ISTITUTO GEOGRAFICO MILITARE
Servizio Geodetico

Final results of the Italian “Rete Dinamica Nazionale” (RDN) of Istituto Geografico Militare Italiano (IGMI) and its alignment to ETRF2000

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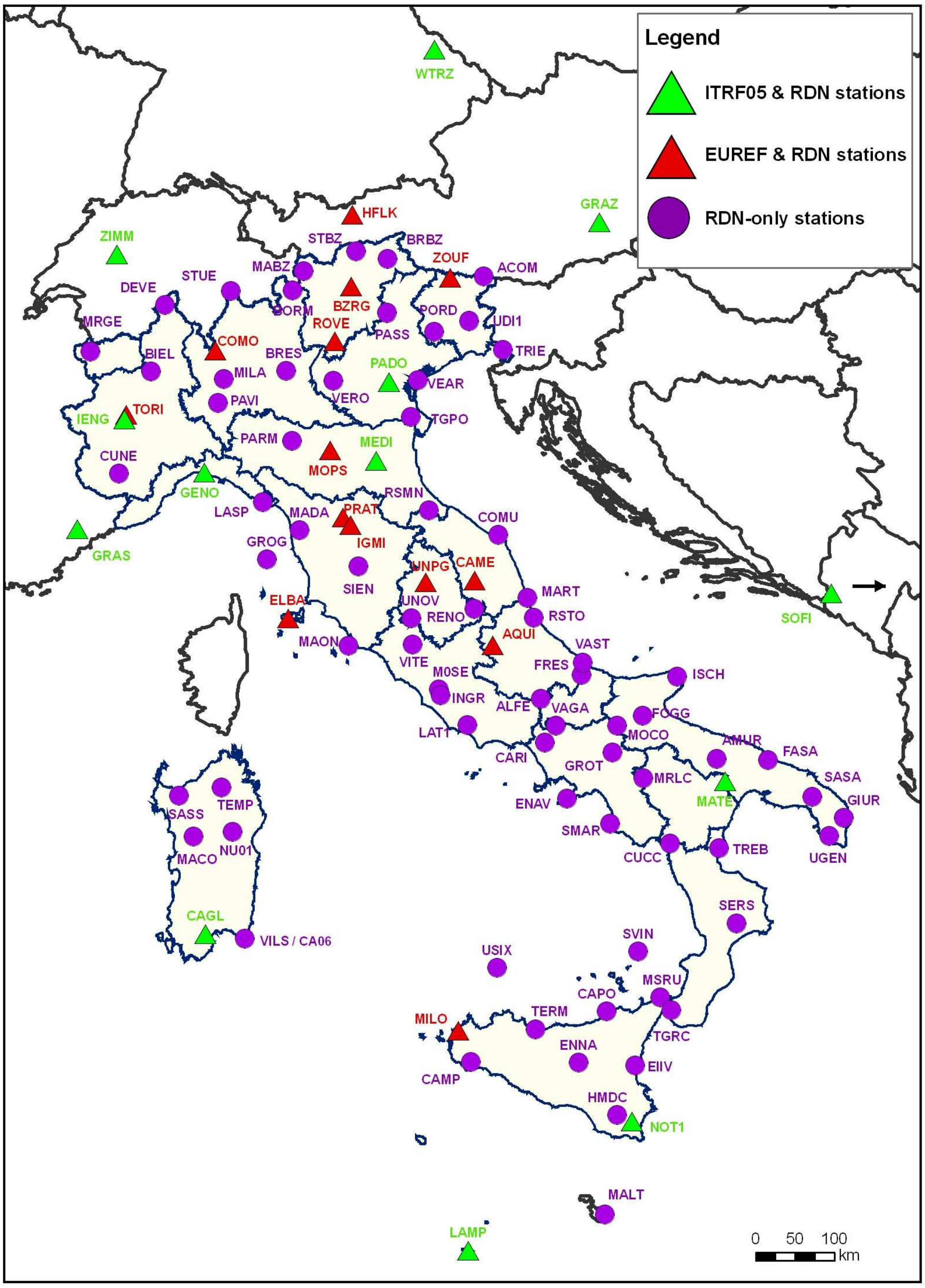

Fig. 1 – Location of RDN permanent stations

1. *Introduction*

The Italian "Rete Dinamica Nazionale" consists of a network of 99 GPS permanent stations, with stable materializations, that continuously record satellite signals and trasmit them telematically to a Data Processing Centre situated in the Geodetic Service of IGM.

The continuous satellite observations will allow to perform different technical and scientific activities, related for example to crustal movements studies and to local and regional deformation monitoring.

For IGM, the most interesting results are those related to the materialization and monitoring of the Global Reference System on the Italian territory. The current realization of ETRS89 (European Terrestrial Reference System 89. Adam et al., 2002) in Italy dates back to 1996, when a network of 1250 epoch points were surveyed in campaign style by personnel of IGMI, and least squares adjusted by constraining nine points with known ETRF89 coordinates. The network, known as IGM95 (Surace, 1997), was densified in the following years with the addition of 2000 points from the GEOTRAV project, the Italian contribution to the European Unified Leveling Network (Ihde et al., 2002). The Regional Authorities contributed with additional 2000 points.

Since 1996 equipment and processing models have evolved to the extent that an update of the national network was felt necessary. For example, Italian networks for Real-Time-Kinematic (RTK) applications need reference systems with very high precisions, not always observed by the current Italian realization of the Global System. It was also considered that the ETRF2000 realization of ETRS89 was going to be updated in consideration of the published ITRF2005 (Altamimi et al. 2007), and that the upcoming implementation of the INSPIRE directive (http://eur-lex.europa.eu/JOHtml.do?uri=OJ:L:2007:108:SOM:EN:HTML) urged for an updated realization of the ETRS89 at the national level.

These arguments were sufficient to justify a national effort for the updated network "Rete Dinamica Nazionale" (which was identified with the acronym RDN) and the adoption of the most recent official ETRS89 frame, that is ETRF2000, at epoch 2008.0.

The computation here exposed was performed by the Data Processing Centre of the Geodetic Service of IGM, using BERNESE software (version 5.0). To test the results, the same computation was performed independently by the G3 group in Milano (prof. Sansò) and by the University of Padova (prof. Caporali).

2. *Network consistency*

RDN consists of 99 GPS permanent stations (fig. 1). They are already installed by public agencies and are homogeneously distributed on the Italian territory. The distance among the stations is about 100-150 km, in order to have one station every 3.000 km^2. A special care was given to the coverage of marginal zones.

Actually, 99 stations are more than those really needed for these purposes, but it was decided to include all these stations in case some of them will be lost for inactivity or change of location.

The network includes all the Italian stations already computed in the international networks ITRF and IGS (Matera, Noto, Medicina, Padova, Torino, Genova, Cagliari e Lampedusa). The other stations were selected taking into account the homogeneous spatial distribution and the quality of location and equipment. Some selected stations belong to networks that provide RTK corrections, in order to make easier the alignment of these networks to the official National Reference System.

In order to have known points also in marginal areas, in the network also the following ITRF stations located outside Italy are included: Sofia, Graz, Wettzel, Zimmerwald and Grasse.

3. Data Analysis

The observation window lasts 28 days, from 23/12/2007 to 19/01/2008, corresponding to the following four GPS weeks: 1459, 1460, 1461 and 1462.

The data are daily files in RINEX format with 30 seconds sample rate.

Some stations were not collecting data for all the 28 days, however they were included in RDN because they belong to one of the following category:

- ITRF2005 stations, necessary for the alignment of the Datum;
- stations belonging to regional networks, strategic for RDN;
- stations being the only ones working in particular zones.

The stations not fully operating, together with stations with very “noisy” data (e.g. CUCC), will be replaced in future computations if these problems won’t be solved.

The actual data availability is illustrated in Table 1.

The receivers, the antennas and the antenna offsets of each station are illustrated in Table 2.

In the computation, the following parameters were taken into account:

- Earth rotation parameters (.erp) and precise IGS orbits (.sp3);
- absolute antenna phase centre model (igs05.atx available at ftp://igscb.jpl.nasa.gov/igscb/station/general/pcv_proposed/igs_05.atx);
- ocean tide loading corrections with model GOT00.2

All the RINEX files were checked comparing the information (antenna, receiver, marker name, and so on) in the file header with those in the station log file.

Stations		Julian Day																											
		Year 2007									Year 2008																		
		357	358	359	360	361	362	363	364	365	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	ACOM																												
2	ALFE																												
3	AMUR																												
4	AQUI																												
5	BIEL																												
6	BORM																												
7	BRBZ																												
8	BRES																												
9	BZRG																												
10	CA06																												
11	CAGL																												
12	CAME																												
13	CAMP																												
14	CAPO																												
15	CARI																												
16	COMO																												
17	COMU																												
18	CUCC																												
19	CUNE																												
20	DEVE																												
21	EIIV																												
22	ELBA																												
23	ENAV																												
24	ENNA																												
25	FASA																												
26	FOGG																												
27	FRES																												
28	GENO																												
29	GIUR																												
30	GRAS																												
31	GRAZ																												
32	GROG																												
33	GROT																												
34	HFLK																												
35	HMDC																												
36	IENG																												
37	IGM I																												
38	INGR																												
39	ISCH																												
40	LAMP																												
41	LASP																												
42	LAT1																												
43	M0SE																												
44	MABZ																												
45	MACO																												
46	MADA																												
47	MALT																												
48	MAON																												
49	MART																												
50	MATE																												
51	MEDI																												
52	MILA																												
53	MILO																												
54	MOCO																												
55	MOPS																												

Stations		Julian Day																											
		Year 2007									Year 2008																		
		357	358	359	360	361	362	363	364	365	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
56	MRGE																												
57	MRLC																												
58	MSRU																												
59	NOT1																												
60	NU01																												
61	PADO																												
62	PARM																												
63	PASS																												
64	PAVI																												
65	PORD																												
66	PRAT																												
67	RENO																												
68	ROVE																												
69	RSMN																												
70	RSTO																												
71	SASA																												
72	SASS																												
73	SERS																												
74	SIEN																												
75	SMAR																												
76	SOFI																												
77	STBZ																												
78	STUE																												
79	SVIN																												
80	TEMP																												
81	TERM																												
82	TGPO																												
83	TGRC																												
84	TORI																												
85	TREB																												
86	TRIE																												
87	UDI1																												
88	UGEN																												
89	UNOV																												
90	UNPG																												
91	USIX																												
92	VAGA																												
93	VAST																												
94	VEAR																												
95	VERO																												
96	VITE																												
97	WTZR																												
98	ZIMM																												
99	ZOUF																												

Table 1 – Data availability (green cells for available data, red cells for missing data)

n.	Station	Receiver	Antenna	Dome	N (m)	E (m)	U (m)
1	ACOM	TPS GB-1000	ASH701945E_M	SCIT	0.0000	0.0000	0.0083
2	ALFE	TRIMBLE NETRS	TRM29659.00	UNAV	0.0000	0.0000	0.0000
3	AMUR	LEICA GRX1200PRO	LEIAT504	SCIT	0.0000	0.0000	0.0083
4	AQUI	TRIMBLE 4700	TRM29659.00	NONE	0.0000	0.0000	0.0000
5	BIEL	TRIMBLE 5700	TRM41249.00	NONE	0.0000	0.0000	0.0000
6	BORM	TPS ODYSSEY_E	TPSCR3_GGD	CONE	0.0000	0.0000	0.0749
7	BRBZ	LEICA GRX1200PRO	LEIAT504	LEIS	0.0000	0.0000	0.0000
8	BRES	TPS ODYSSEY_E	TPSCR3_GGD	CONE	0.0000	0.0000	0.0540
9	BZRG	LEICA GRX1200GGPRO	LEIAT504GG	LEIS	0.0000	0.0000	0.2120
10	CA06	LEICA SR530	LEIAT504	NONE	0.0000	0.0000	0.0000
11	CAGL	TRIMBLE 4700	TRM29659.00	NONE	0.0000	0.0000	0.0450
12	CAME	TRIMBLE 4000SSI	TRM29659.00	NONE	0.0000	0.0000	0.0000
13	CAMP	TPS ODYSSEY_E	TPSG3_A1	NONE	0.0000	0.0000	0.0000
14	CAPO	LEICA GMX902	LEIAX1202GG	NONE	0.0000	0.0000	0.0000
15	CARI	TPS ODYSSEY_E	TPSCR.G3	NONE	0.0000	0.0000	0.0000
16	COMO	TPS E_GGD	TPSCR3_GGD	CONE	0.0000	0.0000	0.2134
17	COMU	JPS E_GGD	TOP_CR3_GGD	NONE	0.0000	0.0000	0.0000
18	CUCC	LEICA GRX1200PRO	LEIAT504	SCIT	0.0000	0.0000	0.0083
19	CUNE	TRIMBLE 5700	TRM41249.00	NONE	0.0000	0.0000	0.0000
20	DEVE	LEICA GRX1200PRO	LEIAT504	NONE	0.0000	0.0000	0.0000
21	EIIV	LEICA GRX1200PRO	TRM29659.00	NONE	0.0000	0.0000	0.9930
22	ELBA	TRIMBLE 4700	TRM29659.00	NONE	0.0000	0.0000	0.0000
23	ENAV	LEICA SR520	LEIAT504	LEIS	0.0000	0.0000	0.2000
24	ENNA	LEICA GMX902GG	LEIAX1202GG	NONE	0.0000	0.0000	0.0000
25	FASA	LEICA GRX1200GGPRO	LEIAT504	LEIS	0.0000	0.0000	0.0000
26	FOGG	LEICA GRX1200GGPRO	LEIAT504	LEIS	0.0000	0.0000	0.0000
27	FRES	LEICA GRX1200PRO	LEIAT504	SCIT	0.0000	0.0000	0.0083
28	GENO	TRIMBLE 4000SSI	TRM29659.00	NONE	0.0000	0.0000	0.0000
29	GIUR	LEICA GRX1200GGPRO	LEIAT504	LEIS	0.0000	0.0000	0.0000
30	GRAS	ASHTECH UZ-12	ASH701945E_M	NONE	0.0000	0.0000	0.0350
31	GRAZ	TRIMBLE NETRS	TRM29659.00	NONE	0.0000	0.0000	1.9640
32	GROG	LEICA GRX1200PRO	LEIAT504	LEIS	0.0000	0.0000	0.0000
33	GROT	LEICA SR520	LEIAT504	SCIT	0.0000	0.0000	0.0083
34	HFLK	TRIMBLE NETRS	TRM29659.00	GRAZ	0.0000	0.0000	0.1720
35	HMDC	LEICA GRX1200PRO	LEIAT504	SCIT	0.0000	0.0000	0.0083
36	IENG	ASHTECH Z-XII3T	ASH701945C_M	NONE	0.0000	0.0000	0.0000
37	IGMI	TPS ODYSSEY_E	TRM29659.00	NONE	0.0000	0.0000	0.0000
38	INGR	LEICA GRX1200PRO	LEIAT504	NONE	0.0000	0.0000	0.0000
39	ISCH	LEICA GRX1200GGPRO	LEIAT504	LEIS	0.0000	0.0000	0.0000
40	LAMP	TRIMBLE 4700	TRM29659.00	NONE	0.0000	0.0000	0.0000
41	LASP	LEICA GRX1200PRO	LEIAT504	SCIT	0.0000	0.0000	0.0083
42	LAT1	LEICA GX1230	LEIAX1202	NONE	0.0000	0.0000	0.0000
43	M0SE	LEICA GRX1200GGPRO	LEIAT504GG	LEIS	0.0000	0.0000	0.0000
44	MABZ	LEICA GRX1200PRO	LEIAT504	LEIS	0.0000	0.0000	0.0000
45	MACO	LEICA GRX1200	LEIAX1202	NONE	0.0000	0.0000	0.0000
46	MADA	LEICA GX1230	LEIAX1202	NONE	0.0000	0.0000	0.0000
47	MALT	LEICA SR520	LEIAT504	SCIT	0.0000	0.0000	0.0083
48	MAON	LEICA GRX1200PRO	LEIAT504	SCIT	0.0000	0.0000	0.0083
49	MART	TRIMBLE NETRS	TRM29659.00	UNAV	0.0000	0.0000	0.0000
50	MATE	TRIMBLE 4000SSI	TRM29659.00	NONE	0.0000	0.0000	0.1010
51	MEDI	TRIMBLE 4000SSI	TRM29659.00	NONE	0.0000	0.0000	0.0000
52	MILA	TPS ODYSSEY_E	TPSCR3_GGD	CONE	0.0000	0.0000	0.0540
53	MILO	TRIMBLE 4000SSI	TRM29659.00	NONE	0.0000	0.0000	0.0000

n.	Station	Receiver	Antenna	Dome	N (m)	E (m)	U (m)
54	MOCO	LEICA GRX1200PRO	LEIAT504	SCIT	0.0000	0.0000	0.0083
55	MOPS	LEICA GRX1200GGPRO	LEIAT504GG	NONE	0.0000	0.0000	0.0083
56	MRGE	LEICA GRX1200	LEIAT504	SCIT	0.0000	0.0000	0.0083
57	MRLC	LEICA SR520	LEIAT504	SCIT	0.0000	0.0000	0.0083
58	MSRU	LEICA GRX1200PRO	LEIAT504	SCIT	0.0000	0.0000	0.0083
59	NOT1	TRIMBLE 4000SSI	TRM29659.00	NONE	0.0000	0.0000	0.0000
60	NU01	LEICA GX1230	LEIAX1202	NONE	0.0000	0.0000	0.0000
61	PADO	TRIMBLE NETRS	TRM29659.00	NONE	0.0000	0.0000	0.0000
62	PARM	LEICA GRX1200PRO	LEIAT504	SCIT	0.0000	0.0000	0.0083
63	PASS	LEICA GRX1200GGPRO	LEIAT504GG	LEIS	0.0000	0.0000	0.0000
64	PAVI	LEICA GRX1200PRO	LEIAT504	NONE	0.0000	0.0000	0.0000
65	PORD	TRIMBLE NETRS	TRM29659.00	UNAV	0.0000	0.0000	0.0000
66	PRAT	TRIMBLE 4000SSI	TRM29659.00	NONE	0.0000	0.0000	0.0280
67	RENO	TPS ODYSSEY_E	TPSCR3_GGD	CONE	0.0000	0.0000	0.0000
68	ROVE	LEICA RS500	LEIAT504	LEIS	0.0000	0.0000	0.0940
69	RSMN	LEICA GRX1200PRO	TRM41249.00	NONE	0.0000	0.0000	0.3000
70	RSTO	LEICA GRX1200GGPRO	TRM29659.00	NONE	0.0000	0.0000	0.0000
71	SASA	LEICA GRX1200GGPRO	LEIAT504	LEIS	0.0000	0.0000	0.0000
72	SASS	LEICA GMX902	LEIAX1202	NONE	0.0000	0.0000	0.0000
73	SERS	LEICA GRX1200PRO	LEIAT504	SCIT	0.0000	0.0000	0.0083
74	SIEN	LEICA GRX1200GGPRO	LEIAT504GG	NONE	0.0000	0.0000	0.0000
75	SMAR	TPS ODYSSEY_E	TPSCR.G3	NONE	0.0000	0.0000	0.0000
76	SOFI	TPS E_GGD	AOAD/M_T	NONE	0.0000	0.0000	0.2200
77	STBZ	LEICA GRX1200GGPRO	LEIAT504GG	LEIS	0.0000	0.0000	0.0000
78	STUE	LEICA GRX1200PRO	LEIAT504	LEIS	0.0000	0.0000	0.0000
79	SVIN	LEICA GRX1200PRO	LEIAT504	NONE	0.0000	0.0000	0.0000
80	TEMP	LEICA GMX902	LEIAX1202GG	NONE	0.0000	0.0000	0.0000
81	TERM	LEICA GMX902GG	LEIAT504	NONE	0.0000	0.0000	0.0000
82	TGPO	TRIMBLE NETRS	TRM41249.00	NONE	0.0000	0.0000	0.0000
83	TGRC	LEICA GRX1200GGPRO	LEIAT504	LEIS	0.0000	0.0000	0.0000
84	TORI	TRIMBLE 4000SSI	TRM29659.00	NONE	0.0000	0.0000	0.0000
85	TREB	LEICA GRX1200GGPRO	LEIAT504GG	LEIS	0.0000	0.0000	0.0000
86	TRIE	TPS GB-1000	ASH701945E_M	SCIT	0.0000	0.0000	0.0083
87	UDI1	TPS GB-1000	ASH701945E_M	SCIT	0.0000	0.0000	0.0083
88	UGEN	LEICA GRX1200GGPRO	LEIAT504	LEIS	0.0000	0.0000	0.0000
89	UNOV	TPS ODYSSEY_E	TPSCR3_GGD	NONE	0.0000	0.0000	0.0000
90	UNPG	TPS ODYSSEY_E	JPSREGANT_DD_E	NONE	0.0000	0.0000	0.1000
91	USIX	LEICA GRX1200PRO	LEIAT504	SCIT	0.0000	0.0000	0.0083
92	VAGA	LEICA GRX1200PRO	LEIAT504	SCIT	0.0000	0.0000	0.0083
93	VAST	TRIMBLE NETRS	TRM29659.00	UNAV	0.0000	0.0000	0.0000
94	VEAR	TPS LEGACY	TPSCR3_GGD	NONE	0.0000	0.0000	0.0000
95	VERO	LEICA GMX902	LEIAX1202GG	NONE	0.0000	0.0000	0.0000
96	VITE	LEICA GX1230	LEIAX1202	NONE	0.0000	0.0000	0.0000
97	WTZR	TPS NETG3	AOAD/M_T	NONE	0.0000	0.0000	0.0710
98	ZIMM	TRIMBLE NETRS	TRM29659.00	NONE	0.0000	0.0000	0.0000
99	ZOUF	TPS GB-1000	ASH701945C_M	SCIT	0.0000	0.0000	0.0083

Table 2 – Hardware installed in the RDN stations

4. Data Processing

The processing strategy followed the standard procedures adopted by AIUB and the most recent EUREF guidelines, *EPN Processing Instruction for Local Analysis Centres*: http:///www.epncb.oma.be/_organization/guidelines/guidelines_analysis_centres.php.

Each daily session was processed independently. The processing was carried out using Bernese GPS Sofware 5.0 (vers. 30th May 2008) from AIUB, and it was automated using the Bernese Processing Engine (BPE). The stacking of the 28 daily normal equations was done manually with the program ADDNQ2.

Processing strategy:

- Data pre-processing

  Zero difference L3 code processing to give receiver clock offsets.
  Baselines built up using automatic procedure based on OBS MAX strategy with a maximum length of 200 km (fig. 2)
  Data cleaned by removing data with elevation < 3°, unpaired observations and small (<5 minutes) data periods. Checking for cycle slips and fixing is possible using residuals from triple difference solution.

- Ambiguity free processing

  Single difference, single baseline processing with Ambiguity free (FLOAT).
  Ionosphere effects removed by processing the L3 linear combination whenever possible.

- Ambiguity resolution

  Single difference, single baseline processing with resolution of ambiguities with QIF (Quasi-Ionosphere-Free) algorithm processing.
  A priori troposphere model used - Dry Neill function.

- Daily processing

  Double difference level, multi-base processing.
  Previously resolved ambiguities introduced as integers, unresolved ambiguities pre-eliminated.
  Troposphere delays estimated every 1 hours with Wet Neill function.
  Ionosphere-free linear combination of dual-band measurements.
  The stations with a rms value higher than 20 mm for North, East component and higher than 30 mm for up component are eliminated and the daily data set are re-computed.
  28 daily normal equation (.NQ0 file) saved in SINEX format.

- Normal equation stacking

  Daily .NEQ files combined to produce solution based on whole four weeks of data. A minimal solution constrained to 13 fiducial stations to give final ITR2005 solution.

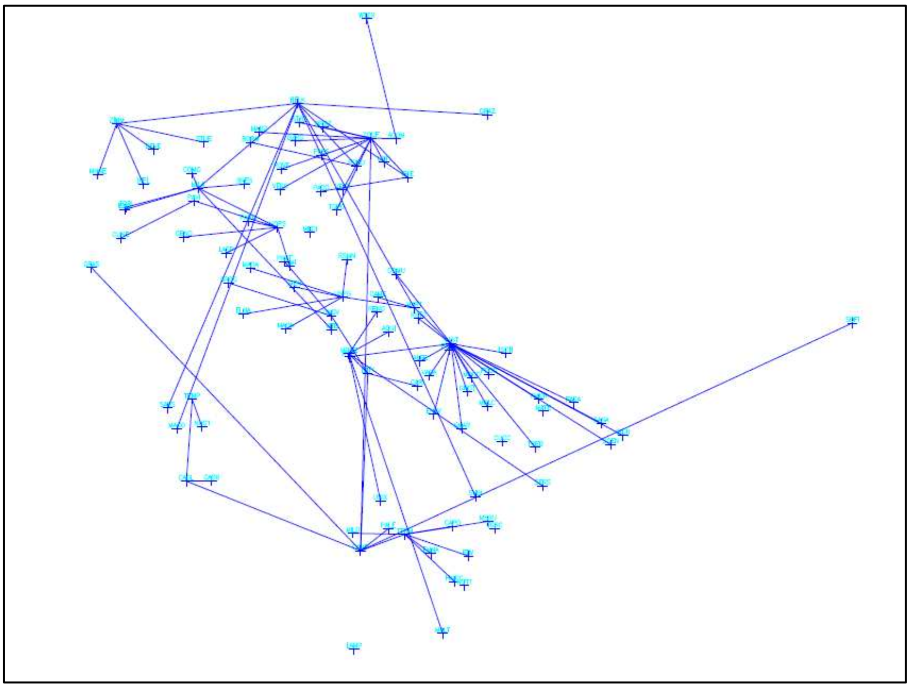

Fig. 2 –Baselines from daily observations (10th January 2008)

5. Datum alignment

The datum was aligned to ITRF2005, that represents the most recent frame of the ITRS (International Terrestrial Reference System). For this purpose, a set of 13 stations (fig. 3), belonging to this frame and active in the period of data collection, were considered..

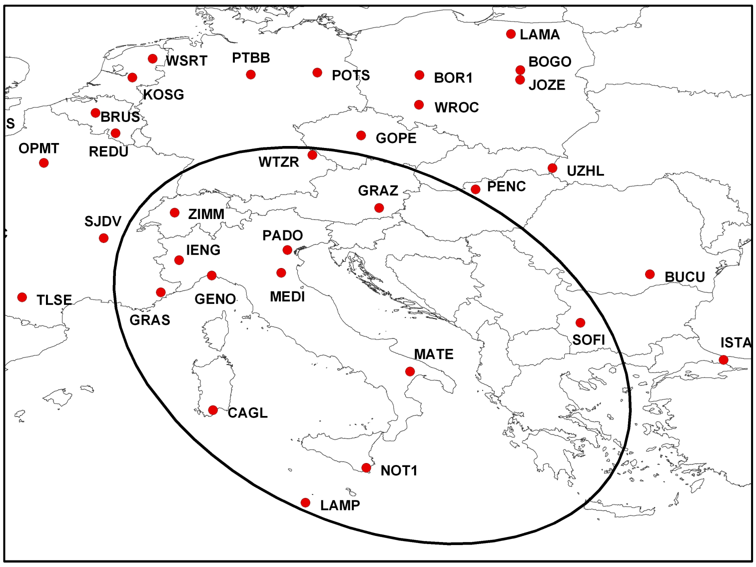

Fig. 3 – Stations for datum alignment.

As ITRF2005 is referred to epoch 2000.0, first of all it was necessary to propagate the coordinates to the conventional epoch chosen for RDN (2008.0). This was obtained by the well-known equation:

$$X_{2005}^{I}(2008.0) = X_{2005}^{I}(2000.0) + V_{2005}^{I}(2000.0)(2008.0 - 2000.0)$$

using the velocities estimated in the same solution.

Coordinates and velocities were downloaded from the following site: http://itrf.ensg.ign.fr/ITRF_solutions/2005/ITRF2005_files.php

The propagation of ITRF2005 coordinates at epoch 2008.0 is illustrated in Table 3.

STATION	ITRF2005 (2000.0) X, Y, Z [m]	Vx, Vy, Vz [m/Y]	Shift from 2000.0 to 2008.0 [m]	ITRF2005 (2008.0) X, Y, Z [m]
CAGL 12725M003	4893378.8895	-0.0132	-0.1056	4893378.7839
	772649.6883	0.0197	0.1576	772649.8459
	4004182.0985	0.0127	0.1016	4004182.2001
GENO 12712M002	4507892.3897	-0.0139	-0.1112	4507892.2785
	707621.3852	0.0189	0.1512	707621.5364
	4441603.4530	0.0116	0.0928	4441603.5458
GRAS 10002M006	4581690.9745	-0.0139	-0.1112	4581690.8633
	556114.7440	0.0186	0.1488	556114.8928
	4389360.7387	0.0116	0.0928	4389360.8315
GRAZ 11001M002	4194423.9047	-0.0167	-0.1336	4194423.7711
	1162702.6028	0.0181	0.1448	1162702.7476
	4647245.3599	0.0107	0.0856	4647245.4455
IENG 12724S001	4476537.4748	-0.0120	-0.0960	4476537.3788
	600431.3354	0.0189	0.1512	600431.4866
	4488761.2723	0.0123	0.0984	4488761.3707
LAMP 12706M002	5073164.8296	-0.0147	-0.1176	5073164.7120
	1134512.4796	0.0168	0.1344	1134512.6140
	3683181.0677	0.0153	0.1224	3683181.1901
MATE 12734M008	4641949.6474	-0.0179	-0.1432	4641949.5042
	1393045.3337	0.0188	0.1504	1393045.4841
	4133287.3848	0.0155	0.1240	4133287.5088
MEDI 12711M003	4461400.8331	-0.0182	-0.1456	4461400.6875
	919593.4838	0.0190	0.1520	919593.6358
	4449504.7104	0.0110	0.0880	4449504.7984
NOT1 12717M004	4934546.3174	-0.0175	-0.1400	4934546.1774
	1321264.9237	0.0172	0.1376	1321265.0613
	3806456.0422	0.0155	0.1240	3806456.1662
PADO 12750S001	4388882.1126	-0.0171	-0.1368	4388881.9758
	924567.3734	0.0177	0.1416	924567.5150
	4519588.6769	0.0113	0.0904	4519588.7673
SOFI 11101M002	4319372.1716	-0.0163	-0.1304	4319372.0412
	1868687.6889	0.0190	0.1520	1868687.8409
	4292063.8891	0.0093	0.0744	4292063.9635
WTZR 14201M010	4075580.6330	-0.0151	-0.1208	4075580.5122
	931853.7122	0.0173	0.1384	931853.8506
	4801568.0814	0.0114	0.0912	4801568.1726
ZIMM 14001M004	4331297.1313	-0.0126	-0.1008	4331297.0305
	567555.7888	0.0181	0.1448	567555.9336
	4633133.8719	0.0127	0.1016	4633133.9735

Table 3 – Propagation of ITRF2005 solution at epoch 2008.0.

The 28 daily normal equations were stacked to produce the final solution and aligned to ITRF2005 (2008.0) under minimum constraint condition using the 13 fiducial stations. The minimum constraint condition was applied adopting a 3 parameter (only translation) Helmert transformation.

The coordinates of RDN stations in ITRF2005 at epoch 2008.0 are illustrated in following table 4.

STATION	X	Y	Z
	[m]	[m]	[m]
ACOM	4273810.7131	1027226.7129	4608635.0230
ALFE	4625139.9124	1156125.3800	4224241.4339
AMUR	4626450.9382	1379560.0767	4155004.8655
AQUI	4592507.5212	1089876.4200	4276393.0358
BIEL	4429584.5389	626326.5529	4531541.9606
BORM	4329794.4409	791852.3149	4602160.9857
BRBZ	4280148.5586	905194.7139	4626969.5812
BRES	4401985.8771	794641.4099	4531684.9268
BZRG	4312657.4439	864634.7045	4603844.4801
CA06	4885197.2646	819339.0112	4004669.5657
CAGL	4893378.7833	772649.8463	4004182.1987
CAME	4542009.0873	1058964.3123	4336933.0154
CAMP	4933160.7024	1115797.4990	3873025.1889
CAPO	4856453.2945	1277652.1914	3919231.4798
CARI	4664233.4236	1160692.6124	4178813.4220
COMO	4398306.2372	704149.9093	4550154.7040
COMU	4496867.6688	1081164.7769	4377441.3431
CUCC	4708408.4878	1333725.3937	4077888.6166
CUNE	4525690.5409	600123.7966	4439976.5629
DEVE	4368538.4129	634264.2780	4590604.5708
EIIV	4891068.1463	1318070.7593	3862815.8518
ELBA	4616533.8783	831568.7283	4307570.0347
ENAV	4700260.8258	1201129.5992	4127657.5541
ENNA	4906175.3751	1248225.2543	3868307.0065
FASA	4612625.2651	1441887.9577	4148677.7790
FOGG	4612763.6774	1282018.8849	4200293.3842
FRES	4594459.0275	1202703.3072	4243687.3152
GENO	4507892.2806	707621.5386	4441603.5484
GIUR	4633414.1364	1544029.4673	4088639.2445
GRAS	4581690.8647	556114.8907	4389360.8325
GRAZ	4194423.7694	1162702.7485	4647245.4454
GROG	4570722.8952	797061.2668	4362184.5136
GROT	4650262.3278	1251243.6612	4168853.4665
HFLK	4248504.8750	855575.7713	4667172.1834
HMDC	4934274.8572	1302135.9797	3814112.5769
IENG	4476537.3725	600431.4831	4488761.3639
IGMI	4523251.2271	896760.0816	4391796.3767
INGR	4646739.1789	1031416.6791	4231464.0475
ISCH	4572564.3243	1302230.4443	4237949.0046
LAMP	5073164.7196	1134512.6185	3683181.1950
LASP	4522360.7245	784371.0799	4414006.3320
LAT1	4665378.1090	1068638.3672	4201803.7427
M0SE	4642432.4360	1028629.4923	4236854.2826
MABZ	4309779.2426	802742.1902	4618682.4335
MACO	4816951.8873	743078.7448	4101246.9690
MADA	4539637.8362	830400.7516	4387906.1920
MALT	5011123.5615	1298409.4007	3713675.1180
MAON	4626515.1733	910260.3428	4280983.4697
MART	4543297.9091	1125695.7804	4318217.6894
MATE	4641949.5028	1393045.4862	4133287.5072

STATION	X	Y	Z
	[m]	[m]	[m]
MEDI	4461400.6969	919593.6306	4449504.8052
MILA	4421849.5793	718507.7103	4525043.5848
MILO	4911058.9255	1096340.3522	3906215.0616
MOCO	4627440.4688	1253655.3517	4194153.6223
MOPS	4463919.3391	863590.9255	4458193.9919
MRGE	4424083.5146	547997.3455	4548669.0207
MRLC	4663041.6824	1292189.2981	4142383.6929
MSRU	4832083.2549	1340812.4307	3928723.6616
NOT1	4934546.1791	1321265.0630	3806456.1683
NU01	4806419.2379	788231.9735	4105067.5961
PADO	4388881.9776	924567.5183	4519588.7718
PARM	4462867.1412	812021.1341	4468896.0757
PASS	4328740.9644	912367.7881	4581146.9988
PAVI	4444603.1933	714786.1537	4503373.2664
PORD	4333820.4534	973585.6636	4561967.5880
PRAT	4518264.1125	886376.7511	4399019.3852
RENO	4566234.5965	1062015.6008	4311095.9079
ROVE	4364680.5329	851736.8952	4557204.9567
RSMN	4492950.1482	992011.5344	4403302.9797
RSTO	4558252.6356	1136625.0752	4299739.5878
SASA	4627991.1559	1500565.2680	4110719.8143
SASS	4787064.3522	721178.7299	4139196.0830
SERS	4752770.1258	1424861.5384	3996182.1403
SIEN	4556016.5164	911455.8062	4355465.6511
SMAR	4708765.0345	1256509.1198	4100873.5139
SOFI	4319372.0377	1868687.8384	4292063.9602
STBZ	4280131.5772	865014.9689	4634805.2398
STUE	4343319.1686	714929.1870	4602977.7056
SVIN	4802269.4427	1307824.5511	3975355.3992
TEMP	4766973.2389	763529.3485	4155104.6010
TERM	4890360.9696	1192337.3026	3904013.3690
TGPO	4414891.8505	956817.9193	4487623.7004
TGRC	4838809.1550	1355666.7726	3914997.5447
TORI	4472544.3146	601634.4024	4492545.2390
TREB	4699617.0346	1394494.8089	4066929.0862
TRIE	4333581.6813	1061504.6455	4543010.6708
UDI1	4317298.1751	1016828.9705	4568247.9032
UGEN	4653957.5623	1526724.6681	4071930.9365
UNOV	4589198.0342	984938.7362	4304620.4373
UNPG	4555145.6956	997822.4795	4337432.7725
USIX	4852628.6085	1136318.4883	3967233.9837
VAGA	4643698.3850	1177998.7846	4197652.9689
VAST	4583659.8184	1203175.9563	4254848.0551
VEAR	4379203.6105	959452.7194	4521665.9788
VERO	4400201.2124	855506.6501	4522247.7055
VITE	4611056.5895	990163.5914	4280267.6793
WTZR	4075580.5085	931853.8483	4801568.1673
ZIMM	4331297.0236	567555.9341	4633133.9701
ZOUF	4282709.9953	986659.4960	4609469.8335

Table 4 – ITRF2005 coordinates of RDN stations at 2008.0.

6. *Error estimation*

The mean square errors resulting from the computation are very small (some millimeters or even less). Anyway, these errors are underestimated because stocastic models were applied to variables with correlations and systematic errors not easy to estimate.

To estimate the network errors in a more reliable way, a check of the repeatability of the coordinates of each station in the four-week observation period was performed. The root mean square of the mean distribution of the 28 daily solutions is illustrated in table 5, for North, East and height coordinates. The values are smaller than 1 cm for planimetric coordinates and smaller than 1,3 cm for height, as required for Class B networks.

STATION	r.m.s. N [mm]	r.m.s. E [mm]	r.m.s. h [mm]
ACOM	0.7	1.3	3.2
ALFE	1.0	1.0	4.5
AMUR	0.6	0.6	2.5
AQUI	0.5	0.4	2.8
BIEL	1.3	0.6	4.4
BORM	1.2	1.0	6.1
BRBZ	1.0	0.7	3.5
BRES	0.8	0.6	1.7
BZRG	0.7	0.3	1.8
CA06	1.1	1.6	3.7
CAGL	0.9	1.2	3.8
CAME	2.1	2.3	6.9
CAMP	0.6	0.6	3.7
CAPO	0.7	0.8	4.8
CARI	0.6	0.9	3.1
COMO	0.6	0.5	1.6
COMU	0.6	0.5	1.7
CUCC	0.5	0.8	5.3
CUNE	2.5	2.3	11.9
DEVE	5.0	3.0	11.0
EIIV	0.8	0.6	3.1
ELBA	1.2	1.1	3.4
ENAV	1.1	1.1	7.4
ENNA	0.9	1.2	4.2
FASA	0.6	0.9	2.5
FOGG	0.5	0.6	1.5
FRES	0.8	0.9	3.7
GENO	1.7	0.6	7.2
GIUR	0.6	0.8	2.4
GRAS	3.7	4.8	4.5
GRAZ	0.5	0.5	2.4
GROG	1.1	0.9	5.2
GROT	0.6	0.6	2.2
HFLK	1.4	1.1	2.7
HMDC	1.3	1.0	10.4
IENG	3.2	2.9	3.5
IGMI	0.6	0.5	1.9
INGR	9.2	6.2	8.5
ISCH	0.9	0.7	3.1

STATION	r.m.s. N [mm]	r.m.s. E [mm]	r.m.s. h [mm]
LAMP	0.6	0.8	2.8
LASP	0.6	0.6	3.2
LAT1	0.8	0.8	3.9
M0SE	0.4	0.4	2.1
MABZ	0.7	0.8	3.9
MACO	0.9	0.9	2.7
MADA	1.2	1.1	6.1
MALT	0.6	0.5	3.7
MAON	1.0	0.8	3.5
MART	0.8	0.4	1.8
MATE	0.9	1.0	8.6
MEDI	1.5	7.8	9.0
MILA	0.7	0.7	2.3
MILO	1.7	0.8	12.6
MOCO	1.4	0.9	3.1
MOPS	1.8	1.2	3.4
MRGE	1.3	0.9	5.7
MRLC	1.5	0.9	3.1
MSRU	0.7	0.9	3.2
NOT1	0.6	1.0	2.8
NU01	6.0	2.6	13.1
PADO	0.8	0.7	2.6
PARM	2.6	0.9	1.6
PASS	1.0	1.1	5.8
PAVI	0.9	0.8	2.3
PORD	0.4	0.3	1.3
PRAT	0.8	0.7	10.5
RENO	1.3	1.0	6.9
ROVE	0.7	0.5	3.3
RSMN	1.1	0.8	3.6
RSTO	0.7	0.6	1.4
SASA	0.6	0.7	2.1
SASS	0.8	1.2	12.0
SERS	0.5	1.0	3.9
SIEN	0.5	0.5	2.3
SMAR	0.7	0.7	2.9
SOFI	2.6	2.0	3.4
STBZ	1.0	1.0	4.9
STUE	4.5	2.0	4.0
SVIN	1.9	1.5	2.8
TEMP	1.1	0.9	3.4
TERM	4.2	2.1	11.0
TGPO	0.5	0.3	2.4
TGRC	0.8	0.7	1.8
TORI	0.7	0.7	2.8
TREB	1.4	0.9	4.5
TRIE	0.7	0.5	2.2
UDI1	1.6	1.4	6.4
UGEN	1.2	0.9	2.9
UNOV	0.7	0.7	3.0
UNPG	1.8	0.8	10.5
USIX	0.9	0.6	3.6
VAGA	0.6	0.5	3.8

STATION	r.m.s. N [mm]	r.m.s. E [mm]	r.m.s. h [mm]
VAST	0.5	0.4	2.1
VEAR	1.1	1.3	7.2
VITE	0.5	0.7	3.7
WTZR	1.0	1.0	10.1
ZIMM	1.4	0.9	3.1
ZOUF	1.0	0.8	3.7
VERO	1.9	1.3	5.3
Mean	**1.3**	**1.1**	**4.5**
Std. Dev.	**1.3**	**1.1**	**3.2**

Table 5 – Evaluation of the repeatability of North, East and height coordinates.

7. Comparison with results from other Data Processing Centers

To make further controls of the data processing procedures and of the quality of the solution, the two solutions obtained from the two other Data Processing Centres in Padova and Como were examined. Each Data Processing Centre followed slightly different procedures for data processing, data cleaning and datum alignment: on the other hand, every Centre used the same data and aligned RDN to the same System (ETRF2000 at epoch 2008.0).

The comparison among the various solutions was made by calculating the difference between each solution and the mean of all the three solutions (Table 6; the RMS is referred to the mean of the three solutions).

STATION		IGM [mm]	UNPD [mm]	G3 [mm]	RMS [mm]
ACOM	φ	0.0	0.2	-0.2	0.2
	λ	-0.2	0.3	-0.1	0.3
	h	-3.1	-0.9	3.9	3.6
ALFE	φ	0.4	-0.2	-0.2	0.4
	λ	0.0	0.1	-0.1	0.1
	h	0.3	-2.7	2.2	2.3
AMUR	φ	0.0	-0.3	-0.3	0.3
	λ	0.2	0.2	-0.2	0.2
	h	-6.3	-1.4	-4.9	9.7
AQUI	φ	0.2	0.3	-0.5	0.4
	λ	0.0	0.1	-0.1	0.1
	h	-1.9	0.5	1.2	1.7
BIEL	φ	0.4	0.1	-0.4	0.4
	λ	0.0	0.0	-0.1	0.1
	h	-1.4	-1.3	2.5	2.2
BORM	φ	0.1	0.2	-0.3	0.3
	λ	0.1	0.1	-0.2	0.2
	h	-1.7	-0.5	2.4	2.2
BRBZ	φ	0.5	0.1	-0.5	0.5
	λ	0.0	0.0	0.0	0.0
	h	-1.3	-1.8	2.9	2.5

STATION		IGM [mm]	UNPD [mm]	G3 [mm]	RMS [mm]
BRES	φ	0.0	0.1	-0.1	0.1
	λ	0.2	0.2	-0.4	0.3
	h	0.5	-1.2	0.7	1.1
BZRG	φ	0.2	0.1	-0.3	0.3
	λ	0.1	0.0	-0.2	0.1
	h	-1.5	-0.8	2.1	1.8
CA06	φ	0.1	0.4	-0.5	0.5
	λ	0.0	0.2	-0.2	0.2
	h	-2.0	0.4	1.4	1.8
CAGL	φ	0.3	0.0	-0.3	0.3
	λ	0.1	-0.1	-0.1	0.1
	h	-1.4	-1.3	2.6	2.3
CAME	φ	-0.2	0.2	-0.1	0.2
	λ	0.3	0.1	-0.3	0.3
	h	-1.0	-0.7	1.5	1.3
CAMP	φ	0.8	-0.3	-0.6	0.7
	λ	0.2	0.2	-0.4	0.4
	h	2.1	-1.0	-1.4	1.8
CAPO	φ	0.1	0.2	-0.4	0.4
	λ	0.2	0.1	-0.3	0.3
	h	-2.8	2.5	0.1	2.7

CARI	φ	0.6	-0.4	-0.3	0.5
	λ	-0.1	0.1	-0.1	0.2
	h	-0.8	-1.4	2.3	2.0
COMO	φ	0.3	0.0	-0.4	0.3
	λ	0.1	0.1	-0.2	0.2
	h	-2.0	-0.4	2.4	2.3
COMU	φ	0.5	0.4	-1.0	0.8
	λ	0.5	0.2	-0.7	0.7
	h	-4.7	-2.5	6.9	6.1
CUCC	φ	0.4	0.0	-0.8	0.7
	λ	0.0	0.5	-0.1	0.1
	h	-10.0	-0.6	-4.6	12.9
CUNE	φ	-0.2	1.1	-0.9	1.0
	λ	0.2	0.3	-0.5	0.4
	h	-0.9	-1.3	2.4	2.1
DEVE	φ	-0.4	-0.5	1.0	0.9
	λ	0.5	0.3	-0.7	0.7
	h	-2.1	-2.4	4.9	4.3
EIIV	φ	0.3	0.2	-0.6	0.5
	λ	0.0	0.2	-0.2	0.2
	h	-0.7	-0.6	0.8	0.7
ELBA	φ	0.2	0.1	-0.4	0.3
	λ	0.2	-0.1	-0.1	0.2
	h	-0.9	-0.7	1.6	1.3
ENAV	φ	0.0	0.1	-0.1	0.1
	λ	0.0	0.1	-0.2	0.2
	h	0.0	-0.7	0.7	0.7
ENNA	φ	0.3	-0.3	-0.1	0.3
	λ	0.2	-0.1	-0.1	0.1
	h	-1.4	0.1	1.1	1.3
FASA	φ	0.3	0.1	-0.4	0.3
	λ	0.1	0.1	-0.1	0.1
	h	-1.6	0.0	1.2	1.4
FOGG	φ	0.2	-0.1	-0.1	0.2
	λ	0.1	0.2	-0.2	0.2
	h	-1.1	-0.1	0.9	1.0
FRES	φ	0.1	-0.2	-0.5	0.5
	λ	0.1	0.2	-0.2	0.2
	h	-6.4	-1.8	-4.4	9.4
GENO	φ	0.3	0.0	-0.3	0.3
	λ	0.1	-0.1	-0.1	0.1
	h	-1.4	-0.6	1.9	1.7
GIUR	φ	0.1	0.1	-0.2	0.2
	λ	0.3	0.0	-0.2	0.2
	h	-1.5	-0.1	1.2	1.4
GRAS	φ	0.2	0.7	-0.8	0.8
	λ	-0.4	0.3	0.1	0.4
	h	-0.9	-1.0	1.8	1.6
GRAZ	φ	0.2	0.1	-0.3	0.3
	λ	0.1	0.2	-0.2	0.2
	h	-0.5	-1.6	2.2	2.0

GROG	φ	0.3	0.1	-0.4	0.4
	λ	-0.1	0.1	-0.1	0.1
	h	-1.3	-0.2	1.5	1.4
GROT	φ	0.1	-0.2	-0.6	0.5
	λ	0.1	0.2	-0.1	0.1
	h	-6.4	-0.7	-4.3	9.3
HFLK	φ	0.8	0.1	-0.8	0.8
	λ	-0.2	0.0	0.2	0.2
	h	-2.5	-0.7	3.2	2.9
HMDC	φ	0.3	-0.8	-0.3	0.3
	λ	0.1	0.2	-0.2	0.2
	h	-4.0	-3.8	-4.8	7.7
IENG	φ	-0.3	-0.3	0.6	0.5
	λ	-0.6	-0.5	1.1	0.9
	h	0.7	-0.8	0.2	0.8
IGMI	φ	0.3	-0.1	-0.3	0.3
	λ	0.1	0.0	-0.2	0.1
	h	1.2	-1.8	0.4	1.5
INGR	φ	-0.2	0.2	0.0	0.2
	λ	-0.1	0.1	0.0	0.1
	h	-0.5	-0.9	1.2	1.1
ISCH	φ	0.4	-0.2	-0.2	0.3
	λ	0.2	0.0	-0.1	0.2
	h	-1.1	-1.1	1.8	1.6
LAMP	φ	-0.2	0.1	0.0	0.2
	λ	0.1	0.2	-0.4	0.3
	h	-0.9	0.1	0.5	0.8
LASP	φ	-0.2	0.0	-0.5	0.6
	λ	0.0	0.0	-0.2	0.1
	h	-6.8	-0.6	-4.7	10.0
LAT1	φ	0.4	0.0	-0.5	0.5
	λ	-0.1	0.2	-0.1	0.2
	h	-0.9	-1.4	2.2	1.9
M0SE	φ	0.0	0.2	-0.3	0.2
	λ	-0.1	0.2	-0.1	0.2
	h	-2.1	-0.3	2.3	2.2
MABZ	φ	0.3	0.1	-0.4	0.4
	λ	0.2	0.0	-0.3	0.3
	h	-0.8	-0.9	1.9	1.6
MACO	φ	0.4	0.0	-0.4	0.4
	λ	0.1	-0.2	0.0	0.1
	h	-1.5	-1.1	2.5	2.2
MADA	φ	0.2	0.0	-0.2	0.2
	λ	0.0	0.1	-0.2	0.2
	h	-0.4	-0.7	0.9	0.8
MALT	φ	-0.1	-0.1	-0.3	0.4
	λ	0.1	0.3	-0.3	0.3
	h	-6.9	-0.2	-5.4	10.6
MAON	φ	0.1	-0.1	-0.7	0.7
	λ	0.1	0.1	-0.1	0.1
	h	-6.3	-1.6	-4.2	9.2

MART	φ	0.5	-0.3	-0.3	0.5
	λ	0.1	0.2	-0.3	0.3
	h	2.0	-2.9	0.7	2.4
MATE	φ	0.1	0.0	-0.2	0.2
	λ	0.0	0.2	-0.2	0.2
	h	-2.0	-0.2	2.0	2.0
MEDI	φ	0.3	-0.3	0.0	0.3
	λ	-2.3	-2.9	5.2	4.5
	h	0.5	1.9	-2.4	2.2
MILA	φ	0.3	0.2	-0.4	0.4
	λ	-0.2	0.2	0.1	0.2
	h	-0.8	-1.3	2.2	1.9
MILO	φ	0.5	-0.2	-0.3	0.4
	λ	0.2	0.1	-0.3	0.3
	h	0.8	-0.5	-0.5	0.7
MOCO	φ	0.1	-0.3	-0.5	0.4
	λ	0.2	0.2	-0.1	0.1
	h	-7.0	-1.1	-4.5	10.0
MOPS	φ	0.6	0.2	-0.7	0.7
	λ	0.4	0.1	-0.5	0.5
	h	-3.1	0.0	3.2	3.2
MRGE	φ	0.0	0.4	-0.7	0.7
	λ	0.1	-0.2	-0.1	0.1
	h	-7.7	-1.5	-4.2	10.4
MRLC	φ	0.0	-0.1	-0.6	0.6
	λ	0.1	0.2	-0.1	0.1
	h	-7.2	-0.2	-5.5	11.0
MSRU	φ	0.1	-0.4	-0.4	0.4
	λ	0.2	0.3	-0.4	0.3
	h	-7.4	-1.4	-4.5	10.4
NOT1	φ	0.2	-0.6	0.4	0.6
	λ	0.6	-0.9	0.3	0.8
	h	0.7	-1.9	1.2	1.7
NU01	φ	-0.4	0.5	-0.1	0.5
	λ	-0.9	0.4	0.4	0.8
	h	-5.0	0.8	4.2	4.6
PADO	φ	-0.3	0.2	0.1	0.2
	λ	0.2	0.0	-0.1	0.1
	h	-4.0	0.4	3.7	3.9
PARM	φ	-0.2	0.3	-0.7	0.8
	λ	-0.1	0.1	0.0	0.1
	h	-7.1	-0.8	-3.8	9.6
PASS	φ	0.0	0.3	-0.2	0.2
	λ	0.2	0.0	-0.2	0.2
	h	-0.5	-0.8	1.3	1.1
PAVI	φ	0.2	0.1	-0.3	0.3
	λ	0.2	-0.1	0.0	0.2
	h	-1.1	-1.4	2.4	2.1
PORD	φ	0.0	0.2	-0.2	0.2
	λ	0.1	0.2	-0.3	0.2
	h	-2.0	-0.9	2.8	2.5

PRAT	φ	0.3	0.0	-0.4	0.4
	λ	0.1	0.1	-0.1	0.1
	h	-2.4	-0.4	2.8	2.6
RENO	φ	0.4	0.0	-0.4	0.4
	λ	0.2	0.0	-0.3	0.3
	h	-0.9	-1.3	1.9	1.6
ROVE	φ	0.4	-0.1	-0.3	0.4
	λ	0.4	0.0	-0.5	0.4
	h	1.4	-2.2	0.7	1.9
RSMN	φ	0.4	0.0	-0.5	0.5
	λ	0.1	0.1	-0.2	0.2
	h	-1.5	-0.9	2.2	2.0
RSTO	φ	0.3	0.0	-0.3	0.3
	λ	0.1	0.1	-0.2	0.2
	h	-0.9	-0.8	1.4	1.2
SASA	φ	0.2	-0.1	-0.2	0.2
	λ	0.1	0.2	-0.2	0.2
	h	-0.7	-1.3	1.7	1.4
SASS	φ	0.3	0.5	-0.8	0.7
	λ	0.0	-0.3	0.2	0.2
	h	-1.1	-2.5	3.5	3.1
SERS	φ	0.0	-0.2	-0.4	0.4
	λ	0.1	0.1	-0.2	0.1
	h	-7.3	-0.7	-5.6	11.2
SIEN	φ	0.3	-0.2	-0.1	0.3
	λ	0.1	0.2	-0.2	0.2
	h	0.4	-0.5	-0.1	0.3
SMAR	φ	0.1	0.3	-0.4	0.4
	λ	0.1	0.1	-0.2	0.2
	h	-1.6	1.4	0.0	1.7
SOFI	φ	0.0	-0.1	0.1	0.1
	λ	0.0	0.5	-0.4	0.5
	h	-1.7	-1.4	3.0	2.6
STBZ	φ	0.3	0.1	-0.4	0.4
	λ	-0.2	0.3	0.0	0.3
	h	-2.1	-0.5	2.6	2.4
STUE	φ	0.6	-0.1	-0.5	0.6
	λ	0.1	-0.1	0.0	0.1
	h	-1.6	-0.7	2.5	2.2
SVIN	φ	0.5	-0.4	-0.1	0.5
	λ	0.3	0.1	-0.3	0.3
	h	0.1	-1.7	1.5	1.6
TEMP	φ	0.4	0.3	-0.7	0.6
	λ	-0.1	0.0	0.1	0.1
	h	-2.1	-0.7	2.5	2.3
TERM	φ	-0.4	0.2	0.2	0.4
	λ	0.2	0.3	-0.5	0.4
	h	-0.6	-1.2	1.5	1.3
TGPO	φ	0.3	0.2	-0.4	0.3
	λ	0.0	0.1	-0.1	0.1
	h	-3.5	-2.8	5.9	5.2

TGRC	φ	0.5	-0.3	-0.2	0.4
	λ	0.0	0.2	-0.2	0.2
	h	-0.6	-1.6	1.9	1.7
TORI	φ	0.4	0.0	-0.4	0.4
	λ	-0.1	0.0	0.0	0.1
	h	-0.3	-1.0	1.7	1.6
TREB	φ	0.1	0.0	-0.1	0.1
	λ	0.1	0.1	-0.2	0.1
	h	-0.3	-0.3	0.3	0.3
TRIE	φ	0.3	0.0	-0.2	0.3
	λ	0.1	0.3	-0.4	0.3
	h	-2.3	-1.0	3.3	2.9
UDI1	φ	-0.1	0.1	0.0	0.1
	λ	-0.3	0.4	-0.1	0.4
	h	-3.4	0.3	3.1	3.3
UGEN	φ	0.2	-0.1	-0.1	0.2
	λ	0.0	0.3	-0.2	0.2
	h	-1.0	-1.5	2.2	1.9
UNOV	φ	-0.2	0.7	-0.5	0.6
	λ	-0.4	0.6	-0.2	0.5
	h	1.7	-5.8	3.8	4.9
UNPG	φ	0.7	-0.2	-0.5	0.6
	λ	0.3	0.0	-0.3	0.3
	h	-2.1	-1.0	2.8	2.5
USIX	φ	0.0	-0.3	-0.4	0.4
	λ	-0.1	0.1	-0.1	0.2
	h	-6.8	-1.1	-5.5	10.7

VAGA	φ	-0.3	0.2	-0.7	0.9
	λ	0.2	0.1	0.0	0.2
	h	-8.4	0.7	-5.7	12.3
VAST	φ	0.5	-0.3	-0.2	0.4
	λ	0.2	0.1	-0.3	0.3
	h	1.3	-2.7	1.0	2.0
VEAR	φ	0.1	0.1	-0.2	0.2
	λ	-0.2	0.2	-0.1	0.2
	h	-2.0	0.2	2.1	2.1
VERO	φ	0.0	0.0	0.0	0.0
	λ	0.3	0.0	-0.3	0.3
	h	-1.1	-0.4	1.2	1.2
VITE	φ	0.2	0.0	-0.2	0.2
	λ	0.1	0.1	-0.3	0.2
	h	-1.3	-0.8	1.9	1.7
WTZR	φ	0.4	0.4	-0.8	0.7
	λ	-0.1	0.0	0.1	0.1
	h	0.0	-3.0	3.2	3.2
ZIMM	φ	0.5	0.1	-0.6	0.5
	λ	0.0	0.0	0.0	0.0
	h	0.6	-1.8	1.3	1.7
ZOUF	φ	0.2	-0.1	-0.1	0.1
	λ	-0.1	0.1	0.0	0.1
	h	-2.1	-0.7	2.5	2.4

Table 6 – Comparison with results from other Data Processing Centers
(φ= north latitude, λ= east longitude, h= height above the GRS80 ellipsoid)

The differences are very small and they confirm the correctness of the calculations.

Only the station CUCC presents higher differences. Data from this station were initially very noisy, so they were cleaned using different procedures in the various Data Processing Centers: this is the reason for the higher differences. If the quality of the data from this station does not improve, in future computations it will be replaced.

8. Coordinate changes on fiducial stations

As the computation of RDN was performed under minimum constraint condition using the 13 ITRF2005 fiducial stations, the changes in the coordinates of these stations were evaluated at the end of the computation.

As shown in table 7, the differences are in most cases not significant (about 5 mm in almost all the 3 components). This confirms the accordance between RDN and ITRF2005. Note that HFLK, although in the ITRF2005 list, was not used for Minimum constraints because of an undocumented height change relative to its predicted value. However it was included in the computation of RDN.

STATION	ΔE [mm]	ΔN [mm]	Δh [mm]	Module [mm]
CAGL	-0.7	0.5	-1.3	1.6
GENO	0.2	1.9	3.5	4.0
GRAS	-0.1	-2.3	1.5	2.8
GRAZ	0.9	1.4	-1.0	2.0
IENG	-0.1	-2.8	-9.6	9.9
LAMP	-0.9	2.5	9.7	10.0
MATE	-0.7	2.4	-1.6	2.9
MEDI	-0.8	-7.3	10.6	12.9
NOT1	0.4	1.1	2.9	3.2
PADO	1.4	3.0	4.9	5.9
SOFI	0.4	-0.9	-5.3	5.4
WTZR	-0.3	-1.6	-6.7	6.9
ZIMM	2.5	1.5	-7.1	7.7
Rms|x|	0.7	1.7	3.4	3.5

Table 7 - Coordinate changes on fiducial stations

9. *Transformation to the conventional frame ETRF2000*

According to EUREF instructions (Boucher et al., 2008) the transformation between ITRF2005 and ETRF2000 was obtained through the following equation:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{ETRF2000(2008.0)} = (1+K_{(2008.0)}) \cdot \begin{bmatrix} 1 & -Rz & Ry \\ Rz & 1 & -Rx \\ -Ry & Rx & 1 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{ITRF2005(2008.0)} + \begin{bmatrix} Tx \\ Ty \\ Tz \end{bmatrix}_{(2008.0)}$$

using the following parameters:

Tx	*Ty*	*Tz*	*K*	*Rx*	*Ry*	*Rz*	*epoch*
[mm]	[mm]	[mm]	[10^{-9}]	[mas]	[mas]	[mas]	
52.5	**51.0**	**-68.2**	**1.04**	**1.539**	**9.310**	**-15.048**	**2008.0**

The final coordinates of RDN in ETRF2000 at epoch 2008.0 are illustrated in Table 8 (cartesian coordinates) and in Table 9 (geographic coordinates).

STATION	X	Y	Z
	[m]	[m]	[m]
ACOM	4273811.0530	1027226.4188	4608634.7744
ALFE	4625140.2447	1156125.0633	4224241.1700
AMUR	4626451.2837	1379559.7606	4155004.6031
AQUI	4592507.8510	1089876.1052	4276392.7729
BIEL	4429584.8462	626326.2476	4531541.7019
BORM	4329794.7634	791852.0165	4602160.7328
BRBZ	4280148.8904	905194.4191	4626969.3314
BRES	4401986.1967	794641.1068	4531684.6706
BZRG	4312657.7718	864634.4074	4603844.2285
CA06	4885197.5627	819338.6768	4004669.2873
CAGL	4893379.0780	772649.5112	4004181.9196
CAME	4542009.4175	1058964.0007	4336932.7546
CAMP	4933161.0162	1115797.1624	3873024.9104
CAPO	4856453.6222	1277651.8602	3919231.2060
CARI	4664233.7542	1160692.2931	4178813.1563
COMO	4398306.5510	704149.6062	4550154.4473
COMU	4496868.0024	1081164.4683	4377441.0845
CUCC	4708408.8266	1333725.0722	4077888.3501
CUNE	4525690.8423	600123.4849	4439976.2995
DEVE	4368538.7234	634263.9767	4590604.3149
EIIV	4891068.4744	1318070.4260	3862815.5767
ELBA	4616534.1907	831568.4112	4307569.7688
ENAV	4700261.1571	1201129.2777	4127657.2870
ENNA	4906175.6984	1248224.9198	3868306.7302
FASA	4612625.6148	1441887.6427	4148677.5177
FOGG	4612764.0178	1282018.5694	4200293.1217
FRES	4594459.3641	1202702.9926	4243687.0530
GENO	4507892.5899	707621.2283	4441603.2866
GIUR	4633414.4909	1544029.1514	4088638.9829
GRAS	4581691.1607	556114.5753	4389360.5662
GRAZ	4194424.1208	1162702.4600	4647245.2014
GROG	4570723.2075	797060.9526	4362184.2496
GROT	4650262.6646	1251243.3431	4168853.2021
HFLK	4248505.2050	855575.4784	4667171.9347
HMDC	4934275.1820	1302135.6436	3814112.2997
IENG	4476537.6761	600431.1746	4488761.1028
IGMI	4523251.5480	896759.7708	4391796.1156
INGR	4646739.5025	1031416.3606	4231463.7817
ISCH	4572564.6678	1302230.1314	4237948.7441
LAMP	5073165.0264	1134512.2731	3683180.9101
LASP	4522361.0382	784370.7689	4414006.0701
LAT1	4665378.4340	1068638.0476	4201803.4763
M0SE	4642432.7596	1028629.1741	4236854.0169
MABZ	4309779.5666	802741.8932	4618682.1816
MACO	4816952.1841	743078.4146	4101246.6932
MADA	4539638.1521	830400.4395	4387905.9297
MALT	5011123.8816	1298409.0598	3713674.8372
MAON	4626515.4902	910260.0253	4280983.2039
MART	4543298.2434	1125695.4689	4318217.4290
MATE	4641949.8483	1393045.1692	4133287.2442
MEDI	4461401.0220	919593.3239	4449504.5471
MILA	4421849.8931	718507.4057	4525043.3271

STATION	X	Y	Z
	[m]	[m]	[m]
MILO	4911059.2394	1096340.0169	3906214.7840
MOCO	4627440.8069	1253655.0351	4194153.3590
MOPS	4463919.6605	863590.6185	4458193.7333
MRGE	4424083.8170	547997.0404	4548668.7616
MRLC	4663042.0210	1292188.9793	4142383.4282
MSRU	4832083.5876	1340812.1013	3928723.3894
NOT1	4934546.5049	1321264.7270	3806455.8912
NU01	4806419.5382	788231.6440	4105067.3211
PADO	4388882.3061	924567.2163	4519588.5171
PARM	4462867.4593	812020.8270	4468895.8168
PASS	4328741.2947	912367.4901	4581146.7468
PAVI	4444603.5058	714785.8476	4503373.0076
PORD	4333820.7873	973585.3654	4561967.3362
PRAT	4518264.4329	886376.4406	4399019.1243
RENO	4566234.9258	1062015.2876	4311095.6460
ROVE	4364680.8578	851736.5947	4557204.7026
RSMN	4492950.4765	992011.2258	4403302.7207
RSTO	4558252.9698	1136624.7628	4299739.3268
SASA	4627991.5082	1500564.9523	4110719.5527
SASS	4787064.6491	721178.4015	4139195.8084
SERS	4752770.4676	1424861.2143	3996181.8724
SIEN	4556016.8367	911455.4933	4355465.3886
SMAR	4708765.3687	1256508.7980	4100873.2468
SOFI	4319372.4247	1868687.5442	4292063.7154
STBZ	4280131.9065	865014.6740	4634804.9897
STUE	4343319.4855	714928.8875	4602977.4515
SVIN	4802269.7750	1307824.2235	3975355.1281
TEMP	4766973.5396	763529.0215	4155104.3277
TERM	4890361.2904	1192336.9689	3904013.0930
TGPO	4414892.1799	956817.6157	4487623.4447
TGRC	4838809.4881	1355666.4428	3914997.2723
TORI	4472544.6184	601634.0942	4492544.9781
TREB	4699617.3773	1394494.4881	4066928.8205
TRIE	4333582.0208	1061504.3476	4543010.4196
UDI1	4317298.5125	1016828.6735	4568247.6525
UGEN	4653957.9148	1526724.3508	4071930.6739
UNOV	4589198.3576	984938.4213	4304620.1738
UNPG	4555146.0214	997822.1669	4337432.5107
USIX	4852628.9280	1136318.1569	3967233.7091
VAGA	4643698.7177	1177998.4667	4197652.7043
VAST	4583660.1555	1203175.6424	4254847.7934
VEAR	4379203.9416	959452.4182	4521665.7248
VERO	4400201.5360	855506.3472	4522247.4498
VITE	4611056.9122	990163.2751	4280267.4148
WTZR	4075580.8499	931853.5671	4801567.9271
ZIMM	4331297.3311	567555.6351	4633133.7155
ZOUF	4282710.3323	986659.2012	4609469.5842

Table 8 – Cartesian coordinates of RDN stations in ETRF2000 (2008.0)

STATION	Latitude	Longitude	h(ellis.)
	[sexagesimal degrees]	[sexagesimal degrees]	[m]
ACOM	46°.32' 52,5539''	13°.30' 53,6222''	1774.685
ALFE	41°.44' 02,1241''	14°.02' 03,7608''	969.798
AMUR	40°.54' 26,1300''	16°.36' 14,5242''	549.454
AQUI	42°.22' 05,6529''	13°.21' 00,8804''	713.081
BIEL	45°.33' 38,6785''	8°.02' 52,9841''	480.474
BORM	46°.28' 05,4442''	10°.21' 50,2976''	1263.367
BRBZ	46°.47' 47,5834''	11°.56' 28,8118''	903.754
BRES	45°.33' 53,7322''	10°.13' 57,9407''	224.971
BZRG	46°.29' 56,4757''	11°.20' 12,4543''	329.131
CA06	39°.08' 33,2537''	9°.31' 15,4439''	101.731
CAGL	39°.08' 09,2724''	8°.58' 21,8963''	238.372
CAME	43°.06' 43,1382''	13°.07' 26,3795''	498.681
CAMP	37°.37' 45,3262''	12°.44' 41,5753''	146.089
CAPO	38°.09' 26,4745''	14°.44' 22,4368''	62.548
CARI	41°.11' 40,9865''	13°.58' 27,0700''	142.407
COMO	45°.48' 07,7774''	9°.05' 44,2270''	292.286
COMU	43°.37' 00,8558''	13°.31' 07,7359''	97.010
CUCC	39°.59' 37,6793''	15°.48' 55,9552''	669.320
CUNE	44°.23' 41,9629''	7°.33' 12,8391''	598.073
DEVE	46°.18' 48,8037''	8°.15' 39,5839''	1679.418
EIIV	37°.30' 48,9578''	15°.04' 55,4819''	88.897
ELBA	42°.45' 10,4312''	10°.12' 39,9362''	271.762
ENAV	40°.34' 56,2893''	14°.20' 05,5666''	541.226
ENNA	37°.34' 11,1208''	14°.16' 27,4718''	989.517
FASA	40°.50' 05,3867''	17°.21' 32,5005''	175.785
FOGG	41°.27' 07,9276''	15°.31' 55,6596''	148.376
FRES	41°.58' 24,6181''	14°.40' 09,4796''	404.697
GENO	44°.25' 09,7850''	8°.55' 16,1021''	155.531
GIUR	40°.07' 27,9777''	18°.25' 48,0926''	121.884
GRAS	43°.45' 17,0457''	6°.55' 14,0507''	1319.317
GRAZ	47°.04' 01,6578''	15°.29' 36,5144''	538.292
GROG	43°.25' 34,6754''	9°.53' 31,1855''	241.077
GROT	41°.04' 22,2211''	15°.03' 35,5192''	499.886
HFLK	47°.18' 46,4477''	11°.23' 09,9182''	2383.952
HMDC	36°.57' 32,4515''	14°.46' 59,1913''	586.609
IENG	45°.00' 54,4662''	7°.38' 21,8444''	316.620
IGMI	43°.47' 44,3256''	11°.12' 49,6637''	95.074
INGR	41°.49' 41,0925''	12°.30' 53,2654''	104.456
ISCH	41°.54' 15,5122''	15°.53' 47,5170''	373.497
LAMP	35°.29' 59,1774''	12°.36' 20,3501''	57.813
LASP	44°.04' 23,8231''	9°.50' 22,7419''	87.149
LAT1	41°.28' 14,6992''	12°.54' 05,1983''	97.918
M0SE	41°.53' 35,1987''	12°.29' 35,7169''	120.584
MABZ	46°.41' 09,5503''	10°.33' 03,7305''	1092.049
MACO	40°.16' 08,9560''	8°.46' 10,2100''	637.707
MADA	43°.44' 50,9598''	10°.21' 57,8305''	56.874
MALT	35°.50' 16,7141''	14°.31' 34,2926''	72.415
MAON	42°.25' 41,4351''	11°.07' 50,4823''	228.399
MART	42°.53' 07,1375''	13°.54' 57,4418''	61.896
MATE	40°.38' 56,8643''	16°.42' 16,0398''	535.663
MEDI	44°.31' 11,8360''	11°.38' 48,5196''	50.030
MILA	45°.28' 47,9481''	9°.13' 45,6271''	187.267

STATION	Latitude	Longitude	h(ellis.)
	[sexagesimal degrees]	[sexagesimal degrees]	[m]
MILO	38°.00' 29,3832"	12°.35' 03,5232"	92.490
MOCO	41°.22' 16,1681"	15°.09' 30,8330"	1072.644
MOPS	44°.37' 45,6617"	10°.56' 57,0845"	92.199
MRGE	45°.46' 11,1681"	7°.03' 39,8806"	1722.779
MRLC	40°.45' 23,1320"	15°.29' 19,4559"	631.495
MSRU	38°.15' 49,7266"	15°.30' 29,9938"	396.773
NOT1	36°.52' 33,0302"	14°.59' 23,2202"	126.359
NU01	40°.18' 52,7354"	9°.18' 48,0718"	586.717
PADO	45°.24' 40,1430"	11°.53' 45,8095"	64.701
PARM	44°.45' 52,4409"	10°.18' 43,8597"	121.831
PASS	46°.11' 34,7622"	11°.54' 07,2370"	1418.681
PAVI	45°.12' 10,7322"	9°.08' 10,1042"	143.643
PORD	45°.57' 24,3812"	12°.39' 40,3227"	81.764
PRAT	43°.53' 08,0146"	11°.05' 56,8438"	119.969
RENO	42°.47' 34,1667"	13°.05' 35,1085"	669.122
ROVE	45°.53' 36,6089"	11°.02' 31,5524"	261.685
RSMN	43°.56' 00,4543"	12°.27' 02,6630"	767.444
RSTO	42°.39' 30,1757"	14°.00' 05,3105"	102.603
SASA	40°.23' 06,5960"	17°.57' 52,5594"	99.289
SASS	40°.43' 15,9450"	8°.34' 02,1652"	302.471
SERS	39°.02' 09,3711"	16°.41' 18,6590"	1214.983
SIEN	43°.20' 29,7203"	11°.18' 46,7323"	417.668
SMAR	40°.16' 08,1201"	14°.56' 27,3727"	90.390
SOFI	42°.33' 21,9306"	23°.23' 41,0222"	1119.542
STBZ	46°.53' 53,6957"	11°.25' 32,0852"	1043.741
STUE	46°.28' 19,9363"	9°.20' 50,3174"	1964.651
SVIN	38°.48' 10,0899"	15°.14' 03,0328"	119.256
TEMP	40°.54' 29,0640"	9°.05' 59,3068"	597.278
TERM	37°.58' 59,7129"	13°.42' 07,7788"	55.310
TGPO	45°.00' 11,0014"	12°.13' 41,9389"	49.354
TGRC	38°.06' 29,9489"	15°.39' 03,7000"	139.239
TORI	45°.03' 48,1127"	7°.39' 40,5997"	310.747
TREB	39°.52' 08,7224"	16°.31' 37,0025"	138.366
TRIE	45°.42' 35,1151"	13°.45' 48,6582"	323.416
UDI1	46°.02' 14,9143"	13°.15' 10,8556"	149.298
UGEN	39°.55' 39,7318"	18°.09' 43,2152"	152.212
UNOV	42°.42' 57,0720"	12°.06' 47,2458"	379.587
UNPG	43°.07' 09,7991"	12°.21' 20,5173"	351.099
USIX	38°.42' 28,1152"	13°.10' 45,2294"	282.679
VAGA	41°.24' 55,5693"	14°.14' 03,6328"	784.819
VAST	42°.06' 37,3656"	14°.42' 28,4143"	209.791
VEAR	45°.26' 16,5988"	12°.21' 28,2044"	46.764
VERO	45°.26' 40,9181"	11°.00' 08,7543"	123.856
VITE	42°.25' 03,3335"	12°.07' 10,0614"	453.886
WTZR	49°.08' 39,1042"	12°.52' 44,0608"	666.026
ZIMM	46°.52' 37,5407"	7°.27' 54,9834"	956.332
ZOUF	46°.33' 25,9830"	12°.58' 24,7726"	1946.509

Table 9 – Geographic coordinates of RDN stations in ETRF2000 (2008.0)

10. Recomputation of IGM95 network from ETRF89 to ETRF2000

The Italian IGM95 static network, composed by more than 4000 vertexes on all the Italian territory, is affected by local deformations that, even if smaller than 10 cm, didn't allow the coordinates to be transformed from ETRF89 to ETRF2000 simply through rototranslations. So 45 RDN stations were connected through GPS measurements to those IGM95 points that, established from 1992 to 1996, were part of the fundamental network adjustment. Each station was connected to at least three IGM95 neighbouring points.

The differences between the ETRF89 and the ETRF2000 coordinates of the 45 stations are shown in table 10 and in fig. 4, 5, 6.

STATION	***Δ Latit.***	***Δ Longit.***	***Δ Height***
	[sec]	***[sec]***	***[m]***
ACOM	0.0002	0.0011	0.162
BORM	0.0008	0.0007	0.051
BRBZ	0.0003	0.0015	0.116
BRES	0.0009	0.0002	0.032
CAGL	0.0002	0.0007	0.012
CA06	0.0001	0.0010	0.026
COMU	0.0023	0.0003	-0.058
CUCC	0.0024	0.0008	0.026
CUNE	-0.0008	0.0026	0.034
DEVE	0.0003	0.0027	0.073
EIIV	0.0018	-0.0007	-0.002
ENAV	0.0019	0.0007	0.011
FOGG	0.0022	0.0017	-0.006
GENO	0.0007	0.0008	-0.020
GIUR	0.0019	0.0009	0.067
LASP	0.0018	-0.0009	-0.043
MACO	0.0000	0.0004	0.046
MAON	0.0013	0.0011	-0.056
MART	0.0017	0.0010	-0.053
MATE	0.0024	0.0012	0.005
MEDI	0.0023	-0.0020	-0.058
MILA	0.0005	0.0013	0.035
MILO	0.0021	-0.0031	-0.016
MOSE	0.0005	0.0048	-0.117
MRGE	-0.0004	0.0034	-0.004
MRLC	0.0023	0.0011	0.016
MSRU	0.0015	0.0001	0.030
NOT1	0.0016	-0.0010	-0.014
NU01	-0.0002	0.0004	0.046
PADO	0.0015	-0.0006	0.035
PARM	0.0019	0.0000	0.005
PASS	0.0009	0.0010	0.093
RENO	0.0020	0.0004	-0.063
SASS	-0.0001	0.0004	0.011
SERS	0.0009	0.0012	0.093
STBZ	0.0004	0.0015	0.117
STUE	0.0008	0.0004	0.019
TEMP	-0.0002	0.0003	0.004
TGRC	0.0014	-0.0001	0.014
TORI	-0.0001	0.0020	0.010

STATION	*Δ Latit.*	*Δ Longit.*	*Δ Height*
	[sec]	***[sec]***	***[m]***
TRIE	0.0012	0.0002	0.146
UNPG	0.0021	-0.0004	-0.112
VAGA	0.0020	0.0020	-0.063
VAST	0.0018	0.0018	-0.014

Maximum	**0.0024**	**0.0048**	**0.162**
Minimum	**-0.0008**	**-0.0031**	**-0.117**

	[m]	**[m]**
Maximum	**0.072**	**0.111**
Minimum	**-0.024**	**-0.072**

Tab. 11 – Differences between ETRF89 and the ETRF2000 coordinates

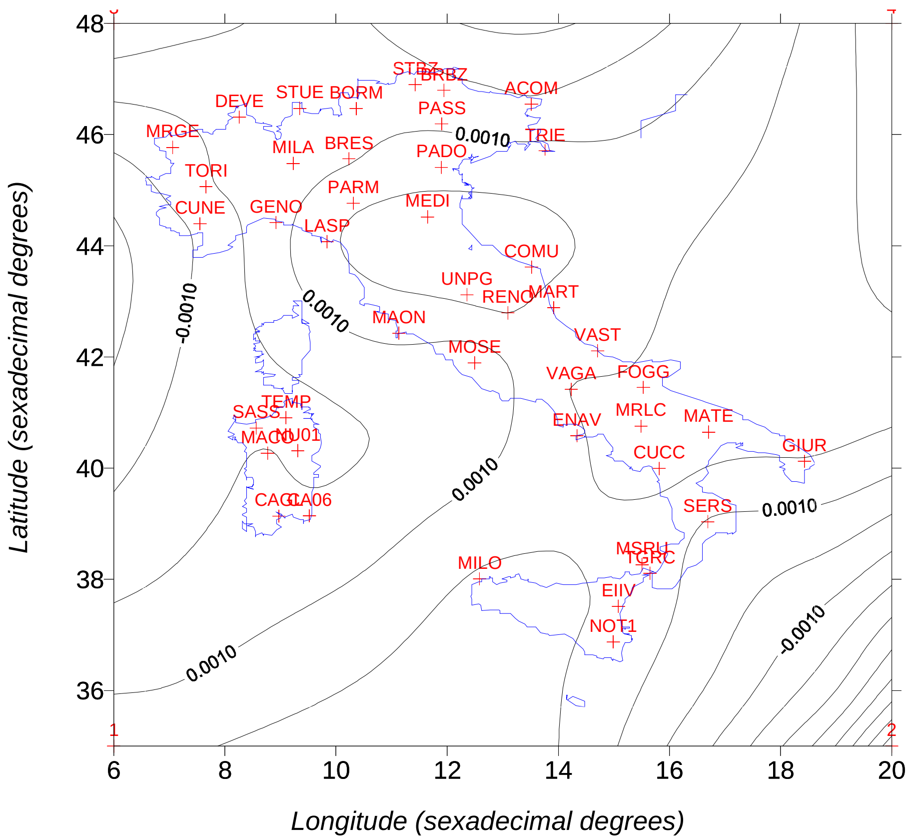

Fig. 4 - Latitude differences between ETRF89 and ETRF2000

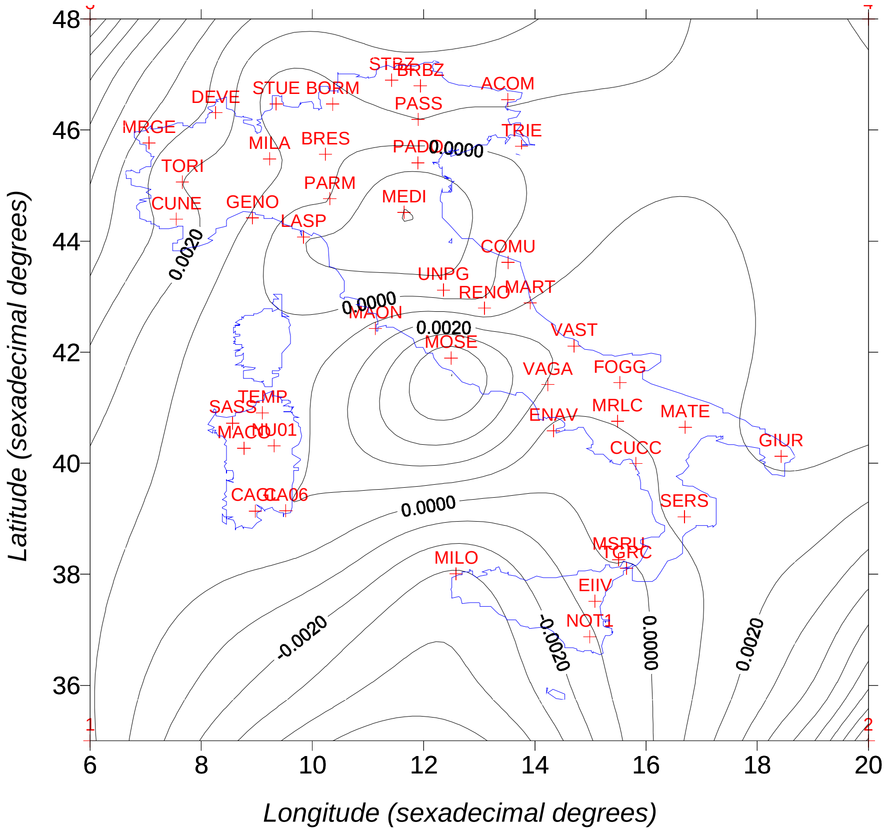

Fig. 5 - Longitude differences between ETRF89 and ETRF2000

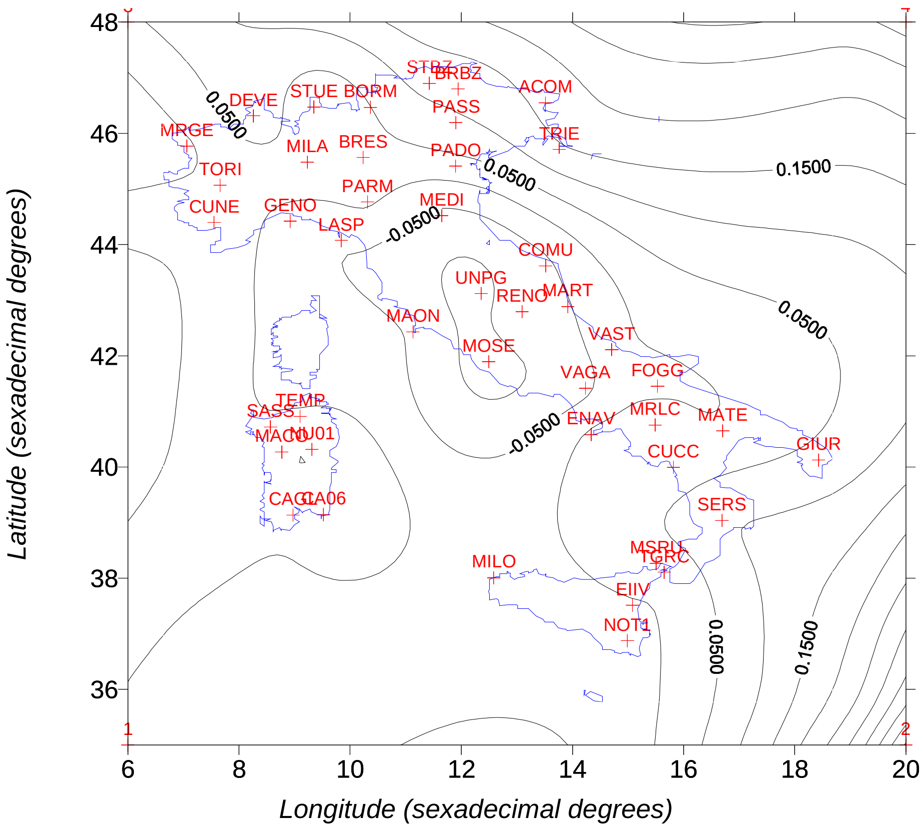

Fig. 6 – Height differences between ETRF89 and ETRF2000

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