# IRIS

## *IONOSPHERIC RESEARCH FOR BIOMASS IN SOUTH AMERICA*


**IRIS team**

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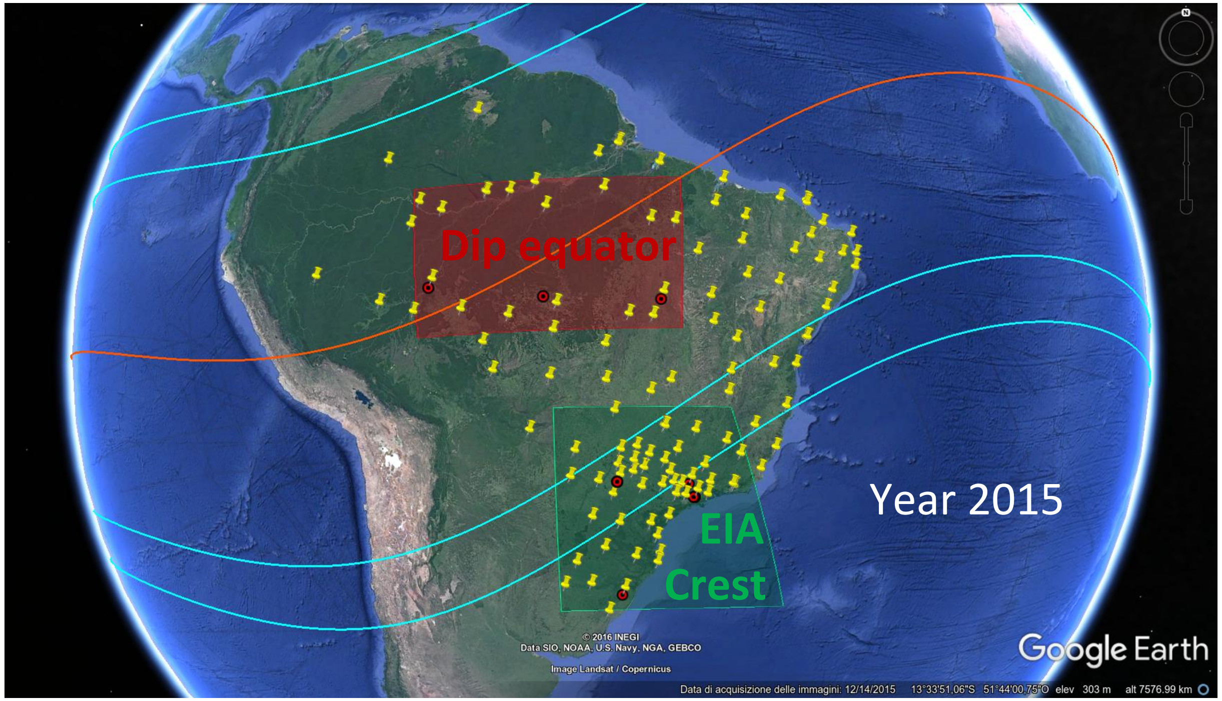
# methodology

- limatology (1 year) of the ionosphere in the two quietest days of each month in the considered period over Brazil
- pecial focus is given to the times of the foreseen Biomass orbital passes, i.e. 06 AM and 06 PM
- ariation of TEC (including its spatial and temporal variation) and amplitude scintillations ($S_4$)
- he sensitivity of TEC and TEC gradients mapping has been tested to assess the actual reliability of the method
- ase events and climatology from ionosonde data
- TIDs detection

e network
GNSS
eivers*



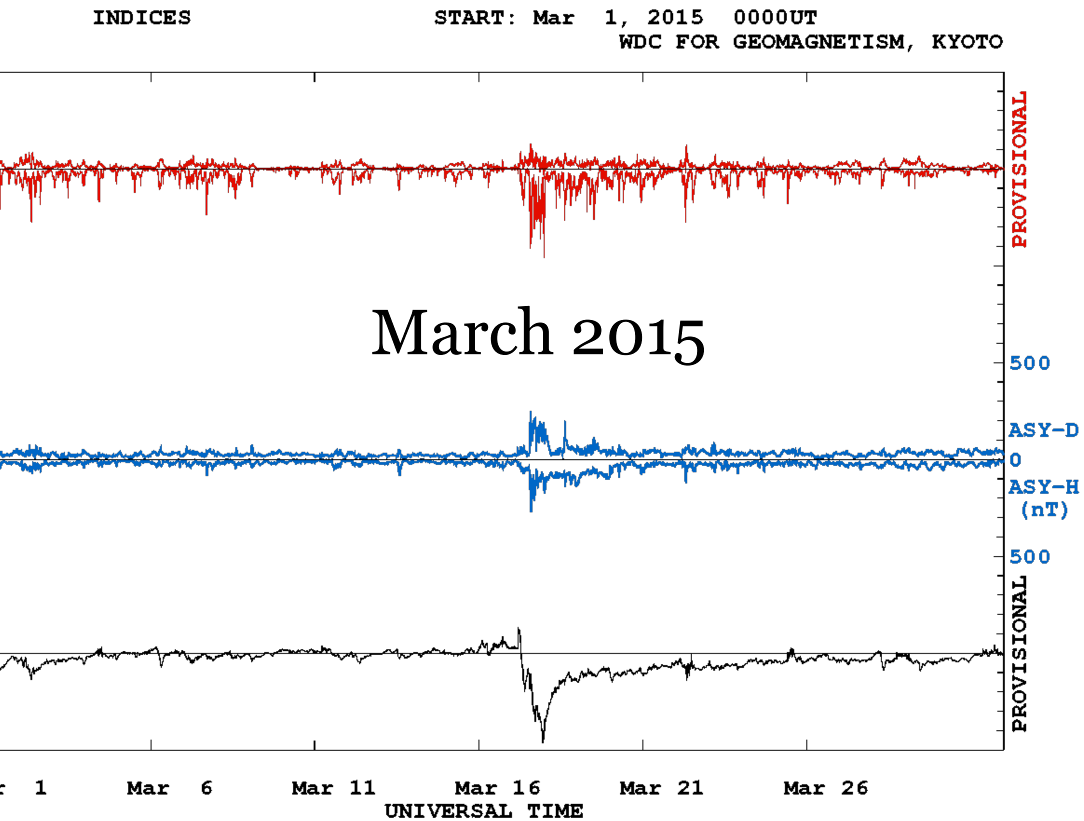

Pins: geodetic receivers
(1 Hz – TEC measurement)

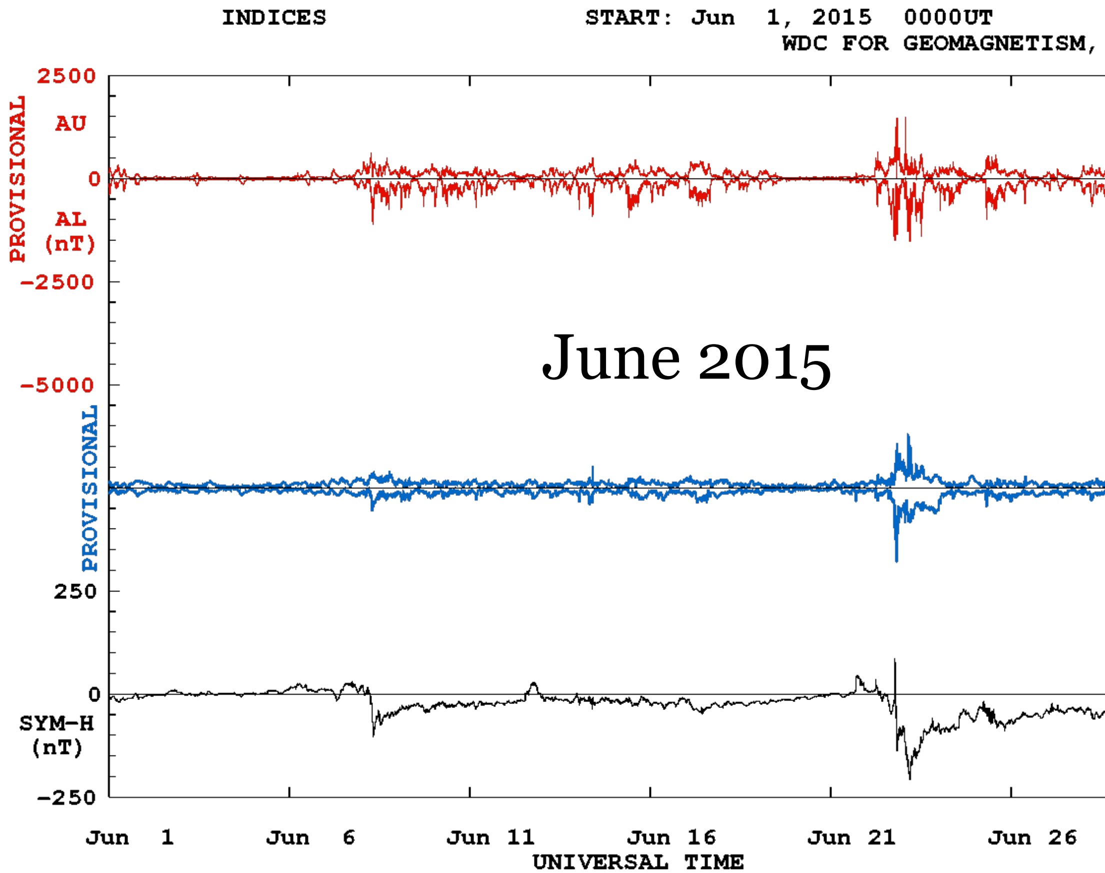
Circles: scintillation receivers
(50 Hz – S4 and TEC measurement)

*from partners + additio

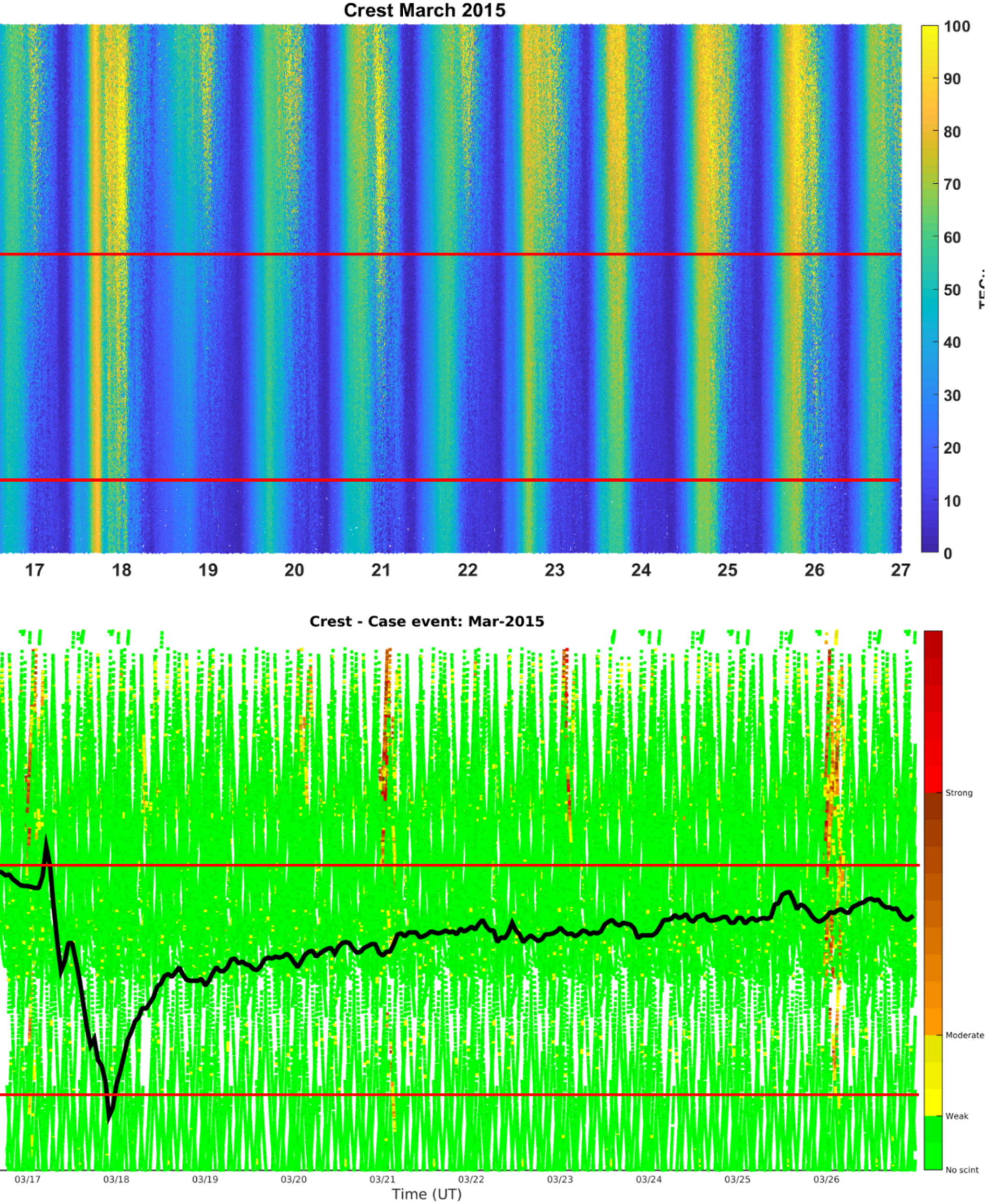
# Highlights of the scientific results:

# Applications to ionospheric science

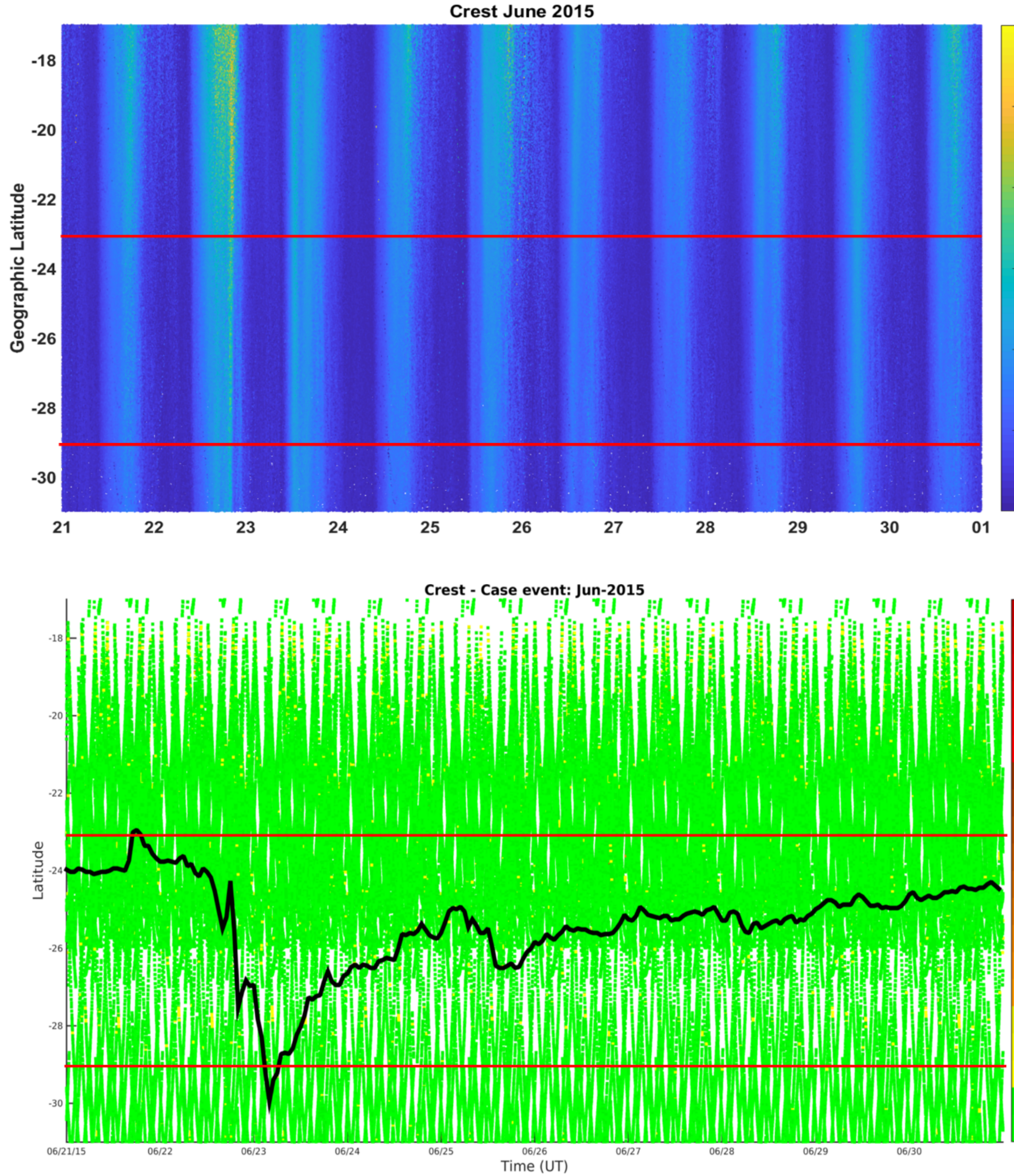


# March 2015




# June 2015



# Lessons learnt from the case studies

The two storms of **March and June 2015** were investigated by analysing the **TEC** and $\mathbf{S_4}$ variations.

The comparison between the geomagnetic indices variations in the two case studies reveals a quite **differ configuration of the magnetosphere-ionosphere coupling**. The event happened in Marcl characterized by a long recovery phase, but the SYM-H assumes higher values soon after the peak. At storm onset the auroral regions show high level of the electrojet with impulsive substorm signatures.

**Although the average TEC level was significantly larger in March, the ionospheric irregulari were suppressed mainly in June.** That storm, in fact, induced an almost complete inhibitio scintillations over SA investigated areas. Such effect is well explained looking at the TEC variability, th quite smooth in June, testifying a significant modification of the EIA.

The **lower level of scintillation found for the June 2015 storm with respect to the March 2** one is somehow expected. In fact, solsticial months are characterized by a lower occurrence of scintilla with respect to equinoctial ones. Thus, in the case of the June 2015 storm the lack of strong scintillation le is due to the interplay between the regular seasonality of the equatorial ionosphere and the inhibition of ionospheric irregularities formation due to the prompt penetration of electric fields from the auroral latitu and to the disturbance dynamo.

As stressed by several authors (e.g., Alfonsi et al., 2011; Ray et al., 2006; Anderson et al., 2004; Spogli e 2016)**, it is not yet clear whether an enhancement in upward ExB drift is necessary sufficient or simply necessary for creating the conditions driving to scintillation occurre** Certainly, the upward **ExB** drift is a key driver for developing scintillation models at low latitudes.

# ighlights of the scientific results:

# pplications to Biomass external alibration

xisting Facilities in Latin America have been used to characterize Equator/Crest regions
he analysis of the GNSS data has produced the following outputs:

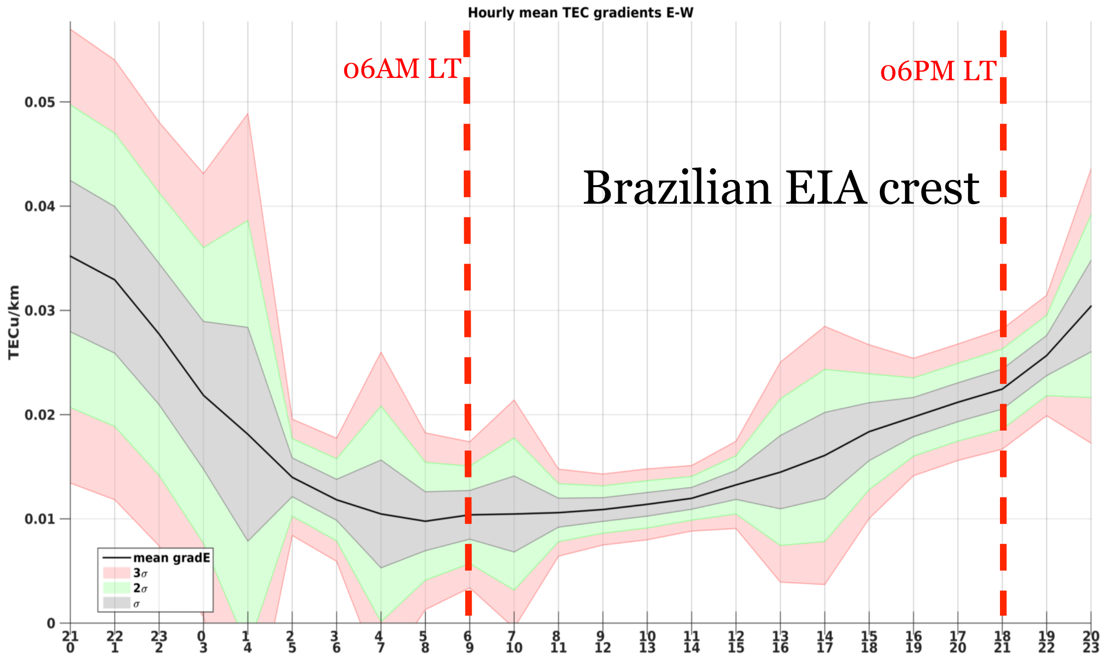
- TEC temporal gradients derived from meridional chains of receivers;
- TEC spatial gradients;
- Scintillation occurrence;
- Detection of TIDs from TEC maps covering the regions of the dip equator and under the EIA southern crest.

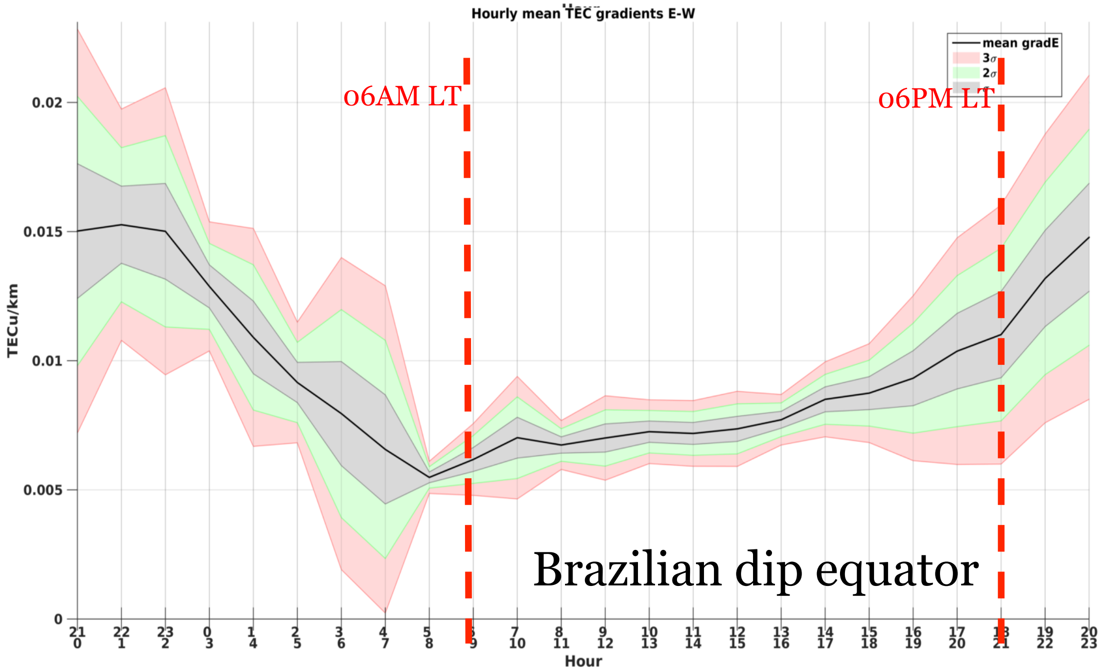
ompanion data analysis: ionosondes

- foF2

ata refers to the 2 quietest days of 2015

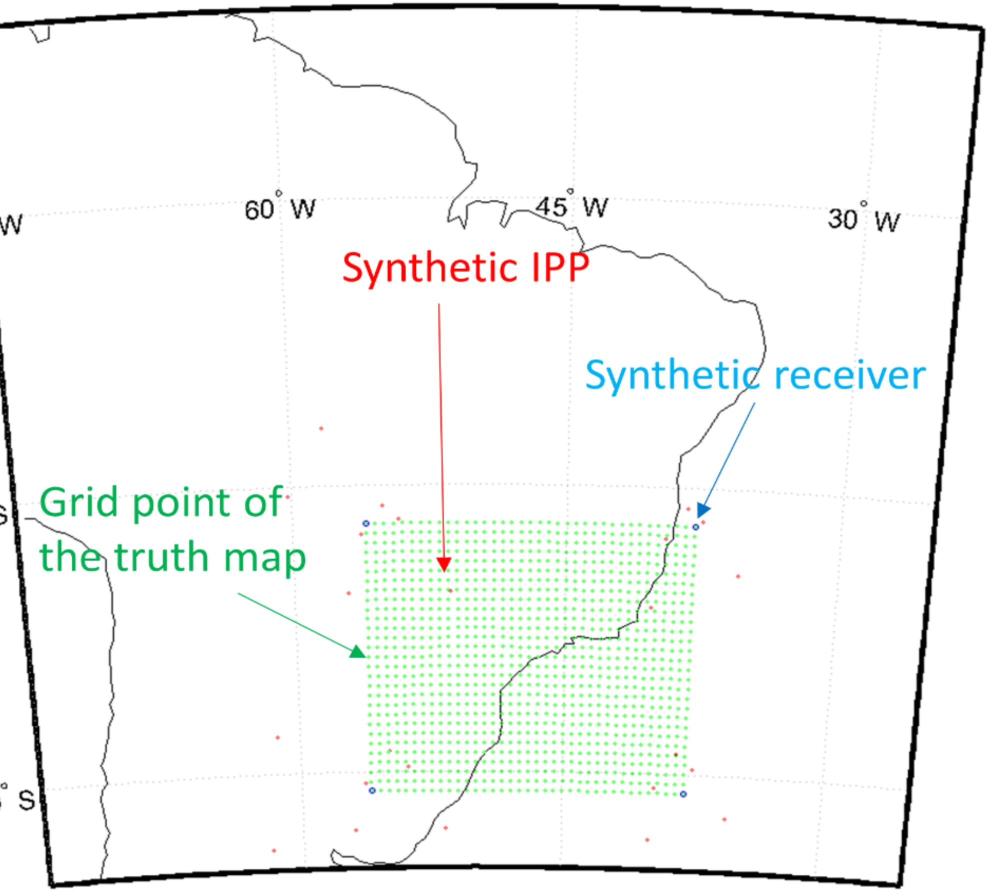
# TEC spatial gradients (E-W): daily variation

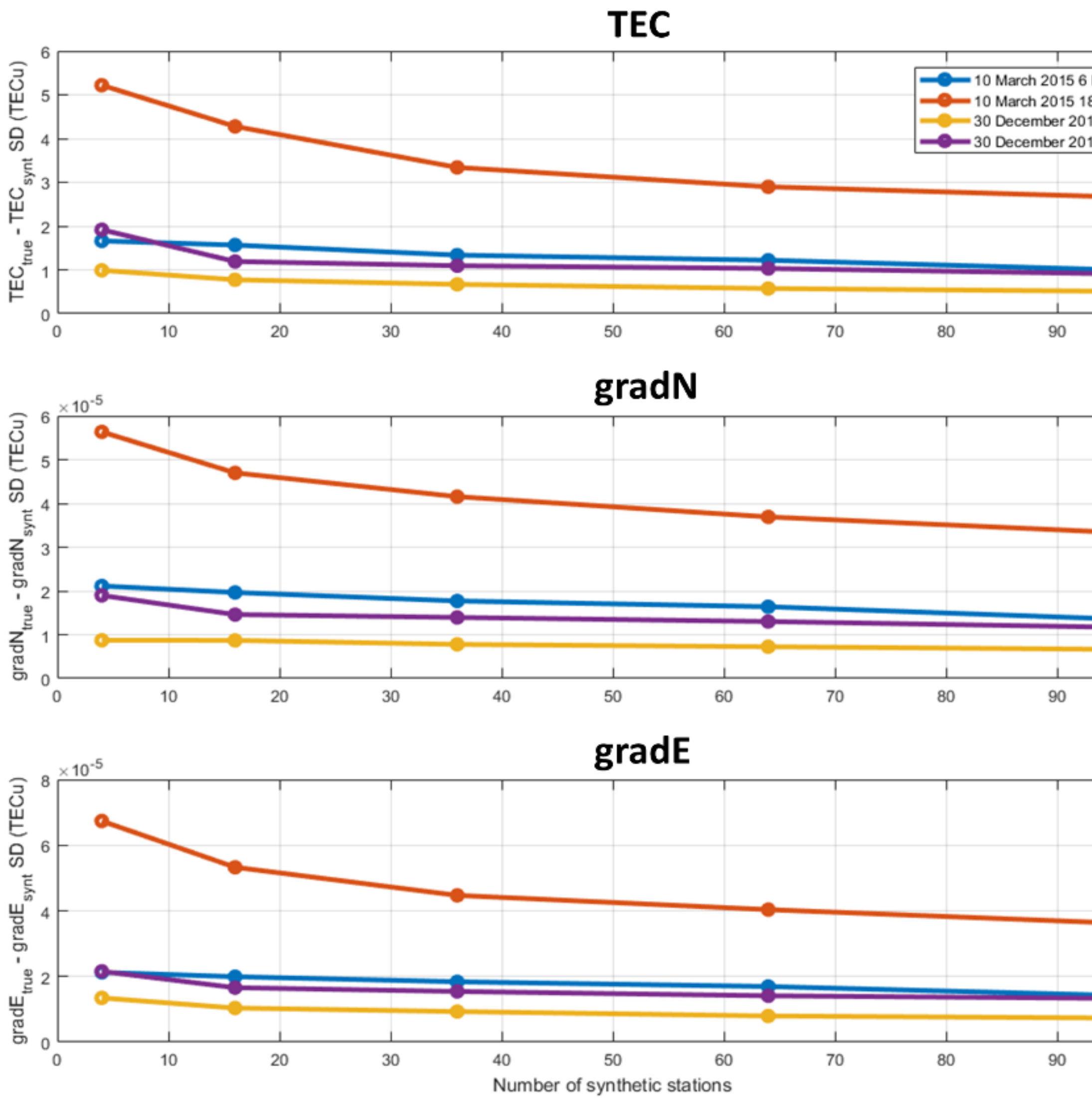


# TEC spatial gradients: method sensitivity

provide a figure of merit, differences between truth
synthetic maps have been evaluated for the
owing days:
March 2015 at 6AM/PM
December 2015 at 6AM/PM



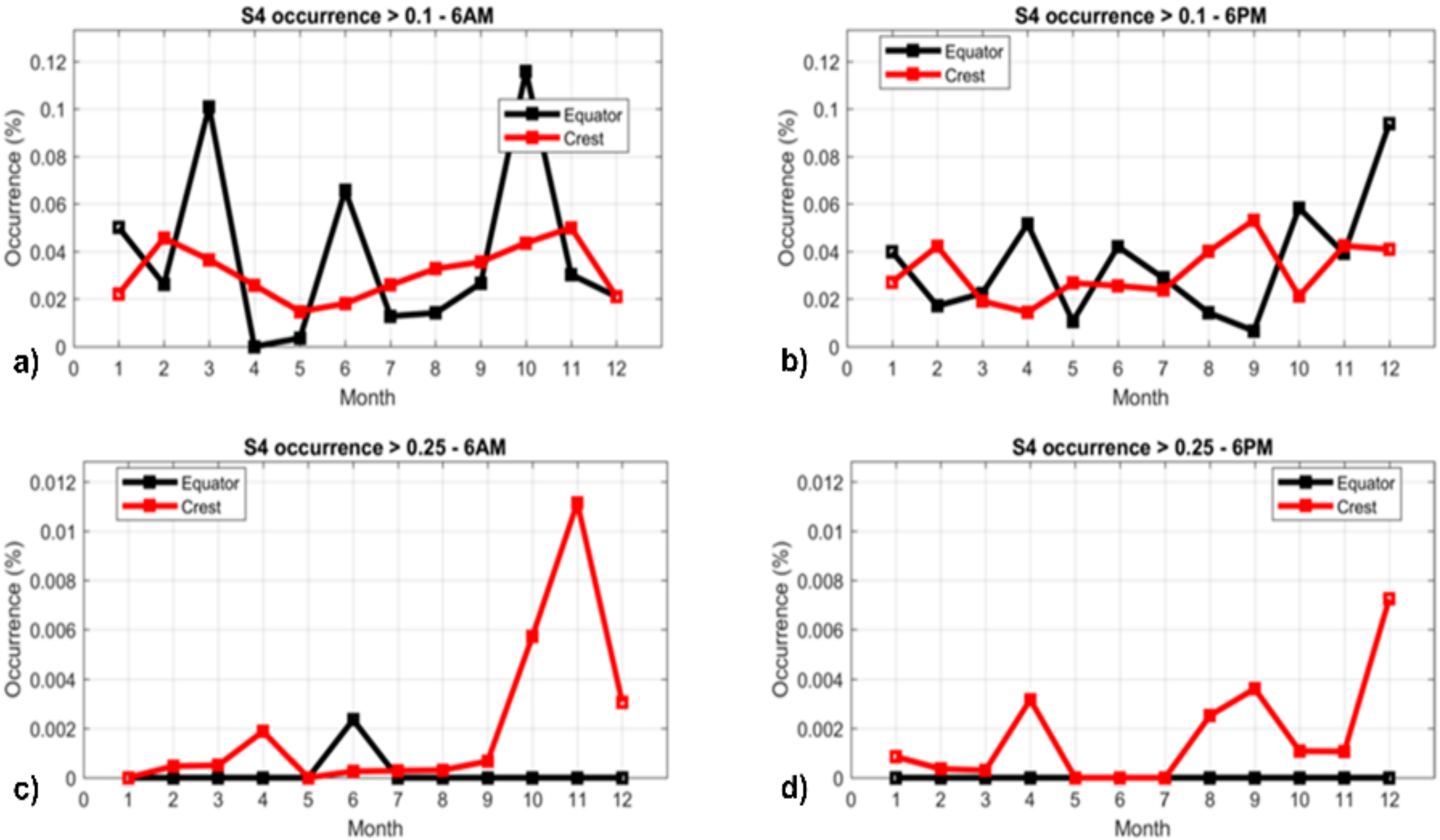




SD saturates when increasing the number of stations, indic
that few tenths of receivers can be sufficient to efficiently
regions like the one here considered.

# Scintillation occurrence (S4>0.1, 0.25): monthly variation

AM LT

06PM LT



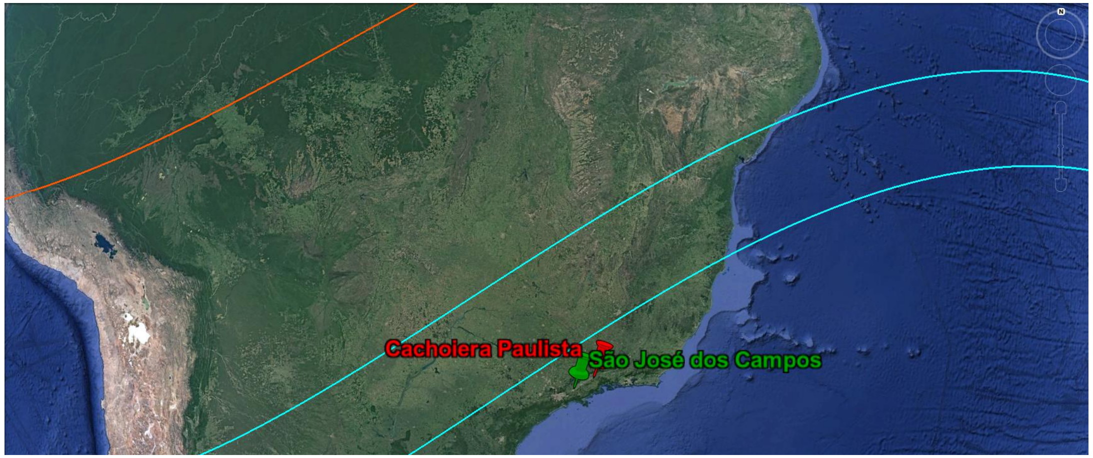

**l crest**

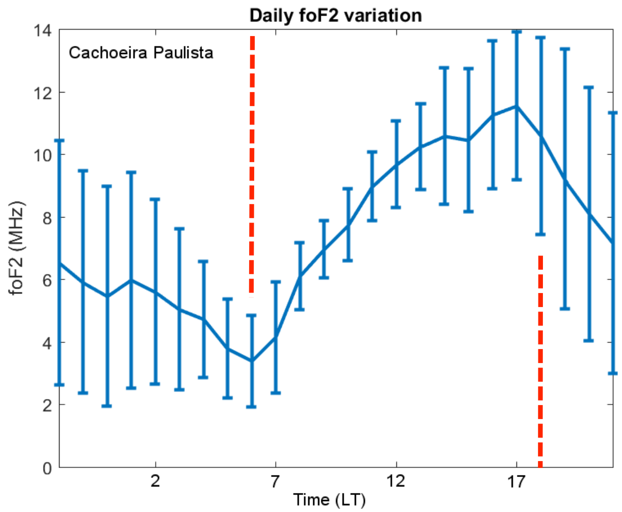
**l dip-equator**

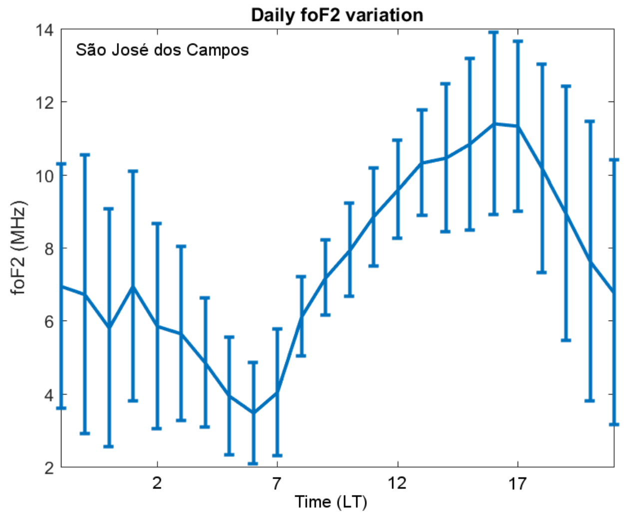
# Table of requirements from SoW

| tity onitor | Temporal scale | Spatial Domain (Lx,Ly) | Spatial resolution (Dx,Dy) | Accu |
|---|---|---|---|---|
| | 30 s | Brazil Crest: (-31°;-17°) lat, (-56;-38) lon<br><br>Brazil Equator: (-12°;-2°) lat, (-65;-47) lon | Brazil Crest: 0.5° lat x 0.5° lon<br><br>Brazil Equator: 1° lat x 1° lon | 1 TEC |
| llation cteristics | 50 Hz data providing 1 minute indices | Brazil Crest: (-31°;-16°) lat, (-57;-40) lon<br><br>Brazil Equator: (-12°;-4°) lat, (-65;-45) lon | Brazil Crest: 1° lat x 1° lon<br><br>Brazil Equator: 1° lat x 1° lon | 0.05 ( |

# Ionosonde data analysis



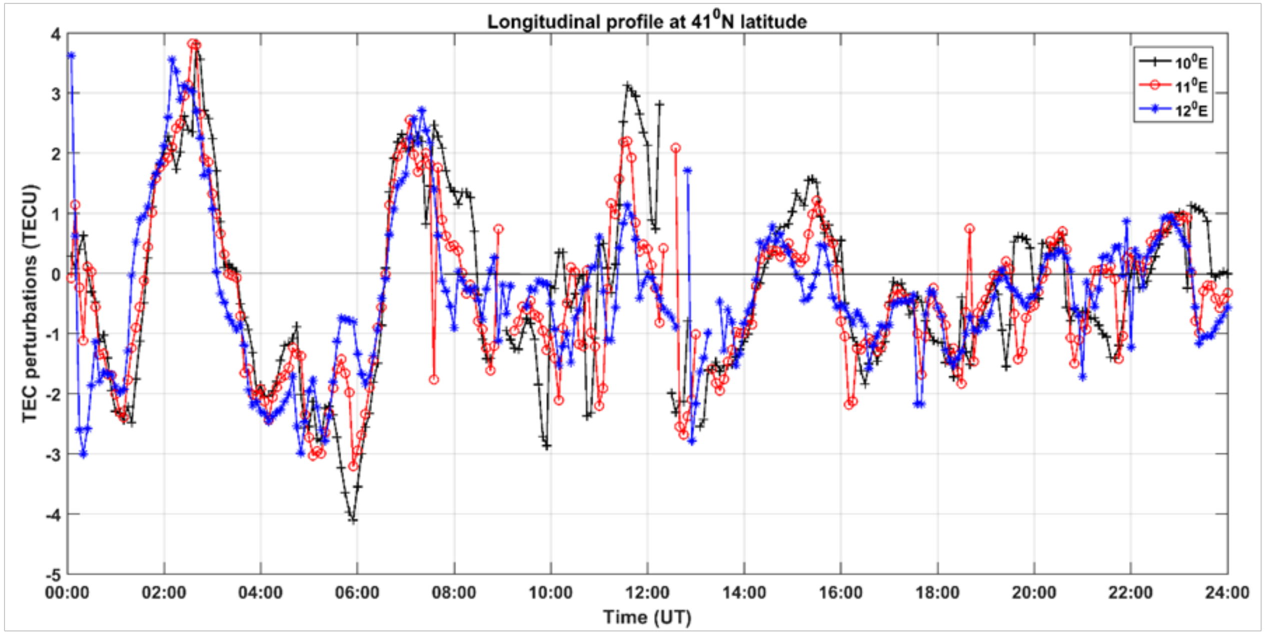




Climatological behaviour of the critical frequency (*foF2*) of the F2 layer

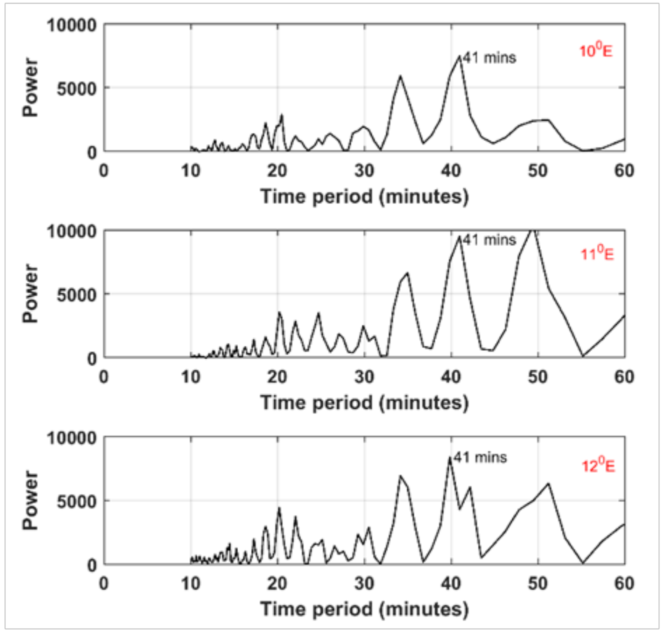
# TID detection

TEC data was detrended by subtracting a 4 hour running average in each latitude-longitude bin

## Validation of the method on a known TID




Temporal longitudinal profile at 41°N on 15 November 2012




FFT spectrum of TEC perturbations at the three latitudes along the latitude 41°N

## Results

Crest

| Day number | Apparent velocity (km/s) | Time period (minutes) | Wavelength (km) |
|---|---|---|---|
| 018 | 0.124 | 14 | 106 |

Equator

| Day number | Apparent velocity (km/s) | Time period (minutes) | Wavelength (km) |
|---|---|---|---|
| 226 | 0.0833 | 25 | 125 |
| 329 | 0.1852 | 45 | 500 |

# Ionospheric impact on Biomass ESA mission

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Paper ready to be submitted to

Journal of Space Weater and Space Climate

# Infrastructures to support Biomass

## razil

**IVAP and INPE can mediate the operation agreements with other stitutions by following the commendations provided by the Brazilian ace Agency (AEB)**

Ionosondes

| strument nagement | Observatory | Geographical Coordinates | Local Institution Facility |
|---|---|---|---|
| INPE | Boa Vista | 2º50' N; 60º42' W | UFRR |
| | São Luis | 2º36' S; 44º13' W | INPE[1] |
| | Fortaleza | 3º52' S; 38º25' W | INPE[2] |
| UNIVAP | Manaus | 3º06' S; 60º01' W | INPA |
| | Araguatins | 5º39' S; 48º07' W | IFTO |

nanent array of ionosondes installed close to the netic dip equator

GNSS

1. RBMC/IBGE + SIRGAS (more than 100 GNSS receivers) are available upon request. The IBGE c not guarantee the maintenance of the existing GN stations during mid-long term due to possible changes on its internal policy of priority research cartography and geodesy.
2. EMBRACE/INPE network consists of 17 GNSS receivers. Actually, four (4) GNSS scintillation monitors are expected to be operational for a lon period and their infrastructure could be consider to support the BIOMASS calibration needs.
3. UNESP, INPE and UNIVAP: CIGALA/CALIBRA network. Currently, 10 GNSS receivers for scintillation monitoring are in operation, 3 of wh (Manaus, São Luis e Fortaleza) are installed close magnetic equator at or near the same facilities of ionosonde stations.

# Infrastructures to support Biomass

## razil

### uatorial experiment campaign in the Amazon region

e deployment of instruments for continuous monitoring in the Amazon region is a hard task.
e conduction of measurement campaigns in the Amazon rain forest during a short period is a possibili
ld be taken into account to overcome the difficulties.
ce logistics in the region are very complicated, support from outsourced companies and even from the Br
itary is a possibility that should be considered during the planning of a scientific campaign by the Amazon.
s experience can be shared by the Physicists from INPE that organized in 2002 the Conjugate Point Equ
periment (COPEX) campaign with support from Brazilian army and air force.
order to support BIOMASS activities, a campaign in the Amazon region with the objective to investiga
ospheric impact under the northern EIA crest can be considered in the near future.
etwork of GNSS and P-band receivers could be deployed in strategic dip equatorial locations and until th
st region.
asurement campaigns conducted in 15-30 days during different seasons can provide a perspective on the d
and medium-term variabilities of the ionosphere at the northern EIA crest region, and its influen
ospheric scintillation activity.

# Infrastructures to support Biomass

## azil

**ncial and man power resources**

stly of the ionosonde instruments and GNSS receivers from the above mentioned stations are operating
tainer shelters.

facilities provided a space inside or in the top of the buildings to install equipment and antennas.

host institutions have not been responsible for the costs of the entire infrastructure for installation, inc
ntenance of the instruments and air conditioner.

local institutions have not charged for renting but some of them charge electricity (average electricity p
0/MWh) to maintain the existing sites.

he contract agreement of scientific collaboration with the local institutions, a researcher or engineer was t
perate the instruments.

collaborator from the local institution is in general involved in the scientific activities.

wever, the maintenance of the instruments due to shutdown (for any reason) is always under the responsib
owner institution (INPE, UNIVAP or UNESP).

means that eventually, a technician/engineer from São Paulo has to move until the observatory to f
ruments.

pending on experience, the annual salary of a technician in Brazil may attain €12.200, whereas for a
ineer a maximum value is of about €37.000.

# emarks

The statistical analysis of the **TEC temporal gradients reveals a highly skewed distribution**, where the extreme cases in its t need to be taken into account.

- **Temporal gradients are generally larger in SEA** than in Brazil (up to 1 TECu/min)
- Over **SEA**, **TEC temporal gradients** are found to be **larger in the East SEA sector** than in the West one.
- Over **Brazil**, **TEC temporal gradients** are found to be **larger over the crests** than over the dip equator.

The statistical analysis of the TEC spatial gradients reveals important **differentiation of the meridional variation with respect the zonal variation.**

- **E-W gradient** is generally **larger than N-S** (less evident over SEA)
- **Over both SEA sectors the equinoxes results into largely variable meridional TEC gradients**, even if in the West S also the winter months show a significant excursion.
- The **largest concentration and variability of meridional TEC gradients** is in the afternoon/evening hours, mainly **in t post-sunset, and around midnight.**
- **Method sensitivity: few tenths of receivers can be sufficient** to efficiently cover regions like the one here considered.

The statistical analysis of GNSS scintillations results in a clear definition of **the role of EIA crests in hosting the ionospher irregularities**, mainly in the local post-sunset hours.

- **Strong scintillation events are not negligible over West SEA**, even with a low probability, at the time of the Biomass passe

The analysis based on ***foF2*** data showed that:

- the climatological behaviour of the ionospheric plasma in the **Brazilian sector is the one expected at low latitudes**.
- the climatological behaviour of the ionospheric plasma in SEA has a **strong dependence on the longitude**.
- **Noontime bite out observed in Brazil and in West SEA, but not in East SEA.**

**Over Brazil LSTIDs were not detected** on any of the analysed days; **MSTIDs** were detected on 3 days, **1 day over the anoma crest and on 2 days over the equatorial region.**

**<u>Paper is ready to be submitted to JSWSC</u>**

**Infrastructures availability for Biomass** operation is discussed

# RIS – Contribution of the external partners

| me | Institution | Role in the study | Contribution to the study |
|---|---|---|---|
| cio Tadeu de s Honorato lla | UNIVAP | External Researcher | • Coordination of the External Research<br>• Survey of the current and foreseen infrastructures useful to support Biom<br>• Assessment of financial and man powe resources necessary to suppor Biomass |
| inia usner de eira | UNIVAP | External Junior Researcher | • Knowledge of TEC and ionosonde data coverage and interaction with the data providers.<br>• Contribution to the TEC calibration analysis.<br>• Contribution to the TEC gradients computation. |
| lia Correia | INPE | External Researcher | • Knowledge of scintillation data covera and interaction with the data providers<br>• Contribution to the interpretation of th scintillation mapping. |