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[Extended abstract]

Solar Wind and Seismic Activity in the Balkan Peninsula: a 2019- 2023 Progress Report

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Abstract: This brief progress report provides an update on the ongoing research that aims to test the statistical significance and explore the potential causal relationship between earthquakes and increased solar wind parameters, distinguishing whether these events occur randomly or are interconnected. The updated research confirmed that heightened solar wind parameters, such as proton density and velocity, cannot be differentiated from the random distribution of these events prior to earthquakes in the Balkan Peninsula region.

Keywords: proton density, proton velocity, earthquakes

Introduction

Previous research correlating solar wind parameters to global increased seismic activity displayed a positive correlation between the two (Marchitelli et al. 2020). In the study conducted by Arnaut et al. (2021), the researchers examined the correlation between heightened solar wind parameters, specifically proton density and velocity, and their potential to trigger earthquakes (EQs) in the Balkan Peninsula region. The research findings indicate that there is no causal relationship that can be distinguished from random chance.

Inferring a causative relationship for EQs and any causing external factor is a difficult task due to the complex subsurface activities that cause them. However, several mechanisms have been proposed. An example of such a mechanism is the magnetohydrodynamical interaction between the solar wind and the Earth's magnetic field, which can influence the rotational velocity of the Earth (Simpson, 1967). This, in turn, can impact the timing of EQs and potentially lead to a shorter timeframe for their occurrence. Marchitelli et al. (2020) proposed a mechanism in which a reverse piezoelectric effect initiates subsurface currents that subsequently destabilize fault zones and induce EQs. The solar wind induces heightened subsurface currents, while the EQ is primarily tectonically driven, although its initiation is influenced by external factors.

Both mechanisms are rooted in physical principles. However, the objective of previous and subsequent studies is to determine the statistical significance of these events. The goal is to determine whether the anomalies can be differentiated from random chance when given the same input parameters. This brief progress report presents the continuation of analysis conducted in the original research paper (Arnaut et al. 2021) covering the period 1996-2018, incorporating updated data with a time span of 2019 to 2023.

Methods and data

The dataset used in this research employed EQ data from the EQ catalog of the United States Geological Survey (https://earthquake.usgs.gov/earthquakes/search/). The retrieved data comprised of EQs that occurred between 2019 and 2023 in the region encompassing the Republic of Serbia and its neighboring countries. The data specifically included EQs with a magnitude of M≥5.0, which aligns with the methodology presented in Arnaut et al. (2021).

The proton density and velocity of the solar wind were acquired from OMNIWeb (https://omniweb.gsfc.nasa.gov/form/dx1.html), which collects data from the Solar Heliospheric Observatory (SOHO). The SOHO satellite positioned at the L1 Lagrange point (beyond Earth's magnetosphere) measures various parameters, including in situ measurements of the solar wind (Ipavich et al., 1998).

An anomalous day, as was defined in Arnaut et al. (2021), refers to any day in a given year where at least one value for proton density or velocity exceeds the mean for that year by three standard deviations. Further statistical analysis was conducted to determine which EQs exhibited an anomalous day within 14, 7, 4, or 1 day(s) prior to the EQ itself.

Results and discussion

The analysis results revealed that all EQs had an anomalous value for the proton density parameter in the 14 and 7 days leading up to it (Table 1). By contrast, the percentages from the previous analysis conducted between 1996 and 2018 were 80 and 62 percent, respectively. Regarding the four days leading up to the EQ, the findings remain relatively consistent with the previous analysis. In the sample of EQs from 2019 to 2023, 7 out of 20 EQs (35%) had an anomalous proton density day, which is in congruence to the 46% observed in the period from 1996 to 2018. Additionally, only 6 out of 20 EQs (30%) displayed an anomalous proton density value in the day preceding the EQ.

Table 1. Results of the conducted analysis for period 2019-2023

EQ date-time	Two-weeks		One-week		4-days		1-day	
	PD	PV	PD	PV	PD	PV	PD	PV
2/14/2023 13:16	●		●					
2/13/2023 14:58	●		●					
11/3/2022 4:50	●		●					
4/22/2022 21:07	●		●		●			
3/27/2021 13:47	●		●		●		●	
12/29/2020 11:19	●	●	●	●				
11/11/2020 3:54	●		●		●		●	
3/22/2020 5:24	●		●					
1/28/2020 20:15	●		●		●		●	
11/28/2019 10:52	●		●		●		●	
11/27/2019 14:45	●		●					
11/26/2019 9:19	●		●					
11/26/2019 6:08	●		●					
11/26/2019 3:02	●		●					
11/26/2019 2:59	●		●					
11/26/2019 2:54	●		●					
9/21/2019 14:15	●		●		●		●	
9/21/2019 14:04	●		●		●		●	
6/1/2019 7:00	●		●					
6/1/2019 4:26	●		●					

EQ- Earthquake; PD- Proton density; PV- Proton velocity;
●- confirmed anomaly

From the previous research, the proton velocity parameter displayed anomalous values of 56%, 32%, and 18% for the periods 14, 7, and 4 days prior to the EQs, respectively. Only one EQ exhibited an anomalous proton velocity value during the 14 and 7 days leading up to the EQ.

Appling the same simulation procedure as conducted in Arnaut et al. (2021), it was determined that the anticipated number of EQs exhibiting an anomalous proton density within the two weeks preceding them is 19.58. This finding aligns with the observed occurrence of 20 out of 20 EQs. During the one-week timeframe, the value is 17.2, which is relatively close to the value obtained, which is also 20. The expected value for the 4-day period is 13, while the obtained value is 7. The close proximity between the expected/simulated values and the true values are so minimal that it is impossible to distinguish a random occurrence from any other possible correlation. This conclusion aligns with findings from previous research (Arnaut et al., 2021).

Conclusions

This brief progress report presents ongoing research on identifying any possible correlation between solar wind parameters (such as proton density and velocity) and EQs that have taken place in the Balkan Peninsula region. The examination of EQ and solar wind data spanning from 2019 to 2023 has reaffirmed previous obtaining that differentiating between the presence of heightened solar wind parameters and registered EQs is exceedingly challenging, as it is difficult to ascertain whether their co-occurrence is merely a result of random chance or possible causal relationship indicator. The most likely explanation is that solar wind cannot be definitively identified as a trigger of EQs registered on the Balkan Peninsula.

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