# NKG2008 transformation and new common reference frame

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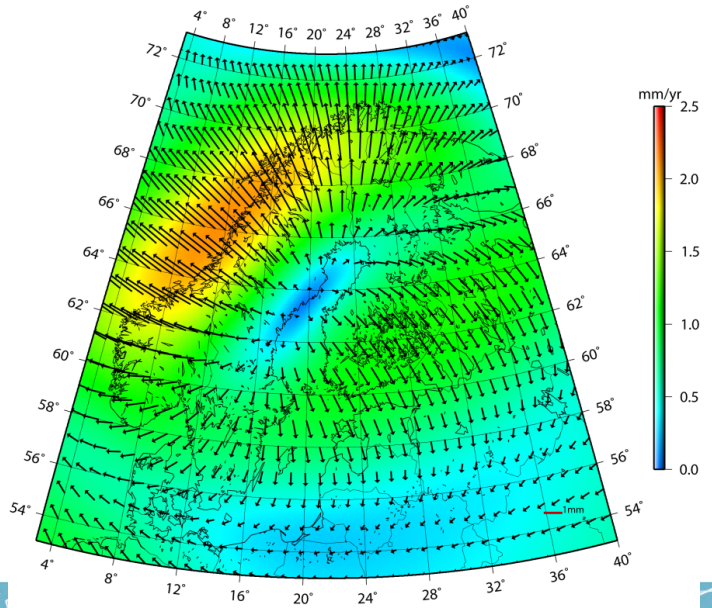
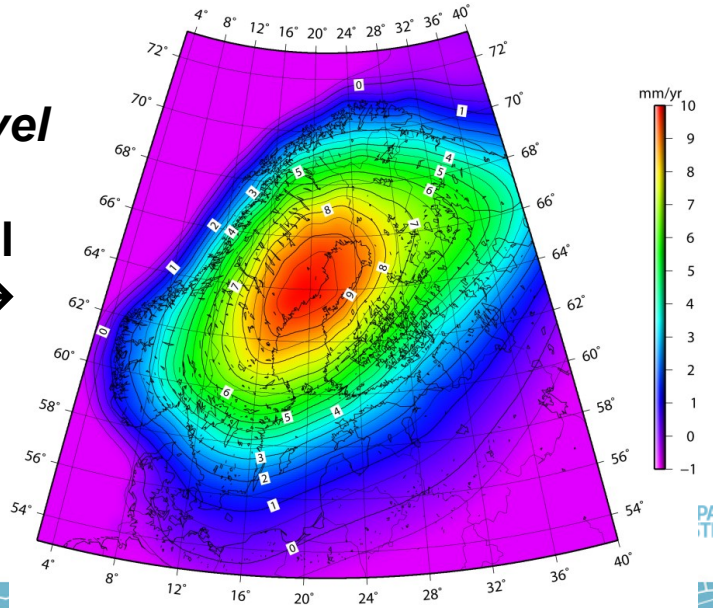
# Background

- 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 most georeferencing applications and in the maintenance of national ETRS89 realizations

→ Nordic Geodetic Commission (NKG) has created a deformation model *NKG_RF03vel* and an *NKG2003* transformation method to account for the effect of PGR




***NKG_RF03vel* velocities**
**←Horizontal**
**Vertical →**



# Motivation

- Existing deformation model and transformation method are already more than 10 years old → second GNSS campaign *NKG2008* in the Nordic-Baltic-Arctic region, processed in ITRF2008 at epoch 2008.75:

→ Improve and update the transformations from ITRF to the national ETRS 89 realizations in the area

- Existing transformations not supporting new ITRF frames and all Nordic-Baltic countries

→ Establish a common reference frame in the Nordic-Baltic-Arctic region e.g. for:

- expressing GNSS/levelling data in a common reference frame in order to evaluate new Nordic geoid model
- cross-border applications

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# Methods and alternatives

- Common NKG reference frame:
  1. Realization – ETRS89: conventional frame ETRF2000
  2. Epoch – most Nordic/Baltic EVRS realizations have land uplift epoch 2000.0

  → To be consistent with these conventions, ETRF2000 at epoch 2000.0 chosen as the common frame (*NKG_ETRF00*)
- Transformation to be developed should include at least:
  1. NKG2008 (ITRF2008@2008.75) → National ETRS89 realizations
  2. NKG2008 (ITRF2008@2008.75) → Common NKG reference frame *NKG_ETRF00*
  3. Preferably any ITRFxx(t) supported too

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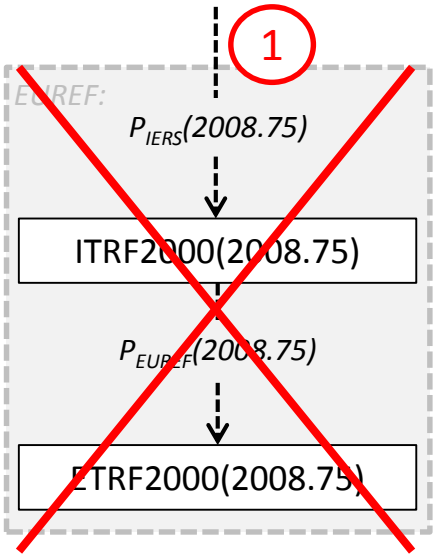
# NKG2008 campaign

**ITRF2008(2008.75)**

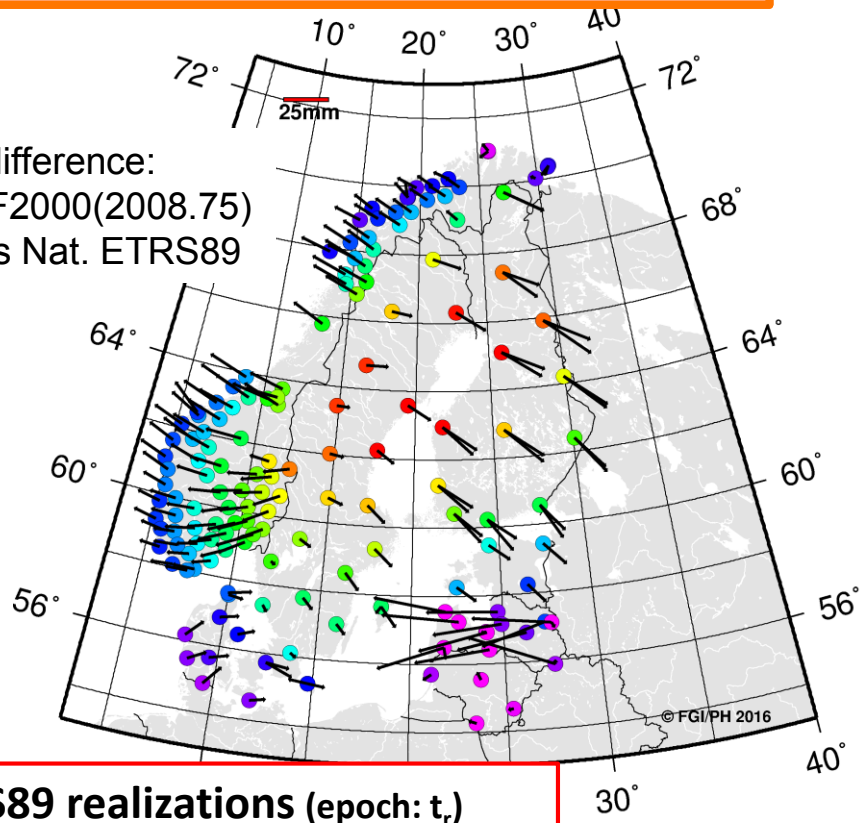


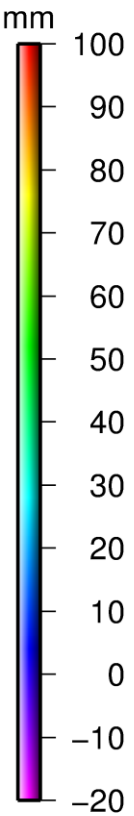

**ETRF2000(2000.0)**

***EUREF (memo) transformation:***

**→No PGR/intraplate correction – not cm-level accurate for accessing national realizations**

Crd difference:
ETRF2000(2008.75)
minus Nat. ETRS89

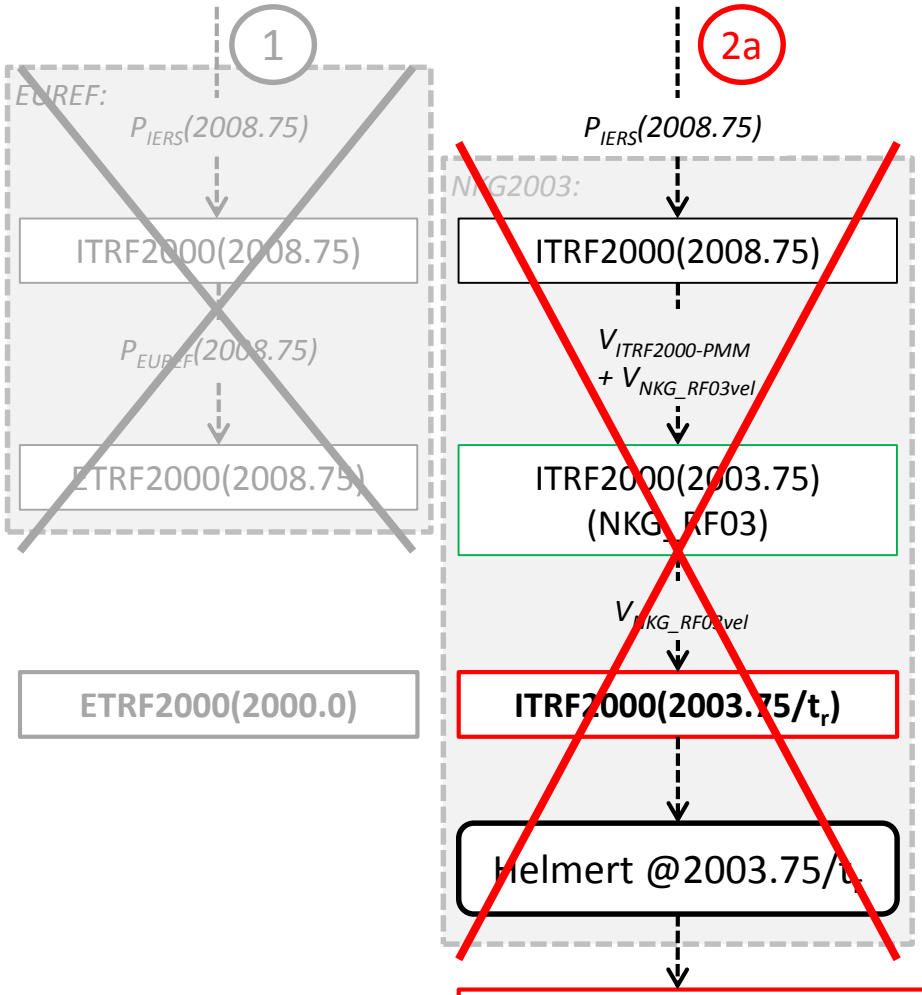



## National ETRS89 realizations (epoch: $t_r$)

- 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)**




***Existing NKG2003 transformation:***

- **using deformation model NKG_RF03vel together or without the ITRF2000-PMM to simulate ITRF2000 or ETRF2000 station velocities to be used for epoch reductions**

**→ Does not support common frame in ETRF2000(2000.0)**
**→ No transformation parameters for all Nordic/Baltic countries**

**National ETRS89 realizations (epoch: $t_r$)**

- DK: ETRF92(1994.704)
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- FO: ETRF2000(2008.75)
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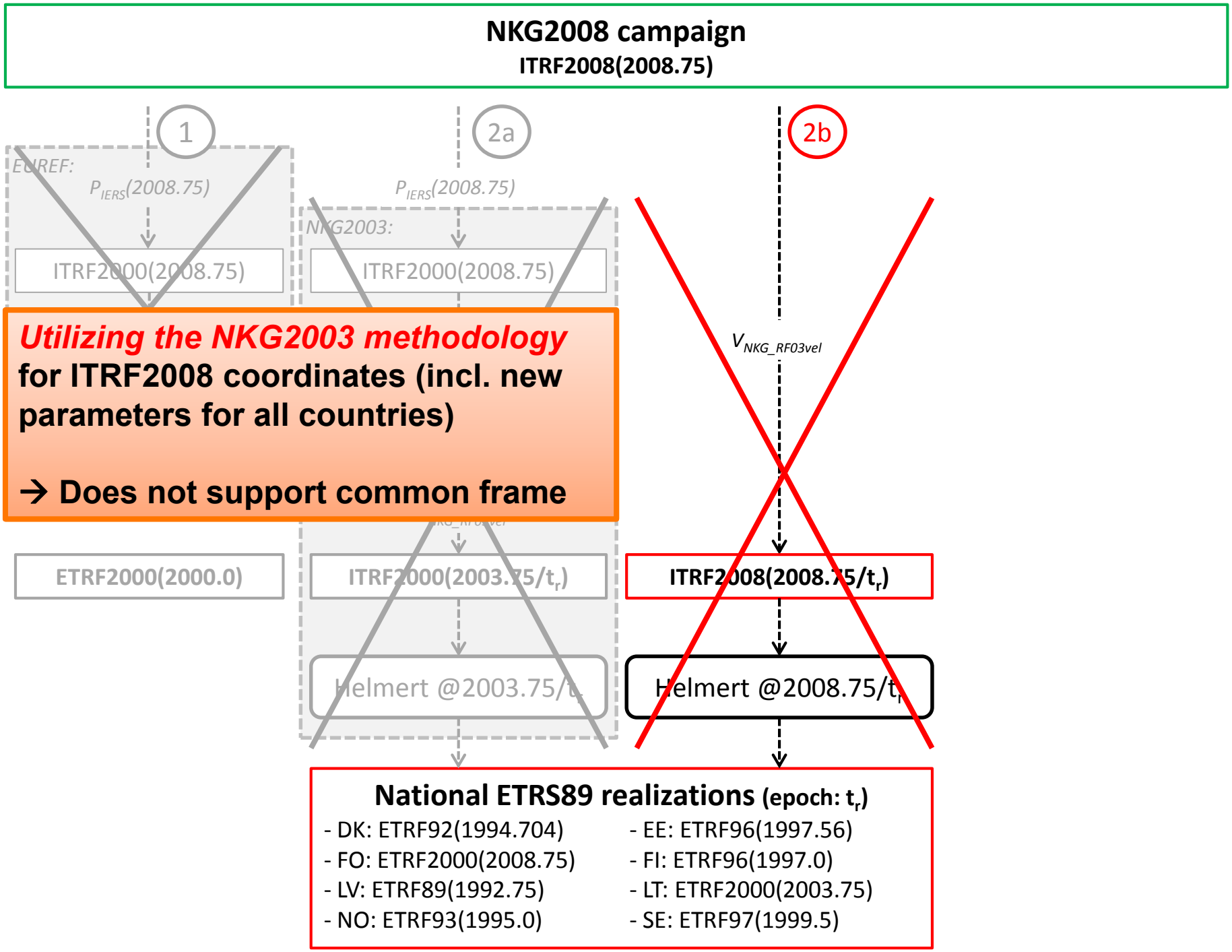
NKG2008 campaign
ITRF2008(2008.75)
1
2a
2b
EUREF:
$P_{IERS}(2008.75)$
$P_{IERS}(2008.75)$
NKG2003:
ITRF2000(2008.75)
ITRF2000(2008.75)
Utilizing the NKG2003 methodology
for ITRF2008 coordinates (incl. new parameters for all countries)
→ Does not support common frame
$V_{NKG\_RF03vel}$
ETRF2000(2000.0)
ITRF2000(2003.75/$t_r$)
ITRF2008(2008.75/$t_r$)
Helmert @2003.75/$t_r$
Helmert @2008.75/$t_r$
National ETRS89 realizations (epoch: $t_r$)
- DK: ETRF92(1994.704)
- EE: ETRF96(1997.56)
- FO: ETRF2000(2008.75)
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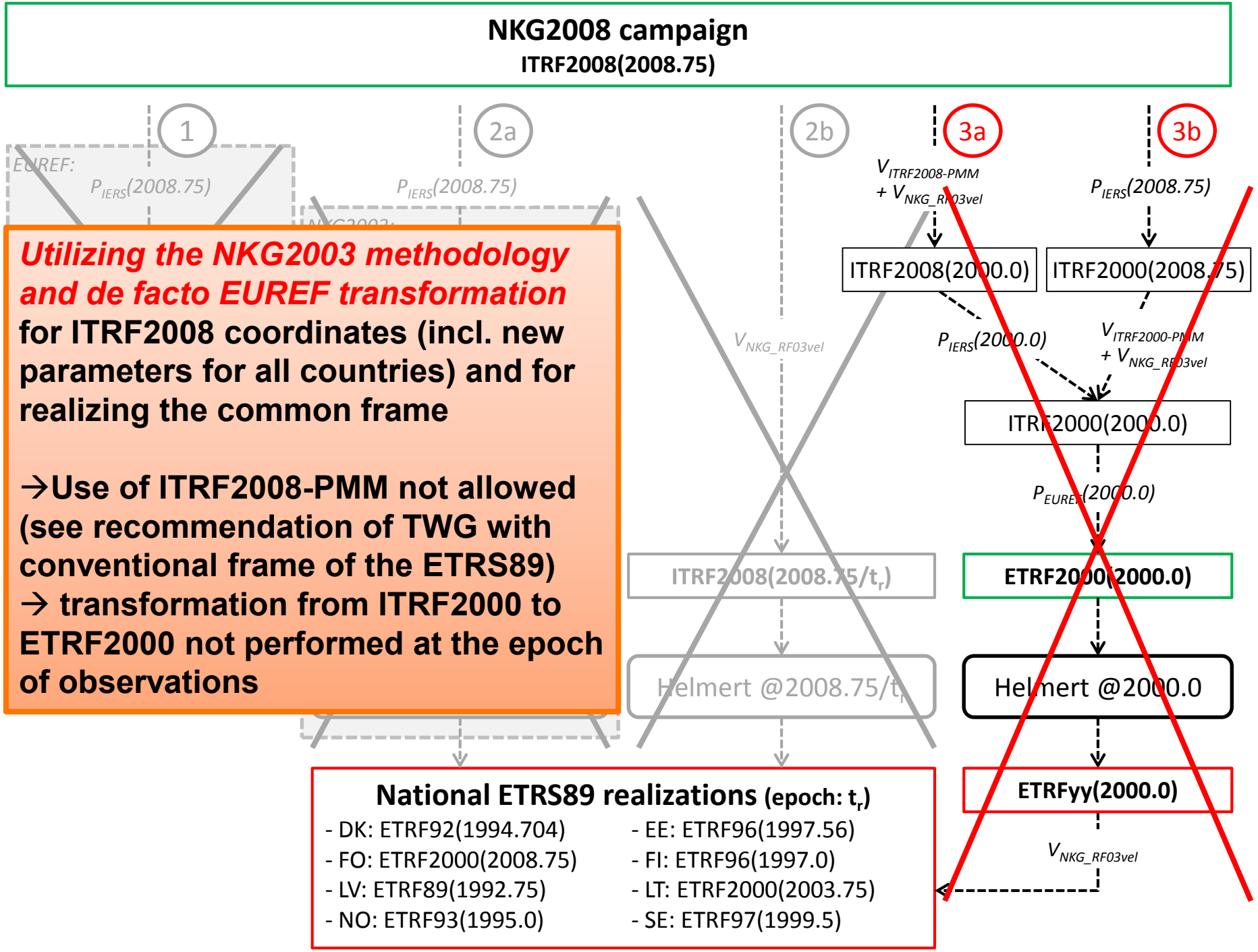
NKG2008 campaign
ITRF2008(2008.75)
1
2a
2b
3a
3b
EUREF:
$P_{IERS}(2008.75)$
$P_{IERS}(2008.75)$
$V_{NKG\_RF03vel}$
$V_{ITRF2008\text{-}PMM}$ + $V_{NKG\_RF03vel}$
$P_{IERS}(2008.75)$
ITRF2008(2000.0)
ITRF2000(2008.75)
$P_{IERS}(2000.0)$
$V_{ITRF2000\text{-}PMM}$ + $V_{NKG\_RF03vel}$
ITRF2000(2000.0)
$P_{EUREF}(2000.0)$
ITRF2008(2008.75/$t_r$)
ETRF2000(2000.0)
Helmert @2008.75/$t_r$
Helmert @2000.0
ETRFyy(2000.0)
$V_{NKG\_RF03vel}$
Utilizing the NKG2003 methodology and de facto EUREF transformation
for ITRF2008 coordinates (incl. new parameters for all countries) and for realizing the common frame
→Use of ITRF2008-PMM not allowed (see recommendation of TWG with conventional frame of the ETRS89)
→ transformation from ITRF2000 to ETRF2000 not performed at the epoch of observations
National ETRS89 realizations (epoch: $t_r$)
- DK: ETRF92(1994.704)
- EE: ETRF96(1997.56)
- FO: ETRF2000(2008.75)
- FI: ETRF96(1997.0)
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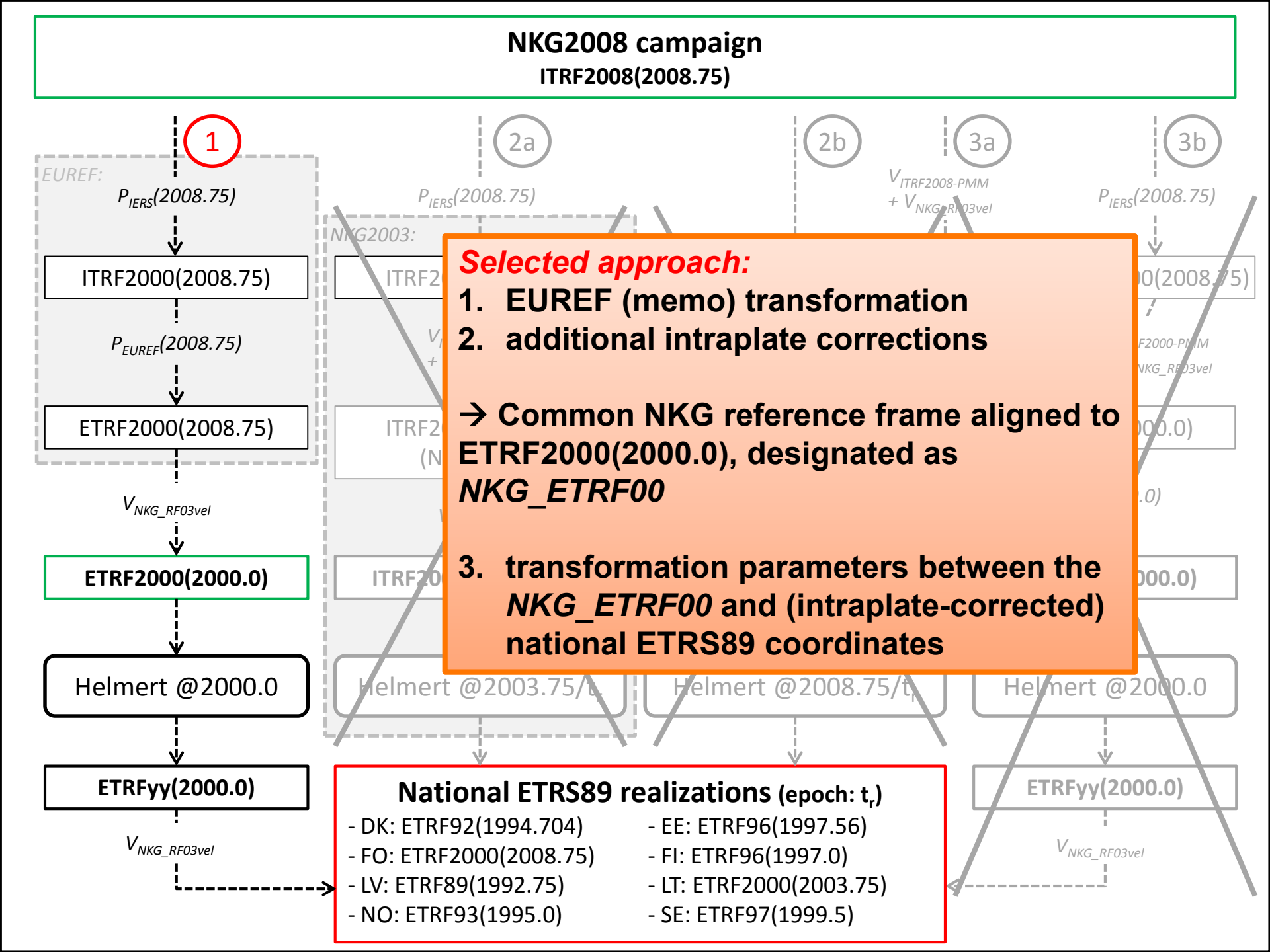
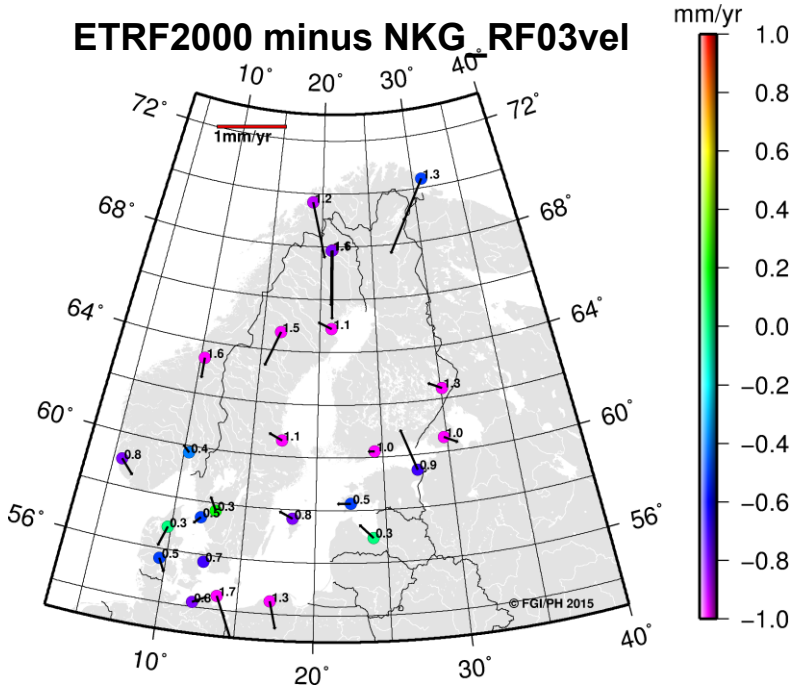
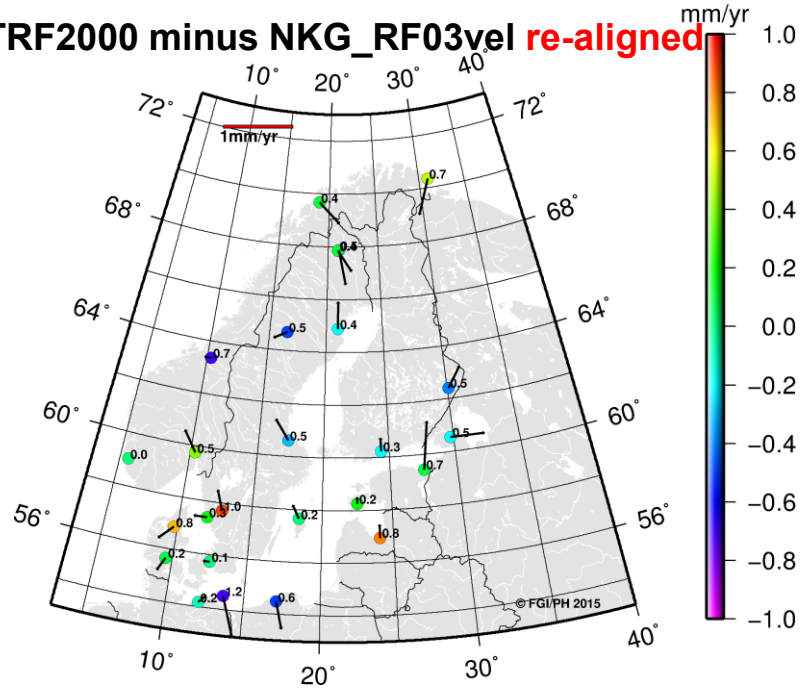

NKG2008 campaign
ITRF2008(2008.75)
1
2a
2b
3a
3b
EUREF:
$P_{IERS}(2008.75)$
ITRF2000(2008.75)
$P_{EUREF}(2008.75)$
ETRF2000(2008.75)
$V_{NKG\_RF03vel}$
ETRF2000(2000.0)
Helmert @2000.0
ETRFyy(2000.0)
$V_{NKG\_RF03vel}$
NKG2003:
$P_{IERS}(2008.75)$
$V_{ITRF2008-PMM}$ + $V_{NKG\_RF03vel}$
$P_{IERS}(2008.75)$
Selected 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
Helmert @2003.75/t
Helmert @2008.75/t
Helmert @2000.0
ETRFyy(2000.0)
$V_{NKG\_RF03vel}$
National ETRS89 realizations (epoch: $t_r$)
- DK: ETRF92(1994.704)
- EE: ETRF96(1997.56)
- FO: ETRF2000(2008.75)
- FI: ETRF96(1997.0)
- LV: ETRF89(1992.75)
- LT: ETRF2000(2003.75)
- NO: ETRF93(1995.0)
- SE: ETRF97(1999.5)

# Velocity comparison NKG_RF03vel vs. ETRF2000

- Intraplate corrections are applied in ETRF2000 → should be consistent with ETRF2000 velocities (EPN cumulative solution of class A stations used as a reference)
- NKG_RF03vel not optimally aligned to ETRF2000 velocities (no need for a strict alignment until now) → velocities re-aligned

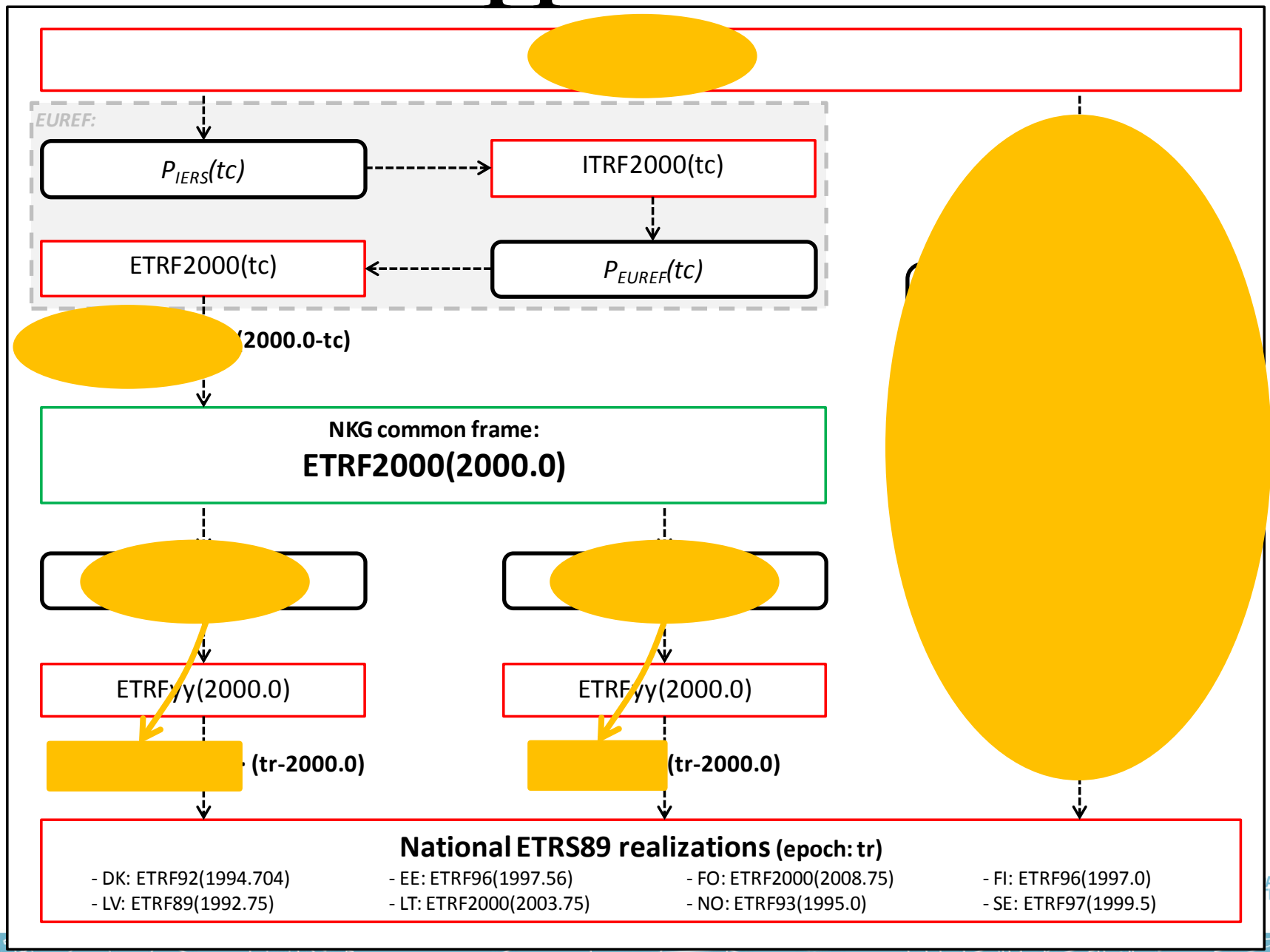



**Mean (NEU): -0.20/-0.05/-0.79 mm/yr**
**RMS (NEU) : 0.45/0.20/0.91 mm/yr**




**Mean (NEU): -0.01/0.00/0.00 mm/yr**
**RMS (NEU) : 0.34/0.18/0.42 mm/yr**

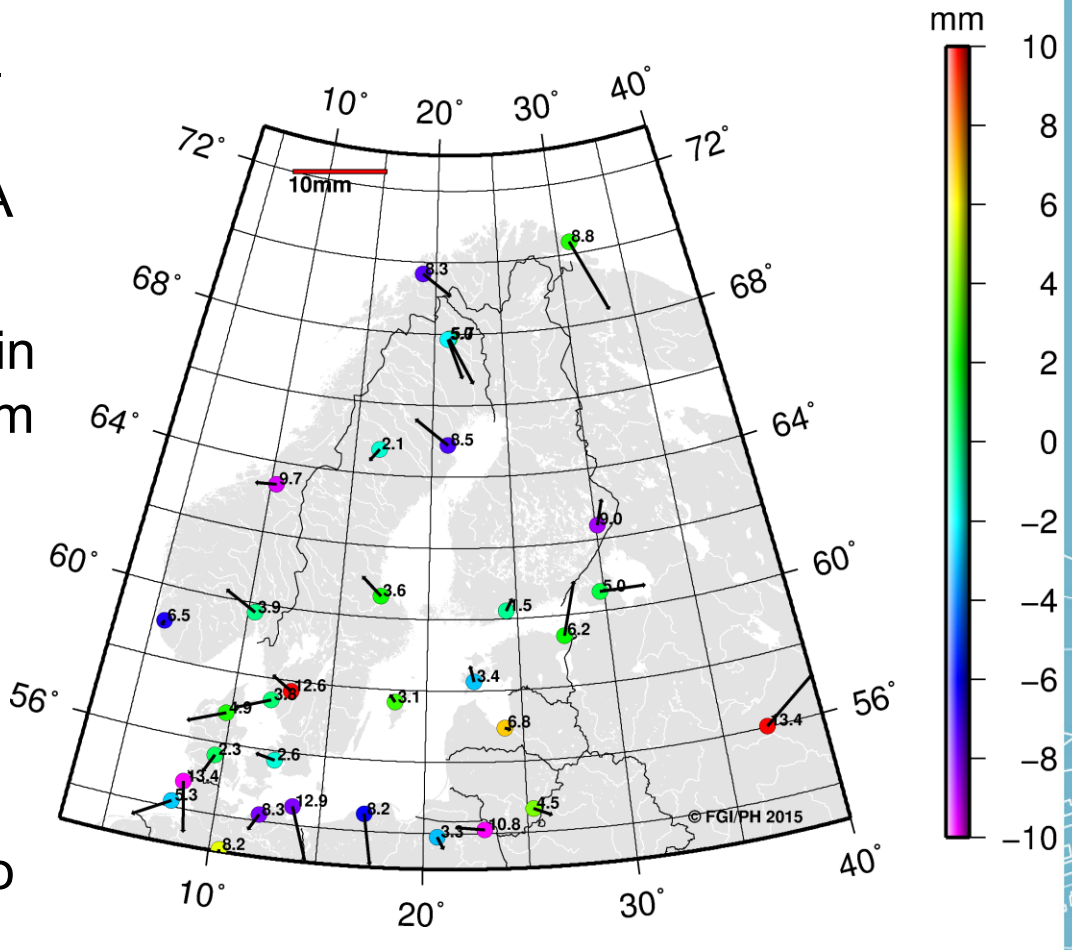
# Selected approach



# New NKG common reference frame NKG_ETRFoo

- Reference frame alignment – comparison to EPN cumulative solution of class A stations, RMS (NEU):
  - initial NKG2008 solution in IGb08(2008.75): 1/1/3 mm
  - resulting coordinates in the common frame in ETRF2000(2000.0): 3.5/2.4/5.4 mm

→ NKG_ETRF00 well-aligned to ETRF2000

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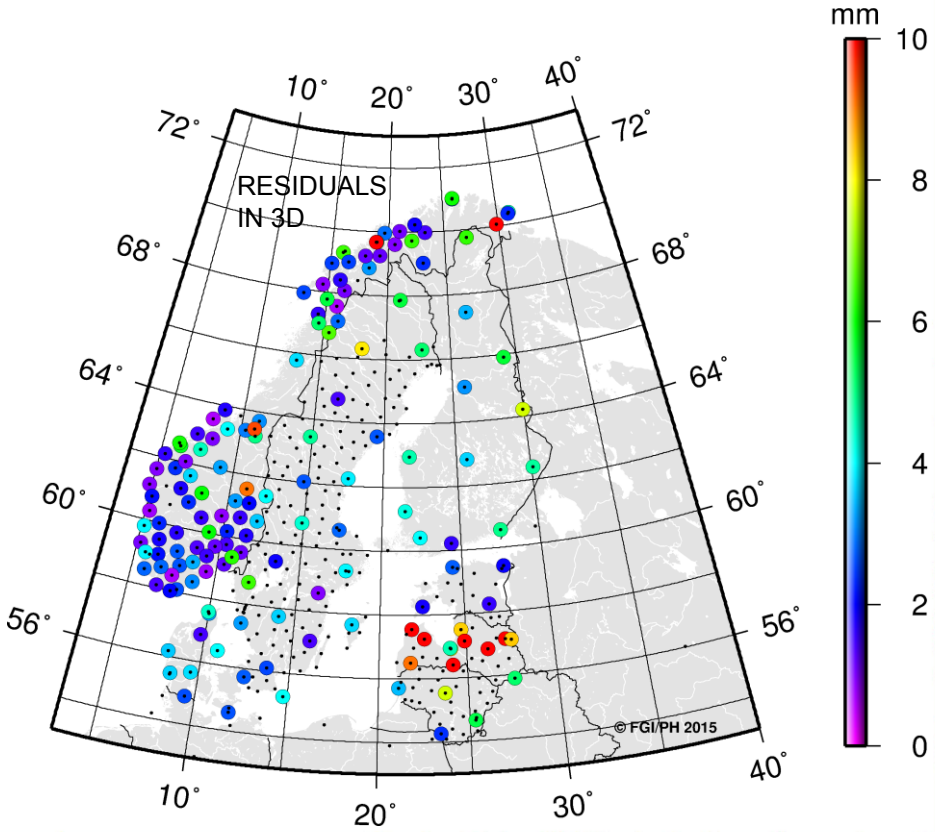
# Transformation residuals

- Country-wise residuals show the expected accuracy level when transforming coordinates from ITRF to national ETRS89 realizations
- Reflect the consistency of input coordinates (NKG2008 and national ETRS89) and used deformation model
- Mostly some mm-level

| RMS | # pts | N [mm] | E [mm] | U [mm] |
|---|---|---|---|---|
| DK | 12 | 2.67 | 1.94 | 3.60 |
| EE | 4 | 0.89 | 0.94 | 1.64 |
| FO | 5 | 0.52 | 0.29 | 0.80 |
| FI | 12 | 2.37 | 2.35 | 3.40 |
| LV | 11 | 8.95 | 2.75 | 13.44 |
| LT | 10 | 3.07 | 1.92 | 4.56 |
| NO | 92 | 1.53 | 1.62 | 2.94 |
| SE | 31 | 2.58 | 2.08 | 3.71 |



# Conclusions and Future Work

- The developed transformation and common frame fulfill current (urgent) needs, e.g.:
  - GNSS/levelling data for a new Nordic geoid model
  - Updated transformations from global ITRFxx to national ETRS89 realizations
- On-going and future work:
  - Testing of the ITRF2014
  - Creating a new and updated PGR model in progress in the NKG
  - Use of time series in the transformations instead of campaigns, new BIFROST solutions available as well as NKG GNSS analysis centre solutions in near future
  - Keeping up-to-date with e.g. EUREF activities/recommendations

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# More information:

- Article in the Journal of Geodetic Science, Volume 6, Issue 1 (Mar 2016), open access: http://www.degruyter.com/view/j/jogs.2016.6.issue-1/jogs-2016-0001/jogs-2016-0001.xml?format=INT
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