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STUDY OF CLIMATE CHANGE IN INTERNATIONAL ANZALI WETLAND

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ABSTRACT

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Climate change is one of the modern problems for human beings. It is a disaster for the earth. Anzali wetland is located in south-west of Caspian Sea and regarded as the most important wetland in Iran. The trend of temperature and precipitation change in the annual and monthly scale in the Anzali wetland has been investigated. For measuring temperature and rain changes, 55 years (1951-2005) of Anzali station weather data has been used. This research has used Mann-Kendal non-parametric test and showed that in Anzali station, maximum temperature had a negative trend, minimum and average temperatures had positive trends and precipitation had no trends. Also, time and type of changes in temperature parameters imply sudden changes. The sudden increase in minimum temperature and decrease in maximum temperature were observed. Also, minimum temperature shows more intense changes compared to other two temperature parameters. Generally, it can be concluded that climate change of the region is more adapted with temperature changes compared to precipitation changes.

Key words*: anzali wetland, climate change, mann-kendall, trend*

INTRODUCTION

The climate system is consisted of subsystems including atmosphere, hydrosphere, lithosphere, biosphere and cryosphere. Changes in system trend, reaction and performance of each subsystem during time or space cause transformations in temporal changes and diversity of spatial climate changes (Asakareh 2001). The historical documents show that the climate has had fundamental changes over thousands and millions years (Kaviani and Alijani, 1995). Climate change is change of climatic behavior of an area compared to the behavior expected according to the recorded data and observed during the area's long period of time (Alizadeh 2010). Changing forests and pastures into agricultural lands, today has turned into one of the considerable concerns in the field of global climate change. Several factors cause disturbance of the conditions prevailing different components of the earth's climate system that can impact the other components. Among these factors, the only factor affecting the earth's climate system abnormally is the increase of greenhouse gasses (IPCC, climate change, 2007). One of the study methods for evaluation of temperature variations and prediction is the statistical method. Since the temperature is one of the essential elements in formation of climate, its variations can change climatic structure of each area. For the same reason, investigating the temperature trend in different temporal and spatial scales has devoted a large part of climatologic researches to itself. The researches show that temperature has been increasing in most parts of the world over the past century. (Niedzwiedz *et al.* 1996) have studied the day and night temperatures in Central and South East Europe. As predicted by climatic models, the precipitation rate is expected to be increased globally too, but prediction of precipitation trend in different areas does not seem possible. Monthly precipitations are probably increased in higher latitudes in winter, but what happens in mid-latitudes and tropical latitudes depends on details of specific climatic models and the opinions about production and release of pollutants (WMO 1997). Several researches have been conducted on importance of precipitation's effect on the climate system among which we can mention the studies done by Turgay and Ercan, (2005), Keily *et al.* (1998), Piccarreta *et al.* (2004), Matyasovszky *et al.* (1993), in all of which the trend analysis of precipitation time series has been carried out using non-parametric tests. A time series is a set of observations sorted by date. Lots of meteorological parameters taken overtime, form time series. Hydrological processes are generally known as static processes; but the new researches have shown that lots of hydrological time series have long-term trends and variabilities which may be due to the effect of human factors or natural features of earth's climate. The trends may be found in time series of hydrological and climatic variables and be divided into two types: sudden fractures, and a uniform and oriented trend; if the hydrological data time series be monotonously ascending or descending, we say that the data have trends (Azarakhshi *et al*. 2013). The climate changes, especially the growing trend of current global warming influences all life aspects of the organisms on the earth. Since the system of wetlands is an almost closed one and its organisms are unique and these ecosystems usually form small systems, they show reactions to slight changes too and the rapid trend of current global warming may endanger the lives of many of them. The biggest weakness of these systems is their closed and limited water resources; because, in terms of water resources, they have an almost closed system and they have no permanent connections with the seas and rivers. That's why factors like desiccation of wetlands or contamination caused by acid rains or human activities can destroy the whole ecosystem and lots of unique organisms of the wetland may extinct during this process; the process that most of the Iranian wetlands have faced. Accordingly, monitoring variation trends of wetlands and their surrounding areas can be useful in management of this valuable ecosystem. Understanding the mechanism of change and evolution of ecosystems in general and wetlands in particular, can be helpful in predicting their future if the current trend continues. The study of climate change and its effects on the past and present can greatly help the challenges of the managers and environmental planning in future periods. Considering importance of the change phenomenon and the relation of the global changes with regional and local changes, it has been attempted in this research to study and analyze the variables such as temperature and precipitation which cover a wider range of climate change.

MATERIALS AND METHODS

Anzali wetland catchment area with an approximate area of 374 thousand acres is located between northern 36^0 55′ to 37° 32′ and also, eastern 48°45′ to 49°42′ in northern part of Iran and 42 minutes in northern part of Iran and. in Guilan Province. In the area the land use distribution is; 53.9% forest and pasture, 33.2% farmlands, 8.7% sealings and pools and 3.7%. The average annual precipitation rate in Anzali wetland catchment area is approximately 1500-2000 mm. These precipitations are driven through 25 large and small rivers. (Akbarzadeh and Arbabi, 2010) believe that, this wetland is one of the important ecosystems in Northern Iran, some parts of which were declared as a protected area during Ramsar Convention in 1975. The researchers conducted on this vital ecosystem show that the wetland itself is one of the important factors in reducing the impacts of climate change. Considering that the year 2010 has been named as the international year of biodiversity by the UN, Ramsar convention has selected the phrase "taking care of the wetlands, a response to climate change" as the theme of world wetlands day (February 2^{nd}) in year 2010. This article has used weather data of Anzali station with a height of -26.2m above the sea level during a 55 year statistical period which includes monthly and annual temperature, minimum temperature, maximum temperature and average monthly precipitation, in order to study the climate change and its effect on Anzali wetland. The method used in this research for detection of the climate change in the studied catchment is Mann-Kendall graphical statistical test method which is used to investigate the randomness and determine trends in the series. First, independence and homogeneity tests were done on temperature and precipitation data in order to evaluate accuracy of the data. The null hypothesis in independence test is independence of the two variables and hypothesis one is dependence of the two variables. In homogeneity test, the null hypothesis is equality and homogeneity of the two variables and hypothesis one is inequality and non-homogeneity of the two variables. Mann-Kendall test was presented by Mann on 1945 and it was developed by Kendall on 1975. One of the strengths of this test is its suitability for being applied for the time series that do not obey any specific statistical distributions. Also, the low effects of limit values on this method observed in some time series are another advantage of using this method (Hejam *et al.* 2008). Thus, considering the abilities of this test in detecting the changes occurred in time series of climatic variables, it has attracted the attentions of researchers from the climate change study fields. The non-parametric Mann-Kendall test studies the null hypothesis of absence of trends in time series. In this regard, it also recognizes the sudden change points too. The procedure is as follows: In the first step, a table is provided for each parameter of each station (Table 1) that its first column, the second column is year and the third includes the studied variable (here minimum annual temperature of Anzali station). In the fourth column, first the minimum annual data are sorted in an ascending order (from low to high) and then, each number will be given a rating from 1 to 55 according to length of the statistical period, based on its position in the studied time series. The fifth column that is obtained according to ratings of the fourth column is number of the rows placed above each row. In the sixth column also, cumulative frequency is obtained from sum of the fifth column. To test the null hypothesis of absence of trend, Kendall's statistic (t) was calculated based on the following formula:
T stands for Kendall statistic, P is the total number of ratings greater than ni row placed after it and it is obtained from the following formula:

$$T = 4p/(n(n-1))$$

$$P = \sum_{i=1ni}^{n}$$

And n is the total statistical years used or Σxi. In order to test significance of the statistic, T is calculated through the following formula:

$$Tt = \pm \text{ tg} \sqrt{(4n+10)}/(\sqrt{((9n(n-1)}$$

Here tg equals the critical value of normal or standard score z with probability level of the test and with probability level of 95% it equals 1.96. In case of applying this value, t (T) will equal ±0.18. Considering the critical value obtained for t (T), different states will be observed as follows:

If + (T)t > T >- (T)t or -.18 < T < +.18 no important trend is observed in the series and the series are random. Also, if T< t(T) or T<0.18, it shows the negative trend in series and if T> t(T) or t (T)> +18, the positive trend will be prevalent in the series. In order to determine direction of the trend, type and time of the change, Kendall graphical test is required. In second step, in case of approval of trend's significance, time and type of the changes were determined using Mann-Kendall's graphical statistic. To achieve this purpose, U and U′ components were calculated in seventh column of table1 of the number of ratings smaller than rating of each row (ti). The eighth column is also the cumulative frequency of seventh column. Then, mathematical expectation, variance and U component are calculated respectively based on following formulas. U (ti) values are significant only if an increasing or decreasing trend is observed in it and this depends on either its value is greater than zero {u (ti) >0} or smaller than zero {u (ti) <0}.

$t_i = \sum_{i=1}^{n}$

That its distribution function asymptotically equals the mean and variance if the null hypothesis is dominant.

$Et_i = n(n-1)/4$

$Var(ti) = (n(n-1)\ (2n+5)$

U (ti) = [ti -E (ti)] ⁄ √ Var (ti)

In these formulas, ni is the row number. The results from these formulas have been presented respectively in columns 9, 10 and 11 of the table1. Calculation of U′ component is opposite of U component. To calculate this component, the ratings smaller than rating of each column is written in column 4 placed before the mentioned row; (ti) is summed cumulatively from bottom (∑ti') in column 12 of table1 in column 13 of these ratings, in a way that the highest value is written in front of first row. Mathematical expectation, variance and U′ component were calculated respectively and based on following formulas.

$(t'i) = \sum_{i=1}^{n} ni$

$E't_i' = (N-n_i+1\ \ )(N-n_i)/4$

$V'(t_i = (N-n_i+1)(N-n_i)(2((N-ni+1)+5)/75$

$Ut_i' = \sum ti' - E' / \sqrt{V'}$

Results from the formulas mentioned above have been presented in columns 14, 15 and 16 of table 1. After calculating the above values, U and U′ values will be drawn in form of diagrams (Alijani *et al.* 2011). After conducting the above calculations and drawing the related diagrams, existence of any type of trend in the series appears negatively and when there is a significant trend in the data, ui and u'i lines intersect. If the mentioned lines intersect inside the critical limits (±1.96), it shows the beginning of sudden change and if they intersect out of the critical limits, it implies existence of trends in time series (Sueyers 1990).

RESULTS AND DISCUSSION

According to the results from independence test on temperature and time series data, since Pearson's chi-squared statistic (0.322) is more than 5 percents, H_0 is not rejected and the two variables are independent of each other, therefore they are homogeneous variables too. The results from independence test on precipitation and time series data show that significance level of Pearson's chi-squared statistic (0.328) is also more than 5 percents, thus H_0 is not rejected and the two variables are independent of each other and homogeneous. Also, to determine either the studied sample is obtained from a population with normal distribution, the Kolmogorov-Smirnov test has been applied (Bayazidi *et al.* 2012). The results from this test and normal Q-Q plot diagram of annual precipitation and temperature show that the data are almost placed on the normal line and according to Kolmogorov-Smirnov test, p-value of average annual temperature (0.921) and annual precipitation (0.510), these values are bigger than 0.05 which means that, there is no reason to reject the null hypothesis "the studied sample has been obtained by normal distribution". This conclusion is exactly what we were expecting.

Analysis of Mann-Kendall Method on Monthly and Annual Data

The results from applying statistic test (T) and critical statistic (T_t) on annual average temperature show that the annual average temperature has not changed during the studied period. In order to determine the type and time of the changes, first the Mann-Kendall diagram was drawn for annual average temperature, using u and u′ components, then considering the features of Mann-Kendall's graphical test, type and time of the change was determined. The results from analysis of diagrams show that according to diagram (1), since the u and u′ curves have collided inside critical limits in year 1998, so there has been an increasing sudden change. Also, analysis of Mann-Kendall method on annual and monthly maximum temperature of Anzali station shows that annual maximum temperature has a negative trend. Also, the results obtained from above test imply that May, June, July and August has had a negative trend and no trend has been observed in rest of the months. To determine type and time of the changes, first Mann-Kendall's diagram was drawn using u and u′ components for monthly and annual maximum average temperature for each month separately. Then, considering the features of Mann-Kendall's graphical test, type and time of the change was determined that the results have been presented in table (2). According to the results in most of the months, the maximum temperature has experienced a decreasing sudden change.

Table 1. Results of Kendall test statistic T and T_t critical annual and monthly average maximum temperature in Anzali station

	Jan	Fer	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Average maximum temperature	-.04	-.07	-.03	-.01	-.29	-.34	-.32	-.33	-.13	-.06	-.04	-.01	-.24

Table 2. Evaluation of (letters) and time (numbers) the maximum annual and monthly average temperature in Anzali station

	Jan	Fer	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Average maximum temperature	CI2003	CI65	-	-	CD83	CD89	CD86	CD68	-	CD53	CD56	CD55	CD74

Table 3. T-Kendall test results and test at least yearly and monthly average temperature T_t critical Anzali station

	Jan	Fer	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Average maximum temperature	.24	.03	.24	.38	-.01	.1	.48	.5	.35	.23	.6	.28	.5

Table 4. Check the type (letters) and time (numbers) the annual and monthly mean minimum temperature at station Anzali

	Jan	Fer	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Average maximum temperature	CI98	-	CI93	CI75	CI97	CI77	CI81	TI89	CI89	CI95	TI74	TI81	TI88

Considering table (3) the results of Kendall's statistic T and critical statistic T_t of annual and monthly minimum average temperatures of Anzali Station show that annual minimum average temperature has a positive trend. Also, the results from above test imply that May, June and February have had no trends and in rest of the months, a positive trend has been observed. For time and type of changes, we observed an increasing sudden change for 8 months and a positive trend for 3 months (Table 2). The calculations conducted on annual precipitation climatic element during the statistical period imply, precipitation in Anzali station with rate of T=-0.16 has had no change during the period. The results from analysis of the Mann-Kendall's diagram have showed that annual average precipitation has had no change during the studied statistical period.

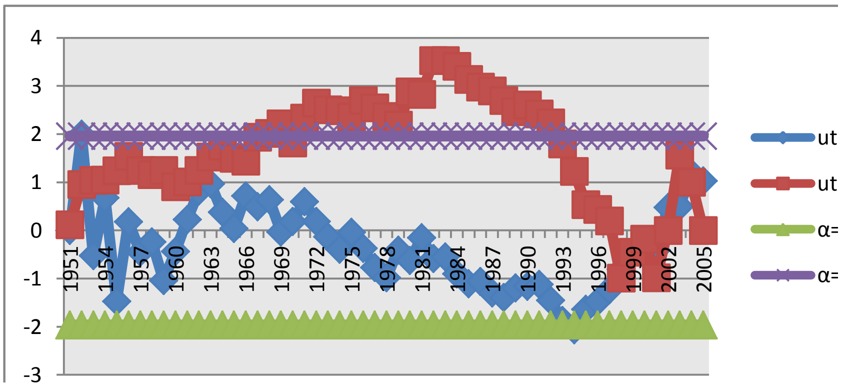

Fig. 1. Changes statistic U, U 'annual mean temperature in Anzali station

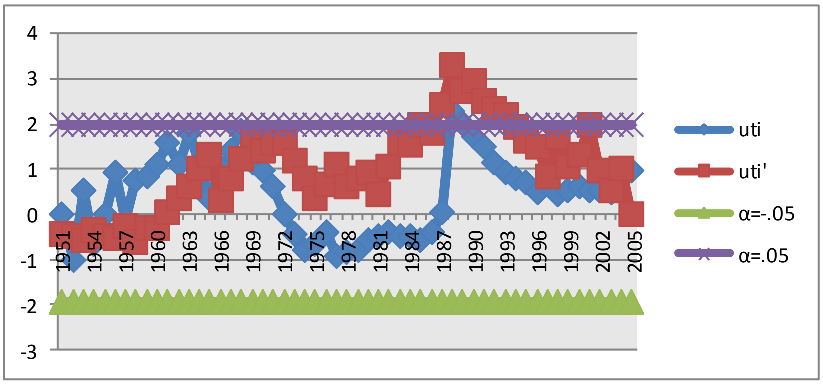

Fig. 2. Changes in statistics, U, U 'average annual maximum temperature Anzali

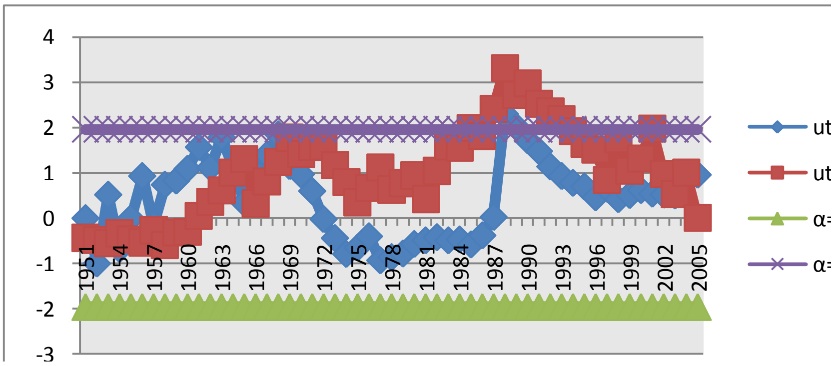

Fig. 3. Changes in statistics, U, U 'Maximum temperature December Anzali station

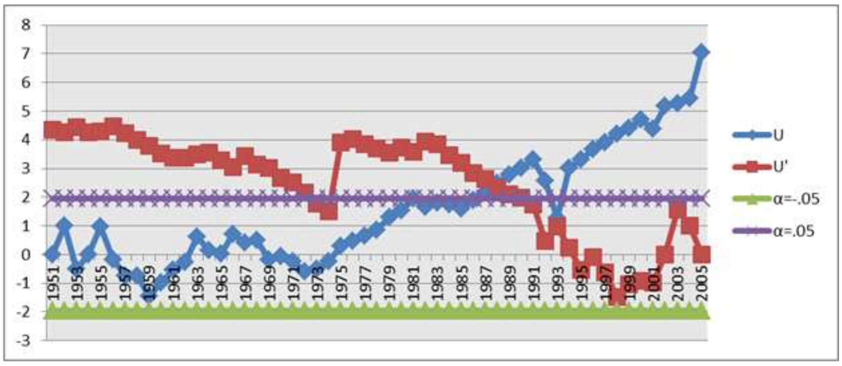

Fig. 4. Changes statistic U, U 'average annual minimum temperature Anzali

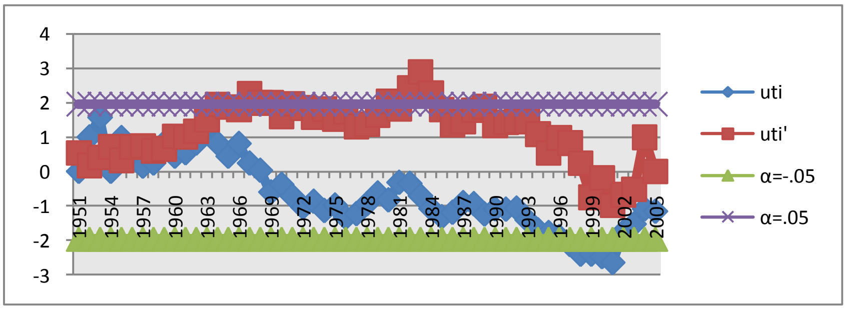

Fig. 5. Changes in statistics, U, U 'average maximum temperature February Anzali station

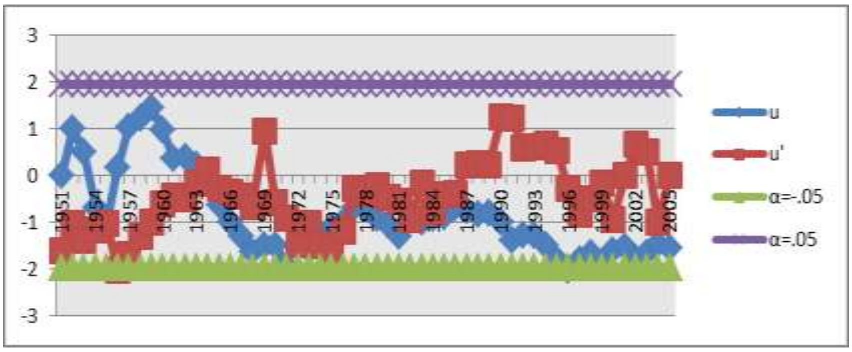

Fig. 6. Changes statistic U, U 'average annual precipitation Anzali

CONCLUSION

Kendall's statistic test (T) and critical statistic (T_t) on temperature and precipitation elements show that the average annual temperature during the studied period has had no trend, annual maximum temperature has experienced a negative trend and maximum monthly temperature has had no trend in most of the months and it has observed a negative trend only in 4 months; but the annual and monthly minimum temperature, unlike the maximum annual temperature, has had a positive trend in annual scale and has experienced a positive trend in most of the months in monthly scale. The average annual precipitation has shown no trend, despite its changes during the studied period. The results obtained from diagrams show that annual average temperature has had an increasing sudden change. Also, annual and monthly maximum temperatures have had decreasing sudden changes in most of the months and the annual minimum temperature has had an increasing sudden change and in monthly scale, it has experienced an increasing sudden change for 8 months and a positive trend for 3 months. It also didn't show any changes with annual average growth either. Finally, the most important factor regarding the Anzali wetland's crisis problem is watershed management and program-oriented actions (revival and preservation). The thought of saving the wetland after it is dried is totally wrong, while we should preserve this available resource by good management. Unfortunately, we are usually managing the crisis. Agricultural amendments and making serious changes in subsistence pattern of people and giving roles to them and involving them in preservation of the wetland are important.

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