Temporal and Spatial Variability of Maximum Monthly Precipitation over Southern Parts of the Caspian Sea

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Extended Abstract

Introduction
Precipitation is one of important climatic elements that vary considerably over space and time. One of the important aspects of precipitation study is the extreme precipitation. Because of economical effect, in recent years extreme climatic events have proved to be one of the most popular topics in contemporary climatology. It is well understood that climatic features in precipitation records are hidden in relative variables such as monthly and annual precipitation amounts, 24-hour annual precipitation extremes, rainfall intensities and temporal scale of rainfall variation ranges from minutes in a storm cell to decades and longer. The variability and spatial distribution of precipitation at different scales are the main cause of flood and drought events. For analysis of variability of precipitation, we can use harmonic method. Harmonic analysis is a particularly useful tool in studying precipitation temporal patterns as it reveals the spatial variation of various precipitation characteristics. It delineates the geographic extents of various precipitation regimes and highlights the boundaries between them.

Materials and Methods
North of Iran as a particular region has very different climatic condition. Harmonic analysis with the aid of forty years data of the well distributed network of 32 stations used to study of precipitation variability at this region. A brief explanation of the principles of harmonic analysis is presented concerning the nature and interpretation of this technique.

For the monthly values of the examined frequencies \( f_t \) \( (f_t = 0 \text{ at the origin}) \), harmonic analysis can be written as follows:

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\[ \hat{f}_t = \bar{f} + \sum_{k=1}^{6} \left( A_k \cos \left( \frac{2\pi}{12} kt \right) + B_k \sin \left( \frac{2\pi}{12} kt \right) \right) \]  

(2)

Where \( A_k, B_k \) are the coefficients of the \( k \)Th harmonic \((k=1, 2 \ldots 6)\). These coefficients are given by (Panofsky and Brier (1958) and Wilks (2006)) as

\[ A_k = \frac{1}{6} \sum_{t=1}^{6} f_t \cos \left( \frac{2\pi}{12} kt \right) \]  

(3)

and

\[ B_k = \frac{1}{6} \sum_{t=1}^{6} f_t \sin \left( \frac{2\pi}{12} kt \right) \]  

(4)

Where \( f_t \) represents the monthly frequency of the annual 24-hour maximum precipitation amounts at the \( t \)Th month. The amplitude of a given harmonic is

\[ C_k = \left[ A_k^2 + B_k^2 \right]^{1/2} \]  

(5)

The variance of each harmonic can be calculated (Livada et al. 2008) as:

\[ V_k = \frac{C_k^2}{2} \]  

(6)

And the percentage of variance (PVR(k)) of each harmonic can be determined by the ratio:

\[ PVR(k) = \frac{V_k}{\sum_1^6 V_k} \]  

(7)

The phase angle of the \( k \)th harmonic can be obtained (Wilks 2006) by:

\[ \phi_k = \begin{cases} 
\tan^{-1}(B_k/A_k), & A_k > 0 \\
\tan^{-1}(B_k/A_k) \pm \pi, \text{or} \pm 180^\circ, & A_k < 0 \\
\frac{\pi}{2}, \text{or} 90^\circ, & A_k = 0
\end{cases} \]  

(8)

And the date of the occurrence of the maximum of each harmonic is given by (Livada et al. 2008):

\[ T_k = \left( \frac{12}{360k} \right) \phi_k \]  

(9)

Results and Discussion

With aim of 32 stations harmonic analysis of the inter-annual variability of the frequency of month-to-month monthly maximum precipitation for north region of Iran was applied. With the separation of the data into orthogonal components, in the form of harmonics, the variation of the data can be explained. Harmonic analysis produces the maximum and minimum occurrence instances along a time axis. Normally in the monthly data, six harmonics are adopted for application, but in practice, the first three harmonics are used over the western and central parts of region, in order to explain the variability of the examined annual frequency patterns of the monthly maximum precipitation amounts.

**First harmonic**

- PVR(1) value at the western part of this area is high
- Generally the PVR (1) values decrease from north to south and west to east.
With increase the distance of sea and costal area PVR (1) values decrease.

Second harmonic
The spatial pattern of the second harmonic over area shows that the effectiveness of the second harmonic is the same at most part of northern Iran.

Third harmonic
The spatial pattern of the third harmonic shows over the eastern parts of this region three or more harmonics are needed to describe the month-to-month variation of precipitation frequencies.

Amplitudes
The amplitude of the first harmonic describes the natural variation in a single cycle. Amplitude charts show the spatial distribution of the size of particular types of seasonal variations. The amplitude of the first harmonic describes the tendency towards a single annual variation in the observed frequency curves. High amplitudes occur over coastal parts of western part of area. With increasing longitude a reduction in amplitude of first harmonic is observed.

Conclusion
The main results of the estimated percentages for the first, second and third harmonics, as well as the amplitudes and the phase angles, are plotted as contour charts from which the following conclusions can be drawn:

- the first harmonic at this region explain more variances
- after first harmonic second harmonic has more role for explain of variances
- Over eastern parts that precipitation occurrence is chaotic, values of PVR(2,3,4) explain the variance
- time of first harmonic varies from October to April
- Generally yearly cycle is dominant variability in maximum monthly precipitation at the most parts of this region.

Keywords: Variability, Harmonic, Precipitation, Monthly, Variance, Maximum.