SOLAR LUMINOSITY, SURFACE EARTH TEMPERATURES, SUNSPOTS SOLAR EFFECTS AND EARTH CLIMATE IN THE CLOSE FUTURE.

M.Cattani (mcattani@if.us.br)
Institute of Physics of the University of São Paulo

Abstract. This a didactical paper written to graduate students of Physics to show the fundamental contribution of the solar luminosity to the Earth climate. Are analyzed temperatures measured from 800 AD to 2000 AD and, in particular, the effects of temperatures generated by sunspots solar effects in the period that goes from 1600 AD to 2000 AD. Climate predictions to a close future are also analyzed.
Key words:Solar luminosity; surface Earth temperatures; sunspots effects; little ice age.

(I)Introduction.

This paper was written in a simplest possible way, almost in a journalistic style, leaving to the readers more detailed aspects that can be found in references mentioned in the text. In **Section 1** is estimated the Earth surface temperature due to energy emitted by the Sun using the black body radiation. **In Section 2** are defined Ice Ages or Glacial Periods, Interglacial Periods or "Greenhouse Periods", are mentioned the five major Ice Ages and main causes for glaciations and deglaciations. In **Section 3** will be shown the recent period that goes from 800 AD up to 2000 AD. In **Section 4** are seen the Sunspots observed in the Little Ice Age that goes from 1645 and 1715 and their effects at the Earth surface temperatures. In **Section 5** are presented some predictions of the Earth climate to a close future.

(1)Solar Energy absorbed by the Earth.

Let us estimate the effect of the solar luminosity on the temperature of the surface Earth. Thus, supposing that the Sun and the Earth are "black bodies" [1] we will estimate the surface Earth temperature taking into account the solar energy incident on the Earth.[2] So, the Sun with a surface temperature T_S and surface area A_S, according to the Stefan-Boltzmann law,[1] radiates a total energy power given $E_S = \sigma A_S T_S^4 = 4\pi\sigma R_S^2 T_S^4$. If the distance between the Sun and the Earth is equal to a_o the flux of energy received by the Earth would be $\phi_E \approx \pi R_E^2(E_S/4\pi a_o^2)$. Supposing that the Sun and Earth are in thermal equilibrium and that the Earth surface has an area A_E and temperature T_E, we can write

$$\sigma A_E T_E^4 \approx \pi R_E^2 (E_S/4\pi a_o^2) \qquad \rightarrow \qquad T_E \approx (R_S^2/4a_o^2)^{1/4}\, T_S \qquad (1.1),$$

showing that the Earth surface temperature T_E is *directly proportional* to the solar temperature T_S.

Taking into account[2] that $R_S = 6.96\ 10^8$ m, $T_S = 5780$ K and $a_o = 1.49\ 10^7$ km, we see using Eq.(I.1) that $T_E = 279$ K = 6 ^oC. Of course, T_E must be taken only as a *rough average value* of the surface temperature. Due to the Earth spherical form the incidence of the solar rays will be very different in equatorial and poles regions.

It is very important to note that in the T_E estimation, given by Eq.(1.1), are not considered, for instance, *atmospheric effects*[3] like the "greenhouse effect" and the "albedo". The first one is responsible for the heating of the surface temperature and the albedo is the fraction of the incident solar energy reflected by the Earth. Since the albedo[3] is ~ 0.3, which means that almost 1/3 of the incident Solar energy is reflected, the average surface temperature of the Earth would be 0.7 T_E, that is, 0.7 T_E = 255 K ≈ -18 ^oC. Taking into account that the nowadays measured *average temperature* is $\theta_E \approx 15$ ^oC [3] and that at the poles we can have, for instance, - 70 ^oC and at the equatorial region ~ + 50 ^oC we see that the simple estimation $T_E = 6$ ^oC is inadequate.

For example, Mars surface temperatures, are ~ 293 K = 20 ^oC at noon, at the equator, and ~120 K = - 153 ^oC at the poles.

Finally, note that the very hot nucleus of the Earth[4]gives is an insignificant contribution to the Earth surface temperature. The surface heating of the Earth is essentially due to the incident solar energy, estimated above.

(2) Ice Ages.

Ice Age is a long period of reduction in the temperature of Earth´s surface and atmosphere during which a significant part of the continents is frozen.[5-8] Results in the presence or expansion of continental and polar ice sheets. Ice ages are also known as "glaciations", "glacial periods", "glacials"...The intermittent warm periods within ice ages are called "interglacials". The Earth history is marked by evidences of numerous glacial periods, since billions of years ago.[5-8] The Earth conserve the marks of these old glaciations. The glaciation of 750 million-years, for example, was particularly significant. The ice seems to have covered during this period almost all the planet, till the equator. There have been at least five major ice ages : Huronian, Cryogenian, Andean-Saharan, late Paleozoic, and the latest Quaternary Ice Age. Between these five *ice ages* or *glacial periods*, there were "deglaciations" periods, that is, when all or most part of glaciers melt, even in high latitudes. These are known as *interglacial* or *greenhouse periods*.[5-8]

Many theories have been proposed to explain the glaciations and deglaciations[5-8] supposing that they are mainly caused by:

(a)Variations in the Sun´s energy output.

(b)Variations in Earth´s orbit (Milankovitch cycles).

(c)Volcanism.

(d)Tectonic motions (continental and oceanic).

(e)Meteor falls.

(f)Atmospheric effects ("greenhouse effect").

(g)Human-induced changes.

In **Figure (2.1)** is shown the temperature of the Earth from 500 million years up recent years.[9]

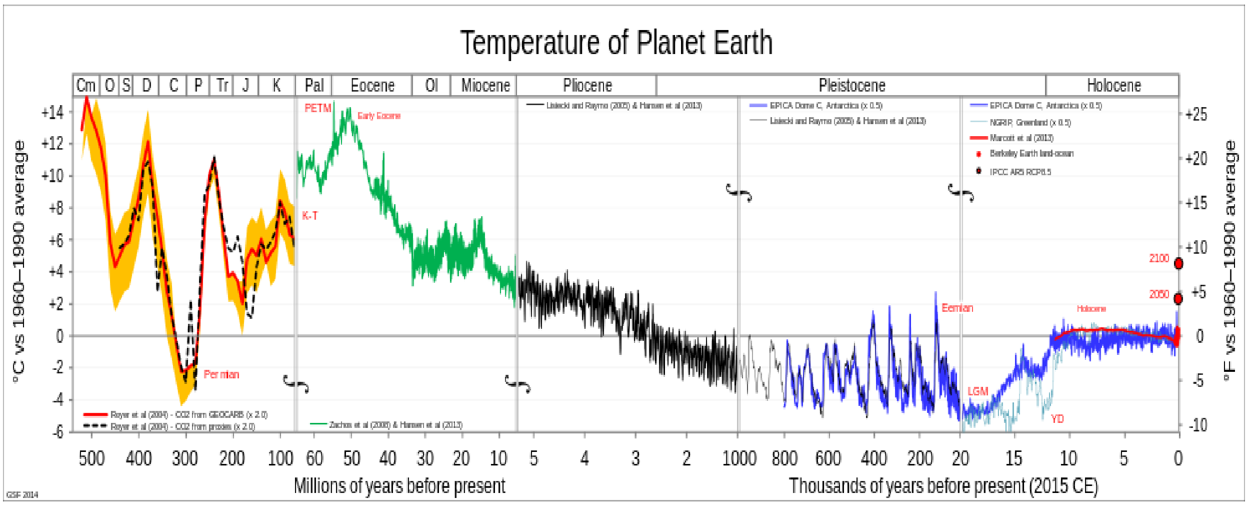


Figure (2.1). The horizontal line indicates the temperature T = 15 ^oC.

From **Fig. (2.1),** in the **Pleistocene**, from 1 million year up to ~10.000 year, the Earth temperature was $\theta_E \sim -20\ ^oC$. Between 20.000 and 15.000 years we had $\theta_E \sim -25\ ^oC$. In the "hot" **Holocene** $\theta_E \sim 15\ ^oC$ (see also **Fig.(2.3)**).

In **Figure (2.2)** is shown the reconstruction of the temperature deviations ΔT(°C) over past 5 million years of climate history.[9] The dotted horizontal line, as before, indicates the temperature T =15°C.

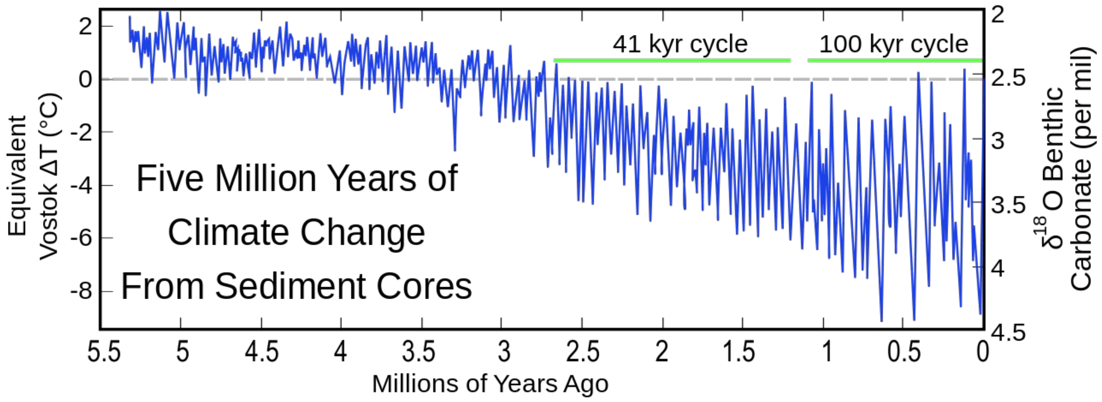


Figure (2.2). Sediment records showing the fluctuating sequences of glacials and interglacials during the last several million years. Note that kyr = 10^3 years.

The latest Quaternary Ice Age started about 2.6 million years ago with the formation of the Arctic ice cap. Since then, the world has seen cycles of glaciations with ice sheets advancing and retreating on 40,000 and 100,000-years time scales called *glacial periods:* glacial advances and glacial retreats. The last **glacial period ended about 10,000 years ago** and the Earth is currently in an interglacial period called **Holocene.**[9,10] All that remains of the continental ice sheets are the Greenland and Antarctic ice sheets and smaller glaciers such as on Baffin island. In **Figure (2.3)** is shown the temperature variations during the Holocene.[9,10]

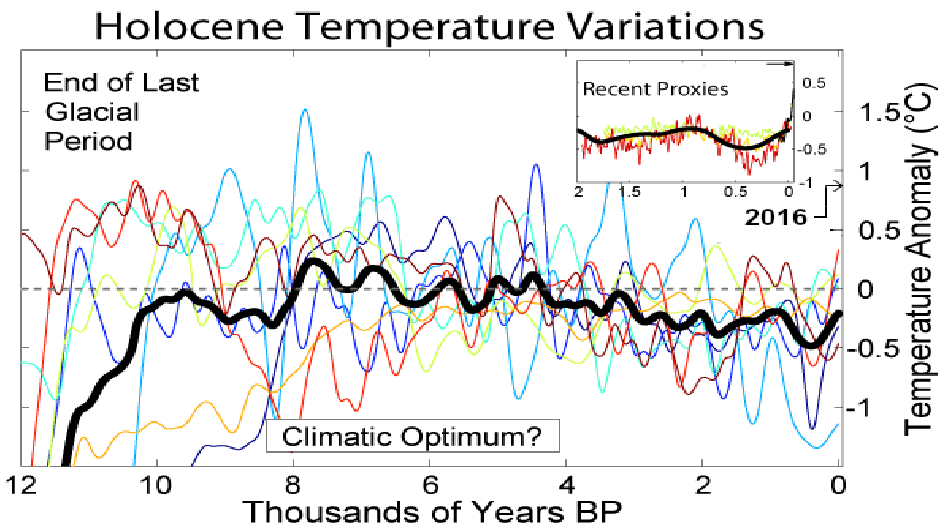
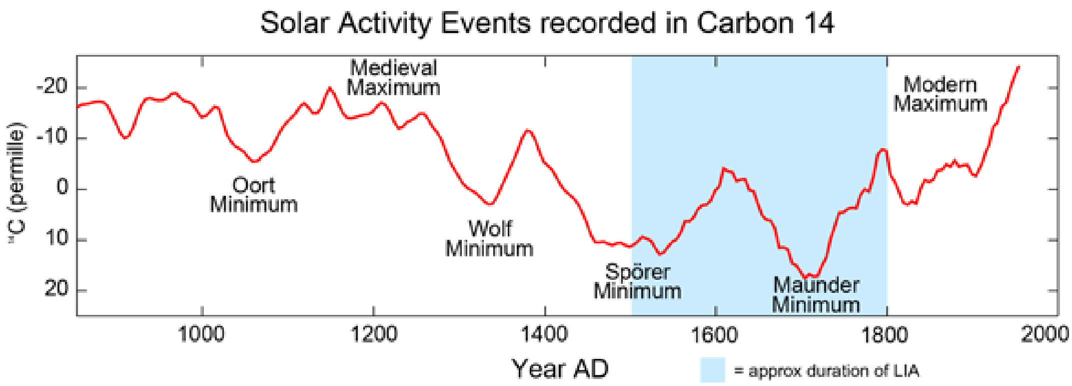


Figure (2.3). Detailed temperature variations during the Holocene. The horizontal dotted line indicates the temperature T = 15 °C.

(3)Period from 800 AD to 2000 AD.

In **Figure (3.1)** is shown the solar activity recorded in C^{14} as a function of the year, from 900 AD up to 2000 AD.[6]



Figure(3.1). Solar Activity events recorded in C^{14} from 900 AD to 2000 AD.

In **Figure (3.2)** is seen the reconstructed temperature anomaly in °C as a function of the year, in the period from 800 AD to 2000 AD.[6]

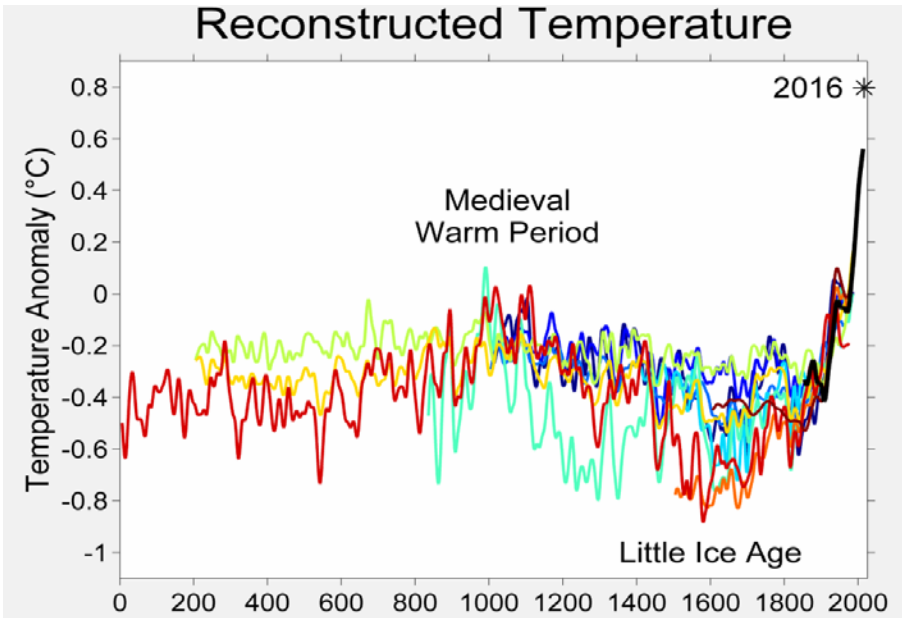


Figure (3.2). Reconstructed temperature anomaly in °C in the period from 800 AD to 2000AD. The 0 of the reconstructed temperature indicates T = 15°C.

(4) Period from 1600 AD to 2000 AD and the Little Ice Age.

In this period, from 1600 AD to 2000 AD,[11] were performed the first measurements of the number of Sunspots in the history of Physics. In **Figure (4.1)** is shown the observed evolution of these sunspots numbers during these 400 years.

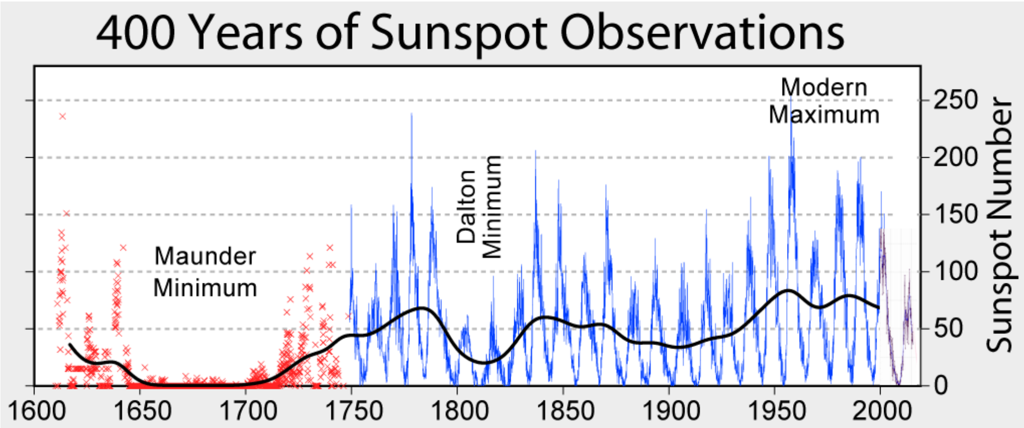


Figure (4.1). Sunspot observations in the period from 1600 AD to 2000 AD.

The period named "**Little Ice Age"** shown in **Fig. (3.2)** that goes from 1645 AD to 1715 AD does not correspond really to a glaciation period but to a *cold climatic fluctuation* inside the interglacial Quaternary Ice Age period. It was also called "Little Glaciation". The minimum value of temperatures shown in **Figure (3.2)** was observed mainly in the North hemisphere between 1400 and 1900. The thermal minimum period is between 1645 and 1715 (see **Figures (3.1) and (3.2)**), named "Maunder Minimum". The winter of this season was the strictest observed.

It is very important to note that they clearly show, by the first time, a direct evidence for a cause-and-effect connection between the solar luminosity and the measured temperatures on Earth. For instance, the minimum of temperatures, seen **Figs.(3.1)** and **(3.2),**coincides with the minimum of the solar luminosity called **Maunder Minimum** at 1675 seen in **Fig.(4.1).** According to **Fig.(3.1)**,with the increasing luminosity the temperatures also increase reaching the **Modern Maximum** close to 2000.

In **Fig. (4.2)** is seen a picture of the frozen river Thames[5] in 1677.

Figure (4.2). Picture with the frozen river Thames.[5]

(5) Predictions for the Earth Climate in a close future.

From the mathematical point of view, **exact predictions are impossible** because some physical causes responsible for the climate are stochastic, as mentioned in **Section 2.** First, to propose reliable climate done, *at least*, in the predictions is prudent analyze climate observations last 10.000 years. In this way, let us consider the past 10.000 years in the **Holocene Period**, seen in **Fig.(5.1).** One verify that in these 10.000 years, the Earth temperature remained approximately constant (compared with turbulent preceding periods) close to 15 ^{o}C. There is only one exception: the "miniglaciation" (Little Ice Age) between 1645 and 1715.

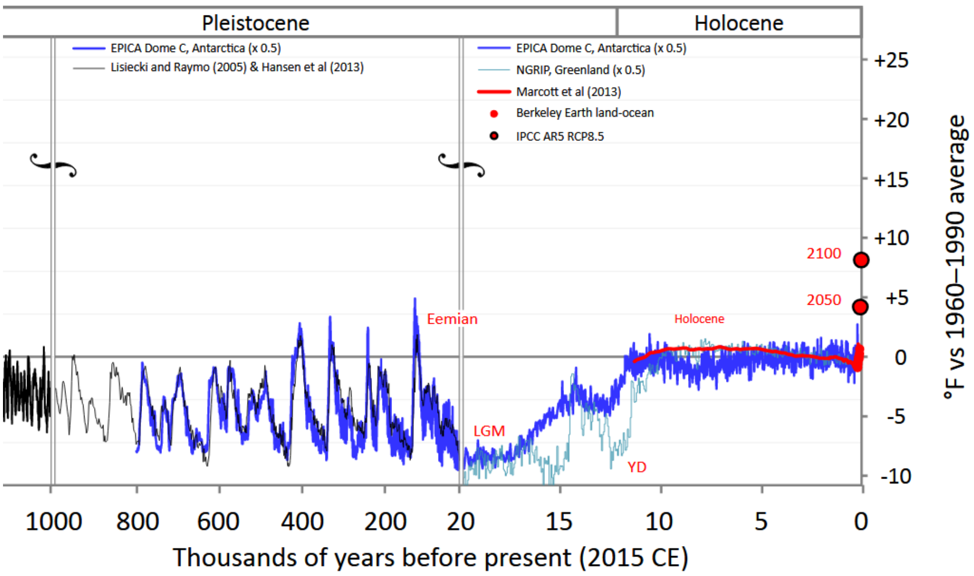


Figure (5.1). Holocene Period in details.

With a more detailed analysis, **Figures (2.3)**, **(3.1**) and **(3.2)** it is possible to distinguish clearly 3 different climate regions: **Warm Medieval**

Period (1100-1300), **Ice Age Period** (1600-1800) and the **Warm Modern Period** (1900 - **?**). In the last Warm Period that doesn't seem to be over yet, have been detected[12] temperature anomalies as large as 0.6 ^{o}C and 0.9^{o}C.

Let us analyze two different predictions that have been proposed for the Earth climate in the close future:

(I) Natural continuation of the Interglacial Holocene period.

Recent researches have shown that 0.6 and 0.9 ^{o}C temperature anomalies are **regional shifts** rather than **global**.[13] These would have been created by a new increasing of the **solar activity**[11,14] that began in ~ 1900 hitting a new maximum between 2010 and 2013. The Solar cycles have an average period of 11 years (see **Fig.(4.1)**). In this way, it is expected that the **Modern Warm Period** would finish at ~ 2.200. That is, with a lifetime of 300 years, like the **Medieval Warm Period**. It is also conjectured[15] that at 2021 the Solar activity will have a sharp decrease and the temperatures will begin to fall sharply by 2030. The temperatures could reach such low levels that will occur a "miniglaciation" similar to that of the Little Ice Age.

Predicted changes in orbital forcing suggest that the next glacial period would begin at least 50.000 years from now, due to the Milankovitch cycles.[15]. However, anthropogenic forcing from increased greenhouse gases is estimated to potentially outweigh the orbital forcing of the Milankovitch cycles for hundreds of thousands of years.[16]

(II)Global Heating.

Based in detected[12] temperature anomalies, like 0.6 ^{o}C and 0.9^{o}C, would occur a high "global heating" of the Earth. Mathematical models have been proposed predicting temperature anomalies like + 5^{o}C at 2050 and + 9^{o}C at 2100 (see two red dots in **Fig.(5.1)**). Note that these are very large anomalies that have been found only in extremely hot periods, Pliocene and Miocene, about 5 to 40 million years ago(see **Fig.(2.1)**). Thus, the "Global Heating" would be catastrophic.

This prediction is criticized because:

(1)Are not taken into account extraterrestrials factors like solar effects and cosmic radiation effects in the planet atmosphere.[13]

(2)Up to now, no reliable physical process was developed to explain how only men and their greenhouse gases emissions would be able to create a catastrophic global heating.[17]

REFERENCES

[1]livro básico "corpo negro"
[2] https://paralysisbyanalysis52.wordpress.com/2013/07/14/curiosidades-v-qual-e-a-temperatura-da-terra/
[3] https://en.wikipedia.org/wiki/Greenhouse_effect
[4]https://www.google.com/search?client=firefox-b-d&q=hot+earth+nucleus
[5] https://fr.wikipedia.org/wiki/Glaciation
[6]https://www.google.com/search?q=mini+glaciation+at+the+middle+age&client=firefox-b-d&tbm=isch&source=iu&ictx=1&fir=6XbKbsz49Bca9M%253A%252Ce6BPgm1bzr6WxM%252C_&vet=1&usg=AI4_-kSTgv0MLlBMKAYeOk3biab4tda1sg&sa=X&ved=2ahUKEwjF4t_ZkN7mAhXVD7kGHVHiBNUQ9QEwAHoECAYQAw#imgrc=_&vet=1
[7] https://en.wikipedia.org/wiki/Ice_age
[8]https://en.wikipedia.org/wiki/Greenhouse_and_icehouse_Earth
[9]https://en.wikipedia.org/wiki/Geologic_temperature_record
[10]https://pt.wikipedia.org/wiki/Holoceno
[11]https://pt.wikipedia.org/wiki/M%C3%ADnimo_de_Maunder/
[12] https://earthobservatory.nasa.gov/features/GlobalWarming/page4.php
[13]https://www.smithsonianmag.com/science-nature/modern-climate-change-only-worldwide-warming-event-past-2000-years-180972719/
[14]P.Foukal, C.Frölhich, H.Spruit and T.M.L.Wigley. Nature 443,161(2006).
[15]https://steemit.com/life/@alanparker/scientists-with-tears-in-their-eyes-predict-imminent-mini-glaciation-by-2030-thedayaftertomorrow
[16] https://en.wikipedia.org/wiki/Milankovitch_cycles.
[17] https://pt.wikipedia.org/wiki/Luiz_Carlos_Molion