THE EFFECTS OF MAGNETIC STORM PHASES ON F-LAYER IRREGULARITIES FROM AURORAL TO EQUATORIAL LATITUDES

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LONG-TERM GOAL

The long term goal of the grant is to understand the key forcing functions for the development of irregularities at high and equatorial latitudes. Deep fades occur on the 250 MHz transmissions from FLEETSATCOM and AFSATCOM at equatorial, auroral, and polar latitudes. There is also phase and amplitude scintillation on the 1.2 and 1.6 GHz higher frequencies of the Global Positioning System's set of 24 satellites. With a knowledge of the forcing functions we have a chance to forecast and predict when these irregularities interfere with communication and navigation systems. We are particularly interested in assessing the effect of high latitude perturbations on producing effects on the equatorial region.

SCIENTIFIC OBJECTIVES

During a magnetic storm, the electric field increases at auroral latitudes. Slowly a shield is built up at high latitudes. At times the shield has an effect in limiting magnetic storm effects at lower latitudes. We would like to contrast storms which affect equatorial irregularities and those that fail to affect these regions.

APPROACH

Our approach includes using GPS data collected at a number of stations at equatorial and high latitudes. We correlate experimental multipath multistation data from this group of stations. The studies find Total Electron content (TEC) and rate of change of TEC (phase scintillation). For both high and equatorial latitudes, we are using data from the International GPS Service for Geodynamics (IGS). Thirty second values of phase differences between the 1.2 GHz and the 1.6 GHz signals of each GPS satellite were used. With the data set consisting of 30 second samples, thus limiting spectral characteristics, we have chosen to call the component of phase scintillation, phase fluctuations.

Measurements are made by BU personnel of optical recordings of the 6300 A emission of oxygen. We have compared these with radio measurements of many types. At high latitudes we

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study auroral expansion and contraction. At equatorial latitudes we study the depletion of 6300 A airglow by turbulent plumes. With radio and optical observations, we would like to find the triggering mechanism for irregularity development. These could range from lower atmosphere conditions to substorm activity at high latitudes. The processes involve neutral winds in the ionosphere, North South and East West horizontal gradients of electron density, vertical and horizontal velocity of F layer plasma, and shears in electron density.

WORK COMPLETED

Consider the following completed works:

1. *Auroral Irregularity Development*:
   We have shown that the irregularity oval while matching the auroral oval in much of its behavior expands as a function of storm dynamics. When magnetic time dominates there are therefore effects at some longitudes and not at others. This was the case with the January 9-10, 1997 magnetic storm. This storm modified irregularity development near magnetic midnight but did not dominate irregularity development at all longitudes. We found however that some virulent magnetic storms (such as that of May 14, 1997) dominate the development of irregularities at all longitudes and produce strong scintillations at all longitudes even during local day at sites.

   With GPS data, the auroral oval where the irregularities develop can be determined at various levels of magnetic index; thus leading to a possible means of forecasting the development of high latitude irregularities as a function of latitude and longitude; and

2. *Equatorial Region*:
   For the equatorial region we have recently published a means of determining from a single station the altitude of irregularities. The determination of the altitude of irregularities means that one can forecast whether depletion regions which produce scintillations will reach the anomaly latitudes where 20 dB fades at GPS frequencies have been found to occur in high solar flux years.

   The connection between magnetic storm activity as shown by high latitude irregularity development and equatorial irregularity development was shown for the first time by simultaneous measurements at high and equatorial longitudes; this took place during the October 1996 ABC Campaign with BU teaming with other ONR sponsored groups. Figure 1 shows intense phase fluctuations for three stations during the month of October 1996. At Santiago and at Bogota, both in the anomaly region of the equator, the magnetic storm of October 22-23, 1996 produced intense fluctuations. For most of the month there were fluctuations mainly near the magnetic equator.

RESULTS

Present research has yielded the following results:

1. *Equatorial Latitudes*:

   a) The altitude of irregularity development can be shown by observing GPS data from a single station. From this altitude one can forecast whether there will be effects in the more disturbing region of the anomaly.

b) There are specific days that showed activity of thin layers of irregularities or of plumes moderate in altitude (400-600 km) over all of South America; these will not produce disturbing scintillations.

2. *High Latitudes*:

a) At high latitudes, we can track a sub-storm's effect on irregularity development both in time and in position. We have established intensity factors. This will allow us to study the unfolding of events during magnetic storms. Through the study of several magnetic storms, the long term feeding of turbulence into the auroral oval has been established as the source of irregularities associated with the auroral oval.

IMPACT/APPLICATION

With the October 1996 campaign, observations have now supplied a fundamental data base that can be used to test and constrain models. Although a comprehensive theory exists for the development of plumes, it is believed that a data base validating those hypotheses does not exist. It is necessary to quantitatively show observational parameters necessary and sufficient to produce plumes as well as levels of these parameters which fail to satisfy these conditions.

TRANSITIONS

We expect to work with auroral data and equatorial data to distinguish storms which have effects at the equator and those that do not. We expect to develop additional data in this period of increasing solar flux to determine the changes that increasing solar flux and electron density do to the development of irregularities.

RELATED PROJECTS

Other programs are being pursued by NSF and by DoD. The emphasis of the NSF program is to study the physics of equatorial irregularities. Our emphasis is to determine the necessary and sufficient conditions for the development of irregularities and the impact of the irregularities on trans-ionospheric systems from 250 MHz to 1.6 GHz.

For intensive studies, which used a host of measuring techniques, we have interacted with the NSF MISETA studies. Radar backscatter data are vital to determine the existence of the plumes-at least those developing along the longitude of the radar which is located at Jicamarca, Peru. Now however with our own data base (the campaign of October 1996), we can move further in relating optical, amplitude scintillation, phase fluctuation and radar backscatter data.

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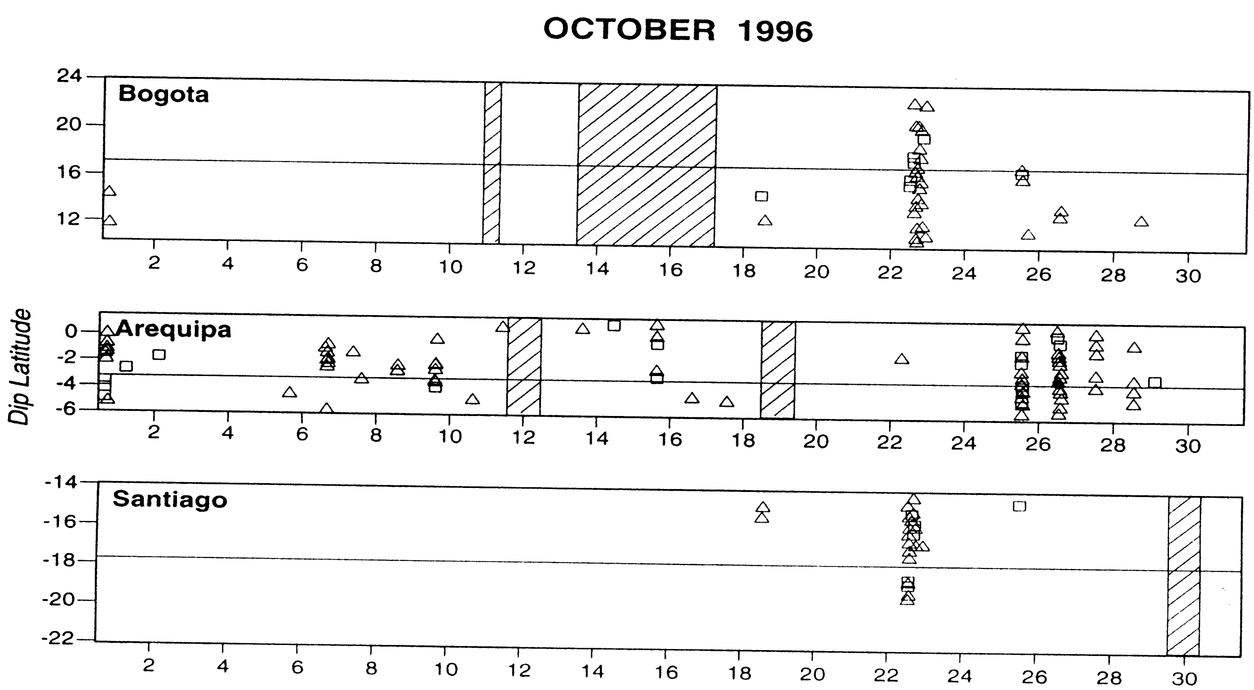

Figure 1. Total Electron Content for Each Day of October 1996.

The campaign month, using data from GPS analysis. The very high TEC night of October 22-23, during a magnetic storm, resulted in strong phase scintillations at Santiago, Chile which is 18 degrees from the magnetic equator.