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On relationship between Galactic Cosmic Rays and Cloud cover

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Abstract

Intriguing relationship between Galactic Cosmic Ray (GCR) and Cloud Cover (CC) puts a challenge in understanding climate variability and global warming. Correlation obtained between Galactic Cosmic Ray and Cloud Cover is explained by ionization of air molecules due to cosmic rays. This atmospheric ionization affects cloud nucleation and hence changes distribution of cloudiness. On the other hand, clumping of aerosols resulting from ionization is yet to prove. Uncertainty in cloud measurements is another barrier for proving any specific relationship between Galactic Cosmic Ray and Cloud Cover.

Keywords: *Cosmic rays, Cloud cover, Climate, atmosphere, Global warming.*

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1. Introduction

Climate variability is an important research topic, quite beneficial for human kind. Earth's climate is believed to be influenced by several factors viz., changes in earth's orbital motion, changes in atmospheric and oceanic circulation, volcanic eruptions, changes in concentration of greenhouse gases and changes in solar activity.

Sun plays an important role in the climate of the Earth. Solar forcing of Earth's climate can be either direct or indirect. The most obvious and simplest direct way solar activity could influence Earth's climate is through changes in solar irradiance. But solar radiative output is known to vary by 0.1% over the last solar cycle, which corresponds to a change of 0.3 W/m^2 at the top of the Earth's atmosphere [1]. Hence, these effects are too small to have a dominant influence on Earth's climate.

Other indirect effects include solar induced changes in atmospheric transparency influencing Earth's radiative budget. Another interesting mechanism can be speculated because of observed GCR-cloud correlation [2-4].

2. Cosmic Ray and Cloud Cover Relation

GCR are highly energetic particles (90% protons, 9% alpha particles and small amount of heavier elements with energies 1-20 GeV) [5] that originate from stellar processes within our galaxy. The cosmic ray data are being recorded at ground based neutron monitors, which detect variations in the low energy part of the primary cosmic ray spectrum. The lowest energy that can be detected at the top of atmosphere depends on the geomagnitude latitude and ranges from 0.01 GeV at stations near the geomagnetic poles to about 15 GeV near the geomagnetic equator. GCR flux through solar system is modulated by the shielding effects of the solar wind, whose strength depends on level of solar activity and hence cosmic ray intensity shows well known inverse relation to sunspot cycle [2]. GCR is responsible for atmospheric ionization at altitudes 1-35 km with a maximum at about 5 km. These are regions of the atmosphere in which cloud formation takes place. Clouds play vital role in radiation budget of the planet. It reflect incoming short wave radiation resulting in cooling and traps outgoing long wave radiation resulting in heating. The net radiative impact of a particular cloud depends upon its height above the surface and its optical thickness. High optically thin clouds tend to heat, while low optically thick clouds tend to cool. GCR- total cloud cover correlation implies that

Earth's climate is influenced by average state of the heliosphere. The current climatic estimate for the net forcing of the global cloud cover is ~ 27.7 W/m^2 cooling [6].

If correlation is believed, then one should expect effect to be least near the geomagnetic equator where the magnetic field lines are horizontal, shielding ionizing particles to enter atmosphere. Svensmark and Christensen [2] proved that correlation between zonal average cloud data and cosmic ray flux is stronger at higher latitudes thereby supporting Cosmic ray cloud cover (CR-CC) hypothesis.

Ionization caused by galactic cosmic rays affect sulphate aerosol formation and cloud nucleation in the vicinity of tropopause and hence can possibly change the distribution of cloudiness [7]. Local decrease in amount of cloud cover with short term changes in the cosmic ray flux due to increased solar activity reported by Pudovkin and Veretenenko [8, 9]. If this could be present on global scale, then this would imply very effective amplifying mechanism for climate forcing because the energy needed to change cloudiness is small [2]. Observed cloud modulation can be due to combined effect of aerosol solute [10] together with charges [11] on the droplets.

However, there are studies which give no support to CR/CC correlation. Sloan & Wolfendale, and Erlykin *et al.*, [12-14] have presented evidence against the CR hypothesis. They believed that correlation found between GCR and cloud cover does not prove cause and effects. This correlation may reflect changes in solar irradiance, which is inversely proportional to cosmic rays. Theoretically, ionizations of air caused by GCR impart electric charge to aerosols and this could encourage them to clump together to form larger particles, which prevent cloud droplets formation. But such clumping is yet to show. Also, if ionization of the air is the mechanism of CR influence on CC formation then, maximum of CR flux and ionization is at height of about 12-15 km, whereas, correlation of CC and CR is noticed only for LCC (low Cloud Cover) i.e., for clouds below 3 km above sea level. Moreover, clouds are one of the greatest uncertainties in climate science and satellite measurements. Thus, further studies are required for analysis of possible origin of cloud cover and cosmic rays correlation.

Aerosol formation induced by GCR is being investigated by the CERN CLOUD experiment. Enghoff *et al.*, [15] have demonstrated some success in inducing aerosol formation under laboratory conditions, although they have yet to test the process under atmospheric conditions.

However, growth of aerosol to CCN (cloud condensation nucleation) through condensation of gases in atmosphere is often ignored by those supporting the GCR warming theory because freshly nucleated particles must grow by approximately a factor of 100,000 in mass before they can effectively scatter solar radiation or be activated into a cloud droplet [16].

Pierce and Adams [17] investigated growth of aerosol to CCN by using a general circulation model with online aerosol microphysics in order to evaluate the growth rate of aerosols from changes in cosmic ray flux, and found that they are far too small to play a significant role in cloud formation or climate change.

Laken *et al.*, [18] also could not any evidence of link between the cosmic ray flux and clouds. Krissansen-Totton & Davies [19] found "no statistically significant correlations between cosmic rays and global albedo or globally averaged cloud height and no evidence for any regional or lagged correlations". Erlykin *et al.*, [20] noted that decrease of a cosmic ray with time in recent measurements has been reversed. Thus, even if cosmic rays enhanced cloud production, there would be a small global cooling, not warming [21].

3. Methodology and Data collection

State-of-the-art satellite observations of cloud properties are available as monthly averages from the (ISCCP) D2 analysis derived from the top of atmosphere (TOA) radiance. Infrared (IR) measurements are preferred due to their superior spatial and temporal homogeneity. Cloud cover is obtained from an algorithm using the TOA IR statistics to identify the cloudiness on an equal area grid (280km × 280km). Cloud top temperatures (CT) and pressures (CP) are obtained from an ISCCP IR model constrained by water vapor and vertical temperature profile retrieved from the TIROS observed vertical sounder (TOVS) [22]. CT and CP are found by assuming an opaque blackbody cloud, and adjusting the cloud's pressure level (effectively cloud height) in the model until the reconstructed outgoing IR flux at TOA matches that observed.

Other data set is provided by Defense Satellite Meteorological Program (DMSP) Special Sensor Microwave/Imager (SSM/I) [23, 24]. Nimbus-7 CMATRIX Project [25] has data set covering time period 1979-1985.

Clouds vary on time scales from 10 min to 10 year and even longer with spatial range in scales from 30 m to the circumference of the earth. Hence, clouds can be monitored with high accuracy by satellites only. Such a monitoring system should have uniform global coverage with a spatial/temporal sampling interval of less than 50 km and sampling frequency of at least six times a day [25]. There are several satellite cloud datasets, one of which partially fulfills the above requirements. Observational statistics of the cloud cover implies that geostationary satellites provide the highest observation frequency and cloud cover over ocean behaves significantly different from the cloud cover over land. Different atmospheric processes over sea and land or increased difficulties with interpretation of satellite data in terms of cloud cover over the land may be the plausible reasons. Longest and most comprehensive series of cloud cover data has been compiled in International Satellite Cloud Climatology Project (ISCCP) [26].

4. Conclusion

Systematic variation in cloud cover affects incoming solar radiation and hence can explain the tropospheric and stratospheric 10-12 year oscillations. Such studies are extremely useful in estimating natural climate variability and hence will help in assessing man-made signal so that proper political proposal can be made for increased amount of greenhouse gases.

Such studies are noteworthy not only for their own right but also because they are concerned with global warming.

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