Contribution of changing galactic cosmic ray flux to global warming

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The well established excellent correlation between low-level clouds and primary cosmic ray intensity, which act as nuclei for cloud condensation, clearly shows that a decrease in primary cosmic ray intensity results in lesser low cloud cover. Reduced albedo radiation reflected back into space, due to lesser low cloud cover, results in an increase in the surface temperature on the earth. Extrapolation of the intensity of galactic cosmic radiation using ^{10}Be measurements in deep polar ice as the proxy, clearly shows that the primary cosmic ray intensity has decreased by 9% during the last 150 years, due to the continuing increase in solar activity. We present evidence to show that the radiative forcing component due to the decrease in primary cosmic ray intensity during the last 150 years is 1.1 Wm^{-2}, which is about 60% of that due to CO_2 increase. We conclude that the future prediction of global warming presented by IPCC4 requires a relook to take into the effect due to long-term changes in the galactic cosmic ray intensity.

Keywords: Cloud cover, climate change, cosmic rays, global warming.

THE working group of the Fourth Inter-Governmental Panel on Climate Change[1] (IPCC-4) has made a comprehensive assessment of the effect of anthropogenic greenhouse gases on global warming and its consequences under different scenarios for the increase in greenhouse gas emission. Since the average growth rate of CO_2 (1.9 ppm/year) is by far the largest compared to other greenhouse gases and is also expected to increase due to the growing global demand for energy, a realistic assessment of the actual contribution of CO_2 to global warming is essential to accurately predict the increase in temperature and its consequences on weather and climate. In addition to the uncertainties involved in predicting the growth rate of CO_2, many scientists believe there are additional causes contributing to the global climate change, which have not been fully taken into account in the report. New experimental evidence provides evidence to show that the primary galactic cosmic ray changes, which generate cloud condensation nuclei, can significantly affect global temperature.

The role of primary galactic cosmic rays in generating low-level cloud condensation nuclei, which reflect solar energy back into space affecting the temperature on earth, was first reported by Svensmark and Christensen[2]. The effect of long-term changes in galactic cosmic ray intensity on low level cloud cover formation and its impact on global warming was however not clearly understood due to non-availability of reliable estimate of cosmic ray intensity changes over a long period. In this paper we present recent results on galactic cosmic intensity changes since 1800, obtained using accurate measurements of ^{10}Be derived from deep ice core measurements[3] as proxy, in order to estimate the realistic contribution of long-term cosmic ray intensity changes to climate warming.

It is well known that ^{10}Be nuclei in deep polar ice is a reliable proxy measure of the ~2 GeV/nucleon cosmic ray intensity impinging on the earth. By merging long time cosmogenic ^{10}Be data derived from deep ice core measurements with actual cosmic ray observations during 1933–1965, McCracken *et al.*[4] have reconstructed the long-term changes in cosmic ray intensity during 1428–2005. Figure 1 shows the long-term changes in cosmic ray intensity as seen in neutron monitor counting rates and corresponding changes in helio-magnetic field (HMF) during 1800–2000, reproduced from McCracken's papers[5,6]. From a critical analysis of the data, McCracken

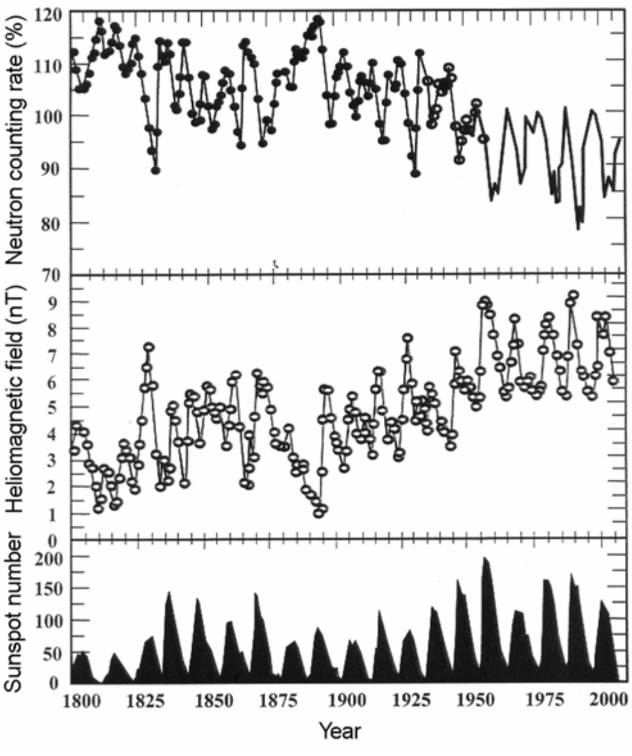

Figure 1. Long-term changes in cosmic ray intensity (top panel) along with the corresponding variation in near-earth heliomagnetic field (middle panel) obtained by inversion of cosmic ray data and sun spot number (bottom panel). In the top panel showing cosmic ray intensity, continuous line represents estimated Climax neutron monitor counting rate (1956–2000), open circles denote ionization chamber measurements during (1933–1956) and filled circles represent cosmic ray intensity derived from ^{10}Be (1801–1932) (reproduced from K.G. McCracken[6]).

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has shown that the average cosmic ray intensity near the earth during 1954–1996 was lower by 16% compared to the average for the period 1428–1944. The primary cosmic ray intensity recorded during the space era 1960–2005 is the lowest in the last 150 years. Similar conclusion has been independently reached by Taricco *et al.*[7] by analysing the ^{44}Ti activity in meteorites. During the last 150 years when the carbon-dioxide intensity increased from around 280 ppm to 380 ppm, we find the corresponding decrease in cosmic ray intensity is about 9%, as seen from the data presented by McCracken and Beer[3,4].

The change in galactic cosmic ray flux due to its modulation by HMF is a very well-established fact. Enhancement in solar magnetic activity increases the galactic cosmic ray modulation potential φ which is given by $\varphi = V_p/K(r)$, where V_p is the solar wind velocity and $K(r)$ is the cosmic ray diffusion coefficient[8], which in turn causes a corresponding reduction in cosmic ray flux impinging on the earth. The actual cosmic ray flux in interplanetary space derived from ^{10}Be observations during 1800–2000 has been used to calculate the average HMF which clearly shows that HMF has increased[6,9] by a factor of 3.5 from a 11-year average of about 2 nT to about 7 nT, which is consistent with the magnetic field observations by the Advanced Composition Explorer[10].

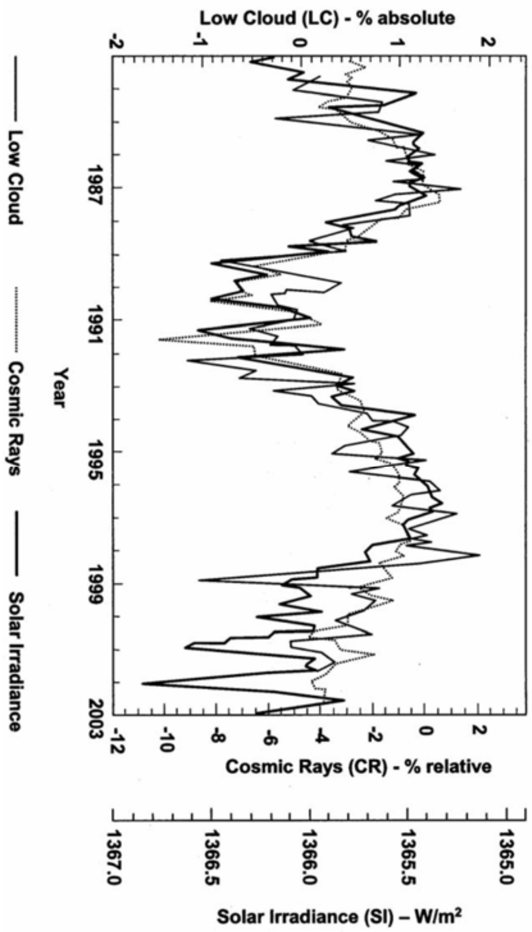

Figure 2. Correlation between cosmic ray intensity as measured by neutron monitors and the low level cloud intensity during 1983–2003. The corresponding values of solar irradiance are also shown (reproduced from Jan Veizer[12]).

There are at least two ways in which galactic cosmic ray intensity variation can affect global temperature. Cosmic rays, composed predominantly of high-energy protons, are the primary source of ionization in the upper atmosphere, which act as nuclei for cloud condensation[11,12]. Figure 2, which is reproduced from Jan Veizer[13], clearly shows the excellent correlation among cosmic ray intensity, low cloud coverage and variation in solar irradiance. The modulation due to increased HMF resulting from increased solar activity reduces galactic cosmic ray intensity, which in turn reduces low level cloud coverage. Reduction in low level clouds due to the decrease in cosmic ray intensity results in reducing the albedo radiation reflected back into space, thus causing warming of the atmosphere and increasing the global surface temperature. A 8% decrease in galactic cosmic ray intensity during the last 150 years as derived from ^{10}Be records will cause a decrease of 2.0% absolute in low cover clouds[12] which in turn will result in increasing earth's radiation budget by 1.1 Wm^{-2}, which is about 60% of the estimated increase of 1.66 Wm^{-2} forcing due to increased CO_2 emission during the same period.

The second effect due to long-term changes in cosmic ray intensity arises through stratospheric chemistry. A 9% decrease in cosmic ray flux and NO will cause 3% increase in ozone according to the well established relationship[14,15].

$$\frac{3}{8} = \frac{\Delta NO}{NO} = -\frac{\Delta O_3}{O_3}.$$

Ramanathan *et al.*[16] have shown that 14% increase in O_3 results in the increase in earth's surface temperature by 0.13°C. Thus, 3% increase in ozone will increase the earth's surface temperature by about 0.05°C, which is relatively small.

If we account for the contribution of 1.1 Wm^{-2} from galactic cosmic ray induced warming, the net contribution from non-anthropogenic factors including solar irradiance towards global warming goes up to 1.22 Wm^{-2}, as against the total net contribution from anthropogenic factors of 1.6 Wm^{-2}. Consequently, the contribution of increased CO_2 emission to the observed global warming of 0.75°C would be only 0.42°C, considerably less than that predicted by the IPCC model, the rest being caused by the long-term decrease in primary cosmic ray intensity and its effect on low level cloud cover, due to the increase in HMF.

The IPCC working group report has also projected globally averaged surface warming and sea level rise at the end of the 21st century under different scenarios which ranges between 1.8°C (1.1–2.9°C) under the best scenario and 4°C (2.4–6.4°C) under the worst scenario. The effect of cosmic ray intensity over long periods, however, could add or subtract to the global warming depending on whether the long-term variation of primary cosmic ray intensity shows a decreasing or an increasing trend. We conclude that the contribution to climate change due to the change in galactic cosmic ray intensity is quite significant and needs to be factored into the prediction of global warming and its effect on sea level raise and weather prediction.

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