Asia-Pacific Network for Global Change Research

Development and Application of Climate Extreme Indices and Indicators for Monitoring Trends in Climate Extremes and Their Socio-Economic Impacts in South Asian Countries

Final report for APN project 2005-10-NSY-Sheikh

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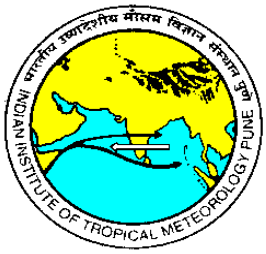

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Final Report submitted to APN

Overview of project work and outcomes

Non-technical summary

The project was implemented in two parts:

i) A one week long APN Regional Workshop on Climate Extreme Indices and Indicators for South Asia was held in Islamabad, Pakistan during the period 2-6 January, 2006. It was organized jointly by GCISC and Pakistan Meteorological department (PMD). Dr. Michael Manton from Bureau of Meteorology Research Centre (BMRC), Australia and Dr. Sultan Hameed from Stony Brook University, U.S.A were the main resource persons. Dr. Manton conducted all the training sessions. Dr. Sixiong Zhao from ICCES, Institute of Atmospheric Physics (IAP), Beijing, China also joined as a Resource Person. Overall 34 participants, 4 from India, 3 each from Bangladesh, Nepal and Sri Lanka and 21 persons from Pakistan joined this activity.

ii) A three day APN Concluding Meeting on Climate Extremes for South Asia region was held in Islamabad, Pakistan during 21-23 August, 2006 to discuss and finalize the work done by each country. Dr. Sultan Hameed was the only resource person as Dr. Michael Manton could not come due to his other engagements. Two delegates from India also could not come due to visa problem. Team Leaders from Bangladesh and Nepal and a representative from Sri Lanka attended the meeting. Country reports were presented by the respective team leaders. The country report from India was presented by the PI of the project. The results were compiled which will be presented in a paper for its publication in an international journal.

Objectives

The main objectives of the project were:

1. to build/enhance the capacity of the participants from Bangladesh, India, Nepal, Pakistan and Sri Lanka.
2. to prepare and archive metadata as a data base for each participating country for use in further studies.
3. to consolidate the results for a publication in an international journal

Amount received for each year supported and number of years supported

One (01) Year: US $ 37,600/-

Participating Countries

A: Developing Countries:

1. **Bangladesh** (Lead Organization, LO: Bangladesh Unnayan Parishad, BUP);
2. **India** (LO: Indian Institute of Tropical Meteorology, IITM);
3. **Nepal** (LO: Department of Hydrology and Meteorology, DHM);
4. **Pakistan** (LO: Global Change Impact Studies Centre, GCISC & Pakistan Meteorological Department, PMD);
5. **Sri Lanka** (LO: Department of Meteorology)

B: Developed Countries and International Organizations:

1. **Australia** (Lead Organization): Bureau of Meteorology Research Centre, BMRC);
2. **U.S.A.** (LO: Stony Brook University, New York).

Work undertaken

The work undertaken is summarized as under:

1. Collection, digitization and preparation of metadata using appropriate software like RClimdex and Rhtest;

2. A week-long APN Regional Workshop on Climate Extreme Indices and Indicators for South Asia in Islamabad during the period 2-6 January, 2006. Scientists from the participating countries developed expertise in the use of softwares like Rclimdex and RHtest for the quality control and homogenization of daily climate data and in the development of trends in climate extreme indices;

3. A 3-Day Concluding Meeting on Climate Extremes for South Asia was held in Islamabad during the period 21-23 August, 2006. The Team Leaders/ representatives from the participating countries developed trends in 19 out of 27 ETCCDM (Expert Team on Climate Change Detection Monitoring and Indices) core indices. These included 11 indices for temperature and 8 indices for precipitation. The list of indices is shown in Table 1.

4. Consolidation of results for international publication. (It is in the process of being completed).The purpose of this paper is to summarize the state of our knowledge of possible future changes in the statistical aspects of weather and climate extremes. (Meehl G.A et al; 2000).

Results

A total of 209 precipitation and 160 temperature stations have yielded trend changes in 19 core climate indices. Both temperature and precipitation indices are generally seen to show rising trends over the South Asia region. Detailed results are elaborated under Section 3.0 (Results and Discussion).

Relevance to APN scientific research framework and objectives

The climate extreme Index (CEI) was first introduced in early 1996 (Karl et al 1996) with the goal of summarizing and presenting a complex set of multivariate and multidimensional climate changes in United states so that the results could be easily understood and used in policy decisions made by non-specialists in the field. This is the first tool developed as a framework for quantifying observed changes in climate extremes. The transfer of knowledge through this project falls well within the domain of APN science Agenda that supports the identification of existing methods and development of new methodologies and tools for improving the effectiveness of user communities. Sound scientific results on the trends in the core climate indices and their linkages with various important climate phenomena worldwide will help greatly in the policy making processes and help the policy-makers adopt the most appropriate adaptation measures.

Self evaluation

The project proved highly useful for the South Asia Region lying in tropics, sub-tropics and partly in temperate regions, which often are subjected to climatic extremes like floods, droughts, tropical cyclone etc. This one-year project greatly enhanced the capacity building of the participating countries in the analysis of climate extremes and strengthened the collaboration among the developing and developed countries and institutions within the South Asia region.

The project is thus evaluated to be of immense use for the region and will open up new vistas for future research helping policy makers for appropriate adaptation measures in the region.

Potential for further work

The results from the concluded project showed that climate extreme indices in some parts of South Asia are highly correlated with natural forcing phenomena like ENSO, NAO etc; while some other climate extreme indices are highly correlated with globally averaged temperatures. This provided a strong motivation to the Team Leaders and Resource Persons to propose to APN a two-year extended investigation based on more stations and on all the 27 core climate extreme indices to study the region in a more comprehensive way.

Publications

A publication on the results collected during the 1-year project is being prepared under the guidance of Dr. Michael Manton, the Resource Person and is expected to be completed within 2-3 months. National Reports prepared by the participating countries are, however, attached.

References

1. Klein Tank et al., 2006; Changes in Daily Temperature and Precipitation Extremes in Central and South Asia; Journal of Geophysical Research, Vol. 111, D16105, 2006.1;

2. L.V. Alexander et al; 2005: Global Observed Changes in daily Climate Extremes of Temperature and Precipitation. British Crown Copyright (Pages 13 of 65)
3. APN Strategic Plan, 2005-2010;

4. Jason L. Bell et al., 2003: Regional Changes in Extreme Climatic Events: A Future Climate Scenario. Journal of Climate, American Meteorological Society 17: 81-87 (2004);

5. Brunetti M. et al., 2001: Droughts and Extreme Events in Regional Daily Italian Precipitation Series, Int. J. Climatol. 22: 543-558 (2002);

Acknowledgments

Global Change Impact Studies Centre, Islamabad jointly with Pakistan Meteorological Department greatly acknowledge the Asia Pacific Network (APN) for Global Change Research for its generously awarded funding for the project. The Resource persons Dr. Michael Manton from BMRC, Australia and Dr. Sultan Hameed, Professor, Stony Brook University, USA deserve our full appreciation for

making their best contributions for the project in transferring their expertise to the south Asia region. The Team Leaders and the other scientists from the participating countries also deserve our acknowledgement for their wholehearted efforts in making this project a success. The role of Meteorological Organizations in the participating countries is also acknowledged for their support in providing the digitized daily climate data.

Technical Report

Preface

Under the one-year project: “Development and Application of Climate Extreme Indices and Indicators for Monitoring Trends in Climate Extremes and Their Socio-economic Impacts in South Asian Countries” (APN-10-NSY) awarded by APN, Japan, trends in extreme daily temperatures and rainfall have been analyzed using 1971-2000 as the base period for 209 precipitation and 160 temperature stations over the five South Asian countries comprising Bangladesh, India, Nepal, Pakistan and Sri Lanka. The raw daily temperature and precipitation data for the whole period is passed through extensive quality control and homogeneity testing and then using this high quality data, trends in climate extremes are calculated using 19 core indices, 11 for temperature and 8 for precipitation. Results are drawn on country basis as well as on regional basis.

Table of Contents

1.0 Introduction

The project falls under the APN Theme: “Climate Change and Variability”. The climate extreme events are related to the climatic variations whether natural or human induced which alter the frequencies, intensities and locations of extreme events. Any change in them would have profound impacts on socio-economic sectors and can jeopardize the development goals related to water resources, agriculture, biodiversity and human health etc. The project was thus a need for the South Asia region and was jointly initiated by GCISC and PMD in line with the project already completed for SEA/TEA and Oceania region by the Bureau of Meteorology Research Centre, Australia. The project has two broad objectives, first the building/enhancing the capacity of South Asian Countries in the area of climate extreme indices and indicators and their socio-economic impacts and second to promote the application of climate trend indicators for government policy developments.

2.0 Methodology

2.1 Project Aims

Extreme weather and climate extremes have received attention in the last few years, due to the often large loss of human life and increasing costs associated with them.(Karl and Easterling, 1999).These can have major impacts on society, the economy and the environment (Manton M.J. et al. 2001). The purpose of this APN project (APN2005-10-NSY) is to get a set of indices and indicators to monitor the trend of climate extremes over the South Asia region and to help the individual participating countries to (i) assess the expected corresponding changes on water resources, agricultural production, biodiversity, human health etc. and (ii) prepare a set of recommendations for appropriate adaptation measures. This information is a prerequisite requirement to add to the understanding of the national policy makers in the region to develop appropriate strategies leading towards the mitigation of adverse impacts of climate extremes.

2.2 Selection Criteria for the Meteorological stations used for the Project

The selection of meteorological stations picked up for study for each region was based upon the following criteria:

i. High quality time series data of key climate variables (daily rainfall totals and maximum and minimum temperature) are available with the guidelines that the records are as long as possible and include preferably the standard reference period of 1961-1990; not more than 20% of the values are missing in each year; the stations are of high quality, preferably non-urban stations and well maintained; the station, in most cases, has a documented history of changes such as those involving instrumentation and observational practices etc. and the station preferably has been located at a single site during the period of record.

ii. The stations give coverage to the whole country;

iii. The different climatic zones get due representation.

The details of the Meteorological Stations used for different countries and the climate zones in each country are discussed below alphabetically:

2.2.1 Bangladesh

2.2.1.1 A Brief Description of Climate Zones

Bangladesh is heavily influenced by monsoon circulation. It receives sufficiently high rainfall during the five peak monsoon months, starting from June and ending in mid-October. The remainder of the year receives only less than 20% of all available rainfall. In general terms, the western parts of Bangladesh are found to be drier than the eastern parts. Rajshahi (station ID 41895), located in central western Bangladesh, receives only about 30% rainfall compared to that of Sylhet in the north-eastern Bangladesh (station ID 41891). From the perspective of rainfall, the country may easily be divided into two regions: wet region (on the eastern side, touching the tip of the north-western part), and the dry region (central and western parts of the country). Fig.1 shows the wet and dry regions in Bangladesh.

2.2.1.2 Data Availability / Quality

Data of well distributed nine stations were used for the study. Table-2 shows the names of the stations along with their coordinates. Map showing these stations is also attached as Fig. 2. Out of the nine stations considered for the study, only two fall within the demarcated area of wet region (i.e. Cox's Bazar and Sylhet), while the station Barisal falls on the fringe of the wet region, and the remaining six stations fall within the dry region. There are only a few stations in the wetter climate zone of the country, whereas the coverage of meteorological stations in the drier climate zone is much higher. Generally, Rainfall, Tmax and Tmin data are available for all the stations for the period 1961-2000, with an exception of Rajshahi where data are available for the period 1964-2000. There are large number of data found missing in the datasets, which is why the model could not analyze indices such as TX10p, TX90p, TN10p, TN90p, WSDI, and CSDI. Dummy data shows data gaps in temperature for a unified baseline (1971-2000).

In the process of preparing datasets (for each individual station) for the model RClimDex, outlier data have been identified by using 5 and 3 (sigma) SD levels. A large number of suspect data for Tmax and Tmin have thus been identified for each of the nine stations. The obvious ones are immediately sorted out as per instructions provided in the manual of ClimDex (for example, when Tmin was found greater than or equal to Tmax, the data were replaced by default -99.9). A record of all such suspect data has been maintained for future reference and potential data checking with the Bangladesh Meteorological Department (BMD). The corrective measures, of course, resulted in adding up to the tally of missing data, which is why a number of temperature related indices could not be estimated.

The other problem was poor homogeneities in the available datasets, even after considering corrective measures. Due to having large number of missing data (even at times, data could not be made available for one or two years in a row), data in most of the stations have been found having poor homogeneity.

In course of the current study, it was not possible to check the entire suspect data from the metadata sets kept at the BMD. There were two basic reasons for that:

(a) paucity of time and means, and (b) non-cooperation of BMD to allow the Research Team to physically check the metadata sets. It is expected that, in future an official attempt will be made to examine the suspect data at their sources (in metadata sheets of BMD) and due corrections will be facilitated in the computerized climate datasets.

2.2.2 India

2.2.2.1 Homogeneous zones for precipitation

The homogeneous zones for precipitation have been delineated based on the data for 306 uniformly distributed stations for which monthly rainfall data are available from 1871. Indian mainland can be divided into five homogeneous regions as far as precipitation is concerned: 1) Northwest India, 2) Central Northeast India, 3) Northeast India, 4) West Central India, and 5) Peninsular India (Fig. 3). The hilly regions consisting of four meteorological subdivisions of India lying parallel to Himalayan mountain range have not been considered in view of the meager rain-gauge network and low aerial representation of a rain-gauge in a hilly area. Two island subdivisions far away from mainland have also not been included. The contiguous area having network of 306 stations over 30 meteorological subdivisions measures about 2,880,000 sq. km., which is about 90 percent of the total area of the country.

2.2.2.2 Homogeneous zones for temperature

The homogeneous regions for surface air temperature have been delineated based on their distinct climatic and geographical settings. These are (Fig. 4): Western Himalaya (WH), Northwest (NW), North Central (NC), Northeast (NE), West Coast (WC), East Coast (EC) and Interior Peninsula (IP).

(Other details are available under IITM web site: www.tropmet.res.in)

2.2.2.3 Data Details

All the data for the precipitation, maximum temperature and minimum temperature data mentioned in the report are originally sourced from the Monthly Weather Reports, Indian Daily Weather Reports and All India Daily Weather Summaries published routinely by the India Meteorological Department (IMD). A well-distributed network of 146 stations has been selected for precipitation data for the analysis of extremes. Fig. 5 shows the locations of the stations for precipitation data, for details of the stations, Table 3 is referred to. For temperature data, though the network is slightly less dense, it may be adequate for the present purpose, keeping in view the relatively greater spatial representativeness of the stations for air temperature. Fig. 6 show locations of the stations used for maximum and minimum temperature data. Exact locations, altitude and other details are given in Table 4

2.2.2.4 Data Availability and Quality

Preliminary analysis was done with the network of 40 stations for precipitation as well as minimum and maximum temperatures over the Indian region. To avoid the mis-interpretations due to data gaps, an attempt is made to fill up the gaps and also to improve the density of the network further. Now, minimum and maximum temperature data are available for the 121 well-distributed stations over the Indian

mainland as shown in Fig. 5 for the period 1970-2000. All the data are checked as per the guidance of the Rclimdex manuals. No station is found doubtful in any regard. There are no data gaps in the above-mentioned period.

Precipitation data are now available for the 200 stations over the Indian region (source Indian Daily Weather Report by India Meteorological Department). Out of these, 54 stations have long data gaps and hence are not considered for further analysis. Thus, only 146 well distributed stations over the Indian region (Fig. 6) for the period 1951-2000 form the basis for the present study. Some of these stations may have some small-data gaps which may not have a significant impact on the analysis and interpretation.

All the data sets are checked for the homogeneity and quality control for the outliers, Tmax < Tmin, sudden jumps in the series, and repeated values. Exploratory data analysis is done for each station individually which allowed identification of some outliers and gave an indication of potential homogeneities and missing values in the data sets. Some of the major gaps are removed with possible alternate data sources and also some unreasonable outliers reported by the RClimDex are checked with available documentations on the meteorological data to decide on their inclusion in the study. Preliminary run of RClimDex is made to all stations to generate climate extreme indices. All extreme indices are checked for unexpected extreme values if any, and the values are rechecked with available data documentation.

2.2.3 Nepal

2.2.3.1 Brief Description of Climate Zones

Nepal lying in the southern flank of the Himalaya is affected profoundly by the monsoonal circulation of South Asia. Though small in size, it has a complex topography with altitude ranging from almost sea level in the south to the highest place on the earth (Mt. Everest) to the north. This large north-south variation of topography gives rise to different climatic regions. The southern plain (called Tarai) region of the country has a tropical climate and as we go to north, the climate is dominated by alpine type. The Himalaya plays very important role in the monsoonal circulation. The physiography of the country is depicted in Fig. 7.

2.2.3.2 Data Availability/Quality

Looking at the quality and the continuous records of the available datasets, 6 stations are considered for the temperature and 27 for the precipitation. The details of the stations used for the computation of the temperature and precipitation indices are presented in Tables 5 and 6 respectively. The network of temperature stations is also shown in Fig. 7 and the precipitation network is depicted in Fig. 8. The main part of this study is to perform the test of data for the homogeneity and it is important to undertake this task to be confident to have a good dataset. The data have been checked for the outliers, the sudden jumps in the series and others. The software RClimDex has the capability to identify these aspects. Since the main topic of this research is to look at the extreme events, it is often true that the outliers may be the one we are looking at. The validation of the results given by the software has to be scrutinized carefully so that a proper identification of the extreme can be made.

It is agreed upon that the minimum segment to be considered is 10, however some tests were performed for the consideration of the segment. At station 0101 (Figs. 9a & 9b) for example, the cases for different segment lengths were considered and in case of the homogeneous data it does not show much difference. And since there are no jumps found, the series is considered to be the good one. In the other sample case, the station 0205 (Figs. 10a & 10b) exhibit differently. There is a sudden jump and the F-test shows that the jumps are significant and looking at the stations data more carefully; this type of data is rejected.

2.2.4 Pakistan

2.2.4.1 Location of Pakistan and its Climatic Zones

Pakistan is a country in South Asia and is located approximately within the latitudes 24° N to 37° N and longitudes 61°E to 76°E. It is bordered on the west by Iran, on the west and northwest by Afghanistan, on the north and northeast by China, on the east and southeast by India, and on the south by the Arabian Sea. The country has an area of 796,095 sq. km or 307, 375 sq. miles. Physically, it is the vast valley of mighty Indus River and its tributaries, running through the whole country as its bloodlines. Northern Pakistan inherits one of the highest lands of the world. The three great mountain ranges: Hiamalayas, Karakorams and the Hindukush meet in a very complex system of mountains, separated by narrow gorges of the rivers. Map showing the meteorological sites with orographic details is shown in Fig. 11 and in Table 7 with their WMO numbers and other details.

2.2.4.2 Climatic Zones of Pakistan

Six climatic zones covering the whole of Pakistan starting from Arabian Sea in the extreme south to the Himalayan mountains in the extreme north are shown in Table 8 and in Fig. 12

2.2.4.3 Data used

Daily data of 17 meteorological stations are used for the study. The stations were picked in such a way that it gave coverage to all the zones (Table 8). Adequate coverage could not be provided because of the non-availability of digitized data of other around 36 stations. The data were passed through extensive quality control and homogeneity testing and the gaps due to missing values were filled in to the extent possible. For that the original data available in the archives of Pakistan Meteorological Department at Lahore and Islamabad were physically checked and all the anomalies sorted out by the software were reconciled to the extent possible. In this regard neighbouring stations were also seen for comparing the data. The data used for this report is homogeneous and missing values are mostly within the permissible limits. Table 8 shows the percentage of missing values in the data of all the stations.

2.2.5 Sri Lanka

Map of Sri Lanka with orography and the meteorological stations used for analysis is shown in Fig. 13.

2.2.5.1 Climatic Zones of Sri Lanka

The three climatic zones based on the rainfall distribution in the country are shown in Figure 14

2.2.5.2 Data Used for the study

11 stations were selected for this study representing all three climatic zones as mentioned above are shown in Tables 9 (a, b, c). For the Precipitation analysis 1961-2000 data were used and for the Temperature analysis, 1971-2000 data were used. Percentage of missing data is given in Table 10

2.3 First Major Activity under the Project

This was undertaken at Islamabad during the period 2-6 January, 2006 where, besides the project related introductory presentations by the Resource persons and other scientists, the scientists from the participating countries were trained in the quality control and homogenization of climate data, introduction to the core climate indices and the trend analysis of climate extreme indices. The participants made the preliminary runs for all the stations and generated climate extreme indices. The participating countries, on return to their respective countries, checked the extreme indices for unexpected extreme values, if any, and rechecked them with the available documented data.

2.4 Concluding Meeting of the Team Leaders/Representatives

The Team Leaders/ Country Representatives, using the RClimdex software, applied the trend analysis to the individual stations and calculated the trend changes in the climate extremes, 11 for temperature and 8 for precipitation. These are shown in Table 11.

Table 11

Trend Changes in Climate Extreme Indices in South Asian Countries

S. No.	Indices	Bangladesh		India		Nepal		Pakistan		Sri Lanka	
		+	-	+	-	+	-	+	-	+	-
1	TXx	6	3	91	30	5	1	13	4	5	2
2	TXn	*5	4	63	58	3	3	9	7	*7	0
3	TNx	*3	6	66	55	5	1	*3	14	6	1
4	TNn	5	3	76	45	5	1	13	4	7	0
5	TN10p	NA	NA	24	97	0	6	6	11	0	7
6	TX10p	NA	NA	26	95	1	5	6	11	1	6
7	TN90p	NA	NA	78	43	6	0	13	4	7	0
8	TX90p	NA	NA	81	40	5	1	13	4	5	2
9	WSDI	NA	NA	77	33	5	1	*9	8	6	1
10	CSDI	NA	NA	33	88	1	5	6	11	0	7
11	DTR	*6	3	53	68	3	3	7	9	3	4
12	RX1day	*3	6	91	48	15	12	10	6	5	6
13	RX5day	6	3	87	52	18	9	12	5	*5	6
14	SDII	5	4	61	78	15	12	8	9	*9	1
15	CDD	2	7	51	88	3	24	8	9	*10	1
16	CWD	*6	3	51	88	*15	11	*12	6	3	8
17	R95p	*3	6	92	47	20	7	11	6	*3	8
18	R99p	4	5	90	49	*15	12	*11	6	4	7
19	PRCPTOT	8	1	80	59	24	3	13	4	*2	9

In addition to the above, Pakistan developed two additional indices, one for the 24-hour heaviest precipitation during 24 hours and the other for the highest daily temperature over the 40-year period (1961-2000). The stations recording these extremes were checked for their frequency and intensity with regard to the base period of 1961-1990 during different decades and their linkage to global warming was studied. The results are shown in Tables 12 and 13

3.0 Results and Discussions

Results drawn from the national reports of participating countries are discussed below:

3.1 Bangladesh

3.1.1 Temperature Indices

The summary results for temperature extreme indices are shown in Table 14a. Findings are summarized below:

i. The results pertain only to the 5 temperature indices: TXx, TXn, TNx, THn and DTR as no adequate temperature data was available;

ii. TXx, the monthly maximum value of daily maximum temperature i.e. the monthly maximum highest temperature is seen positive at six out of nine stations. TNn, the monthly minimum value of daily minimum temperatures i.e. the coldest night temperatures show no significant trend;

iii. Trend changes for TXx are higher than TNn showing higher diurnal temperature range at more stations;

iv. Inadequate number of stations used for the project does not offer a systematic and a clear picture of the country.

3.1.2 Rainfall Indices

The summary results for rainfall indices are shown in Tables 14b & 14c. Findings are summarized below:

i. The total rainfall is on the rise at all stations except at Barisal, a central coastal station;

ii. R10mm and R20mm are seen to have increased at all the stations whereas R50mm has also increased at 6 out of 9 stations. 5 day heaviest rainfall (RX5day) has also increased;

iii. Heavy and very heavy rain-spells (R95p and R99p) show a decreasing trend;

iv. Consecutive Dry Days (CDD) have decreased at more stations whereas the consecutive Wet Days (CWD) have increased.

3.2 India

11 Temperature and 11 precipitation extreme indices are calculated for India. These are separately discussed:

3.2.1 Temperature Extremes

121 stations have been used for analysis with 1971-2000 as the base period. Trend analysis is applied to individual stations and is presented in Table 15a. The findings are summarized as under:

i. Extreme analyses over the region show increase in occurrence of warm extremes and decrease in occurrence of cold extremes;

ii. There is a decrease in cold spell durations and an increase in warm spell durations. Magnitude of decrease in cold spell duration is greater than that of warm spell duration;

iii. Highest maximum temperature and coldest minimum temperature are seen to have increased over the region;

iv. Cool days and cool nights are seen to have decreased whereas warm days and warm nights have significantly increased.

3.2.2 Precipitation Extremes

146 rainfall stations have been used for analysis with the same base period as used for temperature. The trend changes are shown in Table 15b. The findings are summarized as under:

i. In general there is increase in precipitation activities in terms of their extremes through all indices;

ii. Results are consistent with the global analysis done by Alexander et al. (JGR, March 2006), and south and central Asia by Albert Tank et al; (JGR, August 2006) and are wide spread over the country;

iii. El-Nino/La-Nina events are shown to have impact on monthly temperature extremes over India, in terms of their frequencies as well as intensities.

3.3 Nepal

Temperature indices have been calculated using only 6 stations whereas precipitation indices are with 27 stations. These are discussed separately as under:

3.3.1 Temperature Indices

Trend changes in temperature indices are shown in Table 16a. The findings are summarized below:

i. TXx, the monthly maximum value of daily maximum temperature is positive over 5 out of 6 stations. TNn, the monthly minimum value of daily minimum temperature also shows a similar trend;

ii. The cool days and cool nights have decreased whereas the warm nights and warm days have increased. Both the trends are quite significant;

iii. Warm spell duration indicator (WSDI) shows a positive trend. This as well as other trend values complement each other showing also the good quality of data.

3.3.2 Precipitation Indices

Trend changes in precipitation indices are shown in Table 16b. The findings are summarized below:

i. Maximum one day precipitation amount (RX1) does not show a significant positive trend whereas it is quite significant in case of Maximum 5 day precipitation trend where it shows positive trend in 18 out of 27 stations;

ii. Consecutive dry days have significantly decreased where 24 stations indicate a negative trend;

ii. Very wet days as depicted by R95p have significantly increased whereas the extremely wet days do not have a very significant positive trend;

iv. Over all, the precipitation indices indicate that there is an increasing tendency of precipitation in Nepal.

3.4 Pakistan

17 meteorological stations have been used for the calculation of both temperature and precipitation indices. In all 19 indices, 11 for temperature and 8 for precipitation have been calculated. Annual mean maximum and minimum temperatures are also analyzed. These are discussed separately:

3.4.1 Temperature Indices

The trend changes are shown in Table 17a. The findings are summarized below:

i. TXx, the monthly maximum value of daily maximum temperature has increased except in the monsoon dominated region (Islamabad, Jhelum and Lahore) and at Hyderabad in the Lower Indus Plains;

ii. TXn, the monthly minimum value of daily maximum temperature has increased at most of the stations. Decreasing trend is seen at 4 stations in the Upper Indus Plains and at 2 in the Western Highlands;

iii. TNx, the monthly maximum value of daily minimum temperature has shows a decreasing trend at most of the stations except at Faisalabad, Jhelum and Karachi;

iv. TNn, the monthly minimum value of daily minimum temperature has decreased at more than 75 % of stations;

v. Warm days have increased compared to the cool days and warm nights have increased as compared to the cool nights;

vi. In the case of very wet and extremely wet days, Greater Himalayan region (except Gilgit) and monsoon dominated region show increasing trend. Other parts generally show decreasing trend;

vii. Warm days have increased compared to the cool days and warm nights have increased compared to the cool nights;

viii. Diurnal Temperature Range (DTR) shows a positive trend in the Greater Himalayan region whereas it is negative in the monsoon dominated region;

ix. Annual mean maximum temperature is seen to have increased at 12 stations and decreased at 5 stations. The decrease is mostly seen in the monsoon dominated region. Annual mean minimum temperature has increased at more stations but it has decreased in Greater Himalayan region. No significant trend is seen at other places.

3.4.2 Trends in Precipitation Indices

Based on the base period of 1961-2000, these are summarized in Tables 17 b. Findings are discussed as under:

i. Rx1 day and Rx5 day both show increasing trend in the Himalayan Mountains including Greater Himalayas and the sub-montane regions. Lower Indus plains also show increasing trend. The remaining stations show a decreasing trend;

ii. Very wet and extremely wet days show increasing trend in Greater Himalayan region (except Gilgit) and monsoon dominated region. Other parts generally show a decreasing trend;

iii. Annual total wet day precipitation (PRCPTOT) has shown an increasing trend at 13 stations compared to the 4 stations.

3.5 Sri Lanka

Temperature and precipitation indices are separately discussed below and are shown in Tables 18a & 18b:

3.5.1 Temperature Indices

There is an increasing trend in Maximum temperature (TXx) at all the stations, except Ratnapura, which is in Wet zone and also there is no trend in Nuwara Eliya. Increasing trend for Minimum Temperature (TNn) is seen at all the stations. There is an increasing trend in all the stations for both the minimum of maximum (TXn) and maximum of minimum (TNx). Decreasing trend for Cool days is seen at all the stations except Ratnapura. There is an increasing trend in Warm days except at Ratnapura and Nuwaraeliya. Decreasing trend in Cool nights is observed all the stations. Increasing trend in Warm nights is seen at all the stations.

Summary for the temperature Indices

i. Maximum Temperature is increasing
ii. Minimum temperature is increasing
iii. Cool days are seen decreasing
iv. Warm days are increasing
v. Cool nights are decreasing
vi. Warm nights are found increasing

vii. Cold spell duration indicator is decreasing

viii. Warm spell duration indicator is increasing

ix. No significant change is found in diurnal temperature range

x. There is an increasing trend in both the minimum of maximum and maximum of minimum temperature

3.5.2 Precipitation Indices

There is a decreasing trend in annual total precipitation especially in the dry zone and intermediate zone. Very wet days and the extremely wet days show a decreasing trend over most parts. Decreasing trend in the number of heavy precipitation days and very heavy precipitation days are seen in many places is seen except at Ratnapura and Nuwaraelya. Consecutive dry days have increased and wet days have decreased.

Summary for the Precipitation Indices

i. Total precipitation is decreasing;

ii. Heavy precipitation days and very heavy precipitation days are decreasing;

iii. Wet days and extremely wet days are decreasing;

iv. Consecutive dry days are increasing, consecutive wet days are decreasing

3.5.3.1 Discussion of Results on Regional Basis

i. All the temperature indices TXx, TXn, TNn except TNx has increased across the South Asia region.TNx has increased in Sri Lanka and India whereas it has decreased in Bangladesh and Nepal and evenly poised in Nepal;

ii. Cool nights have decreased whereas the warm nights increased in all the participating South Asian Countries;

iii. Cool days have decreased and warm days increased across the region;

iv. Very wet days (R95p) and extremely wet days (R99p) have increased in Nepal, Pakistan and India whereas these have decreased in Sri Lanka but a mixed trend in Bangladesh;

v. Precipitation total (PRCPTOT) has increased across the region except in Sri Lanka where it has decreased. Indian values are not available.

4.0 Conclusions

4.1 Findings and Conclusions in the context of overall Study Aims

i. The participating countries have enhanced their capacity building in the field of climate extremes which has always been a threatening issue in the region bringing huge losses in their wake. The project will open up new vistas for research in the region.

ii. The pattern of climate indices developed for the region, some complementary to each other, confirm that the metadata developed by the participating countries is well quality controlled and homogenized. They are now in a much better position to use their data-sets for research in the field. However, this data needs to be authenticated with an expanded network of stations, particularly in the Himalayan region, to give a better and meaningful coverage to the region as a whole.

4.2 Existing Gaps

i. The number of meteorological stations used by each country (except India), as a whole, are not adequate to draw a very comprehensive picture for the region. Mountainous North region, the source house of water availability in the region, is not adequately covered. India even has neglected the hilly region because of meager data.

ii. In India, rainfall data-sets are said to have some gaps. These need to be filled up to generate all indices. Similar is the case with Bangladesh where percentile based indices and some others are missing due to data gaps.

iii. The study lacks development of linkage of climate extremes with the natural forcing phenomena like ENSO, NAO etc; global warming and climate extremes worldwide. This requires that the network be expanded and all the core climate indices be studied.

iv. The seasons, in particular, the monsoon season has a key economic role to play in the South Asia region. It is therefore necessary to look into the features leading to the seasonality of the indices.

5.0 Future Directions

The desired aims of the project can comprehensively be achieved if the project is allowed some additional time of two years and it uses an expanded network of stations and all the 27 ETCCDMI core indices to develop their linkage to the natural forcing phenomena, global warming, climate extremes observed worldwide. This is highly essential for South Asia, a region which is particularly vulnerable to changes in climate extremes due to high population density, agrarian based economy, exposure to tropical cyclones, frequent floods and droughts and to other meteorological disasters.

References

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2. Easterling D.R. et al., 1999: Observed Variability and Trends in Extreme Climate Events: A Brief Review, Bulletin of the American Meteorological Society. Vol. 81 No. 3, March 2000, 417-424;

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Appendix

Conferences/Symposia/Workshops

1. *Agenda/Program of the APN Workshop (2-6 January, 2006) and Concluding meeting (21-23 August, 2006) is attached as Annex-1*

2. *Participants list of APN Workshop (2-6 January, 2006) and APN Concluding meeting (21-23 August, 2006) is attached as Annex-2*

Funding sources outside the APN

In-kind support was provided by Global Change Impact Studies Centre (GCISC) and Pakistan Meteorological Department (PMD).

Glossary of Terms

All acronyms and abbreviations are defined in the above text.

In the Appendix section, the report may also include:

The participating countries, particularly India and Pakistan are not agreeable to share their Actual climate data; however, products are included in this report.

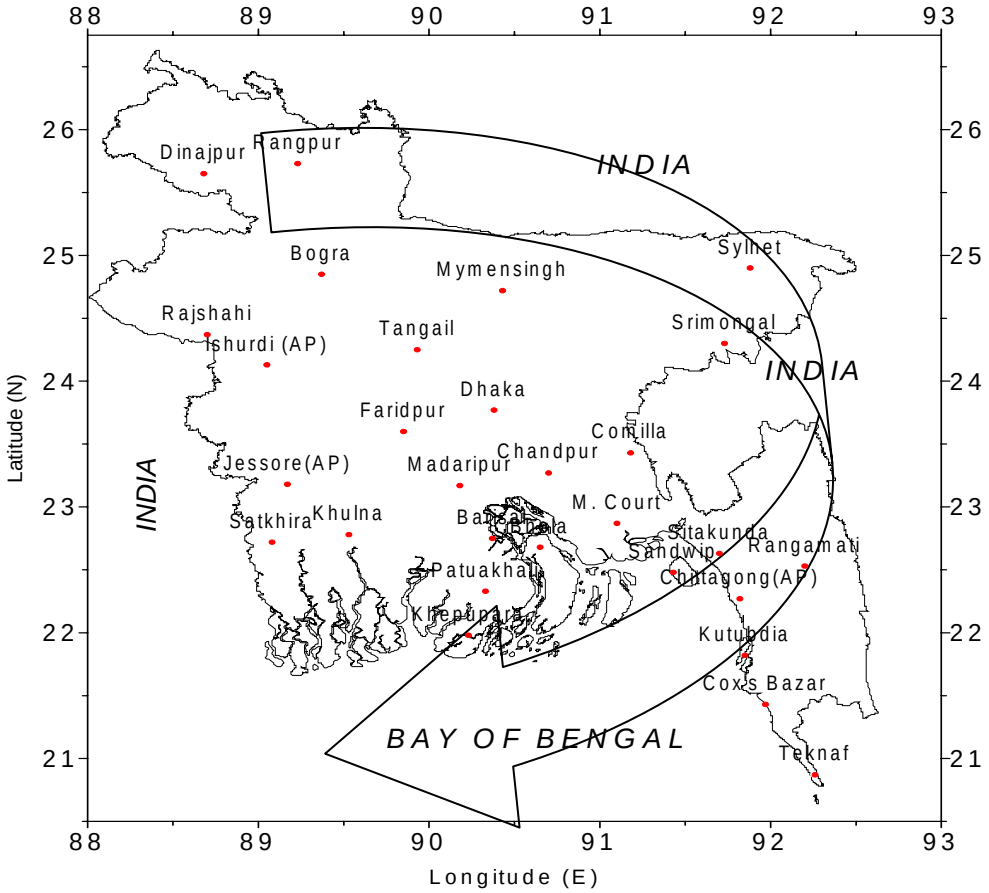
Abstracts, Power Point Slides of the workshop (2-6 January, 2006) and the concluding meeting (21-23 August, 2006) are not included in this report. However, the same will be included in the bound copied and will be sent shortly by courier. Soft copy version in the form of CD-ROM will also be included.

Table 1

List of ETCCDMI core Climate Indices used in the Project

ID	Indicator name	Definitions	Units
TXx	Max Tmax	Monthly maximum value of daily maximum temp	°C
TNx	Max Tmin	Monthly maximum value of daily minimum temp	°C
TXn	Min Tmax	Monthly minimum value of daily maximum temp	°C
TNn	Min Tmin	Monthly minimum value of daily minimum temp	°C
TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
TX10p	Cool days	Percentage of days when TX<10th percentile	Days
TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
TX90p	Warm days	Percentage of days when TX>90th percentile	Days
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN<10th percentile	Days
DTR	Diurnal temperature range	Monthly mean difference between TX and TN	°C
RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	Mm
Rx5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	Mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year	Mm/day
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
R95p	Very wet days	Annual total PRCP when RR>95th percentile	Mm
R99p	Extremely wet days	Annual total PRCP when RR>99th percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm

Fig. 1



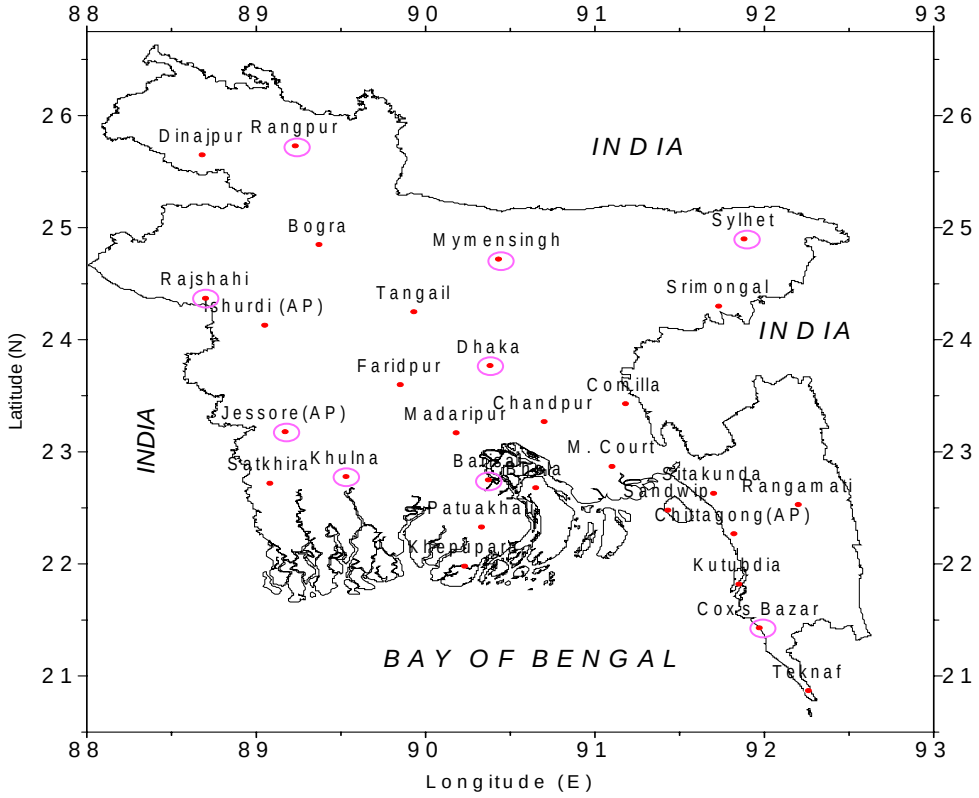
Map of Bangladesh showing the wet (within the arrow) and dry regions

Table-2

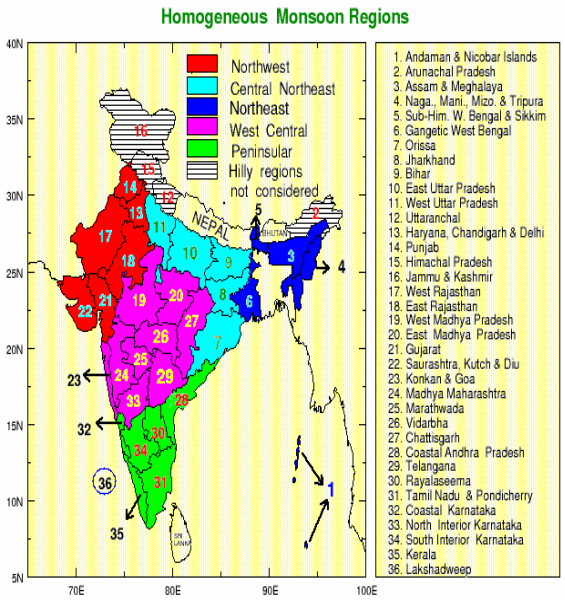
Summary of basic information on the data stations of Bangladesh considered for the study

Station ID	Name of station	Latitude	Longitude	Altitude (m from MSL)	Period of data availability
41992	Cox's Bazar	91.93	21.43	2	1961-2000
41923	Dhaka	90.38	23.77	5	1961-2000
41936	Jessore	89.23	23.16	6	1961-2000
41947	Khulna	89.53	22.78	3	1961-2000
41950	Barisal	90.40	22.67	4	1961-2000
41886	Mymensingh	90.43	24.72	18	1961-2000
41895	Rajshahi	88.70	24.37	17	1964-2000
41859	Rangpur	89.23	25.73	33	1961-2000
41891	Sylhet	91.88	24.90	34	1961-2000

Fig. 2



Map of Bangladesh showing the meteorological stations (in circles)



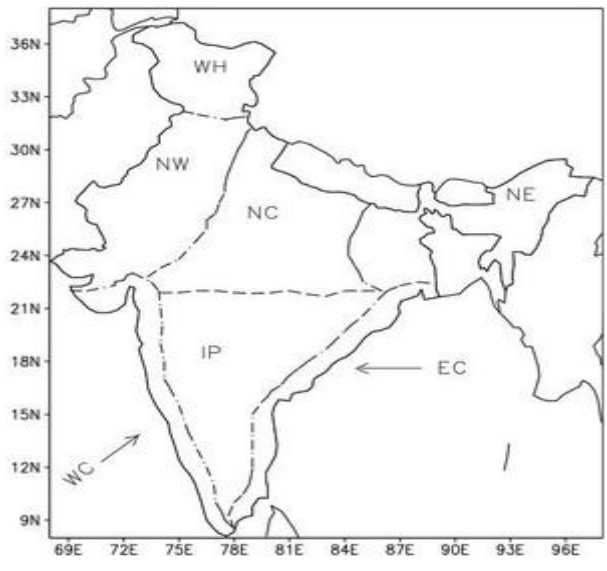
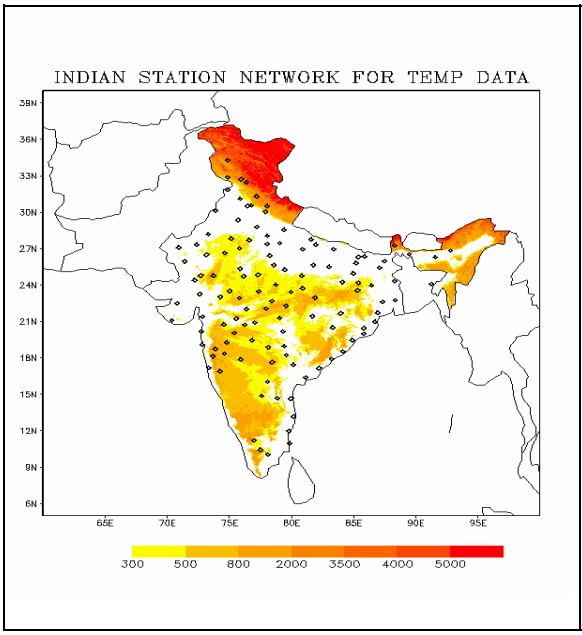


Fig. 3: Homogeneous zones of India for precipitation	**Fig. 4** : Homogeneous zones of India for Temperature



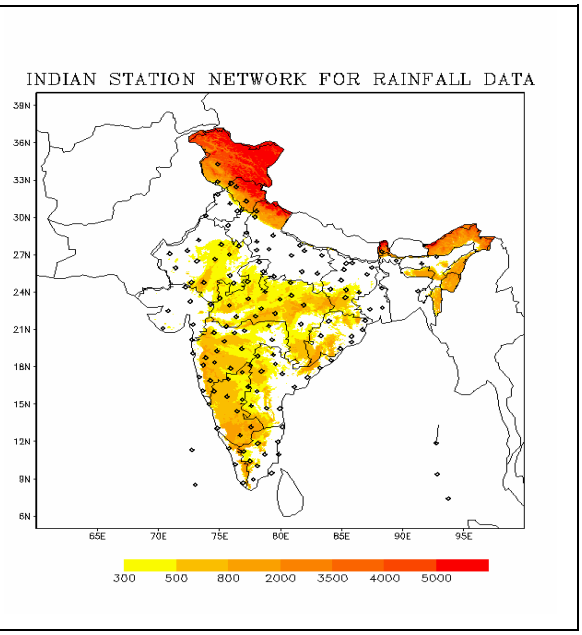


Fig 5: Location of Temperature Stations

Fig 6: Location of Precipitation Stations

Table 3

Stations available for the precipitation analysis

S. N.	Longitude	Latitude	Alt (m)	Name of the Station	Code	First year	Last year
1	91.25	23.88	16	Agartala	42724	1951	2003
2	91.58	26.1	54	Guwahati A. P	42410	1951	2003
3	92.78	26.62	79	Tezpur	42415	1951	2003
4	88.27	24.13	19	Berhampore	42603	1951	2003
5	88.33	22.53	6	Calcutta	42807	1951	2003
6	89.47	26.33	43	Cooch Behar A. P	42403	1951	2003
7	88.27	27.05	2127	Darjeeling	42295	1951	2003
8	87.32	22.42	45	Midnapore	42803	1951	2003
9	86.93	21.52	20	Balasore	42895	1951	2003
10	85.83	20.25	46	Bhubaneshwar A. P	42971	1951	2003
11	86.73	20.78	6	Chandbali	42973	1951	2003
12	84.88	19.27	17	Gopalpur	43049	1951	2003
13	85.82	19.8	6	Puri	43053	1951	2003
14	83.97	21.47	148	Sambalpur	42883	1951	2003
15	83.3	20.3	211	Titlagarh	42961	1951	2003
16	84.07	24.05	221	Daltongang	42587	1951	2003
17	85.9	26.17	49	Darbhanga	42391	1951	2003
18	86.43	23.78	257	Dhanbad	42703	1951	2003
19	84.95	24.75	116	Gaya A. P	42591	1951	2003
20	85.37	23.98	611	Hazaribagh	42699	1951	2003
21	85.4	26.12	53	Muzaffarpur	42387	1951	2003
22	85.17	25.62	53	Patna A. P	42492	1951	2003
23	87.47	25.77	38	Purnea	42500	1951	2003
24	85.33	23.38	652	Ranchi	42701	1951	2003
25	87.07	25.23	37	Sabaur	42499	1951	2003
26	78.03	27.17	169	Agra	42261	1951	2003
27	78.07	27.88	187	Aligarh	42262	1951	2003
28	81.73	25.45	98	Allahabad A. P	42475	1951	2003

29	81.6	27.57	124	Baharaich	42273	1951	2003
30	79.4	28.37	173	Bareilly	42189	1951	2003
31	78.03	30.32	682	Dehra Dun	42111	1951	2003
32	81.97	27.13	110	Gonda	42274	1951	2003
33	83.37	26.75	78	Gorakhpur	42379	1951	2003
34	78.58	25.45	251	Jhansi	42463	1951	2003
35	80.88	26.75	111	Lucknow A. P	42369	1951	2003
36	79.05	27.23	157	Mainpuri	42265	1951	2003
37	77.88	29.85	274	Roorkee	42140	1951	2003
38	83.02	25.3	85	Varanasi	42483	1951	2003
39	76.77	30.38	272	Ambala	42103	1951	2003
40	75.73	29.17	221	Hissar	42131	1951	2003
41	77.2	28.58	216	New Delhi	42182	1951	2003
42	74.87	31.63	234	Amritsar A. P	42071	1951	2003
43	75.87	30.93	247	Ludhiana	42099	1951	2003
44	76.47	30.33	251	Patiala	42101	1951	2003
45	75.97	32.53	1959	Dalhousie	42059	1951	2003
46	76.38	32.27	1211	Dharamsala	42062	1951	2003
47	77.17	31.1	2202	Shimla	42083	1951	2003
48	74.83	32.67	367	Jammu A. P	5	1951	2003
49	74.83	34.08	1587	Srinagar	42027	1951	2003
50	72.72	24.6	1195	Abu	42540	1951	2003
51	74.62	26.45	486	Ajmer	42343	1951	2003
52	76.58	27.5	271	Alwar	42255	1951	2003
53	71.38	25.75	194	Barmer	42435	1951	2003
54	73.3	28	224	Bikaner	42165	1951	2003
55	73.88	29.92	-999	Ganganagar	42123	1951	2003
56	75.8	26.82	390	Jaipur A. P	42348	1951	2003
57	70.92	26.9	242	Jaisalmer	242	1951	2003
58	76.17	24.53	321	Jhalawar	42555	1951	2003
59	73.17	26.3	412	Jodhpur A. P	42339	1951	2003
60	75.85	25.15	274	Kota A. P	42452	1951	2003
61	72.37	27.13	234	Phalodi	42237	1951	2003
62	75.13	27.62	432	Sikar	42249	1951	2003
63	73.7	24.58	514	Udaipur	42543	1951	2003
64	77.93	21.87	653	Betul	42860	1951	2003
65	77.35	23.28	523	Bhopal A. P	42667	1951	2003
66	77.32	24.65	432	Guna	42559	1951	2003
67	78.25	26.23	207	Gwalior	42361	1951	2003
68	75.8	22.72	567	Indore A. P	42754	1951	2003
69	79.95	23.2	393	Jabalpur	42675	1951	2003
70	76.37	21.83	318	Khandwa	42855	1951	2003
71	79.45	25.07	229	Nowgong	42467	1951	2003
72	78.43	22.47	1075	Pachmarhi	42767	1951	2003
73	81.9	22.77	625	Pendra	42779	1951	2003
74	81.65	21.23	298	Raipur	42875	1951	2003
75	75.05	23.32	486	Ratlam	42661	1951	2003
76	78.75	23.85	551	Sagar	42671	1951	2003
77	80.83	24.57	317	Satna	42571	1951	2003
78	79.55	22.08	619	Seoni	42771	1951	2003
79	80.88	23.53	459	Umaria	42679	1951	2003
80	72.63	23.07	55	Ahmedabad A. P	42647	1951	2003

81	72.2	24.2	136	Deesa	42539	1951	2003
82	74.27	22.83	333	Dohad	42751	1951	2003
83	70.78	22.3	138	Rajkot A. P	42737	1951	2003
84	72.83	21.2	12	Surat	42840	1951	2003
85	70.37	20.9	8	Veraval	42909	1951	2003
86	77.03	20.7	282	Akola	42933	1951	2003
87	74.8	19.08	657	Ahmadnagar	43009	1951	2003
88	75.4	19.85	581	Aurangabad A. P	43014	1951	2003
89	74.58	18.15	551	Baramati	43069	1951	2003
90	76.23	20.53	650	Buldhana	42931	1951	2003
91	79.3	19.97	193	Chandrapur	43029	1951	2003
92	72.72	19.97	5	Dahanu	43001	1951	2003
93	75.57	21.05	201	Jalgaon	42851	1951	2003
94	74.23	16.7	570	Kolhapur	43157	1951	2003
95	73.67	17.93	1382	Mahabaleshwar	43111	1951	2003
96	74.53	20.55	437	Malegaon	42925	1951	2003
97	72.82	18.9	11	Mumbai	43057	1951	2003
98	79.05	21.1	310	Nagpur A. P	42867	1951	2003
99	76.83	19.27	423	Parbhani	43017	1951	2003
100	73.85	18.53	559	Pune	43067	1951	2003
101	73.33	16.98	67	Ratnagiri	43110	1951	2003
102	75.9	17.67	479	Sholapur	43117	1951	2003
103	77.62	14.68	350	Anantpur	43237	1951	2003
104	78.83	14.48	130	Cuddapah	43241	1951	2003
105	79.57	18.02	269	Hanamkonda	43087	1951	2003
106	78.47	17.45	545	Hyderabad A. P	43128	1951	2003
107	82.23	16.95	8	Kakinada	43189	1951	2003
108	84.13	18.33	6	Kalingapatnam	43105	1951	2003
109	80.15	17.25	112	Khammam	43137	1951	2003
110	78.07	15.83	281	Kurnool	43213	1951	2003
111	81.13	16.18	3	Machilipatnam	43185	1951	2003
112	79.98	14.45	20	Nellore	43245	1951	2003
113	78.1	18.67	381	Nizamabad	43081	1951	2003
114	79.43	18.77	156	Ramagundam	43086	1951	2003
115	83.23	17.72	3	Vishakhapatnam	43149	1951	2003
116	80.18	13	16	Chennai A. P	43279	1951	2003
117	76.97	11	409	Coimbatore	43319	1951	2003
118	79.77	11.77	12	Cuddalore	43329	1951	2003
119	77.47	10.23	2343	Kodaikanal	43339	1951	2003
120	78.08	9.83	133	Madurai A. P	43360	1951	2003
121	79.85	10.77	9	Nagapattinam	43347	1951	2003
122	77.75	8.73	51	Palayamkottai	43376	1951	2003
123	79.3	9.27	11	Pamban	43363	1951	2003
124	78.17	11.65	278	Salem	43325	1951	2003
125	78.72	10.77	88	Tiruchirapalli A. P	43344	1951	2003
126	73.63	15.87	-999	Vellore	43303	1951	2003
127	77.58	12.97	897	Bangalore	43295	1951	2003
128	74.53	15.85	747	Belgaum	43197	1951	2003
129	76.85	15.15	449	Bellary	43205	1951	2003
130	77.53	17.92	664	Bidar	43125	1951	2003
131	75.72	16.82	594	Bijapur	43161	1951	2003
132	76.43	14.23	733	Chitradurga	43233	1951	2003

133	75.63	15.42	650	Gadag	43201	1951	2003
134	76.85	17.35	458	Gulbarga	43121	1951	2003
135	74.13	14.78	4	Karwar	43225	1951	2003
136	74.85	12.87	22	Mangalore A. P	43284	1951	2003
137	76.7	12.3	767	Mysore	43291	1951	2003
138	77.35	16.2	400	Raichur	43169	1951	2003
139	76.27	9.95	-999	Cochi A. P	43353	1951	2003
140	75.78	11.25	5	Kozhikode	43314	1951	2003
141	76.95	8.48	8	Thiruvananthapuram A. P	43371	1951	2003
142	92.83	9.17	10	Car Nicobar	43367	1951	2003
143	93.73	7.22	8	Kondul	43385	1951	2003
144	92.72	11.67	79	Port Blair	43333	1951	2003
145	72.73	11.12	4	Amini Divi	43311	1951	2003
146	73	8.3	2	Minicoy	43369	1951	2003

Table 4

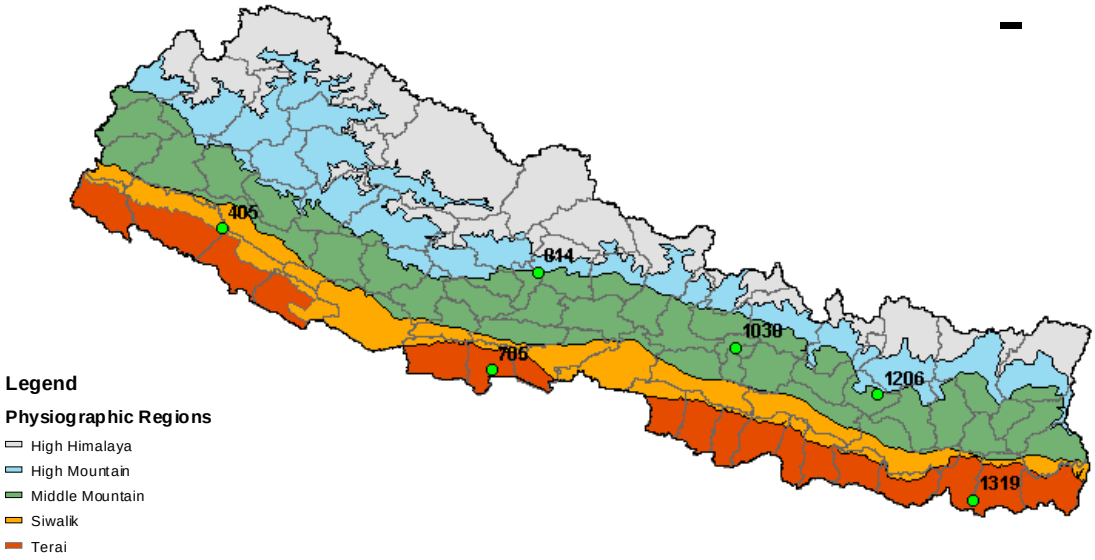
Stations Available for Temperature Analysis

S. No.	Longitude	Latitude	Alt (m)	Station Name	Code No.	First Year	Last Year
1	78.03	27.17	169	AGRA	42261	1970	2003
2	73.3	28	224	BIKANER	42165	1970	2003
3	75.86	30.93	247	LUDHIANA	42099	1970	2003
4	74.53	20.55	437	MALEGAON	42925	1970	2003
5	75.73	17.66	479	SOLAPUR	43117	1970	2003
6	79.3	19.95	193	CHANDRAPUR	43029	1970	2003
7	82	19.08	553	JAGADALPUR	43041	1970	2003
8	78.1	18.67	381	NIZAMABAD	43081	1970	2003
9	69.1	22.36	11	DWARKA	42731	1970	2003
10	72.83	21.2	12	SURAT	42840	1970	2003
11	70.36	20.9	8	VERAVAL	42909	1970	2003
12	76.98	15.1	449	BELLARY	43205	1970	2003
13	79.76	11.76	12	CUDDALORE	43329	1970	2003
14	79.85	10.76	9	NAGAPATANAM	43347	1970	2003
15	79.98	14.45	20	NELLORE	43245	1970	2003
16	79.3	9.26	11	PAMBAN	43363	1970	2003
17	79.1	12.91	214	VELLORE	43303	1970	2003
18	84.88	19.26		GOPALPUR	43049	1970	2003
19	87.25	25.26	149	DUMKA	42599	1970	2003
20	88.13	25	31	MALDA	42503	1970	2003
21	84.05	24.05	221	DALDAONGANJ	42587	1970	2003
22	83.36	26.75	78	GORKHAPUR	42379	1970	2003
23	91.73	25.25	1313	CHERAPUNJI	42515	1970	2003
24	73.33	16.96	67	RATNAGIRI	43110	1970	2003
25	86.93	21.5	20	BALASORE	42895	1970	2003
26	88.04	21.65	3	SAGAR ISLAD	42903	1970	2003
27	77.88	29.85	274	ROORKEE	42140	1970	2003
28	81.6	27.71	124	Baharich	42273	1970	2003
29	74.61	26.45	486	AJMER WMO	42343	1970	2003
30	79.45	25.04	229	NOWGONG	42467	1970	2003
31	74.9	24.64	496	NIMACH	42547	1970	2003
32	81.9	22.76	625	PENDRA	42779	1970	2003

33	82.23	16.96	8	KAKINADA	43189	1970	2003
34	74.53	15.85	753	BELGAON	43197	1970	2003
35	75.78	11.25	5	KOZIKODE	43314	1970	2003
36	79.65	29.46	2311	MUKTESHAWER	42147	1970	2003
37	88.71	26.32	83	JALPAIGURI	42399	1970	2003
38	77.46	10.23	2343	KODIAKANAL	43339	1970	2003
39	72.73	11.1	4	AMINIDEVI	43311	1970	2003
40	78.08	30.45	2042	MUSSORIE	42112	1970	2003
41	79.4	28.36	172	BAREILY	42189	1970	2003
42	79.05	27.23	155	MAINPURI	42265	1970	2003
43	88.26	27.05	2128	DARJEELING	42295	1970	2003
44	95.02	27.48	111	DIBRUGARH	42314	1970	2003
45	85.9	26.16	49	DARBHANGA	42391	1970	2003
46	73	8.38	2	MINICOY	43369	1970	2003
47	89.08	26.02	35	DHUBRI	42404	1970	2003
48	75.85	25.16	274	KOTA	42451	1970	2003
49	87.46	25.76	38	PURNEA	42500	1970	2003
50	80.86	24.56	317	PATNA	42571	1970	2003
51	69.66	23.25	80	BHUJ (A)	42634	1970	2003
52	85.36	23.98	611	HAZARIBAGH	42699	1970	2003
53	87.84	23.23	32	BURDWAN	42709	1970	2003
54	88.51	23.4	15	KRISHNANAGAR	42711	1970	2003
55	70.78	22.29	138	RAJKOT	42736	1970	2003
56	77.76	22.76	302	HOSHANGABAD	42763	1970	2003
57	78.4	22.44	1075	PACHMARHI	42767	1970	2003
58	79.53	22.08	619	SEONY	42771	1970	2003
59	85.81	22.55	226	CHAIBASA	42795	1970	2003
60	87.31	22.41	45	MIDNAPORE	42803	1970	2003
61	72.19	21.74	12	BHAUNAGAR (A)	42838	1970	2003
62	76.36	21.83	318	KHANDWA	42855	1970	2003
63	77.78	20.92	370	AMRAOTI	42937	1970	2003
64	85.09	20.83	139	ANGUL	42969	1970	2003
65	74.91	19.08	657	AHMEDNAGAR	43009	1970	2003
66	75.33	19.88	581	AURANGABAD	43013	1970	2003
67	79.56	18.02	269	HANAMKONDA	43087	1970	2003
68	84.13	18.33	6	KALINGAPATNAM	43105	1970	2003
69	77.53	17.91	664	BIDAR	43125	1970	2003
70	77.35	16.19	400	RAICHUR	43169	1970	2003
71	74.13	14.78	4	KARWAR	43225	1970	2003
72	76.43	14.23	733	CHITRADURG	43233	1970	2003
73	78.83	14.43	130	CUDDAPAH	43241	1970	2003
74	76.15	13	960	HASSAN	43263	1970	2003
75	75.73	12.41	1152	MERCARA	43287	1970	2003
76	76.7	12.29	767	MYSORE	43291	1970	2003
77	76.73	11.4	2249	OOTAKAMUND	43317	1970	2003
78	76.96	11	278	SALEM	43325	1970	2003
79	92.71	11.66	79	PORT BLAIR	43333	1970	2003
80	76.73	30.38	278	AMBAL	42103	1970	2003
81	91.58	26.16	54	GAUHATI	42410	1961	2003
82	92.78	26.61	79	TEZPUR	42415	1961	2003
83	88.26	24.13	19	BERHAMPORE	42603	1961	2003
84	88.33	22.53	6	CALCUTTA	42807	1961	2003

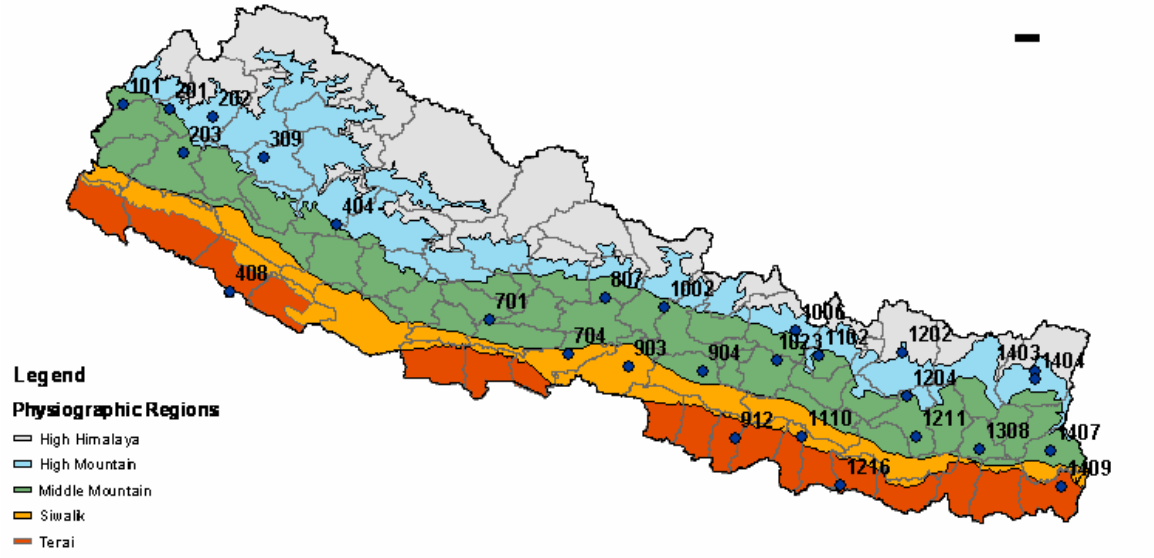
85	85.92	20.8	27	CUTTACK	42970	1970	2003
86	85.98	19.8	6	PURI	43053	1961	2003
87	83.23	17.71	3	VISHAKHAPATNAM	43149	1961	2003
88	83.96	21.35	148	SAMBALPUR	42883	1961	2003
89	85.08	25.6	60	PATNA	42492	1961	2003
90	85.31	23.31	652	RANCHI	42701	1961	2003
91	81.65	21.23	298	RAIPUR	42875	1961	2003
92	77	20.73	282	AKOLA	42933	1961	2003
93	79.11	21.15	310	NAGPUR	42866	1961	2003
94	78.6	25.45	251	JHANSHI	42463	1961	2003
95	75.8	22.71	567	INDORE(A)	42754	1961	2003
96	79.96	23.16	393	JABALPUR	42675	1961	2003
97	78.75	23.85	551	SAGAR	42671	1961	2003
98	84.95	24.75	116	GAYA	42591	1961	2003
99	81.73	25.45	98	ALLAHABAD	42475	1961	2003
100	80.03	26.86	128	LUCKNOW	42368	1961	2003
101	73.2	28.58	233	DELHI	42182	1961	2003
102	74.52	31.18	231	AMRITSAR	42071	1961	2003
103	75.8	26.8	390	JAIPUR	42348	1961	2003
104	77.16	31.09	2202	SIMLA	42083	1961	2003
105	74.83	34.08	1587	SRINAGAR	42027	1961	2003
106	73	26.3	217	JODHAPUR	42339	1961	2003
107	72.7	24.58	1195	ABU	42540	1961	2003
108	72.63	23	55	AHAMADABAD	42647	1961	2003
109	72.2	24.2	136	DEESA	42539	1961	2003
110	72.81	18.9	11	BOMBAY	43057	1961	2003
111	76.95	8.48	64	TRIVANDRUM	43371	1961	2003
112	73.85	18.53	559	POONA	43063	1961	2003
113	78.46	17.45	545	HYDERABAD	43128	1961	2003
114	78.06	15.83	350	KURNOOL	43213	1961	2003
115	75.71	16.81	594	BIJAPUR	43161	1961	2003
116	77.58	12.96	897	BANGALORE	43295	1961	2003
117	74.85	12.86	22	MANGALORE	43283	1961	2003
118	81.13	16.18	3	MASULIPATANAM	43185	1970	2003
119	76.06	11	409	COIMBATORE	43319	1970	2003
120	80.18	13	16	MADRAS	43278	1970	2003
121	94.63	26.98	97	SIBSAGAR	42311	1970	2003

Fig. 7



Physiography of Nepal with stations used for temperature indices

Fig. 8



Network for precipitation stations

Table 5

Details of the stations (6) considered for the temperature indices

Index No	Station	Longitude	Latitude	Altitude (m)
1319	BIRATNAGAR AIRPOART	87.27	26.48	72
1030	KATHMANDU AIRPORT	85.37	27.70	1337
705	BHAIRHAWA AIRPORT	83.43	27.52	109
814	LUMLE	83.80	28.30	1740
1206	OKHALDHUNGA	86.50	27.32	1720
405	CHISAPANI (KARNALI)	81.27	28.65	225

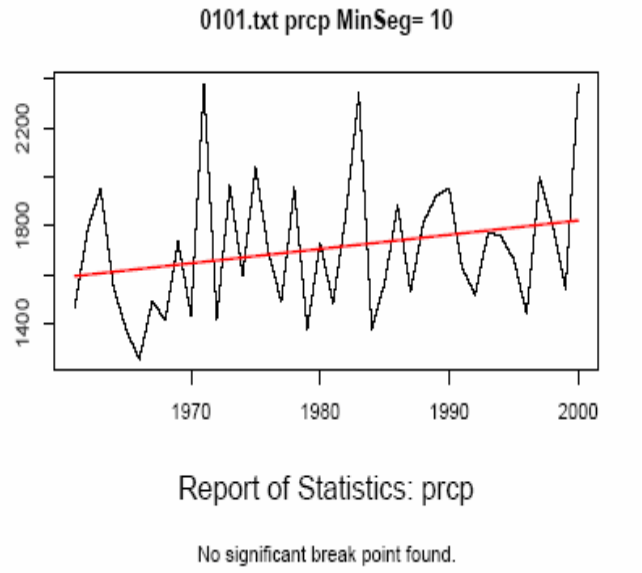
Table 6

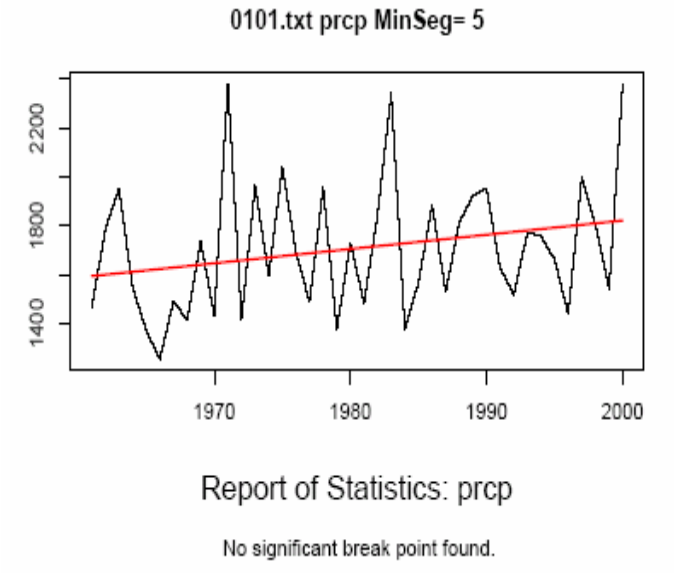
Details of the stations (27) considered for the precipitation indices

Index No.	Station Name	Longitude	Latitude	Elevation (m)
101	Kakerpakha	80.50	29.65	842
201	Pipalkot	80.87	29.62	1456
202	Chainpur (west)	81.22	29.55	1304
203	Silgadhi (Doti)	80.98	29.27	1360
309	Bijayapur	81.63	29.23	1814
404	Jajarkot	82.20	28.70	1231
408	Gulariya	81.35	28.17	215
701	Ridi bazar	83.43	27.95	442
704	Beluwa (girwari)	84.05	27.68	150
807	Kunchha	84.35	28.13	855
903	Jhawani	84.53	27.58	270
904	Chisapani gadhi	85.13	27.55	1706
912	Ramoli bairiya	85.38	27.02	152
1002	Aru ghat bazar	84.82	28.05	518
1006	Gumthang	85.87	27.87	2000
1023	Dolal ghat	85.72	27.63	710
1102	Charikot	86.05	27.67	1940
1110	Tulsi	85.92	27.03	457
1202	Chaurikhark	86.72	27.70	2619
1204	Aiselukhark	86.75	27.35	2143
1211	Khotang bazar	86.83	27.03	1295
1216	Siraha	86.22	26.65	102
1308	Mul ghat	87.33	26.93	365
1403	Lungthung	87.78	27.55	1780
1404	Taplethok	87.78	27.48	1383
1407	Ilam tea estate	87.90	26.92	1300
1409	Anarmani birta	87.98	26.63	122

Test for precipitation data at station 0101.

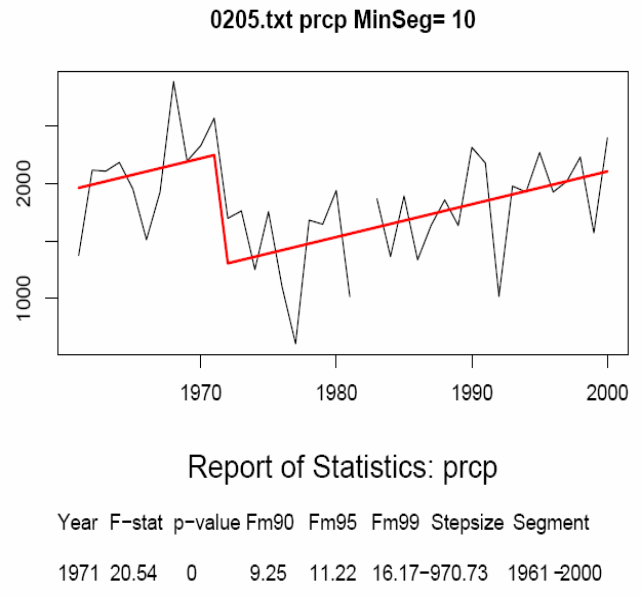
Fig. 9a **Fig. 9b**





Test of the precipitation data at station 0205

Fig. 10a **Fig. 10b**



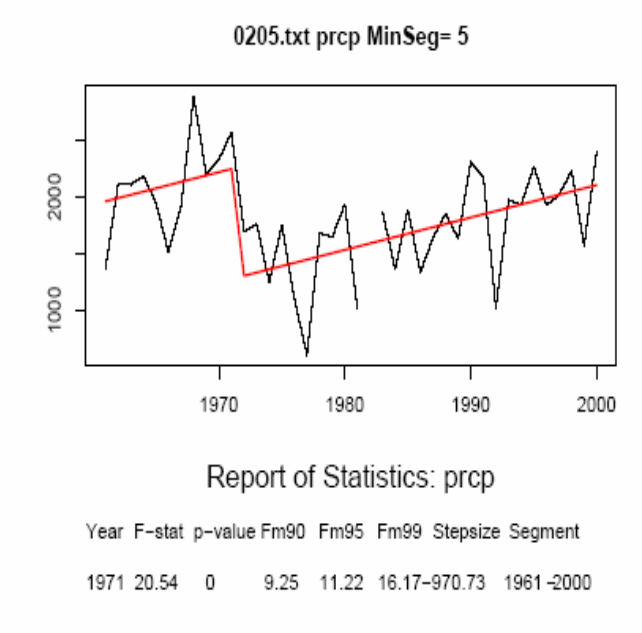


Fig. 11

Physiographic map of Pakistan showing the meteorological sites with orographic details

Table 7

Meteorological Stations along with their coordinates used for the study

Sr. #	Station	WMO#	Lon	Lat	Elevation (m)
1	Bhawalpur	41700	71.78	29.33	110
2	Chitral	41506	71.83	35.85	1500
3	Dalbandin	41712	64.40	28.88	850
4	D. I. Khan	41624	70.93	31.82	171
5	Faisalabad	41630	73.10	31.43	185
6	Gilgit	43516	74.33	35.92	1460
7	Hyderabad	41765	68.42	25.38	41
8	Islamabad	41571	73.1	33.62	508
9	Jacobabad	41715	68.47	28.30	55
10	Jhelum	41598	73.73	32.93	287
11	Karachi	41780	67.13	24.90	22
12	Lahore	41640	74.33	31.55	214
13	Multan	41675	71.43	30.20	122
14	Murree	41573	73.38	33.92	2168
15	Parachinar	41560	70.08	33.87	1725
16	Quetta	41660	66.88	30.25	1601
17	Zhob	41620	69.47	31.35	1405

Table 8

Climatic Zones of Pakistan showing meteorological stations in respective zones

Regions	Stations
Zone I(a): Greater Himalayas (Winter dominated)	Chitral, Gilgit
Zone I(b): Sub-montane Region (Monsoon dominated)	Islamabad, Jhelum, Lahore, Murree
Zone II: Western Highlands	D.I. Khan, Parachinar
Zone III: Central & Southern Punjab	Bahawalpur, Faisalabad, Multan
Zone IV: Lower Indus Plains	Hyderabad, Jacobabad
Zone V(a): Balochistan Province (Sulaiman & Kirthar Ranges)	Quetta, Zhob
Zone V(b): Balochistan Plateau	Dalbandin
Zone VI: Coastal Belt	Karachi

Fig. 12

Climatic Zones of Pakistan

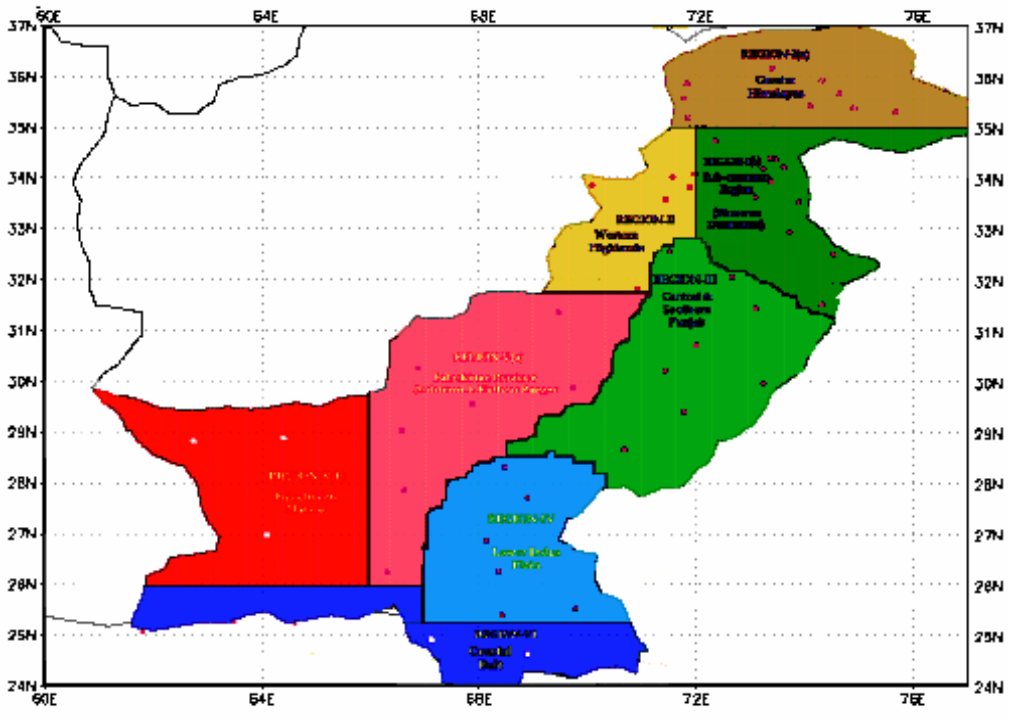


Table 9

Percentage of missing values in the data

Stations	Precipitation	Max Temp	Min Temp
Bahawalpur	7.15	4.16	4.41
Chitral	1.32	1.04	0.93
Dalbandin	0.49	0.92	4.56
D.I. Khan	1.29	1.24	1.35
Faisalabad	1.55	1.58	1.28
Gilgit	1.45	0.42	0.93
Hyderabad	5.43	3.72	3.73
Islapt	1.68	0.84	0.83
Jacobabad	3.10	1.28	1.16
Jhelum	1.93	0.68	0.68
Karachi	1.93	2.27	2.16
Lahore	0.11	0.22	0.22
Multan	1.08	0.36	0.32
Murree	4.65	3.28	2.83
Parachinar	1.89	2.74	4.19
Queta	7.90	10.94	11.30
Zhob	0.99	7.72	5.25

Fig. 13

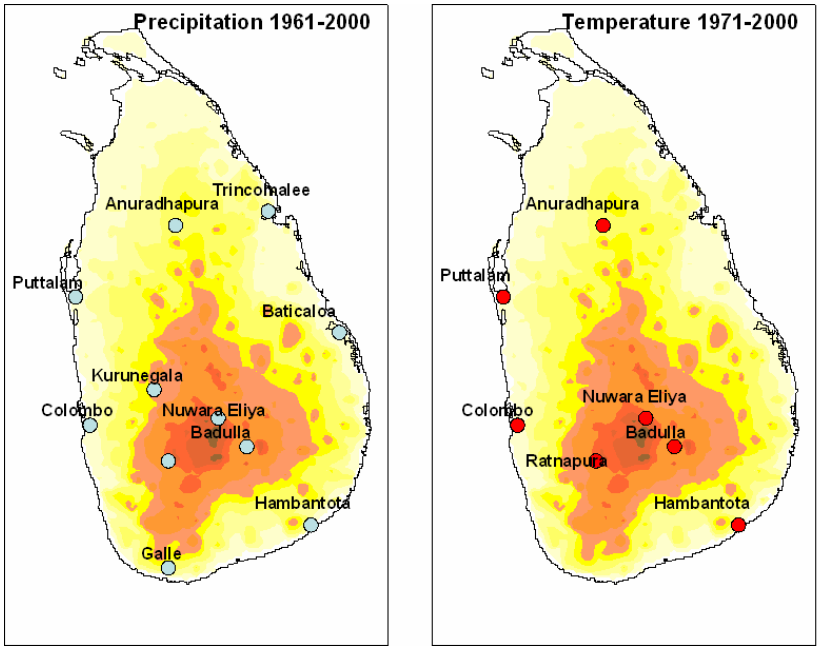


Fig. 14

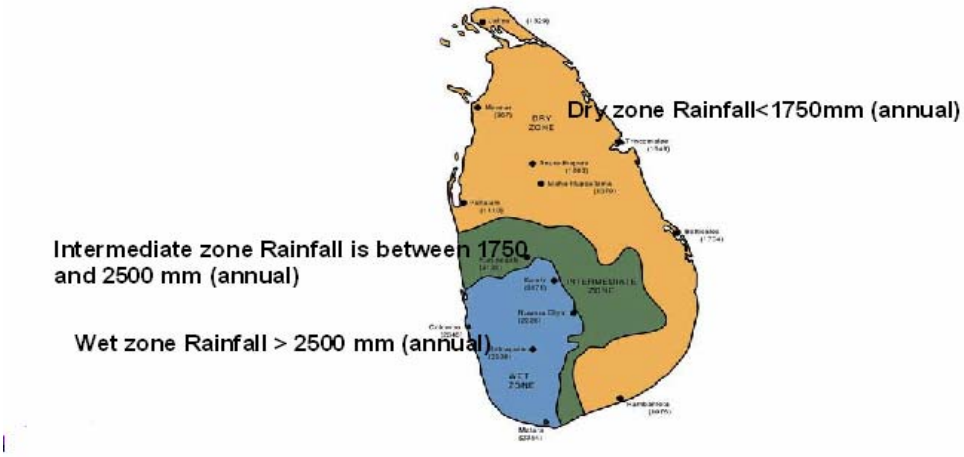


Table 9a

5 stations from dry zone

WMO Station ID	Station	Long	Lat	Altitude
00043421	ANURADHAPURA	80.383E	8.333N	92.5 M
00043436	BATTICALOA	81.700E	7.717N	7.8 M
00043497	HAMBANTOTA	81.133E	6.117N	15.5 M
00043424	PUTTALAM	79.834E	8.033N	2.1 M
00043418	TRINCOMALEE	81.250E	8.583N	79.0 M

Table 9b

4 stations from wet zone

WMO Station ID	Station	Long	Lat	Altitude
00043466	COLOMBO	79.867E	6.900N	7.3 M
00043495	GALLE	80.217E	6.033N	12.5 M
00043473	NUWARA ELIYA	80.767E	6.967N	1895.0 M
00043486	RATNAPURA	80.400E	6.683N	86.3 M

Table 9c

2 stations from intermediate zone

WMO Station ID	Station	Long	Lat	Altitude
00043479	BADULLA	81.050E	6.984N	669.6 M
00043441	KURUNEGALA	80.350E	7.467N	116.0 M

Table 10

Percentage of Missing data

Station	Precipitation	Max Temperature	Min Temperature
Base Period	1961-2000	1971-2000	
Anuradhapura	0.5%	0.5%	0.8%
Colombo	0.2%	0%	0%
Badulla	0.1%	0.1%	0.2%
Hambantota	0.3%	0.4%	0.6%
Kurunegala	0.2%	Rejected	
Nuwara Eliya	0.2%	0%	1.4%
Puttalam	0.1%	0.1%	0.3%
Ratnapura	0.2%	0.1%	0.5%
Trncomalee	1.1%	-	-
Batticaloa	2.1%	-	-

Table 11

Trend Changes in Climate Extreme Indices in South Asian Countries

S. No.	Indices	Bangladesh		India		Nepal		Pakistan		Sri Lanka	
		+	-	+	-	+	-	+	-	+	-
1	TXx	6	3	91	30	5	1	13	4	5	2
2	TXn	*5	4	63	58	3	3	9	7	*7	0
3	TNx	*3	6	66	55	5	1	*3	14	6	1
4	TNn	5	3	76	45	5	1	13	4	7	0
5	TN10p	NA	NA	24	97	0	6	6	11	0	7
6	TX10p	NA	NA	26	95	1	5	6	11	1	6
7	TN90p	NA	NA	78	43	6	0	13	4	7	0
8	TX90p	NA	NA	81	40	5	1	13	4	5	2
9	WSDI	NA	NA	77	33	5	1	*9	8	6	1
10	CSDI	NA	NA	33	88	1	5	6	11	0	7
11	DTR	*6	3	53	68	3	3	7	9	3	4
12	RX1day	*3	6	91	48	15	12	10	6	5	6
13	RX5day	6	3	87	52	18	9	12	5	*5	6
14	SDII	5	4	61	78	15	12	8	9	*9	1
15	CDD	2	7	51	88	3	24	8	9	*10	1
16	CWD	*6	3	51	88	*15	11	*12	6	3	8
17	R95p	*3	6	92	47	20	7	11	6	*3	8
18	R99p	4	5	90	49	*15	12	*11	6	4	7
19	PRCPTOT	8	1	80	59	24	3	13	4	*2	9

NA: Not available

* Trend is different from other countries

Table 12

TXx: Daily Temperatures Extremes (1961-2000)

Decade	1961-70	1971-80	1981-90	1991-2000
No. of stations with highest daily temperature	4	12	16	20

- Intensity of extreme values in the last has increased by 1.5°C (32.7%) compared to the extreme values in 1961-90

Table 13

R x 1 day (Heaviest 24-hour precipitation) (1961-2000)

Period	1961-70	1971-80	1981-90	1991-2000
No. of stations with highest daily temperature	6	18	11	17

- Intensity of precipitation in the last decade has increased by 78% in 1991-2000 as compared to the normal period of 1961-90

Table 14a

Summary Results for Temperature Indices (Bangladesh)

	TXx	TXn	TNx	TNn	DTR
Cox's Bazar	0.014	0.006	0.009	0.038	0.006
Dhaka	0.035	-0.026	0.012	0.05	-0.002
Khulna	0.023	0.078	-0.003	-0.029	0.021
Jessore	0.083	-0.026	0	0.04	0.014
Barisal	-0.003	-0.011	-0.013	-0.035	0.029
Mymensingh	0	-0.011	0.008	-0.01	-0.01
Rajshahi	0.128	-0.091	-0.018	-0.053	0.008
Rangpur	-0.057	-0.027	0.012	0.015	-0.04
Sylhet	0.019	0.004	0.01	0.032	0.008
Positive trend	6 stations	3 stations	5 stations	5 stations	6 stations
Negative trend	2 stations	6 stations	3 stations	4 stations	3 stations

Table 14b

Summary Results for Rainfall Indices (Bangladesh)

	Rx1day	Rx5day	PRCPTOT	R95p	R99p	sdii	cdd	cwd
Cox's Bazar	-1.062	-1.579	3.009	-5.556	-5.76	-0.027	-0.363	0.018
Dhaka	-0.678	-0.715	5.235	0.287	0.589	0.044	-0.017	-0.041
Khulna	-0.399	-0.809	2.766	-1.214	-1.483	-0.127	-0.796	0.082
Jessore	-0.057	-0.174	4.67	-0.259	1.03	0.009	-0.247	-0.007
Barisal	-0.245	-2.057	-2.089	-7.133	-0.773	-0.083	-0.576	0.014
Mymensingh	0.222	-0.483	6.551	-0.413	-0.267	-0.042	-0.188	0.113
Rajshahi	-0.092	1.318	1.119	-1.2	-2.697	-0.108	-0.339	0.025
Rangpur	0.424	2.137	11.818	6.223	3.531	0.1	0.295	0.02
Sylhet	0.131	0.936	7.745	0.998	2.333	0.004	0.059	-0.005
Positive trend	3 stations	6 stations	8 stations	3 stations	4 stations	4 stations	2 stations	6 stations
Negative trend	6 stations	3 stations	1 station	6 stations	5 stations	5 stations	7 stations	3 stations

Table 14c

Summary Results for other Rainfall Indices (Bangladesh)

	R10mm	R20mm	R50mm
Cox's Bazar	0.097	0.128	0.086
Dhaka	0.148	0.121	0.043
Khulna	0.119	0.026	-0.01
Jessore	0.154	0.062	0.003
Barisal	0.124	0.024	-0.077
Mymensingh	0.301	0.116	0.004
Rajshahi	0.074	0.043	-0.015
Rangpur	0.303	0.279	0.058
Sylhet	0.258	0.077	0.055
Positive trend	all 9 stations	all 9 stations	6 stations
Negative trend	0 station	0 station	3 stations

Table 15a

Trends in annual temperature extremes (India)

SN	NAME OF STATION	TXx	TXn	TNx	TNn	TX90p	TX10p	TN90p	TN10p	WSDI	CSDI	DTR
1	AGRA	0.08	-0.69	-0.52	-0.71	0.97	-0.43	-2.8	5.73	2.01	12.9	0.77
2	BIKANER	0.29	0.1	-0.08	0.47	2.38	-1.24	2.47	-3.53	3.22	-3.6	-0.2
3	LUDHIANA	-0.41	0.29	-0.38	0.3	-2.75	-2.18	-0.64	-3.09	-5.83	-4.87	-0.11
4	MALEGAON	0.46	-0.46	-0.72	0.42	-0.33	2.16	-0.33	0.47	0.83	3.97	-0.18
5	SOLAPUR	0.18	-0.12	0.45	-0.01	-0.98	0.12	1.84	3.08	-3.29	7.73	0
6	CHANDRAPUR	0.55	-0.04	-0.31	-0.09	3.17	-1.84	-2.7	-1.16	2.36	-2.85	0.32
7	JAGADALPUR	0.02	-0.04	-0.32	-0.43	3.01	-0.92	1.37	-0.97	1.79	-0.45	0.12
8	NIZAMABAD	0.41	0.31	0.15	-0.06	0.07	-0.74	-0.76	-1.28	-0.42	-2.94	0.03
9	DWARKA	0.31	0.44	0.22	0.33	3.02	-2.48	3.31	-3.43	2.67	-2.8	0
10	SURAT	-0.34	-0.13	0.15	0.56	-0.53	0.51	5.49	-2.69	-1.02	-2.58	-0.46
11	VERAVAL	-0.13	0.54	0.24	0.87	2.93	-2.6	4.63	-3.85	4.81	-1.63	-0.23
12	BELLARY	0.65	0.06	-0.68	-1.08	2.34	-2.63	-4.3	6.07	2.73	16.66	0.87
13	CUDDALORE	0.32	0.24	0.1	0.38	4.93	-3.63	2.67	-2.52	5.67	-1.39	0.15
14	NAGAPATANAM	-0.19	0.62	-0.11	-0.27	2.77	-3.56	-0.62	0.07	2.93	0.95	0.3
15	NELLORE	0.46	0.07	0.06	0.11	1.27	0.13	2.09	-3.46	2.24	-3.55	-0.15
16	PAMBAN	0.25	0.34	0.08	0.21	3.74	-6.14	3.39	-6.11	0.4	-5.43	0.01
17	VELLORE	0.4	0.21	-0.61	-0.45	1.08	-1.69	-3.47	4.41	2.69	6.05	0.53
18	GOPALPUR	0.11	-0.01	0.22	-0.01	1.92	-0.35	3.54	-4.89	3.52	-6.79	-0.25
19	DUMKA	-0.76	-0.02	-0.57	0.75	-0.57	-2.58	-0.51	-8.98	-7.62	-16.97	-0.37
20	MALDA	-0.33	-0.24	0.19	0.38	-1.31	-0.27	2.59	-4.39	-5.02	-7.31	-0.42
21	DALDAONGANJ	0.25	0.08	-0.2	0.2	-1.52	-0.59	0.04	-4.4	-2.36	-4.32	-0.22
22	GORKHAPUR	0.08	-1.06	-0.06	0.07	-0.71	0.32	2.08	-3.85	-1.71	-2.67	-0.46
23	CHERAPUNJI	0.08	-0.06	-0.32	-0.23	2.37	-1.3	-0.28	2.91	5.79	8.26	0.32
24	RATNAGIRI	0.16	-0.04	-0.11	-0.29	1.27	-0.8	-0.93	-1.47	-0.56	-1.01	0.08
25	BALASORE	0.33	-0.23	0.07	0.1	-0.41	0.38	3.09	-2.08	-0.17	-2.62	-0.27
26	SAGAR ISLAD	0.45	-0.65	0.15	-0.89	2.64	1.98	1.04	-2.47	2.29	-1.36	-0.05
27	ROORKEE	-0.27	0.33	0.2	0.34	0.89	-1.07	3.01	-2.04	0.76	-2.2	-0.13
28	BAHARICH	-0.05	-0.96	-0.1	0.2	-0.54	-0.43	1.91	-3.29	-0.59	-2.3	-0.28
29	AJMER WMO	-0.11	0.04	0.47	1.65	2.62	-1.2	6.6	-7.43	4.21	-11.92	-0.81
30	NOWGONG	0.29	0.39	-0.57	0.18	0.27	-1.95	-1.82	-0.67	2.08	2.57	0.18
31	NIMACH	0.33	0.05	0.63	0.5	4.12	-1.76	5.66	-2.45	8.35	-1.54	-0.11
32	PENDRA	0.32	-0.02	0.27	0.04	1.56	-1.75	2.04	-3.46	3.53	-1.69	-0.08
33	KAKINADA	0.71	0.15	-0.3	-0.17	3.7	-2.96	1.74	-0.71	5.28	0.05	0.28
34	BELGAON	-0.13	0	0.08	0.5	-0.81	-0.25	2.85	-3.43	-1.75	-5.14	-0.27
35	KOZIKODE	0.33	0.24	0.39	0.04	0.36	0.17	1.86	-1.56	-0.31	-0.46	-0.11
36	MUKTESHAWER	0.5	0.04	0.11	0.29	7.81	-3.21	3.22	-3.84	9.14	-1.74	0.08
37	JALPAIGURI	0.29	-0.52	0.21	-1.28	0.49	-0.26	3.38	2.01	2.8	3.78	0.07
38	KODIAKANAL	-0.15	0.88	0.26	0.58	1.27	-3.61	2	-2.73	1.15	-0.46	0.11
39	AMINIDEVI	0.46	0.41	-0.01	0.28	5.32	-2.51	1.57	-1.69	6.35	-0.68	0.28
40	MUSSORIE	0.18	0.25	-0.04	0.63	2.22	-4.84	1.27	-4.93	0.57	-1.44	0.04
41	BAREILY	-0.11	0.7	0.15	0.09	1.63	-1.32	2.84	-2.01	4.13	-1.55	-0.03
42	MAINPURI	0.21	-1.38	0.4	0.06	-0.24	0.1	3.15	-4.87	0.38	-6.21	-0.34
43	DARJEELING	-0.19	-0.75	-1.05	-0.26	-2.45	-0.64	-2.04	1.82	-0.26	7.5	0.11
44	DIBRUGARH	-1.11	1.08	0.21	0.24	-1.49	-5.6	-0.21	-5.93	0.36	-6	0.01
45	DABHANGA	0.33	-0.12	0.31	0.45	3.96	0.61	4.21	-3.44	3.18	-3.08	-0.21
46	MINICOY	0.06	-0.56	-0.58	-0.48	0.71	-1.06	-4.94	0.87	-0.54	-5.68	0.42
47	DHUBRI	0.55	0.15	0.28	0.64	8.04	-4.06	4.83	-9.82	9.26	-11.81	-0.23
48	KOTA	-0.45	0.17	-0.12	0.55	-0.5	-2.3	1.49	-3.26	0.58	-1.22	-0.11
49	PURNEA	0.59	0.52	0.2	0.26	3.7	-1.49	4.68	-3.13	5.53	-2.25	-0.09
50	PATNA	-0.65	0.13	0.38	0.87	0.64	-2.47	0.5	-8.68	-6.04	-10.75	-0.26
51	BHUJ (A)	0.21	-0.26	0.46	-0.1	1.18	-1.22	1.78	-2.52	2.37	-2.92	-0.09
52	HAZARIBAGH	0.01	0.12	0.34	0.42	1.34	-0.42	2.62	-1.16	1.98	0.16	-0.11
53	BURDWAN	0.03	0.56	-0.3	0.01	-1.29	-1.65	-1.43	-3.67	-3.7	-4.8	0.01
54	KRISHNANAGAR	-0.04	-0.16	-0.08	-0.23	-0.24	-0.15	-2.48	-0.58	-1.93	-4.43	0.13
55	RAJKOT	0.42	-0.86	-0.35	0.21	-0.69	-1.9	-2.78	-3.35	-6.64	-6.63	0.02
56	HOSHANGABAD	-0.01	0.87	0.33	0.76	0.99	-3.79	4.1	-5.34	3.45	-3.28	-0.16
57	PACHMARHI	-0.2	-1.05	-0.24	0.12	-2.76	1.26	-0.8	-1.71	-0.45	-0.83	-0.48
58	SEONY	0.22	-1.38	-0.05	-0.12	-0.64	1.84	-2.47	0.02	-1.41	0.66	-0.14
59	CHAIBASA	0.13	-0.09	0.2	0.17	0.95	-1.47	4.98	-1.89	1.39	1.83	-0.23
60	MIDNAPORE	-0.37	0.4	-0.37	0.11	-1.48	-2.04	-0.16	-2.7	-1.67	-2.3	-0.03

61	BHAUNAGAR (A)	-0.75	0.19	-0.11	0.57	-1.59	-0.98	1.24	-6.14	-1.21	-7.98	-0.35
62	KHANDWA	0.21	0.22	0.06	0.81	0.65	-1.35	1.96	-4.09	1.17	-2.42	-0.25
63	AMRAOTI	0.08	-0.23	-0.13	0.53	-0.58	0.1	0.71	-4.47	-2.93	-7.49	-0.45
64	ANGUL	0.41	-0.26	-0.37	-0.68	1.39	-0.82	-1.82	4.09	1.62	6.4	0.39
65	AHMEDNAGAR	0.18	0.6	-0.24	0.25	1.98	-2.71	-0.05	-6.69	-0.85	-12.46	-0.15
66	AURANGABAD	0.18	-0.4	-0.45	-0.14	-4.64	1.83	-1.32	0.93	-5.63	0.46	-0.22
67	HANAMKONDA	0.19	-0.21	-0.77	-0.23	-2.1	1.73	-0.07	2.38	-4.31	4.27	-0.09
68	KALINGAPATNAM	0.19	-0.07	-0.36	0	-0.11	-1.8	0.09	-2.88	1.25	-3.4	-0.04
69	BIDAR	-0.46	-0.43	0.02	0.44	-1.53	3.84	1.97	-3.72	-0.63	-9.07	-0.49
70	RAICHUR	0.65	0.02	-0.11	-0.51	3.91	-2.49	-0.38	1.06	5.62	0.56	0.4
71	KARWAR	0.68	0.56	-0.21	0.18	4.34	-5.91	-1.18	-2.76	4.98	-2.11	0.45
72	CHITRADURG	0.2	0.24	0.06	0.78	4.93	-2.9	3.54	-5.04	3.84	-4.28	-0.05
73	CUDDAPAH	0.21	-0.26	-0.15	-0.12	2.37	-1.56	1.5	-1.35	1.83	-0.94	0.09
74	HASSAN	0.41	0.72	-0.35	0.1	1.88	-1.96	-2.47	1.72	3.43	10.93	0.43
75	MERCARA	0.22	0.04	0.4	1.02	0.04	0.92	3.8	-7.72	-1.34	-12.33	-0.66
76	MYSORE	0.47	0.07	-0.1	-1.37	1.79	-3.07	-0.68	3.24	-3.2	0.68	0.56
77	OOTAKAMUND	0.27	0.65	-0.14	0.36	4.36	-2.59	3.47	0.71	7.6	5.06	0.18
78	SALEM	0.05	0.35	0.05	0.74	0.9	-1.22	1.44	-2.34	0.31	-2.05	-0.02
79	PORT BLAIR	0.15	0.39	0.23	0.15	3.56	-2.19	-0.66	0.68	0.97	0.57	0.32
80	AMBAL	-0.04	0.04	0.67	0.28	1.83	-1.46	5.2	-4.3	0.14	-2.84	-0.36
81	GAUHATI	-0.12	-0.87	-0.17	-0.28	-0.88	1.07	0.97	0.77	-1.89	2.89	-0.1
82	TEZPUR	0.21	0.04	0.21	0.29	1.2	-0.44	2.88	-3.39	1.39	-0.82	-0.24
83	BERHAMPORE	0.09	-0.68	0.05	0.24	-3.62	2.24	0.33	-2.51	-9.92	-2.76	-0.53
84	CALCUTTA	-0.44	0.43	-0.43	-0.19	1.68	-2.58	0.11	-1.57	2.43	0.64	0.17
85	CUTTACK	0.12	-0.94	0.09	-0.29	-0.62	0.12	0.76	-1.38	-1.12	0.05	-0.11
86	PURI	-0.02	-0.08	-0.01	-0.35	-1.56	-1.68	-1.03	-3.46	-1.31	-7.63	-0.09
87	VISHAKHAPATNAM	0.51	-0.43	0.33	-0.15	2.52	-1.43	1.19	-3.92	5.87	-0.94	-0.23
88	SAMBALPUR	-0.51	-0.67	0.17	0.23	-0.74	2.02	1.54	-1.35	-0.91	-1.55	-0.23
89	PATNA	0.45	0.9	-0.58	-0.07	0.21	-3.93	-1.42	1.15	-0.51	3.58	0.46
90	RANCHI	0.09	-1.02	0.19	-0.43	-0.92	0.15	0.58	-1.89	0.13	-0.9	-0.27
91	RAIPUR	0.09	-0.23	0.14	-0.32	1.33	-3.11	1.67	-1.08	1.36	0.33	0.17
92	AKOLA	-0.06	-0.51	-0.21	-0.44	-0.58	-0.58	-2.07	-0.46	-1.41	-0.49	0.03
93	NAGPUR	0.12	-0.37	-0.75	0.65	-1.14	-0.28	-1.83	-1.81	-2.15	2.09	-0.08
94	JHANSHI	0.38	0	-0.24	-0.92	0.21	-0.49	-2.39	1.68	-0.87	0.03	0.31
95	INDORE(A)	0.45	-0.71	-0.52	0.16	0.28	-2.36	-1.1	-3.6	1.41	-6.93	-0.01
96	JABALPUR	0.34	-0.73	0.5	0.28	2.01	-1.65	1.09	-2.46	1.68	-1.47	0.02
97	SAGAR	0.15	-0.59	0.18	0.21	-2.8	0.98	1.46	-3.32	-3.83	-3.44	-0.59
98	GAYA	0.44	-0.77	0.12	-0.41	1.22	-1.44	1	-1.25	1.67	-2.07	0.06
99	ALLAHABAD	0.13	-0.45	-0.29	-0.36	-1.41	0.13	-2.41	-0.04	-2.65	-3.09	0.06
100	LUCKNOW	0.07	-1.11	0.52	0.22	1.06	-0.87	3.65	-4.54	2.23	-3.65	-0.38
101	DELHI	0.3	-1.21	0.09	0.1	1.37	-1.53	0.56	-2.82	1.24	-3.85	0.07
102	AMRITSAR	0.39	-0.31	0.09	-0.11	0.04	0.01	0.25	-0.73	2.23	1.01	0.02
103	JAIPUR	0.27	-0.72	-0.32	0.2	-0.85	0.59	0.31	-0.43	1.23	-0.83	-0.1
104	SIMLA	0.48	0.24	0.31	0.53	2.98	-1.54	3.59	-4.14	5.19	-1.77	-0.16
105	SRINAGAR	1.06	1.31	0.84	1.44	5.12	-4.59	5.54	-5.11	8.84	-1.85	0.05
106	JODHAPUR	0.22	0.19	0.28	0.53	1.23	-1.53	1.39	-2.31	4.63	-3.26	0.04
107	ABU	0.21	0.01	0.27	0.47	1.54	-0.42	1.38	-2.33	4.89	-1.07	-0.19
108	AHAMADABAD	0.36	0.52	-0.57	-0.66	1.02	-1.23	-5.65	3.1	4.64	5.19	0.89
109	DEESA	-0.16	0.55	0.3	-0.07	0.02	-0.53	1.13	-2.04	1.12	-3.3	-0.18
110	BOMBAY	-0.05	0.5	0.14	0.06	1.28	-1.25	0.29	-0.87	3.76	-0.39	0.12
111	TRIVANDRUM	0.43	0.31	0.17	-0.27	3.56	-3.48	1.2	0.45	3.8	3.04	0.34
112	POONA	0.62	0.18	0.01	-0.47	5.9	-3.67	-0.05	-1.21	6.18	0.39	0.34
113	HYDERABAD	0.12	-0.47	0.17	0.28	-0.28	-0.07	-0.03	-1.15	2.28	-1.62	-0.05
114	URNOOL	0.29	-0.78	0.13	0.01	1.99	-1.47	-0.13	-0.71	3.04	-2.07	0.12
115	IJAPUR	0.42	0.23	0.45	1.15	0.94	-1.16	2.98	-6.04	-1.73	-6.75	-0.32
116	BANGALORE	0.04	0.29	0.02	0.39	-0.74	-1.03	3.51	-2.32	-1.01	-1.46	-0.22
117	MANGALORE	0.26	0.24	0.48	0.36	2.65	-1.8	3.6	-3.94	1.51	-3.13	-0.03
118	MASULIPATANAM	0.9	-0.37	-0.45	-0.36	4.32	-5.19	-3.86	-1.23	2.94	-6.05	0.6
119	COIMBATORE	0.59	-0.14	-0.08	0.42	2.79	-1.4	2.85	-6.97	-6.75	-14	-0.24
120	MADRAS	0.16	0.66	0.15	0.04	2.45	-2.9	1.52	-2.47	0.62	-1.24	0.11
121	SIBSAGAR	0.47	-0.03	-0.12	-0.16	4.65	-3.68	-0.1	-1.12	5.61	-0.87	0.44
	Positive trend	91	63	66	76	81	26	78	24	77	33	53
	Negative trend	30	58	55	45	40	95	43	97	44	88	68

Table 15b

Trends in annual precipitation extremes (India)

SN	Station name	RX1day	RX5day	R10mm	R20mm	R30mm	SDII	R95p	R99p	CDD	CWD	Prcptot
1	Agartala	-2.15	-8.35	-1.14	-0.53	-0.36	-0.6	-21.42	-6.38	-0.06	-0.06	-44.09
2	Guwahati A. P	-2.32	-1.25	0.83	0.55	0.65	0.01	7.56	-5.82	0.56	0.56	28.77
3	Tezpur	3.01	2.85	0.91	1.09	0.79	0.33	51.31	15.22	0.23	0.23	56.24
4	Berhampore	6.38	14.84	1.39	0.82	1.45	0.9	80.38	25.03	0.06	0.06	76.47
5	Calcutta	13.39	19.25	2.54	2.14	1.46	0.72	49.75	31.63	-0.4	-0.4	111.67
6	Cooch Behar A. P	-5.74	1.79	2.17	1.1	1.04	0.46	87.74	9.57	0.4	0.4	137.78
7	Darjeeling	****	****	****	****	****	****	****	****	****	****	-99.9
8	Midnapore	7.69	9.72	2.32	1.19	0.92	0.24	60.4	16.54	0.06	0.06	94.41
9	Balasore	-1.49	-0.18	-0.01	-0.13	0.05	-0.18	-37.37	-4.89	-0.06	-0.06	-23.5
10	Bhubaneshwar	****	****	****	****	****	****	****	****	****	****	-99.9
11	Chandbali	6.67	4.11	-0.19	-0.41	0.37	-0.61	-5.2	10.77	0.14	0.14	11.56
12	Gopalpur	0.39	-5.74	-0.78	-0.5	-0.58	-0.43	-32.48	-11.98	-0.24	-0.24	-48.99
13	Puri	4.09	3.66	0.26	-0.21	0.21	-0.13	9.13	1.73	0.01	0.01	6.78
14	Sambalpur	6.44	1.59	-1.76	-0.75	-0.52	-0.26	1.42	20.57	-0.27	-0.27	-37.85
15	Titlagarh	6.96	-1.47	-1.53	-0.45	-0.14	0.34	36.57	26.07	-0.44	-0.44	-1.97
16	Daltongang	14.71	23.39	0.33	0.15	0.33	0.78	62.96	33.69	-1.25	-1.25	51.84
17	Darbhanga	-1.24	-16.96	-1.99	-2.1	-1.78	-0.61	-26.64	-5.61	-0.38	-0.38	-102.16
18	Dhanbad	3.54	11.34	3.64	1.25	0.58	-0.16	34.26	18.9	0.81	0.81	108.94
19	Gaya A. P	2	6.02	0.58	0.21	0	-0.1	1.84	5.64	0.07	0.07	18.48
20	Hazaribagh	-2.29	8.39	-0.07	0.28	1	1.43	3.58	-14.33	-0.91	-0.91	4.16
21	Muzaffarpur	****	****	****	****	****	****	****	****	****	****	-99.9
22	Patna A. P	1.95	11.21	1.65	1.31	0.61	-0.04	38.33	16.77	0.3	0.3	74.82
23	Purnea	14.69	14.18	0.92	0.32	0.12	0.36	57.18	40.09	-0.17	-0.17	59
24	Ranchi	5.42	3.67	-0.87	-0.25	0.38	-0.59	38.05	7.3	0.76	0.76	27.78
25	Sabaur	0.9	2.09	1	0.16	0.42	-0.09	0.1	13.18	-0.03	-0.03	38.66
26	Agra	-4.91	-15.43	-0.5	-0.85	-0.81	-0.99	-45.41	-17.78	-0.14	-0.14	-47.25
27	Aligarh	-20.75	-41.84	-1.14	-1.45	-1.44	-3.35	-44.98	-33.84	-0.1	-0.1	-141.9
28	Allahabad A. P	-8.5	-7.89	0.51	0.08	0.25	-0.7	-10.45	-20.9	-0.19	-0.19	5.49
29	Baharaich	9.29	28.8	1.54	1.19	0.47	0.41	48.79	32.36	0.27	0.27	78.26
30	Bareilly	1.13	6.92	0.45	0.71	0.79	0.14	25.16	2.51	-0.2	-0.2	37.2
31	Dehra Dun	3.73	-6.2	0.68	0.47	-0.04	-0.47	41.64	-1.5	1.33	1.33	37.09
32	Gonda	11.83	14.01	0.11	-0.47	-0.78	-0.2	15.01	22.73	0.69	0.69	-11.3
33	Gorakhpur	-0.21	-0.19	0.58	0.68	0.6	0.56	17.91	-3.85	-0.02	-0.02	38.89
34	Jhansi	-15.53	-22.43	-0.73	-0.43	-0.28	-0.43	-44.16	-26.14	-0.46	-0.46	-50.5
35	Lucknow A. P	0.92	1.9	-0.31	-0.06	-0.06	-0.48	1.81	0.17	-0.12	-0.12	2.13
36	Mainpuri	-9.71	-12.61	0.53	0.35	0.22	-0.08	-25.02	-21.44	-0.12	-0.12	-8.81
37	Roorkee	-14.06	-19.04	1.07	0.12	-0.32	-6.12	-32.73	-16.3	0.82	0.82	-4.78
38	Varanasi	7.48	2.82	0.98	0.27	-0.06	-0.06	1.76	3.33	-0.3	-0.3	22.49
39	Ambala	6.46	9.85	0.74	0.51	0.01	-0.67	8.98	20.56	-0.02	-0.02	24.1
40	Hissar	3.72	-0.31	-0.25	0.23	-0.09	-0.38	-6.46	9.95	0.02	0.02	1.96
41	New Delhi	-5.29	-6.66	0.15	0.18	-0.21	-0.47	-13.07	-10.42	-0.17	-0.17	-3.77
42	Amritsar A. P	0.14	-4.38	0.17	-0.71	-0.8	-1.12	-13.18	12.88	-0.37	-0.37	-16.7
43	Ludhiana	3.29	-11.79	0.02	-0.53	-0.64	-1.35	-29.26	-0.09	-0.14	-0.14	-18.53
44	Patiala	12.68	14.31	0.27	-0.18	-0.22	-0.2	32.3	31.92	-0.12	-0.12	32.29
45	Dalhousie	****	****	****	****	****	****	****	****	****	****	-99.9
46	Dharamsala	-4.08	-33.25	0.07	-1.32	-2.08	-4.57	-90.84	-57.18	0.78	0.78	-149.7
47	Shimla	1.81	-3.69	-0.14	-0.83	-0.73	-0.34	5.79	12.44	-0.85	-0.85	-16.73
48	Jammu A. P	-1.08	-5.71	1.61	1.18	1.13	-0.17	-2.19	-0.48	-0.12	-0.12	65.96
49	Srinagar	2.2	4.15	-0.82	0.13	0.12	-0.08	8.35	9.34	-0.09	-0.09	-3.79
50	Abu	****	****	****	****	****	****	****	****	****	****	-99.9
51	Ajmer	0.52	0.16	0.12	0.07	0	0.37	11.96	-3.21	-0.11	-0.11	5.8
52	Alwar	9.21	0.08	-0.93	-0.14	-0.1	-1	2.41	18.97	-0.22	-0.22	7.73
53	Barmer	5.57	7.29	0.03	0.15	0.31	-0.27	18.72	7.25	0.08	0.08	20.35
54	Bikaner	5.09	4.14	0.77	0.34	0.18	0.37	20.33	11.9	0.16	0.16	26.15
55	Ganganagar	4.69	2.65	0.52	0.22	-0.01	-0.95	13.06	9.54	0.11	0.11	24.88
56	Jaipur A. P	0.64	2.63	-0.17	-0.14	-0.26	0.02	1.76	5.66	-0.42	-0.42	-7.12
57	Jaisalmer	5.22	1.45	-0.12	-0.07	-0.05	0.69	7.61	10.02	-0.04	-0.04	3.87
58	Jhalawar	4.93	0.83	-1.17	-0.61	-0.3	-0.25	-13.34	10.21	-0.29	-0.29	-54.12
59	Jodhpur A. P	15.58	21.04	0.05	-0.03	0.06	0.99	26.74	24.83	-0.13	-0.13	22.41
60	Kota A. P	-1.71	-0.44	-0.19	-0.47	-0.47	-0.46	-9.15	-7.81	0.02	0.02	-14.79
61	Phalodi	-1.71	-8.22	-1.25	-0.59	-0.41	-1.47	4.59	6.69	-0.27	-0.27	-26.88

62	Sikar	2.79	-3.58	-0.21	-0.08	0.3	1.77	3.61	7.5	-0.18	-0.18	-5.96
63	Udaipur	4.7	2.64	-0.3	-0.41	-0.31	0.08	2.6	7.41	-0.32	-0.32	-9.72
64	Betul	11.2	11.42	0.38	0.9	0.58	0.13	14.62	6.21	-0.16	-0.16	37.25
65	Bhopal A. P	5.23	8.19	1.28	0.63	0.45	0.05	26.48	17.27	0.19	0.19	54.34
66	Guna	10.95	-0.18	-0.96	-0.26	-0.1	-0.19	-1.1	27.55	-1.03	-1.03	-13.43
67	Gwalior	1.52	-9.34	-0.73	-1.16	-0.71	-1.08	-27.5	-7.04	-0.22	-0.22	-49.5
68	Indore A. P	6.16	10.99	0.53	0	0.04	0.13	15.63	16.59	0.59	0.59	18.96
69	Jabalpur	6.76	8.9	0.2	0.46	0.31	0.27	21.36	13.83	-0.58	-0.58	19.52
70	Khandwa	-1.41	-13.41	-0.77	-1.02	-0.81	-0.59	-45.72	-1.6	-0.44	-0.44	-55.52
71	Nowgong	-5.38	-4.89	-0.11	-0.18	0.55	0.6	29.21	-8.83	-0.77	-0.77	17.76
72	Pachmarhi	4.76	14.29	-0.21	-1	-0.22	0.49	11.02	14.37	-3.14	-3.14	-23
73	Pendra	6.82	5.86	-1.43	-0.66	-0.25	-0.27	5.01	17.23	-1.01	-1.01	-23.18
74	Raipur	****	****	****	****	****	****	****	****	****	****	-99.9
75	Ratlam	-0.6	6.25	0.48	0.53	0.1	-0.13	-6.22	5.77	0.99	0.99	2.33
76	Sagar	-4.97	-13.99	-0.39	-0.43	-0.48	-0.67	-32.5	-21.06	-0.53	-0.53	-37.3
77	Satna	5.35	7.47	-0.73	-0.26	-0.3	-0.31	10.79	8.78	0.15	0.15	-5.05
78	Seoni	4.86	6.2	-1.5	-0.58	-0.3	0.26	12.17	10.01	-1.64	-1.64	-26.47
79	Umaria	1.09	-3.65	-0.17	0	-0.86	-0.1	-19.58	6.87	-1.09	-1.09	-25.35
80	Ahmedabad A. P	11.92	25.81	0.23	-0.02	-0.18	0.73	29.63	18.35	-0.23	-0.23	13.75
81	Deesa	5.12	7.22	0.09	0.14	0.28	0.79	32.38	11.52	-0.64	-0.64	26.02
82	Dohad	1.82	5.22	0.21	-0.04	0.18	0.48	10.33	-3.88	-1.24	-1.24	1.1
83	Rajkot A. P	3.63	0.23	-0.49	-0.59	-0.39	-0.84	-25.41	-5.41	-0.36	-0.36	-31.72
84	Surat	-0.89	6.3	0.22	0.09	0	0.01	-17.44	-0.86	-1.21	-1.21	-9.79
85	Veraval	14.26	18.62	-0.81	-0.45	-0.39	0.16	22.87	29.75	-0.57	-0.57	-2.64
86	Akola	-1.43	-2.42	1.03	0.73	0.4	0.17	11.95	-0.27	0.03	0.03	25.72
87	Ahmadnagar	1.48	7.94	0.84	0.57	0.38	0.64	32.17	8.75	0.29	0.29	27.96
88	Aurangabad A. P	2.1	-0.45	0.37	0.71	0.46	0.42	28.48	10.39	0.22	0.22	36.68
89	Baramati	3.37	5.05	-0.06	0.33	0.45	0.38	20.46	6.9	-0.09	-0.09	16.5
90	Buldhana	0.9	2.26	0.19	-0.08	0.18	0.05	1.81	-12.63	-0.5	-0.5	5.74
91	Chandrapur	-2.07	0.97	-0.29	-0.37	0.12	0.25	37.07	5.71	-1.15	-1.15	7.81
92	Dahanu	-27.5	-44.54	-1.47	-1.64	-1.28	-2.35	-80.53	-89.82	-1.18	-1.18	-208.52
93	Jalgaon	8.33	4.11	0.21	0.38	0.21	0.09	16.43	21.21	-0.07	-0.07	18.25
94	Kolhapur	-3.09	-10.81	-0.75	-0.18	-0.2	-0.25	-14.08	-14.01	-0.79	-0.79	-27.49
95	Mahabaleshwar	3.18	-0.33	-2.46	-2.8	-2.73	-1.49	-82.9	-3.48	-5.29	-5.29	-236.86
96	Malegaon	7.52	16.75	1.75	1.07	1.28	0.3	52.24	21.91	0.22	0.22	84.08
97	Mumbai	9.7	8.74	-1.03	-0.94	-0.82	-0.14	32.47	31.61	-1.84	-1.84	-30.67
98	Nagpur A. P	-1.97	-12.18	0.48	0.08	-0.25	-0.16	-14.83	2.19	0.15	0.15	-12.1
99	Parbhani	6.82	1.87	-0.03	-0.23	0	0.03	14.37	11.95	-0.05	-0.05	9.8
100	Pune	2.74	6.98	0.5	0.54	0.4	0.27	18.36	8.62	-0.3	-0.3	23.65
101	Ratnagiri	7.89	18.25	0.11	0.9	0.96	0.95	54.29	35.55	-2.23	-2.23	84.94
102	Sholapur	-3.04	-5.08	0.24	-0.22	-0.25	-0.33	-7.74	-8.31	-0.11	-0.11	-1.29
103	Anantpur	4.57	2.73	-0.27	-0.19	-0.05	-0.18	10.74	2.18	-0.2	-0.2	0.84
104	Cuddapah	-1.34	-2.93	-0.34	-0.19	0.2	-0.24	9.87	-7.66	-0.04	-0.04	4.5
105	Hanamkonda	-3.12	-3.28	-1.78	-0.24	0.03	-0.3	-1.73	-14.65	-0.43	-0.43	-42.78
106	Hyderabad A. P	3.72	2.42	0.09	0.06	0.4	0.29	32.57	4.3	0.08	0.08	12.08
107	Kakinada	-1.8	1.19	0.62	0.08	-0.08	-0.31	-11.2	13.94	0	0	0.91
108	Kalingapatnam	0.11	0.68	0.18	0.23	0.09	-0.38	-8.75	-3.34	-0.07	-0.07	6.41
109	Khammam	3.19	0.77	-1.75	-0.63	-0.06	-1.21	1.43	15.75	-0.08	-0.08	-16.77
110	Kurnool	-0.94	1.95	0.78	0.67	0.57	-0.27	1.46	-5.79	0.27	0.27	19.85
111	Machilipatnam	2.96	11.67	-0.23	0.21	0.26	-0.09	22.94	8.87	0.09	0.09	10
112	Nellore	-4.86	2.01	0.64	0.55	0.22	-0.18	9.03	6.01	0.17	0.17	21.56
113	Nizamabad	0.12	-0.17	-0.56	-0.41	-0.22	-0.32	4.66	-1.83	-0.4	-0.4	-19.69
114	Ramagundam	3.77	7.43	-0.19	0.22	0.18	0.04	15.06	8.7	0.02	0.02	17.49
115	Vishakhapatnam	-0.7	2.97	0.5	0.19	0.26	-0.23	-4.03	-3.54	-0.03	-0.03	6.88
116	Chennai A. P	-1.65	9.56	0.84	0.83	1.14	0.46	22.65	-8.32	0.62	0.62	57.24
117	Coimbatore	9.66	8.95	-0.1	0.26	0.51	0.22	32.59	22.65	-0.19	-0.19	23.64
118	Cuddalore	-8.66	9.71	0.79	0.95	0.64	0.1	-4.27	-18.98	0.01	0.01	17.56
119	Kodaikanal	4.29	8.66	-1.87	-0.49	0.36	0.27	42.83	12.88	0.24	0.24	-22.85
120	Madurai A. P	-0.83	-5.06	-0.33	-0.18	-0.02	-0.04	3.88	2.23	0.09	0.09	-11.02
121	Nagapattinam	1.13	11.39	0.32	0.83	0.88	0.4	5.95	5.14	0.25	0.25	42.3
122	Palayamkottai	7.7	7.76	0.17	0.34	0.18	0.21	14.82	13.07	0.05	0.05	16.3
123	Pamban	-2.32	-7.17	-0.01	0.01	-0.05	-0.39	-1.39	-9.73	0.51	0.51	-8.93
124	Salem	1.6	2.21	0.73	0.57	0.54	0.17	17.19	5.01	-0.06	-0.06	20.48
125	Tiruchirapalli A. P	0.2	0.89	0.5	0.22	0.19	-0.18	-7.13	7.85	0.19	0.19	2.42
126	Vellore	3.31	3.26	-0.34	-0.13	0.06	-0.18	24.34	8.58	0.21	0.21	3.63

127	Bangalore	2.01	-3.66	0.39	0.27	0.22	0.08	4.79	10.99	-0.21	-0.21	11.41
128	Belgaum	-3.05	-20.07	-2.11	-2.05	-1.38	-0.81	-59.05	-22.92	-1.09	-1.09	-112.32
129	Bellary	-1.35	-0.84	-0.86	-0.19	-0.21	-0.3	-1.67	-4.92	-0.11	-0.11	-21.55
130	Bidar	-2.73	1.8	0.38	0.42	0.33	0.17	10.18	-0.35	-0.15	-0.15	11.98
131	Bijapur	-0.97	-1.99	0.6	0.25	0.31	0.2	4.48	-4.4	0.02	0.02	12.47
132	Chitradurga	6.84	4.34	-0.04	0.33	0.29	-0.04	28.33	19.99	0.18	0.18	18.91
133	Gadag	0.71	-2.96	-0.71	-0.46	-0.23	-0.48	-11.13	6.53	0.1	0.1	-18.81
134	Gulbarga	-1.56	-4.63	-0.13	0.03	0.09	0.14	-11.45	-3.71	-0.48	-0.48	-10.55
135	Karwar	9.23	29.94	-1.63	-1	-0.95	-0.15	8.34	30.77	-1.19	-1.19	-51.41
136	Mangalore A. P	13.37	26.18	-1.26	-0.32	0.12	0.49	84.32	44.22	-3.82	-3.82	38.36
137	Mysore	3.91	1.48	0.84	0.34	0.37	-0.22	16.04	14.08	1.09	1.09	41.04
138	Raichur	1.94	4.31	-0.24	0.08	0.01	0.07	14.84	14.06	-0.03	-0.03	-0.29
139	Cochi A. P	-6.21	-17.86	-0.9	-1.04	-1.12	-0.4	-89.73	-39.25	-1.05	-1.05	-113.8
140	Kozhikode	-2.63	-14.93	-2.05	-1.41	-0.81	-0.21	-5.34	2.82	-1.51	-1.51	-75.85
141	Thiruvananthapuram A. P	8.56	6.84	-0.4	0.74	0.13	0.2	16.73	12.26	0.23	0.23	-1.11
142	Car Nicobar	-4.38	-1.13	-1.48	-0.31	-0.43	0.42	-43.81	6.14	-0.44	-0.44	-77.74
143	Kondul	****	****	****	****	****	****	****	****	****	****	-99.9
144	Port Blair	-2.5	-30.75	-2.14	-1.85	-2.13	-1.07	-36.66	-99.32	-0.2	-0.2	-188.81
145	Amini Divi	4.11	3.15	1.38	0.81	0.35	-0.03	23.66	13.68	0.83	0.83	43.52
146	Minicoy	2.8	0.53	0.17	0.44	0.44	0.16	20.75	4.85	0.24	0.24	10.69
	Positive trend	**91**	**87**	**71**	**73**	**77**	**61**	**92**	**90**	**51**	**51**	**80**
	Negative trend	**48**	**52**	**68**	**66**	**62**	**78**	**47**	**49**	**88**	**88**	**59**

***** indicates trends not calculated

Table 16a

Trends of the Temperature Indices (Nepal)

	TXx	TXn	TNx	TNn	TN10p	TX10p	TN90p	TX90p	WSDI	CSDI	DTR
Biratnagar Airport	0.019	-0.069	0.003	0.005	-0.183	-0.101	0.194	0.325	0.425	-0.900	-0.089
Kathmandu Airport	0.039	-0.186	-0.002	0.041	-0.233	-0.059	0.131	0.354	0.509	-0.321	-0.001
Bhairhawa Airport	-0.077	-0.079	0.024	0.063	-0.560	0.135	0.271	-0.680	-0.867	0.017	0.014
Lumle	0.097	0.035	0.001	-0.005	-0.211	-0.467	0.098	0.926	1.156	-0.044	0.071
Okhaldhunga	0.100	0.041	0.024	0.023	-0.399	-0.306	0.294	1.106	1.424	-0.528	0.06
Chisapani (Karnali)	0.035	0.015	0.015	0.009	-0.124	-0.146	0.157	0.271	0.237	-0.006	-0.002
Positive Trend	5	3	5	5	0	1	6	5	5	1	3
Negative Trend	1	3	1	1	6	5	0	1	1	5	3

Table 16b

Trend of Precipitation Indices (Nepal)

	RX1	RX5	SDII	CDD	CWD	R95p	R99p	PRCPTOT
Kakerpakha	1.11	0.29	0.00	-0.22	0.07	3.77	3.21	3.96
Pipalkot	0.21	1.38	-0.25	-1.15	0.21	3.47	-0.89	8.95
Chainpur (west)	-0.54	-1.82	-0.01	-0.64	-0.05	2.34	-3.82	6.34
Silgadhi (Doti	-0.56	0.21	0.08	0.07	-0.07	0.09	0.28	0.46
Bijayapur	0.98	1.29	0.06	-0.08	0.06	1.75	2.23	8.60
Jajarkot	0.74	0.07	0.03	-0.31	-0.09	2.83	2.45	2.76
Gulariya	0.86	0.32	-0.06	-0.31	0.07	-0.26	2.08	0.03
Ridi bazar	-0.36	1.59	0.07	-0.09	0.04	5.04	-1.79	5.76
Beluwa (girwari)	0.41	0.47	0.17	0.00	-0.10	0.18	2.23	1.72
Kunchha	-1.78	-1.07	-0.08	-0.21	0.00	-6.91	-7.31	0.61
Jhawani	0.05	0.37	-0.06	-1.41	0.12	4.44	0.12	2.92
Chisapani gadhi	-0.02	-0.56	-0.11	-0.31	0.04	-0.35	-0.28	5.86
Ramoli bairiya	0.13	-0.17	0.11	-0.12	-0.01	5.07	3.74	5.86
Aru ghat bazar	0.80	1.69	0.08	0.09	0.05	6.21	1.62	11.38
Gumthang	0.22	-0.47	0.11	-0.18	-0.02	0.37	-0.04	2.15
Dolal ghat	0.54	0.40	0.05	-0.37	0.04	3.28	0.51	9.77
Charikot	0.33	0.10	0.00	-0.37	0.00	5.49	2.15	3.56
Tulsi	-0.74	-0.92	-0.06	-0.28	0.10	-1.45	-1.07	5.40
Chaurikhark	-0.15	0.45	0.07	-0.16	-0.29	5.73	0.51	12.93
Aiselukhark	-0.76	-0.45	-0.04	-0.42	-0.14	2.07	-0.17	2.27
Khotang bazar	0.74	0.07	0.03	-0.31	-0.09	2.83	2.45	2.76
Siraha	-0.63	-1.26	-0.05	-0.16	0.28	-5.30	-7.55	-2.34
Mul ghat	-0.15	0.82	0.22	-0.13	-0.07	3.07	-0.41	7.13
Lungthung	0.54	0.37	0.01	-0.10	-0.23	-2.08	0.69	-3.65
Taplethok	-0.63	0.32	0.13	0.16	0.72	0.85	-4.04	29.87
Ilam tea estate	0.83	0.01	-0.17	-1.12	0.33	1.08	3.18	-0.93
Anarmani birta	-0.72	-0.53	-0.01	-0.41	0.65	-0.87	-1.47	1.12
# of Positive trend	15	18	15	3	15	20	15	24
# of Negative Trend	12	9	12	24	11	7	12	3

Table 17a

Trends of Temperature, Pakistan

Station	TXx	TXn	TNx	TNn	TX10p	TX90p	TN10p	TN90p	WSDI	CSDI	DTR
Bahawalpur	0.07	-0.10	-0.07	0.01	-0.03	0.03	0.01	-0.37	-0.43	-0.18	0.04
Chitral	0.02	0.05	-0.06	0.03	-0.11	0.44	0.15	-0.16	0.55	-0.14	0.07
Dalbandin	0.08	0.10	-0.04	0.10	-0.23	0.39	-0.19	0.34	0.30	-0.21	0.01
D.I. Khan	0.00	0.00	-0.03	0.04	-0.09	0.05	-0.06	0.06	-0.08	0.02	0.00
Faisalabad	0.01	-0.12	0.00	0.08	0.00	0.00	-0.31	0.24	-0.05	-0.23	-0.03
Gilgit	0.06	0.02	-0.11	-0.01	-0.16	0.40	0.22	-0.24	0.37	0.21	0.08
Hyderabad	-0.03	0.01	-0.01	0.04	0.16	-0.18	-0.04	0.14	-0.19	-0.12	-0.04
Islamabad	-0.04	-0.04	0.00	0.06	-0.06	0.06	-0.27	0.17	-0.07	-0.26	-0.01
Jacobabad	0.08	0.02	-0.02	0.04	0.04	0.08	-0.06	0.13	0.05	-0.01	-0.01
Jhelum	-0.02	0.00	0.00	0.05	0.04	-0.09	-0.25	0.15	-0.06	-0.28	-0.03
Karachi	0.00	0.02	0.01	0.07	-0.28	0.22	-0.15	0.51	0.22	0.03	-0.01
Lahore	-0.02	-0.06	-0.01	0.05	0.05	-0.04	-0.42	0.44	-0.02	-0.55	-0.05
Multan	0.06	-0.11	-0.03	0.08	0.16	0.03	-0.24	0.11	-0.04	-0.33	-0.03
Murree	0.11	0.04	-0.04	-0.05	-0.38	0.84	0.39	0.03	0.75	1.07	0.15
Parachinar	0.02	-0.04	-0.33	-0.26	-0.31	0.52	2.57	-0.82	0.66	4.49	0.37
Queta	0.03	-0.02	-0.05	0.05	-0.27	0.28	-0.43	0.17	0.01	-0.60	0.00
Zhob	0.04	0.03	-0.02	-0.09	-0.04	0.58	0.34	0.11	0.62	0.55	0.12
Positive	13	10	4	13	5	13	6	13	9	6	9
Negative	4	7	13	4	11	3	11	5	8	11	8

Table 17b

Trends in Precipitation, Pakistan

Station	Rx1day	Rx5day	SDII	CDD	CWD	R95p	R99p	PRCPTOT
Bahawalpur	0.076	0.272	-0.033	-0.869	0.03	0.391	0.195	2.014
Chitral	0	0.632	-0.006	-0.532	0.012	-0.251	-0.634	0.42
Dalbandin	-0.996	-1.5	-0.067	0.707	0.002	-1.735	-1.527	-1.118
DI Khan	0.388	0.157	-0.016	-1.026	0.012	0.64	0.493	1.534
Faisalabad	0.196	0.197	-0.052	0.316	-0.008	0.02	1.021	0.547
Gilgit	-0.137	0.028	0.001	0.015	0.017	-0.015	-0.319	0.235
Hyderabad	-0.872	-0.631	-0.032	0.682	0.001	-0.257	-0.756	-1.705
Islamabad	0.989	1.911	0.076	0.173	0.01	4.814	2.645	7.958
Jacobabad	0.979	1.148	0.144	-1.034	-0.004	0.786	0.737	2.391
Jhelum	0.384	0.946	0.027	0.082	0.006	1.362	0.948	4.947
Karachi	-0.869	-1.222	-0.094	-0.907	-0.016	-1.956	0.555	-2.545
Lahore	0.186	0.077	0.059	-0.409	0.009	2.813	0.558	5.475
Multan	0.11	0.366	0.043	0.092	0.005	0.622	0.092	1.06
Murree	1.589	2.496	0.111	-0.037	-0.042	8.461	5.247	11.127
P-Chinar	-1.026	-1.609	-0.156	0.254	-0.046	-9.62	-3.78	-12.61
Quetta	0.484	0.141	0.027	-0.107	0.027	1.122	0.374	2.294
Zhob	-0.347	-0.48	-0.001	-0.036	0.005	0.292	-0.75	1.39
Positive	10	12	8	8	12	11	11	13
Negative	6	5	9	9	5	6	6	4

Table 18a

Summary of Temperature Indices (Sri Lanka)

Indices	Puttalam	Colombo	Hambantota	Ratnapura	Apura	Badulla	Nuwaraeliya
txx	0.021	0.024	0.004	-0.01	0.061	0.072	0
tnn	0.054	0.05	0.029	0.06	0.061	0.04	0.064
txn	0.029	0.004	0.025	-0.009	0.03	0.046	0.027
tnx	0.027	0.02	0.004	0.003	0.013	0.046	0.008
tx10p	-0.225	-0.284	-0.267	0.138	-0.364	-0.353	-0.045
tx90p	0.448	0.251	0.377	-0.184	0.524	0.809	-0.01
tn10p	-0.339	-0.321	-0.187	-0.234	-0.516	-0.178	-0.292
tn90p	0.642	0.498	0.338	0.212	0.369	0.348	0.387
wsdi	0.6	0.329	0.459	-0.176	0.4	1.055	0.113
csdi	-0.001	-0.061	-0.061	-0.156	-0.464	-0.129	-0.062
dtr	-0.006	-0.013	0.009	-0.031	0.061	0.029	-0.025

Table 18b

Summary of Precipitation Indices (Sri Lanka)

	RX1day	RX5day	SDII	CDD	CWD	R95p	R99p	PRCPTOT
Puttalam	0.681	1.446	0.042	0.363	-0.062	1.863	2.771	-3.317
Colombo	-0.031	-2.084	-0.005	0.42	-0.071	-6.904	-3.393	-13.211
Batticaloa	-1.396	-3.46	0.031	-0.071	-0.019	-1.375	-4.079	-6.724
Galle	0.036	-0.427	0.009	0.329	-0.01	-2.414	-0.778	-8.967
Hambantota	-0.898	-1.239	0.013	0.567	-0.031	-0.771	-0.926	-6.204
Trinco	-0.672	-0.043	0	0.119	0.017	-2.045	-3.3	-8.176
Ratnapura	0.953	0.314	0.052	0.07	-0.117	4.792	0.415	2.972
Apura	-0.219	-0.519	0.034	0.716	-0.035	-4.138	-0.772	-6.699
Kurunegala	-0.232	0.12	0.021	0.173	0.003	-2.943	-0.864	-6.733
Badulla	0.694	0.55	0.003	0.064	-0.051	-1.491	0.678	-6.302
Nuwaraeliya	0.403	0.43	0.013	0.231	0.017	0.505	0.168	1.241

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