S04: "Development of ETRS89 and EVRS for Geo-information Applications“

Extensions and Upgrades of ETRF2000 in Italy

UNIVERSITÀ DEGLI STUDI DI PADOVA

DIPARTIMENTO DI GEOSCIENZE

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Outline:

1.- ETRS89 (ETRF2000) densification in Italy.
2.- Time Series Analysis.
3.- BSW 5.0 vs BSW 5.2: upgrading, tests and results.
4.- Perspectives

UPA LAC's background:

- The LAC center at the University of Padova **operates since 1999** in support of the EPN weekly computations.

- **The parallelism between the EPN and the National networks is crucial** to synchronize the processing standards (e.g. antenna files, solution numbers of EPN class A sites included in the processing). Time series of the national network are created by normal equation stacking. Guidelines of EUREF densifications are applied.

Scientific Goals:

- **densification and maintenance of the INSPIRE** standard ETRS89 at the national level, which is requested by Governmental Agencies (Cadastre, Regional MCA's, the Italian NMCA IGMI)
- **monitoring of the horizontal gradients** of the velocities, i.e. the **strain rate tensor**, and **its relationship to seismic provinces**, in collaboration with the Civil Protection and the National Institute of Geophysics and Volcanology.
- Support IAG WG on Dense Velocity fields by supplying weekly the normal equations of the Italian network to A. Kenyeres for network combination

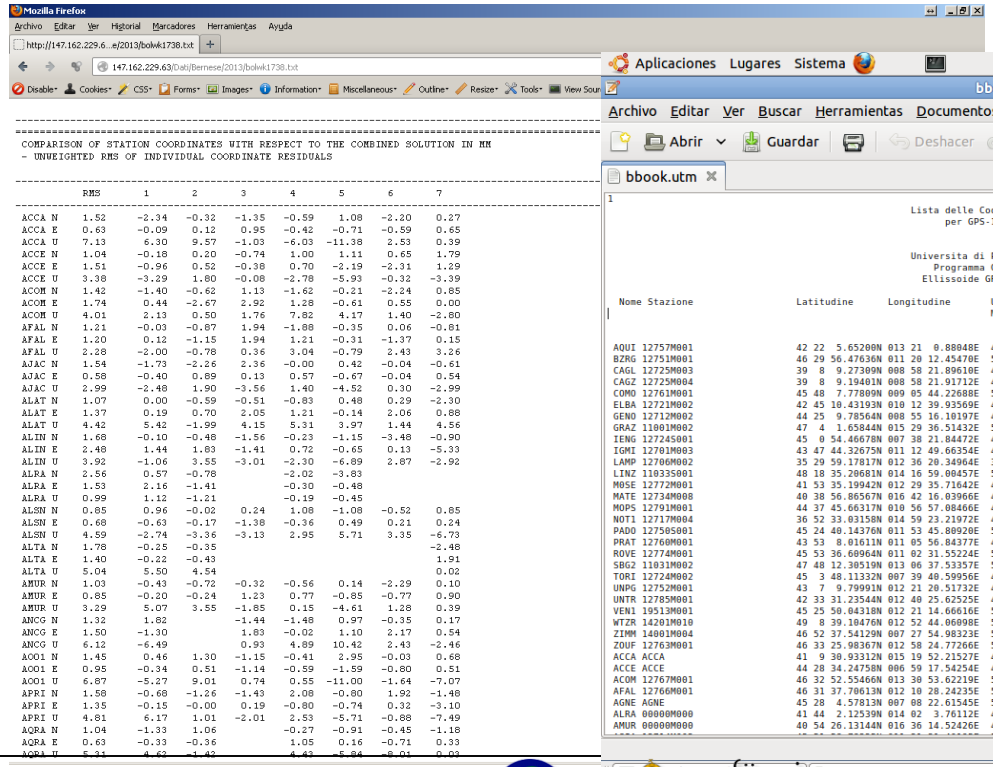
Maintain an up-to-date Data Base of the stations of the Italian network, mirroring the EPN Data Base for the common stations

- **STA file** is being permanently updated by:
  - ✓ Add new set-ups of sites (**TYPE 001**),
  - ✓ Add antenna/receiver changes (**TYPE 002**),
  - ✓ Set problems in sites (**TYPE 003**),
  - ✓ Set relative constraints between sites (different/new set-ups), **TYPE 004**.
- **TYPE 001** maps the EUREF's sites to the session numbering in the EPN solution's numbers.
- Once the **stacking is finished**, **detailed velocities' fields** are mapped for the different study areas.

ETRS89 Densification in Italy: weekly maintenance.

- A weekly bulletin is issued containing:
- ETRS89(ETRF2000) cartesian coordinates of the processed stations (300-400)
- Daily residuals relative to the weekly mean in NEU, for each station
- Geodetic coordinates (GRS80 lat, lon, ellipsoidal height) and UTM
- Convergence of the meridian
- Geoidal height and deflection of the vertical based on the EGG08 European Gravimetric Geoid (Univ. of Hannover)
- Maps of the processed/missing stations

Update Web page with velocity maps, time series



COMPARISON OF STATION COORDINATES WITH RESPECT TO THE COMBINED SOLUTION IN MM
- UNWEIGHTED RMS OF INDIVIDUAL COORDINATE RESIDUALS

	RMS	1	2	3	4	5	6	7
ACCA N	1.52	-2.34	-0.32	-1.35	-0.59	1.08	-2.20	0.27
ACCA E	0.63	-0.09	0.12	0.95	-0.42	-0.71	-0.59	0.65
ACCA U	7.13	6.30	9.57	-1.03	-6.03	-11.38	2.53	0.39
ACCE N	1.04	-0.18	0.20	-0.74	1.00	1.11	0.65	1.79
ACCE E	1.51	-0.96	0.52	-0.38	0.70	-2.19	-2.31	1.29
ACCE U	3.38	-3.29	1.80	-0.08	-2.78	-5.93	-0.32	-3.39
ACOM N	1.42	-1.40	-0.62	1.13	-1.62	-0.21	-2.24	0.85
ACOM E	1.74	0.44	-2.67	2.92	1.28	-0.61	0.55	0.00
ACOM U	4.01	2.13	0.50	1.76	7.82	4.17	1.40	-2.80
AFAL N	1.21	-0.03	-0.87	1.94	-1.88	-0.35	0.06	-0.81
AFAL E	1.20	0.12	-1.15	1.94	1.21	-0.31	-1.37	0.15
AFAL U	2.28	-2.00	-0.78	0.36	3.04	-0.79	2.43	3.26
AJAC N	1.54	-1.73	-2.26	2.36	-0.00	0.42	-0.04	-0.61
AJAC E	0.58	-0.40	0.89	0.13	0.57	-0.67	-0.04	0.54
AJAC U	2.99	-2.48	1.90	-3.56	1.40	-4.52	0.30	-2.99
ALAT N	1.07	0.00	-0.59	-0.51	-0.83	0.48	0.29	-2.30
ALAT E	1.37	0.19	0.70	2.05	1.21	-0.14	2.06	0.88
ALAT U	4.42	5.42	-1.99	4.15	5.31	3.97	1.44	4.56
ALIN N	1.68	-0.10	-0.48	-1.56	-0.23	-1.15	-3.48	-0.90
ALIN E	2.48	1.44	1.83	-1.41	0.72	-0.65	0.13	-5.33
ALIN U	3.92	-1.06	3.55	-3.01	-2.30	-6.89	2.87	-2.92
ALRA N	2.56	0.57	-0.78		-2.02	3.83		
ALRA E	1.53	2.16	-1.41		-0.30	-0.48		
ALRA U	0.99	1.12	-1.21		-0.19	-0.45		
ALSN N	0.85	0.96	-0.02	0.24	1.08	-1.08	-0.52	0.85
ALSN E	0.68	-0.63	-0.17	-1.38	-0.36	0.49	0.21	0.24
ALSN U	4.59	-2.74	-3.36	-3.13	2.95	5.71	3.35	-6.73
ALTA N	1.78	-0.25	-0.35					-2.48
ALTA E	1.40	-0.22	-0.43					1.91
ALTA U	5.04	5.50	4.54					0.02
AMUR N	1.03	-0.43	-0.72	-0.32	-0.56	0.14	-2.29	0.10
AMUR E	0.85	-0.20	-0.24	1.23	0.77	-0.85	-0.77	0.90
AMUR U	3.29	5.07	3.55	-1.85	0.15	-4.61	1.28	0.39
ANCG N	1.32	1.82		-1.44	-1.48	0.97	-0.35	0.17
ANCG E	1.50	-1.30		1.83	-0.02	1.10	2.17	0.54
ANCG U	6.12	-6.49		0.93	4.89	10.42	2.43	-2.46
AOO1 N	1.45	0.46	1.30	-1.15	-0.41	2.95	-0.03	0.68
AOO1 E	0.95	-0.34	0.51	-1.14	-0.59	-1.59	-0.80	0.51
AOO1 U	6.87	-5.27	9.01	0.74	0.55	-11.00	-1.64	-7.07
APRI N	1.58	-0.68	-1.26	-1.43	2.08	-0.80	1.92	-1.48
APRI E	1.35	-0.15	-0.00	0.19	-0.80	-0.74	0.32	-3.10
APRI U	4.81	6.17	1.01	-2.01	2.53	-5.71	-0.88	-7.49
AQRA N	1.04	-1.33	1.06		-0.27	-0.91	-0.45	-1.18
AQRA E	0.63	-0.33	-0.36		1.05	0.16	-0.71	0.33
AQRA U	5.31	4.62	-1.42		4.43	-5.84	-8.01	0.03

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Lista delle Coordinate finali
per GPS-1234

Universita di Padova
Programma GP TO UTMs del NGS-USA VERSIONE 2.1
Ellissoide GRS80/WGS84

Nome Stazione	Latitudine	Longitudine	UTM NORD(Y) METRI	UTM EST (X) METRI	ZONA	CONVERGENZA G M S	SCALA FATTORE	ELEV (M)	EllGEOIDEica h(M)
AQUI 12757M001	42 22 5.65200N	013 21 0.88048E	4691980.538	364159.972	33	-1 6 42.94	0.99982704		
BZRG 12751M001	46 29 56.47636N	011 20 12.45470E	5152147.609	679307.217	32	1 41 43.70	0.99999521		
CAGL 12725M003	39 8 9.27309N	008 58 21.89610E	4331859.102	497644.802	32	-0 1 1.92	0.99960007		
CAGZ 12725M004	39 8 9.19401N	008 58 21.91712E	4331856.664	497645.306	32	-0 1 1.91	0.99960007		
COMO 12761M001	45 48 7.77809N	009 05 44.22688E	5072071.003	507430.311	32	0 4 6.79	0.99960068		
ELBA 12721M002	42 45 10.43193N	010 12 39.93569E	4734086.222	599109.455	32	0 49 19.93	0.99972084		
GENO 12712M002	44 25 9.78564N	008 55 16.10197E	4918457.738	493722.130	32	-0 3 18.70	0.99960048		
GRAZ 11001M002	47 4 1.65844N	015 29 36.51432E	5212741.913	537469.766	33	0 21 40.69	0.99961725		
IENG 12724S001	45 0 54.46678N	007 38 21.84472E	4985531.534	392792.226	32	-0 57 44.76	0.99974133		
IGMI 12701M003	43 47 44.32675N	011 12 49.66354E	4851558.011	678099.072	32	1 31 57.16	0.99999015		
LAMP 12706M002	35 29 59.17817N	012 36 20.34964E	3931184.097	282827.850	33	-1 23 27.39	1.00018124		
LINZ 11033S001	48 18 35.20681N	014 16 59.00457E	5359080.252	446840.378	33	-0 32 7.41	0.99963472		
M0SE 12772M001	41 53 35.19942N	012 29 35.71642E	4640947.266	292042.938	33	-1 40 28.06	1.00013218		
MATE 12734M008	40 38 56.86567N	016 42 16.03966E	4501204.826	644108.043	33	1 6 37.86	0.99985562		
MOPS 12791M001	44 37 45.66317N	010 56 57.08466E	4943625.279	654613.668	32	1 22 10.60	0.99989398		
NOT1 12717M004	36 52 33.03158N	014 59 23.21972E	4081099.325	499089.478	33	-0 0 22.07	0.99960001		
PADO 12750S001	45 24 40.14376N	011 53 45.80920E	5032706.146	726614.078	32	2 3 48.02	1.00023145		
PRAT 12760M001	43 53 8.01611N	011 05 56.84377E	4861304.106	668620.015	32	1 27 19.79	0.99994972		
ROVE 12774M001	45 53 36.60964N	011 02 31.55224E	5084242.683	658426.453	32	1 27 59.86	0.99990856		
SBG2 11031M002	47 48 12.30519N	013 06 37.53357E	5296180.068	358514.098	33	-1 24 0.40	0.99984599		
TORI 12724M002	45 3 48.11332N	007 39 40.59956E	4990861.161	394604.569	32	-0 56 51.91	0.99973659		
UNPG 12752M001	43 7 9.79991N	012 21 20.51732E	4777467.171	284880.043	33	-1 48 29.25	1.00016931		
UNTR 12785M001	42 33 31.23544N	012 40 25.62525E	4714431.101	309038.147	33	-1 34 25.67	1.00004868		
VEN1 19513M001	45 25 50.04318N	012 21 14.66616E	5034188.554	293029.349	33	-1 53 8.25	1.00012671		
WTZR 14201M010	49 8 39.10476N	012 52 44.06098E	5445651.680	345311.226	33	-1 36 16.64	0.99989395		
ZIMM 14001M004	46 52 37.54129N	007 27 54.98323E	5192649.567	383055.111	32	-1 7 13.10	0.99976809		
ZOUF 12763M001	46 33 25.98367N	012 58 24.77266E	5157956.019	344671.416	33	-1 28 17.84	0.99989657		
ACCA ACCA	41 9 30.93312N	015 19 52.21527E	4556415.429	527785.134	33	0 13 4.66	0.99969950		
ACCE ACCE	44 28 34.24758N	006 59 17.54254E	4926731.718	340001.169	32	-1 24 35.23	0.99991483		
ACOM 12767M001	46 32 52.55466N	013 30 53.62219E	5156000.700	386145.942	33	-1 4 41.62	0.99975933		
AFAL 12766M001	46 31 37.70613N	012 10 28.24235E	5156498.093	283307.435	33	-2 3 4.51	1.00017721		
AGNE AGNE	45 28 4.57813N	007 08 22.61545E	5036617.922	354572.015	32	-1 19 35.12	0.99986003		
ALRA 00000M000	41 44 2.12539N	014 02 3.76112E	4620685.241	419696.770	33	-0 38 34.16	0.99967935		
AMUR 00000M000	40 54 26.13144N	016 36 14.52426E	4529700.464	635093.220	33	1 3 1.94	0.99982463		

Texto plano Ancho de la tabulación: 8 Ln 11, Col 1 INS

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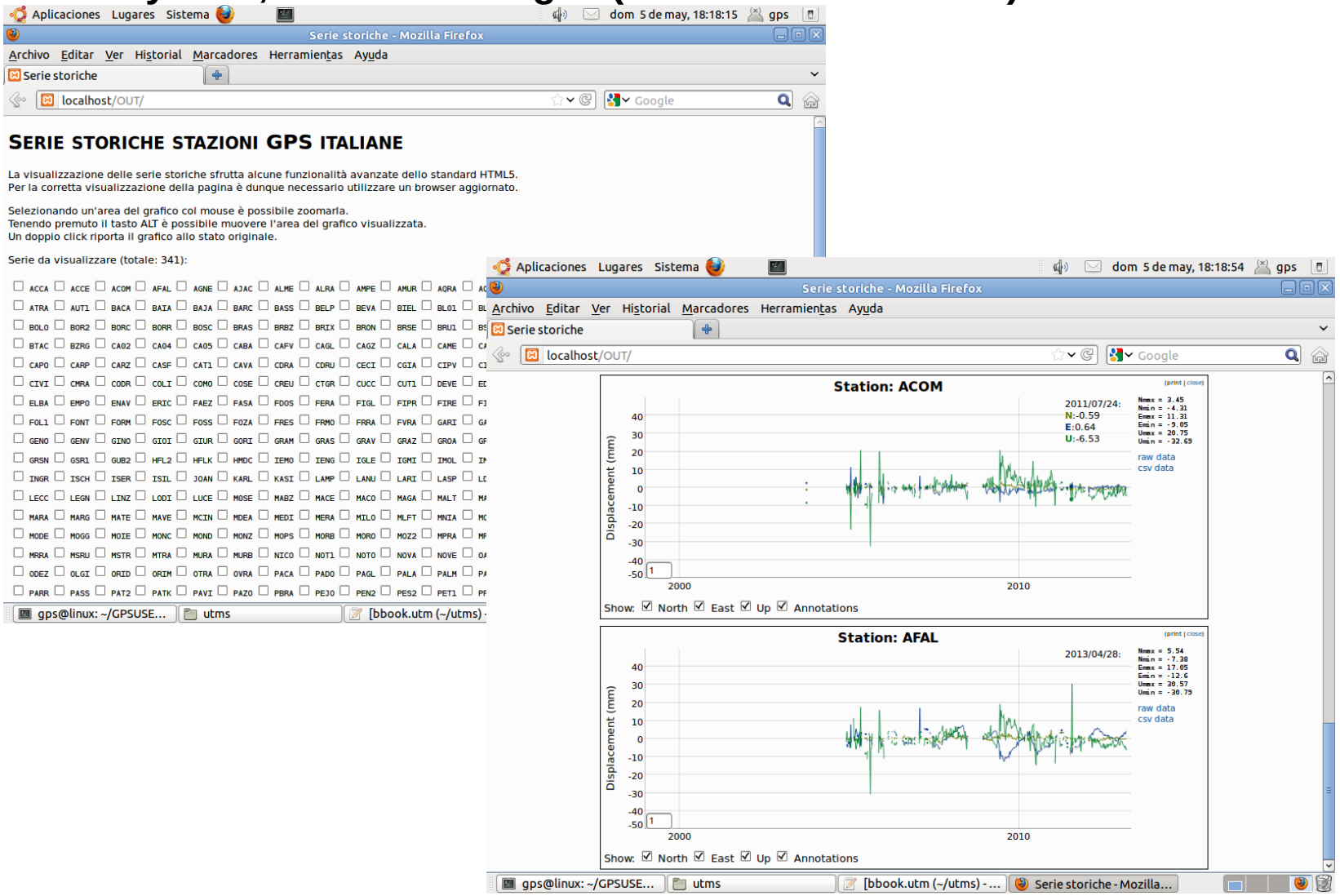
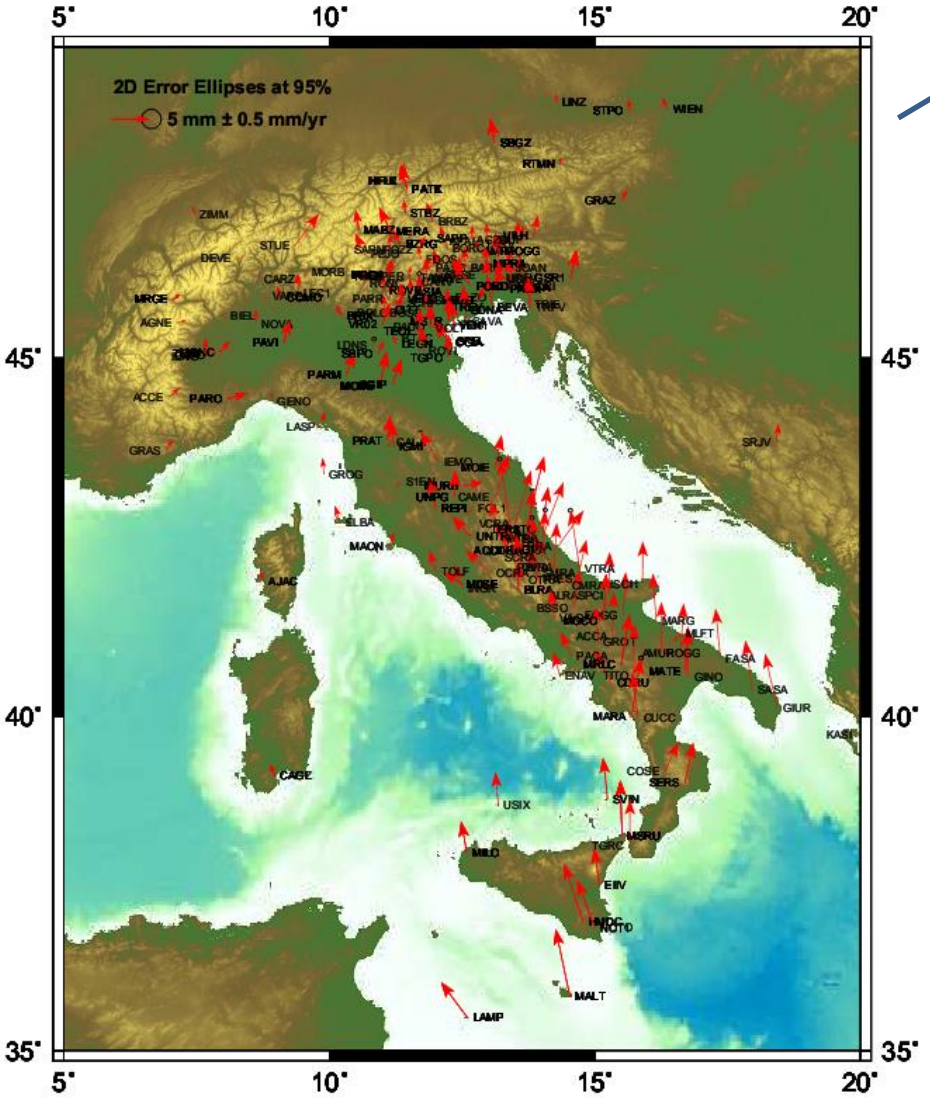
Visualize interactively time series to understand jumps, deletion of noisy data, antenna changes (linked to the STA file)



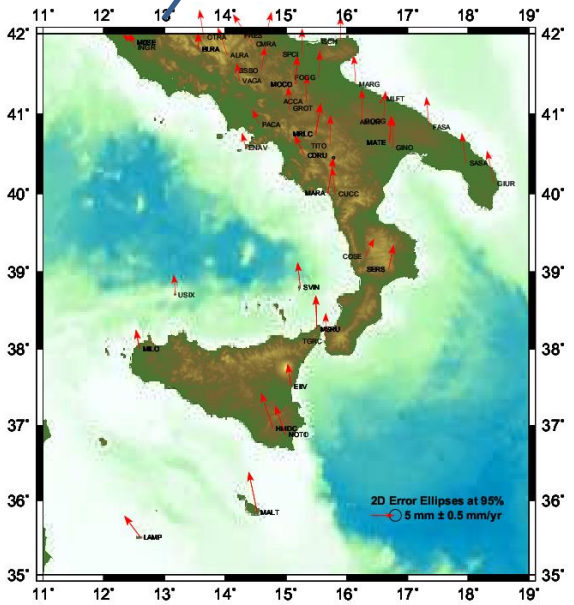
ETRS89 Densification: updated horizontal velocities, in support of the EPN WG on Geokinematic modeling (M. Lidberg chair)



Summary map

Velocities are estimated only for stations with >3 years activity, otherwise are constrained to ETRF2000 predictions

Detailed map (example)



BSW 5.2 installation:

- Linux machine (ubuntu 10.10), with cpp 4.4.5 and gfortran 4.4
- Installation scripts: straightforward (same for QT4).
- Only one problem, sorted out by following the advised setting in D_PHAECC.F90 (SR search_off, lines 1772 and 1966):

```
                    isys  = INT(prn/100)
                    isPrn = (prn/=isys*100)
  ! Values for satellite antennas are buffered in isys=0
      IF (antnam(1:3) == 'MW ' .OR. antnam(1:5) == 'SLR
                        R') isys = 0
    ! Take always GPS offsets for receiver antennas
       isys = 0 ! decomment this line if necessary
```

- Running the examples: without problems
- Additional tasks (addressed in the V50_TO_V52.TXT file):
  - ✓ Import the previous INP files
  - ✓ Modify some of the variables

BSW 5.0 vs BSW 5.2:

- Data for GW1725 to GW1731 have been processed using both packages.
- Options and input data have been “the same” in both processings.
- Some files cannot be the same due to the updates in BSW52 (Satellite info file and constant and datum files)
- To check the quality, a Helmert 3D was computed for each weekly solution:

Week	TX (mm)	TY (mm)	TZ (mm)	RX ('')	RY ('')	RZ ('')	PPM
1725	7.94	5.48	3.77	-0.000122	0.000091	0.000063	-0.00143
1726	7.2	1.34	7.12	0.000001	0.000001	-0.000017	-0.00161
1727	8.67	7.04	4.58	-0.000155	0.000088	0.000097	-0.00164
1728	7.65	4.06	5.26	-0.000072	0.000053	0.000042	-0.00152
1729	6.04	8	3.73	-0.000167	0.000053	0.000146	-0.00129
1730	7.04	5.56	3.68	-0.000103	0.000077	0.000091	-0.00132
1731	5.41	5.19	4.88	-0.000088	0.000014	0.000092	-0.00127

- Biases in the 7 parameters (rotations, very small)

BSW 5.0 vs BSW 5.2: weekly NEQ-ing. CHI2 and statistics…

BSW52: Wk1725

Total number of authentic observations	1060166
Total number of pseudo-observations	3
Total number of explicit parameters	126
Total number of implicit parameters	15381
Total number of observations	1060169
Total number of adjusted parameters	15507
Degree of freedom (DOF)	1044662
A posteriori RMS of unit weight	0.00124 m
Chi**2/DOF	1.53
Total number of observation files	286
Total number of stations	42
Total number of satellites	0

BSW50: Wk1725

Total number of authentic observations	1060166
Total number of pseudo-observations	3
Total number of explicit parameters	126
Total number of implicit parameters	12734
Total number of adjusted parameters	12860
Total number of observations	1065959
Degree of freedom (DOF)	1053099
A posteriori RMS of unit weight	0.00125 m
Chi**2/DOF	1.57
Total number of observation files	286
Total number of stations	42
Total number of satellites	0

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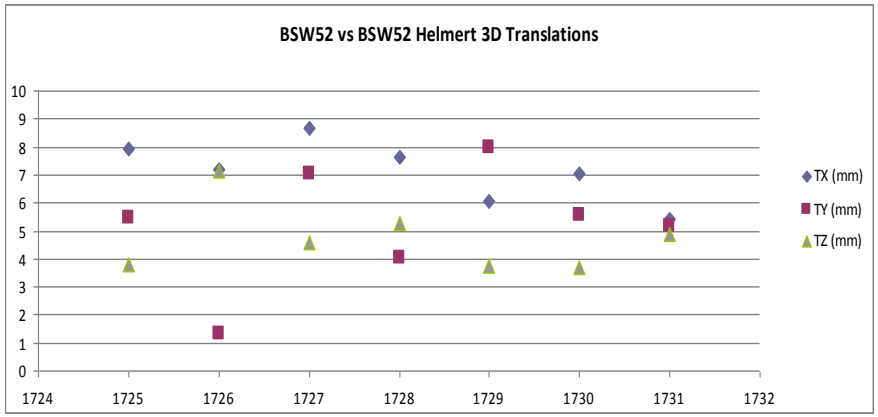
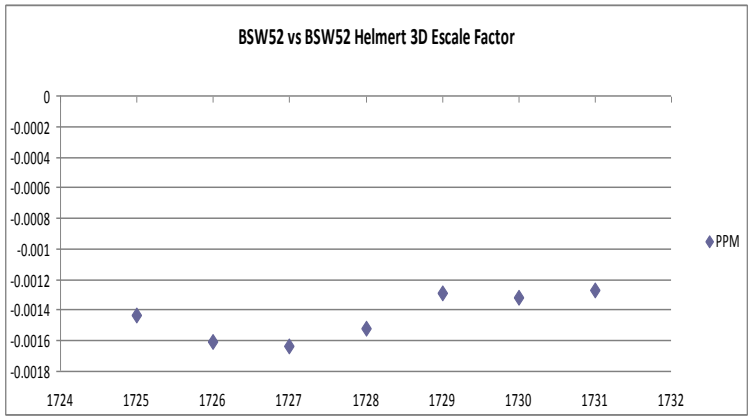
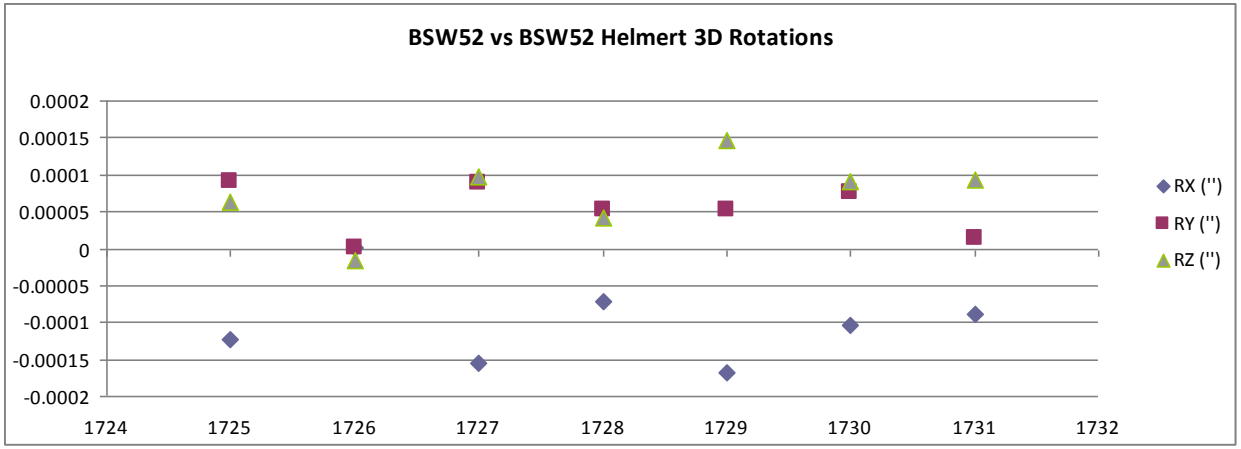
BSW 5.0 vs BSW 5.2: weekly solutions.

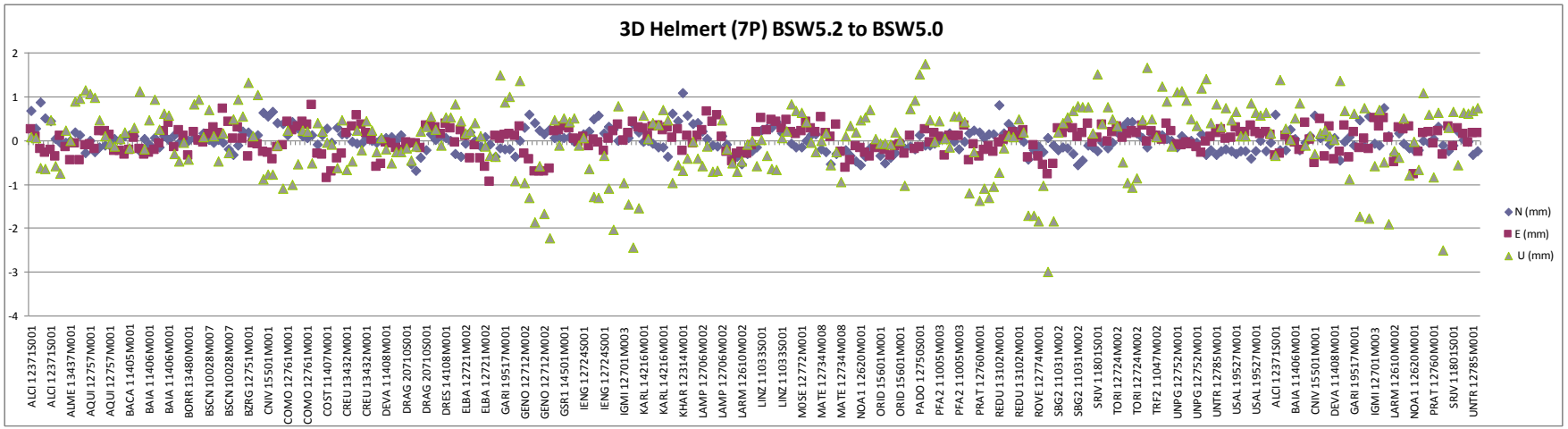






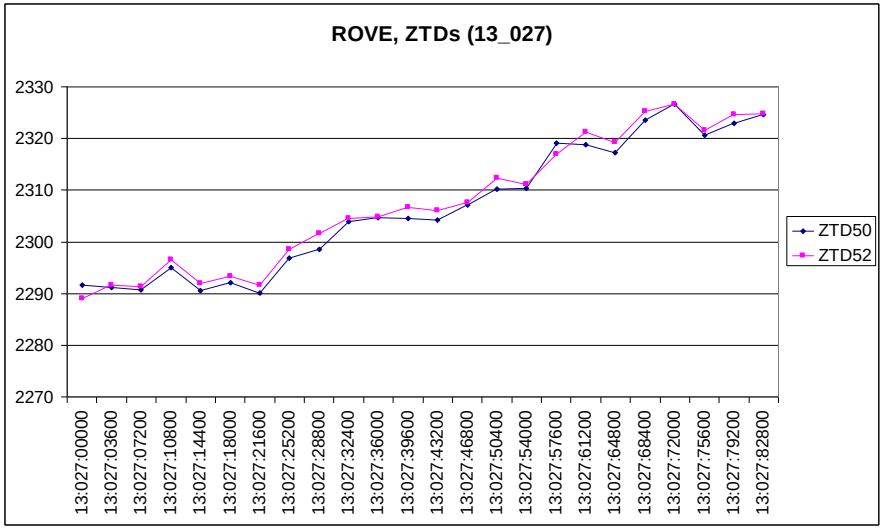
BSW 5.0 vs BSW 5.2: station by station solutions

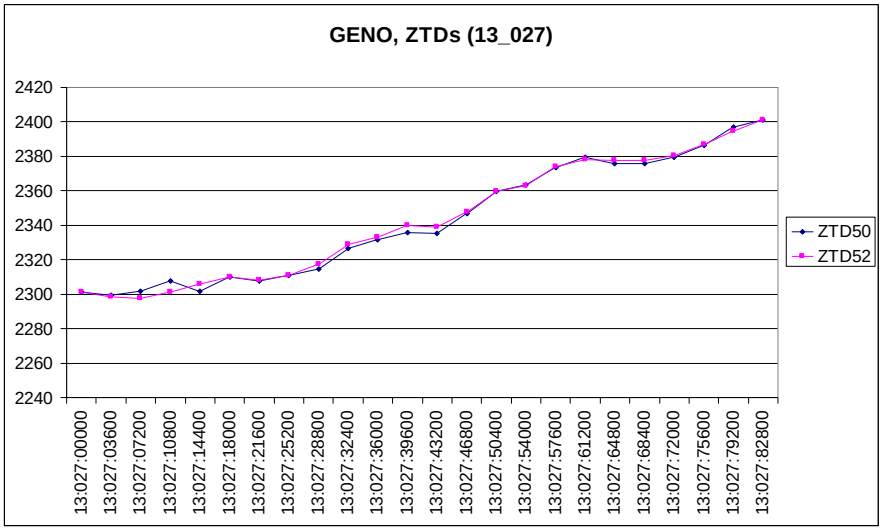
	N	E	U
min. (mm)	-0.68	-0.95	-2.99
Max. (mm)	1.09	0.8	1.74
rms (mm)	0.2674	0.3029	0.7823
Mean (mm)	0.0080	0.0039	0.0027

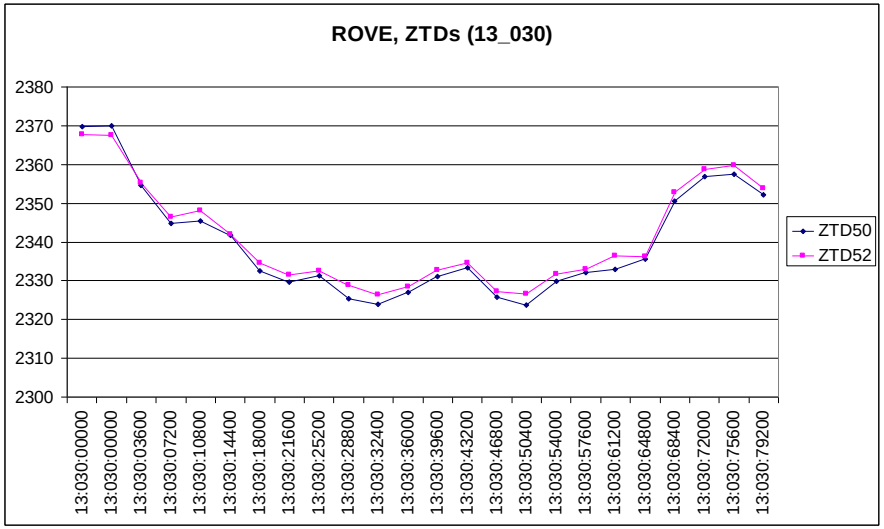


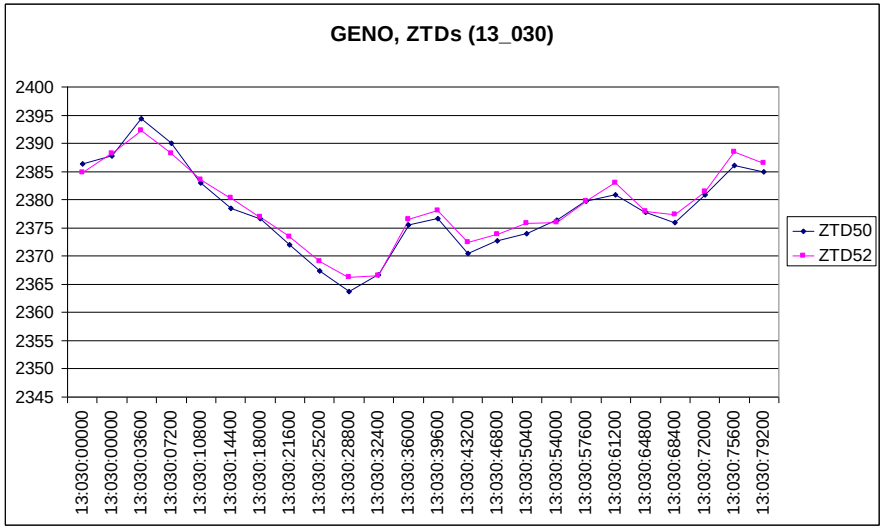
- Similar differences occur in same stations
- No biases detected in differences (means of differences below 0.01 mm!)

BSW 5.0 vs BSW 5.2: small biases (round 2 mm) in ZTDs.









Perspectives

The activities carried out lead to some proposal on how the **UPA LAC can provide an additional contribution to the EPN**, besides the weekly computation of the assigned sub network.

For example, the following activities could be foreseen, on account of the ongoing EPN work on ETRS89 maintenance and monitoring, and on the densification of the velocity field in Europe:

- **Combination of the EPN long term solution with national network** solutions
- **Rigorous spectral analysis** of time series of each station, and cross correlation of time series of different stations as a function of their relative distance, to detect common mode systematics, in the NEU directions
- **Rigorous computation of the uncertainty in the station velocities** taking into account the noise profile and non white noise component of the time series
- **Computation of the spatial gradient of the velocity**, to highlight the local deformation in the coordinate grid (and hence departures from nominal coordinates).

Thank you for your attention