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Discussions

Interactive comment on "Structural characterization of the equatorial F region plasma irregularities in the multifractal context" *by* Neelakshi Joshi et al.

Neelakshi Joshi et al.

neelakshij@gmail.com

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Thank you Dr. Abraham Chian for the feedback, suggestions with detailed references and also for the endorsement. It has certainly improved the article.

Specific Comments:

A number of sounding rocket experiments have been launched in Brazil and other sites to study the equatorial plasma bubbles and polar ionosphere apart from the two sounding rocket experiments described by this paper which were not mentioned

in this paper. Costa and Kelley (JGR 83(A9) 4359–4364 (1978)) showed that the Rayleigh-Taylor instability that initiates in the bottomside equatorial F-region can non-linearly develop very sharp gradients leading to the formation of steepened structures responsible for the power-law spectra observed by a rocket experiment in Natal, Brazil. Shock waves were observed by numerical simulation performed by Zargham and Seyler (JGR 92(A9), 10073–10087 (1987)) of the generalized RayleighTaylor instability at the bottomside and topside F-region equatorial ionosphere, which was confirmed by rocket and satellite in situ data reported by Kelley, Seyler and Zargham (JGR 92(A9), 10089–10094 (1987)). Hysell et al. (JGR 99(A5), 8827–8840 (1994a); JGR 99(A5), 8841–8850 (1994b)) proposed a model of plasma steepening, evolving from plasma advection that occurs on the vertical leading edges of plasma depletion wedges, to interpret shock waves detected in the equatorial ionosphere by rockets launched from Kwajalein Atoll. Jahn and Labelle (JGR 103(A10), 23427–23441 (1998)) measured shocklike structures characterized by the density waveforms at the bottomside and topside F-region of the equatorial ionosphere in a rocket experiment in Alcântara, Brazil. To help the readers to understand better the results of this paper, a detailed discussion of the aforementioned papers and the relation between the results of this paper and the previous rocket experiments should be inserted. In addition, a recent paper by Spicher et al. (JGR 120, 10,959-10,978 (2015)) reported a multifractal study of intermittent turbulence in the polar ionosphere based on a sounding rocket experiment. Since the paper by Spicher et al. (2015) is very closely related to the approach and subject matter of this paper, it is important to insert a discussion to compare the two studies.

Response:
As per the suggestions provided in the specific comments section, we have included all the references and adopted your discussion on the PSD studies reported earlier.

In addition, we performed power spectral analysis and structure function analysis of two downleg time series from the first experiment for which maximum and minimum multifractal width, , was observed, to check whether our results are consistent with the previous works. We found our results to be consistent. Time series $< 292.37 >$ km has maximum $\Delta\alpha$ and spectral index -3.31 is observed in the frequency range $18 - 92$ Hz. Time series $< 429.65 >$ km has minimum $\Delta\alpha$ and spectral index -5.4 is observed in the frequency range $12 - 57$ Hz. Structure function analysis shows that both time series deviate from the Kolmogorov scaling $(m/3)$ and fall below the $m/3$ line, indicating intermittent behavior. Time series $< 292.37 >$ km shows the most intermittent behaviour. These figures are placed at end.

We have added three paragraphs in the Introduction section. Please find the additional paragraphs below:

page 2, line 3:
Various rocket experiments and numerical simulations have been performed and contributed to our understanding of the generation and development of ionospheric irregularities and possible instabilities causing mechanism. Costa and Kelley (JGR 83(A9) 4359–4364 (1978)) showed that the Rayleigh-Taylor instability that initiates in the bottomside equatorial F-region can nonlinearly develop very sharp gradients leading to the formation of steepened structures responsible for the power-law spectra observed by a rocket experiment in Natal, Brazil. Shock waves were observed by numerical simulation performed by Zargham and Seyler (JGR 92(A9), 10073–10087 (1987)) of the generalized RayleighTaylor instability at the bottomside and topside F-region equatorial ionosphere, which was confirmed by rocket and satellite in situ data reported by Kelley, Seyler and Zargham (JGR 92(A9), 10089–10094 (1987)). Hysell et al. (JGR 99(A5), 8827–8840 (1994a); JGR 99(A5), 8841–8850 (1994b)) proposed a model of plasma steepening, evolving from plasma advection that occurs on the vertical leading edges of plasma depletion wedges, to interpret shock waves detected in the equatorial ionosphere by rockets launched from Kwajalein Atoll. Jahn

and Labelle (JGR 103(A10), 23427–23441 (1998)) measured shocklike structures characterized by the density waveforms at the bottomside and topside F-region of the equatorial ionosphere in a rocket experiment in Alcântara, Brazil.

Page 2, line 28 :
Structure function analysis performed on ionospheric in situ data have revealed the intermittent nature of ionospheric irregularities owing to the large deviations from the Kolmogorov's K41 universal power-law index proposed for neutral fluid turbulence (Spicher et al., JGR 120, 10959-10978 (2015)).

page 2, line 31:
In all the above mentioned studies, the main feature that gets highlighted is that the power spectra point to large deviations from the homogeneous turbulence described by the Kolmogorov spectrum $(-5/3)$. Also, higher order statistics like structure function analysis confirmed the deviation from the Kolmogorov scales. Thus affirming non-homogeneity and intermittency in ionospheric irregularities. In the complex scenario of ionospheric turbulence, an important question that arises in the context of this paper is, “is non-homogeneity, which can be characterized by multifractal spectra, a cause for the large deviations from $-5/3$?" To answer this question, we propose to use the multifractal detrended fluctuation analysis (MFDFA) on the equatorial F region plasma irregularities.

Table 1. Power spectral analysis for the both rocket experiments : For the time series at mean heights listed in the first column, the second column shows the first spectral exponent β_1, the third column gives corresponding lower frequency range. Columns 4 shows multifractal width ($\Delta\alpha$) obtained in the MFDFA, respectively.

Rocket experiment 1			
$< height >$ (km)	β_1	lower frequency range (Hz)	$\Delta\alpha$
264.58	-3.67	12-73	0.53
270.22	-3.58	12-73	0.82
292.37	-3.31	18-92	0.93
324.00	-3.44	10-78	0.72
358.56	-4.08	10-78	0.52
429.65	-5.40	12-57	0.28
Rocket experiment 2			
339.94	-3.41	10-80	0.53
348.99	-3.19	10-100	0.82
400.24	-2.91	10-80	0.93

Figures:

Fig 1. PSD analysis for downleg time series at mean height $< 292.37 >$ km for which maximum $\Delta\alpha$ is obtained

Fig 2. PSD analysis for downleg time series at mean height $< 429.65 >$ km for which minimum $\Delta\alpha$ is obtained

Fig 3. Structure function analysis of above mentioned series for order m = 1 to 4

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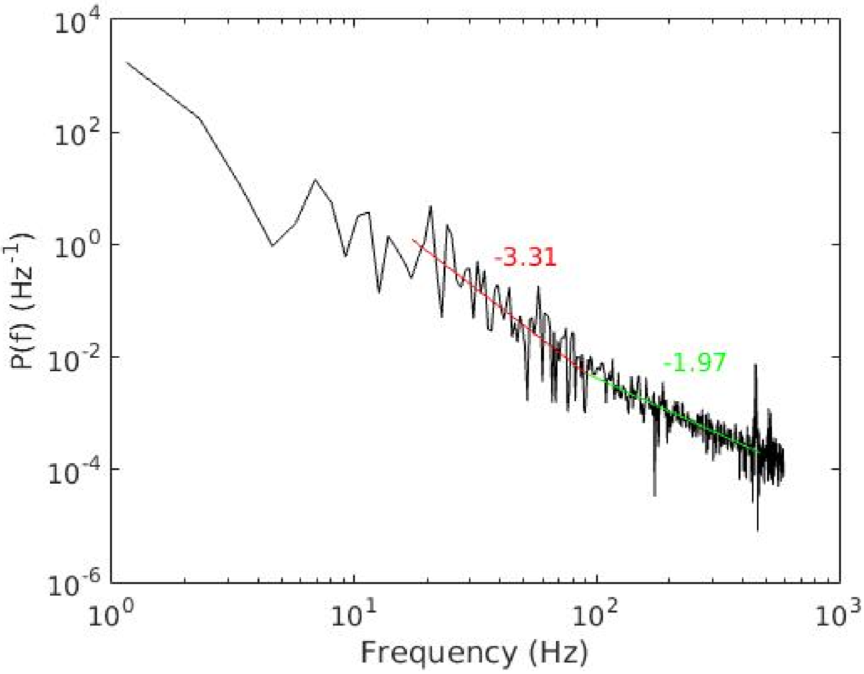
P(f) (Hz^{-1})
Frequency (Hz)
10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
10^0
10^1
10^2
10^3
-3.31
-1.97

Fig. 1.

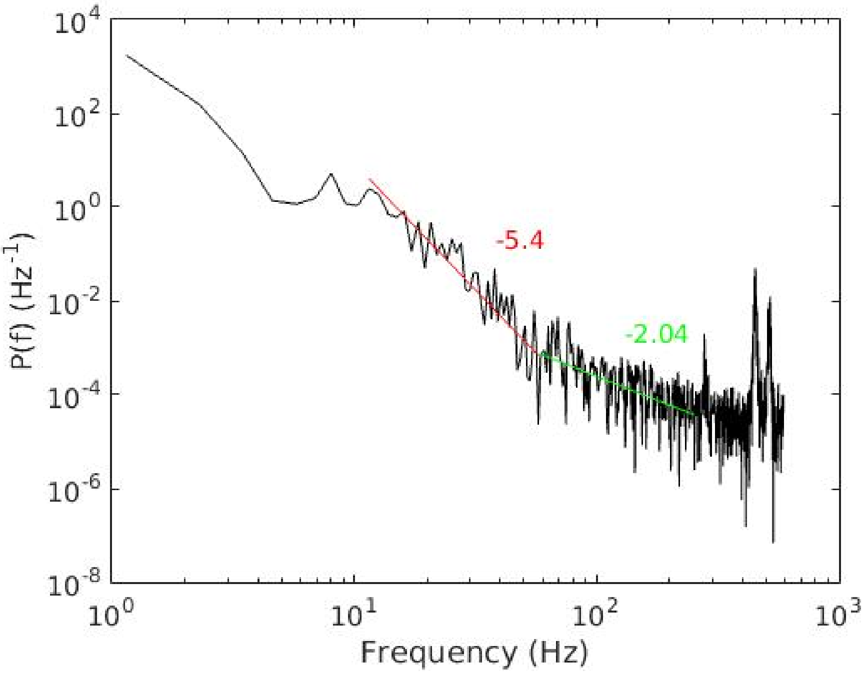
P(f) (Hz^{-1})
Frequency (Hz)
10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^0
10^1
10^2
10^3
-5.4
-2.04

Fig. 2.

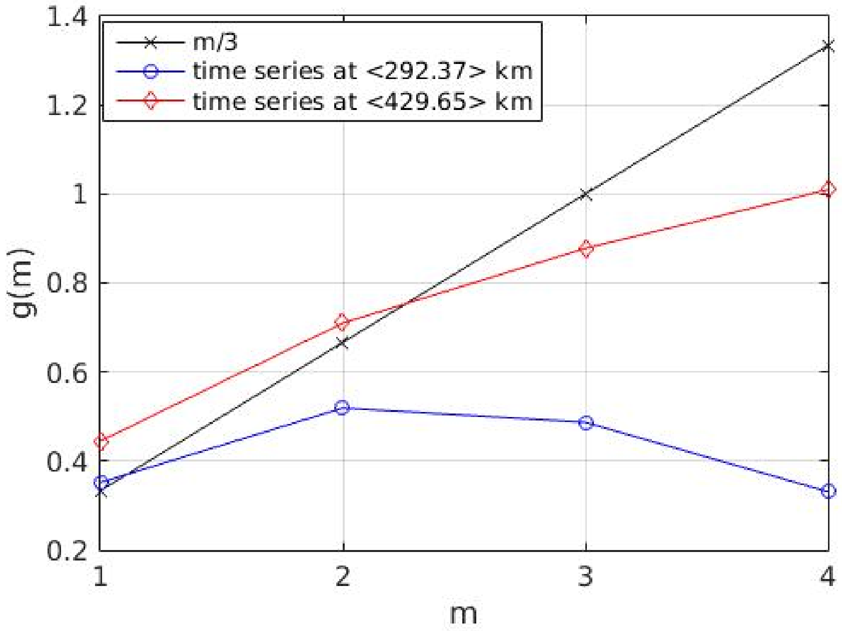
m/3
time series at <292.37> km
time series at <429.65> km
g(m)
m
1.4
1.2
1
0.8
0.6
0.4
0.2
1
2
3
4

Fig. 3.