In the scope of TCS GNSS Data and Products, daily and weekly position time series of stations in Europe are produced by various EPOS analysis centres: BFKH, INGV, UGA-CNRS and EUREF (IAG Reference Frame Sub-Commission for Europe). These time series show the variations of the position of these GNSS stations over time due to various geophysical phenomena such as tectonic plate motion and post-glacial rebound. The latter is caused by the weight of the ice that covered most of northern Europe around 10,000 years ago. This extra weight depressed the Earth’s surface and, although the ice has meanwhile melted away, the surface is still slowly returning to its initial shape.

Other phenomena that can be studied by solid Earth scientists using GNSS time series are the deformations caused by earthquakes and their associated post-seismic deformations. From the estimated motions one can derive a strain rate map from which we can obtain the stress in the Earth’s crust. These stress maps are additional sources of information that can help scientists to estimate the amount of seismic hazard. GNSS time series are also used to study deformations of volcanoes and the region around seismic fault lines.

GLASS - In a previous article (EPOS Newsletter issue 03 July 2017 | Article 04), we explained that within our TCS we are developing an open source software named GLASS (Geodetic Linking Advanced Software System) to provide a distributed and consistent platform to access data and products (and their associated metadata) and a coherent mechanism for storing and processing GNSS data. In the current article we will describe which quality control procedures have been implemented in order to provide accurate GNSS data and products.

Quality control process - The quality control process steps are shown in Figure 1 and start by validating the log-files associated with each GNSS station which describe the type of installed receiver, antenna and other essential settings that influence the quality of the measurements.

The validation of the log-files is handled by the online Metadata Management and distribution system for Multiple GNSS Networks[LMCF1]. This validation is essential to avoid systematic errors in the data and products. In the second step, each file with raw GNSS observations is subjected to quality control using the Anubis software[LMCF2]. This provides, among other things,
information about the signal-to-noise ratio of the signal, the data gaps, number of clock-jumps, cycle-slip detection and number of satellites in sight. For each station, the long-term behaviour of the quality of the GNSS observations will also be monitored.

The EPOS analysis centres can use these statistics to eliminate data with problems such as being too noisy. The position time series are subjected by each EPOS analysis centre to a set of quality control procedures to detect and model jumps in the time series and remove outliers (i.e. obvious measurement values that cannot be correct). Only afterwards the time series are made available at the GNSS Product Portal. At this portal documentation with more information about these procedures can be found.

Since more than one analysis centre processes the GNSS data of a station, each using a slightly different approach, we can compare the various time series produced to ensure that no mistakes were made and to obtain an indication of the standard deviation between the solutions. This information will be made available at the GNSS product portal. In the fourth step, all-time series will again be subjected to another time series analysis to check if all outliers and jumps have been found and corrected.

**Power spectrum** - While these steps already provide state of the art position time series, we go further and also investigate the stochastic properties of the noise of these time series. Like many other geophysical time series, GNSS noise has a red power spectrum. This means that the noise at longer periods is larger than at short periods. An example is shown in Figure 2 which shows the power spectrum for station BUCU in the Romania for the three components. The blue dots are estimated from the observations while the red line is a fitted model following a power-law.

One of the purposes of these power spectral density plots is to detect strange periodic signals which would show up as peaks. The annual and semi-annual signal show up in Figure 2, especially for the North and vertical component. In addition, if the power is very large, then this might indicate that the GNSS station is not very stable. The reason for this might be obvious, such as the occurrence of several earthquakes, or not in which case information about the dominant period of the variations, provided by these plots, might help to find the cause.

**High value** - To summarise, GNSS data and products provided by EPOS are subjected to a series of strict quality control procedures which will be of high value for Solid Earth scientists that intend to use this type of data and products in their research.

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