Independent strategies for GPS data processing applied to the New Italian Geodetic Reference Network (RDN)

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Introduction

- During the last two years the IGMI has decided to define a new Geodetic Reference Frame based on GNSS permanent stations homogeneously distributed along the Italian territory

- Considering the presence in Italy of more than 400 GNSS stations, realised for many scientific and technical purposes, IGM has decided to define the reference system using a selection (about 100) of the already working GNSS permanent stations

- For the computation of this network a dataset of GPS data and the Bernese scientific software have been used by IGM following the guidelines defined by EUREF for network densification

Aim of this research

- **Study on accuracy and precision evaluation of the network solutions coming from different strategies of computation and the use of different scientific software.**
  - The processing of these data has been indeed performed using three software:
    - **Bernese,**
    - **Gamit-Globk**
    - **Gipsy-Oasis II** (used in Precise Point Positioning approach).
- Starting from the mandatory guidelines defined by EUREF, others parameters have been considered.
  - *In particularly considering limits and peculiarity of each software, some different choices (strategies) which can affect the final solution have been considered.*

Other considerations

- Different solutions coming from different software constitute and added value for the determination of the best values (in term of positions and velocities) of a GNSS permanent network.

- Using different software some systematical error can be found and removed.
  - In detail, the realization of automatic (semi-automatic) procedures for GNSS permanent stations data processing impose the realization of files containing, for each station information on Antenna, Receivers, offset, etc…
    - **(a mistake introduced in this files introduce a bias non detectable without external comparison).**

From the Euref guidelines something is mandatory somethings is recomended …

Processing Options

1. Use the final IGS products.
2. Introduce ocean-loading corrections for the stations.
3. Use a 10° elevation cut off angle and elevation dependent weighting of observations.
4. Use the Niell mapping function to map the tropospheric delay in zenith direction.
5. Recommendations
   - a. Estimate hourly station specific troposphere parameters.
   - b. Fix the initial phase ambiguities to integer numbers.

EUREF Permanent Network (from *Processing Options Table*)

	Type	Value	GPS week from	GPS week to
Ambiguity fixing	Reccomended		860	
Antenna Phase Center Corrections	Mandatory		860	
Observation Cut Off Angle	Reccomended	15°	860	1129
	Mandatory	10°	1130	
Observation Weighting	Mandatory	Apply elevation dependent weighting to the observations. AC's which can not use an elevation dependent weighting scheme are advised to continue using a 15° elevation cut off angle	1130	
Observation Sampling Rate	Reccomended	Use an observation sampling rate of 180 sec for the final parameter estimation.	860	
GPS Satellite Orbits	Mandatory	Use IGS or CODE orbits	860	1129
	Mandatory	IGS Final Orbits.	1130	
Orbits and Earth Orientation Parameter Consistency	Mandatory	GPS satellite orbits and earth orientation parameters have to be consistent.	860	
RMS in SINEX files	Reccomended	Specification : If you use Bernese GPS Software include the RMS of unit weight, number of unknowns and number of observations in weekly SINEX file generation.	1130	
Tidal Displacements	Mandatory	Apply ocean loading corrections for the stations	1130	
Troposphere Mapping Function	Mandatory	Niell Mapping Function	1130	
Number of Troposphere Parameters	Reccomended	Estimate one troposphere parameter for every 2 hours for each station.	860	1129
	Reccomended	Estimate hourly troposphere parameters for each station. This option is mandatory for ACs contributing to the Troposphere Special Project	1130	
Troposphere Parameter Reference	Reccomended	Specification : Save the estimated troposphere parameters in the daily normal equation files. Generate a weekly coordinate solution. Re-generate the daily troposphere parameter solutions with fixing the weekly coordinates (coordinate "re-substitution").	1130	
Global Troposphere Parameters	Reccomended	Specification : Introduce the troposphere parameter estimates of the global network solution as a-priori values.	1130	
Global Troposphere Parameters	Reccomended	No introduction of global troposphere parameter estimates (delete version A of this option).	1130	
A Priori Weight of Troposphere Parameters	Reccomended	Specification : Use 10 cm respect. 5 m a priori weight for the absolute respect. relative parameters.	860	
A Priori Weight of Troposphere Parameters	Reccomended	Specification : Use 5 m a priori weight for the absolute and relative parameters.	860	

Principal boundary condition adopted foreach software at the beginning of the research

- **Bernese V5.0 (BPE):**
  - All the condition in agree with the Euref Guidelines
- **Gamit (V 10.34):**
  - All the condition in agree with the Euref Guidelines
- **Gipsy-Oasis II (V 5.1):**
  - PPP approach whitout ambiguity resolution,
  - **Stacov2x** script for determination of transformation parameters computed using daily PPP solution and the ITRF2005 sinex files for the 13 common permanent stations

RDN and IGS/Euref permanent stations

- **IGS & EUREF:**
  - yellow dots
  - 13 stations
- **RDN (National Dynamic Network):**
  - blue dots
  - 85 stations
- **The considered dataset is 28 days (between 2007 december and 2008 january)**

Adopted post-processing procedure for the data comparison and Outlier detection

GAMIT output: SINEX

BERNE output: SINEX

GIPSY output: SINEX

Conversion fro Geocentric (X,Y,Z) to Geographic (φ,λ,h) and NEU (Local Geodetic System)
Including variance/covariance matrix propagations

3σ detection and rejection criteria foreach component and computed on a single coordinate dataset

Parameter estimation of linear coefficient for each component vs time (YYY.xxx)
including variance/covariance estimation relative to the estimated parameters

Graphs and results

$\forall$Site
$\forall$ Software

Graphs of XYZ and NEU

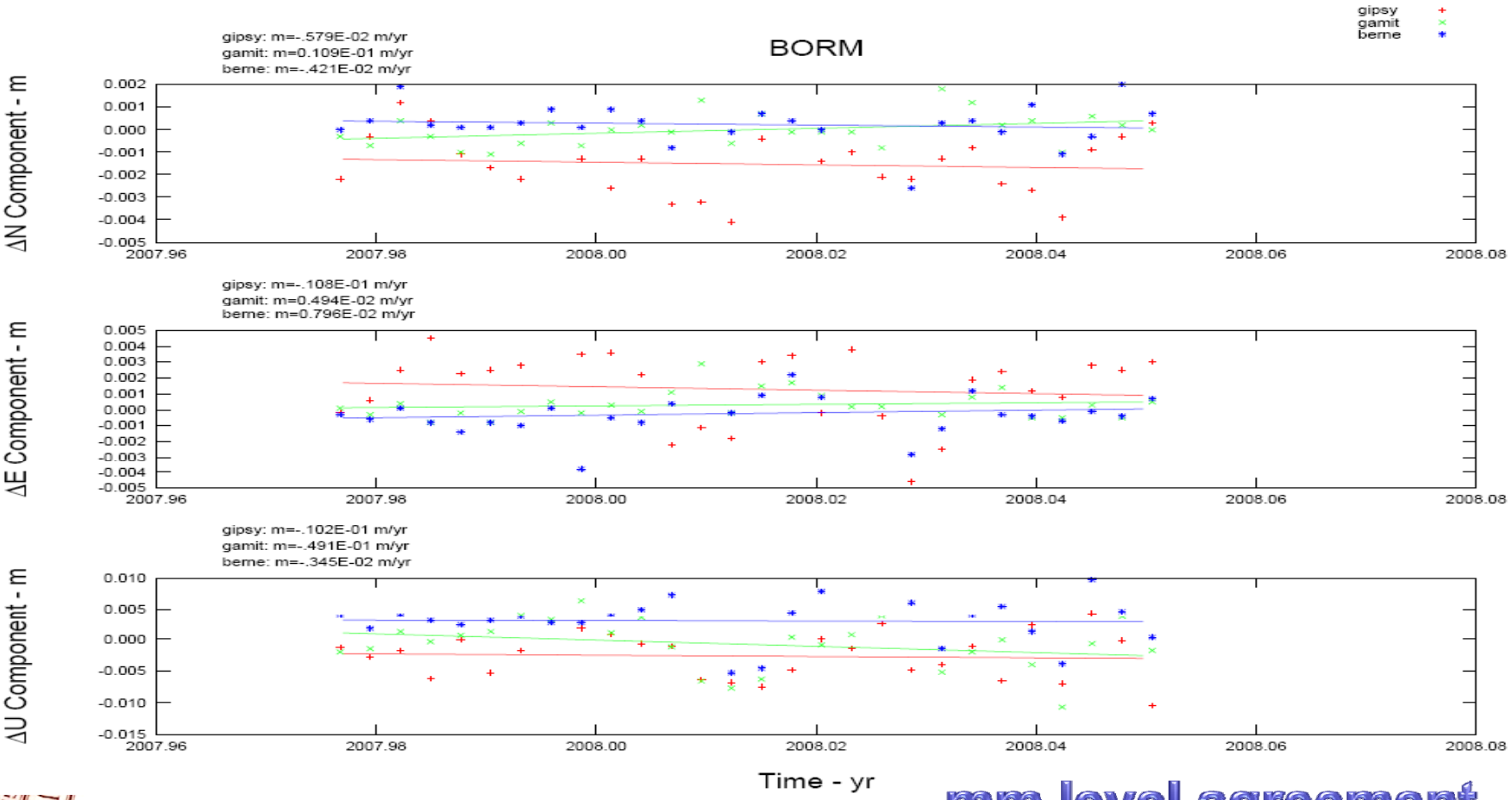
$\forall$Site
Graphs of XYZ and NEU
Of the three solutions

$\forall$Site
$\forall$ software
Final solutions
Rejected solutions
Statistical reports

Automatic procedure in linux c-shell using some scripts from Gipsy and Gamit, and the realisation of some Fortran codes and Graphs performed using GNUPLOT

Some results (comparison of the three solutions):

- **solutions for RDN (Bernese – Gamit – Gipsy)**

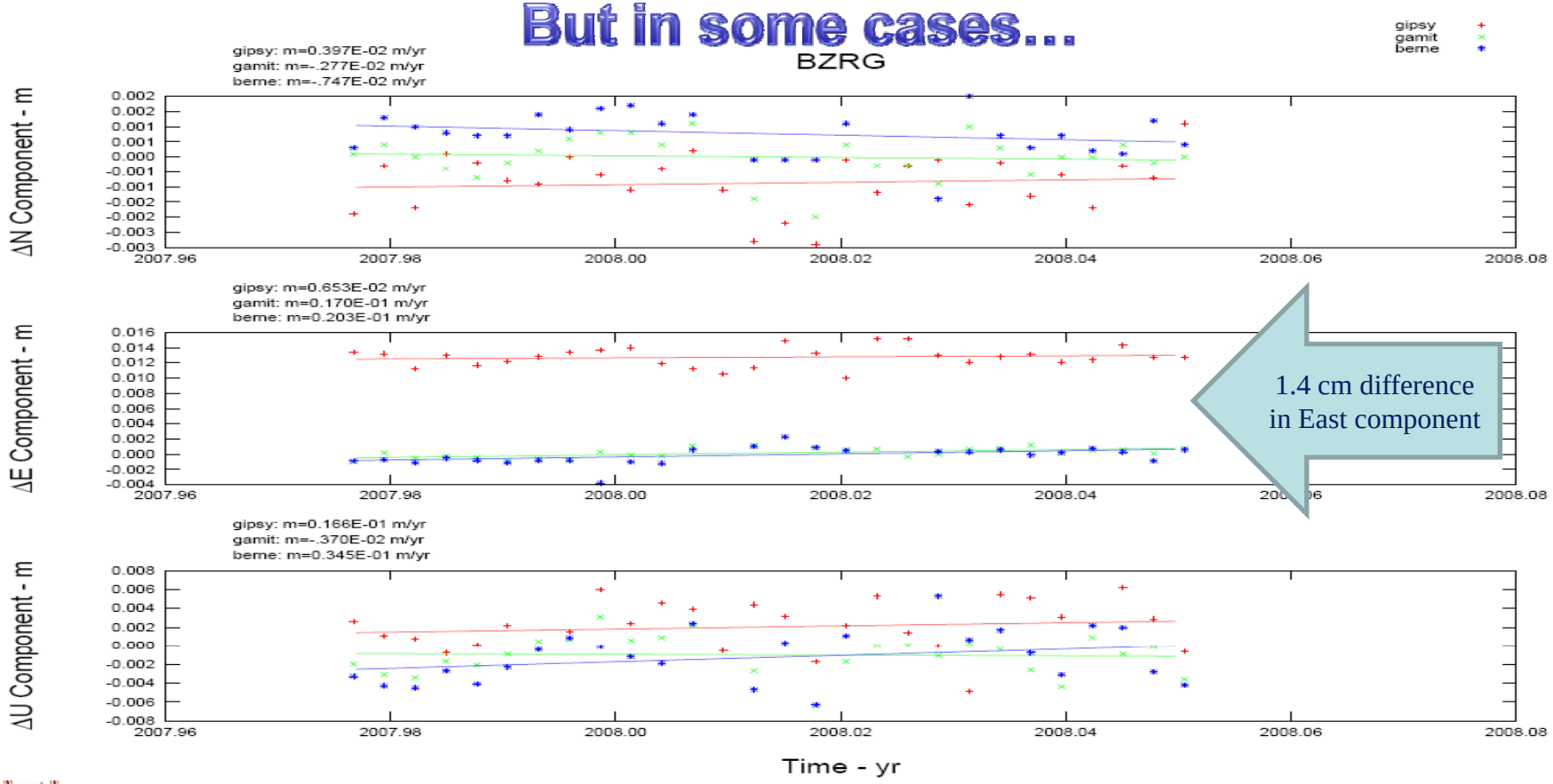


mm level agreement

Some results (comparison of the three solutions):

- **solutions for RDN (Bernese – Gamit – Gipsy)**

But in some cases…



Only the Gipsy solution evidence this problem (?)

Level Agreement between Bernese and Gamit

- **Bernese vs Gamit**
- **North – comp.**
- **Average solutions**

- **No differences bigger than 5mm**

Level Agreement between Bernese and Gamit

- **Bernese vs Gamit**
- **East – component**
- **Average solutions**

- **No differences bigger than 5mm**

Level Agreement between Bernese and Gamit

- **Bernese vs Gamit**
- **Up – component**
- **Average solutions**

Some results (comparison of the three solutions):

- **Bernese vs Gipsy**
- **North – component**
- **Average solutions**

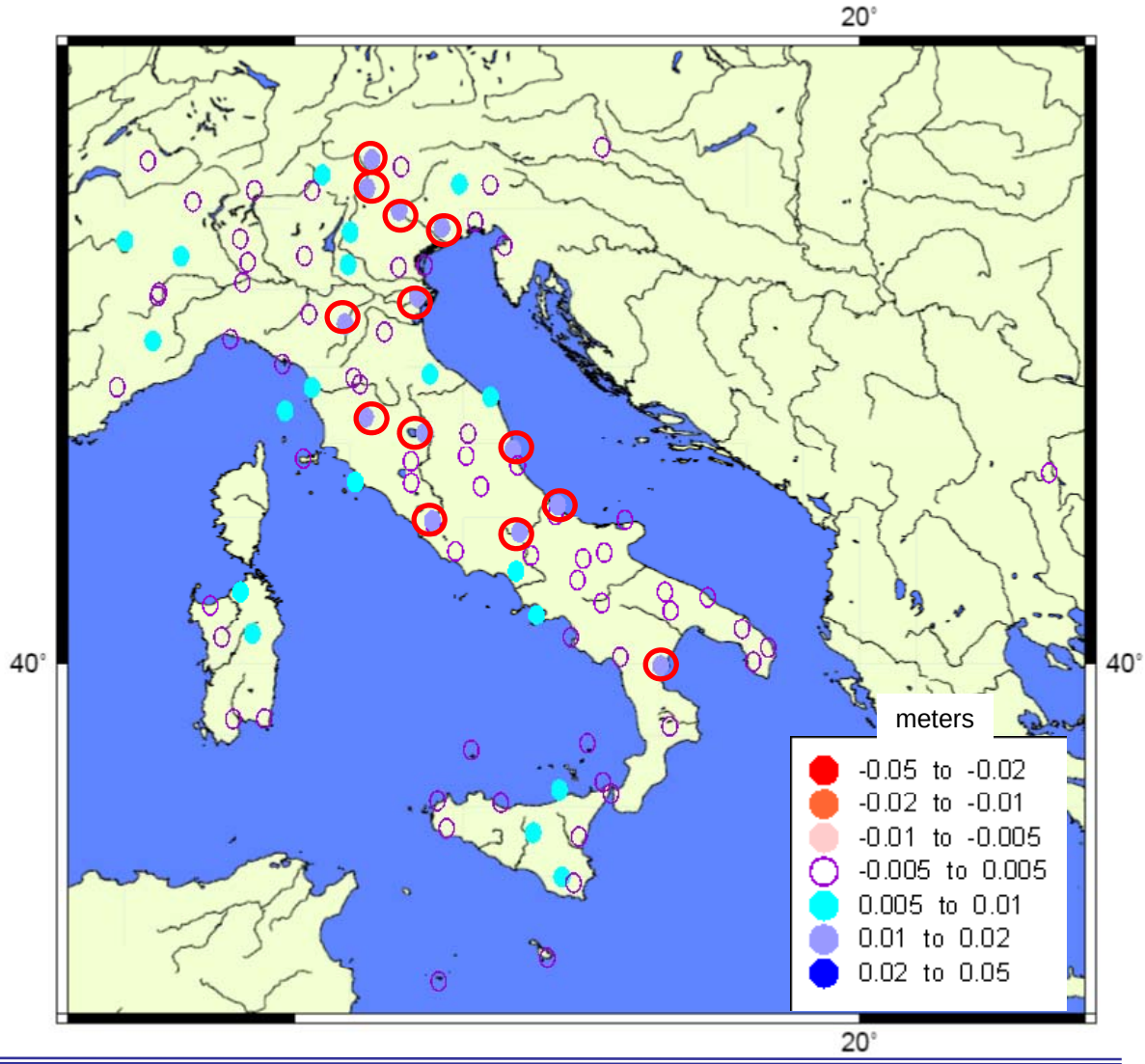
- **Agreement at cm level**

Some results (comparison of the three solutions):

- Bernese vs Gipsy
- East – component
- Average solutions

- A bias (of about 7 mm up to 1.4 cm) in East component for many stations

…



Some results (comparison of the three solutions):

- **Bernese vs Gipsy**
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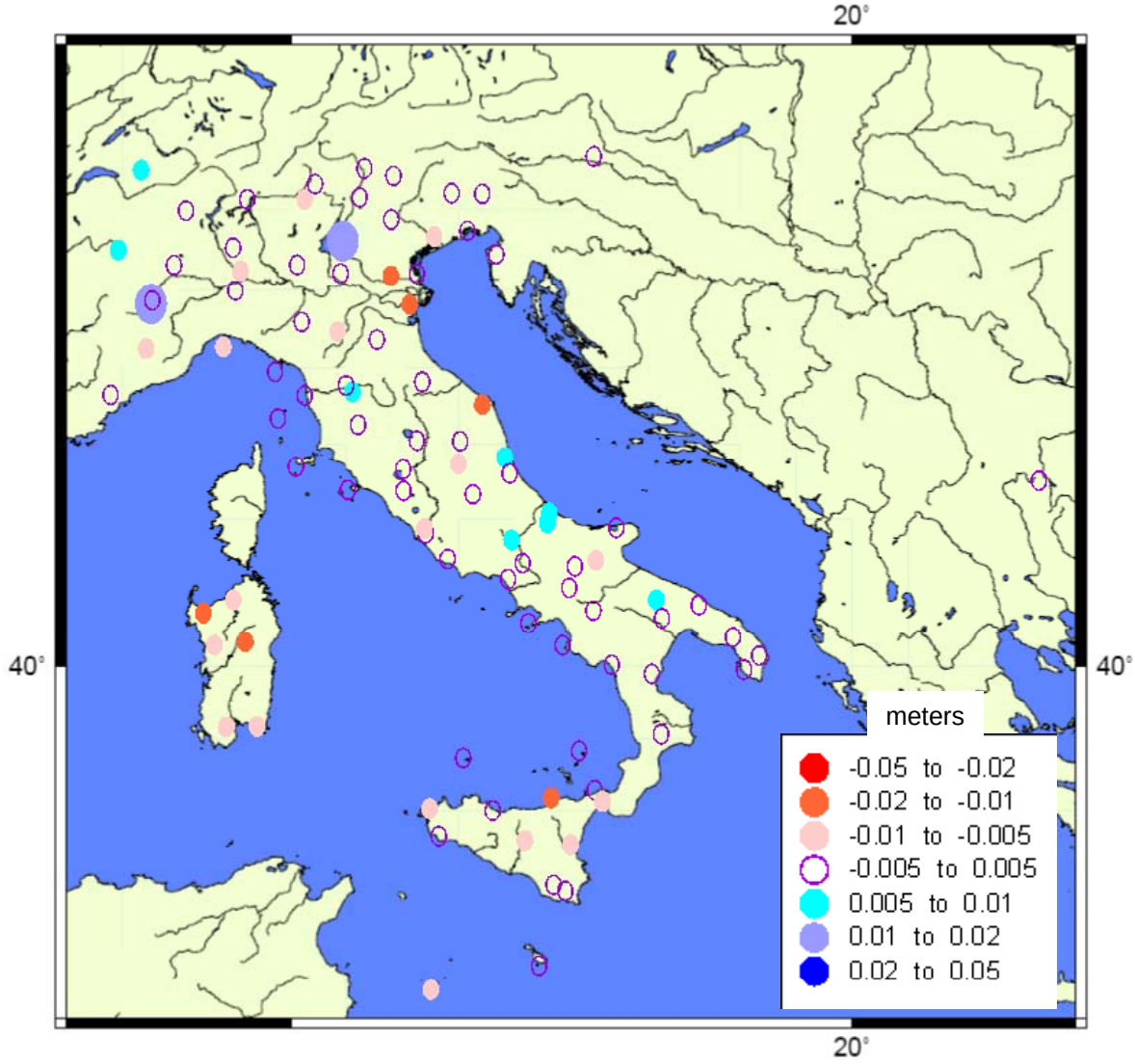
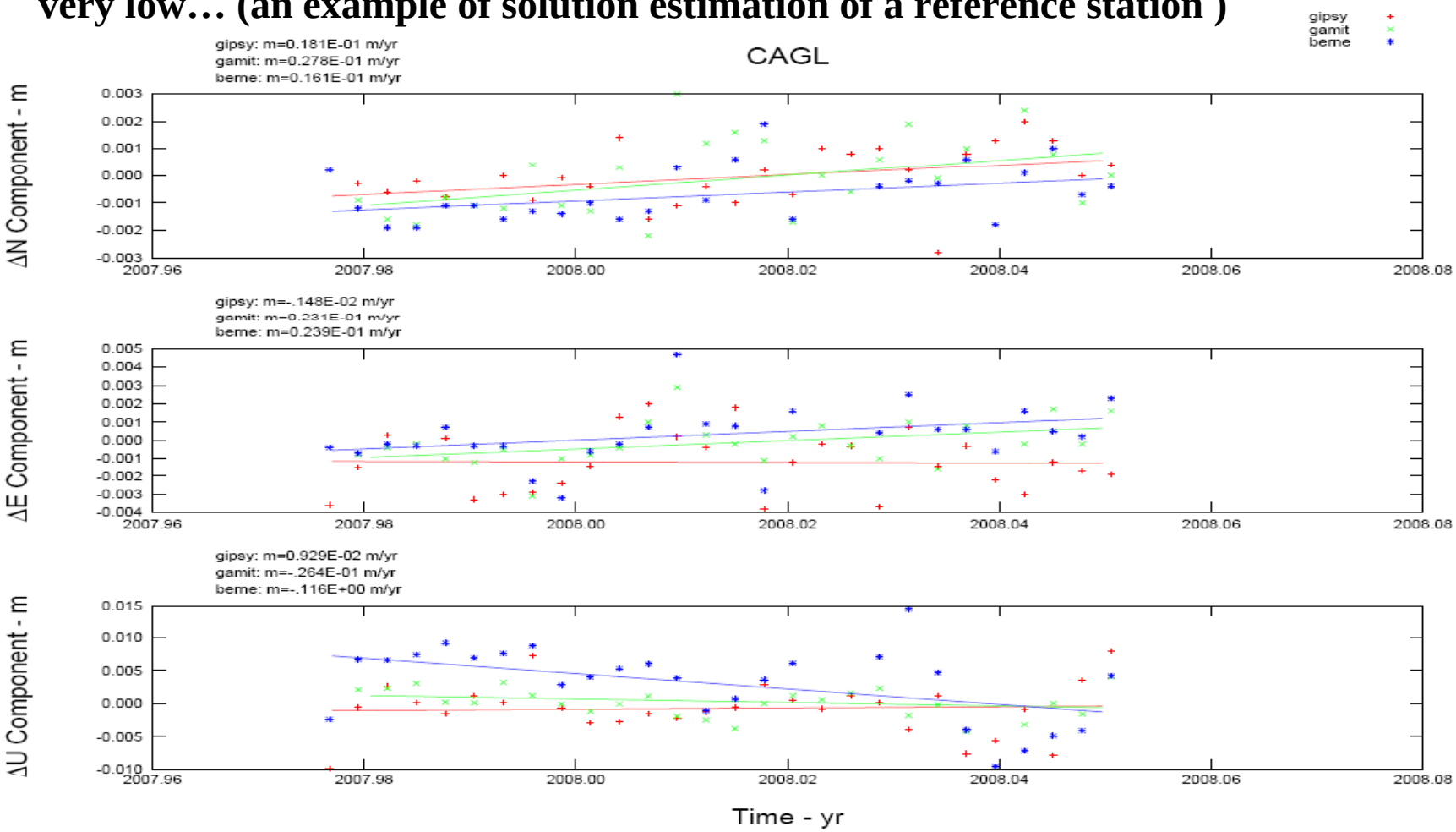
- **Average solutions**

- **Agreement at cm level**



What about the gipsy solution ?

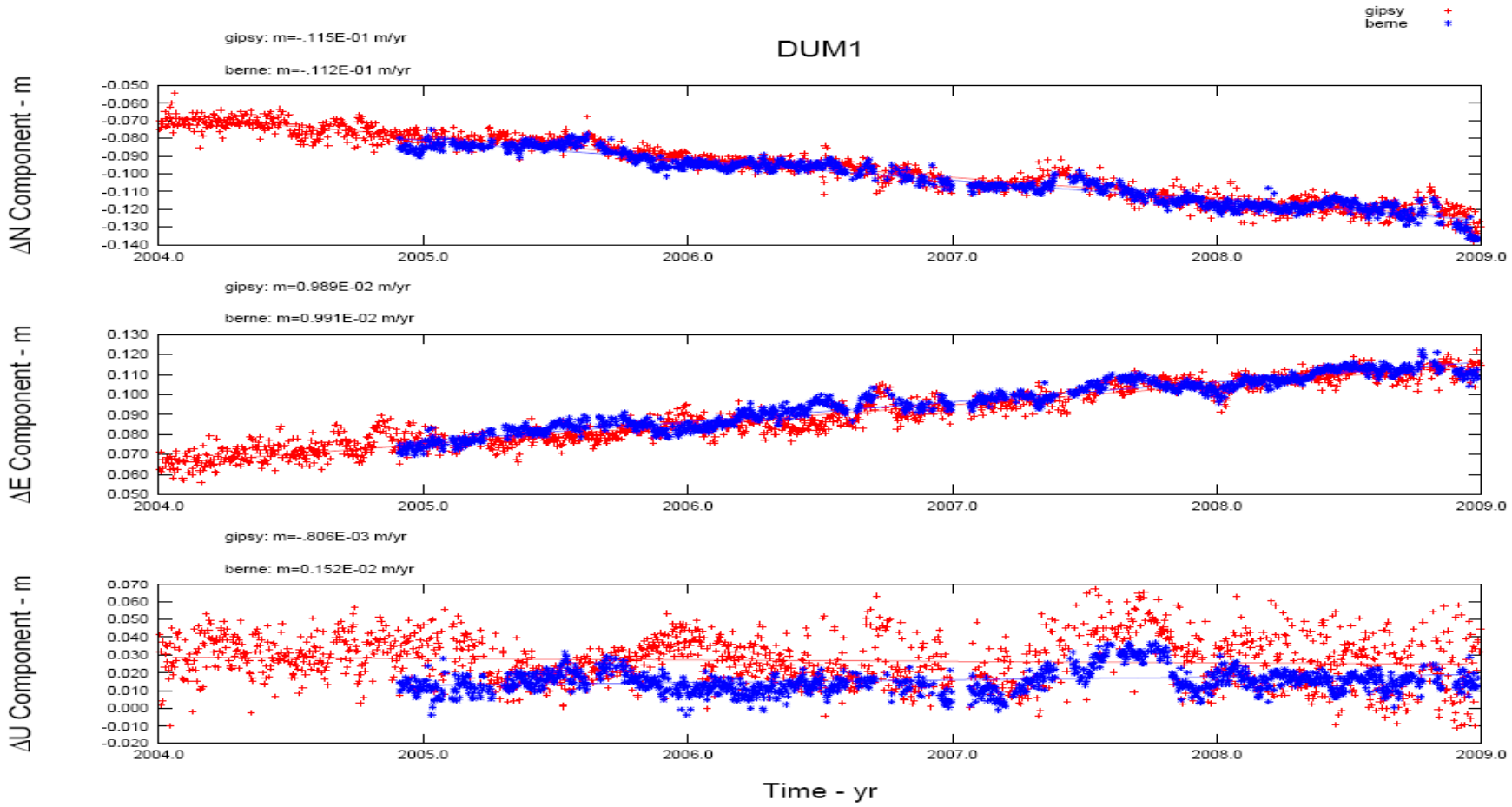
- **Is not a problem of framing procedure … (residual in the all used IGS stations are very low… (an example of solution estimation of a reference station)**



What about the gipsy solution ?

- **Velocities estimation parameter are in agree to the others software**

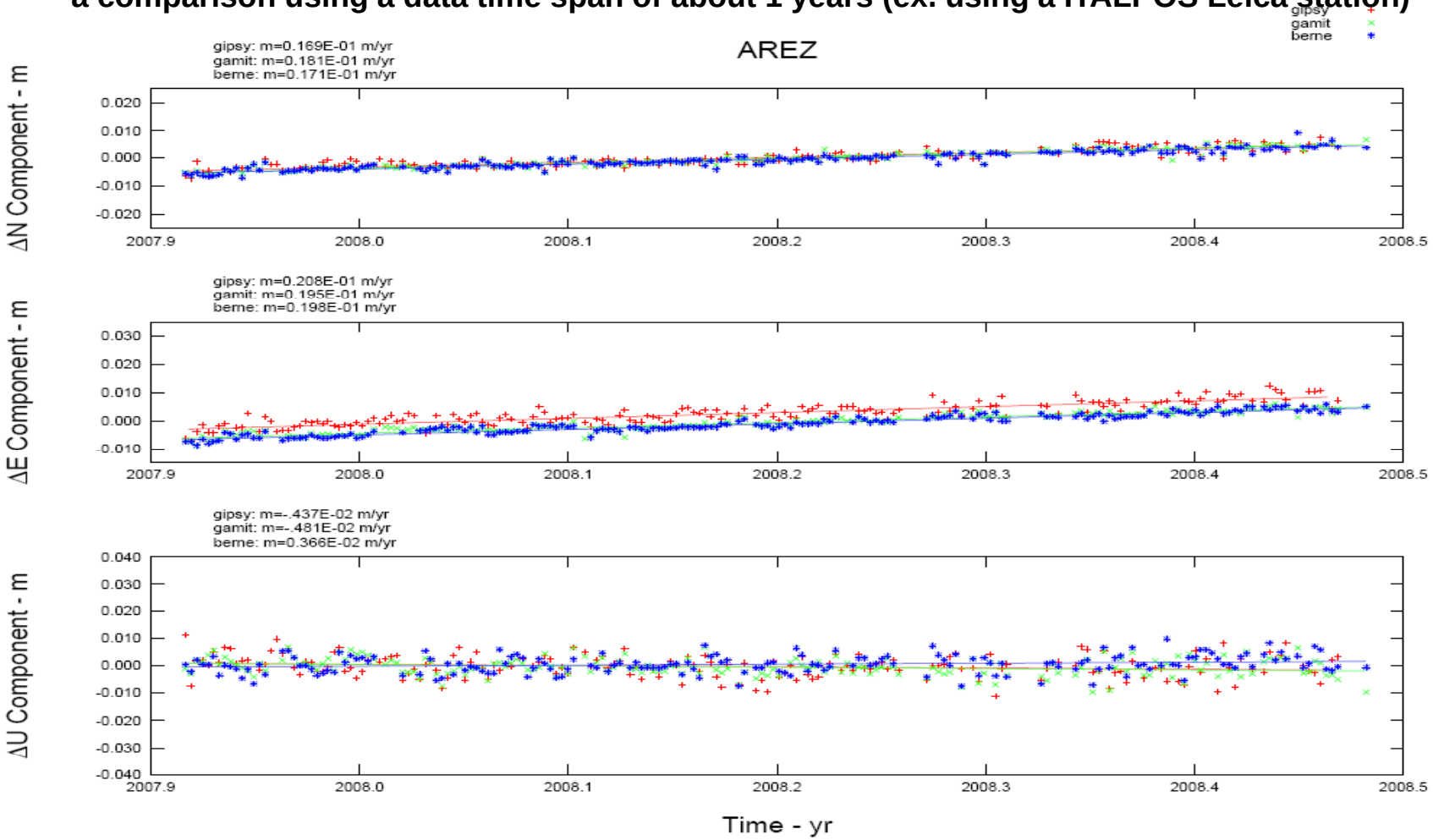
Bernese vs Gipsy a comparison using a data time span of about 4 years (ex. using an Antarctic station)



What about the gipsy solution ?

- **Velocities and position (Bernese – Gamit – Gipsy)**

  a comparison using a data time span of about 1 years (ex. using a ITALPOS Leica station)



Many tests to find the solution to this problem!!

- **IGS products but without azimuth corrections for antenna calibration**
- **JPL orbits and relative Phase Center Variations**
- **GPS_Receiver_types changes ….**
- **Old GIPSY version (version 4)**
- **New JPL products**
- **Cut-off angle changes**

  – Any obtained solution is different from the others but in term of less than 1mm and no changing of the East component has been found.

An interesting aspects…

site	D_North (Gipsy-Bernese)	D_East (Gipsy-Bernese)	D_Up (Gipsy-Bernese)	Antenna type	Radome
PORD	-0.0002	0.0164	-0.0067	TRM29659.00	UNAV
PASS	-0.0024	0.0154	0.0037	LEIAT504GG	LEIS
ALFE	-0.0001	0.0143	0.0061	TRM29659.00	UNAV
BZRG	-0.0013	0.0135	0.004	LEIAT504GG	LEIS
VAST	0.0008	0.013	0.0081	TRM29659.00	UNAV
TGPO	0.0004	0.0125	-0.0146	TRM41249.00	NONE
MART	0.0002	0.0121	0.0071	TRM29659.00	UNAV
SIEN	-0.0002	0.0118	0.0031	LEIAT504GG	NONE
TREB	0.0009	0.0116	-0.0042	LEIAT504GG	LEIS
MOPS	-0.0001	0.0115	-0.0099	LEIAT504GG	NONE
M0SE	-0.0006	0.0113	-0.0068	LEIAT504GG	LEIS
STBZ	-0.0013	0.0104	-0.0028	LEIAT504GG	LEIS
UNPG	0.0005	0.0101	-0.0049	JPSREGANT_DD_E	NONE
VERO	-0.0012	0.009	-0.0002	LEIAX1202GG	NONE
RSMN	0	0.0089	-0.0044	TRM41249.00	NONE
CUNE	-0.0023	0.0086	-0.0077	TRM41249.00	NONE
ENAV	-0.0008	0.0075	-0.0022	LEIAT504	LEIS
BIEL	0.0014	0.0074	-0.0014	TRM41249.00	NONE
ENNA	0.0012	0.0073	-0.0098	LEIAX1202GG	NONE
MADA	-0.0002	0.0071	0.0002	LEIAX1202	NONE
…	…	…	…	…	…

Sorted respect East component (decreasing)

Seem that the most bias in the east component are in correspondence of two antenna types:

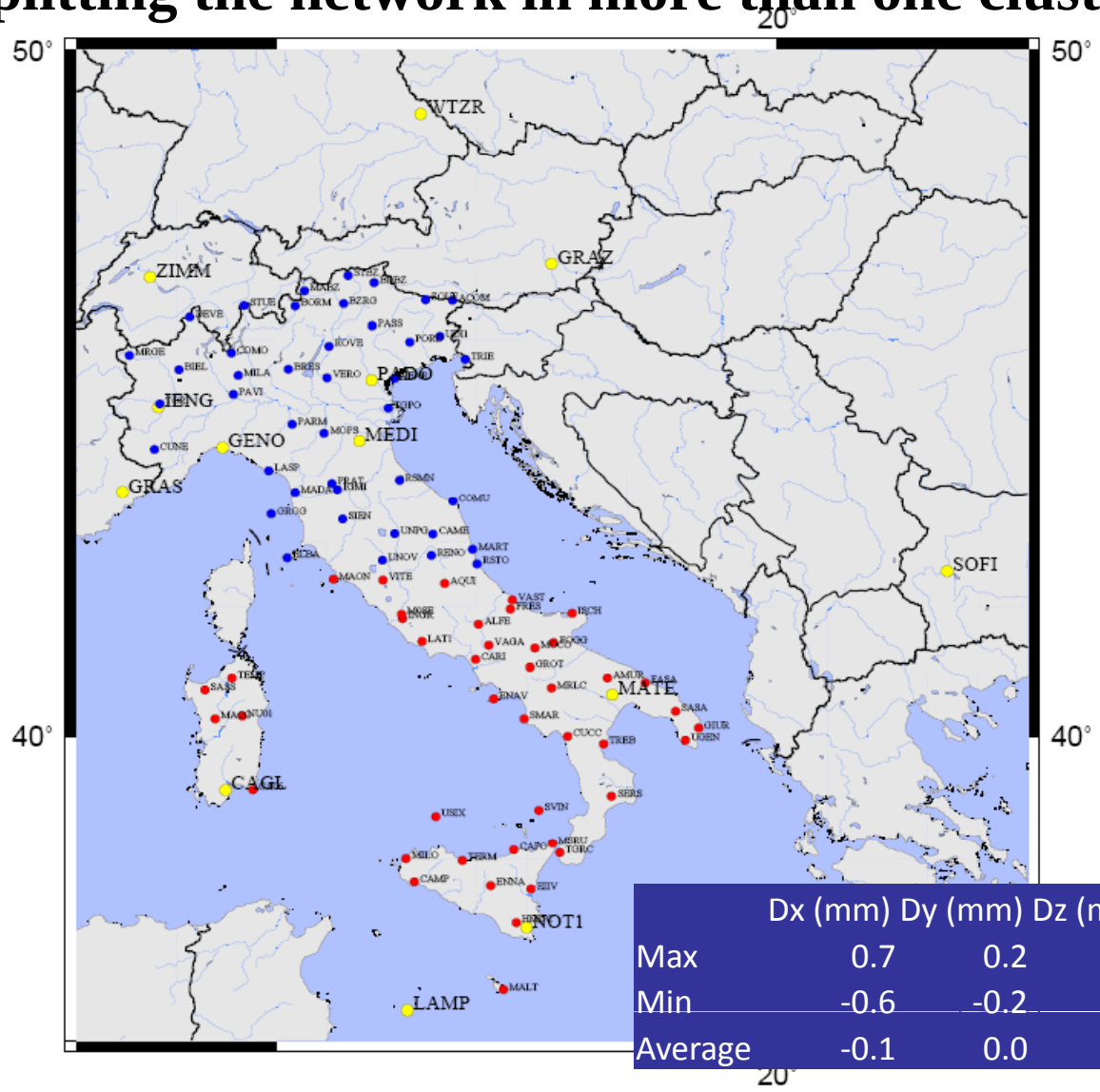
Leiat504GG LEIS
TRM29659.00 UNAV

Work still in progress and any suggestion are welcome!

(We have used the last IGS05_*wwww*.atx file)

Gamit: Others test splitting the network in more than one cluster

Site	Dx (mm)	Dy (mm)	Dz (mm)
acom	0.1	-0.1	0
alfe	-0.2	0	-0.2
amur	-0.3	-0.1	-0.2
aqui	0.1	0.1	0
biel	0.1	-0.1	0.2
borm	0	-0.1	0
brbz	0.1	0.1	0.2
bres	0	-0.1	0
bzrg	-0.2	-0.1	-0.2
ca06	-0.2	0.1	-0.2
cagl	-0.1	0	0
came	0	0	0
camp	-0.3	-0.1	-0.2
capo	-0.1	0	0.1
cari	0	0	0
como	0	0	0
comu	0.4	0.2	0.6
cucc	-0.3	-0.2	-0.4
cune	0.7	0	0.8
deve	-0.5	-0.1	-0.4
eiiv	-0.3	-0.1	-0.2
elba	0	0	-0.1
enav	-0.2	0	-0.1
enna	0	-0.1	0.3
fasa	-0.2	-0.1	-0.2



	Dx (mm)	Dy (mm)	Dz (mm)
Max	0.7	0.2	0.8
Min	-0.6	-0.2	-0.4
Average	-0.1	0.0	0.0

Some conclusions and considerations

- **The data analysis obtained by the comparison of Gamit and Bernese are in agree at mm level (also splitting the network in more than one cluster).**
- **Gipsy solution present in some points, some bias in east component at cm level that still under investigation (a mistake in the PCV correction?).**
- **Velocity estimation obtained by the three software (using a long time span) are in agree.**

- **But we have to consider that:**
  - Gamit and Bernese solution are obtained using the same approach (in all the aspects)
  - Gipsy solution is obtained using a undifferenced approach and no correlation between station due to the network is present

- **For the future …**
  - Perform RDN network using Gipsy and Ambizap approach (for fix ambiguity) …

Thank you !

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