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On the Magnetospheric Disturbance Effect on Tropical Cyclogenesis

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Abstract

The collected data on magnetic storms and tropical cyclones, which were observed in the North Atlantic, East Pacific, and West Pacific, are analyzed for understanding of the mechanism of magnetospheric disturbances effects on complicated nonlinear system of atmospheric processes. A study of effects of geomagnetospheric storms on tropical cyclogenesis is necessary, because character of some influence has regional peculiarities.

1 Introduction

The book [5] is particularly welcome at a time at which many astronomers, space scientist, geophysicist, and meteorologists are entering the field of Sun-weather/climate investigation. This book provides an excellent opportunity for a scientist considering this new field to get an overall view of the present status of the subject in its many disciplinary aspects. The existing correlations provide a strong suggestion that some physical mechanism exists linking the variable Sun and the weather and climate, but the details of such a mechanism or mechanisms are quite unknown.

Statistical correlations were found between geomagnetic activity, atmospheric pressure and temperature [1] and [7]. Authors of [3] suggested that the observed climate response to solar variability is brought about by a dynamical response in the troposphere to heating predominantly in the stratosphere.

It is known that 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". 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 revealed coincidence between the time of origin and evolution of the 23-24 Aug 2005 Hurricane Katrina with the powerful geomagnetic storm main phase also boosted the research in this trend.

The link between the enhanced solar wind (geomagnetic) forcing, the North Atlantic Oscillation (NAO) and changes in the troposphere was suggested in [1] showing that the strengthening of thermospheric winds generates vertical downward winds in the aurora [2].

In [6] author examined the possible connection between atmospheric parameters measured at low and middle altitudes and geomagnetic storms occurred in 2000 and 2003. The results presented in [6] may show evidence to support that atmospheric parameters at heights of the troposphere and lower stratosphere could be possibly related to geomagnetic storms.

The objective of this paper is to investigate effects of geomagnetic activity on meteorological processes and a possible effect of magnetospheric disturbances on the tropical cyclogenesis evolution character.

Usually, researchers considered magnetospheric and atmospheric problems in separate papers. This paper is an attempt to combine consistent parts taken from the meteorology, ionospheric and magnetospheric physics.

2 Discussion of results

The power of the ionosphere's Joule heating U_j is calculated either through the Assimilative Mapping of Ionospheric Electrodynamics (AMIE), or estimated based on empirical formulas as the AE-index function: $U_j=0.33\times AE$, where U_j is in GWatt, and the AE-index is in nT; E- is an electric field; Σ_p – is Pedersen conductivity integrated on height. The power of the energetic particles precipitating into the ionosphere U_a can be also estimated based on empirical formulas $U_a=1.75\times(AE/100+1.6)\times10^{10}$ (W). I also used the databases for hurricanes at [http://www.nhc.noaa.gov/pastall.shtml], [http://www.csc.noaa.gov/hurricane_tracks], and [http://www.aoml.noaa.gov/hrd/hurdat/ushurrlist18512007.txt]. To study the surface pressure, the temperature, and other characteristics, we used the data at [ftp://ftp.cdc.noaa.gov]. The information on tropical cyclones was obtained from: <http://russian.wunderground.com/hurricane/hurrarchive.asp?region=at>.

It's known that for average storms -100 nT ≤ Dst-index ≤ -50 nT; for strong storms -200 nT ≤ Dst-index ≤ -100 nT; for extreme powerful storms Dst-index ≤-200 nT.

The 1986 May 3 magnetospheric storm over the (0000-1100) UT interval was studied within the international CDAW9C (Coordinated Data Analysis Workshop) Project, and represented a 4-substorm chain [8]. This event refers to magnetospheric storms occurred during solar Cycle 21. It featured the AE-index reaching the values of about 1400-1500 nT, whereas the Dst-index reached only -70-80 nT (see Figures 1-2). Because this storm comprised 4 substorms, we detected the substorm phases by timing each of the 4 substorms. Following [8], I will term these phases the growth phase (1), the actively-convective phase (2), the expansion (explosive) phase (3) and the recovery phase (4).

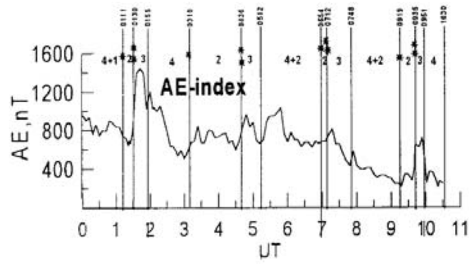

Figure 1. AE-index for the chain of substorms, May 3, 1986. Timing of the chain of substorms CDAW9C. Single and double asterisks indicate the actively-convective phase and the expansion (explosive) phase of the substorm, respectively.

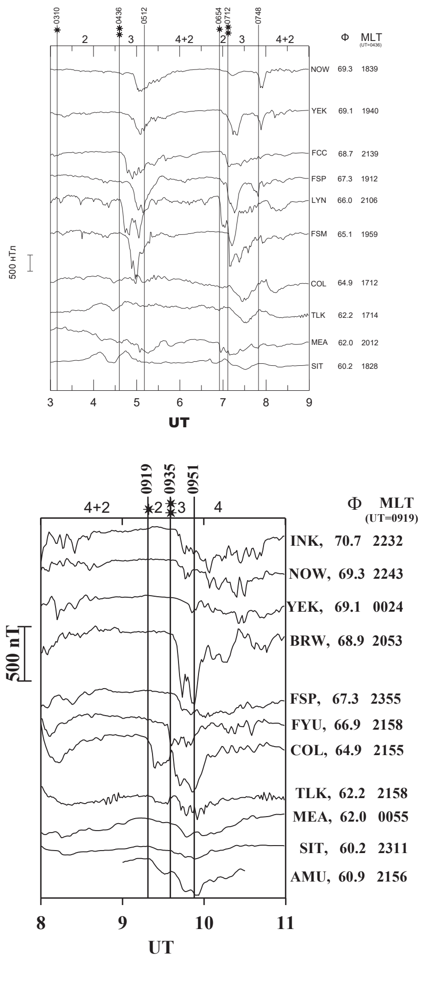

Figure 2. Timing of the chain of substorms CDAW9C. Magnetograms of the ground-based magnetometers for the chain of substorms; May 3, 1986.

In summary, the data on the 1986 May 3 event (Figures 1-2) could be used to trace the each substorm phase contribution (energy loading-unloading) to the composite set of processes in the lower atmosphere.

The 1989 March 13-14 magnetospheric storm refers to one of the strongest magnetospheric storms observed since the space era onset, and occurred during solar Cycle 22. The geomagnetic storm reached the maximal intensity on 1989 Mar 13 when the Dst-index reached a record value of about -600 nT. To save space, we do not give the illustrations for the 1989 March 13-14 event here. There are many papers describing this storm.

The 2003 Oct-Nov solar activity sharp burst led to strong magnetospheric storms with the 2003 Oct 28-31 high AE-index values and Dst-index of about -400 nT.

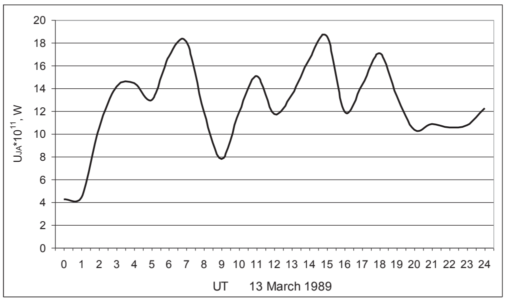

Figure 3. Estimations of power of Joule heating and of power of particles precipitation into the ionosphere (U_j+U_a) for the magnetospheric storm - March 13, 1989.

The result of our investigation is that the 1989 March magnetic storm did not directly affect the tropical cyclogenesis evolution character. As for the 2003 Oct-Nov storms, one can not answer unambiguously, either, because 5 plus intense and long-lived cyclones were observed then. The 13 Oct - 1 Nov strong storm in the North Atlantic had existed extremely long (19 days), taking into account that the cyclone life average duration in Atlantic is 9 days. In 2003 Oct, 3 tropical cyclones were observed in the East Pacific: Hurricane Nora (Oct 1-9, the maximal wind being 41m/s); Tropical Storm Olaf (Oct 3-8, 30 m/s); Tropical Storm Patricia (Oct 20-26, 31 m/s). However, all of the strong storms in the East Pacific were observed prior to the magnetic storm onset.

I analyzed the data base for hurricanes in USA within ±2 weeks relatively to the magnetospheric storms under study and found no events on these days. It is well known that tropical cyclones in the Northern hemisphere start forming since June and have a seasonal maximum in August-September when the ocean surface at low latitudes is warm enough. As we considered the magnetospheric events in March, May and November, there was a little chance to find a tropical cyclone over USA which would be associated with these events. An appearance of a tropical cyclone over USA (which would be associated with these magnetospheric disturbances) would mean that presence of magnetospheric storms could stimulate the tropical cyclogenesis evolution. But it has not occurred. Then there is still a variant, that the magnetosheric storm presence might suppress the tropical cyclogenesis evolution.

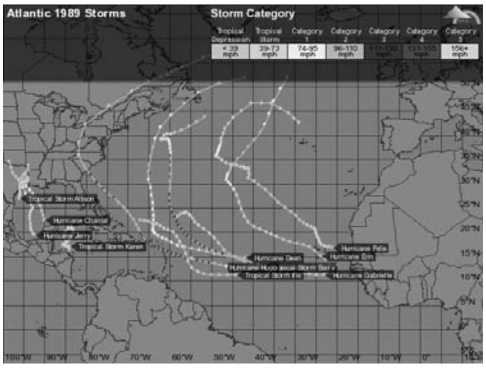

Figure 4. A) The example of the trajectory of the cyclone observed in the North Atlantic, for events in 1989. B) The example of the trajectory of the cyclone observed in Eastern Pacific, for events in 1989.

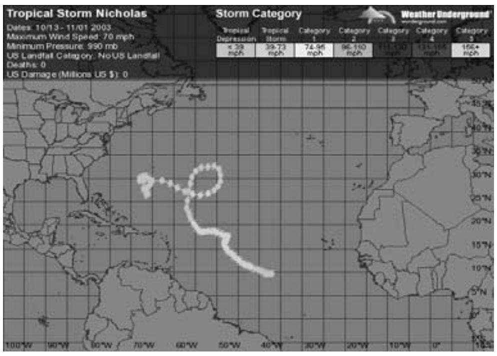

Figure 5. The example of the trajectory of the cyclone observed in the North Atlantic on 31 October - 1 November 2003. This cyclone was observed during the magnetic storm and has existed for the longest time (19 days), considering the average life time of cyclones of 9 days in the North Atlantic.

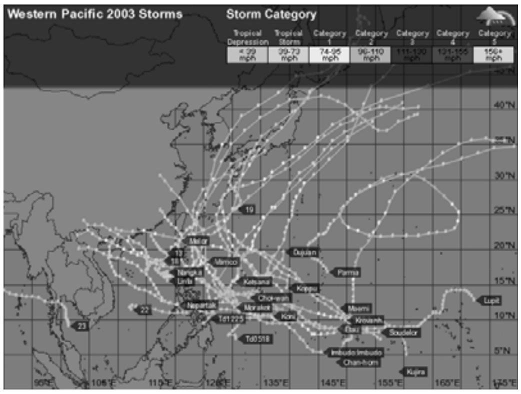

Figure 6. A) The example of trajectories of the cyclone observed in Eastern Pacific. In October, 2003 in East part of Pacific ocean 3 outputs of a tropical cyclone were observed: Hurricane Nora, October, 1-9, 2003, with the maximal speed of wind – 41m/s; Tropical Storm Olaf , October, 3-8, 2003, with maximal wind speed of 30 m/s; Tropical Storm Patricia, October, 20-26, 2003, with the maximal wind speed of 31 m/s. All storms were observed prior to the beginning of action of the magnetospheric storm.
B) The example of trajectories of the cyclone observed in Western Pacific for events in 2003. In October - November, 2003, more than 5 intensive and long cyclones were observed.

3 Conclusions

Methods for weather prediction are improving every year. Nowadays, extensive use is made of numerical weather predictions which have become available in near real time due to computer simulation. This process involves complicated computations and processing of a vast dataset; it can be completely accomplished only by high-power supercomputers. The numerical weather prediction model is a computer program based on a physical system of equations, which employs real-time data to make meteorological predictions. This model may be global, covering the whole Earth, or local, comprising a separate area of the planet. Such models are known to rely on mathematical equations describing aero- and thermodynamics atmospheric processes and linking such parameters as density, velocity, pressure, and temperature. These equations are nonlinear and have no exact solution; therefore they are solved by numerical methods. Initial equations are discretized in time and space and are transformed into a system of linear equations that connects sets of physical parameters at given points (computer network nodes). The greater is the number of points, the higher is the accuracy of the model, but at the same time the higher are requirements on the processing power of computers. As initial data for the models we employ data from weather balloons, weather satellites, and ground-based weather stations. One way to improve weather forecasting is to include additional parameters affecting weather in the models. Findings of the research into effects of magnetospheric-ionospheric disturbances on weather may be used for refining numerical weather prediction models. One major goal of developing more and more new and powerful models of atmosphere is to predict extreme weather events. Extreme weather events cause considerable financial loss. If we know about them in advance, we will be able to preserve property and save people's lives. It should be understood that electric power transmission and consumption are sensitive to variations in weather conditions. Moreover, weather prediction is important for ships; data on high-altitude turbulence, for airplanes. In these areas of activities, there is a paramount need for improved accuracy and quality of predicting both extreme weather and general conditions in the atmosphere, sea and ocean waters. A further study of geomagnetospheric storm effects on tropical cyclogenesis is necessary, because character of some influence has regional peculiarities. In the next paper, we are going to investigate a probable effect of such magnetospheric disturbances as sawtooth events [9-12, 13], extraordinary powerful magnetic storms, and some others on meteorological processes in the lower atmosphere.

4 Acknowledgements

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