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Analysis of Atmospheric Precursor Anomalies Associated with Earthquake Events: Role of Machine Learning

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Abstract

This paper investigates the signature effects of earthquake (EQ) seismic activities on the lower atmospheric levels mainly in the troposphere region. Significant changes and anomalies in temperature, relative humidity, and radio refractive index profiles are observed in most of these seismic events prior to the impending event and after the event, thereby providing a precursor method to predict the occurrence of EQ in the concerned zones. Temperature and relative humidity anomalies with their analysis using electromagnetic signals have been considered in this review work pertaining to the field of communication engineering. In this context, a better understanding of the precursory signals involving seismic complex dynamics based on tropospheric conditions associated with such devastating events and prediction with machine learning knowledge is very important.

Keywords - Signature effect, anomaly, precursor, Radio refractive index, EQ.

Introduction

Earthquakes (EQ) are considered to be one of the worst natural catastrophes leading to immense irreparable loss to life, property of an individual and to the society. It is a kind of seismic activity where sudden energy is released in the earth's crust in the form of seismic waves. These waves travel through the interior of the earth leaving the focus like body waves or may spread from the epicenter in the form of surface waves. Tectonic shifts in the lithosphere, volcanic and surface effects are the prominent factors behind such a hazard. This seismic activity is assessed according to the frequency, type and magnitude of the event. In the past years, several techniques have been employed to specify the time, location and magnitude of the EQ within stated limits. EQ precursor indicates the approach of the event. Some commonly used earthquake precursor techniques are listed below:-

i) Sensing of tectonic plate movement.

ii) Electro-sensitivity experiments and extraction of seismic signal.

iii) Reverse tracing of precursor.

iv) Radio wave techniques using atmospheric studies.

Various other precursor methods including animal behavior and geochemical observations have been studied leading to the prediction of seismic event in the faulty zones [1]. However, the prediction of EQ is of immense challenge which requires modern technology and high-resolution data. Recognizable precursors along with proper detection of anomalies are not precise enough to predict the occurrence of the EQ event. This paper discusses about the few observations based on the lower atmospheric parameters and how the characteristic modification in the parameter profile can possibly lead to the indication of the forthcoming disaster. Understanding this fundamental connection between the nature of EQ precursor and the EQ event will definitely contribute to EQ hazard reduction that will have an enormous impact, contributing to both humanitarian and socio-economic aspect [2].Data mining along with machine learning techniques can pave the way for better prediction model so as to minimize such havoc.

Signature Effect on Troposphere

The troposphere is the lowest layer of our atmosphere starting at ground level, which extends upward to about 10-12 kms above sea level. Air pressure drops and temperature gets colder according to height at the typical rate of 6.5^{0}C/km. In this paper, anomalies are observed for important parameters like temperature profile, relative humidity and radio refractive index of the lower atmosphere region just few days prior to the event and its repercussion.

Consistent efforts are being made to investigate a possible correlation between atmospheric parameter observation and EQ events, which would have an impact on our further understanding of the physics of EQ and the phenomena related to their energy release [1-3].Three different physical parameters are studied characterizing the state of the atmosphere during the periods associated with the major earthquake events, having magnitude greater than 6 (M>6).Those are mainly:-

1. Temperature profile.
2. Humidity profile.
3. Radio refractive index and Infra-Red (IR) emissions.

The sudden deviation of atmospheric parameters associated with the EQ event is commonly termed as the signature effect of the seismic activity on lower atmospheric profile [3-4].

Effect on Temperature Profile

Normally in the troposphere the air pressure and air density decreases with increasing altitude. EQ events are accompanied by strong gravity waves which interfere with the normal temperature profile of the troposphere. Few days before the occurrence of any seismic activity in a particular fault zone, the tropopause level temperature rises. The temperature profile variation can be observed using a Radiosonde or GPS data extended over a period of 3-4 months prior to the EQ event, as the case may be.

Furthermore, the gravity waves have the tendency to move upwards in the lower atmosphere levels thereby causing lower tropospheric temperature profile to deviate unexpectedly. This temperature variation might indicate about the impending EQ event. As radon gas is emitted from underground, the increase of the temperature is marked immediately on the ground surface region. Temperature difference between faults area and far from the faults leads to horizontal air movements, air mixture and air temperature rise over all around the EQ preparation zone, leading to thermal anomaly [4-6].Close examination of the precursor anomalies as observed from remote sensing measurements for the EQ preparatory zones indicate the strong effect of air ionization on the thermal balance of the boundary layer of the atmosphere.

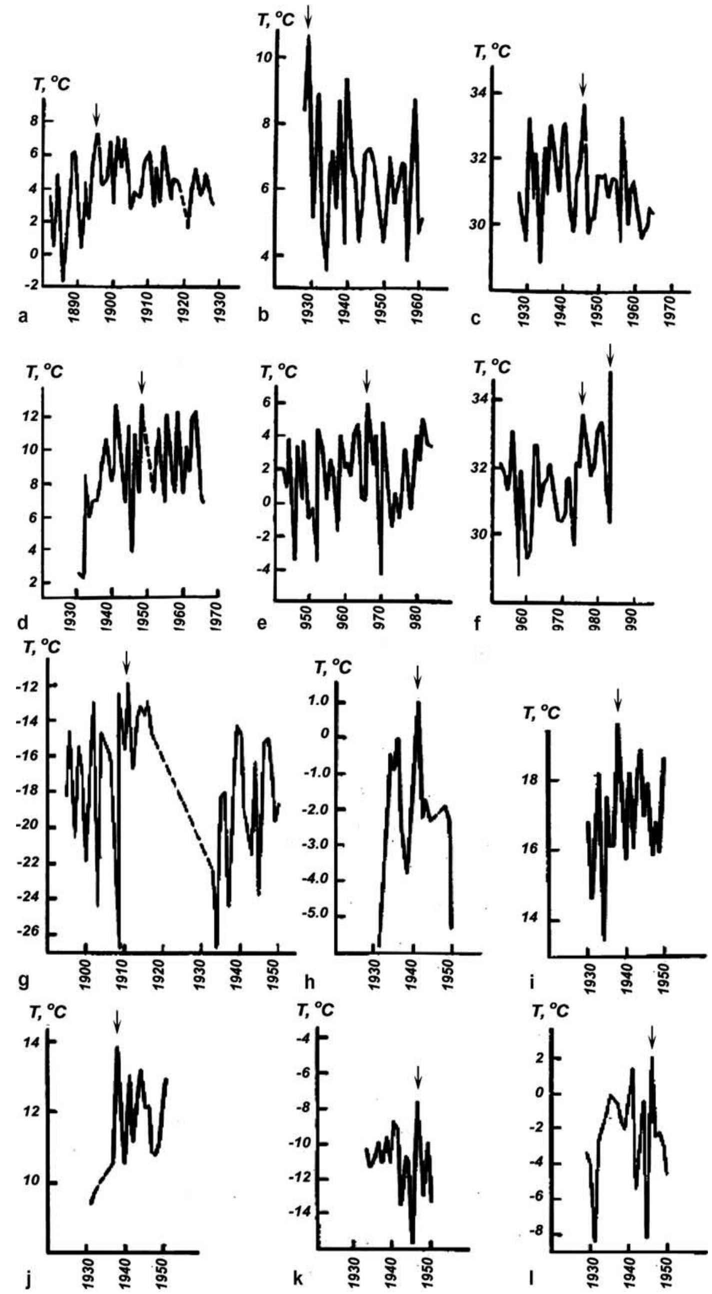

Fig. 1 shows rise in air temperature as strong precursor anomaly is observed for various stations. Results show that within interval of tens of years the mean monthly temperature for the EQ year in all cases is anomalously high [6].

Fig.1. Air temperature rise in the multi-year regime as precursor anomalies of strong EQ (data from the meteorological stations close to the epicenter): (a) Krasnovodsk earthquake; (b) German earthquake; (c) Kazandzhik earthquake; (d) Ashkhabad 1948 earthquake; (e) Tashkent earthquake; (f) Gazly 1976 and 1984 earthquakes; (g) Sarez earthquake; (h) Garm earthquake; (i, j) Kemine-Chuy EQ, average monthly temperature in May at the Tokmak meteorological station (i) and the Novorossiyka station (j); (k, 1)

Chatkal average monthly temperatures for February at the Chatkal (k) and the Toe River Mouth (l) meteorological stations.

Similar observation is done with Nepal Gorkha EQ (latitude and longitude positions are 28.1^0N & 103.7^0W respectively). The event took place on 25th April, 2015 with magnitude M=7.8. Again on May 12, 2015 second seismic shock was witnessed in Nepal with M=7.3. During their occurrences, abrupt increase in greenhouse gases like CO2, CH4, H2 etc., and enhancement of radon emanations were observed leading to huge latent heat release .The data collected from climate data online during April in the year 2015 for Kathmandu region shows rise in air temperature just few days prior to the EQ event [9].

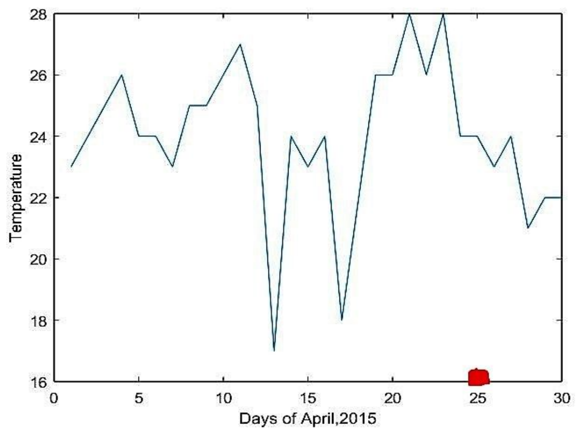

Fig.2. Variation of average air temperature for Kathmandu Gorkha EQ for the month of April,2015. Dotted mark indicates the occurrence of the EQ event.

From the above Fig.2, it is observed that 4-5 days before the EQ event there is sharp increase in air temperature profile, that could possibly be one important precursor information indicating about the catastrophe.

Effect on Humidity Profile

The possible EQ zones release huge amounts of radon causing increase in the ionization intensity of the lower atmospheric levels. The water vapor molecules adhere to these ions leading to the formation of light and heavy ions or aerosols. Water vapor attachment to these ions decreases the free water vapor content in air, and so relative humidity decreases accordingly. Relative humidity is inversely proportional to the water holding capacity of the air, and when the air is dry then it decreases. In this entire process, large amount of latent heat is released leading to thermal anomalies in the lower atmosphere. Consequently, change in the relative humidity parameter is another important precursor anomaly associated with the seismic event [3,6].

Value	Temperature Profile	Humidity Profile

High	28^0C(21st Apr,2015)	100%(4th Apr,2015)
Low	10 ^{0} C(5TH Apr,2015)	21%(23rd Apr,2015)
Average for the month	18 ^{0}C	71%

Table 1: Climate Profile (April, 2015) for Nepal EQ

From Table 1, it is observed that temperature is maximum on April 21, 2015.Humidity level is low few days just before the impending EQ event i.e., on April 23, 2015, indicating as prominent precursor anomalies for the Nepal zone EQ.

Effect on Radio Refractive Index and IR Emission

The troposphere also causes bending of Line of Sight (LOS) path of EM waves. The effective limit to the path of a signal that propagates through the troposphere is determined by the Earth's curvature, known as the LOS path or popularly radio horizon. However, this horizon does not remain constant, and the major influence on LOS propagation comes from changes of the refractive index (n). The humidity of the troposphere modifies this parameter, but the variations are very small and this is designated by a factor N = (n - 1) x10^6, called as radio refractive index (RRI) or radio refractivity and its gradient is denoted by (dN/dh) with respect to height (h). The atmospheric radio refractive index modifies and thereby decreases the gradient of radio refractive index parameter (dN/dh) few days prior to the EQ event. When (dN/dh) decreases rapidly then atmospheric ducts are formed, allowing the wave to reach beyond the LOS limit.

Modification in atmospheric refractive index followed by drop in relative humidity levels above the epicenter region few days prior to the EQ event could possibly be another signature effect of the alarming event. Temperature rise and drop in relative humidity often accompany it [5-7].

Additionally, increased ionization intensity of the lower atmosphere gives rise to large number of aerosols which are both positively and negatively charged. Electric field is generated by charge separation in the atmosphere which further tends to accelerate the charged particles. This electron energy is sufficient to cause excitation and further emission of quanta of energy in the Infra red(IR) region, which particularly is due to the excitation of CH_4,CO,CO_2,N_2O and O_3 molecules, occurring in the lower atmosphere levels during earthquake preparation times [7-10].

There is increase in LOS due to change in radio refractive index with respect to distance. This peculiar anomalous condition happens when the refractive index decreases with height much more rapidly than the normal lapse rate, forming atmospheric ducts, where a trapped wave can propagate in a waveguide mode, extending the LOS limit. Atmospheric stratification and permittivity changes cause the electromagnetic waves to bend more [7].

Conclusion

Significant changes are observed in the temperature, humidity and refractivity gradient profiles prior to the seismic activity or EQ event. But proper identification of anomalies should be done based on long term regional analysis to eliminate subjectivity. Statistical evidence for a correlation is lacking as the pattern of such precursors may vary from one EQ to another. The probability of occurrence has to be determined dealing with parameters having adequate precision, reliability and accuracy so as to minimize the aftermath of such vulnerable havoc. There can be strong heterogeneity and temporal modifications in the atmospheric parameters. Furthermore, local seasonal changes, instrumentation errors or background noise must be filtered out prior to the proper identification of the precursors. This review paper mainly takes into account atmospheric parameters like air temperature, humidity profile and changes in radio refractive index for the consideration of EQ preparation zones and their sudden deviation that form precursor anomalies for seismic zones. This incorporates the interlink between signal processing and machine learning data engineers.

In this context, attempts are being made to establish a better prediction model. It is relevant to mention in this connection that enhanced accuracy of prediction necessitates use of advanced machine learning algorithms which generates scope for quantification of variation of atmospheric parameters related to earthquake.

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