Space Weather of the Heliosphere: Processes and Forecasts
Proceedings IAU Symposium No. 335, 2017
C. Foullon & O.E. Malandraki, eds.

doi:10.1017/S1743921317008043

Ground-Based Observations of Powerful Solar Flares Precursors

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Abstract. The opportunity of development the short-term forecasting technique of geoeffective solar flares is presented in this study. This technique is based on the effect of growth the fluctuations of horizontal component of geomagnetic field before the solar proton flares, that is considered as a prognostic parameter of solar proton flares.

Keywords. (Sun:) solar-terrestrial relations, Sun: flares, methods: data analysis

1. Introduction

An important problem of Solar-terrestrial physics is regular forecasting of solar activity phenomena, which negatively influence human health, operating safety, communication, radar sets and others. In this context the search for new prognostic factors and patterns becomes more urgent, including finding flare precursors that would be very important and can significantly improve the quality of the forecasts of solar flare activity.

Previously carried out data analysis of H-component of the Earth's magnetic field values demonstrated that during the period from 3 to 1 day prior to the onset of solar flare associated with the enhancement of solar protons affecting the Earth environment there is an increase in the amplitude of pulsations with periods of 30-60 min compared to "magnetocalm" values (Bystrov, Kobrin & Snegirev 1978, Kobrin, Malygin & Snegirev 1985 and Snegirev, Fridman & Sheiner 2000). The data used for analysis have been taken from 100 geomagnetic observatories with a resolution of 1 min during 1991, 2001, 2005 –2007 (http://swdcwww.kugi.kyoto-u.ac.jp/ caplot/index.html).

2. Overview

The phenomenon of growth of the long-period fluctuations of the horizontal component of geomagnetic field before the solar proton flares is global in nature (Figure 1). See, for example, data for 19-23.03.91, obtained from 52 stations (solar flare 22.03.91, X9, starts at 22:43E UT; it is marked with a red triangle). As one can see from the left part of picture, at stations located on close geomagnetic latitudes, pre-flare pulsations are identical and occur simultaneously: their power differs insignificantly. The correlation coefficient of the spectral densities (averaged over the periods of 30-60 min) is very high, which indicates the reliability of the observed effect. For geomagnetic stations located on close geomagnetic meridian, the power of long-period oscillations decreases with decreasing latitude. At medium-latitude stations the oscillations appear several hours ahead of the same at higher latitudes' stations.

A possible reason for the enhancement of long-period pulsations-precursors is the relationship between oscillatory processes in the solar atmosphere before the flare events and in the Earth's atmosphere. Fluctuations in the physical parameters of the solar atmosphere must modulate the emission in a wide range of electromagnetic waves.

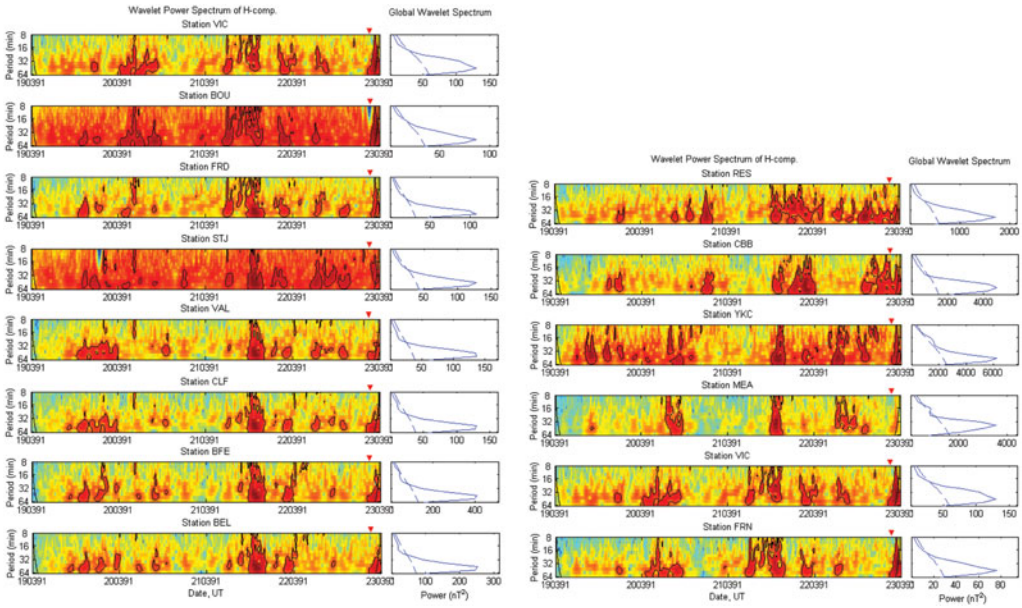

Figure 1. Spatial distribution of pulsations in latitude (left) and in longitude (right).

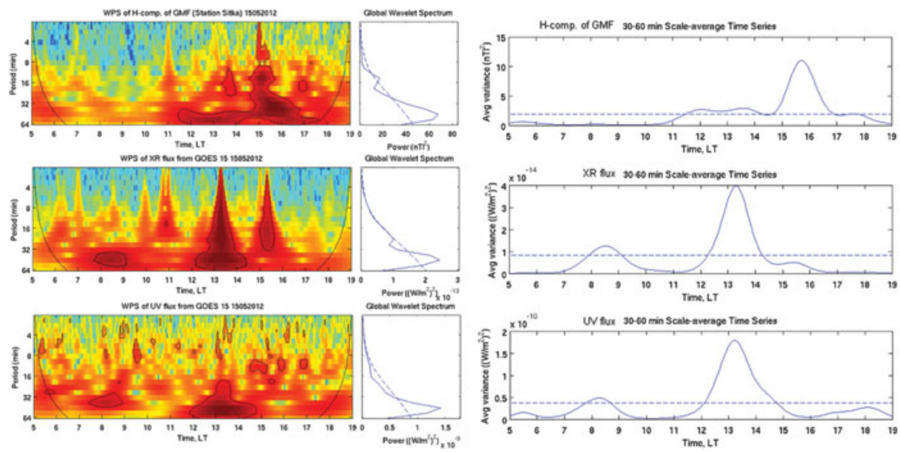

Figure 2. Left: wavelet spectra, top – H-component of Earth's magnetic field, middle – X-ray, and bottom – ultraviolet radiation. Right: the long-wave components in abovementioned data. The dotted line indicates the significance level.

The change in radiation in the X-ray and ultraviolet ranges entails a change in the electron concentration in the terrestrial ionosphere, that lead to fluctuations in ionospheric currents and, accordingly, the geomagnetic field. Comparison of the wavelet spectra of the long-wave ultraviolet (115–127 nm) and X-ray (1.0–8.0 Å) radiation with the spectra of the horizontal component of the Earth's magnetic field illustrates the similar behavior of long-period spectral components of X-ray and ultraviolet emission prior to proton flares (Figure 2). For example, 2 days prior to proton flare on 17.05.2012 (starts at 01:25 UT, M5) there are the power increase in the spectrum of ultraviolet, X-ray radiation and H-component of geomagnetic field. Increasing of preflare pulsations in long-wave ultraviolet and X-ray radiation is observed a little ahead than in the H-component.

https://doi.org/10.1017/S1743921317008043 Published online by Cambridge University Press

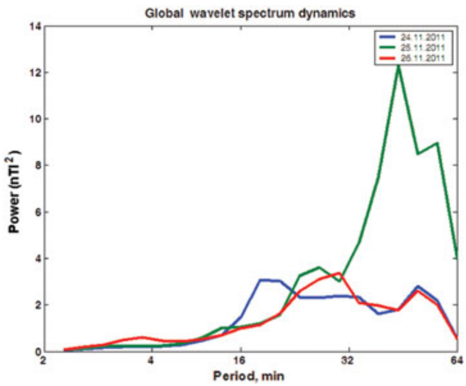

Figure 3. Global wavelet spectrum of the horizontal component of the geomagnetic field, MOS station for the period 24-26.11.2011. Solar flare was observed on 26.11.11, at 06:09 UT.

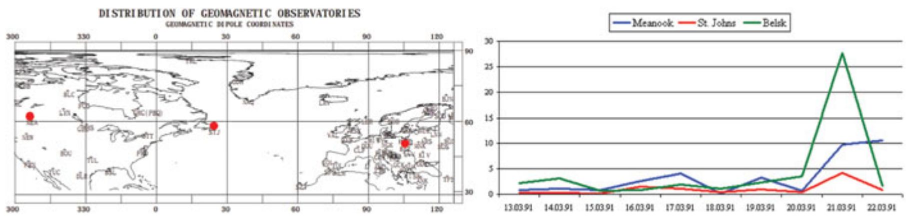

Figure 4. Left: Location of geomagnetic observatories. Right: The ratio of the powers of long-period pulsations on the current day to the day with weak flare activity; vertical axis is in relative units, horizontal - days of the month.

3. Application

Exploring the possibility of short-time solar activity forecasting, we have found that the global wavelet spectra of the horizontal component of the geomagnetic field can be considered as prognostic parameter. Actually, there is the increase in the power of long-period oscillations as the flare approaches (Figure 3). Based on these conclusions, we have developed an algorithm for predicting geoeffective solar flares (Snegirev, Sheiner & Smirnova 2012). Below we present an example of the application of this algorithm for predicting the solar flare on March 1991 using geomagnetic data.

We select 3 mid-latitude geomagnetic observatories separated by not less than 1000 km in latitude: Meanook (MEA) (54,62 N, 113,35 W), St. Johns (STJ) (47,6 N, 52,68 W), Belsk (BEL) (51,84 N, 339,21 W). Then we trace the dynamics of the following ratio value: the power of long-period pulsations on the current day to the day with weak flare activity for these three geomagnetic observatories. Figure 4 illustrates the location of the stations and ratio behavior: Meanook – blue line, St. Johns – red line, Belsk – green line; x-axis is the date. One can see that on 21.03.91 the power value of the long-period components exceeds by more than 4 times weak value for all three observatories. This fact indicates a high probability of a large proton flare within next 3-1 days. A flare actually occured on 22.03.1991 at 22:43E UT, which confirms the obtained result.

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