Temperature and Precipitation: GLOF Triggering Indicators in Gilgit-Baltistan, Pakistan

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Abstract

GLOFs are some of climate change induced hazards which are most common in Gilgit-Baltistan. Gilgit-Baltistan has observed more than 35 GLOF events in the last 200 years history but their frequency has increased in the recent years with five GLOF events in the Gojal Valley (Upper Hunza) during the year 2008. In order to study the relation of GLOF events with weather conditions, well known GLOF events for the period from 1990 to 2012 were selected and two type of meteorological data sets, real time and reanalyzed data has been used. This paper suggests that among other factors, temperature and precipitation (Rain fall) plays the role to enhance the probability of outburst of a lake resulting in a GLOF. Most of GLOF events occurred in Gilgit-Baltistan during the study period have been found to have linked with extreme weather conditions, i.e. either there was an abrupt rise in temperature, heat wave or rain fall a short time before or during the GLOF phenomenon. GLOF hazards can be reduced and risks to the communities can be minimized by continuous Hydro-meteorological monitoring of the affected areas.

Key Words: GLOF, global warming, climate change, glacier retreat, ablation, accumulation

Introduction

Climate change is a fact and is happening today. The weather pattern of whole world i.e. temperature trends, precipitation patterns, humidity has changed over last five decades (Vuille, et al 2008).According to new studies the rate of increase in temperature is 0.32 °C to 0.34 °C per decade compared to 0.10 °C for decades after 1939 (Oxfam, 2009).Pakistan being a developing country is also facing the issue of climate change and global warming. The warming trends of Pakistan are different for different regions. The high elevation regions including Gilgit-Baltistan, has almost double warming trends as compare to the low elevations. According to the studies conducted by Chaudary et al (2009) the rise in temperature during last 40 years was 0.76 °C for Pakistan, whereas the increase in temperature for mountain regions hosting thousands of glaciers was recorded 1.5 °C .The frequency and persistence of heat waves in the glaciated regions has also increased. Due to these reasons the melting rate of glaciers has increased causing glacier retreat where as some studies suggest that more than 35 glaciers of Karakorum Range are advancing with 11 exceptional surges. (Hewitt et al, 2009). The changing behavior of glaciers has caused formation of new lakes and extension in volume and size of preexisting lakes (Rasul et al., 2011). Thus the probability of sudden discharge of water from these lakes generally known as Glacial Lake Outburst Flood (GLOF) has increased. Another factor which has caused to increase the frequency of GLOF events in the region is the change in pattern of rain fall (Awan, 2000).GLOF is actually a catastrophic discharge of water under pressure from a glacial lake. GLOF can create two conditions for flooding, upstream flooding as a result of impoundment, less dangerous for human life due to slow rise in water level but property damage can be significant as basin of impoundment fills and Downstream flash flooding as a result of dam failure, both ice and moraine. The latter has significant threat to life and property, can sweep the infrastructure, crop lands, also can cause the life losses if it happens without any alert signal.

Gilgit-Baltistan has observed almost 35 destructive GLOF events in the past 200 year's history (UNDP, 2007). According to the available records, the frequency and intensity of GLOF events has increased during the recent years. Five GLOF events have occurred during the year (2008-2009) in Gojal valley of Hunza. Analysis of GLOF events shows that these events were linked to the weather conditions in terms of temperature rise, rainfall, and heat waves.Rise in temperature, sudden rainfall particularly in summer

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season and heat waves are the meteorological parameters which can enhance the probability of outburst if they will couple with other factors.

Data and Methodology

Two types of meteorological data sets, (Observed data from Pakistan Meteorological Department, Water and Power Development Authority Pakistan and Reanalysis data from National Centre for Environmental Prediction) have been used to study the current weather conditions for GLOF events. Large scale circulation patterns affecting the study area have been elaborated by drawing isobaric charts for different levels with relative humidity and wind vector/wind stream profiles using GrADS (Grid Analysis and Display System) software for domains 0°-50° N and 10°- 110° E. Microsoft Excel 2007 has been used to arrange the observed data, to apply statistical tools, to find mean values and to draw graphs.

Exact date and location of GLOF events have been collected from several reports published by government and private organizations as well as printed media. The summary of significant events is given in Table 1

Table 1: Historical GLOFs in Gilgit-Baltistan

Year	Date	Glacier	River
1994	29-Jul	Sosot/Gupis	Gilgit
1999	6-Aug	Khalti/Gupis	Gilgit
2000	10-Jun	Shimshal	Hunza
2000	27-Jul	Kand/Hushe	Indus
2005	25-Jul	Sosot/Gupis	Gilgit
2007	5-Apr	Ghulkin	Hunza
2008	6-Jan	Passu	Hunza
2008	2-Apr	Ghulkin	Hunza
2008	22-May	Ghulkin	Hunza
2008	24-May	Ghulkin	Hunza
2008	14/15 June	Ghulkin	Hunza
2009	26-Mar	Ghulkin	Hunza
2012	08-Jul	Sosot/Gupis	Gilgit

(Source,Archer 2001, UNDP 2007, NARC 2008, Pamir Times June 2008. FOCUS, 2012)

Results and Discussions

The meteorological indicators which have caused to increase the chances of GLOFs in Gilgit-Baltistan during the study period have been identified by using observed and reanalysis meteorological data sets. The broad scale circulations during the GLOF events have been discussed by drawing Isobaric charts at 300 mb and 700 mb pressure level with wind vectors/streams and Relative Humidity profile using GrADS (Grid Analysis and Display System). Observed data from Pakistan Meteorological Department and Pakistan Water and Power Development Authority has been used.

Analysis of GLOF Events

The GLOF events mentioned in table 1 have been analyzed with respect to meteorological conditions. Regional circulation pattern at the relevant period has been carried out by drawing isobaric charts at 300 mb to 700 mb with wind, temperature and humidity profiles using National Centre for Environmental Prediction data sets. Its impacts on the region have been investigated by analyzing the observed data from the nearest weather stations of study area corresponding to the relevant date in terms of temperature and precipitation as meteorological parameters. The detail of analysis is as below.

Event No. 1

The 1st GLOF event was occurred on 29th July 1994 in Sosot Nala with mud and debris flow. As a result Ghizar River was blocked and lake was formed due to impoundment in upstream. Houses and property of the whole village were submerged into the water. 65 households of Sosot village were affected due to flooding with losses of five lives and thousands of fruit bearing trees. Thousands Kanals of crops land were also damaged. (Local government record)

Synoptic Conditions

Figure 1 shows the isobaric charts of 700 mb with wind vector and relative humidity profile for 27-30 July 1994. It is clear that the Himalayan- Karakorum region was under the influence of south easterly system which was initially developed over Arabian Sea and was moving towards Bay of Bengal where it get intensified and moved towards Gilgit-Baltistan region with South Easterly winds. Thus moisture was transported to Gilgit-Baltistan region from Bay of Bengal and Arabian Sea.

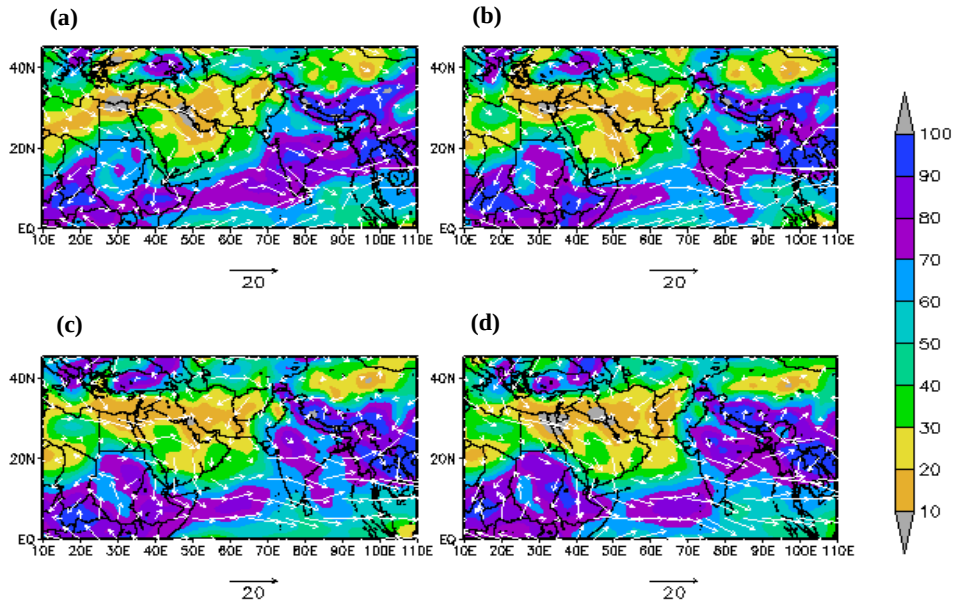

Figure 1: (a) 27 July **(b)** 28 July (c) 29 July **(d)** 30 July, 1994.

Local Meteorological Conditions

Meteorological Data from Pakistan Meteorological Station Gupis (Figure 2), located in Gupis proper valley, nearly at a distance of 15 Km in east of Sosot village shows the weather conditions of the region during the GLOF phenomenon.

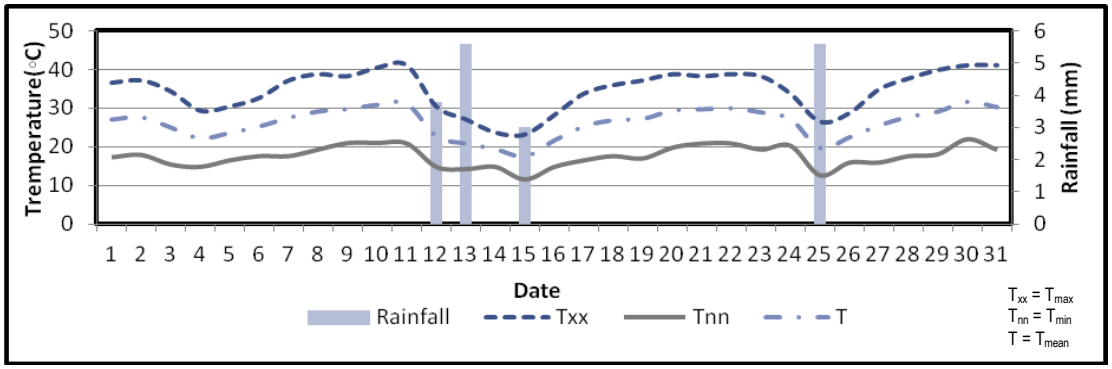

Figure 2: Temperature and rainfall pattern of Gupis during the month of July 1994.

From the analysis of data it is clear that weather was enough warmer during the period from 16th of July to 24th of July which can be seen from the temperature pattern in Figure 2. During the last week of July 1994, rain fall occurred over the region and 5.5 mm rain was recorded at Gupis station on 25th July whereas temperature started to rise from 26th July and maximum temperature reached to 40 ºC on 29th July, 1994 which was the Flood day.

Event No.2

A GLOF event occurred in Gupis (Khalti) of District Ghizar on 6th August 1999 and blocked the Ghizar River and created a 1.5 km long lake, now known as Khalti lake as reported by UNDP 2007. The event has occurred at a distance of 2 km from PMD Met station Gupis in west. The weather conditions during the event period of source area are discussed as under.

Synoptic Conditions

Isobaric Charts at 300 mb and 700 mb level are shown in (Figure 3) and (Figure 4) to illustrate the synoptic conditions and moisture transportation for the period 31st July to 3rd August, 1999.

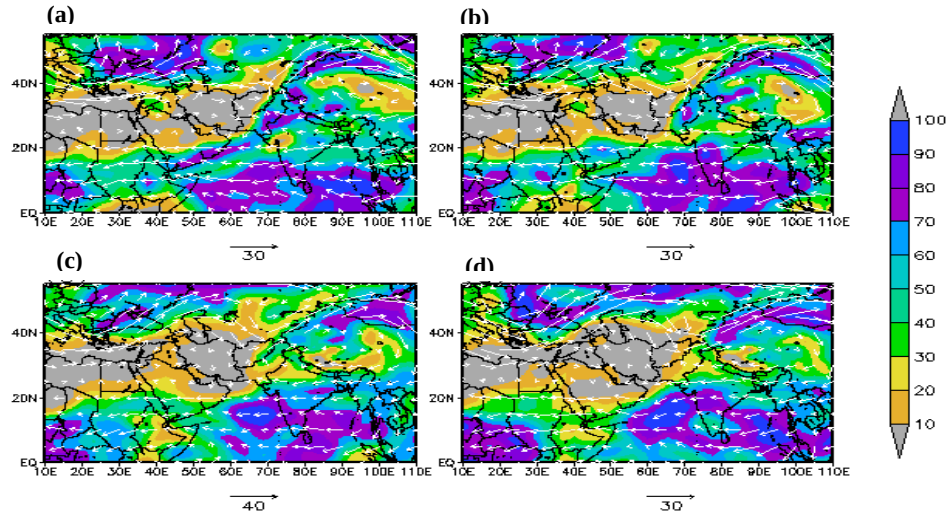

Figure 3: Isobaric Charts 300 mb **(a)** 31 July **(b)** 01Aug **(c)** 02Aug **(d)** 03 Aug, 1999.

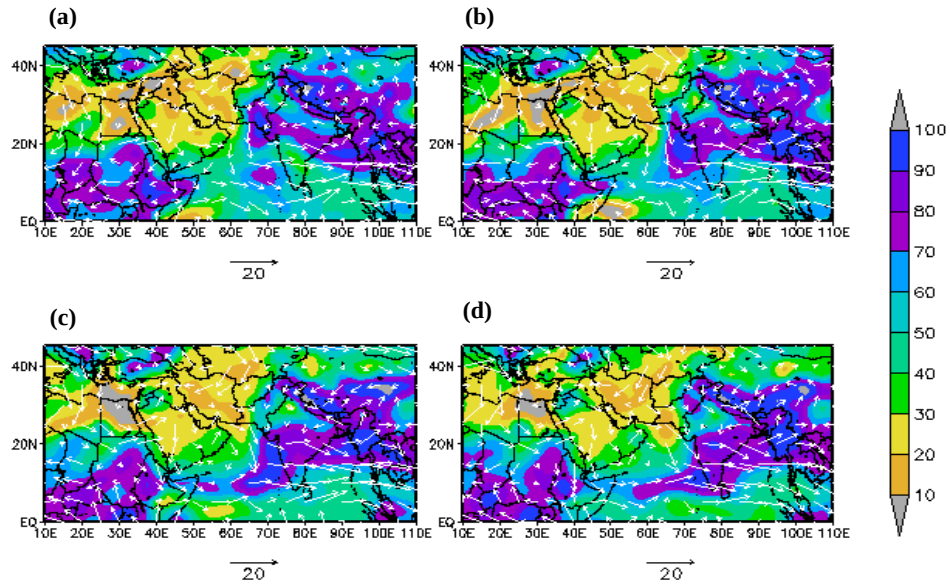

Figure 4: Isobaric Charts 700 mb **(a)** 31 July **(b)** 01Aug **(c)** 02 Aug **(d)** 03 Aug, 1999.

From the isobaric charts 700 mb level with wind vector and relative humidity profile shown in (Figure 4) it is clear that the summer monsoon low was initially developed over bay of Bengal and was also following the principal path along subtropical high (STH). At upper level it merged with the seasonal low (Figure 3). Position of seasonal low changed its path and it moved to the northeast side over Baluchistan. Thus large amount of moisture was transported to the northern parts of Pakistan from Bay of Bengal. The interaction of easterly and westerly flows enhanced the rainfall activity over the study area.

Local Meteorological Conditions

To illustrate the local meteorological conditions which enhanced the probability of breach of lake, data from Pakistan Meteorological Department Gupis has been used. The graph of temperature and precipitation (rainfall) for August-1999 recorded at PMD weather station Gupis is shown in (Figure 5). As a result of synoptic conditions shown in (Figure 3) and (Figure 4) significant amount of rainfall has occurred in the study area which is shown in (Figure 5)

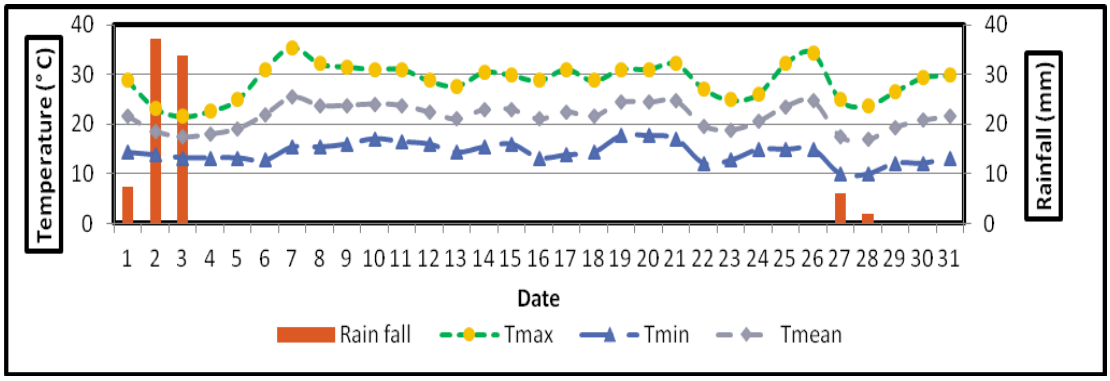

Figure 5: Temperature and Precipitation pattern of Gupis (August - 1999)

From graph shown in Figure 5 it can be observed that this station has received 86 mm rainfall in 1st 3 days of the month. During the rainfall day's temperature remained comparatively low and maximum temperature dropped up to 20 °C on 3rd August 1999. Then temperature started to rise from 4th August 1999 which indicates that weather began to clear and short wave solar radiations were received by the region. This caused a continuous increase in temperature up to 6th August 1999 and maximum temperature crossed 31 °C on the breach of lake (6th August, 1999).

The continuous rainfall for 3 days played a significant role to raise the level of water in the lakes because the rain water can melt the ice of glacier as the former is warmer than latter. The ice consumes heat from environment as well as from rain water. Rain and glacier melt water reaches the lakes directly and causes to raise the level. When the rain stopped and temperature started to rise then the melting of ice also may have increased resulting in rise of water level in the lakes. Thus the hydrostatic pressure of water on the walls might have increased and caused to breach the lake from weaker places, thus GLOF was occurred.

Event No. 3

On July27, 2000 a GLOF and debris-flow occurred at Kand from a tributary of Hushe River (UNDP, 2007). The event occurred in the middle of the day, during a period with enough warmer weather. The meteorological conditions of Hushe during the event are shown in (Figure 6) and (Figure 7)

Synoptic Conditions

The isobaric charts shown in (Figure 6) elaborate the synoptic conditions from July-25, 2000 to July-28, 2000.

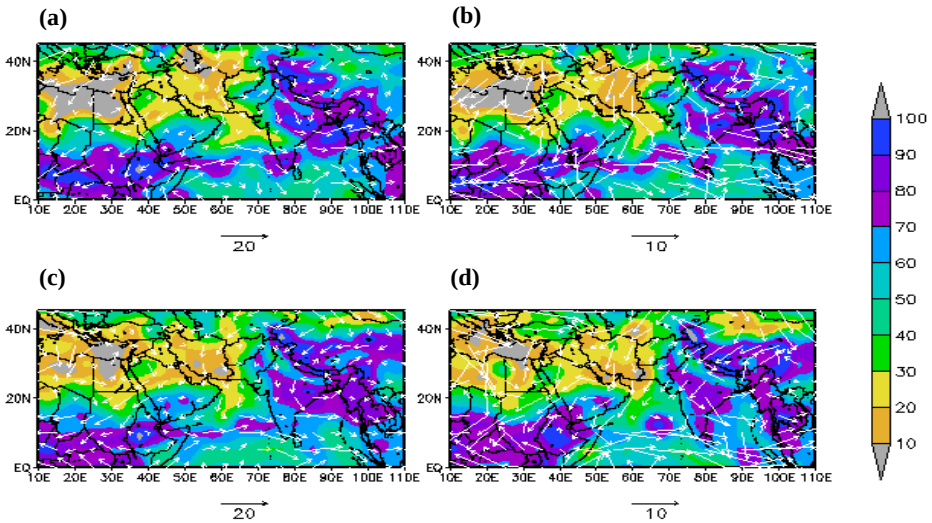

Figure 6: Isobaric charts at 700 mb level showing moisture transport on 25th to 28th July, 2000.

From the synoptic charts with wind and Relative Humidity profiles shown in (Figure 6) it is clear that there was a deep cyclonic circulation over India which was initially developed over Bay of Bengal. The trough of this low pressure cell was extended to the northern parts of India including Kashmir valley. This trough also affected the northern parts of Pakistan adjacent to Indian held Kashmir. This trough also interacted with some north westerly winds. Thus the weather phenomenon was developed over Gilgit-Baltistan.

Local Meteorological Conditions

(Figure 7) represents the local meteorological conditions in terms of temperature and precipitation (Rainfall) recoded at WAPDA Met. Station Hushe for the month of July 2000.

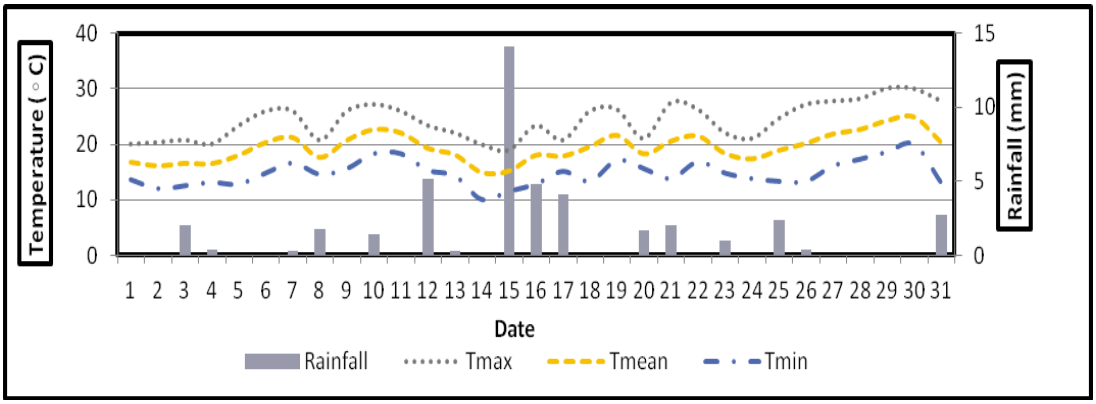

Figure 7: Temperature and precipitation trend of Hushe July 2000.

From above graph the decrease in temperature can be observed from July-22, 2000 to July-25, 2000 which may be due to cloudy weather as high value of RH profile can be observed in the synoptic charts at the study area shown in (Figure 6) and rain fall has also been recorded over the station during these days (Figure 7). A total of 9 mm rain fall has also been recorded during the period from 20th July to 26th July 2000 at the same station. The increase in temperature from July-27, 2000 to July-30, 2000 shows that weather was clear and the region received the solar energy. These conditions coupled with other factors i.e. physical conditions of glacier enhanced the chances of outburst .Thus GLOF took place.

Event.No.4

A flood occurred on 25th July 2005 in Sosot Nala which caused to damage sufficient property in Sosot, a small village of tehsil Gupis (Local government record). Sosot Bridge was again damaged and was closed for all types of transport. Thus the upper parts of Tehsil Gupis were cut off from Tehsil head Quarter.

Regional Meteorological Conditions

The isobaric charts showed in Figure 8 illustrate the synoptic situation of the affected area during the period from 23rd to 26th, July 2005. There was a low pressure cell over Bay of Bengal. At the same time westerly jet stream was passing over the northern parts of Pakistan. Some currents from Bay of Bengal were approaching towards northern parts of Pakistan as south easterlies. These currents were interacted by westerly winds at the upper parts of Pakistan. Thus easterly westerly interaction caused to develop weather phenomenon.

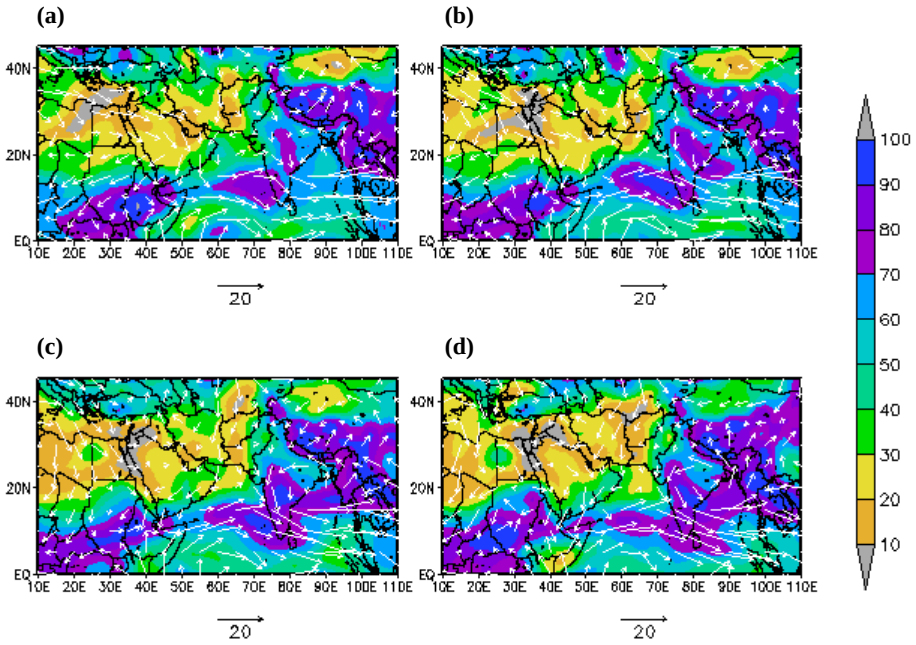

Figure 8: Isobaric Charts **(a)** 23July **(b)** 24 July **(c)** 25 July **(d)** 26 July 2005.

Local Meteorological Conditions

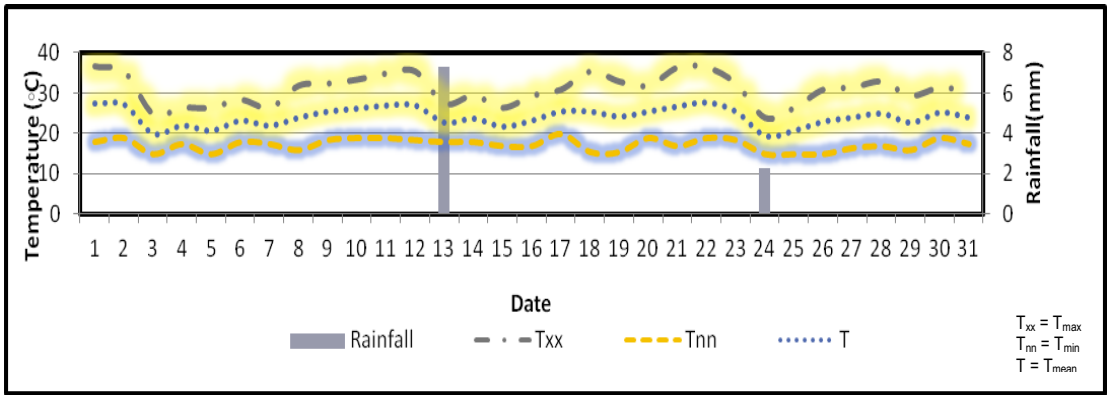

Figure 9: Temperature and Rain fall of Gupis for July 2005

Figure 9 shows the temperature and precipitation in terms of rain fall profile of Meteorological Station Gupis, the nearest weather station to Sosot village. The local meteorological conditions show that Maximum temperature of the region remained above 30ºC for 8 consecutive days (From 16th July to 23rd July, 2005). Thus the whole region was facing heat wave conditions. On 24th of July, 2005 i.e.

one day before of GLOF event, more than 2 mm rain has been recorded over the station which may have been due to Indian summer monsoon currents which approached to the affected region as shown in the isobaric charts as shown in Figure 8. The temperature suddenly decreased on 24t^{h} July which may have been due to cloudy weather but it started to rise from 25th of July. Thus heat waves and then rainfall caused fast melt of glacier which might have increase the volume of water in the lake. As water content can also weaken the soil strength of debris and thus the chances of failure of dam from a weaker side is enhanced which further leads to outburst.

Event No. 5

A GLOF event was reported on April-5, 2007 at Ghulkin glacier Gojal valley Hunza. (FOCUS Humanitarian Assistance Pakistan Gilgit). The meteorological conditions during the event time are shown in (Figure 10) and (Figure 11)

Synoptic Conditions

The isobaric charts at 700 mb level for the period from 3rd April to 6th April 2007 are shown in (Figure 10) to illustrate the wind flow pattern and moisture transportation to the study area during GLOF phenomenon.

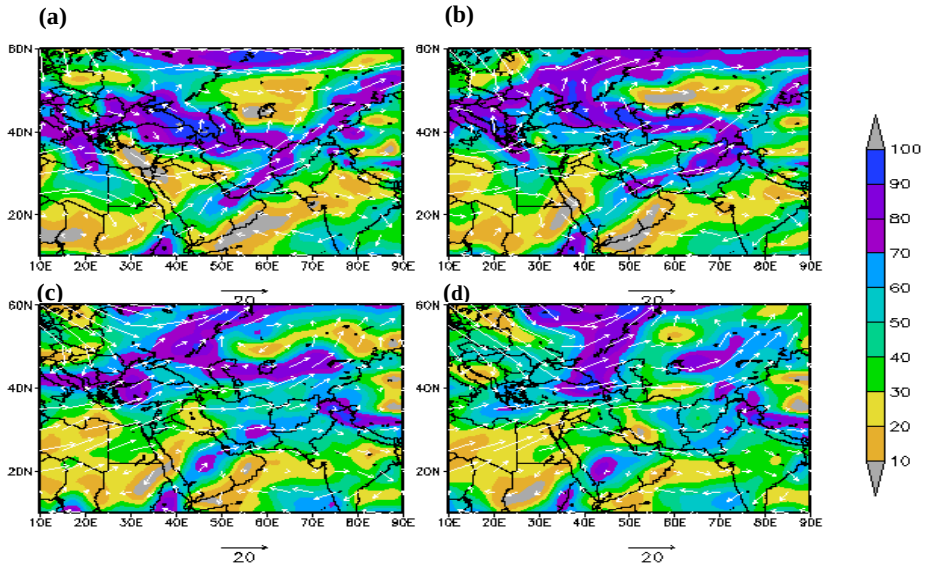

Figure 10: Isobaric Charts **(a)** 03April **(b)** 04April **(c)** 05April **(d)** 06 April 2007

(Figure 10) it is illustrated that there was a remarkably high pressure with RH values less than 30 % over Central Africa at 700 mb level. Less values of RH shows that on April 3, 2007 moisture conditions were not favorable but 700 mb winds were strong. The heavy anticyclonic circulation developed over Central Africa pushed the winds into Saudi Arabia as northeasterlies but the winds took a sharp bend due to a small high pressure cell in southern regions of Saudi Arabia and passed over the region as westerlies. The winds passing over Persian Gulf were driven towards north due to a deep cyclonic circulation developed over Central Asia and a high pressure cell over south India. Thus these winds entered into the northern parts of Pakistan as south westerly. High value of RH (>90 %) profile in the northern parts of Pakistan is evident that these winds have served as a source of moisture supply from Persian Gulf to the study area.

Local Meteorological Conditions

As a result of above prevailing large scale circulation, rainfall occurred in the study area. (Figure 11) shows the local weather conditions in terms of temperature and precipitation of the PMD Met Station Karim Abad Hunza for the month of April, 2007, the nearest weather station to Ghulkin glacier.

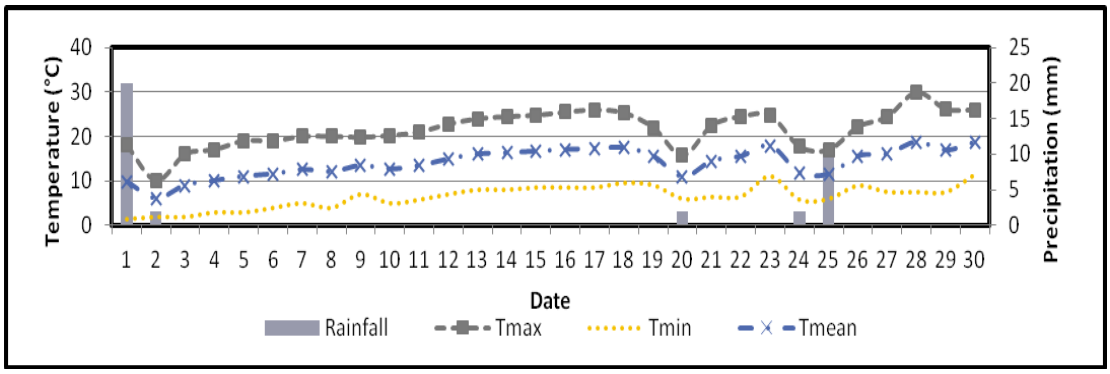

Figure 11: Temperature and Precipitation trend of Karimabad (Hunza) for April 2007

From (Figure 11) it can be observed that continuous rainfall occurred for first two days of the month and stopped after a total precipitation of 23 mm. Temperature fell down in the same days and Max. Temperature on April 2, 2007 was 10 °C .When rainfall stopped then temperature started to rise up to 19 °C (Maximum temperature) on April 5, 2007. The continuous rainfall and after then increase in temperature caused to fast glacier melt resulting raise in Lake water level and hydrostatic pressure. Thus lake breached from a weaker side and the whole water drained out in the form of flood.

Event No. 6

A GLOF event was reported on January 6, 2008 at Passu glacier in Gojal valley (Upper Hunza) (FOCUS Humanitarians Assistance Pakistan Gilgit).The meteorological conditions during the event time are discussed as follow.

Synoptic Conditions

The prevailing synoptic conditions in terms of wind circulation pattern with relative humidity profile during the GLOF event are shown by isobaric charts in (Figure 12)

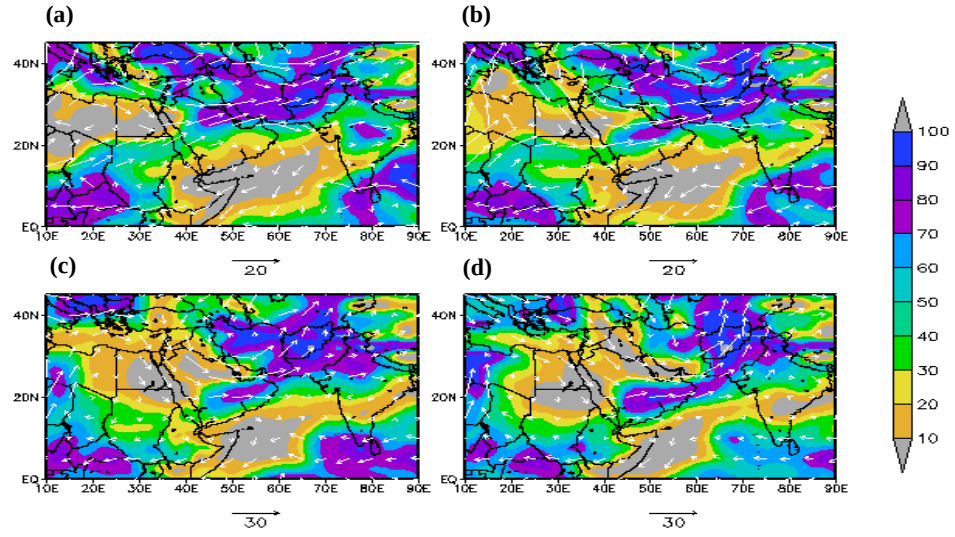

Figure 12: Isobaric Charts **(a)** 04 Jan **(b)** 05 Jan **(c)** 06 Jan **(d)** 07 Jan 2008.

The whole wind circulation pattern is a result of two deep anticyclonic circulations developed over Central Africa and southern India and deep low pressure cells over northern parts of Iran and Central Asia. The winds entered in Saudi Arabia as North westerly and took a bend in the southern parts of Saudi Arabia and passed over Arabian Sea and entered in Baluchistan as south westerlies. These winds passed over northern Pakistan as south westerly due to low pressure over central Asia. Thus

these winds picked moisture from Red sea and Arabian Sea and served as a mean of moisture supply for study area which is clear from high value profile of relative humidity in the study area.

Local Meteorological Conditions

Due to above prevailing large scale circulations, precipitation occurred in the study area. Met station Karimabad Hunza, the nearest PMD station to Passu glacier has recorded Trace and 2 mm rain fall on January 6, 2008 and January 7, 2008

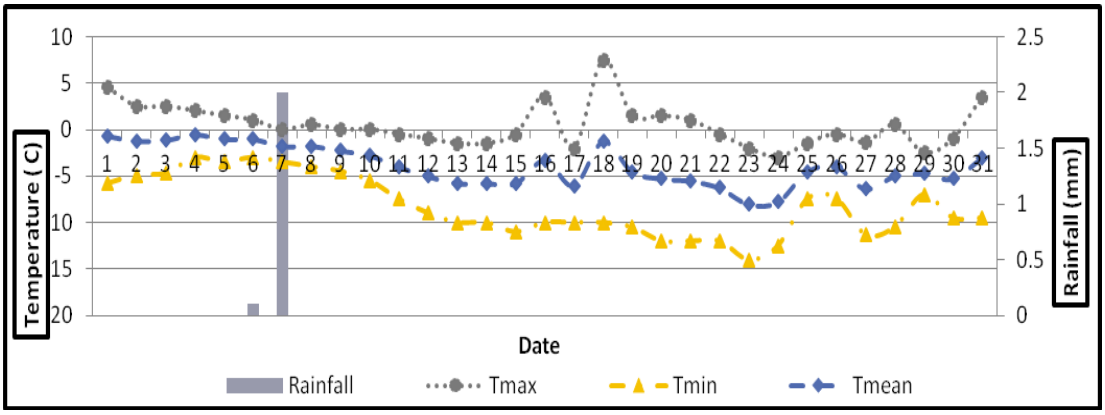

Figure 13: Temperature and Precipitation Karimabad Hunza (Jan 2008)

The local meteorological conditions of study area during the GLOF event have been described in (Figure 13). It can be observed from (Figure 13) that 0.5 mm rainfall has been occurred on event day at Met. Obsy Karimabad Hunza. It implies that more rain fall might have occurred on the glacier due to the high elevation. Further 2 mm rain is shown on the next day of event in the same station which is evident that weather was cloudy in the said area. Although temperature trends were not so high but the precipitation in liquid form increases the melting rate of ice due to its latent heat. Rain water widens the narrow cracks during its infiltration into the gaps of ice. Huge ice masses may be detached from each other and slide down due to slope causing to outburst of an existing lake in down slope.

Event No. 7

A GLOF event again occurred on April-2, 2008 at Ghulkin glacier Gojal (Upper Hunza) (FOCUS Humanitarian Assistance Pakistan Gilgit). The weather conditions during the event period are shown in (Figure 14) and (Figure 15)

Synoptic Conditions

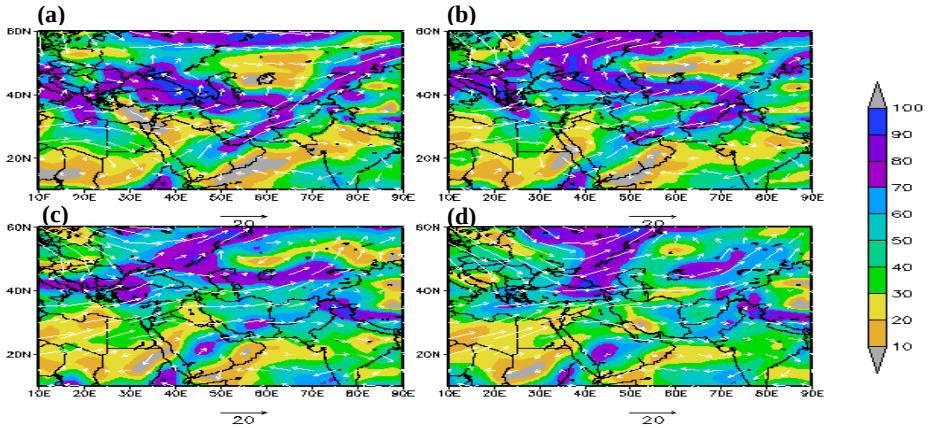

Figure 14: Isobaric Charts **(a)** 31 Mar **(b)** 01 April **(c)** 02 April **(d)** 03 April 2008.

The large scale wind circulation pattern with RH profile affecting the study area during the GLOF phenomenon has been illustrated by isobaric charts at 700 mb level in (Figure 14).

Wind flow in (Figure 14) indicates that the whole region was under the influence of western system. Moisture was driven from Red sea and Persian Gulf by the south westerly winds to the northern parts of Pakistan due deep low developed over Central Asia and a small anticyclonic circulation over Tibetan Plateau and caused to rise RH value. (RH >90 %)

Local Meteorological Conditions

The meteorological parameters in terms of temperature and precipitation (Rain fall) during the event period in the source vicinity are shown in (Figure 15).

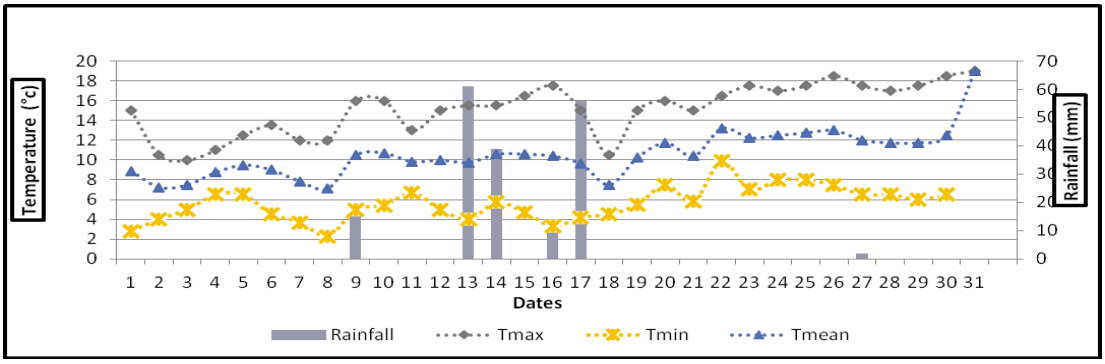

Figure 15: Temperature and Precipitation Karimabad Hunza (April 2008)

The abrupt decrease in maximum temperature and raise in minimum temperature on April 2, 2008 indicates that weather might be cloudy at the observation station which is located in the valley. This weather condition has might cause rainfall over the glacier due to high elevation. Rainfall might had coupled with other factors and enhanced the chances of outburst.

Event No.8

Two GLOF events occurred on May-22, and May- 24, 2008 at Ghulkin glacier. (FOCUS Humanitarian Assistance Pakistan Gilgit). According to prevailing meteorological conditions during the event period Westerly system was active and rainfall was recorded at Met. Obsy Karimabad Hunza as Trace, 02 mm and 40 mm on May 22, 23 and 24, 2008 respectively. The meteorological conditions are discussed below.

Synoptic Conditions

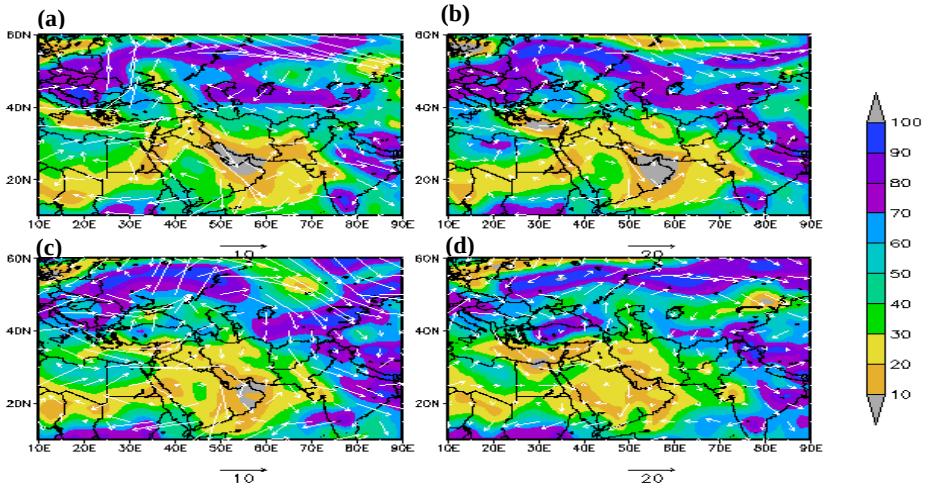

Figure 16: Isobaric Charts **(a)** 21 May **(b)** 22 May **(c)** 23 May **(d)** 24 May 2008.

(Figure 16) is showing the broad scale circulation patterns at 700 mb pressure level on May-21, 22, 23 and 24, 2008.

The synoptic charts in Figure 16 show that the northern parts of Pakistan were under the effect of western system initially developed over Mediterranean Sea. A strong cyclonic circulation over Arabian Sea and adjoining areas caused the SW winds over central Asia to take a sharp turn and entered into the Pakistan as north westerly passing over Afghanistan. High value of RH profile on May-22, May-23 and May-24, 2008 indicates weather system was intensified during the breach of lake. As a result above synoptic situation weather phenomenon was developed and significant amount of rainfall has been recorded by the PMD weather station Karimabad Hunza on relevant days.

Local Meteorological Conditions

(Figure 17) is the graphical presentation of local meteorological conditions of event area during May 2008.

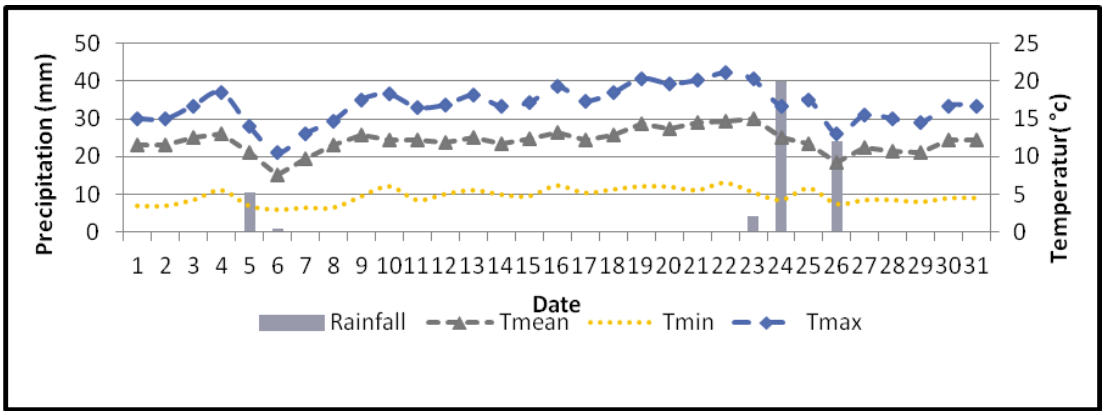

Figure 17: Temperature and precipitation pattern of Karimabad weather station Hunza (May, 2008)

According to prevailing broad scale meteorological conditions Westerly system was active during the event period and has caused to rainfall over the whole region. Weather was cloudy during 21st to 25th of May 2008 .Trace rain has been recorded on 22nd May whereas Graph in (Figure 17) shows a remarkable rainfall at Met. Station Karimabad Hunza on 23rd and 24th May which has caused to accelerate the melting of ice resulting in rise of water level in the glacier lakes. Thus event has occurred.

Event No. 9

A GLOF event was occurred on June-14/15, 2008 again at Ghulkin glacier (FOCUS Humanitarian Assistance Pakistan Gilgit). According to meteorological conditions both at regional and local level, (Figure 18) and (Figure 19) heat wave conditions were persisted over the region during the event time. WMO recommended definition of heat wave states that, when the daily maximum temperature for more than five consecutive days exceeds the average maximum temperature by 5°C the normal period being 1961-1990, heat wave will persist. Pakistan experiences two types of heat wave conditions. (Maida et al., 2011)

i. Pre-Summer (March/April) heat waves which are developed due to the grip of Arabian STH over Pakistan. These heat waves generally approach Pakistan from South West and effects Sindh, Baluchistan and lower Punjab.

ii. Pre-Monsoon (May/June) heat waves generated due to the position of Tibetan STH and approaches from North East i.e. from upper Indian side and effects upper Punjab Khyber Pakhton Khawa and Gilgit-Baltistan. According to meteorological data of Karimabad station Hunza, (Figure 18) the maximum temperature began to rise from June-5, and remained above 30 °C up to

June-14, 2008 then abruptly increased up to 37 °C on June-15. Although minimum temperature also remained above 15 °C during the period. This caused to burst out the glacier.

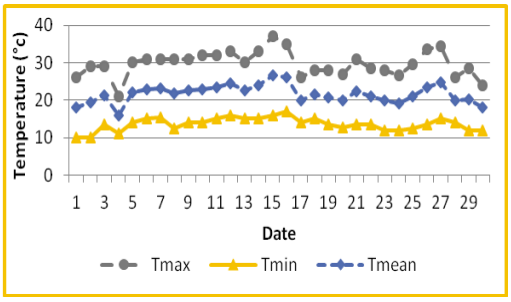

Figure 19: Temperature Trend Karimabad Hunza (June 2008)

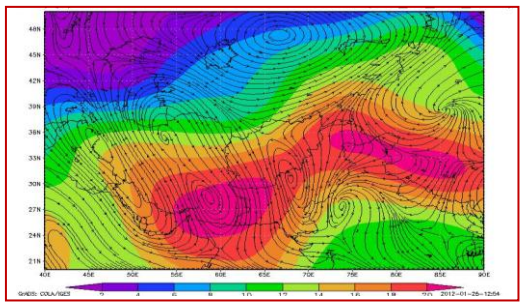

Figure 19: Temperature distribution over study area on event day

Event No. 10

A GLOF event was occurred on March-26, 2009 on Ghulkin glacier Gojal Hunza (FOCUS). The meteorological conditions during the event time are discussed as below.

Synoptic Conditions

The synoptic situation on March-24, 25, 26 and 27, 2009 is shown in (Figure 20). It can be observed that winds were initially driven from south west, and then they took a turn from Afghanistan and entered in to northern parts of Pakistan as westerly due to the ridge of high pressure cell developed over Tibetan Plateau. The moisture was driven from Red Sea and Persian Gulf to the study area. The high value of RH profile in the study region shown in charts indicates that weather was intensified on event day.

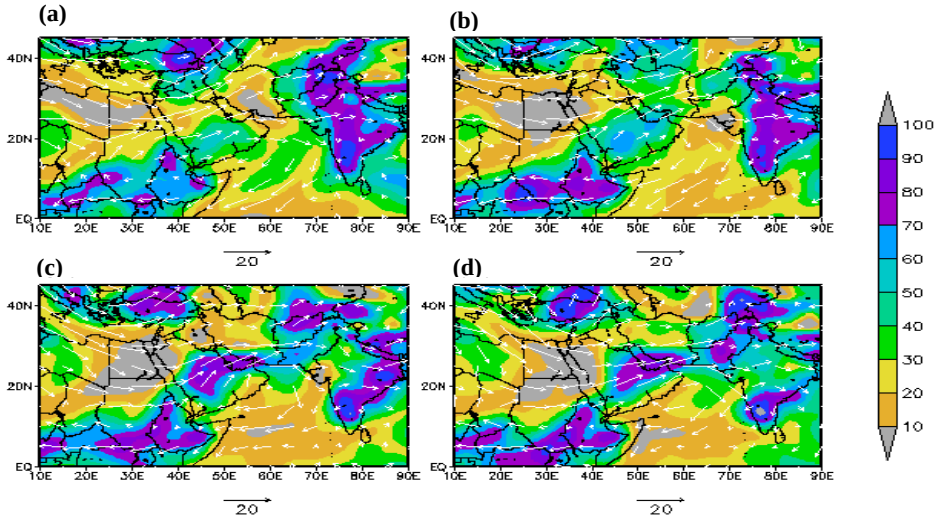

Figure 20: Isobaric Charts **(a)** 24 March **(b)** 25 March **(c)** 26 March **(d)** 27 March 2009.

Local Meteorological Conditions

Figure 21 shows the current weather condition of study area during the month of March, 2009. The graphic representation of weather parameters in Figure 21 indicate a sharp fall of maximum temperature and a significant rise of minimum temperature on, March-26, which is an evidence of cloudy weather on the study area. However no precipitation has been recorded at PMD weather station Karimabad Hunza but 5 mm rain has been occurred on March-28, 2009. Hence there is a probability that rain fall might has occurred on source glacier on March-26 due to high elevation and caused to trigger the GLOF event.

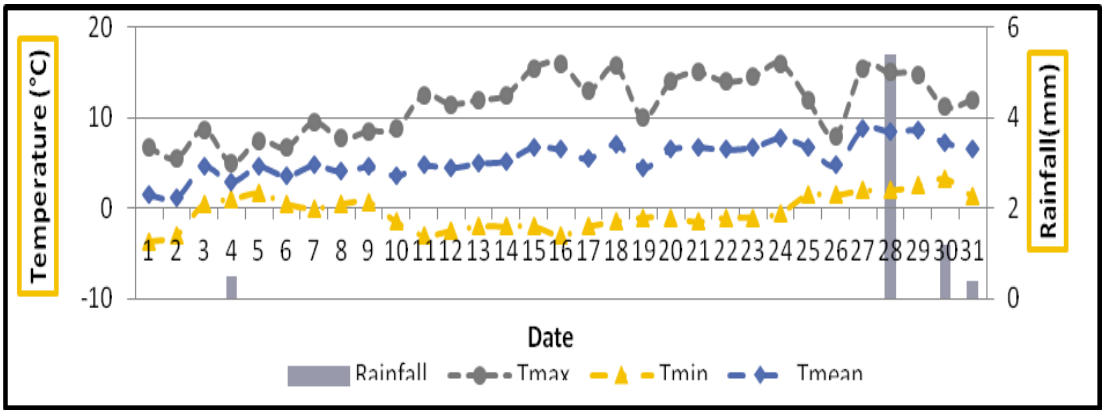

Figure 21: Temperature and Precipitation Karimabad Hunza (March 2009)

Event.No.11

A devastating flood in Sosot Nala was occurred on 8th July 2012 with dangerous effects on the village. The possible weather conditions which caused to enhance the probability of outburst are discussed in below.

Regional weather Conditions

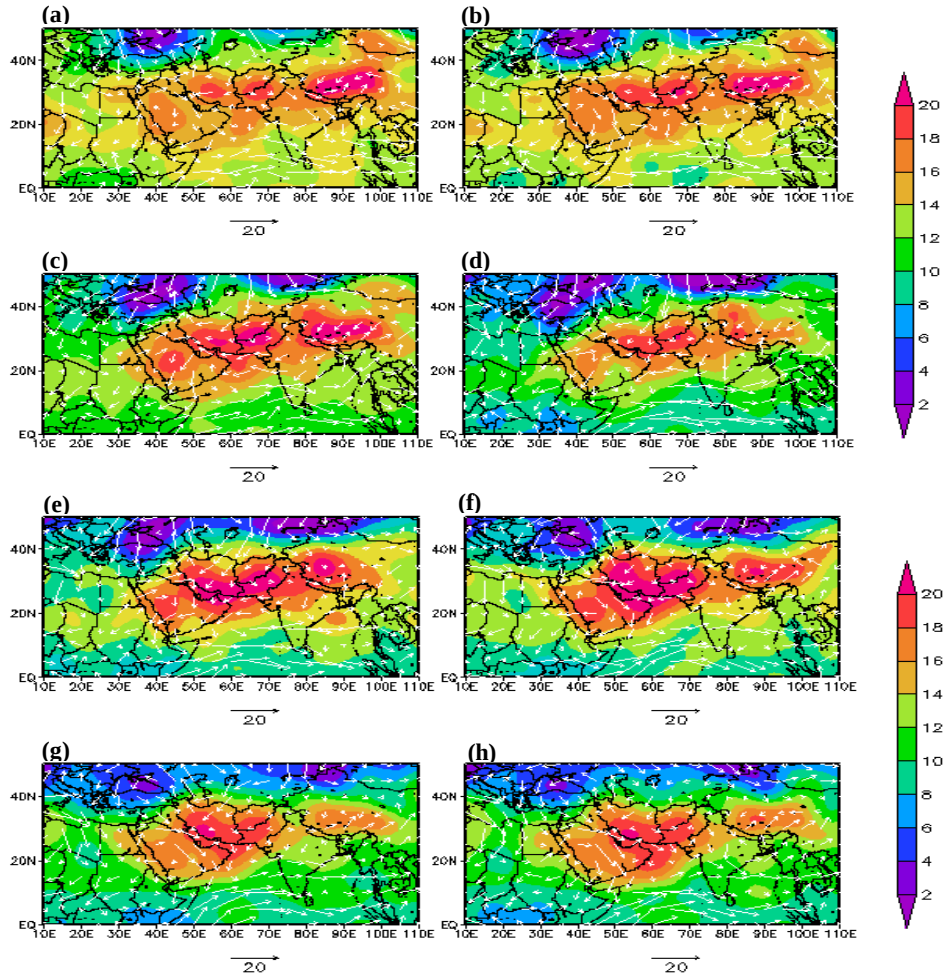

Figure 22: Temperature distribution with wind pattern from 1st July to 8th July 2012

The weather charts in Figure 22 show temperature distribution and wind pattern in upper air over the study area. The temperatures of upper atmosphere were higher over Saudi Arabia, Iran, Afghanistan and Pakistan from 1st July to 8th July 2012. Thus there were heat wave conditions during the event phenomenon.

Local Meteorological Conditions

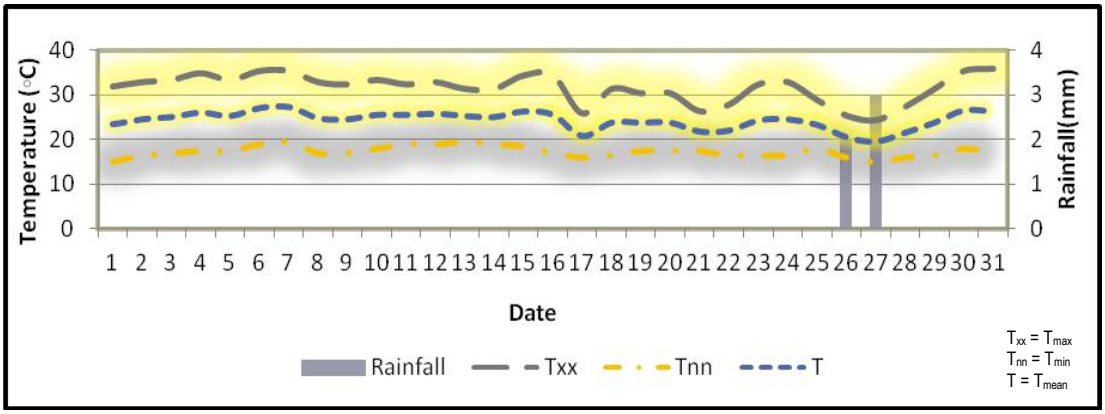

Figure 23: Temperature and precipitation trend of Gupis/Sosot for the month of July 2012.

From graph Shown in Figure 22, it is clear that during the 1st week of July 2012, the maximum temperature of the effected region remained above than 33 ºC (Figure 23). Snowfall has been reported in Gupis during the last week of April, 2012 which was an unusual phenomenon. When snow fall occurs during winter season i.e. from mid of November to the mid of February gets compact due to seasonal fall of temperature and becomes ice. If snow fall occurs after winter season then it does not compact properly due to seasonal rise in temperature. Fresh snow can melt quickly than ice. Thus due to late snowfall i.e. in end of spring season it did not compact properly.

During the 1st week of July the maximum temperature remained above than 33ºC and it behaved as a heat wave condition. Due to these factors the melting of glacier was increased and finally it took the form of flood on 8th July 2012.

Conclusion and Recommendations

Conclusion

The present study reveals that occurrence of GLOF events are related to melting of glacier ice. Temperature and rain fall enhance the melting of ice resulting in rise of water level in the lakes. These meteorological parameters can cause mass movement in form of avalanche, rock fall and slump of ice in the glacier. Thus Lakes can be triggered to outburst.

From the analysis of meteorological data for the study area following conclusions can be drawn:

1. The analysis of GLOF events of Gilgit-Baltistan for the period from 1994 to 2012 with exact dates and locations show that the events have occurred after a short duration of rainfall or temperature rise. This indicates that rain fall; temperature rise and heat waves can enhance the chances of outburst of glacial lakes if they are coupled with other geophysical conditions of Lake Environment.
2. Year wise distribution of events shown in table 1 indicates that the year 2008-2009 has the maximum frequency with five GLOF events with respect to the past history. This indicates that frequency of GLOF events is linked to global warming as the decade 2001-2010 was the warmest decade of the century.

3. Past GLOF history since 1994 shows that 08 out of 13 events have occurred in Gojal valley (upper Hunza) (table 1). This implies that Gojal glaciers are more prone to GLOF events than other glaciers of Gilgit-Baltistan and Ghulkin glacier has been found more active towards GLOF events.
4. Table 1 shows that most of GLOF events have occurred during the months of March to August. This indicates that GLOFs are related to seasonal rise in temperature as a result of increase in ice melt.
5. Threshold values of temperature for GLOF phenomenon in Ghizar District (West of Gilgit city) has been found above than 35ºC Maximum temperature whereas this type of value cannot be established for Hunza Glaciers which may be due to glacier characteristics, area topography and geological / geographic settings of glacial lakes.
6. As 06 GLOF events have occurred from Ghulkin Glacier of Gojal valley Hunza which may be due to advancing nature of this glacier.

Recommendations

From analysis of GLOF events, it is clear that GLOFs are linked to the Hydro meteorological conditions of area. Melting rate of ice is increased with seasonal rise in temperature and high solar radiation, thus causes to raise the water level of lakes. Melt water increases the pore water content of unstable masses that may cause slope failure. Melt water inflow into the crevasses may widen the crevasses and thus huge ice masses may get detached from each other which can slip down due to steep slopes and gravity. In this way they can cause flood in downstream.

In the light of above discussion following recommendations are put forward.

1. According to available history, GLOF events have occurred since 1533 A.D (David Archer 2008) in G-B but in recent years their frequency has increased (5 events during one year , 2008) which may be due to climate change and global warming. Thus they have become a serious threat to property, infrastructure, and even human life in downstream. Therefore due concentration is required to be focused on analysis of GLOF events.
2. In most publications about the impact of climate change on Northern Pakistan (G-B) the main focus is on biodiversity and water availability related issues but there is a very little consideration on GLOF risk for mountain dwellers. It is suggested that proper consideration may be given to GLOF risk reduction in glaciated regions.
3. As population of the region is growing day by day and thus infrastructure such as roads, bridges, buildings etc. are expanding respective to population needs. Thus GLOF hazards have increased as compared to the past in these regions. Therefore necessary steps should be taken to develop awareness related to GLOF hazards in local communities both at government and community level.
4. As the most of existing hydro-power projects in G-B are located near to the river flow channels. Further the purposed ambitious hydro-power projects such as Diamir-Basha Dam is also in the downstream of the glaciers of Gilgit-Baltistan, thus GLOF hazards have increased not only on local level but also at national level. Therefore it is suggested that an organized approach may be adopted to cope with this issue.
5. As the GLOF events are actually hydro meteorological hazards, therefore hydro meteorological network may be extended up to the glaciated regions of Gilgit-Baltistan in order to monitor the actual glacier environment. PMD has installed AWSs and river discharge measuring gauges at Passu glacier Gojal Hunza with the financial assistance of ICIMOD. This type of joint activities may be also conducted at glaciers in other parts of Gilgit-Baltistan

6. Long terms hydro meteorological observations and a comprehensive scientific study is needed to know the exact GLOF triggering factors.

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