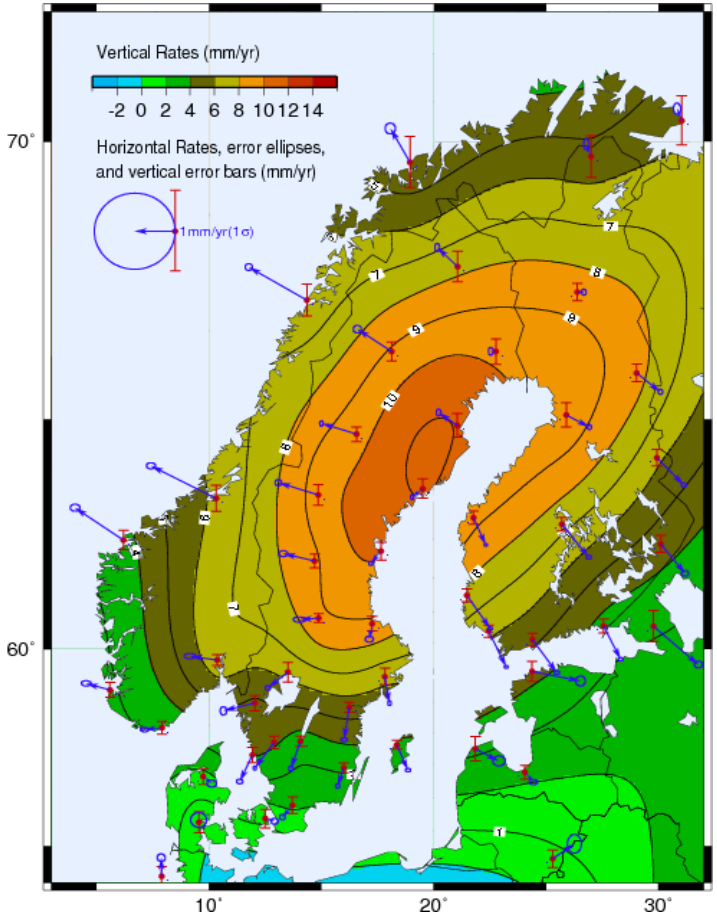
The BIFROST Project: 21 years of search for the "true" crustal deformation in Fennoscandia



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Lantmäteriet, Sweden

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CHALMERS

LANTMÄTERIET

Kartverket

BIFROST 1993-2015

Chalmers Univ. of Technology and Onsala Space Observatory, Sweden

Lantmäteriet, Sweden

SP Technical Research Institute, Sweden

Finnish Geodetic Institute, Finland

Kartverket, Norway

University of Ottawa, Canada

Lamont-Doherty Earth Observatory of Columbia University, USA

Harvard University, USA

uOttawa

CHALMERS

LANTMÄTERIET

Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE

Kartverket

SP

VE RI TAS
HARVARD

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TKK

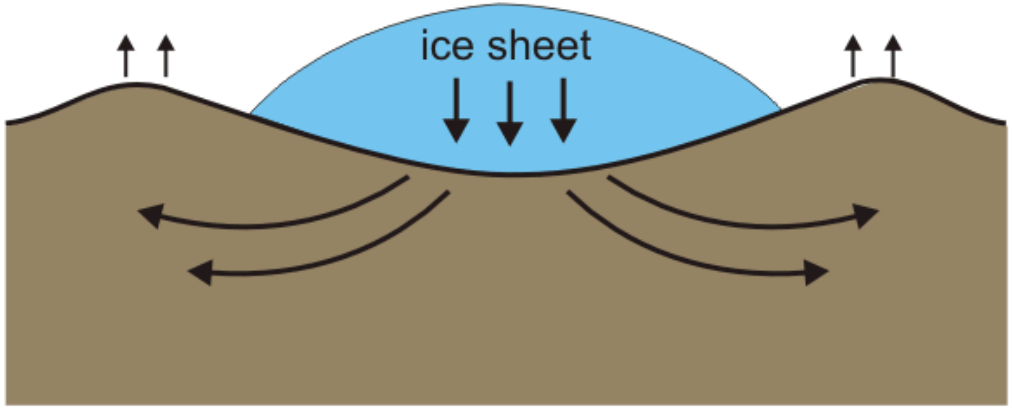
BIFROST

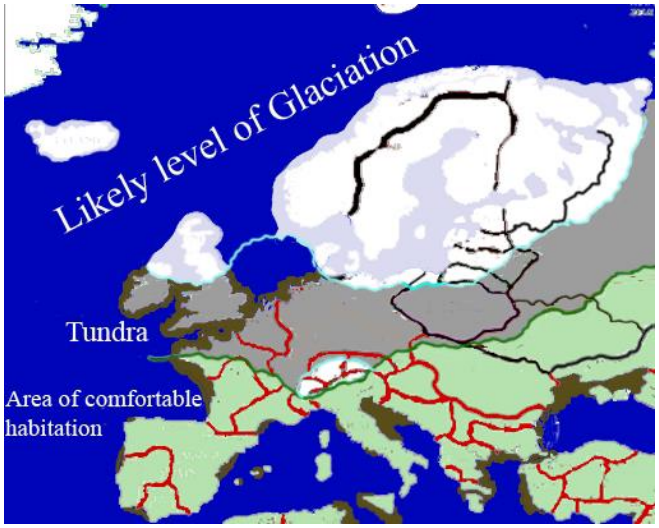
Baseline
Inferences for
Fennoscandian
Rebound
Observations
Sea level and
Tectonics

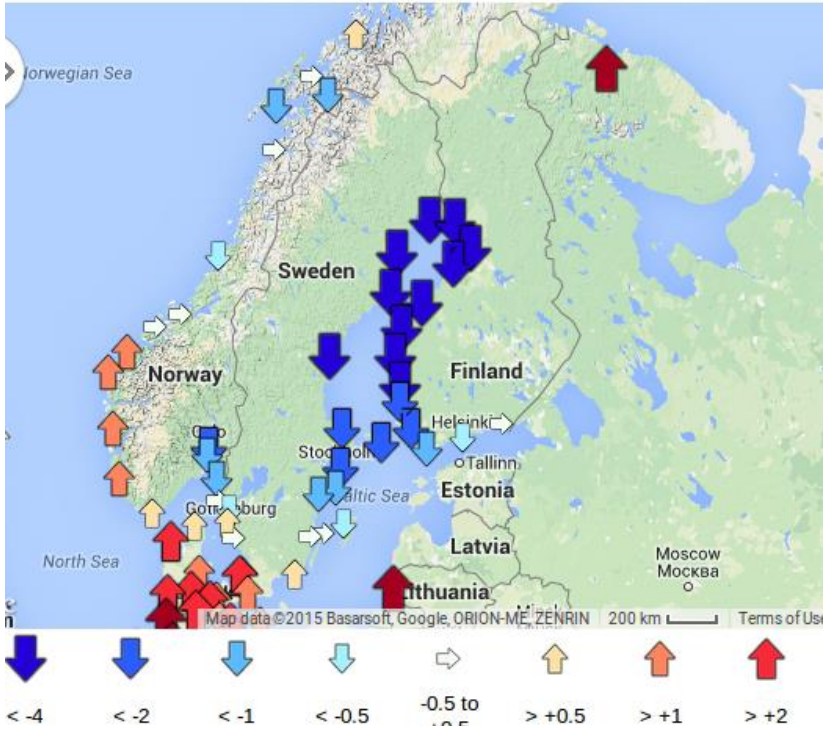
Outline

- The BIFROST project
- New velocity solution
  - GPS analysis
  - Evaluation of the velocity field and comparison to GIA model
- Conclusions
- Next steps

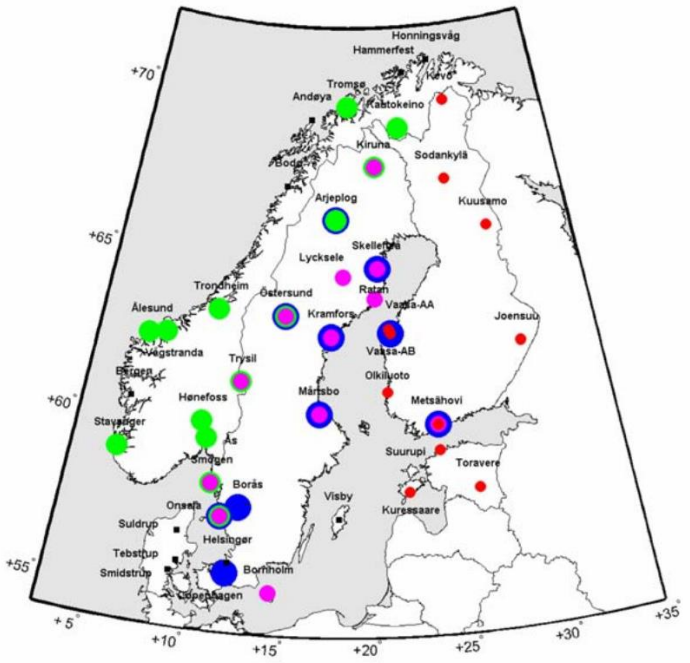
Glacial Isostatic Adjustment (GIA) and observation methods







Tide gauge network, From: http://www.psmsl.org/products/trends/

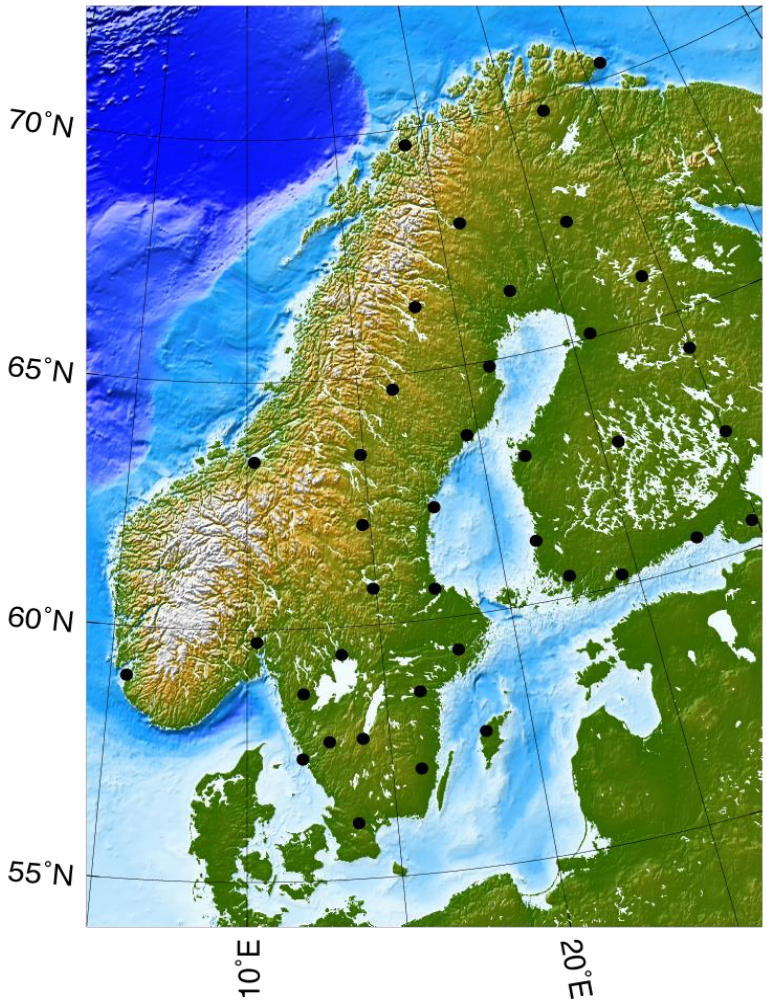


(b) 2008.

Absolute gravity network, 2008 campaigns from Gitlein (2009)

BIFROST Project - GNSS

- Permanent GPS systems across Norway, Sweden, and Finland
- First observations 1993
- Started with 16 sites, quickly increased to about 40 sites, ~100–200 km spacing
- First 3-D map of GIA (anywhere) produced 2001



Published velocity results:

2002 Johansson et al, JGR
GIPSY, Aug 1993 - May 2000

2007 Lidberg et al, J Geodesy
GAMIT, 1996 - June 2004

2010 Lidberg et al, J Geodynamics
GAMIT, 1996 - fall 2006

BIFROST Core Network – FINNREF, SATREF, SWEPOS

FinnRef (Finland)

SatRef (Norway)

SWEPOS (Sweden)

GNSS reprocessing 2015

We use common analysis strategy for GIPSY and GAMIT

- Using 10 degree cut of elevation
- Using VMF1 mapping function
- Using Atmospheric tidal loading, but not the non-tidal atm loading
- Only use type calibrated antenna pvc corrections (We leave individual antenna calibration for test purposes)
- FES2004
- Center of mass (including solid earth and ocean)
- Not to include higher order ionosphere

GIPSY solution

- PPP with ambiguity solution using the JPL products
- ITRF2008 realized using the JPL products

GAMIT was processed in several sub-networks

- NORW, SWEP, FINN, BALT, WEST, CEUR and some regional networks in Norway and Sweden and three global network with approx 55 stations each
- All networks were combined to common daily solutions

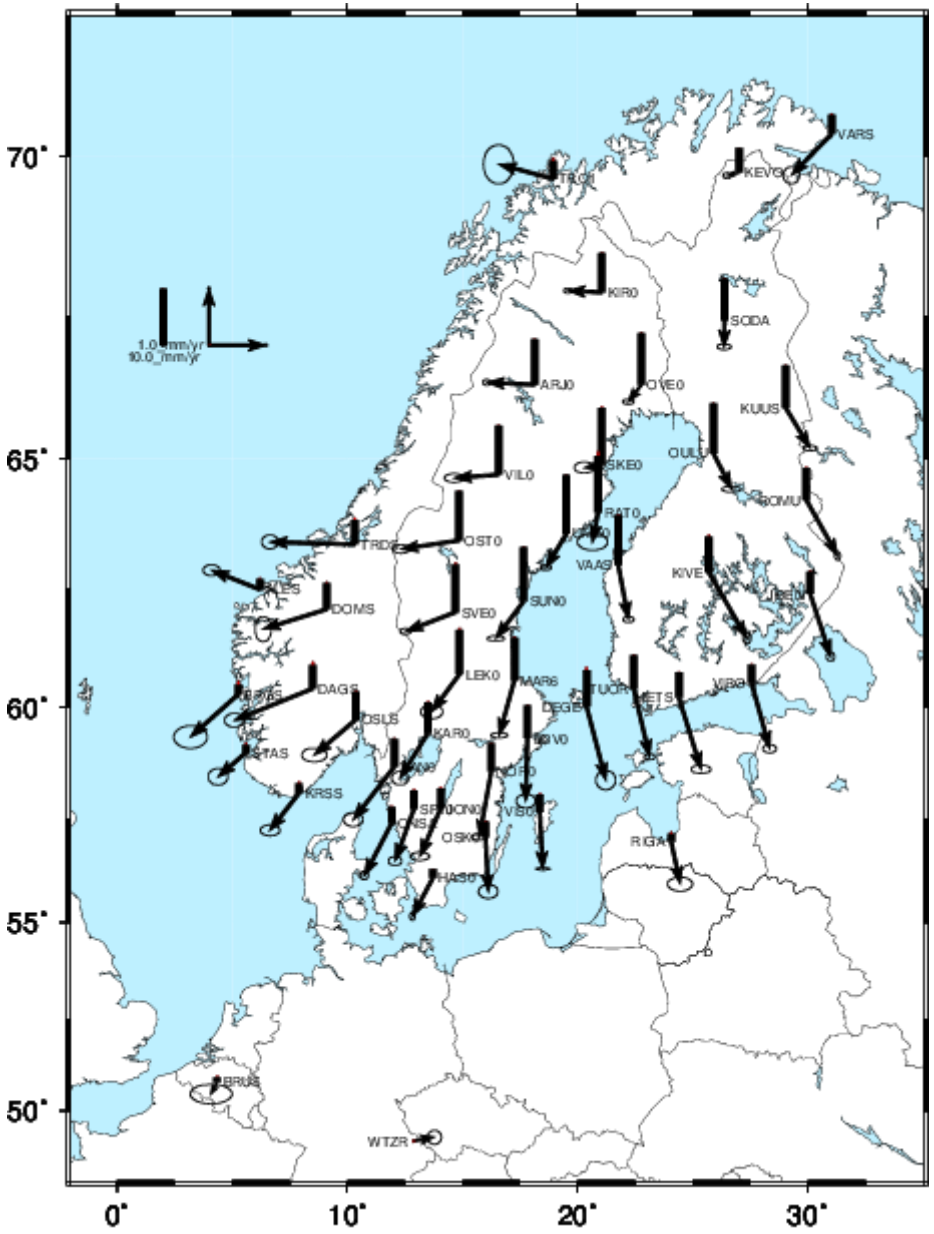
We have to different realizations of ITRF2008 for the GAMIT solution

- ITRF2008-glob; using the global GNSS stations in the combined solution to connect to ITRF2008
- ITRF2008-reg; using the Fennoscandian GNSS stations to connect to the ITRF2008-glob

New GPS velocity solution 2015

GIPSY v6.3

- Johansson and Kristiansen
- 10° elevation cut off angle
- Trop. zenith delay & gradients
- VMF1 mapping function
- Absolute antenna PCV (type cal)
- IGS/JPL products
- ITRF2008 (well: IGS08…)
- PPP with ambiguity fixing
- 1 Aug 1993 – 31 December 2014



New GPS velocity solution 2015

GIPSY v6.3

GAMIT/GLOBK

- Kierulf, Steffen and Lidberg
- Some 180 stations in N Europe
- A global reference frame realization based on a global network of +100 stations (some 50 in the reference frame realization)
- Combination of several regional and a global solutions

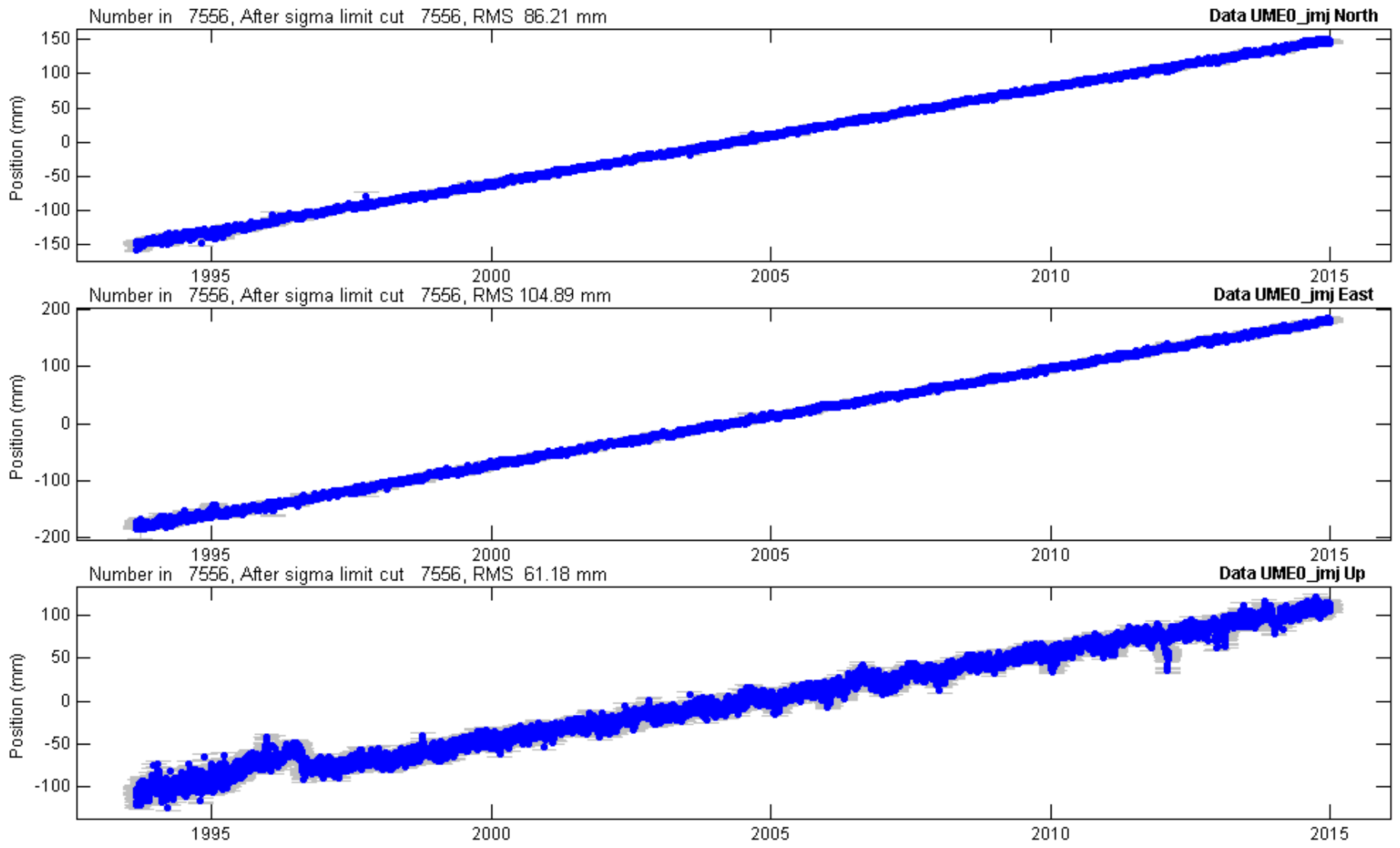
In this presentation, most evaluation will be on the GIPSY solution

RAW GPS time series (GIPSY solution 1993-2014)
- ex time series analysis of Umeå (UME0)

North
± 150
mm

East
± 200
mm

Up
± 100
mm

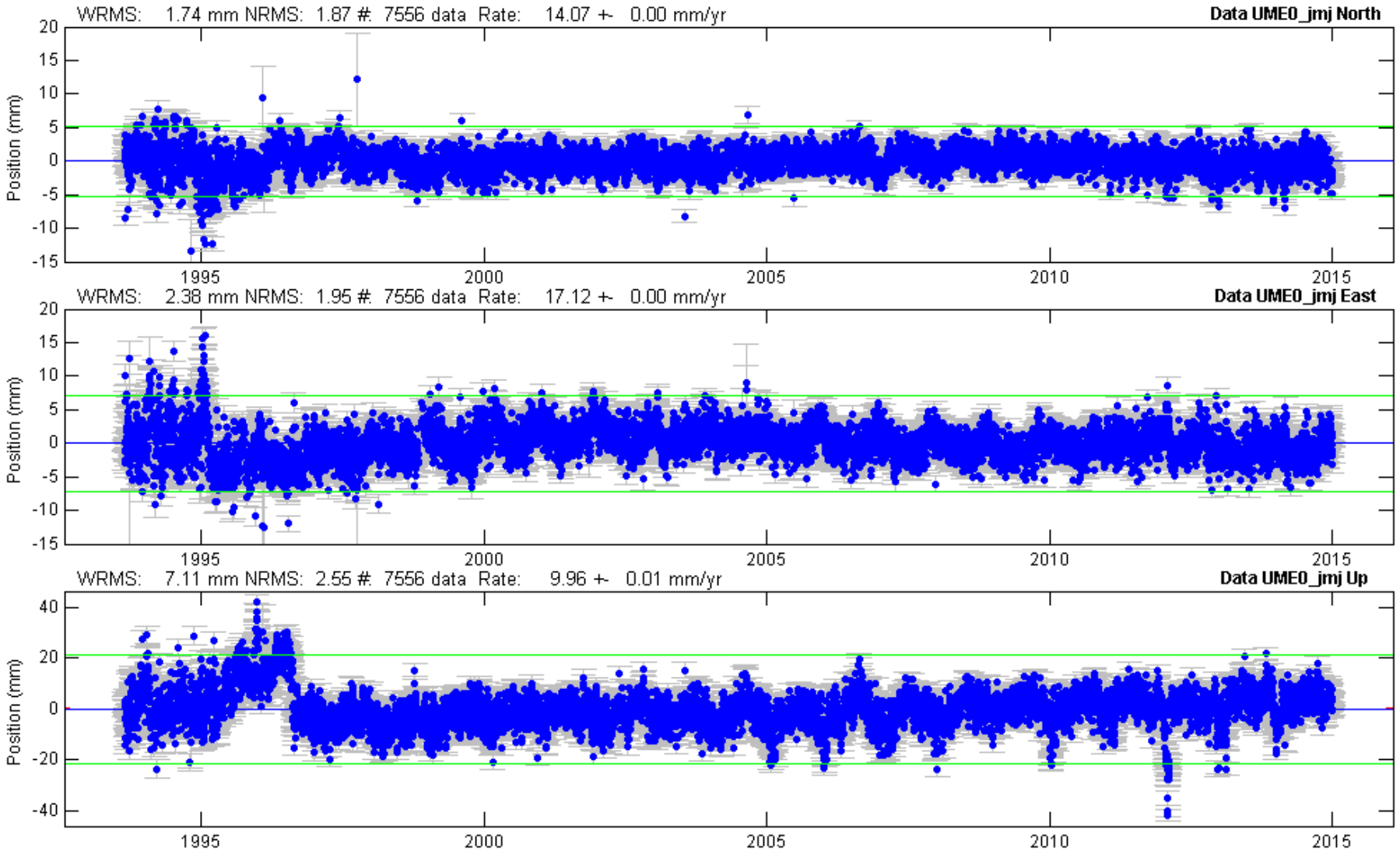


"Detrended" time series (GIPSY solution 1993-2014)
- ex time series analysis of Umeå (UME0)

North
± 20 mm

East
± 20 mm

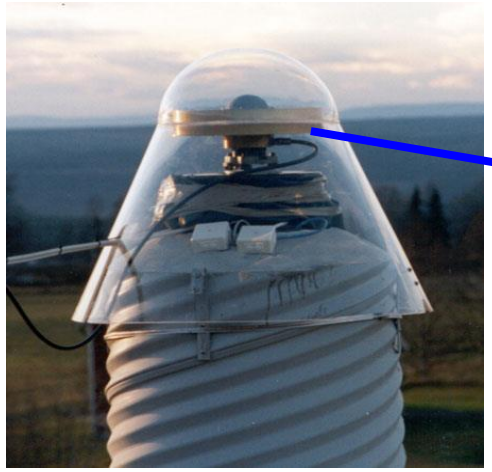
Up
± 40 mm

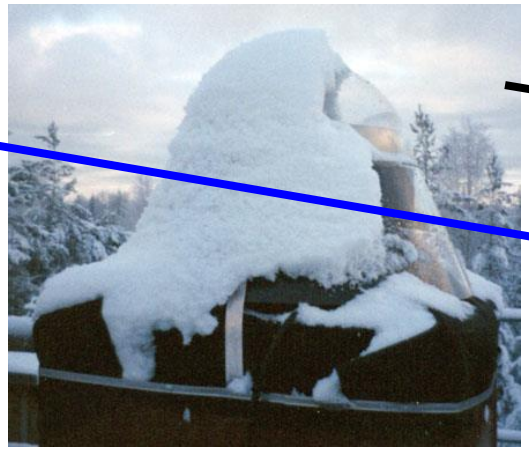


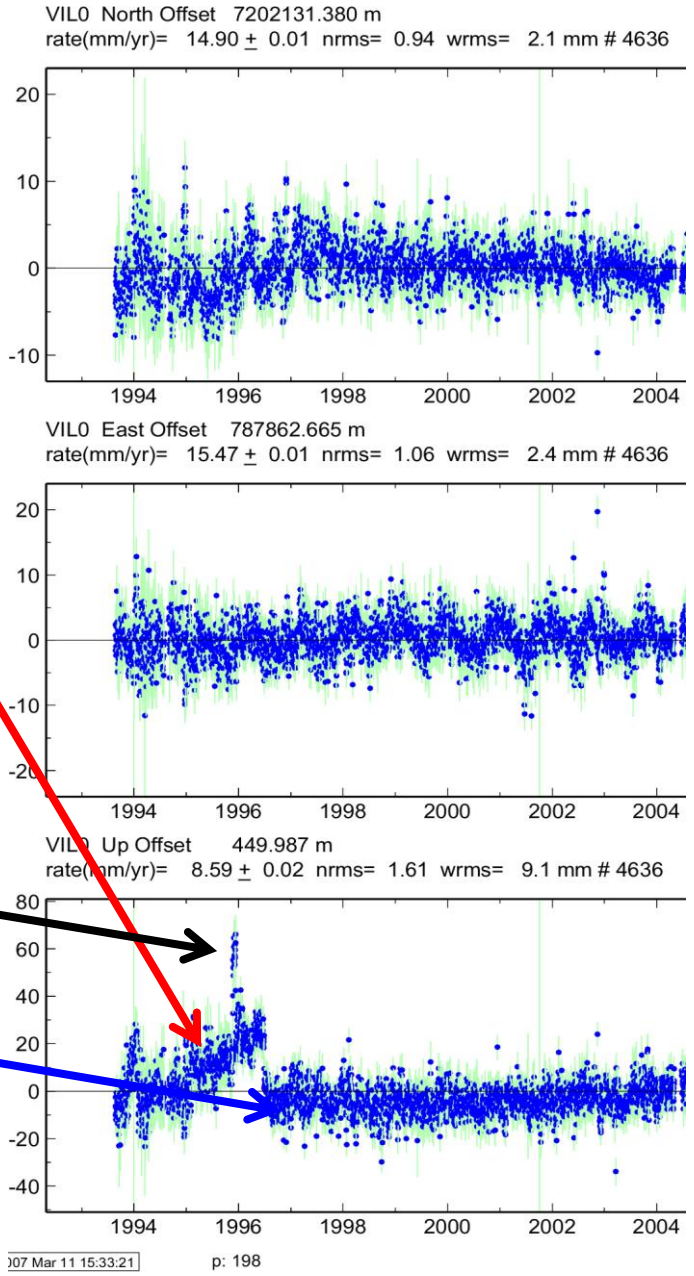
Site dependent effects

Several important issues were studied and published (1993-1997)

- Antenna model and attachment
- Radom model and attachment
- Distance to reflective or blocking environment
- Rain, condense, ice and snow





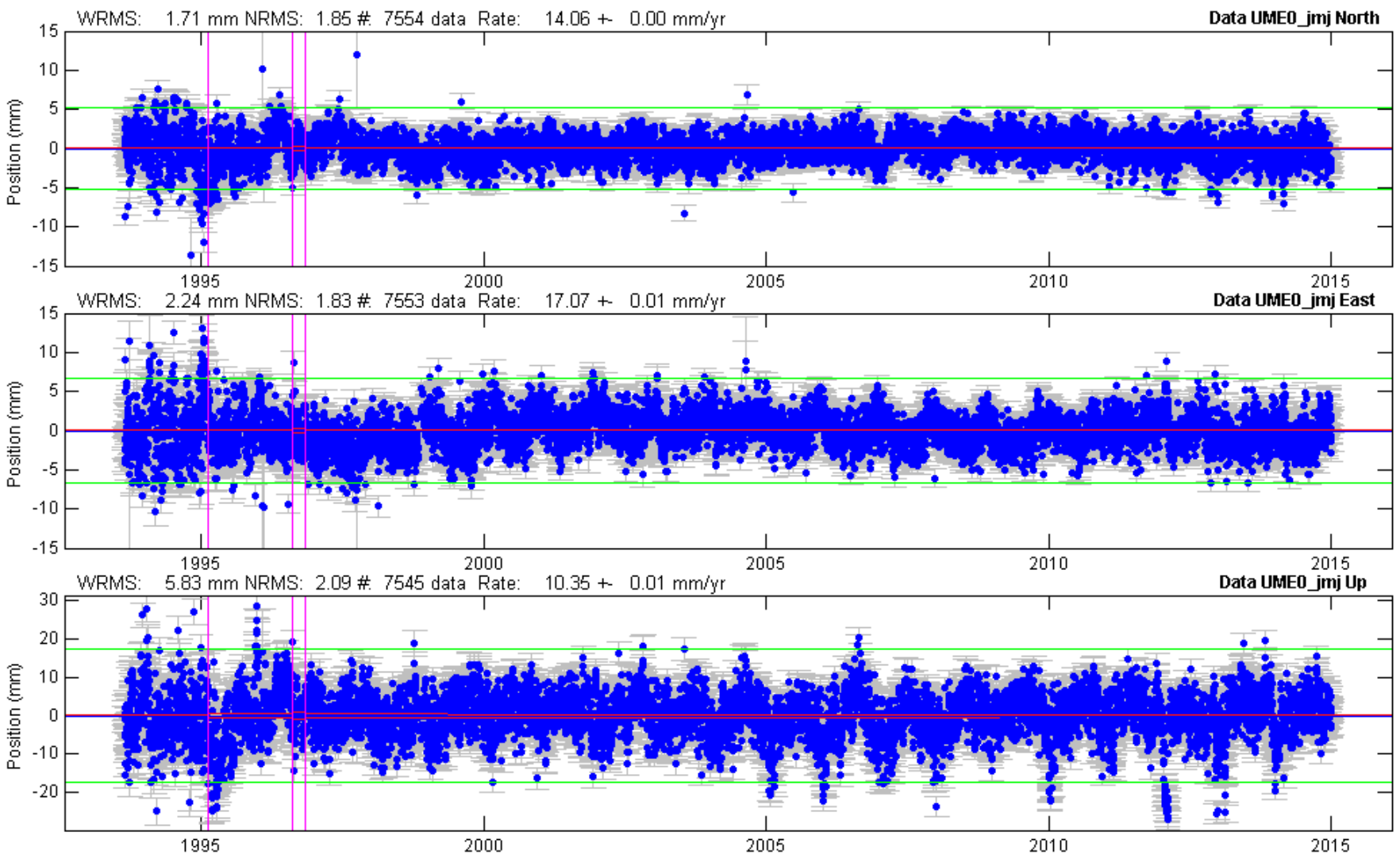


Insert breaks for radome shifts (GIPSY solution 1993-2014)
- ex time series analysis of Umeå (UME0)

North
± 15 mm

East
± 15 mm

Up
± 30 mm

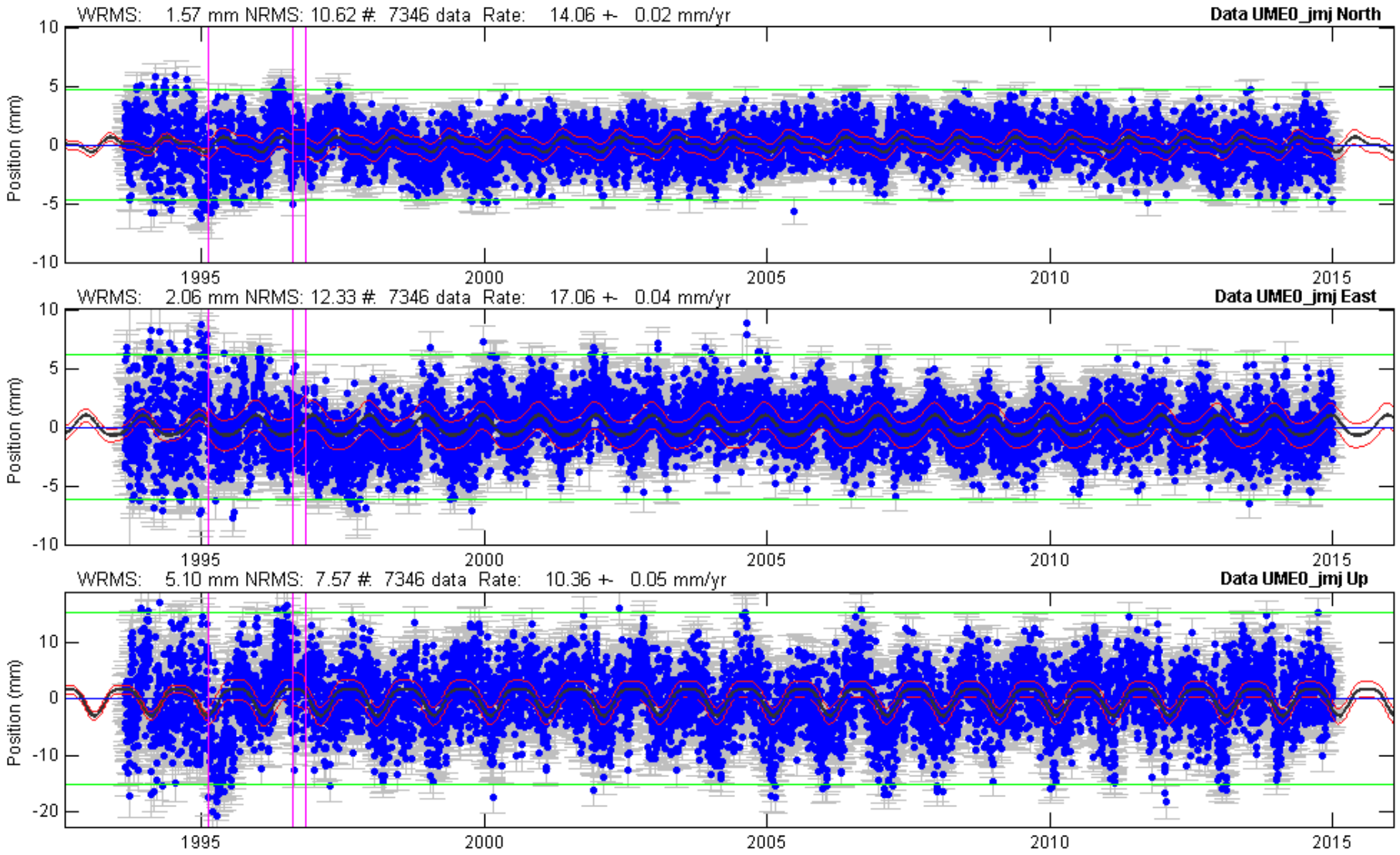


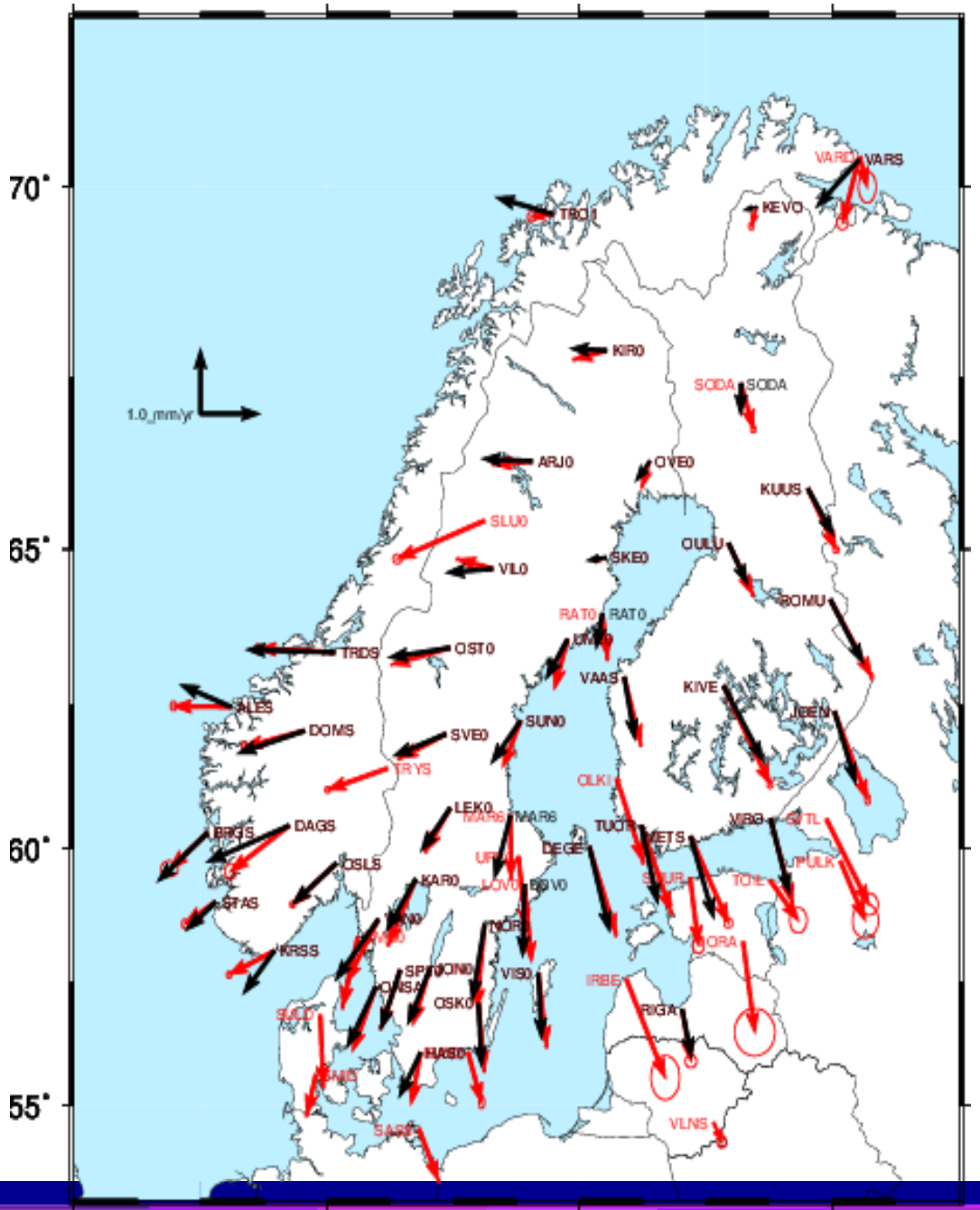
Periodic differences (GIPSY solution 1993-2014)
- ex time series analysis of Umeå (UME0)

North
± 10 mm

East
± 10 mm

Up
± 20 mm





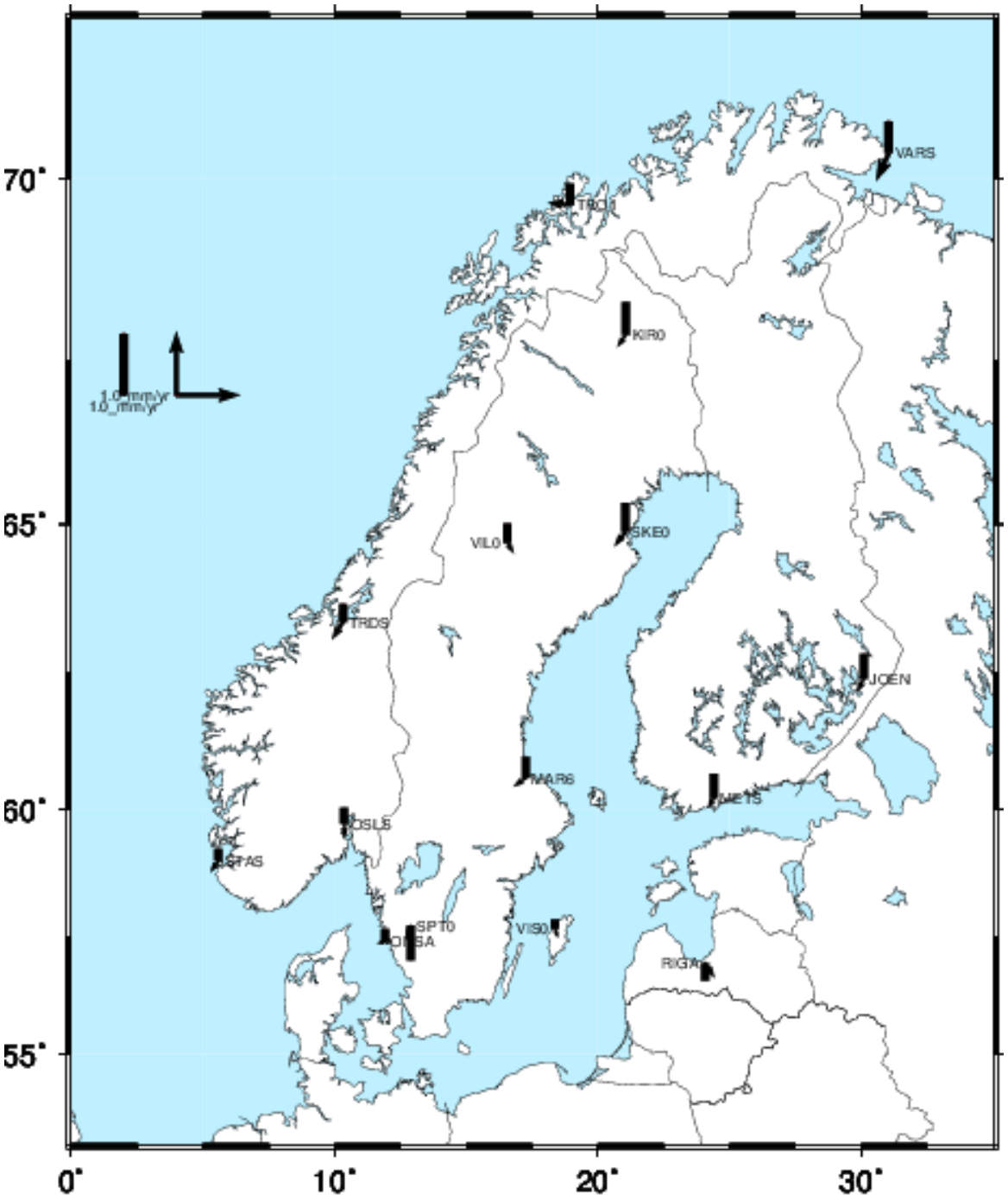
Comparing GIPSY (black) and GAMIT (red);

ITRF2008 Euler pole rotation to Eurasia

In the plot there are some more recent sites in the GAMIT analysis.

Statistics (n, e, u) mm/yr

Mean	**0.09**	**-0.13**	**0.31**
RMS	**0.16**	**0.19**	**0.41**
Std	**0.14**	**0.14**	**0.27**



Also comparison to the recent cumulative EPN (w1830) solution

GIPSY minus EPN.

Statistics (n, e, u) mm/yr

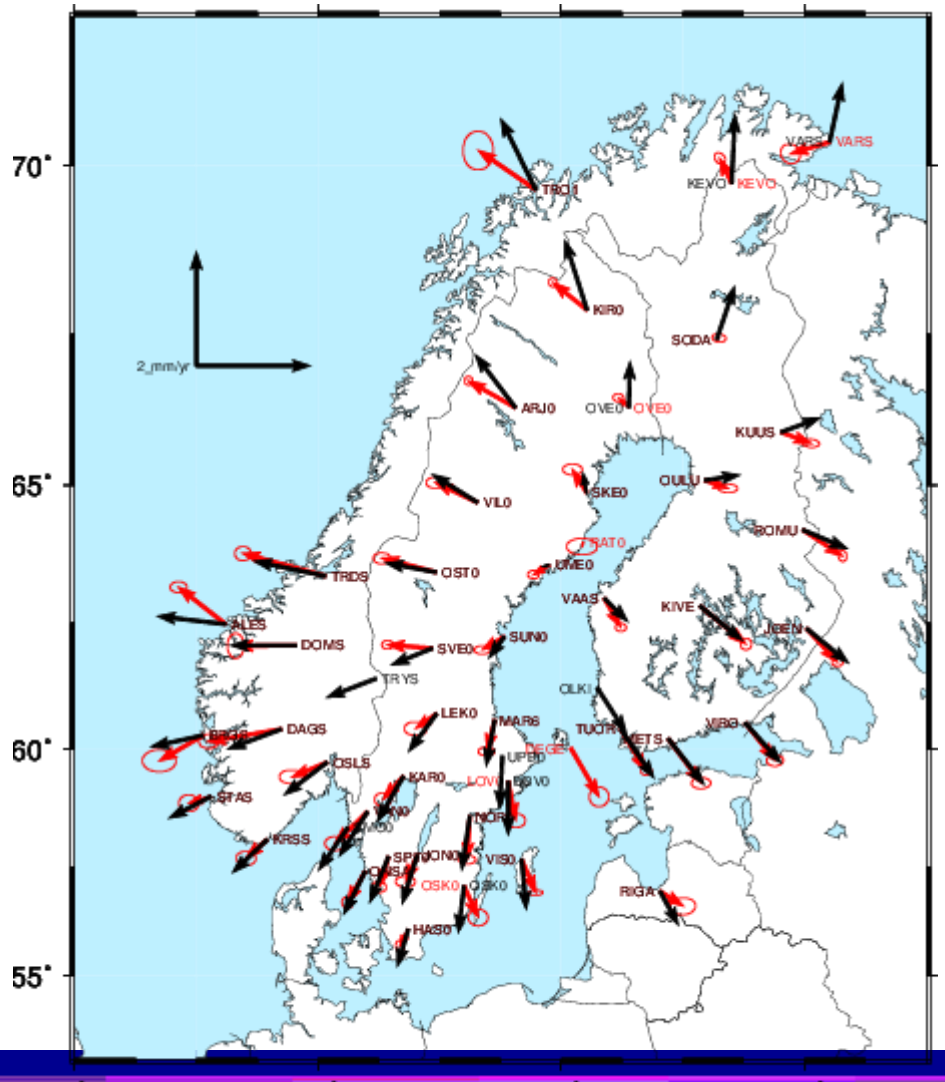
Mean	**-0.16**	**-0.09**	**0.21**
RMS	**0.19**	**0.15**	**0.37**
Std	**0.11**	**0.12**	**0.32**

Note the good agreement despite:
Independent processing
Different reference frame realization
Independent screening of data

Evaluating station velocity results

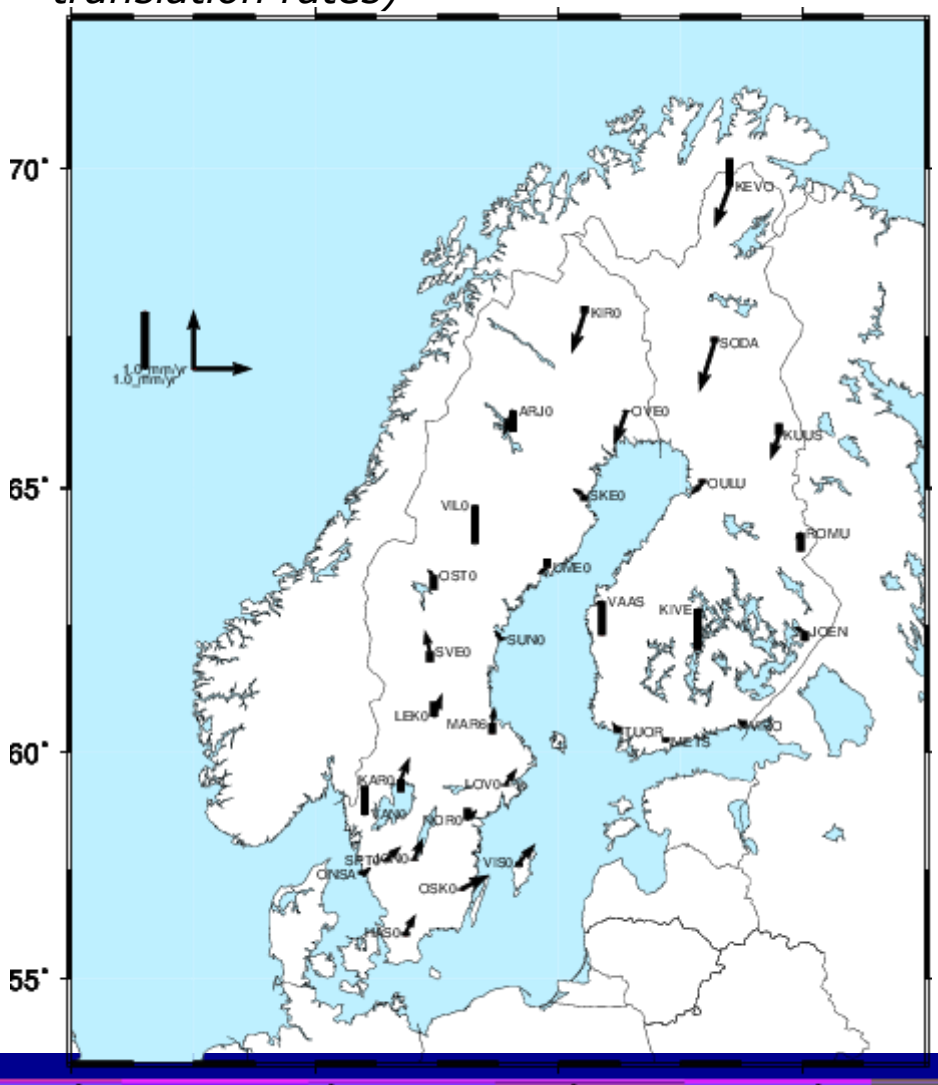
GIPSY vs GIA model

RMS-p : 0.46 mm/yr (all sites)



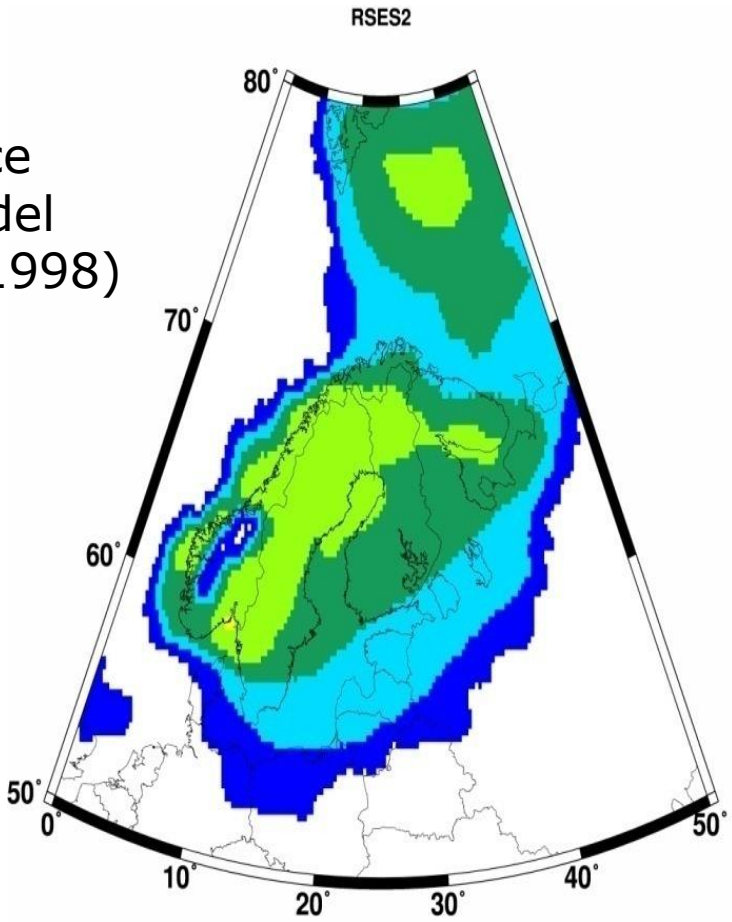
GIPSY minus GIA model "best sites" : (0.3, 0.2, 0.3) (n,e,u) mm/yr std.

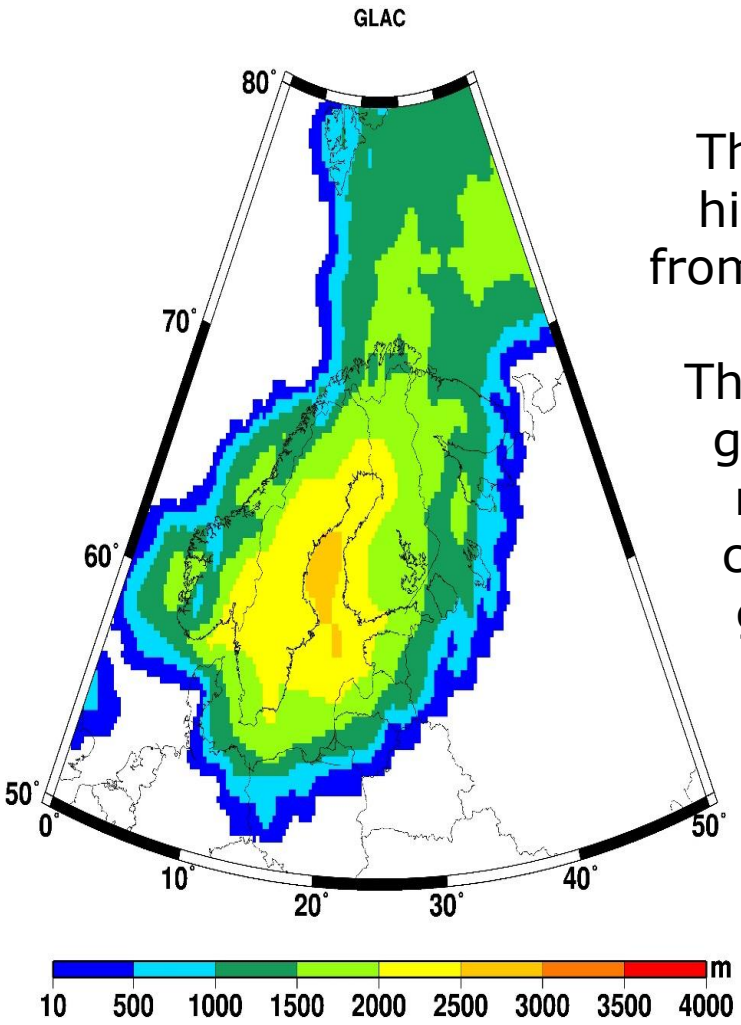
(after 6-par fit, applying rotation and translation rates)



New Thermo-mechanical ice model examples at LGM

The ”old” ice history model (Lambeck 1998)



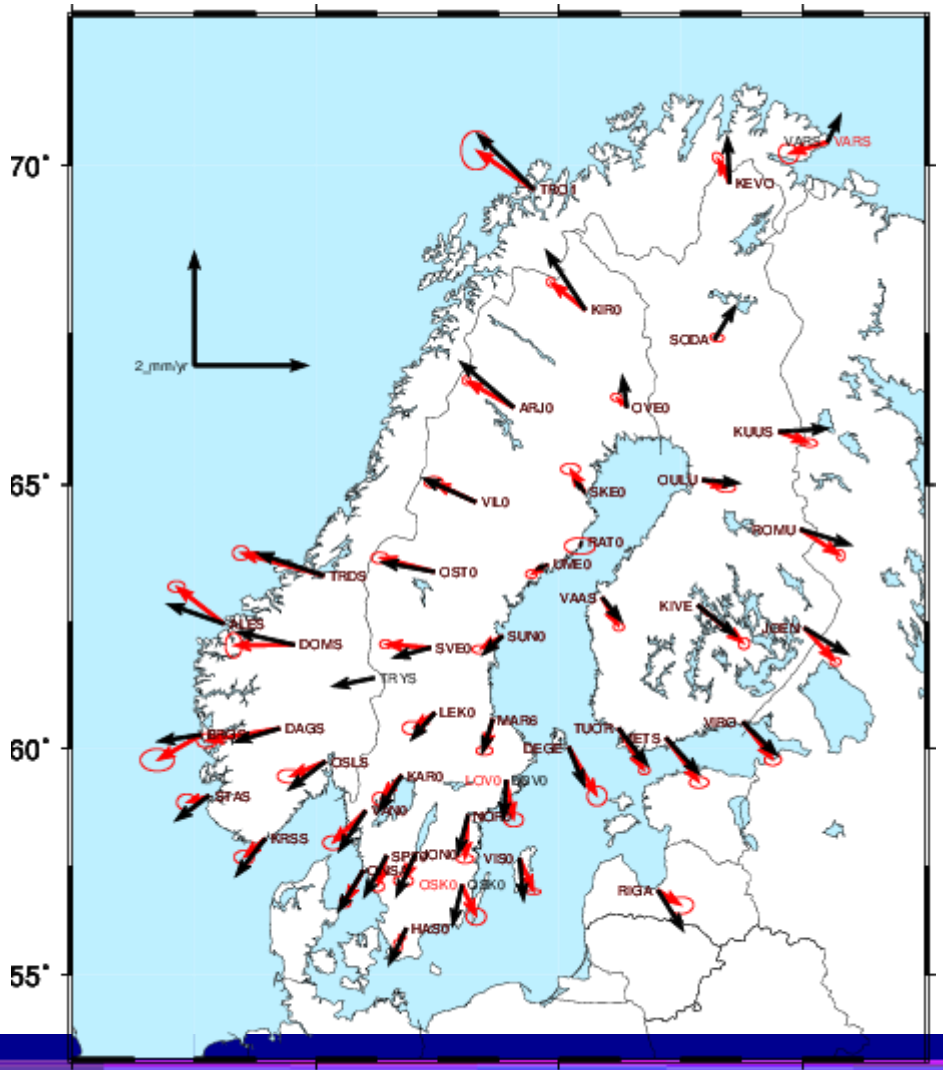


The ”new” ice history model from Lev Tarasov.

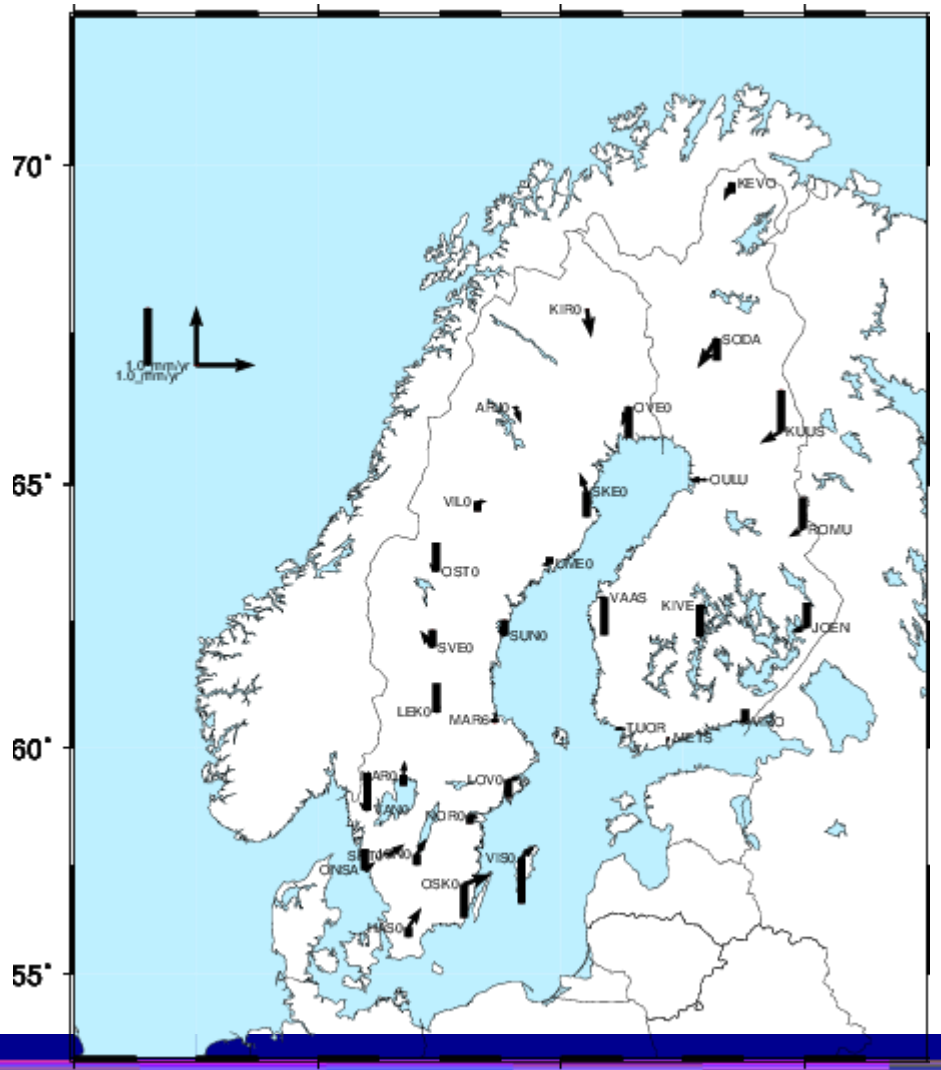
The ice history governed by models for climate and glaciology.

Evaluating station velocity results vs new ice model

GIPSY vs GIA model (new)
RMS-p : 0.45 mm/yr (all sites)



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



Conclusion and outlook

- The velocity solutions presented here are preliminary. However, GPS-velocities and GIA-model agree at the 0.5 mm/yr level (1σ) in both horizontal and vertical components

- Our results are highly dependent on the used reference frame

- Modernization of our observing system (GNSS stations) need special attention in order to keep long unbroken time series of observations

- Reprocessing also with Absolute Site PCVs!
- Many new sites are added to the analysis, but need some more analysis