RECENT GEOKINEMATICS OF SLOVAKIA BASED ON HOMOGENIZED SOLUTIONS OF PERMANENT AND EPOCH GPS NETWORKS

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Motivation

- The geokinematics of Slovakia is influenced by contact of three regions – Eastern Alps, Carpathians and Panonian Basin. It is situated at the north border of Adriatic microplate. In previous studies was proved the clockwise horizontal motion of the microplate.
- The regular geo-kinematic motivated regional and local GPS campaigns started in Slovakia already in 1993 and are still in some form continuing. Besides, a set of permanent stations is continuously operated in the region.
- Recently a significant effort has been paid to homogeneous reprocessing of all available data to obtain a complex picture of geokinematics of the region of interest.
- We will demonstrate the recent developments of the velocity field at the territory of Slovakia based on velocities from ~ 70 epoch/permanent sites.
Content

- Permanent stations and epoch networks in Slovakia - main information.
- Rigorous approach of velocity field adjustment using GPS reprocessing results and the SINEX based combination.
- Analysis of horizontal velocity field, smoothing, interpolation, strain analysis.
- Geokinematical implications – global tendencies and local phenomena.
- Discussion about quality and further consequences.
Smoothed intraplate velocities in Central Europe and East Balkan Region

- Signal part of horizontal velocities inferred from combination of continental, regional and local GPS networks.
- Main Feature: clock-wise rotation of Adria-Pannonian Basin and South Carpatian and Noth-East Grece
- The rotation rate is not uniform. The general pattern of velocities in Slovakia is influenced by strong smoothing applied indicates small eastward motion.
Data available

- Permanent stations in Slovakia and in regions close to Slovakia – EPN sites (MOPI, BBYS, GANP, TUBO, BUTE, PENC, UZHL, KRAW, ZYWI), DTG sites (LOMS, RISO). Observation interval from 3 to 12 years.
- Central Europe Geodynamic Reference Network (CEGRN), relevant are 8 epoch stations with 3 – 13 year observing interval.
- Slovak Geodynamic Reference Network (SGRN), ~ 40 epoch sites, 3-15 year observing interval.
- Local epoch monitoring network of Mochovce Nuclear Power Plant (EMO), 11 sites, 3-8 year interval.
- Local geodynamic epoch network in Tatra Mountains, 14 sites, 10 year of observations.
GPS sites in Slovakia with potential of velocity estimation

- The station geometry is not uniform. There are several gaps (south-west, north-west, close east of Slovakia). Mainly the low-land area are uncovered (complicated monumentation?)
- The backbone – the permanent stations are quite reasonably distributed.
The method applied for combination of networks velocities - ‘reprocessing/SINEX’ approach

- To obtain homogeneous velocity estimates the complete new network coordinate estimation and combination of all available partial solutions has to be performed.
- The optimum strategy is the recently applied ‘reprocessing’ approach which is based on new processing of all past observations with unified most sophisticated models and software.
- The combination of networks solutions and the velocity estimation should be rigorous using the full variance-covariance matrices and simultaneous processing of all data in one complex batch.
- Our combination is based on weekly SINEX coordinate files from permanent CE network reprocessing and SINEX coordinates files from epoch campaign solutions.
Reprocessing scheme applied for GPS networks in Slovakia

- Analyzing software: BERNESE V5.0
- Orbits and EOPs: The Potsdam/Dresden IGS reprocessing (Steinberger et al., 2006) until 2006.0. After 2006.0 the IGS routine processing products are used.
- Elevation mask 3 degrees (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.
- Combination procedure – CATREF software (Altamimi et al., 2009).
Consistency of permanent network solution and the CEGRN, SGRN, EMO and TATRY epoch coordinates – residuals from velocity estimates
Comparison of individual velocity estimates from analyses of reprocessed permanent CEPER, and epoch SGRN, CEGRN and TATRY networks (reduced for global EURA motion)
Intraplate horizontal velocities

- The CATREF based combination results in 3D velocities which were transformed to horizontal and vertical velocity constituents.
- Horizontal velocities related to ITRF2005 are reduced for APKIM2005d model.
- The magnitudes of intraplate horizontal velocities are below 3 mm/year, their accuracy is very variable. The velocity field does not follow any general pattern.
Effect of the plate motion model used for reduction of global horizontal plate motion

- As the intraplate velocities in Slovakia are small their general trend is strongly dependent on the plate motion applied for the reduction of Eurasia related velocities.
- We checked several ‘kinematic’ models (APKIM) and the geophysical NUVEL 1A models.
- We found that the global motion of Slovakia is best represented by APKIM2005d model.
- Consequence: It is dubious to geokinetically interpret the trends of intraplate motions if they are below 2 mm level.
Accuracy of intraplate horizontal velocities

- Accuracy of estimated velocities is very variable, from 0.1 mm/year to 0.8 mm/year, occasionally exceeding 1 mm/year.
- Of course, the permanent stations velocities are most reliable. The accuracy of epoch stations is varying, it is mostly dependent on the intervals among observing epochs.
Smoothing and interpolation of velocity field

- The scattered velocities with very variable accuracy are not suitable for direct interpretation and strain analysis.
- We applied a smoothing and interpolation procedure for horizontal and vertical velocities using the Least Squares Collocation (LSC) method.
- The LSC procedure respects the variable accuracy and geometry of input data.
- The parameters $\sigma^2$ and $c$ of the covariance function applied for signal modeling were chosen to fulfill the criterion to obtain $v^T C^{-1} v / (n-k)$ close to unity, where $v$ is the vector of residuals from the LSC filtering. In this manner the applied smoothing degree corresponds to the accuracy of input velocities.
Smoothing and interpolation of velocity field

Prediction and filtration of velocities using LSC

\[ \mathbf{v}_{\text{pred}} = \mathbf{C}_S \mathbf{C}_v^{-1} \mathbf{v}_{\text{obs}} \]

Covariance matrix of predicted signal

\[ C(d) = \sigma_{0s}^2 \exp(-c^2 d^2) \]

Used covariance function

Vpred – predicted velocities
Cs – covariance matrix of signal
Cv – covariance matrix of observed velocities
Vobs – observed velocities
Smoothed intraplate velocities and interpolation to 0.4 x 0.2 deg grid

- Plane smoothing by LSC – ‘signal’ part of the velocities
- The smoothed velocities are mostly less than 1.5 mm/year.
- No general pattern is visible, the relation to Adriatic microplate is not pronounced.
- The regions with locally dependent behavior can be distinguished.
Surface deformations inferred from interpolated intraplate velocities

Surface compression
Surface extension
Range: 0 – 100 nanostrain/year
(0-10 mm/100km/year)
Total shear deformation
☐ Several regions with significant deformations exceeding $2\sigma$ level are visible, however no general pattern can be recognized.
☐ The uncertainties of estimated deformations are relatively large ($\sim 30$ nanostrain) due to limited integration area used for strain evaluation.
Surface deformations inferred from interpolated intraplate velocities

Orientation and magnitude of main axes of extension and compression

- No deformations exceeding $2\sigma$ level are detected
- Only some local deformations are above $1\sigma$
- No general pattern are recognized
Smoothed intraplate velocities and interpolation to 0.4 x 0.2 deg grid - new estimate with more stronger smoothing of velocities

- We applied the scaling of velocity uncertainties due to colored noise of GPS long-term monitoring – factor 4 for permanent and factor 2 for epoch stations.
- The re-weighting lead to covariance function with stronger smoothing effect.
- Eastward and westward tendencies as well as counter clock-wise trend < 2 mm/year are dominating
Surface deformations inferred from interpolated intraplate velocities – stronger smoothing

**Surface compression**
**Surface extension**
Range: 0 – 20 nanostrain/year
(0-2 mm/100km/year)

**Total shear deformation**
- No significant compression or extension exceeding 2σ level are visible.
- The significant ~30 nanostrain/year shear deformation with regional pattern is dominant in Central Slovakia.
Surface deformations inferred from interpolated intraplate velocities

Orientation and magnitude of main axes of extension and compression

For the Central Slovakia the north-south compression and east-west extension is characteristic
Conclusions

- We performed almost complete reprocessing of all relevant GPS data available in Slovakia for velocity evaluation. The reprocessing was followed by 3D velocity estimates using the SINEX based combination procedure.
- The RMS of velocity amplitudes are from 0.1 mm/year to 0.8 mm/year for majority of stations. However this estimate is too optimistic and introduction of the colored noise model is necessary. We applied the scaling of the uncertainties of velocities by factor 2 and 4.
- The regional trends in the velocities are visible when the stronger smoothing is applied. They are related to significant shear and linear compressions and extensions mainly in Central Slovakia. The relation with Adria microplate has still to be investigated.
Thank you for your attention!