Ionospheric dynamics over South America observed by TEC mapping

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1. OH Temperature measurement at King George Is.
2. GNSS Groundbased receiver network
3. Equatorial ionization Anomaly (EIA)
4. Equatorial Plasma Bubbles (EPBs)
5. Medium scale travelling Ionospheric Disturbances (MSTIDs)
6. Geomagnetic storm event
OH Temperature measurements at King Georg Is.

Year 2001-2005
Fotantar 1:  
2001 – 2003

Fotantar-2: 2004
Tilting filter photometer: FOTANTAR -1

Measurement of atmospheric temperature at 85~90 km altitude

Using OH(8-3) band P branch
Fotantar 1 at Ferras Station (62°S, 58° W): Feb. 2001
Seasonal variation

Nightly-averaged OH temperature

Temperature (K)

Year

2001 2002 2003 2004

OH(8-3) OH(8-3) OH(8-3) OH(6-2)

data

Fotantar -1 Fotantar -2

MSIS-90 model
Planetary waves during July to August 2002, observed in the stratospheric ozone layer.
TOH Comparison, C. Ferraz vs. Davis 2001 and 2002

C. Ferraz, Temperature via OH(8-3) - year 2001
Annual Mean = 216 ± 10 K

C. Ferraz, Temperature via OH(8-3) - year 2002
Annual Mean = 210 ± 13 K

Davis, Temperature via OH(6-2), year 2001
Annual Mean = 203 ± 9

Davis, Temperature via OH(6-2), Year 2002
Annual Mean = 205 ± 10

Temperatura média noturna
FOTANTAR-3
2005-2009
FOTANTAR-3

Espectro-Imageador, FOTANTAR-3

Step motor

External shutter

Field stop

Fresnel lens

Interference filter

Objective lens

L1

L2

22.8°

20 cm

40 cm

λ = λ₀ \left(1 - \frac{L^2}{2\pi θ_θ}\right)

STL-1001E Class 1
(SBIG), 1024 x 1024, 20 μm

Courtesy of Bageston

PROANTAR REDE 1  Monitoramento da temperatura mesosférica
METODOLOGIA (1)

(simetria azimutal) \[ \Rightarrow \int_{0}^{2\pi} \left( \text{sinal} - \text{dark noise} \right) d\phi \Rightarrow J = J(r) \]
Resultados: comparação com o modelo MSISE-90

02 Set. 2005

13 Set. 2005
Groundbased GNSS receiver network in South America and TEC Mapping
GNSS groundbased network over South America

In total, there are ~150 sites

- RBMC (Brazilian)
- IGS (International)
- RAMSAC (Argentine)
- LISN (BU)
TECMAP over South America

Spatial resolution: 50 to 500 km depending on the density of observation points.
Temporal resolution: 10 minutes

Dot: ionosphere pierce point (at 350 km altitude),
Color shade: TECu from 0-30 (blue) to 70-80 (red)
1. Equatorial Ionization Anomaly: EIA

- Large day to day variability
- Difficulty to preview location of EIA
TECMAP: 2018 March 23 – 30, at fixed time 23:00 UT

2018 03 23
Symmetric to Magnetic equator

2018 03 24
EIA only the southern part

2018 03 25

2018 03 26

2018 03 27

2018 03 28

2018 03 29

2018 03 30
No EIA cresta
2. Equatorial Plasma Bubbles

• Development of EPB from the sunset to midnight. (video) (Feb. 15, 2014),

• Day to day variability of activity (Feb. 2014),

• Bubble – No Bubble – Bubble (Jan. 3-5, 2015)
Plasma Bubble development:

Example: 2014 Feb. 15/16, 22:00 → 03:00 UT, development of several bubbles.
Plasma bubbles: Seeding and development

Example: 2014 Feb. 15-16

23:00 UT  00:00 UT  01:00 UT  02:00 UT

Dashed line: solar terminator at 110 km altitude
Periodic bubble structures observed in 2014 February 10 to 17 (02:00 UT fixed)
Day to day variability of EPB occurrence

2015 01 03
23:00 UT

2015 01 04
23:00 UT

2015 01 05
23:00 UT

Bubbles

No Bubbles

Bubbles
MSTID Event

- Case study 2015_03_08 (video)
- dTEC keogram to calculate, MSTID wavelength, period, phase velocity and propagation direction
MSTID: dTEC Map: 2015_03_08

dTEC(t) = TEC(t) - <TEC(t -/+ 30 min.>
Latitudinal (15° – 30°S) variability of dTEC at 45°W

MSTID Charac.

<table>
<thead>
<tr>
<th>When (UT)</th>
<th>Horiz.-WL</th>
<th>Period</th>
<th>Phase</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 – 23 UT</td>
<td>760 km</td>
<td>22 min.</td>
<td>570 m/s</td>
<td>North</td>
</tr>
</tbody>
</table>
**MSTID:** Medium Scale Travelling Ionospheric Disturbance

Characteristics:

1. **Observed time:** Mostly from afternoon to evening time zone,

2. **Horizontal wavelength:** 100 – 1000 km

3. **Period:** 15 – 60 minutes

4. **Phase velocity:** 100 – 300 m/s
Seasonal variations of occurrence

- EPB activity:
- MSTID activity:
- Same day occurrence of MSTID and EPB
EPB and MSTID occurrence in 2014-2015
TECMAP during the Geomagnetic Storm
Large day to day variability with geomagnetic storm
2015 March 17 – 20, 01:00 UT fixed
Storm Event: 2015 03 17 (St. Patrick day storm)
Nighttime LSTID at 23:00 UT

dTEC maps of the Southern (C and D) hemisphere observed during the period of 23:00-23:20 UT on March 17, 2015. The LSTID propagates Northwestward. The black continuous line is the magnetic equator. The arrows indicate the direction of propagation of LSTID.
dTEC maps of the Northern (A and B) hemisphere observed during the period of 23:00-23:20 UT on March 17, 2015. These images shows LSTIDs propagating southwestward. The arrows indicate the direction of propagation of LSTID.
Discussions: Auroral activity at NH and SH

Tsugawa et al. [2006] suggested that the period and the wavelength of LSTIDs should be dependent on a priori condition of the source in the auroral region. Valladares et al. [2009] attributed the difference on auroral currents between the NH and SH polar regions on March 17, 2015.

The horizontal geomagnetic field (H) component (Figure A) along the northern (Husafell) and southern (Syowa) auroral regions on March 17, 2015.

The difference between Husafell and Syowa

Tsugawa et al. [2006] suggested that the period and the wavelength of LSTIDs should be dependent on a priori condition of the source in the auroral region. Valladares et al. [2009] attributed the difference on auroral currents between the NH and SH polar regions.
Discussion: Conjugate Points

Temporal variations of dTEC at conjugate points in NH and SH.
Three regions in SH (30.0 ° S, 27.5 ° S and 22.5 ° S) and NH (16.75 ° N, 14.90 ° N and 30.11 ° N) are selected.
Summary

- Usefullness of TECMAP and dTEC map to monitor the ionospheric weather:
- Day to day variability of EIA,
- Day to day variability of EPB,
- Occurrence of MSTID in the ionosphere,
- Response of the ionosphere against geomagnetis Strom.
Abstract:

- Equatorial Plasma Bubbles (EPBs) and Medium Scale Travelling Ionospheric Disturbances (MSTIDs) have been monitored by Total Electron Content Map (TECMAP) observed by ground based GNSS (Global Navigation satellite System) receiver networks in South America. We observed that daytime MSTIDs are frequent during the period from March to September while EPBs are frequent during the period of September to March, just in an opposite phase in each other. Investigating the same day occurrence of MSTID and EPBs, however, we found that there is a close relation between the inter-bubble distance and horizontal wavelength of MSTID, suggesting contribution of MSTID in generating the EPBs. TECMAPs during intense geomagnetic storms revealed latitudinal propagation modes of Large Scale Travelling Ionospheric Disturbance (LSTID) and non-symmetric propagation feature between the Northern and southern hemispheres.
Comparação do Instrumento SABER com o FotAntar-3

• Dados Obtidos para os meses de Julho, Agosto e Setembro de 2005;
• Total de dados bons do Fotantar-3 para comparação: 52 noites;

FOTANTAR-3 X TIMED/SABER

- TIMED/SABER: Perfil médio lat/long [-75;-45] e Alt.(km) [85-90]
- FotAntar 3: Média noturna