International Technical Laser Workshop on SLR Tracking of GNSS Constellations

50 Years of Satellite Geodesy and Geodynamics

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Metsovon Conference Center
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Processing large volume GPS data via Bernese V4.2 software

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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 statistical models (Least Squares/Kalman filter etc).
- Users and software products have to address the growing demands for accuracy, high resolution, observation volume, reliability estimates.

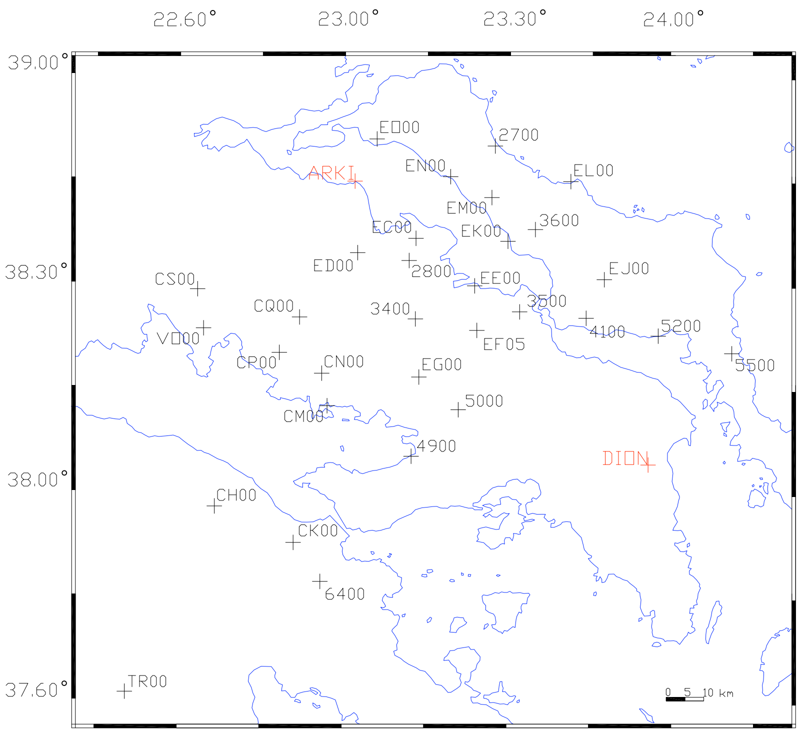
Data analysis

- 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.



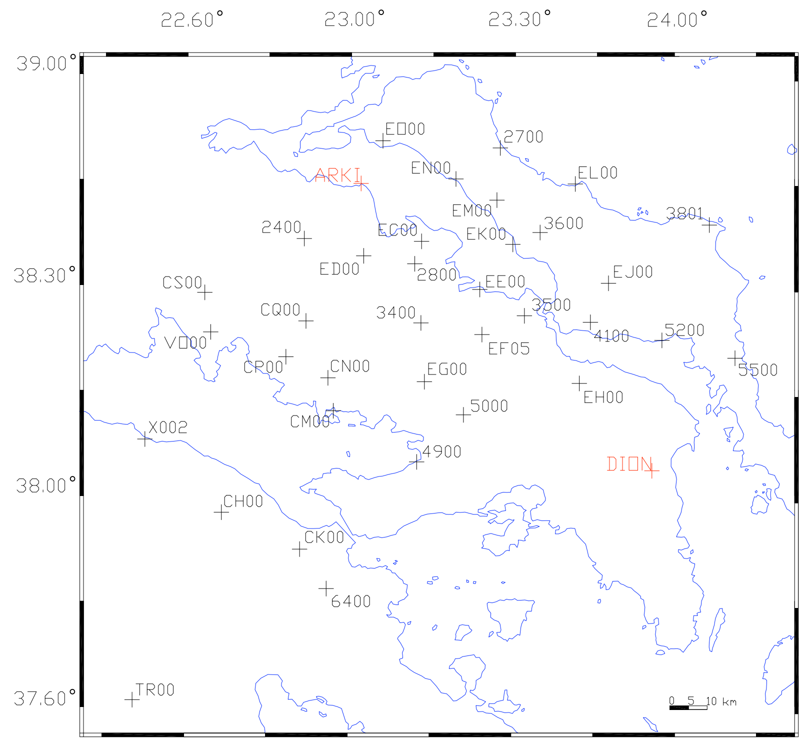


Figure 1

Epoch 1997.76 1st order network

Epoch 2005.76 1st order network

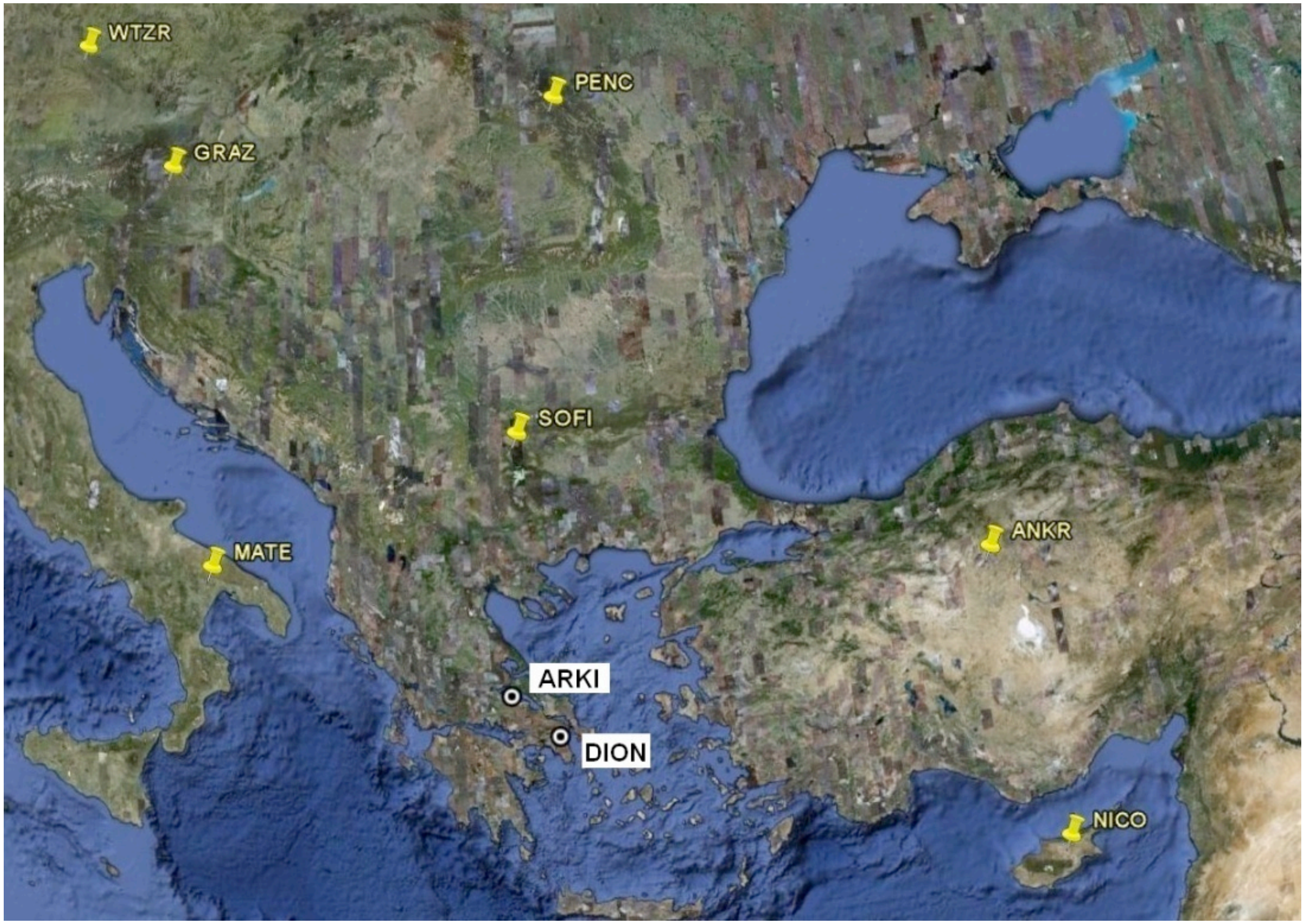


Figure 2 IGS stations used for referring to the ITRF 2000

- 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

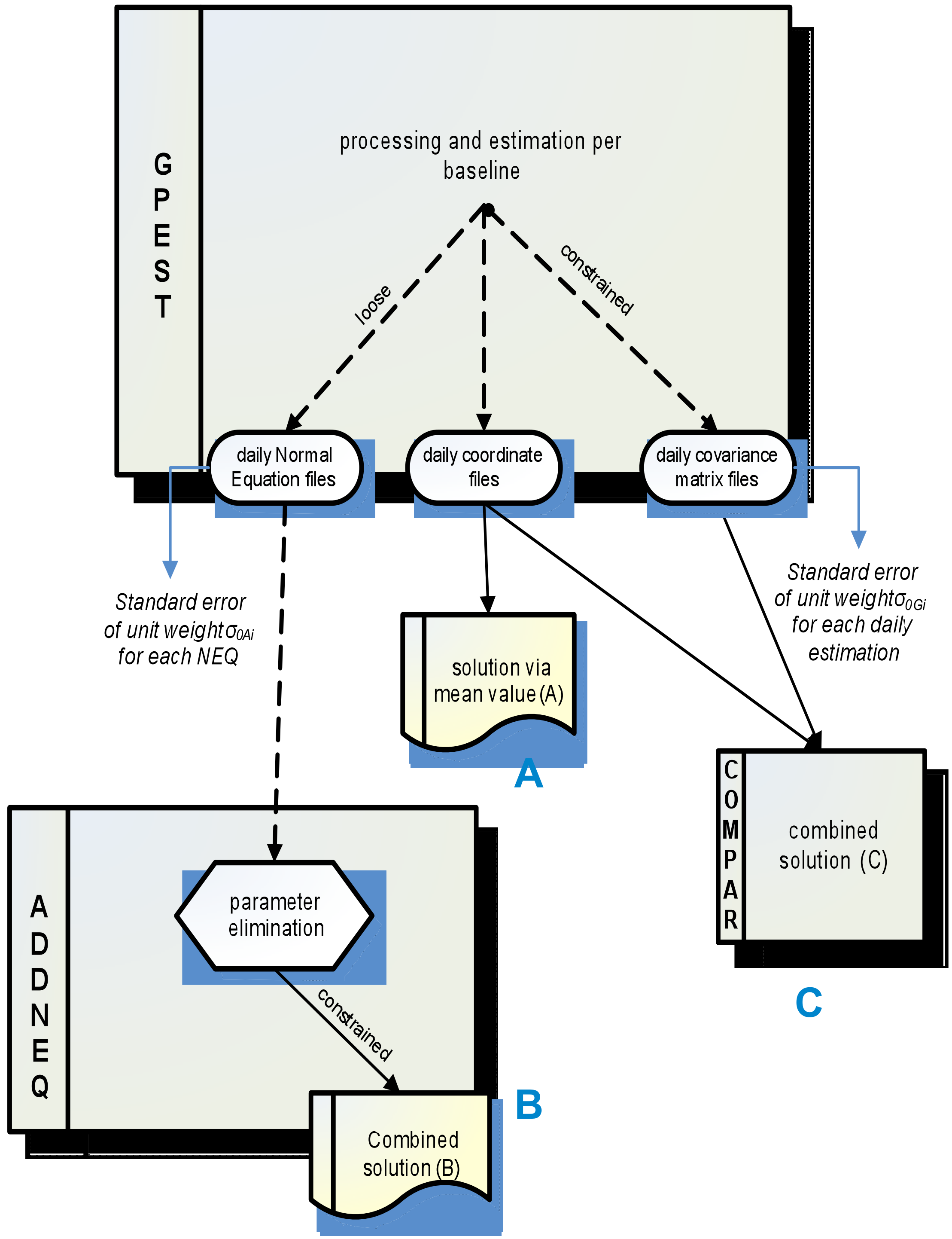


Figure 3

Comparison of the Solutions

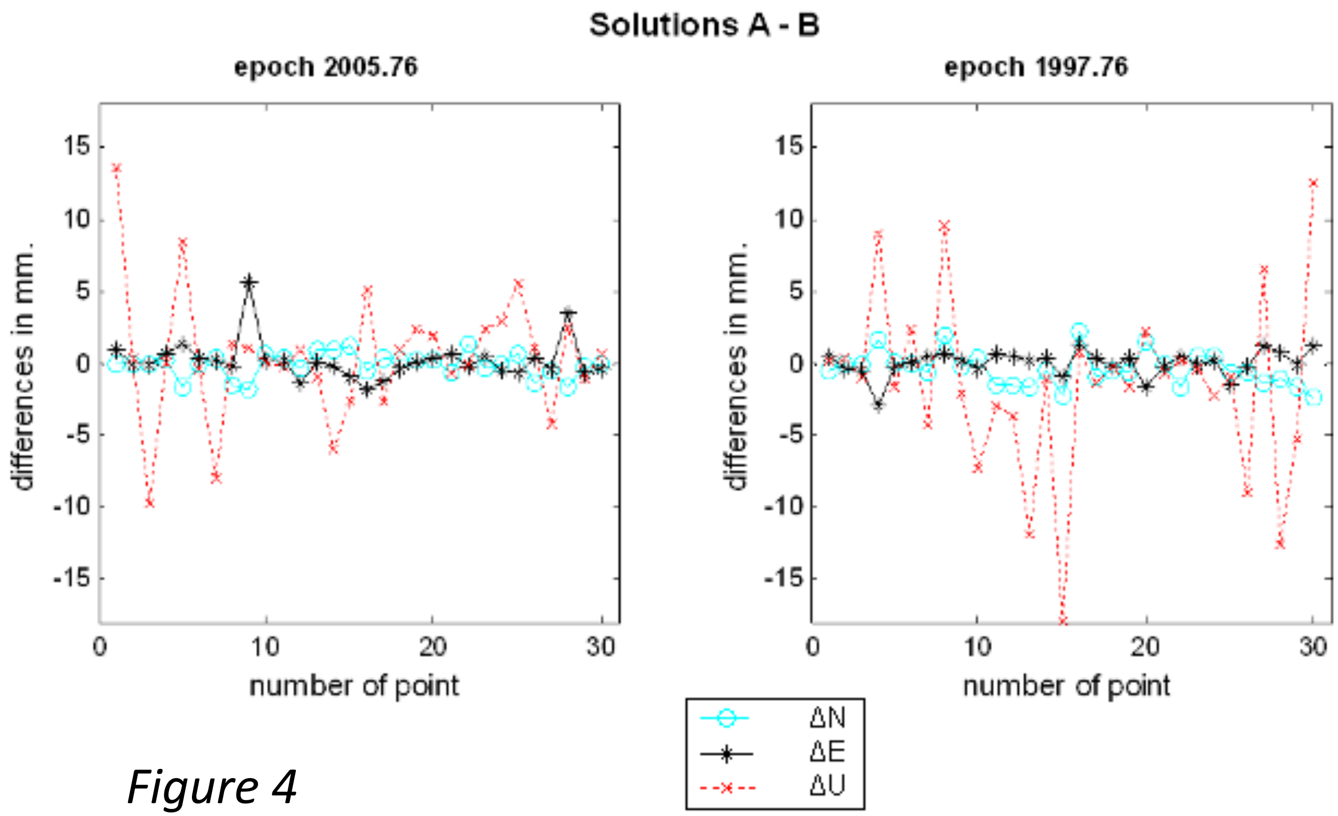


Figure 4

- 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

Solutions A - C

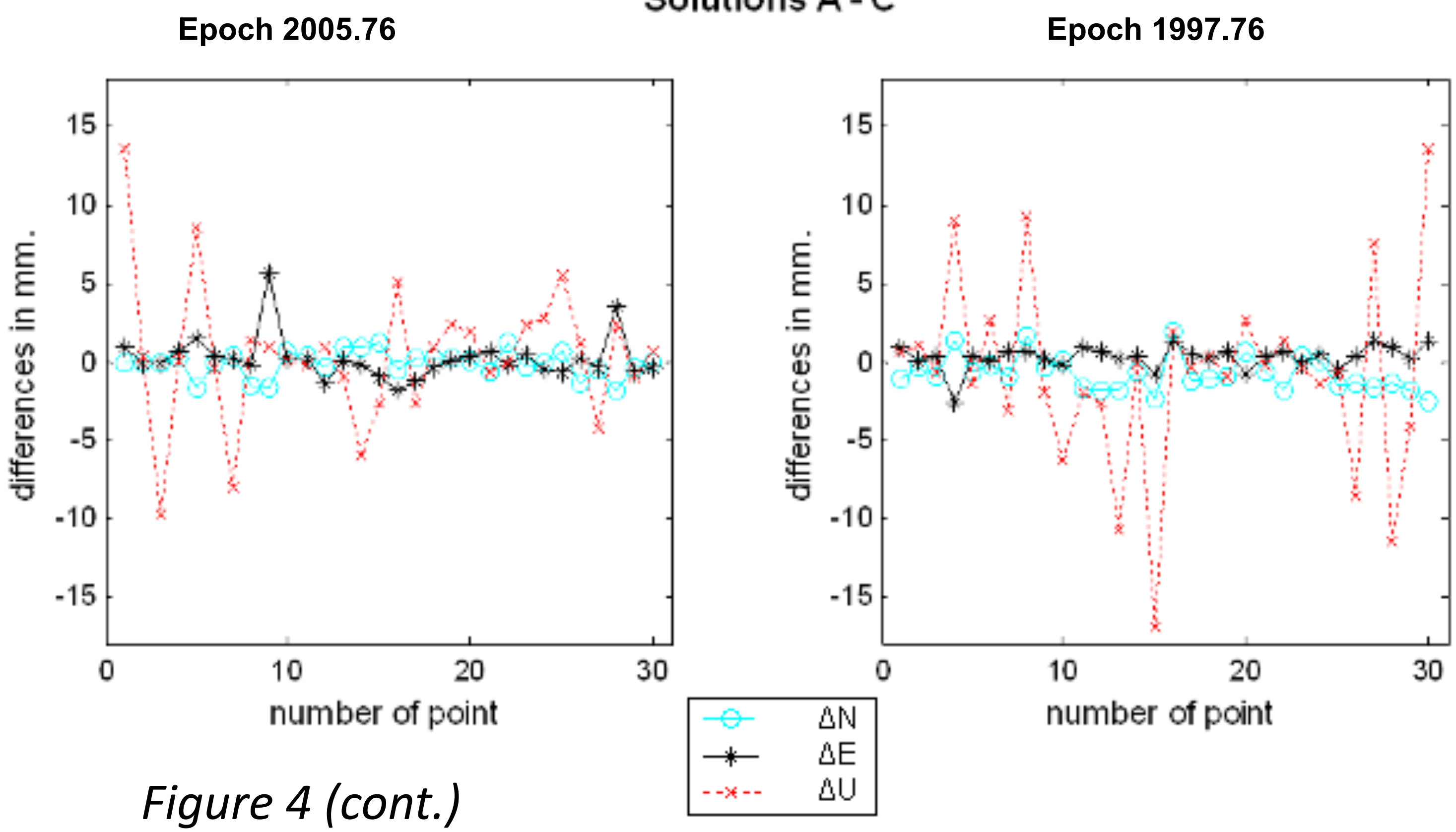


Figure 4 (cont.)

- 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

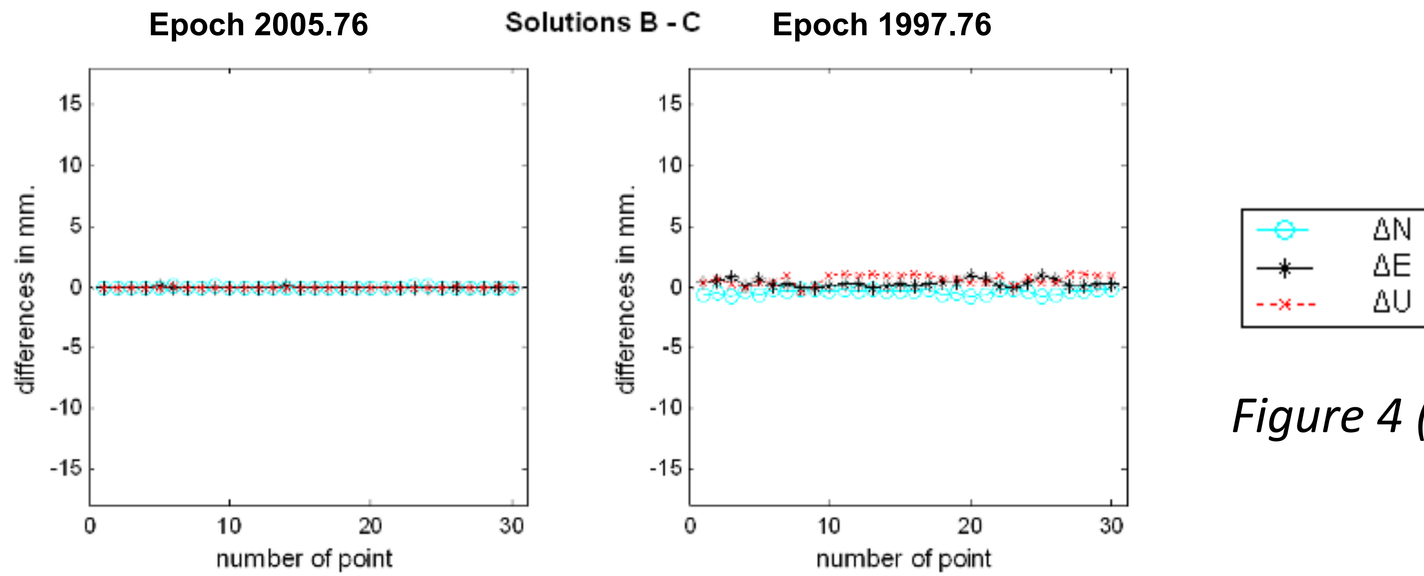


Figure 4 (cont.)

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 ⇒ 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.

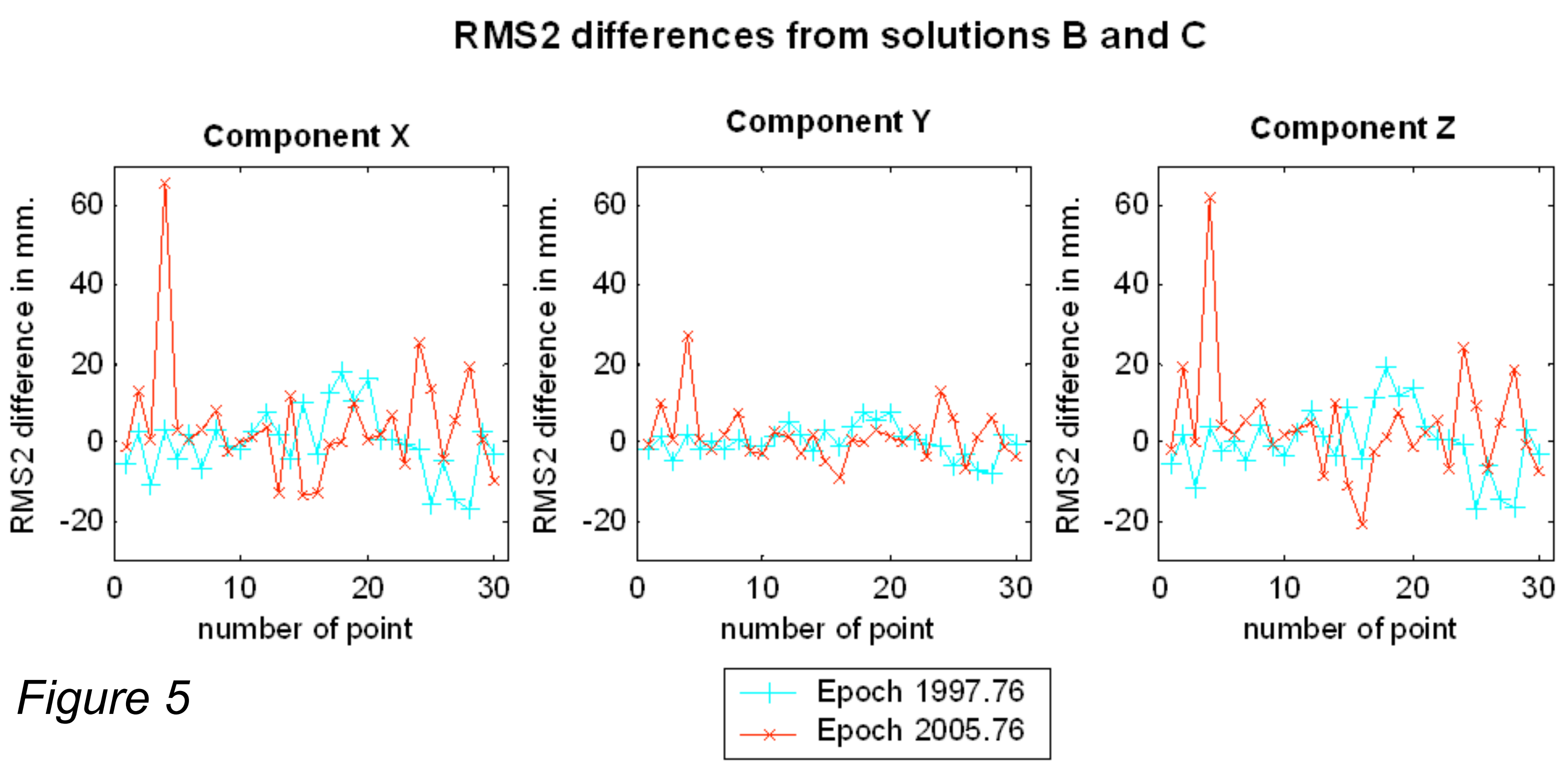


Figure 5

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

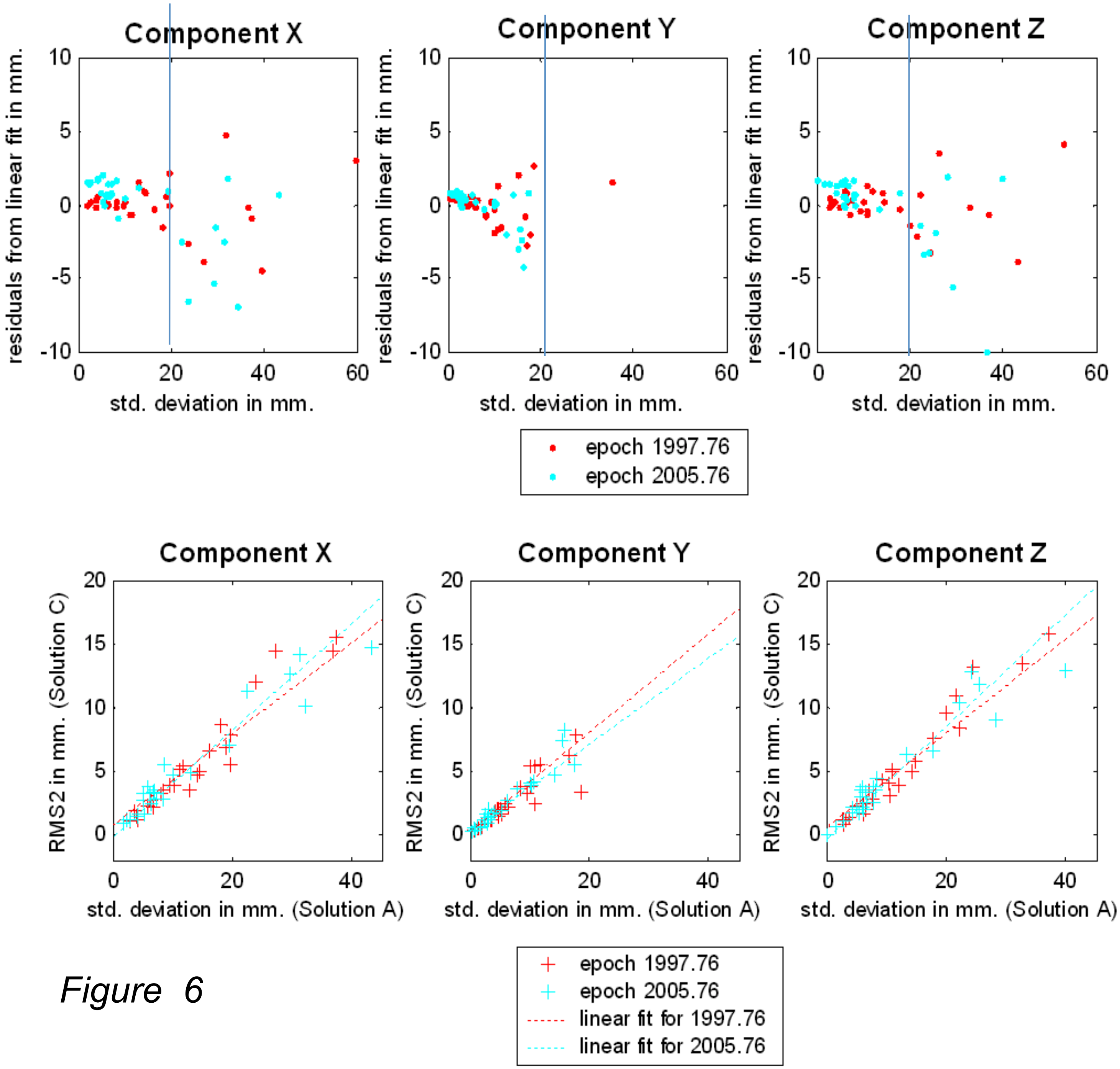
$\hat{\sigma}_{0AC}$ aposteriori standard error of unit weight of the coordinate group computed from ADDNEQ (Solution B)

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

- A posteriori standard error values for solution C seem to be in close (linear) relation with standard errors from solution A

- 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
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	**b**	**a**	**b**	**a**	**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

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- **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