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Temperature changes in Büyük Menderes Basin (Turkey): has there been a warming hiatus at early 2000s ?

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Abstract: In the recent decade, a speculation has arisen on the evolution of global mean surface temperature, that there has been a slowdown in the rate of temperature increase or a cooling after the unusually strong El-Nino event in 1997/1998. This phenomenon is called as "slowdown", "hiatus" or "pause". Beside of global evidences, some studies in regional or sub-regional scales have also shown the existence of a hiatus, for example in China and Spain. The aim of this study is to examine the possible existence of so-called hiatus in a basin scale, in Büyük Menderes basin located in western Turkey. Temperature data covered the period from 1969 to 2013 for five climatic stations scattared homogeneously over the basin. Mann-Kendall test, Sen's Slope Estimator and an innovative trend analysis technique were used to assess the temperature changes. The results showed that Büyük Menderes basin has experienced a continued warming at early 2000s with a weaker rate and insignificant at %95 level in comparison to the strong warming at the last one or two decades of 20th century. Consequently, the warming slowdown detected in global scale is also evident in Büyük Menderes basin.

Keywords: Büyük Menderes basin, climate change, global warming, Turkey, warming hiatus

Büyük Menderes havzasında sıcaklık değişimleri: 2000'li yılların başında sıcaklık artışında bir fasıla yaşandı mı?

Öz: 1997/1998'deki kuvvetli El-Nino hadisesi sonrasındaki geçen sürede, küresel ortalama sıcaklık artışında bir yavaşlama veya soğuma olduğu yönünde bir spekülasyon ortaya çıkmıştır. Bu olay, "yavaşlama", "fasıla" veya "durma" olarak adlandırılmaktadır. Global ölçekteki kanıtlar yanında, bazı bölgesel veya alt-bölgesel çalışmalar, örneğin İspanya'da ve Çin'de, bu fasılanın varlığını göstermiştir. Bu çalışmanın amacı, Türkiye'nin batısında yer alan Büyük Menderes havzası özelinde söz konusu fasılanın varlığını araştırmaktır. Çalışmada, havzada homojen olarak yayılmış beş klima istasyonuna ait 1969-2013 yılları arasındaki sıcaklık verileri kullanılmıştır. Sıcaklık değişimleri, Mann-Kendall testi, Sen'in Eğim Tahmincisi ve yeni bir trend analizi tekniği kullanılarak değerlendirilmiştir. Bulgular, Büyük Menderes havzasında, yirminci yüzyılın son on veya yirmi yılında yaşanan hızlı sıcaklık artışı ile karşılaştırıldığında, 2000'li yılların erken döneminde nispeten daha yavaş ve %95 düzeyinde istatistiksel olarak önemli olmayan bir sıcaklık artışının gerçekleştiğini göstermiştir. Sonuç olarak, global ölçekte saptanan sıcaklık artışındaki yavaşlama, Büyük Menderes havzasında da geçerlidir.

Anahtar kelimeler: Büyük Menderes havzası, iklim değişikliği, küresel ısınma, Türkiye, fasıla

1. Introduction

Global warming is the most widespread and important environmental problem of our time (Yeşilırmak and Atatanır, 2016). The global average surface temperature data showed a linear warming trend of 0.85 °C over the period 1880-2012 (Hartmann et al., 2013). On the other hand, the rate of temperature change was not uniform over that period. The earth experienced an accelarated warming from 1910 to 1941 with a rate of 0.12 °C per decade, then a small negative trend of 0.04 °C per decade from 1941 to 1971

(Meehl, 2015). From 1970s to 1998 a warming has been observed until 1998 when a strong El-Nino event has occurred. Since then, it appears that warming have stopped or decreased in intensity (Gonzalez-Hidalgo et al., 2016). This period after 1998 or at early-2000s in which no or less warming rate has been detected is called as "hiatus", "global slowdown" or "pause" (Li et al., 2015). Trenberth and Fasullo (2013) indicate that the warming slowdown has occurred mainly from 20° to 65° latitude, where Turkey is covered. The latest hiatus has prompted the speculations on the climate change theory and model projections (Trenberth, 2015)

Some hypotheses have been proposed to explain the hiatus. Some of them are: the decrease in stratospheric water vapour content, the heat redistribution between upper and lower oceanic layers, particularly in the Pacific, the combination of internal climate variability and radiative forcing, including anthropogenic factors (Gonzalez-Hidalgo et al., 2016), the prolonged minimum in the 11-year solar cycle, volcanic eruptions (Meehl, 2015). Another explanation is that greater use of buoys to measure sea surface temperature resulted in a shift during last couple of decades, because buoy measurements are lower than those of ships (Karl et al., 2015; Wendel, 2015). Karl et al. (2015) state that, when corrected sea surface temperature bias, there is no "slowdown" in the increase of global surface temperature. On the other hand, a number of studies detected so-called hiatus in regional and subregional scales, for example in Spain (Gonzalez-Hidalgo et al., 2016) and in China (Li et al., 2015).

In this study, the aim is to search whether the early-2000s hiatus has occurred in Büyük Menderes basin located in western Turkey, by analyzing annual mean temperature changes from 1969 to 2013.

2. Materials and Methods

This study analyzed the annual mean temperature trends in Büyük Menderes basin in western Turkey with a special emphasis on the recent warming hiatus. The original data for five stations scattared homogeneously over the basin was supplied from State Meteorological Service of Turkey (MGM) as daily minimum and maximum temperatures. The stations are tabulated in Table 1. The locations of the stations within the basin are shown in Figure 1.

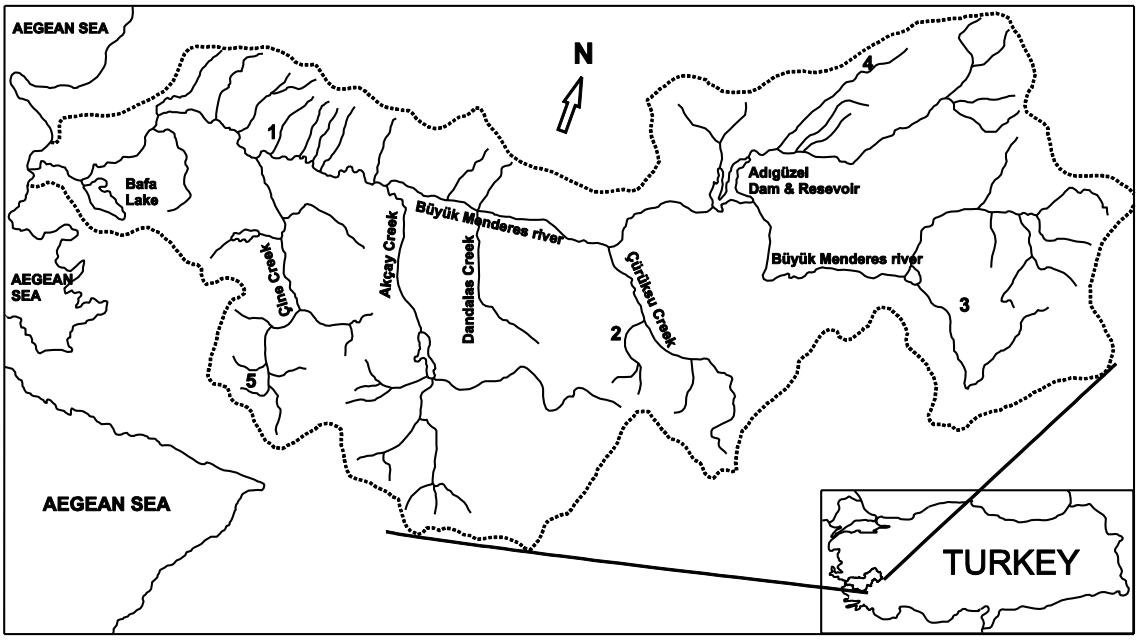

Figure 1. Study area

These are the major climatic stations in the basin which have the longest duration of minimum and maximum temperature data. Besides, they have the least amount of missing data. Other climatic stations in the basin contain huge amount of missing data as long as 3 to 5 years between 1969 and 2013. Therefore, only the data of the stations listed in Table 1 were used.

Table 1. Details of stations

No	Station ID	Station Name	Data Period	Lon	Lat	Elevation (m.a.s.l.)
1	17234	Aydın	1969 – 2013	27° 51′ E	37° 51′ N	56
2	17237	Denizli	1969 – 2013	29° 05′ E	37° 47′ N	425
3	17862	Dinar	1969 – 2013	30° 10′ E	38° 04′ N	864
4	17188	Uşak	1969 – 2013	29° 24′ E	38° 41′ N	919
5	17886	Yatağan	1969 – 2013	28° 08′ E	37° 21′ N	365

These stations given in Table 1 cover both the longest data period and the least number of missing data in the order of a few days in any month.

Daily minimum and maximum temperature series at each station were subjected to a basic quality control procedure such as non-existent days, minimum temperature greater than maximum temperature; and such days assigned "missing" (Klein Tank et al. 2002). Any month (and consequently the year) was considered to be missing if that month contained missing days more than three consecutive days or more than five random days (Vincent and Mekis, 2006). Daily mean temperatures were calculated as average of daily minimum and maximum temperatures, which were then used to calculate monthly and annual averages. Annual mean temperature series at each station were expressed as anomalies from 1969-2013 average. Then, the anomaly series of the stations were simply averaged to obtain basin-wide anomaly series of mean annual temperature.

Mann-Kendall test wes used to test significance of lineer trends, and the rates of trends (in °C year^{-1}) were quanitifed by Sen's Slope estimator (Gilbert, 1987; Yeşilırmak, 2014). Trend significances and rates were estimated by using the Excel template MAKESENS (Salmi et al., 2002). Another technique used for trend analysis is an innovative trend analysis recently proposed by Şen (2012). In this method, whole time series is divided into sub-periods with equal number of data. Data in each sub-period is sorted in ascending order. Then, two sub-periods are plotted against each other in a cartesian coordinate system, putting the first sub-period on x-axis and the second sub-period on y-axis. While points in the diagram above1:1 line show increasing trend, those below 1:1 line indicate decreasing trend.

3. Results and Discussion

Mean annual temperature anomaly series for each station and whole basin are given in Figure 2. This figure shows that mean annual temperature, not only at each station but also in the basin as a whole, had a flat pattern from 1969 to the begining of 1990s, then, increases until 2001. A relatively cool period was evident between 2002 and 2006. From 2007 to 2013 there has been no clearly distinguishable trend pattern, with a relatively extreme hot year in 2010 and cold year in 2011. When overall change of temperature after 1998 were considered, a weaker upward trend can be observed as shown in Figure 2.

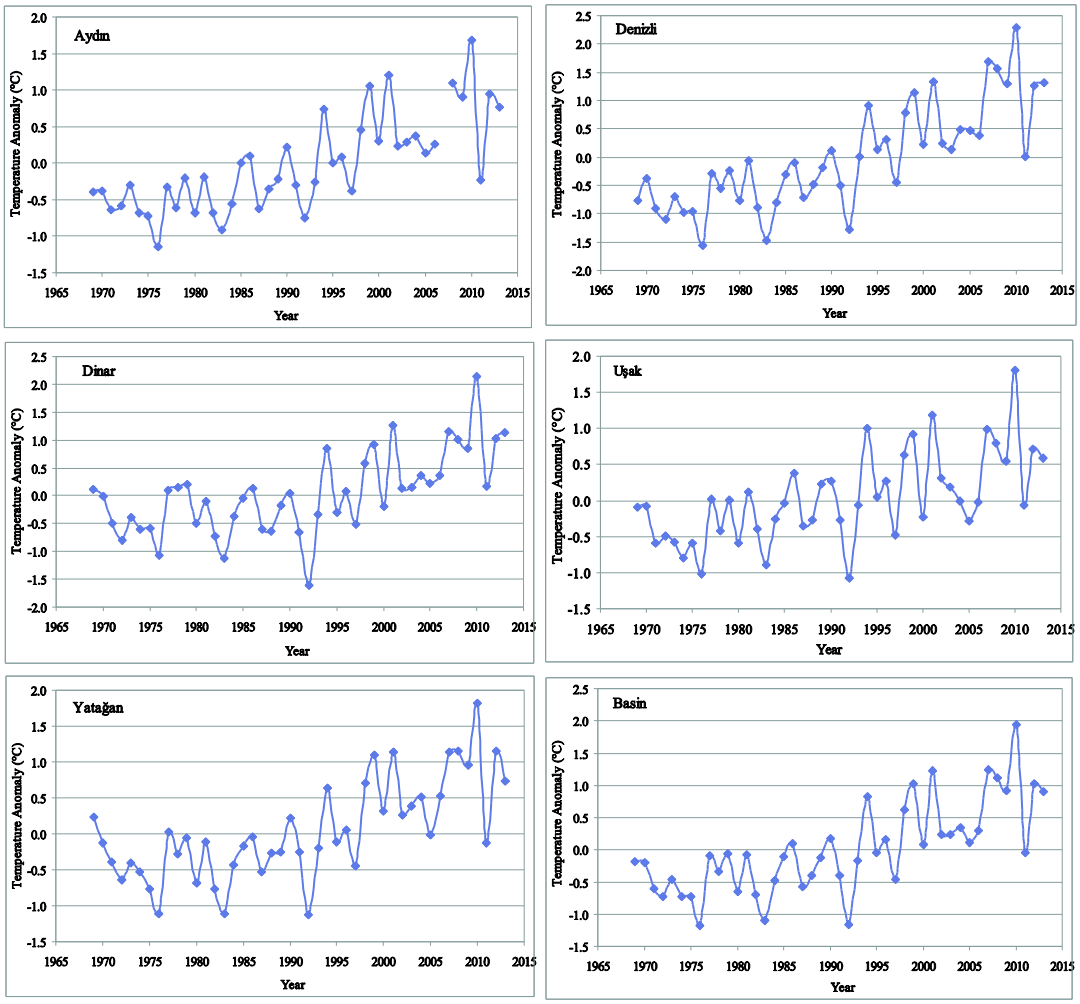

Figure 2. Anomaly series of mean annual temperature at each station and in the basin as a whole

The basin-wide mean annual temperature anomaly series of 45 years was divided into three sub-periods, each of which lasts 15 years: 1969-1983, 1984-1998 and 1999-2013. Last two sub-periods were compared with the preceeding one, namely 1969-1983 vs. 1984-1998 and 1984-1998 vs. 1999-2013, using innovative trend analysis methodology (Figure 3 and Figure 4). As shown in Figure 3, the sub-period 1984-1998 was warmer than the sub-period 1969-1998. And also, the sub-period 1999-2013 was warmer than the sub-period 1984-1998 (Figure 4). These results suggest that each sub-period is warmer than the before, and that there is no cooling but the warming continues in Büyük Menderes basin after 1998.

Trend rates of temperature changes confirm the previous findings. Figure 5 demonstrates the lineer trend rates at each sub-period together with whole period from 1969 to 2013. Whole period demonstrated a statistically significant ($p<0.05$) warming trend with the rate of 0.036 °C y However, there was a coooling in the sub-period 1969-1983 with a rate of 0.015 °C year^{-1}, and then warming in the sub-periods 1984-1998.

Another approach is to search the trends in consecutive decreasing temporal windows (from 1969-2013 to 2004-2013) as shown in Figure 6. This figure depicts that the intensity of trend rate increased until the begining of 1990s, then decrased rapidly and fluactuated in a wider range with an average trend rate of 0.048 °C year^{-1} until the temporal window 2001-2013. Here it is worthwhile to note that the trends in temporal windows starting from 1994 are not statistically significant at 95% level. These results confirm the

results of previous approaches used in this study, that Büyük Menderes basin experienced not a cooling but warming at a decreased rate at early 2000s.

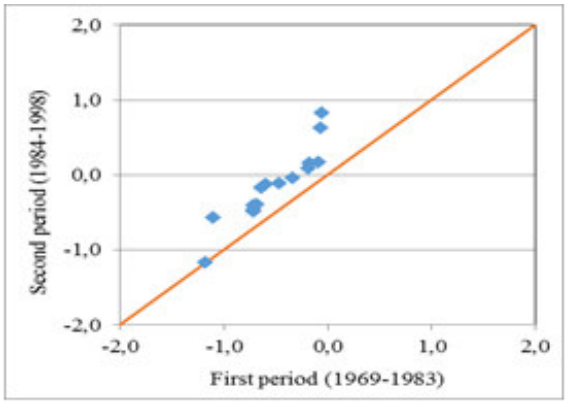

Figure 3. The comparison of the sub-periods 1969-1983 vs. 1984-1998

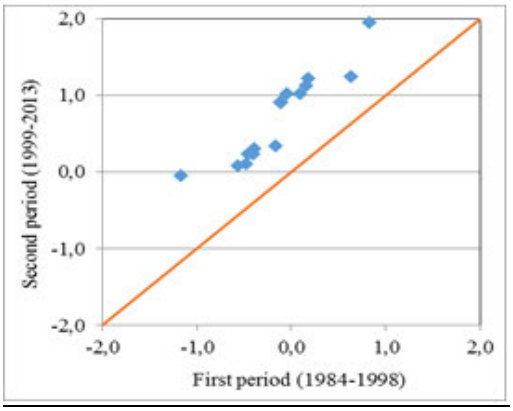

Figure 4. The comparison of the sub-periods 1984-1998 vs. 1999-2013

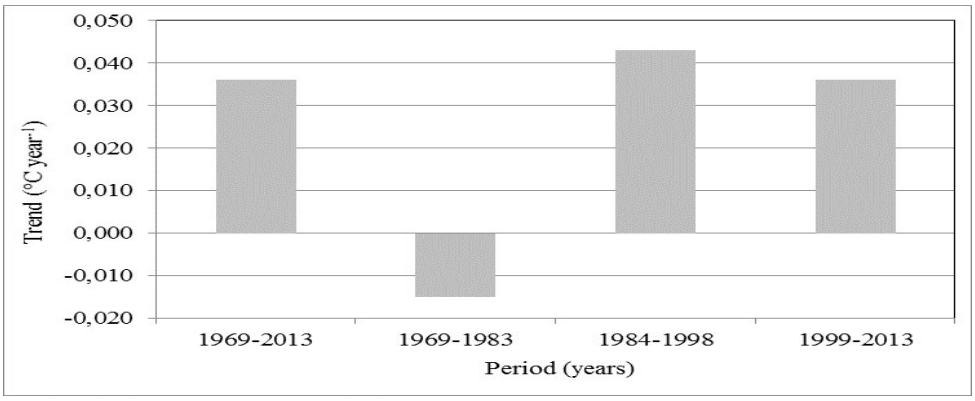

Figure 5. Trend rates for whole period and three sub-priods

A number of studies also detected hiatus at early-2000s in regional and sub-regional scales. Gonzalez-Hidalgo et al. (2016) found that warming rates in the Spanish mainland reached a maximum value between 1970 and 1990, then decreased until present. This suggests a slowdown in warming in the Spanish mainland. Li et al (2015) detected a hiatus period in China during 1998-2012, with a decresing trend in mean annual maximum temperature and a static pattern in mean annual minimum temperature.

The most widely accepted one among the explanations which have been proposed to explain the hiatus at early-2000s is related to the variability modes of sea surface temperature anomalies mainly in Pacific Ocean like ENSO (El-Nino Southern Oscillation), PDO (Pacific Decadal Oscillation), IPO (Interdecadal Pacific Oscillation) (Meehl, 2015; Trenberth, 2015; Trenberth and Fasullo, 2013). Trenberth (2015) indicates that global mean surface temperature increases during the positive phase of PDO but stagnates during its negative phase. Kosaka and Xie (2015) argue that IPO began the transition toward negative phase in the 1990s, and that the recent negative IPO trend has offset a large part of greenhouse gas induced global warming and substantially contributed hiatus after 1998 or at early-2000s. In another study, Kosaka and Xie (2013) indicate that the current hiatus is due to the La-Nina-like decadal cooling. In a regional study by Vuille et al. (2015), the cooling at coastal part

along the western side of the Andes, Southern America, is attributed to the negative phase of PDO.

Another aspect of the issue is related with start and end of the period for which a possible trend is searched. Easterling and Wehner (2009) state that one can find any period of cooling as long as a decade or two superimposed on the long-term warming trend due to anthropogenic greenhouse gas forcing.

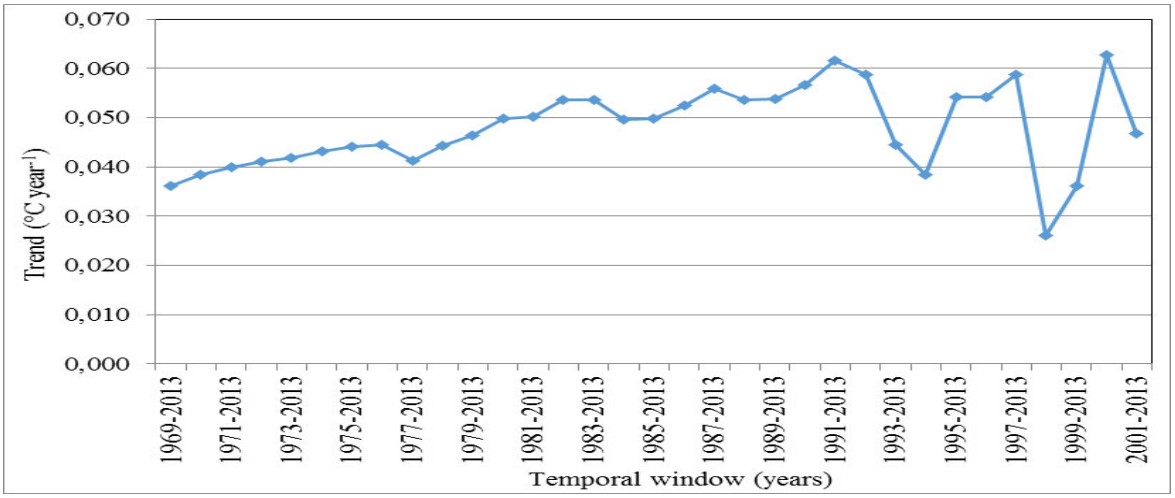

Figure 6. Trend rates according to decreasing length of running temporal window (small markers indicate insignificant trends at %95 level)

In an example given by Easterling and Wehner (2009), if the year 1998 which is the unusually warm year due to the strong 1997-1998 El-Nino event is chosen as a start year of a period, then a small and statistically insignificant positive trend is obtained. This is the case in our study in Büyük Menderes basin. As shown in Figure 6, the trend for the period 1998-2013 was 0.026 °C year^{-1} and insignificant at %95 level, which is the lowest one among all temporal windows.

4. Conclusion

The slowdown detected in the first decade of 21th-century in the rate of global mean surface temperatures increase has been a hot topic not only in scientific community but also in the public. This slowdown is mainly attributed to the use of uncorrected data or to the internal natural variability. The results of this study indicate the existence of the current warming hiatus in Büyük Menderes basin, western Turkey. Each of the last two sub-period of 15 years length has been warmer than the previous one over the whole period from 1969 to 2013. Trend rates increased until the temporal window 1991-2013, then stabilizes, which suggests a pause in the rate of warming.

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