SITE VELOCITIES IN CENTRAL EUROPE OBTAINED FROM EPOCH OBSERVATIONS 1994-2003 WITHIN THE CERGOP AND CERGOP-2/ENVIRONMENT

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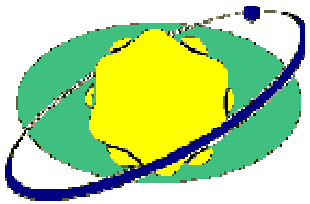

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Acknowledgement

- The epoch observations within the CERGOP and CERGOP-2 from 1994 to 2003 are results of scientific, organisational and technical activities of tens specialists from 12 Central European countries
- Without ambition to be complete I would like to mention Peter Pesec, Istvan Fejes, Ewald Reinhart, Janusz Sledzinski, Guenter Stangl, Georgi Milev, Matthias Becker, Alessandro Caporali, Francesco Vespe, Jaroslav Simek, Dumitru Ghitau, Marcel Mojzes, Florjan Vodopivec, Fedir Zablotskij, Medzida Mulic, Jerzy Rogowski, Ambrus Kenyeres, Miljenko Solaric, and others which contributed significantly to organization, observation, processing and analysis of GPS data used in this presentation

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CONTENTS

- Central Europe Regional Geodynamics Project – CERGOP and CERGOP-2 /Environment
- EPOCH GPS campaigns in framework of CERGOP and CERGOP-2 from 1994 to 2003
- Mathematical background for velocity estimation and referencing principles
- Results obtained from nine-year observing span, velocity field, quality
- Effects of referencing and of interval of observations

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CENTRAL EUROPE REGIONAL GPS GEODYNAMICS PROJECT (GERGOP)

- Initiation of common project in 1993 - cooperation of 11 countries, 1st phase till 1998
- 2nd phase - CERGOP-2: „A multipurpose and Interdisciplinary array for Environmental research in Central Europe“, 2003 – 2006 (14 countries)
- Some of the main objectives: providing precise geodetic frame for geodynamic research in the region, estimation of 3D velocities in the area, derivation of geo-kinematical models
- Experimental basis for geo-kinematical investigations: Central European GPS Geodynamic Reference Network (CEGRN), untill 2004 observed for 7 times

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CENTRAL EUROPEAN GPS GEODYNAMIC REFERENCE NETWORK

- CEGRN epoch observing campaigns – continual activity since 1994
- Progressive augmentation of number of observed sites
- CERGOP database – FOMS, Austria
- Epoch campaigns analysis at 2-4 processing centres, combination of 1994 - 2001 campaigns at FOMS, 2003 at SUT, Bratislava
- Outputs available: combined solutions from epoch campaigns – coordinates and covariance matrices in SINEX format
- CEGRN observations at some sites are covering 9-year span

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COMBINED SOLUTIONS OF CEGRN AVAILABLE FOR VELOCITY ESTIMATION

Observing campaign	Epoch of observation	No. of processed sites in the final solution	No. of solutions forming the network combination	Rms of unit weight for the combined solution (m)
CEGRN'94	1994.34	27	3	0.0023
CEGRN'95	1995.41	36	3	0.0029
CEGRN'96	1996.45	37	3	0.0030
CEGRN'97	1997.43	45	4	0.0026
CEGRN'99	1999.46	61	3	0.0024
CEGRN'01	2001.47	55	2	0.0027
CEGRN'03	2003.46	72	4	0.0024

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CEGRN STATUS IN 1995

- Totally 32 stations
- 10 permanent stations
- 22 epoch stations
- CEGRN processed with additional 4 IGS stations (KOSG, METS, ONSA, ZIMM)

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CEGRN STATUS IN 2003

- Totally 68 stations
- 28 permanent stations
- CEGRN processed with additional 4 IGS stations (KOSG, METS, ONSA, ZIMM)

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Mathematical model for velocity estimation

- **Simultaneous estimation of site coordinates and site velocities**
- **„Observations“: coordinates from combined solutions of m=7 CEGRN epoch campaigns $\mathbf{x}_{ti}$ and ITRF velocities $\mathbf{v}_{ref}$**
- **Parameters: site coordinates y , velocities $\mathbf{v}_y$ and transformation parameters Θ_i**

$$\begin{bmatrix} \mathbf{x} \\ \mathbf{v}_{ref} \end{bmatrix} = \begin{bmatrix} \mathbf{x}_{t_1} \\ \mathbf{x}_{t_2} \\ \vdots \\ \mathbf{x}_{t_m} \\ \mathbf{v}_{ref} \end{bmatrix} = \begin{bmatrix} \mathbf{I} & \mathbf{D}_1 & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{I} & \mathbf{D}_2 & \mathbf{T}_2 & \cdots & \mathbf{0} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \mathbf{I} & \mathbf{D}_m & \mathbf{0} & \cdots & \mathbf{T}_m \\ \mathbf{0} & \mathbf{E} & \mathbf{0} & \cdots & \mathbf{0} \end{bmatrix} \begin{bmatrix} \mathbf{y} \\ \mathbf{v}_y \\ \Theta_2 \\ \vdots \\ \Theta_m \end{bmatrix} + \begin{bmatrix} \boldsymbol{\varepsilon}_{x_1} \\ \boldsymbol{\varepsilon}_{x_2} \\ \vdots \\ \boldsymbol{\varepsilon}_{x_m} \\ \boldsymbol{\varepsilon}_v \end{bmatrix}$$

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Mathematical model for velocity estimation

- **Reference velocities: 8 IGS stations with velocities derived at least from two space techniques (GPS and SLR or VLBI) – BOR1, GRAZ, KOSG, MATE, METS, WTZR, ONSA, ZIMM**
- **Covariance matrices of combined epoch solutions are scaled with variance component factors ϑ_i**

$$\Sigma = \mathrm{var}\begin{pmatrix} \mathbf{x} \\ \mathbf{v}_{ref} \end{pmatrix} = \begin{bmatrix} \vartheta_1\Sigma_{xt\,1} & \mathbf{0} & \cdots & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \vartheta_2\Sigma_{xt\,2} & \cdots & \mathbf{0} & \mathbf{0} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \mathbf{0} & \mathbf{0} & \cdots & \vartheta_m\Sigma_{xt\,m} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \cdots & \mathbf{0} & \Sigma_{v\,ref} \end{bmatrix}$$

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VELOCITY ESTIMATION FEATURES

- Selection of sites where the velocity is estimated: only sites where more than 3 relevant epoch coordinates are available and are covering at least 4 years span
- Only one variance factor ϑ common for all epoch combined solutions is estimated
- Two alternatives of reference velocity field: ITRF2000 and ITRF2000-NUVEL NNR
- Statistics: 850 “observations”, 51 non-reference sites, 378 parameters

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INTRAPLATE VELOCITIES ESTIMATED FROM CERGOP EPOCH OBSERVATIONS 1994.4 - 2003.0

- Main features:
- Velocities of majority of stations are oriented to north with 2-5 mm/year amplitude
- Exceptions:
  (1) Part of Balkan stations
  (2) Some „continental“ stations – SNIE, GRMS, DISZ

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INTRAPLATE VELOCITIES WITH 2σ CONFIDENCE ELLIPSES

- Significant differences among accuracy of velocities
- Reasons:
- (1) time span of site re-observations
  (2) quality of station observations
  (3) number of epoch campaigns
- Consequences: classification of CEGRN stations

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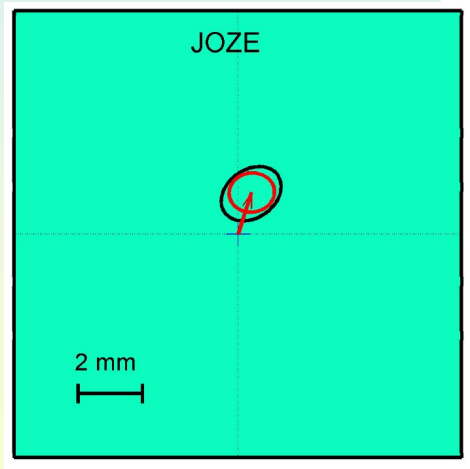
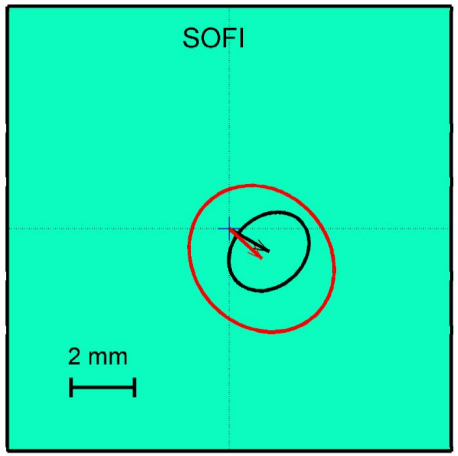
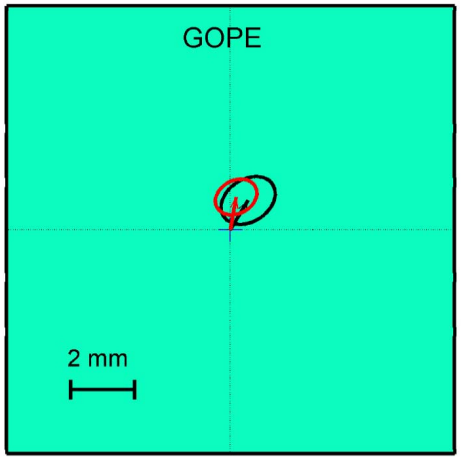
Comparison of estimated CEGRN velocities with ITRF velocities for non-reference sites

- 11 non-reference CEGRN sites have velocity in ITRF2000
- At 8 sites is very good consistency between CEGRN and ITRF2000 velocities
- **CEGRN velocities** and **ITRF2000 velocities** with 2σ confidence (EURA plate motion removed):







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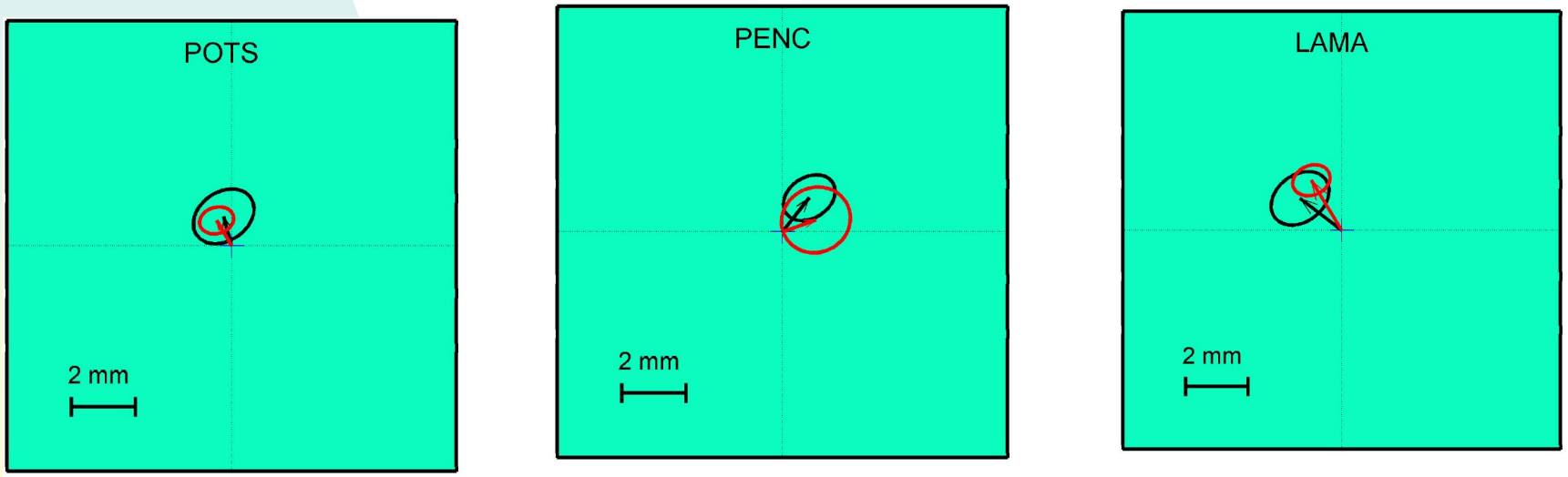
Comparison of estimated CEGRN velocities with ITRF velocities for non-reference sites

- **CEGRN velocities and ITRF2000 velocities with 2σ confidence (EURA plate motion removed):**



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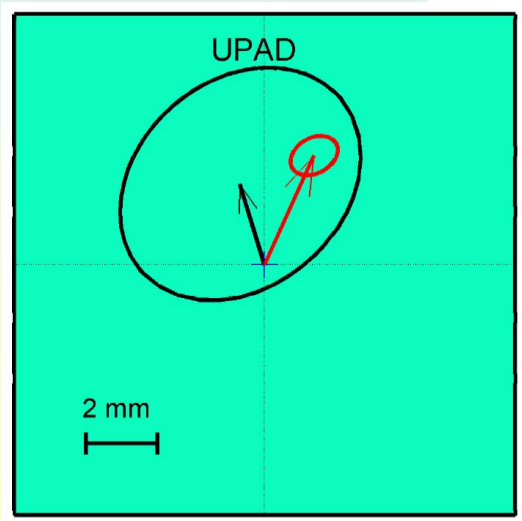
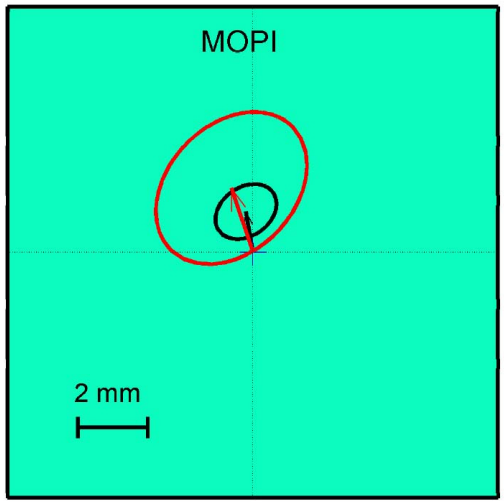
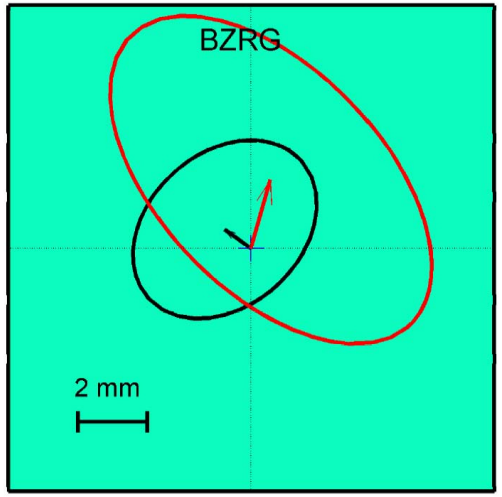
Comparison of estimated CEGRN velocities with ITRF velocities for non-reference sites

- Only at 3 sites larger differences between CEGRN and ITRF
- For UPAD has CEGRN much larger confidence ellipse than ITRF.
- MOPI and BZRG ellipses smaller than ITRF – reason: CEGRN has longer observation history
- **CEGRN velocities** and **ITRF2000 velocities** with 2σ confidence:







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EFFECT OF EXTENSION OF NUMBER OF REFERENCE STATIONS

- Alternative solution: all 17 sites processed within CEGRN with ITRF2000 velocities are used for reference
- Blue vectors – 8 reference stations
- Black vectors – 17 reference stations
- Not noticeable differences at non-reference stations
- Differences are observed only at some references stations

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INTRAPLATE VELOCITIES WITH 3σ CONFIDENCE ELLIPSES: SITES WITH „HIGHER QUALITY VELOCITIES‘

- 27 CEGRN sites observed more than 3 times, time span more than 6 years
- Accuracy of velocity coordinate components (1σ)
- North-south: 0.3 - 0.9 mm/year
- East-west: 0.2 - 0.7 mm/year
- Height: 1.4 - 2.5 mm/year

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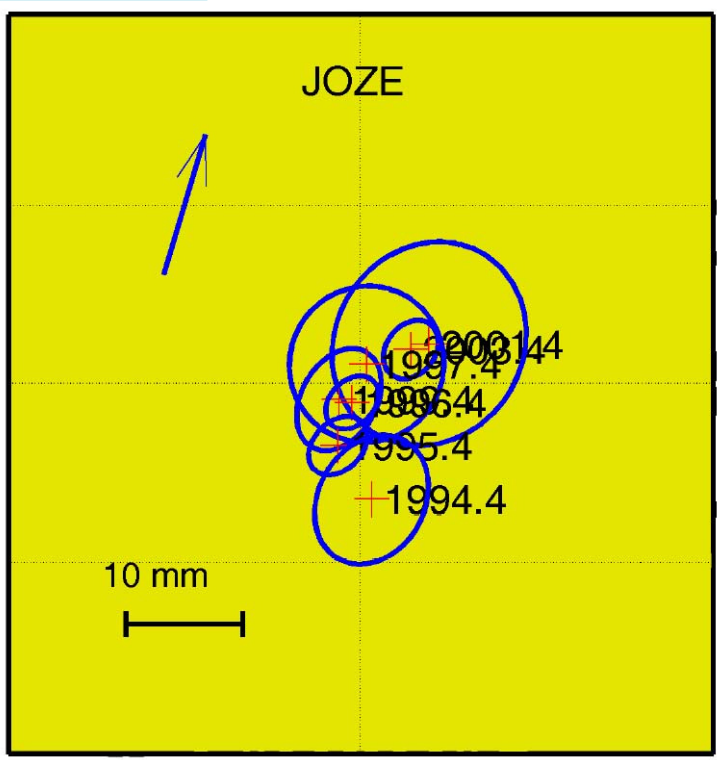
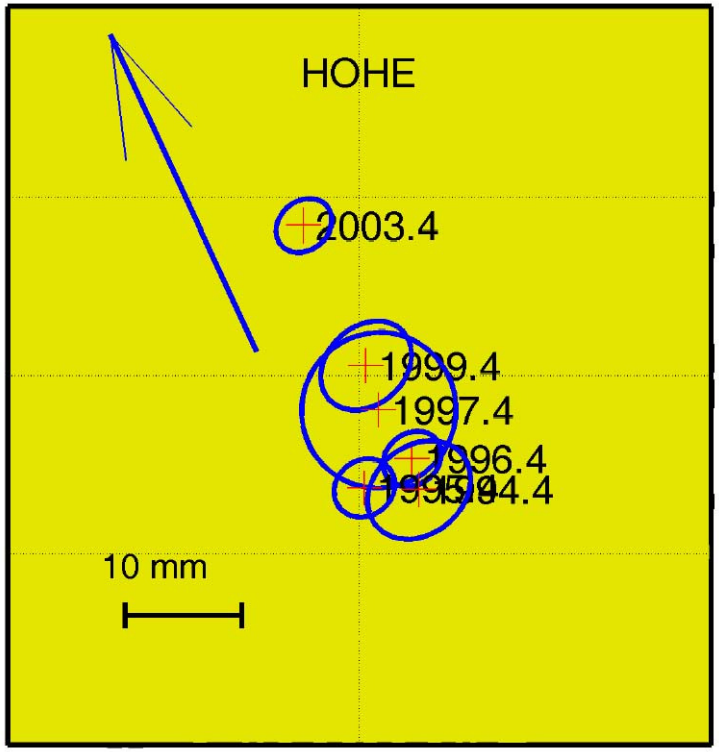
Evolution of site position during 9 years

- Position from individual epoch campaigns with EURA global plate motion removed
- Vector in upper left part represents the estimated site trajectory during 9 years





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Evolution of site position during 9 years

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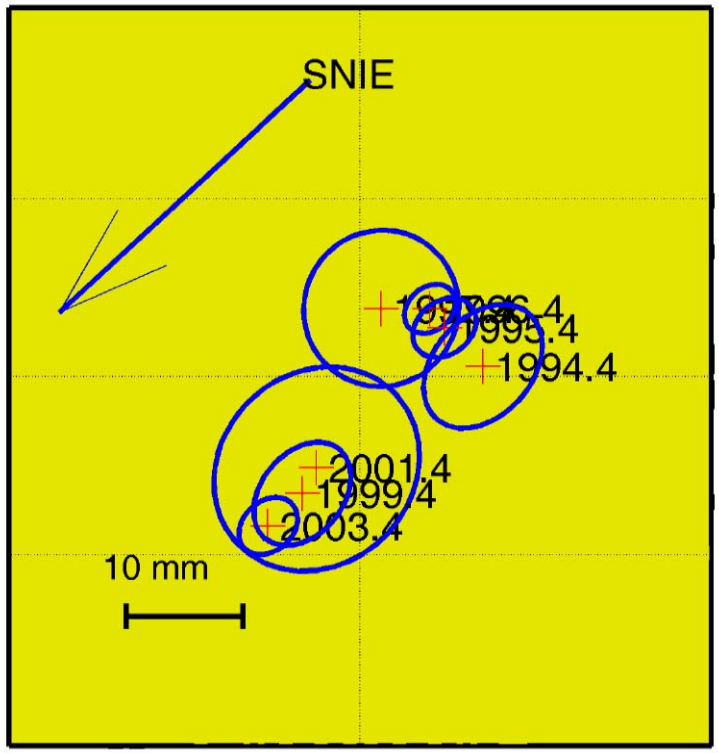
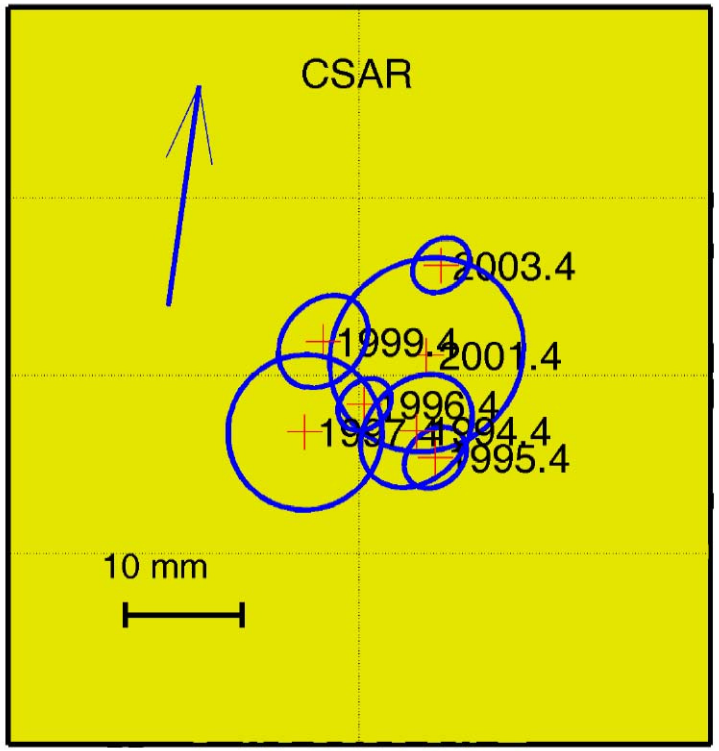
- Vector upper left represent the estimated site trajectory during 9 years





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INTRAPLATE VELOCITIES – COMPARISON OF TWO SUB-INTERVALS

- CEGRN sites observed more than 6 times)
- Velocity estimated from 1994-1997 (4 epochs)
- Velocity estimated from 1997-2003 (4 epochs)
- Significant differences observed at majority of sites
- Conclusion: 3 year span, even if with 4 epochs is insufficient for velocity estimate

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VERTICAL VELOCITIES

- CEGRN sites observed more than 5 times, observation span more than 6 years
- Annual vertical velocity estimates with RMS from 1.4 to 2.5 mm (1σ)
- General vertical tendency observed – decrease 1 – 3 mm/year

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CONCLUSIONS

- One of the products of CERGOP are site velocities for more than 50 sites in central and south-east Europe
- New velocity estimation from 7 epoch campaigns covering 9-years time span in available now
- Comparison of ITRF2000 and CEGRN velocities at non-reference sites proved good consistency of CEGRN solution
- Note: compared sites are the permanent stations with stable equipment, for the non-permanent sites we should expect more scattered results

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