Quality and Latency of the data within the EUREF Permanent Network

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1. Introduction

In support of our activities as EUREF Permanent Network (EPN) Central Bureau (CB), we created at the Royal Observatory of Belgium (ROB) different tools for monitoring the quality of the RINEX data from the EPN. Within the frame of the quasi real-time applications, we also monitor the latency of the hourly RINEX data files at the EPN data centres.

2. Monitoring of the latencies of the hourly data

Within the EPN, 61% of the stations deliver hourly data. To encourage these stations to deliver data with a minimal latency, we monitor the hourly data flow day-to-day by checking the latency of these data in the different EPN data centres. To do this, we use the creation time of the RINEX files on the FTP servers of these data centres.
We decided to monitor on one hand the status of the data centres and on the other hand the status of the stations.

2.1 Monitoring of the individual data centres

In order to monitor the data centres, we make, for each data centre, the difference between the creation time of the available hourly RINEX files and the corresponding theoretical creation time of these files (xx:00). This difference corresponds to the latency of the hourly data file. Using this info, we compute over the last three days, the percentage of hourly RINEX files arriving with a specific latency and this using two-minute intervals. Files arriving after 3 days are considered as missing. The resulting percentages give an indication of the most recent latencies of the hourly RINEX data within each data centre (Bruyninx et al., 2003).
Figure 1 shows examples of the monitoring of some of the EPN data centres. ASI, which is a local data centre receiving data from several operational data centres shows larger delays then ROB which is a local data centre that also operates as an Operational Centre managing a local network. ROB has consequently a high percentage of short delay hourly data files. Figure 1 also shows that at the regional data centre of BKG a lot of hourly data files are made available within a time delay of about 6 minutes. On the other hand, the regional data centre of GOP retrieves most of its hourly data from other data centres, which explains why the majority of the files at GOP arrive at least 10 minutes after the hour.

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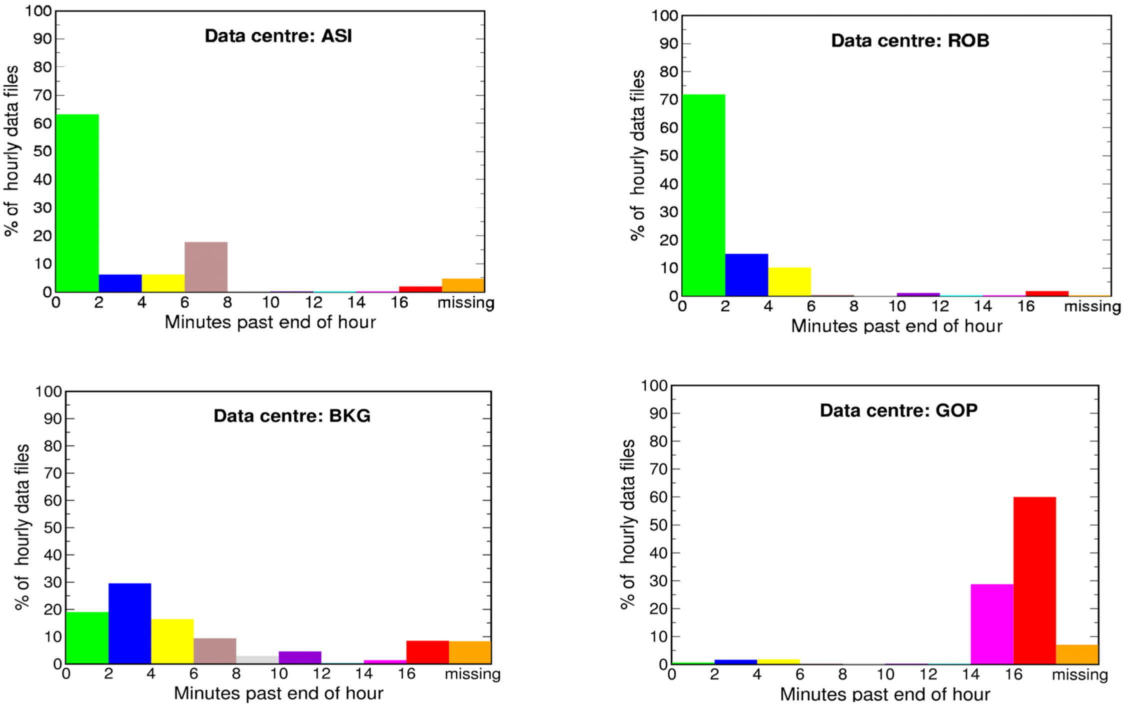


Figure 1 – *Hourly data latencies for several EPN data centres.*

2.2 Monitoring of the individual stations

For each EPN station, we create two kinds of files. On one hand, the so-called "min" files, which contain the filenames of the hourly RINEX data files together with the name of the data centre where this data file arrived first (note that station data are available in different data centres) and the corresponding latency (which is now the minimal latency). On the other hand, the so-called "max" files are similar to the "min" files but they contain instead the data centre (and the corresponding latency) where the hourly data files arrived last.

For a given station and a given hour, it is obvious that the time in the "min" file has to be coherent with the latency information in the hourly dataholding file of the corresponding data centre. We can illustrate this using the station ZWEN where we compare the "min" file (Table 1) and the dataholding file hourly.BKGI, doy 173, hours Q to T (Table 2): the latencies of the hourly dataholding file in Table 2 agree with those of the "min" file. However, for the "S" hour, we see that the data came very late at BKG, so that it is the IGN data centre which provided the zwen173s.04d.Z file with the shortest latency.

month	doy	creation_date	file	latency	data centre
Jun	173	17:02	ZWEN173Q.04D.Z	002	bkg
Jun	173	18:02	ZWEN173R.04D.Z	002	bkg
Jun	173	19:57	zwen173s.04d.Z	057	igni
Jun	173	20:02	ZWEN173T.04D.Z	002	bkg

Table 1 - *Part of ZWEN "min" file, doy 173, year 2004*

******	B	B	T	U	U	W	W	Y	Z	Z
BKG	A	O	H	L	N	A	T	E	I	W
******	N	R	U	A	S	R	Z	B	M	E
1=03M	2	1	3	B	A	N	R	E	M	N
**************************										
04-173-T	5	1	*	.	*	4	5	2	1	1
04-173-S	5	1	.	.	*	2	2	2	1	*
04-173-R	5	1	*	.	*	3	6	1	1	1
04-173-Q	6	3	.	.	3	2	3	2	1	1

Table 2 - *Part of check hourly. BKGI, doy 173, year 2004*

The mean values (computed over the last 3 days) of these minimal and maximal latencies are computed daily for each EPN station and displayed in data flow plots, like the ones in Figure 2 for the stations DELF and MLVL. The data of the station DELF are made available at three data centres: DUT, BKG and GOP. At first, the data are transmitted to DUT, which is a local data centre. This data centre will be responsible for the shortest (minimal) latency. BKG and GOP are regional data centres, but as we showed before, GOP retrieves the data from the other data centres. It will therefore generally be responsible for the largest (maximal) latency of DELF. The MLVL data are transmitted to one data centre only, which is IGN, so the minimal and maximal latencies are identical.

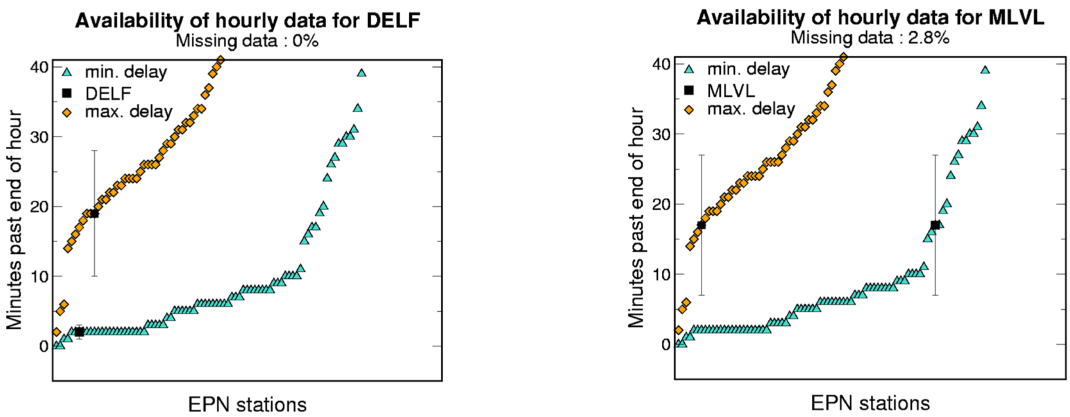


Figure 2 – *Latencies of hourly data averaged over the last 3 days and their standard deviation. Example for the stations DELF and MLVL.*

In addition to the 3-day averages, we also generate for each station graphs that give a monthly overview of the minimal latencies of the hourly RINEX data files (see Figure 3). Latencies below 10 minutes (horizontal line in Figure 3) indicate that the data are usable for near real-time applications. The graph truncates latencies exceeding one hour (they are indicated by a vertical dotted line without green cross). Files arriving after 3 days are again considered as missing. These plots are available at the EPN CB since August 2003. Figure 3 shows the minimal latencies for the stations WARE, VILL and ELBA.

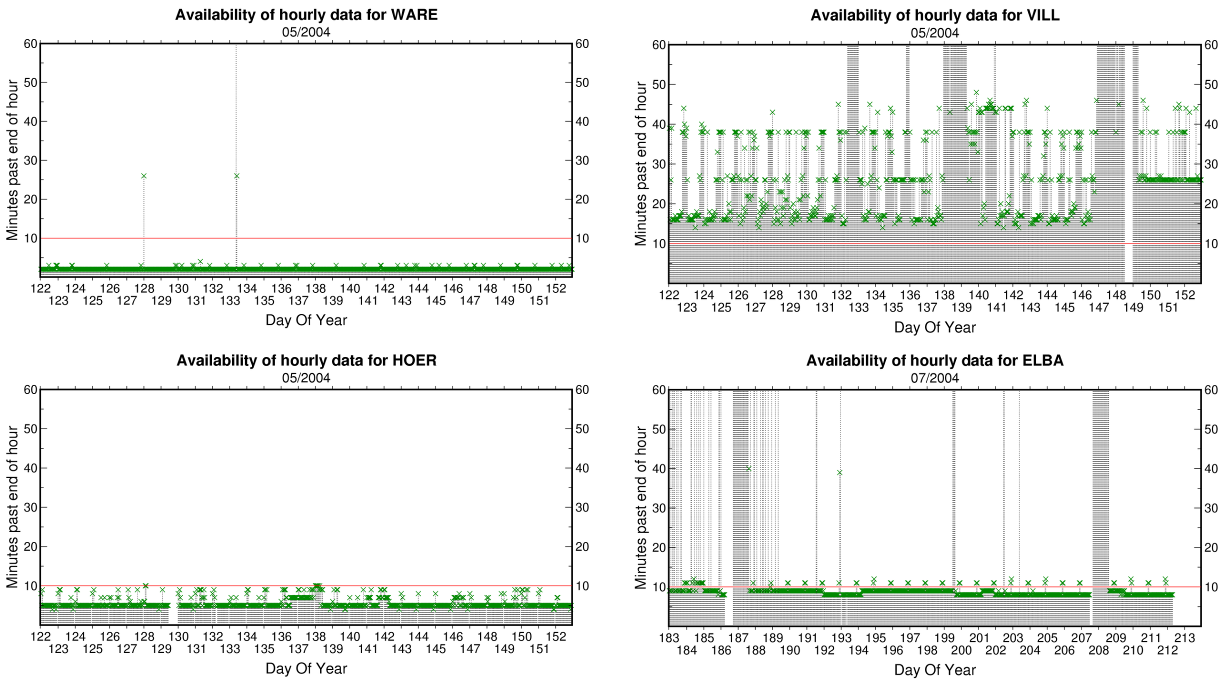


Figure 3 - *On a monthly basis, minimal latency of the hourly RINEX data files computed over the whole set of the EPN data centres. Example for the stations WARE, HOER, VILL and ELBA.*

Furthermore, the mean minimal latencies are also computed on a monthly basis and distributed through email to the EUREF community (Table 3).

```
*********************************************************************
EUREF Electronic Mail  10-Feb-2004 10:15:04 UTC  Message Number 1920
*********************************************************************
Author: EPN CB/Bruyninx C.
Subject: EPN hourly data latency - January 2004
Dear colleagues,
The information below reflects for each EPN station the
average latency of its hourly RINEX files at the EPN
local and regional data centres (listed in
http://www.epncb.oma.be/_dataproducts/datacentres/).
Hourly RINEX data files delivered within :
- 10 minutes can be used for NRT applications;
- 24 hours are still considered useful for NRT applications
  (for sliding window analysis) and should be delivered as
  quickly as possible.
Hourly RINEX data files delivered after :
- 24 hours are only useful for generating daily RINEX data
  files;
- 3 days are considered as missing. After this delay, only
  daily RINEX files can be submitted.
         January 2004 (DOY 001/2004 --> 031/2004)
```

	00m-04m	05m-09m	10m-59m	01h-24h	01d-03d	03d-mis
ACOR	---	---	---	---	---	100%
AJAC	---	---	---	---	---	100%
ALAC	---	---	---	---	---	100%
ALME	---	---	---	---	---	100%
ANKR	---	---	---	---	---	100%
AQUI	77%	13%	1%	6%	---	2%
BELL	---	---	---	---	---	100%
BOGI	---	68%	3%	12%	---	17%
BOGO	76%	1%	0%	14%	---	10%
BOR1	98%	1%	1%	---	---	---
BORK	10%	86%	3%	1%	---	0%
BRST	---	---	34%	62%	---	4%
BRUS	97%	0%	1%	1%	---	---

Table 3 - *Monthly issued EUREF mail with an overview of the latencies of the hourly EPN data*

A recent computation performed over the last 3 months from mid-June to mid-September 2004 show that the number of hourly RINEX files delivered within 10 minutes is 61% in average and the number of missing files is 18% in average. Although some stations do perform well, a lot of stations submit hourly data with unacceptable high latencies. In addition, for several stations, a one out of five hourly data file never arrives.

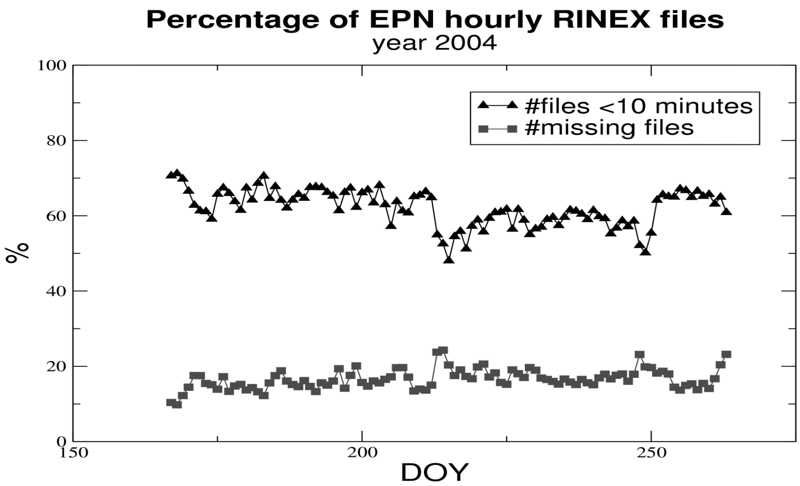


Figure 4– *Percentage of EPN hourly RINEX files on one hand, delivered within 10 minutes and on the other hand, considered as missing, over the period from doy167 to 263, year 2004*

3. Quality plots using RINEX observations files

3.1 Plots created from TEQC output

In order to monitor the data quality of the EPN data, we run daily the TEQC software (*Estey and Meertens,* 1999) on all the observations from the EPN. The inputs are the daily RINEX observation and navigation (necessary to compute the predicted observations) files. We describe below the different steps which we follow to process the files.

1. First, we use (if necessary) the –R option of TEQC to extract GPS data from mixed GPS/GLONASS data files (for instance: `teqc -R GOPE0830.02O  > GOPE083G.02O`).
2. Then, we use TEQC to determine the cut-off inserted in the receiver. This cut-off is defined as being the elevation below which no data is acquired. To compute it, we iterate TEQC until "the number of observations below mask" becomes equal to zero. At this iteration, the corresponding elevation mask is equal to the cut-off.
3. As a last step, we perform the data quality check using the following command:
   ```
   teqc +qc -plot -P -set_mask <computed cut-off> -nav <IFAGxxx0.yyN> <ssssxxx0.yyo>
   ```
   with:
   - +qc: process for quality checking static and dynamic dual-frequency GPS data
   - -plot: to suppress creation of the compact format plot file
   - -P: don't expect P-codes
   - -set_mask: to set the cut-off (see step 2) to be value degrees above the horizontal plane
   - -nav: to request that a specific RINEX navigation file is used

   This command generates a short report segment from which we use the summary line containing the key tracking statistics (see Table 4).

	first epoch	last epoch	hrs	dt	#expt	#have	%	mp1	mp2	o/slps
SUM	04 8 14 00:00	04 8 14 23:59	23.99	30	23424	20229	86	0.24	0.31	519

Table 4 TEQC *summary line with: dt as observation interval in seconds, #expt as number of predicted observations, #have as number of complete observations (both L1 and L2 are observed), % (called CO/PO afterwards) = (#have / #expt) x100, mp1 and mp2 as the RMS of the L1 and L2 multipath, and o/slps as the number of observations per cycle slip.*

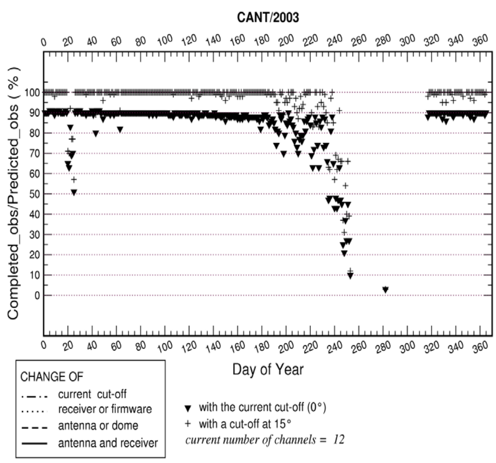
4. Step 3. is repeated for an elevation cut-off angle of 15°.
5. Finally, we complete these statistics with the number of channels of the receiver and with the date of any receiver and /or antenna changes; this information comes from the EPN database and is based on the site logs.

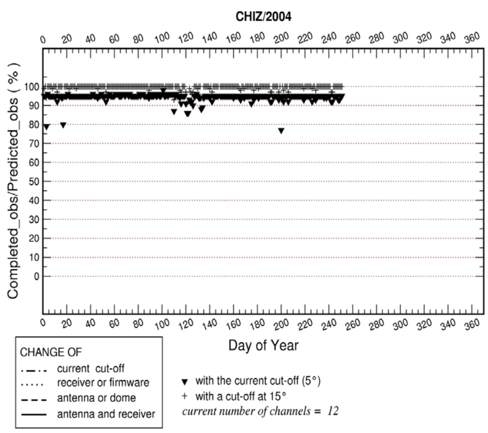
We don't process the files when the following errors occur:

- RINEX format errors: such as line lengths exceeding 80 characters, the presence of unexpected characters and non-chronological observation time stamps ;
- Observation intervals different from 30s; they produce a false evaluation of the number of predicted observations and so, an unreliable computing of CO/PO.

3.1.1 Yearly plots

The long-term tracking performance of a station is monitored using the daily parameters #have, mp1, mp2, cycle slips (1/ (o/slps) x1000) as we can see in Figure 5 (single line plots). The daily CO/PO are also monitored (Figure 5-double line plots). The + line of the CO/PO plots gives the percentage for a fixed elevation cut-off angle of 15°. It should, in principle, only vary when there is a change in the receiver/antenna equipment or environment. The black line gives the percentage with the receiver-depend elevation cut-off angle. Generally, when the cut-off decreases, the percentage will also decrease (more low-elevation satellites will be lost).These plots are available for each EPN station at the EPN CB web site. They are updated daily, when new RINEX observation data become available. The earliest plots have been created starting January 2001 (CO/PO) and January 2003 (daily number of observations, cycle slips, RMS of the L1 and L2 multipath).





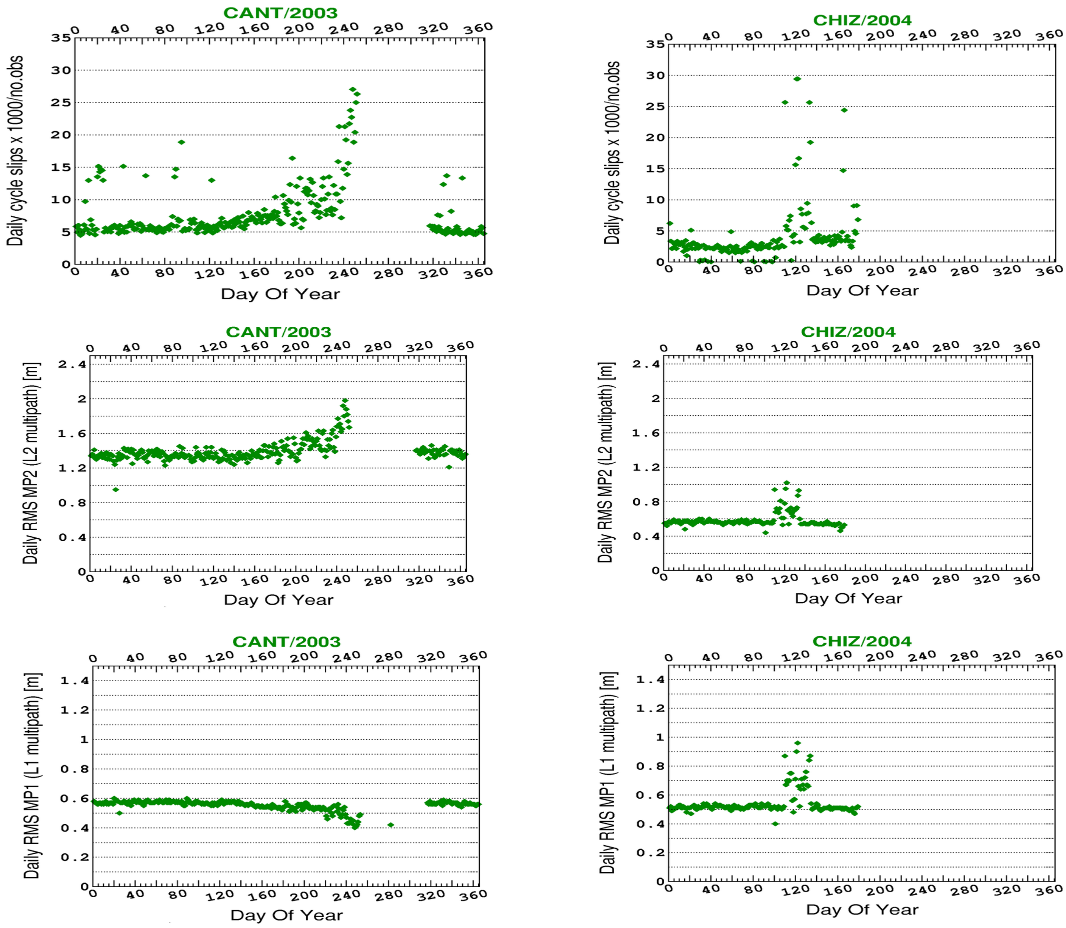


***Figure 5** -Yearly plots for the stations CANT (left) and CHIZ (right).*

As we can see from Figure 5, starting doy 175, due to a cable connector malfunction, the CANT station began to have bad satellite tracking. This can be seen from the increasing number of cycle slips, the rising multipath on L2 and the decreasing number of complete observations and CO/PO. For this reason, the station manager decided to stop the data submission on doy 250. CANT was operational again from doy 316.

For CHIZ, an increase of the daily number of cycle slips occurred around doy 108, while the number of observations remained almost steady. The problem affected the daily RMS multipath on L1 and L2 too. The reason was that the antenna choke rings were obstructed by a large amount of small seeds brought by a bird. The obstruction of the antenna choke rings resulted in a variable amount of water in the choke rings (depending on the local precipitation/evaporation conditions). The problem has been solved by cleaning the antenna (EUREFmail 2017).

3.1.2 Averaged plots over the last 45 days

For each station, by averaging #have, mp1, mp2 cycle slips over 45 days, we create plots which allow evaluating the tracking quality of a particular EPN station with respect to the other EPN stations. Examples of such plots are given in Figure 6 (*Bruyninx et al, 2003).*
These graphs are available at the EPN CB web site starting January 2003.

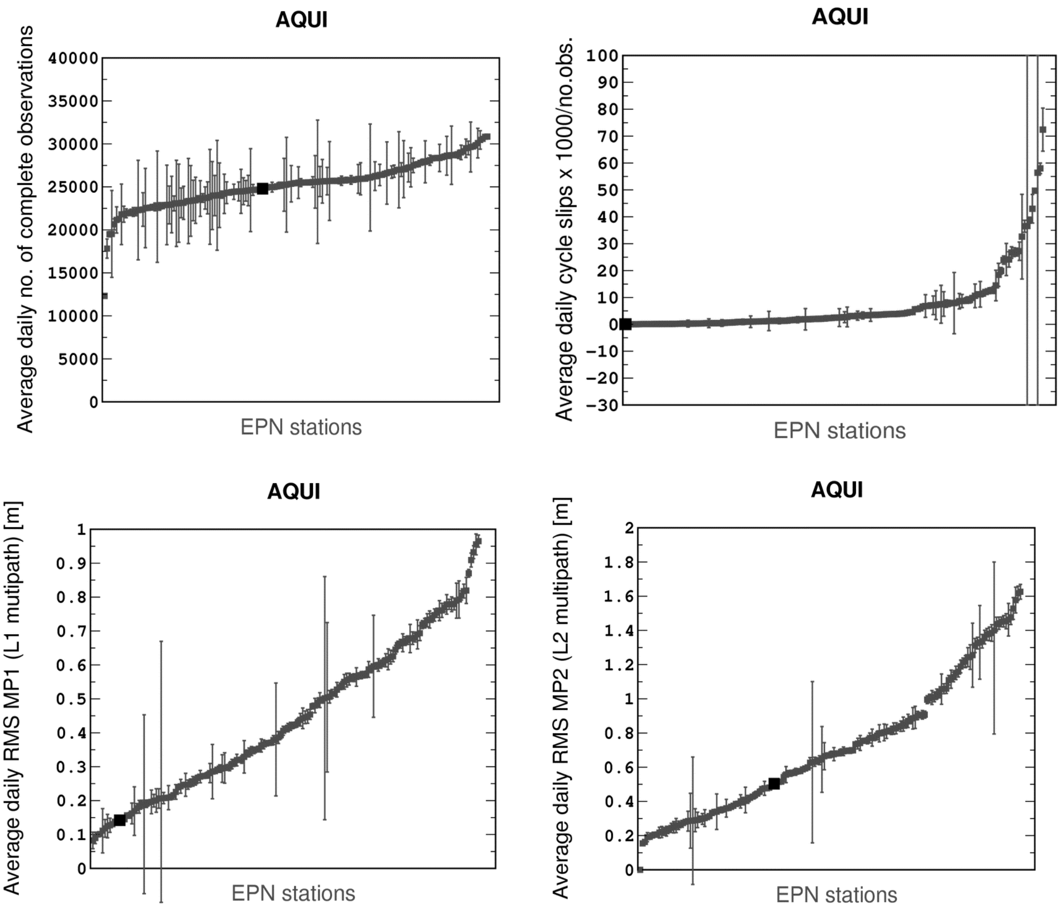


Figure 6 – *Averages of the TEQC key statistics over the last 45 days and their standard deviation. Example for station AQUI.*

3.2 Sky plots

The sky plots, as in Figures 7, are created monthly and show the observed L1 and L2 phase data from the RINEX observations (*Takacs and Bruyninx, 2001*). They give a snapshot of the tracking for a specific date. These plots are available at the EPN CB web site since March 2003.

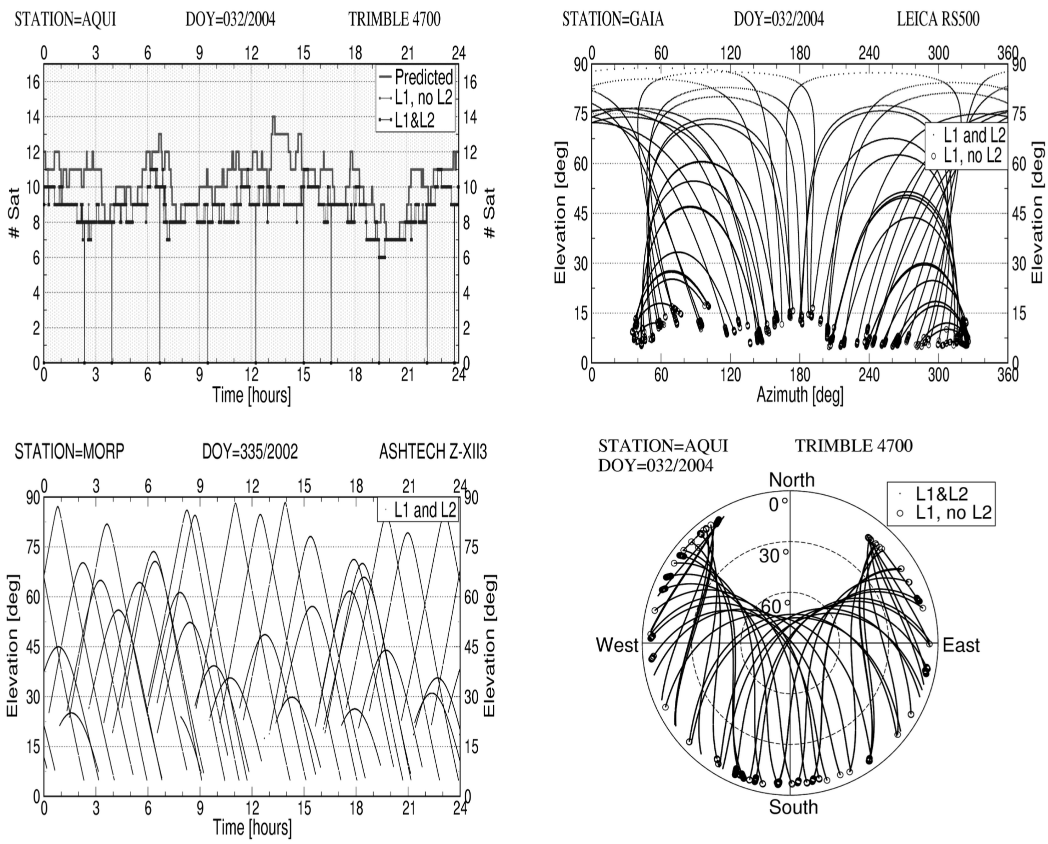


Figure 7a, b, c, d- *Monthly overview of the satellites tracked at a specific station. Example for different stations.*

Figure 7a is useful for the detection of the tracking interruptions, Figures 7b and d for the detection of obstructions and finally, and Figure 7c for the detection of receivers problems (for example: initial satellite lock at elevations higher than 15° as shown in Figure 6c*).*

4. Station events

For each station, we maintain a web page, which contains the events occurred since 2001 and this page is available at http://www.epncb.oma.be/_trackingnetwork/events/SSSS.html, with SSSS: the station 4-char abbreviation. At first, we indicate in this page the date and the nature of the event (tracking problems, earthquake, change of hardware...). Then, we show the different plots (time series, yearly plots and sky plots) in which the event is visible. We illustrate here these station events using two stations: BORK and QAQ1.

In consequence of degraded L2 tracking (see EUREF mail No 1663 and 1697), a dramatic decrease occurred for both the up component of the times series and the yearly CO/PO plots of BORK station (see Figure 8, left picture). The event was also visible in the daily RMS MP1 plots on L1.After changing the antenna, the L2 signal was recovered and all the plots came back to the usual values.

In March 2003, to avoid incorrect values of P1 and P2, the EPN CB has asked all the stations using Ashtech receivers to disable the smoothing corrections. That has produced a jump in the RMS mp1 and mp2 multipath as we can see for QAQ1 in Figure 8, right picture.

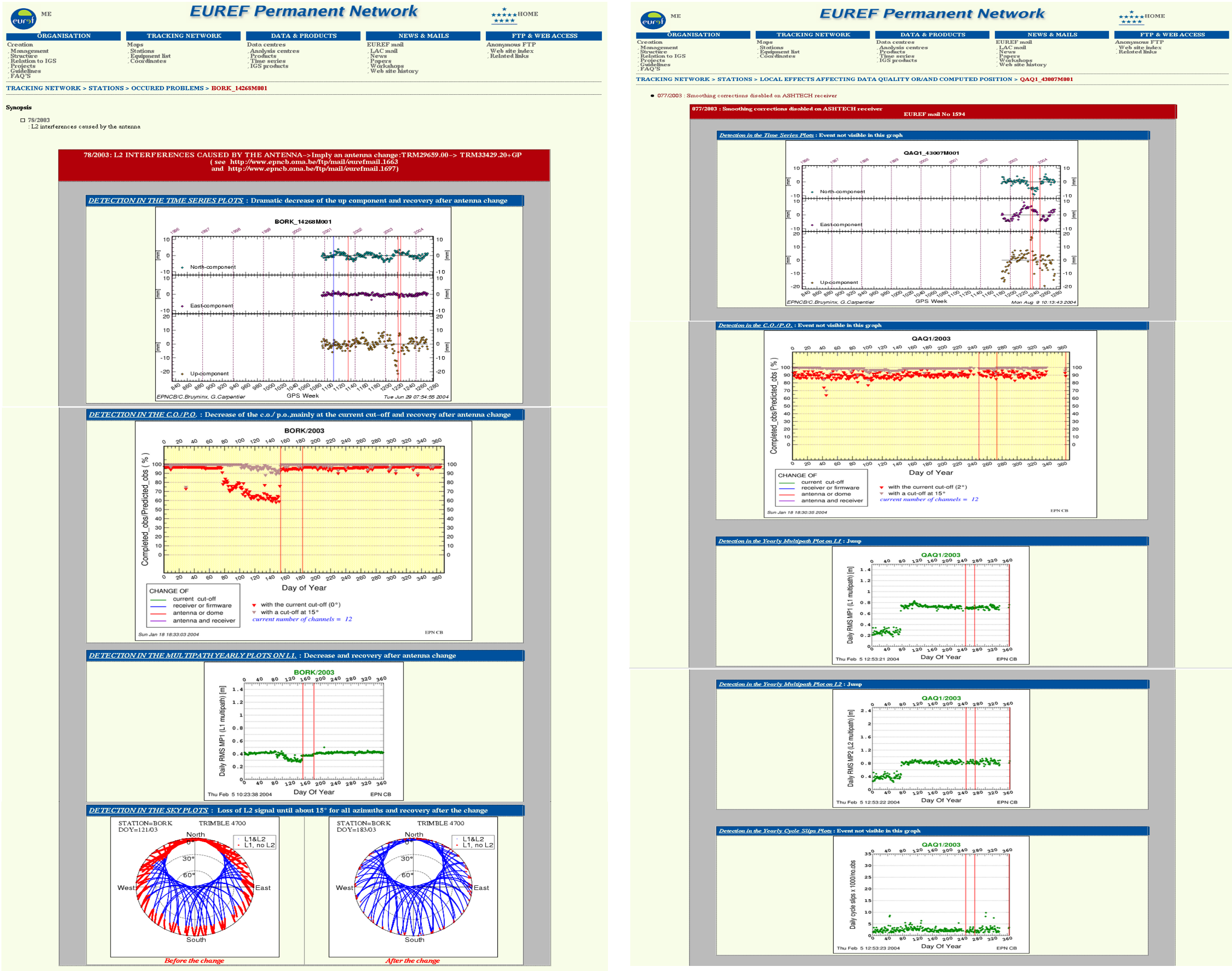


Figure 8–*Example of web page "local effects affecting data quality or/and computed position" for BORK and QAQ1 stations*

5. Summary

The different tools created at ROB monitor the EPN data and output:
I) The latency of the hourly data resulting on one hand in latencies for the individual datacentres ("hourly files vs. minutes past end of hour" graphs), and on the other hand latencies for the individual stations (monthly and averaged graphs).
II) The data quality of the RINEX observations files with on one hand the number of # have, mp1, mp2 and cycle slips computed day-to-day by the TEQC software (showed in the yearly plots and in 45-days averages) and on the other hand, the sky plots created from L1 and L2 phase data.
Relevant changes are communicated to the user community through e-mails and through the CB web site http://www.epncb.oma.be/.

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References

Bruyninx C., Carpentier G. and Roosbeek F. (in press)
Today's EPN and its network coordination
Proc.of the EUREF symposium held in Toledo, Spain, 2003.

Estey L.H. and Meertens C.
TEQC: the multi-purpose toolkit for GPS-GLONASS data
GPS Solutions, 3, No 1, 42-49, 1999.

Takacs B. and Bruyninx C.
Quality Checking the Raw Data of the EUREF Permanent Network
EUREF publication No. 10, ed. J.A.Torrès and H. Hornik, pp. 53-61, 2002