RELATIONSHIP BETWEEN SEA-SURFACE TEMPERATURE ANOMALIES AND PRECIPITATION ACROSS TURKEY

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ABSTRACT

Due to their semi-arid climate and continued population growth, the major climate regions of Turkey are vulnerable to shifts in precipitation patterns and the associated cycles of groundwater availability. Previous analyses of rainfall data from stations throughout the country have revealed pronounced seasonality and inter-annual variability[1]. Cyclone track and frequency, proximity to the sea, local and regional orographic features, strength of anticyclonic flow, equatorward penetration of polar fronts, stage of the El Nino-Southern Oscillation and North Atlantic Oscillation, and strength and placement of 700 hPa height anomalies have all been shown to directly impact the quantity and distribution of precipitation[2],[3],[4],[5],[6]. Kadioğlu et al.[7] examined the regional variability of mean seasonal total precipitation and found that each region exhibited its own rainfall regime, especially in the high plateaus and rugged mountainous areas of Anatolia.

Taha et al.[8] and Martyn[9] found that most climate regions in Turkey were characterized by aridity and continentality, and thus they concluded that the influence of the surrounding Mediterranean and Black seas was restricted. However, because of the modulating influence of sea surface temperature (SST) anomalies on many of the factors identified by the above authors, it is important to re-examine its role. This study seeks to build on the Taha et al.[8] and Martyn[9] studies by identifying and examining the relationship between SST anomalies (from NCEP/NCAR reanalyses) in the Mediterranean and Black seas and rainfall in selected sites across Turkey (from the Turkish State Meteorological Agency). Pearson correlations coefficients will be computed and tested for significance. By isolating the relationship between SST anomalies and rainfall, community planning decisions can be made based on anticipated SST variation and subsequent rainfall expectations.

INTRODUCTION

Understanding climatic change and global warming is vitally important to human existence and continuance, and especially so in regions sensitive to shifts in water resources and precipitation[10]. Turkey is one such location. Because of the high year-to-year and seasonal variability in rainfall, much of the country lacks regular and sufficient water during the year[7]. Recent studies of precipitation distribution across Turkey[1],[6],[11] showed a noticeable decrease in both winter and annual rainfall in the Black Sea and Mediterranean precipitation regions. Also, periodic dry spells were noticed in the early 1930s, late 1950s, early 1970s, 1980, and the early 1990s. Several wet spells were observed to interrupt the dry conditions, especially in 1935-1945, around 1960, and in the late 1970s. Widespread dry conditions over much of Turkey were documented in the 1970s and 1980s[11].

The Turkish State Meteorological Service maintains a well-dispersed network of rain gauges across the several sub-climate regions of Turkey[10]. This precipitation data has been used by several authors who examined the role of meso- and synoptic-scale atmospheric features in determining the precipitation amount and distribution over Turkey. Taha et al.[8] and Martyn[9] found that most climate regions in Turkey were characterized by aridity and continentality, and thus they concluded that the influence of the surrounding Mediterranean and Black seas was restricted. Other authors have identified several factors as directly impacting the quantity and distribution of precipitation across Turkey: proximity to the sea, strength of surface and mid-tropospheric anticyclones, equatorward extent and strength of cold fronts, mid-latitude cyclone track and frequency, local and regional orography, stages of the El Nino-Southern Oscillation and North Atlantic Oscillation, and location and intensity of 700 hPa height anomalies[2],[3],[4],[5].

Generally speaking, many of the worldwide climate research centers have recently focused their research endeavors in the area of global climate change. One popular research approach examines the sensitivity of global climate models (GCMs) to various initial condition and parameterization perturbations. However, a resonable physical interpretation of GCM output requires a priori knowledge of the current climatological system and its characteristics. One method helpful in understanding the earth-climate system is to systematically examine the near-historical record, looking for secular trends in the observations and drawing conclusions from the observations. This study is such a method, building on the earlier Taha et al.[8] and Martyn[9] research by investigating the relationship between sea surface temperature (SST) of the Mediterranean and Black seas and precipitation across twenty-seven selected sites across Turkey.

DATA

Sea surface temperatures from the period 1900 to 2006 were obtained from the U.S. National Climatic Data Center (NCDC), a division of the U.S. National Oceanographic and Atmospheric Agency (NOAA). The "extended reconstructed sea surface temperatures" (ERSST) dataset, version two, contains global monthly SSTs averaged on a two degree grid. Two points in the eastern Mediterranean basin were chosen as representative sea surface temperatures: 34°N, 30°E and 34°N, 22°E. One point in the western Black sea was chosen as a representative sea surface temperature: 42°N, 32°E.

Rainfall data were obtained from the NCDC's Global Historical Climatology Network (GHCN). Observing locations were selected across Turkey using several criteria: (1) length of the historical record available; (2) completeness of the historical record available; and (3) spatial distribution across Turkey's various climatic regimes. It is important to realize that, while this study aims to use only highest-quality data, inhomogeneities in both the precipitation (GHCN) and SST (ERSST) datasets are possible. However, no other observational data will be without similar problems, and the historical record (107 years for SST and an average of 75 years for precipitation) is sufficiently long that, in the author's opinion, some of the inaccuracies will be smoothed.

The twenty-seven selected precipitation sites, along with their abbreviations and the length of the historical record used in this study, are listed below in Table 1. Figure 1 (courtesy of M. Turkes) below plots the distribution of the selected sites. Notice the twenty-seven sites are spread roughly evenly through Turkey's identified climate regimes[10].

WMO Code	City	Abbreviation	Period of Record
170220	ZONGULDAK	ZON	1938-2006
170400	RIZE	RIZ	1929-2004
170500	EDIRNE	EDI	1929-2006
170620	ISTANBUL / GOZTEPE	IST	1929-2006
170840	CORUM	COR	1931-2006
170900	SIVAS	SIV	1929-2006
170920	ERZINCAN	ERZ	1931-2006
170980	KARS	KAR	1931-2006
191120	KANAKKALE	KAN	1931-2006
171160	BURSA	BUR	1931-2006
171300	ANKARA / CENTRAL	ANK	1926-2006
171500	BALIKESIR	BAL	1937-2006
171700	VAN	VAN	1938-2006
171880	USAK	USK	1931-2006
171900	AFYON	AFY	1931-2006
171950	KAYSERI / ERKILET	KAY	1951-2004
172100	SIIRT	SIR	1938-2006
172200	IZMIR / GUZELYALI	IZM	1929-2004
172400	ISPARTA	ISP	1931-2006
172440	KONYA	KON	1931-2006
172500	NIGDE	NIG	1938-2006
172550	KAHRAMANMARAS	KAH	1961-2006
172700	SANLIURFA	SAN	1932-2006
172800	DIYARBAKIR	DIY	1929-2006
172920	MUGLA	MUG	1935-2006
173000	ANTALYA	ANT	1929-2006
173400	MERSIN	MER	1961-2006

Table 1: The twenty-seven precipitation sites across Turkey used in this study.

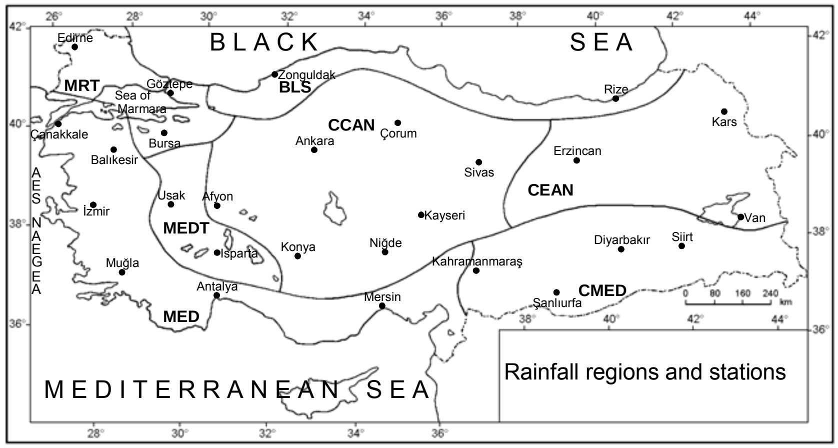

Figure 1: Location of the 27 stations over the rainfall regions of Turkey. Regions are identified as follows: **BLS**: Black Sea; **MRT**: Marmara Transition; **MED**: Mediterranean; **MEDT**: Mediterranean Transition; **CMED**: Continental Mediterranean; **CCAN**: Continental Central Anatolia; **CEAN**: Continental Eastern Anatolia. Figure provided courtesy of Dr. M. Türkeş[10].

METHODOLOGY AND RESULTS

To gauge the relationship between precipitation amount and SST, Pearson correlation coefficients were computed between the monthly precipitation data and the monthly SSTs. Because precipitation and sea surface temperatures exhibit strong seasonality[7], it is important to correlate monthly precipitation with the SST anomalies. Monthly SST data from 1900-2006 was averaged to calculate the mean. Then the mean was subtracted from each monthly value to compute the SST anomalies. Correlation coefficients were calculated between the SST anomaly and the precipitation value for each month where data was available. Annual correlation coefficients were also calculated between SST anomalies and rainfall data, but the values never deviated significantly from 0.00 (not shown). Monthly correlation coefficients between Mediterranean SSTs (at the grid point 34N, 22E) and precipitation data are summarized in Table 2 below. Correlation coefficients that exceed the "weak" threshold of relationship (above 0.30 or below -0.30) are highlighted in bold. No "strong" relationships (coefficients above 0.60 or below -0.60) were found, however several values do approach 0.50.

Most of the stations have very little correlation between monthly rainfall and SST anomalies, as evidenced by correlation coefficients between -0.20 and 0.20. However, the coefficients do reveal a few interesting relationships. First, the only weakly positive relationships (correlation coefficients greater than 0.30) are found in June and July, at stations SIV, KAR, VAN, KAY, NIG, SAN, DIY, and MER. This suggests that, for these locations, above-normal Mediterranean SSTs are related to increased summer precipitation. Second, the only weak negative relationships (correlation coefficients less

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ZON	(0.07)	(0.09)	(0.08)	**(0.37)**	(0.15)	0.20	(0.01)	(0.08)	(0.17)	0.04	(0.00)	(0.06)
RIZ	(0.13)	(0.11)	(0.15)	(0.29)	0.08	(0.10)	0.03	(0.08)	0.03	(0.17)	(0.08)	(0.10)
EDI	0.00	0.18	0.10	(0.10)	(0.17)	(0.15)	0.18	(0.10)	(0.16)	(0.02)	(0.04)	0.18
IST	(0.23)	(0.06)	(0.13)	**(0.30)**	**(0.31)**	(0.08)	(0.11)	(0.02)	(0.24)	(0.09)	(0.03)	(0.07)
COR	(0.12)	(0.08)	(0.07)	(0.13)	0.02	(0.12)	0.19	0.09	(0.04)	(0.23)	(0.00)	(0.15)
SIV	(0.20)	(0.11)	(0.10)	(0.05)	0.10	(0.04)	**0.36**	0.08	(0.10)	(0.09)	0.02	(0.07)
ERZ	(0.16)	0.10	0.20	(0.09)	0.00	0.12	0.25	0.14	0.07	(0.12)	(0.10)	0.06
KAR	(0.00)	(0.14)	0.19	0.20	0.22	0.09	**0.49**	0.13	0.04	(0.03)	0.14	0.05
KAN	(0.08)	0.21	(0.09)	(0.10)	(0.26)	(0.27)	0.01	(0.02)	(0.16)	(0.01)	(0.05)	0.17
BUR	(0.17)	0.11	0.01	(0.21)	**(0.31)**	(0.13)	(0.07)	0.06	(0.12)	(0.02)	0.05	(0.05)
ANK	(0.17)	0.08	0.05	(0.15)	0.00	0.13	(0.03)	(0.06)	(0.08)	(0.10)	(0.14)	(0.03)
BAL	(0.08)	0.22	(0.02)	(0.23)	(0.10)	(0.24)	(0.18)	**(0.32)**	(0.15)	(0.11)	0.09	0.05
VAN	0.05	(0.12)	0.11	(0.03)	(0.06)	**0.31**	0.14	0.25	0.26	0.11	0.13	0.09
USK	(0.08)	0.07	(0.03)	(0.15)	(0.05)	0.19	0.18	0.22	(0.04)	(0.16)	(0.04)	0.09
AFY	(0.18)	0.11	(0.13)	(0.12)	0.01	0.19	0.04	0.08	0.05	(0.12)	0.04	(0.08)
KAY	(0.27)	(0.06)	(0.05)	0.02	0.04	0.21	**0.34**	(0.07)	(0.23)	(0.12)	(0.15)	(0.09)
SIR	(0.10)	(0.27)	(0.09)	(0.12)	(0.02)	0.28	0.22	0.21	0.13	(0.09)	0.08	0.01
IZM	(0.13)	0.12	(0.15)	(0.27)	**(0.34)**	(0.22)	(0.24)	0.22	(0.01)	(0.04)	(0.03)	0.03
ISP	0.02	0.15	(0.19)	(0.05)	0.02	0.05	0.12	0.09	0.01	(0.12)	(0.04)	0.02
KON	(0.12)	(0.06)	(0.27)	0.03	0.15	0.15	0.14	0.08	0.02	(0.11)	(0.08)	(0.02)
NIG	0.16	0.09	(0.14)	(0.08)	0.07	0.24	**0.35**	0.04	0.06	(0.05)	0.11	(0.06)
KAH	(0.25)	0.15	(0.20)	(0.18)	0.05	(0.15)	0.07	**(0.35)**	0.09	(0.25)	0.14	(0.13)
SAN	0.05	(0.29)	(0.26)	(0.08)	0.05	0.13	**0.44**	0.21	0.19	(0.03)	0.21	(0.13)
DIY	0.01	(0.20)	(0.21)	(0.05)	0.15	0.04	**0.36**	(0.19)	0.33	0.05	0.07	(0.07)
MUG	(0.06)	0.13	(0.14)	(0.18)	0.02	0.02	0.28	0.24	0.12	(0.10)	(0.01)	0.14
ANT	0.18	0.09	(0.21)	0.00	0.14	0.07	0.25	0.17	0.04	(0.10)	0.00	(0.08)
MER	(0.25)	0.14	(0.28)	0.10	(0.05)	**0.34**	0.12	0.12	**(0.32)**	(0.27)	(0.02)	(0.13)

Table 2: Correlation coefficients between monthly precipitation and SST anomalies at 34°N, 22°E, in the Mediterranean Sea.

than -0.30) are found in April-May and August-September at stations ZON, IST, BUR, IZM, BAL, KAH, and MER. This suggests that higher than normal Mediterranean SSTs are related to lower precipitation values. Third, no stations exhibit significant (either weak, or strong) relationships in the winter months (November-February), suggesting that Mediterranean SST anomalies are not related to precipitation during this season.

Turkey is bordered by not only the Mediterranean sea to its south and southwest, but also by the Black sea to its north and northeast. Thus, in addition to looking for relationships between Mediterranean SST anomalies and precipitation in Turkey, correlation coefficients were computed for the Black Sea (represented at the point 42°N, 32°E). The coefficients are presented in Table 3 below.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ZON	0.16	(0.02)	0.01	**(0.36)**	(0.22)	0.17	(0.09)	(0.12)	(0.20)	0.05	(0.08)	0.02
RIZ	(0.10)	(0.04)	(0.23)	**(0.33)**	0.08	(0.06)	0.00	0.03	(0.08)	**(0.33)**	(0.23)	(0.29)
EDI	0.19	0.05	0.18	(0.10)	(0.24)	(0.11)	0.18	(0.05)	(0.08)	0.02	0.06	0.24
IST	0.06	(0.08)	0.02	**(0.32)**	(0.29)	(0.03)	(0.11)	0.01	**(0.31)**	(0.13)	(0.12)	(0.06)
COR	(0.05)	(0.15)	0.06	(0.17)	(0.08)	(0.15)	0.18	0.11	(0.04)	(0.25)	(0.10)	(0.10)
SIV	(0.22)	(0.20)	(0.08)	(0.15)	0.09	(0.03)	**0.43**	0.15	(0.07)	(0.16)	(0.13)	0.04
ERZ	(0.02)	(0.05)	0.14	(0.01)	(0.03)	0.16	**0.34**	0.15	(0.03)	(0.26)	(0.21)	(0.02)
KAR	(0.05)	(0.24)	(0.05)	0.11	0.17	0.06	**0.43**	0.08	(0.02)	(0.19)	0.02	(0.09)
KAN	0.15	0.10	0.03	(0.11)	(0.26)	(0.14)	0.01	(0.09)	(0.14)	(0.03)	0.05	0.16
BUR	0.05	0.10	0.17	(0.28)	(0.26)	(0.08)	(0.10)	(0.02)	(0.14)	(0.14)	(0.02)	(0.02)
ANK	0.02	(0.05)	0.14	(0.13)	0.01	0.17	0.08	0.01	(0.01)	(0.12)	(0.20)	0.05
BAL	0.08	0.17	0.07	(0.15)	(0.01)	(0.23)	(0.19)	(0.27)	(0.10)	(0.16)	0.10	0.20
VAN	(0.05)	(0.22)	(0.18)	(0.11)	0.06	0.19	0.17	0.23	0.25	(0.05)	0.08	(0.06)
USK	0.09	(0.05)	0.06	(0.23)	(0.04)	0.18	0.09	0.11	0.04	(0.12)	(0.04)	0.20
AFY	(0.10)	0.04	(0.02)	(0.23)	0.04	0.08	0.06	0.02	0.00	(0.17)	(0.08)	(0.05)
KAY	(0.17)	(0.25)	(0.08)	0.05	0.05	0.20	**0.30**	(0.15)	(0.29)	(0.27)	**(0.30)**	0.02
SIR	(0.10)	(0.28)	(0.37)	(0.14)	0.03	0.13	**0.30**	0.25	0.09	(0.16)	0.04	(0.11)
IZM	0.11	0.08	(0.02)	(0.25)	(0.27)	(0.08)	(0.23)	0.11	0.03	(0.02)	0.02	0.18
ISP	0.16	0.22	(0.10)	(0.14)	(0.01)	(0.00)	(0.00)	0.03	(0.06)	(0.11)	(0.08)	0.14
KON	0.07	(0.09)	(0.28)	(0.03)	0.23	0.12	0.15	0.09	(0.01)	(0.11)	(0.21)	0.07
NIG	0.25	(0.12)	(0.26)	(0.04)	0.09	0.25	**0.34**	0.07	0.07	(0.08)	0.04	(0.10)
KAH	(0.08)	(0.17)	**(0.40)**	(0.14)	0.07	0.01	(0.23)	**(0.40)**	0.08	**(0.39)**	0.02	(0.10)
SAN	0.01	(0.26)	**(0.35)**	(0.13)	0.10	0.07	**0.49**	0.22	0.13	(0.13)	0.10	(0.06)
DIY	0.04	(0.25)	(0.27)	(0.05)	0.15	(0.00)	**0.43**	(0.19)	**0.31**	(0.07)	0.05	(0.02)
MUG	0.12	0.08	(0.15)	(0.11)	0.08	0.09	**0.30**	0.09	0.11	(0.11)	0.08	0.25
ANT	0.26	0.07	(0.16)	(0.12)	0.02	0.10	0.20	0.04	(0.06)	(0.03)	0.03	(0.05)
MER	0.04	0.11	**(0.37)**	(0.05)	(0.18)	0.29	(0.01)	0.12	(0.26)	(0.26)	(0.03)	(0.23)

Table 3: Correlation coefficients between monthly precipitation and SST anomalies at 42°N, 32°E, in the Black Sea.

Like the correlations between Mediterranean Sea SST and precipitation, the correlations between Black Sea SST also reveal mostly no relationship (coefficients hovering around 0.00). However, several patterns similar to the Mediterranean emerge. For the month of July, seven stations' precipitation is weakly positively correlated (coefficients greater than 0.30) warm SST anomaly. Also, the weakly negative (coefficients less than -0.30) correlations are found in March-April and September-October. This suggests similar relationships exist between Mediterranean and Black Sea SST anomalies and precipitation across Turkey.

CONCLUSIONS

The data presented above reveal that precipitation across Turkey is largely unrelated to SST anomalies in both the Black and Mediterranean Seas. However, this study found indications that weak relationships may exist for some sites in some months. The correlation coefficients were not randomly dispersed throughout the year. Weakly positive coefficients were found in the summer months of June and July, implying that warmer than normal SSTs are connected with increased precipitation. Weakly negative coefficients were found in the transition months of March-April and August-September, implying that warmer than normal SSTs are connected with decreased precipitation.

Several possible reasons exist to explain these relationships. For the majority of sites across Turkey, precipitation has no relationship with SST anomaly. Precipitation is, in a basic sense, a function of local vertical motion and water vapor quantity. These two variables are influenced by a variety of global-, synoptic-, and meso-scale features, including planetary waves, mid-latitude cyclones, upper-tropospheric subsidence, mid-tropospheric humidity, local topography, and local soil moisture. Therefore, it is not surprising to find little correlation between SST and precipitation.

However, it is interesting to examine the few sites and few months that do exhibit weak correlation. In the summer months of June and July, precipitation is mostly generated by random convective cells. As SSTs increase, boundary layer relative humidity will also increase. The stations that reported weakly positive correlations are mostly located in an arc across east-central Turkey, from NIG in the south-central to KAR in the northeast. This area is mountainous and its climate continental[10]. It is possible that in June and July, local orography acts to generate convective updrafts, and the greater boundary layer relative humidity (which must be transported to these locations, as they are not adjacent to either sea) enhances the convective precipitation. In this case, positive SST anomalies can be considered as one of the forcings for increased summer precipitation over the central and eastern interior of Turkey.

In the transition months of March-April and August-September, weakly negative correlation coefficients are found in an arc through northwest to northern to northeastern Turkey, from IZM to IST to RIZ. This area is in the Black Sea and Mediterranean Sea climate zones[6]. During these months, positive SST anomalies are possibly related to increased subsidence and thus increased solar radiation. The increased subsidence would act to suppress cloud cover and precipitation. Thus, in this case, positive SST anomalies are possibly responding to the same external forcing that causes decreased precipitation, and the two are therefore weakly negatively correlated.

Although mostly unrelated, future work is necessary to further define the relationship between SST anomalies and precipitation across Turkey. Examining wind direction and speed, and also surface temperature, would be beneficial in determining the causal relationship, i.e., if SST anomalies are able to force precipitation changes or if the two are related but forced by an external mechanism. Finally, it would be interesting to perturb SST in a GCM simulation and compare the results to the observations summarized in this study to see if similarities exist.

As the earth continues to warm, SSTs in the Mediterranean and Black seas will likely increase as well. If the relationships identified in this study hold during climate change, city planners, politicians, and citizens will be able to plan accordingly.

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