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Actuaries Institute

The New Grand Minimum

New Skills have been developed by actuaries if they are to understand the changes in risks that are occurring in the new solar grand minimum.

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Brent Walker - May 2013

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Introduction

The intention of this paper is to update the information presented in the "Extra-Terrestrial Influences on Nature's Risks" paper and explain how the decreased levels of sunspot activity that have already commenced will affect long-term weather risks as well as long-term earthquake and volcanic risks. Further, because of the effect on volcanic risks, there are feedbacks, which also increase the risks of weather extremes. This paper, and the earlier Extra-terrestrial Influences on Nature's Risk paper, should encourage the actuarial profession to develop skills in space weather forecasting and understand the risk management activities that stem from such abilities. For example, this paper will help actuaries understand why, at certain times, when solar flares that hit Earth, they have the ability to temporarily significantly change climatic conditions, earthquake and volcanic risks. Understanding just these mechanisms should convince the profession to develop important real-time risk management tools and capabilities that can be applied in many areas of our expertise as well as in new areas where actuaries so far do not have a role. But there are many more space-age data sets and that we should understand and use. Failure to recognise these opportunities will be detrimental to the profession as others, much less trained in risk assessment and risk management, will take the initiative.

It is not the intention of this paper to argue whether the International Panel on Climate Change is right or wrong. The intention of this paper is to show how natural forces (in particular the current prolonged low sunspot activity of the sun) affect a number of risks that should interest actuaries. These include human mortality, natural events such as major earthquakes and volcanic eruptions, direct weather related risks, in particular, from weather extremes. There are a second category of risks that are important. These include risks relating to food and energy security, the political risks arising from unaffordable increases in the price of these commodities, crop insurance and other forms of insurance that are affected by climatic extremes. There is also the risk that if our profession does not recognise the risk implications of these changes in the sun our reputation could be significantly impaired.

New Solar Grand Minimum

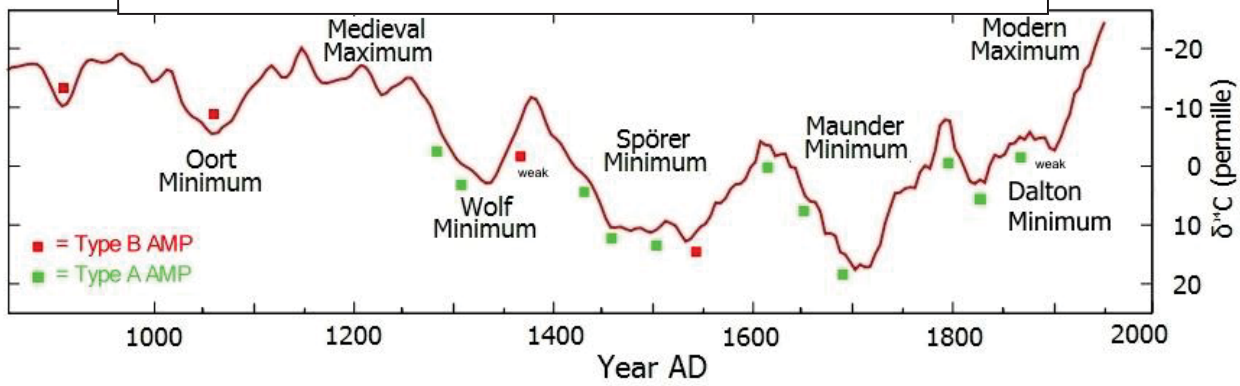
The new solar grand minimum, which commenced early this century, has been named by the astrophysics community. They have called it the "Eddy Minimum" after John A Eddy (1931-2009). John is the American astronomer who named the Maunder and Spörer Solar Grand Minimums in a landmark paper published in the Science Journal in 1976. John also headed up the NASA "Living with a Star" program. The name has not yet become official. Many scientists believe it should be named the "Landscheidt Minimum" after Theodore Landscheidt because, in 1981, he was the first to predict that this minimum would occur.

History of Solar Activity over Last Millennium

During the Maunder and Spörer Minimum periods of low solar sunspot activity there was also an increase in the ratio of radio-carbon 14 (^{14}C) to ^{12}C in tree rings and there were documented changes in the aurora borealis. Each of these periods were known for the sometimes bitterly cold and prolonged winters in the Northern Hemisphere. The Maunder Minimum occurred during most of the 17th Century and the first decade or so of the 18th Century. The Spörer Minimum occurred in the last 4 decades of the 15th Century and for the first half of the 16th Century. A later period of relatively low sunspot activity commenced in the last two decades of the 18th Century and lasted for the first three decades of the 19th Century. This period is known as the Dalton Minimum. The three grand minima were collectively called the "Little Ice-Age" although that term is sometimes used to describe each of the separate periods.

Radio-carbon 14 is produced when a high energy proton hits a nitrogen atom and beryllium 10 can be produced when it hits either oxygen or nitrogen. Only some protons that have originated from outside the solar system can have the energy to produce these radio-nuclides. These arrive in greater numbers during deep solar minimums due to the reduced strength of the solar magnetic field[1]. The analysis of ^{14}C concentrations in tree rings and ^{10}BE in ice cores suggest that during the 2nd millennium AD there were two other periods of high levels of ^{14}C and ^{10}Be. These are known as the Wolf Minimum in the last decades of the 13th Century and the first half of the 14th Century and the Oort Minimum in the 11th Century. Northern Hemisphere history shows that sometimes there were excessively cold prolonged winters during these two periods. However, these appear to have been weaker grand minimums than the Maunder Minimum. In total there have been 5 grand minima in the 2nd millennia AD. They commenced roughly every 200 years.

Chart 1 - Solar Activity Events from $^{14}C/^{12}C$ Ratio



The chart 1[2] shows $^{14}C/^{12}C$ deposit ratios (the RHS axis is reversed) along with the grand minimum periods and indications when there were significant perturbations of the sun caused by the gravitational pull of the planets. (AMP means angular momentum perturbation at the surface of the sun). These occur specifically when Uranus and Neptune are more or less in alignment with Jupiter and Saturn with the strongest events apparently occurring when Saturn is on the opposite side of the sun to the other 3 and they all become in close alignment on the same plane. The steep line towards the modern maximum is due to increases in ^{12}C caused by the burning of fossil fuels in the 20th C and therefore caused the ratio to decrease. It should not be confused with perceived increase in average global temperatures. A similar graph can be produced from examination of ^{10}Be.

According to these analyses of ^{14}C deposits there were also two periods of relatively low formation of this compound in Earth's atmosphere during the second millennium AD. The first of these periods were for most of the 12th Century and the first 7 or 8 decades of the 13th Century. The second occurred during the second half of the 19th Century and virtually all of the 20th Century. The first period was known as the Medieval Maximum because it appears to have been a relatively warm

[1] Walker B W Extra-terrestrial Influences on Nature's risks. Refer to Section 8.
[2] http://www.landscheidt.info/images/newc141.jpg

period in Western Europe, which suggests that the then higher sunspot activity translated into warmer temperatures – at least in Europe.

A type A AMP perturbation has more effect than type B. But note that the use of angular momentum mechanics is only approximately expressing the effects of gravity on the torque and rotation of the plasma in the equatorial region of the sun. It is the unevenness of the rotation and torque of the plasma around the sun at various latitudes that appears to be primarily responsible for its magnetic storms that we call sunspots.

The last grand minimum – the Dalton Minimum – commenced in the late 18th Century so, logically if these are occurring roughly every 200 years, it would seem that the next grand minimum should have already commenced or will very soon.

International Panel on Climate Change View

According to models used by the International Panel on Climate Change, the second, most recent, period of higher sunspot activity was not the primary cause of an increase in temperature. On this latest occasion most of the increase in global temperatures was caused by mankind. More specifically it was mankind's industrialisation and its concomitant requirement for energy that caused higher emissions of the greenhouse gas carbon dioxide. These higher levels of this atmospheric gas then caused the observed increase in global temperatures. More likely is that there were a number of factors that caused the 20th Century global warming. However more responsibility should be given to the sun.

Use of Predictive Models

The computer models that are currently being relied upon to forecast climate change have so far proved fairly unreliable. On the other hand the NASA ephemeris models, that are used by some solar and astrophysicists to predict changes in the sun due to gravitational forces of other bodies in the solar system, are extremely reliable in predicting exactly where all relatively large extra-terrestrial bodies in our solar system will be located at any point in time in the past, present and future. Without these models NASA and other space agencies would not have had the successes in interplanetary exploration and satellite positioning that they have had to date[3].

There are many disparate forces that intertwine in ways to make each grand minimum different. Russian scientist Dr Habibullo Abdussamatov, of the St Petersburg Pulkovo Astronomical Observatory and head of the Russian/Ukrainian section of the International Space Station uses different models that predict that this new grand minimum will be as severe as the Maunder Minimum. But many astro-physicists and solar physicists who have used the NASA ephemeris model predict it will be more like the preceding Dalton Minimum. If the latter are correct, given that there has been some global warming for about 150 years, the climate changes that will occur will not be too extreme - unless there are some really large volcanic eruptions that drag global temperature

[3] 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.

down rapidly[4]. But if Dr Abdussamatov is correct then this grand minimum will cause many economic and political changes and some may be very unpleasant.

The Little Ice-Age Climate Paradox

NASA now believes that a grand minimum is likely. NASA reports that not only do these occur to our sun but they occur in other stars and also suggested that stars could be in this phase about 10% to 30% of the time[5]. NASA is now able to predict sunspot activity of the following cycle from magnetic activity of the sun hundreds of thousands of kilometres below its surface. At this stage NASA believes this deep activity is so weak that there may be very few sunspots in the next solar cycle (cycle 25). *"Indeed, the sun could be on the threshold of a mini-Maunder event right now. Ongoing Solar Cycle 24 is the weakest in more than 50 years. Moreover, there is (controversial) evidence of a long-term weakening trend in the magnetic field strength of sunspots. Matt Penn and William Livingston of the National Solar Observatory predict that by the time Solar Cycle 25 arrives, magnetic fields on the sun will be so weak that few if any sunspots will be formed. Independent lines of research involving helioseismology and surface polar fields tend to support their conclusion"*[6].

The term "Little Ice-age" is a misnomer as icy conditions did not occur all over the Northern Hemisphere during every winter month during the periods when solar sunspot activity was very weak. Paradoxically, often it was very strong solar flares or the long term effects of stratospheric volcanic eruptions that caused these conditions to occur. Ice-age type conditions certainly didn't occur over much of the Southern Hemisphere during their winters although it is likely winters were relatively cold in some countries.

Table 1 indicates why there are differences in climate effects between the hemispheres. Oceans, lakes etc. make up 61% of the surface area of the northern hemisphere and 81% of the surface area of the southern hemisphere. Water is a heat sink and it generally takes about four times as much heat energy as land to increase the surface by the same unit of temperature (for the same area). On the other hand the conversion of ice to water at 0° C takes approximately 80 times the heat energy that is required to heat water by 1 degree (or ice by 2 degrees). To get water from 0 degrees to 100° C and converted to steam takes 8 times as much heat energy as it takes to melt ice.

Table 1 - Oceans are heat sinks			
Earth's Water	**Ratio of Land Surface at latitude**		
97.5% in oceans		North	South
2.05% Ice (90% in Antarctica)	30°	2	1
61% of surace of Northern Hemisphere	40°	10	1
81% Surface of Southern Hemisphere	50°	28	1
	60°	61% land	0% land
In terms of heat required to raise water temperature by 1°			
Increase Ice temperature by 1°			0.5
Melt Ice at 0°			80
Heat from 0° to 100° and turn to vapour			640

Other statistics to be considered are that 97.25% of Earth's water is in the oceans with just 2.05% being locked up as ice and nearly 90% of the planet's ice is located on Antarctica. So the combined

[4] Walker B W – Extra-terrestrial Influences on Nature's risks. Sections 5 & 8 discuss how the incidence of great earthquakes and volcanic eruptions is changed by extra-terrestrial influences.
[5,6] Solar Variability and Terrestrial Climate, NASA Science News, Jan 8, 2013

effect of 90% of Earth's ice being on Antarctica and 81% of the southern hemisphere's surface area being covered in water means changes in heat energy from the sun (or other sources) must have much less effect in the southern hemisphere than in the northern hemisphere. But even this comparison between hemispheres can be misleading. There are even more important land mass differences between the northern and southern hemispheres at the latitudes where there are most civilisations. The northern hemisphere has more than 2 times the land mass of the southern hemisphere at the 30 degrees latitude, more than 10 times at 40 degrees and around 28 times the land mass of the southern hemisphere at 50 degrees. At 60 degrees there is no land in the southern hemisphere but about 61% of the northern hemisphere is covered by land[7].

Because of the differences between hemispheres it doesn't make sense to compare any climate change in Europe, North America, Northern Asia and the Mediterranean countries with any climate change that might be occurring in Australia, New Zealand, South Africa and South America. Even to talk about climate change in a global context within a timeframe of a few years is misleading as the leads and lags in the climatic effects of small temperature changes vary enormously from region to region. These lags, for example, might be very short in a landlocked region like Switzerland to decades on an island like Tonga in the middle of the Pacific Ocean.

Food Security a Concern

In December 2012 senior economist Abdolreza Abbassian of the United Nations Food and Agricultural Organisation expressed ongoing concern about the continuing downward trend in the level of world grain stores[8]. He said that the outlook for 2013 was uncertain due to a large drawdown in stocks in 2012, and that much would depend on the weather situation ensuring better crop production levels in 2013. "The lower the stocks, that means any unexpected development creates more variability in the prices than would otherwise." The considerable delays in the commencement of the 2013 Northern Hemisphere cropping season must be causing additional concern in the UN FAO. If the crop planting delays become normal during this grand minimum and the extreme weather conditions continue then food security issues will become high priority for many countries. Already at least one country (India) is already rapidly increasing grain stocks. The UN FAO Food Outlook[9] publication should be read by actuaries whose clients would be affected by the political repercussions of international food shortages.

There would be severe repercussions if there was a substantial volcanic eruption into the stratosphere since this would lead to massive crop failures over a wide area of the globe for possibly several growing season.

[7] G.A. McBean, M. Hantel, Interactions between global climate subsystems, Geophysical Monograph No 75 (1993).

[8] Reuters – December 6, 2012. Also FAO Food Outlook Report November 2012

[9] Refer http://www.fao.org/index_en.htm for publications of the FAO.

Summary

The sun's sunspot activity during a grand minimum, paradoxically, plays a significant role in producing extreme "ice-age" type cold weather events in the Northern Hemisphere while at the same time causing arctic regions to become warmer. This activity also can cause conditions that increase the short term risks of major, even great earthquakes and volcanic eruptions.

There will be increased risks for the insurance industry during the Eddy Minimum. These are:

1. The increased incidence of violent storms will lead to higher property claims and increased crop insurance claims.
2. The colder and sometimes very much colder Northern Hemisphere winters will lead to higher business costs from lost production.
3. Longer winters, increased droughts and stalled monsoons will cause significant crop losses.
4. The continuing high incidence of great earthquakes causing sometimes catastrophic property and business losses which will be increased, particularly if they are followed by large tsunamis.
5. Higher mortality rates result from extreme weather, droughts, failed monsoons and seismic events. (For example, it was estimated that there were 6000 excess deaths from the March 2013 cold weather in the UK.)

The secondary effects of these also have risk consequences. These result from political instability caused by:

1. High food inflation due to failed crops and reductions in grain stores.
2. High energy price inflation due to the lack of enough energy supplies in some locations during periods of excessively cold conditions.
3. Population concerns about the future leading to political unrest.
4. Major business disruptions due to extreme weather or major seismic events.

This paper identifies why the Actuarial Profession should be using space weather and other space age tools to identify changes in a number of short-term and long-term risks.

Variations in the Sun's Emissions

Solar Cycles

The sun's emissions are not constant. Its emissions are modulated by its planets due to the interacting gravitational effects and also by internal mechanisms. These appear as cycles. First, there is the approximate 11 year Schwabe cycle, which normally seems to be tied to the conjunctions of Saturn, Jupiter, Earth and Venus (Jupiter's orbit is 11.86 years). Second the Hale cycle which occurs every second conjunction. (This cycle occurs because of the reversal of the sun's magnetic poles around each mid cycle so it takes two cycles to return the sun to the same state of polarity). Third, there is an approximate 30 year cycle due to the period of Saturn's orbit (29.45 years), a 60 year cycle (double that period) and one around every 150 - 200 years, when the 4 gas giants get into alignment with the sun. (The orbit of Uranus is 84.02 years and Neptune 164.79 years)[10,11]. A further cycle relates to the period of time that it takes for all the planets to return to the exact same positions in their orbits and relative to each other. This cycle is around 2,400 years. There are other cycles.

The Schwabe cycle can vary between about 9 years and up to about 14 years. During the Maunder Minimum, according to paleo-climate carbon 14 analyses, there appeared to be two consecutive cycles that lasted around 14 years[12]. This is an example of how one solar cycle can be disturbed by other cycles. Even within a Schwabe cycle there can be a much shorter cycle. For the last 18 months there has been an approximate 27 day cycle that consists of a burst of sunspot activity for around a week followed by a quieter period for the following 3 weeks. This seems to correspond to the sun's approximate period of rotation at its equator which is 25.6 days while at the poles 33.5 days. (Note that as the Earth is orbiting the sun it takes about 27 days for a place on the sun to again directly face Earth.) This cycle suggests that the sun's current sunspot activity is currently rather unevenly distributed.

Differences in Solar Emission Spectrum

Table 2 is from NASA's Sun/Climate report and shows the variation of fractions of the solar emission spectrum. The total solar irradiance (TSI) varies little but there is some debate over how much. It appears to vary with amplitude of around 0.3% on a day by day basis and this is mainly sunspot activity based. On a year by year basis, which is important for the climate on Earth, the variation is about

Table 2 Source	Total Energy (Watts/m^2)	Solar Cycle Change (Watts/m^2)	Solar Cycle Change %	Level of Deposition in the Earth's Atmosphere
Solar Radiation				
Total Irradiance	1366	1.3	0.10%	Throughout
Visible and Near Infra-red				
300-1200 nm	1090	1.1	0.10%	Surface and Troposhere
Near Untraviolet				
200-300 nm	15.4	0.16	1.00%	10-50 km
Xray and UV				
0-200 nm	0.1	0.02	20.00%	50-500 km
Energetic particles				
Protons	0.002			30-90 km
Galactic Cosmic Rays	0.000007			0-90 km
Solar wind	0.0003			500+ km

[10] Scafetta N., Empirical evidence for a celestial origin of the climate oscillations and its implications. Journal of Atmospheric and Solar Terrestrial Physics. 2010

[11] Wilson I.G., Do Periodic Peaks in the Planetary Tidal Forces Acting Upon the Sun Influence the Sunspot Cycle? The General Science Journal, 2012

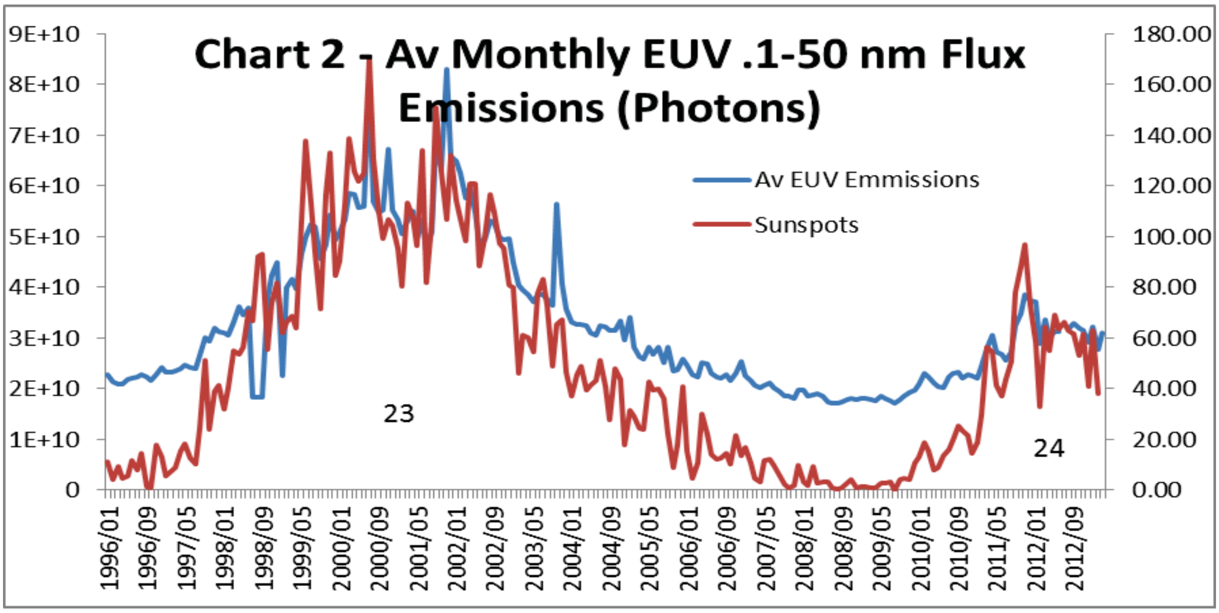
[12] Miyahara H. Solar Activity and Climate, Kavli Frontiers of Science, University of Tokyo. 2012

0.1%. So over a long period of time this 0.1% would translate to an increase in average temperature on Earth of about 0.05° C[13]. These calculations are based on data retrieved by satellite since 1978. The remaining spectra of solar radiation is infra-red. By subtraction it is 260 W/m2. Its solar cycle variation will also be about 0.10% with a low cycle variation of between 1 and 1.3 W/m2. Its distribution is mainly at the surface.

Others disagree with the very low variability of TSI. Dr Abdussamatov suggests that there is an approximate 200 year cycle in TSI that peaked in the early 1990s and will trend down for about 100 years with the average temperature dropping about 0.5%. The lags in warming/cooling due to the ocean heat sinks mean that global cooling will be noticed within a year or so[14]. But all seem to agree that there are amplification factors at work. These may include forcing caused by anthropogenic carbon dioxide and factors that amplify the heating effect of the sun's radiation.

Looking at just the TSI is like looking at the mean of a distribution of non-homogenous data. For example ultraviolet light can be split into 5 spectra (see table 3). But note that Far UV consists of part of the UVC spectrum. According to NASA the variability of Extreme UV is greatest at about a factor of 10. Like the sun's magnetic field this varies from minute to minute. The highest rate of Extreme UV emissions usually only occur for short periods and probably have little effect on Earth's atmosphere. However the average differences from month to month are important particularly when these emissions are amplified or reduced for a whole solar cycle. Chart 2 is of monthly average data taken from daily average data compiled by the Space Sciences Centre of the University of California to March 2013. It shows the relationship

Table 3	**Spectrum split of Ultra Violet Light**	
Ultra Violet Light	Spectrum	Energy/Photon
UVA	400-315 nm	3.1-3.94 eV
UVB	315-280 nm	3.94-4.43 eV
UVC	280-100 nm	4.43-12.4 eV
Far UV	200-122 nm	6.2-10.16 eV
Extreme UV	121-10 nm	10.25-124 eV



[13] Eddy J.A. The Sun-Climate Connection, NASA, The Sun Climate Report. 2003

[14] Abdussamatov, H. Bicentennial Decrease of the Total Solar Irradiance Leads to Unbalanced Thermal Budget of the Earth and the Little Ice Age, Applied Physics Research Vol. 4 No 1, 2012

between EUV emissions and sunspot activity. This indicates that even the monthly average EUV data varies by around a factor of 4. So far, for solar cycle 24, the average EUV emissions are just 60.9% of those for solar cycle 23 for same number of cycle months.

Solar cycle 23 (June 1996 - December 2010) was also considerably weaker in average EUV emissions than Solar cycle 22 (Sept 1986 – May 1996). Although these EUV records only go back to when the Solar and Heliospheric Observatory was launched in December 1995 it is possible to estimate the variation in EUV average from F10.7 cm flux data, which has been continuously collected since February 1947[15]. In the past F10.7 cm flux was often used as a proxy for EUV. But for the same period the average variation in F10.7 cm flux appears to understate the variation of EUV by around 24%. From adjusting this proxy data it appears that the EUV average output of solar cycle 23 was 34% less than the average output of EUV than solar cycle 22. So, in comparison to solar cycle 22, EUV emissions in solar cycle 24 appear to have been reduced by around 60%. In other words, at his stage of solar cycle 24, the sun has only produced around 40% of EUV emissions of solar cycle 22. By contrast the reduction of UVB emissions has been estimated by a number of scientists to be only about 10%.

Solar Emissions and the Atmosphere

One would think that the relative reduction in EUV emissions compared to UVB emissions might have a significant effect on the atmosphere and therefore, in time, the climate. But nature also provides feedbacks, which ameliorate the climate effect. Understanding how nature provides these feedbacks helps one understand the many complexities of climate science and why it is unwise to rely upon one forcing mechanism without full understanding of possible, even apparently unrelated feedback mechanisms. NASA indicates this complexity in its recent Sun-Climate report:
"Understanding the sun-climate connection requires a breadth of expertise in fields such as plasma physics, solar activity, atmospheric chemistry and fluid dynamics, energetic particle physics, and even terrestrial history. No single researcher has the full range of knowledge required to solve the problem."

Figure 1 on the following page is a copy of the graph that was included in Extra-terrestrial Influences on Nature's Risks. It shows how in "normal" conditions the upper troposphere (10 km above sea level in mid-latitudes) has a temperature of about -50° C, the stratosphere (from 10 km to 50 km above sea level) gradually warms to about 0° and the mesosphere (50 km to about 88km above sea level) gradually cools to about -100° C. The thermosphere (88km to 500 km above sea level) then warms to about 450-500° C. In February 2011, a representative of NASA reported to a space weather conference that the deep minimum between cycles 23 and 24 had collapsed the thermosphere and the exosphere above it by about 225 km. The temperature of the ionosphere had reduced by 100° below normal[16]. This collapse was mainly caused by the low output of EUV during the previous few years.

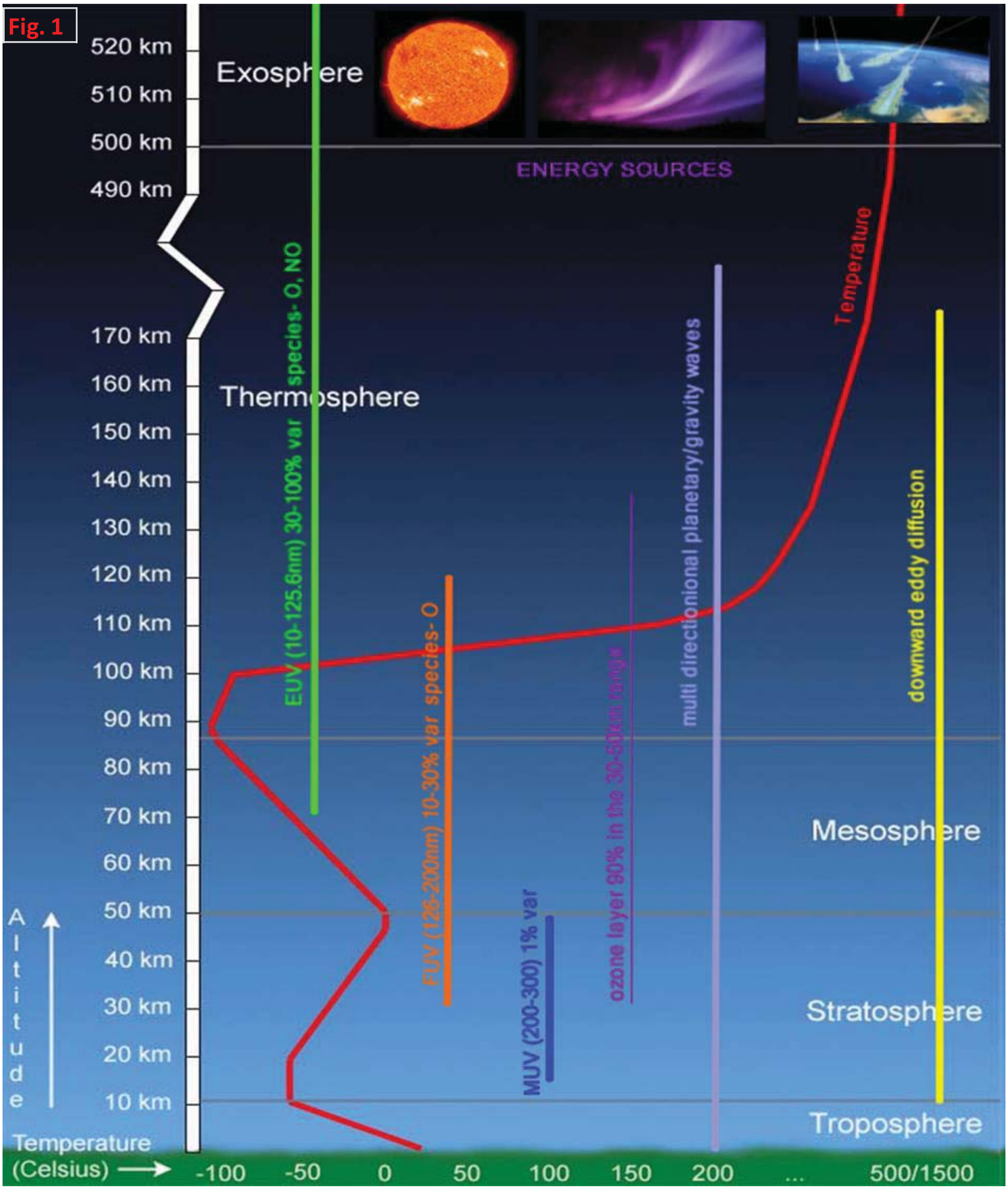
Table 4 - Approximate Relative Mass of Atmosphere		
Troposphere		76%
Stratosphere		19.9%
Mesosphere		<4%
Thermosphere		<0.1%
Exosphere		<0.001%

[15] Data available at http://www.usc.edu/dept/space_science/semdatafolder/semdownload.htm

[16] Walker B.W. Extra-terrestrial Influences on Nature's Risks, IAA Congress Hong Kong 2012 (p17)

Table 4 indicates the approximate relative mass of each layer of the atmosphere. It shows that the upper layers contain miniscule percentages of the total atmospheric mass.

The exosphere and the ionosphere are influenced by particulate (hydrogen and helium atoms and ions) emissions from the sun via the solar wind. The thermosphere mainly consists of ions (of oxygen and nitrogen) which are created by EUV photon emissions. EUV and FUV emissions also reach the



lower levels of the atmosphere if they don't collide with non-ionised molecules in the thermosphere. The temperature and chemical composition of mesosphere, stratosphere and the upper troposphere are therefore affected by EUV and FUV photon emissions from the sun. In this denser atmosphere the collision between a photon of sufficient energy (short enough wavelength) with oxygen and nitrogen will create ions that will then combine with other molecules of air. Ozone (O3) is one result.

Others include nitrogen oxides (NO and NO2). The lower part of the mesosphere and the stratosphere plus the very upper part of the troposphere is where ozone is formed and destroyed in complex ionising processes that include the interaction with nitrogen oxides and, near the poles in spring, chlorine. However this doesn't explain why the mesosphere gets colder with height. This is due to yet another process influenced by the sun that counters the effect of the relative changes in EUV and UVB.

The atmosphere is quite fluid where the processes that form and decompose ozone occur. This means there is movement between the troposphere, stratosphere and mesosphere but much less above that because the atmosphere in the thermosphere and above has very low density. In practice the troposphere varies in thickness from about 16-18 km above sea level at the equator and 6 km above sea level at the poles during winter. So at the South Pole in winter the stratosphere is only about 3 km above the ice.

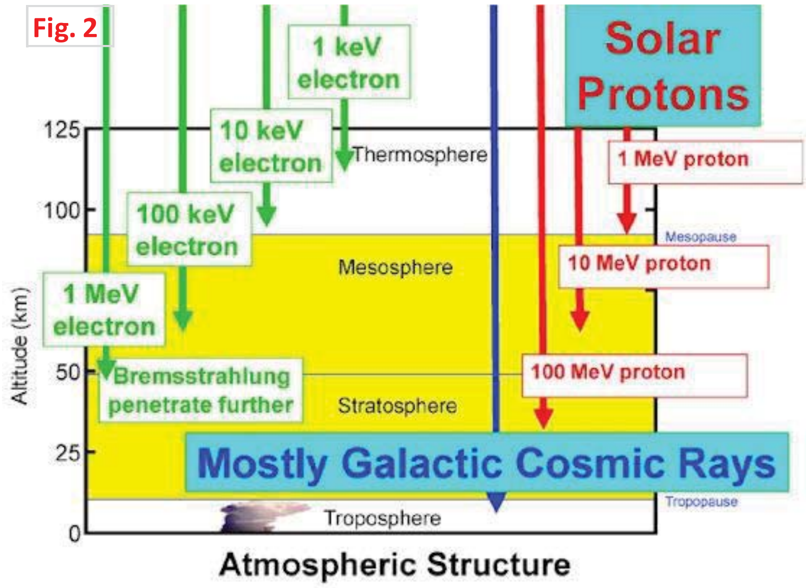
Polar stratosphere temperatures can also vary considerably. For example near the South Pole in winter the temperature of the lower stratosphere can get well below -100° C. Atmospheric chlorine is then created from various aerosol compounds of chlorine including CFC's and some emissions from volcanoes, catalysing with carbon dioxide in the form of dry-ice clouds. For carbon dioxide ice clouds to form the temperature has to be below -83° C. In spring these recently created chlorine molecules ionise with photons with a wavelength below 110 nm. Then in turn the chlorine ions react directly with ozone and destroy it. (Hence holes in the ozone layer form near the South Pole in spring but not in winter when there is no sun). Ozone holes had not been observed in the Northern Hemisphere spring until the last few years. This is because in recent years the winter temperatures have become colder in the stratosphere near the North Pole (but not all the time at the North Pole).

Only photons with a wavelength of less than 241 nm have sufficient energy to break the O=O bond of an O_2 molecule. This is in the UVC range. Not all Far UV and Extreme UV emissions are absorbed by ionising processes in the ionosphere, exosphere and thermosphere. Some therefore reach the mesosphere and stratosphere. Those that do ionise oxygen molecules (and others) in these layers of the atmosphere don't reach the troposphere or ground. In chemistry the ionising process is $O_2 + hv = O + O$. (hv is the proton). There is also an immediate further reaction $O + O_2 + M = O_3 + M^*$ Where M is another body (usually O_2 or N_2) that carries away the heat generated by this reaction. That is M becomes hotter as a result of the ionisation. In practice the chemistry is much more complicated than this as oxides of nitrogen are also produced in these reactions. (N_2 ionises with photons below a wavelength of 85 nm.)

Ozone is also destroyed by photons with a wavelength less than 320 nm, so much of the UVA range and all of the UVB range of photons can destroy ozone. The O_3 molecule that is hit by these photons splits into $O_2 + O$, the subsequent combining of two oxygen ions then form another O_2 molecule. Heat is produced by these reactions and this is the other main reason why the stratosphere warms with height and the mesosphere cools with height. The ozone layer is densest at approximately the intersection of these two layers.

In the mesosphere and upper stratosphere there is a second process initiated by the sun that can make and destroy ozone. The solar wind brings charged particles (mainly electrons, protons or hydrogen ions and helium ions) to Earth and these help form the ionosphere and exosphere (See Figure 2). Heavier particles, mainly protons, get deflected by Earth's magnetic field. Some penetrate through to the thermosphere and react with any nitrogen there and even continue on to the mesosphere – even possibly the stratosphere with very few making it all the way to ground level. The heavier particles, mainly protons, also tend to get deflected towards the poles as they do not have anywhere near the energy of protons of galactic cosmic rays which are not affected by Earth's relatively weak magnetic field. When these protons hit nitrogen, oxygen and water molecules they produce nitrogen oxides and HO molecules. These can lead to both the production and destruction of ozone. Heat is a by-product of some of these processes. Occasionally a coronial mass ejection will deliver a many hundreds of tons of protons into the thermosphere via a magnetic portal. It seems that a magnetic field line of Earth and of the sun join together while the main body of the CME is being deflected away from Earth. It is possible that this occurs more frequently when the average magnetic field strength of the sun is low.

Fig. 2



To get an idea of the relative energy levels of these protons a proton with the energy of 10 MeV has approximately the energy of 1 million photons at around the beginning of the EUV range. However there are trillions more photons passing through Earth's atmosphere than protons although protons have probably a million times better chance of hitting something. (Note that there aren't any photons passing through the atmosphere at the poles during winter.)

Sun Forces Climate Change

The dynamic equilibrium and the heat of the air in the ozone layer are affected by long term relative changes in the photon emissions of the sun across the UV spectrum and the proton and electron emissions that arrive via the solar wind. With relatively low emissions of EUV compared to UVA and UVB less ozone is formed and the temperature of the stratosphere and upper troposphere reduces. The temperature increases in this part of the atmosphere when the sun emits more UV in the shorter wavelengths or if the layers of the atmosphere above the mesosphere were depleted thus allowing more solar protons to destroy ozone. This is one of the complicated methods by which the sun can force climate change. This dynamic equilibrium in the ozone layer can also be disturbed by volcanic eruptions. The frequency and magnitude of volcanic eruptions is also changed by the sun and the planetary influences on the sun[17]. Very large coronial mass ejections (CME's), also known as solar proton events (SPE's), that hit Earth have been observed by satellite to rapidly deplete the upper layers of the ozone layer particularly close to the poles (these produce auroras). It appears that, paradoxically, even if the incidence of SPE's is lower during periods when the sun is less active, there impact is magnified if the magnetic field of the sun is also weak at the time they reach Earth.

[17] Walker B.W. Extra-terrestrial Influences on Nature's Risks, IAA Congress Hong Kong 2012 (sections 5 & 8)

The sun's "top down" effect on climate due to its relatively variable output of UV spectrum photons initially will show up in regional variations. The January 2013 NASA release stated: Isaac Held of NOAA took this one step further. He described how loss of ozone in the stratosphere could alter the dynamics of the atmosphere below it. "*The cooling of the polar stratosphere associated with loss of ozone increases the horizontal temperature gradient near the tropopause*,". And "*This alters the flux of angular momentum by mid-latitude eddies. [Angular momentum is important because] the angular momentum budget of the troposphere controls the surface westerlies*. *In other words, solar activity felt in the upper atmosphere can, through a complicated series of influences, push surface storm tracks off course*." This is important because he is saying that the jet streams are altered due to temperature changes in the polar stratosphere and it is these altered jet streams that affect the tracks of storms and, by implication, other weather systems.

NASA has also indicated that carbon dioxide and nitrogen oxide in the thermosphere act as a reflector of infra-red radiation[18]. Apparently, some X class solar flares on March 8-10, 2012, caused the thermosphere to absorb some 26 Billion kilowatts of energy. This was enough to have powered New York for two years. But a relatively new satellite indicated that within 2 days 95% of this energy had been re-radiated back into space by CO_2 and NO. This is interesting because given that the thermosphere contains less than .01% of the atmosphere it is likely that there wouldn't be enough of these molecules to do this. This is because the thermosphere, if it were to be compressed to the same pressure as the troposphere at ground level, would form a layer of just a few centimetres thick (some scientists estimate it to be just one centimetre thick). Carbon dioxide would make up probably less than 0.04% of that layer and nitrogen oxide something of the same order so between the two of them one would think that there just wouldn't be enough to re-radiate 95% of the extra energy back into space. So assuming NASA is correct, then carbon dioxide and nitrogen oxide in the mesosphere, stratosphere and possibly even in the top of the troposphere would be involved in the re-radiation of the additional energy pumped into Earth's atmosphere by this X Class flare.

How exactly the molecules of CO_2 and NO did this was not explained by NASA. The majority of this energy would have arrived in the form of very fast electrons which would have further ionised the upper parts of the atmosphere. Presumably as these ions converted back to CO_2 and NO which because they were then so hot they radiated their energy into space in the form of infra-red spectrum photons.

This has implications for the theory as to how carbon dioxide radiates infra-red radiation. It suggests that it radiates, at least in the stratosphere and above infra-red radiation in all directions – hence the claimed 95% into space. So extra carbon dioxide in the atmosphere, at least in the stratosphere and below, must also radiate in all directions the infra-red photons it has absorbed as heat from Earth. This is different from one theory as to how CO_2 forces climate change but it helps to explain why global cooling occurs after major stratospheric volcanic eruptions. This is because these eruptions spew vast quantities of sulphur dioxide, carbon dioxide (and other chemicals) into the stratosphere and these in turn capture more heat from the sun (and Earth) and re-radiate a large portion of it back into outer space.

[18] NASA, Science News "Solar Storm Dumps Gigawatts into Earth's Upper Atmosphere, 22 March 2012

Magnetic Portals between Sun and Earth

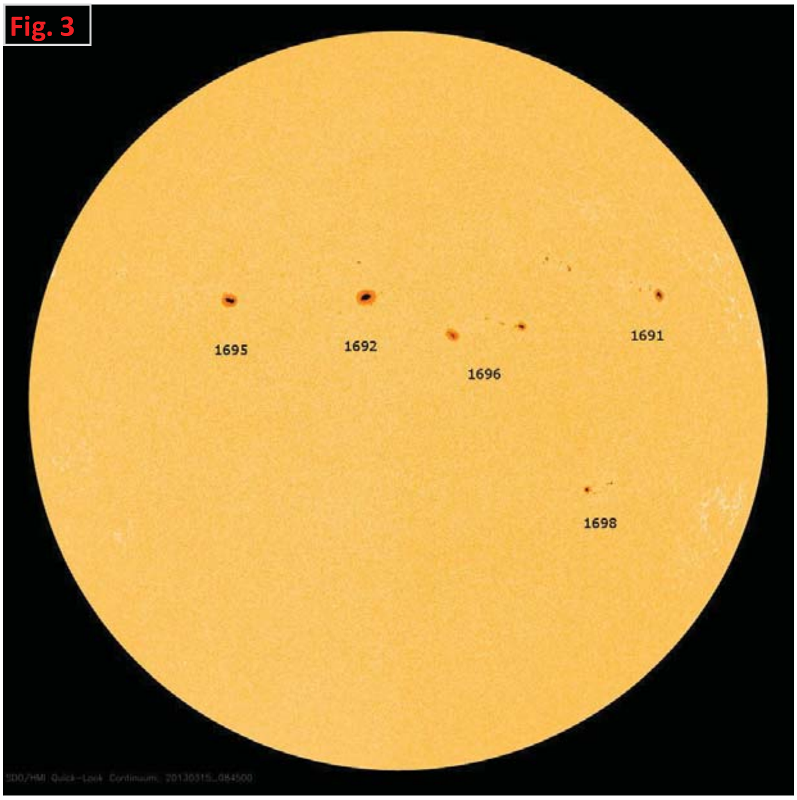
In October 2008 the discovery of sun/Earth magnetic portals was reported by NASA scientists at an international assembly of space physicists at the 2008 Plasma Workshop in Huntsville, Alabama. These portals provide the mechanism for the transfers of tons of energetic plasma from the Sun into Earth's ionosphere when these portals are open. Intriguingly, NASA reported that these "flux transfer events" were then occurring 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. This produces the Van Ellen radiation belts.

Jet Streams, Polar Vortices and Coronal Mass Ejections

Jet streams circulate the globe from west to east in usually a meandering wavy path. These waves are called Rossby waves. They are caused by the sidereal rotation of the planet being faster than the atmosphere and both vertical and horizontal differences in temperature between large air masses. In each hemisphere there are normally two jet streams. The polar jet stream is formed close to the poles. It is located around 7 kilometres high and is caused by the extreme differences between the polar temperature and the temperature in the mid-latitudes. The equatorial jet stream is normally much closer to the equator. It is located perhaps 12 to 14 kilometres high and is caused by the temperature differences between the mid-latitudes and equatorial region. In the summer time the jet streams are usually located closer to the poles than in the winter time. Jet streams are both influenced and influence local weather conditions. They are also influenced by the sun and by changes in local sea-level temperatures. Normally the atmospheric pressure where there are jet streams is between 1/5th and 1/3rd of the atmospheric pressure at ground level.

What changes have been observed in the jet streams over the last 15 years? This is not an easy question to answer as the jet streams are always changing. Until a few years ago there were many IPCC papers that referred to the gradual progression of the jet streams towards the poles. Based on these trends there were predictions of, for example, increasing droughts in South Eastern Australia and winters without snow in the UK. But this century the trends in the movement of the jet streams have reversed and, not only have they migrated closer to the equatorial regions, they seem to have become more "loopy" and erratic. In other words the Rossby waves that were gentle swells in the atmospheric ocean have become more storm tossed even to the point that they can sometimes travel more

Fig. 3



in a north/south or south/north direction than in a west/east direction and, on occasion, even travel for a short distance in an east/west direction . The progression of the Rossby waves around the planet seems to have slowed and, at times, even stalled. When they are travelling in a more north/south (or south/north) direction the side of the side of jet stream that is closest to the pole (or would be if it were travelling more west/east tends to drag the cooler polar air along with it and the side nearer the equator does the opposite that is drag the warmer moister, more tropical (or desert) air along with it. When a Rossby wave becomes stalled then the weather systems that follow the Rossby waves also become stalled. This causes prolonged hot/cold, dry/wet weather or, what is generally known as, extreme weather. These changes are exaggerated when the stalled Rossby waves are travelling in a more north/south or south/north direction than usual or when the normal progression of the weather is more north/south such as a monsoon.

Examples of extreme weather caused by stalled Rossby waves include the floods in Pakistan and Southern Russian heat wave in July/August 2010, the numerous extreme weather events in the US in 2011 and 2012 including hurricane Sandy in October 2012, the heat wave in Australia in January 2013 and the drought in New Zealand in February, March and April 2013. New Zealand had its "hottest summer ever" in early 2013 because of a south/north then north/south Rossby wave well to the East of NZ caused a blocking high, which lasted for months. The heat wave in Australia in November 2012 to Jan 2013 was caused by a similar south/north Rossby wave which tended to be near or along the East coast of Australia. This stalled high pressure systems in the middle of Australia.

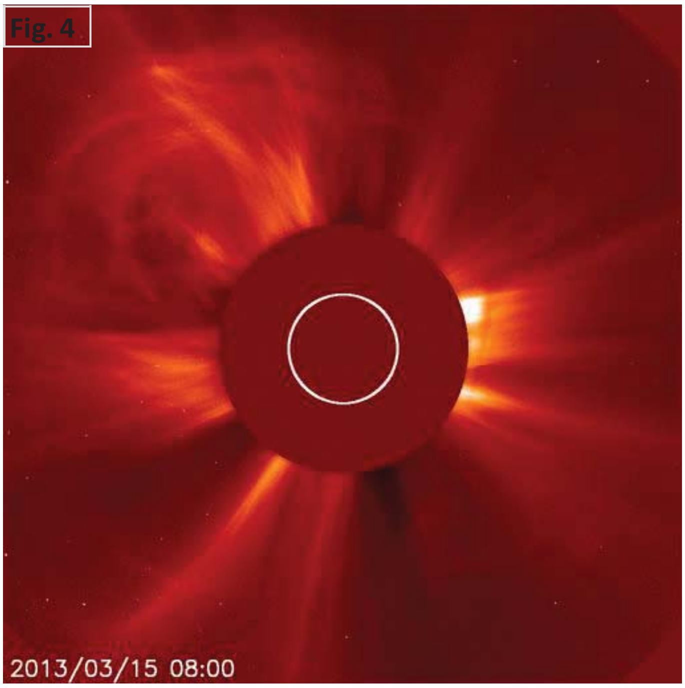


Fig. 4

Sometimes the polar jet stream can be dramatically affected by Solar Proton Events that hit Earth's atmosphere. A good example of this occurred in late March 2013. Figure 3, is a picture of the sun on March 15, 2013 that was provided by NASA. Sunspot No 1692, which had a darkness ratio of 73%, emitted a long duration (36 minutes) M1 type flare which was directly aimed at Earth's northern hemisphere. Although only a relatively small ejection, it still ejected billions of tons of plasma into space at a speed of around 1500 kilometres per second. Some of the solar protons from this ejection began striking Earth's atmosphere on March 17 and produced particularly spectacular auroras in the Northern Hemisphere for the next three nights. This indicates that the majority of the ejected protons were deflected by Earth's

Fig. 5

magnetic field to the North Pole region. Figure 4 is from NASA and shows that ejection and Figure 5 is of the aurora on March 17 at Prudhoe Bay, Alaska.

The very weak magnetic strength of the sun on March 17 (according to the Wilcox Solar Observatory data) enabled the magnetic field lines of the sun and Earth to combine causing tons if not hundreds of tons of plasma to enter the atmosphere and get channelled to the poles. The effect on the poles commenced on the 17th with brilliant auroras. By March 20 the Arctic Oscillation index was very low indicating that the westerly polar vortex had stopped and become easterly. The stratosphere over the North Pole had increased in temperature by some 60° C. A high pressure system then formed over Greenland, which is not unusual in spring, but this one recorded a high of at least 1,074 mb, which apparently was the highest ever recorded over Greenland. (1,083.3 mb is the highest barometric pressure ever recorded anywhere and was over Siberia on December 31, 1968). Therefore the jet streams in the Northern Hemisphere changed appreciably. By the end of March and through much of April very cold weather occurred over large parts of the northern hemisphere.

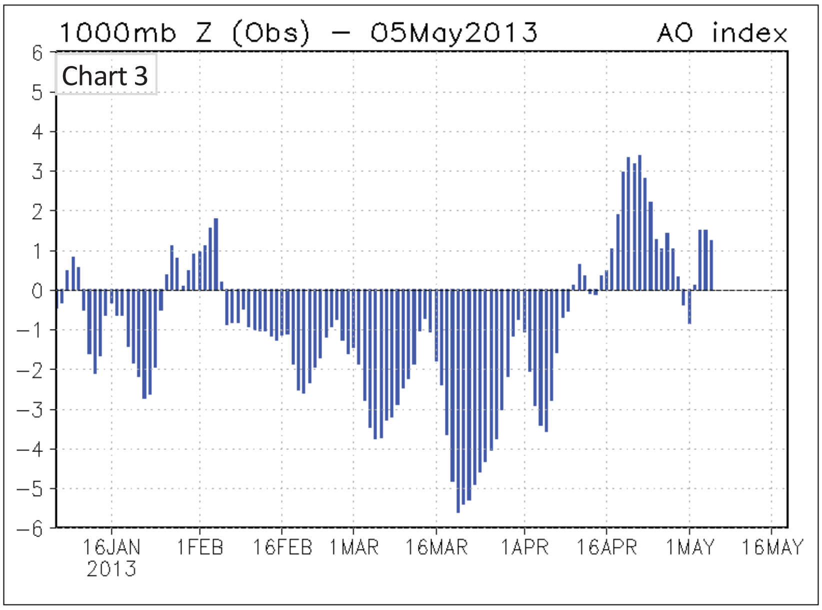
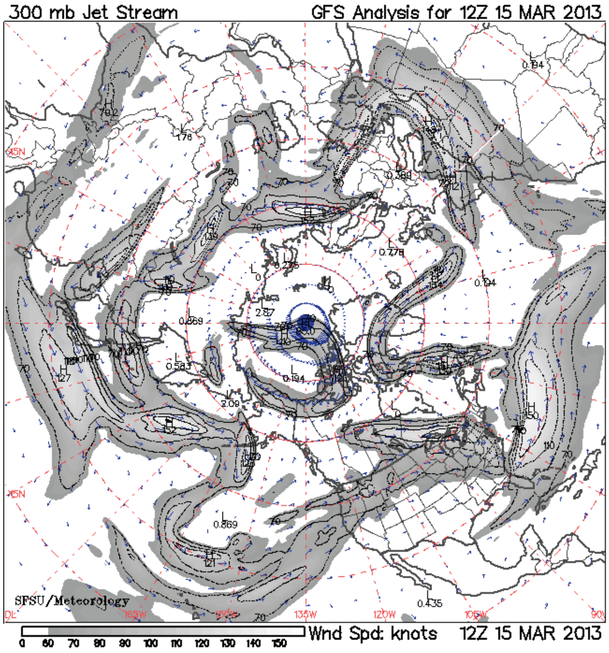


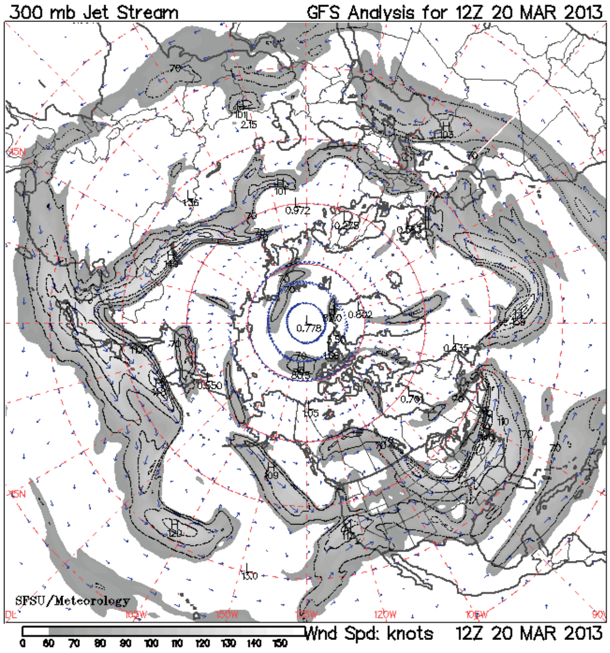
Chart 3 is the daily Arctic Oscillation Index[19] for 2013. On March 20th the daily Arctic Oscillation index was the 16th lowest recorded since 1950. There have been only 4 other occasions when the arctic oscillation has been below -5 for 3 or more days. These were in Feb 1969, March 1970, Dec 2009 and Feb 2010. This means there have been 3 of these occasions in the first half of cycle 24 and the 2 other occasions occurred in the first half of the only other weak cycle since 1950. That was cycle 20.

The next 8 images are of the Northern Hemisphere jet streams[20] on March 15, 2013 and every 5 days thereafter. They are maps of the jet streams at 300 millibars pressure. (At ground level the atmospheric pressure is roughly 1000 millibars). On the March 15, the Northern Hemisphere appeared to have a polar and an equatorial jet stream although they do link up in places. That was still the case on March 20. But by March 25 the polar jet stream has largely disappeared with just a few remnants left and by the 30th there is even less remaining. By the 19th April there still weren't two relatively distinct jet streams. Record breaking (for April) snow was still being reported in some central and western districts of the US but at least there was warmer air being directed onto the UK by a more south/north jet stream that had reformed. There were still freak snow storms in parts of the US in early May 2013.

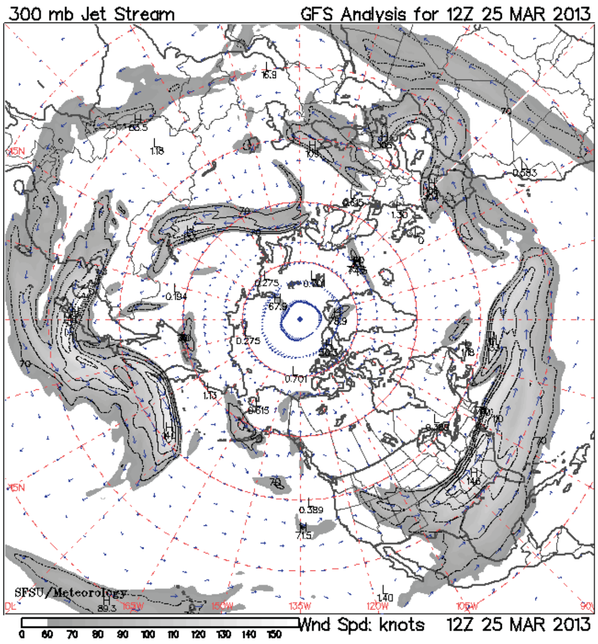
[19] Refer http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/history/method.shtml for methodology.
[20] From the California Regional Weather Server

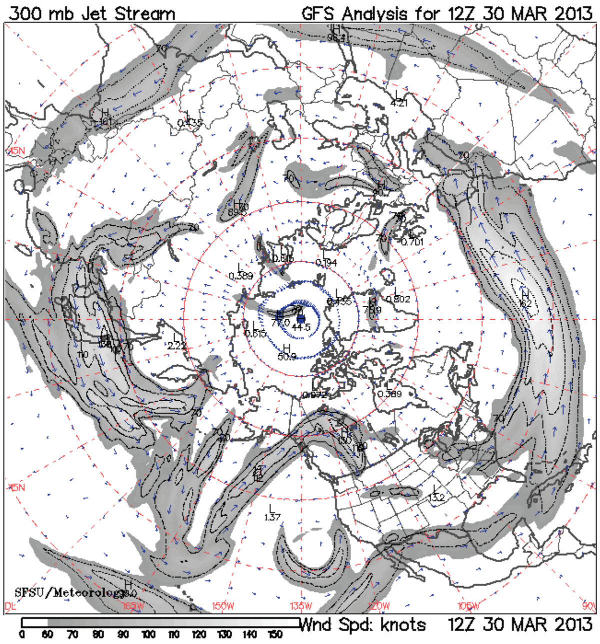
One of the most interesting aspects of this coronal mass ejection event that was directed at Earth





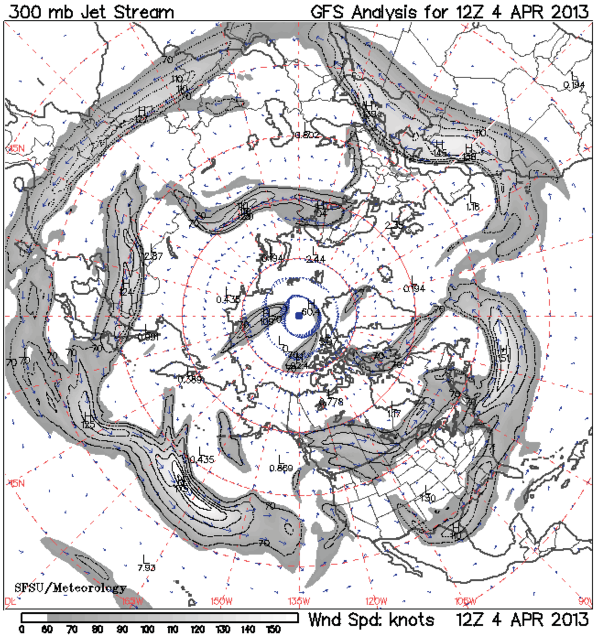
was its timing. Right at the North Pole the sun returns with the Northern Hemisphere spring equinox and remains until the Northern Hemisphere autumn equinox. So from the spring equinox the chlorine molecules that have been created during the winter over the pole begin to ionise when they encounter photons of less than 110 nm. These chlorine ions then, in turn, start to breakdown ozone.

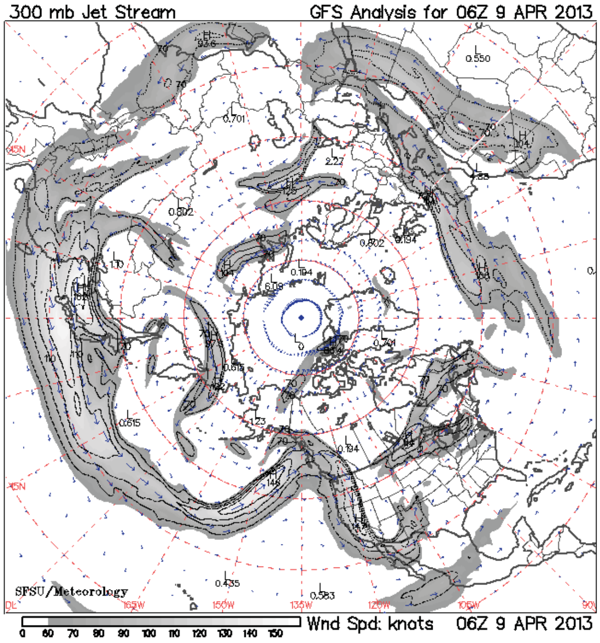




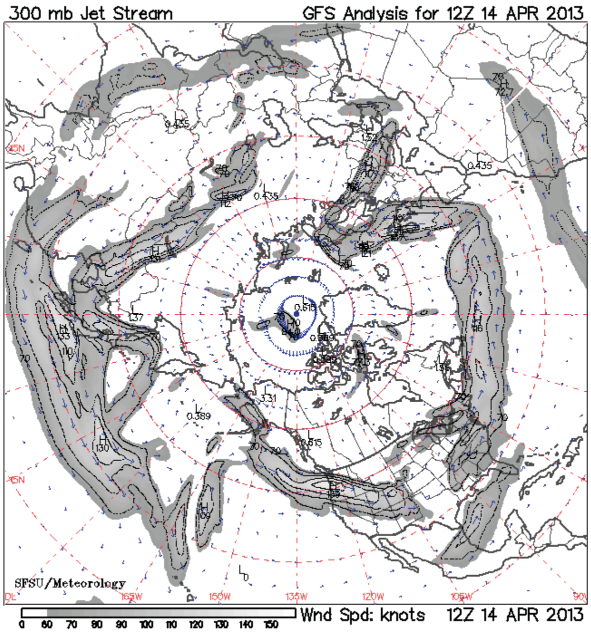
So perhaps the timing of the CME was more important than the strength of it in causing the extremely cold end of March, early April weather. Paradoxically this also caused the North Pole and Greenland to be even warmer than they had been. This is because the warmed upper atmosphere was drawn downwards towards the Pole and this helped to displace colder air, which then moved to lower latitudes.

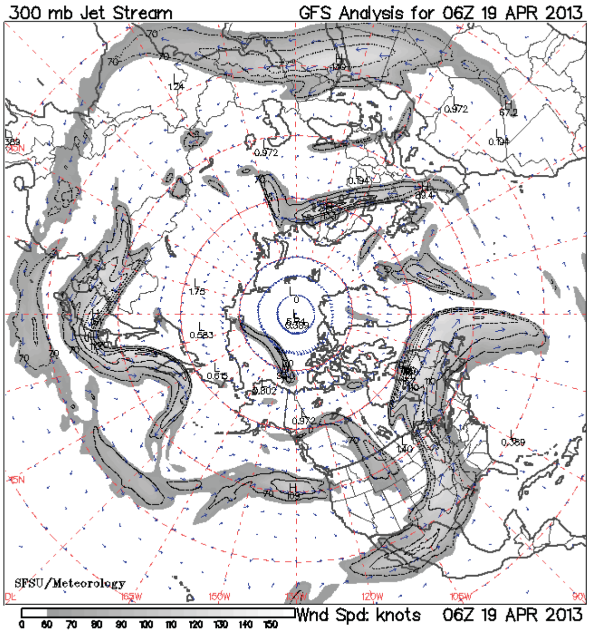
The Antarctic oscillation index did not seem to react significantly to the CME so presumably there





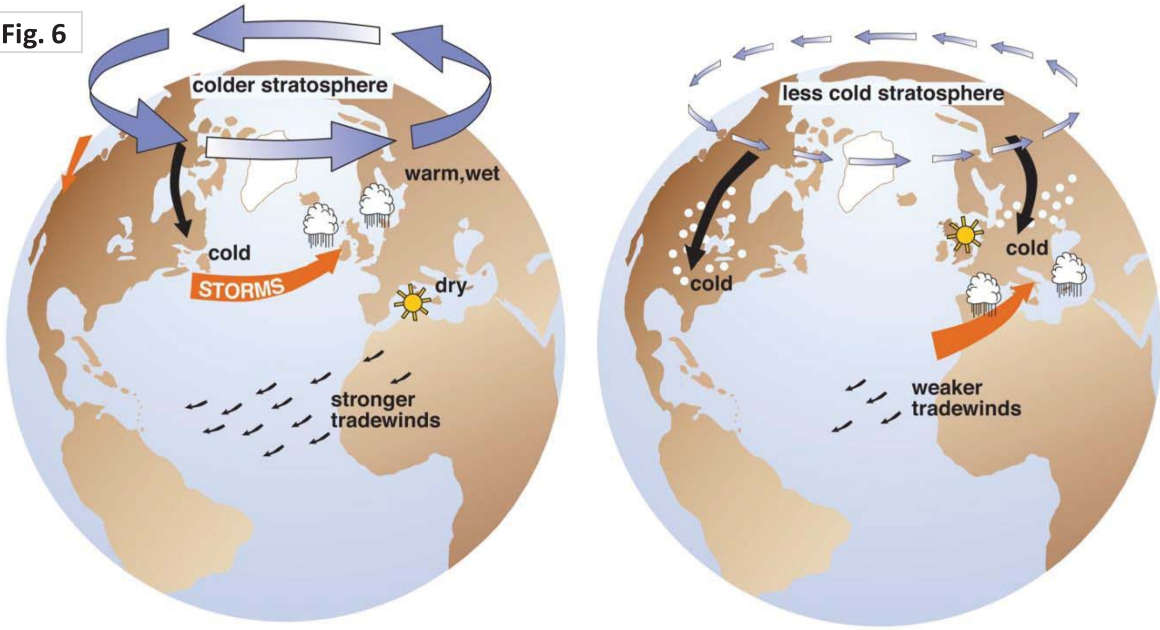
wasn't much leakage of ejected plasma into the Southern Hemisphere. Sunspot 1962 was sufficiently north of the sun's equator to ensure that the ejected plasma would have mainly been directed towards Earth's northern hemisphere.





Another very significant coronal mass ejection occurred on January 22nd, 2012. It was a M8.7 class flare (much stronger than the one on March 15, 2013). The sunspot flared for nearly an hour and the ejected plasma travelled to Earth at a speed approaching 2,250 kilometres per second. The sun's magnetic field strength was also low when ejected plasma hit Earth's atmosphere. The Arctic Oscillation had been positive for all of January until the 20th. By the 22nd it was -2.01 and by 28th it had reached its minimum value of -3.41. The jet streams were also affected and for a time the Northern Hemisphere mainly had one equatorial jet stream. Although a weak polar jet stream formed over Eastern Europe and pushed very cold air down into the region. Then it was Hungary, Romania, the Balkans, Greece and Italy that were affected with freezing weather. The Danube partially iced over for around 2000 km for about two weeks although that bout of cold weather lasted much longer than a month in some places.

Fig. 6



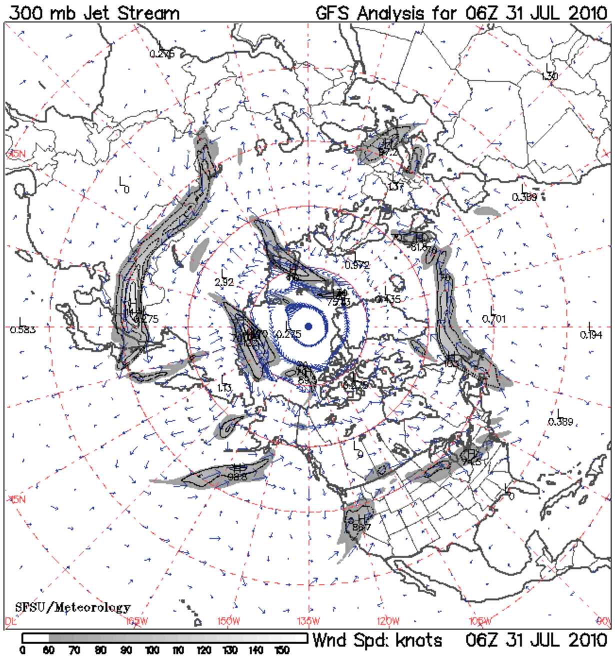
The US National Oceanic and Atmospheric Administration provided figure 6, which is a representation of what occurs when the stratosphere becomes relatively warmer over the North Pole and eventually makes ground level temperatures at the Pole and Greenland warmer (thus eventually reducing sea ice). There are a number of reasons why the stratosphere over the pole would warm up in comparison to the stratosphere at lower latitudes:

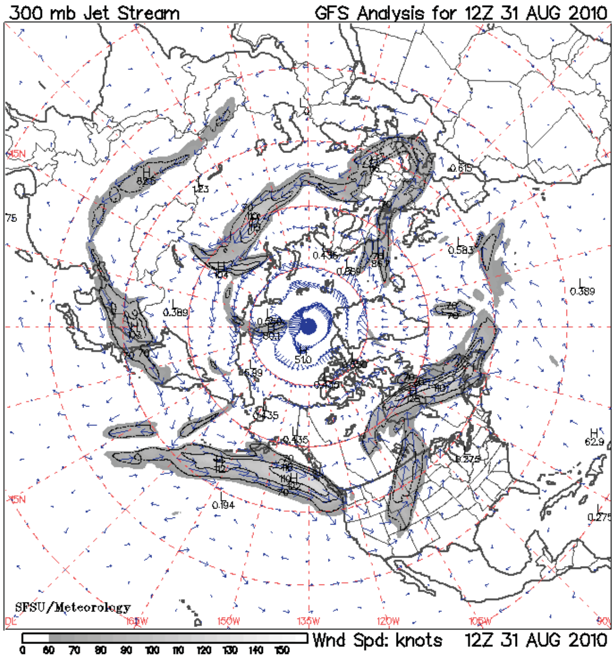
1. The impact of large amount of plasma from a coronal mass ejection.
2. Volcanic eruptions that push large quantities of sulphur dioxide, carbon dioxide, nitrogen oxides and particulate matter into the Stratosphere. At this height these emissions, particularly sulphur dioxide, act as cooling agents, reflecting infra-red photons from the sun back into space. This would increase the relative difference in the temperature in the Stratosphere at the poles and the lower latitudes if the sun produces coronal mass ejections that are aimed at Earth but in any event the particulate matter at the poles would probably precipitate more quickly because of the normal downwards draft at the poles that in turn causes the surface winds to blow away from the poles.
3. High levels of fluorocarbons in the atmosphere that cause free chlorine atoms to form in winter (particularly if the surrounding stratosphere is colder than normal during winter).
4. The impact of a higher than usual number of very high energy protons from beyond the solar system (Cosmic Galactic Rays). Much higher numbers of these penetrate the sun's weakened magnetic field during grand minimums and are responsible for the relatively high incidence of auroras that are reported at these times. Each of these protons can have more than one million times the energy of a proton coming from the sun or 10^{12} times the energy of a EUV photon.
5. Planetary waves that are long atmospheric waves that originate in the troposphere and push up into the stratosphere due to troposphere conditions and ground level terrain.

6. Gravity waves that drag warmer air from the troposphere at lower latitudes to the lower stratosphere closer to the pole. Presumably these may also facilitate the mixing of upper warm stratosphere air with cold lower stratosphere air.

An example of the fifth reason occurred in the second week of January 2013. Several major storms in the northern pacific created a major planetary wave of relatively warm air which travelled through the troposphere into the stratosphere and on up to the pole. Ironically these major storms could have been the result of wind shear caused by higher than normal differences in temperature between sea level and the upper troposphere. This is in turn would have been caused by higher sea-level temperatures (global warming) even though elsewhere there was a colder lower stratosphere caused by the long-term reduction in EUV emissions.

The locked jet stream that caused the Pakistan floods and the southern Russian drought in 2010 is shown on the jet stream maps for July 31 and August 31, 2010, below. The jet stream to the north of





Pakistan stayed basically stationary for a month and stalled the South Asian monsoon. This kept the air to the north dry and, because it was mid-summer, hot.

Other Natural Risks

Extreme changes in the arctic oscillation can have secondary effects on other risks. An example was provided very recently in a Russian warning to its Pacific fleet and to the US. Apparently the extremely high pressure system over Greenland put increased strain on the already severely stressed San Andreas Fault line and also the New Madrid Fault line. This increased strain was signalled by changes in the ionosphere above these fault lines. Russian scientists believed that there was a significant increase in the risk of a great earthquake occurring anywhere along the western seaboard of Canada, the US or Mexico as well as an increase in the risk of another significant earthquake on the New Madrid fault line in Arkansas, Tennessee, etc,. These would be devastating to the US and the former could cause a significant tsunami in the Pacific. The Madrid fault line had a major earthquake in 1811 (in the middle of the last grand minimum). There have been 5 nuclear power stations have been built close to this fault line.

The Antarctic oscillation can also have a climatic effect on the southern hemisphere. Antarctica is surrounded by water and mostly lots of it before there is any land masses with significant populations. When the Antarctic Oscillation turns deeply negative the surrounding ice and oceans act as heat sinks and ameliorate the impact of the frigid cold air flowing northwards.

Weather Extremes and Other Risks during Grand Minima

Dalton Minimum Weather Extremes

The two appendices detail the weather extremes that occurred in England and Australia during the last grand minimum. These have been compiled from weather records that are far from complete, but they do give a general picture of what seems to have occurred in that period. Clearly the weather was extreme in the Northern Hemisphere for some years after major stratospheric volcanic eruptions. This is why the decade of 1810-20 is regarded as the coldest decade in the Northern Hemisphere for several hundred years. The eruption of Mt Pinatubo on June 15, 1991 demonstrated how the planet cools after a major volcanic eruption. But this eruption was small. It erupted less than 10% of the tephra that was ejected by the Mt Tambora's stratospheric volcanic eruption in 1815 and probably around 20% of another major volcanic eruption that occurred in 1809. The location of the volcano that erupted in 1809 is unknown but ice core analysis suggests it was in the tropics.

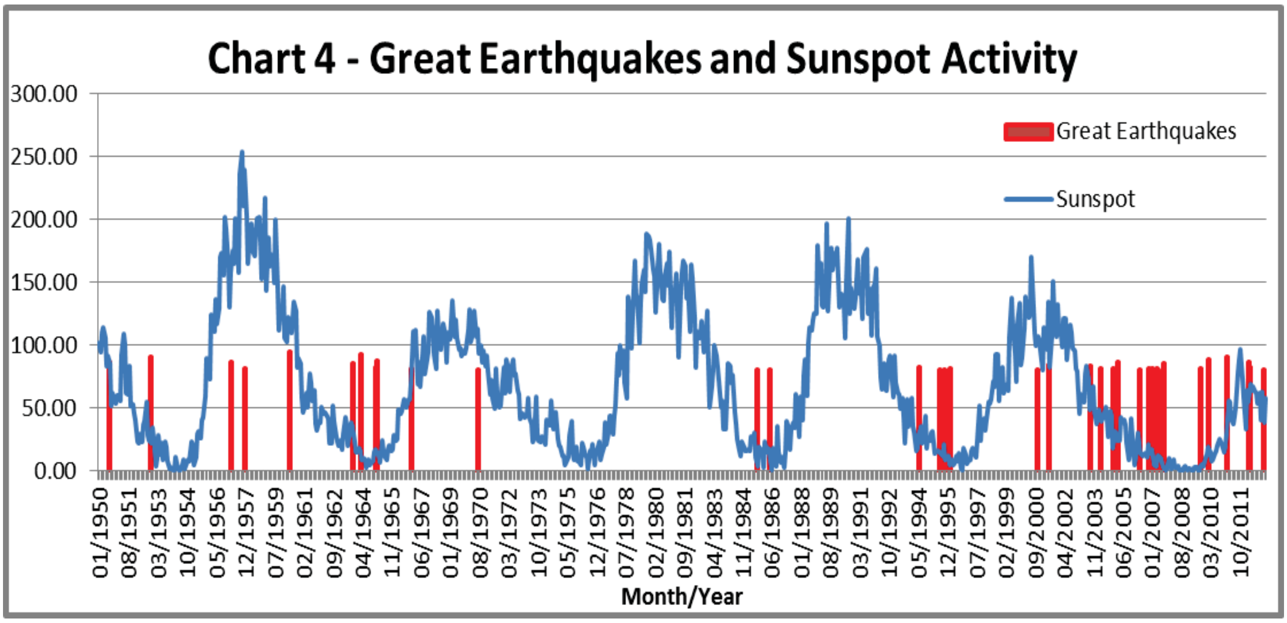
The Laki volcano, in Iceland, erupted on June 8, 1783 and continued erupting for 8 months. It played havoc with the climate in the Northern Hemisphere. Being in Iceland it was well away from the tropics where stratospheric eruptions are said to cause the most damage to the climate. It also only emitted about 10% of the tephra of Tambora but it did emit gas fountains as high as 14,000 metres, which is around 6,000 to 7,000 metres into the stratosphere at that latitude. Hence the Stratosphere would have cooled over much of the Northern Hemisphere and, as it warmed directly over the pole for other reasons, this combination would have reversed the direction of the polar vortex.

Although Australia (Sydney) doesn't appear to have suffered extremes of cold during the Dalton Minimum it does appear to have had many violent storms with large deluges in the Hawkesbury river basin. These resulted in significant flooding along the Hawkesbury River. Sydney and its environs seem to have had many heat waves and significant droughts during this time. Extreme wet weather events seem to have also occurred quite frequently in Sydney. So from what is now known of the weather patterns along eastern Australia, it seems very likely that Queensland, NSW and Eastern Victoria also had an increased frequency of extreme wet weather events during the Dalton Minimum.

The volcanic eruptions that had significant multiple year effects on the winter climate in the Northern Hemisphere apparently did not have the same effect on the winters in the Southern Hemisphere. This, presumably, is because at the higher latitudes most of the Southern Hemisphere is water and the one significant land mass (Antarctica) is virtually completely covered in ice. These heat sinks would have modulated winter climate fluctuations. However it does seem possible that the Mt Tambora eruption increased the incidence of extreme wet weather events in and around Sydney for at least the following five years. This is also the expected result given that the stratosphere would have been cooled by that event. But, as it would have been impossible for the oceans in the Southern Hemisphere to have cooled much, the additional temperature differential between the ocean and the upper troposphere would have created the conditions for the increase in extreme weather.

Great Earthquakes

Chart 4 shows the incidence of great earthquakes (magnitude 8 or more) since 1950, which is when reliable earthquake data began to be compiled. This is plotted against the sunspot activity as provided by the Solar Institute Data Centre. The earthquake data should be very reliable since 1950 because it was around then that the US set up very sensitive measuring devices around the world. It is striking that of the 36 great earthquakes that have been recorded since 1950, 22 have been recorded since 1995 and 16 of them have been recorded since 2004, which is when the significant gravitational perturbation of the sun's plasma commenced. This suggests a six or sevenfold increase in frequency has resulted from that. However if the theory explained in the Extra-terrestrial Influences on Nature's Risks paper contributes to the incidence of these then there should



eventually be a slowdown in the frequency of these earthquakes. The reason why the incidence of great earthquakes is particularly altered is because they nearly always these occur on the boundaries of tectonic plates. Paradoxically, the frequency of lesser earthquakes on secondary fault lines should be high for some decades as the movements in tectonic plate boundaries will create stresses in subsidiary fault lines that could take many years, decades or even longer to be released.

Stratospheric Volcanic Eruptions

The incidence of stratospheric volcanic eruptions is very limited. These are eruptions that emit large amounts of gases and particulates into the stratosphere. There were three large stratospheric volcanic eruptions during the Dalton Minimum and the records for earlier periods are very patchy. However examination of ice core data suggests that during the Maunder Minimum there were a series of smaller stratospheric eruptions that seemed to have had the same effect as those in the Dalton Minimum. There were three known stratospheric volcanic eruptions in the 1980's: Mt St Helens, El Chichon and Mt Nevado but these only put a fraction of the volume of ejected matter into the stratosphere that was put there by Mt. Tambora in 1815.

Logically, if there is already an increased frequency of great earthquakes, then there will eventually be an increased frequency of major stratospheric volcanic eruptions since the increase in great earthquakes indicates a slightly increased movement of tectonic plates. But the lag times are variable ranging from years to multiple decades or longer. In the last few years there seems to be a higher incidence of volcanic eruptions in the higher latitudes and one factor that will have caused these eruptions is the increased penetration of muons into volcanic calderas at higher latitudes as a result of the higher levels of galactic cosmic rays[21]. This factor alone should further increase the incidence of volcanic eruptions in lower latitudes over the next few decades if the next solar cycle (25) and perhaps the one after have very weak sunspot activity, as NASA predicts.

[21] Walker B W – Extra-terrestrial influences on nature's risks, section 8

Appendix

UK weather from 1780-1820

During grand minimums sometimes the winters in the UK were mild, sometimes very wet and sometimes very cold. Often there were extremes, sometimes all in the one winter. The summers were sometimes hot, sometimes very wet and other times quite mild. Sometimes there were extremes of heat and rain in the same summer. During these periods there were many severe storms in the UK.   The following list of extreme weather events was compiled from various sources that relate just to the period of 1780 to 1820. This is from 10 years before the Dalton Minimum was said to have started and for the first 30 years of that grand minimum. Many of the records are from Selbourne. Solar cycle 5 (1798-1810) was the first weak cycle of this period but the Laki volcano erupted during the deep minimum between cycles 3 and 4 and affected the weather for a few years. The solar perturbation that is believed to have caused the grand minimum occurred around 1790-1793. (The solar perturbation that is believed to have caused the current grand minimum occurred around 2004 – 2010.)

1780 January was frosty. There were some frosts in February and March then spring rains. June - hailstorm at Warminster (Wilts). The stones measured from 3 to 9 inches in circumference much destruction of crops and glass. October 15 – tornado hit Hammersmith (London) and damaged a church.

1781. No extremes recorded. Warm and rainy recorded for November and December through to February 1782

1782 February 4 – 25 very frosty then cold, snowy and rainy weather until end of March with floods in Northumberland and Hexham in early April. September 23 – hail storm in Middlesex. November until Mid-December – hard frosts. Then rainy for rest of December.

1783 A week of frost in February then cold, rainy and windy through to May, thick ice recorded on 5th May. (The Laki volcano eruption commenced in June – its toxic gasses killed more than 50% of the livestock of Ireland and more than 25% of the population later died of starvation. The eruption continued into 1784) Early November was mild and warm. November 25 - big storms in Hampshire and Wiltshire. There was frost for 89 days straight in the winter of 1783/84. The Thames froze below Gravesend.

1784 Huge snow storms over much of England through to April 2. A big storm on North Coast on December 5. Frost for 118 days in winter of 1784/85. Temperature in London was recorded as low as -18.1° C on December 10. Summer was warm.

1785 Drought in May. Forest fire in Windsor forest burnt for days. June – hailstorms in Suffolk, Sussex, Yorkshire and Cambridge. September 15 – there were hailstorms in Cumberland, Hampshire and Warwickshire. During September there were floods in many counties.

1786 Winter was mixed weather with some rain, some snow and a little frost. The last frost was April 13. There was a big storm in the English Channel in January. Several ships were lost. There were big hail storms in Ireland and Bickington (probably a tornado). August 16 – there was a big hail storm in North Shields and on September 12 one in Hampshire.

1787 The winter of 1786/87 was mixture of mild rainy weather with some frosts. Some storms in England. The November 12 storm in Ireland caused the flooding of Dublin Cathedral - 8 feet of water. November and December were generally mild with some rain and a few frosts.

1788 January to March was alternately wet or windy with some frosts – no snow recorded. There were storms in June and July that caused flooding in London and Scotland. Also a hailstorm in Cheshire. There was a drought in much of England in July and August with over 5000 head of cattle perishing in August. By December the drought was declared the worst ever in Scotland. From November 25, 1788 to mid-January 1789 it was very cold. The Thames was frozen at many places for some time and frost fairs were held. (It was also very cold in Europe and North America. -35.6° C was recorded in Bremen, Germany, -14.4° C in London. The Baltic Sea totally froze and all but 200m of the strait between Denmark and Sweden. The English Channel was frozen until about 10Km off the coast.)

1789 It was very wet in England and Wales – crops were severely affected. From June 29 to August 22 there were many bad storms, which caused flooding. There was a very mild winter, some rain and few frosts.

1790 On July 30, there was a large hailstorm at Monymuch, Scotland with very big hailstones to 3' deep and on November 21 in London, Hampshire and Wiltshire. There was another on December 23.

1791 June 21-24 there were several violent storms bringing hail and snow to various counties. On July 18 there was a great hail storm in Berkshire, Gloucestershire, and Wiltshire. On August 3 there was a hailstorm in Leicestershire that caused a lot of damage and another in Kent and Sussex on October 22. Lightning destroyed a church in Kent on October 25 and there was a further hail storm in Cornwall. On November 20 the Don, Derwent and Kent significantly flooded. The winter was mostly wet and mild with a few frosts.

1792 January 27 a storm inundated Plymouth and breached the sea wall. In April, June and July there were several storms at various parts of the country. A waterspout severely damaged Bromsgrove on April 18. There were big floods in Lancashire in August. December 6 was regarded as one of the stormiest nights in history across most of England. There is no record of there being a cold winter.

1793 March – storms in Sheffield and Whitehaven. It was very hot and dry in the UK and Europe during summer with extensive drought.

1794 On January 16, there were storms across much of England and again on July 6, August 7 and October 6. There were more storms in November. December turned very cold and there was a violent overnight snow storm in Scotland that dumped 8' to 10' of snow. Many animals and humans perished.

1795 On January 1 it was very cold in England. One newspaper reported that the Thames iced over in 10 minutes as the tide turned. The Antiquarian Society of Newcastle recorded that the ice on the Tyne was 20" thick in January. The frost lasted until February 24 with just one day's respite. The thaw in late February caused extensive flooding. On June 12 there was a large hailstorm in Wiltshire, Herefordshire, Middlesex, and Monmouthshire. It killed many newly shorn sheep. The English Channel had many storms in December and January

1796 June 7 - a storm at Petersburgh caused losses of 90 vessels. June 16 A Hailstorm at Lancashire. November 5 – a severe hailstorm at Norwich. There was frost for the whole of December with - 15° C recorded in London on Christmas day.

1797 May 6 – a severe hailstorm in London and Sussex. June 5 – another hail storm in London and Sussex. Hail stones up to 3”. August 5 – another hailstorm in Sussex.

1798 Hot and dry spring and summer. London recorded 30° C on June 28.

1799 The winter of 1798/99 was severe. The Baltic completely froze so did the Seine and other rivers in France. No record of English weather but it is likely to have been very cold.

August 16 – there was a large hailstorm in Gloucestershire and Somersetshire. It was very cold in the UK in December – the temperature in London on Dec 31 was -8.3° C.

1800 There were food riots in England over the price of bread. Summer was very hot all over Europe including England.

August 19 a hailstorm with irregular hail stones up to 11” in circumference killed wildlife in Oxfordshire and Bedfordshire. This was followed by further severe storms on August 22 September 10 and September 15. (The latter was very severe and was across the whole of the UK). A similar storm occurred on November 8 and caused a lot of damage – particularly in London. Apparently there was a mild winter.

1801 Some storms but also drought. Both houses of Parliament had enquiries into how to obtain food. Grain was imported from the US. The winter of 1801/2 was very cold. The Thames had ice but apparently wasn’t frozen over.

1802 January 22 – a big storm in southern England followed by floods across the country in Late January and February. There was considerable damage from floods when the river Liffey overflowed in Ireland. There was a hot summer across Europe. But the UK also had severe storms on 18/7, 10/8, 18/8, 24/8 and on 2-3 December the Liffey overflowed again. The grain harvest was the best ever in the UK but it was very poor in France.

1803 The winter was late but very cold. A lot of rivers froze in Europe and in France the last frost was recorded on June 21. A tornado on January 1 took off every roof in Falmouth and damaged Plymouth. The Thames dried up. People crossed on foot. On June 9, a localised hailstorm (tornado-type storm perhaps) damaged Haymarket but not the rest of London. There was a hailstorm in Leicestershire on July 21. There was a very hot dry summer in Europe again.

1804 There were hurricanes in Devonshire and Cornwall on January 8 and 19. On May 8th there were many storms including a deluge that caused a lot of damage in Bath. A hailstorm on November 1 considerably damaged Cornwall. The Thames tide was the highest ever recorded on December 28.

1805 There were bad storms recorded on June 28, July 6 and July 30 in the UK. On November 8-9 there was a very severe storm in the English Channel, many ships and hundreds of lives were lost.

1806. A stormy summer. Major storms recorded on 6/6, 7/7, 22/7, 24/7 and 29/8 in England. Also the 9/8 and 21/8 there were bad storms in Ireland. There was another very high tide on December 26. People rowed boats on Palace Yard.

1807. Another stormy summer. Hailstorms occurred in the UK on 2/5, 10/5, 26/7 (hailstones the size of chooks eggs). It was also a very hot midsummer but there was also a lot of snow in November and December.

1808 Apparently there was a lot of snow in February. But later there were a lot of floods. There were bad hailstorms recorded in the UK on 13/7, 15/7, 16/7 and 16/8. But it was also a hot summer. 34.2° C was recorded in London in July. There was a lot of snow in the UK in November and December. (A live sheep was unearthed on December 18 that had been buried under a snow drift for a month.) The Thames overflowed its banks on December 9 causing considerable damage in London. Southern Europe had a mild winter but it was very cold in Northern Europe. The Baltic was frozen for some time and allowed two Russian armies to invade Finland. The mercury froze in the thermometers in Moscow several times in February (it freezes at -39° C).

1809 Bad storms were recorded in England on March 28 and May 18. The winter of 1809/10 was very cold in Southern Europe with -15° C recorded in parts of France. There is no record of how cold it was in London. In Moscow the mercury in thermometers froze several times in March

1810 There was a severe storm over almost the whole of England July 1. Other large storms occurred on 15/7, 4/8 and 14th and 15th of August. The winter of 1810/11 was very cold. In Moscow the mercury in thermometers froze several times in January, 1810.

1811 The Thames froze on January 8. There were severe storms on 27/5, 28/5, 5/6 and 3/8 (Ireland).

On June 4, it was reported that the tide suddenly went out in Plymouth leaving the port dry, then it returned in half an hour with great violence and much higher before going out again. This sounds like a small tsunami but the only large earthquakes recorded in 1811 near the Atlantic were the New Madrid Earthquakes in the US the first of which occurred on December 16. Could there have been a major subterranean earthquake of the coast of Alabama, or Mississippi/Louisiana that triggered the instability in the fault line? Also was this connected to the very cold winter then being experienced in parts of the Northern Hemisphere, which would have been caused by a very negative arctic oscillation that would have created a very strong high pressure system over Greenland? Snow storms had commenced in Connecticut in mid to late November suggesting that this might have occurred.

The summer in England was warm but it was very hot and dry in the south of France. There was a huge rainstorm in Scotland on the night of November 1, said to have been the greatest quantity of rain ever.

1812 There was a very dense fog in London on January 10. It was almost completely dark at midday, visibility was down to 10'. There was a drought for most of 1812 in England and south of France. But the Thames flooded the Palace Yard again on October 21. There were very thick fogs in London from November 20-27. This was followed by a very cold winter. The Thames froze from source to sea as did most rivers in Europe. The Baltic, Adriatic Sea and the Sea of Marmara all froze and Hellespont and the Dardanelles were blocked with ice as were the straits between Norway and Sweden and

Denmark and Sweden. Napoleon lost 400,000 of his returning troops from Russia where frigid conditions started early in November and continued right through December. It also apparently snowed all over North Africa and ice flows were recorded on the Nile in Egypt.

1813 Red snow and hail fell in Calabria on March 14. This indicates that there was a large stratospheric volcanic eruption a few years before. From Greenland and Antarctica ice core analysis the eruption was dated as 1809 and probably occurred in the tropics. It is thought to have been a larger eruption than Pinatubo but perhaps half the size of the 1815 Mt Tambora eruption.

There were hailstorms in England on 17/5, 9/6, 26/7 and in October (no day recorded) in Bedfordshire. Lightning strikes burnt several buildings. Winter was cold with severe fog in London lasting 8 days from late December. There were non-stop frosts for 6 weeks felt over the whole of UK.

1814 A sudden storm in Belfast killed 100 on January 10. This was followed by a very large snowfall over most of England on January 14. A Frost Fair was held on the Thames on February 2 and extended from Blackfriars to London Bridge. It lasted for some days. There were large hailstorms recorded on 28/7 and 1/9. A severe storm hit the UK and Ireland on December 16-17 and caused a lot of damage and loss of shipping. It was recorded as a hurricane.

1815 - 1820 Mt Tambora commenced erupting on April 10, 1815. It ejected between 150 and 160 km^3 of tephra into the troposphere and stratosphere. This changed the world’s weather for several years. For example in 1816 the Northern Hemisphere had the year without a summer. Snow fell in even in June in parts of the US. Crops failed everywhere partly because of cold and partly because of drought. Italy got red snow in 1816 and Slovenia in 1819. The Slovenian snow was analysed and found to contain silica, alumina and oxide of iron. (Could there have been yet another later large volcanic eruption that wasn’t recorded?) The Northern Hemisphere winters were very cold through to 1820. This was also a period of many storms. Frost fairs were held on the Thames in the winter of 1819/20 as there was up to 4 metres of ice in some parts.

Australian Weather from 1788-1820

For much of the Dalton Minimum Sydney was only place in Australia where the weather was recorded and only because it was first colonised by the English in 1788. The records are patchy and are made up from letters sent back to England and diary entries. They seem to suggest that there droughts and heat waves in the early years of colony. Later there were big hailstorms and huge dumps of rain. It seems that there were weather extremes particularly for some decades from the late 1790's.

1788 Early January - there were small patches of snow at the waterline on the east coast of Tasmania as the first fleet sailed past (Mid-summer). Severe storms were encountered up the east coast to Botany Bay and damaged six of the seven ships of the second convoy. The swells were the biggest encountered on the whole voyage. The fleet took shelter in Botany Bay on January 19. Later it was decided to push on to Sydney but big seas stopped the fleet travelling to Sydney from January 24 until January 26. That year crops generally failed, but perhaps this was due to strange soils and climate.

1789 There appears to have been a drought for much of the year through into 1790 as the colony only grew enough food in two years and three months to provide for themselves for three weeks (according to Chief Surgeon, John White in a letter to a colleague in England).

1790 Apparently no rain fell between June and December. Then a heat wave started and continued off and on into February 1791. Temperatures of in excess of 100° F (37.8° C) were regularly reported this summer and the previous. 109° F (42.8° C) recorded on December 29.

1791 A temperature of 105° F (40.6° C) was reported on February 10 and 11. The following day there were extensive bushfires from Parramatta to the Blue Mountains.

1792 The colony was still in drought but had managed a wheat crop in farmland near Parramatta.

1793 Drought still recorded in summer and autumn. Winter rains didn't come until August.

1794/1795 Drought recorded. Sometimes there were months without rain.

1796 A severe hailstorm hit the Hawkesbury area in December. A day later the hailstones on the ground were measured at 8" long.

1797/98 Drought recorded with heat waves. 107° F (41.7° C) recorded at Windsor in December 1797

1799 The first of the big floods of the Hawkesbury River occurred. The table is of Hawkesbury River floods of which records were found. The river heights are at Windsor and are above the normal water mark. There was also drought and bushfires in 1799.

Hawkesbury River Floods 1799 -1820	
Date	Height
Mar/1799	50'
Mar/1800	40'
Mar/1806	48'
May/1809	48'
Aug/1809	48'
June/1816	45.5'
Feb 1817	46'
Feb 1819	46'
June 1819	46'

1800 In March the town of Windsor was again destroyed by flood so it was then relocated onto higher ground.

1801-1805 there seems to have been drought. On May 29, 1803 it was recorded that there had been virtually no rain except passing showers since July 1882. The drought continued through into 1804. Presumably 1805 had reasonable rainfall because there are records of good crops.

1806. The flood at Windsor was particularly damaging as the colony lost much of its stores of wheat and current crops. At least 5 lives were lost. Then in August it flooded again almost to the same height. From various accounts these were very significant rainfall events. They must have come from super cell storms. On September 24 there was a heavy hailstorm that inflicted more damage on crops.

1807-08 apparently there was reasonable weather.

1809 April, the Dewent river (Tasmania) overflowed its banks. May and again in August – there were more great Hawkesbury River floods. Then there was drought for most of the time for the next 2 years with very poor crops.

1811 By March 1811 water sold for 6*d* a pail in the colony. This drought was regarded to be as bad as the 1789/91 drought.

1812 On January 18 there was a severe hailstorm near Sydney with hailstones 8" across.

1813 Drought recorded in NSW.

1814 A drought for most of the year. A severe hailstorm hit Sydney in 1814 and broke every pane of glass in the colony[22].

1815 There was mainly drought in 1815.

1816 In June there was another Hawkesbury River flood.

1817 In February there was another Hawkesbury River flood.

1818 Apparently there was good weather.

1819 There were two Hawkesbury River floods this year.

1820 The Hunter River flooded to a peak of 37' above normal level.

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[22] J. H. Heaton, Australian Dictionary of Dates and Men of the Times containing History of Australasia from 1542 to May1879