Statistical Analysis of Meteorological Data over Western India

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Abstract: ***Monthly precipitation data of 70-80ºE, 20-25ºN was studied and analyzed which includes western Indian parts of Maharashtra, Gujarat, and Madhya Pradesh. This data was sourced from NASA's GES-DISC Interactive Online Visualization and Analysis Infrastructure (Giovanni) which displays Earth science data from NASA satellites directly on the internet. Exploratory data analysis was conducted to find trends and insights pertaining to rainfall over the region. Standard deviation from mean annual rainfall value for 1980-1994 is noticeably higher compared to that of 1995-2010 which clearly indicates that variability in rainfall has decreased considerably over the years although mean rainfall figures are nearly the same. The anomalies in rainfall figures of 1994 and that of 2002 were found where excessive rainfall was observed in 1994 and drought in 2002. Reasons for the same is also discussed.***

Keywords: Monsoon, Exploratory Data Analysis, Draught, Variation

1. Introduction

The Indian summer monsoon is very crucial for the country's economic development. Agriculture which contributes 16 % to the GDP of our country, is completely dependent on Indian monsoon. Apart from this, biodiversity hotspots like the western ghats depend upon monsoon which brings the showers for the various flora and fauna. They also replenish lakes and underground aquifers.

Monsoon also affects the inflation rate, as a bumper farm output that keeps food prices under control since food accounts for 50 % of the country's consumer price index, which is monitored by RBI. A good monsoon can increase rural spending on items such as televisions, cars, and gold. The FMCG and fertilizer sectors would benefit the most from the normal monsoon. Up to 40 % of India's cement demand comes from rural housing.

Despite seasonality, monsoon is also affected by other climatic conditions like El Nino also referred to as "boy child" in Spanish, El-Nino is a weather phenomenon characterized by an abnormal warming of the eastern Pacific Ocean that triggers weaker rains and droughts in the Indian subcontinent Some of the years receive less amount of rain due to these effects, affecting the agricultural economy of our country.

According to Indian Meteorological Department, monsoon is considered normal if the rains are 96 - 104 % of the 50-year average rainfall of 89cm. The monsoon is taken to be below normal if rains are between 90-96 %. If less than 90, it is considered deficient. Therefore, analysis of the rainfall data is important. The National Aeronautics and Space Administration (NASA) has acquired a rapidly growing archive of Earth remote sensing data, originating with the Landsat and Nimbus satellite missions in the 1970s and continuing with increasingly ambitious and technologically advanced missions to the present year, marked by the recent launches of the Global Precipitation Mission (GPM) and Orbiting Carbon Observatory-2 (OCO-2) satellites. Since its inception in 2003, the NASA Geospatial Interactive Online Visualization andAnalysis Infrastructure (Giovanni) system provides access to a wide variety of NASA remote sensing data and other Earth science data sets, allowing researchers to apply selected data to a broad range of research topics. Currently hosted by the Goddard Earth Sciences Data and Information Services Centre (GES DISC, Giovanni includes data from many different NASA missions and projects. An in-progress Advancing Collaborative Connections for Earth System Science (ACCESS) project titled "Federated Giovanni" will expand the data available in the system by including data from other NASA data centres.

This variety of data gives potential for the investigation of rainfall trend in India. In this paper we have analysed the rainfall patterns over the region of Maharashtra, Madhya Pradesh covering West India area from 1980 - 2010. Variation of rainfall for each month over the course of 30 years is also presented. Similarly, the deviation from mean rainfall is also analysed for each month. Similarly, various other trend graphs were presented, and their reasons were mentioned.

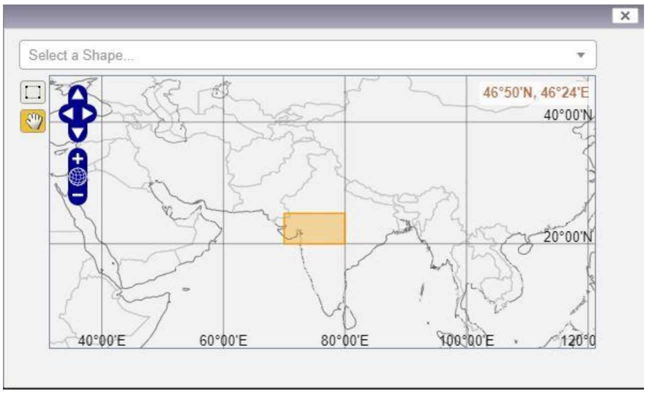

Figure 1: Data taken from highlighted portion

Table 1: Monthly data for 1980-2010

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	4.492429	14.74926	11.23522	8.6747	1.372984	1236.752	1126.762	1460.025	215.5946	4.402471	11.10289	53.18845
1981	19.67195	9.819799	16.5651	5.432071	29.06249	443.551	1437.655	1576.577	846.1129	74.52264	51.30757	29.32578
1982	23.03793	17.70731	22.012	7.065924	38.93177	392.2697	1179.849	1300.823	421.1973	66.82514	76.05065	5.8441
1983	12.97483	11.35528	12.53453	7.530837	13.37542	568.537	1612.622	1763.25	1254.59	178.8079	3.290118	11.52124
1984	18.82627	35.26782	8.646544	2.043822	4.980565	378.9247	1075.374	1662.793	364.346	108.2406	5.554975	4.916195
1985	30.35198	9.484716	15.82931	12.91772	11.06133	467.9271	1277.872	1304.13	404.7464	164.535	4.805631	6.752029
1986	29.36647	26.10497	17.73968	6.113957	26.05158	842.7015	1149.652	1149.512	236.1949	27.11006	12.98755	26.67586
1987	25.26514	18.28452	28.41122	5.040124	23.99695	429.7539	666.6979	1224.244	217.649	83.2144	38.15424	35.52447
1988	5.218087	8.779226	19.56019	13.05891	2.80038	522.6458	1639.502	1193.03	876.4963	69.70326	15.29825	8.109919
1989	9.399231	9.156052	22.49495	8.756071	11.76873	671.9291	902.8623	1279.794	478.3123	10.10971	2.15156	35.43751
1990	4.986854	19.65988	17.80113	8.420919	36.55247	812.6054	1330.153	2210.1	842.0742	110.894	14.67988	12.50154
1991	24.25879	11.70091	21.97932	12.85122	6.23357	749.1004	1580.546	989.77	124.1485	3.560821	27.70861	6.633065
1992	6.797127	15.46294	12.90978	7.99642	18.46361	276.8575	1009.732	1371.038	982.2168	66.17909	6.710575	3.666533
1993	5.000156	23.65398	19.19577	6.803165	23.88451	549.1613	1696.329	840.5511	1059.418	117.3607	21.7444	15.11286
1994	23.60216	14.49473	12.06958	11.76657	11.25128	744.3205	2003.217	1673.568	1218.699	92.05054	14.50538	3.750093
1995	28.64024	15.60881	24.297	10.80077	8.908329	381.9597	1730.466	816.2624	731.5909	90.92218	3.610908	7.896114
1996	31.68739	13.67585	21.92107	11.58016	21.60812	394.1412	1851.239	1318.983	733.6082	149.7505	19.05654	6.589802
1997	18.61032	17.18994	18.26121	8.410441	23.93812	639.5256	1272.16	1399.703	509.8863	76.10823	61.71846	31.72097
1998	7.765794	21.56427	12.61534	8.729468	22.18268	443.1819	1256.235	1253.392	1093.351	114.4494	21.15199	8.01488
1999	7.929497	28.73921	11.62954	7.10016	12.41965	784.8134	1088.466	926.967	1231.994	178.7223	5.80414	5.118376
2000	6.301612	17.14885	24.84308	9.31798	26.42403	450.2158	1910.505	773.7213	189.9182	19.9717	7.637736	6.899413
2001	19.91584	12.72621	26.02576	13.02878	25.1101	1093.75	980.7164	827.8868	130.0843	110.9757	9.362018	6.300122
2002	7.61473	9.302114	12.27258	8.724515	5.91713	854.7196	246.8951	1265.23	489.3711	39.69452	17.59784	6.135663
2003	6.225858	24.91673	20.38886	3.562262	13.97124	660.9877	1652.155	1331.898	897.6764	29.25708	5.040218	22.62045
2004	38.59826	23.79255	16.86149	5.935938	22.60332	650.749	1052.762	1618.623	397.6447	70.55931	33.39368	3.799114
2005	16.68058	7.363566	14.75634	3.552626	12.36958	663.0539	1841.597	996.9128	1313.956	57.08566	3.810424	8.275868
2006	3.486332	21.19627	26.25876	6.270606	14.41042	472.4575	1653.205	1864.383	926.6717	25.87328	37.10264	7.233834
2007	5.514404	12.89144	21.24221	6.118895	13.29386	586.4208	1503.054	1620.621	723.2823	3.82255	12.42069	7.562363
2008	2.788853	19.6768	15.9547	7.352855	14.56372	680.7004	1125.39	1151.944	799.5812	25.96816	13.34633	6.737897
2009	6.422984	17.41882	15.61966	8.926973	13.96711	405.6812	1771.489	861.8698	600.9352	113.754	71.21572	30.74463
2010	7.267996	9.525122	3.141289	3.523844	7.946175	508.3034	1680.845	1817.678	756.3134	66.38257	118.5023	5.275134

2. Literature Review

[0]P. Guhathakurta and M. Rajeevan analysed monthly rainfall data of a fixed network of 1476 rain gauge stations of India for the period 1901-2003. This data was then used to construct annual rainfall time-series of 36 meteorological subdivisions. Linear trend analysis was carried out to anticipate long term trends in rainfall over different subdivisions. The outcome of the analysis over south-west monsoon season revealed a decreasing trend in Jharkhand, Chhattisgarh, Kerala and eight subdivisions viz. Gangetic WB, West UP, Jammu and Kashmir, Konkan and Goa, Madhya Maharashtra subdivision, ŋRayalseema, Coastal AP and North Interior Karnataka showed significant increasing trends. It has been found that the contribution of June, July and September rainfall to annual rainfall is decreasing for few subdivisions while the contribution of August rainfall is increasing in few other subdivisions. The main result of the study can be summarized as an increase in rainfall activities in Konkan and Goa and Maharashtra. This calls for further analysis of the rainfall patterns in this region.

3. Methodology

The NASA Giovanni data analysis system has been recognized as a useful tool to access and analyse many different types of remote sensing data. The variety of environmental data types has allowed the use of Giovanni for different application areas, such as agriculture, hydrology, and air quality research.

4. Trends in Rainfall pattern

4.1 Total Annual Rainfall pattern

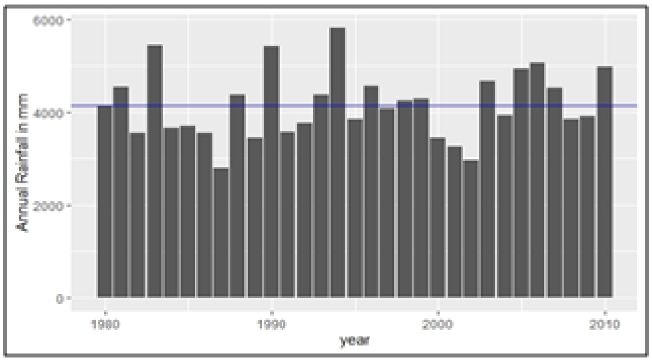

Figure 2: Annual Rainfall Bar Plot

Monthly rainfall data of 31 years viz. 1980 - 2010 is enough to be a representative of the general trend that is followed by rainfall in India. Studying the total annual rainfall over these years reveals occasional highs and lows. Local peaks can be observed in 1981, 1983, 1988, 1990, 1994, 1996, 2006 and

2010. Troughs are observed in 1982, 1987, 1989, 1991, 1995, 2002, 2004, 2008. Close observation of annual rainfall in 1980-1994 and 1995-2010 reveals interesting insights.The standard deviation from mean annual rainfall value for 1980-1994 is 859 mm whereas for 1995-2010 is 619 mm which clearly indicates that variability in rainfall has decreased considerably over the years although mean rainfall figures stand at 4146 and 4163 when calculated over 1980-1994 and 1995-2010 respectively. Also, the three major peaks viz. 1983, 1990, 1994 are all in 1980-1994.

4.2 Monthly Rainfall Pattern

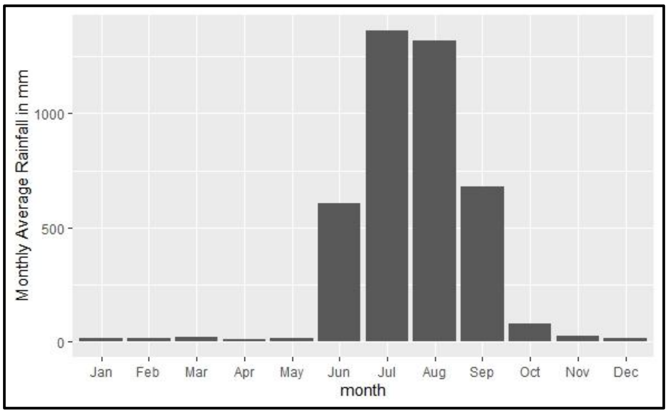

Figure 3: Monthly Average Rainfall over 1980 - 2010

Table 2: Month-wise average rainfall data

Month	Monthly Average(mm)
Jan	14.796
Feb	16.723
Mar	17.583
Apr	7.98
May	16.755
Jun	605.087
Jul	1364.709
Aug	1317.589
Sep	679.601
Oct	75.832
Nov	24.091
Dec	13.867

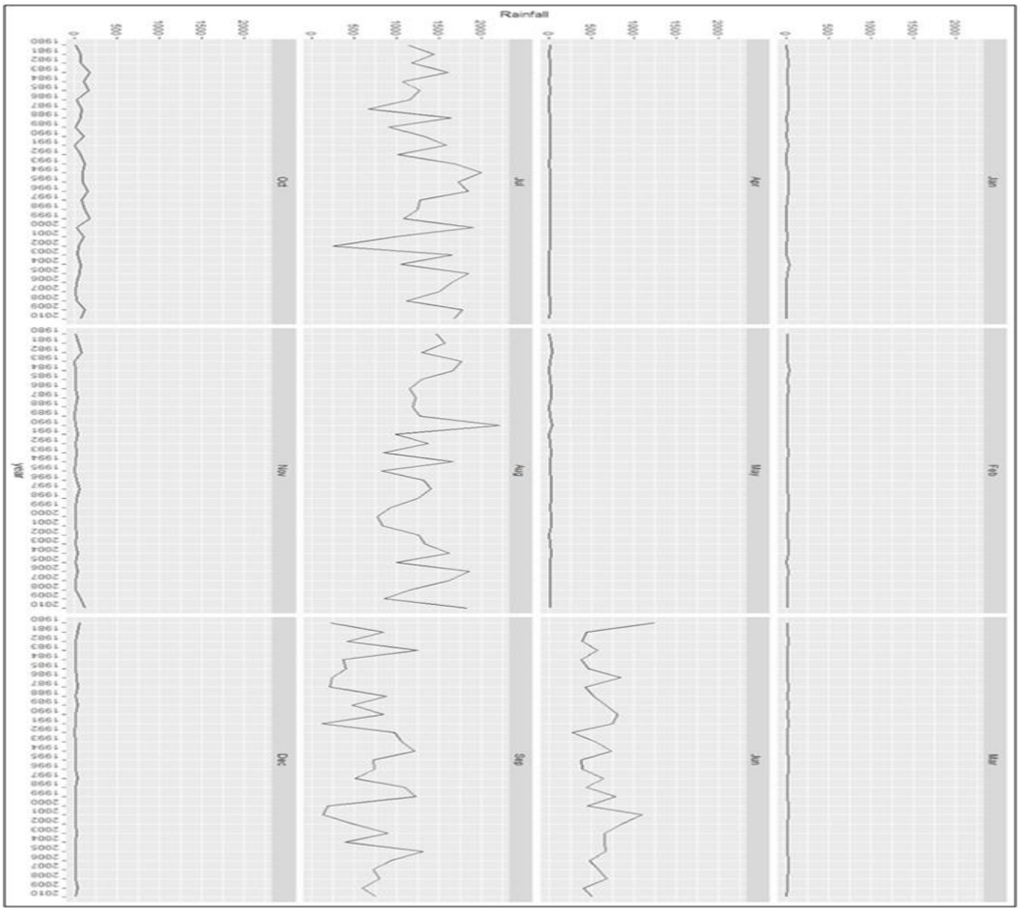

Figure 5: Monthly data for 1980-2010

South-west monsoon winds are the major contributor to the annual rainfall in India. As expected, the months of June, July, August, September, and October to some extent see heavy rainfall compared to the rest of the months throughout the year. Maximum rainfall is observed in the month of July, closely followed by August. All other months

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4.3 Monthly Variation

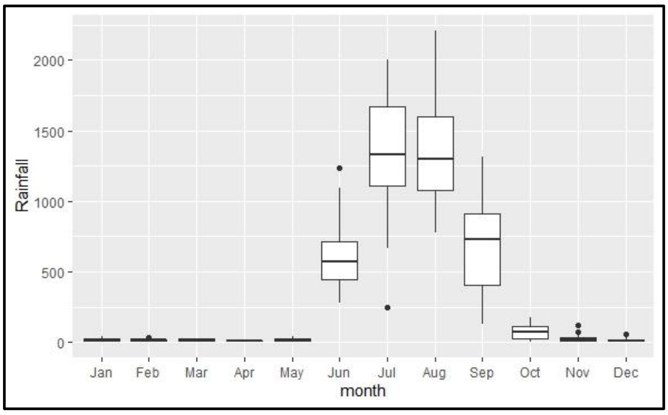

Figure 5: Month-wise box-plot of rainfall over 30 years

To study the secular variations of regional rainfall, we have carried out the trend analysis for the monthlyrainfall series of all the months in the duration of 1980-2010. It is evident from the visual plot that June, July, August and September experience notable variation in the rainfall over the years.

Table 3: Month-wise deviation from mean rainfall

Month	Standard Deviation
Jan	10.31508
Feb	6.651103
Mar	5.731993
Apr	2.982746
May	9.38452
Jun	215.6105
Jul	398.2026
Aug	353.2467
Sep	359.3329
Oct	50.89221
Nov	26.63812
Dec	12.60381

4.4 Global Maxima or Minima

In the duration of 1980-2010, maximum annual rainfall was observed in the year 1994 viz. 2963mm. The year 2002 experienced notably low rainfall of 5823mm. A further analysis of deviation in monthly rainfall keeping monthly mean as the base reveals that in 1994, heavy rainfall was observed in the month of July and Septemberwhich contributed hugely to annual rainfall. Interesting insights were drawn on carrying out a similar analysis on the year 2002 which experienced minimum annual rainfall. In 2002, the month of June experienced rainfall higher than the mean rainfall observed in June over 1980-2010. The rainfall reduced considerably in the months to follow, namely July, August, September and October which resulted in an overall decrease in the annual rainfall in 2002.

The reason for unusually high rainfall in 1994 can be attributed to diabetic heating anomaly for June to August in 1994. The diabetic heating anomaly field indicates that much of the 12% excess rainfall over India occurred in northwest India with, if anything, reduced rainfall over the southern peninsular. The strong moisture fluxes associated with southwesterly winds that cross the west coast of India from the Arabian Sea caused excessive rainfall in the month of July.

4.5 Draught Years

Here we present 2002, 2004 and 2009 rainfall – corresponding to draught years. They observed less than 90% of the average annual rainfall.

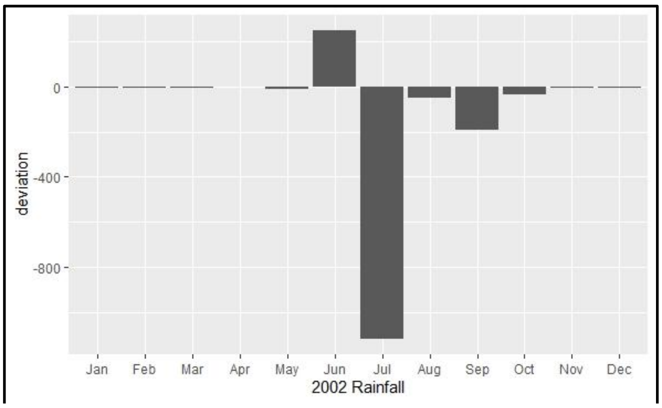

Figure 6: Monthly deviation in 2002

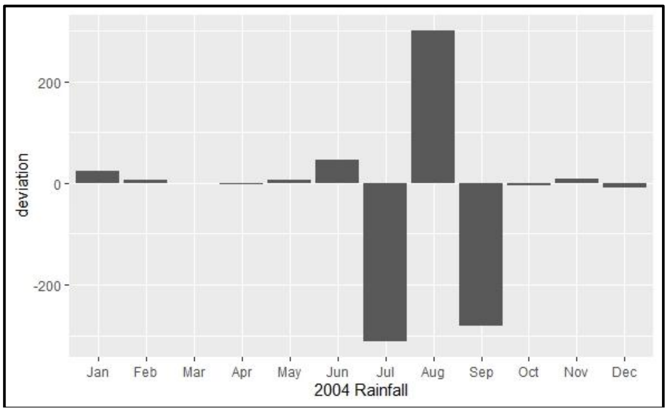

Figure 7: Monthly deviation in 2004

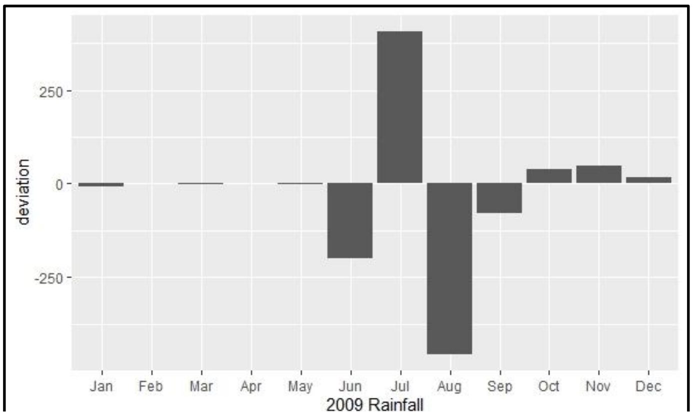

Figure 8: Monthly deviation in 2009

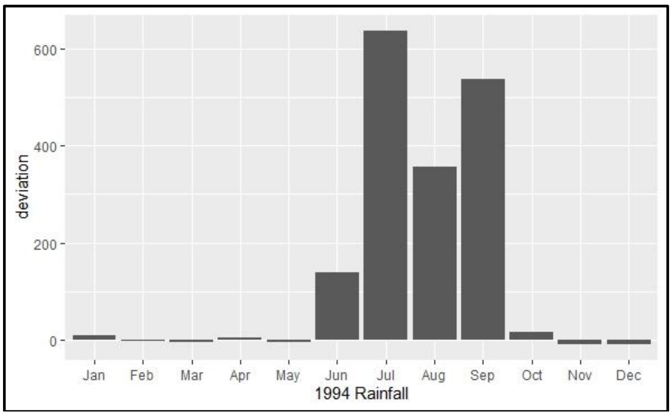

Figure 9: Monthly deviation in 1994

5. Results

The standard deviation from mean annual rainfall value for 1980-1994 is 859 mm/hr whereas for 1995-2010 is 619 mm/hr which clearly indicates that variability in rainfall has decreased considerably over the years although mean rainfall figures stand at 4146 and 4163 when calculated over 1980-1994 and 1995-2010 respectively.

South-west monsoon winds are the major contributor to the annual rainfall in India. As expected, the months of June, July, August, September, and October to some extent see heavy rainfall compared to the rest of the months throughout the year.

The reason for unusually high rainfall in 1994 can be attributed to diabetic heating anomaly for June to August in 1994 which caused strong moisture fluxes in the south-westerly winds over the west coast resulting in excessive rainfall in the month of July.

The reasons for 2002 drought were negative phase of EQUINOO in the equatorial Indian Ocean, high MJO and typhoon activity in the central and west Pacific. Persistent and strong inversion near 800 hPa prevented the growth of convective clouds during the first half of July and towards its end causing less rainfall than usual in the month of July.

References

[1] P. Guhathakurta and M. Rajeevan, “Trends in rainfall pattern over India”, INTERNATIONAL JOURNAL OF CLIMATOLOGYInt. J. Climatol.28: 1453 – 1469 (2008)
[2] Gaurav Choudhury, “Here’s why the monsoon rains are important for India”, Moneycontrol.com, April 16, 2018
[3] TWC India Edit Team, “Repeated Below-Normal Rainfall Likely to Lower Long Period Average for India”, The Weather Chnnel, 18 July, 2019
[4] SulochanaGadgil, “The Indian Monsoon and Its Variability”, Annu. Rev. Earth Planet. Sci. 2003. 31:429–67
[5] Hazrat Mir, “On the 1994 Indian monsoon rainfall anomaly”, Pakistan Journal of Meteorology vol. 1 Issue:1 (Jan – March 2004)
[6] By G.S. Bhat, “The Indian drought of 2002—a sub-seasonal phenomenon”, Q. J. R. Meteorol. Soc. (2006), 132, pp. 2583–2602 doi: 10.1256/qj.05.13