EVALUATING THE QUALITY OF VIRTUAL REFERENCE STATION (VRS) OBSERVATIONS

Pasi Häkli
Finnish Geodetic Institute

INTRODUCTION

Networking CORS stations enable real-time bias estimation to improve e.g. real-time kinematic measurements. This method is referred to as Network RTK (NRTK). Biases can be determined and handled in different ways. One approach is VRS (Virtual Reference Station) in which VRS observations, referred here to as virtual data, are generated from the network to virtual position within the network coverage. Virtual data is generated by displacing the master (nearest) reference station observations geometrically to the position of virtual reference station and adding associated biases, interpolated from the network, into it. Virtual data can thus simulate real data at any location within the network. Several studies have shown that bias estimation expands the area of operation and increases reliability and accuracy in real-time positioning. However, a major disadvantage of VRS concept is that virtual data does not include any information of its accuracy and the quality has to be verified on statistical basis. Inaccurate virtual data prejudice all solutions using virtual data as a reference station and errors may even leave unnoticed. This study aims at giving quality of virtual data with statistically sufficient data for both real-time and post-processing applications. In the study the quality was quantified with accuracy of zero-baselines between virtual and real data at same position. Virtual data were generated from the GNSSnet.fi VRS network to the station positions of another detached (independent) permanent FinnRef GPS network. Virtual data was investigated against temporal and spatial variability.

QUALITY OF VIRTUAL DATA

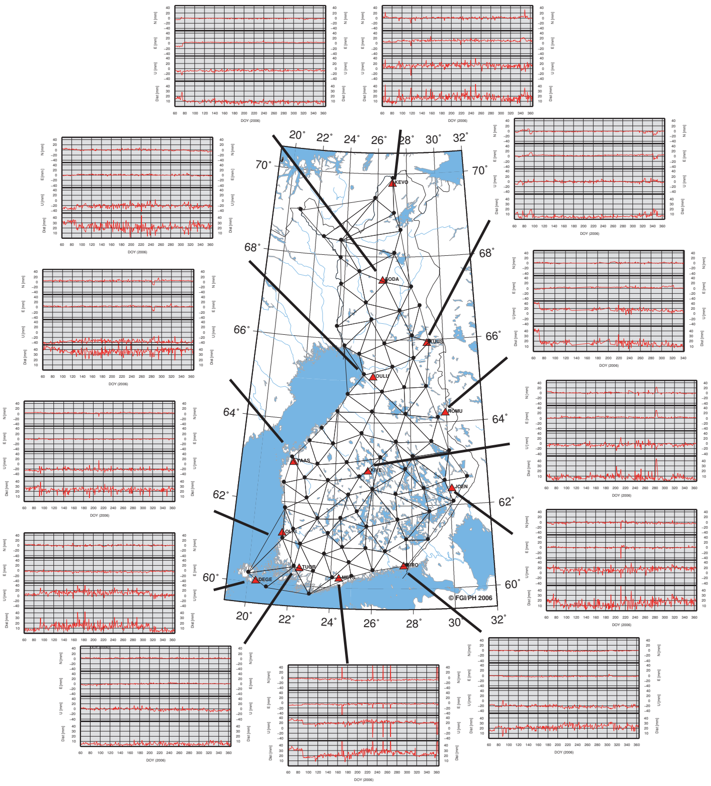

Fig.1. Time series of daily zero-baseline solutions at the locations of the FinnRef stations.

TEMPORAL QUALITY. Temporal quality includes long-term stability but also short-term variations. Long-term quality was evaluated with time series of virtual data. 10-month time series were computed for the period March–December 2006. Long time series of daily static zero-baseline solutions reveal systematic errors and homogeneity of data. Table 1 summarizes time series of daily solutions. Time series show that virtual data has good repeatability but some systematic biases remain to the results. The cause of these biases is estimated below. Daily solutions do not give detailed information about sub-daily variations that affect ordinary static or kinematic surveying. Therefore also hourly and kinematic solutions were computed but the results will be analysed later.

SPATIAL QUALITY. Spatial quality was evaluated both nationwide and locally. Nationwide quality was analysed from the virtual data distributed around the Finland and plotting the accuracies on map. The accuracy of virtual data seems to be spatially correlated (see Fig. 4 and text below for more analysis). Local variability was analysed with the distance of virtual reference station to the master station. Atmosphere causes delays to GNSS signals that are in NRTK determined at the reference stations and modelled for the rest of the network coverage in real-time. Interpolation (or extrapolation) from the model will result some bias to delays. This interpolation error is typically distance dependent and getting larger with increasing distance from the master station. Fig. 3 shows possible interpolation error computed from the time series.

Table 1. Accuracy of daily solutions

Station	std (mm)			rms (mm)		
	N	E	U	N	E	U
DEGE	2.4	2.1	8.0	2.5	5.2	12.7
JOEN	2.9	2.4	6.9	4.1	2.4	15.7
KEVO	3.3	3.1	6.8	3.4	11.3	13.7
KIVE	2.5	2.2	4.9	2.5	4.1	7.4
KUUS	2.1	2.3	3.7	2.6	4.6	3.9
METS	2.7	2.2	5.6	8.3	5.8	23.0
OLKI	1.2	1.0	3.7	3.8	2.0	23.4
OULU	3.1	2.3	5.9	3.1	2.4	23.6
ROMU	2.0	2.8	5.4	2.1	4.5	15.7
SODA	1.1	1.0	2.7	2.3	4.3	8.4
TUOR	1.4	2.4	4.3	2.6	2.4	4.8
VAAS	1.8	1.6	5.0	5.7	3.7	37.2
VIRO	1.4	1.4	4.0	2.6	3.7	22.8
average	**2.1**	**2.1**	**5.1**	**3.5**	**4.3**	**16.3**

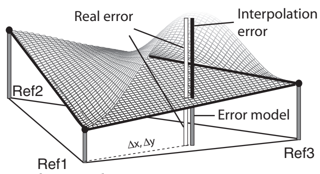

Fig. 2. Interpolation error in NRTK.

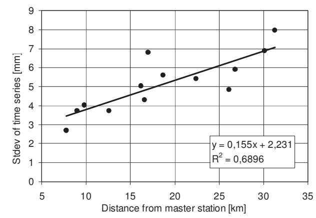

Fig. 3. Correlation of standard deviation and distance to master station.

WHAT EFFECTS ON QUALITY?

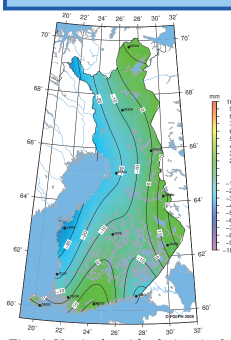

Fig. 4. Vertical residuals (mm) of virtual data time series.

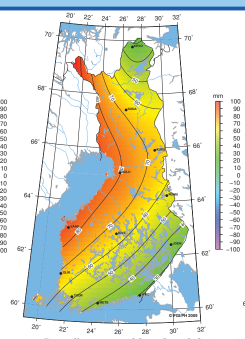

Fig. 5. Influence of land uplift (mm) 1997.0-2006.5.

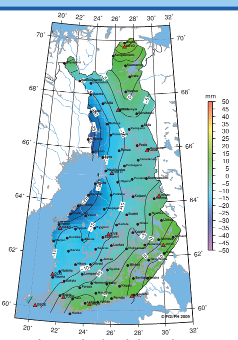

Fig. 6. Residuals of the reference frame fixing (mm) between ITRF2000 and EUREF-FIN.

REFERENCE FRAME. Nordic reference frames are deformed by postglacial rebound (PGR). Finnish ETRS89 realization, EUREF-FIN, has deformed already approx. 10 cm by PGR since its reference epoch 1997.0. Fig. 5 shows the influence on heights in mm between 1997.0 and the approximate mean epoch of VRS observations (2006.5). When a GPS network is adjusted by forcing it to the fixed coordinates in such frame, the network becomes deformed. One zero-baseline in Southeast Finland (Fig. 4) differs from the pattern and is probably due to deformed GNSSnet.fi network in this area (also residuals from the adjustment support this conclusion). In order to estimate deformations, GNSSnet.fi network was processed also in ITRF2000(2006.5). Figure 6 shows the difference (mm) in resulting coordinates when adjustments are made in ITRF2000 and EUREF-FIN. ITRF coordinates were transformed to EUREF-FIN by taking into account intraplate deformations caused by PGR. Accuracy (rms) of the transformation is better than 1 cm. The pattern of the residuals agrees with the accuracy of virtual data time series in Fig. 4. Hence it is obvious that the influence of PGR is seen in virtual data. This makes accurate determination of station positions challenging in the Nordic countries.

STATION COORDINATES. Station coordinates have significant influence on virtual data quality. Figure 7 shows the effect of updating the network coordinates at DOY 90 (dashed line). In this case previous GNSSnet.fi coordinates resulted from adjustment where GPS processing software caused wrong reference coordinates for one fixed station because of misinterpretation of antenna offsets. Correcting the antenna offset in new adjustment with +11 mm shows approximately similar jump in time series.

ENVIRONMENTAL EFFECTS. Also seasonal effects in time series are visible. The jump in Fig. 8 shortly after DOY 70 is most likely caused by snow dropping off from the top of the antenna radome. This is an annual effect at some stations with adequate conditions for snow accumulation.

INSTRUMENTATION. It is a common recommendation at permanent GNSS stations not to change especially antennas and site monumentation if not necessary. Usually when change in instrumentation occurs it can be seen from the time series. The phenomenon can be seen also from virtual data time series. Fig. 9 shows a case where antenna was replaced at the master station at DOY 210. The small jump is most likely caused by (inaccurate) antenna calibration tables.

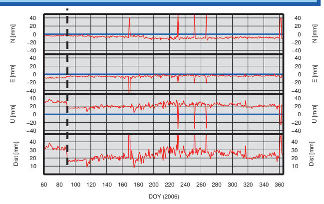

Fig. 7. Update of reference station coordinates occurred at DOY 90.

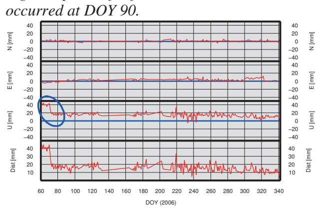

Fig. 8. Snow dropping off from the antenna radome.

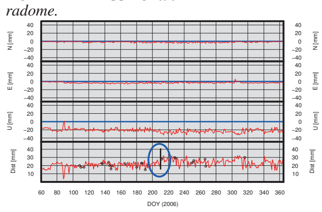

Fig. 9. Antenna change at master station.