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A new transformation including deformation model for the Nordic and Baltic countries

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29 May – 2 June, 2017, FIG Working Week 2017, Helsinki, Finland

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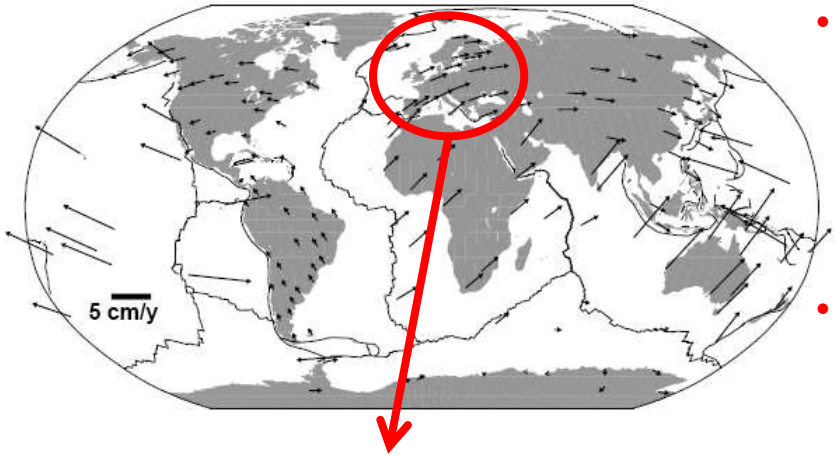
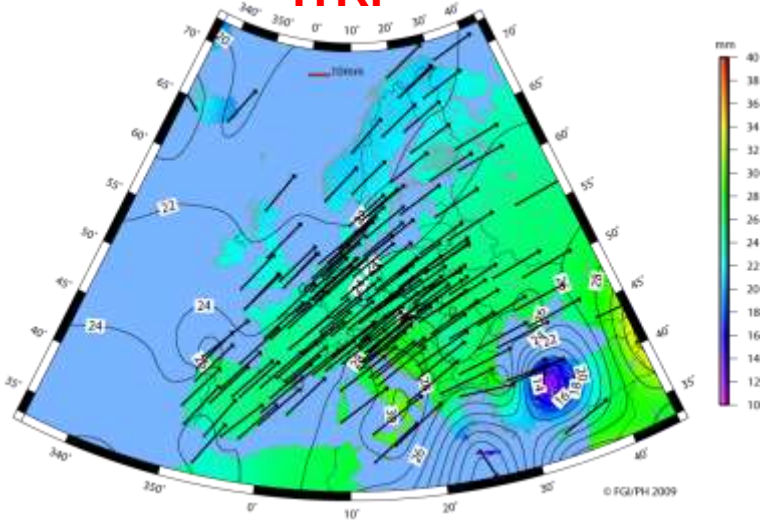
N K G

Global, regional and local reference frames



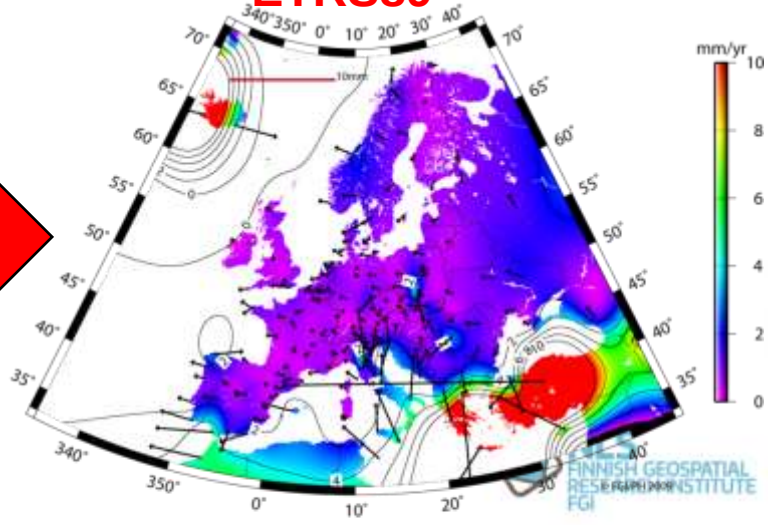
- Global RF: dynamic/kinematic
  - Rigid plate motions, deformations at plate boundaries, intraplate and local motions
- Regional/local RF: mostly static
  - Minimized coordinate variations in time

ITRF

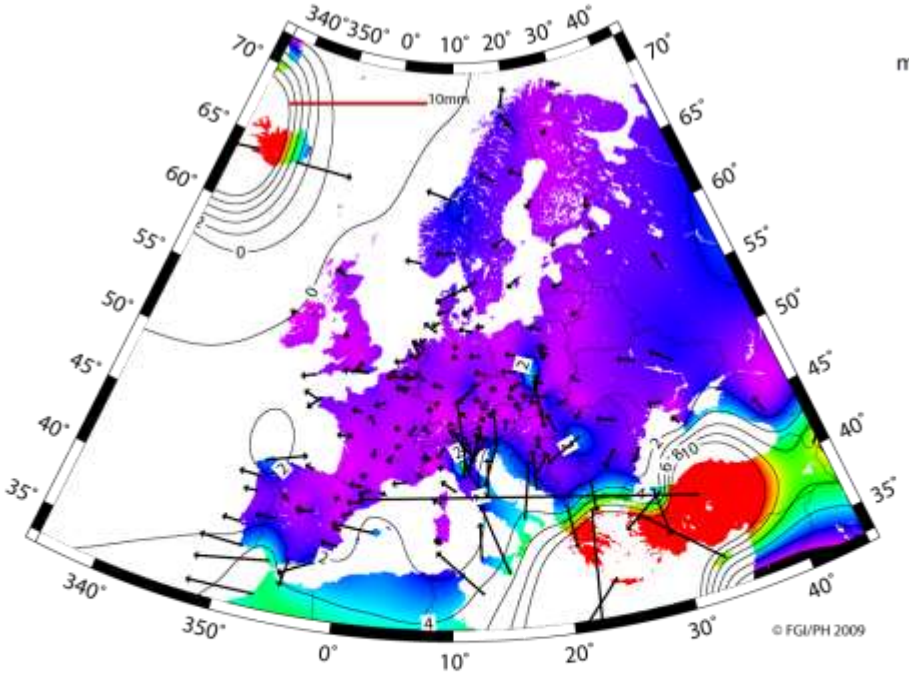


14 (6) par.

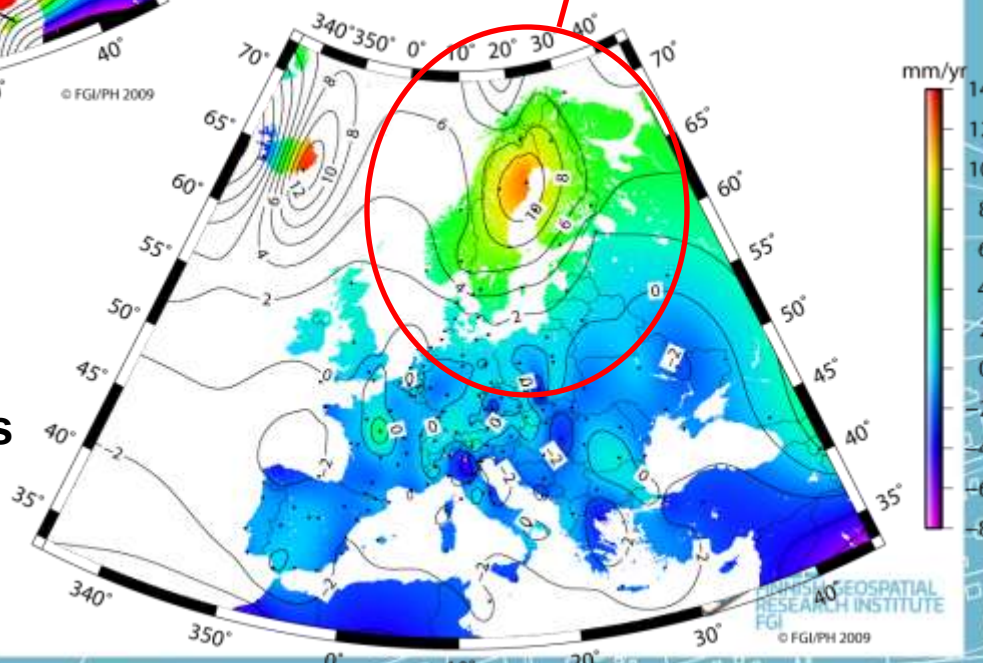
ETRS89



Case ETRS89



… Eurasian plate is not stable: intraplate deformations caused by the post-glacial rebound in the Nordic countries. Also deformations at the plate boundary zones.

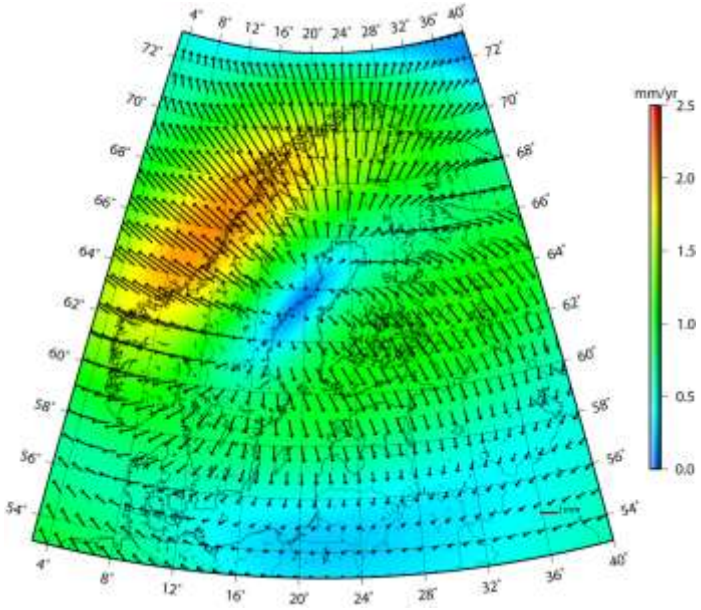


By definition ETRS89 is coincident with ITRS at epoch 1989.0 and co-moving with the stable Eurasian plate → **goal to minimize coordinate variations in time…**

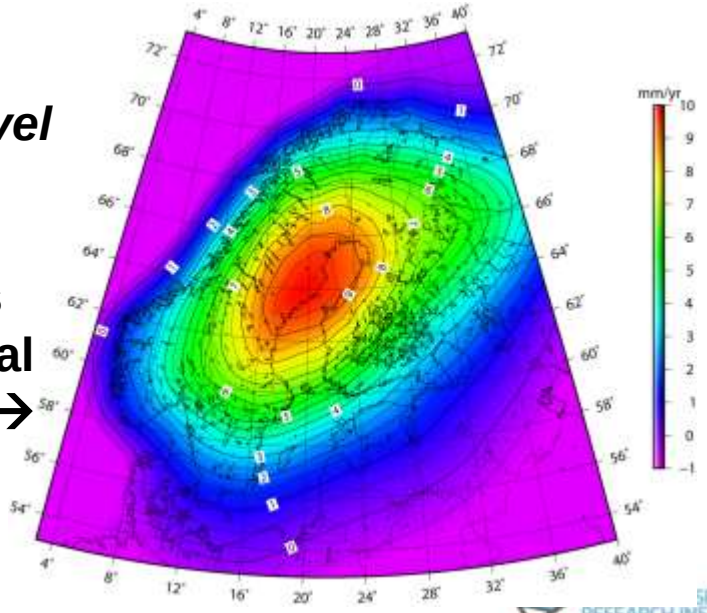
BUT…

Post-glacial rebound (Glacial Isostatic Adjustment, land uplift)

- Post-glacial rebound (PGR) changes coordinates in the Nordic-Baltic area, affects mostly to heights (up to 10 mm/yr) but small horizontal component as well
- Nordic-Baltic ETRS89 realizations mostly established in the 1990's → 10-20 years of deformations compared to present-day coordinates → **PGR effect cannot be neglected in accurate georeferencing applications and in the maintenance of national ETRS89 realizations**



NKG_RF03vel **intraplate model velocities ←Horizontal Vertical →**



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Consequences of the PGR effect

- Eventually static reference frame becomes too distorted - deformations must be accounted for somehow
  - → Regular updates of static reference frame or semi-dynamic or dynamic reference frame
  - → Time tag for the coordinates a prerequisite!
  - → Good deformation model crucial
  - → Common practices (standards) for utilizing the model needed

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Motivation

Project of the Nordic Geodetic Commission (NKG):

1. To ensure, improve and update the accurate transformations (incl. deformation model) from global ITRFs to the national ETRS89 realizations in the Nordic/Baltic area
   - Needed for most accurate georeferencing/geospatial data that is collected in a global frame (using e.g. GNSS) and needs to be stored in a national reference frame (semi-dynamic reference frame)
2. Establish an accurate and homogeneous common reference frame in the Nordic-Baltic-Arctic region e.g.:
   - expressing GNSS/levelling data in a common reference frame in order to evaluate new Nordic geoid model
   - cross-border applications

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NKG2008 campaign
ITRF2008(2008.75)

Input coordinates in ITRF2008:

- **Nordic Geodetic Commission (NKG) set up a Nordic-Baltic-Arctic GPS campaign in 2008**

Nordic-Baltic common frame:

- **Conventional frame of ETRS89: ETRF2000**
- **Conventional epoch in the Nordic-Baltic countries for land uplift: 2000.0**

ETRF2000(2000.0)

National coordinates in ETRS89:

- **Different versions of ETRFyy and realization (reference) epochs tr**

National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- FO: ETRF2000(2008.75)
- LV: ETRF89(1992.75)
- NO: ETRF93(1995.0)
- EE: ETRF96(1997.56)
- FI: ETRF96(1997.0)
- LT: ETRF2000(2003.75)
- SE: ETRF97(1999.5)

NKG2008 campaign
ITRF2008(2008.75)

1

EUREF:

$P_{IERS}(2008.75)$

ITRF2000(2008.75)

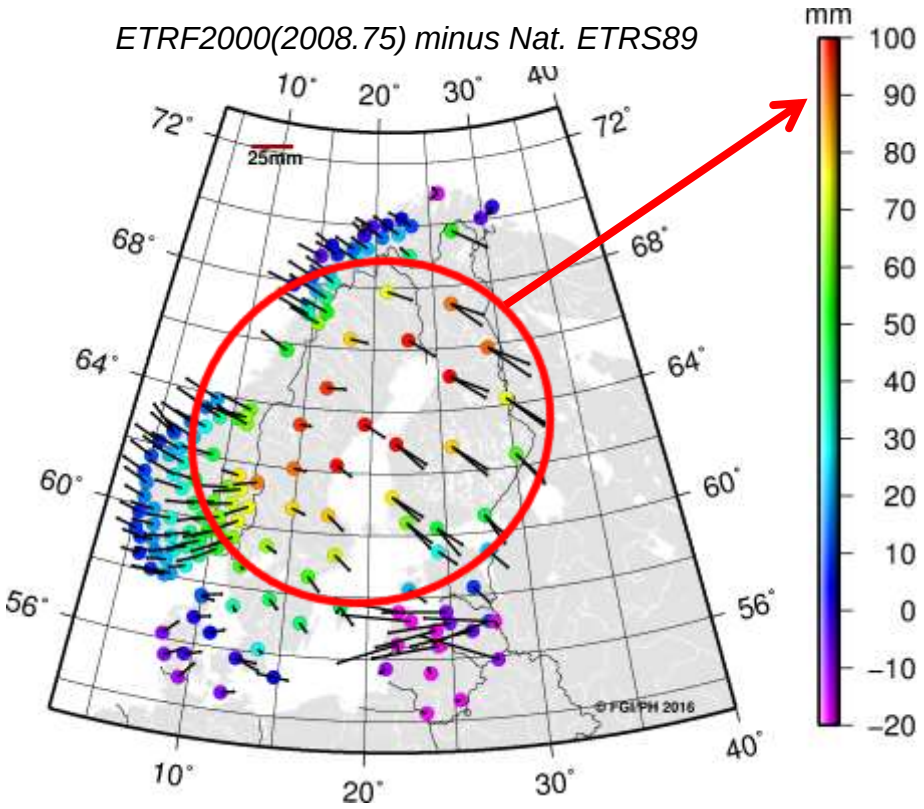
$P_{EUREF}(2008.75)$

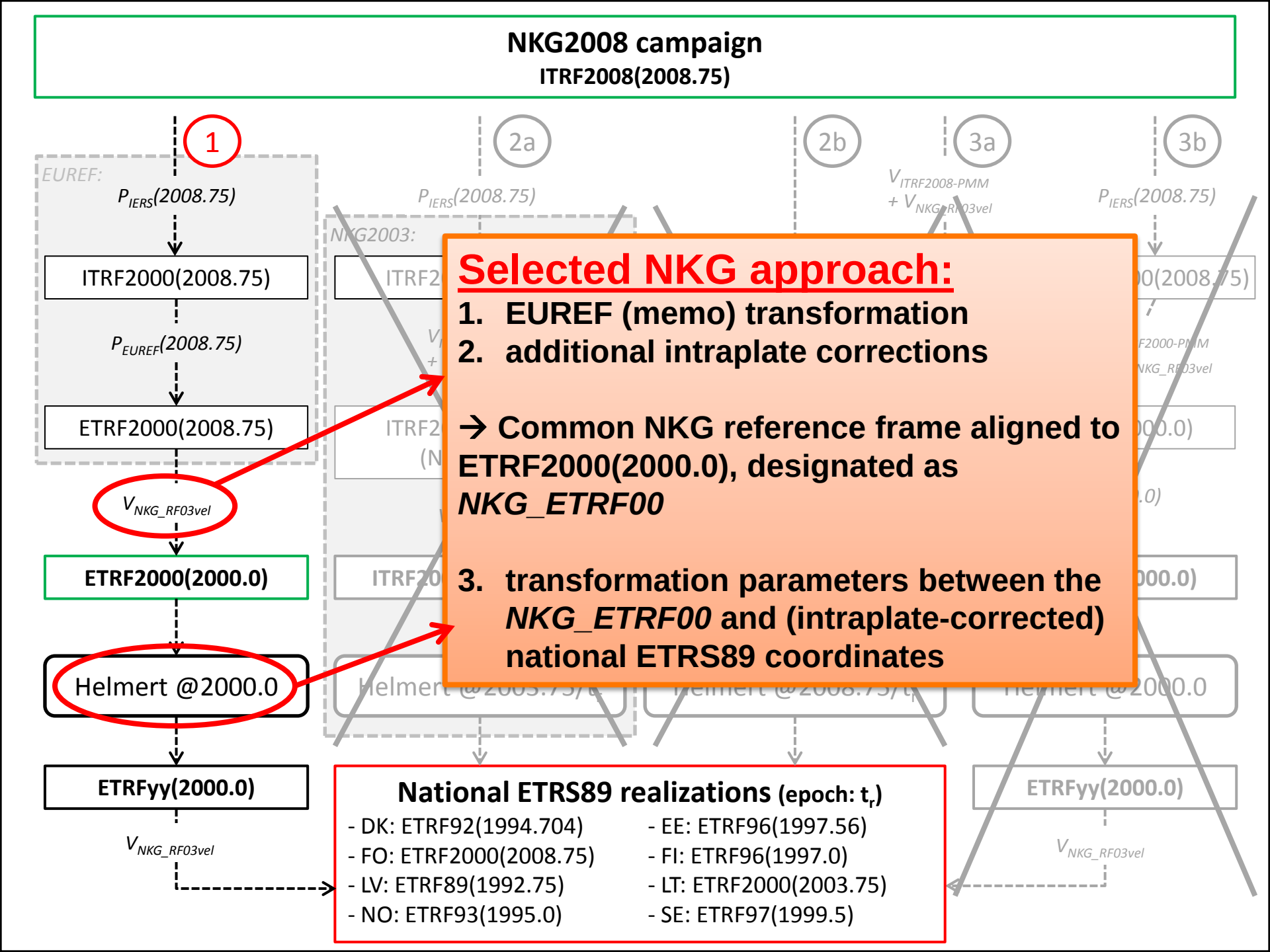
ETRF2000(2008.75)

ETRF2000(2000.0)

De facto EUREF (memo) transformation:

- No epoch/PGR correction
- **NOT sufficient for cm-level access to the national realizations**




NKG2008 campaign
ITRF2008(2008.75)
1
2a
2b
3a
3b
EUREF:
$P_{IERS}(2008.75)$
ITRF2000(2008.75)
$P_{EUREF}(2008.75)$
ETRF2000(2008.75)
$V_{NKG\_RF03vel}$
ETRF2000(2000.0)
Helmert @2000.0
ETRFyy(2000.0)
$V_{NKG\_RF03vel}$
NKG2003:
$P_{IERS}(2008.75)$
$V_{ITRF2008\text{-}PMM}$ + $V_{NKG\_RF03vel}$
$P_{IERS}(2008.75)$
Selected NKG approach:
1. EUREF (memo) transformation
2. additional intraplate corrections
→ Common NKG reference frame aligned to ETRF2000(2000.0), designated as *NKG_ETRF00*
3. transformation parameters between the *NKG_ETRF00* and (intraplate-corrected) national ETRS89 coordinates
ETRFyy(2000.0)
$V_{NKG\_RF03vel}$
National ETRS89 realizations (epoch: t_r)
- DK: ETRF92(1994.704)
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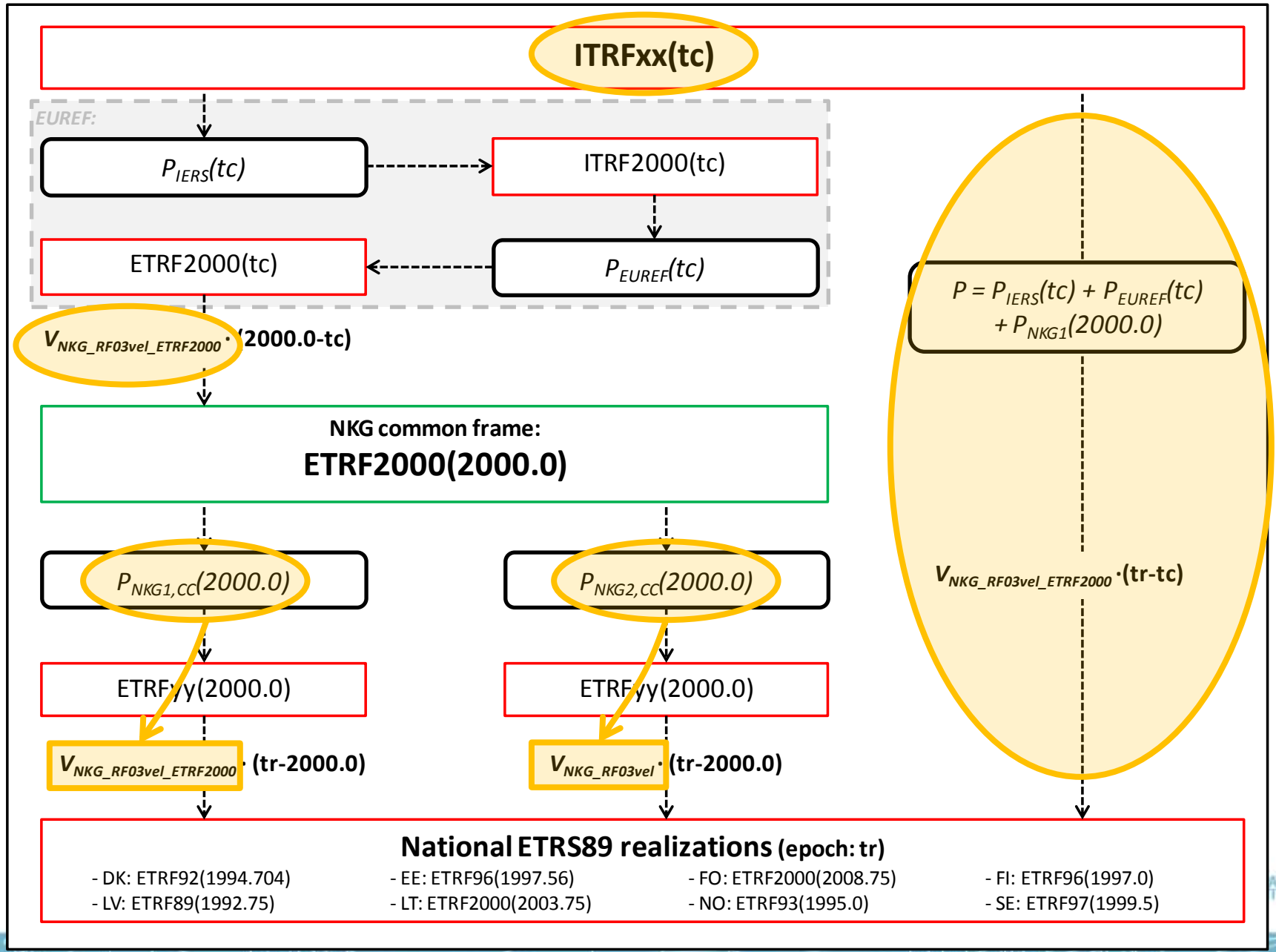
NKG2008 transformation



NKG2008 campaign

ITRF2008(2008.75)

1

EUREF:

$P_{IERS}(2008.75)$

ITRF2000(2008.75)

$P_{EUREF}(2008.75)$

ETRF2000(2008.75)

$V_{NKG\_RF03vel\_ETRF2000}$

ETRF2000(2000.0)

Helmert @2000.0

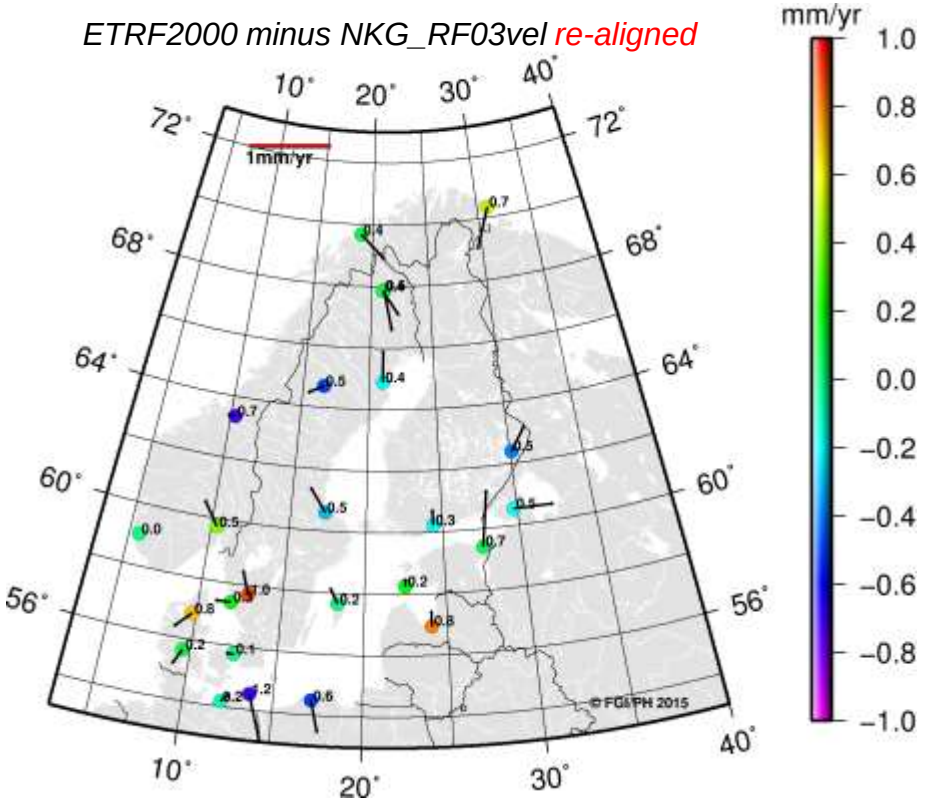
ETRFyy(2000.0)

$V_{NKG\_RF03vel}$

Accuracy of the intraplate velocity model:

- Intraplate corrections are applied in ETRF2000 → should be consistent with ETRF2000 velocities (EPN cumulative solution of class A stations used as a reference)
- **RMS (NEU): 0.34/0.18/0.42 mm/yr**

ETRF2000 minus NKG_RF03vel re-aligned



NKG2008 campaign

ITRF2008(2008.75)

1

EUREF:

$P_{IERS}(2008.75)$

ITRF2000(2008.75)

$P_{EUREF}(2008.75)$

ETRF2000(2008.75)

$V_{NKG\_RF03vel\_ETRF2000}$

ETRF2000(2000.0)

Helmert @2000.0

ETRFyy(2000.0)

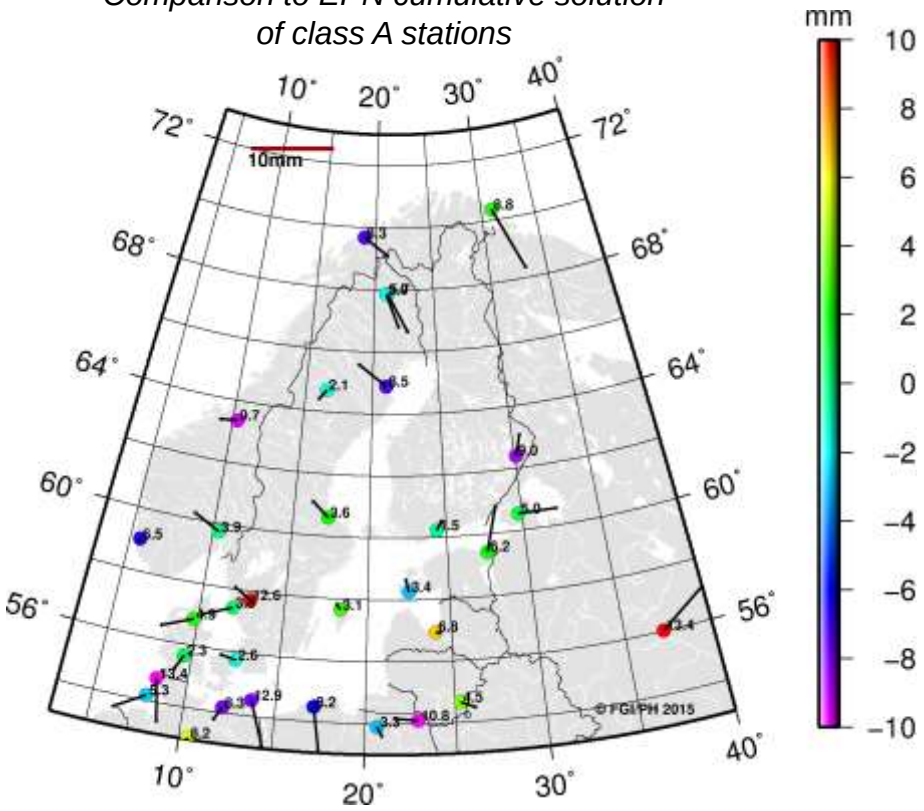
$V_{NKG\_RF03vel}$

Common NKG reference frame alignment:

RMS (NEU):

- Initial GNSS solution in IGb08(2008.75): 1/1/3 mm
- Common RF in ETRF2000(2000.0): **3.5/2.4/5.4 mm**

Comparison to EPN cumulative solution of class A stations



1

EUREF:

$P_{IERS}(2008.75)$

ITRF2000(2008.75)

$P_{EUREF}(2008.75)$

ETRF2000(2008.75)

$V_{NKG\_RF03vel\_ETRF2000}$

ETRF2000(2000.0)

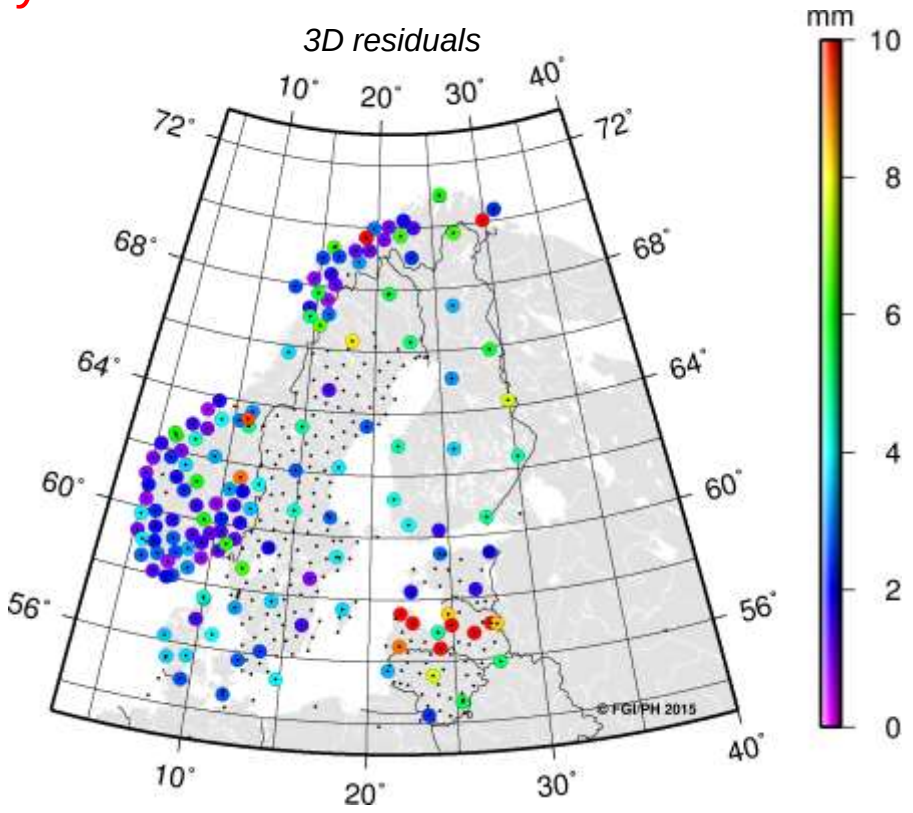
Helmert @2000.0

ETRFyy(2000.0)

$V_{NKG\_RF03vel}$

Transformation residuals (country-wise):

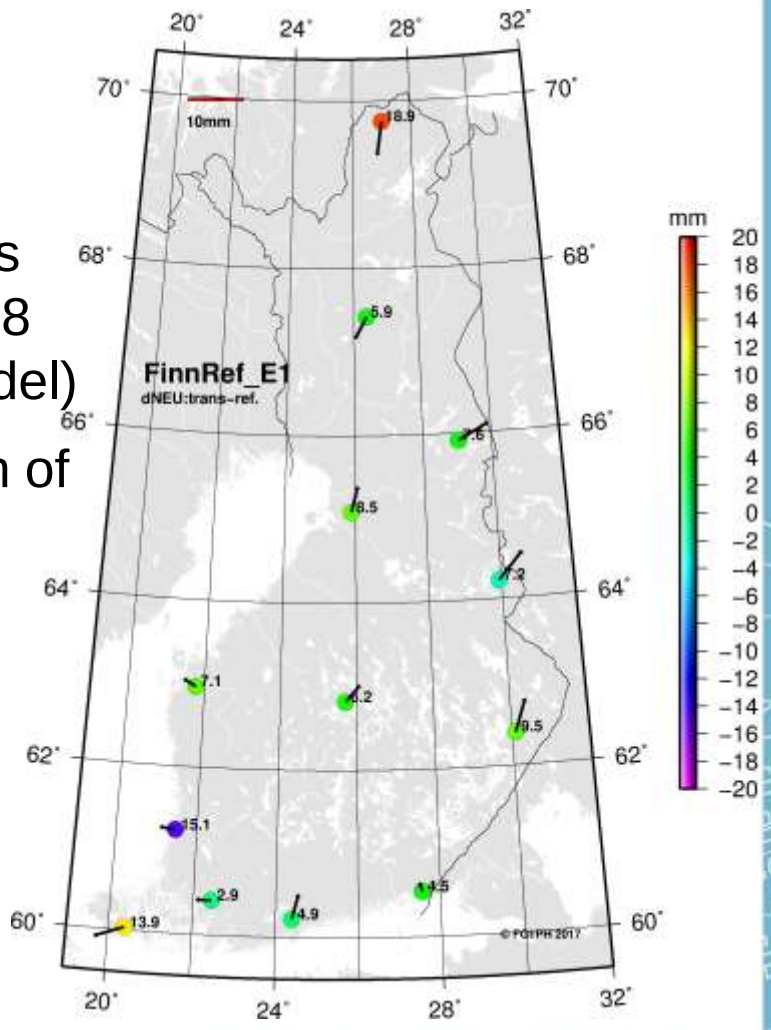
- Reflect the consistency of input coordinates (NKG2008 and national ETRS89) and used deformation model
- Mostly some mm-level



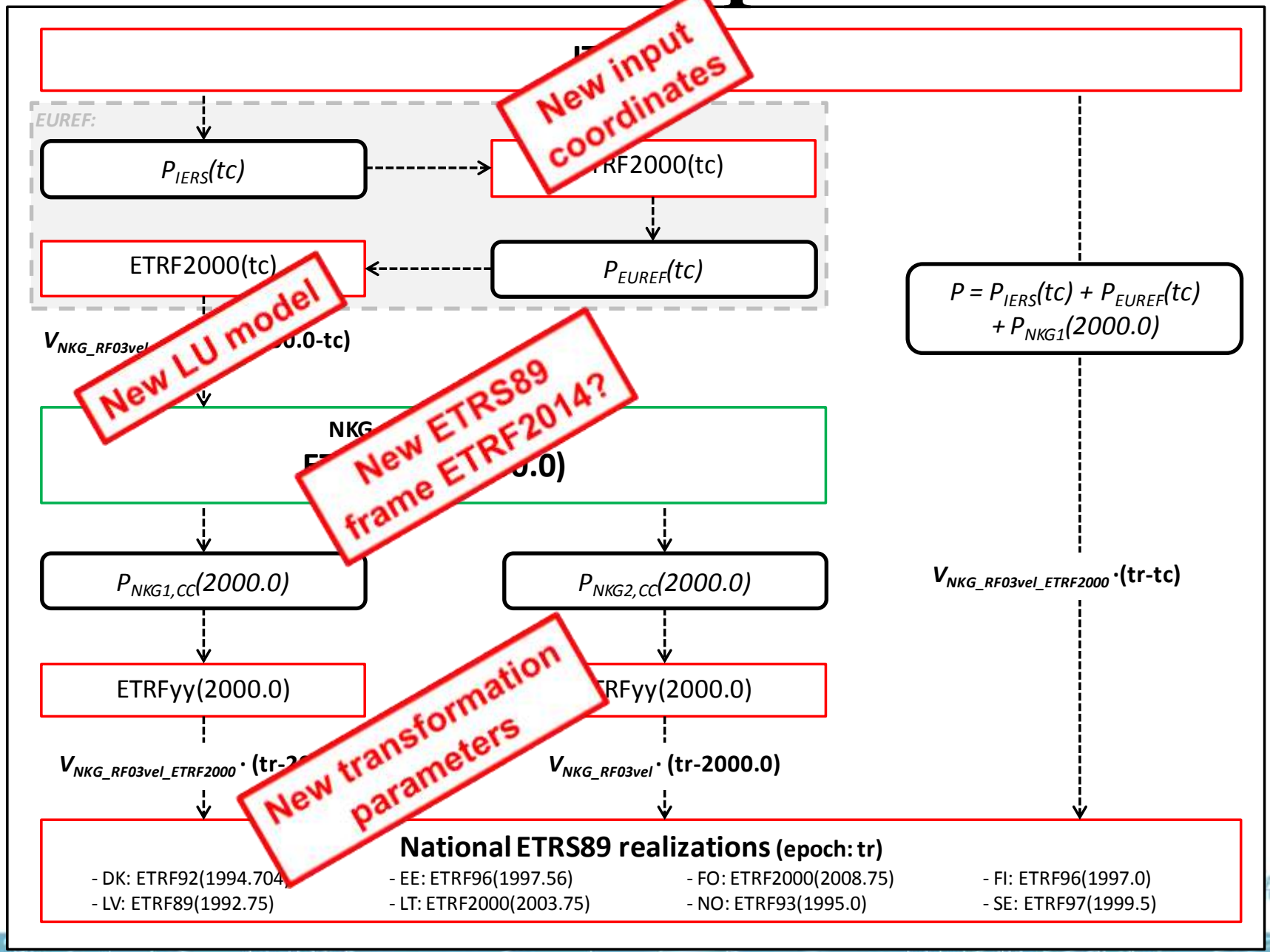
Examples of the use of NKG2008 transformation

- Nordic-Baltic NKG2015 geoid model:
  - GNSS/levelling data to the common reference frame
- Finland: official EUREF-FIN coordinates for network-RTK services with NKG2008 transformation (incl. NKG_RF03vel model)
  1. Positions in latest ITRFyy at epoch of observations
  2. NKG2008 transformation

  → National EUREF-FIN coordinates (ETRF96 at reference epoch 1997.0)
  - Better than 1cm agreement



Future work and updates



Conclusions

- The developed transformation allows accurate access to national realizations and is an implementation for national semi-dynamic reference frames
- Common NKG frame fulfill current (urgent) needs, e.g. for GNSS/levelling data for a new Nordic geoid model
- But we'll continue improving the procedure and models
- Also more focus on making these (still non-standardized) transformations available to users
  - See presentation 9156 by Evers and Knudsen: Transformation pipelines for PROJ.4, Thursday 11:00-12:30

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More information:

- Articles:
  - Häkli et al.: The NKG2008 GPS campaign – final transformation results and a new common Nordic reference frame, *Journal of Geodetic Science*, Volume 6, Issue 1 (Mar 2016), open access: https://doi.org/10.1515/jogs-2016-0001
  - Häkli et al.: FIG2017 Working Week paper
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