EUREF 2016 NATIONAL REPORT OF BELGIUM

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1. Contribution to the EPN

1.1 EPN Central Bureau

As EUREF Permanent Network Central Bureau (EPN CB), the Royal Observatory of Belgium (ROB) continued to manage the EPN CB and perform the following routine tasks:

- Daily data quality checks of the daily RINEX data;
- Daily checks of the meta-data of the daily RINEX data;
- 2-hourly checks of the meta-data and latency of the real-time EPN data streams;
- Daily checks of the latency and availability of the hourly and daily RINEX data;
- Daily updates of the residual position time series of the EPN stations;
- Regular updates of several EPN meta-data files (station site logs, antenna calibrations, ocean loading parameters, site coordinates,…) in support of EPN data analysis.
- Monthly updates of our historical EPN data center

Since June 2015, ROB integrated 20 new stations in the EPN network: 4 in Spain, 4 in Sweden, 3 in Italy, 2 in France, 3 in Serbia, 2 in the Netherlands, 1 in Latvia and 1 in Germany.
The EPN CB was upgraded to perform additional monitoring tasks:

- Check the adherence of the EPN regional broadcasters to the newly released EPN broadcaster guidelines. This includes new verifications of the meta-data in the broadcasters' sourcetables and crosschecking them with the observation streams and the site logs. A summary of the results is provided on the EPN ftp site ftp://epncb.oma.be/pub/center/broadcasters/COMPARE_BRDC.txt
- Verify the availability of the new RINEX 3 data (short and long filenames) in the EPN Data Centers, provide the information on the EPN CB web site, and inform station managers if data are missing.
- Verify the compliance between the satellite systems (e.g. GPS, GLONASS, Galileo) included in the station RINEX observations files against the information in the site logs.

We are presently in the process of upgrading the internal software, databases and external web pages to switch to the new international standard 9-character station identification codes (instead of 4 characters).

In support of the EPN Densification Working Group, ROB maintains a complete new section of the EPN CB web site (http://epncb.oma.be/_densification). We also developed a script that allows third parties to validate their site log meta-data without using the EPN CB web form; it was distributed to IGN France to receive first feedback. We also contacted agencies over all Europe to gather meta-data from their densification stations. Presently, ROB has collected meta-data for 701 densification stations.

In Oct. 2015 a new version of "EPN guidelines for data centers and EPN broadcasters" and of the "Guidelines for EPN stations and Operational Centers" was released (http://epncb.oma.be/_documentation/guidelines/guidelines_station_operationalcentre.pdf). It provides more detailed information on the usage of RINEX 3 in the EPN.

ROB is now running the data quality checks of the EPN stations with G-Nut/Anubis (Vaclavovic and Dousa, 2014) on a daily basis in parallel to the operational EPN data quality checks done with TEQC (Estey and Meertens, 1999) and Qualcheck (inhouse developed software). Before then end of 2016, the operational multi-GNSS data quality checks at the EPN CB will be purely based on G-Nut/Anubis.

The full design of the EPN CB web site (http://www.epncb.oma.be) is presently revisited in order to improve its usage on tablets and smartphones.

1.2 ROBs EPN Tracking Stations

In the fall of 2015, we installed new multi-GNSS antennas in all our EPN stations so that they can all track the GPS L5 signal and Galileo signals at full strength. In addition, since the beginning of 2016, all our stations are providing RINEX 3 data using the long file name conventions.

1.3 Data Analysis

ROB continued to deliver daily rapid and final position and tropospheric zenith path delay estimates to EUREF. Since June 2015, five new stations were added in the ROB network (KOS100NLD, ONS100SWE, DLF100NLD, BCLN00ESP and BRMF00FRA), bringing the total of EPN stations submitted to EUREF at 77.

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-IONO software (Bergeot et al. 2014, 2015a), and based on the real-time GNSS data from the EPN, are maintained on the www.gnss.be web pages. These models (IONEX format) are freely available in real-time through the ftp server (ftp://gnss.oma.be). Based on this product, ROB is maintaining a public database with identified ionospheric events since 2012 (Bergeot et al., 2015b). In 2015, six abnormal ionospheric activities due to space weather event were reported (http://gnss.be/ionospheric_event.php). The EPN data were also used to monitor the impact of the March 20th 2016 eclipse on the ionosphere in near-real time (http://sidc.be/eclipse2015/).

2.2 Tropospheric Products and E-GVAP Analysis Centre

ROB maintained its GNSS analysis centre participating to the E-GVAP program (Pottiaux E. 2015a) and provided European meteorological institutes with near real-time (NRT, i.e. hourly) GPS-based tropospheric Zenith Path Delay (ZPD) estimates for assimilation in the Numerical Weather Prediction (NWP) models. In its continuous development process, the analysis centre strategy was upgraded from GPS-only to GPS+GLONASS, uses the Bernese GNSS v5.2, and includes 50% more stations (~550 stations). Aside from this legacy processing, two new contributions to E-GVAP were developed: 1) a new hourly global analysis of ~290 stations (mainly IGS sites) to support global NWP models and 2) a processing running every 15 minutes to support nowcasting applications in the Benelux + U.K. area. The latest is based on the processing of real-time observations from ~225 EPN and national GNSS stations. First tests of assimilating ROB's tropospheric products within the high-resolution ALARO NWP model running at the Royal Meteorological Institute (RMI) of Belgium have been achieved. It demonstrated neutral to positive impact on the prediction scores of the next hours (De Cruz et al. 2015).

3. EPOS

The H2020 project EPOS-IP (European Plate Observing System Implementation Phase) started on Oct. 1, 2015, ROB contributes to

- The preparation of the consortium agreement for the GNSS component of EPOS
- The structure and content of the GNSS meta-data database to be used within EPOS
- The future EPOS data (and meta-data) flow

4. Research Activities

4.1 IAG Working Group ‘Integration of Dense Velocity Fields in the ITRF’

The IAG Working Group “Integration of dense velocities fields in the ITRF” chaired by ROB ended in 2015. Based on 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, the Working Group derived a global velocity field for about 2600 stations having more than 3 years of data. Based on this velocity field, the intraplate deformations have been derived for the major tectonic plates (Figure 1) highlighting the very good agreement with ITRF2008 plate motion model and the quality of the estimated combined velocity field that shows very small residual velocities in stable zones.

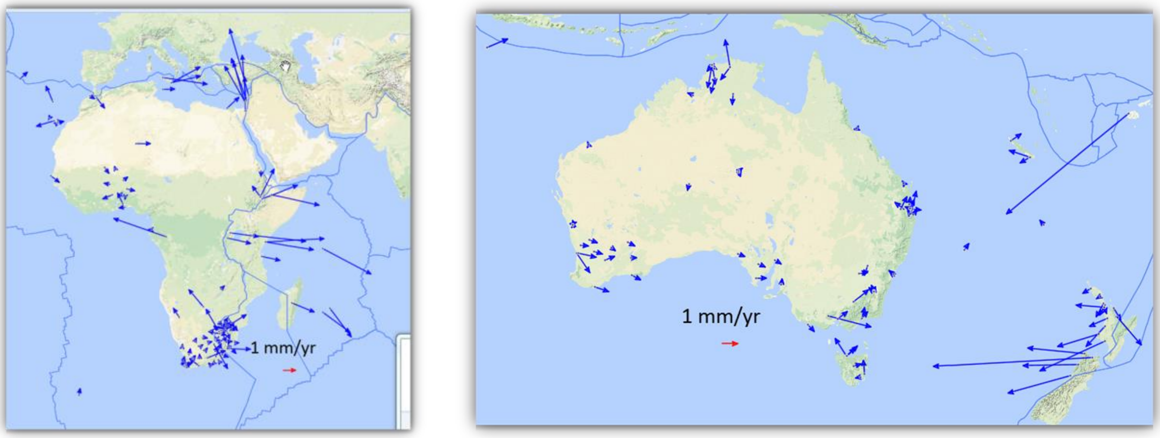


Figure 1: Residuals velocity field for African and Nubian plate (left) and Australian plate (right).

4.2 Long-term Stability of GNSS-based Tropospheric Zenith Path Delays

ROB collaborated with the Royal Meteorological Institute (RMI) of Belgium and the Belgian Institute of Space Aeronomy (BISA) to assess the trends observed in the Integrated Water Vapour (IWV) derived from the IGS repro1 tropospheric product by comparing them with IWV time series derived from the ERA-interim re-analysis and GOMESCIA satellite data (Van Malderen et al. 2015). We also started a new activity in collaboration with RMI (in the framework of the COST Action ES1206) on the homogenisation of IWV time series derived from the IGS repro 1 product (Pottiaux et al. 2015d). In addition, we collaborated with ESGT (France) and other partners to study the global validity and behaviour of tropospheric gradients estimated by GPS (Morel et al 2015). This last study will be extended world-wide next year. Finally, in the framework of the national project CORDEX.be, we started a reprocessing activity to produce GNSS-based tropospheric products for the verification and validation of high-resolution climate model runs over Belgium (Pottiaux et al 2015e). This re-processing is almost finished.

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

ROB continued to co-chair the WG2 of the E.U. COST Action ES1206 “Advanced GNSS Tropospheric Products for monitoring Severe Weather Events and Climate” (GNSS4SWEC) and to contribute to the Action with a particular emphasis on 1) using real-time GNSS observation and orbit and clock products to provide real-time troposphere estimates computed with the GNut TefNut Software (Figure 2) in support of severe weather forecasting/nowcasting (Pottiaux et al. 2015b+c); 2) producing Slant Tropospheric Delays (STDs) with the Bernese GNSS software based on the benchmark campaign setup in GNSS4SWEC. ROB’s STDs were compared to STDs produced by others partners and from other techniques, which demonstrated that ROB’s STDs are of the same quality level as other state-of-the-art STD products; and 3) on the trends and homogenisation of IWV time series derived from the IGS repro 1 tropospheric product (Pottiaux et al. 2015d). About the latest activity, we organised a dedicated workshop on ROB's premises on 'Data Homogenisation'.

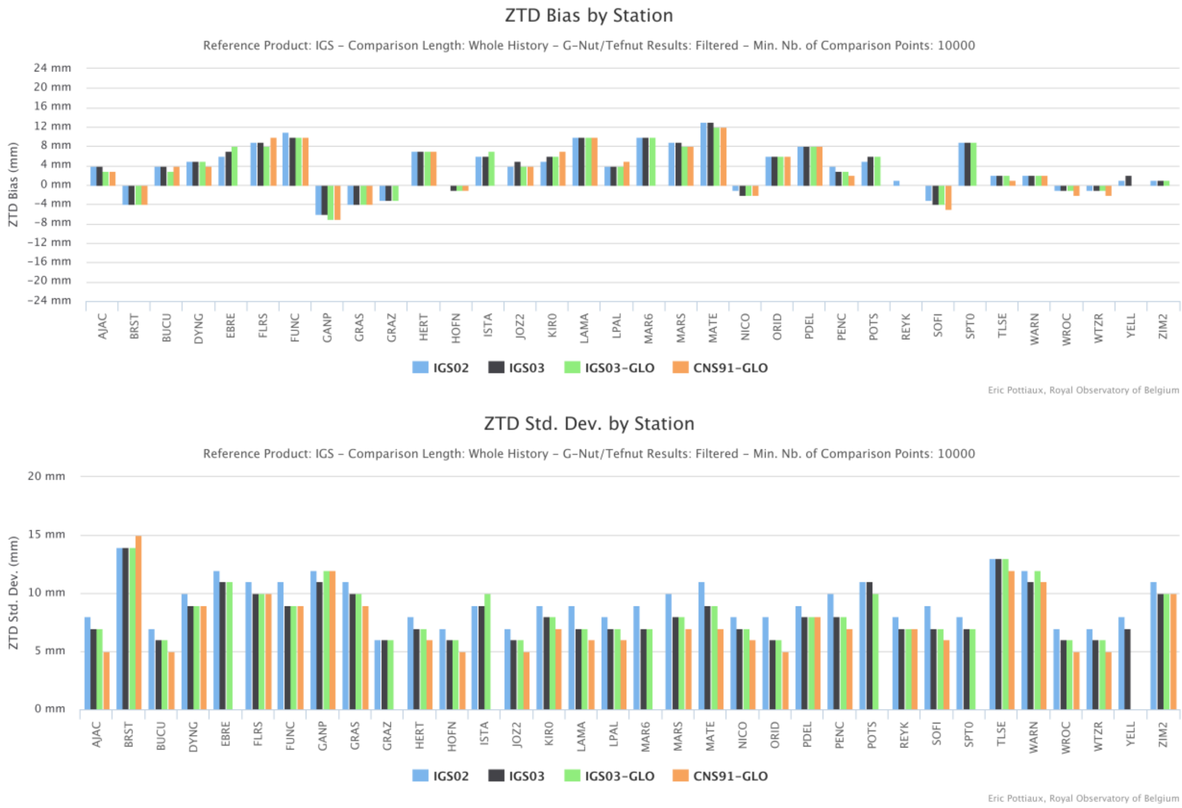


Figure 2: Average bias (Top) and average standard deviation (Bottom) per station over 1 year between the ZTDs computed in real-time with the GNut/Tefnut software with respect to our PPP Bernese post-processed solution.

4.4 Research on Space Weather impact

ROB reprocessed the entire EPN to produce IONEX files since 1998. Based on this new data set, we developed an empirical model in order to predict the vertical total electron content (vTEC) over Europe using only one solar index in entrance. Among all the tests, the optimal model to predict the vTEC every 15 min. presents mean differences with observed values of 2.4 ± 2.8 TECu and 10.0 ± 25.2 % for the relative differences. Differences larger than 15 TECu occurred during abnormal ionospheric activity correlated to space weather events (Figure 3, Bergeot et al. 2015c).

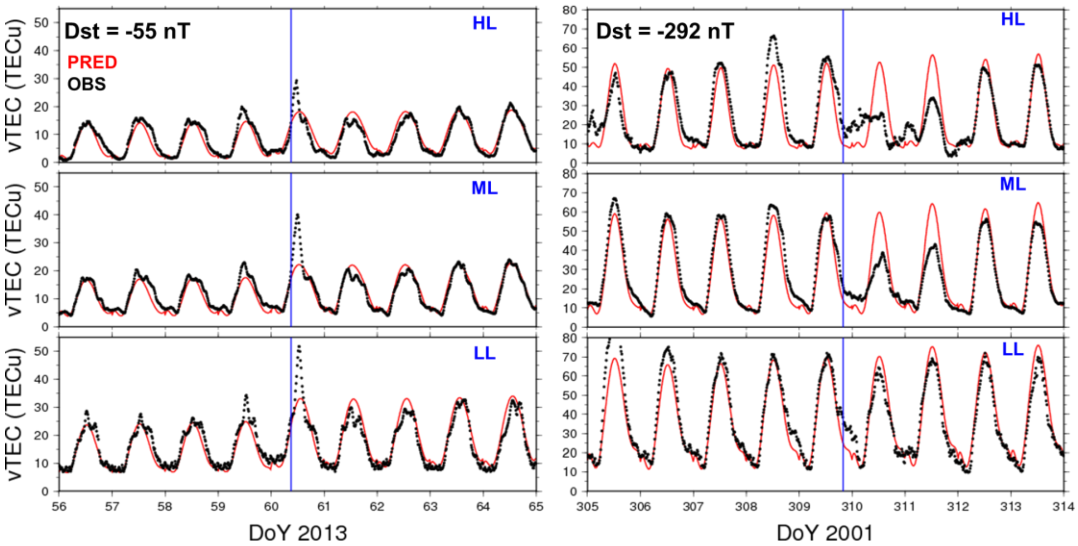


Figure 3: Observed and predicted vTEC during two identified space weather events at high, mid and low-latitudes (HL, ML and LL i.e. 61°N, 50.5°N and 36°N respectively). The red line represents the prediction. The black dots are the observations. The Dst index is delivered by the WDC Kyoto Observatory. The blue line is the storm onset. Left: moderate geomagnetic storm (01/03/2003); Right: intense geomagnetic storm (05/11/2001).

ROB investigated the impact of solar radio bursts emitted close to the GNSS frequencies on GPS and GLONASS receiver carrier to noise density (C/N0) over Europe between 1998 and 2013. A 4-level index is now routinely estimated in near-real time for detecting and quantifying solar radio burst degrading the GNSS signals reception (Figure 4, Chevalier et al. 2015). Already in 2015, 2 events were detected with this new tool.

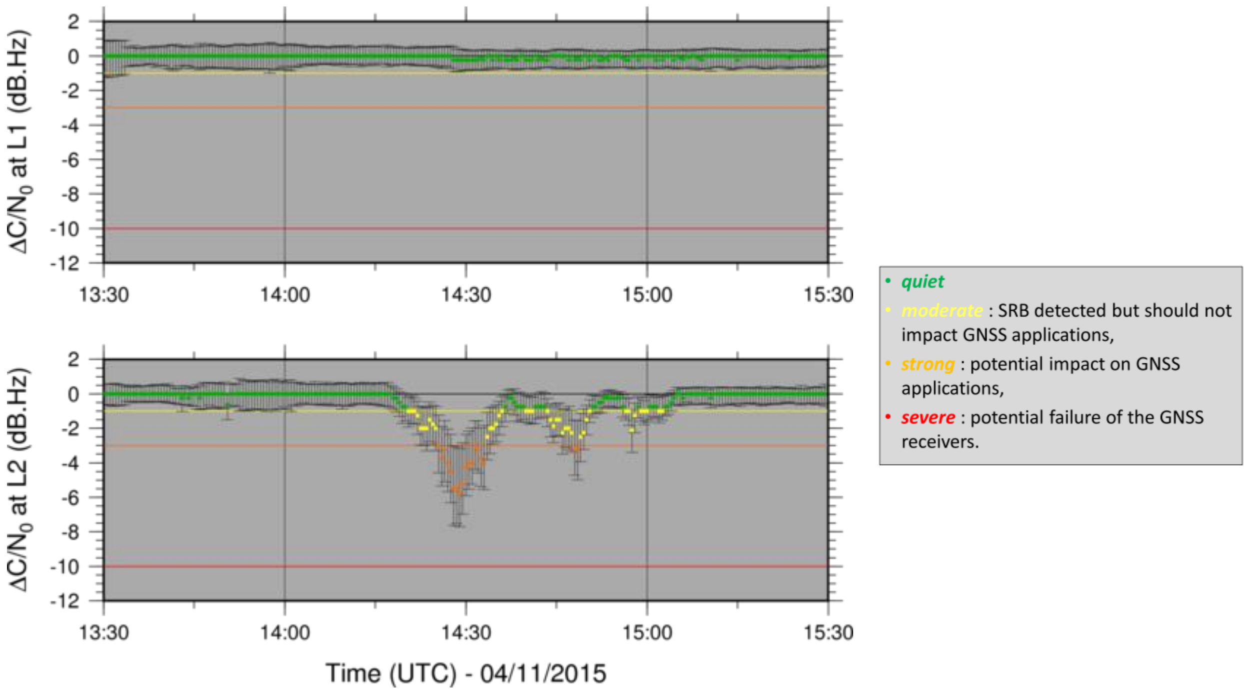
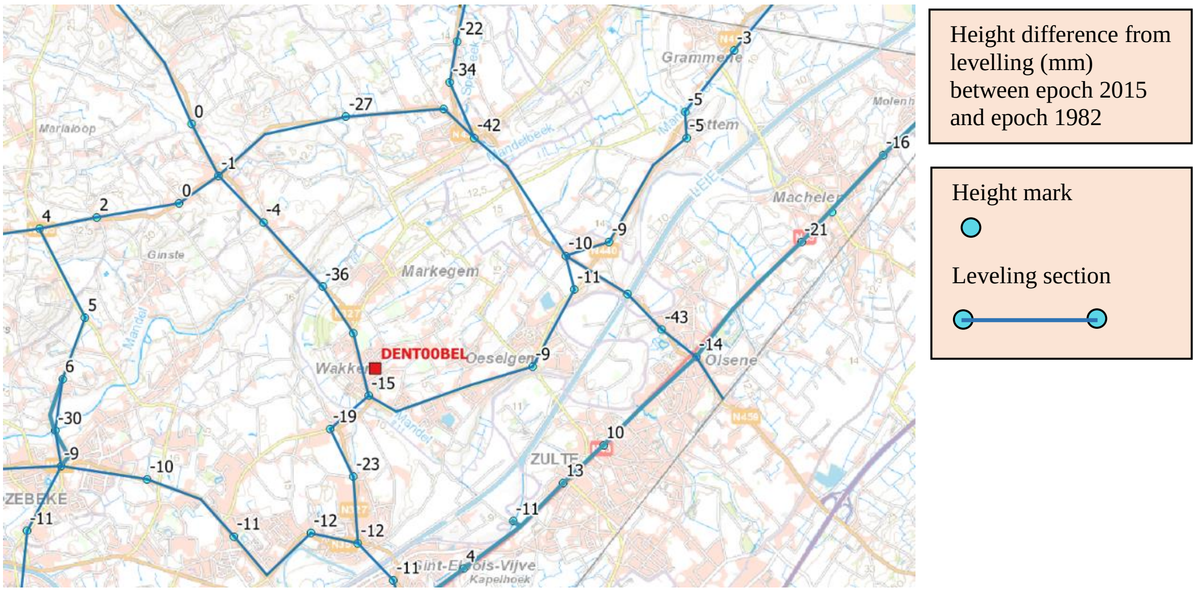


Figure 4: Median of the abnormal fades of the carrier to noise density (ΔC/N0) at the 2 main GPS frequencies of the real-time EPN (89 stations) during the solar radio bursts of the 25th November 2015.

5. Update of a part of the national levelling network

As mentioned during the most recent reports to the EUREF sub commission, we have not been able to obtain the necessary budgets for the systematic maintenance of the national levelling network. So we concentrate on areas for which we have indications of height changes. One of these signals was provided with the long term behaviour of the EPN station of Dentergem (DENT00BEL). Compared to the results of the rest of Belgian EPN stations – all of them are active since 1996 - DENT00BEL seems to be subsiding slightly, but more or less continuously. So over a period of several decades, the difference could become significant. This subsidence has been confirmed by means of the levelling campaign we carried out last year where we compared the height with respect to the previous levelling results obtained in 1982.



6. Update of the distribution of the geodetic points

Since the beginning of this century all information about the Belgian geodetic points has been available via a web application. Last year, this application has been redesigned and adapted to the techniques that are used on the internet nowadays. All data concerning the geodetic points, including the precise coordinates can now be accessed by smartphones too. Of course we focus on the Belgian users, so this application (http://www.ngi.be/gdoc) is limited to the national languages.

7. AGN (Active Geodetic Network)

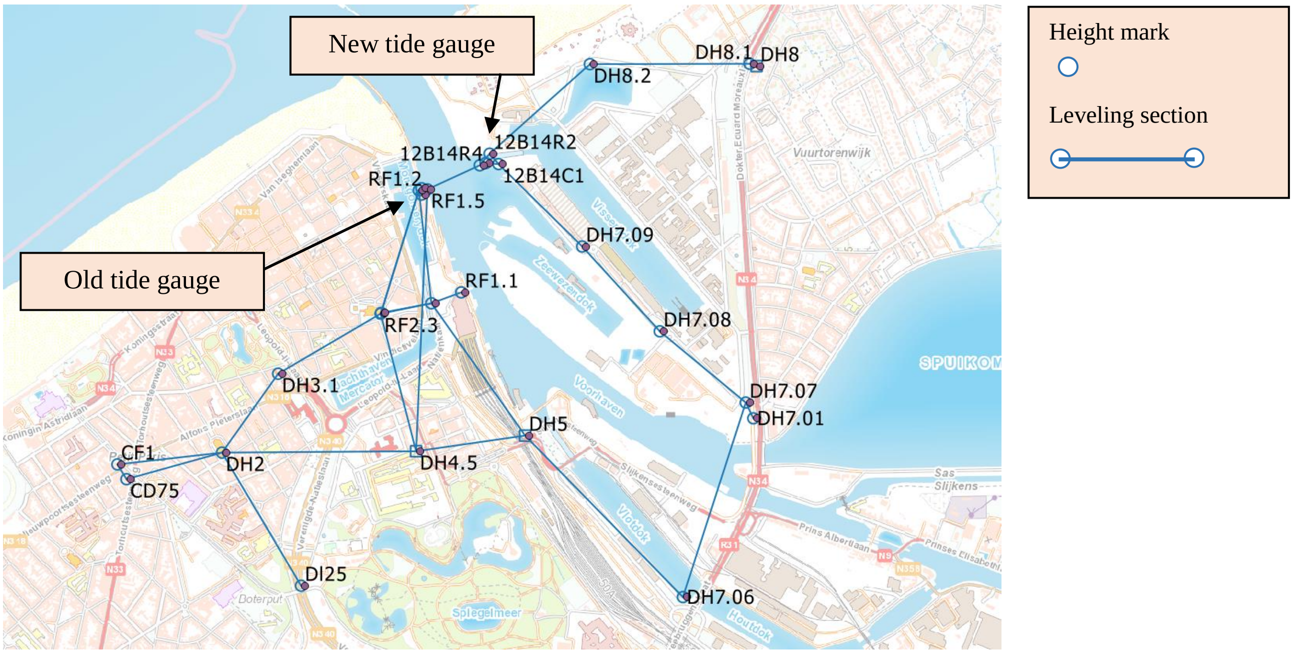
Since 2002 we perform a daily and weekly solution for all the permanent GNSS stations in Belgium that are part of the three Belgian RTK networks. We continue doing this work to see the stability of those stations.

Since the beginning of 2015 we are taking part in the **EPN Densification project** and we deliver every week a solution to this project from all those permanent GNSS stations. We have been delivering all our weekly solutions starting **from week 1656** (2 October 2011). This was the start of the "EUREF BE/2011 campaign" for which we submitted our final report (V2.4, May 2012) to the EUREF Technical Working Group for evaluation.

8. Future plans

The port of Ostend houses our most important tide gauge, which was used to fix the origin of the national height system. This tide gauge will have to be pulled down soon, so a new one has been constructed a couple of hundreds of meters away. Recently the NGI has done intensive observations, both with GNSS and classical methods, to assure the best possible link between these two tide gauges. During this campaign, we experienced some strange behavior of the static GNSS observations, for which we believe that near field multipath might be the cause. For the sake of this project, but also for height determination with GNSS in general, we plan to do further intensive testing to understand more about this phenomenon.

Integrating the new tide gauge in Ostend by classic leveling and GNSS observations



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