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Ionospheric precursors of earthquakes recorded by VLF receiver at Tashkent IHY station

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Abstract

Tashkent International Heliophysical Year (IHY) station is a member of Atmospheric Weather Electromagnetic System for Observation, Modeling and Education (AWESOME) network being operated globally to study the ionosphere and the magnetosphere with the help of electromagnetic waves in Very Low Frequency (VLF) band. Regular monitoring of the D- and F-layers of ionosphere over Central Asia territory is being performed on the permanent basis starting year 2008. We have studied VLF amplitude anomalies related to the EQs occurred in 2008–2009 years with magnitude more than 5 on the path way from the VLF transmitters to the Tashkent station assuming that propagation of VLF ground-based transmitters signals can be perturbed by EQ preparation detectable from the ground-based measurements in the VLF bands. For analyzing narrowband data we have used the nighttime fluctuation (NF) method paying attention to the data obtained during the local nighttime (20:00 LT–04:00 LT) in Tashkent where the VLF receiver is operating. The mean nighttime amplitude (or trend) and nighttime fluctuation are found to increase significantly before the EQ occurred on the path way from the transmitters to the receiver. The obtained results have revealed an agreement with VLF amplitude anomalies observed in Tashkent VLF station during the strong EQs occurred on the path way from the transmitters to the receiver. Some results are presented to show the probing potentiality of VLF waves to predict short term EQs with high magnitude.
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Keywords: VLF; Strong earthquakes; Anomalies variation; Ionospheric precursors

1. Introduction

Earthquake (EQ) precursory signature is recently known to appear not only in the lithosphere, but also in the atmosphere and ionosphere (see, e.g. Hayakawa, 1999; Hayakawa and Molchanov, 2002). It is assumed that EQs can be preceded by electromagnetic signals in the Ultra Low Frequency (ULF), Extremely Low Frequency (ELF), and Very Low Frequency (VLF) bands detectable from ground- and space-based measurements (Gokhberg et al., 1982; Fraser-Smith et al., 1990; Parrot and Lefeuvre, 1985). EQs are the results of a sudden release of energy in the Earth's crust that creates seismic waves and EQs are produced by movement and interaction of tectonic plates, which can be characterized by the location of epicenter as well as the main parameters of the rupture (magnitude, seismic moment, source mechanism, orientation of the fault plane and direction of motion). In the recent review (Hayakawa, 2011) the statistical evidence on the correlation between the VLF/LF propagation anomalies and EQs (especially with large magnitude and with shallow depth) and VLF/LF radio sounding of seismo-ionospheric perturbations are presented.

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Except for mechanical properties, there is sufficient evidence to show the ionospheric perturbations are caused by EQs. For example, Kachakhidze et al. (2012) have developed simple theoretical model to explain qualitatively the mechanism of VLF electromagnetic emission initiated in the process of an EQ preparation. Even the electromagnetic emissions (ULF, ELF, VLF ranges) emitted during EQs modify the ionosphere while propagating through it. Cohen and Marshall (2012) have recently presented the first record of broadband ELF/VLF radio emissions made during an exceptionally strong earthquake close to the epicenter ($\sim$ 100 km) which may play a unique and highly fortuitous window into the ELF/VLF environment before and during the most serious and damaging EQs.

Perturbations in VLF data have been reported to occur before large EQs being associated with phase and amplitude variations. The terminator time (TT), is defined as the time where a minimum occurs in the received phase (or amplitude) during sunrise and sunset. A few days before the EQ the evening TT may be deviated significantly from the monthly average (Hayakawa et al., 1996) and the observed effect could be theoretically explained by decreasing the VLF reflection height by up to few kms. Many electromagnetic phenomena possibly associated with seismic activities have extensively discussed in a lot of reports (see e.g. Gokhberg et al., 1982; Hayakawa and Fujinawa, 1994; Molchanov and Hayakawa, 2008; Hayakawa, 2007; Pulinets and Boyarchuk, 2004). Among these seismo-electromagnetic phenomena, the lower ionosphere has been found to be very sensitive to seismic activity, as based on event and statistical studies by means of subionospheric VLF/LF propagation anomalies (Hayakawa, 2007; Hayakawa et al., 2010). In the recent paper Schwingenschuh et al. (2011) authors have presented the Graz seismo-electromagnetic (VLF) facility, as part of the European VLF receiver network and the related scientific events related to terrestrial VLF propagation over Europe during two years period.

This paper delineates the results obtained from Tashkent VLF radio receiver observation station operating at middle latitude Uzbekistan. Tashkent station was set up by collaboration between the Ulugh Beg Astronomical Institute, Tashkent and Stanford University, USA under the International Heliophysical Year 2007/United Nations Basic Space Science Initiative program. This station is part of Atmospheric Weather Electromagnetic System for Observation, Modeling and Education (AWESOME) network (Scherrer et al., 2008) to study the ionosphere and the magnetosphere with the help of electromagnetic waves in VLF band. It provides additional facilities to study the VLF phenomena at middle latitudes which were not studied earlier, like direction finding of events like whistlers, emissions, etc. and D-region ionospheric perturbation caused by the astrophysical and geophysical phenomena such as Solar Flares, lightning induced electron precipitations, cosmic gamma ray flares, terrestrial gamma rays flares, geomagnetic storm effect, etc. Simultaneous observation at multiple sites provides opportunity to study in more detail the application of VLF data to the EQ ionospheric precursors. Here we have used the VLF data to analyze

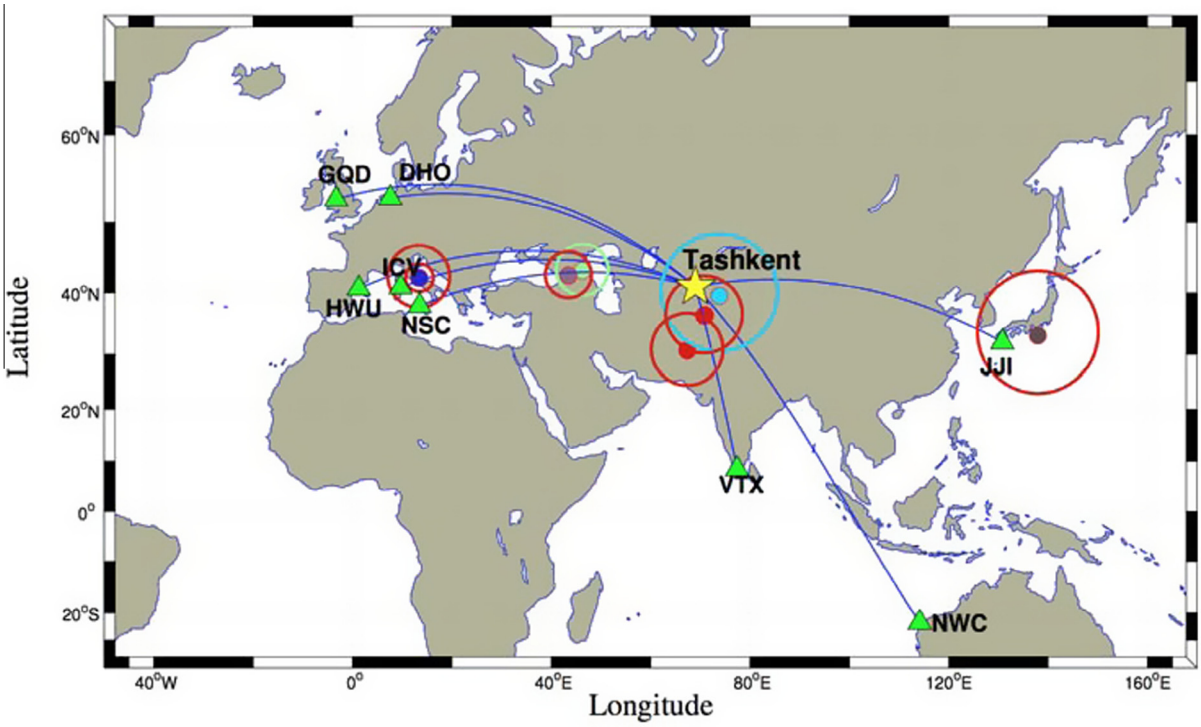

Fig. 1. Map for Tashkent VLF station and EQ epicenters. Yellow star indicates the position of Tashkent VLF station, green triangles indicate the positions of transmitters and circles indicate the position of EQ preparation zones. (For interpretation of the references to colour in this figure caption, the reader is referred to the web version of this article.)

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