Daily Static Monitoring of the SWEPOS™-stations

Lotti Jivall

Lantmäteriet, SE-801 82 Gävle, Sweden, lotti.jivall@lm.se

1 Abstract

The original 21, well monumented SWEPOS™-stations are the main carrier of the Swedish ETRS 89 realization SWEREF 99. Today we have another 36 stations mainly built up for Network-RTK. Most of them are monumented on buildings, so the possibility of small movements could not be excluded. The Network-RTK services, the SWEPOS Post Processing Service and other accurate post-processing will provide accurate co-ordinates in SWEREF 99. It is therefore very important to check that the co-ordinates for all SWEPOS-stations are valid. For stations, where movements have been discovered, we are considering the possibility to update the co-ordinates regularly. A system based on daily solutions, quality control and co-ordinate checks as well as routines for co-ordinate updates is under development.

This paper describes the system for daily static monitoring of SWEPOS and outlines the ideas behind this.

2 Introduction or how it started

Most of the SWEPOS-stations are stable and has not caused any problems depending on non-valid co-ordinates. The first and until now experienced problem was when we analysed test-mearurements from Network-RTK in west Sweden, observed in November-December 2000. Measurements close to Gothenburg (station GOTE.0) showed systematic errors in the east-west component.

At this time we performed static post processing of SWEPOS regularly with a couple of months delay, but we did not have any routines or good tools to analyse the results.

A plot of the Gothenburg time series indicate that this station is moving with an annual period with especially large variations in the east component – see figure 1. The plot is based on residuals from ADDNEQ in the Bernese GPS Software. This means that the “zero-line” is the average position and not the actual used co-ordinates. The co-ordinates of the station is based on the first 18 days of observations. As could be seen in the graph, the east component is diverging c. 12-15 mm between the start of the observations and the winter 2000/2001.

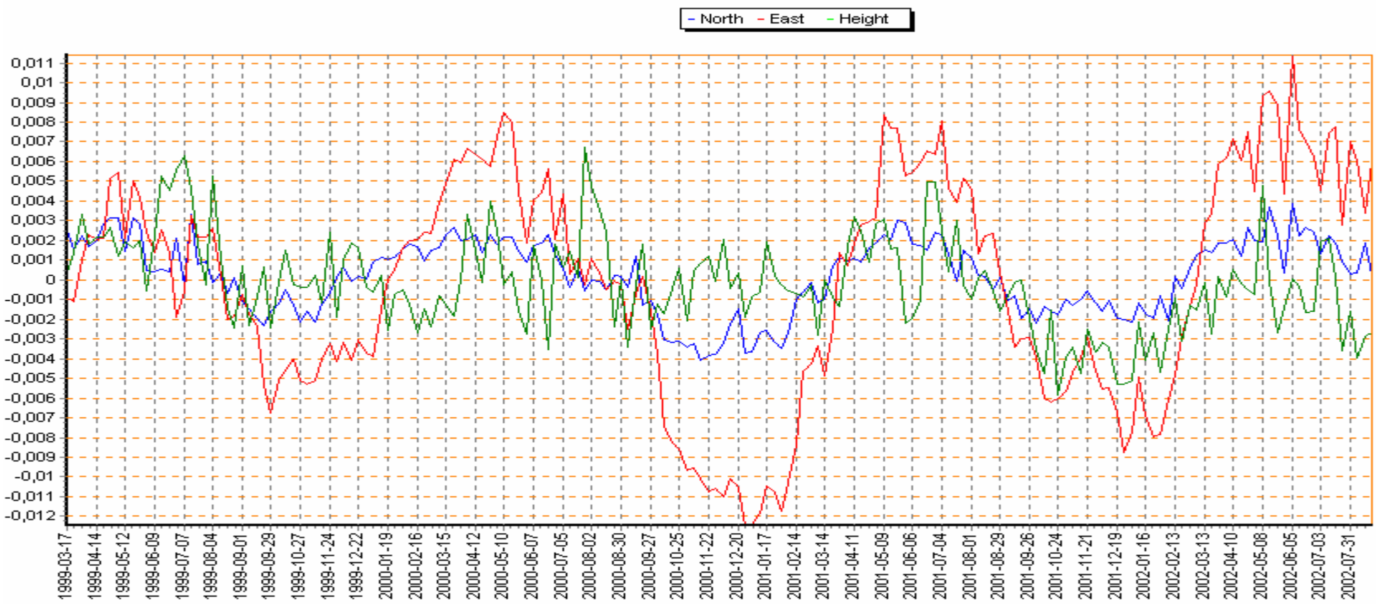


Figure 1: *Time series of the Gothenburg station. Unit of the residuals: meter.*

The station is monumented on the top of the roof of a four-storeyed building, which partly rests on solid bedrock and partly on piling. The antenna is (unfortunately) placed on the part of the house that is founded by piling. When new stations are established, we try of course to find as stable buildings as possible , but it is sometimes hard to judge the stability of a building beforehand and it could be hard to find a suitable building at a certain location. There are also many other aspects that has to be taken into account when choosing a location for the station.

After discovering the problems with the moving Gothenburg station we realised that we have a need for an accurate static monitoring of the SWEPOS-stations in near real time. A system for this was designed and is now under development.

3 Design of the system

The processing of the whole SWEPOS network will be run each day as soon as all input data (daily raw-data files, orbits and EOPs) are available.

The Bernese GPS Software will be used for a common multi-station adjustment of the whole network.

The quality of the solution will be analysed and after that the co-ordinates will be checked and if necessary up-dated. The automatic update of a station's co-ordinates is mainly designed for stations that are slowly moving, like the Gothenburg station, but should also be able to handle shifts/jumps of the co-ordinates. Before a station could be automatically updated it has to be classified as an "unstable" station by human decision interaction.

Weekly solutions and an accumulated time series for each station will be produced.

At the end the results are archived.

The system is developed using Borland C^{++} Builder 5.0 and the Bernese GPS Software ver 4.2. The platform will be Windows NT/2000. Figure 2 shows an overview over the system.

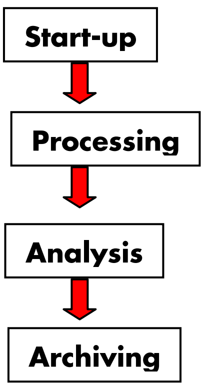


Figure 2: *System overview.*

4 Start-up

In this step the daily RINEX files from SWEPOS and IGS Ultrarapid orbits are fetched. The process could start as soon as the files are available, which normally is in the morning when the daily RINEX files have been checked.

In the processing in the next step one station is constrained, normally the EPN station MAR6. The system checks if this station is available otherwise an other station is chosen as constrained station.

The co-ordinates for the above mentioned constrained station is calculated in the epoch of the day of the latest ITRF-frame with the Bernese program COOVEL. Those co-ordinates are then edited into the latest 7-day solution (see section 5) to achieve apriori co-ordinates for the next step.

The SWEREF 99-coordinates that actually are in use at the SWEPOS-stations are retrieved from a data base.

5 Processing

The Bernese Processing Engine (BPE) of the Bernese GPS Software ver 4.2 is used for the processing. The whole network, today 42 stations but soon 57, is processed in a common adjustment. The final solution is an ionosphere free linear combination with fixed ambiguities (solved with QIF) and troposphere parameters estimated every second hour.

New SWEREF 99 co-ordintes are calculated for each station in the following way. The daily solution is for each station fitted to the five closest original SWEPOS-stations, i.e. the main carrier of the SWEREF 99 system, with a six parameter Helmert-transformation (fixed scale).

Further more a one week solution consisting of the last 7 days is computed. The point with this solution is to get a solution with lower noise. This solution is also used for a check of the co-ordinates and Helmert fittings are produced in the same way as for the daily solutions. The 7-day solution could also be used if the co-ordinates need to be updated.

Last the daily solution is combined with all previous daily solutions to get a time series out of the residuals in this combination.

6 Analysis of quality and coordinates

6.1 Analysis of quality

First the quality of the GPS-solution will be checked to see if the solution is reliable enough to be used for the co-ordinate check. The number of baselines, percentage of resolved ambiguities and rms of the final solutions are parameters that are checked. Those parameters are also saved in a summary table

The accumulated time-series from ADDNEQ could be examined with a program that makes a graphical presentation. The tool is used to display the time series in figure 1 and 3.

6.2 Analysis of co-ordinates

The new computed SWEREF 99 co-ordinates both from the daily solution and from the 7-day-solution are compared to the SWEREF 99 co-ordinates in use at the stations. The check of the daily solutions are used to get a fast warning when something is happening. The differences are saved in a table for each day and the values exceeding the warning limit will be marked.

The 7-day solution is used to judge if the station co-ordinates should be updated and also to produce the updated co-ordinates.

The automatic system for co-ordinate update is mainly designed for stations that are slowly moving and just stations that have been manually classified as moving or unstable stations could have their co-ordinates automatically updated. Large differences that likely not are connected to slowly moving stations will just generate error or warning messages and manual actions have to be taken.

There are three limits when checking the 7-day-solutions; a maximum limit, a warning limit and an up-date limit. A similar type of table as for the daily solutions will be produced, where values exceeding each limit will be marked in different ways.

The maximum limit is used to find outliers. An error message will be sent to the operator of SWEPOS, but no action will be taken automatically. The hypothesis is that large differences rather depend on a bad GPS-solution (that for some reason passed the quality control) than a real movement of the station. If the large differences continue in the subsequent solutions, the co-ordinates could be manually updated.

Then the stations are tested for the warning limit. If a station, that is classified as stable, exceeds the warning limit, a warning message is sent to the SWEPOS operator and after a manual decision the station could be re-classified as unstable. Unstable stations exceeding the warning limit will be tested against the up-date limit. This limit is smaller than the warning limit. The idea is that a station that is slowly moving should be continuously updated to avoid jumps. Though, the corrections should not be smaller than the precision of the solution.

If large differences are found on one of the original 21 SWEPOS stations, the main carrier of SWEREF 99, the selection of stations for the Helmert-fits have to be adjusted accordingly.

6.3 Limits

The different limits have to be related to the normal quality and precision of the solutions. As starting values for the limits the values in table1 are suggested.

Table 1: *Suggested (initial) limits*

Quality	Resolved Amb	85%
	Rms	4 mm
Daily solution	Horizontal	10 mm
	Vertical	20 mm
7-day solution	Max horizontal	10 mm
	Max vertical	20 mm
	Warning horizontal	7 mm
	Warning vertical	10 mm
	Up-date horizontal	3 mm
	Up-date vertical	5 mm

They are based on rough estimates of the normal precision of daily and weekly solutions in the SWEPOS-network. After analysing the results from a test period more thoroughly, statistical based limits could be estimated. It might even be so that different stations should have different limits.

6.4 Updating co-ordinates

There are two types of movements that could be expected at the stations (except for the very slow movements depending on the post-glacial re-bound that will be handled in an other way outside this system). On one hand there are the movements that have a clear trend over a longer time period, like for the Gothenburg station, on the other hand there are single jumps depending on e.g. earthquake or change of antenna/radome .

For the long-term movements the following simple algorithm might be suitable:

New co-ordinates = Average (old co-ordinates, latest 7-day-solution)

There will be a latency but the impact of temporary noise will be reduced.

This algorithm would also work quite well for single jumps below the maximum limit on stations classified as unstable, as the station after a while would be corrected to the new position.

For larger jumps a manual correction is needed in the first place.

When stations classified as stable having a jump, one possibility would be to temporary re-classify the station as unstable. When enough observations have been gathered after the jump, a better estimation of the jump could be made and the original co-ordinates could be updated.

It is of course very important that the new co-ordinates are introduced in all files and systems needed and to have control on which co-ordinates have been used at each station during a certain time period. The new co-ordinates will be saved in the co-ordinate data base of SWEPOS, which includes also the history of co-ordinates. From this data base files for Network-RTK, RINEX-headers, DPGS-corrections, the Automated Processing Service e.t.c. will be updated.

A serious alternative to update the co-ordinates of a moving station is of course to move the station to another more stable location. This is actually what we have done with the Gothenburg station before the Prototype Network RTK Service started in this part of Sweden. Before such a decision and before it is possible to move a station, the wrong (non-valid) co-ordinates have to be handled in some way. The proposed strategy would make the problems with moving station invisible to the users of the SWEPOS-services.

7 Archiving

When the analysis is finished and possible co-ordinate updates have been performed, important files are archived and the processing directory is cleaned on the files that are not needed any more. Example of files that are archived are daily and weekly (7-day) solutions in form of co-ordinates and normal equations, daily summary result files, result-files from Helmert-fittings and residual time series from ADDNEQ.

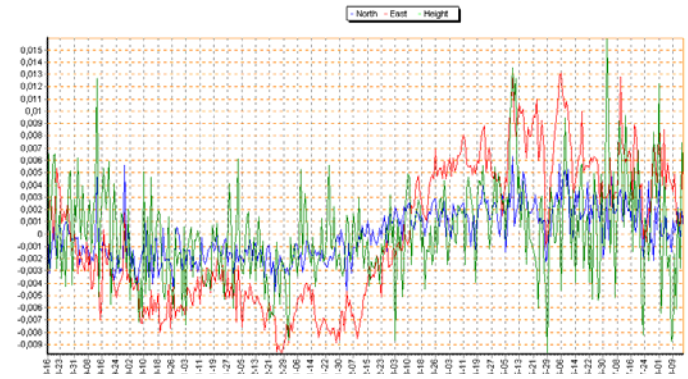
8 Concluding Remarks

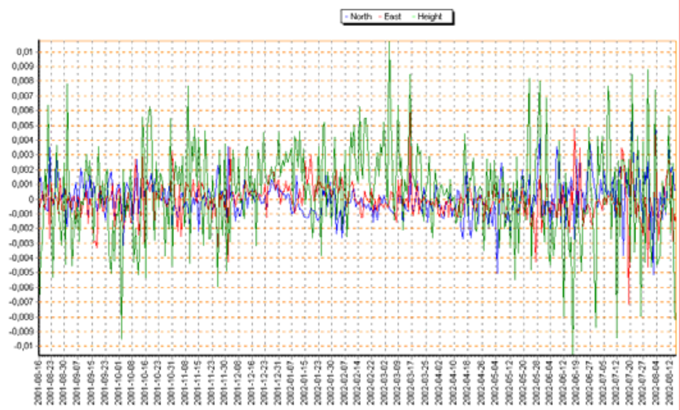
The system described is mainly developed to have control on the positions of the SWEPOS-stations. Possible movements of the stations should be discovered early and if necessary corrected so that the SWEPOS services realising SWEREF 99 still would give correct results. The static monitoring will also give information on the quality of the GPS-solutions, which could e.g. be used to confirm user problems with static data.

The status of the system development is that prototypes for the start-up, the processing, plot of time series and parts of the analysis are already developed.

Daily solutions have been produced in a half–automatic way since August 16 2001. The time series for the stations have been examined and the results from the 13 months gathered so far indicates that no other station than the Gothenburg station could be classified as unstable. Example of three different time series are shown in figure 3. The behaviour of the Gothenburg station (GOTE.0) could be compared to the more normal station in Jönköping (JONK.0) which is one of the original SWEPOS-stations. Kiruna (KIR0) show larger noise, probably depending on the larger ionosphere problems so far north and maybe snow related problems.

A rough overview on the SWEREF 99 coordinates, calculated by Helmert-fittings, for the 13 months show that the discrepancies from the SWEREF 99 co-ordinates in use at the SWEPOS-stations are acceptable.





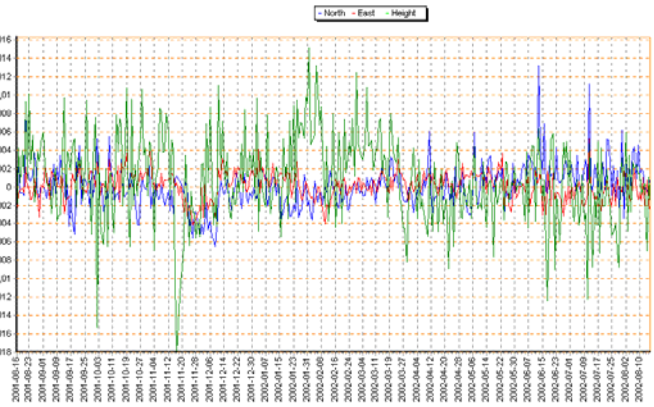


Figure 3: *Time series from the static monitoring of SWEPOS from August 2001 – may 2002. Gothenburg upper to the left, Jönköping upper to the right and Kiruna lower to the left.*

References

Norin D (ed) (2002): Geodetic activities in Sweden 1998-2002. NKG, 14th General Meeting of the Nordic Geodetic Commission, Esbo.

Jivall L (2002): Daily Static Monitoring of the SWEPOS Stations. EUREF, Symposium of the IAG Subcommission for Europe (EUREF), Ponta Delgada.

Jonsson B, Hedling G, Wiklund P (2002): Some experiences of network-RTK in the SWEPOS™-network. NKG, 14th General Meeting of the Nordic Geodetic Commission, Esbo.