First results and experience from determination of the new Slovakian ETRS89 reference frame - SKTRF09

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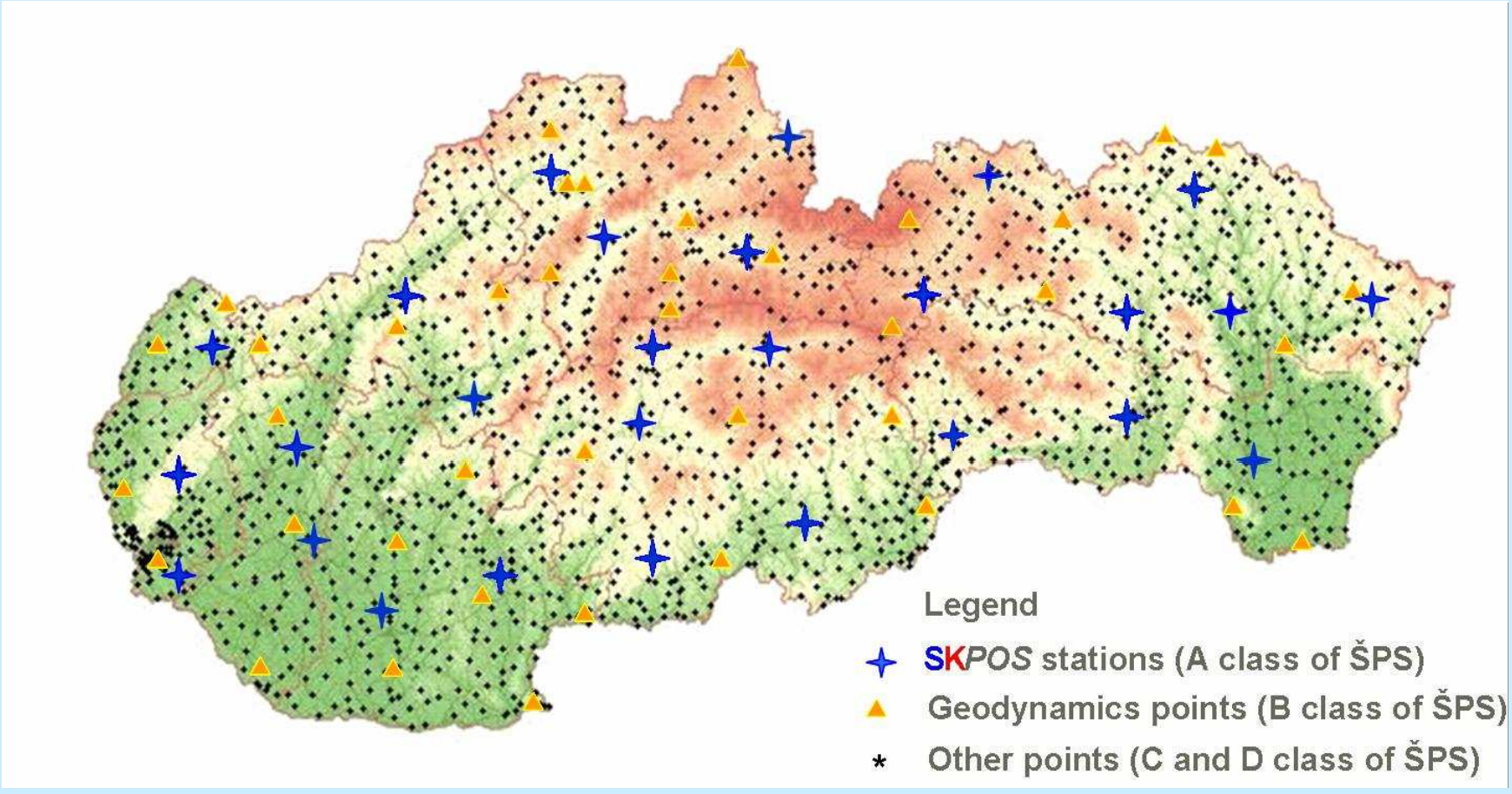
Motivation

- **Year 2009 (from the geodetic point of view)**
  1) SK*POS* – Slovakian positioning service celebrate his 3rd anniversary
  2) 9th epoch campaign measurement on the geodynamic points (SGRN network) across whole country
- **Decision** to perform revision of the national geodetic controls (quality and homogeneity evaluation)
- **Result** – necessity of the new reference frame determination – SKTRF09

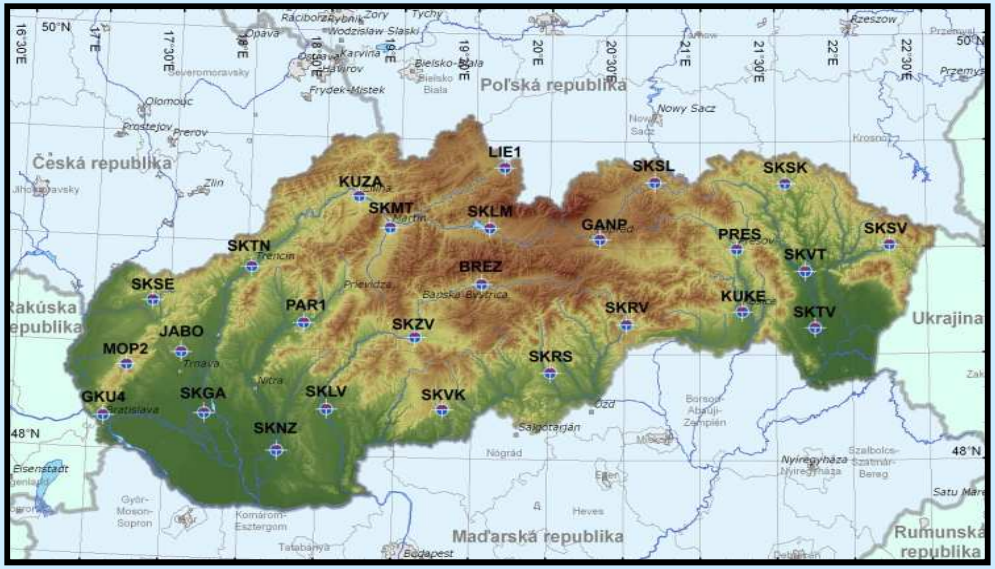
Geodetic controls in Slovakia
ETRS89 realization

- **National spatial network (ŠPS)** = cca 1700 points
  - Active part (permanent stations)
  - Passive part



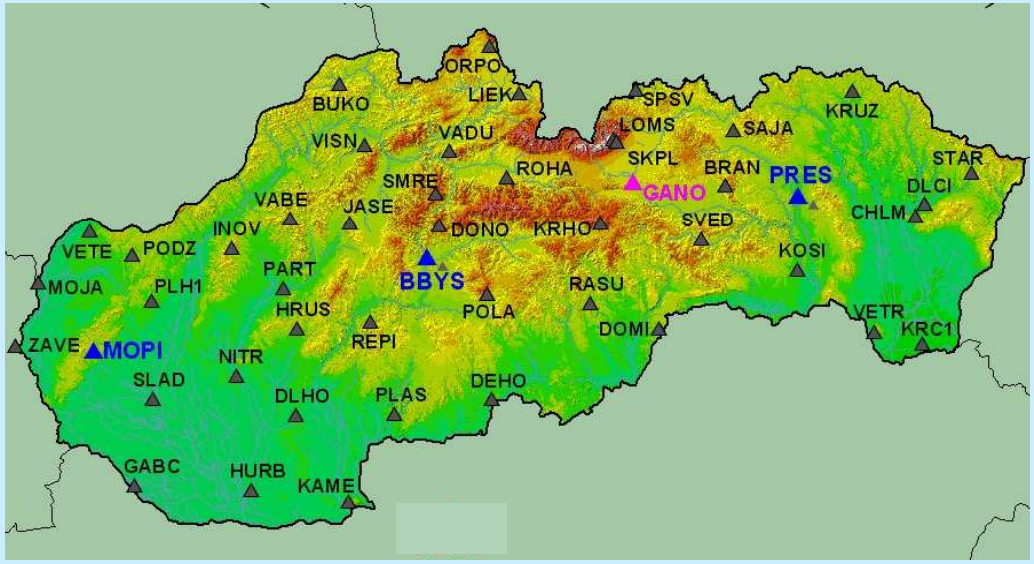
SKPOS
Short overview

- Totally 26 permanent stations
  - All 26 are GPS+GLONASS
- Stabilization
  - 22 stations have force centering stabilization to the roofs,
  - 4 stations stabilized as deep pillar
- SK*POS* is a member of *EUPOS*
  - Followed *EUPOS* standards



Passive part of the geodetic controls
Basic information

- B class or SGRN points (cca. 50 points)
  - force centering stabilization to bedrocks
  - for national reference frame realization as well as for geodynamics purposes
  - measured mostly biyearly from 1993 as epoch campaigns



- C and D class points
  - simple stabilization, surveying marks
  - determined and derived from B class points

Revision of the geodetic controls

Geodetic controls	Reference frame	Epoch	Antenna phase center model	Input data time span
Active part (SK*POS*)	ETRF2000	2006.636	relative	GPS week 1380-1386
Passive part (Gedynamics points)	ETRF2000	1997.000	relative	Campaigns 93, 95, 98, 99, 01, 03, 05, 07

Result – **necessity of the new reference frame determination**

New reference frame determination
Basic steps

1) SK*POS* stations coordinates determination from the whole observations from the beginning of the service
2) Reprocessing of the passive part of the geodetic controls
   - geodynamics campaigns (SGRN campaigns)
   - other relevant quality campaigns and measurements (e.g. LGS Tatry, WHS, CERGOP)

- Important condition: New reference frame have to follow the new trends from computations and analysis and have to be defined in the recommended ETRF2000 and the epoch will be defined by mean epoch of whole SK*POS* observations

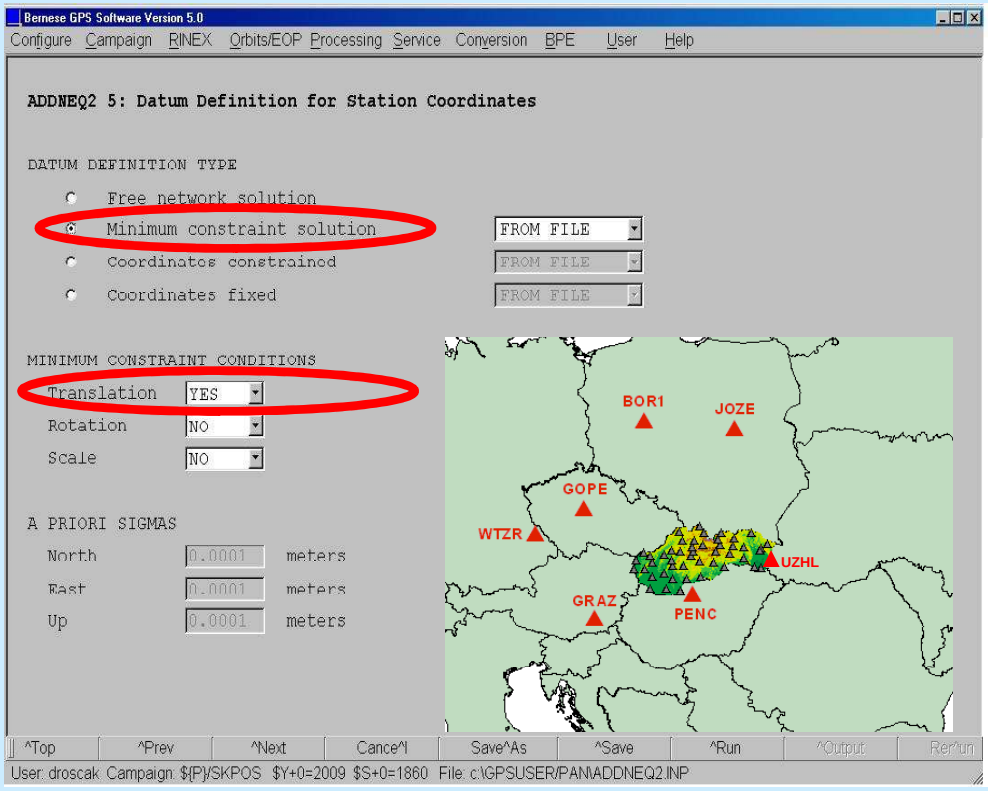
GNSS data reprocessing comparison

- Bernese software 5.0
- EPN strategy (EPN guidelines for ETRS89 densification)

	Input data	Antenna phase center model	Adjustment	Ephemeris	Result
Active part (SK*POS*)	GPS weeks 1400-1556	absolute	Minimal constraint condition	IGS05	ITRF2005 for particular weeks
Passive part	All relevant campaigns	absolute	Minimal constraint condition	PDR, IGS05	ITRF2005 for particular campaigns

GNSS data reprocessing
minimal constraint

- Bernese software 5.0
  - Daily processing - free network solution constraint to one reference station
  - Daily normal equations stacking with minimal constraint – no net translation condition on selected A class IGS/EPN stations
- Result
  - ITRF2005 coordinates for particular week or campaign middle epoch (XYZ)



Residuals creation

- MathCAD 14 software
  - Elimination of the Eurasian plate velocity - (Memo, Altamimi et. al.)

$$\mathbf{X}^{Corr}{}_i(t) = \mathbf{X}_i(t) - \mathbf{v}_i^{ITRF\,2005}(t)$$

$$d\mathbf{X}_i(t) = \mathbf{X}^{Corr}{}_i(t) - \overline{\mathbf{X}}^{Corr}{}_i(t)$$

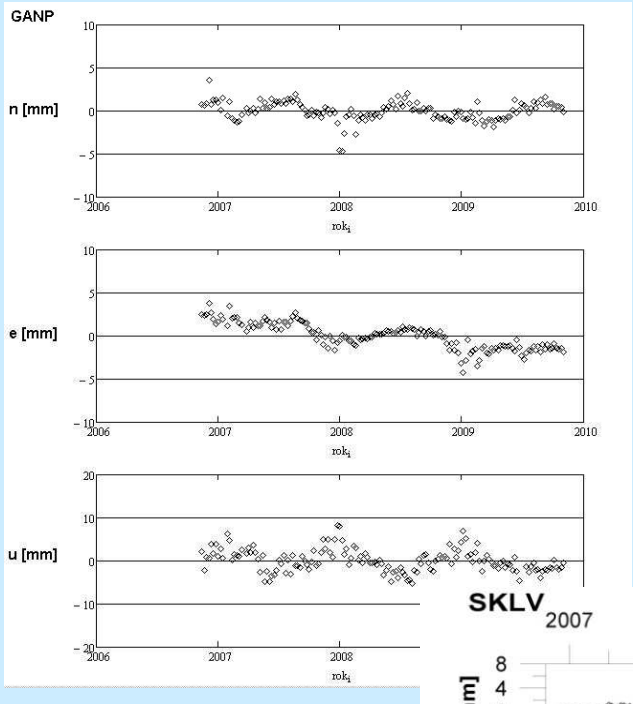
  - (XYZ) weekly or campaign coordinates transformation to topocentric coordinate system (neu)

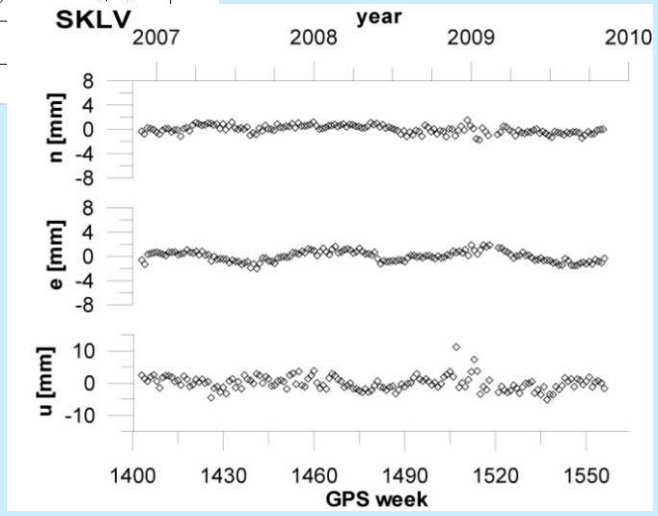
$$d\mathbf{N}_i(t) = \begin{pmatrix} dn_i(t) \\ de_i(t) \\ du_i(t) \end{pmatrix} = \mathbf{R}(B_i, L_i) \cdot d\mathbf{X}_i(t)$$

  - Creation of the residual time series (neu in ETRF2000(R05))

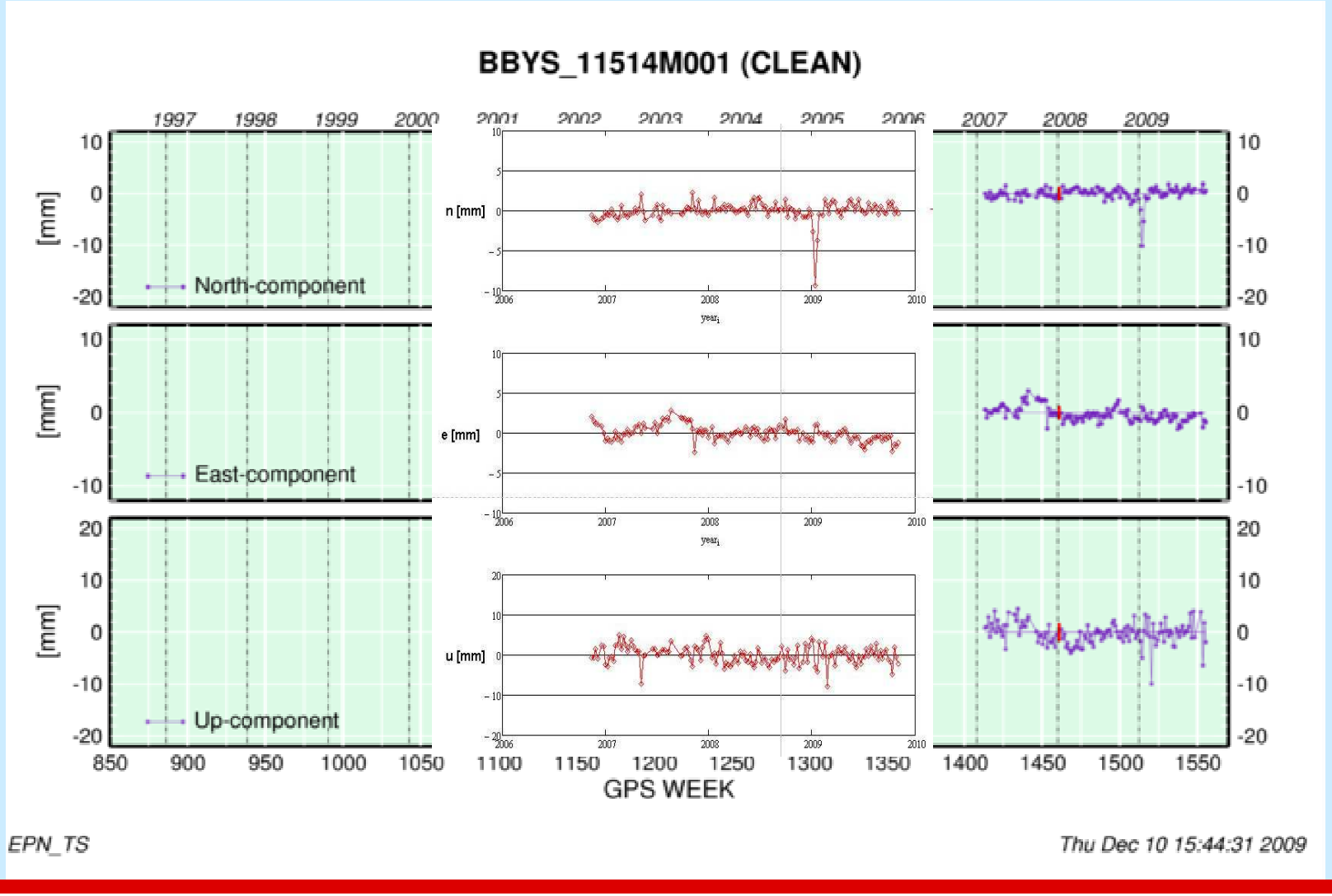
Time series monitoring

- Time series plot and analysis (MathCAD 14 software)
- Residual check for the quality and reliability (bad data excluding)
- Time series decomposition:
  - Trend
  - Season variation
  - Periodic variation





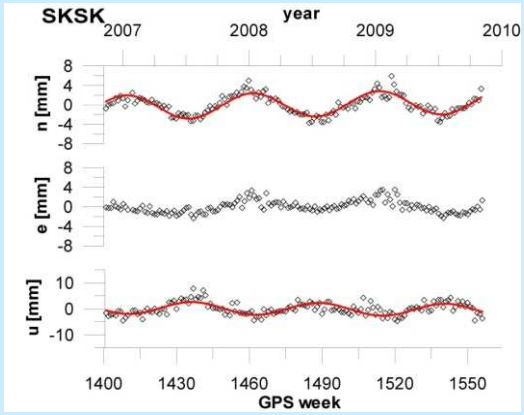
Residual correction check with EPN solution



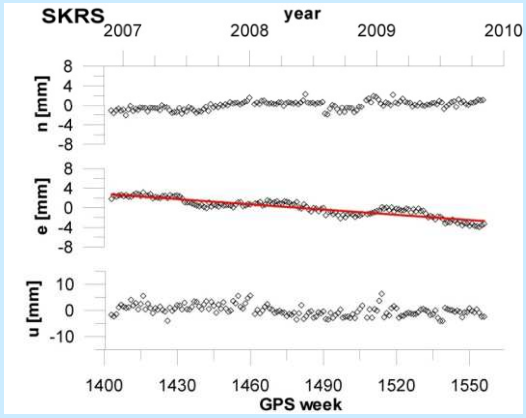
Time series monitoring

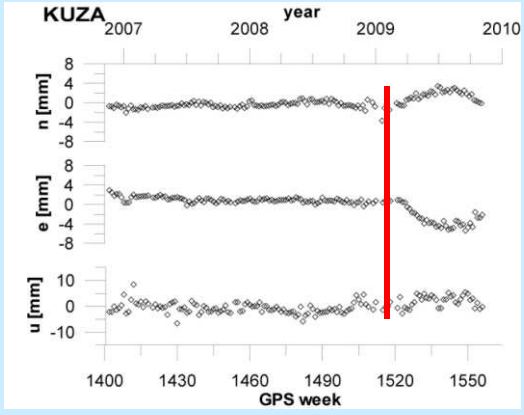
- Station classification depending on the behavior
  - trend
  - seasonal variation
  - anomaly behavior
  - “stabile” station (90 percent of SK*POS* stations)

Periodic

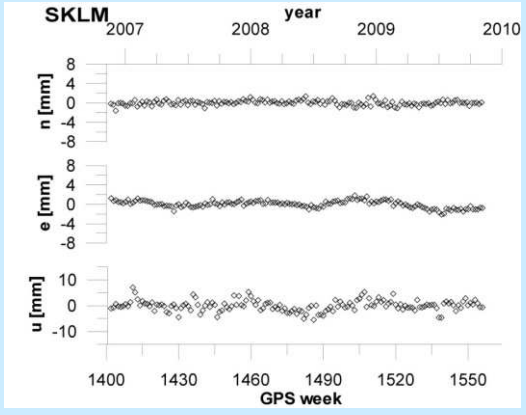


Trend



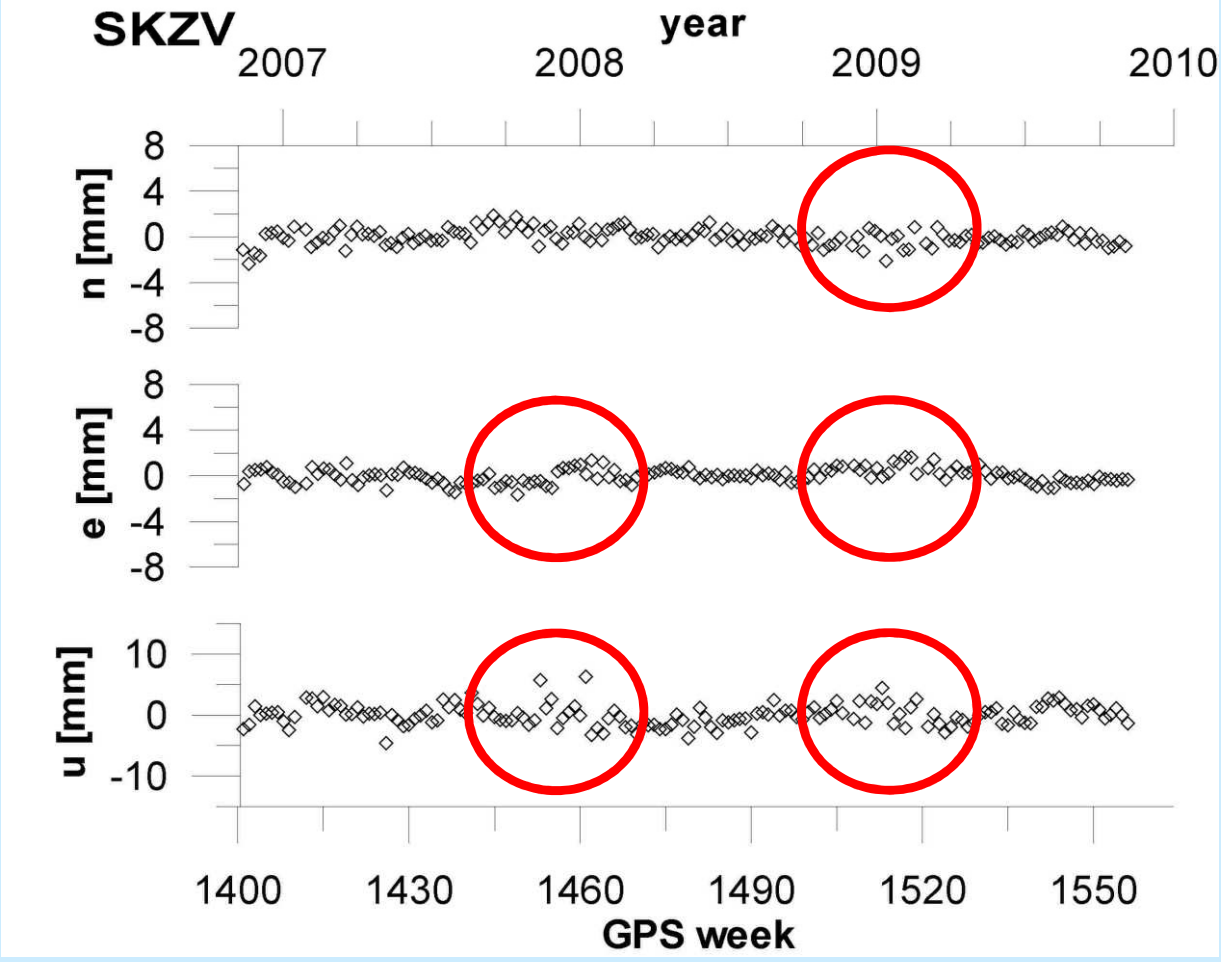


Anomalous



„stabile“

Influence of the winter (e.g. snow, ice) = bigger variation

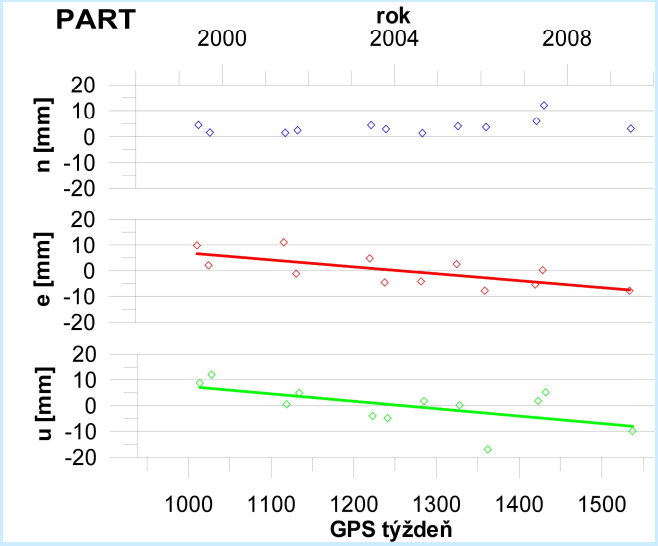


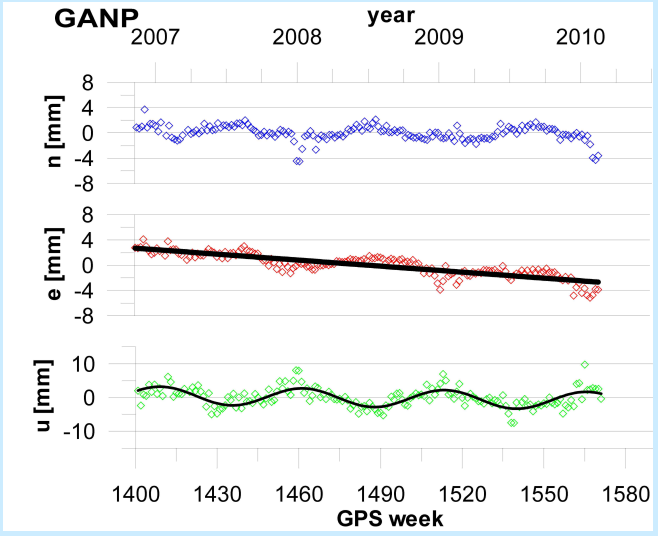
Final coordinates determination

- Bernese software 5.0
  - Problematic weekly or campaign parts exclusion (detected by time series monitoring)
  - normal equations combination (ADDNEQ2) with MC condition to IGS/EPN A class points
  - 2008.5 epoch coordinates of IGS/EPN A class points determined from ITRF2005 epoch 2005.0 coordinates and velocities file
  - Quality check - individual weeks comparison
- MathCAD 14
  - Transformation ITRF2005 → ETRF2000 (R05)
    - 14 parametric transformation (*Memo*)
- Homogenous set of coordinates – **ETRS89 ETRF2000(R05) epoch 2008.500**

Velocities estimation

- Another product from the time series monitoring
- Trend = station velocity
  - Determined by linear regression in MathCAD14
    - Horizontal component
    - Vertical component

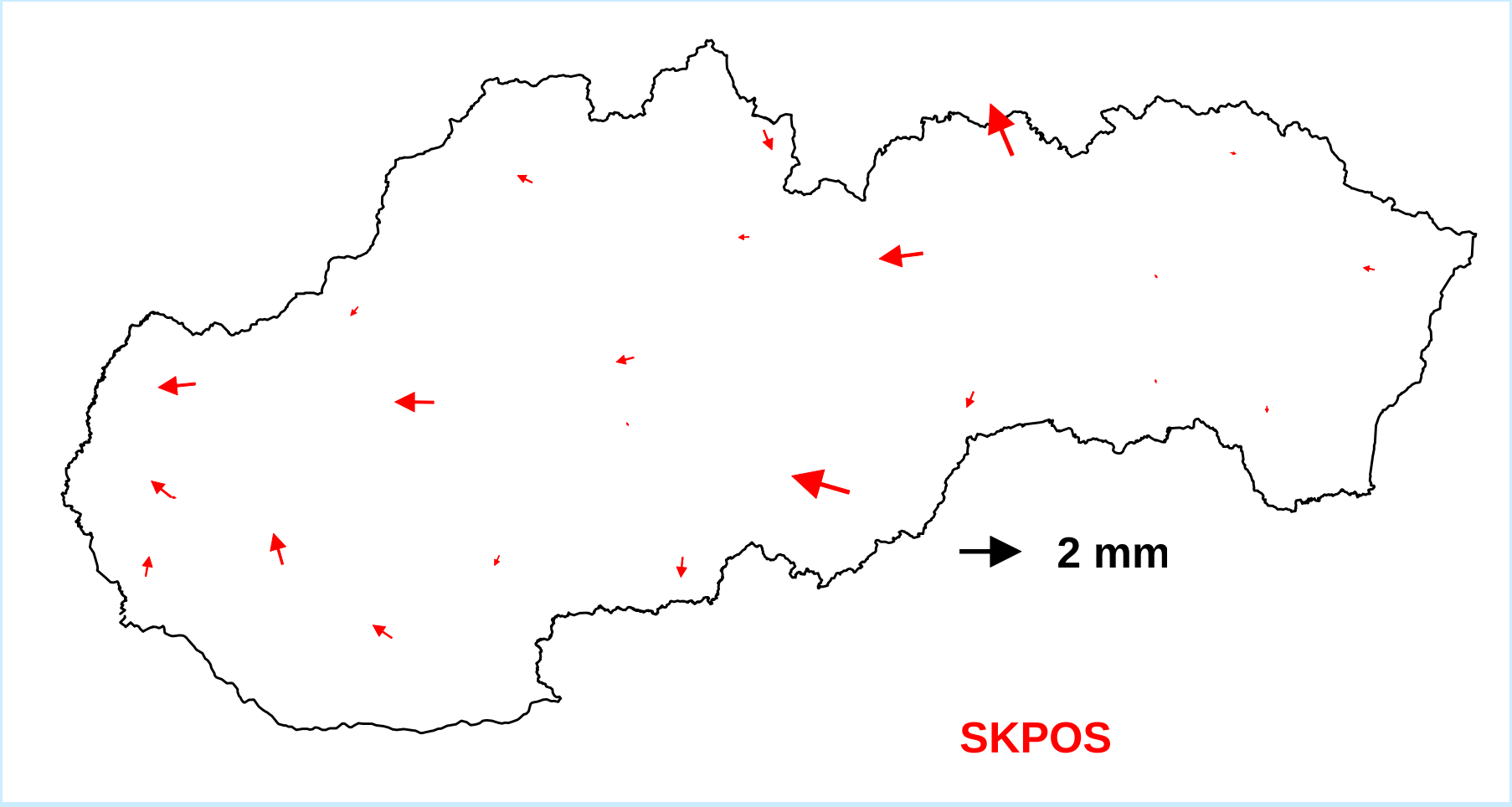




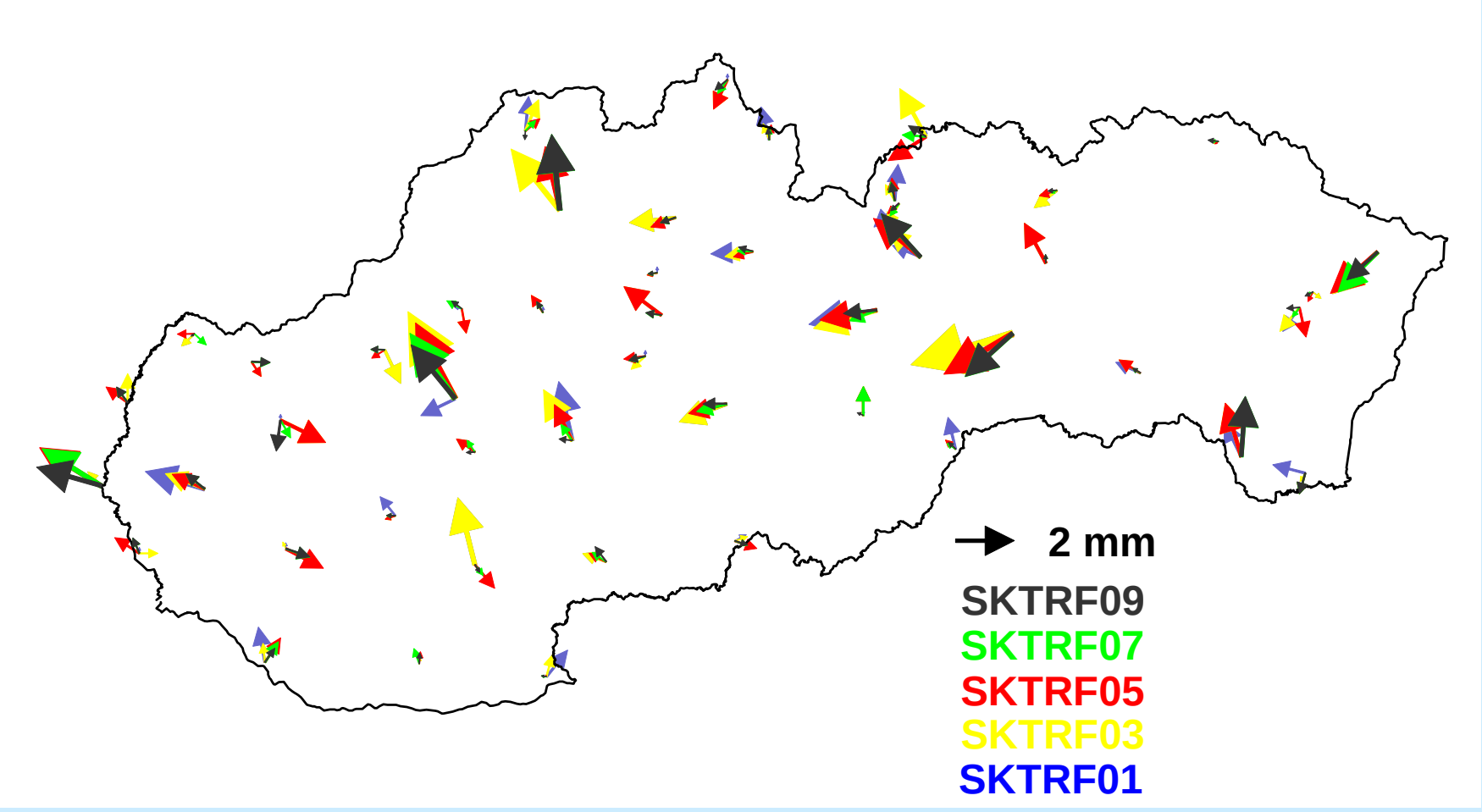
Velocities estimation
important remarks, questions

- Permanent stations velocities (trend)
  - Behavior of the antenna handle/monument or ground movement (intraplate velocity)?
  - Velocity estimation just from 3 years time interval – sufficient interval or not?
- Geodynamic SGRN points (B class of the geodetic controls)
  - Usage of different kinds of equipment during campaigns = jumps (impossible to determined)
  - Campaigns takes only 3-6 days – sufficient?
  - Quality of SGRN velocity equal to permanent stations velocity?

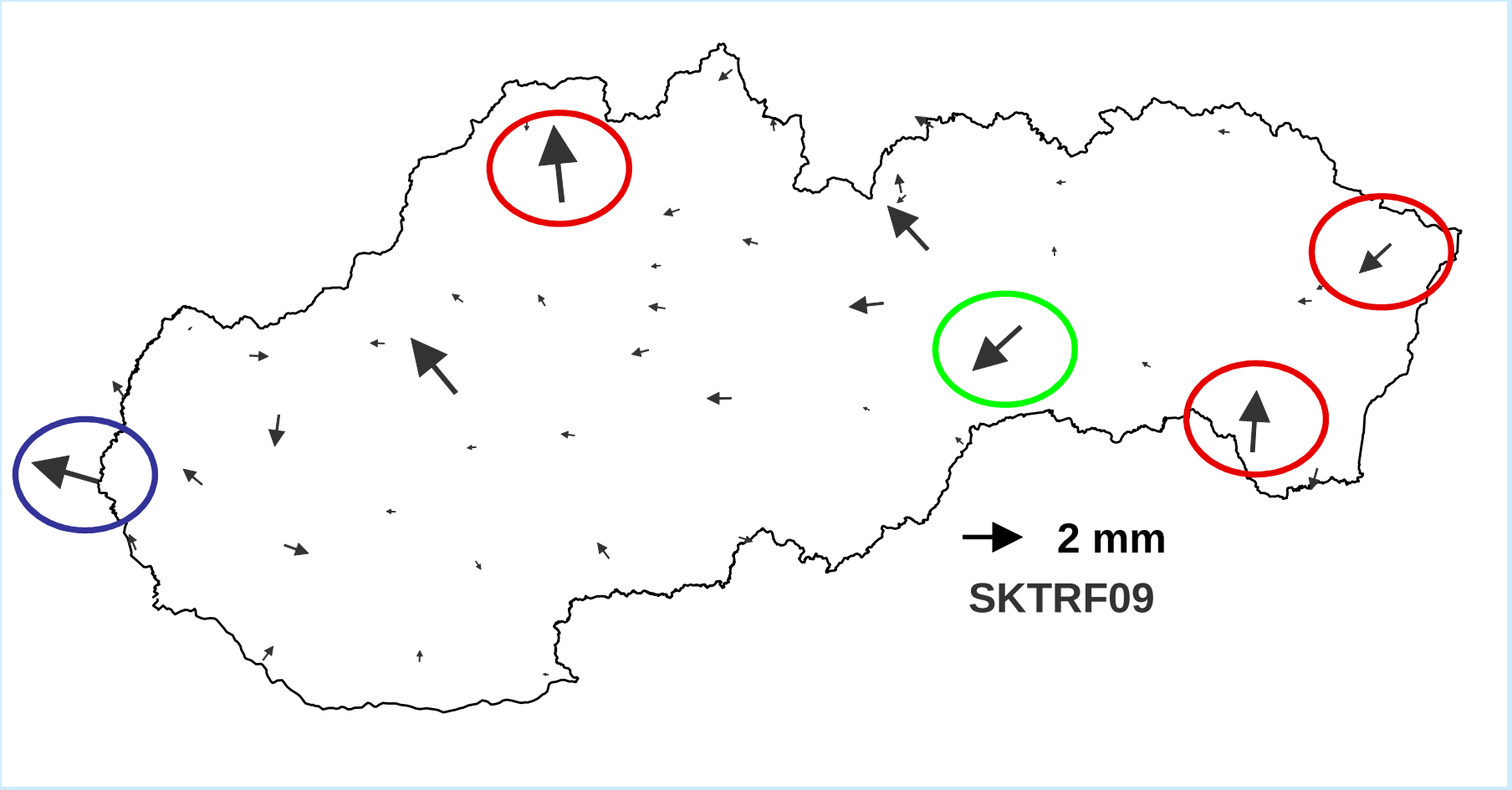
SKPOS station velocities
velocity field from 3 years



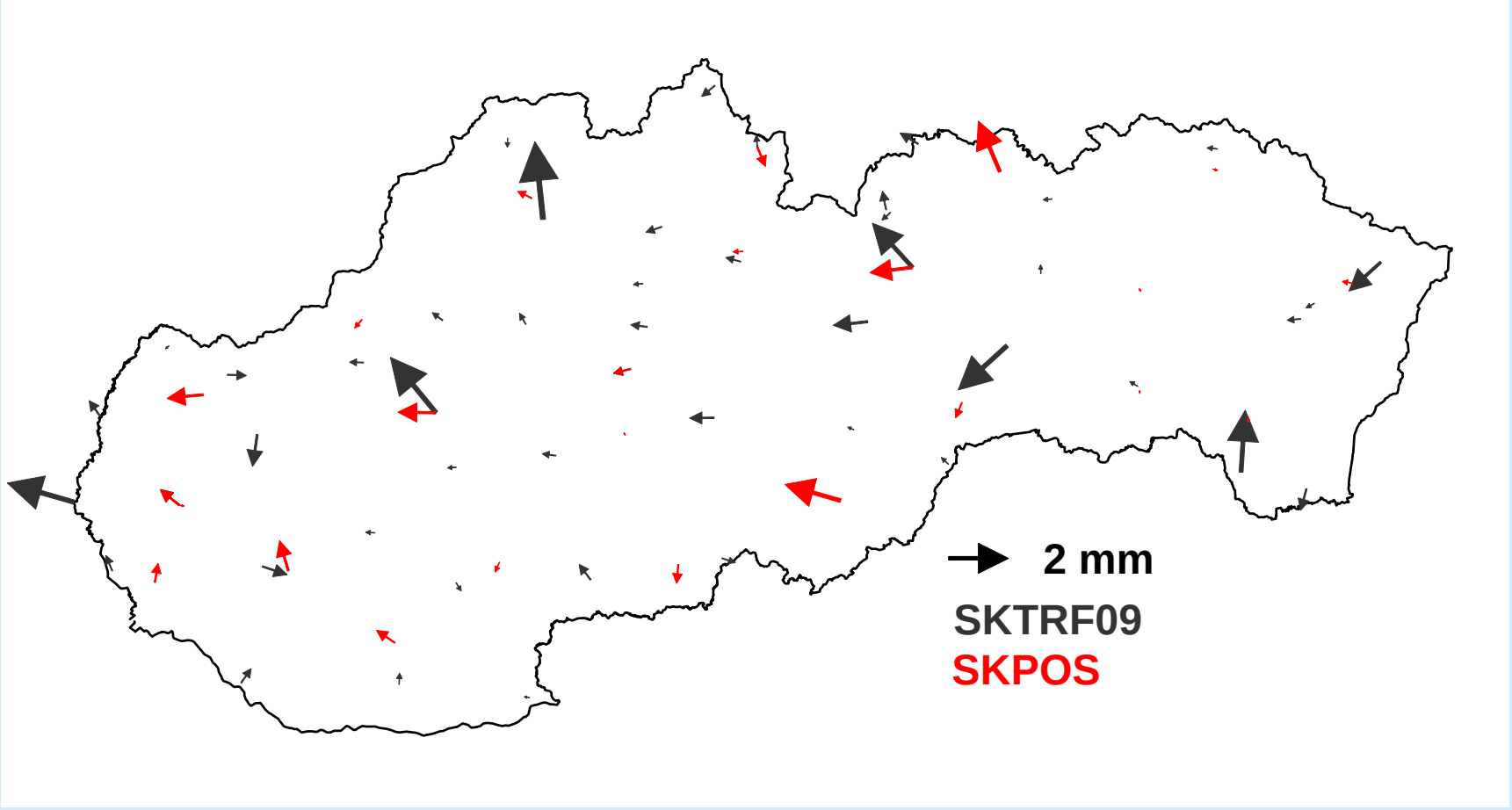
SGRN points velocities
evolution from 2001 to 2009



Geodynamic points velocities the last realization



SKPOS + SGRN points velocity field



Next steps for the near future

- Evaluation of all computations
- Quality verification

- Next EUREF TWG meeting
  - Ask for coordinates validation

- SKTRF09 – The new Slovakian ETRS89 reference frame introduction
  - Homogenous (active and passive part)
  - High quality
  - Satisfied users and customers

Thank you for your attention

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