Cosmic Rays and Global Warming

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1. INTRODUCTION

It is well known that there is a strong correlation of low cloud cover with cosmic ray intensity (at least for the period 1980-2000), as evinced by the neutron-monitor count-rate (eg Svensmark and Friis-Christensen, 1997) and cloud data (ISCCP). The question is: is the relationship causal, or does it arise because both variations are caused by a further parameter, specifically the solar irradiance (SI) ?

2. CLOUD PROPERTIES

Three properties of clouds can be put forward immediately in opposition to the: Low Cloud Cover (LCC), CR hypothesis:

1. Presumably much of any additional CR-induced cloud will be on the periphery of existing clouds; the contribution to the **measured** LCC will thus be small.
2. Of order 40% of the LCC is in the form of cumulus clouds, which are thought not to be very sensitive to the density of cloud condensation nuclei (CCN) (Norris, 2008). Furthermore, the sensitive fraction is variable in space and time.
3. The atmospheric supersaturation needed for droplets to form is much higher than observed; such charges are typically 2 for 0.1 μ aerosols, in comparison with ~1000 needed.

3. EFFECTS OF IONIZATION ON CLOUD FORMATION

The LCC, CR hypothesis relies on CR-induced ions causing the production of CCN. We have, consequently searched for LCC associated with other sources of ions, as follows:

1. Chernobyl. No excess LCC appeared, leading us to estimate that the efficiency of ions causing CCN is < 3 %.
2. Nuclear bomb tests. The BRAVO 15 Mton nuclear bomb test of 1954 produced many radioactive particles to size 10 – 100 μ. Well away from the characteristic mushroom cloud the ion-yield was many orders of magnitude greater than the CR-yield but no excess cloud appeared. We estimate an efficiency < 0.01%.
3. Radon. After CR, radon is usually the most important source of ionization near the earth's surface. In some parts of the world radon levels are very high. South-west India is one such place but studies of LCC distribution in the region show no excess. We estimate an efficiency less than 25%. Ramsauer in Iran holds the world record with 100 times the ambient CR-ion production rate. No excess LCC has been reported.

4 LATITUDE VARIATION OF THE LCC, CR CORRELATION

A useful diagnostic of the validity of the LCC, CR hypothesis is an examination of the magnitude of the effect (defined by us as the 'dip' in the LCC between solar minimum and solar maximum) as a function of vertical rigidity cut-off (VRCO) for CR reaching the Earth. Clearly, the dip should be a maximum near the Poles, where the CR variation over the solar cycle is a maximum. In an earlier work we (Sloan and Wolfendale, 2008) plotted the dip vs VRCO for different latitude bands. In no case was there a significant downward trend – even within a latitude band, indicating that even if there were a latitude-dependent 'efficiency' for the generation of CCN by way of CR ions, the LCC, CR correlation could not be causal.

Further work in this important area has related to explaining such non-constancy of the dip as exists. It is likely that the changes seen at high latitudes arise from various atmospheric instabilities which increase with latitude, particularly in the Northern hemisphere. Changes near the Equator can probably be attributed to precipitation effects.

5. THE EVIDENCE FROM THE POWER SPECTRA

In an attempt to distinguish between CR and solar irradiance (SI) as the cause of the correlation (SI goes roughly as the sunspot number) we have examined the power spectra of LCC, CR and SSN for the 20 years period from 1984. Various spikes are present, including the 11-year period, in the plot of intensity vs frequency but some are difficult to interpret from the significance standpoint. However, the exponent of the spectra (γ) at frequencies above 0.1 month^{-1}

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appears to be useful. Figure 1 shows the results for LCC as a function of latitude together with the values for CR and SSN. It is apparent that SSN (ie solar irradiance) give a better fit to the LCC points although this does not prove the SI hypothesis. Nevertheless, it is bad news for the LCC, CR model. It is interesting to note that there is a difference in mean gamma for the two hemispheres, a result that could be due to the higher ratio of ocean to land in the Southern Hemisphere.

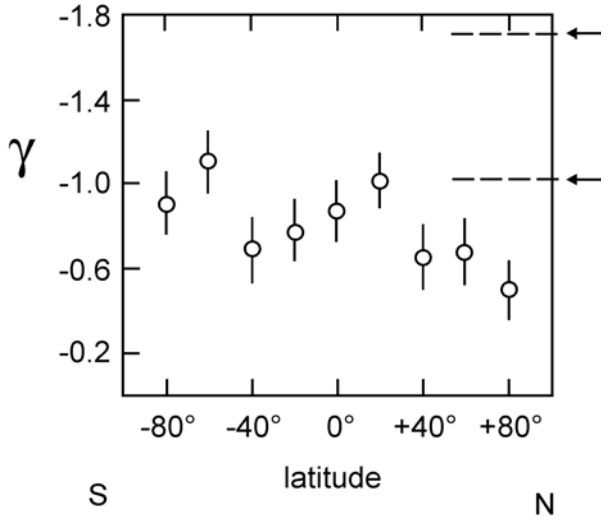
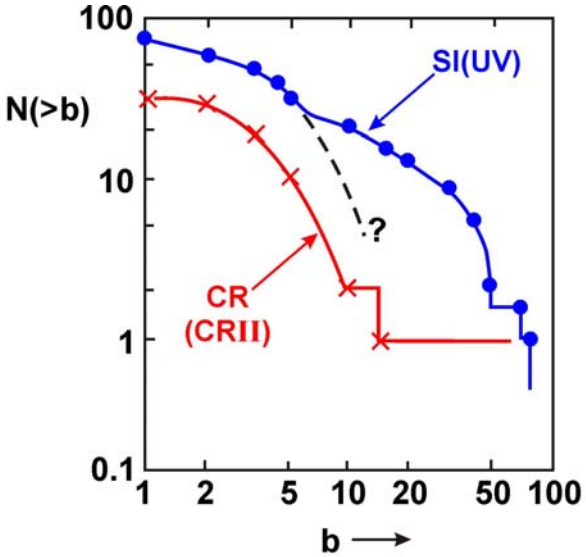


Figure 1. Slopes of the power spectra
frequencies above 0.1 mont



From Voiculescu et al. (2006) LCC : correlations with CR (positive) and SI (negative). Contiguous bins of correlation, each bin is 5° x 5°

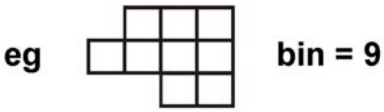


Figure 2

6. THE POSSIBILITY OF VARIATIONS IN THE CORRELATIONS OVER THE GLOBE

In an important paper, Voiculescu et al (2006) endeavoured to disentangle contributions from CR and SI and have presented maps showing the areas over which significant correlations occur. We have carried out a 'log N, log S' study on these maps for the LCC with the results shown in Figure 2. The caption to the Figure describes the meaning of the plot.

There seems little doubt that there is a significant 'tail' to the distribution above about b=5 (i.e. 125 deg^2) for the LCC, SI hypothesis. The evidence for a tail for CR is marginal, and the region favoured (N. Atlantic and W. Europe) seems to have no climatic properties which would make it susceptible to CR-induced ionization.

The conclusions are not yet firm, however, because of a lack of explanation for the initial part of the N(>b) curves, ie the part rapidly falling by b = 10. Insofar as all the N(>b) curves – for all cloud regions: HCC, MCC and LCC, 12 in all, have similar widths and it is tempting to assign them to some sort of 'noise' (ie 'local' atmospheric correlations) but this is by no means certain. Work is continuing.

7. LONG-TERM VARIATIONS IN CLOUD COVER AND TEMPERATURE

CR measurements have been available since 1956 and we have studied correlations of the CR intensity (smoothed over 11-years) and the proxy cloud cover, Norris (2008), both high, HCC, and low, LCC. Figure 3 shows the results. It will be noted that there is a strong anti-correlation between HCC and CR intensity and a small positive correlation for LCC. The

latter is in accordance with the results over the last two 11-year cycles. The correlation with SSN, and thus SI, would be of opposite phase to that for CR. It would be more reasonable to explain a positive correlation of HCC with SI than a negative correlation with CR because the essence of the CR explanation is the presence of CR ions which act as CCN and, furthermore, the CR ion density for the high clouds is an order of magnitude greater than that for low clouds.

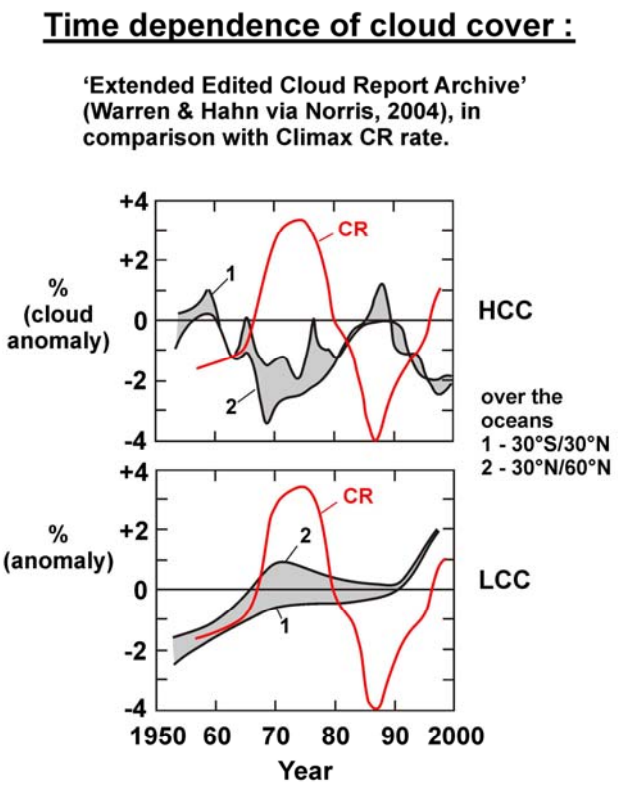


Figure 3

Turning to temperature, very recently, we (Erlykin et al) have examined the average surface temperature of the Earth as a function of CR intensity over the last 50 years. Using the relationship between the 11-year cycle changes in temperature and in LCC we conclude that the maximum increase in the Global temperature during the last half century which can be ascribed to cosmic rays is 0.02°C (ie ~ 4% of the actual) at the 90% Confidence level.

8. CONCLUSIONS

We have found no evidence favouring the explanation of the correlation of low cloud cover with cosmic ray intensity over the solar cycle in terms of cause and effect. Although the cyclical change of solar irradiance may provide the answer, it is premature to be sure.

ACKNOWLEDGMENTS

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