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Long-Term Trends of Sunshine Durations in Relation with Cloudiness and Relative Humidity in GAP Area, Turkey#

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Abstract: Long-term trends of monthly mean sunshine durations were analyzed utilizing non parametric tests for Southeastern Anatolian Project (GAP) region. Correlation coefficients between sunshine durations and relative humidity and cloudiness variable were determined over the years. Climatic data between 1970 and 2005 from nine meteorological stations scattered in the region were collected and used. The non-parametric test results revealed that an upward trend was dominant especially in the summer and early autumn months. Mann-Kendall test indicated that the strongest trend was in August at Gaziantep station with Z value of -6.63. Therefore, declining significant trends never observed in the months of January, February, March, November, and December. Although, the highest upward trend was observed in April at Mardin station, there was no significant rising trend in the whole region for the same month. Cloudiness and relative humidity data was satisfactorily explained the variation in sunshine durations. A common significant negative correlation was found using non parametric test between sunshine duration and relative humidity and cloudiness series. There were also a few positive correlations, but none of them was significant. Additionally, basic linear regression equation was employed in order to determine changes in sunshine duration that Gaziantep station showed the highest decrease in July with a value of 0.13 hours per year. Downward trends of sunshine duration could be attributed to air quality changes which could affect adversely the hydrological cycle and agricultural production. The overall findings support the view that there is a climate change regionally or globally.

Keywords: *Sunshine durations, non-parametric trend tests, Spearman Rho correlation test, GAP area.*

Introduction

Sun provides energy to the earth that helps water cycle, heating, photosynthesis, etc processes. Sun lights must pass atmosphere to reach the earth surface. Therefore, its durations are a function of quality and pollution of the earth's atmosphere. In the same manner, there is a debate on climatic change or changes in climatic parameters regionally and/or globally. After industrial revolution, atmosphere was exceedingly polluted especially by developed countries (Proedrou *et al*., 1997; Stanhill and Cohen, 2001; Chen et al., 2006). Besides harmful byproducts of industrial production, agricultural activities, land use changes, urbanization, and burning fossil fuels expose noticeable amount of pollution to the atmosphere (Karl *et al*., 1988; Kalnay & Cai, 2003). A combined result of above mentioned pollution may provide lower sunshine and increasing surface temperature.

Currently many researches are doing work on the climatic change around the world. These studies mainly focus on some major climatic change indicators such as surface air temperature, rainfall, and stream flows (Türkeş *et al*., 2002, Serrano *et al*., 1999; Kahya & Kalaycı, 2004). Studies on trend analysis related to air temperature usually showed increasing temperatures on earth (Türkeş *et al*., 2002; Yue & Hashino, 2003). This increasing trend has likely contributed to the increases in greenhouse gases, deforestation, urbanization etc (Boucher *et al*., 2004; Chung *et al*., 2004). On the other hand, a few studies exposed a decreasing component of temperature series. This is due to sunshine durations received less interest.

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Sunshine durations could be a function of cloudiness and air quality and/or global dimming. Air pollution sources are very common in developing regions such as Southeastern Anatolia Project (GAP) area where an integrated regional development project was initiated in 1970s. The project covers nearly 7.5-million-hectare area; of which 1.7 million hectares will be irrigated when the project is completed (GAP, 2007). In addition to agricultural production, industry showed a great jump in western parts of the area in recent years. Population was also increased from 1970 to 2000 as 2 832 247 and 6 604 205, respectively (TUIK, 2007). At the same time span, irrigated agricultural fields changed from 16 337 to 193 092 hectares (GAP, 2007). The aims of this study were to: 1) establish trends of monthly mean sunshine durations in the GAP area, 2) determine the relationship between sunshine durations with relative humidity and cloudiness.

Material and Methods

Material

Monthly mean sunshine duration (hours), relative humidity (%) and x/10 records complied by Turkish State Meteorological Affairs were utilized from 1970 to 2005 with varying lengths. Even tough there are many meteorological stations in GAP region, only 9 out of them were used, considering availability of long-term climatic data. Monthly and yearly data were rearranged and missing data were filled using the preceding and following monthly average in a series (Karaca et al., 1995).

Methods

In this study, non-parametric tests were employed in order to identify trends and magnitude. Limited details of the techniques used were given below except linear regression, which can be easily found in statistical literature (Draper and Smith, 1981).

Sequential Mann Kendall test

Non parametric Sequential Mann-Kendall (SMK) test is used commonly by the researchers for analyzing likely trends of the series. This test provides starting point of the detected trends and long-term behavior of the series analyzed. There are two final test statistics of the SMK test those are u (t) representing direction of the trend in a series and the other one is u'(t) standing for detection of the beginning of the trend that intersection of two statistics approximately gives the starting point of the trend. Test statistics u (t) was calculated using equation (1) and u'(t) was determined following same procedures as u (t) but starting from end of the series (Sneyers, 1990; Türkeş et al., 2002; Tonkaz et al., 2003).

$$\left. \begin{aligned} & t_i = \sum_{k=2}^{i} n_k \; ; \quad i = 2,3,4,...,n \; ; \quad E(t_i) = \frac{i(i-1)}{4} \\ & Var(t_i) = \frac{i(i-1)(2i+5)}{72} \; ; \quad u(t_i) = \frac{t_i - E(t_i)}{\sqrt{Var(t_i)}} \end{aligned} \right\} \qquad (1)$$

where,

t_i : Test statistics of Sequential Mann-Kendall test

$E(t_i)$: Expected value

$Var(t_i)$: Variance

$u(t_i)$: Standardized value

$u'(t_i)$: Standardized value (calculated from backward series)

Mann Kendall test

This test is commonly used to detect possible trends in a deseasonalized different kind of series. Mann-Kendall (MK) test a special application of the test known as Kendall's tau statistics. At the end of calculation procedure, MK test provides a Z value using test statistics (S) for whole series that expose upward or downward trends depending on sign of it. Details of the test could be found in many articles (Yu et al., 1993; Kahya and Kalaycı, 2004), but here the only test statistics (S) is given as following,

$$\left.\begin{array}{l} S = \sum_{i>j} \operatorname{sgn}(x_i - x_j) \\ \operatorname{sgn}(\theta) = \begin{cases} 1 & if\theta > 0 \\ 0 & if\theta = 0 \\ -1 & if\theta < 0 \end{cases} \end{array}\right\} \quad (2)$$

Spearman's Rho correlation test

The Spearman Rho correlation test gives the magnitude and direction of the association between two variables that are on an interval. In this test, the null hypothesis (H_o) states that there is no association between the two variables. The alternative hypothesis (H_1) of two-sided test is that there is an association between the two variables. Test statistic (z) based on r_s are given below (Siegel and Castellan, 1988);

$$\left.\begin{array}{l} r_s = \left[1 - \dfrac{6\sum d_i^{\,2}}{N^3 - N}\right] \\ z = r_s \sqrt{N-1} \end{array}\right\} \quad (3)$$

where,

r_s: Spearman's Rho correlation coefficient

d_i: The difference between the paired ranks

N: number of paired ranks

Results and Discussions

Likely trend behavior of monthly mean sunshine durations were analyzed using Sequential Mann Kendall test. Mann-Kendall tests were employed to find out overall trend significance of the series. Sequential Mann-Kendall test resulted in a significant indication of long-term trends of monthly mean sunshine hours in GAP area. Even tough this work relied on monthly analysis, findings showed seasonal similarities among the stations. In summer and early autumn months, a significant downward trend appeared in all stations examined except in Mardin and partially in Diyarbakır. Significant downward trends initiated roughly in 1978s, then in early 1990s, became statistically significant. In summer months at Diyarbakır station, a weak decreasing trend was also detected. At this months, starting in late 1980s and in early 1990s, trend line almost fluctuating on lower confidence interval of test and it was sometime becoming significant lying down below the confidence interval.

Mardin station observation behaved a little bit differently in the same time span in comparison to the other stations. No significant upward or downward trend was observed in Mardin station for all the months. Trend lines were randomly oscillated between upper and lower confidence intervals. In other seasons' months, upward or downward trend were also observed, but it was not as regular as summer and early autumn months. For example, in January at Birecik station, a declining trend rose in the beginning of the 1970s, then it became significant in late 1980, then after 1990 randomly non significant fluctuation behavior became dominant up to date (Figure 1).

Another type of trend behavior showed up that starting 1975, a gradually rising trend line to upper confidence interval indicating a signal of future significant upward trend in April at Mardin station (Figure 2). Overall result of sequential Mann-Kendall test declared that in every station at least one or more months has declining or rising trend for the examination period, but most of summer and early autumn months showed a significant downward trend. In addition to SMK, MK test showed an overall trend magnitude of the series examined. Findings of MK were almost similar to SMK tests. The highest Z scores were determined for summer and early autumn months with -6.63, -6.41 and -6.14 for August, July and September at Gaziantep station, as a declining trend. Results revealed that there was no significant upward trend across the study area in any months. However, the highest trend magnitude was determined in April of Mardin indicating a potential upward significant trend.

Therefore, during the months of January, February, March, November and December, no significant declining trend was determined.

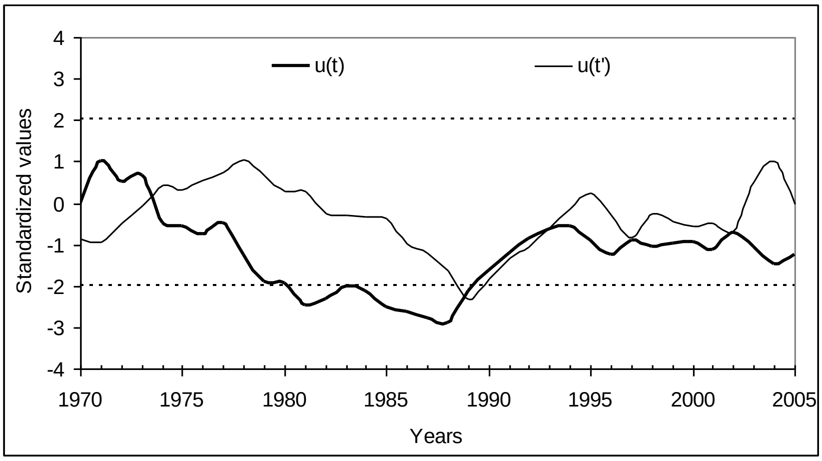

Figure 1. Long-term trends of sunshine duration in January of Birecik station (dashed lines represents upper and lower confidence intervals)

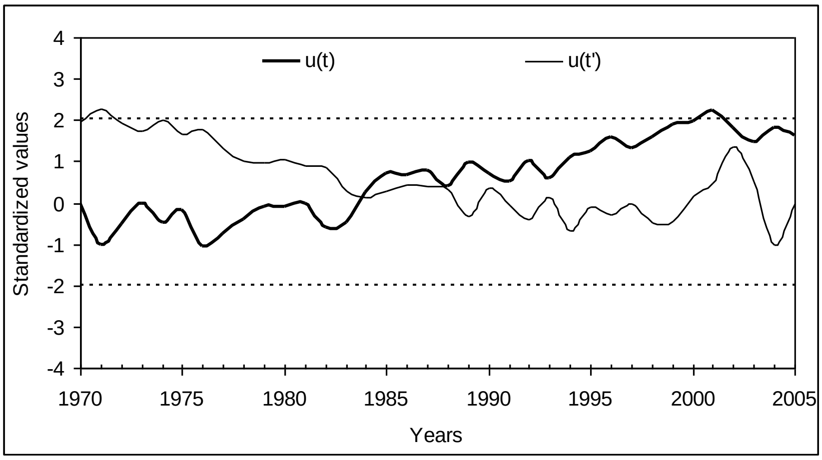

Figure 2. Gradually increasing behavior in April of Mardin station (dashed lines represents upper and lower confidence intervals)

Among the months, September was found to be the most critical month that seven stations out of nine showed statistically significant rising trend. September followed by August, July, June, October, May, and April with number of significant trends 6, 6, 4, 3, 2 and 1, respectively (Table 1). It was interesting to note that December showed declining trend for all the stations even though there was no significant trend. On the contrary, February showed upward trend for all stations except Şanlıurfa station, regardless of significance of the trend.

The overall findings support the view that there is a climate change regionally or globally. Our results are similar to those of Aksoy (1999), who examined annual variation of sunshine duration for Ankara station and found a significant declining trend starting from 1972 until 1996. In an other study conducted by Aksoy (1997) he calculated the amount solar radiation using sunshine duration across Turkey and found an increasing for Mardin, and decreasing trends for Şanlıurfa, Gaziantep, and Diyarbakır. Among the stations, Gaziantep showed the highest increasing behavior, as in our study. Chen et al. (2006) found similar trends for global radiation and sunshine hours in China using 51 stations. Their study indicated that there was a decreasing trend at 42 stations and 36 of them were found statistically significant at the 5% level, using F-test. Power (2003) analyzed available data on daily sunshine hours considering trend components at 13 stations in Germany out of which at 9 stations increasing and 4 stations, however, decreasing trend, were noticed and statistically significant downward trend were determined at only 2 stations. Stanhill and Cohen (2001) suggested that aerosol loading and cloud cover contribute significantly to the sunshine duration trend.

Table 1. Mann-Kendall test results of monthly mean sunshine duration of GAP area. (*The value less than -1.96 or higher than 1.96 indicates significant downward or upward trends, respectively.)

Stations	Adıyaman	Birecik	Cizre	Diyarbakır	Gaziantep	Mardin	Siirt	Siverek	Şanlıurfa
January	-0.71	-1.05	-0.42	0.79	-1.12	-0.03	0.04	-0.71	-0.34
February	1.38	0.53	0.19	0.59	0.76	0.89	0.30	0.34	-0.16
March	0.34	0.14	0.65	-0.41	-0.10	0.41	0.52	0.20	-0.11
April	0.96	-0.25	0.46	0.00	**-2.05**	1.79	0.93	1.45	-1.04
May	-0.49	**-2.18**	-0.60	-0.04	**-5.07**	1.05	-0.44	0.46	-1.10
June	**-3.25**	**-5.35**	**-3.14**	-0.03	**-5.24**	1.73	-1.20	-0.53	-1.00
July	**-4.18**	**-6.39**	**-4.13**	-1.55	**-6.41**	0.52	**-3.61**	**-4.47**	-1.91
August	**-4.80**	**-3.98**	**-2.79**	-1.44	**-6.63**	1.26	**-2.28**	-0.47	**-3.31**
September	**-3.11**	**-3.82**	**-3.16**	**-2.41**	**-6.13**	0.74	-1.25	**-2.75**	**-3.20**
October	-1.53	-1.79	**-2.16**	0.25	**-2.32**	-0.78	-0.68	-1.53	**-2.92**
November	0.25	-1.72	-0.57	1.27	-1.17	0.11	-0.25	-1.86	-1.04
December	-0.74	-1.28	-0.40	-0.85	-0.97	-0.53	-1.20	-1.12	-1.71

Following the identification of major trend components in sunshine duration in the GAP area, they were correlated with relative humidity and cloud cover using a non parametric correlation test. A significant negative correlation was determined especially for all seasons except at summer months with relatively low humidity. The correlation coefficient reached the peak value in March at Şanlıurfa station as -0.866 (Table 2). On the contrary, the highest positive correlation was found with a non-significant value of 0.056 in July at the Gaziantep station. Similar to relative humidity, correlation coefficient was slightly higher in all seasons except summer months. These findings support the previous views that decrease in sunshine hours implies more cloud cover in the region. Decrease in sunshine duration in winter month may affect adversely the heating costs. Nevertheless, summer time temperature decreases is reasonable for the same purpose but plant do not like lower sunshine duration considering the photosynthesis. Positive relations were found in July, August, and September, but none of them were statistically significant. Cloudiness data are also largely explained sunshine duration variations across the study area, but are relatively higher than relative humidity. Findings revealed that the correlation coefficient for November of the Siirt station was statistically significant with value of -0.950 (Table 3).

Table 2. Correlation coefficients (Spearman Rho) between sunshine duration and relative humidity (*Bold values indicate significant negative or positive correlations depend on sign.)

Stations	Adıyaman	Birecik	Cizre	Diyarbakır	Gaziantep	Mardin	Siirt	Siverek	Şanlıurfa
January	-0.68	-0.68	-0.51	-0.63	-0.70	-0.61	-0.17	-0.81	-0.82
February	-0.39	-0.54	-0.71	-0.53	-0.44	-0.67	-0.82	-0.68	-0.68
March	-0.73	-0.64	-0.64	-0.60	-0.63	-0.62	-0.62	-0.56	-0.87
April	-0.49	-0.58	-0.50	-0.32	-0.73	-0.59	-0.44	-0.28	-0.61
May	-0.76	-0.51	-0.50	-0.67	-0.70	-0.68	-0.78	-0.54	-0.61
June	-0.58	-0.56	-0.34	-0.30	-0.66	-0.22	-0.56	-0.35	-0.35
July	-0.40	-0.54	-0.37	0.15	-0.41	-0.02	-0.12	-0.46	-0.38
August	-0.38	-0.24	-0.31	0.09	-0.63	0.02	-0.55	0.15	-0.35
September	-0.49	-0.49	-0.56	-0.13	-0.53	0.33	-0.22	-0.28	-0.33
October	-0.71	-0.48	-0.72	-0.46	-0.54	-0.73	-0.71	-0.70	-0.68
November	-0.66	-0.60	-0.79	-0.45	-0.59	-0.71	-0.71	-0.52	-0.69
December	-0.56	-0.76	-0.65	-0.67	-0.67	-0.72	-0.57	-0.77	-0.68

Table 3. Correlation coefficients (Spearman's Rho) between sunshine duration and cloudiness (**Bold values indicate significant negative or positive correlations depend on sign.)

Stations	Adyaman	Birecik	Cizre	Diyarbakır	Gaziantep	Mardin	Siirt	Siverek	Şanlıurfa
January	-0.88	-0.87	-0.65	-0.83	-0.84	-0.76	-0.81	-0.91	-0.94
February	-0.88	-0.81	-0.77	-0.94	-0.81	-0.85	-0.91	-0.86	-0.88
March	-0.86	-0.78	-0.90	-0.86	-0.76	-0.82	-0.93	-0.89	-0.83
April	-0.86	-0.74	-0.66	-0.79	-0.45	-0.73	-0.83	-0.90	-0.73
May	-0.76	-0.75	-0.68	-0.85	-0.08	-0.72	-0.88	-0.88	-0.74
June	-0.65	-0.62	-0.37	-0.71	0.06	-0.71	-0.81	-0.70	-0.50
July	-0.55	-0.44	-0.38	-0.60	0.01	-0.57	-0.67	-0.77	-0.46
August	-0.65	-0.23	-0.57	-0.64	-0.40	-0.76	-0.62	-0.84	-0.47
September	-0.81	-0.47	-0.65	-0.51	-0.17	-0.67	-0.83	-0.82	-0.45
October	-0.95	-0.86	-0.87	-0.85	-0.77	-0.86	-0.86	-0.94	-0.72
November	-0.89	-0.85	-0.85	-0.88	-0.86	-0.85	-0.95	-0.94	-0.87
December	-0.88	-0.86	-0.81	-0.93	-0.78	-0.88	-0.91	-0.93	-0.93

Linear trend analyses results were in agreement with existing data that the highest decrease was found in July at the Gaziantep station. In this month, there was, on average, 0.13 hours decrease per year in sunshine duration and that decrease was found statistically significant with the R^2 value of 0.84 (Figure 3).

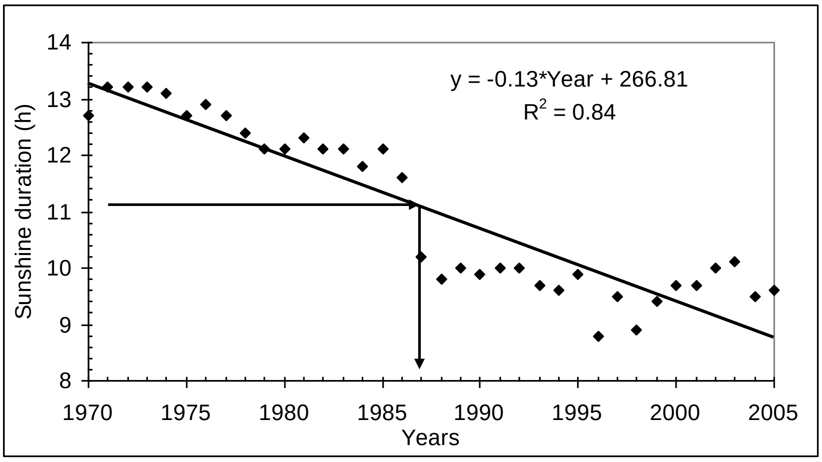

Figure 3. Linear relationship between sunshine duration and years in July of Gaziantep station

Another notable point in this analysis is long term average of trendy series. For example, long-term average of July was 11.01 hours for the examination period. As seen in Fig. 3, the average is almost similar to value of 1987. In other word, all observations before the year 1987 is higher than long-term average and all remaining observations are lower than calculated average. As mentioned above, long-term average must represent almost the whole series, but it was not. Climatic data users should be careful about the long-term average when working on trendy series.

Conclusions

Sunshine duration data have been evaluated considering long-term climatic trends in GAP area using nine meteorological stations data between 1970 and 2005. Results revealed that a salient downward trend was observed especially in summer and early autumn months. Declining trends were usually statistically significant, but rising trends were not. No significant decreasing or increasing trend was detected for the most of winter and spring months. Overall, downward trends of sunshine duration could be attributed to global or regional climatic change.

As it is known, continued regional and water resources development projects may have contaminated the atmosphere in this region. Especially, industry-induced pollution over industrialized cities where the highest trend was observed, such as Gaziantep, may cause lowering the sunshine hours. Evaporation/evapotranspiration from artificial large water bodies and newly opened irrigated systems may have trigger cloud formation and prevented sun lights reaching the earth surface. These possible causes of decreasing behaviors of sunshine duration should be examined in details and exposed their likely effects on agricultural production or engineering structures.

The use of long-term means for any given meteorological series is a common practice. Trends analysis of our work exhibited that long-term average of any trendy series may not used safely. One needs to be careful when working on long-term averages of any trendy series. The overall findings support the view that there is a climate change regionally or globally.

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