Evidence for Climate Variations Induced by the Solar Cycle

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Abstract

We argue that the solar activity cycle induce periodic variations in rain-snow precipitation and sea-air temperatures, that cause mean sea level oscillations. We present observational evidence in favor of the above hypothesis, starting with a brief historical background of studies of solar cycle influence on climate. The evidence indicate that the Solar and Cosmic rays cycles are correlated with changes in temperature and precipitation. We analyzed data for the monthly mean sea level at San Juan and Magueyes Island in Puerto Rico, seeking correlations between sea level fluctuations and solar, cosmic rays and temperature cycles. Our analysis suggest that a solar activity cycle minimum (cosmic ray intensity maximum) correlates with lower than average temperatures and mean sea levels. We discussed, as a posible explanation of the above correlations, that the solar and cosmic rays cycles could cause larger than average accumulation of continental water and snow with lower temperatures contracting the oceans, thus implying lower mean sea levels. If this is the case, we predict that lower than average temperatures and mean sea levels will occur around the year 2009,with a delay of about 2 year after the 2007 solar activity minimum.

Introduction

The surface of the Sun manifest deviations from uniform brightness, like the well known sun-spots (darker areas, illustrated in Figure 1) and flares (brighter areas, Figure 2). The intensity and number of these irregularities varies with a periodicity of approximately 11 years, a phenomenon called "The Solar Cycle". The relevance of the Solar Cycle on earth climate became an important issue with the publication of an article by J.A. Eddy in the Journal Science in 1976. In this research strong evidence was presented about an historical period between 1645 and 1715, called "The Maunder Minimum", where solar spots virtually disappeared, coinciding this with much lower than average temperatures.

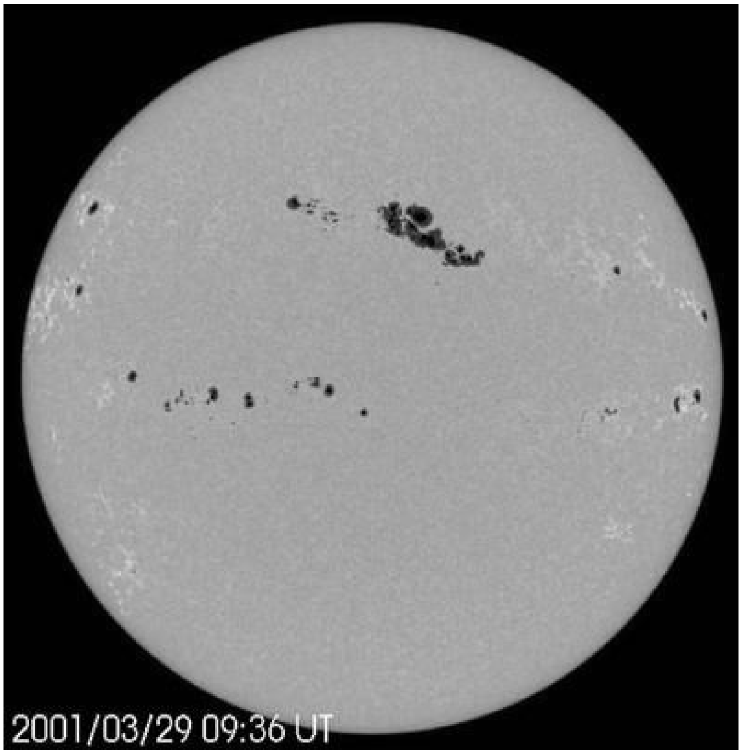

Figure 1: Sunspots

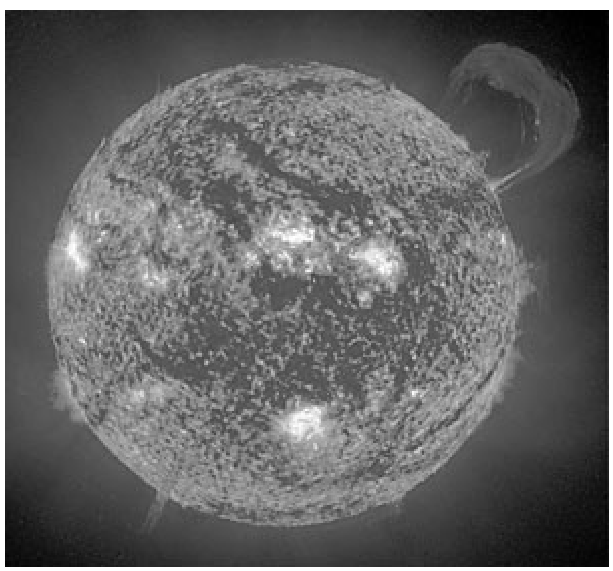

Figure 2: Solar Flares

The absence of solar spots during the Maunder minimum was mentioned by Wolf (1856,1868) and Spörer (1887). The investigations was continued by Maunder (1890, 1894, 1922), who strongly defended the observational evidence from the skeptical scientific community that questioned the reliability of the observations. Eddy was able to convince many that Maunders arguments were sound and robust, and he added new observational evidence, like the absence of solar corona and variations of the Carbon 14 isotopes in the atmosphere, during the Maunder minimum. Carbon 14 production in the atmosphere is sensitive to the intensity of the galactic cosmic rays flux, which in turn is modulated by the solar activity cycle, as we will describe later on.

Recent Investigations

Now days measurements by artificial satellites demonstrate indeeed that during the solar cycle we have a variation of about 0.1% in the total solar flux, that could trigger important climatic effects principally due to absorption of ultraviolet light in the upper atmosphere (Haigh, 1996, 1999, Schindell et al, 1999). Furthermore, as we mentioned earlier, the solar activity also alter climate in an indirect way by modulating the intensity of the Galactic Cosmic Ray Flux (GCRF). The solar wing magnetic field serves as a shield that deviates cosmic rays, and this produces a reduction in cosmic rays during the solar maximum activity. Therefore, this interaction creates an anti-correlation between the solar cycle and the induced Galactic Cosmic Rays Cycle (Figure 3). Cosmic rays help in the production of ions that facilitates condensation of water vapor and, hence, in the development of atmospheric cloud cover. Observational evidence in favor of an increase in cloud cover and precipitation that correlate with cosmic ray flux are given by Svensmark (1997, 1998), and Kniveton and Todd (2001) (Figure 4).

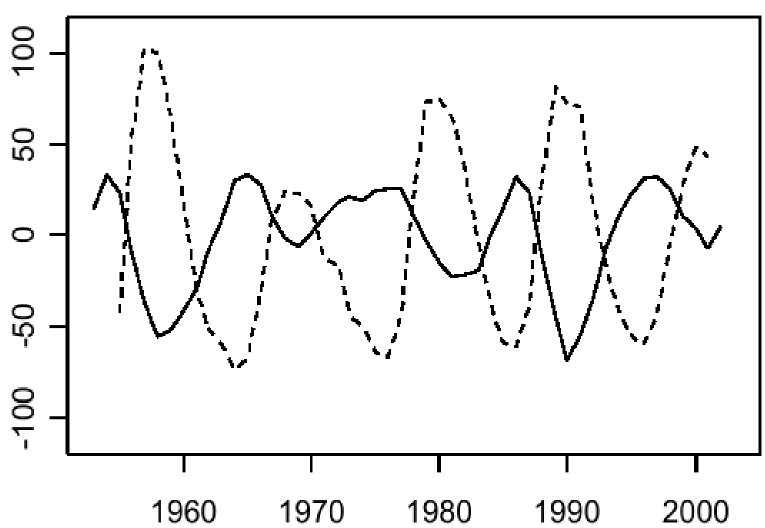

Figure 3: Anti-correlation between sunspots cycle (dash line) and galactic cosmic rays (solid line)

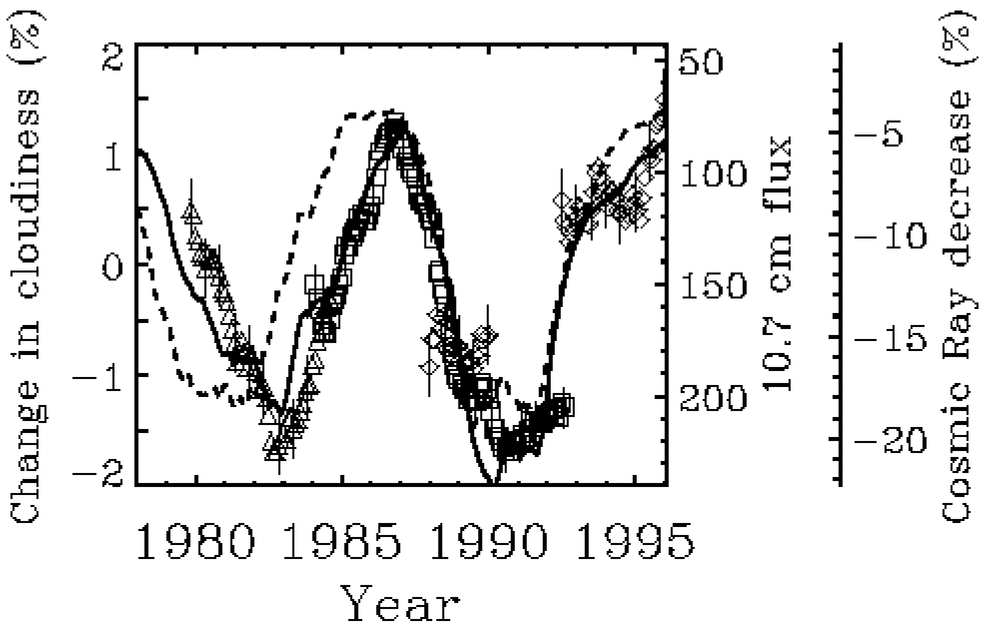

Figure 4: Comparison of cloud cover (symbols) and galactic cosmic rays flux (solid line) (Svensmark 2007)

Lower radiation together with a larger cloud cover at solar cycle minimum (Galactic Cosmic Rays maximum) suggest an effect in Earth surface temperatures, and indeeed we have found a correlation (anti-correlation) between the variations in five years average global temperatures and the Solar (Cosmic rays) Cycle, as illustrated in Figure 5. The above considerations motivates the following hyphotesis: At Cosmic Rays Flux maximum more clouds are developed and precipitation, while the solar radiation flux is at minimum, thus decreasing the energy reaching the earth surface, and then lowering temperatures. On the other hand, cyclical variations in global temperatures will also have a cyclic effect in the thermal expansion and contraction of the Oceans. Furthermore, with lower temperatures and higher precipitations we will also increase the amount of water and snow accumulation in the continents, thus reducing the mean sea level. In favor of the above hypothesis we have that Robinson and Banzai (2001) observed high quasi-decadal correlations between temperatures and snow cover in the northern hemisphere. Moreover, in what follows, we will describe indications of periodic amplitude modulations in the seasonal mean sea level minima at two sites in the seashores of Puerto Rico that correlates with the sun spot cycle.

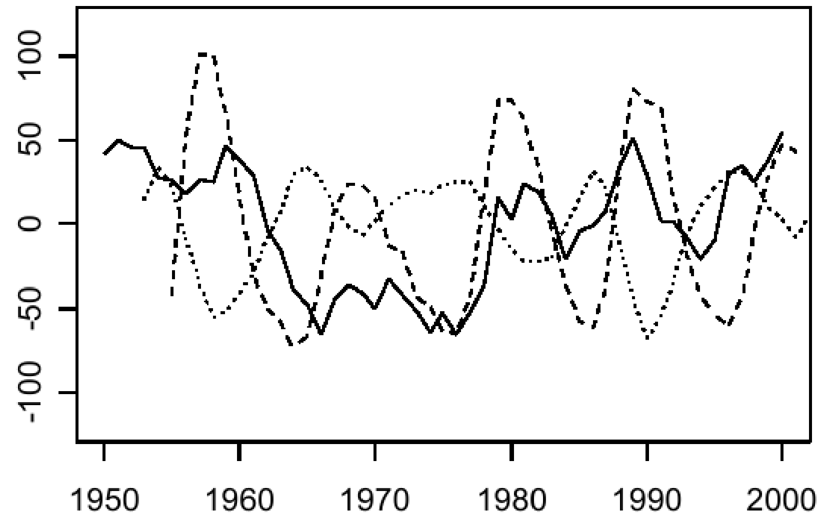

Figure 5: Sunspot cycle (dash line), galactic cosmic rays cycle (dot line), and global 5 years average surface temperature

Evidence of Correlation Between Sea Level Fluctuations and the Solar Cycle

Data from the monthly mean sea levels at San Juan (18°27'N, 66°05'W) and Magueyes Island (17°58'N 67°03'W) Puerto Rico where analyzed seeking correlations between sea level fluctuations and the well known sunspot cycle. The monthly mean sunspot data was obtained from the NOAA (National Oceanographic and Atmospheric Administration) in the period between 1955 and 2002. The data was smoothed by taking the average of two adjacent 12-month running means of monthly means. The sea level data was obtained from GLOSS (Global Sea Level Observing System) and consisted of the monthly means of sea levels for the two locations mentioned above. The San Juan data contains 39 years from 1962 to 2001 and the Magueyes data contains 46 years from 1955 to 2001. Besides some gaps in the San Juan time series, between 1974 and 1979 and between 1988 and 1990, both data sets are remarkably similar in the measurements levels and the observed fluctuations. This perception was tested objectively by calculating the correlation coefficient between the time series during the period between 1980 and 2000, resulting in a correlation $r = 0.97$. Given the strong correlation between both series , we reconstructed the missing data for the San Juan data set by using the data from Magueyes (Figure 6). Both series show a seasonal cycle with a variable amplitude that, when compared with the solar cycle data (Figure 7), suggests that the mean sea minima are in lower than average level with a periodicity similar to the one in the sunspot cycle. To put that possibility to test an analysis of the sea level data was carried out, where the data set was linearly detrended, the minimum sea levels extracted from the data and three years average taken (see Figure 8). We took three years averages, since this time is approximately equal to the full width half maximum (FWHM) over the average sunspot number in a cycle, which better take into account the fact that the solar maxima or minima effects spread over more than one year. We found that a cross-correlation function analysis between solar spot number and the curves in Figure 8 from Magueyes reveals a strong anti-correlation of $r = -0.71$ for a delay of 2.97 years, and a significant correlation of $r = 0.64$, for a delay of 7.97 years. The corresponding analysis for San Juan show an anti-correlation of $r = -0.63$ and a correlation $r = 0.46$ with similar delays.

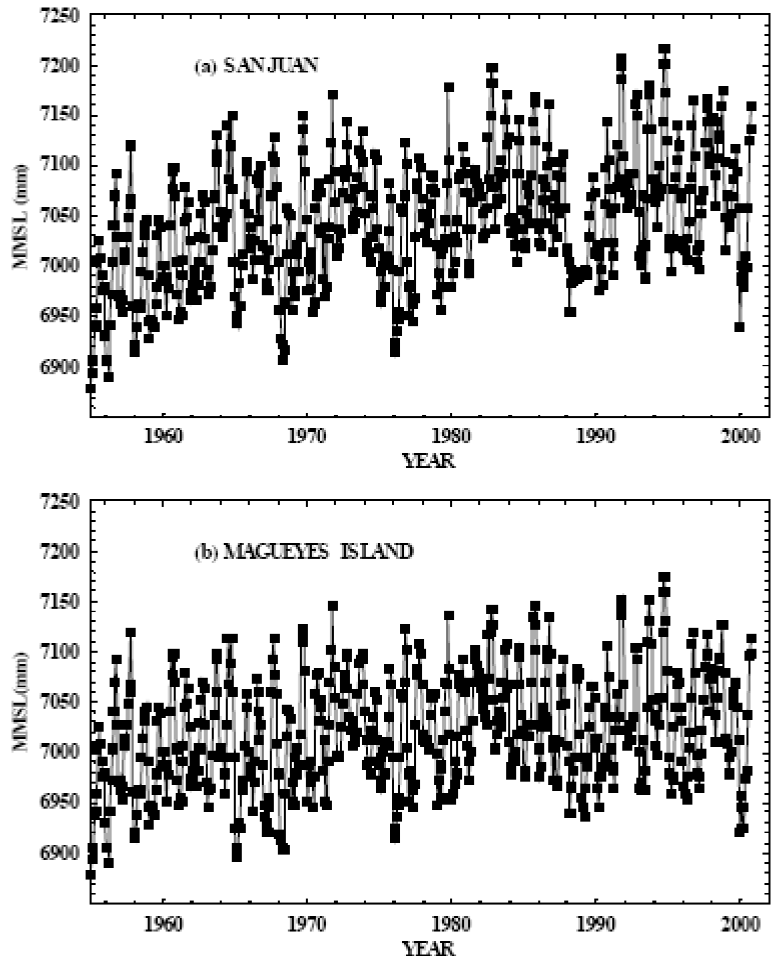

Figure 6: Time Series of Monthly Mean Sea Level (MMSL) for (a) San Juan (b) Magueyes Island

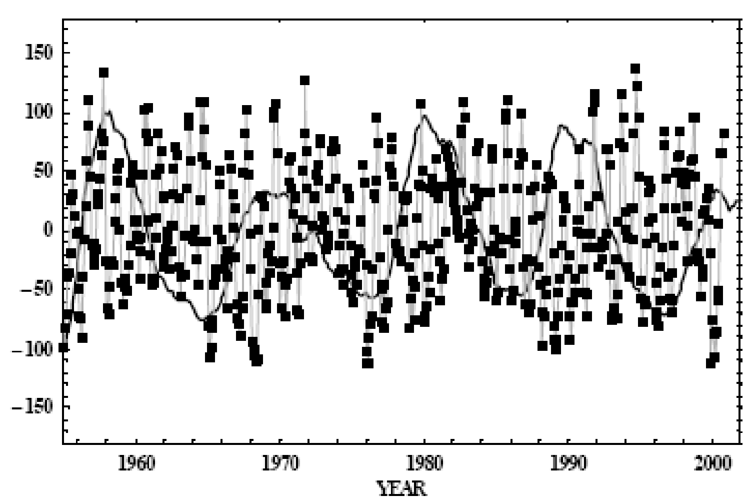

Figure 7: Comparison of detrended sunspot data (dark line) and monthly sea levels for Magueyes Island (light gray)

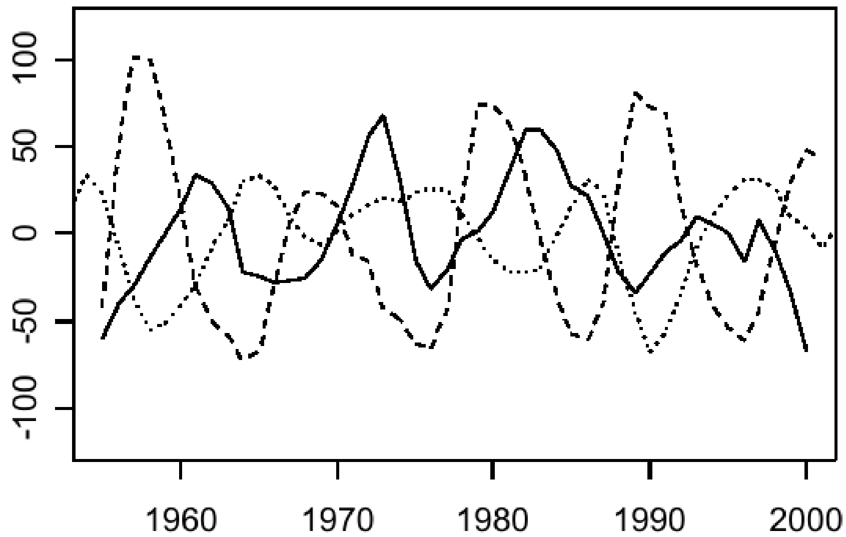

Figure 8: Sunspot cycle (dash line), galactic cosmic rays cycle (dot line), and mean sea level at Magueyes Island (solid line).

Conclusions

We are in the process of extending our investigations to other stations, and to actualice the studies in Puerto Rico. Similar correlations of mean sea level and the solar cycle are already found in data from Charleston, South Carolina, and Fernandina Beach, Florida. Preliminary results from new data, since 2001, suggest that the pattern continues. If we then extrapolate this correlations we will expect the new sea level minimum around the year 2009, which is about two years after the solar minimum of 2007.

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