Available online at www.ewijst.org

ISSN: 0975-7112 (Print)
ISSN: 0975-7120 (Online)

Environ. We Int. J. Sci. Tech. 9 (2014) 29-38

Environment & We
An International
Journal of Science
& Technology

Temporal Trend Analysis of Climatic Parameters in Barinallah Catchment over a Himalayan Region, India

Deepak Khare[1], Rajinder Singh[2], Rituraj Shukla[1*]
[1] Departement of Water Resources Development and Management,
Indian Institute of Technology, Roorkee, Uttarakhand, India
[2]Deparment. of Himachal Pradesh Irrigation cum Public Health, Himachal Pradesh, India
[*]Email: srituraj11@gmail.com

Abstract

In current study, for assessment of climate change, the statistical analysis approach is used to find out trend analysis with historical precipitation and temperature data. Temperature and Precipitation data of 50 years for the period 1952 to 2002 has been analysed over Barinallah catchment located between the longitudes $76^0$01'45"E to $76^0$06'18"E and latitudes $32^0$38'00"N to $32^0$40'00"N This paper analyzes the trend of climatic parameter mainly precipitation and temperature in Barinallah catchment which drains into river Siul, a tributary of river Ravi which contributes to Indus river basin. The methodology adapts various statistical approaches viz. moving average method, Mann-Kendall test, and Sen.'s estimator of slope in order to detect possible annual and monthly trend in precipitation and temperature. The results of trend analysis confirm climatic changes in precipitation pattern with positive insignificant trend on monthly basis, only the month of October and December shows the negative trend over the study area. Moreover, estimation of temperature trend over the region is insignificantly increasing trend for annual time series.

Keywords: Trend analysis, Parametric and Non- parametric methods, Precipitation, Temperature, Climatic parameter, Mann-Kendall test, and Sen.'s estimator.

Introduction

Climate change is one of the major challenges to researchers in recent times. The impact of climate change on water resources around the globe has serious implications like, changing water levels and climatic temperatures, which in turn affect the economy and future as a whole. In addition, water resources are depleting day by day due to the exponential demand from sectors like irrigation, domestic consumption and industry. Water availability and quality will be the main pressures on, and issues for, societies and the environment under climate change. Along with quantity, quality is also deteriorating mainly due to the indiscriminate use of water to hazardous levels, pollution of rivers and improper management of wastewater.

India being the monsoonic country, the rain falls only for 3 to 4 months in a year with high intensity, which results in more runoff and soil erosion. Total rain occurs in about 100 hours out of 8760 hours in a year. Further, the rainfall is erratic and fails once in every 3 to 4 years. This is very common in many parts of the country.

Current study area is the part of District Chamba enjoys a pleasant climate. Summers are generally warm and winters are cold. During winter, the temperature varies from 1^{o}C to 12^{o}C and in summer, it varies between 25^{o}C to 39^{o}C respectively. Mean daily maximum temperature is highest in the month of June being 39^{o}C and mean daily minimum temperature is lowest in the month of January being 1^{o}C. This area receives about 1265 mm of annual rainfall, during southwest monsoon (July to September) which contributes about 60-70% of the annual rainfall and due to western disturbances (December to March) which contributes about 30-40% of the annual rainfall. The relative humidity in monsoon months varies from 70% to 95%. The annual average evaporation rate of the area is 5.6 mm/day. Evaporation in the dry season of April to June is relatively higher than in the winter season of November to March.

One of the most important consequences resulting from the climate change may be the alteration of the regional hydrological cycles and subsequent changes in steam flow regimes. Studies of general circulation model (GCM) reveals that increased global temperature could lead to increase the amount and intensity of regional precipitation. Precipitation is a good indication in the impact from climate change on water resources. Precipitation is one of the most important climate elements directly affecting human society (water availability, consumption, social and political stability), natural systems (water stress, fires, erosion) and economic activities (location of dams, water planning, irrigation, industrial demand) (Randall *et al*., 2007). Many authors have indicated that precipitation is the climate element which has spatial and temporal variability (Mitchell and Jones, 2005; Karagiannidis *et al*., 2008). Thus, precipitation changes can be detected only if a network of observations is used (Vinnikov *et al*., 1990; Groisman and Legates, 1994; Hulme *et al*., 1995; Auer *et al*., 2005; Brunetti *et al*., 2006; Valero *et al*., 2009). This fact is particularly true where the amount of precipitation is concentrated in time and space, and rainfall station data is only representative of a very small area (Cosgrove and Garstang, 1995; Mosmann *et al*., 2004; del Rio *et al*., 2005).

Trend detection in temperature and precipitation time series is crucial for planning of crop management system and designing of regional water resources management system.. Changes in precipitation patterns are very important for water resources managers to deal with the water resources planning and management. Variations in precipitation over daily, seasonal, annual and decadal timescales influence water resources systems. Several recent studies on climatologic trends conclude that trend in observed precipitation comprises a complex function of the climatic environment, precipitation intensity and season (Osborn et al. 2000; Ventura et al. 2002).

Relevant reviews on trend analysis in temperature and precipitation time series include the studies of Andrighetti et al. 2009; Gadgil and Dhorde 2005; Feidas et al. 2004; Turkes and Sumer 2004; Mosmann et al (2004), Yue and Hashino 2003; Xu et al.

(2003), Ventura et al. 2002, Zhang et al. (2000), Turkes (1996) , Lettenmaier et al. (1994).

In order to investigate climate changes scenarios and enhance climate impact research of the trend detection is an active area of interest for both hydrology and climatology. Monthly temperature and precipitation records from the recording stations were summed to provide annual totals for each year. Monthly and annual time series were analyzed statistically by using Mann-Kendall (MK) test.Therefore, the objective of this study was to investigate a long-term trend detection of climatic parameter likewise, precipitation and temperature which is essential for understanding the potential impact on water resources resulting from climate change in Barinallah catchment.

Study area

Barinallah catchment in the Ravi river, Chamba district of Himachal Pradesh has been selected for present study. Himachal Pradesh, situated north of India, is also known as the 'Land of Snow' rests in the foothills of Himalayas. The total area of the state is 55,673 km^2. It is surrounded by landforms from all sides, Uttaranchal on the southeast, Punjab on the west, China on the east, Haryana on the southwest and Jammu and Kashmir on the north. It lies between the latitudes 30°22’40” North to 33°12’40” North and longitudes 75°45' 55" East to 79°04' 20" East. The entire region of Himachal Pradesh is hilly with the altitude ranging from 350 m to 7000 m above MSL. The altitude increases from west to east and from south to north.

Chamba district is situated North West of Himachal Pradesh. The Barinallah catchment is located between 76°01’45’’E to 76°06’18’’E longitudes and 32°38’00’’N to 32°40’00’’N latitudes on the western hills in Chamba district. This catchment has some springs and small nallahs. Water supply schemes for drinking water have been constructed to the nearby villages from these springs and nallahs. This area is characterized by elevation 760 m to 1880 m ranging mountains and valleys with drainage features. The location map of the study area is shown in Figure 1.

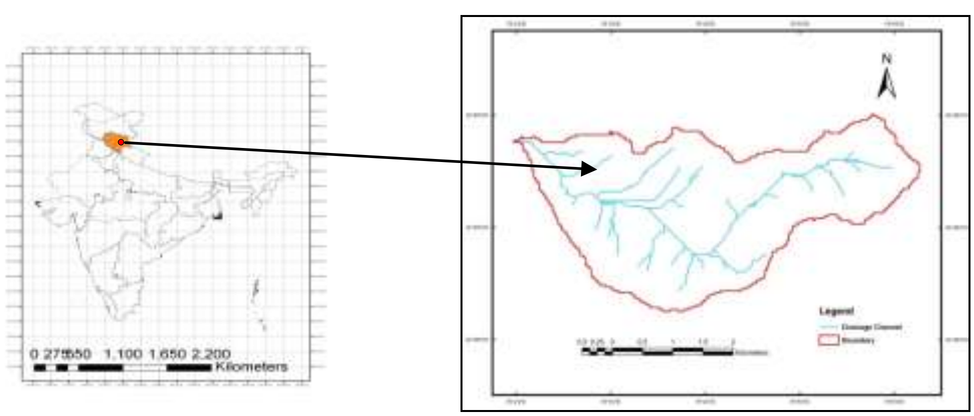

Figure 1 Map of Study area

Meterial and Methods

The methodology adopted consist of review the climate change using statistical method to evaluate the trend that the climate has exhibited in the past in order to determine recent climate behaviours. Observational and historical hydro-climatic data are generally used for planning and designing water resources projects. Therefore precipitation is important to study the climate change trends in the Barinallah catchment. Employing the statistical methods discussed below, the temporal trends and their spatial distribution of historical annual precipitation series in the study area has been examined. The diverse statistical approaches involved in the assessment of the precipitation trend in the study area based on long term data are Mann-Kendall test, Sen.'s Slope Estimator and moving average method.

Mann Kendall (MK) Test

There are many parametric and non- parametric methods which have been applied for detection of trends. Non-parametric trends tests only require the data to be independent and can tolerate outliers in the data. The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The test compares the relative magnitudes of sample data rather than the data values themselves (Gilbert, 1987). One benefit of this test is that the data need not conform to any particular distribution. Moreover, data reported as non-detects can be included by assigning them a common value that is smaller than the smallest measured value in the data set. The procedure that will be described in the subsequent paragraphs assumes that there exists only one data value per time period. When multiple data points exist for a single time period, the median value is used. The data values are evaluated as an ordered time series. Each data value is compared to all subsequent data values. The initial value of the Mann-Kendall statistic, S, is assumed to be 0 (*e.g.,* no trend). If a data value from a later time period is higher than a data value from an earlier time period, S is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decremented by 1. The net result of all such increments and decrements yields the final value of S.

The Mann Kendall test searches for a trend in a time series without specifying whether the trend is linear or nonlinear. The trend test is applied to a time series x_i ranked from i=1, 2………n-1, and x_j ranked from j=i+1, 2,………n. Each data point x_i is used as a reference point and is compared with all other data points x_j such that

$$\text{Sgn}\,(x_j - x_i) = \begin{cases} +1 > (x_j - x_i) \\ 0 = (x_j - x_i) \\ -1 < (x_j - x_i) \end{cases} \quad (1)$$

The Kendall statistics S is estimated as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sgn}(x_j - x_i) \quad (2)$$

The variance of the statistic S is defined by

$$Var(S) = \frac{n(n-1)(2n+5) - \sum t_i (i)(i-1)(2i+5)}{18} \tag{3}$$

In which t_i denotes the number of ties up to sample i.

The test statistics z_c is estimated as

$$Z_c = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} if, S > 0 \\ 0 if, S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} if, S < 0 \end{cases} \tag{4}$$

Where,

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sgn}(x_j - x_i) \tag{5}$$

In which Z_c follows a standard normal distribution. A positive (negative) value of Z indicates an upward (downward) trend. A significance level α is also used to test for either an upward or downward monotone trend (a two-tailed test). If Z_c is greater than $Z_{\alpha/2}$ where α denotes the significance level, then the trend is significant.

Sen's Slope Estimator

In the time series, where a linear trend is present, the true slope can be calculated by using a simple non-parametric procedure developed by Sen (1968). The slope estimate of N pairs of data are first computed by

$$Q_i = \frac{x_j - x_k}{j-k} \qquad \text{for } i = 1,2,3 \ldots\ldots\ldots\ldots.. N \tag{6}$$

Where, x_j and x_k are data values at times j and k (j>k) respectively. The meridian of these N values of Q_i is Sen's estimator of slope. If N is odd, then Sen's estimator is computed by $Q_{med} = Q_{(N+1)/2}$ and if N is even, then Sen's estimator is computed by $Q_{med}=[Q_{N/2}+Q_{(N+2)/2}]/2$. Finally Q_{med} is tested by a two sided test at 100(1-α) % confidence interval and true slope may be obtained by the non-parametric test.

Moving Average method

In statistics, a moving average, also called running average, is used to analyze a set of data by creating a series of averages of different subsets of the full data set. Given a series of numbers and a fixed subset size, the moving average can be obtained by first taking the average of the first subset. The fixed subset size is then shifted forward, creating a new subset of numbers, which is averaged. This process is repeated over the entire data series. The plot line connecting all the (fixed) averages is the moving average. Thus, a moving average is not a single number, but it is a set of numbers, each of which is the average of the corresponding subset of a larger set of data points.

Results and Discussions

Monthly temperature and rainfall records from the recording stations were summed to provide annual totals for each year. Monthly and annual time series were analyzed statistically by using Mann-Kendall (MK) test.

The statistics for annual temperature and rainfall are given in table 1, which shows that the annual temperature ranges from 8.3 to 28.1°C, with an average 19.4°C. The annual rainfall range from 1008 to1738 mm, with an average of 1265 mm during the study period from 1953-2002.

Table1 Statistics of annual temperature and rainfall in the watershed

Statistics	Temperature (°C)	Rainfall (mm)
Average	19.4	1265
Standard Deviation	0.48	231.67
Coefficient of Skewness	0.23	0.354
Maximum value	28.1	1738
Minimum value	8.3	1008

A five-year moving average analysis was carried out for annual average air temperature and annual rainfall. The annual temperature data were tested to show trend of temperature change in the Barinallah watershed in (Figure 2) and the annual rainfall data was tested to show trend of change in rainfall pattern in the Barinallah watershed in (Figure 3).

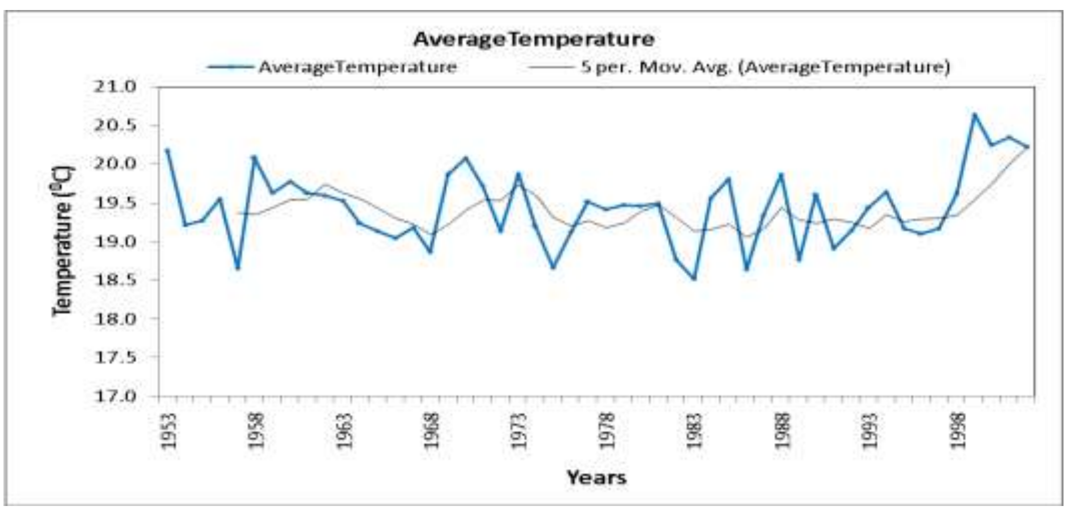

Figure 2 Five years moving average annual temperature (1952-2002)

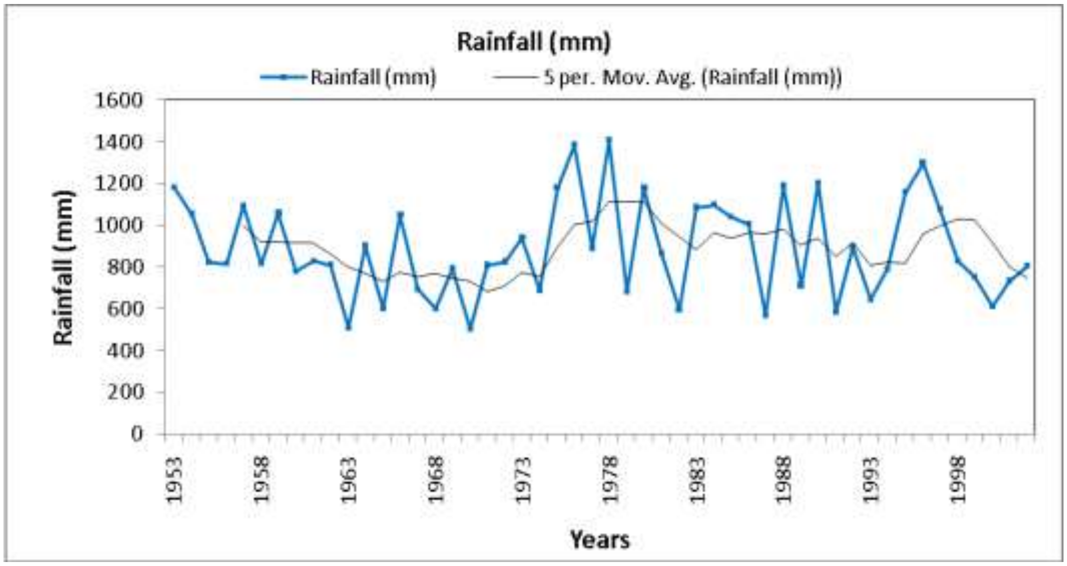

Figure3 Five years moving average annual rainfall (1952-2002)

Monotonic Trend in Air Temperature Time Series (1952-2002)

The mean temperature varies from 1°C to 12°C in winter and from 30°C to 39°C in summer. Typical seasonal annual air temperature trends for the long-term period (1953-2002) were analyzed using Mann-Kendall test.

The values of Mann-Kendall statistics Z_{mk} and Sen's slope in long-term period for different months are given in table 2. January and May gives the greatest slope 0.03°C, followed by December 0.02°C, February, April and November showed the smallest tendency, with slopes of 0.01°C. June gives the maximum negative trend -0.02°C, followed by July, August and September with slopes of -0.01°C while the months March and October shows no trend.

Table 2 Variations of the long-term period temperature (°C) in The Barinallah catchment.

Months		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mann Kendall	Z_{mk}	2.21	0.87	-0.38	0.67	1.92	-2.48	-1.15	-1.07	-1.16	0.38	1.69	1.80	0.23
Sen's Slope	Q	0.03	0.01	0.00	0.01	0.03	-0.02	-0.01	-0.01	-0.01	0.00	0.01	0.02	0.001

Generally, temperature slopes are positive during the winter season and are negative during the rainy season. But during the summer season the temperature have positive slopes in May and negative slope in June in the above table.

Monotonic Trend in Precipitation Series

The values of Mann-Kendall statistics Z_{mk} and Sen's slope in long-term period for different months are given in table 3. Long-term trend during fifty years period, in the rainfall is tested with Mann-Kendall (MK) methods. The values of Mann-Kendall statistics Z_{mk} and Sen's slope in long term period for different months is given in table 3. It is seen that two months out of the twelve months showed a decreasing trend. October gives the greatest trend at -0.32 mm, December gives the trend at -0.11 mm. Two of the ten months showed an increasing trend. June gives the greatest trend at 0.75 mm, February gives the trend at 0.35 mm, May and August gives the trend at 0.15 mm, July gives the trend at 0.12 mm, January and April gives the trend at 0.09 mm, March gives the trend at 0.01 mm and November gives no trend.

In Monthly series, only month October is indicating downwards tendency and showing a significant downward trend at the □ = 0.05 significant level, but month June is indicating upwards tendency. The Sen's slope is positive indicating upwards tendency (except for the month of October and December). The month of June and February are showing a significant upward trend at the $P<0.05$ significant level.

Table 3 Variations of the long-term period Precipitation (mm) in Barinallah catchment.

Months		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Mann Kendall	Z_{mk}	0.39	1.57	0.03	0.69	0.95	1.38	0.08	0.18	0.03	-2.70	0.54	-0.68	-0.18
Sen's Slope	Q	0.09	0.35	0.01	0.09	0.15	**0.75**	0.12	0.15	0.04	-0.32	0.00	-0.11	-0.317

Conclusions

Based on the present study these conclusions are drawn: (i) Trend analysis was done using Mann-Kendall test, Sen's Slope Estimator and Moving Average method. Trend analysis of temperature and precipitation for 50 years (1953-2002) confirms changing climate in the region. The annual mean temperature in the region is increasing gradually. Dry spell in the region is also frequent. Precipitation pattern is becoming erratic with high intensity rainfall. (ii)Annual temperature time series shows the positive insignificant trend over a Barinallah catchment. (iii) Annual precipitation time series shows the negative insignificant trend over a Barinallah catchment. (iv) It is observed that on monthly basis, during trend analysis that temperature is showing an increasing tendency in six months out of twelve months of the year. January and May gives the greatest slope 0.03°C, followed by December 0.02°C, February, April and November showed the smallest tendency, with slopes of 0.01°C. June gives the maximum negative trend -0.02°C, followed by July, August and September with slopes of -0.01°C while the months March and October shows no trend. Temperature slopes are positive during the winter season and are negative during the rainy season. (v) Precipitation trend when analyzed, it is observed that two months i.e. October and December out of the twelve months witnesses decreasing insignificant trend with values -0.32 mm and -0.11 mm respectively. However, remaining months in the year shows the increasing insignificant trends excepting the month of November showing no trend.

Authors Contributions: Prof. Deepak Khare is a professor and Project guide done final editding the menuscript; Rajinder Singh is Excutive Engineer and Rituraj Shukla a research scholer preform the experiment and map preparation, wrote the menuscript and correpessponing author of menuscript.

References

Auer I, B¨ohm R, Jurkovic A, Orlik A, Potzmann R, Sch¨oner W,Ungersbock M, Brunetti M, Nanni T, Maugueri M, Briffa K,Jones P, Epthymiadis D, Mestre O, Moisselin JM, Begert M,Brazdill R, Bochniker O, Cegnar T, Gajic-Capka M, Zaninovic K,Majstorovic Z, Szalai S, Szentimrey T, Mercalli L. 2005. A new instrumental precipitation dataset for greater Alpine region for the period 1800–2002. *International Journal of Climatology* 25, 139–166.

Andrighetti M, Zardi D, Franceschi M 2009 History and analysis of the temperature series of Verona (1769–2006). *Meteorology and Atmospheric Physice* 103, 267–277

Brunetti M, Maugeri M, Monti F, Nanni T. 2006. Temperature and precipitation variability in Italy in the last two centuries from homogenised instrumental time series. *International Journal of Climatology* 26, 345–381.

Cosgrove CM, Garstang M. 1995. Simulation of rain event from raingauge measurements. *International Journal of Climatology* 15, 1021–1029.

Del Rio S, Penas A, Fraile R. 2005. Analysis of recent climatic variations in Castile and Leon (Spain). *Atmospheric Research* 73, 69–85.

Feidas H, Makrogiannis T, Bora-Senta E. 2004, Trend analysis of air temperature time series in Greece and their relationship with circulation using surface and satellite data: 1955–2001, *Theorotical and Appllied Climatology* 79,185–208.

Gadgil A, Dhorde A. 2005. Temperature trends in twentieth century at Pune, India. *Atmospheric Environment* 39, 6550–6556.

Gilbert, R.O., 1987. Statistical methods for environmental pollution monitoring. Van Nostrand Reinhold, New York.

Groisman P.Y, Legates D. R. 1994. The accuracy of United States precipitation data. *Bulletin of the American Meteorological Society*, 75: 215–227.

Hulme M, Conway D, Jones PD, Jiang T, Barrow EM, Turney C.1995. Construction of a 1961–1990 European climatology for climate change modelling and impact applications. *International Journal of Climatology* 15, 1333–1363.

Karagiannidis AF, Bloutsos AA, Maheras P, Sachsamanoglou Ch.2008. Some characteristics of precipitation in Europe. *Theoretical and Applied Climatology* 91, 193–204.

Lettenmaier, D.P., Wood, E.F., Wallis, J.R., 1994. Hydro-climatological trends in the continental United States, (1948-88). *Journal of Climate*, 7, 586-607.

Mitchell TD, Jones P. D. 2005. An improved method of construction a database of monthly climate observations and associated highresolutiongrids. International *Journal of Climatology* 25, 693–712

Mosmann V, Castro A, Fraile R, Dessens J, Sanchez J.L. 2004. Detection of statistically significant trends in the summer precipitation of mainland Spain. *Atmospheric Research* 70, 43–53.

Osborn, T.J. Hulme, M., Jones, P.D., Basnett, T.A., 2000. Observed trends in the daily intensity of United Kingdom precipitation.*International Journal of Climatology*, 20, 347-364

Randall DA, Wood RA, Bony S, Colman R, Fichefet T, Fyfe J, Kattsov V, Pitman A, Shukla J, Srinivasan J, Stouffer RJ, Sumi A,Taylor KE. 2007. Climate models and their evaluation. *ClimateChange 2007: The Physical Science Basis. Contribution of WorkingGroup I to the Fourth Assessment Report of the IntergovernmentalPanel on Climate Change*. Cambridge University Press: Cambridgeand New York.

Sen P. K. 1968 Estimates of the regression coefficient based on Kendall’s tau, *Journal of the American Statistical Association*, 39, 1379–1389

Turkes, M., 1996. Spatial and temporal analysis of annual rainfall variations in Turkey. *International Journal of Climatology*, 16, 1057-1076.

Valero F, Mart´ın ML, Sotillo MG, Morata A, Luna MY. 2009. Characterization of the autumn Iberian precipitation from longterm datasets: comparison between observed and hindcasted data. *International Journal of Climatology* 29, 527–541.

Ventura, F., Rossi Pisa, P., Ardizzoni, E., 2002. Temperature and precipitation trends in Bologna (Italy) from 1952 to 1999. *Atmospheric Research*, 61, 203-214.

Vinnikov KYa, Groisman PYa, Lugina KM. 1990. Empirical data on contemporary global climate changes (temperature and precipitation). *Journal of Climate* 3, 662–677.

Xu, Z.X., Takeuchi, K., Ishidaira, H., 2003. Monotonic trend and step changes in Japanese precipitation. *Journal of Hydrology*, 279:144-150.

Yue S, Hashino M. 2003. Long term trends of annual and monthly precipitation in Japan. *Journal of the American Water Resources Association* 39: 587–596.