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ORIGINAL PAPER

An improved reconstruction of May–June precipitation using tree-ring data from western Turkey and its links to volcanic eruptions

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Abstract We developed a high quality reconstruction of May–June precipitation for the interior region of southwestern Turkey using regional tree-ring data calibrated with meteorological data from Burdur. In this study, three new climate sensitive black pine chronologies were built. In addition to new chronologies, four previously published black pine chronologies were used for the reconstruction. Two separate reconstructions were developed. The first reconstruction used all site chronologies over the common interval AD 1813–2004. The second reconstruction used four of the chronologies with a common interval AD 1692–2004. R^2 values of the reconstructions were 0.64 and 0.51 with RE values of 0.63 and 0.51, respectively. During the period AD 1692–1938, 41 dry and 48 wet events were found. Very dry years occurred in AD 1725, 1814, 1851, 1887, 1916, and 1923, while very wet years occurred in AD 1736, 1780, 1788, 1803, and 1892. The longest dry period was 16 years long between 1860 and 1875. We then explored relationships between the reconstructed rainfall patterns and major volcanic eruptions, and discovered that wetter than normal years occurred during or immediately after the years with the largest volcanic eruptions.

Keywords Dendroclimatology · Tree ring · Precipitation reconstruction · Black pine · Volcanic eruption · Turkey

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Introduction

Previous tree-ring studies on past climate of the eastern Mediterranean basin have provided valuable information about past dry and wet years and their multi-year periods. These studies were initiated by Gassner and Christiansen-Weniger (1942) and have continued in earnest with several studies published in recent years (D'Arrigo and Cullen 2001; Hughes et al. 2001; Touchan et al. 2003, 2005a, b, 2007; Griggs et al. 2007; Akkemik and Aras 2005; Akkemik et al. 2005, 2008; Köse et al. 2005, 2011). These recent studies developed reconstructions of past spring–summer precipitation trends and focused specifically on drought events, which then were corroborated by historical records. For example, the longest reconstructions were built by Touchan et al. (2007) and Griggs et al. (2007), which cover the periods of 1097–2000 and 1089–1989, respectively. The first large-scale systematic dendroclimatological sampling in the eastern Mediterranean region was later performed by Touchan et al. (2005a), who extracted large scale climate signals of extreme dry and wet events across larger geographic scales. Touchan et al. (2005b) also reconstructed the standardized precipitation index (SPI—a probability index of drought based solely on rainfall; Guttman 1998) from four Greek juniper (*Juniperus excelsa* M. Bieb.) chronologies. Köse et al. (2011) developed four local reconstructions and a larger spatial reconstruction of May–June precipitation for western Turkey and found that the driest year during the last 215 years occurred in 1887 throughout western Anatolia.

Despite this growing number of studies, higher quality reconstructions are needed for the eastern Mediterranean basin to better evaluate the spatial variability of past climate so that changes occurring in the region's current climate can be placed in historical context. Furthermore, we have little information on volcanic eruptions and tree growth in the Mediterranean basin. For example, Akkemik et al. (2005) found anomalous growth in the year AD 1816, also known as the "Year without a Summer" that occurred due to the effects of the eruption of Tambora in 1815. Pearson et al. (2009) observed changes in specific elements in tree rings formed in the middle of the seventeenth century BC. They claimed that a volcanic eruption can cause the presence of a replicable element change. Pearson and Manning (2009) observed an increase of zinc, copper, and aluminum in tree rings formed during and after the year 1815 in Scots pine (*Pinus sylvestris* L.) and black pine (*Pinus nigra* Arnold) trees from Turkey and Cyprus.

The linkages between volcanic eruptions, their effects on global climate, and the changes in wood formation of trees affected by these changes in different climates are particularly intriguing. Briffa et al. (1998) used a network of tree-ring density chronologies to reconstruct Northern Hemisphere summer temperature to compare temperature changes with the largest explosive volcanic eruptions documented in recent centuries. Their results showed that cold conditions occur after eruptions. Similar results were found by Fisher et al. (2007), who found an influence of major tropical eruptions on European climate. Their results showed significant summer cooling in the same year and/or next year, with the strongest cooling effect found in the summer of the year after the eruption. They also demonstrated statistically significant changes in precipitation and a tendency for wet conditions in the Mediterranean after eruptions, as well as over northern Europe in post-eruption summers. Whether major volcanic eruptions affect the climate of Turkey, however, remains unclear.

The purpose of this study was to (1) create a high quality reconstruction of precipitation that improves our understanding of rainfall regimes above that obtained from these previous studies, and (2) investigate the relationships between reconstructed rainfall patterns and major volcanic eruptions.

Material and methods

Geology and climate of the study area

Our study area is located in southwestern Turkey. The region lies in a transition zone between the arid climate of North Africa and the temperate and rainy climate of the Black Sea region. Furthermore, the area lies on the path of cyclogenesis centers and is frequently subjected to mid-latitude cyclone events. These features make the region a zone potentially vulnerable to climatic change (e.g., Lionello et al. 2006). Although the study area is characterized by Mediterranean subhumid-to-humid climates (Touchan et al. 2003), Unal et al. (2003) demonstrated that the region surrounding Burdur (and the study sites from which tree-ring samples were collected) is actually more similar to the Central Anatolian climate region based on variations of temperature and precipitation. As a result, the climate of the region is considered intermediate between the Mediterranean coastal zone and central Anatolian continental regimes, with dry summers and wet winters. Mean annual precipitation and temperature values are about 430 mm and 13 °C, respectively (Fig. 1). Average May–June precipitation and temperature range from 26 to 40 mm and from 16.5 to 21.3 °C, respectively.

Tree-ring data and chronology development

Three tree-ring sites were sampled in the Bolu and Eskişehir districts of Turkey (Table 1; Fig. 2). Increment cores were taken from living black pine trees while cross-sections were collected with a chain saw. Samples were fine-sanded and crossdated using standard dendrochronological techniques (Swetnam 1985; Stokes and Smiley 1996). Once crossdated, the widths of all annual rings on all cores were measured to the nearest 0.01 mm. We used the quality control program COFECHA to test the accuracy of crossdating of all ring sequences, within and between sites (Holmes 1983; Grissino-Mayer 2001). We next standardized each ring-width series using the ARSTAN program (Cook 1985) by fitting a 67 % cubic smoothing spline with a 50 % cutoff frequency to remove non-climatic trends, especially those related to normal aging over time, those caused by the effects of stand dynamics on tree growth, and those related to year-to-year biological persistence not related to climatic variations (Cook et al. 1990a). The individual indices from each series were combined into single averaged chronologies for each site using a bi-weight robust estimate of the mean to remove possible adverse effects of anomalous ring widths during any particular year on the trend-fitting process (Cook 1985; Cook et al. 1990b; Grissino-Mayer et al. 1996). We elected to use residual chronologies, the chronology type that has effects of autocorrelation removed so that the previous year's radial growth has no effect on the current ring width. In addition to these three new chronologies, four site chronologies from Burdur, Kütahya, and Ankara developed by Köse et al. (2011) and Mutlu et al. (2011) were also used for the reconstruction (Fig. 2).

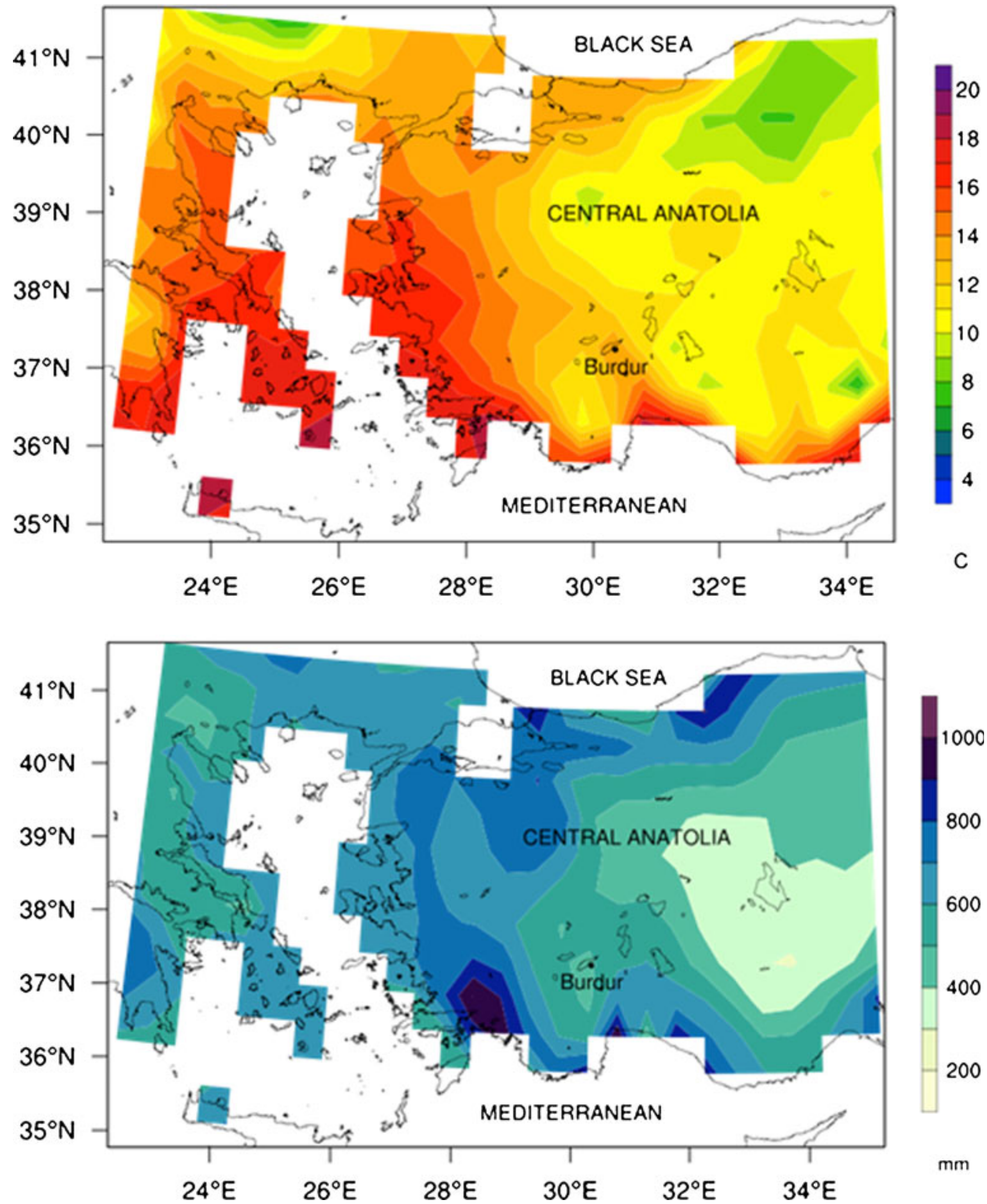

Fig. 1 Distribution of annual average temperature (*top*) and total precipitation (*bottom*) over the Anatolian Peninsula for 1961 to 1990 (data from the Climate Research Unit, University of East Anglia)

Reconstruction of precipitation

Monthly precipitation and temperature data between AD 1939 and 2004 were obtained for the Burdur meteorological station from the State Meteorology Service of Turkey. Response function analyses (Fritts 1976) were performed to initially identify the relationship between tree growth and monthly temperature and precipitation using the DENDROCLIM2002 program (Biondi and Waikul 2004).

The minimum sample depth (the number of trees for each site chronology) to ensure a strong climate signal was based on years when the subsample signal strength (SSS) was greater than 0.85 (Briffa and Jones 1990). Next, principal component analysis (PCA) was conducted on the tree-ring chronology data sets so that a subset of eigenvectors, in which the majority of climate variance was captured, could be used as predictors for climate reconstructions. Calibration equations were then developed that retrodicted precipitation data before the instrumental data period, using the maximum number of observations and degrees of freedom to evaluate model significance in the final regression. To verify the model stability, we used a split-sample procedure that divided the full period into two subsets of equal length to generate two calibration equations that predicted precipitation data that could be compared with the actual data from the twentieth century (Meko and Graybill 1995; Grissino-Mayer 1996). We used the reduction of error (RE) statistic to test whether our reconstructions were statistically significant (RE > 0), as well as correlation coefficients and sign test results as additional comparisons between actual and estimated values (Fritts 1976,

Table 1 Site information for chronologies used in the reconstruction

Site name	Site code	Species	No. trees/ cores	Aspect	Elevation (m)	Latitude (N)	Longitude (E)
Eskişehir, Mihalıççık-Tanaçlar	TAN[a]	*Pinus nigra*	19/28	S	1577	40° 01'	31°10'
Eskişehir, Ekşielma	EKS[a]	*P. nigra*	10/19	W	681	40° 02'	31°11'
Bolu, Yukarı Baltalı Köyü	YUB[a]	*P. nigra*	11/20	SE	1250	40°43'	31°50'
Kütahya, Simav, Akdağ	SIU[b]	*P. nigra*	6/11	SW	1630	39°15'	28°44'
Ankara, Tekke Dağı	TEK[b]	*P. nigra*	16/29	S	1535	40°15'	31°58'
Burdur, Tefenni, İkizce	TEF[b]	*P. nigra*	26/47	S	1800	37°22'	29°38'
Burdur, İbecik, Havut, Boncuk Tepe altı	BON[b]	*P. nigra*	26/44	S	1535	36°56'	29°25'

[a] New chronologies developed by this study

[b] Chronologies from previous studies in Turkey (TEF, BON, TEK: Köse et al. 2011; SIU: Mutlu et al. 2011)

1991). The resulting models for the full period were then used to calculate reconstructions.

To identify extreme dry and wet events, we converted the reconstructed precipitation values to standard deviation (SD) units. Years in which precipitation amounts were 1 and 2 SD above/below the mean were identified as wet/very wet or dry/very dry years, respectively (e.g., Grissino-Mayer 1996; D'Arrigo and Cullen 2001; Akkemik et al. 2005; Akkemik and Aras 2005; Köse et al. 2011). Finally, we tabulated years of documented volcanic eruptions to compare with our precipitation reconstruction to evaluate possible effects of these eruptions on the climate of the eastern Mediterranean basin.

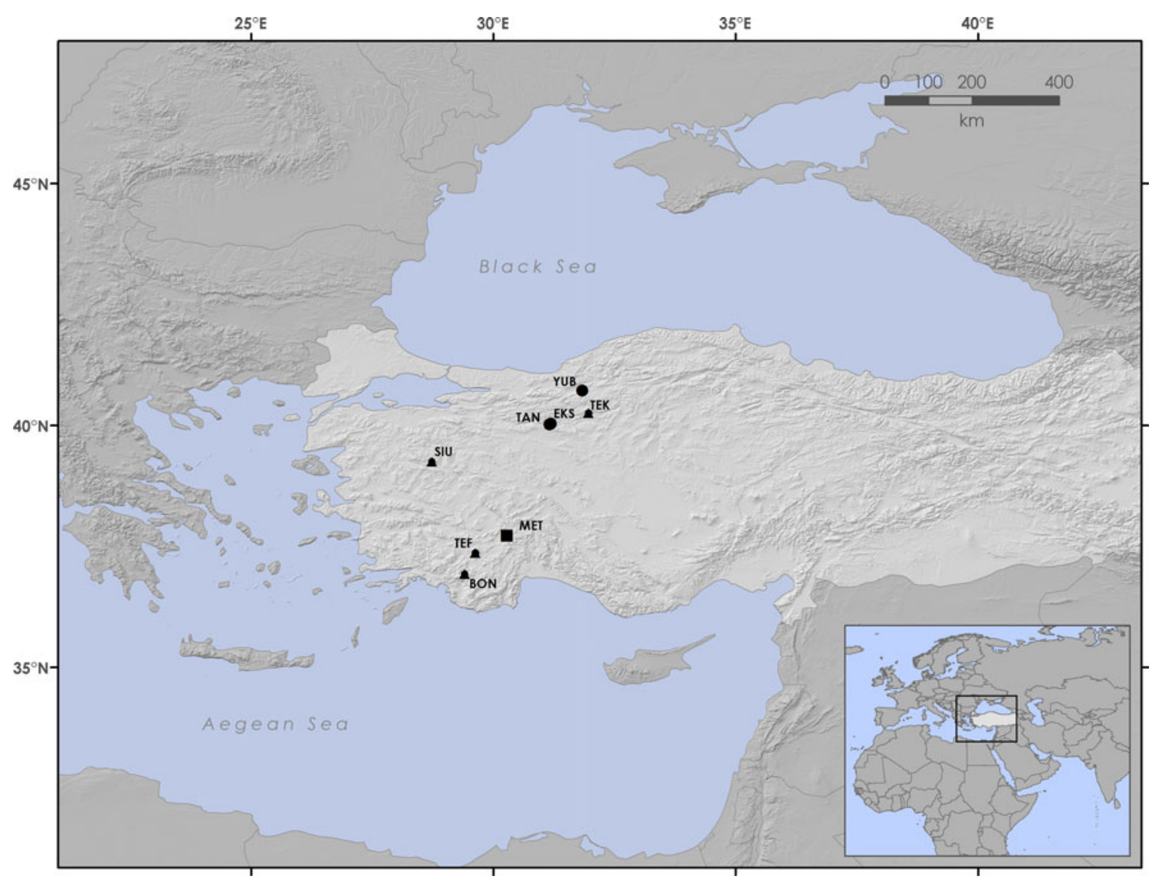

Fig. 2 Tree-ring chronology sites in Turkey used to reconstruct temperature. *Circles* New sampling efforts from this study, *triangles* previously published chronologies (TEF, BON, TEK Köse et al. 2011; SIU: Mutlu et al. 2011). *Square* (MET) Burdur Meteorological Station

Table 2 Summary statistics for the new chronologies developed by this study in Turkey. *SSS* Subsample signal strength (Wigley et al. 1984), *PC* principal component

	Total chronology			Common interval		
Site code	Time span	1st year (SSS > 0.85)	Mean sensitivity	Time span	Mean radii correlation/radii vs mean	Variance explained by PC_1 (%)
TAN	1533–2005	1,594	0.23	1703–2005	0.48/0.71	51
EKS	1641–2008	1,692	0.21	1802–2005	0.41/0.66	45
YUB	1802–2008	1,813	0.23	1860–2008	0.48/0.71	51

Results and discussion

Tree-ring chronologies

The longest chronology (AD 1533–2005) was constructed from samples collected at the Eskişehir Mihalıçç ık site (Table 2). At each site that was used in the reconstruction, trees have synchronized radial growth and share a strong ring-width signal. The interseries correlations among the individual radii range from 0.41 to 0.48. Explained variances by the first principal components were high, from 0.45 to 0.51. Furthermore, the chronologies were found to be sensitive to climate, with mean sensitivity values ranging between 0.21 and 0.23. Previous studies conducted on black pine in Turkey revealed ranges for mean sensitivity between 0.13 and 0.25 (Köse et al. 2011; Akkemik et al. 2008). The correlation matrix of all chronologies used in the reconstruction (Table 3) shows statistically significant ($P \leq 0.001$) relationships between the chronologies, again confirming that all site chronologies share a similar climate signal across the region. The response function results (see below) further support this finding.

Reconstruction of May–June precipitation

Results from the response function analyses showed a positive relationship between precipitation from May through August and tree growth. The effect of temperature on radial growth was generally positive during early spring (March and April) and negative during late spring and summer (May–August) (Table 4). However, the strongest relationship was found between tree growth and May–June precipitation, the climate variable we therefore chose to reconstruct. Two separate reconstructions were developed to accommodate the varying chronology lengths because PCA allows reconstructions based on the shortest data set used (i.e., the common interval). The first reconstruction used all site chronologies with a common interval AD 1812–2004 (Table 5, Fig. 3). PC_1, PC_2, PC_3, PC_5 and PC_7 were selected by stepwise regression and explained 90 % of the total variance. The reconstruction model was:

$$May - June\ PPT(mm) = 76.82(PC_1) + 44.25(PC_2) - 141.85(PC_3) - 82.52(PC_5) - 147.08(PC_7) - 124.5$$

The second reconstruction used four of the chronologies (TAN, TEF, BON, and EKS) with a common interval AD 1692–2004 (Table 5, Fig. 3). PC_1, PC_2, and PC_4 were selected and explained 76 % of total variance. The reconstruction model was:

$$May - June\ PPT(mm) = 108.91(PC_1) + 61.09(PC_2) - 174.48(PC_4) - 163.93$$

Table 3 Correlation coefficients between chronologies

Chronology	TAN	EKS	YUB	TEF	BON	TEK
EKS	0.73***					
YUB	0.57***	0.59***				
TEF	0.56***	0.45***	0.47***			
BON	0.57***	0.48***	0.37***	0.63***		
TEK	0.67***	0.68***	0.58***	0.60***	0.42***	
SIU	0.56***	0.40***	0.34***	0.44***	0.46***	0.49***

***Correlation coefficients statistically significant at $P \leq 0.001$

Table 4 Results of the response function analyses, previous year's October to current year's October. + Positive effects on tree growth, − negative effects on tree growth.

	Temperature													Precipitation												
	O	N	D	J	F	M	A	M	J	J	A	S	O	O	N	D	J	F	M	A	M	J	J	A	S	O
TEF	−	+	+	−	−	−	+*	−	−	−	−	+	+	+	−	+	+	−	+	+	+*	+	+	+	−	+
BON	−	+	+	−	−	+	+	−	−	−	−	+	−	+	−	−	−	−	+	+	+	+	−	+	−	−
TEK	−	−	+	+	−	+	+	−*	−*	−	−	−	−	+	−	−	+	−	+	+	+	+*	+	+*	+	+
YUB	+	+	+	−	+	+*	−	−	+	−	−	−	−	+	−	−	−	−	+	+	−	+*	+	+	−	−
EKS	−	+	+	+	+	+	−	−	+	+	−	−	+	+	+	−	+	+	+	−	+*	+*	+	+	−	−
TAN	−	+	+	+	−	+	+	−	−	−	−	−	+	+	−	−	−	+	+	−	+	+	+	+	−	−
SIU	+	+	+	+	−	+	+	−	−	−	−	+	−	+	+	−	−	−	+	+	+	+	+	+	−	+

*Statistically significant ($P<0.05$) results

Because the derived calibration equations and verification test results were similar, the full calibration period (AD 1939–2004) was used for both reconstructions (Fig. 3). We eventually generated a 203-year long (AD 1812–2004) and a 313–year long (AD 1692–2004) reconstructions of May–June precipitation for the Burdur region (Fig. 4).

Previous tree-ring based precipitation reconstructions for Turkey (Köse et al. 2005, 2011; Akkemik et al. 2008) were generally more successful in capturing dry years rather than wet years. In our study, both reconstructions were more efficient at classifying wet years. All 13 wet years in the actual data over the historical period AD 1939–2004 were also observed in the first reconstruction, while 12 of the wet years were captured in the second reconstruction. Four of the seven dry years in the actual data were captured in both reconstructions (Fig. 3).

Extreme dry and wet events

For the period between AD 1692–1929, we found a total of 41 dry and 48 wet events with values exceeding ±1 (dry/wet) and ±2 (very dry/very wet) standard deviation units (Table 6). The extremely dry and wet events lasted usually only 1 year, with the longest extreme dry and wet events lasting 3 years. A 13-year low-pass filter fit to the reconstructed values indicates that the longest dry period in our study region occurred between AD 1860 and 1875 (50 mm) (Fig. 4).

Anatolia has many drought events recorded in its history, and natural hazards (such as severe droughts) are considered reasons for major societal changes, such as human warfare, effects brought on by famine and plague, and political rebellions (Kadıoğlu 2008). Our reconstruction of precipitation for the Burdur region shows several years that coincide with major historical events in Anatolia and neighboring countries.

Table 5 Results of the statistical calibrations and cross-validation between May–June precipitation and tree growth. *F* F-value, *RE* reduction of error, *ST* sign test, *P* *P*-value significance

	Calibration period	Verification period	Adjusted R^2	F	RE	Calibration		Verification	
						ST	*P*	ST	*P*
1813–2004	1939–1971	1972–2004	0.66	13.30 $P\leq0.0001$	0.63	$26^+/6^-$ $P\leq0.01$	0.84 $P\leq0.001$	$24^+/9^-$ $P\leq0.05$	0.76 $P\leq0.001$
	1972–2004	1939–1971	0.63	11.64 $P\leq0.0001$	0.63	$25^+/8^-$ $P\leq0.01$	0.83 $P\leq0.001$	$25^+/7^-$ $P\leq0.01$	0.78 $P\leq0.001$
	1939–2004		0.64	23.83 $P\leq0.0001$		$47^+/17^-$ $P\leq0.01$	0.82 $P\leq0.001$		
1692–1812	1939–1971	1972–2004	0.56	14.60 $P\leq0.0001$	0.52	$26^+/6^-$ $P\leq0.01$	0.78 $P\leq0.001$	$24^+/9^-$ $P\leq0.05$	0.65 $P\leq0.001$
	1972–2004	1939–1971	0.44	9.45 $P\leq0.0001$	0.51	$25^+/8^-$ $P\leq0.01$	0.70 $P\leq0.001$	$26^+/6^-$ $P\leq0.01$	0.71 $P\leq0.001$
	1939–2004		0.51	23.61 $P\leq0.0001$		$46^+/19^-$ $P\leq0.01$	0.73 $P\leq0.001$		

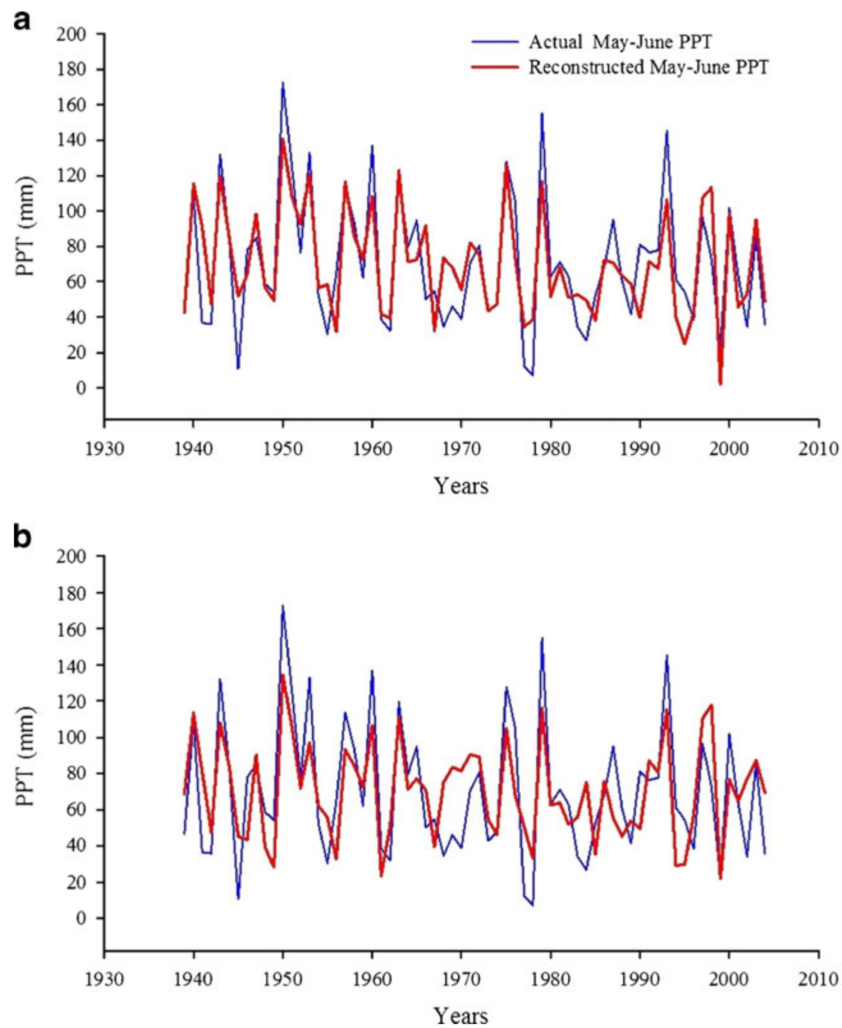

Fig. 3 Comparison of actual (*blue*) and reconstructed (*red*) May–June precipitation (PPT) for the period 1939–2004 based on **a** seven and **b** four chronologies

First, precipitation in AD 1725 was non-existent (i.e., 0 mm) in Burdur which, along with the dry year of AD 1726, has been documented historically to be a major drought period in Anatolia and Syria (Panzac 1985). Moreover, an outbreak of plague was also recorded in AD 1725 (White 2006), which might have been triggered (or at least intensified) by this drought. Second, a catastrophic drought was observed in the years AD 1873 and 1874 (Kuniholm 1990). Our findings also support a major drought event in 1873 (only 18 mm precipitation). Moreover, some historical events, such as prohibition of wheat exports due to shortage (Ottoman Archives, AD 1850–1923) and rebellions in the Balkan states (Kadıoğlu 2008), are concurrent with this drought event.

Third, a major famine was observed throughout the Ottoman Empire because of severe drought (Gül 2009) in AD 1887. Our reconstruction for the Burdur region showed that no or little rainfall (0 mm precipitation) occurred during this year. In AD 1887, very narrow tree-ring formation was observed on pine samples in Central Anatolia by Gassner and Christiansen-Weniger (1942). This year was also described as a dry year in all previous tree-ring reconstructions (D'Arrigo and Cullen 2001; Touchan et al. 2003, 2005a, b, 2007; Akkemik and Aras 2005; Akkemik et al. 2005, 2008; Köse et al. 2005, 2011). Moreover, this year was the driest year during the last 215 years throughout western Anatolia (Köse et al. 2011). Fourth, we found low precipitation occurred in AD 1893 and 1909 (4 mm and 30 mm, respectively). In these years, wheat exports were prohibited because of drought-related shortages (Ottoman Archives 1850–1923). Finally, a sustained famine occurred in Anatolia from 1925 to 1928 (Purgstall 1983; Kadıoğlu 2001 and 2008), and both years were reconstructed as dry years with only 26 mm total precipitation during May and June.

In previous tree-ring based precipitation reconstructions for Turkey, catastrophic drought and famine events only were compared with historical records (Köse et al. 2011; Akkemik et al. 2005, 2008; Akkemik and Aras 2005; Touchan et al. 2005b, 2007). However, we found two of the wet years calculated in the reconstruction corresponded with two flood events in the Isparta distinct, which is very close to the Burdur district. For the year 1780, precipitation

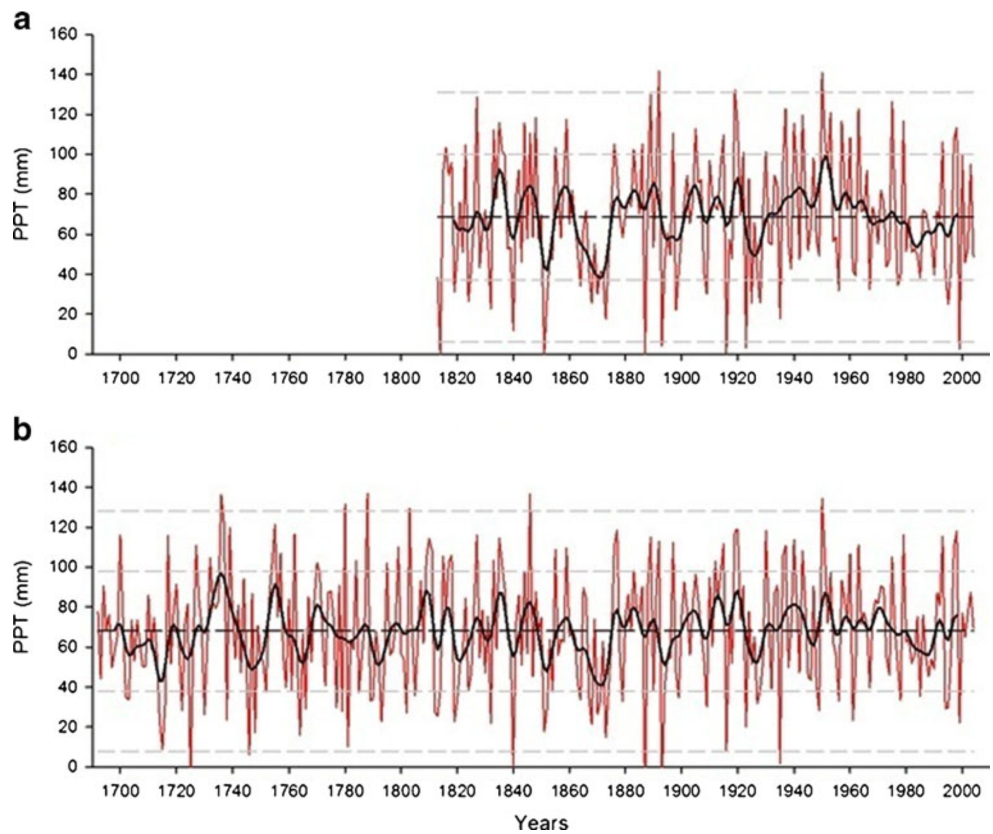

Fig. 4 May–June precipitation reconstructions for the periods **a** 1812–2004 and **b** 1692–2004 based on data from the Burdur meteorological station. *Central horizontal line* mean, *inner horizontal lines* 1 SD unit, *outer horizontal lines* 2 SD units, *red curve* 13 year low-pass filter

was 131 mm based on our reconstruction, the same year catastrophic floods occurred in Tekke and Yayla streets of Isparta due to flooding from Gölcük Boğazı (Gönüllü 2010). Similarly, Tabakhane, Fazlullah, and Iskender streets of Isparta were destroyed in AD 1848 because of flooding from the Isparta River (Gönüllü 2010). This year was observed as a wet year with 118 mm precipitation in the reconstruction.

Links to volcanic eruptions

To clarify how major volcanic eruptions affected the climate of Turkey in the past, we compared our results with important and well-documented volcanic eruptions. We considered the major eruptions mentioned by Briffa et al. (1998), Stothers (1996), Stothers (1999), Self et al. (1981), Mass and Portman (1989), Tomascik et al. (1996), Fisher et al. (2007) and listed which coincidence with extreme events in the reconstruction (Table 7). The year of volcanic eruption (AD 1739, 1883, 1886) or the year following eruption (AD 1784, 1816, 1823, 1855, 1876, 1957), or both (AD 1810–1811 and 1835–1836) were generally found to be wet years. Years of volcanic eruptions were also searched for in the published literature that reconstructed spring-summer precipitation for various locations (Köse et al. 2011; Akkemik et al. 2005, 2008; Akkemik and Aras 2005; Touchan et al. 2005a; D'Arrigo and Cullen 2001) and found to display similar wet conditions (Table 7).

Table 6 Dry and wet years obtained from May–June precipitation reconstruction

Precipitation	Years
Very dry years (-2 SS)	1725, 1814, 1851, 1887, 1893, 1916, 1923
Dry years (-1 SS)	1702–1703, 1714–1716, 1722, 1725, 1730, 1738, 1746, 1748, 1764, 1766, 1777, 1779, 1781, 1789–1790, 1793, 1802, 1812, 1814, 1819, 1824, 1832, 1840, 1851-1852, 1864, 1868, 1870, 1873, 1887, 1893, 1898, 1909, 1916, 1923, 1925, 1928, 1935
Wet years (+1 SS)	1700, 1717, 1727, 1732, 1736–1737, 1739, 1754–1755, 1757, 1762, 1770, 1780, 1784, 1788, 1795, 1799, 1803–1804, 1807, 1809–1811, 1816, 1823, 1827, 1833, 1835-1836, 1844, 1846, 1848, 1855, 1859, 1876, 1883, 1886, 1889, 1892, 1897, 1905, 1915, 1919–1920, 1922, 1930, 1937
Very wet years (+2 SS)	1736, 1780, 1788, 1803, 1892

As mentioned above, tree rings have been used extensively as proxy records for understanding the effects of volcanic eruptions on climate and tree growth (Lough and Fritts 1987; Jones et al. 1995; Briffa et al. 1998; Salzer and Hughes 2007). The footprints of volcanic eruption in tree rings represent narrow rings (Salzer and Hughes 2007; Grudd et al. 2000), frost rings (Salzer and Hughes 2007; LaMarche and Hirschboeck 1984), and light rings that include very thin latewood cells (Filion et al. 1986) in Europe and America. In our study, however, we observed an increase in tree-ring width. In previous dendroclimatological studies in Turkey, only Akkemik et al. (2005) mentioned a volcanic eruption-precipitation relation, observing that AD 1816 (the "Year without a summer") occurred as a wet year.

It is well known that Northern Hemisphere temperature dropped after the largest explosive volcanic eruptions (Briffa et al. 1998; Salzer and Hughes 2007). Mass and Portman (1989) suggest that, after volcanic eruptions, a significant signal in precipitation does not appear to exist. On the other hand, Fisher et al. (2007) found low statistical significance for precipitation changes after eruptions and a tendency to wet conditions of the Mediterranean in post-

Table 7 Volcanic eruptions coincidence with wet years in May–June precipitation reconstruction of Burdur meteorological station

Year	Volcano	In reconstruction	In previous reconstructions
1739[a]	Shikotsu (Tarumai), Japan	1739 wet	1739 is wet in the Afyon[h], Eskişehir[h], Isparta[h] reconstructions
1783[b, c]	Laki, southern Iceland Asama, Japan	1784 wet	1783 is wet in the northwestern Turkey precipitation[i], Kastamonu[j], Eastern Mediterranean [l] and Sivas[m] reconstructions and 1784 is wet in the Afyon[h] reconstruction.
1810[f]	Gunung Api, Indonesia	1810 and 1811 wet	1810 is wet in Isparta[h], Sivas[m] and 1811 is wet in the Afyon[h], Eskişehir[h], Isparta[h], Kastamonu[j] reconstructions
1815[a, b, d, g]	Tambora, Indonesia	1816 wet	1816 is wet in Isparta[h], Kastamonu[j], north-western Turkey precipitation[i] and streamflow[i], Eastern Mediterranean [l], Sivas[m] reconstructions
1822[d, g]	Galunggung, Indonesia	1823 wet	
1835[a, g]	Cosiguina, Nicaragua	1835 and 1836 wet	1835 is wet in Afyon[h], Eskişehir[h], Kütahya[h] Isparta[h], Sivas[m] reconstructions, spatial reconstruction for western Anatolia [h], Eastern Mediterranean [l] and 1836 is wet in Afyon[h], Eskişehir[h], Kütahya[h] Isparta[h] reconstructions, spatial reconstruction for western Anatolia [h]
1854[a]	Sheveluch, Kamchatka	1855 wet	1855 is wet in Afyon[h], Eskişehir[h], Kütahya[h] Isparta[h], Eastern Mediterranean [l], Sivas[m] reconstructions, spatial reconstruction for western Anatoia[h]
1875[d]	Askja	1876 wet	1876 is very wet in Afyon[h], Eskişehir[h], Kütahya[h], Isparta[h], Eastern Mediterranean [l] reconstructions, spatial reconstruction for western Anatoia [h] and wet in Konya[k] reconstruction
1883[a, d, e,g]	Krakatau, west of Java	1883 wet	1884 is wet in Afyon[h] and 1885 is wet in Afyon[h], Eskişehir[h], Kütahya[h], Isparta[h], Eastern Mediterranean [e] reconstructions, spatial reconstruction for western Anatolia[h]
1886[a, d, e]	Okatania (Tarawera), New Zealand	1886 wet	
1891[f]	Gunung Api, Indonesia	1892 very wet	1891 is wet in Afyon[h], Eskişehir[h], Kütahya[h] Isparta[h] and 1892 is wet in Isparta[h], Konya[k] reconstructions.

[a] Briffa et al. 1998
[b] Stothers 1996
[c] Stothers 1999
[d] Self et al. 1981
[e] Mass and Portman 1989
[f] Tomascik et al. 1996
[g] Fisher et al. 2007
[h] Köse et al. 2011
[i] Akkemik et al. 2008
[j] Akkemik et al. 2005
[k] Akkemik and Aras 2005
[l] Touchan et al. 2005a
[m] D'Arrigo and Cullen 2001

eruption summers. In our current reconstruction, we found that wet conditions occurred in western Turkey after large explosive volcanic eruptions.

Conclusions

In our study, three new black pine chronologies that were found to be highly sensitive to climate variability were added to the Turkish tree-ring network. Moreover, a 203-year-long and a 313-year-long reconstruction of May–June precipitation were developed, which were better able to capture wet years than previous reconstructions. For the reconstructed period AD 1692–1938, the very dry years were AD 1725, 1814, 1851, 1887, 1916, and 1923, and the very wet years were AD 1736, 1780, 1788, 1803, and 1892. The longest driest period lasted 16 years (AD 1860–1875). Extreme years not only coincided with catastrophic drought and famine events, but also with flood events.

The question "How did past volcanic eruptions, especially Laki in AD 1783 and Tambora in AD 1815, affect the climate of Turkey?" was unclear, when their effect on global climate was particularly known. Our research discovered that the year of the volcanic eruption, the following year, or both, are wet years. In addition to our reconstruction for southwestern Turkey, similar wet conditions were observed in reconstructions for Afyon, Kütahya, Eskişehir, Isparta, Kastamonu, Sivas, northwestern Turkey, western Anatolia, and the eastern Mediterranean, developed by different researchers.

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