Belgian Report to the IAG-subcommission "EUREF"

C. Bruyninx[1], P. Defraigne[1], B. Ducarme[1], M. Everaerts[1], E. Pottiaux[1], F. Roosbeek[1], P. Voet[2], R. Warnant[1]

Presented at EUREF Symposium, May 16-18, 2001, Dubrovnik, Croatia

This national report has been prepared based on the contributions of two Belgian Institutes: the *National Geographic Institute* (NGI) and the *Royal Observatory of Belgium* (ROB).

1. Maintenance and densification of the national networks (NGI)

The NGI completed last year the revision and densification of the Belgian horizontal network. This means that easily accessible, GPS-friendly, ground points with a mean density of 1 point/ 8 km² are now available over the whole belgian territory.

2. Status of the National Gravity Network (ROB)

During the year 2000 the Royal Observatory of Belgium was charged by the "Région Wallonne" to realise two gravity networks (Everaerts, 2001), the first one in the South West of Belgium (Philippeville area, 439 stations, 2.000 km^2) and the second one in the centre East (Waremme area, 248 stations, 1.200km^2). As a result there are now 63251 validated gravity stations homogeneous in the first order gravity network FOBGN78 and covering the whole Belgian territory with densities ranging from 0.2 to 1 station per km^2. The internal errors of the adjustment are generally slightly lower than 10µgal.
First applications to the study of geological structures can be found in Everaerts, 2000.

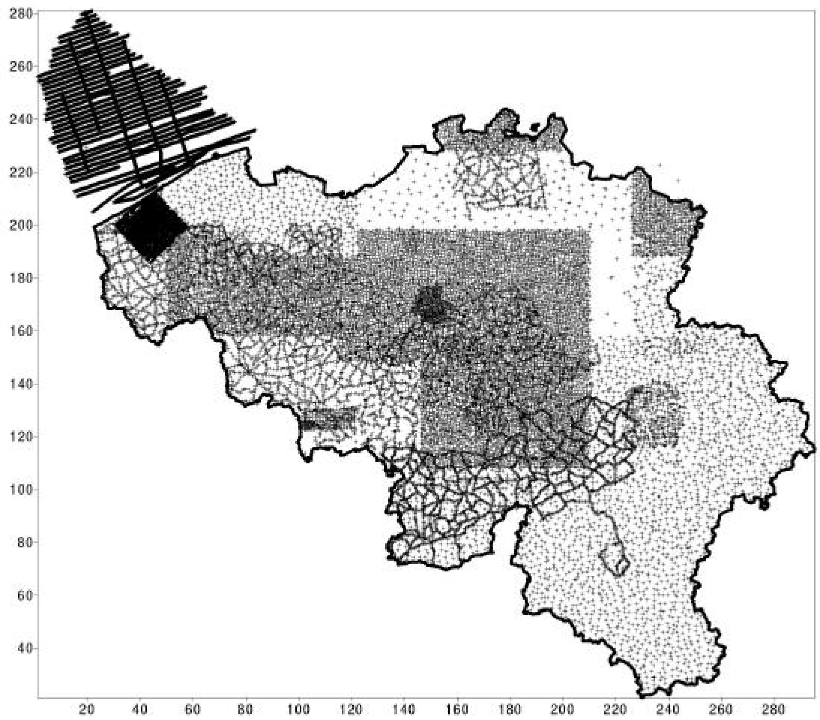

Figure 1- ***Gravimetric coverage of Belgium***

[1]CARINE BRUYNINX, MICHEL EVERAERTS, ERIC POTTIAUX, FABIAN ROOSBEEK, RENE WARNANT, Royal Observatory of Belgium, Av. Circulaire 3, B-1180 Brussels, Belgium
[2] PIERRE VOET, National Geographic Institute, Adbij Ter Kameren 13, B-1000, Brussels, Belgium

3. Network of permanent reference stations

3.1 NGI network

Towards the end of 2000, the NGI installed a small experimental network of permanent GPS stations in the region of Brussels. The main goals are:

- To collect some vital experience with Integrity Monitoring (IM)
- To distribute the phase measurements for RTK applications
- To provide DGPS corrections nation-wide

The network that has been installed consists of:

- 4 « Leica SR530 » receivers with choke ring antennas
- Power supply with backup
- A mobile phone for communication of data to the NGI office (for IM)
- Communication with the users

The communication with the users is ensured by two different means: two of the stations are equipped with a mobile phone. At the other stations, the output signal (RTCM) is sent to a “port-sharing device”, which splits the signal in four parallel copies that are sent to a modem. As a result, four users can, by calling over a regular phone line, capture the phase data of a particular station at the same time.
For the IM, the NGI uses the CRNet software (developed by “Geodetics”); it is based on the RNA-technology (Rapid Network Analysis). It computes the entire network epoch by epoch and seems to be very useful to detect local, temporary problems. However, the main disadvantage is that it can’t treat the data on line (at least not in the version we use). Therefore we are now investigating the features of other IM-software.
The difficulties and problems we encountered so far are mainly situated in the domain of communication. It is clear that this small network still is running in a test phase. At present the data of two stations is freely made available to all users, the other stations are reserved for NGI-applications.

3.2 ROB network

The ROB has continued in 2000-2001 to operate its network of 7 permanent GPS stations (see Figure 2).
Presently, the network is in a transition phase: the old ROGUE SNR-8000 receivers are being replaced by new ASHTECH receivers. In addition the data download and data transfer software to the ROB is adapted to work with the ASHTECH receivers.
As a first step, in Brussels, an ASHTECH Z-XIIT receiver has been installed in March 2001. This receiver is a geodetic receiver modified to allow time transfer applications.
Dourbes will be the second station where the old ROGUE –SNR 8000 will be replaced by an ASHTECH. We expect to do this change in the summer of 2001.

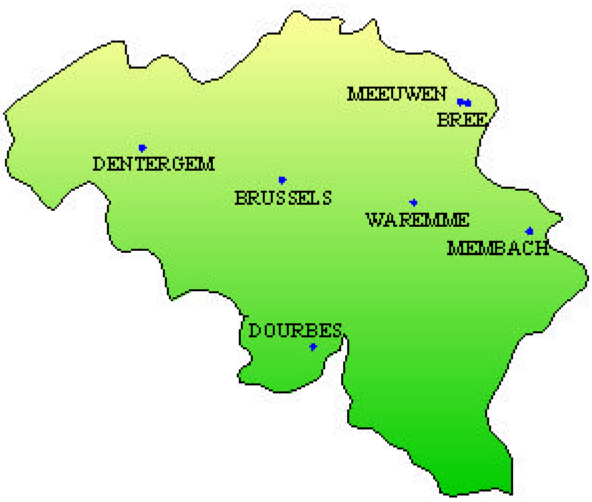

Figure 2 - ***Permanent GPS network operated by the ROB in Belgium***

4. Contribution to the EUREF Permanent Network (ROB)

4.1 Tracking Network

Four of the ROB stations: Brussels (BRUS), Dentergem (DENT), Dourbes (DOUR) and Waremme (WARE) belong to the permanent EUREF network (EPN) since 1996. The station in Brussels belongs also to the IGS network (since 1993) and submits hourly data. In the summer of 2001, Dourbes will start to submit hourly data to EUREF too.

In addition to this, the ROB continues to operate, since 1996, the "ROB" EUREF Local Data Centre, the "ROB" EUREF Local Analysis Centre and it is responsible for the coordination of the activities related to the permanent EUREF network (*Bruyninx,2000).*

4.2 Local Data Centre

The ROB’s EUREF local data centre receives each day the data from its 7 permanent GPS tracking stations. Both daily and hourly observation files are made available. The goal is to run all procedures fully automatically:

- The ROB compresses the received data using the Hatanaka compression scheme, which was especially developed for the efficient compression of RINEX data
- Data holding files are generated. These ASCII files give a quick overview to the users which data files are available to the users. In addition to this, these data holding files allow checking quickly if a data file has been properly transferred to the Data Centre.

4.3 Local Analysis Centre

Within its function as EUREF local analysis centre, the ROB analyses daily the GPS data of a network of about 28 EUREF tracking stations. The results of the daily ROB data analysis flow each week to the EUREF Combination Centre where they are combined with the solutions of the other EUREF Local Analysis Centres. The weekly combined EUREF solution will finally be sent by the Combination Centre to the International Earth Rotation Service, which will upgrade the realisation of the ITRS and ETRS89. It should be mentioned that the ROB’s daily data analysis is done following international standards and that the coordinate results are validated through their permanent comparison to the results obtained by other scientific institutes over Europe and through their inclusion in the ITRS. In addition to the coordinate information, the daily GPS data analysis gives long-term information about the behaviour of the permanent tracking stations, which is essential for the monitoring of their stability.

4.4 EPN Central Bureau

As the Central Bureau of the EUREF Permanent Network, the ROB coordinates the activities of the tracking stations, data centres and analysis centres. It distributes standards and guidelines. It maintains the history information of all tracking stations, checks the individual coordinate time series and notifies the EUREF community when a station does not fulfil the standards or when irregular behaviour is detected through a coordinate variation. This coordination is performed at the ROB since 1996.

During last year,

- 16 new permanent stations were added to the network. The total number of stations in the EUREF network is now almost 120 ;
- the web site containing all the information related to the permanent network was completely redesigned and moved to a new server (http://www.epncb.oma.be/);

more details can be found in the paper “Network Coordination of the EUREF Permanent GPS Network” (in this volume).

5. Ionospheric refraction (ROB)

The Royal Observatory of Belgium is performing a long-term study of the ionospheric refraction effect on GPS measurements. In particular, the ionospheric Total Electron Content behaviour is monitored since April 1993 using GPS measurements. Since the end of 1998, a stronger ionospheric activity is observed. In mid-latitude stations, this stronger activity is characterized by:

- A larger Total Electron Content;
- A larger number of Travelling Ionospheric Disturbances;
- Several strong mid-latitude geomagnetic storms in 2000 and 2001 which were followed by severe scintillation phenomena; these scintillations caused high frequency changes in GPS phase measurements which gave strong disturbances in real-time and in rapid static positioning.

6. Tropospheric refraction (ROB)

At the present time, the effect of the neutral atmosphere on GPS measurements remains the main error source in GPS positioning. In particular, the influence of water vapour is very difficult to remove from the observations. For this reason, the Royal Observatory of Belgium is performing a research program on the tropospheric refraction. The goal of this project is to get a better understanding of the atmospheric water vapour effect on GPS position time series. In a first step, the water vapour behaviour is being studied using measurements collected by GPS receivers, radiosonde and water vapour radiometers. In 2000, first comparisons between the water vapour content derived from GPS and radiosonde observations collected at Brussels gave promising results. At the beginning of 2001, a water vapour radiometer has been installed at Brussels. This instrument will give us a third source of information about the water vapour.
In a second step, all the information obtained on the water vapour will be used to refine the correction of the wet tropospheric delay.

7. Time transfer applications with geodetic receivers (ROB)

7.1 Contribution to TAI with geodetic receivers

The International Atomic Time scale (TAI) is computed by the Bureau International des Poids et Mesures (BIPM) from a set of atomic clocks distributed in about 40 time laboratories over the world. The time transfer between these remote clocks is mostly performed by the so-called GPS common view method: the clocks are connected to a GPS time receiver whose internal software computes the offsets between the remote clocks and GPS time. These data are collected in a standard format called CCTF.
In an attempt to take advantage of the permanent EUREF/IGS GPS stations driven by a external frequency standards, we developed both the procedure and the software tool that allow to generate the CCTF files needed for time transfer to TAI using RINEX files produced by these geodetic receivers (Defraigne and Bruyninx, 2001).
The clock resets of the geodetic receivers are accounted for by monitoring with a time interval counter the 1pps out signal of the receiver. Applied to IGS (International GPS Service) receivers, this procedure will provide a direct link between TAI and the IGS clock products.
We applied this procedure successfully on different types of geodetic receivers. The correctness of the method was demonstrated from the comparison of the results with collocated time receivers.

7.2 Time and frequency transfer using geodetic GPS/GLONASS receivers

We used GLONASS P-codes from RINEX files of geodetic GPS/GLONASS receivers (R100 from 3S-Navigation), involved in the IGEX campaign, to perform frequency/time transfer between remote clocks (Roosbeek, Defraigne and Bruyninx, 2001). We pointed out that the GLONASS broadcast ephemerides give rise to a considerable number of outliers in the time transfer, compared to the precise IGEX ephemerides. Due to receiver clock resets at day boundaries, characteristic of the R100 receivers from 3S-Navigation, continuous data sets exceeding one day are not available. In this context, it is therefore impossible to perform RINEX-based precise frequency transfer with GLONASS P-codes on a time scale longer than one day. Because the frequency emitted by each GLONASS satellite is different, the time transfer results must be corrected for the different receiver hardware delays. After this correction, the final precision of our time transfer results corresponds to a root-mean-square (rms) of 1.8 nanoseconds (ns) (maximum difference of 11.8 ns) compared to a rms of about 4.4 ns (maximum difference of 31.9 ns) for time transfer based on GPS C/A code observations (see Figure 3).

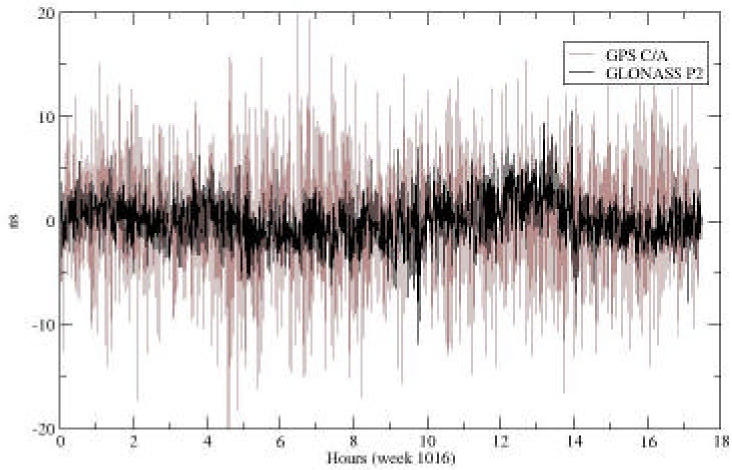

Figure 3 - ***Time transfer between BRUG and NPLC for the first day of the GPS week 1016***

6. Outlook

The active engagement of the ROB in the permanent EUREF network will be continued.

The Royal Observatory of Belgium will continue its research program on the atmospheric refraction. In particular, the effect of geomagnetic storms and scintillations on real-time GPS positioning will be studied in more details. In addition, the water vapour radiometer measurements will be processed in order to have a better understanding of the water vapour behaviour influence on GPS position time series.

7. References

Bruyninx C. (2001), *"Review of the Coordination Tasks within the EUREF Permanent GPS Network (EPN)"*, EUREF Publication, eds. J. Torres, H.Hornik, Bayerischen Akademy der Wissenshaften, München, Germany, No 9, pp 381-382

Defraigne P. and Bruyninx C. "*Time transfer for TAI using a geodetic receiver, an example with the Ashtech ZXII-T*", GPS Solution, in press.

Everaerts M., (2000), "*Interprétation structurale de la Manche au Rhin: l'apport du filtrage des champs de potentiel"*. Dissertation doctorale, Université Catholique de Louvain, Faculté des Sciences.

Everaerts M., (2001), "*Levés gravimétriques des régions de Philippeville et de Waremme"*, Report, Royal Observatory of Belgium

Roosbeek F., Defraigne P. and Bruyninx C. (2001), "*Time Transfer experiments using GLONASS P-codes measurements from RINEX files"*, GPS Solutions, in press.