NATIONAL TECHNICAL UNIVERSITY OF ATHENS
school of rural & surveying engineering
department of topography
higher geodesy laboratory   Dionyssos satellite Observatory

Evaluating large volume GPS data for deformation studies

C. MITSAKAKI, A. MARINOU, X. PAPANIKOLAOU, K. PAPAZISSI

The 7th FIG Regional Conference
Spatial Data Serving People
Land Governance and the Environment – Building the Capacity
Hanoi, Vietnam, 19–22 October 2009

Introduction

- Deformation monitoring studies combine large amount of GNSS data and offer high quality products (coordinates/velocities).
- Data analysis is performed via software packages applying various techniques (e.g., Least Squares/ Kalman filtering etc).
- Software products have to address the growing demands of users for accuracy, high quality resolution, consistent reliability estimates and the constantly increasing observation volume.

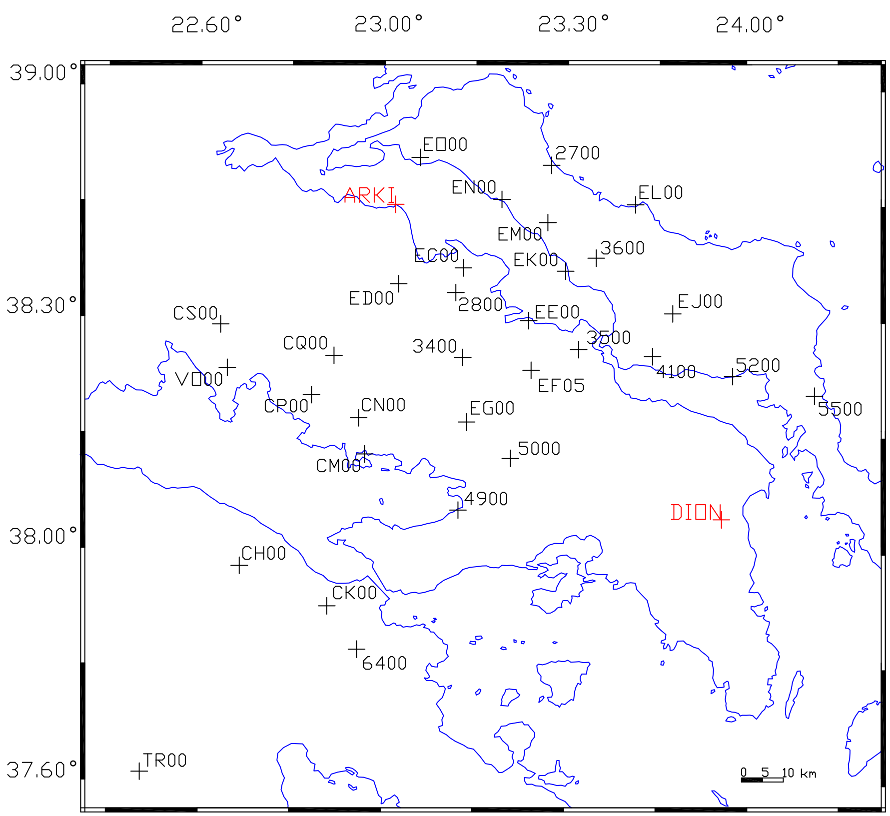
Data analysis

- For more than the last decade, Higher Geodesy Laboratory and Dionysos Satellite Observatory of NTUA have participated in a European inter-disciplinary research programme by establishing and maintaining a network throughout Central Greece, to study the long term tectonic behaviour.

- Two GPS campaigns are analyzed and discussed:
  1. Epoch 1997.76 (11 days of observations -150 network points)
  2. Epoch 2005.76 (10 days of observations - 71 network points)

- Both networks were tied to the ITRF2000 via 7 IGS stations

- The results of the 30 first order network common points are discussed here.



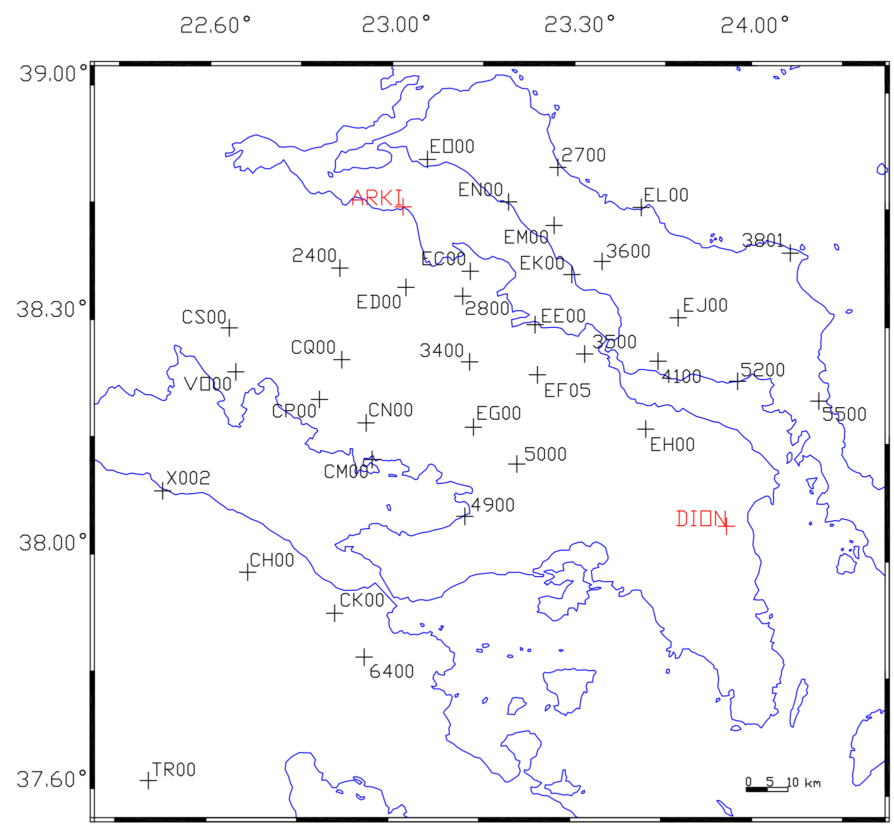


Figure 1

Epoch 1997.76 1st order network

Epoch 2005.76 1st order network

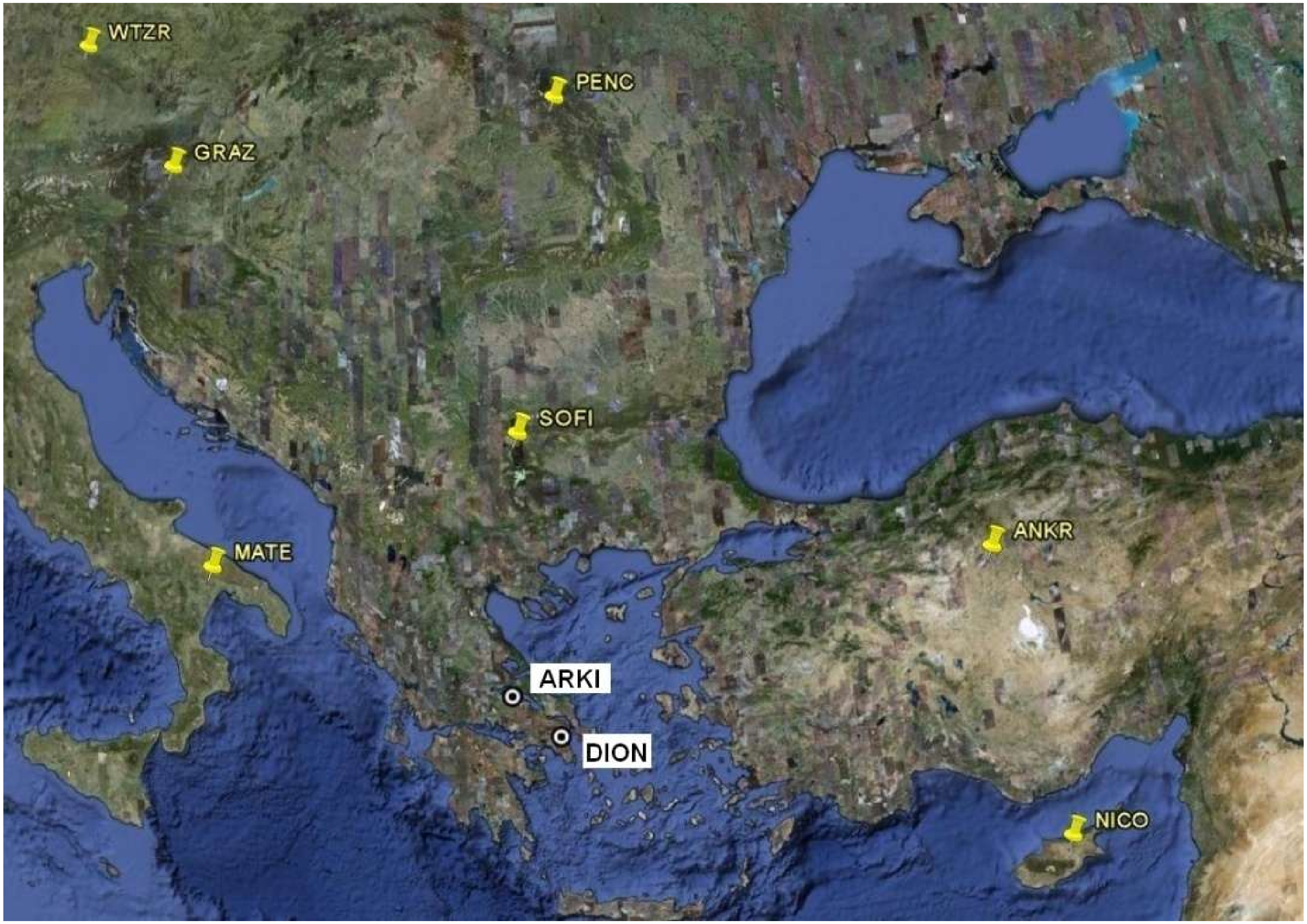


Figure 2 IGS stations used for referring to the ITRF 2000

- Data analyzed by BERNESE V4.2 GPS software
- Precise IGS orbits and corresponding pole
- IGS phase eccentricity file
- Baseline approach was used
- Ambiguities resolved using the Q.I.F (Quasi Ionosphere Free) method with rejection limit of 85%.
- Ionosphere model used for baselines longer than 400km
- Daily normal equations evaluated for the adjustment /estimation procedures.

Solution A — daily coordinate estimations as a non-weighted average using only sub-programme GPEST

Solution B — Combined adjustment of daily normal equations, using parameter elimination for troposphere parameters (via sub-programme ADDNEQ)

Parameter elimination is an algorithm to reduce the volume of parameters, while no a-priori information is lost. Troposphere parameters occupy the biggest part of NEQ files.

Solution C — Combined adjustment of daily coordinates using corresponding daily VarCovar matrices (via sub-programme COMPAR)

A-*priori information are the results from sub-programme GPEST (Solution A)*

Final estimates were calculated by ***three different methods*** :

Solution A

Solution B and

Solution C

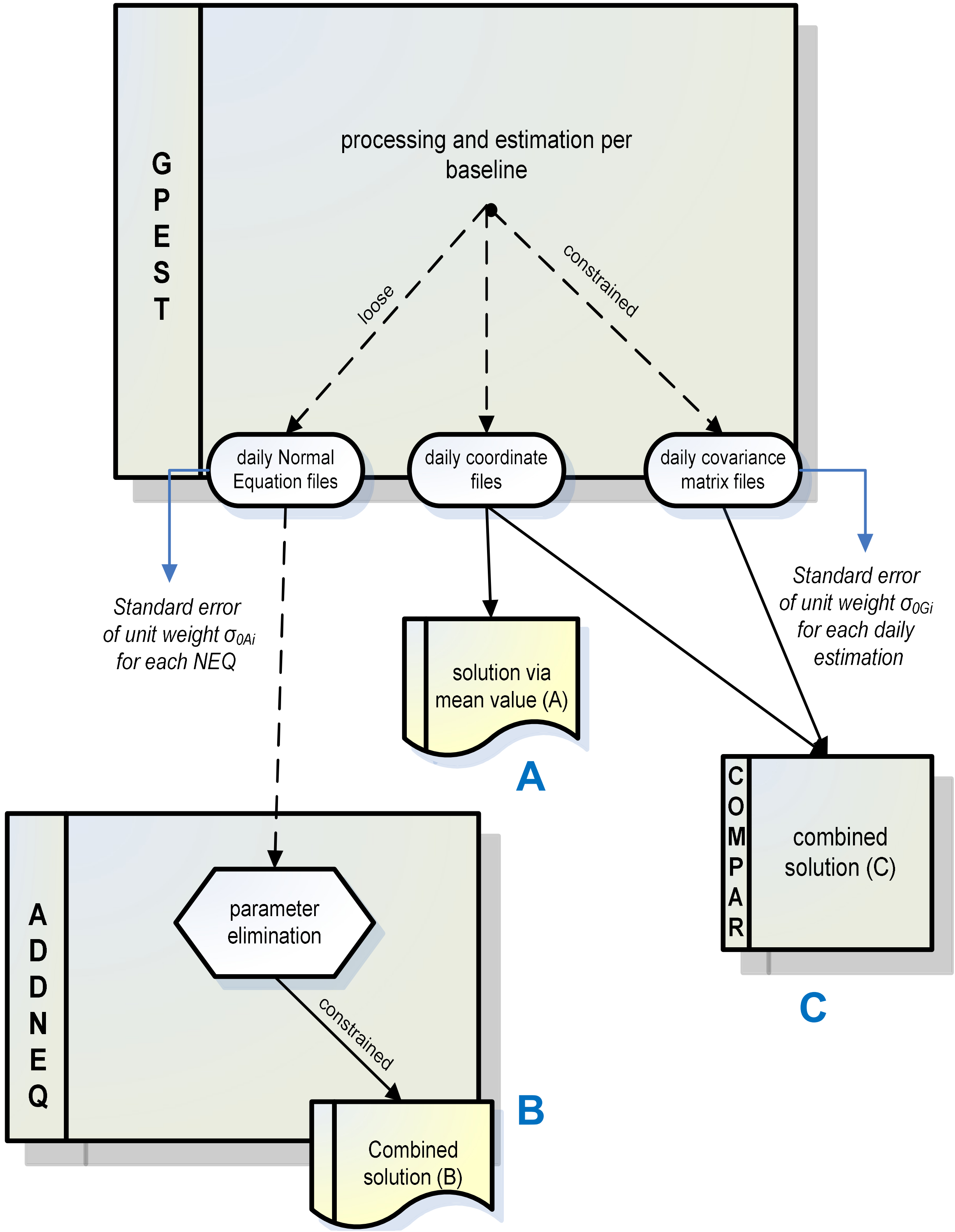


Figure 3

Comparison of the Solutions

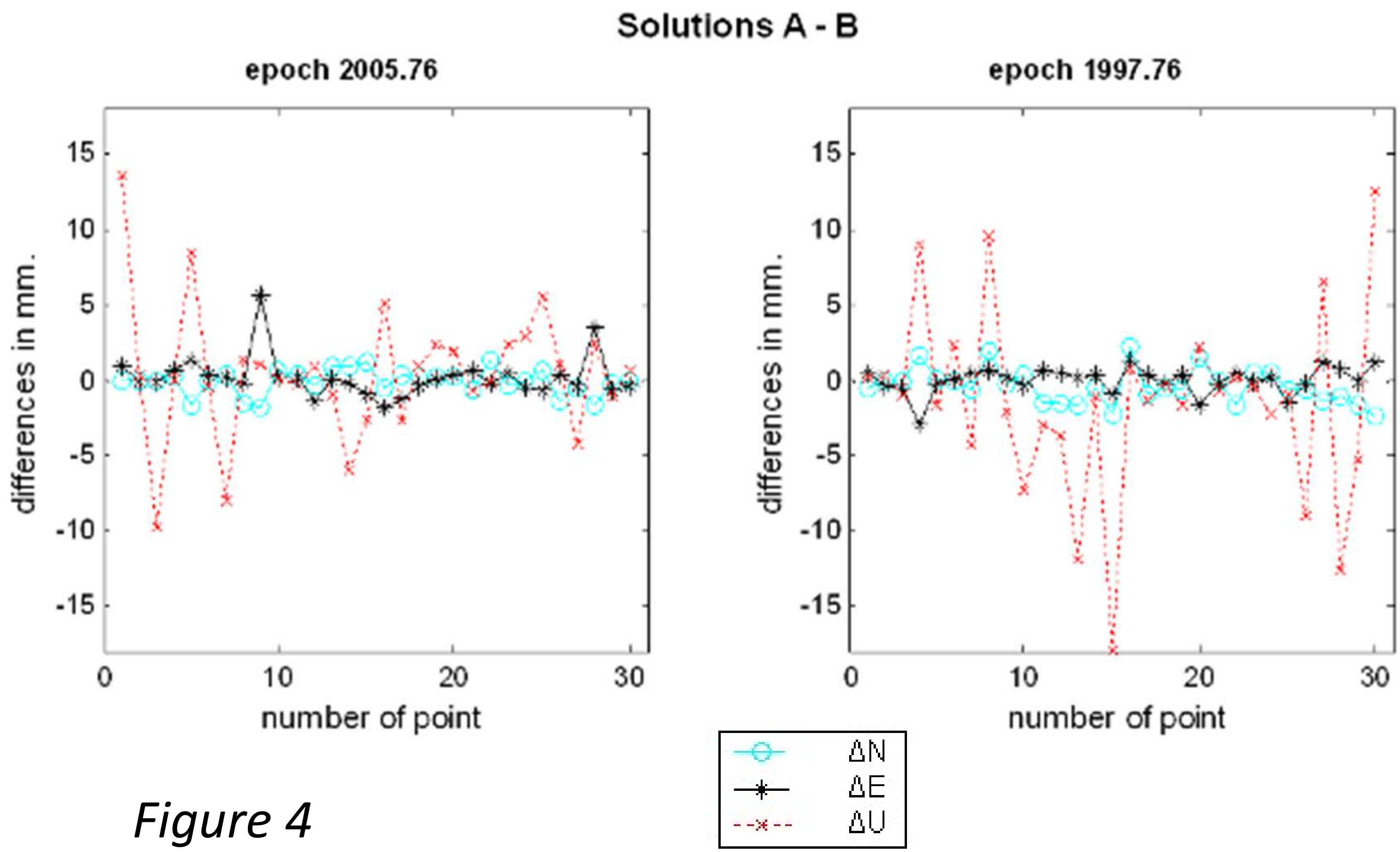


Figure 4

- Coordinate discrepancies vary up to 6mm for the ***horizontal*** and up to 18mm for the ***height components***
- Discrepancies are in most cases within observation noise

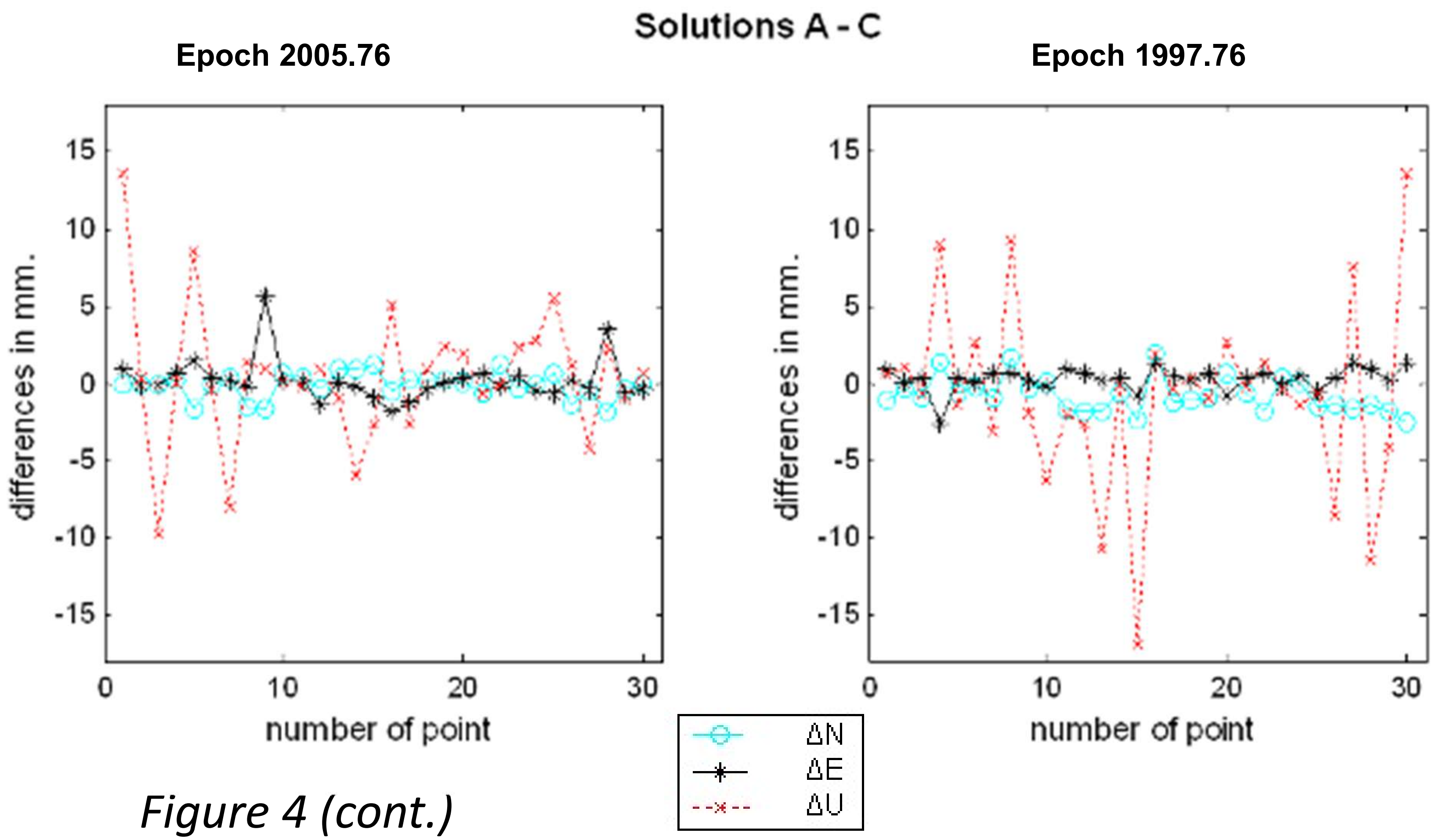


Figure 4 (cont.)

- Coordinate discrepancies vary up to 6mm for the ***horizontal*** and up to 20mm for the ***height components***
- Discrepancies are in most cases within observation noise

- **Solutions B** and **C** provide practically identical results

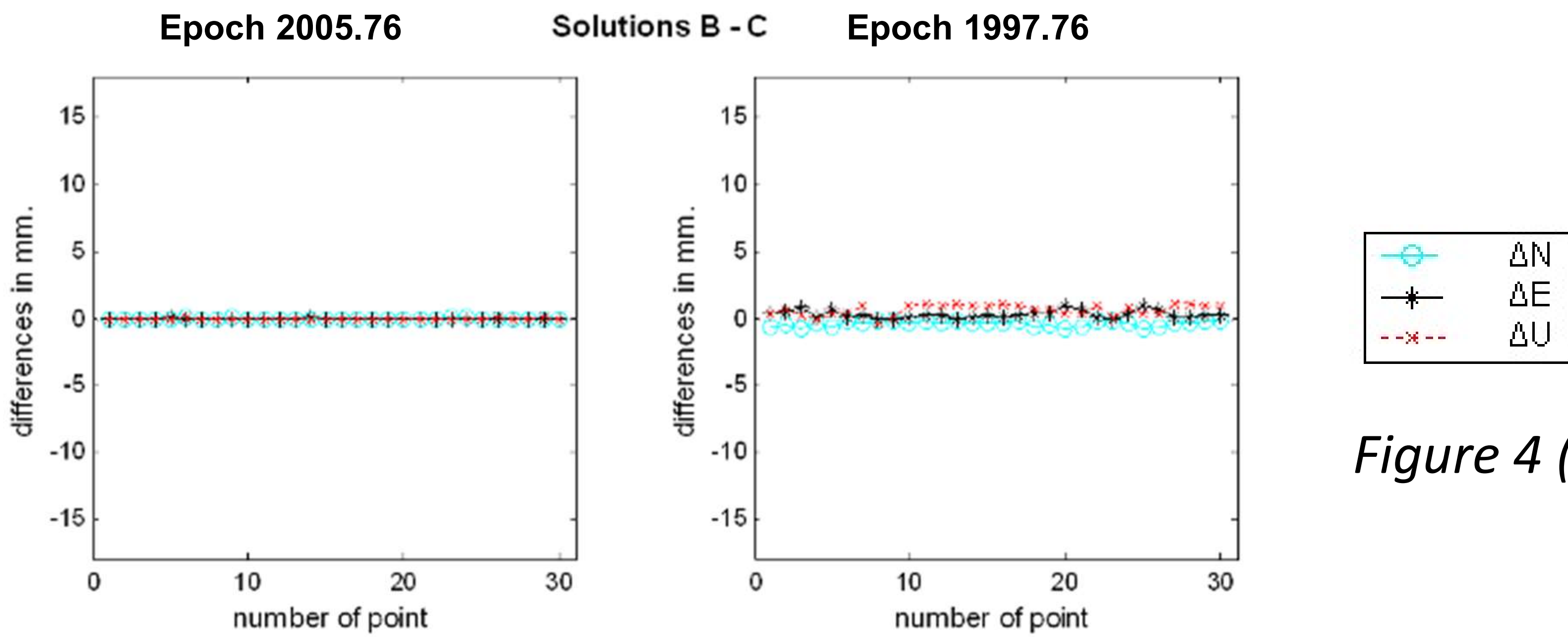


Figure 4 (cont.)

discrepancies between solutions	*Epoch 1997.76*			*Epoch 2005.76*		
	ΔN (mm)	ΔE (mm)	ΔU (mm)	ΔN (mm)	ΔE (mm)	ΔU (mm)
mean	0.1	-0.1	0.4	0.2	-0.5	0.6
max	1.8	5.7	13.5	2.5	2.9	17.9

Table 1

- Coordinate discrepancies vary up to 6mm for the *horizontal* and up to 18mm for the *height components*
- Discrepancies are in most cases within observation noise

Error Analysis

- Each estimate is accompanied by an aposteriori standard error value for all solutions. Apart from solution A, quality estimates are unrealistic (large volume of data $\Rightarrow$ excessive degrees of freedom).

- Despite the small discrepancies in coordinate estimates between the Solutions B and C the corresponding a posteriori standard error values are not the same.

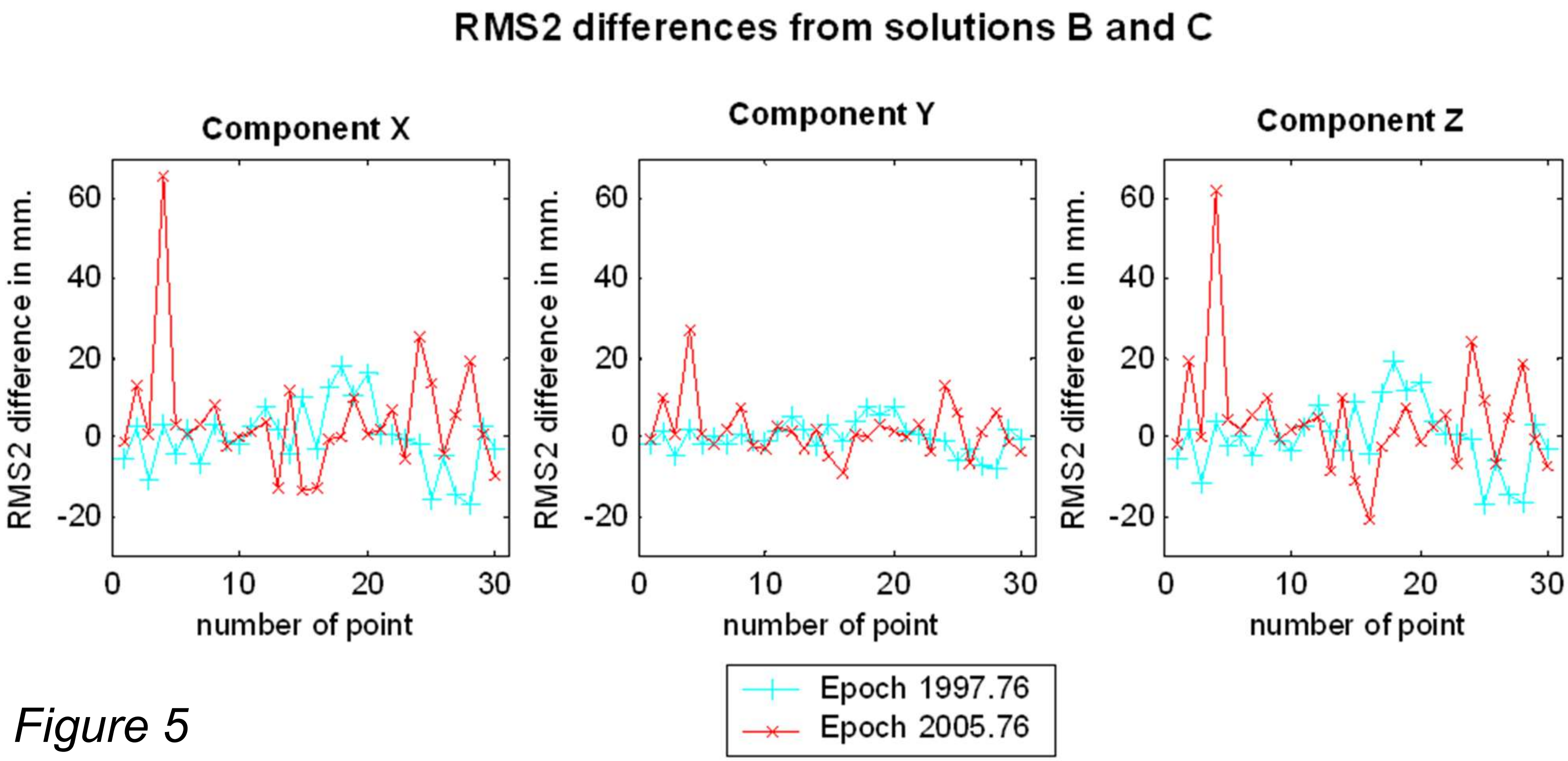


Figure 5

- After each day is processed two slightly different aposteriori standard error values (in our case < 0.8mm) may be computed:
  - $\rightarrow$ One is computed from the sub-programme GPEST to be used by the sub-programme COMPAR (Solution C) σ_{0Gi} .
  - $\rightarrow$ The second one from the sub-programme ADDNEQ (Solution B) σ_{0Ai}

- Therefore the a priori variance of the combined solutions (B or C) may be calculated from:

$$\sigma_{0c}^2 = \frac{\sum\limits_{\text{sum over all days}} r_i \cdot \sigma_{0i}^2}{\sum\limits_{\text{sum over all days}} r_i}$$

where:

σ_{0c}^2 : the apriori variance of unit weight of the combined solution,

r_i : the degrees of freedom for day ***i***,

σ_{0i}^2 : the variance of unit weight computed from day ***i***

	Solution B		Solution C		Epoch
a-priori (mm)	σ_{0Ai}	1.2	σ_{0Gi}	1.7	1997.76
		1.4		2.0	2005.76
a-posteriori (mm)	$\hat{\sigma}_0$	$\hat{\sigma}_{0AC}$	$\hat{\sigma}_0$	$\hat{\sigma}_{0CC}$	
	1.3	20.1	1.2	13.1	1997.76
	1.5	25.4	1.5	23.9	2005.76

Table 2 Apriori and aposteriori standard errors of unit weight for the combined solution (B and C) and for both epochs of GPS observations

σ_{0Ai} apriori standard error of unit weight computed from day ***i*** from the sub-programme ADDNEQ

σ_{0Gi} apriori standard error of unit weight computed from day ***i*** from the sub-programme GPEST

$\hat{\sigma}_0$ aposteriori standard error of unit weight of the combined solution

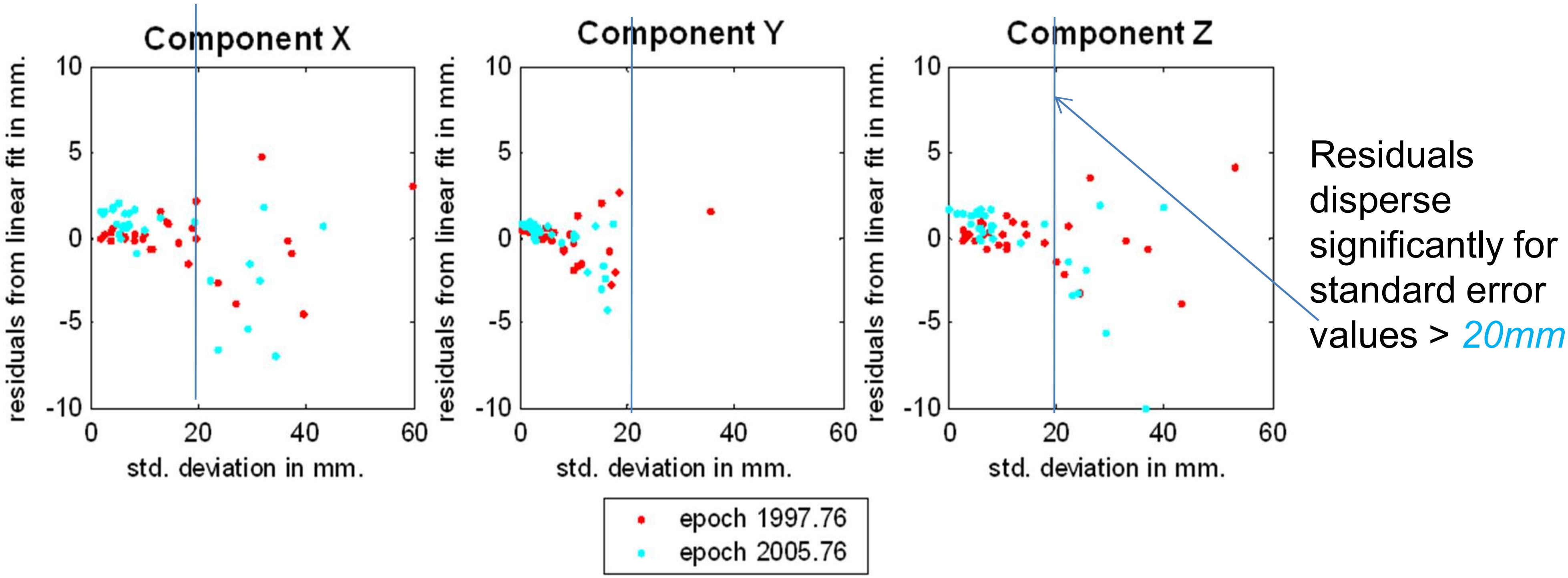
$\hat{\sigma}_{0AC}$ aposteriori standard error of unit weight of the coordinate group computed from ADDNEQ (Solution B)

$\hat{\sigma}_{0CC}$ aposteriori standard error of unit weight for coordinate comparison computed from COMPAR (Solution C)

- A posteriori standard error values for *solution C* (sub-programme COMPAR) appear to be in close (linear) relation with standard errors from *solution A* (daily solutions)

- A linear model was applied to the two epochs data sets. Residuals disperse significantly for standard error values > *20mm*.

- Discarding such points and re-applying the linear model, resulted in almost identical parameters (for all components and both epochs).


Component X
Component Y
Component Z
residuals from linear fit in mm.
std. deviation in mm.
epoch 1997.76
epoch 2005.76
Residuals disperse significantly for standard error values > 20mm.

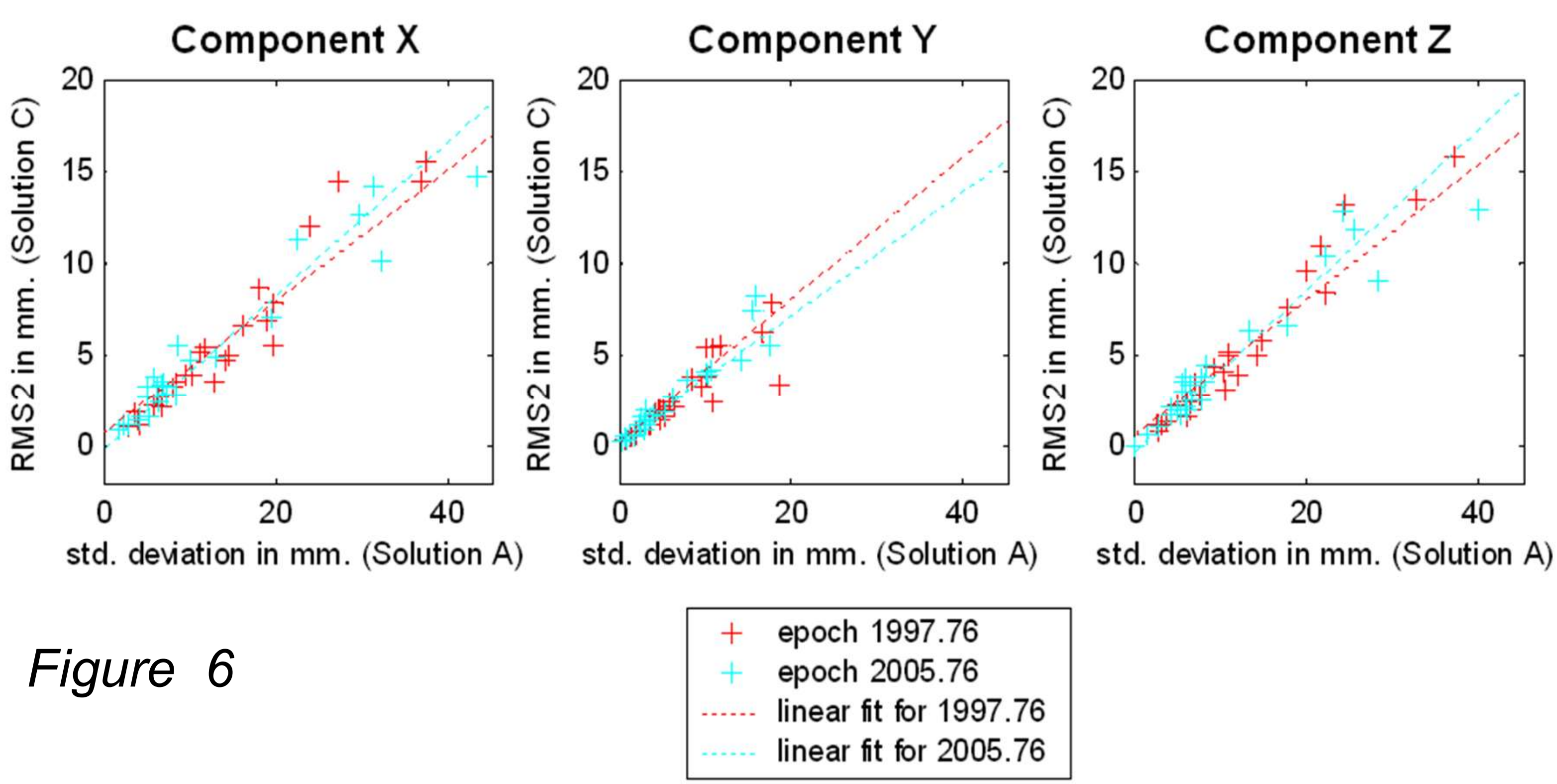

Component X
Component Y
Component Z
RMS2 in mm. (Solution C)
std. deviation in mm. (Solution A)
epoch 1997.76
epoch 2005.76
linear fit for 1997.76
linear fit for 2005.76

Figure 6

Component	X		Y		Z	
	a *(slope)*	**b**	**a** *(slope)*	**b**	**a** *(slope)*	**b**
Epoch 1997.76	0.36	0.7	0.39	0.2	0.37	0.7
Epoch 2005.76	0.42	-0.2	0.34	0.3	0.44	-0.3

Table 3 Parameters of the linear model for each coordinate component and both epochs

- So far no reliable conclusions maybe reached.

Conclusions

• **Solution A** provides realistic standard error values	• It is rather time-consuming (not fully automated) • Can be heavily influenced by errors since it considers equally weighted estimates
• **Solution B** provides reliable coordinate estimates • Offers a wide variety of options • Can process all kind of parameters	• Not realistic standard error values • Rather time consuming (parameter elimination)
• **Solution C** offers reliable coordinate estimates • Easy to use • Standard error values seem to be in close relation with the values from Solution A	• Can only be used for coordinate estimation (geodetic applications) • Cannot change the initial minimum set of constraints chosen for the solution


Thank you for your attention