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The Atmospheric Response to Geomagnetic Disturbances

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Abstract

The Sun-climate connection is a matter of cutting-edge research on Earth. A storm in the Earth's magnetosphere causes numerous processes in this area of the near-Earth space. The Earth ionosphere processes undergo essential variations during this kind of a magnetospheric disturbance. Convection electric fields of magnetospheric origin have dynamical importance for the high-latitude thermosphere–ionosphere. The magnitude and the orientation of the interplanetary magnetic field is a major factor that shapes the structure of the associated convection patterns. During the very powerful magnetospheric storms, the processes in the geomagnetosphere had a large-scale character. Heavy flows of precipitating energetic auroral particles and magnetospheric electrical fields transported energy into the highlatitude thermosphere. This huge energy increased the ionosphere temperature, caused large-scale ionic drifts and neutral winds. The dynamics of the upper atmosphere is strongly controlled by the intensity of the solar EUV radiation. Between the solar-terrestrial disturbance parameters, on the one hand, and the cyclogenesis characteristics, on the other, various researchers endeavor to trace hard-to-detect statistical communications associations. The aim of this paper is research and the analysis of effect of magnetic storms and substorms on the powerful cyclones. The collected data on magnetic storms and tropical cyclones are analyzed for understanding of the mechanism of magnetospheric disturbances effects on the atmospheric processes.

1. Introduction

The Space Weather Program refers to the magnetic disturbances and high radiation levels that result from solar activity. Auroras, power outages, and radio blackouts are some of the manifestations of space weather that we experience on Earth [1]. The Sun-climate connection is a matter of cutting-edge research on Earth. The paradigm of interplanetary space weather sets the stage for it to be cutting-edge research on our planet. How do magnetic storms and substorms affect the density of the atmosphere? How do cosmic rays influence cloud cover on Earth? How do long-term changes in total solar irradiance alter surface temperatures of the planet? These are questions that can be answered as scientists learn more about space weather throughout the solar system. Moreover, comparative climatology shows that these questions must be answered to get to the bottom of what is happening in the system solar wind-magnetopshere-ionosphere-lower atmosphere [1]. Convection electric fields of magnetospheric origin have dynamical importance for the magnetopshere-ionosphere-lower atmosphere interaction [3], [4], [5]. The magnitude and the orientation of the interplanetary magnetic field is a major factor that shapes the structure of the associated convection patterns [6]. Two major sources of energy deposition from the magnetosphere to the magnetopshere-ionosphere-lower atmosphere interaction are Joule dissipation and auroral particle precipitation, which can impact the morphology of the highlatitude upper thermosphere [15], [16]. According to the paper [17], a tropical cyclogenesis may be "a mechanism for effective discharge of the surplus heat in the atmosphere under the conditions when the routine mechanism effect becomes insufficient." There is the Eigenson-Usmanov hypothesis of a possible solar activity impact on tropical cyclogenesis. Between the solar-terrestrial disturbance parameters, on the one hand, and the cyclogenesis characteristics, on the other, various researchers endeavor to trace hard-to-detect statistical communications associations [15-17], [18,19]. In the study, the correlation between tropical cyclones and the 23-solar-cycle storms was investigated. The revealed coincidence between the time of origin and evolution for the 23-24 Aug 2005 Hurricane Katrina with the powerful geomagnetic storm main phase [2] also boosted the research in this trend.

The magnetopause el. potential is functionally linked to the solar wind parameters [3-5]. I followed [3], [5], [8-12] in the approach to the description of the bow shock and magnetospheric processes. All obtained equations in [8], [10], [12], [13], [14] can be applied to calculate key parameters and to model the processes of solar wind-magnetopshere-ionosphere-lower atmosphere interaction.

A storm in the Earth's magnetosphere causes numerous processes in this area of the near-Earth space. Also, the Earth ionosphere processes undergo essential variations during this kind of a magnetospheric disturbance [7], [14]. The aim of the paper is to investigate a possible effect of magnetospheric disturbances on the magnetopshere-ionosphere-lower atmosphere interaction.

2. Results of study

During the very powerful magnetospheric storms, the processes in the geomagnetosphere had a large-scale character [3-14]. Heavy flows of precipitating energetic auroral particles and magnetospheric electrical fields transported energy into the highlatitude thermosphere. This huge energy increased the ionosphere temperature, caused large-scale ionic drifts and neutral winds. A lot of papers are devoted to researches of magnetic storms. It is quite cumbersome to include any plots of magnetograms, indexes for these events in the paper and in order to save space I do not give it here. I selected any types of magnetospheric storms for the investigation, and I analyzed the effect of storms on the powerful cyclones. I analyzed the collected data on magnetic storms and tropical cyclones that were observed in the North Atlantic, East Pacific, and West Pacific to understand the mechanism for the magnetospheric disturbance effect on the complicated non-linear system of atmospheric processes. One of the key issues is that the atmosphere-ocean phenomena in tropical regions, large-scale in time and space, form a complex node of interdependent phenomena whose association with magnetospheric disturbance has remained unclear at present. There is a difficult natural system: solar wind-magnetosphere-ionosphere-lower atmosphere.

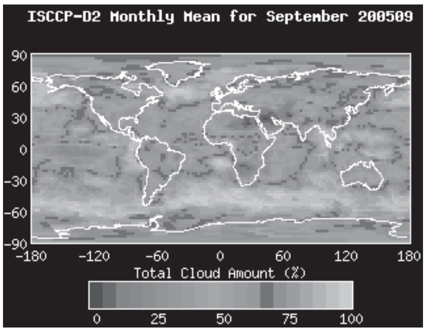

Figure 1. The example of data for researches.

Cloud layers play an important role in Earth’s radiation balance [18], affecting the amount of heat from the Sun that reaches the surface and the heat radiated back from the surface that escapes out into space. There is special attention to the effect of the solar wind electric field sharp increase (via the global electric circuit during magnetospheric disturbances) on the cloud layer formation. It is necessary to test the assumptions that this layer may function as a screen decelerating radiative cooling of the air located on the Central Antarctic ice dome (as a result, there would be warming in the ground atmospheric layer, and cooling above the cloud layer [19]. Authors in the paper [19] suggested that the interplanetary electric field influences the katabatic system of atmospheric circulation (typical of the winter in the Antarctic), via the global electric circuit affecting clouds and hence the radiation dynamics of the troposphere. The global atmospheric electric circuit is connected through a high-altitude ionosphere, and magnetospheric disturbances can effect on the stationary and changes of an atmospheric electric field. Process of electric field penetration from the solar wind is complicated; this phenomenon is nonlinear. Plasma convection generation in the geomagnetosphere is associated with processes at the bow shock front.

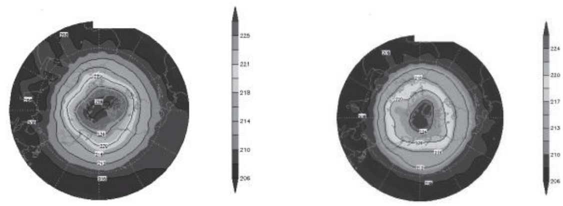

Figure 2. Examples of data for researches.

The electrodynamic coupling between the geomagnetosphere and the ionosphere-lower atmosphere coupling is very complex and described by the global electric circuit. Many aspects are not well understood. My study shows that coupling influences both the electron density and electrical conductivity. Variation of conductivity and external current in the lower atmosphere lead to the perturbation of electric current flowing in the global electric circuit of magnetosphere- ionosphere-lower atmosphere interaction. Detection of connection between magnetospheric storms and substorms and meteorological effects in the atmosphere is complicated because of weakness of effect of geomagnetic storms on troposphere in comparison with set of other factors influencing it. This study is devoted to researches of probable effect of magnetospheric disturbances on character of development of meteorological processes in the lower atmosphere (in the high-latitude regions, in the mid-latitude regions). But one should not to make the same conclusions as at research of influence of magnetospheric disturbances on the difficult nonlinear system: atmosphere - ocean. This problem should be allocated into separate research.

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