# Selcuk Online Processing System With Case Study In IGNSS Stations

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**Key words**: GSS/GPS, data processing, web-based processing,

## SUMMARY

It has been important for many disciplines to obtain high-precision positions through the post-processing techniques with the development of new approaches and methods. Today, it is necessary to employ Global Positioning System (GPS) intensively in areas such as earthquake engineering, geophysics and seismological studies, early warning land earthquake predictions systems, monitoring the deformation and plate tectonics, high precision determination of geodetic point coordinates. Establishment of national continuous networks (CORS) and cm level Network-Real-Time Kinematics (RTK) positioning has become a practical method. Today's engineering requirements is constantly increasing and more precise GPS data processing methods are needed. In this study, we adopted a web-based approach to high precision GPS data processing, Selcuk Online Processing which integrates the complex data modeling methods in the server side with a user-friendly interface in the client side. A complete application was also given in details with case study in International Global Navigation Satellite Systems (IGNSS) stations

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## 1. INTRODUCTION

GPS had been limited to navigation without any user interaction or any post-processing or further modeling start with NAVSTAR program. The state of art in GPS has improved the error models, such as global reference frame, satellite orbit, site specific errors, atmospheric greadients and antenna phase center variations. Thus baseline precision of up to submilimeter has been obtained, as well (Teunissen and Kleusberg, 1998). In that point, many probes and studies focused on improving the precision of GPS observations by post-processing and modeling. Such efforts has been leading to sophisticated research and academical software packages such as GAMIT/GLOBK (King and Bock, 1998) and Bernese (Beutler et al., 2001), GIPSY (Zumberge et al., 1997). Because of sophisticated structure, users avoid such research and academicals software packages at the commercial applications.

After increasing of national CORS (continuously operating reference stations) networks, online processing services have been suggested and happened succesfully such as in Canada (Heroux et al., 1993), in USA (Weston et al., 2007a; Weston et al., 2007b; Soler et al., 2006) in Australia (Dowson et al., 2002). In these online GPS processing services, main focus is static and rapid-static surveys and the reference sites are usually fixed and the national mapping authority controls centrally the service (Erickson, 1992). Furthermore, an abstraction is applied which does not allow the full control of the computing process. Now real-time applications have been done by establishment of continuous networks. Although real-time continuous networks have provided instant access to moderate precision but there is still a serious lack of the necessary precision for demanding applications such as deformation monitoring. Both the static continuous and Real Time Kinematic (RTK) continuous networks are getting more popular, while user may obtain position accuracy within a few centimeters

The commercial software packages can not process complex error models (e.g. earth rotation parameters, atmospheric loading and gradient, ionospheric and tropospheric errors, ocean tide effect, etc.) on long baselines. Thus these software packages can produce worst solutions at deformation studies and precise processing of long baselines because of inappropriate parameters and not uploading model files (some IGS products) to these software packages (Sanlioglu, 2004). The users still have to use complicated scientific research software for the most precise applications. The users have to be equipped with sufficient technical background and they have to receive a long training fro these software packages. The alternative models and strategies available in such software should be exercised with caution and also they could lead to large differences. From another point of view, many people in several fields need high precision GPS results without the necessary technical background. So they need a practical tool to obtain high-precision GPS results. Such a tool should be independent of the operating system of the users because operating system is the one of major hindrances of scientific software in practice.

The few national institutions provided centrally the online service. This service has to be extended to allow for near-real time applications and more user interaction. In this study, the design and implementation of such a processing system are presented. It was named as Selcuk Online Processing since it has been designed at Selçuk (Seljuk) University in Konya (SOGDP Service, 2010). The proposed online system has the advantage of ultra high precision. Also It has user-friendly interface and practicality. Because GAMIT/GLOBK 10.34 software includes new technologic models it has been chosen as background processing engine (Maraş 2010). To work efficiently in the proposed online processing system, some of the original modules of GAMIT/GLOBK software have been modified. The suggested service has been web-based. GAMIT/GLOBK can run in the Unix/Linux platform. Thus, the user does not have to allocate to a Unix/Linux computer to process data

The user can choose stations from the reference network to process in this system. If the user prefers not to get into the details about the network, the application was so designed that the optimal set of network stations are used in the system. To obtain millimeter level precision, a single observation file is sufficient in this configuration. The reference network in the system can optionally be designed in hierarchical manner. The user can choose the remoter station with better accuracy or nearer ones with relatively lower accuracy. In any case, user supplied observations are processed by the processing engine simultaneously. The server runs in Linux Debian 2.6.24- etchnhalf.1-686 platform (Maraş et al, 2011)

## 2. DESIGN OF THE PROCESSING SERVICE

### 2.1 Workflow and employed Technologies

The interface of the web-based rocessing service was purposely designed in pure HTML pages to avoid dependency of the third-party products (Adobe Flash, Microsoft Silverlight etc.) and make the service platform (Mac OS, Windows, Linux etc.) independent. The service allows the user to input GPS observation data in RINEX format by upload (Maraş, 2010).

The general workflow of the service can be summarized as follows:

1. Uploading user data and choosing settings and reference stations by web interface.
2. Checking data integrity and updating default settings.
3. Processing the data by the engine.
4. Presenting the results to the user via e-mail in numerical and graphical format

Various technologies and methods have been employed for the design of the processing system. The tools were chosen as much flexible as possible and are shown in Table 1. The user preferences and settings have been designed to work without any input from the user. Such a procedure helps the beginner with an appropriate list of default choices. The default settings were also carefully adjustment to meet the requirements of a practical user. The user interface for the preferences is given in Figure 1.

**Table 1.** The employed technologies for various stages of the service (Maraş et al, 2011)

| Modules | Web technology |
|---|---|
| User interface | Web technology |
| System settings | PHP, HTML, JavaScript |
| Data input/output | PHP, HTML, JavaScript |
| Data checking/Integrity monitoring | PHP |
| IGS data/products/FTP process | Flash, ShellScript |
| Data processing | ShellScript, Flash |
| Kalman filtering | ShellScript, Flash, GAMIT |
| Preliminary results/visualization and mapping | ShellScript, GLOBK |
| Coordinate transformations | PHP, HTML, JavaScript, Google Maps |

The options offered to the users are as follows:
**(a) Solution type:** The user can choose between different strategies for the solution (L1&L2, L1_ONLY, L2_ONLY, LC_ONLY, L1_L2_INDEPEND, LC_AUTCLN) which has an impact on the solution. Detailed information may be found in (Herring et al., 2006).

**(b) Zenith delay estimation:** The user can opt for estimating the zenith delays explicitly in the processing. (Bisnath et al., 1997).

**(c) Atmospheric gradient:** This option is also related with the zenith delay estimation. The details of the gradient modeling can be found in (Mendes and Langley, 1994).

**(d) Atmospheric loading:** Atmospheric loading can also have an impact on the results. The main grid files are applied as given in (Tregoning and van Dam, 2005)

**(e) Tropospheric constraint:** This option is useful when the user decides to estimate the zenith delays explicitly. In this case, a constraint is applied to the residual zenith delays to improve the estimation.

**(f) Elevation mask:** In general, elevation mask is applied at the observations level. For instance, the GPS receiver equipment can be set to collect data at higher than a specified elevation angle.

**(g) IGS data provider:** International Global Navigation Satellite Systems Service (IGS) consists of data and analysis centers. The online processing system then uses the related configuration to download the necessary data from the specified IGS data center.

**(h) Number of IGS stations in data analysis:** The processing service can be configured to run with as many reference stations as available. However, the user can choose fewer stations to minimize the computation time.

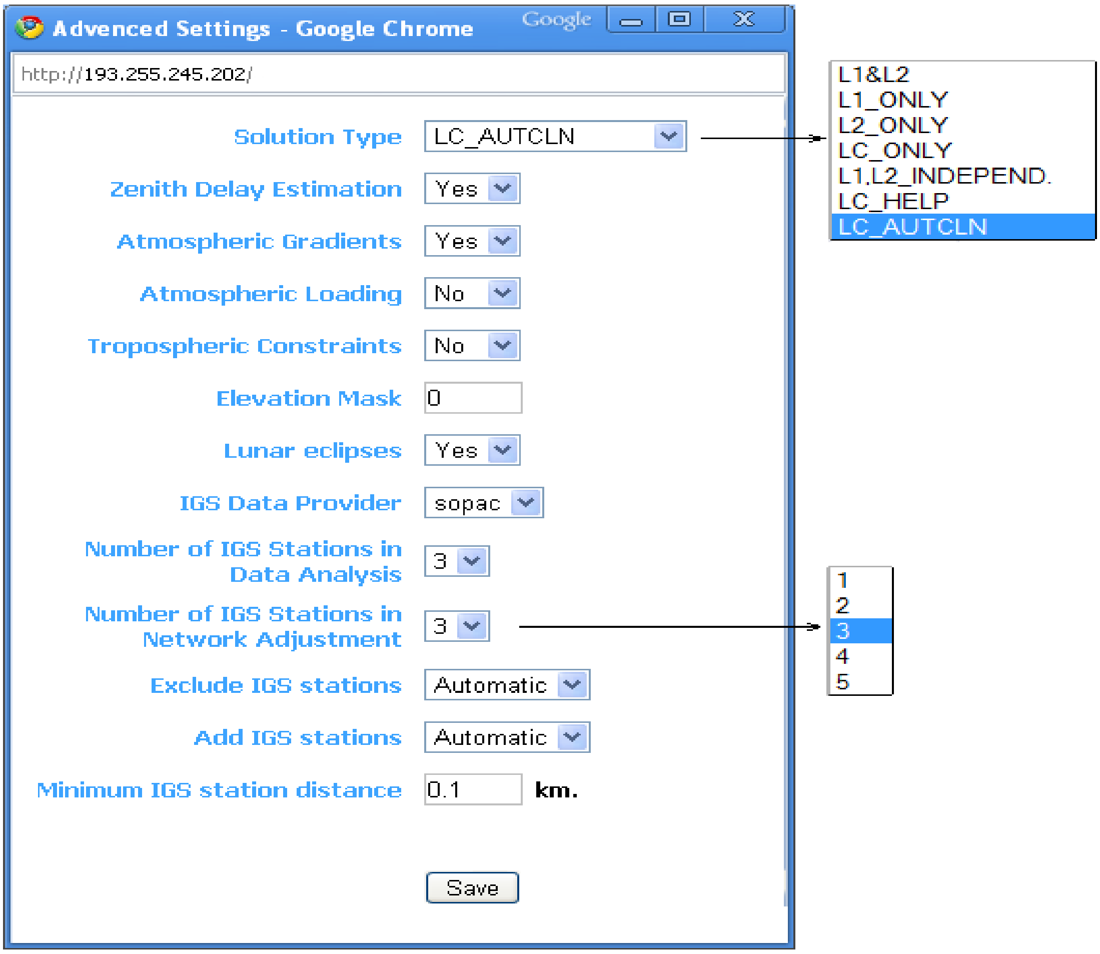


**Figure 1.** Settings for the users.

**(i) Number of IGS stations in network adjustment:** The processing service was configured to run with at least three reference stations. However, the user can choose fewer stations.

**(j) Exclude IGS stations:** In this option, the user can exclude certain IGS stations from the analysis for testing purposes or to be able to use only the nearest reference station. Alternatively, the user can exclude stations which appear to noisier.

**(k) Minimum IGS station distance:** The errors of the GPS observations in double-difference processing are a function of baseline length. In this respect, remote stations can be excluded from the analysis based on the distances.

## 2.1 Graphical user interface

The introduction page was designed in pure HTML. The introduction page is shown in Figure 2. Since the user is supposed to provide the service with various inputs such as antenna height and antenna type, HTML form objects are formed in run-time through PHP based scripts.

In the second part of the introduction page, the user can upload his/her own RINEX data through the service provided by the online processing system. The upload service supports uploading of up to 7 files simultaneously.

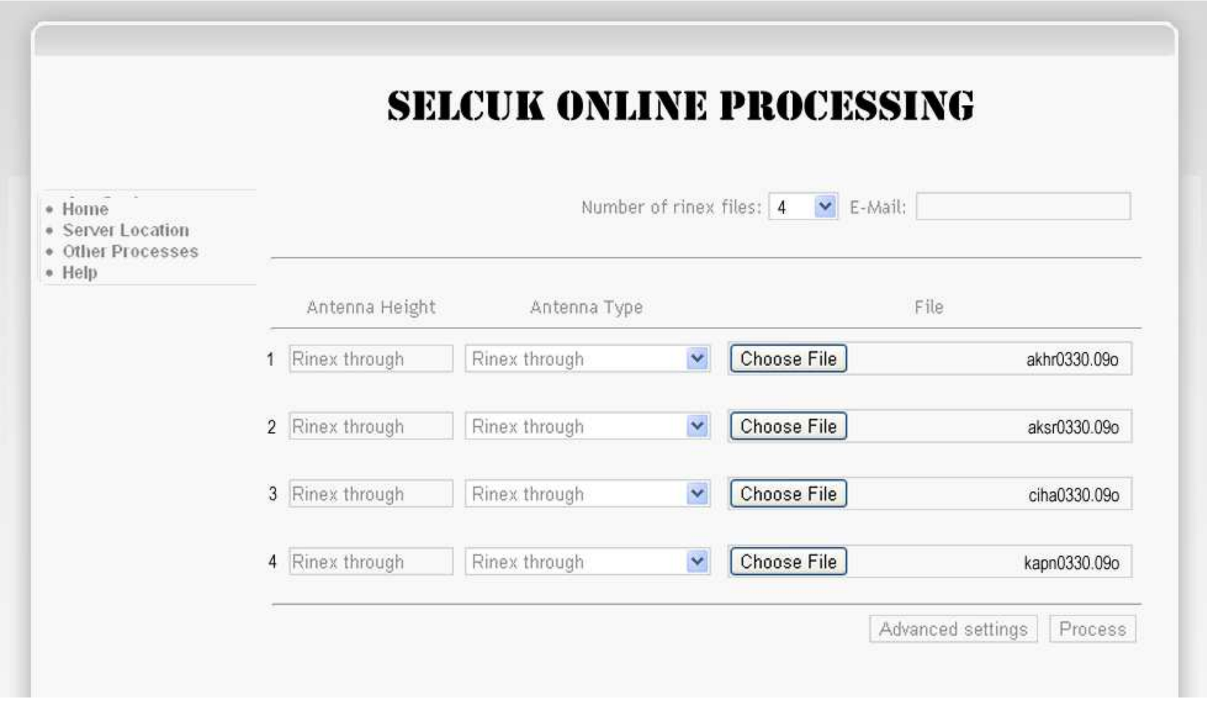


**Figure 2**. Introduction page.

## 3. EXECUTION OF THE PROCESSING SERVICE

The data processing is initiated through the button located on the main page. The processing service will run with the pre-configured default values and will produce an optimal solution. After submitting the files, a concise report is sent to the user verifying the integrity of the observation files and giving a process ID. The processing service appoints a unique process ID for each submission. Another useful property of the processing service is the automatic quality checking of the GPS observations.

After completion of the data, processing engine is started and the progress bar is shown as in web map. The results can be shown online and/or through e-mail.

## 4. APLICATION WITH IGNSS STATIONS

For this study, four stations, CIHA, AKHR, AKSR, and KAPN were chosen from Continuously Operating Reference Stations of Turkey (CORS-TR) at 02 February 2009. The rinex files of these stations are downloaded from (CORS-TR, 2009). These data were uploaded through the service by the online processing service. Following the uploading of the files, antenna type and antenna height information were entered.

The proposed processing service treats the data with the antenna properly as long as the meta-data is provided by the user. If the user does not provide the meta-data, then processing service look for the necessary information in the observation files.

Firstly three, four and then five IGS stations (ANKR, ISTA, NICO, KABR, NSSP) were chosen from the main page of online processing service. Lc_Autocln was chosen as the solution type. This option is ambiguity-free and ambiguity fixed solutions with LC. Elevation mask angle was determined as 15 degree. Zenith delay estimation and atmospheric gradient was computed. The baselines and neighboring three reference stations are also displayed on the screen through Google Maps as shown in Figure 3.

The final evaluation of the results can be done by checking the normalized root-mean-square (NRMS) of the overall data processing. Any discrepancy between the ambiguity-fixed and ambiguity-free solutions can be traced back a problem with the ambiguity fixing procedure. (Table 2). The result which is sent online and/or through e-mail are ellipsoidal coordinates as given in Table 3, the Cartesian coordinates and sigmas with three reference stations are in Table 4, with four reference stations Table 6 and with five reference stations in Table 7, the correction distribution of observations in Figure 4 and Figure 5.

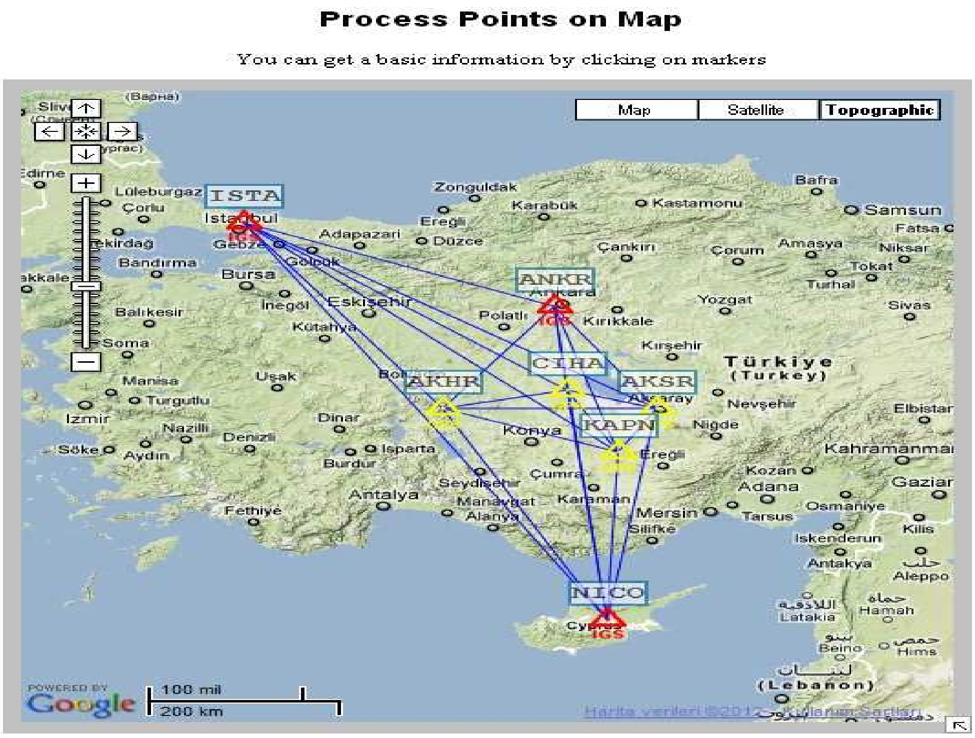


**Figure 3.** The display of the baselines and the stations.

**Table 2.** In the output mail, the results can be done by checking the normalized root-mean-square (a good solution produces a NRMS of about 0.25)

| | | Biases | Loose Const. | reduct. | reduct. |
|---|---|---|---|---|---|
| **free** | Normalized rms | 0.185 | 0.187 | 0.181 | 0.183 |
| **fixed** | Normalized rms | 0.151 | 0.148 | | |

**Table 3.** In the output mail, the ellipsoidal coordinates of three reference stations and user points

| | Latitutde | | | Longitude | | | Ellipsoidal Height |
|---|---|---|---|---|---|---|---|
| **STATION** | **D** | **M** | **S** | **D** | **M** | **S** | **m** |
| AKHR_GPS | 38 | 22 | 09.3801 | 31 | 25 | 47.0736 | 1046.4055 |
| AKSR_GPS | 38 | 22 | 13.4063 | 33 | 59 | 53.3392 | 1005.7963 |
| ANKR_IGS | 39 | 53 | 14.5373 | 32 | 45 | 30.4925 | 976.0121 |
| CIHA_GPS | 38 | 39 | 01.3949 | 32 | 55 | 20.6625 | 1012.7414 |
| ISTA_IGS | 41 | 06 | 16.0123 | 29 | 01 | 09.6303 | 147.2405 |
| KAPN_GPS | 37 | 42 | 52.7959 | 33 | 31 | 36.9392 | 1039.5063 |
| NICO_IGS | 35 | 08 | 27.5525 | 33 | 23 | 47.2090 | 190.0157 |

**Table 4.** In the output mail, the Cartesian coordinates and sigma of user points determined by Global Kalman Filtering with three reference stations in GLOBK

| STATION | X m | sigma mm | Y m | sigma mm | Z m | sigma mm |
|---|---|---|---|---|---|---|
| AKHR_GPS | 4273150.852 | ±5.78 | 2611388.100 | ±3.93 | 3938311.894 | ±5.12 |
| AKSR_GPS | 4151745.969 | ±5.63 | 2800192.952 | ±4.10 | 3938384.041 | ±5.15 |
| CIHA_GPS | 4187342.437 | ±5.31 | 2711236.736 | ±3.79 | 3962713.225 | ±4.75 |
| KAPN_GPS | 4212053.469 | ±5.10 | 2790745.047 | ±3.70 | 3881074.845 | ±4.55 |

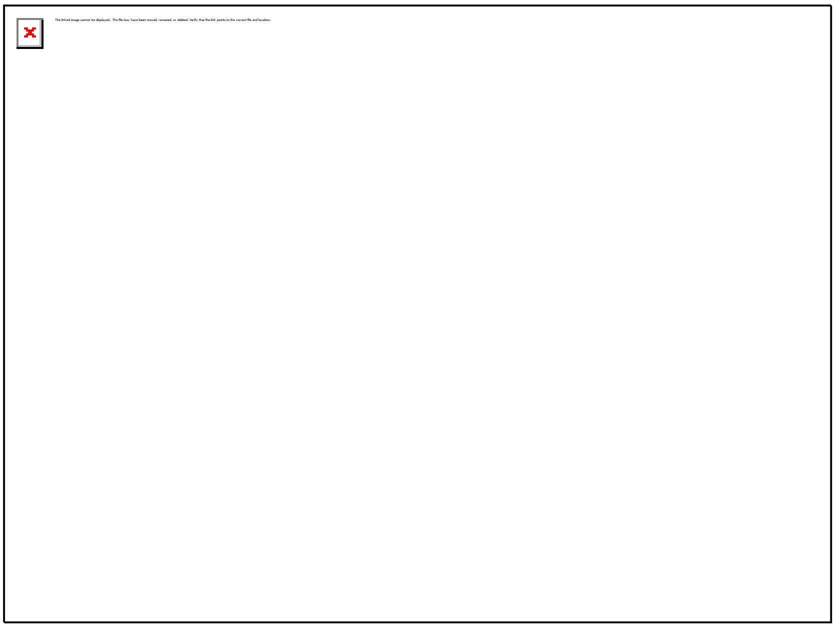

**Figure 4.** In the output mail, the post-fit one-way residuals for station AKHR were evaluated in GAMIT analysis fro every sation satellite pair at every mesaurement epoch

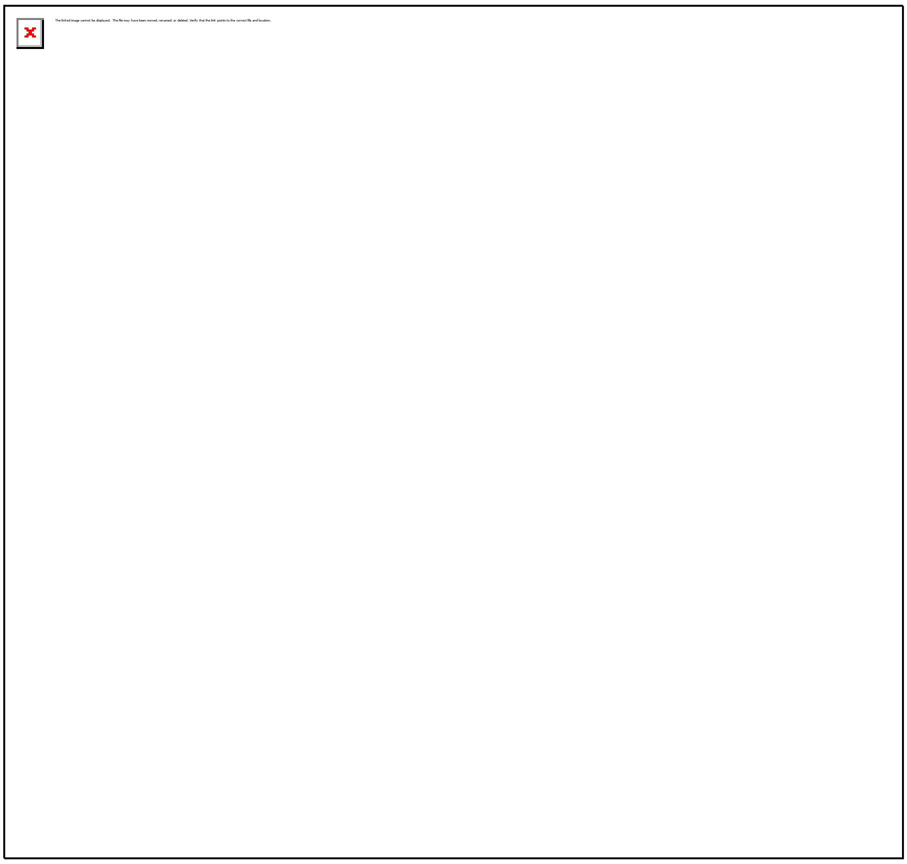

**Figure 5.** In the output mail, AKHR station rms dependent on azimuth and elevation angle and post-fit Lc phase residuals plotted of elevation angle.

**Table 6.** In the output mail, the Cartesian coordinates and sigma of user points determined by Global Kalman Filtering with four reference stations in GLOBK

| STATION | X<br>m | sigma<br>mm | Y<br>m | sigma<br>mm | Z<br>m | sigma<br>mm |
|---|---|---|---|---|---|---|
| AKHR_GPS | 4273150.841 | ±6.05 | 2611388.095 | ±4.15 | 3938311.891 | ±5.39 |
| AKSR_GPS | 4151745.958 | ±5.88 | 2800192.946 | ±4.24 | 3938384.037 | ±5.33 |
| CIHA_GPS | 4187342.425 | ±5.46 | 2711236.729 | ±3.85 | 3962713.220 | ±4.86 |
| KAPN_GPS | 4212053.458 | ±5.25 | 2790745.041 | ±3.77 | 3881074.842 | ±4.65 |

**Table 7.** In the output mail, the Cartesian coordinates and sigma of user points determined by Global Kalman Filtering with five reference stations in GLOBK

| STATION | X<br>m | sigma<br>mm | Y<br>m | sigma<br>mm | Z<br>m | sigma<br>mm |
|---|---|---|---|---|---|---|
| AKHR_GPS | 4273150.840 | ±6.02 | 2611388.094 | ±4.04 | 3938311.893 | ±5.32 |
| AKSR_GPS | 4151745.960 | ±5.81 | 2800192.945 | ±4.22 | 3938384.041 | ±5.32 |
| CIHA_GPS | 4187342.425 | ±5.54 | 2711236.729 | ±3.92 | 3962713.223 | ±4.93 |
| KAPN_GPS | 4212053.460 | ±5.16 | 2790745.040 | ±3.71 | 3881074.845 | ±4.58 |

The quality of the results was also analyzed. Since the main objective is to investigate the performance of the web based processing service with different IGS stations and to investigate the coordinates and their accuracies specified by the station submitted by the user.

## 5. CONCLUSION

Web-based online processing services have several advantages: homogenization of the produced coordinate sets, cost-efficiency due to the require minimal hardware, minimizing the training to make use of high-end processing software, instant visualization of the results, correct application of newest error models, detailed reporting , automation.

Minimization of the user interaction together with well configured default settings has the potential of producing high precision coordinates in a very short time. On the other hand, the proposed processing service has also the necessary tools for fine tuning. Many complex modeling such as atmospheric modeling of tropospheric delays, zenith delays, atmospheric loading can be applied with or without any user interaction. The custom selection of the reference network to be incorporated into the analysis is also found to be very useful. The proposed processing service is designed to be scalable to networks of any dimension. The working principles of the design were deliberately made flexible to enable easy adaptation.

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