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Cosmic Rays and Global Warming

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Abstract: It has been claimed by others that observed temporal correlations of terrestrial cloud cover with 'the cosmic ray intensity' are causal. The possibility arises, therefore, of a connection between cosmic rays and Global Warming. If true, the implications would be very great.
We are investigating this claim and our tentative conclusions are to doubt it since our tests so far do not support the hypothesis. Such correlations as appear are likely to be due to the small variations in solar irradiance, which, of course, correlate with cosmic rays; these appear at about the 10% level for mean global temperature.

Introduction

A phenomenon with strong politico-social implications is the apparent correlation of cosmic ray (CR) intensity with low level cloud cover (CC) - and thereby with mean global temperature [1][2]. Insofar as there is a possible link of clouds with CR via ionization the correlation cannot be dismissed out of hand. It is not sufficient to say that the energy content of CR is minute in comparison with solar irradiance (SI) and therefore the effect must not be causal; the atmosphere is a highly complex system with subtle properties and the idea must be tested.

CR and Cloud Cover

Figure 1 shows the results of the analysis of Marsh and Svensmark [1]. The cloud cover ordinate is described in the caption as is the source of the CR data. It is undoubtedly true that there is a correlation for 'low clouds' (<3.2 km in altitude), at least over the period shown (1983, where CC data start, to 1995); but does the CR variation **CAUSE** that in the CC, rather than both being due to another variable?

The first problem that arises is that the correlation is quite absent in the data for two other atmospheric depths: 'middle levels' (3.2 - 6.5 km) and 'high levels' (>6.5 km altitude).
This result is surprising in view of the fact that the CR ionization (mainly from muons and electrons) increases with height. Specifically the rate of production of ions, in $cm^{-3}s^{-1}$, for the 3 levels is estimated to be: high, 130(50); middle, 30(13) and low, 4(3) where the values are for $60°$N (the equator).
A possibility, and one needed by the proponents of the CR/CC model, is that the efficiency of the conversion from CR ions to cloud droplets (presumably by way of aerosols) falls with increasing height above sea level. Such behaviour cannot be ruled out but seems rather ad hoc. The implication would be that even in the low region the efficiency in not 100% and, as will be shown shortly, there are already problems in this respect.

Efficiency of CR ions for cloud production

An important aspect is that of the likely efficiency of CR ions for initiating cloud droplets and we

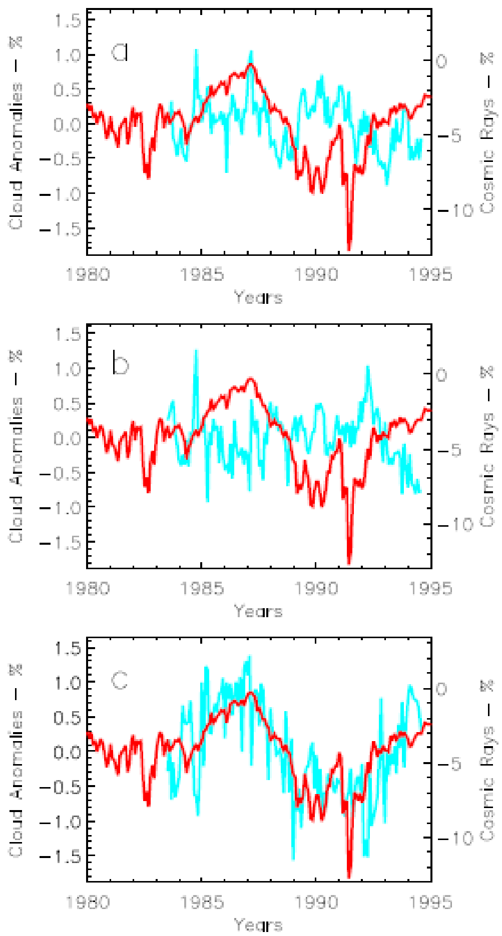

Figure 1: The graphs are from reference [1]. They show the global monthly cloud anomalies for a) high ($< 440\ hPa$). b) middle ($440 - 680\ hPa$) and c) ($> 680\ hPa$) cloud cover (blue curve). To compute the monthly cloud anomalies the annual cycle is removed by subtracting the climatic monthly average (July 1983 - June 1994) from each month on an equal area grid before averaging over the globe. The global average of the annual cycle over this period for high, middle and low IR detected clouds is 13.5%, 19.9% and 28.7%, respectively. The cosmic rays (red curve) represent the neutron counts observed at Huancayo (cutoff rigidity 12.9 GV) and normalised to October 1965. The CR results extend over the whole period.

start by estimating the density of cloud droplets that could be produced by CR (muons) at the lowest level. With a rate of ions, of $4\ cm^{-3}\ s^{-1}$ and assuming they all give 'small ions' the rate of production of small ions will be the same, giving, for a mean lifetime of 50 s [3] $200\ cm^{-3}$. To produce significant nucleation rates much larger ion densities than this are required [4, 5] Hence the ionisation rate in CR seems too small to produce significant numbers of water droplets such as would be necessary in a cloud. Despite this, we continue with the analysis.

Latitude dependence of 'the effect'

It is well know that the magnitude of the CR time variation (the 11-year cycle caused by the sunspot (SS) cycle, with its modulation of Galactic CR by the solar wind) varies with latitude. More accurately, it is a function of the vertical cut-off rigidity (VCRO), the reason being the effect of the geomagnetic field deflecting away more low energy particles as the geomagnetic equator (highest VCRO) is approached. Since SS modulation falls with increasing primary CR energy, the modulation is most severe in the polar regions.
We have studied this effect in some detail by plotting the CC for different VRCO bands and the results are given in Figure 2. It is evident that there is no support for the expected rise in amplitude of the correlation with falling VRCO. In fact, as shown in Figure 3, the amplitude of the CC modulation is smallest towards the Poles (VRCO < 4GV), where it should be biggest.

Alternative explanation of the CR/CC correlation

Lack of space precludes a more detailed examination of this problem but it seems likely that the origin of the undoubted solar cycle modulation of the CC seen in Figures 1 and 2, and quantified in Figure 3, is the 11-year cycle in solar irradiance, SI (e.g. [6]). The slow droop in CC with time, most evident in Figure 2 for the period after 1997, is possibly due to anthropic factors although it has been suggested that this may be due to instrumental drift [7]. This reduction is greater

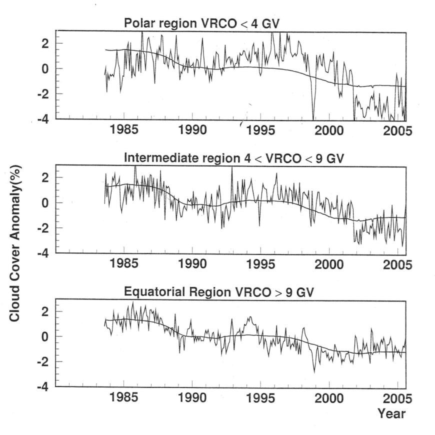

Figure 2: Cloud cover (spiky) compared with a best-fit sunspot number profile, including a slow droop in magnitude. VRCO is the vertical cut-off rigidity.

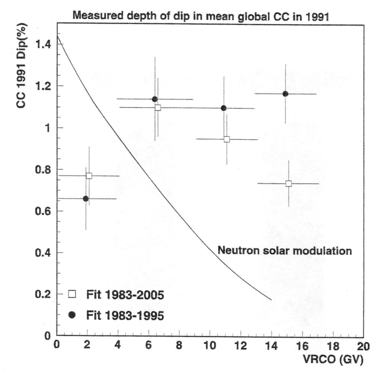

Figure 3: Comparison of the observed cloud cover modulation with that shown by the neutron count (normalised). The 'modulations' are expressed by the dip in the mean at the time of solar maximum (1991).

than adopted by us, in linear form, and applied to the SS variation, suggesting an accelerating 'global warming'.

The contribution of SI to global warming is estimated by us as having a peak to peak (SS cycle) magnitude of about 10% of the observed rise in mean global temperature over the last 25 y. The CR contribution appears to be much less than 10%.
Finally, it is instructive to examine the energetics of the various processes. The ratio of energy input from the sun (SI) to that from CR is $\sim 2.10^8$. Of order 50% of the CR energy appears as ionization in the atmosphere, thus an 'efficiency' as low as 10^{-8} for SI in converting to ionization in the atmosphere - or in other ways and resulting in cloud cover - is all that is needed for SI to dominate. Haigh (1994) has, in fact, proposed such a mechanism involving solar-UV-ozone induced dynamical feedback.

Conclusions

The correlation of cloud cover at low altitudes with cosmic ray intensity is most easily explained in terms of the CR being a proxy indicator of solar irradiance. However, the subject is so important that more detailed analyses would be useful.

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