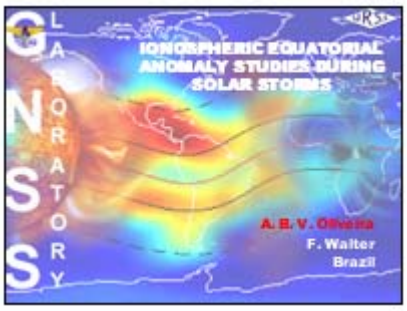
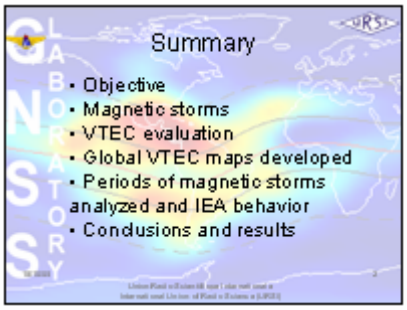


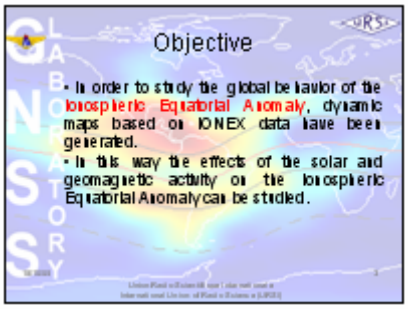
Good afternoon everyone.
My name is A.B.V. Oliveira. My presentation is about the IONOSPHERIC EQUATORIAL ANOMALY STUDIES DURING SOLAR STORMS.



↵ Firstly, I am going to tell you the obj**e**ctive of this work.

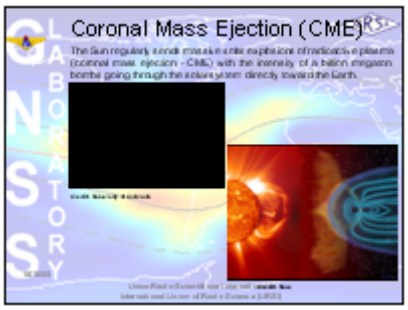
- Next, I'll tell a little about the Magnetic storms and the VTEC evaluation by trigonometric relation **,** then I show some examples of the VTEC Maps developed.

- After will be shown the periods of magnetic storms analyzed and the effects on the IEA behavior.
- And finally, some conclusions and results about the work will be presented.



↵ Our main objective was to study the global behavior of the Ionospheric Equatorial Anomaly during periods with solar storms.

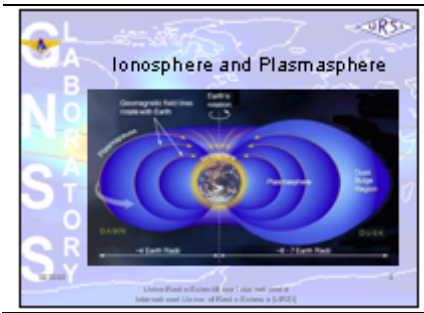
- In this way, dynamic maps based on IONEX data have been generated, allowing to visualize the effects of the solar and geomagnetic activity in a global way.



↵ The Sun regularly sends massive solar explosions of radioactive plasma, that are called coronal mass ejection (CME)

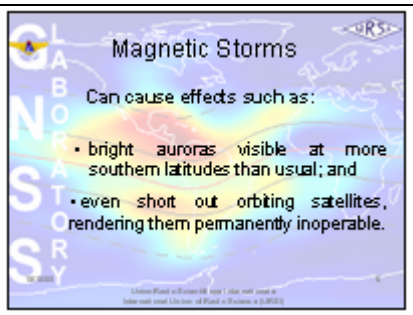
- The CME can produce an energy with intensity of a billion megaton bombs going through the solar system directly toward the Earth.

- In this video we can see the moment when a CME was emitted in direction of the earth causing the formation of a bright aurora.



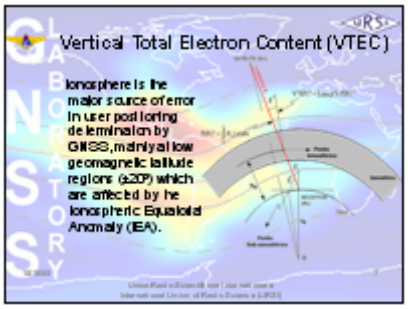
↵ The solar storm produces a magnetic storm over the layers of the Earth.

- This magnetic storm affects the electron concentration over the Plasmasphere and mainly over the Ionosphere, resulting an increase in the electron content.



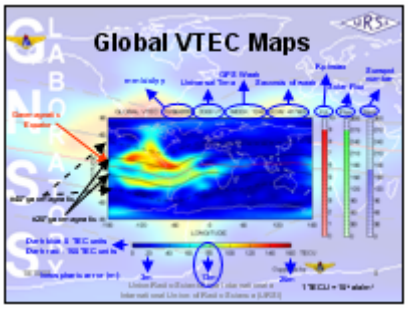
↵ Magnetic Storms can cause effects like:

- bright auroras visible at more southern latitudes than usual;
- And even short out orbiting satellites, rendering them permanently inoperable.



↵ The Ionosphere is the major source of error in user positioning determination by GNSS,

- The Ionosphere effects can be studied by the electron content along the path of the satellite and receiver, that is called Total Electron Content, in the case of GNSS.
- Making a relation between the Total Electron Content and the qsi angle, the Vertical Total Electron Content is obtained.
- Studying the global behavior of the VTEC, it's possible to understand how the Ionospheric Equatorial Anomaly is affected by the magnetic storms.



↵ In this way, tools to generate Global Vertical Total Electron Content maps were developed. The maps were generated in a particular format, that shows

↵ the reference date

↵ hour in Universal Time

↵ week number

↵ and the seconds of week. The maps also has been related with the

↵ Kp index,

↵ the Solar Flux

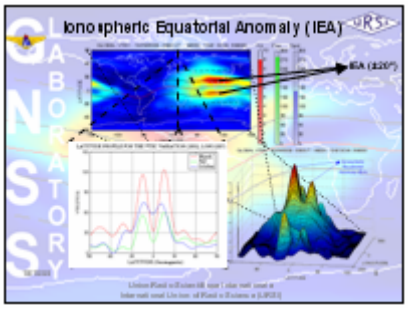
↵ and the Sun Spot Number.

↵ The map scale varies from zero, dark blue, to one hundred sixty, dark red.
- as an example, eighty TEC units correspond to an error of about thirteen meters, in the pseudorange measurements.

↵ It was introduced in the maps the Geomagnetic Equator,

↵ plus and minus 20 degrees geomagnetic latitudes and

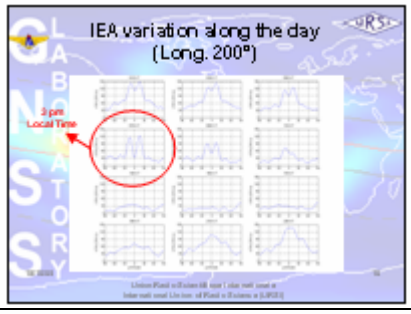
↵ plus and minus 40 degrees geomagnetic latitudes.



↵ The Ionospheric Equatorial Anomaly is characterized by the concentration of electrons over plus and minus 20 degrees geomagnetic latitude.

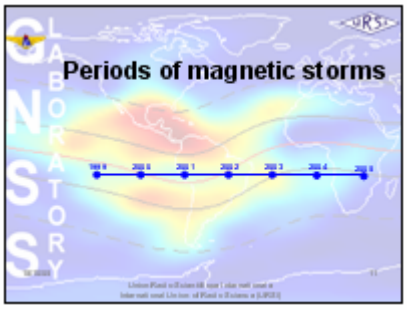
↵ Here we can see a three D visualization showing the Ionospheric Equatorial Anomaly formation across the geomagnetic equator.

↵ In this figure the Ionospheric Equatorial Anomaly in three different months of the year can be visualized. There are higher concentrations between March and April and September and October and a lower concentration during June and July.

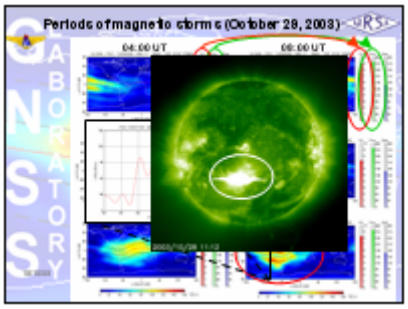


↵ Here we can see the Ionospheric Equatorial Anomaly behavior along the day.

↵ We also can notice that the major concentration over plus and minus 20 degrees geomagnetic latitude is about 3 p.m. of Local time.



↵ The global maps were analyzed since 1999 until now and there were identified the main periods geomagnetically perturbed, that is, with higher Kp index.



↵ One of the most important periods of magnetic storms was the solar storm of October 2003.
- Here, we can see the maps for October 29 when the CME reached the Earth,

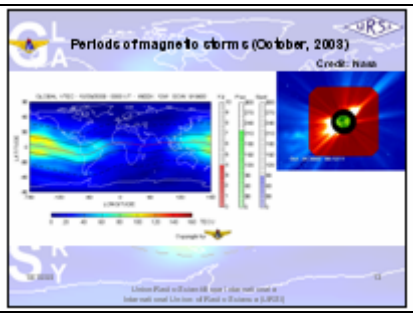
↵ Producing high levels of Kp index

↵ And high levels of Solar Flux

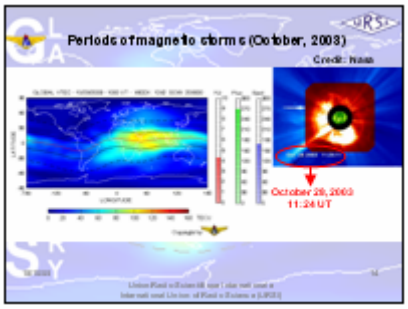
↵ In this picture it can be also seen that high values of VTEC reached the USA

↵ Producing a specific Ionospheric Equatorial Anomaly in October 29 at 20 hours Universal Time.

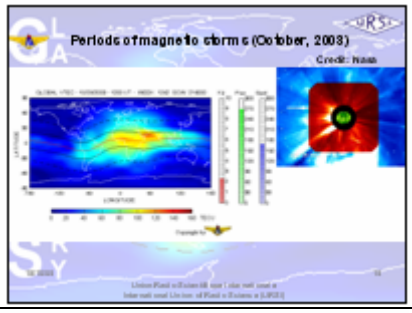
↵ This image of Nasa shows the moment of the solar storm that occurred on October 28 around 11 hours Universal Time, that is, the effects of the solar storm reached the Earth about 28 hours after this moment.



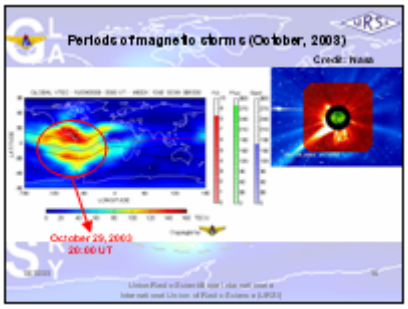
↵ The VTEC maps were related with images from Nasa when the Solar Storm ocurred.



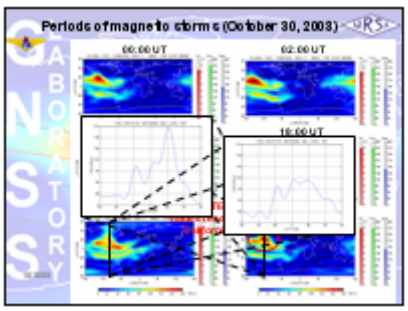
- We can see here that the solar storm occurred at October 28 around 11 UT.



↵ But it was possible to visualize the VTEC effects 28 hours after that moment.



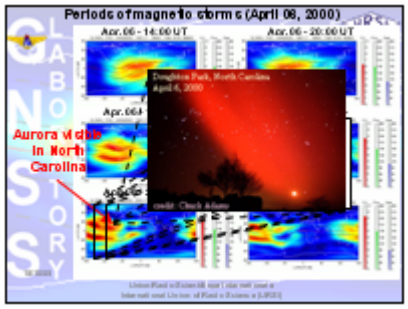
- As we can see in this image.



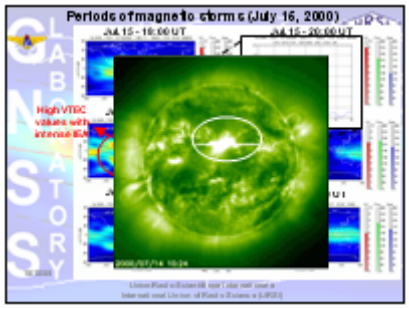
↵ During October 30 was visualized high VTEC values over California,

↵ Producing a specific Ionospheric Equatorial Anomaly concentrated also over plus 40 degrees geomagnetic latitude.

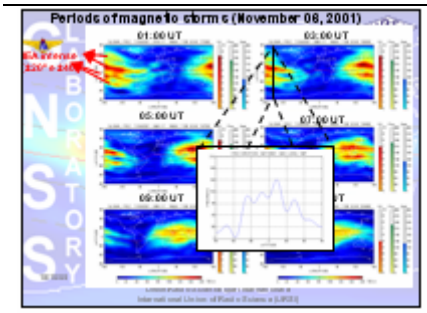
↵ Two hours before there had been visualized high electron concentration between zero and 90 degrees geomagnetic latitude.



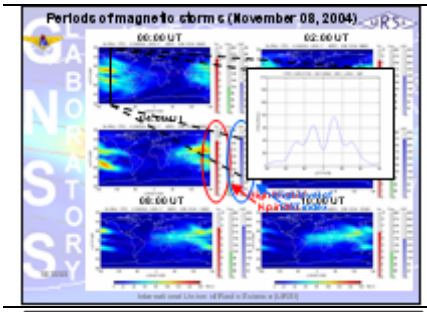
- Another period analyzed was April 6, 2000 presenting high VTEC values.
- In this figure we can see the specific Ionospheric Equatorial anomaly that reached the United States of America
- In this day it was possible to visualize a bright aurora in North Carolina.



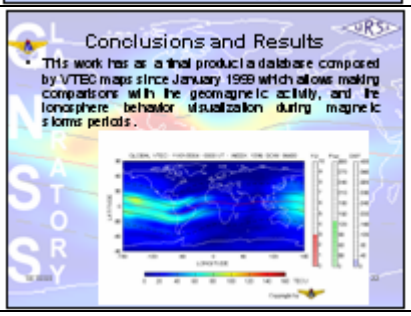
- In July 15 of the year 2000 it could be visualized the intense formation of the Ionospheric Equatorial Anomaly in a period of low solar activity.
- So we see that occurred an intense electron concentration over plus and minus 30 degrees geomagnetic latitudes.
- And in this image of Nasa the solar storm occurred 24 hours before our visualization.



- In the following figure we can see November 6 of the year 2001 when an intense concentration of electrons over plus and minus 40 degrees geomagnetic latitudes also occurred.
- Producing an unexpected Equatorial Anomaly.

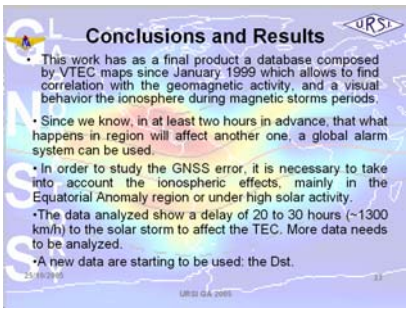


- In November 08, 2004 the global maps were correlated with the DST (Disturbance Storm Time) index.
- And in this day was also visualized the concentration in plus and minus 40 degrees geomagnetic latitudes.



Conclusions and Results

- This work has as the final product the database composed by VTEC maps since January 1999 which allows making comparisons with the geomagnetic activity, and observing the ionosphere behavior visualization during magnetic storms periods.

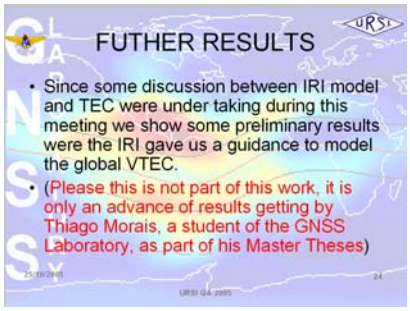


↵ Since we know, in at least two hours in advance, that what happens in region will affect another one, a global alarm system can be used.

In order to study the GNSS error, it is necessary to take into account the ionospheric effects, mainly in the Equatorial Anomaly region or under high solar activity.

The data analyzed show a delay of 20 to 30 hours (~1300 km/h) to the solar storm to affect the TEC behavior. More data needs to be analyzed.

A new data are starting to be used: the Dst.



↵ Since some discussion between IRI model and TEC were under taking during this meeting we show some preliminary results were the IRI gave us a guidance to model the global VTEC.

- (Please this is not part of this work, it is only an advance of results getting by Thiago Morais, a student of the GNSS Laboratory, as part of his Master Theses)

↵ I'd like to thanks FINEP and the organizers of this event for sponsoring my participation in the URSI GA at New Delhi as Young Scientist.