Improvement and extension of ETRS 89 in Latvia and Lithuania based on the NKG 2003 GPS campaign

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Outline

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- Description of the Campaign
- Processing strategy
- Results
- Transformation to ETRS 89
- Comparison to other ETRS 89 realizations
- Summary

Introduction

The Nordic and Baltic countries have implemented national realizations of ETRS89 during the 90s accommodating the needs of the National Mapping Agencies and international standards.

Different epochs and different ITRFs for the individual national realizations caused differences up to a few cm.

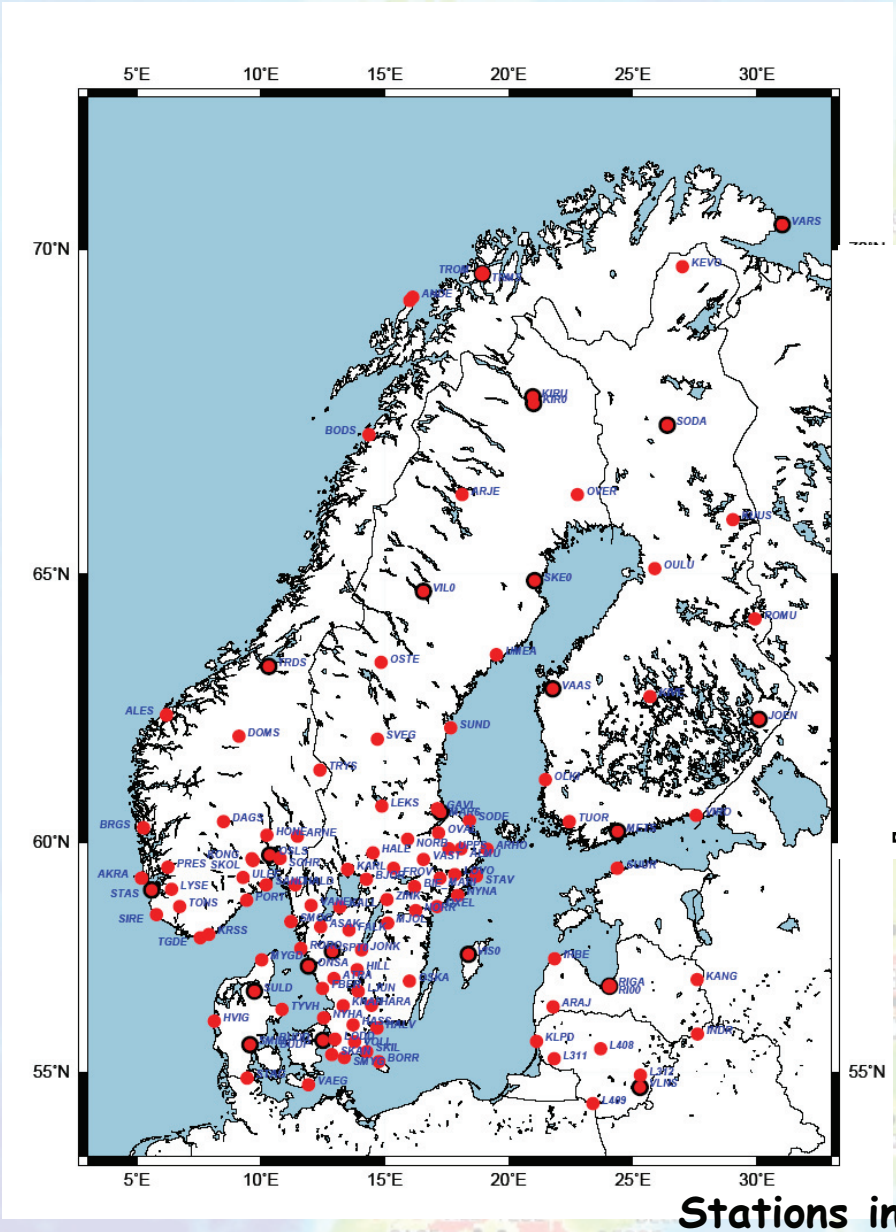
Hence, we have a situation, where a common Nordic-Baltic reference frame would be useful.

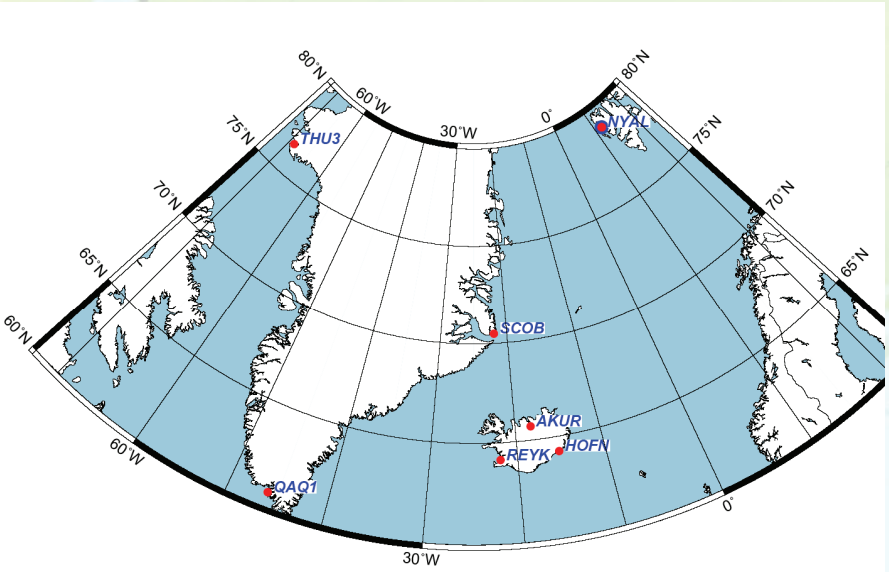
A common reference frame could also act as a link between the different national realizations and between those realizations and ITRF.

The present ETRS 89 realizations in Latvia and Lithuania are based on the EUREF-BAL´92 campaign, which has an estimated accuracy of the same level as the original EUREF 89 campaign (class C).

Latvia and Lithuania wish to replace their EUREF-BAL´92 realization with an ETRS 89 realization based on the NKG 2003 GPS campaign and ask for the results submitted to the EUREF Technical Working Group to be accepted as class B standard.

Description of the Campaign (1)





Stations in the Atlantic part of the NKG 2003 campaign

Stations in the Nordic-Baltic part of the NKG 2003 campaign

Description of the Campaign (2)

Campaign specifications

Network:

133 stations (old defining bench marks, EPN stations, other national permanent stations in the Nordic countries),
+Baltic countries (Latvia 6 (4); Lithuania 6 (4); Estonia (1))
+Iceland +GR

Duration:

7 days,
Week 40 in 2003,
GPS week 1238,

Coordinator:

F.B. Madsen, DK/DNSC

Description of the Campaign (3)

Points in Latvia

Equipment used in Latvia

Station	Antenna	Receiver	H	E	N
ARAJ	TRM33429.00+GP	TRIMBLE 4700	1.5561	0.0000	0.0000
INDR	TRM33429.00+GP	TRIMBLE 4700	1.5759	0.0000	0.0000
IRBE	ASH700936D_M	TRIMBLE 4000SSE	5.1115	0.0000	0.0000
KANG	TRM33429.00+GP	TRIMBLE 4700	1.4089	0.0000	0.0000
RI00	TRM22020.00+GP	TRIMBLE 4000SSE	1.3633	0.0000	0.0000
RIGA	ASH700936D_M	ROGUE SNR-8000	0.0850	0.0000	0.0000

Description of the Campaign (4)

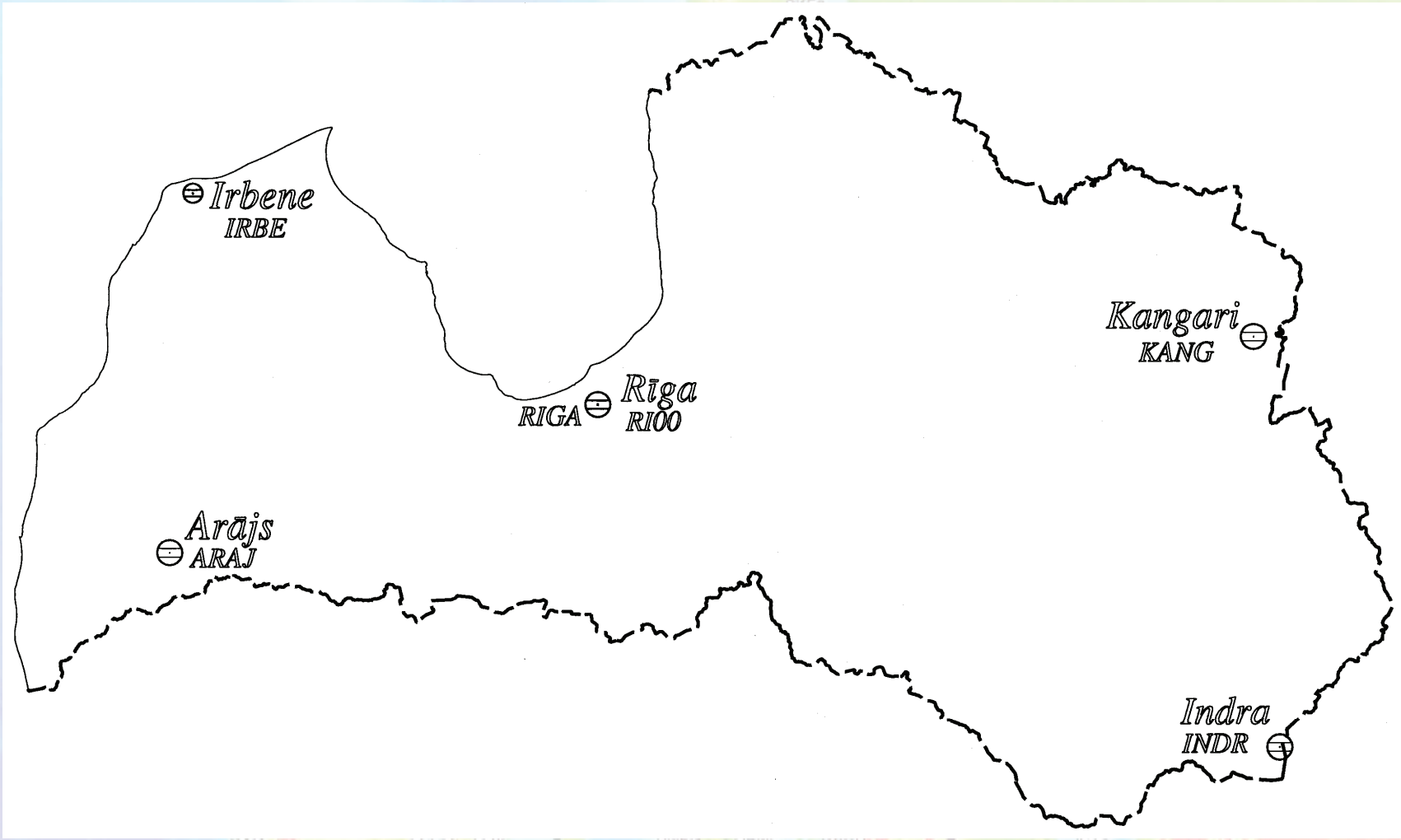
Points in Latvia - Indra

Description of the Campaign (5)

Points in Latvia - Kangari

Description of the Campaign (6)

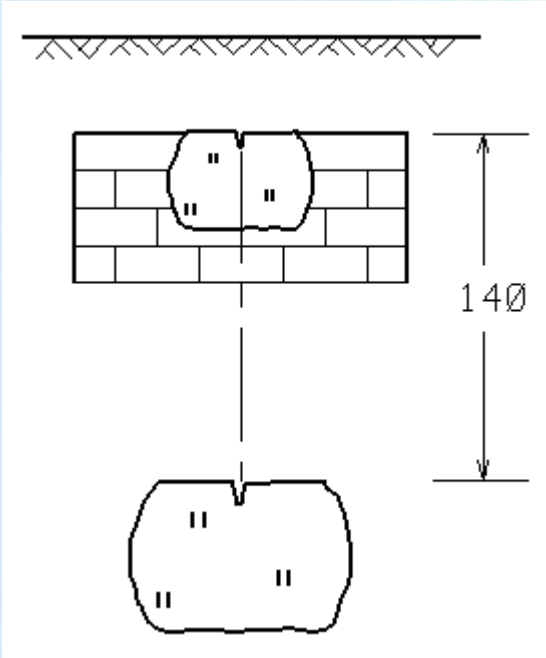
Points in Latvia – EUREF points



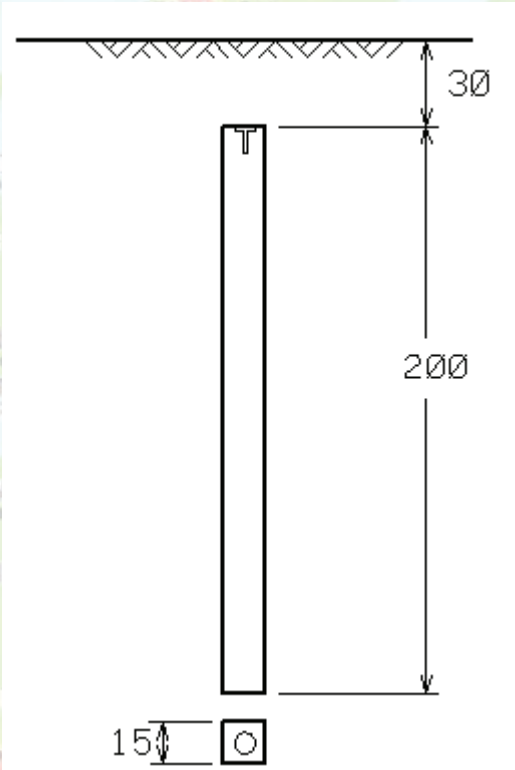
Description of the Campaign (7)

Points in Latvia - Monuments

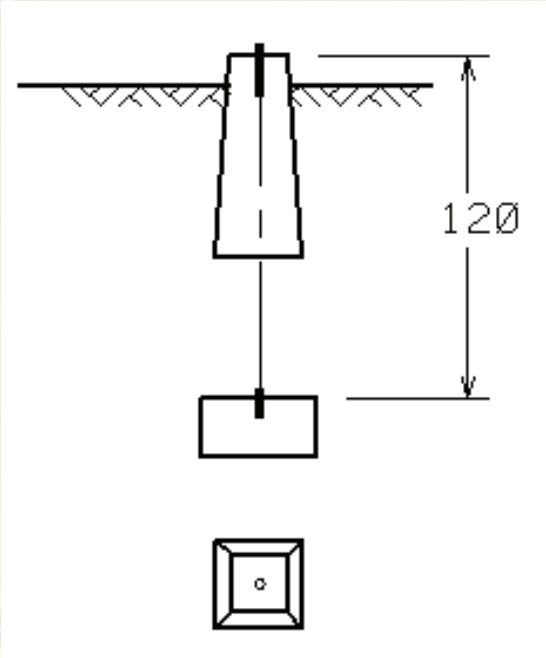
Arajs



Rl00



Indra, Kangari



Description of the Campaign (8)

Points in Lithuania

Equipment used in Lithuania

Station	Antenna	Receiver	H	E	N
KLPD	ASH700936E	ASHTECH Z-XII3	0.0000	0.0000	0.0000
L311	ASH701008.01B	ASHTECH UZ-12	1.7700	0.0000	0.0000
L312	ASH700228D	ASHTECH Z-XII3	1.6513	0.0000	0.0000
L408	ASH701008.01B	ASHTECH UZ-12	1.6760	0.0000	0.0000
L409	ASH701008.01B	ASHTECH UZ-12	1.7503	0.0000	0.0000
VLNS	ASH700936A_M	ASHTECH Z-XII3	0.0730	0.0000	0.0000

Description of the Campaign (9)

Points in Lithuania - VLNS

EPN site

Description of the Campaign (10)

Points in Lithuania - KLPD

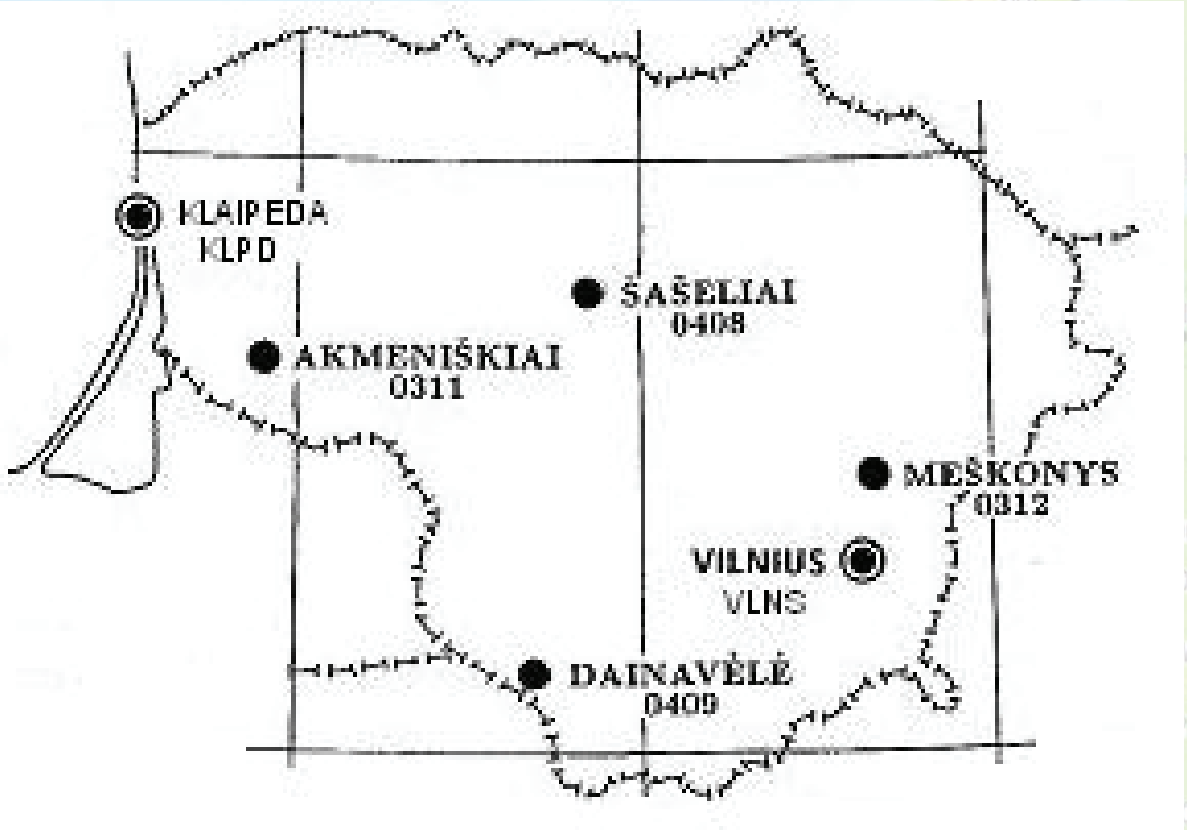
CGPS antenna

CGPSBM

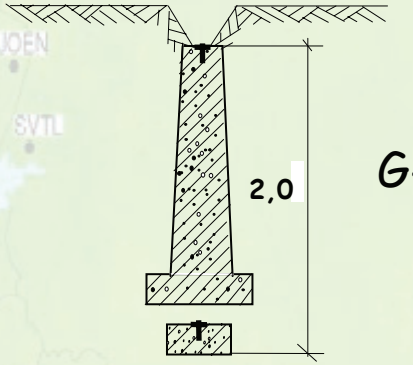
ESEAS, TIGA-IP site

Description of the Campaign (11)

Points in Lithuania - EUREF points

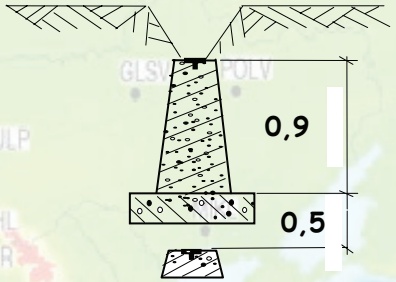


Monuments



G-04

0311, 0312, 0408



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0409

Description of the Campaign (12)

Campaign run

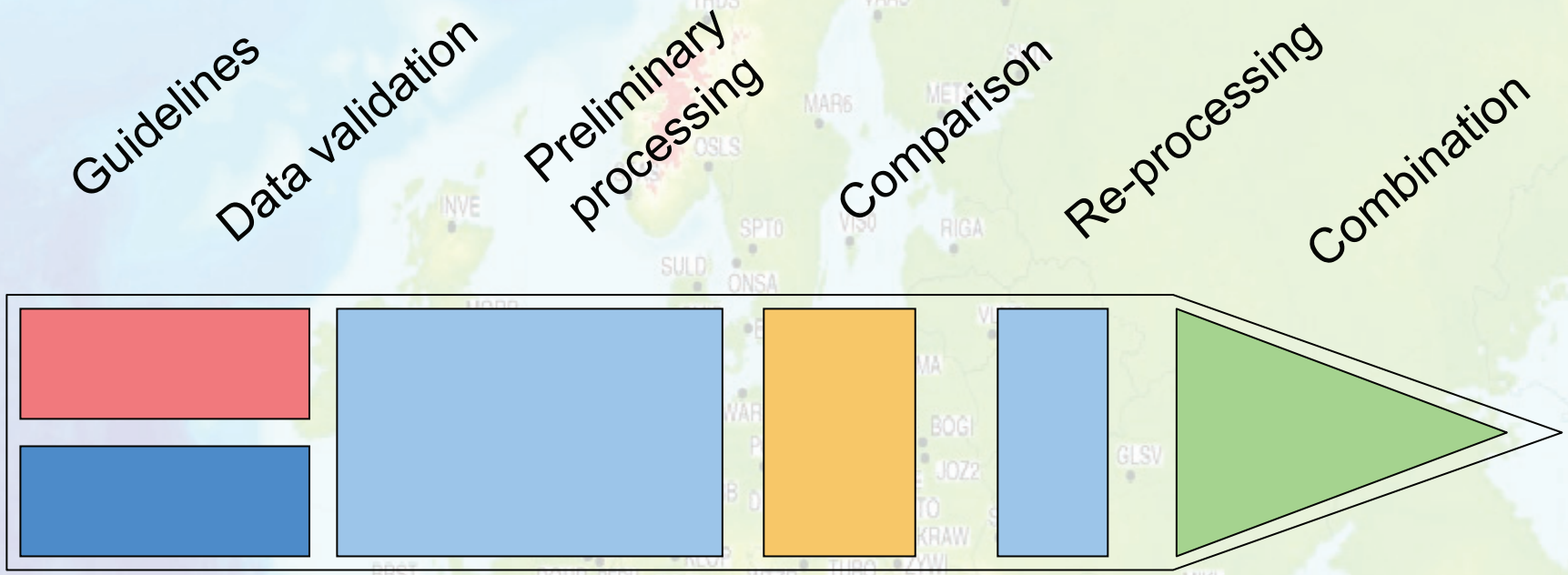
The Lithuanian colleagues noticed problems with one of their stations (L311). To be sure to have this station included in the resulting coordinate set from the campaign, this station was observed for 5 extra days (292-296), ten days after the campaign together with the Lithuanian stations VLNS and KLPD.

Data and sitelog information for all stations have been transferred to an ftp-server (ftp2.kms.dk) at KMS in Copenhagen.

The RINEX-files and site log files were checked for quality, completeness and correctness by Henrik Rønnest at KMS. This quality control is documented in a special Data Validation Report.

Processing strategy (0)

Time frame



Processing strategy (1)

Guidelines/common settings

Use recommended settings for each program

10 deg cut-off angle

Elevation dependent weighting

Niel mapping function for tropospheric corrections

Common ocean tide loading (FES 99)

No atmospheric loading corrections

Antenna pcv from IGS if available

Final IGS orbits and clocks (if possible)

Sub-division of the network not necessary

ITRF 2000, epoch of the campaign (2003.75)

Processing strategy (2)

Softwares:

Norway: NMA - GIPSY
Sweden: OSO - GAMIT/GLOBK
Sweden: LMV - Bernese ver 5.0
Denmark: KMS - Bernese ver 4.2

Use recommended settings for each programme
ITRF 2000, epoch of the campaign (2003.75)

Coordinator:
Lotti Jivall, S/LMV

Processing strategy (3)

Four different solutions

AC	Software	Ambiguities	ITRF connection
NMA	GIPSY	float	Global 7 parameters
OSO	GAMIT	Fixed (?)	Global 7 parameters
LMV	Bern 5.0	Fixed (88%)	Regional 3 parameters
KMS	Bern 4.2	Fixed (66%)	Regional 3 parameters

Processing strategy (4)

Bernese connection to ITRF

3 alternatives were considered

Directly use IERS ITRF 2000 coordinates - not enough stations with good coordinates/velocities

For the Nordic-Baltic part an EPN-based ITRF was considered (5 weekly EPN-solutions densifying IERS ITRF for the EPN-network)

Using IGS cumulative solution (which is connected to ITRF 2000)

Processing strategy (5)

NMA, GIPSY/OASISII, strategy

Fiducial free PPP, 5 min epoch intv

JPL orbits, clocks and EOP

No ambiguity resolution

Transformation with JPL X-files (7 parameters) to ITRF 2000 (parameters based on a global fit of 65-70 IGS stations)

Weekly combined solution

Processing strategy (6)

OSO, GAMIT/GLOBK, strategy

Network solution divided into 7 sub-networks with many common stations

Ambiguity fixing

Saastamoinen apriori, Niell mapping functions, gradients

Orbits from SOPAC, solving for orbits

Quasi observations calculated by GAMIT

Combination with quasi observations from SCRIPPS (IGS global network) using GLOBK

39 ”good” IGS stations globally distributed are constrained in the GLOBK stabilization while 7 Helmert par are solved for.

Processing strategy (7)

LMV, Bernese ver 5.0, Strategy

Network solution (all 133)

Ambiguity fixing

Data files < 12 h rejected

Saastamoinen apriori, Niell mapping functions, gradients

Minimum constrained adjustment (no translation) to ITRF 2000 from IGS cumulative solution (up to GW1294)

Processing strategy (8)

KMS, Bernese ver 4.2, Strategy

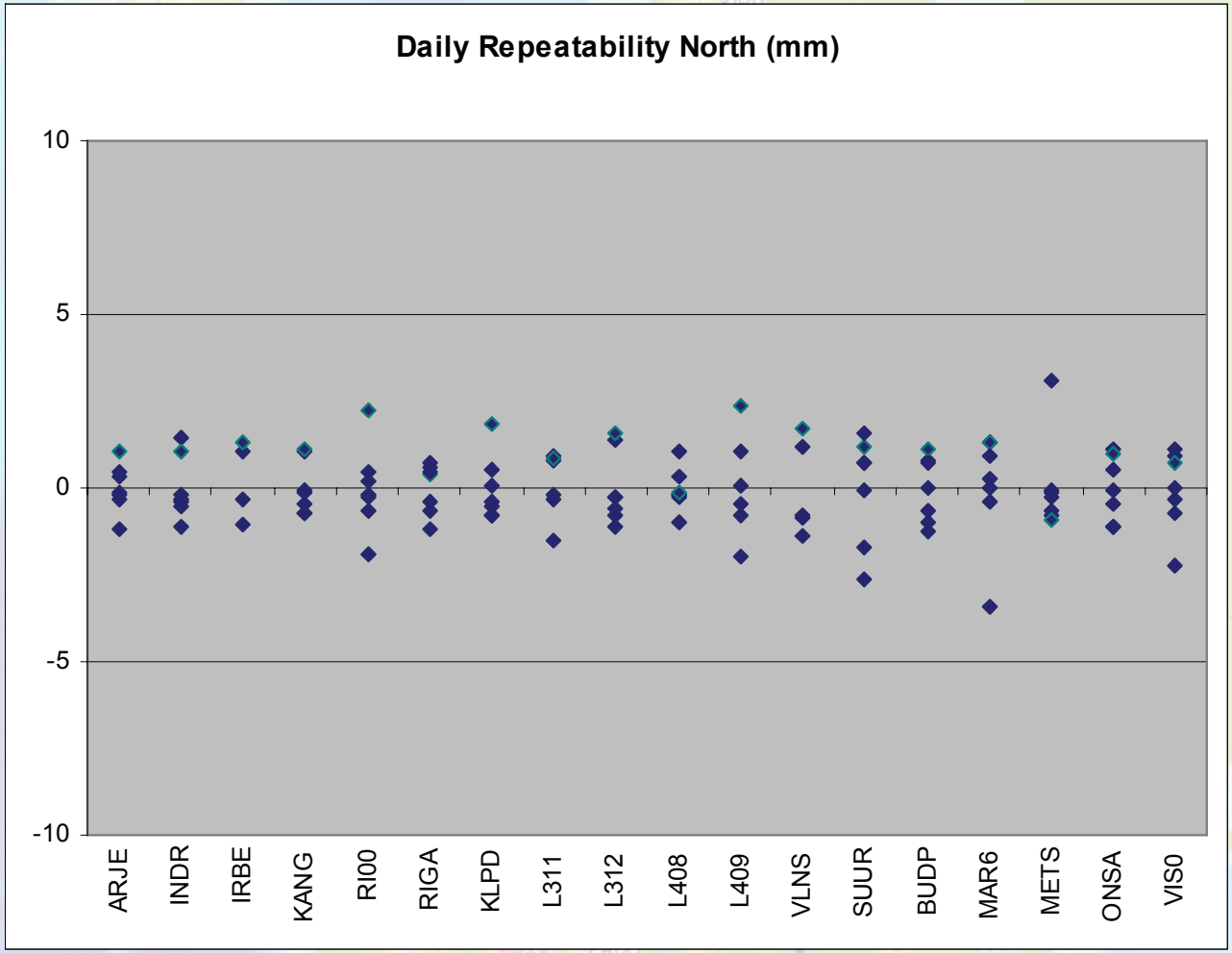
Network solution, 6 clusters (4 in Nordic-Baltic, 2 in Atlantic part (one basline connecting two clusters)

Ambiguity fixing

No apriori trop model, dry Niell

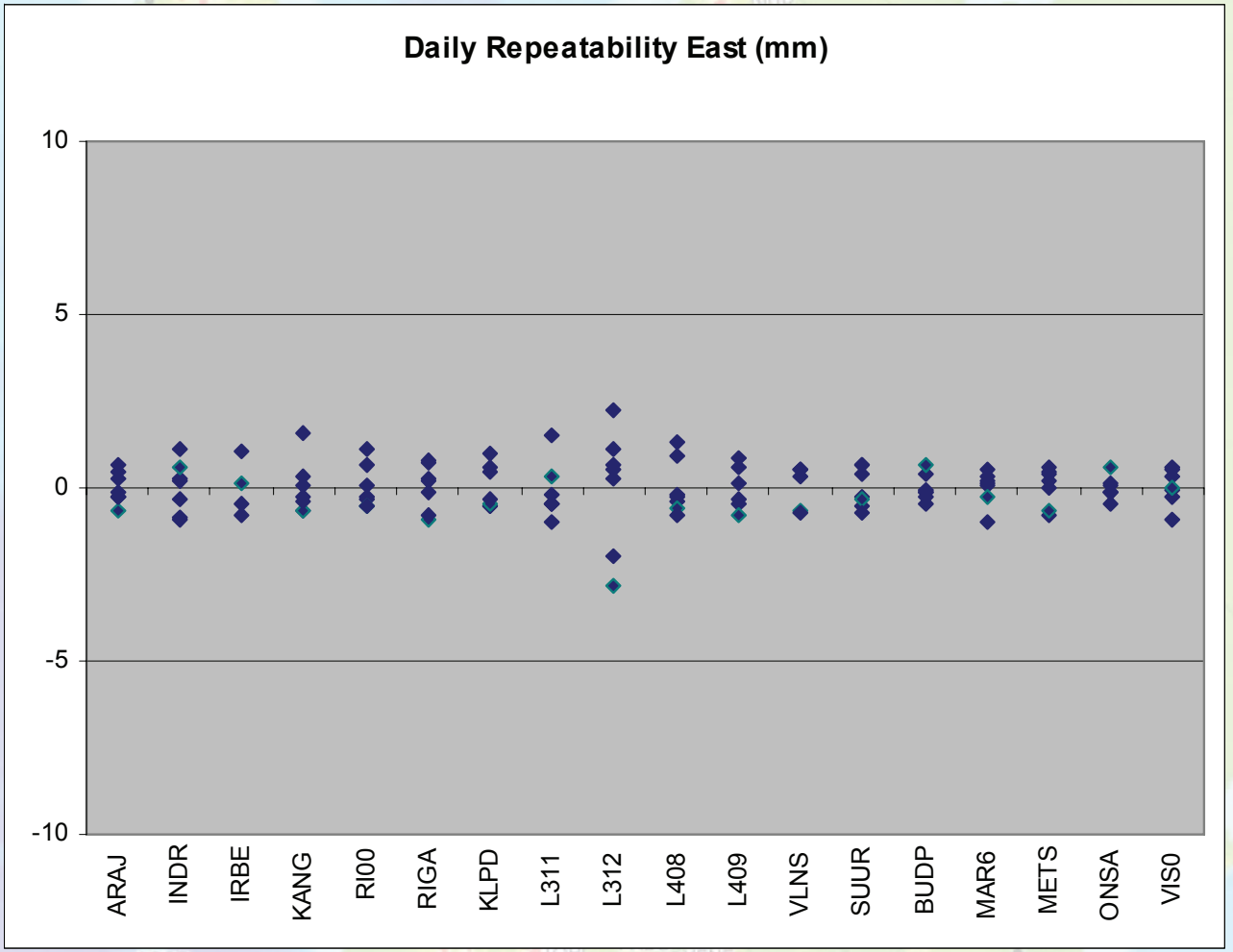
Minimum constrained adjustment (no translation) to ITRF 2000 from IGS cumulative solution (up to GW1294)

Processing strategy (9)



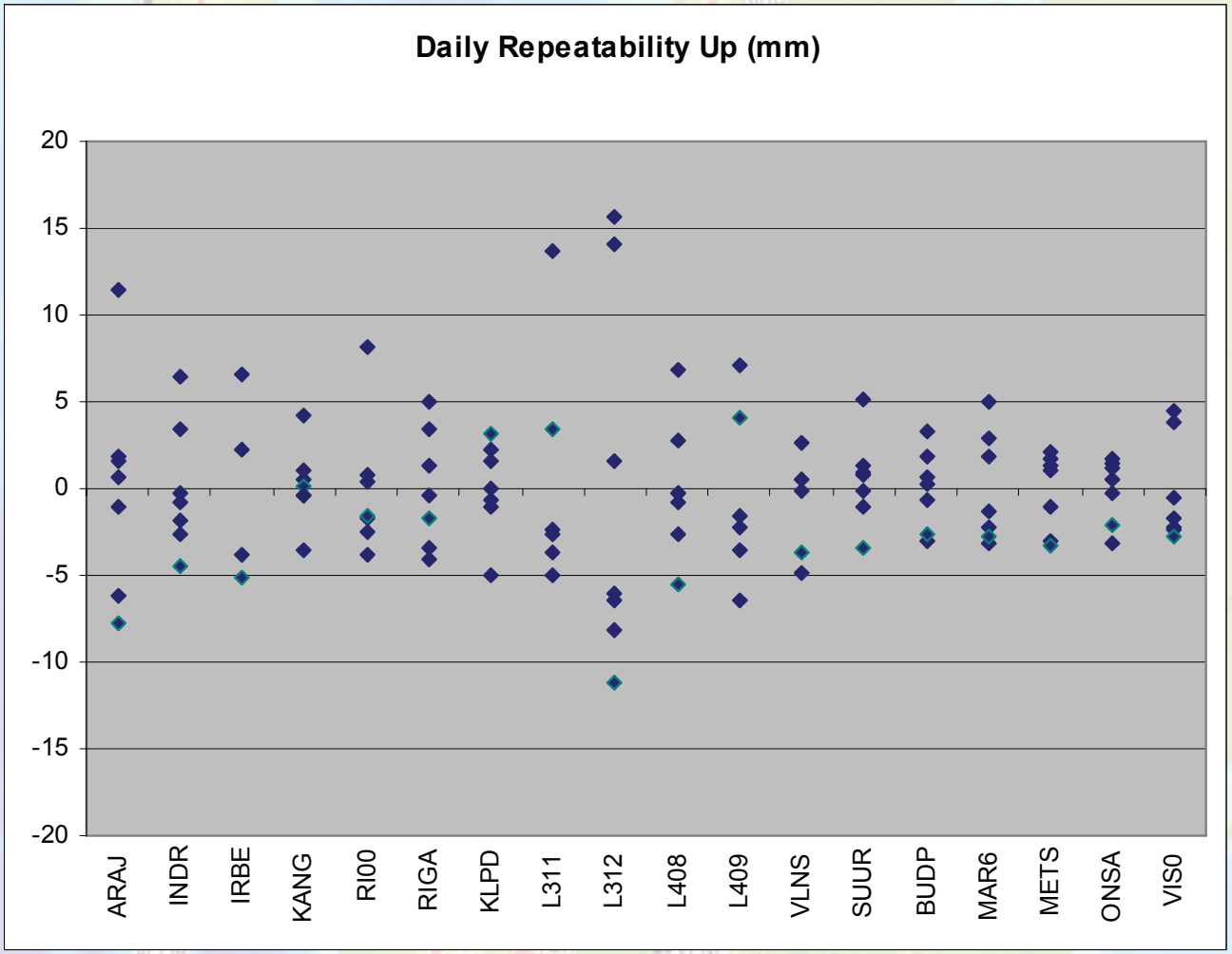
Daily repeatability. LMV solution, north component

Processing strategy (10)



Daily repeatability. LMV solution, east component

Processing strategy (11)

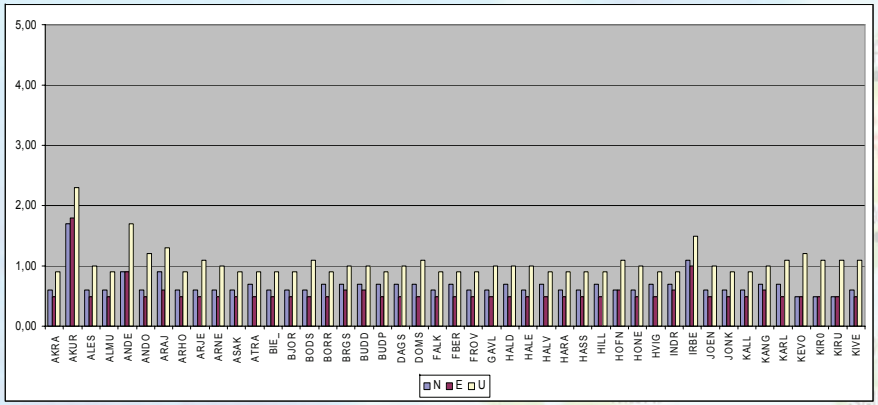


Daily repeatability. LMV solution, Up component

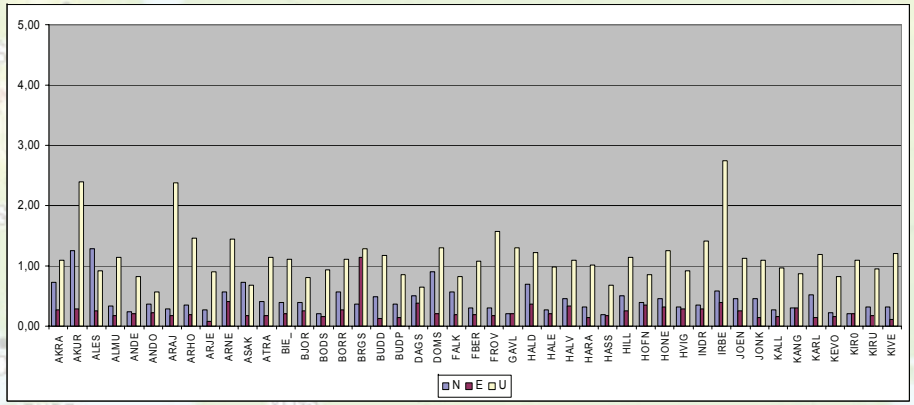
Processing strategy (12)

Position standard errors

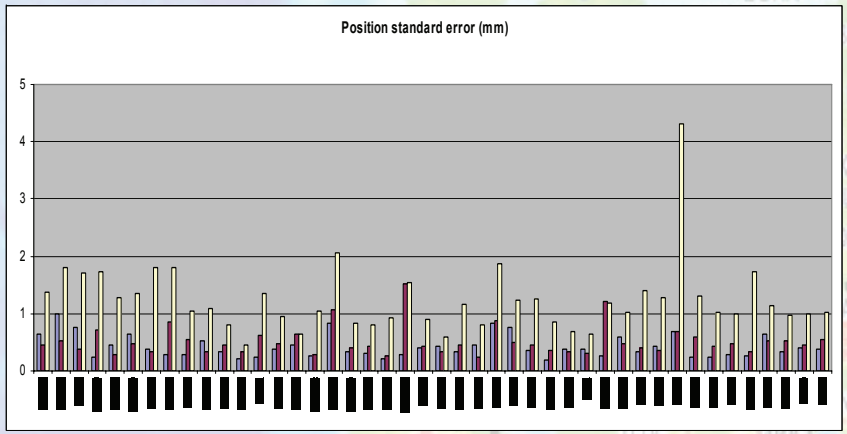
NMA



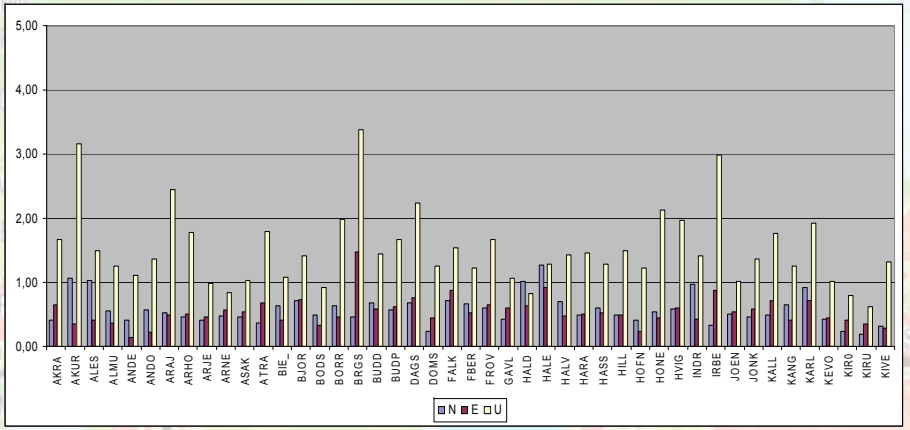
LMV



OSO

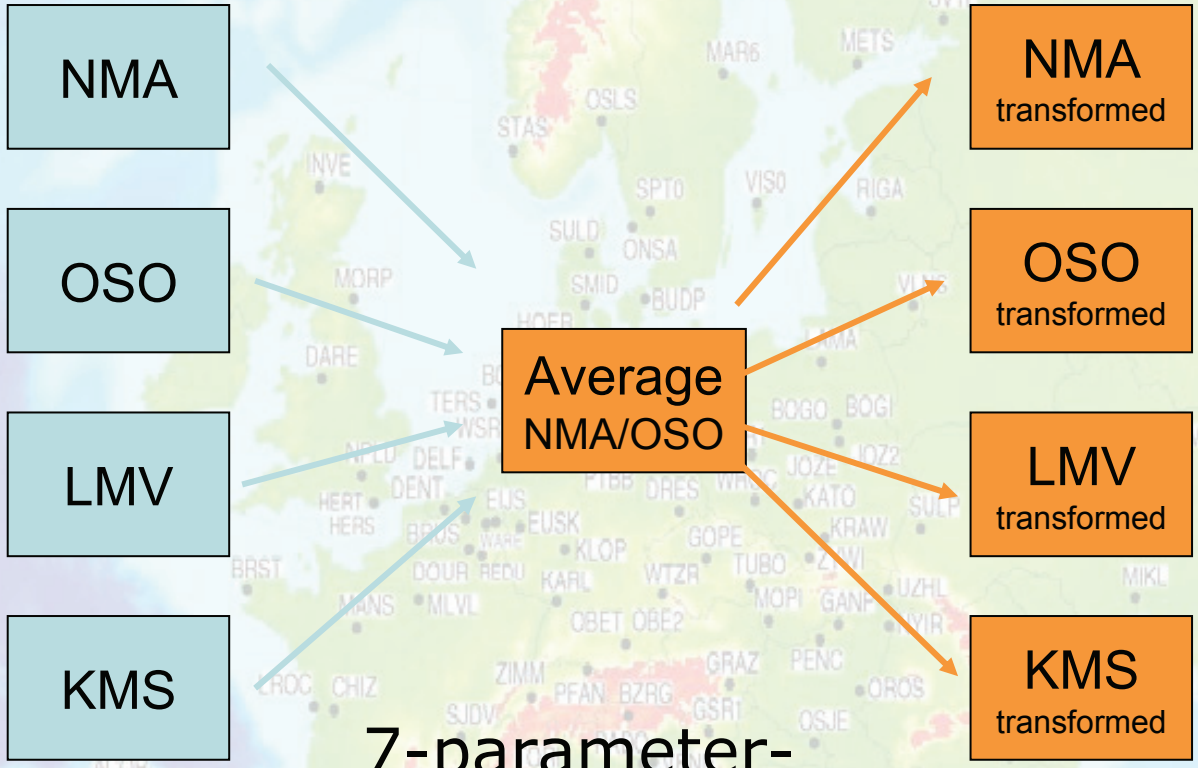


KMS



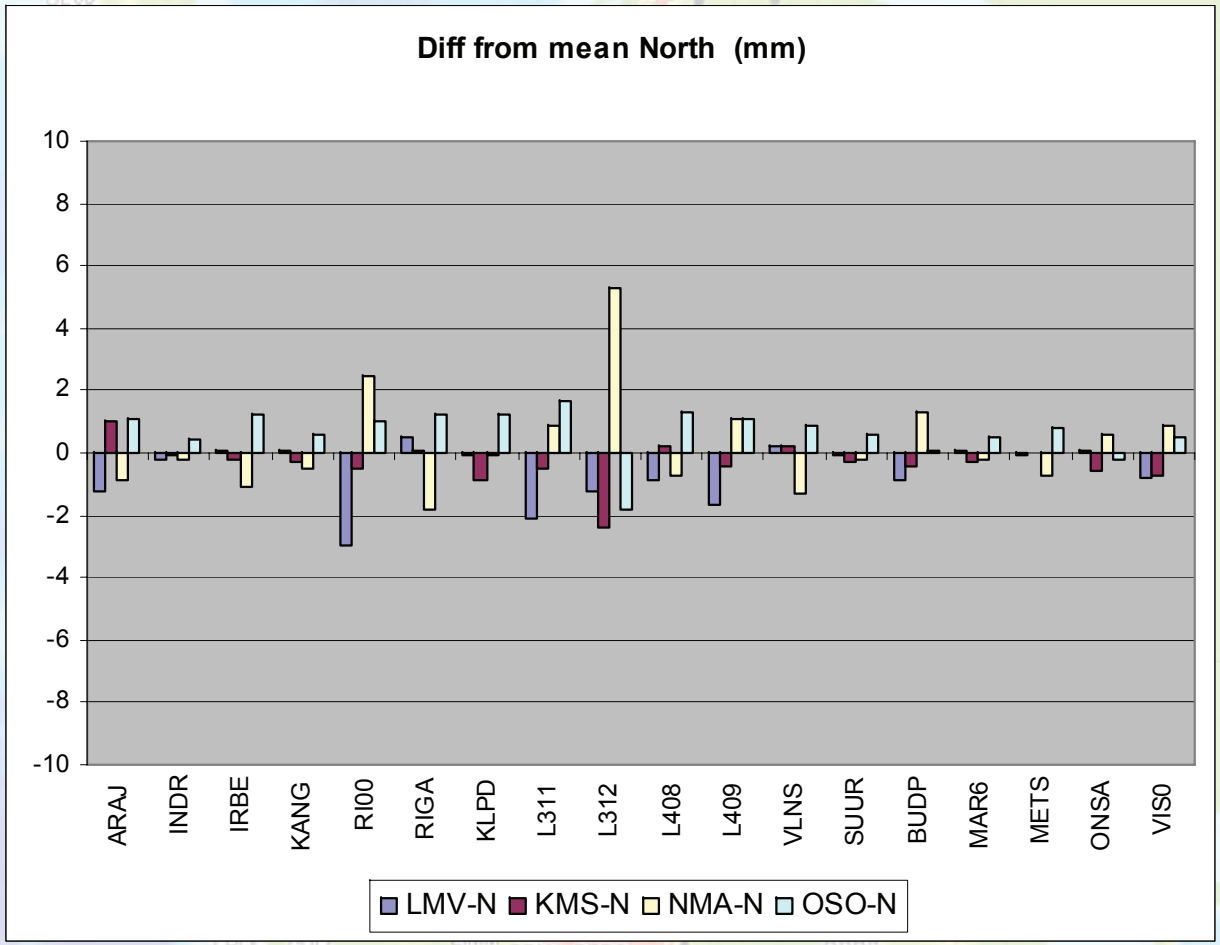
Processing strategy (13)

Harmonizing the solutions (Jivall, S/LMV)



7-parameter-transformation

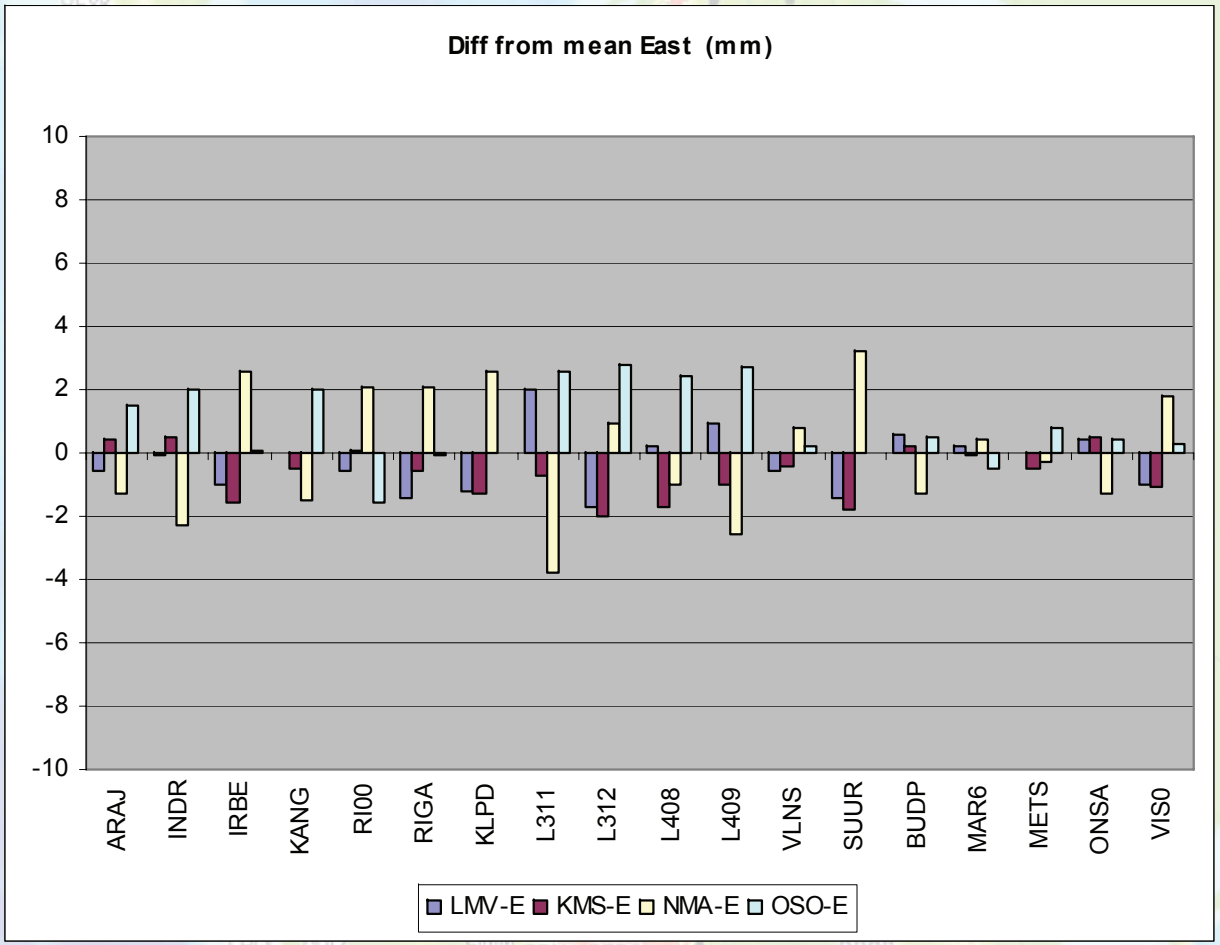
Processing strategy (14)



Comparison between harmonized solutions, north component.

Baltic stations + some EPN stations.

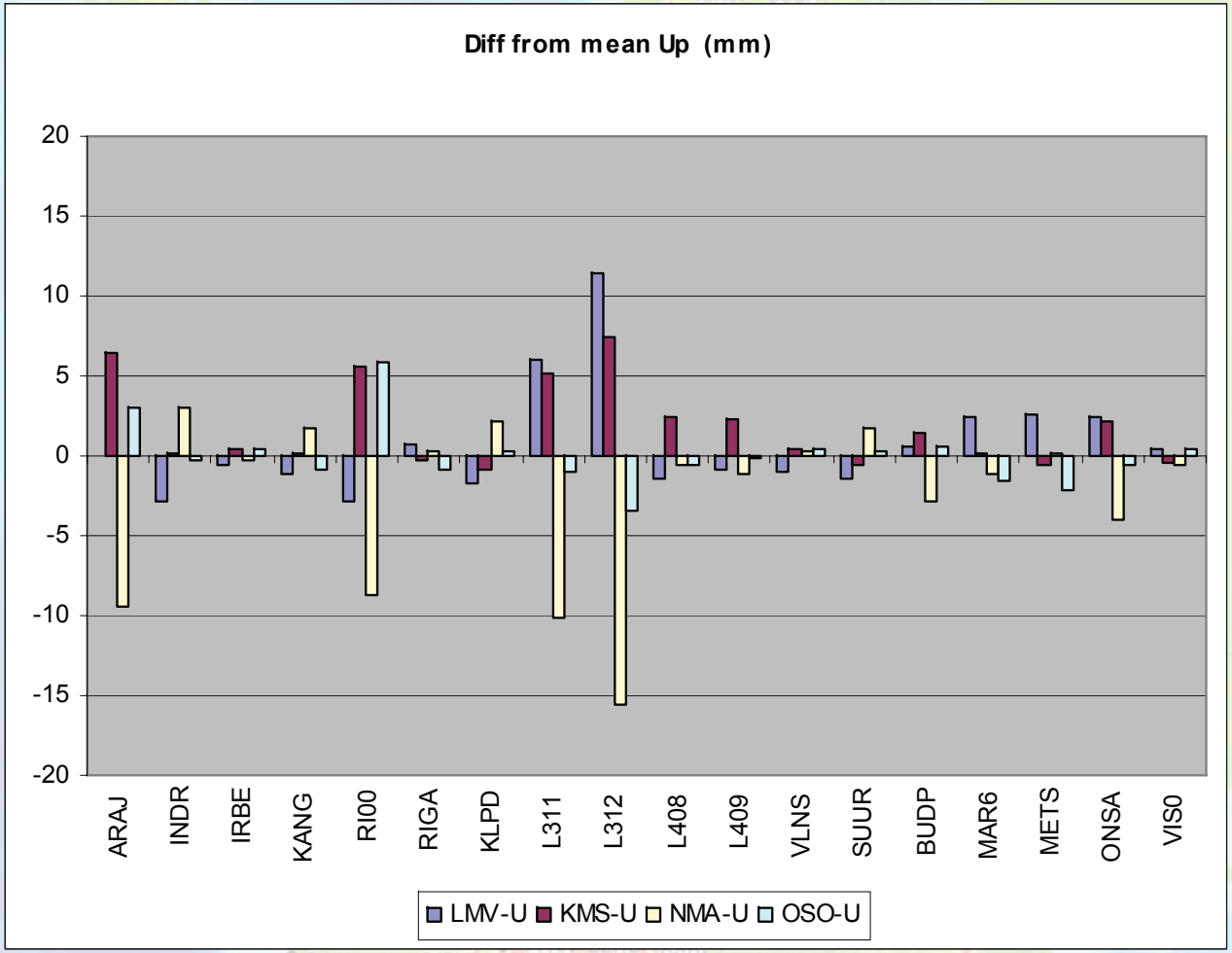
Processing strategy (15)



Comparison between harmonized solutions, east component.

Baltic stations + some EPN stations.

Processing strategy (16)



Comparison between harmonized solutions, Up component.

Baltic stations + some EPN stations.

Processing strategy (17)

7-par fits between solutions

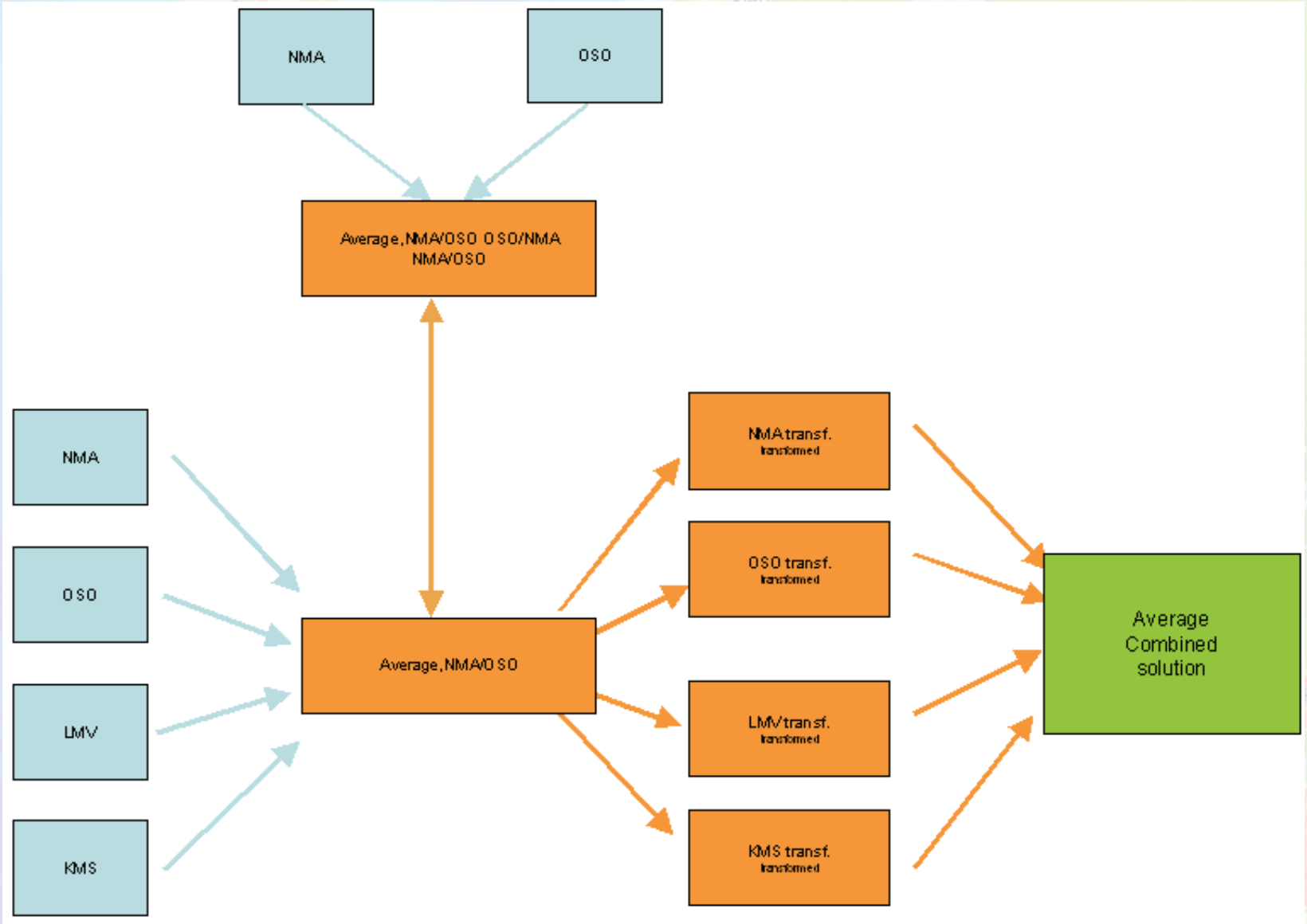
Solution	rms	Scale	dN	dE	dU
NMA	mm	ppm	Translations (mm)		
OSO	2,6	0,0000	2,2	-1,7	3,2
LMV	3,5	0,0028	-0,2	-0,5	9,5
KMS	3,7	0,0024	-0,2	0,2	6,0

Solution	rms	Scale	dN	dE	dU
OSO	mm	ppm	Translations (mm)		
LMV	2,1	0,0028	-2,4	1,2	6,3
KMS	2,1	0,0023	-2,4	1,9	2,8

Solution	rms	Scale	dN	dE	dU
LMV	mm	ppm	Translations (mm)		
KMS	1,8	-0,0005	0,0	0,7	-3,5

Processing strategy (18)

Combined solution



Processing strategy (19)

Estimated accuracy (95%-level)

Accuracy of the ITRF connection (few mm in horizontal, 1 cm in height)

Systematic effects depending on un-modelled errors or wrong models (few mm in horizontal, 0.5-1 cm in height)

Random errors, noise in the solutions (few mm both in horizontal and height with some exceptions)

Generally: 0.5-1 cm in the horizontal and 1-2 cm in the vertical on 95%-level. (e.g. ANDO and L312 less accurate in height)

Processing strategy (20)

Extra Lithuanian observations (1)

L311 was re-observed 5 days (292-296) together with VLNS and KLPD due to problems during GW1238 (271-277)

The processing of L311 in GW1238 turned out be of normal quality

The extra days were also processed by LMV to check if there was any systematic difference to the original campaign

Processing strategy (21)

Extra Lithuanian observations (2)

Differences at L311

	Extra - original	original+extra - original
N (mm)	0.6	0.3
E (mm)	0.7	0.4
U (mm)	5.9	1.5

Conclusion: no need to add the extra observations

Transformation to ETRS 89 (1)

The final coordinates of the NKG 2003 campaign in ITRF 2000 epoch 2003.75 was converted to ETRS 89 according to the guidelines in "Specifications for reference frame fixing in the analysis of a EUREF GPS campaign" version 5.0 (2001-12-04) by C.Boucher and Z. Altamimi.

The last step, which is to take the velocities within the European plate into account, has not been performed, which means that we ended up with a realization of ETRS 89 in epoch 2003.75.

Transformation to ETRS 89 (2)

$$X_E(2003.75) = X_{00}(2003.75) + \begin{bmatrix} T1_{00} \\ T2_{00} \\ T3_{00} \end{bmatrix} + \begin{bmatrix} 0 & -\dot{R}3_{00} & \dot{R}2_{00} \\ \dot{R}3_{00} & 0 & -\dot{R}1_{00} \\ -\dot{R}2_{00} & \dot{R}1_{00} & 0 \end{bmatrix} \cdot X_{00}(2003.75) \cdot (2003.75 - 1989.0)$$

$X_E(2003.75)$ = coordinates in ETRS 89 at epoch 2003.75

$X_{00}(2003.75)$ = coordinates in ITRF 2000 at epoch 2003.75

$T1_{00} = 5.4\,\text{cm}$

$T2_{00} = 5.1\,\text{cm}$

$T3_{00} = -4.8\,\text{cm}$

$\dot{R}1_{00} = 0.000081''/\text{Y}$

$\dot{R}2_{00} = 0.000490''/\text{Y}$

$\dot{R}3_{00} = -0.000792''/\text{Y}$

Transformation to ETRS 89 (3)

Concering the internal epoch of the solution. We have chosen not to reduce the solution for intraplate deformations, which means the internal epoch remains to be 2003.75.

Test was performed to reduce for the intraplate deformations to epoch 2000.0.

NKG 2003 (2003.75) minus NKG 2003 (2000.0). Unit: mm

Point	N	E	U
ARAJ	-1.8	-0.1	3.1
INDR	-1.2	-0.4	0.0
IRBE	-2.7	0.6	6.6
KANG	-1.8	0.2	1.7
RI00	-2.0	0.4	3.1
RIGA	-2.0	0.4	3.1
KLPD	-1.5	-0.3	1.8
L311	-1.2	-0.6	0.8
L312	-0.6	-0.7	-0.9
L408	-1.4	-0.6	0.4
L409	-0.5	-0.7	-1.3
VLNS	-0.9	-0.8	-1.2

Conclusion is that the differences are so small for the new stations so it is better to stay in the internal epoch of the campaign.

Results (1)

Geocentric Cartesian coordinates in ETRS 89 epoch 2003.75 (based on ITRF 2000) for a subset of the NKG2003 campaign

Station	Country	X	Y	Z
ARAJ	Latvia	3277266.901	1309685.665	5295146.602
INDR	Latvia	3177703.862	1662049.956	5257080.228
IRBE	Latvia	3183612.378	1276706.499	5359310.711
KANG	Latvia	3078175.306	1608797.614	5331767.505
RI00	Latvia	3183914.38	1421473.491	5322796.718
RIGA	Latvia	3183899.552	1421478.321	5322810.644
KLPD	Lithuania	3359228.479	1297490.297	5246690.181
L311	Lithuania	3376643.347	1352769.794	5221718.728
L312	Lithuania	3320254.356	1570665.037	5197158.071
L408	Lithuania	3311606.955	1453968.652	5236111.119
L409	Lithuania	3425868.215	1482315.546	5154672.319
VLNS	Lithuania	3343600.978	1580417.56	5179337.131

Results (2)

Geodetic coordinates in ETRS 89 epoch 2003.75 (based on ITRF 2000) for a subset of the NKG2003 campaign

Station	Latitude			Longitude			Height
ARAJ	56	29	36.583375	21	46	58.8127	208.5617
INDR	55	52	44.774145	27	36	40.09091	213.6403
IRBE	57	33	15.896995	21	51	7.177188	40.6837
KANG	57	5	40.532341	27	35	37.1829	163.8277
RI00	56	56	54.462143	24	3	30.94915	29.3677
RIGA	56	56	55.021188	24	3	31.56767	34.7296
KLPD	55	42	55.269141	21	7	7.968095	42.7467
L311	55	19	6.736029	21	49	56.29229	92.5081
L312	54	55	51.389147	25	19	0.314766	229.5565
L408	55	32	44.811092	23	42	14.35198	138.3876
L409	54	16	19.514616	23	23	50.3639	228.4221
VLNS	54	39	11.305031	25	17	55.19055	240.8512

Comparison to other ETRS 89 realizations (1)

ETRS 89 based on NKG 2003 minus EUREF-BAL´92. Unit: mm

	N	E	U
ARAJ	-3.7	-37.2	-42.7
INDR	631.4	-262.6	321.9
KANG	6.5	-46.7	-24.7
RI00	-9.1	-27.9	30.3
L311	13.5	-16.4	30.7
L312	28	-25.9	42.6
L408	5.7	-9.4	18.8
L409	19.3	7.4	34.9
RMS	15.9	30.1	35.8

At **INDR** different markers have been used in the two campaigns.

Comparison to other ETRS 89 realizations (2)

ETRS 89 based on NKG 2003 minus EUREF-POL´92. Unit: mm

	N	E	U
RI00	-27.1	-4.7	24.0
L311	1.7	-8.2	-1.2
L312	-8.8	-25.3	31.9
JOZE	14.7	-5.2	-187.1
RMS	18.5	15.9	110.5

At **JOZE** different antenna heights have been used in the two campaigns.

Comparison to other ETRS 89 realizations (3)

ETRS 89 based on NKG 2003 minus EUREF-POL´2001. Unit: mm

	N	E	U
BOR1	7.3	-5	-17.1
JOZE	0.2	-17.6	0.5
LAMA	-5.4	-9.6	-1.4
WROC	8.2	-7.4	-3.9
RMS	7.1	12.7	10.2

ETRS 89 based on NKG 2003 minus EUREF-Estonia-1997. Unit: mm

	N	E	U
SUUR	-6.7	14.4	29.1

ETRS 89 based on NKG 2003 minus SWEREF 99. Unit: mm

	N	E	U
HASS	-2.9	7.7	37.7
NORR	-4.4	12.8	49.6
OSKA	-4.4	11.2	42.2
VIS0	-6.3	12.9	38
RMS	5.4	13.1	48.7

Summary (1)

New ETRS 89 coordinates based on the NKG 2003 campaign have been calculated. The campaign resulted in a set of coordinates in ITRF 2000 epoch 2003.75. All stations in Latvia and Lithuania as well as a sub-set of stations in neighbouring countries were converted to ETRS 89 using the standard procedure described by Boucher and Altamimi. No intraplate deformations have been taken into account, so the epoch of the ETRS 89 coordinates is 2003.75.

The ITRF 2000 solution of the NKG 2003 campaign is used as a node in the transformation between the Nordic national ETRS 89 realizations. Choosing this solution for the basis of the Latvian and Lithuanian ETRS 89 realization, will give a direct link to the Nordic ETRS 89 realizations.

Summary (2)

- Estimated accuracy: 0.5-1 cm (95%) for the horizontal co-ordinates and 1-2 cm (95%) for the vertical at the epoch of the observation.
- Improvement and extension of ETRS 89 in Latvia and Lithuania based on the NKG 2003 GPS campaign was done.
- NMA's of Latvia and Lithuania ask EUREF to adopt this solution as an ETRS 89 realization and to accept the selected 12 points (located in Latvia and Lithuania) as national EUREF-points as class B standard (about 1 cm at the epoch of observations).