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## **A brief study on Ionosphere monitoring over Manaus (- 3° 5' 34", - 60° 2' 24") with GNSS data in the magnetically calm period in solar cycle # 25.**

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### **Abstract**

The monitoring of the Ionosphere over the city of Manaus is a topic of strong relevance, since the city is located between the Geographic and Magnetic Equators (drifting), it is a region with a high incidence of ionospheric plasma bubbles and traveling ionospheric disturbances (TID), for this, the GNSS system with (NovAtel and Septentrio Polarx5s) is used to acquire TEC and S4. GNSS has shown effectiveness in this type of task.

### **Introduction**

Manaus (-3° 5' 34"; -60° 2' 24"), an intermediate point between the geographic and magnetic equators, is intrinsically important in the scope of ionospheric investigation in the equatorial region of the Brazilian sector, where several interesting phenomena occur in the upper atmosphere in the generation of large-scale ionospheric irregularities that at this latitude are the plasma bubbles, better understood in Kelley (1989) and Lima (2009 and 2011). The Amazon is located in a region of maximum in the global distribution of occurrence of plasma bubbles (large-scale ionospheric irregularities), that is, in Brazil, there are more bubbles than in any other region of the planet (BURKE et al., 2004). The Sun has an 11-year cycle, in which half is

magnetically disturbed and half magnetically calm; we are currently going through the calm period moving towards disturbed cycle # 25 since the terrestrial ionosphere is strongly influenced by the 11-year solar cycle, (<https://swpc.noaa.gov>). This ionospheric survey over Manaus, AM, is being carried out by ULBRA institutions (**Fig. 1**), in partnership with UNIVAP (São José dos Campos – SP | Brazil) and is composed of an ionospheric GPS network. It is in integration with the LISN (Low-latitude Ionosphere Sensor Network) project in order to provide scintillation (S4) and **TEC** maps over Manaus in real-time. Research data will be available in digital formats for researchers on the network, at <http://lisn.igp.gov.pe/stations/status.php>, and also in physical form (Handbook), in a FAPEAM publication, available at Geoscience students and researchers (Space Climate) with Ionospheric GPS data in the equatorial region, at: [https://www.researchgate.net/publication/350640220\\_Observacao\\_da\\_Ionosfera\\_sobre\\_Manus\\_2011-2012\\_GPS](https://www.researchgate.net/publication/350640220_Observacao_da_Ionosfera_sobre_Manus_2011-2012_GPS). An Ionospheric GNSS (Experimental), GPS type, with an Arduino platform for monitoring S4 on the target (Manaus-AM|Brazil) is currently under development.

**Methodology**

The site



**Fig. 1:** Ionosphere Laboratory – Yogeshwar Sahai (Ulbra Manaus Campus. Lat. -3.1087; Long. -59.9751).

**Instrumentation.**

The Y. Sahai Laboratory has 2 ionospheric acquisition instruments (GNSS) (Fig. 2 and Tab. 1) (NovAtel and Septentrio) in partnership with the UNIVAP network (LISN), another phase of adaptation and data acquisition from UNESP (Presidente Prudente – SP / Brazil). For Total Electronic Content (TEC) and S4 (Flicker data) acquisition.



**Fig. 2:** Instrumentation (left), receiver and antenna (NovAtel - NOV GSV4004B - Antenna NOV702rev.4). On the right. Septentrio PolaRX5s GNSS receiver and antenna. (Source: UNIVAP-UNESP).

**Table 1 – Station data in Manaus – AM.** (Source: LISN; UNESP)

Manaus		Manaus	
Country	Brazil	Country	Brazil
Net	UNIVAP	Net	UNESP
Latitude	-3.1082690	Latitude	-3.1082690
Longitude	-59.9746552	Longitude	-59.9746552
Altitude (m)	45.4900017	Altitude (m)	45.4900017
Receptor	NOV GSV40048	Receptor	INCT GNSS NAVAER
ANTENA	NOV702 VER 4	ANTENA	PolaNt*MC

**Method**

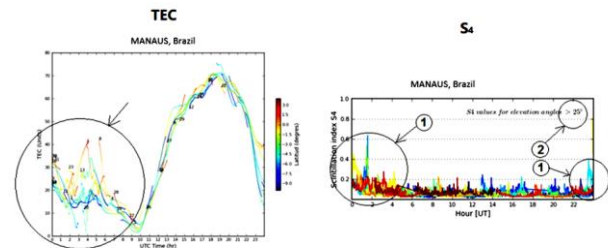
The use of instrumentation using GNSS for monitoring the upper atmosphere is possible from the error

associated with the refraction of the signal sent from the satellite, which when passing through the ionospheric plasma is inversely proportional to the square of the frequency and directly proportional to the total content of electrons (TEC – Total Electron Content), along the path traveled by the GNSS signal in the ionosphere and also by the variation of amplitude and phase of the signal by the scintillation effect (S4). The TEC varies in time and space and is influenced by several variables, such as: solar cycle, time of year, time of day, geographic location, geomagnetic activity, among others, its effect on the GNSS system is of delay, while the flickering, ie S4, can cause loss (stuttering) and positioning degradation. The TEC, presented in TECU units (TECU), where 1 TECU corresponds to  $1 \times 10^{16}$  electrons/m<sup>2</sup> (Eq. 1 and Fig. 3 from the right) and the S4, (Eq.2 and Fig. 3 from the left), are the main parameters that describe the effect of the ionosphere on the GNSS signal.

The research is based on the monitoring of the solar cycle # 25, in the equatorial region, through GNSS data (NovAtel - NOV GSV4004B - Septentrio PolaRX5s GNSS). This is performed with the aid of TEC (Total Electron Content) and S4 scintillation graphic analysis, which show the variation in the intensity of free electrons per area in the terrestrial ionosphere and the recombination with photon emission, respectively. The number of electrons along the length of the path is referred to as the total electron count and is defined by the expression:

$$TEC = \int_{receiver}^{satellite} n_e dl \quad (1)$$

Where  $n_e$  is the electron density.



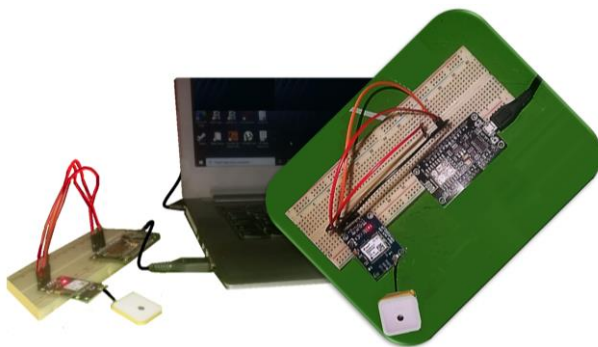
**Fig. 3:** TEC and S4 graphs in the ionosphere over Manaus (AM | Brazil). TEC (left) the detail in the figure reports irregularities in the Plasma Bubble type ionosphere. S4 (right) being (1) flickering irregularities and (2) maximum elevation of collected information. (Source: LISN).

In Muella, (2008) scintillation, which is a variation in the amplitude and phase of a radio wave, when it crosses irregularities in the ionosphere, that is, leaves the GNSS

system unavailable, and its mapping is carried out through the values of the radiofrequency index. S4, in other words, is the standard deviation (dispersion of samples) of one minute of data at a rate of 50 samples per second (Eq. 2).

$$S_4^2 = \frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2} \quad (2)$$

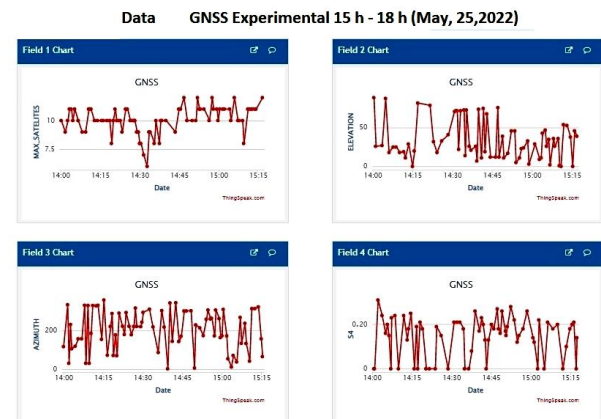
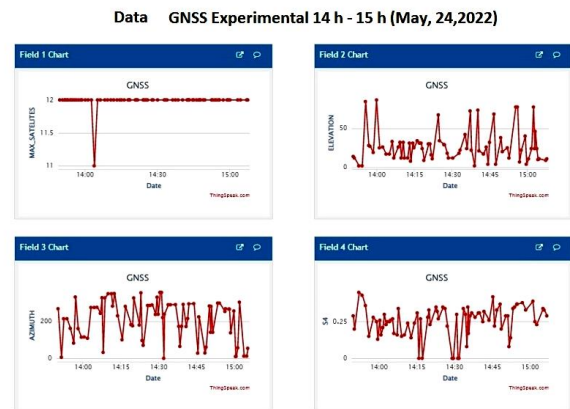
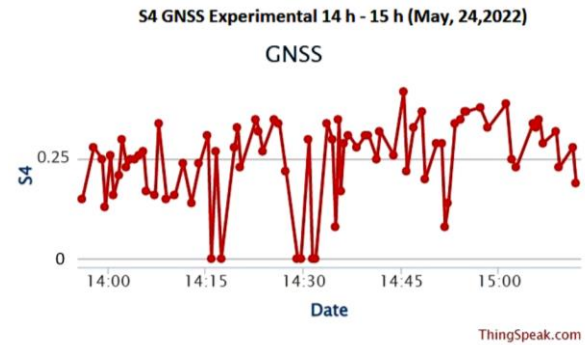
As of February 2022, students from electrical, environmental and mechanical engineering in the Y. Sahai Laboratory (LABION – Laboratory of Ionosphere) have developed an Experimental receptor GNSS with Arduino (Fig. 5), for data acquisition S4. Currently the data from the receiver with Arduino comes being confronted with data from the Septentrio PolaRX5s (GNSS receiver). Monitoring data from Experimental GNSS receiver with Arduino (LABION), is also being calibrated by Trimble platforms (<http://www.gnssplanning.com/>) and UNAVCO (<https://www.unavco.org/data/>).



**Fig. 5:** GNSS system with Arduino developed at the Y. Sahai Laboratory (CEULM/ULBRA2022).

## Results and Discussion

Data from the GNSS-Arduino system (LABION - Y. SAHAI), in hourly intervals, can be viewed at <https://thingspeak.com/channels/1744159>. at the point (-3° 5' 34"; -60° 2' 24"), that is, over the city of Manaus – Amazonas | Brazil. (Fig.6).

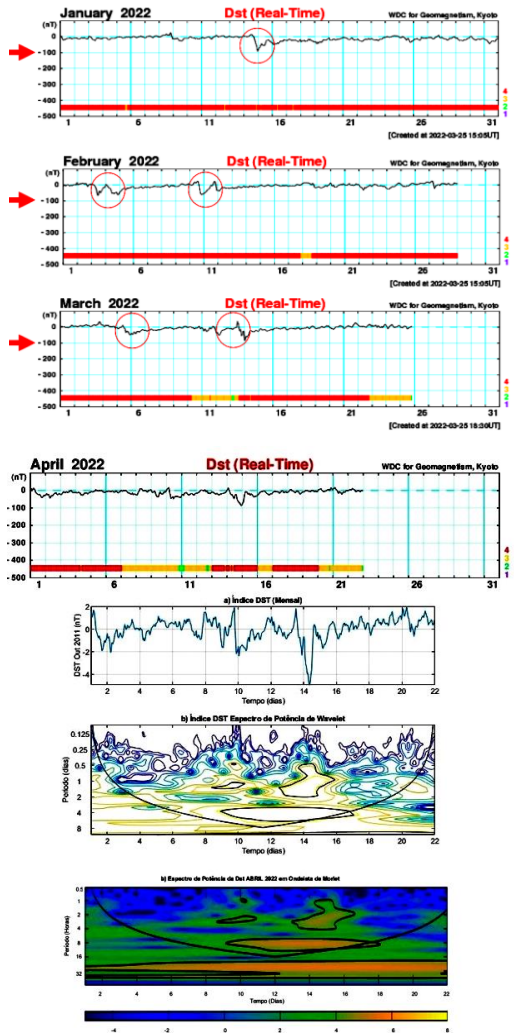


**Fig. 6:** Shows the graphs of S4 (on a scale of 0 to 1) plus Maximum Satellite Number, Elevation, Azimuth and S4 over target (-3° 5' 34"; - 60° 2' 24"), on two different days and times.

Solar Cycle # 25 is still in the growth phase of turbulent events, in the year 2022 the events of solar storms (Dst Index - Disturbances Storm Time) with an index close to -100 nT (one in January, three in February, and three in March) (Fig. 7). We observed slight growth in Cycle #25. These days of strong **dst (disturbance storm time)** favor ionospheric irregularities, mainly in the formation of ionospheric plasma bubbles in the equatorial region, also

visible in the Morlet Wavelet Transform, within the reliability cone (95%) according to Bolzan and Rosa (2010).

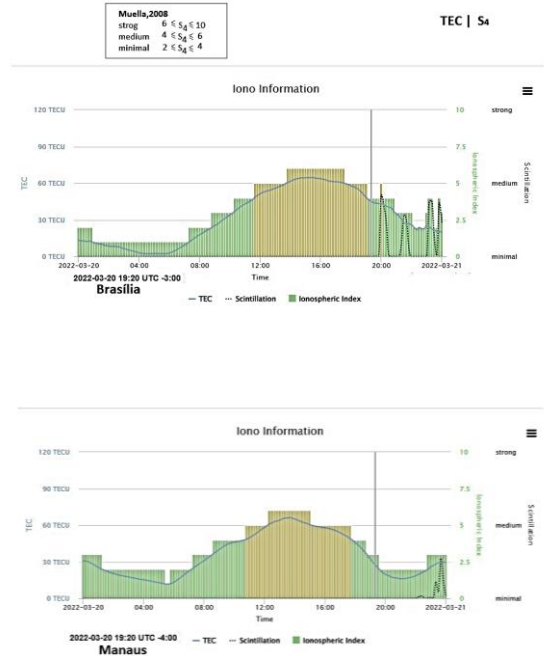
+ e<sup>-</sup> → O + photon) in color scale and date in (Fig. 9), very close to the Magnetic Equator.



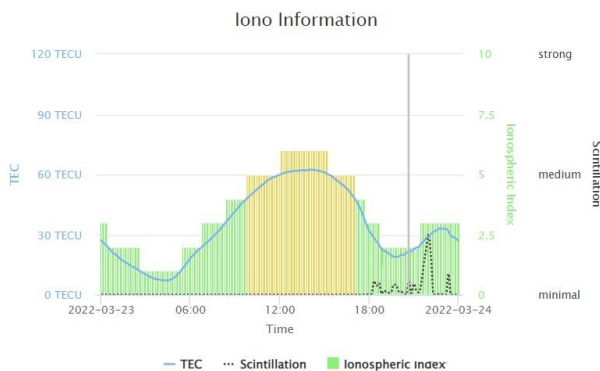
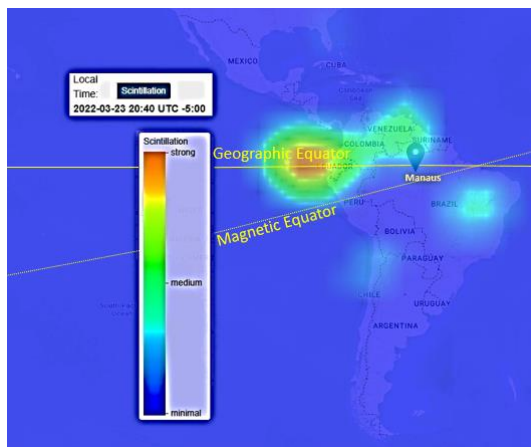
**Fig. 7:** Dst Panel for the months of January, February, March, and April 2022, with DST Index Profile (Disturbance Storm Time) and Morlet Wavelet Transform. Source: WDC for Geomagnetism – Kyoto, 2022).

Using information from Trimble (GNSSPlanning), (Fig. 8 and Fig. 9) it was possible to monitor details of TEC and S4 Flicker irregularities over the cities of Manaus and Brasília, in order to understand the degradation of the GNSS signal in these cities in March of 2022.

The Fig. 8, denotes the reality of TEC in Amazonian and central Brazil at night. However, the correlation between the instrumentations and the TEC and S4 graphs obtained on the target is of importance. Mainly in the peaks (19h, 21h 22h, and 23 h) for the S4 scintillation (O<sup>+</sup>



**Fig. 8:** Values of the TEC and S4 indexes for the cities of Brasília and Manaus for the 20th of March 2022. (Source: GNSSPlanning).



**Fig. 9:** Observation in Manaus (Manaus City between the Geographic and Magnetic Equators, in the Central Amazon - Brazil, northern South America) of the TEC and S4 indexes, for March 23rd, 2022. (Source: GNSSPlanning).

### Conclusion

The data and information acquired with the GNSS system in the Central Amazon, provides knowledge about the behavior of the ionospheric plasma in the region. However, continuous monitoring is responsible for understanding seasonal anomalies in the Sun's 11-year solar cycle over the target.

### Acknowledgment

The authors are grateful to the web platforms (UNAVCO, Trimble, LISN, NOAA, NovAtel, Septentrio, WDC for Geomagnetism - Kyoto) for making strong scientific information available to the community at large. We also thank the Universities UNIVAP (SJC-SP) and UNESP (Pres. Prudente-SP) for the instrumentation partnership (GNSS) on the Ulbra-Manaus campus. Thanks to the advisors and the Institution for their support and also to researchers Christopher Torrence and Gilbert P. Campus of the University of Colorado, Program in Atmospheric and Oceanic Sciences, for the package of wavelet scripts. It is available at the URL: <http://paos.colorado.edu/research/wavelets/>

### References

BOLZAN, M. J. A. & ROSA, R. R. (2010). TRANSFORMADA EM ONDELETAS Teoria e Aplicações com Matlab,

BURKE, W. J.; HUANG, C. Y.; GENTILE, L. C. AND BAUER, L., 2004. Seasonal-longitudinal variability of equatorial plasma bubbles. *Annales Geophysicae* 22, 3089–3098.

[https://www.researchgate.net/publication/350640220\\_Observacao\\_da\\_Ionosfera\\_sobre\\_Manaus\\_2011-2012\\_GPS](https://www.researchgate.net/publication/350640220_Observacao_da_Ionosfera_sobre_Manaus_2011-2012_GPS)

<https://septentrio-polarx5s-datasheet.pdf>

<https://www.unavco.org/data/gps-gnss/gps-gnss.htm>

<https://gnssplanning.com>

[http://wdc.kugi.kyoto-u.ac.jp/dst\\_realtime/202203/index.html](http://wdc.kugi.kyoto-u.ac.jp/dst_realtime/202203/index.html)

KELLEY, M. C. 1989. *The Earth's Ionosphere Plasma Physics and Electrodynamics*, Academic Press, San Diego – USA – California, 487p.

LIMA, N. S., FERREIRA, A. S., ARAÚJO, R. C., YAMAMOTO, K. C. (2011). Observations of MSTIDs/GWs at the F2 layer heights in the near equatorial region. Geophysical Research Abstracts Vol. 13, EGU2011-122, 2011 EGU General Assembly.

LIMA, N. S., (2009). Study of the Propagation of Gravity Waves in the Equatorial Ionosphere, using Observations in Manaus (2.9°S, 60°W), Master's Dissertation in Geosciences, Federal University of Amazonas, UFAM/Brazil.

MUELLA, Marcio Tadeu de Assis Honorato. Morphology and dynamics of small-scale ionospheric irregularities and ionospheric GPS imaging. 2008. 386 f. Thesis (Doctorate) – Space Geophysics, National Institute for Space Research, São José dos Campos.