Improved coordinate time series from reprocessing of permanent GPS stations in Central Europe

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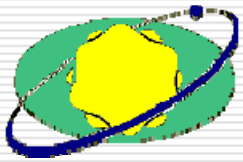

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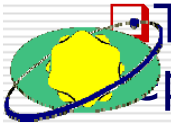
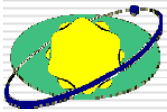
Motivation

- The region of Central Europe and adjacent territories is since 1994 monitored by regional epoch-wise campaigns within the CERGOP project. The reprocessed GERGOP campaign solutions are available from 1994 to 2007.
- The territory of interest is covered by increasing number of permanent stations (from 10 in 1996 to hundreds in 2009). Some of them were included in CEGRN epoch solutions as epoch stations.
- The aim of the paper is to report about the reprocessing of representative set of permanent GPS stations situated in the region of CE to be able get a homogeneous combination of epoch and permanent networks.
- This activity is also a preliminary study related to planned EPN reprocessing.



Content

- Basic information about reprocessed network
- The reprocessing strategy
- Compilation of coordinate time series, transformation to ITRF2005
- Evaluation of the homogeneity of the series
- Velocities and seasonal variations
- Comparisons with other data
- Conclusions

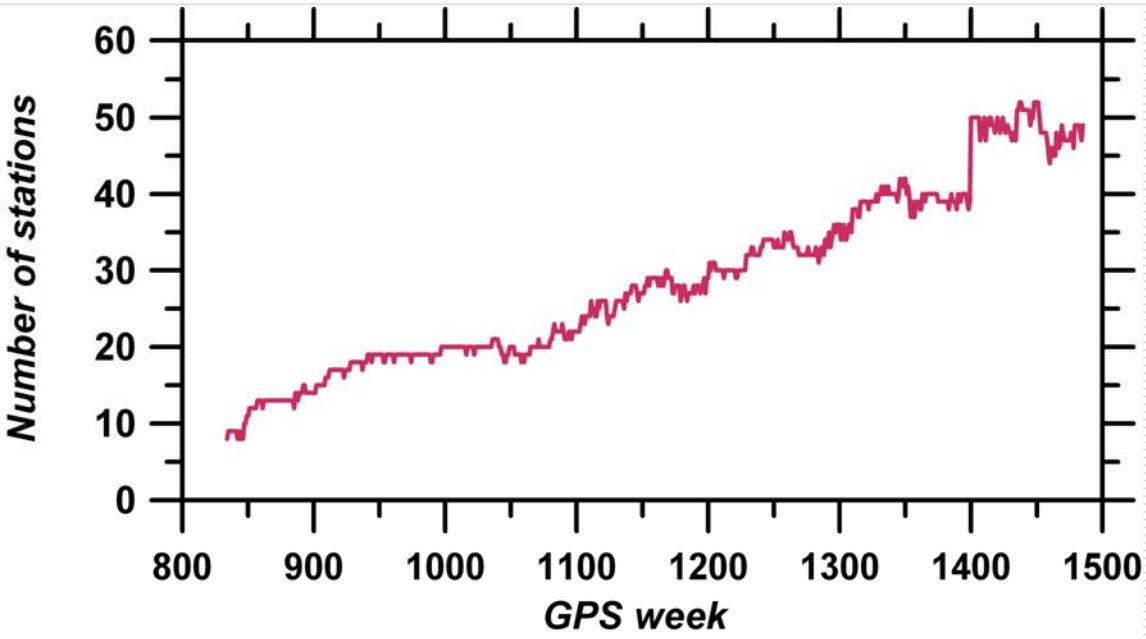


Analyzed network of GPS permanent stations

- Status in Dec. 2008 – 54 sites in Central Europe, Balkan and West Alpine region.
- 45 EUREF permanent network stations and 9 non- EPN sites
- 30 stations are CEGRN sites or are analyzed within CEGRN epoch campaigns.

Evolution of number of analyzed GPS permanent stations

- Start in 1996.0 – 9 stations: BOR1, GOPE, GRAZ, JOZE, LAMA, MATE, POTS, UPAD, ZIMM
- Progressive increase till week 1400 (up to 40 stations)
- In week 1400 (Nov. 2006) 10 stations added
- Recently are 50 – 55 sites analyzed.



Processing scheme

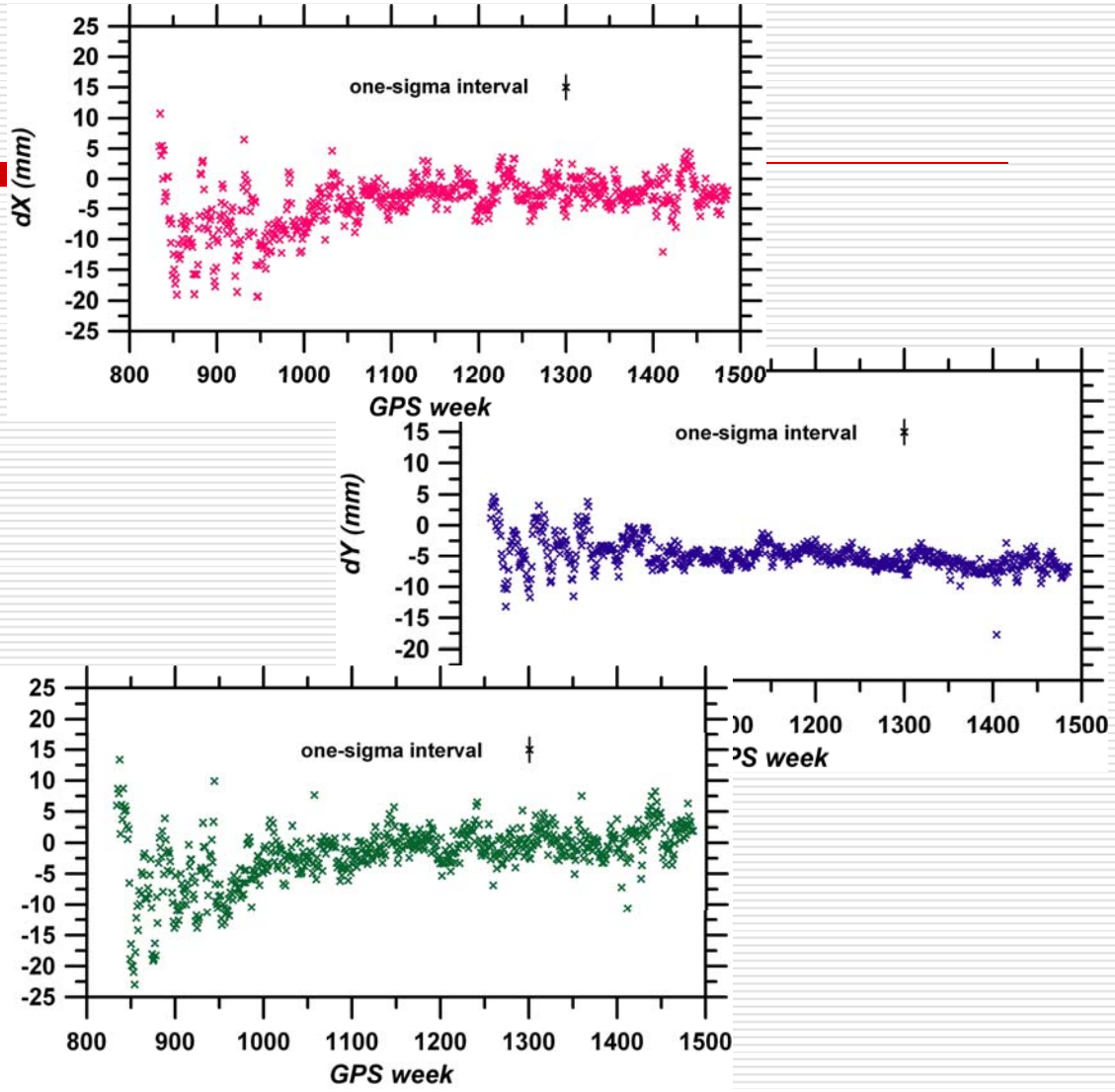
- Analyzing software: BERNESE V5.0, installed in LINUX environment
- Orbits and EOPs: The Potsdam/Dresden IGS reprocessing (Steinberger et al., 2006) untill 2006.0. After 2006.0 the IGS routine processing products applied.
- 30 s sampling for preprocessing and ambiguity resolution, 180 s for final coordinate estimates. Final solution with constraining to BOR1.
- Elevation mask 3 deg (if available), elevation dependent weighting.
- Dry Niell and wet Niell mapping functions, 1-hour troposphere zenith delays and 24-hour troposphere gradients estimated.
- Satellite and receiver antenna from the IGS05 absolute calibration models
- Ocean loading model FES2004.
- The reprocessing started with year 2006.

Formation of coordinate time series

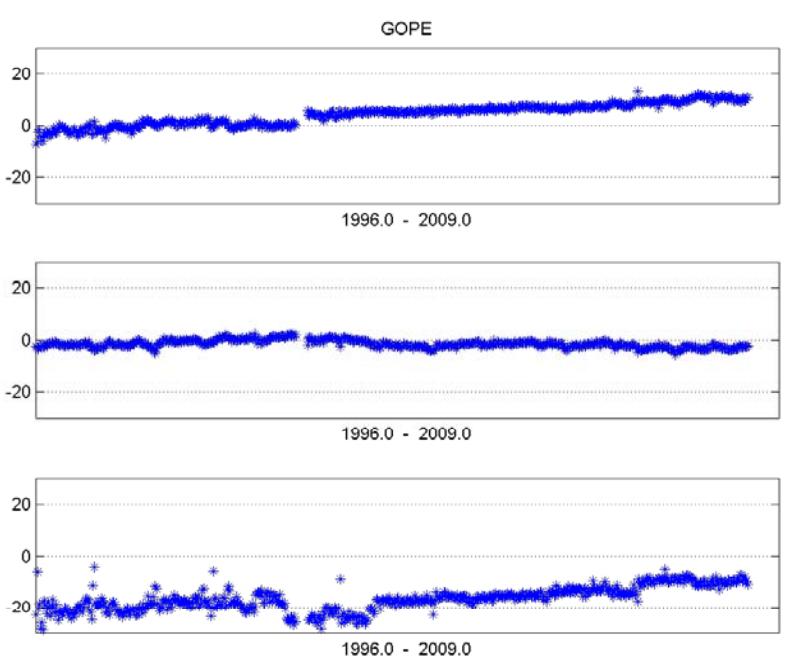
- Combination of daily solutions into weekly station coordinates
- Transformation to ITRF2005 using 9 reference sites: BOR1, BUCU, GOPE, GRAZ, MATE, PENC, SOFI, WTZR, ZIMM. 6- parameter transformation applied.
- Problematic ITRF2005 sites for referencing: BOGO, JOZE, LAMA, MEDI, WROC due to various reasons.
- Elimination of offsets in time series: setting offset parameter in case of known reason (from EPN site logs and/or additional station information). Velocity is assumed to uninfluenced by offset.
- Non-reported significant offsets (>2mm) found for 5 stations (BBYS, JOZE, KLOP, OROS, WROC). Problematic estimates for stations with more offsets.
- Reduction of ITRF2005 referenced series for APKIM2000 model.

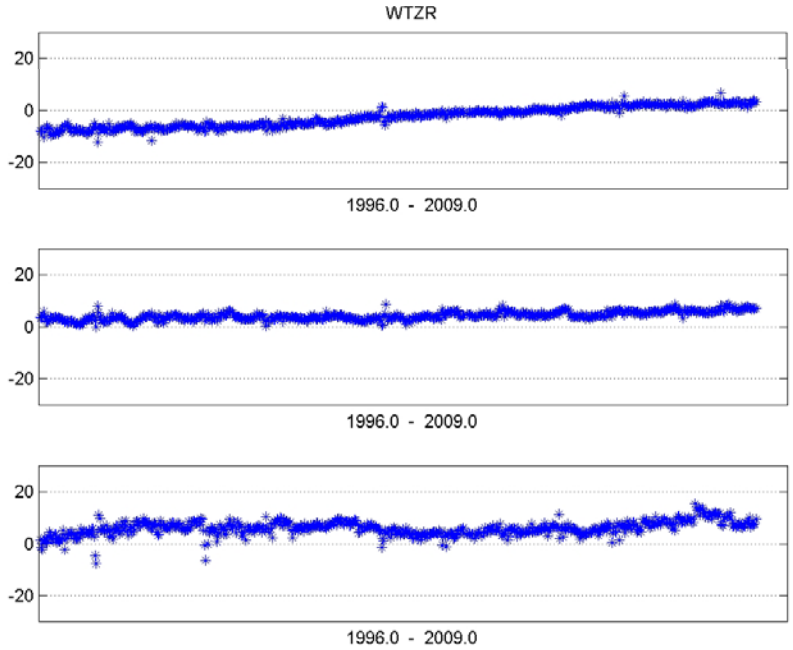
Time evolution of transformation parameters – translation components

- After ~ GPS week 1000 (1999.3) are dX, dY and dZ parameters in range < 10 mm
- Before week 1000 the significantly larger scatter (up to 30 mm) with semiannual periodicity is observed
- Similar pattern is observed for rotation components



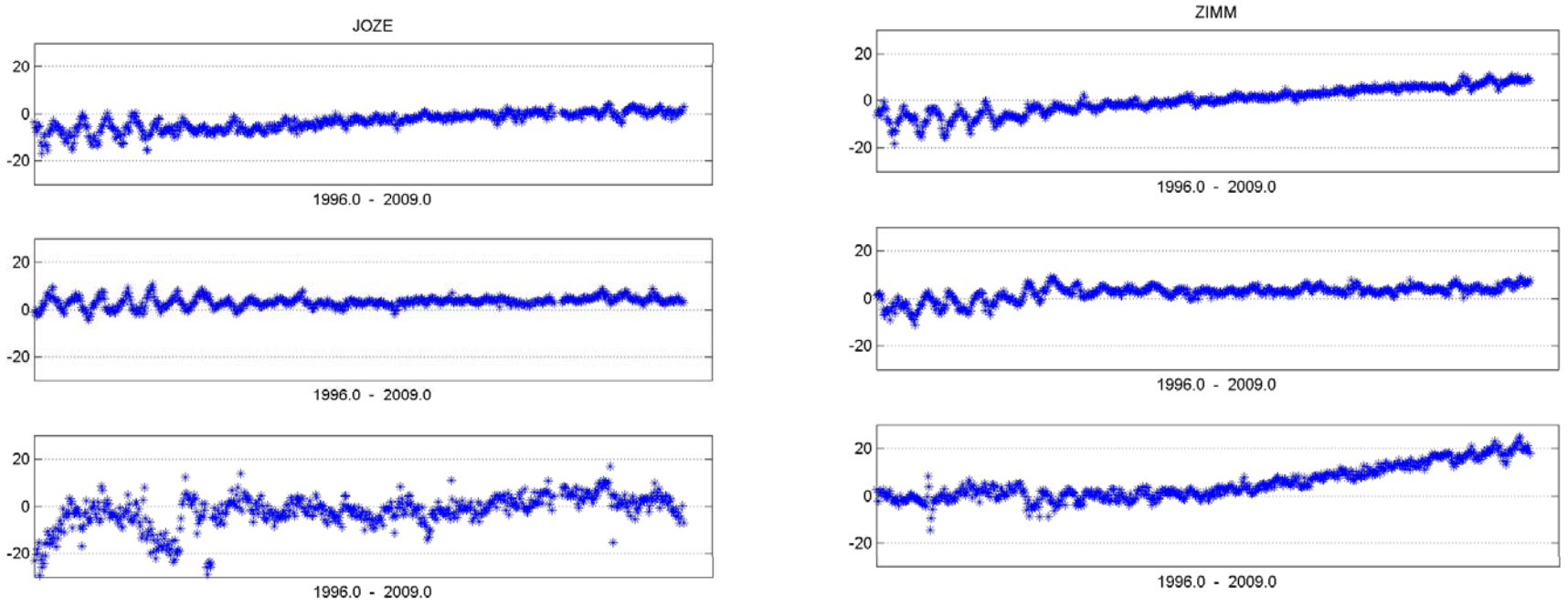
Examples of coordinate time series reduced for APKIM2000





- Stations GOPE and WTZR – non-problematic stations with smooth homogeneous series, despite of more offsets introduced (GOPE)

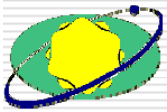
Examples of coordinate time series reduced for APKIM2000



- Stations JOZE and ZIMM – spurious behavior before week 1000, strange semi-annual variations in horizontal components

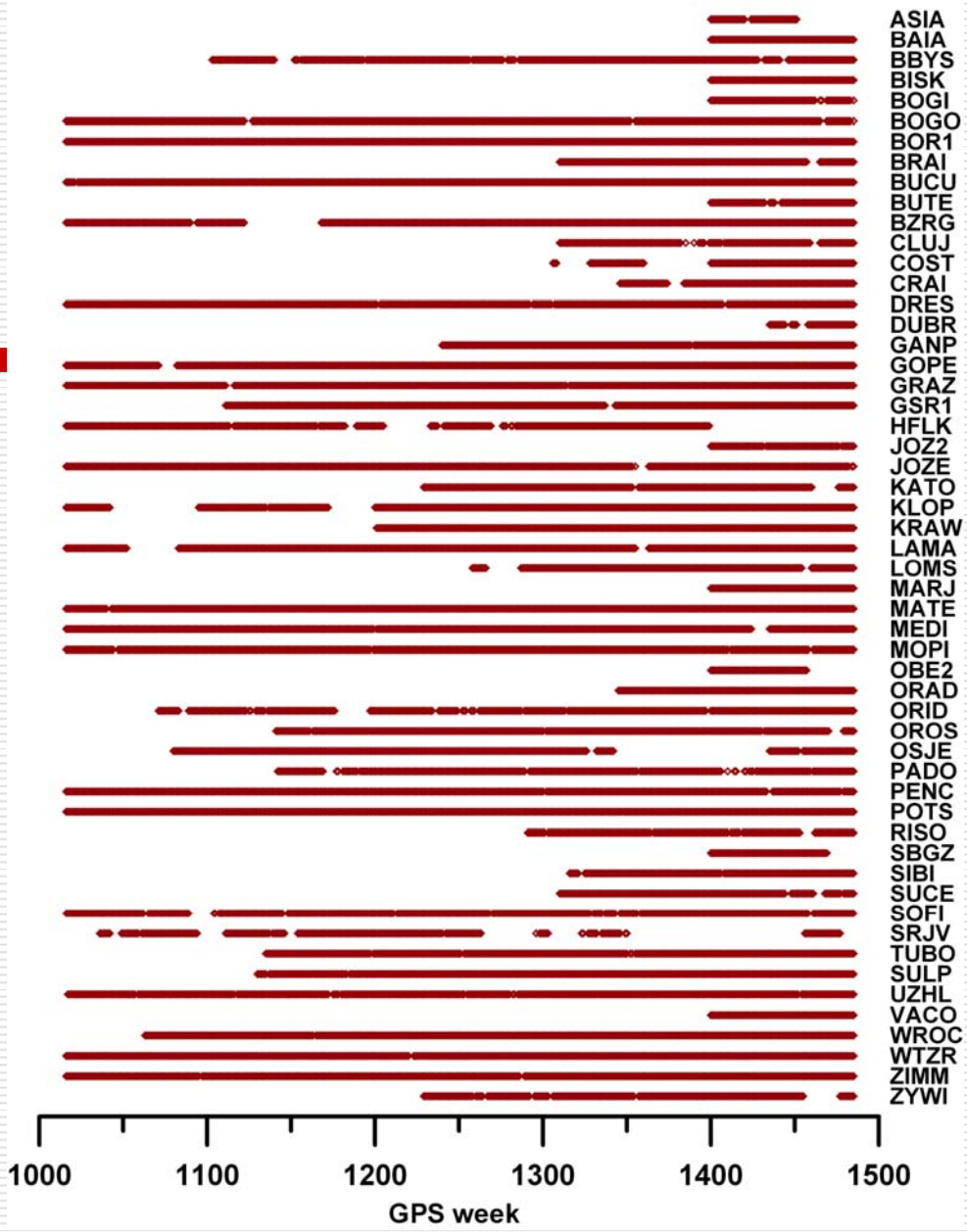
The analysis of reduced time interval from 1999.5 to 2008.5

- The problem with some station series before week 1000 is up to now not resolved
- Majority of sites available until 1999 (10 sites from 15) have strange semiannual horizontal variations before week 1000 with amplitude up to 2 mm and variable site dependent phase.
- The same phenomena are observed if network with limited subsets of sites and different constraining is adjusted.
- The new time series formation including the offsets estimates was performed for limited interval with data starting at 1999.5
- Velocities, seasonal terms and all offsets were simultaneously adjusted for all the reprocessed series.



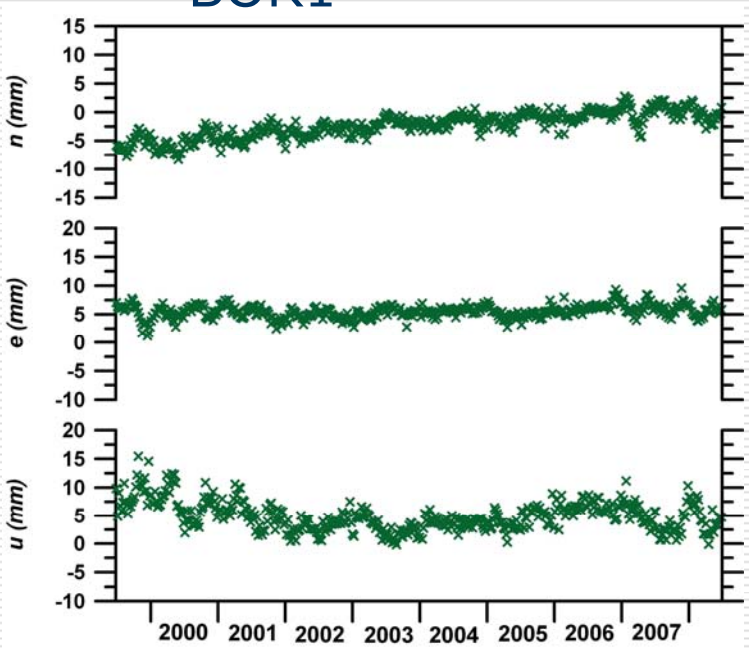
Availability of observations after exclusion of problematic data

- The 'raw' time series were cleaned for outliers, short intervals between antenna changes, etc.
- 40 stations have observation interval longer than 3 years, 18 stations cover 9-years.
- For all these stations velocities, seasonal terms and offsets were estimated.

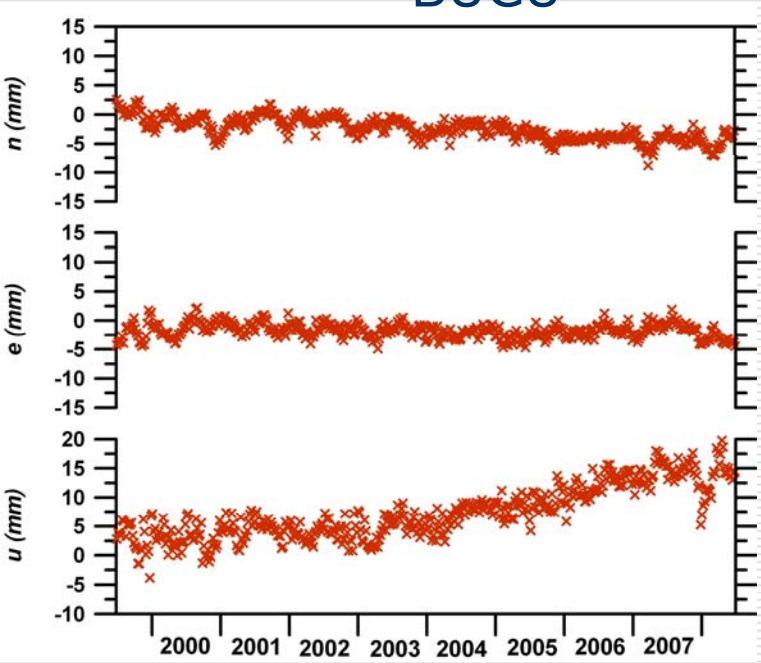


Example of stations with ‘smooth’ coordinate series

BOR1



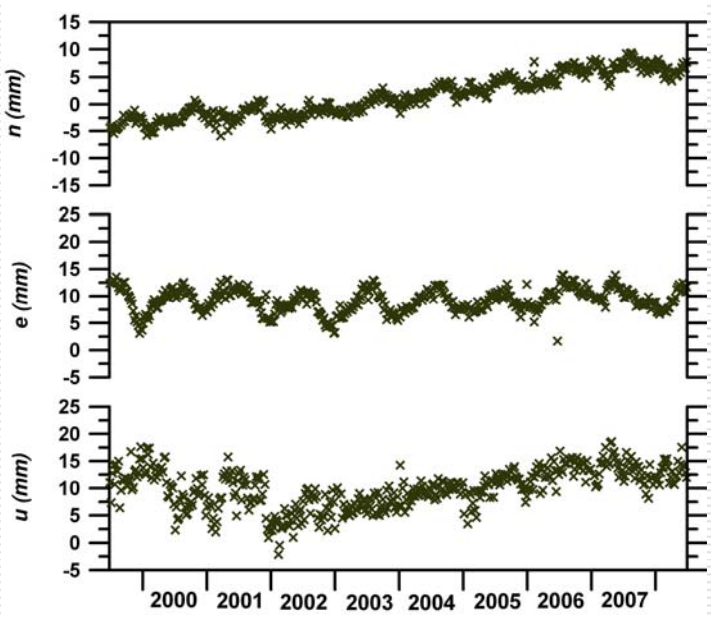
BUCU



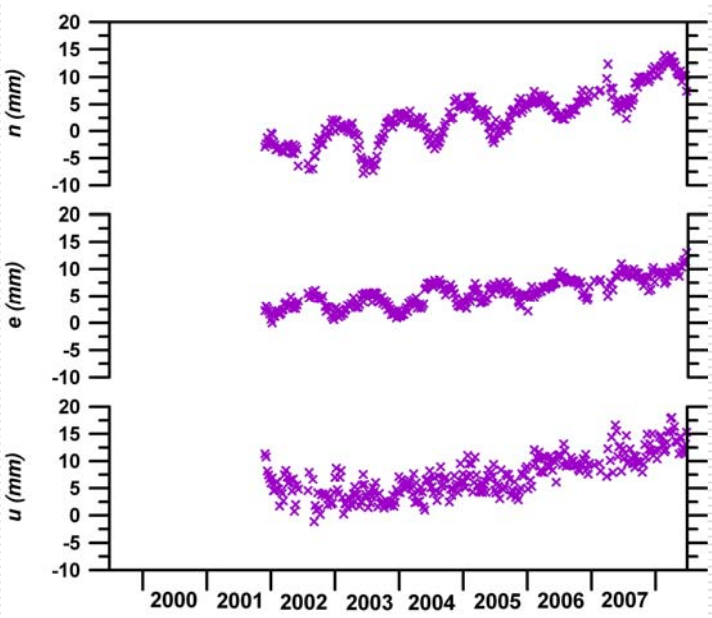
- Only linear trend is visible

Example of stations with stable seasonal variations

DRES



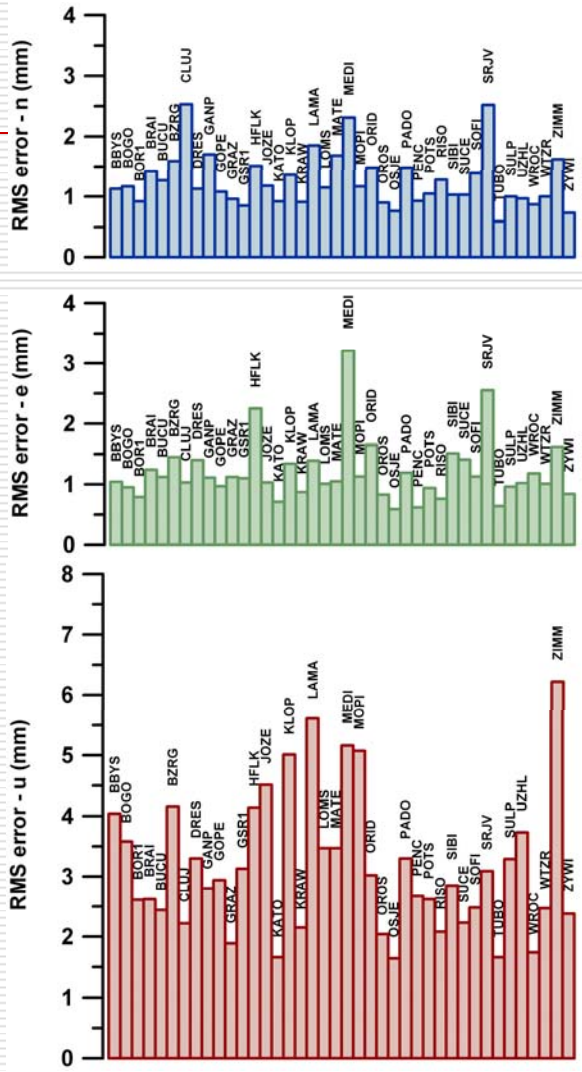
PADO



- Seasonal signal > 2mm is observed at 6 sites only
- The seasonal pattern at these stations is stable

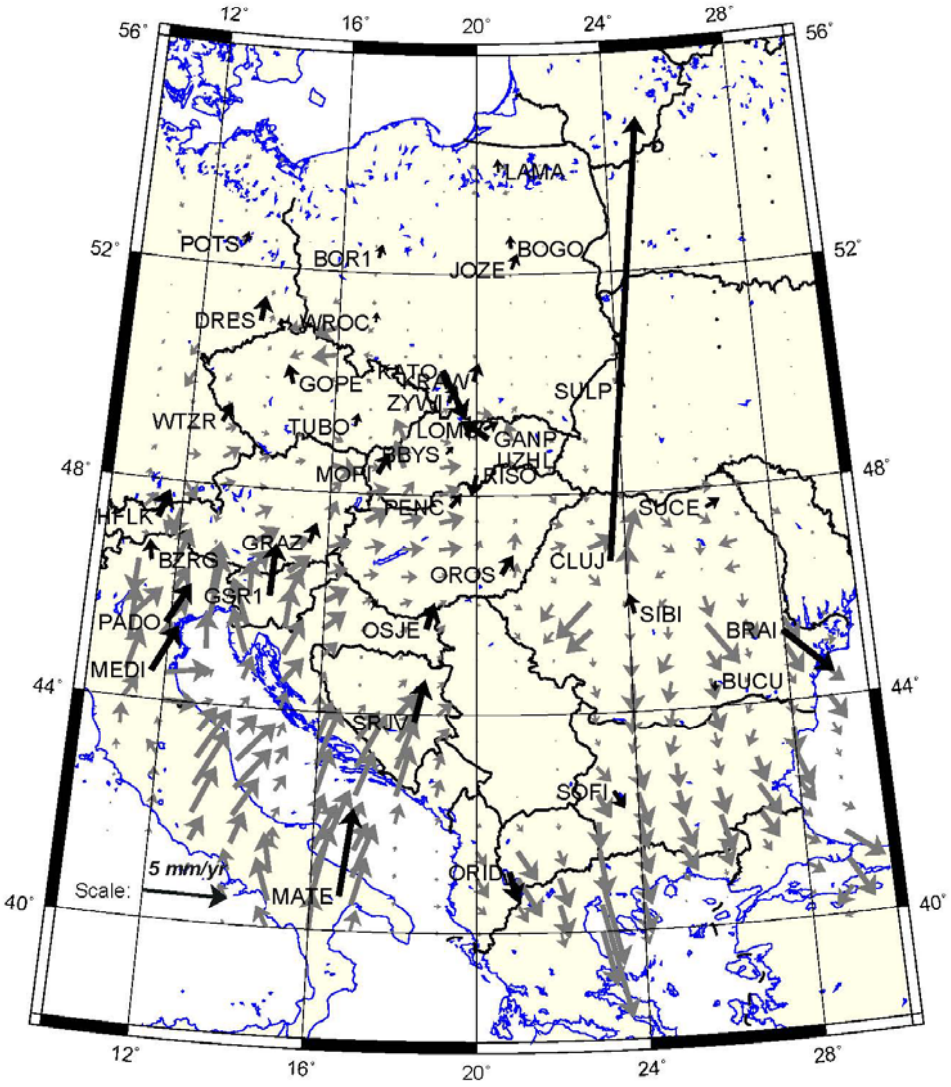
Residual station RMS of unit weight after adjustment of linear trend, offsets and seasonal variations

- The station time series are well represented by offsets, linear trend and annual and semi-annual variations.
- The characteristic RMS residuals from weekly coordinates are
  ~ 1 mm in horizontal components and
  ~ 2-3 mm in height.
- There are several stations significantly exceeding these values. It probably indicates the problematic behavior of the station.



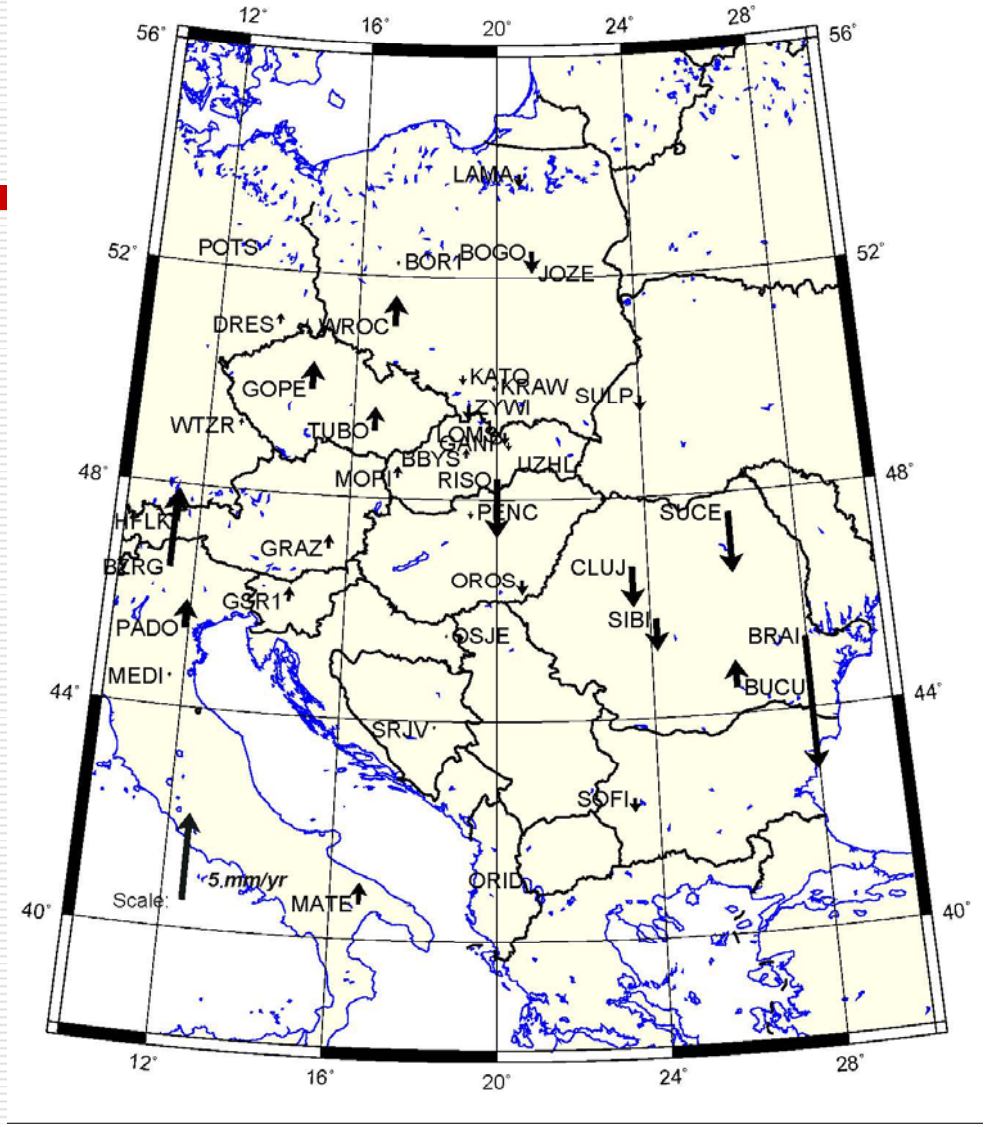
Horizontal velocities of CE permanent stations

- The velocities obtained from reprocessing of permanent GPS stations follow the general pattern resulting from combination of various regional and local sources.
- Only CLUJ and KATO represent strong local phenomena.
- We expect that new velocity combinations in CE will be even more relied on the reprocessing products



Vertical velocities of CE permanent stations

- The vertical velocities are extremely sensitive to offsets modeling and referencing to ITRF.
- Example: only one station in the set of reference sites may dramatically change the velocity pattern of the whole network (ITRF2005 v_{up}: JOZE +2.4, BOGO -1.8 mm/year)
- Extreme velocities: BZRG, RISO, Romania sites CLUJ, SUCE, BRAI



Comparison with ITRF2005 velocities

v_n, v_e and v_{up} components in mm/year

- 16 analyzed sites are included in ITRF2005 catalogue
- For 10 of them is the consistency better than 1mm/year
- For 6 sites differs our estimate from ITRF2005 for more than 1 mm/year
- Our estimates give generally smaller velocities in the up component than ITRF2005

GOPE 15.2 19.7 1.6 14.3 21.2 2.6	JOZE 14.4 21.0 0.7 14.2 20.7 2.4
MEDI 17.1 22.2 0.2 17.6 22.3 -2.3	SOFI 12.2 23.8 -0.8 11.9 23.9 0.8
WROC 14.4 20.1 1.7 15.0 20.3 3.8	WTZR 15.4 20.3 0.4 15.7 20.2 1.5

Stations with significant seasonal pattern (amplitudes > 2 mm)

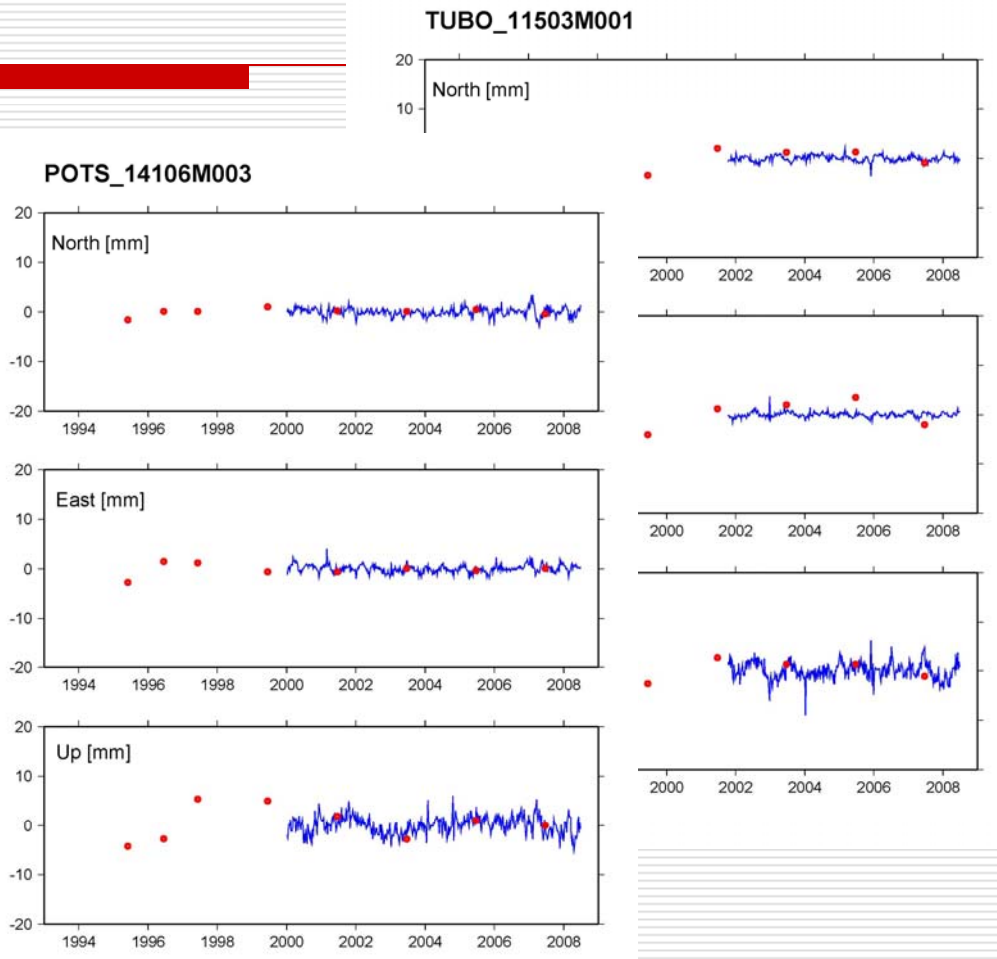
- Reprocessing significantly diminished the seasonal terms, namely in the up component.
- 16 stations show seasonal variations of one of the coordinated > 1mm. Only 6 stations have amplitude > 2mm.
- We believe that the observed seasonal changes are due to real station or environment phenomena and not the artifact of processing. No regional pattern is visible.

Amplitudes of annual terms (mm)

a_n	a_e	a_{up}	a_n	a_e	a_{up}
DRES			HFLK		
1.0	2.1	1.0	4.2	2.0	3.2
KRAW			MOPI		
2.4	1.2	1.7	0.8	0.8	3.0
ORID			PADO		
1.0	1.1	2.0	3.0	1.4	1.0

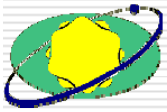
Consistency of permanent network solution and the CERGOP epoch coordinates

- The reprocessed permanent observations were combined with CERGOP epoch campaigns using the CATREF software
- Usually the consistency of both solutions is better than 1 mm, however for some stations exceeds 2-5 mm
- Residuals at POTS and TUBO are examples of perfect and less perfect consistency



Conclusions

- The main unresolved problem of the reprocessing of complete history is the spurious behavior of the series before 1999.5.
- The reprocessing of interval 1999.5 – 2008.5 yielded homogeneous coordinate time series with only several problematic items.
- The important issue is proper referencing to ITRF, especially for the up component and modeling of non-reported offsets.
- We believe that the estimated velocities and seasonal variations well reflect the reality and will be a serious background for geokinematic interpretation and combination with epoch data.



Thanks you for your attention !