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Scientific efforts in the direction of successful Earthquake Prediction

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ABSTRACT

Making a successful earthquake forecast is still one of the biggest challenges before the scientific community. Because the loss caused by the earthquakes alone is greater than the loss caused by any other natural calamity. Many attempts have been made from ancient times to predict seismic events, but success has not been achieved yet. Here we present a review of the studies which have been conducted in the past in the direction of making successful earthquake forecasts. We have touched upon those studies which come under the domain of seismo-electromagnetism and ionospheric perturbations. The various studies carried out in the past in this direction have made us believe that at least seismic precursors do exist although we have not been able to isolate a universal one.

Keywords: Seismo-Electromagnetism, Seismic precursor, Ionosphere

1. Introduction

Natural events like Earthquakes, Tsunamis and Volcanic eruptions are inevitable. What makes these events more dangerous and disastrous is not that these events are inevitable but that these are still unpredictable. Therefore it is one of the major challenges felt presently by the scientific community world over to find a reliable seismic precursor. The researchers have started efforts in this direction a couple of decades ago. The studies carried out in the past using traditional seismological methods (Gokhberg et al., 1995) have solved the problem of long term prediction to a much extent. However the problem of short term prediction remains yet unsolved. Although the field of short term prediction is in its initial stages of study, yet precursors recorded for certain earthquakes indicate that there is reason enough to believe that precursors do exist and can be observed for forecasting earthquakes. In case of an earthquake rupture, certain precursory activity can be expected, if the observation is made in the near vicinity of causative rupture. These precursory activities may include; radon and helium emanation; electromagnetic emissions; water level and temperature changes; ground uplift and tilt; changes in ionospheric parameters and so on.

Among all earthquake precursors, those related to electromagnetic effects are most important as well as puzzling. The interest in electromagnetic phenomena caused by lithosphere and related to earthquake preparation increased considerably during the last ten years. The case studies have shown that these can be the most promising tools for earthquake prediction. The subjective study of seismo-electromagnetism refers to electric

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and magnetic field anomalies (Molchanov, 1994) observed during seismicity. Recent studies have shown that these pre-seismic electromagnetic emissions occur in wide frequency band ranging from few mHz to few MHz.

2. Historical Review

Global efforts to predict earthquakes were started about a century ago and peaked during 1970s. The first scientifically well documented earthquake prediction was made on the basis of temporal and spatial variation of ts/tp relation in Blue mountain Lake, New York on 3rd August, 1973 (Aggarwal et al., 1975). Seismologists then successfully predicted the Heicheng China earthquake of February 4, 1975 (Cha Chi Yuan), which raised the hopes that it could be possible to make reliable earthquake forecasts. The seismologists have now narrowed down their studies from long term prediction to short term prediction. The studies carried out in past two decades have given birth to the new field of seismo-electromagnetism. Several enthaustic research groups all over the world have shown evidences of electromagnetic emissions and anomalies before earthquakes. Nitsan (1977) first observed electromagnetic signals in the frequency range of 1-7MHz on applying stress to certain quartz bearing rocks and other piezoelectric materials. Yamada et al. (1989) reported that stressed rocks emitted electromagnetic and acoustic waves when micro fracturing took place. In 1980 electromagnetic wave was first observed at Sugadaira (Japan) before a large earthquake (Gokhberg et al., 1982). After this observation, electromagnetic waves associated with earthquakes have been reported by many researchers (Fujinawa et al., 1990; Fraser-Smith et al., 1990 etc). Such emissions have been found to normally account between ultra low frequency (ULF) and high frequency (HF) range. However the frequency band in ultra low frequency (ULF) range (0.01-10Hz) has been found to yield more reliable precursors because of their large skin depth and low attenuation (Kopytenko et al., 2001). The generation mechanism of ULF emissions prior to a seismic event is possibly related to fracturing processes like piezoelectric effect, electrokinetic effect and turboelectric effect. The ULF emissions can penetrate the crust and propagate through ionosphere and magnetosphere (Molchanov et al., 1995, Parrot et al., 1994) hence are easily recorded by ground and space based systems. Moreover these emissions occur few hours to few days before the main shock and their presence is felt even after main shock for an inconsistent time period. Hence these ULF/ELF emissions could be used as short term precursors in the area of earthquake prediction (Parrot et al., 1995).

Although very low frequency emissions have also been detected in the range of 500-3600Hz before Korguelen Island earthquake (Parrot, 1993). However, scientists have been most attracted by ULF range, because there have been convincing evidences on precursory occurrence of such emissions before large earthquakes like Spitak (Kopytenko et al., 1990), Loma Pieta (Frase-Smith et al., 1990), Guam (Hayakawa, 1996). These effects have also been recently reported by Gotoh et al. (2002), Hattori et al. (2002); Khuswah et al. (2007) and Bhattacharya et al. (2007). Eftaxias et al. (2003) have reported that precursory time of such emissions can be from few days to several weeks. These experimental evidences have been positively supported by the theortical work, wherein

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efforts have been made to explain their generation mechanism (Molchanov et al., 1994; Molcchanov and Hayakawa, 1998). On the otherhand some models discussing the conditions prior to dynamical main shock have been proposed (Matsu'ura et al., 1992). The Plasmon model (Kamoga and Ohtsuki, 1999) suggested that by increase of strong stress on the rocks, exoelectrons are excited and emitted and bulk plasmon can be produced. The density and surface roughness transforms the plasmon into photon (EM wave).

Recently efforts have been made to utilize ULF data for direction finding of emitted signals from epicenter regions (Ismaguilov et al., 2003; Haung, 2004). Hayakawa and Hattori (2004) found that ULF emissions can be observable within the epicentral distance of ~100Km for an earthquake of magnitude 7 while ~70-80 Km for an earthquake of magnitude 6. However long distance propagation of ULF emissions has also been reported by Qian et al. (2002) and Ohta et al. (2005).

Schekotov et al. (2006) found that seismic associated ULF emissions are accompanied by an additional signal which differentiates them from non-seismic ones. The additional signal appears only few days before the earthquake and its horizontal magnetic field is more linear and rotated towards meridonal direction. The difference being clearly visible in polarization parameters than in spectral power with maximum effect at frequencies between Schumann resonances. The unusual enhancement in magnetic field components prior to seismicity has also been reported.

Japanese and French institutes have developed network of observatories to completely monitor pre-seismic emissions and highly advanced methods and techniques to process the data (Hayakawa et al., 2007). More recently other aspects associated with seismogenic ULF/ELF emissions are being evaluated with the help of LEO (Low earth orbiting) Satellites.

Among the different precursory phenomenon mentioned in the publications on earthquake prediction, the ionospheric ones are youngest. It has been now established that ionosphere is not only sensitive to solar influences, but it is also affected by lithospheric processes. The occurrence of some specific phenomenon at different altitudes and in different layers of ionosphere are believed to be caused by lithospheric processes happening prior to a seismic event. The researchers are of the view that there is a perfect connection between lithosphere and ionosphere, which may be established either from ground or from space. Above the epicenter of future earthquake, there appears macroscopic changes in the ionospheric parameters at an altitude between 400Km to 1000 Km.

In recent years, the existence of ionospheric precursors of earthquakes has attracted much attention of space physics research community (Parrot et al., 1993; Fujinawa and Takahashi 1994). There are many evidences of seismic associated ionospheric disturbances (Hayakawa and Fujinawa, 1994, Parrot et al., 2006) The first publication concerning seismic associated ionospheric effects came just after Alaska "Good Friday"

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earthquake in 1964 (Davies and Baker 1965, Moore, 1964). Since then a wide range of ionospheric-seismogenic phenomena has been acquired by in-situ satellite and ground based measurements. Using data of ground based ionosondes Antselevich (1971) studied variation of foE parameter before Tashkent earthquake. In 1985 Sobolev and Husamiddinov reported increase in foF2 two days before the main shock while Fatkulin (1989) reported a decrease in foF2 before the main shock. Similar results have been obtained by Pulinets et al. (2002) and Liu et al. (2004). Satellites have registered specific variations and plasma disturbances associated with earthquakes (Rodger et al., 1996; Pulinets 2004). In addition the plasma density, ion composition were also analyzed and reported by Boskova et al. (1993).

Ionospheric perturbations linked with earthquakes have also been studied extensively by number of researchers (Parrot and Hobara, 2005; Parrot et al., 2006; Singh et al., 2004). These are due to propagation of acoustic gravity waves which interact with ionosphere as suggested by first seismo-ionosphere coupling mechanism (Yuen et al., 1969; Birfeld, 1973). Attempts have also been made to study and establish lithosphere-ionosphere coupling (Liperrovsky et al., 1991, Shalimov and Gokhberg, 1998, Hayakawa and Molchanov, 2002).

Total Electron Content (TEC) from GPS has also proved to be a useful tool in studying ionospheric effects associated with earthquakes (Liu et al., 2004; Devi et al., 2004). It has been found that smooth variation in TEC is replaced by rapid fluctuations during seismicity. Ground based measurements of ionospheric perturbations associated with seismic activity have also been done with ionosondes (Chuo et al., 2002; Pulinets et al 2004; Dutta et al., 2007).

The successful launch of DEMETER satellite by French agency CNES (French National Space Agency) in 2004 was a big landmark in the history of earthquake Physics. The satellite is a dedicated mission to monitor seismo- ionospheric perturbations. The satellite has provided an extensive database to study ionospheric disturbances during earthquakes. Parrot et al. and Gwal et al. have been continuously using DEMETER data since its launch to study electromagnetic emissions and associated ionosphercic perturbations linked to seismic activity.

3. Conclusions

The studies conducted previously suggest that nature provides clues for making successful earthquake forecasts. The earthquakes do provide signatures but the domain is quite wide and at the same time all earthquakes do not emit one type of precursor. Therefore it can be well concluded that seismic precursors do exist but there is need to have a comprehensive study to isolate a universal seismic precursors.
The studies carried out in past suggest a positive correlation between emission of electromagnetic waves and occurrence of earthquakes. However the generation and propagation mechanisms are not fully established yet. These waves have precursory nature and hence can be useful in the mitigation of earthquake hazards. To arrive at a

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juncture where earthquake prediction becomes possible, there is need to have comprehensive observations.

4. References

1. Aggarwal Y.P., Sykes L.R., Simpson D.W. and Richards D.G., (1975) “Spatial and temporal variation variations in ts/tp and in P wave residuals at Blue Mountain lake, New York: Application to earthquake prediction”, J. Geophys. Res., 80, pp 718-732.

2. Antselevich, M.G., (1971) "The influence of Tashkent earthquake on earth's magnetic field and the ionosphere," Tashkent earthquake 26 April 1966. FAN publ., Tashkent, 187-188.

3. Bhattacharya S., Sarkar S., Gwal A.K. and Parrot M., (2007) “Satellite and ground based ULF/ELF emissions observed before Gujarat earthquake in March 2006”, Current Science, 93(1).

4. Birfeld Y.G., (1973) “The Earth’s Seismicity Effect on the Ionosphere via Acoustic Waves,” Otkrytiya Izobret. Promyshl Obraztsy Tovarn. Znaki, No. 42.

5. Boskova J., Shmilaur J., Jiricek F. and Triska P., (1993) “Is the ion composition of outer ionosphere related to seismic activity”, J. Atmos. Terr. Phys., Vol. 55, pp 1689-1695.

6. Cha C., Proceedings: Lectures by Seismological Delegation, NASA, 1976, 5.

7. Chou Y.J., Liu J.Y., Pulinets S.A. and Chen Y.I., “The ionospheric perturbations prior to Chi-Chi and Chia-Yi earthquake”, Journal of Geodynamics, Vol.32, pp 509-517, 2002.

8. Davies K. and Baker D.M., (1965) “Ionospheric effects observed around the time of the Alaskan earthquake Of March 28, 1964”, J. Geophys. Res., 70, pp 2251-2253.

9. Devi M., Barbara A.K. and Depueva A., (2004) “Association of total electron content (TEC) and foF2 variation with earthquake event at anomaly crest region”, Ann. Geophys., 47, pp 83-91.

10. Dutta H. N., Dabas R.S., Rupesh M. D., Sharma K. and Singh B., (2007) “Ionospheric perturbations over Delhi caused by the 26 December 2004 Sumatra earthquake” International Journal of Remote Sensing, 28, pp 3141 – 3151.

11. Eftaxias K., Kaparis P., Olygiannakis J., Peratzakis A., Kopanas J., (2003) Antonopoulos G. and Rigas D., “Experience of short term earthquake precursors

with VLF-VHF electromagnetic emissions", Nat. Hazards Earth Syst. Sci., 3., pp 201-228.

12. Fatkullin, M. N., Zelenova, T. I., Legen'ka, A. D., (1989) "On the ionospheric effects of asthenospheric earthquakes", Phys. Earth Planet. Int., 57, pp 82.

13. Fraser-Smith A.C., Bernardi A., McGill P.R.,Ladd M.E., Helliwell R.A. and Villard Jr A.D., (1990) "Low frequency field measurements near the epicenter of the Ms=7.1 Loma Prieta earthquake", J. Geophys. Res. Lett., 7, pp 1465-1468.

14. Fujinawa Y. and Takahashi K., (1990) "Emissions of electromagnetic radiations preceding the Ito seismic swarm of 1989", Nature, 347, pp 376-378.

15. Fujinawa Y. and Takahashi K., (1994) "Electromagnetc phenomena related to earthquake prediction", Ed. Hayakawa M. and Fujinawa Y., Terra Sci. Pub. Co. Tokyo, 131.

16. Gokhberg M.B., Morgounov V.A., Yoshino T. and Tomizawa I., (1982) "Experimental Measurement of Electromagnetic Emissions Possibly Related to Earthquakes in Japan", J. Geophys. Res., 87, pp 7824-7828.

17. Gokhberg M.B., Morgounov V.A and Pokhotelov O.A., (1995) "Earthquake prediction: Seism electromagnetic phenomena", Reading Philadelphia, Gordon and Breach Science Publishers, pp 287.

18. Gotoh K., Akinaga Y., Hayakawa M. and Hattori K., (2002) "Principal component analysis of ULF geomagnetic data for Izu island earthquake in July 2000",J. Atmos. Electr., 22, pp 1-12.

19. Hattori K., Akinaga Y., Hayakawa M., Yumoto K., Nagao T. and Uyeda S., (2002) "ULF magnetic anomaly preceding the 1997 Kagoshima earthquake", In Seismo Electromagnetics: Lithosphere-Atmosphere-Ionosphere Coupling; Hayakawa M., Molchanov O.A., Eds.; Terra Pub. Tokyo, pp 19-28.

20. Hayakawa M. and Fujinawa Y., (1994) "Electromagnetic Phenomena related to earthquake prediction", Terra. Pub. Tokyo.

21. Hayakawa M., Kawate R., Molchanov O.A. and Kiyohumi Y., (1996) "Results of ultra low frequency magnetic field measurements during the Guam earthquake of 8 August 1993", J. Geophys. Res. Lett., Vol. 23, pp 241-244.

22. Hayakawa M. and Molchanov O.A., [Eds.], (2002) "Seismo Electromagnetics, Lithosphere-Atmosphere-Ionosphere Coupling", Terra Sci. Pub. Co. Tokyo, pp 11-55.

Research article ISSN 0976 – 4380

23. Hayakawa M. and Hattori K., (2004) "Ultra low frequency electromagnetic emissions associated with earthquakes, Special report on recent progress in electromagnetic theory and its application", Inst. Electr. Engrs. Japan, Trans. Fundamentals and materials, 124, pp 1101-1108.

24. Hayakawa M., Hattori K. and Ohta K., (2007) "Monitoring of ULF (ultra-low frequency) geomagnetic variations associated with earthquakes", Sensors, 7, pp 1108-1122.

25. Huang Q., (2004) "Seismicity pattern changes prior to large earthquakes- an approach of the RTL algorithm", TAQ, 15(33), pp 469-491.

26. Ismaguilov V., Kopytenko Y., Hattori K. and Hayakawa M., (2003) "Variations of phase velocity and gradient values of ULF geomagnetic disturbances connected with the Izu strong earthquake", Natural Hazards and Earth System Sci., 3, pp 211-215.

27. Kamogawa M. and Ohtsuki Y.H., (1999) "Plasmon model for origin of earthquake related electromagnetic wave noises", Proc. Japan Acad. Ser. B, Vol. 75(B), pp 186-189.

28. Kushwah V., Singh V. and Singh B., (2007) "Ultra low frequency (ULF) amplitude anomalies associated with recent Pakistan earthquake of 8 October, 2005", J. Ind. Geophys. Union, 11, pp 197-207.

29. Kopytenko Y.A., Matiashvili T.G.,Voronov P.M., Kopytenko F.A. and Molchanov O.A., (1990) "Ultra low frequency emissions associated with Spitak earthquake and following aftershock activity using geomagnetic pulsation data at observatories Dusheti and Vordziya ", Preprint of IZMIRAN, N3(888).

30. Kopytenko Y., Ismagilov V., Hayakawa M., Smirnova N., Troyan V. and Peterson T., (2001) "Investigation of ULF electromagnetic phenomena related to earthquakes: Contemporary achievement and the perspective", Ann. Geofis, 44, pp 325-334.

31. Liperovsky V.A., Gladyshev V.A., Shalimov S.L., (1991) "Lithosphere ionosphere connections before earthquakes", Physics of Solid Earth, 3, pp 26-35.

32. Liu J.Y., Chen Y.I., Jhuang H.K. and Lin Y.H., (2004) "Ionospheric foF2 and TEC anomalous days associated with M=5.0 earthquakes in Taiwan during 1997-1999" TAQ, 15, pp 371-383.

33. Matsu'ura M., Kataoka H. and Shibazaki B., (1992) "Slip-dependent friction law and nucleation processes in earthquake rupture", Tectonophysics, 211, pp 135-148.

Research article ISSN 0976 – 4380

34. Molchanov O.A., (1994) "Generation of electromagnetic emissions by micro fracturing", Journal of Geophysical Research Letters, 22, pp 3091-3094.

35. Molchanov O.A., Hayakawa M. and Rafalsky V.A., (1995) "Penetration characteristics of electromagnetic emissions fro an underground seismic source into atmosphere, ionosphere and magnetosphere", J. Geophys. Res., 100, pp 1691-1712.

36. Molchanov O.A. and Hayakawa M., (1998) "On the generation mechanism of ULF seismogenic electromagnetic emissions", Phys. Of Earth Planet Int., 105, pp 201-210.

37. Moore G.W., (1964) "Magnetic disturbances preceding the 1964 Alaska earthquake", Nature, 203, pp 508-509.

38. Nitsan U., (1977) "Electromagnetic Emission Accompanying Fracture of Quartz-Bearing Rocks", J. Geophys. Res. Let., 4, pp 333-336.

39. Ohta K., Watanabe N. and Hayakawa M., (2005) "The observation of ULF emissions at Nakatsugawa in possible association with the 2004 Mid Niigata prefecture earthquake", Earth Planets Space, 57, pp 1103-1108.

40. Parrot M. et al., (1993) "High frequency seismo-electromagnetic effects", Phys. Earth Planet Int., 77, pp 65-83.

41. Parrot M., (1994) "Study of ELF/VLF emissions recorded by a low latitude satellite during seismic events", Journal of Geophysical Research, 99, pp 23339-23347.

42. Parrot M., (1995) "Use of satellites to detect electromagnetic effects", Adv. Space Research, Vol. 15, pp 1127-1135.

43. Parrot, M.,(1993) "Statistical study of ELF/VLF emissions recorded by a low-altitude satellite during seismic events", J. Geophys. Res., 99, pp 23339–23347.

44. Parrot M. and Hobara. Y., (2005) "Ionospheric perturbations linked to a very powerful seismic event", J. Atmos. Sol-Terr. Phys., Vol. 67, pp 677–685.

45. Parrot M., Berthelier J.J, Lebreton J.P., Sauvard J.A., Santolik O. and Bleck J., (2006) "Examples of unusual ionospheric observations made by DEMETER satellite over seismic regions", Physics and Chemistry of the Earth, 31, pp 486-495.

46. Pulinets S.A., Boyarchuk K.A., Lomonosov A.M., Khegai V.V. and Liu J.Y., (2006) "Ionospheric precursors to earthquakes: a preliminary analysis of the foF2 critical frequencies at Chung-Li ground based station for vertical sounding of the

Research article ISSN 0976 – 4380

ionosphere (Taiwan Island)", Journal of Geomagnetism and Aeronomy, 42, pp 508-513.

47. Pulinets S., (2004) "Ionospheric precursors of earthquakes: recent advance in theory and practical applications", TAQ, 15 (3), pp 445-467.

48. Qian S., Hao J., Zhou J. and Gao J., (2002) "In Seismo-Electromagnetics: Litosphere-Atmosphere-Ionospheric Coupling" Ed. Hayakawa M., and Molchanov A., Terra Scientific Pub. Co. Tokyo, pp 19-53.

49. Rodger C.G., Dowden R.L. and Thomson N.R., (1996) "A search for ELF/ VLF activity associated with earthquakes using ISIS satellite data", J. Geophys. Res., 101, pp 13369-78.

50. Schekotov A., Molchanov O.A., Yagova N., Fedorov E., Chebrov V., Sinitsin V., Gordeev E., Belyaev G. and Hayakawa M., (2006) "Seismic activity in kamchatka and the parameters of natural ULF/ELF emissions", Physics of Auroral Phenomena, Proc. XXIX Annual Seminar, Apatity, pp 161-164.

51. Shalimov S.L. and Gokhberg M.B., (1998) "Lithosphere-Ionosphere coupling mechanism and its application to the earthquake in Iran on June 20, 1990: Interpretation of its ionospheric effects", J. Earthq. Pred. Res., 7, pp 98-111.

52. Singh B., Kushwah V., Singh O.P., Lakshmi D.R. and Reddy B.M., (2004) "Ionospheric perturbations caused by some major earthquakes in India", Physics and Chemistry of Earth, 29, pp 537-550.

53. Sobolev, G. A. and Husamiddinov, S. S.,(1985) "Pulsed electromagnetic Earth and ionosphere field disturbances accompanying strong Earthquakes", Earthquake Prediction Res., 3, pp 33–41.

54. Yamada I., Matsuda K. and Mizutani H.,(1989) "Electromagnetic and acoustic emission associated with rock fracture", Phys. Earth Planet Int., 57, pp 157-168.

55. Yuen P.F., Weaver P.F, Suzuki R.K, and Furumoto A.S., (1969) "Continuous traveling coupling between seismic waves and the ionosphere evident in May 1968 Japan earthquake data", J. Geophys. Res., 74, pp 2256-2264.