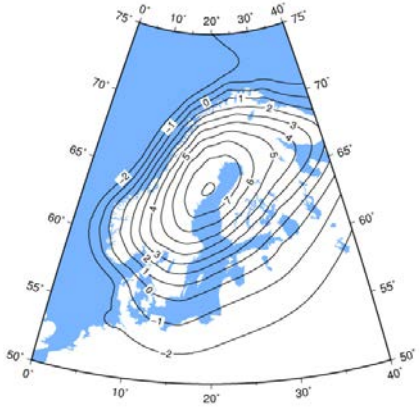
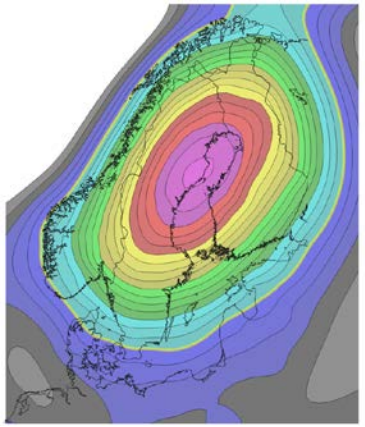
A new updated empirical land uplift model





Olav Vestøl, Jonas Ågren, Tarmo Kall, Ivars Aleksejenko, Eimuntas Paršeliūnas, Andres Rüdja

GENERAL ASSEMBLY 2014

Kartverket

Outline

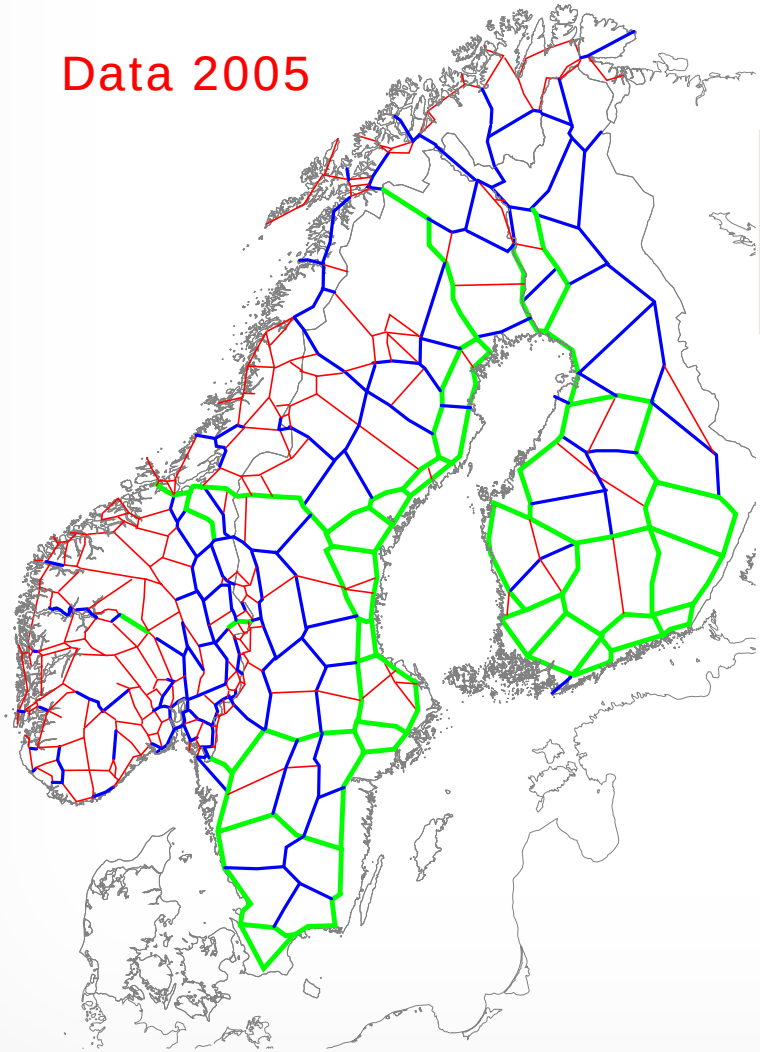
- The observations
- Short about the method
- The result
- Some comparisons

Background

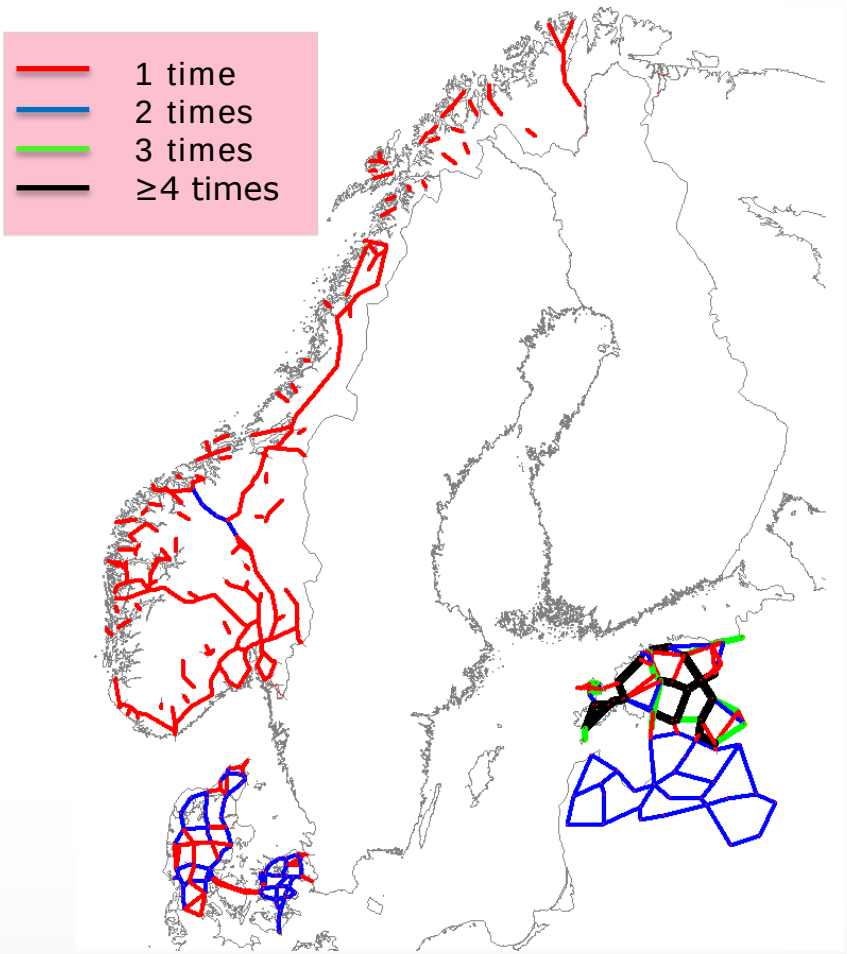
- NKG2005LU was released in 2005.
- Now, 9 years later, more data are available.
- New GIA-models are available

The leveling network

Data 2005



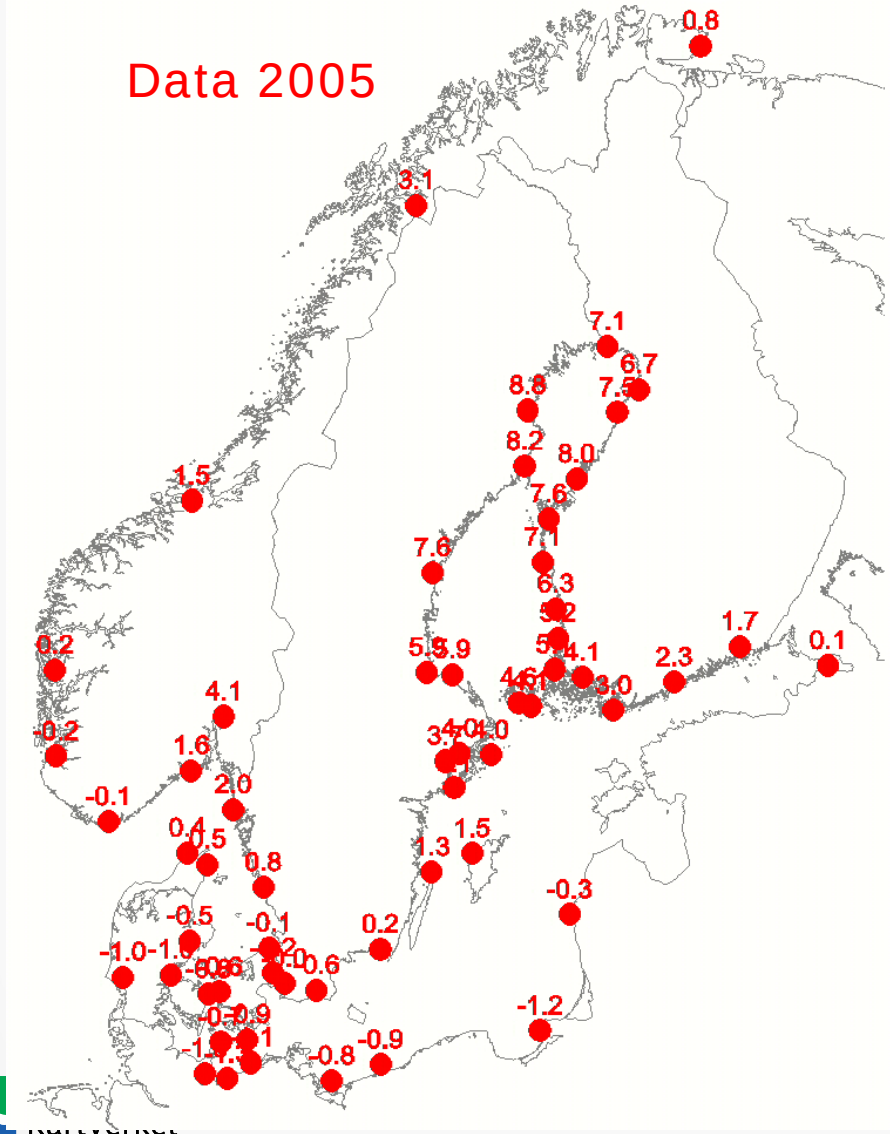
New data included



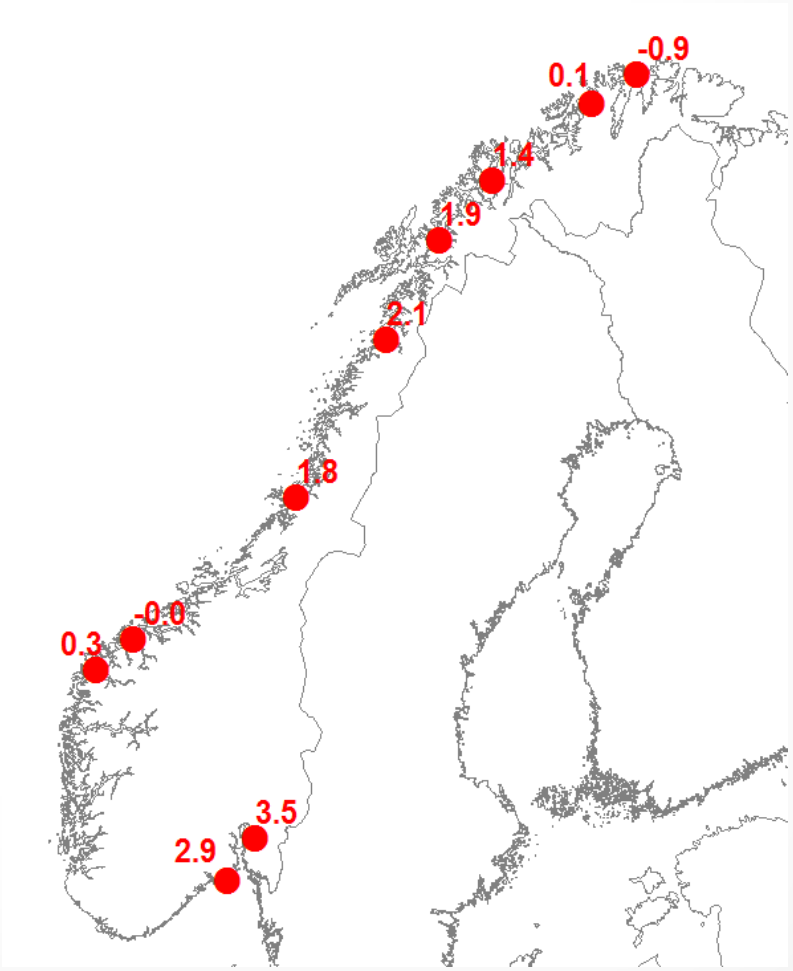
Kartverket

The tide gauges

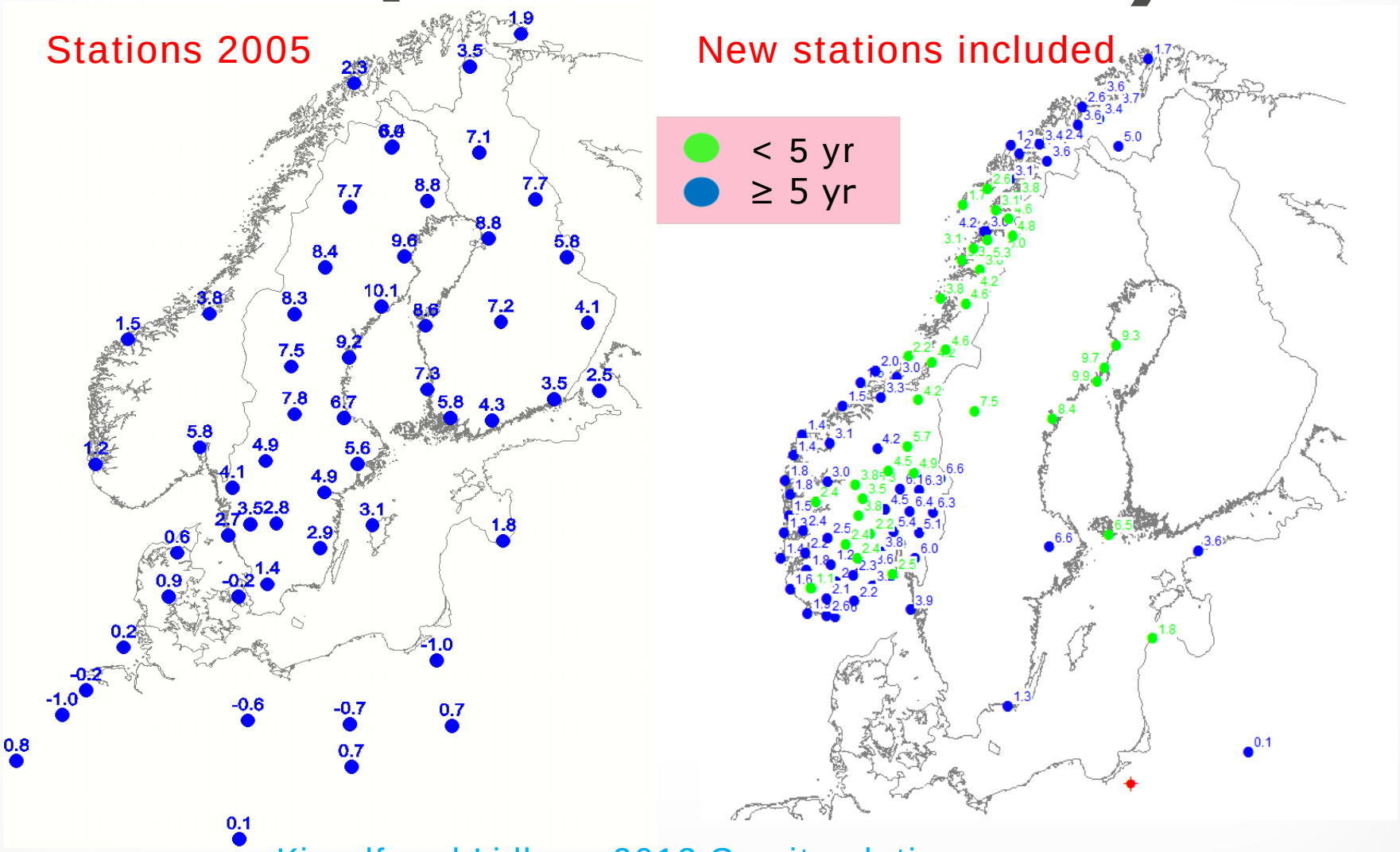
Data 2005



New data included



CORS (GPS-stations)



Kierulf and Lidberg 2013 Gamit-solution

Kartverket

How to handle the new tide gauge rates

The new tide gauges are from 1956 – 2005, (and the Ekman from 1891 – 1990)

	Diff (Short÷Long)			Diff (Short÷Long)
Helsinki	-0,155		Oslo	-0,136
Hanko	-0,187		Tregde	-0,012
Stockholm	-0,064		Stavanger	-0,077
Landsort	-0,094		Bergen	-0,093
Kungholmsfort	-0,074		Heimsjø	-0,073
København	-0,097		Narvik	-0,117
Ratan	-0,032		Smøgen	-0,109
Oulu	-0,077		Esbjerg	-0,076
Vasa	-0,107		Århus	-0,021
			Weighted mean	**-0,074 cm/yr**

Kartverket

How to handle the new GPS-rates

The time span vary from 3 to 13 year.

Systematic differences:

Solved for an extra constant

Weighting strategy: (from simple regression)

$$m_b = m_0 \sqrt{\frac{n}{\left(\frac{1}{6}\left(n^2(n+1)(2n+1)\right) - \frac{1}{4}\left(n^2(n+1)\right)\right)}}$$

where m_0 = 2mm

n = number of years

Examles:
5 yr: 0.6 mm/yr
10 yr: 0.2 mm/yr

A summery of the data

Leveling

- Relative land uplift values between nodal points.
- Reference surface: the rising geoid

Tide gauges

- Apparent land uplift values.
- Reference surface: the rising mean sea level

GPS-stations

- ’Absolute’ values observed in a geodetic reference frame.
- Reference surface: the unstable ellipsoid

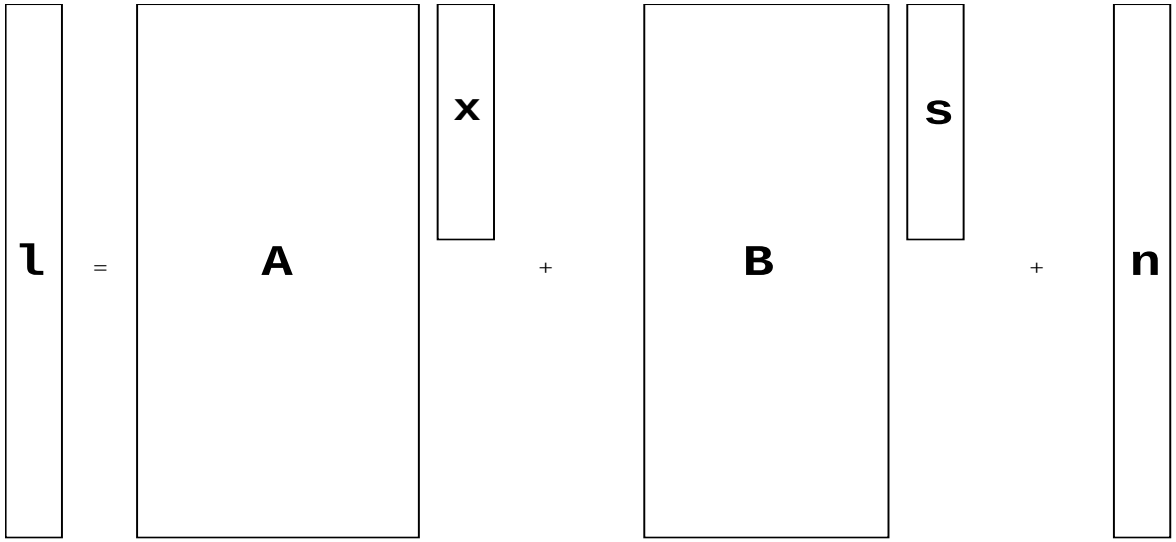
Assumptions and simplifications

1. We select the rising mean sea level, in the 1891-1990 period, as reference surface
2. The uplift is linear in time
3. The rise of the geoid is proportional to the land uplift
4. The difference between ellipsoidal and mean sea level related land uplift values can be expressed with constants and a scale

..which implies

The relative sea surface topography is unchanged in the period of interest.

The LS-collocation method



Where

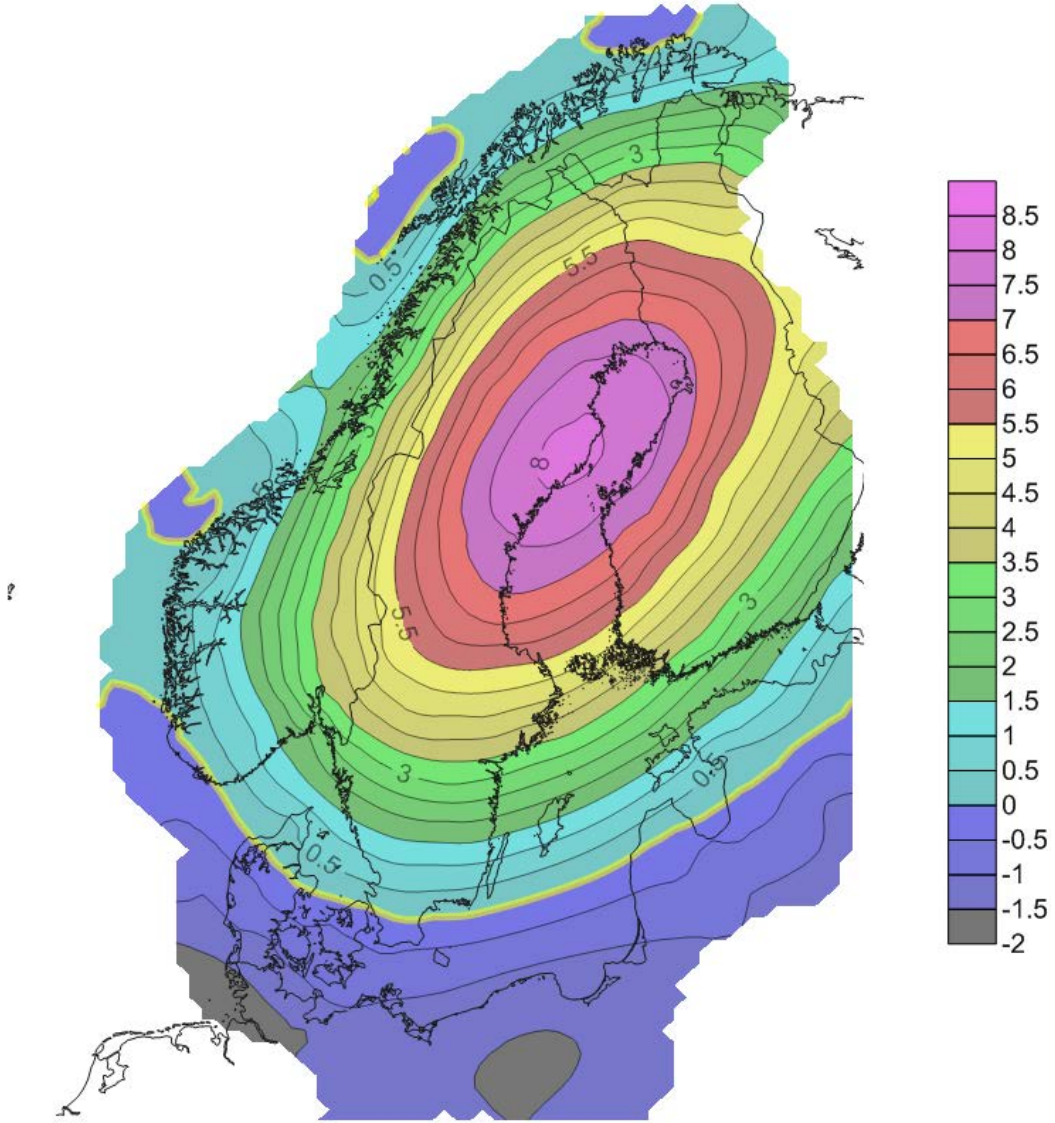
L = Observations
A = Design matrix
X = Unknown heights and trend coefficients
B = Design matrix for the signals
s = Signals (unknown land uplift.)
n = Noise

The unknowns

Leveling:	Heights
	Polynomial coefficients
	Signals
Tide gauges	Polynomial coefficients
	Signals
GPS stations	Polynomial coefficients
	Signals
	Constant
	Scale

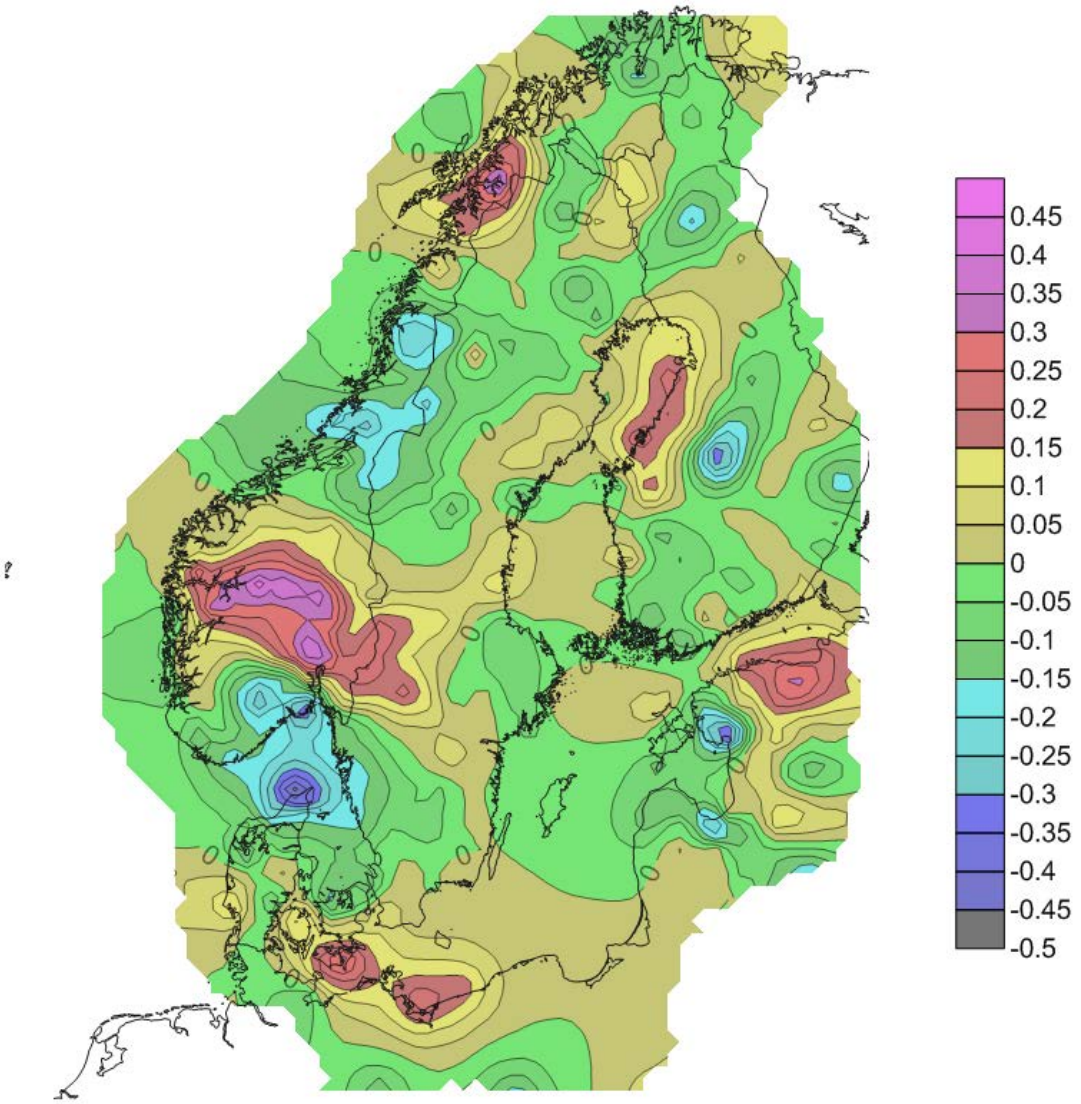
Kartverket

The pure empirical model



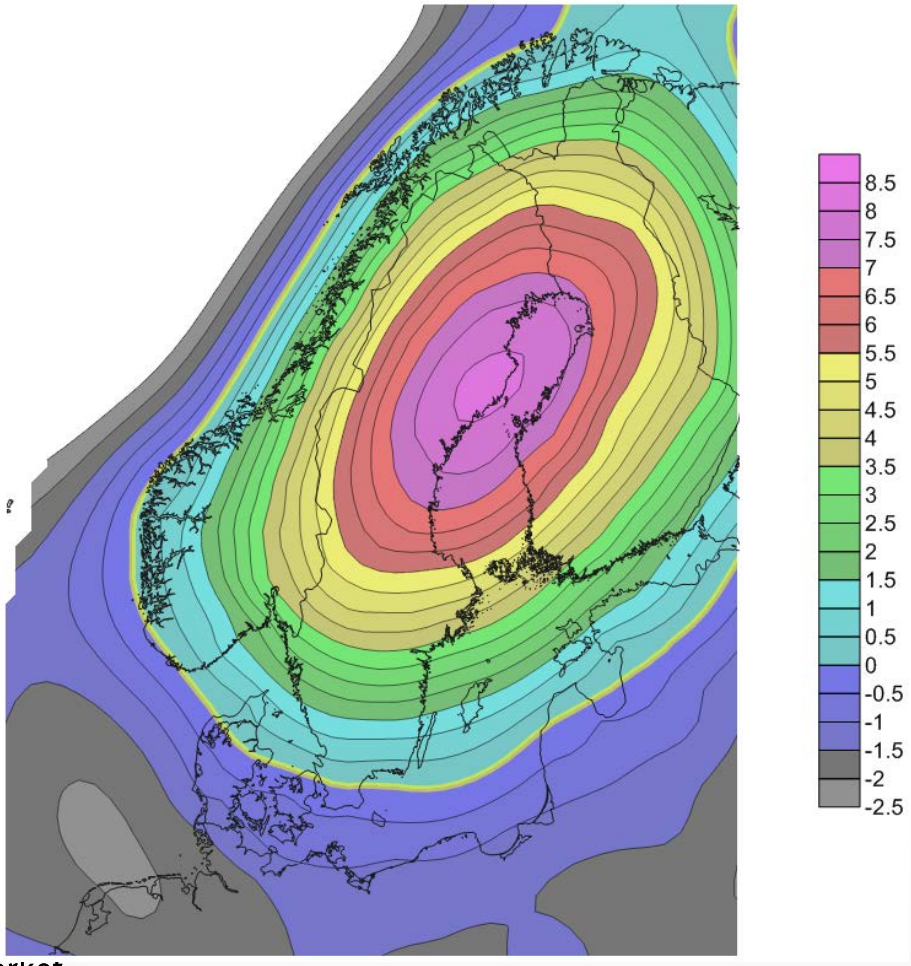
Kartverket

The signal

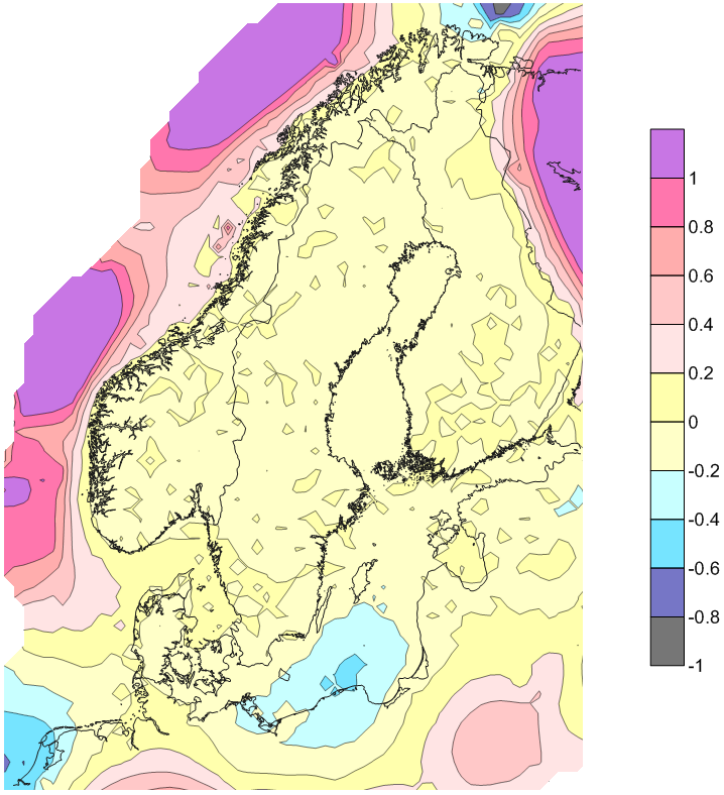


Kartverket

After combined with GIA (i82_g5102 from Holger Steffen)



Differences
Pure emperical ÷
combined solution

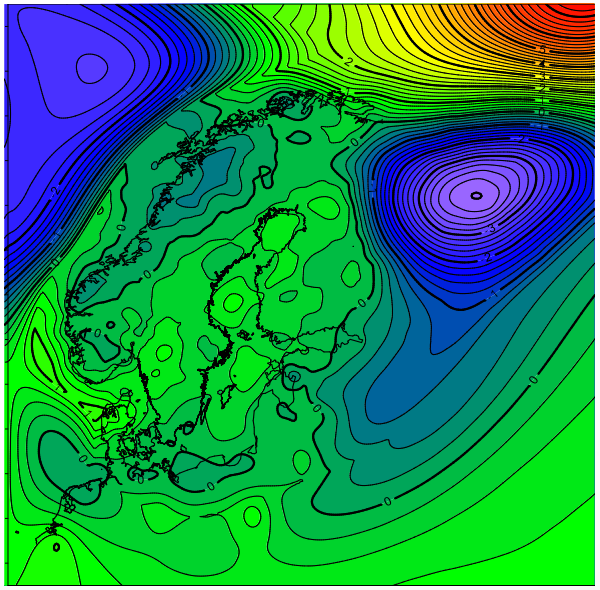


Kartverket

NKG2014LU_test ÷ NKG2005LU

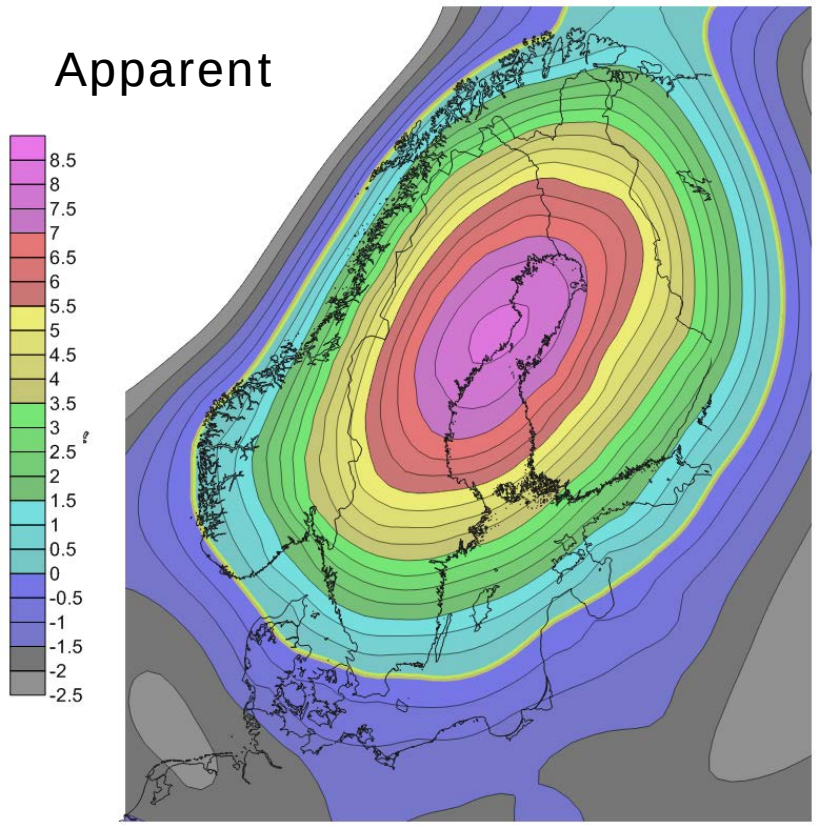
Observation area

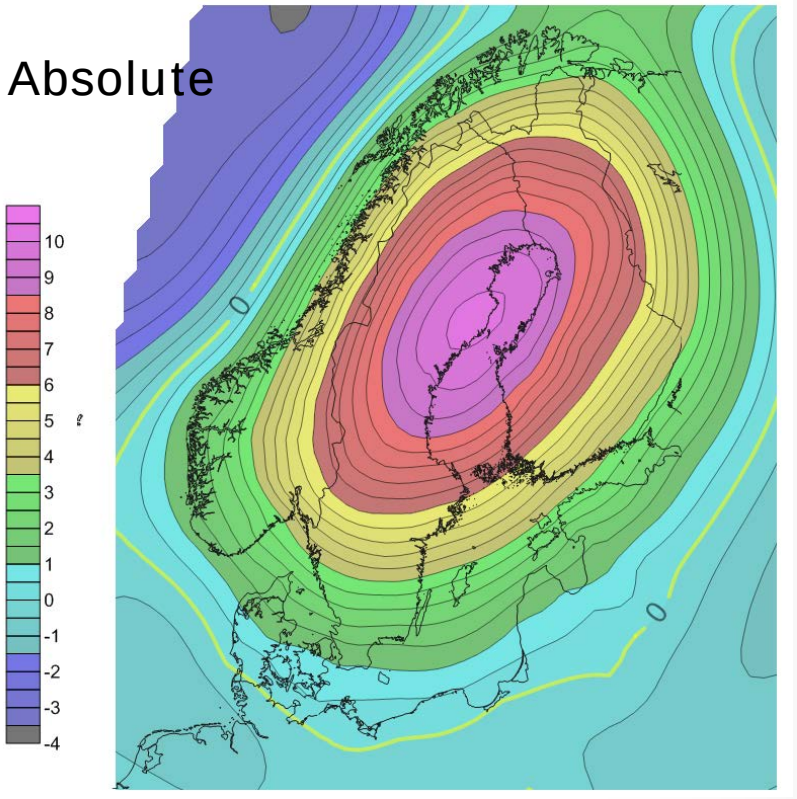
For the whole area



Kartverket

Final results



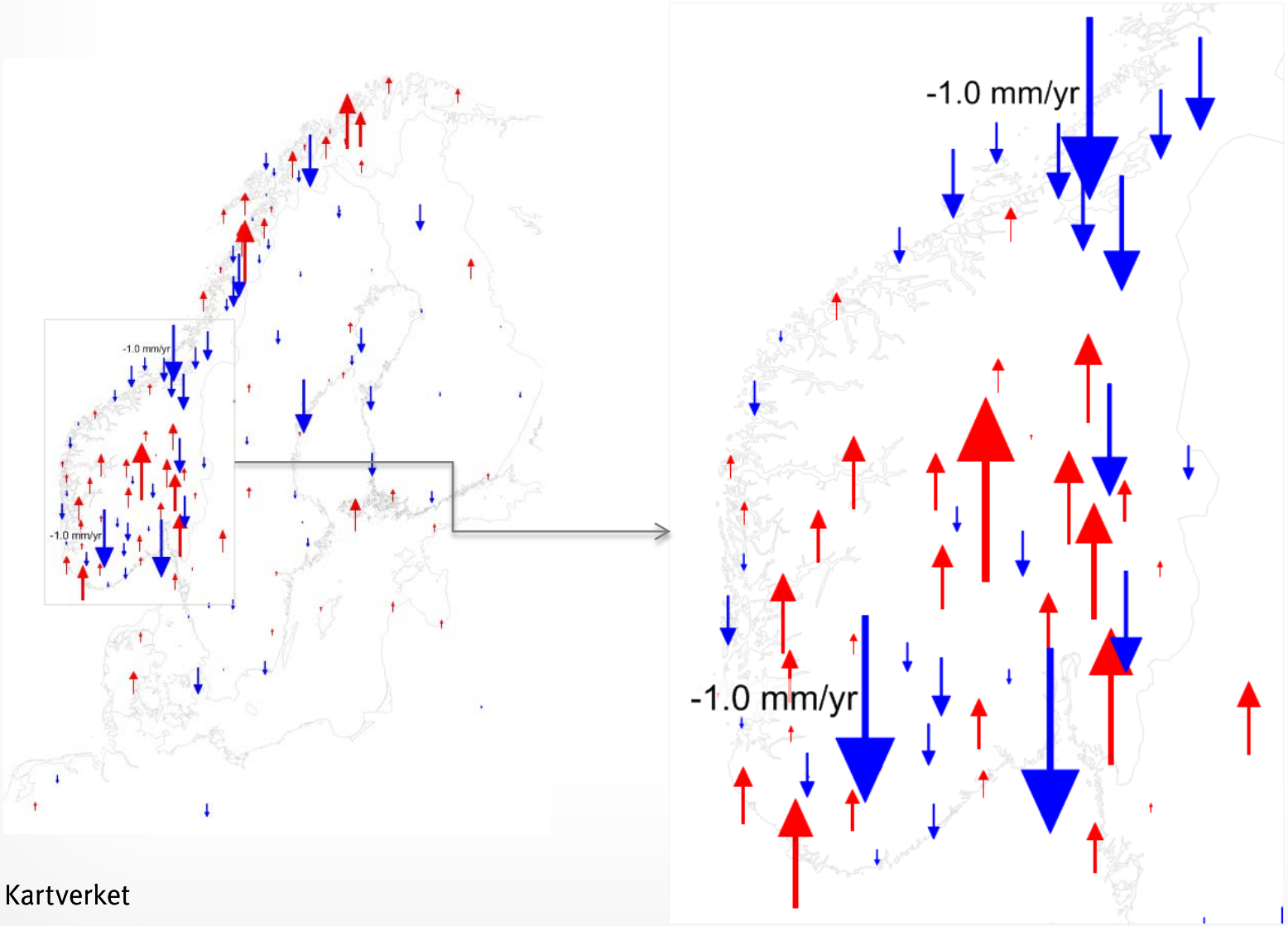


$$ABS = (APP + 1.27) \cdot 1.079$$

Kartverket

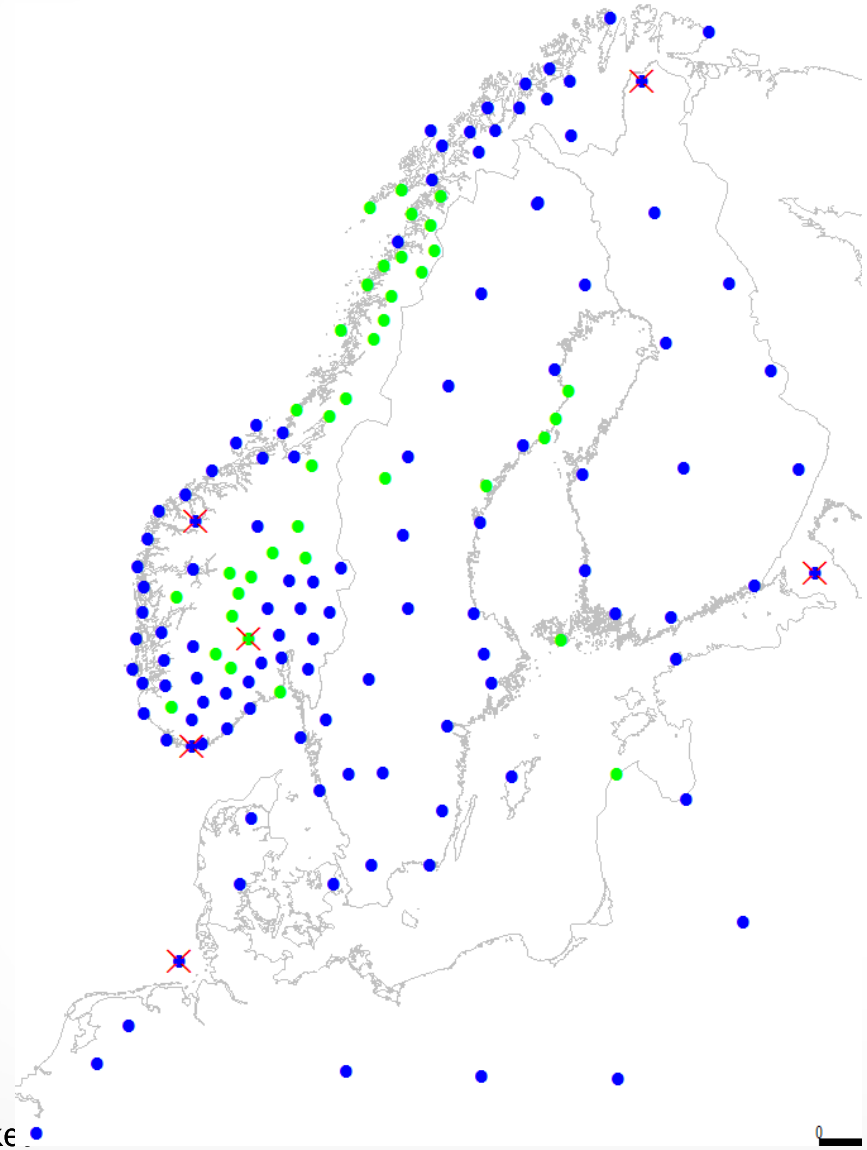
If there is still time.....

GPS-rates Residuals



Kartverket

GPS-rates Outliers



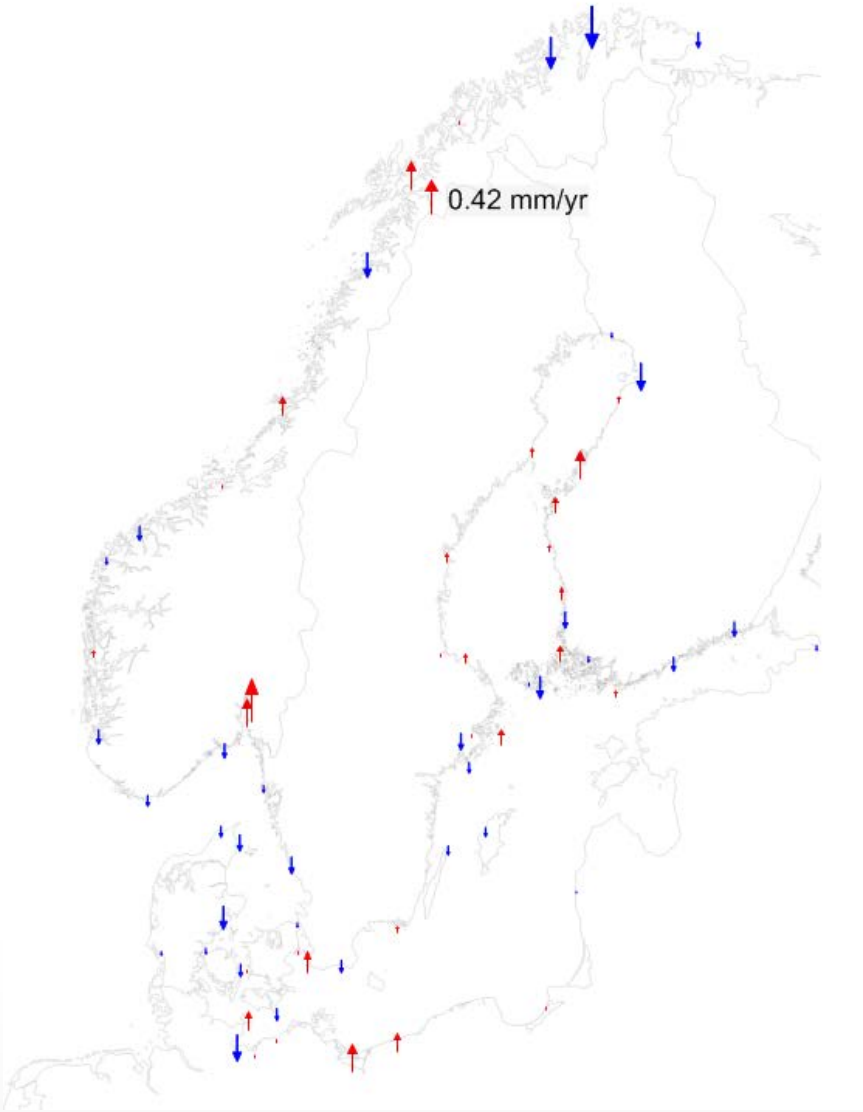
< 5 yr
≥ 5 yr

Station	Outlier mm/yr
KEVO	1.1
HELG	1.1
SVTL	1.4
VEGC	-1.6
TGDE	1.1
HELC	1.0

Kartverket

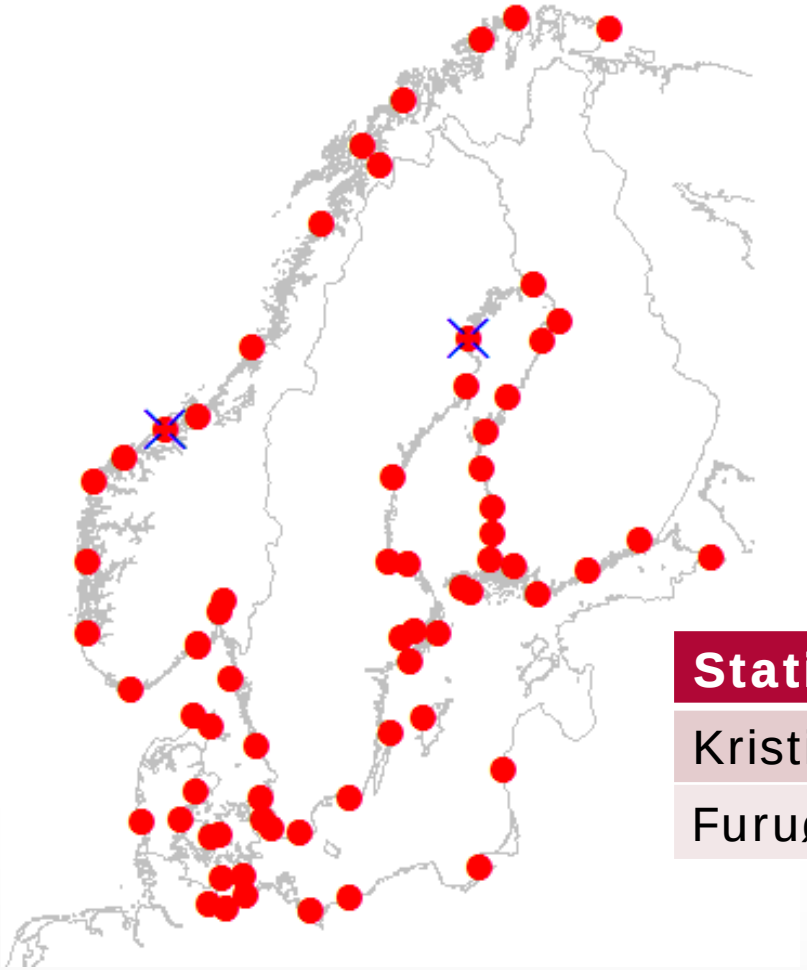
If there is still time #2

Tide Gauges Residuals



Kartverket

Tide Gauges Outliers



Station	Outlier mm/yr
Kristiansund	1.1
Furuøgrund	0.8

Kartverket

If there is still time #3

The fit of the GPS-rates

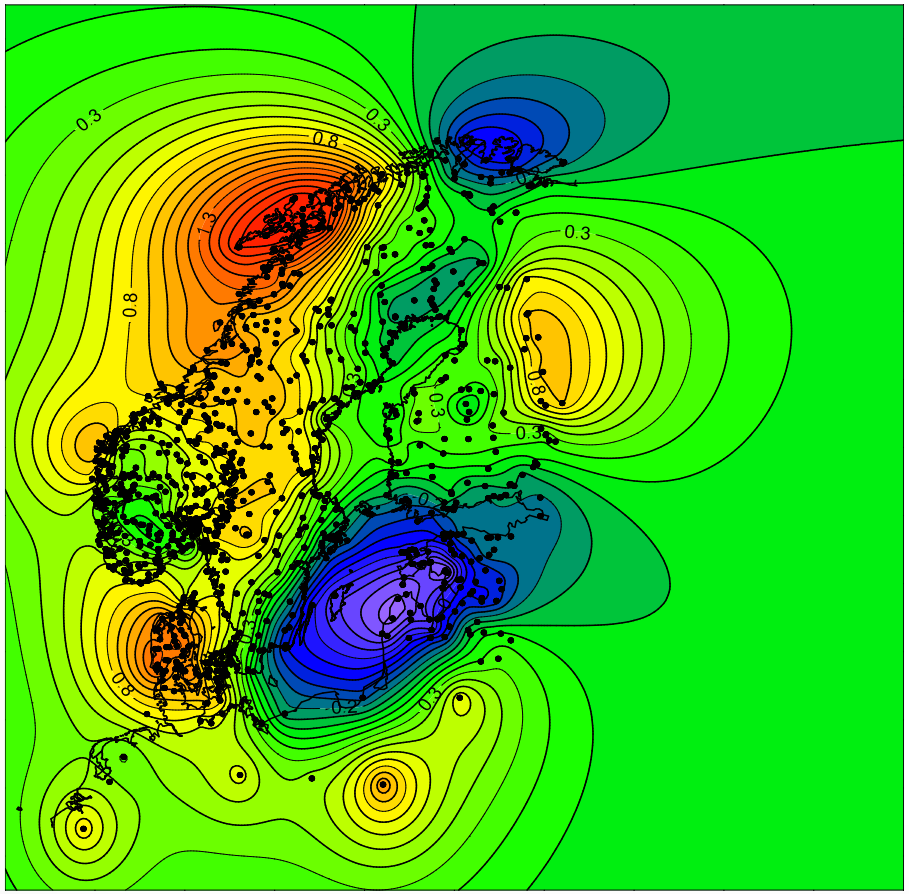
Model	Const. 1 (mm/yr)		Const. 2 (mm/yr)		Scale (%)	
	Value	$\hat{\sigma}$	Value	$\hat{\sigma}$		$\hat{\sigma}$
NKG2005LU	1.32	0.14			5.7	2.3
NKG2014LU_test	1.27	0.08	1.01	0.12	7.3	1.5

Short GPS-series

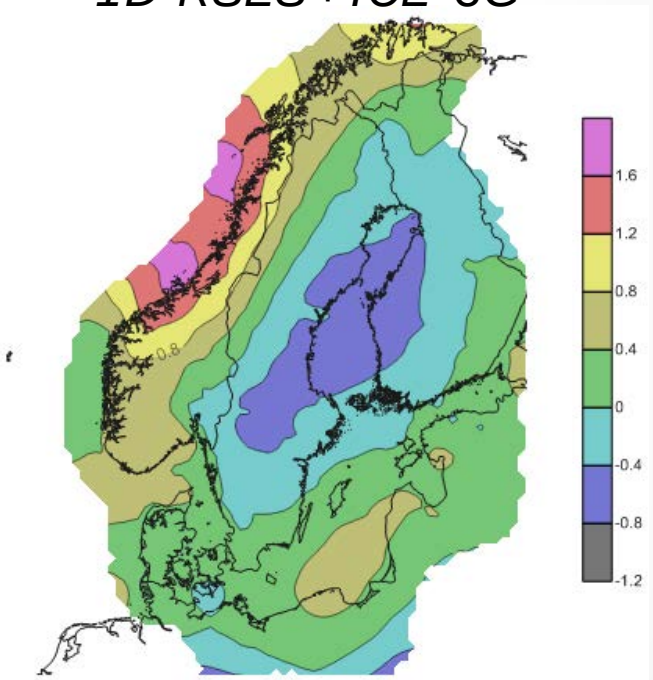
The GPS-rates in NKG2005LU are expressed in ITRF2000, and in ITRF2008 for NKG2014LU_test!

NKG2014LU_test ÷ *GIA*

i82_g5102



1D RSES+ICE-3G



Kartverket

Thank you for your attention!

Observations in NKG2005LU

Leveling observations

From Norway, Sweden and Finland. Geopotential differences between nodal points. From 1890 - 2003

Tide gauges

58 stations. Martin Ekman's values, published in 1996.

GPS-rates

55 stations. Results from Martin Lidberg's Licentiate Thesis in 2004. Reference frame: ITRF2000

Empirical land uplift model vs. GIA-models

GIA (Glacial Isostatic Adjustment):

- Based on Earth Model + Ice history model + Sea Level Equation
- Need observations to tune the parameters

Empirical land uplift models:

- Based on geodetic observations only
- Can be smoothed and extended by a GIA-model