REGIONAL RECONSTRUCTION OF PRECIPITATION IN THE NORTH AEGEAN AND NORTHWESTERN TURKEY FROM AN OAK TREE-RING CHRONOLOGY, AD 1089-1989

MEŞE YILLIK HALKA KRONOLOJİLERİ İLE KUZEY EGE VE KUZEYBATI TÜRKİYE'NİN 1169-1984 DÖNEMİNDEKİ PALMER KURAKLIK ŞİDDETİ İNDEKSLERİ VE YAĞIŞININ BÖLGESEL DÜZEYDE YENİDEN OLUŞTURULMASI

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Key Words: Oak tree-ring chronology, North Aegean, calibration, Palmer drought severity index
Anahtar sözcükler: Meşe yıllık halka kronolojisi, kuzey Ege, uyarlama, Palmer kuraklık şiddeti indeksi

Kuzey Ege ve Türkiye'nin kuzeybatısındaki meşe ağaçlarının yıllık halka genişliklerindeki değişimler, bölgede, ağaç gelişimi için temel sınırlayıcı faktör olan Mayıs-Haziran yağışının etkilerini ortaya koyar. Meşe kronolojilerinin halka genişliklerindeki değişimler, M.S. 1169-1984 yılları arası Mayıs-Haziran yağışlarındaki değişimlerin temel göstergesidir. Bu değişim aynı zamanda, Haziran ayı 'Palmer kuraklık şiddeti indeksi'ndeki değişimlerin de eşit düzeyde temel göstergesidir.

Bu çalışmadaki en önemli amaç, Cornell Üniversitesi Ege ve Yakın Doğu için Malcolm ve Carolyn Wiener Dendrokronoloji Laboratuar'ında arşivlenen, son bin yıllık dönemi kapsayan 517 meşe örneği üzerinde iklim faktörlerinin etkilerini belirlemektir. Bu yapıldıktan sonra, günümüzden 7 000 yıl öncesine kadar uzanan yıllık halka kronolojilerindeki bu etkiler yorumlanmaya başlanacaktır.

INTRODUCTION:

Annual variability in the oak ring growth of the North Aegean region from northeastern Greece extending into northwestern Turkey (Figure 1) reveals May-June precipitation as the primary growth-limiting factor. Our tree-ring chronology, built of oak samples from modern forests and historic buildings, contains a good record of the late spring precipitation for AD 1169-1989 across the region, and for AD 1089-1168 in northwestern Turkey.

The June Palmer Drought Severity Index (PDSI) is a measurement that includes weighted monthly temperature and soil moisture values along with precipitation of June and the preceding months, and was calculated for 2.5° x 2.5° grids in Dai et al. (2004). The June PDSI correlates very well with the annual growth of the oaks since 1931; because of this the oak chronology was also tested as potential proxy data for the June PDSI for the region back in time.

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THE TREE-RING DATA.

511 oak samples in 56 site chronologies represent seven forests plus 39 churches and mosques built in the last millennium (Figure 2, Table 1). Six species are represented by the forest oaks: *Quercus petraea, Q. sessiliflora, Q. dschoruchensis, Q. hartwissiana, Q. frainetto, and Q. robur*. The southern boundary of our study area, at 39°N latitude, loosely represents the southern limit of the forest species' ranges. All are included in order to cover all the species that were used in the historic buildings for an accurate interpretation of the ring growth patterns prior to AD 1773. The buildings' samples can be identified only as *Quercus sp.*, suborder Oersted (Schweingruber 1990).

Each sample's ring-width measurements were standardized with a spline curve designed to remove most variability on time scales greater than a decade to accent year-to-year ring-width differences.

THE CLIMATE DATA.

Monthly precipitation (*sigma*P for precipitation anomalies) and temperature (*sigma*T) data were taken from the NCDC/NOAA website,
HYPERLINK
http://www.ncdc.noaa.gov/oa/ncdc.html
http://www.ncdc.noaa.gov/oa/ncdc.html, and the stations are shown on the map. The monthly precipitation and temperature data sets for the region were combined into three 5°x 3° grids by using only stations with records that go back to at least 1931 and weighting each station's anomalies by the area of the grid that is unique to that station. The three grids' data sets were then averaged together as the regional *sigma*T and *sigma*P. The Climate Research Unit's gridded precipitation data sets covering 40-45º N latitude, 20-40º longitude, were also used to confirm the reconstruction.

The PDSI data was downloaded from the website HYPERLINK http://www.cad.ucar.edu http://www.cad.ucar.edu for six 2.5° x 2.5° grids in the study region. These were averaged into a regional PDSI.

CALIBRATION, VERIFICATION, AND RECONSTRUCTION OF THE MAY-JUNE PRECIPITATION.

Correlation coefficients between the monthly climate variables and the oak chronology clearly indicated that the May and June precipitation is the primary limiting growth force for ring growth (Griggs et al., 2006). Three forest chronologies (the predictors), one from each climate grid, were used in a regression analysis with the May-June precipitation anomalies as the predictand. Figure 3 shows the May-June reconstructed precipitation from that chronology compared to the chronology of the four forests used for independent data verification.

With the results of that test, and a similar test that split the data into two series of 1941-1970 and 1931-1940 plus 1971-1985 for calibration and verification, we reconstructed the May-June precipitation from the complete oak chronology back to 1169. Figure 4 shows the last 200 years of reconstructed May-June precipitation anomalies, with a comparison with the meteorological data. The correlation coefficient between the oaks and the May-June precipitation for 1931-1985 is 0.761. With the CRU May-June precipitation anomalies, the correlation for 1900-1930 is 0.509. All are significant at the < 0.05 probability level.

The correlation coefficients between the June PDSI and the oak forest chronology are $r = 0.676$ from 1928-1985, but $r = 0.378$ prior to 1928. The positive or negative sign in year-to-year ring-width differences for 1931-1985 agree in 38 out of the total 54 which is statistically significant, but only 26 out of 44 differences prior to 1931 are the same which is not significant. This comparison over time of the June PDSI for the region indicates that the PDSI data set contains inadequate meteorological data for our higher altitude areas prior to 1931. This is not surprising since only 2 of the 13 meteorological stations within the study region have data from prior to 1931, and both are coastal stations. We decided from these results to concentrate only on the reconstruction of the May-June precipitation for this study.

RESULTS.

The variations in ring widths from year to year in the oak chronology are direct indicators of the variations in the May-June precipitation from AD 1169 to 1984 over the entire region, and limited to northwestern Turkey from AD 1089 to 1168. Figure 4 shows the May-June precipitation anomalies reconstructed from the tree-rings for 1785-1989. The complete reconstructed data set is available upon request.

Figure 5 shows the complete oak chronology back to AD 1089. This chronology represents the May-June precipitation anomalies, but with one difference: the low-frequency variance that was removed for an accurate precipitation reconstruction is contained in this chronology. The difference is particularly noticeable since 1960 when the ring-widths increase substantially, but the regional May-June precipitation does not (Figure 4). The Gaussian-filtered line in Figure 5 indicates the low-frequency variance removed by fitting the spline curves to each sample for detrending. At least in the second half of the 20th century, that variance was due to something other than the variance in regional May-June precipitation, and we are looking at other possible factors.

Exploratory research indicates that the North Atlantic Oscillation (Hurrell 1995, Jones et al., 1997) is at least partially responsible for the low-frequency variance in a chronology containing only the oak samples from the western grid (Figure 6). Further study is underway to determine other possible force(s) that caused the long-term variance and whether a reconstruction of any of the forces is possible.

Here we have shown that combining data from many securely crossdated oak samples, originally collected for dating historical buildings, substantially increases the period covered by modern forests alone and adds to the paleoclimate proxy record. The ultimate goal of this research is to determine the climate factors recorded in the collected tree-ring samples archived at the Malcolm and Carolyn Wiener Laboratory for Aegean and Near Eastern Dendrochronology at Cornell University. Once these are determined we will be able to reconstruct those records from our tree-ring chronologies, going from the present back to ca. 7,000 BC.

ACKNOWLEDGMENTS:

This research was supported by the National Science Foundation, the Malcolm H. Wiener Foundation, and patrons of the Aegean Dendrochronology Project.

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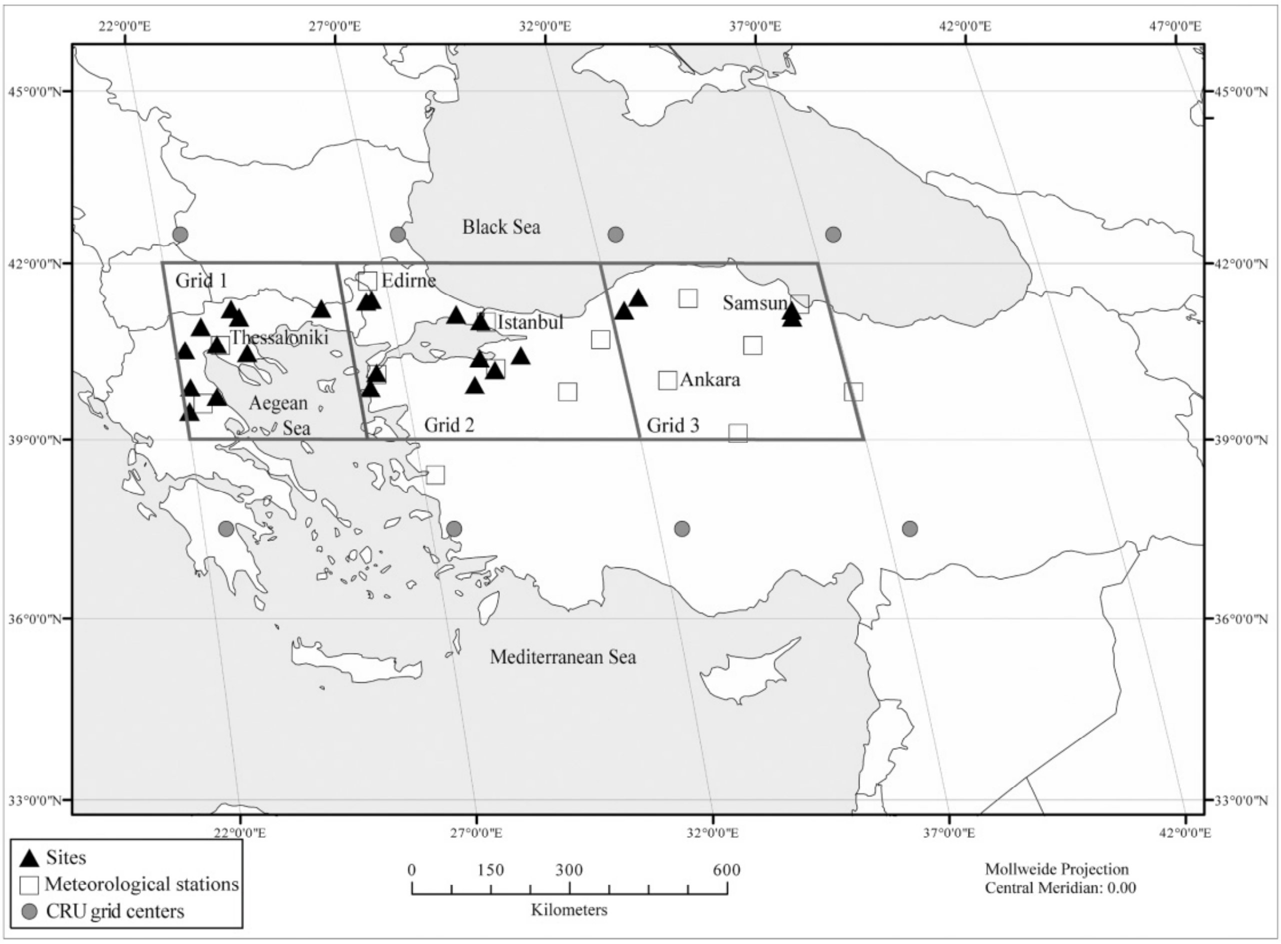

Fig. 1 Map of the sites, meteorological stations, and grid centers of the Climate Research Unit's 5º x5º data grids.

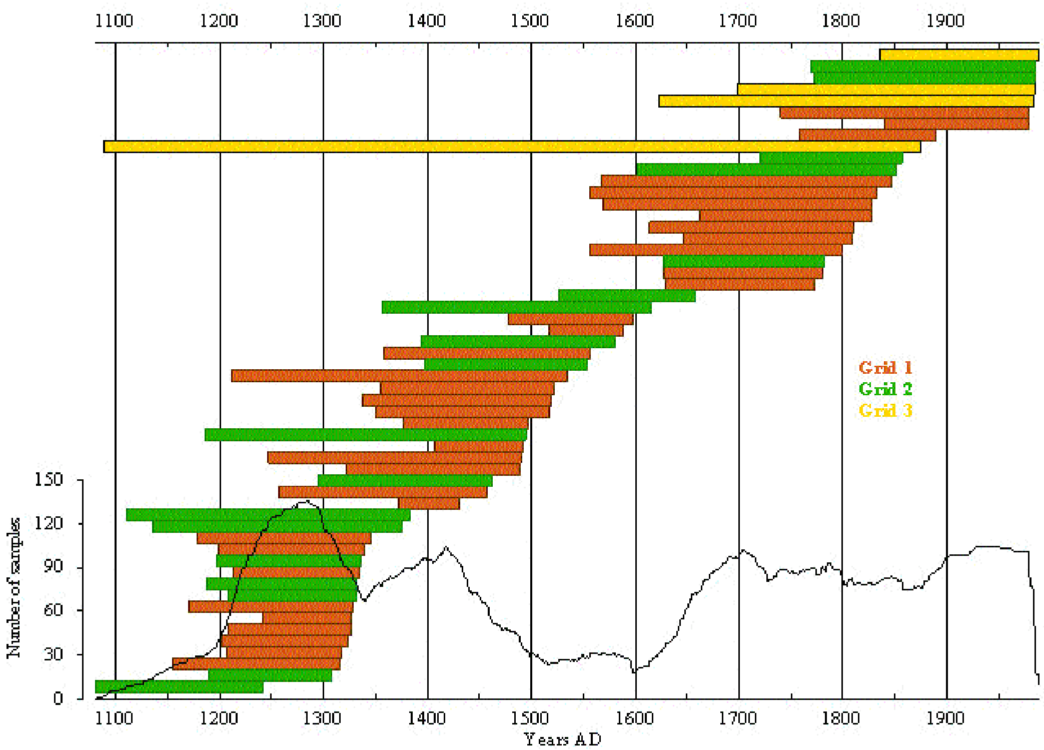

Fig. 2 The temporal location of the 56 site chronologies that were combined into the master chronol - ogy to reconstruct the May-June precipitation.

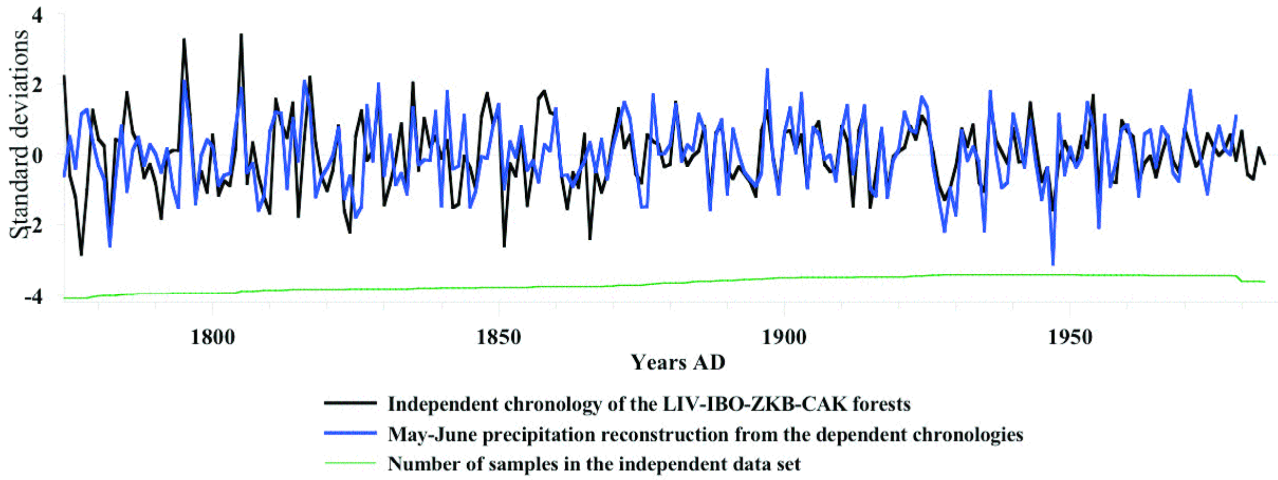

Fig. 3 Comparing the May-June precipitation reconstruction from the dependent tree-ring chronology of the CAB-DEV-ZYB forests to the independent tree-ring chronology of the LIV-IBO-ZKB-CAK forests. See Table 1 for the forest loca - tions.

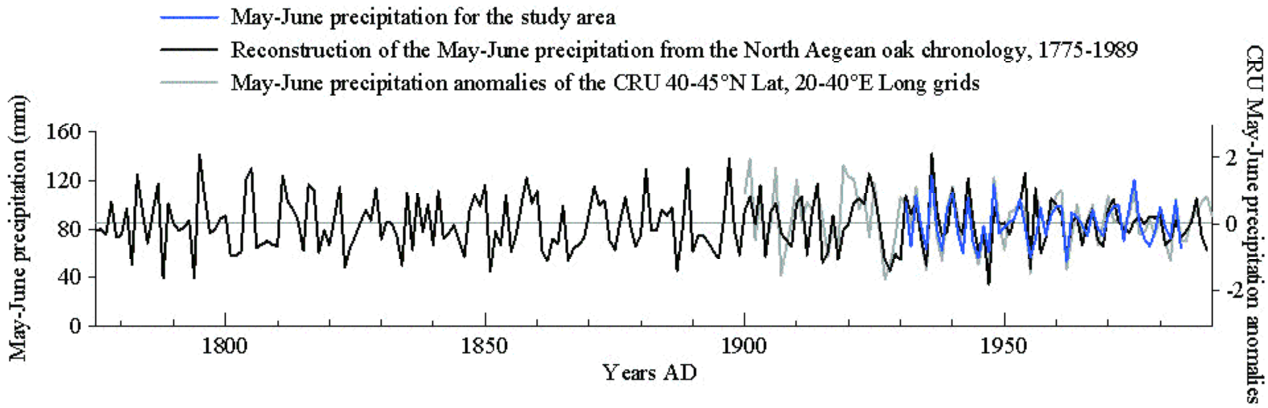

Fig. 4 The reconstruction of the May-June precipitation for the 1775-1989. The actual May-June precipitation values for the study region and the CRU May-June precipitation anomalies are shown for comparison.

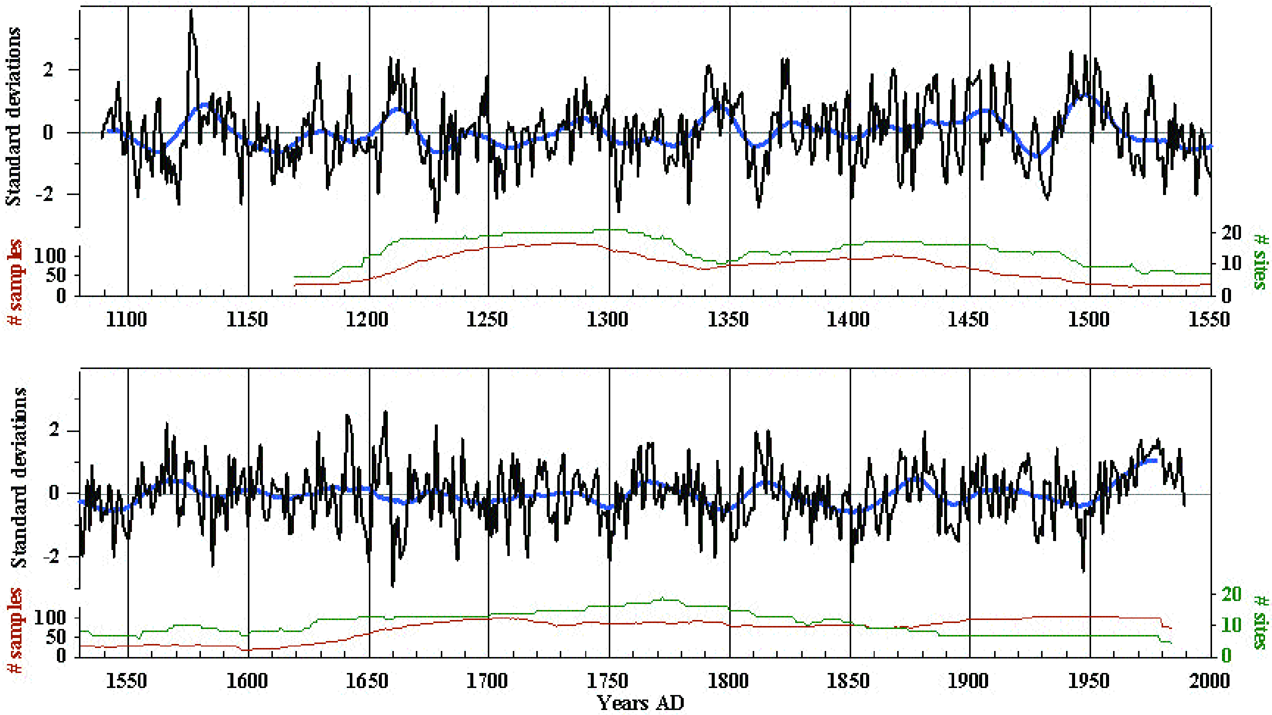

Fig. 5 The oak chronology with low-frequency variance retained. Of note are the difference between this chronology and the one shown in Figure 4A, with the low-frequency variance removed.

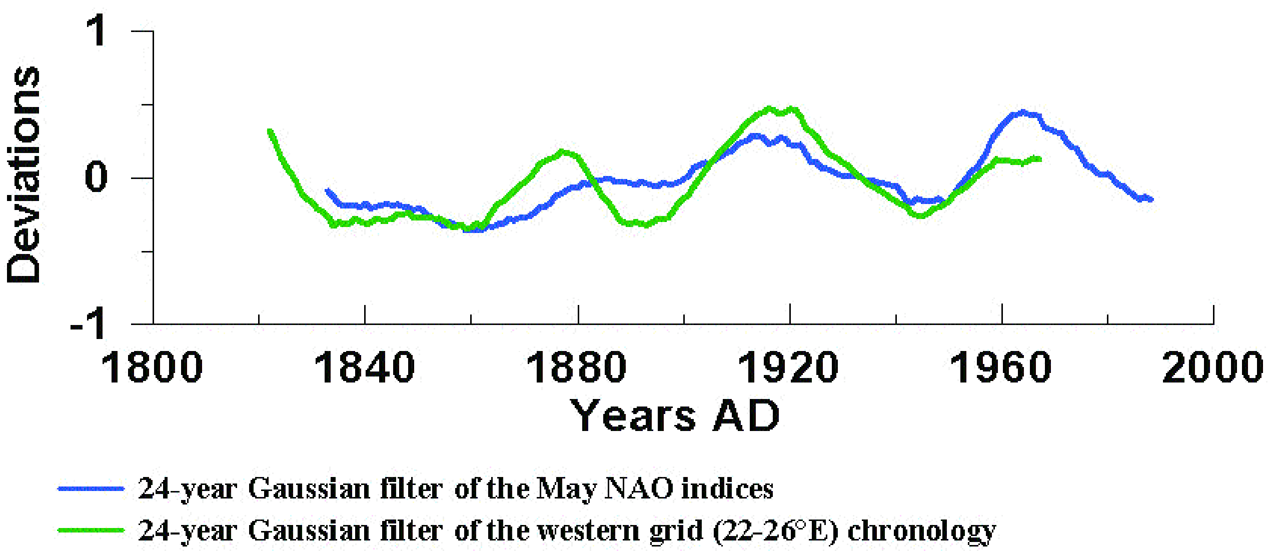

Fig. 6 The filtered western grid chronology and the May NAO indices (Jones et al., 1997).