Input paper: [[1]](#footnote-1) ENG13-3.1.3.10

Input paper for the following Committee(s): check as appropriate Purpose of paper:

**□** ARM **X** ENG **□** PAP **□** Input

**□** ENAV **□** VTS **X** Information

Agenda item [[2]](#footnote-2) n.n

Technical Domain / Task Number 2 …………………………………

Author(s) / Submitter(s) …………………………………

Software receiver implementation of SBAS Guidelines for Maritime

# Summary

This paper analyses the implementation of Satellite Based Augmentation System (SBAS) for Maritime and Inland Waterways Navigation in the gLAB [1] tool in order to evaluate its performance across the European region and at the northern part of the Atlantic Ocean.

Global Navigation Satellite System (GNSS) and SBAS in particular are widely used in many applications, but mainly for operations in the aviation sector due to its enhanced accuracy and integrity provision. However, it must be assessed its compliance with the performance requirements in Maritime and Inland Waterways, before it is proposed to be applied.

So that this system is intended for Maritime operations, the SBAS Maritime service performance must be over the required threshold established in the International Maritime Organization (IMO) regulation, whose values are 99.8% and 99.97% for availability and continuity respectively as stated in [2]. Therefore, the aim of this paper will be focused on providing evidences that SBAS Maritime processing according to the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) guidelines is feasible and that will be able to comply with that requirements, providing an additional integrity layer and significantly improving the position accuracy.

To proceed with this partial evaluation, the first step will consist of modifying the software provided by Universitat Politècnica de Catalunya: gLAB. It is an educational tool promoted by the European Union, part of the EDUNAV program and designed to help future European generations to easily learn the fundamentals of GNSS Its main objective consists of analysing and processing GNSS data from observation, navigation and EGNOS Message Server files. The version used as a starting point in this case was the 5.4.4.

Previous studies have already assessed the coverage, availability and continuity of SBAS in the European territory (for more information APPENDIX 1). However, those analysis only use as the input for the calculation the SBAS messages and the navigation files, which means that they do not consider the observation data, unlike this study. Therefore, it should be expected changes in the results, since the observation files introduce a receiver processing dependence, which affects significantly for example in terms of satellites in view.

The calculation evaluation can be easily performed by combining the gLAB tool and some Python scripts that allow to calculate several stations and days at the same time, without having to manually execute gLAB for the complete set of stations and configurations.

Therefore, the results obtained for the SBAS availability are:

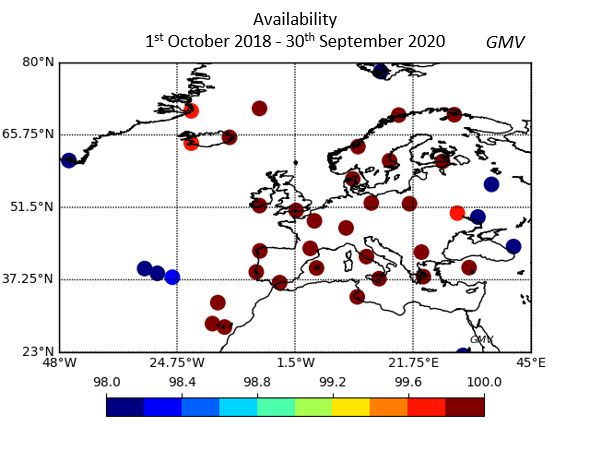


Figure 1‑1 Discrete map of availability over 2 years. 1st October 2018-30th September 2020 (SBAS)

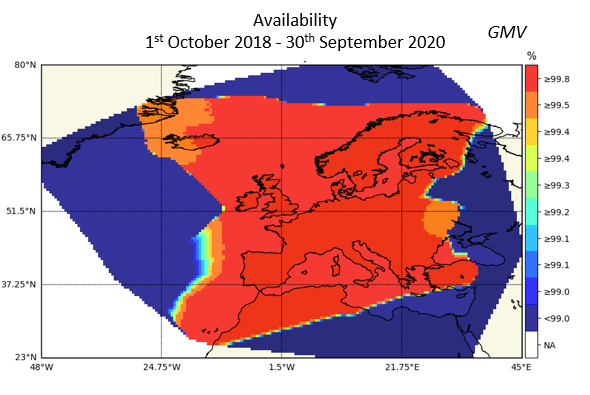


Figure 1‑2 Interpolated map of availability over 2 years. 1st October 2018-30th September 2020 (SBAS)

As seen in the previous figure, the availability comply with the requirements established by the guidelines (99.8%) in the majority of the European territory.

Regarding the continuity of the system, the results obtained are:

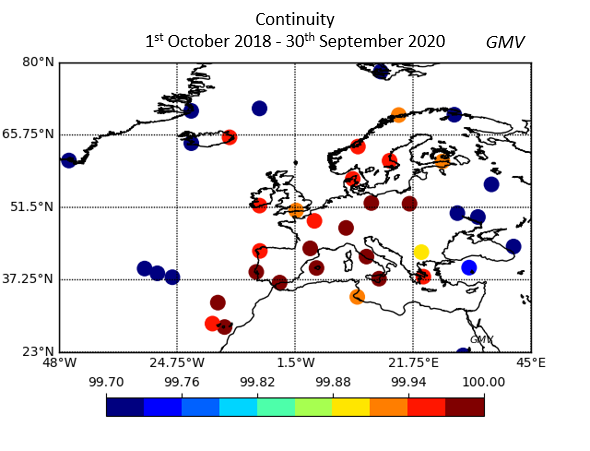


Figure 1‑3 Discrete map of continuity over 2 years. 1st October 2018-30th September 2020 (SBAS)

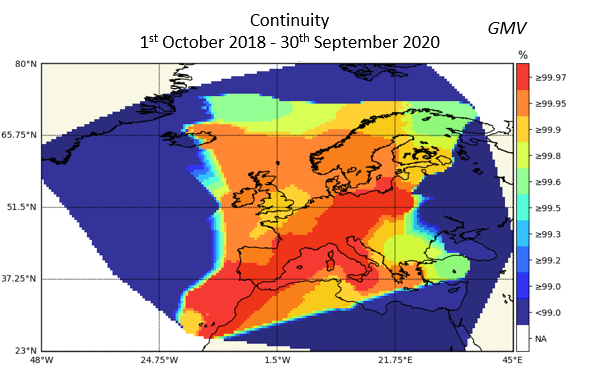


Figure 1‑4 Interpolated map of continuity over 2 years 1st October 2018-30th September 2020 (SBAS)

Again, the requirements are meet on a great area of the European territory, with values above the 99.97% requirement especially at the Mediterranean Sea and at the centre of the continent.

Therefore, gLAB allows to easily evaluate the performance of SBAS over the whole continent, obtaining uncourageous results. In addition, this results are highly related to those presented in previous studies with minor differences. This anomalies in the results are mainly due to the different approach using real observation and not for the tool used itself.

The first conclusion extracted from this study is that the accuracy is highly increased when SBAS is used in comparison with Global Positioning System (GPS) standalone (see APPENDIX 1). Besides, although the availability decreases when SBAS is introduced, the availability performance within the coverage area is good enough so that this system can be implemented as a new method for the navigation solution. Regarding the continuity, it is the most difficult requirement to comply with but, even so, this feature is quite good in areas of interest like close to maritime and inland waterways, specifically in the Mediterranean Sea. Finally, it was corroborated the ease of calculation of this results by combining Python scripts and the gLAB tool.

For further information about the project and the code used for these assessments please contact Manuel López Martínez (GSA, <Manuel.LOPEZMARTINEZ@gsa.europa.eu>) and see APPENDIX 1.

## Purpose of the document

This paper aims to show the benefits of the future SBAS Maritime service according to the IALA guidelines in the Maritime and Inland Waterways Navigation across the European region by presenting the results obtained by a validated tool as it is gLAB. In addition, the real data used along this study supports the results by noting its validity.

# References

|  |  |
| --- | --- |
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# Action requested of the Committee

The Committee is requested to:

1. Take into consideration this information and provide feedback.
2. Take into consideration that this analysis is made with a certain data set and every committee member is encourage to explore the software tools and perform their own assessments under their consideration to understand the outcomes.
4. Related documents
   1. EGNOS SIS performance based on IMO Res. A.1046

Along this first document [3], the necessity of evaluating the future EGNOS maritime service is presented. The paper pretends to show performance figures and maps which proves the performance for that service with the current infrastructure (2016-2018). Therefore, the results are focused on the 1st May 2016 to 30th June 2018, although they also include a specific study for the last three months.

Among the parameters established by IMO 1046 [4], the most challenging ones are the availability and continuity of the system for “ocean waters” and “harbour entrances, harbour approaches and coastal waters” since the accuracy, time to alarm and system integrity have been largely assessed. Therefore, these performance parameters are evaluated for the given period in order to state whether the level of performance acquired comply with the requirements.

The paper used actual data of stations spread across Europe and considered a fault-free receiver fed with EGNOS messages and broadcast navigation messages. However, what was not used in this case is the observation data provided by the reference stations, thus creating a service volume. The calculation was done with a grid of points (2x2 degree) and interpolated to get maps from the grid.

The results extracted from this study are positive since a quite good coverage around the European region is found, especially in terms of availability”. However, although the majority of the availability comply the requirements, those obtained for the continuity are more limited due to the restrictive threshold of 99.97%, as shown in Figure 3‑3.

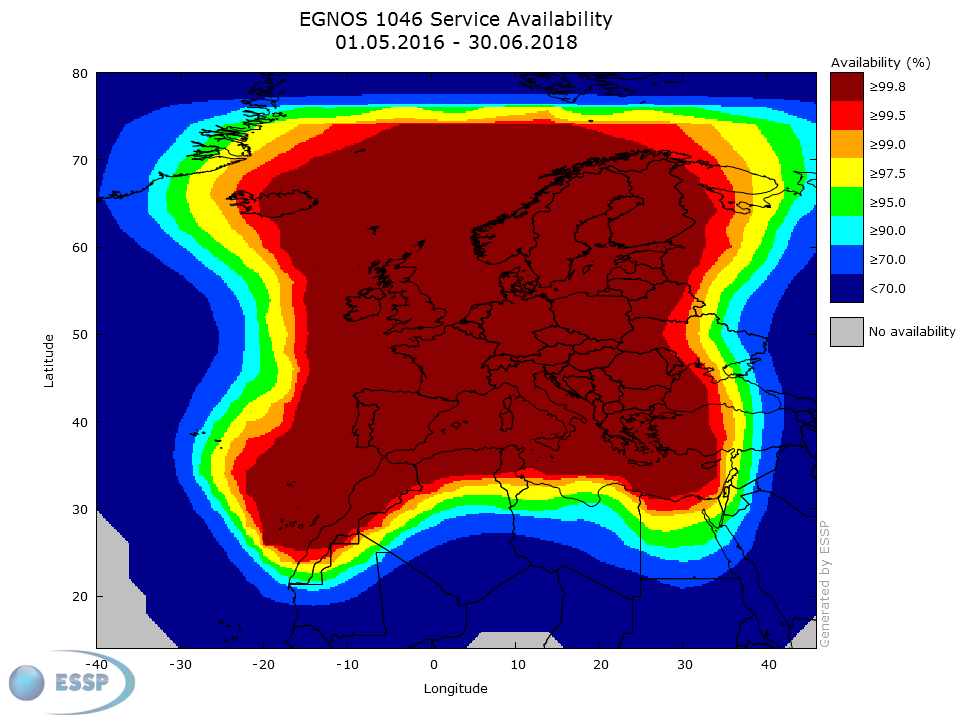


Figure 3‑2 EGNOS 1046 Service Availability from May 2016 to June 2018

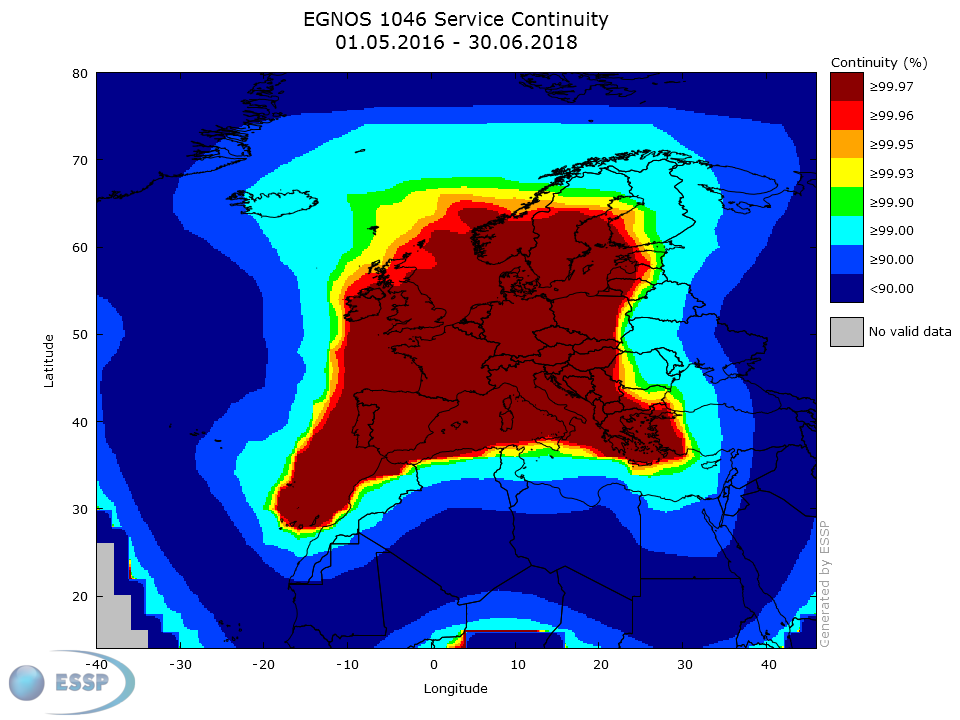


Figure 3‑3 EGNOS 1046 Service Continuity from May 2016 to June 2018

* 1. An independent validation of the EGNOS Availability, Continuity, and Coverage for Maritime Navigation.

This study [5] appears as a joint venture of UPC and GSA which aims to assess if EGNOS is able to meet the IMO requirements set in [4] for navigation in harbour entrances, harbour approaches, and coastal waters. Among those requirements, a 99.8% of availability and a 99.97% for continuity are showcased. Alike the previous study, this one also focuses on a period of 24 months, from 1 May 2016 to 30 April 2018.

This paper uses a total of 108 stations spread across Europe and placed at a location within 20 km of the coast or in islands (Figure 3‑4). This evaluation focuses on the geometry of the satellites because, alike the aforementioned study, considers a fault-free receiver approach, where it is only necessary to decode navigation files and EGNOS messages. Thereby, the study keeps its scope to what it is known as a service volume, since it does not take into account real data from the observation files of the receivers at the stations.

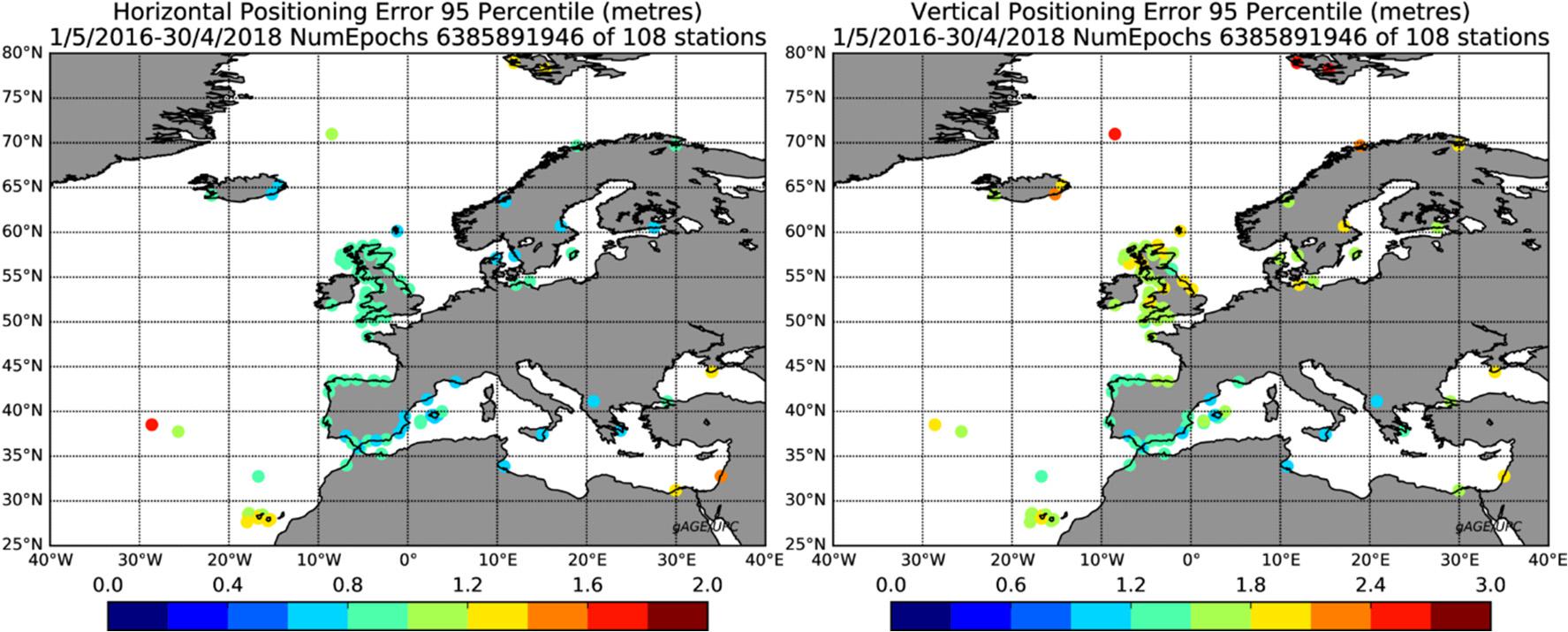


Figure 3‑4 Distribution of permanent stations used for the study and their accuracy

In this study the gLAB tool was also applied to compute the position of the reference stations, as well as for the representation of the maps. Thereby, the results expose a signal availability around 99.99% for the period studied with at least one of the GEO satellites, which supposes a service availability that comply with the requirements over the European region, as presented in Figure 3‑5. On the other hand, although over a reduced area, the service continuity also complies with the requirements in a wide region of the continent (Figure 3‑6).

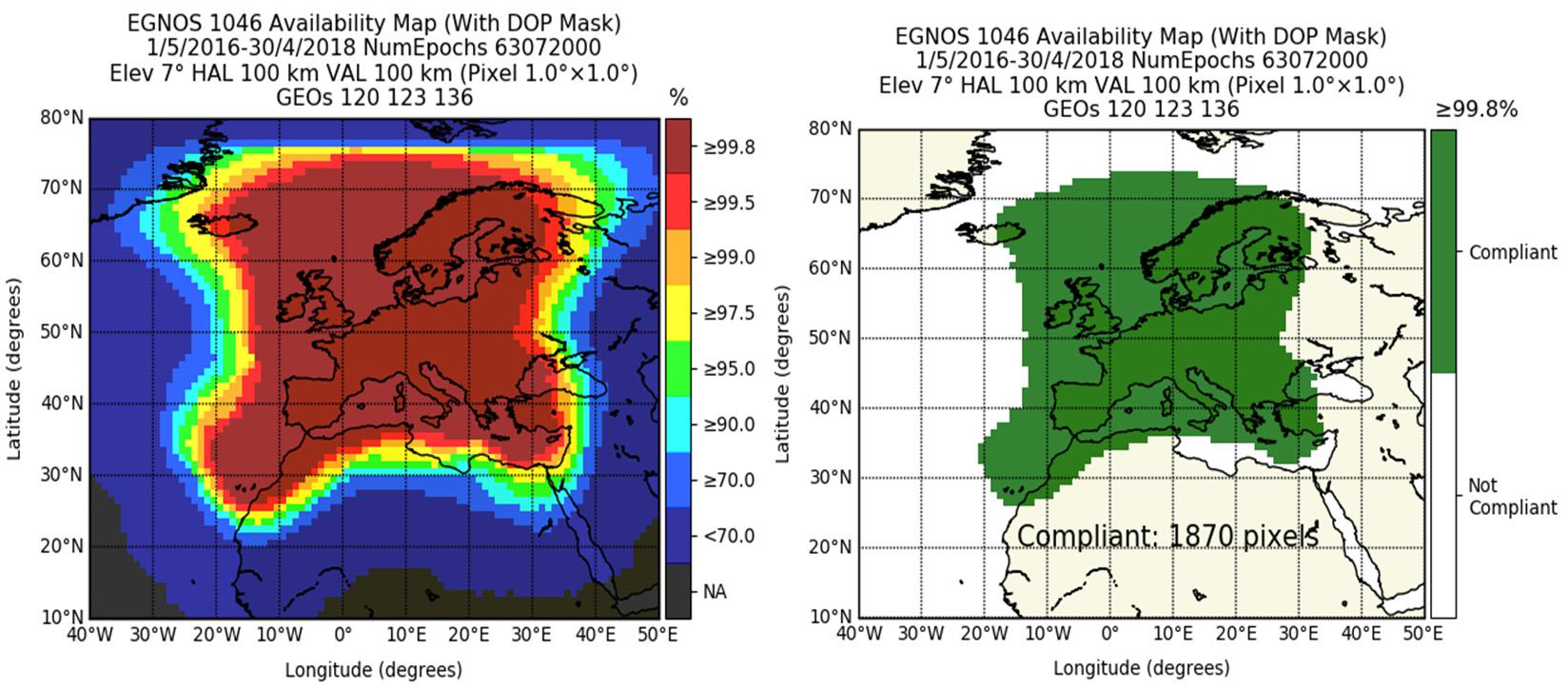


Figure 3‑5 Availability of the EGNOS 1046 Maritime Service

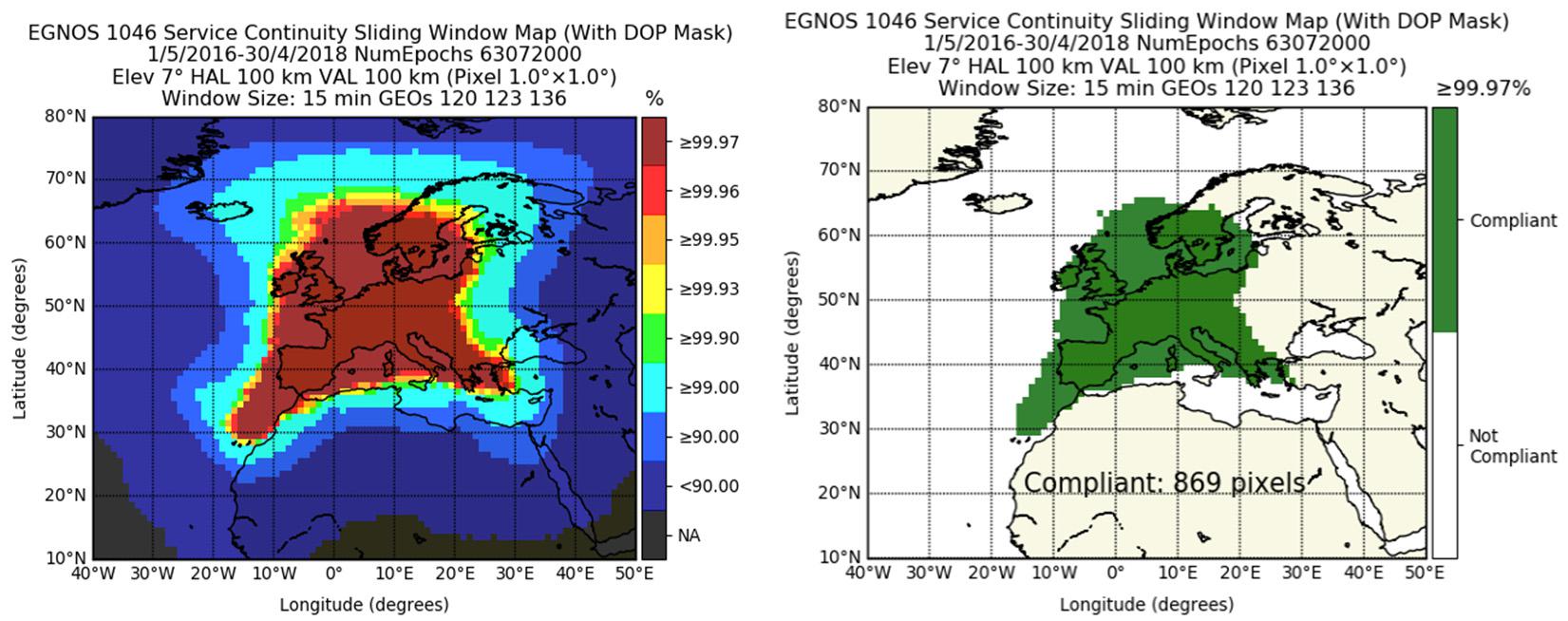


Figure 3‑6 Continuity of the EGNOS 1046 Maritime Service

1. Background

As stated in [6], Global Navigation Satellite System (GNSS) is a set of constellations, initiated by the deployment of the GPS constellation. The US Department of Defence launched the first set of satellites of this constellation between 1978 and 1985, although it was not until 1996 when this system became available to civilian users. The development of this Navigation System was followed by different constellations, promoted by other countries or regions, but with similar objectives, like GLONASS (Rusia), BeiDou (China), Galileo (European Union) or QZSS (Japan).

GPS was the first system fully functional, with the completion of the first version of satellites around 1985. Regarding the performance of this system, the Standard Positioning Service (SPS) provides values ≤ 0.715 m (2.3 ft.) the 95% of the time, according to [7]. As the first system fully operative, this has been the service widely used in many applications, from aviation to the maritime sector, even becoming a requirement as stated by IEC in [8].

However, GPS alike other aforementioned systems is very sensitive to failures in the signal transmitted by the satellites, which in turn generates faulty solutions. That is why IEC [8] requires the use of GPS equipment that incorporates integrity monitoring with fault detection in order to fulfil the integrity IMO requirement. Therefore, according to [9], Receiver Autonomous Integrity Monitoring (RAIM) appears as “a technique used to provide a measure of the trust which can be placed in the correctness of the information supplied by the total system”. RAIM is able to send alerts to the user when the established tolerance levels are overcome. To do so, this algorithm checks the integrity of the signal “via measurement consistency check operations”. The steps that must be followed are:

* Step 1: Calculate the navigation solution.
* Step 2: Apply fault detection mechanism (Fault Detection).
* Step 3: Isolate faulty satellites (Fault Exclusion).
* Step 4: Recalculate the navigation solution.
* Step 5: Determine Protection Radius.

Among the limitations that may be observed when using RAIM, it is firstly found the assumption which states that we can only have one faulty satellite at the same time, being a multi-failure practically negligible. Besides, RAIM uses a pessimistic approach since it assumes that the worst-case scenario can always be found, triggering a clearly conservative scenario. On the other hand, since ICE sets that the RAIM thresholds can be manually selected, this can lead to a likely wrong selection by the mariners due to the usual fluctuation of the alerts when GPS is notably outside of the positioning requirements. Another limitation is related to how the algorithm handles the assumption that fault-free errors are biased by an amount to which a bound is known, because although it is known, it is difficult to characterize. It is also important to highlight that RAIM is not sensitive to jamming and spoofing. Although RAIM implementations can provide warnings of malfunction, it is possible that the RAIM could not notice the interference of the signal neither by jamming nor spoofing. Finally, the RAIM unlike other systems cannot improve the accuracy of the position.

After exposing what has been used as a maritime navigation solution since now, other options can be presented to overcome the aforementioned RAIM problems and one of them is focused on SBAS. This augmentation system has been widely used in aviation for many years and among its advantages are found the increase in the accuracy and the integrity. They finally send those corrections to the final user which can correct the position measurements provided by the GPS satellite.

Among those corrections transmitted through the SBAS message, two groups of them must be highlighted due to their importance. The first one is that related to the ionosphere corrections (message 26), which supposes one of the most influent sources of error, since it can exceed 10 m even in a relatively quiet ionosphere [10]. On the other hand, the SBAS messages include several ones related to the integrity as it is explained in [11], which allows to get confidence thresholds and alarms in case anomalies are detected in the functioning of a satellite. This integrity information is key to overcome on top of RAIM some of its main limitations and provide a much more robust integrity concept. These are some of the many reasons that are encouraging the implementation of SBAS in the maritime environment.

However, before introducing this new feature in the navigation guidelines, it is necessary to do an assessment of the performance of the proposed SBAS Maritime service. In this case, it is missing an assessment with the latest implementation of the IALA guidelines using real observation data, specifically in the European region, since this system is only available in some geographical regions.

Therefore final purpose of this project is to prove the suitability of the SBAS Maritime service over the European region in terms of availability and continuity, so that the requirements stated in the guidelines can be achieved (Table 3‑1). Because, as aforementioned in Section 6, the improvement in accuracy and integrity has been widely shown in many studies. Although the improvement in the accuracy is widely known, we considered of interest to include a demonstration in this study.

Table 3‑1 IMO requirements

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **SYSTEM LEVEL** | | | | **SERVICE LEVEL** | |
| **Absolute horizontal position** | **Integrity** | | | **Availability**  **(2 years)** | **Continuity**  **(over 15 minutes)** |
| **Alarm limit** | **Time to Alarm** | **Integrity risk** |
| **Area/Unit** | m | m | s | % | % | % |
| **Ocean Waters** | ≤100 | N/A | N/A | N/A | ≥99.8 | N/A |
| **Harbour entrances, harbour approaches and coastal waters** | ≤10 | 25 | 10 | 10-5 | ≥99.8 | 99.97 |

A method that allows the evaluation of SBAS, consists of studying the continuity and availability of the systems, whose values must be over the thresholds set in the Maritime guidelines and to perform the aforementioned evaluation, this study will use the gLAB tool [1].

This software is an educational tool promoted by the European Union, part of the EDUNAV program and designed to help future European generations to easily learn the fundamentals of GNSS. This technology is becoming very important worldwide and it is an essential factor to ensure the proper development of the European region towards the future that is to come. This tool was developed under ESA contract by the research group of Astronomy and Geomatics (gAGE) from the Universitat Politècnica de Catalunya (UPC).

Its main objective consists of analysing and processing GNSS data in an interactive way through a multipurpose package which allows to precise modelling of GNSS observables at the centimetre level for both standalone GPS and PPP.

The version used as a starting point was the 5.4.4 which presents minor changes in relation to the previous version.. It is expected that future gLAB versions (v6.0) will take into account minor modifications for SBAS Maritime service and also multi-constellation processing including Galileo constellation.

1. Discussion

The aim of the project presented in the current paper under the contract GSA/OP/09/16/Lot 3/SC7 is to analyse the use of SBAS in maritime along a period of two years, with the objective of supporting the future implementation of an EGNOS maritime service based on SBAS L1 and to complement it, so that it can fulfil the requirements stated in [4]. This project also pretends to modify the gLAB software for it to be in line with the last version of the SBAS Guidelines.

In order to perform the first task, the aforementioned gLAB tool is used to compute a final position from the data introduced with the observation and navigations files, together with EMS messages provided by EGNOS. Thereby, this project is using real data, in every sense, when compared with the previously exposed studies in the Section5.

On the other hand, as it was mentioned, gLAB does not contain a feature that allows to interpolate the results provided for each station when using this kind of data and this process of computation. Therefore, as part of this project, it was created a code that allows to interpolate the results over the whole area, so that the representation feature of gLAB can plot the results in a similar way to previous analysis. Therefore, gLAB outcomes are represented both in the discrete results with the values of availability and continuity, and the continuous results provided by the interpolation.

* 1. Project analysis considerations

It is important to note that the region of interest covers from 48ºW to 45ºE of longitude and from 23ºN to 80ºN of latitude in order to encompass all the RIMS and European IGS selected stations. In addition, in comparison with previous studies, in this case we will use the observation files which will highly affect the results.

The EMS files may contain the messages from GEO satellites with a PRN 123 or the PRN 136, or even both of them. Thus the geoswitching option will be allowed and activated when both of them are provided.

To be noted that, after checking the behaviour of many reference stations, a conclusion was stated about the faulty functioning of some of them. The reason which was producing unexpected results was the use of observation files with odd data for some epochs, where some satellites suddenly disappeared. Since a big difference in the number of satellites (three or more satellites) between one epoch and the next one is unexpected, this data was concluded fault.. The elimination of faulty epochs with unjustified satellites losses has been equally applied to all the scenarios studied, stating a fault-free scenario.

* 1. Methodology

Not only the GNSS information of a set of specific stations is required, but also a formal procedure definition to obtain the availability of those stations together with their continuity. When the EMS information provided to gLAB does not exist or when the number of visible satellites is lower than 4 a failure in the solution will be raised, generating an unavailable epoch and thus reducing the total availability for the chosen period. Therefore, as stated by IMO [4], the availability may be defined as “the percentage of time that the services of the system are usable under stated conditions”.

Regarding the continuity, IMO defines it as “the capability of the system to perform its function under stated conditions without scheduled and/or unscheduled interruptions during the intended operation” [4] According to these instructions, the continuity risk is evaluated over a Continuity Time Interval (CTI) of 15 minutes and using the Mean Time Between Failures (MTBF) for the whole studied period. Therefore, the following expression presented by the International Association of Maritime Aids to Navigation and Lighthouse Authorities (IALA) is applied in order to obtain this essential feature:

The Mean Time Between Failures consists of computing the average duration of the interval between failures, knowing the number of intervals and the duration of that interval. Although the approach applied in this case is easy to calculate, it assumes that only one discontinuity occurred during a time span of one CTI.

The aforementioned heat map requires the interpolation of the result of each station computed over the whole region, which for this study will be linear.

* 1. Dataset

In order to perform this simulation, a set of 84 stations was initially proposed, although some of them were discarded due to poor performance, so that enough information within the required area may be obtained to plot the availability and continuity maps. Thereby, a clear view about the performance in coastal and inland waters can be presented. Part of the information to be extracted is provided by the IGS14 European network through public NASA-CDDIS[[3]](#footnote-3), whereas the other source of information is the EDAS RIMS[[4]](#footnote-4). The data covers 24 months of information, from the 1st of October 2018 to the 30th September 2020. As previously commented, this area covers the European continent, as well as some maritime locations placed over the northern region of the Atlantic Ocean.

Afterwards, only 42 stations were selected, mainly focused on the RIMS stations, as it was performed in previous analysis like [3], but some IGS were also included. This addition aims to support the coverage of other RIMS stations and to shape the coverage area. Thereby, in the Figure 3‑7 both IGS stations and RIMS stations are represented in blue and red respectively:

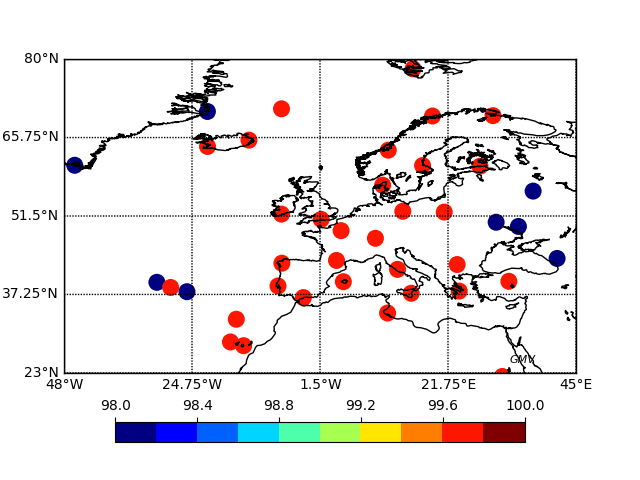


Figure 3‑7. Used stations of the IGS network and the RIMS network

Once the specific observation, navigation and EMS files of each station are acquired through the correspondent database, the execution of gLAB allows to compute the availability and continuity of the chosen period of time.

* 1. Performance

This last section of the document is focused on the performance assessment obtained after the implementation of Maritime SBAS Service.

* + 1. Accuracy

As widely known, the accuracy provided by the SBAS infrastructure is a determinant aspect that encourages the implementation of this service. Therefore, the purpose of this section is to prove the improvement in terms of this parameter when we compare the GPS and SBAS solutions.

The first solution that will be shown is the horizontal error for the percentile 95. It is clearly seen through the following figures that the error achieved with the SBAS infrastructure is smaller than that obtained with just a GPS infrastructure. For example, the station located in Malaga reduces its error from a value that is located between 2.625 m and 3.5 m to a value below 0.875 m. This is a clear trend observed in the majority of the stations over Europe.

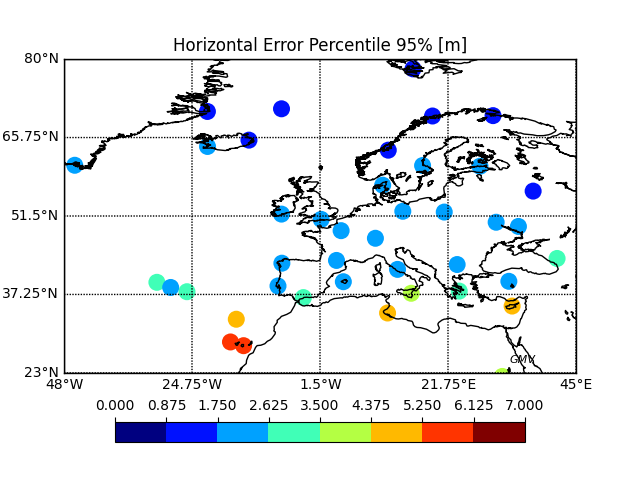


Figure 3‑8 Horizontal Error Percentile 95% (GPS)

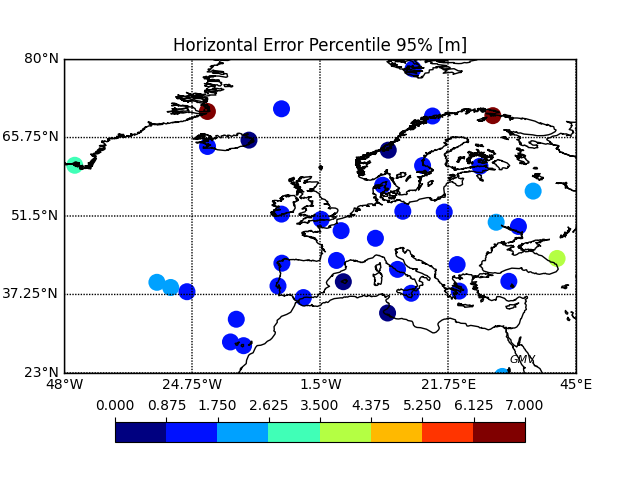


Figure 3‑9 Horizontal Error Percentile 95% (SBAS)

After showing the results for the horizontal error, the next parameter to be analysed is the vertical error:

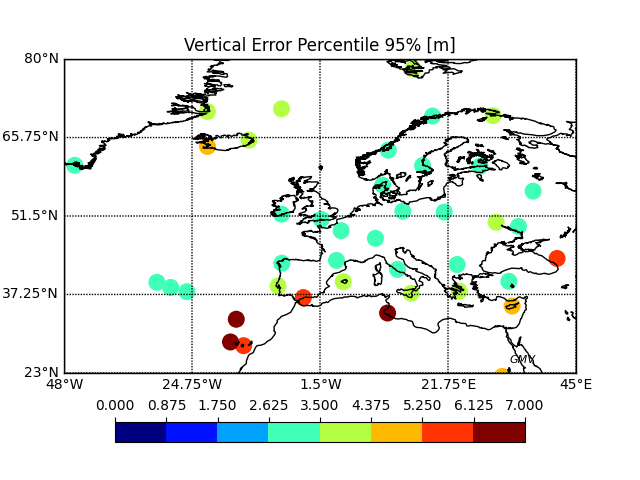


Figure 3‑10 Vertical Error Percentile 95% (GPS)

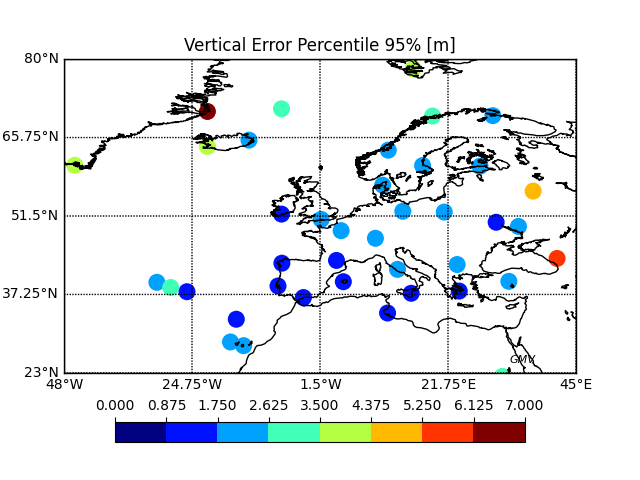


Figure 3‑11 Vertical Error Percentile 95% (SBAS)

Again, the results provided by the incorporation of SBAS prove the improvement that this augmentation system provides to the position. Using the same reference station located at Malaga, the value that initially falls between 6.125 m and 5.25 m, is reduced to one that is between 0.875 m and 1.75 m.

* + 1. Availability

As aforementioned, the availability measures how many times the service is not available due to failures in terms of percentage. In this case a comparison may be performed in order to asses if the improvement in accuracy is not limited by values of availability below the threshold stablished by the IMO requirements in [4]. Thereby, this evaluation will be performed thanks to the representation of the discrete maps with the values of each station, so that the total coverage of the region can be then easily studied.

Starting with the GPS scenario, the following values are obtained:

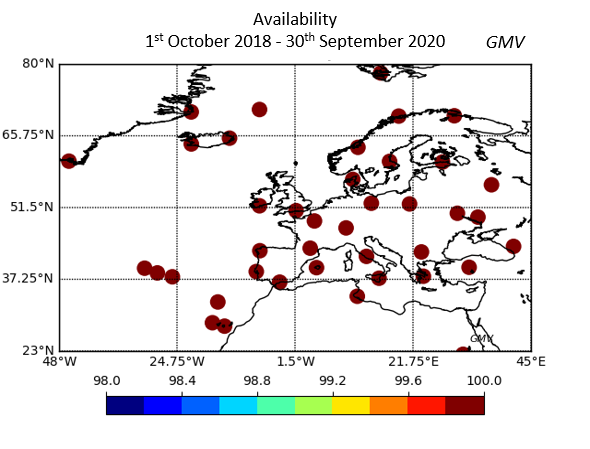


Figure 3‑12 Discrete map of availability over 2 years (GPS).

1st October 2018-30th September 2020

As shown in the figures above, the value of availability is over the threshold of 99.8% established in the IMO requirements. Therefore, it may be stated that this service complies with the requisites.

The interpolated map can be also presented in order to better understand the behaviour over the whole region:

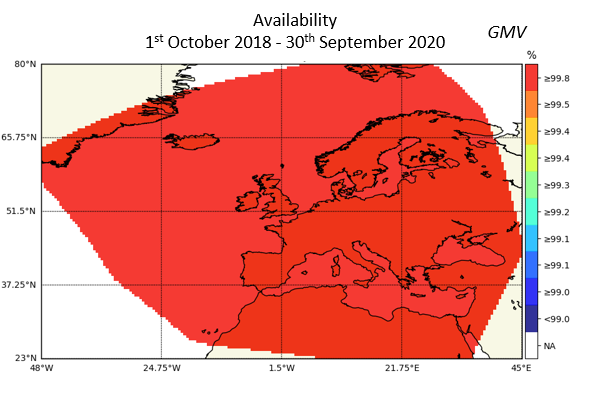


Figure 3‑13 Interpolated map of availability over 2 years (GPS)

1st October 2018-30th September 2020

Again, thanks to this map, we can conclude that the aimed availability is achieved in the whole area of interest, since values below the threshold are observed.

Once, the GPS results are shown, the next step will suppose presenting the availability of the system when SBAS is incorporated to GPS in order to improve the accuracy and integrity of the service.

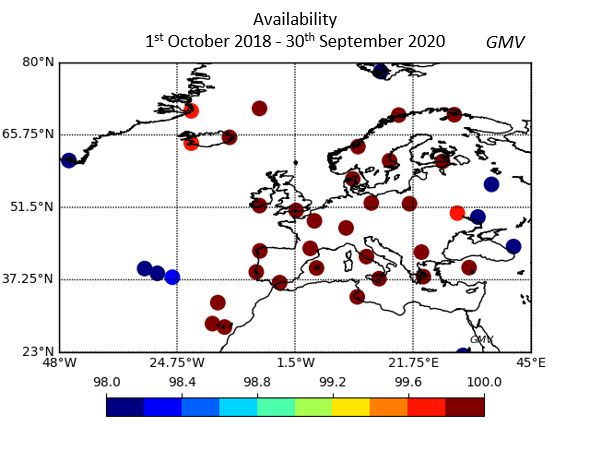


Figure 3‑14 Discrete map of availability over 2 years (SBAS)

1st October 2018-30th September 2020

As expected, the service availability is reduced in the farthest regions to the centre of the continent. It is in those areas where the performance should be lower to other parts of Europe due to the disposition of the RIMS stations network.

Following the previous procedure, it results of interest to show the interpolated results of the aforementioned discrete map for SBAS in terms of availability.

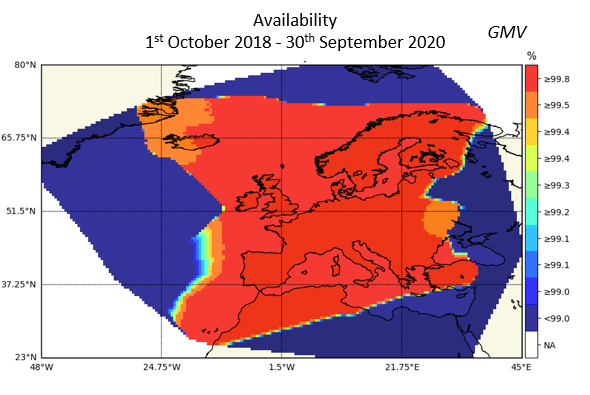


Figure 3‑15 Interpolated map of availability over 2 years (SBAS)

1st October 2018-30th September 2020

The results presented in Figure 3‑15 actually match those presented in the 5, since EGNOS is not able to provide elevated levels of availability on the limits of the area of interest. That is why values below the 99% are found at those regions. Even so, the system is able to provide the desired availability in the European continent.

* + 1. Continuity

The last parameter to be studied in this document is the continuity of the system, feature which is assessed using the Mean Time Between failures. Therefore, this variable allows us to know for how long the system is available without failures in terms of percentage. Thereby, in order to meet the requirements, the service must be able to provide a continuity over 99.97% for the whole period of time studied.

The first scenario to begin with will be the continuity when only GPS is implemented:

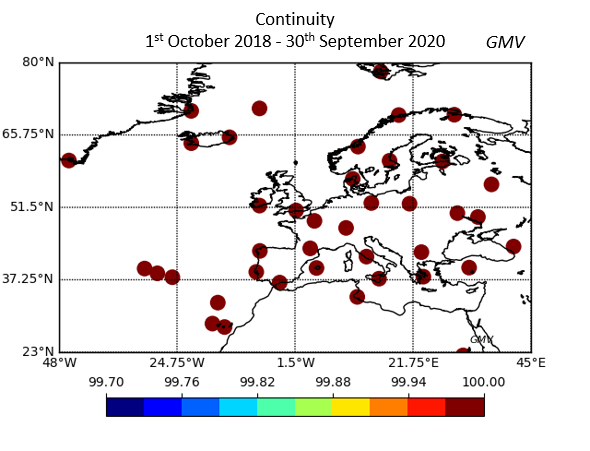


Figure 3‑16 Discrete map of continuity over 2 years (GPS)

1st October 2018 - 30th September 2020

The results show that, alike the availability, the continuity complies with the requirement thanks to getting values over 99.97% over the whole continent. This results may be corroborated when the results at the stations are interpolated, as presented in the next figure:

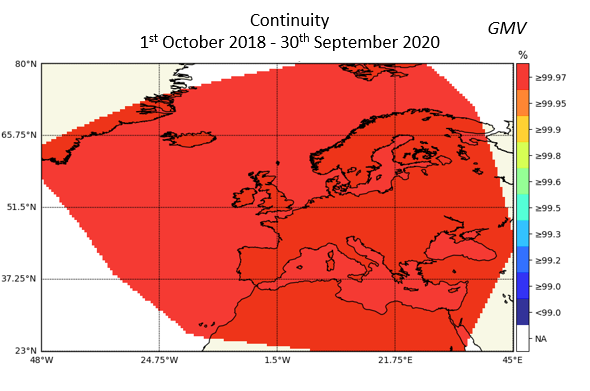


Figure 3‑17 Interpolated map of continuity over 2 years (GPS)

1st October 2018 - 30th September 2020

As expected, the system is able to meet the requirements when only GPS is used, providing coverage for all the chosen areas.

However, since the performance in terms of accuracy and integrity wants to be improved, the use of SBAS becomes of importance. Therefore, the assessment of this service for maritime is extracted from the following discrete figure:

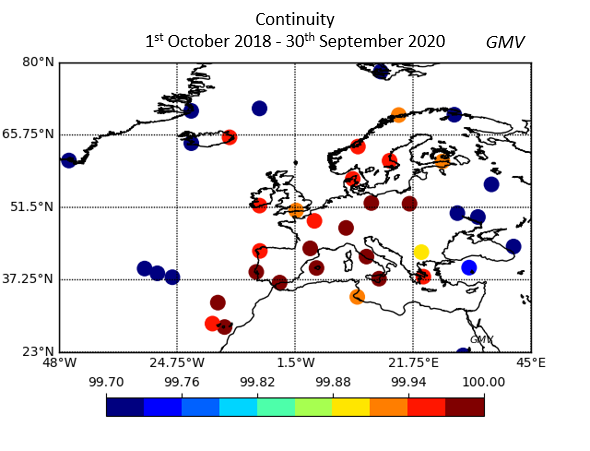


Figure 3‑18 Discrete map of continuity over 2 years (SBAS)

1st October 2018 - 30th September 2020

The continuity decreases over the whole continent when compared to the only GPS option, since just 21 failures will mean not compliance with the requirements, over the selected period. In this case, only eleven stations are able to achieve the requirements. Thereby, the continuity is highly limited by the availability of the EMS. Even so, there are many stations (9) which are really close to the objective in terms of continuity.

However, to better analyse the coverage of the continuity in Europe, the interpolated results must be represented, obtaining:

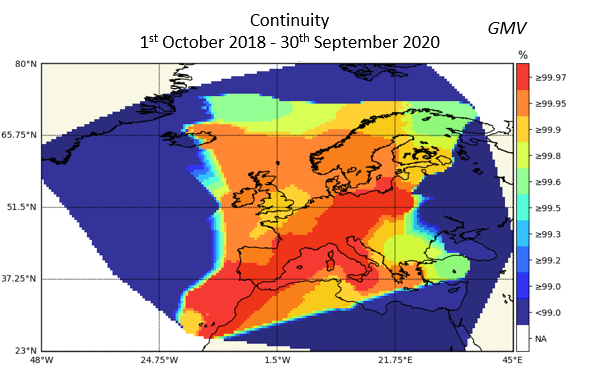


Figure 3‑19 Interpolated map of continuity over 2 years (SBAS)

1st October 2018 - 30th September 2020

Although limited, the continuity over the region is acceptable for the main areas of interest, especially in countries like Spain, Italy or those located at the centre of the continent like Germany. Besides, the results are similar to those exposed in Section 5, even though this study focuses on the implementation of real data, which is expected to reduce the performance in comparison with the previously presented maps.

It must be noted that the scale used on the discrete figure and on the continuous figure is different which may cause some discrepancies in terms of the representation.

1. Conclusion

SBAS is presented as an alternative to the traditional methods which ensure integrity. The main advantage in comparison with GPS standalone or RAIM is that this service is able to increment the accuracy achieved thanks to the corrections sent by the GEO satellites. In addition, the system is able to provide integrity information on real time, detecting more than only one faulty satellite as it is done with classical RAIM algorithms. This system is even able of finding a faulty constellation. It cannot be forgotten the fact that SBAS messages contain information about the estimation of the error components in comparison with classical RAIM which is based on a priori information about the measurement components (too conservative). Finally, SBAS provides a reduction in the miss detection probability with a value below 5%

However, in order to implement this system in the Maritime sector, it must comply with the requirements stated by IMO [4], so that it may be included as a new method to ensure a proper navigation solution in this environment.

Therefore, some of the conclusions extracted from this study are:

* The accuracy is highly increased when SBAS is used in comparison with GPS standalone, especially at the centre of the continent, where the system is able to provide continuous EMS messages with the correspondent corrections. Besides, as seen Figure 3‑9, the requirements of Table 3‑1 are met (<10m).
* Although the availability decreases when SBAS is introduced, its performance within the coverage area is good enough so that this system can be implemented as a new for the navigation solution.
* The continuity is the most difficult requirement to comply with, especially due to the restrictive value established by IMO. Only 21 discontinuities cause the performances not to meet IMO requirements. Even so, this feature is quite good in areas of interest like close to maritime and inland waterways, specifically in the Mediterranean Sea.
* The results obtained are similar to those previously seen in other studies like the ones presented at the beginning ( [3] and [5]).

1. User manual

This section of this document will be focused on establishing the procedure that the user should follow in order to calculate the solution.

Using gLAB[[5]](#footnote-5) is quite straightforward since it has an intuitive interface which just needs the input of the observation, navigation and EMS (in case SBAS is activated) files for a specific day. Then, it contains a set of windows that allow to determine the modelling procedure, as well as the filtering. Here you can enable features like cycle-slip detection, geoswitching, SNR mask, etc. Finally, this software allows to set the output file, together with the kind of messages that you want to obtain (satellites selection, information, output values, etc.).

Therefore, in order to perform the analysis previously presented, we have created some python scripts. In those scripts we can select the stations to be analysed and then Python will look for the necessary files in order to compute the solution. Besides, the desired period of study may be also set, so that only that period of time is calculated.

In addition to the stations and the period of time to study, it is also important to state the desired configuration for the gLAB configuration lie for example GPS, SBAS, GPS+RAIM or SBAS+RAIM. Thereby, Python will generate a file which contains the command window commands to be executed in order to calculate the complete period of time for the selected stations. In order to achieve it, the directory of folder should be set in a specific order so that this script is able to reach the input files (which should be previously downloaded).

Once the calculation is performed, this program is able to find the corrupted files generated by gLAB due to, for example, an incomplete output file. Besides, in case SBAS is used and geoswitching was activated, our code is able to try a calculation with just one satellite in the configuration to then select the one with the best result.

After this initial checking, the next procedure consists of combining the results of each day for the whole desired period of time, computing the total availability and continuity.

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-1)
2. Leave open if uncertain [↑](#footnote-ref-2)
3. cddis.nasa.gov [↑](#footnote-ref-3)
4. egnos-edas.eu [↑](#footnote-ref-4)
5. https://gage.upc.edu/glab-download/ [↑](#footnote-ref-5)