Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research 57 (2016) 1338–1344

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

www.elsevier.com/locate/asr

Intermittency on simultaneous observations of riometer at several Antarctic locations

E.M. Ovalle [a,*], A.J. Foppiano [a], M.V. Stepanova [b], A.T. Weatherwax [c]

[a] Departamento de Geofísica, Universidad de Concepción, Casilla 160-C, Concepción, Chile
[b] Departamento de Física, Universidad de Santiago de Chile, Av. Ecuador 3493, Santiago, Chile
[c] School of Science and Engineering, Merrimack College, North Andover, MA 01845, USA

Received 1 June 2015; received in revised form 24 August 2015; accepted 31 August 2015
Available online 12 September 2015

Abstract

It is well known that auroral radio wave absorption, as measured by riometers, consists of periods of relative quiescence which are interrupted by short bursts of activity. Such patterns in activity are observed in systems ranging from the stock market to turbulence, i.e. they exhibit intermittency. In the case of the auroral absorption it has also been found that intermittency strongly depends on the magnetic local time, being largest in the night-time sector. This can be interpreted as indicating that the precipitating particles responsible of the absorption exhibit intermittency, especially near the substorm eye, where the level of turbulence increases. Here, we analyse simultaneous observations of riometer absorption at seven Antarctic locations, to determine whether they exhibit intermittency. We determine the Probability Distribution Functions of the fluctuations of riometer absorption for absorption events larger than 0.1 dB, as well as those for the time-intervals between absorption events. Observations are for locations within the austral auroral absorption zone and on the polar cap. It is found that the parameters of a power law used to describe the calculated PDFs are consistent with the formation of coherent structures being more frequent within the auroral zone, as a manifestation of intermittency.

Keywords: Intermittency; Riometer radio-wave absorption

1. Introduction

Intermittency in fluid turbulence can be shown through the analysis of Probability Distribution Functions (PDF) of velocity and density fluctuations (Sorriso-Valvo et al., 2001). In particular, the statistics of a series of values u can be characterised by the PDF's of the values differences $u_\tau = u(t+\tau) - u(t)$ for several time-scales τ (Frisch, 1995). In general, for a small τ, the PDF is approximately Gaussian, but, as τ increases, the wings of the distribution become increasingly stretched, so that large departures from the Gaussian distribution are evident. This is a statistical description.

On the other hand, from an experimental point of view, a phenomenon is said to present intermittency when in a time series the signal is amplified by short time periods, as with the appearance of gusts in a wind field. To illustrate this, a synthetic random series was built such that the deviations from the mean value produce a Gaussian PDF (Fig. 1, upper panel). Then, the series was modified, amplifying the signal at some intervals to emulate the presence of bursts. The new PDF is thus modified clearly showing stretched "wings" (Fig. 1, lower panel).

Therefore, the intermittency of a phenomenon can be described by the PDF analysis of the amplitude changes (bursts) of the time series of a given variable, or alternatively,

* Corresponding author. Tel.: +56 41 2203153/+56 41 220 4136.
E-mail address: eo@dgeo.udec.cl (E.M. Ovalle).

http://dx.doi.org/10.1016/j.asr.2015.08.038
0273-1177/

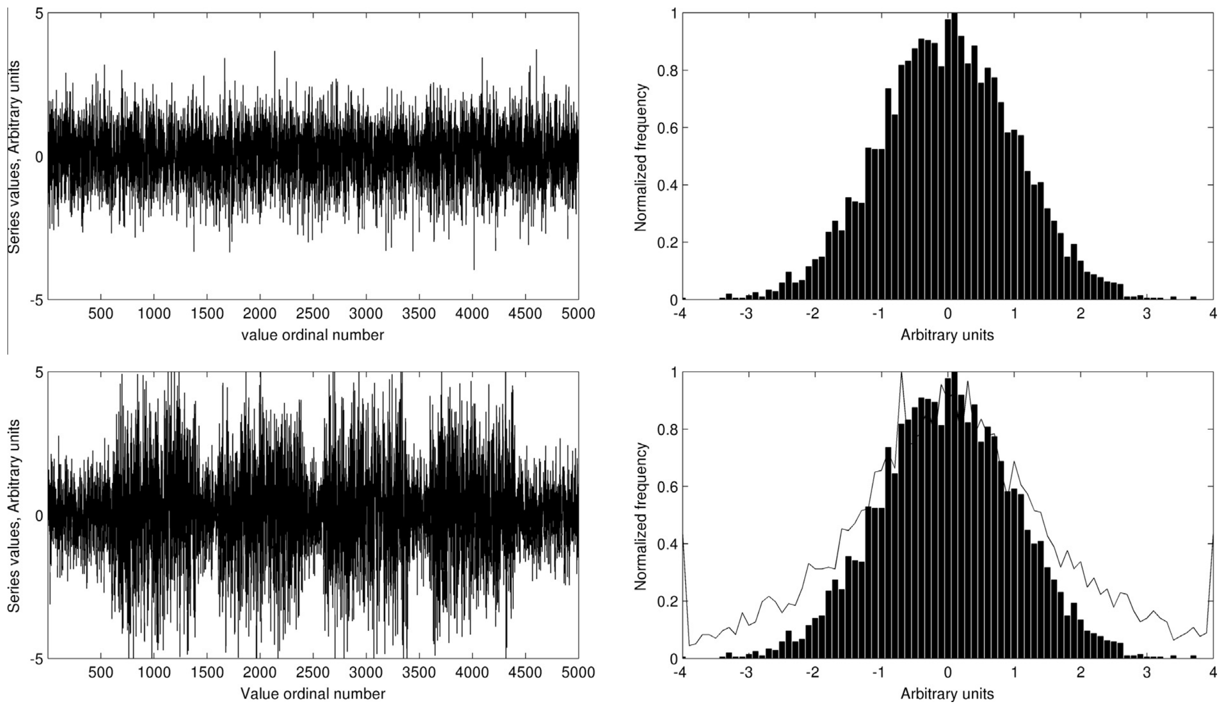

Fig. 1. Time series and their Probability Distribution Functions (PDF's). (top) Random synthetic series. (bottom) Modified random synthetic series by bursts like amplitude changes.

by the analysis of the time series of the intervals between bursts.

As our understanding of the space environment progresses, it increasingly becomes incontrovertibly evident that a tight coupling exists among various space plasma regions in the Sun–Earth system. Also, that the dynamic processes in these regions exhibit disturbances over a wide range of scales both in time and space. The relationship between the phenomenon of intermittency and the deviation from Gaussian PDF's is explained by Chang et al. (2006). In his words, complex dynamical systems exhibit global nonlinear stochastic behaviour due to the strong nonlinear interaction between formed coherent structures having a multitude of different scale sizes. Thus, their behaviour is vastly different from the one that could be surmised from the original elemental dynamical equations.

In a MHD plasma embedded in a dominant background magnetic field, magnetised coherent structures are usually in the form field-aligned flux tubes. When such coherent magnetic flux tubes with the same polarity migrate toward each other, strong local magnetic shears are created and sporadic non-propagating fluctuations will generally migrate toward the strong local shear region. Eventually, the mean local energies of the coherent structures will be dissipated into these concentrated fluctuations in the coarse-grained sense and would induce reconfigurations of the magnetic field geometry. Then, the complexity of creation and dissipation of coherent structures in a plasma is similar to the occurrence of avalanches; both have associated non-Gaussian fluctuations PDF distributions. The phenomena of intermittency have been observed in the solar wind (Bruno et al., 2001) and in the plasma sheet (Consolini et al., 2005).

Here, observations of riometer auroral radio-wave absorption over a latitude range on the southern hemisphere absorption zone are analysed for intermittent behaviour. For all purposes the present paper is a follow up of the one by Stepanova et al. (2005). These two analyses can be thought of as alternatives to previous studies of the structure and spatial coherence spectra of absorption (e.g. Hargreaves and Berry (1976)).

2. Data analysis

2.1. Absorption determination

Radio-wave absorption has been determined at several manned Antarctic stations for many years from observations made by different types of riometers (relative ionospheric opacity metre, Little and Leinbach (1959)) and associated antennas, using various techniques to derive the absorption values (see Hargreaves (1969), for a review on early riometry). In the previous quoted study (Stepanova et al., 2005) 38.2 MHz cosmic noise intensities received at South Pole by a riometer using a broad-beam antenna (Rosenberg et al., 1991) were used. The analyzed absorption values were those routinely derived using the so-called 'inflection point' method to determine a reference 'quiet day curve' (QDC) as reported by Krishnaswamy et al. (1985). In this method, a distribution of received