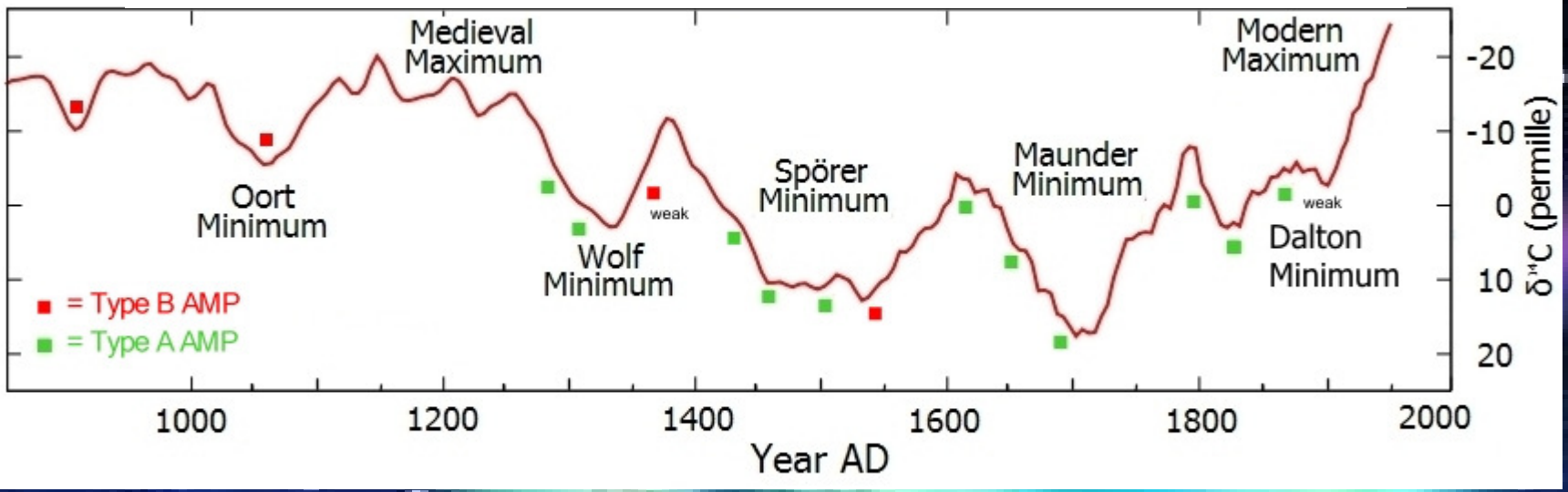

The New Grand Minimum
Brent Walker – May 2013

The new solar grand minimum requires actuaries to evaluate new risks and develop new skills.

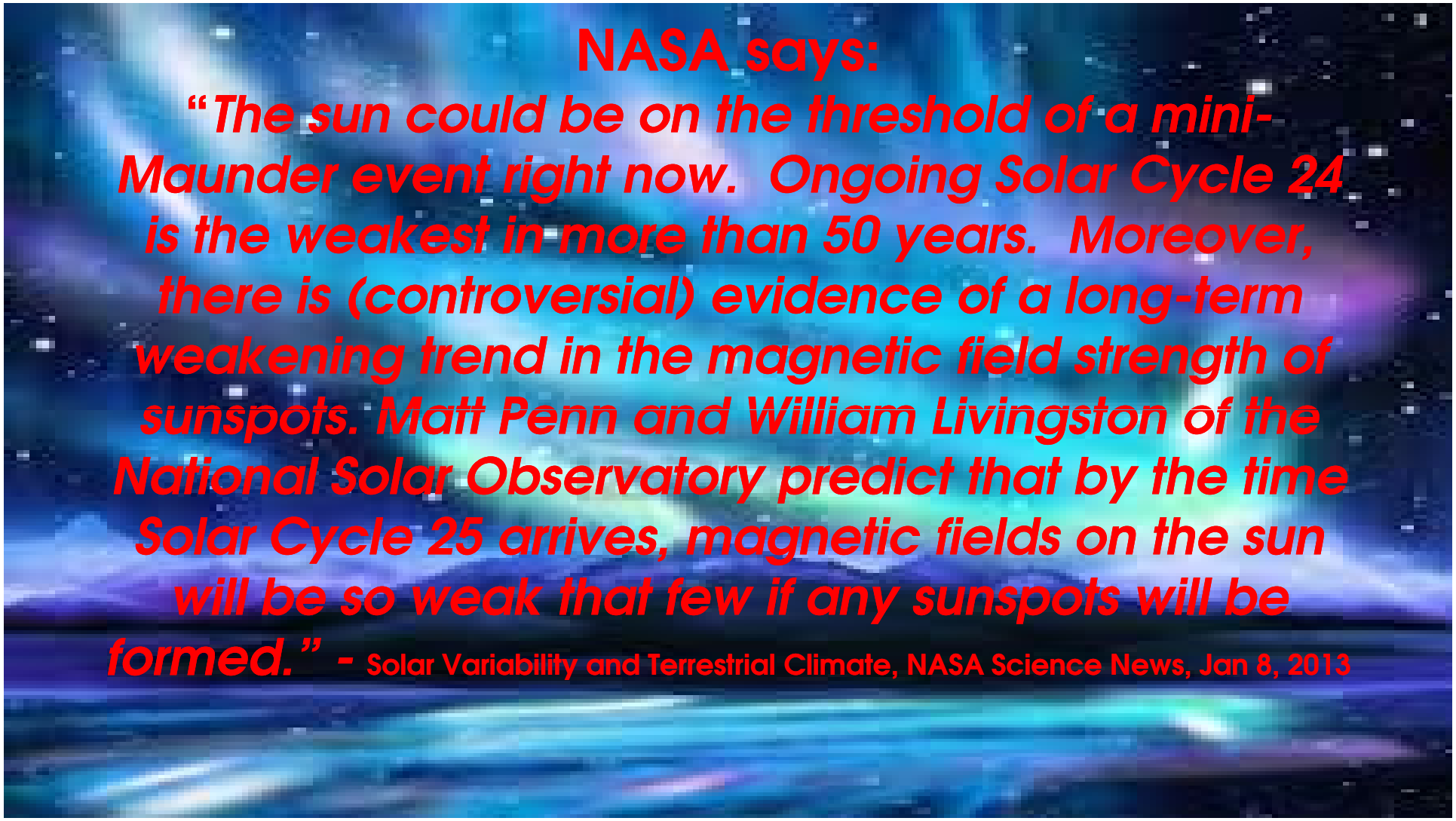
Actuaries Summit
get involved, get ahead
20–21 May 2013
Hilton Sydney

Actuaries Institute

Solar Activity in $^{14}C/^{12}C$ Ratio - RHS Scale is reversed



The Paradox: The ratio slopes strongly upward in the 20th C because of mankind's emissions of $^{12}CO_2$. This ratio is not a proxy for global temperatures nor does it reflect the strength of the solar cycles in the 20th C.


NASA says:
"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." - Solar Variability and Terrestrial Climate, NASA Science News, Jan 8, 2013

Solar Cycles

- Schwabe – One solar cycle of 8-14 years. Believed to be modulated by the orbits of Venus, Earth, Jupiter and Saturn. Sun's magnetic poles reverse in middle of this cycle.
- Hale – pair of Schwabe cycles. Return to original solar polarity.
- 30 yrs and 60 yrs - relating to Saturn's approximate 30 year orbit
- 150 – 200 years - relating to approximate grand alignment of all gas giants (Neptune's orbit is 165 yrs)
- 2400 years - return of all planets into exactly same relative positions.
- Also 27 day cycle because the sun's equatorial plasma rotates on a 25 day cycle and with Earth's rotation of the sun it takes around 27 days for the same location on the sun to face Earth.

Oceans are heat sinks

Earth's water

- 97.25% in oceans
- 2.05% ice (90% in Antarctica)
- 61% of surface – Northern H.
- 81% of surface – Southern H.

Land surface at latitude
30° North = 2 x South
40° North = 10 x South
50° North = 28 x South
60° North = 61% land, South = 0%

In terms of heat to raise water temp by 1°
Melt ice at 0° requires 80x
Heat from 0° to 100° & turn to steam requires 640x

Local climate change lags are determined by geography

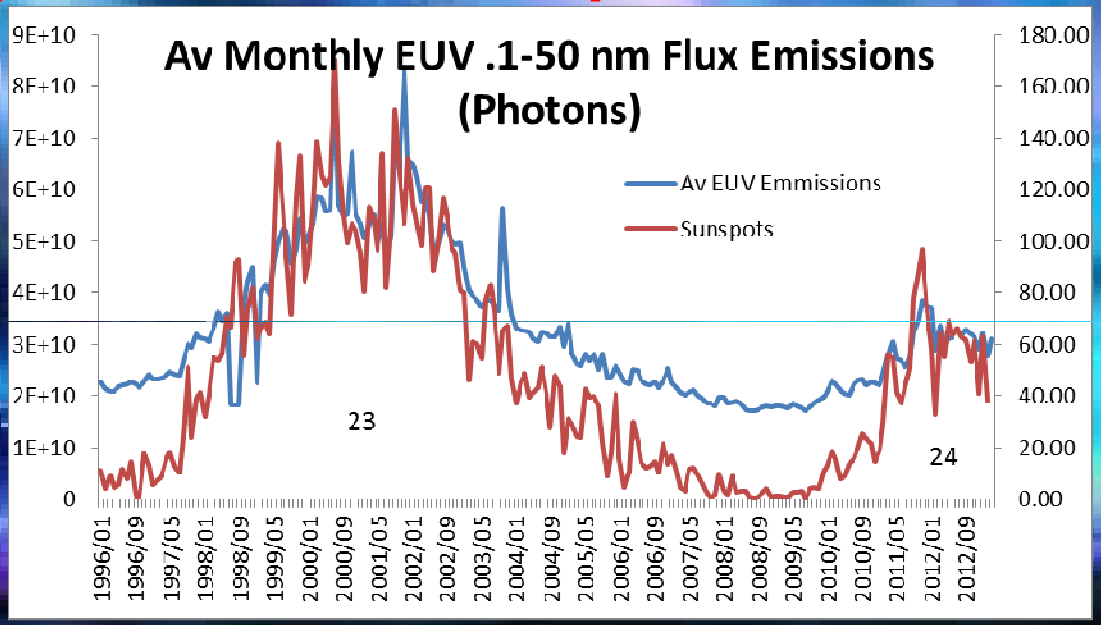
Sun's radiated energy

According to NASA Sun/Climate report

Source	Total Energy (W/m^2)	Solar Cycle Change (W/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
Infra-red	**260**	**0.2**	**0.10%**	Surface and Troposphere

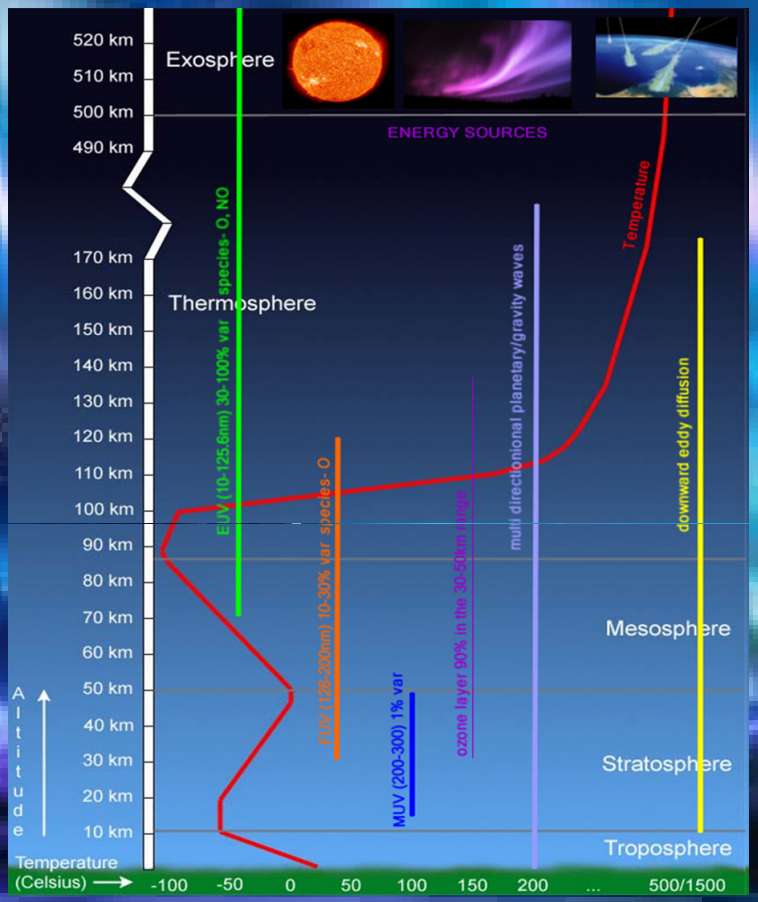
Spectrum split of Ultra Violet Light		
Ultra Violet Light	Spectrum	Energy/Photon
UVA	400-315 nm	3.1-3.94 eV
UVB	315-280 nm	3.94-4.43 eV
UVC	280-100 nm	4.43-12.4 eV
Far UV	200-122 nm	6.2-10.16 eV
Extreme UV	121-10 nm	10.25-124 eV

Solar Cycle 24 average EUV output is just 60% of Cycle 23 & 40% of Cycle 22 (C22 ended 5/1996)



EUV photons provide the energy to create the ozone layer and heat the upper stratosphere.

Monthly average EUV fluctuates by a factor of 4 over a solar cycle

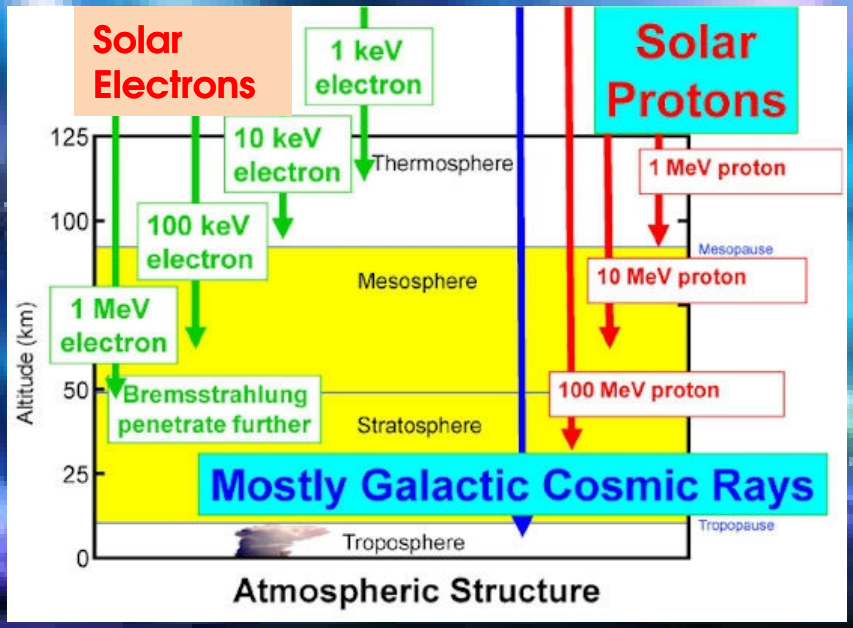


Approximate Relative Mass of Atmosphere	
Troposphere	76%
Stratosphere	19.9%
Mesosphere	<4%
Thermosphere	<0.1%
Exosphere	<0.001%

Borders are approximate.
Troposphere height is about16 km at equator and 6km at poles in winter.

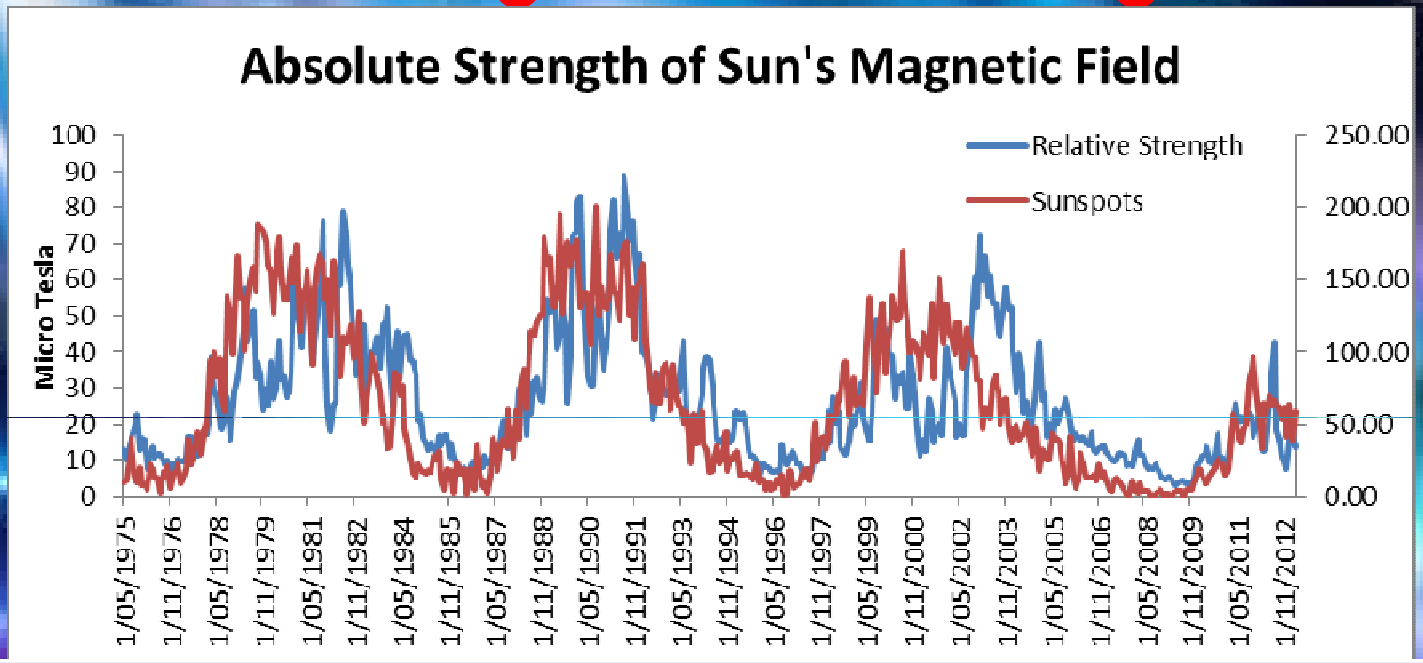
At ground level atmospheric pressure the thermosphere would be 1cm – 2cm thick. When the sun is very quiet the thermosphere can shrink by 2/3rds.

How far do charged particles penetrate Earth's atmosphere?



Normally, most solar protons don't penetrate Earth's magnetic field.
But it seems likely that when the solar magnetic field is weak magnetic portals more frequently form between the sun and Earth. These can rapidly transfer many tons of plasma (charged particles) into the upper atmosphere.

Solar Magnetic Field Strength



Wilcox Solar Observatory data used in this study was obtained via the web site http://wso.stanford.edu on 2013:04:31 courtesy of J.T. Hoeksema.

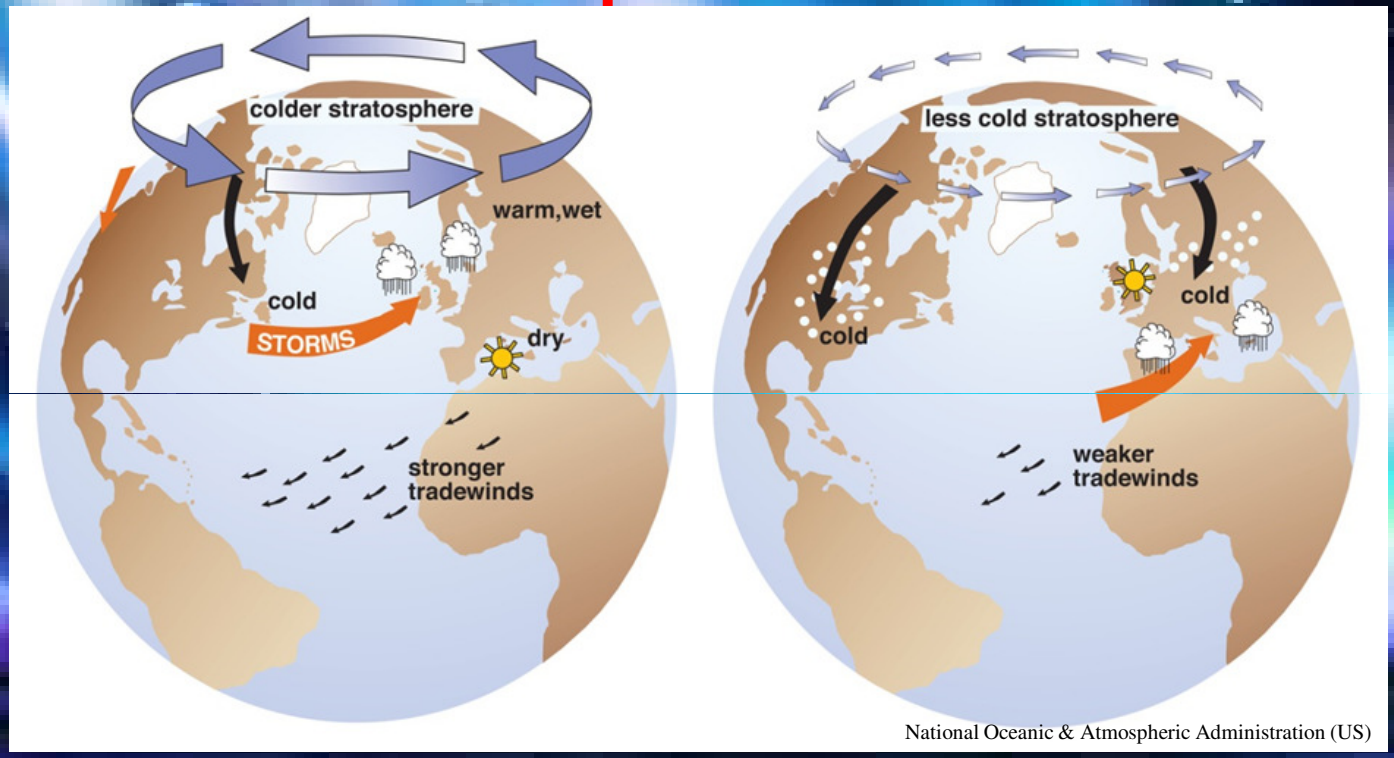
To date the average magnetic strength of cycle 24 is 66% of cycle 23 and 55% of cycle 21 - for the same period of time of each cycle. The ratio of highest to lowest monthly average is 31.

Links between altered jet streams and the sun

Normally - 2 wave like jet streams in each hemisphere at approximately the boundary of the troposphere and stratosphere:

- Polar jet forms between polar air and temperate mid latitude air at about 7,000m.
- Equatorial jet forms between mid latitudes and warm equatorial regions at about 14,000m.
- With strong solar cycles they gradually move towards poles and become more regular.
- With weak solar cycles they gradually move towards the equator and become more erratic.
- Changes in the polar vortex can have a major influence on jet streams.
- Large high and low pressure systems can interact with them.

The polar vortex

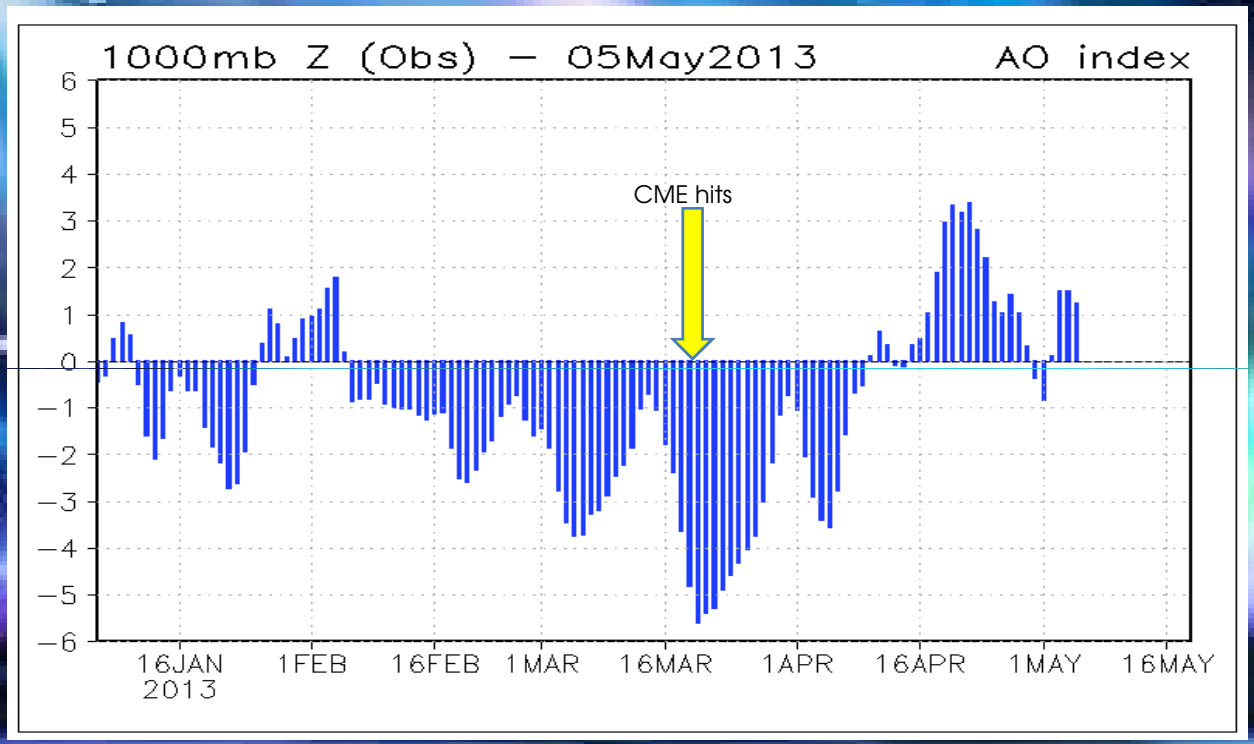


National Oceanic & Atmospheric Administration (US)

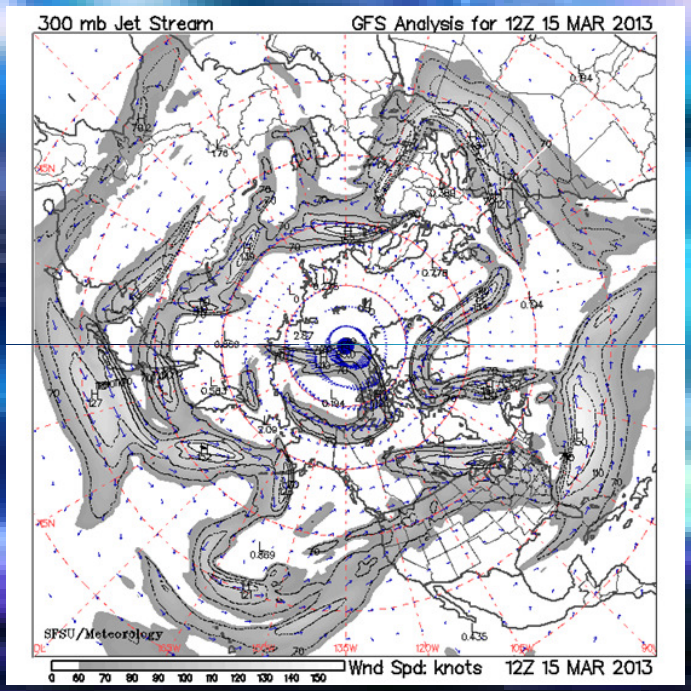
March 2013 CME Sequence of Events

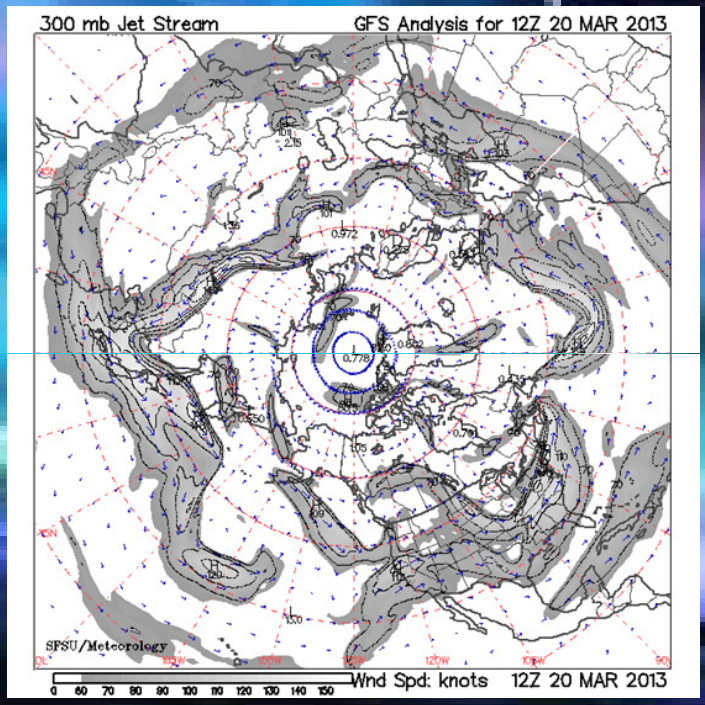
- March 15 sunspot 1692, in the sun's northern hemisphere produced a M class (medium) flare when it was directly facing Earth. The flare lasted a relatively long 36 minutes.
- March 17 the CME hit Earth's magnetic field. For a short time a magnetic field line of Earth and another of the sun joined and channelled tons (possibly hundreds of tons) of plasma into Earth's ionosphere and thermosphere.
- Earth's magnetic field then channelled these energetic protons to the poles – particularly the North Pole.
- Massive aurora's occurred in both hemispheres on March 17th, 18th and 19th.
- The ionosphere above the North Pole increased in temperature by around 60° C.
- The polar vortex stopped going anticlockwise and started going clockwise.
- The Arctic Oscillation went deeply negative. 16th lowest daily recording since 1950.
- Over the next few weeks the polar jet stream virtually disappeared.
- The North Pole got much warmer as cold polar air went south over the Northern Hemisphere.
- A strong pressure system formed over Greenland. It was the highest pressure ever recorded there. Has it destabilised the New Madrid and San Andreas fault lines?

Arctic Oscillation 2013

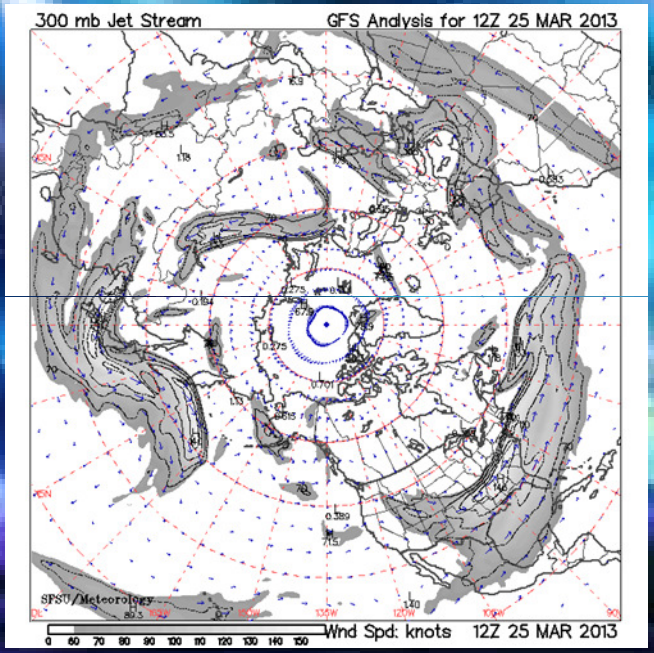


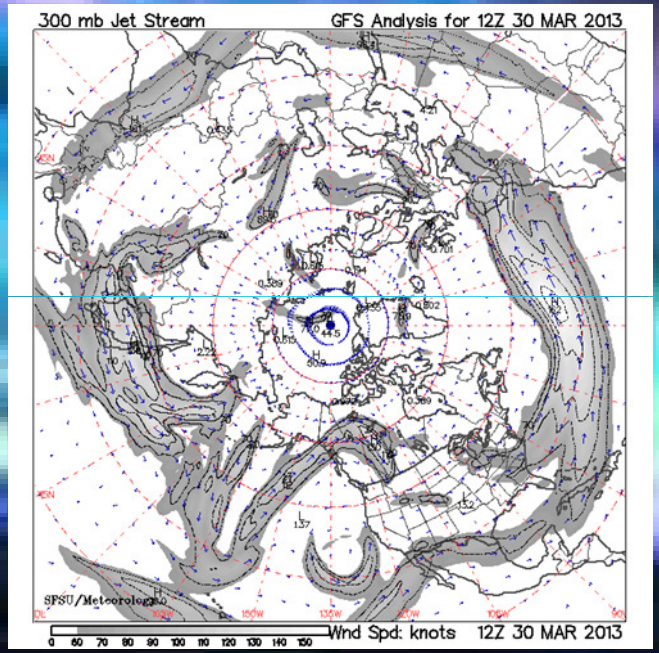
Changes in Jet Streams – March 15, 20 2013



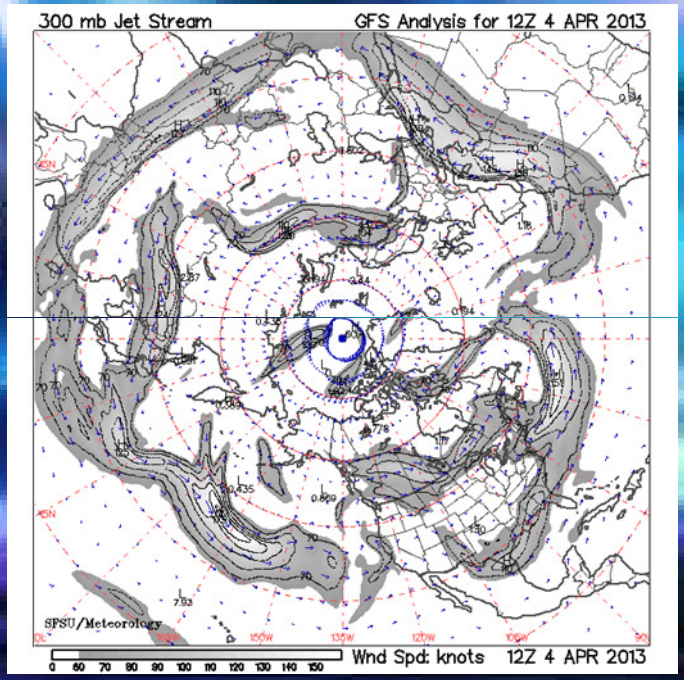


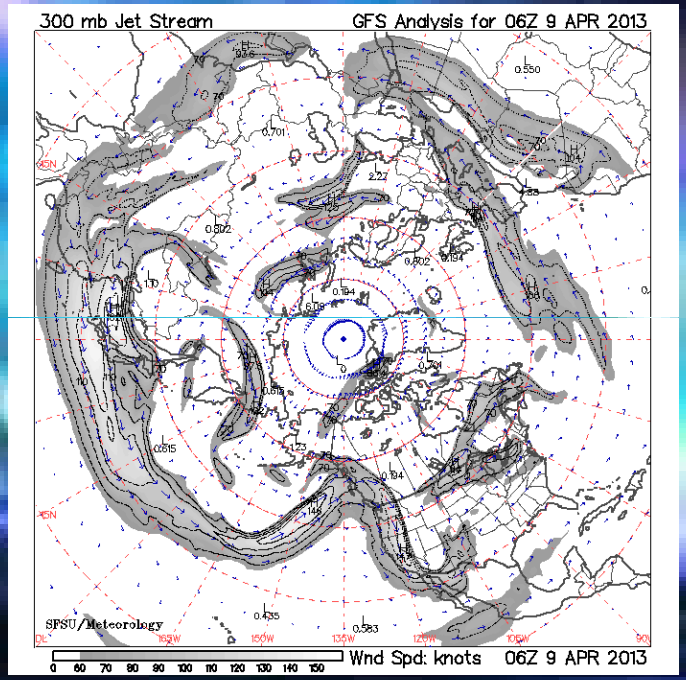
Changes in Jet Streams –March 25, 30 2013



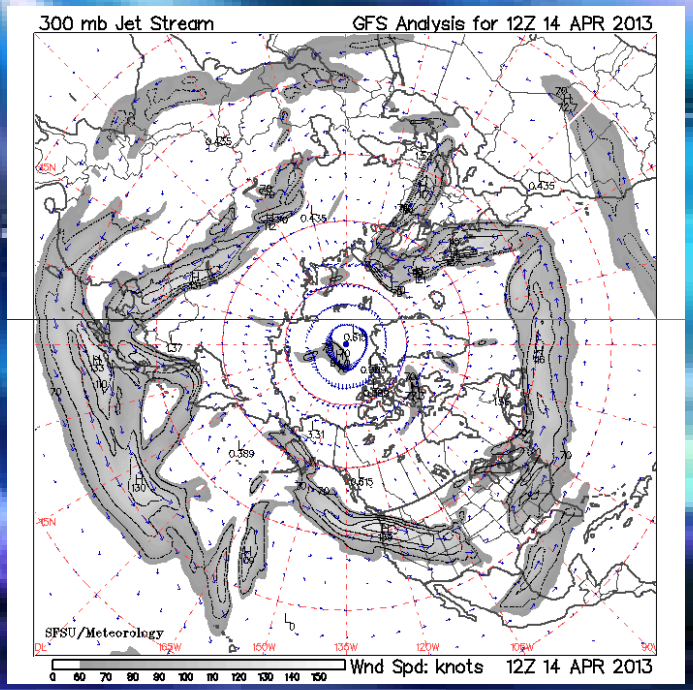


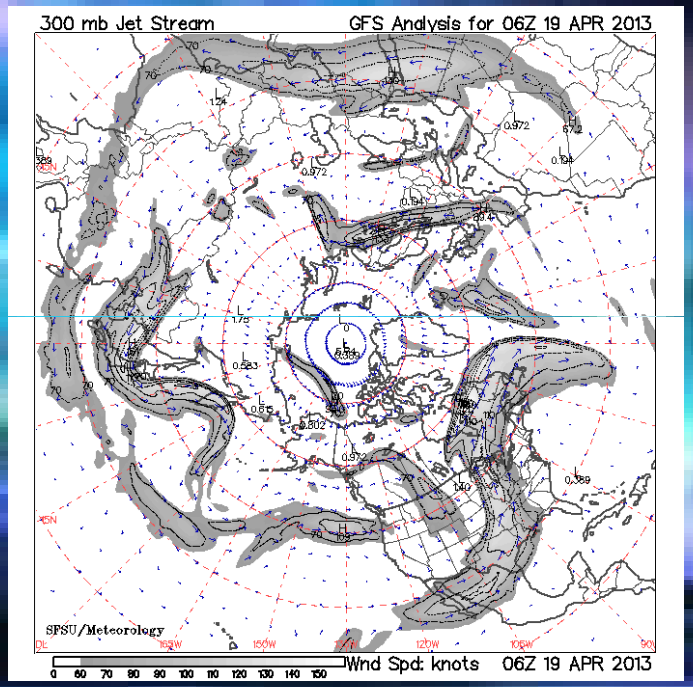
Changes in Jet Streams – April 4, 9 2013





Changes in Jet Streams –April 14, 19 2013





Incidence of other significant AO lows

Since 1950 there have been 4 other occasions when the arctic oscillation has been below -5 for 3 or more days.

- February 1969 – during solar cycle 20, which was weak
- March 1970 – solar cycle 20
- December 2009 – solar cycle 24 which is very weak
- January 2010 – solar cycle 24

What will occur during the next few decades?

January/February 2012

- January 22 an M8.7 flare sent plasma at 2250km/sec towards Earth.
- January 24 tangentially hit Earth's Northern Hemisphere.
- Arctic Oscillation dropped from -1.775 on January 24 to -3.451 by January 28.
- Jet streams affected enough to cause wave of frigid air to flood Eastern Europe, Balkans & Italy, Greece.
- Danube partially iced over for two weeks also canals in Venice and parts of the sea of Azov.

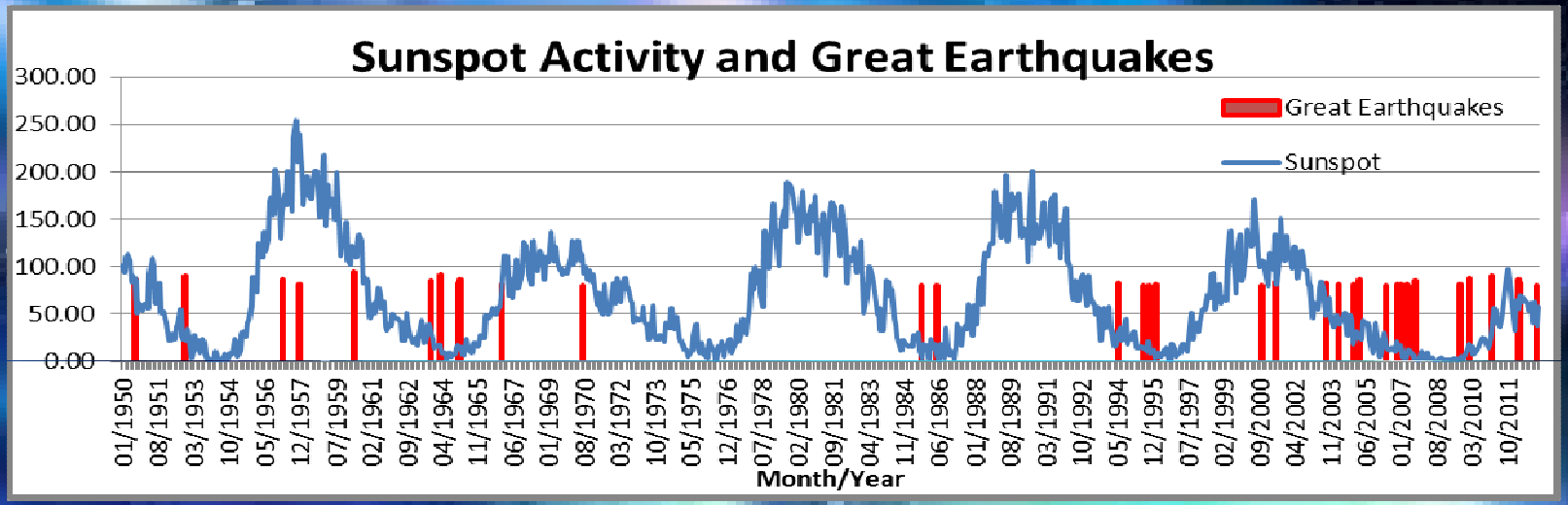
How Arctic stratosphere can warm

- Impact of Plasma from CME.
- Stratospheric volcanic eruptions
  - More common in deep minimums due to extra CGRs that produce extra muons.
- High levels of fluorocarbons destroying Ozone in Spring.
- Impact of very high energy protons in CGRs.
  - More during deep solar minimums due to weak solar magnetic field.
  - From nearby supernova (perhaps once in 1000 Years. But there was 3 in 11th C.)
- Long planetary waves from high latitude troposphere.
- Gravity waves from warmer stratosphere/mesosphere.

Some incidences of locked jet streams

- Pakistan floods and Russian wheat-belt drought in 2010
- Cyclone Sandy 2012
- Australian heatwave December 2012/January 2013
- NZ “best summer ever” and drought January – March 2013

Incidence of great earthquakes since 1950



This implies there should be extra volcanic activity for some time.

Major Stratospheric volcanic eruptions during last grand minimum

Maunder Minimum

- There were a number of eruptions – but none as big as Tambora.

Dalton Minimum

- Undocumented (possibly Indonesia or Vanuatu) 1809 (deaths unknown)
- Laki (Iceland)1783 - 84 (20% of Iceland population died plus 10s of thousands in Ireland, UK and Europe)
- Tambora Indonesia 1815 (est. 71,000 direct deaths plus 100s of thousands from secondary effects (starvation and disease caused by crop losses)

New Grand Minimum

- There currently seems to be a lot of volcanic activity – but, fortunately, nothing major – so far. Records are too poor for comparison.

What to Expect During New Grand Minimum

- More variable weather due to erratic changes in jet streams
- Northern Hemisphere
  - Cold waves, heat waves, storms, droughts and stalled monsoons.
  - Loss of crops or very poor cropping in some years.
- Southern Hemisphere
  - Often colder winters and hotter summers due to erratic and locked jet streams and stalled monsoons.
  - Droughts and significant rain events.
  - Erratic crop results.
- Major volcanic eruption(s) could cause a serious downturn in world-wide temperatures for a few years.

Actuarial Risks

- Increase in natural disaster risks.
- Increasing mortality rates – particularly in Northern Hemisphere due to cold winters.
- Political instability due to food inflation and occasional temporary localised fuel shortages.
- If major volcanic eruption
  - Crop losses in excess of grain reserves will cause significant political dislocation.
  - Potential for catastrophic loss of life.
- Reputational risk – from wrong risk assessment.


End