A Study on Correlation between Temperature Increase and Earthquake Frequency with Emphasis on Winter and Summer Periods, Northern Pakistan

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Abstract—In this paper an attempt is made to study the correlation between temperature increase and earthquake frequency in Northern Pakistan during summer (May, June, July and August) and winter (November, December, January and February) periods. 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 temperature of study area has increased gradually in winter period and remained nearly steady in summer period. This increase of temperature in winters is probably causing less accumulation of ice on glaciers than their melting in summers. The expected loss in mass of glaciers is resulting in unloading phenomenon and possibly causing earthquakes. In general, both summer and winter periods show rising trends in their average earthquake frequencies, however the winter period shows a significant increase. During 2001 to 2004, the winter earthquake frequencies show about three fold increase.

Keywords—Global warming; glacier melting; isostatic rebound; increase in seismic activity with temperature; winter and summer period variations

I. INTRODUCTION

The northern Pakistan contains numerous varied size glaciers (Fig. 1) and plays a critical role in governing the economy of the country by supplying water for agriculture, hydrothermal power generation and drinking purposes. The average surface temperature of northern areas has increased by 0.52 °C during the period 1961 to 2005 [1]. This rise in temperature is probably causing the glaciers of study area to melt. As the glaciers have weigh billions of tons and their melting can cause the crust of the study area to rebound. As wasting ice sheets and caps unload the Earth, stresses released can both deform the Earth’s surface [2] and decompress the mantle [3]. The study area, marked with numerous active faults, (Fig. 2) [4] is seismologically very active and experience frequent earthquakes than any where else in Pakistan.

All over the world, the last twenty years data shows a noticeable increase in the number of earthquakes per year. This may also contributed to tremendous increase in number of seismograph stations and the improved global communications [5].

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 the study one of the main factors for this increase can be the temperature. Increase of temperature is producing earthquakes resulting from isostatic rebound of earth caused by loss in mass of glaciers [6].
Although, a few larger glaciers in the Karakoram and adjacent areas are expanding [8,9] however, most of the Himalayan glaciers have retreated more than 1200 m since 1840 [10]. It has also been predicted that the Himalayan glaciers will disappear within 40 years causing drastic changes in river flow and severe water shortages [11,12]. These differences could be the result of higher winter temperature and lower summer temperature variations [13]. 

The annual melt water of 135 million m³ for Hinarch Glacier in Bagrot Valley shows the magnitude of glacier runoff in such environments [14]. The Earth’s climate model projections suggest that global surface air temperature will considerably increase in future due to radiative effects of atmospheric gases [15].

II. MATERIAL AND METHODS

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

A. 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 (Fig. 1, 2). The effects of temperature increase on earthquake frequency 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 installed by PMD.

B. Temperature Study

A network of four observatories was used to collect temperature data (Fig. 1). The decadal and five yearly variations of average temperature during the period 1961 to 2005 were selected to study the earthquake frequency. Temperature data has also been divided into winter (November to February) and the summer (May to August) periods.

C. Seismological Study

The seismic data of the study area for the selected time duration was used to calculate the monthly average earthquake frequencies. The seismic data has also been divided into winter (November to February) and the summer (May to August) periods.

Table 1. Average Monthly and Cumulative Average Temperature Values (in °C) for the Period 1961-2005.
<table>
<thead>
<tr>
<th>Months</th>
<th>Duration</th>
<th>Jan  (AF)</th>
<th>Feb  (AF)</th>
<th>Mar  (AF)</th>
<th>Apr  (AF)</th>
<th>May  (AF)</th>
<th>Jun  (AF)</th>
<th>Jul  (AF)</th>
<th>Aug  (AF)</th>
<th>Sep  (AF)</th>
<th>Oct  (AF)</th>
<th>Nov  (AF)</th>
<th>Dec  (AF)</th>
<th>Cumulative Ave. Temp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991-00</td>
<td></td>
<td>3.79</td>
<td>6.49</td>
<td>11.08</td>
<td>16.77</td>
<td>21.25</td>
<td>25.27</td>
<td>27.08</td>
<td>26.21</td>
<td>22.98</td>
<td>16.7</td>
<td>10.93</td>
<td>6.41</td>
<td>16.25</td>
</tr>
</tbody>
</table>

Table 2. Monthly and cumulative average earthquake frequency (AF) for the period 1961-2004.
III. RESULTS AND DISCUSSION

The net surface mass balance for the glaciers is determined by changes in climate. Net surface mass balance is the sum of winter accumulation and summer losses of mass from glaciers and ice sheets. A positive mass balance value represents glacial growth whereas negative value is an indication of glacial retreat [16]. In the upper Indus basin, higher winter temperature and lower summer temperature trend is observed [13]. In Pakistan the temperature in the month of January has increased by 0.60 °C during the period 1961 to 2006 [17].

The rise of temperature is not symmetric and changes with the changing latitude and longitude of the observer. Even the same zone shows different trends in temperature increase as the season changes. Similarly, the northern Pakistan zone shows different trends in temperature increase in summer and winter periods.

In the study area, the monthly and cumulative average frequencies of earthquakes have been shown in Table 2 and Fig. 4 respectively. The monthly average temperature has been depicted in Table 1. The last column in the Table 1 shows decadal average from 1961 to 2000 and a five year average from 2001 to 2005 (Fig. 3). The temperature of study area has increased steadily in the winter period (Fig. 7). While Fig. 8 shows that the average summer temperature did not change significantly with the exception of 1971 to 1980 period, showing an increase. This leads to infer that glaciers of study area will most probably show negative net surface mass balance due to increased winter temperature and no change in summer temperatures. This negative mass balance is contributing to the phenomenon of unloading resulting in isostatic earth rebound [18]. This isostatic rebound releases stresses causing seismic activity in the faults. The study area is thickly populated with active faults [4], therefore the loss in mass of glaciers can result in local earthquakes [1].

The Fig. 5 and 6 indicate that both summer and winter periods show an increase in the average frequency of earthquakes. However this increase is more prominent in winter. From period 2001 to 2004 the average earthquake frequency has increased three fold during winter period than summer period, and this is due to the sudden increase in average earthquake frequency in the month on November as shown in Table 2.

On the basis this study, the future temperature variation and earthquake frequency correlation can be predicted. In other words the present is a key to the future.

IV. CONCLUSIONS

The temperature of study area has increased gradually in winter period and remained nearly steady in the summer period. The seasonal temperature variations result in negative net surface mass balance for the glaciers of study area. The decrease in glacier mass balance causes Earth to rebound and is responsible for enhanced seismic activity in the study area. The periodic temperature trends show that earthquake frequency is greater in winter than in summer period. For the period 2001 to 2004 the earthquake frequency for the month of November is responsible for sudden rise in cumulative average earthquake frequency in the winter period.

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