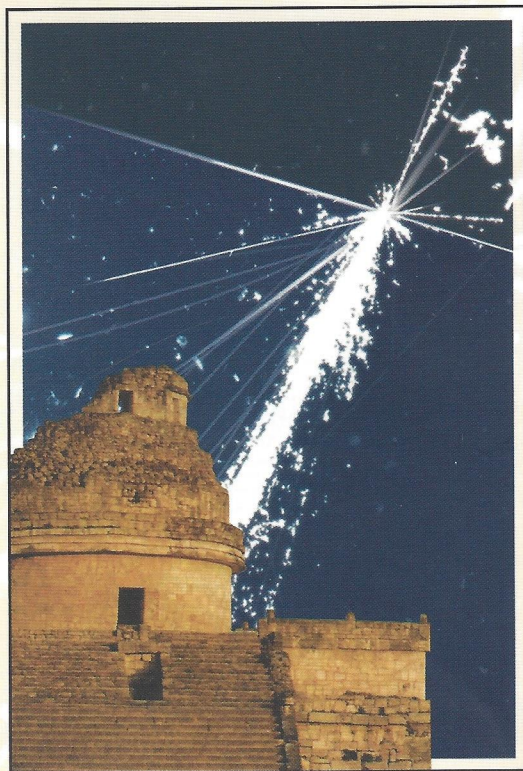


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On the trend of Atlantic Hurricane with Cosmic Rays

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Abstract: The purpose of this study is to examine the cosmophysical periodicities that could possible be related with a modulation in the process of hurricanes development. One of the ways to analyze two nonstationary series, to discern whether there is a linear relation or not is by means of the CoherenceWavelet method, which furnish valuable information about when and which periodicity do coincide in time, and about its nature, linear or non-linear relation, provided there is not a noticeable di-phase among them. In the present work we use the Morlet wavelet technique for the annual number of North Atlantic hurricanes between 1851 and 2005. To find the relationship between hurricanes and cosmophysical phenomena series in time-frequency space, we use then the Wavelet Coherence analysis: it is found that the more prominent periodicity with a coherence > 0.95 , is that of 30 ± 2 yrs.

Introduction

One of the main goals of Space climate research is to know how and when the periodicities of space phenomena do modulate terrestrial Climatic changes. One of the principal difficulties in quantifying the role of the space phenomena on climate changes has been the absence of long-term measurements of both, the climatic and space phenomena. In the last years more and more investigations show that the solar activity [1, 2] and Cosmic Rays, have noticeable impact on the meteorological parameters. However, the influence of cosmophysical phenomena on climatic phenomena is currently debated (e.g., [3, 4]). Previous work by means of a correlational analysis seems to indicate that certain extraterrestrial phenomena could have some kind of relation with the occurrence of Hurricanes [5, 6]. It is even speculated that such kind of correlations could seat the basis of deeper studies to use the results as indicators of hurricanes precursors. To give to those results a higher meaning, it is convenient to carry out spectral studies of the different involved timeseries to delimitate with more preciseness the existence of those potential relationships. That is,

to find incident cosmophysical periodicities that may modulate terrestrial phenomena. In this context, little attention has been given to the large scale climatic phenomena: the Atlantic Multi-decadal Oscillation (AMO). As the question about the role of the Sun in modulating these phenomena has not been clarified, it requires further assessment. In the present study we investigate the behavior of the main periodicities presented by the AMO in relation to some solar activity phenomena and Galactic Cosmic Rays (GCR). The AMO has been linked with the frequency of Atlantic hurricanes.

Data and Analysis Technique

Instrumental records of climatic phenomena exist mainly from the end of the 19th century, direct measurements of solar activity come from sunspot numbers since 1749, and direct and trustable Cosmic Ray data since 1950s decade. Then, to assess the long-term relations between space phenomena and indicators of the global climate, it is necessary to use reconstructions of GCR, solar

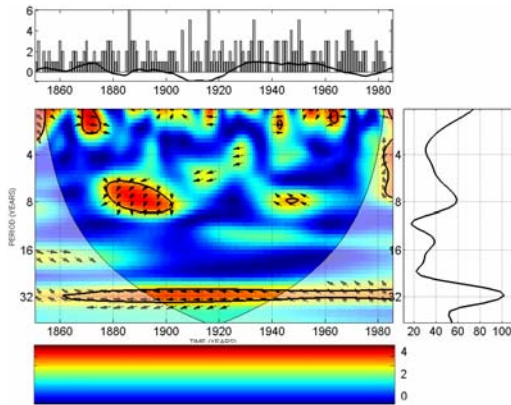


Figure 1: Amo- hurricanes of all magnitudes

and climate phenomena. We work with the annual data for AMO between 1851-1985. The time series were obtained from the World Data Center for Paleoclimatology: (<http://www.ncdc.noaa.gov/paleo/>). Solar Activity is characterized by different indexes, among one of them it is the daily number of Sun Spots number (SS) web page (<http://www.ngdc.noaa.gov/stp/SOLAR>). Data on Sea-Surface temperature in the north atlantic is given as Temperature Anomalies in the literature. We took data from (<ftp://ftp.ncdc.noaa.gov/pub/data/paleo/treering/reconstructions/amogray2004.txt>), for the period 1851-2005. The ^{10}Be , is considered as a Proxy of Galactic Cosmic Rays. We have considered the ^{10}Be concentration in the Dye - 3 ice core (65:2 N, 43:8 W, 2477 m altitude). Data was taken from [7] for the period 1851-1985. The Web for hurricanes, there are a lot of cyclone data , we have considered the following: (<http://weather.unisys.com/hurricane>).

Wavelet Analysis

The Coherence is defined as the cross-spectrum normalized to an individual power spectrum. It is a number between 0 and 1 and gives a measurement of the cross-correlation between two time-series and a frequency function. The wavelet squared coherency is a measure of the intensity of the covariance of the two series in time-frequency space [8]. If two time series have similar periodicities this does not imply a cause and effect situation. A way to study if there is a relation between two non-stationary time series and to discern whether there is a lineal or non linear

relation is by means of the *Wavelet Coherence Method*. In the present study this e done, with cosmic data, e.g., Galactic Cosmic Rays (GCR) versus parameters of the hurricanes, as well as with climatic phenomena, presumable associated with hurricanes, as for instance the Atlantic Multidecadal Oscillation AMO [9]).

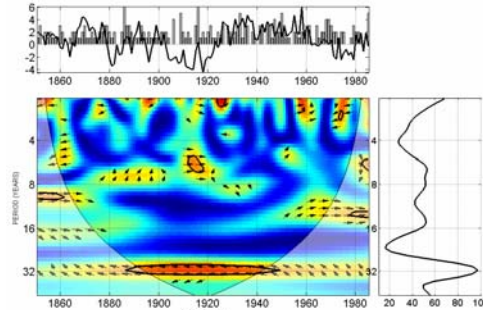


Figure 2: SST anomalies- hurricanes of all Magnitudes

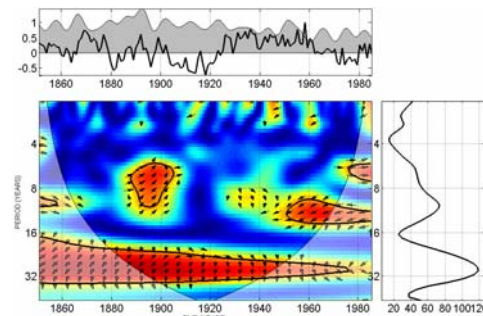


Figure 3: SST anomalies - ^{10}Be

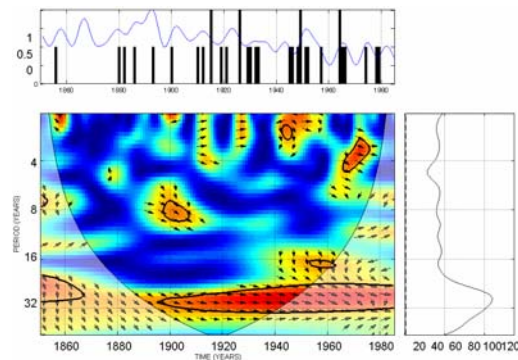


Figure 4: hurricanes of magnitude- 4 - ^{10}be

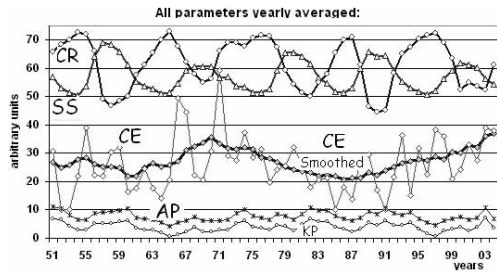


Figure 5: Cyclic behavior of the Change of total energy of all north Atlantic hurricanes.

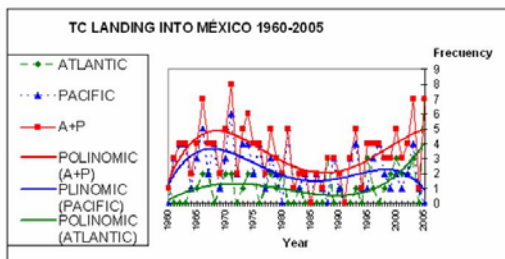


Figure 6: Cyclic behavior of Tropical Cyclones in a period of 45 years.

For the Wavelet spectrum, we estimate the significance level for each scale using only values inside the cone of influence (COI). The COI is the region of the wavelet spectrum in which edge effects become important. The arrows in the coherence spectra show the phase between the phenomena: arrows at 0° indicate that both phenomena are in phase and arrows at 180° indicate that they are in anti-phase; these two cases imply a linear relation between the considered phenomena. Arrows at 90° and 270° indicate an out of phase situation, which means that both phenomena have a non-linear relation. Based on these explanations, we may state that the wavelet coherence is specially useful in highlighting the time and frequency intervals where two phenomena have a strong interaction.

Results

The wavelet Morlet spectral analysis of each of the time series of ^{10}Be (proxy of GCR), hurricanes, AMO and SST anomalies shows common periodicities, from which the more prominent is that of 30 ± 2 years. Results can be summarized as follows: a) there is a coherence of 0.95 inside the COI between the AMO and SST anomalies through the band of 15-40 years in the time inter-

val 1870-1960. The oscillations in the 30 years frequency are completely in phase, indicating a linear relation among both phenomena, something which is not surprising and very well known by climate specialists. b) there is a coherence of 0.90 inside the COI between the AMO and the SST anomalies with the total number of hurricanes (including all magnitudes from 1 to 5) at the 30 years frequency in the time interval 1890-1945. The oscillations have a tendency to be in anti-phase, indicating a linear relation among both phenomena (Fig 1-2). When seen an individual kind of hurricanes, e.g. those of Magnitud-4, the relation is not a linear one but rather it presents a complex relation. c) there is a coherence of 0.95 inside the COI between the AMO and SST anomalies with ^{10}Be at the 30 years frequency, in the time interval 1880-1945. The oscillations have a tendency to be quasi-perpendicular, indicating a complex relation among both phenomena and GCR (Fig. 3). d) there is a non-linear coherence 0:9 inside the COI between the hurricanes of magnitude-3 and ^{10}Be at the 30 years frequency, in the time interval 1890-1945. For hurricanes of magnitude-4 the coherence is 0.9 at the same frequency, with a tendency of the oscillations to be in anti-phase, indicating a linear relationship among both phenomena, whereas for hurricanes of magnitude-4 the periodicities are in phase (Fig. 4). e) there is a non-linear coherence of 0.9 inside the COI between the AMO and SST anomalies with SS at the 30 years frequency, in the time interval 1880-1890. This is gradually attenuated during the minimum of the modern secular solar cycle (1890-1930), with a coherence of 0.5 and a complex phase between the oscillations.

Analysis and Conclusions

We have found that there are common periodicity between some extraterrestrial and terrestrial phenomena, namely 3.5, 5.5, 7, 11 and the more prominent one, that of 30 ± 2 yrs. If the coherence at the later frequency with other phenomena may be interpreted as a modulator factor, then, from the analysis of the previous results it could be said that the modulator agent of terrestrial phenomena is the open solar magnetic field, translated in GCR (via the ^{10}Be). This modulation seems to be more important in the period 1880 – 1960. That does not mean there is no modulation after and before, but according to the coherence

wavelet technique the significance level is lower of 95%: It seems then that GCR are modulating in some way both the AMO and SST (e.g. Fig. 3), and these in turn modulate in some way hurricanes as it can be seen from the Coherence wavelet analysis (e.g. Figs. 1-2) which confirms the conventional statement of hurricanes to be linked to warmer oceans. This is to a certain extent confirmed by the good coherence between GCR (^{10}Be) and the number of hurricanes of magnitude-4 (Fig. 4). In contrast, the indicator of closed solar magnetic field (via SS) presents, within the COI, a lower and attenuated coherence with the terrestrial phenomena. It should be emphasized that we have put in evidence, for the first time from a Coherence wavelet study, the existence of fluctuations in the flux of GCR in the frequency of 30 ± 2 years, through the study of historical data (^{10}Be). On the other hand, it is shown in Fig. 5 that the yearly change of Total Energy (CE and CE smoothed) released from all the cyclones may be well approximated with two overlapping sinusoids: one of them - with a period approximately 3.5 years, the other one about 30 years. Besides, based on a worldwide analysis of Accumulated Cyclone Energy (ACE), it has been recently shown [10] the existence of a large increasing trend in tropical cyclone (TC) intensity for the North Atlantic basin, and a considerable decreasing trend for the Northeast Pacific. In the particular case of TC into Mexican coasts, we show in Fig. 6 the same tendency: i.e. a frequency increases in the Atlantic and a decrease in the Northeast Pacific at least during the last decade. The sum for the two basins is dominated by the Atlantic trend. It can be seen from Fig. 5 that a similar increasing trend is followed by the total cyclone energy CE during the last years. Also, it should be noted that in both curves (Fig. 6 and the CE smoothed curve in Fig. 5, there is a cyclical behavior dominated by a quasi-30 years wave. It is worth mentioning that an analysis of the total number of Tropical Cyclones (TC) and the number of category 4-5 (Saffir-Simpson scale) in the Northwest Pacific basin also shows such a cyclic behavior [11], as it does other index of TC intensity, namely the Potential Destruction index (PDI) [12]. Through Figs. 5 and 6 we can draw information about the years of minimum and maximum number of hurricanes, during cycles of 30 yrs, which is not a casual cycle, since we have shown

it prolongs at least back to 1851. Finally, we claim that the incidence of GCR on the clouds is an additional warming factor of the SST and AMO, as it does the greenhouse gases on the earth's surface temperature [13], which is translated in the development of hurricanes in a non-linear way according to the higher or lower GCR flux.

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