

Wavelet Characterization of Seismicity and Geomagnetic Coupling at Coastal Regions of Pakistan

Syed M. Haroon Rashid, M. Ayub Khan Yousufzai* and Faisal Ahmed Khan Afridi

Institute of Space & Planetary Astrophysics, University of Karachi, Karachi-75270, Pakistan

Abstract: Earthquake recurrence is depicted on the basis of the time following subsequent seasons at the coastal regions of Pakistan. Recurrence time for intricate shock waves is simulated by using earth positions at equinoxes and perihelion-aphelion positions of the earth from the Sun. In connection to the spatial and temporal behavior of earth, the external geomagnetic variation is significant not only influenced by the distances between the Sun and earth and annual revolving period of earth around the Sun at heliocentric path but also affected by a lunar revolving period on an elliptical path around the earth. The Apparent path of the Sun during the year where earth is the center of the celestial sphere and relative to earth, the Sun appears on ecliptic sphere which intersects the celestial equator in two points known as the vernal equinox of 21st march and autumn equinox of 21st September. The perihelion position on earth is nearest to the Sun and aphelion is the furthest position of the earth from the Sun, these are empirically distributed on the basis of mutual interaction. The seasonal effects are recognized by the wavelet characterization on maximum amplitudes of shock waves with reference to vernal – autumn equinoxes of distributed perihelion-aphelion periods. The seasonal period of geomagnetic seismicity is a manifestation of the mean time between earthquakes within a specified region where many faults are activated. The cyclic nature of earthquakes and geomagnetic influences on seismic waves by stress-strain tectonic process and releasing energy for the relaxation mechanism are experienced in nature, therefore the issues relevant to their aphelion – perihelion periodicities, influential conditions of geomagnetic instability and their coupling for shock waves propagation are tackled by the wavelet applications.

Keywords: Seismicity, Geomagnetism, Equinoxes, Perihelion-aphelion, Liquefaction.

INTRODUCTION

The earth behaves as a great magnet and its magnetic field extends from the core out into space where it creates the tear-shaped activity in the solar wind known as the magnetosphere. A major part of the Earth's field more than 90%, the main field is originated by magneto-hydrodynamic process in the core. Temporal and spatial variations superimposed on the main field are manifestations of the external time variable field and the crustal field. Temporal variations revealed by continuous magnetic records, are attributable to magnetospheric and ionospheric currents. Some variation exhibit well-defined periodicities, others are seen as irregular disturbances. The dynamic range of the time variable field is extremely large extending from decades of solar cycle to milliseconds of ELF pulsations. Amplitudes are similarly variable, ranging from about 5×10^3 nT of intense magnetic storm to less than 10^{-2} nT of Pcl micro-pulsations. In comparison with other higher frequency ranges, ULF has an advantage of propagation in the crust due to skin depth. Significantly high instability index in ULF geomagnetic data shows the relationship with the occurrence of large earthquakes and intense seismic clusters [1].

As far as concern to any magnetic measurement, it contains contributions from the main field, the external field and the crustal field. One further, but less tangible contribution is particularly relevant in the field of modern geomagnetic measurements. A seismic electric signals (SES) activity and the research in the same field can give a clue about a gradually increasing stress in the focal region of an earthquake in the future. If this stress reaches a critical value, a cooperative orientation of the electric dipoles which are present in the focal area due to lattice imperfections in the ionic constituents of the rocks, is attained. This leads to the emission of a transient electric signal that constitutes an SES and its cooperativity is a hallmark of criticality [2].

The variation of external magnetic fields induces currents in conductive rocks, thereby generating secondary magnetic fields. The recorded time variable field at a measurement site, therefore, combines an inducing and an induced component, so that the measurement contains information related to the physical properties of the underlying rocks and geological structures. The relationship of strong earthquakes with magnetic storms has been noticed long ago. However, it is hard to reveal the features concerned with seismic activity because of geomagnetic disturbances heterogeneity. A lot of research is conducted to find dependencies between geomagnetic activity and earthquake characteristics relevant to probability, magnitude and depth with the purpose of their possible prognostication.

*Address correspondence to this author at the Institute of Space & Planetary Astrophysics, University of Karachi, Karachi-75270, Pakistan; Tel: 02134112410; Mob: 03323688972; E-mail: ayubzai@yahoo.com

The method is used for assessment by distinguishing the shock waves on the basis of documentation from the vernal equinox period to autumn equinox period and vice versa. It is one of the reasonable methods for assessment of geomagnetic variations in somehow stationary seasonal periodic intervals and non stationary seismicity pattern. It depends on distances from Sun to earth, though the earth continuous revolving path of orbit shows a stationary behavior. Hence, the periods are used for analysis with approximately 100 years of recurrence time generating seismicity patterns of coastal regions. Data is acquired by geographical coordinates of latitude from 23° to 28° and longitude from 62° to 71° . The positions of 135 epicentral magnitudes are categorized on the basis of aphelion and perihelion periods.

Seasonal Characteristics of Seismicity Pattern

The earth is the center of the celestial sphere and relative to earth; the Sun appears on an ecliptic sphere with its apparent path of two intersectional points known as the vernal equinox of 21st march and autumn equinox of 21st September at the celestial equator of the earth. The sun's declination in the North Pole of equator increases from 0° about March 21 to a maximum of 23° 27' about June 21, which is called the summer solstice. Similarly, the Sun about December 21 has its greatest southerly declination - 23° 27' is called the winter solstice.

Moreover, the earth revolves around the sun at elliptic plane from west to east direction. In perihelion position, earth is nearest to the Sun whereas aphelion is the furthest position of the earth from the Sun. The length of the semi-major axis is denoted by "a" and perpendicular length from semi-major axis are known as semi-minor axis, denoted by "b". The ratio between the half of semi-major axis and position of Sun distance from this half-length point on the semi-major axis is called the eccentricity which is denoted by "e" the semi-minor axis b can be expressed in terms of 'a' and 'e' by the equation :

$$b^2 = a^2(1-e^2)$$

Where the perihelion distance is $a(1-e)$ and the aphelion distance is $a(1+e)$. The product of the linear velocities at perihelion and aphelion is independent of the eccentricity of the orbit. In an aphelion, velocity is minimum with maximum radius of earth motion, whereas the maximum velocity with least radius of earth motion is recorded in perihelion.

It is documented that the gravitational attraction of the planets on the earth, the elements of the earth's orbit are not quite constant. In particular, the longitude of perihelion undergoes small changes. The interval between two successive passages of the earth, in its orbit through perihelion or the interval between two successive passages of the sun, in the apparent orbit, through perigee is called anomalistic year. The moon rotates around the earth in a plane inclined to 5 degrees and nine minutes to the ecliptic plane. The positions of the moon when it is nearest to the earth and farthest from the earth are called perigee and apogee respectively. The highest correlation of geomagnetism is observed near local midnight, while the lowest correlation is registered near the local noon. The ultra low frequency emissions are most pronounced in the late evening, night and early morning hours because of geomagnetic effects on the fractal characteristics of ultra low frequency (ULF). It is preferable hours for investigation of magneto-spheric processes, whereas the time interval near the noon, the influence of geomagnetic activity is depressed. Therefore, lithospheric process is conducted for investigation in these preferable hours. Moreover, the earthquake precursory affects on ULF emission fractal characteristics. In fact, it is most pronounced at the local noon. The system of ULF emission sources is naturally involved in the process of self organization. Such natural evolution is disturbed by changeable environmental conditions where a decreasing geomagnetic activity that means the reduction of the solar-wind driving forces.

So far as, the gravitational attraction of the earth alone is considered, when the moon's orbit would be an ellipse. Due to the gravitational influence of the sun, but a lesser degree of the planets, the elements of the orbit undergo considerable changes with an indication of perturbation. In anomalistic month, perturbations are recognized by an altering in the direction of perigee where the interval is required by the moon to move in its path around the earth from perigee to perigee. It is another reason of perturbations that the moon's ascending node has a backward movement along the elliptic, the longitude of the node decreasing at the rate of nearly 20° per annum.

The tide is the periodic rising and falling of the level of the sea caused by the gravitational attraction of the moon and the sun on the rotating earth. In semidiurnal tides, a lunar day comprises usually two high and two low tides known as spring tides and neap tides respectively. Both occur close to the period of full moon

and new moon in the first and third quarters of the moon. Whereas, in diurnal tides, water level varies sinusoidally having only one high and one low water with a small range. That is why, tides show closer to the moon as compare to the sun influences in this regard. As the lunar day is 50 meters longer than the solar day, the tides occur on the average 50 meters later each day. The water level in the sea rises and falls in a rhythmic fashion repeating periodically with the time period of 12 and ½ hours, so flood tide exposes whenever the water at a place be more above the mean sea level whereas ebb tide must be below the sea level. When the moon is at perigee, it has its greatest tide producing effects on the earth.

Geomagnetic Seismicity

The solar magnetic field is the source of the interplanetary magnetic field. The field is divided into characteristic sectors in which the magnetic polarity, directed either toward or away from the Sun, remains constant for several days at a time. The field polarity is apparently connected to the Sun, and as it rotates, the field also rotates so that the sectors and boundaries sweep past the earth. The Earth’s crust for variations in the geomagnetic field is characterized by a number of periodicities and several amplitude levels. Different sources play their roles in variations of geomagnetic dynamo, the intensity of solar activity, perturbations in the magnetosphere and ionosphere of the Earth, geodynamic processes on the crust of earth, etc. The geomagnetic variations are characterized by clearly manifested spatial inhomogeneity [3].

The Interactions between the interplanetary magnetic field and the geomagnetic field produce magnetospheric disturbances. In addition, on a statistical basis, there does appear to be a lunar modulation effect on geomagnetic activity due to the appearance of the moon with 4 degrees of the ecliptic

plane on the morning side of earth. The positions are acquired between full and the last quarter of the moon, which are explicated by the activation of magneto-hydro dynamical process. The moon interacts the Earth’s magneto tail to prop up energetic particle into the ionosphere, thereby the production of electric currents that perturb the magnetic field. In this relation to the transient induced variations, periodic components also produce a group of diurnal and semidiurnal signals such as diurnal solar variation, or a group of annual and semiannual signals such as annual geomagnetic variations caused by rock’s magnetization changes due to meteorological temperature variations [4].

DATA ANALYSIS METHODOLOGY

The statistical analysis by wavelets is required to investigate the seismicity pattern by lunar and solar activity duration with seasonal variations. By using maximum amplitudes, earthquake parameters are distributed on the basis of perihelion and aphelion periods. It is depict able for inducing phenomena of tidal forces signifying the vulnerability of liquefaction during earthquakes. The pursuit regression technique is used by approximation iteration and retained energies with some errors are determined by more than 98 % quality. Autocorrelations, plotting histograms and cumulative histograms , FFT spectrum are developed after residuals of the magnitudes of seismic events indicating geomagnetic seasonal variation as factor variable to yield the Figures 1-6. The descriptive statistics of residuals for both periods are given by Tables 1 and 2. Their means, maximum and minimum values are calculated by using bin for technical implementation. The spatial distribution of epicentral coordinates at coastal regions and distribution of events with magnitudes are shown by the result of coefficient of indices in order to explain variation of the

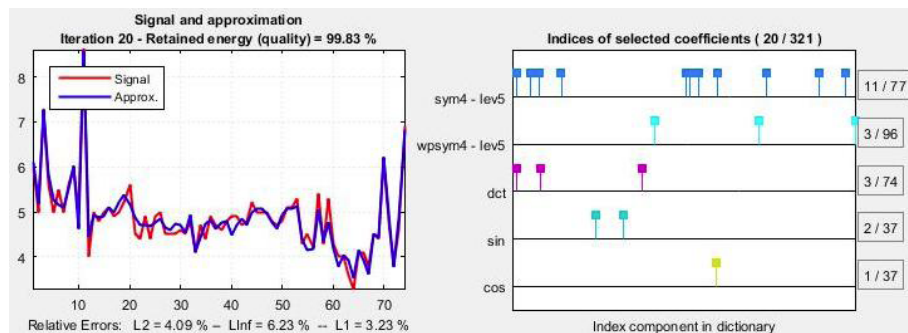


Figure 1: Pursuit Regression method for Signal and approximation signals with iteration 20 (left side) and index component in dictionary with symlet-4 level -5, wpsymlet-4 level-5, dct and sine -cosine indices of selected coefficients (20/321) of Aphelion Period.

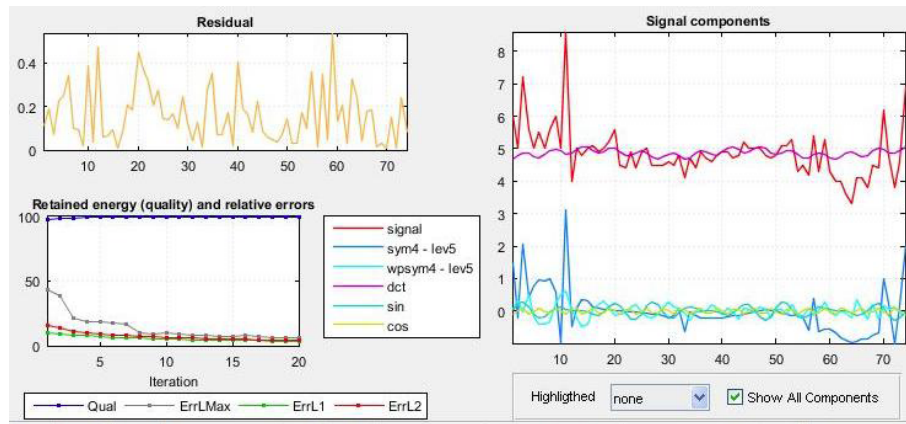


Figure 2: Aphelion Periodic Residual and retained energy quality with relative errors by using iteration20 (left side), Signal components by application of sym4-lev5, wpsym4-lev5, dct, sine and cosine simulations (right side).

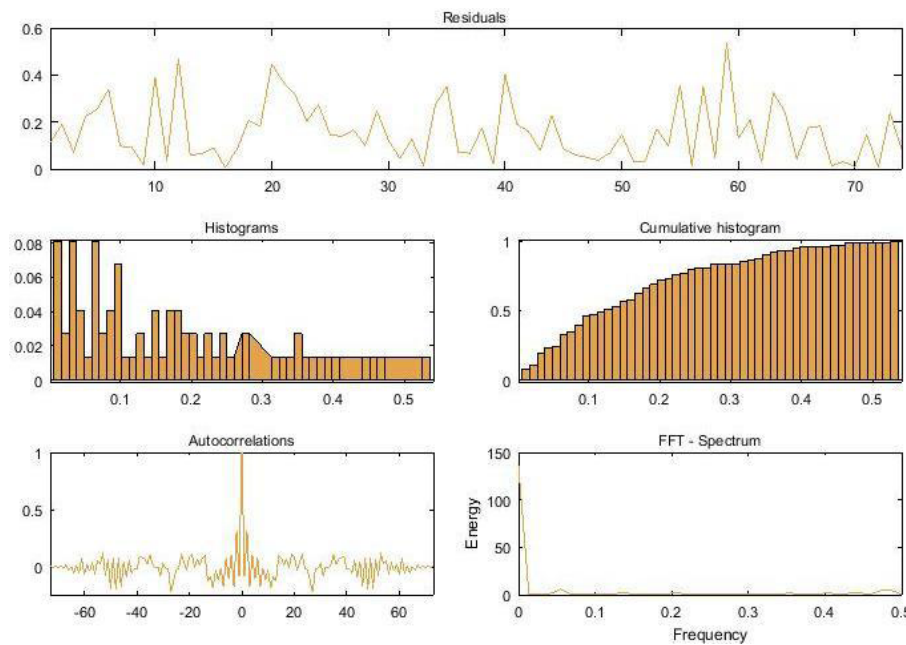


Figure 3: Signal residuals, Histograms, Cumulative Histograms, Auto correlation and FFT- Spectrum of Aphelion Period.

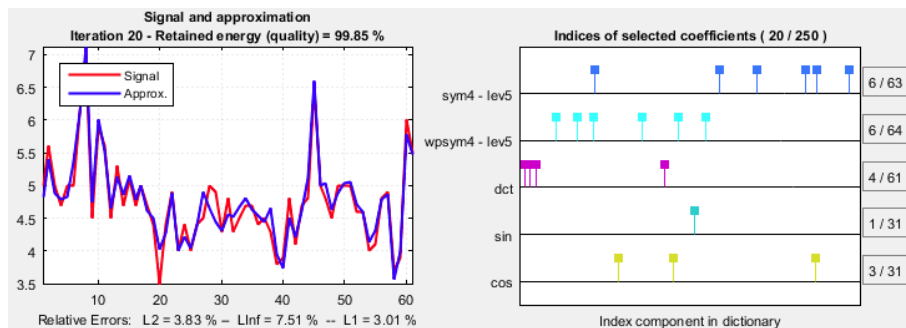


Figure 4: Pursuit Regression method for Signal and approximation signals with iteration 20 (left side) and index component in dictionary with symlet-4 level -5, wpsymlet-4 level-5, dct and sine -cosine indices of selected coefficients (20/250) of Perihelion Period.

aphelion and perihelion periods. An effective method of eliminating the contaminant signals originating from external magnetic fluctuation in the frequency range of

0.0001 to 1.0 Hz has been developed. This method is based on the interstation transfer function approach with the application of a continuous wavelet transform.

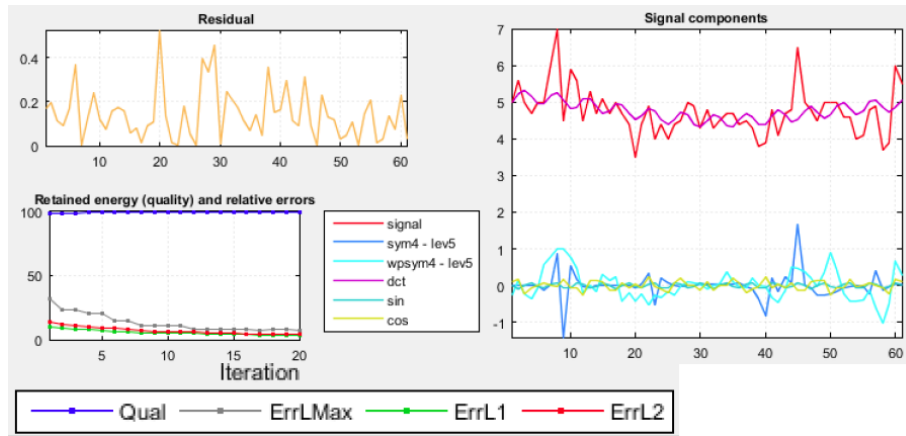


Figure 5: Perihelion Periodic Residual and retained energy quality with relative errors by using iteration20 (left side), Signal components by application of sym4-lev5, wpsym4-lev5, dct, sine and cosine simulations (right side).

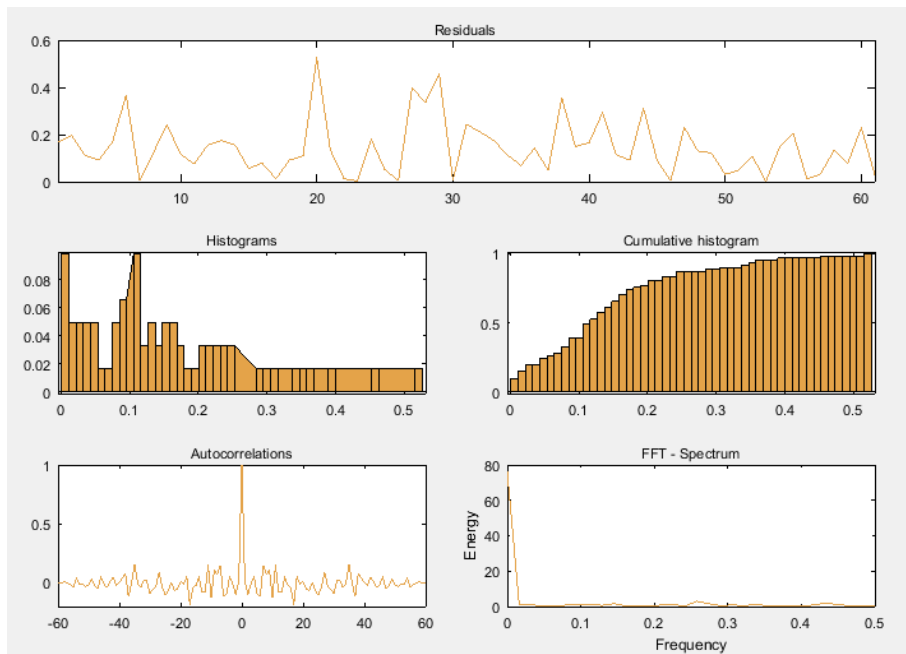


Figure 6: Signal residuals, Histograms, Cumulative Histograms, Auto correlation and FFT- Spectrum of Perihelion Period.

The analysis of ULF geomagnetic signals using empirical mode decomposition (EMD) method is carried out. The EMD-FD-based analysis is a suitable tool to detect geomagnetic anomalies related to seismic activity [5].

The Schauder basis on $[0,1]$ consists of the primitives of the Haar basis functions, the triangle functions. The autocovariance function of the wavelet-transformed time series exhibits very different behavior. Related discussions are elaborated with references to Mallat [6], Walter [7] and Wornell [8]. The early research on wavelets was generated to address related problems in geophysics, especially in turbulence, an overview in Kumar and Foufoula-Georgiou [9]. Power laws as predicted by Kolmogorov's theory 1999, such

laws describe the energy transport in the inertial range of turbulent flows. Relevant reference is a book by Frisch 1996. Both probability and time series where the problems are formulated in terms of continuous wavelet transformations [10-12]. Characterization of regularity and results concerning local regularity are illustrated by Jaffard [13-14], and Holschneider and Tchamitchian [15].

RESULTS AND DISCUSSIONS

In statistical technique, vanishing moments are significantly determined by the application of wavelet and coefficient indices are shown by projections. There is a convincing remark that a small portion of coefficients from each time series in wavelet domain is

capable of conserving the energy and turbulent fluxes. In the light of analysis, it can be notified about the liquefaction of the regions when those regions are used for constructions, including bridges, underpass tunnels, aqueduct, water main conduits, sewerage pipes and foundation and concrete pilling of high rise buildings etc.

Table 1: Descriptive Statistic of Residuals for Aphelion Period

Mean	0.157
Median	0.129
Mode	0.011
Maximum	0.535
Minimum	0.006
Range	0.529
Standard Deviation	0.126
Median Abs. Dev.	0.081
Mean Abs. Dev.	0.102
No. of Bins	50

Table 2: Descriptive Statistic of Residuals for Perihelion Period

Mean	0.143
Median	0.122
Mode	0.006
Maximum	0.526
Minimum	0.001
Range	0.525
Standard Deviation	0.117
Median Abs. Dev.	0.066
Mean Abs. Dev.	0.087
No. of Bins	50

The direction of rupture spreading and their heterogeneity produce details of high frequencies. By analyzing a random process, the heterogeneity is also defined in statistical method. In wavelet simulation of seismic magnitudes for Aphelion and Perihelion periods, residuals are determined with histograms, cumulative histogram, autocorrelation and FFT-spectrum, whereas signals of seismic maximum amplitudes are illustrated by signals of approximation iteration 20 with retained energies. In Figures 5 and 6, Fast Fourier spectrum for residuals of both periods can be observed by their retaining energies at 0.5 range of frequencies.

In matching pursuit, approximation can be improved by orthogonalizing the direction of projection with Gram-Schmidt procedure. This approach was proposed by Pati, Rezaifar, and Krishnaprasad [16]. Method of frames is given for time frequency localization [17-18]. It is one of the decided methods of matching pursuit, whereas Basis pursuit is illustrated by Chen and Donoho [19-20] and Chen [21]. Best Orthogonal basis is explained using entropy algorithms by Coifman and Wickerhauser [22].

The seismicity pattern shows very complex behavior during geomagnetic variation due to seasonal cycles. The energy released depends on the strength of faults and subduction zones even if aperiodic it must be characterized by a mean of recurrence time. Though, stressing rate is also measured by mean of recurrence time. The comparative results of perihelion and aphelion periods are collected by matching regression pursuit. The maximum amplitudes are provided for wavelet analysis retaining energies, though the graphs illustrate signals and approximations with iteration 20. Although retained energies 99.83% and 99.85% are determined for qualities. Indices of coefficients are selected from index component in the dictionary, whereas signal components are developed by using sym4 level-5, wpsym4 level5, dct, sine and cos simulations. The effect of sun on the producing tide on earth is 46% of that of the moon. Hence the tidal fluctuation will be a maximum when the sun, the moon and the earth are in the same line and on the same side of the earth. Whereas, a minimum effect related to the sun and the moon is noted, if both of them are present on the opposite side of the earth. The effect of confining tidal basin is to amplify the tidal fluctuation, if the time period is close to the natural period of oscillation hours. The perihelion period shows high temperature for generating heat on continental crust at the northern hemisphere as compare to aphelion period but its impact on surface of ocean by producing high tides. Therefore, water saturated zones are extended towards land from sea level of coastal regions. Their combined effects are determined through inferior geomagnetism of continental crust and the coupling of seismicity during propagation of longitudinal waves. But, aphelion period is more robust for geomagnetic sustainability and rheological properties of material consolidation in cold environment are associated to the propagation of shear waves during earthquakes.

Viscoelastic Process

The viscoelastic behavior is determined for the profile of seismic wave's propagation, including

longitudinal, shear waves and surface waves as well. If the plastosphere relaxation time, is shown by the relation of viscosity and rigidity $t = \eta / \mu$, this relaxation time is much less than the recurrence time T , the surface velocity field will gradually extend over the earthquake cycle as stress diffuses outward in the plastosphere. Whenever, relaxation time is more than a half of recurrence time ($t > T/2$), then this time dependent spreading becomes negligible and the velocity profile of the surface becomes similar to the deep slip model. Wave disturbances, which are naturally referred to short-term electromagnetic precursors, are characterized here by the clear structure of wave packets. Here, we can record the change in the frequency and the amplitude of vibrations at the moment a main shock arrives, which indicates the occurrence of dilatant structures in the seismic source zone, which belong to resonance formations [23]. The analysis shows the observed characteristics of the seismic propagation by inducing geomagnetic variations. The slip rates of faults are present in the seismically active zones where materials participate deeper than a few kilometers at the base of the seismogenic zone. It is observed that the shear zone reflects the plastic behavior as compared to the frictional activity. After shocks impact on the deep fault slip are recognized by undergoing strain rate with hot creeping. The curve of the surface deformation with time decay is appeared to be a quite similar in frictional and plastic behaviors. Moreover, it is significant that a crustal rock loses their magnetization at the Curie point temperature, and their ability to generate detectable magnetic anomalies is disappeared and they become paramagnetic rocks. The process allows determination of the magnetic layer's at bottom, which could be either the ferromagnetic minerals pass to a paramagnetic state under the effect of increasing temperature at the depth or the depth of compositional change where magnetic rocks are replaced with non-magnetic [24]. In the library of non decimated wavelets, matching pursuit is discussed by Walden and Crisan, whereas the matching pursuit by undecimated discrete wavelet transform for arbitrary-length time series [25].

By the investigation of rheological profile, three layers of the crust are identified from top to bottom as nonmagnetic, magnetic and regressive magnetic layers. It is also found as the distribution of the geomagnetic bottom interface, identified as Curie surface which is consistent with the lower interface of the upper crust and the top interface of the middle crust of the velocity structure of the crust [26].

Earthquake - Regional Liquefaction

Earthquakes are dominantly activated by the interaction of their stress fields. These are relevant to the development of seismicity in areas by increasing coseismic stress, and seismic quiescence in stress drops shadow areas. The propagation of seismic waves is effected through water saturated zones, including water logging area and the water table potential of underground zones. Though, the coastal regions continuously fluctuate due to tidal impact on the propagation of seismic waves. In this condition, longitudinal seismic waves are allowed to travel through the zones, but impermissible for shear seismic waves. The vanishing and attenuation of seismic waves are more dominant. Although secondary waves are more responsible for producing disastrous shock waves on the surface of earth by conversion in the forms of Rayleigh and Love waves.

In lithological profile, unconsolidated materials contain uniform size of loose grain, this type of soil deposits shows high liquefaction susceptibility. Thus, water saturated in the depositions of fluvial, colluvial and aeolian environment are expected for disposing liquefaction. Coastal regions, estuarine deposits and deposition of soils in alluvial fan, alluvial plain, and terrace are more affected by liquefaction. Sedimentary facies of saturated soils, and at the depth to groundwater and either strata or country rocks of ground water table significantly show the impacts of liquefaction. By increasing groundwater depth, induced energy reflects decreasing of liquefaction. Within a few meters below the ground surface, the ground water is most commonly affected by liquefaction. But the fluctuating level of groundwater to the surface of earth activates the hazards of liquefaction at the sites. Soil deposits that are susceptible to liquefaction are formed within a relatively narrow range of geological environments [27]. The depositional environment, hydrological environment, and age of a soil deposit all contribute to its liquefaction susceptibility and geological settings [28].

Occasionally, three or more earthquakes are capable of rupturing the identical zone because the releasing energies from the cluster of microplate boundaries. Each recurrence time T is normalized by the regional average time, where the standard deviation of the recurrence time with the mean shows quasi periodic behavior. The probability function for recurrence can be appropriately determined, even in the case of the earthquake recurrence is not periodic.

The magnetic field can comprise various processes of wave propagation, which are oriented in different directions and have different amplitudes. Occasionally overlapping background signals that occur simultaneously in the sought process may shift this process in time and cause its transformation. The direct influence of the components of the seismic event vector of the magnetic field at the locations of magnetic stations is strongly non uniform [29].

In the connection to post seismic events, hydrological effects aftershock propagation in near surface sediments of Indus delta may also show the result from shaking induced diffusivity. Those regions commonly consist of shallow after slip, extending from the main rupture to the surface, where thick sediments overlie the fault while the coseismic slip terminates before reaching the surface and another condition; this is impeded in the near surface layers. Generally, cracks are exposed on the crust at all scales, their poroelastic behavior on the lithological structure produce regional poroelastic effects. If fluid diffusion takes place preceding or following earthquakes, the electro-kinetic effect induced by the fluid diffusion may give rise to a geomagnetic or geoelectric phenomenon associated with earthquakes [30].

The mechanism of earthquakes and faulting system comprise nonlinear dynamics. Though, the dynamic system is recognized by the full behavior of inhomogeneity, identification of proper friction functions and dynamic crack propagation. A quantitative basis for research on how a geomagnetic field disturbance occurs with seismic effects in the zones of tectonic structures and for the building of the corresponding models [31].

The duration of the earthquakes of a second to decades of time, are often activated by a Coulomb stress transformation. The poroelastic effect plays an important role in the delay of time for susceptible shocks, although the rate of friction may also associate with the variation of normal stress effectiveness. Whereas the threshold time for energetic structures is investigated by optimality criteria. By using the optimality criteria, both the conservation of the energies and conservation of the fluxes are included, as required in Townsend's hypothesis. The constant stress layer for the turbulent structure where turbulent fluxes do not vary by more than 10% and the decomposition of attached and detached eddy motions are recognized in stress layer.

The global thunderstorm activity prevails at higher frequencies, whereas the range of frequencies (4–6 Hz) almost indicates no significant influence of the global geomagnetic activity, so these are determined as lower frequencies. Their applications are used for the standard deviation of the ellipse (SPE) analysis of seismic and nonseismic intervals with identical seasonal distribution by excluding the possible influence of random inhomogeneity in the seasonal distribution of earthquakes [32].

The Makran coastal region is apparently a region of active subduction. The earthquakes with focal mechanism are reported from this region confirm a trench arc subduction zone along the continental margin of Makran. Oceanic lithosphere of the Arabian plate is being underthrust beneath the Makran accretionary wedge. Seismic refraction survey at Lasbella, Baluchistan conducted by the Geological survey of Pakistan was produced Refraction and profiles. Those were oriented transverse to the coastline in east and southeast directions and longitudinally oriented along the coast in a northeast direction. Identifying areas with sand lithology in terrigenous clastic depositional systems such as delta, shelf and deep sea fan are essential for understanding seismic wave's propagation through the medium. Seismic sequence and facies analysis of these features are important for developing seismicity pattern. The development of extensive mudflats on the north shore of the Gulf of Kutch and within the Rann of Kutch indicates that the transport to the southeast of silt and clay is significant. The salt covered deserts of the Rann of Kutch and the broad Gulf of kutch embayment receive their fine grained sediments from storm tide floods of the southwest monsoon after sediments are transported southeast by wave and wind induced long shore currents. The transform zone of eastern margin is formed by the Quetta Line, along which the sediments of the Khojak flysch belt come into contact by the platform of sediments in the subcontinent. This line is formed by a series of faults of different character. The Zhob thrust is extended from north to south, the Ghazaband fault, and the Ornach–Nal fault. These faults have a complex Cenozoic history, starting with obduction of ophiolite with all showing evidence of neotectonic activity. The Zhob fault is currently a thrust that brings flysch belt sediments over the ophiolite complex. The Ghazaband fault probably begins as a thrust, but the neotectonic features along its trace strongly suggest strike –slip motion. The Ghazaband fault is connected to the Ornach Nal structural line, but appears to be a complex fault set. The Khuzdar knot,

a complex of folding at the northern end of the Ornach-Nal fault, is also an expression of the structural transition from the Ghazaband to the Ornach –Nal fault lines. Neotectonic strike-slip motion is also suggested from studies of imagery.

CONCLUSION

The tectonic movements are considered as one of the causes of strain accumulation at the coastal seismic belt of Pakistan. The plate boundaries with accretion wedges are mutually activated by convergent transformation. By using the pursuit matching in the wavelet domain, it is practicable not only in the coastal regions of Pakistan, but also useful for other coastal regions of the world. The trend of the recurrence earthquakes on the basis of geomagnetic variability effects in different coastal regions. On the basis of perihelion earth's nearest position and aphelion earth's furthest position from the Sun, it is convenient for depicting evaluation about influential limits for earthquake related to either Sun spots eleven years cycle or sun flares influenced earthquakes with their recurrence time on the same earthquake prone regions. In summer solstice by increasing the temperature of the surface, the permeable and porous strata of coastal regions significantly contain water in order to provide saturated zones, though the occurrence of the viscoelastic behavior of rocks are not much favorable in the propagation of secondary seismic waves but anyhow primary waves can travel through the media. On the other condition, in winter solstice by decreasing temperature, freezing of water and also consolidation of viscoelastic materials can be more suitable for travelling secondary seismic waves. Another point of view related to the magnetism of rocks and other components in the strata is notable about the favorable condition for rocks sustaining dominant magnetic properties in the winter solstice.

ACKNOWLEDGEMENT

The authors acknowledge the assistance of personnel, who provides computational access in the preparation of this research paper, at the Institute of Space & Planetary Astrophysics (ISPA), University of Karachi, Karachi, Pakistan. The seismic data is recorded by Pakistan Meteorological Department (PMD), Geophysical Centre, Quetta, Pakistan. The generated data which provide information regarding Magnitudes not only recorded by PMD, but also quoted by the International Seismological Centre, United Kingdom.

REFERENCES

- [1] Telesca L, Hattori K. Analysis of non-uniform scaling features in ultra low frequency geomagnetic signals and correlation with seismicity. Proceedings of the IEEE International Conference on Signal Processing and Communications (ICSPC 2007), 2007: Nov 24-27; Dubai, United Arab Emirates; 2007: p. 488-491.
<https://doi.org/10.1109/ICSPC.2007.4728362>
- [2] Skordas ES, Sarlis NV. On the anomalous changes of seismicity and geomagnetic field prior to the 2011 Mw 9.0 Tohoku earthquake. *J Asian Earth Sci* 2014; 80: 161-164.
<https://doi.org/10.1016/j.jseaes.2013.11.008>
- [3] Adushkin VV, Ryabova SA, Spivaka AA, Kharlamov VA. Response of the seismic background to geomagnetic variations. *Doklady Earth Sci* 2012; 444(1): 642-646.
<https://doi.org/10.1134/S10283334X12050157>
- [4] Currentia G, Negroa CD, Lapennab V, Telesca L. Scaling characteristics of local geomagnetic field and seismicity at Etna volcano and their dynamics in relation to the eruptive activity. *Earth Planet Sci Lett* 2005; 235: 96-106.
<https://doi.org/10.1016/j.epsl.2005.02.043>
- [5] Sanchez JPA, Alegria OC, Rodriguez MV, Abeyro JAC, Almaraz JRM, Gonzalez AD. Detection of ULF geomagnetic anomalies associated to seismic activity using EMD method and fractal dimension theory. *IEEE Lat Am Transac* Feb. 2017; 15(2): 197-205.
<https://doi.org/10.1109/TLA.2017.7854612>
- [6] Mallat SG. *A wavelet tour of signal processing*. San Diego, USA: Academic Press; 1998.
- [7] Walter GG. *Wavelets and other Orthogonal systems with applications*. Florida, USA: CRC Press Inc.; 1992.
- [8] Wornell GW. *Signal processing with Fractals: A wavelet based approach*. New Jersey, USA: Prentice Hall; 1996.
- [9] Kumar P, Foufoula-Georgiou E. Wavelet analysis for geophysical applications. *Rev Geophys* 1997; 35(4): 385-412.
<https://doi.org/10.1029/97RG00427>
- [10] Cambanis S, Masry E. Wavelet approximation of deterministic and random signals: convergence properties and rates. *IEEE Trans. Inform. Theory* 1994; 40(4): 1013-1029.
<https://doi.org/10.1109/18.335971>
- [11] Cambanis S, Houdre C. On the continuous wavelet transform of second-order random processes. *IEEE Trans. Inform. Theory* 1995; 41(3): 628-642.
<https://doi.org/10.1109/18.382010>
- [12] Houdre C. Wavelets, probability and statistics: Some bridges. In J. J. Benedetto and M.W. Frazier, editors. *Wavelets: Mathematics and Applications*. Florida, USA: CRC Press Inc. 1993; p. 361-394.
- [13] Jaffard SL. Point wise smoothness, two microlocalization and wavelet coefficients. *Publ. Mat.* 1991; 35: 155-168.
https://doi.org/10.5565/PUBLMAT_35191_06
- [14] Jaffard SL. Exposans de Holder en des points donnees et coefficients d'ondellets. *C. R. Acad. Sci. Paris Ser. Mat.*, 308:79-81, 1989.
- [15] Holschneider M, Tchamitchian P. 1990 (Expose no. 8), Regularite locale de la fonction 'non differentiable de Riemann. In P.G. Lemarie, editor, *Les Ondelettes en 1989*, volume 1438 of Lecture notes in Math. Springer Verlag, New York.
- [16] Pati YC, Rezaifar R, Krishnapardas PS. Orthogonal matching pursuit: Recursive function approximation with application to wavelet decomposition. Proceedings of the 27th Asilomar Conference on Signals, Systems, and Computers; 1993: 1-3 Nov; CA, USA.
<https://doi.org/10.1109/ACSSC.1993.342465>

- [17] I. Daubechies, Time frequency localization operators: A geometric phase space approach. *IEEE Trans. Inform. Theory* 1988; 34(4): 606-612.
<https://doi.org/10.1109/18.9761>
- [18] Mallat SG, Zhang Z. Matching pursuits with time frequency dictionaries. *IEEE Trans. Inform. Theory* 1993; 41(12): 3397-3415.
<https://doi.org/10.1109/78.258082>
- [19] Chen SS, Donoho DL. Basis Pursuit. Technical report, Department of Statistics, Standford University, California, USA, 1994.
- [20] Chen SS, Donoho DL. Atomic decomposition by basis pursuit. Technical report 479, Department of Statistics, Standford University, California, USA, 1995.
- [21] Chen SS. Basis Pursuit. Ph.D. thesis, Department of Statistics, Standford University, California, USA, 1995.
- [22] Coifman RR, Wickerhauser MV. Entropy-based algorithms for best basis selection. *IEEE Trans. Inform. Theory* 1992; 38(2): 713-718.
<https://doi.org/10.1109/18.119732>
- [23] Rogozhina EA, Sobisevicha AL, Toa S, Ziao L. Instrumental observations of geomagnetic disturbances prior to seismic events in several regions of China. *Seismic Instrum* 2017; 53(1): 28-45.
<https://doi.org/10.3103/S0747923917010091>
- [24] Trifonova P, Zhelev Zh, Petrova T, Bojadgieva K. Curie point depths of Bulgarian territory inferred from geomagnetic observations and its correlation with regional thermal structure and seismicity, *Tectonophysics* 2009; 473(3-4): 362-374.
<https://doi.org/10.1016/j.tecto.2009.03.014>
- [25] Walden AT, Cristan AC. Matching pursuit by undecimated discrete wavelet transform for arbitrary-length time series. Technical Report TR -96-02, Imperial College of Science, Technology and Medicine, Statistics Section, London, U.K., 1996.
- [26] Zhao L-F, Dong B-Z, Niu X, Zhang P-Q. Research on geomagnetic tectonic characteristics of the crust in Haicheng seismic area. *ACTA Seismologica Sinica* Nov 1993; 6(4): 949-958.
<https://doi.org/10.1007/BF02651830>
- [27] Youd TL. Mapping of earthquake-induced liquefaction for seismic zonation. *Proceedings of the 4th International Conference on Seismic Zonation, Earthquake Engineering Research Institute, Stanford University*; 1: 111-147, 1991.
- [28] Youd TL, Hoose SN. Liquefaction susceptibility and geologic setting. *Proceedings of the 6th World Conference on Earthquake Engineering, New Dehli*, 3: 2189-2194, 1977.
- [29] Moskovskaya LF. Directional and correlation analysis from the geomagnetic monitoring and seismic data on the Boso Peninsula in 2000. *Izvestiya Phys Solid Earth* 2012; 48(6): 532-546.
<https://doi.org/10.1134/S1069351312060043>
- [30] Mizutani H, Ishido T. A new interpretation of magnetic field variation associated with the Matsushiro earthquakes. *J Geomag Geoelectr.* 1976; 28: 179-188.
<https://doi.org/10.5636/jgg.28.179>
- [31] Lukishov BG, Spivak AA, Ter-Semenov AA. Geomagnetic field variations in seismic waves traveling across a fault. *Doklady Earth Sci* 2012; 442(1): 135-138.
<https://doi.org/10.1134/S1028334X12010163>
- [32] Schekotov Y, Molchanov OA, Hayakawa M, Fedorov EN, Chebrov VN, Sinitsin VI, Gordeev EE, Belyaev GG, Yagova NV. ULF/ELF magnetic field variations from atmosphere induced by seismicity. *Radio Sci* Dec 2007; 42(6).
<https://doi.org/10.1029/2005RS003441>

Received on 30-10-2017

Accepted on 25-11-2017

Published on 28-12-2017

<https://doi.org/10.6000/1927-5129.2017.13.106>© 2017 Rashid *et al.*; Licensee Lifescience Global.

This is an open access article licensed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0/>) which permits unrestricted, non-commercial use, distribution and reproduction in any medium, provided the work is properly cited.