Trend analysis of soil surface temperature in several regions of Iran

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Abstract
The purpose of this study was to assess changes in soil surface temperature over the period 1976-2005. Monthly data of soil surface temperature of 7 synoptic stations of Iran were obtained from Iran Meteorological Organization (IRIMO). These stations represent different climates of the country based on Koppen climatic classification. All seasonal and annual series have been checked for normality with the Kolmogorov-Smirnov test. Time trends of the variable were analyzed using parametric and non-parametric techniques (Least square linear regression, Mann-Kendall, Pearson and rho-Spearman correlation coefficient). Regression analysis method showed no significant trend for all of the time series. The three other tests showed similar results (decreasing or no trend) in different seasonal series. In general, no increasing trend was observed in any of times series in study stations. In spring and annual series the highest percentage, i.e. number of stations with significant trend to total number of study stations, was observed using the Mann-Kendall and Pearson non parametric tests.

Key Words
Soil surface temperature, trend, Iran.

Introduction
The importance of soil temperatures can be seen on many levels. The temperature of the soil controls seed germination, as the soil temperatures must be at an optimum level for a specific crop to grow strong seedlings. Surface temperature, on the other hand controls plant emergence and growth. Soil temperature varies in response to exchange processes that take place primarily through the soil surface. Soil temperature varies from month to month as a function of incident solar radiation, rainfall, seasonal swings in overlying air temperature, local vegetation cover, type of soil, and depth in the soil. The temperature of the soil fluctuates both daily and annually and those changes are most evident at or near the surface where sunlight has the most influence. Several previous studies concerning long-term climatological trends have focused on air temperature or rainfall. For example, Lettenmaier *et al*. (1994) looked for evidence of long-term trends in rainfall, over the continental USA by adopting the Mann–Kendall test and an increase in rainfall during autumn was found in a quarter of the entire stations. Increasing rainfall trends were reported in Argentina (Viglizzo *et al.* 1995), Australia and New Zealand (Suppiah and Hennessy, 1998; Plummer *et al.* 1999). Decreasing rainfall trends were found in the Russian Federation (Gruza *et al*. 1999), Turkey (Türke 1996), and Africa (Hess et al., 1995; Mason, 1996) and in China (Zhai *et al.*1999). In 19 northern and central European weather stations, Heino et al. (1999) found no changes in precipitation extremes. The minimum temperature increased almost everywhere and the maximum and mean temperature increased in northern and central Europe, over the Russian Federation, Canada (Bootsma 1994) and in Australia and New Zealand (Plummer *et al.*1999). These results support the suggestion of Smit *et al.* (1988) that mid-latitude regions such as the mid-western USA, southern Europe and Asia are becoming warmer and drier, whereas the lower latitudes are becoming warmer and wetter. Marengo and Camargo (2008) studied surface air temperature in southern Brazil. The comparison showed that the frequency of warmer days increased during both summer and winter, especially during the last two decades. Ghahraman (2006) studied the mean annual temperature in Iran and reported both decreasing and increasing trend but in general, most of the stations showed a positive trend. Little works have been done on soil temperature trend analysis in Iran; therefore the aim of this study was to assess the time trend of soil surface temperature in different regions of Iran using parametric and non-parametric tests.

Materials and methods
The weather stations
High-quality weather data for the period of 1976 to 2005 were obtained from the Islamic Republic of Iran Meteorological Organization (IRIMO). These stations represent some of different climates of Iran based on Koppen climatic classification. They were Tabriz (H = 1361m a.s.l.; latitude = 38◦05'N; longitude =

46◦17'E), Tehran (H = 1190.8m a.s.l.; latitude = 35˚41'N; longitude = 51˚19'E), and Zahedan (H = 1370m a.s.l.; latitude = 29˚28'N; longitude = 60˚53'E), Mashhad (H=992m a.s.l.; latitude = 36˚16'N; longitude = 59˚38'E), Kerman (1753m a.s.l.; latitude = 30˚15'N; longitude = 56˚58'E), Kermanshah (1318m a.s.l.; latitude = 34˚21'N; longitude = 47˚09'E) and Shiraz (H=1484m a.s.l.; latitude = 29˚32'N; longitude = 52˚36'E)

Figure 1. Spatial distribution of study stations

Data analysis

The collected data were carefully examined for missing data but no gap was revealed. Time trends of soil surface temperature were studied for annual and seasonal time series. All time series have been checked for normality with the Kolmogorov-Smirnov test. Least squares linear regression was used to test the increasing or decreasing trends in the study variable. For normally distributed data ($P \leq 0.05$), the statistical significance of the trends was indicated by the Pearson test. In all other cases the non-parametric Mann-Kendall and rho-Spearman test were applied instead.

Results and discussion

The results of trend analysis for different time series are presented in Tables 1 to 5. Also as an example, the results of time trend analysis for Mashhad station is shown in Figure 2.

Table 1. Results of the application of the parametric and non-parametric tests to annual series at 95% level of significance in study stations (1976-2005).

	Method			
Station	Pearson	rho Spearman	Regression analysis	Mann-Kendall
Shiraz	C	C	C	C
Kerman	B	B	C	B
Kermanshah	B	B	C	B
Mashhad	B	B	C	B
Tabriz	B	B	C	B
Tehran	C	C	C	C
Zahedan	B	B	C	B

B: Decreasing trend and C: Non significant trend.

Table 2. Results of the application of the parametric and non-parametric tests to winter series at 95% level of significance in study stations (1976-2005).

Station	Method			
	Pearson	Spearman	Regression analysis	Mann-Kendall
Shiraz	C	B	C	B
Kerman	C	B	C	B
Kermanshah	B	B	C	B
Mashhad	C	C	C	C
Tabriz	C	C	C	C
Tehran	C	C	C	C
Zahedan	C	C	C	C

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

Table 3. Results of the application of the parametric and non-parametric test to spring series at 95% level of significance in study stations (1976-2005).

Station	Method			
	Pearson	Spearman	Regression analysis	Mann-Kendall
Shiraz	C	C	C	B
Kerman	B	B	C	B
Kermanshah	B	B	C	B
Mashhad	B	B	C	B
Tabriz	B	B	C	B
Tehran	C	C	C	C
Zahedan	C	B	C	C

Table 4. Results of the application of the parametric and non-parametric test to summer series at 95% level of significance in study stations (1976-2005).

Station	Method			
	Pearson	Spearman	Regression analysis	Mann-Kendall
Shiraz	C	C	C	C
Kerman	C	C	C	C
Kermanshah	B	B	C	B
Mashhad	C	C	C	C
Tabriz	B	B	C	B
Tehran	C	C	C	C
Zahedan	B	B	C	B

Table 5. Results of the application of the parametric and non-parametric test to autumn series at 95% level of significance in study stations(1976-2005).

Station	Method			
	Pearson	Spearman	Regression analysis	Mann-Kendall
Shiraz	C	C	C	C
Kerman	B	C	C	C
Kermanshah	B	B	C	B
Mashhad	C	C	C	C
Tabriz	B	B	C	B
Tehran	C	C	C	C
Zahedan	B	B	C	B

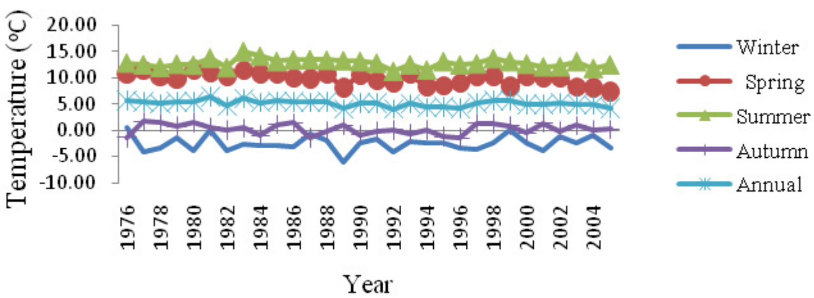

Figure 2. The soil surface temperature variations in Mashhad station.

For all of the time series in study stations parametric method of regression analysis did not show any significant trend. Whereas, the all other three methods showed a similar behavior in trend detection, which means regardless the type of the applied test, existence or non-existence of the trend was same in all stations.

Conclusion

In general, the soil surface temperature in study stations during the last 30 years has not changed significantly or has slightly decreased. This, to some extent, does not coincide with previous studies on air temperature across Iran which indicated a slightly increasing trend in most cases. Therefore, to come to valid conclusion further studies would be required especially on microclimate scales using more station data. None of these three tests showed a superiority to the others.

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