

SHINING MORE LIGHT ON THE SOLAR FACTOR

*A DISCUSSION OF PROBLEMS WITH THE ROYAL
SOCIETY PAPER BY LOCKWOOD AND FROHLICH*

by

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SUMMARY FOR POLICY MAKERS

The authors of a newly published paper on the role of the sun's variability on global temperatures overstate their case that there has been no impact of solar variations on the earth's temperature history during the past several decades. Antithetically, changes to the sun are generally known to influence the earth's climate on all time scales, from eons to hours. However, the difficulty comes in trying to fully measure the magnitude of the sun's variability and then to understand how such changes result in changes to the earth's climate.

In a new paper, authors Lockwood and Fröhlich seem to ignore these difficulties and uncertainties, dismissing any work on this complex subject that doesn't agree with their pre-conclusions.

For instance, in a series of papers published within the past two years, researchers Scafetta and West have concluded that the solar variations may have been responsible for 10 to 30 percent of the observed global surface temperature increase from 1980-2002. Lockwood and Fröhlich fail even acknowledgment of these widely-publicized findings. This is but one example of the inadequacies of the research of Lockwood and Fröhlich.

The following discussion reviews the analysis and conclusions of Lockwood and Fröhlich and then asks other notable scientists in the field of solar/terrestrial relations to comment on the findings. In doing so, it is found that the conclusions being forwarded by Lockwood and Fröhlich—that the sun has had no impact on the earth's surface temperature history during the past several decades—is not consistent with the thinking of many other researchers, and instead, indicates more a personal dogma rather than scientific truth.

- Robert Ferguson

SHINING MORE LIGHT ON THE SOLAR FACTOR

Since the release of the IPCC report a number of peer review papers and analyses found the sun was not given enough credit for the changes in climate in the Fourth Assessment. In chapter 2, the AR4 discussed at length the varied research on the direct solar irradiance variance and the uncertainties related to indirect solar influences through variance through the solar cycles of ultraviolet and solar wind/geomagnetic activity. They admit that ultraviolet radiation by warming through ozone chemistry and geomagnetic activity through the reduction of cosmic rays and through that low clouds could have an effect on climate but in the end chose to ignore the indirect effect. They stated:

Since TAR, new studies have confirmed and advanced the plausibility of indirect effects involving the modification of the stratosphere by solar UV irradiance variations (and possibly by solar-induced variations in the overlying mesosphere and lower thermosphere), with subsequent dynamical and radiative coupling to the troposphere. Whether solar wind fluctuations (Boberg and Lundstedt, 2002) or solar-induced heliospheric modulation of galactic cosmic rays (Marsh and Svensmark, 2000b) also contribute indirect forcings remains ambiguous. (AR4 2.7.1.3)

For the total solar forcing, in the end the AR4 chose to ignore the considerable recent peer review in favor of Wang et al. (2005) who used an untested flux transport model with variable meridional flow hypothesis and reduced the net long term variance of direct solar irradiance since the mini-ice age around 1750 by up to a factor of 7. This may ultimately prove to be AR4's version of the AR3's "hockey stick" debacle.

NEW PAPER CLAIMED TO BE THE NAIL IN THE COFFIN

The effort to debunk the sun did not end with the IPCC. Just recently, with the release in the Proceedings of the Royal Society of the paper "[Recent Oppositely Directed Trends In Solar Climate Forcings And The Global Mean Surface Air Temperature](#)" by Mike Lockwood and Claus Frohlich¹, the global warmers declared victory and went home.

In their abstract, the authors noted "There is considerable evidence for solar influence on the Earth's pre-industrial climate and the Sun may well have been a factor in post-industrial climate change in the first half of the last century. Here

¹ http://www.pubs.royalsoc.ac.uk/media/proceedings_a/fulltext.pdf

we show that over the past 20 years, all the trends in the Sun that could have had an influence on the Earth's climate have been in the opposite direction to that required to explain the observed rise in global mean temperatures."

Hansen chimed in "These half-baked notions are usually supported by empirical correlations of climate with some solar index in the past. Thus, by showing that these correlations are not consistent with recent climate change, the half-baked notions can be dispensed with.

Dr. Lockwood said the study was "another nail" in the coffin of the notion that solar activity is responsible for global warming.

Lockwood's involvement and statement was a surprise as he was one of those whose previous work is frequently cited as evidence for a solar role in climate during the industrial era. Lockwood and colleagues at the Rutherford Appleton Laboratory in 1999 found that the Sun's magnetic field has doubled over the century, and that this natural "solar forcing" will have affected the earth's climate (Nature 399 437). Lockwood and Stamper (GRL 1999) in "*Long-Term Drift Of The Coronal Source Magnetic Flux And The Total Solar Irradiance*" tested the method of Lockwood et al. [1999] and found a linear relationship between this magnetic flux and the total solar irradiance. From this correlation, they showed that the 131 percent rise in the mean coronal source field over the interval 1901-1995.

Claus Frohlich, meanwhile, constructed a composite time series from satellite observations of total solar irradiance (TSI) made since the late 1970's. His composite, the so-called 'PMOD' model, modifies the published results of the Nimbus7/ERB and ACRIM1 science teams to provide better agreement with the predictions of a statistical model by Judith Lean based on linear regressions against solar emission and absorption line proxies for TSI.

To learn more about this I went to Dr. Richard Willson of Columbia University, the Principal Investigator for the series of NASA ACRIM projects, designed to provide high precision monitoring of TSI and detect variations of significance for climate change and solar physics..

RICHARD WILLSON ON LOCKWOOD/FROLICH

Construction of a TSI composite time series stretching over the past, nearly three decades of satellite observations, requires connecting the results of the ACRIM1 and ACRIM2 TSI monitoring experiments across the two

year 'ACRIM gap' between them. Two, relatively low precision satellite experiments measured TSI during the gap: the Nimbus7/ERB and the ERBS/ERBE. Unfortunately connecting ACRIM1 and ACRIM2 results using these two experiments gives dramatically different results for multi-decadal TSI composites. The Nimbus7/ERB 'gap' connection produces a significant upward solar trend during solar cycles 21 – 23, and a return to cycle 21 levels in cycle 24 as shown by the ACRIM TSI composite (Willson & Mordvinov, 2003). The ERBS/ERBE connection produces a multidecadal TSI composite without a significant trend. ERBS/ERBE results are by far the least reliable of the two 'gap' experiments and their difference from the Nimbus7/ERB results during the 'gap' is readily shown to be uncorrected sensor degradation. Nevertheless, Lean and Frohlich chose to use the ERBS/ERBE connection for their (PMOD) composite. It agreed better with the predictions of Lean's proxy model and demonstrated no significant long term trend, supporting the anthropogenic global warming scenario of the United Nations' IPCC reports.

The recent Lockwood/Frohlich publication's assessment depends on the absence of a significant trend in the Lean/Frohlich (PMOD) TSI composite. A more objective use of the TSI satellite observational database does not support the PMOD model or their conclusions. Just as it would be premature to claim we understand TSI variability on climate time scales with extant satellite data, it is equally premature to use the existing TSI database to relegate TSI's role in climate change to negligible levels. The selective use of data and models and the rush to judgment by Lockwood and Frohlich do not lend credibility to their investigation.

Willson believes the most convincing and recent work on the significance of TSI variability in climate change has come from Scafetta and West, experts in systems analysis who have used a phenomenological approach to study the solar impact on 400 years of a global surface temperature record since 1600. This period includes the pre-industrial era (roughly 1600–1900), when negligible amount of anthropogenic-added climate forcing was present and the sun realistically was the only climate force affecting climate on a secular scale, and the industrial era (roughly since 1800–1900), when anthropogenic-added climate forcing has been present in some degree. In their abstract, they noted, the use a recent secular Northern Hemisphere temperature reconstruction (Moberg et al., 2005), three alternative total solar irradiance (TSI) proxy reconstructions (Lean et al., 1995; Lean, 2000; Wang et al., 2005) and a scale-by-scale transfer climate sensitivity model to solar changes (Scafetta and West, 2005, 2006).

The phenomenological approach they propose is an alternative to the more traditional computer-based climate model approach, and yields results proven to be almost independent of the secular TSI proxy reconstruction used. They found good correspondence between global temperature and solar induced temperature curves during the pre-industrial period such as the cooling periods occurring during the Maunder Minimum (1645–1715) and the Dalton Minimum (1795–1825). And importantly, the sun might have contributed approximately 50% of the observed global warming since 1900 (Scafetta and West, 2006).

As Dr. Willson noted, Scafetta and West use much more sophisticated analytical techniques than Lean, Frohlich or Lockwood and their approach doesn't rely on complex and uncertain modeling of climate phenomena. The simple statistics used by Lean, Frohlich, Lockwood et. al. and the large uncertainties associated with TSI forcing models in GCM's cannot compete with Scafetta's phenomenological approach in deriving new understanding of complex systems from observational data.

So next I wrote to Dr. Scafetta at Duke and asked him to review the Lockwood/Frohlich paper.

SCAFETTA'S RESPONSE TO LOCKWOOD AND FROLICH

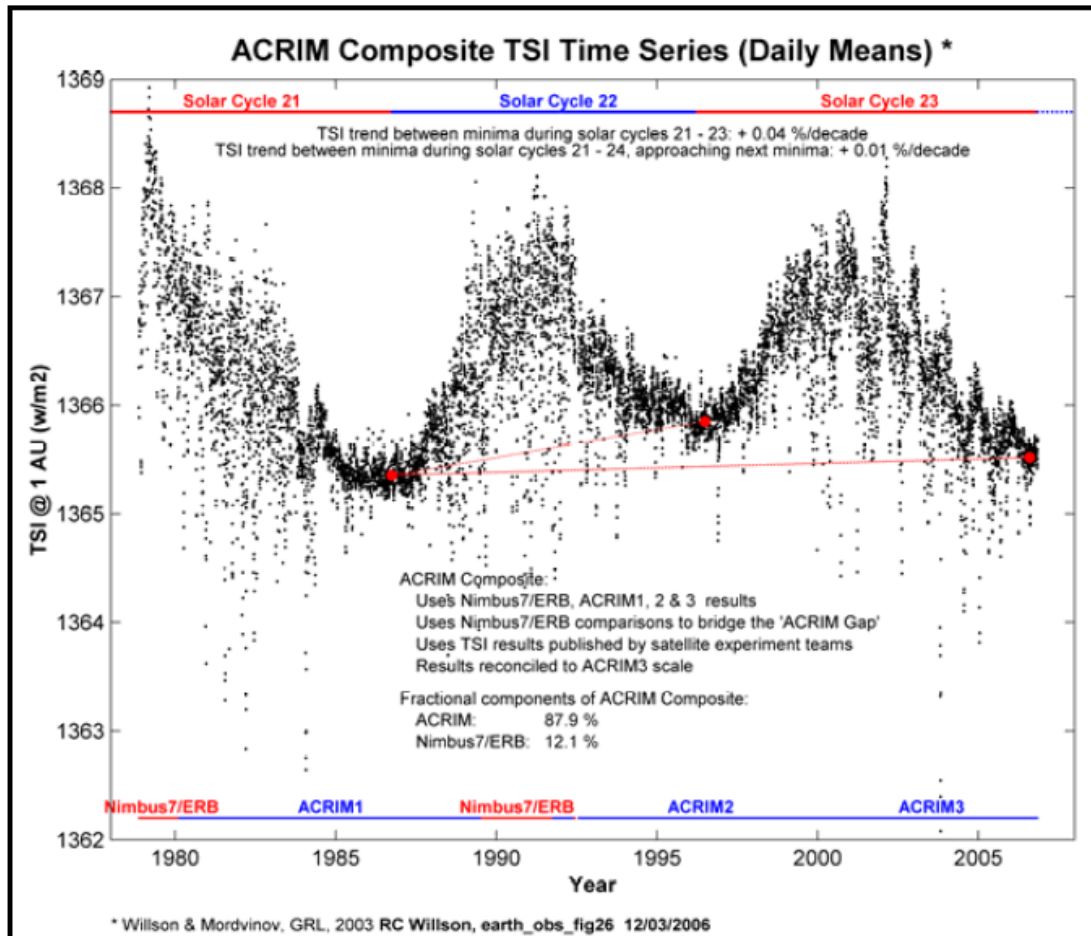
Lockwood and Frohlich are using the PMOD TSI composite (prepared by Frohlich himself) to deduce their conclusions. By using ACRIM TSI composite (prepared by Willson) the result would be quite different. Lockwood and Frohlich just "assume" that ACRIM is wrong and PMOD is right, and do not care to repeat their calculation with the ACRIM TSI composite. In our own works, we always try to repeat the calculations with both data sets to be fair to both groups.

But, what is the difference between ACRIM and PMOD TSI composites?

This is an important question because many scientists do not seem to know the real difference. ACRIM is just a composite of the published TSI satellite data, everybody with basic mathematical knowledge can obtain such a result by downloading the published satellite data and following the instruction found in the Willson and Mordinov's paper. So, ACRIM faithfully reproduces the observations as the experimental groups have really seen.

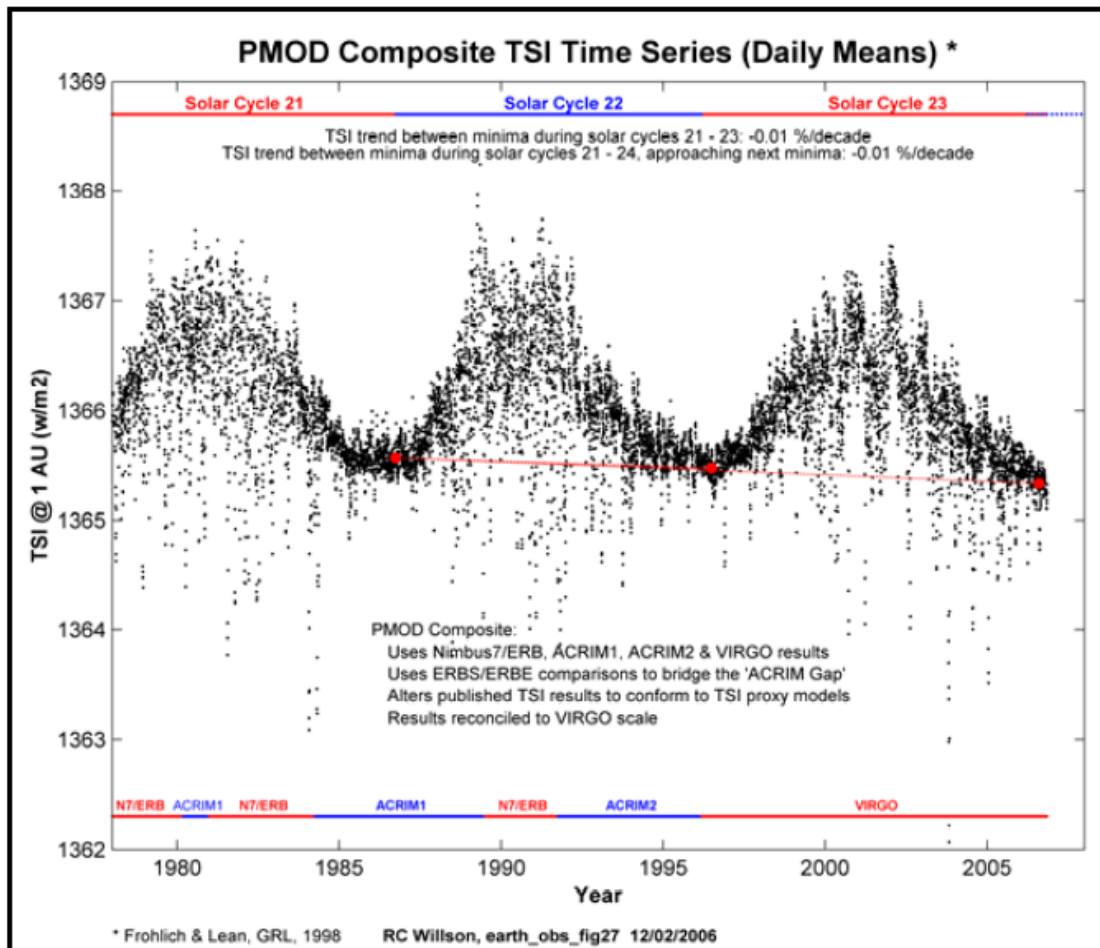
PMOD, instead, assumes that the published TSI satellite data are wrong and that they need several additional corrections. It is important to stress that the

experimental groups, which published the satellite TSI data, do not agree on the fact that their data require the additional corrections implemented by Frolich. So, the PMOD composite would be right only if the modifications implemented by Frolich are indeed the right ones, but that those calculations are the right ones is not really known right now. Frolich himself improve his calculations every a few years!



In particular, PMOD severely alters the data from the Nimbus7/ERB TSI record during the ACRIM gap from 1989 to 1991. Nimbus7/ERB satellite TSI data during such a short period show a clear upward trend while the PMOD during the same period is almost constant. So the Nimbus7/ERB satellite TSI data has been altered. The alteration of the Nimbus7/ERB data during the ACRIM gap is responsible of the different shape between the ACRIM and PMOD TSI composites. ACRIM composite suggests that TSI underwent a 22-year like cycle: the average TSI value during solar cycle 21-22 (1980-1991) was lower than the average TSI value during solar cycle 22-23 (1991-2002), which seems is larger than the predicted average TSI value during solar cycle 23-24 (2002-2003). PMOD

instead shows a very slight negative average trend during the overall three cycles.



Thus, it is evident that with ACRIM the sun would have contributed to the global warming during the last decades. But, what if PMOD is right? Does the adoption of PMOD imply that the sun did not contribute to the warming of the last decades as Lockwood and Frolich claim in their paper? The answer to this question is:

No, it doesn't.

But there is the need of some comment about the mathematical/physical mistakes made by Lockwood and Frolich. I see two of them.

a) The mathematical way they calculate the running means does not have the physical meaning they infer in the test.

In fact, Lockwood and Frolich would like to compare the trend in the solar data with the global temperature trend. To do this they calculate the average during a given period, for example 11-year between 1991 and 2001 and set such a value in the center of such period, that is, in 1996 (their figure 2). Then they move the period to cover the entire available interval from 1978 to 2006. Finally, they compare these moving averages with the temperature trend and deduce their conclusions.

It is evident that this mathematical methodology is physically erroneous. In fact, it assumes that the climate is partially conditioned by the "future" behavior of the sun! Note that by using the above example, the moving average value set in 1996 depends on the TSI values for 5 years in the past and the TSI values for 5 years in the future! And these values are compared with the temperature record.

The problem is that I am not aware of any climate model, nor of any physical phenomenon, according to which the present state of a thermodynamic system is a function of the "future" values of the forcings!

The present state of a thermodynamic system, such as the climate, is evidently a function of the present and past values of the forcings, not of the future ones. Thus, it is evident that Lockwood and Frolich are "anticipating" what eventually might be happening in the future.

b) Thus, what is the right way to do the calculations? The answer is simple, by using a climate model that uses the temporal evolution of the forcings as they are without doing multi-year moving averages that would improperly mix past and future!

The problem is that the actual climate models might be severely incomplete about the sun-climate coupling mechanisms. However, some general properties are well known. In particular, it is well known that because of the thermal inertia of the ocean, the climate response to an increase of the forcing is smoothed and delayed.

Lockwood and Frolich are indeed vaguely aware of this general climate property, (see the first paragraph in their section 3). However, without doing any calculation they conclude that such effect can be neglected!!!

Indeed, the thermal inertia of the climate has a relaxation time response of the order of 10 years, this means that the thermal equilibrium might require approximately 50-100 years. So, Lockwood and Frolich cannot conclude anything by looking at just the last 20 years of solar data. They must look at a larger temporal picture, that is, at what happened at least during the last 50-100 years. And what it is observed during the last century is a net increase of solar activity, and this happens both if we use PMOD or ACRIM since 1978. This net increase of solar activity is indeed lasting since the Little Ice Age of the 17th century. Thus, the sun has surely given a positive contribution to the climate change during the last 50-100 years.

Indeed, this larger picture effect is evident if we look at the figure 4d in Lockwood and Frolich, even if these authors seem not to realize it. The Be10 record, which is one of the solar records, is monotonically decreasing during the entire 20th century. This means that the solar activity has been likely increasing during the entire century and that, therefore, the sun has contributed to the global warming up to the recent years. Because of the thermal inertia of the ocean the solar induced warming would last even if during the last few years the sun has cooled a little bit as PMOD would suggest.

What can be said is that if the recent predicted cooling of the sun for the solar cycle 23-24 (2002-2013), (which is recovered by both ACRIM and PMOD) will last, it will affect the future climate, not the past one!"

OH YES, ONE MORE THING, THE EARTH STOPPED WARMING

As David Whitehouse noted in a [response](#)² to the Lockwood/Frolich paper, that the temperatures of the world have leveled off the last decade after peaking in 1997/98. "Statistically the world's temperature is flat. The world certainly warmed between 1975 and 1998, but in the past 10 years it has not been increasing at the rate it did."

Indeed, temperatures have declined and then leveled off in the past 8 years. This year despite the predictions by Jones (Hadley Center) as early as January that the year would end up warmest on record, looks to be cooler than 2006, with the record cold Southern Hemisphere winter and a cooling Pacific, and continuing that trend.

² <http://www.telegraph.co.uk/opinion/main.jhtml?xml=/opinion/2007/07/15/do1508.xml>

Addendum:

The truth is, we can't ignore the sun

By David Whitehouse

Last Updated: 12:01am BST 15/07/2007

According to the headlines last week, the sun is not to blame for recent global warming: mankind and fossil fuels are. So Al Gore is correct when he said, "the scientific data is in. There is no more debate."

Of that the evangelical BBC had no doubt. There was an air of triumphalism in its coverage of the report by the Royal Society.

It was perhaps a reaction to the BBC Trust's recent criticism of the Corporation's bias when reporting climate change: but sadly, it only proved the point made by the Trust.

The BBC was enthusiastically one-sided, sloppy and confused on its website, using concepts such as the sun's power, output and magnetic field incorrectly and interchangeably, as well as not including any criticism of the research.

But there is a deeper and more worrying issue. Last week's research is a simple piece of science and fundamentally flawed. Nobody looked beyond the hype; if they had, they would have reached a different conclusion.

The report argues that while the sun had a significant effect on climate during most of the 20th century, its influence is currently dwarfed by human effects. It says that all known solar influences since about 1990 are downward and because global temperature has increased since then, the sun is not responsible.

No. The research could prove the contrary. Using the global temperature data endorsed by the Inter-national Panel on Climate Change, one can reach a completely different conclusion.

Recently the United States' National Oceanographic and Atmospheric Administration said that 2006 was statistically indistinguishable from previous years.

Looking at annual global temperatures, it is apparent that the last decade shows no warming trend and recent successive annual global temperatures are well within each year's measurement errors. Statistically the world's temperature is flat.

The world certainly warmed between 1975 and 1998, but in the past 10 years it has not been increasing at the rate it did. No scientist could honestly look at global temperatures over the past decade and see a rising curve.

It is undisputed that the sun of the later part of the 20th century was behaving differently from that of the beginning. Its sunspot cycle is stronger and shorter and, technically speaking, its magnetic field leakage is weaker and its cosmic ray shielding effect stronger.

So we see that when the sun's activity was rising, the world warmed. When it peaked in activity in the late 1980s, within a few years global warming stalled. A coincidence, certainly: a connection, possibly.

My own view on the theory that greenhouse gases are driving climate change is that it is a good working hypothesis - but, because I have studied the sun, I am not completely convinced.

The sun is by far the single most powerful driving force on our climate, and the fact is we do not understand how it affects us as much as some think we do.

So look on the BBC and Al Gore with skepticism. A scientist's first allegiance should not be to computer models or political spin but to the data: that shows the science is not settled.

[Dr David Whitehouse is an astronomer, former BBC science correspondent, and the author of *The Sun: A Biography* (John Wiley & Sons)]

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Richard C. Willson, Principal Investigator, ACRIM Experiments

Richard C. Willson holds a doctoral degree in Atmospheric Sciences from the University of California-Los Angeles, and B.S. and M.S. degrees in Physics from the University of Colorado. He is a Senior Research Scientist in the employ of Columbia University's Center for Climate Systems Research. His work in this field, which began at the University of Colorado and continued at the Jet Propulsion Laboratory and Columbia University, has been in the area of development of state-of-the-art solar irradiance measurement techniques for both total and spectral irradiance. He developed prism, grating, and interference spectroscopy instrumentation for spectral observations in both laboratory and flight environments. He developed the Active Cavity Radiometer instrumentation for total irradiance observations and has conducted flight

experiments on balloons, sounding rockets, the Space Shuttle, and satellite platforms. He has served as the Principal Investigator for the Solar Maximum Mission ACRIM I, Space Shuttle Spacelab I and Atmospheric Laboratory for Applications and Science (ATLAS) ACRIM's, Upper Atmosphere Research Satellite (UARS) ACRIM II and EOS/ACRIM III experiments.

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