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Stochastic Model of Precipitation Prediction

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ABSTACT

Investigation of the precipitation is considered one of the most important agricultural problem. The evaluation of precipitation anomaly role in this field is too significant. So, more or less precipitation falling in the area, particularly in agriculture pose serious consequences for productivity. Drought forming from the less precipitation falling is the serious danger source not only for agriculture, but also to economy. There were billions of damages on world economy every year as a result of this event, people have had to leave their places of residence. Prediction of this event gives opportunity to reduce half of the inflicted damage. That is why prediction of drought is on the agenda as one of the modern problems. Taking into account the significance of this problem it was implemented the precipitation anomaly and drought prediction for the first time, for the economically important region of Azerbaijan.

Key words: Periodicals, Prediction, Anomaly, Guba, Classification.

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INTRODUCTION

Population growth, a decline in soil fertility and planting areas makes the World countries face with new issue, food shortages. As if all these were not enough, on the other hand as a result. According to carried out assessments product loss inflicted the agriculture can be reduced by half. For example, drought prediction provides to reserve grain sown on the area. Drought is the most dangerous atmospheric event for agriculture. Because it is not possible to determine the initial signs of drought, it occurs gradually. During drought sustainably the weather temperature is a few degrees higher than normal, precipitation is significantly lower than norm, in such sustainably weather condition, the amount of water in the soil exhaust and plants are in danger of being destroyed. Of course, in case when the weather temperature is close to the norm and there is no precipittion for long time, drought can be. Therefore, precipitation is more important indicator for drought. it is difficult to determine drought by the preliminary indicators, it happens gradually.Though a lot of researches were carried out in the field of predicting drought in the XX century, the solution of the issue still remains open (Sazonov, 1991; Roberts, 1975; Thomson, 1973). It is going wide scale investigations on precipitation and drought prediction all over the world (Hoerling et al., 2014; Griffin and Anchukaitis, 2014).

Of course while carrying out the prediction, first physical nature of the issue, its causing reasons must be identified. During compiling drought prediction the search of the first signs almost has no results. For example, while compiling precipitation, on the basis of pre-changes in synoptic situation it is possible to forecast 30 to 40% accurately. Therefore, as many processes, initial indicators of drought must be disclosed.

In general, all events happening in the nature take place under the influence of two types of forces, stationary and random (Hoerling et al., 2014; Wang et al., 2014).

Stationary forces stem from the Sun and internal energy of the Earth. Determining paid prediction consists of detecting the impact of the both forces. Of course, as the

Table 1. Severity degree of drought according to SPİ method.

SPİ	Degree of Drought
0,0-(-0,99)	Weak
(-1,0)-(-1,49)	Middle
(-1,5)-(-1,99)	Severe
-2,0 or less	Very severe

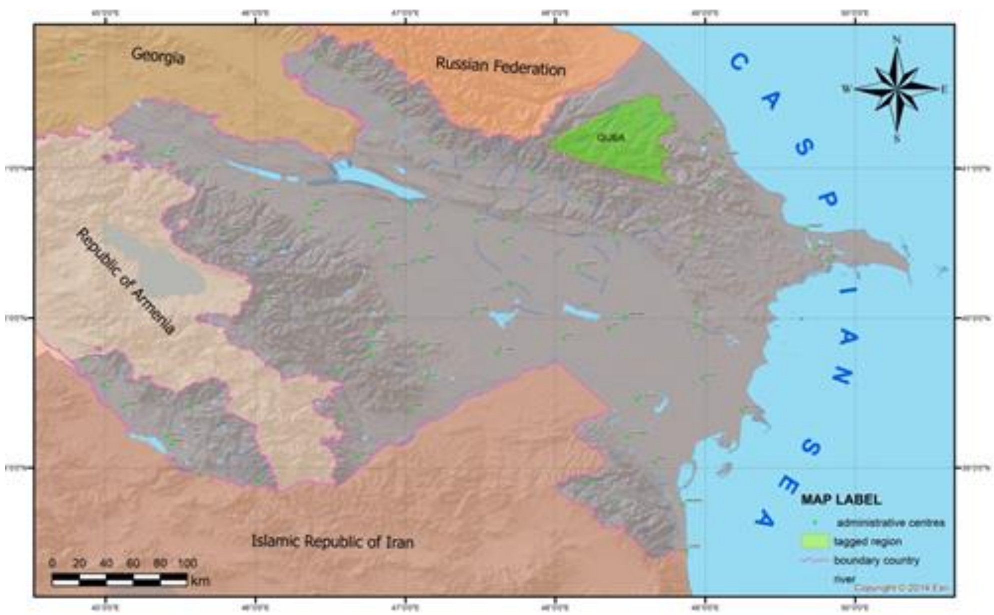

Figure 1. Location of Guba region (Azerbaijan Republic).

initial observation data order is changeable, its analysis have great difficulty to a certain extent. In order to overcome such difficulties, for detecting impact of the forces of stationary nature averaging of orders is used. At present, this method is considered the most simple method. It is known that any observational data order can be expressed in the harmonic function. In drought research a lot of criteria are used (Sheffield et al., 2012; Mammadov and Abdullayev, 2014). The simplest and more frequently applied is Standardized Precipitation Index (SPI): This index is calculated according to the following formula:

$$SPI = \frac{X_i - \overline{X}}{S_x} \qquad (1)$$

Here, X_i - is the quantity of atmospheric precipitation for each season; $\overline{X}$ - is middle number of precipitation order; S_x - middle quadratic inclination. According to SPİ method severity degree of the drought can be determined on the following table (Table 1). The results of these researches (Dai, 2013; Mammadov and Abdullayev, 2014). were published. As can be seen, the only change used here is precipitation anomaly. Thus, by determing the precipitation predicting drought also can be done. Of course as in the case of all predictions this one is also qualitative in character.

PRIMARY INFORMATION

Precipitation data for 1900 to 2008 was taken from archive of Azerbaijan Hydrometeorology Department. The data about Solar activity was determined by using internet (www.astronom2000.info/астрономия/солнечная-активность/).

THE STUDY AREA

Thus the results of calculation carried out in the Guba region (Figure 1) is given in Table 2 and in this work according to Table 1 weak, mild and strong concepts were kept.

Table 2. Drought years for Guba region during 1900 to 2008.

Degree of Drought	Winter	Spring	Summer	Autumn
Weak	1902,1936,1941, 1948,1952,1960, 1968,1971,1981, 1983,1987,2000, 2002,2005,2007	1901,1903,1906, 1909,1935,1939, 1951,1953,1958, 1964,1968,1977, 1979,1983, 1997, 1998,2001,2005	1903,1940,1942, 1948,1949,1953, 1954,1961,1969, 1971,1979,1980,1989, 1990,1991, 1996, 2004	1913,1928,1931, 1950,1954,1964, 1966,1969,1970, 1978,1979,1989, 1994,2004
Mild	1953,1955,1958, 1962,1963	1947,1950,1961, 1962,1970,1975, 1989,2000	1901,1972,1975, 1986,1998,1999, 2005	1952,1957,1968,1971,1974, 1990, 1991,1998,2002, 2006,2007,2008
Strong	1966,1999,2001	1995,2008	2000,2001,2006, 2007	1937,2001

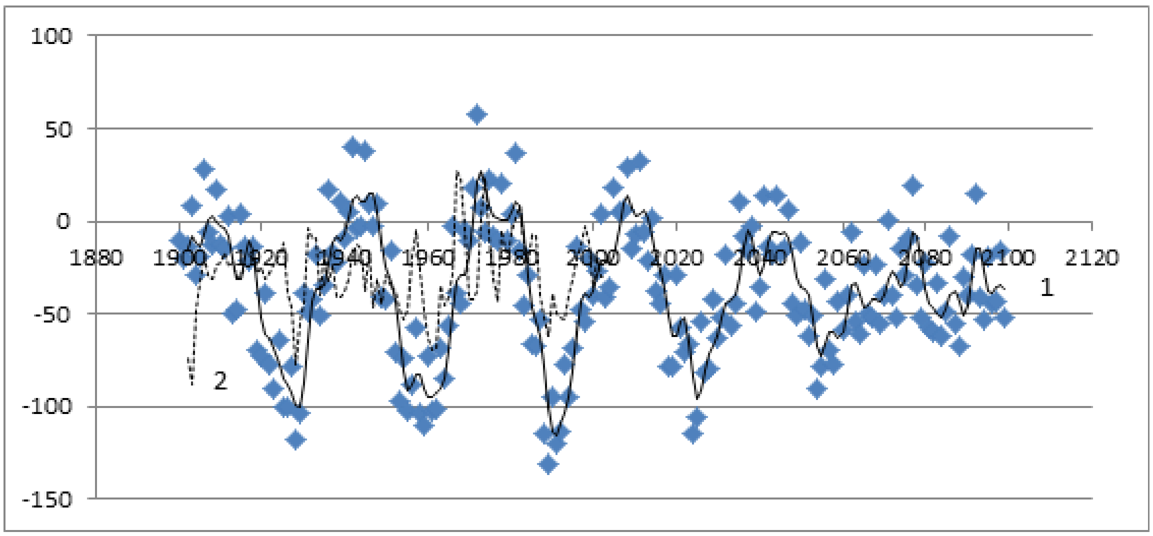

Figure 2. Long-term change of precipitation anomalies in spring in Guba. 1-calculated, 2- actual.

METHODS

The proposed prediction method is based on the following sinusoidal polynomial:

$$\gamma = \hat{\gamma} + A_1 \sin\left(\frac{2\pi}{\lambda} * t + \varphi_1\right) + A_2 \sin\left(\frac{4\pi}{\lambda} * t + \varphi_2\right) + \cdots + A_k \sin\left(\frac{2\pi k}{\lambda} * t + \varphi_k\right) + \cdots \quad (2)$$

In the above equation A – is the phase amplitude, ŷ – middle number of the given order, $\lambda -$ periodicity, t- time.

$A_1 sin(\frac{2\pi}{\lambda} * t + \varphi_1)$ – shows the first harmony.

$A_1 = \sqrt{a^2 + b^2}$, $a = \frac{2}{\lambda} \sum_{t=1}^{\lambda-1} (\bar{\gamma} \cos \frac{2\pi}{\lambda} * t)$,

$b = \frac{2}{\lambda} \sum_{t=1}^{\lambda-1} (\bar{\gamma} \sin \frac{2\pi}{\lambda} * t)$, $\varphi = arctg \frac{a}{b}$

If the studied order consists of a lot of periodic function, then the order can be approximated as following (Brooks and Carruthers, 1953).

$$\hat{\gamma} = A_0 + A_1 \sin\left(\frac{2\pi}{\lambda} * t + \varphi_1\right) + A_2 \sin\left(\frac{4\pi}{\lambda} * t + \varphi_2\right) + \cdots + A_k \sin\left(\frac{2\pi k}{\lambda} * t + \varphi_k\right) + \cdots + \bar{\theta}. \quad (3)$$

$\bar{\theta}$ – shows the impact of random forces. Thus, on the basis of carried out investigations it has been found out that there were 2, 3, 4, 5, 7, 9, 11, 35, 36, 37 and 38 annual periodics. So by expressing the impact of the stationary forces with found periodics, on the basis of Equation 3 we can find charts expressing precipitation distribution for each season. For clearness two of these periodics were described in the following charts (Figure 2 and 3). In Figures 2 and 3 only 2 of above mentioned periodics are described. As it is seen from both charts, the conditions of curves reflecting observation and calculated data are fully compatible. This pattern is compatible with charts reflecting other periodics. Thus, by expressing the impacts of stationary forces with periodics determined beforehand, on the basis of last written

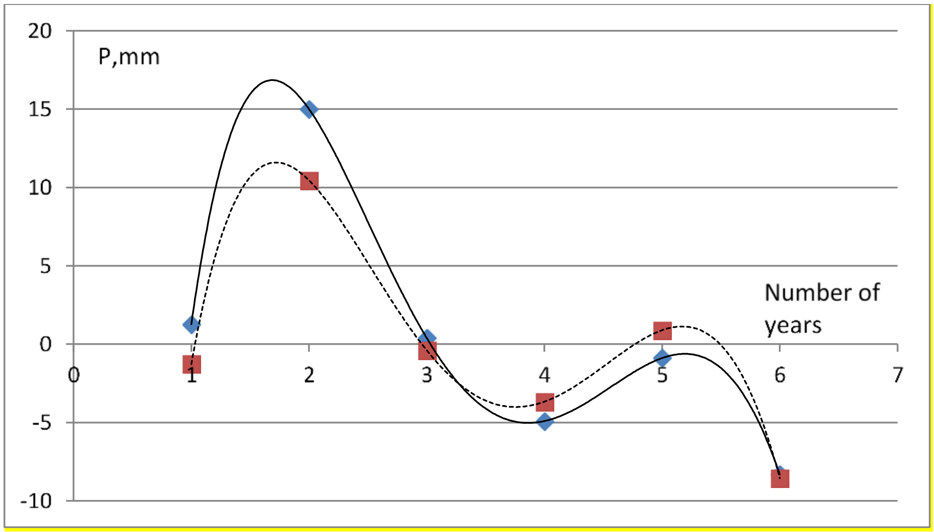

Figure 3. 6 years periodics for precipitation anomalies.Straight line was done by observation, dashed line by calculation way.

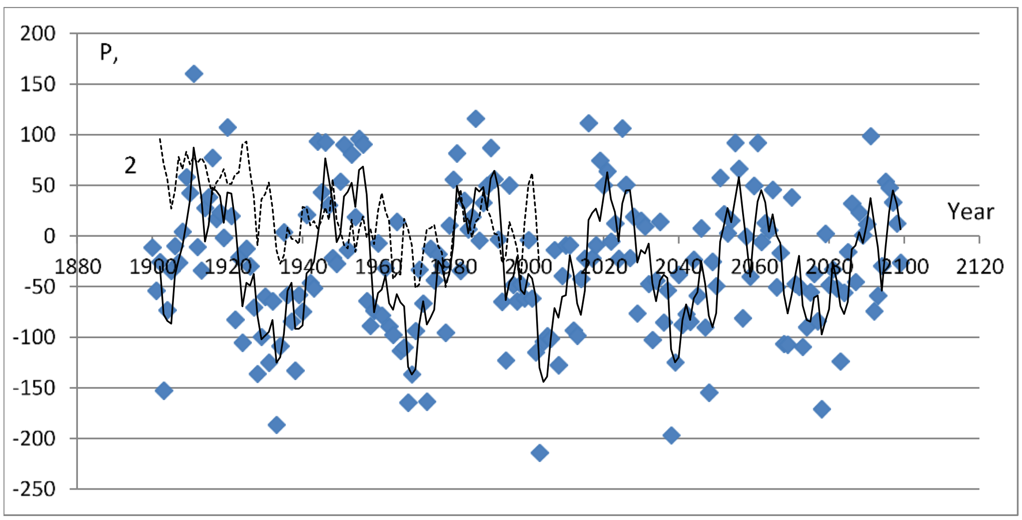

Figure 4. Long term change of precipitation anomalies in autumn in Guba region. Straight line calculated, dashed line actual.

formula (1) we get charts expressing precipitation distribution for each season. Each calculated prediction chart covers the period up to 2100.

RESULTS AND DISCUSSION

It must be noted that, in other periodics determined as in Figures 2 and 3 the suitability of actual and calculated curves is high. This allows to determine the impact of the stationary forces in nature. According to a preset schedule for the autumn season, it can be noted that, actual and observation data of distributions vary in accordance. Thus, precipitation anomalies in observation data and in calculations in 1910 years was maximum 50 mm. The big difference between 1900 to 1910 is explained by the absence of observations at the time (the data of those years have been restored through interpolation). Approximately from 1922 till 1930, the precipitation decreases. This decrease as in observation data in calculations also overlap.

The only difference is in their numerical value. Since then till 1950, there was increase in precipitation and compliance was kept in the condition of both curve. In 1970 a slight decrease, and between 1980 to 1990 observed increase was expressed in the condition of both curve (Figure 4). Thus, by taking into account quality consistency between the actual data and calculations in

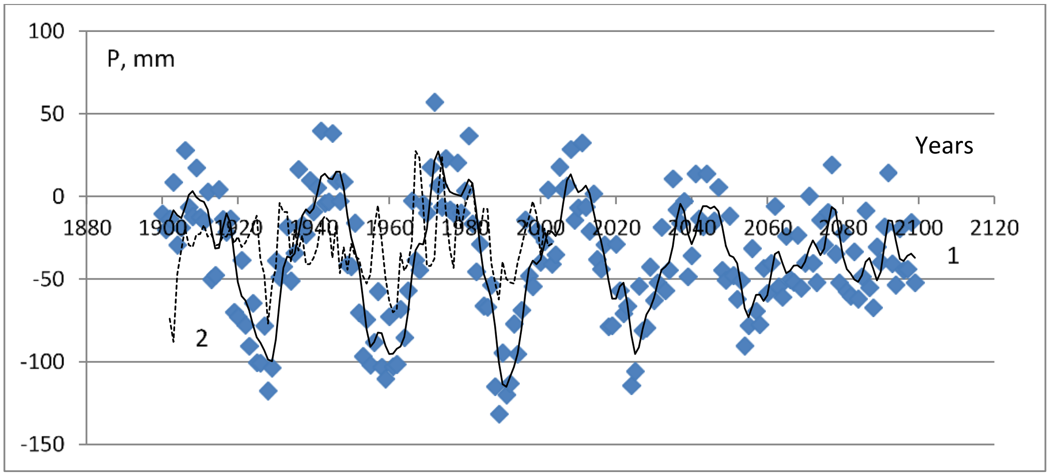

Figure 5. Long term change of precipitation anomalies in spring in Guba region. Straight line calculated, dashed line actual.

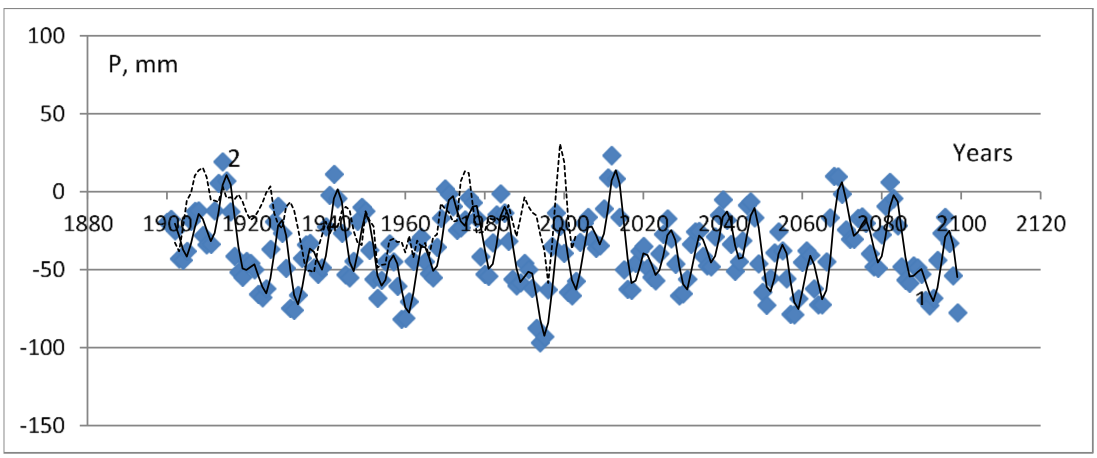

Figure 6. Long term change of precipitation anomalies in winter in Guba region. Straight line calculated, dashed line actual.

autumn in 2020 to 2028 precipitation will increase, in 2028 to 2040 will decrease, in 2040 to 2060 will increase again, between 2065 to 2080 will decrease again and then it is predicted that it will increase a bit (Figure 4). The correlation link between the actual data and calculation data for spring is more high, approximately 0.7. Unlike autumn here value difference between observed and calculated data is very little. According to the curve condition got from chart, in 2018 to 2030, 2050 to 2055 and 2080 to 2090 the decrease of precipitation is expected. Generally, beginning from 2020 by the end of the century, it is expected that the precipitation will be below the norm. Therefore, it is predicted that in spring drought repetition will be (Figure 5).

In Figure 6 long-term distribution curves for precipitation 3 are given. Here, aspects belonging to previous charts also can be mentioned. The condition of curves expressing observation and calculated data is consistent. The chart differs from previous charts only because the precipitation is below during all peiod. By taking into account that the precipitation norm is below 80%, in the years when precipitation anomalies are below 50 mm the drought can be predicted. The quantity of precipitation in studied area in summer is relatively less, is 112 mm. The value of amplitude is relatively less. The condition of calculation curve passes considerably below. However, it can be said that there is certain regularity between curves. Thus, 100 mm precipitation decrease between 1920 to 1950 reaches to 250 mm in calculations. 150 mm decrease taking place in 1970 to 2002 is twice more in the calculations. In spite of big difference, this defined prediction for summer also can be considered acceptable. According to summer prediction, it is pedicted that precipitation will decrease between 2018 to

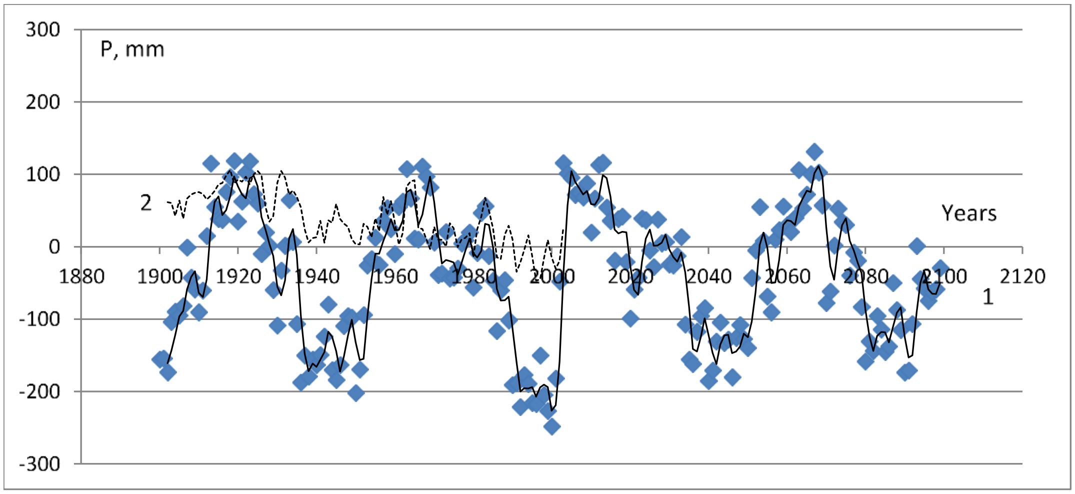

Figure 7. Long term change of precipitation anomalies in summer in Guba region. Straight line calculated, dashed line actual.

2040, since then till 2070 it will maximum increase, in 2070 to 2090 it will gradually decrease, and the last 10 years till the end of the century (keeping the trend of below norm) it will slightly increse (Figure 7). While comparing data from Table 2 with the graphics such a regularity can be found.

A precipitation decrease till -50 in charts means drought will be weak, decrease between -50- (-150) means drought will be mild and when it is below -150 mm it is predicted that drought will be strong. While coming to $\bar{\theta}$ in assesment random value that is already mentioned (1), in prediction expression, the sun is the only energy source which is known to us now. There area lot of scientific studies reflecting the role of the solar energy in formation air processes. At the same time, it was defined that there is a link between 11 years solar cycle and drought repetition (Mammadov and Abdullayev, 2014). According to preliminary investigations, changes in solar activity and changes in precipitation anomaly have positive correlation links. So, how many percent solar activity changes so many precipitation changes and by this random part was assessed ($\bar{\theta}\approx 38 \div 96$). During determining these coefficients 200 year's data about Solar activity was used (Mammadov and Veliev, 2014). As a result of this investigated method, we can predict precipitation and drought in any region of the Earth. Justifying yourself of these prognoses is as (like) 70%

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