"Physics of Auroral Phenomena", Proc. XXVI Annual Seminar, Apatity, pp. 169-172, 2003

Polar Geophysical Institute

COSMOGENIC RADIONUCLIDE BE-7 VARIATIONS RELATED WITH COSMIC RAYS AND ATMOSPHERE CIRCULATIONS

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Abstract

Results of the Be-7 radionuclide monitoring in high and low latitudes: Apatity (N67.55, E33.33) and Tokyo (N 35.75, E 139.72) during one year interval of 2002 have been considered. The variations of its content in the lower atmosphere exhibit large irregularity. Some of these variations may be related to cosmic ray intensity changes as indicated by neutron monitor data in Apatity. The other cause of strong variations can be the atmospheric circulation. The maxima of Be-7 concentration have been observed in spring and in autumn when there is a regular seasonal penetration of air masses from the stratosphere into the lower atmosphere. The paper also presents the correlative study of Be-7 concentration and troposphere ozone content measured simultaneously. Some correlated changes of both Be-7 and surface ozone content can be explained by vortex movement of atmospheric air close to the atmospheric front.

Introduction

Galactic cosmic rays (GCR) and solar energetic particles (SEP) interact with Earth's atmospheric nuclei and produce many different isotopes through nuclear interactions. In particular, Be-7 is a short-lived radioisotope (half-life is 53.3 days) which is produced in spallation reactions of energetic protons with atmospheric N and O nuclei. About two thirds of Be-7 are produced by GCR in the stratosphere and one third is produced in the upper troposphere (Lal and Peters, 1967). The Be-7 emits a gamma ray line at 478 keV due to the electron-capture process of $^7Be + e^- \rightarrow {}^7Li + \nu$.
The difference in Be-7 production between the sunspot minimum and maximum is 70 % in the polar region at altitude above 14 km and 7 % in the lower equatorial atmosphere. Moreover, the SEP intensity above 10 MeV is strongly enhanced by more than 10^4 as compared to the GCR intensity) when an intense SEP event occurs (Yoshimoriet al., 2003). In fact, the NASA LDEF experiment indicated a surprisingly large concentration of Be-7 measured in the upper atmosphere at altitudes above 320 km in association with the large SEP event (Phillips *et al.*, 2001).

Observations

In Fig. 1 both solar cosmic ray (SCR) spectrum (1) and galactic cosmic ray (GCR) spectrum (2) are shown. The solar proton spectrum (Vashenyuk et al. 2003 a,b) is determined during the SPE of 14.07.2000, the most powerful one in the current cycle of solar activity. Nonetheless, after this event, there was no appreciable increase of Be-7 in the lower atmosphere (Yoshimori et al., 2003). This means that intensive processes of stratosphere- troposphere air exchange are needed for Be-7 to occur close to the ground. Such processes of seasonal character proceed regularly in autumn and in spring.
Fig. 2 shows the seasonal dependence of Be-7 concentration in Tokyo (low latitudes) and in Apatity (high latitudes). It is seen that the seasonal variations of Be-7 with minimum in summer and winter months are observed at both low and high latitudes. The peak Be-7 concentration observed in Apatity in July, 2002 could be most probably associated with a dusty storm occurred in this period in Apatity.
There is a noticeable correlation between the surface ozone and Be-7 measured in the same period over the Kola Peninsula (monthly mean concentrations) (Fig.3). The troposphere ozone is created in the stratosphere in the same manner as the Be-7, though it has shorter life-time (several days) than Be7 (53 days). In addition to the purely seasonal effects, the simultaneous enhancements of both the Be-7 and ozone on the ground may be related to the large-scale break-through of stratospheric air into the lower atmosphere at the edges of atmospheric fronts and jet currents. Possible scheme of such transport of ozone and Be-7 from stratosphere into the lower atmosphere along a zone of a cold atmospheric front is shown in Fig.4.

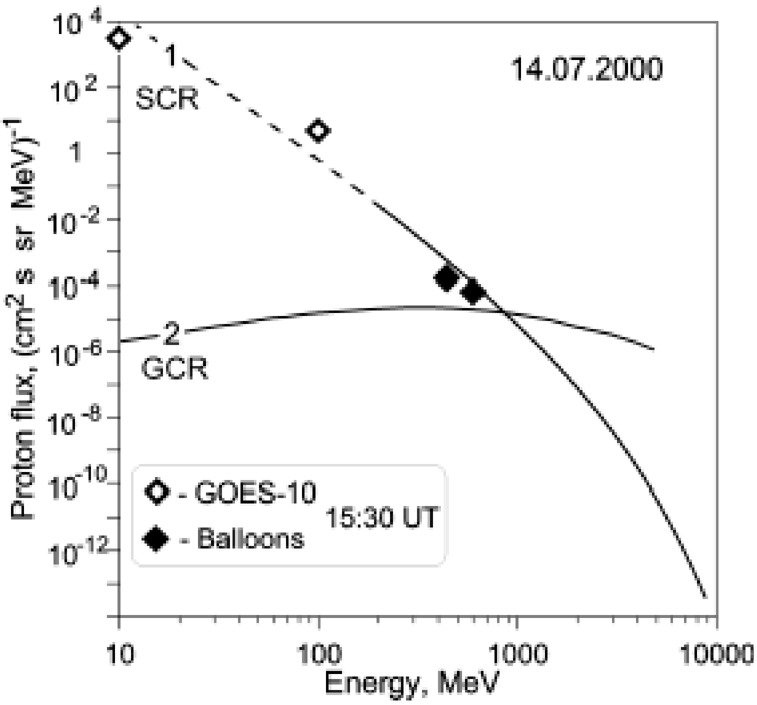

Fig.1. Solar proton spectrum as derived from the neutron monitor data in the SPE 14.07.2000 (the Bastille Day GLE) (1) in comparison with the galactic cosmic ray spectrum (2). The points indicate direct solar proton measurements by balloons and spacecraft GOES-10

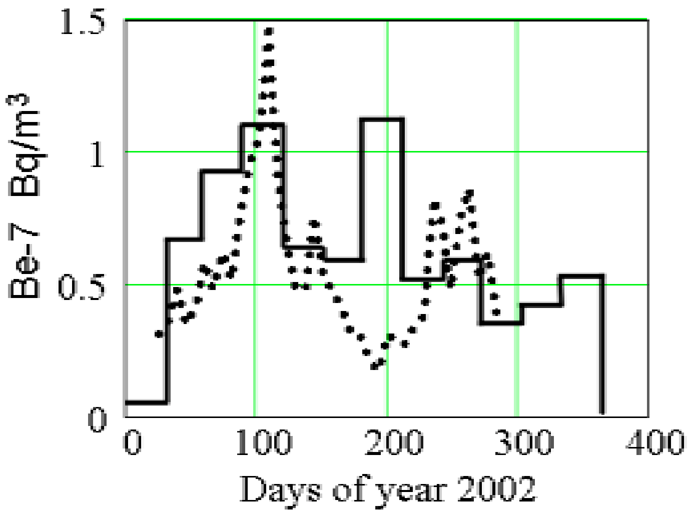

Fig.2. Time variation of Be-7 in 2002 in Tokyo (points) and in Apatity (hystogram)

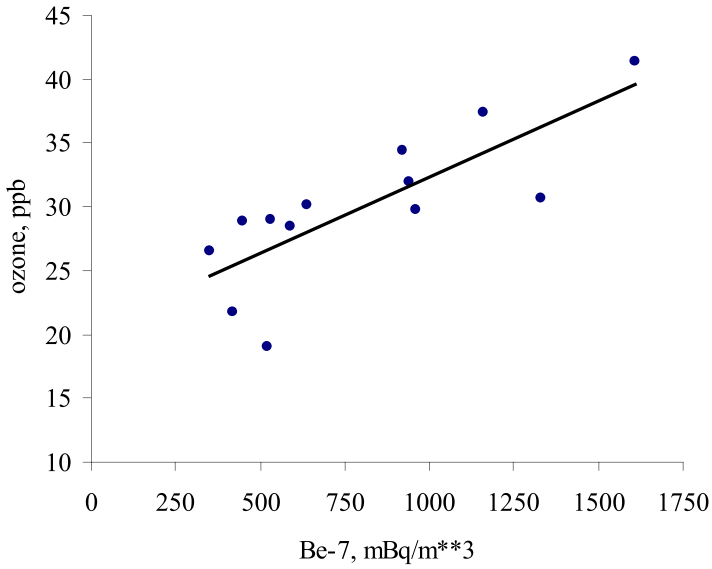

Fig.3. Surface ozone and Be-7 correlation at Kola Peninsula region

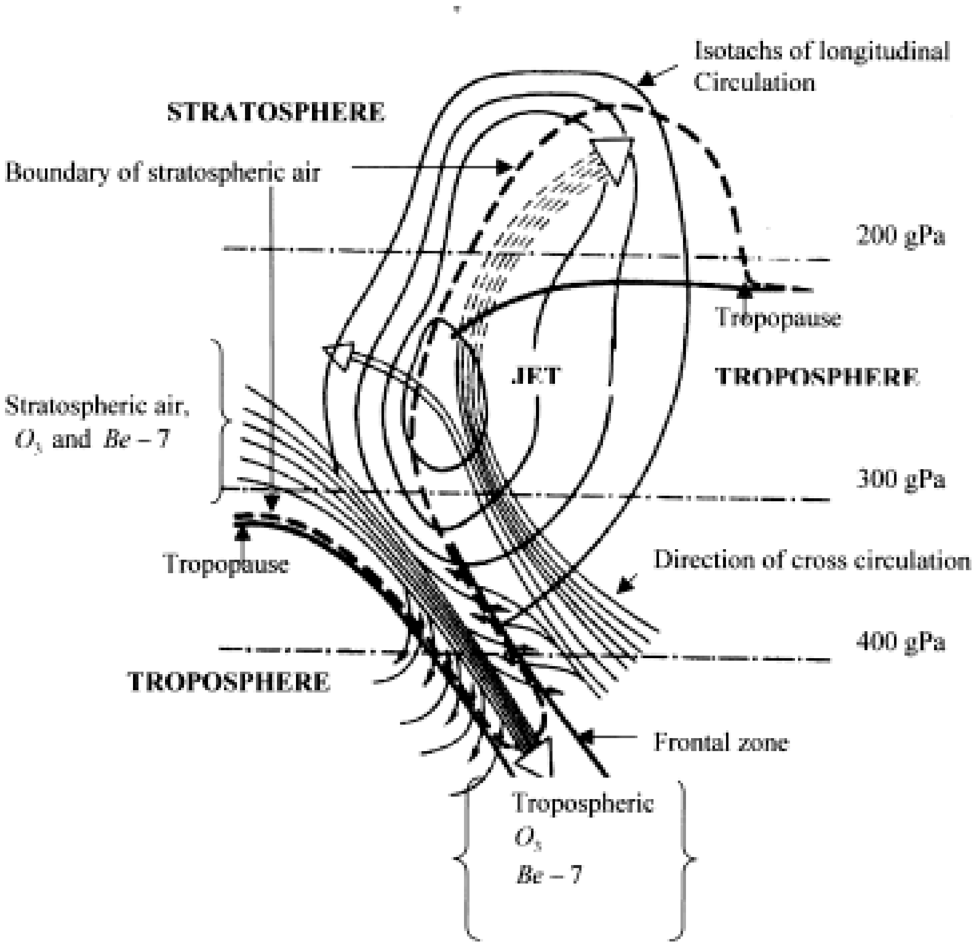

Fig.4. The scheme of possible penetration of Be-7 and ozone from the stratosphere into the troposphere along the atmospheric cold front. The tropopause and its breackthrough in a zone of jet stream are shown.

Summary

1. Though the basic source of Be-7 in the atmosphere are cosmic rays, no direct connection between large solar cosmic ray events and Be-7 concentration have been revealed on the ground.
2. Seasonal variations of Be-7 concentration associated with global spring-autumn rebuilding in the atmosphere seem to have identical character both in low (Tokyo) and high latitudes (Apatity) of the Earth's northern hemisphere.
3. The correlation between Be-7 concentration and troposphere ozone observed in the Kola region may be related to the large-scale break-through of stratospheric air into the lower atmosphere at the edges of atmospheric fronts and jet currents.

Acknowledgements: This work is supported by the RFFI (Russian basic research foundation) grants 02-05-64-114, 03-05-96179-p2003, 03-02-96026-p2003 and INTAS 2000-752, 01-0016

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