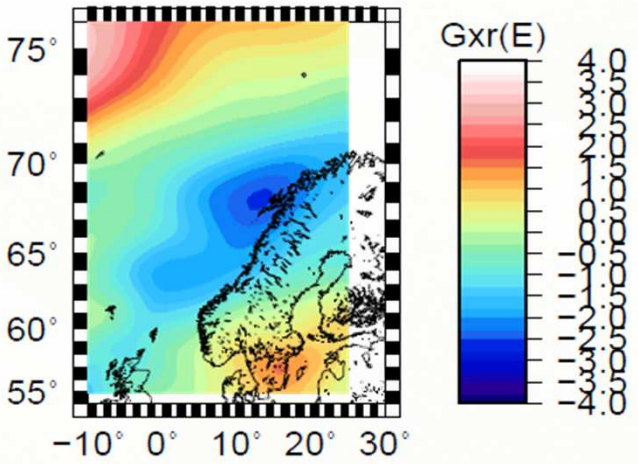


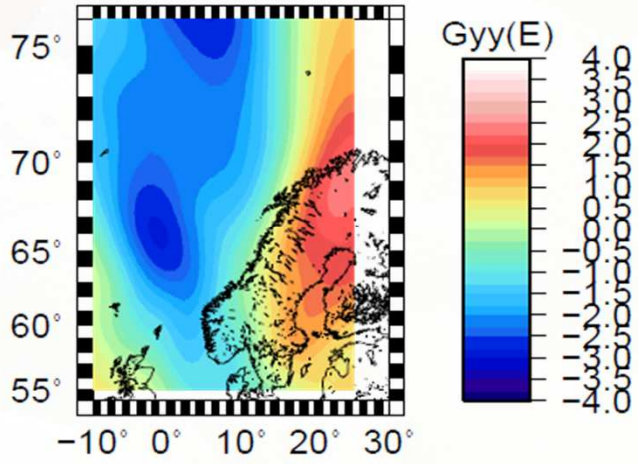


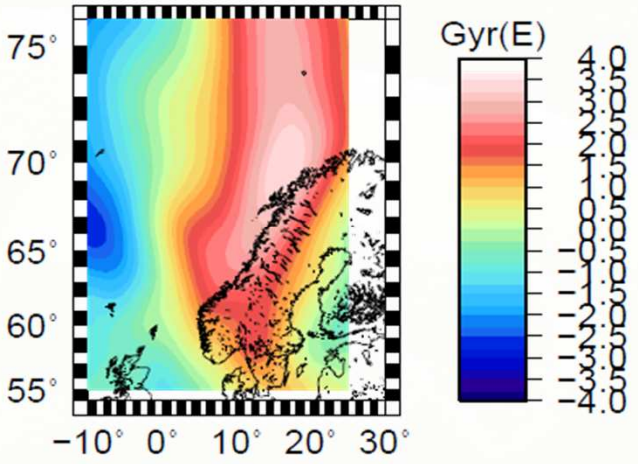
Uieda 2011

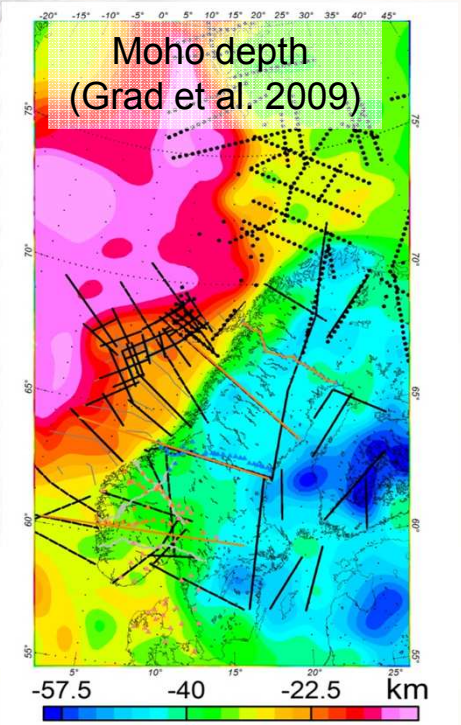


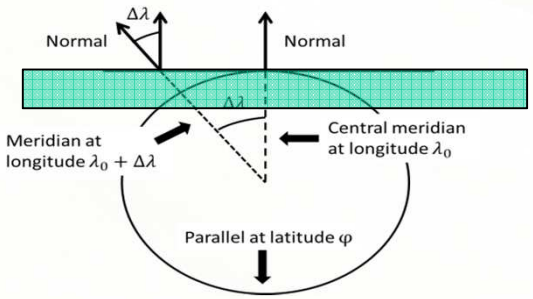


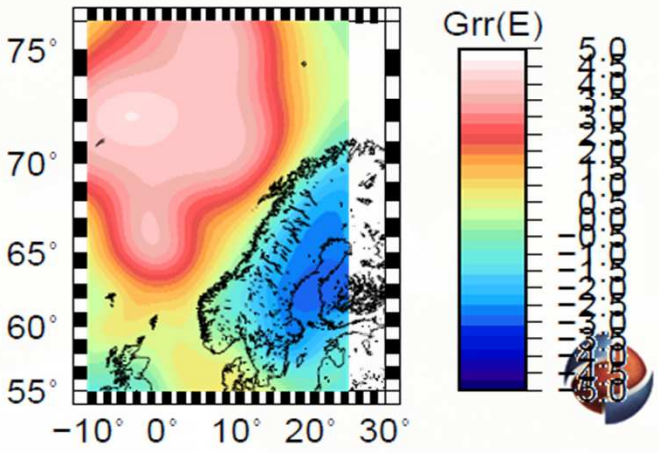




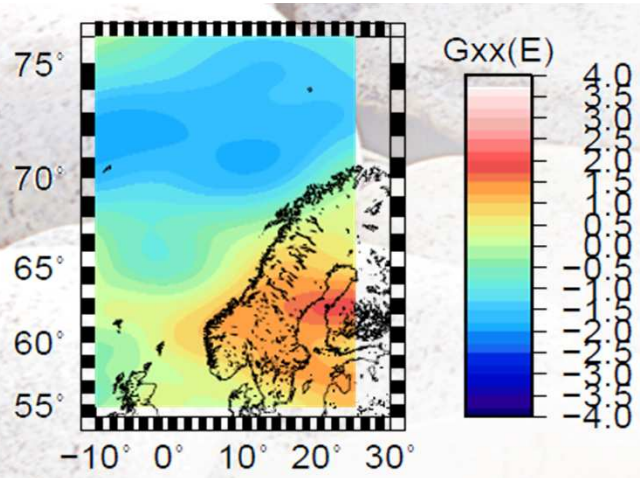


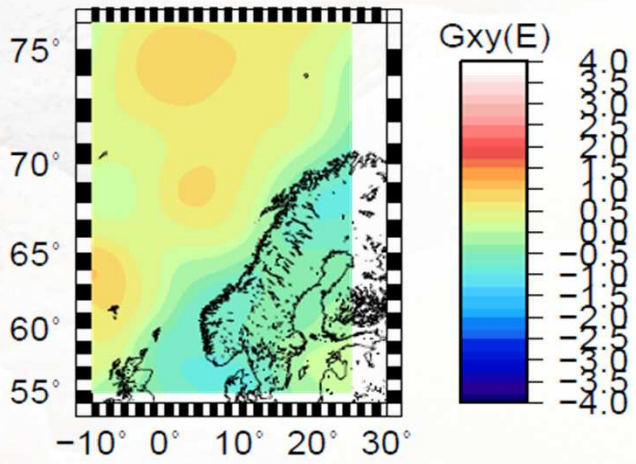


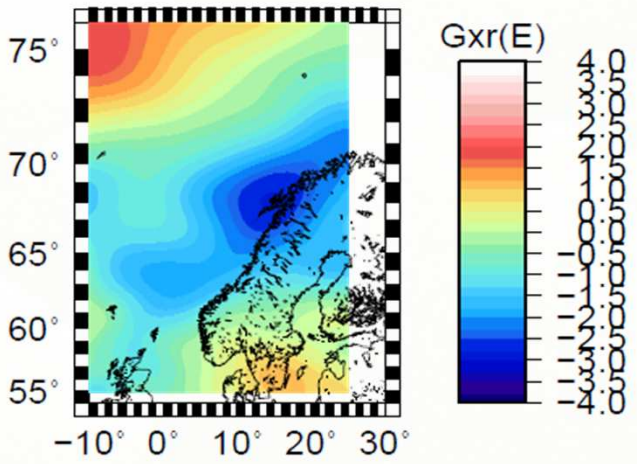


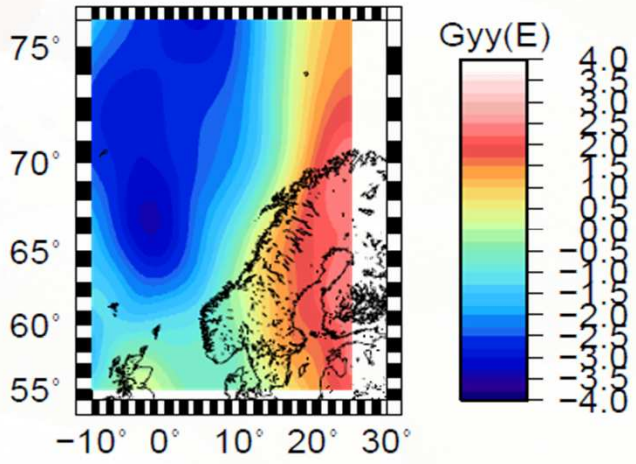


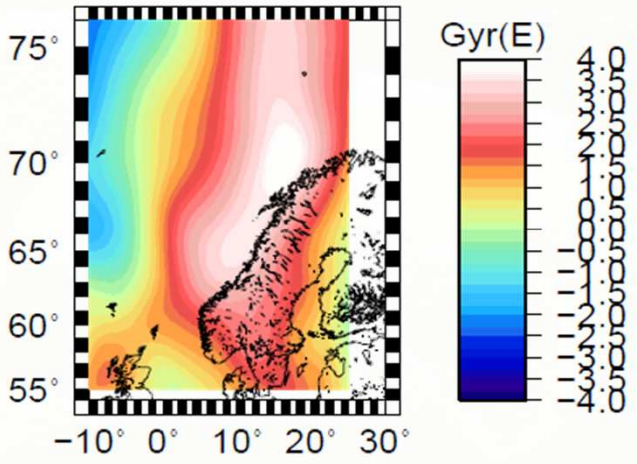
Moho model gradients: Flat Earth

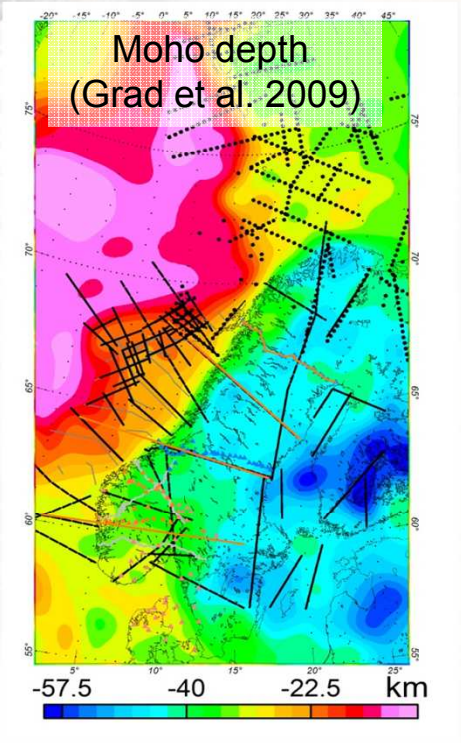


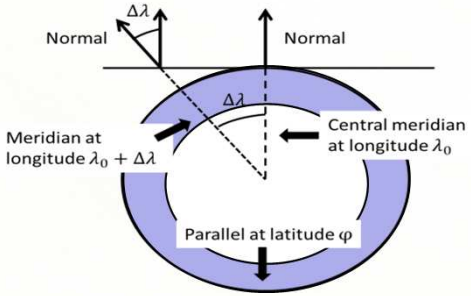


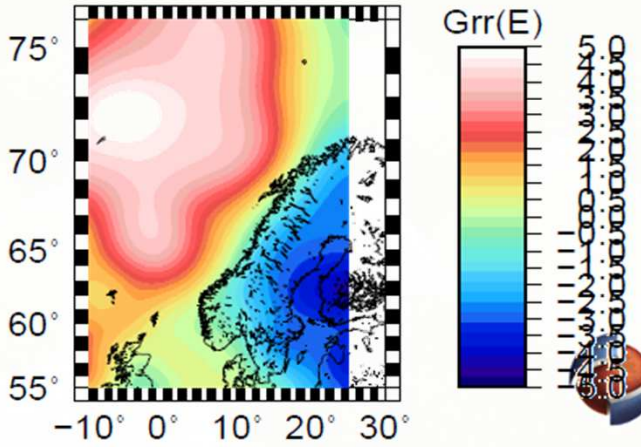












Moho model gradients: Spherical Earth

Depth sensitivity of GOCE gravity gradients

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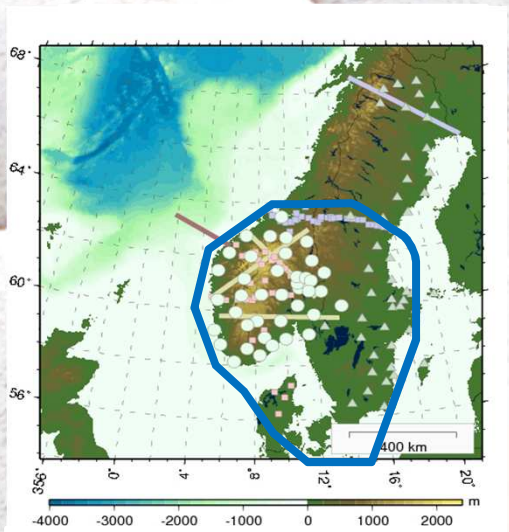
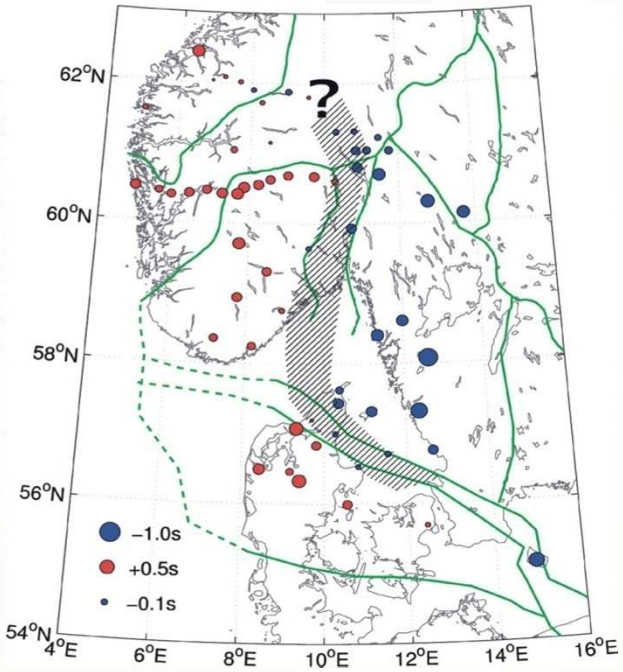
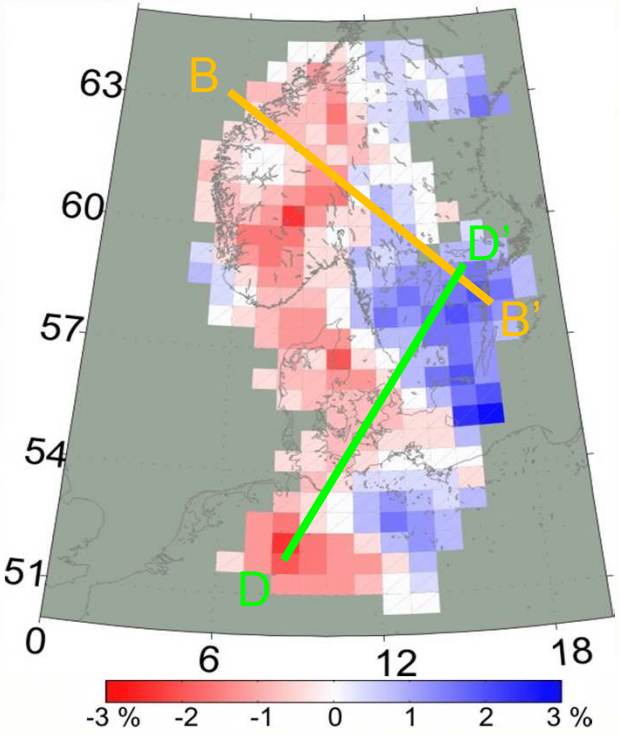
Case study: Southern Norway

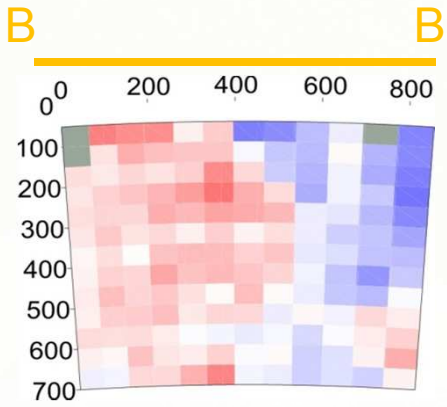


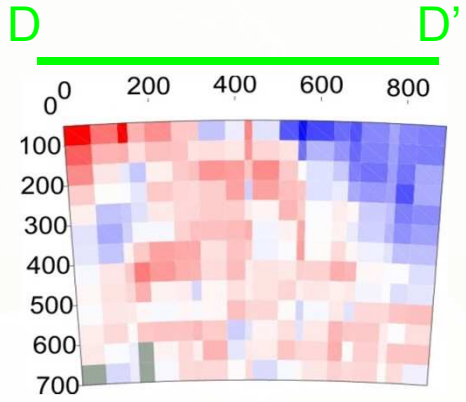


P-wave Residuals
Bondo Medhus et al. (2009)

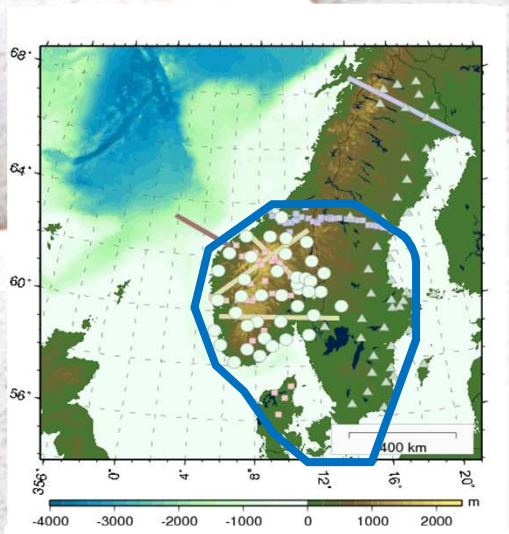
Relative P-wave Tomography (100-200 km)
Bondo Medhus et al. (in press)



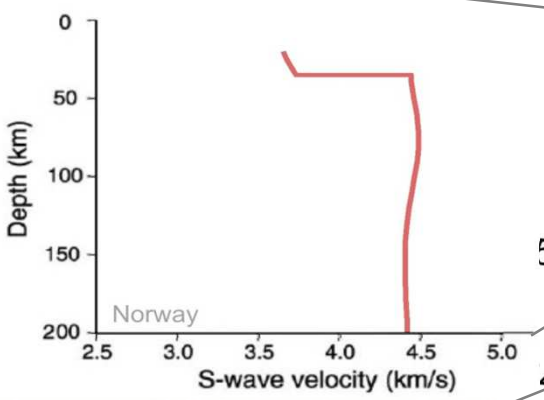




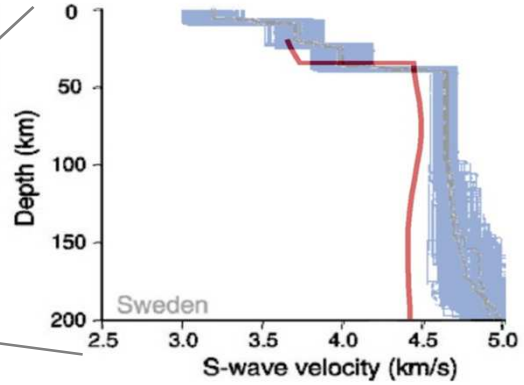
Mantle Velocities and Structure



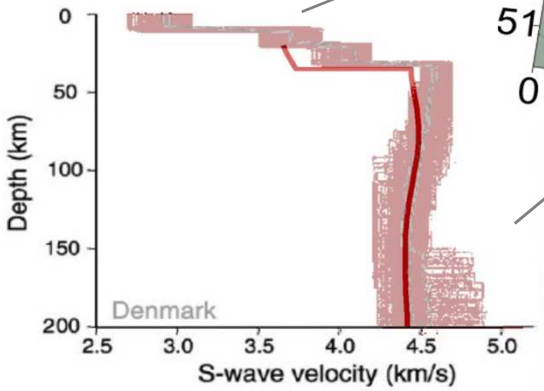
S-wave Velocities
Southern Norway
Maupin (2011)

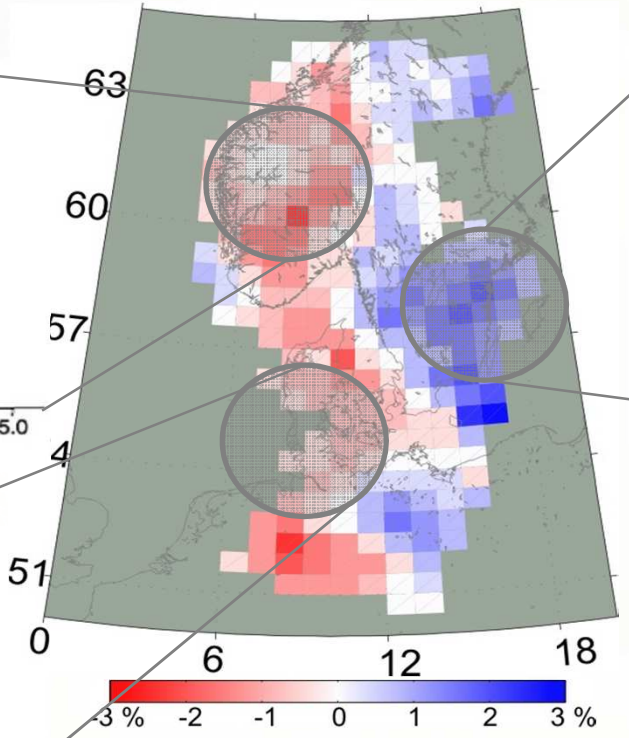


S-wave Velocities
Southern Sweden
Cotte et al. (2002)



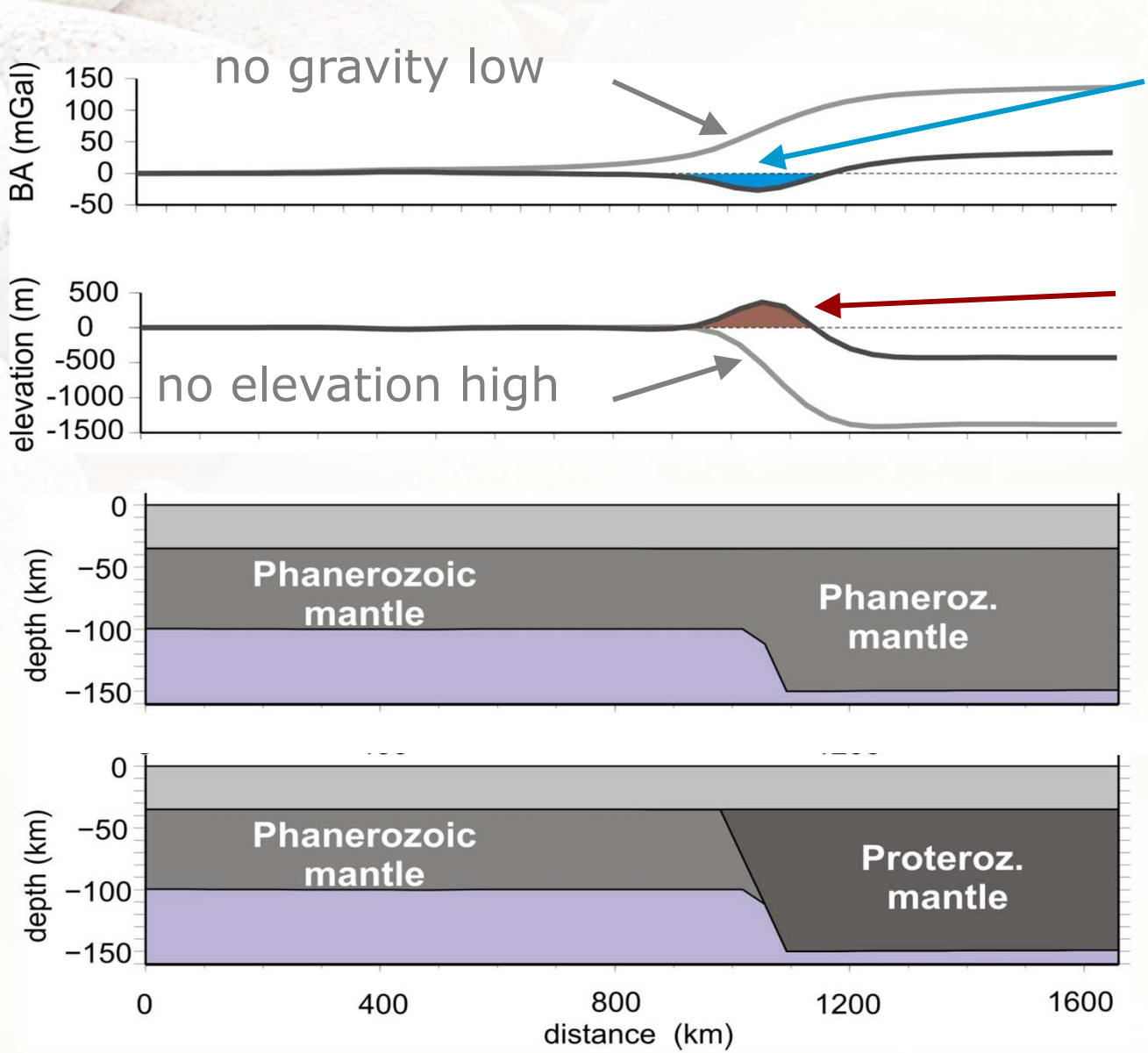
S-wave Velocities
Denmark
Cotte et al. (2002)





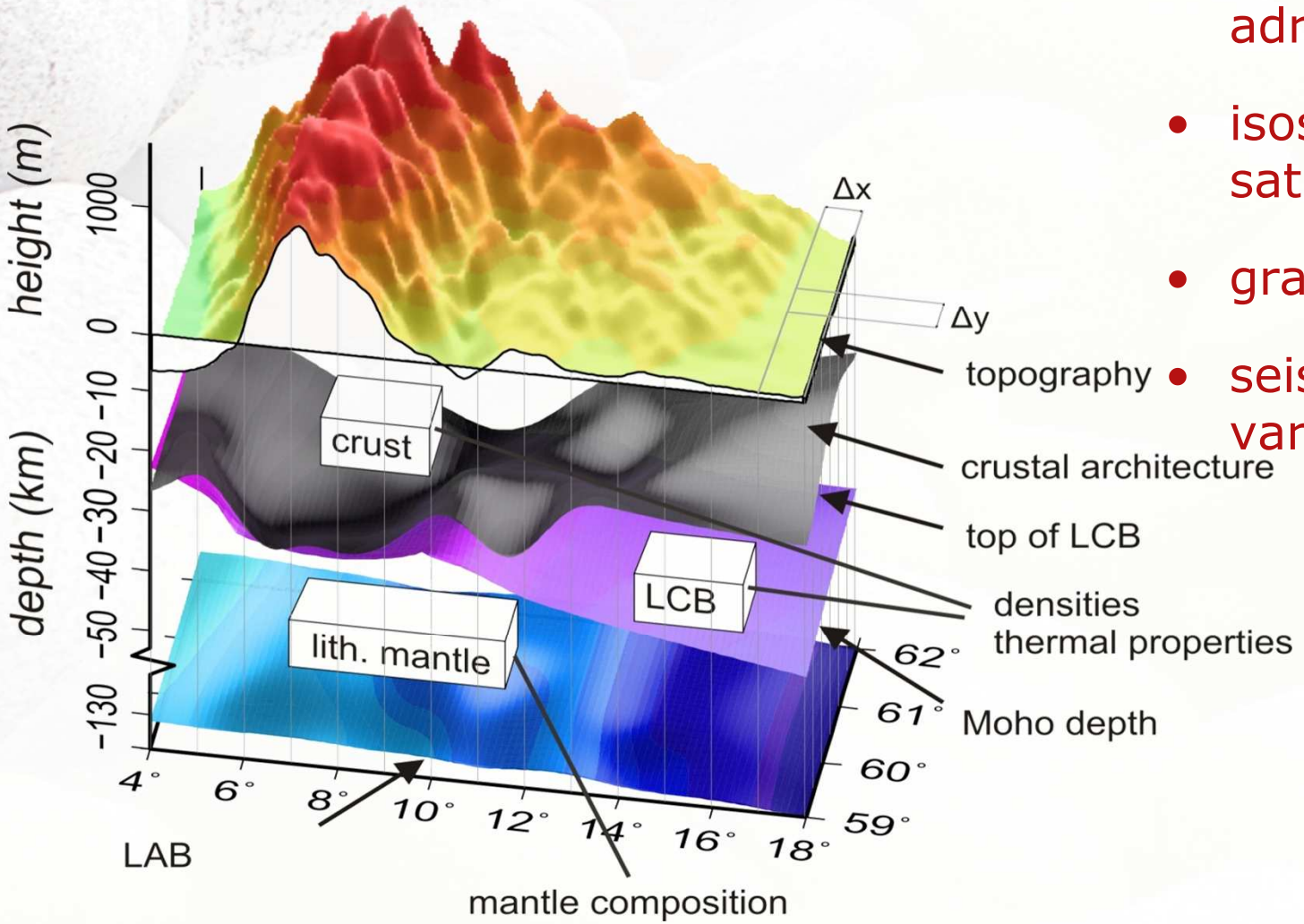
Relative P-wave Tomography (100-200 km)
Bondo Medhus et al. (2012)

Effects on Geophysical Observables



Self-consistent 3D Subsurface Model

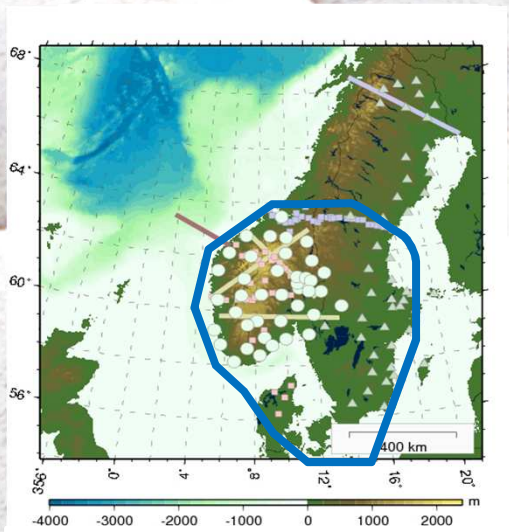
LitMod3D, Fullea et al. (2009)

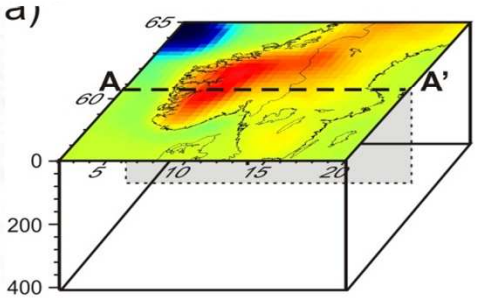


adresses:

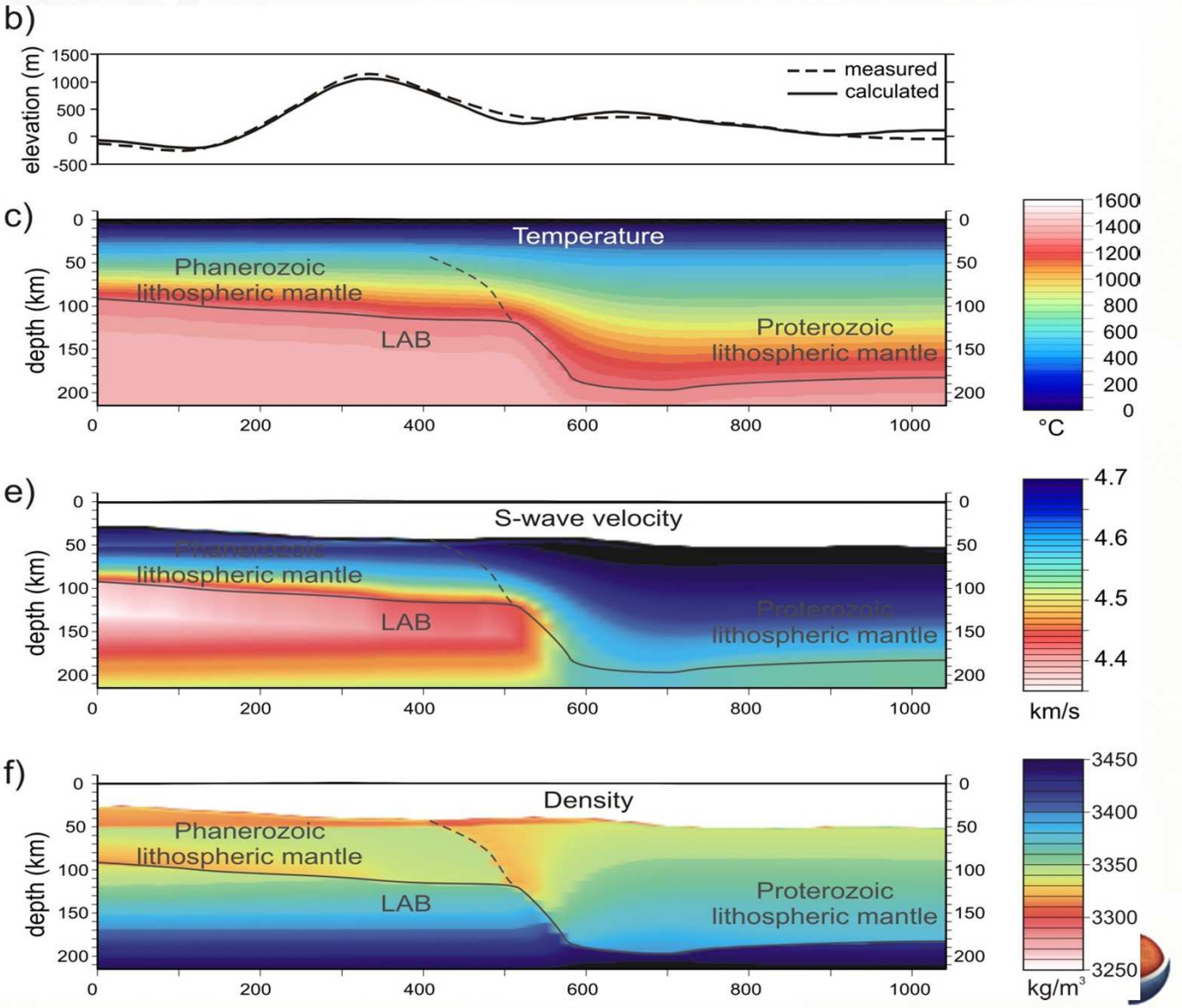
- isostatically compen-sated topography
- gravity anomalies
- seismic velocity variations

Forward modelling with LitMod3D

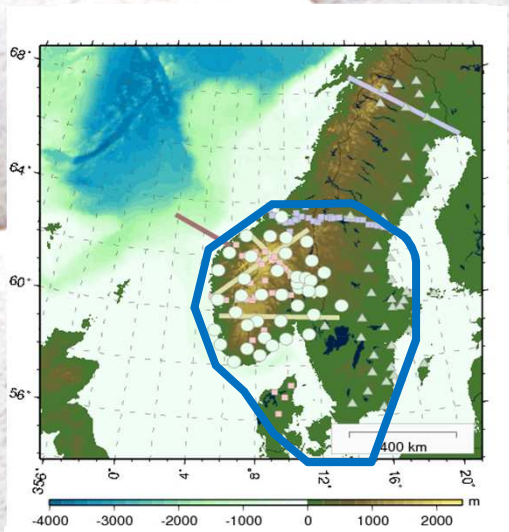


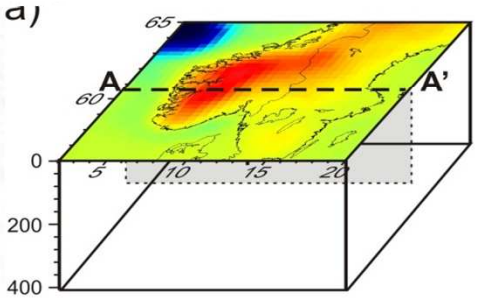


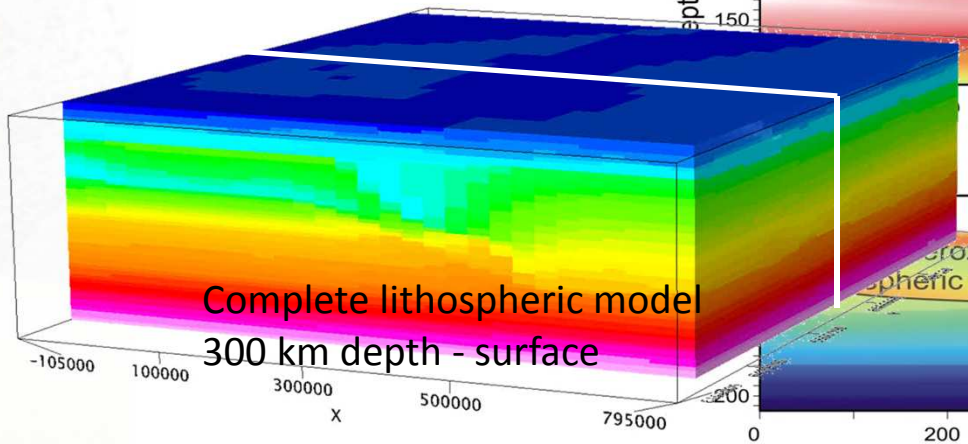
Gradmann et al. 2012

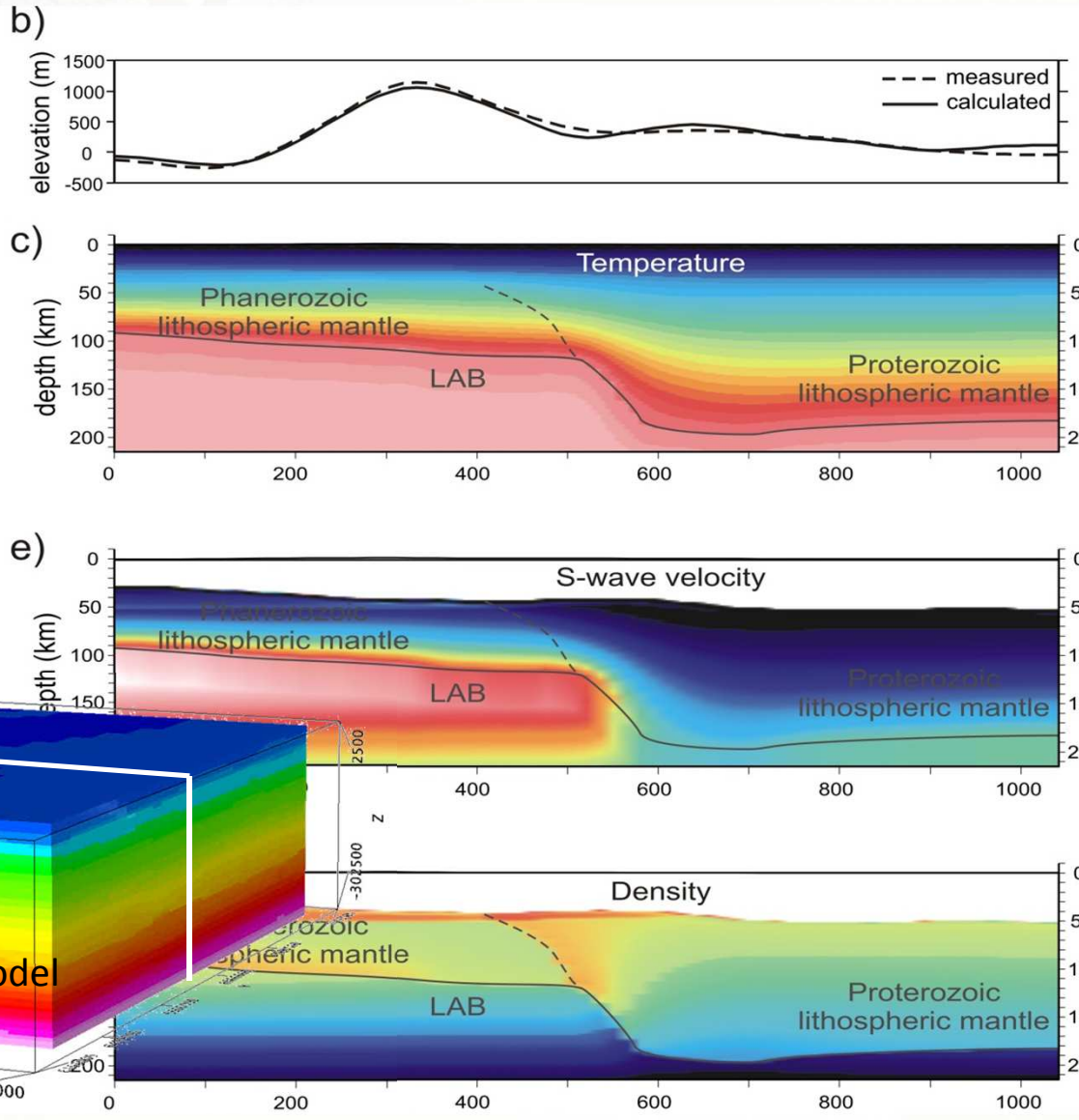


Forward modelling with LitMod3D

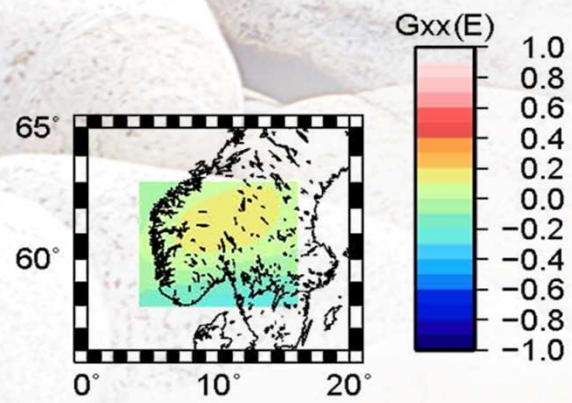


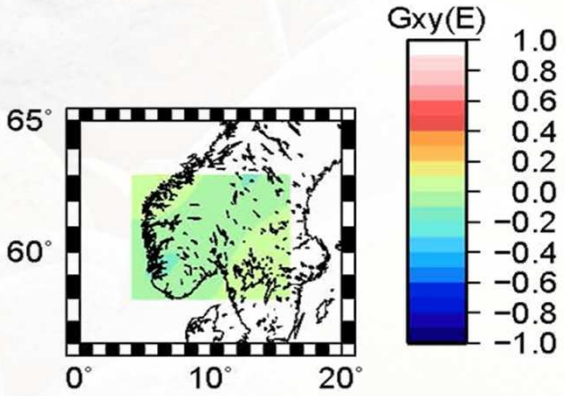


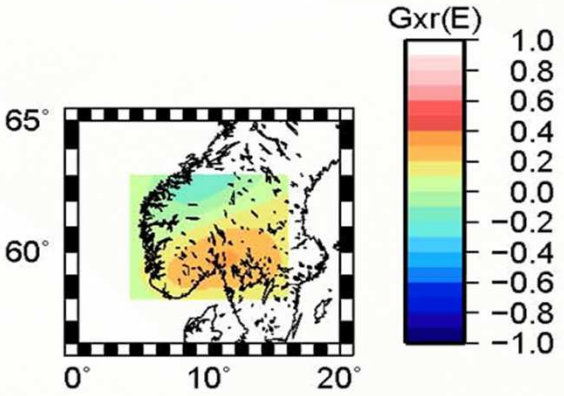


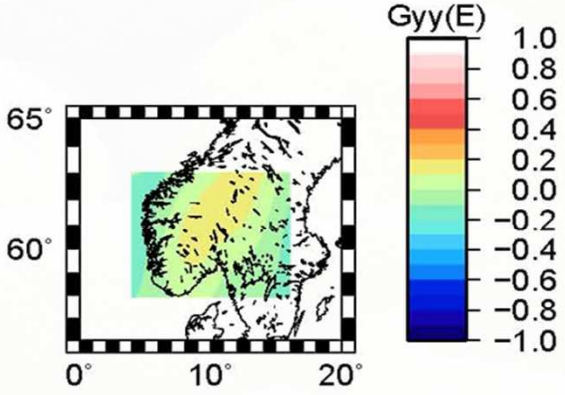


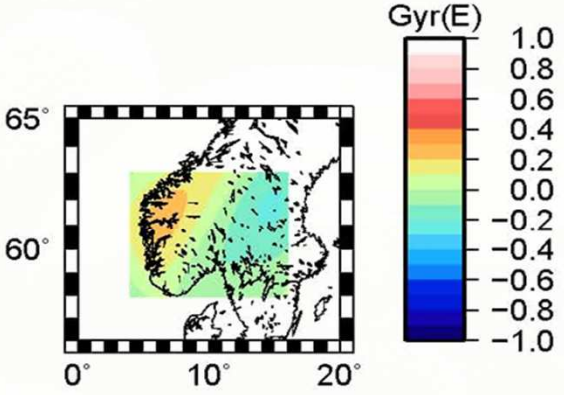
Gravity gradients from complete model at satellite height

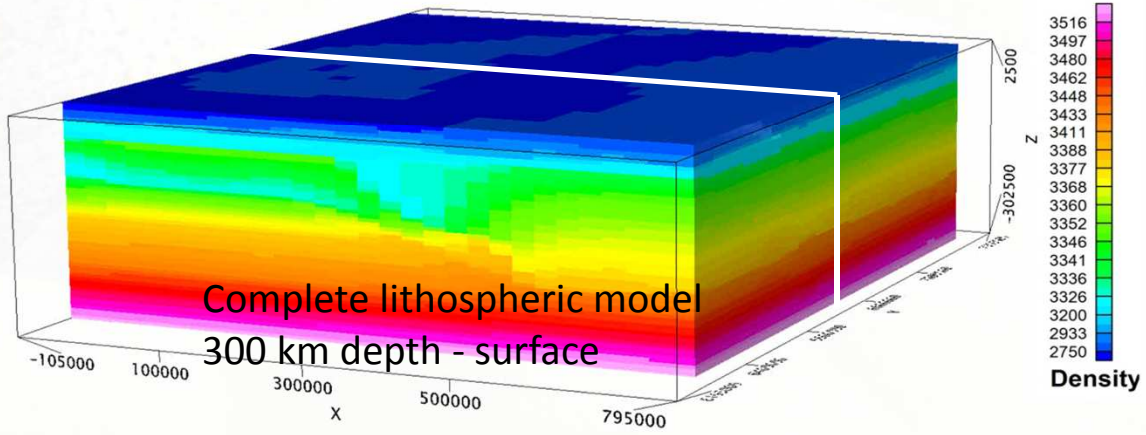




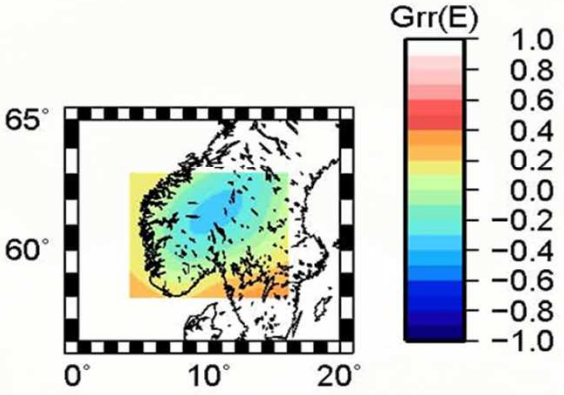








Complete lithospheric model
300 km depth - surface



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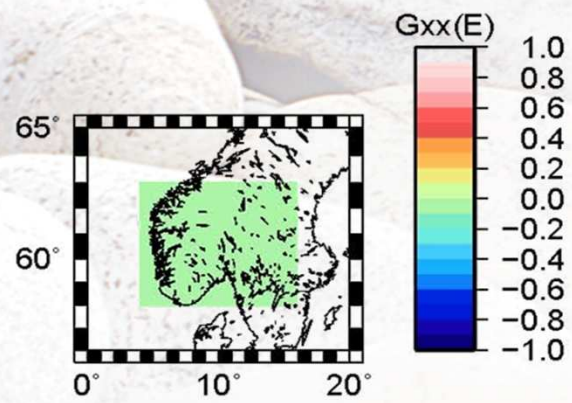

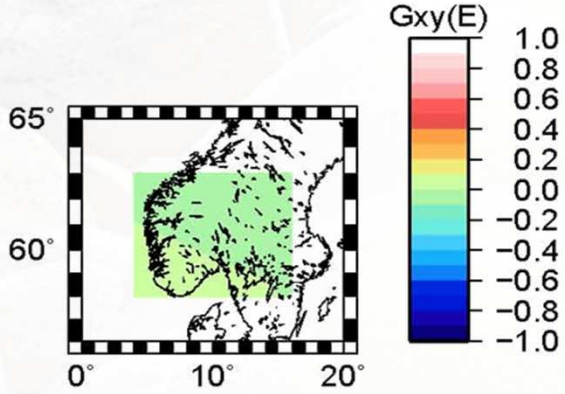

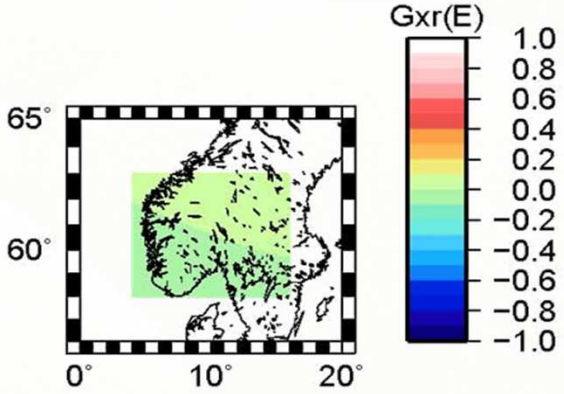

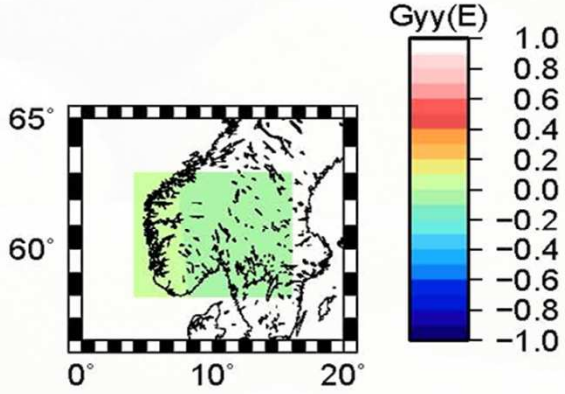

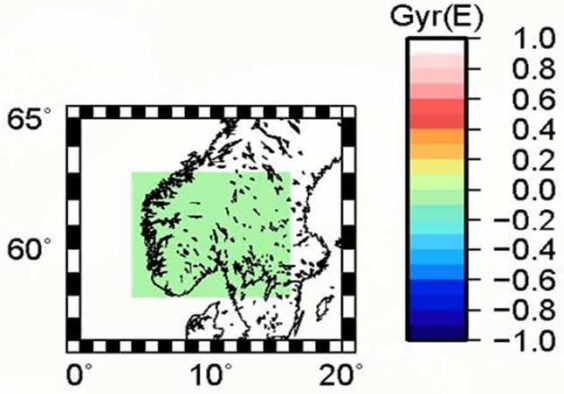

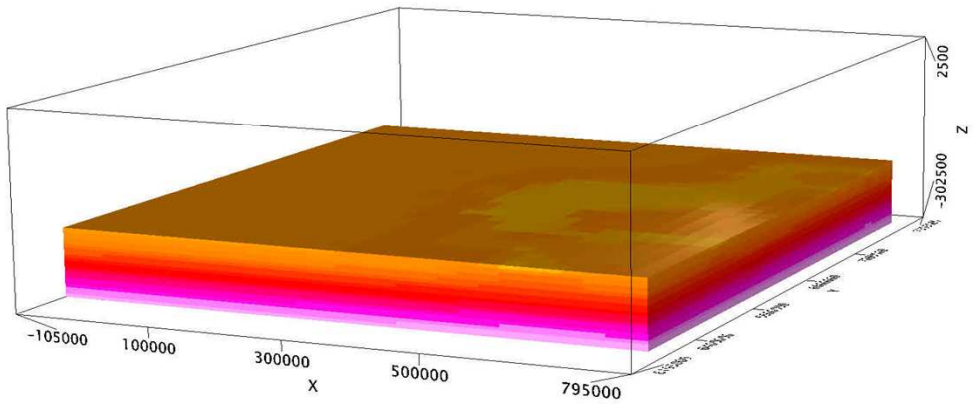

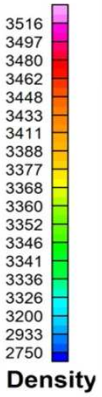

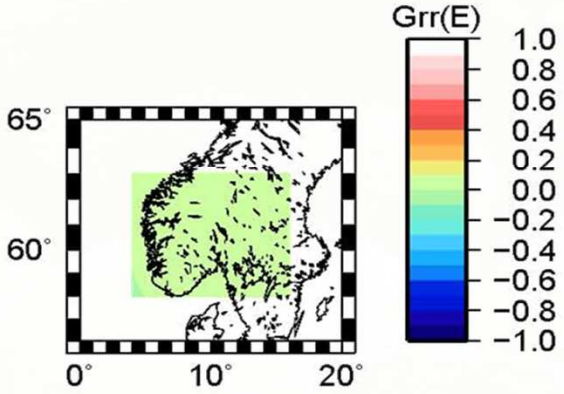

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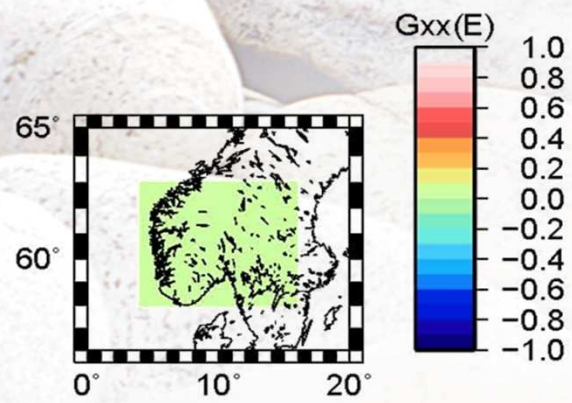
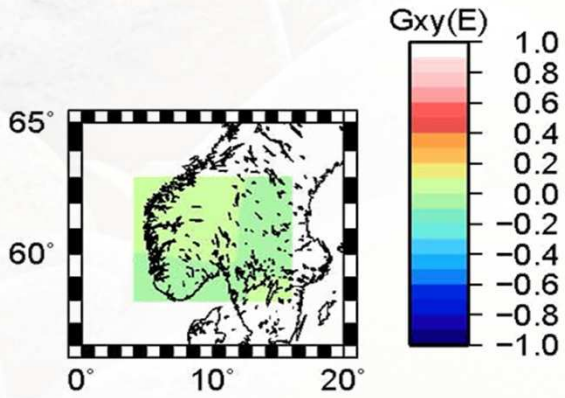
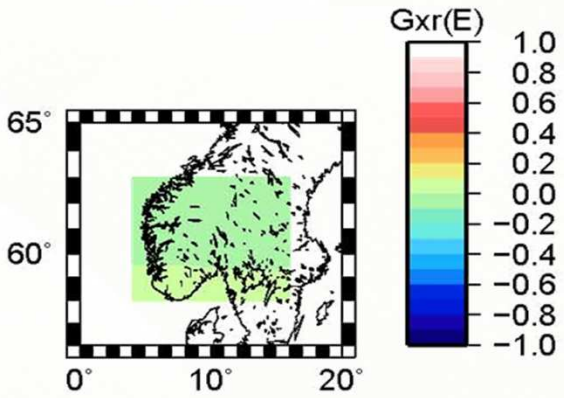
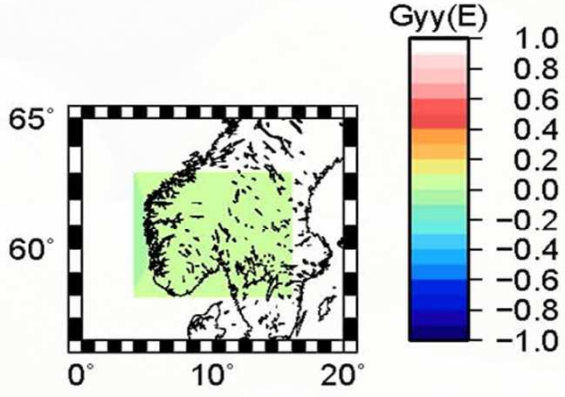
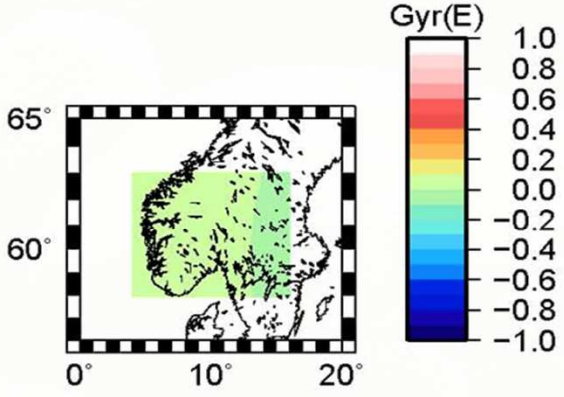
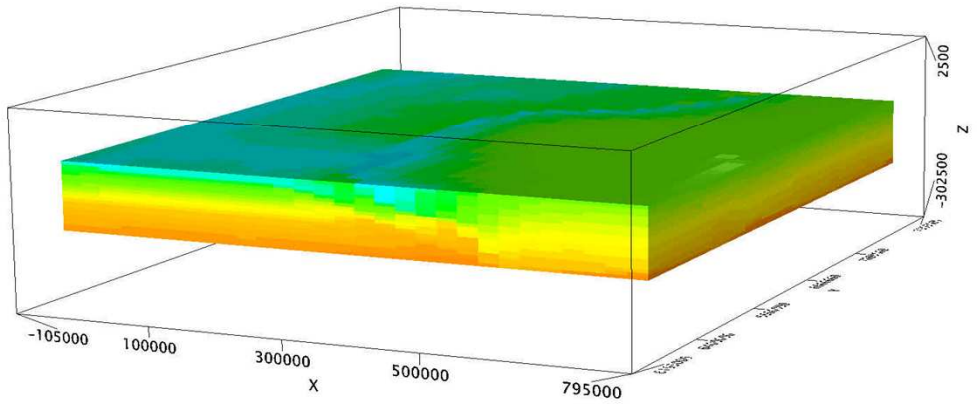


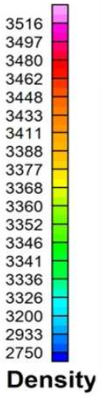


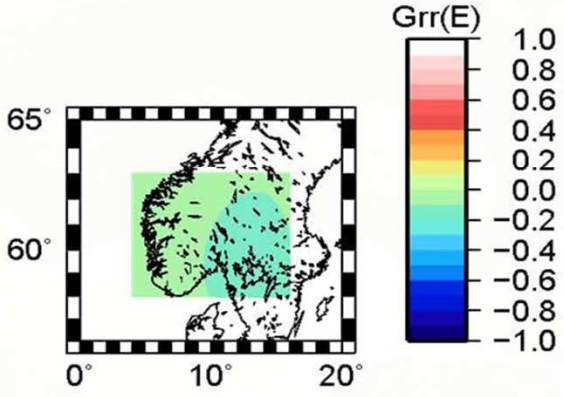




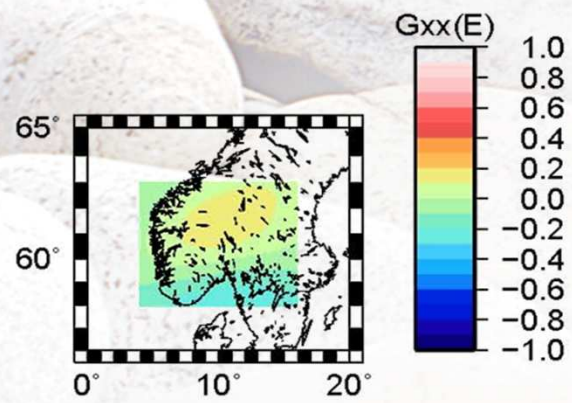


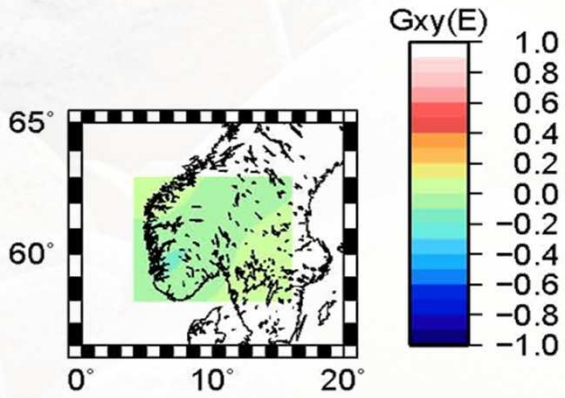


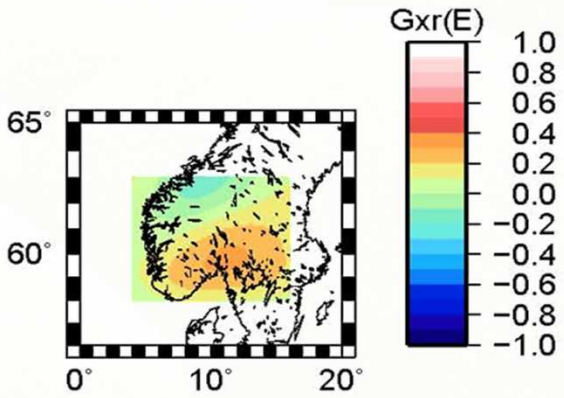


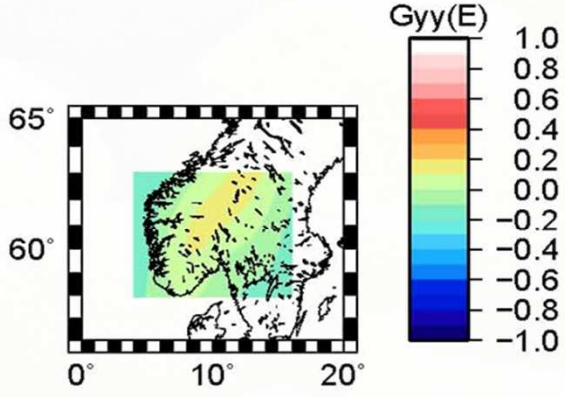


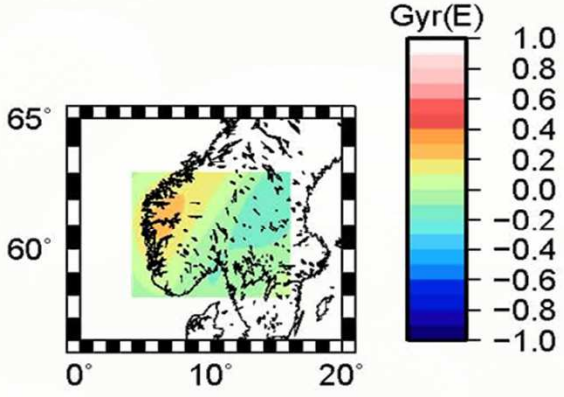
Gravity gradients from 100-0 km depth at satellite height

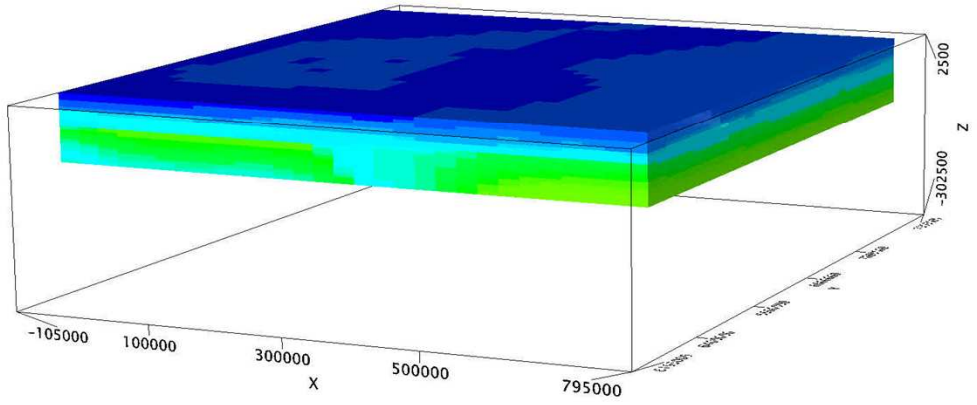


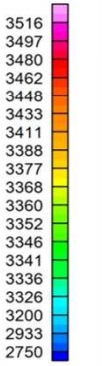


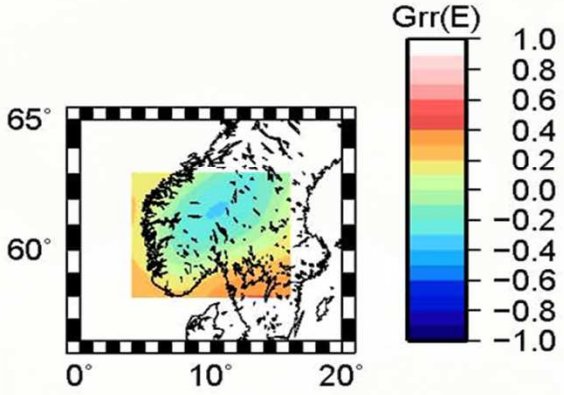




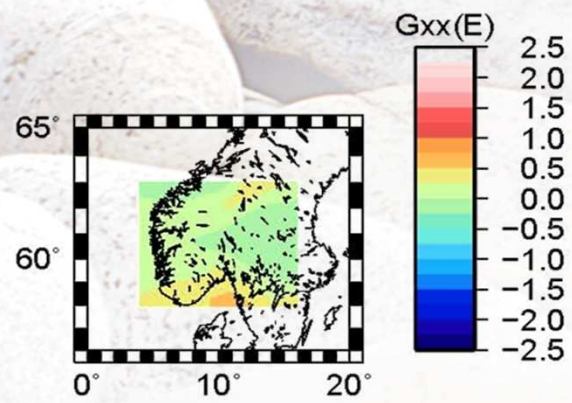


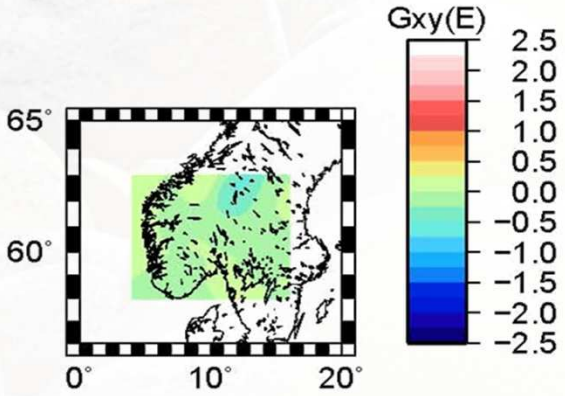


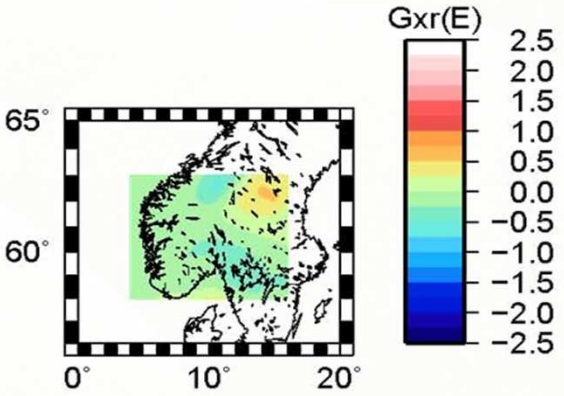




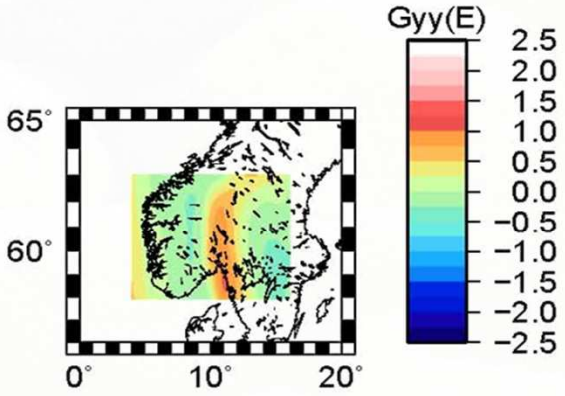
A detailed look at the uppermost mantle and crust

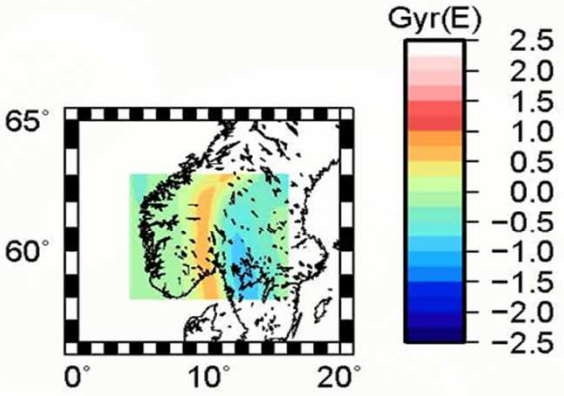


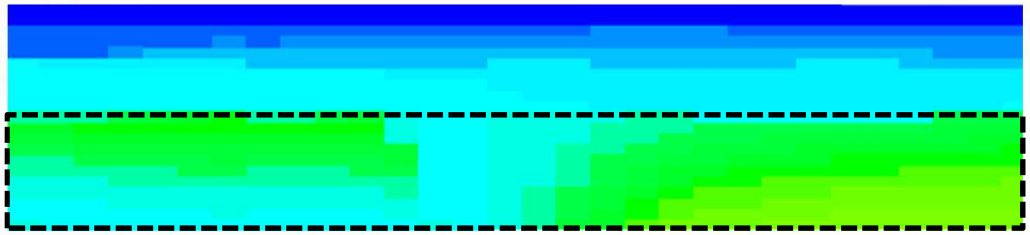




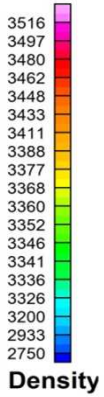
Gravity gradients from 100-50 km depth at satellite height

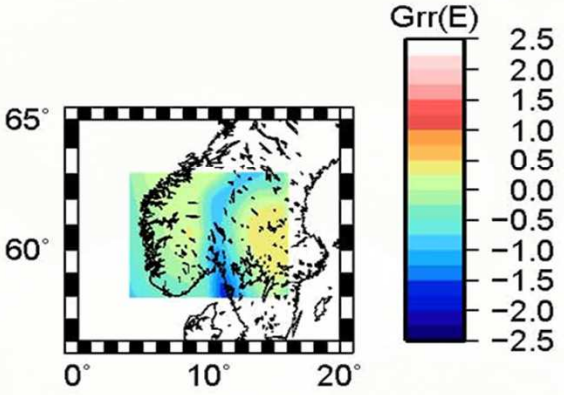




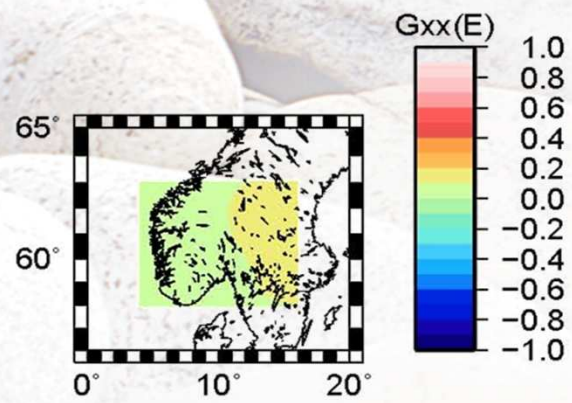


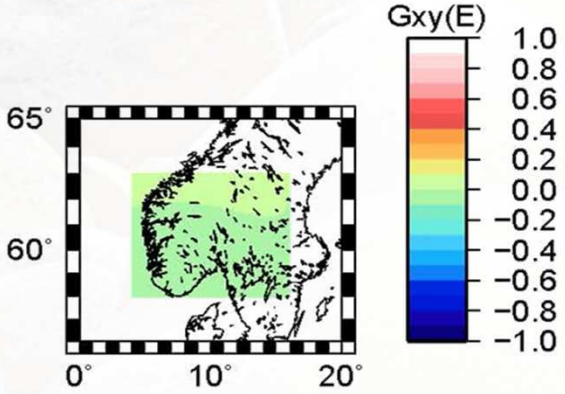
100-50 km depth

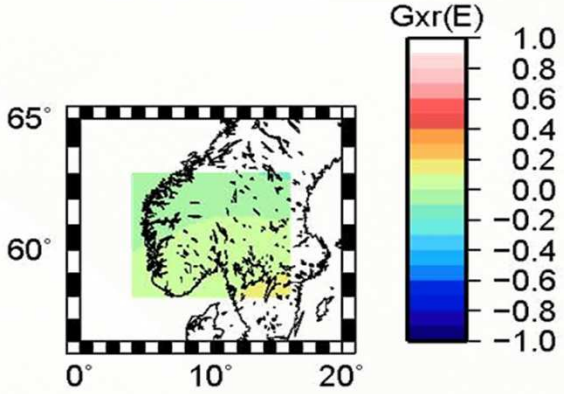


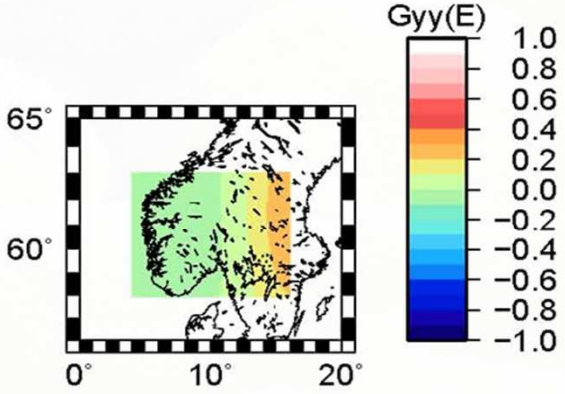


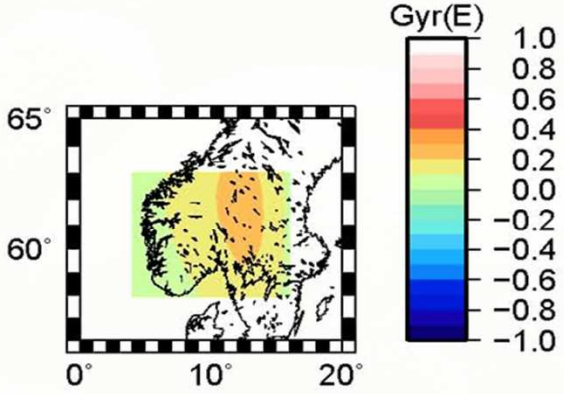
Gravity gradients from 50-40 km depth at satellite height

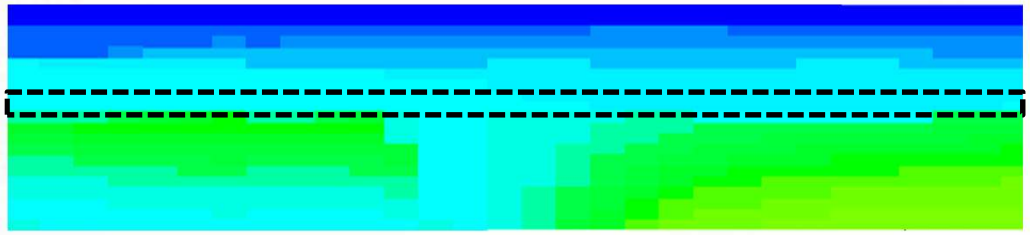




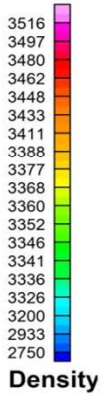


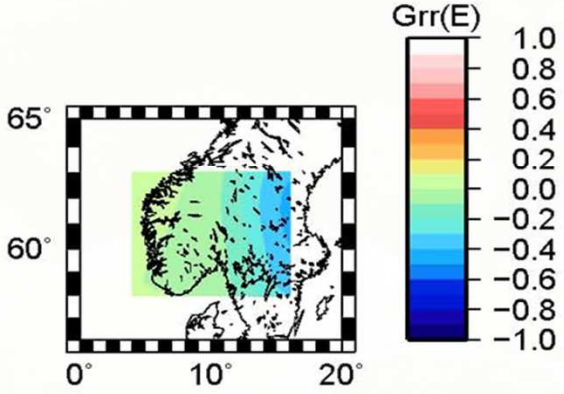




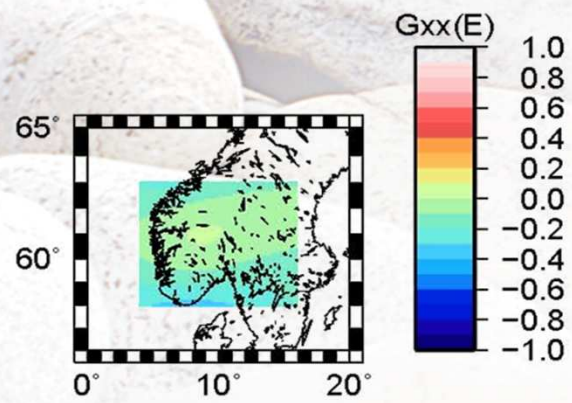


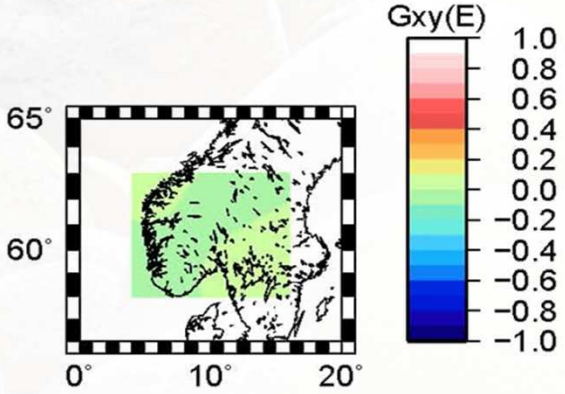
50-40 km depth

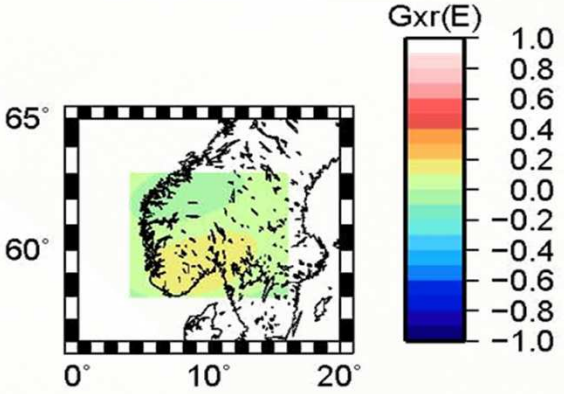


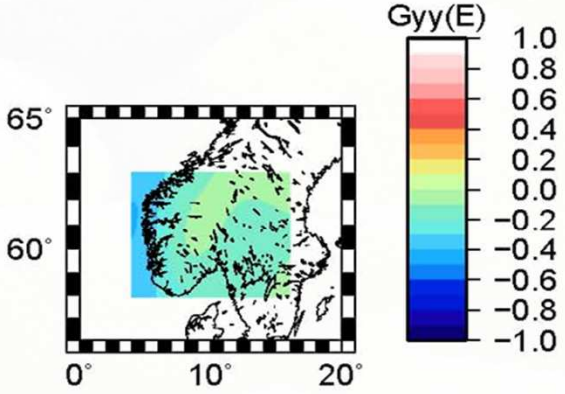


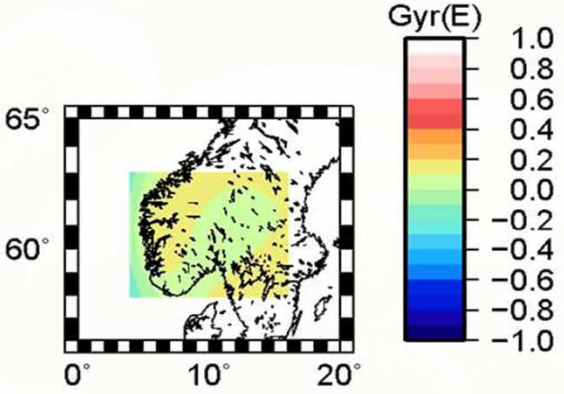
Gravity gradients from 40-30 km depth at satellite height

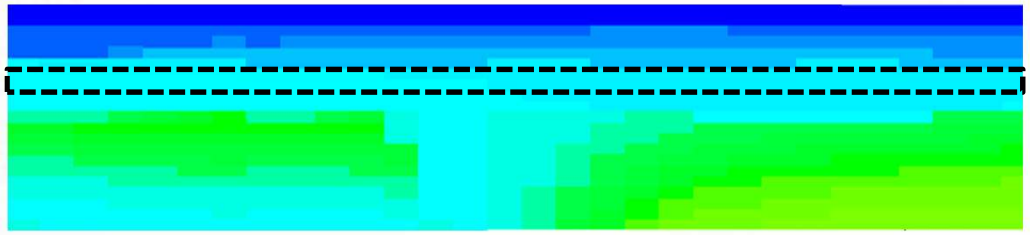




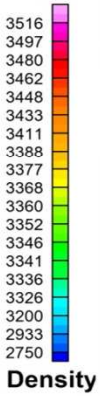


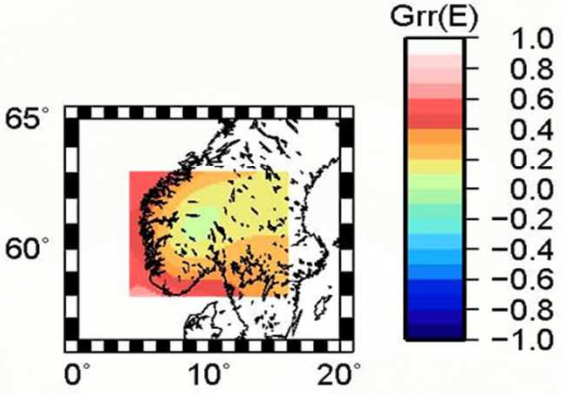




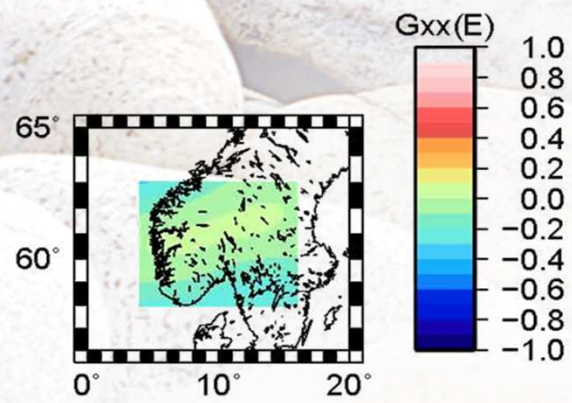


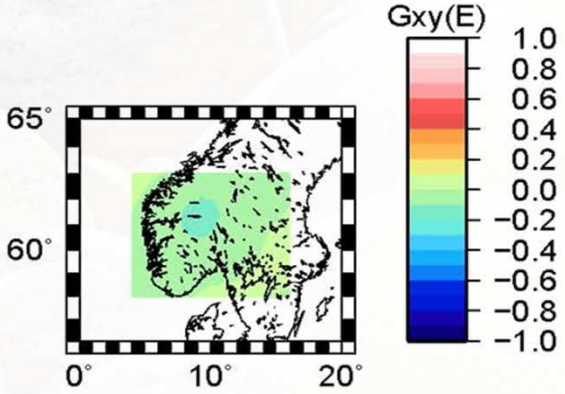
40-30 km depth

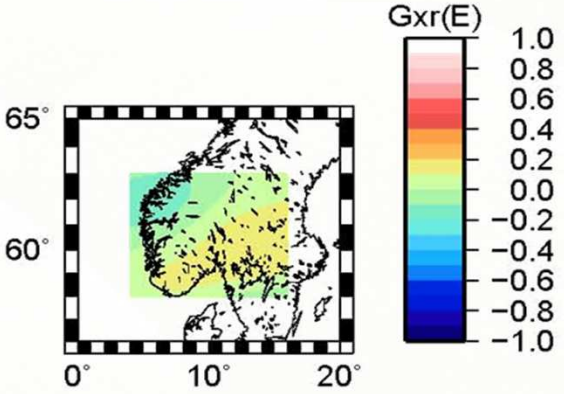


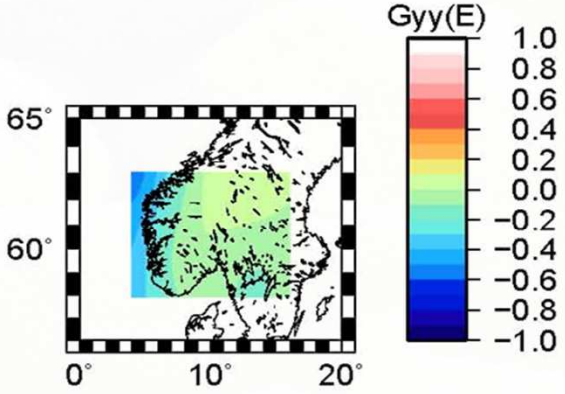


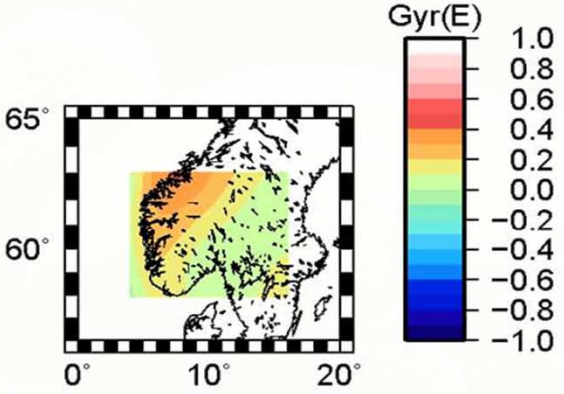
Gravity gradients from 30-20 km depth at satellite height

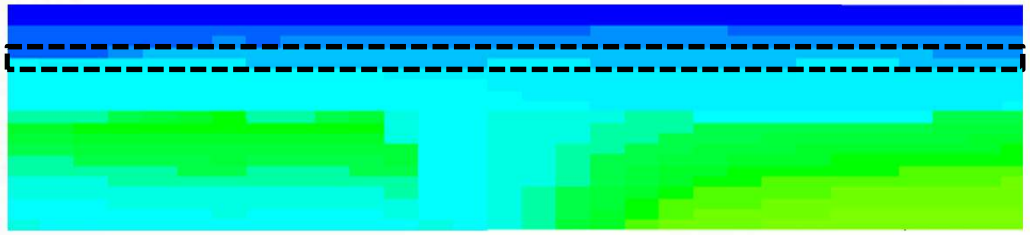




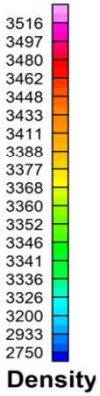


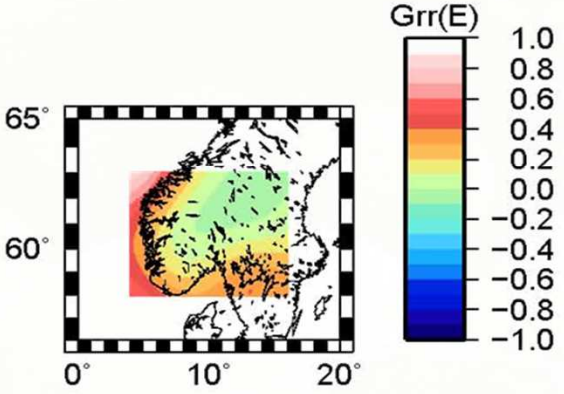




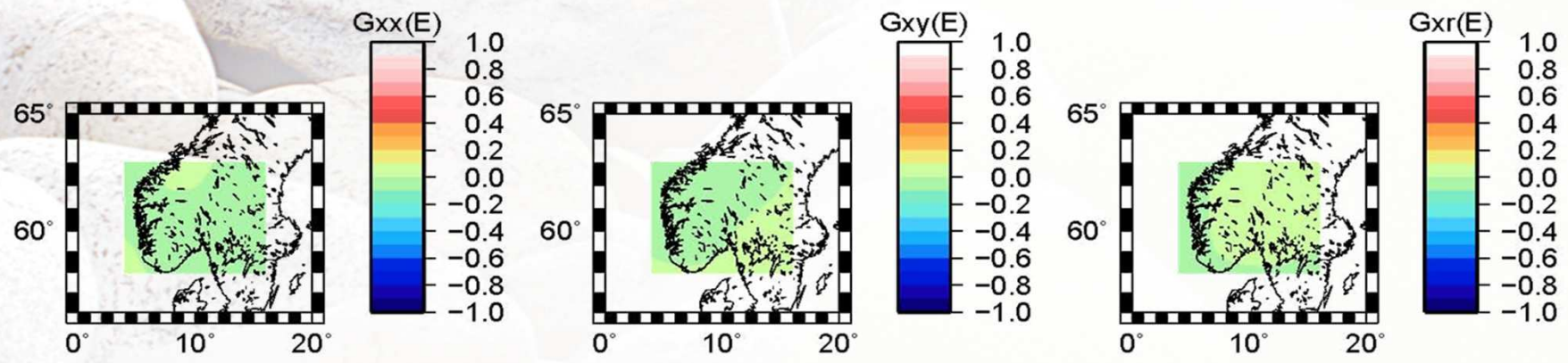


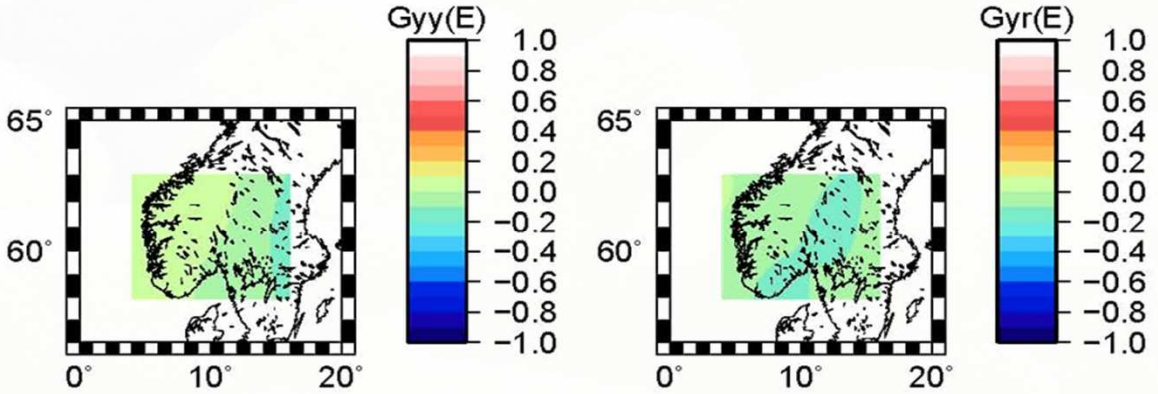
30-20 km depth

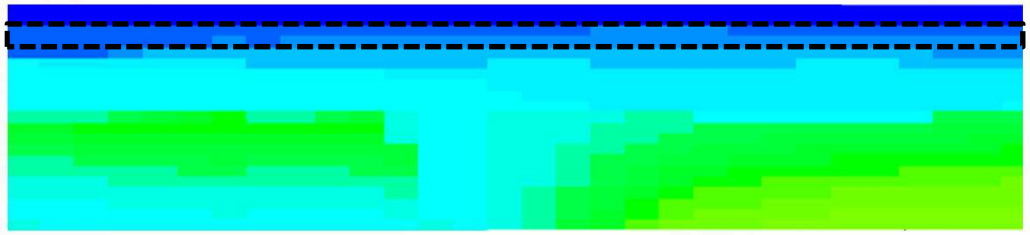




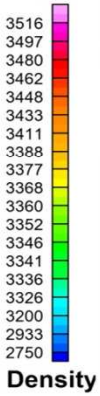
Gravity gradients from 20-10 km depth at satellite height

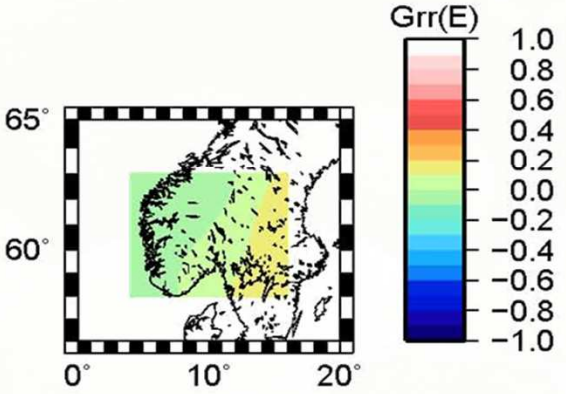


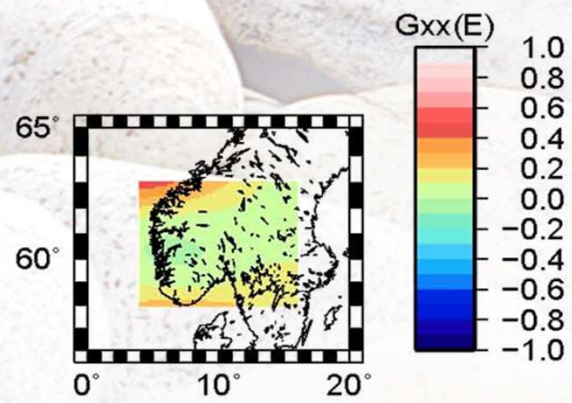


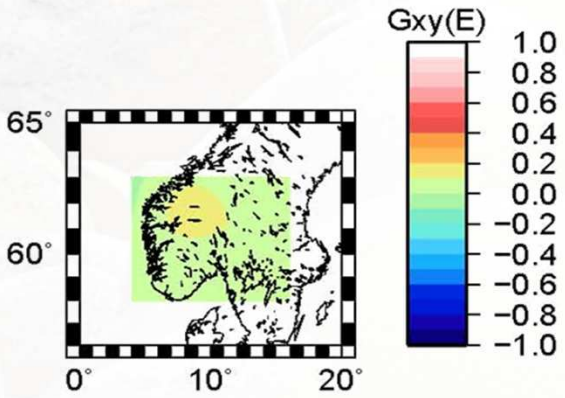


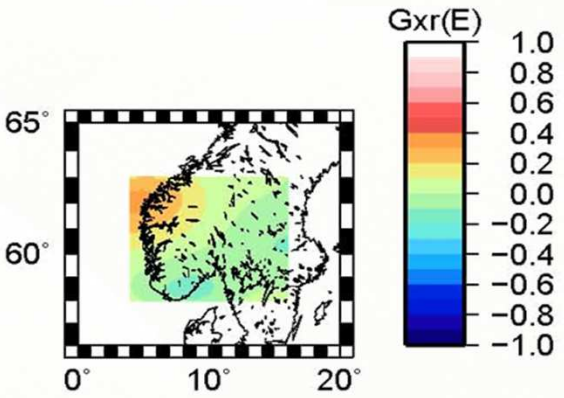
20-10 km depth



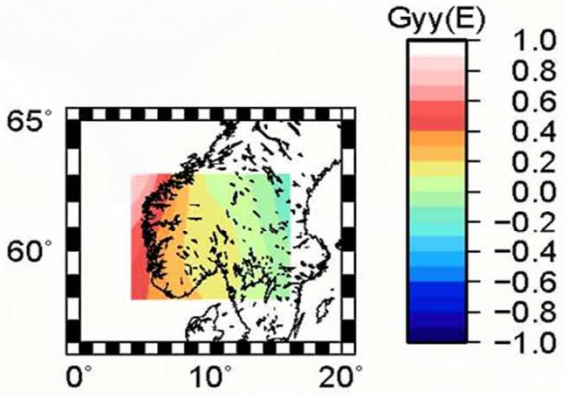


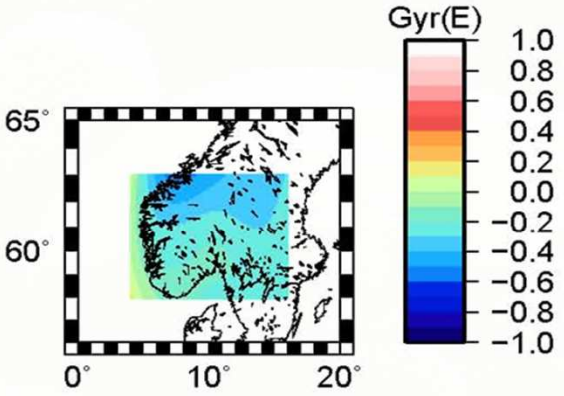


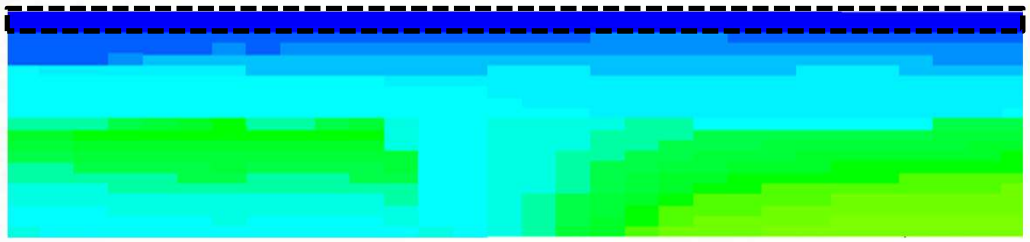




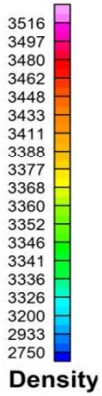
Gravity gradients from 10-0 km depth at satellite height

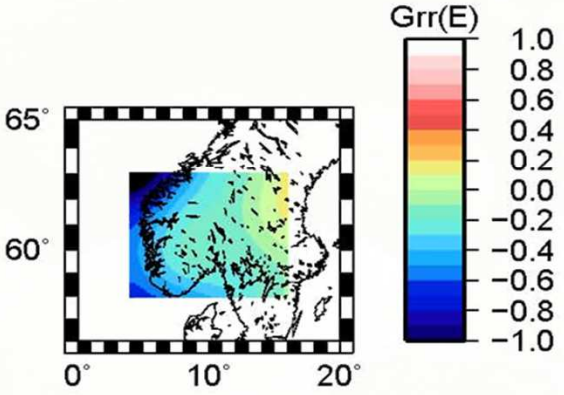






10-0 km depth





Conclusions and outlook

GOCE gravity gradients are sensitive to upper 100 km of the lithosphere

- low sensitivity to thickness of the lithosphere
- Not affected by regional trends

GOCE gradients can complement seismic tomography

- Seismic tomography has low resolution from Moho to 100 km depth
- GOCE gradients are sensitive to this depth range

Satellite gradients should be used jointly with gravity and geoid data to model the entire lithosphere


Thank you for your attention!