

# Ionospheric response to geomagnetic storm during low solar activity

Cláudio Machado Paulo<sup>1</sup>, Diogo Akia Wakabayashi<sup>2</sup>, Paulo Roberto Fagundes<sup>2</sup>, Nelson Jorge Schuch<sup>1</sup>, Kazuo Makita<sup>3</sup>, Yogeshwar Sahai<sup>2</sup>, Alessandro de Abreu<sup>2</sup>, Lilian Piecha Moor<sup>2</sup>, Rodolfo de Jesus<sup>2</sup>, Tardelli Ronan Coelho Stekel<sup>1</sup>, Gelson Lauro DalForno<sup>1</sup>.

1 - Southern Regional Space Research Center - CRS/CCR/INPE - MCT, in collaboration with the Santa Maria Space Science Laboratory - LACESM/CT - UFSM, Santa Maria, RS, Brazil.  
 2 - University of Vale do Paraíba – UNIVAP, São José dos Campos, SP, Brazil.  
 3 – University of Takushoku, Tokyo, Japan.  
[cmpaulo@lacsms.ufsm.br](mailto:cmpaulo@lacsms.ufsm.br)

## ABSTRACT

The main objective of this investigation is to study the ionospheric F-region response due to moderated geomagnetic storm which took place during 22-23 July, 2009. During the period studied the geomagnetic Dst index reached minimum value of -79 nT at 1000 UT on 22 July and Kp index reached 6-. This investigation is carried out using a chain of 15 GPS stations and another chain of 3 digital ionosondes stations. Both chains are located in the South American sector and the instruments cover from low-latitudes to equatorial region. The total electron content (TEC) recorded during the disturbed period presented both positive and negative storm phases. Also, the ionospheric sounding data showed presence of traveling ionospheric disturbances (TIDs) during the recovery phase. The present geomagnetic storm is very interesting because it took place during atypical low solar activity (LSA) period, this low solar cycle was one of longest and presented very high number spotless solar days.

## Observations and Instrumentation

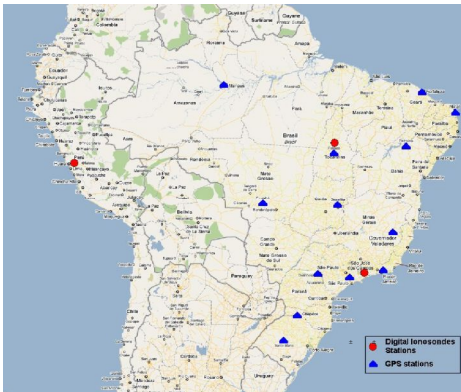


Fig. 01: A map showing the locations of the GPS and digital ionosonde stations used in the present study.

Table 01: Details of the Global Positioning System (GPS) sites used in the present study

Name GPS Stations	Geomagnetic Lat.
São Gabriel da Cachoeira	0°
Fortaleza	3° S
Manaus	3° S
Natal	5° S
Petrolina	9° S
Palmas	10° S
Brasília	15° S
Cuiabá	15° S
Gov. Valadares	18° S
Ourinhos	22° S
Rio de Janeiro	22° S
São Paulo	23° S
Chapecó	27° S
Santa Maria	29° S

Table 02: Details of the digital ionosonde sites used in the present study

Name Digital Ionosondes Stations	Code	Geomagnetic Lat.
Jicamarca, Peru	JIC	0.05° S
Palmas, Brazil	PAL	5.7° S
São José dos Campos, Brazil	SJC	17° S

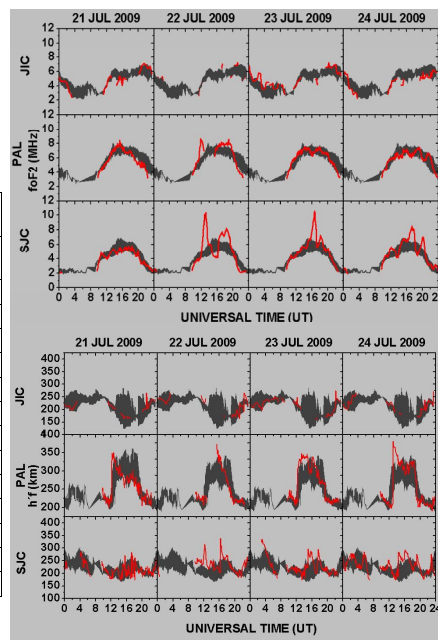


Figure 5 – Variations of the ionospheric parameter foF2 and h'F obtained at Jicamarca (JIC), Palmas (PAL) and São José dos Campos (SJC), during the period July 21-24, 2009 (red lines). The black bands are +/- 1 standard deviation of the average quiet day values.

## Period studied

July 21-24, 2009

## Results

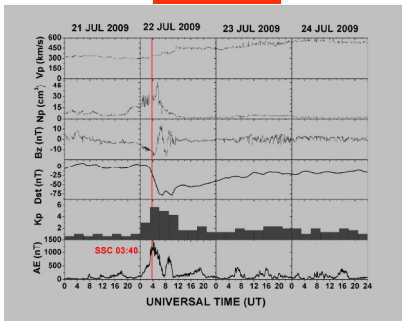


Fig. 02: Variations of the solar wind proton bulk velocity  $V_p$ , solar wind ion density  $N_p$ ,  $B_z$  component of IMF in the GSM coordinates, and geomagnetic indices Dst, Kp, and AE for the period July 21-24, 2009. The red vertical line indicates the sudden storm commencement (SSC)

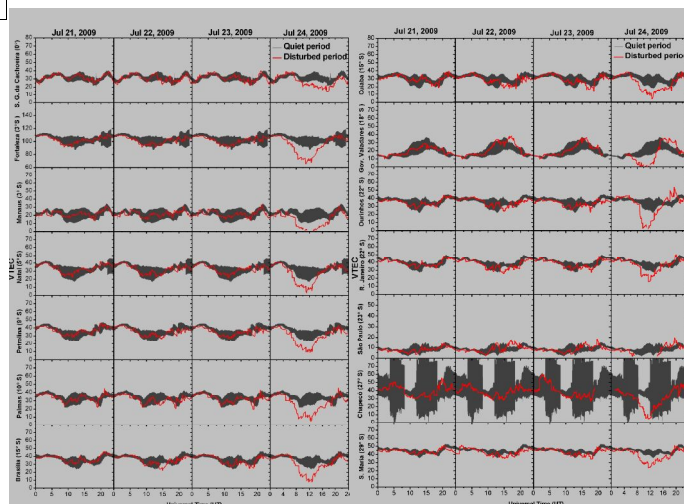


Figure 4 – Variations of the vertical total electron content (VTEC) from GPS observations from different satellites at 14 receiving stations during the period July 21-24, 2009 (red lines). The black bands are +/- 1 standard deviation of the average quiet day (four quiet days) values.

## Conclusions

In this paper we have presented and analyzed ionospheric data from 14 GPS receiver stations located from 0°S to S. Maria 29°S, as well as ionospheric sounding data obtained at JIC (12.0°S), PAL(10.2°S) and SJC (23.2°S) low-equatorial regions in the South American sector, during the moderated geomagnetic storm of July 22-24, 2009. Some of the salient features related to these observations and analysis are summarized below:

- 1) During the recovery phase (July 24, 2009), the observed VTEC show a strong and long-lasting negative ionospheric phase from equatorial to low latitude.
- 2) The foF2 and h'F variations suggested that a TID was generated at high latitudes, during the main phase, and reached low latitudes, during the recovery phase (July 22-23, 2009).