**Agenda Item 4:** **Assessment of operational requirements to determine the implementation of improvements in communications, navigation and surveillance (CNS) capabilities for operations in route and terminal area**

# Results of ionosphere impact evaluation on GBAS operation in Brazil

(Presented by Brazil)

**SUMMARY**

This working paper presents the results of the ionosphere impact evaluation on GBAS operations in Brazil using data collected during solar cycle 24 by SLS-4000 station installed in SBGL airport and L1/L2 GPS receivers. It was concluded that the mid-latitude ionosphere threat model is not directly applicable to low latitudes.

**REFERENCES:**

- Annex 10, Volume I, to the ICAO Convention
- SIRIUS Program from Brazil
- SAM/IG/7 – WP/7
- SAM/IG/8 – WP/18
- GREPECAS/16 – IP/15
- SAM/IG/14 – WP/20

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| ***ICAO strategic objectives:*** | *A - Safety*<br>*B - Air navigation capacity and efficiency* |

## 1 Introduction

1.1 The research carried out by DECEA (Department of Airspace Control) in Brazil with respect to the GBAS (Ground Based Augmentation System) was launched in 2003 with the installation of a prototype station LAAS (Local Area Augmentation System) from FAA (Federal Aviation Administration) at Rio de Janeiro International Airport (SBGL).

1.2 Since then, a series of flight tests were conducted to demonstrate the possibility of using that system for precision approaches.

1.3 During the tests, the international community identified several phenomena that occur in the ionosphere at low latitudes, such as storms, scintillation and bubbles that affect the operation of this system and are directly related to the solar cycle.

1.4 In June 2011, a Honeywell SmartPath GBAS SLS-4000, certified by the FAA and configured with the threat model for mid-latitudes was installed at Rio de Janeiro International (SBGL).

1.5 The purpose of this facility was to study the impact of the ionosphere on the operation of the SLS-4000 station during solar cycle 24.

1.6 Also during this period, GPS receivers operating in L1 and L2 located throughout the Brazilian territory have been used to provide data for evaluation of the threat model installed in station SLS-4000.

## 2 Discussion

2.1 GBAS system, in accordance with ICAO Annex 10, Volume 1, allows performing precision approach Category I with increasing values of GPS signals accuracy and integrity.

2.2 This system has several advantages over ILS as services to multiple simultaneous runways with different glide angles, possible touchdown point displacement, curved approach and the significant reduction of critical and sensitive areas.

2.3 In Brazilian new CNS/ATM concepts program of implementation called SIRIUS (http://www.decea.gov.br/sirius/ ) is planned the use of GBAS technology in airports.

2.4 According to the planning for GBAS implementation in Brazil, in June 2011 a SmartPath station SLS-4000, from the company Honeywell, was installed in SBGL (Rio de Janeiro), to serve as a testbed for the Solar Cycle 24.

2.5 This station is configured with an ionospheric threat model developed by Stanford University for use in the mid-latitudes (http://waas.stanford.edu/~wwu/papers/gps/PDF/LeeIONGNSS06.pdf ).

2.6 The SLS-4000 is the only GBAS station certified and in CAT I operation at airports in Newark (USA), Houston (USA), Malaga (Spain), Bremen (Germany) and Sydney (Australia), all located in the middle latitudes.

2.7 Since its installation in the SBGL airport, the SLS-4000 presented availability lower than required, and it was necessary to disable the internal monitors so it could be possible to collect data continuously. (Importantly, this station has not been available for use by aircraft, serving only as a test.)

2.8 Located in a region of low latitude, the SBGL airport has an intense ionosphere activity, as well as countries located between 20° N and 20° S (approximately) from the geomagnetic Ecuador (Fig. 1), especially during periods of maximum solar activity.

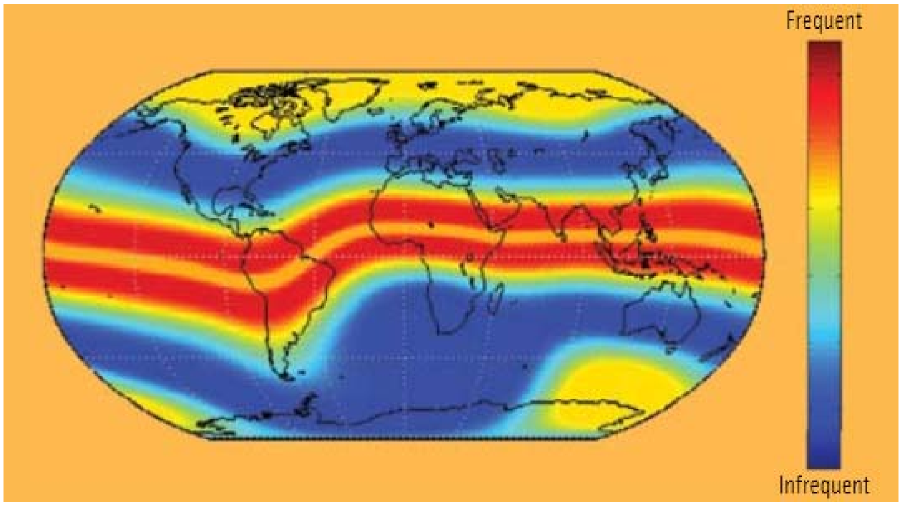


**Fig. 1 –** Frequency of disturbances in ionosphere

2.9 In order to assess the real impact of the ionosphere on GBAS system at low latitudes, the Institute of Airspace Control (ICEA), DECEA´s research agency developed a joint work with FAA, Stanford University, National Institute of Space Research (INPE), Boston College, NAVTAC, KAIST and companies soch as Mirus Technology and SDTP Foundation.

2.10 To develop this work, data collected from the SLS-4000 station was used as well as more than 110 L1 and L2 GPS stations installed in Brazil (Fig. 2).

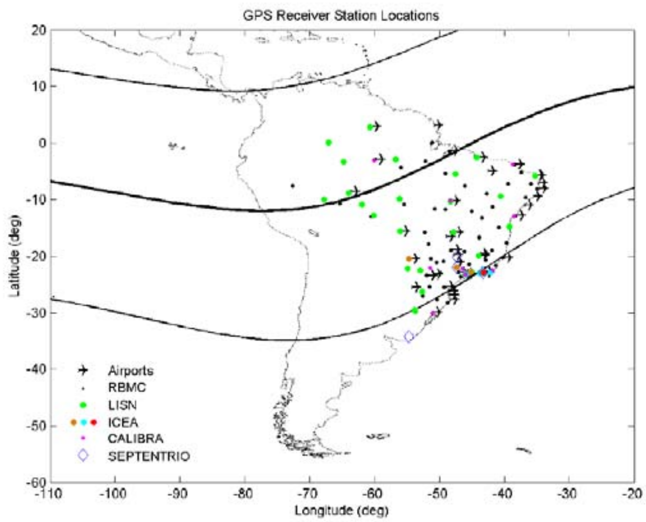


**Fig. 2 –** GPS stations network in Brazil

2.11 Data was collected during the period of maximum solar activity in cycle 24 (Fig. 3) which, however, was the least active in the last 100 years (Fig. 4).

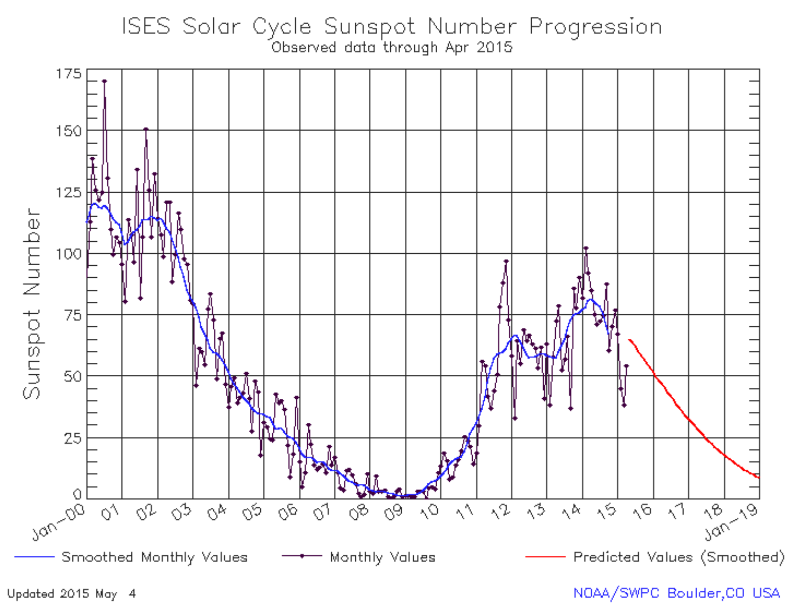


**Fig. 3 –** Solar cicle 24 (http://www.swpc.noaa.gov/products/solar-cycle-progression)

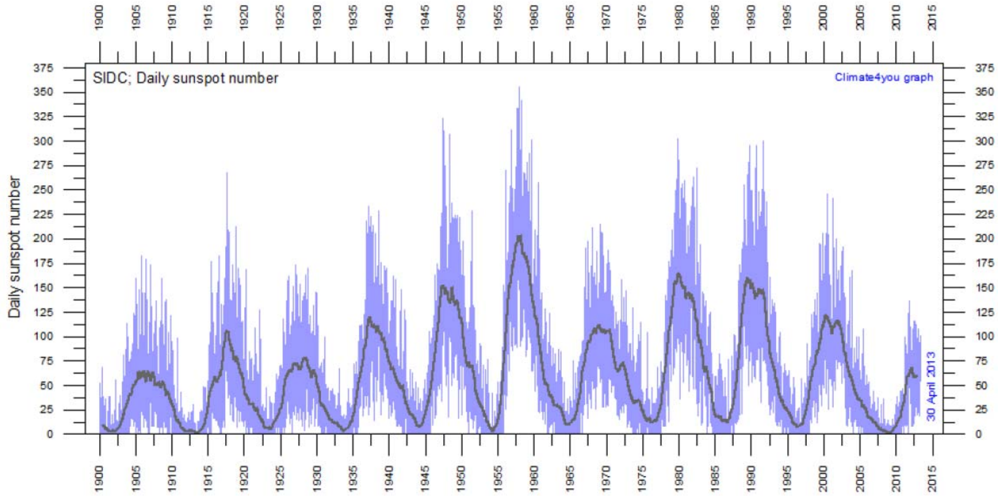


**Fig. 4 –** Variability of sunspot from 1900 to present

2.12 In the development of the work the following steps were taken:

- Identification of relevant data to be collected by the GPS stations network in Brazil;
- Identification of the days of interest on the basis of Kp and Dst indices and parameter L-band scintillation (S4);
- Processing of data relating to the days of interest;
- Identification and characterization of the ionosphere at low latitudes;
- Validation of the threat model.

2.13 The threat model for middle latitudes was developed from the model that takes into account the ionosphere disturbance as a front wedge-shaped with a certain speed, width and gradient. (Fig. 5).

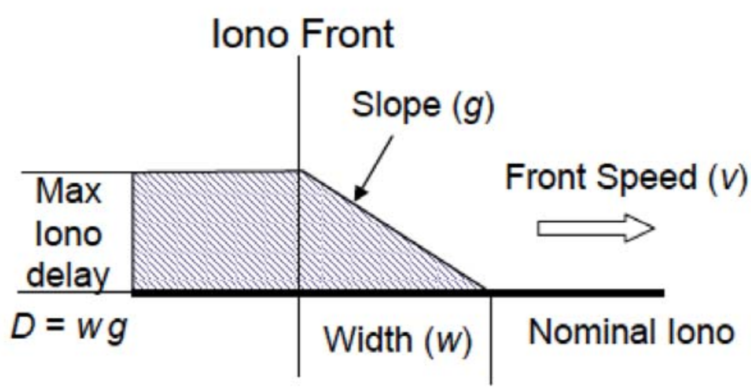


**Fig. 5-** Ionosphere storm model

2.14 Using this model, the most critical situation for GBAS operation would be an aircraft on approach receiving wrong correction from the ground station caused by different ionosphere delay received by aircraft and ground station (Fig. 6).

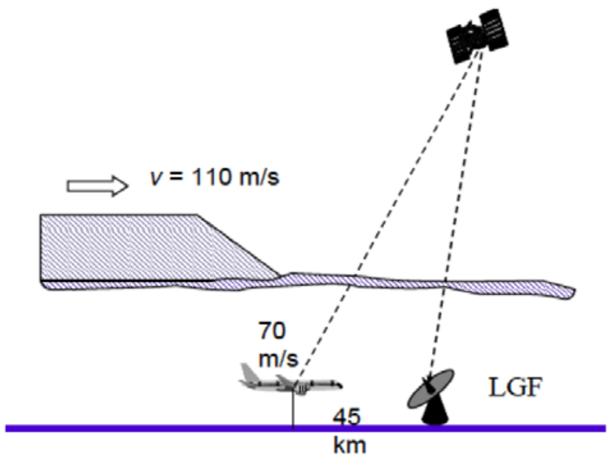


**Fig. 6 –** Ionosphere threat to GBAS

2.15 It is noteworthy that this is a critical situation for station projects that are not able to detect variations of the ionosphere as a function of distance (as in the case of SLS-4000), which are forced to have an ionosphere threat model that is able to absorb variations within a range of predefined values.

2.16 The Threat model for the middle latitudes was developed using data collected in the United States and presents the limits as shown in Fig. 7.

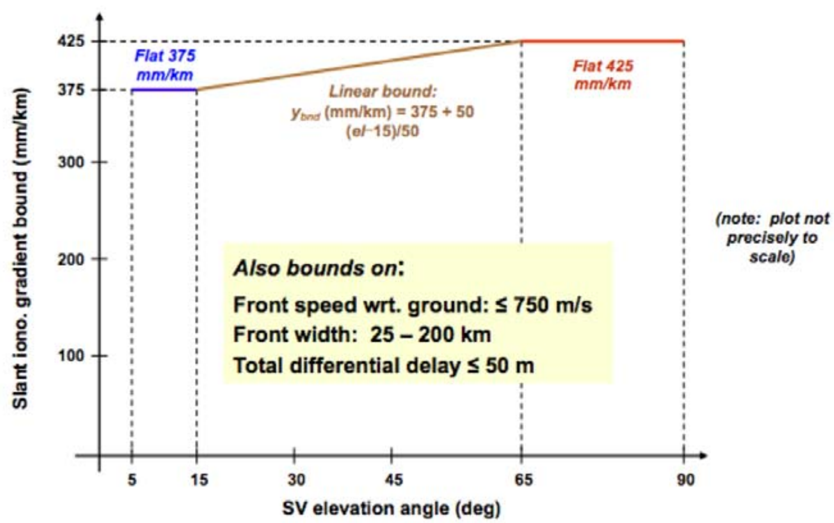


**Fig. 7 –** Threat model for mid-latitudes

2.17 To assess the possibility of using the threat model from middle latitudes in SBGL, 123 days with the worst behavior of the ionosphere (identified from indices Kp, Dst and S4) were identified between 2011 and 2014.

2.18 Among these data, it was identified that several measuring points were outside CONUS (Continental US) threat model installed in the SLS-4000 (Fig. 8), representing a possible impact in the integrity and availability of the station.

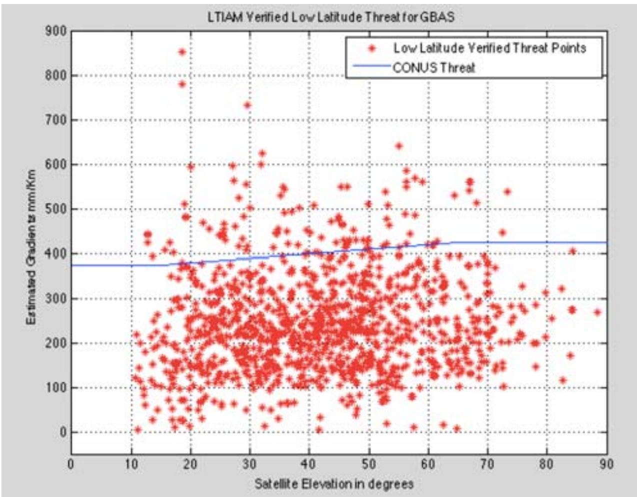


**Fig. 8 –** Low latitude observed gradients

2.19 As a result, it was also observed that between 5h and 21h (local time) the ionosphere behaves within the boundaries of middle latitudes model. (Fig. 9).

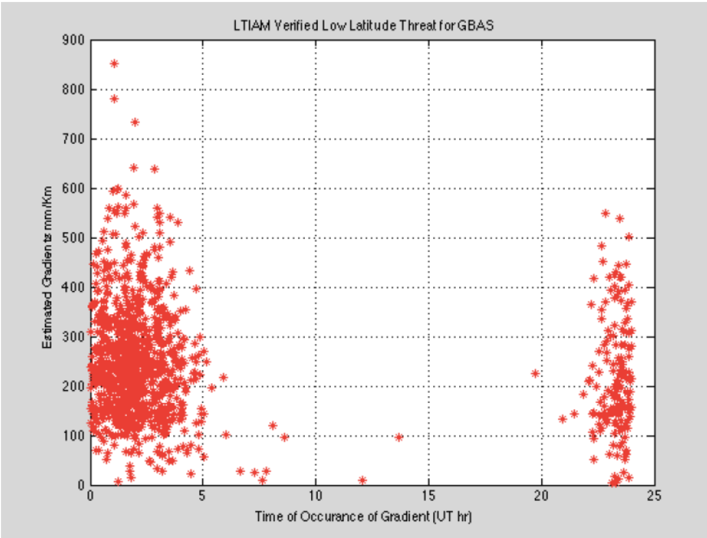


**Fig. 9 –** Ionosphere events time distribution

2.20 From the results obtained, Brazil identified that at the time, the SLS-4000 station may not be used in complete capacity for CAT I operations in low-latitude regions and will continue research in collaboration with universities and Honeywell, looking for develop a threat model applicable to these regions.

**3. Suggested actions**

3.1 The Meeting is invited to:

a) Note the information presented; and

b) discuss the results and their impact on the use of GBAS at low latitudes.

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