CHARACTERISTICS OF LOW LATITUDE BACKSCATTER FROM IONOSPHERIC *E* AND *F* REGION FIELD-ALIGNED IRREGULARITIES OBTAINED WITH THE PIURA VHF RADAR

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ABSTRACT

We present a summary of the characteristics of echoes from ionospheric (*E* and *F* region) field-aligned irregularities obtained with the Piura VHF radar (~7.0^o dip latitude, outside the equatorial electrojet region). Our results are based on (1) intermittent monostatic observations made between 1991 and 1999, (2) continuous monostatic observations made between January 2000 and June 2001, and (3) intermittent interferometric observations since August 2001. Among other important results, we have found that the *E*-region echoes are stronger and occur more frequently during local summer. In addition, we have observed that the seasonal and daily occurrences of Piura *F*-region irregularities are similar to the occurrence of topside ESF irregularities over Jicamarca.

INTRODUCTION

We have used the Piura VHF radar (5°12'S, 80 ^{o} 38'W, ~7.0 ^{o} N dip latitude, just outside the equatorial electrojet (EEJ) region) in northern Peru to gather echoes from 3-m *E* and *F* region field-aligned irregularities (FAI). Similar irregularities have been intensively studied in the equatorial and auroral zones using ground-based radar systems and in-situ (rocket-borne) probes. Mid-latitude *E*-region FAIs have been the subject of far fewer experiments over the years, however this situation is rapidly changing and multi-instrument experiments are being conducted and planned [1]. On the other hand at low-latitudes but outside the equatorial electrojet (EEJ), i.e., outside ±3° from the magnetic equator, there have been not many radar observations, only those reported from a recent backscatter experiment in India [2], and the 1958 forward-scatter experiments in South America [3]. The Piura radar is part of a wind profiler network in the tropical Pacific. The main purpose of this system is to study the lower atmospheric dynamics.

Until December 1999, this system has been interrupted intermittently in order to observe the ionospheric FAI. The preliminary results from these sporadic observations have been published by [4] and [5]. Since January 2000, continuous observations of these irregularities are being conducted, without interrupting much the lower atmospheric observations of the Piura system. These new observations have a poor time resolution but allow us to extract good seasonal and day-to-day characteristics from these irregularities.

Finally in order to get a better insight in the spatial and temporal morphology of theses echoes and the physical mechanisms behind them, a multiple baseline interferometer system is being installed to perform imaging experiments like those already performed at Jicamarca [6].

INTERMITTENT MONOSTATIC OBSERVATIONS

Our preliminary observations based on intermittent campaigns taken between 1991 and 1999, show that the *E*-region FAI over Piura are confined to the 95-120 km altitude and present spectral characteristics similar to type 2 EEJ echoes. However, they appear mainly at nighttime and early morning, therefore, do not present a temporal similarity to EEJ. Moreover, we observe the existence of two well-defined types of echoes: 1) lower *E*-region echoes (95-105 km), and upper *E*-region echoes (105-120 km). In addition, from experiments taken with high time resolution we have been able to observe quasi-periodic (QP) echoes like those reported at mid latitudes. However our QP echoes present, most of the time, a vertical and a positive slope rather than the most predominant negative slope observed with the MU radar. In Fig. 1 we present an example of the coexistence of the continuous and QP type echoes.

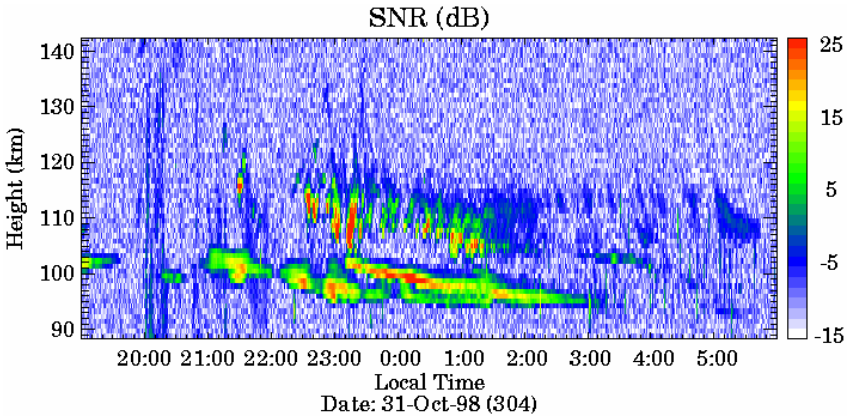


Fig. 1. Example of height-time signal-to-noise values from E region echoes.

In some occasions we have made concurrent observations with the Jicamarca Radio Observatory. From these concurrent observations of *E* and *F* region FAI at Jicamarca and at Piura, we have found that the Piura *E* region irregularities are not correlated with the *F* region irregularities at Piura or Jicamarca. In addition, when *F* region irregularities are observed over Piura, topside *F* region irregularities are observed over Jicamarca.

CONTINUOUS MONOSTATIC OBSERVATIONS

As we mentioned above, since January 2000 we are performing continuous observations of *E* and *F* region irregularities without interrupting much the lower atmospheric observations. These ionospheric observations are made every 11 minutes for approximately 1 minute; therefore the time resolution is very poor. However, we have been able to extract very important seasonal and diurnal characteristics from this database.

For example, some of the *E* region characteristics are (see, e.g., Fig. 2):

- The daily maximum signal-to-noise ratio (SNR) as function of the day of the year shows a well-defined annual periodicity, being the highest between December and March months, in both the lower and upper *E* -region echoes.
- The echoes highest occurrences of these echoes are also between December and March months.
- These echoes are observed mainly at night, but their time of appearance changes with as function of time. For example the lower *E*-region echoes in from February to June tend to appear earlier.
- The diurnal mean Doppler velocity also shows a well-defined annual periodicity. Moreover, the lower *E* region echoes show a well-defined semidiurnal characteristic between the months of April and July, when the echoes tend to occur less and to be weaker. The upper *E* region echoes show a predominant positive Doppler velocity (i.e., downward/southward) all year long.

- There is a significant day-to-day variability in the power, occurrence of these echoes.

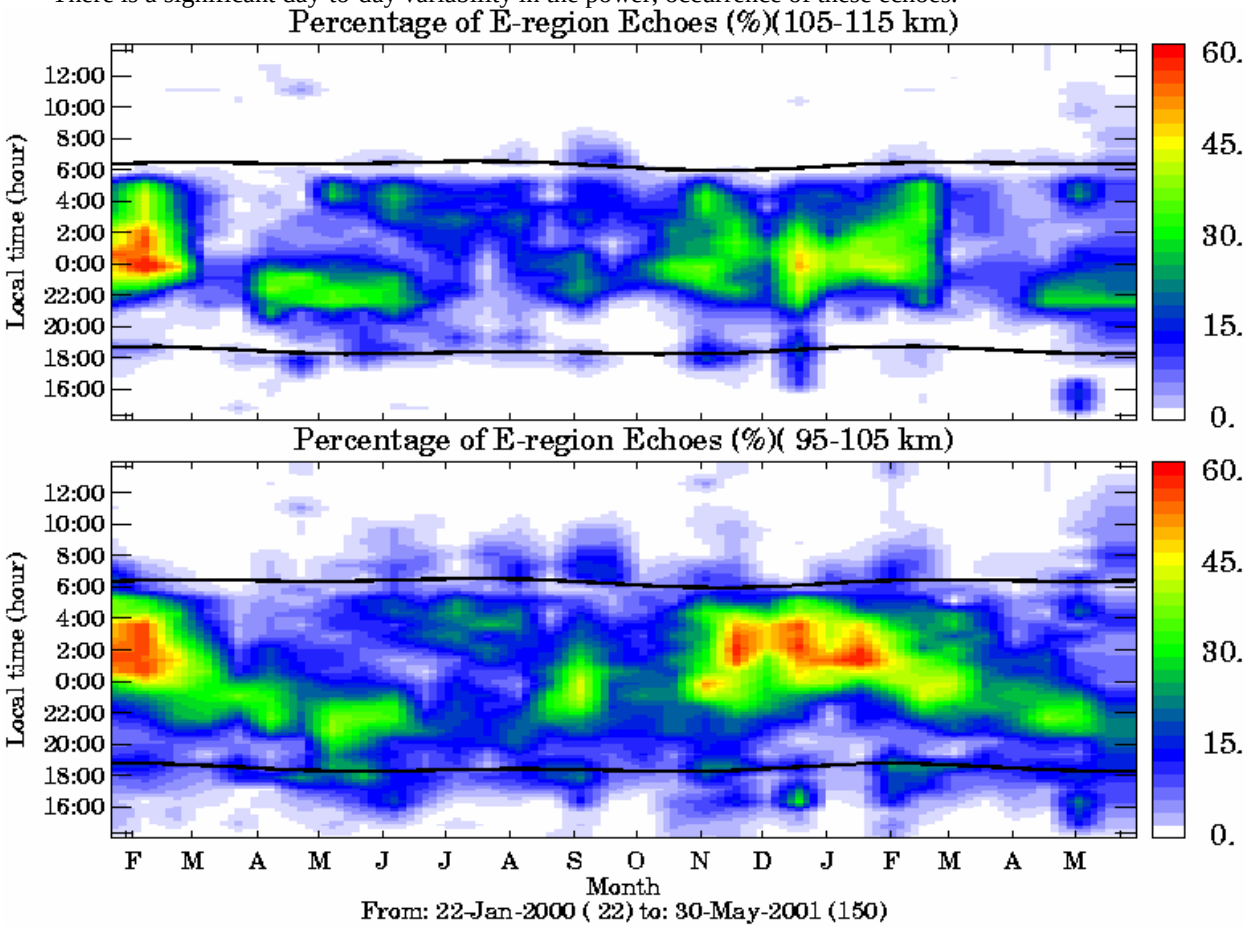


Fig. 2. Seasonal variability of the diurnal percentage of occurrence of the *E* region echoes. These statistics have been obtained by processing 15 days at the time. The local sunrise (sunset) times are shown with the upper (lower) black curve on each plot.

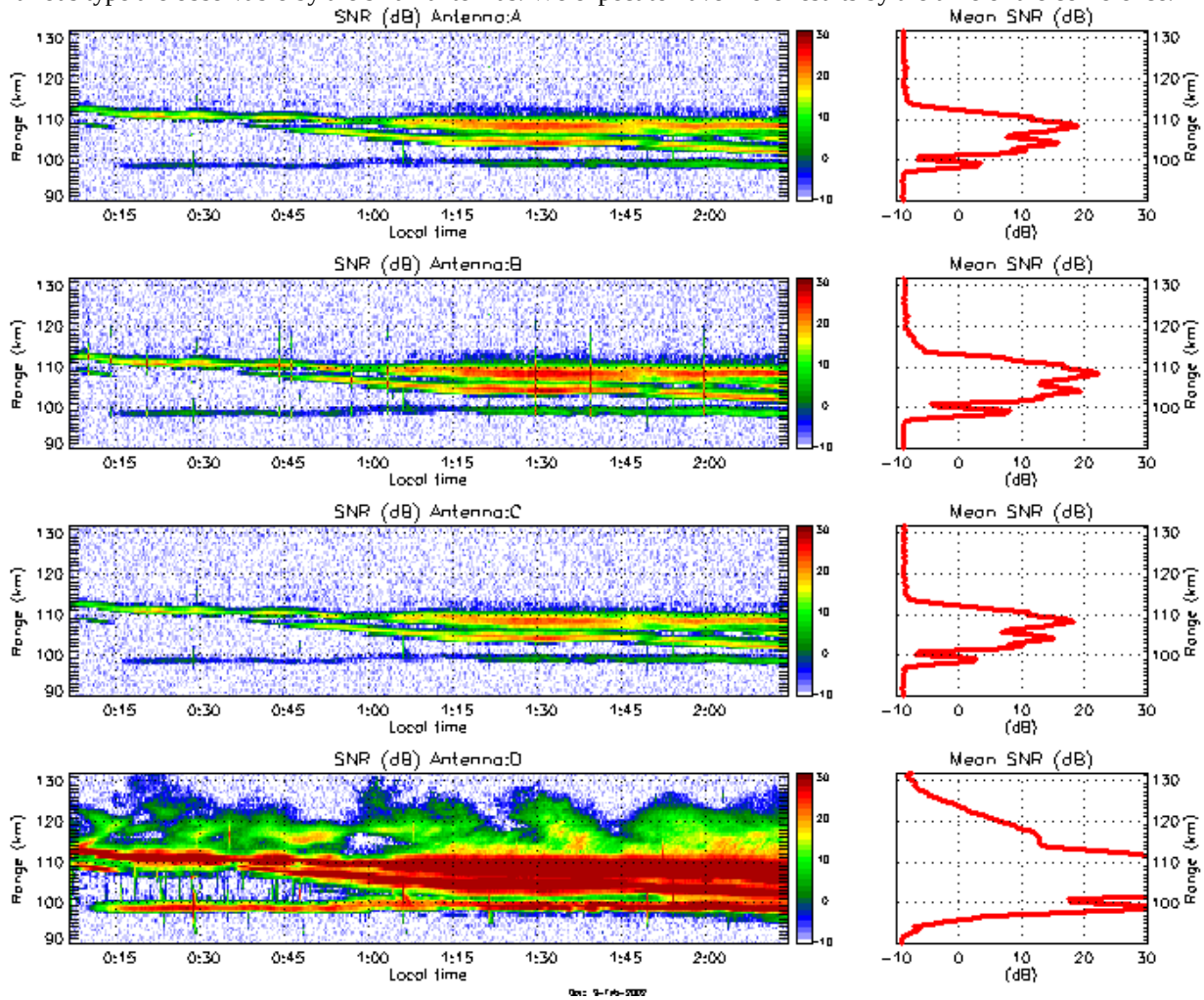
The main characteristics of the *F*-region FAI derived from the continuous observations are (1) that they occur between the months of September and April and (2) present a significant day-to-day variability. More results on these continuous observations are given by [7].

INTERMITTENT INTERFEROMETRIC OBSERVATIONS

Although we have been able to determine the seasonal and diurnal characteristics of these echoes, there is still a lot to learn and observe in order to understand their physical mechanisms and to get more information from these irregularities. For example it has been suggested that from the Doppler shift of the lower *E* region echoes it could be possible to extract the neutral wind information (in the case of Piura, the meridional wind). In some cases, the observations with a monostatic system could be misleading due the temporal and spatial variability of the irregularities.

In order to improve the studies of these irregularities, we are in the process of upgrading the Piura system by adding an additional receiving array of 5 groups. Last summer we implement the first stage of this project and took data with four receiving antennas, three of them (channels A, B, C) consisting on 4 Yagi antennas of 5 elements, and the main antenna (used also for transmission) as the fourth antenna (channel D). The idea is to generate enough interferometric baselines with reasonable sensitivity to performed imaging experiments like those performed at

Jicamarca. In Fig. 2 we show preliminary results taken with the new interferometric configuration. As one can see, channels A, B, and C do not have enough sensitivity to observe the QP-type echoes, and only the very strong continous type are observable by the small antennas. We expect to have more results by the time of the conference.



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