The EUREF Analysis Centres Workshop
October 16-17, 2019, Warsaw, Poland

The EUREF Analysis Centres Workshop

Different methodologies in EPN Densification

J. Zurutuza

ARA OC and DAC
UPA OC, DAC and LAC

Introduction:

- The EPN Densification Project consists of a very dense net of permanent GNSS stations that span throughout all Europe.
- The combined solution is computed regularly and it is based on the combination of the different SINEX files that a number of European Institutions (NMAs, Universities, Institutes,…) provide.
- This combination will be referred to as **week-wise**.

However, a different strategy, we will call **AC-wise**, has been tested:

- There is a lack of tests on the combination of multiyear dense regional networks that span for several years, so this case study goes in depth in this sort of (P+V) combinations applied to the EPN D.
- The results of both approaches should be the same, at the sigma level.
- I will show the results we get from this TWO different approaches:
  - **Week-wise** stacking: after the stacking of the weekly files each AC provides, we stack these combined (only P) weekly normal equations.
  - **AC-wise** stacking: stack all the SINEX files for each AC and then combine all these multiyear solutions (P+V).

The week-wise combination has some

PROS:

- The NEQ files are stacked and the weekly combination of all the contributions provides the QC of the individual solutions site by site, AC by AC.
- If no logsheet is available, we can compare the equipment in the SINEX files of the different providers. This will help to remove stations with inconsistent antennas/eccentricities.
- We have full control of all the residuals, threshold values,… We can decide when a discontinuity should be introduced.
- Eventually, the alignment of the reference stations (P+V) to the published values will give the final assessment of the quality of the results (e.g. Helmert transformation).

CONS:

- If reprocessed or new solutions are received, we must start from scratch the whole analysis.
- Very slow procedure: not just the final combination, but the definition of the discontinuities, outlier detection,…
- What if any trustworthy agency provides a multiyear SINEX file (P+V), instead of daily/weekly (only P) solutions?

Available data and editing criteria

We will use 7 different SINEX files that are combined together with the EPN weekly solutions (as foreseen in the Densification Guidelines). This makes 8 NEQs (P+V) to be combined.

All the provided SINEX files are comparable since they were created using standard Guidelines (EUREF or EPOS).

Metadata is rigorously checked with logsheets, when available: **inconsistent antennas are dismissed; or eccentricities, if different, are corrected.**

Week-wise:

- We use the available SINEX files (weekly/daily). Residual exclusion criteria: 10 mm/20 mm, iteratively.
- Combine them in a weekly solution (if daily).
- Stack the weekly files to get the multiyear solution.
- Different antennas/ecc. discarded.

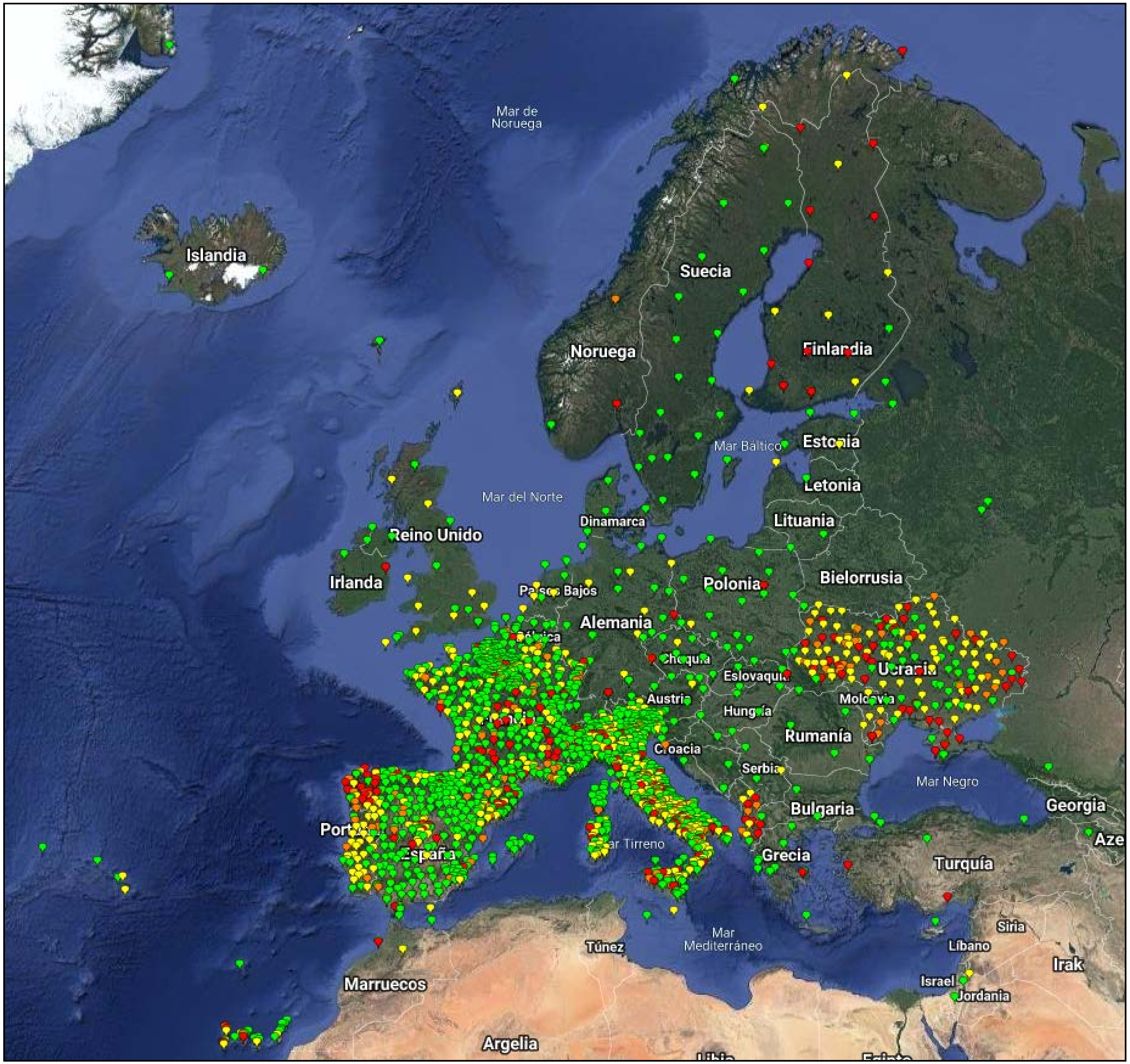
AC-wise:

- SAME SINEX files.
- We combine all the SINEX files from each AC. This we call AC-wise solution: 1 multiyear SINEX file for each AC.
- We combine all the AC-wise SINEX files.
- Residual exclusion criteria: 15 mm/30 mm.

Because the analysis extends until GPSW 2060, I have used my own discontinuity file, created using the C2055 discontinuity/CRD/VEL files (EPN stations) and after the visual inspection of all the time series.

TBD: IGb08-IGS14 position corrections (switch from igs08.atx to igs14.atx).

Test Network (velocities estimated only if they span +3 years):

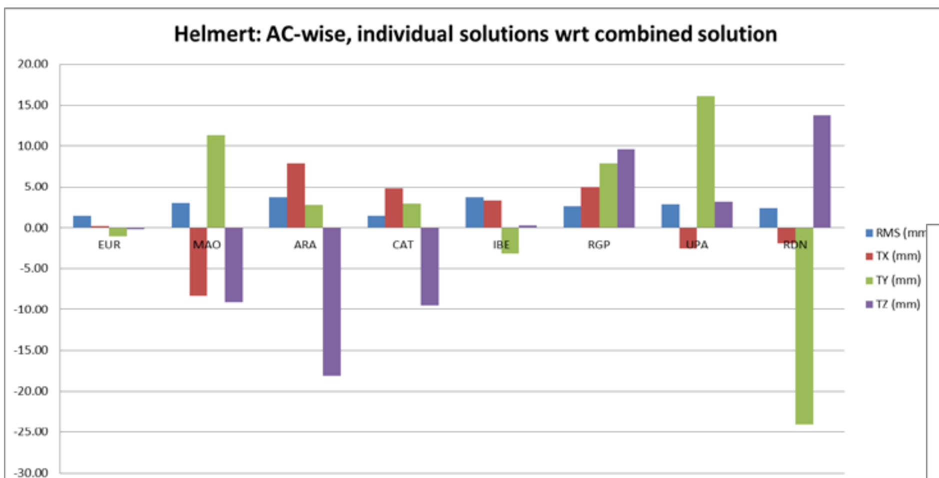


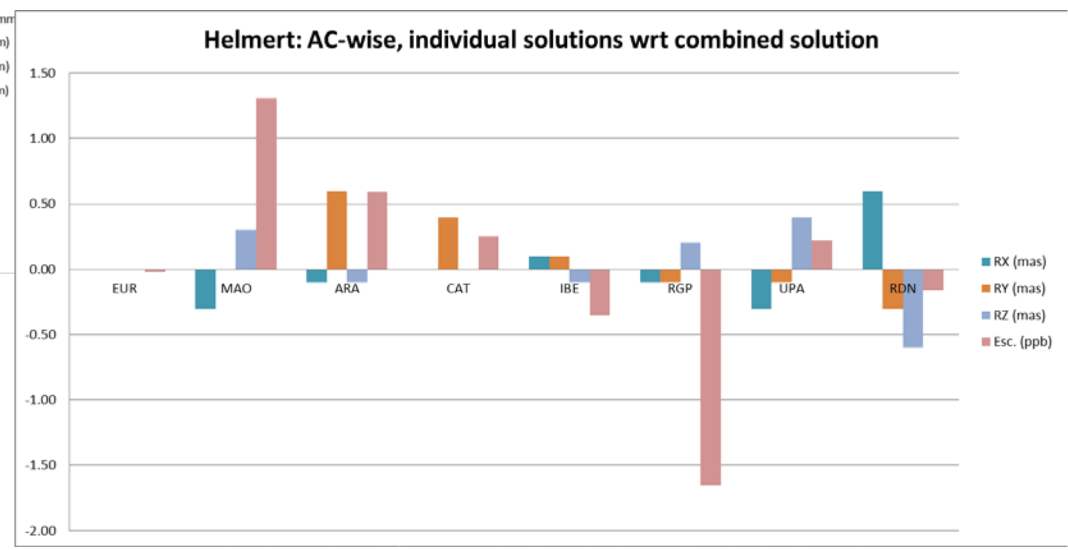
< 1 year | between 1 and 2 years | between 2 and 4 years | > 4 years

Test Network: AC-wise, Helmert parameters (combined vs individual solutions).

	RMS (m)	TX (m)	TY (m)	TZ (m)	RX ('')	RY ('')	RZ ('')	Esc. (ppm)
EUR	0.00144	0.0002	-0.001	-0.0002	0	0	0	-0.00002
MAO	0.00304	-0.0083	0.0113	-0.0091	-0.0003	0	0.0003	0.00131
ARA	0.00374	0.0079	0.0028	-0.0181	-0.0001	0.0006	-0.0001	0.00059
CAT	0.00145	0.0048	0.0029	-0.0095	0	0.0004	0	0.00025
IBE	0.00373	0.0033	-0.0032	0.0003	0.0001	0.0001	-0.0001	-0.00035
RGP	0.00266	0.005	0.0079	0.0096	-0.0001	-0.0001	0.0002	-0.00165
UPA	0.00282	-0.0026	0.0161	0.0032	-0.0003	-0.0001	0.0004	0.00022
RDN	0.00236	-0.0019	-0.024	0.0138	0.0006	-0.0003	-0.0006	-0.00016

EUR: all parameters very close to 0. This shows the agreement of the combined solution with EPN.





Test Network: Positions and velocities (Weekly vs AC-wise, A class)

The direct comparison of all the **A CLASS** coordinates, release C2055 (differences at epoch 2010.0) gives the following results:

```
Class A DIFFERENCES IN LOCAL SYSTEM (NORTH, EAST, UP), AT EPOCH 2010.0
---------------------------------------------------------------------
                              COORDINATE DIFFERENCES IN MILLIMETERS
---------------------------------------------------------------------
|     | RMS / COMPONENT  |     |         0.02      0.02      0.09 |   |
|     | MEAN             |     |        -0.00     -0.00      0.00 |   |
|     | MIN              |     |        -0.23     -0.24     -0.56 |   |
|     | MAX              |     |         0.16      0.16      0.94 |   |
---------------------------------------------------------------------
```

For the coordinates, the maximum differences in absolute value are below 0.25 mm (N, E) and 1 mm (Up)

	Velocity differences [mm/y]					
	X	Y	Z	Latitude	Longitude	Height
Min.	-0.05	-0.04	-0.08	-0.06	-0.03	-0.10
Max.	0.20	0.04	0.20	0.03	0.09	0.28
Mean	0.00	0.00	0.00	0.00	0.00	0.00
STD.	0.01	0.00	0.01	0.01	0.01	0.02

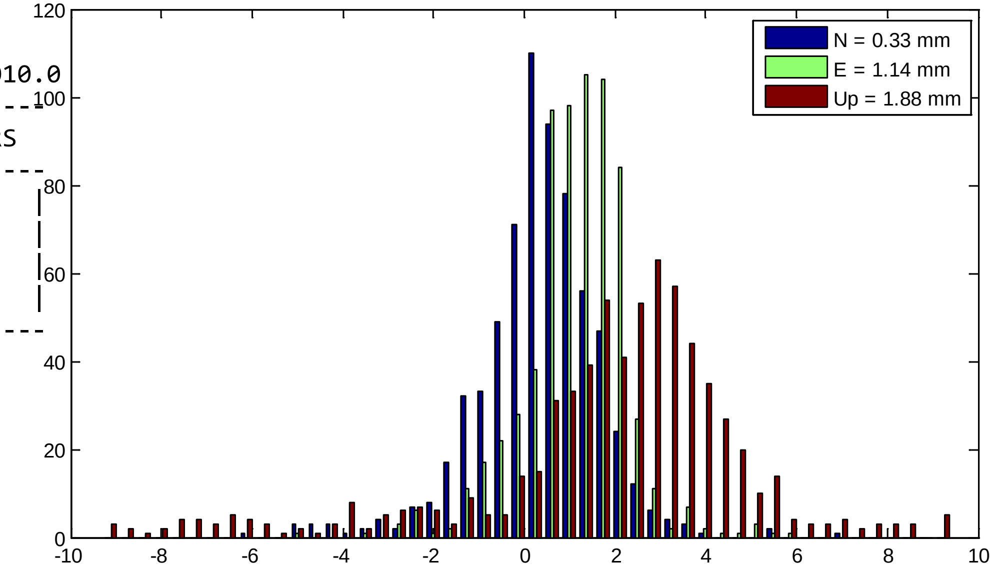
Respect the velocities, the differences are below 0.10 mm/year for the N and E velocities and below 0.30 mm/year for the Up component.

Test Network: (AC-wise vs C2055 published values)

The direct comparison of all the **A CLASS** coordinates, release C2055 (differences at epoch 2010.0) gives the following results:

Class A DIFFERENCES IN LOCAL SYSTEM (NORTH, EAST, UP), AT EPOCH 2010.0

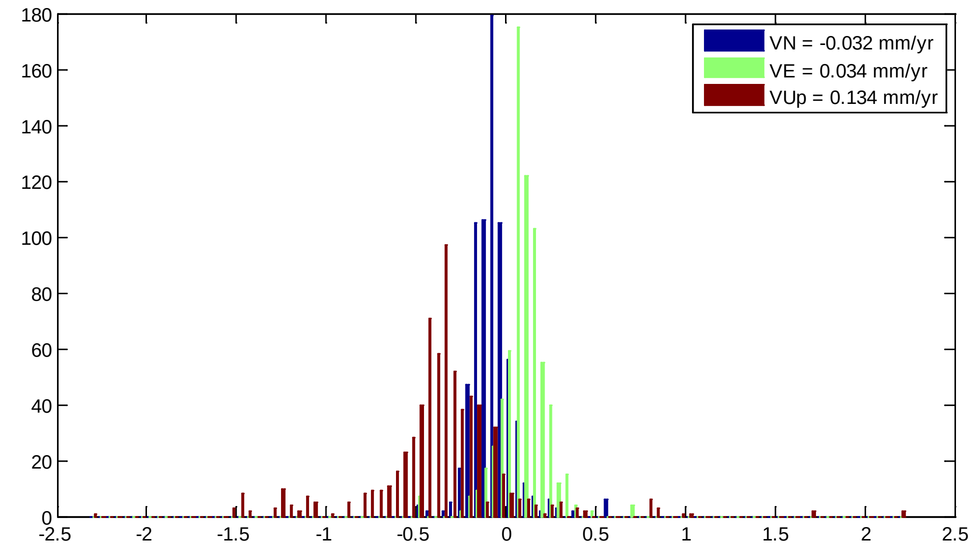
	COORDINATE DIFFERENCES IN MILLIMETERS		
RMS / COMPONENT	1.40	1.61	3.56
MEAN	0.33	1.14	1.88
MIN	-6.24	-5.10	-9.31
MAX	7.17	5.86	9.42



Sites with differences > **10 mm (any component)** have been excluded: 26 rejected out of 674 (3.86%). This implies the AC-wise agrees with the C2055 release better then than 10 mm in any component at least at the 95% confident level (actually at the 96.14%).

Velocity differences [mm/y]

	X	Y	Z	Latitude	Longitude	Height
Min.	-1.50	-0.50	-1.79	-0.47	-0.49	-2.32
Max.	1.68	0.55	1.47	0.56	0.71	2.23
Mean	-0.22	0.07	-0.31	-0.07	0.10	-0.36
RMS	0.28	0.12	0.30	0.12	0.13	0.39

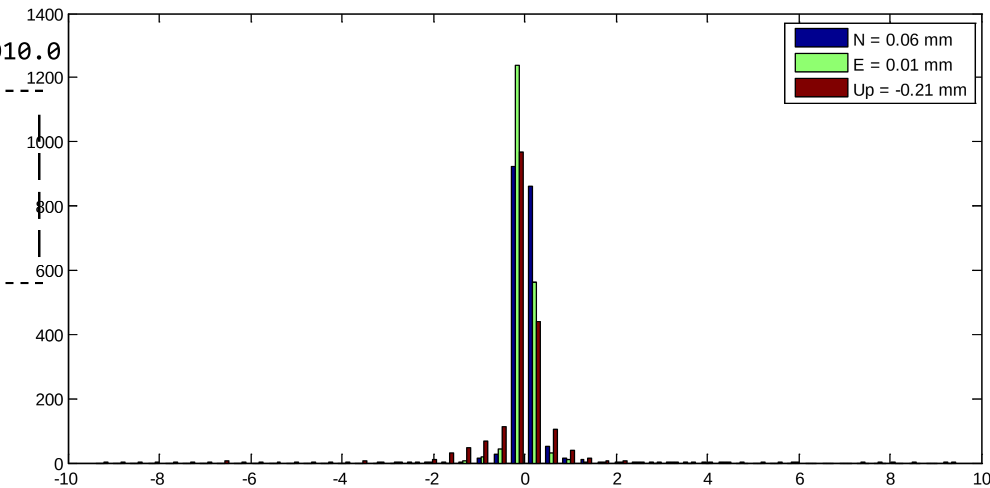


Respect the velocities, the differences are below 0.10 mm/year for the N and E velocities and below 0.40 mm/year for the Up component.

Test Network: Positions and velocities (Weekly vs AC-wise)

The direct comparison of all the coordinates, (differences at epoch 2010.0) gives the following results:

```
Class A DIFFERENCES IN LOCAL SYSTEM (NORTH, EAST, UP), AT EPOCH 2010.0
---------------------------------------------------------------------
|     | RMS / COMPONENT  |     |      0.40      0.40      1.07 |    |
|     | MEAN             |     |      0.05      0.01     -0.16 |    |
|     | MIN              |     |     -2.54     -3.14     -9.44 |    |
|     | MAX              |     |      9.49      8.37      9.22 |    |
---------------------------------------------------------------------
NUMBER OF PARAMETERS  :     0
NUMBER OF COORDINATES :  7884
RMS OF TRANSFORMATION :    0.70 MM
 ACCEPTED STATIONS     :  2628 REJECTED STATIONS     :    31
```



31 out of 2628 (SN included) exceed 10 mm in any component. This implies that the 98.82% of the differences are abs(10 mm).

Respect the velocities, almost all the AC-wise vs Week-wise are below 0.5 mm/year. However, we find some large differences due to the differences in the solutions submitted by the different ACs. These deserve to be individually analyzed.

The differences between AC-wise and week-wise are (all NEU components, 1 vel/site):

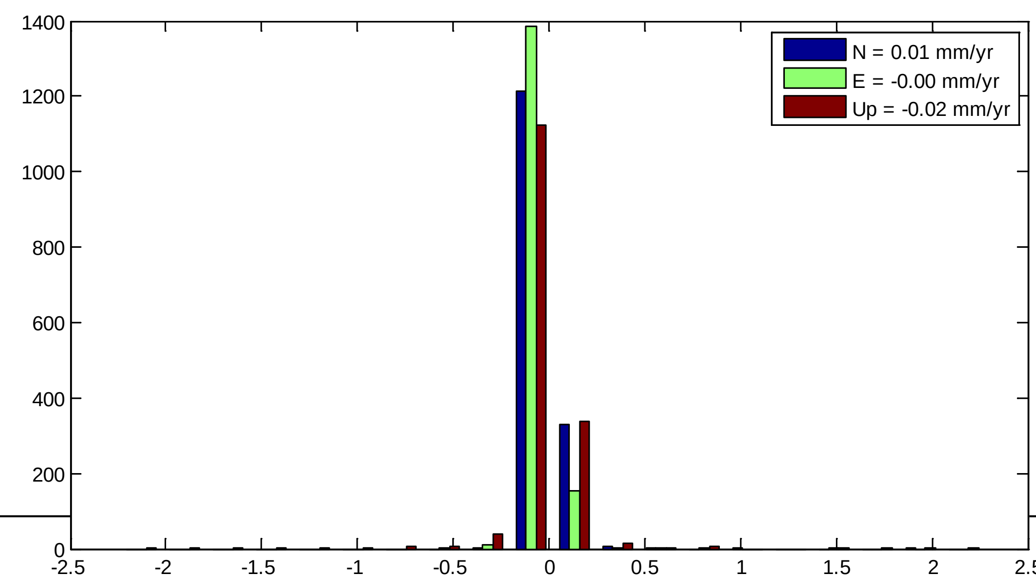
<=-0.25 mm/yr : 49/1557 (3.15%)

-0.25<=DIF<=0.25 mm/yr : 1479/1557 (94.99%)

>=0.25 mm/yr : 29/1557 (1.86%)

The 95% of the differences are less than abs(0.25 mm/yr)

	Velocity differences [mm/y]		
	Latitude	Longitude	Height
Min.	-0.37	-0.44	-2.24
Max.	1.84	1.57	2.28
Mean	0.01	0.00	-0.02
RMS	0.07	0.07	0.23



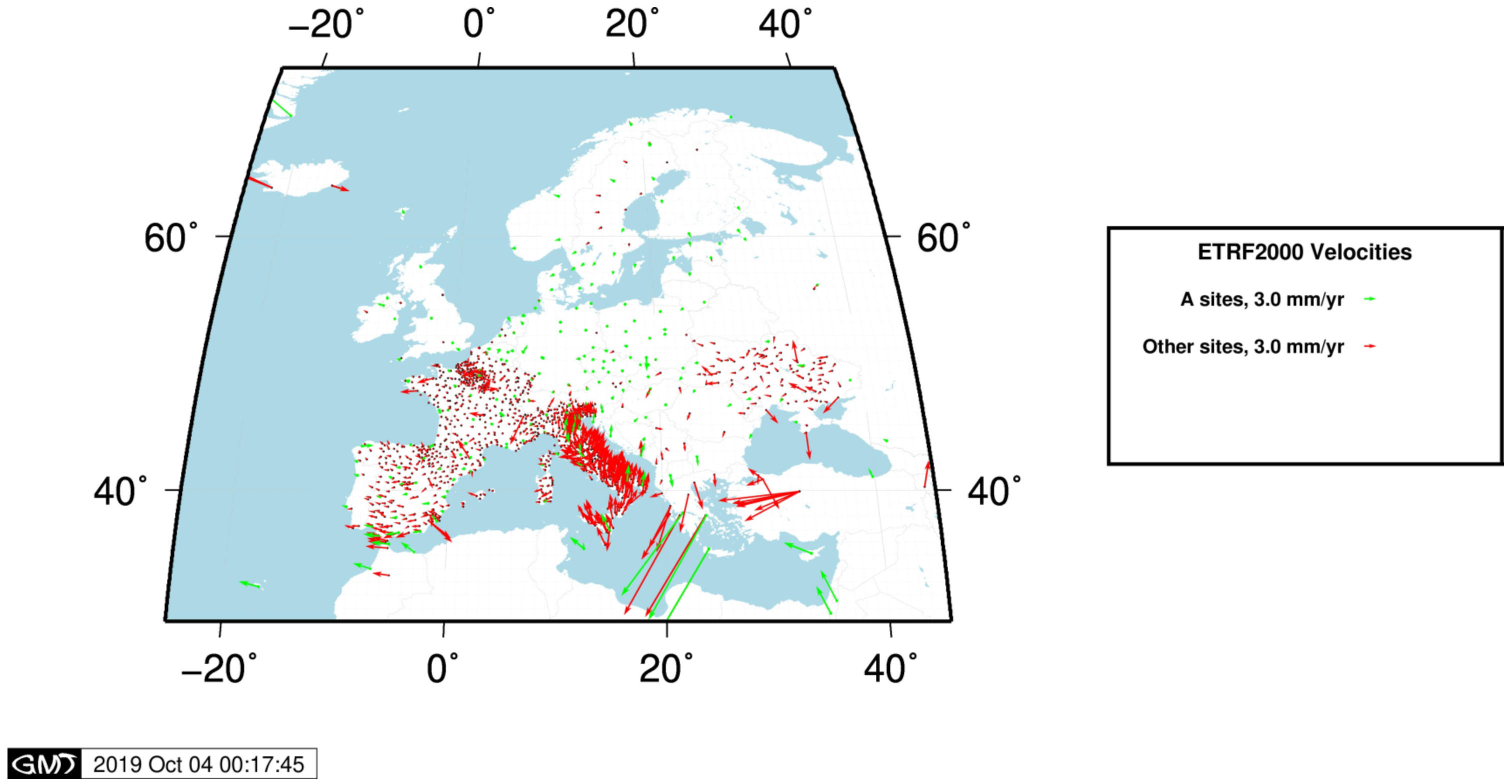
Test Network: EXTERNAL VALIDATION (http://pnac.swisstopo.admin.ch/divers/dens_vel/)

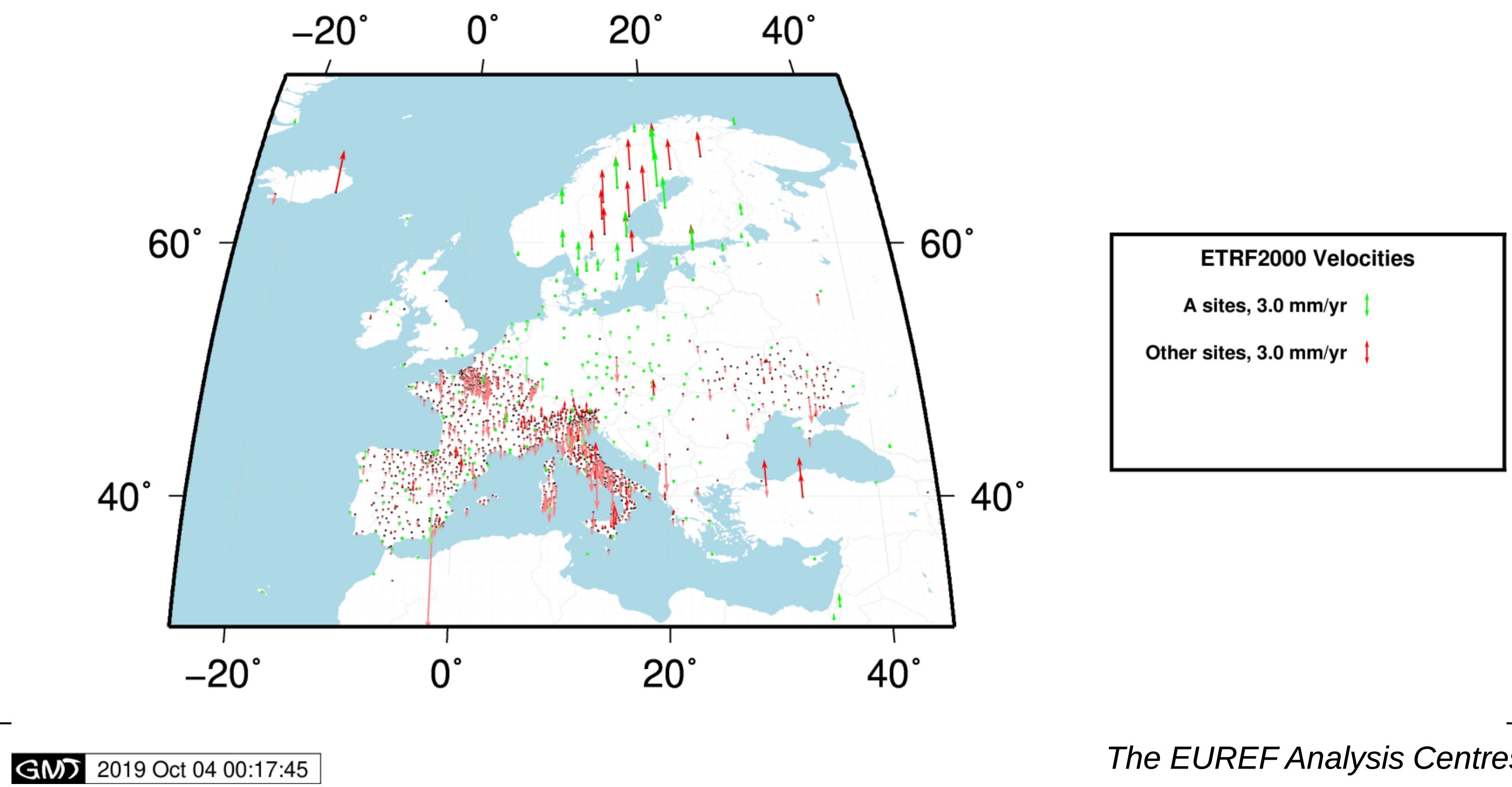
In order to verify the AC-wise results, we now show the differences we get wrt other EPN Densification solutions.

Cross validations in mm/y

(Sortable table)

SOL1	SOL2	NUM ▲	MEAN_N	SDEV_N	MEAN_E	SDEV_E	MEAN_U	SDEV_U
epndmy	epndmy	1539	0.00	0.00	0.00	0.00	0.00	0.00
epndmy	epnd14	1013	0.14	0.34	-0.04	0.31	0.30	0.80
epndmy	cgn14	743	-0.02	0.30	0.01	0.32	-0.16	0.79
epndmy	gsrm14	663	0.09	0.46	-0.16	0.49	0.00	0.00
epndmy	it08	449	0.20	0.66	-0.05	0.47	-0.44	1.13
epndmy	rgp08	324	0.33	0.33	-0.17	0.42	0.36	0.97
epndmy	basc08	249	0.13	0.35	-0.19	0.37	0.53	0.68
epndmy	esp08	242	0.41	0.46	0.09	0.40	-0.19	0.96
epndmy	epn14	231	0.06	0.14	-0.09	0.14	0.36	0.45
epndmy	alp08	228	-0.05	0.38	-0.34	0.44	-0.16	0.92
epndmy	walp08	142	-0.09	0.32	-0.40	0.40	-0.11	0.81
epndmy	cat08	142	0.09	0.16	-0.07	0.15	0.36	0.57
epndmy	ch08	131	-0.01	0.18	-0.03	0.20	0.12	0.61
epndmy	ch16	129	0.05	0.18	-0.17	0.20	0.16	0.61
epndmy	alps17	108	0.15	0.27	-0.01	0.34	0.15	0.71
epndmy	itrf14	92	0.11	0.24	-0.04	0.41	0.49	0.48
epndmy	igs08	76	-0.00	0.25	0.00	0.36	0.24	0.66
epndmy	gut14x	55	0.08	0.14	-0.05	0.15	0.47	0.43
epndmy	noqu08	44	0.00	0.24	-0.22	0.29	-0.40	0.63
epndmy	nkg03	37	-0.24	0.38	-0.14	0.16	-0.41	0.38
epndmy	gr08	28	-0.39	0.87	-0.62	0.67	-0.34	0.89
epndmy	gurn08	23	-0.05	0.31	-0.29	0.30	0.00	0.00
epndmy	gref08	19	-0.02	0.27	-0.19	0.22	-0.37	0.61
epndmy	gurn08d	17	0.10	0.23	-0.12	0.36	-0.96	0.81
epndmy	ch08l	10	0.00	0.00	0.00	0.00	-0.51	0.58
epndmy	turk14	5	0.26	0.30	-0.07	0.37	-0.45	0.23
epndmy	cgn08	2	-0.04	0.06	0.17	0.44	0.15	0.57
epndmy	svn14	0	nan	nan	nan	nan	nan	nan
epndmy	hepos	0	nan	nan	nan	nan	nan	nan
MEAN			0.05	0.30	-0.12	0.32	-0.03	0.63
SDEV			0.16	0.18	0.16	0.14	0.38	0.27


-20°
0°
20°
40°
60°
40°
ETRF2000 Velocities
A sites, 3.0 mm/yr
Other sites, 3.0 mm/yr
2019 Oct 04 00:17:45


-20°
0°
20°
40°
60°
40°
ETRF2000 Velocities
A sites, 3.0 mm/yr
Other sites, 3.0 mm/yr
2019 Oct 04 00:17:45

Conclusions:

- The results show that it is possible to use the AC-wise approach.
- The AC-wise and week-wise solutions agree at the mm-level (P) and at the 0.30 mm/year level (V) in the CLASS A stations.
- If we compare all the stations, AC-wise and week-wise, the agreement, at the 95% level of confidence, is 10 mm in any component (P) and 0.25 mm/year (V).
- AC-wise allows to use new solutions in a stragihtforward way.
- No approach (AC/week-wise) should be dismissed: they both should be computed regularly and used as an internal QC of the solutions.
- All the results, metadata validation,… are available at: http://147.162.183.197/EPNDMY/

Some remarks after this analysis:

- All Station Managers should maintain the IGS style log-sheets. This should be mandatory for all stations included (or to be included) in the analysis. **MOREOVER**, this is a requisite in the **guidelines** for the **DENSIFICATION stations**.
- All ACs should agree the discontinuities and the SN and report to the EPN.
- Repeated 4 char names should not be admitted, no matter whether the stations are in different countries.
- This eases working at the SINEX level! BSW-users use 4char (and even 2!).
- EPOS GNSS data gateway uses 4char as well: http://gnssdata-epos.oca.eu/#/metadata/marker=PASA
- WEEKLY files should always be provided, rather than daily. This way we avoid any manipulation of the original data: stacking daily files.

Thank you for your attention