Comprehensive Space Weather Monitoring and Analysis in Brazil and Neighboring Regions

Clezio De Nardin and EMBRACE/INPE Team

National Institute for Space Research (INPE), Brazil

UNOOSA (COPUOS), Vienna (Austria) on February 1st, 2024

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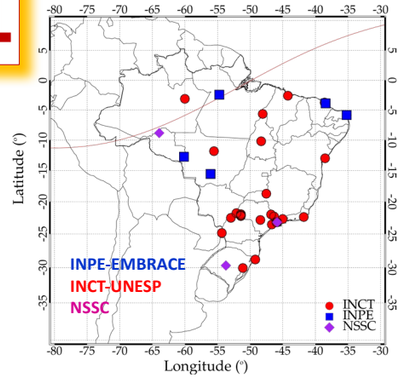
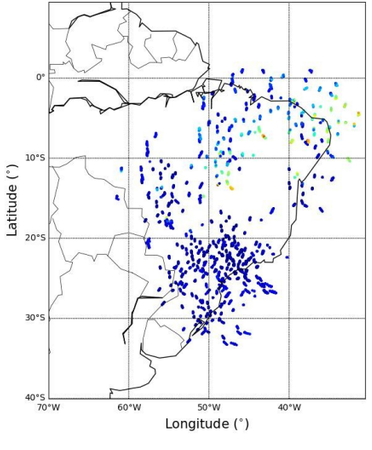
Scintillation Monitoring

PI's: Cristiano M. Wrasse, Diego Barros
Toyese T. Ayorinde

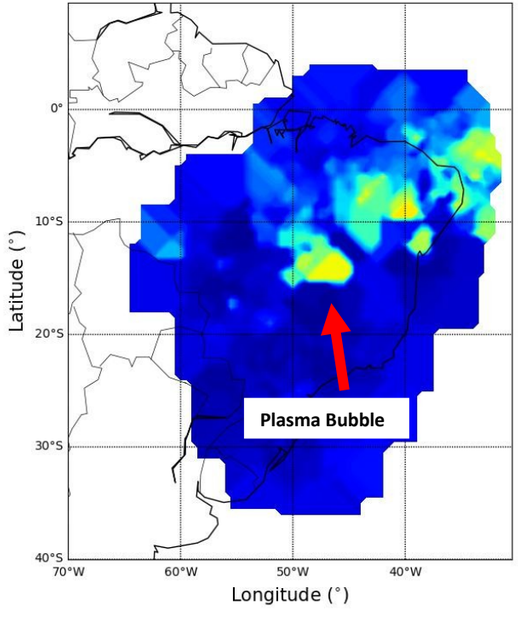
GNSS receivers

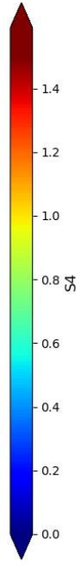


Ionospheric Piercing Points (IPPs)

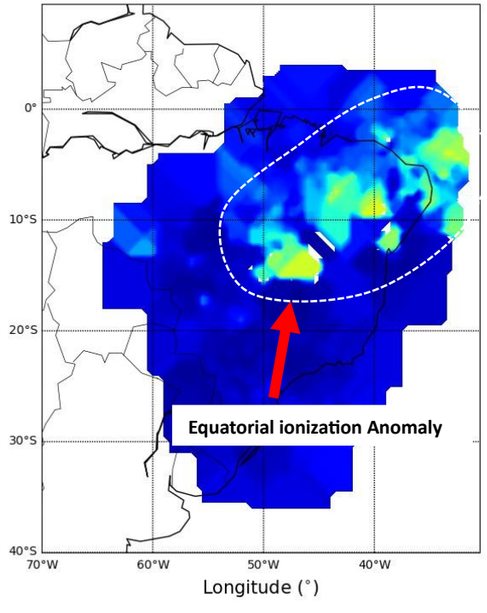


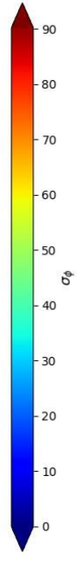
S4 maps - Phase

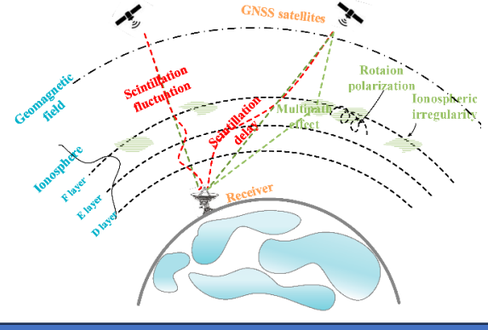




S4 maps - Amplitude





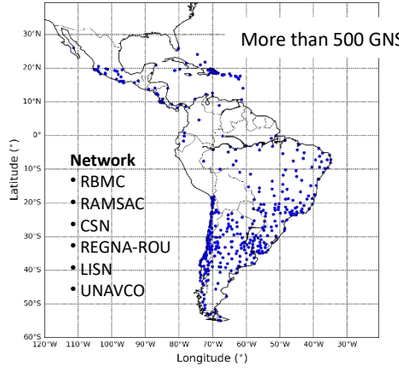


- **Scintillation** are measured to study **ionospheric irregularities** such as Plasma Bubbles/Spread-F, Ionization Anomalies, Small-Scale Irregularities, Sporadic E-Layer, Ionospheric Storms
- **Better understand** these ionospheric **irregularities** and **their impact** on radio wave propagation, communication systems, and navigation systems.

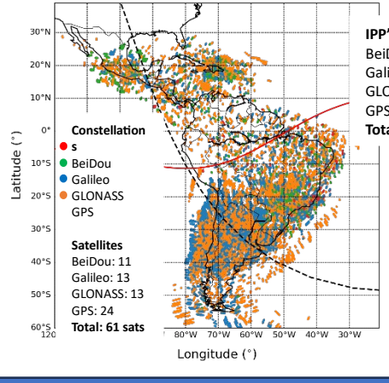
2 Total Electron Content (TEC) and Plasma Bubbles Monitoring/Modeling

PI's: Cristiano M. Wrasse, Diego Barros
Toyese T. Ayorinde

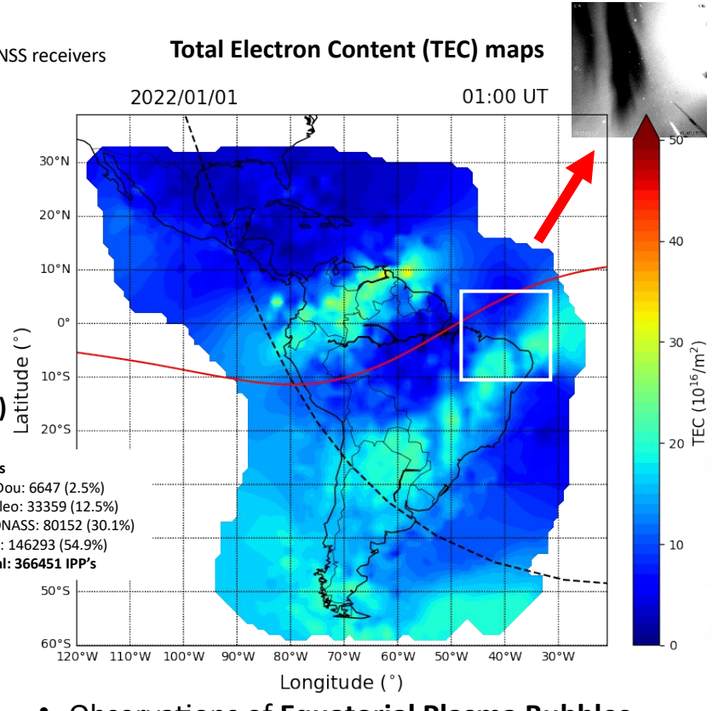
GNSS receivers



Ionospheric Piercing Points (IPPs)



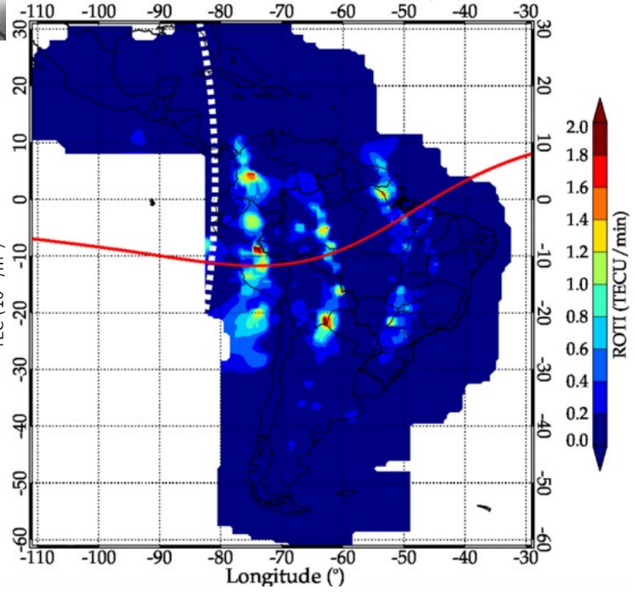
Total Electron Content (TEC) maps



OI 630 nm

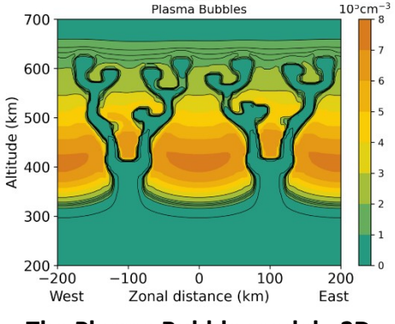
- Observations of **Equatorial Plasma Bubbles** and **Equatorial Ionization Anomaly** in both hemisphere

Rate of TEC Index (ROTI) Maps



- **ROTI is independent** of the **bias** receivers
- The detection of EPBs can be **easily automated**

FORECASTING

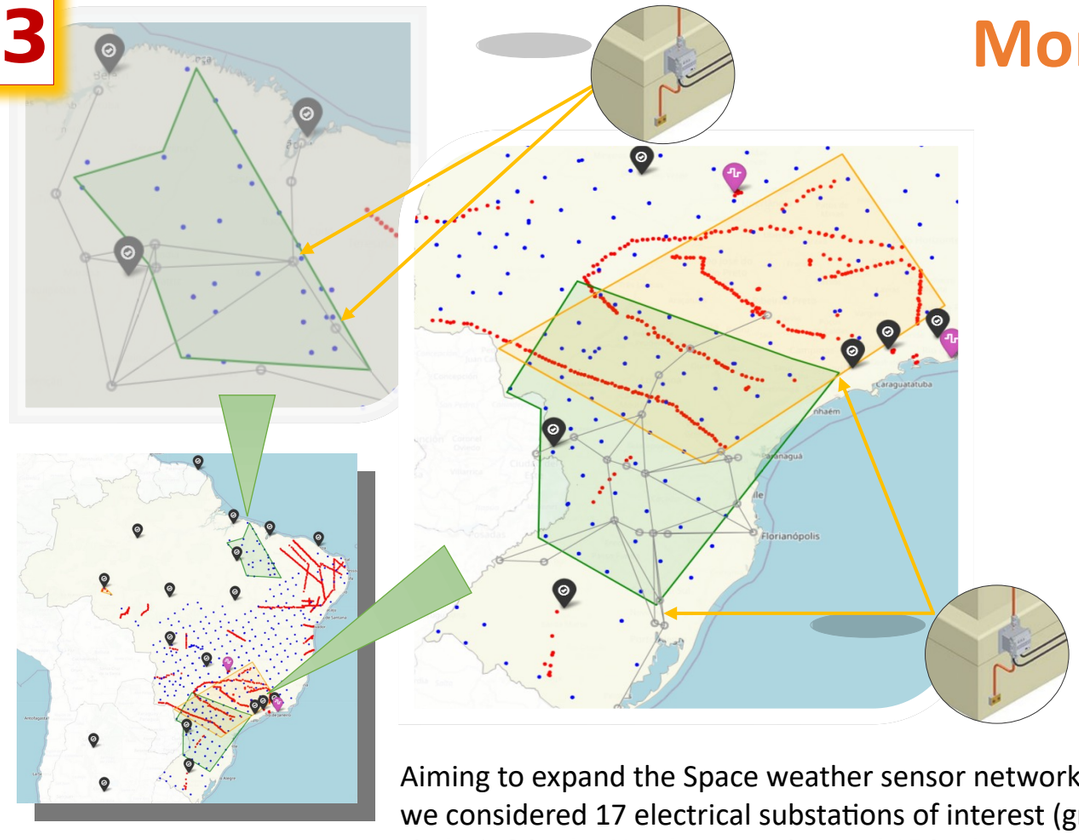


The Plasma Bubble model - 2D can forecast the **occurrence, structure, and dynamics** of plasma bubbles

3

Monitoring and modelling GICs

PI's: Ribeiro, Livia; Sarmiento, Karen



Aiming to expand the Space weather sensor network, we considered 17 electrical substations of interest (gray circles), 2 in the Northeast region and 15 in the Southeast region, analyzing the following criteria:

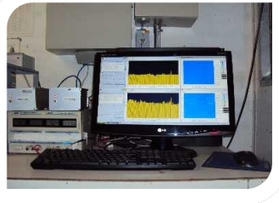
1. Conductivity (green) and developing (orange) 3D model available.
2. AC high voltage transmission line (525 kV).
3. A minimum of magnetometers (markers in black) that make it possible to obtain magnetic field data or the interpolation process, aiming at real-time modeling of the geoelectric field and GICs.

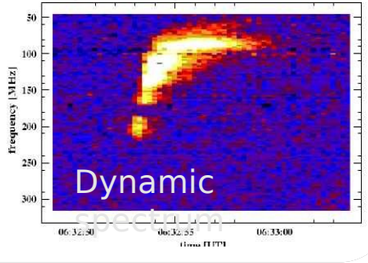
The two purple markers represent the location of the Itumbiara sensor that operated until 2016 and the possible location of the first sensor in Rio.

4 Solar monitoring

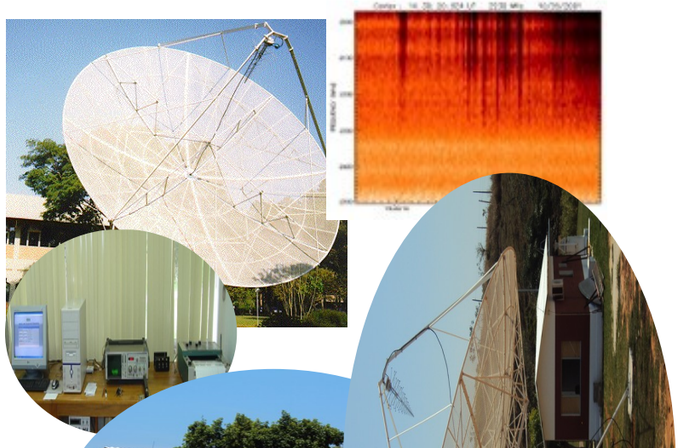
PI's: Costa J.E.R., Cecatto, J.R.

Dual polatization
40-840MHz



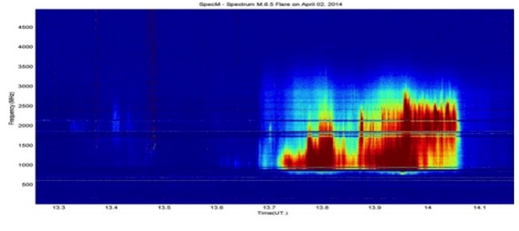


CALLISTO receiver operational since 2012



Brazillian Solar Spectrometer 1000-2500MHz

9m dish being reforbushed to restart operation in 2024

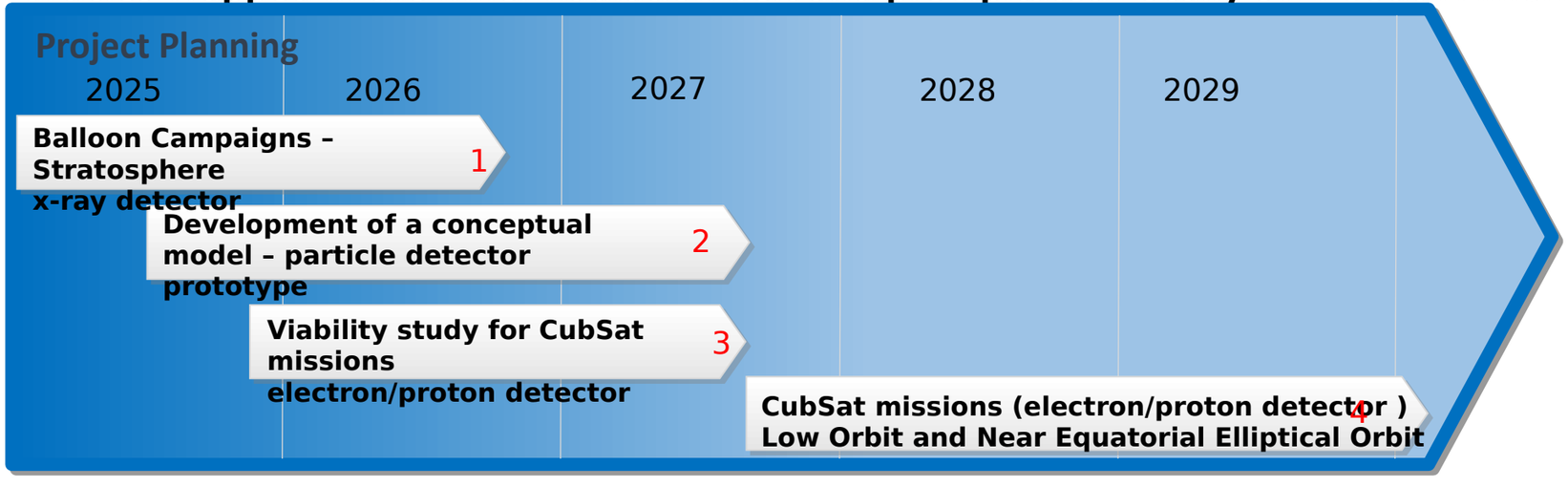


SPECM -Spectrometer in cm-wavelength (1-18GHz) with new receivers being tested. Restart operations in 2024

5

PROJECT PARTICLES – PI: Ligia Da Silva

Charged Particles Trapped in the Inner Radiation belt and preCipitated Locally ovEr South America



1- Particle precipitation – impact on the Ozone distribution in the stratosphere (Da Silva et al., 2016)

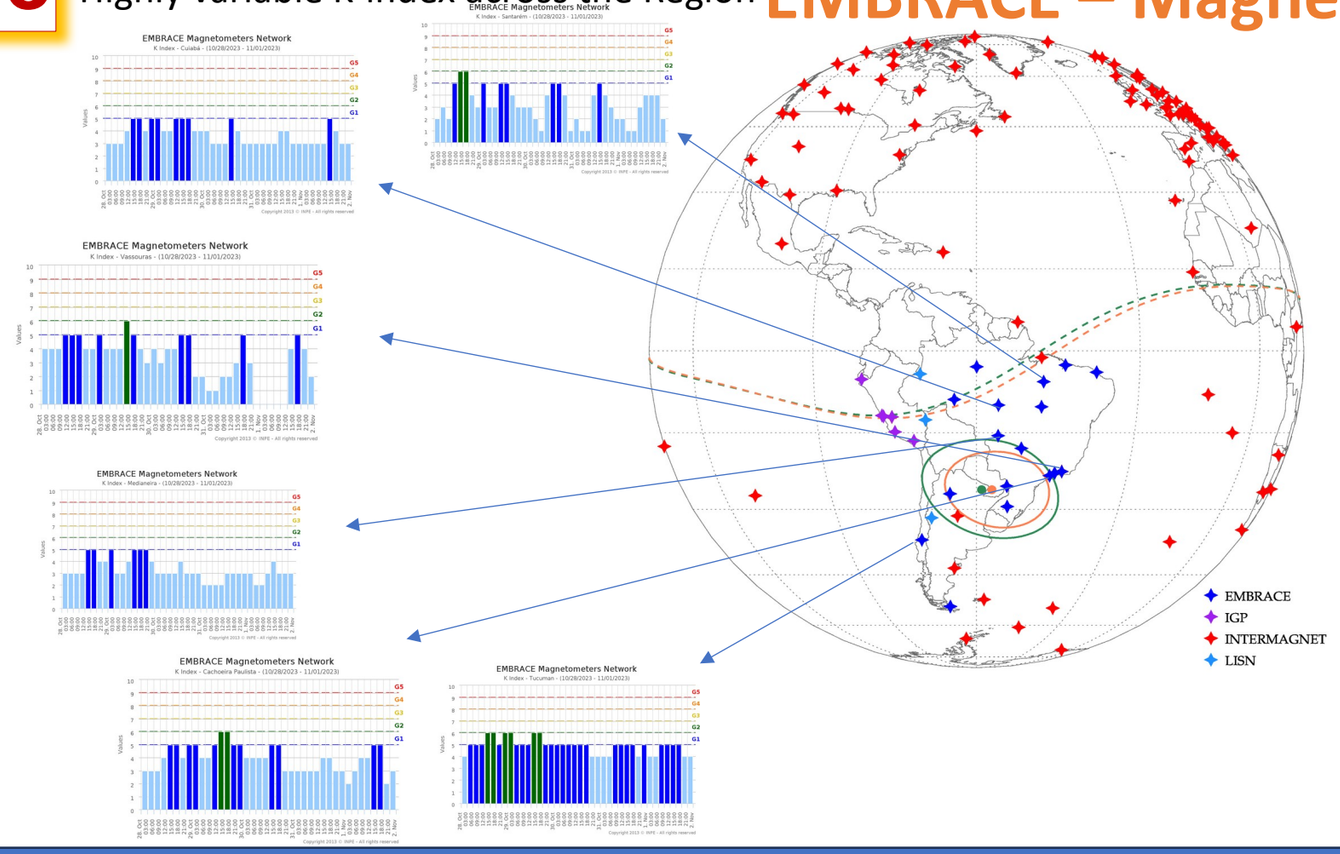
2- Development of a particle detector prototype appropriated to measure electron/proton over South America – Brazilian team capacitation

3- Viability study for measurements of electron/proton over South America using CubSats – Considering the impact over ionosphere in South America (Da Silva et al., 2022)

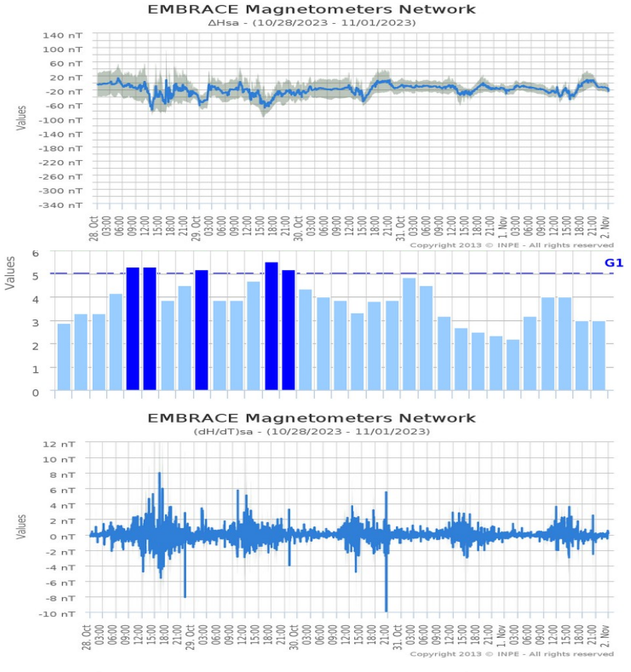
4- CubSat missions for measurements of electron/proton trapped in the inner radiation belt and precipitated over South America – physical processes in the inner radiation belt and the ionosphere during the generation of the auroral-type sporadic E Layers over South America (Agapitov et al., 2020; Da Silva et al., 2022)

6 Highly variable K-index across the Region EMBRACE – Magnet

PI's: Denardin, C., Chen, S.



KSA is K-South_America



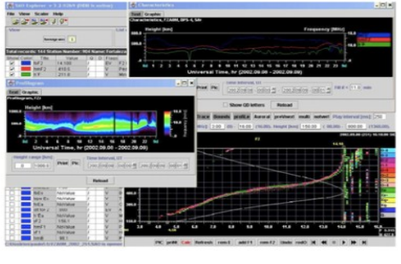
The EMBRACE Magnet covers Brazil and some neighbor countries. The plan is to expand from 19 to 30 elements in 2030.

7 Digisonde -Network

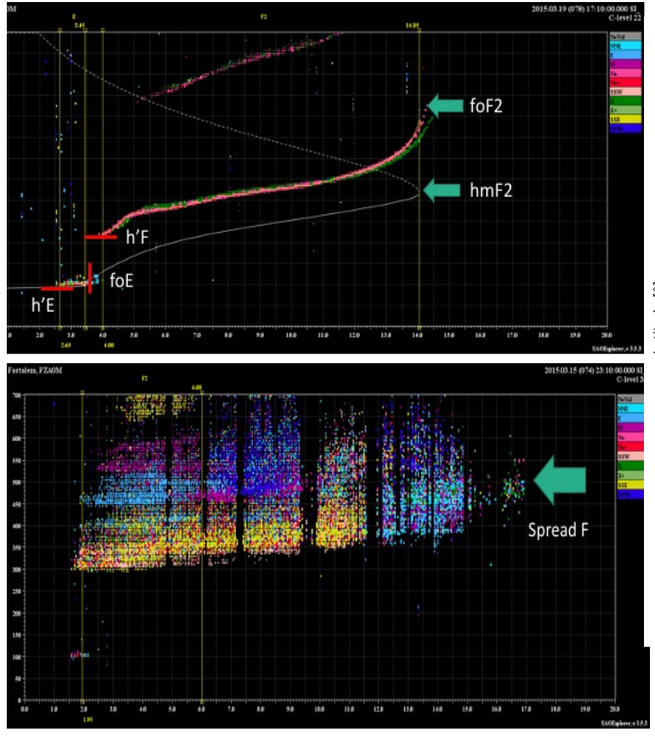
PI: Laysa Resende

The Embrace program has strategically placed digisondes in designated areas to assess the ionospheric profile and irregularities within it, including phenomena like plasma bubbles, sporadic layers of irregularities, and particle precipitation. The ionosphere in the Brazilian sector exhibits distinctive behavior due to the magnetic equator's high declination and the presence of the South American Magnetic Anomaly (SAMA). Therefore, it becomes crucial to deploy additional digisondes near both the magnetic equator and the SAMA region.

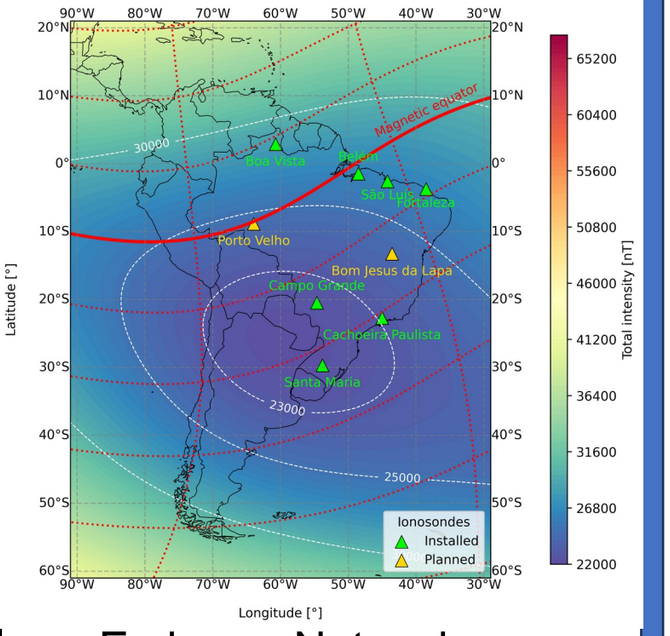
Digisonde



SAO -Explorer



Ionogram examples showing different parameters of the ionospheric layers, and the spread-F



Embrace Network Digisonde

All-Sky Imager and FPI Network

PI's: Cristiano M. Wrasse
Prosper K. Nyassor

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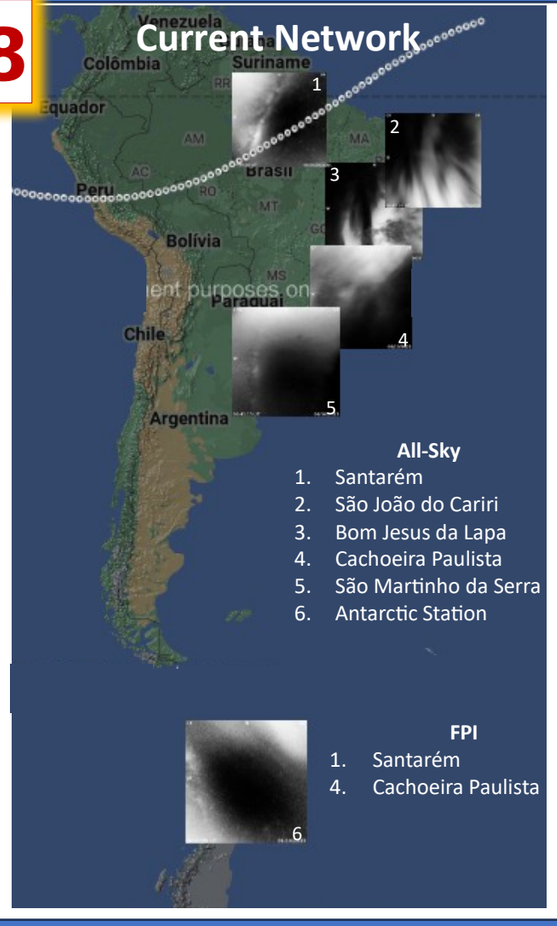
Current Network



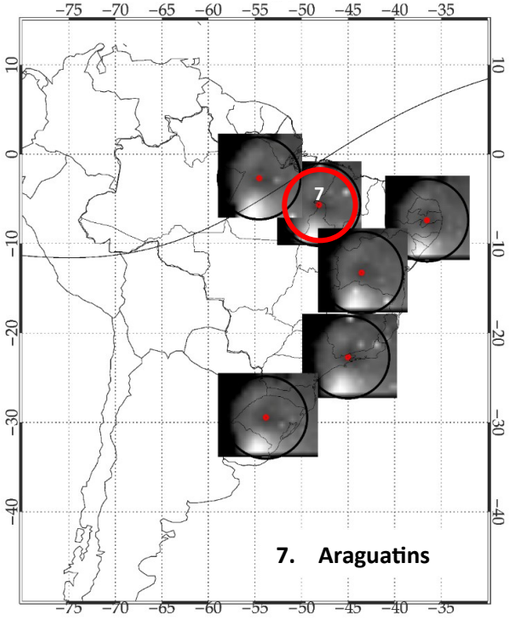
All-Sky

1. Santarém
2. São João do Cariri
3. Bom Jesus da Lapa
4. Cachoeira Paulista
5. São Martinho da Serra
6. Antarctic Station

FPI

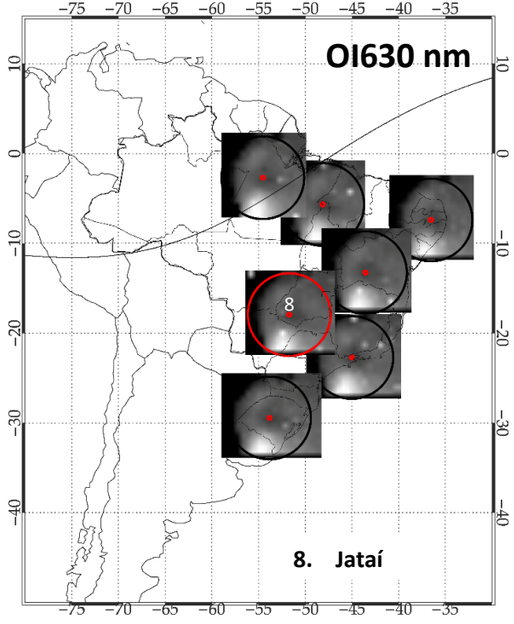
1. Santarém
4. Cachoeira Paulista

Network Status in DEC 2023

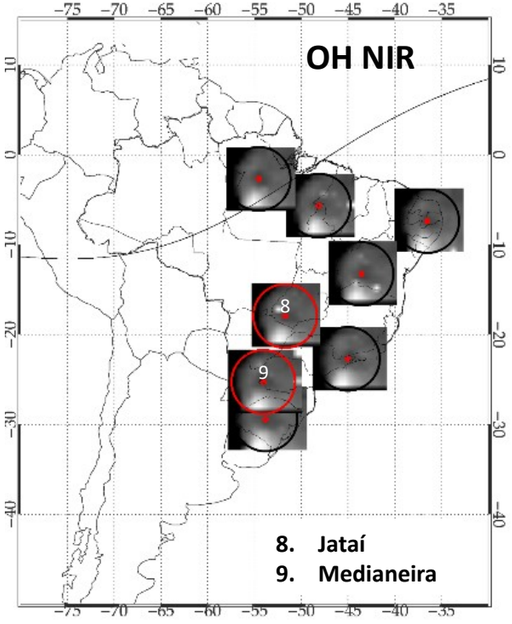


7. **Araguatins**

Network Status in Dec 2024



8. **Jataí**



8. **Jataí**
9. **Medianeira**

- **OI630 nm images** are used to study Ionospheric Irregularities (such as **Plasma Bubbles** and **Traveling Ionospheric Disturbance**) in the F-layer/Thermosphere region
- **OH NIR images** are used to study **Gravity Waves** in Mesosphere and Low Thermosphere region
- **Fabry-Perot Interferometer (FPI)** is used to measure Thermospheric **winds** and **temperature**

9 VLF receivers and Riometers

PI:Correia, Emilia

Both VLF receivers and riometers are essential for understanding and monitoring the ionosphere, which is critical for space weather prediction, communication systems, and various scientific studies. These instruments play a key role in advancing our knowledge of the Earth's ionospheric conditions and their response to external influences from space

VLF receivers:

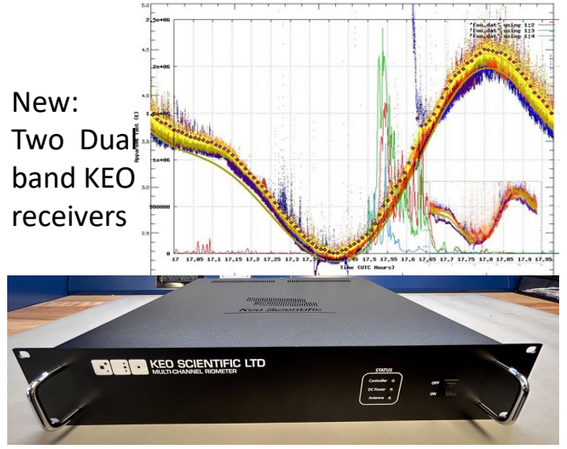
- Atibaia (ATI), Brazil - S23.183 - W46.60
- Antarctica Station: Comandante Ferraz (EAC), Brazil - S62.083- W58.40;

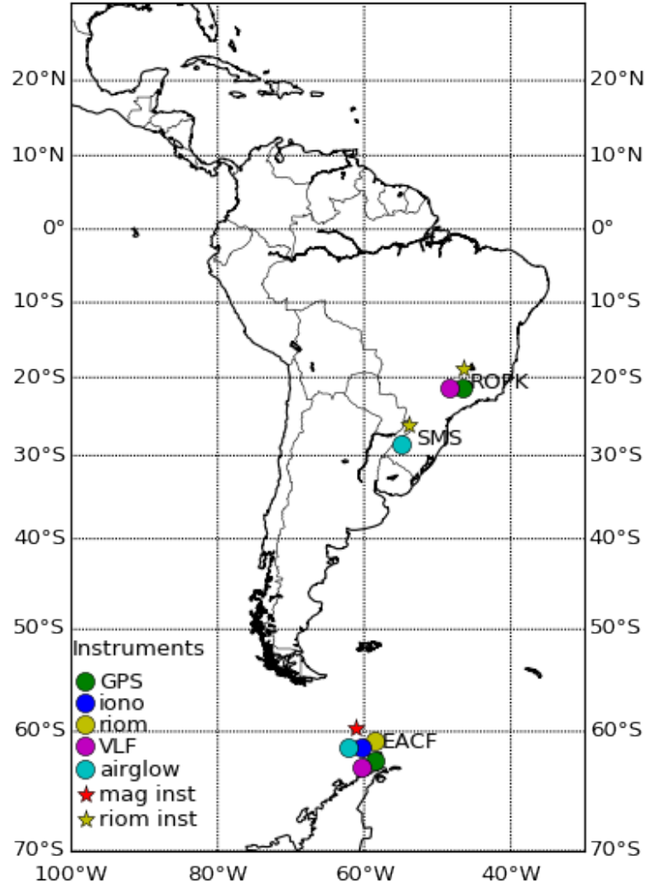
Riometers:

INPE has 3 (2 dual band to be installed this year).

- Antarctica Station: Comandante Ferraz(EAC), Brazil - S62.083- W58.40;
- San Martinho da Serra (SMS), Brazil - S29.44 - W53.82
- Atibaia (ATI), Brazil - S23.183 - W46.60

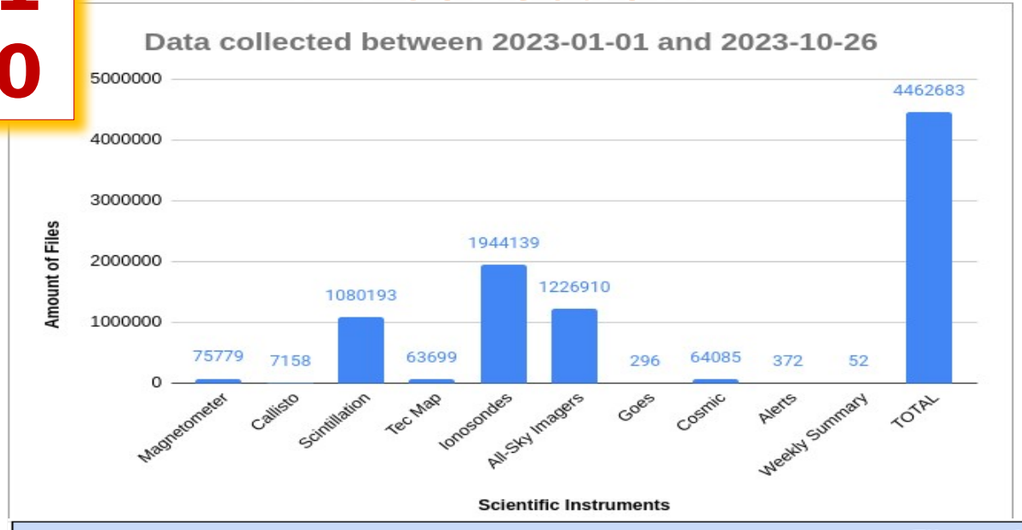
New: Two Dual band KEO receivers



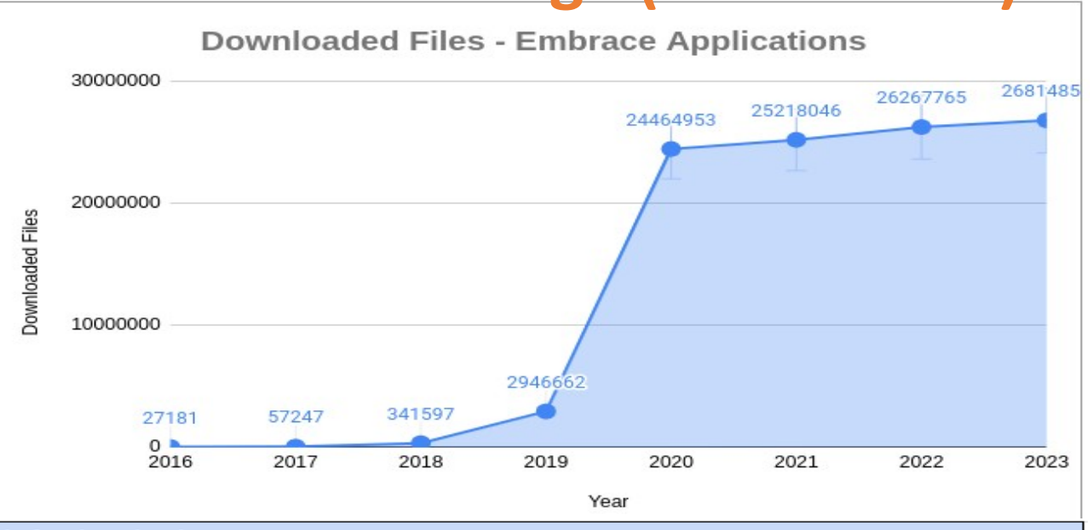


10

DATA Collection.



DATA Usage (Downloads)



Files available for download									
Instrument	Magnetometer	Callisto	Scintillation	Tec Map	Ionosondes	All-Sky Imagers	Goes	Alerts	Weekly Summary
Extensions	.txt	.fit	.dat	.ionex .amap .gtex	.png .rsf .xml .dvl .dft .sao .sky .grm	.tif	.txt	e-mail	.pdf
Sample	1 minute	15 minutes	1 minute	10 minutes	2/4 minutes	1 minute	1 minute	when events occur	weekly

The program includes a range of essential instrument networks, including magnetometers, ionosondes, GIC sensors, all-sky imagers, Fabry-Perot interferometers, VLF receivers, riometers, CALLISTO spectrometers, and scintillation sensors. Future plans include network expansion, technological upgrades, and enhanced collaboration to strengthen data acquisition capabilities and distribution.

Space weather analysis methods, such as Total Electron Content (TEC) mapping, Rate of TEC Index (ROTI) mapping, and real-time All-Sky imaging (OI 630 nm airglow), Fabry-Perot Interferometers, and scintillation studies, offer profound insights into regional ionospheric dynamics, geomagnetic disturbances, and atmospheric phenomena. These methods are pivotal for scientific research and applications like GNSS-based navigation and radio wave propagation. The digisonde network plays a crucial role in assessing ionospheric profiles and irregularities, particularly near the magnetic equator and the South American Magnetic Anomaly region complemented by the significance of VLF receivers and riometers in advancing our understanding of Earth's ionospheric conditions and their response to external space influences.

With extensive coverage, cutting-edge instrumentation, and advanced analysis methods, the program significantly contributes to regional and global space weather research and services, fostering a safer and more technologically resilient world.

For Geomagnetically Induced Current (GIC) measurements, the program plans network expansion, tests and upgrades, GIC sensor installation, and modeling. The EMBRACE magnetometer network aims to expand its elements to 30 by 2030.

UNITED NATIONS
Office for Outer Space Affairs