OFFICE OF NAVAL RESEARCH

QUARTERLY REPORT

for

1 October 1994 through 31 December 1994

GRANT No.: N00014-89-J-1754

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

Jules Aarons and Michael Mendillo, Co-Principal Investigators

Boston University
Center for Space Physics
Boston, MA 02215

PRIMER CONSORTIUM

In the last quarter additional work was done on the collaborative program PRIMER. A preamble was developed for the group to organize the aims and program for the three year effort.

THE NORTHEAST CONSORTIUM PROPOSAL ON A PLAN TO DEVELOP PREDICTIVE CAPABILITY FOR EQUATORIAL SCINTILLATION STORMS

THE NORTHEAST ONR CONSORTIUM:

Cornell University
Boston University
Applied Physics Laboratory, Johns Hopkins University

During the past twenty years our understanding of Equatorial Scintillation Storms (ESS) has reached a considerable maturity. We understand the average occurrence pattern and underlying physics quite well. We also understand many of the processes which create the day to day variability and which are crucial to the development of forecasting techniques. Yet there remains a persistent, illusive quality in predicting degradation of signals propagating through the ionosphere because no one has created a synthesis of this understanding. The purpose of this joint study is to outline a three year program which brings together the capabilities of the three major ONR groups in the Northeast for a cooperative venture to predict ESS on time scales of 3-6 hours.

Initially we shall formulate hypotheses for the development of the plume structures along the magnetic equator. With criteria for the development or lack of development of plume structures along the magnetic equator, we shall evaluate these criteria using our available data base. The data base is from experiments in two quite diverse longitude sectors, the severe sea-mountain interface region of Peru wherein the Jicamarca Radio Observatory and its associated instrumentation are located, and the South Pacific region (Kwajalein) located in the Inter-tropical Convergence Zone. These two sectors have already been intensely studied and have existing experimental results and instrumentation which will make the proposed study very cost-effective.

Scintillation activity produces fading on signals ranging from the 250 MHz transmissions from FLEETSATCOM and AFSATCOM to the 1.2 and 1.6 GHz transmissions from the Global Position System satellites. Fading at 1.6 GHz ranges from levels of 5-6 dB within 5-6 degrees of the magnetic equator to a high greater than 20-30 dB at equatorial anomaly regions. These regions located approximately 15 degrees from the magnetic equator, include for example Hong Kong and Taiwan, the northern coast of South America, as well as areas in the Persian Gulf. Fades of the magnitude of 15 to 20 dB can prevent acquisition of GPS signals for many equipments. Fades of this magnitude will cut off communications at 250 MHz for many equipments.

ESS originates from a post sunset plasma analog to the Rayleigh-Taylor instability (sometimes called equatorial spread-F) whose physics is well understood. A forecasting plan is outlined in broad brush strokes in the next paragraphs based on our physical understanding. In our opinion the four most important aspects which lead to the day to day variability of ESS are (1) the magnitude and duration of the pre-reversal enhancement of the eastward electric field in the sunset ionosphere; (2) the magnitude and variability of meridional neutral winds and the ionospheric asymmetries they drive (e.g., the ratio of the plasma content between the southern

and northern hemispheres in this same time period); (3) the level of atmospheric gravity wave activity in the thermosphere and the structure it induces in the ionosphere; and (4) the penetration of electrical activity from the high latitude zone when the region 1 and region 2 currents are out of balance. Our combined groups are uniquely qualified to undertake this study since we have pioneered the experimental tools needed to address this effort and have applied them to the very problems we wish to study in several dozens of refereed articles, several Encyclopedia articles and a book on Ionospheric Physics.

A. THE AVAILABLE DATA STREAM FROM THE GLOBAL POSITIONING SYSTEM

Approximately 50 stations through the world have been set up to give almost real time observations on characteristics of the Global Position System signals. A large data collection base is being made available thru the Internet System. These data with an accompanying presentation of orbital elements have been made available to the scientific community by Jet Propulsion Laboratories. For the user of GPS, the study of errors due to single frequency observations allows the evaluation of position errors due to the delay produced thru passage of the ionosphere's electron content. For the scientific community, the data base allows the study of total electron content thru out the world. We have tapped into this data base in order to study primarily equatorial irregularity development; in addition the data will allow the study of effects of irregularities on acquisition of signal or losing lock on GPS signals after acquisition.

B. ANOMALY REGION-MIDDLE LATITUDE IONOSPHERIC STUDIES

While we have pointed out the variation of the effective latitude of the anomaly region, we have not studied it. The importance of this region is seen in recent studies of 4 GHz signals at a variety of latitudes encompassing the anomaly latitudes and the lower middle latitudes. During periods of both high and low solar flux, studies in India, in Japan, and in South America have shown that GPS frequencies and downlink 4 GHz frequencies used in satellite communications show scintillation activity particularly during magnetic storms. At this time the intensity of scintillation during years of low solar flux can reach at GPS frequencies 10 dB but it reaches these values on relatively infrequent occasions. Using data from the GPS Global Data Base, we are attempting to study one storm in April 1994 and its effect at various latitudes.

C. GPS SIGNALS AND FORECASTING FADING ON FLEETSATCOM

While we have developed the following paragraph for the earlier quarterly report, it is believed that it should be repeated with some changes since it is of possible use in the PRIMER program. From preliminary observations of global GPS, it appears to be possible to use measurements of GPS signals at one station to forecast GPS scintillation problems for that stations and nearby areas.

In the equatorial region, the plumes which produce fading on 250 MHz transmissions from FLEETSATCOM and GPS develop as the sunset line goes west. Once developed the patches, which maintain their integrity for many hours move eastward. If one has the entire sky covered in real time by what might be termed scintillation sensors, short term forecasting might be possible. These sensors would be recordings of the scintillation on the paths to the 4 to 7 satellites in view. If the path to FLEETSATCOM is for example directly overhead, one might look at a

GPS satellite path or a FLEETSATCOM satellite signal to the east to see if this night might be termed an active night for irregularities. In the hours after overhead sunset, if scintillations were observed in real time recordings of a satellite on a western path, then it would be reasonable to expect the wind to bring these patches eastward. One could then forecast for the latter part of the night that there would be scintillation activity on the overhead path to FLEETSATCOM. This is a simplification of the output which might emerge from a warning system of this type.

D. THE ONR ASSERT PROGRAM IN UPPER ATMOSPHERE AND IONOSPHERIC PHYSICS

In the past quarter, the all-sky imager installed in Goose Bay, Canada was upgraded. The upgrade consisted of the installation of two phone lines at the Goose Bay site. This upgrade gave us the capability to remotely control the imager from Boston University. One phone line allows us to control all imager functions i.e. the number of coadded frames, integration time. The other is a video phone line which allows us to view the data collected by the imager, monitor the quality of the data and insure the correct operation of the imager. Ms. Colerico is actively involved in remote observation of the Goose Bay imager and its collected data. In addition in the past quarter, Ms. Colerico prepared and presented a poster paper at the December AGU conference on the results of ground based imaging of equatorial irregularities. Preliminary results include observing a feature which could be described as a broad region of enhanced airglow which moves from north to south through the field of view of the imager installed in Arequipa, Peru. This event occurs at approximately local midnight and seems to coincide with a reversal in the meridional winds observed by an FPI installed at the same site. Other results from the paper include the calculation of the zonal drift of F-region ir- regularities, and a comparison between magnetic activity and spread F activity.