

Solar “Grand Minima” Threat Analysis

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[Abstract] We are approaching a period when the sun is going quiet. In the past, these periods with few sunspots, such as the Dalton Minimum, Maunder Minimum, & Spörer Minimum, produced decades of global cooling, famine and plagues. This paper provides an analysis of the global cooling threat.

I. Solar Cycles

Solar activity, visible by the number of sunspots, varies over a cycle of approximately 11 years. This variation is defined as a solar sunspot cycle. The periodic cycle begins at a solar minimum, peaks at a solar maximum and then falls back down to the next solar minimum. The International Sunspot Index is used to define the beginning and end of each solar cycle. Currently the Earth is in a solar minimum transitioning into Solar Cycle 24.

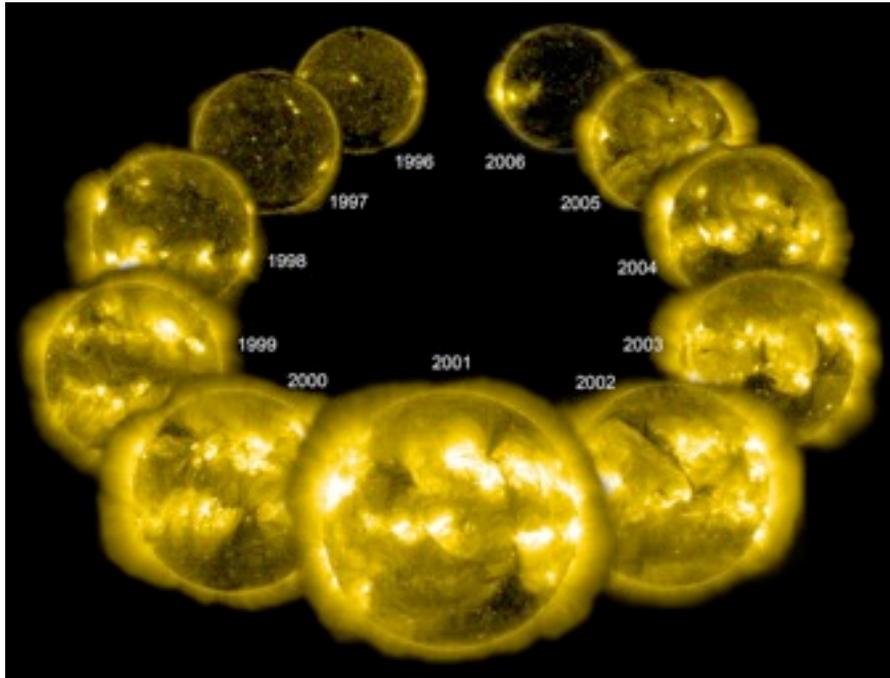


Figure 1. Image of Solar Cycle 23 from the Solar and Heliospheric Observatory (SOHO) by Steele Hill (NASA GSFC).

The Sun undergoes a magnetic pole reversal approximately once every 11 years. The Sun’s magnetic field is normally dipolar but during solar maximum, quadrupole and octupole components exist as well.

It has been suggested that the sunspot cycle is related to the planetary cycle of the four major planets: Jupiter, Saturn, Uranus and Neptune.¹ There are three centers of mass that are of interest, the sun, the major planets, and the solar system. Approximately once every eleven years, the four major planets are grouped ahead of the sun as the solar system moves through galactic space. This causes the sun to occupy a reciprocal position

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on the opposite side of the solar system's center of mass. About eleven years later the major planets are grouped behind the sun causing it to occupy a reciprocal position ahead of the solar system's center of mass.

The sun therefore alternately accelerates as it moves forward through galactic space and then decelerates to occupy a position behind the solar system's center of mass. All this occurs while the solar system as a whole moves forward through galactic space. The acceleration and deceleration cause the sun to wobble in its path. The wobble creates turbulence in the sun's interior, which is characterized by changes in sunspot activity.

II. The Quiet Sun - "Grand Minima"

The sun exhibits great variability in the strength of each solar cycle. This activity ranges from the extremely quiet "Grand Minima" such as the Maunder Minimum (1645-1715 A.D.) to a very active "Grand Maxima" such as the enhanced activity observed during most of the 20th century (1940-2000 A.D.). High energy galactic cosmic rays enter Earth's atmosphere collide with sufficient force to cause a nuclear spallation reaction with atmospheric molecules. Some of the fission products include radionuclides ¹⁴C and ¹⁰Be, which settle down on Earth's surface. Their concentration can be measured in ice cores, allowing a reconstruction of solar activity levels into the distant past.

The sun's magnetic field wrapped in the solar winds deflects galactic cosmic rays trying to enter the solar system and is therefore responsible for modulating production of these radioactive isotopes. Usoskin et al. details the reconstruction of solar activity during the Holocene period from 10,000 B.C. to the present.² Refer to Figure 2.

The reconstructions indicate that the overall level of solar activity since the middle of the 20th century stands amongst the highest of the past 10,000 years. This time period was a very strong "Grand Maxima". Typically these grand maxima are short-lived lasting in the order of 50 years. The reconstruction also reveals "Grand Minima" epochs of suppressed activity, of varying durations have occurred repeatedly over that time span. A solar Grand Minima is defined as a period when the (smoothed) sunspot number is less than 15 during at least two consecutive decades. The sun spends about 17 percent of the time in a Grand Minima state.

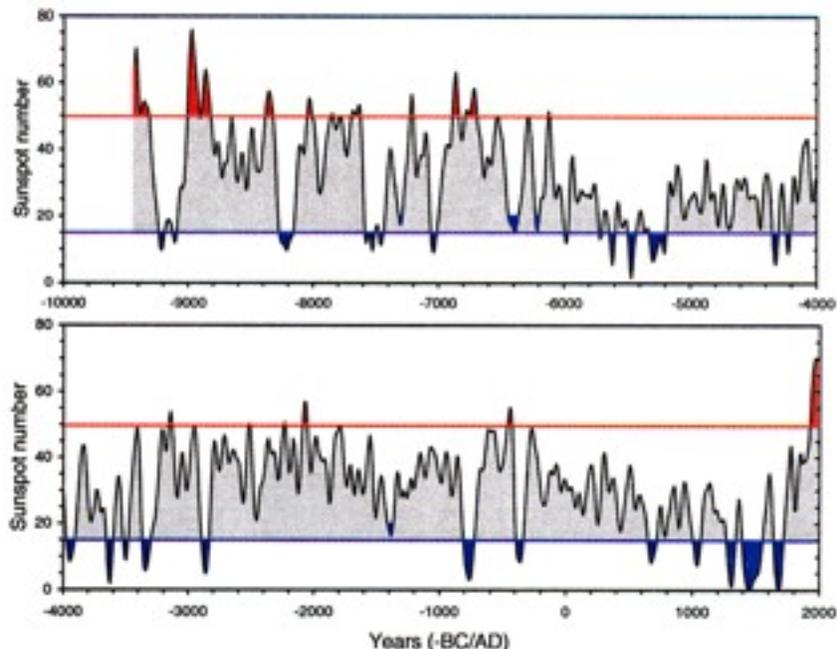


Figure 2. Sunspot activity throughout the Holocene. Blue and red areas denote grand minima and maxima, respectively. The entire series is spread out over two panels for better visibility.²

A “Grand Minima” state can last for several decades. Approximately 27 “Grand Minima” have occurred during the Holocene covering the past 12,000 years. The following table identifies the approximate dates and durations of these “Grand Minima”.²

<u>Center of Grand Minima</u>	<u>Duration</u>
1680 A.D.	80 years
1470 A.D.	160 years
1305 A.D.	70 years
1040 A.D.	60 years
685 A.D.	70 years
360 B.C.	60 years
765 B.C.	90 years
1390 B.C.	40 years
2860 B.C.	60 years
3335 B.C.	70 years
3500 B.C.	40 years
3625 B.C.	50 years
3940 B.C.	60 years
4225 B.C.	30 years
4325 B.C.	50 years
5260 B.C.	140 years
5460 B.C.	60 years
5620 B.C.	40 years
5710 B.C.	20 years
5985 B.C.	30 years
6215 B.C.	30 years
6400 B.C.	80 years
7035 B.C.	50 years
7305 B.C.	30 years
7515 B.C.	150 years
8215 B.C.	110 years
9165 B.C.	150 years

III. Galactic Cosmic Rays

Galactic Cosmic Rays (GCRs) are high-energy charged particles that originate outside our solar system. About 85 percent are protons (nuclei of hydrogen atoms), 12 percent alpha particles (helium nuclei) and the remainder are electrons and the nuclei of heavier atoms. The energy levels of GCRs observed in deep space generally lie in the 100 MeV (million electron volts) to 10 GeV (billion electron volts) range. Above 1 GeV, the particle flux rate decreases significantly according to a power law with an exponent of approximately 2.5. Cosmic rays are produced when a star exhausts its nuclear fuel and explodes into a supernova. These stars are generally new short-lived blue stars of the spectral type O (20-100 solar masses) or blue-white stars of spectral type B (3-20 solar masses).

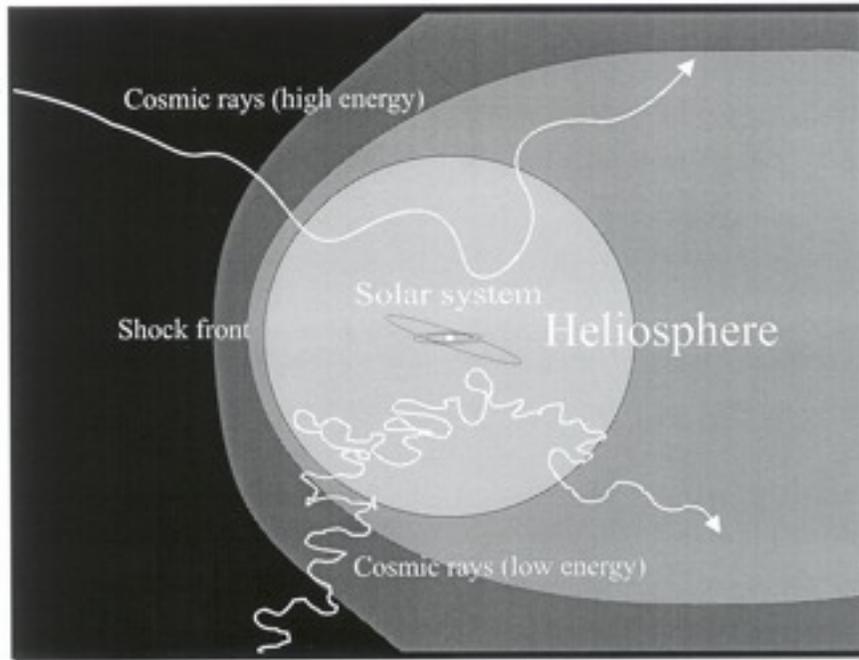


Figure 3. Pictorial of GCR interaction with the Sun’s Heliosphere.

The Sun’s magnetic field modulates the GCR flux rate on Earth. Just as cosmic rays are deflected by the magnetic fields in interstellar space, they are also affected by the interplanetary magnetic field embedded in the solar wind (the plasma of ions and electrons blowing from the solar corona at about 400 km/sec), and therefore have difficulty reaching the inner solar system. The effects from the solar winds are felt at distance approximately 200 AU from the sun, in a region of space known as the Heliosphere. Refer to Figure 3.

The relationship between solar cycles and GCR flux rate at the Earth’s surface is shown in Figure 4. R_z is the Sunspot Number. J is the cosmic ray flux. This flux rate measured energetic galactic cosmic rays in the energy range of 145-440 MeV using ground based neutron monitors. During solar maximum the GCR flux rate is at its minimum. During solar minimums, the GCR flux rate increases significantly. The graph covers the period from 1974-2001.

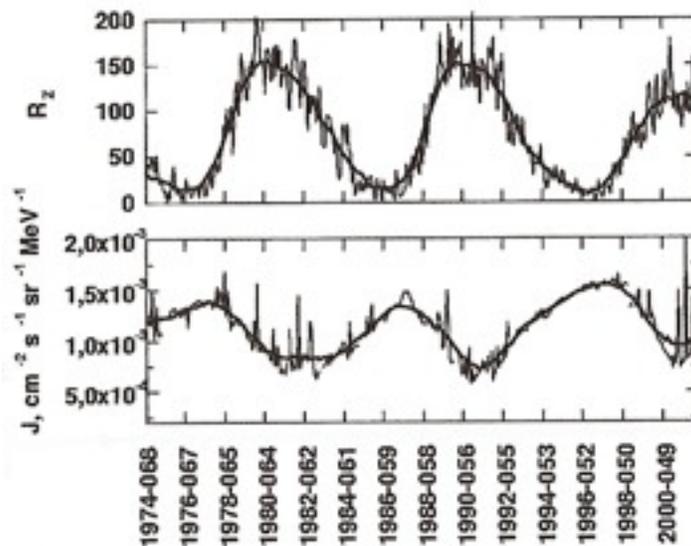


Figure 4. Sunspot Cycle vs. GCR flux rate.³

IV. Clouds

The sun is a major influence on climate change on Earth in that it provides solar irradiance that warms the planet and a far reaching magnetic field that shields Earth from the effects of galactic cosmic rays, which cools the planet. The magnetic field wrapped in the solar winds modulates the flux rate of cosmic rays which affects cloud formation and thereby the planet's global albedo. Past studies have shown a relationship between the flux rate of galactic cosmic rays and low-level ocean cloud formation.

Research by Nigel Marsh, Henrik Svensmark and Eigil Friis-Christensen provides a good foundation in understanding the relationship between galactic cosmic rays and cloud formation.^{4,5,6}

When GCRs collide with the Earth's atmosphere, they release in nuclear collision a cascade of secondary particles (protons, neutrons and muons), which continue to penetrate deeper and deeper into the atmosphere. This cascading effect continues until the particle's energy falls too low to undergo further collisions. This generally ends around 16 kilometers above the Earth's surface in the lower atmosphere. The ions produced within the troposphere by cosmic rays are important element of aerosol production. In the troposphere, ionization contributes to gas-particle formation of ultra fine (<20nm) aerosols that build into cloud condensation nuclei (CCN). Charged raindrops are ten to a hundred times more efficient in capturing aerosols than uncharged drops. In slightly supersaturated water vapor, when aerosol is dissolved in the tiny haze particles the droplets' vapor pressure lowers, which increases droplet growth. The water vapor condenses into larger water droplets that form clouds.

Earth's ocean cloud cover is strongly correlated with GCR flux modulated by solar cycle variations. Refer to Figure 5.

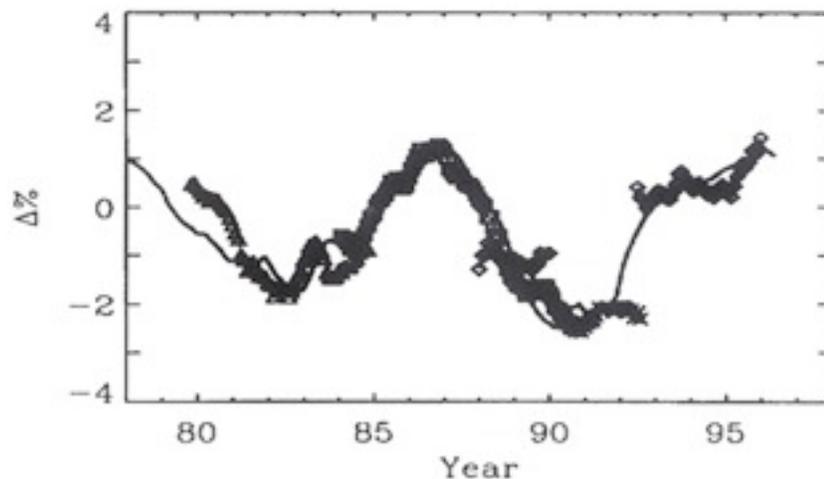


Figure 5. A strong correlation between Galactic Cosmic Rays (GCRs) and Earth's cloud cover. Figure shows cosmic rays fluxes from Climax (thick curve) plotted against four satellite cloud data sets over the ocean. Triangles are the Nimbus-7 data, squares are the ISCCP-C2 data, diamonds are the DMSP data, and crosses are the ISCCP-D2 data.⁶

Low clouds tend to be optically thick and are efficient at reflecting sunlight back into space. An increase in low altitude clouds will result in planetary cooling. GCRs are a very effective amplifying mechanism for climate forcing because the energy needed to change cloudiness is small compared with the resulting changes in solar radiation received at the Earth's surface.

Interestingly, during the 20th Century, the Sun's magnetic field which shields Earth from cosmic rays more than doubled, thereby reducing the average influx of cosmic rays. The resulting reduction in cloudiness, especially of low-altitude clouds, may be a significant factor in the global warming Earth has undergone during the last century.

In 2006, the Danish National Space Center in Copenhagen conducted experimental studies of aerosol nucleation in air, containing trace amounts of ozone, sulfur dioxide and water vapor at concentrations representative of Earth's atmosphere over the oceans. Their experiments confirmed the causal mechanism by which cosmic rays facilitate the production of clouds in Earth's atmosphere.⁷ Specifically the experiments showed that (1) stable cloud aerosol clusters were formed in the presence of ions, (2) the nucleation rate was proportional to the ion density, (3) the characteristic time for producing stable clusters was very short (2 seconds or less).

V. Global Temperature

Historically observations show the strength of the Sun's magnetic field is not constant. One gauge of this variation in solar magnetic field intensity is visible in sunspot activity. The Maunder Minimum (1645-1715 A.D.) provides insight into the influence of the Sun's magnetic field on natural global climate change on Earth. Refer to Figure 6. During the 30-year period from 1672-1699 A.D., there were less than 50 sunspots detected, whereas during the past century over the same period between 40,000-50,000 sunspots appeared. During the Maunder Minimum, the solar wind was depressed, which allowed greater penetration of GCRs into the inner solar system. This period of minimal solar magnetic field resulted in a prolonged period of greater cloud cover producing a significant decline in Earth's temperature. The Maunder Minimum which is referred to as the Little Ice Age is noted as one of the coldest periods during the past 2,000 years.

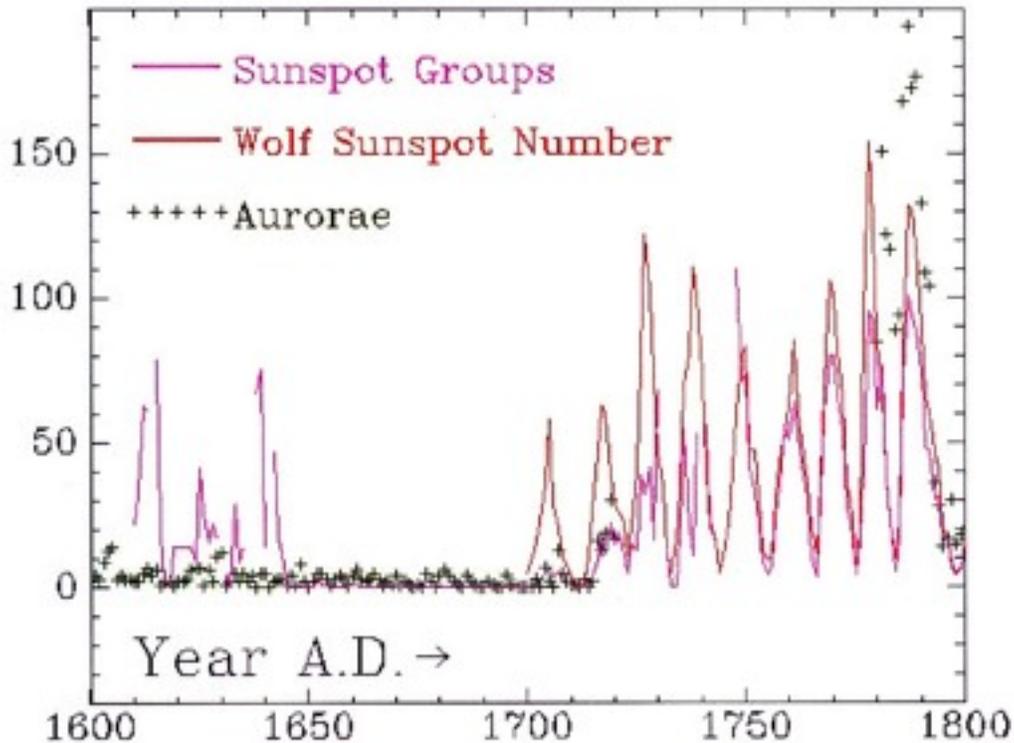


Figure 6. From 1645-1715 A.D, the sun's magnetic field went quiet. This was known as the Maunder Minimum. This plot shows the variation in the number of observed sunspots during the time period 1600-1800 A.D. The red curve is the Wolf sunspot number, and the purple line a count of sunspot groups based on a reconstruction by D.V. Hoyt. The green crosses are aurora counts, based on a reconstruction by K. Krivsky and J.P. Legrand.

The oceans are the key to unlocking the mysteries of climate change. About 70 percent of the Earth's surface is covered in water, which absorbs sunlight and warms. The oceans act as a large planetary heat sink because they retain heat better than land masses. Considering the available data, it is clear that the oceans warmed over the 20th Century by about the same amount as the atmosphere. This agreement should not be entirely surprising as 70 percent of the mean global air temperature comes from over oceans. The inconvenient truth that is generally ignored, is that the atmosphere is not capable of warming the oceans to any significant degree – 99.9 percent of ocean heat is derived from sunlight at wavelengths less than 3 microns. The balance is mostly from heat leaking from the interior of the Earth. The Greenhouse Effect involves a delay in the loss of infra-red radiation at wavelengths greater than 5 microns.⁸

Variations in the amount of sunlight reaching the oceans control the rate at which the oceans warm. This is influenced at long time scales by changes in the Earth's orbit. At short time scales there are changes in the amount of solar irradiance associated with the sunspot cycle. These changes are small. However, the main driver in climate change is the amount of cloud and ice cover. Clouds and sea ice reflect sunlight before it can be absorbed by the oceans, and is referred to as albedo. Albedo changes have a greater influence on climate than the Greenhouse Effect. Oceans lose heat through evaporation (53 percent), infra-red radiation (41 percent) and conduction (6 percent). The Greenhouse Effect can slow the loss of the infra-red radiation, thereby warming the atmosphere but not the oceans. However, evaporation accounts for more than half the heat loss. Evaporation produces clouds, and hence there is a feedback loop – warming the oceans results in more evaporation, producing more clouds, which increases albedo, which cools the oceans. This is exactly what was observed during The Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Response Experiment (TOGA COARE) that was set up to investigate the Pacific Warm Pool – the warmest ocean water in the western equatorial Pacific Ocean. COARE also found that rainfall would cool the ocean surface, so increased evaporation producing rain is another feedback loop.⁸

What does this have to do with the 20th Century? Well the observed climate change is consistent with variations in albedo and associated ocean warming and cooling, suggesting that it is just a natural cycle. This pattern of behavior is evident in paleoclimate data for most of the last 10,000 years. None of this is simulated in climate models..

Is the link between the intensity of the sun's magnetic field and surface ocean temperature quantifiable? Because the area represented by the oceans is large; a long-term change in low level clouds over the ocean should have a significant effect on planetary temperature. Most of the natural background radiation over the oceans is derived from cosmic radiation rather than natural sources. As a result, the effect of GCR cloud modulation is greatest over the oceans where there is less dust to form clouds and there is a shortage of cloud forming ions. Rain removes the ions, so they must be constantly replenished.

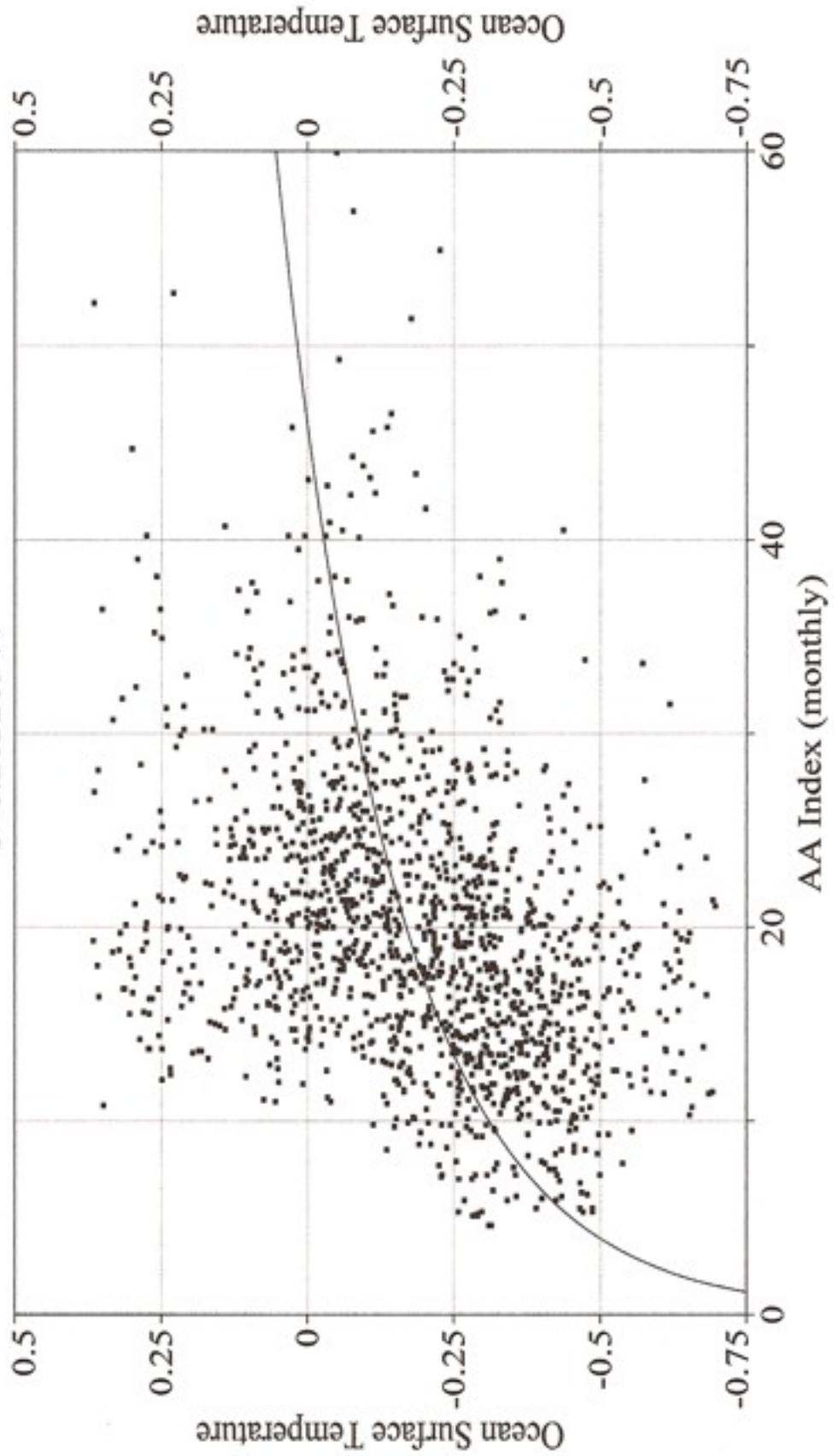
One method of measuring the sun's magnetic strength is by measuring the production of sunspots. But Georgieva recommends a better method by measuring the ability of the magnetic field wrapped in the solar winds to interact and distort the Earth's magnetic field. The high speed solar wind stream is produced by Coronal Mass Ejections, Coronal Holes and Magnetic Clouds. The geomagnetic activity reflects the impact of solar activity originating from both closed and open magnetic field regions on the sun, so it is a better indicator of solar magnetic activity than sunspot number which is related to only closed magnetic field regions.⁹ This geomagnetic distortion has been measured at two locations on the opposite side of the globe, one in Great Britain and the other in Australia, since 1868 A.D. This combined distortion is referred to as the "AA index". Figure 7 graphs global monthly ocean temperature anomalies in relationship to the "AA index" for the past 120 years.

The relationship is described by the formula:

$$\text{Ocean Surface Temperature Anomaly} = 0.203 \ln (\text{AA Index}) - 0.778^{\circ}\text{C} \quad (1)$$

Figure 7. Ocean Surface Temperature as a Function of AA Index

Rank 1 Eqn 13 $y=a+blnx$
 $r^2=0.13278604$ DF Adj $r^2=0.13157654$ FitStdErr=0.20201121 Fstat=219.72429
 $a=-0.77768987$
 $b=0.20320944$



This figure was derived using the Smith-Reynolds Extended Reconstructed Sea Surface Temperature (ERSST.v3)¹⁰. The time series in ASCII format was accessed through <ftp://eclipse.ncdc.noaa.gov/pub/ersst/pdo/> by selecting dataset `aravg.mon.ocean.90S.90N.asc`. The monthly dataset `aravg.mon.ocean.90S.90N.asc` was used which covers Sea Surface Temperature (SST) for the period from January 1880 to October 2007 for the entire ocean from 90° North latitude to 90° South latitude. The temperature anomalies are computed from the analyzed monthly field minus the climatology for that month using the years 1971-2000 as a baseline. The second parameter used was the monthly “AA Index” which covers the period from January 1868 to September 2007.¹¹ [The time series is accessed by selecting the dataset `AA_Month`.] Since major volcanic eruptions are known to affect Earth’s climate, the database provided by the Smithsonian National Museum of Natural History on Large Holocene Eruptions was used to filter out this climatic effect.¹² All eruptions with a Volcanic Explosivity Index (VEI) of 6 or greater were identified and the temperature data from the time of eruption until two years later were deleted from the dataset. These eruptions include Krakatau (27 Aug. 1883), Santa Maria (24 Oct. 1902), Novarupta (6 Jun. 1912) and Pinatubo (15 Jun. 1991).

One might question if the natural log drop-off as the “AA Index” approaches zero is a real phenomena. Figure 8 shows an ocean surface temperature reconstruction in the Sargasso Sea, a 2 million square mile region of the Atlantic Ocean as determined by isotope ratios of marine organism remains in sediment at the bottom of the sea. During the depths of the Little Ice Age, ocean temperatures were approximately 1°C colder than present. Although the Maunder Minimum preceded the start of “AA Index” measurements; it is my opinion that the Maunder Minimum represents a timeframe when this parameter approached zero. When an “AA Index” of near-zero (0.1) is entered into equation (1); it produces a temperature drop of approximately 1°C as compared to present day temperatures. Thus there appears to be agreement between the formula and observed sea temperatures on the extremes of the quiet sun.

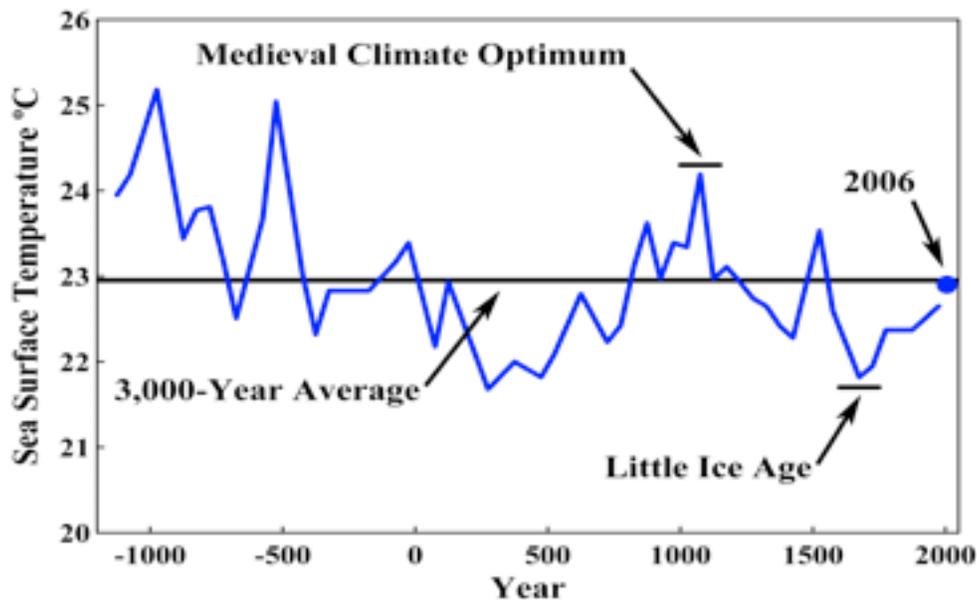


Figure 8. Surface temperatures in the Sargasso Sea, a 2 million square mile region of the Atlantic Ocean, with time resolution of 50 to 100 years. The horizontal line is the average temperature for this 3,000-year period. The Little Ice Age and Medieval Climate Optimum were naturally occurring, extended intervals of climate departures from the mean.¹³

This leads to the observation that the Earth’s climate system is fairly robust. Medium to high levels of solar magnetic fields produce fairly stable warm temperatures. Only when the sun is magnetically quiet does temperature take a dramatic plunge.

VI. Global Cooling Threat

In the Anthropogenic Global Warming (AGW) theory according to the Intergovernmental Panel on Climate Change (IPCC); the sun and Earth's cloud cover play only minor roles in climate change. In the AGW theory, rising atmospheric carbon dioxide levels cause rising temperatures on Earth. But actual temperatures have been falling. From the peak year 1998, the lower Troposphere temperatures globally has fallen around 1/2 degrees Celsius. (1998 vs. 2008) This is despite the fact that during that same time period, atmospheric carbon dioxide has risen 5 percent from 367 ppm to 386 ppm. The AGW theory failed to predict this trend. Some might argue that weather is being confused with climate. The range of this data is over ten years. I assert that a decade of global temperatures represents a climate change and 1/2 degrees Celsius is too significant to be ignored. The AGW theory is hinged on untested (unvalidated) computer models. These falling temperatures occurred at the same time as the sun went quiet as it is transitioning into Solar Cycle 24. This observation conforms to the Natural Global Cooling (NGC) theory. The NGC theory has a long history of defining past climate changes, a history of observed cooling events such as the Dalton Minimum, Maunder Minimum, Spörer Minimum and Wolf Minimum. Any warming theorized by AGW appears to be insignificant in comparison to the large rapid fall observed in lower Tropospheric temperature being driven naturally by the weakening solar magnetic field during this solar minimum.

Climate change is primarily driven by nature. It has been true in the days of my father and his father and all those that came before us. Because of science, not junk science, we have slowly uncovered some of the fundamental mysteries of nature. Our Milky Way galaxy is awash with cosmic rays. These are high speed charged particles that originate from exploding stars. Because they are charged, their travel is strongly influenced by magnetic fields. Our sun produces a magnetic field that extends to the edges of our solar system. This magnetic field is wrapped in the solar winds.

This field deflects many of the cosmic rays away from Earth. But when the sun goes quiet (minimal sunspots), this field collapses inward allowing cosmic rays to penetrate deeper into our solar system. As a result, far greater numbers collide with Earth and penetrate down into the lower atmosphere where they ionize small particles of moisture (humidity) forming them into water droplets that become clouds. Low level clouds reflect sunlight back into space. An increase in Earth's cloud cover produce a global drop in temperature. These periods of quiet sun are referred to as a Grand Minima. The Maunder Minimum (1645-1715) and the Dalton Minimum (1790-1830) are examples.

During a Grand Minima the Earth begins to slowly cool. The start of the planting season is delayed and in the fall early frost limits the harvest. Earth's abundant bounty is put on hold and starvation takes its ghastly grip. Historian, John D. Post, referred to the last period of quiet sun, the Dalton Minimum, as the "last great subsistence crisis in the Western world". With the cold came massive crop failures, food riots, famine and disease.

Several scientists including David Hathaway (NASA)¹⁴, William Livingston & Matthew Penn (National Solar Observatory)¹⁵, Khabibullo Abdusamatov (Russian Academy of Science)¹⁶, Cornelis de Jager (The Netherlands) & S. Duhau (Argentina)¹⁷ and Theodor Landscheidt (Germany)¹⁸, have forecasted that the sun may enter a period similar to the Dalton Minimum or a more severe "Grand Minima" a decade from now in Solar Cycle 25.

A few scientists including David C. Archibald (Australia)¹⁹ and M. A. Clilverd (Britain)²⁰ have warned this might even begin in Solar Cycle 24. We are at the transition into Solar Cycle 24 and this cycle has already shown itself to be unusually quiet. The number of spotless days (days without sunspots) during this solar minimum appears to be tracking 3 times the typical number observed during the last century (Solar Cycles 16-23).

There are several lessons learned from studying very early global cooling events in Europe. Lessons learned include:

- * Onset of these conditions can be very abrupt and very severe.
- * A decline in food production due to:
 - Dramatic increase in days with overcast skies.
 - Decline in the intensity of sunlight.
 - Decline by several degrees in global temperature
 - Regions of massive rainfall and flooding
 - Limited regions experienced droughts
 - Shortened growing season
- * A string of major and minor famines
- * Malnutrition lead to weakened immune system. Produced influenza epidemics.
- * Reoccurrence of plagues such as the Black Plague.
- * Lack of feed for livestock
- * Parasites (i.e. fusarium nivale), which thrived under snow cover, devastated crops.
- * Grain storage in cool damp conditions produced fungus (Ergot Blight). Contaminated grains when consumed caused an illness (St. Anthony's Fire) producing convulsions, hallucinations, gangrenous rotting of extremities.
- * Flooding created swamplands that became mosquito breeding grounds and introduced tropical diseases such as malaria throughout Europe.
- * During hot summers, cold air aloft produced killer hailstorms (hailstones that could kill a cow).
- * Higher frequency of powerful storms produced major devastations.
- * Glacier advance swallowed up entire alpine villages.
- * Ruptured glacial ice dams produced deadly floods.

Temperatures are already falling. The main threat from a "Dalton Minimum" or "Maunder Minimum" event is famine and starvation (affecting millions or hundreds of millions worldwide) due to shortened growing seasons and harsher weather. In the past, in addition to great famines, this cold harsh weather has also lead to major epidemics.

Historical Pattern of Cold Weather Associated with a Quiet Sun

Historical evidence exists of the Mississippi River, Ohio River, Allegheny River, Delaware River and Hudson River at the New York Harbor freezing and of very harsh winters.

A few decades after the Dalton Minimum

In the spring Eliza, a slave, carrying her young son, fled from Kentucky by crossing the **Ohio River** on foot. The river was "swollen and turbulent, great cakes of floating ice were swinging heavily to and fro in the turbid waters." She leaped from one chunk of ice to the next until she reached freedom on the Ohio shore.²¹ [Harriet Beecher Stowe lived in Cincinnati, Ohio from 1832 to 1850. In 1851, she wrote "Uncle Tom's Cabin". Her life in Ohio was intertwined in this work of fiction.]

During the Dalton Minimum

The **Hudson River** at the New York Harbor froze, enabling people to walk across the ice from Manhattan to Staten Island. The Hudson froze over completely during particularly brutal winter of 1779/1780, when the surface was solid for five weeks straight and the British rolled cannons over the ice. In 1821, taverns were constructed in the middle of the river to offer warmth and refreshment to pedestrians.^{22,23}

During the Dalton Minimum

From 1803 to 1806, Captains Lewis and Clark lead a transcontinental expedition to explore the greater Northwest. During the winter of 1804/1805, the explorers set up a winter base camp near the Big Knife River near what is today the town of Bismarck, North Dakota. The winter was bitterly cold. There were 6 days with temperatures of -31°F or lower. These occurred in 1804 on December 12 (-38°F), December 17 (-45°F), December 18 (-32°F), in 1805 on January 10 (-40°F), January 11 (-38°F), and January 13 (-34°F). Compare this to the current low temperatures of Bismarck, North Dakota in which only one

day in the past decade fell below -30°F. On January 15, 2009 the temperature fell to -44°F.^{24,25}

During the Dalton Minimum

Early settlers routinely waited till winter to cross the frozen Mississippi river in their wagon trains. In 1799, George Frederick Bollinger led a group of early pioneers from North Carolina to establish early settlements in Missouri. They hoped to cross their largest obstacle, the **Mississippi River**, on the ice, frozen solid in mid-winter. They arrived on the east bank of the Mississippi river opposite St. Genevieve in late December, pitched camp and explored potential river crossings. St. Genevieve is located about a hundred miles downstream from St. Louis. Daily the thickness of the ice was measured and then on December 31, a chopped hole in the ice indicated thickness well over two feet. The next day the settlers successfully drove their heavy loaded wagons across the river.²⁶

Between the Dalton Minimum and the Maunder Minimum

December 1776 was a desperate time for George Washington and the American Revolution. During the night of December 25, Washington led his small Continental army of 2,400 troops from Pennsylvania across the **Delaware River** made dangerous and barely navigable by huge chunks of ice. Once across they launched a surprise attack on the Britain's Hessian mercenaries at Trenton, New Jersey, capturing 1,000 prisoners and seizing muskets, powder, and artillery.^{27,28}

Between the Dalton Minimum and the Maunder Minimum

In **Boston, Massachusetts** on February 22, 1772, Anna, a young school girl, writes in her diary "Since about the middle of December, we have had till this week, a series of cold and stormy weather - every snow storm (of which we have had abundance) except the first, ended with rain, by which means the snow was so hardened that the strong gales at northwest soon turned it, and all above ground to ice." In some streets about town this mixture of ice and snow is 5 feet thick. On March 11, she writes that the snow is now 7 feet deep in some places around her house.²⁹

Between the Dalton Minimum and the Maunder Minimum

Just before the opening battles of the French and Indian War in December 1753, George Washington, then 21 years old, crossed the **Allegheny River**. In their first attempt, Washington and a guide used a raft to cross the ice-choked river and this ended in disaster as Washington was knocked overboard in deep water and saved himself only by catching the raft as it swept by. The severe cold that night froze their clothes and the guide's fingers. The river also froze, however, allowing them to walk across on the ice the next morning. Soon they reached the safety of an English trader's settlement.³⁰

During the Maunder Minimum

During the Great Frost of (1683–1684) in England, the River Thames was completely frozen for two months, the ice was 11 inches thick at London. Sea ice was reported along the coasts of southeast England, and ice prevented the use of many harbors. The sea froze, so that ice formed for a time between Dover and Calais, joining England and France. (It is more likely that the shorelines froze and a great mass of densely packed icebergs, some 11 feet thick, built up along the coastlines fusing into a semi-rigid structure that may have connected the two shorelines together.) The Thames was recorded to have frozen over at London during the years: 1649, 1655, 1663, 1666, 1667, 1684, 1695, 1709, and 1716.^{31,32,33,34}

During the Little Ice Age, growing seasons in England and Continental Europe generally became short and unreliable, which led to shortages and famine. These hardships were nothing compared to the more northerly countries: Glaciers advanced rapidly in Greenland, Iceland, Scandinavia and North America, making vast tracts of land uninhabitable. The Arctic pack ice extended so far south that several reports describe Eskimos landing their kayaks in Scotland. Finland's population fell by one-third, Iceland's by half, the Viking colonies in Greenland were abandoned altogether, as were many Inuit communities.³⁵

During the Spörer Minimum

By 1518, early explorers made significant progress in probing and surveying the New World. They described North America as a “land of frozen seas, horrid, barren and scarcely habitable for cold”. “In the New World, cold predominates. The rigor of the frigid zone extends over half of those regions which should be temperate by their position. Countries where the grape and the fig should ripen, are buried under snow one half of the year; and lands situated in the same parallel with the most fertile and best cultivated provinces in Europe, are chilled with perpetual frosts, which almost destroy the power of vegetation.”³⁶

VII. Plague Causal Relationship

Great famines and plagues appeared together historically, not only because malnourished populations are more susceptible to disease but because they share a common causal link. I assert that the plagues did not just coincide with past global cooling events but were directly spawned by the increasing levels of GCR radiation. Two examples, which appeared at the onset of both the Dark Ages and the beginning of the Little Ice Age, are the *Yersinia Pestis bacillus*, and the Rinderpest virus.

Radiation is a powerful mutagen. The long-term effects of radiation are genetic alteration, cancer induction, damage to the central nervous system and peripheral neurons and accelerated aging. Densely ionizing radiation like alpha particles or heavier ions generate a greater biological effect than the same dose of X-rays. X-rays can produce isolated single and double DNA strand breaks, which can be repaired by the cells rather quickly and cleanly. Proton and ion radiation produces complex cluster damage to the DNA strands that are significantly less repairable. A macroscopic tumor may originate from only one transformed cell. If a single mutated cell survives, cancer may develop.

The primary means that multicellular organisms utilize to repair radiation damage is to identify and discard the affected cell and manufacture replacements. But single cell organisms do not have that luxury. As a result, many single cell organisms have evolved very complex and redundant repair mechanisms that ensure their survivability even under higher levels of radiation damage. The most resistant organisms are single-stranded viruses, followed by double-stranded viruses, bacteria, algae and yeast. Under nuclear radiation, many of these single cell organisms will mutate and survive. The genetic variations will spawn new mutated single cell organisms that are extremely virulent and deadly especially to the future host they infect. That is why great plagues are intertwined with the great famines at the onset of major global cooling events.

Sensitivity of Prokaryotic and Eukaryotic Organisms to Radiation

<u>Name</u>	<u>Species</u>	<u>D0 (Grays)</u>
T1-phage	Virus	2600
Escherichia. coli B/r	Bacteria	30
Bacillus subtilis cells	Bacillus	33
Saccharomyces cerevisiae	Yeast	150
Chlamydomonas	Algae	24
Human	Human	1.4

D0 is defined as the dose necessary to reduce survival to 1/e (37%). Gray is a unit of measure defined as 1 joule per kilogram of absorbed radiation.³⁷

This table shows that typically viruses, bacteria and bacilli can survive the damage from greater ionizing radiation exposure than many multicellular organisms. But very high energy GCRs will damage these organisms producing new mutated and lethal strains.

Water is a natural shield to nuclear radiation. These genetic mutations are most likely to occur where the Earth’s natural atmospheric shielding is thinnest, and the air is the driest, such as the high deserts.

Rinderpest

An extremely virulent variant of Rinderpest struck animals immediately at the onset of the first Little Ice Age in 1315 A.D. producing an animal plague that wiped out vast herd of oxen, sheep, goats, camels, buffaloes, yaks, etc. In several large herds, only a couple animals survived. This plague was also present during the Dark Ages that began in 536 A.D.

Black Death (Bubonic Plague)

Yersinia Pestis is a pathogen that has undergone large-scale genetic flux. Global cooling at the beginning of the Dark Ages began in 536 A.D. An outbreak of the Bubonic Plague struck Constantinople 6 years later. It was caused by a very deadly variant of the *Yersinia Pestis* bacillus that used fleas (and rats) as a plague transport mechanism. This plague was referred to as the Plague of Justine. As it swept from the Middle East to the Mediterranean Basin, approximately 50 percent of population perished.

Global cooling at the beginning of the Little Ice Age began in 1315 A.D. An outbreak of the Bubonic Plague struck the Chinese Gobi Desert 15 years later. This deadly variant of the *Yersinia Pestis* bacillus killed 35 million Asians and spread westward where it killed approximately 1/3 of the European population. The plague was known as the Black Death. It came in three variants: bubonic plague, primary septicemic plague, and the pneumonic plague. To date, this deadly bacillus has been responsible for 200 million human deaths.

The flea/rat/human plague route still exists today. The Earth is a fertile ground for another great plague. If a mutated form of the bubonic plague were to infect the rat population, the results could be devastating. For example, it is estimated that the number of rats living in New York City is in the range of 44-96 million. The estimated rat population in the United States may exceed 300 million.

Malaria

Another type of plague occurred during past global cooling events. But this time, instead of resulting from genetic mutation, it was due to the GCR induced extensive flooding. The heavy rainfalls produced new swamplands across the globe. These swamps became breeding grounds for major mosquito borne diseases including malaria. Major malaria outbreaks occurred across Europe during the beginning of the Little Ice Age around 1315 A.D.

Malaria is transmitted by mosquitoes. When a mosquito bites an infected person, it ingests microscopic malaria parasites found in the person's blood. When the mosquito then bites another person, the parasites go from the mosquito's mouth into the person's blood. Within a human, the parasite goes to the liver, replicates, and moves into the bloodstream, where it attacks red blood cells for their hemoglobin. Toxins from the parasite are then released into the blood, making the person feel sick. Malaria produces fever and flu-like illness, including shaking chills, headache, muscle aches, and tiredness. Nausea, vomiting, and diarrhea can also occur. Malaria in children can produce anemia, jaundice, kidney failure, seizures, mental confusion, coma, and death. The World Health Organization estimates that 300-500 million cases of malaria occur and more than 1 million people die each year from malaria, mostly children in sub-Saharan Africa.

VIII. Earth's Magnetic Field

Weakening of the Earth's magnetic field, fracturing the strong dipole into several mini-pole reversals, is a strong amplifying mechanism for GCR induced global cooling.

We live in a Great Ice Age called the Pleistocene Epoch which began around 1.8 million years ago and will continue for several million years into the future. During an Ice Age, the Earth cycles between cold Glacial and warm Interglacial periods. An Interglacial is a short warming period where the Earth thaws between the icy grips of the glacial periods. The present interglacial period (the Holocene) began approximately 12,000 years ago.

ICE AGE TRANSITIONS FOR PAST 1.5 MILLION YEARS

Holocene (**interglacial**, 12,000 years ago - present)
 Wisconsin/Weichsel (**glacial** period, 110,000 – 12,000 years ago)
 Sangamonian/Eemian (**interglacial**, 130,000 – 110,000 years ago)
 Illinoian/Saale (**glacial**, 200,000 – 130,000 years ago)
 Yarmouth/Holstein (**interglacial**, 300,000/380,000 – 200,000 years ago)
 Kansan/Elsterian (**glacial**, 455,000 - 300,000/380,000 years ago)
 Aftonian (**interglacial**, 620,000 - 455,000 years ago)
 Nebraskan/Menapian (**glacial**, 680,000 – 620,000 years ago)
 Pastonian Stage (**interglacial**, 800,000 – 680,000 years ago)
 Pre-Pastonian Stage (**glacial**, 1,300,000 – 800,000 years ago)
 Bramertonian Stage (**interglacial**, 1,550,000 – 1,300,000 years ago)

One of the predominant theories describing the cause of glacial/interglacial periods is the Milankovitch cycle theory. According to the theory, small variations in Earth-Sun geometry change determine the amount of sunlight each hemisphere receives during the Earth's yearly orbital cycle around the Sun. These geometry changes include (1) **eccentricity** - small variations in the changing of Earth's orbit around the sun (circular/oval) on a 100,000 year cycle, (2) **obliquity** - the tilt of Earth's spin axis between 22 and 24 degrees every 41,000 years, and (3) **precession** - Earth wobbles toward and away from the Sun over the span of 19,000 to 23,000 years.

But the theory fails in describing (1) the abrupt nature of transition boundaries between glacial and interglacial periods (sometimes occurring within a few short years), (2) because orbitally-induced changes in the solar energy flux received by the Earth is too weak, and (3) because the actual glacial/interglacial period lengths vary significantly from theoretical projections.

When the Earth's magnetic field is strong, it is characterized as a dipole with a north and south magnetic pole on opposite sides of the Earth. But when the magnetic field weakens, it often breaks down into quadrupoles, octupoles and local magnetic field reversals (mini-pole reversals). The appearance of this complex structure allows mini-poles to effectively cancel out the Earth's total magnetic field reducing the overall magnetic field strength to 10 percent or below. During this phase the local fields can reverse polarity several times before they restructure back into a strong dipole configuration. The restructuring can lead to a global polarity reversal or to a restoration of the normal state.

The intensity of the earth's magnetic field has been declining. Scientific analysis of ancient pottery has shown that the magnetic field strength has declined 50 percent in the last 4,000 years. Recently, the decline has become very steep and pronounced. The decline in field strength at the equator has fallen 4.5 percent during the last century. Most of this decline occurred during the last 25 years. Using the International Geomagnetic Reference Field (IGRF) data set, the magnetic field at the equator in Open Ocean shows a decline of 1.7 percent in intensity since 1980. (*Geomag program, IGRF dataset, latitude 0 degrees, longitude 180 degrees, years 1980-2005, a decline from 34,824 to 34,246 nanoTesla (nT)*).

Dr. Heikki Nevanlinna, Research Professor at Geophysics Research, Finnish Meteorological Institute, wrote an article in Helsingin Sanomat, the leading newspaper in Finland, July 27, 2002. In the article, he states that the North Hemisphere magnetic pole has moved 1500 kilometers in the past 100 years while the South Hemisphere magnetic pole has moved only 1000 kilometers during the same period. The structure of the Earth's magnetic field is currently asymmetric.

A South Atlantic Anomaly (SAA) has appeared, which is a major depression in the magnetic field strength. The field strength within this depression approaches only 20,000 nanoTesla (nT).³⁸ The SAA can be described as a large local magnetic field reversal.

The fact that Earth's magnetic field is currently asymmetric combined with the fact that a magnetic field depression has formed would lead one to believe that the Earth's magnetic pole components are being restructured.

When Earth's magnetic field changes are viewed through the prism of GCR/cloud linkage, an interesting observation can be made. Cloud formation due to cosmic rays is temperature dependent and therefore latitude dependent. The earth is protected by a magnetic field that provides the greatest protection at the equator and the weakest at the poles. But the poles are generally the coldest areas on the earth, characterized by very low humidity. Without any moisture and heat to work with, cosmic rays are very ineffectual in forming clouds. But on the other hand the equatorial ocean areas with heat and humidity are great breeding grounds for massive storms, but these are the areas shielded the most by earth's magnetic field. GCR penetration in the equatorial region is a robust mechanism for great cloud formation. Therefore as the Earth's magnetic field begins to weaken and localized areas of magnetic pole reversals form closer to equatorial regions, the effects of GCR cooling greatly increases.

The Earth's magnetic field was extremely robust during the Holocene. The abrupt strengthening in the magnetic field coincided with the abrupt end of the last glacial period. By contrast, the last two interglacial periods came to an end when the Earth's magnetic field was weak and near the point of a magnetic field reversal. I assert that the weakening of the Earth's magnetic field will signal the end of the present Holocene interglacial.

As the Earth's magnetic field weakens further, other regions of magnetic field reversals will materialize. When these regions materialize near equatorial regions where elevated moisture and heat prevail, significant global cooling will begin driving the Earth back into the next Glacial period.

Solar "Grand Minima" occur very abruptly. I assert that these minima will occur during both glacial and interglacial periods. The combination of a mini-pole reversal near the equatorial region with a "Grand Minima" event can explain the abruptness seen in interglacial/glacial transitions.

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