# EDAS (EGNOS Data Access Service): Differential GNSS corrections for land applications

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## BIOGRAPHIES

Juan Vázquez has an MSc. in Telecommunication Engineering from the University of Oviedo. He has worked in the GNSS industry since 2008, when he joined GMV AD. There, he participated in several R&D projects related to GNSS system architecture, applications and integrity concepts. In 2010, he started working as a consultant within the Service Provision Unit of ESSP SAS, as a consultant from GMV. He joined the Service Provision Unit of ESSP by beginning of 2012, where he is in charge of the team responsible amongst others for the EDAS service and EGNOS NOTAM Proposals provision.

Elisabet Lacarra received her master degree in Telecommunication Engineering in 2005. Later she was collaborating in different projects related to GNSS systems in GMV. Since 2009 she has been working inside the ESSP, firstly as performance expert for the analysis and assessment of EGNOS performance and later as EDAS Service expert for the management of all activities related to the EGNOS Data Access Service provision.

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## ABSTRACT

EDAS (EGNOS Data Access Service) is the EGNOS ground-based service (through the Internet), which provides free of charge access to all the data generated and collected by the EGNOS infrastructure. EDAS gathers all the raw data coming from the GPS, GLONASS and EGNOS GEO satellites collected by all the receivers located at the EGNOS stations, which are mainly distributed over Europe and North Africa. Once the data are received, EDAS disseminates them over the Internet in real time and through an FTP archive, resulting in the different services depending on the protocol and on format used, along with the type of information available to users. In addition to the aforementioned data, EDAS is also delivering its own products. Among those EDAS products, this paper will investigate the potential use of EDAS Differential GNSS corrections to support land-based applications such as mapping, transportation and emergency services, with special attention to precision agriculture.

EDAS service provision is performed by ESSP, as EGNOS Services Provider, under contract with the European GNSS Agency (GSA), the EGNOS program manager. The European Commission (EC) is the owner of EGNOS system (including EDAS) and has delegated the exploitation of EGNOS to the GSA. ESSP also manages the EGNOS Helpdesk, which provides technical support to users answering any potential question or clarification about EDAS, along with the registration of new EDAS users.

Firstly, the paper will introduce the EDAS system and its architecture, presenting the main types of data disseminated through its different services and the online information available to the users. As part of this introduction, special attention will be put on the description of the EDAS Ntrip service, which will be the main enabler for the study to be conducted in the scope of this paper. As already mentioned, EDAS is providing differential corrections to the GPS and GLONASS satellites in RTCM format using the Ntrip protocol, taking the EGNOS stations as reference stations. Using this service, GNSS receivers can improve the accuracy of

satellite-based positioning systems up to sub-meter level applying Differential GNSS (DGNSS) techniques. Ntrip is an RTCM standard widely adopted for disseminating differential corrections and GNSS streaming data to stationary or mobile users over the Internet. It supports wireless Internet access through Mobile IP Networks, allowing simultaneous mobile devices or receiver connections to a broadcasting host (caster).

In order to provide some valuable elements to assess the EDAS DGNSS corrections ability to support land applications, a performance analysis in terms of accuracy and availability has been done, which shows the achieved performance results for different locations in Europe. The EDAS DGNSS corrections have been applied to the GNSS measurements from public reference stations at selected locations in real-time to obtain statistics depending on the baseline distance between rover and reference station and the location over Europe. The results have been assessed, identifying in which conditions and baseline restrictions the EDAS DGNSS Service could provide an enhanced navigation position with respect to GNSS stand-alone and position errors lower than 1 meter.

In addition, focusing on the potential added value of the EDAS DGNSS corrections for precision agriculture, the positioning results from the previous exercise have been post-processed to compute the pass-to-pass accuracy according to ISO 12188-1 (Tractors and machinery for agriculture and forestry - Test procedures for positioning and guidance systems in agriculture - Part1: Dynamic testing of satellite-based positioning devices). The pass-to-pass accuracy is a common indicator of the repeatability of measurements specific to agriculture, which is used for assessing the precision of the guidance equipment. The pass-to-pass corresponds to a short-term dynamic performance determined from off-track errors along straight segment passes occurring within a 15 minute time frame. Considering that, for applications like seeding, planting, spreading and spraying, a pass-to-pass accuracy (15 minutes, 95$^{th}$ percentile) below 20 cm is typically required, the obtained results have been analysed to identify the maximum distance from the EDAS reference stations to still meet this performance level.

Finally, based on the baseline restrictions from EGNOS stations driven by the previous performance assessment, estimated coverage maps is provided for at least these performance levels:

- Sub-metric EDAS DGNSS accuracy performance: understanding that this performance level could be enough for a variety of applications in the mapping, transportation and emergency services domains.

- EDAS DGNSS performance improving GNSS only solution: This could be an alternative to improve the GNSS standalone solution for compatible receivers that do not use EGNOS or for users working in challenging environments (e.g. no GEO visibility).

- EDAS DGNSS pass-to-pass accuracy (15 minutes, 95$^{th}$ percentile) below 20 cm: This performance could be sufficient for some precision agriculture applications, such as seeding, planting, spreading and spraying.

With regards to the coverage maps, the GPRS/GSM coverage within Europe will be considered to take into account the fact that EDAS Ntrip service requires Internet access.

In conclusion, the paper provides an indication of the positioning performance supported by the EDAS DGNSS corrections, including the associated coverage areas under different performance criteria which could be of interest for different land applications in the agriculture, mapping, transportation or emergency services domains.

## I. INTRODUCTION TO EDAS

**EDAS Overview**

EGNOS, the European Satellite Based Augmentation System (SBAS), provides corrections and integrity information to GPS signals over a broad area over Europe and is fully interoperable with other existing SBAS systems (e.g. WAAS, the North American SBAS).

ESSP (European Satellite Services Provider) is the EGNOS system operator and EGNOS Service provider, under contract with the European GNSS Agency (GSA), for the following three services:

- **EGNOS Open Service (OS)**, freely available to any user [2].
- **EGNOS Safety of Life (SoL)** Service, that provides the most stringent level of signal-in-space performance for safety critical applications [3].
- **EGNOS Data Access Service (EDAS)**, which is the EGNOS terrestrial data service offering free of charge access to GNSS data to authorised users by GSA (under delegation of EC) [1].

As it can be observed in Figure 1, EDAS gathers all the raw data coming from the GPS, GLONASS and EGNOS GEO satellites collected by all the receivers located at the EGNOS stations. There are currently 39 ground stations (Ranging and Integrity Monitoring Station - RIMS) and 6 uplink stations (Navigation Land Earth Stations - NLES), mainly distributed over Europe and North Africa. EDAS disseminates this GNSS data in real time and in form of archive historical data to EDAS users and/or Service providers that distribute the data locally or to specific set of applications. In consequence, EDAS allows users to "plug in" to the EGNOS system by providing access to GPS/GLONASS satellite navigation and observation data, along with the EGNOS messages received by EGNOS ground stations.

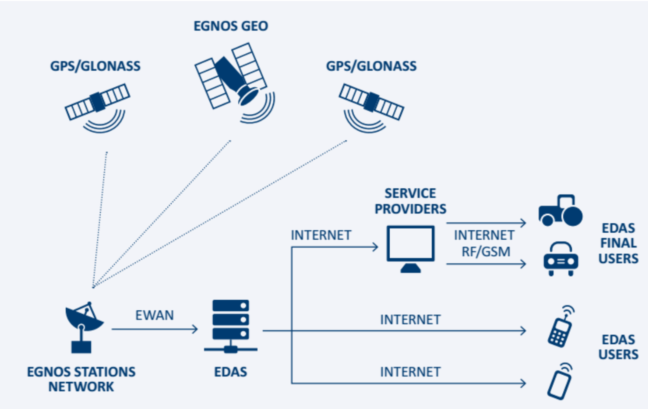


Figure 1: EDAS High-Level Architecture [1]

EDAS therefore provides an opportunity to deliver EGNOS data to users who cannot always view the EGNOS satellites (such as in urban canyons), or GNSS data to support a variety of other services, applications and research programs.

The European Commission officially declared the EDAS services available to EU users in July 2012. In April 2013, a new set of value-added services was subsequently declared available, to extend the initial EDAS portfolio and enable EDAS to support new application domains.

Currently, the services provided by EDAS are as follows (please refer to the EDAS Service Definition Document [1] - for a detailed description, http://egnos-user-support.essp-sas.eu/new_egnos_ops/content/egnos-sdds):

- **Main Data Streams** [4]: GNSS data is provided through the Internet in real time in ASN.1 format [8] (Service Level 0) and RTCM 3.1 [9] format (Service Level 2).
- **Data Filtering** [4]: Filtering capabilities to allow GNSS data to be received from only certain subsets of RIMS stations when connecting to EDAS Service Level 0 and/or 2. Currently 6 different groups of RIMS stations are defined according to geographical criteria.
- **SISNeT Service** [6]: EGNOS messages provided in real time using the SISNet protocol [10] defined by ESA.
- **FTP Service** [5]: Historical GNSS data available through an FTP site including:
    - EDAS SL0, SL2 raw data.
    - GPS/GLONASS navigation and observations (RINEX format [12])
    - EGNOS messages (EMS [13] + RINEX-B formats)
    - Ionosphere information in IONEX [14] format.
- **Ntrip service** [7]: GNSS measurements and corrections in real time using Ntrip protocol, delivered in RTCM 3.1 [9], 2.3 [16] and 2.1 [15] formats. Within the data delivered by the Ntrip service, differential GNSS corrections and phase measurements as well as additional messages for RTK (Real-time kinematic) positioning are provided.

The following table summarizes the types of data that can be retrieved via the different EDAS services.

Table 1: EDAS Services

| Mode | EDAS Service | Type of Data | | | | Protocol | Formats |
|---|---|---|---|---|---|---|---|
| | | Observation & navigation | EGNOS messages | RTK messages | DGNSS corrections | | |
| Real Time | SL/DF 0 | X | X | | | EDAS | ASN.1 |
| | SL/DF 2 | X | X | | | EDAS | RTCM 3.1 |
| | SISNeT | | X | | | SISNeT | RTCA DO-229D |
| | Ntrip | X | | X | X | Ntrip v2.0 | RTCM 2.1, 2.3, 3.1 |
| Archive | FTP | X | X | | | FTP | RINEX 2.11, RINEX B 2.10, EMS, IONEX, SL0 and SL2 |

EGNOS data coming from the EDAS Services can be used for the development of applications based on GNSS data streams, or for the provision of added-value services based on EDAS. As examples, EDAS services are currently used for tracking dangerous goods, high precision positioning, management of airport fleets, engineering activities in the EGNOS programme, monitoring of GNSS performance, atmospheric investigation and R&D activities.

**EDAS registration**

In order to request an EDAS account, users should follow the steps detailed below:

1. Register in the EGNOS User Support Website: http://egnos-user-support.essp-sas.eu
2. Fill and submit the EDAS registration form (only accessible upon registration in the web)

After the verification of the provided data and access authorization from GSA, the EGNOS Helpdesk will provide the user with the credentials and configuration details necessary to connect to the requested EDAS Service. Additionally, the website credentials will allow the user to download user oriented documentation and SW, such as the EDAS Client SW User Manual [4] and the user information packages for each EDAS Service ([5], [6], [7]).

EDAS users are welcome to contact the EGNOS Helpdesk (egnos-helpdesk@essp-sas.eu or +34 911 236 555) for EDAS registration and for any request related to EDAS, including EDAS services status, connectivity issues, technical specifications, data streams structure, conditions of use, etc.

### EDAS online information

The following means of information are made available by ESSP regarding EDAS through the EGNOS support website (http://egnos-user-support.essp-sas.eu):

- **EDAS Service Definition Document** [1]: The EDAS SDD provides information on the EDAS services and their conditions of use. In terms of content, the EDAS SDD describes the EDAS system architecture and provides an overview of the current EDAS services with regards to the information that is transmitted, the data formats, protocols and committed performance.
- **EGNOS User Support Website**: Up-to-date information about the EDAS services, along with the interface with the EGNOS helpdesk and the form to register as EDAS user is located in the EGNOS User Support Website. Since July 2014, the real-time status of all EDAS services is also publicly available on this site.

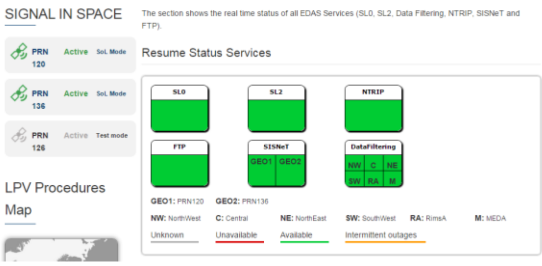

Figure 2: Real-time EDAS services status

- **EGNOS Monthly performance report:** containing the EDAS performance of the last month, in terms of availability and latency for all services.

### EDAS Services Performances

The EDAS SDD [1] defines the committed performance levels for EDAS (levels that should always be met in a nominal situation) in terms of availability and latency:

- **Availability**: percentage of time in which EDAS is providing its services according to specifications. The availability is measured at the EDAS system output (excluding user access network performance).
- **Latency**: time elapsed since the transmission of the last bit of the navigation message from the space segment until the data leaves the EDAS system (formatted according to the corresponding service specification). EDAS latency is a one-way parameter defined for real-time services.

Based on the above definitions, the table below provides EDAS services' minimum availability and maximum latency:

Table 2: EDAS services min availability and max latency

| Performance | SL0 | SL2 | SISNet | FTP | Ntrip | Data Filtering | |
|---|---|---|---|---|---|---|---|
| | | | | | | SL0 | SL2 |
| Availability | 98.5% | 98.5% | 98% | 98% | 98% | 98% | 98% |
| Latency (sec) | 1.30 | 1.45 | 1.15 | N/A | 1.75 | 1.60 | 1.75 |

The availability and latency parameters achieved from September 2014 to June 2015 are shown in the figures below.

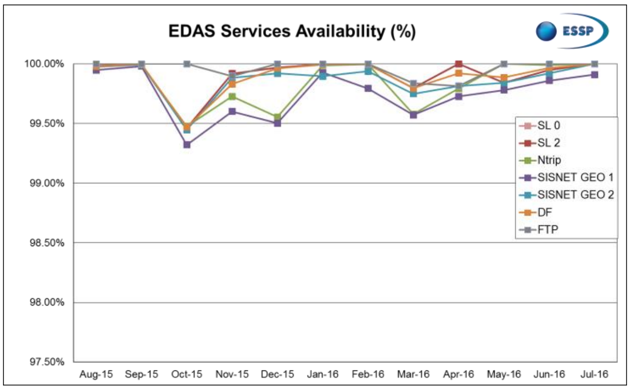

Figure 3: EDAS services availability

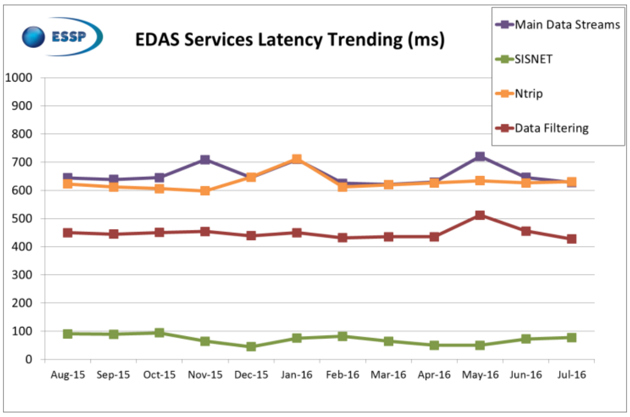

Figure 4: EDAS services latency

As shown above, EDAS availability has always been above 99% and the latency has been consistently below 1 second. Hence, it can be seen that the commitment values have been met for all the services throughout the whole period.

## II. EDAS FOR DGNSS POSITIONING

Differential GNSS (DGNSS) corrections are sent through the EDAS Ntrip Service via the Internet in order to support differential operation using GPS and/or GLONASS[1], obtaining accuracies of sub-meter level for dynamic, navigation applications.

EDAS disseminates this information in real time through the Ntrip (version 2.0) protocol [11], which uses RTSP (Real Time Streaming Protocol) for stream control in

[1] No commitment on GLONASS data is provided

addition to TCP and RTP (Real Time Transport Protocol) for data transport on top of the connectionless UDP.

The EGNOS Stations (RIMS and NLES) are considered as reference receivers, which are placed at a known, surveyed location. Then, since the satellite positions and the reference antenna location are known, the ranges can be determined precisely. By comparing these ranges to those obtained from the satellite observation measurements, the pseudorange errors can be accurately estimated (i.e. ionospheric delays, tropospheric delays, ephemeris errors and satellite clock errors), and corrections determined. These DGNSS corrections can then be broadcast to nearby users, who apply them to improve their position solutions.

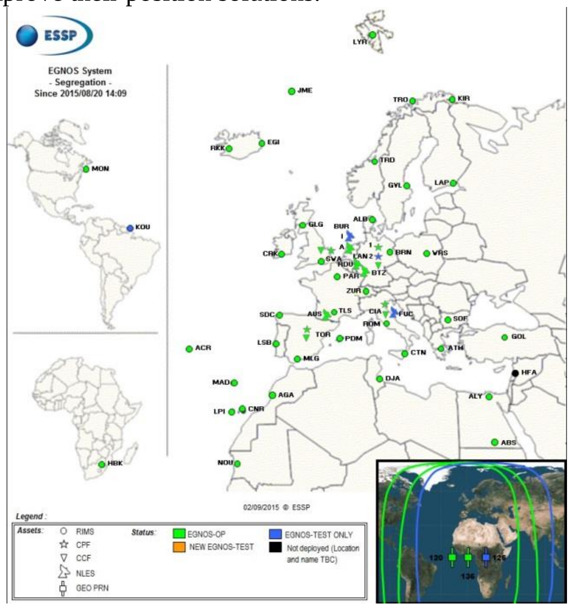

Figure 5: EGNOS RIMS stations

The DGNSS corrections are sent through the EDAS Ntrip Service in RTCM 2.1 and RTCM 2.3 standards, using the messages shown in table below:

| EDAS DGNSS Messages | Message Types | |
|---|---|---|
| | RTCM 2.1 | RTCM 2.3 |
| Differential GPS Corrections | 1 | 1 |
| GPS Reference Station Parameters | 3 | 3 |
| Reference Station Datum | N/A | 4 |
| Extended Reference Station Parameters | N/A | 22 |
| Antenna Type Definition Record | N/A | 23 |
| Antenna Reference Point (ARP) | N/A | 24 |
| Differential GLONASS Corrections | N/A | 31 |
| GLONASS Reference Station Parameters | N/A | 32 |

Table 3: EDAS DGNSS Message Types

For detailed information about the connection and usage of the EDAS Ntrip service, the EDAS Ntrip User Information Package [7] is available for registered users. EDAS Ntrip supports wireless Internet access through mobile IP networks like GSM, GPRS, EDGE, or UMTS, and allowing simultaneous PC, laptop, PDA, or receiver connections to a broadcasting host. Using this service, GNSS receivers can improve the accuracy of satellite-based positioning systems up to sub-meter level applying DGNSS techniques.

However, as already mentioned, EDAS DGNSS corrections are provided for the EGNOS RIMS stations and the user performance will be driven by the physical distance to the closest site. Also, Internet coverage is required to access the EDAS Ntrip service.

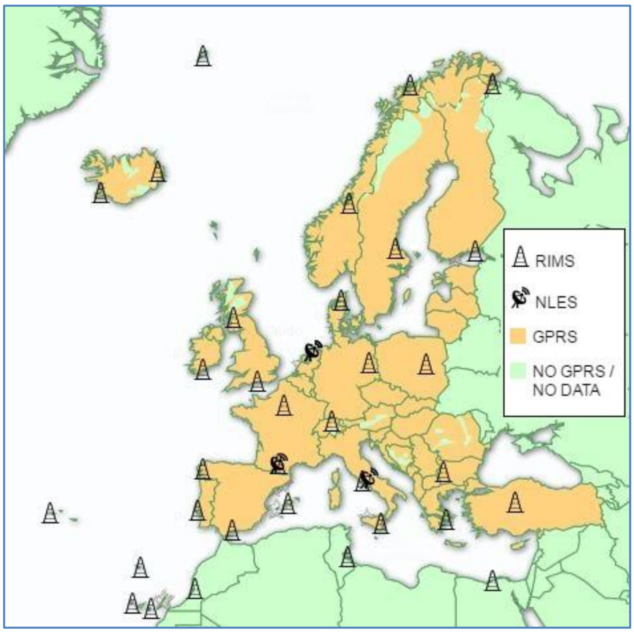


Figure 6: Estimated GPRS coverage (Europe) and EGNOS stations

The GPRS coverage information available from the European states is shown in orange taking into account the coverage maps of several telecommunications providers (it should be noted that the GPRS coverage information is qualitative, and has been obtained from the public information provided by the main telecomm providers in Europe). Those land masses not analysed or in which no GPRS Coverage is identified, are plotted as light green.

Based on the achieved performance results obtained in this paper, the map provided in Figure 6 will be complemented with the maximum estimated distances from the EGNOS stations (baseline restrictions) to obtain a DGPS position solution compatible with different performance targets.

## III. EDAS based DGPS performance assessment campaign

For the present study, ten different user locations (stations from the EUREF permanent network (EPN), http://www.epncb.oma.be) have been selected to assess the EDAS Ntrip service based DGPS positioning performance in different geographical areas of Europe, and selecting different EGNOS stations as reference, ensuring a wide diversity geographically and also in terms baseline (distance from user location to reference station). The positioning performance results presented in this paper have been derived by the AlberdingMonitor software. This monitoring software is based around the Alberding EuroNet application that is also used here to compute position solutions from GNSS raw data and DGNSS correction data input streams. Real-time status information and history data can be monitored on a web interface. The AlberdingMonitor software provides performance reports and can send automatic warning messages to network operators if a service outage or performance degradation is detected.

Hence, for this test campaign, GNSS raw measurements at multiple locations were obtained from EPN Ntrip caster, while the DGPS corrections were retrieved from EDAS Ntrip caster. Combining these real-time GNSS streams, the AlberdingMonitor SW computed the positioning solutions in real-time.

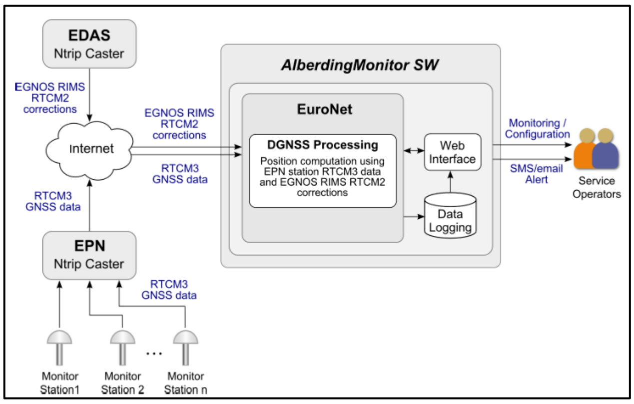

Figure 7: Performance assessment campaign: set-up.

Multiple combinations of rover and reference station locations were selected to obtain different baseline length scenarios: short (<150km), medium (150-350km), and long (350-500km).

Table 4: Stations for DGPS solutions

| DGPS Solution | | Distance type (Km) |
|---|---|---|
| Rover receiver (EPN) | Reference station (EDAS) | |
| BOR10 | BRNA | Medium (241) |
| | WRSA | Medium (272) |
| DARE0 | SWAA | Medium (288) |
| CASC0 | LSBA | Short (27) |
| | MLGA | Long (486) |
| HOFN0 | RKKA | Medium (327) |
| | EGIA | Short(119) |
| LPAL0 | CNRA | Medium (262) |
| | LPIA | Short (20) |
| MELI0 | MLGA | Medium (210) |
| OBE40 | ZURA | Medium (215) |
| ONSA0 | ALBA | Short (127) |
| SCOA0 | TLSA | Medium (257) |
| TLSE0 | TLSA | Short (14) |

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The above solutions are graphically represented in the following map, where the user location is shown with a tractor icon and the selected reference stations are indicated as a antenna.

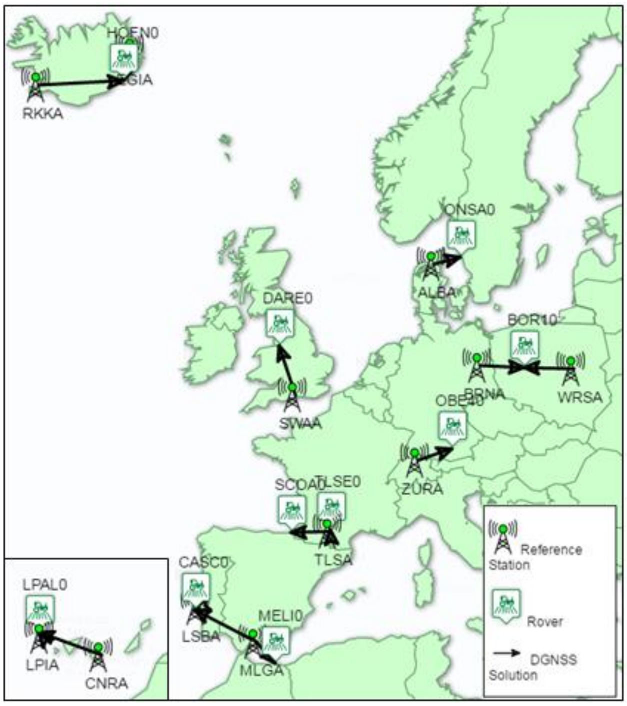

Figure 8: Performance assessment campaign: solutions.

Finally, it is worth mentioning that the above scenario was monitored during more than one month and all the results from the present paper are based on data from July 2nd 2016 to August 6th 2016 (35 days).

In the next paragraphs, the naming convention used to identify the performance results from a given solution from Table 6 is "*Rover_ReferenceStation*" (e.g,. BOR10_BRNA).

## EDAS based DGPS performance results

As a first result, Table 5 shows the cumulated statistics of all the solutions from Table 4 during the whole period (35 days) classified in the same baseline category (short, medium and long according to Table 4). Also, the accumulated performance for the GPS only solutions is provided to set a reference that can allow understanding the performance improvement that is achieved.

Table 5: GPS only and DGPS results using EDAS DGNSS

| Type of solution at rover receiver | Horizontal Error (95th %ile) | Vertical Error (95th %ile) | Availability |
|---|---|---|---|
| **GPS only** ***Rover rec.*** | 1.93 m | 3.13 m | 96.51 % |
| **DGPS** ***Short*** | 0.68 m | 2.00 m | 96.23 % |
| **DGPS** ***Medium*** | 1.01 m | 2.17 m | 95.85 % |
| **DGPS** ***Long*** | 1.46 m | 1.82 m | 93.88% |

As expected, in terms of accuracy (95th percentile -%ile-), the EDAS based DGPS performance is better than the GPS standalone one for all solution types.

When looking at the availability performance in Table 5, it is noted that:

- The combined availability of the GPS standalone solutions depends on the reception of GNSS data from the corresponding station from the EPN Ntrip caster.
- The combined availability of each group of DGPS solutions based on EDAS depends on the reception of GNSS raw data from the EPN Ntrip caster and the reception of the DGPS corrections from the EDAS Ntrip caster.
- The cumulated statistics for the long solutions are less representative than the other categories since only one solution has been considered in this category (CASC0_MLGA).

Hence, the availability performance shown in Table 5 is over the whole period (35 days), which is driven by the availability of the EPN station data acting as rover (user location) for each solution. Hence, in order to understand the availability that can be supported by EDAS DGPS corrections, only those epochs when observation measurements were available in the rover receiver are to be considered. Figure 9 shows the availability performance of each EDAS based DGPS solution within the periods when the rover receiver was available.

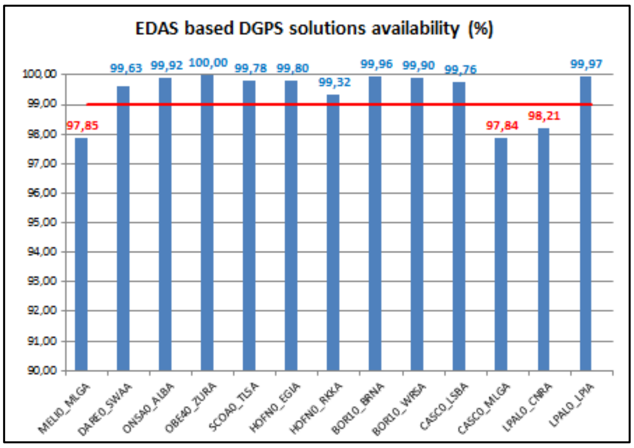


Figure 9: EDAS based DGPS solutions availability (02/07/2016-06/08/2016).

Hence, EDAS DGPS corrections enable DGPS positioning solutions with availability in excess of 99%. As one can see in Figure 9, the solutions using MLGA or CNRA RIMS stations as reference had lower availability than the others. The reason for this was the execution of some maintenance activities on the sites during July 2016 which penalised the stations availability.

In relation to the accuracy, Table 5 already indicated that a significant accuracy improvement was observed for all solution types (short, medium, long baselines) on both directions (horizontal, vertical), based on cumulated data. Figure 10 and Figure 11 below show the comparison of the percentile 95 of the horizontal and vertical accuracy respectively, for all the DGPS solutions with respect to the GPS standalone solution for the same rover receiver.

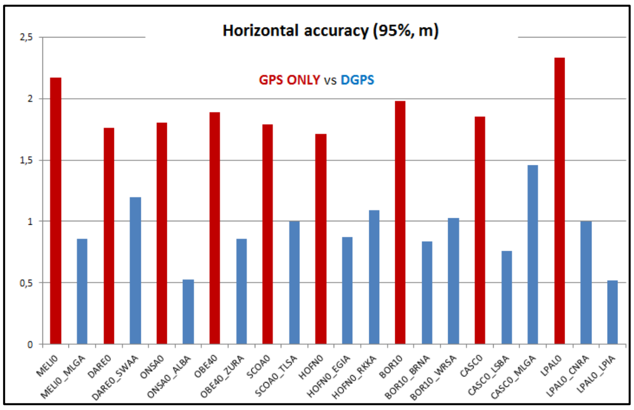


Figure 10: GPS only and EDAS based DGPS solutions horizontal accuracy (02/07/2016-06/08/2016).

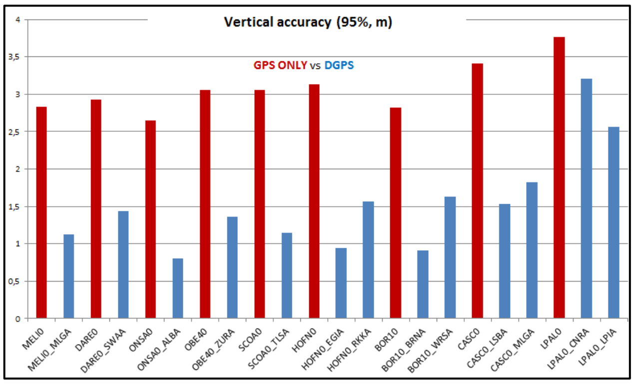


Figure 11: GPS only and EDAS based DGPS solutions vertical accuracy (02/07/2016-06/08/2016).

As one can easily see in the figures above, EDAS based DGPS performance significantly improves the GPS standalone one for all the solutions under analysis. Horizontally, errors are typically reduced to at least half of the GPS only ones (from the 2 meter range to the 1 meter –or less- range). Vertically, the error reduction is even larger with EDAS based DGPS positioning errors being in the order of one third of the GPS standalone errors.

On the vertical direction, there is one exception to the abovementioned qualitative assessment of the error reduction which is the case of the DGPS solutions at LPAL0. For this particular case, a large altitude difference exists between the reference station and the rover receiver, leading to a less accurate correction of the tropospheric error.

In order to further illustrate the performance improvement achieved by the application of EDAS DGPS corrections, the following figures show the statistical behaviour of the horizontal and vertical error on the differential solution with respect to the GPS standalone one for three specific solutions: ONSA0_ALBA (horizontal), HOFN0_RKK and HOFN0_EFI (vertical).

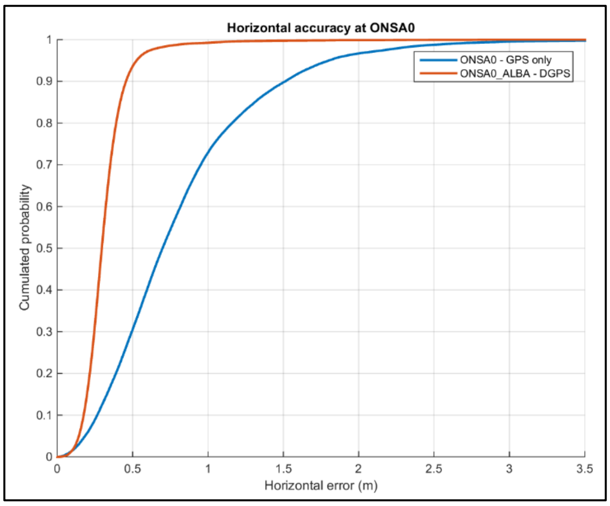


Figure 12: Cumulative distribution function of horizontal error (ONSA0 –GPS only- vs ONSA0_ALBA –DGPS-)

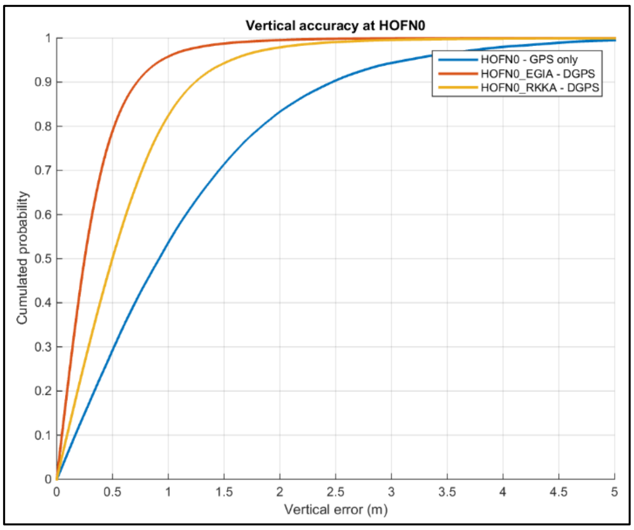


Figure 13: Cumulative distribution function of vertical error (HOFN0 -GPS -, HOFN0_EGI and HOFN0_RKK –DGPS-)

**Pass-to-pass performance using EDAS DGPS**

In the agriculture domain, the pass-to-pass accuracy is used for assessing the precision of guidance equipment. In addition to a sufficient absolute horizontal accuracy (at least 1 meter -95$^{th}$ percentile- is required for cereal and dry soil cultivation), the repeatability of the position solutions is critical.

In ISO 12188-1 [20] , pass-to-pass accuracy is called short-term dynamic accuracy in the standard terms and definitions. For the pass-to-pass accuracy definition, the ISO 12188-1 definition is the reference used for the calculations in this paper.

Part 1 of ISO 12188 provides a procedure for evaluating and reporting pass-to-pass accuracy of navigation data determined using positioning devices that are based on GNSS (GPS, EGNOS…). It focuses on the performance of the positioning devices and specifies common performance parameters that can be used to quantify performance of different positioning devices.

In this case, the pass-to-pass accuracy both on the North and East directions have been analysed for each day of the observation period, considering 15-minute time windows and using the same static data as for previous results (from July 2$^{nd}$ 2016 to August 6$^{th}$ 2016). The table below shows the maximum value of the pass-to-pass accuracy (between North and East directions), for those solutions which achieved a horizontal accuracy performance (95$^{th}$ percentile) better than 1 meter.

Table 6: EDAS based DGPS: pass to pass accuracy

| Solution | Pass to Pass (cm) -15 min, 95th- |
|---|---|
| LPAL0_LPIA | 13,9 |
| LPAL0_CNRA | 10,1 |
| CASC0_LSBA | 15,7 |
| HOFN0_EGIA | 12,4 |
| ONSA0_ALBA | 10,1 |
| MELI0_MLGA | 11,2 |
| OBE40_ZURA | 20,6 |
| BOR10_BRNA | 13,7 |
| SCOA0_TLSA | 18,6 |
| TLSE_TLSA | 16,5 |

The above pass-to-pass results are below 20 cm in all cases except for OBE40_ZURA when 20,6 cm have been achieved. If confirmed through more extensive analysis and field tests, these pass-to-pass values could enable the use of EDAS DGPS corrections in a wide range of agriculture applications, such as seeding, planting, spreading and spraying for cereals and dry soil cultivation.

## IV. EDAS DGPS estimated coverage

Finally, based on the results from the previous performance assessment, estimated coverage maps have been derived for the following performance levels:

- Sub-metric EDAS DGNSS accuracy performance: understanding that this performance level could be enough for a variety of applications in the mapping, transportation and emergency services domains.
- EDAS DGNSS performance improving GNSS only solution: This could be an alternative to improve the GNSS standalone solution for compatible receivers that do not use EGNOS or for users working in challenging environments (e.g. no GEO visibility).
- EDAS DGNSS pass-to-pass accuracy (15 minutes, 95th percentile) below 20 cm: This performance could be sufficient for some precision agriculture applications in cereal and dry soil cultivation, such as seeding, planting, spreading and spraying.

**EDAS DGPS: tentative sub-meter accuracy coverage.**

The horizontal accuracy performance of all EDAS based DGPS solutions has already been shown (Figure 10) with respect to the GPS only solutions at the same rover receiver. Now, the objective is to analyse how the EDAS based DGPS horizontal accuracy degrades as the distance to the reference station grows. Ultimately, a tentative hard limit to obtain sub-meter accuracy should be identified.

Figure 14 shows the horizontal accuracy (meters, 95th percentile) of all the analysed EDAS based DGPS solutions as a function of the distance from the rover receiver to the corresponding EGNOS reference station (please refer to Table 4 for the baseline distance of each solution).

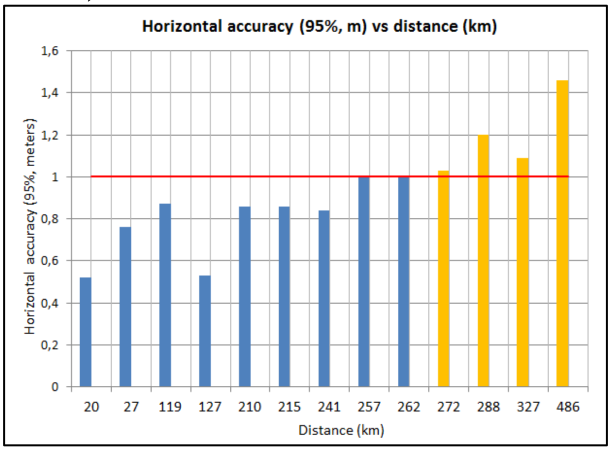


Figure 14: EDAS based DGPS: horizontal accuracy vs distance

Hence, based on the above results (selected locations, performance from July 2nd to August 6th 2016), it could be concluded that a tentative baseline limit to achieve sub-meter accuracy using EDAS DGPS corrections would be 260 km from the EGNOS stations.

To illustrate the coherency of this tentative hard limit with the performance results obtained in this assessment campaign, Figure 15 and Figure 16 show the cumulative distribution function of the horizontal error for those solutions just below and above the proposed threshold (LPAL0_CNRA with 262km baseline and BOR10_WRSA at 272 km distance).It is to be noted that, all solutions with a shorter baseline than LPAL0_CNR have provided sub-metric horizontal accuracy (95th percentile) while all those solutions with a baseline distance longer than BOR10_WRSA present horizontal accuracies (95th percentile) above the 1 meter target.

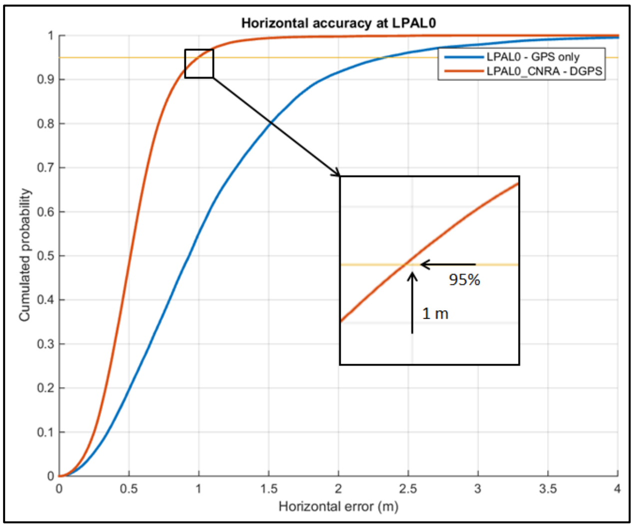


Figure 15: Cumulative distribution function – Horizontal error of LAPL0 and LPAL0_CNRA (DGPS, 262 km baseline)

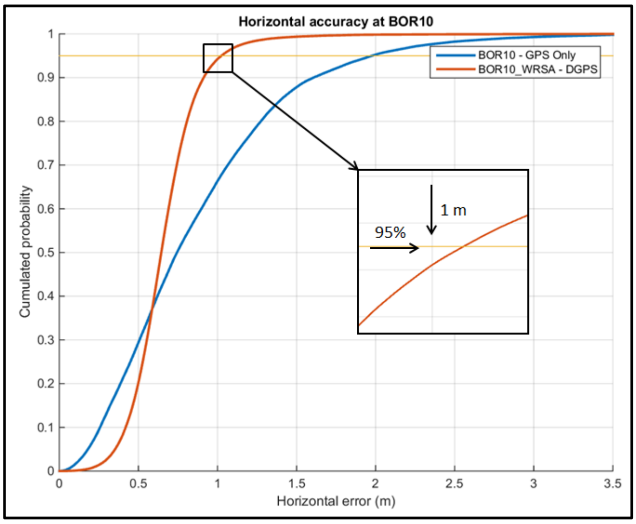

Figure 16: Cumulative distribution function – Horizontal error of BOR10 and BOR10_WRSA (DGPS, 272 km baseline)

Considering all the above (data campaign at specific locations during 35 days of July-August 2016), it could be concluded that a tentative maximum distance to the EGNOS RIMS station used as reference in order to achieve horizontal accuracy performance (95th percentile) lower than 1 meter would be 260 km. The following provides a graphical representation of the resulting EDAS DGPS coverage, representing a significant part of the EU landmasses (remote EGNOS stations not included in Figure 17).

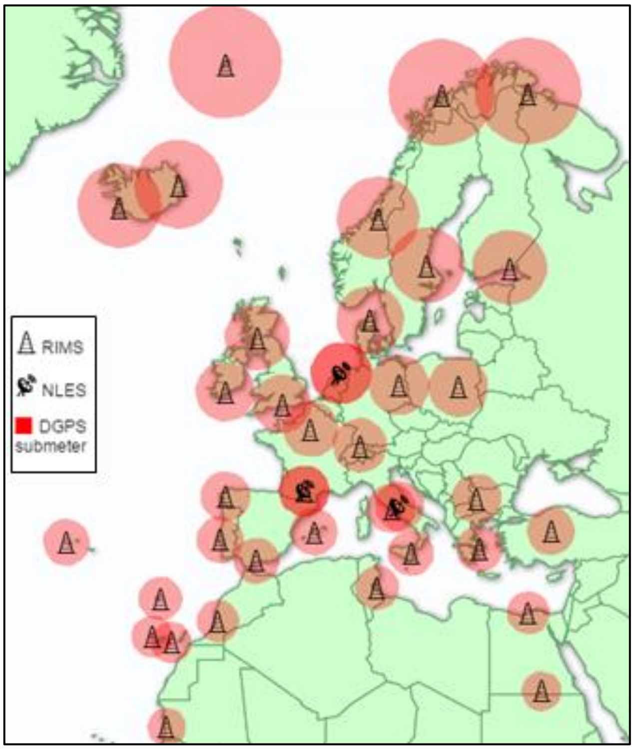

Figure 17: EDAS DGPS submeter accuracy performance - coverage

**EDAS DGPS: tentative coverage for enhanced performance with respect to GPS only.**

In the paper addressing the EDAS DGPS performance that was presented last year [19] , a hard limit for the maximum distance to the reference EGNOS station in order to improve the GPS only performance using EDAS DGPS corrections was tentatively set at 500 km. In the present paper, only one solution with a baseline distance in that range has been used (CASC0_MLGA, 486 km) since the focus was put of the analysis of the limits to achieve horizontal accuracies below one meter (discussed in the previous section). For this specific case, the horizontal and vertical accuracies (95th percentile) remain below the ones for the GPS only solution (see Table 5).

Additionally, in [19] , after an analysis of different long baseline DGPS solutions geographically distributed over Europe, a tentative hard limit of 500 was proposed. Hence, and pending further analysis with increased solutions diversity and longer observation periods, the same potential range is now considered for the definition of the EDAS DGPS coverage for the improvement of the GPS standalone solution.

The following figure shows the resulting EDAS DGPS coverage, considering the two criteria that have been analysed for what regards to the horizontal accuracy: sub-meter accuracy and improvement in performance with respect to GPS only. Also, the GPRS coverage information that was shown in Figure 6 is kept in the background.

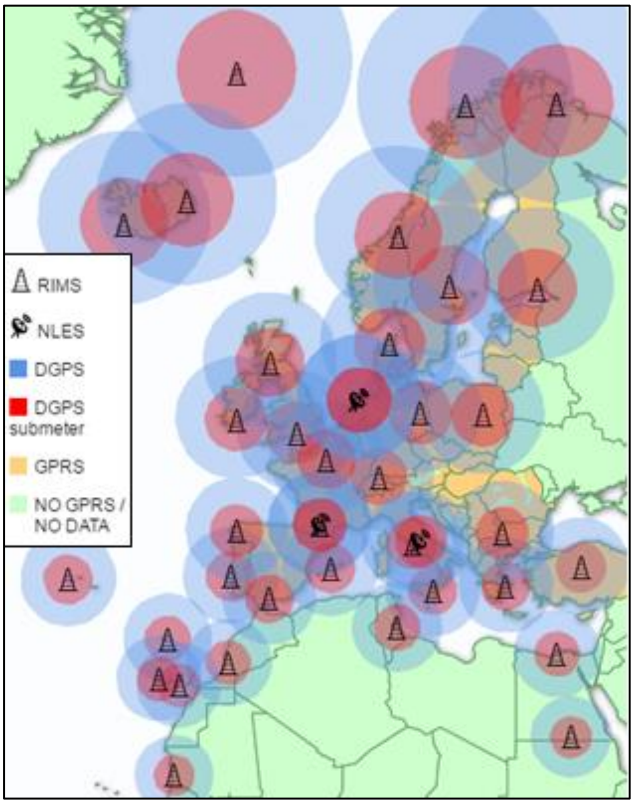

Figure 18: EDAS DGPS coverage

As can be seen in Figure 18, EDAS DGPS coverage area considering a range of 500 km (blue) would include most of the EU land masses, with the exception of some regions of Eastern Europe.

**EDAS DGPS: tentative coverage for pass-to-pass lower than 20 cm**

In previous sections (see Table 6), it has been shown that for all EDAS DGPS solutions providing horizontal accuracy (95th percentile) below 1 meter, the achieved pass to pass accuracy for the whole period was of 20 cm or less.

Figure 19 below provides, as a complement to the information in Table 6, the daily pass to pass results (worst value between East and North directions) for all the solutions presented above. As can be seen below, all solutions present a stable behaviour, with daily values showing a consistent performance and in line with the global results for the period (Table 6). Again, as mentioned previously, the obtained results are based on static data and should be confirmed via in-field testing.

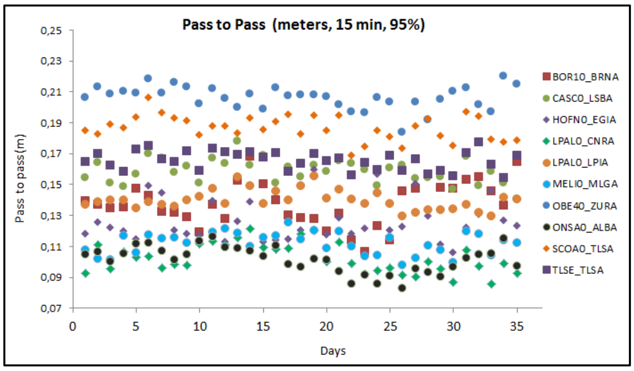


Figure 19: EDAS based DGPS: daily pass to pass accuracy

Hence, it could be concluded that a potential maximum distance allowing pass-to-pass accuracy below 20 cm using EDAS DGPS corrections, would be 260 km (same hard limit as the one identified for the submetric accuracy). Consequently, the resulting coverage map would be the one shown in Figure 17.

## CONCLUSIONS

EDAS is the access point to the data collected and generated by the EGNOS ground infrastructure through the EGNOS stations network in real time and offline through an FTP archive. EDAS is freely available for the GNSS community in the European Union since July 2012, with a minimum availability of 98.5% for the main data services and of 98% for the rest of the EDAS Services [1].

EDAS has already proven to be a versatile service, supporting professional users in different commercial applications. Interested companies and research institutions are welcome to register to the EDAS Services (http://egnos-user-support.essp-sas.eu) or contact to the EGNOS Helpdesk (egnos-helpdesk@essp-sas.eu) for further information.

EDAS can be used for DGNSS positioning since EDAS provides DGNSS corrections for the EGNOS stations, located mainly over Europe and North of Africa, though the EDAS Ntrip service. A performance analysis has been performed using Alberding Monitor SW, gathering performance results from July 2nd to August 6th 2016 for a set of diverse EDAS based DGPS solutions (different locations and baselines), driving the following main conclusions:

- EDAS based DGPS performance significantly improves the GPS standalone one. Horizontally, errors are typically reduced to at least half of the GPS only ones while on the vertical direction the error reduction is even larger (approximately one third of the GPS standalone errors).
- In terms of availability, the obtained results indicated that the EDAS DGPS corrections could support differential navigation with availability in excess of 99%. During the five weeks timeframe of the test campaign, when the rover receiver (EPN station) was available, the availability of the EDAS based DGPS navigation was above 99.5% for all solutions except for three of them (above 97.8%), which were affected by a maintenance activity.
- All EDAS based solutions with baseline distances below 260 km provided horizontal accuracies below 1 meter (95th percentile), resulting in a significant geographical area where EDAS corrections could support a wide range of applications in the transportation, mapping and emergency services domains.
- Within the sub-metric coverage range (up to 260 km) from the EGNOS stations, pass-to-pass accuracies (15 minutes, 95th percentile) below or equal to 20 cm have been obtained for all the solutions under analysis. If these results obtained from static data were confirmed by in-field tests, EDAS DGPS corrections could also be used in a wide range of agriculture applications, such as seeding, planting, spreading and spraying for cereals and dry soil cultivation.

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