HemusNet

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"Advances in understanding crustal deformation in SE Europe using GNSSystems"

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Higher Geodesy Laboratory, N.T.U.A., Faculty of Rural and Surveying Engineering
Institute of Geodynamics, NOA
Institute of Geodesy and Geoinformatics, Wroclaw University of Environmental and Life Sciences

Statistical evaluation of the deformation pattern derived from GPS data for the Kaparelli area

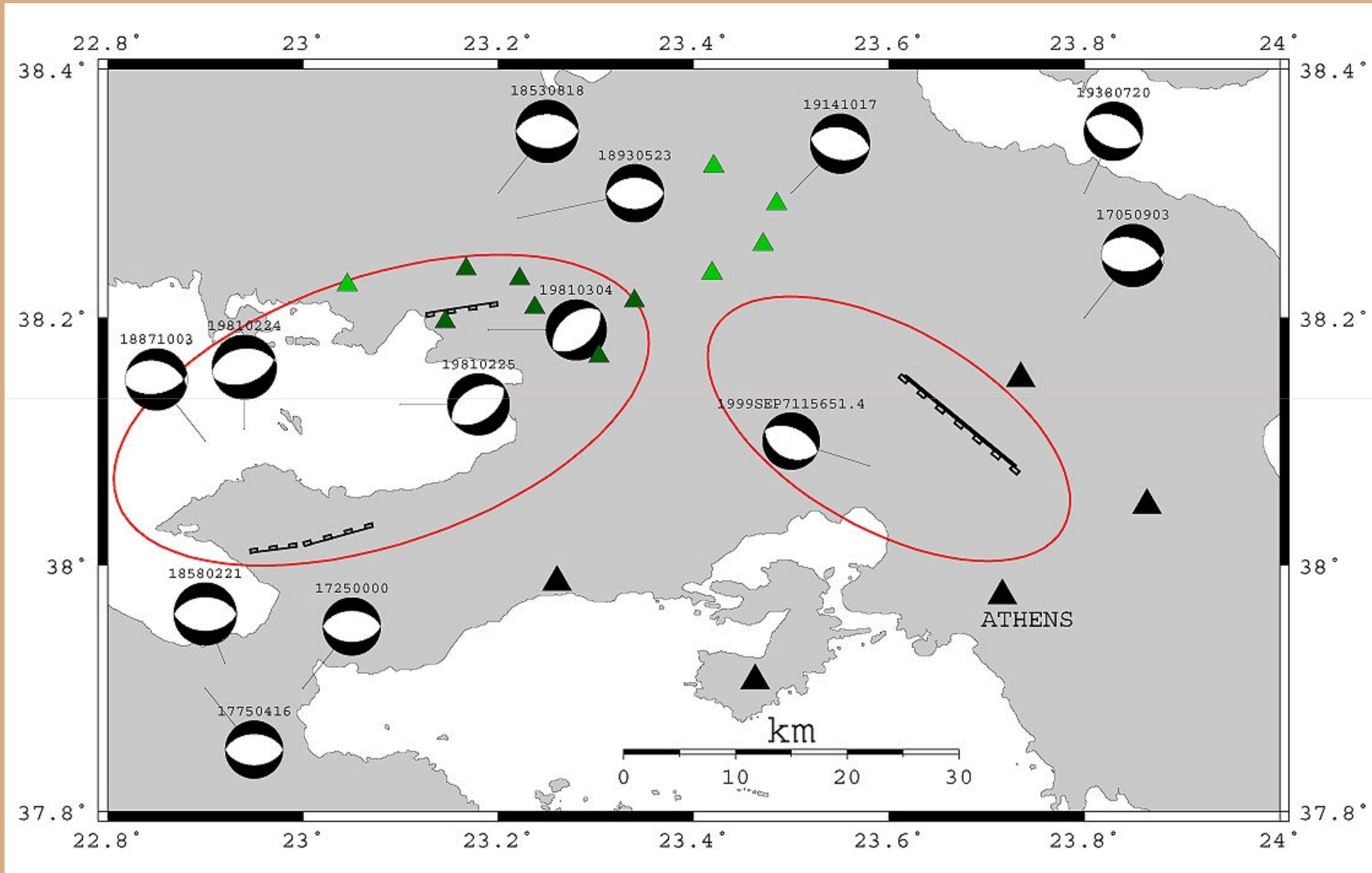
Papanikolaou X[1]., Papazissi K[1]., Ganas A[2], Paradissis D[1], Mitsakaki C[1]. ,
Marinou A[1]., Bosy J.[3] , Drakatos G [2]., Kontny B[3]., Cacon S.[3]

1. Higher Geodesy Laboratory, N.T.U.A., Faculty of Rural and Surveying Engineering – 9, Heroon Polytechniou Str. – GR 157 80, Zographou, Greece
Tel: +302107722667 Fax: +302107722670

2. Institute of Geodynamics, NOA, Lofos Nymfon, 11810 Athens, Greece

3 .Institute of Geodesy and Geoinformatics, Wroclaw University of Environmental and Life Sciences, Grunwaldzka 53, 50-357 Wroclaw, Poland

Seismotectonic setting of the Kaparelli GPS Network
1981 vs 1999 rupture zones



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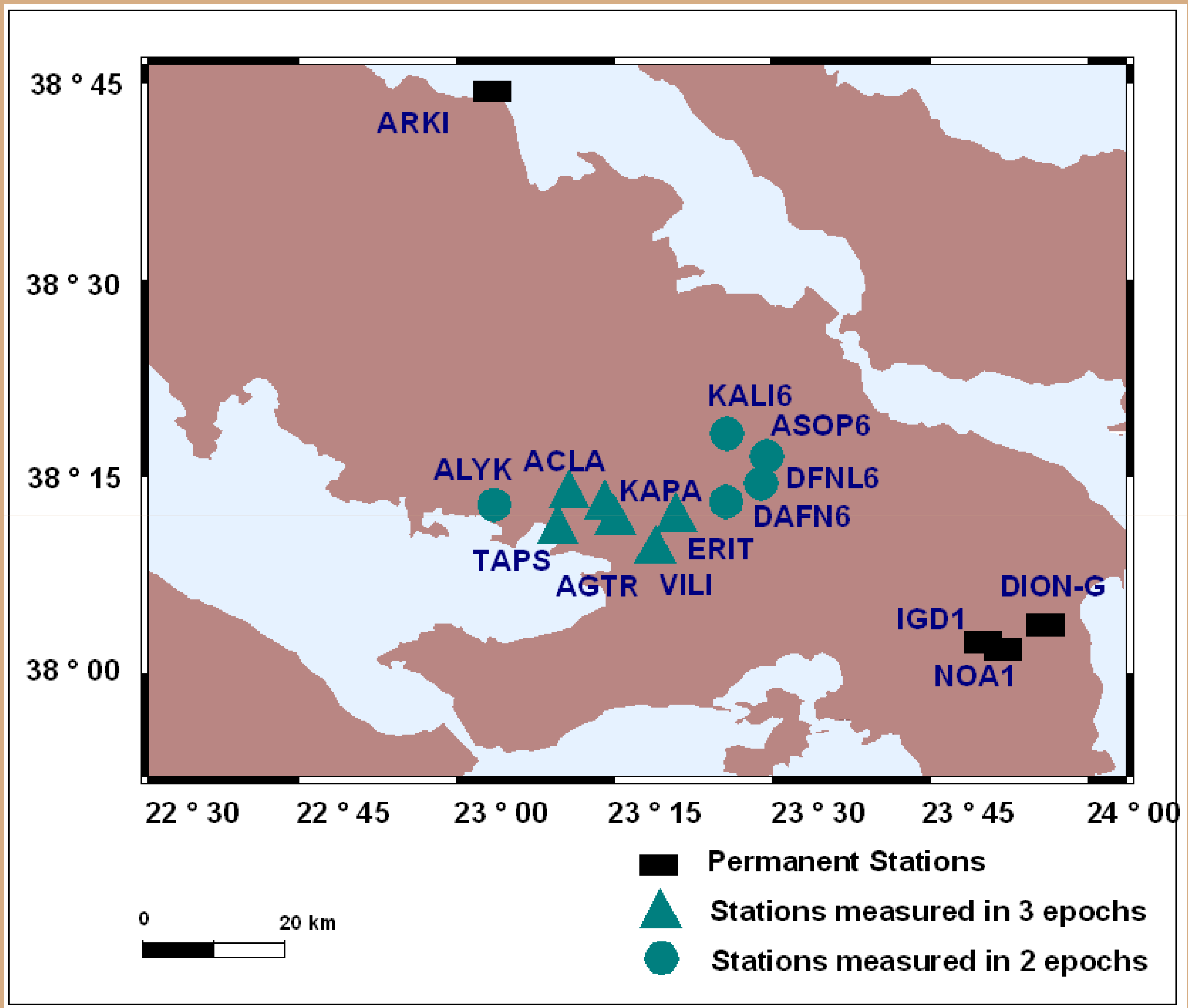
The Kaparelli Local Geodetic Network



- 6 stations were occupied in 2004, 2005, 2006,2008
- 5 stations were occupied in 2005 and 2006
- 4 are permanent stations and were used to tie the local network
- Results for 2004 2005 &2006 are presented in this study

The Realization of the Reference Frame

The International Terrestrial Reference Frame 2005 (ITRF 2005) was realized using 7 European Stations :

- GRAZ
- MATERA
- WETTZELL
- BUCU
- SOFI
- NICO
- ANKR

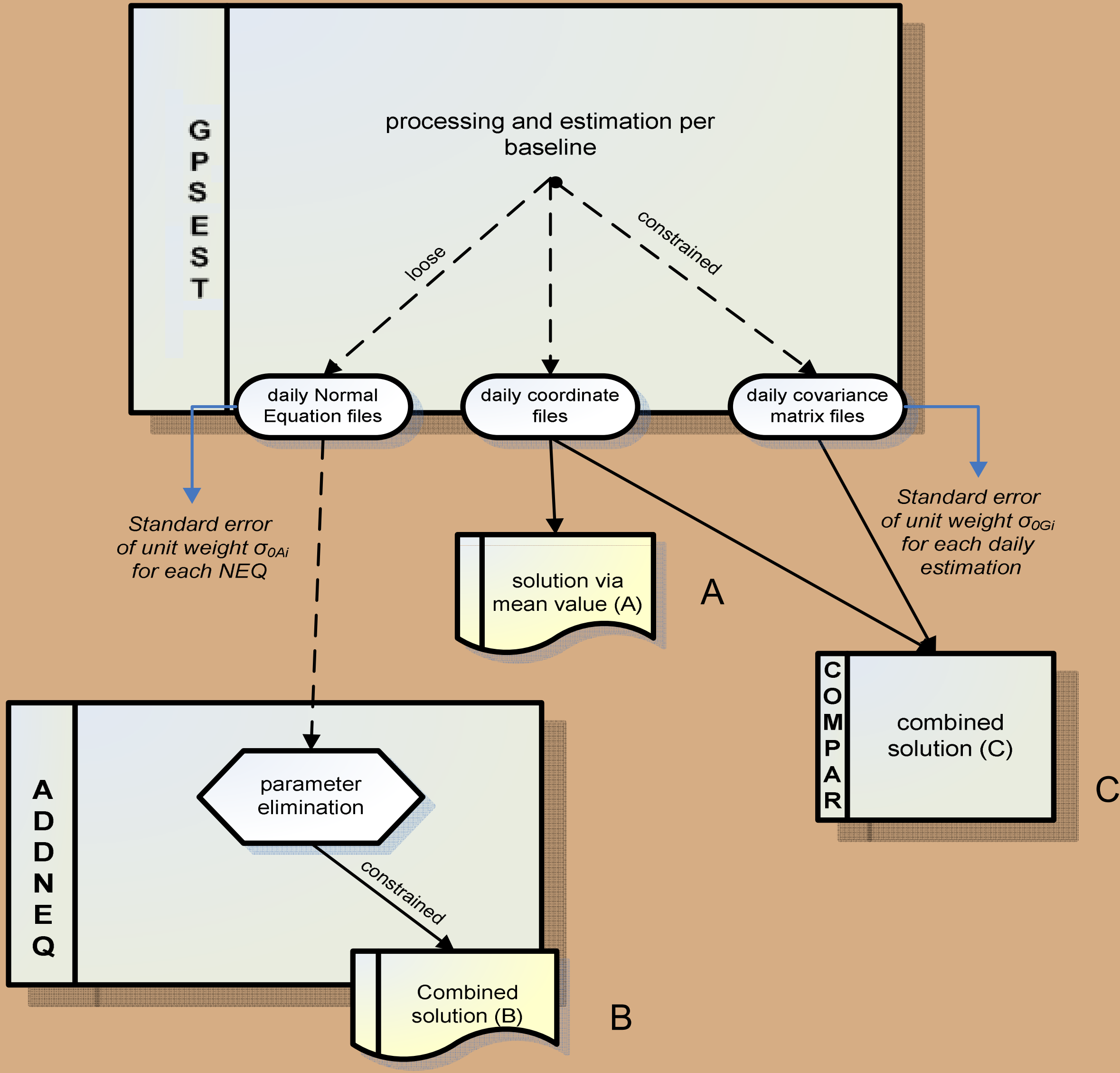
Bernese software V. 4.2 was used for processing both permanent stations and local network data, following the standards below :

- Precise IGS (International Geodetic Service) orbits and corresponding pole
- IGS (International Geodetic Service) phase eccentricity file
- Automatic phase check
- QIF(Quasi Ionosphere Free) ambiguity resolution strategy (accepted baselines with resolved ambiguities more than **70%**)
- Ionosphere model used for baselines longer than 400km
- Normal equations for each day (loose constraints)
- Combined solution using each day’s normal equation file
- Combined solution using each day’s coordinate estimates

Routines used for coordinate estimation

- Solution B was produced for all three epochs

- Solution C was only possible for epoch 2006.3



Precision estimators

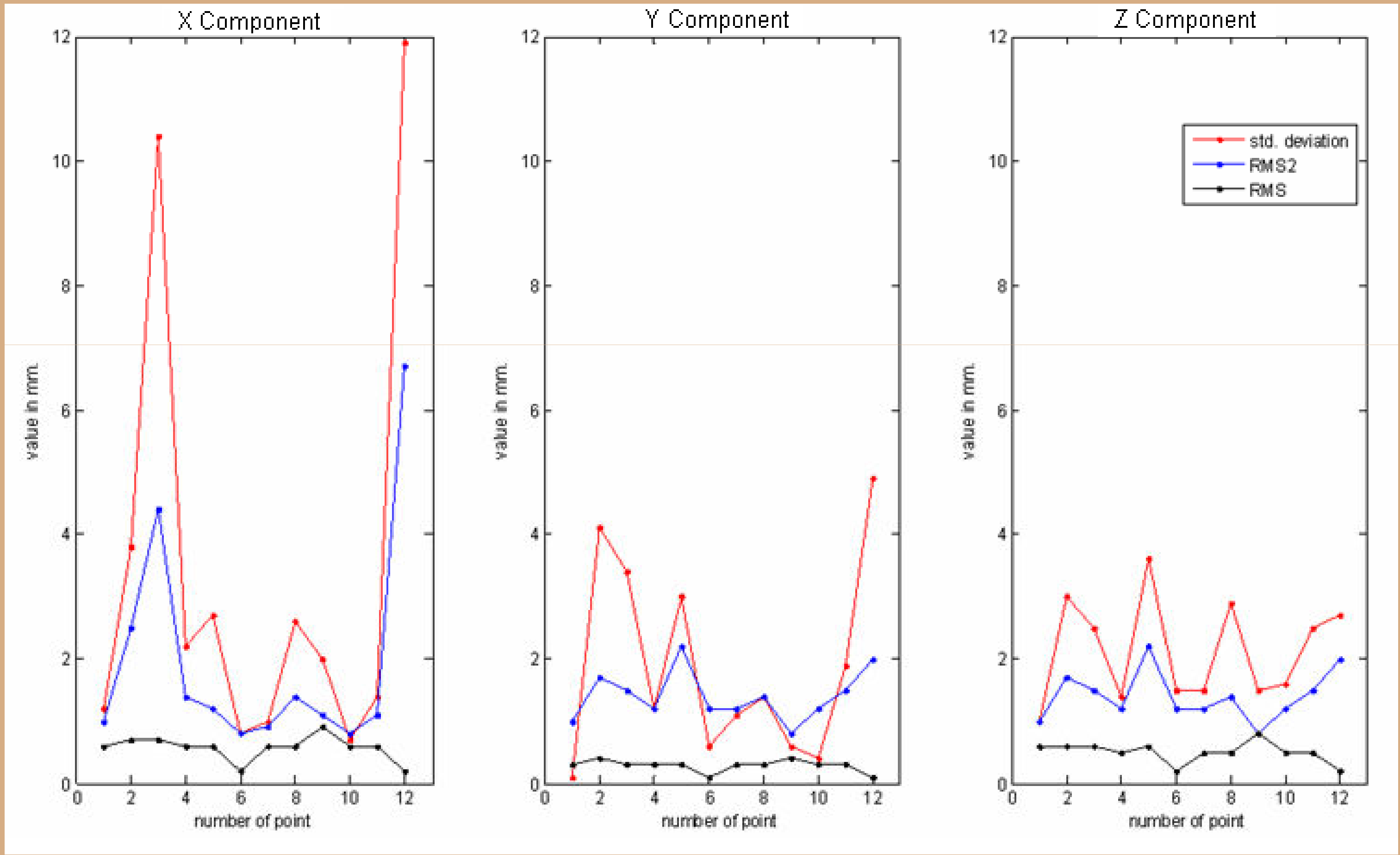
- RMS:
  - Computed by the software
  - Large degree of freedom
  - Observables: Double differences

- Standard deviation:
  - Computed manually from each day's estimations
  - Observables: daily estimations (coordinates)

- RMS2:
  - Computed by the software based on weighted coordinate repeatabilities
  - Observables: daily estimations (coordinates)

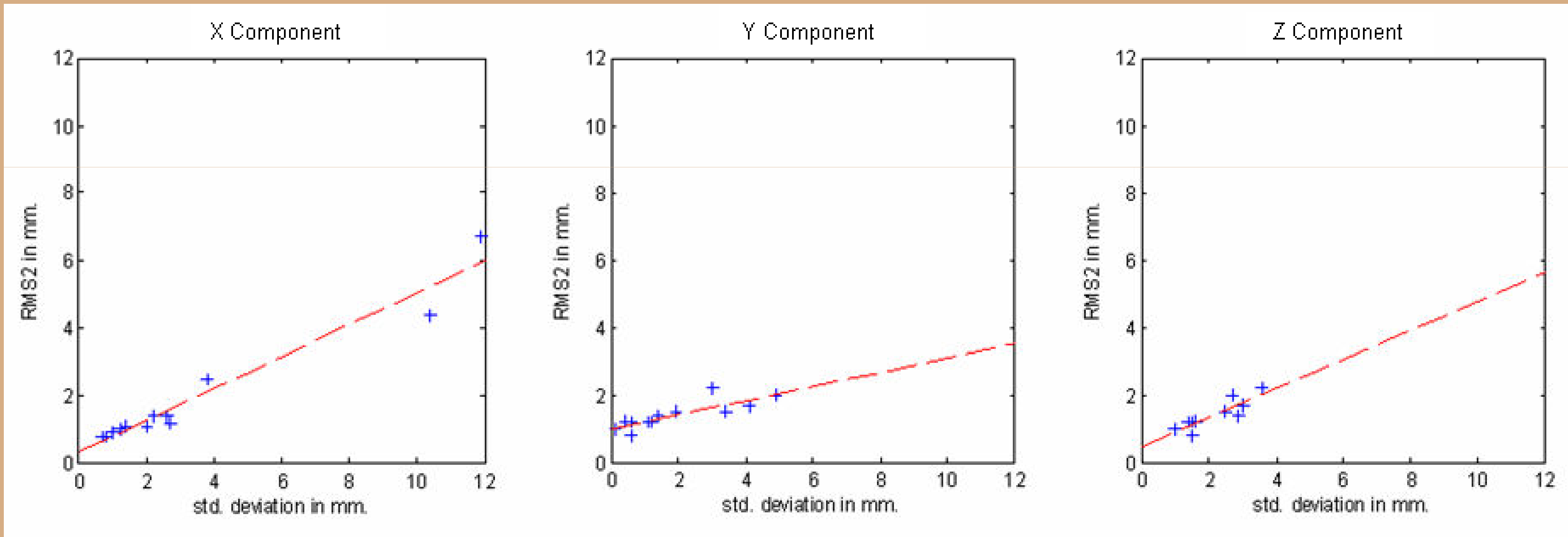
Precision estimations for epoch 2006.3

- RMS values are too optimistic
- RMS2 values are comparable with repeatabilities



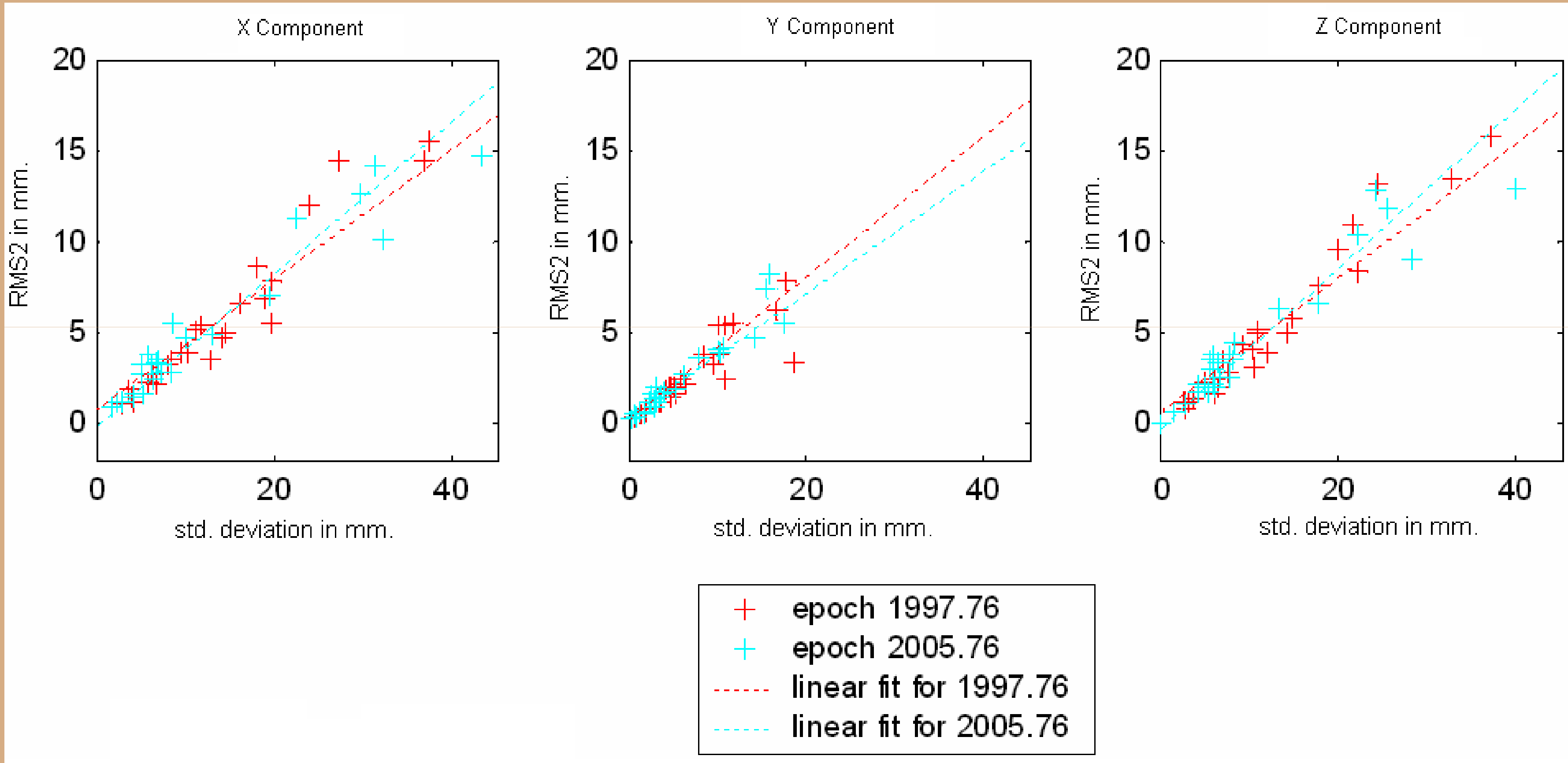
Linear model between std. deviation and RMS2

- In previous work (Evia) with many data a linear relationship was observed
- The same remark applies here as well
- Model coefficients show consistency



Linear model between std. deviation and RMS2

- Results from Evia network for two different epochs:



Model coefficients

- Linear model: $y = a \cdot x + b$

Network	Epoch	Component	a	b
Kaparelli	2006.3	X	0.47	0.3
	2006.3	Y	0.53	0.6
	2006.3	Z	0.43	0.5
Evia	1997.8	X	0.36	0.7
	1997.8	Y	0.39	0.2
	1997.8	Z	0.37	0.7
Evia	2005.8	X	0.42	-0.2
	2005.8	Y	0.34	0.3
	2005.8	Z	0.44	-0.3

Station coordinates for Epoch 2004.4

CODE	X(m)	σ_X(m)	Y(m)	σ_Y (m)	Z(m)	σ_Z(m)
ARKI	4583365.572	± 0.0003	1948697.036	± 0.0001	3971175.033	± 0.0003
ACLA	4611905.325	± 0.0008	1973533.791	± 0.0004	3926609.090	± 0.0002
AGTR	4611515.504	± 0.0008	1980044.843	± 0.0004	3923977.022	± 0.0002
ERIT	4607577.869	± 0.0008	1988081.536	± 0.0004	3924366.515	± 0.0002
KAPA	4610408.533	± 0.0008	1978107.821	± 0.0004	3925854.794	± 0.0007
TAPS	4615322.521	± 0.0008	1972969.832	± 0.0004	3922914.787	± 0.0007
VILI	4611793.274	± 0.0007	1986449.776	± 0.0003	3920623.304	± 0.0006
DION	4595216.469	± 0.0003	2039453.027	± 0.0001	3912626.766	± 0.0003

Remarks

- Only **one** of the two days was taken into account for the final estimates

Station coordinates for epoch 2005.4

CODE	X(m)	σ_X(m)	Y(m)	σ_Y (m)	Z(m)	σ_Z(m)
ARKI	4583365.589	± 0.0004	1948697.066	± 0.0002	3971175.069	± 0.0004
ACLA	4611905.347	± 0.0009	1973533.824	± 0.0004	3926609.126	± 0.0008
AGTR	4611515.516	± 0.0009	1980044.869	± 0.0004	3923977.048	± 0.0008
ALYK	4616899.779	± 0.0008	1964064.653	± 0.0004	3925497.938	± 0.0007
ASOP	4597473.677	± 0.0008	1997616.051	± 0.0004	3931076.621	± 0.0007
DAFN	4603445.517	± 0.0009	1993876.478	± 0.0004	3926358.829	± 0.0008
DFNL	4600042.745	± 0.0009	1997412.494	± 0.0004	3928250.505	± 0.0007
ERIT	4607577.887	± 0.0009	1988081.562	± 0.0004	3924366.551	± 0.0008
KALI	4597842.858	± 0.0008	1991628.965	± 0.0004	3933783.408	± 0.0007
KAPA	4610408.548	± 0.0009	1978107.85	± 0.0004	3925854.821	± 0.0008
TAPS	4615322.536	± 0.0009	1972969.862	± 0.0004	3922914.829	± 0.0008
VILI	4611793.31	± 0.0008	1986449.81	± 0.0004	3920623.349	± 0.0007
IGD1	4604626.403	± 0.0004	2030196.497	± 0.0002	3905963.048	± 0.0004

Remarks

- Only **one** of the two days was used for the realization of the Reference Frame

Station coordinates for epoch 2006.3

CODE	X(m)	σ_X(m)	Y(m)	σ_Y (m)	Z(m)	σ_Z(m)
ARKI	4583365.555	± 0.0003	1948697.062	± 0.0001	3971175.019	± 0.0002
NOA1	4599641.925	± 0.0003	2034827.331	± 0.0001	3909890.622	± 0.0002
ACLA	4611905.318	± 0.0010	1973533.815	± 0.0004	3926609.074	± 0.0008
AGTR	4611515.498	± 0.0007	1980044.864	± 0.0003	3923977.000	± 0.0006
ALYK	4616899.755	± 0.0006	1964064.647	± 0.0003	3925497.883	± 0.0005
ASOP6	4597473.643	± 0.0006	1997616.043	± 0.0003	3931076.560	± 0.0005
DAFN6	4603445.472	± 0.0009	1993876.465	± 0.0004	3926358.759	± 0.0008
DFNL6	4600042.711	± 0.0006	1997412.477	± 0.0003	3928250.438	± 0.0005
ERIT	4607577.860	± 0.0007	1988081.554	± 0.0003	3924366.495	± 0.0006
KALI6	4597842.839	± 0.0006	1991628.962	± 0.0003	3933783.379	± 0.0006
KAPA	4610408.522	± 0.0008	1978107.840	± 0.0004	3925854.768	± 0.0007
TAPS	4615322.522	± 0.0007	1972969.858	± 0.0003	3922914.777	± 0.0006
VILI	4611793.282	± 0.0006	1986449.801	± 0.0003	3920623.292	± 0.0006

Velocity Estimation

- Least squares linear regression model, using two different weight matrices:

    1. Coordinate estimates were considered equally weighted
    2. Coordinate estimates were scaled using the a-posteriori RMS of each epoch's solution: $P_i = (1/\sigma^2_{epoch})$

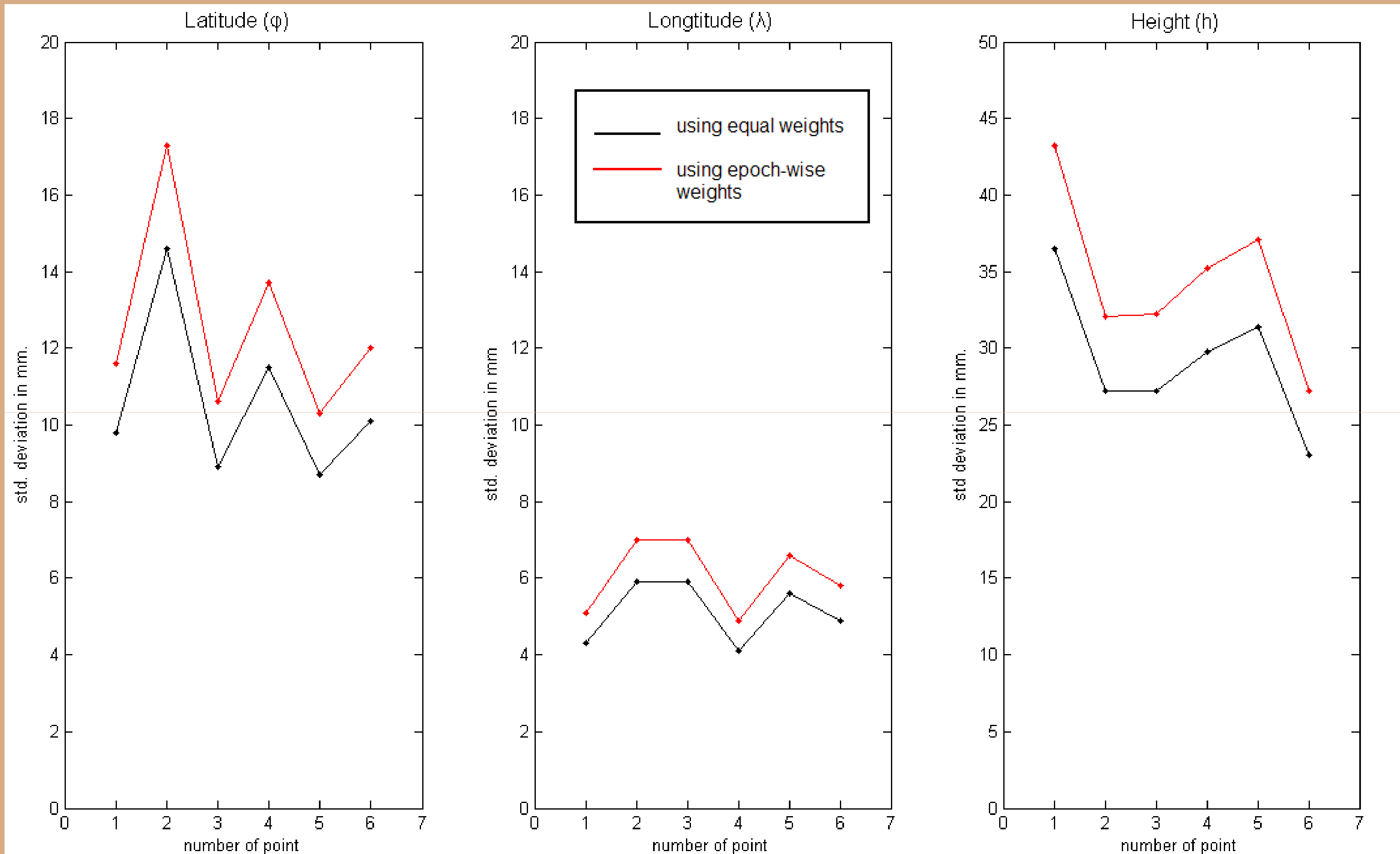
Velocity estimates:

$$\hat{v} = (A^T P A)^{-1} A^T P l$$

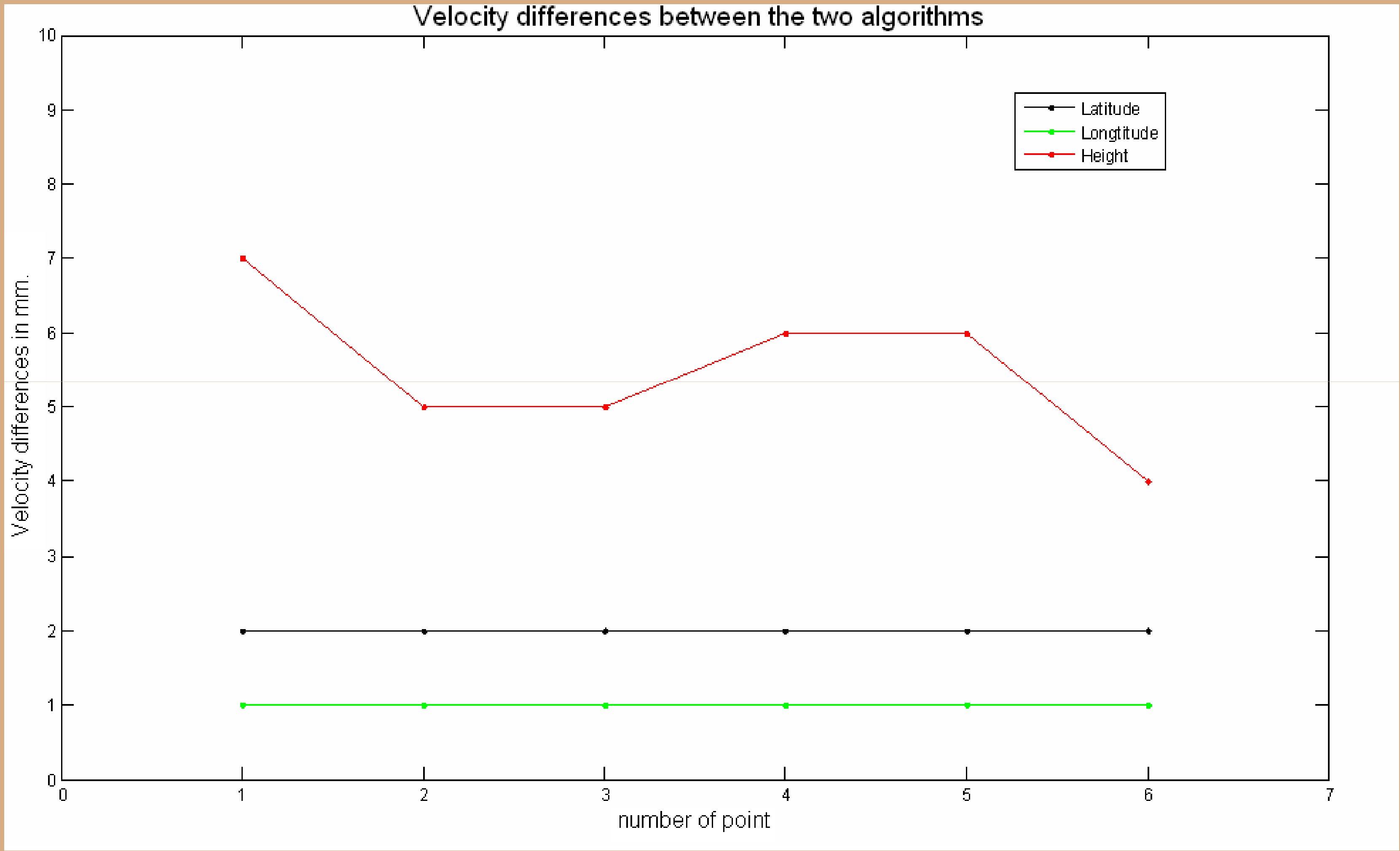
Variance estimates:

$$V_{\hat{v}} = (A^T P A)^{-1}$$

Std. deviations for velocity estimates



Velocity differences



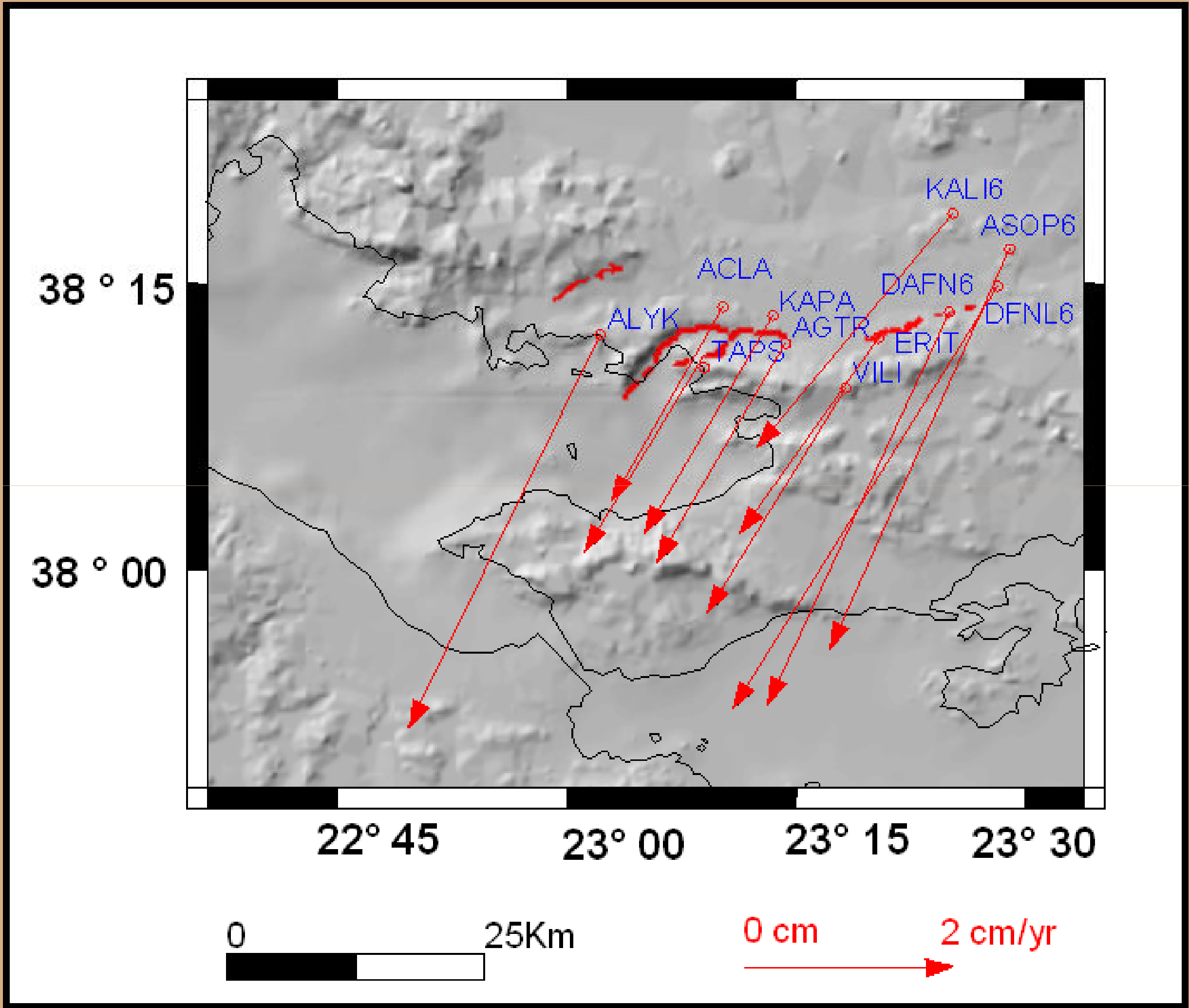
Velocities in ITRF 2005 and with respect to a fixed Europe

Station	Velocities in ITRF2005			Velocities with respect to a fixed Europe	
	Equally weighted observations				
	Vn(m/yr)	**Ve(m/yr)**	**Vu(m/yr)**	**Vn(m/yr)**	**Ve(m/yr)**
ACLA	-0.007	0.013	-0.004	-0.019	-0.011
AGTR	-0.010	0.011	-0.006	-0.022	-0.012
ERIT	-0.008	0.011	-0.007	-0.019	-0.013
KAPA	-0.010	0.011	-0.010	-0.021	-0.012
TAPS	-0.008	0.012	0.001	-0.019	-0.012
VILI	-0.010	0.011	0.003	-0.022	-0.013
ALYK	-0.028	0.004	-0.053	-0.040	-0.020
ASOP	-0.027	0.006	-0.065	-0.039	-0.017
DAFN	-0.027	0.006	-0.082	-0.038	-0.018
DFNL	-0.030	-0.002	-0.074	-0.041	-0.026
KALI	-0.011	0.005	-0.034	-0.023	-0.019

Velocities in ITRF 2005 and with respect to a fixed Europe

Station	Velocities in ITRF2005			Velocities with respect to a fixed Europe	
	Epoch-wise weighted observations				
	Vn(m/yr)	**Ve(m/yr)**	**Vu(m/yr)**	**Vn(m/yr)**	**Ve(m/yr)**
ACLA	-0.009	0.012	-0.010	-0.019	-0.011
AGTR	-0.012	0.010	-0.010	-0.023	-0.013
ERIT	-0.010	0.010	-0.013	-0.021	-0.014
KAPA	-0.012	0.010	-0.015	-0.023	-0.013
TAPS	-0.010	0.011	-0.004	-0.022	-0.013
VILI	-0.012	0.010	-0.004	-0.023	-0.014

Tectonic Velocities with respect to a Fixed Europe



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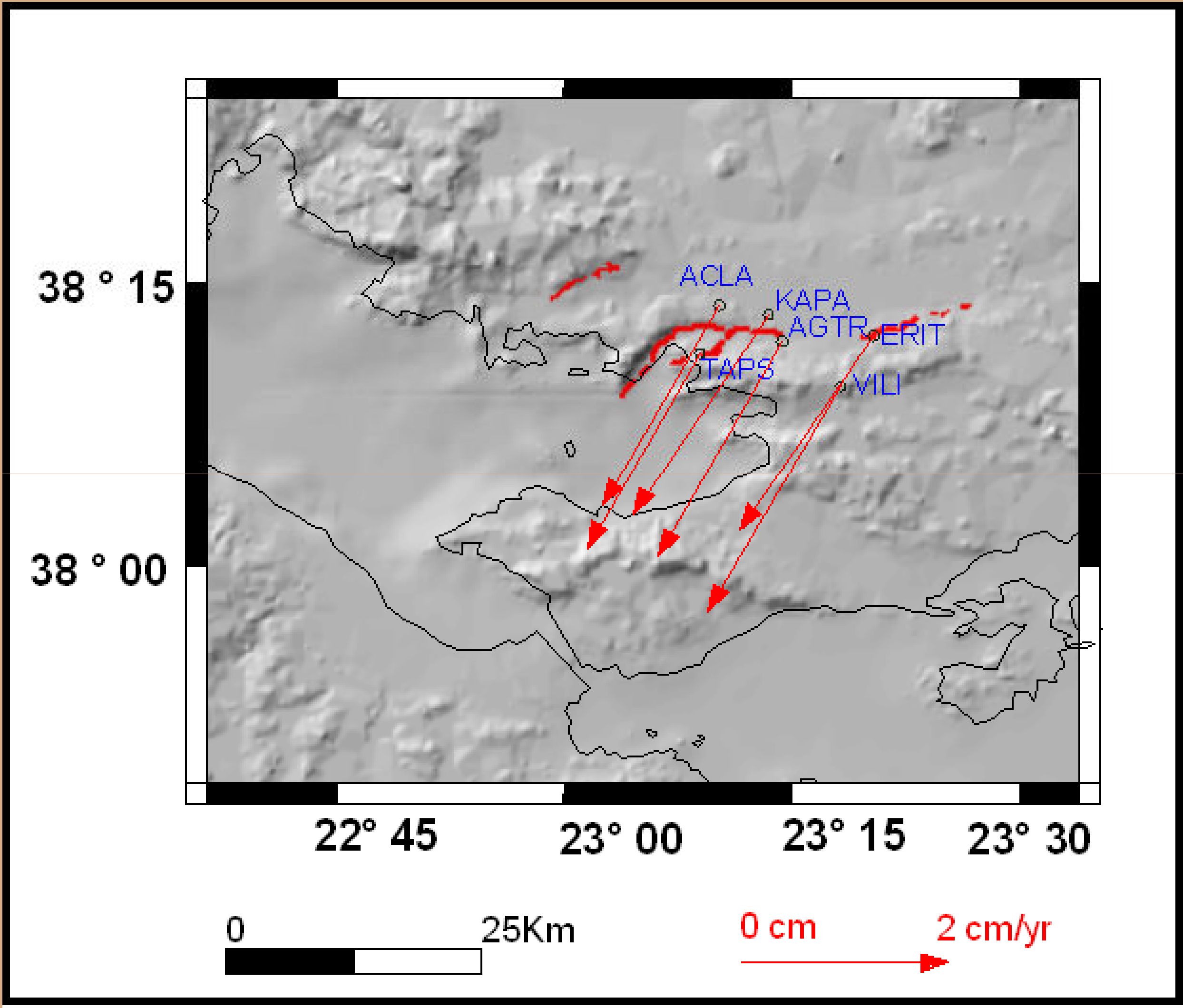
Velocity derived using only epochs 2004.4 and 2006.3

Station	Velocities in ITRF2005			Velocities with respect to a fixed Europe	
	Velocities between epochs 2004.4 and 2006.3				
	Vn(m/yr)	**Ve(m/yr)**	**Vu(m/yr)**	**Vn(m/yr)**	**Ve(m/yr)**
ACLA	-0.007	0.013	-0.004	-0.019	-0.011
AGTR	-0.010	0.011	-0.006	-0.021	-0.012
ERIT	-0.008	0.010	-0.007	-0.019	-0.013
KAPA	-0.010	0.011	-0.009	-0.021	-0.012
TAPS	-0.008	0.012	0.002	-0.019	-0.011
VILI	-0.010	0.010	0.003	-0.022	-0.013

Differences between velocities derived from time series and velocities derived from epochs 2004.4 and 2006.3

Station	Differences to velocity using epochs 2004.4 and 2006.3			
	Equally weighted obs.		Epoch-wise weighted obs.	
	ΔVn(m/yr)	**ΔVe(m/yr)**	**ΔVn(m/yr)**	**ΔVe(m/yr)**
ACLA	0.0000	-0.0001	0.0016	0.0009
AGTR	0.0004	0.0002	0.0023	0.0011
ERIT	0.0000	-0.0002	0.0021	0.0006
KAPA	0.0000	-0.0001	0.0017	0.0010
TAPS	0.0000	0.0005	0.0027	0.0016
VILI	-0.0001	-0.0001	0.0017	0.0007

Velocities computed between epochs 2004.4 and 2006.3 with respect to a fixed Europe



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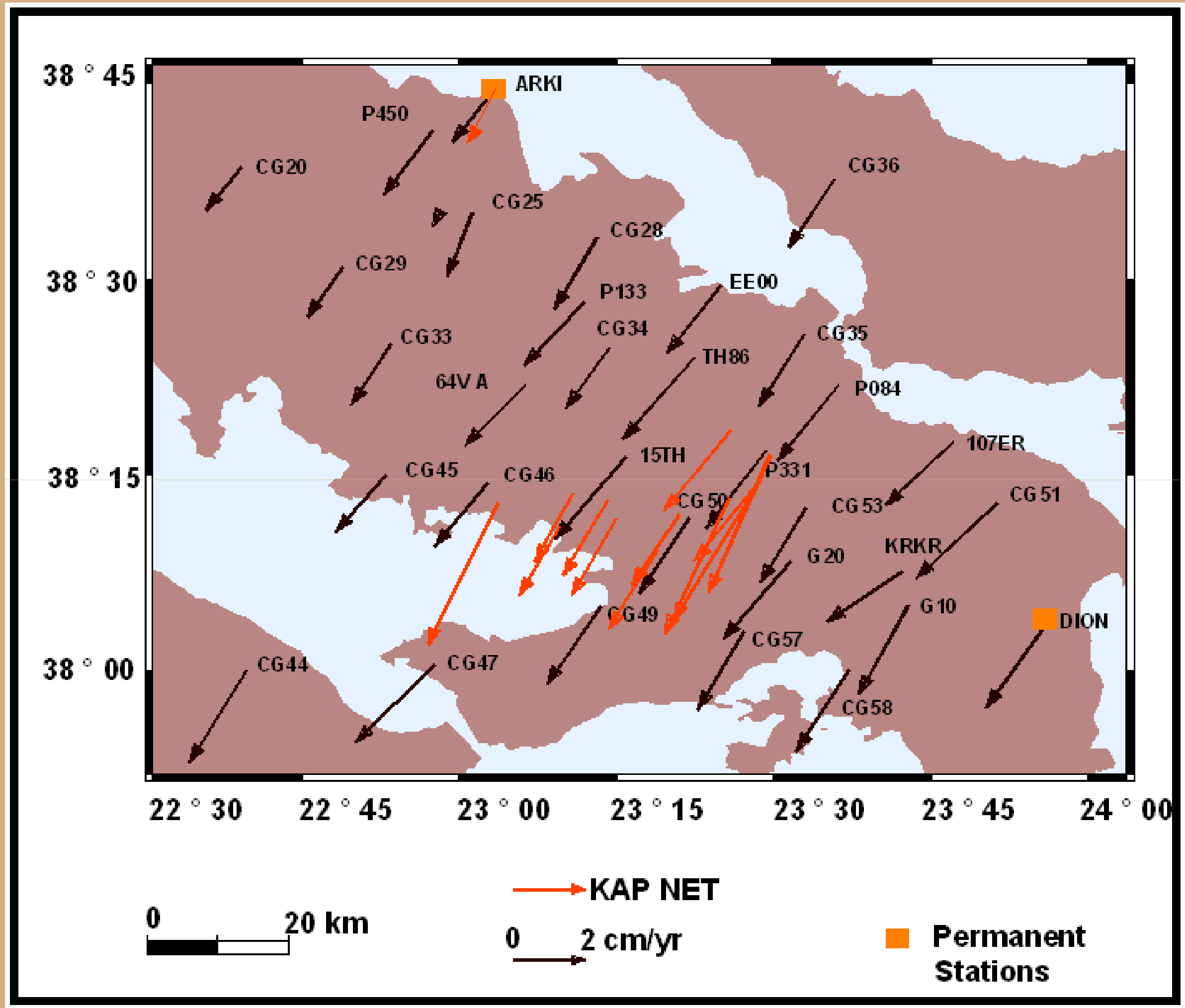
Tectonic Velocities with respect to a Fixed Europe From Atalanti to Parnitha and Alcyonides Fault



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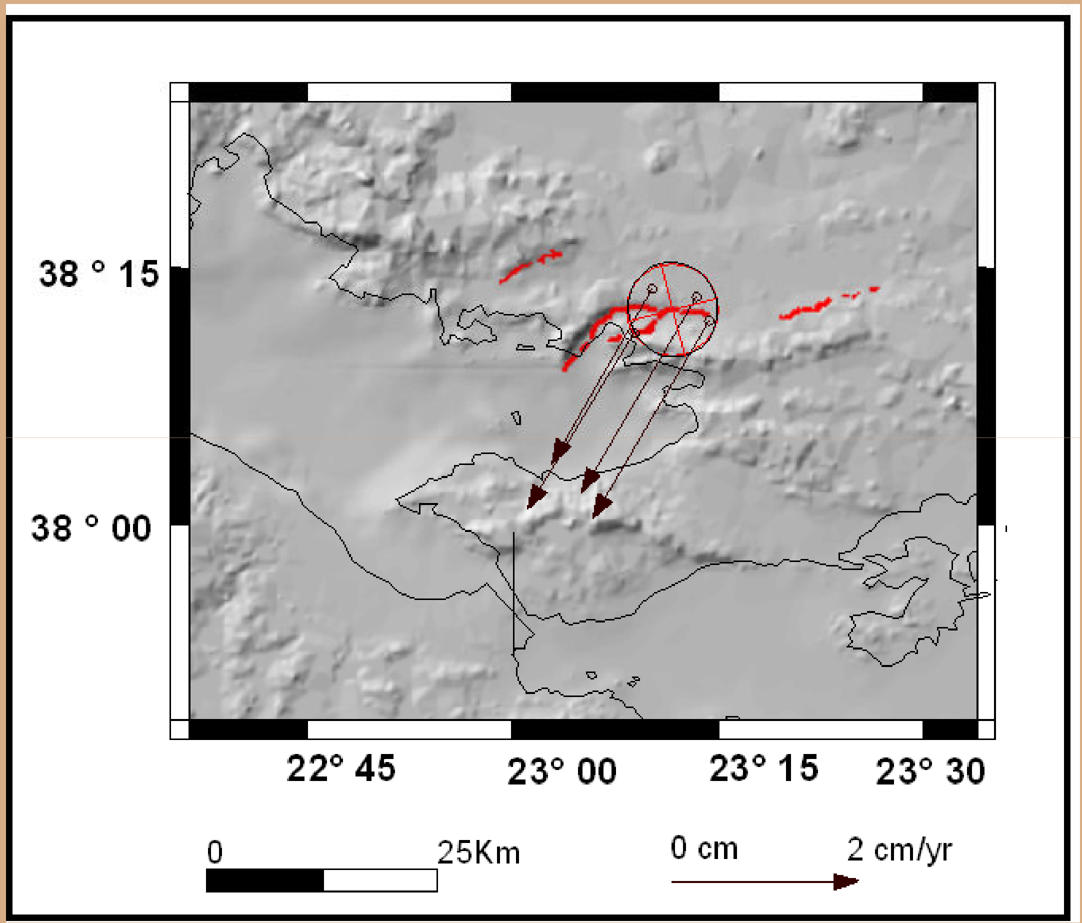
Calculation of Strain Tensor Parameters

Assumptions:

- 2-dimensional deformation of earth's crust in time
- Crust is considered a thin deformable shell on a spherical earth
- Mapping distortions are ignored for regions with radius less than 5°
- Time (earthquakes) or space (faults) discontinuities are not included in the calculation

The Kaparelli Block Strain Tensor



Kmax (ppm)	0.136
Kmin (ppm)	-0.213
Az(deg)	-14.769
γ(ppm)	0.349

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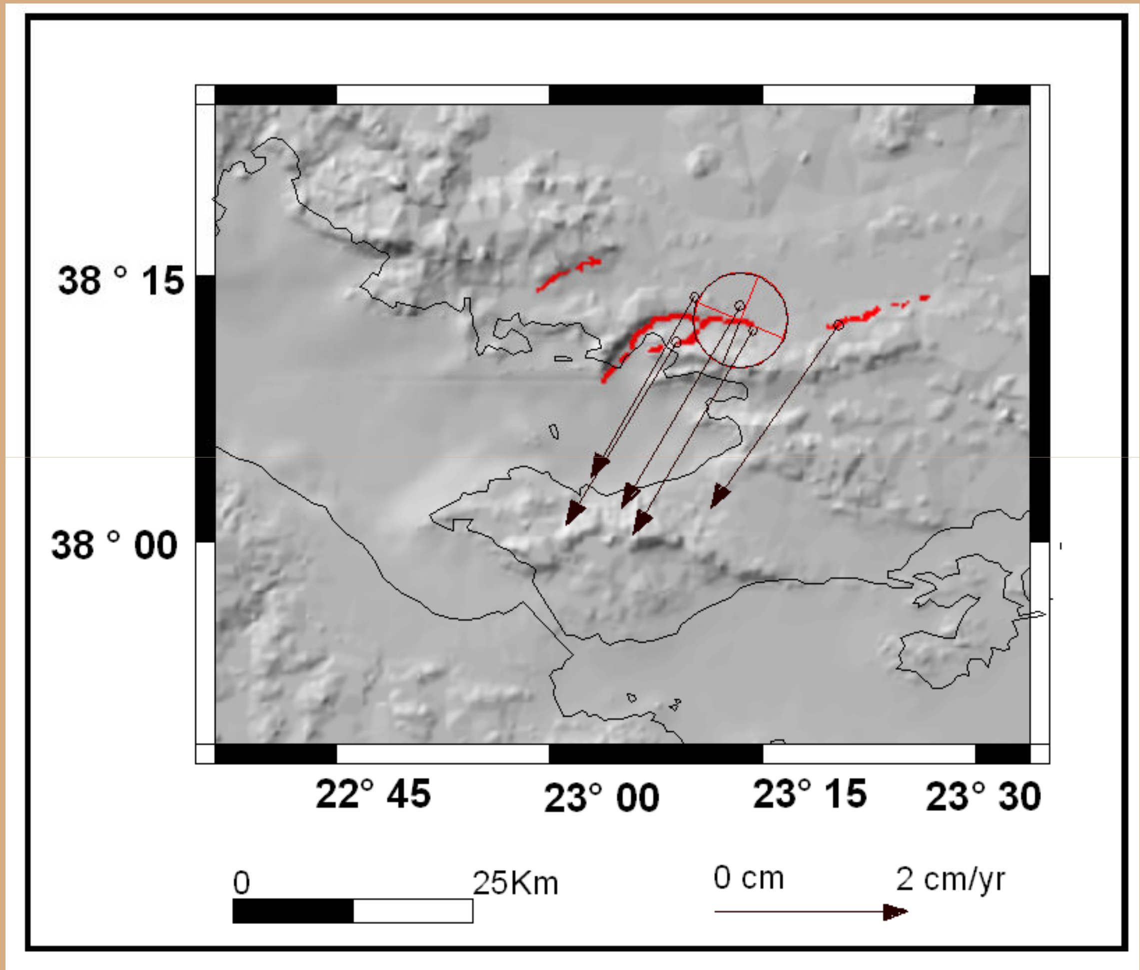
The Kaparelli Block Plus VILI Station Strain Tensor



Kmax (ppm)	0.006
Kmin (ppm)	-0.152
Az(deg)	22.363
γ(ppm)	0.158

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Conclusions

- A linear relationship has been observed between RMS2 values and standard deviations, both in the Kaparelli network results and the previous Evia network.

- Velocities calculated using different weighting show small discrepancies.

- Stations observed only for two epochs appear to move faster. Future campaigns will revaluate this indication.

Conclusions

- Velocity vectors are consistent with the broader picture in central Greece (motion to the SW). Large enough to pass a statistical test. Are they realistic? More campaigns are necessary.

- Preliminary strain tensors were calculated across the Kaparelli fault. For Kaparelli block strain parameters are Kmax= 0.136 ppm , Kmin = -0.213ppm , Az= -14.769.

- The orientation of geodetic strain agrees with the rupture of the 1981 earthquake.

Thank you for your attention