EUREF Related Activities in Belgium

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

1. Maintenance and densification of the national networks

Status of the national horizontal and vertical network (NGI)

At the end of this year, the NGI will have completed 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 will be available over the whole Belgian territory.

The second general levelling was finished at the end of last year. In a period of 20 years, the NGI has used precise horizontal levelling to determine over 19.000 benchmarks. In some cases, especially in the former mining areas, considerable changes in height were noted.

Relation between the national grid and ETRS89 (NGI)

The NGI has integrated the BEREF points (ETRS89 densification network in Belgium, BRONDEEL and VOET, 1997) in the GPS campaigns for the densification of the horizontal network. Consequently, ETRS89 coordinates were computed for the complete horizontal network.

At present, several sets of 7-parameter transformations have been computed between ETRS89 and the national grid (Lambert72). Each one of them is applicable within a radius of 15 km around a central point, and has been derived from about 120 points known in both systems. The transformation errors are characterised by

$$\sigma_{x,y} = 1.5 \text{ cm} \quad \text{and} \quad \sigma_H = 2.5 \text{ cm}$$

The computed sets of transformation parameters are presently not available publicly. The reasons for this are:

- The ETRS89 coordinates of the horizontal network result from a temporary adjustment of several individual blocks. Because of an incomplete densification, there were still some gaps, where no or little GPS observations were available. When the NGI will have finished the complete densification, at the end of 2000, it will dispose of a continuous network of baselines allowing to perform an adjustment of the whole territory. At that time, several adjustment models will be evaluated, including the effect of ellipsoidal heights with respect to "orthometric height".
- The variation of the parameters, even in neighbouring zones, is strong. Covering the whole country with circles of 15-km radius will lead to a great amount of parameter sets. Therefore, to avoid confusion and possible abuse during transformation, the NGI is searching for a more elegant and straightforward solution.

2 Status of the National Gravity Network

In the year 1999, two new gravity (relative) surveys have been carried out (Fig. 1). The first one has been done under the supervision of the Royal observatory of Belgium in the South of the country (province of Luxembourg). The area has a size of 3800 km² and a density of 1 point per 5 km². A second survey has been carried out in the northern part of Belgium in the Kempen by the Meetkundige Dienst from the Dutch Rijkswaterstaat. The area size was 2800 km² and has a density of 1 point per 16 km²

Currently, the ROB aims at measuring two new areas. The first one in south west of Belgium is an area of 2000 km² with a density of 1 point per 5km² and a second one in the centre of the country an area of 1200 km² also with 1 point per 5km².

A new geoid will be computed when the complete coverage of the country is obtained.

3 Link to international permanent GPS/-GLONASS networks

Relation with IGS/EUREF (ROB)

The ROB has continued in 1999-2000 to operate its network of 7 permanent GPS stations. Four of them: Brussels (BRUS), Dentergem (DENT), Dourbes (DOUR) and Waremme (WARE) belong to the permanent EUREF network since 1996. The station in Brussels belongs also to the IGS network (since 1993) and submits hourly data.

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 coordina-

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tion of the activities related to the permanent EUREF network (BRUYNINX,1999), (BECKER,2000).

Due to repeated receiver failures, the ROB has stopped submitting RINEX data from its combined GPS/GLONASS receiver (3S-Navigation R100-30/T) to the IGEX. The ROB participated to the IGEX campaign from Sept. 1998 to March 2000. The time transfer data from the R100-30/T continued to be send to the BIPM, since the timing module of the receiver was not affected by the repeated failures.

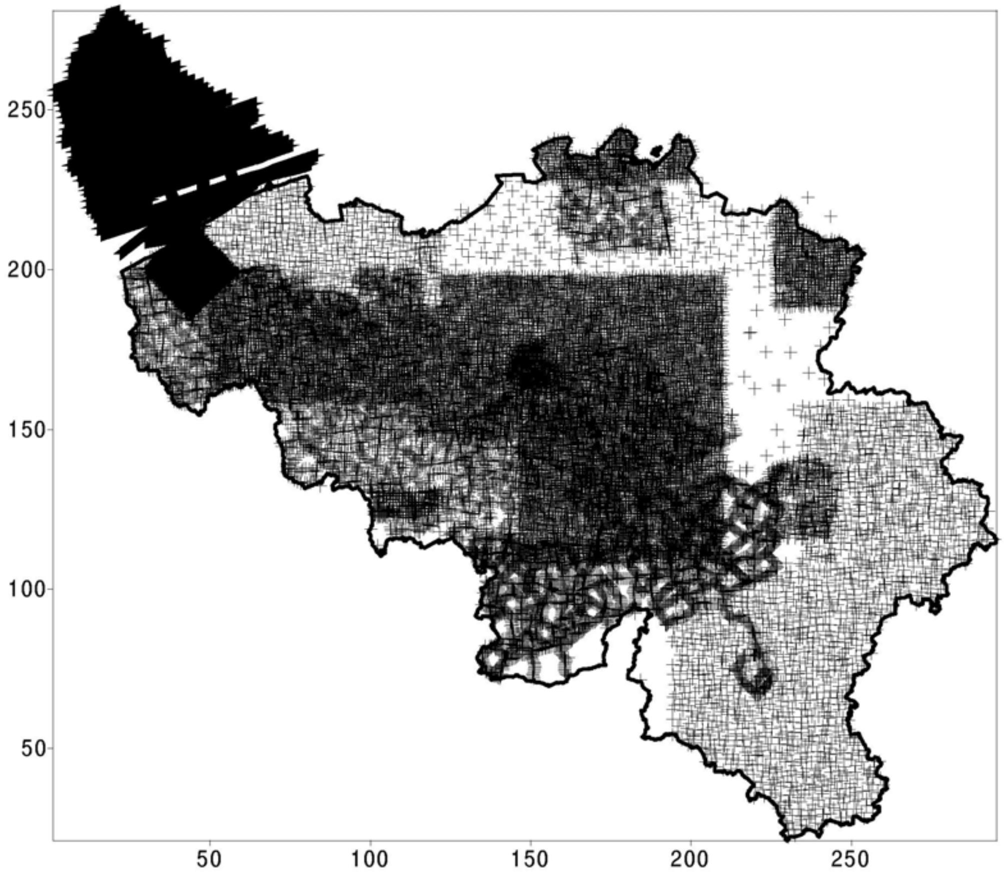

Fig. 1: Gravimetric coverage of Belgium

4 Ongoing Research

Network of permanent reference stations

GIS-Flanders, a regional governmental organisation, intends to optimise the use of geographical information in Flanders (Northern part of Belgium). In a test project, the NGI is working together with the GIS-Flanders Support Centre, in order to assure the best possible tie of geographic information both to the ETRS89 and the national grid.

Apart from that, a joint study on the integrity monitoring of GPS-RTK reference stations is in progress. Similar initiatives are taken in the other Belgian regions (Wallonie and Brussels). We can expect that within a few years Belgium will be covered with a dense network of permanent GPS stations installed for RTK applications.

Recently, different topographic services of the Flemish community purchased several dual frequency GPS receivers. During the training courses two problems were identified: how can the services exchange their measurements and results without introducing biases and what procedure has to be followed to integrate the GPS derived coordinates into the national cartographic system Lambert 72? In order to solve these problems, the RMA proposed to organise and analyse a common measurement campaign. The main focus of this campaign is to determine the coordinates of the reference points, used by each service, in an international established reference system such as ITRS or ETRS89 and consequently to derive a global transformation formula from this frame to the national cartographic system.

Application of WADGPS principles to a geographic small GPS network (RMA)

GPS augmentation systems combine the measurements of a continental network of permanent stations to determine several vectorial differential corrections for navigation purposes. The vectorial ephemeris correction is deduced from an orbit estimator using the observations at the different stations of the wide area network. These observations need to contain sufficient geometric information for a correct estimation of the satellite position. However, the geometry of a geographic small network, such as the network of the Royal Observatory of Belgium is insufficient for determining the position of the satellite. Therefor the RMA investigates the use of predicted IGS precise orbits.

In addition to this, the differential user usually navigates using a L_1-C/A code receiver: he is unable to correct the ionospheric refraction based on his observations. The network of reference stations allows to determine the vertical ionospheric refraction in grid points for the zone of interest (Fig. 1). At the RMA, procedures are being developed and investigated which can be used by the differential user to estimate the true ionospheric delay to a satellite by interpolating between the piercing points.

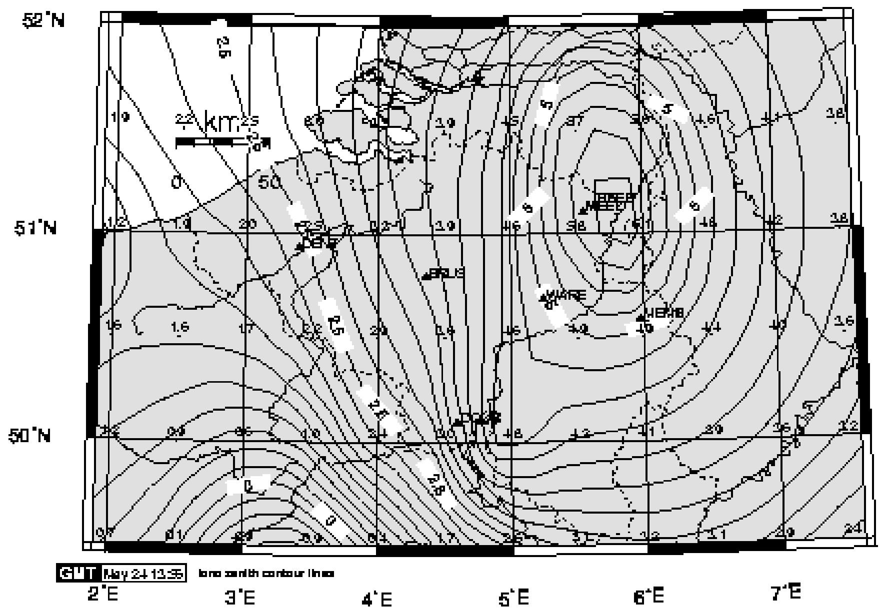

Fig. 2 - Instantaneous vertical ionospheric delay derived from the ROB network

Ionospheric refraction (ROB)

At the Royal Observatory of Belgium, the ionospheric activity is monitored since April 1993 using GPS measurements collected at Brussels. Since the end of 1998, the solar activity is increasing very quickly giving rise to a stronger ionospheric activity (WARNANT and POTTIAUX, 2000). In particular, in mid-latitude stations, this stronger ionospheric activity is characterized by:

- a larger Total Electron Content (TEC): Fig. 2 shows the daily mean TEC as measured at Brussels (latitude 50.8 ° N) using GPS measurements: the TEC was very low during the period 1995 - 1998. Then, several "jumps" have been observed since 1998, with a maximum in March 2000
- an significant increase of the number of ionospheric phenomena is detected (i.e. irregular changes in the TEC due for example to Travelling Ionospheric Disturbances, scintillations, ...).

Fig. 3 displays the number of observed irregular phenomena in the period April 1993 - April 2000. The number of events peaks each year in January; in addition, a tremendous increase of the number of events has been observed since the end of 1998 with a maximum in January 2000.

The present ionospheric activity cycle will probably reach its maximum during the year 2000, but the ionosphere will remain very active over the period 2000-2002.

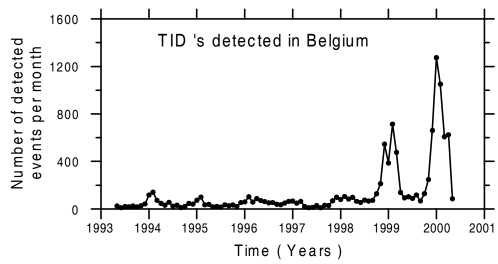

Fig. 3: Number of observed irregular ionospheric phenomena over Belgium

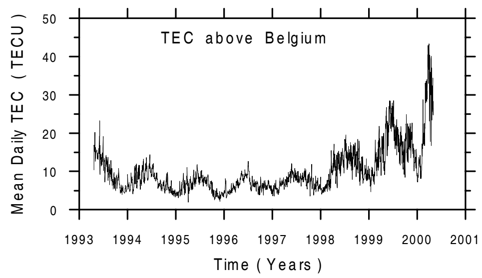

Fig. 4: Daily mean TEC measured in Brussels using GPS

Tropospheric refraction (ROB)

Since the end of 1998, the Royal Observatory of Belgium is involved in a research project entitled: "*Improvement of the tropospheric correction applied in GPS Geodesy by using the measurements of a water vapour radiometer and meteorological sensors*". This project aims improving the correction of the wet component of the tropospheric error by using the measurements collected by water vapour radiometers, radiosondes and GPS receivers collocated with meteorological sensors. In June 2000, a water vapour radiometer, ordered in 1999 at the Swiss Federal Institute of Technology of Zürich, will be installed at Brussels. In the meantime, the ROB is performing some preliminary tests using a radiometer borrowed from the Bundesamt für Kartographie und Geodäsie (Wettzell, Germany).

Time and frequency transfer using geodetic GPS receivers (ROB)

The time and frequency transfer experiments, which started at the ROB in the summer of 1998, were pursued during the last year. Special emphasis was put onto the quantification of the receiver sensitivity to ambient temperature variations. Within that frame temperature coefficients of 30ps/°C (for the L_1 signal path) were derived for the AOA SNR-12 receiver (BRUS, IGS station), connected to a H-maser (BRUYNINX et al, 1999). After the installation of a high performant temperature control (±0.2°C), we demonstrated that frequency transfer with a stabilities of 1.5 to 3.10^{-15} for averaging durations of 4 hours can be obtained routinely using the GPS data from the ROB. Experiments using IGS stations, separated by 280 km and driven by a H-maser demonstrate frequency stabilities reaching 1.610^{-15} for averaging durations of 32 hours (BRUYNINX and DEFRAIGNE, 2000).

In March 2000, after a period of degraded observations, the AOA SNR-12 was returned to the manufacturer. Since that time an Ashtech UZ-12 receiver acts as the IGS receiver in Brussels. Due to the handling of the external frequency within this receiver, it cannot be used for time or frequency transfer applications.

5. Outlook

Since the NGI started with GPS-surveying, 12 years ago, it determined for nearly each GPS-marker in its horizontal network (about 3000 points) also the height H using horizontal levelling. The initial purpose of this procedure was essentially to detect blunders.

Since the mean length of the NGI baselines is about 5 km and since the geoid is rather smooth in Belgium, we expect have: $\Delta h - \Delta H$ » 0 (h=ellipsoidal height).

Nowadays, these data can be used to determine a "correction surface" allowing to transform the GPS-derived ellipsoidal heights h into the national heights H. The purpose of the NGI is to compute, in co-operation with the ROB, a "correction surface" such that:

$$h - H - N = f(\varphi,\lambda),$$

where

- h comes from GPS-observations
- H comes from levelling
- N comes from gravimetric survey.

The ROB will continue its study of the ionospheric and tropospheric refraction. In particular, the measurements collected at Brussels by the water vapour radiometer and by the radiosondes will be used to compute the water vapour content at Brussels.

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

6. References

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