Statistical study of nineteen years of GPS S4 scintillation data over the Brazilian territory

I.J.Kantor*[1], E.R. de Paula[1], J.R.de Souza[1], O. F. Jonah[1], A. O. Moraes[2], M.T.A.H. Muella[3], A. C. Neto[1] and J.V. Costa[1]

[1] National Institute for Space Research (INPE)
Aeronomy Division, São José dos Campos, SP, Brazil
(jelinek.kantor@gmail.com, Eurico@dae.inpe.br, jonas.souza@inpe.br, olusegum.jonah@inpe.br, acacio.cunha@inpe.br)

[2] Instituto de Aeronáutica e Espaço - IAE / Instituto Tecnológico de Aeronáutica - ITA
São José dos Campos, Brazil
(alison.moraes@gmail.com)

[3] Universidade do Vale do Paraíba(UNIVAP), São José dos Campos, SP, Brazil.
(mmuella@univap.br)

ABSTRACT

Ionospheric scintillations are rapid variations of phase and amplitude of an electromagnetic signal passing through the Ionosphere. These signal fluctuations are created by random fluctuations of the medium refractive index, caused by inhomogeneities inside the ionosphere. Ionospheric scintillations occur especially in equatorial and polar regions. They appear after sunset and may last a few hours. At mid-latitudes, the scintillations are rather weak, except during conditions of ionospheric storms. The inhomogeneities are the result of several mechanisms: a) Fluctuation of the electric field; b) Local inhomogeneities evolve and can develop; c) Highly energetic particles and precipitation (particularly in polar regions). In equatorial regions the inhogeneities are mainly sub structures of bubbles which may reach dimensions of several hundreds of kilometers. These bubbles present a patchy structure. They appear after sunset when the sun ionization drops to zero. Instability processes develop inside these bubbles with creation of turbulences inside the medium. As a result, depletions of electron density appear. In the L band transmitted by GPS satellites and for the distances usually considered, the diffraction pattern of inhomogeneities in the range of one kilometer size, is inside the first Fresnel zone and contribute to scintillation.

Scintillation deteriorates GPS/GNSS signals causing error on positioning and even loss of information. This can have disastrous effect for example on navigation. Therefore the importance of the study of the scintillation.

One parameter that represents the amplitude scintillation strength is the S4 index. S4 is the square root of the intensity variance normalized by the mean.

There is S4 scintillation index recorded data over the Brazilian territory from 1997 to 2016, for up to 30 stations. Figure 1 shows the sites over Brazil. Figure 2 shows the solar activity represented by the F10.7 cm index for the period of 1997 up to 2015. The data consists of station ID, date, UT, PRN, S4, elevation, azimuth, Kp and F10.7 cm. Statistics of these data is presented involving dependence on geographical location, local time, season, F 10.7 cm solar flux and Kp. The S4 histograms show the frequency of occurrence of the S4 index amplitude for the different conditions described above.

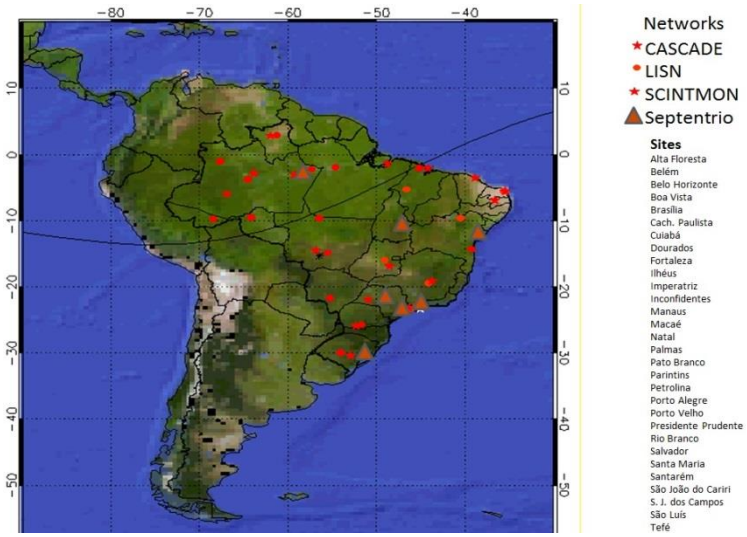

Figure 1. Map and listo f the GNSS receivers over Brazil.

The analysis showed that at the Brazilian longitudinal sector the scintillation occurs from September to April with a peak at the December solstice and from post sunset to midnight LT interval. The S4 intensity and occurrence increases with solar activity and larger amplitude scintillations were observed under the crest of the equatorial Ionization Anomaly (EIA). It is also showed that statistically, when the magnetic activity (Kp) increases, there is a decrease in the scintillation occurrence, however for some magnetic storm events the effect is opposite, mainly when eastward zonal electric field from magnetosphere penetrates to the magnetic equator during the plasma prereversal hours.

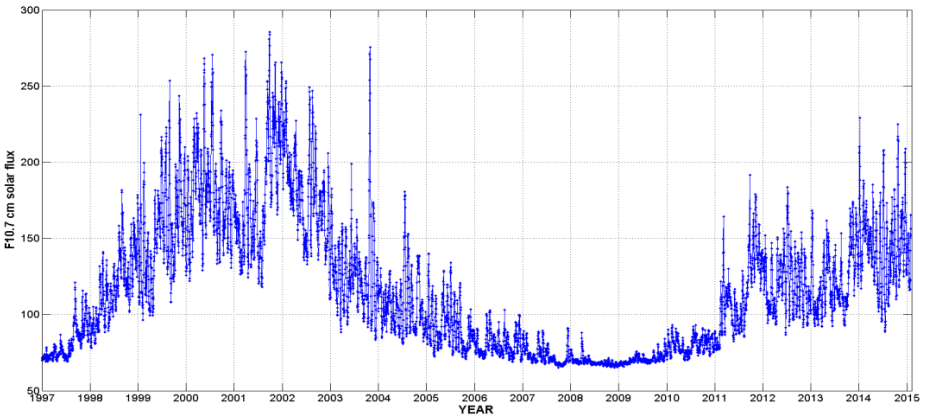

Figure 2. F10.7 cm index of the period of 1997 up to 2015.

This analysis is a first step for the development of the Brazilian Ionospheric Scintillation Model (BISM) (de Paula et al., 2016) that provides the occurrence probability of scintillation over the Brazilian territory.

References

Beach TL, Kintner PM (2001) Development and use of a GPS ionospheric scintillation monitor, IEEE Trans on Geosci Remote Sens 39:918-928. doi:10.1109/36.921409.

de Paula E. R., E. A. Kherani, M. A. Abdu, I. S. Batista, J. H. A. Sobral, I. J. Kantor, H. Takahashi, L. F. C. de Rezende, M. T. A. H. Muella, F. S. Rodrigues, P. M. Kintner, B. M. Ledvina, C. Mitchell, K. M. Groves (2007), Characteristics of the ionospheric irregularities over Brazilian longitudinal sector , Indian Journal of Radio & Space Physics, 36, 268-277.

de Paula E. R., J.R. de Souza, I.J. Kantor, A.O. Moraes, M.T.A.H Muella J. F. G. Monico, B. Vani, J.V. Costa, (2016), Brazilian Ionospheric Scintillation Model, Beacon Satellite Symposium, Trieste, Italy.

Kintner, P. M., B. M. Ledvina, E. R. de Paula (2007), Size, shape, orientation, speed, and duration of GPS equatorial anomaly scintillations, Radio Sci., 39:RS2012. Doi:10.1029/2003RS002878.

Moraes A.O., Rodrigues F.S., Perrella W.J., Paula E.R. (2011) Analysis of the characteristics of low-latitude GPS amplitude scintillation measured during solar maximum conditions and implications for receiver performance. Surv in Geophys 33(5): 1107-1131. doi: 10.1007/s10712-011-9161-z

Moraes A.O., Paula E.R., Perrella W.J., Rodrigues F.S. (2012) On the distribution of GPS signal amplitudes during the low-latitude ionospheric scintillation. GPS Solutions doi: 10.1007/s10291-012-0295-3

Muella M.T.A.H., de Paula E.R., Monteiro A.A. (2013) Ionospheric scintillation and dynamics of Fresnel-scale irregularities in the inner region of the equatorial ionization anomaly. Surv Geophys 34:233-251. doi:10.1007/s10712-012-9212-0

Muella, M.T.A.H., E.R. de Paula, O.F. Jonah (2014), GPS L1-frequency observations of equatorial scintillations and irregularity zonal velocities, Surv. Geophys., 35, 335-357, doi:10.1007/s10712-013-9252-0.

Sobral J.H.A., Abdu M.A., Takahashi H., Taylor M.J., de Paula E.R., Zamlutti C.J., Aquino M.G., Borba G.L. (2002) Ionospheric plasma bubble climatology over Brazil based on 22 years (1977–1998) of 630 nm airglow observations. J Atmos Sol Terr Phys 64(12–14):1517–1524. doi:10.1016/S1364-6826(02)00089-5

Acknowledgements

E. R. de Paula acknowledges the support from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) under process number 310802/2015-6.