A statistical report on atmospheric vertical electric field as a precursory for earthquakes observed from North-East India

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Introduction

Atmospheric vertical electric field (VEF) at the fair weather regions is primarily governed by the global thunderstorm activity maintaining a potential difference between the ground and the ionosphere [*Price 2002*]. This field is normally directed downwards and its intensity close to the ground surface is of order of 100-200 Vm^{-1}. Generally in atmospheric electricity, fair weather electric field is considered as negative [Pawar and Kamra 2002] but in our analysis we took it to be positive as per convention of fair weather atmospheric electricity. The electric field measurements near the ground surface have been performed for a long time to gather cloud charge distribution, studying the number, intensity and polarity of the thunderstorm discharges [*Pawar and Kamra 2002*]. During such fair weather days, there are many scientific reports on variations of atmospheric VEF prior to earthquakes (EQs) in various seismo-active regions of the world. This is evident from onservations from countries like Russia, Japan and China [*Mikhailov et al. 2006, Zhang-Hui et al. 2011, Kondo 1968*]. Interestingly, all of the reports point to negative variation in VEF. The VEF variations usually occur at an interval of a few hours to a few days before the main shock and found to be either a bay-like field intensity decrease or an oscillatory train lasting a few hours [*Mikhailov et al. 2006*].

Several possible mechanisms of lithosphere ionosphere interaction have been suggested in literature to account for this anomalous variation in VEF before earthquakes [*Pulinets and Boyarchuk 2004*]. The surface air ionization caused by radon emanation in the atmosphere before earthquakes has been probed as one of the major source of electric field variations [*Harrison et al. 2010*]. The present study is the first preliminary statistical observation made from the North East India from where no previous studies were made with respect to VEF variation though it is a highly earthquake prone zone. An effort has been made to investigate the association of VEF bay depth and duration with earthquake magnitude depth ratio.

Experimental Setup

The atmospheric VEF is measured by one BOLTEK EFM–100 atmospheric electric field monitor installed at rooftop of laboratory of the Department of Physics (Lat: 23.75^0N, Long: 91.25^0E) at height of 15 m from the ground. The EFM consists of six electronically controlled grounded conductive choppers which alternatively shield and expose six sensor plates to the atmospheric DC electric field. This generate a to-and-fro motion of charges between the ground and sensor plates through a high value resistor, which constitutes an AC current that appears as an AC voltage across the sense resistor. The magnitude of this AC voltage is proportional to the strength of the DC atmospheric electric field. This voltage is amplified and fed into an analog to digital converter. The data is stored in the computer with a sampling rate of one data per second. To maintain time synchronization, the internal clock of the computer is synchronized with a GPS time receiver. The maximum electric field that could be measured by the instrument is $\pm$ 20 kVm^{-1}. Although, after proper calibration and scaling during the fair weather conditions a scale factor of 0.4 was found which restricted the maximum field variation around $\pm$ 8 kVm^{-1}. The EFM is capable of detecting lightning discharges within a radius of 30 km from its location.

Observations and Analysis

Three years' VEF data from July 2009 to December 2012 were considered for the present analysis. The fair weather days were selected from the condition by maximum 4 m/s wind speed, less than 3 octa cloud cover and no cumulonimbus cloud visible in the sky from the observational site and no precipitation at the site. A comprehensive search was made for earthquakes occurring in vicinity of about 2000 kms from the receiver. Among them, 12 cases were found where VEF magnitude variations in the form of bay like depressions were observed as a precursory for Earthquake. Figure 1 depicts the geographical positions of all twelve earthquakes for which precursory are observed (in square) along with the location of the VEF receiver (in triangle).

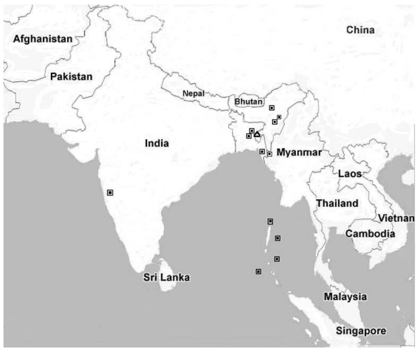

Fig. 1. Geographical location of 12 earthquakes

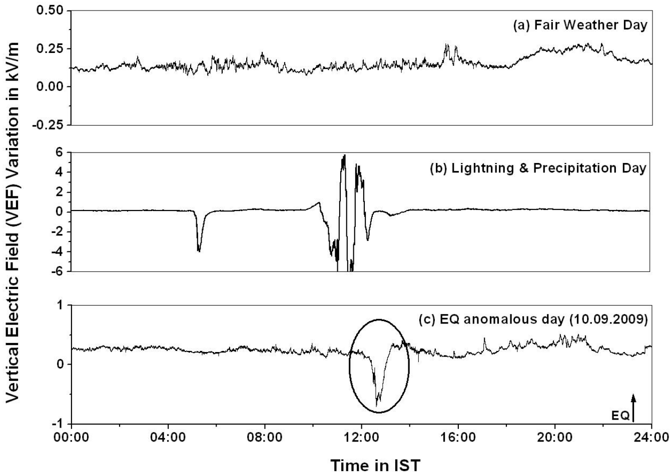

Fig. 2. The difference between fair-weather-day, Lightning day & anomalous day VEF

The earthquakes having the ratio of earthquake magnitude by depth greater than 0.25 has been only considered for this study. Also two successive earthquakes occurring within an interval of 24 hrs have been considered as a single event. Figure 2 shows a typical diurnal variation in VEF for (a) a meteorologically fair-weather day, (b) day with local lightning and precipitation and (c) a day with fair-weather but an anomalous VEF variation preceding an earthquake. The bay like variation has been highlighted by a circle and the time of earthquake is shown by an upward arrow.

The “earthquake magnitude by depth” is plotted with the VEF bay depth and VEF bay duration. A correlation coefficient of 0.74 (Figure 3) and -0.82 (Figure 4) respectively have been found. Whereas, for “distance of earthquake epicenter to observation point” plotted with VEF bay depth and VEF bay duration, correlation coefficients of 0.41 and -0.32 respectively was observed (Figure 5a & 5b).

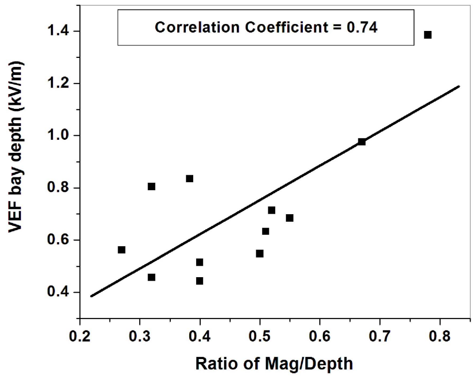

Fig. 3. Plot between ratio of EQ magnitude by depth & VEF bay depth

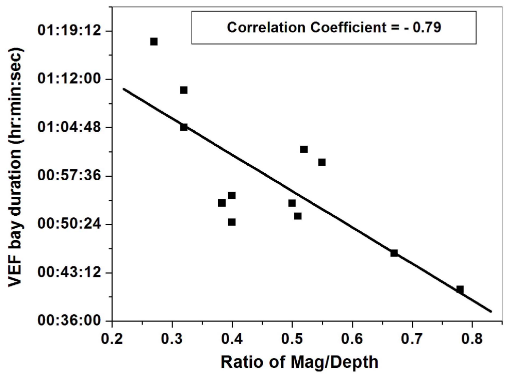

Fig. 4. Plot between ratio of EQ magnitude by depth & VEF bay duration

The “time difference between occurrence of bay like variation in VEF and earthquake” against VEF bay depth and against bay duration are plotted in Figure 6a & 6b. Correlation coefficient of 0.71 and -0.15 has being found respectively.

Discussion

Among the various models proposed in the literature, radon emanation (which is a product of Uranium decay series) is viewed as significant cause of such VEF variations [*Smirnov 2008*]. As a consequence of radon emanation, long living ion complexes of opposite signs are formed in the near ground layer of the atmosphere. Under action of the natural atmospheric electric field, the positive ions would tend to move to the surface of the Earth where they would recombine, but because of their low mobility, after some time, the spatial layer of positive ions is formed at the surface whereas negative ions will move vertically upwards. In that way,near ground surface, an “electrode layer” is formed which diminishes the natural atmospheric electric field. This is known as the “electrode effect” [*Pulinets and Boyarchuk 2004*]. But air ionization by

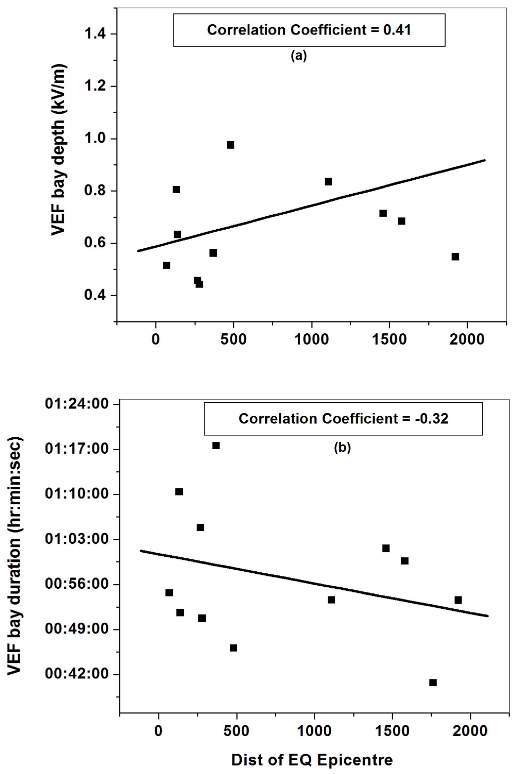

Fig. 5. Plot between distance of EQ Epicenter with VEF bay depth & VEF bay duration

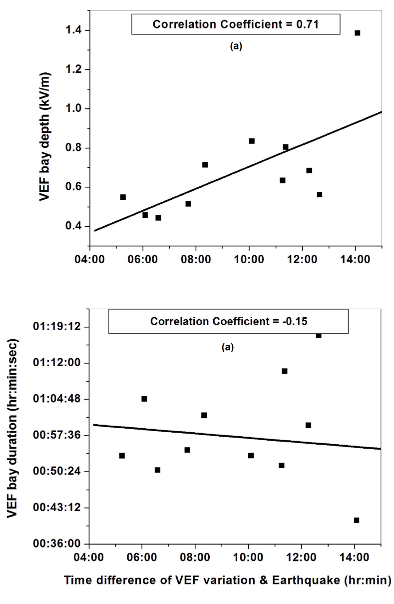

Fig. 6. Plot between time difference of EQ & VEF variation with VEF bay depth & duration

increased radon release before earthquakes might be only a small part of the total ionization balance, as the release of radon into atmosphere is thought to be closely related as well to the state of deformation processes in surface layers of the Earth during the earthquake preparation phase [*Morgunov and Maltsev 2003]. Pulinets and Ouzounov (2011)* introduced a model named as Lithosphere–Atmosphere–Ionosphere Coupling (LAIC) model, discussing a mechanism that exists between different layers of the atmosphere, which could explain the linkage of events occurring simultaneously between the ground surface, atmosphere and ionosphere, before an earthquake. Thus it can be seen that a complex mechanism exists between variations in VEF and impending earthquakes.

Conclusion

1. The average VEF bay depth variation to be around 500 to 800 Vm^{-1}, with a maximum variation around 1385 Vm^{-1}.

2. The average VEF bay duration was found to be within the range of 50 - 70 minutes, with maximum variation as 77 minutes.

3. The most probable VEF precursory was observed 7-12 hours before an impending earthquake, whereas the maximum variation was about 14 hour.

4. A 34.5% probability of earthquake precursor in VEF was observed in our data within 24 hrs before an impending earthquake, only during the meteorologically clear days.

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Статистический отчет по вертикальному электрическому полю атмосферы как предвестнику землетрясений, наблюдаемому на Северо-Востоке Индии

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В качестве предвестника землетрясений были использованы данные аномальных вариаций, наблюдаемые в вертикальном электрическом поле (ВЭП) в атмосфере Земли в виде бухтообразной депрессии и интенсивность его сигнала. В данной работе рассматривается первый статистический отчет по вариациям ВЭП, полученным в одной из сейсмически активных областей Северо-Восточной Индии, расположенной на пересечении трех тектонических плит. Анализ проводился с июля 2009 по декабрь 2012. Было отобрано двенадцать дней с условиями хорошей погоды, в которые наблюдались аномальные вариации в ВЭП приземной атмосферы в виде бухтообразных депрессий в его интенсивности перед землетрясениями. Средняя продолжительность бухты ВЭП составила 50-70 минут, а глубина магнитуды ВЭП - около 500-800 Вм-1. ВЭП проявляло аномальные вариации примерно за 7-12 часов до землетрясения. С помощью данного анализа была установлена 34.5 процентная вероятность предвестника землетрясения. График для глубины бухт ВЭП и соотношения магнитуды землетрясения к глубине имеет положительной коэффициент корреляции 0,74, в то время, как график для продолжительности бухт ВЭП и соотношением магнитуды землетрясения к глубине имеет отрицательный коэффициент корреляции 0.79. Это указывает на то, что в условиях хорошей погоды, ВЭП атмосферы может проявлять эффект предвестника землетрясений относительно глубины и продолжительности бухт ВЭП. Корреляция ортодромического расстояния эпицентра землетрясения до точки наблюдения с глубиной бухты ВЭП составила 0,71, а с продолжительностью бухты ВЭП корреляция очень низкая. Корреляция временной разницы вариации ВЭП и землетрясения с глубиной бухт ВЭП - хорошая, в то время, как корреляция временной разницы вариации ВЭП и землетрясения с продолжительностью бухт ВЭП - слишком низкая. Результаты обсуждаются относительно ионизации недалеко от области подготовки землетрясения.