Temporal And Spatial Variation Of Temperature Over Nepal

IN PARTIAL FULFILLMENT FOR THE REQUIREMENT OF MASTER'S DEGREE OF SCIENCE IN METEOROLOGY

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Recommendation Letter

This is to certify that Mr. Nirajan Sapkota has prepared the dissertation entitled **"Temporal and Spatial variation of Temperature over Nepal"** to fulfill the partial requirements for Master's degree in meteorology. The study done by him has been carried out under my supervision and guidance.

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DEDICATION

This research work from the core of my heart is sincerely dedicated to my mother Dila Devi Sapkota and father Indra Prasad Sapkota who encourage me with hope & vigor.

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Abstract

Temperature is one of the most important key indicators of climatic variables. It has significant role in socio-economic part of the human civilization. Since, global warming and the climate change have been threatening the world seriously; studies have been carried out on climate change over much of the globe since last few decades. This study concerned with the investigation of the temporal and spatial variation of temperature at various locations in Nepal.

In the study, increasing trend in the maximum temperature by 0.08^{o}C/year found for the period from 1970 to 2004 and for the minimum temperature, the increasing trend is found as 0.05^{o}C/year over the nation. After 1986, the maximum (0.05^{o}C/year) and minimum (0.03^{o}C/year) temperatures over the nation were also slightly increasing. Almost constant trend in the maximum temperature was found at Terai region of Nepal, however, in the case of minimum temperature the trend was found slightly increasing. The greatest increased rate in maximum temperature was observed at Himalayas (0.12^{o}C/year) and Middle Mountain (0.09^{o}C/year) region of Nepal, however, in the case of minimum (0.10^{o}C/year) temperature the greatest trend was found at Siwalik. But in the station Jomsom, maximum temperature was observed at cooling rate and minimum temperature was observed at warming rate.

According to season-wise distribution it was observed that the maximum temperature was observed slightly warming rate at monsoon and post-monsoon season of Terai region whereas winter and pre-monsoon seasonal trends were found in slightly cooling rate. In the study, the rate of increase in minimum (0.025^{o}C/year) temperature over Terai region was observed about twice to be decreased in maximum temperature (0.012^{o}C/year) and also observed slightly increasing trends in maximum temperature (0.07^{o}C/year) and minimum (0.10^{o}C/year) in the Siwalik region. The temperature Vs. altitude has also calculated in different region as well as seasons. The values of maximum temperature and minimum temperature were also observed at the decreasing rate of 5.7^{o}C per kilometer and 4.8^{o}C per kilometer respectively. The highest decreasing rate was observed to be 6.9^{o}C per kilometer at pre-monsoonal maximum temperature and 5.3^{o}C per kilometer at monsoonal minimum temperature.

Due to lack of sufficient data of Himalayan region, the study could not cover trend of temperature of the whole Himalayan region, therefore, the study only shows the temperature trends in combined form of both higher mountain and Himalayan region.

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CHAPTER 1

Preliminary

1.1 Introduction

The term temperature refers to the degree of hotness or coldness of the matter. Alternatively, the temperature of the matter is the condition that determines its ability to transfer heat to other matters or to receive heat from them. Temperature is one of the most important key indicators of climatic variables. It is directly related to human health hazard. The agriculture production has directly linked with the fluctuation of the temperature. Thus, it has significant role in socio-economic parts of the human civilization.

Since, global warming and the climate change have been threatening the world seriously; studies have been carried out on climate change over much of the globe since last few decades. IPCC (climate change 2001) report shows the global average surface air temperature have increased by $0.6 \pm 0.2^{o}C$ over 20^{th} century. Models also show that the global average surface air temperature will increase by 1.4 to 5.8 ^{o}C near the end of the year 2100 relative to 1990. In case of Nepal, the temperature is also increasing by 0.05 degree per year.

It is now generally accepted that the increasing rate of greenhouse gas emissions is the prime cause of both global warming and climate change. All the cases of the change in climate are possible due to variability of the temperature from human activity related to agriculture and resource sector. It varies at all time scale and different amplitude. Even minimal climate change can be disturbed the consequences for natural ecosystem. The extreme climatic event can also make great risk for human beings, agriculture and resource sectors.

Nepal has unique topographically pattern within the distance of 150 km span of north and south comprising various type of climate within short distances. Thus Nepal is very sensitive to climate change and its consequences. A study shows that if the temperature increment is continuous at the present rate, then the majority of western region will be converted into bare lands. Nepalese economy is agro-based. In that aspect change in the monsoon circulation pattern also affects our socio-economic status.

Thus, the study of the temperature is also essential in the present scenario. An attempt has been made to analyze both maximum and minimum temperature separately. This study concerned with the investigation of the temporal and spatial variation of temperature at various locations in Nepal.

1.2 Objectives of the study:

- To analyze the annual as well as seasonal temporal variations of maximum and minimum temperature.
- To analyze regional temporal variations of maximum and minimum temperature.
- To analyze spatial variation of maximum and minimum temperature.
- To analyze the temperature trends with altitude over Nepal.

1.3 Data

1.3.1 Availability

In Nepal, collection period of temperature data is very petite. Although systemic collection of meteorological data was started from 1970 and some of the station from early and late 1976, the stations were very few as compared today. At present there are 68 climate stations and 15 synoptic stations under the network of DHM in Nepal. All the meteorological data i.e. temperature data used in this study has been collected from 'Climatological records of Nepal', a publication of Department of Hydrology and Meteorology (DHM), Government of Nepal.

1.3.2 Status of the data

In the mountainous country like Nepal, station operation and collection of data is a quite complicated task. Thus, there is quite inadequate of stations network especially in the Himalayan regions. The long period data of the stations of Himalayas region are not also available. The details of the station descriptive history of some stations are also unavailable. Several stations first operated by

Indian Meteorological Department (IMD) have been closed but some are re-activated by DHM, Nepal. It is interesting that both stations under DHM and IMD have been operated by the same name and same location.

The missing data is a great problem which also affects the data quality. In the period of insurgency, data were observed to be missed in some of the stations for several days as well as for several months. In that case, some simple interpolation techniques have been adopted to fulfill the missing data for the purpose.

1.3.3 Data analysis Methods.

This analysis tool and its formulas measure the intensity or degree of linear relationship between two variables that are scaled to be independent of the unit of the measurement. Correlation coefficient between two variables x and y denoted by r (x, y) is defined by-

$$\mathbf{r\,(x,y)} = \frac{\mathbf{Cov(x,y)}}{\sigma x \,.\, \sigma y}$$

Where, $Cov\,(x, y) = \sum (x_i\, y_i - \bar{y}^2)/\, N$ and

$\sigma_x = \sqrt{\sum (\, x^2_i - \bar{x}^2)\, /N}$, $\sigma_x = \sqrt{\sum (\, y^2_i - \bar{y}^2)/N}$

σ_x = stander Deviation of Variable x. and σ_x = stander Deviation of Variable y.

$\bar{x}$ = mean of Variable x $= \sum (x - x_i)/n$,

$\bar{y}$ = mean of Variable y $= \sum (y - y_i)/n$

N = numbers of observations.

If the value of r^2 is nearly or equal to 1 then a best-fit line is a line that provides a good approximation to the maximum data.

The trend line method:

The trend line helps to determine the rate of change, understanding past behavior, planning future operations, evaluation of the current accomplishment and facilities comparison and can be ascertained tentative estimates concerning future can be made accordingly. Trend means the general, smooth, long-term, average tendency. The graphic method and the method of curve fitting by principles of least squares can be used for determining trend. In the study of the temperature, the slope of the line gives the temperature trend.

Principles of least squares Method:

Let (x_i,y_i) where i = 1,2,3….., n be a given set of n pair values. x being the independent variable and y the dependant variable. The general problem in curve fitted is to find, if possible, an analytic expression of the form y = f(x), for the functional relationship suggested by the given data. It is the mathematical method and with its helps a trend line is the fitted to the data in such a manner that the following two conditions are satisfied.

1. $(y - y_c) = 0$ i.e. the sum of the deviations of the actual values of y and the computed values of y_c is zero.
2. $(y - y_c)^2$ is minimum. i.e. the sum of the square of the deviation of the actual and computed value is least. From this line by method of least squares is obtained using this criterion is known as the line of the best fit.

This method is most widely used in practice. When the time series of increasing or decreasing is almost constant, the straight line trend is used. For the mean annual temperature vary very little from year to year. So straight line trend has been used for the temperature analysis as it can be used to predict the future trend. A straight line trend is given by

$$y_{c\,=}\, a + bx$$

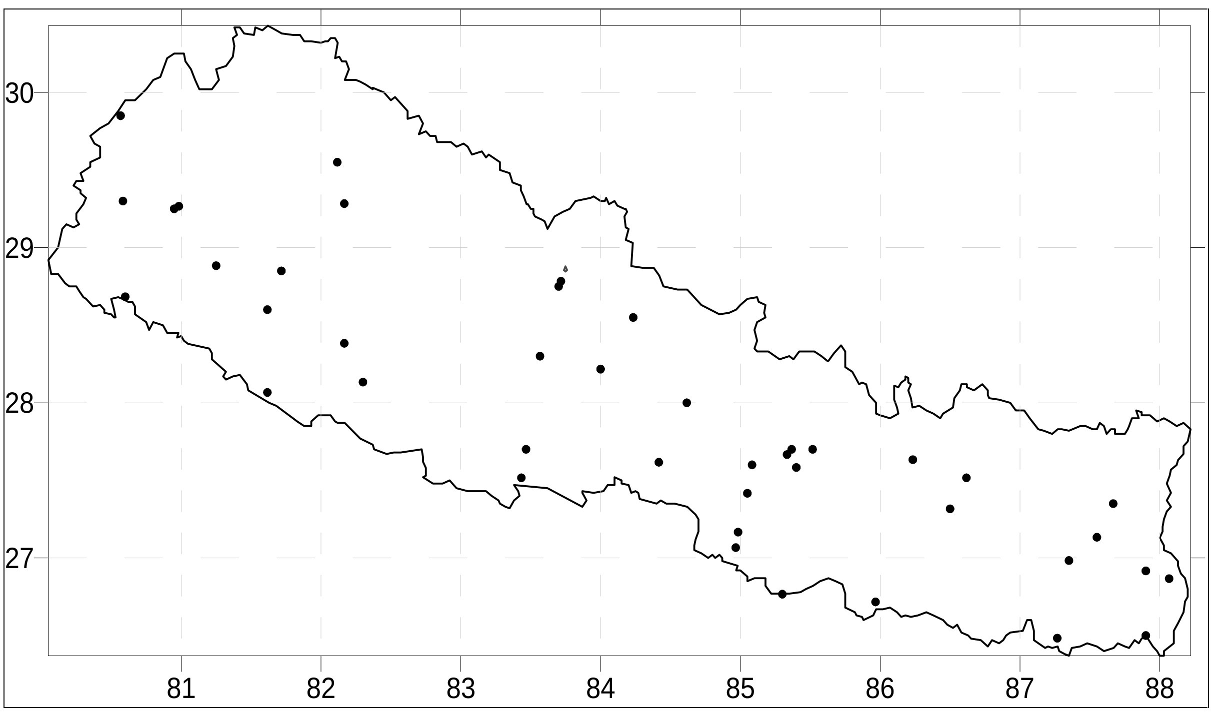
Where, a and b are the constant and x be the slope the trend.

The average monthly maximum and minimum temperature data has been used in the study. Seasonal and annual trends is computed using linear regression technique using Microsoft excel. All Nepal and station-wise seasonal temperature is also computed for spatial distribution for different four seasonal of Nepal with the help of surfer Version 7.02 developed by Golden Software Inc, US.

1.3.4 Station selection for the study

Only 43 stations (including climatic as well as synoptic) have been choosen for the study (Table- 1). These stations have been selected according to nature of topography and altitude of the nation. All the selected meteorological stations are categorized into four regions for the annual temperature variation analysis with respect to topographic i.e. Terai, Siwalik, Middle mountain and Higher mountain & Himalaya Region of Nepal and also into three region for calculation of surface lapse rate with respect to ecological region i.e. Terai, Hilly and Himalaya Region of Nepal.

The complete list of the stations selected for the study is as follows:



Map- 1: Showing the Station Map of Nepal.

S.N	Index No.	Latitude	Longitude	Elevation in meter	Name of the Station	Selected Region
1	104	29.30	80.58	1848	Dadeldhura	MMR
2	107	29.85	80.57	1097	Darchula	HMHR
3	203	29.27	80.98	1360	Silgadi Doti	MMR
4	209	28.68	80.60	170	Atteria, Dhangadi	TR
5	218	29.25	80.95	617	Dipayal Doti	MMR
6	303	29.28	82.17	2300	Jumla	HMHR
7	307	29.55	82.12	3048	Rara, Mugu	HMHR

8	401	28.88	81.25	950	Pusma Camp	MMR
9	402	28.85	81.72	1402	Dailekh	MMR
10	406	28.60	81.62	720	Surkhet, Birendranagar	SR
11	420	28.07	81.62	144	Nepalganj reg. off.	TR
12	508	28.13	82.30	725	Tulsipur	SR
13	511	28.38	82.17	1457	Salyan Bazaar	MMR
14	601	28.78	83.72	2744	Jomsom	HMHR
15	604	28.75	83.70	2566	Thakmarpha	HMHR
16	605	28.27	83.60	984	Baglung	MMR
17	703	27.70	83.47	205	Butwal	SR
18	705	27.52	83.43	109	Bhairahawa Airport	TR
19	804	28.22	84.00	827	Pokhara Airport	MMR
20	809	28.00	84.62	1097	Gorkha	MMR
21	814	28.30	83.57	1740	Lumle	MMR
22	816	28.55	84.23	2680	Chame	HMHR
23	902	27.62	84.42	256	Rampur	SR
24	905	27.60	85.08	2314	Daman	MMR
25	906	27.42	85.05	474	Hetauda	SR
26	909	27.17	84.98	130	Simara Airport	TR
27	911	27.07	84.97	115	Parwanipur	TR
28	922	26.77	85.30	90	Gaur	TR
29	1022	27.58	85.40	1400	Godawari	MMR
30	1029	27.67	85.33	1350	Khumaltar	MMR
31	1030	27.70	85.37	1337	Kathmandu Airport	MMR
32	1043	27.70	85.52	2163	Nagarkot	MMR
33	1103	27.63	86.23	2003	Jiri	HMHR
34	1111	26.72	85.97	90	Janakpur Airport	TR
35	1206	27.32	86.50	1720	Okhaldhunga	MMR
36	1220	27.52	86.62	2770	chialsa	HMHR
37	1307	26.98	87.35	1160	Dhankuta	MMR
38	1314	27.13	87.55	1633	Terhathum	MMR
39	1319	26.48	87.27	72	Biratnagar Airport	TR
40	1405	27.35	87.67	1732	Taplejung	HMHR
41	1407	26.92	87.90	1300	Ilam Tea State	MMR
42	1416	26.87	88.07	1676	Kanyam tea State	MMR
43	1421	26.50	87.90	143	Gaida Kankai	TR

Table: -1: Location selected for the study according to index number of the station.

Index:

TR stands for Terai Region, SR stands for Siwalik Region, MMR stands for Middle Mountain Region and HMHR stands for High Mountain and Himalaya Region.

CHAPTER – 2

Physical and Climatic characteristics

2.1 Physical characteristics of Nepal

Nepal is predominantly-mountainous country. Nepal is a land–locked country, which lies on the central region of the Himalayas Range between India and Tibetan region of the Republic of the china. Nepal is extended from 80^0 4^0 East to 88^0 12^0 East longitude and from 26^0 22^0 North to 30^0 27^0 North latitude. It has an area of 1, 47,181 Sq. Km. (Statistical Pocket Book, Nepal; 2004).

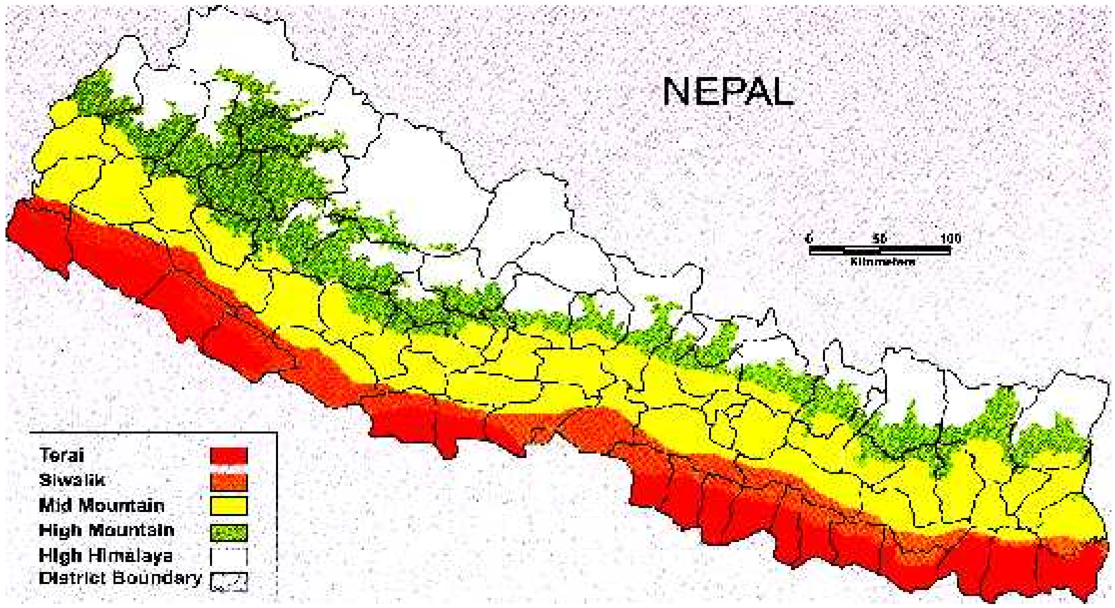
2.1.1 Division of Nepal according to ecological region:

Nepal is located near the northern limit of the tropic region. Nepal is divided into three parts based on the ecological region, namely, Terai, Hilly and Himalayas. (CBS). This division is used in the study for the spatial variation of temperature over Nepal.

1. Terai Region: The lower part of Country is the Terai Region. It elevates from 65m to 200 m. The region is situated under the 'Churre Parvat' (small hill region) and most of the land is plane. Most of the population lives in this region. This land is called agricultural basket.
2. Hilly Region: It elevates from 200 to 1500 m. It lies from above the 'Churre Parpat' and higher mountainous region of the country. Inner valley region such as Surkhet, Chitwan, Dipayal, Kathmandu etc are situated in this region.
3. Himalaya Region: It elevates from 1500 to above or 4000 m. It lies above the Hilly region of Nepal. Less population lives in this region. The weather is always dry and cool.

2.1.2 Division of Nepal according to physiographic regions:

Nepal is also classified into five regions according to physiographic as well as topographic region: Himalayas, High Mountain, Middle Mountain, Siwalik and Terai Region. This physiographic region of Nepal has been used in the study of the temporal variation of temperature over Nepal.

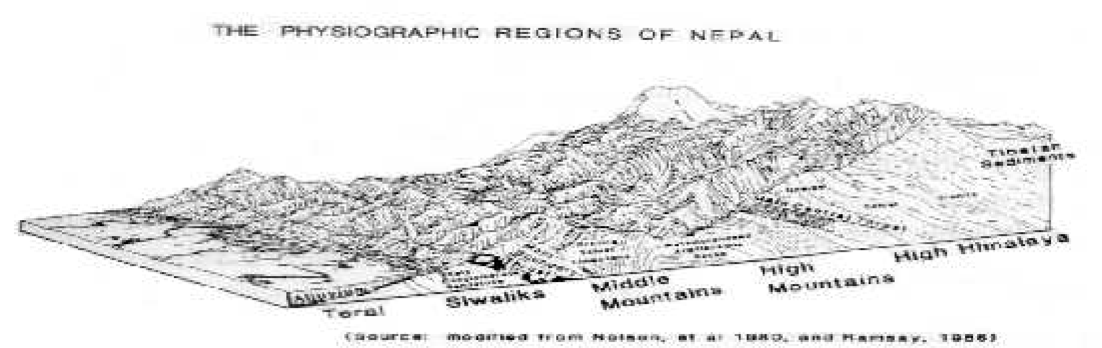


Map- 2: Showing the Topographic Map of Nepal.

1. Himalayas Region: The Himalayas cover about 24 % of the total land of the Nepal. Himalaya region expands up to 8848 m. In the lower part of Himalaya, Annual mean temperature rang from 3^{o}C to 5^{o}C. In winter temperature drops below freezing point i.e. 0 ^{o}C. and in summer temperature does not go up so much. In higher Himalayas range, almost above snowline (4500 m), a permanent cover of snow and ice, Precipitation mostly falls in the form of snow only.
2. High Mountain Region: The high mountain region makes up about 19 % of the total land area of the country and expands from 1500m to 4000m height. Areas of gently sloping land are much less common than in the middle mountains because the rocks are less easily weathered and river cutting is more intense, Deep 'V' shaped valleys are common throughout the region. Annual mean temperature rang from 5 ^{o}C to 10 ^{o}C.
3. The Middle Mountain Region: The Middle high mountain region makes up about 30 % of the total land area of the country and it elevates from 800 meter to 2500 meter. The Mahabharata Hill which runs the length of the southern boundary of the middle mountain region is found. The climate up to 2000m is warm temperate, annual mean temperature rang from 15^{o}C to 18^{o}C. The climate from

the elevation of 2000m to 3000m is cool temperate & mean annual temperature range varies from 10 ^{o}C to 15^{o}C.

4. The Siwalik Region: The Siwalik region is in the north of the Terai, it elevates from about 200 m to 1500 meter. It covers 13 % of the total land area of the Nepal. Within the mountainous landscape of the Siwalik, slopes are generally to steep or unstable and soils too shallow to support any types of agricultural cultivation. Mean annual temperature ranges from 18^{o}C to 20^{o}C in the higher Siwalik region. This is the most important and valuable area from the agricultural point of view. The Dun valley like Surkhet, Tulsipur, Chitwan etc are those lands where virtually the entire presently cultivated land is found. The region has a hottest and humid summer, mild and dry winter.
5. The Terai Region: About 14 % of the total land area of the Nepal is covered by the Terai region. The land is plain, flat with the exception of minimum or local relief caused by river act. It elevates from about 70 m to 200 meter. Mean annual temperature range ranges from 21^{o}C to 25^{o}C and rainfall concentrates in the summer month, winter temperature are mild. A year rounds growing season, good soils, availability of sufficient irrigation water, and advocate optimistic future for agriculture. The region has a hottest and humid summer, mild and dry winter.



Map-3: Physiographic map including regions of Nepal.

Physiological Region	High Himalayas	High Mountain	Middle mountain	Siwalik	Terai Region	Total
Area in 000 ha.	3349.2 (22.7%)	2959.3 (20.1%)	4443.6 (30.1%)	1885.7 (12.8%)	2110.4 (14.3%)	14748. 2 (100%)

Table -2: Percentage area covered table of the Physiological Region of Nepal.

2.2 General climatic features of Nepal

Topographic features, altitude, geographical location controls the whole Nepal in climatic aspects. Generally country can be divided into five climatic divisions.

1. Tundra – climatic type:- Tundra type of climate is found in the higher Himalayas region of Nepal. Almost above snowline (5000 m), a permanent cover of snow and ice, Precipitation mostly falls in the form of snow occurs only.
2. Alpine – climatic type:- In the lower part of the Himalayas region, alpine type of climate is found. Above 4000m, cool summer and frosty winter, snow and ice, precipitation in the form of snow occurs only.
3. Cool temperate – climatic type:- This type of climate is found in the region of High Mountain region of Nepal. Cool summer and cool winter, winter precipitation in the form of snow at high altitude occurs only.
4. Warm temperate – Climatic type:- This type of climate is found in the region of Mahabharata range of middle mountain region of Nepal. Warm summer and cool winter, occasionally snowfall in higher region of hills and precipitation in the form shower may occur.
5. Tropical/Subtropical – climatic type:- The sub-tropical type of climate is found in the lower region of Churre range or Terai of Nepal. The tropical type of climate is found in the Churre range or Siwalik of Nepal. Hottest and humid summer, mild and dry winter occurs. (Adopted from Regmi, 1998)

2.3 General season in Nepal

According to season, Climate of Nepal is divided into four parts; these are as follows (adopted from Nayava, 1981):

A. Pre-monsoon season : (March - May)
B. Monsoon season : (June – September)
C. Post monsoon season : (October - November)
D. Winter season: (December -February)

A. Pre-monsoon season: It starts from March to May. In this period, much of the days of the month remain under the domination of the dry westerly wind. This wind system produces dusty and windy weather in the most of the country. Convective activity produces high to moderate rain shower especially in the hilly region. As a matter of the fact, the distribution of pre-monsoonal rainfall in the country are associated with the thermal convection associated with orographic effects which results thunderstorm associated with precipitation over the narrow bands with in the region.

B. monsoon season: The season starts from June to September in Nepal is known as rainy season. Monsoon arrives from eastern Nepal on June 10^{th}, and it arrives at Kathmandu on June 12^{th}, within 2 to 3 days, it covers the whole country. The normal date of the retreat of the monsoon is September 23. When the monsoon circulation pattern is established, temperature begins to fall; air becomes most compared to other season. Relative humidity of this season becomes high. In Nepal, 60% to 80% of the annual rainfall falls during this season. Rainfall varies sharply from one place to another due to impact of the topography. When the moist south easterly wind approaches, the air stream is forced to rise resulting rainfall on the slope facing southwards. The month of July is the rainiest month of the rainy season.

C. Post monsoon season: The season is the changing period from season to another and harvesting season of monsoon crop field preparation is done for winter season crops. Sometimes, the country receives precipitation by cyclonic storm that develops in the bay of Bangal and Arabian Sea. Regmi (1998) indicates the domination of westerly wind flow with falling in temperature gradually as an indication of pre-winter activity, negligible amount of rainfall occurs in this period.

D. Winter Season or Cold weather season: It runs from December to February. North-westerly wind pre-dominates the country in this season. Except in the region of great Himalayan and a high mountain, the winter is normal with great sunny days (Nayava, 1981). In winter, major weather effective elements are the western disturbances and so western Nepal receives higher amount of rainfall than eastern Nepal. This region is relatively dry & cool weather, lowest temperature and rainfall amount is very less but greater than post monsoon.

CHAPTER – 3

Literature review on Temperature and climate

3.1 Temperature:

The term temperature refers to the degree of hotness or coldness of the matter. Alternatively, the Temperature of the matter is the condition that determines its ability to transfer heat to other matters or to receive heat from them (Shakya et al., 2003). Sun is the prime source of the energy. During day time, after sun rise, the earth receives much of the solar radiation. Consequently, the air Temperature increases and reaches maximum during the day-time usually after the noon.

The temperature of a land surface represents balance between the incoming solar radiation and out going terrestrial radiation. At the day-time, angle of the sun rises reaching a peak in noon, the incoming solar radiation exceeds the outgoing earth radiation. However, the maximum temperature is recorded in late afternoon. This delay in the occurrence of maximum is called lag of the maximum. This is caused because of the fact that although the maximum amount of isolation is received at noon; the earth's surface and the air lying close to it continue to receive more heat than they lose during the afternoon. That is why the temperature continues to rise. But from the middle afternoon to sunrise, the loss of heat by earth radiation exceeds the receipts of solar radiation. Therefore, the temperature continues to drop until about sunrise the following day. With sun set, surface cooling starts with emission of the long wave radiation from the earth. The maximum cooling occurs early in the morning resulting to the lowest air temperature to record. The lowest Temperature recorded in a day is known as a minimum Temperature of a day.

In Nepal, the altitude generally increases from south to north. Hence temperature declines from south to north. The air temperature is the most important element that controls weather. Temperature and humidity are the special features of seasonal changes, which are most effective. Humidity and temperature are closely related with our physical comfort and efficiency. It has serious impacts on agriculture and water resources. During winter time, minimum temperature falls down significantly in comparison to the summer season. Hence, minimum Temperature has a significant role during winter season especially in middle and higher altitude (Shakya et al., 2003). Minimum Temperature affects the morning activities of the human beings and it is one of the major causes of health hazards.

3. 2 Climate:

Climate of Nepal is characterized by large variations in both annual and seasonal domains (Shrestha et al., 1999). Climate is defined as the mean state of the atmosphere for a given time scale (hour, day, month etc) over a specified geographical region. The climate has variability on all the time and space and will be changing.

Climate is fairly dynamic phenomenon. A great change in climate has been investigated over most of the globe. All the cases of the change in climate are possible due to variability of the temperature from human activity related to agriculture and resource sector. According to IPCC, Climate change refers to any change in climate over time, whether due to natural visibility or as a result of human activity.

Climate is variable aspects of natural environment. It varies at all time scale and different amplitude. Even minimal climate change can disturb the natural ecosystem. The extreme climatic event can also make great risk for human beings, agriculture and resource sectors.

Crop yield responses to climate change very widely. These responses depend upon species and cultivation, soil properties, air temperature, water stress, mineral nutrition etc. Agricultural in Nepal is highly varied due to different topographical and cultural characteristics. Land use in Nepal is classified in to agriculture, pasture, forest, shrub and others.

Nepal has an agriculture-based economy. Rice production is the major agriculture activity in the country owing in the complex rice cultivation system in the country. Nepal emits about 550.6 Gg of the CH_4 in 1990/91from flooded rice fields. Regmi (1998) shows the drought is a climatic anomaly characterized by deficient supply of moisture. He also classified the drought into four types on the basis of the study of Thronthwait and Mather (1955), i.e., permanent which has the characteristics of driest climate; seasonal where well defined wet and dry season exists; continent which is due to the rainfall variability can occur any where including seasonal drought area but most characteristics of sub humid and humid area; and invisible which can occur in any area but most common in more moist regions even when there is rain or everyday.

3.3 Controlling factor of the Temperature:

The control of temperature includes those factors that bring about spatial variation in temperature. Following are some of the more important factors that determine the temperature of a particular place on the earth surface.

Latitude:

Latitude is the very important control on the temperature. Intensity of insolation depends on the latitude. The variations of temperature are directly related to local radiation budget. Therefore, insolation is the major factor in determining the temperature of the air. In the vertical plane, the temperature is highest near the ground and decreases upwards for tropospheric level.

Altitude:

Temperature decreases with increasing altitudes from the earth surface. The lower part of the earth contains more water vapor and dust particles than upper. Therefore, Temperature is higher in the lower region than high elevation.

Distribution of land and water:

The Temperature in the water bodies is a greater concentration of insolation than the earth surface. Evaporation from water bodies is greater than that from land surface.

Ocean Current:

Ocean current moves from one place to another in order to equalize temperature. They are large movement of ocean water usually from a place of warm temperature to that of the colder temperature or vice versa. The effects of cold currents are more pounced in the tropics.

Prevailing Wind:

It is obvious that neither ocean nor ocean current can exert maximum influence upon temperature unless the direction of the prevailing wind is such as to carry the moderating effect of the oceans to the adjacent land. The maximum temperature on the windy day is certainly lower than on calm day. Thus, the temperature on day with gusty wind is relatively lower.

Cloudiness:

The amount of the cloudiness affects the temperature of the earth's surface and atmosphere. The general effect of the cloud cover is said to be moderate temperature, lowering the potential maximum and raising the potential minimum temperature.

Mountain barrier:

Landform barriers, particularly high mountain region, exert significant influence on the temperature of a place. Mountain range blocks the movement of the air from one place to another and thus controls the weather and climate of the locality. The mighty Himalayas do not allow the cold winter air masses. Therefore, the south of the mountain regions remains relatively higher than the north part of the mountain region.

Nature of the Surface:

Different kinds of the surface reflect different amount of the incoming solar radiation falling thereon. Dark colored surface absorb more insolation than light colored ones. The temperature over snow cover ground remains low even during the daylight hours.

Relief of the land:

On the local scale, even different in elevation of the land and its slope strikingly control the temperature. Relief also controls the quantity of the insolation and duration of the sunlight. At a certain hour of the day, place located in the valley and of the slope do not get direct sunlight. In those places, temperature remains slightly lower.

Convection and turbulence:

The convection currents and eddy motions moderate the temperature of particular places. In winter streams of air across the mountain barrier and decent on the leeward side, in this process, they get warmer up by compression and thus the air temperature is raised.

Stability of atmosphere:

The Stability of atmosphere is directly related to the fluctuations of temperature. If there is an inversion layer in the atmosphere at a small distance from the ground, than the heat radiated from the earth has to warm relatively smaller volume of air. Therefore, nocturnal cooling is retarded and minimum temperature is little higher. Thus, the inversion of the temperature lowers the range of temperature.

Water vapour content:

Humidity of the air also affects the range of the temperature in the effective manner. Lesser the amount of water vapour in the air, greater the amount of heat lost to space by long wave radiation. Therefore, if more humid air, smaller the range of the temperature and if drier the air, larger the diurnal range of the temperature. So, higher range of the temperature is observed at Desert places.

3.4 Effects of Cloud Cover on temperature:

During the day, the earth is heated by the sun. If skies are clear, more heat reaches the earth's surface (Fig- 125A). This leads to warmer temperatures. However, if skies are cloudy, some of the sun's rays are reflected off the cloud droplets back into space (Fig-126A). Therefore, less of the sun's energy is able to reach the earth's surface, which causes the earth to heat up more slowly. This leads to cooler temperatures.

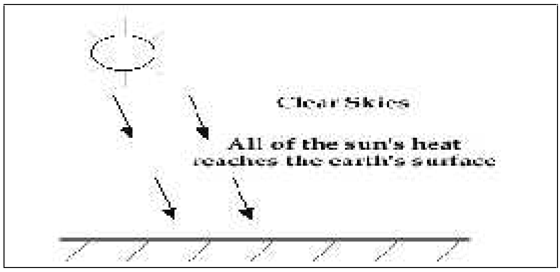


Figure-125A Temp Variations on clear sky during day-time

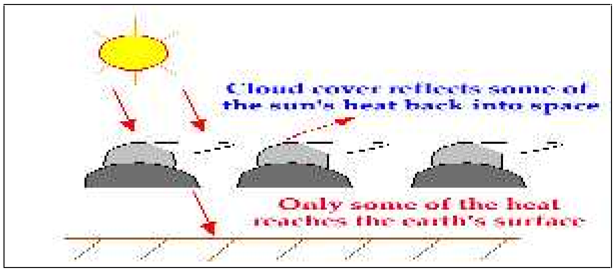


Figure-126A Temp Variations on cloudy sky during day-time

At night cloud cover has the opposite effect. If skies are clear, heat emitted from the earth's surface freely escapes into space, resulting in colder temperatures (Fig. 125B). However, if clouds are present, some of the heat emitted from the earth's surface is trapped by the clouds and reemitted back towards the earth. As a result, temperatures decrease more slowly than if the skies were clear (Fig. 126B).

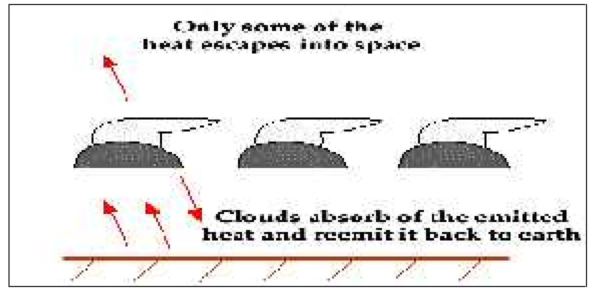


Figure-125B Temp Variations on clear sky sky during night-time

Figure-126B Temp Variations on cloudy during night-time

3.5 Vertical distribution of temperature:

As one move from the equator towards the pole, steadily decreasing temperature is observed. In the same way, there is a steady decrease of the temperature with increasing elevation. This decrease of temperature with increasing altitude in the atmosphere is called the vertical temperature gradient.

Vertical temperature gradients are controlled partly by energy transfer and partly by vertical motion in the air. Vertical motion is closely related to pressure system in which low pressure system give rise to ascending current which cool by expansion.

Lapse rate:

The observed rate of vertical decrease of temperature is called the Lapse Rate. Lapse rate is not constant but varies with height, location or seasons. It should be noted that the lapse rate indicates the temperature condition that are found in a stationary column of air characterized by the absence of any vertical motion.

Temperature decreases with latitude owing to the rarefied air having low content of carbon dioxide, moisture and other particles. Consequently, the sun's ray pass through the air with less warming effect and high proportion reaches the ground surface at mountaintops that rapidly heat up. The primary consequence of altitude is the decreases in air pressure with the increase in elevation. Only in exceptional case such as in the Himalayan areas, this phenomenon has agricultural significance since the effect of decreased pressure are generally observed only above considerably high altitude at which climatic controls such as temperature, precipitation, humidity etc limit agricultural land utilizations. Usually the rarefied air of the high mountain increases transpiration rates of the plants, which unfortunately restricts growth of the plants.

The locational height of the improved land varies with the size of the upland mass, latitude and climate. However, important consequences of increasing elevation, both agronomical and economical significant are: Decrease temperature, Increase precipitation, Increase wind velocity, Poor soil and ragged relief.

3.6 Temperature and Agriculture:

Temperature is especially important as rainfall for the agriculture growth. Plant needs the certain range of the temperature which is known as optimum temperature. Without this, germination of the seeds and growth of the plant are retorted. Temperature regulates all the chemical and physical processes of plant metabolism. The metabolism process begins at certain minimum temperature and increase with rise of temperature until they reach maximum at temperature called the optimum. Further with rise in temperature above the optimum level the metabolic activity is slowed down until it ceases at a temperature.

3.7 The temporal variation on different locations and regions:

3.7.1 Global trend of temperature:

Examinations of surface air temperature data during last 140 years have shown that there are general upward trends in the averaged surface air temperature over both hemisphere and globe (IPCC-2001). That report has stated that the global mean surface (Surface temperature + Sea surface temperature (SST)) have increased by about 0.6 ^{o}c since beginning of 20th century and quoted that 1990s has been the warmest decade and 1998s the warmest year in instrumental record since 1861.

Between 1950 to 1993, on average, the rate of increase in minimum temperature (0.2^{o}C/decade) over the land is about twice the range of increased in maximum temperature (0.1^{o}C/decade) (IPCC-2001). The increase in SST over this period is about half of the mean land surface air temperature.

The year 1998 was the warmest year with average temperature of 0.54 ^{o}C above the same 30-year average (1961-1990). Five warmest years in the decreasing order are 1998, 2002, 2003, 2004 and 2001. The last 10-Year (1995 to 2004) with the exception of the year 2006, were among the warmest on the record.

According to WMO in the paper "status of global climate in 2004; WMO-No.983", the year 2004 was the fourth hottest ever recorded since 1861; the year of measurement of temperature began. The global mean temperature in 2004 was 0.44^{o}C above the 30-Year average (14^{o}C). The surface temperature anomaly in 2004 for the Northern Hemisphere (+0.62^{o}C) was the fourth hottest and for Southern Hemisphere (+0.25^{o}C) was the sixth warmest year in the instruments record. Globally, the land surface air temperature anomalies for October to November 2004 were the warmest on the record for these months. In the Northern Hemisphere, the 1990 was the warmest decade with mean temperature 0.38 ^{o}C above the 30-Year averages. However the mean surface temperature, for the recent 5 year (200-2004), was much higher with positive anomaly of 0.58 ^{o}C.

3.7.2 The projections for global climate change by the IPCC 2001

1. Increase in globally averaged surface temperature of 0.4°C to 1.1°C (1990-2025); 0.8°C to 2.6°C (1990-2050); 1.4°C to 5.8°C (1990-2100) i.e. 2-10 times the central value of observed warming during the twentieth century.
2. All land areas are likely to warm more than these global averages, particularly those at northern high latitudes in winter.
3. Globally averaged precipitation is projected to increase over the next 100 years with regional increases/decreases of the order of 5-20%.
4. Precipitation is likely to increase over high-latitude regions in summer & winter.
5. Cereal crop yields may increase with raised temperatures but high temperatures may reduce them.
6. Ability of livestock producers to adapt herds to changed climate stresses is poorly known.
7. Global warming may increase food prices globally and increase risk of hunger in vulnerable populations. (Adopted from IPCC 2001 Report.)

3.7.3 Temperature trends According to IPCC 2001 Report:

1. Global mean surface temperature is increased by 0.6 ± 0.2°C over the 20^{th} century and land areas warmed more than the oceans (very likely).
2. Northern Hemisphere surface temperature is increased over the 20th century greater than during any other century in the last 1,000 years and the 1990s warmed decade of the millennium (likely).
3. Diurnal surface temperature range is decreased over the years 1950 to 2000 over land and night-time minimum temperatures increased at twice the rate of daytime maximum temperatures (likely).
4. Hot days/heat index is increased (likely).
5. Cold/frost days are decreased for nearly all land areas during the 20th century.
6. Continental precipitation is increased by 5-10% over the 20th century in the Northern Hemisphere (very likely), although decreased in some regions (e.g. north and West Africa and parts of the Mediterranean).
7. Heavy precipitation events are increased at mid- and high northern latitudes.
8. Frequency and severity of drought are also increased summer drying and associated incidence of drought in a few areas. In some regions, such as parts of Asia, the frequency and intensity of droughts have been observed to increase in recent decades.
9. Global mean sea level is increased at an average annual rate of 1 to 2mm during the 20th century.
10. Duration of ice covers of rivers and lakes are also decreased by about 2 weeks over the 20th century in mid- and high latitudes of the Northern Hemisphere.
11. Non-polar glaciers are widespread retreat during the 20th century.
12. Snow cover areas are decreased by 10% since global observations became available from satellites in the 1960s (very likely).
13. El Niño events are become more frequent, persistent, and intense during the last 20 to 30 years compared to the previous 100 years.
14. Growing seasons are lengthened by about 1 to 4 days per decade during the last 40 years in the Northern Hemisphere, especially at higher latitudes.

15. Plant and animal ranges are shifted pole ward and up in elevation for plants, insects, birds and fish.
16. Weather-related economic loss: - Global inflation-adjusted losses raised an order of magnitude over the last 40 years. Part of the observed upward trend is linked to socioeconomic factors and part is linked to climatic factors.

3.7.4 Recent temperature Trends of the Both Hemispheres:

Zhao M. and Dirmeyer (2004) are studies the pattern and trend analysis of temperature based on these mean monthly and annual surface air temperature anomaly data. The departures of the individual station mean monthly temperatures from an average for the period 1951 to 1975 were spatially averaged. Vinnikov et al. (1990) reported that both hemispheres were warming at a rate of 0.5°C/100 yrs. The present update of the series through 2004 shows that the northern hemisphere has warmed at a rate of 0.69°C/100 yrs, and the southern hemisphere (0°-60°S) at a rate of about 0.55°C/100 yrs. The warming rate for the globe (in this case, 90°N-60°S) is 0.62°C/100 yrs. This trend is close to the 0.70°C/100 yrs global trend calculated by Jones and Moberg (2003) for land areas over the period 1901-2000.

However, Zhao and Dirmeyer (2004) found an interesting case to note that the large positive anomalies found in the late 1930s and 1940s in the Jones et al., (2001) global time series are not as evident in the Lugina et al. global series. Relatively large positive anomalies for this period are present mainly in the Lugina et al. series for the latitude band 60°N-90°N. In the 60°S-90°S latitude band, an increase in the annual surface temperatures is shown (0.17°C/10yrs; most of the warming having occurred by 1970), with the largest trend apparent in the months of June to August (0.47°C/10yrs).

According to Zhao M. and Dirmeyer (2004), the annual trend can be compared with the Jacka and Budd (1998) finding of an Antarctic warming of 0.12°C/10 year and Reid and Jones (2001) with a warming of 0.15°C/10 year. These three data based on, while not representing the same network of stations, essentially reflect temperature changes at Antarctic stations, most of which are near the coast of the continent. While these warming trends for the high latitudes of the southern hemisphere are quite large, it must be remembered that:

1) There is extreme inter-annual temperature variability at these latitudes;

2) The atmospheric/surface thermal inertia for this region is low;

3) This area is rather a small fraction of the globe's surface; and

4) The period of record for the region is quite short.

Therefore, one should not place nearly as much emphasis on trends for this polar region as any significant changes nearer the equator, where the atmospheric/thermal inertia is the largest and the percentage of the globe's surface is much larger.

In the global records, as in other records, these anomalies show that the 1980s, 1990s, and the first few years of the twenty-first century were much warmer than the rest of the record. For the globe, the ten warmest years have occurred since 1990. In descending order they are 1998, 2003, 2002, 2004, 2001, 1999, 1995, 1990, 1997, and 1991/2000.

The most recent year of the data record, 2004, saw the fourth warmest global mean temperature departure (0.65°C) on record and the fourth warmest northern hemisphere temperature departure (0.86°C); just barely cooler than 2003 (0.88°C) and 1998 and 2002 (both 0.87°C). The warmest autumn (September-November) temperature departure on record for the globe (0.70°C) and the second warmest winter (1.04°C), spring (tied with 2002; 0.94°C), and autumn (0.88°C) for the northern hemisphere were also recorded in 2004. The 30-60°N latitude bands saw its warmest annual (1.04°C) and autumn (0.93°C) temperature departures to date in 2004, while the southern hemisphere (0-60°S) recorded its warmest spring (September-November) departure (0.50°C) (Mei Zhao and Paul A. Dirmeyer, 2004).

3.7.5 Trend of temperature over India:

In any spatial scales, atmospheric temperature is the most widely used indicator of climate changes. In temporal variation of temperature over India, by Pramanick and Jaganath (1954); no increasing/decreasing trend was observed in maximum and minimum temperature trend of about 30-Indian stations. Hingane et al. (1985), using data from 73 stations for the period of 1901-1982 reported significant warming trends in the all Indian temperature over annual and seasonal (except during monsoon season) scale. During monsoon, no trend was seen. The trends in the all-Indian mean annual temperature was of the record of 0.4 ^{o}c per 100 years. Thapaliya and Kulsheretha (1991) have also reported similar warming trend using data for 1901 to 1989. According to Pai D.S., the warming in the annual mean temperature is mainly contributed by the winter and post monsoon seasons. The monsoon temperature does not show significant trend in India.

Kothawale and Rupa Kumar (2002) using 19 radiosode station over India examined the trends in the all-Indian mean temperature at surface and five stander tropospheric levels. The result shows that there is a significant warming trend of 0.10 oc per decade in recent period. Trough warming trends are visible in tropospheric level, significant only at 850 hpa level. Their study also revealed warming trend in surface and upper air all the seasons. Srivastava et al. (1992) examined the decade trends of the maximum and minimum temperature and he shows that the diurnal asymmetry of the temperature trends over India is quite different from that observed in the other parts of the world. He found that the maximum temperature have much larger increasing trends than minimum over major parts of the India.

3.7.6 Long Term variation of the temperature:

Studies on long term variations in the surface air temp for the entire globe (Jones et al., 1986), Hansen and Lebedeff- 1987 &1989) as well as for the hemisphere (angel and korshover 1978) have shown a raising trend during the last few decades. Similar results have been found for low latitude regions in the Northern Hemisphere.

Mountain hemisphere is considered to be sensitive indicator of climate change (Barry -1990, Store -1992). Several studies in the Himalayas have found that glacier in the region have retreated considerably in the last two decade (Higunchi et el -1980, Miller -1989). Recent studies have identified the formation and growth of the several glacier lakes, possibility due to fast retreat of glacier, which could led to catastrophic outburst flood (Vuichard and zimmermann, 1987). It is possible that global warming is responsible for the recent retreat of the glacier in Himalayas; also precipitation changes may also be important. Mayewski and Jeschke (1979) have suggested that Himalayas glacier have been retreating since 1850 A.D. It is possible that the cooling in 1940 observed in global record caused advancing of these glaciers, and warming after the mid-1970s resulted in accelerated shrinking in the past two decades.

3.7.7 Temperature variation in Nepal:

In temperate zone, the diurnal range is larger in summer than in winter. In summer, the weather is generally clear and the temperature is sun-controlled. On the other hand, in winter, the cyclonic weather with its cloudiness and winds blowing from different directions and with different velocities proves more effective than the direct ray of the sun in determining the temperature. Thus the nights may be warmer than the days under such conditions.

In the winter season, short period nearly one week, of serve cold spell associated with foggy weather prevailing in the period of late December to first week of January over the southern Terai plain. During the cold spell period the day time temperature dropped by 2-5 ^{o}c from the yearly normal in the year 2004.

In the pre-monsoon season, significant warming was observed in March through out the country, remarkable in the western Nepal. Some of the stations in the far and mid-western region recorded the highest maximum temperature. The increase in the maximum temperature was found to be larger than that in the minimum temperature in the most station of middle and low altitudinal region & over the southern Terai plain. During the pre-monsoon, country experience very hot in May.

The western southern regions suffered from serve hot weather condition in May and maximum temp soaring up to 40 ^{o}c or above.

In the monsoon season, monsoon commenced in the eastern and central region from normal date 10th June and reaches in western parts only on 13th June. In 2004, twelve districts from western, mid-western and far-western region experienced deficit in the rain while nine districts from central and eastern region recorded excess of rain. About 215,000 hectares agriculture lands in 10 district of mainly in western and mid-western regions and one district of eastern region were highly affected by drought conditions (DHM / Weather report, 2004). Because of weak monsoon, most of the places of the country observed record breaking maximum temperature in August and September.

In the post-monsoon season, (DHM / Weather report, 2004) post-monsoon season was considered more pounced resulting in above normal rainfall in the most part of the country in October. However November experience poor rain; only light rain was observed at some parts of the country. The maximum temperature was observed above normal almost throughout the country with strong positive anomaly exceeding 4 ^{o}c in the far western and 3 ^{o}c in some parts of eastern regions at 2004. As a result of some stations, the western region (Dadeldhura, Dang) was recorded highest ever maximum temperature for December (2004, beginning of winter-2005). Country experiences the remarkably chilly weather in the last week of December with rapid drop of maximum as well as minimum temperature by 4 ^{o}c to 8 ^{o}c. After 1992, Kathmandu recorded lowest minimum temperature of 0.3 oc on 27th December 2004.

According to Devkota (2004), the maximum temperature series show increasing trend from 1970 to 2000 except Terai and Siwalik, and all Nepal series during pre-monsoon season where slightly decreasing trends was observed. Whereas, most of the seasonal and annual minimum temp series for High mountain region and all Nepal shows decreasing trend and these series of Terai and Siwalik and middle mountain & Hills regions show increasing trend. Magnitude of the trend in maximum temp is found increasing as altitude increases. However, in the case of minimum temp, it is found decreasing as altitude increases.

Shrestha et al. (1999) investigated trend in the maximum trend since 1971 to 1994. He found that trends were almost constant or decreasing before 1976 where as after 1976 the trends are slightly increasing. He also found the warming trends in all five physiographical regions and all Nepal mean seasonal maximum temperature series. For the most of the region greatest warming was observed during the post-monsoon season.

Shrestha et al. (1999) analyzed the distribution of trends in the annual maximum temperature only and found that the revealed warming after 1977 ranging from 0.06 oc to 0.12 ^{o}c per year in most of the middle mountain and Himalaya regions, while Siwalik and Terai region show warming trend less than 0.03 ^{o}c per year. He showed that even the Siwalik and Terai region are at high warming rates for the post-monsoon season. Most of the northern, central and mid-western part of the country shows high rates of increase in temperature in case of annual temperature distributions.

Maximum temperature seasonal lapse rate is higher than the minimum temperature. Pre-monsoonal lapse rate has highest and winter minimum lapse rate has the lowest in Nepal (Devkota -2004). He showed the increasing trends were observed in the most part of the country during seasonal and annual period for both maximum and minimum temperature in the study of spatial distribution. The western higher middle mountain region is increasing the rate up to 0.6 ^{o}c per decade and decreasing trend found in the minimum temperature for the western HMM region especially during monsoon and post monsoon seasons. The increasing trend at the rate of 0.6 ^{o}c per decade was also observed over central HMM and HM region of Nepal during monsoon, post monsoon and annual.

3.7.8 Variation of the temperature on Precipitation:

Precipitation is one of the most climatic parameters, especially it controls the fluctuation of temperature. The place receiving low rainfall is relatively drier than others. The temperature at Mahabharata range, especially on the southern face of the mountain is relatively mild. Pokhrel A., (2003) shows the annual precipitation varies from below 400 mm at Jomsom with latitude 2744 m to 5098 mm at Lumle with elevation 1740 m by the results of 13-year mean annual precipitation. This is due to the extreme special variation of precipitation. Precipitation is high over middle latitude i.e. Mahabharata range and decrease slightly over Terai and decrease rapidly over Himalayas range.

Seasons of Nepal is most important in the study of temperature. The season controls the temperature in natural way. In winter, temperature has remained below the normal. It is very cold season than others. Post-monsoon season is the hottest season. Monsoon season is mild, lower temperature than post-monsoon. During the winter season, the far western region receives maximum precipitation from westerly disturbances as an upper air westerly trough. Thus, western part of Nepal in winter is relatively colder than eastern. According to Pokhrel, (2003), Precipitation receives lower in the Terai region than middle part of Nepal due to the level land having no climatic barrier to obstruct the way of the monsoonal flow. In the hilly region amount of rainfall is very high in those place which are situated along the southern slope and south facing hill region. In the study of the seasonal variation of the precipitation over Nepal from 1968 to 1998, July is the wettest month at Pokhara, Butwal and at Surkhet, Jumla; August is the wettest month. This is due to the late arrival of monsoon in the west. April is the driest month in the western region due to the effect of the BC2 monsoon approach lately.

Evapo-transpiration is also affected the fluctuation of temperature. If evapo-transpiration value is measured as low then the temperature is found to be relatively colder and vice-versa. Nayava (2005) shows that evapo-transpiration values were estimated 51 to 55 mm at the most part of the western region of Nepal and also shows less in mountain region especially on Jumla and Dolpa where evapo-transpiration were at the same rate in January. However, mean annual values were calculated for Terai (1200 to 1350 mm), Hill and Mountain (1100 to 1300 mm) and rain shadow area of Mustang (115 to 165). It is interesting to note that evapo-transpiration were estimated 1200 to 1300 mm in Jumla and Humla in annual; this is due to the effect of aerodynamic. He also shows the energy term is increasing with increasing temperature and aerodynamic effect is decreasing with increasing temperature.

CHAPTER – 4

Result and discussion

4.1 Temporal Variation at selected station:

Slightly increasing trends in annual maximum temperature have been observed at the station Gaur (fig. 9), Gaida Kankai (fig.13), Rampur (fig. 17), Surkhet (fig. 19), Hetauda (fig. 23), Tulsipur (fig. 25), Dipayal Doti (fig. 1), Pokhara airport (fig. 31), Dadeldhura (fig. 35), Darchula (fig. 37), Dailekh (fig. 41), Lumle (fig. 43), Godawari (fig. 45), Okhaldhunga (fig. 47), Dhankuta (fig. 49), Terhathum (fig. 51), Taplejung (fig. 53), Kathmandu airport (fig. 55), Kanyam tea state (fig. 57), Ilam tea state (fig. 59), Jumla (fig. 61), Daman (fig. 63), Thakmarpha (fig. 67), Chame (fig. 69), Nagarkot (fig. 71), Chialsa (fig. 73), Jiri (fig. 75), Khumaltar (fig. 79), Salyan bazaar (fig. 81) and Gorkha (fig. 83). Slightly decreasing trends in maximum temperature has been observed at station Nepalganj (fig. 1), Butwal (fig. 21), Baglung (fig. 33), Jomsom (fig. 65) and Rara (fig. 77). Almost constant trends in maximum temperature have been observed over the station Bhairahawa (fig. 3), Simara (fig. 5), Parwanipur (fig. 7), Biratnagar (fig. 11), Pusma Camp (fig. 27), Silgadi (fig.39), Dhangadi (fig. 15) and Janakpur airport (fig. 85).

However, slightly increasing trends in minimum temperature have been observed in station Nepalganj (fig. 2), Bhairahawa airport (fig. 4), Simara airport (fig. 6), Parwanipur (fig. 7), Biratnagar airport (fig. 12), Dhangadi (fig. 16), Rampur (fig. 18), Surkhet (fig. 20), Butwal (fig. 22), Dipayal Doti (fig. 30), Pokhara airport (fig. 32), Godawari (fig. 46), Okhaldhunga (fig. 48), Dhankuta (fig. 50), Terhathum (fig. 52), Kathmandu (fig. 56), Jumla (fig. 62), Daman (fig. 64), Jomsom (fig. 66), Chailsa (fig. 74), Rara (fig. 78), Khumaltar (fig. 80) and Janakpur airport (fig. 86). Slightly decreasing trends in minimum temperature have been observed at the station Gaur (fig. 10), Gaida Kankai (fig. 14), Hetauda (fig. 24), Tulsipur (fig. 26), Pusma Camp (fig. 28), Baglung (fig. 34), Dadeldhura (fig. 36), Darchula (fig. 38), Silgadi Doti (fig. 40), Dailekh (fig. 42), Kanyam tea state (fig. 58), Ilam tea state (fig. 60) and Jiri (fig. 76). Almost constant trends in annual minimum temperature have been observed over the station of Lumle (fig. 44), Taplejung (fig. 54), Thakmarpha (fig. 68), Chame (fig. 70), Nagarkot (fig. 72), Salyan bazaar (fig. 82) and Gorkha (fig. 84).

4.2 Deviation between Maximum and Minimum Temperature:

In the station wise temperature, the studies of the graphs show the following results in both annual maximum and minimum temperature.

Deviation between annual maximum and minimum temperature has been observed in slight increasing trend at the station Nagarkot (fig. 98), Daman, Jumla, Hetauda (fig. 103), Tulsipur, Silgadi Doti, Darchula, Dhankuta (fig. 101),, Jiri (fig. 91), Okhaldhunga (fig. 102), Thakmarpha, Pokhara airport, Chame (fig. 96), Dadeldhura (fig. 97), Salyan Bazaar, Lumle (fig. 95), Godawari (fig. 100), chialsa, Gaur, Gaida Kankai, Gorkha, Kathmandu (fig. 99), Khumaltar, Taplejung (fig. 92), Ilam Tea State, Jumla and Dailekh (fig. 104).

Deviation between maximum and minimum temperature has been observed in slightly decreasing trend at the station Butwal (fig. 89), Rampur, Rara, Baglung, Jomsom (fig. 87), Nepalganj (fig. 90), Bhairahawa Airport, Parwanipur (fig. 93), Dipayal (fig. 106), Dhangadi, and Janakpur airport (fig. 88).

Almost constant deviation between maximum and minimum temperature has been observed over the station of Pusma camp, Terhathum, Surkhet (fig. 94), Simara Airport (fig. 105), Kanyam tea state, Biratnagar Airport.

4.3 Temporal variation at seasonal trend over individual station:

The annual variation of maximum temperature in winter season, has been occurred in slightly increasing trend at the stations of Hetauda, Nagarkot, Darchula, Daman, Tulsipur, Jiri, Pokhara airport, Jumla, Chame (after 1998), Chaise, Ilam, Khumaltar (raise in nearly triple ratio of minimum), Taplejung, Okhaldhunga, Dhankuta, Gaida Kankai but slightly decreasing trends have been occurred in the station of Jomsom, Thakmarpha, Butwal, Darchula, Pusma Camp, Nepalganj, Bhairahawa airport, Parwanipur, Biratnagar airport, Dhangadi, Baglung. Almost constant deviations have been found in the station Dailekh, Gorkha, Rara, Gaur, Rampur, Simara, Chame (1976 to before 1997) in winter. Similarly in the minimum temperature at winter Season, slightly increasing trends have been observed in the stations of Okhaldhunga, Jomsom, Pokhara airport, Khumaltar, Gaida Kankai, Simara airport, Butwal, Rampur, Darchula and slightly decreasing trend have been occurred in the stations of Jiri, Tulsipur, Baglung, Darchula, Rara, Ilam, Taplejung, Chame, Pusma Camp, Thakmarpha, Dailekh, Gaur but almost constant in the station of Dhankuta, Nepalganj, Bhairahawa airport, Parwanipur, Hetauda, Biratnagar airport.

In the maximum temperature of pre-monsoon season for annual variation, increasing trends have been observed in the station of Nagarkot, Taplejung, Daman, Khumaltar, Dhangadi, Dailekh, Darchula, Darchula, Tulsipur, Okhaldhunga, Chame, Gaida Kankai, Jiri, Pokhara Airport, Jumla, Chailsa, Thakmarpha, Gaur, Biratnagar and Parwanipur. At contrast, slightly decreasing trends have been observed in the pre-monsoon season at the station Jomsom, Butwal, Pusma Camp, Bhairahawa airport, Nepalganj, Baglung and almost constant at the station Jumla, Nepalganj, Simara airport, Rampur, Rara. Similarly in the annual variation of the minimum temperature at Pre-monsoon Season, slightly increasing trends have been observed in the stations of Hetauda, Khumaltar, Darchula, Okhaldhunga, Chame (after 1998), Jomsom, Gaida Kankai, Dailekh, Rara, Darchula, Bhairahawa airport, Simara airport, Butwal, Rampur and slightly decreasing trends in the station of Jiri, Pusma Camp, Hetauda, Tulsipur, Ilam, Baglung but almost constant in the station of Dhankuta, Chame (1976 to 1997), Thakmarpha, Nepalganj, Taplejung, Pokhara airport, Biratnagar airport, Parwanipur.

In the maximum temperature of monsoon season, increasing trends have been occurred in the station of Nagarkot, Daman, Dailekh, Rampur, Okhaldhunga, Jiri, Khumaltar, Ilam, Pokhara airport, Hetauda, Jumla, Tulsipur, Darchula, Taplejung, Chailsa, Bhairahawa airport, Gaur, Gaida Kankai and Biratnagar Airport. The mean maximum temperature of monsoon season, have been occurred in slightly decreasing trends at stations of Chame, Butwal, Baglung, Darchula, Rara, Jomsom, Parwanipur, Pusma Camp, Dhangadi and almost constant at stations of Thakmarpha, Simara. Similarly in the annual variation of the minimum temperature at monsoon Season, slightly increasing trends have been observed in stations of Okhaldhunga, Darchula, Chame (1978 to 1997), Jomsom, Khumaltar, Gaida Kankai, Butwal, Rampur and slightly decreasing trend have been occurred at stations of Dhankuta, Hetauda, Tulsipur, Ilam, Pusma Camp, Taplejung, Dailekh, Darchula, Baglung, Chame (after 1998), Thakmarpha, Rara, Gaur but almost constant at stations of Jiri, Nepalganj, Pokhara airport, Biratnagar airport, Simara airport, Parwanipur, Biratnagar airport.

In the annual maximum temperature of post-monsoon season, increasing trend have been occurred at stations of Okhaldhunga, Dhankuta, Rampur, Nagarkot, Ilam, Khumaltar (raised in nearly double of minimum), Taplejung, Dhangadi, Daman, Dailekh, Hetauda, Jiri, Pokhara airport, Jumla, Tulsipur, Chame, Bhairahawa airport, Gaur. In the mean maximum temperature of post-monsoon season, slightly decreasing trend have been occurred at stations of Thakmarpha, Darchula, Parwanipur, Nepalganj, Darchula, Baglung, Butwal, Pusma Camp, Jomsom and almost constant over the station of Simara Airport, Rara, Chaise. Similarly in the annual variation of the minimum temperature at monsoon Season, slightly increasing trends have been observed at stations of Jomsom, Gaida Kankai, Khumaltar, Pokhara airport, Biratnagar airport, Gaur, Butwal, Rampur, Rara; and slightly decreasing trend at stations of Dhankuta, Darchula, Baglung, Ilam, Taplejung, Dailekh, Darchula, Jiri, Tulsipur, Pusma Camp, Chame, Thakmarpha, Parwanipur but almost constant at stations of Nepalganj, Bhairahawa airport, Simara airport, Hetauda, Okhaldhunga.

4.4 Temporal variation of temp trend over Nepal:

In the case of temperature trend over Nepal since 1971 till 2004, the maximum (0.08^{o}C/year, r^2=0.84) and minimum (0.05 ^{o}C/year, r^2=0.72) temperature is in slightly increasing trend (Fig.107A).

Year	**Since 1970**		**Since 1976**		**Since 1986**	
	^{O}C/year	r^2	^{O}C/year	r^2	^{O}C/year	r^2
Maximum Temperature	0.08	0.83	0.08	0.78	0.05	0.81
Minimum Temperature	0.05	0.72	0.05	0.62	0.03	0.65

Table-5: Temperature trend over Nepal

Note: The entire trends are in ^{o}C/Year and 0.65 ≤ r2 ≤ 0.83

Therefore, the deviation between maximum and minimum temperature have been observed in slightly increasing trend. After 1976, nearly similar results have been observed for maximum (0.08^{o}C/year) and minimum temperature (0.05^{o}C/year) (Fig. 107B). After 1986, the maximum (0.05^{o}C/year) and minimum (0.03^{o}C/year) temperature have been also in increasing trend.

4.5 Temporal variation of temperature trends for Geographical region:

In the case of average temperature trend over Terai of Nepal since 1971, the maximum (0.01^{o}C/year) temperature trend remains nearly constant, however, the minimum (0.03^{o}C/year) temperature trends have been slightly in increasing trend. Therefore, the deviations between maximum and minimum temperature have been observed to be slightly decreased. After 1976, nearly similar results have been observed where maximum trend and minimum temperature trend are found nearly constant. But trend after 1986, maximum trend is almost constant and minimum (0.02^{o}C/year) temperature trend is slightly increasing.

In the case of average temperature trend over Siwalik of Nepal since 1973, the maximum (0.07^{o}C/year) and minimum (0.098^{o}C/year) temperature trend is slightly increasing. Therefore, the deviation between maximum and minimum temperature have been observed to be slightly decreased. After 1976, both of the temperatures have also been observed in slightly increasing trends. However, after 1986, the maximum (0.02^{o}C/year) and minimum (0.01^{o}C/year) temperature trends is found to be slightly increasing. The deviation between maximum and minimum temperature since 1986 has been observed to be nearly constant.

In the case of average temperature trend over Middle Mountain Region of Nepal since 1971, both the maximum (0.09 ^{o}C/year) and minimum (0.046 ^{o}C/year) temperature are in increasing trend. The maximum temperature trend has observed to be increased nearly double of minimum trend. Therefore, the deviation between maximum and minimum temperature has been observed to be increased. The both of the trends have been observed as cooling trend before 1976. However, after 1976, the results have been also observed in increasing trend and after 1986, the maximum (0.076 ^{o}C/year) and minimum (0.01^{o}C/year) trends are also slightly increasing.

Year / Region	**Terai**		**Siwalik**		**MMR**		**HMHR**	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1970	0.01	0.03	0.07	0.10	0.09	0.05	0.12	0.06
1976	0.01	0.02	0.06	0.07	0.11	0.05	0.11	0.03
1986	0.00	0.02	0.02	0.01	0.08	0.01	0.12	0.07

Table-6: Annual temperature trend rate in physiographical region of Nepal

In the case of average temperature trend over HMHR Region of Nepal since 1972, the trends of maximum (0.12^{o}C/year) and minimum (0.06^{o}C/year) temperature have been in increasing order. The trend of maximum temperature has been observed to be increased nearly double of minimum trend. Therefore, the deviation between maximum and minimum temperature has been observed to be increased. However, after 1986, both maximum (0.12 ^{o}C/year) and minimum (0.07 ^{o}C/year) temperature trends are also increasing.

4.6 Temporal variation of temperature trend of all season over Nepal

In the case of winter temperature trend over Nepal since 1971, the maximum (0.07^{o}C/year) and minimum (0.06^{o}C/year) temperature trends have slightly increased (Fig.108A). Therefore, the deviation between maximum and minimum temperature has been observed to be nearly constant. After 1976, nearly similar results have been observed for both maximum (0.07^{o}C/year) and minimum temperature (0.06 ^{o}C/year). (Fig. 108B)

In the case of pre-monsoon temperature trend over Nepal since 1971, the maximum (0.07^{o}C/year) and minimum (0.04^{o}C/year) temperature trends are slightly increasing (Fig. 109A). Therefore the deviation between maximum and minimum temperature is observed to be increased. After 1976, the maximum (0.08^{o}C/year) and minimum (0.05^{o}C/year) temperature trends are also increasing (Fig. 109B).

In the case of monsoon temperature over Nepal since 1971, the maximum (0.08 ^{o}C/year) and minimum (0.05^{o}C/year) temperature are slightly in increasing trend (Fig.-110A). Therefore, the departure or deviation between maximum and minimum temperature has been observed to be increased. After 1976, the maximum (0.07^{o}C/year) and minimum (0.04^{o}C/year) temperature trend are observed to be increasing (Fig.-110B).

In the case of post monsoonal temperature trend over Nepal since 1971, the maximum (0.10^{o}C/year) & minimum (0.07^{o}C/year) temperature trends have been found to be slightly increasing (Fig.-111A). The graph shows the slightly increasing trend from 1971 to 1997, and slightly cooling trend has been observed after 1998. But the departure or deviation between maximum & minimum temperature has been observed to be slightly increasing. After 1976, nearly similar results have been observed for the maximum (0.10 ^{o}C/year) & minimum (0.06 ^{o}C/year) temperature trends (Fig.-111 B).

Region	**Winter**		**Pre-monsoon**		**Monsoon**		**Post-monsoon**	
Year	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1970	0.06	0.06	0.07	0.04	0.08	0.05	0.10	0.07
1976	0.07	0.06	0.08	0.05	0.07	0.04	0.10	0.06
1986	0.03	-0.01	0.06	0.05	0.05	0.01	0.05	0.04

Table-7: Seasonal temperature trend rate over Nepal (Trend rate in ^{O}C/year).

4.7 Seasonal variation of temperature trends for Geographical region:

4.7.1 Analysis of winter temporal variation for Geographical region

In winter temperature over Terai region of Nepal; the deviation between maximum and minimum has been observed as low. Maximum temperature remains almost constant from 1971 to 2004. The graph shows the hottest year is 1988 (25.7 ^{0}c). In the hottest year (1998) of the world, the maximum temperature anomaly value falls below the winter normal value. From the graph of 1976 to 2004, the maximum temperature remains nearly constant (Fig. 112 A) .However, from the graph of 1986 to 2004, the maximum temperature is slightly decreasing (-0.06 ^{o}C/year). However, in the annual winter of Terai after 1970, minimum temperature is increasing (0.04^{o}C/year).

The graph shows the coldest year was 1983 (7.9^{0}C). In the hottest year (1998) of the world, the minimum temperature anomaly value falls above the winter normal value. From the graph of 1976 to 2004, the minimum temperature is slightly in increasing trend. From 1986, a trend remains nearly constant.

In winter of Siwalik region, the deviation between maximum and minimum is slightly low. Maximum (0.09 ^{o}C/year) temperature at winter of Siwalik is increasing since 1972 (Fig. 113 A). The graph shows the hottest year was 1988 (24.2 ^{0}c). In the hottest year (1998) of the world, the maximum temperature anomaly value has been occurred just above the winter normal value. From the graph of 1976 to 2004, the maximum temperature is slightly increasing (0.07^{o}C/year). From the graph of 1986 to 2004, the maximum temperature has been remained almost constant. However, in the winter of Siwalik Region, minimum (0.14 ^{o}C/year) temperature is increasing since 1972 to 2004. The graph shows the coldest year was 1997 (8.1 ^{0}c) after the year 1986. In the year 1998 which was hottest year of the world, the minimum temperature anomaly has been remained above the winter normal value. From the graph of 1976 to 2004, the minimum (0.1^{o}C/year) temperature is slightly increasing. From the graph of 1986 to 2004, the minimum (0.012 ^{o}C/year) temperature is slight increasing.

In the winter of Middle mountain region (MMR), the deviation between maximum and minimum temperature is slightly increasing. Maximum (0.0835 ^{o}C/year) temperature of Middle mountain region at winter is increasing since 1971 (Fig. 114 A). The graph shows the hottest year was 1999 (19.7 ^{0}c). In the year 1998 which was hottest year of the world, the maximum temperature anomaly has been remained above the winter normal value. Since 1976 to 2004, the maximum (0.124 ^{o}C/year) temperature is also increasing. Since 1986 to 2004, the maximum (0.0887 ^{o}C/year) temperature is slightly increasing. However, in the winter of MMR, minimum temperature is increasing (0.0539 ^{o}C/year) since 1971 to 2004. The graph shows the coldest year was 1983 (3.7 ^{0}c) after the year 1971 and 1997 (5.0 ^{0}c) was the coldest one after the year 1986. In the year 1998 which was hottest year of the world, the temperature has been remained above the winter normal value. From the graph of 1976 to 2004, the minimum (0.054 ^{o}C/year) temperature is slightly in increasing trend. From the graph of since 1986, the minimum (-0.02 ^{o}C/year) temperature is decreasing trend.

In the winter of high Mountain and Himalaya region, the deviation between maximum and minimum has been found to be slightly increased. Maximum (0.053 ^{o}C/year) temperature of high mountain and Himalaya region at winter ha been increasing since 1971 (Fig. 115 A). The graph shows the hottest year was 2001 (14.1 ^{0}c). In the year 1998 which was hottest year of the world, the temperature has been remained above the winter normal value. From the graph of 1976 to 2004, the maximum temperature has also been increasing (0.106^{o}C/year). From the graph of 1986 to 2004, the maximum (0.0838 ^{o}C/year) temperature has been slightly increasing. However, in the winter of HMHR, minimum temperature has been slightly increasing (0.0155 ^{o}C/year) from 1971 to 2004. The graph shows the coldest year was 1983 (-0.8 ^{0}c) after the year 1971 and year 1986 (0.0 ^{0}c) was the coldest one after the year 1986. In the year 1998 which was hottest year of the world, the temperature has been remained above the winter normal value. From the graph of 1976 to 2004, the minimum (0.027 ^{o}C/year) temperature has been slightly increased. From the graph of 1986 to 2004, the minimum (0.0244 ^{o}C/year) temperature shows slightly increasing trend.

Season / Region	**Terai** -1970		**Siwalik**-1970		**MMR**-1970		**HMHR**-1970	
	Maximum	Minimum	Max	Min	Max	Min	Max	Min
Winter	-0.01	0.04	0.09	0.13	0.08	0.05	0.05	0.02
Pre-monsoon	0.00	0.02	0.05	0.10	0.09	0.07	0.09	-0.05
Monsoon	0.02	0.02	0.07	0.05	0.08	0.03	0.09	0.06
Post-monsoon	0.03	0.03	0.08	0.14	0.10	0.04	0.11	0.06

Table-8: Temperature trend rate in seasonal as well as physiographical region since 1970

4.7.2 Analysis of Pre-monsoonal Temporal variation

In the pre-monsoonal temperature of Terai, The deviation between Pre-monsoonal maximum and minimum temperature trend has been decreasing slightly. The trend of maximum temperature has been remained nearly constant from 1971 to 2004. The graph shows the hottest year was 1995 (35.4^{0}C) (Fig. 112 B). In the year 1998 which was hottest year of the world, the temp has been remained below the Pre-monsoonal normal value. From the graph of 1976 to 2004, the maximum temperature has been also remained constant. From the graph of 1986 to 2004, the maximum temperature has been slightly increasing (0.0154 ^{o}C/year). However, in the annual Pre-monsoonal minimum temperature of Terai, the trend of minimum temperature has been increasing (0.024^{o}C/year) since 1971. The graph shows the coldest year was 1983 (17.9^{0}C) after 1971 and the year 1989 (18.1 ^{0}c) was the coldest after 1986. In the year 1998 which was hottest year of the world, the normal temperature has been remained above the pre-monsoonal normal value. From the graph since 1976, the minimum (0.03^{o}C/year) temperature has been also increased. From the graph of 1986 to 2004, the minimum temperature has been slightly increasing (0.06^{o}C/year) which was double than that of the trend of 1976 to 2004.

In the Pre-monsoon temperature of Siwalik region, the deviation between Pre-monsoonal maximum and minimum temperature trend has been found to be slightly decreased. Maximum temperature at Pre-monsoon of Siwalik has been slightly increasing (0.045^{O}C/year) since 1971 to 2004 (Fig. 113 B). The graph shows the hottest year was 1995 (34.5^{0}C). In the year 1998 that was hottest year of the world, the temperature has been remained below the pre-monsoonal normal value. From graph since 1976, the maximum temperature has been increasing (0.06^{o}C/year). From the graph since1986, the maximum temperature has been slightly increased (0.04^{o}C/year). However, in the annual pre-monsoonal of Siwalik, minimum (0.099 ^{o}C/year) temperature has been increasing from 1971 to 2004. The graph shows the coldest year was 1997 (17.1^{0}C) after the year 1986. In the year 1998 which was hottest year of the world, the temp has been remained above the pre-monsoonal normal value since 1973 and just below since 1986. From the graph since 1976, the minimum temperature has been also increasing (0.09^{o}C/year). From the graph of 1986 to 2004, the minimum (0.02) temperature has been slightly increasing.

In the Pre-monsoon of Middle Mountain region, the deviation between maximum and minimum has been observed to be slightly increased. Maximum temperature of Middle mountain region at pre-monsoon season has been increasing (0.087^{o}C/year) since 1971 to 2004 (Fig. 114B). The graph shows the hottest year was

1999 (27.7^{0}C). In the year 1998 which was hottest year of the world, the temperature has been remained just below the normal pre-monsoonal value. From the graph of 1976 to 2004, the maximum temperature has been also increasing (0.12^{o}C/year). From the graph since 1986, the maximum (0.089^{o}C/year) temperature has been also increasing. The departure of pre-monsoonal maximum and minimum temperature of MMR has been found to slightly increasing since 1976. However, in the annual pre-monsoon of MMR, minimum temperature has been increasing (0.07 ^{o}C/year) from 1971 to 2004 (Fig. 114 B). The graph shows the coldest year was 1982 (10.8^{0}C) after the year 1976 and the year 1986 (11.7^{0}C) was coldest one after the year 1986. In the year 1998 which was hottest year of the world, the temperature has been remained above the pre-monsoonal normal value since 1971. From the graph of 1976 to 2004, the minimum temperature has been increased (0.09^{o}C/year). From the graph since1986, the minimum (0.05^{o}C/year) temperature trend has been also increasing.

In the pre-monsoon of High Mountain and Himalaya region (HMHR), the deviation between maximum and minimum temperature has been found to be increased. Maximum temperature of high mountain and Himalaya region at pre-monsoon has been increasing (0.093 ^{o}C/year) in graph of 1971 to 2004 (Fig. 115B). The graph shows the hottest year was 2004 (22.8^{0}C). In the year 1998 which was hottest year of the world, the normal temperature value has been remained above the pre-monsoonal normal value. From the graph of 1976 to 2004, the maximum temperature has been increasing (0.12 ^{o}C/year) than the graph from 1971 to 2004. From the graph of 1986 to 2004, the maximum temperature trend has been also increasing (0.12^{o}C/year). The departure of pre-monsoonal maximum and minimum temperature of HMHR has been found to be increased since 1976. However, in the annual Pre-monsoon of HMHR, minimum temperature has been decreasing (-0.045 ^{o}C/year) from 1971 to 2004. The graph shows the coldest year was 1993 (7.2^{0}C). In the year 1998 which was hottest year of the world, the temperature has been remained below the pre-monsoonal normal value. From the graph of 1976 to 2004, the minimum temperature has been decreased (-0.02 ^{o}C/year). From the graph of 1986 to 2004, the minimum temperature shows slightly increasing trend (0.05^{o}C/year).

4.7.3 Analysis of monsoonal temporal variation

In the monsoonal temperature of Terai, the deviation between maximum and minimum temperature trend has been almost constant since 1971. However, the deviation between maximum and minimum temperature trend has been slightly increased since 1976. Maximum temperature has been slightly increasing (0.02^{o}C/year) since 1971 (Fig. 112C). The graph shows the hottest year was 1993 and 1997 (33.9^{0}C). In the year 1998 that was hottest year of the world, the temperature has been remained above the monsoonal normal value. From the graph of 1976 to 2004, the maximum temperature has been also slightly increasing (0.016^{o}C/year). From the graph of 1986 to 2004, the maximum temperature ha been slightly increasing (0.02^{o}C/year). The departure of post monsoonal maximum and minimum temperature of Terai has been almost constant since 1976. However, in the monsoonal minimum temperature of Terai, minimum temperature has been increasing (0.02 ^{o}C/year) from 1971 to 2004. The graph shows the coldest year was 1984 (24.9 ^{0}c) after 1976 and the year 1989 (25.0 ^{0}c)was the coldest one after 1986. In the year 1998 that was hottest year of the world, the temperature has been remained above the monsoonal normal value after 1971. From the graph of 1976 to 2004, the minimum temperature has been almost constant. From the graph of 1986 to 2004, the minimum temperature has been remained also nearly constant.

In the monsoon temperature of Siwalik region, the deviation between Pre-monsoonal maximum and minimum temperature trend has been observed to be nearly constant. Maximum temperature at monsoon in Siwalik region has been slightly increasing (0.067^{o}C/year) in graph of 1971 to 2004 (Fig. 113C). The graph shows the hottest year was 1994 (33.2 ^{0}c) since 1973. In the year 1998 that was hottest year of the world, the temperature has been remained above the all-monsoonal normal value. From the graph of 1976 to 2004, the maximum temperature has been increasing (0.06 ^{o}C/year). From the graph of 1986 to 2004, the maximum temperature has been slightly increased (0.04 ^{o}C/year). However, in the annual monsoon in Siwalik, minimum temperature has been increasing (0.053^{o}C/year) from 1971 to 2004. The graph shows the coldest year was 1982 (22.6^{0}c) after the year 1976 and 2002 (23.2^{0}c). In the year 1998 that was hottest year of the world, the temperature has been remained above the monsoonal normal value since 1973. From the graph of 1976 to 2004, the minimum temperature has been increasing (0.05^{o}C/year). Since 1986 to 2004, the minimum (-0.01^{o}C/year) temperature has been slightly decreasing. The departure of monsoon maximum and minimum temperature of Siwalik has been increasing since 1986.

During the monsoon in Middle mountain region (MMR), the deviation between maximum and minimum has been found to be increased. The rate of minimum temperature was low whereas high in maximum temperature. Maximum temperature of Middle mountain region at monsoon season has been increasing (0.079 ^{o}C/year) in graph of 1971 to 2004 (Fig. 114C). The graph shows the hottest year was 1993 (27.6^{0}C). In the year 1998 that was hottest year of the world, the temperature has been remained above the normal monsoonal value. From the graph of 1976 to 2004, the maximum temperature has been more increasing (0.099 ^{o}C/year) than the graph from 1971 to 2004. From the graph of 1986 to 2004, the maximum (0.05 ^{o}C/year) temperature has been slightly increasing. The departure of post monsoonal maximum and minimum temperature in Terai has been increasing since 1976. However, in the annual monsoon of MMR, minimum temperature has been slightly increasing (0.031 ^{o}C/year) than maximum temperature from 1971 to 2004. The graph shows the coldest year were 1986 (18.1 ^{0}c) after the year 1986 and 2002 (18.2 ^{0}c) after the year 1986. In the year 1998 that was hottest year of the world, the temperature falls high above the monsoonal normal value for all. From the graph of 1976 to 2004, the minimum temperature has been also increasing (0.04^{o}C/year). From the graph of 1986 to 2004, the minimum temperature trend has been remained nearly constant. The departure of monsoonal maximum and minimum temperature of MMR has been increasing since 1986.

In the monsoon of high Mountain and Himalaya region, the deviation between maximum and minimum temperature has been found to be increased. Maximum temperature of high mountain and Himalaya region at monsoon has been increasing (0.09 ^{o}C/year) in graph of 1971 to 2004 (Fig. 115C). The graph shows the hottest year was 1993 (24.6 ^{0}c). In the year 1998 which was hottest year of the world, the temperature has been remained high above the monsoonal normal value. From the graph of 1976 to 2004, the maximum temp has been also increasing (0.097^{o}C/year). From the graph of 1986 to 2004, the maximum temperature trend has been also increasing (0.0675^{o}C/year). The departure of post monsoonal maximum and minimum temperature of Terai has been found to be increased since 1976. However, in the annual monsoon of HMHR, minimum temperature has been increasing (0.058^{o}C/year) from 1971 to 2004. The graph shows the coldest year was 1986 (13.4^{0}c) since 1976. In the year 1998 which was hottest year of the world, the temperature has been found above the monsoonal normal value. From the graph of 1976 to 2004, the minimum temperature has been also increasing (0.058 ^{o}C/year). From the graph of 1986 to 2004, the minimum temperature also shows increasing trend (0.05^{o}C/year). The departure of monsoonal maximum and minimum temperature of HMHR has been remained nearly constant since 1986.

Region / Season	**Terai -1976**		**Siwalik-1976**		**MMR-1976**		**HMHR-1976**	
	Maximum	Minimum	Max	Min	Max	Min	Max	Min
Winter	-0.01	0.04	0.07	0.10	0.01	0.05	0.11	0.03
Pre-monsoon	0.05	0.03	0.06	0.09	0.01	0.09	0.12	-0.02
Monsoon	0.02	0.01	0.06	0.05	0.10	0.04	0.10	0.06
Post-monsoon	0.04	0.03	0.09	0.12	0.13	0.05	0.13	0.05

Table-9: Temperature trend rate in seasonal as well as physiographical regional since 1976

4.7.4 Analysis of Post-monsoonal temporal variation

In the Post-monsoonal temperature of Terai, The deviation between post-monsoonal maximum and minimum temperature trend has been almost constant since 1971. But the deviation between monsoonal maximum and minimum temperature trend has been slightly increasing since 1976. Maximum temperature has been slightly increasing (0.0323 ^{o}C/year) since 1971 (Fig. 112D). The graph shows the hottest year was 1998 (31.8 ^{0}c). In the year 1998 which was the hottest year of the world, the temperature has been remained high above the post-monsoonal normal value. From the graph of 1976 to 2004, the maximum temperature has been also increasing (0.042^{o}C/year). From the graph of 1986 to 2004, the maximum temperature has been slightly increasing (0.025^{o}C/year). However, in the annual post-monsoonal temperature of Terai, minimum temperature has been increasing (0.027^{o}C/year) from 1971 to 2004. The graph shows the coldest year was 1984 (16.1^{0}C) after 1971 and the year 1991 (16.3^{0}C) was the coldest one after 1986. In the year 1998 which was hottest year of the world, the minimum temperature anomaly falls greater above the post-monsoonal normal value after 1971. From the graph of 1976 to 2004, the minimum temperature has been also increasing (0.0318 ^{o}C/year). From the graph since1986, the minimum temperature is increasing (0.0428^{o}C/year). The departure of post monsoonal maximum and minimum temperature of Terai has been slightly increasing since 1986.

In the post monsoon temperature of Siwalik region, the deviation between post-monsoonal maximum and minimum temperature trend has been found to be decreased. Minimum temperature has been found to be more increased than maximum temperature. Maximum temperature at post-monsoon of Siwalik has been increasing (0.0843 ^{o}C/year) in graph of 1971 to 2004 (Fig. 113D). The graph shows the hottest year was 1998 (29.8 ^{0}c) since 1973. In the year 1998 which was hottest year of the world, the maximum temperature anomaly of post-monsoon falls above the all post-monsoonal normal value. From the graph of 1976 to 2004, the maximum temperature has been increasing (0.085^{o}C/year). From the graph of 1986 to 2004, the maximum temperature has been slightly increased (0.047 ^{o}C/year). The departure of post monsoonal maximum and minimum temperature of Terai has been also found to be slightly decreased since 1976. However, in the annual post-monsoonal of Siwalik, minimum temperature has been increasing (0.14 ^{o}C/year) since 1971. The graph shows the coldest year was 1991 (14.5 ^{0}c) after the year 1986. In the year 1998 which was hottest year of the world, the minimum temperature anomaly shows the greatest value which shows the temperature falls above the monsoonal normal value since 1973. From the graph of 1976 to 2004, the minimum temperature has been increasing (0.12^{o}C/year). From the graph of 1986 to 2004, the minimum temperature has been slightly increasing (0.02^{o}C/year).

In the post-monsoonal of Middle mountain region (MMR), the deviation between maximum and minimum in the MMR has been found to be increased (widely spaced). Maximum temperature of Middle mountain region at post-monsoon season has been increasing (0.097^{o}C/year) in graph of 1970 to 2004 (Fig. 114D). The graph shows the hottest year was 1998 (mean 24.3 ^{0}c) in the MMR. In the year 1998 which was hottest year of the world, the maximum temperature anomaly was greater than normal post-monsoonal value. From the graph of 1976 to 2004, the maximum temperature has been also increasing (0.13 ^{o}C/year). From the graph of 1986 to 2004, the maximum temperature has been increasing (0.07^{o}C/year) only. The departure of post-monsoonal maximum and minimum temperature of MMR has been also increasing since 1976. However, in the annual monsoon of MMR, minimum temperature has been slightly increasing (0.04 ^{o}C/year) from 1971 to 2004. The graph shows the coldest year was 1980 (9.9 ^{0}c) after the year 1976 and the year 1997 (10.9 ^{0}c) was the coldest one after the year 1986. In the year 1998 which was the hottest year of the world, the minimum temperature anomaly of this region was the greatest and above the post-monsoonal normal value for all. From the graph of 1976 to 2004, the minimum temperature has been increased (0.047 ^{o}C/year). From the graph of 1986 to 2004, the trend of minimum temperature has been slightly increasing. The departure between post-monsoonal maximum and minimum temperature of MMR has been also slightly increasing since 1986.

In the post-monsoon of High Mountain and Himalaya region (HMHR), the deviation between maximum and minimum temperature has been observed to be increased whereas minimum temperature shows less increasing trend than that of maximum temperature. Maximum temperature of High mountain and Himalaya region at post-monsoon has been increasing at high rate (0.105^{o}C/year) in graph of 1971 to 2004 (Fig. 115D). The graph shows the hottest year was 2001 (20.9 ^{0}c). In the year 1998 which was hottest year of the world, the maximum temperature anomaly of all year was high and it was higher than the post-monsoonal normal value. From the graph of 1976 to 2004, the maximum temperature has been also increasing (0.1297^{o}C/year). From the graph of 1986 to 2004, the maximum temperature trend has been also increasing (0.0954^{o}C/year). The departure of post-monsoonal maximum and minimum temperature trend of HMHR has been also increasing since 1976. However, in the annual post-monsoon of HMHR, minimum temperature has been slightly increasing (0.056 ^oC/year) from 1971 to 2004. The graph shows the coldest year was 1997 (5.1 ^0c) since 1986. In the year 1998 which was hottest year of the world, the minimum temperature anomaly of all year was high and it was above the post-monsoonal normal value. From the graph of 1976 to 2004, the minimum temperature has been increased (0.0495^oC/year). From the graph of 1986 to 2004, the minimum (0.0543^oC/year) temperature has been increasing.

Region / Season	**Terai -1986**		**Siwalik-1986**		**MMR-1986**		**HMHR-1986**	
	Maximum	Minimum	Max	Min	Max	Min	Max	Min
Winter	-0.06	0.00	0.00	0.01	0.09	-0.02	0.08	0.02
Pre-monsoon	0.02	0.06	0.04	0.02	0.09	0.05	0.12	0.05
Monsoon	0.02	0.00	0.04	-0.01	0.05	0.00	0.07	0.05
Post-monsoon	0.03	0.04	0.05	0.02	0.07	0.02	0.10	0.05

Table-10: Temperature trend rate in seasonal as well as physiographical regional since 1986

4.8 Temperature variation with respect to altitude:

According to ecological as well as elevation, Nepal has been divided into three regions for spatial variation; namely Terai Region, Hilly Region and Himalaya Region (CBS-Nepal). This division was carried out due to the lack of accessibility of data. Maximum temperature was high in pre-monsoon season and minimum temperature has been observed in the monsoon season in the Terai and lower parts of the Hilly region (also called- Siwalik). But Maximum and minimum temperature has been observed high in the monsoon season in higher parts of Hilly Region (also called- High Mountainous) and Himalaya region. The values of the surface lapse rate of the different region as well as seasons has been shown in Table 3.

4.8.1 Temperature trends with respect to altitude over Nepal:

The maximum temperature over Nepal has been decreasing towards the higher elevation at the normal rate of 0.57 ^oc (where r^2=96) per 100 m (fig.127A) and annual minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.48 ^{o}c per 100 m(where r^2=96) (fig.127B).

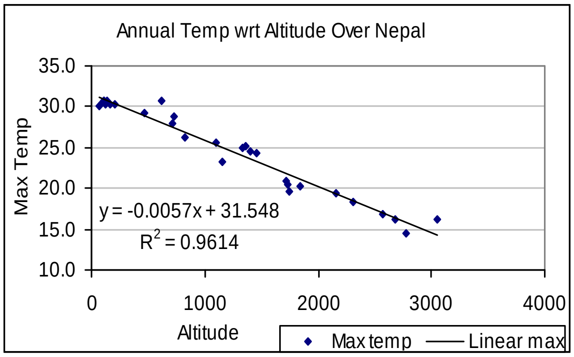


Fig.127A: Annual maximum temperature Vs Altitude over Nepal

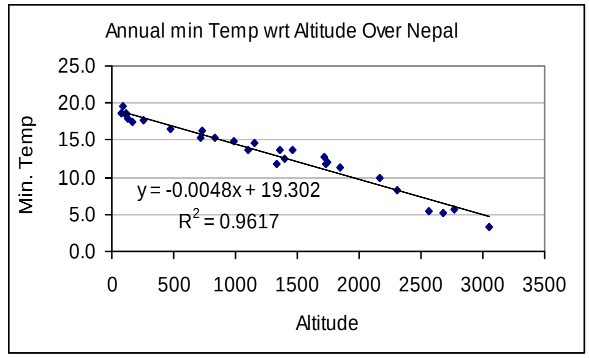


Fig.127B: Annual maximum temperature Vs Altitude over Nepal

4.8.2 Seasonal Temperature trends with respect to altitude over Nepal:

During winter season over Nepal, the maximum temperature has been decreasing towards the higher elevation at the normal rate of 0.53 ^{o}C (where r^2=96) per 100 m (fig.128A) and minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.38 ^{o}C per 100 m (fig.128B).

During pre-monsoon season over Nepal, maximum temperature has been decreasing towards the higher elevation at the normal rate of 0.69 ^{o}c per 100 m (fig.129A) and minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.51 ^{o}c per 100 m (fig.129B).

During monsoon season over Nepal, the maximum temperature has been decreasing towards the higher elevation at the normal rate of 0.51 ^{o}c per 100 m (fig.130A) and minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.53 ^{o}c per 100 m (fig.130B).

During Post-monsoon season over Nepal, annual maximum temperature has been decreasing towards the higher elevation at the normal rate of 0.56 ^{o}c per 100 m (fig.131A) and annual minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.49 ^{o}c per hundred meters (fig.131B).

4.8.3 Temperature trend with respect to altitude in season as well as region:

During winter season over Terai, maximum temperature has been decreasing towards the higher elevation at the normal rate of 0.37 ^{o}C per 20 m (Fig.132A) and minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.4 ^{o}C per 20 m (Fig.132B).

During winter season over Hilly Region, maximum temperature has been decreasing towards the higher elevation at the normal rate of 0.56 ^{o}c per hundred meters (Fig.132C) and minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.16 ^{o}c per hundred meters (Fig.132D).

During winter season over Himalaya Region, maximum temperature has been decreasing towards the higher elevation at the normal rate of 0.38 ^{o}c per hundred meters (Fig.132E) and minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.73 ^{o}c per hundred meters (Fig.132F).

During pre-monsoon season over Terai region, maximum temperature at only central region has been decreasing towards the higher elevation at the normal rate of 0.96^{o}C per 20 m (Fig.133A) and minimum in whole Nepal at the rate of 0.49^{o}C per 20 m (Fig.133B).

During pre-monsoon season over Hilly Region, maximum temperature has been decreasing towards higher elevation at the normal rate of 0.8^{o}C per hundred meters (Fig.133C) and minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.33^{o}C per hundred meters (Fig.133D).

During pre-monsoon winter season over Himalaya Region, maximum temperature has been decreasing towards the higher elevation at the normal rate of 0.42^{o}C per hundred meters (Fig.133E) and minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.76^{o}C per hundred meters (Fig.133F).

During monsoon season over Terai region, maximum temperature at only central region of Nepal has been decreasing towards the higher elevation at the normal rate of 0.59^{o}C per 20 m (Fig.134A) and minimum temperature at all parts of Terai has been also decreasing towards the higher elevation at the normal rate of 0.09°C per 20 m (Fig.134B).

During monsoon season over Hilly Region, maximum temperature has been decreasing towards the higher elevation at the normal rate of 0.47°C per hundred meters (Fig.134C) and minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.54°C per hundred meters (Fig.134D).

During monsoon season over Himalaya region, maximum temperature has been decreasing towards the higher elevation at the normal rate of 0.43°C per hundred meters (Fig.134E) and minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.58°C per hundred meters (Fig.134F).

Over Nepal	Maximum : 5.7°C/km r^2=0.96					Minimum : 4.8 °C/km r^2=0.96			
Season / Regions	Temperature.	Winter	r^2	Pre-monsoon	r^2	Monsoon	r^2	Post-monsoon	r^2
Terai Region in °C/20m	Maximum	0.4	0.80	0.9	0.94	0.6	0.99	0.2	0.78
	Minimum	0.4	0.88	0.5	0.83	.09	0.74	0.6	0.81
Hilly Region in °C/km	Max	5.6	0.82	8.0	0.82	4.7	0.82	5.3	0.88
	Min	1.6	0.72	3.3	0.91	5.4	0.90	4.0	0.75
Himalaya Region in °C/km	Max	3.8	0.91	4.2	0.90	4.3	0.92	3.8	0.91
	Min	7.3	0.97	7.6	0.96	5.8	0.96	7.5	0.95
Nepal in °C/km	Max	5.3	0.96	6.9	0.95	5.1	0.95	5.6	0.97
	Min	3.8		5.1	0.95	5.3	0.98	4.9	0.93

Table- 3: Showing the Values of the regional as well as seasonal surface lapse rate of Nepal: (Note: trends is in °C/km except Terai region and 0.74 ≤ r2 ≤ 0.96)

During post-monsoon season over Terai Region, maximum temperature has been decreasing towards the higher elevation at the normal rate of 0.18 °c (r^2=0.78) per 20 m (Fig.135A) and minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.6°C (r^2=0.802) per 20 m (Fig.135B).

During post-monsoon season over Hilly Region, maximum temperature has been decreasing towards the higher elevation at the normal rate of 0.53°C (r2=0.88) per 100m (Fig.135C) and minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.4°C (r2=0.745) per 100 m (Fig.135D).

During post-monsoon season over Himalaya Region, maximum temperature has been decreasing towards the higher elevation at the normal rate of 0.38 ^{o}c per 100 m (Fig.135E) and minimum temperature has been also decreasing towards the higher elevation at the normal rate of 0.75 ^{o}C per 100 m (Fig.135F).

4.9 Spatial distribution of temperature over Nepal:

In the spatial distribution of the maximum temperature over Nepal, the slightly decreasing trends has been shown in most of the hilly region of western parts of Nepal and lower area between Nepalganj and Dhangadi and near Janakpur airport; it was slightly observed (Map- 4) cooling trend. But in the minimum temperature, the cooling trends has been observed in the in most of the middle mountain western region and eastern region and also show at central region except valley of Kathmandu (Map- 5).

4.10 Seasonal Spatial distribution of temperature over Nepal:

In the spatial distribution of the maximum temperature at winter season over Nepal, the slightly decreasing trends has been observed in most of the Terai and Siwalik region of western parts of Nepal and lower area near Parwanipur and Janakpur airport (Map- 6). But In the minimum temperature, the cooling trends has been observed in the in most of the middle mountain western region and eastern region and it has been also shown at central region except western parts of the valley of Kathmandu (Map- 7).

In the spatial distribution of the maximum temperature at pre-monsoon season over Nepal, the slightly decreasing trends has been observed in most of the Terai region over Nepal except Rapti, Chitwan and eastern parts from Janakpur (Map- 8). But in the minimum temperature, the cooling trends has been observed in the middle mountain and upper parts of central region and eastern region around Ilam and Jhapa and it has been also shown at western region near Rapti (Map- 9).

In the spatial distribution of the maximum temperature at monsoon season over Nepal, the slightly cooling trends has been observed in most of the mountain region over mid and far western Nepal and also observed the region between Nepalganj and Dhangadi at Terai. Warming has been observed at the area of Rapti and Dhankuta area

(Map- 10). But in the minimum temperature, the cooling trends has been observed in the middle mountain and upper parts of western region and Himalayan region of Gorkha region and it has been also slightly shown at eastern parts of Ilam, Jhapa and Gaur region (Map- 11).

In the spatial distribution of the maximum temperature at post-monsoon season over Nepal, the slightly warming has been observed in most of the middle mountain region over far western Nepal and eastern parts of Nepal. (Map-12). But in the spatial distribution of minimum temperature trend, slightly warming has been observed the middle mountain parts of western region. Slightly cooling has been observed middle mountain and higher between 85^0 to 86.5^0 longitudinal area and 87.5^0 to 88^0 longitude (Map- 13).

The present study shows that the slightly cooling and almost constant trend has been observed before 1976 in the most of the stations over Nepal and slightly increasing trend after 1976 most of the stations recording except valley and rain shadow area. The relatively higher rate of warming in high altitude region of Nepal has been observed in the study.

Analysis of surface air maximum and minimum temperature data during last 33 years have been shown that there are general upward trends over Nepal which is similar results of examination of different reports (IPCC-2001; Sheretha et al.; 1999 and Devkota, 2004).

The heat absorbing the earth and its surroundings has played the vital role in fluctuation of temperature. There are mainly two aerosols in the atmosphere which causes either constant temperature or cooling and warming. The first has been sulfur containing aerosols which has been reflected the radiation comes from sun and the surface temperature may remain constant or slightly lower, however, the second is Carbon containing aerosols which absorbs the radiation and the lower atmosphere may warm. The recent reduction of glacier and snow in higher altitudes in Nepal may also be contributed by high warming rate of environment.

A reduction in snow and glacier cover in the high elevation will change the surface albedo of the region, which in turn will increase the surface air temperature, thereby acting as positive feedback mechanism (Shrestha et al. 1999). The temperature over Himalayan region plays a vital role to predict the climate change and glacier mass balance. Warming the temperature in these region has caused the melting it which may possible to rise in glacier lake, GLOF, flood in downstream, raise of sea level. Global warming may increase food prices globally and increase risk of hunger in vulnerable populations.

IPCC-2001 shows the 1990s as the warmed decade of the millennium in the world. The observation also shows the 1990s was the warmest decade but year 1999 (Normal temp.26.3^{o}C) was the warmest year in the maximum and year 1998 (Normal temp.14.3^{o}C) was the high warming year in the minimum temperature in case of Nepal since 1970 to 2004. After 1999, slightly cooling trend has been observed in both day and night temperature.

IPCC report shows that the surface temperature range has been decreasing over the years 1950 to 2000 over land and night-time minimum temperatures has been increased at twice the rate of daytime maximum temperatures. In the case of Nepal, the deviation between surface maximum and minimum temperature trend has been found in decreasing in winter and pre-monsoon season of Terai Region, however, slightly increasing deviation has been found in monsoon and post-monsoon. Similarly, the deviation between surface maximum and minimum temperature trend has been found in increasing at MMR and HMHR, however, the deviation between surface maximum and minimum temperature trend at Siwalik has been found in slightly decreasing except monsoon where deviation have been observed at slightly decreasing. Due to increasing the deviation between them, the possibility of hot days or heat index has been occurring to increase. Hence, extreme events might be likely observed during these periods.

CHAPTER – 5
Conclusion and Recommendation

5.2 Conclusion:

There are several conclusions made from the study of the temperature trend.

I) The maximum temperature trend over Nepal since 1971 has been observed at increasing rate 0.078°C/year (r^2=0.84) and minimum temperature has been also increased at rate of 0.054°C/year (r^2=0.72). After 1976, similar results have been observed in maximum (0.079°C/year, r^2=0.78) and minimum (0.051°C/year, r^2=0.62) temperature trends.

II) Almost constant in maximum temperature has been observed at most parts of Terai region of Nepal with exception of the station of Janakpur, Nepalganj, and Parwanipur where trend has been found slightly cooling. However, slightly warming trend in minimum temperature has been observed at all parts of the Terai region.

III) Warming in maximum temperature trends has been observed in the Siwalik region except Butwal Station. In the minimum temperature, it has also observed at warming rate except Tulsipur, Hetauda and Gaida Kankai Station where the trends have been slightly decreasing.

IV) In the middle Mountain Region, Warming in the maximum temperature trends has been observed except Baglung and Silgadi Doti. In the case of minimum temperature, warming has been observed except most parts of mid and Far western region and Eastern parts of middle mountain region.

V) In the Higher Mountain & Himalaya Region, warming trends in maximum temperature have been observed except Jomsom and Rara. Slightly increasing trend in minimum temperature has been observed except central Himalaya region.

VI) The maximum temperature has been observed in slightly warming rate at monsoon and post-monsoon season of Terai region except in winter and pre-monsoon season where trends has been remained nearly constant and in the case of minimum temperature, trends have been observed at slightly warming rate in all seasons of Terai region.

VII) The maximum and minimum temperature has been observed in warming rate in all seasons of Siwalik and Middle Mountain Region.

VIII) The maximum temperature trend has been observed in warming rate in all season of HMHR and in the case of minimum temperature, trend has been observed at slightly warming rate except pre-monsoon where trend has been observed at cooling rate.

IX) The deviation between surface maximum and minimum temperature trend has been found in decreasing trends in winter and pre-monsoon season of Terai Region, however, slightly increasing deviation has been found in monsoon and post-monsoon. And, the deviation between surface maximum and minimum temperature trend has been found in increasing at MMR and HMHR, however, the deviation between surface maximum and minimum temperature trend at Siwalik has been found in slightly decreasing except monsoon where deviation were observed at slightly decreasing. Due to this effect, extreme events might likely be occurred.

X) In the period of 1970 to 2004 in average, the rate of increase in minimum temperature over Middle Mountain (0.045^{o}C/year) region and higher mountain & Himalayan (0.06^{o}C/year) region (HMHR) of Nepal have been observed about twice to be increased in maximum (0.09^{o}C/year and 0.12^{o}C/year) temperature respectively. But the rate of increase in minimum temperature (0.03^{o}C/year) over Terai regions have been observed to be decreased at more than double in maximum temperature (0.01^{o}Cyear) and also nearly double in minimum (0.1^{o}C/year) with respect to maximum (0.07^{o}C/year) temperature in the Siwalik region.

XI) The observation also shows the 1990s was the warmest decade but year 1999 (Normal temp.26.3^{o}C) was the warmest year in the maximum and year 1998 (Normal temp.14.3^{o}C) was the high warming year in the minimum temperature in case of Nepal since 1970 to 2004. After 1999, slightly cooling trend has been observed in both day and night temperature.

XII) The greatest trend rate ($0.12^{O}C$/year) in maximum temperature has been observed at HMHR and ($0.1^{O}C$/year) in minimum temperature at Siwalik region. In the seasonal temperature over Nepal, the highest trends values have been found in post-monsoon for maximum ($0.1^{O}C$/year) and in winter season for minimum ($0.06\ ^{O}C$/year) temperature.

XIII) Temperature vs. altitude has also been calculated in different regions as well as seasons. The value of maximum temperature and minimum temperature has been observed to be 5.7 ^{o}C per kilometer (r^2=0.96) and $4.8^{o}C$ per kilometer (r^2=0.96) respectively. The highest lapse rate has been observed to be $6.9^{o}C$ (r^2=0.95) at pre-monsoonal maximum temperature and $5.3^{o}C$ (r^2=0.98) at monsoonal minimum temperature.

5.2 Recommendation:

A. The data of the higher mountain and Himalayan region has not been adequately available due to lack of meteorological station. Hence, the existing network should be reviewed as per norms of World Meteorological Organization (WMO) and should be activated regularly as well as consistently.

B. There are some problems in data missing and /or poor in data quality. This may affect on analysis of meteorological condition. Thus the missing of the data and their quality should be controlled and updated as far as possible.

C. Various physiological factors are responsible for warming of earth. So study should be focused for the better results.

D. Further in-depth research in various climatic factors should be done.

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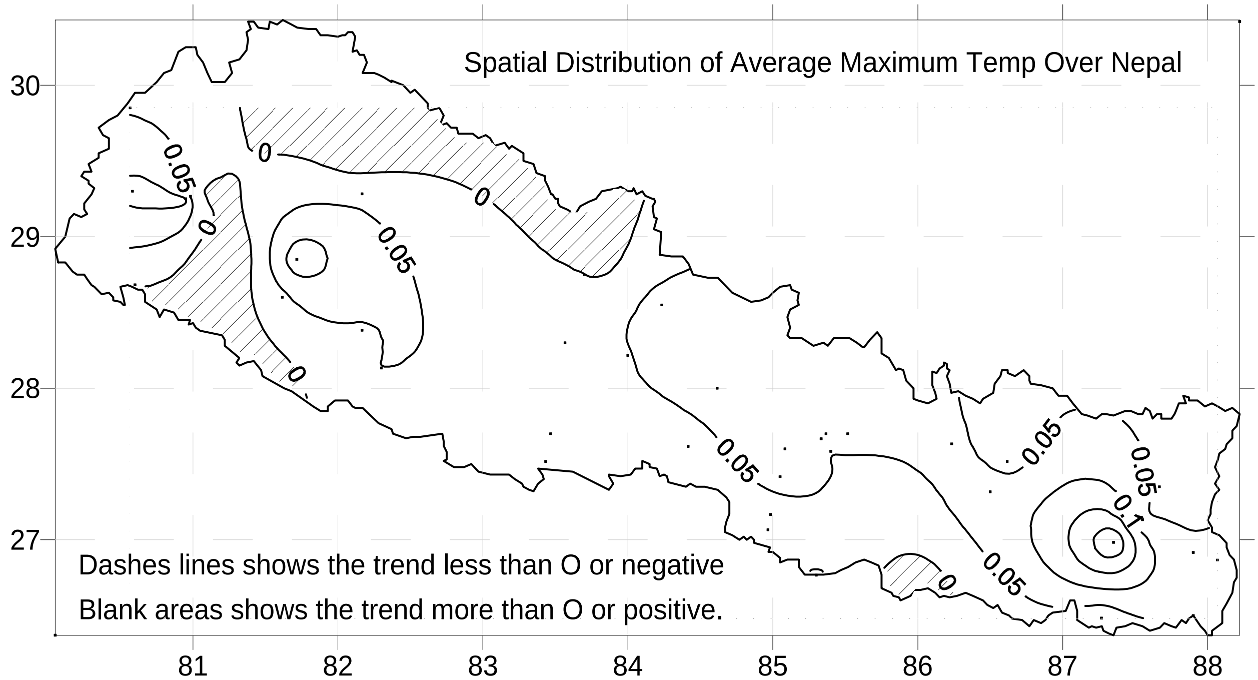
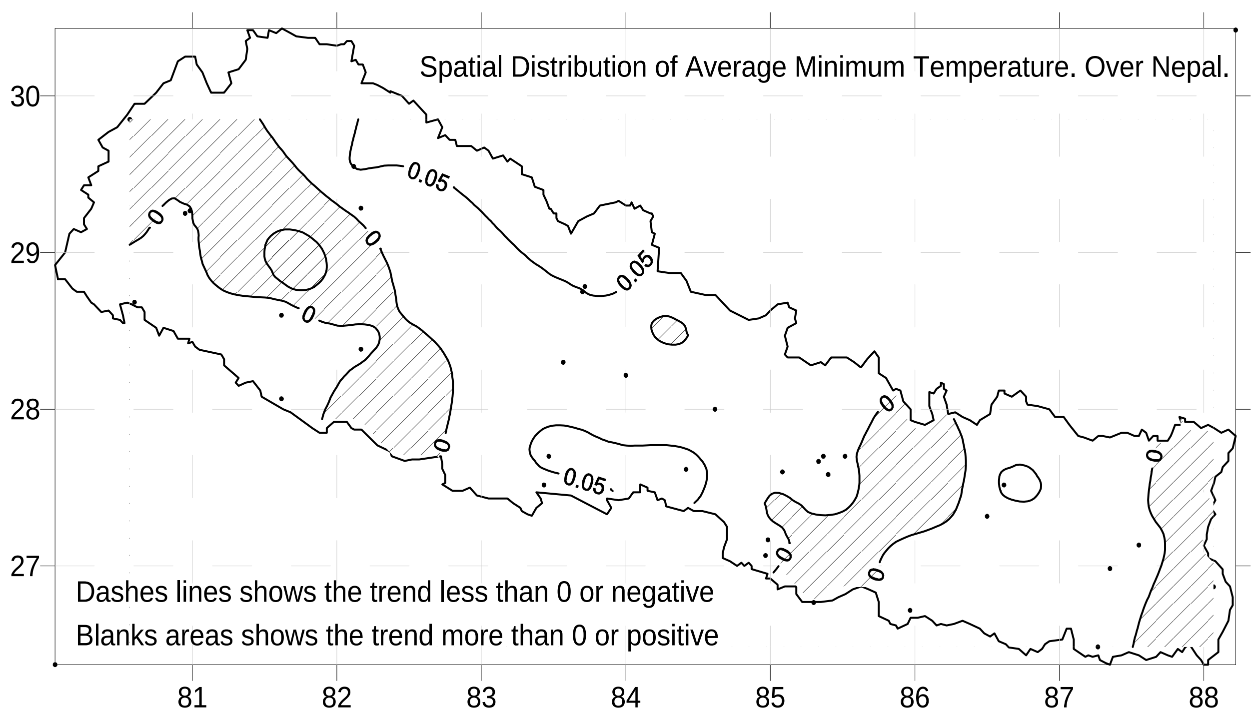
The hottest months of the station and its mean extreme normal temp values are shown.

Name of Station	Maximum Temp		Minimum Temp	
	Hottest Month	Extreme Normal	Hottest Month	Extreme Normal
Gaur	May	37.3	August	25.8
Bhairahawa airport	May	36.3	August	25.7
Parwanipur	May	35.5	July	25.8
Simara Airport	April	34.9	July	25.4
Gaida Kankai	June	33	August	24.6
Nepalganj Reg. off.	May	37.6	July	26.4
Pokhara Airport	June	30.1	August	21.8
Jumla	August	23.4	August	15.2
Nagarkot	June	23	August	15.3
Daman	August	21.9	August	13.6
Chame	June	20.9	August	10.6
Chailsa	August	19.2	July	11.9
Jomsom	**July**	23	**July**	13.6
Thakmarpha	June	21.6	July	13.2
Dadeldhura	June	25.5	July	17.3
Gorkha	June	29.7	July	20.8
Lumle	June	23.4	August	17.2
Godawari	June	25.8	July	18.1
Kathmandu	June	28.5	July	20
Okhaldhunga	June	24.4	July	17.7
Dhankuta	June	26.6	July	20.1
Terhathum	August	25.9	July	17.9
Jiri	June	23.7	August	16.6
Taplejung	August	24.7	July	17.8
Biratnagar Airport	May	33.1	August	25.6
Janakpur Airport	May	34.7	August	26.6
Dhangadi	May	37.3	Jul	25.7
Janakpur Airport	May	34.7	Aug	26.6
Butwal	May	36.3	Jun	25.3
Rampur	May	25.6	Aug	25.2
Hetauda	Apr	33.6	Jul	23.4
Tulsipur	May	34.5	Jul	23.3
Birendranagar, Surkhet	May	34	Jul	23.3
Gorkha	Jun	29.7	Jul	20.8
Ilam Tea State	Jun	25.6	Aug	19.9
Dailekh	May	30.7	Jul	17.4
Salyan Bazaar	May	28.7	June	19.3
Darchula	May	33.6	Jul	21.5
Khumaltar	June	28	July	20.1
Kanyam tea Estate	**August**	22.6	**August**	17.1

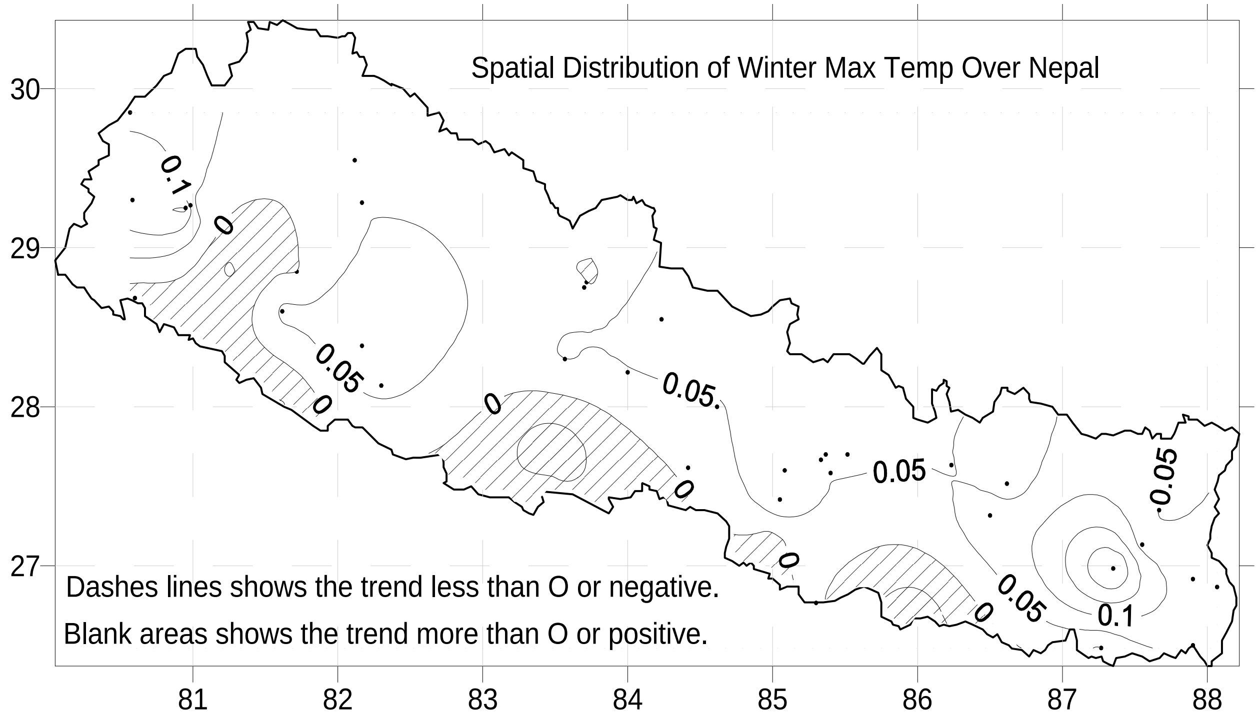
Table- 4: The hottest months and its extreme values for selected period of the station; bold character shows the extreme months of both maximum and minimum temperature falls on the same month .



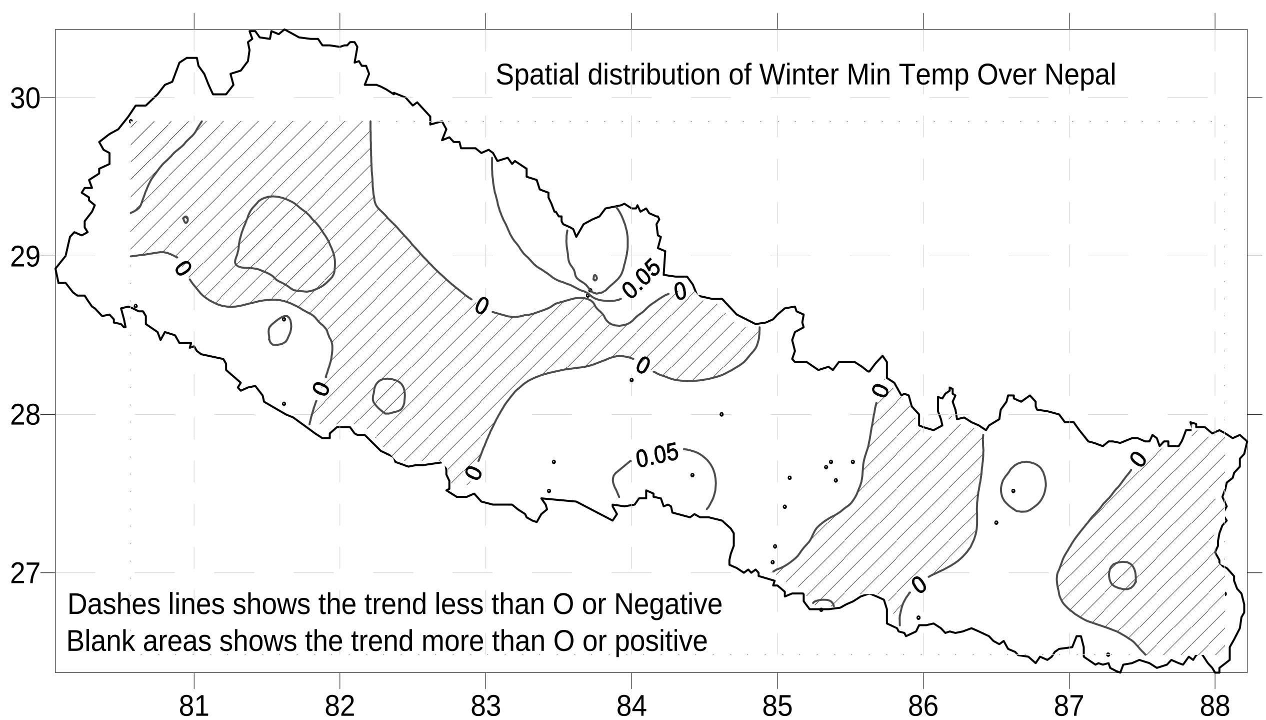
Map - 4: Figure showing the spatial distribution of annual maximum temperature trend over Nepal.



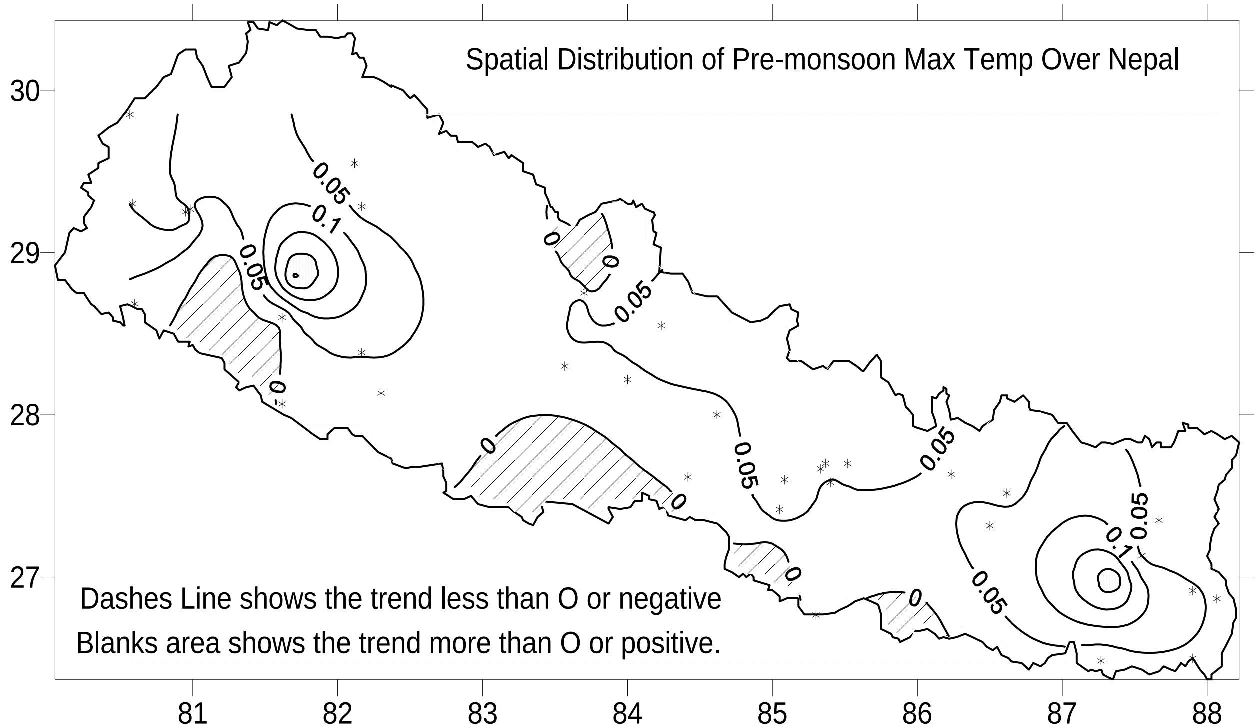
Map - 5: Figure showing the spatial distribution of annual minimum temperature trend over Nepal.



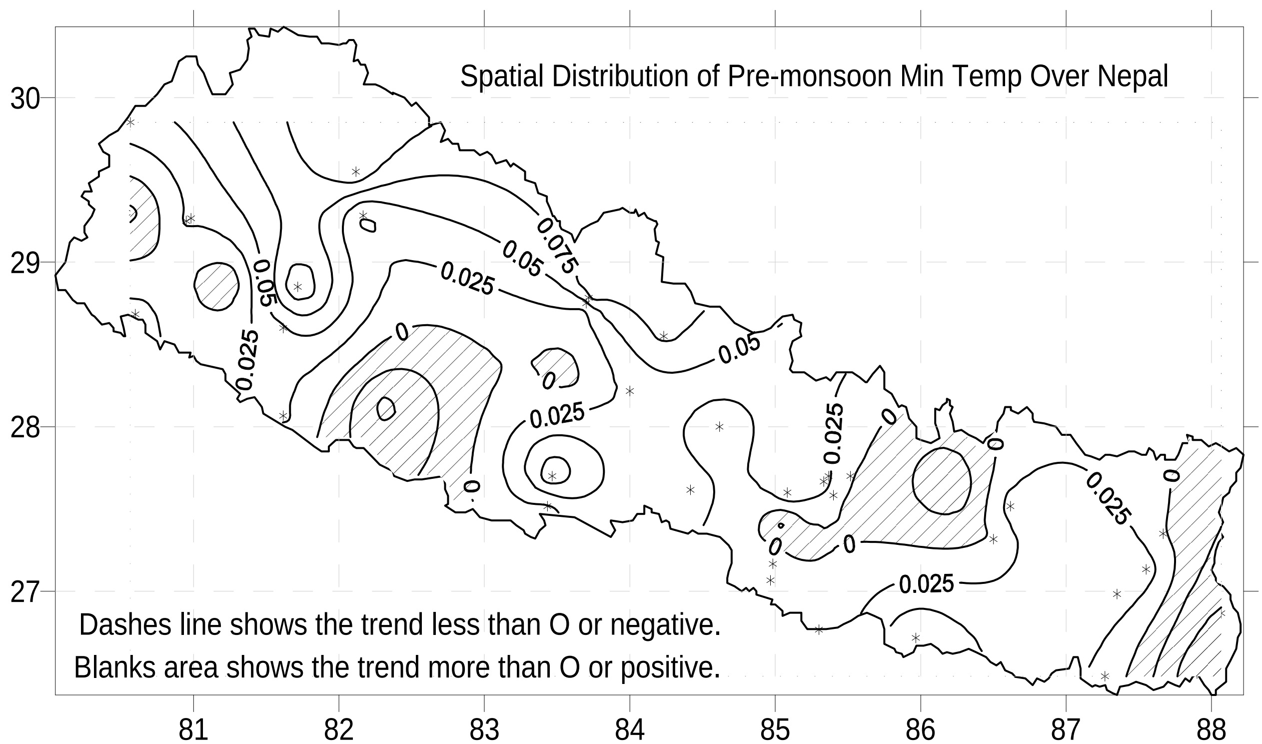
Map - 6: Figure showing the spatial distribution of maximum temperature trend in winter season over Nepal.



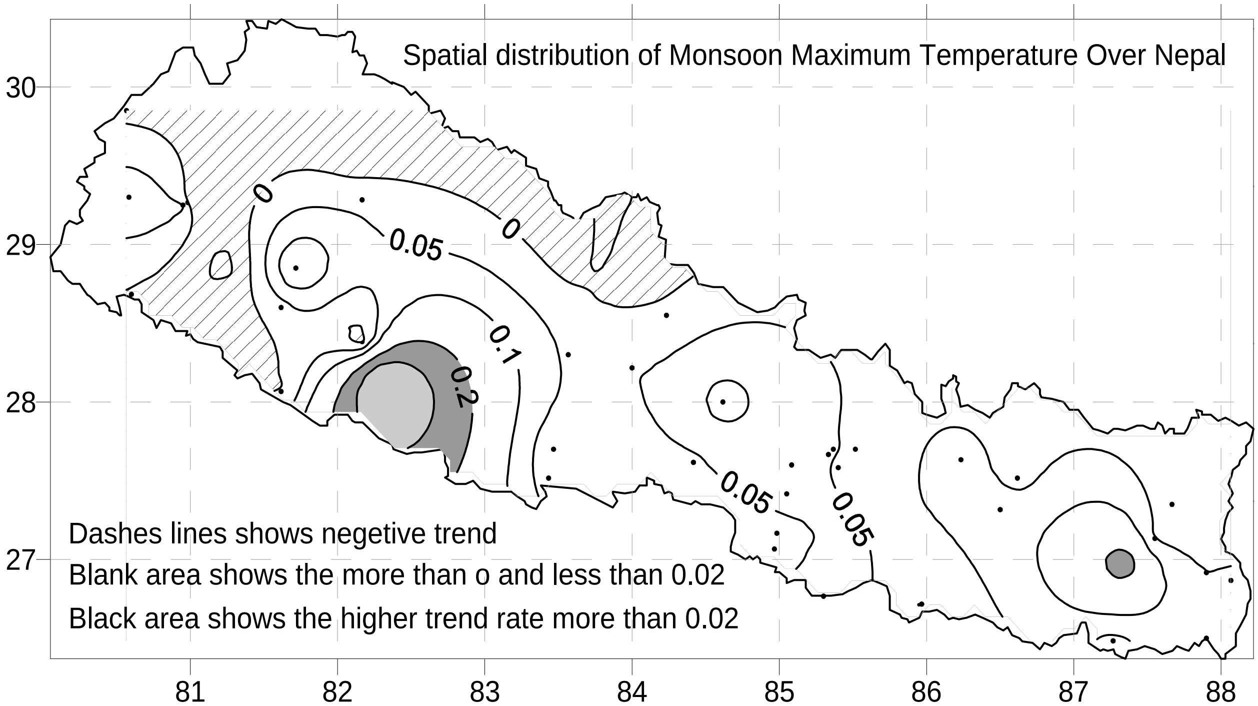
Map- 7: Figure showing the spatial distribution of minimum temperature trend in winter season over Nepal.



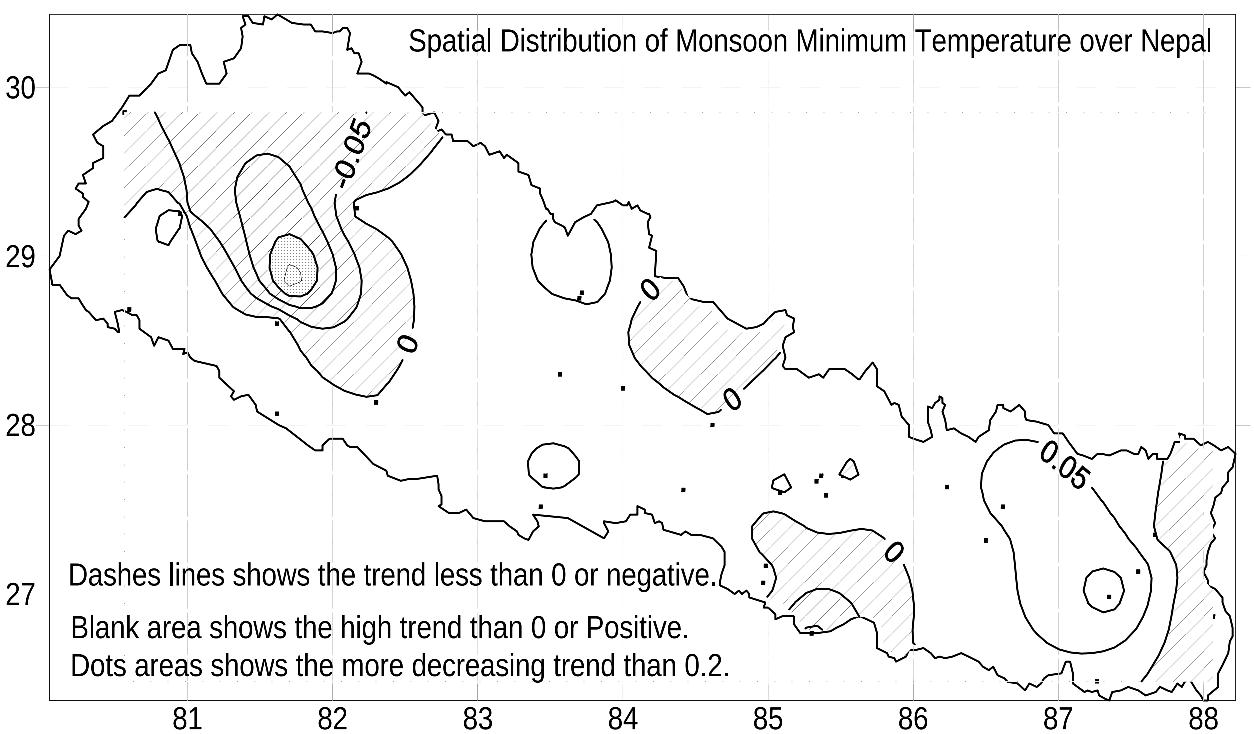
Map- 8: Figure showing the spatial distribution of maximum temperature trend in Pre-monsoon season over Nepal.



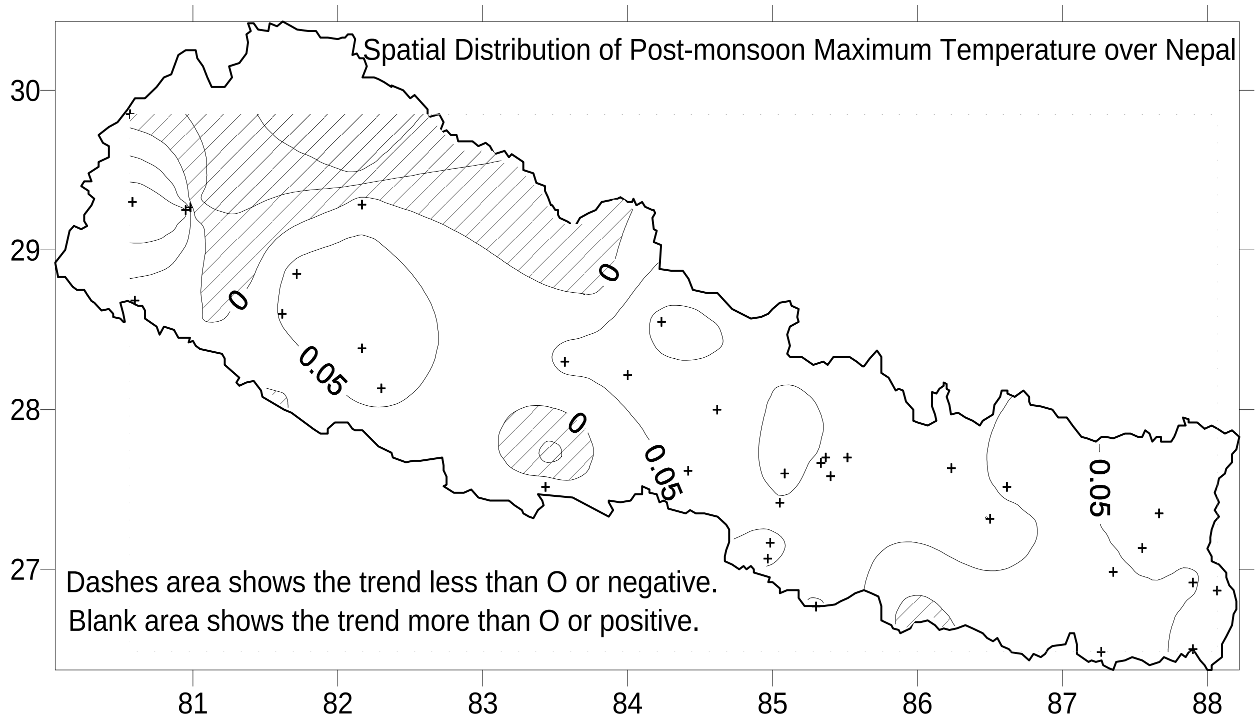
Map- 9: Figure showing the spatial distribution of minimum temperature trend in Pre-monsoon season over Nepal.



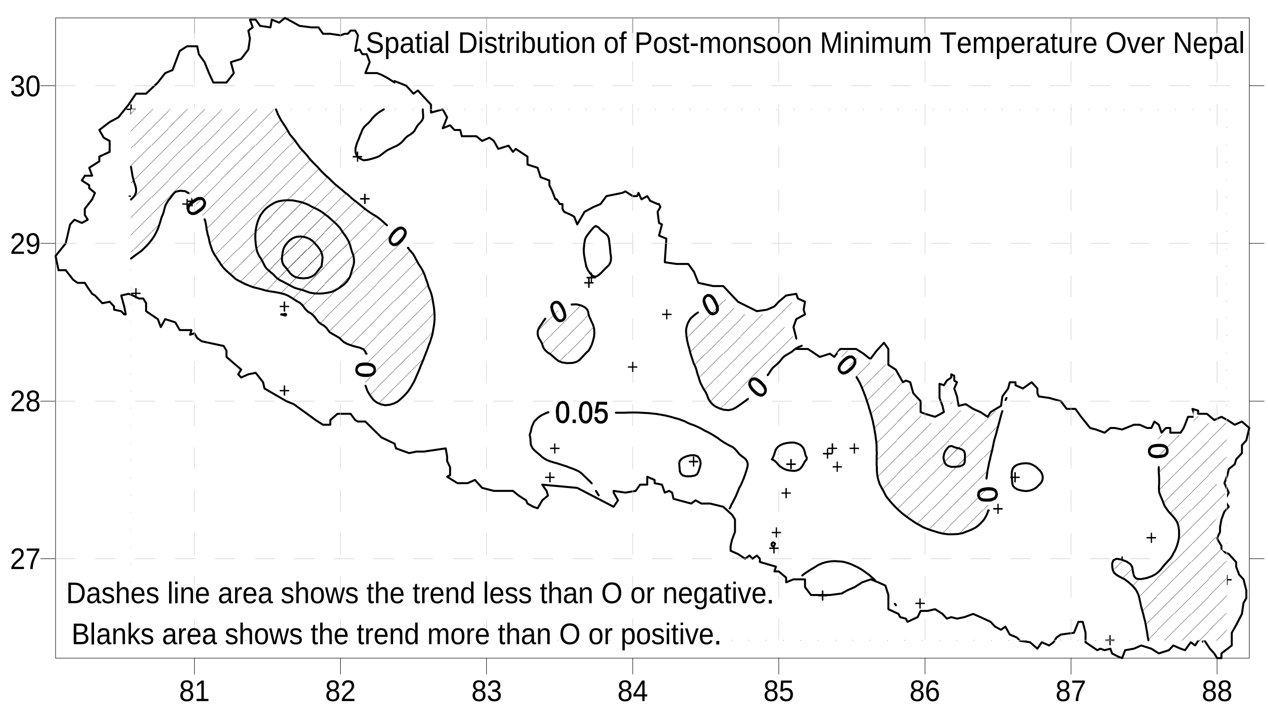
Map- 10: Figure showing the spatial distribution of maximum temperature trend in Monsoon season over Nepal.



Map-11: Figure showing the spatial distribution of minimum temperature trend in Monsoon season over Nepal.



Map 12: Figure showing the spatial distribution of maximum temperature trend in Post-monsoon season over Nepal:



Map 13: Figure showing the spatial distribution of minimum temperature trend in Post-monsoon season over Nepal.

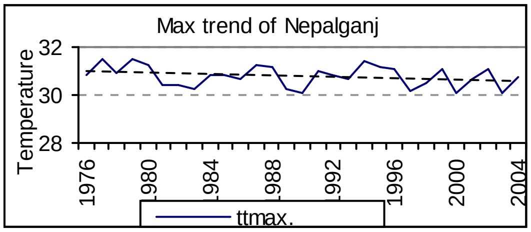


Fig.1: Annual max. Temp. Trend of Nepalganj

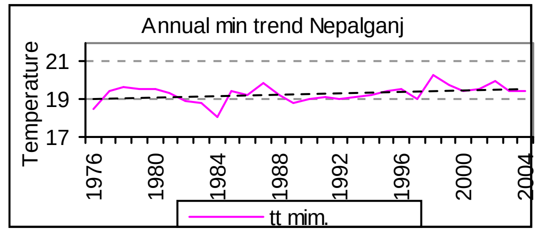


Fig.2: Annual min. temp. Trend of Nepalganj

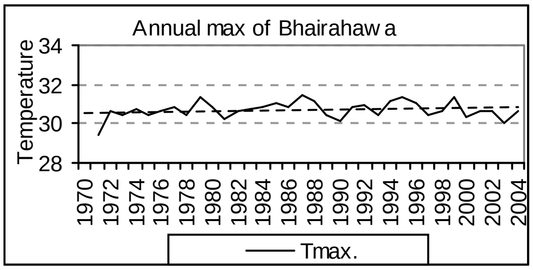


Fig.3: Annual max temp trend of Bhairahawa

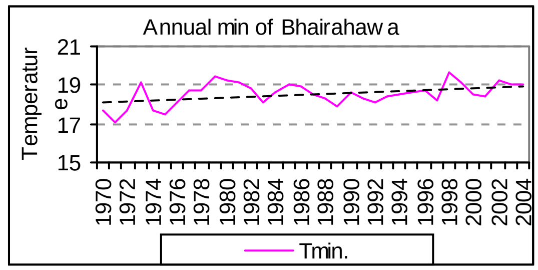


Fig.4: Annual min temp trend of Bhairahawa

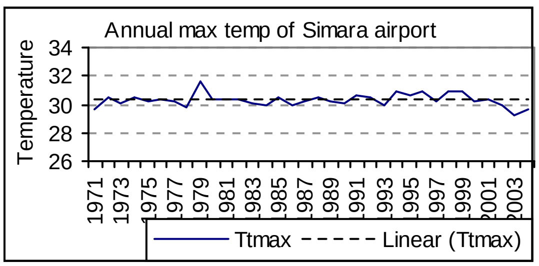


Fig.5: Annual max temp trend of Simara

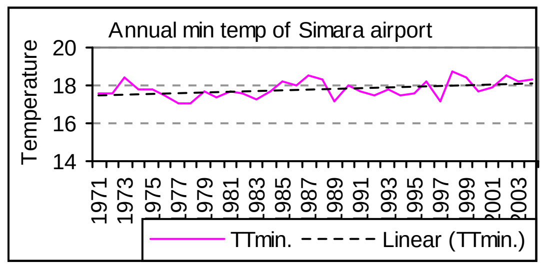


Fig.6: Annual min temp trend of Simara

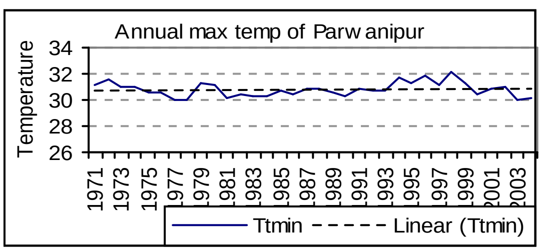


Fig.7: Annual max temp trend of Parwanipur

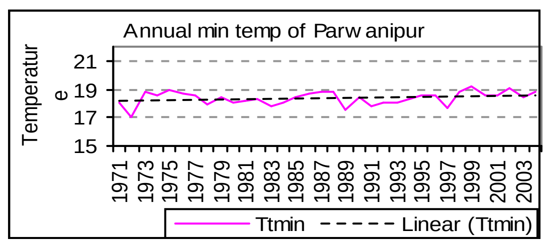


Fig.8: Annual min temp trend of Perwanipur

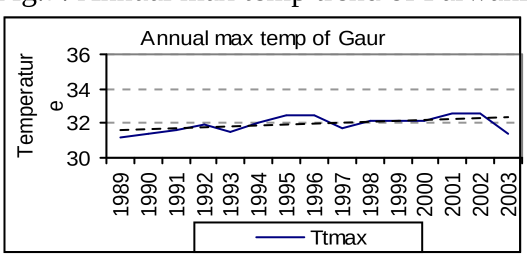


Fig.9: Annual max temp trend of Gaur

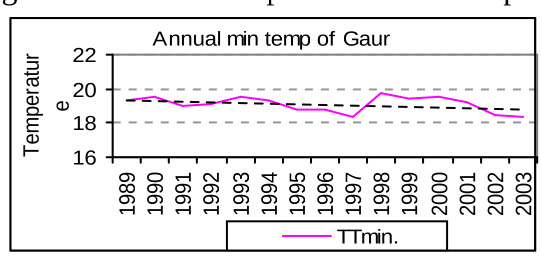


Fig.10: Annual min temp trend of Gaur

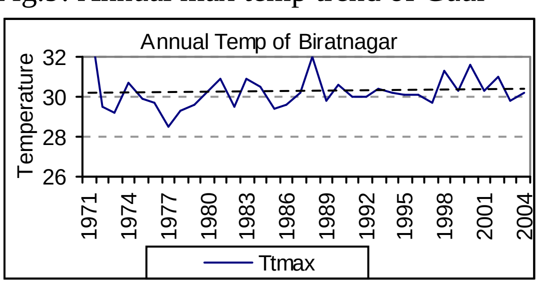


Fig.11: Annual max temp trend of Biratnagar

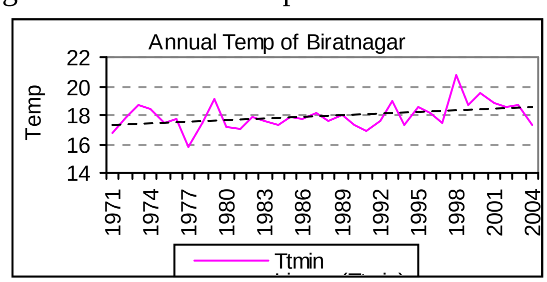


Fig.12: Annual min temp trend of Biratnagar

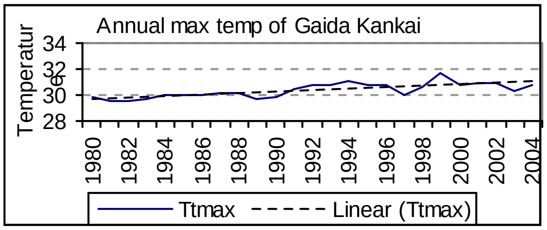


Fig.13: Annual max temp trend of Gaida

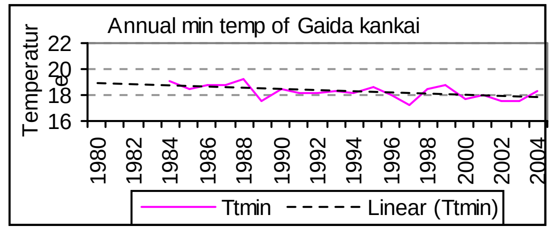


Fig.14: Annual min temp trend of Gaida Kankai

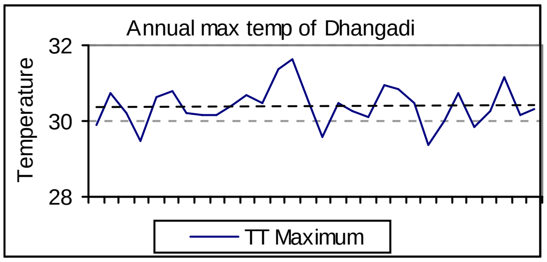


Fig.15: Annual max temp trend of Dhangadi

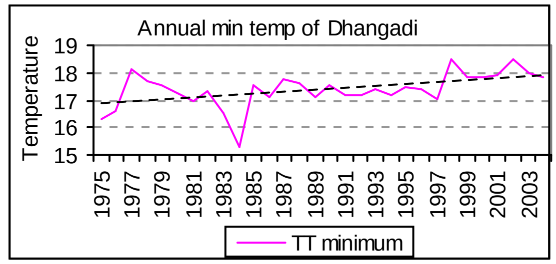


Fig.16: Annual min temp trend of Dhangadi

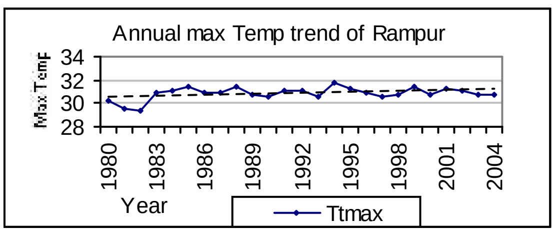


Fig.17: Annual max temp trend of Rampur

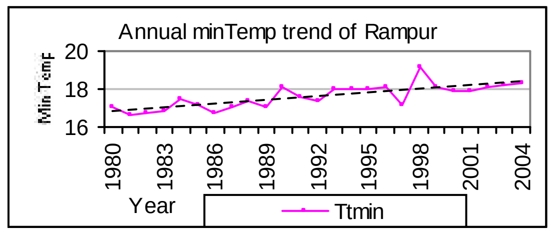


Fig.18: Annual min temp trend of Rampur

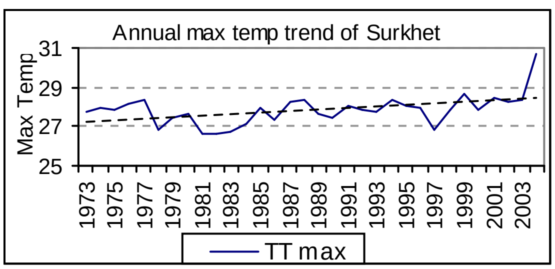


Fig.19: Annual min temp trend of Surkhet

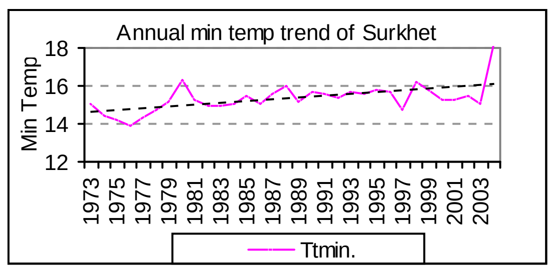


Fig.20: Annual max temp trend of Surkhet

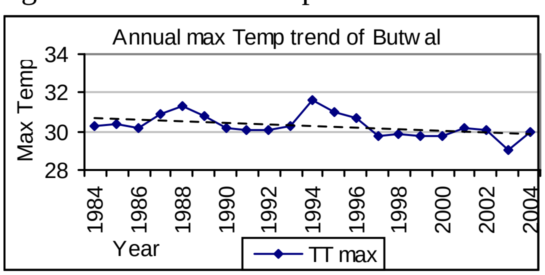


Fig.21: Annual min temp trend of Butwal

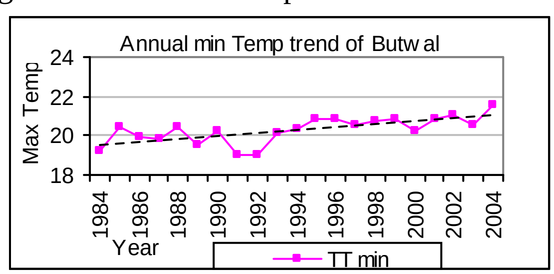


Fig.22: Annual max temp trend of Butwal

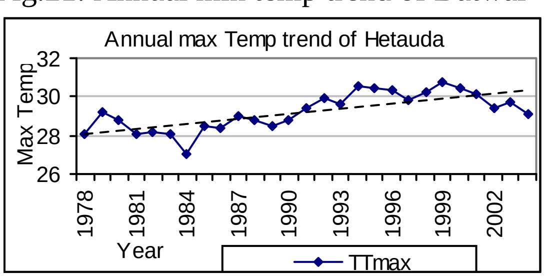


Fig.23: Annual min temp trend of Hetauda

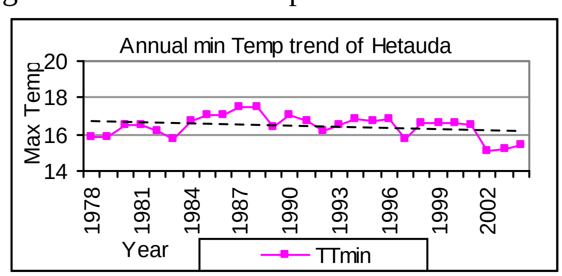


Fig.24: Annual max temp trend of Hetauda

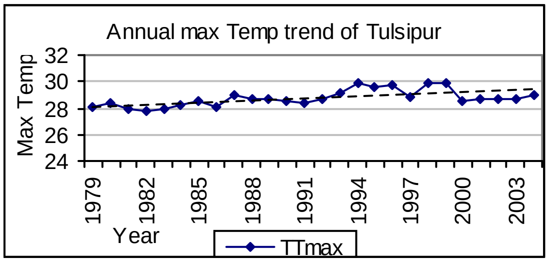


Fig.25: Annual min temp trend of Tulsipur

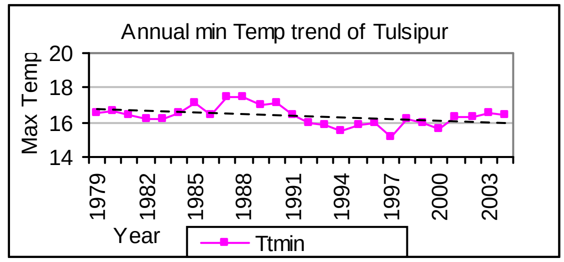


Fig.26: Annual max temp trend of Tulsipur

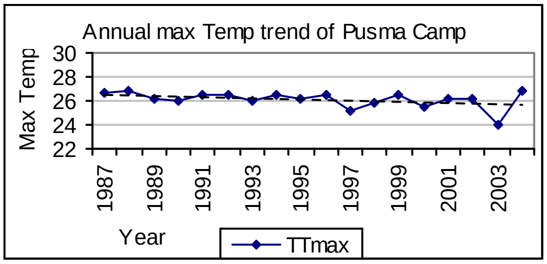


Fig.27 Annual min temp trend of Pusmacamp

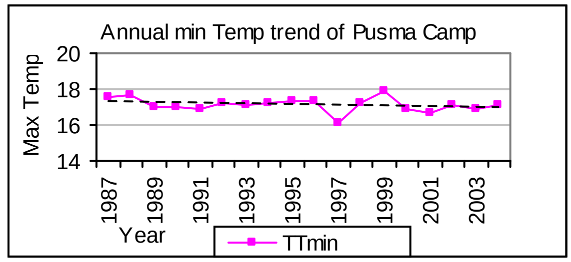


Fig.28: Annual max temp trend of Pusmacamp

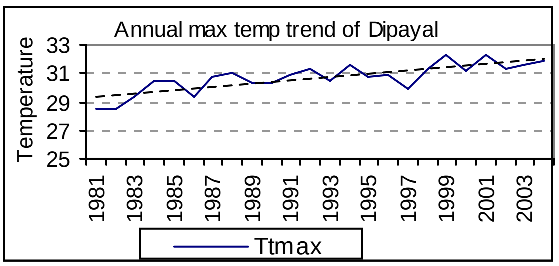


Fig.29: Annual min temp trend of Dipayal

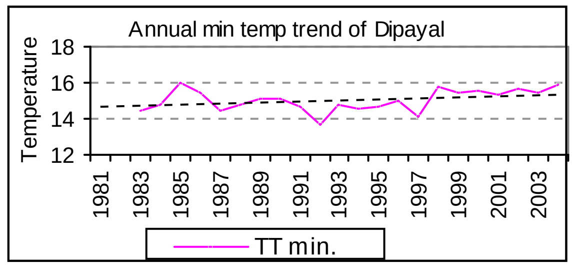


Fig.30: Annual max temp trend of Dipayal

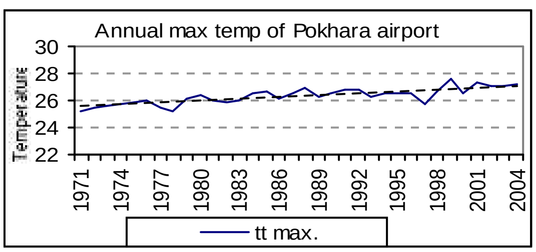


Fig.31: Annual min temp trend of Pokhara

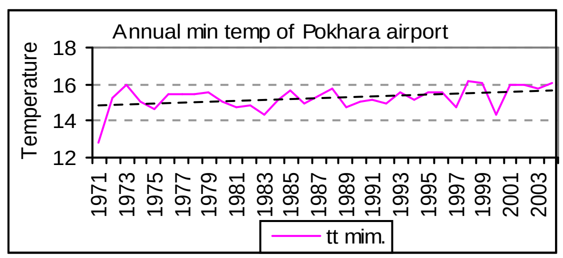


Fig.32: Annual max temperature trend of Pokhara

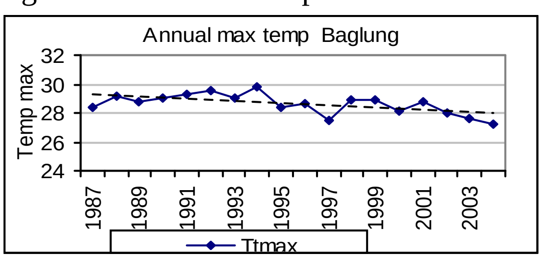


Fig.33: Annual min temp trend of Baglung

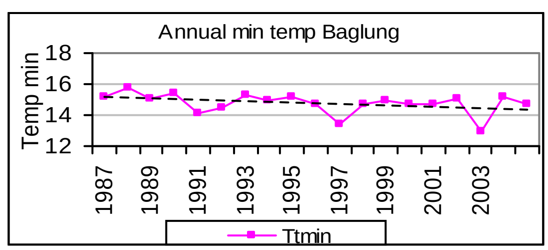


Fig.34: Annual maximum temp trend of Baglung

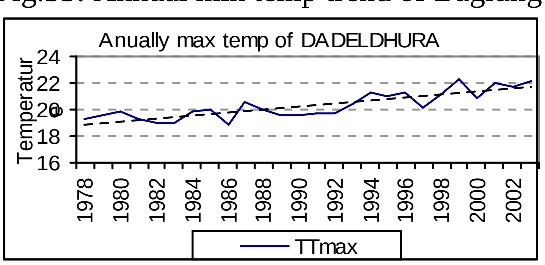


Fig.35: Annual min temp trend of Dadeldhura

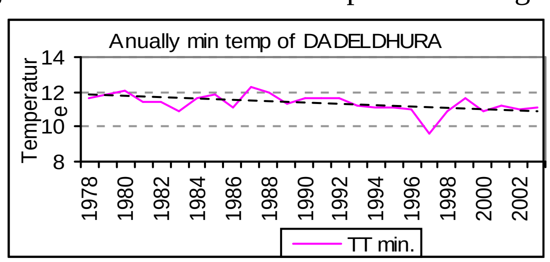


Fig.36: Annual max temp trend of Dadeldhura

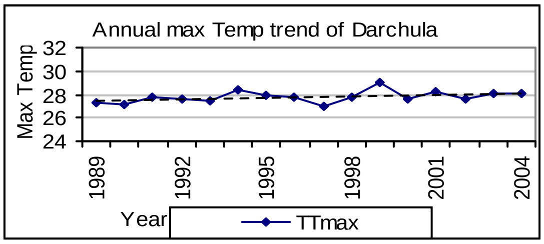


Fig.37: Annual min temp trend of Darchula

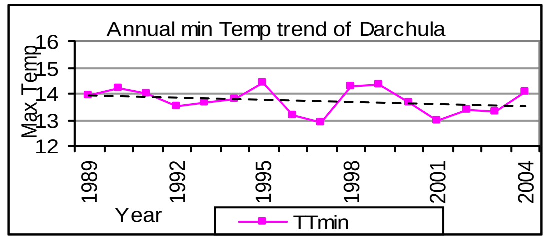


Fig.38: Annual max temp trend of Darchula

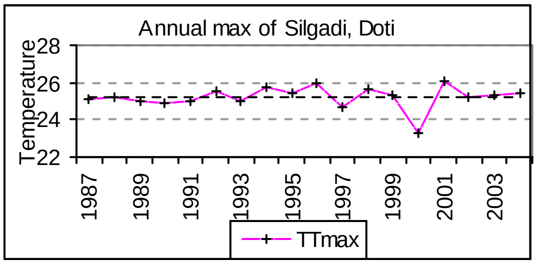


Fig.39: Annual min temp trend of Silgadi

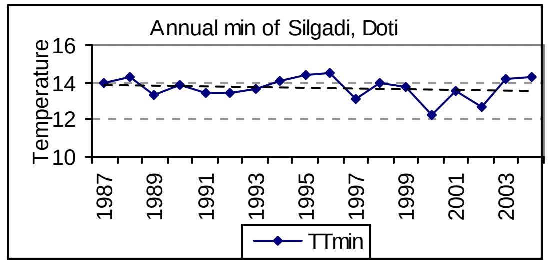


Fig.40: Annual max temp trend of Silgadi Doti

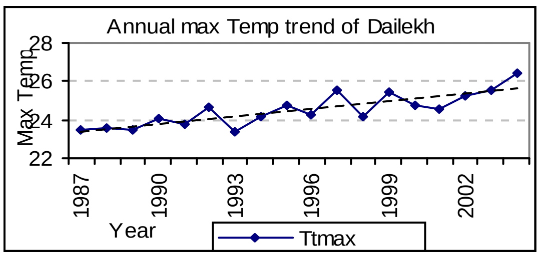


Fig.41: Annual min temp trend of Dailekh

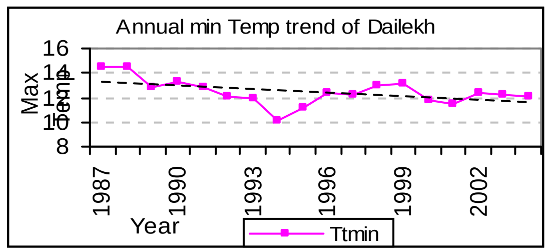


Fig.42: Annual max temp trend of Dailekh

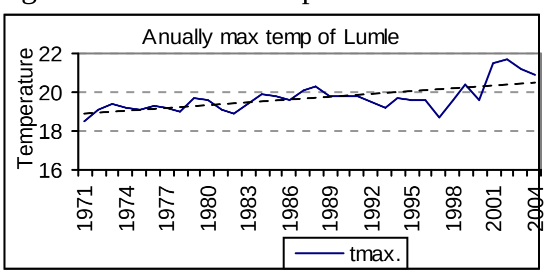


Fig.43: Annual min temp trend of Lumle

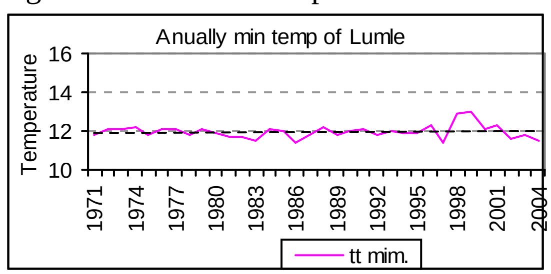


Fig.44: Annual max temp trend of Lumle

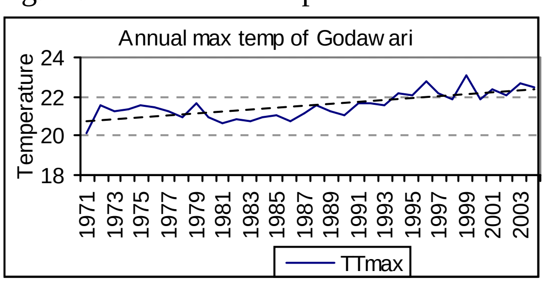


Fig.45: Annual min temp trend of Godawari

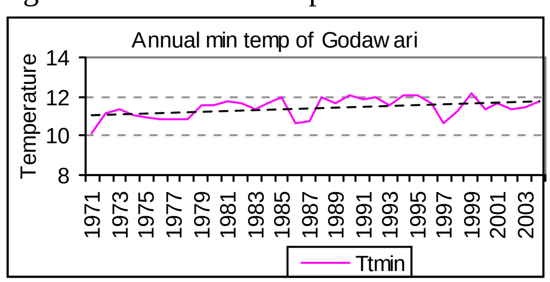


Fig.46: Annual max temp trend of Godawari

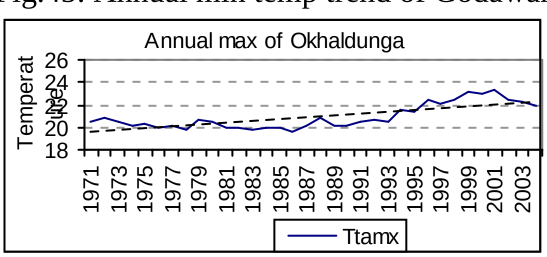


Fig.47: Annual min temp trend of Okhaldhunga

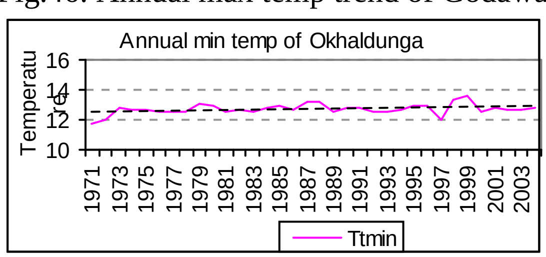


Fig.48: Annual max temp trend Okhaldhunga

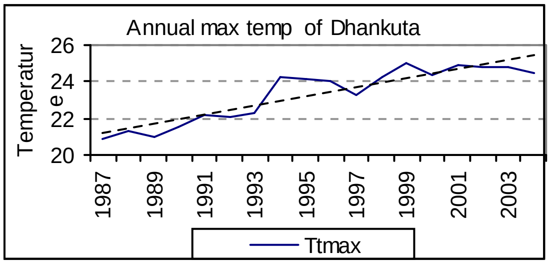


Fig.49: Annual min temp trend of Dhankuta

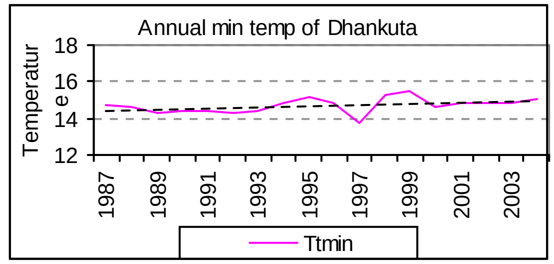


Fig.50: Annual max temp trend of Dhankuta

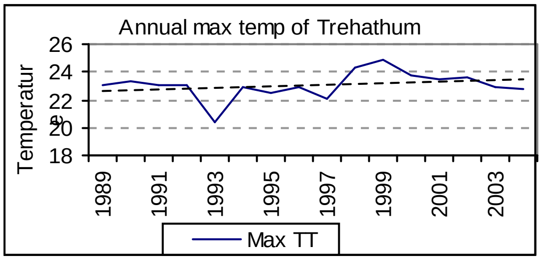


Fig.51: Annual min temp trend of Terhathum

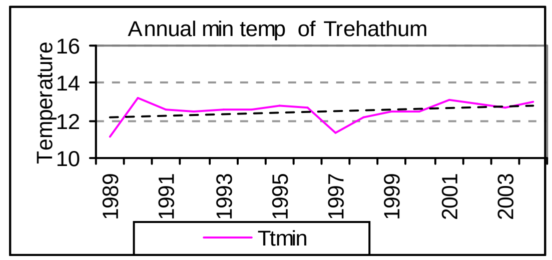


Fig.52: Annual max temp trend of Terhathum

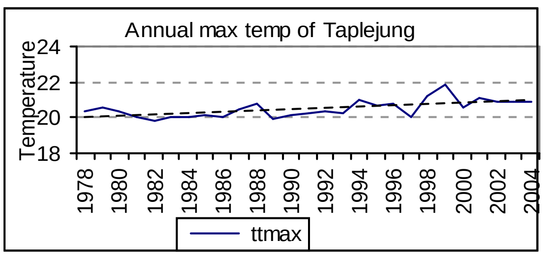


Fig.53: Annual min temp trend of Taplejung

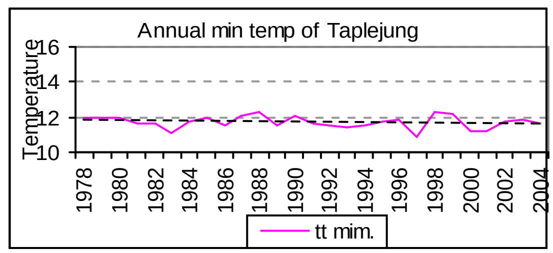


Fig.54: Annual max temp trend of Taplejung

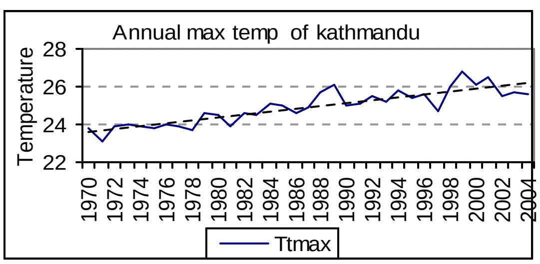


Fig.55: Annual min temp trend of Kathmandu

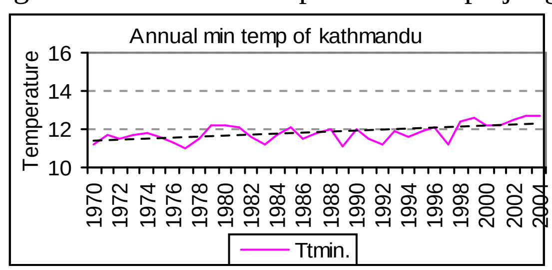


Fig.56: Annual max temp trend of Kathmandu

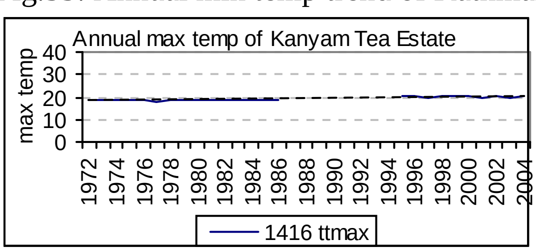


Fig.57: Annual min temp trend of Kanyam

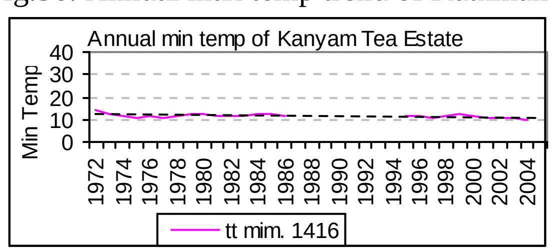


Fig.58: Annual max temp trend of Kanyam

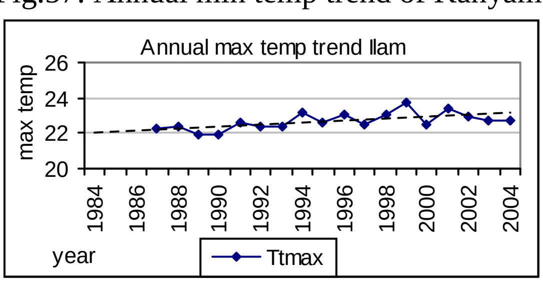


Fig.59: Annual min temp trend of Ilam

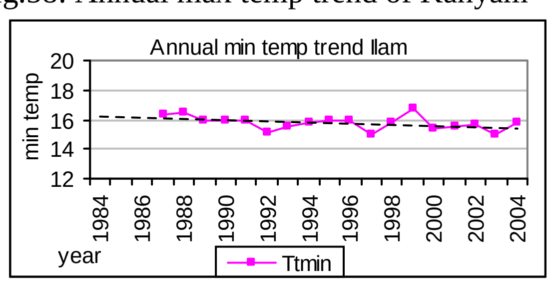


Fig.60: Annual max temp trend of Ilam

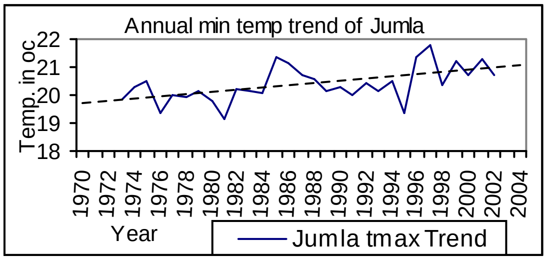


Fig.61: Annual min temp trend of Jumla

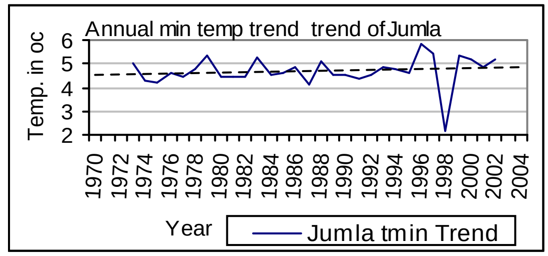


Fig.62: Annual max temp trend of Jumla

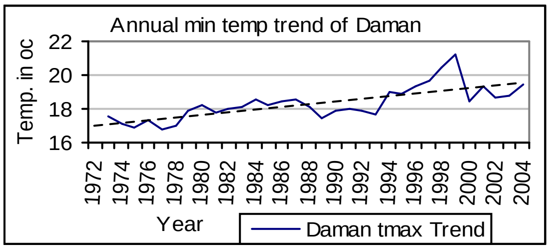


Fig.63: Annual min temp trend of Daman

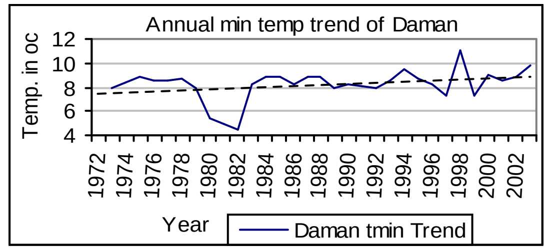


Fig.64: Annual max temp trend of Daman

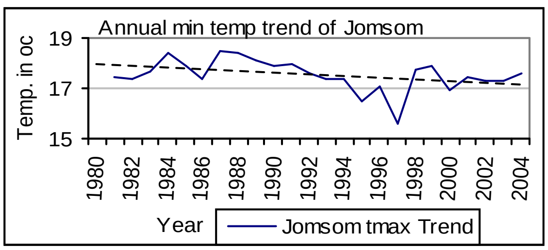


Fig.65: Annual min temp trend of Jomsom

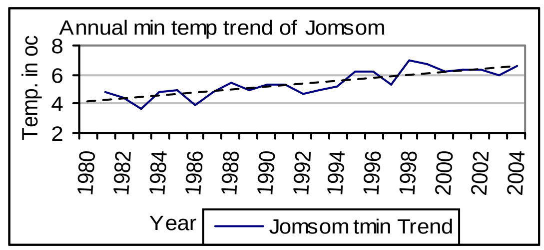


Fig.66: Annual max temp trend of Jomsom

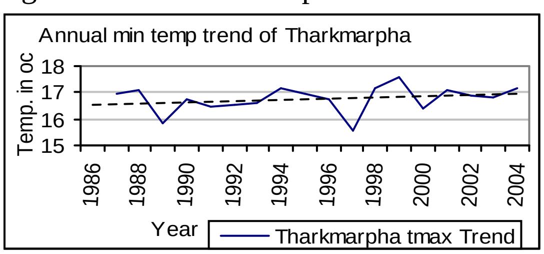


Fig.67: Annual min temp trend of Thakmarpha

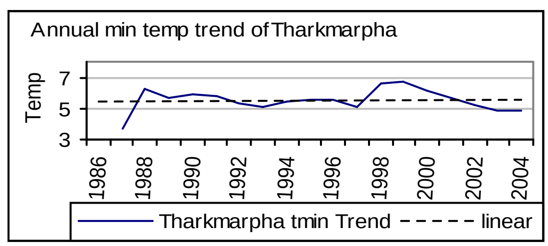


Fig.68: Annual max temp trend of Thakmarpha

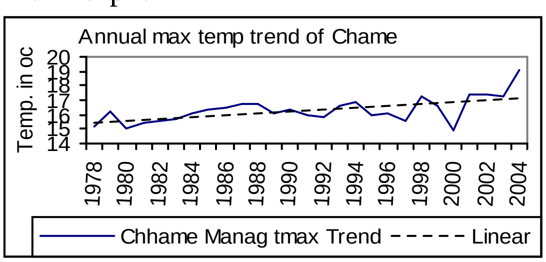


Fig.69: Annual min temp trend of Chame

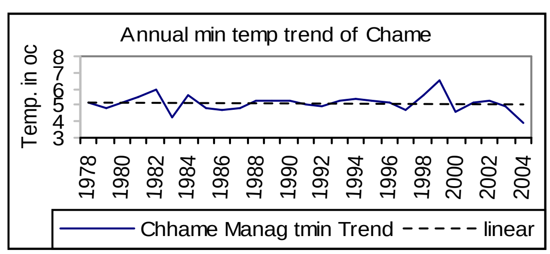


Fig.70: Annual max temp trend of Chame

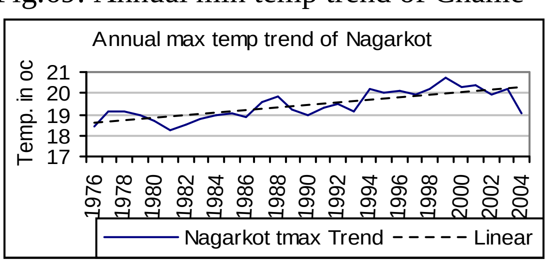


Fig.71: Annual min temp trend of Nagarkot

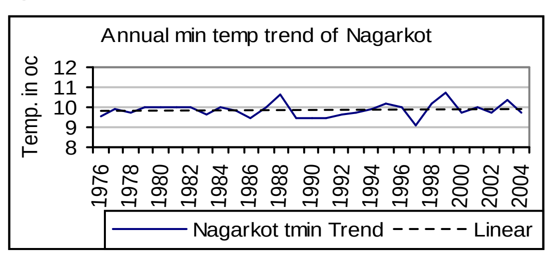


Fig.72: Annual max temp trend of Nagarkot

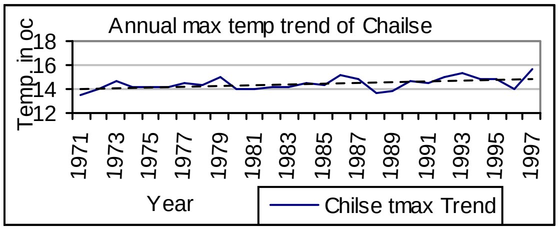


Fig.73: Annual min temp trend of Chailsa

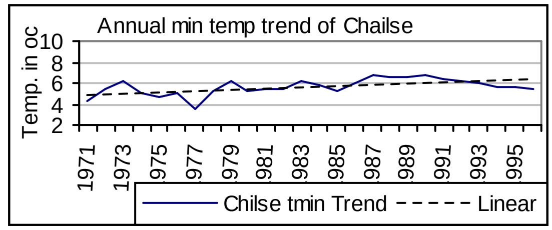


Fig.74: Annual max temp trend of Chailsa

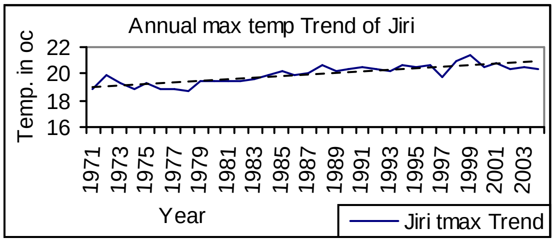


Fig.75: Annual min temp trend of Jir

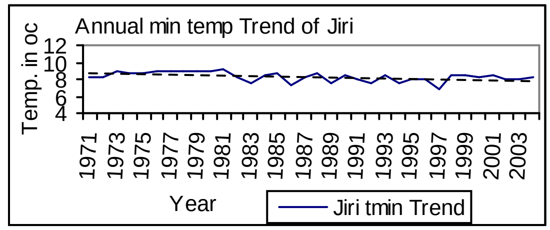


Fig.76: Annual max temp trend of Rara

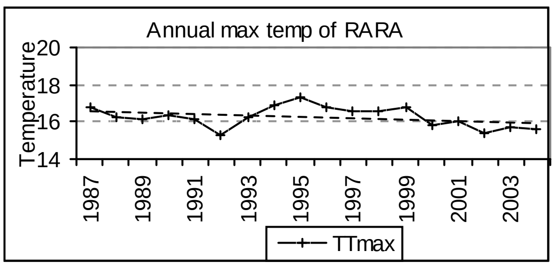


Fig.77: Annual min temp trend of Rara

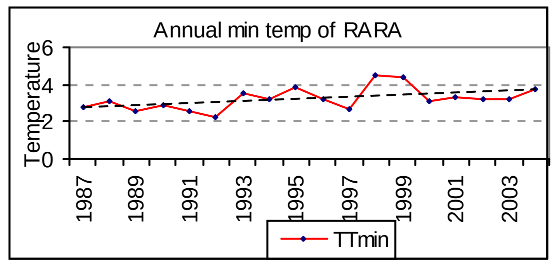


Fig.78: Annual max temp trend of Rara

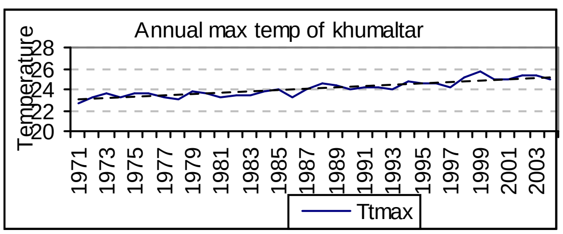


Fig.79: Annual min temp trend of Khumaltar

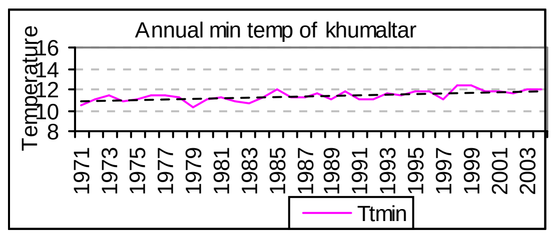


Fig.80: Annual max temp trend of Khumaltar

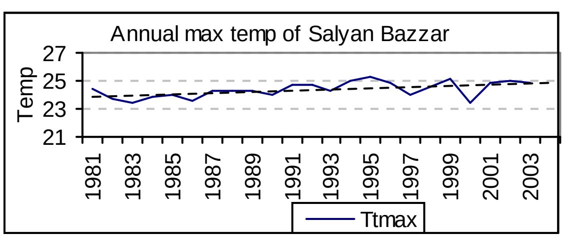


Fig.81: Annual min temp trend of Salyan

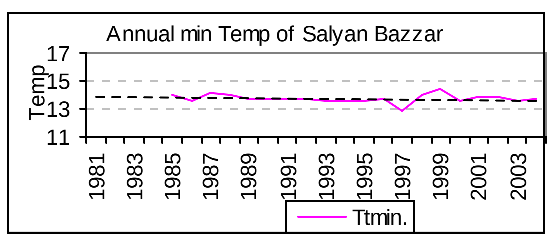


Fig.82: Annual max temp trend of Salyan

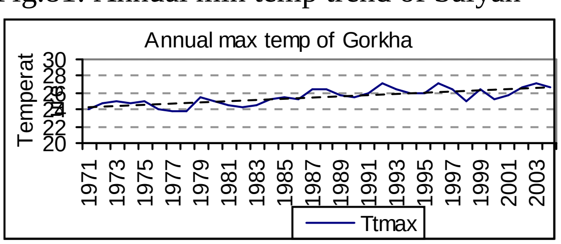


Fig.83: Annual min temp trend of Gorkha

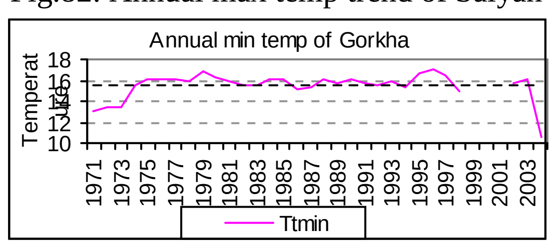


Fig.84: Annual max temp trend of Gorkha

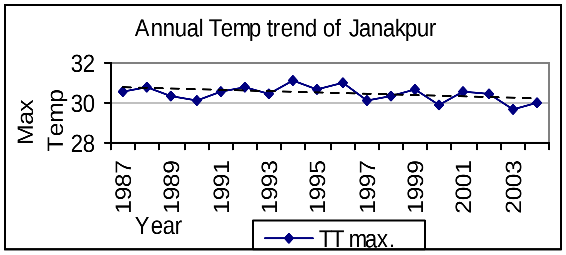


Fig.85: Annual min temp trend of Janakpur

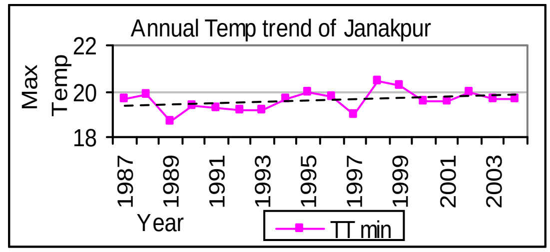


Fig.86: Annual max temp trend of Janakpur

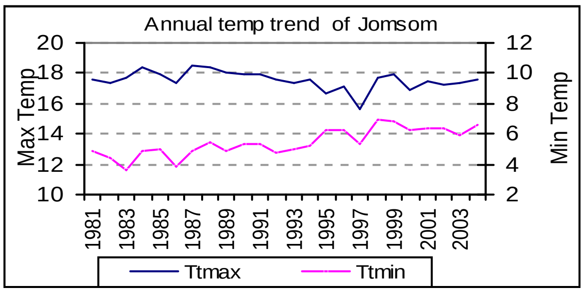


Fig.87 Deviation between max & min of Jomsom

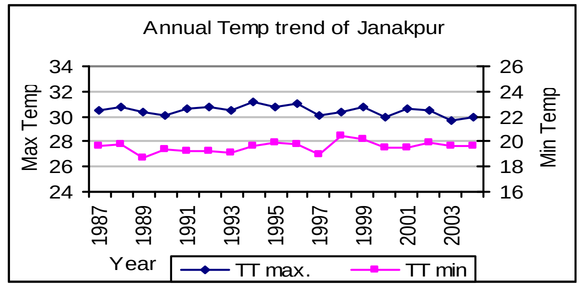


Fig.88 Deviation between max & min of Janakpur

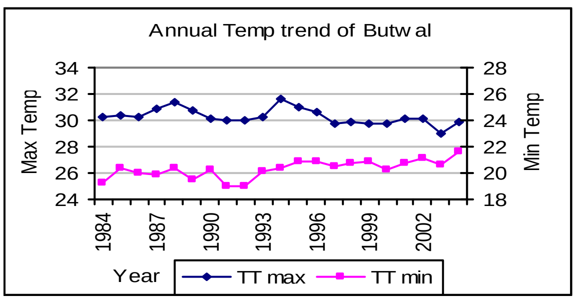


Fig.89 Deviation between max & min of Butwal

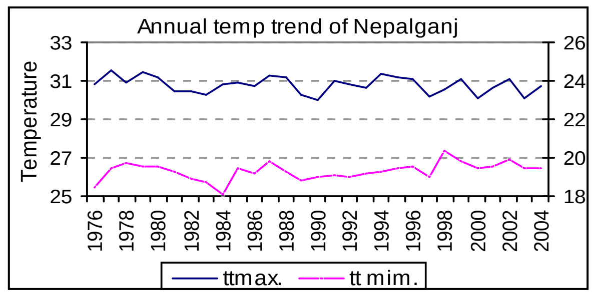


Fig.90 Deviation between max & min of Nepalganj

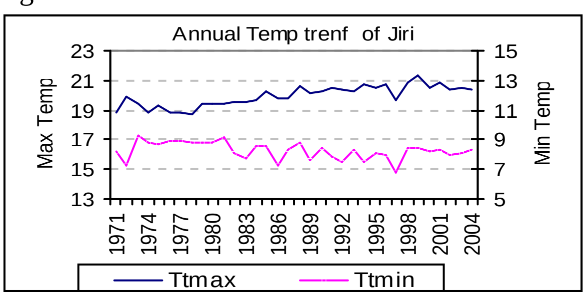


Fig.91 Deviation between max & min of Jiri

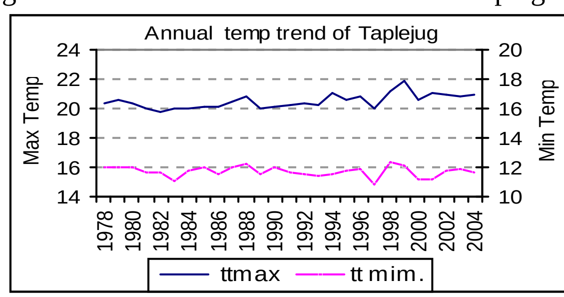


Fig.92 Deviation between Max & Min of Taplejung

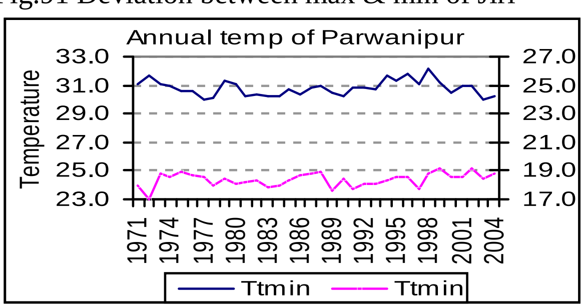


Fig.93 Deviation between Max & Min of Parwanipur

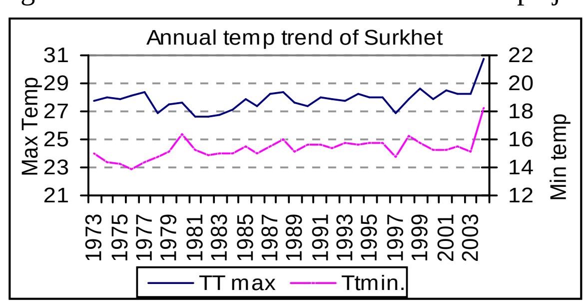


Fig.94 Deviation between Max & Min of Surkhet

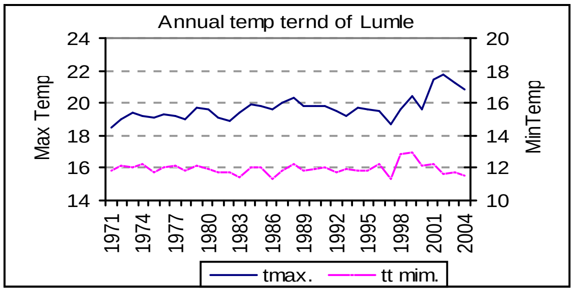


Fig.95 Deviation between Max & Min of Lumle

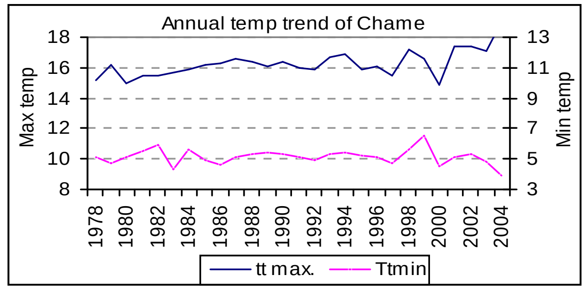


Fig.96 Deviation between Max & Min of Chame

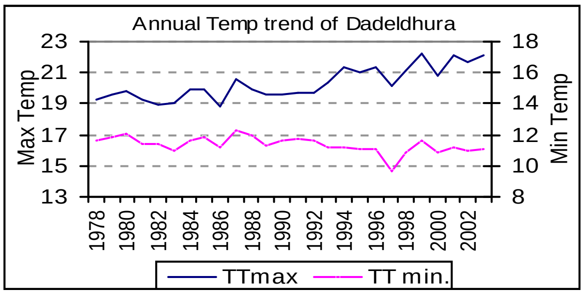


Fig.97 Deviation bet. max & min of Dadeldhura.

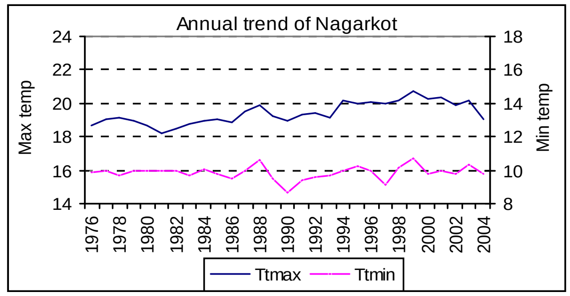


Fig.98 Deviation between Max & Min of Nagarkot

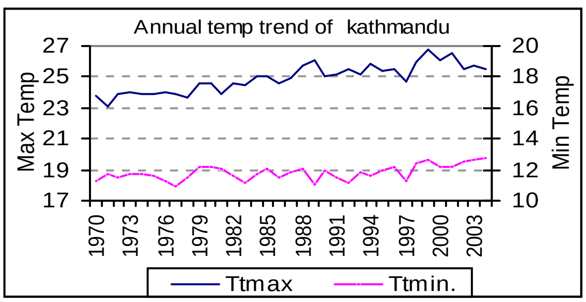


Fig.99 Deviation between max & min of KTM

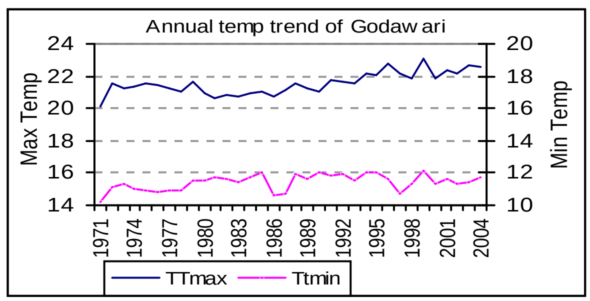


Fig.100 Deviation between Max & Min of Godawari

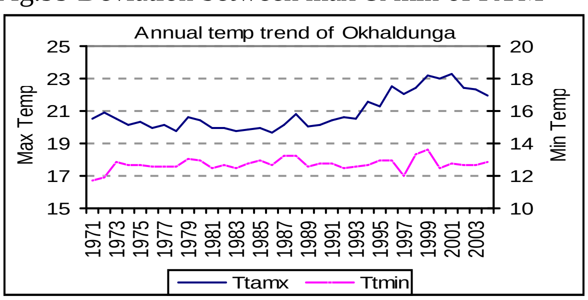


Fig.101 Dev. between max & min of Okhaldhunga

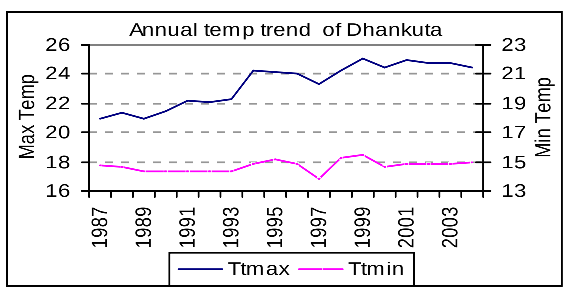


Fig.102 Deviation between max & min of Dhankuta

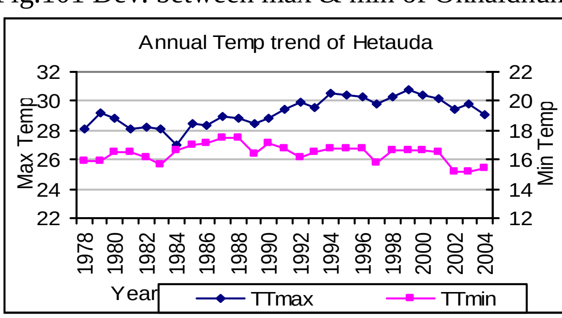


Fig.103 Deviation between max & min of Hetauda

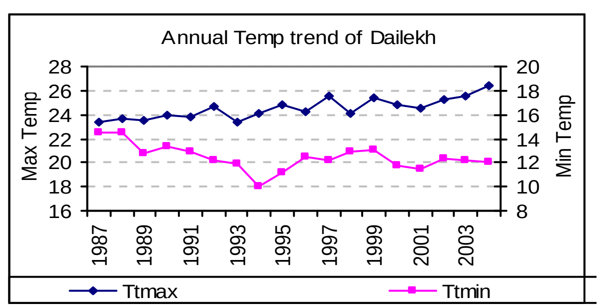


Fig.104 Deviation between max & min of Dailekh

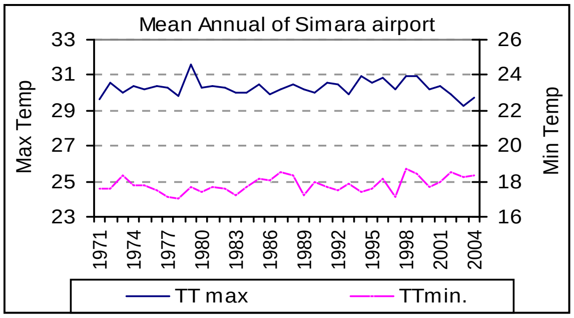


Fig.105 Deviation between max and min of Simara.

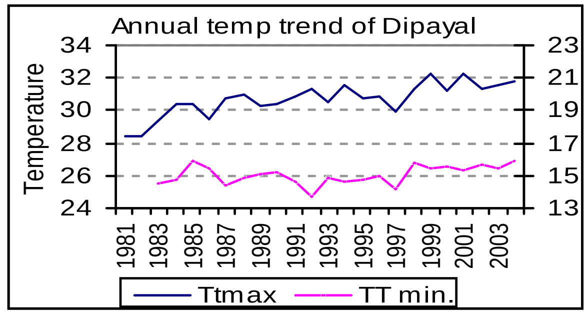


Fig.106 Deviation betw. max & min of Dipayal

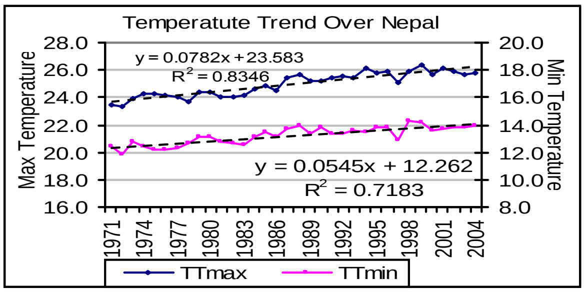


Fig.107A. Annual temp trend over Nepal since 197

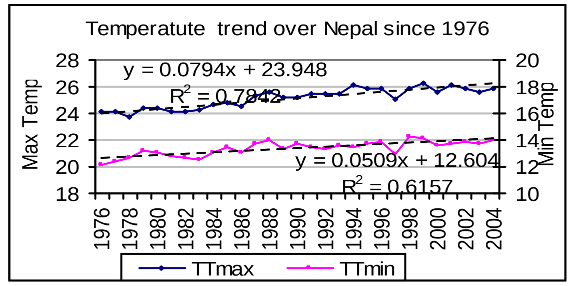


Fig.107B. Nepal Annual temp trend since 1976

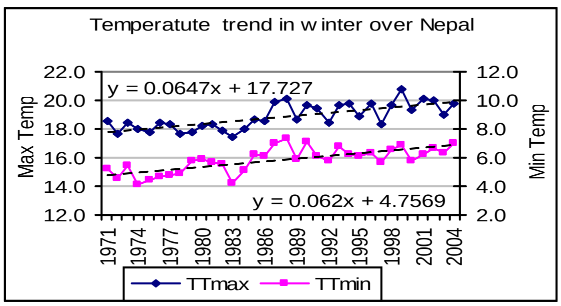


Fig.108A. Annual winter temp trend since 1971

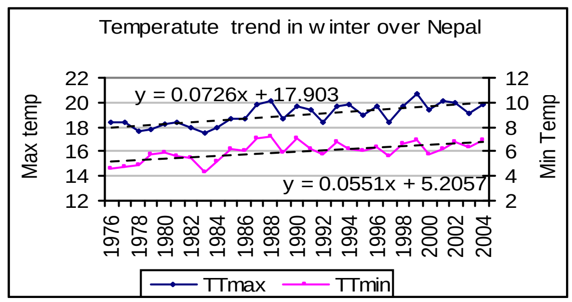


Fig.108B. Annual winter temp trend since 1976

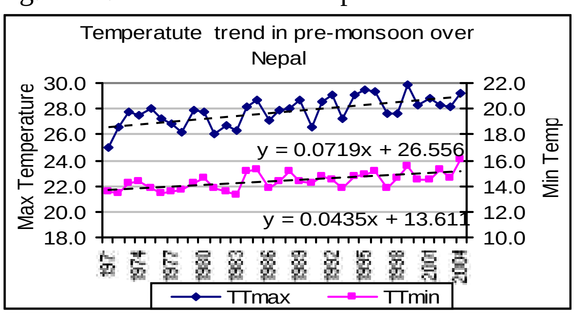


Fig.109A Annual pre-monsoon temp trend since 1971

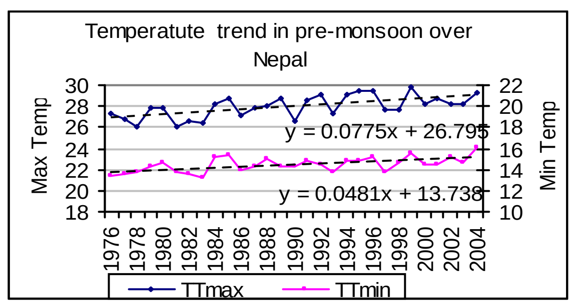


Fig.109B Pre-monsoon temp trend since 1976

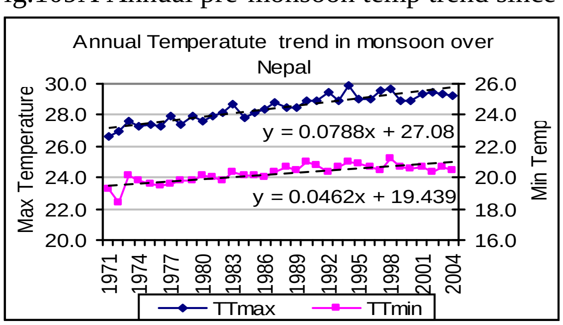


Fig.110A Annual monsoon temp trend since 1971

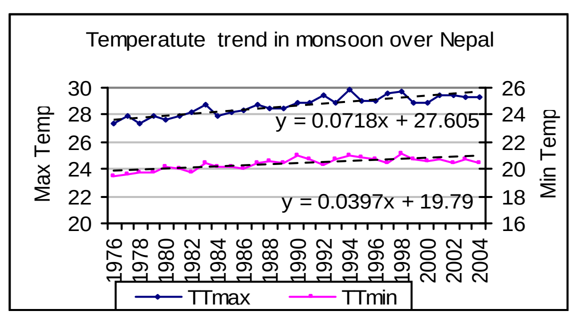


Fig.110B Monsoon temp trend since 1976

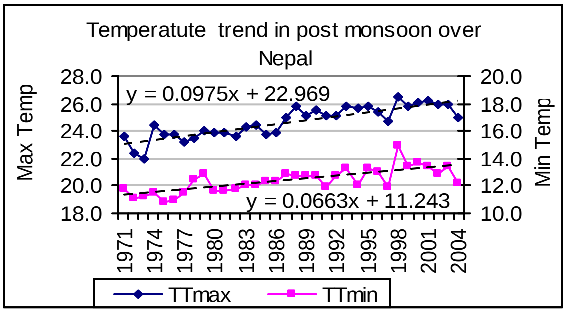


Fig.111A Annual post-mon. temp trend since 1971

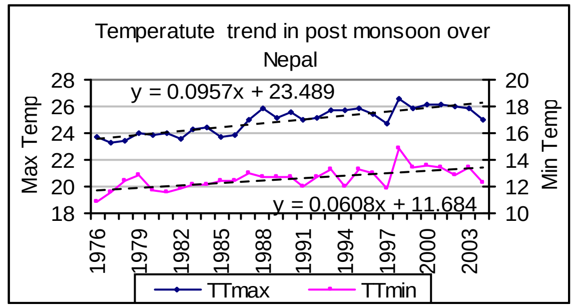


Fig.111B Annual post-mon. temp trend since 1976

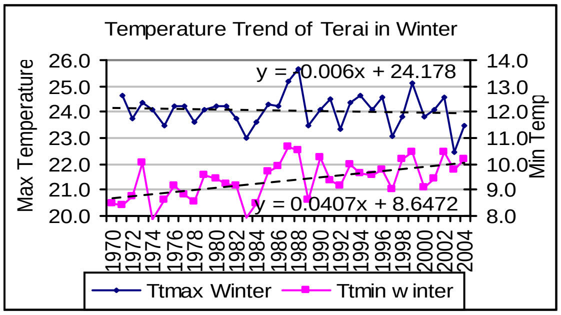


Fig.112A Winter temp trend in Terai

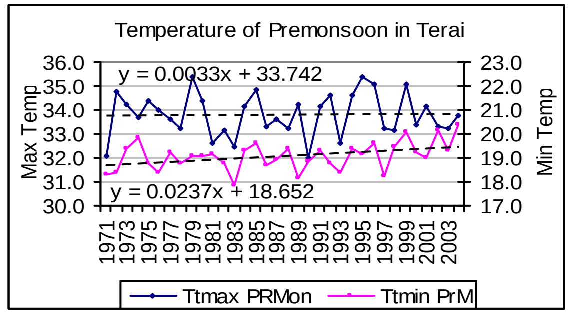


Fig.112B Pre-monsoon temp trend in Terai

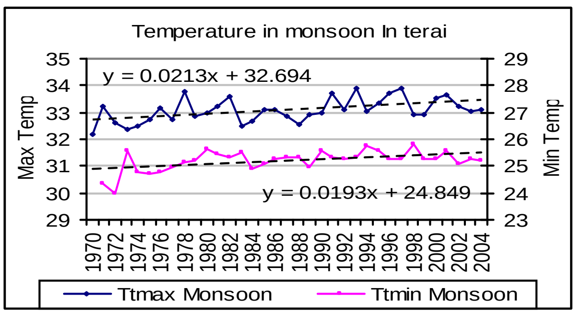


Fig.112C Monsoon temp trend in Terai Region

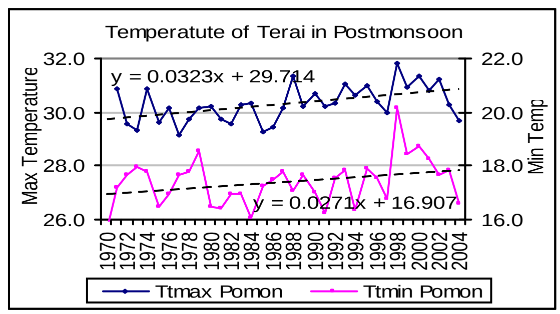


Fig.112D Post-monsoon temp trend in Terai

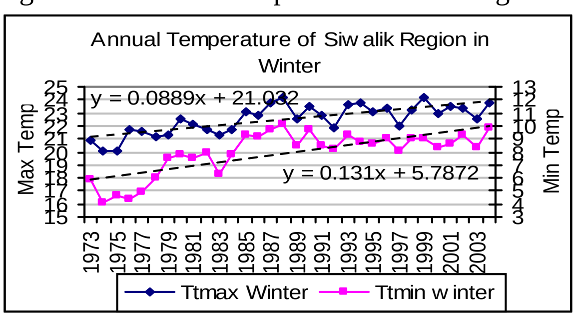


Fig.113A Winter temp trend in Siwalik

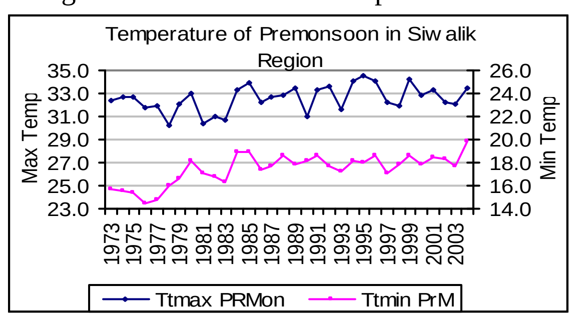


Fig.113B Pre-monsoon temp trend in Siwalik

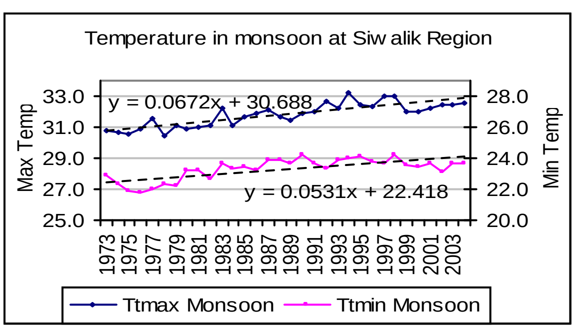


Fig.113C Monsoon temp trend in Siwalik region

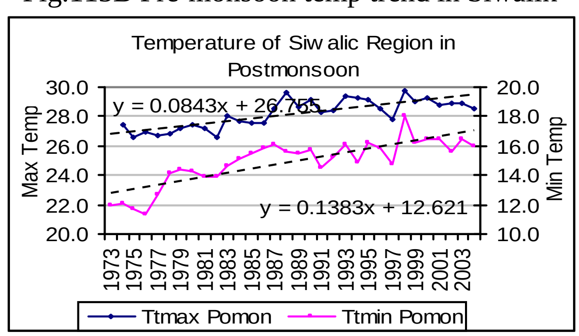


Fig.113D Post-monsoon temp trend in Siwalik

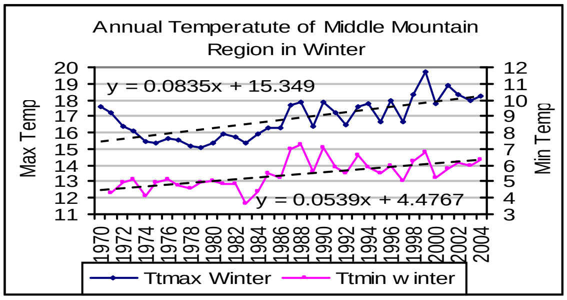


Fig.114A Winter temp trend in MMR

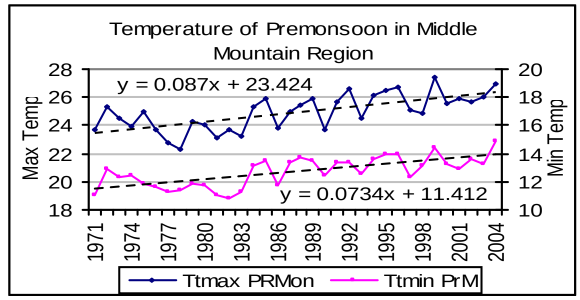


Fig.114B Pre-monsoon temp trend in MMR

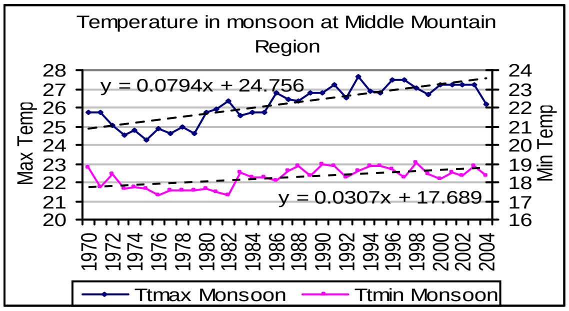


Fig.114C Monsoon temp trend in MMR

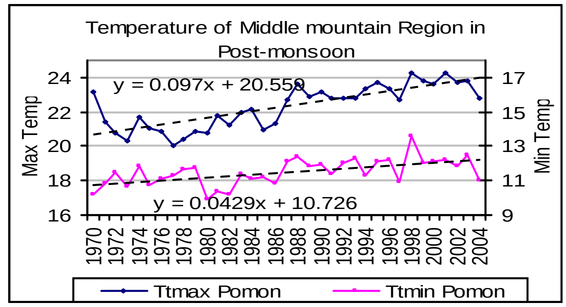


Fig.114D Post-monsoon temp trend in MMR

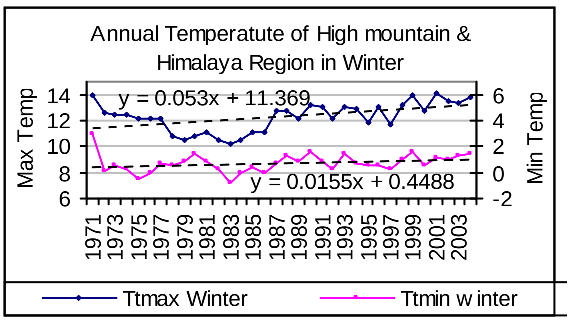


Fig.115A Winter temp trend in HMH. Region

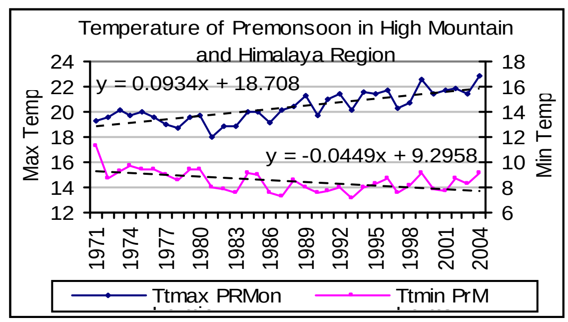


Fig.115B Pre-monsoon temp trend in HMHR

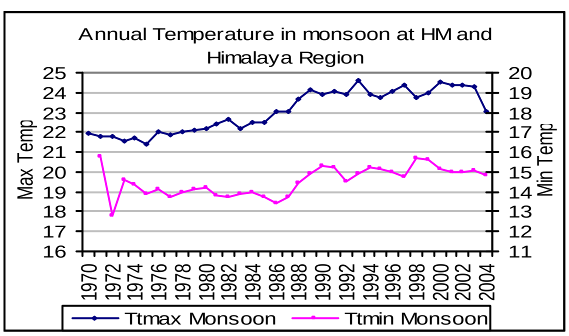


Fig.115C Monsoon temp trend in HMHR

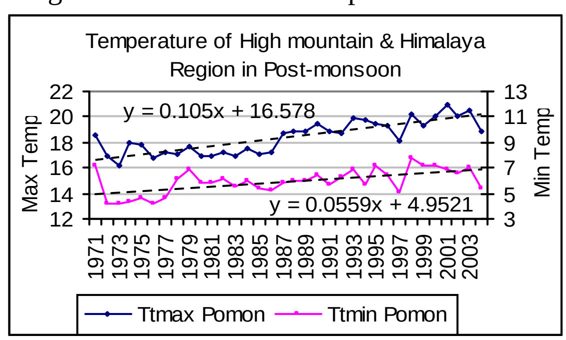


Fig.115D Post-monsoon temp trend in HMHR

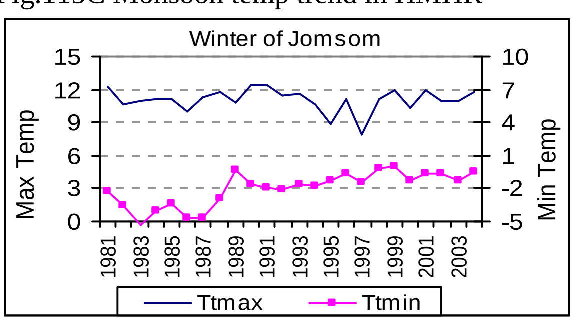


Fig. 116A: Winter Temp trend of Jomsom

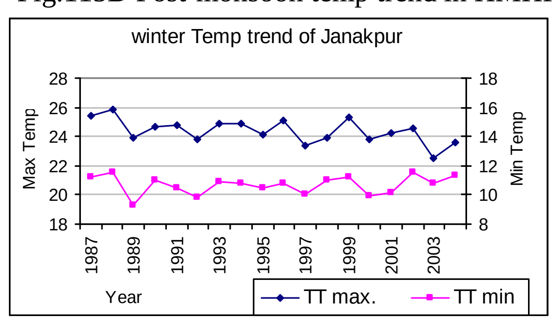


Fig. 116B: Winter Temp trend of Janakpur

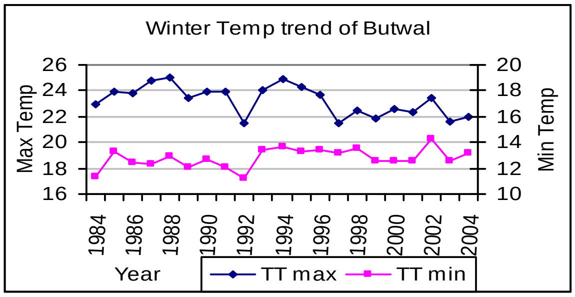


Fig. 116C: Winter Temp trend of Butwal

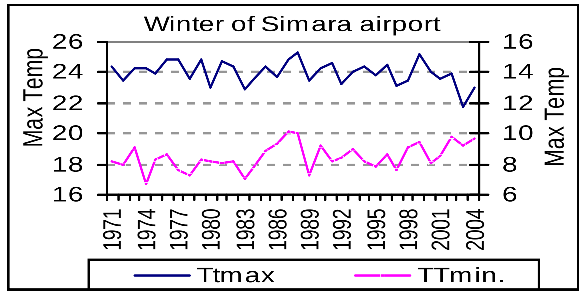


Fig. 116D: Winter Temp trend of Simara

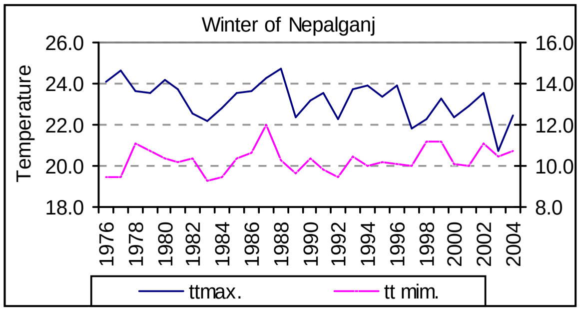


Fig. 116E: Winter Temp trend of Nepalganj

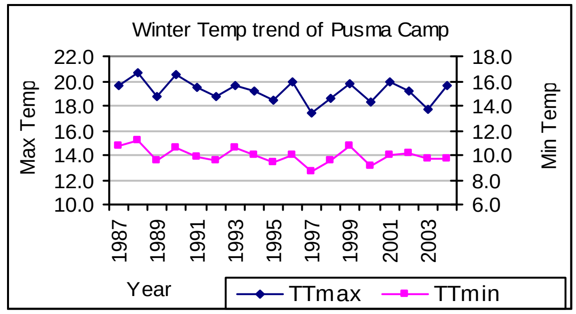


Fig. 117A: Winter Temp trend of Pusma Camp

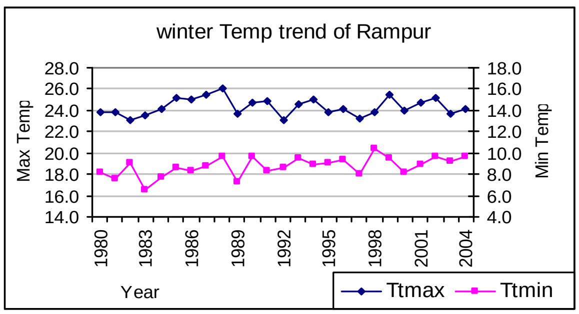


Fig. 117B: Winter Temp trend of Rampur

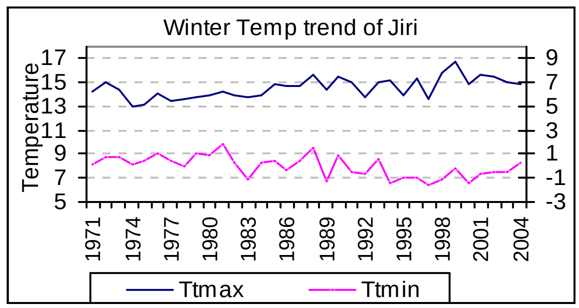


Fig. 118A: Winter Temp trend of Jiri Station

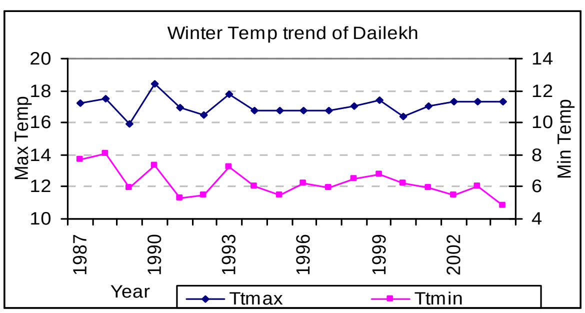


Fig. 118B: Winter Temp trend of Dailekh

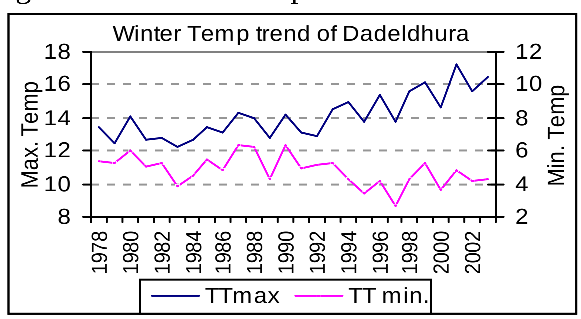


Fig. 118C: Winter Temp trend of Dadeldhura

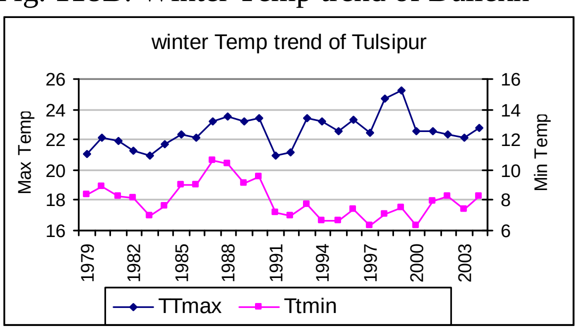


Fig. 118D: Winter Temp trend of Tulsipur

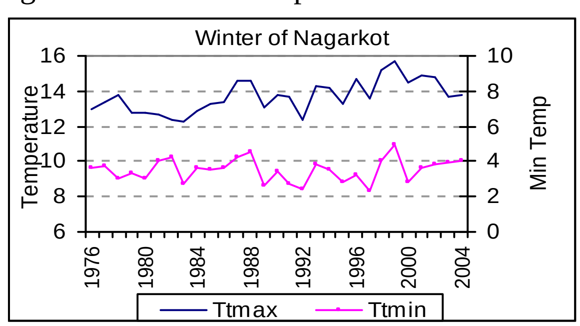


Fig. 118E: Winter Temp trend of Nagarkot

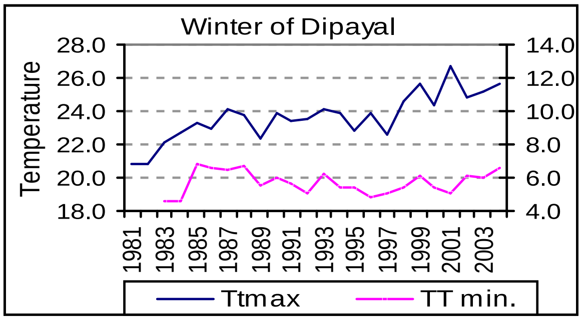


Fig. 118F: Winter Temp trend of Dipayal

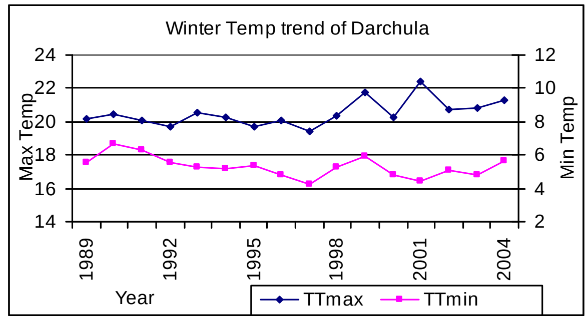


Fig. 118G: Winter Temp trend of Darchula

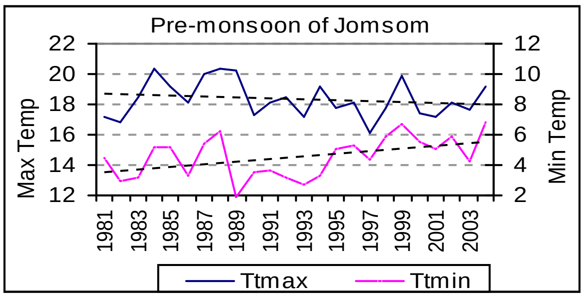


Fig. 119A: Pre-mon. Temp trend of Jomsom

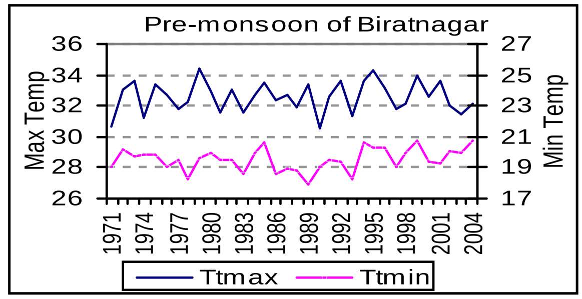


Fig. 119B: Pre-mon. Temp trend of Biratnagar

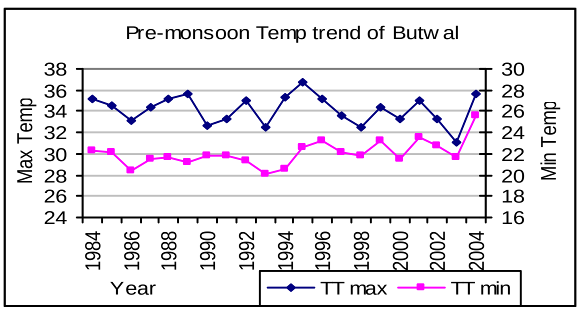


Fig. 119C: Pre-monsoon Temp trend of Butwal

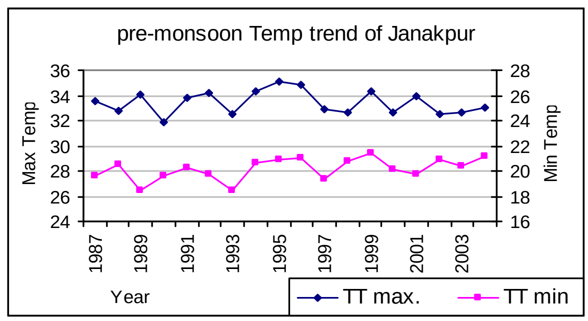


Fig. 119D: Pre-mon. Temp trend of Janakpur

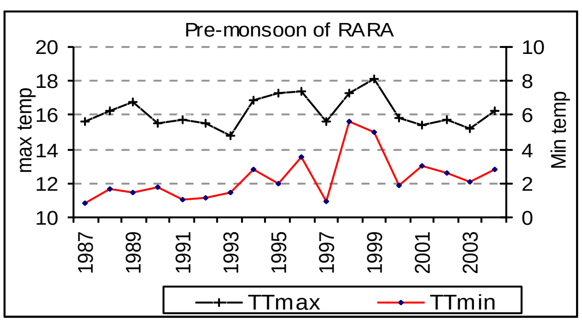


Fig. 119E: Pre-monsoon Temp trend of Rara

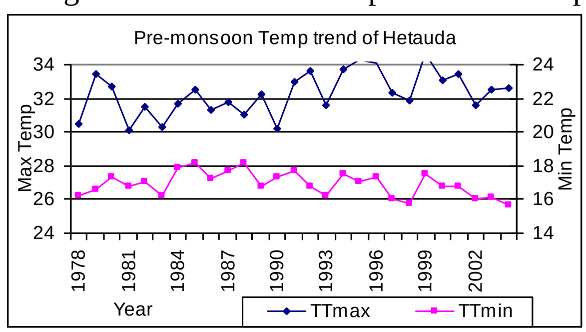


Fig. 120A: Pre-mon. Temp trend of Hetauda

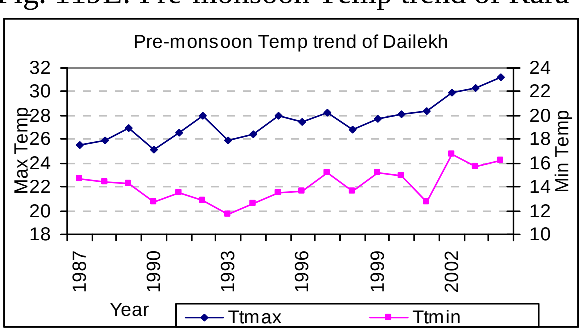


Fig. 120B: Pre-mon. Temp trend of Dailekh

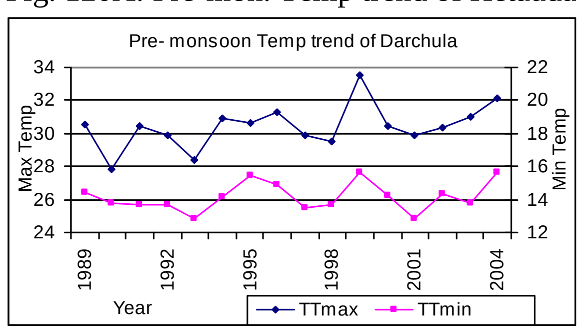
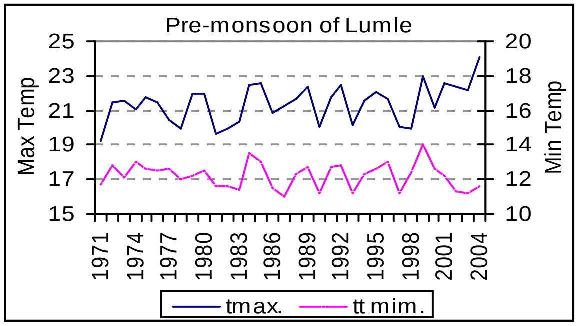


Fig. 120C: Pre-mon. Temp trend of Darchula



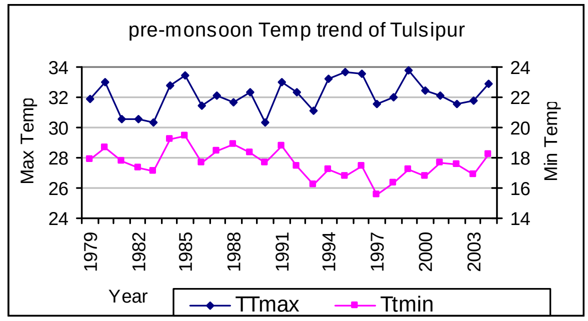
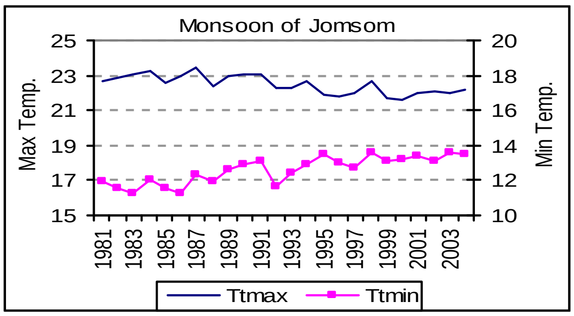


Fig.120D: Pre-monsoon Temp trend of Lumle Fig.120E: Pre-monsoon Temp trend of Tulsipur



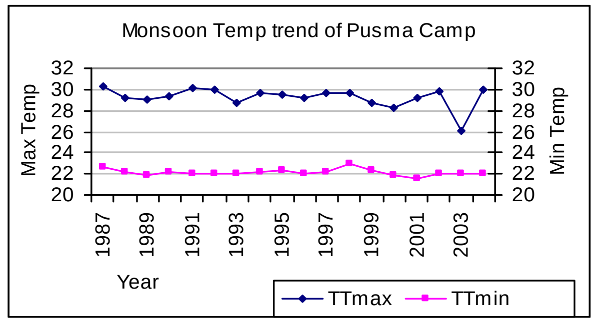
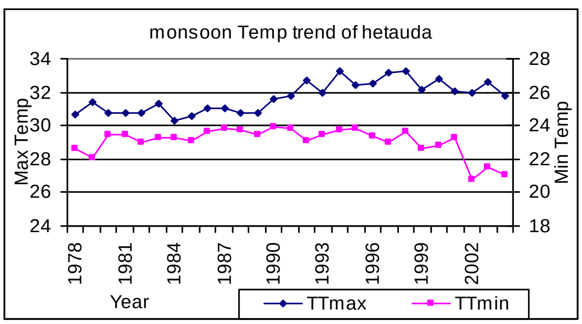


Fig.121A: Monsoon Temp trend of Dailekh Fig.121B: Monsoon Temp trend of Pusma Camp



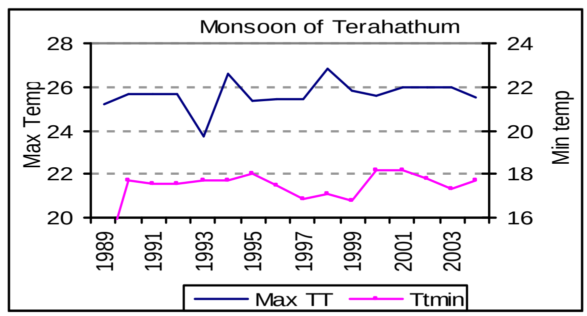
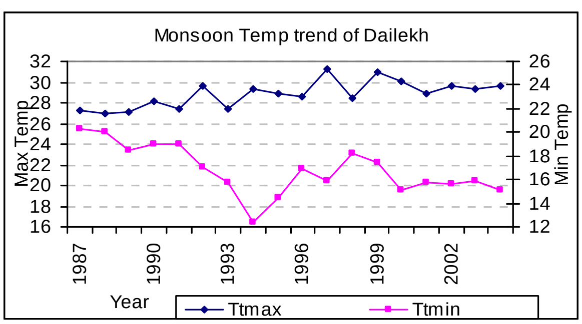


Fig. 122A: Monsoon Temp trend of Hetauda Fig. 122B: Monsoon Temp trend of Terhathum



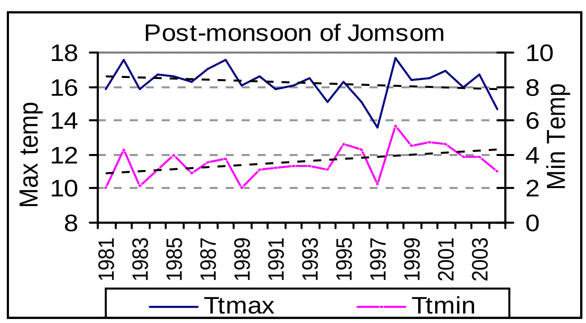


Fig. 122C: Monsoon Temp trend of Hetauda Fig. 123A: Post-monsoon Temp trend of Jomsom

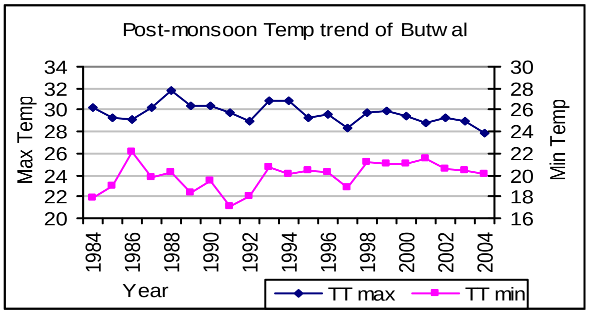


Fig. 123B: Post-monsoon Temp trend of Butwal

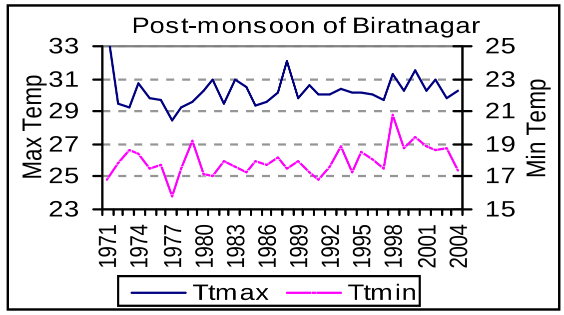


Fig. 123C: Post-monsoon Temp trend of Biratnagar

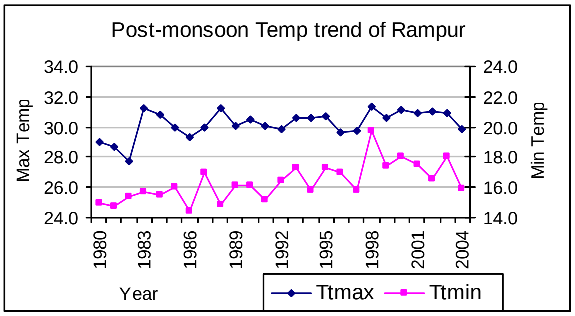


Fig. 123D: Post-monsoon Temp trend of Rampur

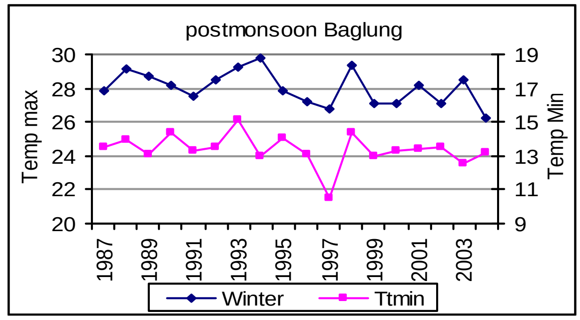


Fig. 123E: Post-monsoon Temp trend of Baglung

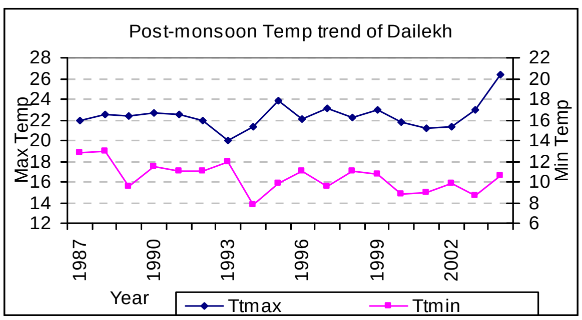


Fig. 124A: Post-monsoon Temp trend of Dailekh

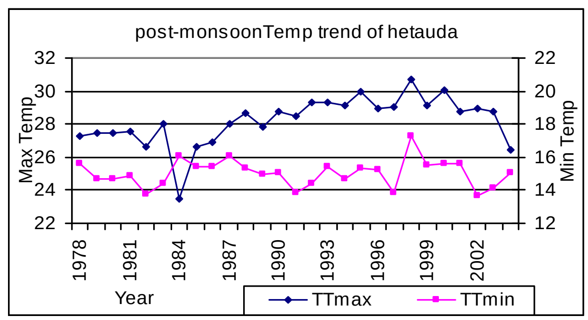


Fig. 124B: Post-monsoon Temp trend of Hetauda

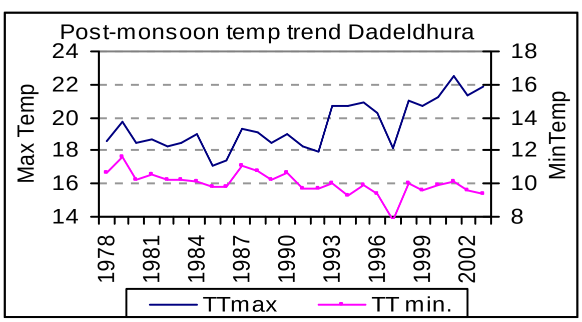


Fig. 124A: Post-monsoon Temp trend of Dadeldhura station

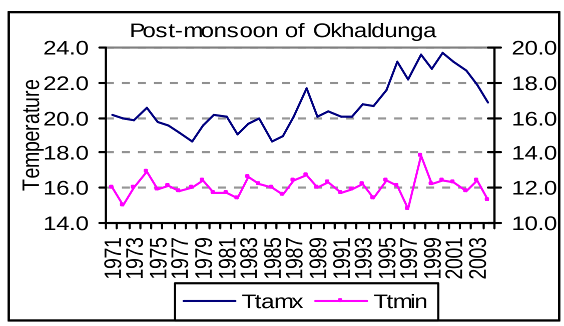


Fig. 124B: Post-monsoon Temp trend of Okhaldhunga station