Comparison of linear trend and periodic components of GPS time series for selected permanent stations of Central Europe.

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Models of GPS site movements

a) Linear

b) Periodic

c) Episodic displacement

\[ \Delta x \]
Input data

Coordinate Time Series in ITRS, extracted from weekly EUREF combined solution (SINEX files).
Data pre-processing (1)

\[
X_{2000} = (I + R)^{-1} \ast (X_{XX} - T)
\]

\[
\begin{bmatrix}
X_{2000} \\
Y_{2000} \\
Z_{2000}
\end{bmatrix} = \left(\begin{bmatrix}
D & -R3 & R2 \\
R3 & D & -R1 \\
-R2 & R1 & D
\end{bmatrix} + \begin{bmatrix}
T1 \\
T2 \\
T3
\end{bmatrix}
\right)^{-1} \ast \begin{bmatrix}
X_{XX} \\
Y_{XX} \\
Z_{XX}
\end{bmatrix}
\]
Data pre-processing (2)

\[
\begin{bmatrix}
\Delta N_j \\
\Delta E_j \\
\Delta U_j
\end{bmatrix} =
\begin{bmatrix}
-\sin B \cos L & -\sin B \sin L & \cos B \\
-\sin L & \cos L & 0 \\
\cos B \cos L & \cos B \sin L & \sin B
\end{bmatrix}
\begin{bmatrix}
\Delta X_{0-i} \\
\Delta Y_{0-i} \\
\Delta Z_{0-i}
\end{bmatrix}
\]
Data pre-processing (3)
### Linear trend estimation (1)

M-Estimation, „Bisquare” weighting function

\[
\begin{bmatrix}
a \\
b
\end{bmatrix}_i = \left( A^T P_i A \right)^{-1} A^T P_i Y
\]

\[
A = \begin{bmatrix}
t_1 & 1 \\
t_2 & 1 \\
\vdots & \vdots \\
t_n & 1
\end{bmatrix}
\]

\[
p_i = \frac{1}{m_{ji}^2 [mm]}
\]

\[
K_s = \frac{1}{0.6745 \cdot m}
\]

\[
\mathbf{u} = \frac{\text{resid}}{K_s}
\]

\[
P_i = \begin{cases} 
0 & \text{for } |u_i| > 1 \\
1 - \left( \frac{u_i}{4.685} \right)^2 & \text{for } |u_i| \leq 1
\end{cases}
\]
Linear trend estimation (2)

Estimated ITRF2000 velocity

Intraplate (local) velocity

NNR-NUVEL 1A [DeMets, 1994]
Determination of periodicity (1)

Residual (detrended) time series
Determination of periodicity (2)

Periodogram (FFT)
Determination of periodicity (3)

Annual signal

[Graph showing annual signal with data points and trend lines for North, East, and Height Components from 1997 to 2016.]
Determination of periodicity (4)

5-years signal
Determination of periodicity (5)

10-years signal
Determination of periodicity (6)
Comparison of the linear velocities

NUVEL1A-NNR
Comparison of the linear velocities

APKIM2000
Comparison of the linear velocities
Comparison of the periodicity parameters

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<tr>
<th>Site</th>
<th>0.5 year</th>
<th>1 year</th>
<th>3,5 years</th>
<th>5 years</th>
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Comparison of the periodicity parameters

ANNUAL PERIODICITY
Comparison of the periodicity parameters

3.5 YEARS PERIODICITY

Map showing locations and directions with labels such as POTS, DRES, GOPE, etc.
Comparison of the periodicity parameters

5 YEARS PERIODICITY
Comparison of the periodicity parameters

10 YEARS PERIODICITY

Magnitude 5 mm
North
East
Up
CLEANED time series
Residuals of cumulative coordinate/velocity solution based on weekly EUREF combined solution (outliers eliminated and discontinuities corrected) prepared for geokinematic interpretation.

Purpose:
Elimination of outliers and introduction of offsets indicated in the "RAW" time series.
Velocity estimation based on the cleaned time series.

The 'CLEANED' time series are computed using the CATREF software (developed by Z. Altamimi, IGN France).
The geodetic datum is defined by BOGO, BOR1, GRAZ, JOZE, KOSG, MATE, METS, ONSA, POTS, VILL and ZIMM stations.
Observations before GPS week 860 are not taken into account, because of the apparent coordinate jump caused by the introduction of the ITRF96 reference frame.
The detected outliers are eliminated and the offsets related to equipment changes are introduced at the time series combination. Tables containing the dates, the estimated values and the possible explanation both of the outliers and offsets are published.

Three types of the CLEANED time series plots are created and published:
Type 1: the eliminated outliers and offsets are indicated.
Type 2: De-trended version of Type 1, linear velocity term is removed and additionally the annual coordinate variation is estimated and plotted.
Type 3: same as Type 2, but the annual periodic term is removed.
EPN Special Project „Time Series for Geodynamics“

Type 1 Time series – WROC station

Created by A. Kenyeres  Version: 08/02/06

North-component

East-component

Up-component

\[ v_N = -0.27 \pm 0.07 \text{mm/y} \]
\[ v_E = -0.28 \pm 0.08 \text{mm/y} \]
\[ v_U = -0.67 \pm 0.28 \text{mm/y} \]
EPN Special Project „Time Series for Geodynamics”

Type 2 Time series – WROC station

Created by A. Kenyeres
Version: 08/02/06

WROC_12217M001

North-component:

East-component:

Up-component:

N_a=0.2 mm/ph=36.0  E_a=0.6 mm/ph=71.3  U_a=1.3 mm/ph=132.6
EPN Special Project „Time Series for Geodynamics”

Type 3 Time series – WROC station

Created by A. Kenyeres
Version: 08/02/06

WROC_12217M001

N_a = 0.2 mm/yr = 36.0
E_a = 0.6 mm/yr = -71.3
U_a = 1.3 mm/yr = 132.6
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Horizontal velocities

Vertical velocities
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Magnitudes and phases of annual signal - North component
EPN Special Project „Time Series for Geodynamics”

Magnitudes and phases of annual signal - East component
EPN Special Project „Time Series for Geodynamics”

Magnitudes and phases of annual signal - Up component
Conclusions

- Linear velocities of analyzed EPN stations related to NUVEL1A-NNR are congruent with known models except SNEC station.
- There is no clear correlation between velocities and general tectonics of Europe.
- Annual, 3.5, 5 and 10 years periods are dominant in the coordinate time series of analyzed GPS stations.
- Vertical amplitudes present much higher values than horizontal components.
- Periodicity parameters of individual components are not correlated for annual period but strongly correlated for longer periods.
- Presented results may be disturbed by influence of fixed station in EPN combined solutions.