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Investigations of multi-parametric anomalies associated with the 2017 Rudraprayag earthquake (M 5.1) in Uttarakhand (India) using wavelet analysis

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ABSTRACT

In this paper, an attempt has been made to examine the existence of electromagnetic precursors of an earthquake of magnitude M 5.1 that occurred at Rudraprayag in India on 6th December 2017. For this purpose, ultra-low frequency (ULF) data, obtained at the Agra station by using a magnetometer are analyzed for the period from 10th November 2017 to 25th December 2017. The analysis has been carried out in two segments of 5 min and 1 min using wavelet transforms and decomposition methods. The results show the occurrence of several minor and major ULF bursts (transient amplitude enhancements) in the data, whose association with the earthquake is determined by examining the presence of electromagnetic pulse in them. It is seen that the bursts on 19th November, 1st December, and 4th December, show electromagnetic characters with pulse frequency lying between 0.04 and 0.05 Hz, pertaining to the ULF frequency range of 0.01 – 30 Hz, may possibly be associated with the Rudraprayag earthquake. This result is also supported by GPS-TEC ionospheric data at the Agra station that show anomalies during December 1-3. To further ascertain the connection between the unusual fluctuations in ULF and TEC data and the Rudraprayag earthquake, we also analyzed meteorological parameters including surface temperature, soil moisture, and soil temperature at the epicenter and Agra station both during the observation period. These analyses reveal anomalous variations starting from five days prior to the earthquake that continuing through the day of the event. The precursory perturbations observed in ULF, TEC, and meteorological parameters are interpreted within the framework of atmospheric gravity waves (AGW) that facilitate coupling between the lithosphere, atmosphere, and ionosphere (LAI), a theory previously reported by other researchers in the field.

Keywords: Ultra-low frequency, Total electron content, Earthquake, Precursors, Magnetic storm, Continuous Wavelet Transform-Wavelet decomposition

INTRODUCTION

During the past few decades, a large number of research papers and monographs have been published on seismo-electromagnetic studies, and significant results are obtained because of the availability of seismo-electromagnetic measurements (SEMs) in a wide range of frequencies from DC to HF (Hayakawa and Fujinawa, 1994; Hayakawa, 1999; Hayakawa and Molchanov 2002; Molchanov and Hayakawa, 2008; Singh, 2008; Hayakawa, 2012, 2015; Pulinets and Ouzounov, 2018; Ouzounov et al., 2021). Chen et al. (2022) published a review on advances and challenges in seismo-electromagnetic studies. In the recent era, monitoring of ultra-low frequency (ULF) emissions has provided significant results and helped to validate the lithospheric origin of anomalous signals. Today, this is one of the most broadly used seismo-electromagnetic techniques because of its large skin depth, low attenuation, less contamination, and penetration through the ionosphere and magnetosphere. To ascertain the earthquake precursors, ULF measurements are examined extensively at national and international levels (Fenoglio et al., 1995; Kushwah and Singh, 2004; Hayakawa et. al., 2007; Singh et al., 2014, 2018; Takla et al., 2018; Swati et al., 2020a). The case studies as well as statistical studies have been conducted extensively by the earlier researchers. Fraser-Smith et al. (1990) reported the impact of the Loma Prieta earthquake (Ms 7.1) on 17th October 1989 on the magnetic noise measurements in the ULF frequency range (0.01-10 Hz) and the VLF range (10 Hz-32 kHz). They detected the magnetic precursors three hours prior to the earthquake event. Zhuang et al. (2005) provided an initial analysis of observations regarding the ultra-low frequency electric field in the Beijing region preceding few earthquakes. Han et al. (2014) conducted a statistical analysis of ULF data spanning from 2001 to 2017 to investigate seismo-magnetic variations. They observed ULF magnetic anomalies occurring 6 to 15 days prior to earthquakes, with the intensity of these anomalies increasing in proximity to and magnitude of the impending seismic events. Fidani et al. (2020) analysed electric and magnetic fields within the extremely low-frequency range in an earthquake-prone area of Italy from August 2016 to January 2017. They discovered numerous sudden spikes in electric and magnetic fields that coincided with significant seismic occurrences.

In India, regular monitoring of ULF measurements was initiated at the Agra station (27.2°N, 78°E) for earthquake studies in 2002. Subsequently, monitoring stations were established at IIG Allahabad, MPGO Shillong, Tripura, WIHG Dehradun, ISR Gandhinagar, and Kolhapur. Magnetometer data was unavailable from 2013 to 2015 due to the suspension of monitoring at the Agra station, as new units were being installed to replace the sensors and other hardware components. Since November 2016, the new system has operated successfully. Researchers have utilized the ULF data recorded at the Agra station, which has revealed timely and precursory signatures in the form of bursts within the data (Kushwah and Singh, 2004; Kushwah et al., 2007, 2009; Singh et al., 2014, 2018; Swati et al., 2020a, b).