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Global Current Circuit Variations Influence on the Spectral Atmospheric Transparency

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Abstract

Events of geomagnetic disturbances (1972, 1973, 1976-78) not associated with solar proton events and Forbush decreases in galactic cosmic rays were considered. It was shown that such geomagnetic disturbances cause atmospheric transparency decreases by approximately 8% and 11% comparison with undisturbed level at high (φ = 60°) and low (φ = 43°) latitudes correspondingly. At middle latitudes (φ = 55°) this effect is almost unobservable, about 3%. Atmospheric transparency recovery after geomagnetic disturbance occurs at high latitudes much faster then at low latitudes.

1 Introduction

The influence of the solar activity on the state of the middle and lower atmosphere is a problem which more and more attracts the attention of geophysicists. There are many articles about influence of the energetic cosmic ray flux variations [4] and solar proton events [3,5] on amount of the solar radiation coming at the Earth surface. Cosmic ray particles (both of galactic and solar origin) have a sufficient energy to penetrate to the stratospheric altitudes and since may affect the temperature regime in the troposphere [6], circulation of the lower atmosphere and process of clouds formation. At the same time, the amount of the solar radiation at the Earth surface and, consequently, the temperature regime directly depends on the spectral atmospheric transparency variations. That why studying temporary and space characteristics of the spectral atmospheric transparency variations are very interesting for us. Furthermore, it may be one of the most plausible agent linking cosmic ray flux variations and solar activity to various weather phenomena.

Pudovkin and Veretenenko (1995) [1] showed that decreases of the galactic cosmic ray flux intensity (is known as Forbush decreases) are associated with decreasing of the cloudiness. At the same time, Pudovkin and Veretenenko (1996) [2] demonstrated increasing of the spectral atmospheric transparency in association to the bursts of energetic solar proton fluxes.

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Global current circuit variations influence on the spectral atmospheric transparency

To study relationships between spectral atmospheric transparency and geomagnetic activity is interesting in association to the global current circuit variations. It is known, that current in the global current circuit is depended on the conductivity of the atmosphere. In turn, the conductivity is influenced by cosmic ray flux variations, bursts of the energetic solar protons and magnetic storms. Magnetic storms also changes ionospheric potential distribution and, as consequence, distribution of the "fine-weather" currents. Those currents charge aerosol particles at the height 10 km, thus forming the "haze layer", and such a way change the atmospheric transparency. However, the precise mechanism of the "haze layer" formation is not clear today.

Thus the aim of this article is to examine whether the observed variations of the spectral atmospheric transparency are caused only by global current circuit variations during that magnetic storms, which isn’t associated with Forbush decreases or bursts of solar protons. Such magnetic storms we will call the "clear" magnetic storms.

2 Analysis of experimental data and discussion

In order to find any relationships between global current circuit variations during "clear" magnetic storm and variations of the spectral atmospheric transparency, the data of the average values of the spectral atmospheric transparency $P_{\lambda} \cdot 10^2$ for $\lambda=369$ nm have been used [9, 10]. We have been chosen ultraviolet range of waves because effects associated with spectral atmospheric transparency variations are more noticeable in this range of waves due to its better scattering. In order to separate geomagnetic disturbances are not associated with Forbush decreases and solar proton events the data from sources [11, 12] were used. The variations of spectral atmospheric transparency during "clear" magnetospheric disturbances have been investigated for three latitudinal belts: $\varphi = 60^0$ (St.Petersburg), $\varphi = 55^0$ (Omsk, Skovorodino), $\varphi = 43^0$ (Vladivostok, Feodosia, Chardjou).

The list of observatories are presented in the table 1.

<table>
<thead>
<tr>
<th>N</th>
<th>Name</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Leningrad</td>
<td>59°0'58&quot;</td>
<td>30°0'18&quot;</td>
</tr>
<tr>
<td>2</td>
<td>Omsk</td>
<td>54°0'56&quot;</td>
<td>73°0'24&quot;</td>
</tr>
<tr>
<td>3</td>
<td>Skovorodino</td>
<td>54°0'00&quot;</td>
<td>123°58'</td>
</tr>
<tr>
<td>4</td>
<td>Vladivostok</td>
<td>43°0'41&quot;</td>
<td>132°10'</td>
</tr>
<tr>
<td>5</td>
<td>Feodosia</td>
<td>45°0'02&quot;</td>
<td>35°0'23&quot;</td>
</tr>
<tr>
<td>6</td>
<td>Chardjou</td>
<td>39°0'05&quot;</td>
<td>63°0'30&quot;</td>
</tr>
</tbody>
</table>

Spectral atmospheric transparency $P_{\lambda}$ have been defined by formula

$$P_{\lambda} = \left( \frac{S_{\lambda}}{S_{\lambda,0}} \right)^{\frac{1}{n}}$$  \hspace{1cm} (1)

$P_{\lambda}$ - spectral atmospheric transparency;
$S_{\lambda}$ - direct solar radiation with wavelength $\lambda$ near Earth surface;
$S_{\lambda,0}$ - direct solar radiation with wavelength $\lambda$ near outside the atmosphere;
m - optical mass of the atmosphere.

The geomagnetic activity indices $\sum_8 K_p$ date have been taken from [13]. The days of the maximum intensity of the geomagnetic disturbances have been used as the key days ($t=0$) in a superposed epoch analysis. These days have been defined by a maximum value of daily $(\sum_8 K_p)_{max}$ indices during the disturbances under consideration. We have taken into consideration period of 1972-1978. Variations of the spectral atmospheric transparency have been calculated with respect to the undisturbed level obtained by the averaging of the min values $P_{\lambda}$ measured for 15 days before and after the maximum of the disturbance.

Variations of the spectral atmospheric transparency $P_{\lambda}(t)$ and geomagnetic activity indices $\sum_8 K_p(t)$ during the "clear" geomagnetic disturbances at high and low latitudinal belts, are presented at Fig.1.

![Figure 1: Variations of the spectral atmospheric transparency $P_{\lambda}(t)$ and geomagnetic activity indices $K_p(t)$ during the "clear" geomagnetic disturbances at high and low latitudinal belts.](image)

A distinct decrease of the $P_{\lambda}$ during geomagnetic disturbance takes place in both cases. At high latitudes decreasing of the spectral atmospheric transparency $P_{\lambda}$ begins simultaneously with an increasing of geomagnetic activity index $K_p$, in turn, at low latitudes $P_{\lambda}$ begins decrease only when $\sum_8 K_p$ amounted to a significant value. Day of minimum $P_{\lambda}$ at low latitudes occurs at the third day after maximum of the disturbance, when it isn’t a significant already. At the low latitudes the recovery phase takes more time (4 days), then it takes in the high latitudinal belt (2 days). It stands together with results of Starkov and Roldugin [8]. They have considered variations of the spectral atmospheric transparency for $\lambda = 344\,\mu m$ and $\lambda = 627\,\mu m$ during a significant geomagnetic disturbances $AE> 500\,\gamma$ for period of 1973-78. They have shown that $P_{\lambda}$ decreases by 4% one day before the maximum of the disturbance and at 4th day it was equal to 5% with respect to undisturbed level. Besides at Feodosia ($\varphi = 43^0$) the recovery phase requires 4 days more then one at Murmansk ($\varphi = 68^0$).

As for middle latitudes, variations of the $P_{\lambda}(t)$ and geomagnetic activity indices $\sum_8 K_p$ during the disturbances are presented at Fig.2.

A detailed analysis of the data shows that no significant effect is observed at middle latitudes $\varphi = 55^0$. The spectral atmospheric transparency decreases about to 3% relative to the undisturbed level. It may be explained by cut-off effect of the geomagnetic field. Also it may shows
that the agent responsible for the atmospheric transparency variations associated with the geomagnetic disturbances does not exist in the middle latitudes. All said above permits us to suppose what decrease of $P_\lambda$ at low latitudes occurs due to the atmospheric circulation and transference of air masses from high to low latitudes, but not due to geomagnetic disturbance. As for amplitude of the effect, spectral atmospheric transparency $P_\lambda$ decreases about 8% and 11% with respect to the undisturbed level (35-50%) at high and low latitudes correspondingly. In the middle latitudinal belt the decrease of $P_\lambda$ is amount to 3%. According to Roldugin and Vasheniuk [7], spectral atmospheric transparency $P_\lambda$ for $\lambda = 344\text{nm}$ decreases about 22% with respect to the undisturbed level (45-50%) during bursts of solar protons with energy $E > 25$ MeV. Thus, the solar proton events largely influence on the $P_\lambda$ then ”clear” geomagnetic disturbances.

3 Conclusions

The results of the analysis permit us to suppose, that global current circuit variations associated with ”clear ” geomagnetic disturbance may cause an observable spectral atmospheric transparency variations.

This variations has an extreme amplitude at low (11%) and high (8%)latitudes. At middle latitudes this effect is almost unobservable, about 3%.

Atmospheric transparency recovery after geomagnetic disturbance occurs at high latitudes much faster then at low latitudes. At high latitudes decreasing of the spectral atmospheric transparency $P_\lambda$ begins simultaneously with an increasing of geomagnetic activity index $K_p$, in turn, at low latitudes $P_\lambda$ begins decrease only when $\sum K_p$ amounted to a significant value.

References


