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Investigation of the relationship between ionospheric *f*oF2 and earthquakes

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Abstract

Variations of the ionospheric F2 region critical frequency (*f*oF2) have been investigated statistically before earthquakes during 1980–2008 periods in Japan area. Ionosonde data was taken from Kokubunji station which is in the earthquake preparation zone for all earthquakes. Standard Deviations and Inter-Quartile Range methods are applied to the *f*oF2 data. It is observed that there are anomalous variations in *f*oF2 before earthquakes. These variations can be regarded as ionospheric precursors and may be used for earthquake prediction.

Keywords: Critical frequency; Earthquake; Earthquake prediction; Ionospheric precursors

1. Introduction

In the ionospheric plasma physics, the ionospheric variabilities are important research fields because of their effect on the radio communications. It is well known that ionosphere plays a unique role in the Earth's environment because of strong coupling processes to regions below and above it (Rishbeth and Mendillo, 2001). There are many reports of possible links between ionospheric phenomena and events at lower levels, e.g., earthquakes, volcanic explosions and severe weather, and some plausible physical mechanism have been suggested (Rishbeth, 2006).

Earthquakes still take place in the first rank in the list of most destructive and harmful natural disasters causing fatalities in human life (Panda et al., 2010; Yao et al., 2012). Because of this, earthquake forecasting is quite important for humanity and one of the major unsolved tasks of modern geophysics (Panda et al., 2010). During the last 20 years the geophysical phenomena which appear prior to a seismic event is the subject of research of many scientists from different disciplines (Kouris et al., 2001). To predict earthquakes accurately many researchers have developed new earthquake monitoring and prediction methods (Chuo et al., 2001; Hayakawa et al., 2010a; Horie et al., 2007; Pulinets et al., 2004). But, earthquakes as a geophysical phenomenon involve processes which are irregular, nonlinear and complicated. These events are so sophisticated that the dynamic relations between their parameters result in high uncertainties (Akhoondzadeh et al., 2010). Although some seismologists have made successful earthquake prediction, especially in short term (few hours and a few days before earthquakes), it's still in discovery stage. It has been established recently that seismic activity is one of the sources of the daily ionospheric variability (Pulinets et al., 2004). Recent field workings and simultaneously satellite observations have showed that

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seismic activities caused variations not only lithosphere, but also atmosphere and ionosphere (Akhoondzadeh et al., 2010; Hayakawa et al., 2010b; Liu et al., 2000; Maekawa et al., 2006; Panda et al., 2010; Yao et al., 2012). This means that earthquake can excite atmospheric and ionospheric perturbations with directly or indirectly interactions. This is called "Lithosphere – Atmosphere – Ionosphere Coupling" (Horie et al., 2007; Liperovsky et al., 2007). These variations of lithosphere – atmosphere – ionosphere parameters occurred prior earthquakes are considered as *earthquake precursors* (Akhoondzadeh et al., 2010; Liu et al., 2000; Muto et al., 2009; Perrone et al., 2010).

The seismo – ionospheric coupling and studies on this area are very important for both ionospheric researches and short term earthquake prediction. Seismo – ionospheric anomalies before big earthquakes have been studied by many researchers. Using ionosondes, satellites and GPS, researchers have studied many ionospheric parameters with various analytical and technical methods and revealed number of evidence associated with earthquakes (Hayakawa, 2007; Horie et al., 2007; Pulinets, 2004; Pulinets et al., 2004). The effect of pre-seismic activity on the ionosphere can be investigated using the ionospheric electron and ion densities or ionospheric critical frequencies. Chuo et al. (2001), Ondoh (1998, 2000), Perrone et al. (2010), Pulinets and Legen'ka (2003), Singh and Singh (2007) and many other researchers found ionospheric precursors 1–6 days before earthquakes by using ionospheric critical frequencies. Pulinets et al. (2004) measured ionospheric electron density by ground based ionosondes and GPS receivers and found sharp drops of the daily correlation coefficient. Pulinets et al. (2000) and Pulinets and Liu (2004) explained physical mechanism between earthquakes and variations in the ionosphere. Liu et al., (2006) investigated 184 earthquakes with magnitude $M \geq 5.5$ during 1994–1999 in Taiwan and defined anomalous decreasing on the *f*oF2 5 days before earthquakes. Increases as well as decreases of the critical frequencies are observed in the F region before earthquakes. Generally it can be said that when the earthquake magnitude is greater than 6.0, abnormal *f*oF2 variation may be detected on the 1–5 days before the earthquake (Xu et al., 2010). Anomalies that appear in the ionosphere before the main shock can be considered as *ionospheric precursors* and are well established not only by physical modeling but statistically as well (Pulinets et al., 2004; Pulinets and Legen'ka, 2003). These anomalies have a relatively stable time scale, which makes them feasible for short term prediction (Yao et al., 2012).

This paper presents a comparative and statistical study of *f*oF2 variations for earthquake precursors. But it's known that geomagnetic activities have a major effect on ionospheric parameters and many kind of anomalous variations in ionospheric parameters are connected with them. Therefore, geomagnetic conditions will be considered during this work.

2. Earthquake and *f*oF2 data

The size of modified area in ionosphere is of the same order of magnitude as the size of the earthquake preparation area on the ground surface (Pulinets et al., 2004). The radius of earthquake preparation zone was estimated by Dobrovolsky et al., (1979) and was calculated for each earthquake by using following expression (Gwal et al., 2010; Pulinets, 2004; Pulinets et al., 2004)

$$\rho = 10^{0.43M} \text{ km} \quad (1)$$

where ρ is radius of earthquake preparation zone and M is the observed magnitude in Richter scale.

In the present study we investigated seven earthquakes had magnitudes with $M \geq 6.0$ during the period 1980–2008. These are crustal earthquakes epicenter depth ($D < 40$ km). Earthquakes data were taken from The Earthquake Hazards Program. In Table 1, earthquake information (their onset date and time, epicenter latitude/-longitude, focal depth and distance from earthquake preparation zone) is given.

Table 1
Characteristics of earthquakes which are studied in this work.

S.N.	Location name	Epicenter	Date	Time (LT)	Magnitude (M)	Depth (D)	Distance from station	Radius of earthquake preparation zone (ρ)
1	South Coast of Honshu	34.808°N 139.181°E	29.06.1980	16:20:05	6.2	15	103.950	463.5
2	West Coast of Honshu	37.23°N 138.75°E	23.10.2004	17:56:00	6.6	16	179.89	688.65
3	Center of Honshu, MT Ontake	35.789°N 137.488°E	14.09.1984	08:48:49	6.1	10	181.290	419.8
4	Near Eastern Coast of Honshu	36.141°N 141.54°E	08.05.2008	01:45:19	6.8	36.6	191.09	839.46
5	Far Eastern Coast of Honshu	34.256°N 141.385°E	30.05.2004	05:56:12	6.5	38.1	236.54	623.73
6	Near Western Coast of Honshu	37.281°N 136.602°E	25.03.2007	09:41:57	6.7	5	311.98	760.33
7	Kobe (West Honshu)	34.583°N 135.018°E	17.01.1995	05:46:52	6.9	22	426.210	926.8

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