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The Role of Cosmic Rays in the Modulation of Lower Atmosphere Temperature

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ABSTRACT Observational evidences suggest that there is an apparent relationship between solar variability and the lower atmosphere. The assumption made in climate models that the variation in solar radiation can explain observed variations in the lower atmosphere is not entirely true. Past studies suggest that cosmic rays of both galactic and solar origin might be responsible for temperature change in the lower atmosphere. It is a fact that solar cycle is strongly correlated with the cosmic ray flux therefore it is desirable to search the physical mechanisms which mediate between solar activity and the global temperature. It is suggested that the observed variation in cloud cover might provide a possible link between varying solar activity and global temperature. Some other mechanisms might also be playing their roles in modulating the earth's atmospheric processes. In this research article, we have attempted to explain how cosmic rays could modify the terrestrial temperature.

KEYWORDS Solar variability, GCR (Galactic cosmic ray), CLOUD (Cosmic Leaving Outdoor Droplet), CCN (Cloud Condensation Nuclei), ISCCP (international satellite cloud climatology project).

INTRODUCTION

The sun plays an important role in effecting atmospheric circulation, ocean circulation and inducing photosynthesis in Biosphere. We note that terrestrial climate is a manifestation of the interactions of the absorbed solar radiation with the atmosphere and oceans. So, any variation in the energy budget of the terrestrial atmosphere is bound to have an immediate effect on the terrestrial environment. A group of atmospheric researchers [2 – 12] has presented reports and reviews to establish a direct link between solar activity and the cosmic rays to explain the role of cosmic rays in the modulation of lower atmosphere temperature.

It has been suggested that solar cosmic rays apparently generated by solar flares can be associated with the variation in temperature of the lower atmosphere. It is stated that the solar magnetic field affects the solar wind flow and hence can modify the characteristic features of cosmic ray incident on the earth's atmosphere. Since the flux of cosmic rays is modulated by the solar magnetic activity, so a link between solar variability and global temperature is quite possible [1]. It is important to mention here that the low energy cosmic ray particles less than 15 GeV undergo 11- year modulation and the flux of cosmic rays with energy in the range 01- 15 GeV decreases more rapidly when solar activity period changes from the minimum to the maximum [2]. It is important to note that the maximum energy of the incident cosmic rays is used in exciting and ionizing air atoms. It is therefore expected that cosmic rays may have significant effect during the period of solar minimum activity.

In 1975, Robert E. Dickinson on “solar variability and meteorological response” stated that some physical processes in the lower atmosphere might be involved in modulating the meteorology of the lower atmosphere [3]. Since then, much research work has been undertaken in this direction.

A detailed investigation has been carried out to correlate solar irradiance with the surface- air temperature of the northern hemisphere. The role of total solar irradiance in influencing the energy budget of the lower atmosphere was further analyzed. It was reported that observed variation in solar irradiance through satellite varies too little to account for the observed change in global temperature [4]. H. Svensmark studied the variation of 11- year average temperature in terms of percentage change in cosmic rays decrease and sunspot number during the period 1935-1995 and suggested some association between solar cycle length and the variation in cosmic rayflux [5]. Solanki and Krivova (2003) further investigated the effect of solar variability on global temperature. They found that global temperature increases sharply with decrease in cosmic ray counts [6]. An attempt has been made to present a comprehensive picture of the physical mechanisms involved in the modulation of lower atmosphere temperature by the cosmic rays.

METHODS

To determine whether cosmic rays can modulate the lower atmosphere temperature, it is imperative to study the possible effect of sunspot number on the global temperature. This can be done by taking into account the variation of cosmic rays with Sunspot number. Cosmic ray data have been obtained fromftp://ftp.ngdcnoaa.gov/STPsolar_data/cosmicrays/huancayo.data.

Relative studies of the problem by the distinguished researchers through graphics have been taken into account. Numerical modeling and data from satellite observations form the basis for the analysis of the effects of cosmic rays on lower atmosphere temperature.

RESULT AND DISCUSSION

The influence of solar activity on cosmic rays

Figure (1) shows variation of cosmic ray flux with sunspot Number [7]. It can be seen that the variation of yearly average cosmic rays is in opposite to the pattern of Sunspot number. We observe that peaks in cosmic ray counts correlate with sunspot minima. It is important to note that the sunspot number is the oldest solar index measuring the solar activity. To understand the cyclic behavior of the sun, data for sunspot number has been taken from SILSO [8]. Variation of global temperature with sunspot number has been discussed in detail. It has been found that temperature increases sharply with decrease in sunspot number after1980 [9].

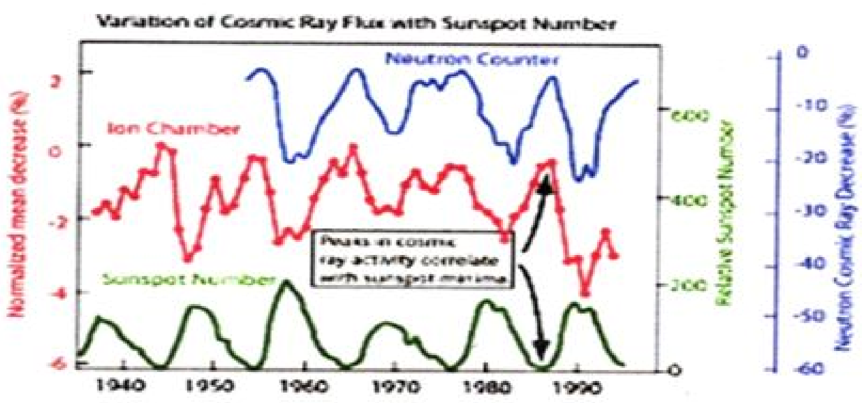

Figure 1: Variation of cosmic ray flux with sunspot number

The role of cosmic rays was also studied experimentally to see whether cosmic rays in anyway affect lower atmosphere temperature. The “ion chamber cosmic ray data” provides experimental evidences for advocating that the high energy cosmic rays play a major role in inducing physical effect in the lower atmosphere and thereby control the variability of atmosphere transparency. This in turn affects the solar radiation flux reaching the lower atmosphere and affects lower atmosphere temperature [10].

Experimental evidences suggest that cosmic rays are the only source of ion production in the lower atmosphere [11]. It is important to note that most of the ions between 1 km and 50 km of the terrestrial atmosphere are generated by the high energy particles known as cosmic rays. Namely, these are (i) Galactic cosmic rays and (ii) solar cosmic rays. Ion production increases with latitude and decreases with solar activity [12].
We have the observation that there are some atmospheric processes which mediate between cosmic rays and the heat budget of the lower atmosphere. We have identified some of the processes that vary with solar activity.

- Ionization produced by cosmic rays in the lower atmosphere produce ultrafine aerosols which may act as cloud condensation nuclei. It is stated that aerosols affect heat balance through scattering of solar beam in the forward direction and hence effectively reduces solar constant [13].
- Cosmic rays influence ozone distribution and so it is expected that ozone depletion might modify terrestrial temperature.
- Cosmic rays affect cloud cover variation. Clouds reflect both the incoming solar radiation flux upward and the earth's thermal radiation back to it. Thus clouds control thermal energy input to the lower atmosphere and establishes a link between cosmic rays and the terrestrial temperature.

In the following section, we present a brief discussion on correlation between cosmic rays and cloud cover variation.

Cosmic rays and the cloud variability

Clouds play an important role in modulating the heat budget of the lower atmosphere. We know that clouds acting as an opaque medium control thermal energy input to the lower atmosphere. So, one can expect a link between cosmic rays and cloud cover over the earth.

Intensive research work has been carried out by various research groups [14-17] to correlate cosmic rays with cloud variability. H. Svensmark et al investigated in detail in this direction and suggested that there is a correlation between cosmic rays and low altitude cloud variation [14].

A detailed study of optical thickness of cloud and its connection with cosmic rays was undertaken and it was suggested that variation in cosmic ray intensity could not explain the optical thickness variation of the cloud. Rather it is the EL Nino activity which could explain the variation in optical thickness of the cloud [15]. Further supportive evidence was provided by analyzing the ISCCP-C2 data set for the period1986 to 1991 by associating cloud cover with the El Nino activity [16]. It is to be noted that the International Satellite Cloud Climatology project (ISCCP) focuses on the distribution and variation of cloud radiative properties to improve the understanding of the effects of clouds on radiation budget and the climate of the earth. F Yu has explained cosmic ray effects on low and high clouds in terms of ion-induced particle production and its recombination rates [17].

In order to understand the mechanism involved, an experiment called CLOUD (cosmic leaving out door droplet) has been setup at CERN, Geneva, Switzerland [18]. It was expected that this experiment would help us to understand the ion-induced nucleation of new aerosols and then activation of CCN into cloud droplets [19]. But, CLOUD experiment failed to address GCR- cloud connection substantially [20].

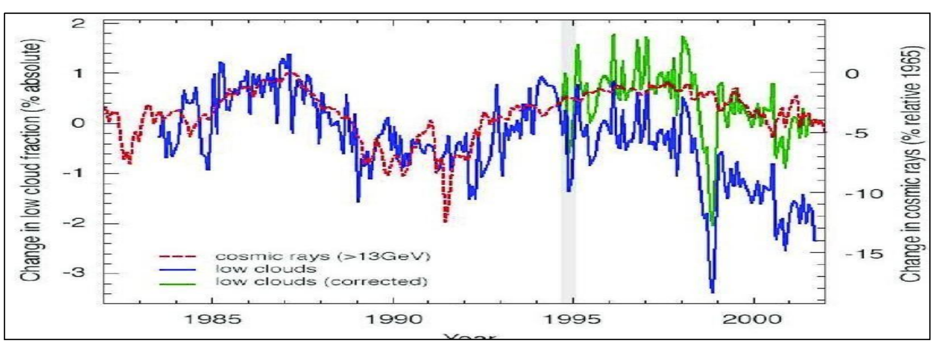

Figure 2: Variation of low clouds with change in cosmic rays

Source: Sciencemag.org
We note that the cloud cover narrows the window of atmospheric transparency which practically obstructs thermal radiation of the earth surface. This compensates cooling produced by the effect of cosmic rays. It is therefore asserted that cloud cover variation presumably caused by the impact of galactic cosmic rays virtually do not contribute to climate change. In fact, it is the amplification of greenhouse effect which presents additional source of heat due to increase in the area of cloud cover [21]. The variation of cloud cover with cosmic rays can be viewed in the figure 2.

It is important to note that 1% change in the total composition of the earth's cloud cover corresponds to 0.5Wm-2 changes in net radiating forcing. Therefore, a change in global cloudiness by approximately 3% may correspond to 1.5Wm-2 radiative forcing during 1987- 1990. Further calculation of the approximate radiative forcing by taking into account the running mean of 11-year average increase of cosmic rays from 1975 to 1989 comes out to be 0.3-0.5 Wm-2 change in cloud forcing. On the other hand, the direct influence of changes in solar irradiance is estimated to be only 0.1%. The cloud forcing from the above data comes out to be 0.2-0.5 % on the assumption that the whole cloud volume is affected by solar activity. We can infer from the above discussion that an increase in the cloud cover may result in lower temperature.

CONCLUSION

We have the observation that solar constant variation, solar activity and cosmic rays have a correlation between one parameter with another. There are some other factors which need attention. These are namely (i) ultrafine aerosol concentration (ii) effect of cosmic rays on cloud cover near the equator and (iii) role of “diffusion-advection process" in mediating between cosmic rays and lower atmosphere temperature.

So, there is a need to develop a realistic model taking stratospheric aerosols, cloud cover, cosmic rays and solar activity as inputs which could explain the effect of cosmic ray ionization on lower atmosphere temperature. Thus the impact of cosmic rays on lower atmosphere process is a complex problem. We propose that with the better monitoring tools it would be possible to analyze the role of cosmic rays in the modulation of terrestrial climate in a better way.

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