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Cloud cover and cosmic ray variations at Lomnický štít high altitude observing site

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ABSTRACT

We studied the relation of cloud cover and cosmic rays during the period 1982–2010 measured at Lomnický štít (2634 m above sea level, in the direction of 49.40°N, 20.22°E, geomagnetic vertical cut-off rigidity for cosmic ray ~3.85 GV). Daily means are used. It is seen that the correlations are insignificant for averaging shorter than about one year. We have found weak positive correlation for longer averaging times. Difference in distributions of cosmic ray intensity between the days with cloudless and overcast sky level at $\alpha = 0.05$ is found in the data. In addition to the experiments and clarification of physical mechanisms behind the relations studied here, longer time intervals and analysis at different sites with respect to cut-off rigidity and sea/continents along with the satellite data are important for progress in understanding the cosmic ray–cloud relation questions, at least from the point of view of empirical description of the dependencies.

1. Introduction

In their paper Svensmark and Friis-Christensen (1997) analyzed correlation between the total cloud coverage over oceans and cosmic ray flux as observed by ground neutron monitors during the years 1983–1991. They identified positive correlation on the basis of data from ISCCP–C2. The data ISCCP represent the geostationary satellites over oceans, excluding the tropics.

A clear positive correlation between the total cloud coverage over oceans and cosmic ray flux as observed by the ground neutron monitors during the years 1983–1991 was identified by Svensmark and Friis-Christensen (1997). Since that time there have been continuing discussion and further research on connections between the cosmic ray flux and cloud coverage. It is a topical one in cosmic ray research oriented at low energies where variability of the flux due to heliospheric modulation and geomagnetic filtering plays important role. The ionization of the atmosphere due to low energy cosmic rays accessing the atmosphere may cause microphysical changes in the properties of clouds (Dickinson, 1975). An important step towards understanding the physical processes behind that connection was done by the experiment on accelerator (Kirkby et al., 2011). The authors found that relatively small ammonia mixing ratios lead to substantial increase in the nucleation rate of sulfuric acid particles. The results of recent studies and reviews of the subject can be found in many papers, recently e.g. in Carslaw et al. (2002), Sloan and Wolfendale (2007), Laken et al. (2012), Sloan (2013), Erlykin et al. (2009, 2013), Singh et al. (2011). Recently Harrison and Ambaum (2013 with references therein) indicated the importance of the link between the cosmic rays and clouds via the mechanisms between the global atmospheric electric circuit and physics of the cloud droplets. Voiculescu et al. (2006) reported that correlation between the production of clouds and ionization due to cosmic ray is not a global effect, but it is observed only in certain regions. In a recent publication (Voiculescu and Usoskin, 2012) analyzed two solar cycles and the authors presented results showing

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that solar signatures in cloud cover persist in some regions for the entire time period and stress that the analysis of solar effects on cloud cover should be done at the regional level. Laken et al. (2012) indicated that evidence from ground-based studies suggests that some weak but statistically significant cosmic ray–cloud relationships may exist at regional scales. Calogovic et al. (2010) indicated that sudden cosmic ray decreases are not accompanied by any change of the cloud cover over the globe. Harrison and Ambaum (2010) analyzed the relations between cosmic ray decreases observed at Climax with meteorological measurements at Lerwick, Shetland. The authors found that larger or smaller neutron count reductions do not coincide with cloud responses exceeding sampling effects.

On the other hand (Svensmark et al., 2009) showed that the loss of ions from the air during Forbush decreases reduces the cloud liquid water content over the oceans. Pudovkin and Veretenenko (1995) in their study of clouds versus galactic cosmic ray Forbush decreases showed that decreases of total cloud cover are most distinctly seen in the latitudinal belt of 60°–64° and disappear at lower latitudes. Analyzing the data from International Satellite Cloud Climatology Project (ISCCP D2) satellite records in the period 1989–1991 Kristjánsson and Kristiansen (2000) found small evidence of connection between cosmic ray flux and cloud cover with some possible exceptions at specific sites and for specific clouds. The correlation between low cloud cover and cosmic rays was found to be weaker than that for solar irradiance and clouds (Kristjánsson et al., 2004). Probably the spatial correlation patterns are more important than correlations using globally averaged characteristics.

Most of the studies on the relation between clouds and cosmic rays are based on satellite measurements by the ISCCP data base. In long term analysis of such data there may be some specific features due to changes in the satellite viewing angles (Evan et al., 2007 and Jokimäki, 2010). Thus to use only the ISCCP data may not be appropriate for certain long-term global studies, especially those focused on trends, and the observations of clouds on Earth should bring also some additional information on the relations discussed.

Discussion on relations between cosmic ray intensity and various atmospheric effects continues using data not only on global scale, but in different regions. Recently solar variability was reported to have statistically insignificant effect on lightning flash and convective rainfall over India (Siingh et al., 2014). Frigo et al. (2013) reported an indirect indication of possible relationship between the variability of galactic rays and climate change on a regional scale.

Assuming that, we checked the relations between the cloud coverage and cosmic ray measured at the same site, specifically at high mountain Lomnický štít at 2634 m a.s.l. over the period 1982–2010 using daily means of the two time series. We analyzed possible correlations of the two variables for various time scales of averaging and for the extreme values of cloud cover as well as for rather large cosmic ray decreases and for the largest increase of cosmic ray flux ever observed at the station during a strong solar flare in September 1989. Results indicate just a marginal relationship between cloud cover and cosmic rays at that site.

2. Statistical study

Lomnický štít observations provide both cosmic ray neutron monitor data (NM, in real time with high resolution and archive of hourly averages at http://neutronmonitor.ta3.sk, more about the history and the measurements in paper by Kudela and Langer, 2009) as well as meteorological parameters (cloud cover, temperature, precipitation, wind velocity, barometric pressure, humidity, sunlight, visibility) recorded and archived by the Slovak Hydrometeorological Institute.

Neutron monitors consist of special gas-filled proportional counters surrounded by a moderator, a lead producer, and a reflector. The incident nucleon component (protons and neutrons) of the secondary cosmic ray flux causes nuclear reactions in the lead, and evaporation as well as low-energy neutrons are produced. These MeV-neutrons are slowed down to thermal energies by the moderator, and in e.g. the NM64 about 6% of the MeV-neutrons are finally detected by the proportional counter tubes. The fact that finally neutrons are detected gives this cosmic ray detector its name: neutron monitor (Fuller, 2009). First data series is daily averages of cosmic rays. The cosmic rays are means of hourly count rates expressed in percent with 100% corresponding to the hourly count rate in September 1986 which was 1745.200 counts per hour. The vertical geomagnetic cut-off rigidity is ~3.85 GV. For Lomnický štít we use counting rate of cosmic rays corrected by barometric pressure with the coefficient at http://neutronmonitor.ta3.sk/description.php, namely 0.72%/mb. The correction standard for neutron monitors is described in detail e.g. in the book by Dorman (2004).

Second data series is daily average of cloud cover (cloud cover — the amount of sky covered by clouds) obtained from the Slovak Hydrometeorological Institute (Vinceová, 2011). Currently, the climatological stations make observations at 07:00, 14:00 and 21:00 o'clock local time. Daily averages of cloud cover are arrived at by calculating the arithmetic average of the measured values. Cloud cover is determined visually without distinction of shape and height of clouds. The extent of cloud formation is measured on a 10-point scale, with a value of 0 corresponding to a cloudless sky and 10 to overcast sky. The shape of the clouds is determined according to an international cloud classification (Židek and Lipina, 2003). Observing clouds always has a subjective character. When the observer is changed, the new observer is always trained by the auditor responsible for the subject on applicable methodology.

The data that have been collected for the analysis in the years 1982–2010 are plotted in Fig. 1.

The characteristics of the time series of cloud cover and cosmic rays are clearly seen to be different. Its power spectrum density obtained from Lomb–Scargle periodogram (no filter) is in Fig. 2.

As is apparent in Fig. 2, the spectral composition of the two time series is very different. The seasonal (1 year) variation is clearly seen in cloud cover data while no such quasi-periodicities are apparent either in cosmic ray or in sunspot numbers. In the second series a clear solar activity periodicity is seen. In addition, especially at sunspot numbers, the ~27 day quasi-periodicity connected with the solar disk rotation and inhomogeneities in the interplanetary magnetic field with field lines frozen in the solar wind