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ADJUSTMENT AND TRANSFORMATION STRATEGIES OF ITALPOS PERMANENT GNSS NETWORK

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OUTLINE

- Purpose of the work
- Description of the GNSS permanent network
- Adjustment strategies
- Transformation parameters estimation
- Results presentation
- Conclusions
- Future work

PURPOSE OF THE WORK

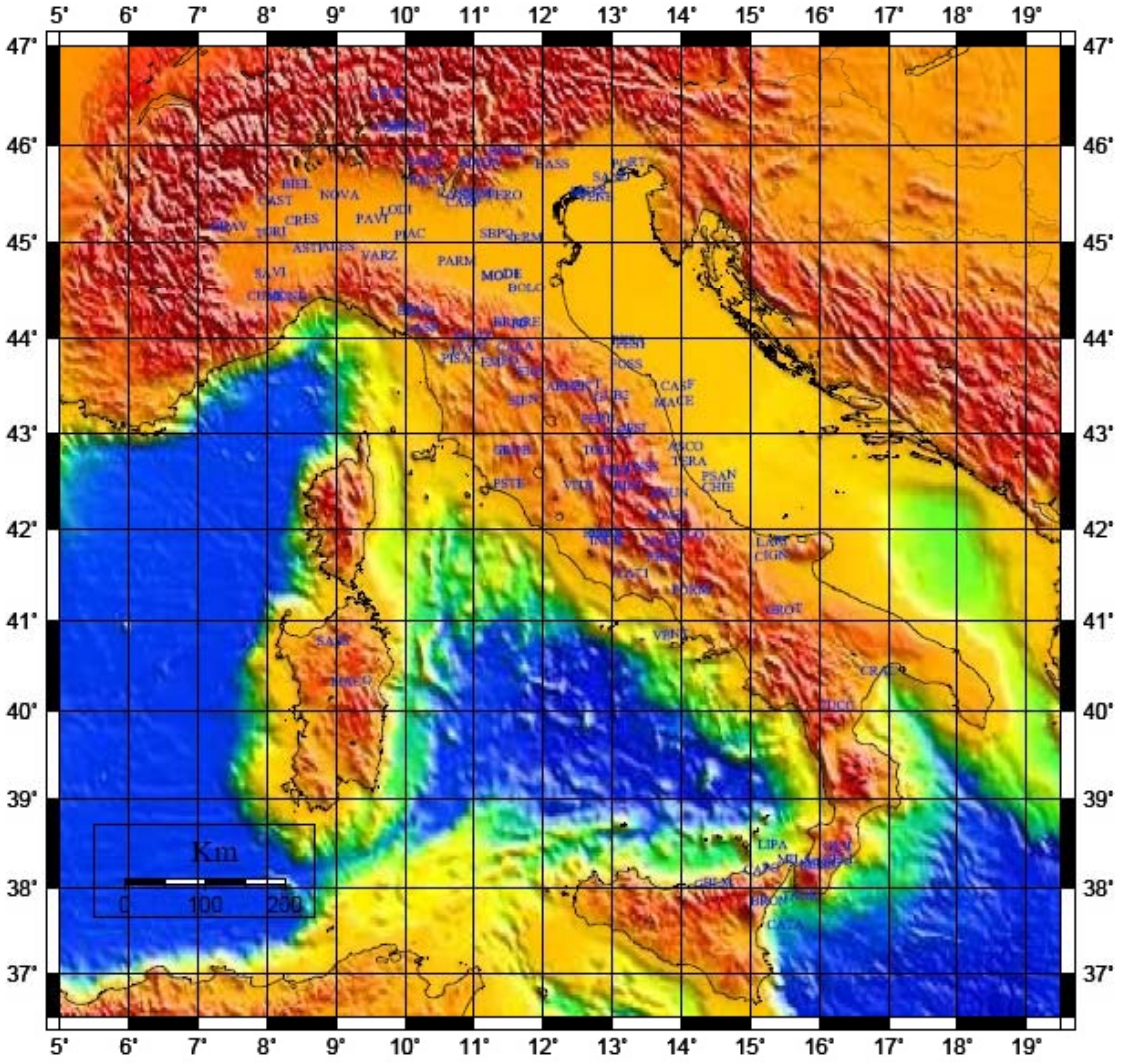
- Adjustment of the ItalPoS permanent GNSS network
- Transformation estimation to the italian national reference frame
- The network computation and coordinates solutions done as scientific support to the ItalPos Centre of Leica Geosytems
- Afterwards Italian University Consortium G3 published the certified solutions (coordinates and transformation)

NETWORK DESCRIPTION

- ItalPoS -Italian Positioning Service-
- Private network (Italian Division of *Leica Geosystems*) with national distribution
- More than 130 stations (public and private administrations; RING network by INGV)
- Service for customers: GNSS data distribution in terms of real time corrections and RINEX files for post-processing
- Real-time service: MAX (*Master-Auxiliary*) approach

ITALPOS GNSS NETWORK

www.italpos.it



ADJUSTMENT STRATEGIES

- Software Gamit/Globk v.10.3
- SOPAC suggestions for regional clusters
- IGS05 reference frame
- Over one month of GPS data (October-November 2007)
- Multi step procedure based on the distributed session approach
- Network (120 sites) divided in 5 clusters
- 1st step: computation of daily observation solutions (Gamit *h-files*)

ADJUSTMENT STRATEGIES

- 2nd step: solutions combination with SOPAC *h-files*
- Final step: stable solutions in the IGS05 by means of 26 EUREF reference stations (known positions and velocities)
- Consistency and stability of solutions checked comparing them with EUREF ones for reference sites

ADJUSTMENT STRATEGIES

Residuals between IGS05 coordinates estimated in our solutions (sw Globk, epoch 2007.860) and those computed by EUREF (sw Bernese 5.0, epoch 2007.795)

SP	*ΔX[cm]*	*ΔY[cm]*	*ΔZ[cm]*	*SP*	*ΔX[cm]*	*ΔY[cm]*	*ΔZ[cm]*	*SP*	*ΔX[cm]*	*ΔY[cm]*	*ΔZ[cm]*
VILL	0.60	0.00	0.50	**ZOUF**	**-0.20**	**0.10**	**0.20**	POTS	-0.40	0.00	-0.20
SFER	0.30	0.00	0.30	WTZR	-0.30	0.10	-0.20	**TORI**	**-0.20**	**0.10**	**-0.10**
RABT	0.30	0.10	0.40	ONSA	-0.40	0.10	-0.10	**NOT1**	**-0.10**	**0.10**	**0.00**
HOFN	-0.10	-0.20	-0.10	NYA1	-0.10	-0.20	0.40	**ROVE**	**-0.20**	**0.10**	**0.00**
REYK	0.00	-0.30	0.50	**PRAT**	**-0.10**	**0.10**	**0.20**	**MOPS**	**0.00**	**0.10**	**0.00**
TRAB	-0.70	-0.10	-0.10	**ELBA**	**-0.10**	**0.20**	**0.00**	BOR1	-0.10	0.20	0.20
RAMO	-0.70	-0.30	-0.30	**COMO**	**-0.20**	**0.00**	**0.10**	**MATE**	**-0.50**	**0.00**	**-0.30**
GLSV	-0.60	-0.30	-0.30	**CAGL**	**-0.10**	**0.00**	**-0.10**	GRAZ	-0.30	0.00	-0.10
METS	-0.40	-0.10	-0.30	ZIMM	-0.30	0.00	-0.10	BRUS	-0.10	0.10	0.20
JOZE	-0.10	0.00	0.30	GRAS	-0.10	0.00	0.20	**M0SE**	**-0.10**	**0.20**	**0.00**
WSRT	-0.30	0.10	0.10								

TRANSFORMATION ESTIMATION

- Transformation required to provide a complete positioning service
- Network reference frame IGS05→ italian reference frame IGM95-ETRF89
- Three macro areas to optimize results
- Different strategies investigated:
  - Helmert transformation

$$X_{E89} = T + (1+k)\cdot R \cdot X_{I05}$$

  - Boucher-Altamimi transformation

$$X_{E89}(1989.0) = T + X_{I05}(\tau) + (\tau - 1989.0)\cdot \dot{R} \cdot X_{I05}(\tau) + (1989.0 - \tau)\cdot \dot{X}_{E89}$$

TRANSFORMATION ESTIMATION

- Two options tested in the Boucher-Altamimi depending on the mean velocity (weighted average of ETRS89 velocities published for the IGS sites around each area):
  - Weights are the inverse of the distance of each IGS station with respect to their barycentre
  - Weights depend on the inverse of the distance of each IGS station with respect to the barycentre of the ItalPoS stations in the area
- Series of test surveys in every italian Regions to simulate the customer behaviour

TRANSFORMATION ESTIMATION

- Purpose: to check the parameters reliability and to suggest the best solution
- Two more GPS surveying at the same time on IGM95 benchmarks
- Post-processing with respect to these known points→IGM95-ETRF89 reference coordinates
- Post-processing with respect to two/three ItalPoS stations→IGS05 coordinates
- All parameters estimated applied to the IGS05→ETRF89 transformed

TRANSFORMATION ESTIMATION

- Comparison between the reference ETRF89 and the transformed ETRF89
- Best parameters set: residuals minimization
- Transition areas: pay attention to congruity
- Last comparison: ETRF89 coordinates transformed by the choosen parameters *vs* the ones obtained by GLORG (Global ORiGin) module of sw Globk thanks to ETRF2000 at epoch 1989.0 using EUREF facility combined solutions

TRANSFORMATION ESTIMATION: Northern area

Val D'Aosta, Piemonte, Liguria, Lombardia, Veneto, Trentino Alto Adige, Friuli Venezia Giulia, Emilia Romagna

Type of transformation	Mean [cm]			Max [cm]			Min [cm]			Std. dev [cm]		
	$\Delta\varphi$	$\Delta\lambda$	Δh_ell	$\Delta\varphi$	$\Delta\lambda$	Δh_ell	$\Delta\varphi$	$\Delta\lambda$	Δh_ell	$\Delta\varphi$	$\Delta\lambda$	Δh_ell
ETRF89 (BA PADO)	0.32	0.04	1.64	4.50	4.40	11.90	-2.10	-3.40	-9.90	2.45	2.88	8.93
ETRF89 (BA IENG)	4.56	-0.42	-4.48	8.60	3.40	5.90	2.30	-3.90	-16.00	2.37	2.80	8.96
ETRF89 (BA IGS barycentre)	2.62	-0.54	-1.96	6.80	3.50	8.30	0.30	-4.00	-13.50	2.43	2.83	8.96
ETRF89 (BA ItalPoS barycentre)	**2.90**	**-0.54**	**-1.98**	**7.00**	**3.40**	**8.30**	**0.50**	**-3.90**	**-13.50**	**2.40**	**2.75**	**8.95**
ETRF89 (North-West)	-1.36	-4.30	-7.62	2.20	6.70	2.10	-7.00	-12.30	-19.90	3.24	6.35	9.28
ETRF89 (North-East)	-0.02	1.68	0.86	3.00	10.40	13.80	-3.60	-2.90	-11.10	2.34	4.67	8.76

- IGS stations for mean velocity estimation: PADO, GRAS, GRAZ, ZIMJ, GENO, IENG, HFLK
- North-Est→15 points available from Leica Geosystems (8 for transformation+7control points)
- North-West→ only 7 points available from Politecnico of Torino GNSS network (4 for transformation+3control points)

TRANSFORMATION ESTIMATION: Central area

Toscana, Umbria, Marche, Abruzzo, Lazio, Molise

Type of transformation	Mean [cm]			Max [cm]			Min [cm]			Std. dev [cm]		
	Δφ	Δλ	Δh_ell	Δφ	Δλ	Δh_ell	Δφ	Δλ	Δh_ell	Δφ	Δλ	Δh_ell
ETRF89 (BA IGS barycentre+SOFI)	2.20	0.11	-8.63	5.37	6.48	-3.28	-2.13	-5.76	-15.45	2.39	4.17	3.71
ETRF89 (BA IGS barycentre)	2.82	0.46	-8.21	5.88	6.81	-2.92	-1.47	-5.34	-15.01	2.37	4.18	3.70
ETRF89 (BA ItalPoS barycentre+SOFI)	3.53	0.14	-8.32	6.66	6.60	-3.01	-0.78	-5.73	-15.13	2.38	4.21	3.72
ETRF89 (BA ItalPoS barycentre)	**2.58**	**0.30**	**-8.30**	**5.67**	**6.78**	**-2.98**	**-1.71**	**-5.52**	**-15.16**	**2.37**	**4.18**	**3.72**

- Very low number of IGS stations
- IGS stations for mean velocity estimation: GENO, CAGL, MATE and the inclusion of SOFI investigated
- According to the previous choice no Helmert transformation has been estimated (lacks of points)

TRANSFORMATION ESTIMATION: Southern area

Campania, Puglia, Calabria, Basilicata, Sicilia, Sardegna

Type of transformation	Mean [cm]			Max [cm]			Min [cm]			Std. dev [cm]		
	$\Delta\varphi$	$\Delta\lambda$	Δh_ell	$\Delta\varphi$	$\Delta\lambda$	Δh_ell	$\Delta\varphi$	$\Delta\lambda$	Δh_ell	$\Delta\varphi$	$\Delta\lambda$	Δh_ell
ETRF89 (BA IGS barycentre)	-0.50	4.41	-3.48	5.67	9.42	6.28	-6.33	-1.77	-13.15	3.49	3.40	7.76
ETRF89 (BA ItalPoS barycentre)	**-1.52**	**4.63**	**-3.48**	**4.68**	**9.57**	**6.34**	**-7.32**	**-1.47**	**-13.16**	**3.49**	**3.37**	**7.77**

- Very low number of IGS stations
- IGS stations for mean velocity estimation: GENO, CAGL, MATE, NOT1, LAMP
- According to the previous choice no Helmert transformation has been estimated (lacks of points)

TRANSFORMATION RESULTS

Transformation parameters	T_x *[m]*	T_y *[m]*	T_z *[m]*	$\dot{R}_x$ *[rad]*	$\dot{R}_y$ *[rad]*	$\dot{R}_z$ *[rad]*
Northern	0.05901380	0.03839360	-0.05564760	4.93E-09	4.73E-08	-7.13E-08
Central	0.07225924	0.04156468	-0.06970175	4.93E-09	4.73E-08	-7.13E-08
Southern	0.08864580	0.07103398	-0.08996419	4.93E-09	4.73E-08	-7.13E-08

Final parameters of the IGS05-ETRF89 transformation for the areas in which ItalPoS network has been divided

TRANSFORMATION TEST

Residuals between ETRF89 cartesian coordinates estimated by means of Globk stabilisation process and Boucher-Altamimi transformation

SP	*ΔX[cm]*	*ΔY[cm]*	*ΔZ[cm]*	*SP*	*ΔX[cm]*	*ΔY[cm]*	*ΔZ[cm]*	*SP*	*ΔX[cm]*	*ΔY[cm]*	*ΔZ[cm]*
GRAV	4.86	1.18	0.34	PALA	5.02	1.24	0.34	STUE	5.01	1.24	0.21
TORI	4.82	1.34	0.38	CASN	3.74	1.55	1.89	COLI	3.87	0.84	0.93
CAST	5.00	1.22	0.38	PARM	4.93	1.11	0.18	MORB	4.78	1.36	0.41
SAVI	5.35	1.09	0.23	CARP	1.43	-0.68	4.23	LODI	4.67	1.45	0.31
CUNE	8.72	3.01	-3.47	SIRM	4.98	1.20	0.21	PIAC	4.90	1.23	0.25
MOND	4.08	1.59	0.12	MAGA	5.14	1.21	0.31	BRUG	4.93	1.15	0.20
BIEL	4.58	1.19	0.78	SBPO	4.97	1.18	0.25	LASP	4.97	1.11	0.20
CRES	4.90	1.23	0.37	VERO	4.97	1.24	0.15	BOLO	4.85	1.10	0.04
ASTI	5.25	0.99	0.07	MOD1	6.76	1.87	-1.81	VENE	5.01	1.23	0.12
NOVA	5.03	1.40	0.18	MODE	4.97	1.12	0.19	SAND	5.02	1.18	0.14
ALES	4.96	-0.03	1.89	ROVE	6.29	1.23	-0.78	PORT	4.96	1.19	0.10
COMO	4.94	1.29	0.36	SERM	4.94	1.22	0.15	BRAS	4.97	1.14	0.17
PAVI	5.39	1.83	-0.21	BASS	5.07	1.19	0.20	FIRE	4.98	1.15	0.10
VARZ	4.90	1.14	0.26	GAZZ	4.73	1.57	0.17				

CONCLUSIONS

- Adjustment→IGS05 ItalPoS stations coordinates
- Service for customers the main purpose
- Transformation→ETRF89 ItalPoS stations coordinates
- Many tests to verify results→IGM95 accuracy maintained (5cm horizontal position, 10cm height)
- ETRF89 required for users but lack of accuracy (due to IGM95 static network)

FUTURE WORK

- ETRF2000: new official italian reference frame
- RDN: official italian GNSS permanent network
- Adjustment with respect to RDN stations
- Transformation to the new ETRF2000
- Suggestions to improving ItalPoS running and management (for instance stations log file to create history of any change?!)

We are grateful to all the operators maintaining the permanent stations belonging to the Institutions involved on ItalPoS permanent service in particular: IGS, INGV, ASI, EUREF and Leica Geosystems GPS division.

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Solutions and results available:
paper in press on "Annals of Geophysics"

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