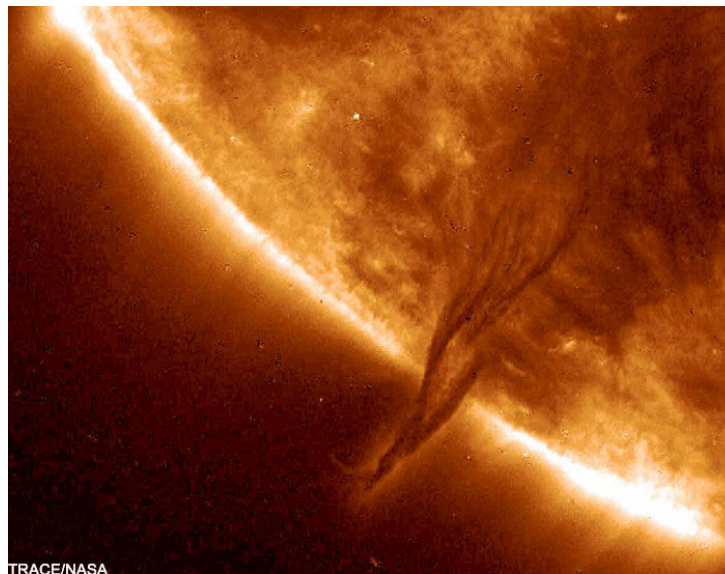


THE “UNRULY SUNNE” CANNOT BE RULED OUT AS A CAUSE OF RECENT CLIMATE VARIATION

Five serious scientific errors in Lockwood and Frohlich (2007)

August 2007



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Five serious scientific errors in Lockwood and Frohlich (2007)¹

*Busie old foole, unruly sunne, why dost thou thus
Through windowes and through curtaines call on us?
... Thine age askes ease and, since thy duties bee
To warme the world, that's done in warming us.
- John Donne, “The Sunne Rising”*

On July 10, 2007, the Royal Society, one of the oldest scientific institutions in the world, published *Recent oppositely-directed trends in solar climate forcings and the global mean surface air temperature* by Lockwood and Frohlich. In the web-page of the journal (Fig. 1), the Society calls the paper “The truth about global warming!”² and says, “The sun is not a factor in recent climate change!”

Figure 1

*The contents page of
“Proceedings of the Royal
Society A”, 10 July 2007,
expressing the journal’s
editorial opinion (arrowed)
on a paper by Lockwood and
Frohlich (2007).*

PROCEEDINGS OF THE ROYAL SOCIETY A | MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Journal summary

Proceedings A publishes refereed research articles in the mathematical, physical and engineering sciences. The emphasis is on new, emerging areas of interdisciplinary and multidisciplinary research. The Editor will also consider short reviews, but only if they contain original and interesting new ideas.

Latest news

The truth about global warming! ←

The sun is not a factor in recent climate change! [Click here](#) to read the article.
To find out more about the author [click here](#).

Some scientists hastily and publicly endorsed³ the paper's conclusions, perhaps without having fully considered the implications of their enthusiastic and sweeping endorsements. For instance:

"These findings completely refute the allegations made by some pseudo-scientists that all recent global warming is due to solar effects."⁴

"This paper is the final nail in the coffin for people who would like to make the Sun responsible for present global warming."⁵

"That's a coffin with so many nails in it already that the hard part is finding a place to hammer in a new one."⁶

Nature magazine's climate blog said:

"To further confuse things and the public, solar changes do seem to have had an impact on past climates. Moreover, it is at least not impossible that cosmic ray intensity does influence clouds and climate. There's nothing wrong with investigating these things — that's how science goes. But blaming the sun for recent global warming is no science-backed position anymore — it is deliberate disinformation."⁷

A spokesman for the Royal Society said:

"This is an important contribution to the scientific debate on climate change. At present there is a small minority which is seeking to deliberately confuse the public on the causes of climate change. They are often misrepresenting the science, when the reality is that the evidence is getting stronger every day. We have reached a point where a failure to take action to reduce carbon dioxide and other greenhouse gas emissions would be irresponsible and dangerous."⁸

The Guardian, a UK newspaper, quoted Professor Lockwood, the lead author, as saying his paper –

"was another nail in the coffin of the notion that solar activity is responsible for global warming."⁹

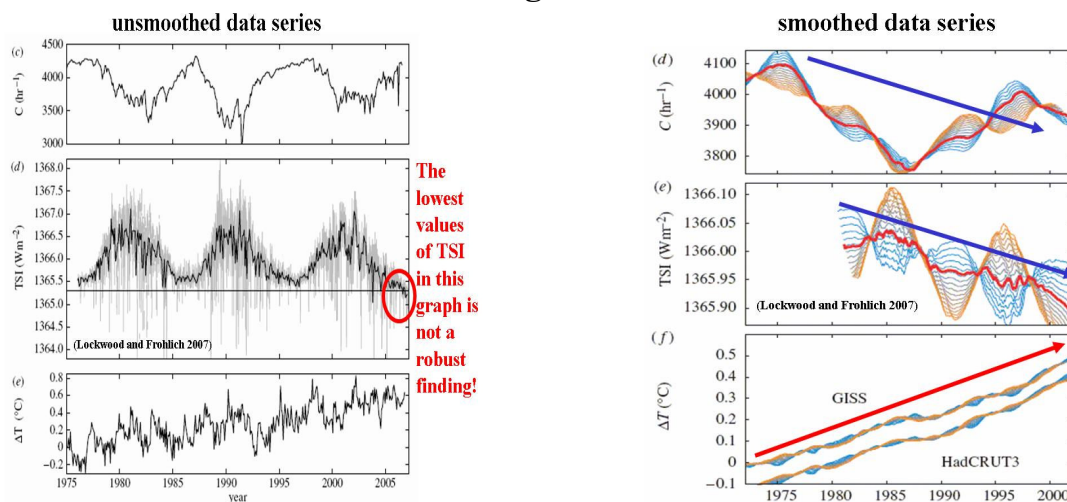
In effect, then, the Professor was declaring that his paper was intended to reach a particular political as opposed to scientific conclusion.

It is, therefore, important to find out what the paper actually demonstrates, and to reassess the validity and strength of its conclusion. Was it really a science-based conclusion, and did the conclusion logically follow from the data presented?

We now document five serious scientific problems in the paper's conclusion that solar climate forcings, "no matter how much the solar variation is amplified," are "oppositely" trended with respect to the observed increase in mean global surface air temperature observed from 1975 to 2006 and accordingly cannot "explain the observed rise in global mean temperatures."

We begin with the key evidence presented by the authors, which is summarized in Fig. 2:

Figure 2



The original (left) and smoothed (right) data series from Lockwood & Frohlich (2007): cosmic-ray intensity index C (top); total solar irradiance TSI (middle); and global temperature (bottom) from the Goddard Institute for Space Studies and the Hadley Centre.

Fig. 2 is intended to tell us that the two key solar activity-related parameters, cosmic-ray intensity index, and total solar irradiance are trending downward while the global surface temperatures is trending upward. Lockwood and Frohlich (2007) are suggesting that since both of the smoothed solar parameters have decreasing trends, it is impossible to attribute recent global warming trends to the Sun.

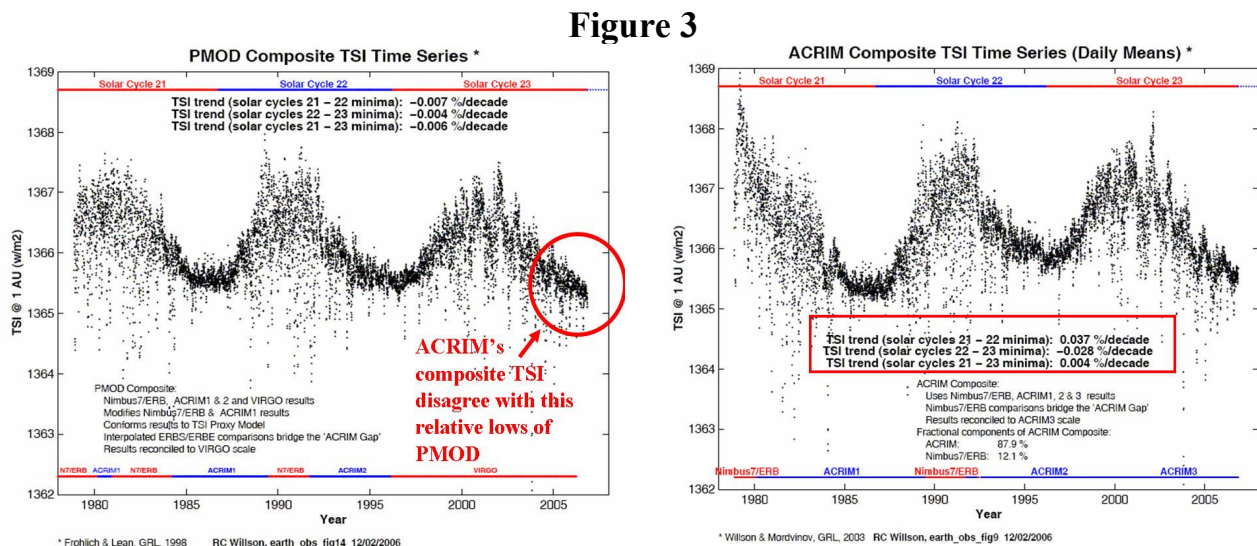
Setting aside several complex but important issues related to climate forcings and related climatic feedbacks discussed in science journals and IPCC reports, we shall show that the authors' seemingly robust conclusion that there is no link between solar activity and global warming in the past 30 years is dubious, and contains errors of data, of logic, and of omission.¹⁰

Problem 1: Undue dependence of the authors' smoothed TSI dataset upon the start and end dates

In the datasets chosen by Lockwood and Frohlich, the smoothed downward trend calculated by the authors for total solar irradiance (TSI) (Fig. 2, right middle panel) is highly sensitive to the non-unique unsmoothed dataset used. More importantly, the downward trend apparent in the smoothed series calculated by the authors is critically dependent on the start and end dates of the unsmoothed data series. This is crucial, given that the total TSI series is *only* 30 years in duration. The net downward trend shown by the smoothed TSI series is partly related to the slight dip in the unsmoothed TSI values around 2005 through the 2006 endpoints (Fig. 2, left middle panel, circled in red) which has no independent confirmation.

Problem 2: Selection of a source dataset inconsistent with other such datasets in the literature

Compare the authors' TSI dataset (Fig. 3, left panel, dataset marked "PMOD") with that of Dr. Richard Willson, the director of the long-running Active Cavity Radiometer Irradiance Monitor (ACRIM) project and designer of the ACRIM satellites¹¹ (Fig. 3, right panel):

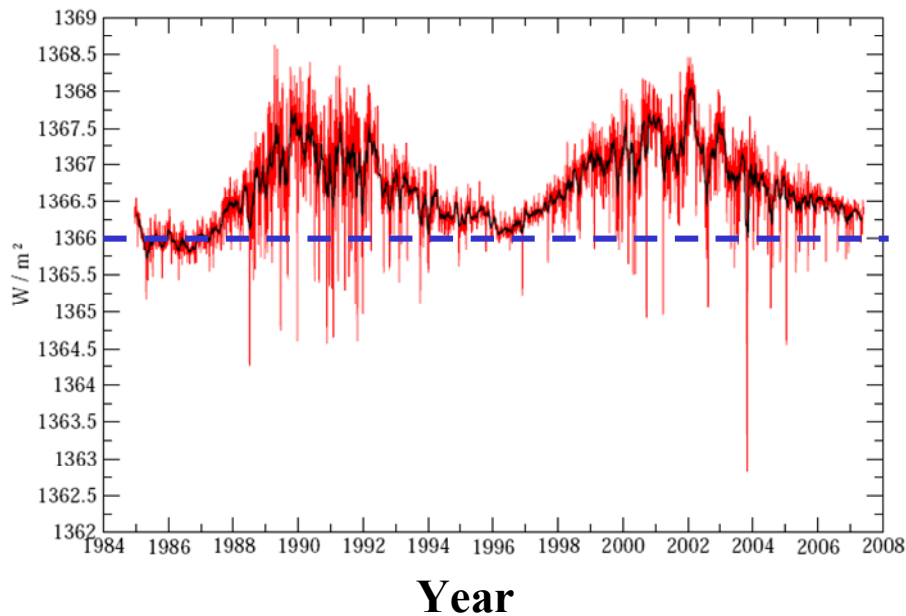


Lockwood & Frohlich's PMOD total solar irradiance (TSI) dataset (left), compared with the ACRIM dataset of Willson (right). Note the discrepancy between the recent data minimum in the PMOD and ACRIM datasets.

Fig. 3 demonstrates that other reconstructions of total solar irradiance, as respectable as that taken by Lockwood and Frohlich (2007), yield different results. In the ACRIM TSI dataset, for instance, there is actually a slight tendency toward neutral or even TSI at the solar minima as

indicated by Willson. Lockwood and Frohlich (2007) may accordingly have “cherry-picked” both their dataset and data intervals to provide a basis for their contention that the TSI series has a downward trend.

Figure 4
RMIB TSI Composite



The total solar irradiance (TSI) dataset (updated through the end of May 2007) from the Royal Meteorological Institute of Belgium (RMIB) also could not confirm the low values of TSI around 2005-2007 shown by Lockwood & Frohlich’s PMOD series.

Fig. 4 shows yet another independent reconstruction of total solar irradiance by the Royal Meteorological Institute of Belgium (RMIB)¹² that simply could not confirm the extreme low TSI values around 2005-2007 shown by Lockwood and Frohlich (2007). The difference between the RMIB and PMOD composite TSI series is especially noteworthy because both records are based on instruments onboard the same spacecraft. If nothing else, Lockwood and Frohlich (2007) is at least obligated to inform their readers of such a difference.

Problem 3: Omission of correlations between fluctuations in solar activity and in temperature

Though Lockwood and Frohlich present data indicating no correlation between solar and temperature variability, such correlations have been recently reported.

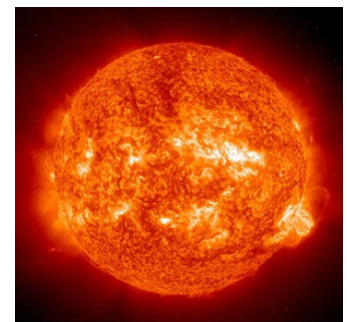
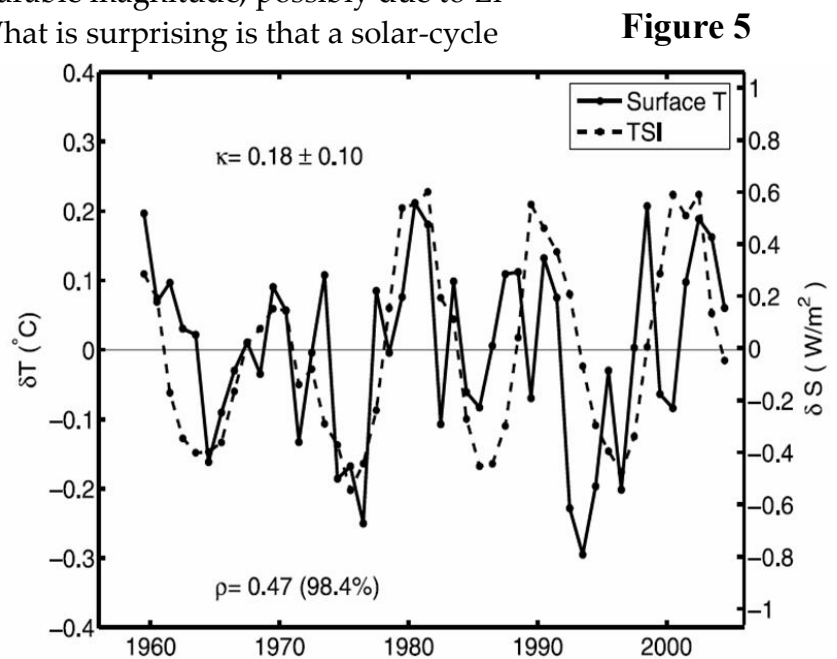


Fig. 5, for instance, documents an interesting new result by Camp and Tung (2007)¹³ demonstrating a correlation between the 11-year solar activity cycles and the global surface temperature variations during more than half a century between 1959 to 2004:

"Since the [solar] forcing is global, theoretically one should expect a global-scale response. When globally and annually averaged and detrended, but otherwise unprocessed, the surface air temperature since 1959 (when the modern radiosonde network was established) is seen in [Fig. 5 of SPPI report here] to have an interannual variation of about 0.2°K, somewhat positively correlated with the solar cycle, although the signal also contains a higher frequency (of 3-5 year period) variation of comparable magnitude, possibly due to El Niño-Southern Oscillation (ENSO). What is surprising is that a solar-cycle

signal is already apparent in this "raw" data. An isospectral Monte-Carlo test shows that the correlation coefficient, $\rho = 0.47$, between the global temperature and the TSI is statistically significant at 98.4% confidence level. This is obtained without any filtering of the global mean signal, and gives confidence that the solar signal is not an artifact of our filtering to be presented below."

Half a century of correlation between solar activity (TSI) and detrended global mean surface air temperature (T). From Camp and Tung (2007).



The availability of scientific results such as those of Camp and Tung suggests that Lockwood and Frohlich have founded their conclusion upon selected data, and that conclusions other than theirs are possible.

Problem 4: The data on cosmic-ray forcing demonstrate the opposite of the authors' conclusion

Svensmark *et al.* (2007a)¹⁴ and Svensmark (2007b)¹⁵ advance the hypothesis that cosmic rays influence cloud formation,



and that when the solar wind deflects cosmic rays away from Earth an additional solar-moderated forcing arises. Lockwood and Frohlich have referenced Svensmark's paper but have made inappropriate deductions, reaching a conclusion opposite from what Svensmark's hypothesis actually suggests. Lockwood and Frohlich say:

"For the cosmic ray mechanism, it has been proposed that the long-term decline in cosmic rays over much of the twentieth century ... would cause a decline in global cover of the low-altitude clouds, for which the radiative forcing caused by the albedo decrease outweighs that of the trapping effect on the outgoing thermal long-wave radiation."

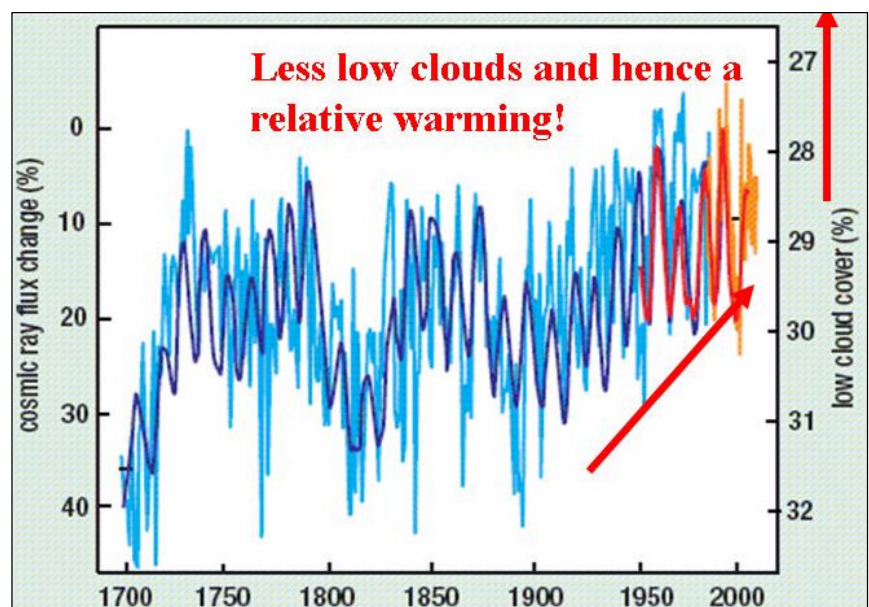
The authors, however, fail to quote the logical conclusion drawn by Svensmark (2007b), even though they cited this reference:

"Here is *prima facie* evidence for suspecting that much of the warming of the world during the 20th century was due to a reduction in cosmic rays and low-cloud cover."

Fig. 6 documents the evidence discussed in Svensmark (2007) about the relation between increasing cosmic-ray flux, at the relevant high-end range of energies, and the formation of more low clouds, and the corresponding inverse relation when there are fewer incoming energetic cosmic rays.

Figure 6

Changes in the flux of galactic cosmic rays since 1700, derived from two independent proxies, ¹⁰ (light blue) and open solar coronal flux (dark blue), taken from Solanki and Fligge (1999). Low cloud amount (orange), is scaled and normalized to observational cosmic-ray data from Climax (red) for 1953 to 2005, with a 3 GeV cutoff. Both scales are inverted to correspond with rising temperatures. The magnitude of the long-term change in mean cosmic-ray flux is equivalent to that of the intra-cyclical solar variation. The change in radiative forcing resulting from a 3% change in low-cloud amount over this half-century is estimated at $\sim 2 \text{ Wm}^{-2}$ (from Svensmark, 2007b).



As Fig. 6 demonstrates, the evidence for a decreasing trend in cosmic-ray intensity shown in Fig. 2 implies a decrease in low cloud and hence warming trend, since fewer low clouds allows more incoming solar radiation (i.e., less sunlight reflected by low clouds), a physical property recognized and accepted in Lockwood and Frohlich's quote above. Accordingly, the observed global warming trend in Lockwood and Frohlich (2007) is actually consistent with the decreasing cosmic ray intensity tendency shown in Fig. 2.

The indications of a decreasing trend in incoming cosmic-ray flux since 1900 can be confirmed not only by Fig. 6 but also by the result shown in Figure 4d of Lockwood and Frohlich (2007) itself (not shown here). It is difficult to conclude that the authors' presentation of a conclusion opposite to that which their data demonstrate was merely accidental. Similar misrepresentations connected with the Svensmark effect have been made elsewhere in the literature. For instance:

"... if we look at long-term observations of cosmic rays (and there have been monitoring sites for cosmic rays in the northern hemisphere for more than 50 years), there are no long-term trends in cosmic rays. In fact, if anything, the cosmic rays have decreased over the last 30 years, and that's what the Lockwood and Frohlich paper shows, a decrease in cosmic rays, which should be leading to a cooling of the climate system, not a warming that we've observed."¹⁶

Problem 5: Omission of data on the amount of solar radiation reaching the surface

Lockwood and Frohlich (2007) appear to have overlooked another key variable: the amount of solar radiation actually reaching the ground, as quantified by satellite telemetry.

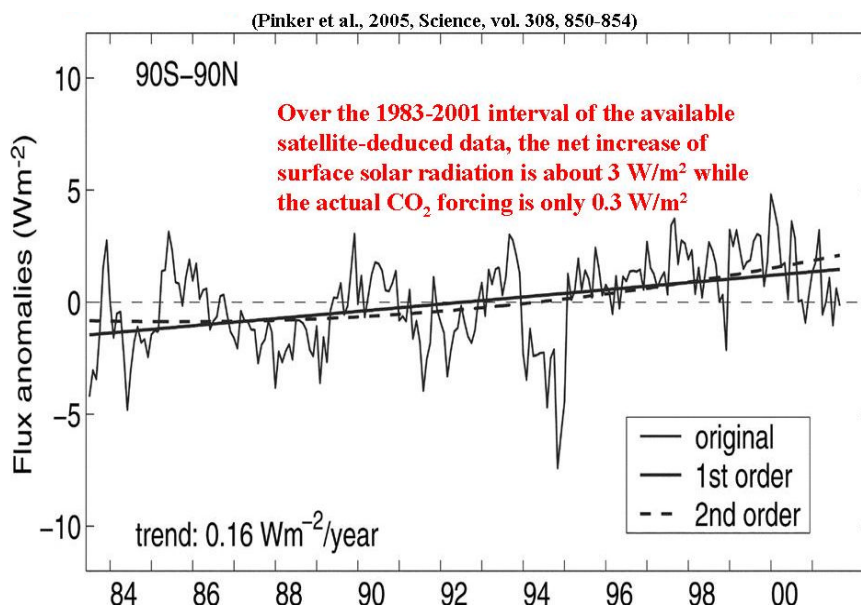


Figure 7

The increase in the amount of solar radiation reaching the surface since 1985 is $\sim 3 \text{ Wm}^{-2}$. Lockwood and Frohlich (2007) have overlooked the fact that this natural forcing is an order of magnitude greater than the CO_2 greenhouse forcing over the same period.

Fig. 7 demonstrates a rising trend in global mean surface solar radiation from 1983 to 2001 – the full interval during which data are available. Pinker *et al.* (2005)¹⁷, presenting the satellite data, say –

"Long-term variations in solar radiation at Earth's surface (S) can affect our climate, the hydrological cycle, plant photosynthesis, and solar power. Sustained decreases in S have been widely reported from about the year 1960 to 1990. Here we present an estimate of global temporal variation in S by using the longest available satellite record. We observed an overall increase in S from 1983 to 2001 at a rate of 0.16 watts per square meter (0.10%) per year; this change is a combination of a decrease until about 1990, followed by a sustained increase. The global-scale findings are consistent with recent independent satellite observations, but differ in sign and magnitude from previously reported ground observations. Unlike ground stations, satellites can uniformly sample the entire globe."

Such an important and relevant conclusion, albeit with cautions and limitations, is consistent with the observed surface global warming trend, but is missing from Lockwood and Frohlich (2007).

Although the increase in surface solar radiation may owe little to intrinsic changes in the Sun's irradiance, such as the TSI parameter in Figs. 2, 3 and 4, the observed increase would still be consistent with changes in transparency of the atmospheric column to solar radiation through modulation of the aerosol loading or of cloud cover.

Fig. 7 also shows that the documented change in global surface solar radiation is about 3 W/m², while the parallel contribution by the anthropogenic CO₂ forcing is estimated to be only about 0.3 W/m² over the 1983-2001 interval. Therefore it is premature to conclude firmly that anthropogenic CO₂ greenhouse forcing is dominant.

Conclusion

We have documented five serious scientific problems in Lockwood and Frohlich (2007):

- 1. The authors' smoothed TSI dataset depends unduly upon the start and end dates.**
- 2. A source dataset inconsistent with other such datasets in the literature was selected.**
- 3. Correlations between changes in solar activity and in temperature are omitted.**
- 4. The data on cosmic-ray forcing demonstrate the opposite of the authors' conclusion.**
- 5. Data on the amount of solar radiation reaching the Earth's surface are omitted.**

The authors of the paper are reported to have been “galvanized” into writing it as a response to “misleading media reports”¹⁸ regarding the role of the Sun. Accordingly, there is evidence of political motivation rather than objective scientific research:

“The impression is often given [that] there is a big scientific debate going on between scientists but I'm afraid it's not, it's a major consensus of greenhouse gas and a few mavericks on the outside.”¹⁹

“I know we're attacking a bit of a straw man here because there is no serious scientific debate about recent warming, but those who disagree are very vocal. We wrote this up specifically to show they are wrong, and wrong in a dangerous way.”²⁰

The uncritical promotion of this sensationalized and scientifically dubious paper by the Royal Society, the world's media and several prominent scientists may yet prove to be a major embarrassment for all those who participated so uncritically in the propagation of its errors. This incident illustrates the danger of allowing emotion and politics to warp scientific research, to the detriment of the public good.

End Notes

¹ Lockwood and Frohlich, 2007, "Recent oppositely-directed trends in solar climate forcings and the global mean surface air temperature", *Proceedings of the Royal Society A*, London, July 10, 2007, doi: 10.1098/prsa.2007.1880.

² This strident, unscientific delaration has since been removed from the Proceedings of the Royal Society A web page.

³ There are notable exceptions like this important caution from Dr. Eduardo Zorita posted in *Nature* magazine's climate blog (http://blogs.nature.com/climatefeedback/2007/07/sun_not_a_cause_of_global_warm.html#comments): "Unfortunately, this is in my opinion another example of what science journalism should not be: take a scientific paper, barely one week old, and elevate it to the final word, which it is almost a crime to argue against. Many of us would argue that in science there is no such final word. Results that had been taken for rock-solid are revisited and found incomplete, or are qualified, or even debunked. This is not different in climatology, and yet policy-makers have to accept this state of affairs take decisions and act in situations which might not been 100% certain. Much more so in the field of climate change. In the present example, it would be clear to many that a lack of trend in recorded solar output rules out any role of the sun in the recent warming. However, a quick look at the published literature reveals that this view might be somewhat superficial. For instance, in a paper by Waple, Mann and Bradley (*Climate Dynamics* vol 18, 563; 2002) a lag between solar irradiance and global mean surface temperature of about 10-15 years has been identified. This would mean that if last solar grand maximum took place in 1985, the corresponding maximum of the temperature response would have occurred between 1995 and 2000. To be fair, this is also just one single paper and perhaps other analyses may have reached different conclusions on the lag between sun and temperature, but it illustrates that things may be more complex than at first sight. Even if the case for solar influence on recent Earth temperatures looks weak, as I think it does, good science journalism should rather try to disentangle these different aspects for the interested non-expert, instead of repeating the well-known political litany, which in any case can be read everyday in the tabloids. But, alas, this would be deliberate misinformation."

⁴ David Karoly, quoted in the Australian news article *The sun is not behind global warming*, by Leigh Dayton (<http://www.theaustralian.news.com.au/story/0,20867,22047040-30417,00.html>).

⁵ Stefan Rahmstorf, quoted in the article *No solar hiding place for greenhouse sceptics*, *Nature*, 448, 8-9 (July 5 2007 issue).

⁶ Ray Pierrehumbert, quoted in the blog at www.realclimate.org under the title *It's the sun! (not)*, July 13, 2007 (<http://www.realclimate.org/index.php/archives/2007/07/friday-roundup>).

⁷ Quirin Schiermeier, quoted at the *Nature* magazine climate blog *Sun not a cause of global warming*, at http://blogs.nature.com/climatefeedback/2007/07/sun_not_a_cause_of_global_warm.html.

⁸ Anonymous spokesman quoted in the UK Guardian news article *New analysis counters claims that solar activity is linked to global warming* by James Randerson (<http://environment.guardian.co.uk/climatechange/story/0,,2123448,00.html>).

⁹ Mike Lockwood, in the UK Guardian news article *New analysis counters claims that solar activity is linked to global warming* by James Randerson (<http://environment.guardian.co.uk/climatechange/story/0,,2123448,00.html>).

¹⁰ We refer to the discussion and criticisms of Lockwood and Frohlich (2007) that are based on physical grounds and reasonings, including issues related to time delays, such as those by Nir Shaviv on "Why is Lockwood and Frohlich meaningless?" at <http://motls.blogspot.com/2007/07/nir-shaviv-why-is-lockwood-and-frohlich.html> and by Joe D'Aleo in "Shining more light on solar factor" (SPPI Report, July 2007).

¹¹ Both datasets are available from Dick Willson's webpage: <http://www.acrim.com/ACRIM%20Composite%20Graphics.htm>.

¹² Mekaoui and Dewitte (2007) *Solar Physics*, in press.

¹³ Camp and Tung (2007) *Geophysical Research Letters*, 34, doi: 10.1029/2007GL030207.

¹⁴ Svensmark et al. (2007a) *Proc. Roy. Soc. A*, doi:10.1098/rspa.2006.1773.

¹⁵ Svensmark (2007b) *Astron. Geophys.* 48, 1.18-1.24.

¹⁶ Quoting David Karoly in the ABC radio program *Sun not responsible for recent warming* (July 14, 2007) hosted by Robyn Williams (<http://www.abc.net.au/rn/scienceshow/stories/2007/1974497.htm>).

¹⁷ Pinker et al. (2005) *Science*, 308, 850-854.

¹⁸ Both quotes were by Mike Lockwood as quoted in the article *No solar hiding place for greenhouse sceptics*, *Nature*, 448, 8-9 (July 5, 2007).

¹⁹ Mike Lockwood, quoted in the ABC radio program *Sun not responsible for recent warming* (July 14, 2007), hosted by Robyn Williams (<http://www.abc.net.au/rn/scienceshow/stories/2007/1974497.htm>).

²⁰ Mike Lockwood quoted in the UK Guardian news article *Temperature rises 'not caused by sun'* (July 5, 2007) by David Adam (<http://environment.guardian.co.uk/climatechange/story/0,,2119695,00.html>).

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