EUREF-Czech-2009 Campaign

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Corrections

of the final report as sent on May 11, 2010 to the EUREF TWG members

- WROC station remained by mistake as a fiducial in specific problematic period
  - no velocity change
  - all coordinates shifted by
    - X : - 0.2 mm
    - Y : + 0.3 mm
    - Z : 0.0 mm
- Table 5 was not correctly presented (different epochs were applied in ETRS89 comparison)
  - no effect for coordinates and velocities
  - no effect on variant selection

New report version has been prepared on May 30, 2010 and is available at
http://www.pecny.cz/CZETS/ETRS89-CZ_FinalReport-V1.pdf

and improvements suggested by Elmar and Gunter were already incorporated:
- mentioned 5 new EPN stations in CZ – marked in map / DOMES in list
- reference coordinates expressed in 2005.0 instead of 2007.0
- included reference to daily raw time-series

Introduction

- **History**

  EUREF-CS/H'91 (1991) – accepted by the EUREF TWG, class 'B'
  - **6 stations in region of the Czech and Slovak Federative Republic**

  CS-NULRAD (1992) – first order densification
  - **6+13 stations**

  CS-BRD (1993) – connecting Czech and German GPS networks
  - **some NULRAD re-observed and recomputed**

  DOPNUL (1993-1994) – second order densification
  - **176 stations**

- **Today**

  Active reference network – CZEPOS (since 2005) is used for new ETRS89 densification as a first step from altogether 46500 points in the Czech Republic with an average distance of 2 km

Campaign configuration

- **Stations**

  44 – Czech permanent stations
  - **23 – CZEPOS (4 EPN: CFRM, CLIB, CPAR, CRAK, CTAB)**
  - **7 – VESOG (2 EPN: TUBO, GOPE)**
  - **9 – GEONAS (4 EPN: BISK, MARJ, POUS, VACO)**
  - **5 – TOPNET**

  18 – EPN in other European Countries
  - **Class 'A' stations with smooth EPN coordinates**
  - **Fiducial stations in EPN cumulative solution**
  - **Close surrounding of the Czech Republic**
  - **Distances of 1000 km in all directions from the centre of network**

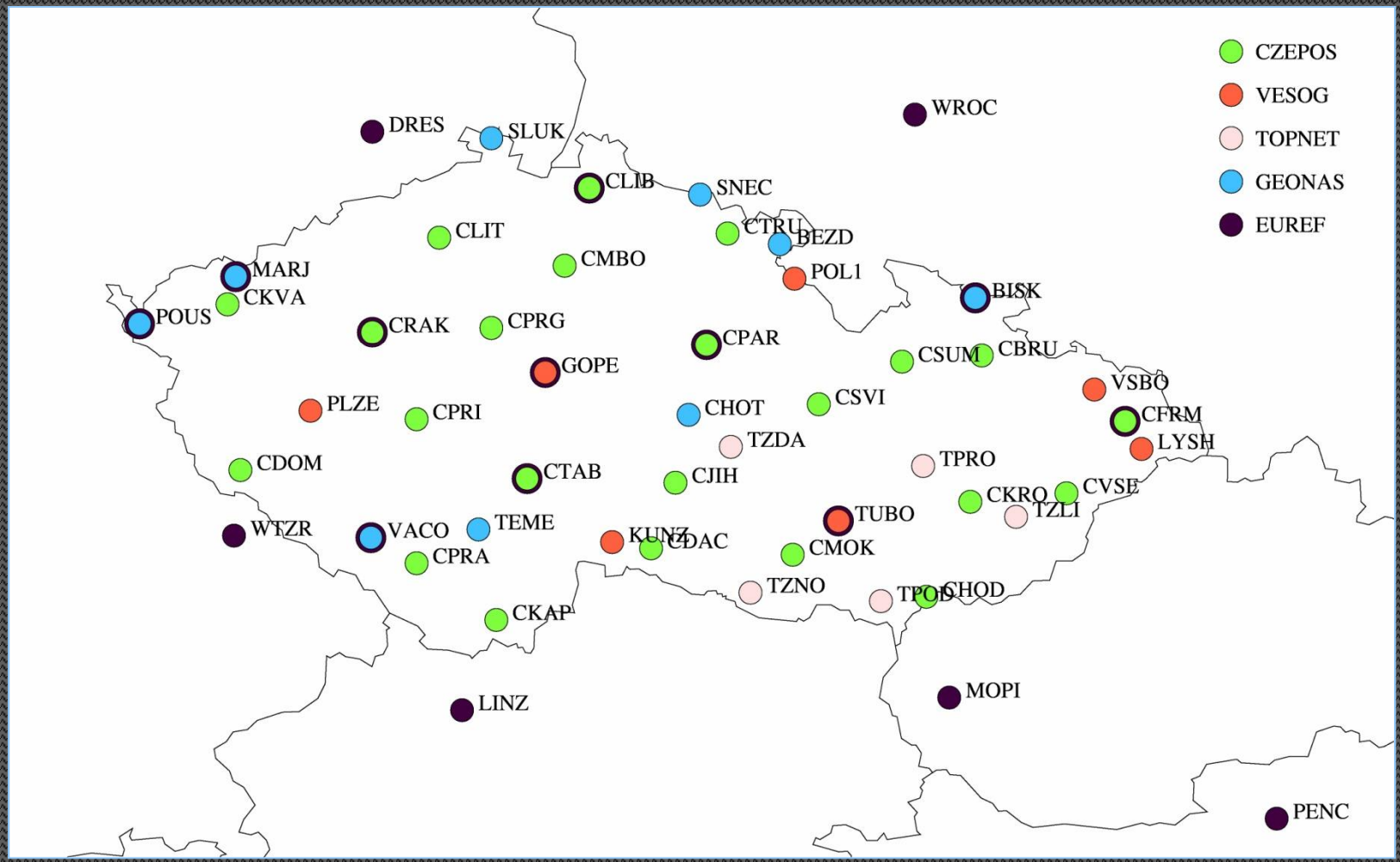
- **Data**

  2005-2009: 1 - 4 years for different stations

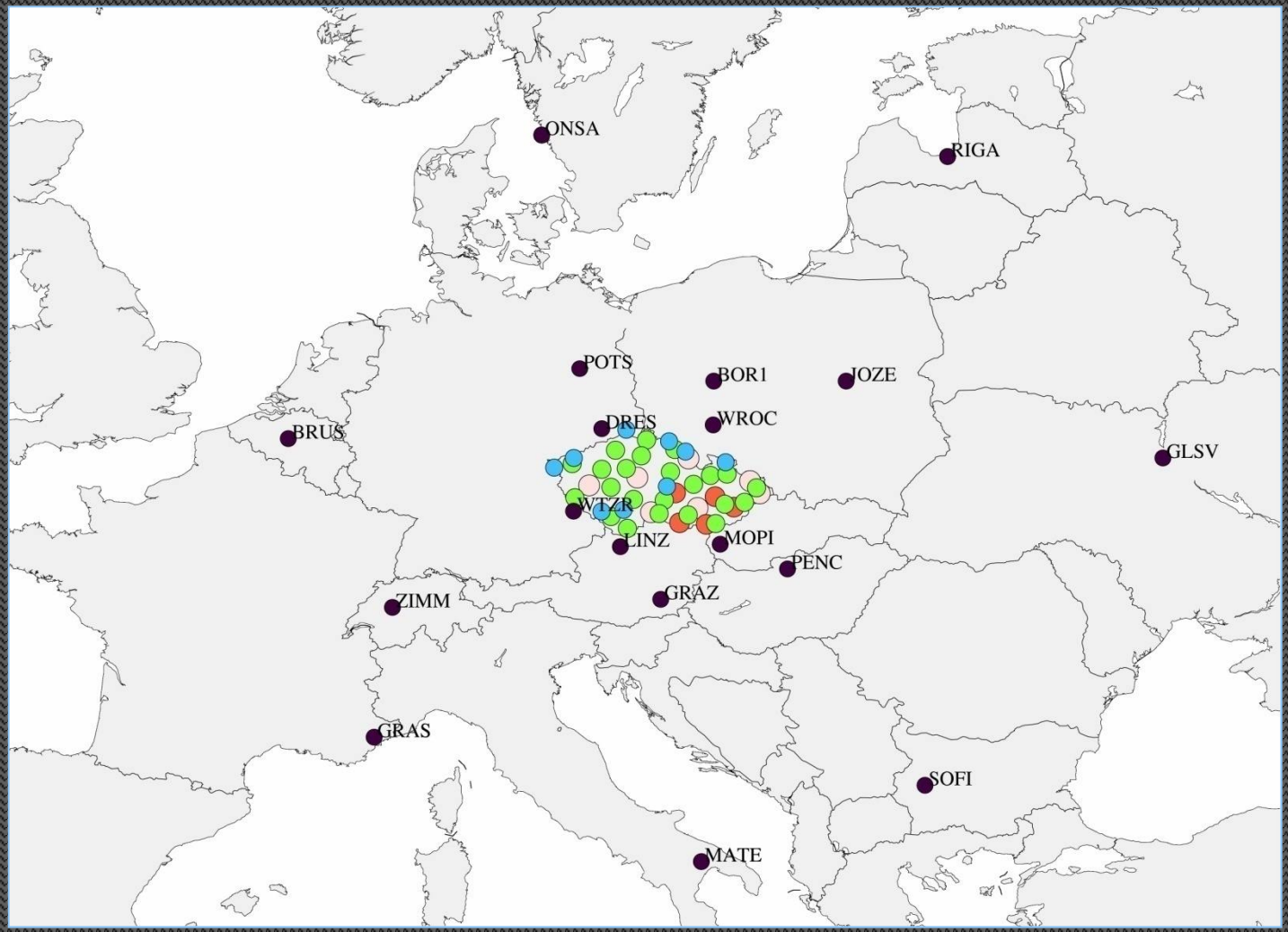
  GPS data used only

  SNEC – only summer periods selected (Jun-Sep)

Map of Czech GPS permanent stations



EPN Class ‘A’ fiducial candidates



Daily processing

- **Strategy consistent with the GOP contribution to EPN**
  - Data and product conversion, a priori input files (CRD, SIG, FIX,..)
  - Single point positioning (receiver clock synchronization)
  - Baseline definition (OBS-MAX)
  - Data cleaning, cycle-slip detection, ambiguity setting
  - Ambiguity-float solution for post-fit residual screening and outlier detection
  - Iterative solution for selection of fiducial stations
  - Integer ambiguity resolution (QIF strategy)
  - Ambiguity-fixed daily solution using no-net translation based on selected fiducial stations
- **Software**
  - Bernese GPS software V5.0
  - Distributed parallel processing in clusters

Applied products and models

- **Products**
  - A priori coordinates from IGS05/ITRF05 solutions
  - IGS final orbits and ERPs
  - CODE ionosphere products
  - Ocean tide loading (FES2004, no CMC corrections)
  - Absolute antenna PCV model (epn_05.atx + CZEPOS individual)
  - Reference coordinates from the EPN cumulative solution (**EPN_A_ITRF2005_1570**)
- **Observations**
  - 30 sec, sampled to 180 sec in final processing
  - 3 deg elevation cut-off (10 deg for ambiguity resolution)
  - Elevation-dependent weighting

Atmosphere modelling

- **Ionosphere**

  Ionosphere-free linear combination (only 1st order-effect)

  2nd and 3rd ionosphere effect neglected

  CODE model used for integer ambiguity resolution

- **Troposphere**

  A priori model Saastamoinen + Niell dry mapping function

  1 correction/60 min/station + Niell wet mapping function

  - Loosely constrained (5m/1m, absolute/relative)

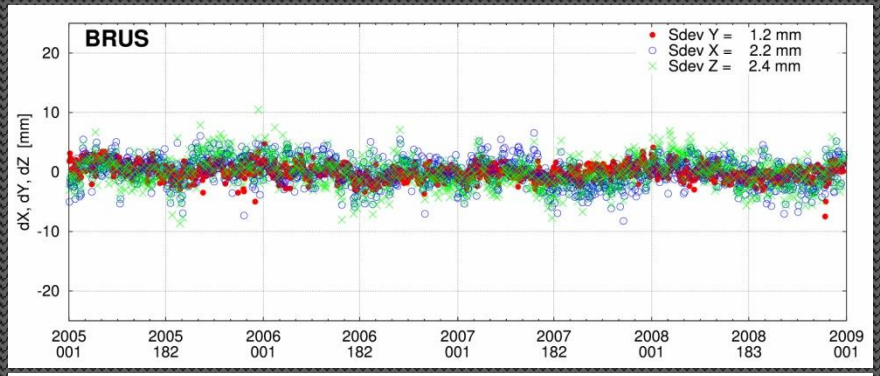
  In final estimation only: horizontal gradients/day/station

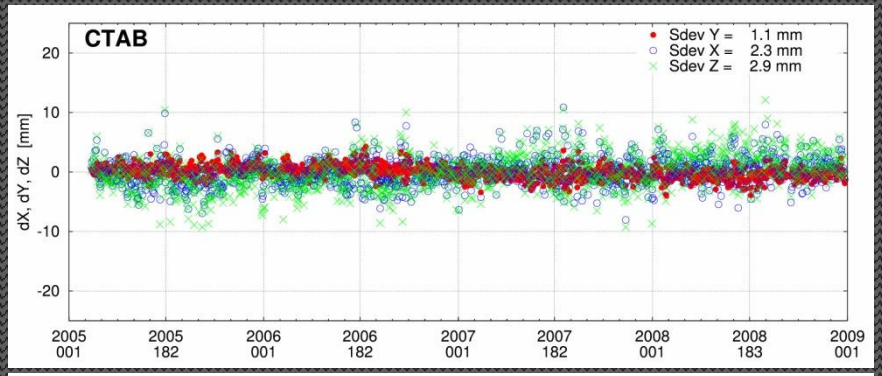
  Parameters pre-eliminated before saving NEQs/SINEX

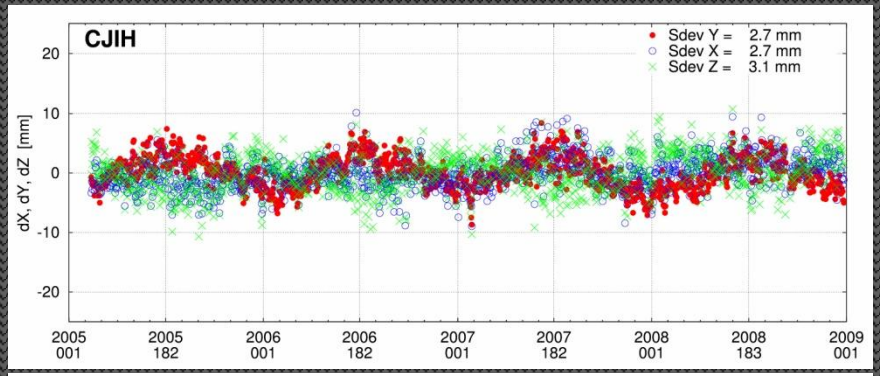
Advanced processing steps

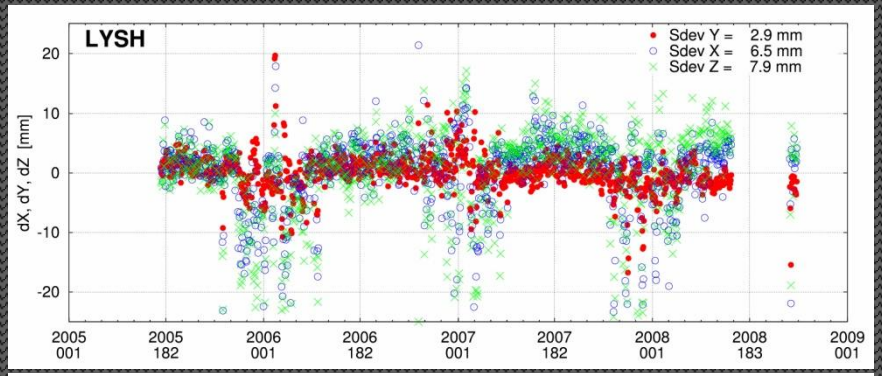
- **Data cleaning**
  - Processing in clusters of ~20 stations
  - Detection of specific problem with station or satellite
  - Robust procedure with possible re-iteration in case of detected problems
- **Datum definition**
  - Iterative selection of best fitting fiducial stations (ambiguity float solution)
  - A priori set of 10 stations used as fiducials in IGS05 realization
    - BOR1, BRUS, GLSV, GRAS, JOZE, MATE, ONSA, POTS, WTZR, ZIMM
  - Typical RMS from residuals: 2.4/4.4/5.0mm (NEU)
  - Stable datum definition provided on daily basis
- **Ambiguity resolution**
  - 10 deg cut-off angle, cluster mode (~4-8 stations)
  - QIF-strategy with support of CODE ionosphere model
  - Coordinates and troposphere introduced from the float solution
  - 85 % average of resolved integer ambiguities

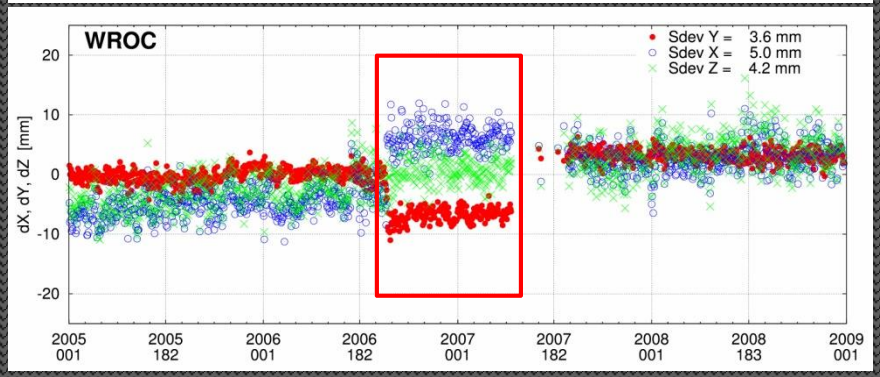
Daily raw time-series

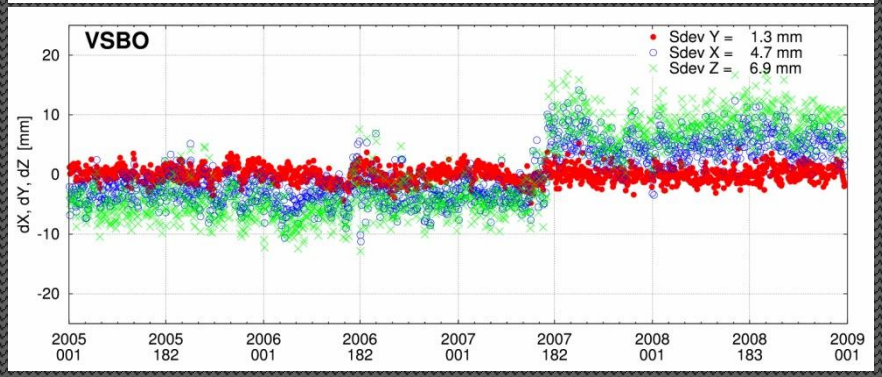












Final combination (1)

- **Fiducial stations - 4 tested variants**
  - A) 11 - EPN stations fiducial in the EPN cumulative solution
  - B) 10 - EPN/IGS stations fiducial in daily solution (and IGS05)
  - C) 24 - all EPN stations excluding GOPE before GPS week 1400
  - D) 20 - all EPN stations excluding those with larger residuals
- **Reference coordinates and velocities**
  - 2007.00 - central epoch of the combination
  - Coordinates and velocities for fiducial stations from EPN_A_ITRF2005_C1570
  - Special handling of reference coordinate changes at GPS week 1400
    - whenever possible extrapolated before week 1400 (until change of antenna)
    - Short-periods not extrapolated for : DRES, GOPE, PENC, RIGA, TUBO, WROC
  - A priori NUVEL1A model for non-EPN coordinate propagation to the central epoch
- **Rejection of outliers**
  - 8, 8, 25mm (NEU) and 15, 15, 40mm for EPN and non-EPN stations, respectively
  - Excluded a priori known problems
    - winter periods (LYSH, BISK, SNEC, KUNZ)
    - instrument malfunctioning (JOZE)
  - 0.5 % rejected outliers from total data (LYSH and SNEC excluded)

Final combination (2)

- **Detection of jumps in coordinate time-series**

  Iterative procedure with screening residuals

  Smooth intervals for individual station coordinates identified

- **Coordinates**

  Estimated for all stations in pre-defined intervals

  4 variants of fiducial stations applied for no-net-translation (NNT)

- **Velocities**

  Heavily constrained for EPN stations to EPN_A_ITRF2005_C1570

  Estimated for non-EPN stations with data span > 3 years

  - Horizontal: loosely constrained
  - Vertical: heavily constrained, but for Variant 'D'

  Single set of velocities for the whole data span

Final variant selection

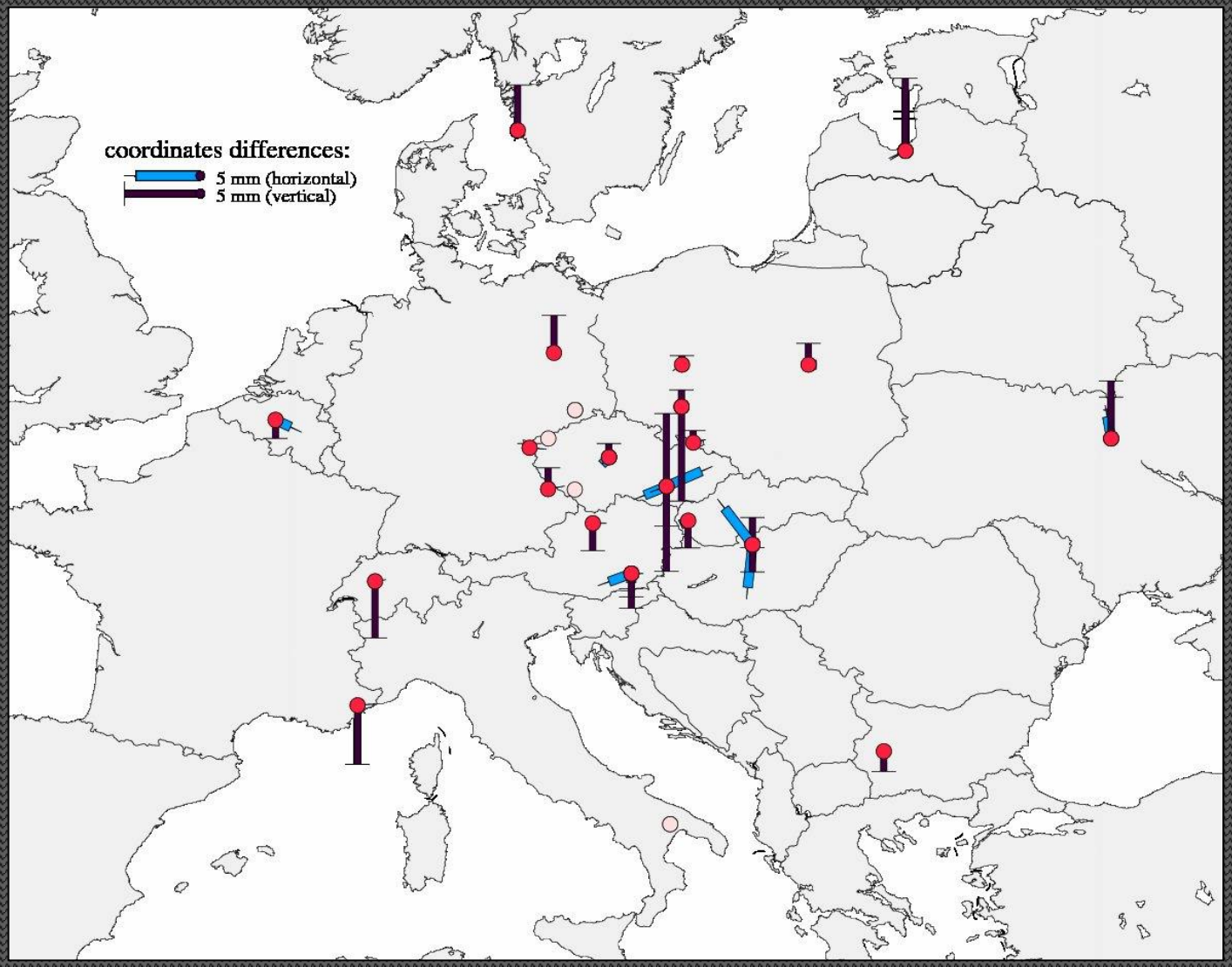
- Compared to EPN_A_ITRF2005_C1570 to reproduce translations
- RMS of 3D Helmert transformation
- Variant 'D' selected as the final

	Translations [mm] (all EPN Class 'A')			Translations [mm] (only fiducial)			RMS of Helm. trafo [mm] (only fiducial)			
	North	East	Up	North	East	Up	North	East	Up	Total
A	0.0	-0.9	-0.5	+0.1	-0.1	0.0	1.0	0.8	3.5	2.1
B	0.0	-0.9	-0.6	+0.1	-0.1	0.0	1.0	0.8	3.6	2.2
C	+0.3	-0.4	-0.9	+0.1	-0.1	0.0	1.2	1.2	3.2	2.1
D	+0.3	-0.5	-1.1	+0.1	-0.1	0.0	1.1	1.1	2.8	1.9

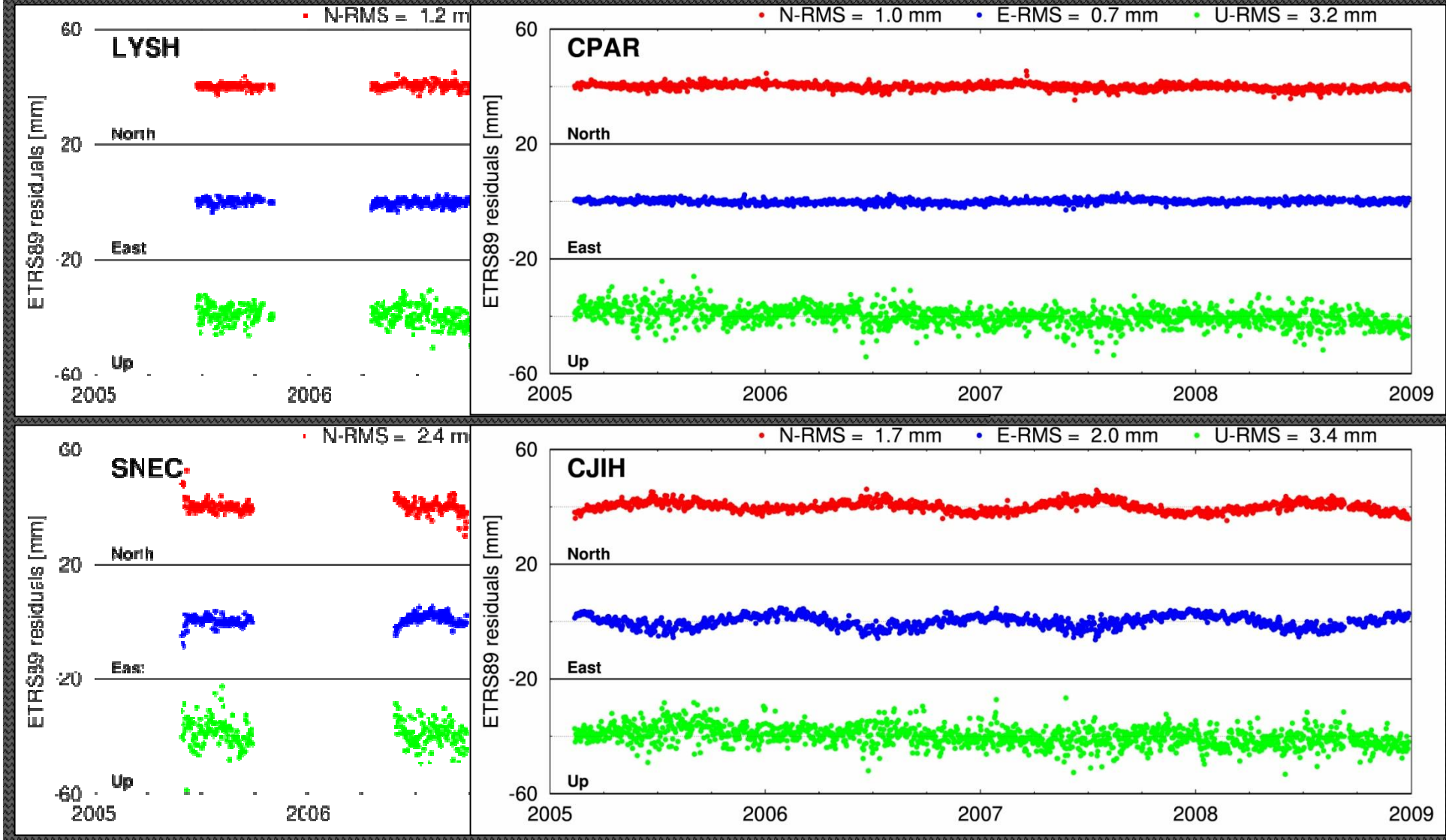
Fiducial stations

Station	Fiducal set				D – final solution			
	A	B	C	D	North [mm]	East [mm]	Up [mm]	Flag
BISK 11520M001			✓	✓	0.2	0.8	0.8	
BOR1 12205M002B	✓	✓	✓	✓	-0.4	-0.6	0.6	
BRUS 13101M004B	✓	✓	✓	✓	-0.8	1.7	-1.2	
DRES 14108M001			✓		-1.4	-2.1	-2.2	M
DRES 14108M001C			✓		-1.2	-1.7	-1.2	M
DRES 14108M001D			✓		2.2	-0.1	6.9	M
GLSV 12356M001B	✓	✓	✓	✓	2.2	-0.4	2.7	
GLSV 12356M001C	✓	✓	✓	✓	1.1	-0.0	3.8	
GOPE 11502M002					3.1	-1.4	-17.0	M
GOPE 11502M002B					2.7	-1.1	-20.2	M
GOPE 11502M002C			✓	✓	0.1	0.1	0.9	
GRAS 10002M006B	✓	✓	✓	✓	0.1	1.2	-3.9	
GRAZ 11001M002			✓	✓	0.2	-0.0	-1.0	
GRAZ 11001M002B			✓	✓	-0.8	-2.2	-2.3	
GRAZ 11001M002D			✓	✓	0.0	0.8	-1.5	
JOZE 12204M001B	✓	✓	✓	✓	-0.0	-0.3	1.4	
LINZ 11033S001B			✓	✓	-0.0	0.9	-1.8	
MARJ 11517M001B			✓		0.2	0.9	0.6	M
MATE 12734M008B	✓	✓	✓		2.3	0.7	-6.3	M
MATE 12734M008C	✓	✓	✓		0.3	1.5	-7.0	M
MOPI 11507M001B			✓	✓	0.1	0.2	-1.8	
ONSA 10402M004B	✓	✓	✓	✓	-0.7	-0.2	3.0	
PENC 11206M006			✓	✓	-3.6	-0.4	-0.2	
PENC 11206M006B			✓	✓	0.1	0.3	1.8	
PENC 11206M006C			✓	✓	3.0	-2.3	-1.8	
POTS 14106M003	✓	✓	✓	✓	-0.3	0.1	2.5	
POUS 11518M001			✓	✓	-0.1	1.1	0.3	
RIGA 12302M002			✓	✓	-0.5	-1.1	2.1	
RIGA 12302M002B			✓	✓	-0.6	-1.0	2.6	
RIGA 12302M002C			✓	✓	0.2	-0.5	4.8	
SOFI 11101M002	✓		✓	✓	0.4	0.3	-1.3	
TUBO 11503M001			✓	✓	-0.9	-2.2	-2.6	
TUBO 11503M001B			✓	✓	1.3	3.0	-5.4	
TUBO 11503M001D			✓	✓	-0.4	-1.1	4.8	
VACO 11516M001B			✓		0.7	0.4	1.7	M
WROC 12217M001			✓	✓	0.1	-0.5	-6.2	
WROC 12217M001C					-0.7	-11.0	-0.7	M
WROC 12217M001D			✓	✓	-0.2	-0.4	1.1	
WTZR 14201M010B	✓	✓	✓	✓	0.2	1.1	1.4	
ZIMM 14001M004B	✓	✓	✓	✓	0.1	0.7	-3.7	

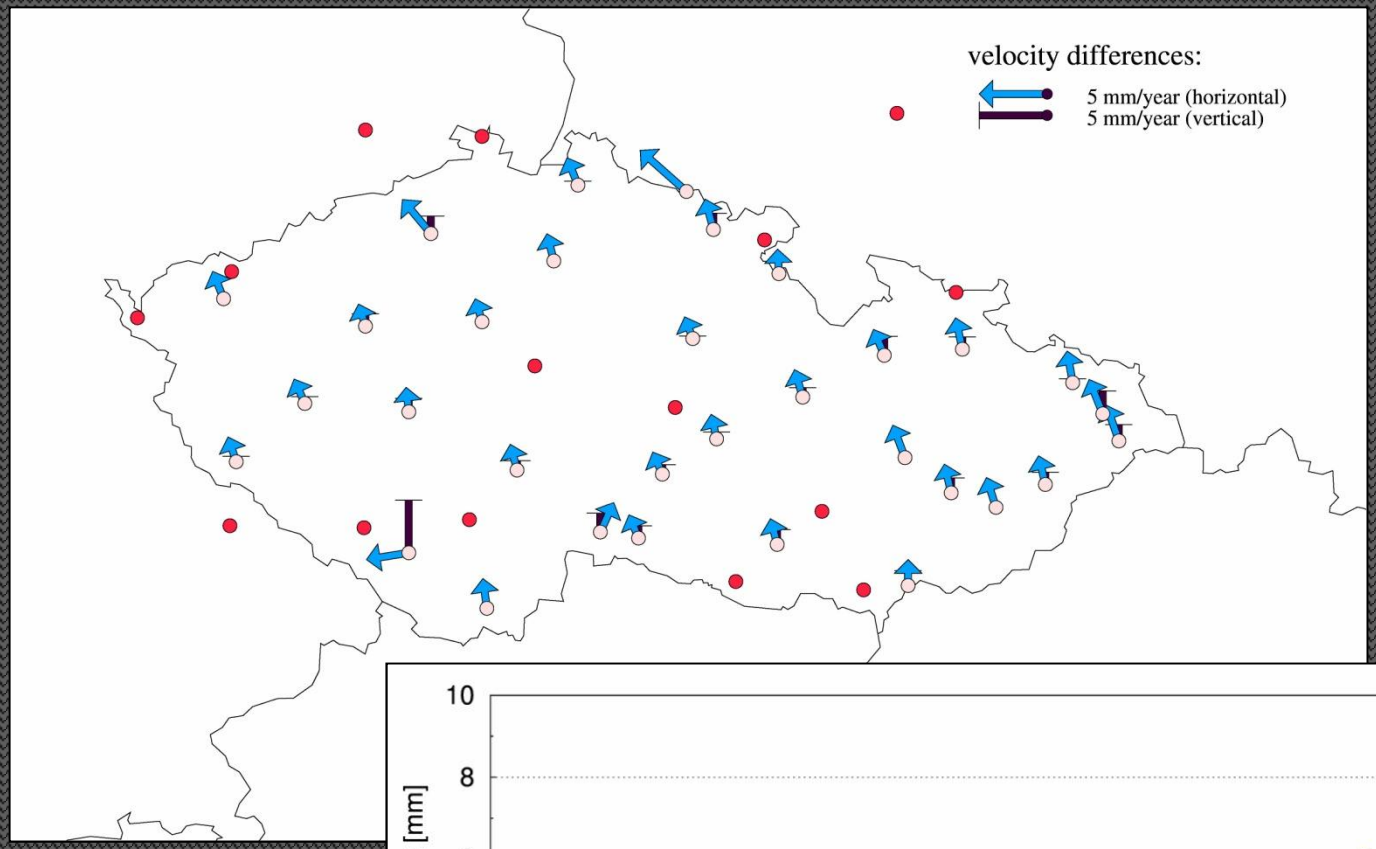
Variant D: Recovery of fiducial stations



Coordinate time-series



Estimated velocities, repeatability

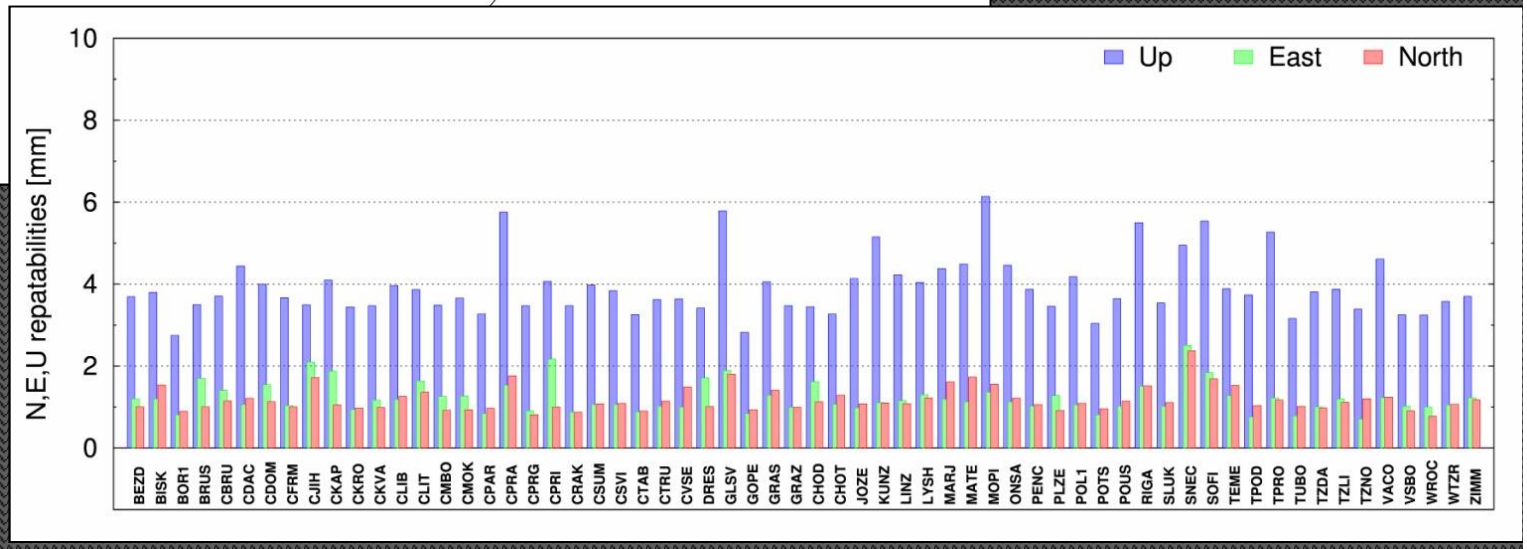


Repeatabilities

North: < 2 mm

East : < 2 mm

Up: < 6 mm



June 1-3, 2010

Transformation to ETRS89

- **Final coordinate list**

  ETRF2000(R05) – ETRS89 via realization in ITRF2005 and using EUREF conventional reference frame (ETRF2000)

- **Transformation method**

  Tested both methods from Memo Ver7 (Boucher and Altamimi)

  - ITRF2005 → ITRF2000 → ETRF2000
  - ITRF2005 → ETRF2000

Results were consistent at a sub-millimetre level

EPN web-page service finally applied (the same results)

Comparison with previous ETRS89 realization

- **Problematic**

  Indirect, no common GPS points
  Previous realization is more than 15 years old
  Multi-step derivation of ETRS89 coordinates involved
  Finally, coordinates from 27 stations were compared by 3D Helmert transf.

- **Results**

  Agreement on cm-level in horizontal and a few cm in vertical components
  Nearly 1 cm offset in North component common to all stations
  Only CPRA stations residuals exceed 15 mm in horizontal component

Number of sites	Translations			RMS of Helmert transformation			
	North [mm]	East [mm]	Up [mm]	North [mm]	East [mm]	Up [mm]	Total [mm]
27	+8.6	+2.3	-1.8	6.7	7.4	22.3	14.1

Conclusion

- 44 + 18 Czech and EPN permanent stations
- 1-4 years processed
- Repeatability better than 2, 2, 6 mm in NEU for all stations
- 4 variants of fiducial stations of no-net-translation according to EPN_A_ITRF2005_C1570 coordinates and velocities
- Overall agreement within 1.1 mm in three translations over all EPN stations
- Selected variant ‘D’ with 20 fiducial EUREF Class ‘A’ stations
- 1.1, 1.1, 2.8 mm (NEU) RMS from the Helmert transformation for all fiducial stations
- Coordinates and velocities expressed in ETRF2000(R05) E2007.0
- Comparison to previous ETRS89 realization on a cm-level

Comparison to ITRF2005

- Original coordinates from ITRF in epoch 2007.00
- All EPN class 'A' coordinates available in ITRF identical

	Translations [mm]			RMS of Helm.trafo [mm]			
	North	East	Up	North	East	Up	Total
A	-0.1	-0.1	-1.7	2.6	2.9	5.5	3.9
B	-0.1	+0.1	-1.5	2.6	2.9	5.5	3.9
C	-0.3	-0.3	-1.2	2.6	2.9	5.4	3.8
D	-0.4	-0.3	-1.1	2.6	2.9	5.4	3.8