

Low latitude ionospheric turbulence observed by Aureol 3 and possible association with seismicity

Y. Hobara*,

Swedish Institute of Space Physics, Box 812, SE-981 28 Kiruna, Sweden

e-mail: yasu@irf.se, FAX: +46-980-79091

F. Lefeuvre, and M. Parrot

LPCE/CNRS, 3A, Avenue de la Recherche Scientifique

45071 Orléans cedex 2 France.

O. A. Molchanov

United Institute of Physics of the Earth, RAS

123995, Bolshaya Gruzinskaya, 10, Moscow D-242,

Russia.

Abstract: Using PSD (Power Spectral Density) data on electron density and electric field variations observed on board Aureol-3 satellite at low-to-mid-latitude ionosphere we analyze a scale distribution of the ionospheric turbulence in a form $k^{-\alpha}$, where k is the wave number and α is the fractal index. At first high-resolution data in the near-equator region for several orbits have been processed. In this case frequency range is from 6 Hz to 100 Hz (corresponding spatial scales from 80 m to 1.3 km), each power spectrum obeys a single power law fairly well, and the mean spectral indices are rather stable with $\alpha_N = 2.2 \pm 0.3$, and $\alpha_E = 1.8 \pm 0.2$ for the density and electric field, respectively. Then we produce statistical study of electric field bursts in the frequency range 10-100 Hz from low-time resolution data (filter bank envelope). These bursts concentrate aside of Equatorial Anomaly crest (geomagnetic latitude 30-40°) and their fractal indices vary in the interval $\alpha_E = 2.0 - 2.5$. There is a clear tendency for increase of their average intensity on about 3-4 dB during periods of seismic activity.

1. Introduction

Multi-scale near-equatorial F-spread turbulence was observed from frequency spectra of electron density and electric field fluctuations observed on rockets (see for example the review by Kelley, 1989). It is usually supposed that frequency spectrum, which is recorded on a moving platform with velocity V_0 , represents k -distribution in a manner $\omega' = 2\pi f' \sim kV_0$ (it is the so-called Taylor hypothesis), where f' is the observed frequency of the variations and k is their wave number along the direction of the movement. Thus power spectrum density in the conventional form $\sim (f')^{-\alpha}$ is converted in the spatial distribution $\sim k^{-\alpha}$ with the same fractal index α . Cerisier *et al.* (1985) analyzed electron density and electric field variations on board the Aureol-3 satellite in the frequency range 30-1000 Hz (scales $L \sim 10$ -300 m). They found $\alpha = 1.7$ -1.9 for distribution of both parameters. However they only analyzed one case at $h \sim 600$ km and at a rather high magnetic latitude $\Phi \sim 63^\circ$. Molchanov *et al.*, (2002) showed the connection between burst position of electric field variations at frequencies 10kHz and 15 kHz ($L \sim 0.5$ -0.8 m) and the Equatorial Anomaly depletion (EA) from observations performed with the satellite IK-24, and found $\alpha_E = 3$ -4. They revealed two regions of short-scale electric field ionospheric turbulence near equator and near polar-ward gradient of the EA (invariant latitudes 20-35°) and demonstrated that the intensity

of the turbulence increased during several cases of seismic activity. In their recent paper, *Molchanov et al.*, (2003) analyzed in addition large-scale ($L= 15\text{-}300$ km) low-latitude density turbulence using Cosmos-900 data and reported α_N values in a range 1.3-2.0. They found a statistical decrease of the turbulence intensity in association with seismicity. We are going to produce a similar research Aureol-3 data but with middle spatial scale, low-altitude, and low-to-middle latitudes, which are not covered by the previous works from Cosmos-900 and IK-234.

2. Data

The low-altitude Aureol-3 satellite was launched on September 21, 1981. The satellite is three-axis stabilized with the z-axis close to vertical and has a nearly polar orbit with a perigee at 400km and an apogee at 2000km. We use the data from electron density measurement and electric field measurement. The electron density is measured by the high-resolution Interferometer Self-oscillating Probe (ISOPROBE) experiment (*Béghin et al.*, 1982) with a time resolution of 0.2ms. Horizontal AC electric field component (E_H) used in this study is obtained by the Très Basses Fréquences (TBF) experiment (*Berthelier et al.*, 1982). High time resolution waveforms in the frequency range from 1Hz to 1500Hz with 5kHz sampling rate are transmitted to the ground, while the data from 6 band-pass filters with frequency range from 10Hz-1000 Hz.

3. Results and discussion

3.1. Case study (High time resolution data)

We use 5 different equatorial passes of the Aureol-3 satellite over KOUROU telemetry station in June 1982. These passes were chosen for the previous work by *Béghin et al.*, (1985) in relation with plasma density irregularities in association with ESF, because the satellite has a perigee near the magnetic equator at local times between 20 and 22. Altitudes for those passes range from 400 km to 550 km. Mean values of spectral indices for 5 different equatorial passes are shown in Figure 1. The linear least square fit to the power spectra from each data window was performed by the selected spatial scale range (6 Hz to 100 Hz) in relation with the break in the spectra around 80m. The mean spectral index for density fluctuations is ranged from 2.08 to 2.32, while mean slope value for electric field is always smaller than that for density (from 1.56 to 1.98). Day-to-day difference of mean spectral index may not be very large (mostly $\delta\alpha\sim 0.2$) and positive correlation in the slope value between electric field and density can be identified. Size of error bars indicating the standard deviation of spectral index within ESF may show the variability of the individual ESF event characteristics observed along the satellite trajectory. Taking into account the mean and variability of the density and electric field fluctuations, we may conclude that the differences between the spectral indices for these two different physical parameters are in the range of error in the same pass.

3.2. Statistical study (Filter bank data)

Low-time resolution electric field data recorded over entire earth by the filter bank system are used to characterize the seasonal and local time dependence of the ionospheric turbulence (IT) by assuming similar properties between the density and electric field fluctuations seen in the case study. Figures 2(a) and (b) are the bar graphs displaying the results from statistical analysis

including 96 burst events for spectral indices and burst intensities, respectively. The number at the top of each bar indicates the number of burst events included. The height of bar represents the mean value calculated from the events in the bin. The error bar indicates the mean value \pm one standard deviation to distinguish statistical difference between bins. The analysis for each parameter is performed for different seasons and local times. One year is separated by two groups of time periods, which are Sp (March to May) and Au (September to November), and Su (June to August) and Wi (December to February). Three different local time periods are examined: Mo and Ev (3 to 9 LT and 15 to 21 LT), Day (9 to 15 LT), and Night (21 to 3 LT). Averaged low frequency portion ($f < 100\text{Hz}$) of spectral indices for the 96 electric field events observed at low-to-mid latitudes are found to be stable and they do not depend on seasons and on local times. The averaged intensities have significant large variability and it is difficult to obtain some quantitative difference, however relative increases in mean values for spring and Autumn and daytime are identified. Results have indicated that the spectral indices with seismic events and without seismic events do not show significant difference, whereas mean intensities of electric field bursts associated with seismic events are larger than non-seismic events by ~ 4 dB for all seasons and local times. It is difficult to statistically prove the difference between the conditions due to large variability. Nevertheless, this systematic increase might indicate that the AGW and /or the atmospheric turbulence association with major seismic activities may influence at least some of the electric field bursts. It intensifies its field power through the IT. The future low altitude satellite like DEMETER (Parrot, 2002) will be one of the ideal missions to resolve this unclear issue.

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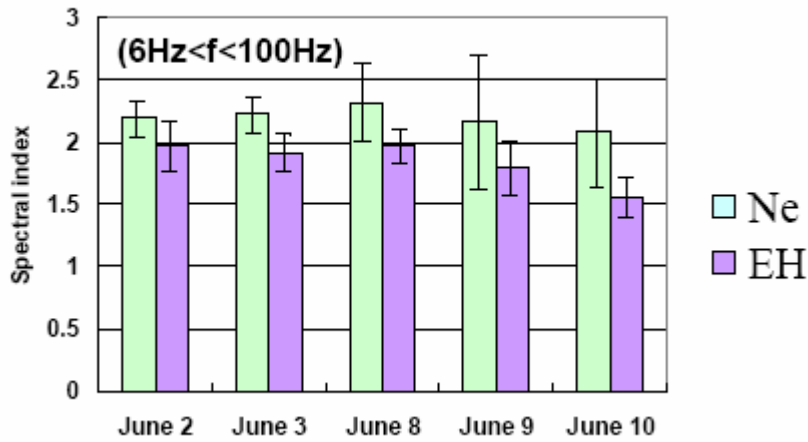


Figure 1. Average spectral indices of the electron density (white) and electric field (shaded) fluctuations inside the ESF for 5 different nights (20~22 LT) for the frequency range between 6 Hz to 100 Hz. Error bars indicate the relevant standard deviations.

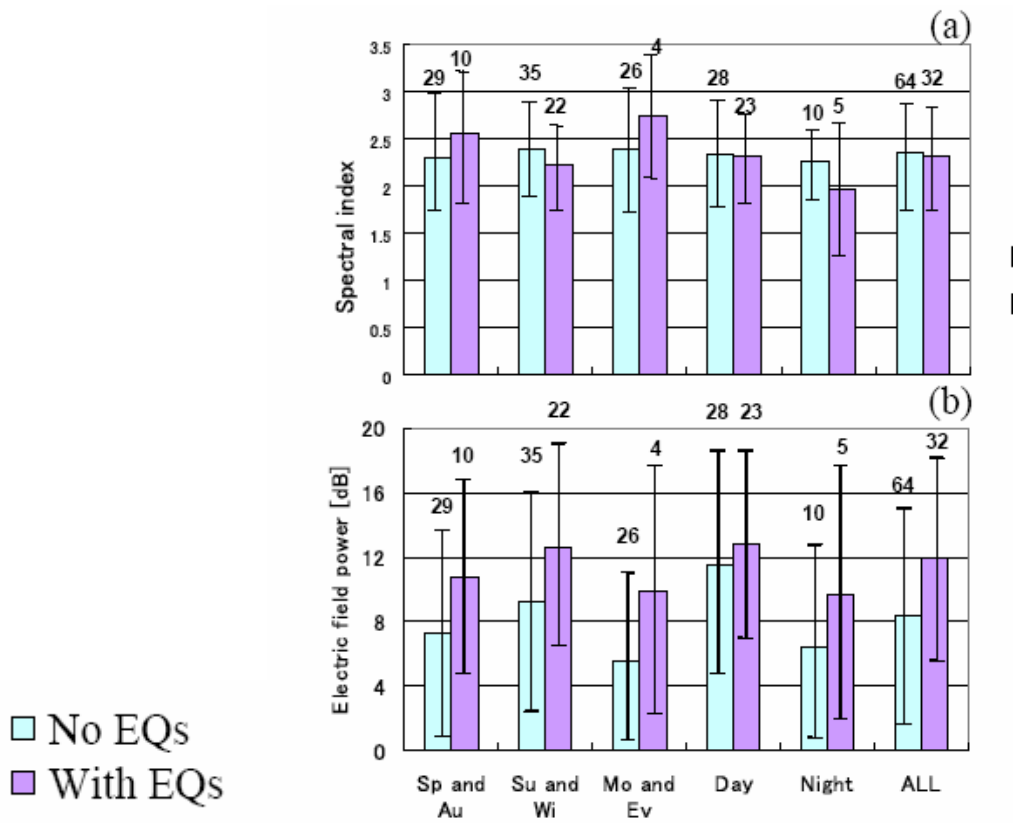


Figure 2. Seasonal and local time dependence of the averaged (a) spectral indices and (b) electric field power of the burst events. Shaded bins represent the bursts with major seismic activities and white bins are for the bursts without seismic activity.