Interpreting gravity data from GRACE and GOCE in Scandinavia and Iceland

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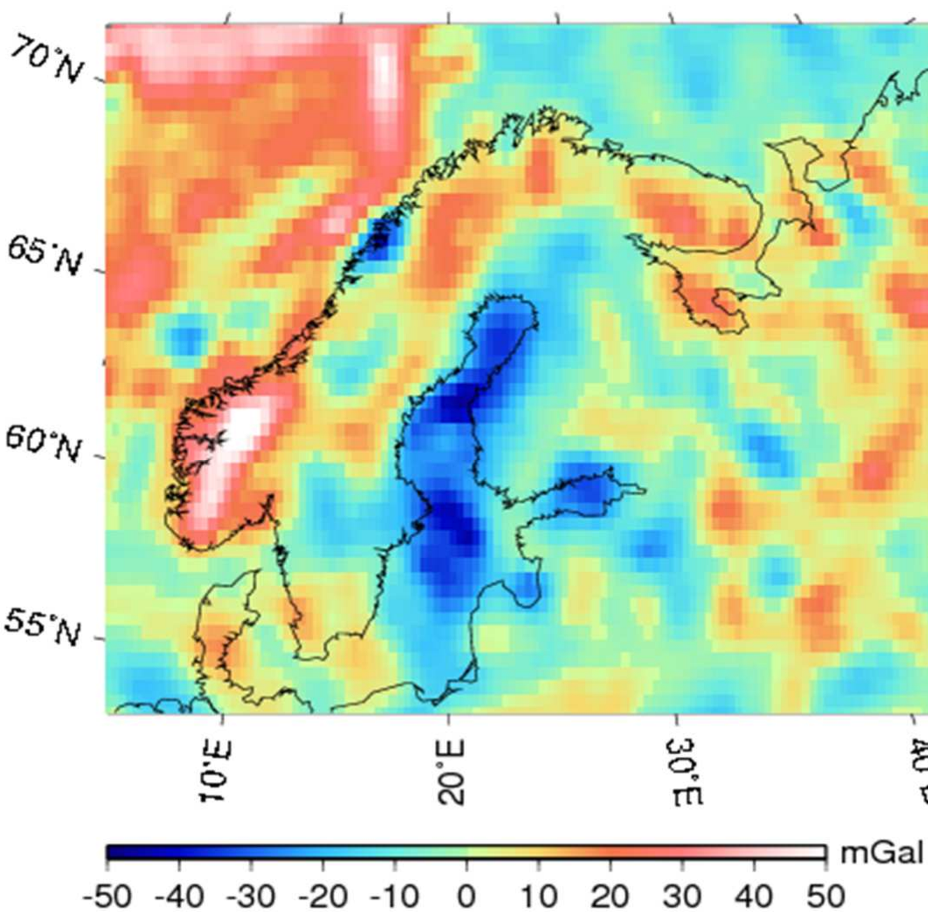
Contents

- Observed gravity field, Glacial Isostatic Adjustment (GIA)?
- GIA model - low degree
- GIA model – high degree
- GIA model – 3D viscosity
- Conclusions

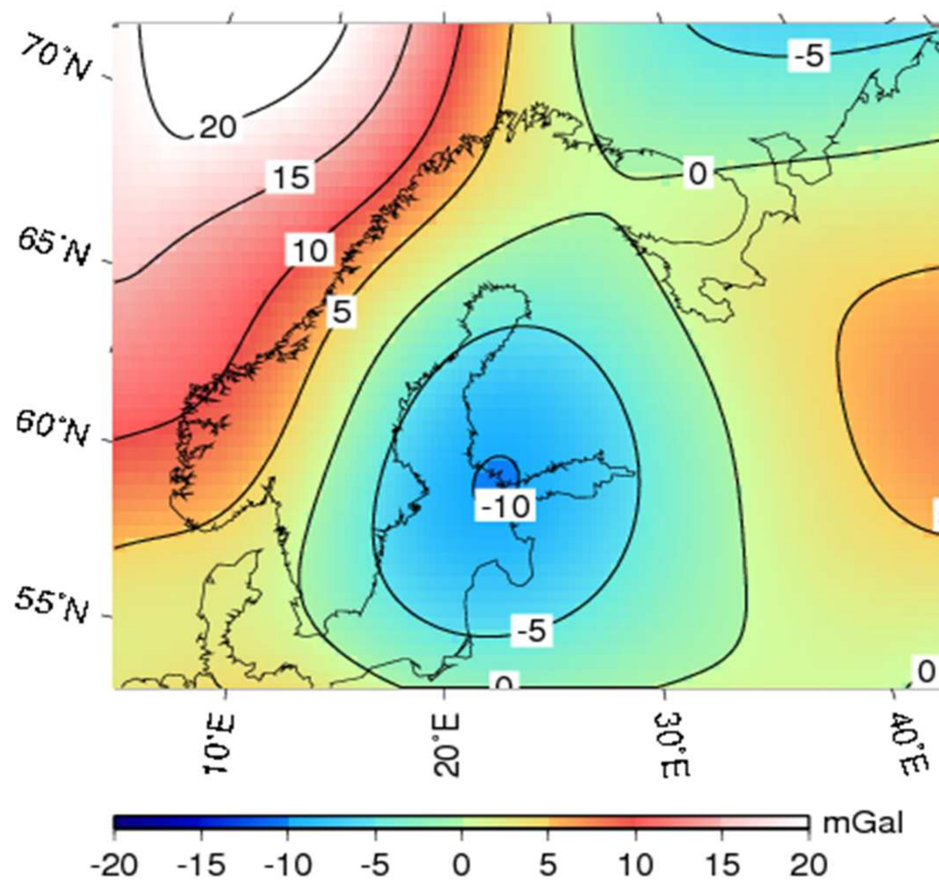
Background

EIGEN-GL04C (Grace + Lageos + satellite altimetry + ground data) Foerste et al (2009)

Full model (up to degree 360)

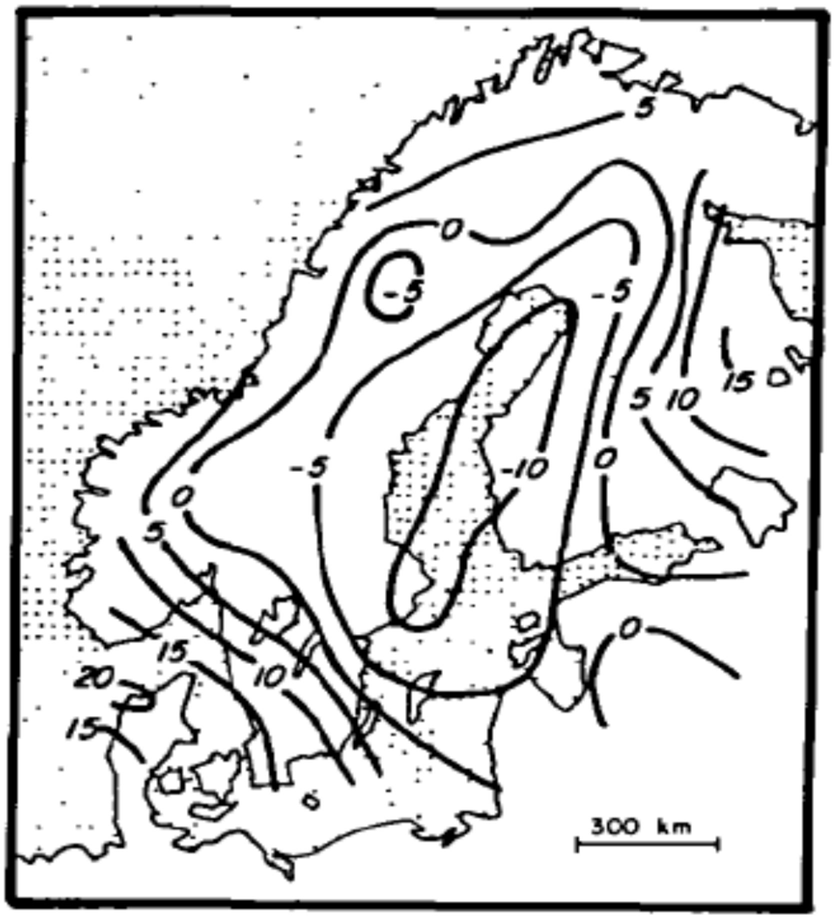


Maximum degree 60
Gaussian filtering of 400 km

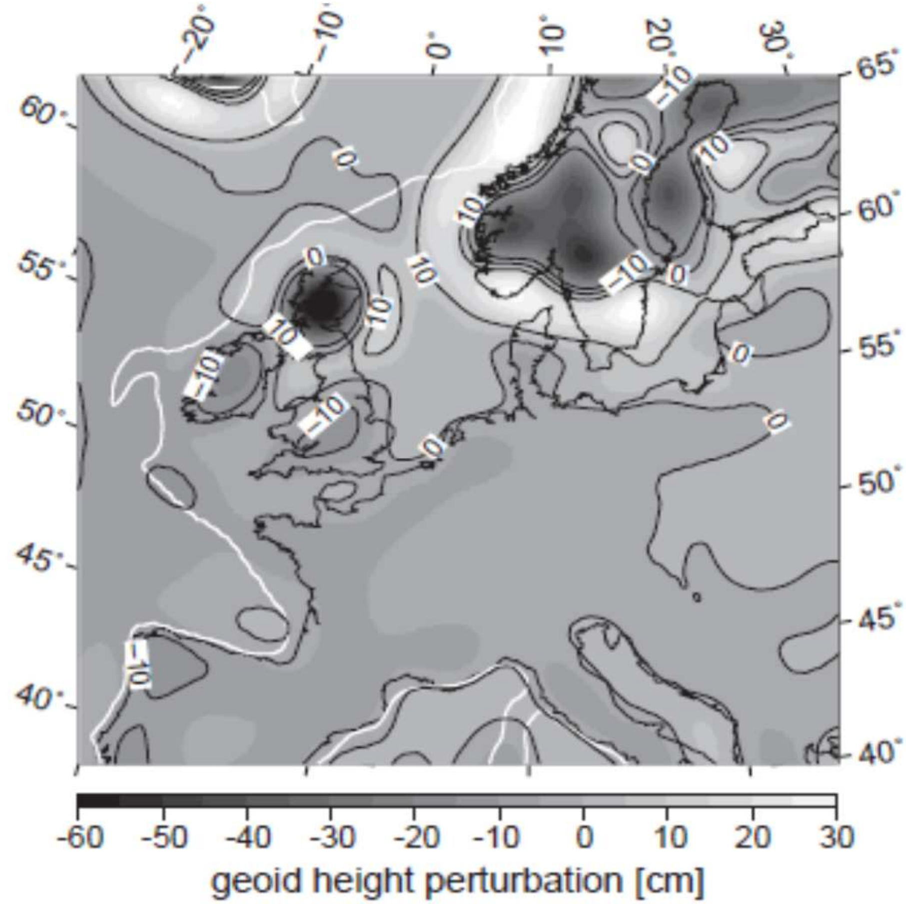


Background

From Balling (1980): GIA component of free-air gravity anomaly



From Schotman et al (2005): effect of low viscosity in crust

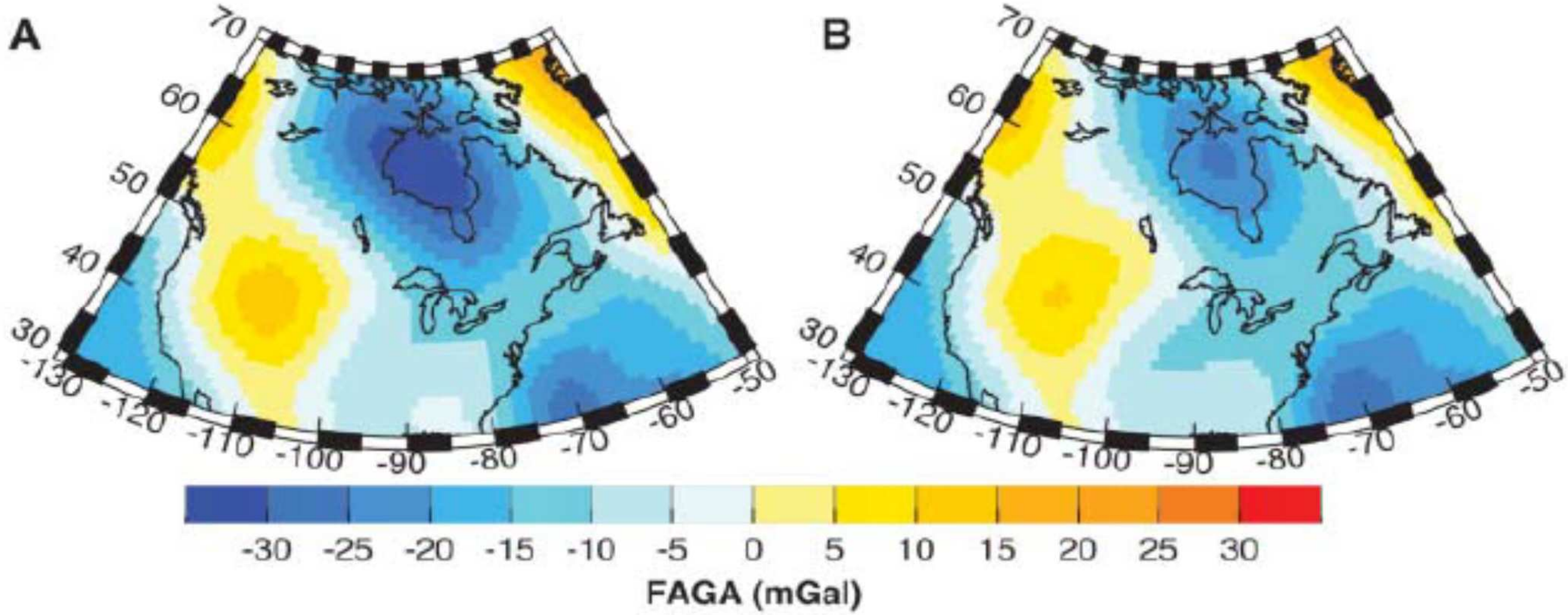


Background

Study	GIA	Remark
Balling (1980)	-15 -20 mGal	4° x 8° mean anomalies
Anderson (1984)		Crustal thickening is more important
Marquart (1989)		Crustal thickening is more important
Sjöberg (1994)	-28 mGal	-12 mGal due to Moho depth
Mitrovica and Peltier (1989)	-15 mGal	peak value (degrees > 7)
Kakkuri and Wang (1998)		high density upper mantle

Background: North America

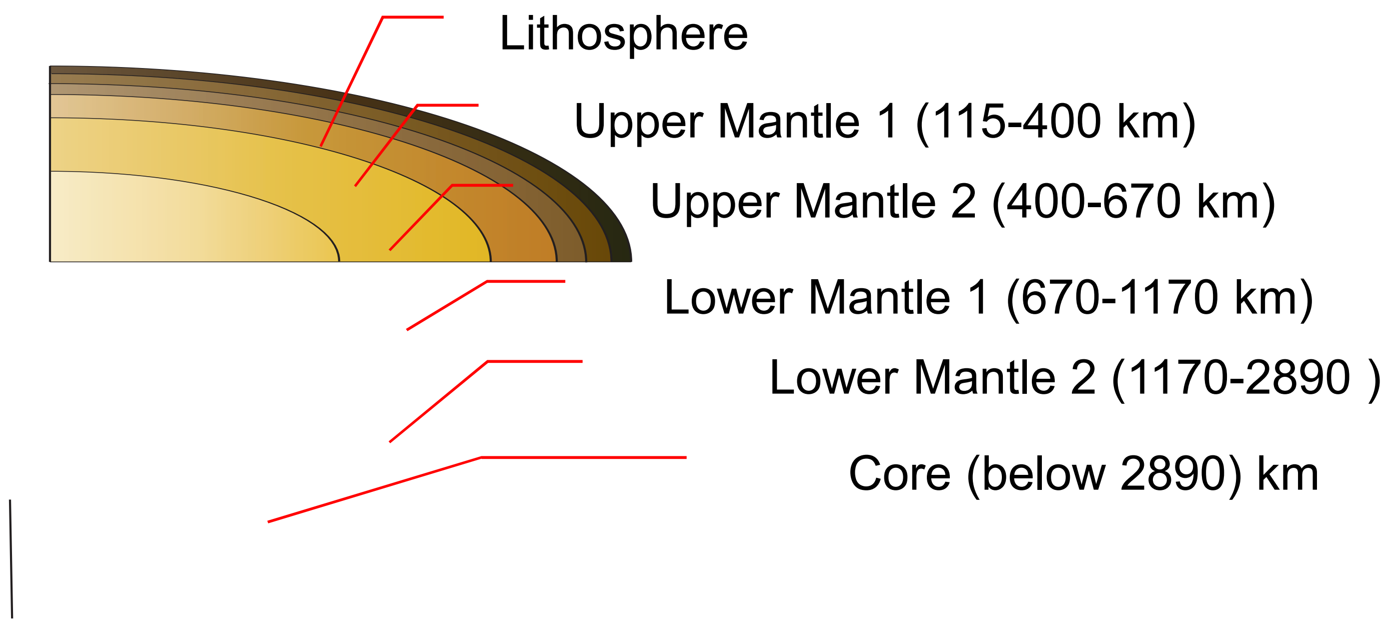
GIA removed



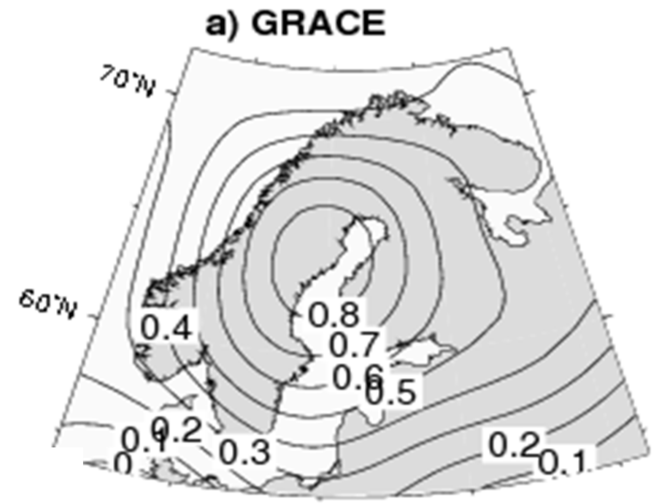
Tamisiea et al (2007)

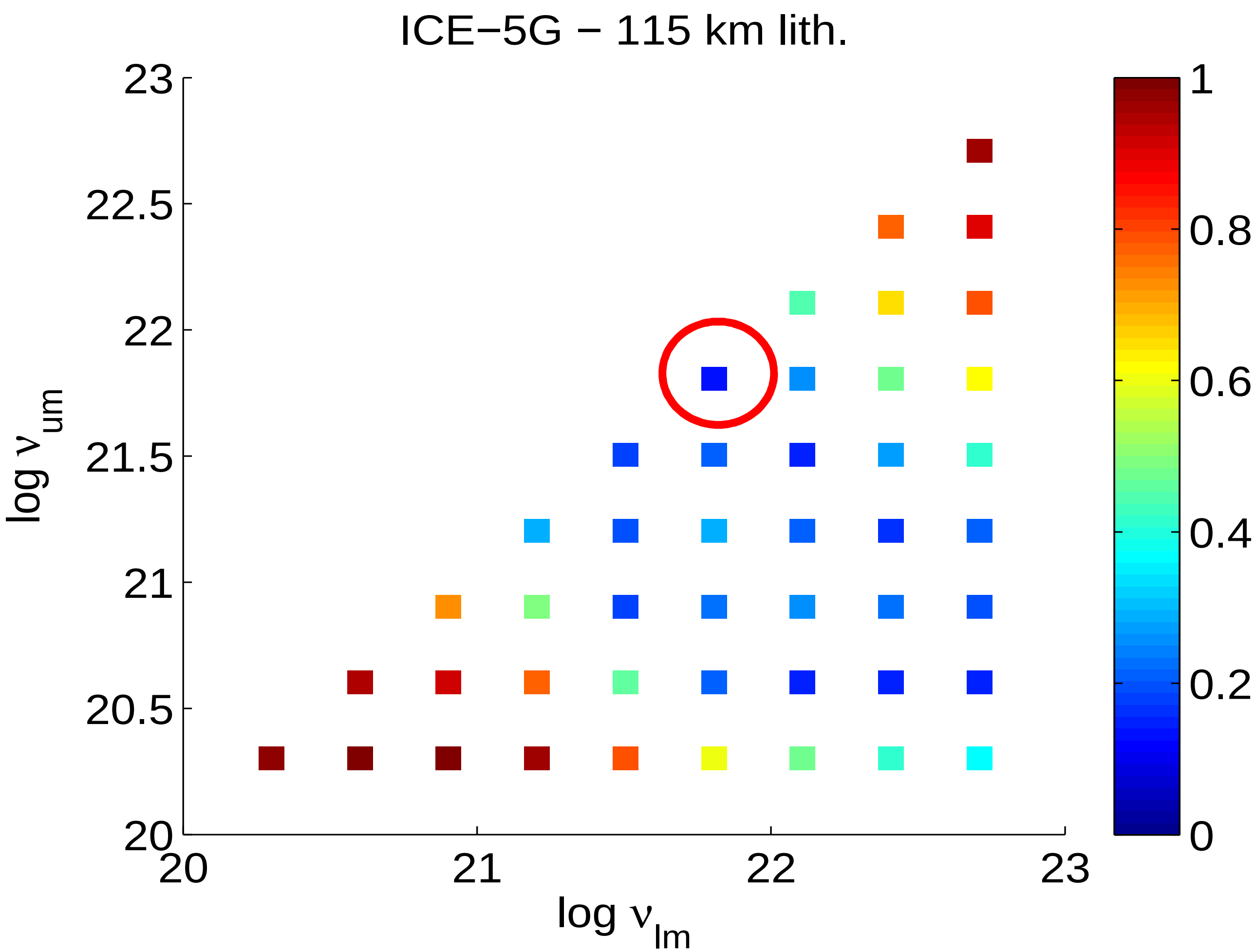
GIA model

- Incompressible (density stays constant)
- Rotational feedback is included
- Vary upper and lower mantle viscosity (2,4,8,…,512 x 10^{20} Pas)
- ICE-5G, no sea-level equation (uniform layer of water)



Model that best fits gravity rate





GIA model: best fit to GRACE data

Only gravity rate > 0.15 μGal/year (~1 mm/year)

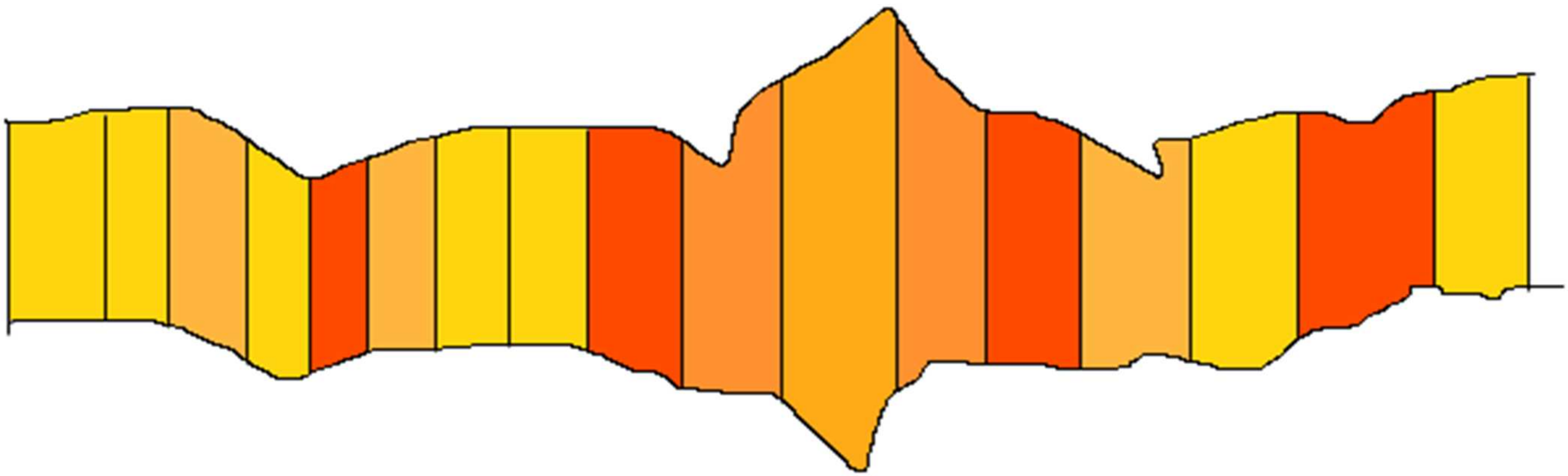
Spherical harmonic degree 60, 400 km Gaussian filtering

	RMS [μGal/year]	**v_{UM} x 10^{20} Pas**	**v_{LM} x 10^{20} Pas**
Fit to GPS	0.82	16	512
Fit to GRACE	0.013	64	64
Lambeck et al (1998)		3-4	>30
Milne et al (2001		5-10	50-500
Steffen and Kauffmann (2005)		3-4	300-1000

Forward modeling crustal density

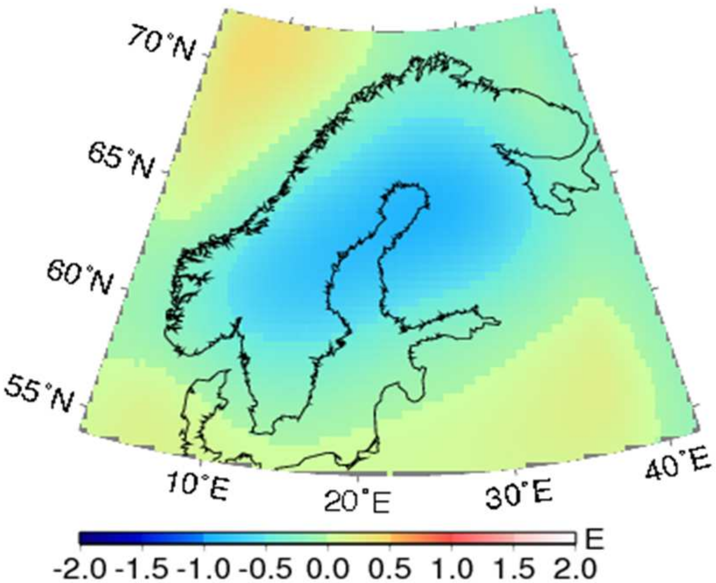
Forward-modeling [Novak,2005]

- Varying upper and lower boundary



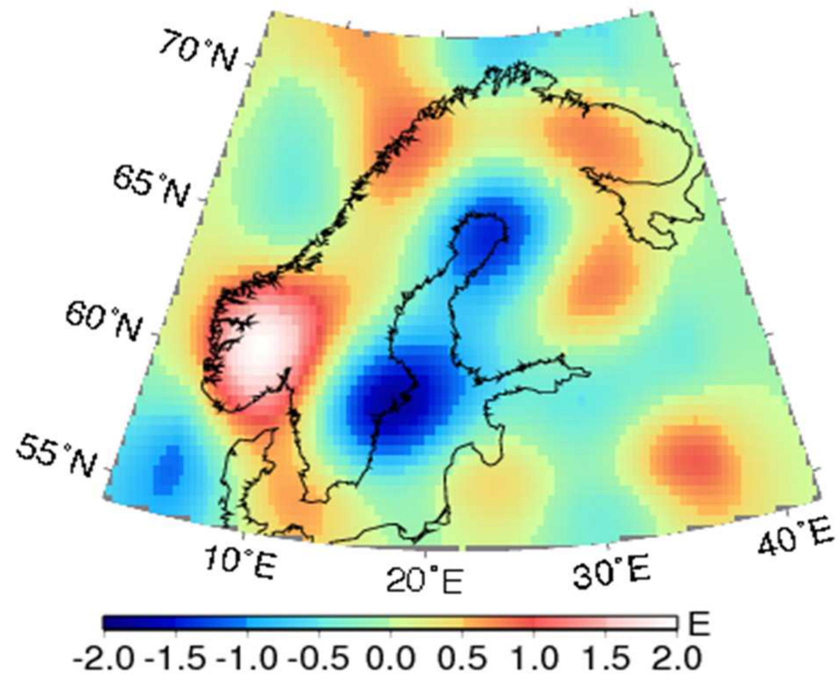
V_{zz} of preferred model

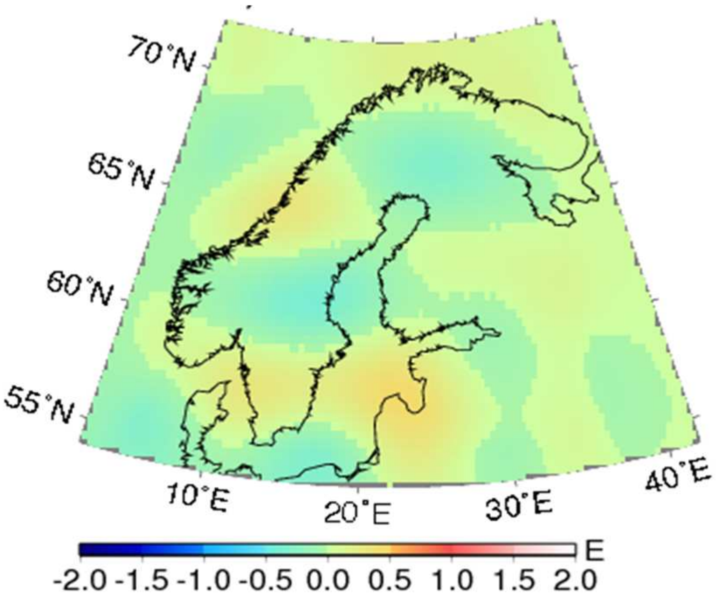
Degrees 11-60, at the Earth's surface



GIA model
-0.9 to 0.5

observed V_{zz}

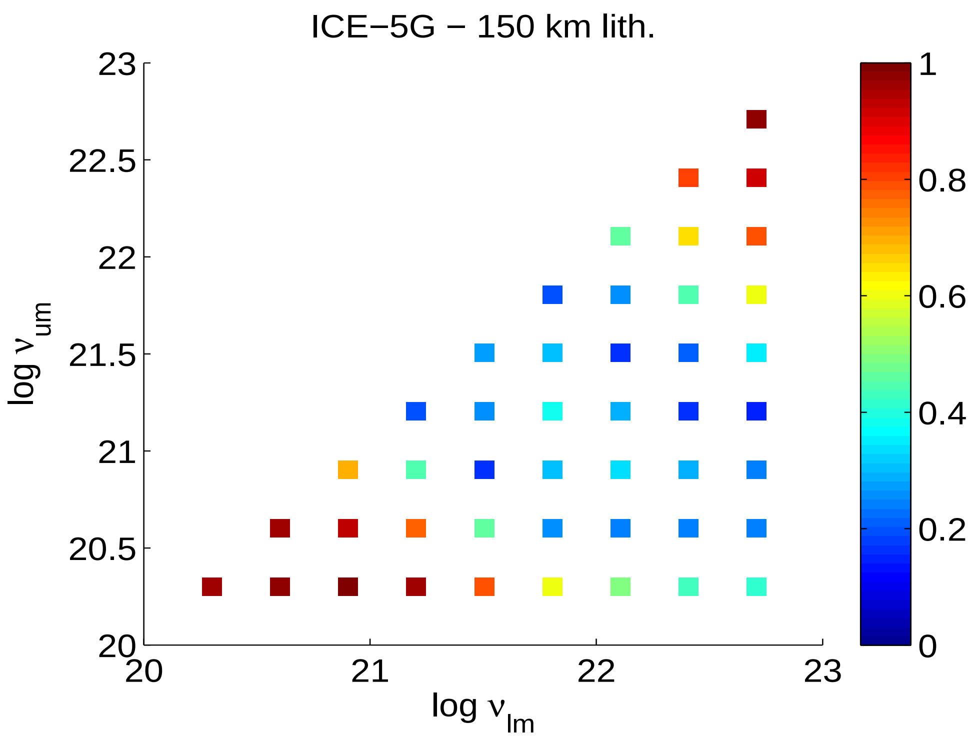


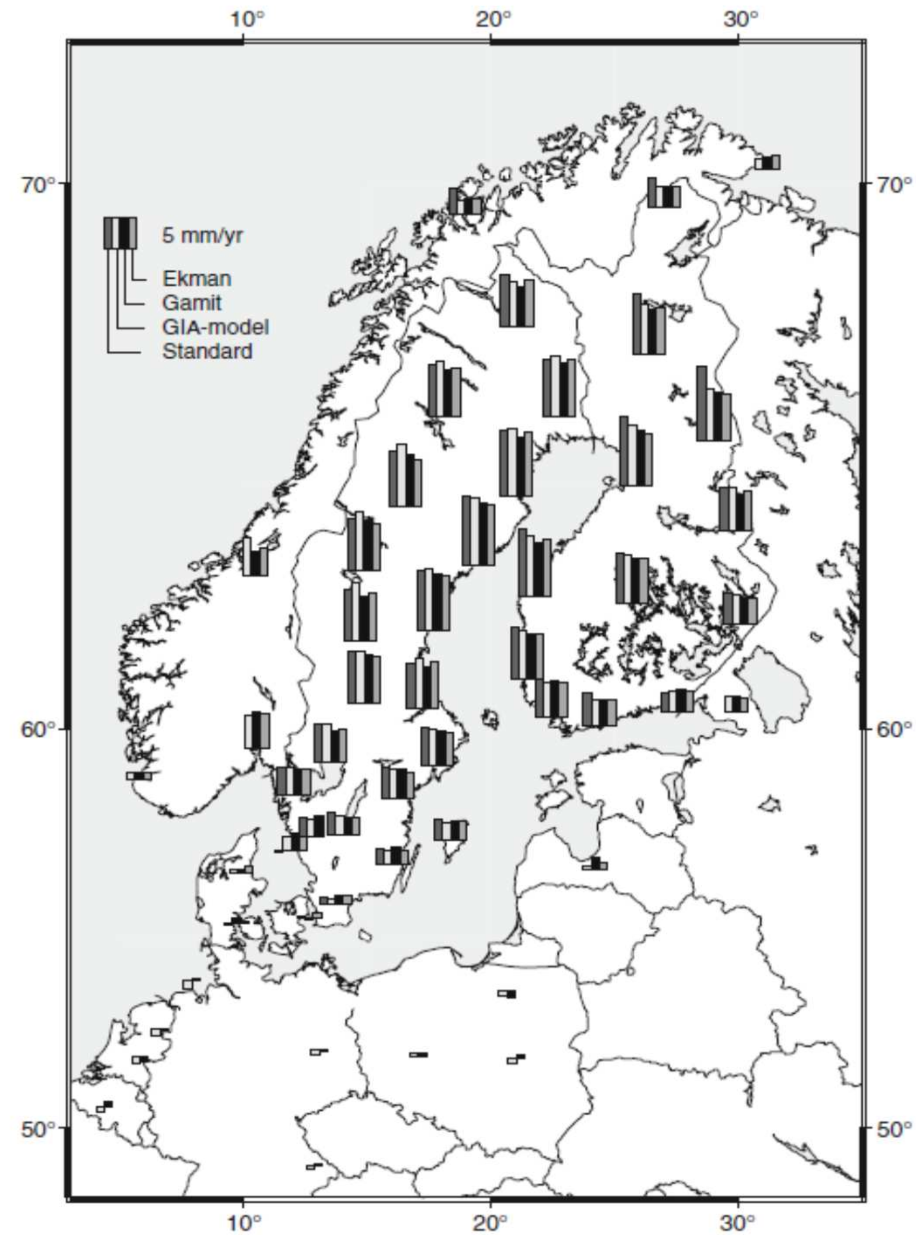


30 kg/m^3 "noise"
upper crustal density (EPcrust)
-0.3 to 0.3 E

Best fit to GPS

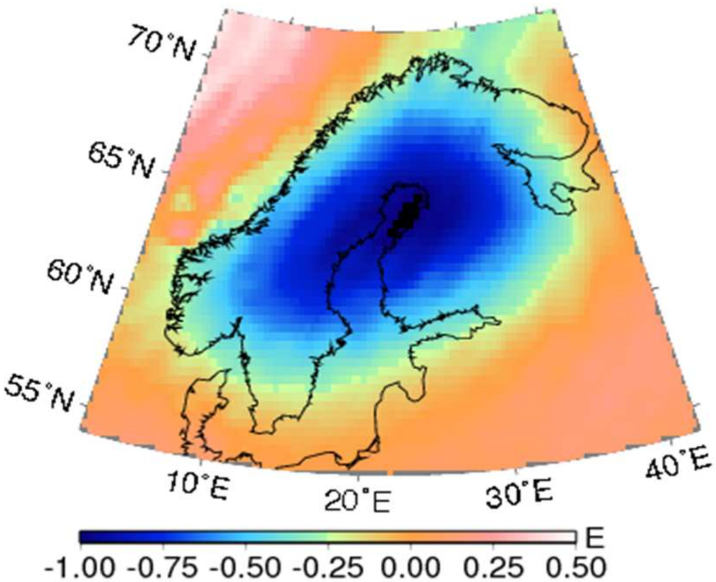
- Min. RMS = 0.82
- vlm = 512 x 10^{20} Pas
- vum = 16 x 10^{20} Pas
- Lithosphere 150 km thick





Lidberg et al. (2007)

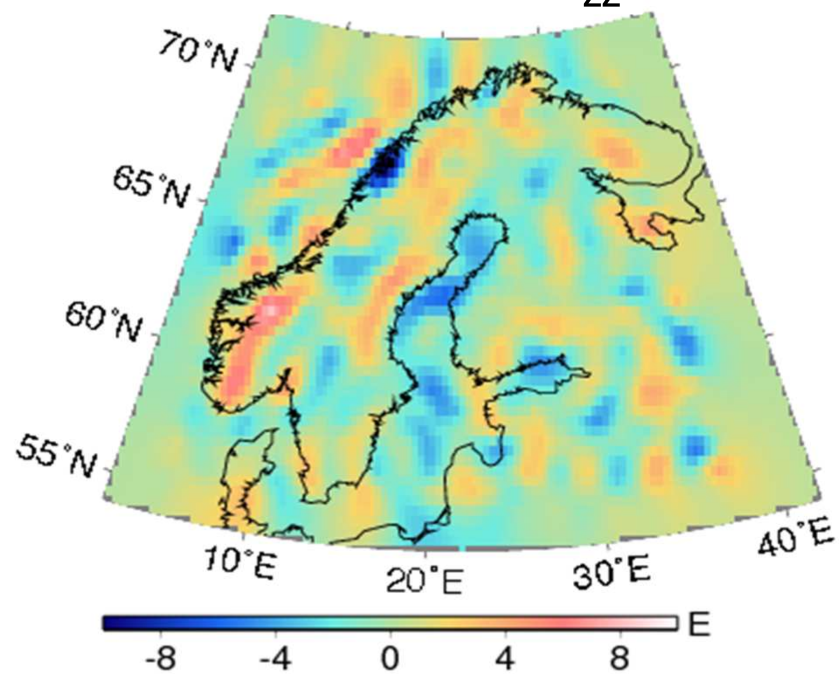
Vzz of preferred model



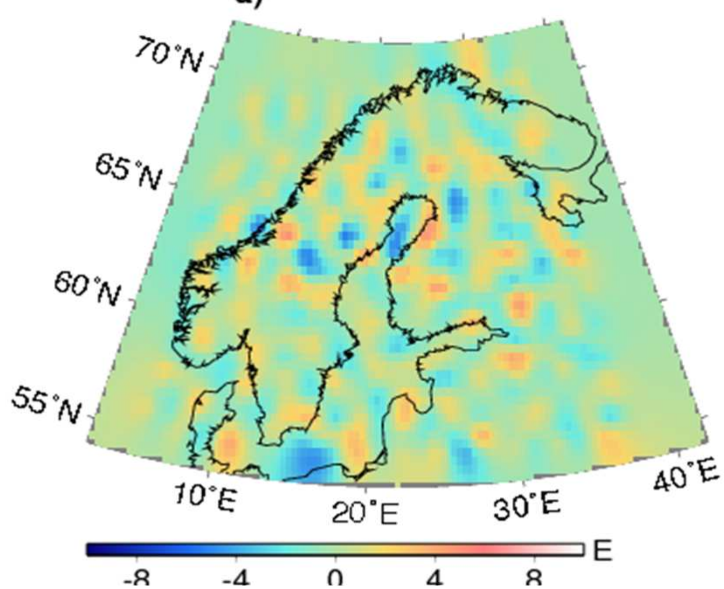
Degrees 0-256 at ground level

GIA model
-1.0 to 0.4

Observed V_{zz}

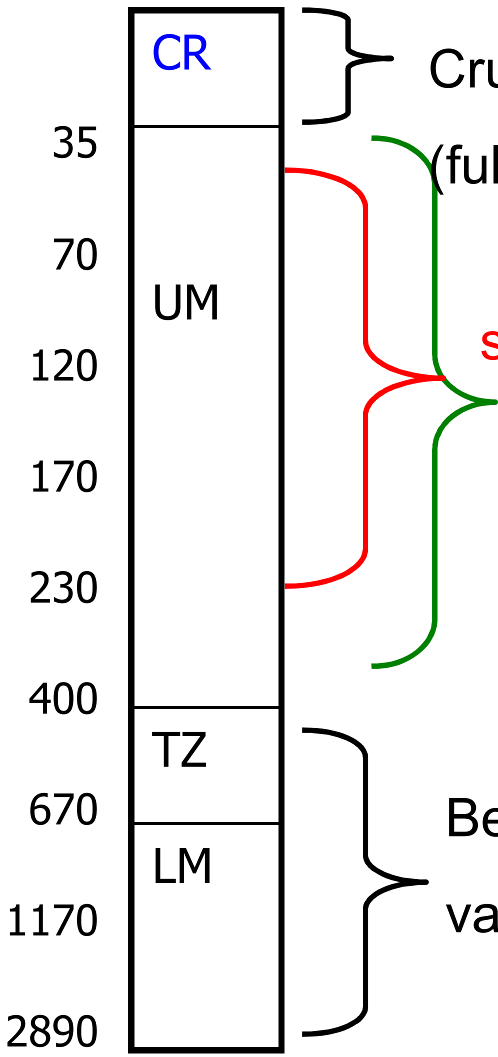


a)



30 kg/m³ "noise"
upper crustal density (EPcrust)
-8 to 7 E

3D Model

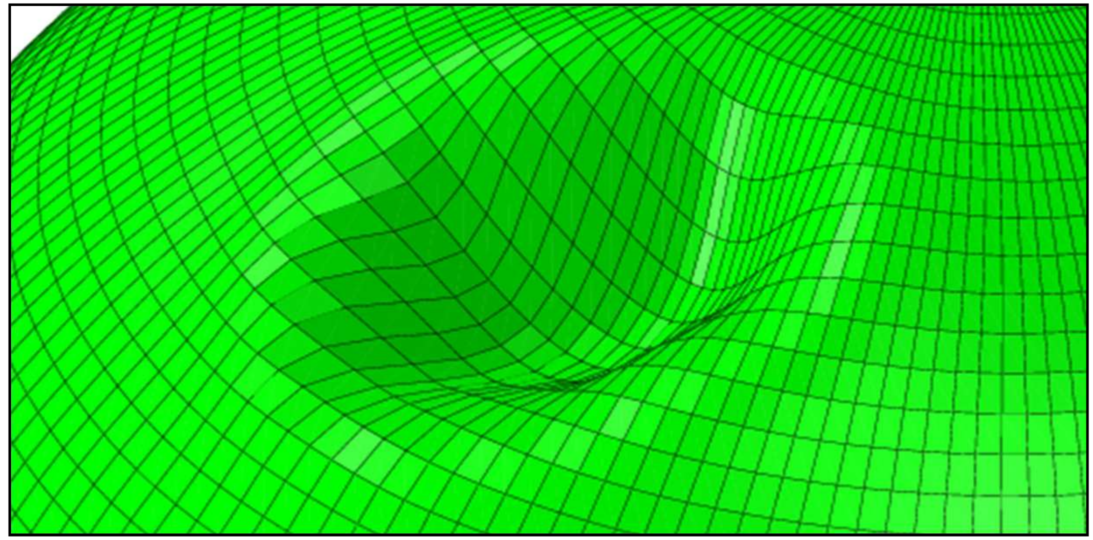


Crust

(fully elastic)

seismic

heatflow

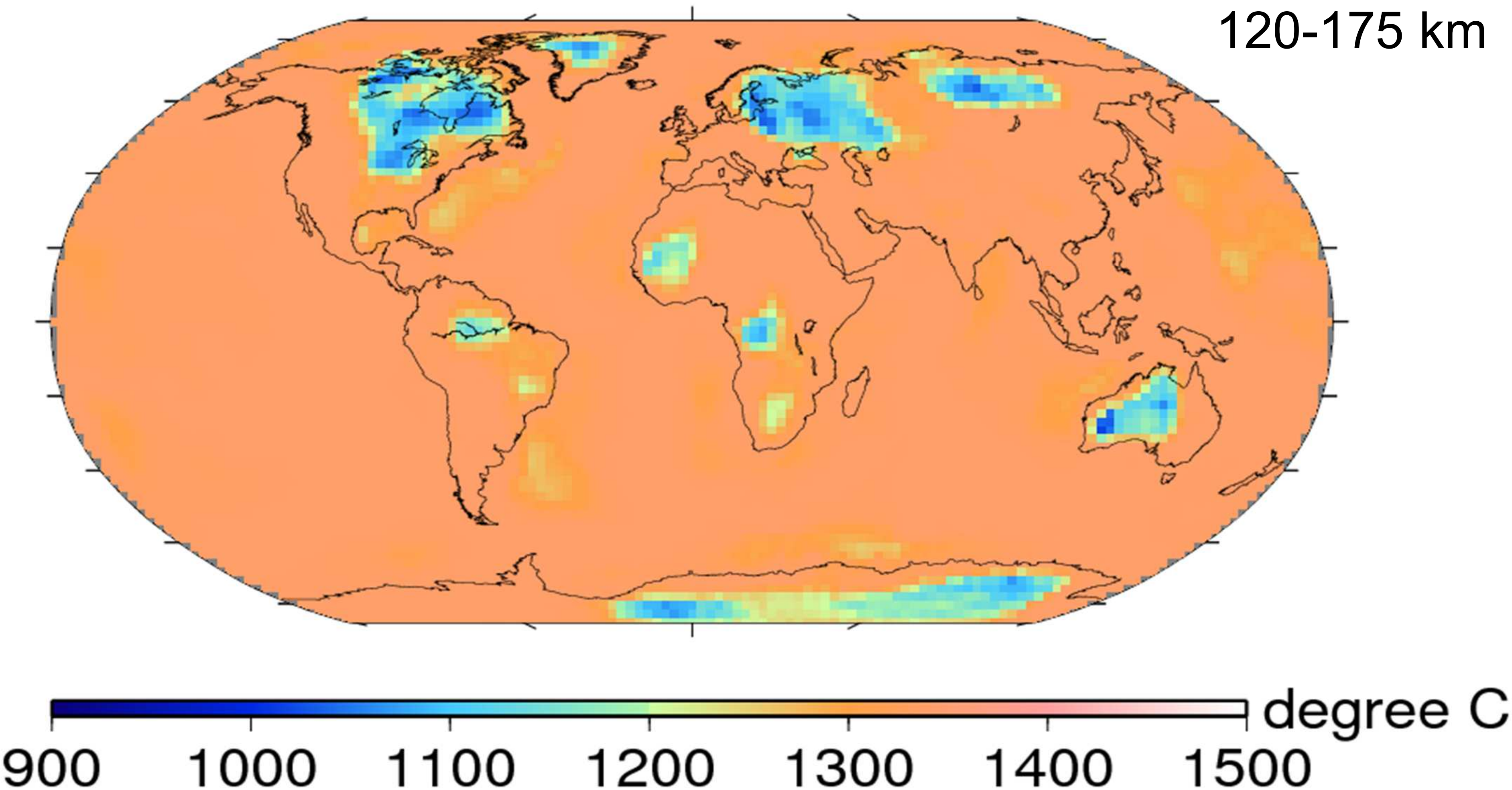


Best fitting composite rheology parameters of

van der Wal et al. (2010)

2 x 2 degree, incompressible, with self-gravitation, no rotational feedback

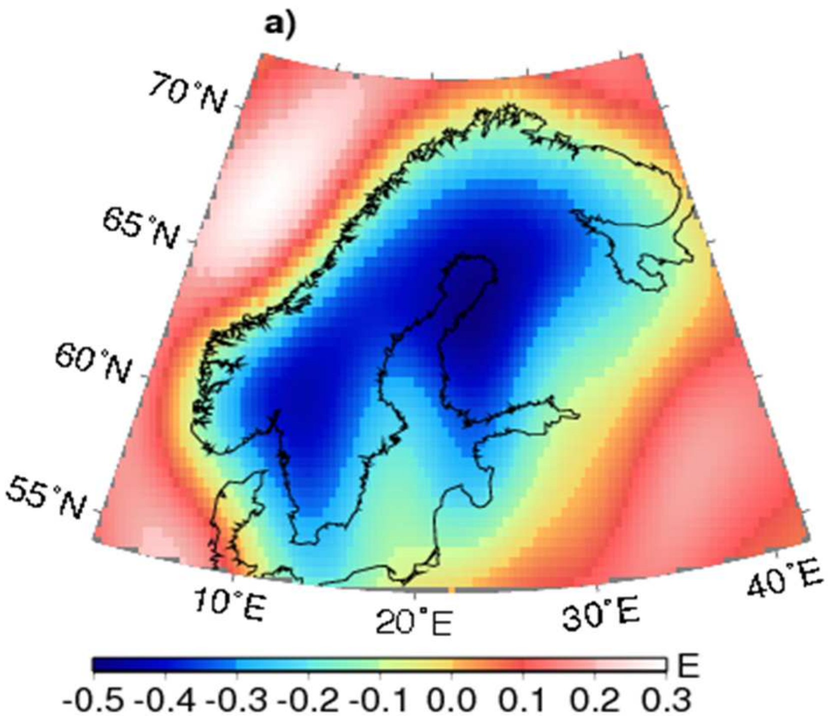
Upper mantle temperature (UMT1)



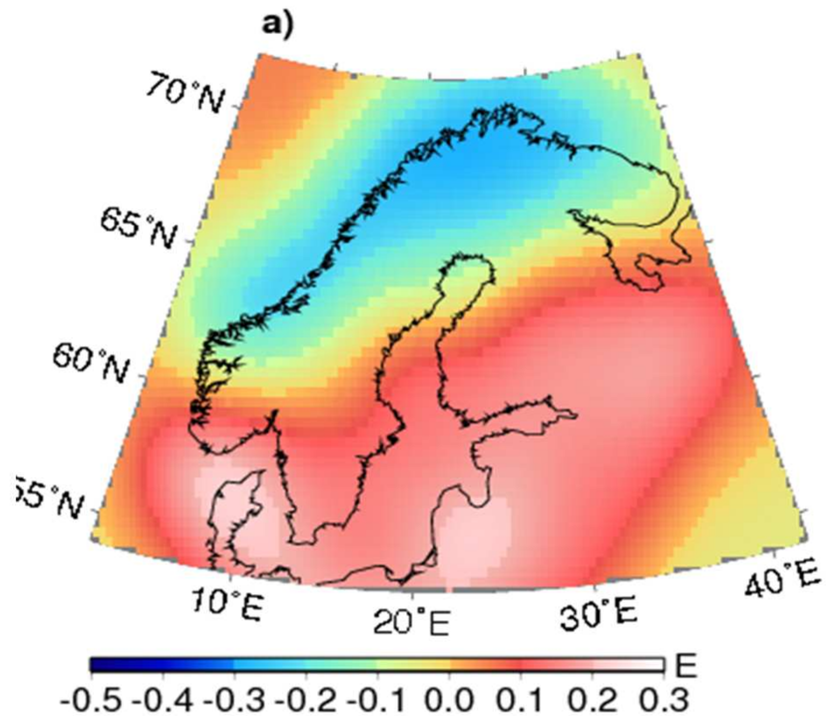
Derived from crustal heatflow

Gradients 3D viscosity

Vzz

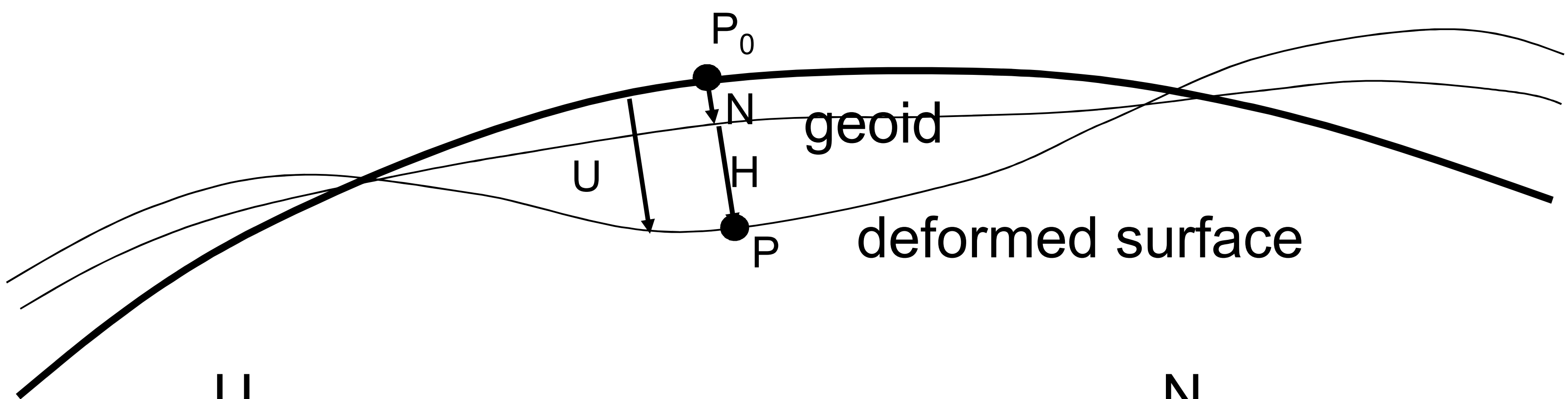


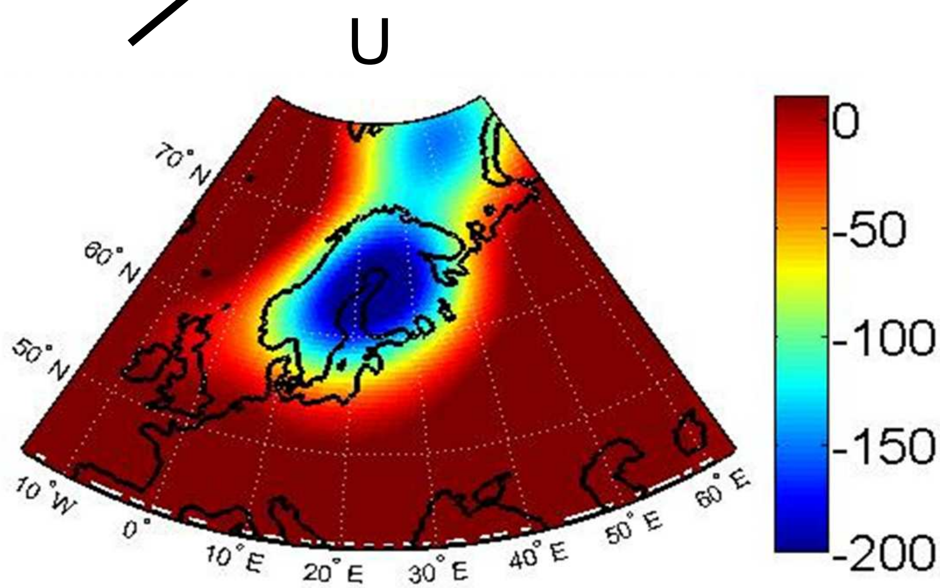
Vxz

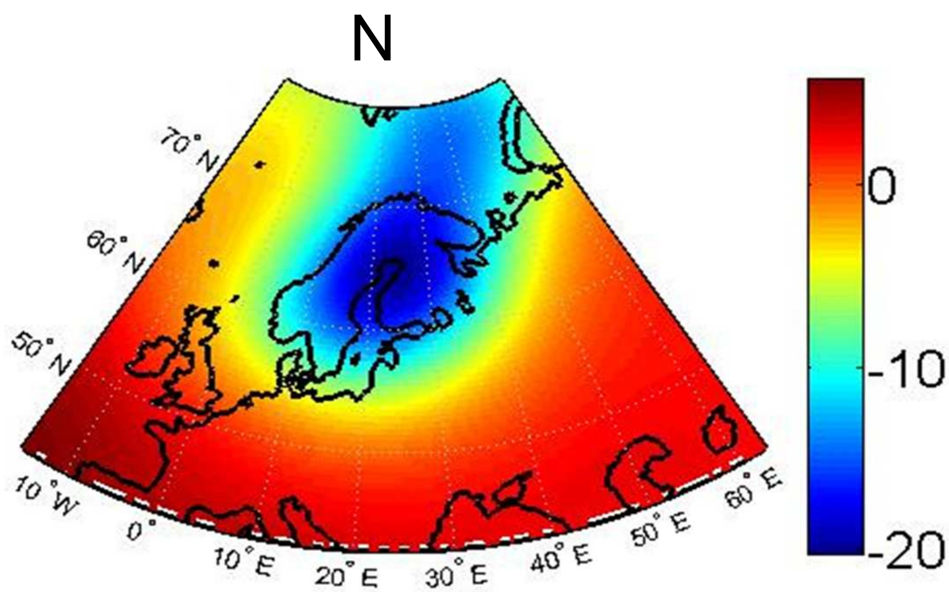


Maximum degree 90, at the Earth surface

Gravity Anomaly from model

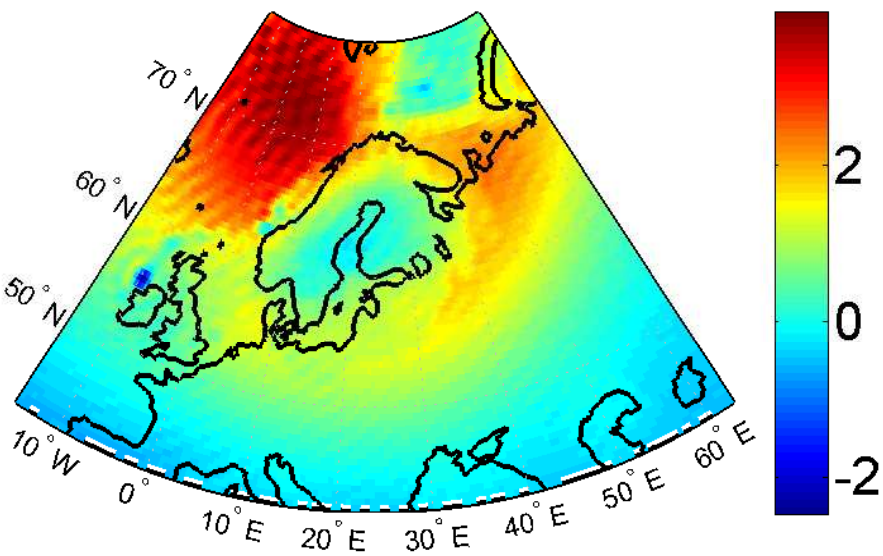




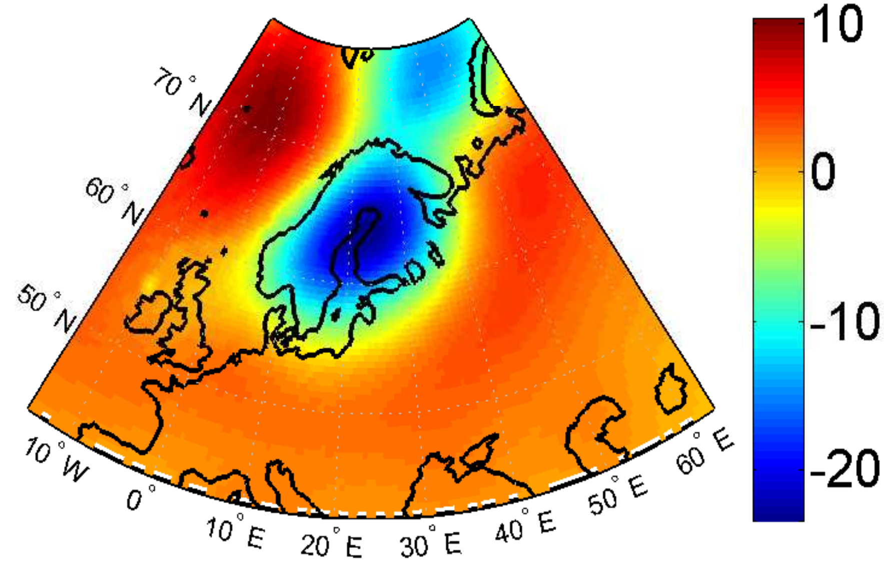


Gravity Anomaly from model

Bouguer gravity anomaly [mGal]



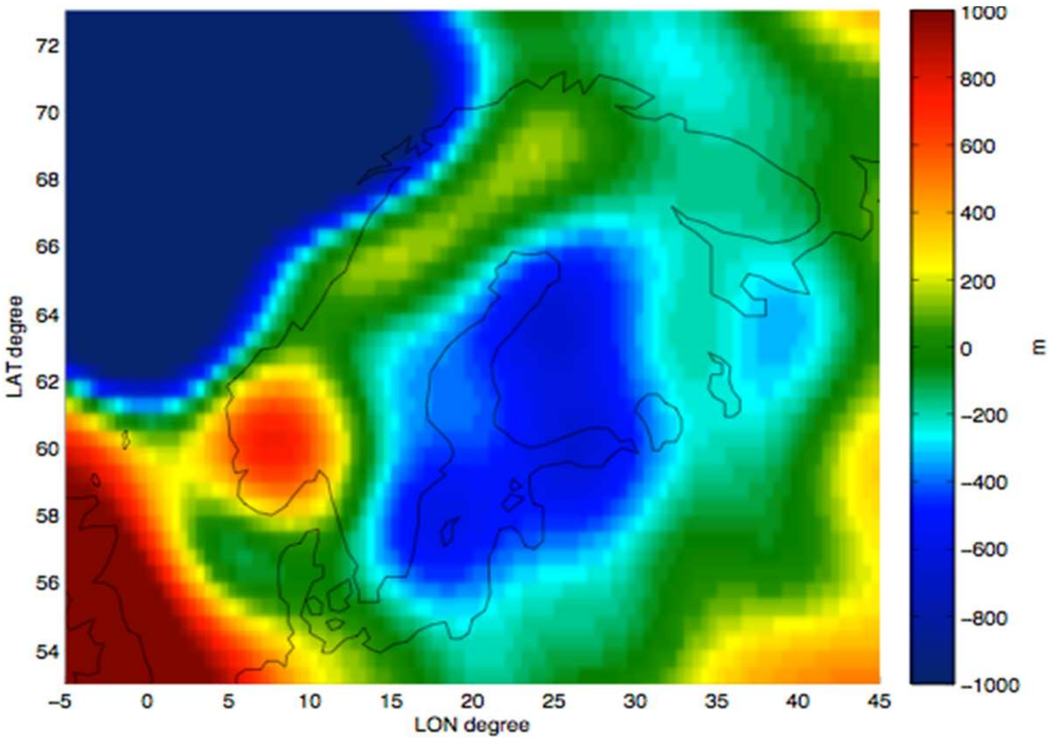
Free-air gravity anomaly [mGal]



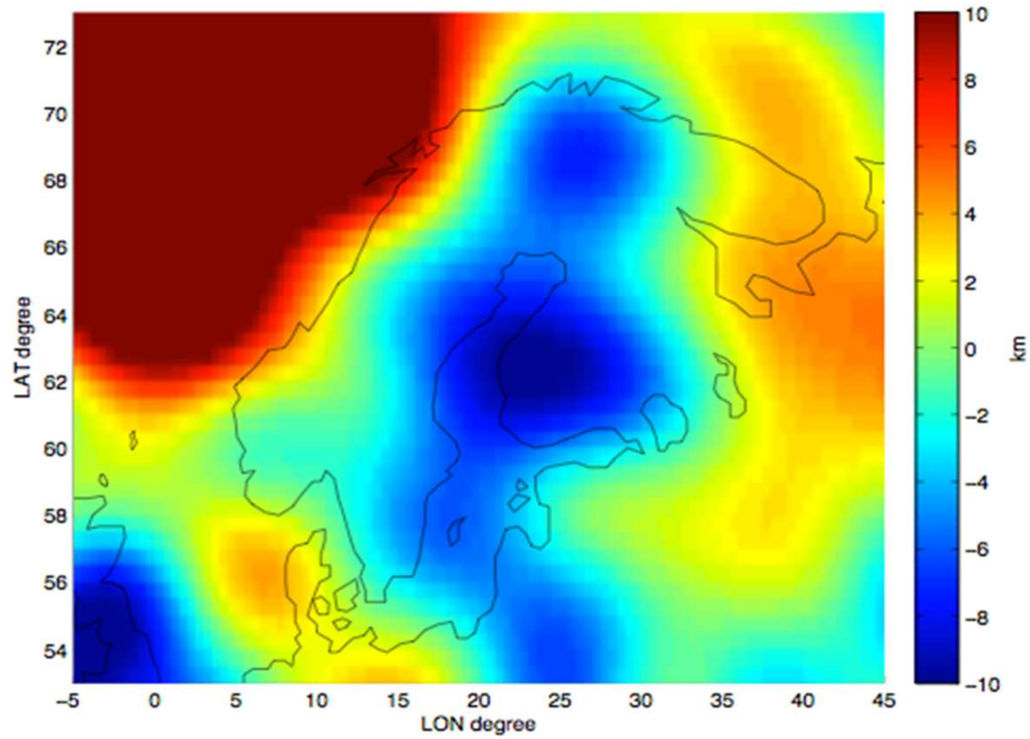
(N-U)*0.1967 [mGal/m]

Observed Displacement

Topography



Moho depth (EuCrust07)



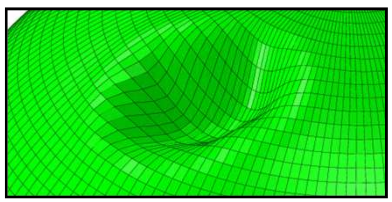
Degrees 11-60

Lithosphere model

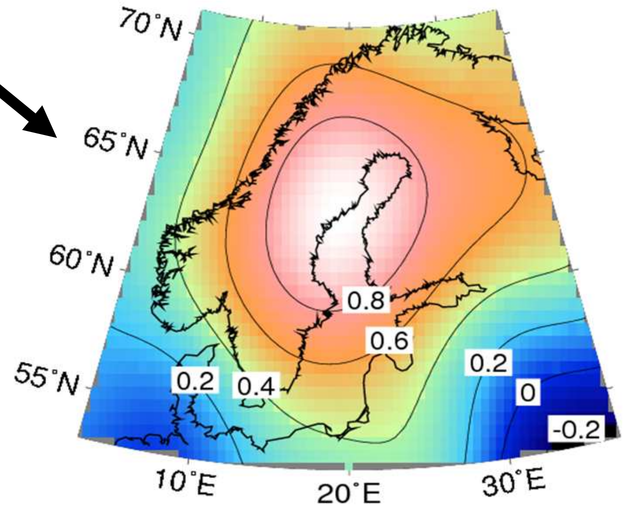
Gravity field information

Seismic models

dv_s to $d\rho$ or dT

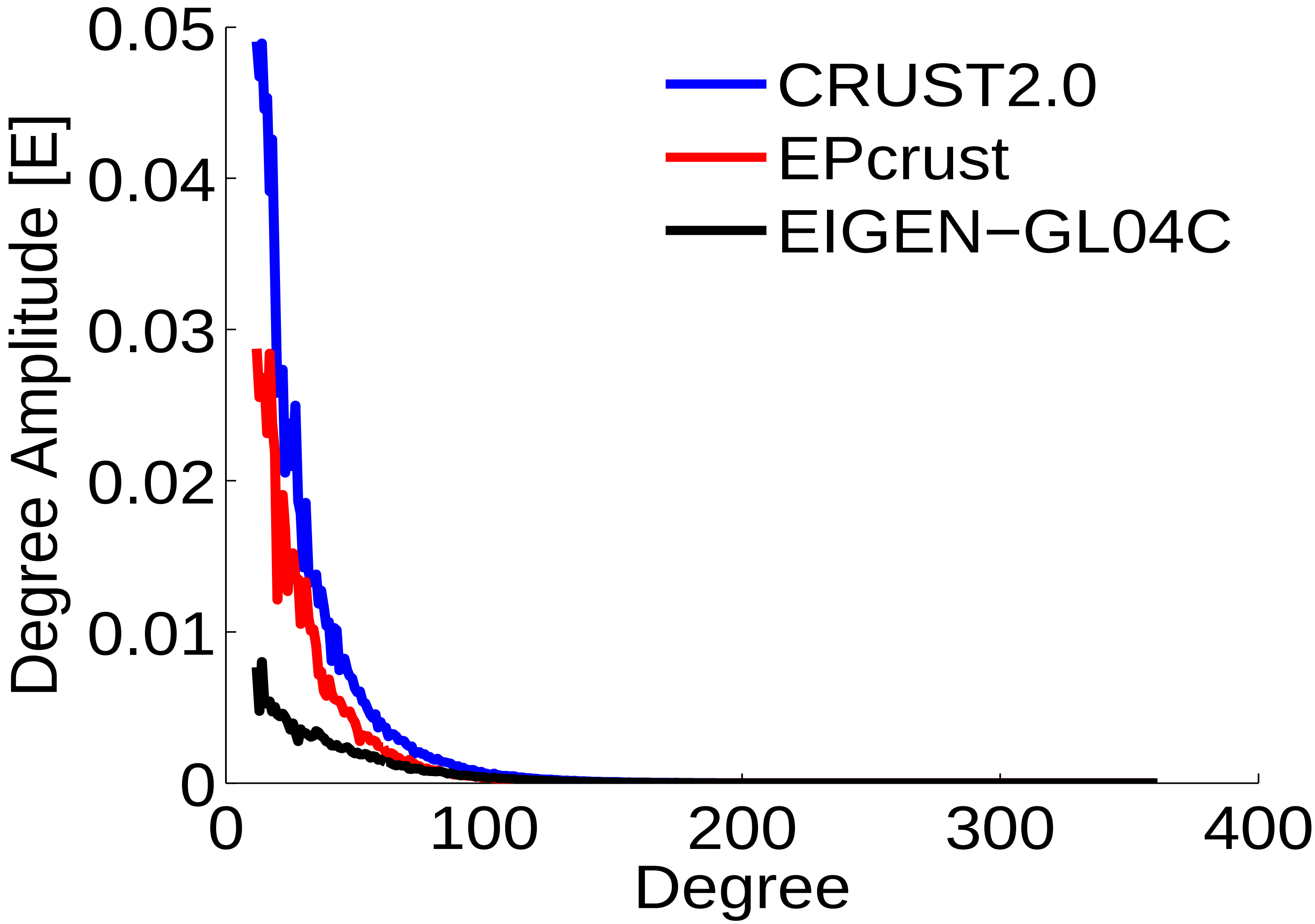


GIA model

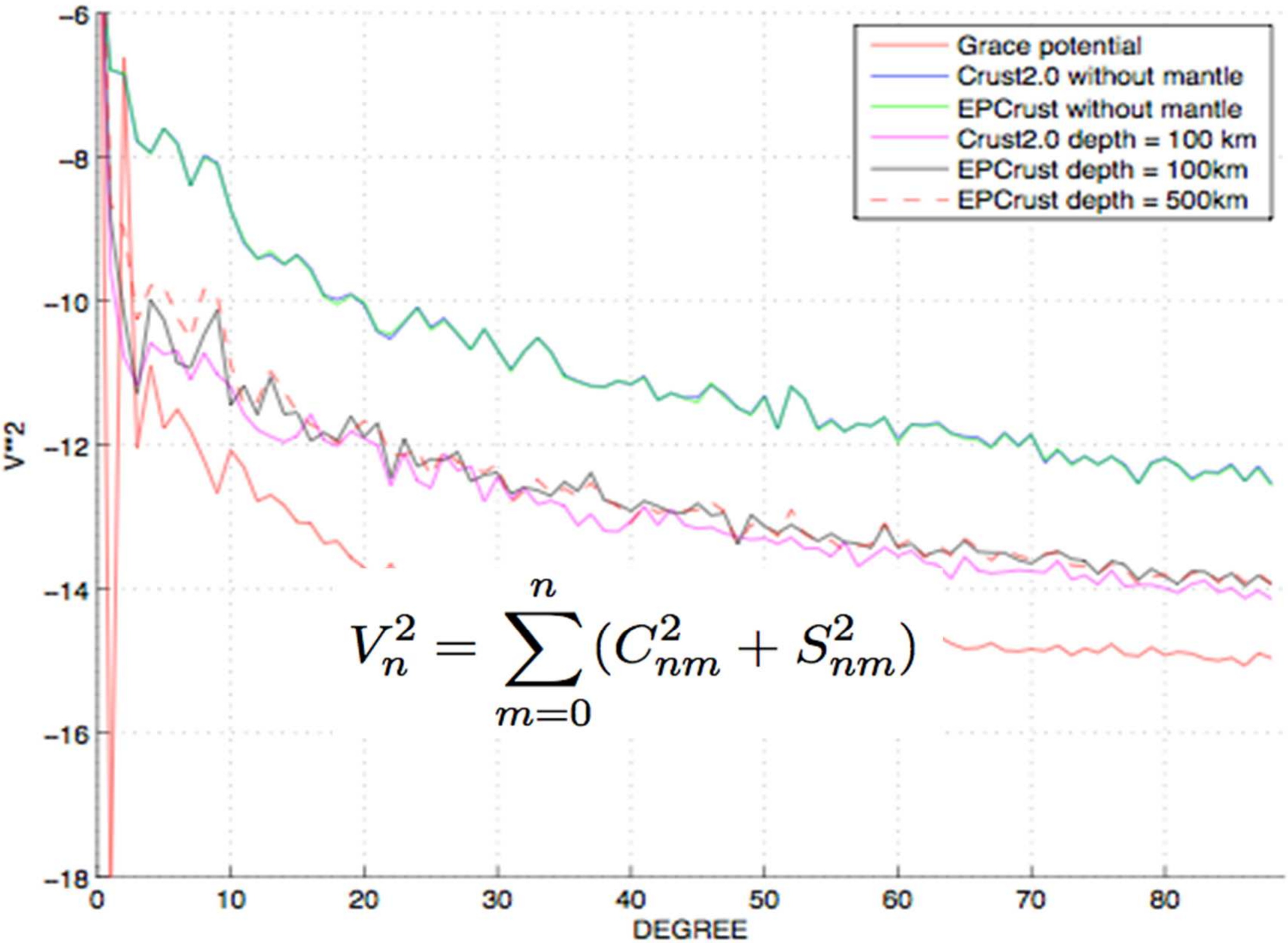


GIA observations

Degree amplitude comparison



Degree variances comparison



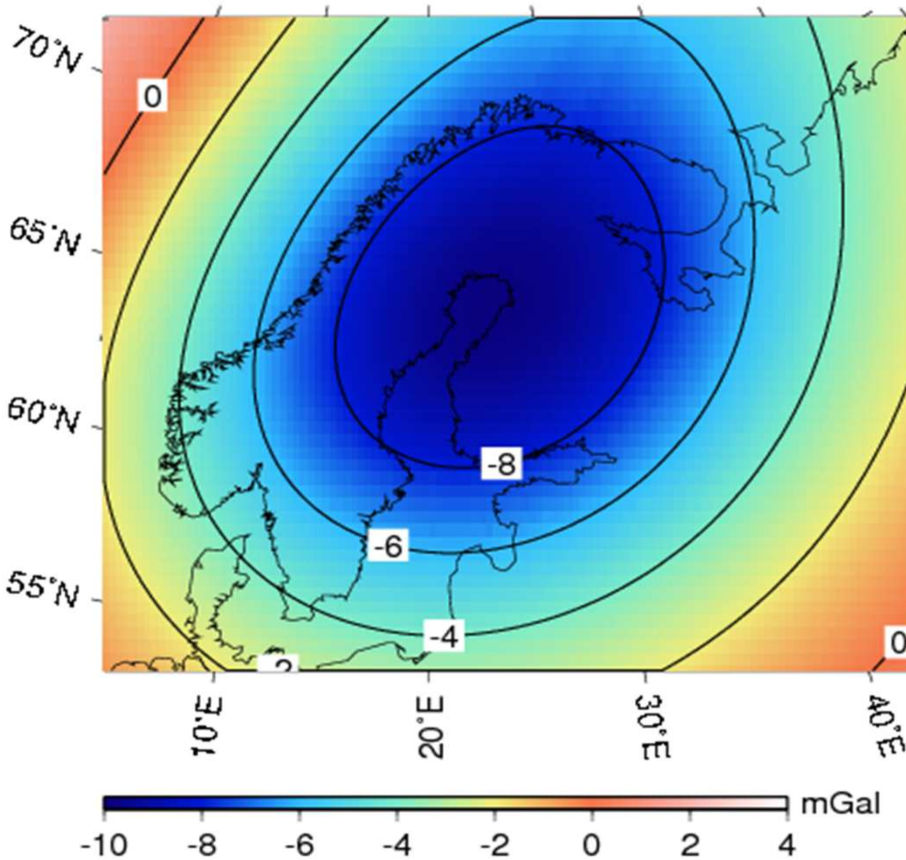
$$V_n^2 = \sum_{m=0}^{n} (C_{nm}^2 + S_{nm}^2)$$

Conclusions

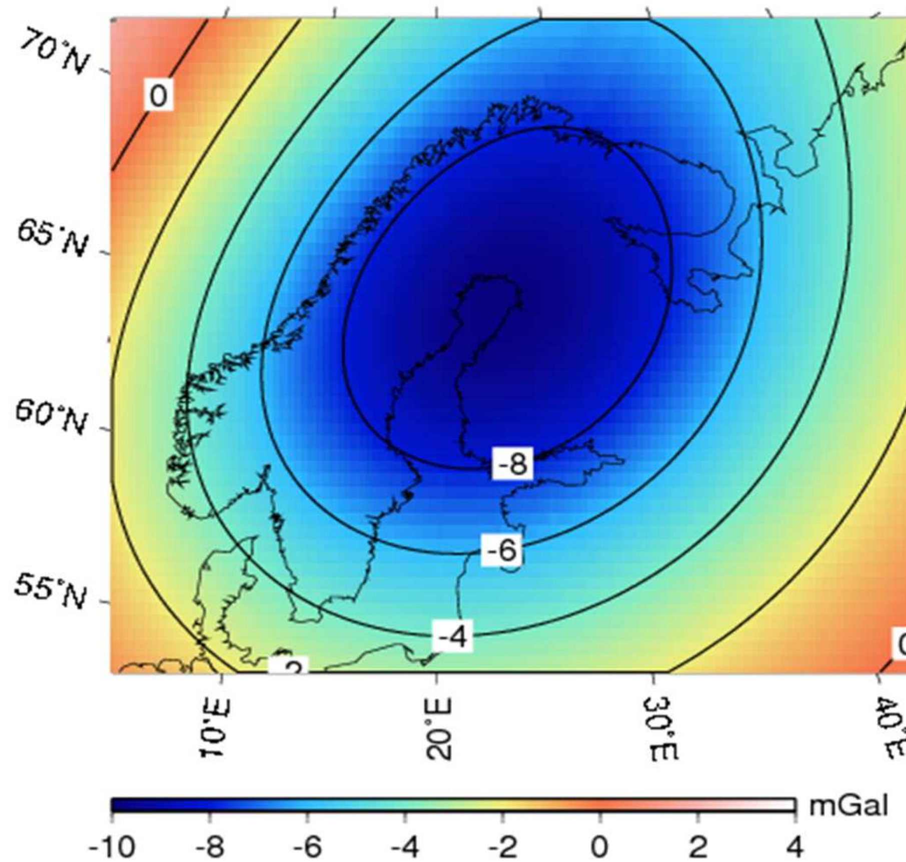
Research

- GIA modeling results in -1 E (peak)
- Hard to extract this signal given uncertainty in crustal densities and thickness
- Topography and Moho boundary contain GIA signal. Topography could be corrected with GIA model

Remainder of previous glacial cycle?



No pre-cycle



1 pre-cycle, little difference..