


OLG REPRO2 – Start of reprocessing the densification networks

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Abstract

OLG (Observatory Lustbuehel Graz) as a joint cooperation of the AAS (Austrian Academy of Sciences) and the BEV (Bundesamt für Eich- und Vermessungswesen) acts also as an international analysis center for GNSS networks since more than 20 years. Apart from the EPN (European Reference Frame Permanent Network) sub-network four densification networks are permanently analyzed with regions in Austria, Central Europe, Greece and around the Arabian Plate. Now the international REPRO2 project enables the reprocessing of about 20 years of data using reprocessed orbits and clocks and new models of the ionosphere and troposphere to reach a precision near several millimeters. The first results and comparisons of the years 2006 and 2007 are presented.

Keywords: GNSS, reference networks, geokinematics, time series, reprocessing

Kurzfassung

OLG (Observatorium Lustbühel Graz) ist ein Gemeinschaftsprojekt der ÖAW (Österreichische Akademie der Wissenschaften) und des BEV (Bundesamt für Eich- und Vermessungswesen). Ein Teil davon ist das internationale Auswertezentrum für GNSS-Netze, das seit mehr als 20 Jahren aktiv ist. Außer dem Sub-Netz des EPN (European Reference Frame Permanent Network) werden vier weitere Netze permanent bestimmt. Die regionalen Schwerpunkte sind dabei Österreich, Mitteleuropa, Griechenland und die Arabische Platte. Das internationale Projekt REPRO2 macht es möglich, dass die Beobachtungen der letzten 20 Jahre mit Bahndaten im aktuellen Referenzsystem und neuen Modellen von Ionosphäre und Troposphäre in einer Genauigkeit von wenigen Millimetern neu ausgewertet werden. Die ersten Resultate der Jahre 2006 und 2007 werden im Vergleich mit den früheren Resultaten vorgestellt.

Schlüsselwörter: GNSS, Referenznetzwerke, Geokinematik, Zeitserien, Reprocessing

1. Introduction

More than 20 years ago the analysis of GNSS signals (at that time GPS only) started to introduce a modern 3D-reference frame. State of the art models have been used to achieve a precision of centimetres. The models of orbits, clocks, ionosphere, troposphere, the antenna calibration and other parameters have been improved since that time. Therefore the coordinates can be estimated almost at the millimetre level. Stacking old and new solutions together results in a time series of products containing systematic biases. This degrades the results even the GNSS signals would have provided better results since the beginning. When it was possible to combine GPS and GLONASS the analysis had to be extended.

The first IGS reprocessing, called repro1, started in 2008 to compute orbits and station coordinates[1)]. Afterwards repro2 started in 2013 and is expected to finish within short time[2)]. The goal is to provide a modern and precise contribution to the current geodetic reference frame, e.g. ITRF2014 (International Terrestrial Reference Frame 2014) coming soon. OLG (Observatory Lustbuehel Graz) is contributing to the densification of ITRF on a regional basis. Out of the four different regions (Austria, Central Europe, Greece, Eastern Mediterranean) the Austrian part is presented in the article. The usual products are weekly coordinate results in SINEX (Solution Independent Exchange) formats. For climatology also zenith troposphere delays are provided too. Reference frames are not only mandatory for geodetic issues but also for several geo-related sciences, like climatology and tectonics [1].

The densification networks of OLG as a joint cooperation between the Federal Office of Metrology and Surveying (BEV) and the Austrian Academy of Sciences (AAS) have two main targets: geodetic reference and reference for geokinematics as a part of modelling crustal deformations. Analysing permanent GNSS stations with international standards the products of time series refer to different models and references and ignored completely GLONASS until 2014. The time series of coordinates combining the different results cause systematic biases which cannot be neglected by increasing the precision to a target of ± 1 mm. The need of improving this

1) http://acc.igs.org/reprocess.html
2) http://acc.igs.org/reprocess2.html

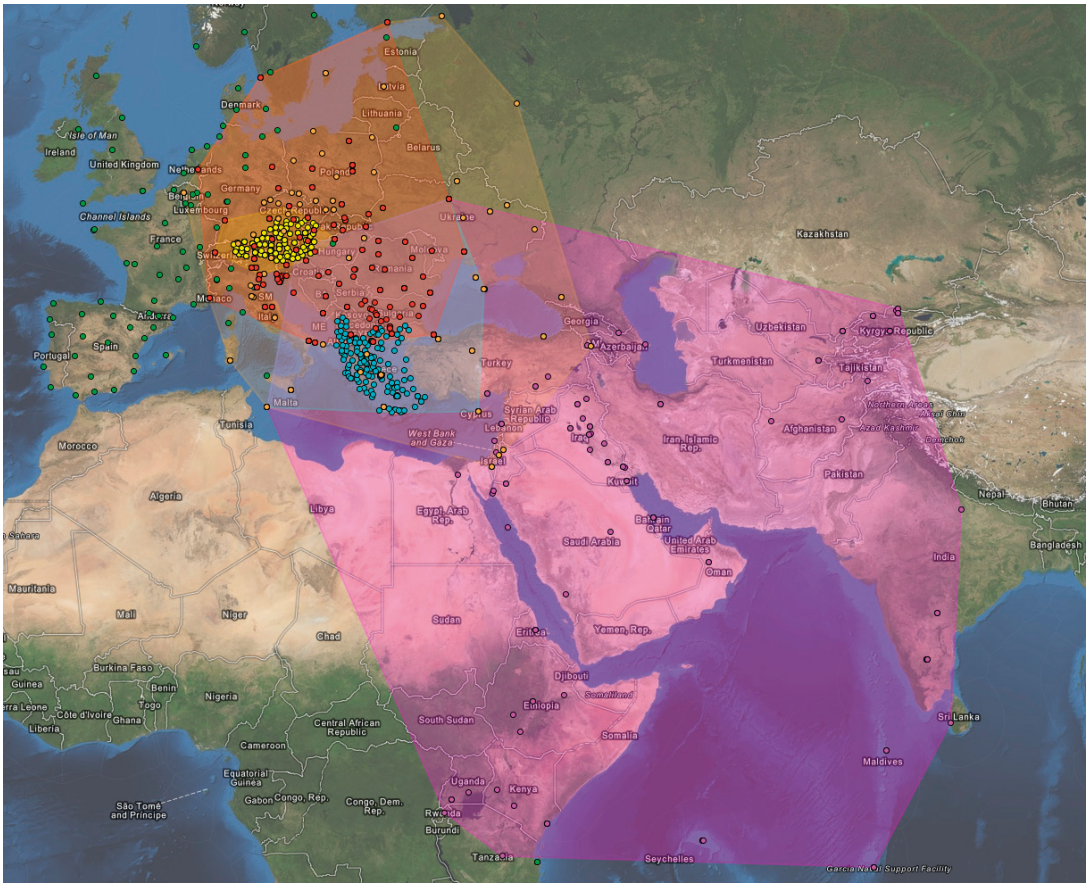

Fig.1: Geographical overview of AMON (yellow), CERGOP (red), GREECE (cyan) and MON (magenta) with selected stations for REPRO2

situation was felt several years ago also at OLG. A small repro1-type effort was done in 2012, only for the Austrian Network and a subnetwork of EPN (EUREF Permanent Network) of year 2006. With new resources, new models and the switch to an analysis of both GPS and GLONASS in 2014 the decision was made to start with the actual analysis like repro2. The features of repro2 were adopted for all OLG networks except EPN. The results should follow the guidelines of the IAG (International Association of Geodesy) Working Group "Integration of dense velocity fields into the ITRF"[3] [2] even if the results will come too late for the new ITRF2014 publication. It is supposed that the work will continue. A further decision was made that OLG REPRO2 should start with the year 2006 because the number of stations increased significantly at that time. The first step would be a reprocessing of the years 2006–2014. The second step should follow with years 2006 back to 1994. The final step should be the inclusion of epoch campaigns 1992–2012 mainly within and around Austria. The reprocessing started late in 2014 with 2006 and is still in progress. Since 2014 the actual weekly results are submitted to the IAG Working Group mentioned above to support the densification. Concerning the reprocessing IAG working group (representation European densification) decided to take over only a reprocessing of all years, therefore the results have to be stored meanwhile.

2. Data Overview

With an increase in the number of stations the extent and also the numbers of analysed networks increased. Presently there are four networks outside the EPN contribution, AMON (Austrian Monitoring Network), CERGOP (Central European Research on Geodynamics Project), GREECE and MON (Monitoring Oriental Network).

3) http://iagvf.oma.be/index.php?page=final_guidelines

While AMON's first target is the monitoring of the Austrian reference tied to ETRS89 (European Terrestrial Reference System 1989), CERGOP tracks intraplate movements of the Eurasian Plate in Central Europe, GREECE the boundary zone between Eurasian Plate, Nubian Plate, Anatolian Plate and diverse other plate fragments around the southern Balkan Peninsula. MON finally is determined to track the movements of the Arabian Plate against its surrounding plates. Between 2006 and 2014 the number of stations to be processed raised from approximately 250 to 400. Before 2006 the numbers drop significantly because several parts are not covered at all or with poor station density (e.g. Greece). In general the networks to be reprocessed contain more stations than those submitted every week for densification. The reason is the inclusion of former stations and also stations with a long history to get a better reference in early times are added. Providing IGb08 values as constraints are consistent and there should be no significant biases due to varying numbers of reference stations within the last 20 years. An overview of the networks is shown in Figure 1.

OLG REPRO2 is mainly focussed on positions, velocities and zenith troposphere delays of the stations. Therefore GNSS orbits and clocks, pole rotations, tidal corrections etc. will be taken from repro2 results of IGS (International GNSS Service) even though they are provisional. The guidelines of analysis are taken from EPN[4]. As reference sites several IGS and EPN sites with their coordinates and velocities in IGb08 (update IGS 2008) are taken trying to have a well distributed coverage if possible. The antenna calibration values are taken also from IGb08, combining IGS, EPN and national (individual) values.

3. Analysis Strategy

For analysis the Bernese Software version 5.2 was used[5]. The processing is based on the guidelines of EPN analysis centres in the current form[6]. They demand a combination of GPS and GLONASS observations. Some adaptions to the guidelines have been made. The GPS and GLONASS orbits and clocks are taken from IGS repro2 and for the troposphere a priori models the VMF1 (Vienna Mapping Function [4]) was chosen. The data were combined to baselines which formed the four networks shown above. It was decided to keep the four networks in general without change to a clustering of all stations into one network. This decision was more a matter of different institutional targets (IAG and BEV, reference frames, CERGOP and others, geokinematics) than keeping the traditional way. Having enough overlapping stations the networks can be combined for a single densification solution as well as the single networks may be submitted to special users and contributors of data. The clustering has to be introduced around 2010 when the number of stations in some networks (AMON, GREECE) starts to reach the number of 100 stations for analysis. At present the computation time of the networks increases exponentially with the number of stations. The final step for one day needs about four minutes for 50 stations while it increases to 25 minutes with 100 stations.

For the analysis the Bernese Processing Engine is used as an automatic procedure to produce results from observations and other inputs. Having different stations from different sources which do not fulfil the IGS and EPN [5] guidelines sometimes a pre-analysis is necessary to add or change meta-information. Also stations with bad data have to be eliminated during the automatic reprocessing. Finally the results are checked by stacking the daily normal equations to a time series which should show outliers, discontinuities or biases by bad referencing stations.

4. First Results and Comparisons

In Table 1 the number of analysed stations for REPRO2 in 2006 and 2007 is shown. The increase of the number of stations from 2006 to 2007 is clearly seen. For all networks an increase can be seen which proceeds until today. Figure 2 and Figure 3 show the changes of the time series for one example station ASCH (Aschau) in Germany. The part of 2006 was already corrected by repro1. Therefore the differences are quite small

Network	Number of stations analysed	
	2006	2007
AMON	87	99
CERGOP	64	80
GREECE	27	39
MON	51	75

Tab. 1: Number of analysed stations for years 2006 and 2007

4) http://www.epncb.oma.be/_documentation/guidelines/guidelines_analysis_centres.pdf

5) The manual is not yet published. Basic features can be seen in [3], the manual of version 5.0

6) http://www.epncb.oma.be/_documentation/guidelines/guidelines_analysis_centres.pdf

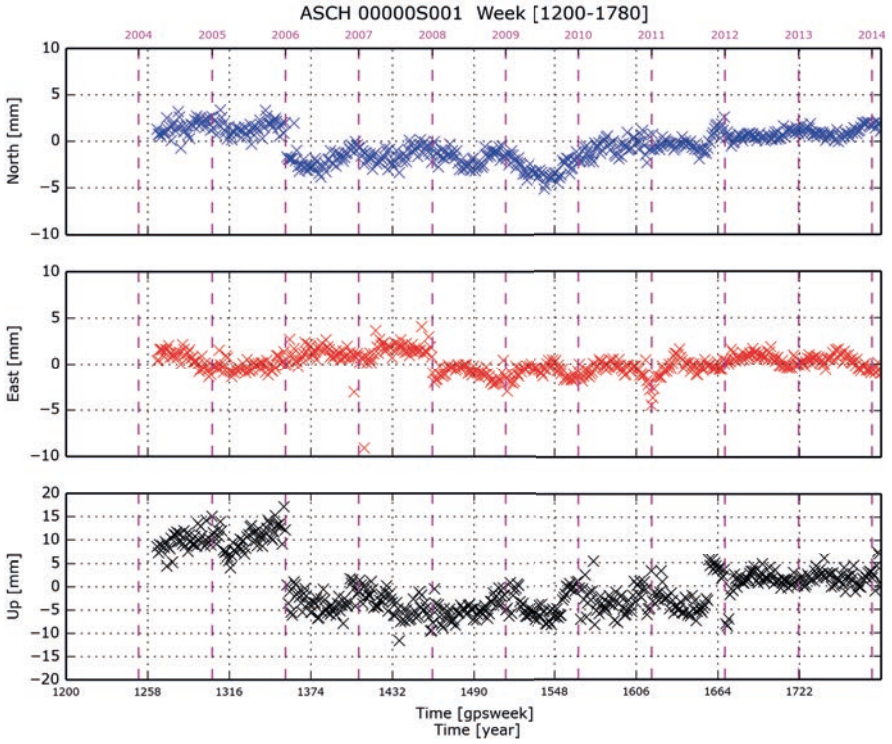

Fig. 2: Example of time series for station ASCH (Aschau, Germany) with REPRO2 2006+2007 included

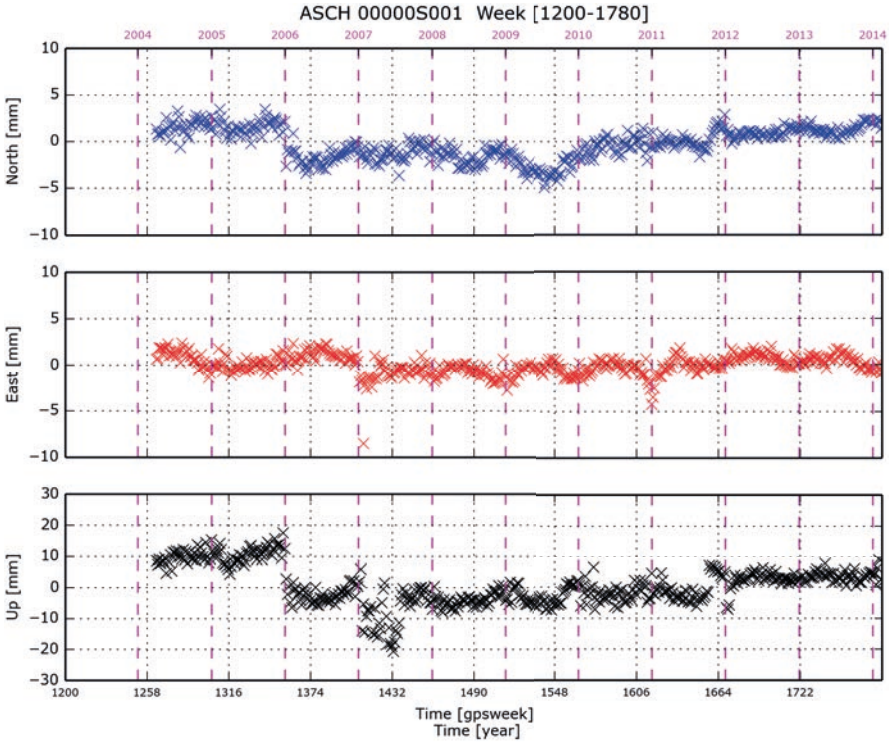

Fig. 3: Example of time series for station ASCH (Aschau, Germany) without REPRO2, but with repro1 2006

because repro1 already improved the original results as can be seen in Figures 2 and 3. The jump in the Up-component before 2006 was located originally in 2006 at GPS week 1400 when several models were changed according to the international standards. However, the 2007 part shows a clear improvement in the Up-component by reducing the largest values from over 20 mm to less than 10 mm. It is assumed that the improved troposphere model is responsible for the reduction.

5. Progress

It is estimated that each year of REPRO2 will need up to two months of work. The improved knowledge of handling wrong or missing meta-information and the increased number of stations will compensate. It is assumed that the effort will remain the same for each year. This would mean that 2015 the years 2006–2013 might be finished in REPRO2. Before 2006 the amount of computer time will be reduced dramatically but the human input of organizing and pre-analysis will increase. There is hope to reduce the effort to one month per year. REPRO2 should basically be terminated by the end of 2016. A further add-on will be started in 2017 to include all valid campaigns within and around Austria (about 300 sites) between 1992 and 2014. While the computation time can be neglected, the time for organization (e.g. correlation of different naming in Austria and internationally) is crucial. There is a pressure on OLG to finish REPRO2 in time for a densification of the international reference frame. Additionally a consistent time series is essential to estimate station velocities for geokinematics. Especially in areas with small intraplate distortions a precision at the millimetre level is requested. There is hope that REPRO2 will be completely finished in 2017 and might be followed by a REPRO3 if it is recommended by the IAG.

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