Towards a new french ETRS89 realization for the RGP network stations

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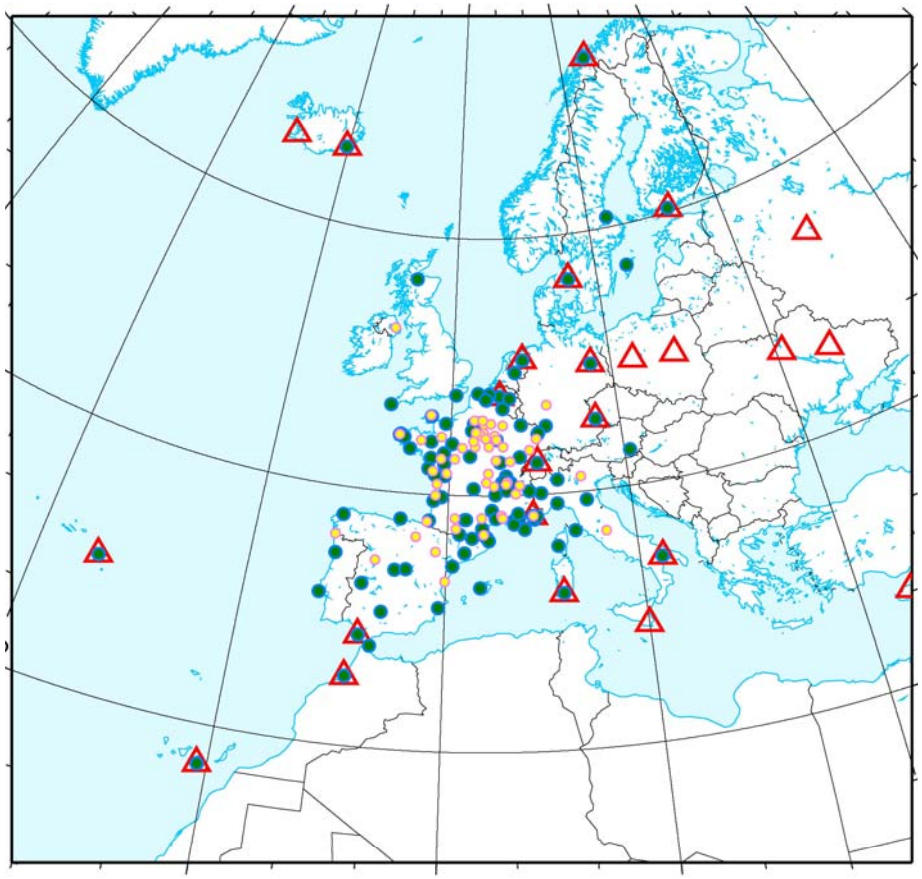
Motivations

The aim of this work was not to change the french ETRS89 realization “RGF93” definition (at least in the near future) which has a legal status, but to propose:

- **A monitoring process of the french GNSS permanent network (RGP)**
- **A cumulative solution expressed in IGS05 for velocity and coordinates estimation**
- **A set of coordinates expressed in ETRF2000 for the stations of the RGP (called ETRF2000(R05)-F) and a grid model based on collocation method from/to the RGF93 reference frame**

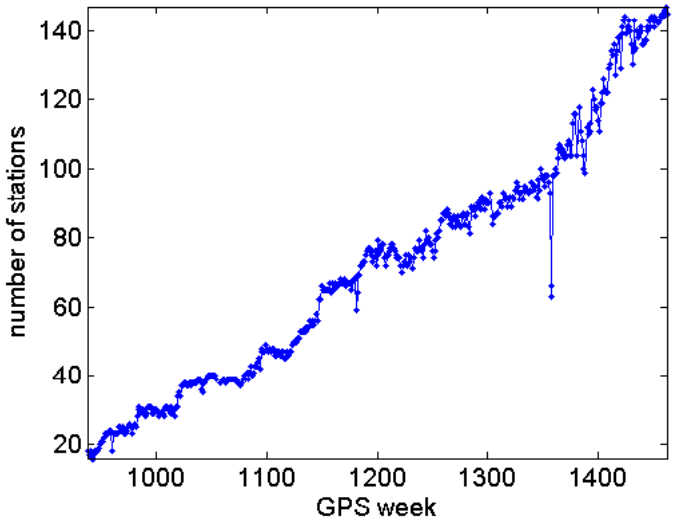
The network and the data included in the analysis



161 stations from the **IGS/EPN, EPN and RGP** networks

- more than 2 years of data
- less than 2 years of data
- ITRF2005/IGS05 reference stations

GPS data only from GPS week 0938 to 1462



The general processing strategy

- **GPS processing : Bernese software 5.0**

  Daily/weekly **free** solutions (SINEX) loosely constrained (1m)

- **Monitoring process using SGN combination programs and analysis tools**

- **Final solution using CATREF package and the minimum constraint approach**

  - A cumulative IGS05 solution (positions and velocities) is processed. A SINEX file is produced.
  - Final coordinates are expressed in the IGS05 at 2008.0 reference epcoh.

- **Velocities are constrainted to be the same within the same site**

- **Conversion to ETRS89 using Approach A formulae to compute a set of coordinates for the RGP stations defining a french realization of the ETRS89 system**

The GPS processing strategy

The processing strategy adopted was those used at the IGN LAC. It is based on ionosphere-free double differences in a network approach using the Bernese 5.0 software and the following options/parameters:

Measurement models

- DE200 planetary ephemeris model
- Earth potential model : JGM3
- **Ground/satellite antenna : IGS absolute/relative elevation-dependent phase center models**
- Ocean loading model : FES2004
- Solid Earth tides applied (IERS Conventions 2003)
- Orbits and ERPs : IGS final products

Processing parameters

- Elevation dependant weighting
- Elevation angle cutoff : 3 degrees
- Troposphere :
  - mapping function : Wet Niell
  - zenith delays estimated once per hour for each station
  - daily horizontal gradient parameters

Estimated parameters

- Adjustment : Weighted least-squares algorithms
- Ambiguity resolution : QIF strategy. Solved ambiguities introduced to final solution
- **Free solutions (loosely constrained) : the 7 daily solutions are combined to produce a weekly solution**
- Troposphere : zenith delays estimated once per hour for each station and daily horizontal gradient

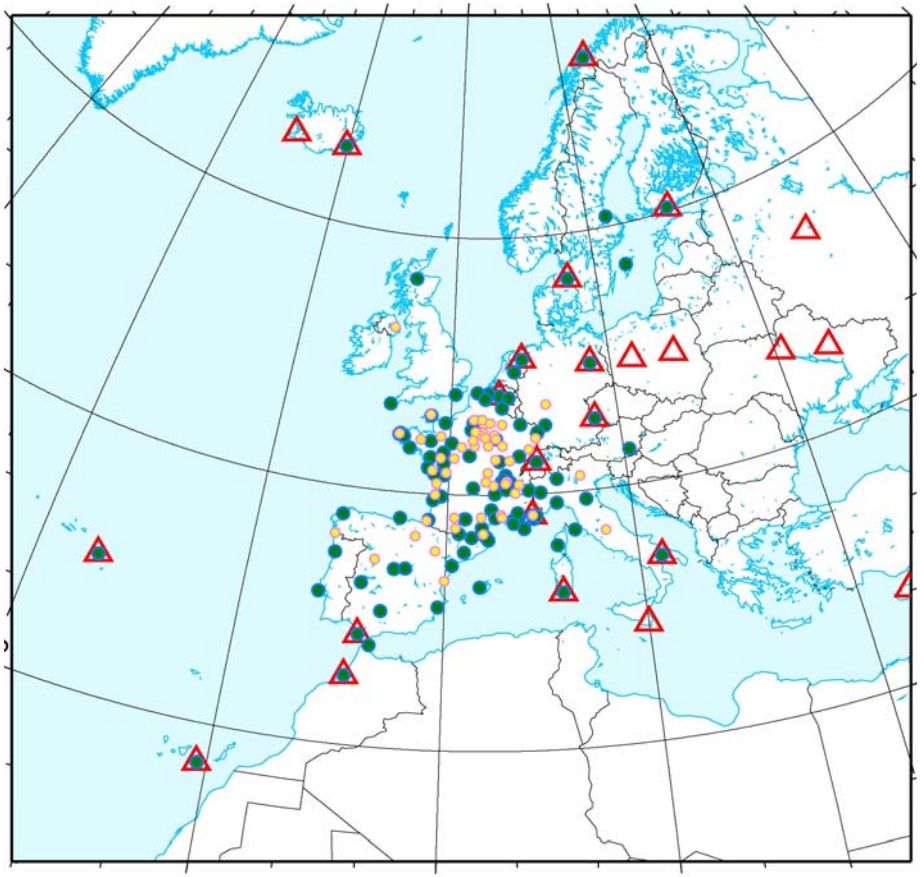
Reference frame definition

Minimun constraints over a set of selected stations of the ITRF2005/IGS05 stations

△ EUROPEAN IGS05 reference stations

```
+SITE/ID
*CODE PT __DOMES__ T _STATION DESCRIP
 BRUS  A 13101M004    BRUSSELS, BELGIU
 CAGL  A 12725M003    Cagliari, Italy
 GRAS  A 10002M006    CAUSSOLS, FRANCE
 HOFN  A 10204M002    HOFN 10204M002
 MAS1  A 31303M002    MASPALOMAS, SPAI
 MATE  A 12734M008    MATERA, ITALY
 METS  A 10503S011    KIRKKONUMMI (40
 ONSA  A 10402M004    ONSALA, SWEDEN
 PDEL  A 31906M004    PONTA DELGADA, P
 POTS  A 14106M003    POTSDAM, GERMANY
 SFER  A 13402M004    SAN FERNANDO (CA
 WSRT  A 13506M005    WESTERBORK, NETH
 WTZR  A 14201M010    KOETZTING, GERMA
 ZIMM  A 14001M004    ZIMMERWALD, SWIT
-SITE/ID
```

IGS05 : more consistent with the use of the receiver Absolute Phase Center Variation models (APCV)



A monitoring approach (1/2)

- **To deal with discontinuities (antenna change / analysis) at reference epoch using IGS05 realization, the position differences from ITRF2005 have been introduced.**

A program has been developped to propagate coordinates at selected epoch using an extended CRD Bernese format

```
RGP IGS05                                                    18-JUN-08 09:19
------------------------------------------------------------------------------
LOCAL GEODETIC DATUM: IGS05             EPOCH: 2008-01-01 00:00:00

NUM  STATION NAME           X (M)          Y (M)          Z (M)     FLAG       FROM        TO

  1  ACOR 13434M0011    4594489.6880   -678367.7079   4357066.1692    E    99:237:00000 00:008:43200
  2  ACOR 13434M0012    4594489.6824   -678367.7044   4357066.1735    E    00:008:43200 01:353:43200
  3  ACOR 13434M0013    4594489.6791   -678367.7029   4357066.1685    E    01:353:43200 07:077:43200
  4  ACOR 13434M0014    4594489.6779   -678367.7027   4357066.1652    E    07:077:43200
  5  AIGL 10059M0011    4578299.9788    286538.9091   4418911.7911    E    02:252:00000
```

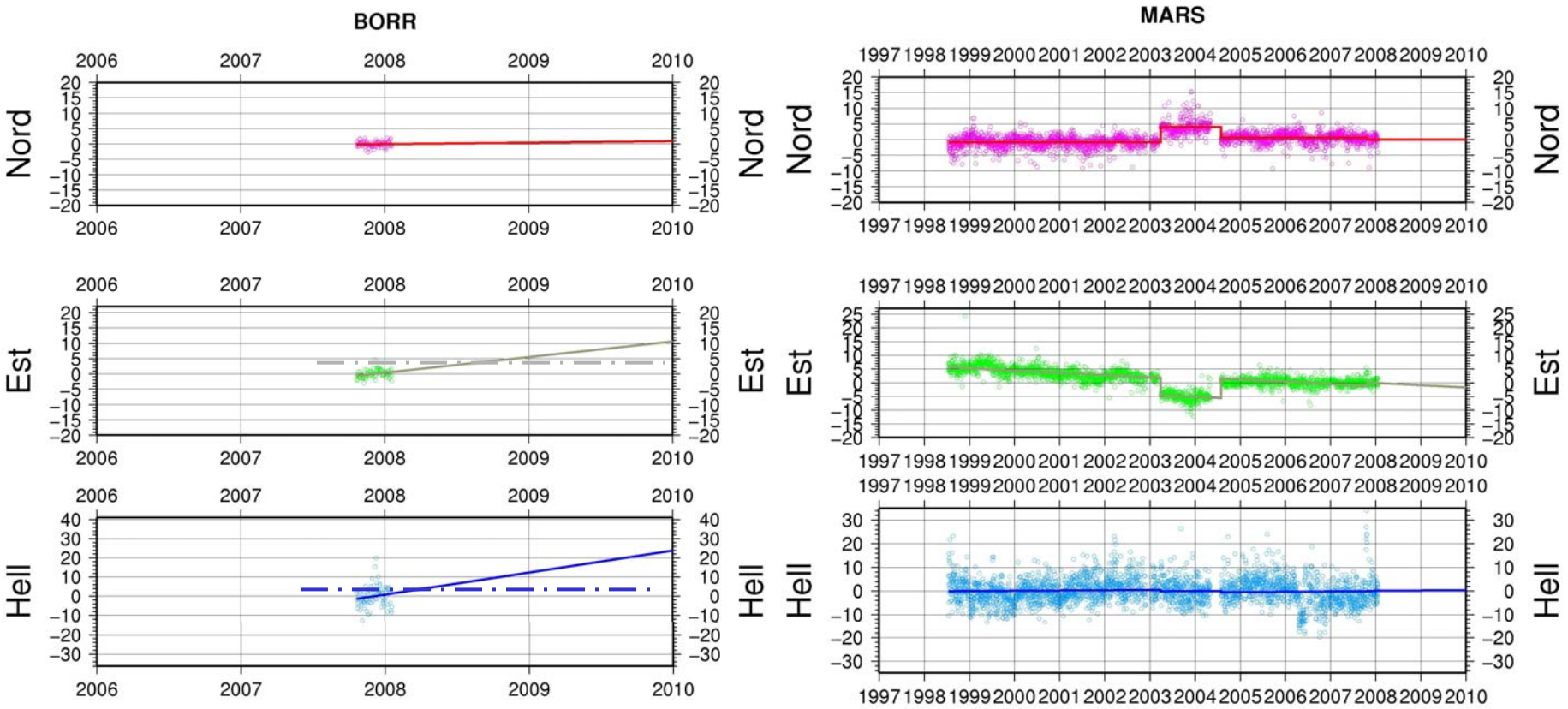
- **Each daily solution is transformed at epoch in the IGS05 reference frame using a 7 parameters Helmert transofrmation, and converted to ETRS89 using the appropriate conventional transformation formulae (approach A)**

A monitoring approach (2/2)

- For each station and solution, residuals are computed and plotted with respect to linear estimated velocity

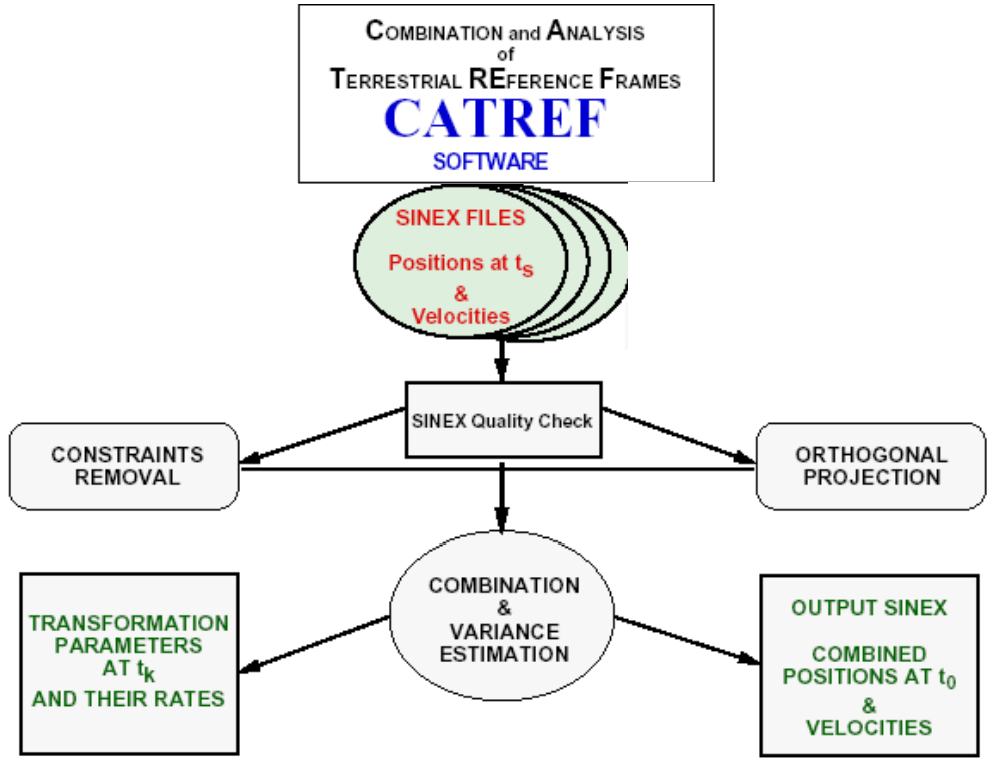
- Outliers are detected and corresponding solution is rejected.
- When a jump is detected on a station, a discontinuity is setup and introduced for the final solution.
- Coordinates are propagated at minimum variance epochs.

Time series residuals



Remark: the 0 horizontal axis corresponds to the position of the station at minimum variance epoch

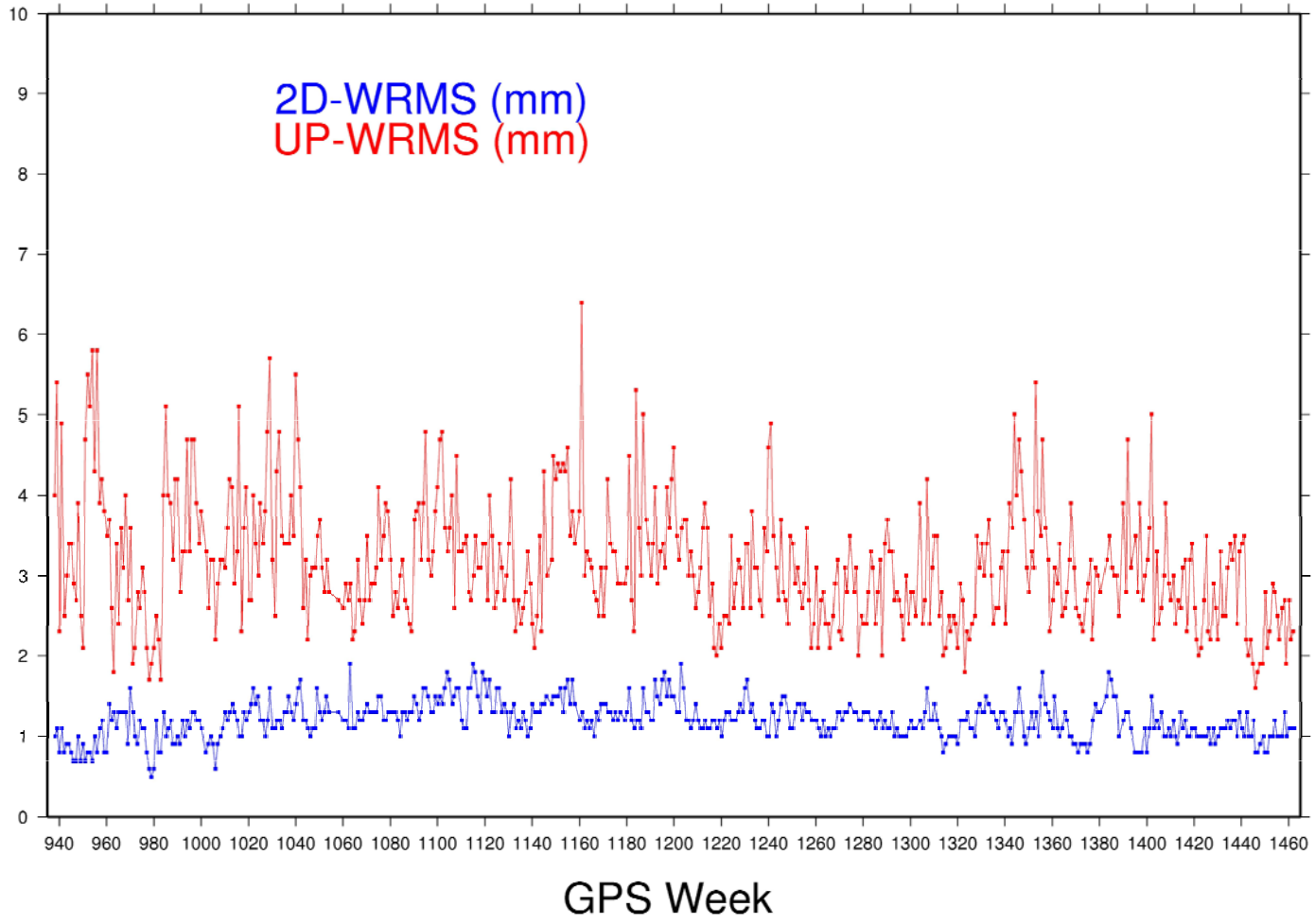
The CATREF software



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

Residuals analysis

RGP weekly solution : weighted RMS



Final coordinates and velocities

- **The reference epoch for the final coordinates delivery is 2008.0**
- **For station with observation period *shorter than 2 years*, reference coordinates are estimated at *minimum variance epoch*, and velocity using the *ITRF2005 eurasian plate rotation model* is used to transfer position at the reference epoch.**
- **For stations with observation period *longer than 2 years*, estimated velocities are used to transfer estimated position at the reference epoch.**

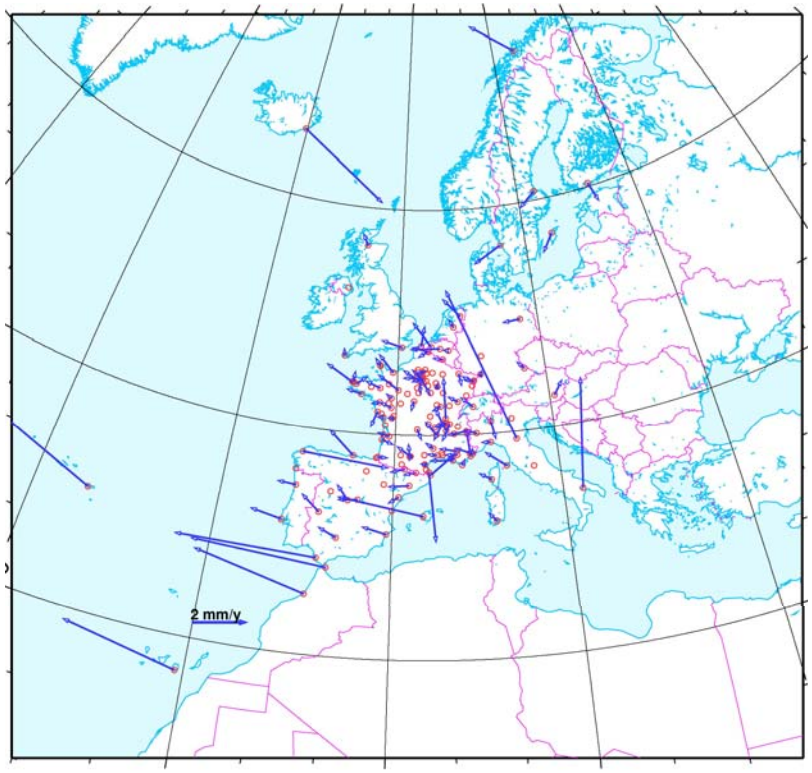
First results

- **Comparison between IGS05 and ITRF2005 realizations has shown a difference of about *0.5 ppb* for the network.**

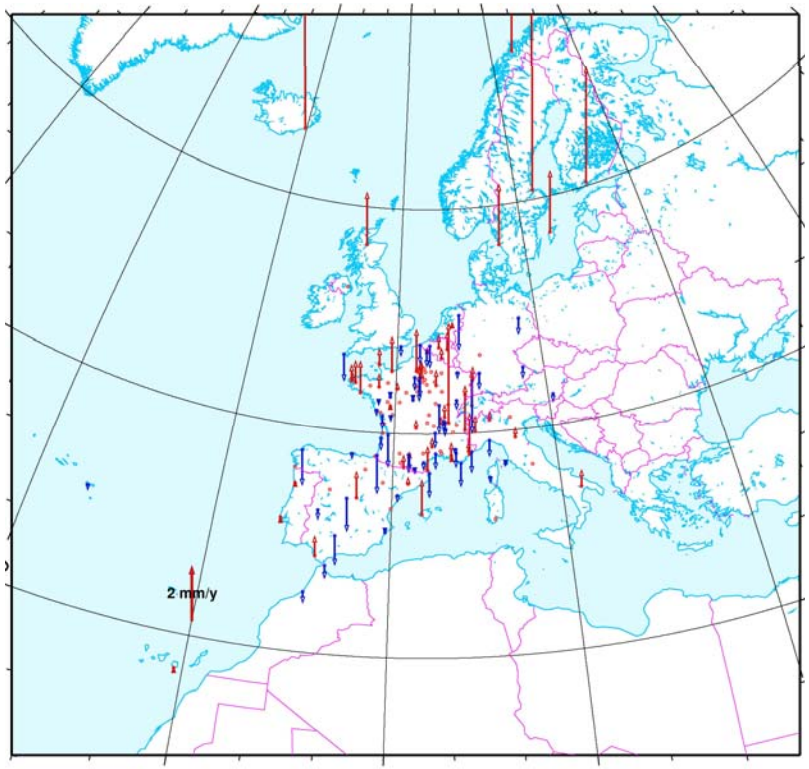
  IGS05 is aligned with the ITRF2005 at a global level whereas we use a regional set of stations.

- **Consistency *at the cm level* between the ETRF2000(R05)-F reference frame and the neighbouring countries ETRS89 realizations**

ETRF2000(R05)-F velocities

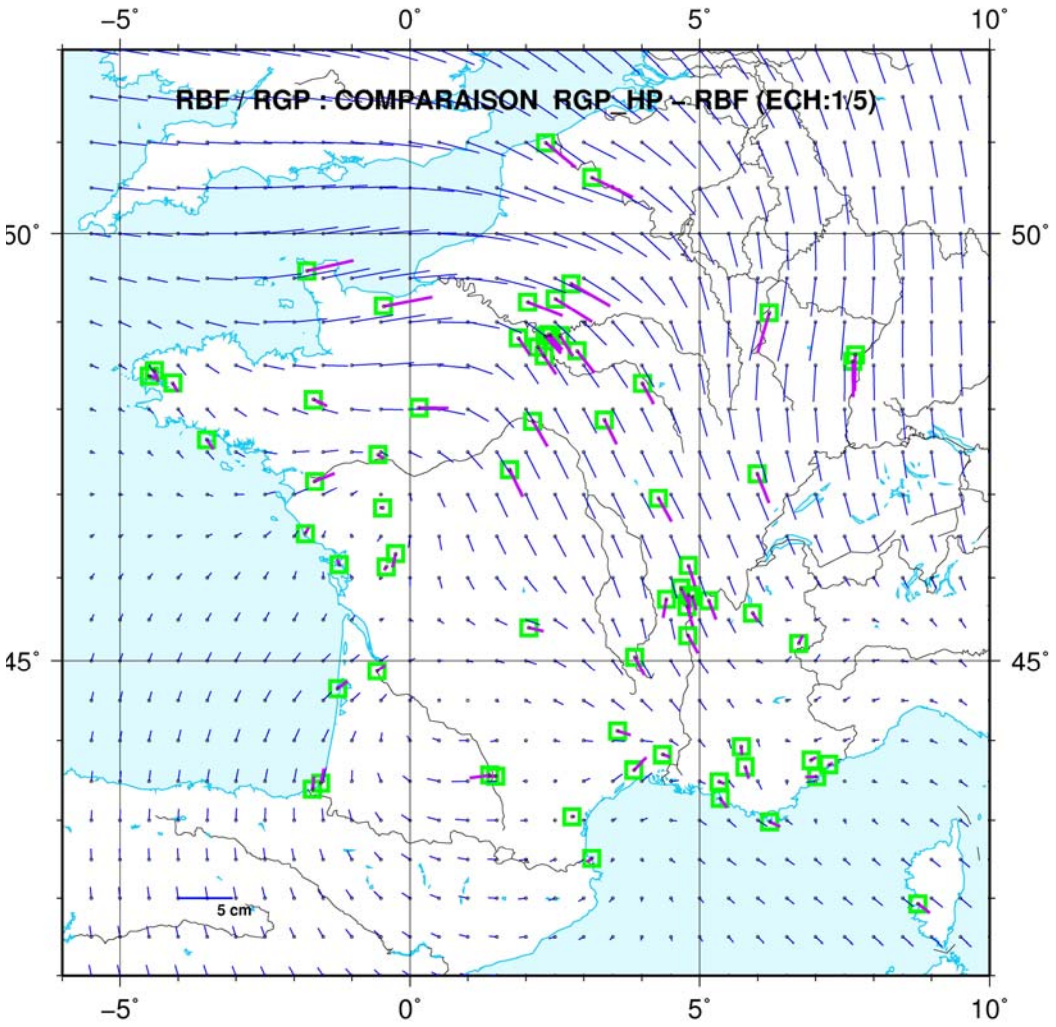


Horizontal



Vertical

Grid model estimation by collocation method



Differences between ETRF2000(R05)-F and RGF93 reference frames can reach 4 cm

RGP stations with coordinates available in the 2 frames

Coordinates availability

For the RGP network, the following set of coordinates will be published:

- for post-processing applications:

IGS05 2008.0 coordinates and velocities

- for real-time positionning applications:

ETRF2000(R05)-F coordinates for EPN stations (EUREF-IP)
legal RGF93 coordinates for the private RTK network stations

Conclusions and coming actions

- **Analysis refinement is still necessary.**
- **From GPS week 1463, the network has been enlarged to a global one including the IGS stations from the core network.**
- **A global network reprocessing will be performed as soon as the IGS reprocessing files are available.**
- **A cumulative weekly solution using CATREF software and the minimal constraint approach, expressed in IGS05 and in the ETRS89 realization using the Approach A formulae, will be maintained for each new solution.**