Ameliorating Future Little Ice Ages While Reducing Global Warming

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Part II: Last Major Ice Age and Predictions for the Next Major Ice Age

For **Part I: Solar Insolation and Ice Ages** go to
http://www.roperld.com/science/InsolationIceAges.pdf
For **Part III: Ameliorating Global Warming** go to
http://www.Roperld.com/science/AmeliorateGlobalWarming.pdf

The Antarctica temperatures for the last 400,000 years, as determined by deuterium in ice core measurements, are highly correlated with some insolation calculations. One would like to be able to predict future Major Ice Ages from the solar insolation. I will use phenomenology to make some predictions. (Phenomenology: Using observed patterns and mathematics to fit time-series data and then predict future values for the data.)

Peaks Damping Model

I have devised a mathematical procedure to apply to the North-Pole insolation calculation to approximately represent the last Major Ice Age and to predict some approximate features of the next Major Ice Age. In a few words, the procedure applies progressive damping factors on the maxima and minima of the insolation as the Major Ice Age progresses in order to calculate the temperature. As described below, only the Minor Ice Age maxima are represented as quadratic equations, while the minima are just joining points. (It can also be done by representing the minima as quadratic equations, while the maxima are just joining points.) The procedure is as follows:

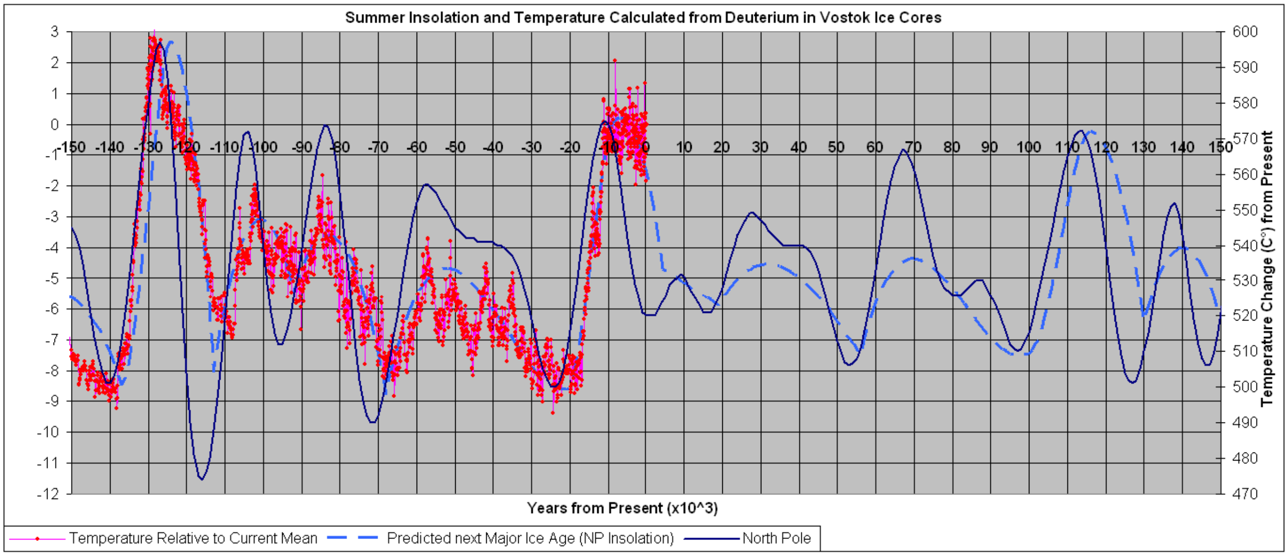
Time Interval	Mathematical Procedure
	Plot the temperature and the insolation on the same graph. Adjust the temperature scale such that the insolation minima just before the last and current Major Interglacials and the insolation maxima of the last and current Major Interglacials approximately match the measured temperatures.
From minimum before a Major Interglacial peak to the Major Interglacial peak:	Use the value of the insolation from minimum to peak.

Major Interglacial peak and the minimum after it:	Use a quadratic equation in time to fit: • The minimum before the peak • The Major Interglacial peak • The minimum after the peak plus (Major Interglacial peak - minimum)/4 These three values then determine the parameters (a,b,c) in $T = at^2 + bt + c$. Use this equation to calculate the temperature values from the Major Interglacial peak to the minimum after it.
Minimum after a Major Interglacial, the peak after it and the minimum after that peak:	Use a quadratic equation in time to fit: • The minimum before the peak plus (Major Interglacial peak - minimum)/4 • The temperature peak value is the value of the minimum before the peak plus 3·(peak – previous minimum)/4 • The minimum after the peak plus (peak – minimum)/4 These three values then determine the parameters (a,b,c) in $T = at^2 + bt + c$. Use this equation to calculate the temperature values from the minimum before the peak to the minimum after it.

Minimum before a Major Interglacial, the peak before it and the minimum before that peak:	Use a quadratic equation in time to fit: • The minimum before the peak plus (peak before the minimum - minimum)/10 • The temperature peak value is the value of the minimum before the peak plus 7·(peak – previous minimum)/20 • The minimum before the Major Interglacial These three values then determine the parameters (a,b,c) in $T = at^2 + bt + c$. Use this equation to calculate the temperature values from the minimum before the peak to the minimum after it. This gives the temperature curve in "insolation units" (See above for conversion to temperature units). Here we use the contingency given below for a case where there is a shoulder on the side of the peak; so we use the equation $T = at^3 + bt^2 + ct + d$.
Minimum before the minimum described directly above, the peak before it and the minimum before that peak:	Use a quadratic equation in time to fit: • The minimum before the peak plus (peak before the minimum - minimum)/4 • The temperature peak value is the value of the minimum before the peak plus (peak – previous minimum)/2 • The minimum before the peak plus (peak before the minimum - minimum)/10 These three values then determine the parameters (a,b,c) in $T = at^2 + bt + c$. Use this equation to calculate the temperature values from the minimum before the peak to the minimum after it. This gives the temperature curve in "insolation units" (See above for conversion to temperature units). Here we use the contingency given below for a case where there is a shoulder on the side of the peak; so we use the equation $T = at^3 + bt^2 + ct + d$.

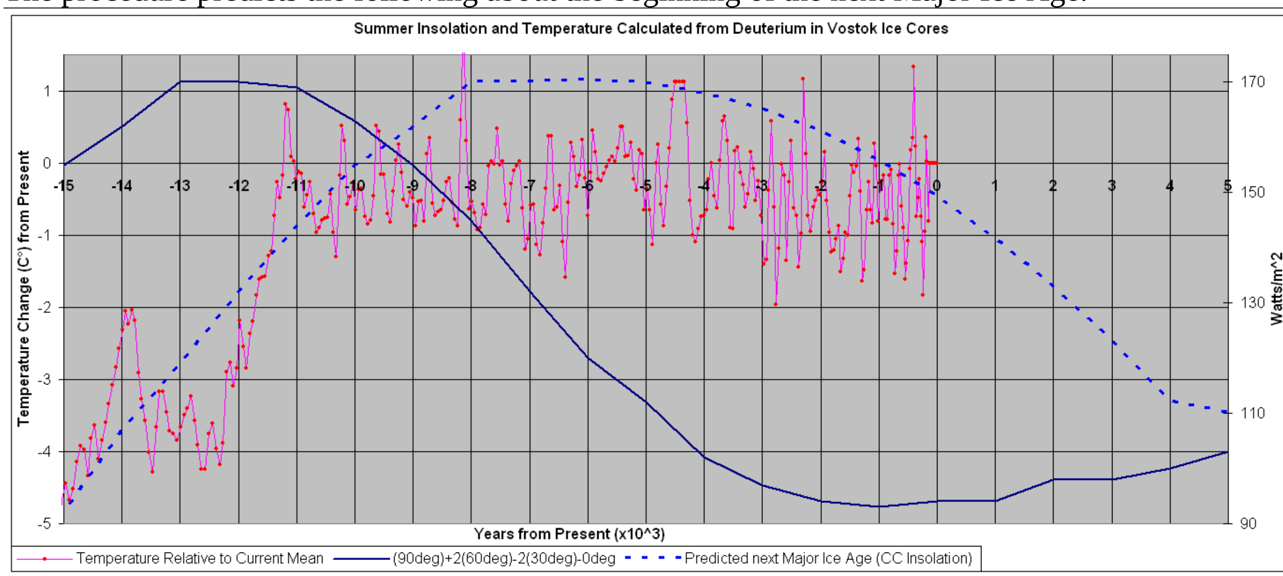
For all other minima, the peaks after them and the minima after those peaks:	Use a quadratic equation in time to fit: • The minimum before the peak plus (previous peak – minimum)/4 • The peak is given as the value of the highest minimum around the peak plus (peak – highest minimum)/2 • The minimum after the peak plus (peak – minimum)/4 for half of the remaining peaks; the divisor is 10 for the rest of the peaks These three values then determine the parameters (a,b,c) in $T = at^2 + bt + c$. --- There is no such situation for the Last Major Ice Age.
Contingency:	If a shoulder or a small minimum occurs in an insolation peak between Major Interglacials, fit with $T = at^3 + bt^2 + ct + d$ as follows: • The minimum before the peak plus (previous peak – minimum)/4 • The peak is given as the value of the highest minimum around the peak plus (peak – highest minimum)/2 • The shoulder or other peak is the value of the closest minimum plus (shoulder or position of other peak – closest minimum)/2 • The minimum after the peak plus (peak – minimum)/4 If the first peak is a Major Interglacial, do not use the “plus (…)” in the first item. If the last minimum is the minimum before a Major Interglacial, do not use the “plus (…)” in the last item. --- Two examples are given above for this contingency in the next Major Ice Age.
Finally	Shift the generated curves by 3000 years into the future, because the best correlation value between the North-Pole insolation and the temperature occurs for a 3000 year temperature lag.

The result of applying this procedure for the North-Pole insolation to the last Major Ice Age and the next Major Ice Age is shown in the following graph:



Note that the procedure gives a decent representation of the last Major Ice Age and its four Minor Ice Ages and three Minor Interglacials on the left. Perhaps then it gives a good approximate prediction of the next Major Ice Age and its three Minor Ice Ages and two Minor Interglacials. The Little Ice Ages within the Minor Ice Ages, due to solar irradiance variations, volcanic eruptions, comet/asteroid collisions, etc. are not attempted to be included in the fits and predictions.

The procedure predicts the following about the beginning of the next Major Ice Age:

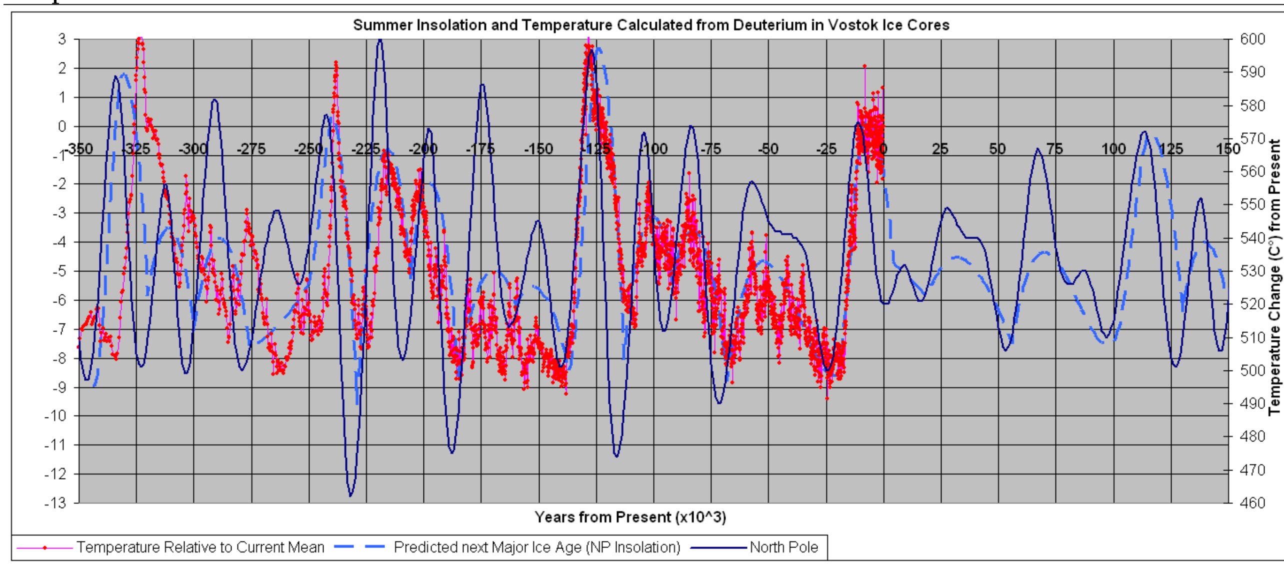


Neglecting short-term solar irradiance variation, which actually increasing solar insolation now, the earth should have headed for colder temperatures about 6000 years ago. But short-term solar irradiance increase and increasing population of humans and their handiwork has leveled out the temperature, instead. As described in **Part III: Ameliorating Global Warming** of this work (http://www.roperld.com/science/AmeliorateGlobalWarming.pdf), there probably will be a short term rise in insolation not shown here, probably due to variation of solar irradiance, which would cause temperature to rise for 500 years or longer. Of course, man-made global warming will add to that temperature rise for a few hundred years until the fossil fuels are all used up.

The next cold period (Minor Ice Age), of about -5C ° below the current temperature, will center around about 20,000 years from now. There will be two other cold periods centered around about 60,000 years from now (about -7C ° below now) and around about 100,000 years from now (about -8C ° below present).

The next Major Interglacial will occur at about 120,000 years from now, with a temperature of about the same as now.

When one extends the procedure for the North-Pole insolation back to the second-to-last and third-to-last Major Ice Ages, the results are not quite so good, but in very rough agreement with the temperature data from ice cores:

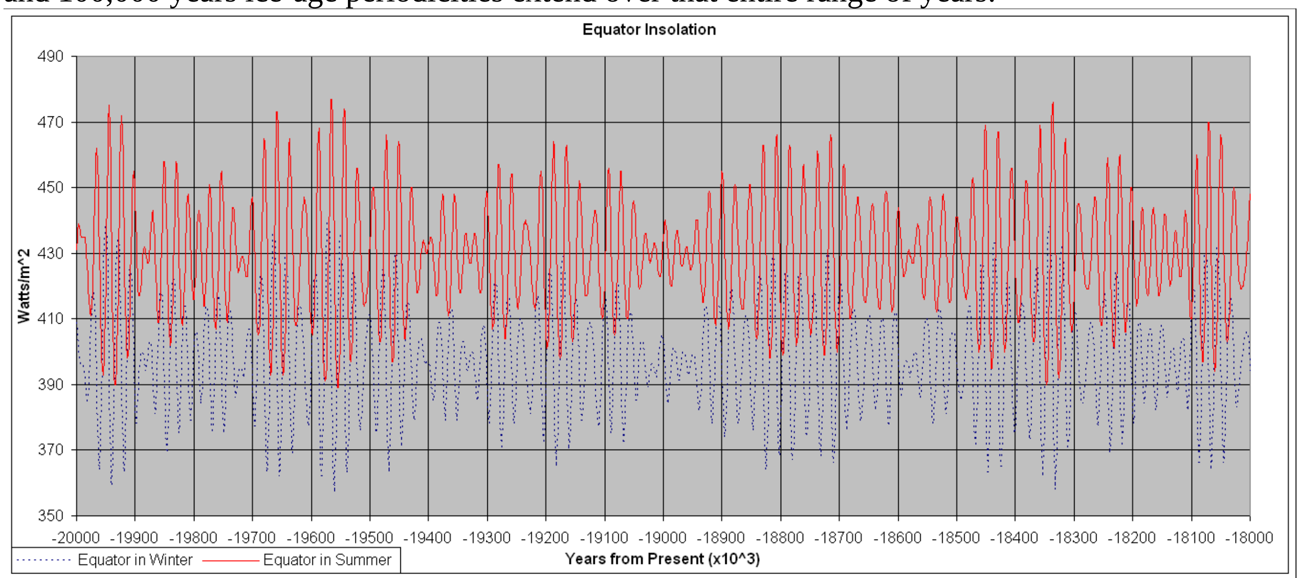


It appears that the times are not correct for the ice-core temperatures for the earlier times.

Ice Ages in the Far Future

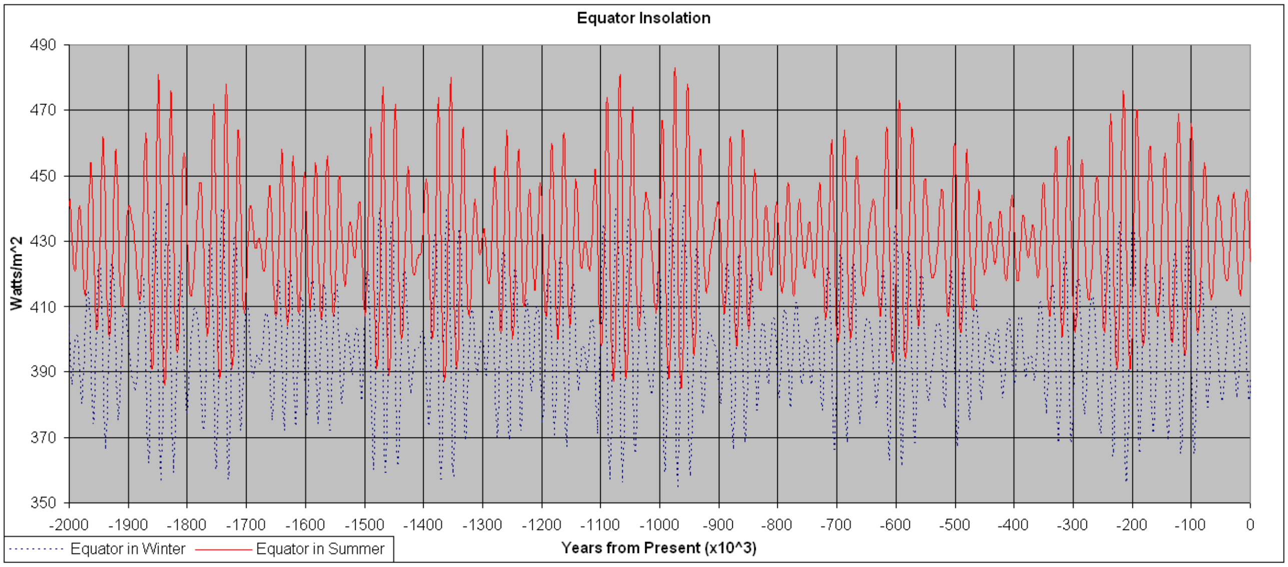
The implication is that there were Major Ice Ages about every 100,000 years back to at least -400,000 years. (100,000 years is about the period of one of the features, the eccentricity, of the Milankovitch theory of the earth orbit.) More recent unpublished ice-core data appear to extend this ice-age periodicity back to about 780,000 ybp.

The Laskar insolation calculation is supposed to be quite accurate from 20,000 kybp to 10,000 kyap. The following insolation graphs for the equator in summer and winter show that the 400,000 year and 100,000 years ice-age periodicities extend over that entire range of years:

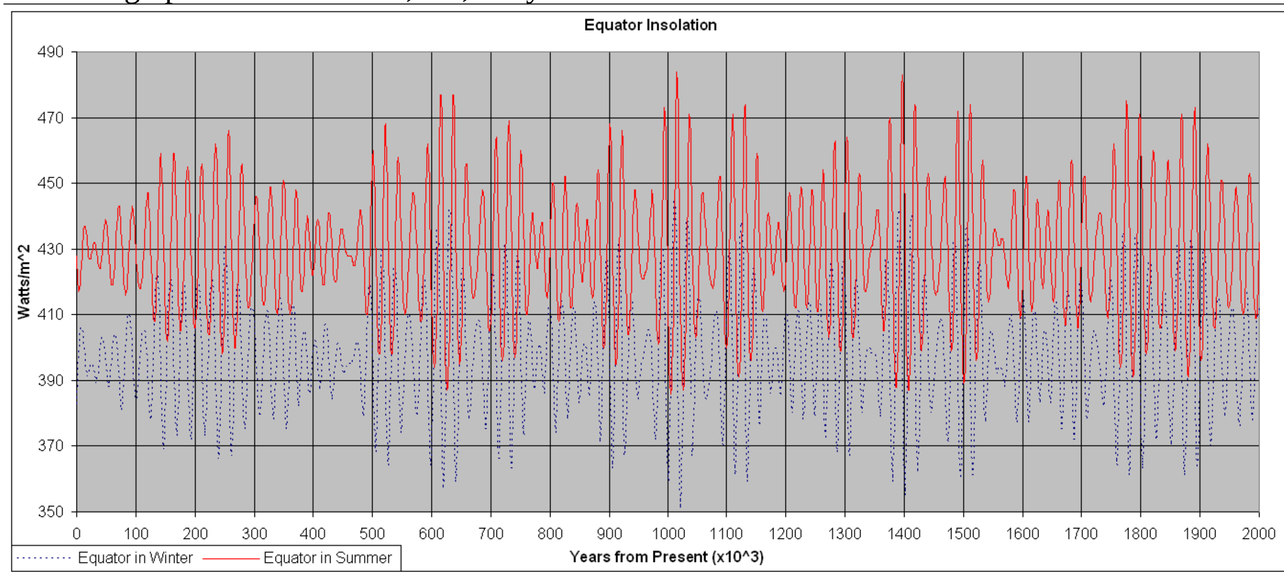


This is for the earliest 2,000,000 years in the calculation range (20,000-10,000 kybp). Note the obvious presence of the shorter ~21,000-year perihelion cycle in all of the insolation graphs shown here. One can regard the 100,000-year and 400,000-year eccentricity cycles as modulators of the 21,000-year perihelion cycle.

Skip to the last 2,000,000 years:

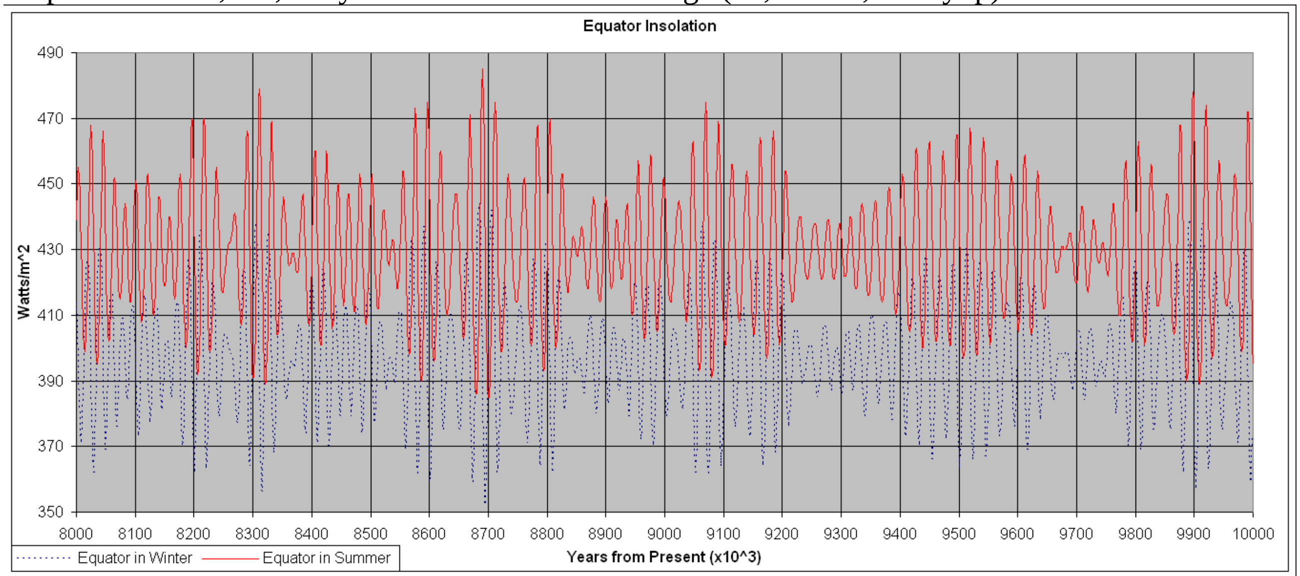


The next graph is for the next 2,000,000 years:



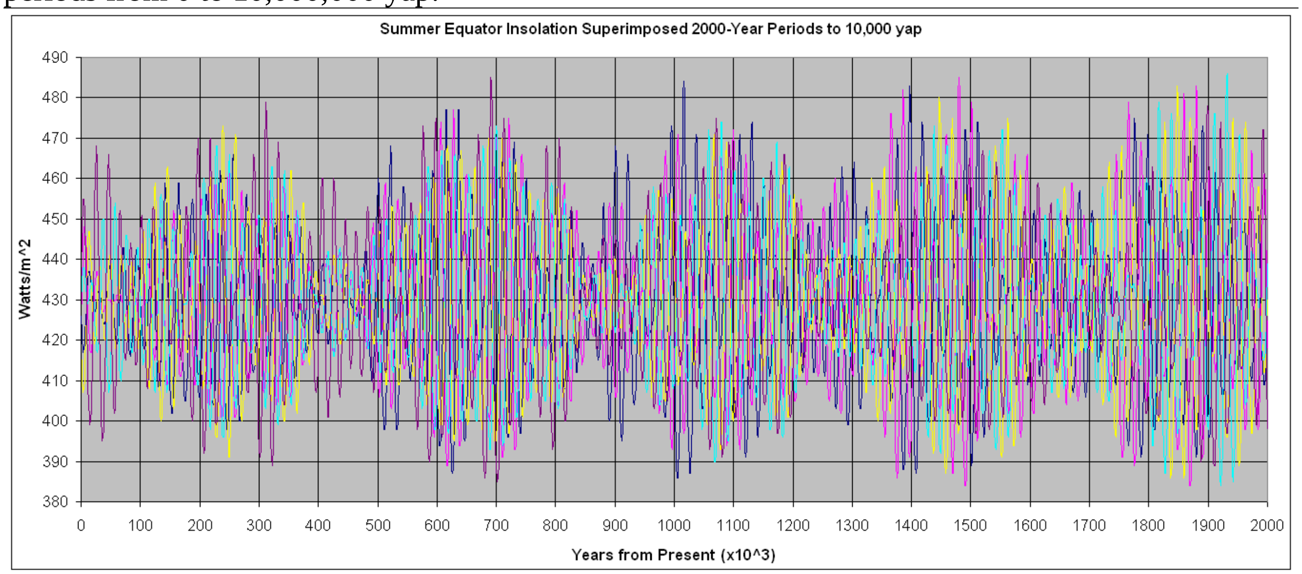
Note that the 400,000 cycle immediately into the future has relatively low peaks.

Skip to the last 2,000,000 years in the calculation range (20,000-10,000 kybp):



I use the Equator calculation for the last four graphs because the periodicities are most clearly seen for it when viewing long time periods. The intervening years not shown here have a similar behavior.

The following graph is a superposition of the Equator summer insolation for the five 2,000,000-year periods from 0 to 10,000,000 yap:



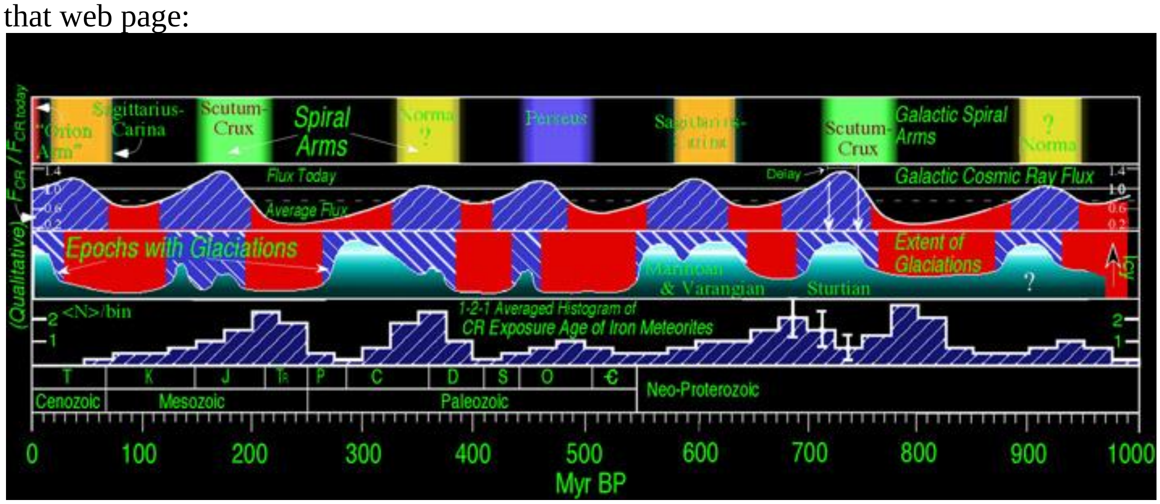
This clearly shows much of the periodic nature; which would probably be even clearer if one used a slightly different period (say 1995 kyears or 2005 kyears). The fact that the periodic nature is so clear indicates that the eccentricity periods are very close to 100 kyears and 400 kyears, both being divisors of 2,000,000. Particularly notable is the small insolation at about the 875,000th year of each 2000-kyear period.

Of course, the locations of the continents (plate tectonics) have varied somewhat over the past 20 Mybp period, which can greatly change the particulars of each Major Ice Age. (For example, the closing of the Isthmus of Panama about 4.5 Mybp (http://earthsci.terc.edu/content/investigations/es2307/es2307page08.cfm) greatly affected the Atlanta Ocean currents which greatly affected the climate for North America and Europe. Also, the raising of the Himalaya mountains 40-10 Mybp greatly affected atmospheric energy transfer and caused much volcanic activity that affected the climate.) (For an animation of the relationship between climate and plate tectonics back 750 Mybp, see http://www.scotese.com/paleocli.htm.) Also, the concentration of CO_2 released into the atmosphere by plant and animal life and volcanic activity can greatly change the particulars of a Major Ice Age.

Note, in the insolation graphs above, that the next Major Interglacial beyond a very cold Major Ice Age about 100,000 yap will probably not be as warm as the several in the recent past, because the insolation peaks are smaller.

Ice Ages Earlier Than 20 Million Years Ago

The web page http://www.phys.huji.ac.il/~shaviv/Ice-ages/ice-main.html gives the best explanation I have seen of a reasonable theory for the seven super-major ice ages, about 150 million years apart, that have occurred back to 1,000 million years in the past. The following picture and caption is taken from that web page:



"The top panel describes our passages through galactic spiral arms. The second panel describes the predicted cosmic ray flux and the predicted occurrence of ice-age epochs. The third panel describes the actual occurrence of ice-age epochs. The fourth panel indirectly describes the variable cosmic ray flux. Due to the fact that the cosmic ray flux is the "clock" used to exposure date meteorites, the meteoritic ages are predicted to cluster around periods when the "clock" ticks slower, which is when the cosmic ray flux was lowest, as is seen in the data"

This picture clearly shows the theory that the passing of the earth periodically, about every 150 million years, through the spiral arms of our galaxy, the Milky Way, exposes the earth to a barrage of cosmic rays, which trigger super-major ice ages. We are in the latter stages of the most recent one, with about 1 million years to go. So, although we are in the "latter stages", this information has no bearing on this proposal to try to ameliorate future minor ice ages of the order of 1,000-10,000 years.

For some research results about the effect of cosmic rays on climate, see http://www.co2science.org/edit/v6_edit/v6n5edit.htm.

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