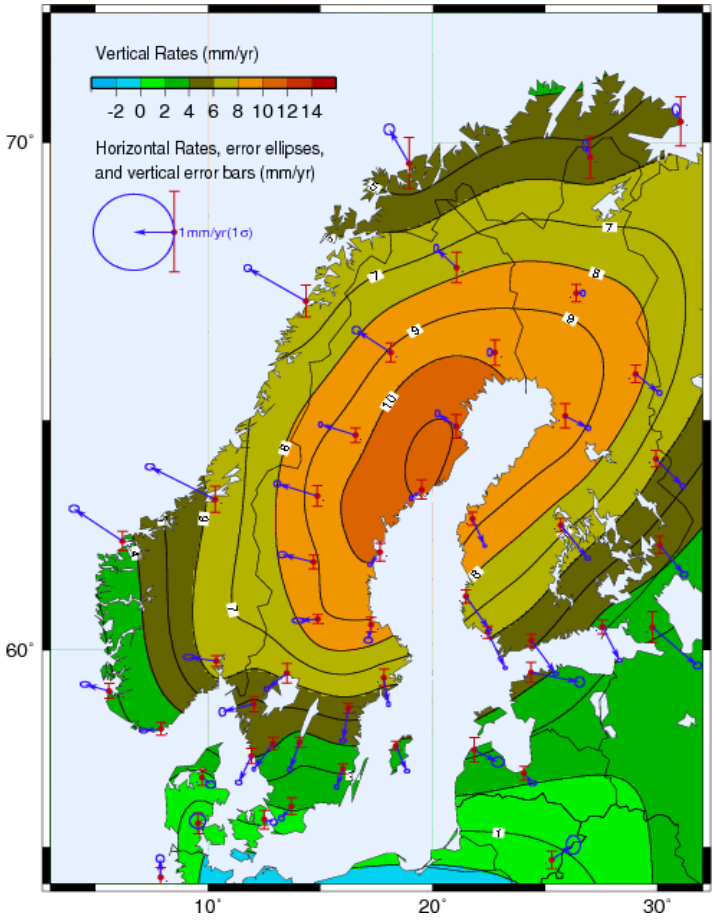
Twenty years of search for the “true” crustal deformation in Fennoscandia from the BIFROST project



Jan Johansson
Chalmers University of Technology
&
Martin Lidberg
Lantmäteriet

CHALMERS

LANTMÄTERIET

BIFROST 1993-2013

Tong Ning, Linda Johansson, Hans-Georg Scherneck, and **Gunnar Elgered**
Chalmers Univ. of Technology and Onsala Space Observatory, Sweden

Gunnar Hedling and **Lotti Jivall**
Lantmäteriet, Sweden

Markku Poutanen and **Hannu Koivula**
Finnish Geodetic Institute, Finland

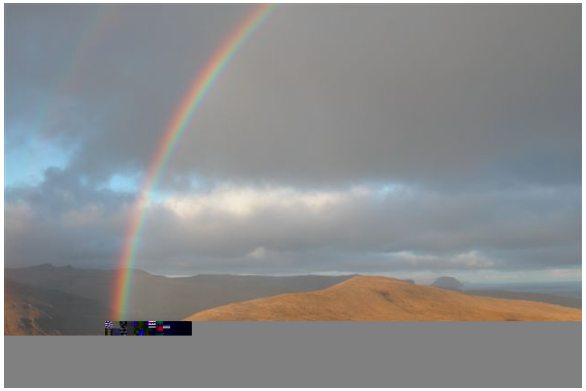
Halfdan Kierulf and **Oddgeir Kristiansen**
Kartverket, Norway

Glenn A Milne
University of Ottawa, Canada

James L Davis
Lamont-Doherty Earth Observatory of Columbia University, USA

Jerry X Mitrovica
Harvard University, USA

Outline



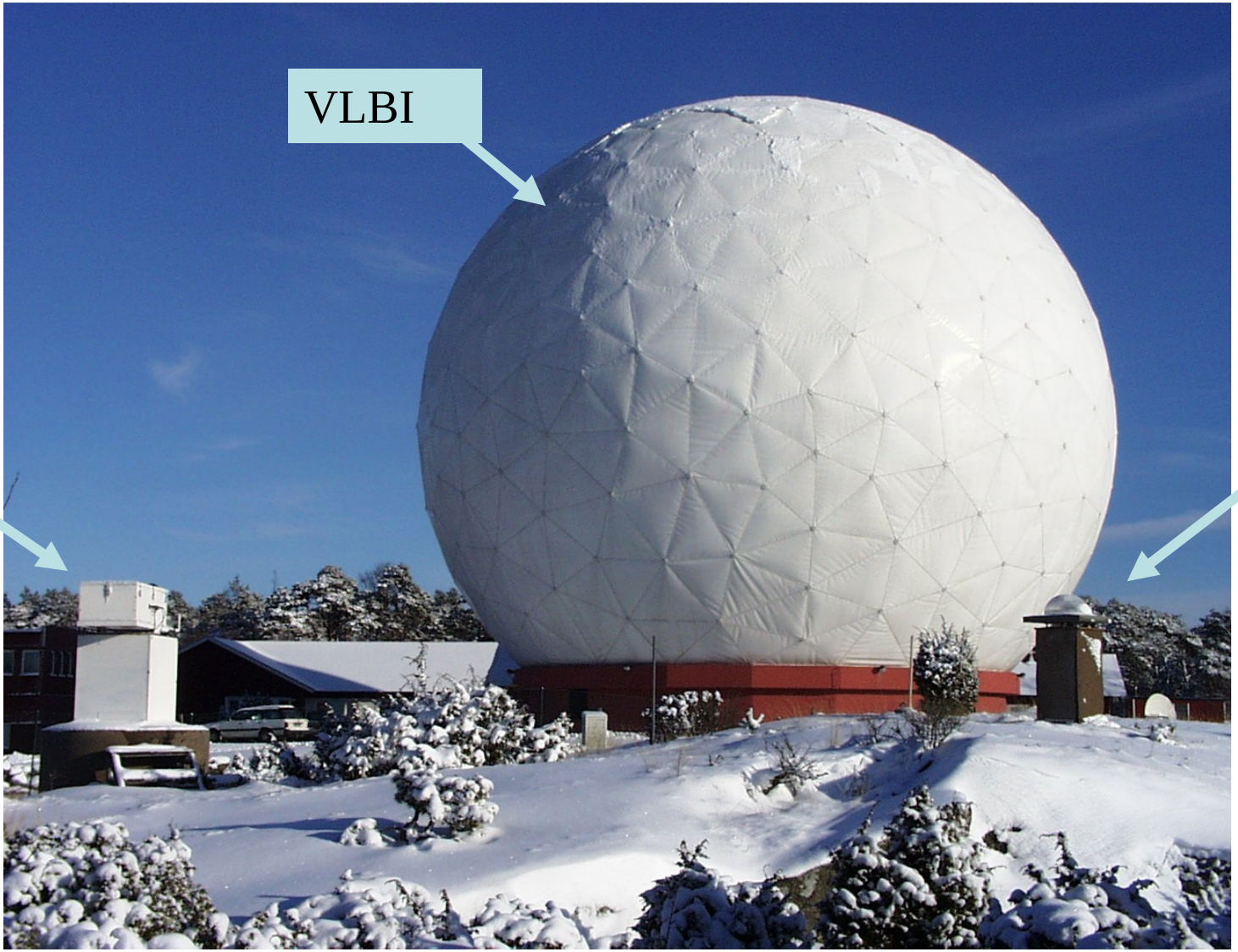
- Historic tour
- The BIFROST project
- New velocity solution
  - GPS analysis
  - Evaluation of the velocity field and comparison to GIA model
- Next steps
- Conclusions

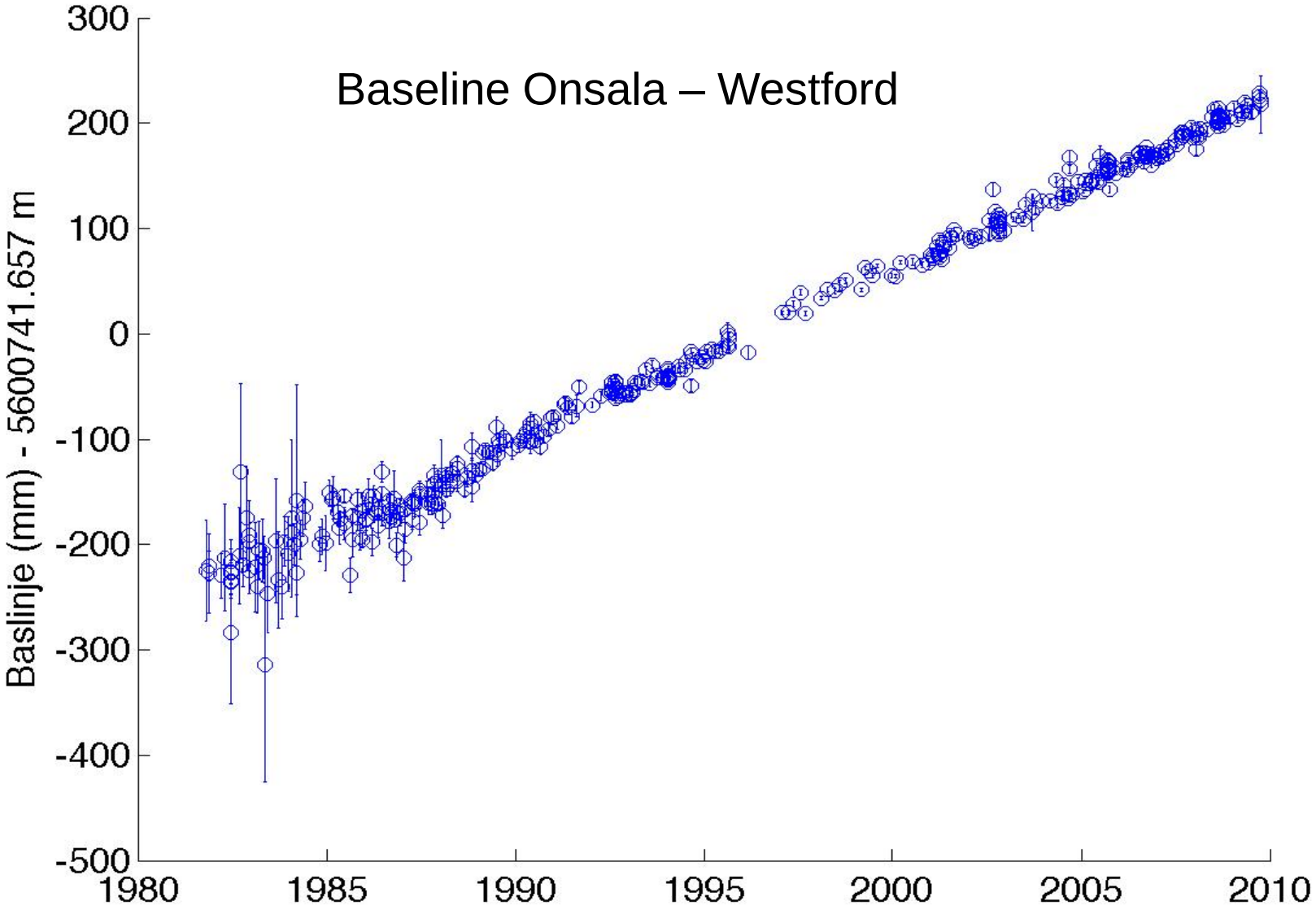
BIFROST

B aseline
I nferences for
F ennoscandian
R ebound
O bservations
S ea level and
T ectonics

uOttawa
CHALMERS
LANTMÄTERIET
Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE
Kartverket
SP
HARVARD
GEODEETTINEN LAITOS · GEODETISKA INSTITUTET
TKK

Geodetic Observations at Onsala Space Observatory




Baseline Onsala – Westford
Baslinje (mm) - 5600741.657 m
300
200
100
0
-100
-200
-300
-400
-500
1980
1985
1990
1995
2000
2005
2010

BIFROST – from initial idea to a project

- Geo-VLBI 1968, 1980-
- CIGNET/IGS station in Onsala 1986

- Why continuous regional GPS observations?
  - Deformation studies and ties to VLBI 1986
  - Investigation of error sources 1988
  - GIA project idea 1989
  - Land Survey contact 1990
  - NASA/DOSE support 1991
  - IGS (GIG) testing 1991
  - Atmospheric monitoring 1992

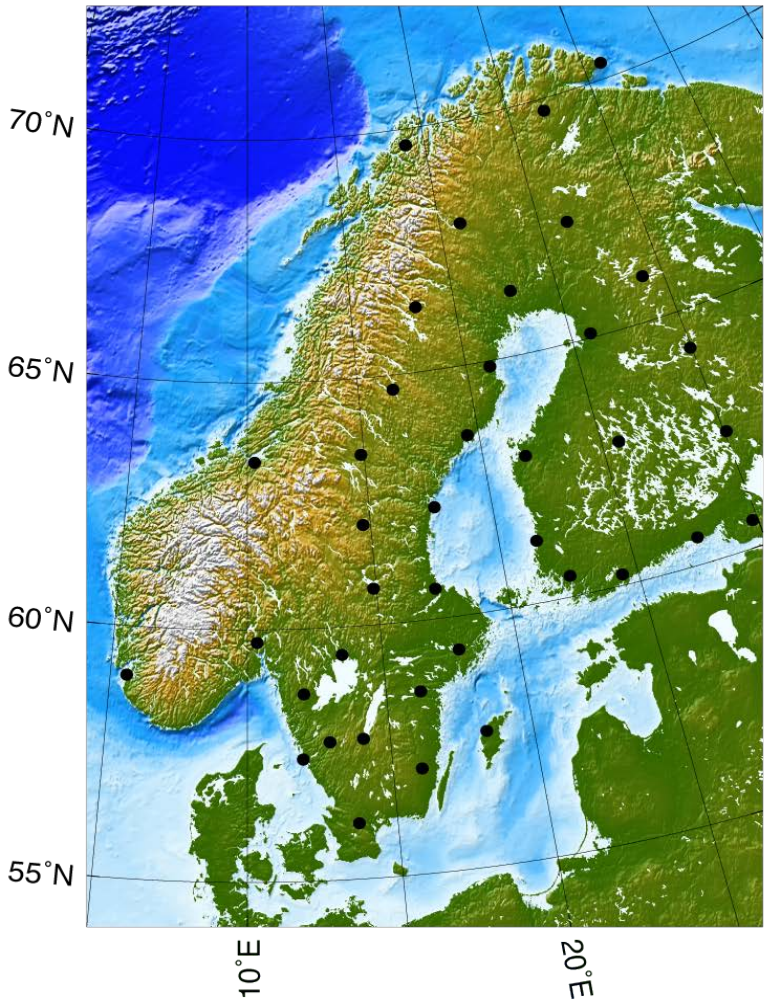
- Proposal research (1991); for equipment (1992)

- Proposal for BIFROST & SWEPOS granted 1992
- First BIFROST data + campaign 1993

- SWEPOS taken over by Lantmäteriet 1995
- BIFROST and SWEPOS 20 years 2013!!!

BIFROST Project

- 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

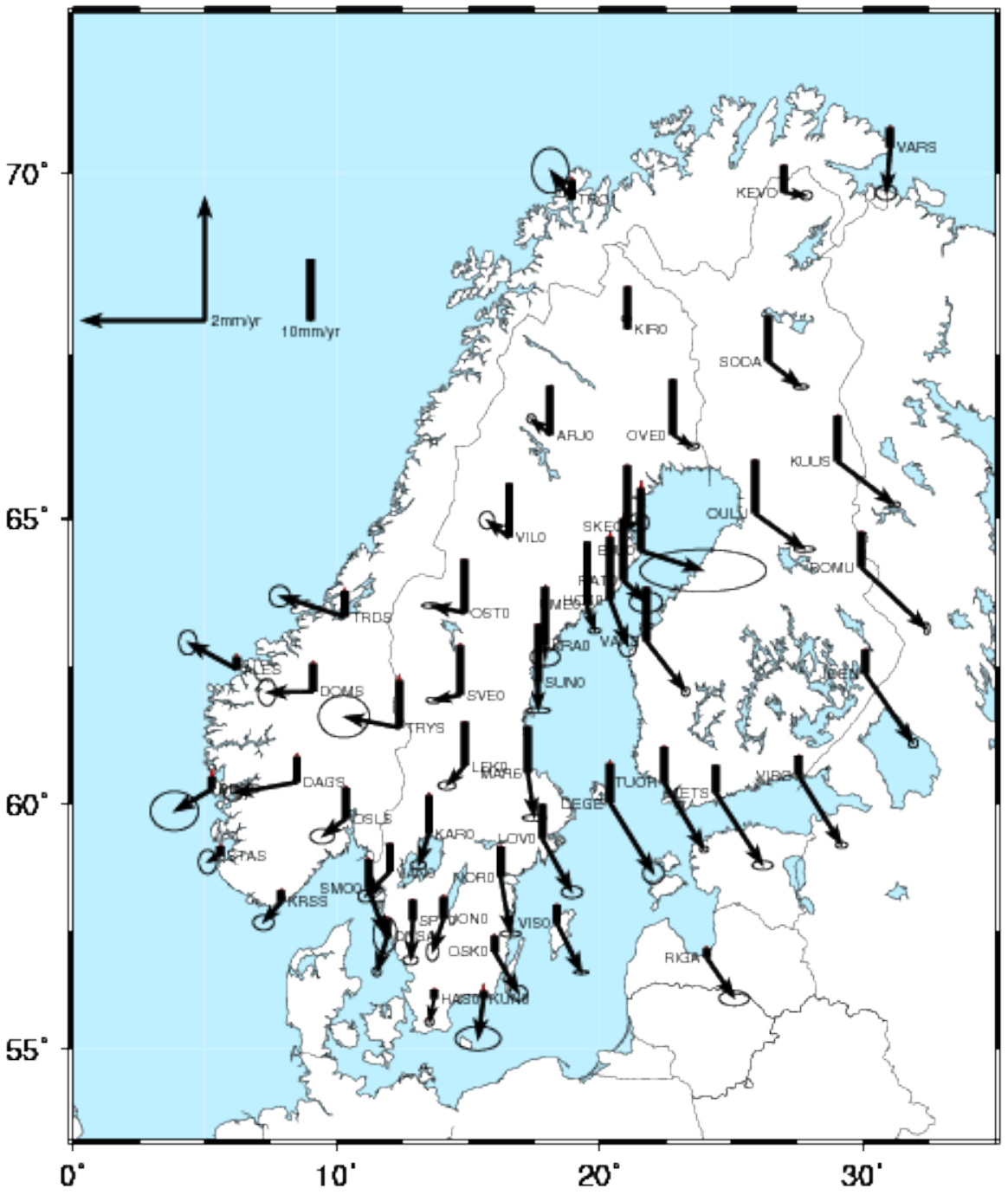
New GPS velocity solution Aug. 2013

GIPSY v6.2

- 10º elevation cut off angle
- Trop. zenith delay & gradients
- VMF1 mapping function
- Absolute antenna PCV
- IGS/JPL products
- ITRF2008 (well: IGS2008…)
- PPP with ambiguity fixing
- Aug 1993 – Aug 2013

GAMIT/GLOBK

- Kierulf and Lidberg combination of several regional and a global solutions



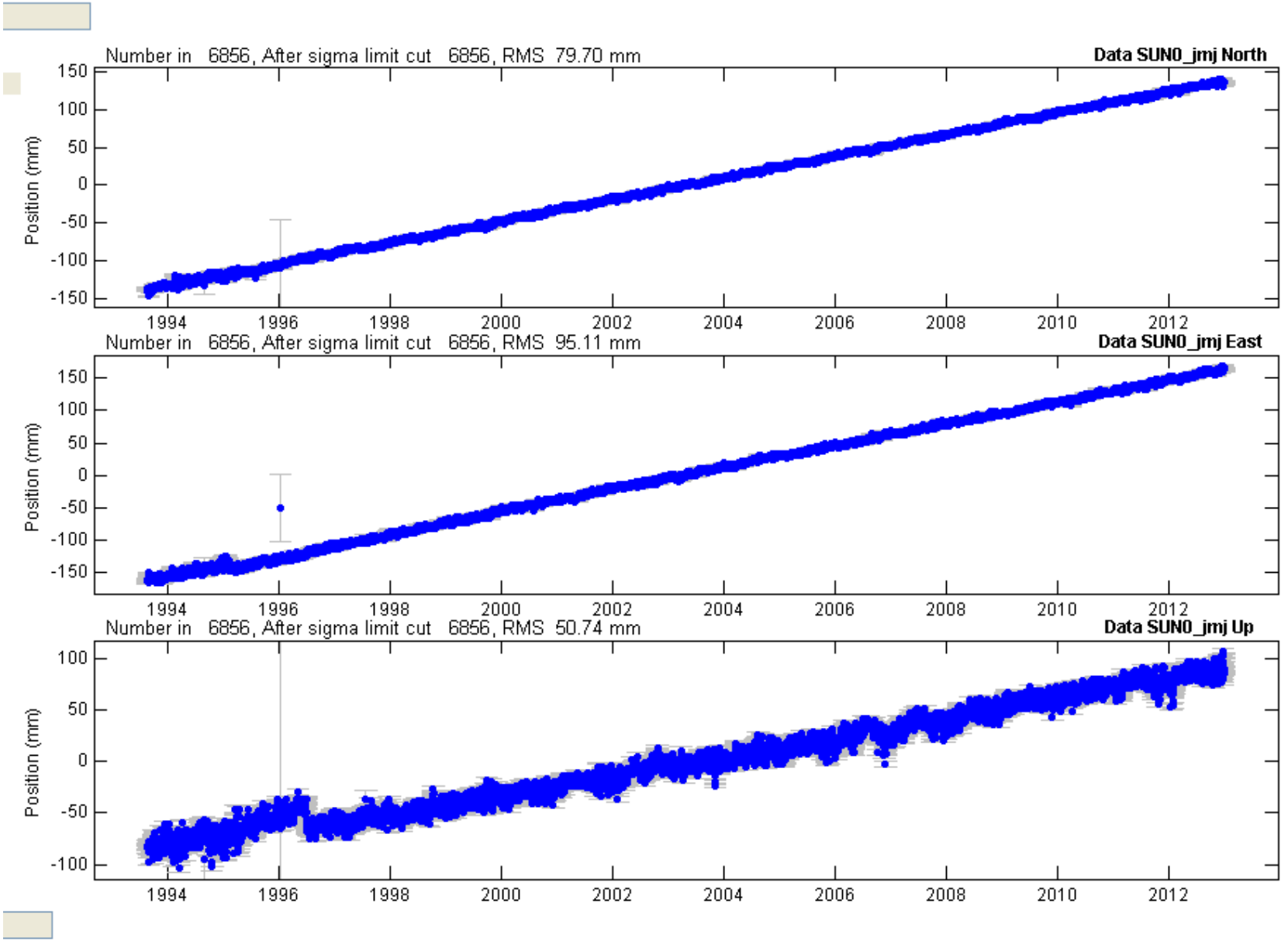
RAW GPS time series (GIPSY solution August 2013)

- ex time series analysis of Sundsvall (SUN0)

North
± 150
mm

East
± 150
mm

Up
± 100
mm

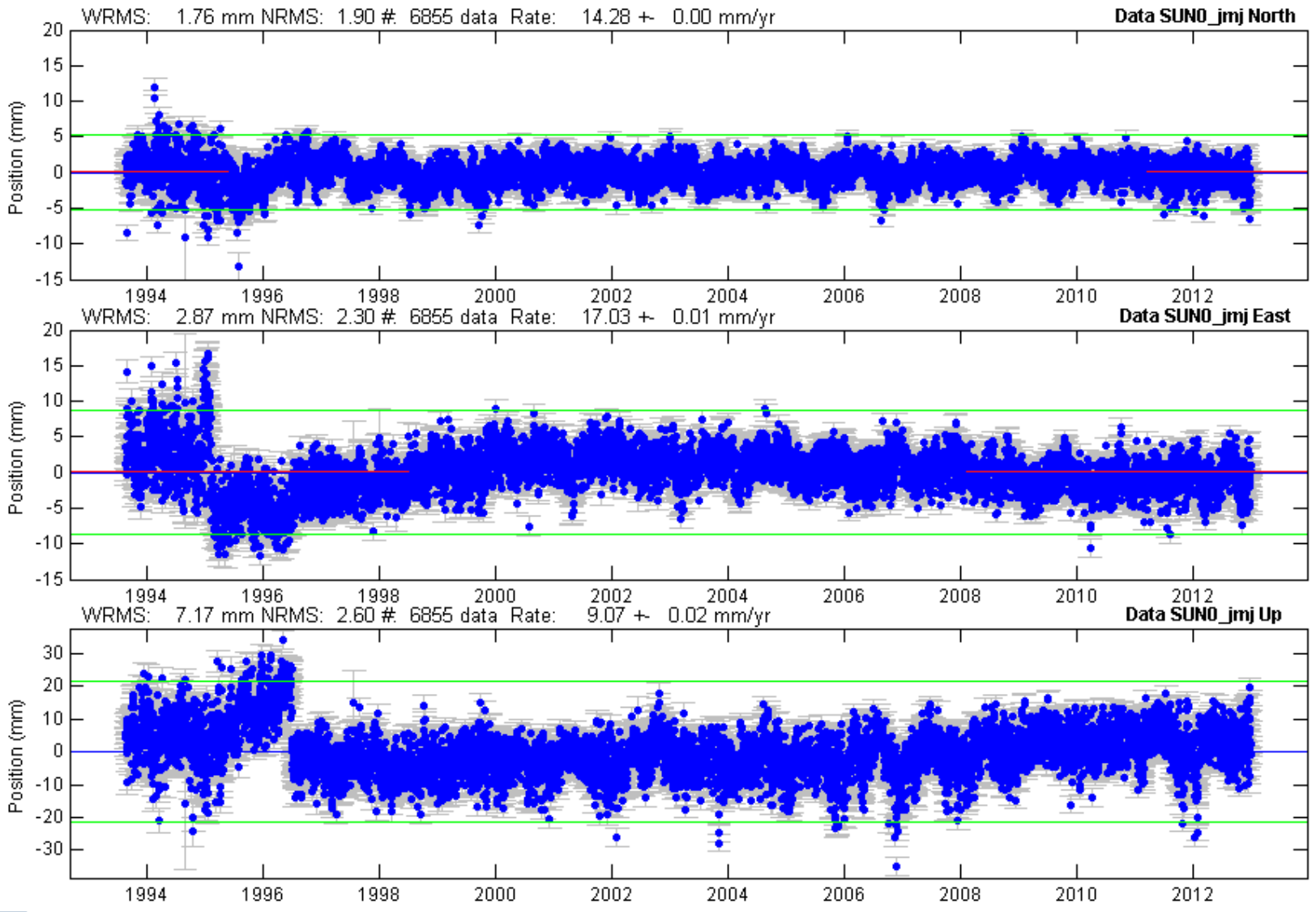


"Detrended" time series (GIPSY solution August 2013)
- ex time series analysis of Sundsvall (SUN0)

North
± 20 mm

East
± 20 mm

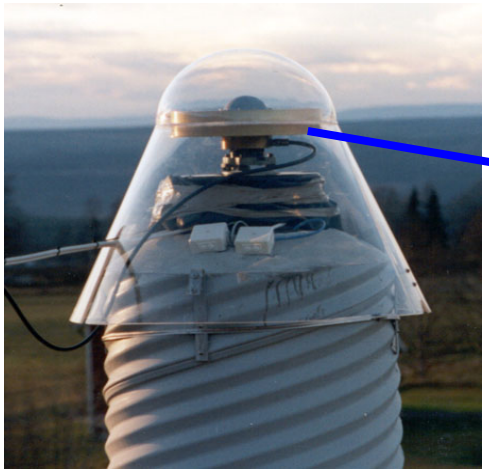
Up
± 30 mm

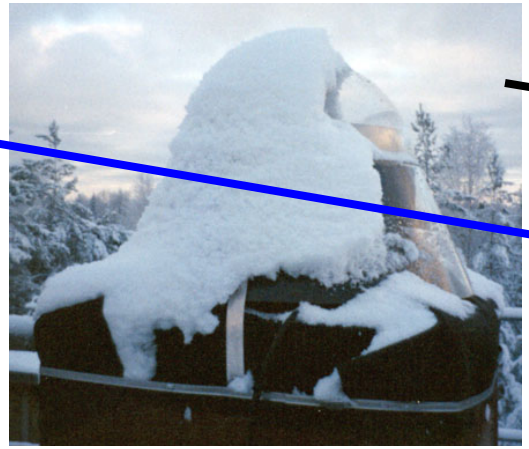


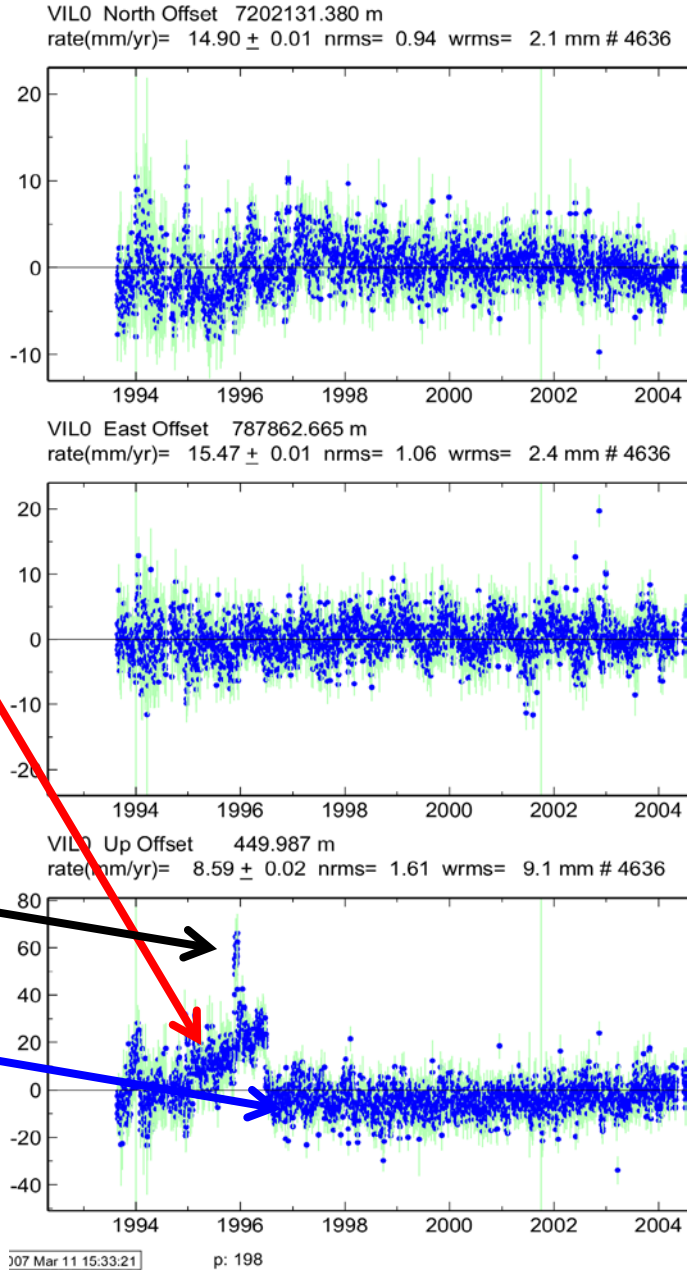
Site dependent effects

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







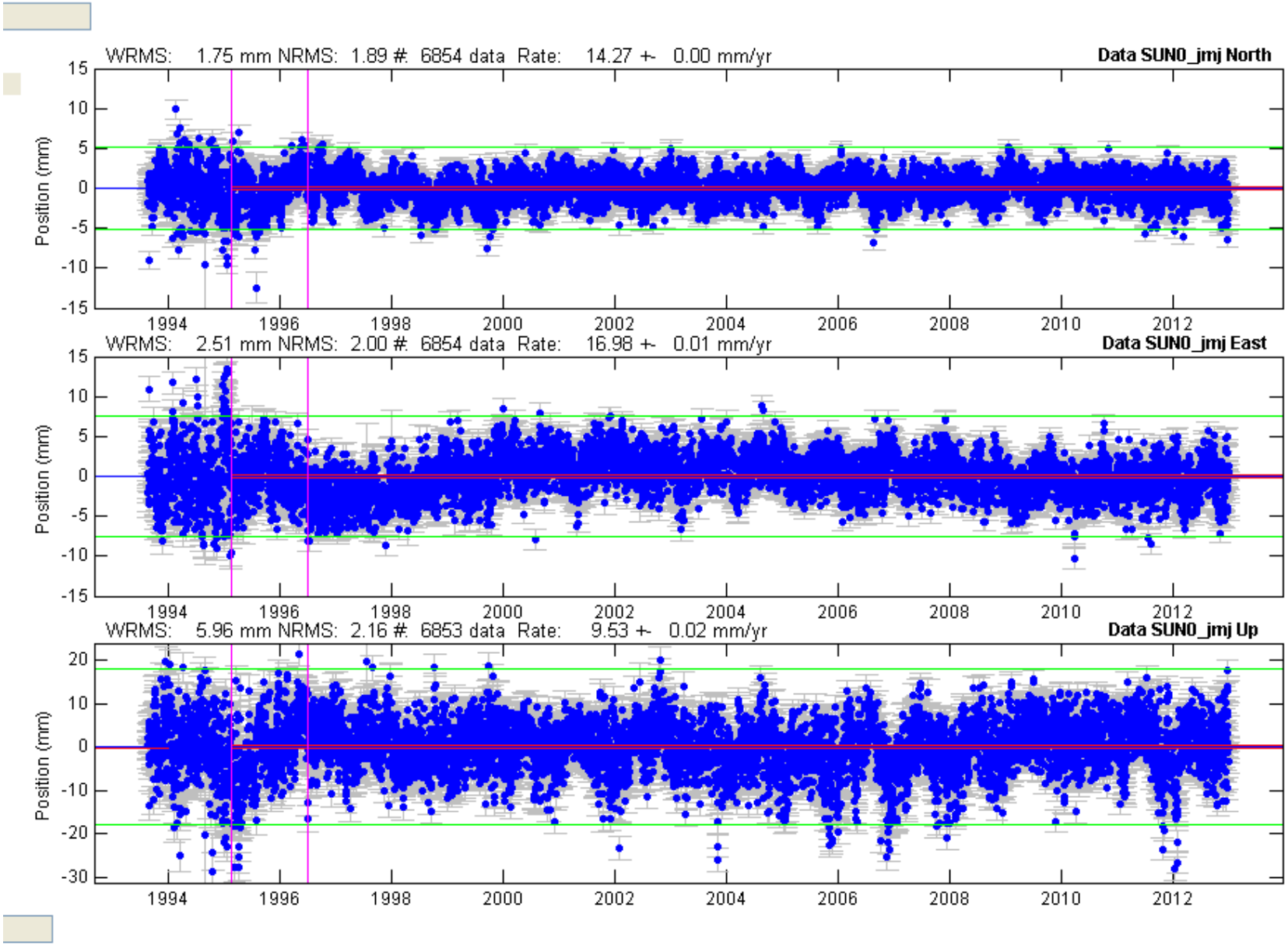
Insert breaks for radome shifts (GIPSY solution August 2013)

- ex time series analysis of Sundsvall (SUN0)

North
± 15 mm

East
± 15 mm

Up
± 30 mm

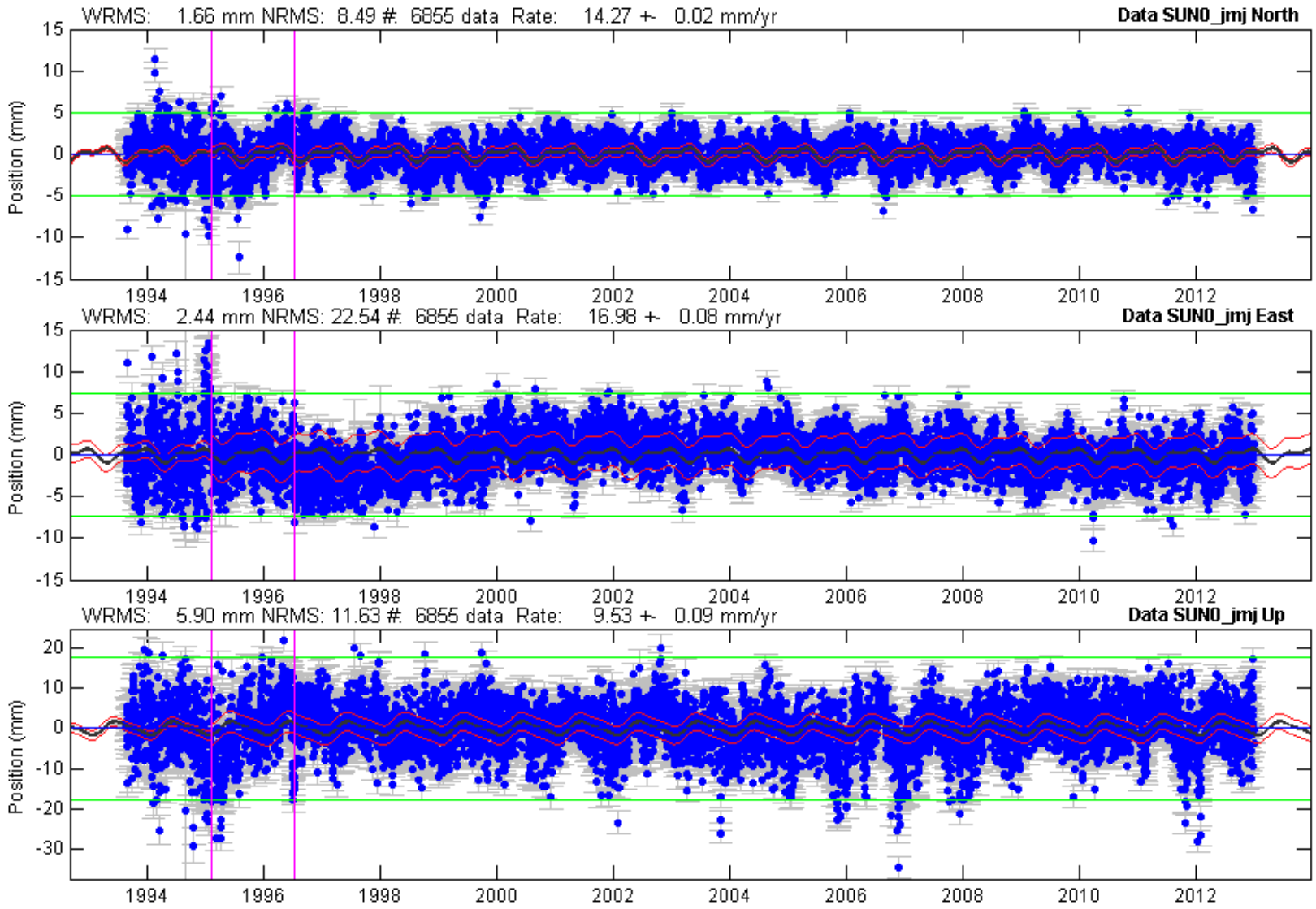


Periodic differences (GIPSY solution August 2013)
- ex time series analysis of Sundsvall (SUN0)

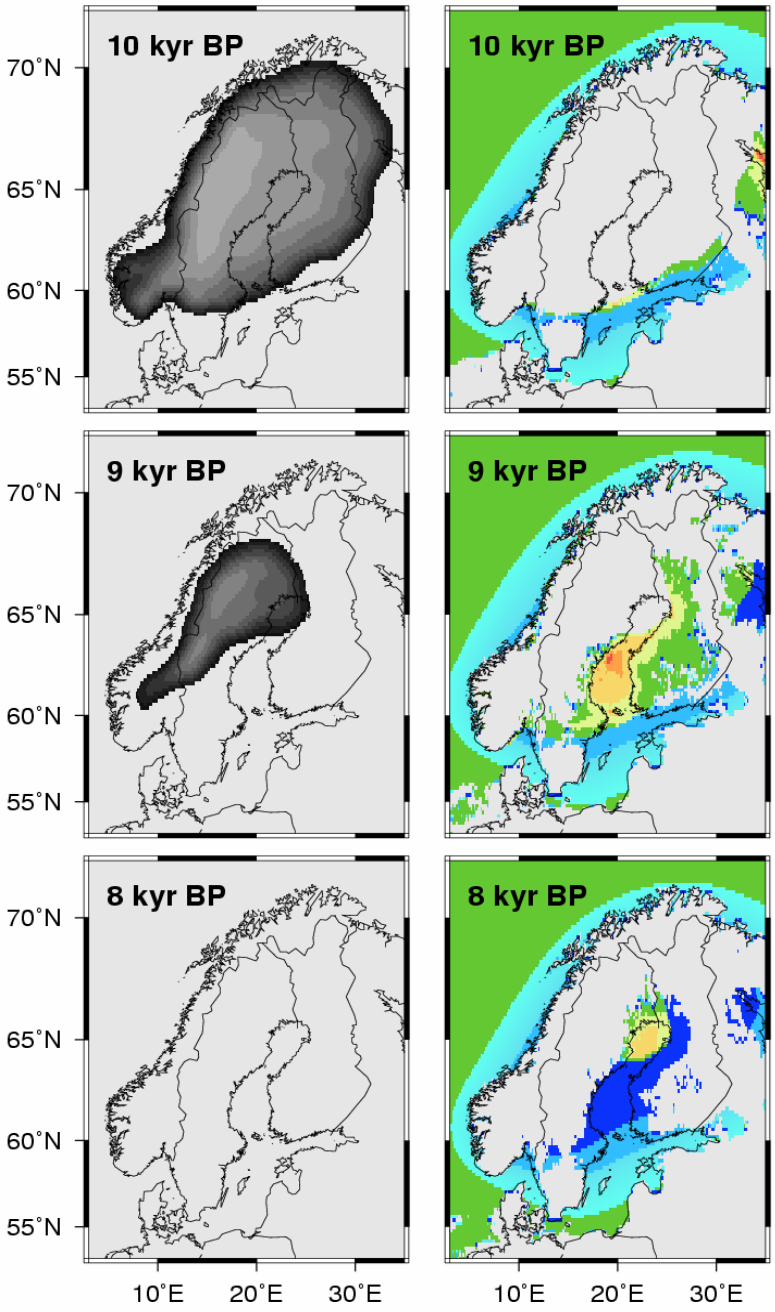
North
± 15 mm

East
± 15 mm

Up
± 30 mm



Glacial Isostatic Adjustment (GIA) model



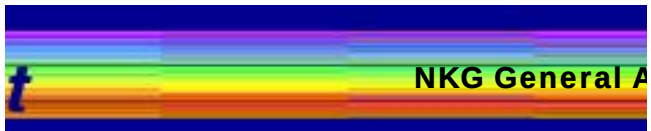
Update of the GIA model developed by (Milne et al Science 2001).

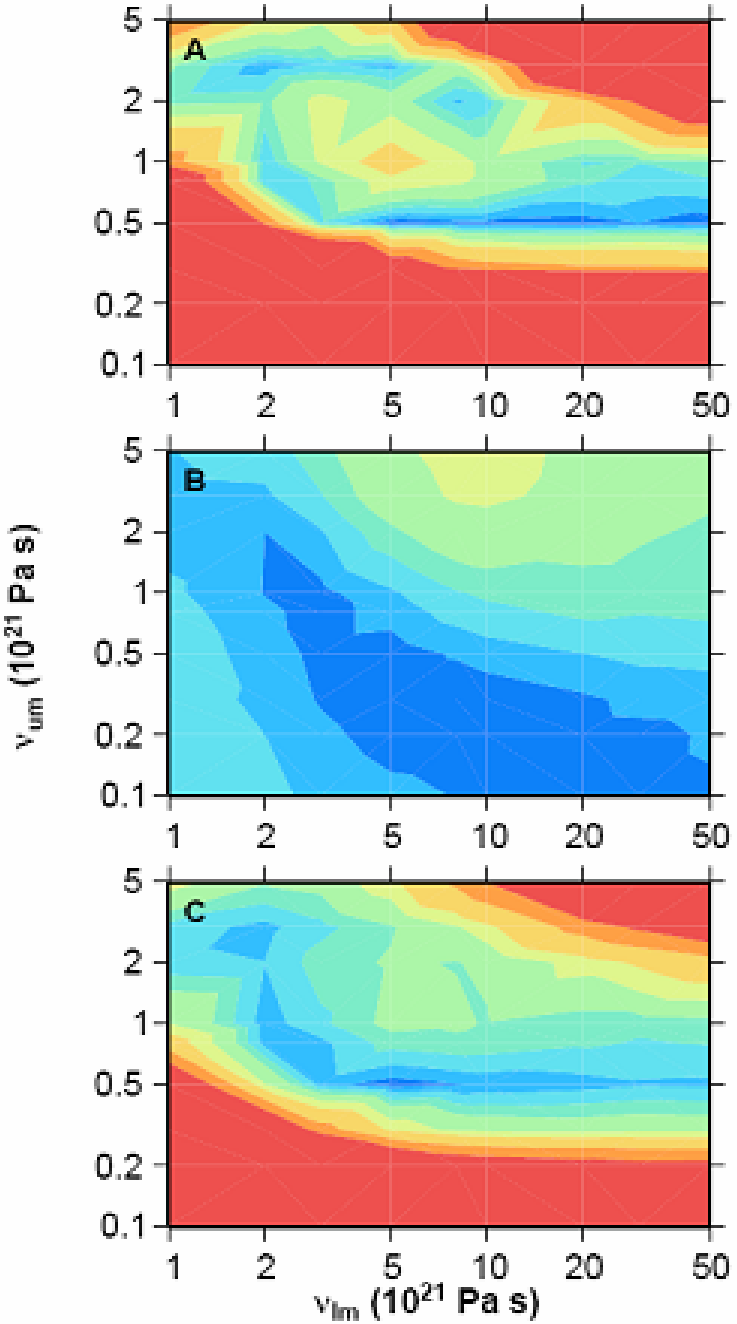
Ice history and method is identical but the new GPS velocity solution (Lidberg et al, 2007) is used for constraining the model, and not the solution in (Johansson et al JGR 2002).

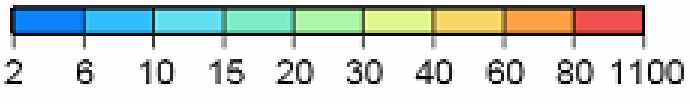
Ice history model from Lambeck

120 km lithosphere,
upper mantle visc. 5×10^{20} Pas
lower mantle visc. 5×10^{21} Pas

Thanks to Glenn Milne, Maaria Nordman, Pippa Whitehouse!!





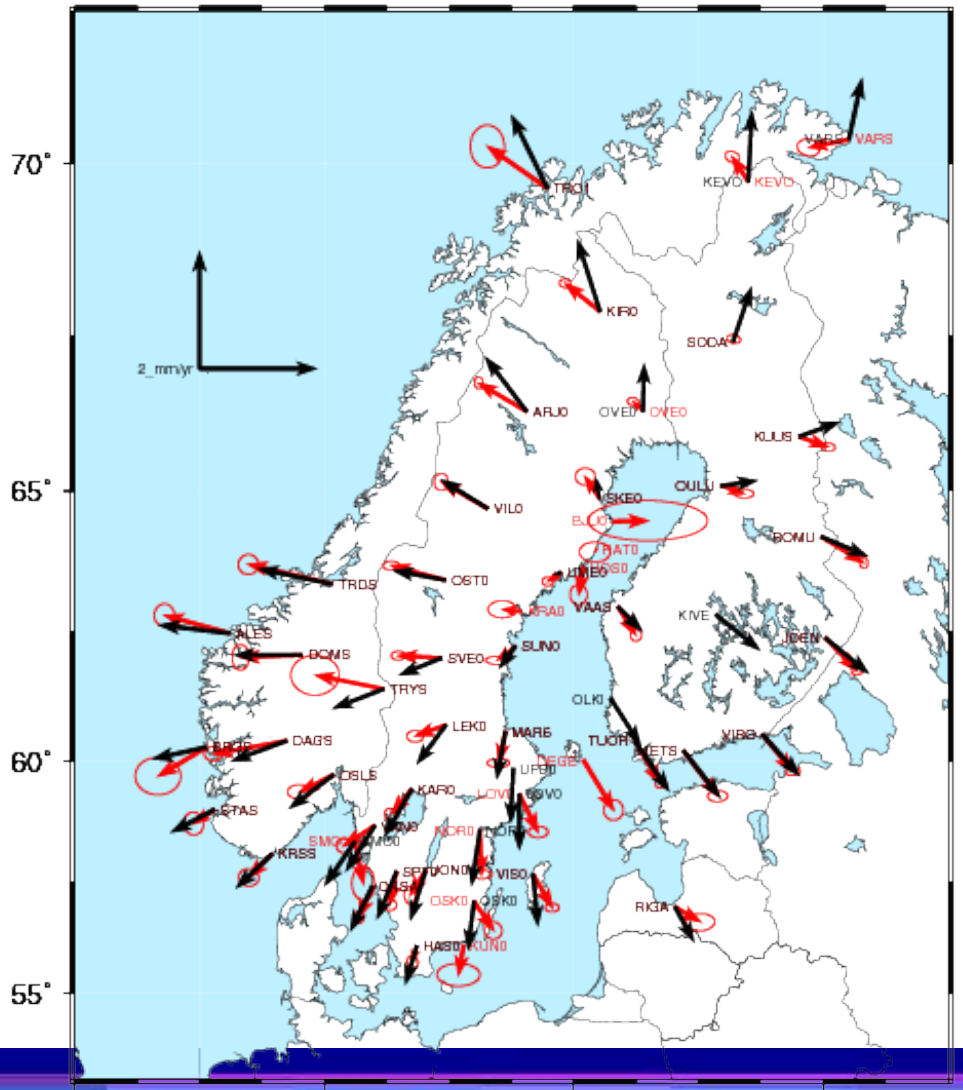


Evaluating station velocity results

New GIPSY vs GIA model

RMS-p : 0.5 mm/yr (all sites)

(GIPSY vs GAMIT, RMS-p: 0.3 mm/yr)

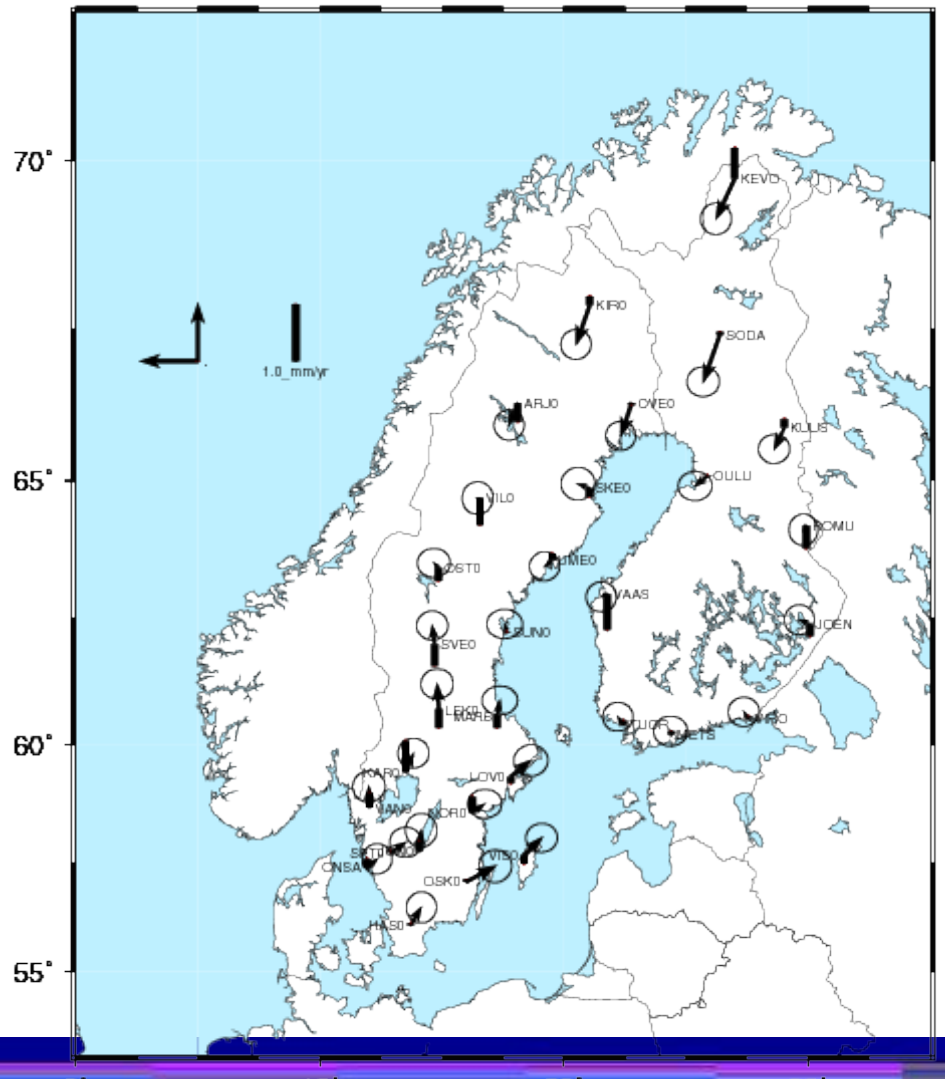


New GIPSY minus GIA model

"best sites" : (0.3, 0.2, 0.3)

(n,e,u) mm/yr std.

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

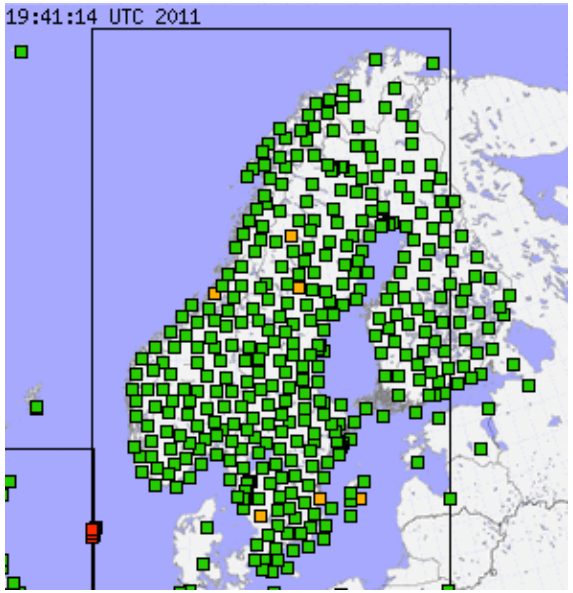


Conclusion and outlook

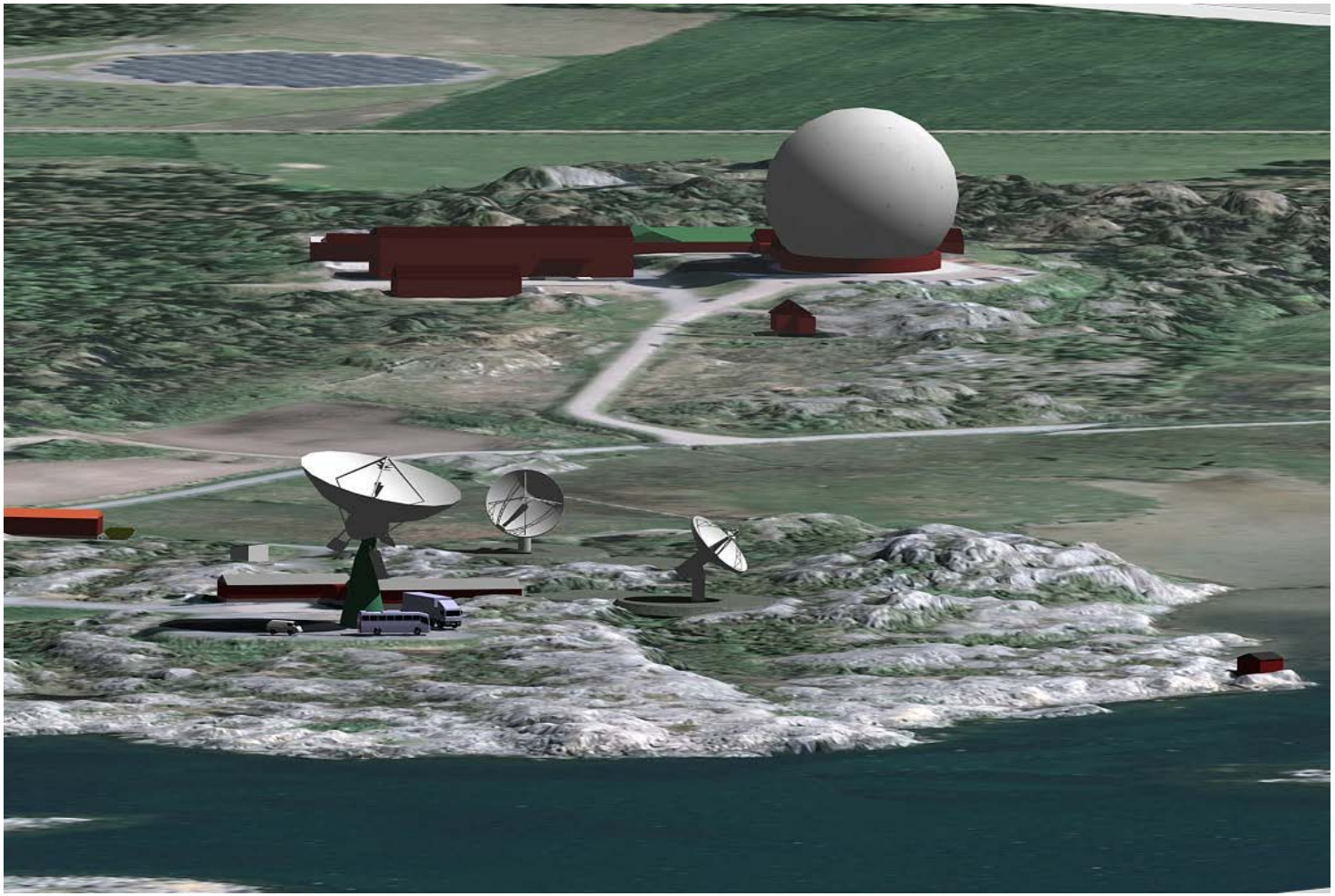
- The velocity solutions presented here are preliminary. However, GPS-velocities and GIA-model agree at the 0.5 mm/yr level (1σ) in booth horizontal and vertical

  $\Rightarrow$ The velocities observed in northern Europe can be explained by the GIA model to the 0.5 mm/yr level!!

- GPS-results are highly dependent on the used reference frame
- Modernization of our observing system (GNSS stations) need special attention in order to keep long un-broken time series of observations
- Re-processing also with Absolute Site PCVs!



Onsala VLBI Twin Telescope



- OTT to be built 2014-2015
- Onsala 20m used for Geo-VLBI 50 days/yr

- Additional GNSS installations
- Gravimeters (SCG etc)
- Seismograph
- Tide Gauge