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Studies in conjunction with J. Clynch of the Naval Post Graduate School showed that very severe magnetic storms have affected GPS reception at auroral latitudes. Analysis of auroral data indicates that some receivers ride through high amplitude scintillation. Receiver characteristics are discussed which keep track so that short term fades do not affect lock immediately.

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QUARTERLY REPORT

for

1 January, 1996- 31 March 1996

GRANT No.: N00014-89-J-1754

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

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A. HIGH LATITUDE PHASE FLUCTUATION AND SCINTILLATION STUDIES

In this quarter, this grant's studies concentrated on the high latitudes while a second grant (the PRIMER grant for the Northeast Consortium) took up equatorial studies.

In order to understand the present series of studies for ONR, we repeat the previously printed background of our use of GPS data.

F layer irregularity studies stem from the scientific community's interest in the physics of plasma instabilities and from the technical interest in the effects of the ionosphere on radio signals. A relatively new data source has been available for these studies, the observations of the International GPS Service for Geodynamics (IGS). To explore this resource a program of studies of phase fluctuations and total electron content (TEC) has been developed at the Center for Space Physics of Boston University.

Phase fluctuations in the present study of Boston University are obtained by examining Total Electron Content variations. Thirty second values of phase differences between the 1.2 GHz and the 1.6 GHz signals of each GPS satellite were recorded. The rate of change of the 30 second values is the source of the phase fluctuation study. With the data set consisting of 30 second samples, thus limiting spectral characteristics, we have chosen to call our data "phase fluctuations". The use of these relatively long samples means that we are studying irregularity structures of the order of several kilometers. It should be noted that amplitude scintillations result from scattering from irregularities of the order of several hundred meters to a kilometer. Jicamarca radar backscatter returns result from probing 3 meter irregularities. From the cascading properties of the development of irregularities, it is expected that the general morphology of the phase fluctuations will follow that of amplitude scintillation data.

One minute dTEC/dt values were obtained from the GPS 30 second TEC data. The analysis then followed several paths. Very large scale changes of irregularities are eliminated. In addition TEC values were computed only where the elevation of the satellite is greater than 5 degrees. This was done in order to avoid problems of tropospheric fluctuations on the signal as well as to minimize the effects of physical obstacles in the propagation paths.

B. DATA SETS

At high latitudes data sets were made for the following stations of the IGS.

Antarctica: McMurdo Sound

In Europe: Ny Alesund, Tromso, Kiruna, Onsala

In North America: Yellowknife, Fairbanks, Algonquin, St. John's

C. RESEARCH PAPER

In this quarter studies were made in conjunction with J. Clynch of the Naval Post Graduate School. A paper was prepared by Clynch and J. Aarons to be presented at the IES Symposium

"High Latitude GPS Observations and Receiver Constraints".

We have summarized that paper in this report.

Observations were made of GPS signals from McMurdo Sound at a Corrected Geographic Latitude of 80 degrees and at the South Pole at a CGL of 74 degrees. In addition routine observations of the International GPS Service for Geodynamics (IGS) taken in Ny Alesund, McMurdo Sound, and Tromso were analyzed. These observations allowed a preliminary evaluation of ionospheric problems for GPS receivers in the polar and auroral latitude regions. In 5 months of data taken in Antarctica, only one period was disturbed to the extent that navigation capability was lost. This was for 20 minutes during the magnetic storm of May 10, 1992 which at maximum reached a Kp of 9-. The phase fluctuations contained in the data of routinely collected IGS observations from McMurdo Sound and Ny Alesund were analyzed for several other storms during years of low solar flux. It was found that even during magnetic storm conditions with large phase fluctuations, the receivers held lock. This indicates a robust nature of the receivers used in these studies. They maintained lock once the signals were acquired. The flywheel effect involved in receiver tracking loops minimized fading problems produced by the high latitude ionospheric irregularities.

Bishop et al., (1994), observing at the polar site of Thule found amplitude scintillation activity. The data were taken during a series of days in winter and in summer in a year of high solar flux. Scintillation levels at 1.2 GHz reached S4 values predominantly of the level of 0.4 in October 1989.

D. PHASE FLUCTUATIONS AT HIGH LATITUDES WITH IGS DATA

Processing data from the International GPS Service, the Center for Space Physics at Boston University is currently studying magnetic storm effects during solar minimum years. Magnetic storm data were analyzed for McMurdo Sound (80 deg CGL), Ny Alesund (76 deg CGL), Yellowknife (70 deg CGL) and Tromso (66 deg CGL). All these sites except McMurdo have Turborogue receivers. McMurdo had a Rogue receiver. The data analysis utilizes 30 second Total Electron Content (TEC) sampling to determine the rate of change of phase for the propagation paths of satellites in view. The 30 second TEC values are determined using phase differences between the GPS 1.2 and 1.6 GHz signals.

During several magnetic storms in 1994 and 1995, there was no loss of lock that could be attributed to high level phase fluctuations. This may have been due to the quality of the receivers.

J. Clynch authored the receiver considerations aspects of the paper. There are several effects on ionospheric data taken with GPS that arise from the design of receivers. These receivers were, after all, designed to be effected as little as possible by ionospheric effects. These effects arise from the tracking loop design of receivers (Spilker 1996, Ward 1996).

Receivers normally track the range (time delay) and phase of the carrier with feedback loops. There are two regimes to this process, acquisition and tracking. During acquisition, a complex scheme of loop type transitions and bandwidths occurs. During tracking in a final state there is usually second order loop with very narrow bandwidth. The bandwidth can be dependent on dynamics, but for static conditions is often .1 Hz or less. For "codeless" receivers, the L2 loop may be aided by the L1 signal and have an even narrower bandwidth. These loops average over a loop time constant (10 sec at .1 Hz) and can "flywheel" or coast through short data dropouts due to low amplitude signals. This effect also often makes re-acquisition much quicker than acquisition.

These tracking loops also make the receivers relatively immune to ionospheric induced phase scintillations. The loops are generally second order and may be cross coupled between range and phase and across the two frequencies. A loop is sensitive to the first unmodeled time derivative. Thus for most, it is the third time derivative, the derivatives of acceleration called jerk, that causes problems.

While the precise tracking scheme is one of the most closely held trade secrets for most manufacturers, these general comments apply across the board. Thus ionospheric effects on GPS receivers performance normally comes as a consequence of amplitude effects. The measurement of the ionosphere will often be limited in frequency by the narrow bandwidth of the tracking loops.

Data is widely available from receivers from many world wide sites of the International GPS Service for Geodynamics (IGS). These are commonly Rogue or Turborogue receivers. They use an averaging technique that averages over the epoch interval. For example the common IGS thirty second data are averaged over 30 sec.

E. FUTURE STUDY; INTERRELATIONSHIP OF HIGH LATTIUDE AND EQUATORIAL IRREGULARITY DEVELOPMENT

It is important to test various receivers for amplitude and phase scintillation effects. Conditions and structure of the scattered signals may differ for different latitudes and for different causes of irregularity development.

It is expected that data sets similar to those cited will be used to study the effect of high latitude magnetic variations and high latitude phase fluctuations on the developments of plumes at the equator. At the equator, it is the generation of neutral winds that is presently thought to be the dominating force in the day to day variations of scintillations. The study of magnetic storms effects on the generation or inhibition of equatorial plume structure for equatorial latitudes in all likelihood requires the use of several magnetic parameters and will include localized effects.

Until the present it was difficult to correlate high latitude development of irregularities with those at equatorial latitudes. The data emanating from the GPS stations allows continuous observations of many sites will allow this. If this data set comes on line then forecasting may be available if we know the right parameters to put into the model. If so the study of the relationship of magnetic observations and high latitude development of irregularities would be of great assistance in forecasting scintillations at the equator; forecasting and warning will be of great importance particularly in the coming sunspot maximum.