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Analysis of Correlation between Temperature Increase and Earthquake Frequency in Northern Pakistan

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Abstract. In this paper an attempt is made to analyze the correlation between temperature increase and earthquake frequency in the Northern Pakistan. The temperature data consists of decadal (1961-2000) and five year (2001-2005) averages for Gilgit, Sakardu, Chitral and Islamabad based observatories. The seismic data is of duration between 1961 and 2004.The study shows that frequency of shallow (0-80km) and intermediate (81-300km) earthquakes for magnitude 3-3.9 show gradual increase during the study period that can be correlated with temperature. On the other hand, the earthquake frequencies for magnitude 4-4.9 exhibit a net increase. During the period 2001 to 2005, the shallow earthquakes for magnitude 3-3.9 and 4-4.9 show sudden jumps in their frequencies for the month of November and the earthquakes of intermediate level (81-300km) for magnitude 3-3.9 show their highest peaks in the month of September and February. As the maximum values for average earthquake frequencies are mostly observed in the cold months, so the temperature also shows an increasing trend in the winter period.

Keywords: global warming; glacier melting; isostatic rebound; increase in seismic activity with temperature.

1. Introduction

The Global warming is becoming very much hazardous to life. This is not only changing our world's climate and economy but, it is also causing direct and indirect changes on and within the surface of the Earth. This effect is very much threatening for Northern zone of Pakistan which has glaciers spreading over a vast area (Fig. 1). Tectonically, this area is marked with numerous active faults (Fig. 2) [1]. Due to these faults, this zone is seismologically very active and experience frequent earthquakes than any where else in Pakistan. It is also affected by Global Warming, causing receding of glaciers. These glaciers weigh billions of tons which on melting can cause the crust of Northern areas to relax and rebound. As wasting ice sheets and caps unload the solid Earth, stresses released can both deform the Earth surface [2] and decompress the Earth's mantle [3].

All over the world, the last twenty years data shows a noticeable increase in the number of earthquakes per year. This is because of tremendous increase in number of seismograph stations and the improved global communications [4].

In Northern areas of Pakistan, the analytical tools such as source, stations and seismographs have remained the same from 1961 to 2005 and the data collected in this period shows increase in earthquake frequency. According to this study one of the main factors for increase in earthquake frequency can be the temperature. Increase of temperature is causing glaciers to melt thus releasing pressure on Earth below which in turn possibly rebounds, causing earthquakes [5].

In the Northern Pakistan the depth affected by enhanced earthquake frequency in correlation with temperature is probably no more than 160km [6].

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An increase in average annual mean surface temperature by 0.6^{0}C ± 0.2 ^{0}C between 1860 and 2000 and a decrease of 10% of snow cover in northern hemisphere since late 1960s has been reported [7]. It has been also predicted that the Himalayan glaciers will disappear within 40 years causing drastic changes in river flow and sever water shortages [8,9].

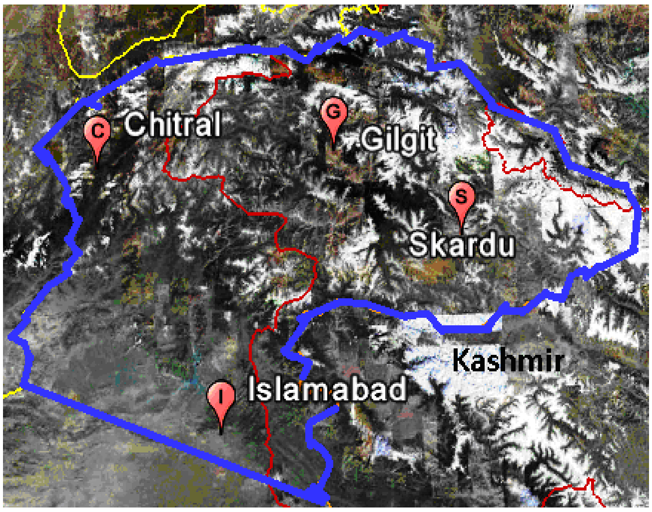

Figure 1. Map showing study area (bounded by blue line) with snow cover. The palace marks show the observatory locations.(Modified Google image)

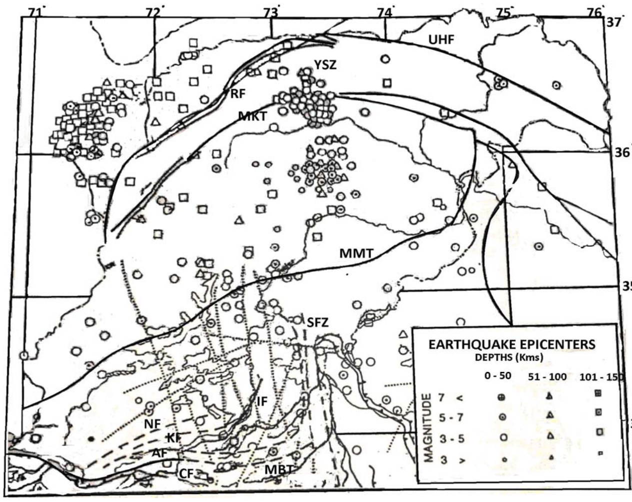

Figure 2. Seismotectonic map showing the locations of Yasin (YSN) and Hamran (HSZ) Seismic zones and Faults in the study aea. [1] UHF=Upper Hunza Fault, RF=Reshun Fault, MKT=Main. Karakoram Thrust, MMT=Main Mantle Thrust, NF=Noushera Fault,. KF=Kund Fault, AF=Attock Fault, IF=Indus Fautlt, MBT=Main Boundary Thrust

A few larger glaciers are expanding in the Karakoram and adjacent areas [10,11], however, reports also indicate that may glaciers are still losing mass [12,13]. Since 1840 most of the Himalayan glaciers have retreated more than 1200 m [14].

The annual melt water of 135 million m^3 for Hinarche Glacier in Bagrot Valley shows the magnitude of glacier runoff in such environments [15]. These differences are considered to be the result of changing trends of higher temperatures in winters and lower temperatures in summers since 1960s [16, 17]. The earth's climate model projections suggest that global surface air temperature will considerably increase in future due to radiative effects of atmospheric gases [18].

2. Material and Methods

The data used in this study contains decadal average temperatures of the period from 1961 to 2000 and a five year averages recorded from 2001 to 2005. The temperature data of Chitral observatory starts from 1971. The duration of seismic data, used in this study, is 1961 to 2004. The temperature and seismic data are provided by Pakistan Meteorological Department (PMD).

2.1 Selection of Study Area and Study Duration

The Northern Areas of Pakistan have been selected for this study because of abundant varied sized glaciers and active faults. The effects of temperature increase have been studied form 1961 to 2004. During the study period there has been no advancement in seismographs and no new seismic stations have been developed by PMD.

2.2 Temperature Study

A network of four observatories has been used (Fig. 1). The study of temperature was done by calculating the decadal and five yearly variations of average temperature during the period 1961 to 2005.

2.3 Seismological Study

The seismic data of the study area for the selected time duration was used to calculate the average earthquake frequencies. The magnitude wise study is made in detail to observe the variation in earthquake frequency in shallow (0-80km) and intermediate (81-300km) depth zones for various magnitudes. The magnitudes < 3 and > 5.9 and deep earthquakes 300km < are not considered as they do not show any significant correlation with temperature increase.

Table 1. Average monthly temperature values and increase for the period 1961-2004.

Months / Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave. Temp. in ^{0}C
1961-70	3.32	6.43	11.85	16.6	20.59	25.62	27.27	26.39	23.06	16.97	9.94	4.58	16.05
1971-80	3.65	5.53	11.06	17.26	20.99	26.18	27.3	26.24	22.45	16.91	10.53	5.55	16.14
1981-90	4.05	6.11	11.21	16.75	21.35	25.21	27.14	26.37	22.69	16.45	10.54	5.65	16.13
1991-00	3.79	6.49	11.08	16.77	21.25	25.27	27.08	26.21	22.98	16.7	10.93	6.41	16.25
2001-05	4.84	7.26	12.97	17.37	21.37	25.55	27.06	26	22.27	16.74	10.92	6.55	16.57

Table 2. Number and frequency of earthquakes for various magnitudes during the period 1961-2004.

	3-3.9 (Magnitude)		4-4.9 (Magnitude)		5-5.9 (Magnitude)		Cumulative Avg. Freq.
	Shallow (AF) 0-80 km	Intermed. 81-300 km	Shallow(AF) 0-80 km	Intermed. 81-300 km	Shallow(AF) 0-80 km	Intermed. 81-300 km	
1961-70	0	0.2	1.5	1.8	0.7	0.1	4.5 (43)
1971-80	0	1.3	6.1	2.3	0.2	0.1	12(10)
1981-90	1.5	5	8.9	6.7	0.8	0.3	23.2 ok
1991-00	6.7	16	7	6.1	0.4	0.4	37.1 (36.6)
2001-04	31	22.75	23	7.5	1.75	0.5	86.5 ok

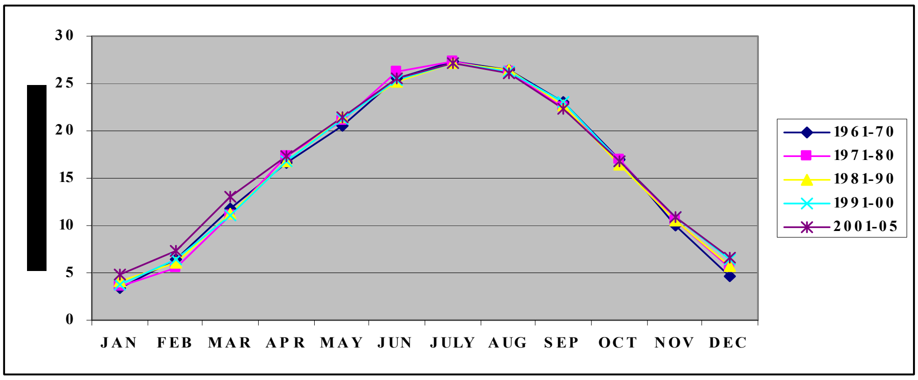

Figure 3. Shows the month wise variations in the temperature of study area

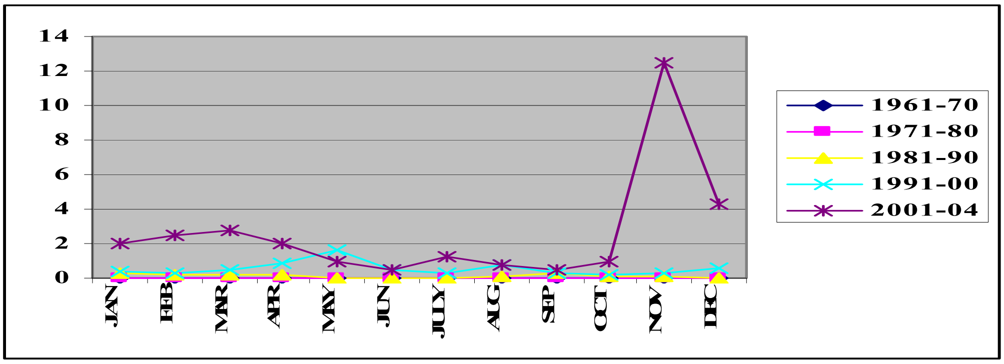

Figure 4. Shows average earthquake frequency of shallow level (0-80km) earthquakes for magnitude 3-3.9

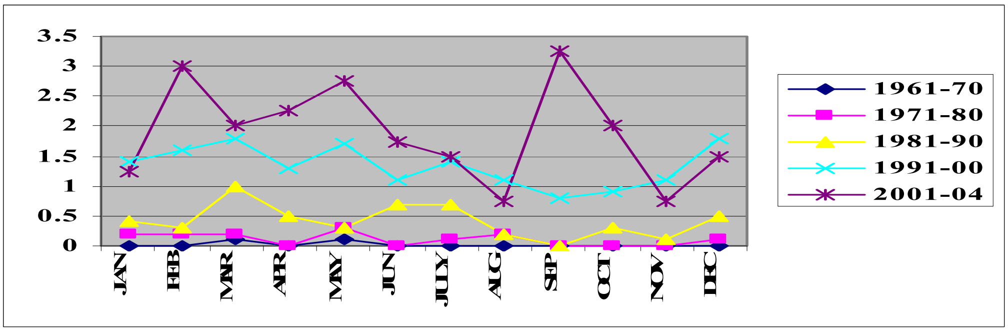

Figure 5. Shows average earthquake frequency of intermediate level (81-300km) earthquakes for magnitude 3-3.9

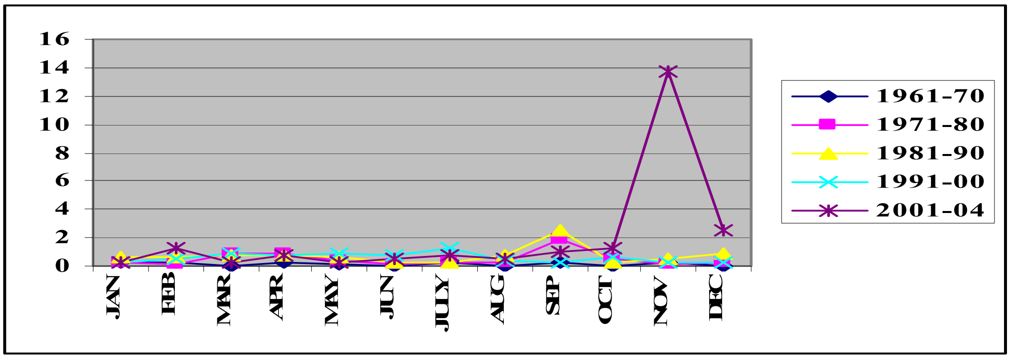

Figure 6. Shows average earthquake frequency of shallow level (0-80km) earthquakes for magnitude 4-4.9

3. Results and Discussion

In Northern areas of Pakistan, the analytical tools such as source, stations and seismographs have remained the same from 1961 to 2005 and the data collected in this period shows increase in earthquake frequency. According to this study one of the main factors for increase in earthquake frequency can be the temperature. Increase of temperature is causing glaciers to melt thus releasing pressure on Earth below which in turn possibly rebounds, causing earthquakes [5]. In the upper Indus basin, there is trend towards higher winter temperatures and lower summer temperatures [16]. In Pakistan the January temperature has increased by 0.60 ^{0}C at national level during period 1961 to 2006 [19]. The temperature of northern Pakistan has increased 0.52 ^{0}C from 1961 to 2005[6]

In the study area average temperature readings have been shown in the Table 1 and Fig. 3. Fig. 3 shows that all the lines for average temperature converge at summer periods and diverge at winter periods. It gives clue that the temperature of study area has increased in winter period and remained steady in the summer periods. It means that this increase in temperature in the winter period is probably causing the less accumulation of ice on the glaciers than their melting in the summer period [20]. The magnitude of earthquakes effected by expected isostatic rebound of earth in northern Pakistan is probably lies in the range 3 to 4.9 [21] The earthquakes for magnitude 3 to 3.9 are depicted in Fig. 4 and 5 for shallow and intermediate earthquakes respectively. These figures clearly indicate that for the magnitude 3 to 3.9 there is a clear increase in earthquake frequency with the passage of time. Where for magnitude 4 to 4.9, the gradual increase for shallow earthquake frequency is not significant except for the duration 2001 to 2004 where earthquakes in the month of November show a sudden Jump. Similarly, for 3 to 3.9 magnitude earthquakes, the highest peaks for average earthquake frequency are also observed in November for shallow and in February and September for intermediate earthquakes. The Table 1 shows that the intermediate earthquake frequency for 5 to 5.9 magnitude earthquakes shows gradual increase with the passage of time.

4. Conclusions

This study shows that the temperature of study area has increased in winters and has trend in summers. This contrasting behavior of temperature rise might be causing the less accumulation of ice on glaciers than their melting in summers. So this expected decrease in the mass of glaciers is probably producing isostatic rebound to cause the earthquakes. In correlation with the increasing temperature in the winters, the highest peaks for average earthquake frequencies are also observed.

5. References

[1] Kazmi, A.H. and Jan, M.Q. 1997. Geology and Tectonics of Pakistan . In: Neotectonics. pp. 408, 416. Graphic Publishers. Karachi.

[2] Pagli, C. and Sigmundsson, F. 2008. Will present day glacier retreat increase volcanic activity? Stress induced by recent glacier retreat and its effect on magmatism at the Vatnajökull ice cap, Iceland.Geophysical Research Letters 35: L09304.

[3] Sigvaldason, G.E., Annertz, K. and Nilsson, M. 1992. Effect of glacier loading/deloading on volcanism: postglacial volcanic production rate of the Dyngjufjöll area, central Iceland. Bulletin of Volcanology 54: 385–392

[4] (February, 2010) [online] Available: http://www.alternat1ve.com/biofuel/2008/06/19/is-global-warming-causing-increased-earth-quake-activity/#respond

[5] Usman, M., Qureshi, S.N. and Amir, N.A. Effects of Global Warming on the Frequency of Earthquakes in Northern Areas of Pakistan. 2010. Science Vision, Volume 15. Islamabad. Comsats (Accepted For Publication).

[6] Usman M., Zafar M., Amir N.A. Effects of Temperature Increase on Earthquake Frequency and Depth in Northern Pakistan. 2010.

[7] IPCC. 2001. Climate Change 2001: Synthesis report. A contribution of working groups I, II and III to the third assessment report of the Intergovernmental Panel on Climate Change. Watson RT (ed). Cambridge University Press, Cambridge.

[8] WWF. 2005. An overview of glaciers, glacier retreat, and subsequent impacts in Nepal, India and China. World Wild Life Fund, Nepal Program.

[9] Pearce, F. 1999. Flooded out: retreating glaciers spell disaster for valley communities. New Scientist 162 (2189): 18.

[10] Hewitt, K. 2005. The Karakoram Anomaly? Glacier expansion and the “elevation effect,” Karakoram Himalaya. Mountain Research and Development 25 (4):332–340. BioOne

[11] Smiraglia, C., C. Mayer, C. Mihalcea, G. Diolaiuti, M. Belò, and G. Vassena. 2007. Ongoing variations of Himalayan and Karakoram glaciers as witnesses of global changes: Recent studies of selected glaciers. Developments in Earth Surface Processes 10:235–248.

[12] Ding, Y., S. Liu, J. Li, and D. Shangguan. 2006. The retreat of glaciers in response to recent climate warming in western China. Annals of Glaciology 43:97–105.

[13] Haritashya, U. K., M. P. Bishop, J. F. Shroder, A. B. G. Bush, and H. N. N. Bulley. 2009. Space-based assessment of glacier fluctuations in the Wakhan Pamir, Afghanistan. Climatic Change 94:5–18.

[14] Ahmed, N. and Rais, Sarwar. 1998. Himalayan Glaciers. In: Climate effects and Himalaya Gaciers. pp. 60-63. New Dehli. A. P. H Pub Co.

[15] Mayer, Christoph., Lambrecht. A.,Mihalcia, C., Belo, M.,Diolaiuti, G., Smiraglia, C and Bashir, F.2010. Analysis of Glacier Melt Water in Bagrot Valley Karakoram. Mountain Research and Development 30(2). PP 169-177.International Mountain society.

[16] Archer, D. R. and H. J. Fowler. 2004. Spatial and temporal variations in precipitation in the upper Indus basin, global teleconnections and hydrological implications. Hydrology and Earth System Sciences 8:47–61.

[17] Fowler, H. J. and D. R. Archer. 2006. Conflicting signals of climatic change in the Upper Indus Basin. Journal of Climate 19:4276–4293.

[18] Delworth, T., Mahlman, J. D. and Knutson, T.R. 1999: Changes in summer temperature and heat related mortality since 1971 in North Carolina, South Finland, and Southeast England.Environ Res 91:1-7.

[19] I., Ahmad, Zhaoboo, S., Weitao, D and Ambreen, R.2010. Trend Analysis of January Temperature in Pakistan over the Period 1961-2006: Geographical Perspective.Vol. 7,Issue 3. pp.11-22. Pakistan Journal of Meteorology.Islamabad.

[20] Usman, M., Zafar M., Morata, M., Adeel, K. and Amir, N.A. A Study on Correlation between Temperature Increase and Earthquake Frequency with Emphasis on Summer and Winter Period, Northern Pakistan.2011. International Conference on Environment Science and Technology Singapore. pp 360-364.

[21] Usman, M., Zafar M., Morata, M., Bangish T and Amir, N.A. Temperature and Earthquake Frequency Correlations used as Indicators used as Indicators for Seismic Acitivity in glacial and non-glacial areas of Pakistan. American Journal of Scientific Research. Pp.88-94. Euro journals Inc.