مجله علمـی - پژوهشـی
علوم و مهندسی آبخیـــزداری ایران
Iran-Watershed Management
Science & Engineering

Vol. 1, No. 1, Spring 2007
سال اول-شماره ۱-بهار۱۳۸۶

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Printed at: Naghsh-e-Sobhan

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Abstract

Prioritization of Hydrologic Units with Respect to Flood Potential in Golestan Dam River Basin

B. Saghafian[1] and H. Farazjoo[2]

Identification and prioritization of subbasin areas in relation to flood potential is a key task in management of large basins. Golestan Dam basin has recently experienced severe floods so that the basin is considered crucial for flood control planning. In this research, HEC-HMS hydrologic model and geographic information system (GIS) were jointly used to investigate the contribution of subbasins to the flood peak at the basin outlet. Unit flood response method was applied to prioritize subbasins with respect to a flood index. The results showed that subbasin flood index was not solely dependent on area but location, river routing characteristics, and rainfall spatial distribution have major effects. It was evident that the southern Galikesh subbasin ranks first in flood index due to receiving high intensity rainfall, whereas Robat-Gharahbill located near the most upstream part of the basin ranks last.

Keywords: Unit Flood Response, GIS, HEC-HMS , Golestan Dam Basin

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Abstract

Sensitivity Analysis of Flood Routing and Transmission Losses Parameters in Arid-region Rivers

M. Fotoohi[1] and S.M. Hosseini[2]

Flow in ephemeral streams of arid regions occurs in a short period of time and is highly variable. Floods in these dry-land rivers change their volume as they travel downstream due to infiltration from the beds and floodplains. This reduction in flow, termed transmission losses, also causes attenuation of flood wave and acts as recharge source for groundwater and qanats. In this research, a model for dynamic flood routing in ephemeral rivers has been developed. To achieve this, the Saint-Venant equations were modified by including transmission losses in them and a computer code was developed in MATLAB to solve the equations. Model was verified because the performance of the model under Lane's hydrograph and the data of Hughes Wash River was satisfactory. To further understand the flow behavior and predict transmission losses, model was run for a reach in Zoshk River in Khorasan Razavi. Sensitivity analysis of parameters of this dynamic-routing model shows that the outputs of the model (peak flow, flood volume and seepage volume) are more sensitive to the length and hydraulic conductivity of the reach of study and peak flow of inflow hydrograph.

Keywords: Arid-region Rivers, Flow routing, Saint-Venant equations, Transmission losses.

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Abstract

An Investigation on Linear Regression and Ordinary Kriging Methods for Estimating Spatial Distribution of Snow Depth at Samsami Basin

M. R. Sharifi[1], A.M. Akhoond-Ali[2], J. Porhemmat[3] and J. Mohammadi[4]

Knowledge on spatial distribution of snow storage in catchments is important in snow hydrology because of its effect on yielding run-off. Therefore, intensive scale is necessary to measure snow depth for collecting observed data. But, difficulties are involved in measuring snow depth at fields. Therefore, methods based on observed data have been developed to predict snow depths for unobserved area. To apply these methods, care is needed because of their abilities to predict snow depth accurately. Therefore, these methods should be evaluated for studied sites to select more accurate method. In the current research, an area of 5.2 Km^2 as part of a small basin (named Samsami) as one of the headwaters of Northern Karoun, is studied for unobserved snow depth points. To do this, Multiple Linear Regression and Ordinary Kriging methods were applied and evaluated to the studied site. To compare and evaluate these two methods snow depths from 258 points were measured then; 208 points of them were used as working points and the others (50 points) as reference points to develop these two models. Finally, predicted results from these two methods for the 50 reference points were compared with their observed data, respectively. Statistical analyses of data showed that 67% of variations in snow depth which were affected by Elevation, North-South aspect and Wind shelter index can be modeled by Linear Regression method at %95 meaningful levels. However, Slope parameter did not show significant result at above confidence limit. Results from application of Ordinary Kriging method for the same data as were used above, showed that 62% of variations in snow depth can be modeled. Comparison of ability of these two models (predicting 67% of variations in snow depth with 62%) shows a little advantage for the Linear Regression which is an advantage for this method over the Ordinary Kriging method. However, the Ordinary Kriging method has another advantage over the Linear Regression which is its ability to show variations in spatial distribution of predicted snow depth smoothly on a map.

Keywords: Spatial Distribution of Snow Depth, Linear Regression, Kriging, Terrain Parameters, Samsami Basin, Northern Karoun.

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Abstract

Calibration, Spatial Distribution and Rain Characteristics of Rainfall Simulation
Case study: Soil Conservation & Watershed Management Research Institute -Rainfall Simulator

M. Mahmoodabadi[1], H. Rouhipour[2], M. Arabkhedri[3] and H. Rafahi[4]

Rainfall simulation is normally used in the context of soil erosion studies and related processes. Recently, a rainfall simulator has been constructed in Soil Conservation and Watershed Management Research Institute (SCWMRI) Iran, which has considerable advantages in comparing with previous ones. The aim of this study was to calibrate the rainfall simulator, in terms of rainfall uniformity, drop size distribution, and calculating of drop velocity and its kinetic energy. Rainfall uniformity measurement carried out at three water pressures (0.01, 0.05 and 0.15 Mpa). The intensity distribution was determined under simulated rainfall both for a single and also for the combination of nozzles on the flume bed and compared with theoretical estimation of such distribution. Determination of drops size distribution performed using flour pellet method. The results showed that the behavior of the nozzles was similar. For combination of nozzles, the rain intensity varied from 35 to 125 mm h^{-1}. The coefficient of uniformity was more than 90%. At a constant pressure, with the increasing number of nozzles, rainfall intensity and also mean drop diameter was increased. It was also concluded that while water pressure is increased, drop diameter decreased. Median drops diameter varied between 1.64 to 2.15 mm. It was concluded that the drops reach their terminal velocity which varied from 5.70 to 6.78 m sec^{-1} and the kinetic energy was changed from 16.24 to 22.97 J m^{-2} mm^{-1}.

Keywords: Rainfall simulation, Calibration, Rainfall uniformity, Drop size distribution.

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Abstract

Experimental Study of Scour Depth at 90 Degree River Confluence

R. Ghobadian[1] and M. Shafai – Bejestan[2]

River channel confluences form important morphological element of every river system that are characterized by complex pattern of three-dimensional fluid motion and the most highly turbulent locations in fluvial systems. Because of variation in velocity, discharge, turbulent and finely bed load in these location a scour hole is developed just downstream of the river confluence. These phenomena can accelerate the rate of bank erosion and affect the river morphology. Therefore it is necessary to clearly understand mechanism of sediment pattern in this location. In this study, first by using dimensional analysis, general non-dimensional equation were developed in which for the firs time the densimetric Froude number was included. Then the total of 55 experimental tests were conducted to investigate the effect of discharge ratio, wide ratio and down stream densimetric Froude number on depth scour at 90 degree confluence. The result of experimental test showed that the depth of scour at confluence increases with increasing of discharge ratio and densimetric Froude number whereas it decreases as width ratio increasing. It was found that scour depth is more related to the densimetric Froude number. Finally, relationship was developed for prediction of scour depth.

Keywords: river confluence, scour depth, discharge ratio, densimetric Froude number, point bar

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Abstract (Technical Note)

Comparative Evaluation of Bridges and Culverts Effects on Flood Depth and Extension in a Reach of Tehran Kan River

S.H.R. Sadeghi[1], M. HajiGholizadeh[2] and M. Vafakhah[3]

Improper design and unsuitable application of bridges and culverts may affect on flood occurrences through changing the river cross section, flow velocity, flood storage capacity, flow level and extension. In the present study the role of three bridges as well as three culverts constructed in a reach of Tehran Kan River with 7Km in length was studied for floods with 5 to 700 years return periods. The effects of studied structures on inundation depth and extension were studied for both the fictitious omission as well as present condition with the help of HEC-RAS software package. The results of the study revealed that each particular structure plays specific hydraulic role on floods having different return periods which is different from others. The results also verified that the culverts have more effects on changing inundation depth and extension compare to bridges.

Keyword: Flood zoning, Bridge, Culvert, HEC-RAS, Kan River, Iran

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of research, Perry and Hollis [8] generated monthly and annual 5km x 5km grided datasets covering the UK for the 1961-2000 period for 36 climatic parameters. Time series approaches may also be generalized to a continuous spatial domain and maps of a specific parameter (e.g. precipitation levels as reported by Johnson et al., [9] may be constructed at any arbitrary location via interpolation of time series model parameters. Kyriakidis et al. [10] presented a framework for stochastic spatio-temporal modeling of daily precipitation as a shorter scale parameter in a hindcast mode. Observed precipitation were modeled levels in space, and time as a joint realization of a collection of space indexed the time series, one for each spatial location.

The above literature supports the use of kriging in space and also in space-time environments. Both of the above techniques fail to operate in the case of a general data-lack in a region. This research has focused on the possibility of a geostatistics application on long term annual rainfall for Mashhad in Iran, where no other regionalization method exists to fill the missed data.

Materials and Methods

Mashhad a city in the center of Khorasan Razavi Province, is located in the northeast part of Iran at a latitude of $36^{o}17^{'}$, longitude of $59^{o}38^{'}$, and an altitude of 946 MSL. The Mashhad synoptic station has annual rainfall data over a 50 year period from 1951 to 2000, prepared from The Islamic Republic of Iran Meteorological Organization (IRIMIO). There is historic rainfall data from 1983 to 1940, just before World War II when the British embassy had priority over the politics of Iran. However, over this period of 107 years, there is a scatter (1894, 1895, 1905, 1918, 1919, and 1929) and a continuous 10 year period of (1941-1950) missed data. Figure 1 shows the Mashhad annual rainfall in Mashhad. The historic data were reported in inches, so the recent data was changed from millimeters to inches in order to have a uniform data set.

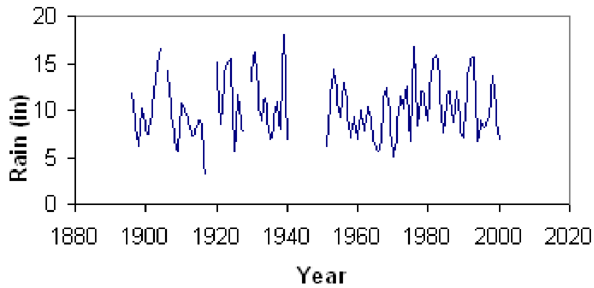

Fig (1) Mashhad annual rainfall time

The normality test of data is performed by Anderson-Darling, Joiner-Ryon, and Kolmogrov-Smirnov tests [11]. Considering the 10-year gap from 1941-1950 in the data, the rainfall time series is divided into two periods, 1893-1941 and 1950-2000. Some standard hypothesis tests were done on these two series. The Equality test of variances [12], parametric tests of the rank-sum test and two-sample test, and the non-parametric test of Kruskal-Wallis [13] were adopted for hypothesis testing for the equality of means. To test whether there is any similarity between the two groups we also traced the linear trend in the form of y=a+b.x (x=number of year- starting from 1- as an independent variable, and y=rainfall as a dependent variable). An ANOVA analysis was carried out to compare the two trend lines corresponding to the two halves [12].

In the kriging system the estimate of a variable value, $Z^*(x_o)$, at a specified location x_o and its corresponding variance, $VAR(Z^*(x_o))$, (minimum estimation error) is computed as follows:

$$Z^*(x_o) = \sum_{i=1}^{n} [\alpha_i Z(x)]_i \quad (1)$$

$$VAR(Z^*(x_o)) = \mu + \sum_{i=1}^{n} [\alpha_i \cdot \Gamma_{io}] \quad (2)$$

where $Z(x_i)$ is the value of the parameter under investigation at location x_i, and Γ_{io} is the semi-variogram between points at (i) and (o). The optimal weights (α_i) and Lagrangian multiplier (μ) are found by matrix algebra [1]. The semi-variogram $\Gamma(h)$, a measure of spatial dependency, is an essential part of the spatial model and can be computed as:

$$\Gamma(h) = \frac{1}{2} N(h) \sum_{i=1}^{N(h)} [Z(x_i) - Z(x_i + h)]^2 \quad (3)$$

where h is the lag, N(h) is the number of paired points with lag h, and $Z(x_i+h)$ is the value of the parameter under investigation at location (x_i+h). The sample semi-variogram consists simply of ordered sets of discrete values and are subject to error. However, there are some well-known semi-variogram models of stationary (Gaussian, Exponential, and Spherical models), and intrinsic non-stationary models (Power, and Linear models) to fit the raw values. The Comprehensive definitions of these models are presented elsewhere [1] and are not dealt with here.

The appropriateness of a semi-variogram model can be tested by standardized residuals [1]. Assume that the sample consists of n point measurements of $z(x_i)$. Drop one measurement, $z(x_k)$, then using the other measurements and the assumed variogram, estimate the value z at location x_i and its mean square estimation error, $\hat{z}_k$ and σ_k^2, respectively. The corresponding standardized residual can then be computed from:

$$e(k) = \frac{z(x_k) - \hat{z}_k}{\sigma_k} \qquad k = 1, \ldots, n \tag{4}$$

The same procedure is repeated for all measurements. Then the following two statistics are determined:

$$S_1 = \frac{1}{n}\sum_{k=1}^{n} e_k \tag{5}$$

$$S_2 = \frac{1}{n}\sum_{k=1}^{n} e_k^2 \tag{6}$$

If the model is consistent with the data, the first number must be near zero, while the second must be near one.

Polynomial fit. The similarities between an undulating rainfall time series and a polynomial may tempt a curious person to fit a polynomial regression on such series. On an annual time scale, however, rainfall behaves so erratically that it can hardly follow a smooth polynomial. Moving average is a technique commonly adopted for smoothing such wild series. By this, wet and dry years are found in a more sensible manner. We have managed different moving averages, up to 11 years, for such smoothening. Which order of the polynomial is more fitted to the data is another issue. It is known that lower orders of a polynomial are less flexible for covering optimal humps and depressions. Higher orders of polynomials, on the other hand, try "sharply" to follow such points, which is a serious danger in the case of sparse data series. This may result in abnormally high or low estimates for the missed values. To resolve this, we roughly bounded any prediction between $1.2 \times y_{max}$ and $0.8 \times y_{min}$, where y_{max} and y_{min} are the maximum and minimum values in the time series, respectively. The maximum order of a polynomial corresponding to these criteria was then selected.

Results and Discussion

1. Statistical considerations

There may be a suspicious thought that the data are not homogeneous before and after the Second World War. Therefore, we divided the data into two main groups of 1893-1940, and 1951-2000. Although the second time series is complete, the first one is not. At this stage we ignored the missed data and considered this series complete. The main statistical characteristics of these 2 series are presented in Table 1. There are no marked differences between these two series. Due to nearly equal means and standard deviations of the series, all data was pooled together and the normality test was conduted [14] over it. Fig. 2 shows an output portrayal for The Ryan-Joiner normality test [11], which supports that the rainfall time series is normal. The other two Anderson-Darling tests, and Darling tests, the Kolmogrov-Smirnov tests were essentially the same, and therefore are not shown here. Based on the normality hypothesis, it followed that at a 5% level of significance, there is no reason to reject the null hypothesis of H_0: $\sigma_1^2=\sigma_2^2$ against the alternative hypothesis of H_1: $\sigma_1^2 \neq \sigma_2^2$. Comparing the means of the two groups by both the rank-sum test as a non-parametric test, and the two-sample t test as a parametric test, [13], could not reject that the two groups are identically distributed with the same means. The Kruskal-Wallis test for multi-groups (k=2) [13] also confirmed the above findings.

Table 2 presents the statistical features of three lines corresponding to different time spans. These statistical features do not illustrate many differences. As statistical tests could not reject the equality of the variances, the equality of the two trend lines was tested [12]. The results are abbreviated in an ANOVA table (Table 3). Based on the results of Table 3, (a) the hypothesis of the equality of the two slopes can not be rejected at α=5% level of significance, (b) there is no reason to reject the equality of intercepts, (c) there is no linear association of time on rainfall (correlation coefficients do not differ from zero).

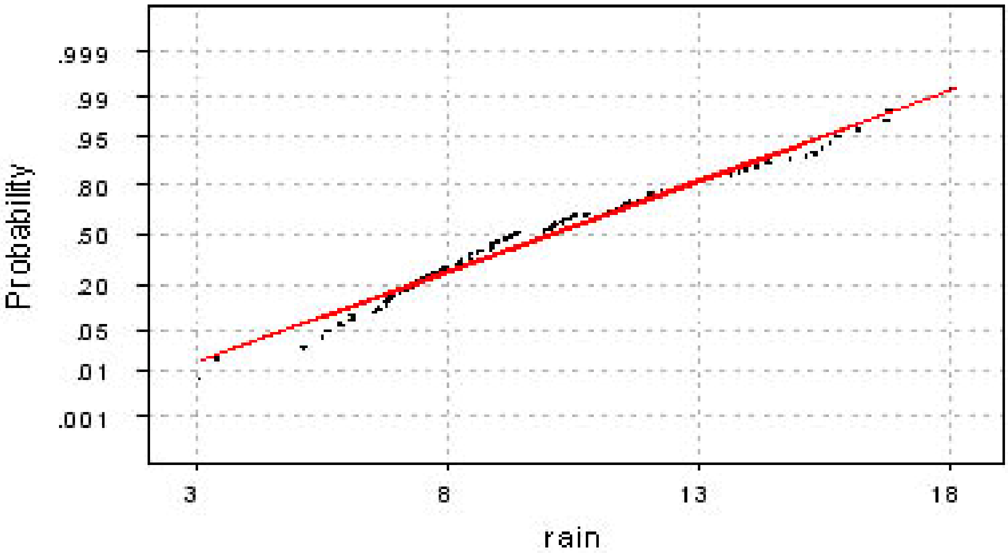

Fig. 2. Ryan-Joiner normality test for Mashhad annual rainfall (in).

Table (1) The main characteristics of the 2 time series of Mashhad rainfall

Series number	N	$\overline{X}$ (in)	SD (in)	min(in)	max (in)	Skewness
1 (1893-1940)	42	10.0017	3.5254	3.12	18.07	0.4040
2 (1951-2000)	50	10.1492	2. 8686	5.15	16.81	0.4261
Total	92	10.0818	3. 1679	3.12	18.07	0.3968
Completed	108	10.1323	2.9506	3.12	18.07	0.3690

Table (2) Statistical features of the 2 trend lines corresponding to two halves of time series*

Parameter	First half (1893-1940)	Second half (1951-2000)	Total span
a (in)	8.8525	9.4188	9.5728
b	0.0452	0.0286	0.0089
r	0.1781	0.1456	0.0912
σ^2 (in^2)	12.3351	8.2223	8.5440
n	42*	50	108

* missed data not included

Table (3) ANOVA table for comparing the 2 trend lines corresponding to 2 halves of time series

Source	Sum of square	Degrees of freedom	Mean square	F-value	
				Measured	Critical
Overall	23.48	1	23.483	2.3269	3.96
Differences in position	0.44	1	0.4429	0.0439	3.96
Differences in slope	1.23	1	1.2266	0.1215	3.96
Residual	888.11	88	10.092		
Total	913.26	91			

2. Estimation methods

a. kriging

Rainfall values did not resemble a meaningful time trend. Therefore, simple point kriging versus universal kriging is a good alternative. Fig. 3 depicts the semi-variogram of the raw data. As the lag proceeds, the semi variogram is computed from fewer paired points. Therefore, an active lag, usually, is taken at most 50% of the total lag. Fig. 3 is prepared for the maximum lag, however. There is no difference between the active and maximum lags on the trends of the semi variogram data points. Different theoretical models are fitted to the semi variogram data of Fig. 3. However, none of the models resulted in a fair fit. The outputs of some of the common models are plotted in Fig. 3 for a rapid comparison with the scatters of raw data. Based on this figure, one may conclude that not only is the nugget variance very high, but also there is a weak dependency of data to each other at any time lag. This weak dependency causes all theoretical semi-variogram models to appear nearly the same. Therefore, outputs of all of the semi-variogram models showed high correlations with each other (Table 4). As a result, we used an average for the kriged values corresponding to every piece of missed data amongst the 5 models. A comparison of Mashhad annual rainfall missed-value estimations by different methods is made in Table 5.

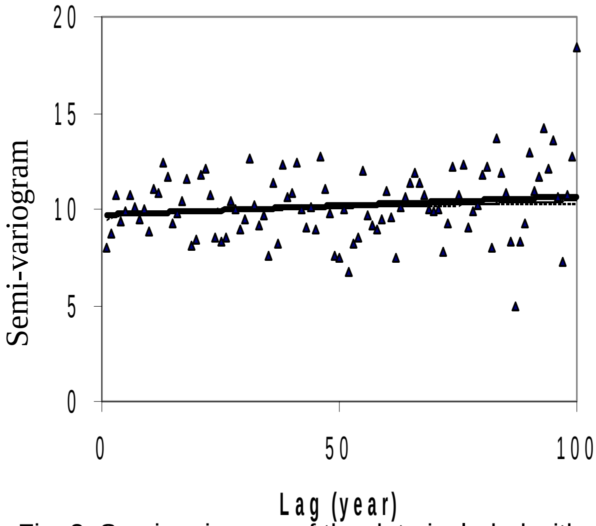

Fig. 3. Semi variogram of the data included with fitted theoretical models (triangle: raw data, thick line: linear model, dashed line: power model, and dashed-dotted line: exponential model)

Table (4) Correlation of different series of estimated Mashhad annual rainfall from some common semi-variogram models

Semi-variogram model	Spherical	Exponential	Gaussian	Linear	Power
Spherical	1	0.9945	0.9938	0.9969	0.9962
Exponential	0.9945	1	0.9767	0.9831	0.9816
Gaussian	0.9938	0.9767	1	0.9994	0.9997
Linear	0.9969	0.9831	0.9994	1	1
Power	0.9962	0.9816	0.9997	1	1

Table 5. Comparison of Mashhad annual rainfall missed-value estimations (inch) by different methods

Year	Method Linear trend	Krging	Degree of moving average for Polynomial fit+						Time series*
			1	3	5	7	9	11	
1894	9.59	8.11	8.38	15.05	10.36	18.83	12.07	3.41	10.07
1895	9.60	8.11	12.05	13.22	8.68	10.81	16.17	8.52	12.88
1905	9.69	12.07	13.43	7.34	7.35	10.62	5.09	8.52	14.09
1918	9.80	8.83	9.82	12.51	19.36	3.39	11.99	18.25	10.07
1919	9.81	9.79	10.41	10.32	8.00	3.67	11.16	9.34	9.26
1929	9.90	11.23	10.64	17.13	5.40	7.40	5.28	15.72	8.05
1941	10.01	10.39	9.46	17.72	10.96	8.93	3.23	13.51	10.16
1942	10.02	10.39	8.93	6.08	10.56	12.94	7.51	15.68	10.16
1943	10.03	10.39	8.41	10.86	7.84	11.18	11.97	10.63	10.16
1944	10.04	10.83	7.95	18.21	17.68	5.52	15.86	8.16	10.16
1945	10.04	10.05	7.62	6.47	6.37	10.25	12.98	10.37	10.16
1946	10.05	11.27	7.46	11.13	10.47	14.47	10.68	6.25	10.16
1947	10.06	9.78	7.51	18.35	10.04	11.97	14.16	7.46	10.16
1948	10.07	10.38	7.76	6.48	7.29	10.08	11.38	9.77	10.16
1949	10.08	10.38	8.20	11.02	17.10	13.98	8.22	7.07	10.16
1950	10.09	10.38	8.76	18.12	5.77	12.03	1.90	16.91	10.16

+ selected polynomial orders for 1, 3, 5, 7, 9, and 11 moving averages are 24, 16, 8, 8, 7, and 5, respectively.
* after Khalili and Bazrafshan [14]

b. Polynomial fit

The best moving average order is not known. While Adopting a low order causes greater variation of rainfall data, a high order for the moving average resulted in losing more data. Fig. 4 is a portrayal showing more sparse time series as the moving average order progress. On the other hand, a low polynomial order causes rigidity in fitting the data, yet a high polynomial order may be responsible for sharp fitting the humps and depressions. While Fig. 5 shows such a sharp fit of the higher order polynomial of 10 to humps and depressions, especially for a 9-year moving average sparse series. The results of polynomial fits are also included in Table 5.

c. Selecting the optimum values

Table 5 portrays some differences amongst the different methods of estimation. Yet the coefficient of variations corresponding to every year of missed-data, on average, is 0.326 (Table 6). The statistical features of the completed series are included in Table 1. The Skewness coefficient of the completed series is lower by around 7%, while the other parameters are in the limit of the raw data.

We compared our results with a time series model (Khalili and Bazrafshan, [14]). Based on the resolution of the figures of this reference, rainfall values corresponding to the data-missed years were determined (Table 5). Our results, on average, differed from those of Khalili and Bazrafshan [14] by 0.38%. However, a constant rainfall value of 10.16" for 10 consecutive years from 1941-1950 seems rather strange. This may be a clue to the mal-functioning of time series modeling for the rainfall time series.

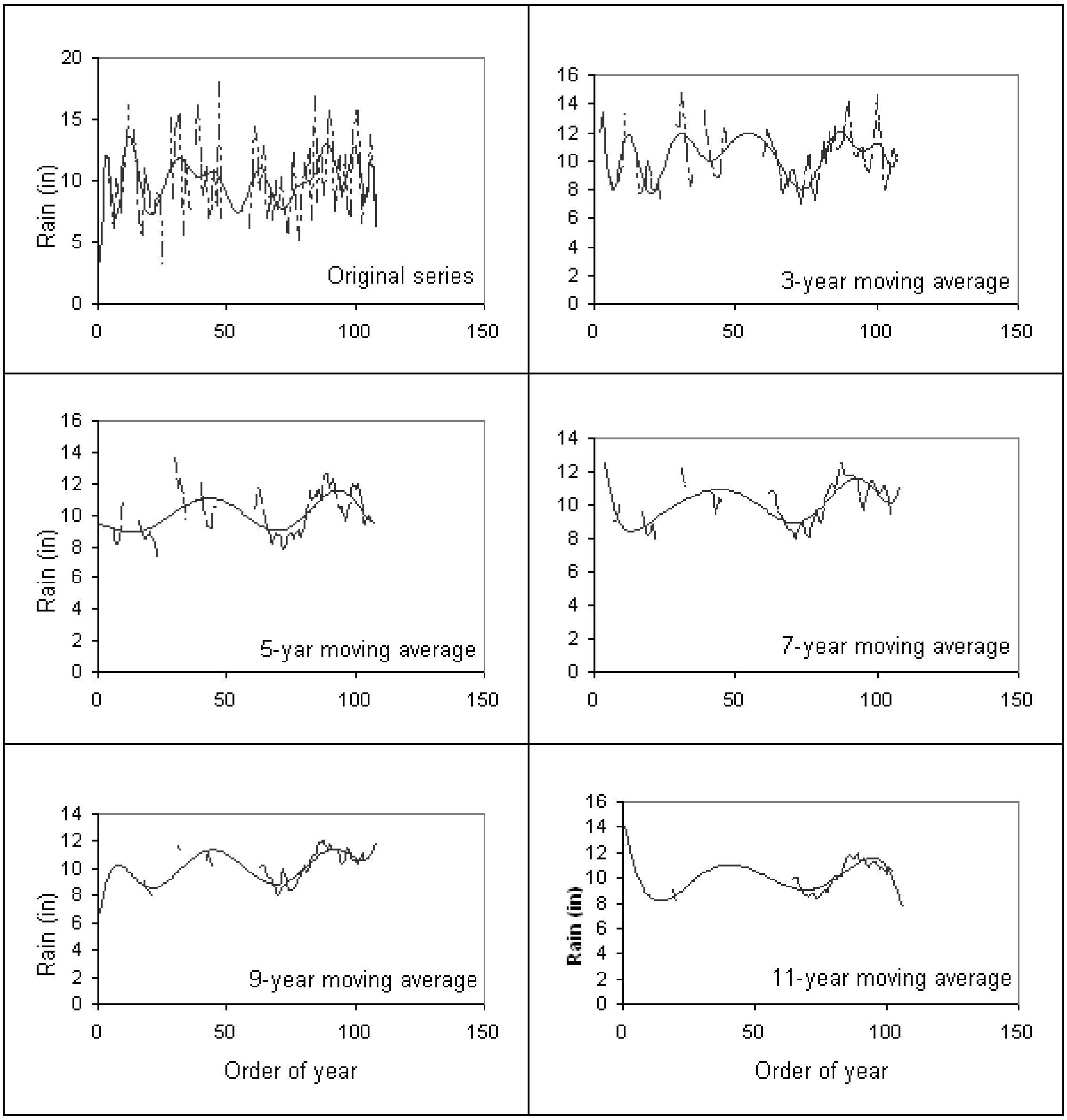

Fig. 4. Measured annual rainfall (in) at different orders (1 for 1886) estimated by polynomial regression (thick line). Thin line is due to actual data.

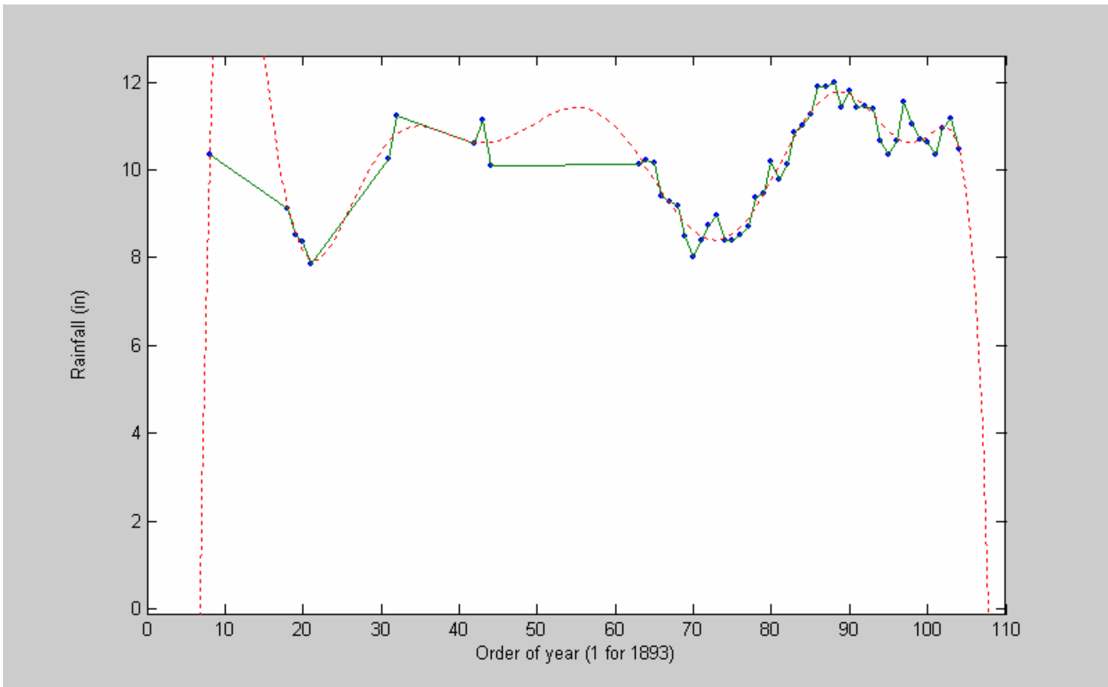

Fig. 5. Danger of high polynomial order to sparse time series (polynomial order 10 for 9-year moving average) (dashed line). Historic data are connected by solid line (ignoring missed data).

Table 6. Simple statistical inferences on different methods of Mashhad annual rainfall missed-value estimations (Table 5).

Year	average (inch)	CV
1894	11.8	0.461
1895	11.10	0.242
1905	8.97	0.302
1918	12.04	0.408
1919	8.43	0.346
1929	10.62	0.394
1941	10.53	0.390
1942	10.26	0.294
1943	10.16	0.137
1944	11.78	0.410
1945	9.27	0.245
1946	10.22	0.244
1947	11.17	0.326
1948	9.15	0.190
1949	10.76	0.310
1950	10.50	0.510
Mean	------	0.326

Conclusion

Having a complete time series is important in design applications. Different methods were utilized to estimate rainfall values for the 16 years of missed values. Geostatistical and kriging techniques were applied to The Mashhad long-term annual rainfall time series. All the semi-variogram models were poor. As a result, the estimated rainfalls were distributed among the mean. Further investigations are needed to reach a firm conclusion on the applicability of geostatistical methods for data filling purposes. We adopted the polynomial regression fits of different moving average orders and also different polynomial orders. Coefficient variation amongst different methods, on average for 16 years of missed-data, was around 0.3. Also the deviation among our results and a literature-reported time series method, was completely negligible. Therefore, different methods verify each others. As none of the methods are crucial, it may be hypothesized that the results are satisfactory.

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