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EGNOS MONITORING PREPARED IN SPACE RESEARCH CENTRE P.A.S. FOR SPMS PROJECT

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ABSTRACT

The European Geostationary Overlay Service (EGNOS) augments Global Positioning System (GPS) by providing correction data and integrity information for improving positioning over Europe. EGNOS Service Performance Monitoring Support (SPMS) project has assumed establishment, maintenance and implementation of an EGNOS performance monitoring network.

The paper presents preliminary results of analyses prepared in Space Research Centre, Polish Academy of Sciences (Warsaw), as one of partners in SPMS project.

Key-words: EGNOS, point positioning, augmentation monitoring

1. INTRODUCTION

EGNOS system is composed of three segments (see EGNOS Book 2007):

- ground segment, which consists of:
    * RIMS (Ranging and Integrity Monitoring Station), reference stations which monitor GPS and GEO satellites,
    * NLES (Navigation Land Earth Station), uplink stations of EGNOS message to GEO satellites,
    * MCC (Mission Control Centre), control centres,
    * EWAN (EGNOS Wide Area Network), communication network
- space segment, which consists of GEO satellites, broadcasting EGNOS Signal in Space (SIS) message over the service area,
- user segment, which consists of all potential users.

EGNOS system currently delivers three services (free of charge):

- an Open Service (OS) providing positioning and synchronisation information
- an Safety of Life (SoL) service dedicated to safety of critical applications which have strict accuracy, integrity, availability and continuity needs,
- an EGNOS Data Access Service (EDAS).

EGNOS Service Performance monitoring Support (SPMS) project has assumed establishment, maintenance and implementation of an EGNOS monitoring network ensuring

efficient support for the management of the EGNOS in-service performance and independence of analyses and investigations.

Space Research Centre (SRC), Polish Academy of Sciences (PAS) (Warsaw) participates in the SPMS project in parts including:

- signal and service availability monitoring for selected GEO satellite PRN136 till 20th of March 2017 and from 21st of March 2017 PRN123

- local assessment of the accuracy, integrity, availability, continuity monitored for SiS and EDAS EGNOS message for satellite PRN136 till 20th of March and from 21st of March 2017 PRN123.

2. ESTABLISHED ASSUMPTIONS AND RECEIVERS CONFIGURATION

According to project proposal, three receivers work in permanent mode in SRC PAS in Warsaw. Two of them receive GPS data and EGNOS correction directly from geostationary satellites while the third one receives GPS data and EGNOS EDAS correction. EGNOS EDAS correction is obtained via Internet connection. Stations configuration is presented in Figure 1.

- **CBKA** – station equipped with Trimble NetR9. It collects observable data for CNES (Centre National d'Études Spatiales) purposes of EGNOS OS monitoring. The main purpose of collecting data from CBKA station is providing data for CNES analysis. Additionally, it could be used in post processing analysis carried out in SRC PAS. CBKA station observes all visible GNSS satellites and all EGNOS satellites. Receiver works with 1 second interval, observing satellites with mask 0 degree. Data is stored in 15-minutes RINEX 2.11 files and diurnal binary file in T02 format. RINEX. Data is stored on ftp server.
- **CSIS** – station equipped with Septentrio PolaRx2 receiver. It is one of Septentrio receivers connected to the common antenna for zero-base preparation. CSIS station collects observable data for SRC analyses. CSIS station observes all visible GPS satellites and EGNOS SIS correction directly from geostationary satellite number 136. Receiver works with 1-second interval and observes satellites with mask 0 degree. The position is computed by the receiver for each epoch with observation. Receiver works in dynamic mode and the position is not pre-defined. Data and results of analyses are stored in diurnal files on ftp server.
- **CNET** – station equipped with Septentrio PolaRx2 receiver. It is one of Septentrio receivers connected to the common antenna for zero-base preparation. CNET station collects observable data for SRC PAS analyses. CNET station observes all visible GPS satellites and EGNOS EDAS correction for satellite number 136 via Internet. Receiver works with 1-second interval and observes satellites with mask 0 degree. The position is computed by the receiver for each epoch with observation. Receiver works in dynamic mode and the position is not pre-defined. Data and results of analyses are stored in diurnal files in ftp server.

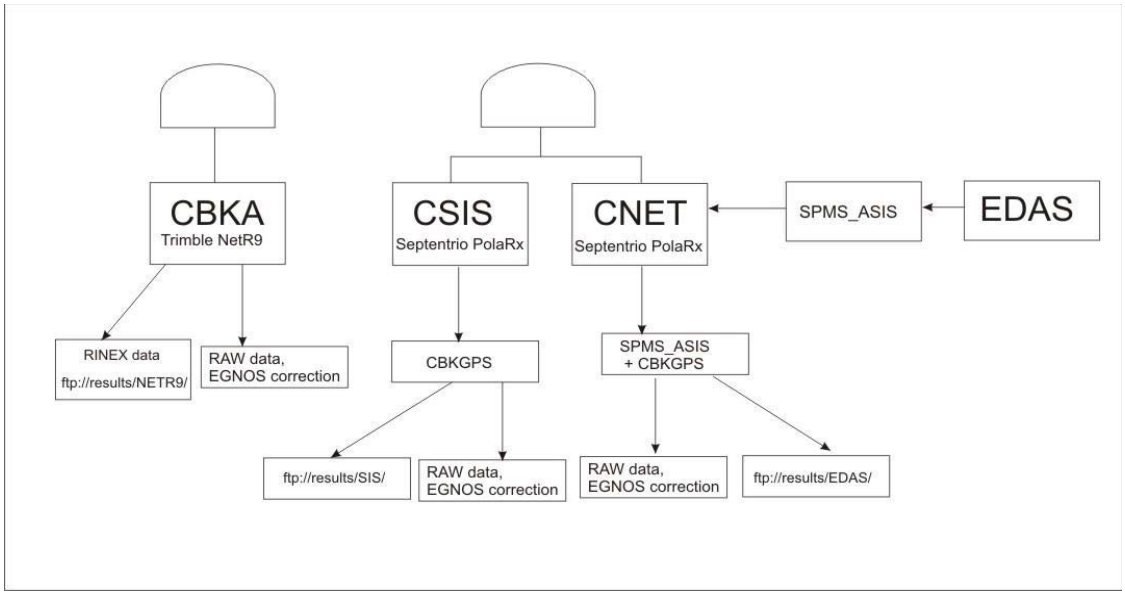

Fig. 1. Receivers involved in SPMS project configuration (Swiatek et al.)

Stations CSIS and CNET have worked in parallel connected to the same antenna. This configuration designed "zero-base". Thus, the same EGNOS SIS and EDAS correction should give the same position.

3. ANALYSES AND RESULTS

Data stored during observation is analysed daily and quarterly.

3.1 DAILY ANALYSES

Diurnal analyses have been prepared basing on RxControl software. The CSIS and CNET receiver have been connected to computers and RxControl software prepared a set of pictures as results of daily observations. All pictured results have been stored on ftp server and available for members of the SPMS project consortium. The results include horizontal and vertical performance analyses as well as station coordinates analyses and have been referred to Key Performance Indicators (KPIs) (see EGNOS Service Definition Document 2015).

The horizontal and vertical performance analysis has been visualised as Stanford plots (see Figure 2) as well as visualisation of HPE/HPL (horizontal position error/horizontal precision level) presented in time of the day (see Figure 3).

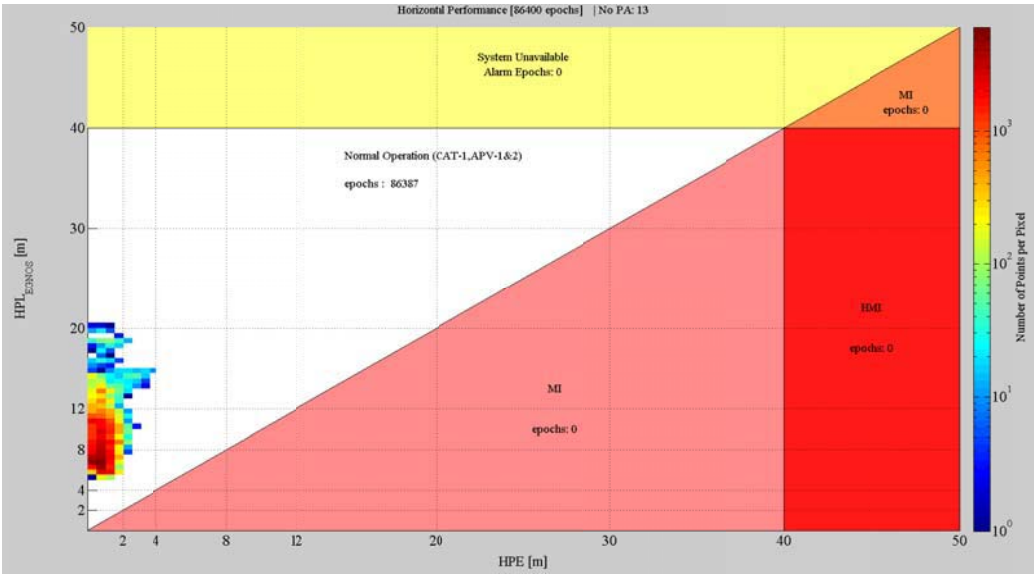

Fig. 2. An example chart of Stanford plot obtained for horizontal performance analysis of CSIS station observation data for 26-th of July 2016.

The HPE/HPL analysis versus time additionally presents current number of satellites observed by the receiver for which the EGNOS corrections are available.

Analyses of coordinates computed by a receiver are presented as a polar plot of horizontal differences from reference station position (see Figure 4). In the plot the circle marks a value defined in EGNOS OS SDD. It corresponds to a 95% confidence bound of the 2D position error in the horizontal local plane for the Worst User location and it is defined as value equal 3m.

Additionally, the coordinate daily analyses are presented as differences from reference position prepared versus time of day separately for latitude, longitude and height (see Figure 5).

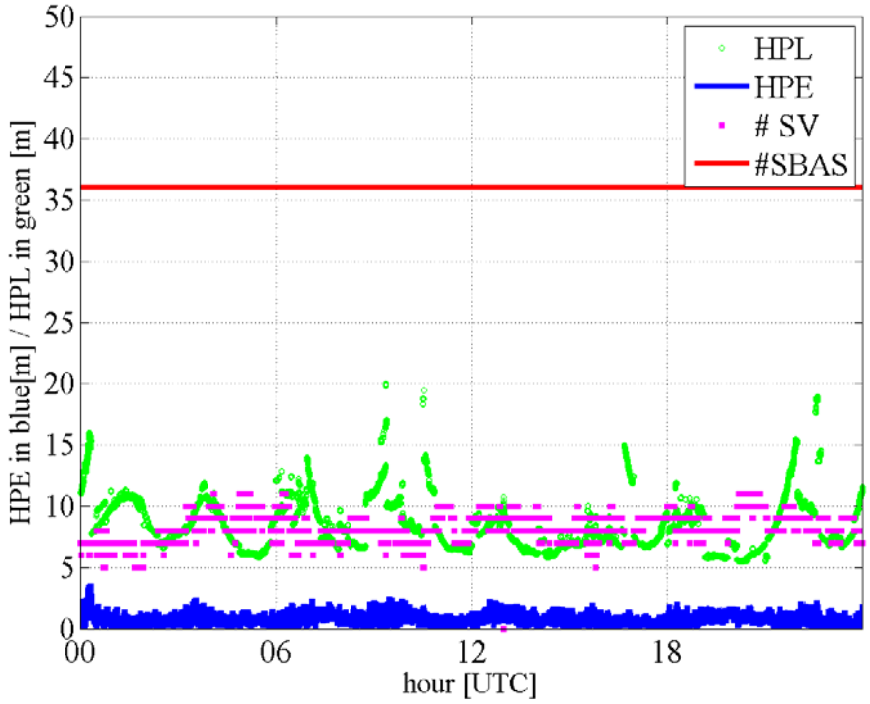

Fig. 3. An example chart of visualisation of HPE/HPL analysis obtained for CSIS station observation data for 26th of July 2016

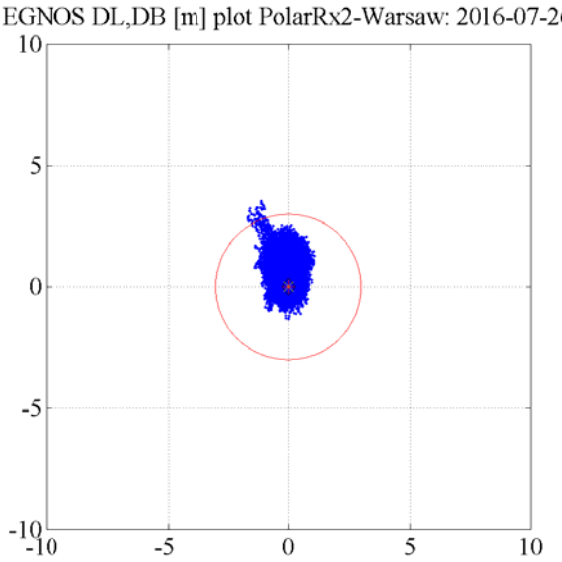

Fig. 4. An example chart of visualisation of differences in horizontal position (latitude and longitude differences) from reference position obtained for CSIS station observation data for 26th of July 2016

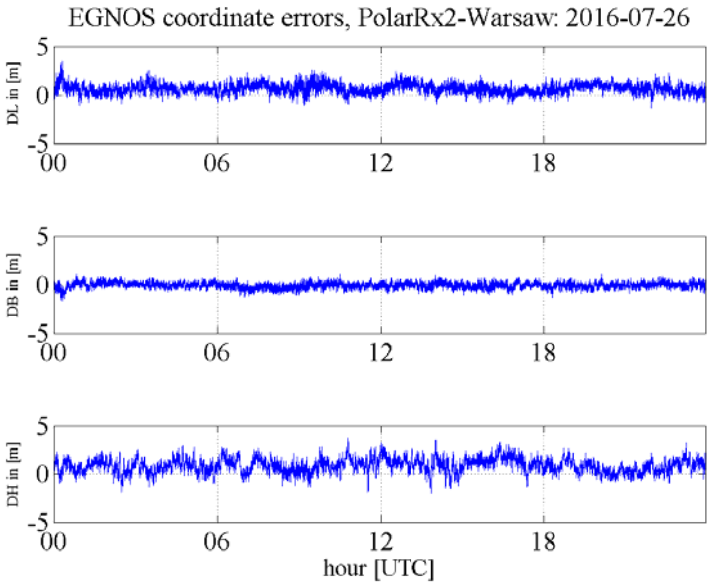

Fig. 5. An example chart of visualisation of differences in latitude, longitude and height from reference position versus time of a day, obtained for CSIS station observation data for 26th of July 2016

3.2 QUARTERLY ANALYSES

For each quarter the analysis of availability of GPS observation and EGNOS corrections for both SiS and EDAS data are prepared. They are presented as a bar chart of percentage values (see Figure 6). The values lower than 100% are reported to the GSA (European GNSS Agency) together with reasons of loss of observations.

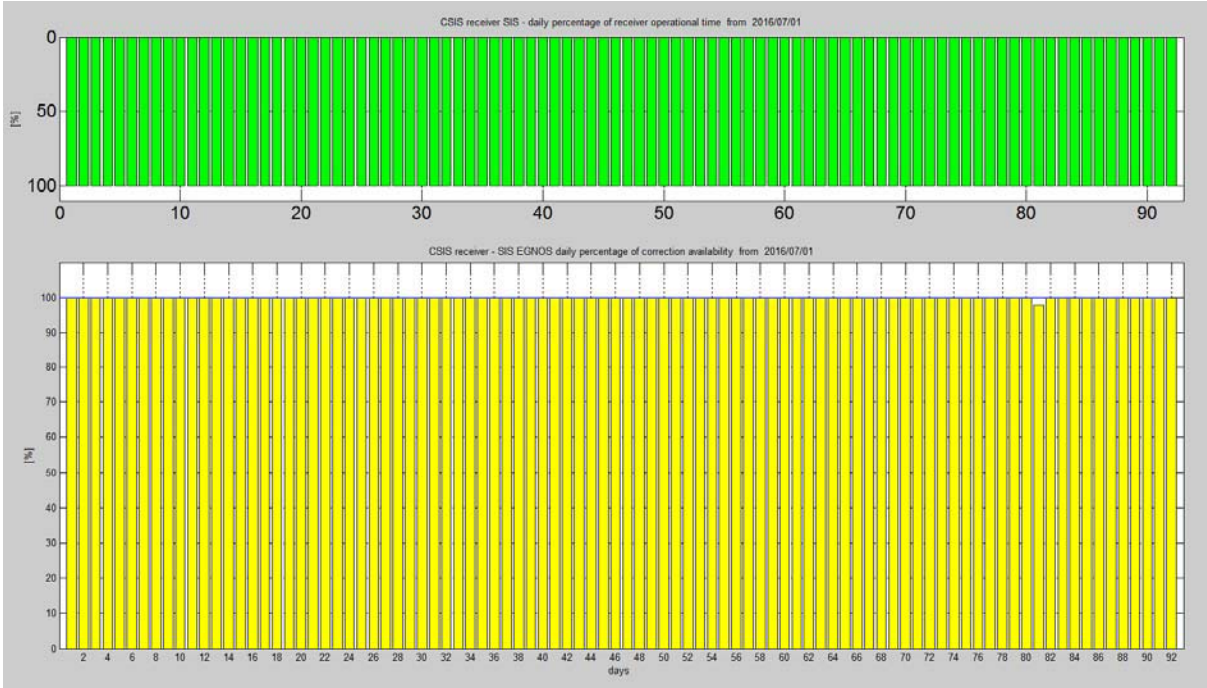

Fig. 6. Example chart of observation availability for station CSIS obtained for 3rd quarter of 2016. Top chart (in green) presents GPS observation availability, bottom (in yellow) EGNOS SiS corrections availability

In the Figure 6 a reduction in EGNOS SiS correction availability for 19th of September 2016 (81st day of 3rd quarter of 2016) could be observed. It was caused by outage registered since 19/09/2016 07:43:35 UTC till 08:14:22 UTC. The outage was defined in ESSP (European Satellite Service Provider) message.

According to EGNOS OS SDD the quarterly analysis of 95% confidence HPE/VPE (Horizontal Position Error/Vertical Position Error) has been prepared. The graphs present a daily value of HPE and VPE obtained for 95% of observations together with average value for all quarter (see Figure 7). For the whole year of First Specific Grant of SPMS project, values of daily HPE and VPE computed for 95% of observations were very stable and for correct observations did not exceed defined values 3m for horizontal and 4 for vertical position errors.

Additionally, analysed differences, in horizontal and vertical position computed by receivers for CSIS and CNET stations, define the differences in horizontal and vertical position computed for EGNOS SiS and EDAS corrections. Figure 8 presents example differences in horizontal and vertical position components for 3rd quarter of 2016. Presented results are stable and the differences in position component between computation with EGNOS SiS and EDAS correction do not exceed few centimetres.

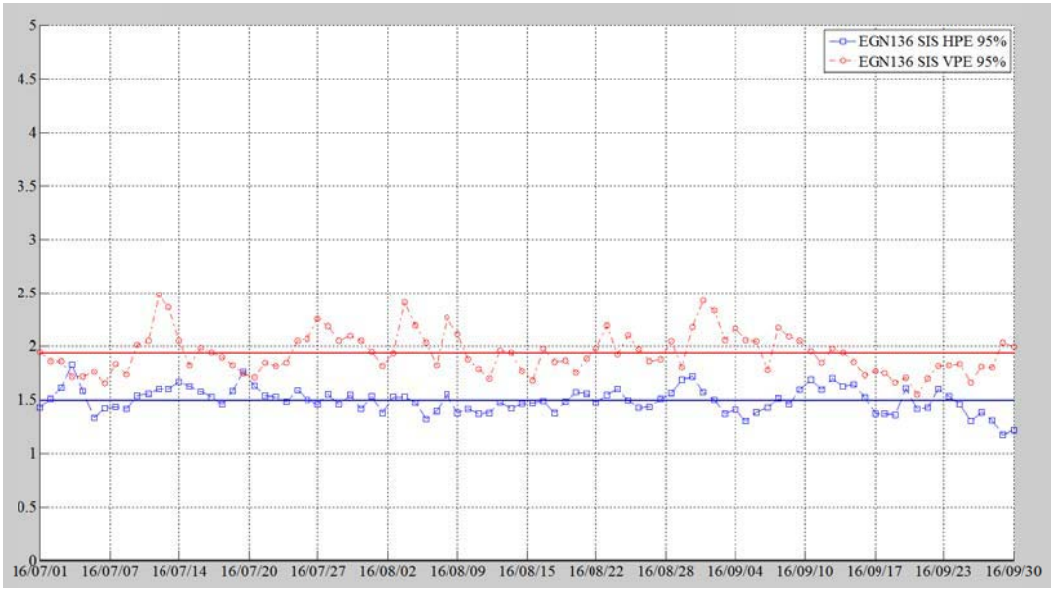

Fig. 7. Example chart of HPE/VPE daily values obtained for observations with confidence level of 95% for 3rd quarter of 2016 (Swiatek et al.)

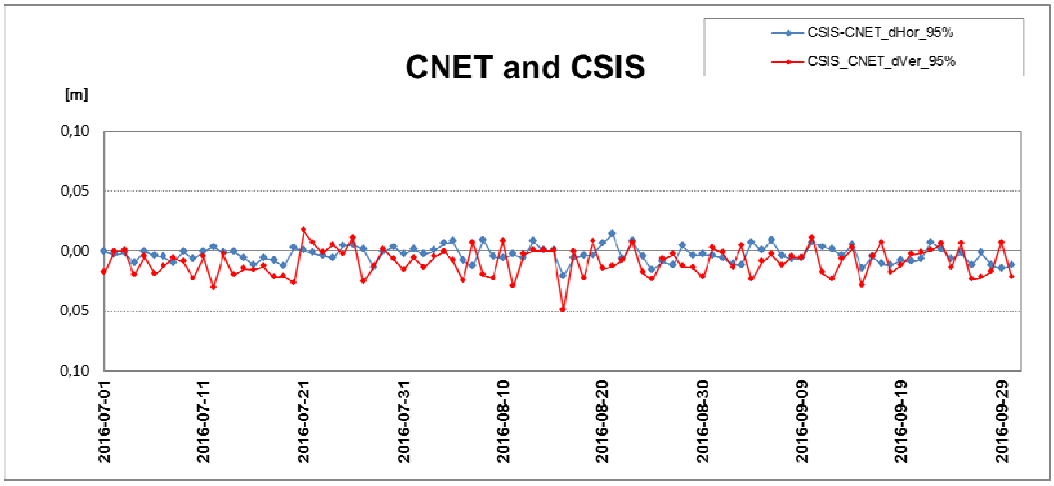

Fig. 8. Differences in horizontal and vertical position components between CSIS and CNET obtained for daily observations with confidence level of 95% for 3rd quarter of 2016 (Swiatek et al.)

4. LONG TERM ANALYSIS

The SPMS project has been running since November 2015 that's why we could prepare first analysis for long term observations. Unfortunately during the first two quarters of project duration (4th of 2015 and 1st of 2016) the Septentrio receivers worked very unstable. For that reason these two periods were excluded from analysis.

For the purpose of that paper, data from April of 2016 till June of 2017 was analysed. This period consisted of 15 months. The duration is still too short for obtaining representative results for trends analysis but first results could be presented.

Figures 9 and 10 present results obtained for horizontal and vertical position error respectively, for confidence level of 95%. HPE and VPE values were calculated for observations from CSIS and CNET stations (for EGNOS SiS and EDAS corrections

respectively). Analysed values did not exceed minimum accuracy of 3m in horizontal and 4m in vertical component defined in OS SDD.

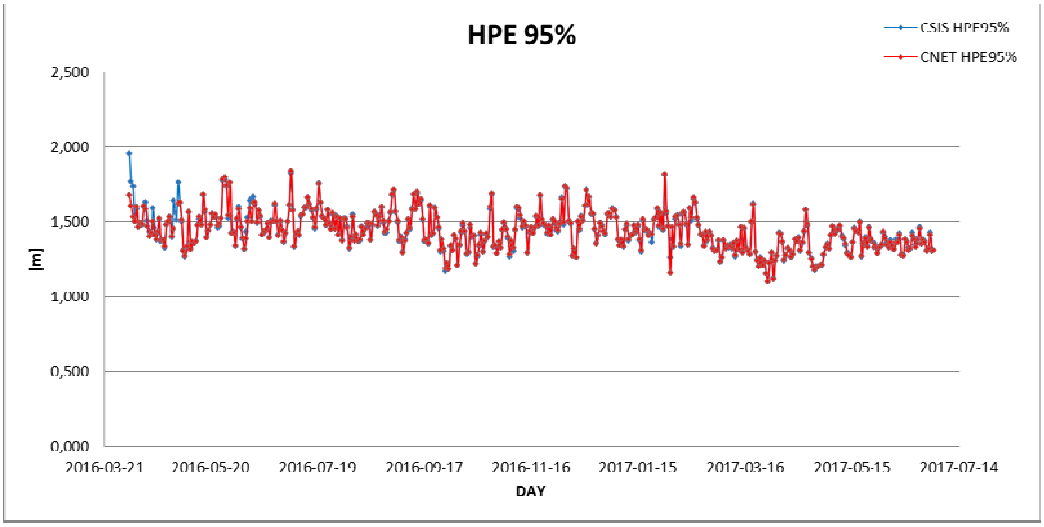

Fig.9. Differences in HPE values obtained for daily observations between CSIS and CNET station for confidence of 95%

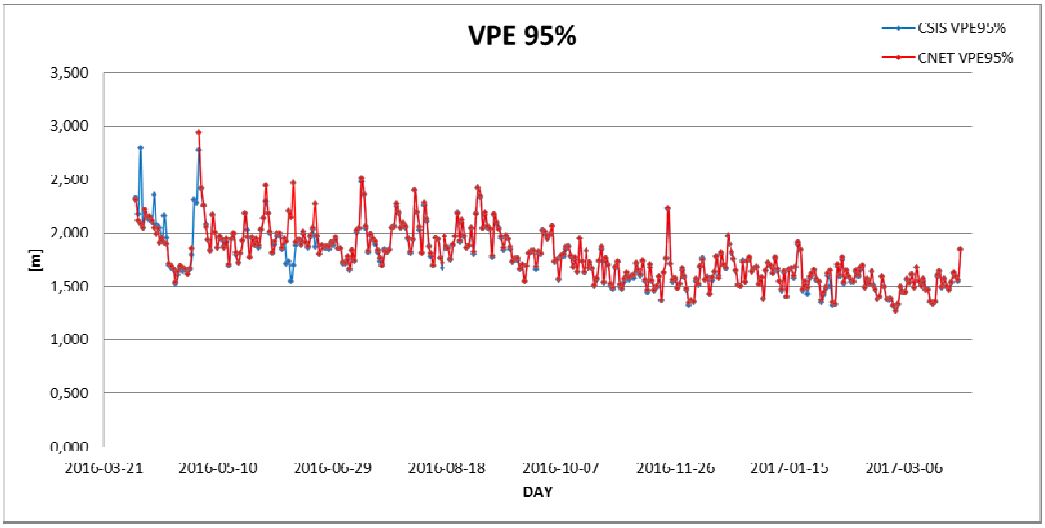

Fig. 10. Differences in VPE values obtained for daily observations between CSIS and CNET station for confidence of 95%

The average HPE values, in analysed period, are very similar for EGNOS SiS and EDAS correction and they are 1.437m for CSIS and 1.436m for CNET station. For VPE parameters the average values computed for SiS and EDAS corrections are slightly bigger and they are 1.739m for CSIS and 1.747m for CNET.

Analyses of differences in position components were prepared for obtained differences from reference position.

For analysed stations CSIS and CNET both Septentrio receivers have been connected to single antenna. This way they have built a zero-base. For both station computed precise position is the same and defined with high precision. The differences of computed navigation position from reference station position have defined the real error of observations.

Figures 11a and b present differences in latitude and longitude respectively. The values of latitude and longitude have been computed as a daily mean navigation position. The presented

differences are very similar for both stations. Some differences observed between results from CSIS and CNET stations are caused by loss of observations taken into account by receivers.

The results have shown some trends but the analysed period of 15 months is too short to make strict conclusions. Due to the fact that the project is planned for 7 years the analysis of trends could be prepared after few years of the project run. It has been observed –that both latitude and longitude present a constant, and similar for both stations, shift from reference values. For latitude it is about 0.61m while for longitude about -0.06m. Additionally, the results for latitude show higher noise than for longitude. Difference between minimum and maximum values is about 0.67m for latitude and 0.31m for longitude.

Figures 12 a and b present differences in horizontal and vertical position component respectively. The values of horizontal and vertical coordinate components have been calculated as a daily mean values. The presented differences are very similar for both stations. Some differences observed between results from CSIS and CNET stations are caused by loss of observations taken into account by receivers. Similarly to figures describing latitude and longitude differences, the trends couldn't be identified properly because of not long enough period. It is seen that both horizontal and vertical components present a constant, and similar for both stations, shift from reference values. For horizontal component it is about 0.58m while for vertical about 0.62m. The vertical coordinate component is two times more noisy than horizontal one.

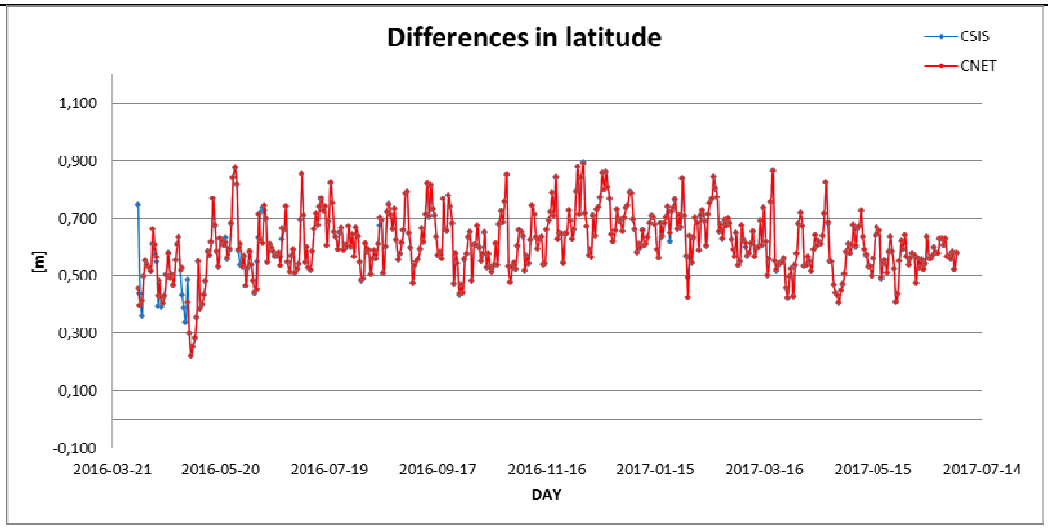

Fig. 11 a. Differences from reference position in latitude for stations CSIS and CNET

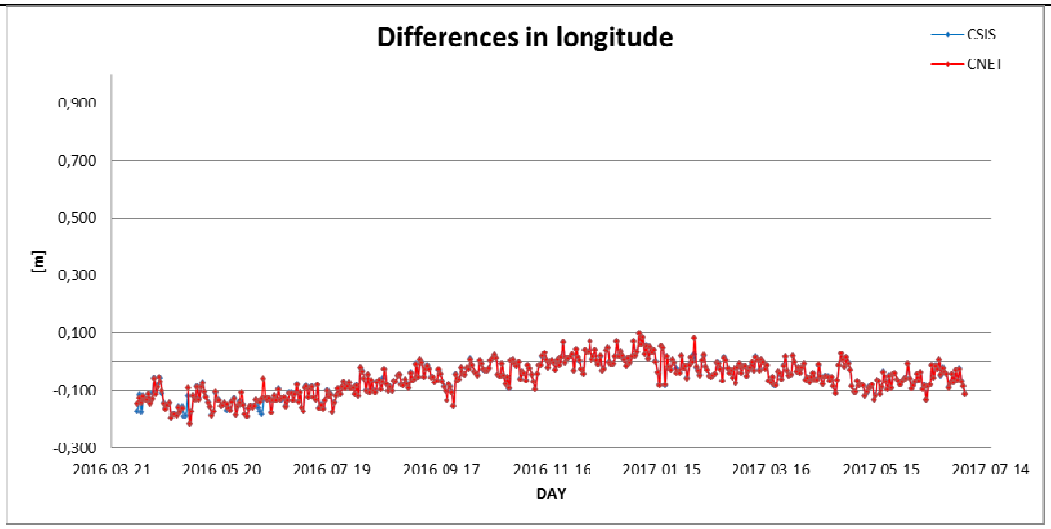

Fig. 11 b. Differences from reference position in longitude for stations CSIS and CNET

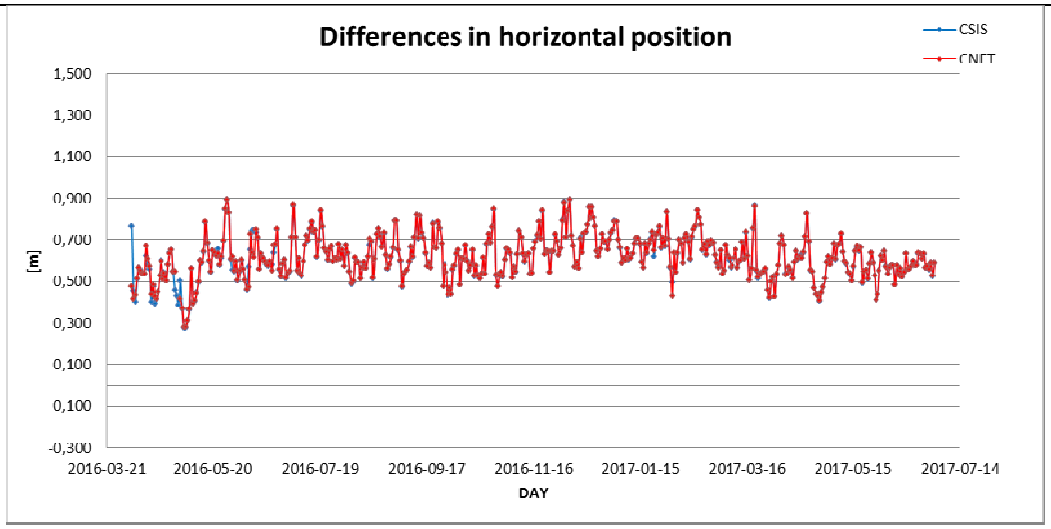

Fig. 12 a. Differences from reference position in horizontal component for stations CSIS and CNET

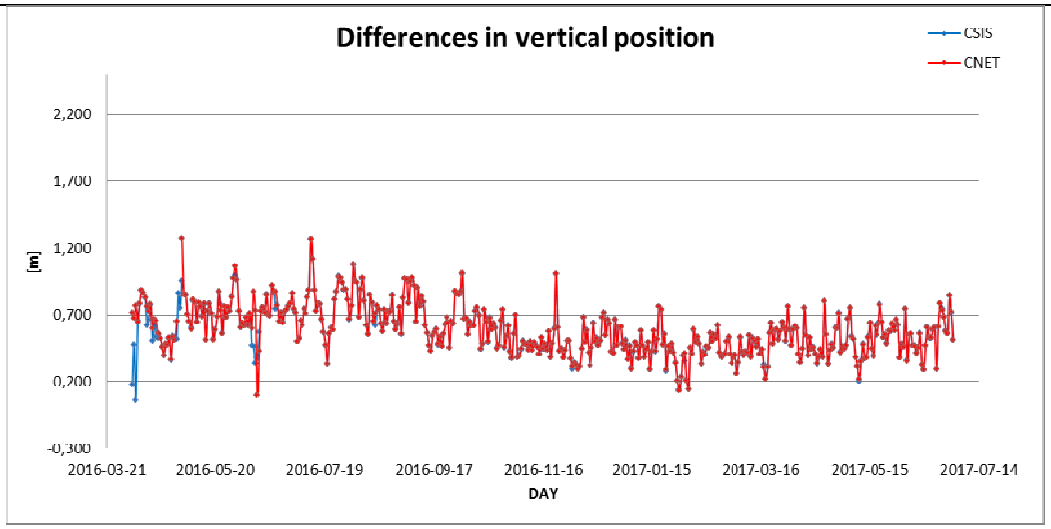

Fig. 12 b. Differences from reference position in vertical component for stations CSIS and CNET

Values of calculated coordinates for both stations (for EGNOS SiS and EDAS corrections) are very similar and for those hard to notice in above figures the additional way of results presentation has been prepared. Figure 13 presents the differences between CSIS and CNET stations position components. The results presented in Figure 13 are stable and small. They do not exceed single centimetres but some exceptions are noticed. Based on that analysis it could be concluded that significant differences weren't noticed between the source of exerted EGNOS correction if Internet connection is stable and continuous.

Deviations from standard results, observed in Figure 13 have been analysed and explained. The observed exceptions result from loss in observations taken for position calculation by one or both receivers (see Figure 14)

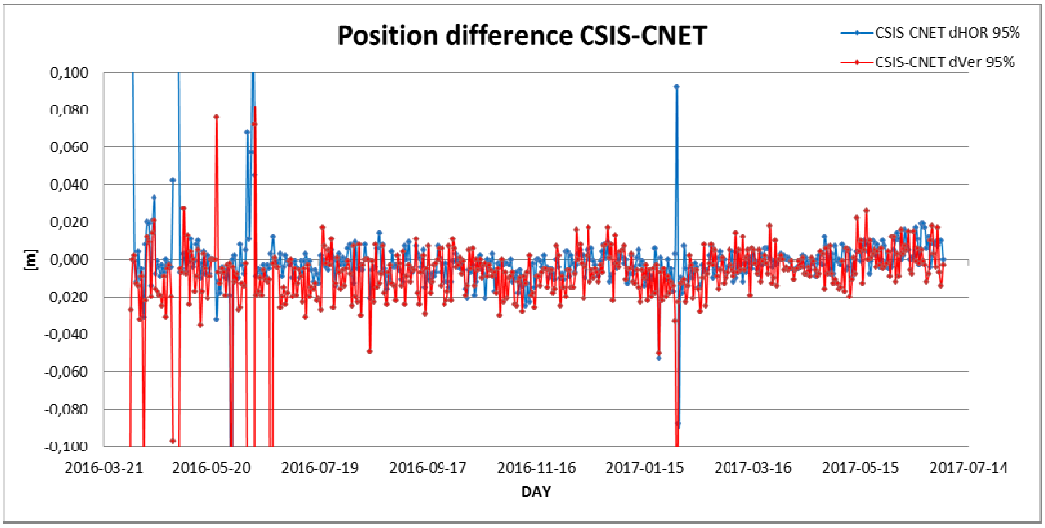

Fig.13. Differences in horizontal and vertical position components between CSIS and CNET stations

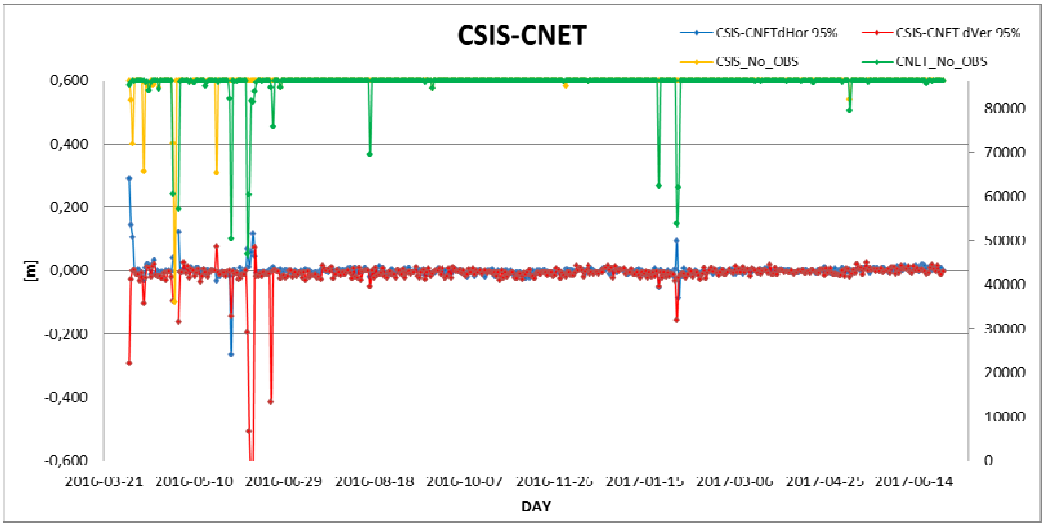

Fig.14. Differences in horizontal and vertical position components between CSIS and CNET versus number of observations for those stations taken into account by receivers

5. CONCLUSIONS

The results of position calculation using EGNOS correction are stable. The position calculated for EGNOS SiS and EDAS is very similar in stable conditions. The differences between EGNOS SiS and EDAS correction used for station position calculation in horizontal and

vertical components do not exceed 0.1m. The loss of observations increases the horizontal and vertical position error. The latitude, longitude and height calculated by receivers show some changes but length of analysed period does not allow to draw valid conclusion yet. In the future it is planned to focus on an investigation of results for special conditions such as ionospheric disturbances and their effect on obtaining stations position.

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