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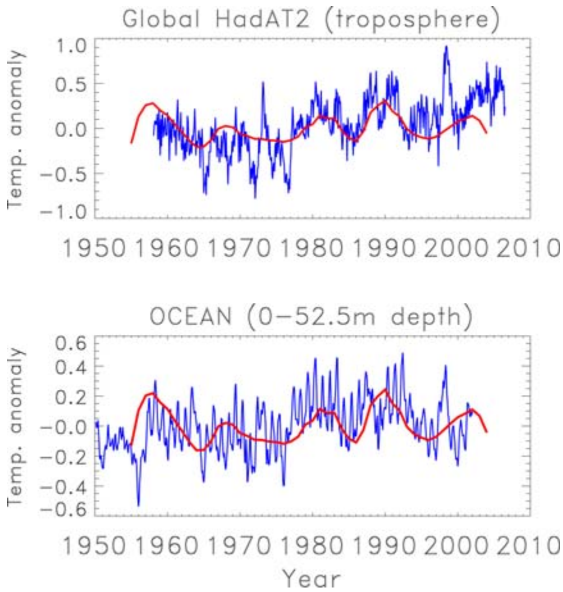

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Reply to Lockwood and Fröhlich - The persistent role of the Sun in climate forcing

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In a recent paper (ref. [1]) Mike Lockwood and Claus Frőhlich have argued that recent trends in solar climate forcing have been in the wrong direction to account for "the observed rapid rise in global mean temperatures". These authors accept that "there is considerable evidence for solar influence on 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." But they argue that this historical link between the Sun and climate came to an end about 20 years ago. Here we rebut their argument comprehensively.

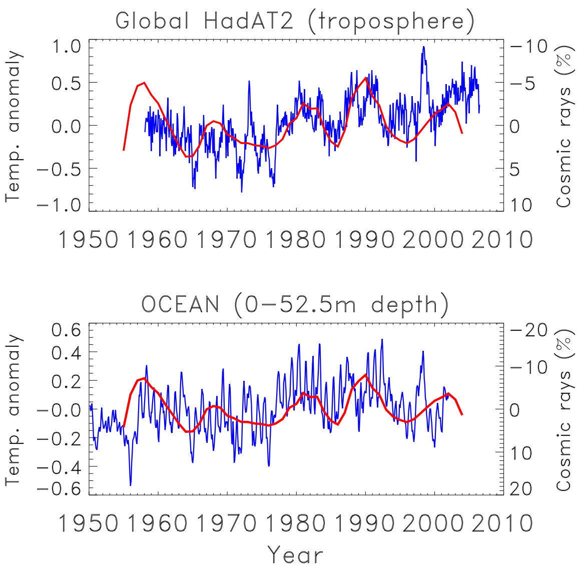

FIG. 1: The solar cycle is represented here in red by Haleakala/Huancayo cosmic ray counts, inverted (ref. [3]). In temperature variations other than those in the surface record favored by Lockwood and Fröhlich, the Sun's influence remains obvious. The tropospheric data are for 850 to 200 hPa (ref. [4]) and the ocean data are from the Simple Ocean Data Assimilation (SODA ref. [5]). There is no detrending of the data. Note also an apparent cooling of the ocean near-surface water since the 1990s.

Their analysis relies on data on surface air temperature which, they say, "does not respond to the solar cycle". Yet over the past 20 years the solar cycle remains fully apparent in variations both of tropospheric air temperature and of ocean sub-surface water temperature (Fig. 1). Here cosmic-ray flux (inverted) is used as an index of solar activity. Fig. 2 shows an analysis of tropospheric temperatures for the European Space Agency's ISAC project (Influence of Solar Activity Cycles) (ref.[2]). After the removal of confusions due to El Ninõ, volcanoes etc. and also a linear trend, as in the middle panel of Fig. 2, the negative correlation between cosmic-ray flux and tropospheric air temperatures is impressive. This is in keeping with the direct link between cosmic rays and cloud cover previously discussed (refs. [6–8]).

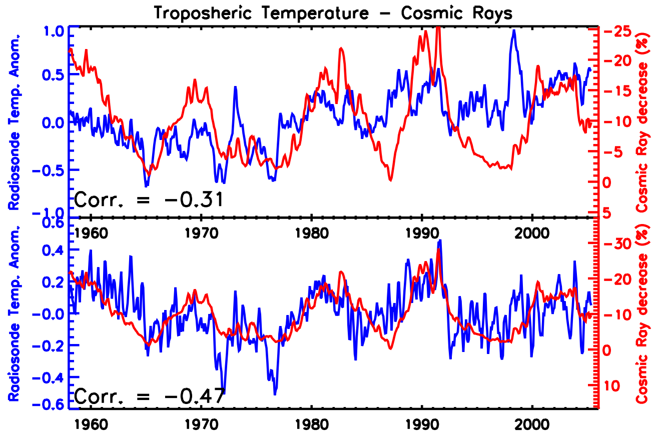

FIG. 2: The solar cycle and the negative correlation of global mean tropospheric temperatures with galactic cosmic rays are apparent in this ESA-ISAC analysis (ref. [2]). The upper panel shows observations of temperatures (blue) and cosmic rays (red). The lower panel shows the match achieved by removing El Ninõ, the North Atlantic Oscillation, volcanic aerosols, and also a linear trend (0.14 ± 0.4 K/Decade).

When the response of the climate system to the solar cycle is apparent in the troposphere and ocean, but not in the global surface temperature, one can only wonder about the quality of the surface temperature record. For whatever reason, it is a poor guide to Sun-driven physical processes that are still plainly persistent in the climate system.

As for the upward linear trend removed from Fig. 2 (lower), it is customary to attribute to greenhouse gases any increase in global temperatures not due to solar changes. While that is reasonable, one cannot distinguish between the effects of anthropogenic gases such as carbon dioxide and of natural greenhouse gases. For example, increased evaporation means that infrared radiation from water vapor, by far the most important greenhouse

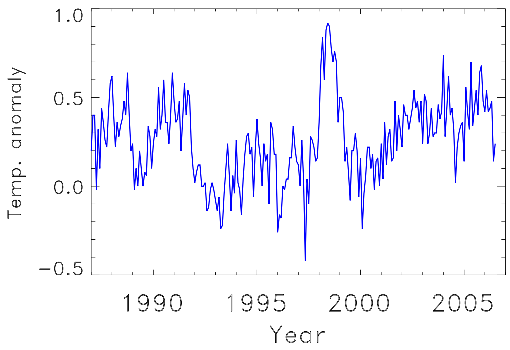

FIG. 3: The temperature of the troposphere (HadAT2 850-200 hPa, ref. [4]) from January 1987 to July 2006 shows only a small trend since the beginning of the 1990s.

gas, will tend to provide positive feedback for any global warming, whether driven by anthropogenic or solar forcing. In any case, the most recent global temperature trend is close to zero.

Lockwood and Fröhlich erase the solar cycle from various data sets by using running means of 9 to 13 years. While these may be appropriate to illustrate trend reversals since about 1985 in various indicators of solar activity, in the case of global mean surface temperatures the use of a long running mean creates the illusion that the temperatures are still rising rapidly early in the 21st Century. Their Fig. 3f (ref. [1]) suggests a remarkable 0.1 K increase between 1998 and 2002, when the curves terminate. In reality, as shown in the unsmoothed presentation of monthly data in their own Fig. 1e, global surface temperatures have been roughly flat since 1998. The apparent pause in global warming is even plainer and of longer duration in the tropospheric data, as sampled in our Fig. 3.

	1960-1975	1975-1990	since 1990
CR (%)/decade	-1.44 ± 0.78	3.80 ± 1.92	-0.48 ± 0.75
Tropos. (K/decade)	-0.13 ± 0.03	0.32 ± 0.05	0.13 ± 0.02
Ocean (K/decade)	-0.07 ± 0.02	0.05 ± 0.03	-0.10 ± 0.02

Table 1. The accompanying Table shows the variation in trends for the three periods 1960-1975 1975-1990, and since 1990. The trends in ocean temperatures changed sign to match the variations in solar activity. For the troposphere the temperature trend changed sign in 1975, and since 1990 its magnitude has been greatly reduced. Note the cosmic ray variation (CR) has been inverted.

By Lockwood and Fröhlich's own data, solar magnetic activity is still high compared with 100 years ago. As to when the recent easing of activity began, counts of cosmic-ray muons at low altitudes were historically low when the muon record-keeping ended in the early 1990s (ref. [7]). That implies an increase in relevant solar magnetic activity continuing till that time. A scarcity of muons can be linked to elevated global temperatures by a reduction in low cloud cover (ref. [8]) and low cloudiness was indeed at a minimum around 1992-93. By other solar indicators, like those cited by Lockwood and Fröhlich, the minimum muon counts may well be a little higher in the current solar cycles. That would explain the pause in global warming evident in our Table as well as in Lockwood and Fröhlich's own Fig. 1e.

That would explain the pause in global warming evident especially in the ocean (Fig. 1) and the troposphere (Fig. 3). The continuing rapid increase in carbon dioxide concentrations during the past 10-15 years has apparently been unable to overrule the flattening of the temperature trend as a result of the Sun settling at a high, but no longer increasing, level of magnetic activity. Contrary to the argument of Lockwood and Fröhlich, the Sun still appears to be the main forcing agent in global climate change.

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[2] ISAC Final Report 2007, "Danish National Space Center Scientific Report 2/2007", ISBN-10 87-91694-12-4 http://www.spacecenter.dk/research/sun-climate/Projects/isac

[3] Climax and Haleakala/Huancayo neutron monitor http://ulysses.sr.unh.edu/NeutronMonitor/

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