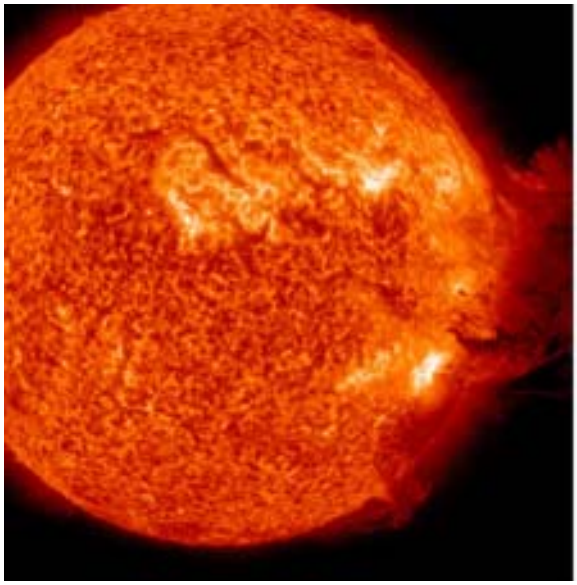
SOHO image - Octtober 2003

What's Up With the Sun:

Are We In For A New Maunder Minimum?

BY THOMAS M. CIESLA

The teachings of Aristotle held that the Sun and the Heavens were the embodiment of unblemished perfection. These teachings deeply affected the ancient Greeks and western European thinkers, causing confusion when sunspots were eventually discovered. It wasn't until the 1600's when Galileo realized that sunspots were on the surface of the Sun and not shadows of planets as some believed. Today astronomers have access to instruments that would amaze Galileo-era scientists. We can view the Sun in visible light, ultraviolet, infrared, x-ray and gamma rays to reveal a wealth of information about our star. Yet despite these advances, there are still many solar puzzles to be solved regarding sunspots, the forces that form them, and the impact on Earth's climate.



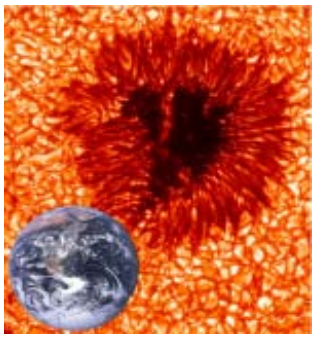
Dateline: 6/7/2011: One of the most spectacular solar prominences ever recorded. Earth received a glancing blow from the CME, creating nice auroral displays. Credit - SDO's Atmospheric Imaging Assembly.

On August 4th, 2011 Sunspot 1261 unleashed a strong solar flare – the third in as many days. The resulting coronal mass ejection (CME) was hurtled almost directly at Earth. By August 5th, the CME impact with Earth's magnetic field was in progress, creating aurora visible in Southern England. On August 9, 2011, the Sun erupted with the largest solar flare of Cycle 24, registering as an X7-class flare. This flare had an X-ray magnitude of X6.9, and the source was Sunspot 1263 which is nearing the western limb of the Sun, therfore pointing away from the Earth.

Despite this recent activity, some scientists believe that the next sunspot cycle will be minimal, if it appears at all. The number of sunspots visible on the Sun waxes and wanes over an approximate 11 year cycle. Our Sun is currently moving towards solar maximum in the midst of the period designated as Cycle 24. This current cycle started late and weak and may not be strong enough to create enough magnetic activity at the Sun's poles, indicating that the 2013 solar maximum will be weak. At solar maximum the number of sunspots should be around 250 a month, up from the average of 50 a month.

Why all this interest in sunspots? Sunspots are the most visible indicator of solar geomagnetic activity. Intense magnetic fields break through the Sun's surface and in doing so create areas roughly 1500 degrees cooler that than surrounding photosphere, therefore appearing as dark spots. The energy fields that form sunspots are also responsible for solar flares and the CME's discussed earlier. CME's can negatively affect our satellites, communications systems, and power grids. We have a fairly good idea of what to expect from an active Sun, but are unsure of all the consequences of a quiet Sun.

Three separate lines of research found a missing jet stream, fading spots and slower activity near the poles of the Sun, possibly indicating that it is heading for a rest period. These studies of the solar interior, the visible surface, and the corona indicate that the next 11-year sunspot cycle – Cycle 25 – will be greatly reduced. Does this mean that the Sun is heading into a hibernation period equivalent to a second Maunder Minimum, a 70-year period with almost no sunspots during 1645-1715?



Size comparision of Earth and a sunspot. Credit: The Royal Swedish Academy of Sciences, V.M.S. Henriques (sunspot), NASA Apollo 17 (Earth).

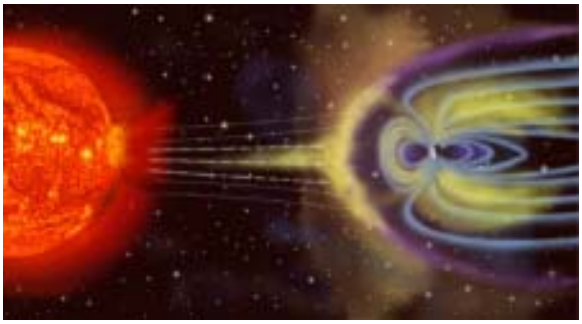
At the annual meeting of the Solar Physics Division of the American Astronomical Society this past June, Dr. Frank Hill of the NSO's Solar Synoptic Network, told attendees, "..the fact that three completely different views of the Sun point in the same direction is a powerful indicator that the sunspot cycle may be going into hibernation." Dr. Hill is the lead author of a paper discussing their discovery of an east-west zonal wind flow inside the Sun, called the torsional oscillation, that starts at mid-latitudes and moves down towards the equator. "we expected to see the start of the zonal flow for Cycle 25 by now, " said Hill, "but we see no sign of it. This indicates that the start of Cycle 25 may be delayed to 2021 or 2022, or may not happen at all."

In another paper, Matt Penn and William Livingston see a long-term weakening trend in the strength of sunspots, and predict that by Cycle 25 magnetic fields erupting on the Sun will be so weak that few if any sunspots will be formed.

In a third paper, Richard Altrock, manager of the Air Force's coronal research program has observed a slowing of the "rush to the poles", the rapid poleward march of magnetic activity observed in the Sun's faint corona. It is a well-known pattern; new solar activity emerges at about 70 degrees latitude at the start of the cycle, then towards the equator as the cycle ages. At the same time new magnetic fields push remnants of the old cycle as far as 85 degrees poleward.

All three of three of these research efforts point to a shutting down of the sunspot cycle. However, Dr. Hill is quick to say, "We are NOT predicting a mini-ice age. We are predicting the behavior of the solar cycle." Some of the coldest winters of the Little Ice Age occurred during the middle of the

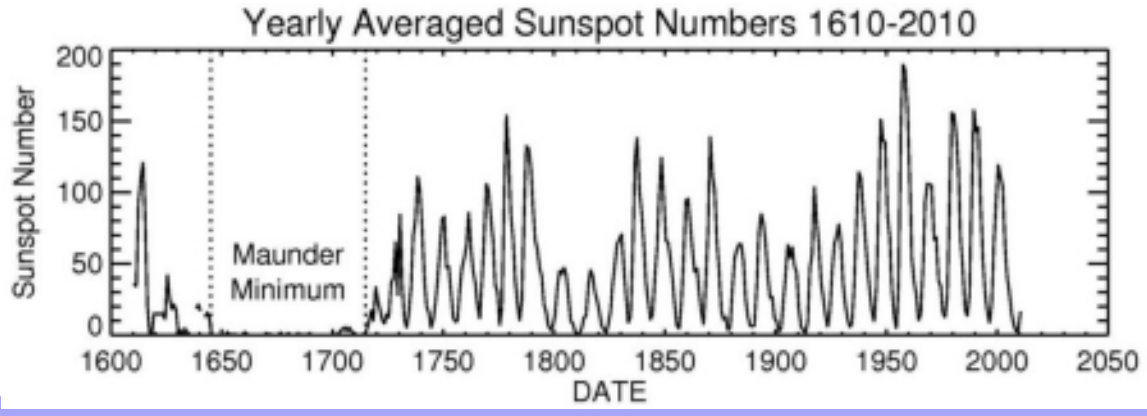
Maunder Minimum. The collapse of European agriculture caused widespread famine in: France (1693-1694), Norway (1695-1696), and Finland & Norway (1696-1697). In the late 17th century, writes anthropology professor Brian Fagan, agriculture had dropped off so dramatically that "Alpine villagers lived on bread made from ground nutshells mixed with barley and oat flour."



Artist depiction of the solar wind interacting with the Earth's magnetosphere, Sheilding life from harmful radiation. NASA

It is still not certain, whether changes in the Sun's energy output during the Maunder Minimum, contributed to the severe cold experienced in North American and Europe in the late 17th century. One team of scientists at the NASA Goddard Institute tackled that question by studying temperature records and feeding the data into a computer model developed under the lead of climate scientist Drew Shindell. The model is a mathematical representation of the way various Earth systems – ocean surface temperature, different types of atmosphere,, energy reflected and absorbed from land, and so forth – interact to produce climate.

The model showed the team how the extreme cold conditions during Maunder Minimum was related to ozone levels. The model also showed how temperature was related to ozone in the stratosphere. Ozone is created when ultraviolet light from the Sun interacts with oxygen. During the Maunder Minimum the Sun emitted less ultraviolet light and so less ozone formed. The decrease in ozone affected planetary waves, the giant wiggly lines we see on television weather reports. This turn affected the North Atlantic



Oscillation (NAO), which is a balance between a low pressure system near Iceland and a high pressure system near the Azores. A weakening of the NOA shifts the Westerlies from Northern to Southern Europe, allowing cold polar air to sweep across Northern Europe which in turn, experiences more severe winters.

So are we in for another Maunder Minimum and another Little Ice Age? We simply don't know, but if the Sun does experience a period of hibernation, it will be a unique opportunity for scientists to study the impact on climate. According to climatologist Michael Mann of Penn State University, the cooling effect of the Maunder Minimum "was probably only a couple of tenths of a degree. It's a tiny blip on the radar screen if you're looking at the driving factors behind climate change."

While it is true that severe cold coincided with the Maunder Minimum, it's important to remember that the Little Ice Age (LIA) started before that solar event. Prior to the Little Ice Age was a period called the Medieval Warm Period from 900-1300 AD. Some place the start of the LIA at 1300 AD and ending in 1715 AD, but NASA dates the LIA to between 1550 – 1850 AD. There is no clear evidence for what caused the LIA, but regardless of whose timeframe you use, it's obvious that the LIA did not begin or end within the Maunder Minimum.

Research has shown, however, that the climate also cooled during other periods of low solar activity: **Oort Minimum** (1010-1050 AD), **Wolf Minimum** (1280-1340 AD), **Sporer Minimum** (1420-1530 AD), and the **Dalton Minimum** (1790 – 1820). The cooler climate at the end of the Dalton Minimum has been attributed to the 1816 explosion of the supervolcano Mt. Tambora in Indonesia.

Cycle 24 is estimated to end in 2019. As we wait with anticipation for the start of Cycle 25, a fleet of solar observing spacecraft will study various aspects of the Sun's energy activity. With this data, scientists around the world will track how space weather might impact Earth's climate.

NUMBERS

4.5 billion years: the estimated age of the Sun

600 million tons: the amount of hydrogen converted to helium every second

27 million: the temperature at the Suns core

1 million mph: the speed of the solar wind

1 million: the temperature of the Suns outer atmosphere (the corona)

869,900 mi: the diameter of the Sun (at its equator)

333,000: the mass of the Sun (Earth mass=1)

9932 F: surface temperature of the Sun

99.8%: percentage of Solar System mass contained in the Sun

One Earth diameter: size of a small sunspot