Time series analysis of the French GPS Permanent Network (RGP)

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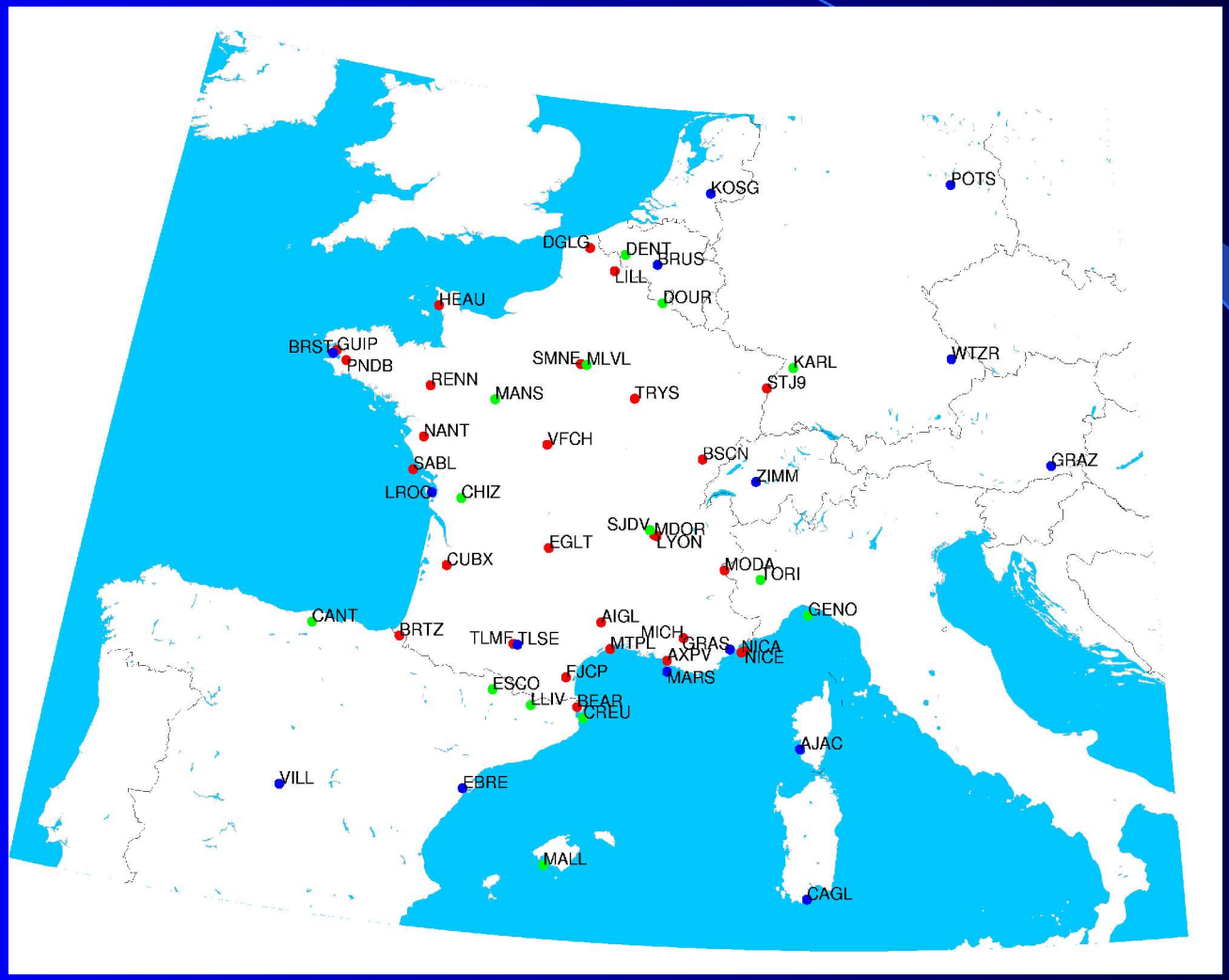
Motivations

- ETRS89 coordinates for the RGP stations
- Improving / replacing the old RGF93 solution
- RGP maintenance / monitoring
- Contribution to the EUREF Velocity Field Project

The network



57 stations including

- **14 IGS/EPN**
- **15 EPN**
- **28 RGP**

The general processing strategy

- **GPS processing : Bernese software 4.2**

  weekly **free** solutions (SINEX)

- **Combination and analysis : CATREF package including combination programs and analysis tools**

  - positions & velocities with Variance-Covariance matrix (SINEX)
  - residuals analysis
  - WRMS per week

- **Conversion to ETRS89**

The GPS Processing strategy

The processing strategy adopted was those used at the IGN LAC

Measurement models

- DE200 planetary ephemeris model
- Earth potential model : JGM3
- **Ground antenna : IGS elevation-dependent phase center models**
- Ocean loading model (H.G.Scherneck)
- Solid Earth tides applied (IERS Conventions96)
- Orbits and ERPs : IGS final products

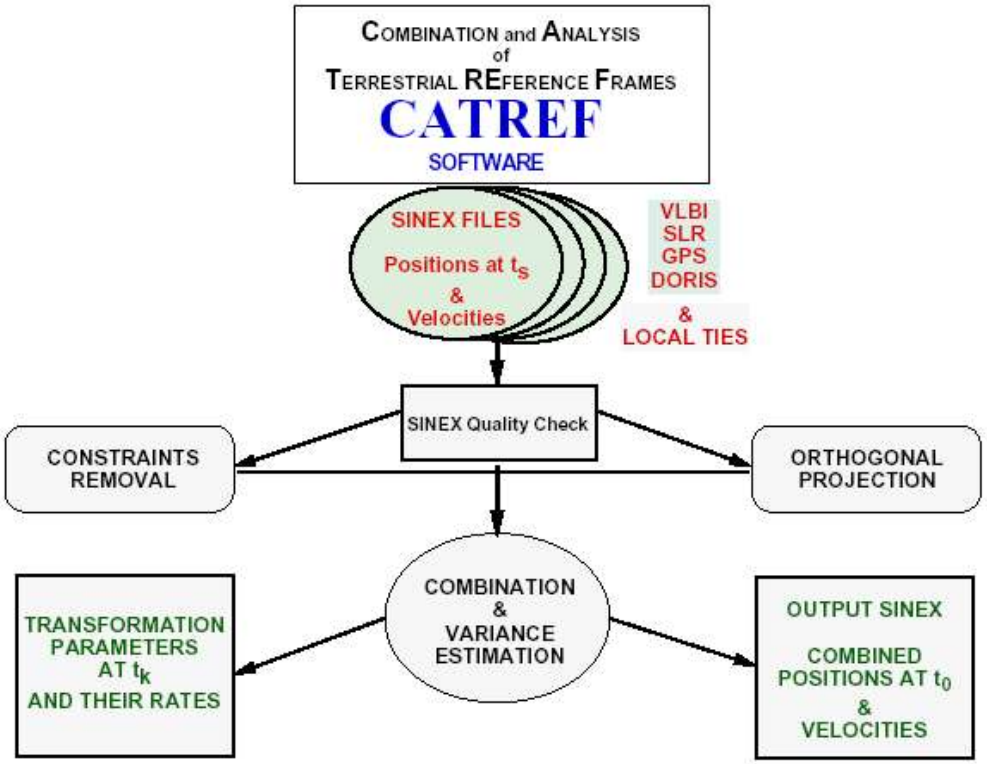
Processing parameters

- Elevation dependant weighting
- Elevation angle cutoff : 10 degrees
- Troposphere :
  - no a priori model
  - zenith delays estimated once per hour for each station
  - mapping function : Dry Niell

Estimated parameters

- Adjustment : Weighted least-squares algorithms
- Ambiguity resolution : QIF strategy. Solved ambiguities introduced to final solution
- **Free solutions (no stations constrained) : the 7 daily solutions are combined to produce a weekly solution**
- Troposphere : zenith delays estimated once per hour for each station

CATREF software



$$\begin{cases} X_s^i &= X_{itrf}^i + (t_s^i - t_0)\dot{X}_{itrf}^i + T_k + D_k X_{itrf}^i + R_k X_{itrf}^i \\ &+ (t_s^i - t_k)\left[\dot{T}_k + \dot{D}_k X_{itrf}^i + \dot{R}_k X_{itrf}^i\right] \\ \dot{X}_s^i &= \dot{X}_{itrf}^i + \dot{T}_k + \dot{D}_k X_{itrf}^i + \dot{R}_k X_{itrf}^i \end{cases}$$

The combination strategy

Datum definition

Minimun constraints over a set of selected stations of the ITRF2000 (ITRF2000_GPS.SNX)

9 stations :
BRUS / BRST / GRAS / GRAZ / KOSG / POTS / VILL / WTZR / ZIMM

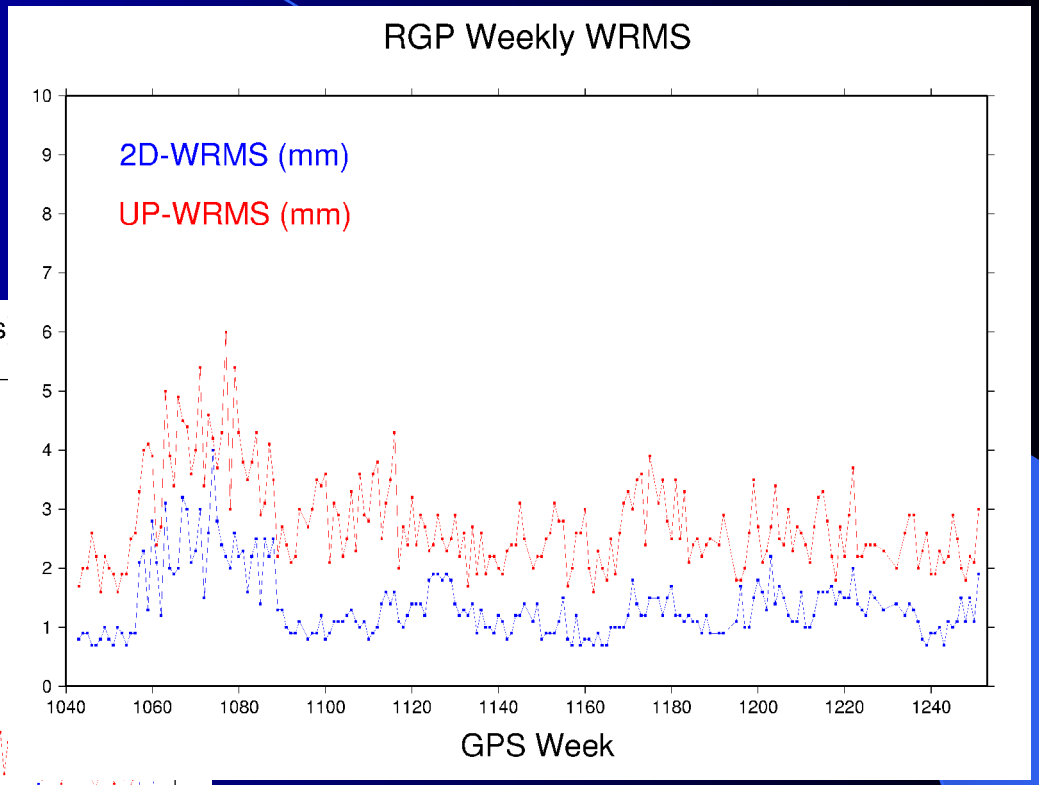
Residuals analysis

- Outliers are removed and jumps (antenna changes) are introduced and estimated

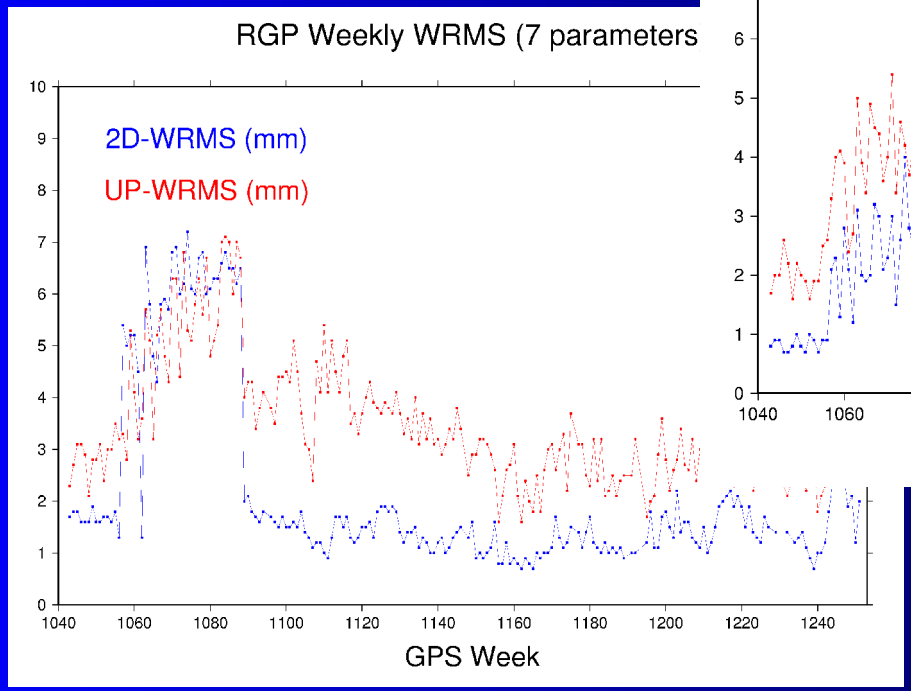
```
CAGL  A 12725M003  2  1:190:00000                 ANT
CREU  A 13432M001  2 01:075:00000 03:154:00000  REC
CREU  A 13432M001  3 03:154:00000                 ANT
DENT  A 13112M001  2  2:072:00000                 ANT
KARL  A 14216M001  2  1:135:00000                 ANT
kosg  A 13504M003  2 03:070:    0                 ANALYSIS van
MALL  A 13444M001  2 03:230:00000                 ANALYSIS
mars  A 10073M008  2  3: 87:00000                 ANT
MLVL  A 10092M001  2 00:089:00000 00:336:00000  ANT
MLVL  A 10092M001  3 00:337:00000                 ANT
PNDB  A 10082M001  2 03:162:00000                 ANT
```

- Velocities are constrainted to be the same within the same site
- For each station and each solution, residuals are computed and plotted after removing linear estimated velocity to produce ITRS time series

Residuals analysis : WRMS



With jumps



Without jumps

MARS time series residuals

Antenna change

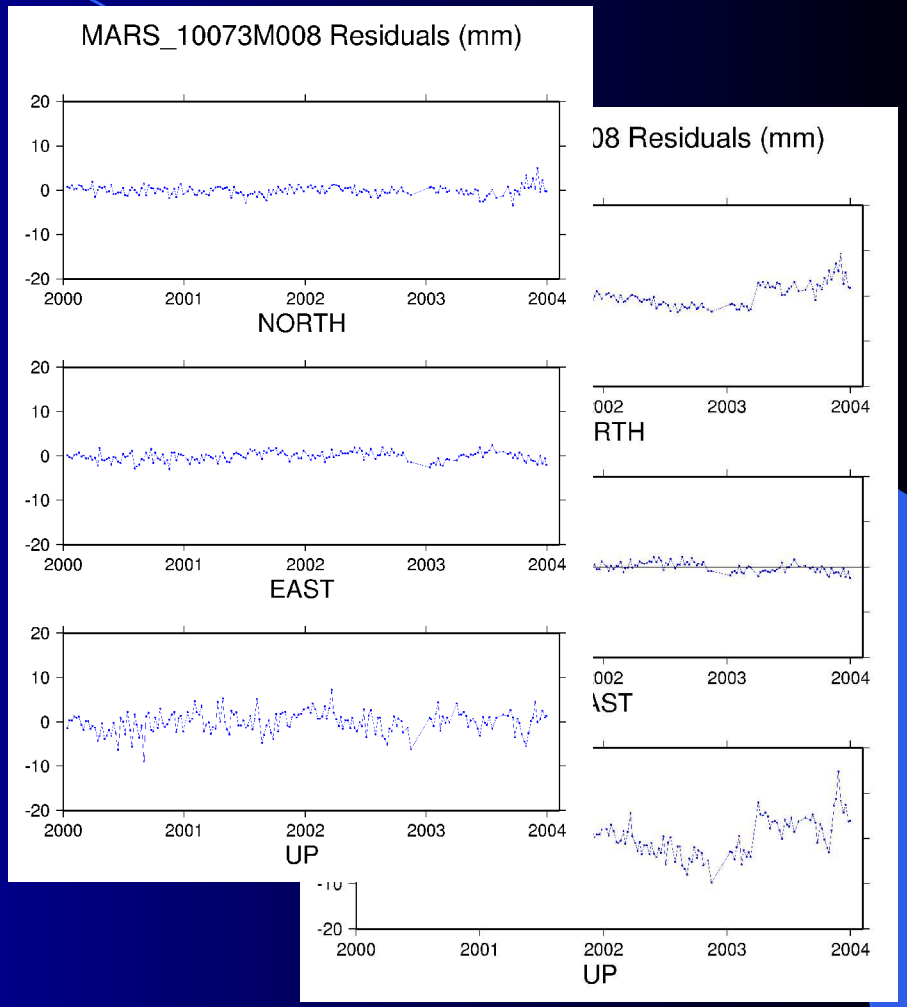
```
…
4.1  Antenna Type              : TRM29659.00     NONE
 …
     Date Installed            : 1998-07-16T15:00Z
     Date Removed              : 2003-03-13T00:00Z
     Additional Information    :

4.2  Antenna Type              : LEIAT504        NONE
…
     Date Installed            : 2003-03-28T00:00Z
     Date Removed              : CCYY-MM-DDThh:mmZ
     Additional Information    :
```

(mars_20030401.log)

Estimated Jump

	DX	DY	DZ
Pos 2 / Pos 1	**0.0017**	**-0.0017**	**0.0098**



PNDB time series residuals

Antenna change

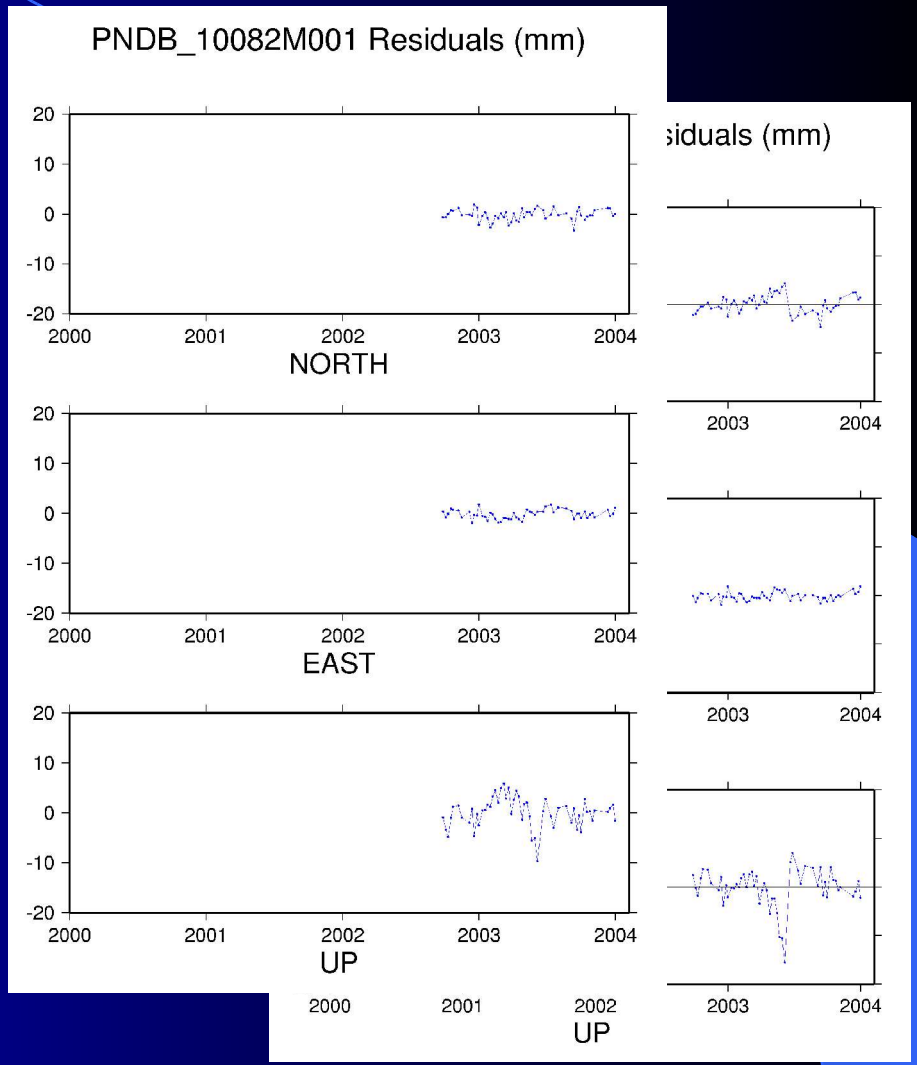
```
…
4.1   Antenna Type              : AERAT2775_42
…
      Date Installed            : 2002-09-17T00:00Z
      Date Removed              : 2003-06-11T08:00Z
      Additional Information    : (multiple lines)

4.2   Antenna Type              : ASH701945E_M
…
      Date Installed            : 2003-06-11T09:00Z
      Date Removed              : (CCYY-MM-DDThh:mmZ)
      Additional Information    : (multiple lines)
```

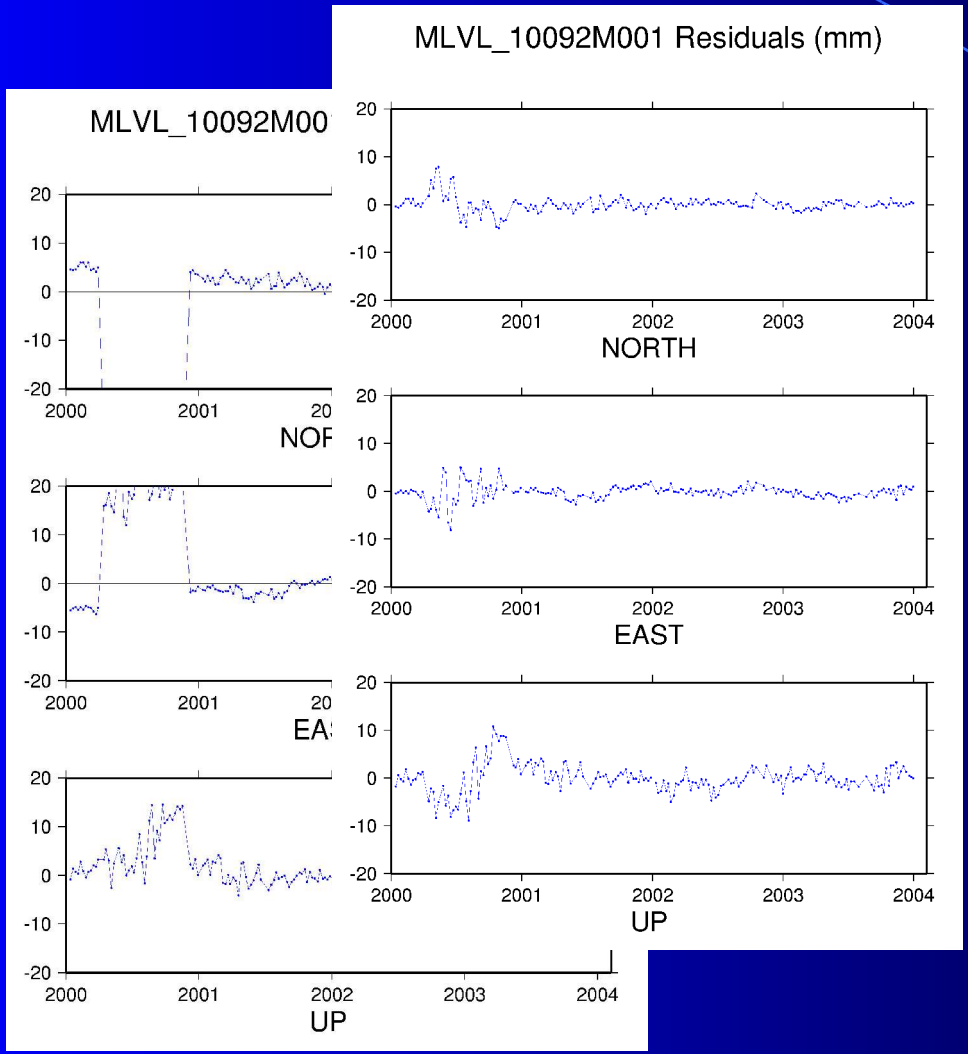
(pndb_20030611.log)

Estimated Jump

	Dx	DY	DZ
Pos 2 / Pos 1	**0.0123**	**-0.0034**	**0.0053**



MLVL time series residuals



Antenna change

…
4.1 Antenna Type : ASH700936A_M
….
Date Installed : 2000-01-22T00:00Z
Date Removed : 2000-11-20T10:00Z
Additional Information : (multiple lines)

4.2 Antenna Type : ASH701073.3 NONE
…
Date Installed : 2000-11-20T16:00Z
Date Removed : CCYY-MM-DDThh:mmZ
Additional Information : (multiple lines)
…

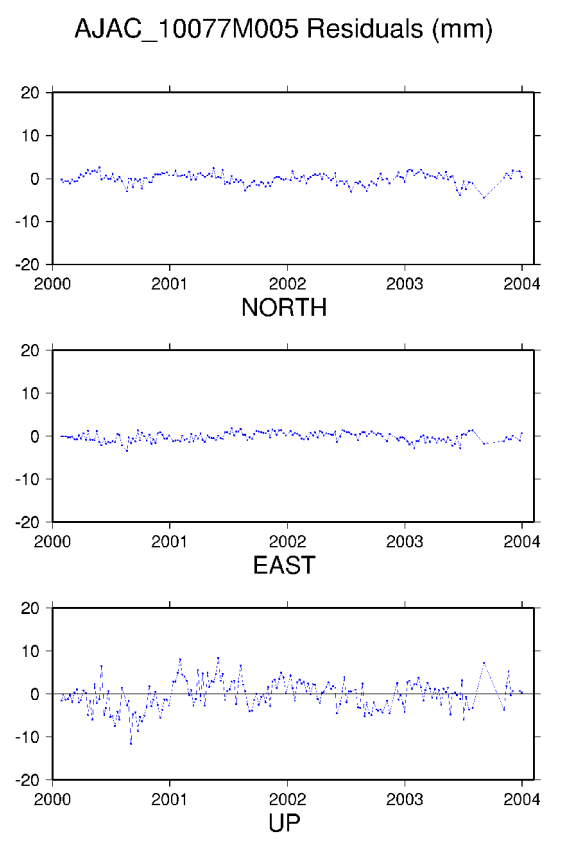
(mlvl_20020902.log)

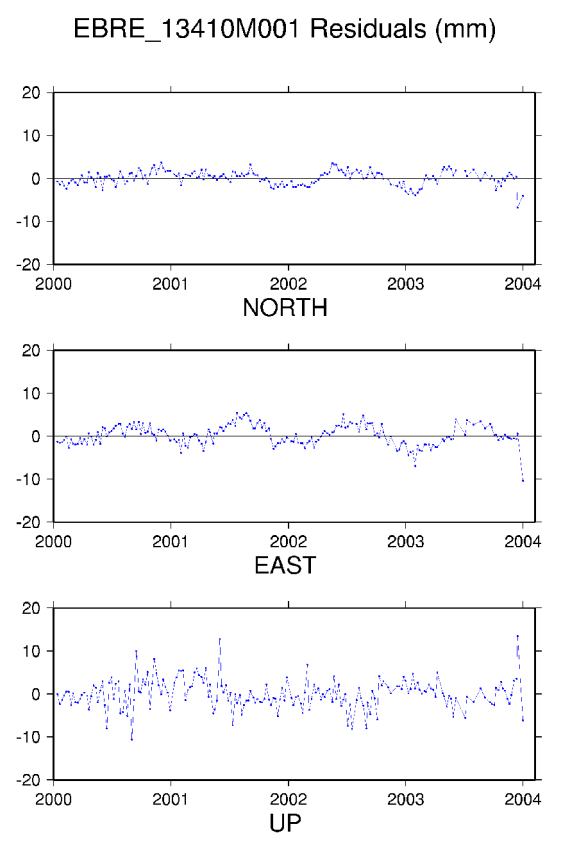
Estimated Jumps

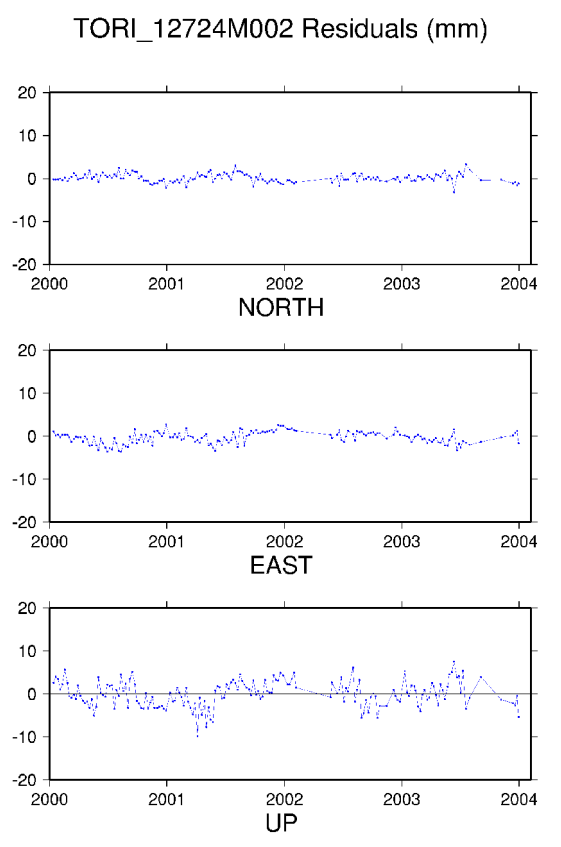
	DX	DY	DZ
Pos 2 / Pos 1	0.0342	0.0278	-0.0194
Pos 3 / Pos 1	-0.0020	0.0030	-0.0019

More time series

EPN stations

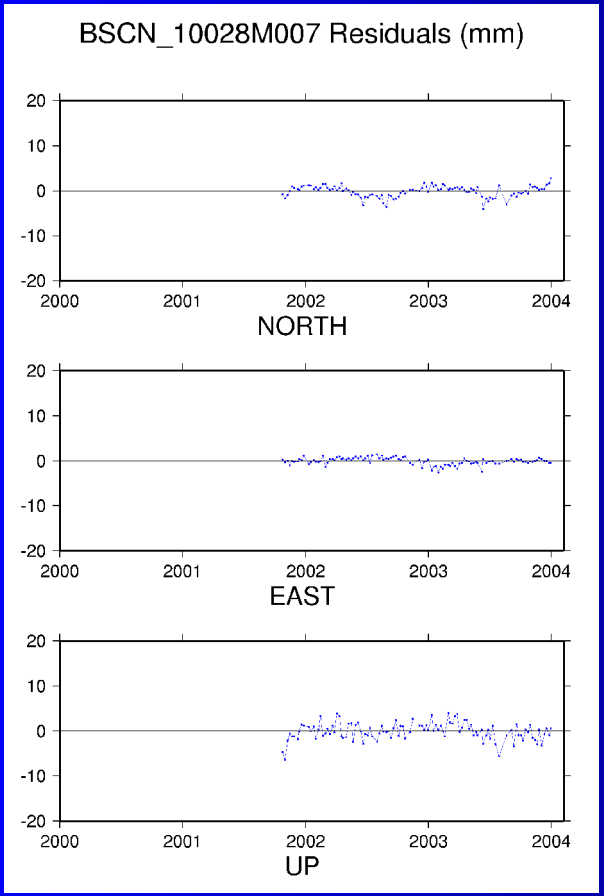


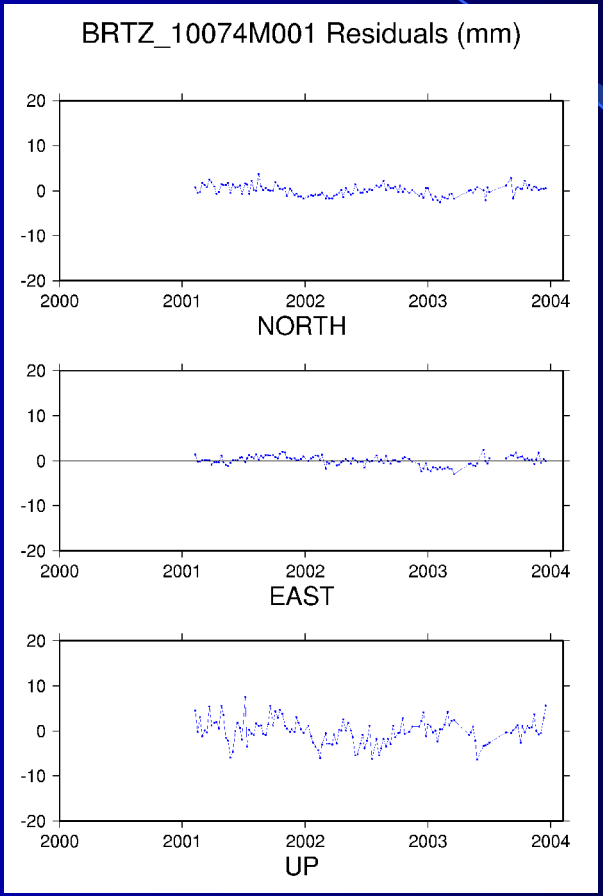


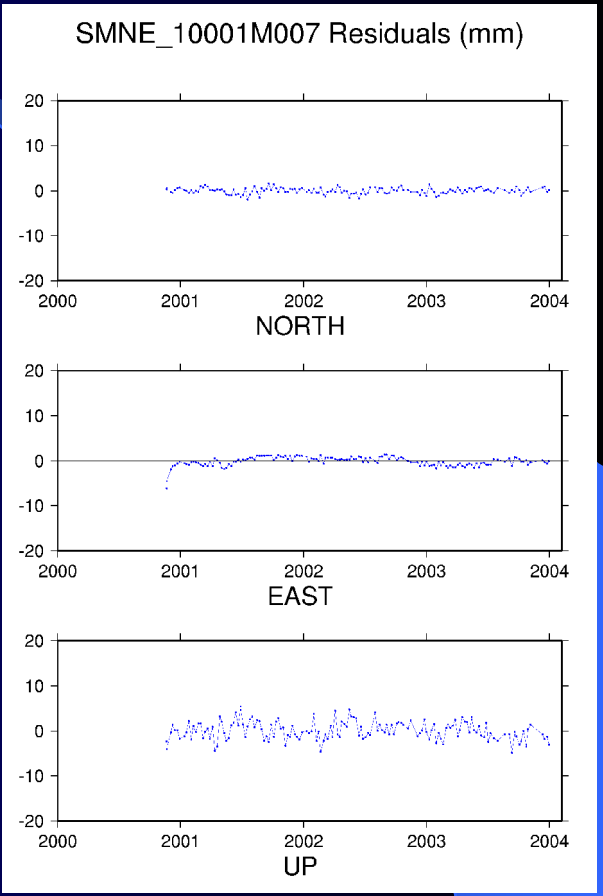


More time series

French non EPN stations



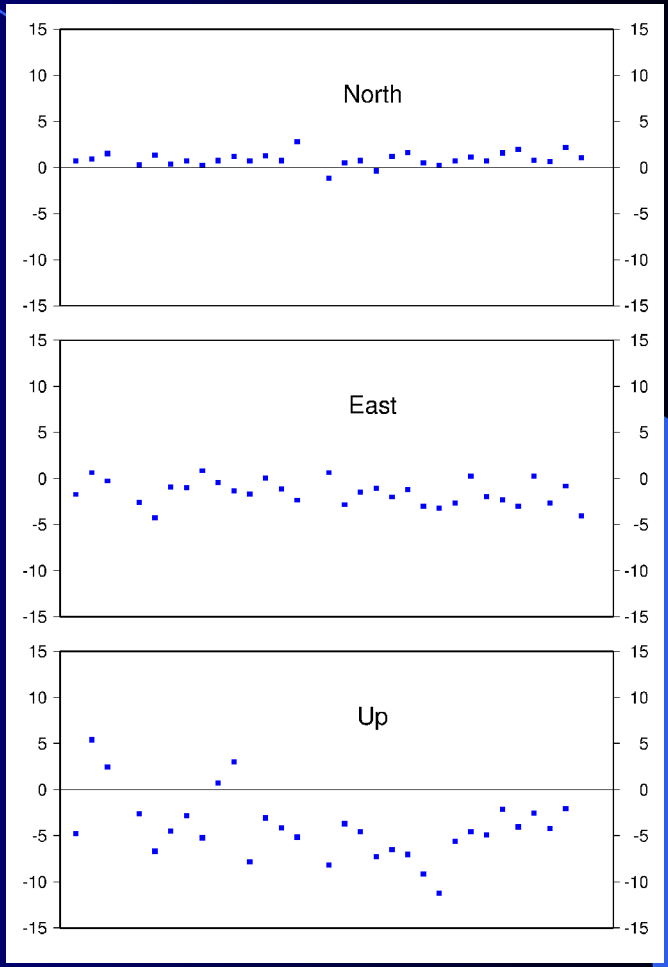




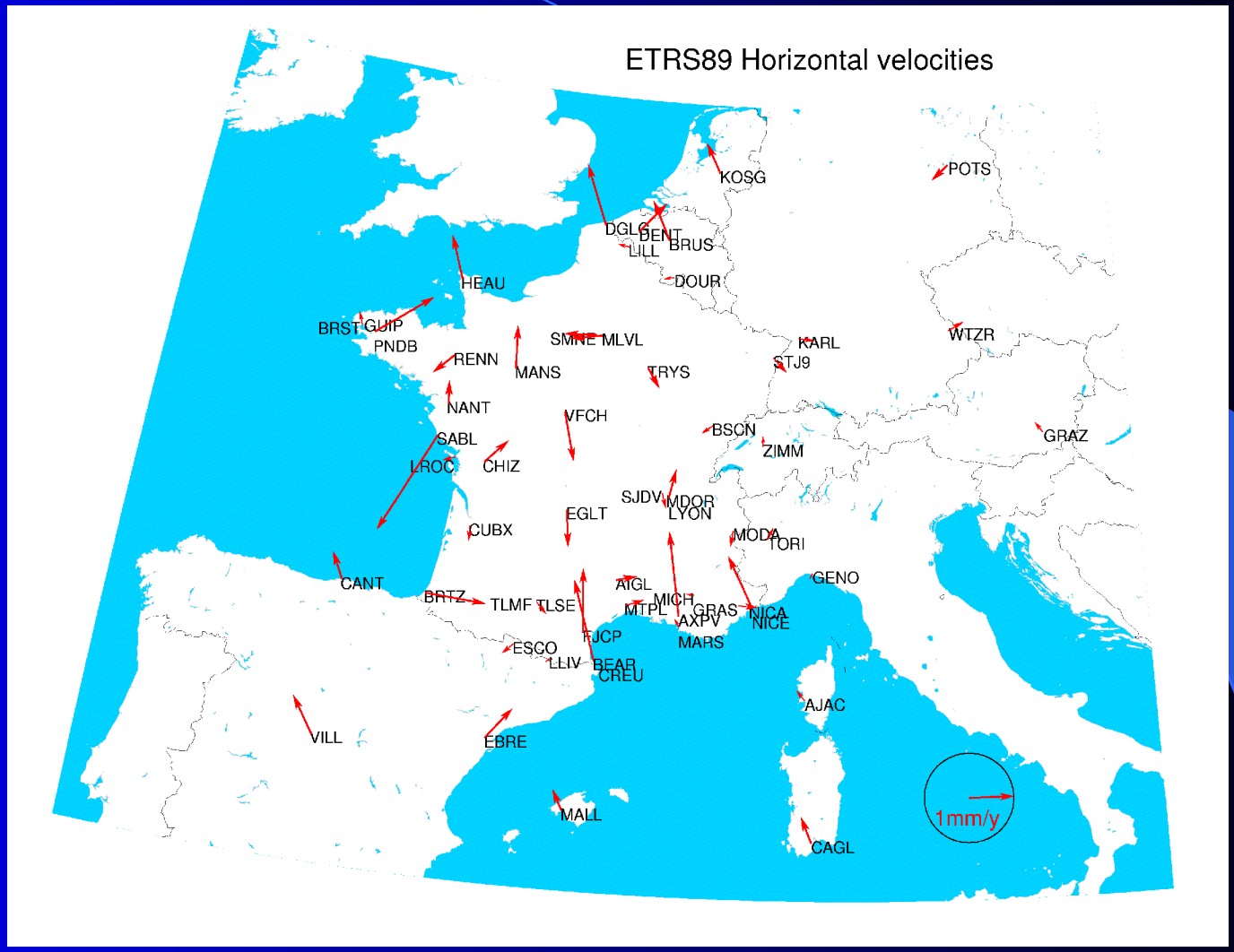
Conversion to ETRS89 and comparisons to other solutions

- « Specifications for reference frame fixing in the analysis of a EUREF GPS campaign » by C. Boucher and Z. Altamimi

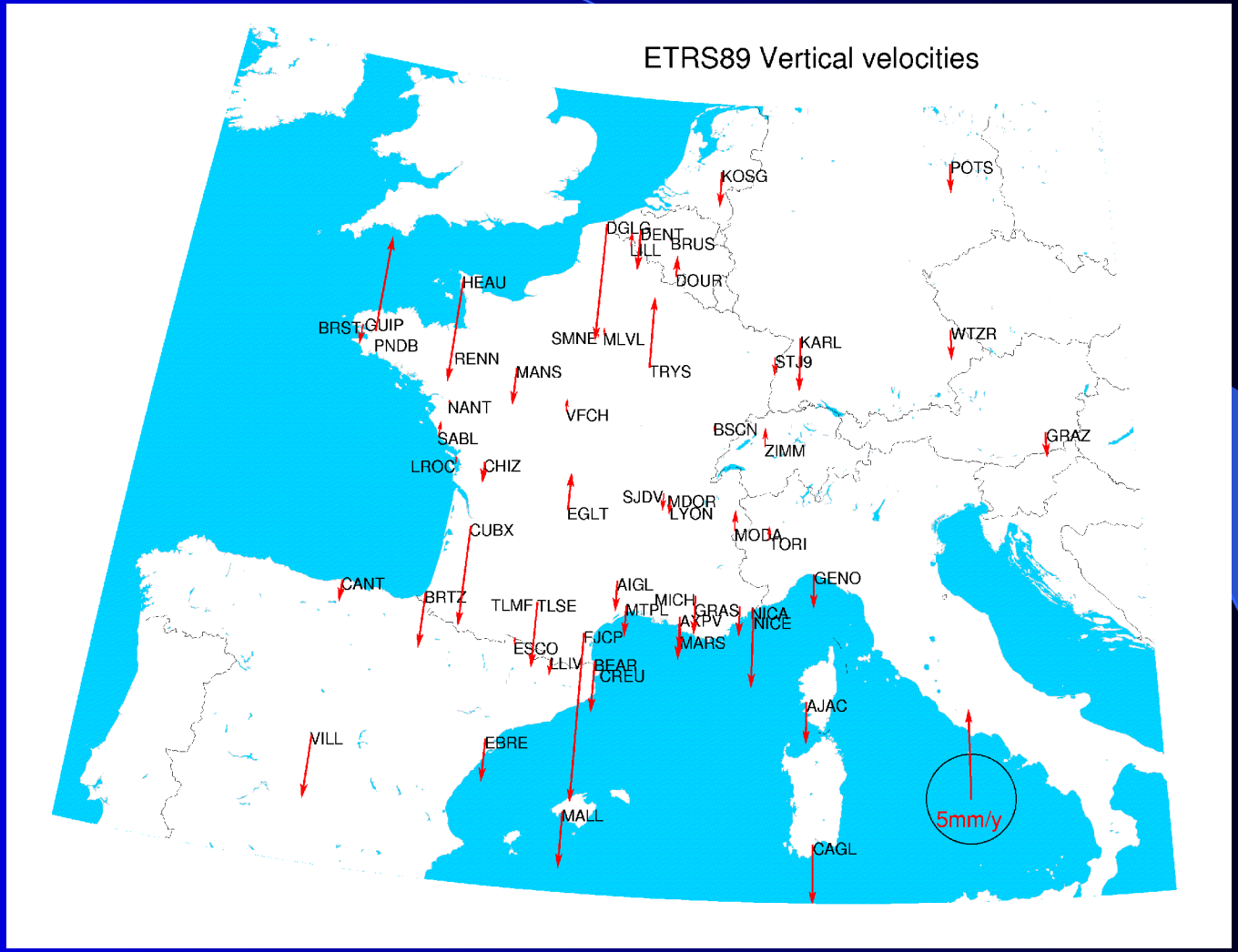
- Comparison (same epoch) to EPN-ETRF2000 solution computed by Z. Altamimi



Horizontal ETRS89 velocities



Vertical ETRS89 velocities



Some conclusions

- **Weekly WRMS**
  - 1-2 mm horizontal
  - 2-3 mm vertical
- **Replace the national reference**
  - More investigation / refinements
  - Add new weekly solutions from year 2004 for recent stations and additional information (ties to the Reference Network)
- **Maintenance of the network**
  - Implement automatic processing
  - Compute ETRS89 coordinates for new station