The Nature of the Sun's Influence on Climate Change

James A. Marusek*
Impact, Bloomfield, Indiana 47424

[Abstract] The sun's magnetic field wrapped within the solar winds is a major force driver modulating natural climate change on Earth. The solar influence affects ocean cloud creation and sea surface temperature. The relationship between ocean surface temperature and the strength of the sun's magnetic field is best fitted using a natural logarithmic function of the AA Index.

I. Introduction

WE are at the verge of the next sunspot cycle, solar cycle 24. How intense will this cycle be? Why is this question important? Because the sun is the major force controlling natural climate change on Earth.

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 within the solar winds. The field deflects many of these 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. A large increase in Earth's cloud cover produces a global decline in temperature.

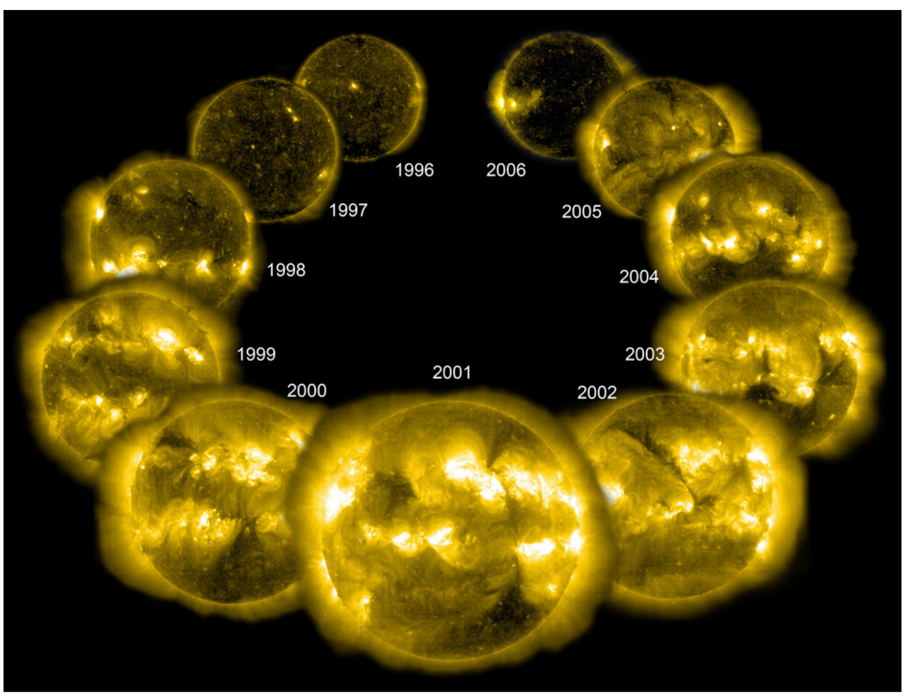


Figure 1. Image of Solar Cycle 23 from the Solar and Heliospheric Observatory (SOHO) by Steele Hill (NASA GSFC).

---

* Nuclear Physicist and Engineer, Impact, RR 6 Box 442.

II. Historic Solar Cycle Intensity

THE sun exhibits great variability in the solar cycle magnetic field strength. This activity ranges from the extremely quiet Maunder Minimum (1645-1715 A.D.) to the enhanced activity observed during most of the 20^{th} century. The solar magnetic activity has been reconstructed from concentrations of cosmogenic isotopes ^{14}C and ^{10}Be in terrestrial archives. As high-energy Galactic Cosmic Rays (GCRs) impact Earth's outer atmosphere, they fracture atoms transforming nitrogen and oxygen into radioactive forms of carbon and beryllium. These isotopes fall to Earth's surface which permits a historical reconstruction. The sun's magnetic field wrapped in the solar winds deflects GCRs trying to enter our 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.[1] Refer to Figure 2. The sun is currently in a grand maxima (1940-2000 A.D.). Typically these grand maxima are short lived lasting in the order of 50 years.

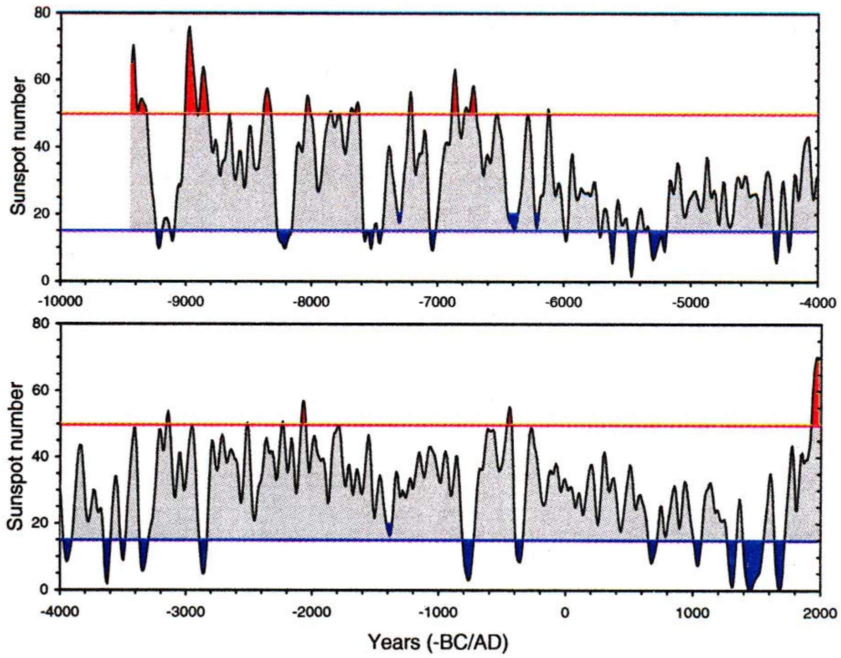


Figure 2. Sunspot activity throughout the Holocene. Blue and red areas denote grand minima and maxima, respectively. The entire series is spread out over two panels for better visibility.[1]

III. Solar Forcing Mechanism

THE sun is a major force controlling natural climate change on Earth. Its magnetic field shield Earth from GCRs. When the sun's magnetic field weakens, GCRs are able to penetrate deeper into our solar system producing global cooling through the production of greater cloud cover.

Earth's ocean cloud cover is strongly correlated with Galactic Cosmic Ray (GCR) flux modulated by solar cycle variations. Refer to Figure 3.

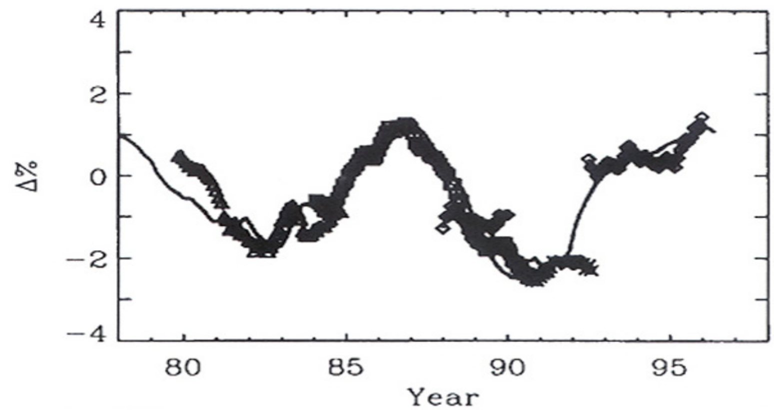


Figure 3. A strong correlation between Galactic Cosmic Rays (GCRs) and Earth's cloud cover. Figure shows cosmic rays fluxes from Climax (thick curve) plotted against four satellite cloud data sets over the ocean. Triangles are the Nimbus-7 data, squares are the ISCCP-C2 data, diamonds are the DMSP data, and crosses are the ISCCP-D2 data.[2]

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. 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.

In 2006, the Danish National Space Center in Copenhagen showed experimentally the causal mechanism by which cosmic rays facilitate the production of clouds in Earth's atmosphere.[3]

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.

IV. Ocean Surface Temperature Analysis

DOES a link exists between the intensity of the sun's magnetic field and surface ocean temperature? The oceans cover 70 percent of the Earth's surface and act as a large planetary heat sink. Because the area of ocean is large; a long-term change in low level clouds over the ocean has 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.[4] 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 4 graphs global monthly ocean temperature anomalies in relationship to the "AA index" for the past 120 years.

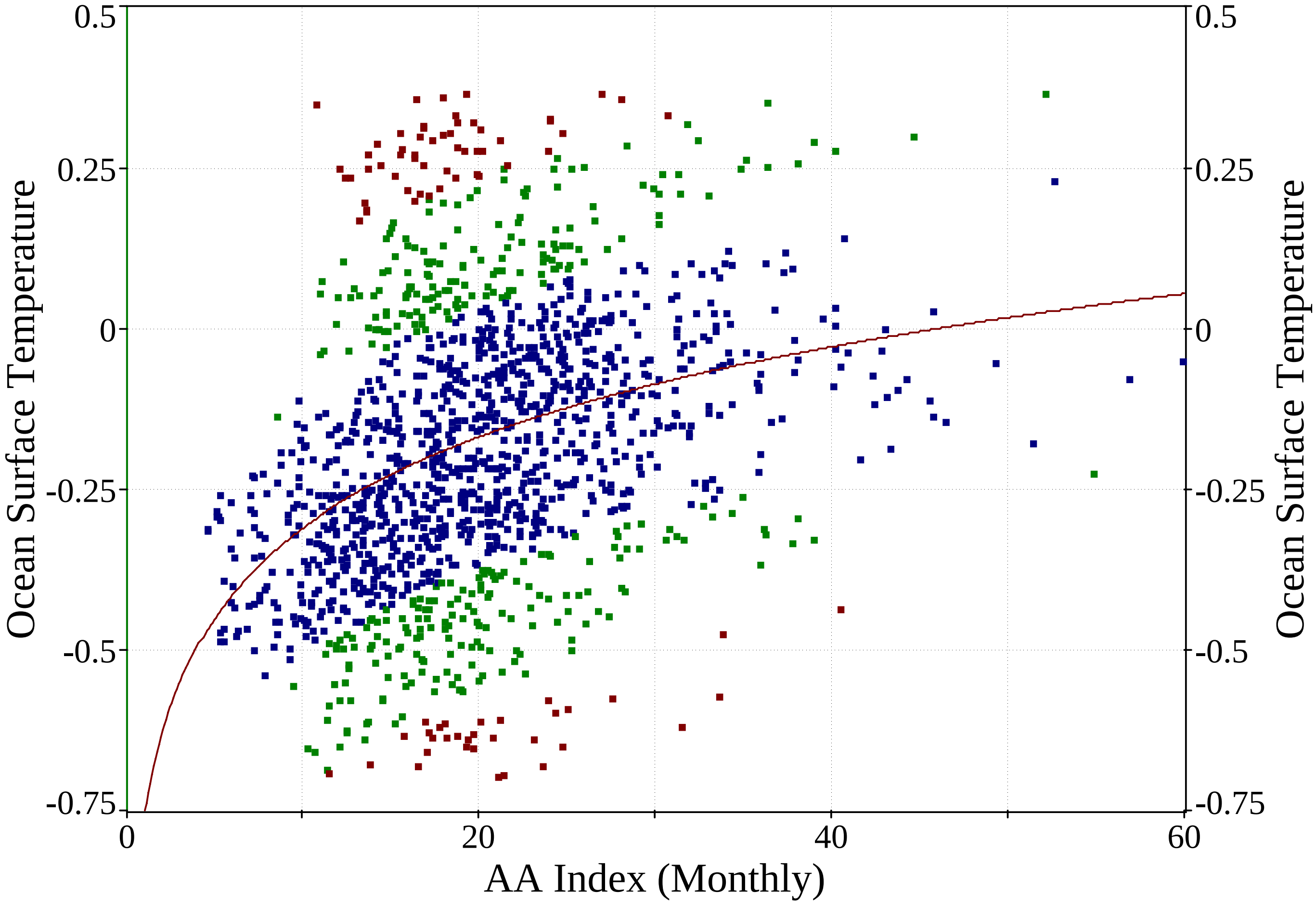
Figure 4. Ocean Surface Temperature as a Function of AA Index

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



The relationship is described by the formula:

$$\textbf{Ocean Surface Temperature Anomaly} = 0.203 \ln(\text{AA Index}) - 0.778°\text{C} \qquad (1)$$

This figure was derived using the Smith-Reynolds Extended Reconstructed Sea Surface Temperature (ERSST.v3).[5] 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.[6] 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.[7] All eruptions with a Volcanic Explosivity Index (VEI) of 6 or greater were identified and the 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 5 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, global temperatures were ~1° C colder than present. This period of time corresponds to the Maunder Minimum (1645-1715 A.D.), a period of time when the sun's magnetic field almost went dormant. For example, during one 30-year period (1672-1699 A.D.) within the Maunder Minimum, astronomers observed approximately 50 sunspots, as opposed to more typical 40,000–50,000 sunspots. Although the Maunder Minimum is prior to the start of "AA Index" measurements; in my opinion, 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 ~1° C as compared to present day temperatures.

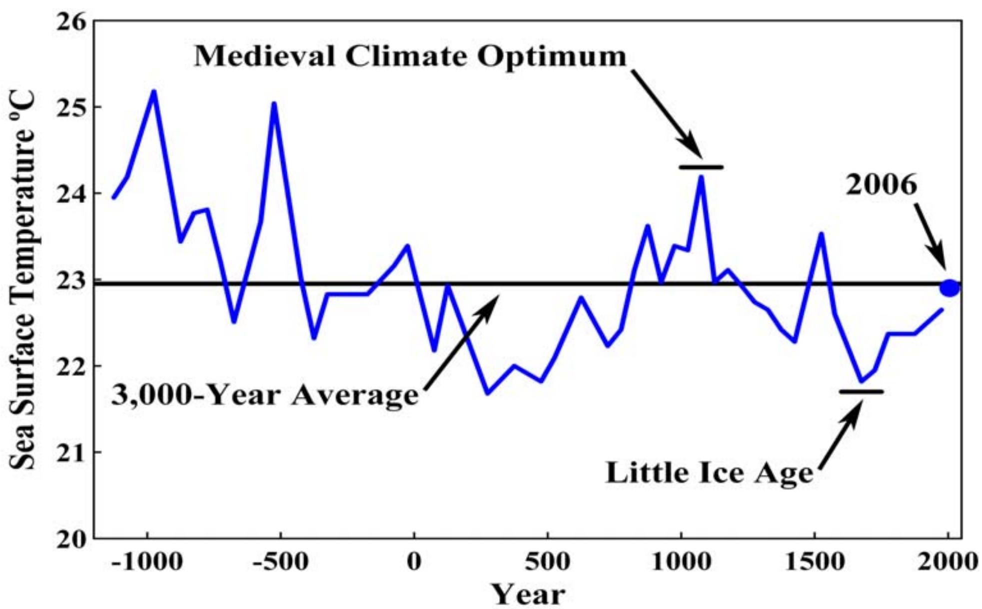


Figure 5: Surface temperatures in the Sargasso Sea, a 2 million square mile region of the Atlantic Ocean, with time resolution of 50 to 100 years. The horizontal line is the average temperature for this 3,000-year period. The Little Ice Age and Medieval Climate Optimum were naturally occurring, extended intervals of climate departures from the mean.[8]

V. Summary

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. Recent experimental studies have confirmed the causal mechanism behind this process. This paper looks at the relationship between the solar magnetic field (as expressed in "AA Index") and ocean surface temperature over the period from 1880 A.D. to present and finds this relationship is best expressed by a natural logarithmic function.

References

[1]Usoskin, I.G., S.K. Solanki, and G.A. Kovaltsov (2007) Grand minima and maxima of solar activity: new observational constraints, *Astronomy & Astrophysics*, **471**, pp. 301-309, doi:10.1051/0004-6361:20077704, URL: http://cc.oulu.fi/~usoskin/personal/aa7704-07.pdf

[2]Svensmark, H and E. Friis-Christensen (1997) *Journal of Atmospheric and Solar-Terrestrial Physics*, **59** (11), pp. 1225-1232.

[3]Svensmark, H., J.O.P. Pedersen, N.D. Marsh, M.B. Enghoff and U.I. Uggerhoj (2007), Experimental evidence for the role of ions in particle nucleation under atmospheric conditions, *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* **463** (2078): pp. 385-396, doi:10.1098/rspa.2006.1773, URL: http://www.journals.royalsoc.ac.uk/content/3163g817166673g7/fulltext.pdf [cited 3 January 2008].

[4]Georgieva, K., C. Bianchi and B. Kirov (2005) Once again about global warming and solar activity, *Mem. S.A.It.*, **76**, 969, URL: http://sait.oat.ts.astro.it/MSAIt760405/PDF/2005MmSAI..76..969G.pdf [cited 3 January 2008]

[5]National Climate Data Center, NOAA, Extended Reconstructed Sea Surface Temperature (ERSST.v3), URL: http://www.ncdc.noaa.gov/oa/climate/research/sst/ersstv3.php#desc [cited 8 January 2008]. The time series in ASCII format can be accessed through ftp://eclipse.ncdc.noaa.gov/pub/ersst/pdo/ by selecting dataset aravg.mon.ocean.90S.90N.asc

[6]National Climate Data Center, NOAA, Solar Data, URL: ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/RELATED_INDICES/AA_INDEX/ [cited 17 December 2007]. The time series is accessed by selecting the dataset AA_Month.

[7]Smithsonian National Museum of Natural History, Large Holocene Eruptions, URL: http://www.volcano.si.edu/world/largeeruptions.cfm [cited 17 December 2007]

[8]Robinson, A.B., N.E. Robinson, and W. Soon [2007] Environmental effects of increased atmospheric carbon dioxide, *Journal of American Physicians and Surgeons* **12**, pp. 79-90, URL: http://www.oism.org/pproject/s33p36.htm [cited 10 January 2008]