Extra-Terrestrial Influences on Nature's Risks

Brent Walker - February 2012

1. Foreword – From Copernicus to this paper

"Among the authorities it is generally agreed that the Earth is at rest in the middle of the universe, and they regard it as inconceivable and even ridiculous to hold the opposite opinion. However, if we consider it more closely the question will be seen to be still unsettled, and so decidedly not to be despised."
- Book One, Chapter V. Whether Circular Motion is Proper to the Earth, and of its Place'; Copernicus: On the Revolutions of the Heavenly Spheres (1543)

Nicolas Copernicus (1473 –1543)

Nicolas Copernicus, a Polish astronomer, is understood to be the first (European) to formulate the heliocentric cosmology that replaced the Ptolemaic science of the Earth being the stationary centre of the Universe. Copernicus was not only an astronomer he was also a mathematician, a jurist with a doctorate of law, a physician, an economist, an artist and a cleric of the Catholic Church. He was fluent in Polish, German and Latin and spent time as a diplomat. His work on the heliocentric theory, De revolutionibus orbium coelestiu (*On the Revolutions of the Heavenly Spheres)* which he commenced around 1530, was published just after his death. However, 16 years earlier, an untitled manuscript known as the Commentariolus expounded this theory. This manuscript was only ever privately circulated. The hand written original of De revolutionibus and a copy of what is believed to be the Commentariolus are still in existence. He is credited with ushering in the scientific revolution, which continues today[1].

Copernicus dedicated his work to Pope Paul 3rd and many cardinals of his day were interested and appreciative of his theory. But later, scientists who further developed this theory, paid severe penalties for their heresy.

Tycho Brahe 1546 – 1601

Tycho Brahe, a Danish astronomer collected a large volume of precise measurements of the positions of the stars and planets, although he did little analysis on his collected data. He also observed a supernova in the year 1573 and noted that this "new star" was evidence against the belief that "the heavens are unchanging".

Giordano Bruno 1548 - 1600,

Giordano Bruno, a Dominican Monk and an astronomer, mathematician and philosopher went beyond the Copernician model to theorize that the Sun was a star and that many other planets with intelligent life existed. He was executed by being burnt at the stake for his views. Some documents of his trial in Rome still exist. These documents point to his heretical views on other intelligent life as giving rise to his sentence but it is believed that his work supporting the Copernican theory weighed heavily against him. How soon before the second component of his theory is proven?

Galileo Galilei 1564 - 1642,

Galileo Galilei, a professor of astronomy heard about the development of the telescope and decided to make his own. On Jan 7, 1610 using his 3rd new telescope with 30x magnification he observed Jupiter with several sources of light ('stars') around it. But the next night he saw that one of the 'stars' was on the other side of Jupiter. After some weeks of observing the rotation of these 'stars' he realized these were satellites of Jupiter and hence developed his own theory that not everything in the heavens revolved around Earth. Galileo's big mistake was to publish his findings in Italian rather than Latin. This caused the Church to take offence at such information being provided to the public. A few years later Galileo Galilei was tried in Rome and upon his repentance and undertaking to never again to publish these theories, he was sentenced to life in prison. This was

[1] Information on Copernicus, Bruno and Galileo has primarily come from Wikipedia. Other information has

served as home detention. After his death 3 of his fingers were removed from his body and one has been kept on display at a museum in Florence.

Einstein called Galileo the father of modern science, while Stephen Hawking refers to him as bearing much of the responsibility for the birth of modern science. Actuaries will appreciate that Galileo was the first to clearly enunciate the theory that the laws of nature are mathematical. In around 1610, he is credited as being the first to recognize a sunspot. But Chinese records suggest that they knew of them around 400 - 500 BC.

Johannes Kepler 1571 – 1630

Kepler had been Tycho Brahe's lab assistant. He analyzed Tycho's collected data after his death and realized that the position of Mars, which at times appears to move in a retrograde direction, could be better explained if both the Earth and Mars moved in orbit about the Sun. He then developed three laws of motion that described the motion of the planets on the Copernicus model. These laws are still used today. The laws basically state that:

1. The orbit of every planet is an ellipse with the Sun at one of the two foci.
2. A line joining a planet and the Sun sweeps out equal areas during equal intervals of time. Thus a planet moves faster when nearer the Sun than when further from the Sun.
3. The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.

Using these laws Kepler precisely predicted the next retrograde motion of the orbit[2] of Mars, and this was considered proof. But these laws offered no explanation as to why they worked. He considered that the force involved would be magnetism.

Sir Isaac Newton (1643 – 1727)

Sir Isaac Newton was a physicist and mathematician. He is said to have observed an apple falling from a tree in 1666 and realized that he had discovered gravity. Eventually in 1687, with the support of astronomer Edmond Halley, Newton published the Philosophiae Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy), which showed how gravity applied to all objects in all parts of the universe. Sir Isaac Newton also worked on calculus, optics (in 1704 he published Optiks, which dealt with light and colour) and was also proficient in history, theology and chemistry. It is understood that Sir Isaac mentored Colin MacLaurin (1698-1746), who was then regarded as the second greatest mathematician in England (to Sir Isaac). Colin played a leading role in the evolution of actuarial science with his development of a widows' fund for the Church of Scotland.

One important aspect of Newton's three laws of the conservation of momentum, energy and angular momentum was that Kepler's laws could be derived from them.

Albert Einstein 1879 – 1955

Albert Einstein was a theoretical physicist and winner of the Nobel Peace prize. He published his general relativity theory in 1916. This extended his relativity theory to incorporate gravitational fields. He also went on to develop his particle theory and the motion of molecules as well as laying the foundation of the photon theory of light. One reason that inspired his work in general relativity was the concern in the scientific community that Kepler's laws didn't seem to apply for Mercury. An important aspect of Einstein's work was that Newton's three laws could be derived from Einstein's general theory of relativity. Hence Einstein's general relativity theory effectively incorporated both Newton's laws and Kepler's laws.

[2] Retrograde with respect to an observer on Earth.

Beyond Einstein

Since Einstein there have been many mathematicians and physicists who have taken his work much further. Stephen Hawking is one well known example. Another is Australian astrophysicist Brian Schmidt who, in 2011, won the Nobel peace prize for his work in showing how dark energy is causing galaxies to accelerate away from each other. Brian's main field of work is in supernovae, which obtain their enormous explosive energy from gravitational forces[3].

To this paper

This paper looks at various aspects of the ongoing scientific revolution in relation to our solar system and beyond. From what is now known and understood in physics, the paper attempts to identify extra-terrestrial risk factors in relation to terrestrial extreme weather, climate risks, seismicity and volcanic eruptions. The paper provides information about various useful data sets including many relatively new data sets and tools that have come into existence since the space age. These various data sets and tools can be used to predict changes in nature's risks. For example;

1. An understanding of the 18.6 year elliptical cycle of the Moon plus the harmonic resonances between the orbital periods of Venus, Earth, Mars and Jupiter and the orbital period of the Moon enable changes to be predicted in the Pacific Decadal Oscillation and the North Atlantic Oscillation. These climate cycles lead to changes in the incidence rates of El Ninos and La Ninas and assist in the prediction of future periods of extreme bushfire risk in Victoria and periods of extreme wet weather in South East Queensland.
2. Volcanic and earthquake activity is influenced by cyclical deviations from the trend in changes in Earth's rotation rate because of the change in the amount of angular momentum that is converted to internal heat energy.
3. Volcanic and earthquake activity are increased during periods when the strength of the sun's magnetic field is low for extended periods, such as during a solar grand minimum.
4. Future sunspot activity can be predicted from planetary gravitational effects. This means that the ephemeris[4] can be used to predict future solar cycles of both high and low sunspot activity and hence give many decades of warning of natural climate changes and changes in the incidences of volcanism and catastrophic earthquakes.

The development of the science of many of the topics of this paper is so extensive and specialized that no one person or even a group of people would be capable of absorbing all of it and understanding all of its implications. The paper has incorporated scientific theory and data that the author has obtained up to mid-March 2012. There is much more available scientific information and data.

[3] A supernovae explosion is equivalent to about a 10^{28} megaton hydrogen bomb

[4] The ephemeris is a computer system used in the exploration of the solar system and accurately plots the position of the sun, planets, their satellites and asteroids at any time past, present or future (within a few thousand year timeframe). It is freely available on the NASA website for anyone to use. There are also other versions of this system that have been developed in other countries.

2. Introduction

"To confine our attention to terrestrial matters would be to limit the human spirit". – Stephen Hawking

If the Global Financial Crisis taught actuaries anything, it would have been that the financial models of countries produced by economists were not infallible. We have learnt that models of the economy should not ignore the interdependence of one country's banking system to those of other countries nor the dependencies between governments, banks, and other institutions including insurers. We should not ignore the influences of governments and not just the government(s) of the country being modeled. We should not ignore the possibility that economic models are sometimes skewed to produce politically determined outcomes. The crisis is still teaching us that there are many moral hazard risks in the financial sector that must not be ignored.

We must not make the same mistakes when we model nature. We should not assume that other professions have got their models correct. We must look beyond the range of variables being taken up in models to make sure important variables haven't been left out. We need to understand the dependencies between the modeled variables and between those variables and the ones that are not included in the models. We should ensure that moral hazard risks were satisfactorily addressed and have not influenced the models to produce pre-determined outcomes. Finally, as actuaries, we must remember the statistical maxim that "*correlation does not imply causation*". In science it is physics that provides causation links. As Sir Ernest Rutherford once elegantly put it "*All science is either physics or stamp collecting*".

This paper is unashamedly about the physics related to extra-terrestrial influences on nature's risks. If actuaries who having read this paper put it down curious to know more about the incredibly powerful extra-terrestrial forces of nature then the author has done the job that he set out to do. There are many references that will enable those with curious minds to explore further.

It will give me great pleasure to learn in my dotage of actuaries using many of the useful data sets that the space age has spawned. These data sets will help actuaries with predictions about the various natural risks that give rise to claims on insurers. Already there are sophisticated risk management systems using space weather forecasting to mitigate the risks arising from major space weather phenomena. As far as I know actuaries are not involved in space weather forecasting but they should be, particularly as the profession wishes to play a substantial role in risk management so as to remain relevant by the end of the 21st Century.

If this paper was written four centuries ago the author would have met the same fate as Giordano Bruno. Even if it had been written a few years ago it would probably have been rejected as being too politically incorrect or maybe not sufficiently "actuarial". But with the Sun now, almost definitely, in a grand minimum, which on previous occasions has produced climatic periods known as "little ice-ages", it is time to look at nature's influence on the environment in addition to looking at man's influence. Although the last little ice-age occurred more than 200 years ago, records do suggest that during it and preceding little ice-age periods, there were times of intense cold in Europe and North America particularly during the Northern Hemisphere winters. The climate during these periods was further complicated by what seems to have been increased volcanic activity. Some of the largest recorded earthquakes also happened during these periods.

Was the extreme cold in Europe in February 2012 just a taste of what is still to come in Northern winters of the next few decades? Let's not forget that collectively mankind has experienced great difficulties obtaining food and energy during previous little ice-ages. It is also worth remembering that the human population on Earth at the beginning of the last one was only 10% of what it is currently.

During the time of the last little ice-age, from 1790 – 1830, Thomas Malthus wrote his treatise, the French Revolution occurred and the Napoleonic Wars were fought.

I am deeply indebted to many people. Firstly, I am indebted to Melinda Howes, Chief Executive of the Australian Actuaries Institute, who encouraged me to write this paper. Secondly, to my peer reviewers: scientist Geoff Sharp, astronomer and mathematician Ian Wilson, members of the IAA environment committee who provided both encouragement and criticism:- Yves Guerard, Jim Murta, Oliver Bettis, who referred the paper on to scientists at the University of East Anglia, and finally actuarial friends, Ian Robinson, Peter Carroll and Geoff Dunsford. Also I must thank my friend Rex Turner, my boss of more than 30 years ago, who provided some structural suggestions.

I must also acknowledge my wife; Jan, my children; Ben and Pip and my older grandchildren; Brandon, Saxon and Tahlia. For more than the year that it is taken to research and write this paper they have had to put up with my odd ravings and my even odder eureka moments.

3. Summary and Conclusions

"To explain all nature is too difficult a task for any one man or even for any one age. Tis much better to do a little with certainty & leave the rest for others that come after than to explain all things by conjecture without making sure of anything." – Sir Isaac Newton

The following is a summary of this paper:

Section 4 (Risk Factors Originating from within the Solar System):

a) The Sun is predominant in a still evolving solar system, with Jupiter being the predominant planet.
b) Transfers of angular momentum between orbiting bodies occur. Some transfers are quantified and these transfers are enormous.
c) There are Moonquakes and they are caused by a number of factors.
d) Sunspot activity is very weak in the current cycle and seems to be getting weaker. Also there is a great variation between sunspots and these variations affect some of the Sun's emissions.
e) The Sun's size slightly changes during solar cycles and between cycles of maximum and minimum activity and thus total solar irradiance also (slightly) varies.
f) How the temperature changes in the various zones in the upper atmosphere and what causes those changes.
g) The Sun's magnetic field varies significantly by several hundred percent over a solar cycle and is very weak for the current stage of solar cycle 24.
h) Extreme ultra-violet and far ultra-violet emissions of the sun (UEV and FUV emissions are mainly in ultra-violet C spectrum) vary by several hundred percent over a solar cycle and are very weak for the current stage of solar cycle 24.
i) The Sun's path around the solar system barycenter is wobbly but predictable from the gravitational effects of the major planets. There are a number of similarities between its movements in 1790/92 and in 2004/10. (The Dalton Grand Minimum is said to have commenced in 1790). Also, once Jupiter's influence is excluded there are a number of similarities in the movement of the solar system barycenter relative to the sun from 1788-1793 and 2004-2011.
j) There is a very strong likelihood that the Sun has entered a new "Grand Minimum".

Section 5 (Gravity and Tidal Forces):

a) Gravity, through tidal forces is gradually imposing a grand order to our solar system through phase locks, resonances and harmonics.
b) The Moon is phase locked and this was caused by gravitational tidal forces.
c) Many large satellites of other planets are phase locked and some harmonically resonate.
d) Many planets are in resonance or near resonance.
e) Charon, Pluto's satellite, is in geostationary orbit. This was caused by tidal forces.
f) Earth's day lengthens due to transfers of angular momentum to the Moon and is caused by tidal forces. But nearly all rotational energy lost by Earth is transferred to internal heat energy.
g) The enormous tidal forces on Io (Jupiter's nearest large satellite) from Jupiter, Europa and Ganymede (Jupiter's next two large satellites) cause quakes and volcanism. The energy produced by this is around 125 trillion watts.

h) Shoemaker Levy 9 was broken up by tidal forces because it approached within Jupiter's Roche limit in 1993. When these pieces next approached Jupiter in 2004 they did not escape Jupiter's gravitation pull.

Section 6 (External Influences on Weather Patterns):

a) EUV, FUV, the solar wind, the magnetosphere and cosmic rays all play a role on the various levels of the atmosphere.
b) EUV and FUV normally regulate the balance between nitrogen oxides and ozone, but solar flares can upset this balance.
c) There is an extra-terrestrial reason for the occurrence of ozone holes. Ozone has a greenhouse role and hence it has a role in climate patterns.
d) The Arctic and Antarctic Oscillations affect the weather, but are influenced by the solar vortex as well as tidal, planetary and gravity waves.
e) There is a link between auroras and weather patterns.
f) There is an explanation for the recent string of very cold winters in the Northern Hemisphere and the particularly freezing February of 2012.
g) There is a relationship between the Pacific Decadal Oscillation (PDO) and El-Ninos or La-Ninas. Also there is a relationship between the PDO and changes in Earth's length of day caused by gravitational forces from within the solar system.
h) Water vapour and carbon dioxide play different roles as greenhouse gases.
i) How extreme weather patterns can occur and the role of extra-terrestrial forces on these occurrences.
j) There are climatic implications of the new solar grand minimum.

Section 7 (The Sun's Magnetic Field):

a) The planets are connected magnetically.
b) The Sun's magnetic field is currently behaving oddly at the outer reaches of the solar system.
c) Galactic cosmic rays are more prevalent during periods when the Sun's magnetic field is weak.
d) Weak galactic cosmic rays are currently able to penetrate the veil of the magnetosphere.
e) There is a periodic direct magnetic connection between Earth's magnetic field lines and the Sun's magnetic field lines.
f) There is a flux tube between Io and Jupiter, which essentially is an electric arc between the two.

Section 8 (Risk Factors that Originate From Beyond the Solar System):

a) There are tiny sub-atomic particles that have a half-life of 1.56 microseconds called Muons. Because of their energy and the general theory of relativity these particles last much longer.
b) Muons have an effect on cloud cover, particularly in higher latitudes.
c) Muons help to precipitate volcanic eruptions and probably some swarms of earthquakes, like those occurring in Christchurch, New Zealand. This is particularly the case in the Northern Hemisphere countries of Iceland, Japan, the Kamchatka Peninsula (Russia) and Alaska and in the Southern Hemisphere the countries of New Zealand, Chile, Argentina and the Antarctic continent.

d) Muon density varies by latitude and is inversely proportional to the strength of the magnetosphere.
e) There is a relationship between the intensity of cosmic ray flux (generating muons) and little ice-ages and climatic warm periods.
f) Cosmic rays affect human health.

The Conclusions

The conclusions that can be drawn from this paper are:

1) Actuarial models used to predict nature's risks should include inputs from extra-terrestrial factors.
2) There is a wealth of data being produced in the space-age that will provide actuaries with predictive tools to assess future changes in many of nature's risks.
3) Actuaries should be aware that the risk of natural catastrophes is not normal during a solar grand minimum. Actuaries should also be aware that these not normal periods only usually occur every few hundred years but they do last for decades. This means that the higher incidence of catastrophic events that have occurred in 2010 and 2011 should not be regarded as a random fluctuation but rather as the new normal for the next few decades.
4) Although research into long term climate change is important for mankind and for the profession, actuaries currently face the considerable threat that they are underestimating the natural risk frequency and severity caused by the new solar grand minimum.

Addendum

On March 28, 2012 Swiss Re published its latest Sigma study which showed that in 2011the economic losses from catastrophes totaled US$370 billion and insurance losses US$116 billion, of which US$110 billion was from natural causes. Although the economic losses were about 1/3rd higher than the previous highest year (2008) the insurance losses were slightly below that year, but only because of the very low proportion of insurance cover of the economic loss caused by the Sendai earthquake. Since 2004, when the sunspot activity went unusually quiet and unusually early in the solar cycle, there have been the four highest years of worldwide economic losses from catastrophes. Two of these years are 2010 and 2011. While the high levels of catastrophic losses in recent years are partially due to the increasing aggregation of economic risks there is also a long term natural cycle involved. This paper is intended to help actuaries better understand the natural forces that influence the risk of natural catastrophes.

4. Risk Factors Originating from within the Solar System

"Not everything that counts can be counted, and not everything that can be counted, counts." (Sign hanging in Einstein's office at Princeton)

Introduction

Conventional scientific theory suggests there was a big bang some 13.7 billion years ago from which all matter was created including our galaxy and our solar system. Billions of other solar systems that make up this galaxy also evolved and that these processes were repeated in the universe of galaxies, which are racing away from each other at a continually decreasing rate. Astronomers that peer into other solar systems see solar systems at different stages of evolution than ours. When they peer into another galaxy they see evolution at a much earlier time. This is because the speed of light is supposed to be finite so peering at solar systems (and other galaxies) that are billions of light years away is like seeing things that happened billions of years ago.

In 2011 the scientific theory of the decelerating spread of galaxies was turned on its head by Australian National University astronomer Brian Schmidt who has been named a joint winner of the 2011 Nobel physics prize for research. Brian's thesis is that the galaxies are racing away from each other at an accelerating rate due to a phenomenon known as dark energy[5]. This leads to the questions; - is the evolution of the galaxies continuing? Is our solar system still evolving?

At least one star system in the Milky Way galaxy explodes about every one or two hundred years. So our galaxy must be still evolving. Our solar system is still evolving and will continue for billions of years. The Sun is slowly using its hydrogen fuel. Current scientific theory is that in about another 4.5 - 5.0 billion years the Sun will have used up most of its fuel. It will then expand to absorb probably the 2 or 3 innermost planets[6]. But the process won't stop there. Eventually the red giant that was our former Sun will probably become a white dwarf and then, in time perhaps a new solar system will be born - perhaps by the Sun combining with another star.

Our solar system is evolving in myriads of other little ways. Some of these will be identified in this section. Because the pace of this evolution is very slow compared to our short time on Earth we tend not to notice and therefore ignore the significance of such evolution.

Nearer to home, scientists advise that the Earth/Moon relationship is still evolving. This is because the radius of the orbit of Moon is gradually increasing by about 3.8 CM per year or 38 meters per 1000 years and 38 kilometers per million years[7]. For this to occur Earth has to continually give angular momentum to Moon and this lengthens Earth's day[8]. (This means that Earth's rotation slows). This might not seem important. But the important principle to keep in mind is that angular momentum (rotational energy) transfers are occurring between Earth and Moon. But some of Earth's rotational energy is also transformed into heat as part of the Earth/Moon evolutionary process (refer Section 5).

Our Solar System

Before we can understand the risk factors that are influenced by events within our solar system it is necessary to know a little about the solar system itself.

---

[5]There are over 100 papers which Brian has contributed to on http://msowww.anu.edu.au/~brian/

[6]There are many different versions of how the Sun will die. This is one. http://www.astronomytoday.com/astronomy/Sun.html

[7]http://nineplanets.org/luna.html

[8] The length of the Earth's day lengthens by 23 milliseconds per 1000 years due to the tidal breaking of the Moon. In addition, the length of the Earth's day shortens by about 6 milliseconds per 1000 years due to crustal rebound since the end of the last ice age. Hence, overall change is a lengthening of the day by 17 milliseconds per thousand years.

The Sun dominates the solar system and contains 99.85% of its mass. The planets contain 0.135% of its mass of which Jupiter has more than 2/3rds. The planets' satellites (moons) contain 0.0005% of the mass of the solar system. Two of these satellites (Ganymede and Titan) are bigger than Mercury. These two satellites plus Callisto and Io are all bigger than Moon and all of these five satellites are bigger than Pluto. The so-called dwarf planets Eris, Pluto and Ceres are no longer regarded as full planets because they lack the gravitational pull to sweep up or scatter nearby objects and they inhabit the zone of asteroids and comets. They also don't orbit the Sun (or the barycenter of the solar system) on the same plane as the other planets.

The dwarf planets are unlike the four outer "gas giant" planets in that they are rocky and therefore more like the 4 innermost planets. More discoveries of dwarf planets and/or large deep space asteroids are likely as the exploration of them continues. For example, in December 2011 NASA reported the ion propulsion Dawn spacecraft's visit to the giant asteroid called Vesta. After a few months, the spacecraft will push on to the dwarf planet Ceres which it will explore in 2015[9].

The two tables below[10] show relevant data on the Sun and the 4 inner "rocky" planets (first table) and the Sun and the 4 outer (or Jovian) "gas giant" planets (second table). Note that Venus and Uranus rotate in the opposite direction to the remaining planets and that Uranus effectively lies on its side compared to the other planets. Only Mercury has a zero equatorial inclination to its orbit. That is, it is perfectly upright. None of the planets orbit exactly around the equator of the Sun but Earth almost does, being only 0.00005 degrees out of alignment.

Measurement	Sun	Mercury	Venus	Earth	Mars
Mean Circumference	4,370,005.6 km	15,329.1 km	38,024.6 km	40,030.2 km	21,344 km
Volume	1,409,272,569,059,860,000 km^3	60,827,208,742 km^3	928,415,345,893 km^3	1,083,206,916,846 km^3	163,115,609,799 km^3
Mass $x10^{21}$	1,989,100,000 kg	330.104 kg	4,867.320kg	5,972.190 kg	641.693 kg
Perihelion (closest)		46,001,009 km	107,476,170 km	147,098,291 km	206,655,215 km
Aphelion (Farthest)		69,817,445 km	108,942,780 km	152,098,233 km	249,232,432 km
Orbit Eccentricity		0.20563593	0.00677672	0.01671123	0.0933941
Orbit Inclination		7.0 degrees	3.39 degrees	0.00005 degrees	1.85 degrees
Equatorial Inclination to orbit	7.25 degrees	0 degrees	177.3 degrees (retrograde)	23.4393 degrees	25.2 degrees
Sidereal Rotation (Length In Earth Days)	25.38	58.646	-243.018 (retrograde)	0.99726968	1.026
Sidereal Orbit (Length in Earth Years)		0.2408467	0.61519726	1.0000174	1.8808476

Measurement	Sun	Jupiter	Saturn	Uranus	Neptune
Mean Circumference	4,370,005.6 km	439,263.8 km	365,882.4 km	159,354.1 km	154,704.6 km
Volume	1,409,272,569,059,860,000 km^3	1,431,281,810,739,360 km^3	827,129,915,150,897 km^3	68,334,355,695,584 km^3	62,525,703,987,421 km^3
Mass $x10^{21}$	1,989,100,000 kg	1,898,130 kg	568,319 kg	86,810.300 kg	102,410 kg
Perihelion (closest)		740,679,835 km	1,349,823,615 km	2,734,998,229 km	4,459,753,056 km
Aphelion (Farthest)		816,001,807 km	1,503,509,229 km	3,006,318,143 km	4,537,039,826 km
Orbit Eccentricity		0.04838624	0.05386179	0.04725744	0.00859048
Orbit Inclination		1.304 degrees	2.49 degrees	0.77 degrees	1.77 degrees
Equatorial Inclination to orbit	7.25 degrees	3.1 degrees	26.7 degrees	97.8 degrees (retrograd	28.3 degrees
Sidereal Rotation (Length In Earth Days)	25.38	0.41354	0.444	-0.718 (retrograde)	0.671
Sidereal Orbit (Length in Earth Years)		11.862615	29.447498	84.016846	164.79132

The circumference of each of the major bodies of the solar system is indicated as a mean. There are two reasons for this. None of the planets are completely spherical. This includes the 4 innermost rocky planets. The Sun and the gas giants also vary in diameter over time due to various forces within the solar system affecting the distribution and density of their plasma and/or gas. For example the Sun's circumference varies by some 800 kilometers during the normal sunspot cycle and around 1900 kilometers between grand minimum and long-term maximum cycles of sunspot activity.[11]

---

[9] Sydney Morning Herald, Dec 7, 2011

[10] Data on planets and moon is obtained from NASA website

[11] Habibullo I Abdussamatov, Dr. Sci. Head of Space Research of the Sun Sector at the Pulkovo Observatory of the Russian Academy of Sciences: http://www.gao.spb.ru/english/astrometr/index1_eng.html

Notice that Earth's sidereal rotation is not quite one earth day. In practice Earth's rotational speed varies slightly from time to time (in addition to the angular momentum transfers to Moon). The other slight variations in the rotational spin of Earth are caused by several factors: very large earthquakes can interrupt rotational spin, transfers of angular momentum caused by gravitational forces of other planets and the Sun and changes in major weather systems such as the Pacific Decadal Oscillation and the North Atlantic Oscillation. Although these changes in the speed of Earth's rotation are small[12] they do cause difficulties with modern Global Positioning Systems (GPS) and mobile phones. This was discussed at a Geneva conference in January 2012[13]. The conference discussed changing Earth time from Greenwich Mean - Time to atomic clock based time. It is being considered to cease using Earth's speed of rotation as time's frame of reference. On January 31, 2012 it was announced that further discussion on this consideration has been deferred until 2015.

Moon

Earth's own natural satellite is the only natural extra-terrestrial body that mankind has visited in person and the only natural extra-terrestrial body from which matter has been bought back to Earth. Moon was previously known as Selena (Classical Greece) and Luna (Roman Empire). Its mass is 73.49×10^{21} kg or 1.23% of the mass of Earth. It has an equatorial radius of 1,738.1km or 27.25% of Earth's equatorial radius. Its volume is 2.03% of Earth's. Its current mean perihelion distance from Earth is 363,300km and its aphelion is 405,500km. These respectively vary from 356,400km to 370,400km and 404,000km to 406,700km. Moon's orbit eccentricity is .0549, its orbit inclination is 5.145 deg. and its inclination to its equator ranges from 18.28 deg. to 28.58 deg. Its sidereal rotation is 27.32 days. Its sidereal orbit (around Earth) is also 27.32 days with an obliquity of 6.68%. This means Moon's orbit and rotation are synchronised. Because of this it shows the same face to Earth all the time. This synchronization did not happen accidently.

The Moon orbits in the same direction as Earth rotates so it takes around 29.5 days to return to the same relative position with respect to the Sun. (The exact timing depends on Moon's distance to Earth). Earth and Moon also orbit around their combined barycenter (common center of mass), which, because of Moon's elliptical orbit, lies in a straight line between Earth and Moon between around 4,412 km and 4,942 km from the center of Earth which is well inside Earth's radius. So, in effect, gravitational forces between Earth and Moon cause Earth to slightly wobble in its orbit around the Sun. From time to time this wobble allows Earth based viewers to see a few degrees of Moon's "far" side.

Moon has moonquakes. Seismometers left on Moon by the Apollo astronauts detected some 50 moonquakes in the 5 years that they were active. There were four different types:

1) Deep but weak ones centered half or more of the distance to its center. Many of these are believed to be caused by gravitational (tidal) effects from Earth as they were concentrated at periods when Moon was at its apogee and perigee from Earth[14].

2) Weak surface moonquakes were thought to be caused by localized thermal expansion when the Sun warmed the crust after a two week long frigid night.

3) At least one was thought to originate from a meteor impact.

4) Some moonquakes originated from up to 30 km deep did not have a known cause. These moonquakes ranged up to 5.5 on the Richter scale and lasted up to 20 minutes. They lasted much longer than similar Earthquakes because Moon's crust is relatively rigid, without oceans, and Moon doesn't have a liquid core. So there isn't the dampening that occurs on Earth with its more fluid

[12] But accumulate to about 1 hour in every 550 years.

[13] Status of Coordinated Universal Time (UTC) study in ITU-R. Refer for link http://www.theregister.co.uk/2011/11/03/atomic_time_could_replace_gmt/

[14] ; R. C. Weber, B. G. Bills and C. L. Johnson: Constraints on deep moonquake focal mechanisms through analyses of tidal stress - JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 114

surface and core. As a result these larger moonquakes have caused harmonic resonances within Moon, much like the resonances of a tuning fork[15][16].

It is generally accepted that Moon was formed some billions of years ago from an impact of a massive (perhaps even a Mars sized) object with Earth. Being originally part of Earth it would have had a much closer orbit when it was first formed. Like Io now (Jupiter's closest satellite) Moon in its much closer orbit would have been seismically active with many volcanoes as many of its craters are filled with magma. So it is possible that the 4th category of moonquakes originate in old fault-lines caused by previous volcanic activity when Moon was much closer to Earth. If this is the case then the incidence of Moonquakes could be changed by the same extra-terrestrial forces that cause changes in the incidence of Earthquakes. Moon doesn't have a magnetic field but rocks bought back to Earth in the Apollo missions indicate that they had been influenced by a fairly strong magnetic field at some previous time - probably Earth's magnetic field when Moon was in a much closer orbit.

The Earth's tidal force that is "stretching" the Moon is approximately 20 times the return force and so theoretically, the Moon should not be able to cause significant Earthquakes [17], (although it is possible that changes in Moon's gravitational force on a location that is about to have an Earthquake might provide a trigger). However the resulting earthquake would have still happened shortly thereafter. Even when the Sun, Moon and Earth are in alignment the extra 46% tidal force exhibited by the Sun (in comparison with Moon) is still not sufficient to make a significant difference to the incidence of Earthquakes except on the very rare occasions when this alignment slightly changes the timing.

As Moon causes tidal movement in Earth's oceans it also produces some tidal movement in Earth's atmosphere but again these effects are very slight. Scientists believe that Moon's orbit has little significance to Earth's climate other than perhaps to help keep it a little more stable. However research detailed in Section 6 suggests that Moon's overall 18.6 year elliptical orbit does have some influence.

As well as Moon causing tides on Earth the Sun also adds its weight to tidal forces when the Sun, Moon and Earth are lined up (syzygy). This is when there is a full moon or new moon and the Sun gives an extra 46% more gravitation force to Moon's gravitational force. The resulting high tides are called spring tides and these are greatest each year when the Sun is closest to Earth (Jan 5 in 2012) and presumably greatest at times when Moon is coincidentally at its perihelion (to Earth). At quadrature, when the Sun and Moon form a right angle with Earth, the Sun's effect is minimized, and the lowest tides, occur. The very lowest tides occur when Earth and Moon are both at aphelion. (Earth's aphelion in 2012 occurs on July 5).

Sun

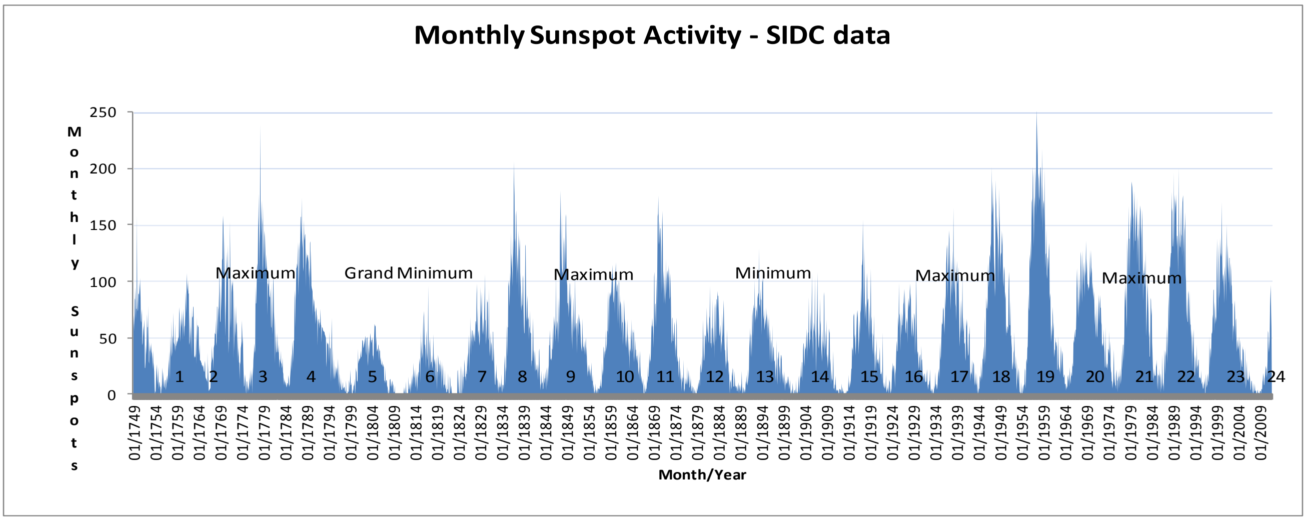
The Sun is a gaseous body comprised primarily of hydrogen (71%) and helium (27.1%) and has a mass of some 333,000 times the mass of Earth. Sun's tremendous gravitational forces give it an average specific density of 1.4 (times that of water) so most of it is in the form of plasma, which is subject to magnetic and gravitational influences. It has a thermo-nuclear core exploding the equivalent of around 700,000 hydrogen bombs per second. Though extremely hot at the core, the surface is only approximately 5,500deg C. But the actual surface temperature varies significantly and above the surface it can be higher than 1 million deg. There are three reasons for these variations:- Firstly, there are very large local variations due to sunspot activity. Secondly, there are Sun-wide changes through the approximately 11 year Sunspot cycle and thirdly, there are longer term changes making it slightly cooler during grand minima and slightly hotter during very active periods. Because the Sun's surface is relatively cool it, fortunately for mankind, does not emit large amounts of x-rays and other harmful forms of radiation. The Sun has an additional peculiarity in that it does not spin at

[15] Tom Irvine: Moonquakes@Vibrationdata.com
[16] NASA website
[17] Courtney Seligman (Professor of Astronomy) http://cseligman.com/text/moons/moonquakes.htm

a constant speed. One revolution takes around 34 days near the poles and around 25 days at the equator. It is believed that its core does spin evenly – presumably at the same rate as near its poles. The difference in the rotation of various components of this plasma body creates turbulent magnetic forces which contribute to sunspot activity. The Sun's magnetic field extends to well beyond Pluto. The objective of the Voyager 2 space mission was to find out what is happening at the outer limits of the Sun's influence (refer section 7 to learn how the magnetosphere changes beyond Pluto).

The Sun's diameter is approximately 1,391,000 kilometers but this also varies with it being slightly smaller at the beginning or end of a sunspot cycle and slightly larger in the middle of a sunspot cycle when it is also slightly hotter. This variation in diameter is of the order of 260 kilometers. There is also greater size variation between solar grand minima when it is smaller and the very active periods when it is larger. This variation is of the order of 600 kilometers. The Russian - Ukrainian Astrometria project on the Russian segment of International Space Station is designed to more accurately measure these variations. The Sun's current transition into what appears to be the 21st century grand minima is providing valuable data for this project.

Since around 1755 sunspot activity has been routinely measured and solar cycles determined and daily/monthly sunspot numbers recorded at the Solar Influences Data Analysis Centre (SIDC) in Brussels and more recently by a number of other centers such as the National Oceanic and Atmospheric Administration (NOAA) in the US. Yearly sunspot numbers are also available from SIDC that start from the early 17th century. Now the Sun is continuously monitored for various types of sunspot activity, changes in the Sun's magnetic field as well as its polar reversal which happens near each cycle's maximum output. Its various outputs are measured. These include the extreme and far ultraviolet light, various types of radiation, the solar wind, (mainly electrons, protons and helium atoms), its magnetic field strength and density, etc. The following chart is of the SIDC data to January 2012[18]. SIDC endeavor to adjust current data to make it consistent with that observed in the eighteenth century. Although today's telescopes are very sophisticated and based on satellites the SIDC sunspot record is still based on a relatively old telescope not much better than Wolf's[19] original observatory scope which had 64x magnification. But Wolf often used only a 40x magnification pocket telescope. He also set a minimum spot size that could be counted when he used his smaller telescope.



The chart suggests that there has been much more sunspot activity in the 20th Century than in the earlier two centuries. But the major reason the last 65 year record is higher than the 1800's is because in 1945 Max Waldmeier at SIDC introduced a new counting method which boosted the

[18] http://sidc.be/Sunspot-data/

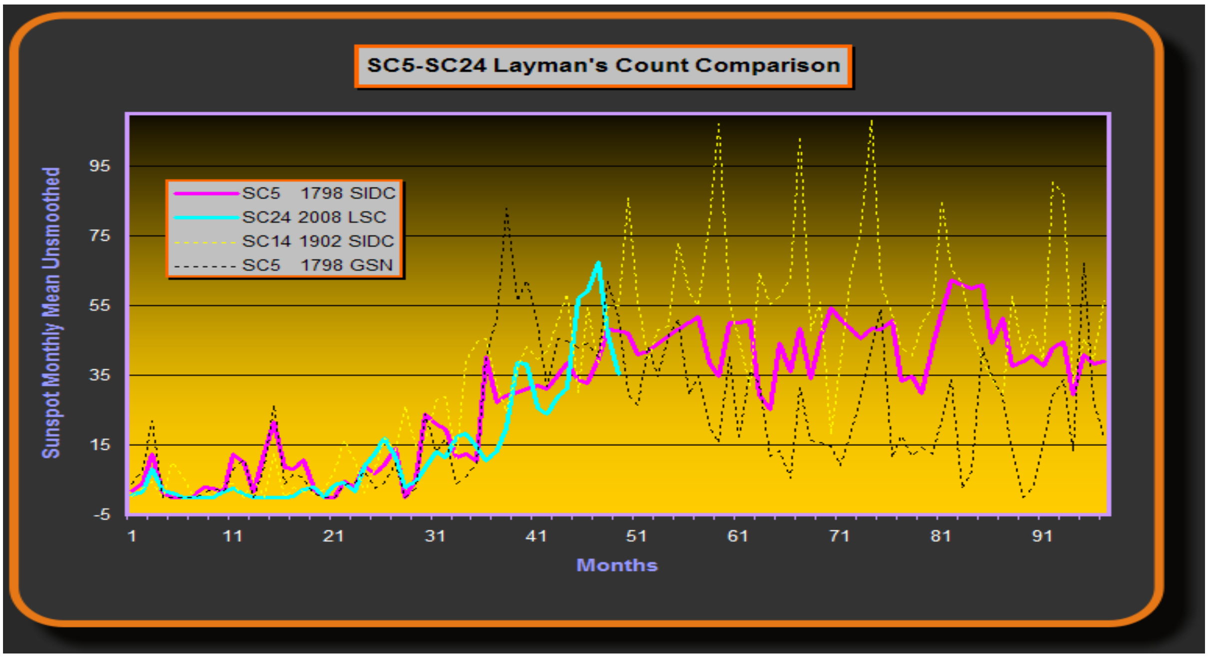
[19] Rudolf Wolf (1816-1893) a Swiss astronomer and mathematician whose method of counting sunspot numbers is still used. But for information on the count changes refer Leif Svalgaard, Stanford University, Updating the Historical Sunspot Record, Sept 2009.

numbers by around 22%. Also the use of the more powerful telescope and change in the way specks are counted increase the current count. So while the sunspot counts look higher in the second half of the 20th Century this is deceptive because of counting changes.

Geoff Sharp from Melbourne adjusts daily sunspot data to get it into conformity with that obtained in the eighteen century. He uses a pixel counting technique to determine whether small sunspots could have been seen with 18th Century 40x magnification telescope[20].

The following graph shows his interpretation of the progress of current cycle 24 against cycles 5 and 14. Cycle 5 was the first cycle of the Dalton grand minimum. Cycle 14 was also a weak cycle that occurred at the beginning of the 20th Century. It can be seen that, according to Geoff Sharp, solar cycle 24 is currently behaving much like cycle 5, or alternatively cycle 14. NASA confirms that cycle 24 is very weak and sensors measuring plasma jet streams deep below the surface of the Sun suggest that cycle 25 will be very weak indeed. These observations add weight to the suggestion that the Sun has begun a new grand minimum.

The Sun should be having its maximum sunspot activity for solar cycle 24 during 2012/13 but when this paper was receiving its final edit on the 29th February 2012, there was just one very weak uni-polar sunspot on the face of the Sun. There had even been a “spotless” day earlier in February. There were only 7 large enough to be counted sunspots that moved across the face of the Sun during February 2012 compared to 16 in January. This adds further weight to the hypothesis that solar cycles 24 and 25 (at least) are solar cycles of a grand minimum.



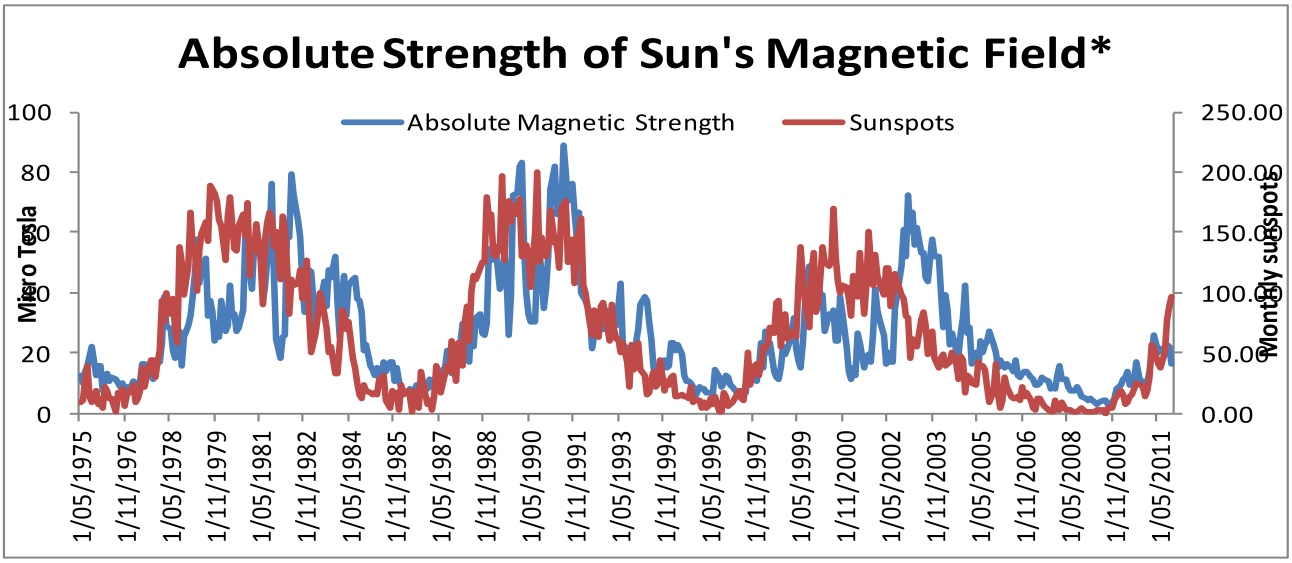
Just like actuaries, not all sunspots behave the same way or have the same strengths. The current cycle seems to be having a lot of negative or uni-polar sunspots. The magnetic field created by uni-polar sunspots is either very weak or non-existent. Even quite large sunspots can be uni-polar. This means that the sunspot activity is not necessarily a good proxy for the extent of the magnetic field of the Sun or perhaps other emissions. The following chart maps the absolute strength of the magnetic field of the Sun[21] each month from 1975. This is superimposed on SIDC data on sunspot activity for the same month. This chart shows that the relative magnetic strength of the Sun. Sunspot activity is usually synchronized but occasionally the sunspot activity is relatively greater or less than the magnetic strength. Usually the magnetic strength is less when there are

[20] http://www.landscheidt.info/?q=node/50

[21] Data obtained from the Wilcox Solar Observatory http://wso.stanford.edu/

many uni-polar sunspots. This happened in 1978-81, from mid 1999 to end 2002 and appears to be occurring again. When it is more, as it was from 2002 to 2010, more magnetically active spots predominate.

The Sun's magnetic strength determines the numbers of very high energy protons from beyond the solar system that can impact Earth. High magnetic strength partially inhibits this activity and the implications of this are discussed in Section 7.



*Wilcox Solar Observatory data used in this study was obtained via the web site http://wso.stanford.edu at 2012:01:13_21:02:29 PST courtesy of J.T. Hoeksema.

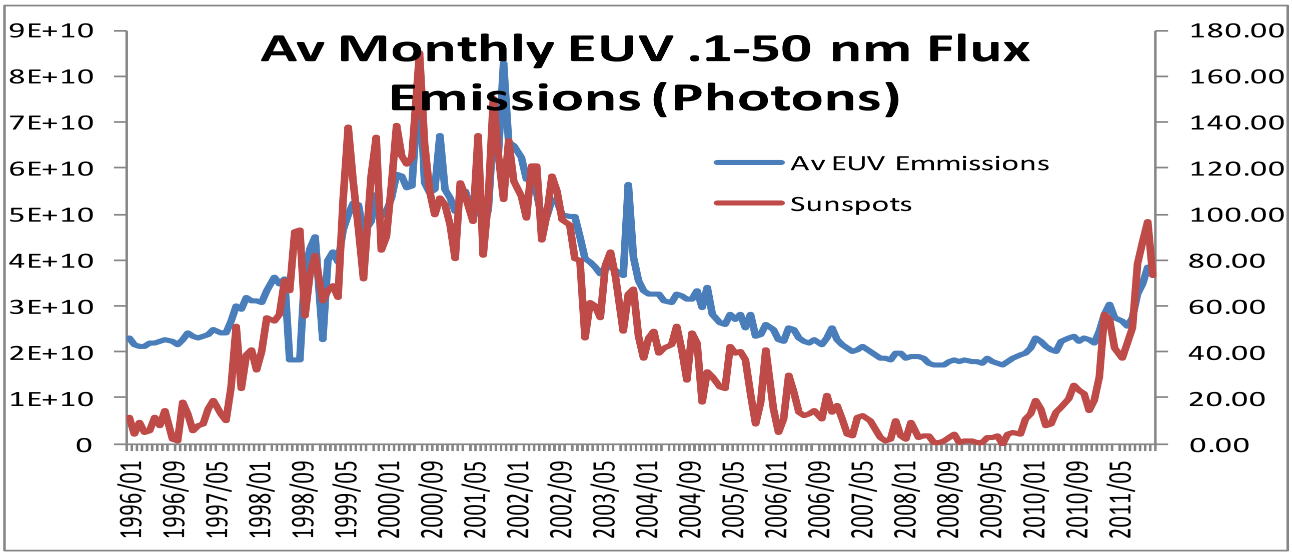
Visible light, ultra-violet A & B and infra-red (heat) emissions of the Sun only vary by small percentages over a sunspot cycle. But parts of the short wavelength (high energy) UVC emissions (known as EUV and FUV) vary by considerably more. The variations in EUV (0.1 – 125.6nm)[22] particularly influence the size, density and temperature of the ionosphere and thermosphere. So the level of these emissions ultimately can affect the temperature difference between the upper atmosphere and Earth's surface. EUV also plays an important role in the regulation of the ozone layer[23] (see section 6). FUV (125.7 – 400nm) emissions are more involved in directly producing ozone. The US Solar and Heliospheric Observatory (SOHO) has been providing data on EUV emissions of the Sun since 1996. The following graph details the monthly summary of that data (taken from the daily averages), again superimposed on the SIDC data.

Although the data is only for seventeen years (roughly 1 ½ solar cycles) and it doesn't measure emissions over all of the EUV spectrum, it seems that EUV emissions do vary by as much as 300% from cycle minimum to cycle maximum. Although not shown here FUV is now understood to vary by about 30% from cycle minimum to maximum. These significant variations produce longer term chemical and temperature changes in both the thermosphere and mesosphere.

This puts some perspective on a presentation to the United Nations Committee On the Peaceful Uses of Outer Space (UNCOPUOS) meeting in Vienna, Austria on February 10, 2011.

[22] Some scientists refer to the lower portion of the spectrum as "Soft X-Ray"

[23] Fuller-Rowell, Solomon and Robel;Impact of Solar EUV, XUV and X-Ray variations on Earth's Atmosphere, Solar Variability and its Effects on Climate, Geophysical Monograph 4, 2004



The presentation was made by Madhulika (Lika) Guhathakurta, PhD. He is the Lead Program Scientist of the Living With a Star Program of the Heliophysics Division, Science Mission Directorate, NASA Headquarters[24]. In this presentation he stated in relation to the extreme solar minimum:

"Since the dawn of the space age (there has been the):

- Longest period with no Sunspots
- Lowest solar X-ray flux
- The Ionosphere Has Collapsed
- Space Junk Is Accumulating
- Radiation Belts are Charged with Killer Electrons
- A Drop in Solar Irradiance affects Earth Temperatures
- The Sun's Magnetic Field is in a Strange State (and)
- Cosmic Rays Hit A Space Age High"

Adding "In 2009, cosmic ray intensities have increased 19% beyond anything we've seen in the past 50 years," says Richard Mewaldt of Caltech. "This is a direct result of the solar minimum and a weakened solar magnetic field." Further "The Ionosphere Has Collapsed. Space Has Never Been Closer To Earth. Sensors onboard the US Air Force C/NOFS satellite recorded a record collapse of the ionosphere. The night-time ionosphere is only 260 miles above Earth's surface, a sharp decrease from the usual value of ~400 miles. The ionosphere is also 100 degrees cooler than expected. This dramatic change affects terrestrial radio communications, curtailing over-the-horizon shortwave reception and causing unusual forms of scintillation in GPS signals. (The) solar minimum is to blame. Extreme UV radiation, which heats and ionizes the upper atmosphere, has dropped 6% compared to previous solar minima[25]. The collapse of Earth's upper atmosphere (also) reduces aerodynamic drag on satellites and space junk."

To understand what Guhathakurta was saying it is necessary to understand how the ionosphere (i.e. the exosphere and thermosphere) and other layers of the upper atmosphere are influenced by solar emissions and cosmic rays.

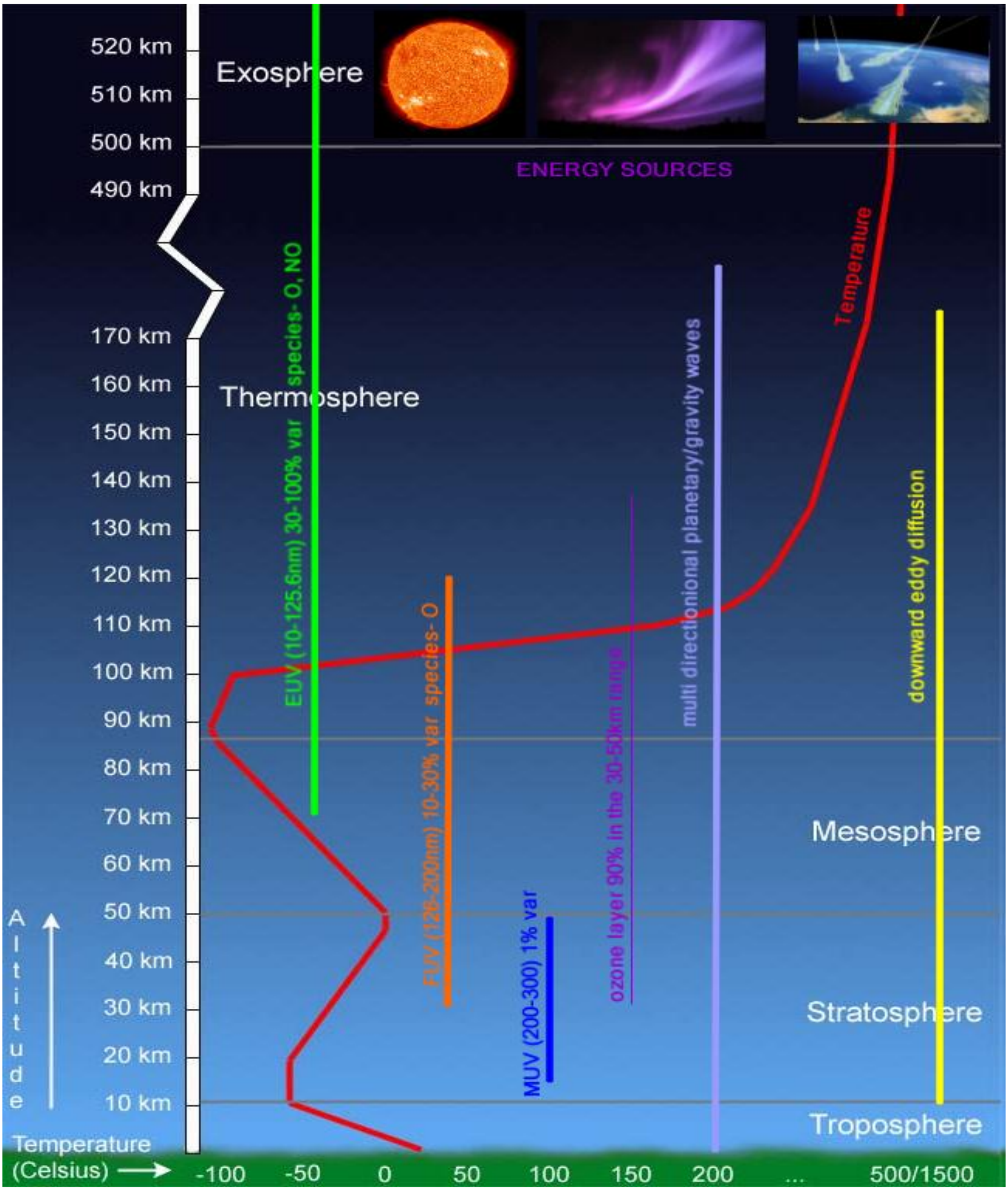
Solar extreme ultraviolet (1 - 125.6nm) and far ultraviolet radiation emissions (125.7 - 400nm) are the main source of energy and ionization in the upper atmosphere. These change frequently in the short term with sunspot activity and solar flares and their average emissions change over the longer term through a solar cycle or cycles. Both short term emission changes and long term emission changes give rise to changes in neutral temperature and density and ion density in the upper atmosphere. The longer term changes in the thermosphere occur through a solar cycle or cycles and can change the drag on low orbiting satellites by at least a factor of 10. These emission

[24] Space Weather Super Storm http://www.oosa.unvienna.org/pdf/pres/stsc2011/tech-14.pdf

[25] Tom Woods of the University of Colorado suggests that it has dropped 15% compared to previous minima. http://lasp.colorado.edu/sorce/news/2010ScienceMeeting/doc/Session3/3.06_Woods_EUV_Min.pdf

changes also impact the propagation of high frequency radio communication signals and induce positioning errors by changing the phase delay in single frequency global positioning systems navigational signals. Also various frequency components of these emissions react with different molecules and ions in various parts of the upper atmosphere to help to either create or destroy ozone[26].

Below is a graphic of the makeup of Earth's atmosphere showing its "normal" temperature at various levels[27].

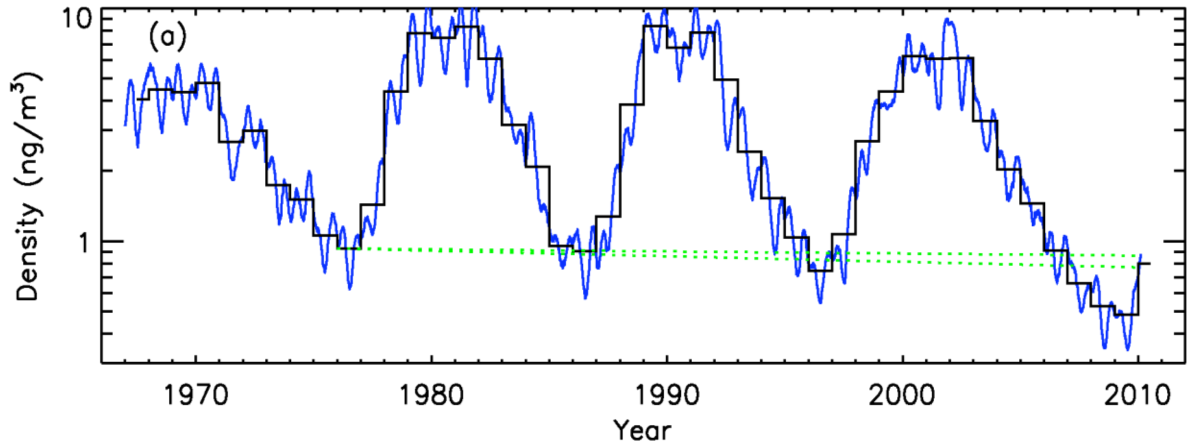


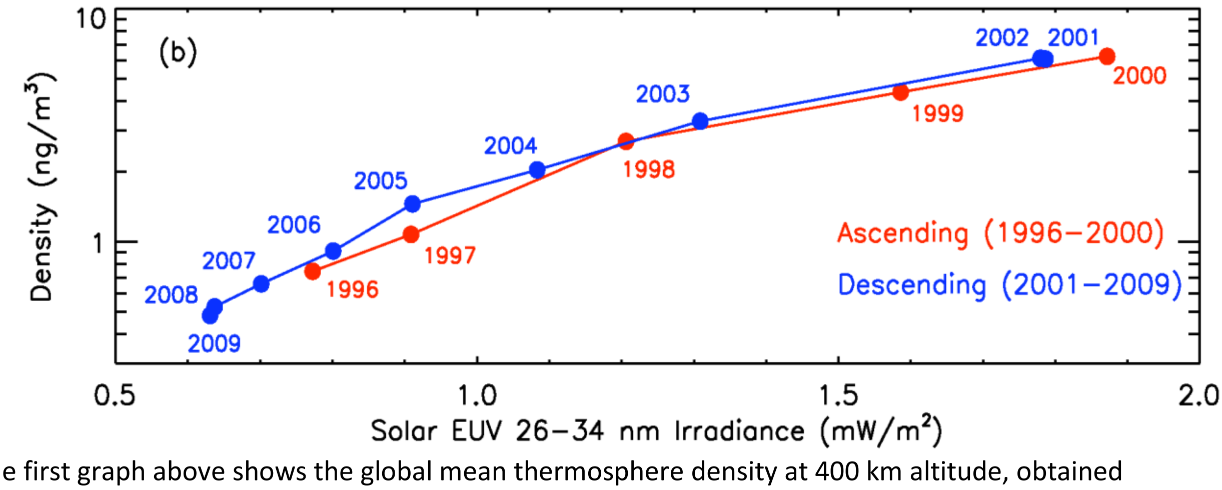
[26] Fuller-Rowell, Solomon, Roble and Viereck; Impact of Solar EUV, XUV and X-Ray Variations on Earth's Atmosphere: Solar Variability and its Effects on Climate, Geophysical Monograph 141, The American Geophysical Union, 2004.

[27] http://www.landscheidt.info/?q=node/236

The boundaries are the approximate boundaries at mid-latitudes. So, for example, the troposphere extends to about 15 km at the equator but only about 5km at the poles in winter. As the South Pole is at an approximate 2.9 km elevation it is the coldest place on Earth in the winter being more than half way up the troposphere at that time.

The temperature decreases rapidly with height to about -50 deg C in the troposphere (long haul aircraft fly at around 10 Km up, which in temperate regions is normally the upper reaches of the troposphere). Then in the stratosphere, which includes the ozone layer from about 20 Km, it commences to increase to around zero degrees C (at 50 Km) before decreasing in the mesosphere to close to -100 deg. C (at 90 Km). In the thermosphere, which is below the exosphere and part generally called the ionosphere it normally increases with height to between 500 degrees and 1500 degrees at around 500 KM from Earth's surface. (The temperature reduces at night and increases during the day but the levels that it gets to are also dependent on the solar cycle[28].) The temperature remains higher in the exosphere – the upper part of the ionosphere (above 500 Km). Guhathakurta was indicating that the temperature in the exosphere and thermosphere was 100 deg. colder than expected for that period of the solar cycle (in 2010) and that the thermosphere had collapsed[29], particularly at night.





The first graph above shows the global mean thermosphere density at 400 km altitude, obtained from satellite orbital parameters over four solar cycles. Blue: 81-day centered running mean. Black: annual average. Green dotted lines: envelope of expected decrease due to increasing CO2 levels, in

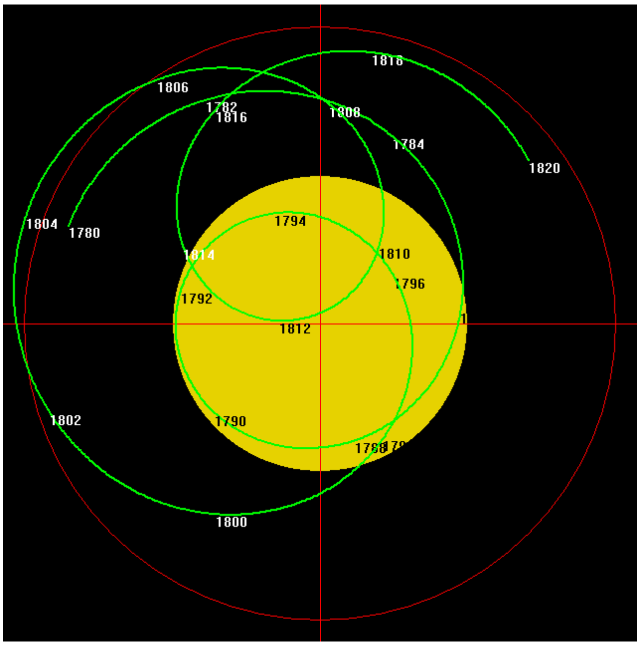
[28] Stanley C. Solomon, Thomas N. Woods, Leonid V. Didkovsky, John T. Emmert, Liying Qian: Anomalously low solar extreme-ultraviolet irradiance and thermospheric density during solar minimum., GEOPHYSICAL RESEARCH LETTERS, VOL. 37, 2010

[29] See also http://science.nasa.gov/science-news/science-at-nasa/2010/15jul_thermosphere/

the range of 2% to 5% per decade, starting with the 1976 annual average. This effectively rules out changing levels of carbon dioxide as the cause of the decrease in temperature recently witnessed.

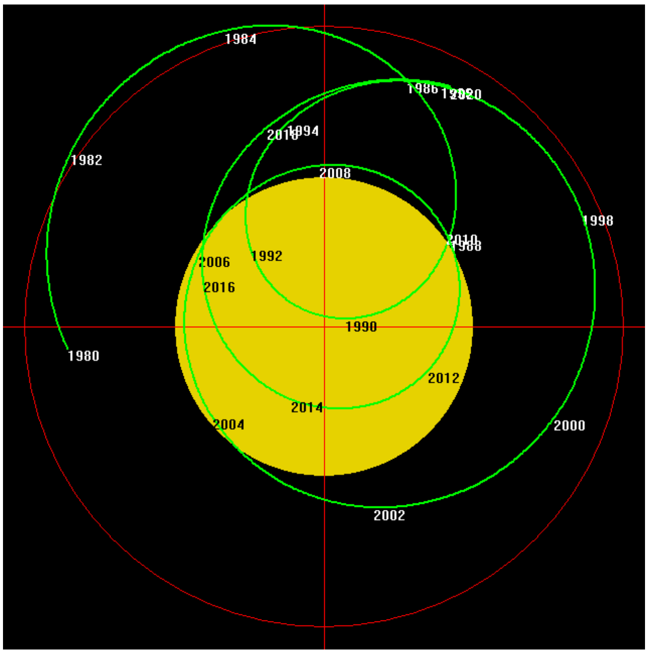
The second graph shows the Global mean thermosphere density annual average plotted as a function of the 26-34 nm solar EUV irradiance annual average measured by the SEM for the ascending (red) and descending (blue) phases of solar cycle 23. Both of these graphs were obtained from the paper: Solomon et al "Anomalously low solar extreme-ultraviolet irradiance and thermosphere density during solar minimum".

The Planetary/Angular Momentum Theory



A lot of the new data about the Sun is being obtained from the Solar Dynamics Observatory satellite, which was launched by NASA in February 2010. It sends back to Earth 1.5 terabytes of data per day. Its purpose is to determine more precisely how the Sun behaves and how its behavior influences Earth's climate. The approximately 11 year sunspot cycle does not normally have much of an effect on Earth's climate since the oceans and to a lesser extent the land masses act as automatic stabilizers and dampeners for relatively short term changes. However, solar grand minima and cycles of stronger sunspot activity can operate over many decades and so are not dampened to the same extent.

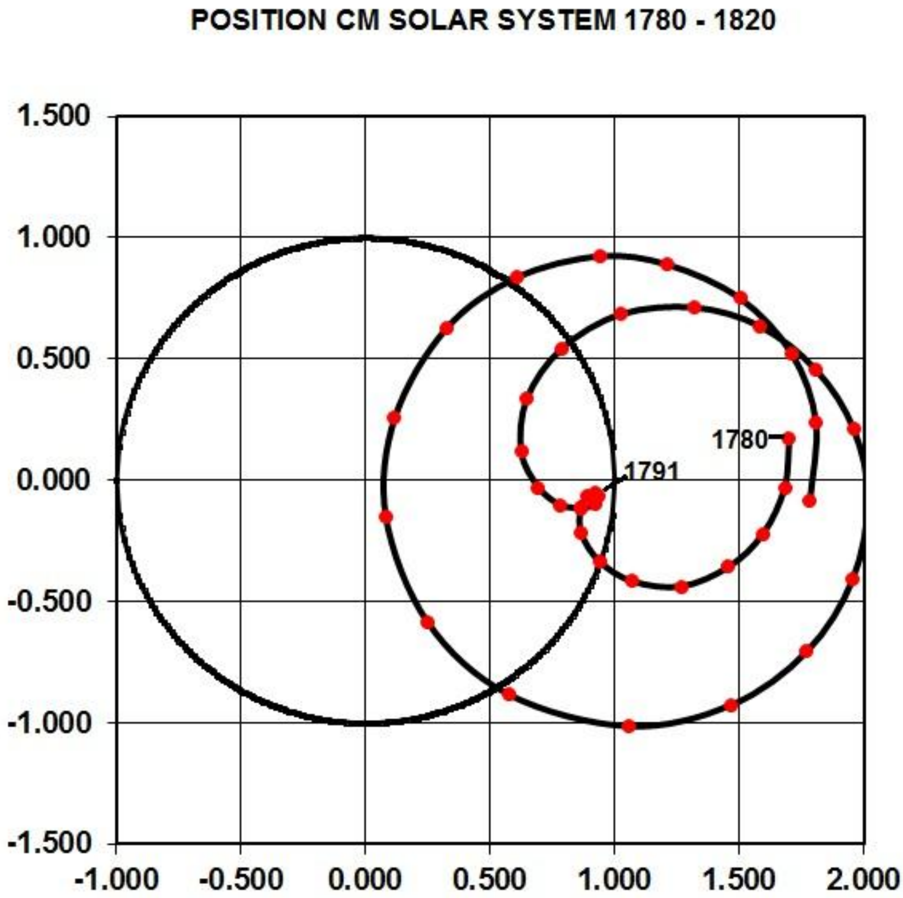
There are many theories as to what causes the Sun to go into grand minima and maxima. Given that Earth is gradually transferring some of its angular momentum to Moon it is not unreasonable to postulate that transfers of angular momentum do occur between the Sun and the planets and even between the planets themselves. Furthermore, it seems likely that these transfers are constantly occurring although at different rates depending on the locations of the planets. The following is a two dimensional picture of the movement of the Sun with reference to the solar system barycenter (SSB) between 1780 and 1820[30]. The center of the Sun was travelling at very close to 1 solar radius from the barycenter from around 1790 to 1793. Note that the Dalton solar grand minimum is said to have occurred between 1790 and 1830.



The second graphic shows the Sun's movement with respect to the SSB from 1980 to 2020. Again from 2004 to around 2010 the center of the Sun was travelling at close to 1 solar radius from the SSB.

[30] These two graphs were supplied by Geoff Sharp and were produced from the same software as the ones found on his website http://www.landscheidt.info/

If Jupiter was the only outer giant (Jovian) planet in the Solar System, the Sun would move about the SSB in a slightly elliptical orbit (e = 0.048) with a semi-major axis of 1.08 solar radii, and a period of 11.86 years (the period of the orbit of Jupiter). This means that the Sun with a single planet Jupiter would revolve smoothly about a point located just above its surface[31]. However as can be seen by the previous two graphs the actual orbit of the Sun around the SSB varies. The actual range of the center of the Sun to the SSB has been calculated to be 2.19 and 0.01 solar radii[32]. This variation is caused by the other three Jovian planets also providing their influence on the Sun's motion.



The four innermost, rocky planets and the asteroids do have an effect as they actually orbit the Sun and not the SSB[33]. In any event the masses of the inner, rocky planets are too small to have much effect on the Sun's motion.

Astronomer Ian Wilson has stripped out Jupiter's influence to show how the remaining three Jovian planets would affect the position of the center of mass of the solar system relative to the Sun (the circle). The first graph shows the period from 1780 to 1820. The path starts in the year 1780, with each successive year being marked off on the curve, as you move in a clockwise direction. This shows that the maximum asymmetry in the SSB motion occurred around 1790-91 with the SSB being almost stationery from 1788 to 1794. The SSB's orbit without Jupiter's influence would tend to repeat itself roughly every 38 years although never exactly the same[34].

The second graph is from 1989 to 2029 and shows a similar asymmetry in the SSB motion occurring from 2004 to 2011 although this time there is less asymmetry and it occurs partly inside and partly outside the surface of the sun.

There are many scientific papers on the angular momentum theory. Their calculations are based on past, present and future estimates of the relative positions of the planets, their satellites, asteroids and the Sun with respect to Solar System Barycenter or other co-ordinates. Information

---

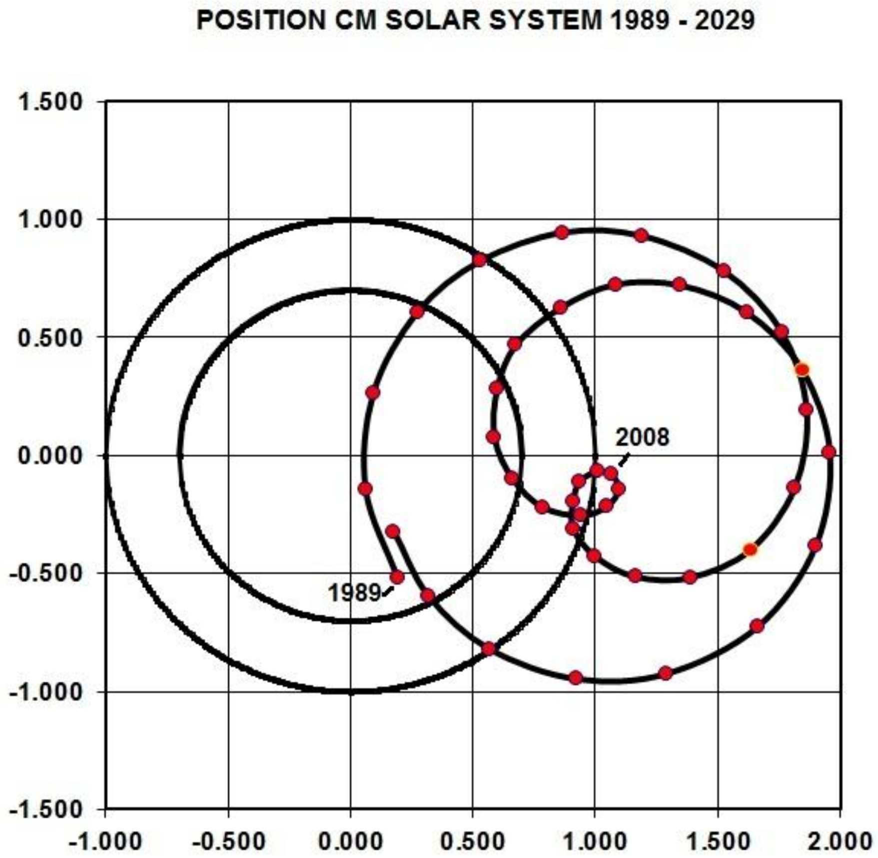
[31] Ian R. G. Wilson, Queensland Department of Education, Training and the Arts: Are Changes in the Earth's Rotation Rate Externally Driven and Do They Affect Climate?, 2011

[32] Sun's motion and Sunspots, Astronomical Journal, 70, 193 Jose 1965

[33] The science on which planets orbit the SSB and which orbit the Sun is not completely settled.

[34] Ian Wilson has privately provided both of the graphs of the position of the solar system center of mass in relation to the sun

and data can be downloaded from the Jet Propulsion Laboratory website. One intriguing paper shows how Uranus and Neptune help to cause solar grand minimums[35].



It seems that planetary influences do cause the Sun to change its velocity, direction and rotational speed. These changes cause various outputs of the Sun and its magnetic field to change - but how does this happen? It seems that just as the torque created on Earth by the gravitational effects of the moon and the Sun in conjunction cause king tides on Earth and some small angular momentum transfers from Earth to Moon, the torque created on the Sun by the gravitational effects of the planets: Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune cause angular momentum transfers from the Sun to and from those planets via tidal forces[36]. These rotational energy transfers cause very small but significant changes in the speed and path of the Sun and the rotational speed of the Sun's plasma particularly when the planets are in certain configurations. Solar scientists and mathematicians have taken this theory to a new level determining the angular momentum of planets including dwarf planets and large asteroids, the spin orbit coupling forces and resonances that amplify the effects on the Sun. This is basically the same principle that causes the spin of ice skaters to increase when they bring their arms closer to their body. Although, unlike the ice-skater, the Sun and the planets are not physically connected they are magnetically connected. By considering how the battery in an electric toothbrush gets recharged when it is placed in the magnetic field of the toothbrush-holder one can appreciate how magnetic fields transport energy. The recently discovered properties of magnetic flow fields of rotating objects are mentioned in Section 7.

Another way that planets influence the activity of the sun is through the release of potential energy to kinetic energy via natural convection processes in the plasma of the hemisphere facing the SSB. Depending on the distance of the sun from the SSB and its velocity, these processes can raise the kinetic energy of a few well positioned elements of convection in the Sun's envelope by up to a factor of seven[37]. It is a physical mechanism by which the planets do have a nontrivial effect on

[35] Geoff Sharp: Are Uranus and Neptune responsible for solar cycle grand minima and solar cycle modulation, Cornell University Library, 2010

[36] Ian R. G. Wilson, Queensland Department of Education, Training and the Arts: Do Periodic Peaks in Planetary Tidal Forces Acting Upon The Sun Influence the Sunspot Cycle? The General Science Journal, 2008

[37] Charles L. Wolff (NASA), Paul N. Patrone (University of Maryland), A New Way that Planets Can Affect the Sun, Solar Physics (2010) 266: 227–246, September 2010.

internal solar motions. It seems very likely that this research by NASA and University of Maryland solar physicists will eventually lead to at least a better understanding of how sunspot activity is generated.

Enormous transfers of angular momentum are involved in the initial formation of a star system as gravitational and other forces combine gases and rocky materials into planets and their satellites. Usually, the planets of any star orbit in the same direction as the star rotates and most planets rotate in the same direction as the star rotates. However, in demonstration of how much angular momentum can be transferred astronomers have found that a few of some of the 500 odd star systems found in recent years have large hot gas planets (called "Hot Jupiters") that orbit close to the star but in the opposite direction to the star's rotation. The orbital mechanics that scientists use in space programs to "slingshot" a space probe using another planet's gravity have been used to show how this happens. This occurs when there are two or more very large gas planets, one orbiting very close to the star and the other much bigger planet orbiting much further away. Because of the gravitational interaction between the planets in their early stages of formation the very large and distant planet can draw so much angular momentum from the smaller internal planet that it moves into a highly elliptical needle-like orbit to the point where it collapses back into a more circular orbit but in the opposite direction to the rotation of the star[38].

According to Kepler's laws the angular momentum of a planet with respect to the center of its trajectory is constant. This means that the speed of planets' rotation around the Sun (or the solar system barycenter) increases as they move towards their aphelion and reduces as they move towards their perihelion. However Kepler's laws ignore the effect of other planets. In practice the angular momentum of the whole solar system should remain constant. But this assumes that the energy locked up in angular momentum could not transform into another form of energy. This assumption is not entirely correct. (Refer section 5).

P A Semi[39] a Czech Republic astrophysicist, has shown that the total angular momentum of the planets (excluding sidereal rotation) is not constant over time and, for the total angular momentum of the solar system (the Sun and the planets) to be constant, the Sun occasionally must have negative angular momentum. In practice a small portion of the orbital (around the solar system barycenter) angular momentum of the Sun would be converted into sidereal rotation, of the plasma near its equator, which would help to explain the rotational differences in the Sun's plasma[40]. However even this theory does not allow for rotational energy to be transformed into other forms of energy, for example heat (Section 5).

The paper[24] by Wilson, Education Dept., Qld, Carter & Waite, Centre for Astronomy, Solar Radiation and Climate – University of Southern Queensland, measured the transfers that occur from just Jupiter and Saturn and these are of the order of 3 – 5 $x10^{40}$ Newton meters and the amount that gets transferred to the equatorial plasma rotation of the Sun is of the order of $4.5x10^{37}$ Newton meters and would change the velocity of the surface plasma by around 4.3 meter/second, which is of the order of 2/3rds of that observed by direct satellite measurements. (Note the influences of the other Jovian planets and the closer rocky planets were ignored in this exercise.)

A portion of the angular momentum transfers may also change the sidereal rotation of planets and some part of the rotational energy could be converted into heat as occurs between satellites or between satellites and their host planet. But to understand how this happens we need to understand gravity and tidal forces (Section 5).

[38] Science Now May 2011

[39] Petr Semi Semerad: Orbital Resonance and Solar Cycles, , Czech Republic, 2009.

[40] I. R. G. Wilson, B. D. Carter, I. A. Waite; Does a Spin-Orbit Coupling Between the Sun and the Jovian Planets Govern the Solar Cycle, Publications of the Astronomical Society of Australia, 2008. http://www.publish.csiro.au/?act=view_file&file_id=AS06018.pdf

5. Gravity and Tidal Forces

"A rising tide lifts all boats" – John F Kennedy (1960)

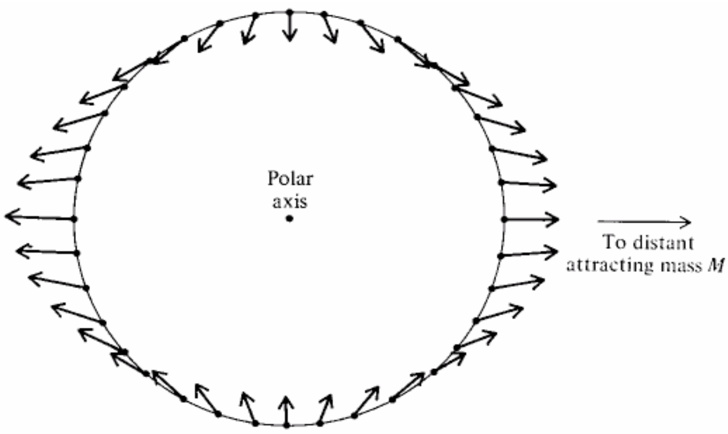
Part of the following has been adapted from a short paper[41] on tidal forces by Richard Macdonald of Kanata, Ontario. He developed the paper as an educational tool. It has been kept elementary so that it can be understood by non-physicists.

What Are Tidal Forces?

Newton's law of gravity defines the attractive force between two bodies as: $F = G\left(\frac{m_1 m_2}{r^2}\right)$ Where $m_1$and m_2 are the mass of each body and r is the distance between them. But this assumes the bodies are zero-dimensional points.

However real objects such as planets and satellites have significant non-zero diameters. The inverse-square force of gravity is significantly different between points on the near sides of two bodies and between points on their far sides. For orbital purposes, objects are considered gravitational point sources. For example, the Moon's orbit around Earth is described by Kepler's 3rd law which, in Newton's format, is: P^2 =$\left[\frac{4\pi^2}{(Me+Mm)}\right]a^3$ Where *P* and *a* are the period and the semi-major axis. In other words, the Moon's position relative to Earth is determined by applying the law of gravity to the center of the Moon and the center of the Earth, ignoring their radii.

If we now consider the Moon to have radius "w", the point on the Moon closest to Earth feels a gravitational attraction: $F = G\left[\frac{m_e m_m}{(r-w)^2}\right]$ The point farthest from Earth feels a gravitational attraction: $F = G\left[\frac{m_e m_m}{(r+w)^2}\right]$. Relative to the center of the Moon, which determines the Moon's orbital position, the near point is pulled toward Earth, while the far point is pushed away from Earth. The difference between these forces is the tidal force. Barger and Olson [1973] show that if you perform this calculation for every point on the Moon, you get the vectors of force, relative to the center, shown here. The Moon exerts similar forces on Earth. Each body is very slightly stretched along an axis pointing toward the other, with the near side being pulled closer and the far side being pushed away, resulting in a "bulge" on both the near and far sides. Hence where there is a liquid (or plasma) the "high" tides occur at opposite sides of the body at the same time.



The tidal force pulling a satellite apart in the long direction is approximated by: $F = 2G\frac{Mmr}{R^3}$ Where M and m are the masses of the primary and satellite, R is the center-center distance, and r is the radius of the satellite. This inverse cube function decreases rapidly with distance. Using known masses, we can estimate tidal forces for familiar bodies as: Moon feels from Earth 1.82x10^{18} Newtons, Earth feels from Moon 6.69x10^{18} N and Earth feels from Sun 3.02x10^{18} N. So Earth feels 3.5 times more tidal force than the Moon from their relationship, because the Earth is bigger, and thus has a bigger differential. The Sun's effect on Earth is only 46% of the Moon's effect on Earth because, while considerably more massive, it is much farther away.

But Earth is also rotating. If Earth were rotating at the same rate as the Moon's orbital period, the bulge would point straight at the Moon all the time but it doesn't, Earth is rotating faster than

[41] Richard McDonald: Tidal Forces and their Effects in the Solar System, September 10, 2005

the Moon's orbital period. Because the tidal bulges can't move as quickly as Earth rotates they end up ahead of the straight line between Earth and Moon centers and this creates a backwards torque on Earth which gradually slows its rotation. So to conserve the angular momentum and energy of the Earth/Moon system the radius of Moon's orbit gradually increases while heat is dissipated internally in Earth. This will continue to happen until Moon's orbital period is exactly equal to Earth's rotation at which time Moon will appear fixed in the sky over a single geographical position on Earth. That is it will be in a geostationary orbit like a number of satellites used for GPS systems and satellite TV. If on the other hand Earth were rotating more slowly than Moon's orbital period then there would be a forwards torque on Earth caused by the tidal forces and so the Moon would be gradually speeding up Earth's rotation while moving closer to conserve angular momentum. Again this process would continue until the eventual geostationary occurs[42]. It will take some billions of years for Moon to eventually reach a geostationary orbit of Earth. Charon, Pluto's satellite has already achieved its geostationary orbit.

Moon rotates at a speed that produces one rotation for each orbit. Therefore it keeps one side facing Earth at all times. This is no accident and is known as being phase-locked. Moon would have had a different rotation speed originally but the tidal forces on Moon would have created either a forwards or a backwards torque either gradually increasing or decreasing its orbital speed (and decreasing or increasing the radius of its orbit) until it became phase locked.

All of the large relatively close satellites in the solar system are phase locked but some small further away ones are not. For example, all of Jupiter's large inner satellites to Callisto are phase locked and the outer ones beyond Callisto are not.

The magic of gravity's tidal forces does not stop with phase-locking and eventual geo-stationary orbits. Higher order resonances also occur due to gravitational interactions between satellites. For example Io, Europa and Ganymede are in a 1:2:4 resonance. The timings correspond to wave functions with integer solutions.

Resonances and Harmonics

Gravitational interactions between planets and/or between planets and the Sun create resonances. For example Mercury is in a 3:2 spin-orbit resonance. That is Mercury takes two orbits of the Sun to have exactly 3 rotations. Other resonances between planets are listed in the table below[43] although none are absolute presumably because of perturbations caused by other planets, satellites or the Sun. It is also possible that the resonances are not absolute because the resonance would not occur at a single point in time but across a time period due to the size of the bodies that are resonating and the fact that they are travelling in the same direction.

There is no apparent direct resonance between the Jovian planets and the inner four. There could be a number of reasons for this. Firstly, the Jovian planets orbit the center of mass of the solar system whereas the inner four directly orbit the Sun. Secondly, the asteroid belt between Mars and Jupiter might interrupt resonances. Thirdly, the asteroid belt could be the remnants of a planet that was destroyed by impact with another body, perhaps an outer dwarf Pluto-like planet or large comet and hence the then established resonances between Mars and it and Jupiter were lost.

---

[42] In practice both Earth and Moon orbit around their center of mass (barycenter), which, because of Moon's elliptical orbit, lies in a straight line between Earth and Moon between around 4,412 km and 4,942 km from the center of Earth so the angular momentum exchanges continuously vary.

[43] P. A. Semi: http://semi.gurroa.cz/Astro/Planets_and_Intervals__Draft-current.pdf,

Planets	Orbital Ratio	Harmonic Ratio	Average Meeting Time (Yrs)
Earth/Venus	1.62552	13/8	1.5957
Venus/Mars	3.05722	3/1	0.9305
Earth/Mars	1.88076	15/8	2.1367
Venus/Mercury	2.55431	23/9	0.3959
Earth/Mercury	4.15209	29/7	0.3475
Jupiter/Saturn	2.48223	5/2	19.7868
Saturn/Uranus	2.85486	20/7	45.3512
Neptune/Uranus	1.96119	2/1 (51/26)	171.4581
Jupiter/Uranus	7.08642	7/1	13.8104
Jupiter/Neptune	13.89785	14/1	12.7821
Pluto/Neptune	1.50462	3/2	165.3184
Saturn/Neptune	5.59894	28/5	35.8690

Ian Wilson has shown that the formation and gradual progression of the solar system has left it with some unique characteristics that must have been formed by harmonics that occurred during its creation. To understand these characteristics it is necessary to understand the Jose cycle. The Jose cycle is the period of time for Jupiter the Sun and Saturn (in opposition to Jupiter) to approximately line up in the same formation with Uranus and Neptune also approximately in line behind Jupiter. This time is approximately 178 years. It is 9 times the Jupiter/ Sun/Saturn apposing synodic period (the time it takes Jupiter and Saturn to re-align themselves with the Sun in the same relative positions[44][45]). He believes, like many others, there is another longer cycle that takes around 4,628 years (26 Jose cycles) for all the planets to return to almost the same relative position in their elliptical orbits.

It is important in the recognition of these longer term cycles that Saturn be on the opposite side of the Sun to the other 3 Jovian planets. This may suggest that angular momentum is being passed between them in that configuration but not to the same extent as when all the Jovian planets are lined up on the same side of the Sun. Possibly Saturn's rings might act as a dampener to any angular momentum passed from Neptune and Uranus across Saturn. Also note that Uranus is in effect lying on its side in the planetary plane and it has a retrograde rotation. So Uranus might not dampen angular momentum transfers from Neptune.

Possibly there is interaction between the helio-magnetic and the planetary magnetic fields that conducts the angular momentum transfers. This is discussed in Section 7.

Ian Wilson has shown that it is likely that at one time there were resonances between the orbital periods of Venus, Earth, Mars and Jupiter and the orbital period of the Moon. He claims that residual evidence of these former resonances appear in the 2nd harmonic in the precession rate of the line of nodes of the orbit of Moon. He finds that ten times this 2nd harmonic lunar period is equal the orbital period of Jupiter. He showed that the interval also appears in the periods between the realignment times for Venus, Earth and Jupiter and in the realignment period for all the planets (i.e. approximately 178 years). Further, dividing the period of the Jose cycle (178 years) by 28 gives the realignment time for the orbits of Venus, Earth and Mars (6.4 years) and dividing 178 years by four gives almost the exact realignment time of Venus, Earth and Jupiter (44.5 years). These harmonic alignments arise from the cumulative effects of billions of years of gravitational resonances which will continue to gradually structure the solar system for billions of years to come.

---

[44] Ian R G Wilson: Possible evidence of the De Vries, Gliessberg and Hale cycles in the Sun's barycentric motion, Australian Institute of Physics 17th National Congress 2006,

[45] Charvatova, Annales Geophysicae, Czech Republic: Can origin of the 2400-year cycle of solar activity be caused by solar inertial motion? Annales Geophysicae, Czech Republic, Charvatova

Tidal Heating and the Roche Limit

Because satellites have a constant sidereal rotational speed but the sidereal orbital speed varies with the distance to the planet the tidal forces exerted on the satellite will not always point in exactly the same direction in relation to the planet. This movement of the direction of the tidal forces creates heat within the satellite. The perturbations in the direction of the tidal force caused by other satellites and orbiting bodies have the same effect. This effect was, for example, used to predict the volcanism on Io before Voyager 1 proved it in March 1979 when it photographed Io's very active volcanoes.

Tidal heating is also caused within the planet by the satellite. This is particularly the case when the tidal forces on the planet vary due to the orbit eccentricities and inclinations. For example, scientists believe that only 1/30th of the rotational energy lost by Earth due to tidal forces exerted on it by Moon is actually transferred to Moon (by increasing its orbit). The rest is absorbed by Earth in the form of heat. This leads to the suggestion that the perturbations in the direction of the tidal forces on Earth, caused by Moon, the Sun and other planets creates internal heating in Earth. Hence this could indirectly lead to a higher risk of volcanism and earthquakes following periods of maximum perturbation.

The tidal forces acting on Io primarily from the gravity of Jupiter, Europa and Ganymede produce tidal bulges that travel through the solid crust of Io up that are up to 100 meters high. This flexing and reflexing of Io's crust creates heat. The thermal heat created is of the order of 125 trillion watts, which is about 2.5 W/m^2 of its surface area[46]. By contrast Moon's outward heat flow is 0.02 W/m^2 and Earth's average outward heat flow is 0.06 W/m^2.

The Roche limit is the distance of an orbiting body from the planet it is orbiting within which the tidal stresses caused by the planet will break up the orbiting body. This distance varies according to the radius of the planet and the cube root of the ratio of the density of the two bodies. So there are practical limits on the size and composition of closely orbiting satellites.

A good example of the power of tidal forces is the breaking up of the Shoemaker-Levy 9 comet during its 1993 approach to Jupiter when it got to 21,000 Km (Jupiter's Roche limit is around 175,000 Km). On that occasion the 20 or so pieces of Shoemaker-Levy 9 escaped from Jupiter's gravity but, in 2004, when these pieces returned to Jupiter they could not escape. Astronomers filmed some of their impacts which provided riveting viewing for TV news bulletins at that time.

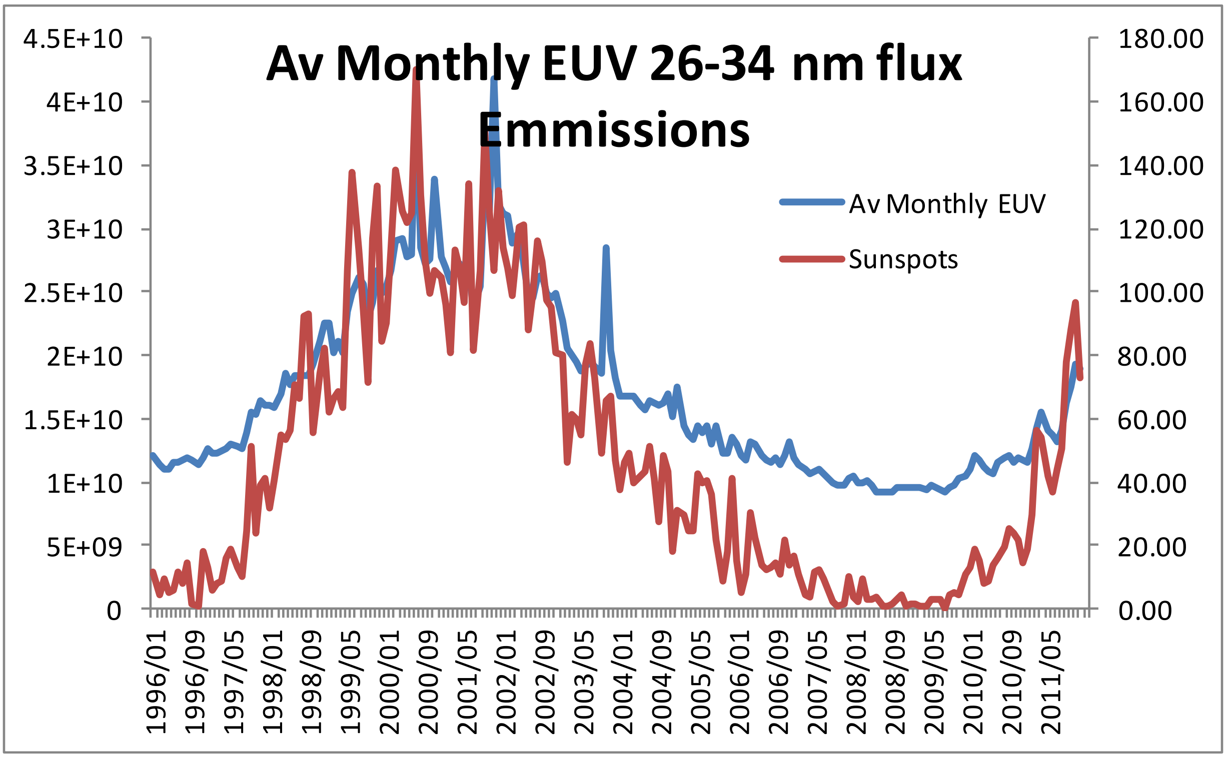
[46] http://www.solarviews.com/eng/iovolcano.htm

6. External Influences on Weather Patterns

"God not only plays dice, he also sometimes throws the dice where they cannot be seen." - Stephen Hawking

The thermosphere and exosphere (ionosphere) are basically created by photons emitted by the Sun at the extreme ultraviolet (1 - 125.6 nm) and far ultra-violet (125.7 – 400nm) wavelengths (EUV and FUV). The table[47] shows the wave length of the emissions from the Sun and the normal percentage of the Sun's energy emitted. Note that UVC is further subdivided into EUV and FUV. However some scientists regard FUV as including the entire UVA and UVB spectrum. But some complicate this further by referring to the radiation in the 0.1 – 30nm range as soft X-Rays or XUV. The graph below has also been obtained from the US Solar and Heliospheric Observatory and excludes the soft X-Ray emissions. The variation over the last solar cycle was still greater than 300%.

Spectral Region	Wavelength	% of Total Energy
Infrared	>700 nm	49.40%
Visible	700 - 400 nm	42.30%
UVA	400 - 320 nm	6.30%
UVB	320 - 290 nm	1.50%
UVC	<290 nm	0.50%
- FUV	125.7 - 290 nm	
- EUV	0.1 - 125.6 nm	



These photons interact at very high altitudes with remnants of the atmosphere (mainly Oxygen and Nitrogen) to form free positive and negative ions, which because of their resultant high energies together with the extremely low atmospheric density remain in plasma form. This is also reinforced by solar wind protons and electrons and helium nuclei, which are also mainly in plasma form. Reinforcement also comes from relatively low energy cosmic rays (mainly protons and electrons). The interactions that create these ions also create heat, hence the temperature in the exosphere and upper levels of the thermosphere can reach as high as 1500 deg. C for that part in daylight but

[47] Dr. James H. Gibson, Senior Research Scientist, Director, USDA UVB Monitoring Program, Natural Resource Ecology Laboratory, Colorado State University: UVB Radiation Definition and Characteristics

drops for the part in night to 500 deg. C or lower. In the lower half of the thermosphere, the mesosphere and the upper part of the stratosphere, ozone and nitrogen oxides are also present, usually in relative balance.

Although solar radiation is the mains source of energy of the upper atmosphere there may also be other sources. These can be[48]:

1. Auroral particles (mainly protons and electrons) percolating down from the magnetosphere can ionize the thermosphere and have local heating effects for a period of time that are much greater than EUV and FUV photons. These auroral particles can be significantly increased by solar flares (geomagnetic storms).
2. Ohmic dissipation of ionospheric currents also from the magnetosphere. This is known as Joule Heating and is driven by the convection electric field mapped by the magnetosphere. This heating is normally much less than that produced by solar radiation but can also be much more during a geomagnetic storm.
3. Tidal, planetary and gravity waves[49] that are propagated from the lower atmosphere. These may particularly transport energy to higher levels of the atmosphere at and near the poles particularly during winter and spring.

During the periods of a quiet sun these other sources of energy can become important as they can affect the strength of the solar vortex and hence the Arctic and Antarctic Oscillation, which seem to help to position the jet streams in the Northern and Southern hemispheres .

Gas	Molecular Structure	Molecular weight
Water Vapour	H_2O	10
Nitrogen	N_2	14
Nitrogen Oxide	NO	15
Oxygen	O_2	16
Nitrogen Dioxide	NO_2	23
Ozone	O_3	24
Carbon Dioxide	CO_2	28
Radiocarbon Dioxide	CO_2	30

Ozone and the two nitrogen oxides are relatively unstable. The EUV emissions of the Sun interact with oxygen and nitrogen molecules (O_2 and N_2) to split these molecules into atoms which can then recombine as 2 nitrogen/oxygen molecules (NO) or a nitrogen atom plus 2 oxygen molecules can form 2 nitrogen dioxide (NO_2) molecules. Heat is a byproduct of these reactions. NO also readily reacts with oxygen molecules to form NO_2 and ozone. $NO + 2O_2 + \text{photon} \rightarrow NO_2 + O_3$. Oxygen ions can also combine with oxygen molecules creating ozone (O_3) directly. NO_2 is more likely to form in the upper part of the ozone layer where it is hotter and NO in the lower part of the ozone layer. At night, when the thermosphere cools, NO_2 tends to react with ozone to reform NO and O_2. $NO_2 + O_3 \rightarrow NO + 2O_2$. Therefore the nitrogen oxides (NO and NO_2) act as agents to both form ozone in the presence of light and heat and destroy ozone without such presence. If the higher levels of NO_2 in the thermosphere are transported down to the mesosphere or stratosphere then the overall level of ozone will be depleted. Conversely in winter and spring lower atmospheric ozone and nitrogen oxides can be transported upward from the stratosphere and mesosphere via planetary waves and the Arctic or Antarctic vortex. So at these times ozone gets diluted in the lower levels of the atmosphere and destroyed in the higher levels of the atmosphere until the normal summer balances between the nitrogen oxides and ozone in those latitudes are re-established.

When there is lower EUV emissions then there is less ozone formed in the upper atmosphere. Hence during the lower solar activity from around 1964 – 1978 (solar cycle 20) there was a larger ozone

[48] Fuller-Rowell, Solomon, Roble and Viereck; Impact of Solar EUV, XUV and X-Ray Variations on Earth's Atmosphere: Solar Variability and its Effects on Climate, Geophysical Monograph 141, The American Geophysical Union, 2004.

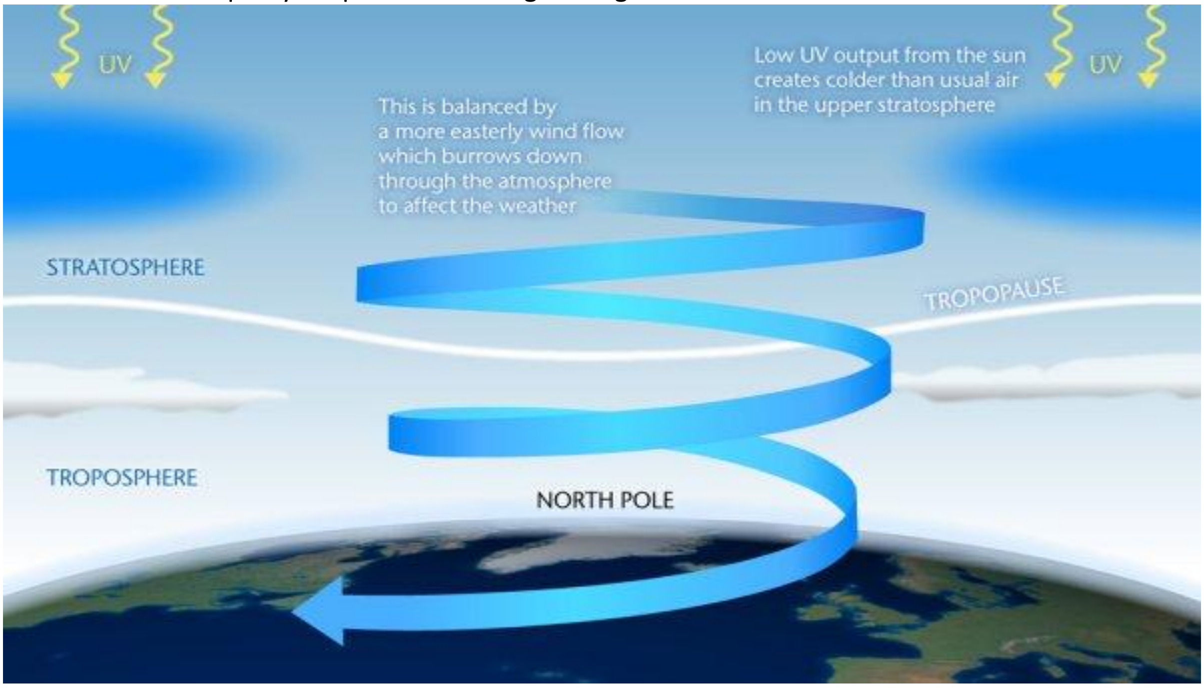
[49] Refer to the following for explanation as to how these occur. Kazimirovsky E; The fluctuations with periods of planetary waves in the variations of ionosphetic parameters for the Eastern Siberia, the Institute of Solar Terrestrial Physics, 7/2010

hole than usual that formed in the southern hemisphere during spring. This larger hole was initially blamed on mankind's increasing chlorofluorocarbon emissions because they had been demonstrated to chemically break up ozone and these emissions were growing rapidly at that time. However now that the sunspot activity is even weaker not only has the spring southern hole in the ozone layer significantly increased but a hole in the ozone layer has been forming in the northern hemisphere spring[50]. These holes can't be blamed on any sudden increase in chlorofluorocarbons.

Ozone acts as a greenhouse gas absorbing long-wave (infra-red) radiation emitted from Earth and this process also heats the atmosphere from about 20 kilometers to about 90 kilometers up (i.e. much of the stratosphere and the mesosphere). Ozone also absorbs UVB and UVC from the Sun and so helps protect life on Earth from those harmful components of ultra-violet light. Therefore the NO, NO_2 and O_3, balance is important for both the climate and for the existence of life.

The following graphic was obtained from the publication of the UK Met Office. Adam Scaife, one of the scientists involved in the research, said "*that while some studies have observed a link between solar variability and winter climate, our research establishes this as more than just coincidence*". He said: "*We've been able to reproduce a consistent climate pattern, confirm how it works, and quantify it using a computer model based on the laws of physics. This isn't the sole driver of winter climate over our region, but it is a significant factor and understanding it is important for seasonal to decadal forecasting*."

A November 2009 paper[51] linked polar temperatures to geo-magnetic activity. It showed statistically significant differences in surface atmospheric temperatures and geomagnetic activity. So when the sun's magnetic activity is low, surface atmospheric temperatures are low (by up to 4 deg. C) and when the sun's magnetic field is high then surface atmospheric temperatures are higher. The scientists were able to prove statistically that these changes were not related to the ENSO or other cycles but couldn't rule out a link between surface atmospheric temperature and what they called the Northern Annular Mode, which is also called the Arctic Oscillation. They did not link the surface atmospheric temperatures directly to the extreme ultraviolet emissions of the Sun because data for this does not exist for much of the study period (1957-2006), so they used F10.7 flux data. F10.7 data is often used as a proxy for periods before geo-magnetic data became available.



[50]Solar variability helps explain cold winters – UK Met Office, 10/11
http://www.metoffice.gov.uk/research/news/solar-variability

[51] Seppala, A., C. E. Randall, M. A. Clilverd, E. Rozanov, and C. J. Rodger (2009), Geomagnetic activity and polar surface air temperature variability, J. Geophys. Res., 114, A10312, doi:10.1029/2008JA014029.

Geoff Sharp published an article[52] in January 2012 (but updated in February 2012) which explains in much greater detail how the various components of ultra violet light react with the atmosphere at various levels and how the changing levels of EUV emissions cause the polar vortices, jet streams and hence climatic conditions[53]. This explanation includes the relevance of the Milankovitch (100,000 year, major ice-age) cycle, the Jose (178 year) cycle, which may produce a solar grand minimum, and the PDO/ENSO (approximately 60 year) cycle.

Nitrogen oxides can also be formed in the mesosphere and thermosphere from interaction between nitrogen, oxygen and cosmic ray protons or higher energy protons from the Sun typically ejected during geomagnetic storms. Geomagnetic storms, or coronial mass ejections (flares) as they are often called, will, if they hit Earth, cause more extensive auroras. Hence in winter the ozone “blanket” can be thinned more than usual during times of either high cosmic ray activity (caused by low sunspot activity), or after there has been a geomagnetic storm that has influenced the thermosphere at high latitudes.

The geomagnetic storm of January 24, 2012 apparently ejected some quite high energy photons and electrons which struck the northern regions of the northern hemisphere and created spectacular auroras as far south as Scotland. This would have heated the thermosphere and possibly overloaded it and the mesosphere with nitrogen dioxide. A day or two later the polar vortex changed. The additional transportation of nitrogen dioxide and ozone from the stratosphere to the thermosphere significantly impacted the local amount of ozone in the lower regions of the ozone layer and the additional updraft was counterbalanced by stronger Easterly flowing downdrafts. The result was much strong easterly winds in the higher latitudes of the Northern hemisphere causing excessively cold air from over Siberia to move westwards and produce the massively cold spell over much of the Northern hemisphere in February.

More generally, auroras wax and wane with the intensity of sunspot cycles. So when the sunspot activity is high, fewer cosmic rays penetrate the magnetosphere and hence there is less ionization in the ionosphere and lower aurora activity. (But the thermosphere is more extensive and denser at these times because of the Sun’s higher activity). When sunspot activity is low there is more ionization in the ionosphere and higher aurora activity. Periods of higher aurora activity are usually correlated with cooler climatic conditions[54].

The table below shows the molecular atomic weight of various molecules in the atmosphere. Avogadro’s hypothesis states that samples of an ideal gas, of the same volume and at the same temperature and pressure, contain the same number of molecules. But In the troposphere the gases tend to be uniformly mixed due to turbulence so molecular weight doesn’t play a significant part in the distribution at this level of the atmosphere.

Gas	Molecular Structure	Molecular weight
Water Vapour	H_2O	10
Nitrogen	N_2	14
Nitrogen Oxide	NO	15
Oxygen	O_2	16
Nitrogen Dioxide	NO_2	23
Ozone	O_3	24
Carbon Dioxide	CO_2	28
Radiocarbon Dioxide	CO_2	30

In higher levels where the air is extremely thin[55] there shouldn’t normally be much turbulence so molecular weight could play a bigger role. The nitrogen oxides are only important above the

[52] http://www.landscheidt.info/?q=node/50

[53] Solar variability helps explain cold winters – UK Met Office, 10/11 ref. http://www.metoffice.gov.uk/research/news/solar-variability

[54] Nicola Scafetta, A shared frequency set between the historical mid-latitude aurora records and the global surface temperature - Journal of Atmospheric and Solar-Terrestrial Physics, October 2011

[55] In the thermosphere air molecules may be as much as 100 metres apart.

troposphere whereas water vapour would seldom get above the troposphere[56]. Oxygen, nitrogen and carbon dioxide do get above the troposphere but with the lack of turbulence a molecule of carbon dioxide in its gaseous form being much heavier than molecules of oxygen and nitrogen will tend to be less concentrated in these higher levels of the atmosphere.

Despite the mixing that occurs in the troposphere a molecule of water vapour is still lightest of the major component gases so it tends to rise. A molecule of carbon dioxide is the heaviest of the common, non-oxidizing atmospheric gasses and this is why it is used in fire extinguishers.

Water vapour cannot rise very high before it turns into a liquid, or, if it is transported higher in strong updrafts, then it will turn into ice crystals. These form cirrus clouds, which provide a localized greenhouse effect by also reflecting back Earth's infra-red radiation emissions. These clouds have to be kept at altitude by wind pressure. Without such pressure they would naturally precipitate.

CO_2 can become dry-ice crystals in the upper troposphere, when it is carried high enough but it also needs a temperature below -56 deg. C at the low pressures of the upper troposphere and above for this to happen. These temperatures and pressures do exist in the troposphere above about 5km at the poles in winter and also in the tropics above around 15km. But elsewhere the upper levels of the troposphere do not normally get this cold nor does the stratosphere or beyond. So carbon dioxide can normally provide an important direct greenhouse effect at the poles in winter and in the tropics. But this effect should be put into perspective. Carbon dioxide concentrations in the tropics will tend to be around 0.25% to 0.5% of total atmospheric greenhouses gases. At the poles it will tend to be around 2.5% to 5% of total atmospheric greenhouse gasses.

During deep solar minima the upper levels of the troposphere would appear to get cooler than usual over much greater areas so more upper atmospheric carbon dioxide will convert to dry-ice cirrus clouds over much more of Earth's surface. During the day the dry-ice cirrus clouds will reflect infra-red heat from the sun back into space just as normal lower level water vapour clouds reflect the sun's heat away and during the night these clouds may help to reflect infra-red emissions from Earth back to its surface. So, particularly during solar grand minimums, atmospheric carbon dioxide will contribute to additional reductions in daytime surface temperatures while perhaps keeping night time surface temperatures slightly warmer. Meanwhile in the thermosphere carbon dioxide's role, according to NASA[21], is to act as a cooling agent.

In comparison with water vapour carbon dioxide's direct greenhouse role in the troposphere is given more weight because it transforms directly from gas to solid form whereas water vapour has an intermediate liquid form and a solid form at quite high temperatures (for the upper levels of the troposphere). But the role of carbon dioxide is mitigated because it is the heaviest of the common lower atmospheric gases and it is highly soluble in water. So it would seem that it should only play a relatively limited direct greenhouse role compared to water vapour, which provides a direct greenhouse effect in its liquid (aerosol) form and well as its solid (ice) form in the atmosphere at the relatively low temperatures and pressures encountered in all geographic locations.

Many scientists believe that carbon dioxide has an additional "forcing" function that increases the amount of water vapour that would otherwise be in the atmosphere and hence they contend that higher atmospheric concentrations of carbon dioxide cause higher temperatures. Scientists also contend that greenhouse effects are caused by all molecules in the atmosphere that have more than 2 atoms. Apparently these more complex molecules capture but re-emit infra-red radiation[57]. In this process a small part of the re-emissions are returned in the direction from whence they came. During the day these more complex air molecules would presumably capture inwards infra-red radiation and reflect a small part of it back into space. Hence it would seem that increased levels of

---

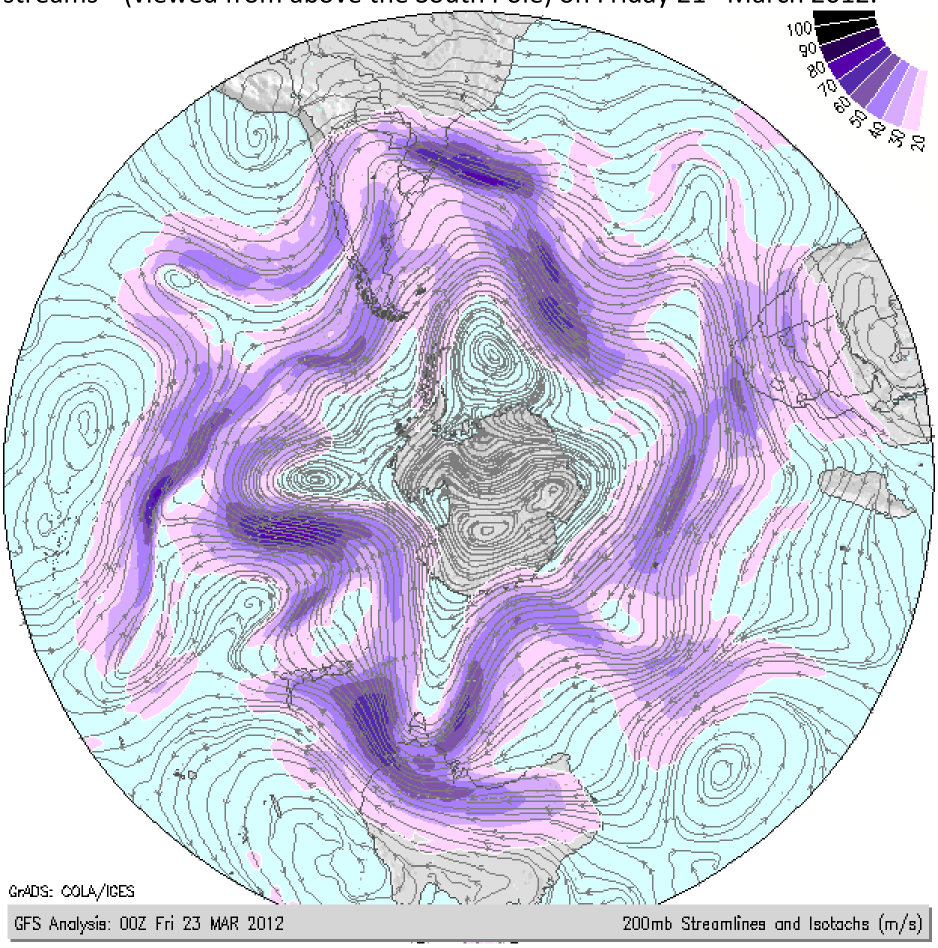
[56] ^{14}C is also formed mainly at higher latitudes in the lower stratosphere from cosmic ray activity and nitrogen. If it combined with O_2, $^{14}CO_2$ has an atomic weight of 3 times that of water vapour. Otherwise the carbon atom will be precipitated.

[57] The initial theory linked the size of the molecule to its ability to absorb and re-emit infra-red radiation. However the "collision diameter" of CO_2 is only about 75% of the "collision diameter" of O_2 and N_2 and so the underlying physics is not so simple.

atmospheric carbon dioxide will tend, if anything, to slightly reduce surface temperatures during the day and slightly increase surface temperatures at night.

Because of the significant reduction of solar EUV and FUV emissions during deep solar minimum there is less energy available to heat the stratosphere, mesosphere, thermosphere and exosphere. This normally would not cause any climate issues during a normal solar cycle because any resultant temperature changes in the stratosphere and the upper troposphere would not be significant as the low sunspot activity of a normal cycle occurs only for a year or two and the temperature normally changes very gradually in these components of the atmosphere. During a solar grand minimum there seems to be a greater average reduction in EUV and FUV and it appears that these outputs will stay suppressed for decades.

So during solar grand minimums it seems that the upper levels of the troposphere could become a few degrees cooler than when solar cycles are normal. As the jet streams occur in the upper troposphere these then tend to be pushed somewhat closer to the equator[58]. Hence the weather systems associated with these jet streams are also moved closer to the equator. This change in weather systems is particularly noticeable in winter. But jet streams are constantly changing and do not circumnavigate Earth at the same latitude. The following graph is that of the southern jet streams[59] (viewed from above the South Pole) on Friday 21st March 2012.



The reduced upper tropospheric temperature in solar grand minimums creates an increased difference in the temperature of the oceans and the mid to upper levels of the troposphere particularly in the mid to higher latitudes. These increased temperature differences cause water vapour to condense and release its heat earlier in its rise into the atmosphere than it otherwise

[58] Jet streams are basically caused by the pressure differences between cold (polar) air and warm (mid latitude) air at the upper levels of the troposphere.

[59] Forecasts issued by the National Centers for Environmental Prediction; http://wxmaps.org/pix/shemi.fcst.html (200mb streamlines and isotachs)

would. This principle is particularly demonstrated in winter in Sydney and Melbourne when the water in backyard swimming pools might only be 10 deg. Celsius but early in the morning when the air is calm and much colder "steam" appears to rise off the water. What is actually happening is that the water is giving up energy through the emission of water vapour which in turn releases its energy to the cold air just above the water by condensing into tiny water droplets, which eventually get dispersed by the warmer air currents caused by the release of this heat.

The reduction in the average atmospheric height at which water vapour releases its energy causes additional near Earth atmospheric instability and this results in more extreme weather phenomena. The additional instability will presumably last for at least the duration of the solar grand minimum unless the grand minimum lasts so long that the oceans give up so much heat to cause the mid troposphere/ocean temperature differential to be restored to more normal levels. However this scenario assumes that the high to mid troposphere temperatures don't also continue to fall with ocean temperatures. The increased volcanic activity during this time can also act as a moderator, particularly if there is a large eruption like that of Mt Tambora in April 1815[60], the middle of the Dalton grand minimum.

Climate scientists also predict that there will be more atmospheric instability if the oceans get warmer due to global warming. It will occur for the same reason, that is the temperature difference between the oceans and the mid-levels of the troposphere would then be greater. This climate change scenario implicitly assumes that the mid to upper troposphere temperatures remain constant or at least don't increase by the same amount as the oceans[61].

The same phenomenon can occur locally when there is a local change in the distribution of ocean heat due to, for example the El-Nino and La-Nina climate cycles. The warmer oceans off the east coast of Australia during La-Nina events produce greater local atmospheric instability and hence greater rainfall in Eastern Australia than for El-Nino events. El-Nino events cause cooler water temperatures off the east coast of Australia and hence reduce local atmospheric instability, which culminate in drier, even drought, conditions. Because the mid to upper troposphere is cooler than it apparently has been for many decades the 2010/11 and 2011/12 La Nina weather patterns have provided more extreme weather in Eastern Australia than has been typically experienced during previous La Nina events.

The Pacific Decadal Oscillation

Ian Wilson[62] found that "*the phases of two of the Earth's major climate systems, the North Atlantic Oscillation (NAO) and the Pacific Decadal Oscillation (PDO), are related to changes in the Earth's rotation rate. We find that the winter NAO index depends upon the time rate of change of the Earth's length of day (LOD). In addition, we find that there is a remarkable correlation between the years where the phase of the PDO is most positive and the years where the deviation of the Earth's LOD from its long-term trend is greatest.*" The following graph uses the extended ENSO (El-Nino Southern Oscillation Index) data set from 1900-2005 to show the PDO, ENSO relationship.

Both actual and proxy records of the PDO show that when the PDO is in its positive phase, El Nino's tend to be more common, and when it is in its negative phase, La Nina's tend to be more prevalent. The graph shows a positive phase of the PDO[63] from around 1915 to the mid 1940's followed by a negative phase from the mid 1940's to the mid 1970's and a positive phase for the rest of the Century. It appears to be now in a new negative phase. Wilson suggests that there is an extra-terrestrial influence as the times of maximum asymmetry in the sun's motion about the solar

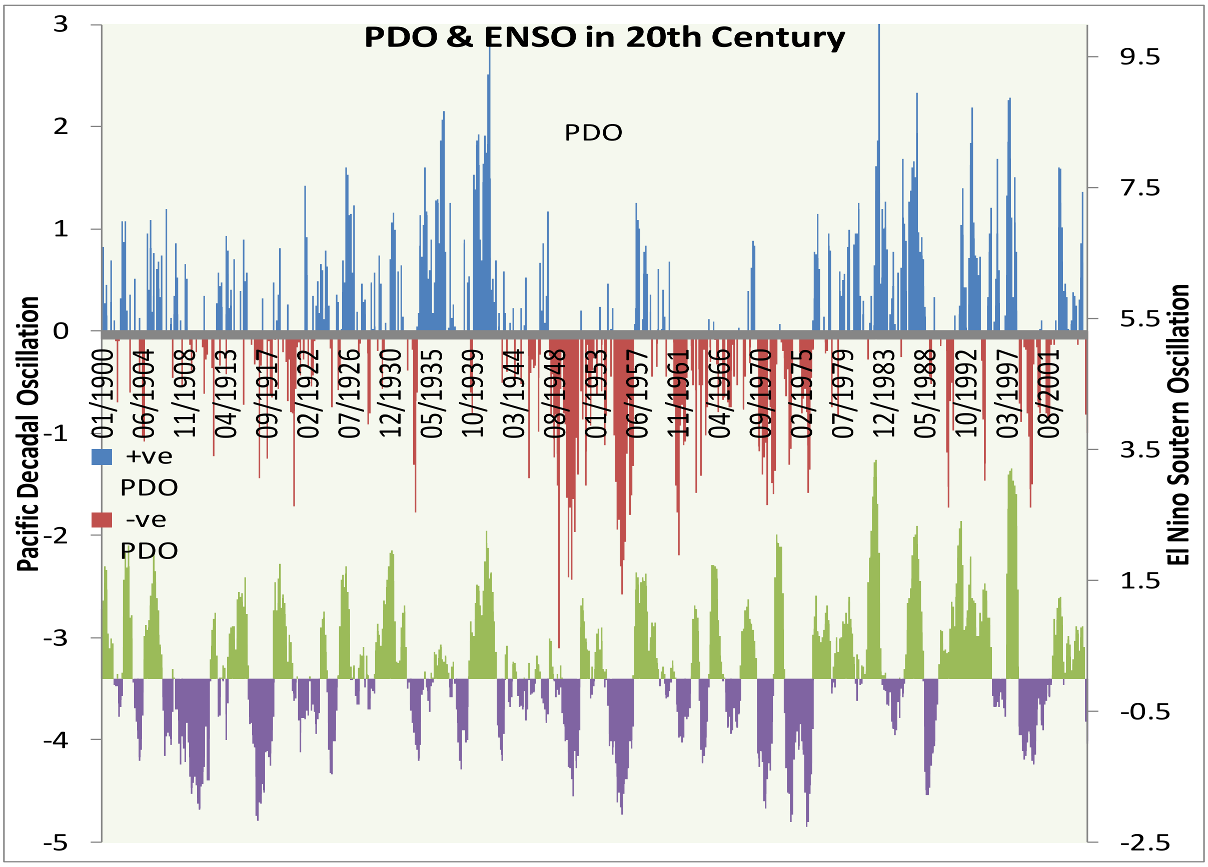
[60] 150 Cubic Kilometres ejected, killed 92,000 people and eliminated the Northern summer of 1816.

[61] Origins of Extreme Weather; adapted to the Southern Hemisphere from the lecture notes of Prof. Stephen A. Nelson: http://earthsci.org/flood/J_Flood04/wea1/wea1.html

[62] Ian Wilson, The General Science Journal, Are Changes in the Earth's Rotation Rate Externally Driven and Do They Affect Climate?, 2011

[63] The NCDC PDO index is based on NOAA's extended reconstruction of SSTs (ERSST Version 3). Refer http://www.ncdc.noaa.gov/teleconnections/pdo/ The PDO data has had the first +ve and -ve 0.5 deleted.

system's barycenter coincide with the maximum deviations of Earth's length of day from the trend in such changes.

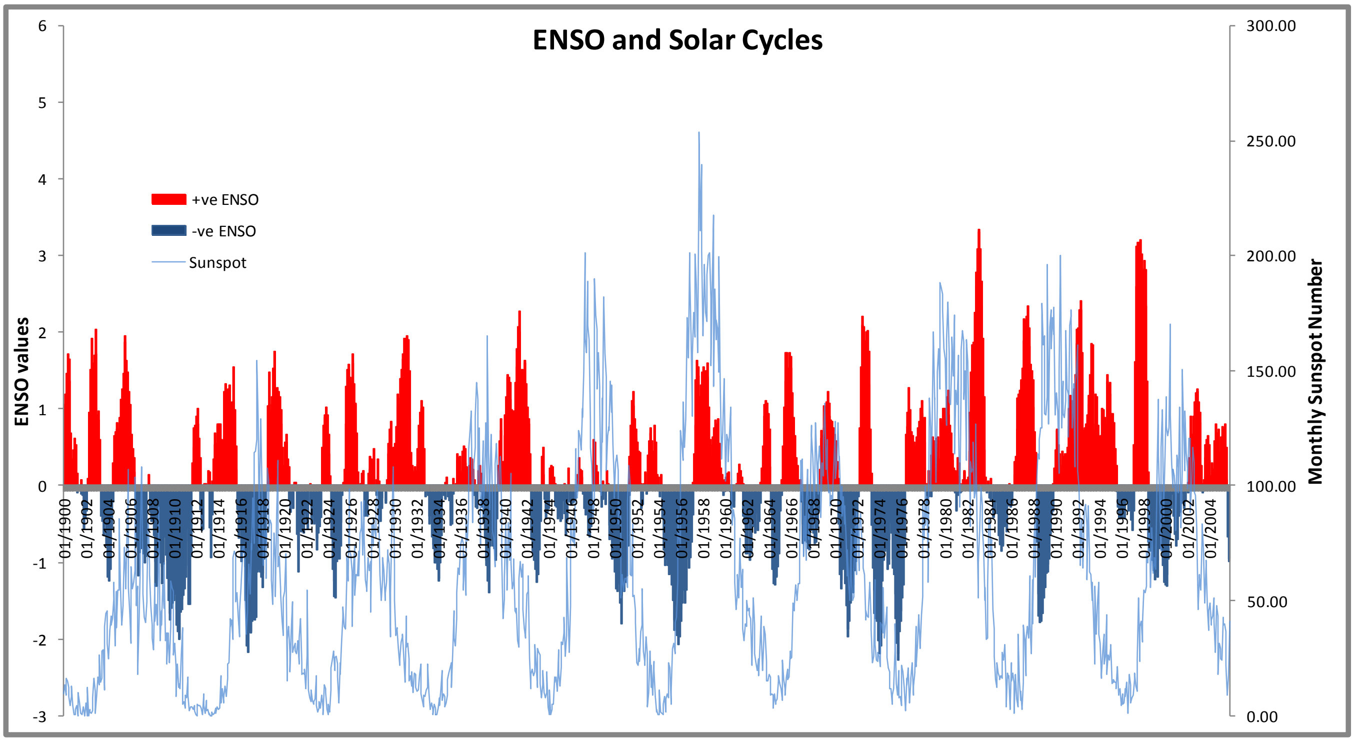


Wilson's paper explains "*why the asymmetries in the solar motion about the CM and changes in the rotation rate of the Earth are synchronized. In order for this apparent correlation to make any sense, there must be some underlying physical process that connects the relative motion of the four Jovian planets to a factor that can influence the rotation rate of the Earth*". Through some detailed mathematical analysis the paper concludes that *"the most likely candidate for the underlying physical process is the synchronization between the precession rate of the line-of-nodes of the lunar orbit and the relative sidereal orbital periods of Venus, Earth, Mars and Jupiter as a result of past resonances between these two phenomena."* In other words the tidal forces of the Sun and the Moon change Earth's length of day more at certain times because of the Moon's past harmonic relationship with Venus, Mars and Jupiter. These changes in the trend coincide with the phase changes in the PDO and NAO.

The graph also shows the relationship between the PDO and ENSO[64]. Generally when the PDO is in its positive mode the El Nino phenomena is stronger, lasts longer and is more prevalent. In the negative phase the La Nina phenomena is stronger, lasts longer and is more prevalent. However the PDO is not the only determinant of the ENSO phenomena. The strength of the solar cycle plays a part, volcanism almost certainly plays a part and it is likely that airborne pollution has an influence.

The graph below shows the relationship between ENSO and solar cycles from 1900 – 2005. The reason for terminating the graph at 2005 is that the extended ENSO data set has been separately compiled and is not linked to the current data collection.

[64] The Multivariate Enso Index is used. Refer: http://www.esrl.noaa.gov/psd/enso/mei/mei.html



The calculations performed by Ian Wilson that are detailed in Section 4 indicate that the PDO would have turned negative around 1790 - 1791 at the commencement of the Dalton Minimum (1790-1830). This suggests that La-Nina's predominated for about 30 years from that time. We do know that the first of the European settlement of Australia commenced in 1788 and the diary of Watkin Tench (Captain of the First Fleet Marines) indicates that Sydney was particularly warm in the summer of 1788/89 and 1789/90. It seems likely that from the early 1790's Sydney had good rainfall for many years. For example in Sydney in the early 19th Century there were sugar cane and pineapple growing competitions. If there had been continual El-Niño's and thus less consistent rainfall during this time the early European settlers may not have survived in Sydney Cove or, at least had been forced to move to a location that had more consistent rainfall patterns.

During the first exploration up the Nepean River it was noticed that there was driftwood tangled in the branches thirty feet up the trees along the banks of a particularly narrow part of the river. That suggests that there were extreme weather events in the Blue Mountains at that time.

The Guardian, the lead ship of the second fleet hit a large iceberg south-east of Capetown in 1789 but fortunately remained afloat and eventually drifted up the east coast of South Africa where it came ashore. Could that accident have been the result of extreme weather in the Southern Ocean? There are other records of sightings of icebergs in the late 18th Century in areas of the Southern Ocean where icebergs were not normally seen.

The PDO has recently turned negative again and Ian Wilson's second graph in Section 4 shows that this would have occurred from around 2008 to 2010. In February 2012 there were reports from the Global Ocean Race fleet of many unexpected large icebergs on the third leg between Wellington (NZ) and Punta del Este. In 2011 there were reports of a very large iceberg off the coast on New Zealand and there have been recent sightings of a number of large icebergs off Macquarie Island (half way between Australia and Antarctica). These recent sightings of icebergs do not in themselves mean much but they do add to the evidence that the Sun is in a new Grand Minimum.

To demonstrate a practical use to which the analysis of extraterrestrial influences on nature's risks can be put, Ian Wilson provided the author with as yet unpublished data that shows the approximate alignment of extreme wet weather patterns that have caused significant floods in South East Queensland with the 18.6 year peak lunar tidal cycle. The peak lunar tidal cycle is particularly important during periods when the Pacific Decadal Oscillation is negative. As the PDO should still be negative in 2029/30 there is a correspondingly higher probability of extreme wet weather in South East Queensland around that time particularly if there is a La Nina, which is more likely during the negative PDO. By then it is hoped that actuaries and others who will have become expert in the analysis of extraterrestrial influences on nature's risks will be influencing flood mitigation strategies (including the maintenance of anticipatory water levels in the Wivenhoe Dam) and will be anticipating the additional risk of that period in their advices in respect of property insurance premiums.

Ian has also put together some intriguing, also unpublished, data on the alignment of extreme summer heat waves in Victoria and South Australia with the maximum lunar tidal cycle. The likelihood is increased during times of positive PDO and a long and strong El Nino. More work in this area could lead to improved mid-term predictions of catastrophic bushfires and provide extra time to deploy enhanced strategies to minimize the loss of property and life at those times of higher risk.

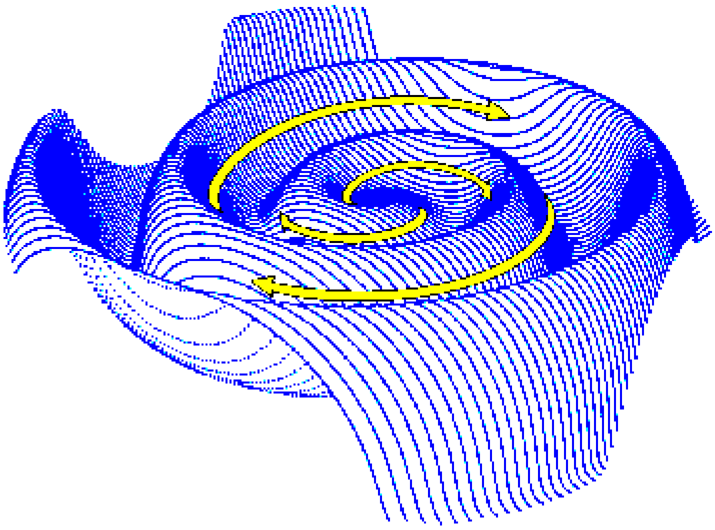
7. The Magnetosphere

"We can scarcely avoid the inference that light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena." – James Maxwell (1832)

The Sun's Magnetic Field

The sun's magnetic field, known as the geo-magnetic field, the helio-magnetosphere or just the magnetosphere is very powerful and exists to the limits of the solar wind, that is, to the outer limits of the solar system. This magnetic field is protective of the solar system from cosmic ray activity (refer section 8) and is integral to the transport of non-heat energy from the sun. The Wilcox solar observatory data, graphed in section 5, showed how the absolute strength of the sun's magnetic field varies considerably over a solar cycle.

So if one could see a magnetic field, what would it look like? Below is how NASA scientists currently understand it.



As the Sun is rotating, its rotation winds up the magnetic field into a large rotating spiral, known as the Parker spiral, which is named after the scientist who first described it[65].

In 2011 the two Voyager spacecraft, which are currently at the outer limits of the solar system made another discovery about the magnetosphere. They discovered that the spiral field breaks up into "frothy magnetic bubbles". So some of the time the Voyagers did not record a magnetic field and other times they did. These magnetic bubbles can be about 150 million kilometers across. These bubbles would hinder cosmic ray activity from entering the solar system but where they don't exist cosmic rays should be able to enter more easily. It is too soon to determine how these bubbles change with the sun's absolute magnetic strength but it would seem likely that they will be bigger and stronger during periods when the sun's magnetic field is at a maximum, that is, when there is maximum sunspot activity. During deep solar minimums and grand minimums the bubbles are likely to shrink. Then there is less hindrance to cosmic rays entering the solar system. The existence of this magnetic froth at the outer reaches of the solar system puts a new dimension to the study of cosmic ray activity because it suggests that both low energy and high energy cosmic rays can penetrate the magnetic veil provided by the sun. The conventional theory prior to this discovery was that the majority of low energy cosmic rays were blocked from entering the solar system.

Magnetic Connection to Earth

Because the sun's magnetic field radiates out in the Parker spiral (a torus shape) resonances between the planets could occur when they are connected magnetically through the Parker spiral rather than gravitationally when they are in a direct line. This view has been reinforced with the discovery of magnetic portals that connect Earth to the Sun via magnetic field lines. This discovery, which was reported in October 2008 by NASA at an international assembly of space physicists at the 2008 Plasma Workshop in Huntsville, Alabama, provides the mechanism for the transfers of tons of

[65] http://helios.gsfc.nasa.gov/solarmag.html

energetic plasma from the Sun into Earth's ionosphere when these portals are open. Intriguingly, NASA reported that these "flux transfer events" occur around every eight minutes and that they are "*often brief, bursty and very dynamic*". During these times magnetic field lines literally reach from Earth to the Sun. It is through this mechanism that the part of Earth's ionosphere that is facing the Sun is loaded with plasma particles from the Sun giving rise to the Van Ellen radiation belts.

Magnetic Connections – Other Planets

Since the Sun directly connects to Earth through magnetic field lines it would seem implausible that it doesn't directly connect to other planets - at least those with magnetic fields. Below is a list of the planets indicating the strength of their magnetic fields relative to Earth's magnetic field. The overall strength is related to the relative strength at surface by their radius cubed.

Solar System Magnetic Fields*

	Overall Strength relative to Earth	Relative Strength at surface
Sun	2.6m - 20,000m	2 - 8,000 approx
Mercury	0.006	0.35
Venus	0	0.00
Earth	1	1.00
Mars	0	0.00
Jupiter	19,519	45.06
Saturn	578	2.23
Uranus	47.9	2.42
Neptune	27	1.50

*Data obtained from http://www.astronomynotes.com/solarsys/plantblb.htm

This shows that the Sun has by far the most powerful magnetic field but its field is also extremely variable. This is because sunspots can have magnetic fields up to 8,000 times more powerful than the surrounding area.

Jupiter has by far the most powerful magnetic field of the planets. Its magnetotail extends well beyond the orbit of Saturn. There is also a very powerful interaction between the magnetic field of Jupiter with the magnetic fields of Io, Europa and Ganymede. Io's dynamo mechanism is similar to the Earth's, based on turbulent flow in an internal layer of liquid magma rich in iron and magnesium. The heat source for the dynamo is tidal heating resulting from Io's orbital resonances with Europa and Ganymede and from the magnetically induced current flow with Jupiter. Jupiter and Io also form a dynamo causing 400,000 volts of potential to form across Io, and 5 million amps of current to flow through it. There is also a powerful current flow between Io and Jupiter, through a line of plasma known as a flux tube. This intense current flow is essentially an electric arc orbiting Jupiter under Io[66][67]. Io also has many massive active volcanos and these emit a lot of matter that escapes Io's gravity and is captured by Jupiter's gravity.

Sun's Magnetosphere Influences on Earth

The sun's magnetic field strength influences Earth in a number of known and unknown ways. Its intensity affects the intensity of cosmic rays striking Earth and their influence on cloud formation, volcanic eruptions and earthquakes. This is the subject of section 8. But there may also be direct processes involving the magnetic fields of the Sun and the Moon that are yet not understood. For example scientists have yet to understand the physics behind the appearance of extra-ordinary large quantities of charged particles in the ionosphere before the incidence of some very large

[66] Richard McDonald, Planetary Magnetic Fields, 2005. www.themcdonalds.net/richard/astro/papers/602-magfields.pdf

[67] http://www.planetaryexploration.net/jupiter/io/io_plasma_torus.html

earthquakes at sub junction boundaries. Is it is possible that the magnetic field distortions of Earth and the Sun play a role? This would seem likely given the Sun's magnetic connection to the ionosphere.

8. Risk Factors that originate from beyond the Solar System

"All science is either physics or stamp collecting*". – Ernest Rutherford*

Sub-Atomic Particles

The more we try to understand nature the more we realise how complex nature is and how difficult it is to explain. Much of the science detailed in this section is evolving but as the scientific evolution continues it is becoming clear that Earth's evolution is being influenced by events that occur in the Milky Way galaxy well outside of the solar system and even events that occur beyond our galaxy. It is not the intention to study the effect on risk caused by the solar system's path through the galaxy as these will normally change very slowly over many millennia but rather the galactic influences that change with predictable patterns of decades and centuries.

But first let us look at the fundamentals of matter. Fifty years ago schools taught that atoms were made up of protons, neutrons and electrons. Hence hydrogen, element 1 on the periodic table, had just 1 proton and 1 electron and pairs of hydrogen (H_2) existed as a gas. The next element on the periodic table was helium and that had 2 protons, 2 neutrons and 2 electrons. Understanding matter seemed as simple as understanding the differences between electrons, protons and neutrons and learning the periodic table. Back then scientists had discovered other sub-atomic particles but these other particles were supposed to be very short lived and so of little interest to someone whose interests focused on changes that could easily be measured.

Protons and electrons are the only sub-atomic particles that are stable. When not part of an atom, they have lifetimes of perhaps 1 trillion years and, in the right environment, so are their antimatter equivalents. Neutrons, on the other hand, only have a half-life of a little more than 10 minutes. All forms of neutrinos are also stable but only because they appear to have little mass - or mass energy in an atomic sense[68].

In 1937 scientists discovered a sub-atomic particle with the charge of an electron. This particle was reacting quite differently to an electron when passing through a magnetic field. The difference seemed due to its significantly higher mass. Furthermore, these "heavy electrons" existed normally at ground level. They were initially given the name of mesotron (meaning heavy electron). Later, in 1947 the particle became known as a mu-meson but soon after it was discovered that it did not have the characteristics of a meson so it became called a muon. One reason for this distinction was that by then scientists realized that mesons had a life of only a few hundred millionths of a second whereas they had observed that muons have a half-life of 1.56 microseconds. It would seem that actuaries should have little reason to be concerned about the importance of a sub-atomic particle, which we cannot see, that lasts a couple of microseconds or, for that matter, other sub-atomic particles that last perhaps a thousandth of that time. But they are important!

In an experiment in 1941mesotrons, as muons were then called, became the first particle to exhibit the time dilation/length contraction properties of the special relativity theory proposed Einstein in 1905[69]. If it wasn't for this special relativity theory very few muons would ever reach Earth's surface. This enables muons, travelling at close to the speed of light to travel many times the distance that their average lifetime would otherwise permit and for a significant proportion of them to reach and penetrate Earth's surface.

Current scientific theory has all matter being made up of 3 leptons and 6 quarks with each having an antimatter equivalent. The three leptons known to science are: electrons, muons and tau particles. These leptons respectively have a mass energy of .000511GEV, 0.1066GEV and 1.777GEV. (An electron volt is equal to the amount of kinetic energy gained by a single unbound electron when it accelerates through an electric potential difference of one volt).The average lifetimes of muons

[68] Sandor Nagy. Eotvos Lorand University, Budapest, Hungary: RadioChemistry and Nuclear Chemistry, Vol II Sub Atomic Particles, Nuclear Structure and Stability –

[69] Rossi, B.; Hall, D. B. (1941). "Variation of the Rate of Decay of Mesotrons with Momentum". Physical Review (3): 223–228

and tau particles are $2.2x10^{-6}$ seconds (2.2 microseconds) and $2.96x10^{-13}$ seconds[70]. The difference is substantial. The two short-lived leptons (and their antimatter equivalents) decay into neutrinos associated with that lepton, photons and an electron. But the processes are far from uniform with lots of in-between particles that may or may not recombine. Typically during the decay process showers of neutrinos are formed. Muons decay to at least one electron and 2 muon neutrinos (always at least a muon neutrino and an anti-muon neutrino at the same instant). They may additionally provide a pair of photons (positive and negative) and even an additional electron and positron.

The theory that protons and neutrons were made up of quarks was proposed in 1964. The first quarks were identified in 1968 at the Stanford Linear Accelerator Centre[71] with the last of the 6 quarks, (the top quark) only being discovered in 1995[72]. Protons and neutrons are made up of 3 quarks. Protons have two up quarks and one down quark and neutrons have two down quarks and one up quark. Mesons (referred to earlier) turned out to be just two quarks bound together.

Neutrinos are considered to be without mass and normally travel at or about the speed of light although recent scientific experiments at CERN suggest that some types of neutrino might have a very tiny mass energy and travel slightly faster than the speed of light[73]. (But by mid October 2011 there were a plethora of papers suggesting why this might have only appeared to have happened.) The Sun generates enormous numbers of neutrinos. About 65 billion neutrinos pass through every square centimeter of Earth facing the Sun every second. Almost all of these go straight through Earth and pass out of its opposite surface. So in the time it has taken you to read this paper at least 10^{18} neutrinos will have passed through your body. Because we neither see them, nor feel them, they do not concern us.

The Sun does not generate muons at its surface because the energy needed to create muons is greater than that even released from the nuclear fusion processes happening at or near its center. The Sun does generate the solar wind which typically travels between 1/1500th and 1/500th of the speed of light. Therefore, protons travelling in this wind do not have enough energy to create muons. (Their energy is often less than 10^{11} eV). So the protons from the Sun that reach Earth tend to be absorbed by the ionosphere including by flux transfer events (refer section 7). Even when a large sunspot produces an X-class flare the energy of the flare's ejected protons are still less than what is needed to create muons. (An X-class flare is the flare with the highest energy level.)

Protons arriving from outside the solar system have been generated by supernova, exploding nebulae, black holes, neutron stars and even perhaps the big bang itself. It has also been suggested that some come from other galaxies. Some scientists have suggested that they may even be continuously generated by dark matter at the galactic nuclei[74]. These high energy protons may also have been accelerated by galactic electromagnetic fields. When these protons reach the solar system they could be travelling almost as fast as the speed of light and so can have extreme levels of energy. For example, in 1991 scientists at the cosmic ray detector at the University of Utah detected a proton with an energy level that would have caused it to travel just 46 nanometers less than light in one year. It became known as the "Oh My God" particle[75]. Its energy level was $3.2x10^{20}$ eV, which is enough energy to power a 40 watt incandescent electric light bulb for a second. Incidentally, due to its speed relative to the speed of light, the special relativity theory indicates that this particle would have appeared to have travelled from the center of the galaxy to Earth (some 32,000 light years) in approximately 3.2 seconds. Or looking at the distance travelled from the particle's point of view the Earth's diameter of 12,756 kilometers would have appeared to be just 0.0399 millimeters.

Many of these extra-galactic protons in the lower energy range (to 10^9 eV) are deflected by the Sun's magnetic field and therefore do not reach Earth's environs. The very high energy protons that

---

70 http://hyperphysics.phy-astr.gsu.edu/hbase/particles/lepton.html
71 Michael Riordan, The Discovery of Quarks, Stanford Linear Accelerator Center, Stanford University
72 http://particleadventure.org/topquark.html
73 New Scientist, September 28, 2011
74 http://imagine.gsfc.nasa.gov/docs/science/know_l1/cosmic_rays.html
75 John Walker, The Oh-My-God Particle:1994. http://www.fourmilab.ch/documents/OhMyGodParticle/

do penetrate may interact with sub-atomic particles in the ionosphere forming hydrogen or neutrons or other particles or they may continue penetrating Earth's ionosphere and atmosphere until they interact with atoms of air or even penetrate the Earth's surface. High energy neutrons either formed in the ionosphere or, less likely, arriving in galactic cosmic radiation can also then interact with nitrogen in the atmosphere to form radio carbon 14 or through spallation with nitrogen and oxygen and or carbon to form beryllium 10 and a number of other radio-nuclides.

Muons are Influential

For muons to be created naturally the extremely high energy galactic protons must collide with the nucleus of an atom of oxygen or nitrogen in the atmosphere and generate many very high energy pions and neutrinos. The pions then immediately decay into muons plus perhaps many more neutrinos. Finally the muons may decay in the atmosphere or after penetration of Earth's surface and create even more neutrinos, photons and an electron. The showers of mainly neutrino particles have been shown to influence cloud formation. This is the subject of continuing CLOUD experiments at CERN and SKY experiments at the National Space Institute in Copenhagen. The Danish solar physicist Henrik Svensmark set up the original SKY experiments that, in 1991, indicated that cosmic rays were instrumental in forming clouds. Hence this led to the consideration that at times when there were more cosmic rays then there would also be more clouds and hence cooler weather[76]. The CERN experiments under Jasper Kirkby are intended to replicate the SKY experiments under more rigid protocols and further advance understanding of the cosmic ray influences on climate.

Muons are also produced in the laboratory using particle accelerators that can increase the speed of protons to more than 0.75xC. These accelerated particles are made to collide with a target consisting of beryllium or carbon to produce pions that immediately decay into muons. Scientists at several locations are experimenting with muons and atoms such as hydrogen that has negatively charged muons that have replaced the electron or even muonium, which is a hydrogen atom with an anti-muon replacing the proton. These experiments have a goal of finding a catalyst or mechanism for cold fusion, perhaps leading to the holy grail of clean energy generation. But don't hold your breath for it may never happen or, at least, it may take many decades yet. Scientists are also discussing the concept of muon accelerators where they will accelerate muons to close to the speed of light so that they will live long enough (perhaps a second or two) so that they can be used for several purposes. The energy needed to accelerate a muon to near the speed of light is much less than the energy needed for a hadron accelerator to accelerate protons. This is because muons are about 10% of the mass of a proton (and about a third of the mass of a quark).

In 2009, a paper in Nature[77] showed that scientists using Muons moving through a form of water known as "spin ice" proved that magnetic fields have similar flow properties to electrical fields. Magnetricity, as this is known, is expected to have enormous implications for future developments in nanotechnology.

Most muons that do reach Earth's surface will decay from within meters to kilometers inside Earth's crust or in the oceans or seabed. Muons are extraordinarily penetrative compared to other sub-atomic particles with substantial mass (compared to a neutrino). This property has been explored in a number of scientific papers with respect to tomography of heavy metals, the internal mapping of pyramids, the prediction of eruptions at specific volcanos and the prediction of earthquakes.

Muon tomography is currently at the frontier of the detection of the transportation of fissionable material and the examination of spent nuclear fuel rods. The former being clearly of high importance given the threat of nuclear terrorism because of the amount of fissionable material stored in relatively unsafe places. Also, the need for better detection methodology arises because a small number of countries with apparent terrorist linkages at high levels of government/armed

[76] http://dahuang.dhxy.info/ClimateChange/j.1468-4004.2007.48118.x.pdf

[77] Steven Bramwell & Sean Giblin, Making the paper. 'Magnetricity' sees monopoles flowing in a magnetic field., Nature, October 2009

forces are producing or are about to produce quantities of fissionable material without the usual international nuclear safeguards in place[78].

Muons gradually lose energy as they pass by other matter. Since energy cannot be created or destroyed except during nuclear processes the energy loss by muons becomes an energy gain by matter that it passes. The process normally involves the muon providing a gift of energy to an electron as it passes. This increase in energy level moves the electron to a higher energy-level orbital or knocks it off the atom entirely. For some elements this may make the atom less stable. When passing through Earth's crust muons that have directly impacted atomic nuclei are also credited with changes to radio-nuclide forms.

As a rough approximation, an average of 1 muon passes through each square centimeter of Earth's surface each minute. This seems almost negligible when compared to neutrinos but that still corresponds to some 10,000 per square meter per minute or more than 14 million per square meter per day. The probability of a muon reaching earth's surface depends on where it has been generated and the energy of the proton at impact. The table below[79] indicates the probability of a muon reaching Earth's surface that has been formed at various heights and within the range speeds observed by undergraduate scientists in experiments at the Massachusetts Institute of Technology in 2007[80]. These tend to be mid latitude probabilities. At high latitudes the troposphere is not as thick and hence muons will tend to form at relatively low heights.

	Probability of Muons Hitting Surface of Earth					
Muon SpeedxC	0.998	0.994	0.998	0.994	0.998	0.994
Distance in metres	10000	10000	5000	5000	2500	2500
Time dilation	15.819	9.142	15.819	9.142	15.819	9.142
Half lives to travel	1.35E+00	2.35E+00	6.77E-01	1.18E+00	3.38E-01	5.88E-01
Probability	39.1%	19.6%	62.6%	44.3%	79.1%	66.5%

These calculations show that muons are significantly more likely to impact Earth the higher their speed and the less distance that they have to travel after formation. Consequently if cosmic ray density was constant then the higher the altitude of an earthbound object the more it will be impacted by muons. Consequently the higher a volcano (for example) the more impact muons would have on its caldera also because the troposphere is much thinner near the poles the closer volcanos are to the poles the more impact muons will have. Also the closer to Earth's surface muons are generated the further they will penetrate Earth's crust. This is because muons lose energy proportionate to the density of matter travelled through and the distance travelled. There are a number of scientific papers that indicate lower atmospheric creation of muons during storms and cyclones. There are also papers that indicate higher muon density at Earth's surface in winter compare to summer and higher densities in temperate regions closer to Earth's poles than closer to the equator. Therefore scientists have shown that muon density at Earth's surface is inversely correlated to temperature and air pressure and positively correlated to latitude (North or South).

One obvious question to come from this analysis is: does the density of cosmic radiation entering Earth's atmosphere vary significantly? The answer to this is in three parts. On a very long timescale cosmic radiation varies enormously and there are a number of scientific papers that link past major ice-ages and ultra-warm periods with the changes in cosmic ray density as the solar system travels through the spiral arm of the Milky Way galaxy[81] in which it is located. The major ice ages tend to appear when the solar system is at the outer reaches of the spiral arm of the galaxy. This is because the majority of star formation is occurring at the edge of the galaxy and hence there

---

[78] http://www.wired.com/wiredscience/tag/muon-tomography/

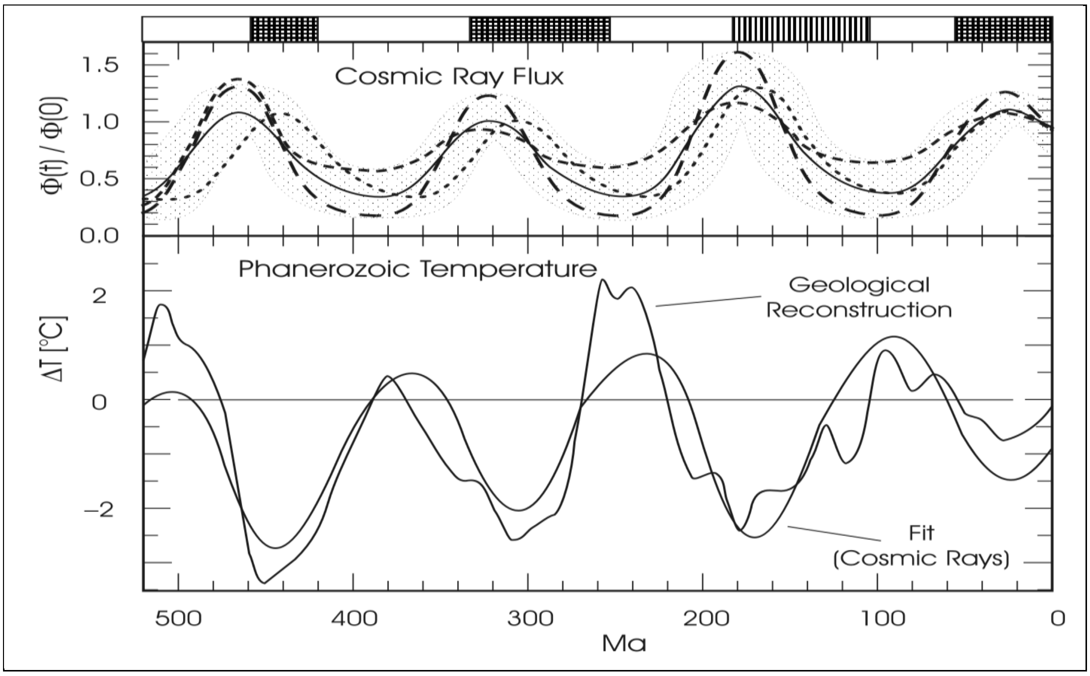
[79] Refer http://hyperphysics.phy-astr.gsu.edu/hbase/relativ/muon.html

[80] Lulu Liu , MIT Undergraduate: The Speed and Lifetime of Cosmic Ray Muons. 18/11/ 2007

[81] Allen Simmons & Doug L. Hoffman, The Resilient Earth: Cosmic Rays, Science, Global Warming and the Fate of Humanity: Amazon

is a higher density of cosmic rays. Apparently the solar system is close to the center of the galaxy at present so it is unlikely that Earth is returning to a major ice-age anytime soon.

On medium timescales of thousands of years the level of cosmic ray density varies inversely to the strength of the Sun's magnetosphere. A number of scientific papers discuss this[82][83]. There do not appear to be any papers that directly correlate the level of density of cosmic ray flux with medium term climatic events but there are many papers that show the correlation of the density of radio carbon 14 production and seemingly cooler climatic conditions. The graph below is taken from – Ján Veizer's paper.



On a timescale of thousands of years the changes in the density of cosmic ray flux is inversely correlated to changes in temperature on Earth. The next graph is of the last two thousand years and is taken from the same paper. A principle argument of some scientists is that the little ice ages that have occurred in the last thousand years were northern hemisphere specific and hence not representative of global changes. This graph shows temperature changes in both the Antarctic (for 2000 years) and Greenland (from around 1500) and indicates that these ice-age periods affected both hemispheres.

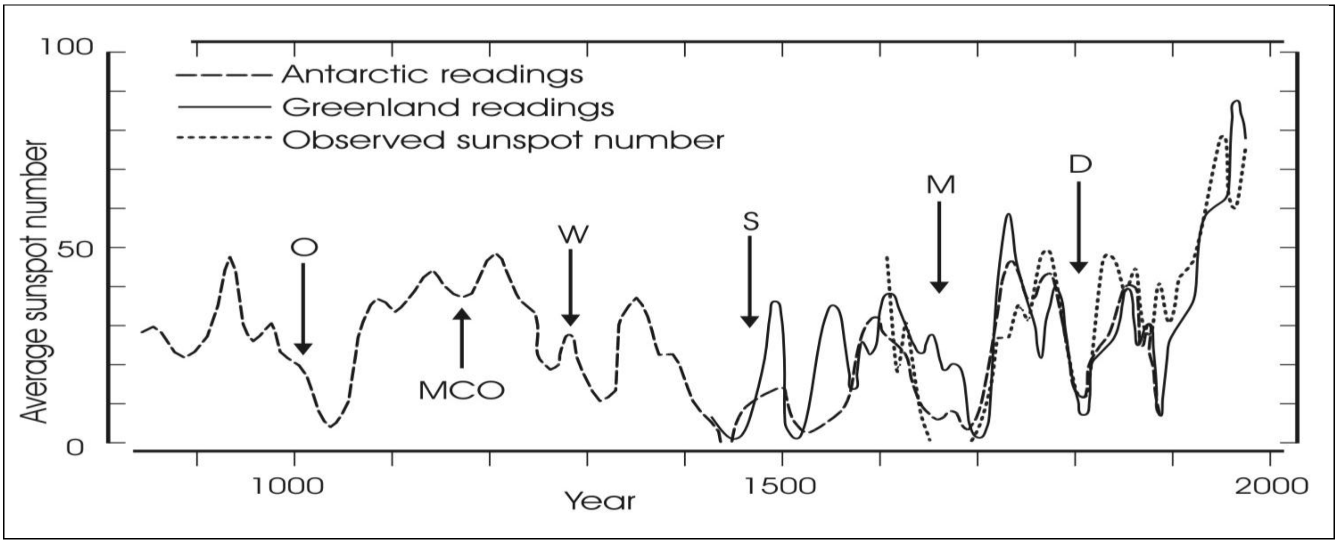
The various solar grand minimums are O – Ort, W – Wolf, S – Spoorer, M – Maunder and D – Dalton. MCO indicates the Medieval Climate Optimum.

The observed sunspot numbers are not fully adjusted for technology improvements which include modern day sunspot specks that could never have been seen by telescopic equipment in the 17th or 18th Centuries. The temperature changes have been calculated from proxy measurements of changes in the levels of ^{18}O radio-nuclide in the ice cores (^{16}O is normal). See also Roy Spencer's paper[84].

[82] Nir J. Shaviv, Racah Institute of Physics, Hebrew University of Jerusalem, Jerusalem, Ján Veizer, Institut für Geologie, Mineralogie und Geophysik, Ruhr Universität, Bochum, Germany, and Ottawa-Carleton Geoscience Centre, University of Ottawa; Celestial driver of Phanerozoic climate?, July 2003.

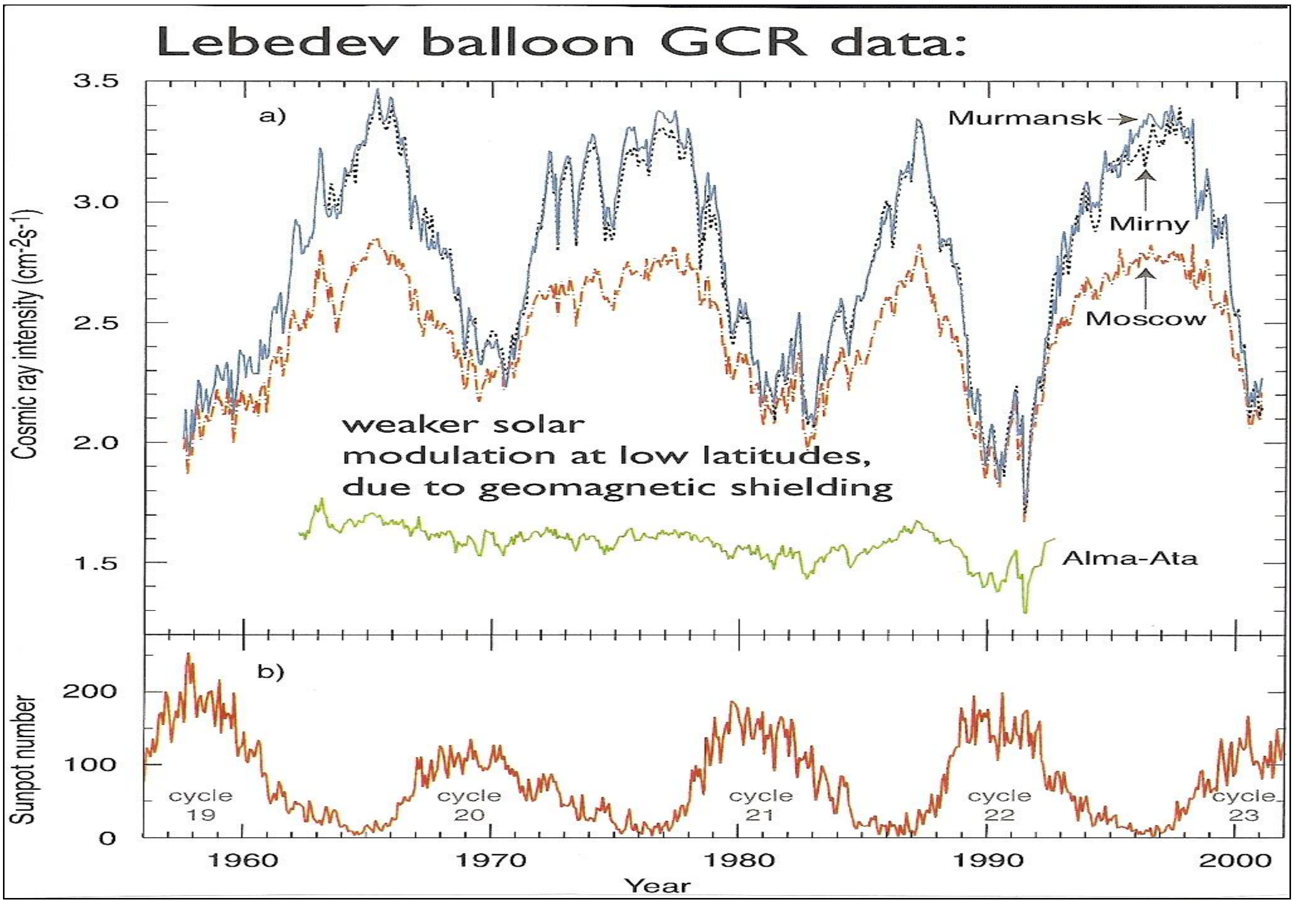
[83] Ján Veizer Ottawa-Carleton Geoscience Centre, Universityof Ottawa, Ottawa, K1N 6N5 Canada & Institut für Geologie, Mineralogie und Geophysik, Ruhr-Universität Bochum, Bochum, Germany, Celestial Climate Driver: A Perspective from Four Billion Years of the Carbon Cycle – March 2005

[84] Roy W. Spencer, Ph. D - May 19th, 2011: Indirect Solar Forcing of Climate by Galactic Cosmic Rays: An Observational Estimate



During the Medieval Climate Optimum the Greenland temperatures would have been higher than they are now because the Vikings were farming part of it then. Greenland is not nearly warm enough to be farmed at present.

For the last 50 years we have accurate data of galactic cosmic ray intensities. The graph below is taken from Jasper Kirkby's presentation to a colloquium at CERN in June 2009[85]. It shows graphs of galactic cosmic ray intensity and sunspot numbers for 50 years to 2002. It shows stronger GCR intensity during weak sunspot activity and that during these periods of low sunspot activity the GCR intensity is greater at higher latitudes.



[85] Ref: http://indico.cern.ch/getFile.py/access?resId=0&materialId=slides&confId=52576

There are a number of scientific papers that link low periods of sunspot activity with increased seismic activity and particularly during solar grand minimums[86][87]. One paper by a multi-disciplinary team of Japanese scientists drawn from Riken Advanced Science Institute, the Institute of Cosmic Ray Research (University of Tokyo), The Japan Atomic Energy Agency and the Riken Computational Science Research Program[88] showed how muons can affect the calderas of certain volcanos and how increased densities of muons can cause explosive eruptions. They do this by changing the chemical composition of matter within silica rich magma, particularly when it is cool, so that aerosols are formed, which eventually lead to increased pressure within the magma chamber and hence explosive eruptions. Presumably a steady state is reached with normal muon penetration of the caldera but with significantly more than usual muons and perhaps when they have higher energies than normal then disequilibrium occurs. If this occurs in active volcanoes then presumably it also occurs in extinct volcanos.

Perhaps higher muon densities during solar grand minimums can weaken some caldera enough to enable the release of pressures in earthquake fault lines produced when the volcano was active. This might be the reason why the Christchurch earthquakes are occurring at this time. (Christchurch is located next to volcanoes on Banks Peninsular that were last active around 8 million years ago and apparently has complex volcanic geology beneath the shingle fan on which it is located). By the end of January 2012 Christchurch had experienced over 10,100 earthquakes in just over 17 months. The Christchurch earthquakes were also relatively shallow. The February 22nd 2011 earthquake that killed 186 people was only about 4 kilometers below the surface. These earthquakes were caused by movement of existing crustal fault lines presumably formed when the volcanoes were active. These fault lines also radiate from the main Alpine fault line where both the Pacific and Indo-Australian tectonic plates are thrusting up the Southern Alps and this is contributing factor.

The current increased muon activity might also help to explain the swarm of more than 10,000 earthquakes in a few months in 2011 on the German/ Czech Republic border, also at the site of an extinct volcano. This follows 8,000 earthquakes some three years earlier, also occurring within a few months.

There is also well established science that shows how cosmic rays can seriously damage DNA. If DNA damage cannot be repaired by the cell, the cell could die. If the damage is copied into more cells, then a mutation could occur. The exposure to large amounts of cosmic rays does increase the risks for cancer, cataracts and neurological disorders. So long term exposure to cosmic rays, or short intense bursts, could even affect the evolution of life on Earth[89]. It is for these reasons extra-ordinary measures are taken to protect astronauts particularly as coronial mass ejections have many high energy particles and atomic nuclei that exhibit properties similar to high energy cosmic rays.

In conclusion muons, which are a by-product of galactic cosmic rays appear to increase cloud formation and volcanic seismic activity during periods of when the Sun's magnetic field is less than normal. The effect of increased muon density will be greater at higher latitudes than nearer the equator so one should particularly expect increased cloudiness and volcanic activity in the Northern Hemisphere in the countries of Iceland, Japan, the Kamchatka Peninsula (Russia) and Alaska. In the Southern Hemisphere there would be more clouds and higher activity in the countries of New Zealand, Chile, Argentina and the Antarctic continent. But this is not to suggest that silica rich volcanoes anywhere in the world will not have an increased risk of eruption during lengthy periods of decreased solar magnetic field strength.

---

[86] Correlation of Solar Activity Minimums and Large Magnitude Geophysical Events: John L. Casey, Space and Science Research Center, March 2010

[87] Ivanka Charvatova, Institut of Geophysics of AS CR, Bočni II, 141 31 Praha 4, Czech Republic: Long-term relations between the solar inertial motion (SIM) and solar, geomagnetic, volcanic activities and climate

[88] ToshikazuEbiska, Hiroko Miyahara, Tatsuhiko Sato, Yasuhiro Ishimine: Explosive volcanic eruptions triggered by cosmic rays: Volcano as a bubble chamber- – Godwana Research, November 2010

[89] http://www.nasa.gov/mission_pages/ibex/IBEXDidYouKnow.html

Increased muon densities may also contribute to earthquake swarms on or adjacent to sites of both active and “extinct” volcanoes.

High energy protons and electrons have the capacity to alter genetic code and so increase the risks of cancer, cataracts and neurological deficiencies.

So there are a number of additional risks to mankind and his property from the enhanced cosmic ray activity that occurs during a solar grand minimum.