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Long-term (50 years) measurements of cosmic ray fluxes in the atmosphere

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Abstract

Since the middle of 1957 till present time the group of researchers of P.N. Lebedev Physical Institute of the Russian Academy of Sciences has carried out the regular balloon borne measurements of charged particle fluxes in the atmosphere. The measurements are performed at polar (northern and southern) and middle latitudes and cover the interval of heights from the ground level up to 30–35 km. Standard detectors of particles (gas-discharged counters) have been used. More than 80,000 measurements of cosmic ray fluxes in the atmosphere have been performed to the present time. In the data analysis the geomagnetic field and the Earth's atmosphere are used as cosmic ray spectrometers.

The main goals of observations are the investigations of galactic cosmic ray modulation in the heliosphere, solar cosmic ray generation and propagation, precipitation of energetic electrons from the Earth's magnetosphere, study of the role of charged particles in the atmospheric processes. Now we have got a large amount of unique data on galactic and solar particles in the energy range of 0.1–20 GeV for the period of 50 years (1957–2007).

In this paper, the main results obtained from the long-term measurements of charged particles in the atmosphere on the problems mentioned above are presented.

Keywords: Cosmic rays; Atmosphere; Solar modulation; Atmospheric electricity

1. Brief history

In the 1950s academician S.N. Vernov (Fig. 1) suggested to perform the regular balloon borne measurements of cosmic ray (CR) fluxes in the Earth's atmosphere. The main goals of the experiment included a study of galactic CR modulation processes, acceleration mechanism of charged particles in powerful solar flares and propagation of solar particles in the interplanetary space. In the middle of 1957 S.N. Vernov together with his friend professor A.N. Charakhchyan (Fig. 2) started this experiment. The special lightweight probes (radiosondes of cosmic rays) for meteorological balloons to detect charged particles in the atmosphere were developed. Since then till the present time the regular measurements of charged particle fluxes in the atmosphere of polar and middle latitudes have been carried out. At present time about 80 thousands of radiosondes of cosmic rays have been launched.

A large amount of experimental data on charged particle fluxes in the atmosphere at different latitudes was obtained by P.N. Lebedev Physical Institute (LPI) of the Russian Academy of Sciences (RAS) in cooperation with other academic and nonacademic institutions. The cooperation included D.V. Skobeltsyn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University (under the charge of professor T.N. Charakhchyan, wife of A.N. Charakhchyan), Kasakh State University, Alma-Ata (charge of professor E.V. Kolomeetz), Polar Geophysical Institute, RAS, Apatity (charge of professor E.V.

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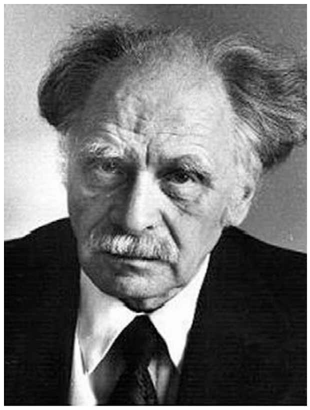

Fig. 1. Photographs of Academician S.N. Vernov (1910–1982) who established the Dolgoprudny scientific station LPI RAS in 1946, put forward an idea of regular monitoring charged particle fluxes in the atmosphere and realized it in the middle of 1957 (together with professor A.N. Charakhchyan).

Fig. 2. Photograph of Professor A.N. Charakhchyan (1905–1981) who, together with academician S.N. Vernov, realized the regular monitoring cosmic ray fluxes in the atmosphere (since the middle of 1957).

Vashenyuk), A.I. Alikhanyan Physical Institute, Yerevan, Armenia (charge of doctor G.A. Asatryan), Cosmophysical Observatory of Yu.G. Shafer Institute of Cosmophysical Research and Aeronomy, RAS, Tixie (charge of doctor A.M. Novikov), Institute of Solar-Terrestrial Physics, RAS, Irkutsk (charge of doctor V.P. Karpov), Leningrad branch of Institute of the Earth's Magnetism, Ionosphere and Radio Wave Propagation, RAS, Voyeikovo (charge of professor M.I. Tyasto), Crimean Astrophysical Observatory, Crimea (Simeiz, charge of professor A.A. Stepanyan), E.K. Fedorov Institute of Applied Geophysics, Moscow, Roshydromet (charge of professor N.K. Pereyaslova), Campinas University, Campinas, Brazil (charge of professor I.M. Martin). Since 1963 the measurements supported by Arctic and Antarctic Scientific Research Institute, Roshydromet, St. Petersburg have been made at the Antarctic observatory Mirny.

After disintegration of the USSR in 1991, the financial support of scientific research in Russia was practically stopped. Regular CR measurements in the atmosphere were saved due to academician A.E. Chudakov's efforts. He persuaded the officials of RAS to support this experiment. The management of LPI made very large contribution in the fulfillment of research. The financial support has been granted by the Russian Foundation for Basic Research and by the special program "Neutrino Physics" of the Presidium of RAS.

2. Devices for cosmic ray flux monitoring in the atmosphere

The devices used in the measurements of charged particles in the atmosphere include detectors of particles, standard radiosondes, ground-based facility for receiving of radio signals from sounds, and installations to calibrate particle detectors and pressure sensors.

The method of radio pulse transmission from each particle registered with detectors is used to get the information on particle flux in the atmosphere. Also we have got the information from the pressure sensor at the several atmospheric levels. The more detailed description of the experiment on regular CR measurements in the atmosphere is given elsewhere (Charakhchyan, 1964; Charakhchyan et al., 1976a; Golenkov et al., 1980; Bazilevskaya et al., 1991; Stozhkov et al., 2004a, 2007a).

2.1. Detectors of charged particles and γ-rays

To ensure the homogeneity of data the same type of detectors has been used during all time of the observations. They were gas-discharge counters of STS-6 type to detect omnidirectional flux of particles, and telescopes with two such counters to detect vertical flux.

A cylindrical STS-6 counter is 98 mm in effective length and 19 mm in diameter. The thickness of steel walls equals 50 mg cm^{-2} Fe. Energy cutoff of detected particles is $E_e = 200$–300 keV for electrons and $E_p = 5$ MeV for protons. A single counter response to γ-rays is less than 0.1%. A telescope has a 7-mm Al absorber between counters, which gives with account of the counter walls the energy cutoff $E_c = 5$ MeV for electrons and $E_p = 30$ MeV for protons. The telescope does not detect γ-rays at all. The geometrical factors of a single counter G_c and of a telescope G_t depend on the angular distribution of detected particles. For isotropic angular distribution of particles in the upper hemisphere these values are equal to $G_c = 16.4$ cm^2 and $G_t = 17.8$ cm^2 sr. The quasi-isotropic distribution of charged particles is valid for the primary particles at the top of the atmosphere and for the particles in the maximum of absorption curve in the atmosphere.

Besides of charged particle measurements in 1960s the flux of γ-rays with energy $E_\gamma > 20$ keV in the atmosphere had been regularly recorded at the northern polar and middle latitudes. For the purpose the radiosondes with NaI(Tl) crystal as a γ-ray detector were used. The crystal was of cylindrical form with diameter of 20 mm and length of