**Supplemental Materials**

## Core Material

The 90 cm long Clear Lake sediment core used in this study (CL1-MW1) was collected from 11 meters water depth in 2004 and captured the intact sediment-water interface. An age model was constructed from $^{210}$Pb dating on the upper 20 cm and nine radiocarbon AMS dates on terrestrial macrofossils. The surface radiocarbon date confirms that the core-top material is modern (post-1950 C.E.). The average sedimentation rate in Clear Lake is ~1 m/kyr, resulting in an average sampling resolution of 10 years/sample.

## Dinosterol purification

Dinosterol was isolated from the sterol fraction via reverse phase (RP)- high performance liquid chromatography (HPLC). An Agilent 1100 HPLC with an integrated autoinjector, quaternary pump, and fraction collector was coupled to an Agilent 1100 LC/MSD SL mass spectrometer with a multimode source that was operated in positive atmospheric pressure chemical ionization (APCI+) mode. The HPLC method used is outlined in Nelson and Sachs (2013). Subsequently to HPLC separation the fraction containing dinosterol was analyzed via GC-MSD to verify sufficient baseline separation. Adjacent HPLC fractions were also analyzed to ensure that no dinosterol eluted into those fractions. Atwood and Sachs (2012) demonstrated significant hydrogen isotope fractionation of sterols across an HPLC peak, thus requiring verification that 100% of the dinosterol from every sample is recovered in the same fraction prior to isotopic analysis. Hydrogen isotopic determinations were made on purified dinosterol samples via GC-irms (see details in supplement), and each sample was measured in at least duplicate.

## $\delta^2$H determination

After the dinosterol was sufficiently isolated from co-eluting compounds, the sample was injected onto a GC-irms for determination of the dD of dinosterol. Hydrogen isotope determinations were made using a Finnigan Delta V Plus Isotope Ratio Mass Spectrometer (irMS) coupled to a Thermo Trace GC Ultra with a Varian VF-17ms FactorFour capillary column (60 m x 0.32 mm x 0.25 μm) and a pyrolysis reactor. Samples were injected into a split/splitless inlet in splitless mode at 310 °C. The oven temperature was ramped from 100 °C to 220 °C at a rate of 20 °C/min, then at 2 °C /min up to 325 °C where it was held for 17 min. The carrier gas, He, was held constant at 2.6 mL/min. The pyroloysis reactor was maintained at 1400 °C. Isotope values, expressed as δD values, were calculated in Isodat software relative to VSMOW using a co-injection standard containing $nC_{28}$ $nC_{32}$, $nC_{40}$, and $nC_{44}$ of known δD values (obtained from Arndt Schimmelmann, Indiana University, Bloomington, IN, USA). The measured isotope values of dinosterol were corrected for the addition of hydrogen atoms (of known δD value) that occurred during acetylation. Each sample was analyzed in at least duplicate, and error bars represent standard deviations of replicate measurements.

## $^{210}$Pb and Radiocarbon dating

$^{210}$Po (which is in secular equilibrium with $^{210}$Pb within 2 years of deposition) was measured on dry sediments from the upper 20 cm of Clear Lake. The $^{210}$Pb chronology was constructed assuming a constant rate of supply (CRS model), and by relating the exponential $^{210}$Pb decay profiles with the cumulative dry mass-depth profiles as determined using bulk density measurements. Radiocarbon ages were determined for 9 plant macrofossil samples using accelerator mass spectrometer at CAMS (LLNL, Livermore, CA).

## Table DR1. $^{210}$Pb dates for Clear Lake core CL1-MW1

| Depth (cm) | $^{210}$Pb Activity Unsupported (DPM/g) | Cumulative dry mass (g/cm$^2$) | Modeled Age (Yrs C.E.) (CRS Model) |
|---|---|---|---|
| 1.5 | 48.88 | 0.072 | 2000 |
| 2.5 | 50.53 | 0.123 | 1997 |
| 3.5 | 55.83 | 0.171 | 1995 |
| 4.5 | 58.66 | 0.215 | 1990 |
| 6.5 | 56.26 | 0.335 | 1978 |
| 8.5 | 39.97 | 0.501 | 1960 |
| 10.5 | 24.66 | 0.670 | 1944 |
| 12.5 | 12.13 | 0.819 | 1933 |
| 14.5 | 8.65 | 0.990 | 1918 |
| 16.5 | 4.68 | 1.164 | 1902 |

## Table DR2. Radiocarbon dates for Clear Lake core CL1-MW1

| Depth (cm) | $^{14}$C Age | 1σ St.Dev |
|---|---|---|
| 0 | >modern | |
| 7.5 | 71 | 27 |
| 9.5 | 134 | 29 |
| 42.5 | 285 | 35 |
| 53.5 | 282 | 22 |
| 61.5 | 346 | 24 |
| 72.5 | 374 | 21 |
| 79.5 | 501 | 24 |
| 86.5 | 820 | 30 |

# Figure DR1. Clear Lake Age Model

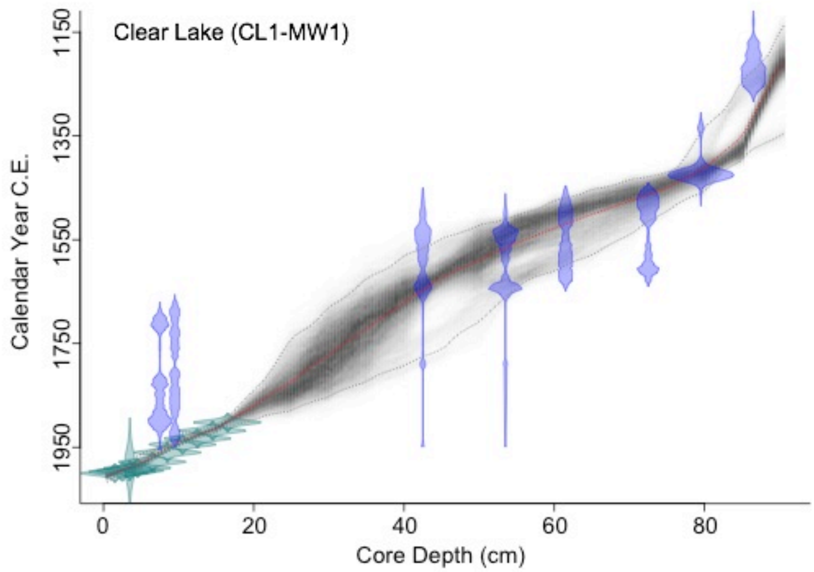


**Figure DR1**. Age Model for Clear Lake. The age model for Clear Lake is based on 10 $^{210}Pb$ determinations (green) and nine $^{14}C$ dates (blue) measured on terrestrial macrofossils (*e.g.* seed pods and leaf fragments). The age-depth relationship and associated uncertainty was determined using BACON (Blaauw and Christen, 2011) Radiocarbon ages were calibrated using the Intcal 09 data set (Reimer et al., 2009). This age model results in a sampling resolution of 8 years per sample.

# Figure DR2. Spooky Lake Age Model

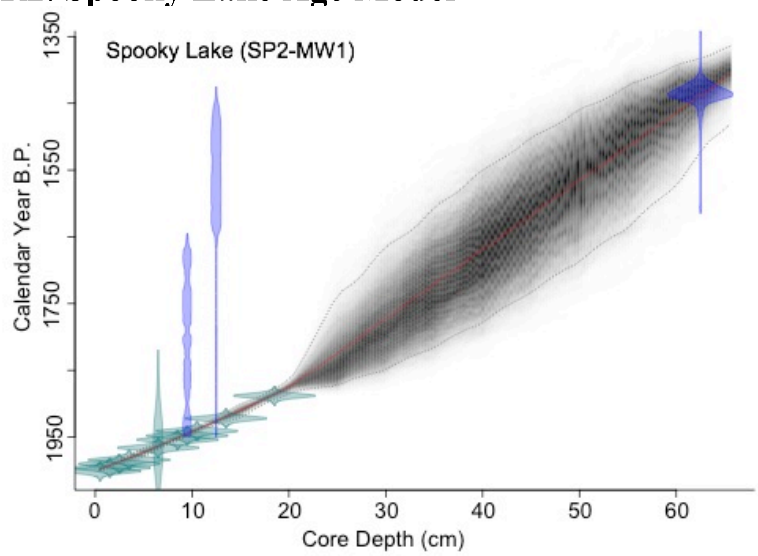


**Figure DR2**. Age Model for Spooky Lake. This alternate age model for Spooky Lake is based on $^{210}Pb$ determinations (green) and $^{14}C$ dates (blue) originally published in Sachs et al. (2009) and Smittenberg et al. (2011). This new age-depth relationship and associated uncertainty was determined using BACON (Blaauw and Christen, 2011) Intcal 09 data set (Reimer et al., 2009). The new calibrated ages are shown along with the original published ages in Table DR3.

**Table DR3**. New Spooky Lake Age Model

| Core Depth (cm) | Original Published Age (Yrs C.E.) | BACON Mean Modeled Age (Yrs C.E.) | BACON Min. Modeled Age (Yrs C.E.) | BACON Max. Modeled Age (Yrs C.E.) | $\delta D_{dino}$ ‰ VSMOW | 1$\sigma$ St.Dev. |
|---|---|---|---|---|---|---|
| 0.5 | 2002 | 2002 | 2004 | 1994 | -278.4 | 1.0 |
| 1.5 | | 1998 | 2002 | 1991 | | |
| 2.5 | 1994 | 1993 | 1999 | 1987 | -290.8 | 4.2 |
| 3.5 | 1989 | 1987 | 1993 | 1981 | -284.7 | 2.4 |
| 4.5 | 1985 | 1981 | 1990 | 1972 | -296.3 | 1.1 |
| 5.5 | 1980 | 1975 | 1987 | 1963 | -295.2 | 0.2 |
| 6.5 | 1976 | 1969 | 1978 | 1959 | -298.1 | 1.7 |
| 7.5 | 1971 | 1963 | 1970 | 1955 | -315.8 | 4.0 |
| 8.5 | 1966 | 1957 | 1963 | 1950 | -313.2 | 1.4 |
| 9.5 | 1961 | 1951 | 1956 | 1944 | -315.4 | 2.4 |
| 10.5 | | 1944 | 1951 | 1936 | | |
| 11.5 | 1951 | 1938 | 1944 | 1932 | -308.7 | 4.4 |
| 12.5 | 1946 | 1932 | 1939 | 1926 | -306.9 | 3.5 |
| 13.5 | 1940 | 1926 | 1935 | 1918 | -303.3 | 4.4 |
| 14.5 | 1935 | 1920 | 1932 | 1910 | -304.1 | 3.2 |
| 15.5 | 1929 | 1915 | 1929 | 1901 | -316.0 | 2.8 |
| 16.5 | | 1907 | 1920 | 1896 | | |
| 17.5 | 1917 | 1900 | 1911 | 1890 | -305.2 | 2.4 |
| 18.5 | | 1893 | 1904 | 1883 | | |
| 19.5 | | 1886 | 1899 | 1874 | | |
| 20.5 | 1899 | 1880 | 1895 | 1865 | -300.3 | 1.9 |
| 21.5 | | 1869 | 1888 | 1847 | | |
| 22.5 | | 1859 | 1884 | 1822 | | |
| 23.5 | | 1849 | 1882 | 1795 | | |
| 24.5 | | 1838 | 1880 | 1767 | | |
| 25.5 | 1865 | 1828 | 1879 | 1739 | -313.4 | 4.7 |
| 26.5 | | 1818 | 1872 | 1730 | | |
| 27.5 | | 1807 | 1867 | 1719 | | |
| 28.5 | | 1797 | 1862 | 1705 | | |
| 29.5 | | 1787 | 1859 | 1690 | | |
| 30.5 | 1826 | 1777 | 1857 | 1669 | -302.6 | 6.6 |
| 31.5 | | 1767 | 1848 | 1660 | | |
| 32.5 | | 1756 | 1839 | 1650 | | |
| 33.5 | | 1746 | 1833 | 1637 | | |
| 34.5 | | 1735 | 1827 | 1623 | | |
| 35.5 | | 1725 | 1823 | 1605 | | |
| 36.5 | 1783 | 1715 | 1812 | 1597 | -293.0 | 4.3 |
| 37.5 | | 1705 | 1804 | 1588 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 38.5 | | 1694 | 1797 | 1577 | | |
| 39.5 | | 1684 | 1791 | 1563 | | |
| 40.5 | 1735 | 1674 | 1784 | 1547 | -298.7 | 2.5 |
| 41.5 | | 1664 | 1773 | 1541 | | |
| 42.5 | | 1654 | 1764 | 1534 | | |
| 43.5 | | 1643 | 1756 | 1525 | | |
| 44.5 | | 1633 | 1750 | 1514 | | |
| 45.5 | 1681 | 1623 | 1744 | 1502 | -288.3 | 4.7 |
| 46.5 | | 1612 | 1731 | 1496 | | |
| 47.5 | | 1602 | 1720 | 1489 | | |
| 48.5 | | 1591 | 1712 | 1481 | | |
| 49.5 | | 1581 | 1703 | 1471 | | |
| 50.5 | 1622 | 1570 | 1696 | 1460 | -286.0 | 5.9 |
| 51.5 | | 1560 | 1683 | 1454 | | |
| 52.5 | | 1551 | 1672 | 1449 | | |
| 53.5 | | 1541 | 1662 | 1443 | | |
| 54.5 | | 1531 | 1654 | 1436 | | |
| 55.5 | | 1521 | 1646 | 1427 | | |
| 56.5 | | 1511 | 1629 | 1423 | | |
| 57.5 | 1528 | 1501 | 1616 | 1419 | -291.1 | 4.5 |
| 58.5 | | 1491 | 1604 | 1412 | | |
| 59.5 | | 1480 | 1594 | 1405 | | |
| 60.5 | | 1470 | 1585 | 1395 | | |
| 61.5 | | 1460 | 1564 | 1391 | | |
| 62.5 | 1454 | 1449 | 1543 | 1386 | -290.2 | 5.0 |

**Table DR3.** This table shows core depth versus original published age, and modeled mean, minimum and maximum age using BACON (Blaauw and Christin, 2011) for Spooky Lake. Original age model, isotope data, radiocarbon and $^{210}$Pb data are published in Sachs et al., (2009) and Smittenberg et al. (2011).

## Table DR4. Clear Lake down core data

| Core Depth (cm) | BACON Mean Modeled Age (Yrs C.E.) | BACON Min. Modeled Age (Yrs C.E.) | BACON Max. Modeled Age (Yrs C.E.) | $\delta D_{dino}$ ‰ VSMOW | 1$\sigma$ St.Dev. |
|---|---|---|---|---|---|
| 0.5 | 2002 | 2004 | 1997 | -280.7 | 3.4 |
| 1.5 | 2000 | 2006 | 1994 | -286.8 | 3.8 |
| 2.5 | 1994 | 1999 | 1988 | -272.5 | 3.0 |
| 3.5 | 1989 | 1995 | 1979 | -272.9 | 2.0 |
| 4.5 | 1983 | 1992 | 1969 | -266.9 | 1.9 |
| 5.5 | 1976 | 1986 | 1961 | -297.1 | 0.7 |
| 6.5 | 1968 | 1976 | 1956 | -287.1 | 3.2 |
| 7.5 | 1960 | 1967 | 1949 | | |
| 8.5 | 1951 | 1958 | 1940 | -294.9 | 3.1 |
| 9.5 | 1943 | 1950 | 1929 | -298.9 | |
| 10.5 | 1937 | 1944 | 1923 | -293.5 | |
| 11.5 | 1931 | 1938 | 1920 | -297.3 | 1.4 |
| 12.5 | 1926 | 1932 | 1918 | -310.9 | 3.2 |
| 13.5 | 1921 | 1928 | 1914 | -290.0 | 3.1 |
| 14.5 | 1916 | 1924 | 1908 | -290.3 | 0.4 |
| 15.5 | 1909 | 1917 | 1902 | -295.4 | 0.4 |
| 16.5 | 1901 | 1910 | 1892 | -287.7 | 3.4 |
| 17.5 | 1892 | 1906 | 1878 | | |
| 18.5 | 1883 | 1903 | 1863 | | |
| 19.5 | 1875 | 1900 | 1848 | -300.8 | 2.9 |
| 20.5 | 1866 | 1895 | 1834 | | |
| 21.5 | 1856 | 1890 | 1819 | -295.4 | 2.1 |
| 22.5 | 1846 | 1886 | 1799 | -281.3 | 4.2 |
| 23.5 | 1836 | 1883 | 1776 | -297.2 | |
| 24.5 | 1826 | 1880 | 1752 | -283.4 | 3.2 |
| 25.5 | 1817 | 1874 | 1736 | -279.9 | |
| 26.5 | 1807 | 1868 | 1727 | -270.8 | 3.0 |
| 27.5 | 1797 | 1863 | 1717 | -271.8 | |
| 28.5 | 1787 | 1860 | 1704 | -288.4 | 2.4 |
| 29.5 | 1777 | 1857 | 1690 | -294.2 | 1.5 |
| 30.5 | 1768 | 1851 | 1678 | -294.5 | 3.6 |
| 31.5 | 1758 | 1844 | 1670 | -289.8 | |
| 32.5 | 1748 | 1839 | 1660 | -280.7 | 4.2 |
| 33.5 | 1739 | 1834 | 1651 | -292.6 | 1.9 |

| | | | | | |
|---|---|---|---|---|---|
| 34.5 | 1729 | 1830 | 1640 | -278.9 | 9.3 |
| 35.5 | 1719 | 1823 | 1631 | -281.0 | 2.4 |
| 36.5 | 1709 | 1816 | 1625 | -286.5 | 0.3 |
| 37.5 | 1699 | 1811 | 1618 | | |
| 38.5 | 1689 | 1807 | 1608 | -288.5 | |
| 39.5 | 1678 | 1802 | 1595 | -288.3 | 0.2 |
| 40.5 | 1669 | 1796 | 1585 | -293.8 | 1.3 |
| 41.5 | 1660 | 1790 | 1580 | -291.3 | 3.5 |
| 42.5 | 1651 | 1784 | 1575 | -284.9 | 0.3 |
| 43.5 | 1642 | 1778 | 1566 | -302.7 | 1.6 |
| 44.5 | 1632 | 1772 | 1555 | -293.8 | 1.4 |
| 45.5 | 1624 | 1762 | 1547 | -306.6 | 1.5 |
| 46.5 | 1617 | 1747 | 1543 | -285.4 | 3.8 |
| 47.5 | 1610 | 1736 | 1539 | -301.0 | 1.3 |
| 48.5 | 1603 | 1726 | 1534 | -291.5 | 0.6 |
| 49.5 | 1596 | 1719 | 1527 | -281.5 | |
| 50.5 | 1588 | 1707 | 1521 | -283.4 | |
| 51.5 | 1581 | 1692 | 1518 | -289.7 | 2.9 |
| 52.5 | 1574 | 1677 | 1515 | -290.7 | 4.0 |
| 53.5 | 1567 | 1662 | 1511 | -308.6 | 4.4 |
| 54.5 | 1560 | 1649 | 1506 | -302.7 | 3.4 |
| 55.5 | 1554 | 1638 | 1501 | | |
| 56.5 | 1548 | 1630 | 1497 | | |
| 57.5 | 1543 | 1624 | 1492 | -311.3 | 2.2 |
| 58.5 | 1537 | 1620 | 1486 | -299.7 | 0.5 |
| 59.5 | 1531 | 1616 | 1478 | -305.3 | 2.4 |
| 60.5 | 1526 | 1610 | 1473 | -292.5 | 10.7 |
| 61.5 | 1521 | 1603 | 1470 | -307.1 | 0.9 |
| 62.5 | 1515 | 1597 | 1466 | | |
| 63.5 | 1510 | 1592 | 1461 | -311.5 | 3.3 |
| 64.5 | 1504 | 1587 | 1455 | -312.0 | 6.9 |
| 65.5 | 1499 | 1579 | 1451 | -312.6 | |
| 66.5 | 1494 | 1568 | 1448 | -309.2 | 1.1 |
| 67.5 | 1489 | 1559 | 1444 | -311.0 | 2.2 |
| 68.5 | 1484 | 1552 | 1440 | -301.8 | 3.2 |
| 69.5 | 1479 | 1546 | 1436 | -307.2 | 1.8 |
| 70.5 | 1473 | 1537 | 1432 | -312.9 | 2.8 |
| 71.5 | 1468 | 1525 | 1430 | -300.6 | |
| 72.5 | 1463 | 1515 | 1427 | -303.6 | 1.0 |
| 73.5 | 1457 | 1507 | 1424 | -285.0 | 1.6 |
| 74.5 | 1452 | 1500 | 1421 | -300.9 | 4.1 |

| | | | | | |
|---|---|---|---|---|---|
| 75.5 | 1446 | 1491 | 1416 | -291.4 | 0.6 |
| 76.5 | 1438 | 1480 | 1407 | -299.8 | 2.3 |
| 77.5 | 1431 | 1472 | 1391 | -298.7 | 1.9 |
| 78.5 | 1423 | 1465 | 1370 | -308.3 | 0.4 |
| 79.5 | 1416 | 1460 | 1348 | -294.9 | 1.9 |
| 80.5 | 1406 | 1448 | 1331 | -310.0 | 4.1 |
| 81.5 | 1395 | 1432 | 1318 | -317.9 | 3.2 |
| 82.5 | 1383 | 1419 | 1305 | -314.9 | 3.4 |
| 83.5 | 1371 | 1410 | 1284 | -292.8 | 3.4 |
| 84.5 | 1359 | 1404 | 1256 | -292.9 | 1.7 |
| 85.5 | 1340 | 1387 | 1236 | -292.4 | 1.4 |
| 86.5 | 1312 | 1374 | 1224 | -298.2 | 4.4 |
| 87.5 | 1284 | 1367 | 1210 | -308.8 | 2.7 |

**FigureDR3.** This table shows core depth versus modeled mean, minimum and maximum age using BACON (Blaauw and Christin, 2011), as well as $\delta^2H$ dinosterol with standard deviation of triplicate measurements for Clear Lake. Radiocarbon and $^{210}Pb$ data are shown in Tables DR1 and DR2.

**Figure DR3. Clear Lake Regime Shifts**

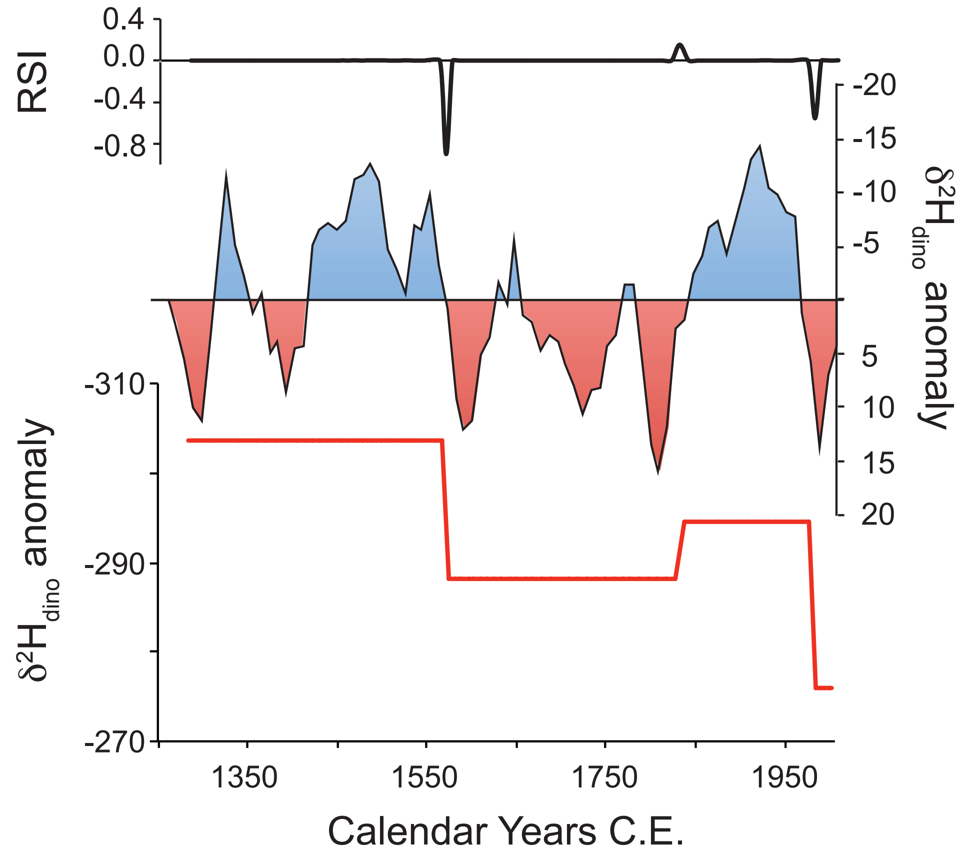


**Figure DR3.** The top panel shows the Regime Shift Index (RSI) — as identified by the Regime Shift Detection (v.3.2) algorithm of Rodinov (2004) —for the Clear Lake $\delta^2H$ record. The middle panel is a plot of the de-trended Clear Lake $\delta^2H$ record plotted as $\delta^2H$ anomalies relative to the 800-year mean. Negative (blue) anomalies are intervals of relative wet and positive (red) anomalies are intervals of relative dry. The bottom panel shows the mean $\delta^2H$ values for distinct regimes in the Clear Lake $\delta^2H$ record. The differences in the means between different regimes are significant at the 0.05 confidence level. The significant regime shifts occur at 1567-1574, 1826-1836, and 1976-1983 C.E.

## Figure DR4. 20th Century Climatology of Palau

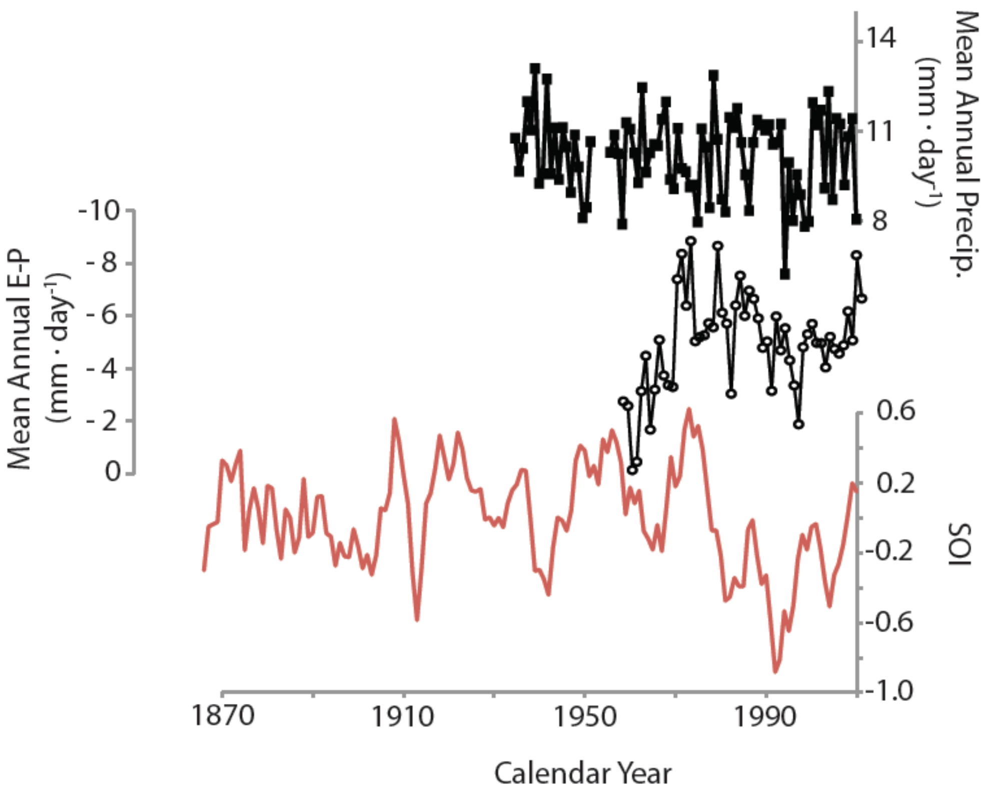


**Figure DR4.** The top panel shows mean annual precipitation from Koror weather station in Palau from 1929-2010. These data are available through NOAA's National Centers for Environmental Information Version 2 Global Historical Climatology Network (Peterson and Vose, 1997). The middle panel shows Evaporation-Precipitation in Palau using a combination of the ERA40 (Uppala et al., 2005) and ERA-Interim (Dee et al., 2011) gridded reanalysis data sets from 1949-2010. The bottom panel shows a 5-year running mean of the mean annual SOI data set (http://www.cpc.ncep.noaa.gov/data/indices/soi).

## Figure DR5. Monthly Climatological Mean Precip.

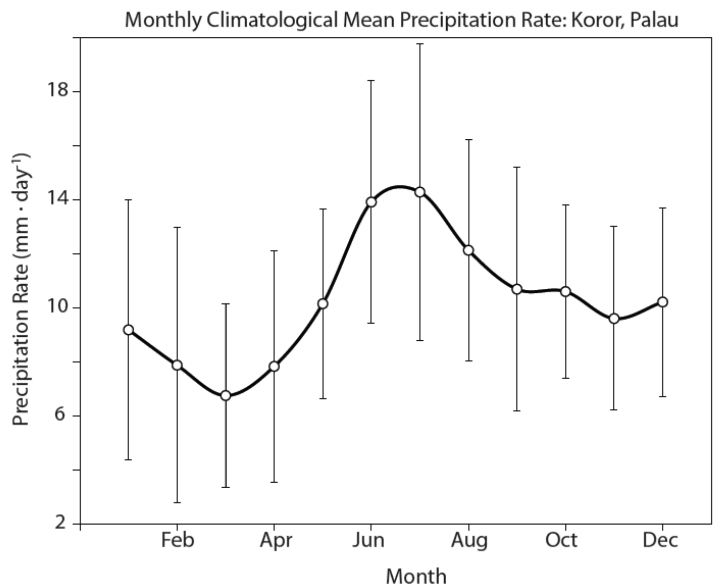


**Figure DR5.** Climatological mean precipitation rate for each month at Koror weather station in Palau from 1929-2010 (Peterson and Vose, 1997). Error bars represent 1σ standard deviation on monthly means.

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