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Extended Modified Inverse Distance Method for Interpolation Rainfall

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Abstract—Local Interpolation and regional analyzing of rainfall are one of the important issues of Water Resources and Meteorology. There are several methods for this purpose. IDW is one of the classic methods for estimating precipitation. This method of interpolation at each point gives a weight to the distance to the reference point. IDW method has been modified in various ways in different research and new parameters such as elevation were added to it. This reform has two modes. The First state is the ratio of elevation to distance and the second is the inverse of multiplying elevation and distance. This paper has three objectives. First is generalizing the alignments of various elevation and distances in MIDW. Second is dimensionless the weights (separately and integrated) according to relationship that is used. Third is analyzing interpolation errors of daily rainfall regionally. Genetic algorithm is used to find optimal answers. Results showed that optimal answers primarily is depending on the reverse effects of multiply of altitude and distance (55%) and with a direct effect of altitude and inverse effect of distance (45%). It's then 71% of cases shows that integrated dimensionless yields better result than separately ones. Impacts of elevation were established in all MIDW methods. Results showed that this parameter should be used in interpolation of rainfall. Case study is a daily rainfall catchment of Mashhad plain.

Keywords—Regionally interpolation, MIDW, Genetic algorithm, Mashhad.

I. INTRODUCTION

Local and areal estimations of rainfall are needed in those projects and researches that used point, areal and regional data of hydrology and climatology, areal and regional water use and weather. Ordinary methods for estimating this Phenomenon includes the Arithmetic mean, Thiessen, Rainfall gradient, Inverse Distance and Isohyetal curves (Horton, 1923, Singh and Birsoy, 1975, Johansson, 2000). Finite element method (Hutchinson and Walley, 1972), Kriging (Vasiliades and Loukas, 2009), Fuzzy Kriging (Bondarabadi and Saghafian, 2007) and splines (Hutchinson, 1998), Neural Networks (Rigol et al, 2001, Moghaddam and et al, 2011) as well as relatively new methods for the spatial estimating for this phenomenon.It can be corrected by conventional methods and acceptable results are achieved. One of these is the Inverse Distance (IDW) method that some researchers have done some changes in it and called it Modified Inverse Distance method (MIDW) (Lo, 1992, Chang et al, 2005). Lo (1992) introduced MIDW such that the impact of elevation difference in the IDW is considered as a factor. Therefore, the weight of each station is to be distance to the elevation ratio with k power. This relation is suitable for mountainous areas. Chen and Liu (2012) applied IDW method for regional analysis of 46 rain gauge stations located in Taiwan. They investigated the influence of stations radiuses neighborhood too. Radiuses of the desired effect are 10 to 30 km and fluctuations in the power of the IDW 1.5 to 4 obtained. Monthly and annual precipitation data were used in their research. Tomczak (1998) performed spatial interpolation of precipitation with IDW method. He studied two parameters, the distance and spherical radius and optimized the parameters of function with cross-validation. Then he attempted with the Jack- Knife to determine the sampling frequency skew, the standard error and confidence intervals for each station. He concluded that this method can obtain satisfactory results with respect to these two points.

Chang et al. (2005) combined the IDW method by Fuzzy theory for interpolation the missing data. Genetic Algorithm also was employed to optimize the fuzzy membership function parameters. Daily rainfall of six rain gauge stations (located in a catchment area of 303 sq km in northern Taiwan) were used for this proposed. Their research investigated the equation errors of interpolation at each station separately. Estimation errors of precipitation from this method are generally reported less than Thiessen and arithmetic averages methods. Lu (1992) added ratio of distance to elevation and Chang et al. (2005) added the inverse of these two parameters products into the IDW method. The regional rainfall analysis is affected by the elevation. It has a negative influence in the adjacent water resources areas (Coastal and Forest) and positive in the remote areas (mountainous region). It is possible that to Modify IDW method by changing places of its parameters and their powers. We can put each one in numerator or denominator of IDW's coefficients separately or tougher. So we have four states that they are more general than Chang et al. and Lo modified methods. We follow three goals in this research. First, we compare these four methods. The various MIDW methods approaches to optimize MIDW interpolation equation locally (Moghaddam et al., 2011, Tomczak, 1998,Chen and Liu, 2012). Second goal is modifying the IDW method for optimizing interpolation equation regionally in Mashhad basin area (regional interpolation). Third we compare two dimensionless weighted methods of MIDW coefficients. So we have eight separated models for regional interpolation MIDW in general. Our case study is Mashhad basin in Iran.

II. MATERIALS AND METHODS

1.2 Study area and data

The study region is the catchment area of Mashhad plain with 9909.4 sq km in longitude 58^0 – 20′ and 60^0 - 8′East and latitude 36^0 - 0′and 37^0 - 5′North in North East of Iran. Mashhad plain is a basin with irregular topography, the climate is arid, semi arid and its north and south is surrounded by tow mountain ranges by the name of Hezar-Masjed and Binaloud, Respectively Number of rain gauge stations in this basin and its adjacent are 49 (each one with a 16 year data 1993-2009). These stations are run under the Iran Ministry of Energy. 71days of daily rainfall data is used. The geographical position and characteristics of stations come in Figure (1) and Table (2) respectively. SQL Server 2008 and VB.NET 2010 used for Descriptive Statistics.

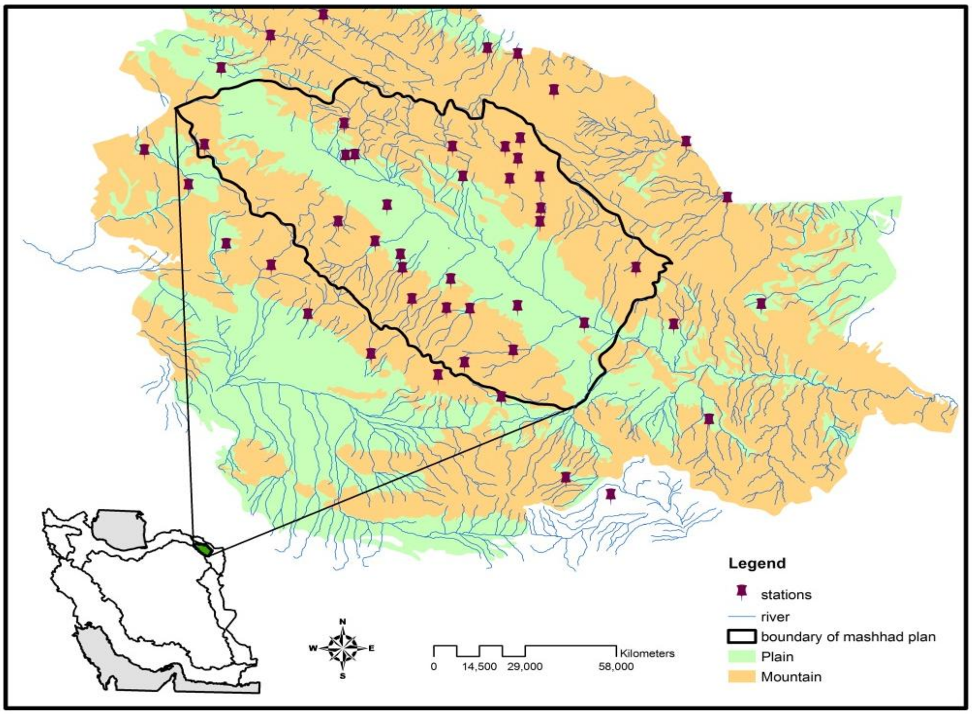

Figure (1) - Catchment location Mashhad plain with rain gauge stations in and around

2.2 Methods of Modified Inverse Distance (MIDW)

Modified Inverse Distance methods are obtained by changing the conventional Inverse Distance (IDW) weight. Distances between stations are used for weighted IDW. While other factors such as elevation are also an important influence on rainfall and can be a weight in IDW. Operating arrangement of elevations and distances in the IDW is leads to a variety MIDW as follows. Lo (1992) introduced the MIDW according to equation (1). The weight of each station ($(\frac{d_{xi}}{\Delta H_{xi}})^k$) is the ratio of distance ($\mathbf{d_{xi}}$) to the elevation difference ($\mathbf{\Delta H_{xi}}$). Indeed, impact of component difference is assumed to be direct and impact of component elevation is reverse with identical power for both.

$$\mathbf{p_x = \frac{\sum_{i=1}^{N}(\frac{d_{xi}}{\Delta H_{xi}})^k . p_i}{\sum_{i=1}^{N}(\frac{d_{xi}}{\Delta H_{xi}})^k} \quad , \quad k > 0} \qquad (1)$$

where p_x is the Point Rainfall estimation, d_{xi} is the distance between each station from the base station. Moreover, N is the number of stations that used, k is the power's parameter and ΔH_{xi} is difference elevation between base station and the ith station.

Chang et al. (2005) have considered the inverse multiply of elevation and distances as a weight in MIDW. They are considered different power for distance (m) and elevation (n) weight. Interpolation error equation in this method is discussed locally (separately for each station). Formula (2) is the model of Chang et al. (2005).

$$P_x = \frac{\sum_{i=1}^{N} h_{xi}^{n} * d_{xi}^{m})}{\sum_{i=1}^{N} h_{xi}^{n} * d_{xi}^{m}} * P_i \quad , \quad m > 0, \; n > 0 \qquad (2)$$

Where: m and n are powers (parameters). h_{xi} is the elevation difference between base station and ith' ones. Other items are the same as formula (1).

The defined model in this study is general pattern of equation (2). So that the distance and elevation difference are allowed that have different alignment (positive or negative sign of m and n). So their effect is direct or inverse. In other words, both appear in the numerator, or both in the denominator or one in the denominator and another in the numerator with different power. Estimating the optimal m and n parameters are needed. Genetic algorithm is suitable for this purpose.

3.2 Genetic Algorithm

Genetic algorithm is a probabilistic search method that surrounds a natural biological process of evolution will follow. This method is based on the Darwinian theory of evolution and Encodes the potential solutions to a problem to chromosomes in a simple format. Then implement the combination operators with a random population of individuals (each one in the form of chromosome), (Kia, 2009). Genetic algorithm can produce many generations. The initial population is generated randomly in the desired interval. New set of approximations in each generation with the best member selection process based on their fitness in the problem domain and the multiplication of the operators are made from natural genetics. This process will ultimately lead to the evolution of population members that have better adaptation of the original members of the original parents in their environment.

Members of the population or in other words, the current approximation of the optimal solution encodes as string by sequence into the chromosome with the variables of the problem. Objective function, provides an index to select the appropriate pair and mating chromosomes in the population. After the initial generation, the next generation is produced using genetic operations such as elitism, mating (crossover) and mutation. Each member shall be entitled to represent the value of its compatibility (with the objective function). Members who have a higher consistency than others will have a higher chance to select and move to the next generation and vice versa (elitism). Mating genetic operator combines the genes of chromosomes together, but does not necessarily act on all the strings of population. The contrary, it is done with probability p. Mutation operator is performed with a random selection of chromosomes and random selection of one or more genes and substituting its contradictory. The mutation also will act with prior probability (pm). Thus continues the cycle of next generations. The end of the genetic algorithm process is achieving optimal solutions (Shabani Nia and Saeed Nia, 2009, Kia, 2009). Genetic algorithm is used for estimation and to optimize the variables of interpolation equations and due to time savings. MIDW method is interpolating method with two m and n parameters where m is power of distance factor and n is power of the elevation factor. Two parameters (m and n) are generated randomly, and the error function is optimized with the repeat the algorithm and produced better m and n in each generation. The objective function in MIDW is minimizing the regional mean absolute errors (MAE), (Equation 9). That is the mean of all local absolute errors. Chromosomes are the two parameters; m and n (20 chromosomes in each generation) and are generated randomly according to GA operators. Two adaptable chromosomes in each generation are transferred directly to the next generation (elitism). Genetic algorithm has been programmed in MATLAB 7.8.0 (R2009). It is necessary to preprocessing data before analyzing that it is explained in Next section.

2.4 Screening and normalization data and dimensionless weights

Available data are often mixed with error. These errors are the basis of false recorded, incorrect transfer, system failures, etc. Data must first be screened. If data are not properly screened the elevation difference and distance should be normalized to the same scale in MIDW (Chang et al, 2006, Hebert and Keenleyside,1995). Equation (3) and (4) is used for normalization. This conversion causes the Elevation difference and distance should be between 1 and 10.

$$d' = 1 + 9 * \left(\frac{d \quad d_{min}}{d_{max} \quad dmin}\right) \qquad (3)$$

$$h' = 1 + 9 * \left(\frac{h \quad h_{min}}{h_{max} - hmin}\right) \qquad (4)$$

- The dimensionless weights obtain with two methods: integration (Equation 5) and separation (Equation 6). If m and n are assumed to be in the denominator (m and n are both negative), then integration and separation methods are the same as equation (5) and (6). Other arrangements can be made similarly.

- The integrated dimensionless: dimensionless factor is the sum of multiplication of the distance and Elevation, (equation 5), (Chang et al, 2005).

$$\sum_{i=1}^{N} \frac{1}{d_{pi}^{m} * h_{pi}^{n}}, \quad m > 0,\ n > 0 \tag{5}$$

- The separation dimensionless: dimensionless factor is the multiplication sum of the distance and elevation, (equation 6), (Chang et al, 2005).

$$\sum_{i=1}^{N} \frac{1}{d_{pi}^{m}} * \sum_{i=1}^{n} \frac{1}{h_{pi}^{n}}, \quad m > 0,\ n > 0 \tag{6}$$

The final equations for MIDW are (7) and (8) in the case that m and n are in the denominator. The rest of the functions for other states of m and n are similar.

$$P_x = \sum_{i=1}^{N} W_{d_{Pi}, h_{P_i}} * P_i = \sum_{i=1}^{N} \frac{\frac{1}{d_{P_i}^{m}} * \frac{1}{h_{P_i}^{n}}}{\sum_{i=1}^{N} \frac{1}{d_{P_i}^{m}} * \frac{1}{h_{P_i}^{n}}} * P_i, \quad m > 0,\ n > 0 \tag{7}$$

$$P_x = \sum_{i=1}^{N} W_{d_{Pi}, h_{P_i}} * P_i = \sum_{i=1}^{N} \frac{\frac{1}{d_{P_i}^{m}} * \frac{1}{h_{P_i}^{n}}}{\sum_{i=1}^{N} \frac{1}{d_{P_i}^{m}} * \sum_{i=1}^{N} \frac{1}{h_{P_i}^{n}}} * P_i, \quad m > 0,\ n > 0 \tag{8}$$

Eight error functions occur according to the descriptions, elevation and distance alignment and type of dimensionless. One of them is in equation (9), (e.g. inverse of the distance and positive impact of the Elevation in separation dimensionless method).

$$E = \sum_{i=1}^{N} e_i = \sum_{i=1}^{N} p_i * \frac{\sum_{\substack{i=1 \\ i \neq j}}^{N} h_{xi}^{n} * d_{xi}^{m} . P_i}{\sum_{\substack{i=1 \\ i \neq j}}^{N} h_{xi}^{n} * \sum_{\substack{i=1 \\ i \neq j}}^{N} d_{xi}^{m}}, \quad m > 0,\ n > 0 \tag{9}$$

Where p_x is the observed rainfall in the ith station, and the second term is estimated rainfall in that station. Other items are the same as formula (1). The error function is regulated similarly to the other seven cases (9).

III. RESULTS AND DISCUSSION

Data analysis in this article is 49 stations daily precipitation of Mashhad plain catchment for 16 years. A sample size of 71 days is randomly selected and analyzed. Initially suspected precipitation was determined and The data were screened. Then data normalized using equation (3) and (4). Analysis based on these normalized data. The purpose of this study is to optimize the interpolation function (MIDW) and considering four general substitution of distance and Elevation to explore the direct or reverse impact on daily rainfall interpolation multiple alignment is obtained by changing the sign of m and n (power distance and Elevation). m and n parameters are optimized with genetic algorithm. Dimensionless of weights of MIDW equation is done with equation (5) and (6). So in order to determine the best interpolation formula was studied in eight states. Four states (substitution distance and elevation) were compared to determine the best relationship MIDW and two for the best dimensionless. Genetic algorithm because of high-volume of calculations was used to determine the optimal parameters. The work is as follows.

- Determine the number of required

First, the necessary population was determined to achieve the optimal response. Ten days were randomly selected and was tested with 5 to 100 generations were divided into steps. Number of generations required to achieve the optimal response was generally less than 50 numbers. Most of the generations required to achieve stability in the optimal solution was obtained with 90 generations. Number of generations was chosen to ensure 100 more. Maximum and minimum errors were calculated separately for each of the eight states MIDW. Errors in the eight-state amplitude were less than 10 mm. The lowest error in each method with its parameters was chosen as the optimal errors and the desired parameters.

- Effect of various alignments and types of Dimensionless

Alignment of distance and elevation were done in MIDW and algorithm were implemented and compared for each state. This was compared with the index negative and positive coefficient for power distance (m) and elevation difference (n). Moreover, dimensionless of weights were done in two ways (equations 5 and 6). Results are shown in Table (2). Dimensionless indicated that all four alignments may not be necessary. Different states of the following below:

Dimensionless with equation (5):

Role of the distance and Elevation is reversed in 54% of cases (method of Chang et al.),31% of cases the influence of distance is reversed and the influence of elevation is direct. For 10% of cases the influence of elevation is reversed and the influence of distance is direct(Lu method) and in 6% of cases the influence of distance and elevation is direct. There are necessary four alignments with different importance in this dimensionless. Distance and elevation never had zero impact on the optimal solution.

B – Dimensionless with equation (6)

The influence of elevation difference and distance in 55% of cases was reversed (Chang et al method, 2005) and in 45% of other states influence of distance was reverse and influence of elevation was direct (of Lo, 1992), (Table 2) . Other alignments in any case no optimal solution. Not eliminate the impact of distance in any equation. However, in the separation dimensionless, In that case, the influence of elevation is director inverse and influence of direct or inverse, m was zero in four cases. The following comparison of two methods showed that 87% of cases, equation (5) (the integration of weight and Elevation) has the optimal solution and separation dimensionless state 13% of the cases has the optimal solution. Regional best interpolation error equation with equation (9) is the calculated and regional average error is shown in Table (4).Analysis of error of regional interpolation equation for each day shows that lowest and highest errors are 1.3 and 8.2 mm respectively (Table 4). Regional daily mean and standard deviation of errors (71 Days) are respectively 4 and 1.58 with a coefficient of variation 39.5%. These results indicate that the accuracy of the interpolation equation is relatively good.

- Analyzing the range of m and n for 8 states of regional interpolation equations

Changes of m and n were evaluated for each eight methods. Results showed that changes of range for each alignment of elevation and distance and each method of dimensionless are different (Table 3). If the influence of distance and elevation is inversely (In both dimensionless methods) interval of m and n is [0, 16]. If the effect of distance to be reversed and the effect of elevation be directed, m is between 1.14 to 15.98 and n between 2.09 to 15.98. When the effect of elevation to be reversed and the effect of distance is directed (In both dimensionless methods), n changes from 0 to 4 and changes m depends to the dimensionless method. So that changes due to the integrated dimensionless between 2.9 to 16 and for the separation dimensionless between 0 and 3.07. More detail is shown in Table (3).

IV. CONCLUSION

The MIDW Interpolation method is used for precipitation. This method adds the elevation as a weight in IDW equations. So far, two forms of MIDW were discussed. The first form is based on the distance to the elevation ratio (with power constant k), and the second is based on the inverse of the distance and elevation with various m and n power. This study extends the MIDW to its general form by considering eight weights which included the two previous forms. It includes four forms of different alignment of distance and elevation and two methods of weights dimensionless (separation and integrated). m and n present the power of distance and elevation in the models. Genetic algorithm was used to optimize the interpolation equation parameters of MIDW. Daily rainfall data for 49 stations of the Mashhad plain catchment was used in this study. The results showed that the contribution of the integrated weights dimensionless is 87% and separate dimensionless is 13% in optimization of different alignment of elevation and distance. Moreover, it is not necessary to considerate all four types of alignment of elevation and distance for the studied areas. The results indicate that in the separated method the role of the distance and elevation in 54% of cases are inverses (Equation 2). However, in 31% of cases, the roles of distance is reverse and the role of elevation is direct, 10% of cases, the role of distance is direct and the role of elevation is inverse (Equation 1), and 6% of cases, role of elevation and distance is direct. But in separated dimensionless, the role of distance and elevation are reversed in 55% of cases, 45% of cases, the role of distance is direct and the role of elevation is reversed. Two other alignments don’t have good answers in separated dimensionless and these equations were excluded from MIDW. So to determine the best regional interpolation function, should not be limited to a specific alignment. The study of six cases MIDW provides the possibility to achieve optimal solutions. A certain range cannot be considered for parameters m and n, since large swings are observed in their intervals for eight states of MIDW. The average error and standard deviation of the regional daily rainfall are 1.58 and 4 with coefficient of variation 39.5% respectively. The results show that the accuracy of the interpolation equation is relatively good. The survey results showed using the MIDW method with six different alignment of distance and elevation with two dimensionless in effective to achieve the optimal results.

Table 1 - Characteristics Geographic stations in and around Mashhad catchment

name	elevation	Long. (North)	Lat. (west)	name	elevation	Long. (North)	Lat. (west)
Dizbad Olya	1880	705752	3997566	Jong	1700	731149	4073827
Tabarokabad	1510	652515	4117177	Abghade Ferizi	1380	685763	4044656

Heyhey	1330	636830	4105749	Goshe Bala	1580	728529	4066718
Eish Abade	1346	664428	4018975	All	1475	738067	4067314
Bar-Erie	1560	652778	4036255	Chenaran	1170	689618	4057478
Marusk	1495	638479	4043758	Moghan	1780	714164	4001945
Yengeje(Abshar)	1680	612457	4076877	Jaghargh	1420	708429	4021113
Cheshme Ali	1540	684471	4004990	Sharif Abad	1455	725852	3989818
Saghibaik	1510	626453	4064663	Talghor	1540	710308	4078053
Farhad Gerd	1500	746352	3961364	Ghadirabad	1175	676396	4074984
Golmakan	1400	693844	4040097	Chakane Olya	1780	631555	4078712
DahaneAkhlomad	1460	674033	4051676	Hesar Dehbar	1220	715841	4020953
Fariman	1395	760631	3955446	Hendel Abad	1210	768676	4035400
Radkan	1210	679342	4075224	Kalate Menar	990	791909	3981966
Dolatabad	1510	694409	4035379	Mayamei	1030	780656	4015387
Sadetorogh	1240	729639	4006280	Bazengan	1020	808510	4022543
Zoshk	1880	697502	4024363	Bahmanjan Olya	1340	675941	4086234
EdareMashhad	990	731039	4021956	Chahchahe	479	797692	4060098
Sar asiyabe Shandiz	1270	709820	4031347	Gharetikan	520	784601	4079834
Androkh	1200	738131	4051588	Darband Kalat	970	742634	4098004
Sade karde	1300	738455	4056330	Archangan	745	731086	4110734
Mareshk	1870	727140	4077931	Hatamghale	490	709790	4132161
Olang Asadi	900	752266	4015822	Kabkan	1435	669345	4124444
Bande Saroj	1310	713617	4067555	LayenNow	876	721485	4112761
Bolghor	1920	731891	4081022				

Table 2 - Effect of alignment of elevation and distance in MIDW with dimensionless weights

Separated (equation6)		Integrated (equation 5)	
percent	**alignment**	**percent**	**alignment**
55.0%	Elevation and distance is inverse	54.0%	Elevation and distance is inverse
0.0%	Elevation is direct and distance is inverse	31.0%	Elevation is direct and distance is inverse
0.0%	Elevation and distance is direct	6.0%	Elevation and distance is direct
45.0%	Elevation is inverse and distance is direct	10.0%	Elevation is inverse and distance is direct

Table (3) – Range of m and n in different MIDW methods

Separated (equation 6)		Integrated (equation 5)		
$1.04 \le n \le 15.98$ $0 \le m \le 13.78$	Elevation and distance is inverse	$0.21 \le n \le 15.98$ $1.14 \le m \le 15.98$	Elevation and distance is inverse	**1**
-	Elevation is direct and distance is inverse	$0.25 \le n \le 15.98$ $2.09 \le m \le 15.98$	Elevation is direct and distance is inverse	**2**
-	Elevation and distance is direct	$8.06 \le n \le 15.98$ $1.59 \le m \le 15.98$	Elevation and distance is direct	**3**
$1.15 \le n \le 3.15$ $0 \le m \le 3.07$	Elevation is inverse and distance is direct	$0.04 \le n \le 3.56$ $2.98 \le m \le 15.98$	Elevation is inverse and distance is direct	**4**

Table (4) - regional rainfall average absolute error Interpolation

Date (in shamsi)	m	n	sign m&n	Mean errors	date	m	n	sign m&n	Mean errors
1372/1/15	**1.313**	**1.297**	**1**	**4.219**	**1380/2/1**	**3.359**	**1.75**	**1**	**3.50**
1372/1/7	**1.188**	**1.344**	**1**	**7.009**	**1380/2/11**	**5.422**	**1.047**	**2**	**3.94**
1372/12/11	**4.656**	**2.156**	**1**	**2.149**	**1380/2/23**	**4.797**	**0.5**	**2**	**6.40**
1372/12/21	**5.719**	**3.094**	**1**	**5.309**	**1381/1/25**	**14.266**	**2.969**	**2**	**4.08**
1373/1/2	**4.844**	**15.984**	**3**	**2.938**	**1381/1/29**	**14.984**	**10.359**	**1**	**4.43**
1373/1/29	**15.984**	**0.797**	**4**	**3.098**	**1381/12/22**	**3.953**	**15.984**	**2**	**2.99**
1373/12/27	**9**	**2.313**	**1**	**6.479**	**1381/2/19**	**3.938**	**0.531**	**1**	**6.70**
1373/2/5	**9.656**	**7.563**	**2**	**2.540**	**1381/3/4**	**4.484**	**0.406**	**1**	**3.27**
1374/1/13	**1.594**	**15.984**	**3**	**2.140**	**1382/1/1**	**2.734**	**1.625**	**2**	**4.69**
1374/1/22	**11.063**	**2.469**	**1**	**3.194**	**1382/1/17**	**8.266**	**0.047**	**4**	**4.63**
1374/12/13	**11.328**	**3.5**	**1**	**6.206**	**1382/12/25**	**2.281**	**0.844**	**1**	**5.29**
1374/12/18	**4.656**	**8.063**	**3**	**6.579**	**1382/2/9**	**6.5**	**3**	**2**	**3.82**
1374/12/24	**15.984**	**6.813**	**1**	**3.979**	**1383/1/6**	**13.109**	**1.453**	**1**	**4.59**
1374/2/31	**4.203**	**1.969**	**1**	**1.864**	**1383/12/24**	**8.219**	**0.813**	**1**	**4.62**
1375/1/11	**14.219**	**0.453**	**2**	**2.575**	**1383/2/21**	**5.25**	**3.313**	**1**	**2.54**
1375/1/30	**5.016**	**1.922**	**2**	**1.848**	**1384/1/19**	**3.484**	**0.922**	**1**	**8.18**
1375/1/6	**4.094**	**2.484**	**1**	**3.423**	**1384/12/10**	**15.875**	**8.422**	**1**	**3.14**
1375/12/10	**4.281**	**1.172**	**2**	**4.163**	**1385/1/11**	**2.438**	**1.781**	**1**	**1.28**

1375/2/11	**5.266**	**2.766**	**2**	**3.396**	**1385/1/2**	**7.266**	**2.813**	**1**	**4.68**
1375/3/12	**7.125**	**12.656**	**3**	**2.310**	**1385/1/26**	**6.984**	**2.609**	**1**	**2.71**
1376/1/6	**15.859**	**1.172**	**2**	**2.861**	**1385/1/8**	**1**	**1.703**	**4**	**5.98**
1376/12/11	**2.203**	**6.047**	**1**	**5.720**	**1385/12/25**	**6.047**	**0.219**	**1**	**5.68**
1376/2/11	**1.719**	**0.375**	**1**	**4.222**	**1385/2/26**	**3.25**	**0.609**	**1**	**5.95**
1376/2/4	**3.766**	**15.984**	**2**	**5.335**	**1386/1/15**	**4.516**	**3.188**	**1**	**3.65**
1377/1/9	**15.984**	**3.125**	**4**	**2.427**	**1386/2/15**	**5**	**0.359**	**2**	**2.23**
1377/12/11	**1.547**	**1.625**	**1**	**6.782**	**1387/1/12**	**0.609**	**1.563**	**1**	**7.80**
1377/12/24	**3.25**	**0.391**	**2**	**3.992**	**1387/1/22**	**6.172**	**0.781**	**2**	**3.26**
1377/2/15	**8.688**	**0.656**	**1**	**4.580**	**1387/1/3**	**4.875**	**3.563**	**4**	**2.61**
1378/12/13	**4.25**	**1.328**	**1**	**2.880**	**1387/1/31**	**8.75**	**1.438**	**1**	**3.42**
1378/3/24	**8.094**	**0.234**	**1**	**3.289**	**1387/12/28**	**2.094**	**3.547**	**2**	**4.21**
1379/1/6	**7.422**	**1.891**	**4**	**5.841**	**1387/2/29**	**6.984**	**2.188**	**1**	**1.65**
1379/2/17	**11.453**	**1.406**	**1**	**2.608**	**1388/1/13**	**7**	**4.438**	**2**	**2.54**
1380/1/11	**8.813**	**5.25**	**2**	**4.718**	**1388/12/8**	**0.156**	**1.313**	**4**	**3.87**
1380/1/23	**2.25**	**0.25**	**2**	**2.441**	**1388/2/17**	**0.828**	**1.531**	**4**	**6.20**
1380/1/3	**4.609**	**1.016**	**1**	**3.078**	**1388/3/11**	**15.984**	**2.297**	**2**	**3.08**
1380/12/15	**6.688**	**0.219**	**1**	**3.255**					

Sign of mو n : $\mathbf{1 : m,n \geq 0, \quad 2 : m \leq 0, \quad 3 : n \geq 0,\ m,n \geq 0, \quad 4 : m \geq 0, n \leq 0}$

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