4.6 DECADAL-SCALE CHANGES IN SOUTHERN CALIFORNIA TREE-RING RECORDS

Franco Biondi (1),* D.R. Cayan (1)(2), and W.H. Berger (1)

(1) Scripps Institution of Oceanography, La Jolla, California; (2) US Geological Survey, La Jolla, California

1. INTRODUCTION

The PDO (Pacific Decadal Oscillation) and CTI (Cold Tongue Index) indices have been used to represent decadal-and ENSO-scale patterns in the Pacific basin (Mantua et al. 1997). Both indices are derived from sea surface temperatures, and their spatial correlation patterns with tree-ring chronologies over western North America (Figs. 1 and 2) show some similarities, but differ in Southern California. We have used a network of existing and newly developed chronologies for Southern and Baja California to investigate multi-annual oscillations of climate at the eastern Pacific boundary.

Fig. 1. Correlation map between PDO and tree-ring chronologies of western North America.

2. MATERIALS AND METHODS

Tree-ring sites were located in a direction roughly parallel to the coastline, from the Transverse Mts. of Southern California to the Peninsular Ranges extending across the US-Mexico border to Sierra San Pedro Martir in northern Baja California (Fig. 3, Appendix). We developed the majority of those 10 chronologies; a few sites were sampled by Dave Meko, Laboratory of Tree-Ring Research, University of Arizona, Tucson, and one site was combined with a previous collection made by A. Douglas and available from the ITRDB. Jeffrey pine (Pinus jeffreyi) was the species sampled in more than half the sites (Fig. 4; Appendix); the other species were big-cone Douglas-fir (Pseudotsuga macrocarpa) and sugar pine (Pinus lambertiana).

Fig. 2. Correlation map between CTI and tree-ring chronologies of western North America.

Measured ring-width series (‘segments’) were combined by site and species to produce tree-ring chronologies. Mean segment length (Cook et al. 1995) ranged between 112 and 355 years, with 11-56 segments in each chronology. Tree-ring indices were computed as ratios between ring widths and their expected value based on the age/size trend (Fritts 1976). Autocorrelation (Box and Jenkins 1976) was not removed, in order to preserve multi-annual variability. Monthly precipitation and temperature records used for calibration with tree-ring chronologies were obtained from on-line databases (NOAA 1997; Fig. 1).

* Corresponding author address: Franco Biondi, Univ. of California-San Diego, Scripps Inst. of Oceanography, La Jolla, CA 92093-0215; e-mail: fbiondi@ucsd.edu.
3. RESULTS AND DISCUSSION

Response functions (Fritts 1976, Guiot 1990, 1991) based on instrumental observations for California Climate Division 6 (D6, dotted line). See the Appendix for details.

Fig. 3. Tree-ring sites (★) in Southern (7) and in Baja (3) California with respect to California climate division 6 (D6, dotted line). See the Appendix for details.

annual (Dec-Nov) precipitation shows a pronounced southwest-to-northeast gradient over the western USA (Fig. 5). The highest correlations are found in Southern California and over the Colorado Plateau.

Correlation patterns between annual (Dec-Nov) precipitation and either PDO (Fig. 6) or CTI (Fig. 7) do not resemble those for tree-ring chronologies (Fig. 5). Both PDO and CTI appear to be modestly correlated with southwestern states. Interannual and interdecadal variability of tree-ring chronologies show remarkable similarities among sites. The first principal component of all 10 chronologies from 1790 to 1992 accounts for 54.5% of the total variance (58.4% for spline-smoothed series; Fig. 9). In the twentieth century (Figs. 8 and 9), the major PDO reversals of 1947 and 1977 are matched by tree growth reversals. Between 1925 and 1947 tree growth fluctuated around the long-term mean, and it was above-average before 1925 (until about 1905). Tree growth and PDO patterns are in close relationship from the 1990s back to about 1930 (Figs. 9 and 10). In the early 1900s, when the PDO index frequently changes sign, there is no agreement with tree-ring records.

The average and the first principal component of tree-ring chronologies are significantly correlated with the PDO (0.33) and, to a smaller degree, with the CTI (0.21). Southern California chronologies have greater correlations (0.23-0.36) with PDO than Baja California ones (< 0.22). Correlations of individual chronologies with the CTI are significant only for a chronology in Baja and one in Southern California.
mean and principal component of the chronologies are highly correlated (0.5) to the PDO. When spline-smoothed series are considered, the correlation exceeds 0.74, and we used this statistical relationship to estimate the PDO back to AD 1660 (Fig. 12).

Overall, this reconstruction suggests that decadal-scale changes have occurred over the past few centuries. The amplitude of such oscillations appears greater in the last 100 years (~1880-1992) than in the preceding 100 years (~1780-1880), and it resembles amplitudes reconstructed for the initial 100 years (~1660-1780; Fig. 12).

4. ACKNOWLEDGEMENTS

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**Fig. 8.** Interannual variability of tree-ring chronologies with respect to years of PDO reversal (dashed lines).

**Fig. 9.** Interdecadal variability of tree-ring chronologies (Fig. 8), computed using a 10-year cubic smoothing spline (Cook and Peters 1981). Winter PDO values (needles) are also shown.

**Fig. 10.** Average (thick line) of interdecadal tree-ring patterns (Fig. 9) and interdecadal PDO patterns (needles) obtained by cubic spline interpolation.

We have then used the seven longest chronologies (Jeffrey pine and big-cone Douglas-fir) to reconstruct PDO variability from 1660 to 1992. The first principal component of the tree-ring chronologies accounts for 57.5% of the total variance (61.1% for spline-smoothed series; Fig. 11). Model calibration was performed without the initial years (1900-1930). From 1931 to 1992, the...
5. REFERENCES


6. APPENDIX

Table 1. Location of tree-ring sites.

<table>
<thead>
<tr>
<th>Site Name (ID)</th>
<th>Species</th>
<th>Elev. (m)</th>
<th>Long. (°W)</th>
<th>Lat. (°N)</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pine Mountain North (PMN)</td>
<td>PSMA</td>
<td>1520</td>
<td>119.37</td>
<td>34.65</td>
<td>D. Meko, F. Biondi</td>
</tr>
<tr>
<td>Fish Creek Trail (FCT)</td>
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<td>2890</td>
<td>116.80</td>
<td>34.12</td>
<td>F. Biondi</td>
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<td>Black Mountain (BMN)</td>
<td>PILA</td>
<td>2369</td>
<td>116.77</td>
<td>33.80</td>
<td>D. Meko, F. Biondi</td>
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<tr>
<td>Santa Ana Mts. (SAM)</td>
<td>PSMA</td>
<td>1200</td>
<td>117.55</td>
<td>33.73</td>
<td>A. Douglas, F. Biondi</td>
</tr>
<tr>
<td>Fry Creek (FRY)</td>
<td>PSMA</td>
<td>1524</td>
<td>116.85</td>
<td>33.35</td>
<td>D. Meko, F. Biondi</td>
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<td>Cuyamaca Peak (CUY)</td>
<td>PJIE</td>
<td>1500</td>
<td>116.60</td>
<td>32.97</td>
<td>D. Meko, F. Biondi</td>
</tr>
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<td>Mount Laguna (MLA)</td>
<td>PJIE</td>
<td>1800</td>
<td>116.42</td>
<td>32.87</td>
<td>F. Biondi</td>
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<tr>
<td>Las Cuevitas (LAC)</td>
<td>PJIE</td>
<td>1580</td>
<td>115.93</td>
<td>31.90</td>
<td>F. Biondi</td>
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<tr>
<td>Observatory Ridges (OBS)</td>
<td>PJIE</td>
<td>2780</td>
<td>115.47</td>
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<td>F. Biondi</td>
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<td>La Tasajera (LAT)</td>
<td>PJIE</td>
<td>2400</td>
<td>115.50</td>
<td>30.97</td>
<td>F. Biondi</td>
</tr>
</tbody>
</table>

PSMA = Pseudotsuga macrocarpa
PJIE = Pinus jeffreyi
PILA = Pinus lambertiana

(1) San Gorgonio Mt.  (2) Palomar Mt.  (3) Sierra Juarez, northern Baja California, Mexico
(4) Sierra San Pedro Martir, northern Baja California, Mexico

Table 2. Summary of tree-ring chronologies (Fig. 3).

<table>
<thead>
<tr>
<th>Site Name (ID)</th>
<th>C (T)</th>
<th>Start</th>
<th>End</th>
<th>SD</th>
<th>MS</th>
<th>A_1</th>
<th>MSL</th>
<th>pPDO</th>
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</thead>
<tbody>
<tr>
<td>Pine Mountain North</td>
<td>29 (13)</td>
<td>1470</td>
<td>1993</td>
<td>0.363</td>
<td>0.358</td>
<td>0.426</td>
<td>355</td>
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<td>Fish Creek Trail</td>
<td>25 (12)</td>
<td>1560</td>
<td>1995</td>
<td>0.290</td>
<td>0.199</td>
<td>0.647</td>
<td>237</td>
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<tr>
<td>Black Mountain</td>
<td>18 (8)</td>
<td>1530</td>
<td>1992</td>
<td>0.150</td>
<td>0.138</td>
<td>0.318</td>
<td>352</td>
<td>NO</td>
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<tr>
<td>Santa Ana Mts.</td>
<td>56 (33)</td>
<td>1660</td>
<td>1995</td>
<td>0.382</td>
<td>0.335</td>
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<td>Fry Creek</td>
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<td>1992</td>
<td>0.291</td>
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<td>0.493</td>
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<td>Cuyamaca Peak</td>
<td>11 (9)</td>
<td>1790</td>
<td>1992</td>
<td>0.264</td>
<td>0.221</td>
<td>0.436</td>
<td>153</td>
<td>NO</td>
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<tr>
<td>Mount Laguna</td>
<td>29 (14)</td>
<td>1650</td>
<td>1995</td>
<td>0.403</td>
<td>0.286</td>
<td>0.680</td>
<td>208</td>
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<td>Las Cuevitas</td>
<td>30 (17)</td>
<td>1786</td>
<td>1995</td>
<td>0.345</td>
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<td>La Tasajera</td>
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<td>0.212</td>
<td>0.173</td>
<td>0.524</td>
<td>332</td>
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C (T) = number of cores (trees)  SD = standard deviation  MS = mean sensitivity
A_1 = lag-1 autocorrelation  MSL = mean segment length  pPDO = used for PDO reconstruction