Linking solar activity and Pacific climate variability

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Overview

Solar variations on both decadal and centennial timescales have been associated with climate phenomena (van Loon et al., 2004; Hodell et al., 2001; White et al., 1997), but the mechanism remains controversial. The energy received by the Earth at the peak of the solar cycle increases by <0.1%, so the question has remained of how this could be amplified to produce an observable climate response. Recent modeling shows that the response of the Earth's climate system to the 11-year solar cycle may be amplified through stratosphere and ocean feedbacks and has the potential to impact climate variability on a number of timescales (Meehl et al., 2009). Here, we report a 1000-year record of changes in the stratigraphy and carbon isotope composition of varved lake sediment that shows variations in primary productivity on centennial timescales and suggests that solar activity may be an important component of Pacific climate variability.

Location: Isla Isabela

Sediment cores were taken from Isabela Crater Lake, (22° N, 106° W) in the subtropical northeast Pacific.

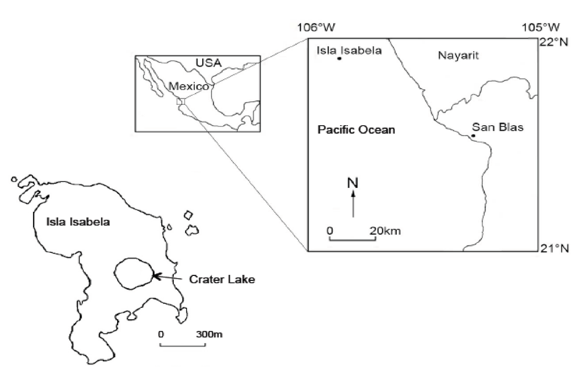


Figure 1.

Stratigraphy

Topmost section of Isabela core, showing mm-scale varves. Section is 65 cm long. Coarse carbonate layers occur at varying frequencies downcore; see Fig. 4 for description.

Fig. 2

Chronology

Age-depth model for the last 6000 years.

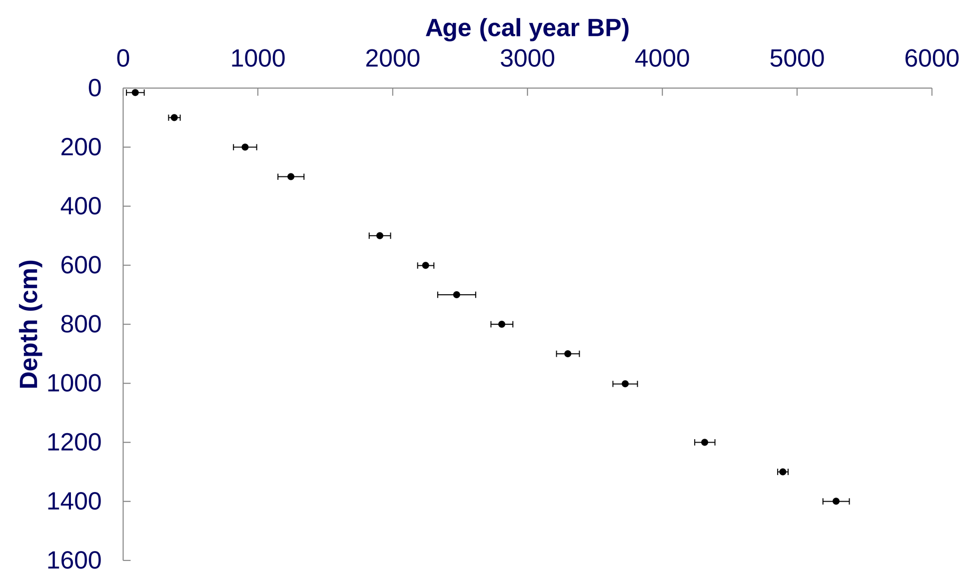


Figure 3.

Table 1.

Lab identifier (CAMS#)	Depth (cm)	^{14}C age (^{14}C yr BP)	±	1s cal age range (cal yr BP)	2s cal age range (cal yr BP)	Median probability age (cal yr BP)
136255	12	360	35	-	-	-
140535	78	580	35	149-186	138-223	182
140536	178	1105	35	661-693	652-730	680
140537	278	1445	35	934-987	930-1018	982
140538	280	1450	35	953-1000	932-1056	988
140539	380	2105	35	1605-1700	1549-1718	1645
140540	481	2445	35	1995-2066	1949-2135	2045
140541	580	2675	35	2311-2352	2300-2359	2330
140542	680	3010	35	2743-2774	2721-2798	2760
140543	780	3500	35	3332-3392	3316-3412	3359
140545	882	3925	35	3826-3900	3808-3928	3850
140546	1080	4515	35	4611-4711	4569-4826	4688
140547	1180	5095	35	5330-5578	5325-5583	5468
131375	1271	5490	40	5761-5809	5749-5830	5834

Results

Productivity and solar records, top to bottom:

Carbonate stratigraphy (Fig. 4A) as a cluster index (number of layers per 10 cm); carbonates infer increased surface productivity.

Solar activity (4B) is shown as $^{14}C/^{12}C$ ratios from the Intcal09 radiocarbon calibration curve (Reimer et al., 2009).

Individual measurements and three-point running mean of sediment $\delta^{13}C$ (4C). Stable carbon isotopes are a well established productivity proxy (MacKenzie, 1985).

Dashed lines show correlative depths and ages. The average interval between $\delta^{13}C$ samples is about 5 yr.

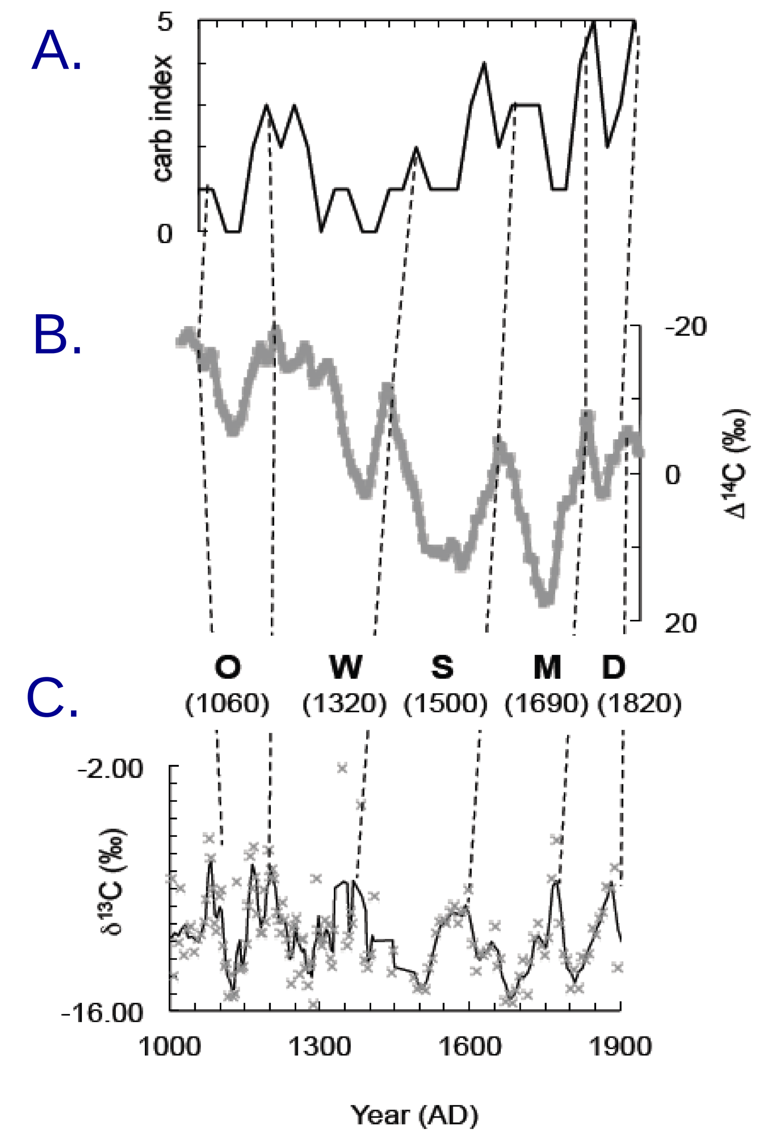
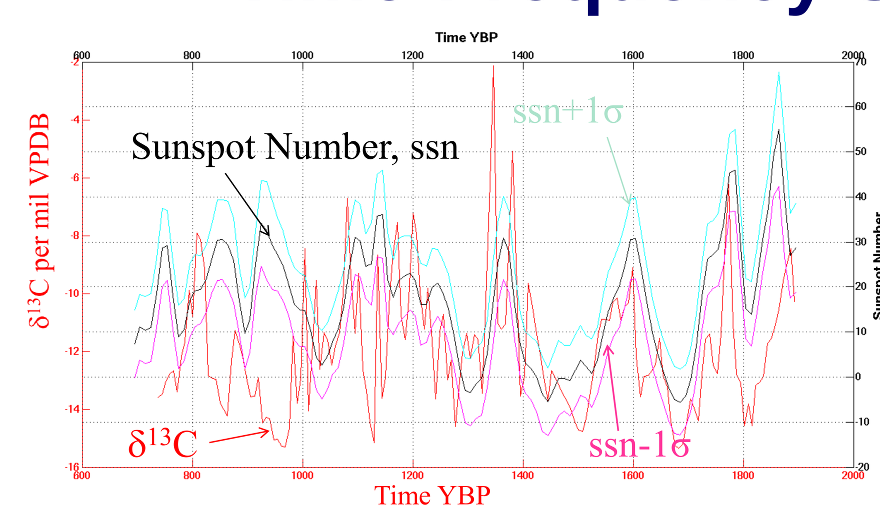


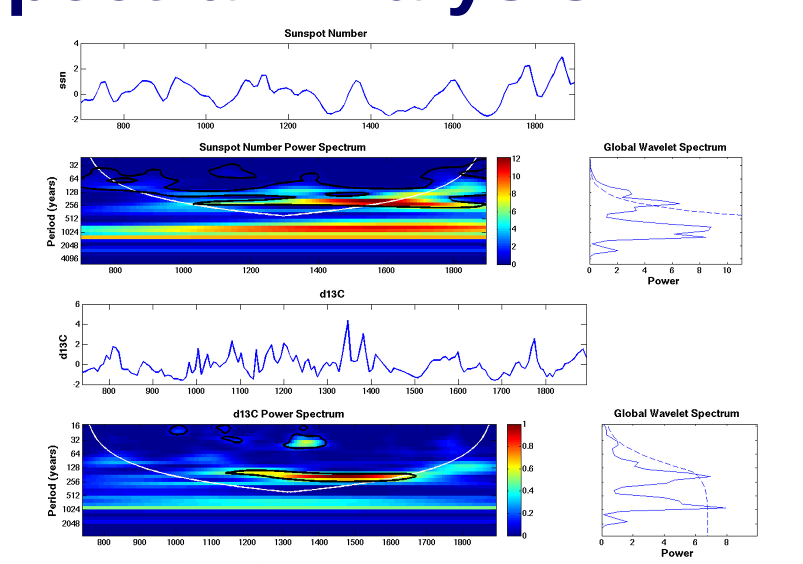
Figure 4.

Grand solar minima, centered on the years in parentheses (Bard et al., 1997) are labeled as follows: Oort (O); Wolf (W); Spörer (S); Maunder (M); Dalton (D). The 20th century is not shown due to the Seuss effect on atmospheric carbon.

Time-Frequency Spectral Analysis



Note the simultaneity in the ssn and $\delta^{13}C$ time series. This suggests some correspondence between solar variability and lake productivity.



Notable similarity between ssn and $\delta^{13}C$ in Wavelet Power Spectra around 200-220 year periodicity. Thick black lines show 95% significant power. Global Power spectra shows similar peaks in two cases.

Figure 6.

Conceptual Model

Following the scenario of Meehl et al. (2009)…

Reduction in cloud cover during solar maxima amplifies solar forcing, warming surface waters across the tropics, enhancing evaporation and transport of water vapor by the trade winds to convergence zones (Fig. 5A).

Increased precipitation in convergence zones strengthens the Hadley and Walker circulations, increasing trade winds and upwelling, leading to lower SST in eastern equatorial Pacific (Fig. 5B).

Enhanced subsidence produces fewer clouds in the eastern equatorial Pacific and expands the subtropical regions, allowing more solar radiation to reach the surface to produce a positive feedback that further magnifies the climate response (Fig. 4).

A. B.

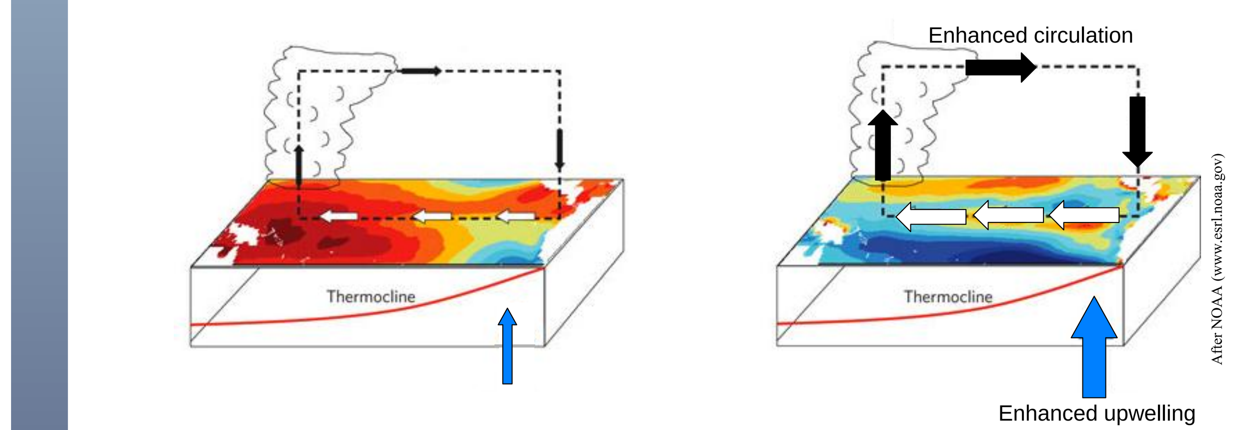


Figure 5.

Conclusions

Lake productivity as studied from 1200 years show connections with solar activity as studied from two approaches:

1. **Time Series Analysis**
2. **Wavelet Power Spectra**

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Reference Datasets

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