The Italian transition from a static to a dynamic reference frame: present transformation and future developments

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Outline

A general definition of positioning service and the present Italian situation: IGM95.

The need of a zero order PN and the first test.

The study of IGM95 deformations:

ItalPos PN adjustment in IGS and link to IGM95, the transformation from IG05 to IGM95.

The new official IGM network: RDN
RDN adjustment in ITRF/IGS05.

Conclusions.

Positioning RT services

A positioning service based on GNSS permanent stations distributes coordinates, data and network products
both for cadastral (RT) and high precision (PP) applications.

It materializes and distributes
one or more reference frames to the user community:

ITRFyy for high precision applications,

the official cartographic RF (in Europe some ETRFyy)
for cadastral surveying.

ITRF2005/IGS05: different 2005 realizations of ITRS;
in the following adjustments, IGSS05 has been used.

The present situation in Italy

≈ 12° × 12°, 301388 Km^2

20 administrative regions: surfaces (Km^2)

Mean ≈ 15000

Max = 25708 (Sicilia)

Min = 3262 (Aosta)

Positioning services are designed, created and managed at the Regions scale.

Usually adjusted in IGS (IGS05).

The official cartographic Italian RF

ETRF89-IGM95 is the official Italian cartographic RF:
2000 benchmarks, adjusted in ETRF89, t0=1989.0;

due to elapsed time
both spatially correlated deformations and sparse blunders.

Our opinion for the future:
Italy should switch from the static ETRF89-IGM95 network
to a continuously monitored realization (zero order PN) of ETRS89.

Present needs:
a transformation between IGS05 and ETRF89-IGM95
must be estimated and provided to the positioning services users.

The requirements for a national zero order PN

(All in EUREF 2007 proceedings, same authors)

Minimal characteristics:

1) homogeneously distributed over the whole nation,

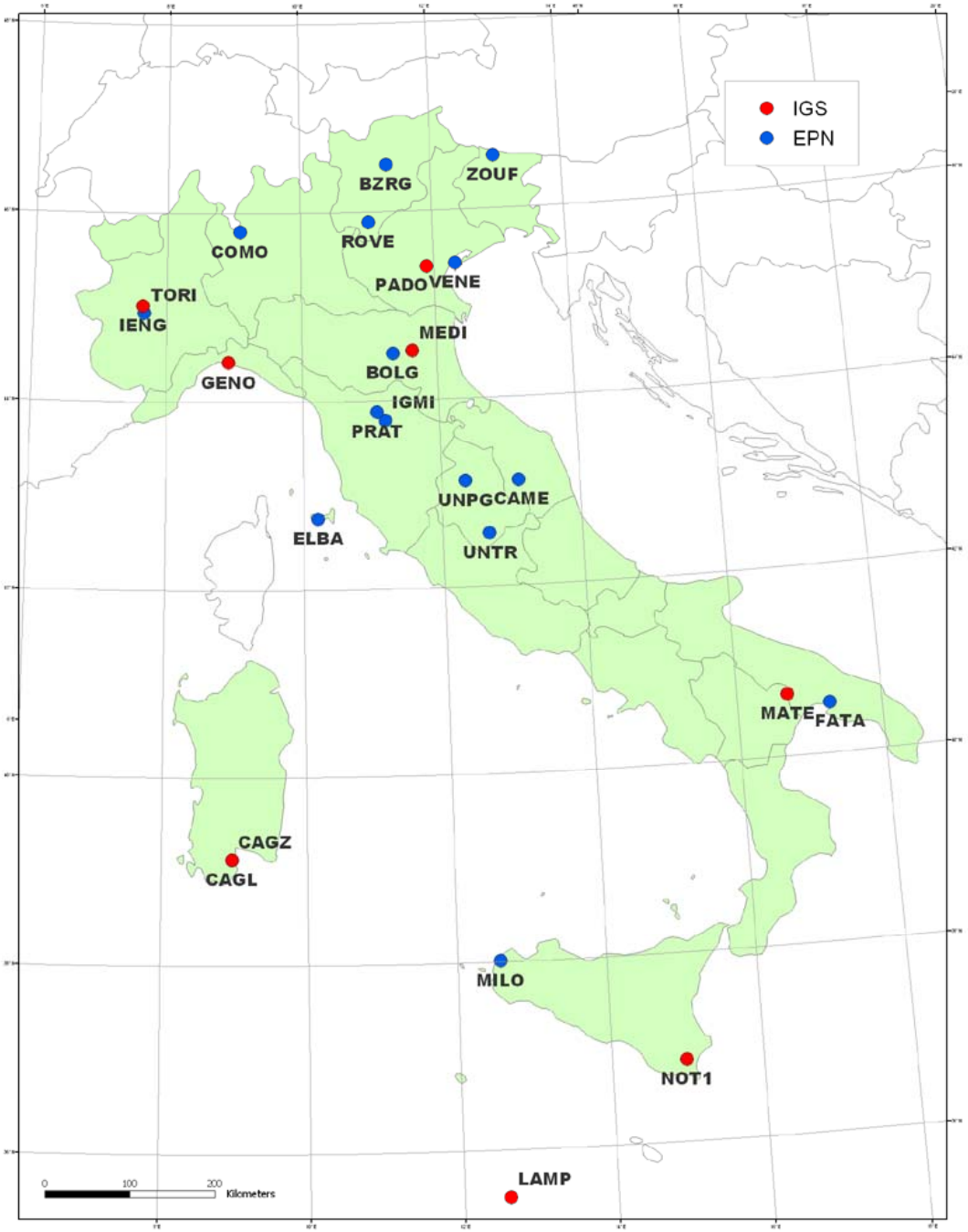
2) including the main PS's of EPN and IGS,

3) including the main PS's of the national geodynamics PN's ,

4) including at least 2 PS's for each local Positioning service,

5) strict rules for PS's, like for IGS and EPN;

6) RINEX data, log files,..., freely available to the community.



The Italian need of a national zero order PN

IGS and EPN PN's alone cannot constitute the zero order PN in Italy:

1) too sparse and not homogeneously distributed;

2) not aimed to monitor/certify local subnetworks;

3) not aimed to materialize national cartographic RF's.

The first test: 2007

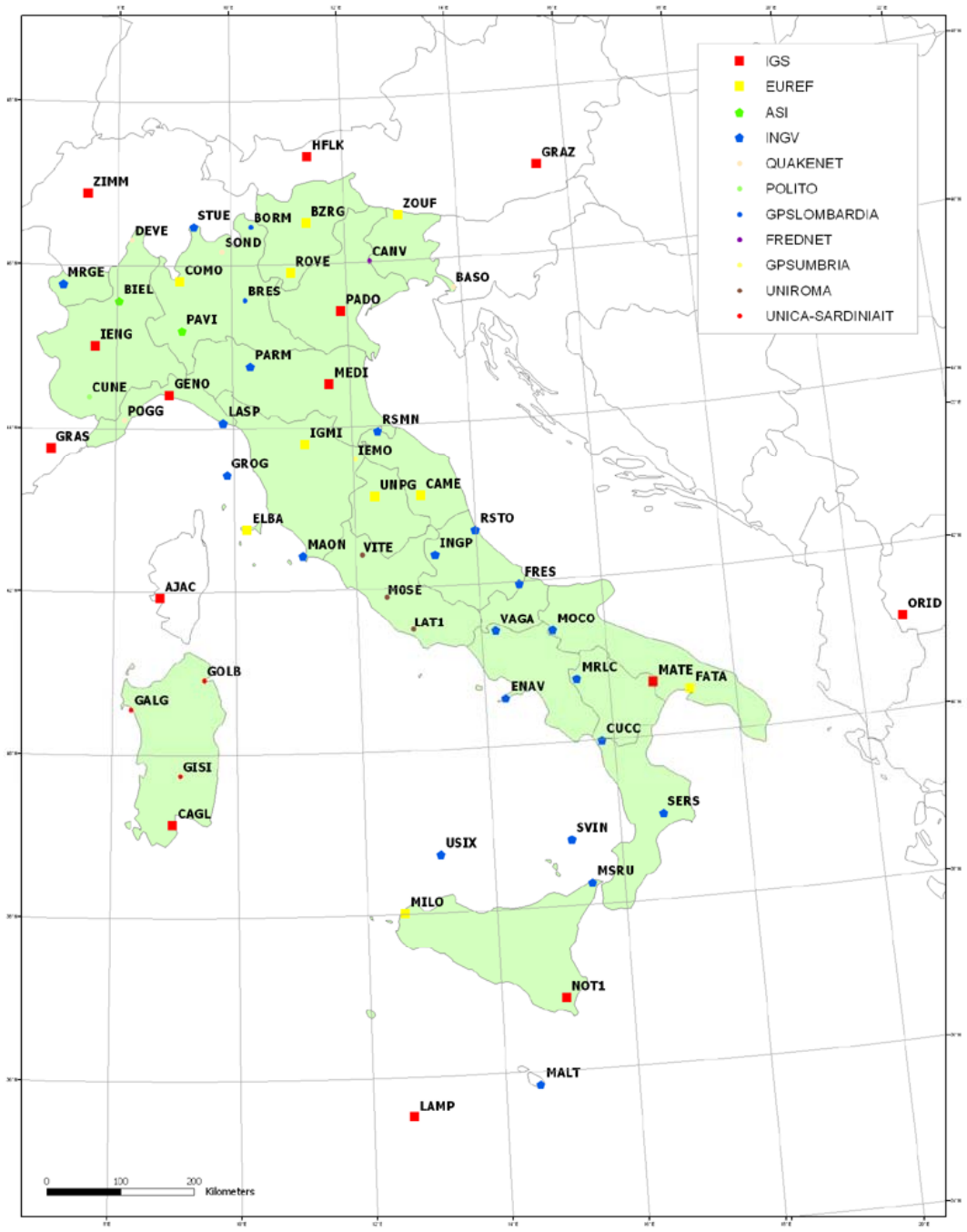
In Italy almost 400 PS's have been catalogued (2008):
in 2007 a trivial test.

Selection of a subset:

62 PS's,
mean distance 100 Km;
analysis of 3 months
(1.1.2007.0-31.3.2007).

Processing with BSW5.0:

extraction of quality indexes and outlier rejection.

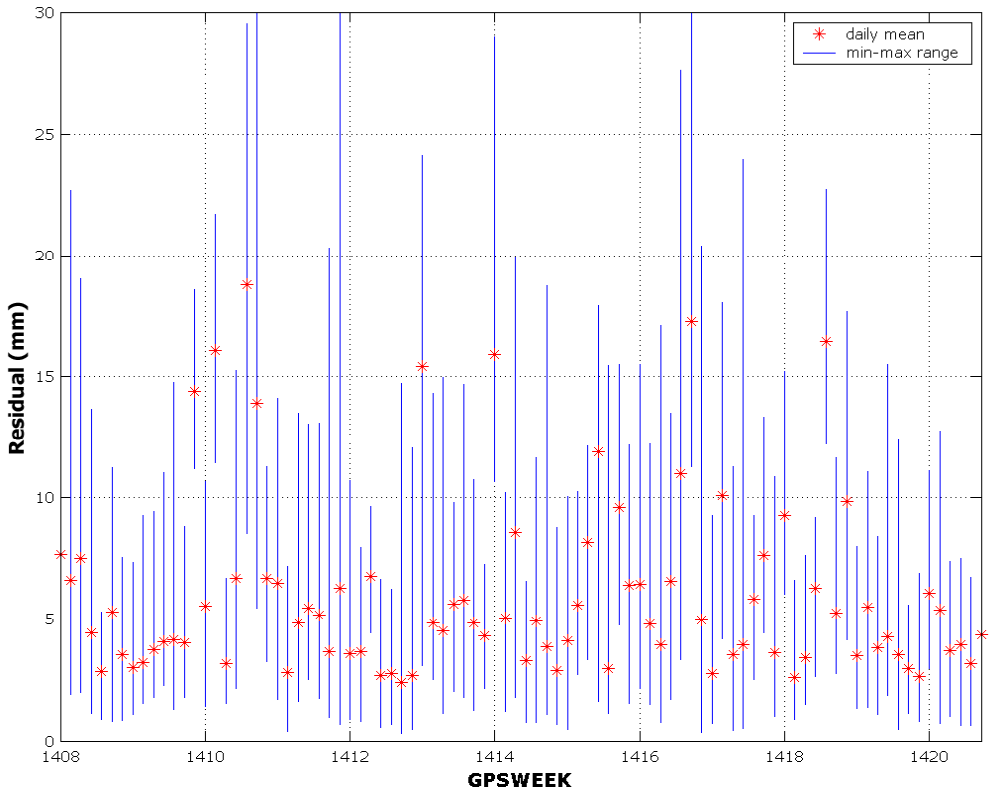


The first test 2/2

Main problems due to RINEX reconstruction from RTCM streams;

no other significant problems.

A well distributed Italian ZO network can be established by **connecting and ruling** a subset of already existing PS's.



Multibase final RMS (mm)	
Mean	1.3
σ	0.2
Min	1.0
Max	1.9

Time series residuals (mm)			
	East	North	Height
Mean	0.0	0.0	0.0
σ	3.5	3.2	6.1
Min	-18.6	-14.3	-62.1
Max	15.6	26.7	63.0

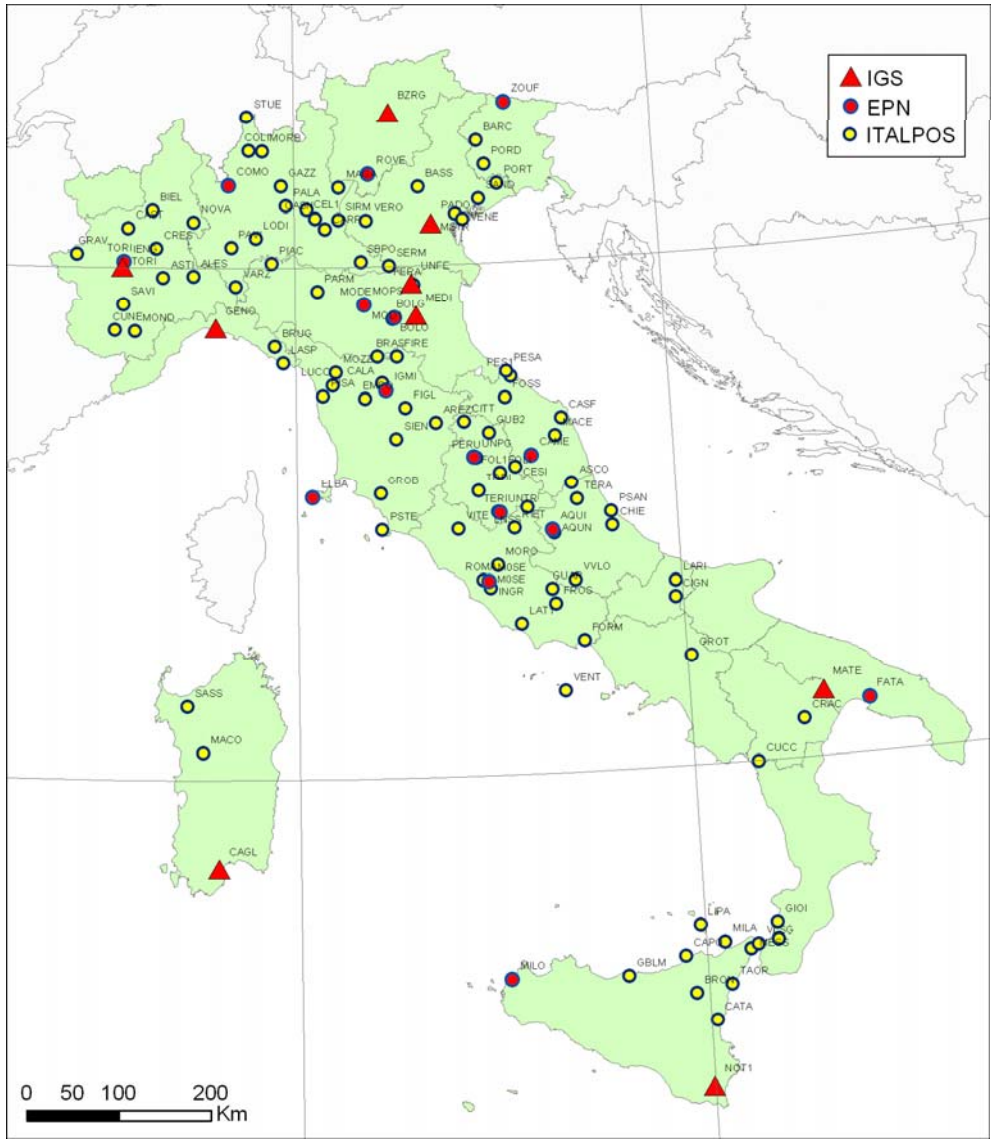
The transformation: ItalPos case study

In Italy
a national PN 104 PS's
is operated by a private firm: ItalPos, Leica Geosystems.

By the
adjustment of ItalPos in IGS,
its link to IGM95:
a first study at the national scale of

1. the transformation between ITRF2005 and IGM95,

2. the local IGM95 deformations.



Adjustment of ItalPos in IGS

Five weeks of data of ItalPos: GPSW 1452-1456, central epoch 2007.9.
Only 7 IGS PS's continuously available and used in the selected period.

1) IGS PS's stochastically constrained to
their official IGS coordinates;

2) adoption of the final IGS
EOP, EPH and PCV's;

3) adoption of the IGS and EPN guidelines
in the raw data elaboration.

4) 180 out of 2800 solution discarded,
satisfactory final statistics.

Global daily residuals time series			
(mm)	East	North	h
σ	3.4	2.8	7.5
min	-19.3	-12.8	-35.8
max	22.4	14.5	44.5

Single station RMS's			
(mm)	East	North	h
Mean	3.6	2.8	7.5
Max	8.5	8.4	13.6

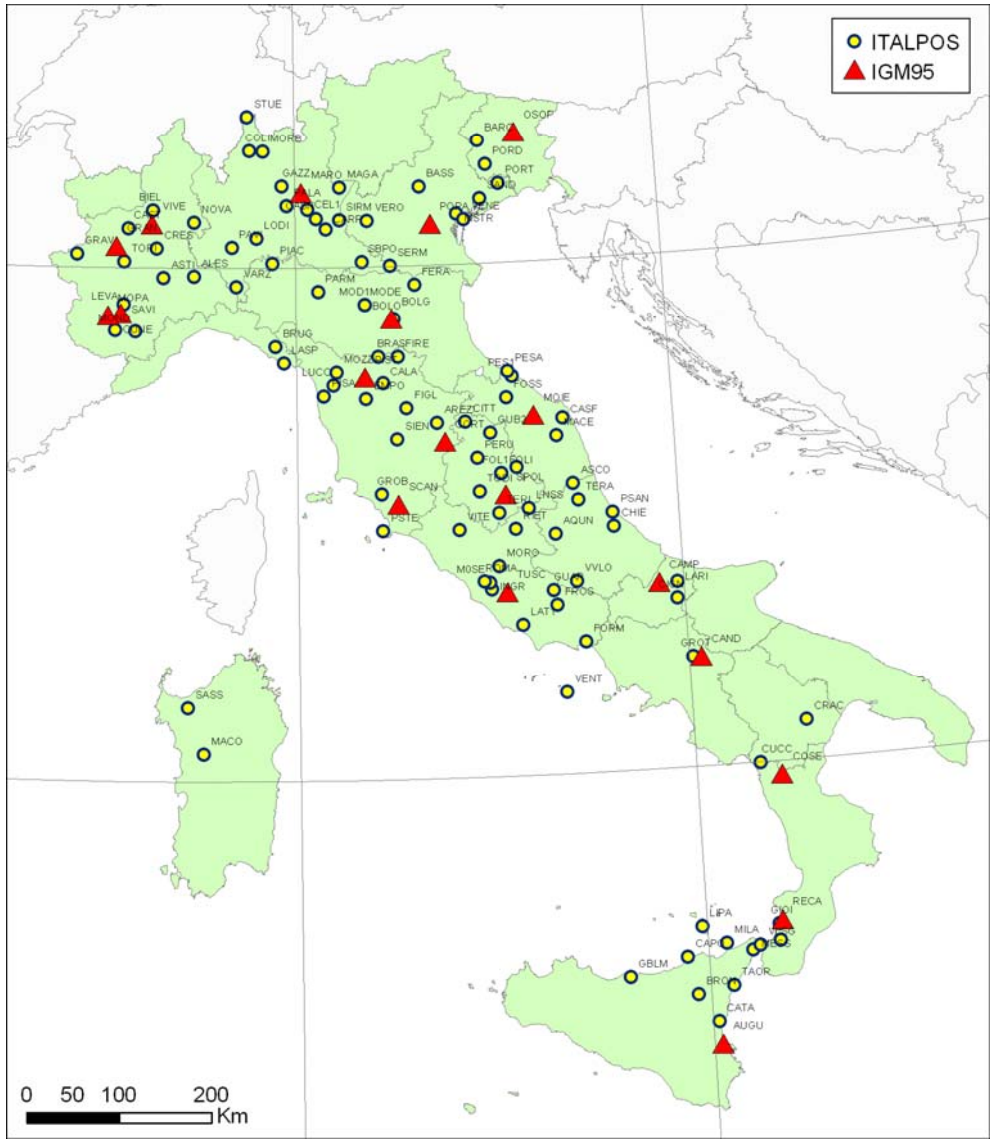
Connection of ItalPos to IGM95

1) 19 IGM95 benchmarks;
3 to 6 hours sessions.

2) each benchmark
connected to 2 to 4 PS's,
constrained;

3) multibase BSW5.0,
to estimate IGS coordinates of
IGM95 benchmarks;

4) typically:
80% of ambiguity fixing,
formal RMS's of about 1.5 mm



Estimated IGS and monograph IGM95 coordinates:
analysis of the transformation from IGS05 and IGM95.

Transformation from IGS05 to IGM95: first method

Starting hypotheses

At the national scale the transformation is the sum of
a national similarity and a deformation field.

The similarity transformation can be estimated in two ways:
1. by the IGS PS's in Italy (IGS05 and ETRF2005 published coordinates);
2. by the IGM95 benchmarks (IGS05 estimated and ETRF89 monographs).

The deformation field can be estimated by
least squares collocation on the IGM95 residuals.

At a smaller spatial scale the transformation
can be modeled by a similarity transformation.

Formulas

Similarity transformation between two RF's

$$\mathbf{x}_{II}(P_i) = \mathbf{t} + (1+k)\mathbf{R}(r_1, r_2, r_3)\mathbf{x}_I(P_i) + \boldsymbol{\Delta}(P_i)$$

$$\mathbf{R} = \mathbf{I} - [\mathbf{r}\times]; \; (1+k)\mathbf{R} = \mathbf{I} + k\mathbf{I} - [\mathbf{r}\times]; \; \mathbf{r} = [r_1 \; r_2 \; r_3]^T$$

Observation equation for a point

$$\mathbf{x}_{II}(P_i) - \mathbf{x}_I(P_i) = \begin{bmatrix} \mathbf{I} & [\mathbf{x}_I(P_i)\times] & \mathbf{x}_I(P_i) \end{bmatrix} \begin{bmatrix} \mathbf{t}^T & \mathbf{r}^T & k \end{bmatrix}^T + \boldsymbol{\Delta}(P_i)$$

Deformation field

$$\boldsymbol{\Delta}(P_i) \Rightarrow [\Delta E(P_i), \; \Delta N(P_i), \; \Delta h(P_i)]^T$$

$$\boldsymbol{\Delta}_i = \boldsymbol{\Delta}(\varphi, \lambda)_i + \boldsymbol{\delta}(\varphi, \lambda)_i + \boldsymbol{\varepsilon}_i$$

$$\boldsymbol{\Delta}(\varphi, \lambda)_i = \mathbf{f}(\varphi, \lambda, a_1, \ldots, a_n)$$ parametric deterministic part

$$\boldsymbol{\delta}(\varphi, \lambda) \; \square \; \boldsymbol{\delta}(\mathbf{0}, \mathbf{C}_{\boldsymbol{\delta}\boldsymbol{\delta}})$$ stochastic part

Estimation by IGS PS's

For each IGS PS:
1. official IGS05 coordinates, at the adjustment epoch;
2. official ETRF2005 coordinates, backpropagated at epoch 1989.0:
backpropagation in time is needed to align the transformation to IGM95 t0)

For each IGM95 benchmark:
application of the transformation and residual analysis.
Clear biases of IGM95 residuals plus a spatial covariance structure:

IGS PS's Residuals			
(cm)	East	North	h
Mean	0.0	0.0	0.0
σ	2.3	2.5	1.9
Min	-3.5	-3.6	-2.5
Max	3.4	3.2	2.6

IGM95 residuals			
(cm)	East	North	h
Mean	1.5	0.8	-3.5
σ	4.1	3.3	6.3
Min	-7.1	-2.6	-16.0
Max	8.6	8.5	8.9

Note on the estimation by IGS PS's

Relatively high residuals on IGS PS's due to
the need of backpropagation in time.

very small residuals in the
transformation IGS05-ETRF2005 at the same epoch (2007.9)

(cm)	East	North	h
Mean	0.0	0.0	0.0
σ	0.1	0.1	0.1
Min	-0.2	-0.2	-0.2
Max	0.1	0.1	0.1

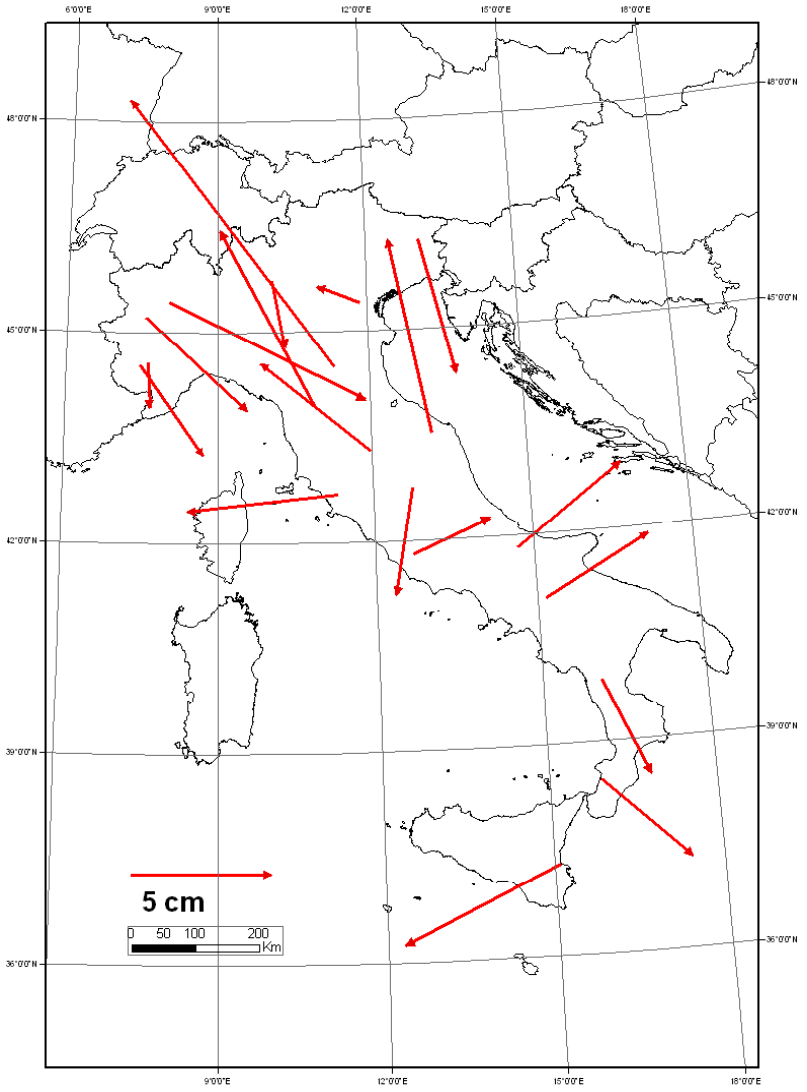
Estimation by IGM95 points

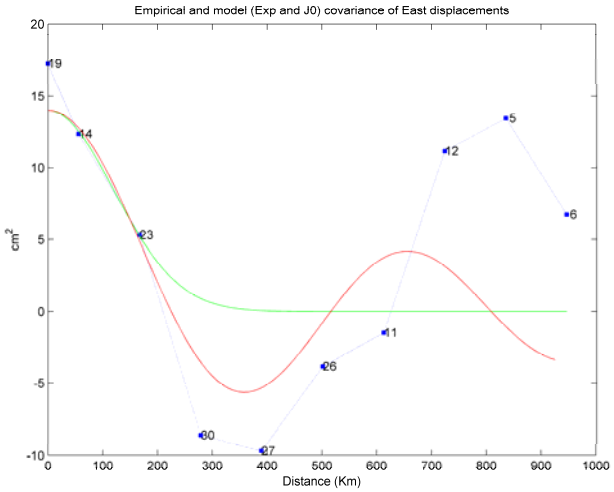
Estimation of a
national similarity transformation.

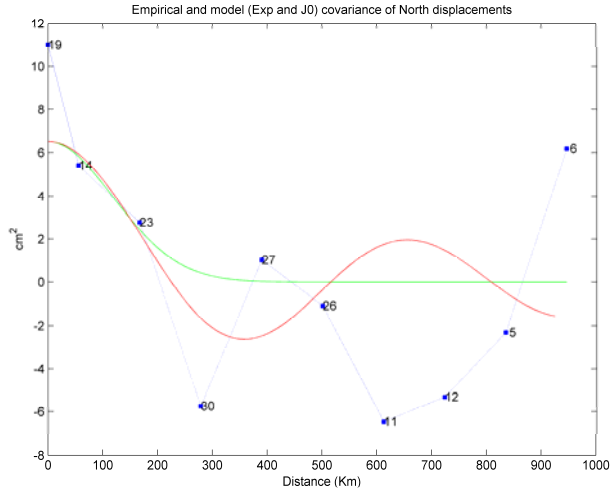
Analysis of the residuals:
a clear spatial structure.

Not 20 years geodynamics:
spatial errors propagation!

(cm)	East	North	h
Mean	0	0	0
σ	4.1	3.2	6.2
Min	-8.3	-3.8	-12.0
Max	7.7	7.6	10.9







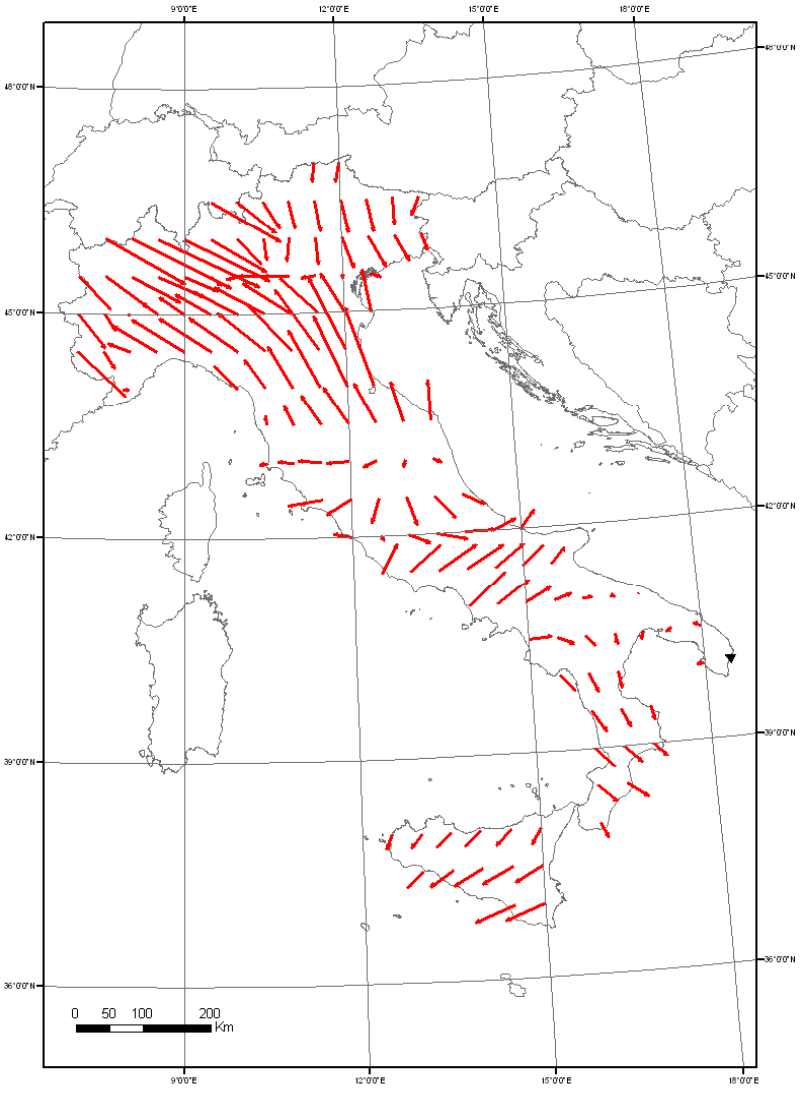
Modeling the residuals

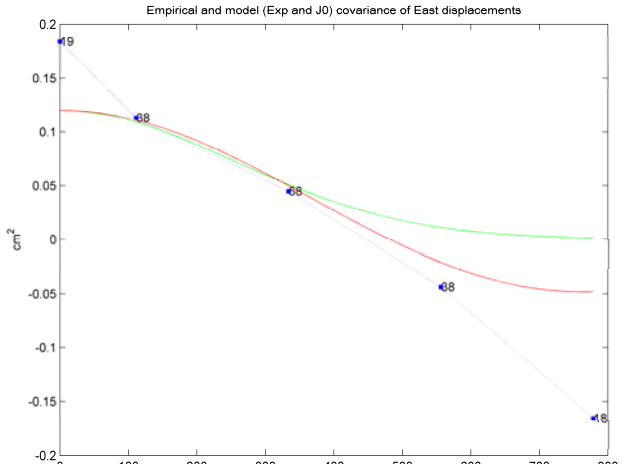
Prediction on a 0.5° × 0.5° grid
by collocation approach
(Biagi, Dermanis).

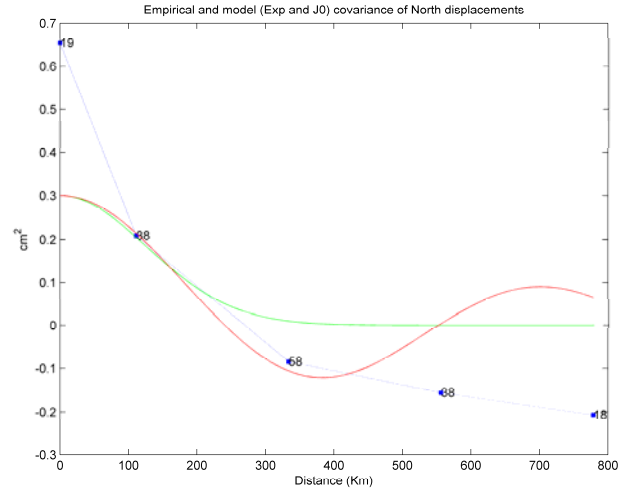
A numerical exercise:
few data,
spatially not well distributed;
RT users cannot use
deformation fields.

Useful for future,
more complete analyses;
final residuals uncorrelated.

Prediction and residuals covariance



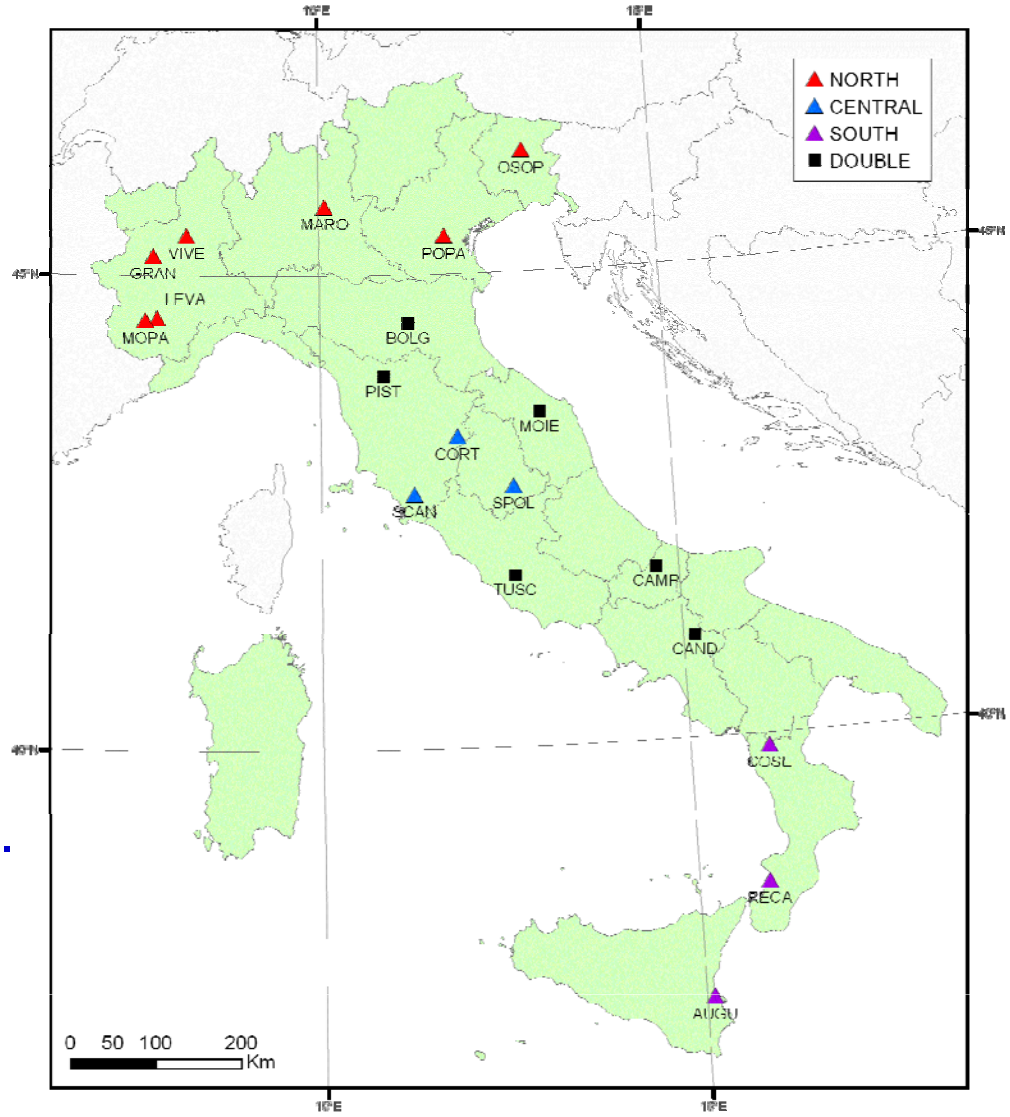




The partitioned approach

Italy split into three regions:
Northern (10 points (*)),
Central (9 points (*) (**)),
Southern (6 points (**)).
(*) 3 in common
between North and Center
(**) 3 in common
between Center and South

For each region a
different similarity transformation.



Results: residual analysis (cm)

More points needed in South.

Satisfactory results for
Center and South.

Unsatisfactory results for North:
more points needed in the
southern Padana Plain
to split into two separate regions.

Different transformations in
common points produce:
5 cm differences in North/Center,
3 cm differences in Center/South.

North	East	North	h
σ	4.0	2.7	5.8
min	-7.0	-2.8	-12.1
max	6.1	6.1	7.1

Center	East	North	h
σ	1.9	2.2	3.1
min	-1.9	-5.4	-5.4
max	3.0	2.1	4.6

South	East	North	h
σ	2.1	1.5	3.5
min	-3.2	-2.5	-4.8
max	3.3	1.6	3.7

The new IGM network: RDN (Dynamic National Network)

96 PS's

(7 IGS's outside Italy)

permanently monumented,

at present

not permanently monitored.

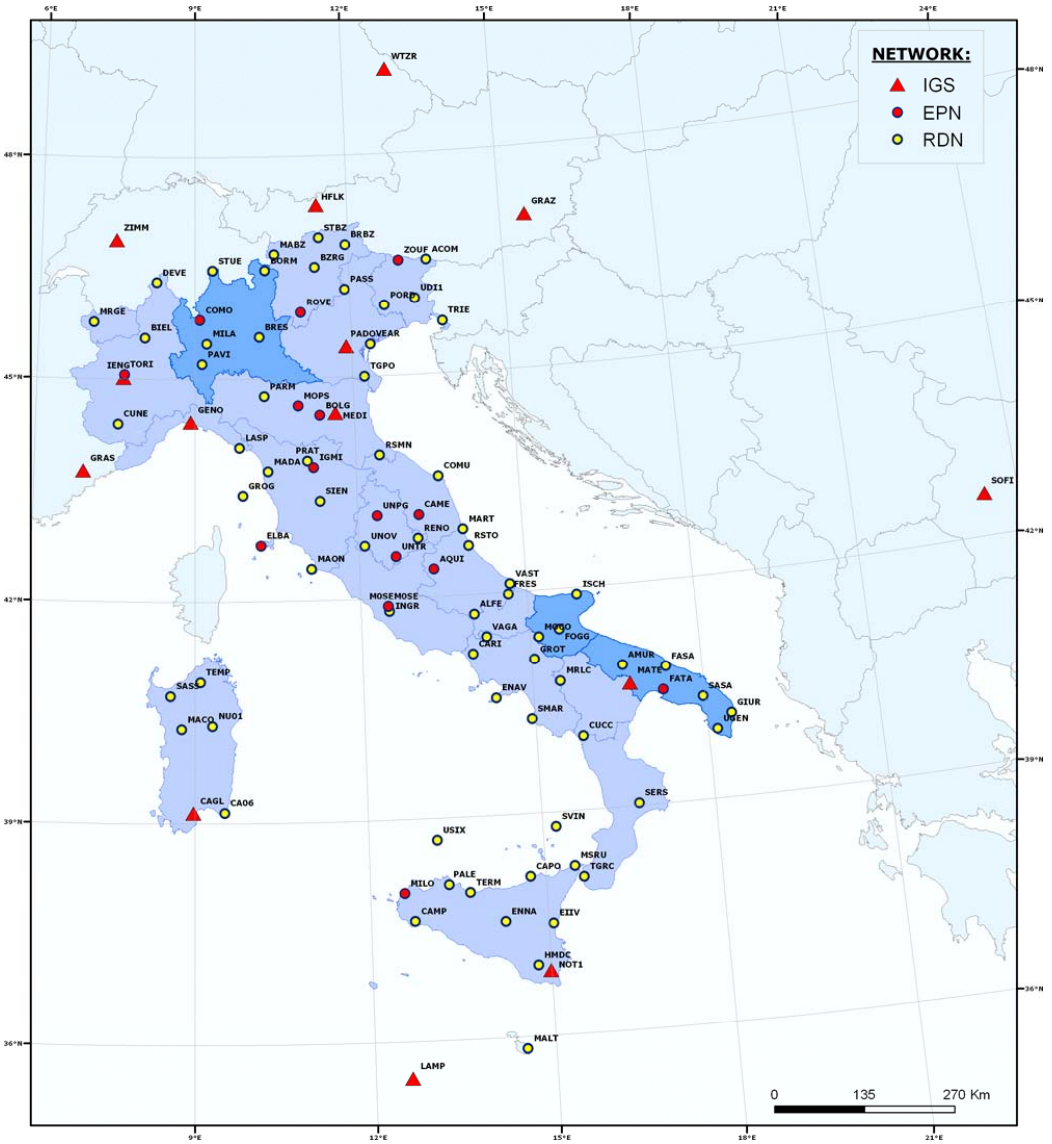
One month of data;

(almost) independent adjustments

by IGM, UniPA, our group,

in order to

cross validate the results.



RDN adjustment approach

Inclusion of all the Italian and neighboring IGS PS's;
IGS PS's stochastically constrained to IGS estimates;
adoption of final IGS products and absolute PCV;

adjustment with BSW5.0, according to BSW guidelines;
30 daily solutions and

outlier rejection:
a) incomplete files,
b) high RMS's in some processing step,
c) great coordinates residuals wrt monthly mean;

Final adjustment of accepted data.

Results

Expected files:

2688

Not available:

196 (7.3%)

Excluded for data gaps:

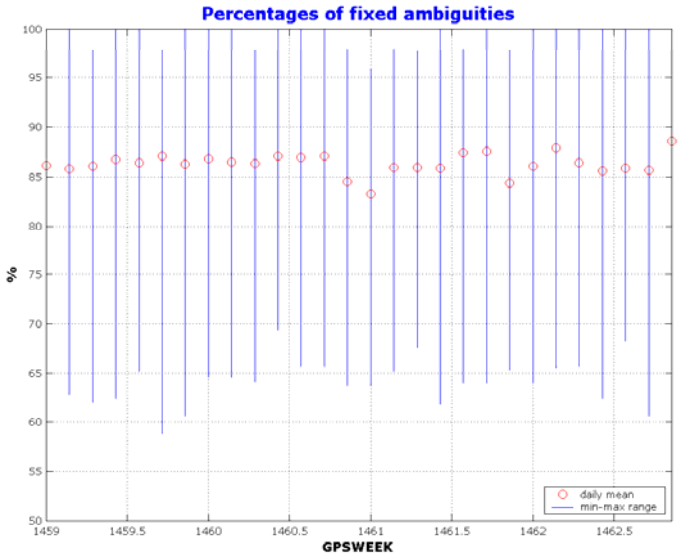
118 (4.4%)

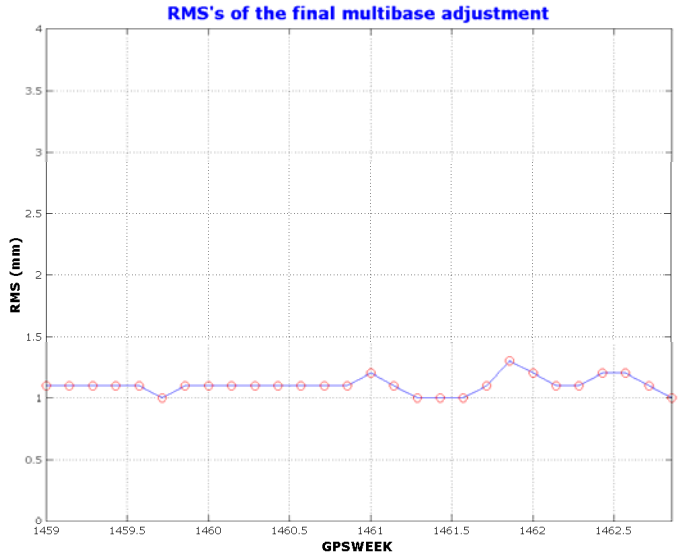
Excluded for quality check:

67 (2.5%)

Final processed:

2307 (85.8%)

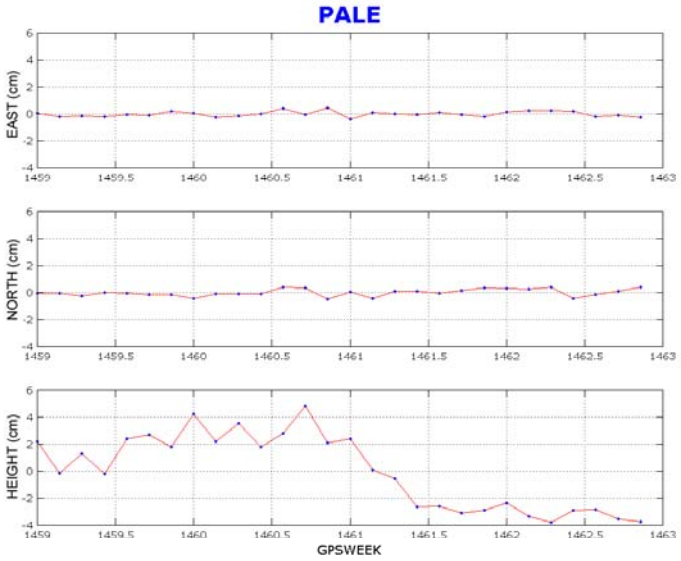




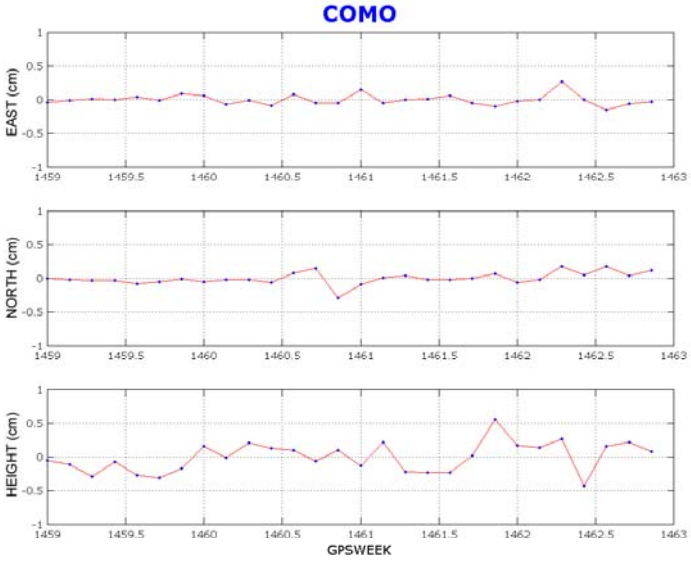
Coordinates estimates

Daily residuals time series			
(mm)	East	North	h
σ	1.2	1.2	3.1
min	-7.0	-2.8	-12.1
max	6.1	6.1	7.1

Daily formal RMS's			
(mm)	East	North	h
Mean(σ)	1.2	1.2	4.0
Max(σ)	2.9	3.3	7.3



Rejected station



Accepted station

Future work and conclusions

Compare IGS05/ITRF2005 in the adjustment;
compare our with IGM, UniPD results;
connect RDN to IGM95;
definitely study the transformation
between IGS05/ITRF2005 and ETRF89-IGM95.

From first results:
IGM95 presents significant deformations and blunders;
time is to switch to a continuously monitored national RF,
by a continuous adjustment of a zero order PN (“RDN”).

Needs:
No new HW but guidelines/rules for RDN PS’s,
management, adjustment and monitoring implementation.