22 year cycle in the planktonic δ^{18}O of a shallow-water Ionian sea core

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Summary. — The δ^{18}O profile of *Globigerinoides ruber* was measured in the GT90/3 Ionian sea core between 1205 and 1898 AD. The high temporal resolution of 3.87 y allowed us to determine the presence in the time series of an 11 y component with an amplitude of 0.07‰, at significance level of 99% (by Monte Carlo singular spectrum analysis, MC-SSA). Here we focus attention on the 22 y periodicity in the time series and we show that SSA principal components (PCs) 15 and 16 carry this oscillation, in phase with the Hale solar cycle, obtained by inverting the odd cycles of the sunspot number series. This result shows that the even and odd Schwabe cycles do not have the same influence on this climatic record.

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1. – Introduction

Climate data from marine sediments with high temporal resolution for the last millennia are a key to obtain information about recurrences and periodicities on the time scale of centuries and decades directly comparable to instrumental observations both of solar and terrestrial type. In fact, calcareous organisms record past conditions of the sea, through the ratio of two main isotopes of oxygen ^{18}O/^{16}O in the calcite of their skeleton. If a proper gauge is provided in modern times to calibrate the influence of marine climatic parameters on the fractionation effects, the time profile of δ^{18}O in the calcite of the foraminiferal shells allows to monitor climatic changes in the past. It may provide a continuous and uniform pre-industrial base level, long and detailed enough to obtain reliable information allowing to evaluate the exceptionality of the present-day warming.

The first condition for these paleoclimatic researches is the availability of a core dated with high precision. In second instance, if we want to investigate the high-frequency range, for example the decadal range, we must achieve high temporal resolution. Finally, if we expect the presence of oscillatory components of small amplitude compared with the noise variance, we should study a record as long as possible. Taking into account these facts, we have measured δ^{18}O in a recent Ionian sea core [1], taken from the Gallipoli Terrace (Gulf of Taranto), that we have previously dated with high accuracy [2, 3]. In fact, we determined an average sedimentation rate $s = (0.0645 \pm 0.0007)$ cm y^{-1}, quite constant along the core and uniform throughout the whole platform during the last two millennia.

The δ^{18}O profile covers the period 1205-1898 AD and has a temporal resolution of 3.87 y. We have shown [1] that the dominant oscillation in this record has a period of about 11 y, identified in the principal components PCs 1 and 2 by Monte Carlo singular spectrum analysis (MC-SSA; see [4-7]) at 99% significance level. This oscillation and the sunspot numbers are in anti-phase, as expected from the measurements of the solar irradiance variations obtained in space during the last two solar cycles (see, *e.g.*, [8, 9]).

In this paper, we focus our attention on the 22 y periodicity and we compare it with the sunspot number record.

2. – Data analysis and discussion of the results

We have sampled the core GT90/3 at consecutive intervals of 2.5 mm, corresponding to $\Delta t = 3.87$ y and we have measured δ^{18}O of *Globigerinoides ruber* in 180 samples, covering the time interval 1205–1898 AD.

In order to search for periodicities, we have used the SSA and the method of superposition of epochs (SE). We have applied SSA, using a window with $\tau_M = M\tau_S =$ 193 y, where $M = 50$ and $\tau_S = 3.87$ y is the sampling interval. This value of M is not critical: in fact we obtain substantially the same results using a wide range of values ($20 \leqslant M \leqslant 60$). Taking into account that we have prior reason, in the framework of solar-terrestrial relationships, to focus our attention on the bidecadal range, we give physical meaning to the oscillation with associated period of about 22 y, carried by PCs (principal components) 15 and 16. In support to this outcome, we show in fig. 1 the 22 y

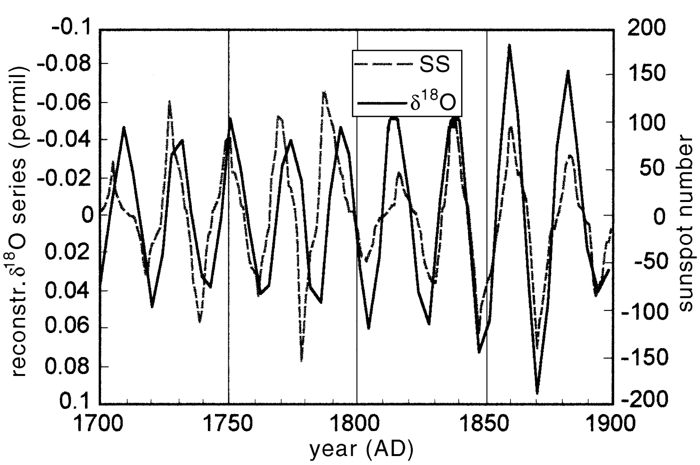

Fig. 1. – 22 y signal, reconstructed from PCs 15 and 16, superposed to the sunspot number series obtained by inverting the odd cycles. The δ^{18}O values are plotted in a reversed scale.

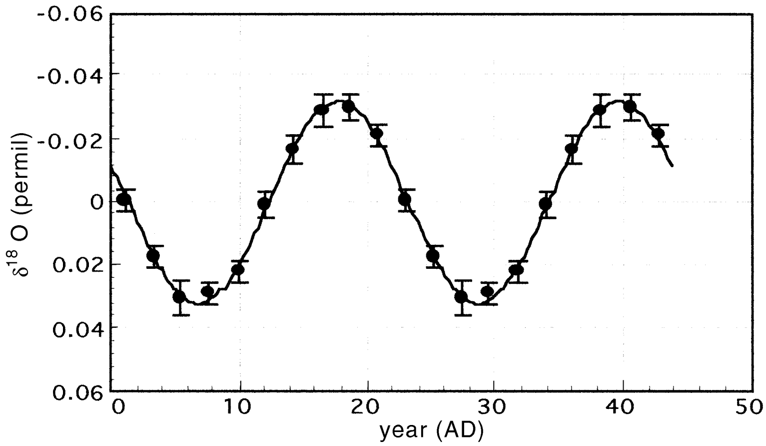

Fig. 2. – Superposed data and least-square fit sinusoid for the reconstructed signal (from PCs 15 and 16), using $T = 21.85$ y. The amplitude and the phase of the sinusoidal fit are, respectively, $A = 0.03‰$ and $\phi = 5.91$ rad (referred to 247.4 AD); its correlation coefficient to the superposed data is $r^2 = 0.99$. In order to better visualize the wave, the superposed data and the sinusoid have been repeated twice.

signal, calculated from PCs 15 and 16, superposed on the sunspot number series obtained by inverting the odd cycles. We note that these two curves are in good agreement. The average amplitude of this signal over the 700 years covered by the record has been determined by applying the method of SE to the signal reconstructed from PCs 15 and 16; in fig. 2 we show the result of SE for the period $T = 21.85$ y, at which we found maximum amplitude $A = 0.03‰$.

3. – Conclusion

Data from satellites [8, 9] indicate that the Sun's brightness decreased by about 0.15% between the maximum of the cycle 21 (1981) and the following minimum (1986). The Sun is more luminous as the number of sunspots on its surface grows larger. The increase in photospheric area covered by bright faculae outweighs the increase in area of dark spots as the solar activity increases. These 11 y changes in the solar constant may be responsible for the deterministic signal of the same frequency found in the climatic δ^{18}O record, revealed with high statistical significance over a period of 700 years. In this paper, we show the presence of an additional 22 y climatic cycle in the same record, in phase with the 11 y δ^{18}O cycle, suggesting that the δ^{18}O index records the Schwabe cycle with higher and lower amplitude alternatively. Evidence for a 22 y solar modulation of Earth's Northern Hemisphere temperatures has also been recently found [10], due to the fact that when the Sun's magnetic field reverses, the tropospheric response also reverses. An alternative possible origin of the effect may reside in the fact that even cycles have usually lower relative sunspot number R_z, suggesting a reduced solar output in even cycles.

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