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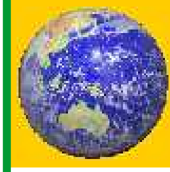

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NCC RESEARCH REPORT

A High Resolution Daily Gridded Rainfall Data Set (1971-2005) for Mesoscale Meteorological Studies

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A High Resolution Daily Gridded Rainfall Data Set (1971-2005) for Mesoscale Meteorological Studies

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Abstract

In this paper, we discuss the development of a very high resolution (0.5^0 x 0.5^0 degree) daily rainfall data set for mesoscale meteorological studies over the Indian region. The data set was developed using quality controlled rainfall data from more than 6000 rain-gauge stations over India. The analysis consists of daily rainfall data for all the seasons for the period 1971-2005. A well tested interpolation method (Shepard's method) was used to interpolate the station data into regular grids of 0.5 X 0.5 degree Lat x Long. The data set was validated against another high resolution daily rainfall data set. A few case studies have been shown to demonstrate the utility of the data set for different mesoscale meteorological analyses.

1. Introduction

Information on spatial and temporal variations of rainfall is important in understanding the hydrological balance on regional scale and water management in agriculture, power generation and drought management. High resolution gridded rainfall data are required to validate regional and mesoscale models and to study the intra-seasonal fluctuations. In recent years, there has been considerable interest in developing high resolution gridded data sets (New et al 1999, Mitra et al. 2003, Yatagai et al. 2005, Rajeevan et al. 2006, Xie et al. 2007). Rajeevan et al (2006) developed a high resolution (1^0 X 1^0 degree Lat X Long) daily rainfall data set for the period 1951-2004, which is being used for research studies (for example, Goswami et al (2006) , Krishnamurthy and Shukla (2008)). However, there have been demands for much higher resolution (say 50 km X 50 km) for mesoscale rainfall analysis and mesoscale meteorological applications.

To meet the requirements of the research community, an initiative was taken up at the National Climate Centre, India Meteorological Department (IMD) to develop a high resolution (50 km spatial resolution) for mescoscale applications using daily rainfall data archived at IMD. In this study, we discuss the development of the high resolution daily gridded rainfall data set using rainfall data from more than 6000 stations for the period 1971-2005.

2. Data and Methodology

For the present analysis, daily rainfall data archived at the National Data Centre, IMD Pune for the period 1971-2005 have been used. Standard quality controls are performed before carrying out the analysis. First, information on the location of the station was verified. The precipitation data themselves are checked for coding and typing errors. Many such errors were identified, which were corrected by referring to the original manuscripts. For the period of analysis, IMD has the rainfall record of 6076 stations with varying periods. Out of these, 547 are IMD observatory stations, 494 are under the hydro-meteorology programme and 74 are Agromet stations. The remaining are rainfall-reporting stations maintained by state Governments. In the rainfall data set developed by Rajeevan et al. (2006), rainfall data of only 2140 stations have been used to minimize the risk of generating temporal inhomogeneities in the gridded data due to varying station densities. However, for the present analysis, we have used all the available stations for interpolating into regular grids. There were about 3500 stations on an average for the daily analysis. However the data density varied from year to year. The network of stations considered for the rainfall analysis is shown in Fig 1 a. The data density is not uniform, however, there are plenty of stations from South India. The daily variation of number of stations used for the analysis is shown in Fig.1b. The data density is more or less satisfactory and uniform till 2004. Data for the year 2005 are however sparse. Since the data density is not kept uniform, there is a possibility of temporal inhomogeneity and therefore, the present analysis cannot be used for trend analysis as done by Goswami et al[6]. However, the data set is useful for many other mesoscale meteorological studies as discussed below.

There are many methods of numerical interpolation of irregularly distributed data to a regular N-Dimensional array. Bussieres and Hogg (1989) studied the error of spatial interpolation using four different objective methods. For application to the specific project grid, the statistical optimal interpolation technique displayed the lowest root mean square errors. This technique and Shepard OA displayed zero bias and would be useful for areal average computations. New et al (1999) used the thin plate splines for interpolation. Mitra et al (2003) used the successive correction method of Cressman for merging satellite derived rainfall data and station data.

For the present analysis, as in Rajeevan et al. (2006), we have used the interpolation scheme proposed by Shepard (1968). In this method, interpolated values are computed from a weighted sum of the observations. Given a grid point, the search distance is defined as the distance from this point to a given station. The interpolation is restricted to the radius of influence. For search distances equal to or greater than the radius of influence, the grid point value is assigned a missing code when there are no stations located within this distance. In this method, interpolation is limited to the radius of influence. A predetermined maximum value limits the number of data points used, which in the case of high data density, reduced the effective radius of influence. We have also considered the method proposed by Shepard (1968) to locally modify the scheme for including the directional effects and barriers. In this interpolations method, no initial guess is required.

We have interpolated station rainfall data into a rectangle grid (69 X 65) for each day for the period 1971-2005. The starting point of the grid is 6.5^0 N and 66.5^0 E. From this point, there are 69 data points towards east and 65 data points towards north. We have created one binary file for each year. For the leap year, we have created data for 366 days.

3. Evaluation of the rainfall data set.

In this section, we examine the quality of the developed 0.5^0 X 0.5^0 daily rainfall data set. Fig.2 a and b show the spatial variation of mean (for the period 1971-2005) and standard deviation of annual rainfall respectively calculated from the present data set. For comparison, the mean and standard deviation of rainfall during the same period derived from the 1^0 X 1^0 degree rainfall data set (Rajeevan et al.[4]) have been calculated and the results are shown in Fig 3 a and b respectively. The mean rainfall pattern shows maximum rainfall along the west coast and over NE India. Another rainfall maximum is observed over the east central parts of India. In comparison, the data set developed in this study with 0.5 degree resolution shows more realistic spatial variation of mean rainfall with finer details of spatial variation. In the mean rainfall pattern with 0.5 degree resolution data, the rainfall maximum around Cherrapunji is clearly observed.

Recently another high resolution rainfall data set was developed at the Research Institute for Humanity and Nature (RIHN). The project is named as Asian Precipitation- Highly Resolved Observational Data Integration Towards Evaluation of the Water Resources (APHRODITE). Under this project a high resolution (0.25 degree X 0.25 degree and 0.5 X 0.5 degree) daily rainfall data set was developed for the Asian region. The basic algorithm adopted by them is based on Xie et al. (2007). Details of the project and the data set are discussed in Yatagai et al.(2005). The daily APHRODITE data set is available at http://www.chikyu.ac.jp/precip/. The data set consists of 0.5^0 X 0.5^0 degree gridded daily rainfall for the period 1980-2002. We have compared the present rainfall analysis with the data set developed under the APHRODITE project. Fig. 4 a shows that correlation coefficient between the southwest monsoon seasonal (June to September) rainfall derived from the present analysis (IMD analysis) and the APHRODITE analysis. Correlation coefficient is very high (exceeding 0.6) over central and NW India. The correlations are however very low along the west coast of India and over some parts of NE India. The differences of the southwest seasonal (June to September) rainfall between the two data sets are shown in Fig. 4 b. The APHRODITE analysis underestimates the rainfall maximum along the west coast and NE India. Otherwise, the differences are mostly within 3 mm/day over the country. The basic difference between the two data sets is the total number of stations used in the rainfall analysis. While IMD analysis used more than 6000 stations as mentioned above, the APHRODITE analysis used on an average only 2000 stations. However, the APHRODITE analysis also could capture the large scale features of monsoon rainfall over the Indian region.

4. Some Case studies

The present IMD rainfall analysis data set can be used for many useful mesoscale applications. In this section, we show the rainfall analysis associated with some important weather situations. Fig 5 shows the daily rainfall maps pertaining to the case studies considered. The first case pertains to the rainfall analysis of 24 August 2000, showing the rainfall distribution associated with the monsoon depression formed over Bay of Bengal and moved northwestwards. The center of the depression is also shown. The maximum rainfall over the southwest sector of the monsoon depression is very well captured in the rainfall analysis. The second case pertains to the disastrous heavy rainfall event occurred over Mumbai on 26/27 July 2005 (Jenamani et al (2006), Bohra et al (2006)) . The rainfall map clearly shows the intense heavy precipitation exceeding 50 cm around Mumbai city. It may be mentioned that the on 26/27 July 2005, intense rainfall amount occurred over a small area less than 2500 km^2 over Mumbai (Jenamani et al. 2006). The third example is heavy rainfall associated with the passage of a tropical cyclonic storm, which crossed the Andhra Coast on 6^{th} October, 1994. The last example is rainfall over NW India, associated with the passage of a winter western disturbance across the northern parts of India on 31 January 2003. These examples are just indicative of many useful applications of the present rainfall analysis.

5. Summary and conclusions

In this paper, we discuss the development of a very high resolution daily gridded (0.5 X 0.5 degree resolution) rainfall data for the Indian region for the period 1971-2005. The data set has been developed using daily rainfall data from more than 6000 stations from the country. A well tested interpolation algorithm was used to interpolate the station rainfall data into regular grids after the basic quality controls were made. The quality of the data set was tested by comparing the present analysis with other gridded data set developed in Japan. Some case studies are shown to demonstrate the utility of the present data set. The data set is available for research studies from the National Climate Centre, India Meteorological Department, Pune (ncc@imdpune.gov.in).

Acknowledgements

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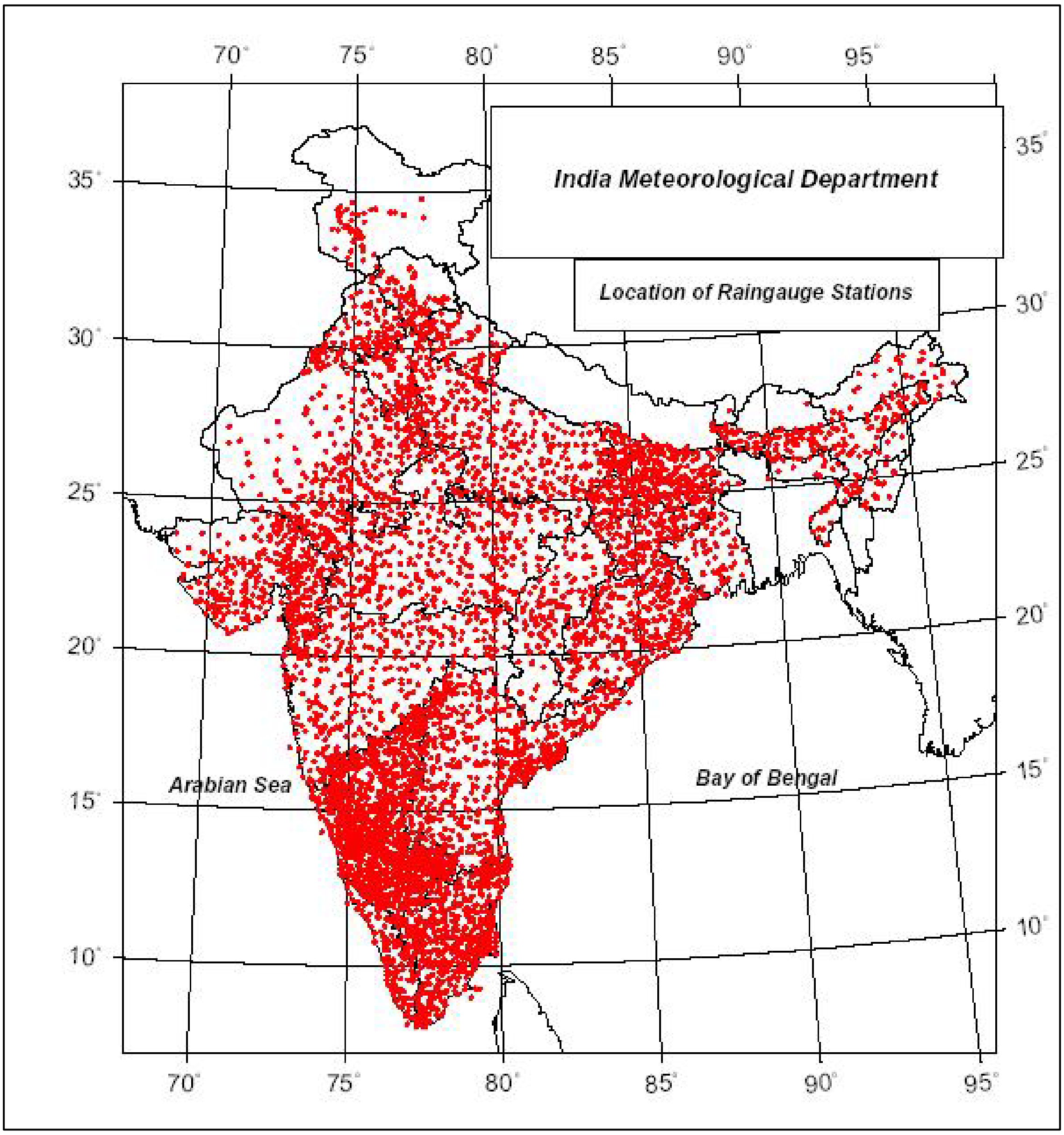


Fig.1a: Network of raingauge stations used for the analysis.
Total number of stations: 6076

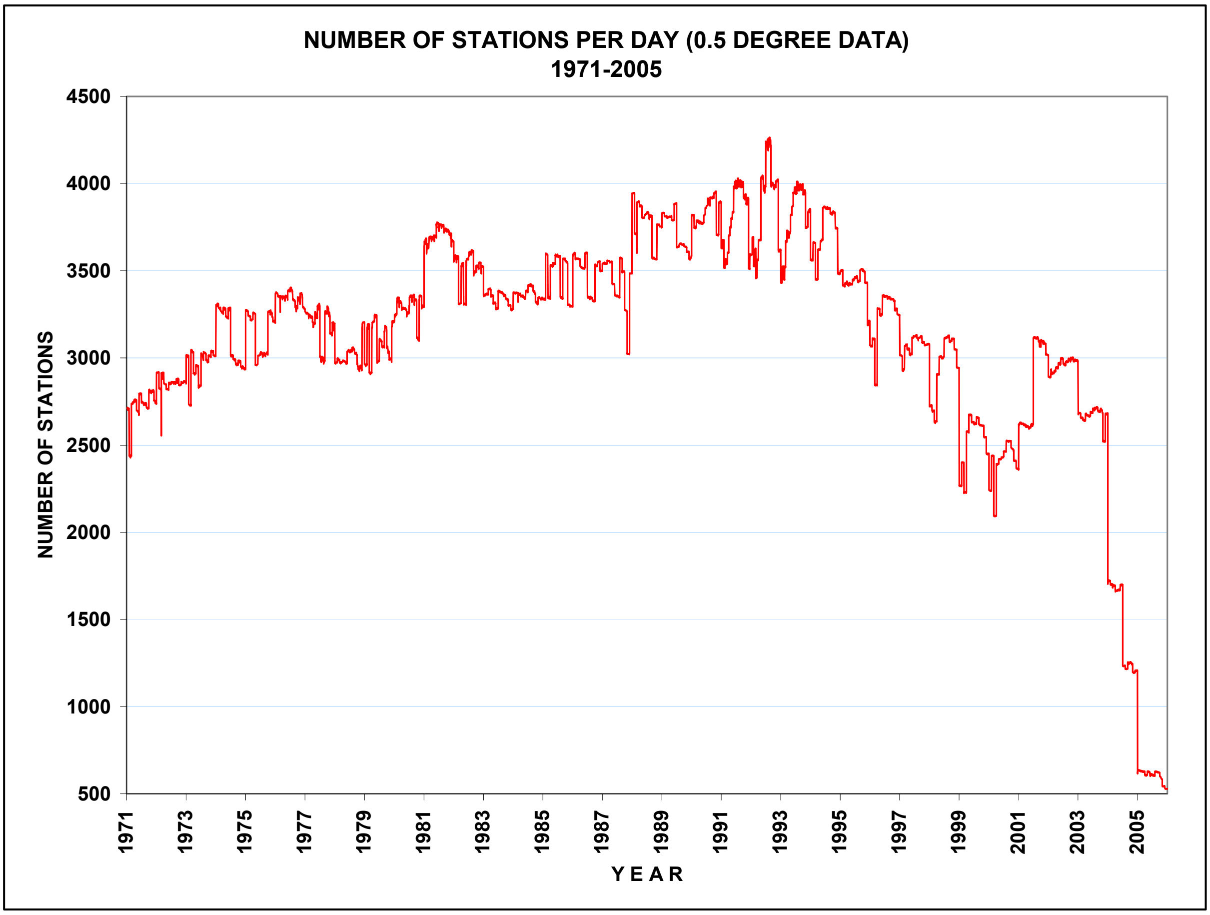


Fig.1 b : Time series of total number of stations used for the rainfall analysis per day for the period 1971-2005.

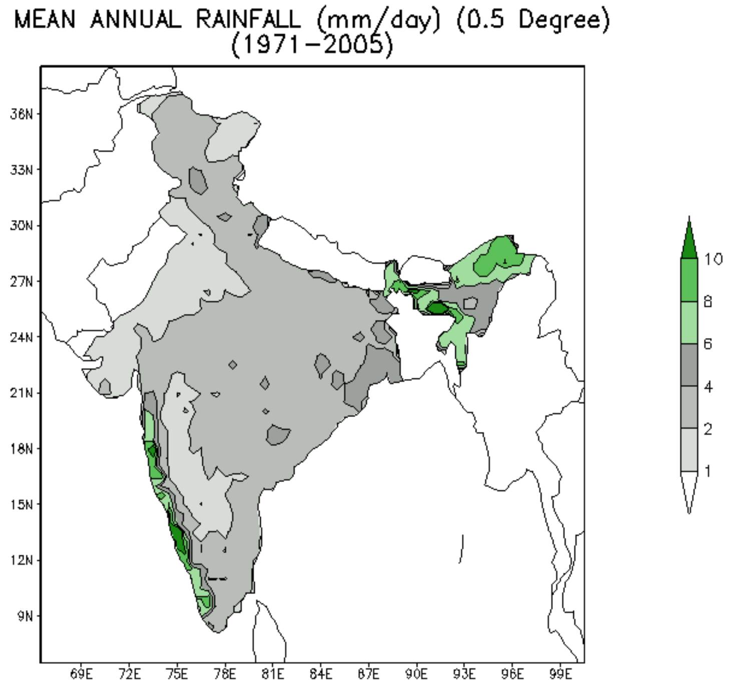


Fig.2 a) : Mean Annual rainfall (mm/day) using the present 0.5 degree analysis

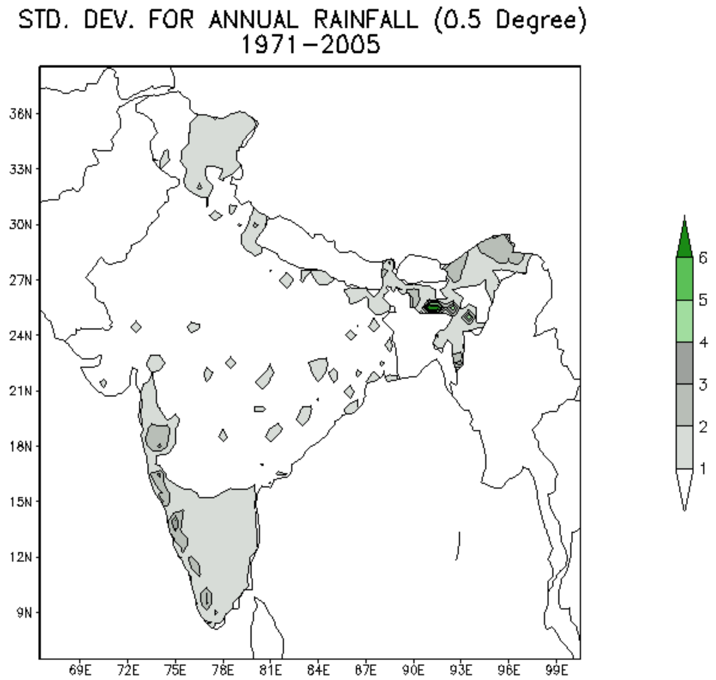


Fig.2 b) : Standard deviation of Annual rainfall (mm/day) using the 0.5 degree analysis.

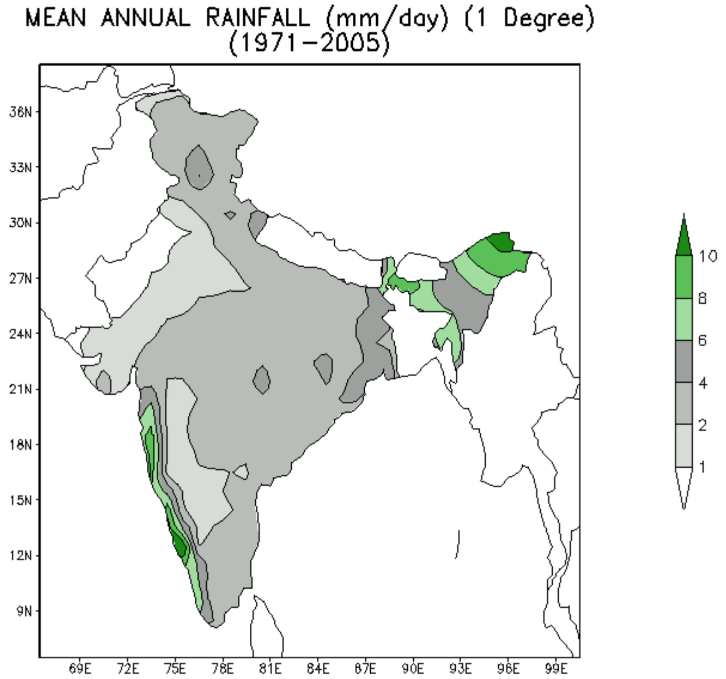


Fig.3 a) : Mean Annual rainfall (mm/day) using the 1.0 degree analysis of Rajeevan et al. (2006)

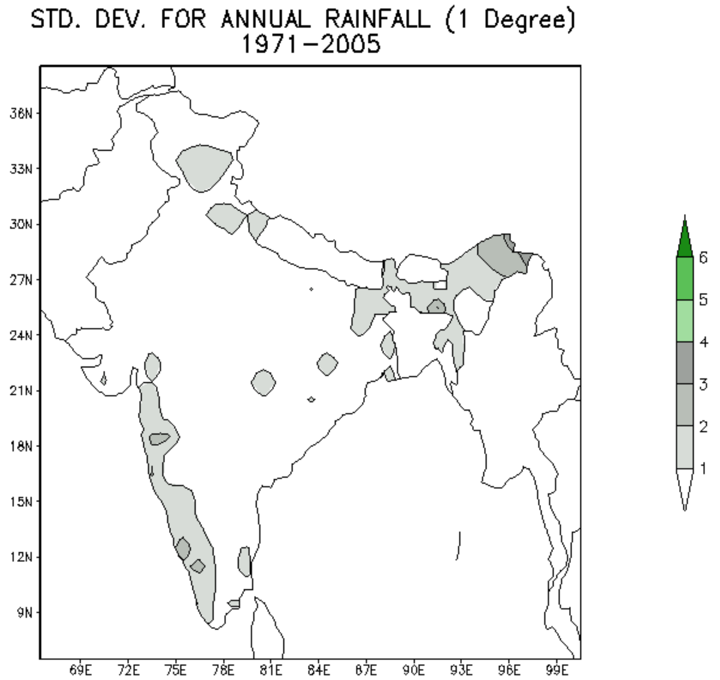


Fig.3 b) : Standard deviation of Annual rainfall (mm/day) using the 1.0 degree analysis of Rajeevan et al. (2006)

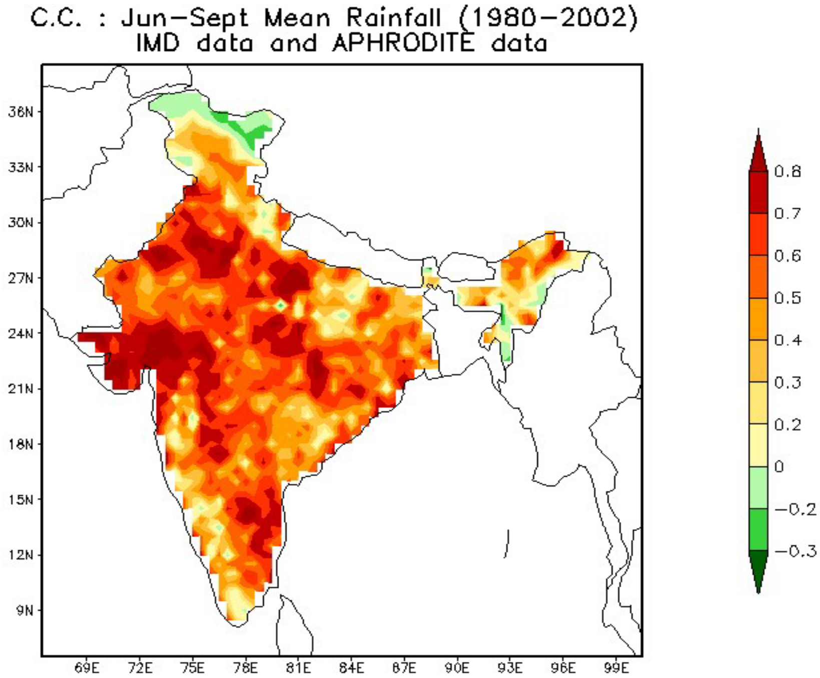


Fig.4 a) : Spatial pattern of correlation between the seasonal rainfall (June to September) from the present IMD rainfall analysis and the APHRODITE analysis. Period: 1980-2002.

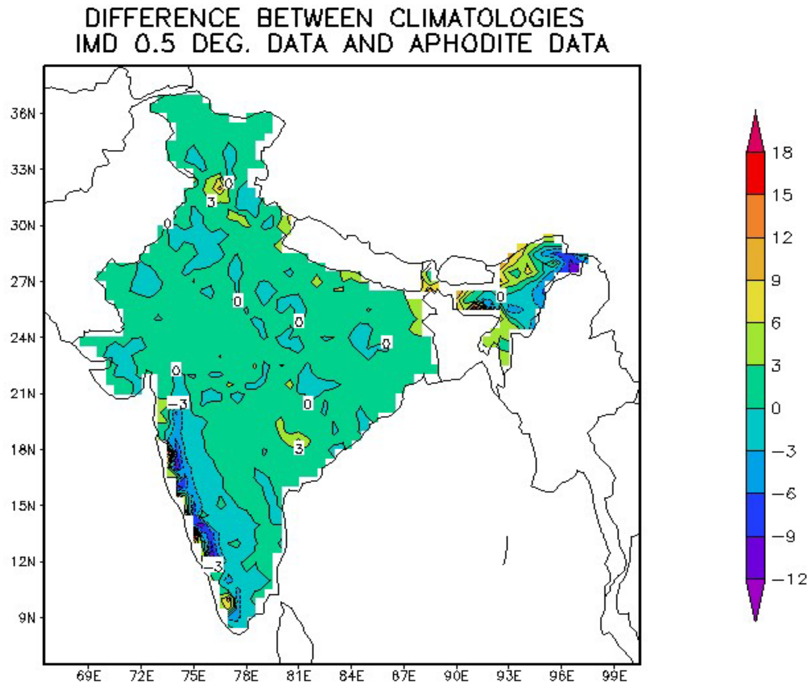
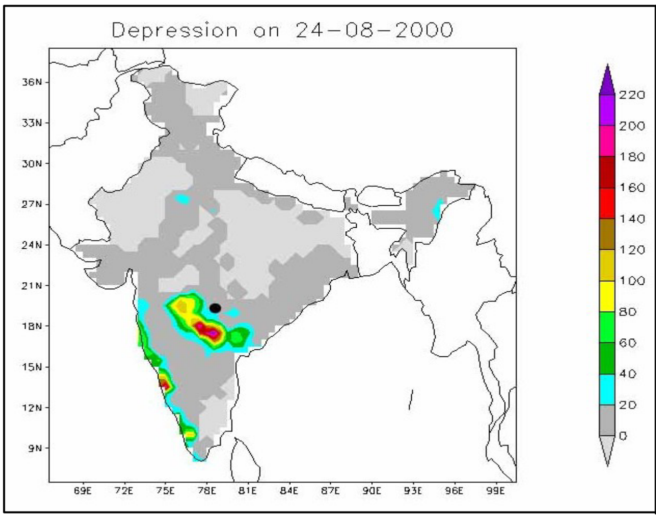
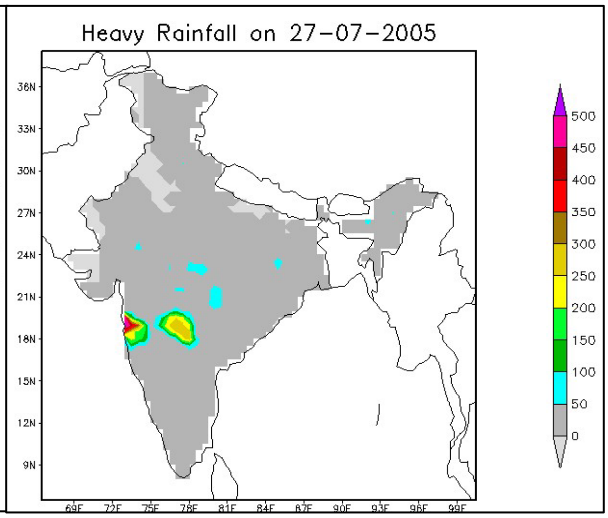


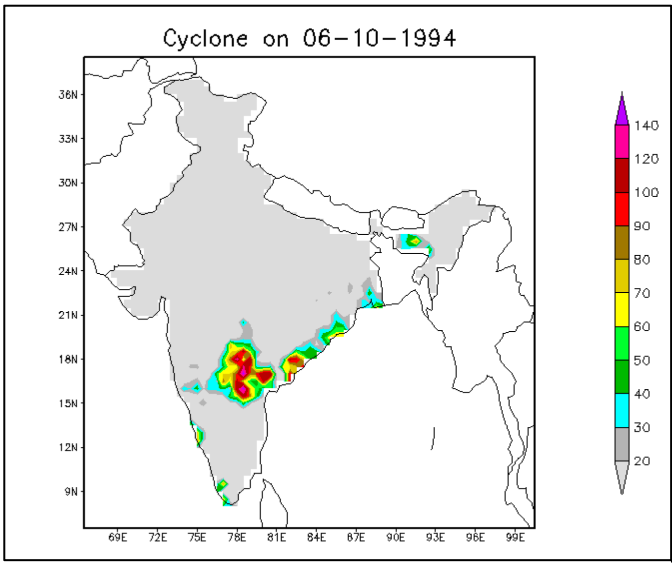
Fig.4 b) Spatial pattern of the differences (mm/day) between the seasonal rainfall (June to September) from the IMD rainfall analysis and APHRODITE analysis. Period: 1980-2002.



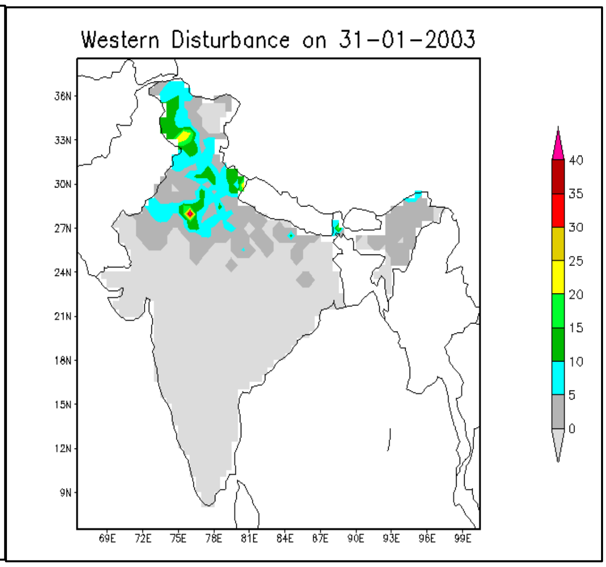
(a)



(b)



(c)



(d)

Fig. 5 : Case studies using the IMD 0.5 degree rainfall analysis a) Rainfall due to the monsoon depression on 24 August 2000 b) Heavy rainfall over Mumbai on 27 July 2005 c) Rainfall due to the Tropical Cyclone on 6 October 1994 d) Rainfall due to a winter western disturbance on 31 January 2003. Note the difference in the rainfall scales.