Most of the warming in the 20th century is due to the sun

Introduction

According to the latest IPCC report, AR5, the influence of the Sun on our climate since pre-industrial times, in terms of radiative forcing, is very small compared to the effect of greenhouse gases. Figure 1 in the introduction (SPM.5 in AR5) is quite misleading, since it compares the TSI at solar minimum around 1745 with TSI around minimum in 2008. They are apparently the same. This covers the fact that the Sun has changed quite a lot in the time between.

The cooling since the Holocene Maximum and the Modern Maximum

The cooling over Central Greenland since the Holocene maximum is very clear in the GISP2 record (Alley, 2000), which is shown below:

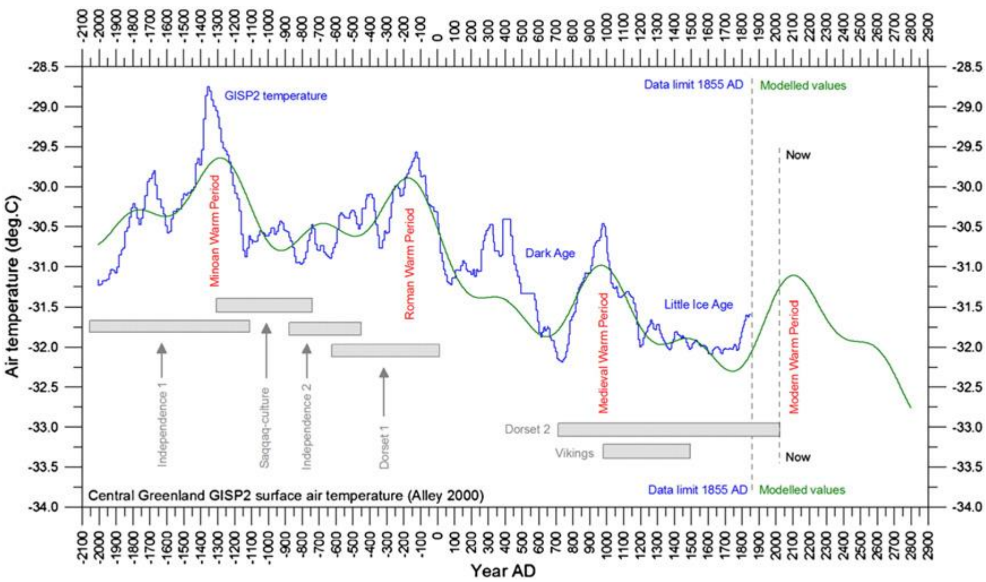

Figure 1: Central Greenland (GISP2) surface temperature the past 4000 years (blue line). Natural cycles modeled and forecasted shown by the green line. Only 3-cycles are included (2800, 1190 and 560 yr) in the model. This model shows a temperature increase for the period 1850-2100 which is called the Modern Warm Period (MWP) (From Humlum et al., 2011)

What we observe in the GISP2 temperature graph is a cooling since the Holocene maximum 4000 years ago, interrupted with temperature peaks about 1000 years apart. The temperature peaks can be identified with historic warm periods.

It should be emphasized that Central Greenland temperature changes are not identical to global temperature changes. However, they tend to reflect planetary temperature changes with a decadal-scale delay. The GISP2 record ends in 1855 before the onset of the 20th Century warming. A simple harmonic model based on wavelet analysis, which we may call a natural cycle model, with only 3 long periods (2800, 1190 and 560 yr) is used to forecast the observed warming until 2800 (Humlum et al., 2011). This indicates that the modern maximum will peak at some time this century. A more detailed harmonic analysis and a comparison with the HadCRUT4 temperature data set shows that we are close to the peak of this long period cycle, which will have a maximum around 2060 (Solheim, 2013a).

This means that an expected future Maunder Minimum will appear when a strong (low frequency) natural cycle provides a temperature peak, and the expected cooling may be less than in the Maunder Minimum, which appeared in a minimum of the low frequency natural cycle.

The "best" solar reconstruction

The reconstruction by D. Hoyt and K. Schatten (1993) updated with the ACRIM data (Scafetta, 2013) gives a remarkable good correlation with the Central England temperature back to 1700. This is shown in the figure below.

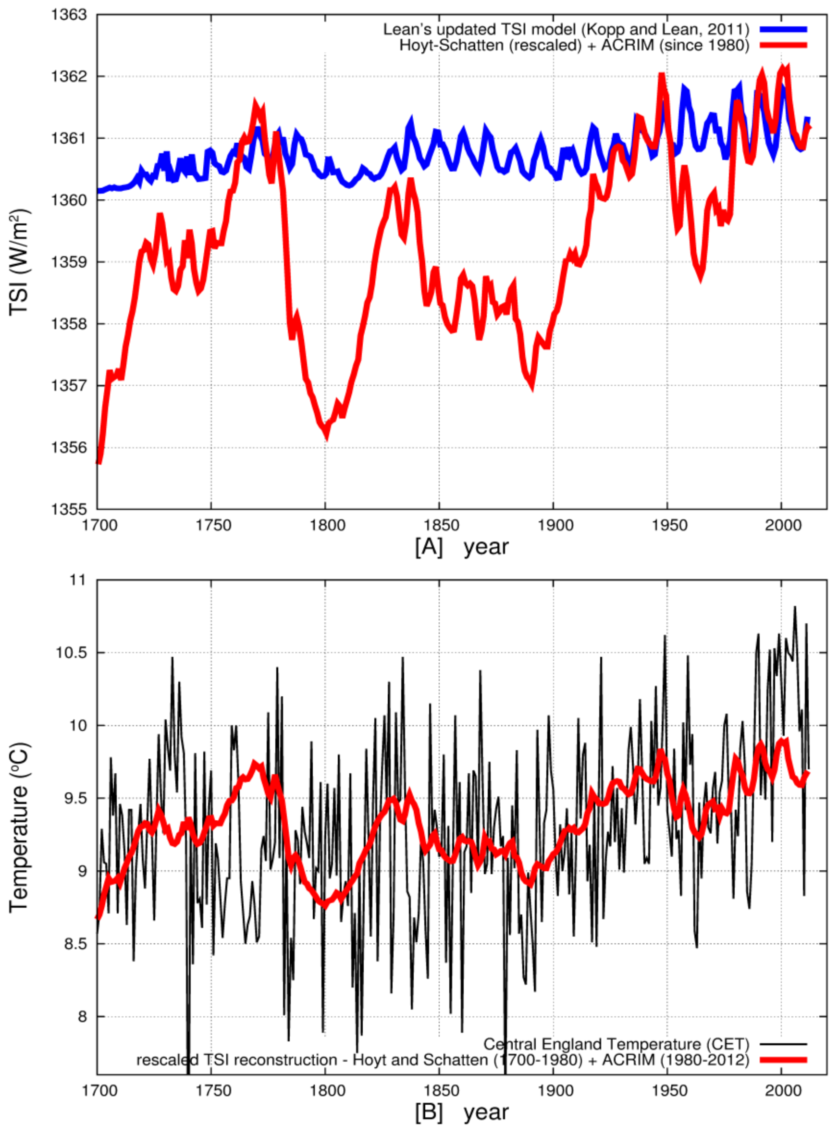

Figure 2: Total solar irradiance reconstruction by Hoyt and Schatten updated with the ACRIM record (since 1980) (the red curve) versus the updated Lean model used in the CMIP5 reconstructions (blue). The lower panel shows a comparison between the TSI model by Hoyt and Schatten and the Central England temperature record (From Scafetta, 2013, figure 15).

The TSI reconstruction of Hoyt and Schatten, also show close correlation with the variation of the surface temperature at three drastically different geographic regions with the respect to climate, as shown in Figure 3 below:

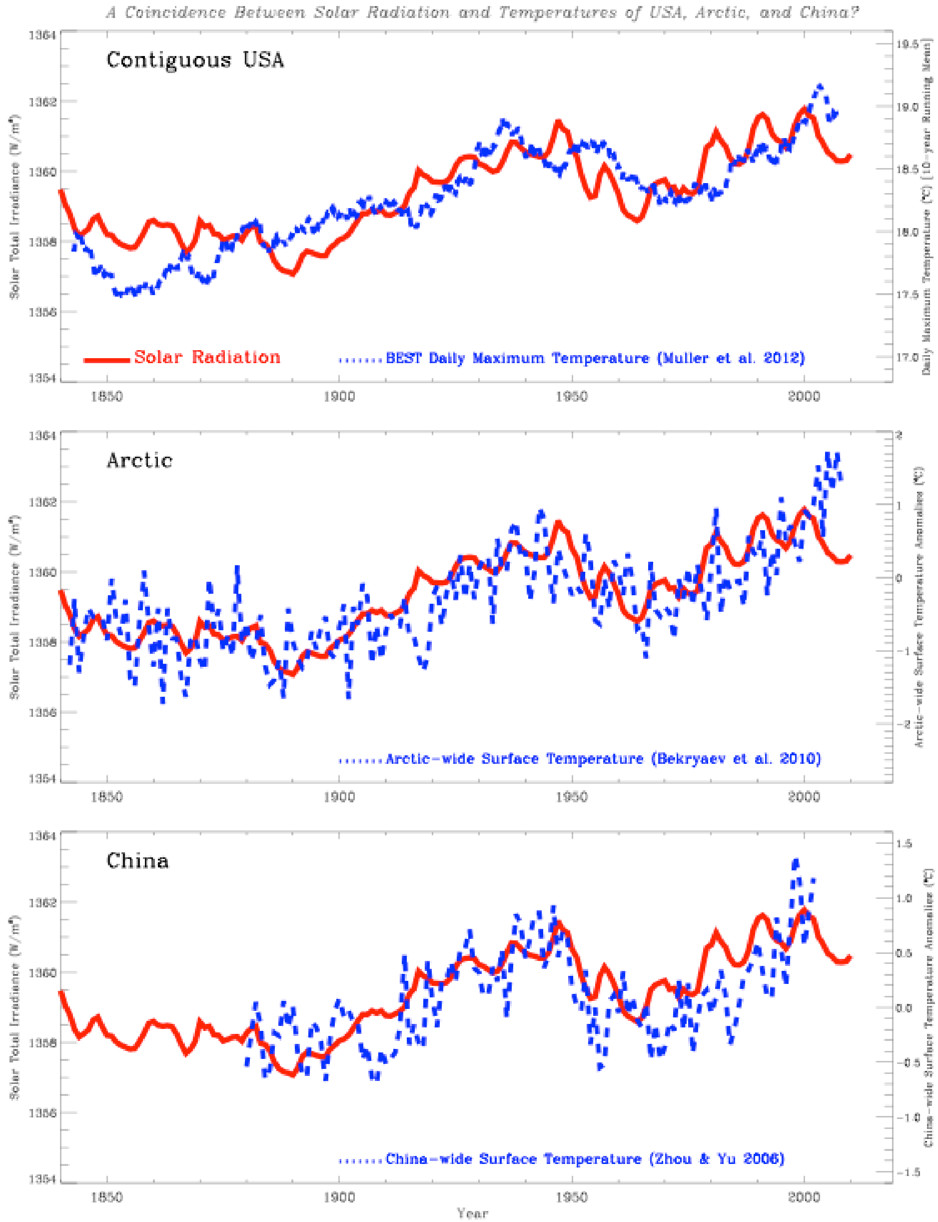

Figure 3: Three radically different climate regions compared with the Hoyt-Schatten TSI reconstruction: Top: Contiguous USA, Middle: Arctic (Soon, 2009) and bottom: China. (Soon et al., 2011)

Finally, the excellent relationship between the TSI and the Equator-to-Pole (Arctic) temperature gradient (EPTG) is displayed in figure 4. Increase in TSI is related to decrease in temperature gradient between the Equator and the Arctic. This may be explained as an increase in TSI results in an increase in both oceanic and atmospheric heat transport to the Arctic in the warm period since 1970.

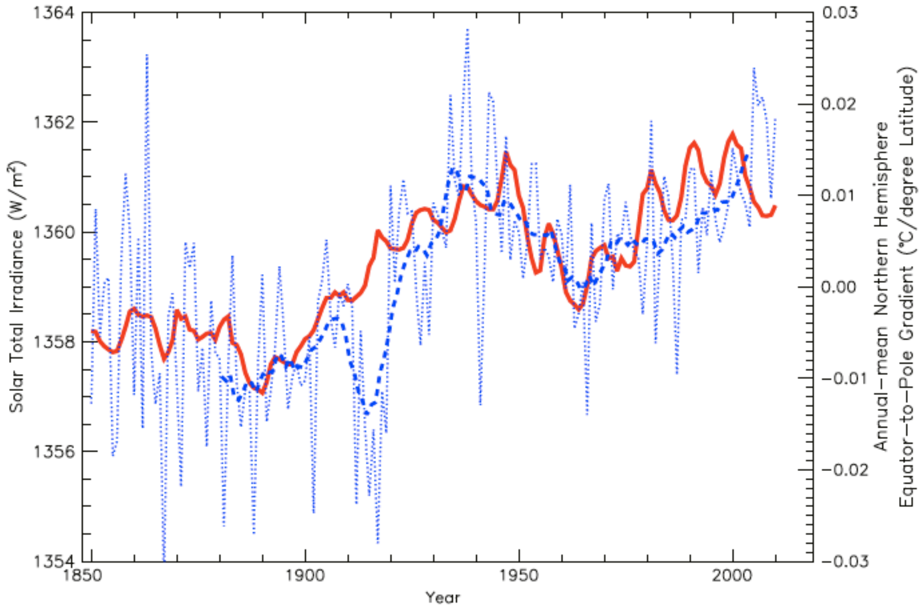

Figure 4: Annual-mean EPTG over the entire Northern Hemisphere (°C/latitude; dotted blue line) and smoothed 10-yr running mean (dashed blue line) versus the estimated TSI of Hoyt and Schatten (Soon and Legates, 2013).

My conclusion is that the Hoyt-Schatten-ACRIM is the "best" TSI reconstruction

Grand Solar Maximum in the 20th century

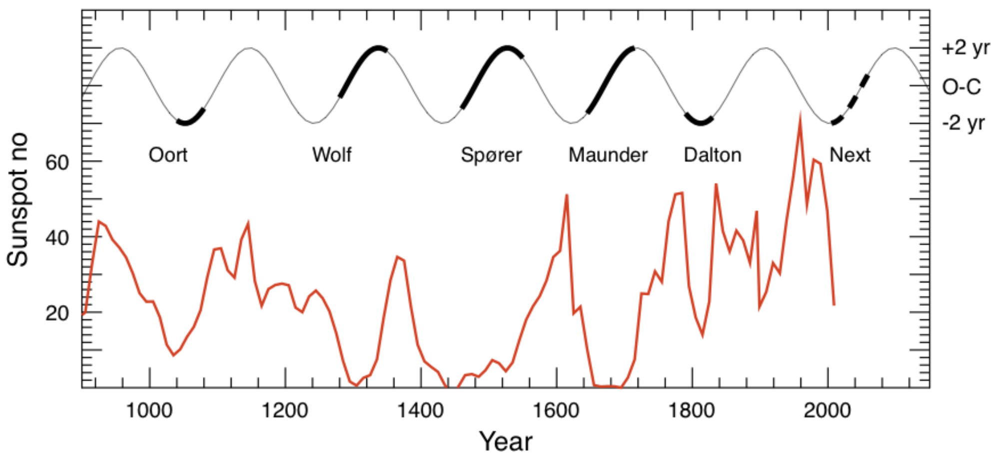

Figure 5: The upper panel shows the timing of sunspot minima related to an average period of 11.07 yr, determined from estimated sunspot minima since 1610 (Solheim, 2013b). Positive values means that the time of minimum is delayed with respect to the expected time. O-C means Observed minus Computed (expected) time of minimum. In the same curve solar minima the last 1000 yrs are marked with a thick line. The lower panel shows reconstructed 10-yr averaged sunspot numbers (Usoskin et al. 2007) and Hoyt-Schatten group sunspot no after 1615 and updated until 2015 with modern scaled sunspot numbers from SILSO (World Data Center for the production, preservation and dissemination of the international sunspot number).

As shown in Figure 5, lower panel, the 10-yr average sunspot no has never been as high the last 1000 yrs as in the last part of the 20th century. In the same graph I have shown a first harmonic component, with period 190 years, of the timing of sunspot minima. This period apparently controls the timing of sunspot minima. When this curve is near minima or is ascending, sunspot periods become longer, and arrive delayed. This was for the first time demonstrated by Richards et al. (2009).

From Figure 5 I conclude that we have had a Grand Solar Maximum in the 20th Century and that we are due to have a Grand Minimum during the next decades.

The Little Ice Age

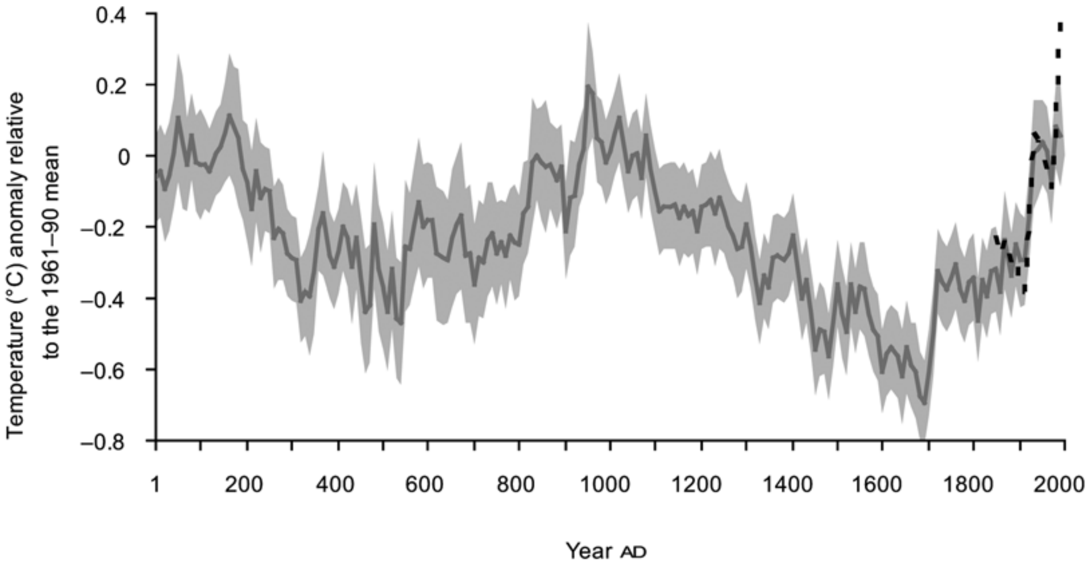

Figure 6: Estimates of extra-tropical Northern Hemisphere (90°-30°N) decadal mean temperature variations AD 1-1999 (dark grey line) with the mean variance adjusted CRUTEM3+HadSST2 mean values for the same area 1850-1999 (Ljungqvist 2010).

My preferred temperature reconstruction for the last 2000 years is Ljungqvist (2010) for the extra-tropical Northern Hemisphere as shown in Figure 6. This reconstruction utilizes many paleo-temperature proxies never before included in any large-scale temperature reconstruction. It shows clearly the Roman and Medieval warm periods. The difference between the warmest decade (950-959) and the coldest (1690-1699) is 0.9 °C in this reconstruction. The author admits there is a divergence problem also in his reconstruction, i.e. that the tree-ring growth shows lower temperature in the last decades of the 20th century than the thermometer measurements suggest. The author also concludes that the cooling during the Little Ice Age (LIA) probably is larger than his estimates, since the trees reflect summer temperatures, while other seasons may have cooled more.

Following Ljungqvist my conclusion is that the LYA NH extra-tropical temperature difference is more than one degree °C for a decadal average temperature compared with the last decade.

Correlation between global temperature and solar activity

Since the sunspot numbers are the longest series that relates to solar activity it has been used to correlate with the Earth's temperature and other climate parameters.

One of the newer attempts to correlate solar activity with climate is done by Stauning (2014). He finds a relation

$$\Delta T_A = 0.009\ (\pm 0.002) \times SSN_A - 0.70\ °C, \quad (1)$$

where SSN_A is the average sunspot number in a sunspot period and ΔT_A is the temperature anomaly for the same period shifted 3 yrs. The correlation calculated for cycles 10-21, excluding cycles 16-19 (which is the high level in the 20th century) is $r = 0.975$. If this relation is used to subtract the solar component of the temperature anomaly, he gets the following:

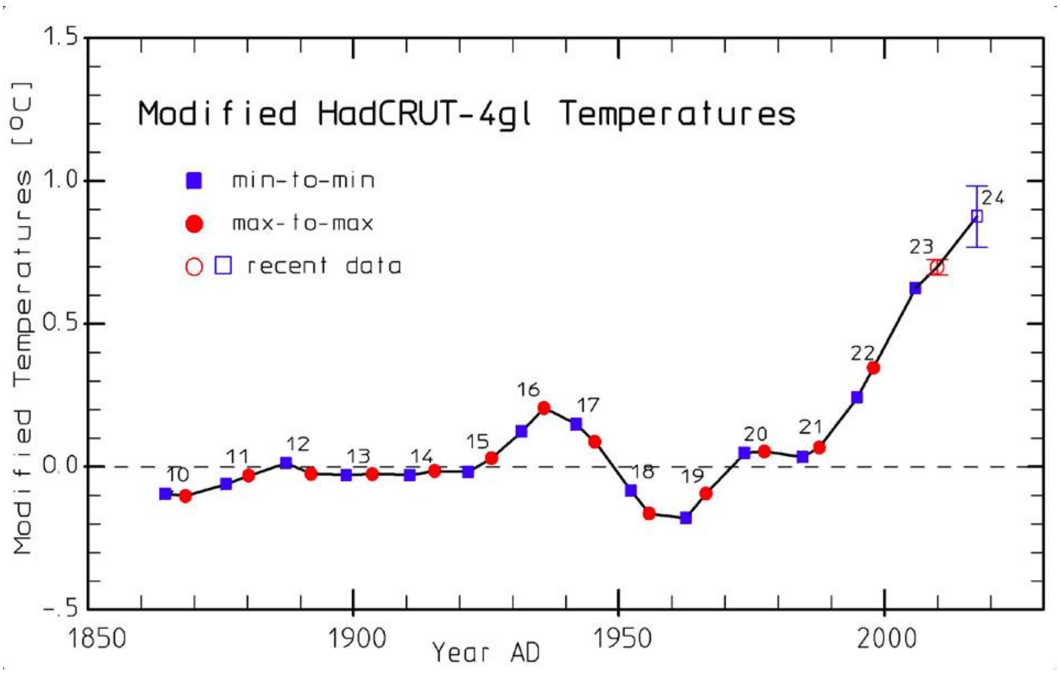

Figure 7: Cycle average global temperature anomalies (HadCRUT4gl) corrected for contributions from solar activity. (Stauning, 2014)

Stauning's conclusion is that the solar activity relation can explain the temperature anomaly in the period 1860-1990, but from then on another components appears. He concludes that the reduction in solar activity disguises a global temperature rise that otherwise would have happened.

Global temperature variation - attribution to the Sun

If all the warming up to 1990 is due to the Sun as proposed by Stauning (2014) in equation (1), this means that we have experienced about 0.5°C warming by the Sun in the period 1900-1990. After 1990 the reduced solar activity related to sunspots has disguised a warming of about 0.6°C (Figure 7), making the observed warming between the decades 1985-95 to 2003-13 only 0.3 °C.

However, this does not include effects of the longer cycles in TSI which peak around 1940 and 1995 (Figs 3 and 4), and the longer period of about 200 yr (fig 5), which controls the length of solar cycles. The change from shorter to longer cycles happened about the year 2000, and if one assume that a longer cycle imply more time for cooling, then the effect will appear some decades ahead. This is the same delayed effect we observe in the yearly cycle of warming/cooling of the Earth. In the Northern Hemisphere we have the minimum solar insolation on Dec 21, but the average temperature minimum appears on Feb 11, which is about 13 per cent time delay with respect to the yearly cycle. Power spectrum analyses of global and hemispherical temperature series shows that 60 and 20 yrs quasi-periodic oscillations are much stronger than the 11 yr sunspot period, and can be attributed to periodic forcing from the mayor planets Jupiter and Saturn (Scafetta 2013). These periods may dominate in the coming decades when the effects of the 11-yr cycle is reduced.

A fair part of the warming after 1990 may be due to the cleaning of the stratosphere of aerosols after the Pinatubo eruption in 1992. Observation of earthshine during lunar eclipses shows that the atmosphere now is very clean (Keen 2008; 2013) The difference in volcanic Aerosol Optical Thickness (AOD) since 1996 is estimated to $\Delta\tau$ = -0.033 which corresponds to ΔT=0.13°C (no feedback calculation). This is based on the relation between aerosol forcing and optical depth $F_a \approx -21\ \Delta\tau$, where F_a is the forcing in Wm^{-2} (Hansen et al. 2000).

If we want to compare insolation today with 1750, we have also to consider the effect of perihelion change. We are in the (lucky) situation that the Earth at present is in the perihelion position around Jan 4th. The difference between the date of perihelion and solistice shifts with one day every 57 or 58 years. This has caused the solar flux on the Earth at the time of vernal spring to increase with 0.24 per cent since 1750. This is significant when compared with the apparent AGW contribution of 0.12 (AR4) or 0.17 per cent (AR5). The increased insolation results in earlier snow melting, which again changes the albedo such that more heat from the Sun is absorbed. This is a non-linear effect that adds heat to the Earth. Steele (2014) has shown that the insolation changes because of Earth orbit change used in climate models are wrongly modeled, and the result as he writes is “worse than useless”, and this needs to be corrected before a difference between the solar forcing around 1750 and now can be realistic estimated in climate models.

Amplification processes

The relations between solar variations and Earth climate are many and complicated. Most of them work locally and regionally, and many are non-linear. The following chart (Figure 8) gives an idea of some of the interactions. In particular I find that the planetary gravity beats are interesting since we may detect periods that are related to orbits of the moon and planets, as demonstrated by Scafetta (2013) and others (Solheim, 2013a). Scafetta (2012) has proposed a physical mechanism for amplification of tiny gravitational interactions by modulation of nuclear reactions in the solar interior. This may generate gravity waves which are transmitted to the solar surface. Such signals are observed in TSI variations (Scafetta and Willson, 2013) and may be imbedded in the solar wind that interacts with cosmic rays that hits the Earth. Variations in cosmic rays may again contribute to cloud formation as proposed by Svensmark (2007) and collaborators. Even if the route from planets to Earth is long and crooked, we are extremely good in detecting periodic signals that may point to a connection.

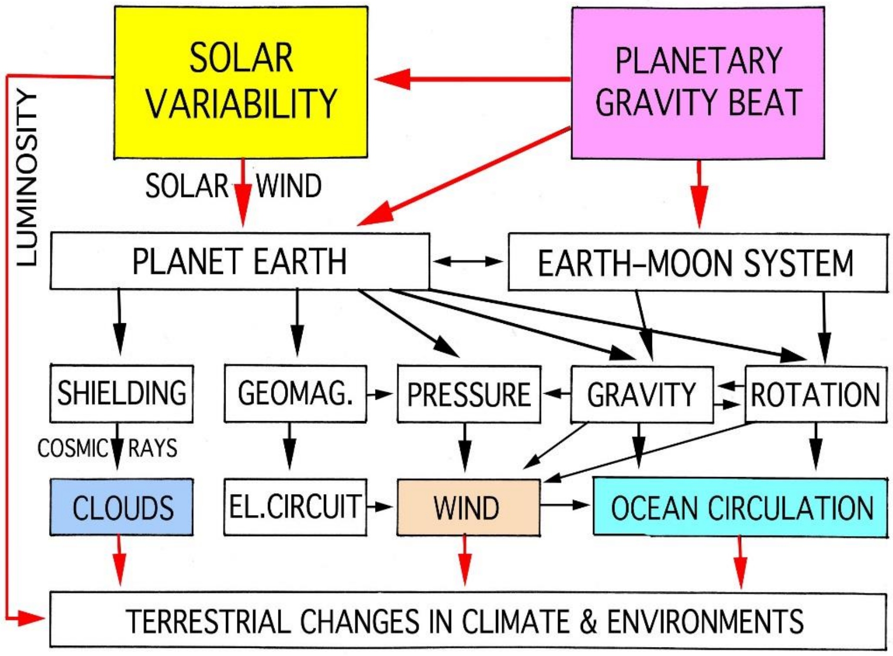

Figure 8: The interaction between planetary beat and solar variability, and changes in climate and environments on the planet Earth (Mörner, 2012)

A new Maunder Minimum?

In the previous sections I have listed a few facts that may help us estimate the solar influence on climate in the next decades:

- We are close to a peak in the 1000yr temperature cycle, which has given the Roman and Medieval warm periods (Figs 1 and 3).
- The modern maximum of the millennium quasi-periodic cycle takes place around 2060. This makes a solar minimum less dramatic than in the Maunder Minimum period, which appeared in a minimum of the millennium cycle.
- A non-solar component of the order 0.1-0.2°C has to be included (Fig .7).
- Since the stratosphere now is clean, and volcanic eruptions that affect the stratosphere happens a few times per century, are unpredictable, we may expect volcanic cooling of the order 0.1-0.2°C in the future.
- The quasi period of about 60 yr will be in cooling direction the next 30 yrs.
- The sunspot cycle will be longer in 21th Century, indicating a cooler climate (Fig 5).
- The pattern of minima the last 1000 yr (Fig. 5-upper panel) indicates that a new minimum is to be expected the coming decades.

Evaluating these parameters, I arrive at the conclusion that the global temperature may during the next solar deep minimum fall to a level slightly higher than around 1900 which means -0.6 ±0.2 °C relative to the last decade.

Biosketch

Jan-Erik Solheim is a retired professor from University of Tromsø, Norway. He received his Cand. Real. degree in Astrophysics from University of Oslo in 1964. He has worked with cosmological models and observational astrophysics during several visits to University of Texas, Department of Astronomy, the McDonald Observatory and other institutions. From 1971 to 2002 he had a position at the Institute for Physics and Technology at the University of Tromsø, where he became interested in fast photometry and detection of signals from pulsating and interacting stars. He participated in establishing the Nordic Optical Telescope at La Palma, Spain and participated in coordinated world wide observing campaigns (Whole Earth Telescope) from 1987. After retirement he has worked as an independent scientist on some aspects of relations between the Sun and Earth and the possibility of detecting signals from planets in solar and climate variations.

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