FIG WORKING WEEK 2017

Helsinki Finland

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On the Use of Crustal Deformation Models in the Management of ETRS89 Realizations in Fennoscandia

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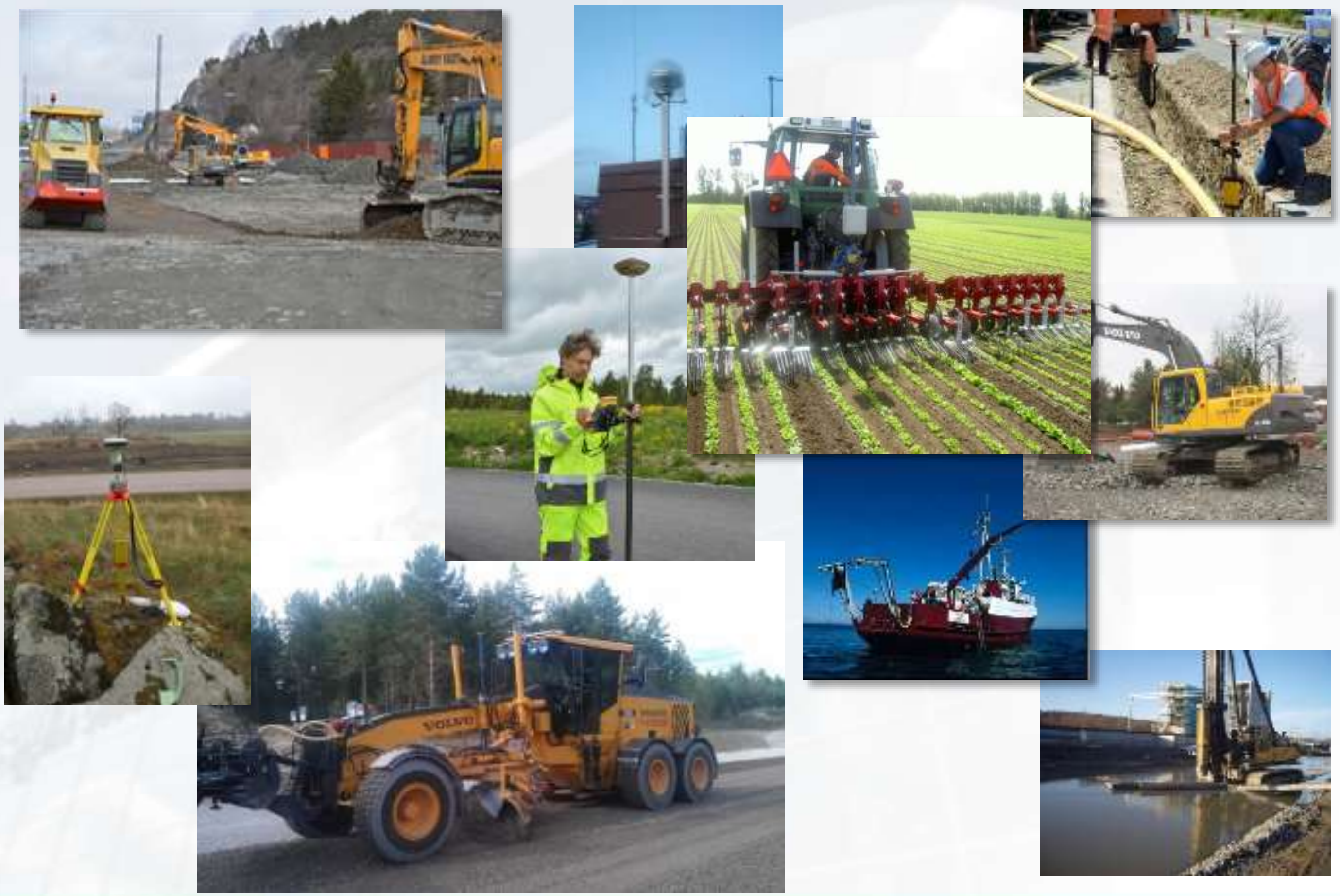
Outline

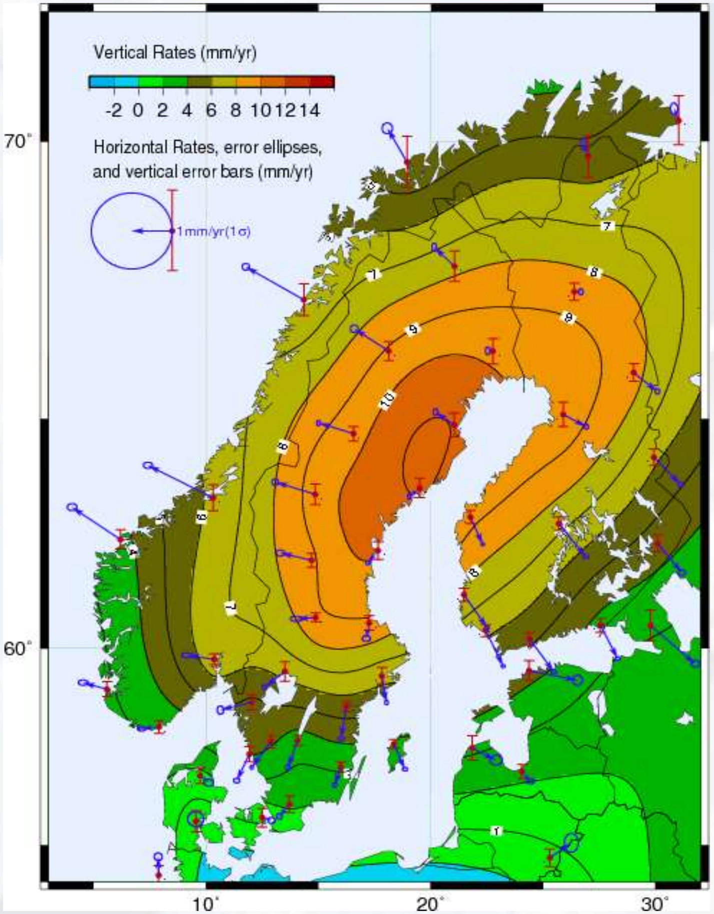
- The Fennoscandia land uplift process
- What is ETRS89?
- Applying models of crustal deformations!
- The new model NKG2016LU
- Details on transformations

  → next talk by Pasi Häkli

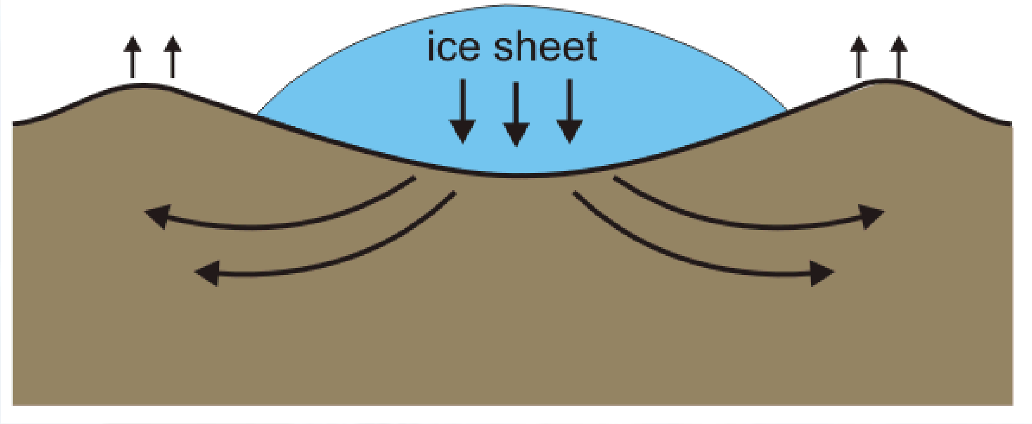
Motivation – users asking for high performance in real time!

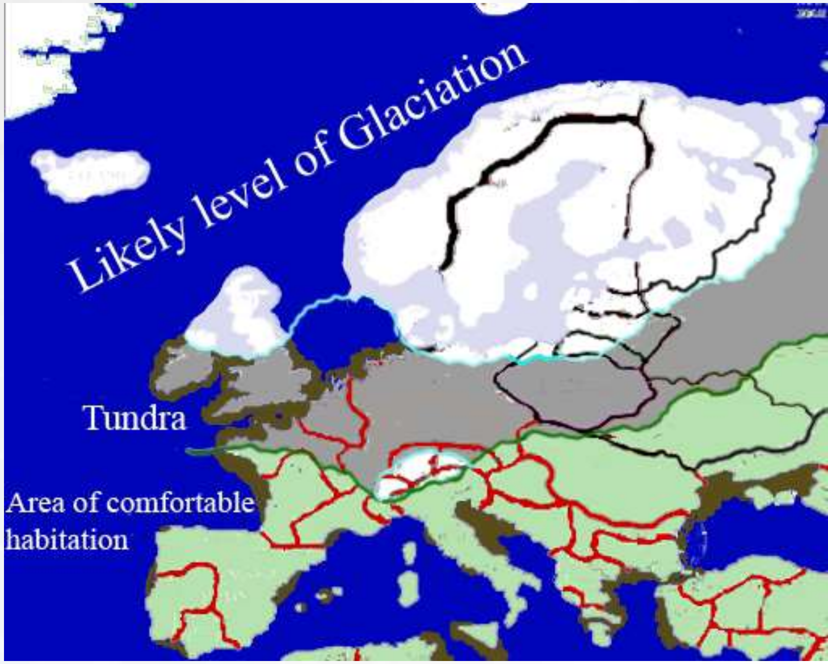


The Fennoscandia Post Glacial Rebound, or GIA process!



The Glacial Isostatic Adjustment (GIA) phenomenon





What is ETRS89?

- The European Terrestrial Reference System
- Coincident with ITRS at epoch 1989.0, and fixed to the stable part of the Eurasian tectonic plate.

- From Boucher&Altamimi (2011) Memo v8, chapter 3:

the plate motion model

$$X^E(t_c) = X^I_{YY}(t_c) + T_{yy} + \boxed{\begin{pmatrix} 0 & -\dot{R}3_{YY} & \dot{R}2_{YY} \\ \dot{R}3_{YY} & 0 & -\dot{R}1_{YY} \\ -\dot{R}2_{YY} & \dot{R}1_{YY} & 0 \end{pmatrix}} \times X^I_{YY}(t_c) \cdot (t_c - 1989.0)$$

Realizations of ETRS89 in Fennoscandia (the Nordic /Baltic countries)

Country	Name of realization	ETRF version	Realization epoch
Denmark	EUREF-DK94	ETRF92	1994.704
Estonia	EUREF-EST97	ETRF96	1997.56
Faroe Islands		ETRF2000	2008.75
Finland	EUREF-FIN	ETRF96	1997.0
Latvia	LKS-92	ETRF89	1992.75
Lithuania	EUREF-NKG-2003	ETRF2000	203.75
Norway	EUREF89	ETRF93	1995.0
Sweden	SWEREF 99	ETRF98	1999.5

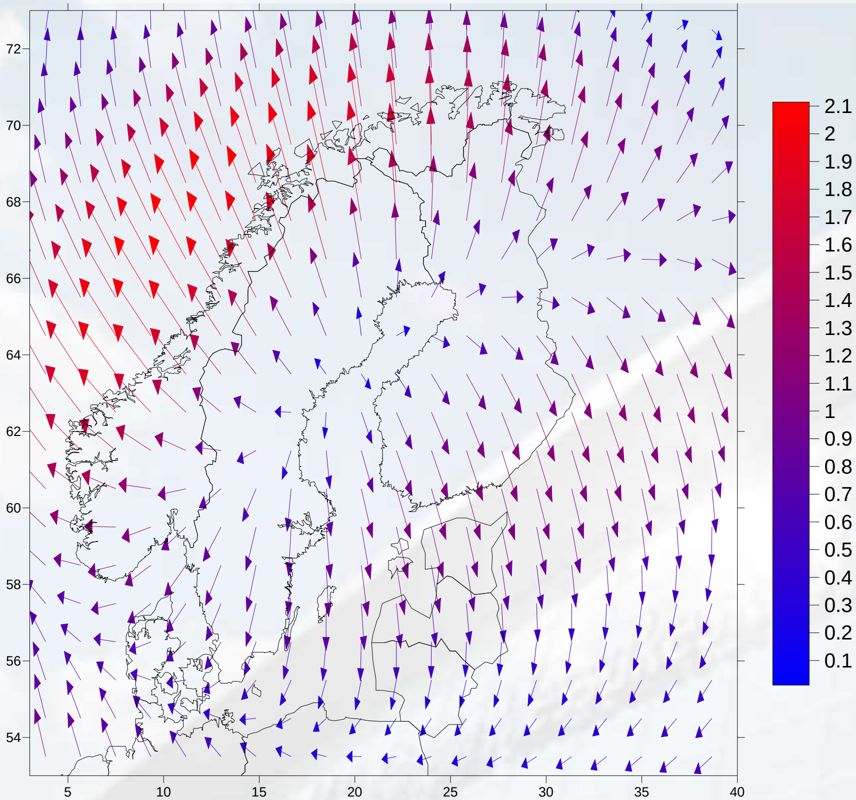
To note:

In presence of crustal deformations, the epoch is crucial.

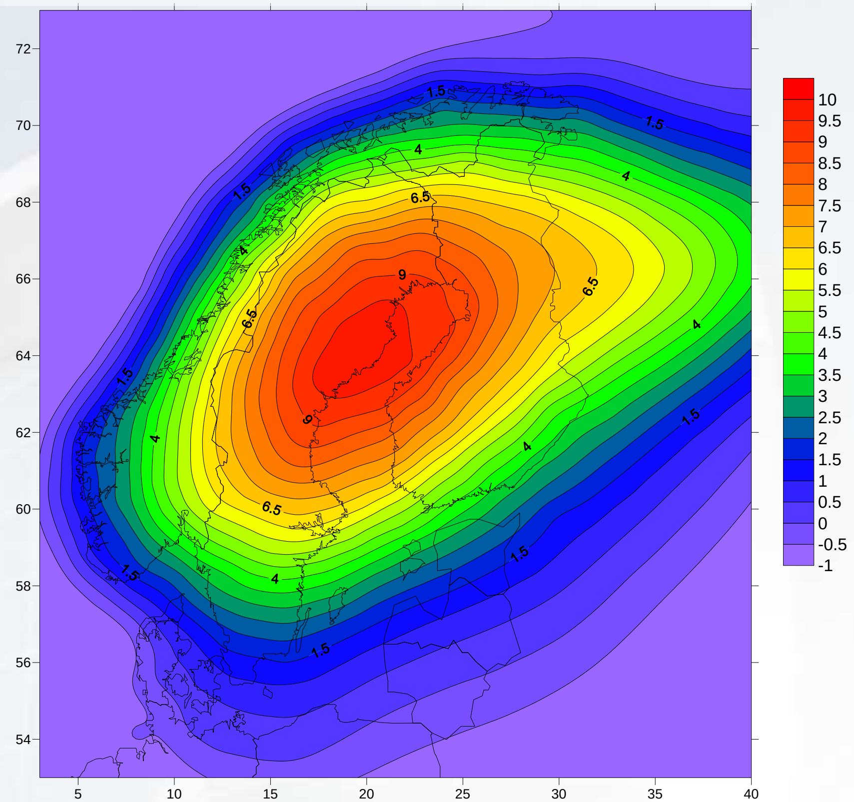
Therefore:

Time tag everything!

The NKG_RF2003_vel velocity model



Horizontal (0 to 2 mm/yr):
The GIA model in Milne 2001 transformed to the GPS-velocities (in Lidberg 2007).



Vertical (-1 to 10 mm/yr):
The NKG2005LU(ABS) model
Based on: TG, repeated levelling, and GPS. (Ågren & Svensson 2006)

Some formulas for the use of the model of crustal (intraplate) deformation

From velocities to coordinate differences

$$\begin{pmatrix} dX \\ dY \\ dZ \end{pmatrix} = \left(t_{target\_epoch} - t_{observation\_epoch}\right) \begin{pmatrix} V_{X_{intra}} \\ V_{Y_{intra}} \\ V_{Z_{intra}} \end{pmatrix}_{NKG\_RF03vel}$$

From velocities in (n,e,u) to (X,Y,Z) frame

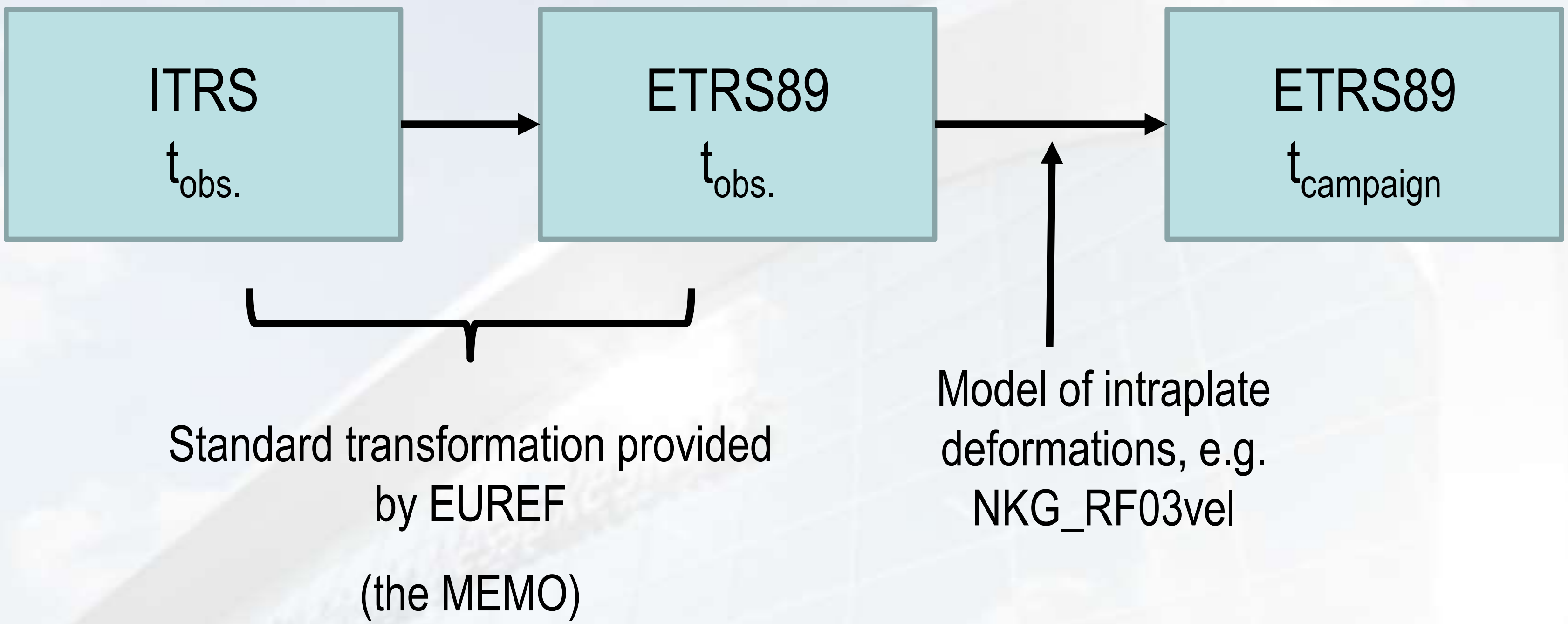
$$\begin{cases} \dot{X} = \dfrac{-Z}{R}\dfrac{X}{P}\dot{n} + \dfrac{-Y}{P}\dot{e} + \dfrac{X}{R}\dot{u} \\ \dot{Y} = \dfrac{-Z}{R}\dfrac{Y}{P}\dot{n} + \dfrac{X}{P}\dot{e} + \dfrac{Y}{R}\dot{u} \\ \dot{Z} = \dfrac{P}{R}\dot{n} + \dfrac{Z}{R}\dot{u} \end{cases}$$

Where: $R = \sqrt{X^2 + Y^2 + Z^2}$

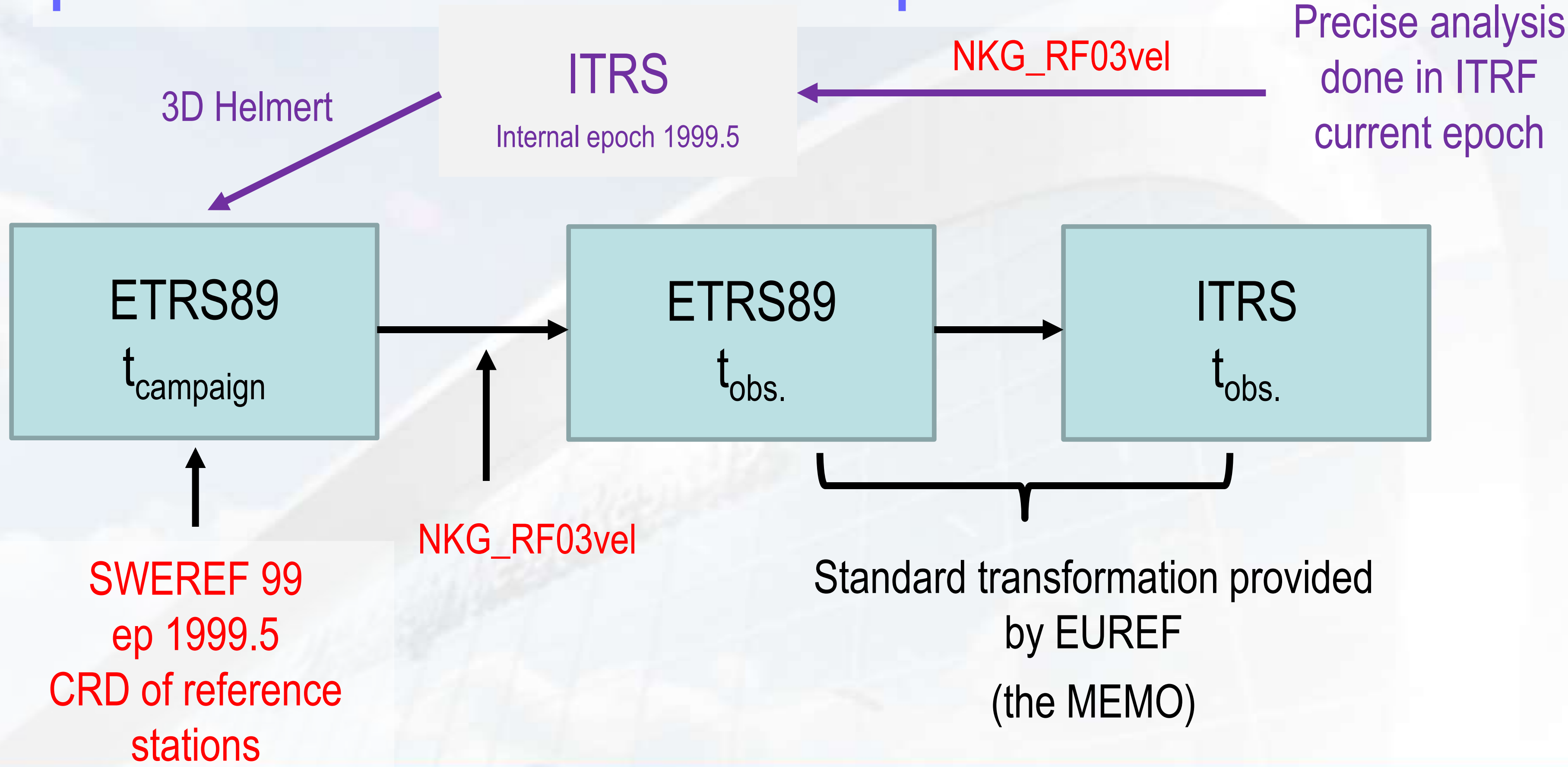
And: $P = \sqrt{X^2 + Y^2}$

(assuming a spherical earth)

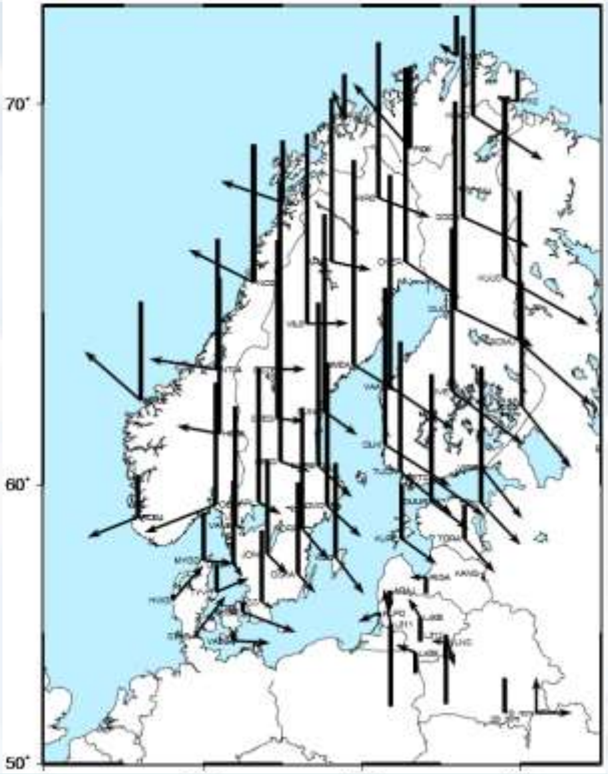
Principle transformation scheme from ITRFs to national realization of ETRS89



Practical transformation scheme while connecting to known permanent GNSS stations – example Sweden



Comparing the national realizations of ETRS89 in Fennoscandia

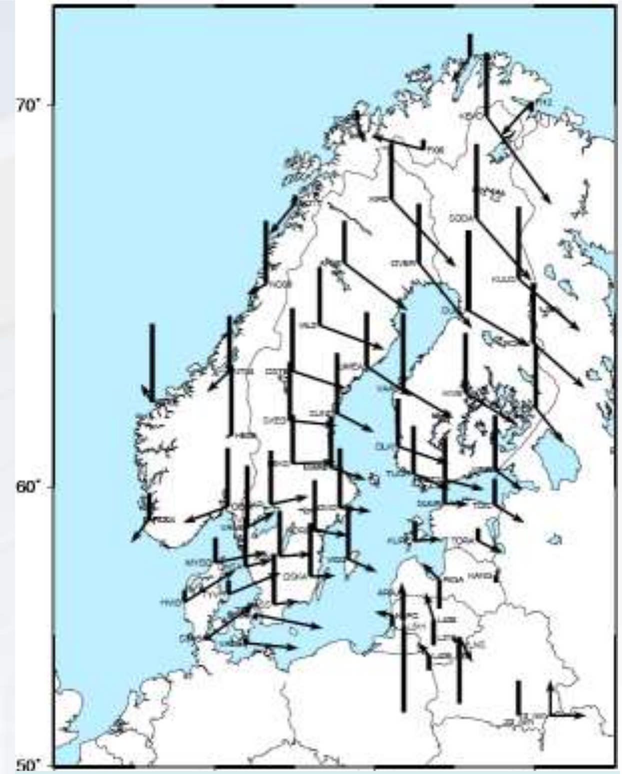


Statistics:(n,e,u) in mm			
RMS	9	12	69
Mean	-4	5	53

The NKG2008 campaign in ETRF2000 compared to national realizations.

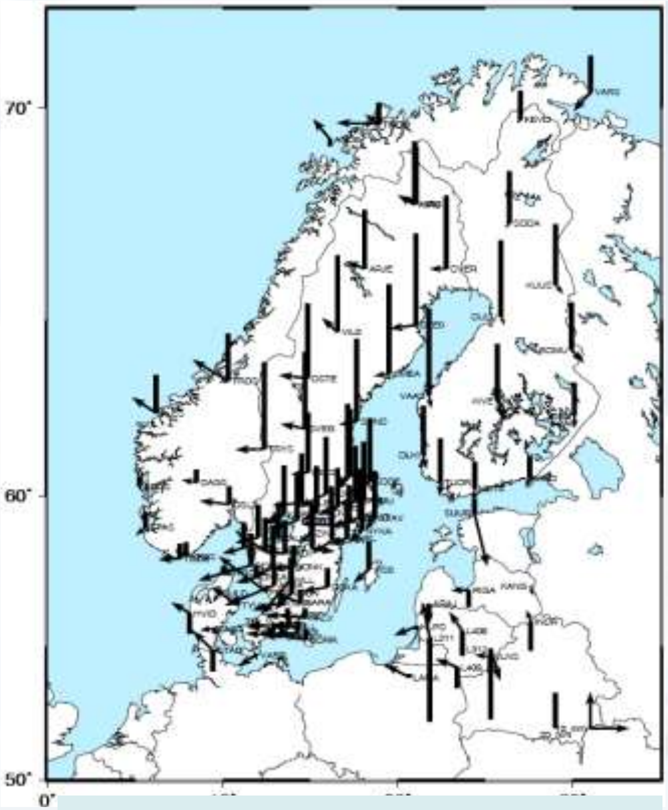
Left, @ epoch 2008.75.

Right, @ epoch 2000.0, using a model for intraplate velocities (NKG_RF03vel)



Statistics:(n,e,u) in mm			
RMS	8	11	28
Mean	-3	7	19

Comparing the NKG2008, and the NKG2003 common campaigns. (ETRF2000)



Statistics:(n,e,u) in mm			
RMS	4	5	24
Mean	-5	-4	16

NKG2003 based on ITRF2000,

NKG2008 based on ITRF2005.

Left, NKG2008 @2008.75; NKG2003 @ 2003.75

Right, booth @ epoch 2003.75, using the model NKG_RF03vel

(No fit – just coordinate differences!)

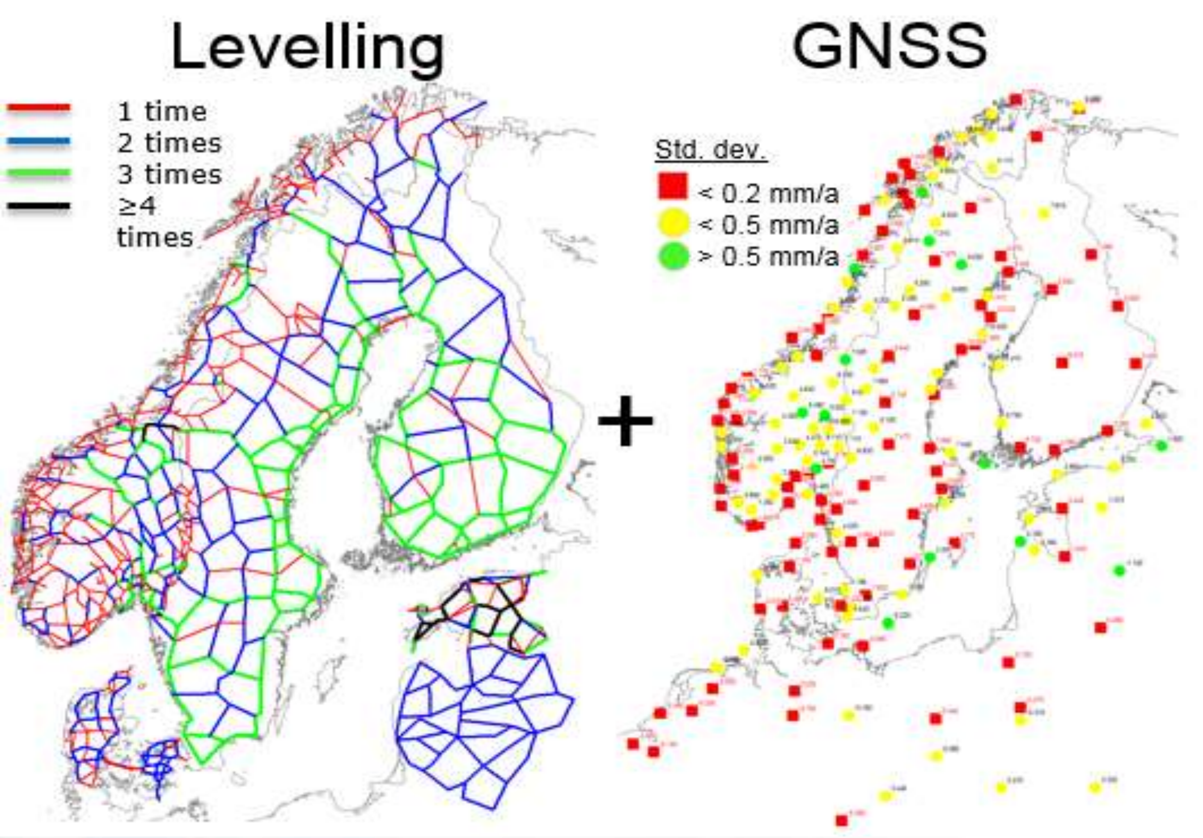
Accidentally good luck in reference frame realization??

Statistics:(n,e,u) in mm			
RMS	4	4	8
Mean	0	-3	-3

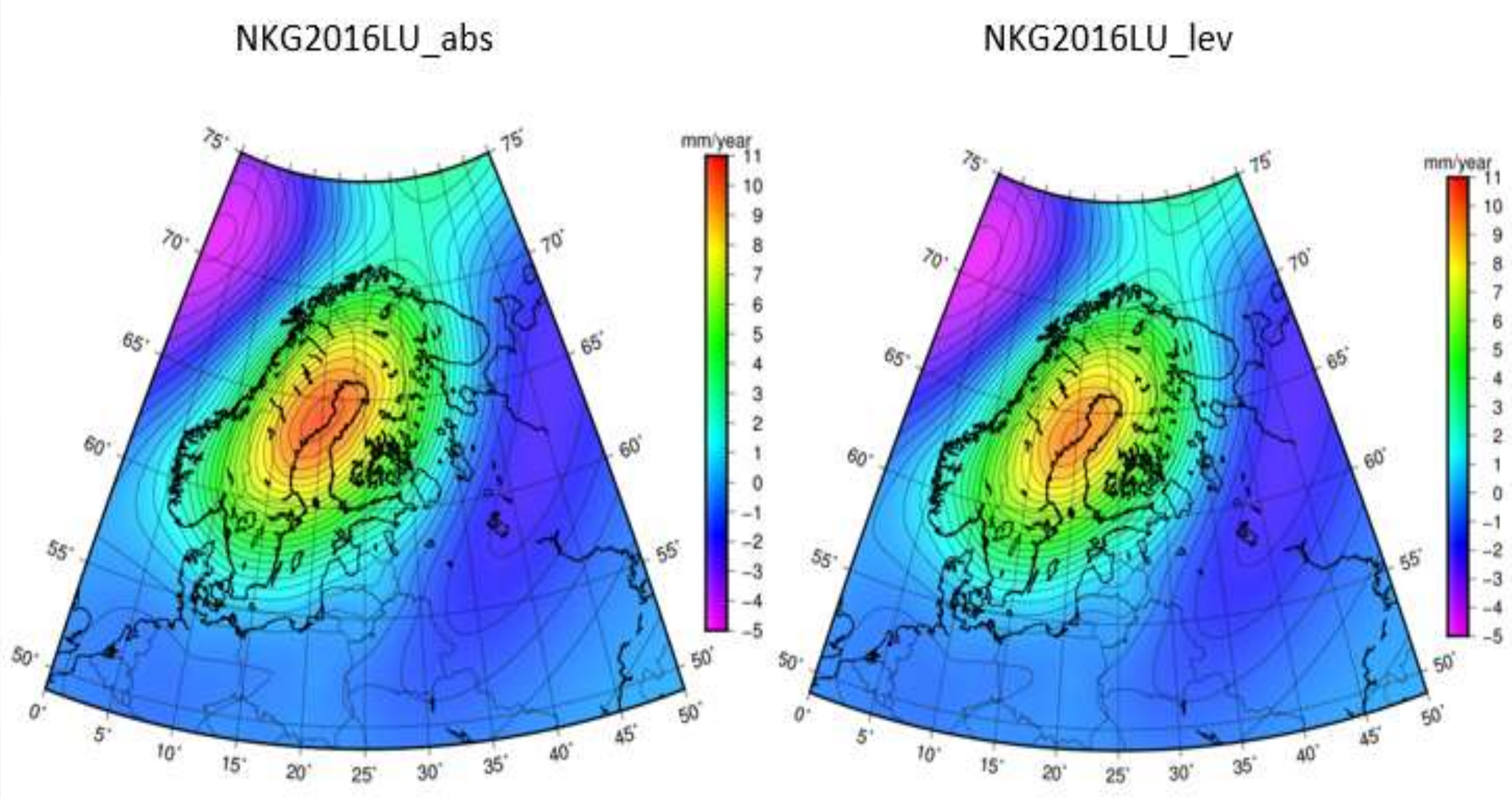
Creating a new model for the Fennoscandia crustal deformations

Input to the modelling

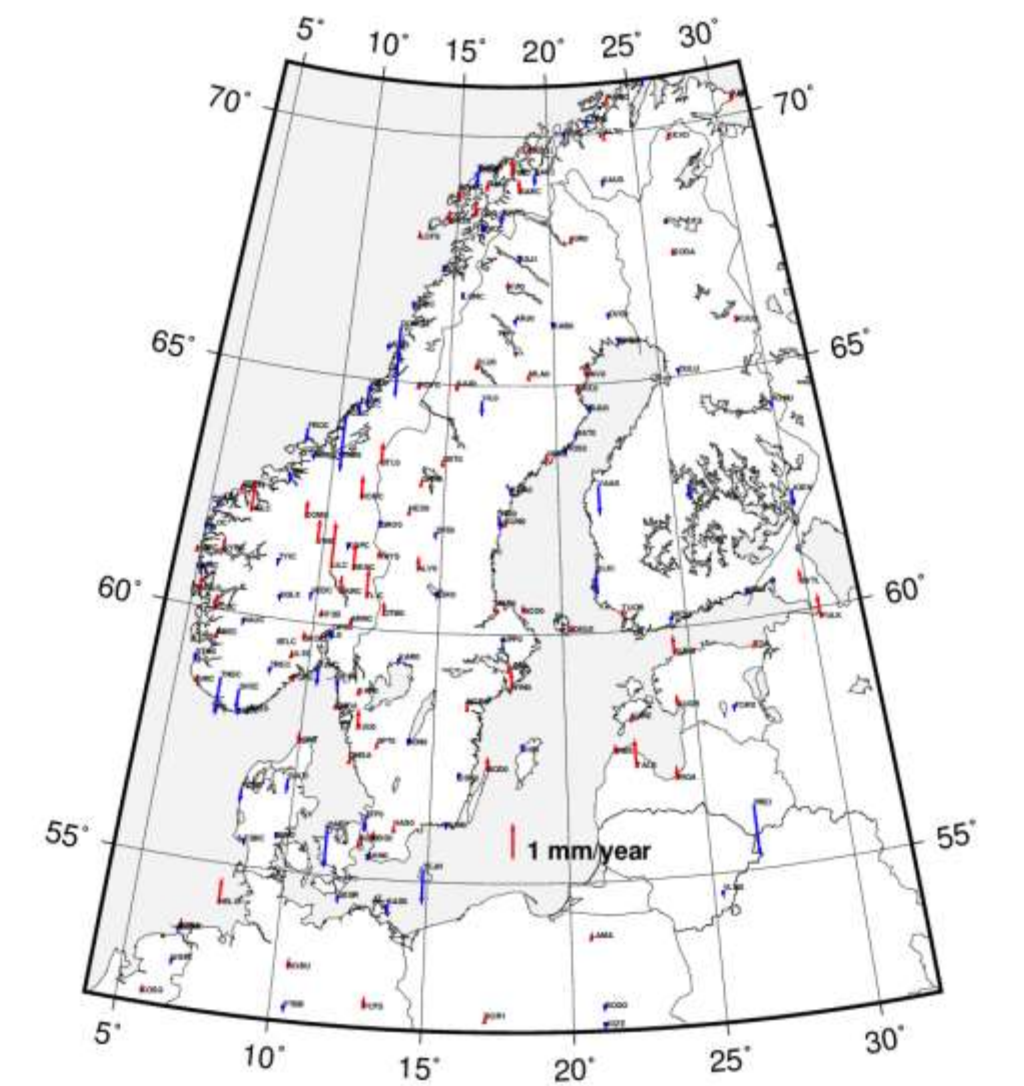
- Observations from repeated levelling
- 3D GPS velocities from the BIFROST project (10-15 year time series)
- Also a GIA-model
- But tide-gauge data is not used for the modelling!



The semi-impirical land uplift model NKG2016LU_abs/lev



Difference between BIFROST GNSS and NKG2016LU_ABS



- Statistics (mm/year):

#	179
Min	-2.00
Max	1.32
Mean	0.02
StdDev	0.42

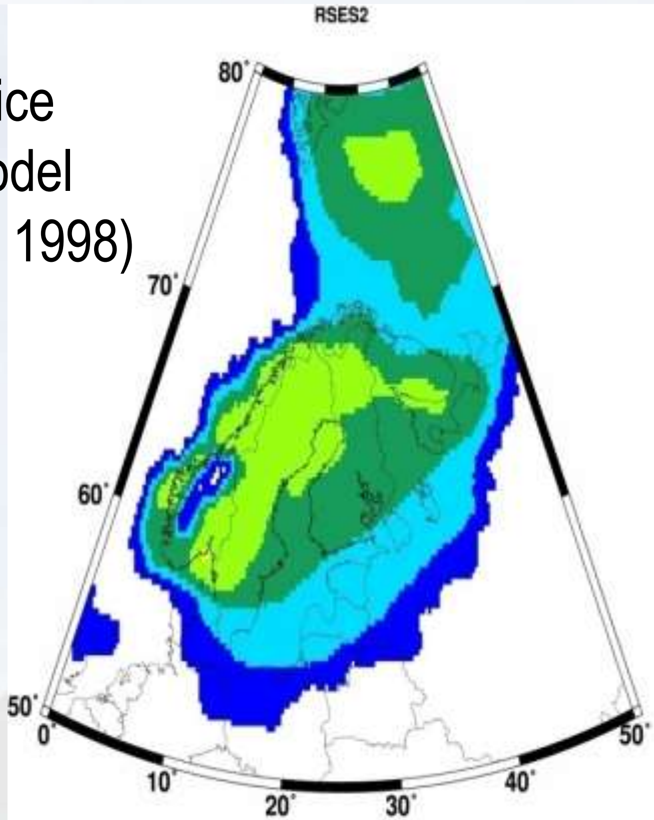
The horizontal velocity model

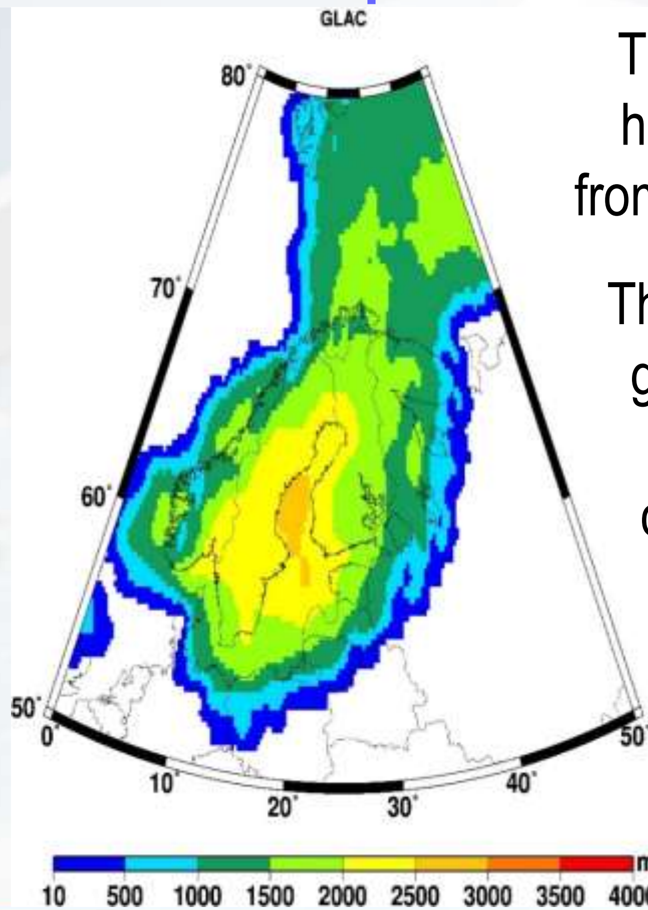
GPS velocities minus GIA model "best sites":
(0.4, 0.2, 0.4) (n,e,u) mm/yr std.
(after 6-par fit, applying rotation and translation rates)

Note the systematic differences in the North direction

Developments in GIA modelling: New Thermo-mechanical ice model examples at LGM

The ”old” ice history model (Lambeck 1998)





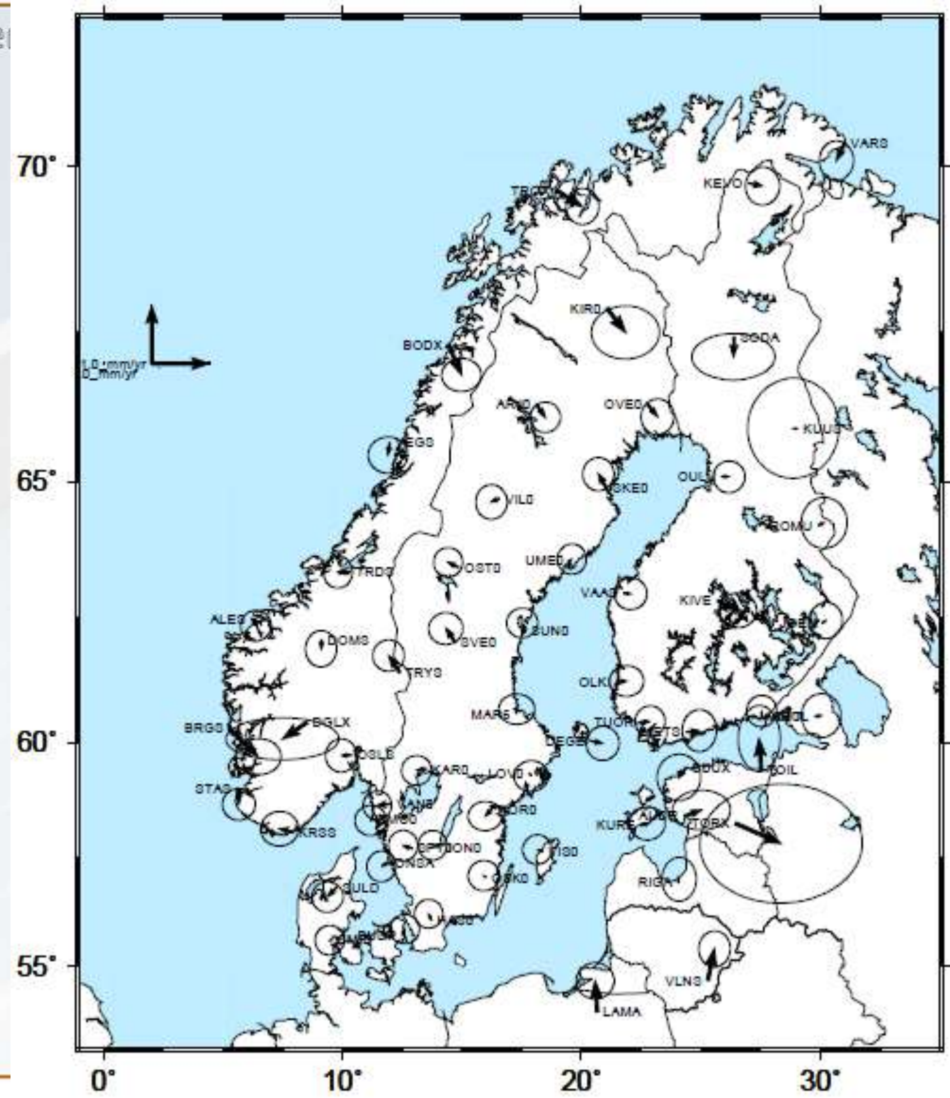
The ”new” ice history model from Lev Tarasov.

The ice history governed by models for climate and glaciology.

New GIA model rotated to the GPS velocities (in ETRS89)

Using 66 well defined GPS sites

RMS: 0.2 mm/year in north and east



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Discussion?!