EUREF 2014 NATIONAL REPORT OF BELGIUM

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1. Contribution to the EPN

1.1 EPN Central Bureau

ROB hosts the EPN Central Bureau (http://www.epncb.oma.be/). In 2013, the site received about 2.2 million hits. Since June 2013, 6 new stations have been included in the EPN and updates of "The Procedure for Becoming an EPN Station" and "Guidelines for EPN Local Analysis Centres" have been released. The EPN CB web site has been updated to include information on the availability of the experimental RINEX 3 data for each of the EPN stations.

1.2 EPN Tracking Stations

ROB operates four permanent GNSS tracking stations which are included in the EPN: BRUS/BRUX, DENT, DOUR and WARE; except for DOUR all are streaming real-time data. BRUX, tracking GPS, GLONASS, Galileo, and BEIDOU satellites, also belongs to the International GNSS Service (IGS) tracking network and contributes to the IGS M-GEX campaign. BRUX daily and hourly RINEX files are available from ftp://gnss.oma.be/gnss/data/rinex/. A real time RTCMv3 stream is available from www.euref-ip.be on mountpoint BRUX0 and a binary SBF stream is available from www.euref-ip.be on mountpoint BRUX1. The latter stream is also used in the IGS-MGEX campaign.
More details on BRUX can be found at
http://www.epncb.oma.be/_trackingnetwork/siteinfo4onestation.php?station=BRUX_13101M010
In 2014, the full ROB network will be upgraded with SEPT POLARX4 receivers (tracking GPS/GLONASS/Galileo on L1/L2/L5) and TRM59800.00/NONE antenna.

1.3 Data Centers and Broadcaster

ROB maintains an historical EPN data center, providing access to all historical EPN RINEX data (ftp://epncb.oma.be/ftp/obs/). This historical data center is used for EPN reprocessing activities.

Real-time data of the ROB stations is available on an EPN NTRIP caster operated by ROB. Besides providing the ROB streams, the streams of other EPN stations are relayed. This way, ROB guarantees load sharing with the main EPN broadcaster at Bundesamt für Kartographie und Geodäsie (BKG), Germany and overall communication traffic reduction. ROB completely revised the real time GNSS data streaming caster. It is amongst others possible to connect the Networked Transport of RTCM via Internet Protocol (NTRIP) relay caster over https (with SSL encryption). At present about 124 EUREF streams are relayed, from 18 different casters. Users can apply for an account by filling in the web form on http://www.gnss.be/data.php#NTRIPaccess.

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In addition, ROB installed the Geodesy Seamless Archive Centers (GSAC, software developed by UNAVCO, http://facility.unavco.org/data/gsacws/gsacws.html). GSAC is web services providing seamless access to GNSS data and meta-data. The goal of the installation is to acquire experience with GSAC (see Baire and Bruyninx, 2014), evaluate its capabilities and provide recommendations to the EUREF Technical Working Group and EPOS WG4 with respect to the future use of GSAC in Europe, and specifically within the EPN. At present, it seems that GSAC does not provide any added-value to EUREF (whose data dissemination procedures are mature and reliable), but, with the appropriate developments, provide an added-value to disseminate data from dense national GNSS networks in the frame of EPOS.

1.4 Data Analysis

The ROB EPN Local Analysis Center is processing an EPN sub-network located around the Benelux (see http://epncb.oma.be/_dataproducts/analysiscentres/subnetwork.php?lac=ROB). During the Summer of 2013, ROB upgraded the GNSS data analysis done for EUREF to use the Bernese V5.2 software (previously V5.0). The new software includes more sophisticated modelling of the troposphere, ionosphere and atmospheric loading. Since the first week of Nov., 2013 all solutions submitted to EUREF are now based on V5.2 and in addition to the weekly submissions, now also final and rapid daily solutions are made available.

2. Services and Products Based on the EPN

2.1 Ionospheric products and Space Weather impacts

The European near real-time ionospheric products generated by the ROB, and based on the real-time GNSS data from the EPN, are maintained on the www.gnss.be web pages (Bergeot et al. 2013; Chevalier et al., 2013). Moreover, these models are freely available through the ftp server (ftp://gnss.oma.be) in real-time in the IONEX format. These IONEX files are used by the external community for research, publications (see Sotomayor-Beltran et al. 2013; Tsagouri et al. 2013) and ionospheric monitoring products (http://dias.space.noa.gr/, Belehaki et al., 2013).

Additionally, ROB is now maintaining a public data base with identified ionospheric events since 2012. For the period 2012-2013, more than 25 events of abnormal ionospheric activity have been reported at www.gnss.be. About 70% of these ionospheric perturbations are associated with coronal mass ejections, while about 20% are due to active geomagnetic conditions (of unclear origin) and 10% cannot be attributed to an identified phenomenon.

2.2 E-GVAP Analysis Centre and Tropospheric Products

The ROB develops and maintains a GNSS analysis centre participating to the E-GVAP program (see Pottiaux et al. 2013). This service uses state-of-the-art estimation techniques to provide the European meteorological institutes with near real-time (NRT) GPS-based tropospheric Zenith Path Delay (ZPD) estimates for assimilation in the Numerical Weather Prediction (NWP) models. The GNSS network analysed every hour includes today about 390 stations (Figure 1).

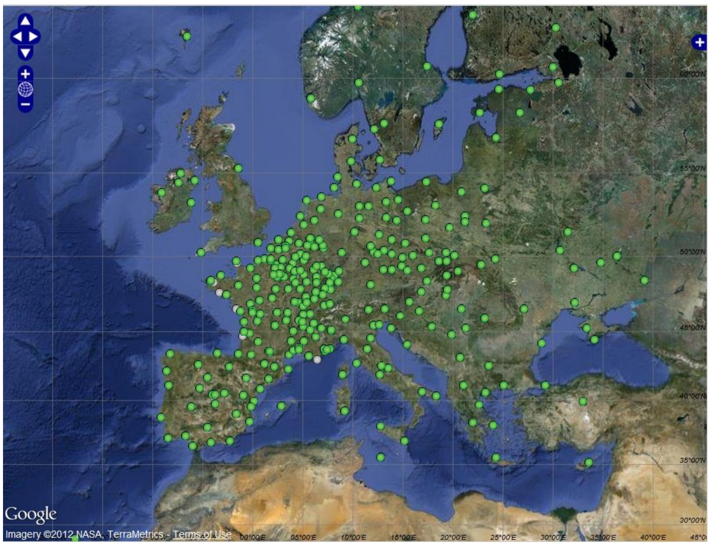

Figure 1: GNSS network processed in near real-time in the framework of E-GVAP (Status: 31 January 2014 some stations are located outside the region represented by the map).

The ROB also continued to develop a new European troposphere monitoring service to provide support to severe weather forecasting/nowcasting (see Pottiaux et al. 2014b). It is based on the exploitation of real-time GNSS observations from about 320 permanent stations (Figure 2) to provide 15-min updated ZPDs. It is currently applied on an hourly-basis and provided within E-GVAP as a prototype, while future developments target a sub-hourly monitoring of the European troposphere. This development anticipates the requirements that will appear in the next E-GVAP phase and the COST Action ES1206 (see section 3.4).

Figure 2: Real-Time GNSS network processed for severe weather monitoring (Status: 6 May 2014 some stations are located outside the region represented by the map).

3. Research Activities

3.1 IAG Working Group 'Integration of Dense Velocity Fields in the ITRF'

ROB is chairing the IAG Working Group "Integration of dense velocities fields in the ITRF". The Working Group is a collaborative effort between the different IAG regional reference frame sub-commissions who are submitting solutions for the GNSS permanent tracking stations installed in their continent to the Working Group with the goal to create a homogenous global velocity field. In 2013, ROB computed a multi-year solution by combining weekly position solutions covering the period 1996.0 - 2012.9 and submitted by 7 individual analysis centers: AFREF, APREF, EUREF, NAREF (NGS, GSB), SIRGAS and IGS.

A preliminary dense global velocity field was presented at the IAG Scientific Assembly in September 2013 in Potsdam, Germany (Legrand et al., 2013a 2013b), see Figure 3 (horizontal) and Figure 4 (vertical).

This current combination contains 1771 GNSS stations with more than 3 years of data and, compared to the individual solutions, it contains longer and more populated time series and has increased reliability thanks to redundancy. Today, the ROB is working on the finalization of this combination by adding about 1000 stations and refining outlier rejection and discontinuities detection.

The main drawback of this solution is the mix of different receiver antenna calibration models (mix of igs05.atx, igs08.atx and individual antenna calibration models). For this reason, all contributors will submit new weekly solutions compliant with IGS repro2 in 2014 and a new combination will be done in 2014.

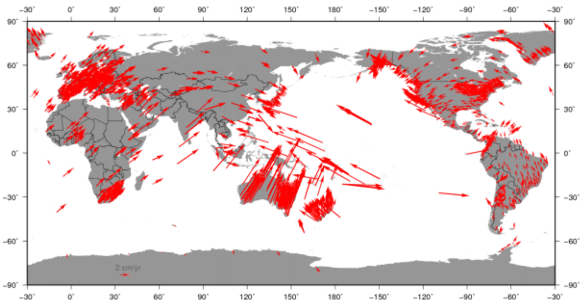

Figure 3: Preliminary horizontal velocity field

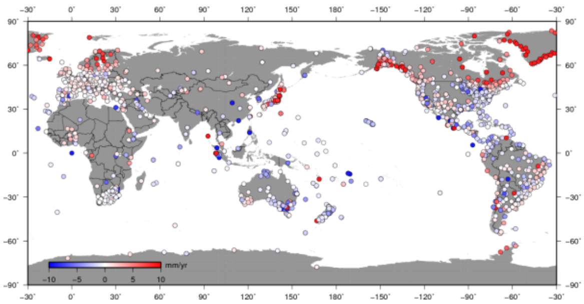

Figure 4: Preliminary vertical velocity field

3.2 Receiving Antenna Calibration Models

ROB finalized a paper on how different antenna calibration models impact estimated GNSS station positions (Baire et al., 2013). Refined outlier removal was applied to the results obtained in 2012 followed by different statistical tests to evidence the significance of the results. Station position changes larger than 1 mm in the horizontal and larger than 2 mm in the vertical were identified as statistically significant. In addition, all results demonstrated that the assumption that a type mean calibration correctly represents the antenna calibration model cannot be made for all antenna/radome types, especially if few samples have been used to generate the mean. Although individual antenna calibrations are far from perfect and affected at the few mm level by near field multipath, we conclude that they are more representative for the antenna phase centre variation of a specific antenna than a type mean calibration.

The study has however confirmed the complexity of GNSS antenna calibrations: 1) the calibrations themselves are not free from errors, 2) on site phase response can differ from the one from the calibration facility, 3) the effect of calibration errors on estimated site positions depends on the data analysis strategy as well as on the station latitude.

3.3 Long-term Stability of GNSS-based ZPD

ROB continued its collaboration with the Royal Meteorological Institute (RMI) of Belgium and the Belgian Institute of Space Aeronomy (BISA) on the inter-comparison of atmospheric water vapour observed by several ground-based (GNSS, sun-photometers), in-situ (radiosondes) and satellite-based (GOME/GOME2/SCHIAMACHY/AIRS) techniques (see Van Malderen et al. 2013; Van Malderen et al, in press).

3.4 COST Action ES1206 (GNSS4SWEC) on GNSS, severe weather and climate

ROB has co-founded and is actively involved in a new E.U. COST Action ES1206 "Advanced GNSS Tropospheric Products for monitoring Severe Weather Events and Climate" (GNSS4SWEC) that started in May 2013 (see Pottiaux et al. 2014a ; Pottiaux et al. 2014b ; Guerova et al. 2013). The Action aims to develop enhanced/new multi-GNSS methods and products for the monitoring of severe weather and climate. In that context, ROB co-chairs the second working group "Use of GNSS tropospheric products for high resolution NWP and severe weather forecasting". To contribute to GNSS4SWEC, ROB investigated the development of a GNSS nowcasting toolbox providing 5-min time resolution ZPD and horizontal gradients to study severe weather in the Benelux. ROB also studied the benefits and the impact of adding GLONASS observations (on top of GPS) in the estimation of ZPD and horizontal gradients with a hourly time resolution for post-processing applications (e.g. climate).

4. Contribution to Galileo

Starting in 2013, the ROB is collaborating with 5 European time laboratories to form the Time Validation Facility (TVF) for the European Global Navigation Satellite System Galileo. Galileo distributes the Galileo-to-GPS Time Offset (GGTO), i.e. the difference between the Galileo System Time (GST) and GPS time, needed for the interoperability with GPS, and furthermore enables the access to the Universal Time Coordinated (UTC) through a prediction of UTC-GST. This prediction is computed by the TVF based on the atomic clocks of 5 European Time laboratories, which are monitored using the IGS or EPN stations co-located with these laboratories (OPMT, PTBB, IENG, ROAP, SPT0). The ROB team is responsible for the validation of these timing informations broadcasted in the navigation message of the Galileo satellites. To that goal ROB developed a new approach to determine the hardware delays of GPS+Galileo stations. This validation shows that UTC is disseminated by Galileo with an accuracy of 10 nanoseconds, and GGTO with a similar accuracy.

More information on the activities of the GNSS research group of the Royal Observatory of Belgium can be found at http://www.gnss.be/.

5. Update of a part of the national levelling network

In the northeaster part of Belgium, in a region where coal was excavated during the second part of the twentieth century, signs of land uplift were noticed. GPS observations from a permanent station showed a more or less constant uplift during the last decade. This was reported in last year's national report. During 2013, a NGI team performed spirit levelling observations in this region, in order to update the levelling benchmarks.

In figure 5, which gives an overview of the levelling results, one can clearly see the correlation between the land uplift and the area of former mining activities. It is important to mention that the limit on the right (easter) side of the image is artificial. In fact the mining zone was at least twice as long, but the other half is situated in the southern part of the Netherlands. Our Dutch colleagues of ‘Rijkswaterstaat’ send us their recent levelling results for that region. They confirm the uplift effect for the entire mining zone.

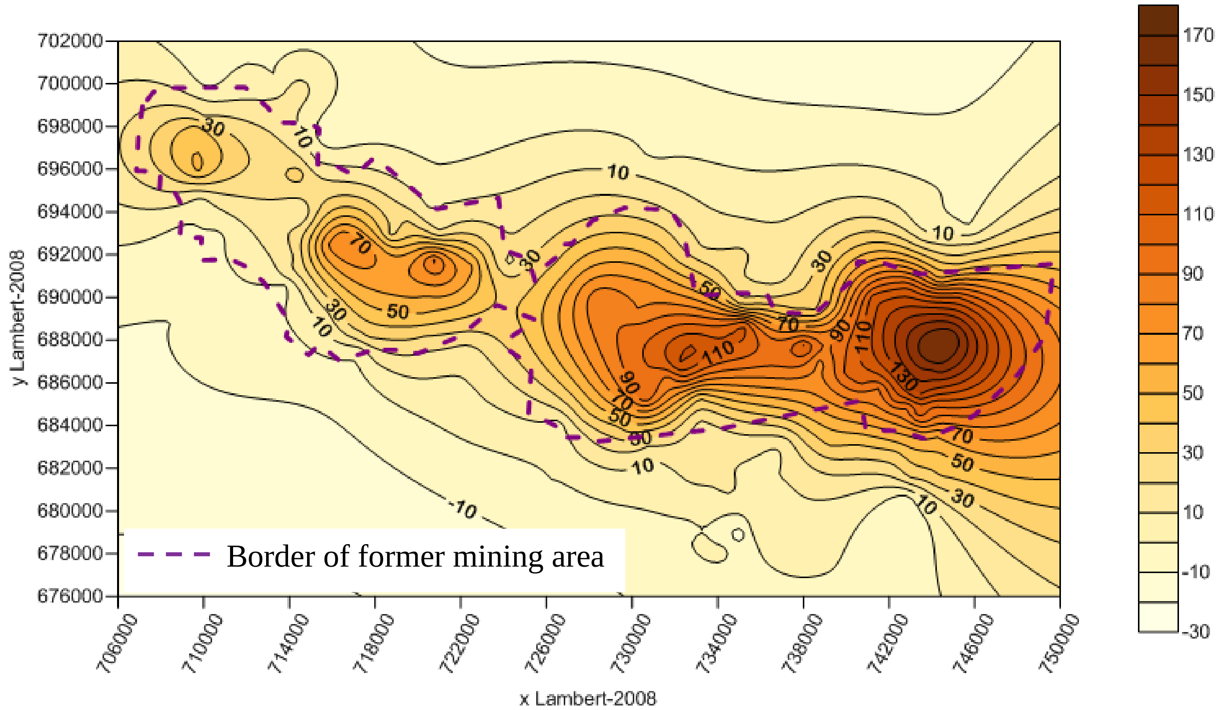

Figure 5: Height differences expressed in mm between levelling campaigns (2013 minus 2000)

It is interesting to point out that this phenomenon has been assessed and quantified by three independent observing techniques: spirit levelling, GNSS and radar altimetry. Professor Ramon Hanssen of the TU Delft treated several successive SAR-images (Synthetic Aperture Radar) covering the timespan 1992 – 2010. His results match perfectly with the outcome of our levelling campaigns.

6. Towards a new quasi-geoid and height-correction model

The models that are disseminated by the NGI to transform ellipsoidal height to ‘Ostend height’ (levelling reference) were established in 2003, combining gravimetric data and more than 3000 GPS-levelling points. Tests have shown that the standard deviation of this transformation is 2 cm. We think that the accuracy can be augmented through a better analysis of the gravimetric data, which is rather inhomogeneous. Next to that, during the last decade, a new set of GNSS-levelling points, with a better quality, has been observed.

Within the framework of the NEVREF-project (Vertical reference frame for the Netherlands mainland, Wadden islands and continental shelf), Professor Roland Klees and his team of the TU Delft are gathering all necessary data for a new geoid model for the Netherlands and the North see. The aim is link terrestrial gravity observations with data from various sources including the satellites GRACE and GOCE. He contacted us in order to obtain the Belgian gravity and GPS-levelling data. Next to these, we also delivered the data for the region south of Belgium, including Luxemburg, half of France and parts of Germany as Professor Klees was prepared to extend the new geoid model and include Belgium in it. Based on this new geoid, we hope to derive a new and more accurate height correction model for our country.

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