Re Soon's 2005 GRL paper on solar variability…report to be added to our critique of the Robinson, Robinson and Soon 2007 paper - by Dave Lowe, Peter Barrett and Lionel Carter (LBC)

In our critique (9 June 08) of the Robinson, Robinson and Soon, 2007 paper we pointed out what appeared to be large unresolved discrepancies between Soon's 2005 Geophysical Research Letters paper on solar irradiance and other peer reviewed literature on the subject. In particular we noted that Soon's 2005 paper was not cited in the AR4 WG1. We asked an expert on the Earth's magnetosphere and solar irradiance, Dr Bill Allan, to provide us with an opinion on the discrepancies between Soon's paper and other literature. His full report follows this summary by us of his main points.

To summarise Bill Allan makes the following points:

1) Total solar irradiance (TSI) has only been measured directly by satellites since 1978. The measurements are very precise (see stats in legend of figure 1) and show a very small variation; only +/- 0.45 Wm^2 about a mean of 1366 Wm^2 for each of the almost three complete solar cycles observed in the 30 years of measurements.
2) Soon's 2005 paper is based on a reconstruction of TSI (from Hoyt and Schatten 1993) using a semi empirical model based on proxies e.g. sun spot numbers. A critical test of the validity of a reconstruction is how well it simulates the precisely measured TSI over the last 30 years. The reconstruction used by Soon (2005) grossly overestimates TSI measured by satellites by more than 5 Wm^{-2} and its variability by a factor of more than five.
3) Reconstructions of TSI by Wang et al (2005) are both consistent with satellite measurements and also reproduce past radio carbon and ^{10}Be records of solar variability. It is these reconstructions as well as the actual satellite measurements of TSI which are used in the AR4 by the IPCC.

Hence after reading Bill Allan's report we assume that the IPCC did not consider Soon's 2005 paper for two reasons. A) The model used was considered to be obsolete B) the model could not predict either absolute TSI or its variance as measured by satellites over the last 30 years. We have written to the IPCC authors involved in this section of the AR4 WG1 and will let you know their response when we hear back from them.

LBC 17 June 2008

Comments on the Total Solar Irradiance reconstruction used by Soon (2005)

W. Allan, BSc (Hons), PhD (St Andrews)
26 Patrick Street
Petone
New Zealand

Version 2 - 16 June 2008

Introduction

Total Solar Irradiance (TSI) has been measured accurately for only 30 years, since the advent of spacecraft with suitably calibrated instruments (although less accurate and more sporadic measurements were made earlier). Time series of TSI including years significantly earlier than 1978 are *reconstructions*, i.e., semi-empirical models of what TSI might have been. A semi-empirical model attempts to combine several *proxies* of TSI, such as sunspot number or the relationship of the Sun to the variability of nearby Sun-like stars, into an estimate of past TSI. The relationship of TSI to these proxies is usually not physically well defined, so the reconstruction generally relies on some weighted combination of factors that are in themselves more or less uncertain. The critical test of such a reconstruction must be how well it reproduces the well-measured TSI since 1978, a period that includes nearly 3 sunspot cycles. This is shown in Figure 1, which is also Figure 1 of Foukal et al. (2006).

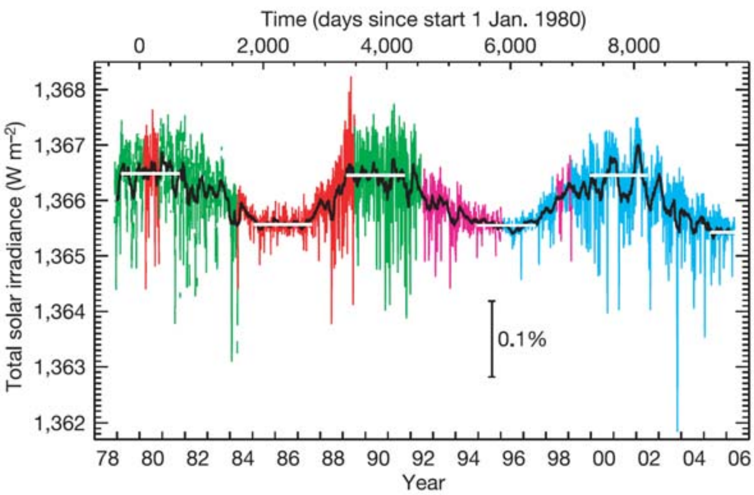

Figure 1 | Temporal variation of total solar irradiance, as measured by radiometers on several spacecraft since 1978. Daily measurements are shown with a 81-day running average. The TSI increases around the maxima of sunspot number that occurred near 1980, 1990 and 2001. The high-frequency variation is caused by the changing projected areas of spots and faculae on the solar disk as the Sun rotates on its axis in approximately 27 days. The TSI variation amplitudes of the three sunspot cycles shown (horizontal lines) are 0.92, 0.89 and 0.90 W m^{-2}, respectively, with an average minimum of 1,365.52 ± 0.009 W m^{-2} and differences of the minima from this average of +0.051, +0.037 and −0.089 W m^{-2}.

It can be seen that the measured TSI varies over the solar cycle between about 1365.5 Wm^{-2} and 1366.4 Wm^{-2}.

The Hoyt and Schatten (1993) TSI reconstruction

Hoyt and Schatten (1993) created a reconstruction of TSI using five proxies, namely sunspot cycle amplitude, solar equatorial rotation rate, sunspot cycle length, fraction of penumbral spots, and decay rate of the 11-year sunspot cycle (none of which are directly related to TSI). The resulting reconstructed TSI time series is shown in the top panel of Figure 2, which is Figure 1 of Soon (2005). Note that the final 8 years of the reconstruction are from an unpublished update by D. Hoyt, 2005.

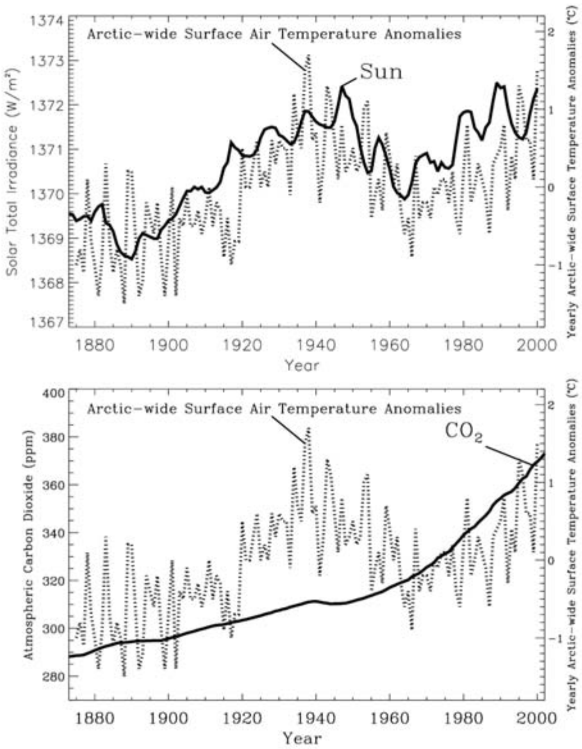

Figure 1. Annual-mean Arctic-wide air temperature anomaly time series (dotted lines) correlated with the estimated total solar irradiance (top panel; solid lines) and with the atmospheric carbon dioxide, CO_2, mixing ratio (bottom panel; solid lines) from 1875 to 2000.

Figure 2. [Figure 1 of Soon (2005)]

Note that the mean value of the reconstructed TSI since 1978 in the top panel of Figure 2 is about 1371.5 Wm^{-2}. This is a very much larger than the measured mean value of about 1366 Wm^{-2} shown in Figure 1, and is a factor of 5 outside the measured range of TSI variability over 3 solar cycles. Thus the Hoyt and Schatten (1993) reconstruction fails the crucial test of being able to reproduce the measured TSI since 1978. Waple et al. (2002) say “Doubts have been raised (Fröhlich and Lean 1998) regarding the reliability of Hoyt and Schatten’s (1993) means of estimating solar irradiance, due both to the underlying assumptions regarding solar physics, and the observation that the HS93 solar irradiance overestimates the actual irradiance increase over the past decade recorded in calibrated satellite measurements (and may therefore falsely attribute too much of the recent warming to solar forcing in correlation-based studies)".

Waple et al. (2002) also state "Our faith in the Lean et al. (1995) series in particular, is also based on striking similarities with independent estimates of solar activity from cosmogenic isotopes measured in ice cores (^{10}Be and ^{14}C) which should also reflect such variability for solid physical reasons (McHargue and Damon 1991). While the distinction between the two reconstructions is relatively unimportant in modelling studies, which seek to diagnose self-consistent relationships between forcing and response, it is quite important in empirical analyses which rely on the fidelity of estimates of past solar variability to diagnose their impact on past climate".

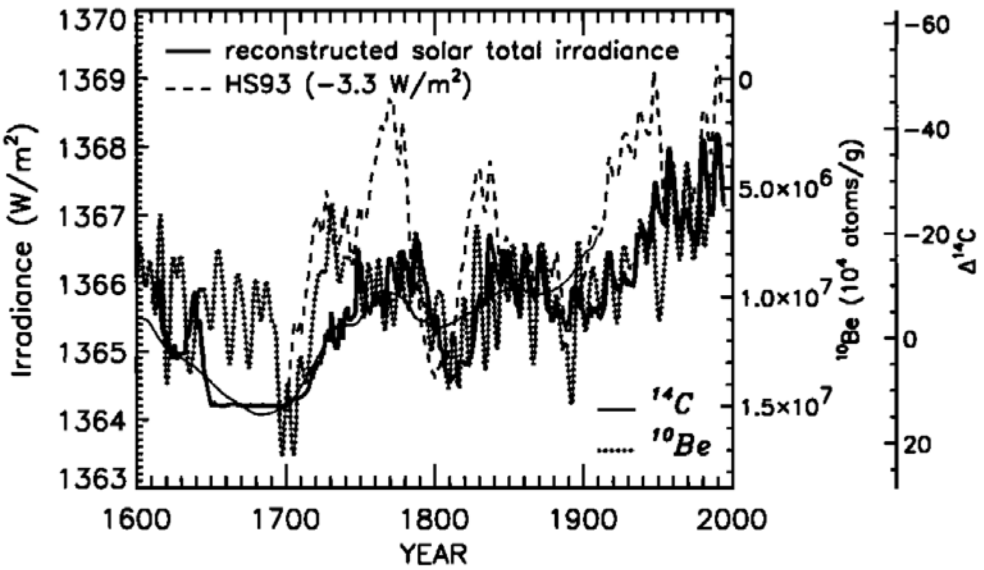

Figure 3. Tree-ring ^{14}C and ice-core ^{10}Be cosmogenic isotope records of solar variability are compared with reconstructed solar total irradiance and with the irradiance reconstruction of Hoyt and Schatten [1993] (HS93) which has a long term component based on Schwabe cycle length (rather than average amplitude).

Figure 3 (from Lean et al., 1995) shows the comparison discussed above. Note that the Hoyt and Schatten (1993) reconstruction has had to be reduced by 3.3 Wm^{-2} to get it on the same graph as the Lean et al. (1995) reconstruction. Lean (2000) developed a further reconstruction based on measured variability of the Sun's spectral irradiance and a comparison with irradiance variability in Sun-like stars. This appeared to do a somewhat better job than the Lean et al. (1995) reconstruction in estimating TSI in the twentieth century.

The Wang et al. (2005) TSI reconstruction
(based on Section 2.7.1.2.1 of Forster et al., 2007)

TSI reconstructions such as those of Hoyt and Schatten (1993), Lean et al. (1995), and Lean (2000) assumed the existence of a long-term variability component in the solar output in addition to the known 11-year cycle. The time-varying structure of this long-term component, typically associated with the evolution of faculae (bright patches associated with sunspots), was assumed to track either the smoothed amplitude of the solar activity cycle or the cycle length. There were three reasons for assuming this: (1) the range of variability in Sun-like stars; (2) the long-term trend in geomagnetic activity; and (3) solar modulation of cosmogenic isotopes. These all suggested that the Sun is capable of a broader range of activity than witnessed during recent solar cycles (shown in Figure 1).

Each of the above three assumptions for the existence of a significant long-term irradiance component is now questionable. For example, the sun is now thought to have “typical” (rather than high) activity relative to other stars. There may also be long-term instrumental drifts in historical indices of geomagnetic activity. Furthermore, the relationship between solar irradiance and geomagnetic and cosmogenic indices is complex, and not necessarily linear.

These considerations inspired a new reconstruction of TSI based on a model of solar magnetic flux variations (Lean et al., 2002; Wang et al., 2005), which does not invoke geomagnetic, cosmogenic or stellar proxies. This reconstruction suggests that the amplitude of the background component of variation is significantly less than previously assumed, specifically 0.27 times that of Lean (2000). This estimate results from simulations of the eruption, transport, and accumulation of magnetic flux during the past 300 years using a flux transport model with variable meridional flow. The estimated open flux (extending into the heliosphere) compares reasonably well with the cosmogenic isotopes for which variations arise, in part, from heliospheric modulation. This gives confidence that the approach is plausible. A small accumulation of total flux (and possibly ephemeral regions) produces a net increase in facular brightness, which in combination with sunspot blocking, permits the reconstruction of TSI shown in Figure 4. The blue shading shows the range of TSI inferred from the reconstruction of Lean (2000). The assumed large long-term component in that work (and in reconstructions like Hoyt and Schatten, 1993) gives a very much larger variability in time than the new Wang et al. (2005) reconstruction shown in red in Figure 4.

The Wang et al. (2005) reconstruction seems much more plausible than earlier reconstructions, as it relies on reasonably well-known physical processes in the solar atmosphere rather than speculative proxies such as solar cycle length or the Sun’s relationship to other stars.

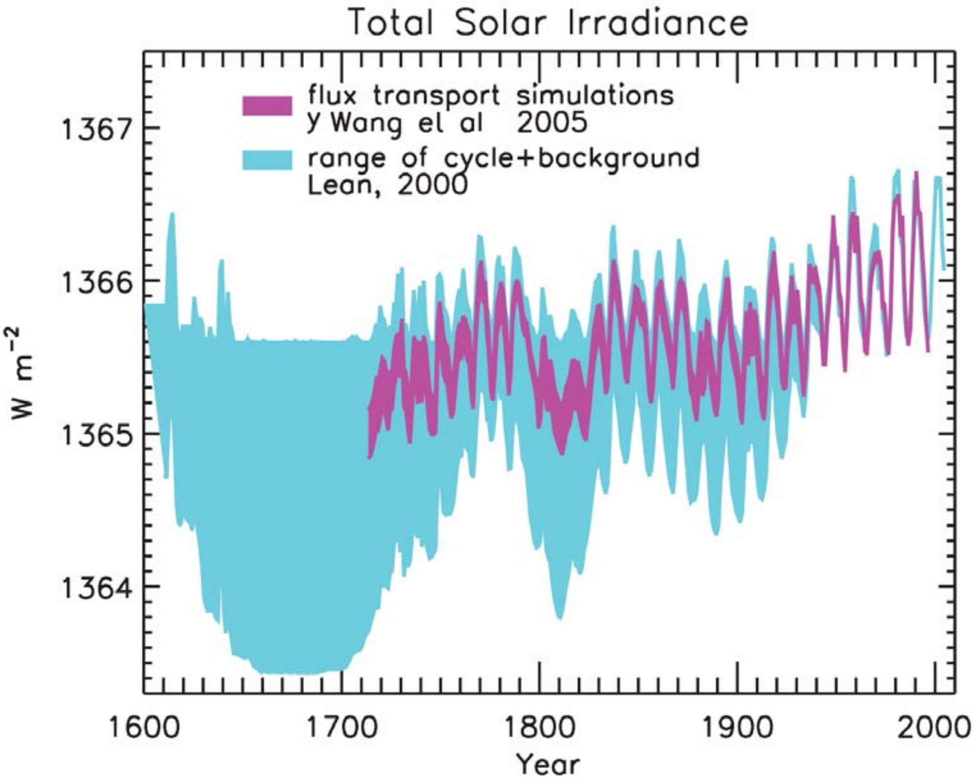

Figure 2.17. *Reconstructions of the total solar irradiance time series starting as early as 1600. The upper envelope of the shaded regions shows irradiance variations arising from the 11-year activity cycle. The lower envelope is the total irradiance reconstructed by Lean (2000), in which the long-term trend was inferred from brightness changes in Sun-like stars. In comparison, the recent reconstruction of Y. Wang et al. (2005) is based on solar considerations alone, using a flux transport model to simulate the long-term evolution of the closed flux that generates bright faculae.*

Figure 4. [Figure 2.17 of Forster et al., 2007].

Conclusion

A major objective of this discussion is to emphasise that proxy reconstructions of Total Solar Irradiance are inherently speculative semi-empirical models, and should not be confused with real measurements. For example, the reconstruction of Hoyt and Schatten (1993) fails the crucial test of reproducing the accurate TSI measurements made since 1978, and in fact grossly overestimates the TSI during this period. The new physically-based TSI reconstruction of Wang et al. (2005) also shows that the Hoyt and Schatten (1993) reconstruction almost certainly greatly overestimates the likely variability of TSI since 1880. Therefore Soon's (2005) correlation of the Hoyt and Schatten (1993) TSI with the annual-mean Arctic air temperature shown in the top panel of Figure 1 appears at best to be coincidental, as the displayed TSI reconstruction must be considered to be very unreliable. It should be noted that reconstructed proxy models of TSI have inherently much less physical basis than, for example, the climate models used by the Inter-governmental Panel on Climate Change.

References

Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 2007: Changes in Atmospheric Constituents and in Radiative Forcing. *In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p. 190.

Foukal, P.; Frölich, C.; Spruit, H; Wigley, T.M.L. (2006). Variations in solar luminosity and their effect on the Earth's climate. *Nature 443:* 161–166

Fröhlich, C.; Lean, J. (1998). The sun's total irradiance: cycles, trends and related climate change uncertainties since 1976. *Geophysical Research Letters 25:* 4377–4380

Hoyt, D.V.; Schatten, K.H. (1993). A discussion of plausible solar irradiance variations, 1700–1992. *Journal of Geophysical Research 98:* 18895–18906.

Lean, J. (2000). Evolution of the Sun's spectral irradiance since the Maunder Minimum. *Geophysical Research Letters 27:* 2425–2428.

Lean, J.; Beer, J.; Bradley, R. (1995). Reconstruction of solar irradiance since 1610: Implications for climate change. *Geophysical Research Letters 22:* 3195–3198.

Lean, J.L.; Wang, Y.M.; Sheeley, N.R. (2002). The effect of increasing solar activity on the Sun's total and open magnetic flux during multiple cycles: Implications for solar forcing of climate. *Geophysical Research Letters 29:* 2224, doi:10.1029/2002GL015880.

McHargue, L.R.; Damon, P.E. (1991). The global beryllium 10 cycle. *Reviews of Geophysics 29:* 141–158.

Soon, W.-H. (2005). Variable solar irradiance as a plausible agent for multidecadal variations in the Arctic-wide surface air temperature record of the past 130 years. *Geophysical Research Letters 32:* L16712, doi:10.1029/2005GL023429.

Wang, Y.M.; Lean, J.L.; Sheeley, N.R. (2005). Modeling the sun's magnetic field and irradiance since 1713. *Astrophysical Journal 625:* 522–538.

Waple, A.M.; Mann, M.E.; Bradley, R.S. (2002). Long-term patterns of solar irradiance forcing in model experiments snd proxy based surface temperature reconstructions. *Climate Dynamics 18:* 563–578.