**Use of geomagnetic indices in weather issues**

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**Abstract**

Solar Flares, Coronal Mass Ejections (CMEs), Solar Energetic Particles (SEPs) are the drivers of the Space Weather Effect in Geo-Space. Geomagnetic indices are important parameter in weather forecasting methods. The development of the global circulation processes are depending on their capacity in, and then the emergence of the local weather. The correlation between geomagnetic storms and meteorological elements (temperature, precipitation, wind) have been determined for Georgian region using meteorological observation and NASA’s Solar Dynamics Observatory and NOAA Space Weather Prediction Center data. The results show that there exist dependence between weather parameters and income radiation.

**Key words:** Geomagnetic storm, weather formation, geomagnetic indices

**Introduction**

Solar transients; Solar Flares, Coronal Mass Ejections (CMEs), Solar Energetic Particles (SEPs) are the drivers of the Space Weather Effect in Geo-Space. When the gigantic cloud of plasma released through solar transient phenomena interacts with the Earth’s magnetic environment it leads to the geomagnetic storms. Geomagnetic storms can be characterized by a depression in the H component of geomagnetic field. This depression in H component of earth’s magnetic field is caused by the Ring Current encircling the Earth in a westward direction. Earth’s ionosphere responds to varying solar and magnetospheric conditions. The ionosphere electron density over an altitude and location depends variably on the solar EUV Flux, X-ray Flux and the dynamic effects of neutral winds and electric fields. During geomagnetic storm due to the compression of earth’s magnetosphere by solar wind electric fields have been observed along the geomagnetic field lines to the high latitude ionosphere. Sometimes this electric field penetrates to low latitudes and energetic particles precipitate into the lower thermosphere and below, increasing ionosphere conductivity and expanding the aurora zone [1]. These intense electric currents are responsible for the coupling of high latitude ionosphere with magnetosphere and the enhanced energy input leads to considerable heating of the ionized and neutral gases. There are two types of effects, in time scale, on the Earth produced by solar transients; prompt and delayed. Geomagnetic Storm effects are delayed effects due to cloud of particles ejected from Sun.

The sun undergoes cyclical (~22 year) pattern of magnetic pole reversals observable in the frequency of sunspot activity. This pattern is comprised of two ~11 year solar cycles phases. In the first phase, the sun’s magnetic poles reverse polarity. In the second phase, the sun reverses the magnetic polarity again returning the poles back to its original polarity. Solar storm activity is strongly phase dependent [2].

Sunspots are the site of origin for great solar storms. The sun spins on its axis. As seen from Earth, the average rotation period of the Sun averages 27 days. Great sunspot groups can stay active for several solar revolutions creating a cyclical ~27 day pattern of solar storms.

Solar flares are magnetically driven explosions on the surface of the sun. Approximately 8 minutes after a solar flare occurs on the surface of the sun, a powerful burst of electromagnetic radiation in the form of X-ray, extreme ultraviolet rays, gamma ray radiation and radio burst arrives at Earth. The ultraviolet rays heat the upper atmosphere which causes the outer atmospheric shell to expand. The x-rays strip electrons from the atom in the ionosphere producing a sudden increase in total electron content. Solar flares produce satellite communications interference, radar interference, shortwave radio fades and blackout and atmospheric drag on satellite producing an unplanned change in orbit and other disturbances in upper atmosphere.

CMEs are vast clouds of seething gas, charged plasma of low to medium energy particles with imbedded magnetic field, blasted into interplanetary space from the Sun. When a CME strikes Earth, the compressed magnetic fields and plasma in their leading edge smash into the geomagnetic field. This produces a temporary disturbance of the Earth’s magnetosphere called a geomagnetic storm and an equatorial ring of currents, differential gradient and curvature drift of electrons and protons in the Near Earth region. The birthplace of CMEs are often seen to originate near the site of solar flares

The severity of a geomagnetic storm depends on the orientation of Earth's magnetic field in relation to the solar storm magnetic orientation. If the particle cloud has a southward directed magnetic field it will be severe, while if northward the effects are minimized.

A CME can produce the following affects: electrostatic spacecraft charging, shifting of the Van Allen radiation belt, space track errors, launch trajectory errors, spacecraft payload deployment problems, surveillance radar errors, radio propagation anomalies, compass alignment errors, electrical power blackouts, oil and gas pipeline corrosion, communication landline & equipment damage, electrical shock hazard, electrical fires, heart attacks, strokes, and workplace & traffic accidents A magnetospheric storm is a 1–3 day long phenomenon spanning all the magnetosphere regions, and it features sharp depressions in the magnetic field. During storms and sub-storms, the ionosphere undergoes rather significant Joule heating with a great power of precipitating energetic particles. Huge energy increases the ionosphere temperature and causes large-scale ion drifts and neutral winds [4].

**Data and methods**

The solar wind conditions that are effective for creating geomagnetic storms are sustained (for several to many hours) periods of high-speed solar wind, and most importantly, a southward directed solar wind magnetic field (opposite the direction of Earth’s field) at the dayside of the magnetosphere. This condition is effective for transferring energy from the solar wind into Earth’s magnetosphere.

The largest storms that result from these conditions are associated with solar coronal mass ejections (CMEs) where a billion tons or so of plasma from the sun, with its embedded magnetic field, arrives at Earth. CMEs typically take several days to arrive at Earth, but have been observed, for some of the most intense storms, to arrive in as short as 18 hours. Another solar wind disturbance that creates conditions favorable to geomagnetic storms is a high-speed solar wind stream (HSS). HSSs plow into the slower solar wind in front and create co-rotating interaction regions, or CIRs. These regions are often related to geomagnetic storms that while less intense than CME storms, often can deposit more energy in Earth’s magnetosphere over a longer interval.

**The aim** of presented paper is to investigate possible effect of magnetospheric storms on the evolution character of meteorological processes in the atmosphere, to study the correlation between magnetospheric disturbances and meteorological background variations. The Sun, together with the Earth’s motion along its orbit, govern changes in the solar–terrestrial environment on time scales ranging from minutes to glacial cycles. Changes in Earth’s climate have been the focal point of recent research in the solar–terrestrial physics (STP), and a special emphasis has been placed on the coupling between the troposphere (below 10–15 km altitude), middle atmosphere (10–100 km altitude), and near- Earth Geo-space (mesosphere, thermosphere, ionosphere, and magnetosphere), and solar activity.

**Kp** has been continuously calculated since 1932 by the GFZ in Potsdam and is available at [www.gfz](http://www.gfz) potsdam.de. The Kp index is probably the most widely used of all magnetic indices. It is intended to express the degree of “geomagnetic activity,” or disturbance for the whole Earth, for intervals of three hours in Universal Time. In order to allow for simple averaging operations, the Kp indices are next converted, by use of a table, from their quasi-logarithmic scale to a roughly linear scale (in nT), yielding the so-called 3-h ap index. Finally, index Ap is defined as the average of the eight 3-h ap indices [5,6,7].

 The disturbance storm time (Dst) index, has been used historically to characterize the size of a geomagnetic storm. In addition, there are currents produced in the magnetosphere that follow the magnetic field, called field-aligned currents, and these connect to intense currents in the ionosphere. All of these currents, and the magnetic deviations they produce on the ground, are used to generate a planetary geomagnetic disturbance index called Kp. This index is the basis for one of the three NOAA Space Weather Scales, the Geomagnetic Storm, or G-Scale, that is used to describe space weather that can disrupt systems on Earth [7].

The intensity of a geomagnetic storm is commonly defined by the **minimum Dstvalue**, or the maximum depressed *Dst* magnitude. The depression of the magnetic field during the main phase is explained as the effect of the ring current in the magnetosphere. Dst index below \_50 nT is indicative of moderate disturbance, which turns to intense when \_100 nT threshold is passed and super-intense or extreme if Dst reaches less than \_250 nT. The Dst index [8], which was introduced as a measurement of the ring current encircling the Earth, is considered as a good estimation of the geomagnetic disturbance at mid-low latitudes. Besides the local or global character of the index, its temporal resolution is also an important issue. K-indices are the typical approach to local indices.

The basic data for further analysis are either the occurrence frequencies of Kp index in different magnitude ranges or the daily Ap index. Apart from conventional harmonic analysis of the monthly values which yields amplitudes and phases of the annual and semiannual components, we use also the standard techniques of obtaining spectra through fast Fourier transform (FFT) or the maximum entropy method (MEM), singular spectrum analysis (SSA). SABER instrument is onboarded on NASA’s TIMED satellite. SABER monitors infrared emissions from carbon dioxide (CO2) and nitric oxide (NO), two substances that play the key role in energy balance of air 100 to 300 km. above Earth surface. By measuring the infrared radiance of these molecules, SABER can assess the thermal state of gas at the very top of the atmosphere. When the thermosphere cools, it shrinks, decreasing the radius of Earth’s atmosphere. Thermosphere Climate Index (TCI)–a number expressed in Watts that tells how much heat NO molecules are dumping into space. During Solar Maximum, TCI is high (“Hot”); during Solar Minimum, it is low (“Cold”). The state of the thermosphere can be discussed using a set of five plain language terms: Cold, Cool, Neutral, Warm, and Hot.



Fig.1. The historical record of Thermosphere Climate Index [9].

As 2018 comes to an end, the Thermosphere Climate Index is on the verge of setting Space Age record for Cold

**Discussion**

In order to understand influence of geomagnetic activity on the formation of weather pattern geomagnetic indices achieve [5,6,7,8] and meteorological observation database for 2018-19 have been analyzed. The 3 location were chosen; namely: Tbilisi- (Kartli Region), Batumi- Adjara Region and Telavi-Kakheti Region. The results showed that always weather pattern change: increasing of wind velocity; temperature change (decrease); precipitation amount increasing follows geomagnetic activity. The correlation between meteorological parameters and Geo-storm for Tbilisi is presented in Tab.1.

Table 1. The correlation between meteorological parameters and Geo-storm for Tbilisi 2018-19

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Date | Temp.(C) | Precipitation | Wind (m/sec) | Geo. magn. index |
| 06.05.19 | +17 | Rain showers | 4 | C9.9 |
| 21.03.19 | +9 | - | 16 | C5.3 |
| 22.03.19 | +8 | - | 16 | Kp 6 |
| 23.03.19 | +7 | - | 13 | G2 |
| 24.03.19 | +6 | - | 13 | C4.8 |
| 11.03.19 | +12 | - | 15 | G1 |
| 08.03.19 | +8 | Rain showers. | 13 | C1 |
| 07.03.19 | +9 | Rain showers. | 17 | K4  |
| 09.03.19 | +9 | - | 4 | K4  |
| 01.03.19 | +5 | - | 14 | G1 |
| 26.02.19 | +6 | MIST. Drizzle. | 11 | G1 |
| 09.02.19 | +5 | Rain showers. Mist. | 4 | G1 |
| 31.01.19 | +5 | - | 5 | G1 (Kp5) |
| 29.01.19 | +7 | Mist. Fog, | 14 | C1.9 |
| 27.01.19 | +7 | Mist. | 10 | C5 |
| 24.01.19 | +5 | Mist. | 8 | G1 |
| 23.01.19 | +5 | - | 13 | G1 |
| 05.01.19 | +5 | - Fog, mist | 13 | G1 |
| 17.12.18 | +4 | Drizzle, Mist. | 3 | G1-G2  |
| 16.12.18 | +6 | Rain showers, slight | 6 | G1-G2  |
| 13.12.18 | +6 | Rain showers, slight | 14 | G1-G2  |
| 09.11.18 | +8 | Rain. Mist. | 4 | G1 |
| 11.11.18 | +9 | - | 4 | G1 |
| 05.11.18 | +8 | - | 6 | G2 |
| 03.11.18 | +10 | Rain. Mist. | 3 | G1- |
| 30.10.18 | +12 | - | 3 | G1 |
| 23.10.18 | +17 | Rain, showers | 10 | G1 |
| 25-26.10.18 | +13 | Rain, showers | 17 | G1 |
| 19.10.18 | +15 | - | 4 | G1 |
| 14.10.18 | +14 | - | 3 | G1 |
| 07.10.18 | +13 | - | 4 | G1 |
| 13.09.18 | +22 | - | 5 | G2- |
| 14.09.18 | +24 |  Thunderstorm.  | 4 | G2 |
| 11.09.18 | +20 | Rain, showers | 11 | G2  |
| 26.08.18 | +24 | Rain, showers | 4 | G1 |
| 27.08.18 | +24 | Thunderstorm. Rain. | 4 | G3 |
| 23.08.18 | +26 | Thunderstorm. | 7 | G3 |
| 20.08.18 | +22 | Rain, showers | 6 | G3 |
| 11.08.18 | +20 | Rain, showers. Thunderstorm. | 5 | G1 |
| 12.08.18 | +20 | - | 5 | G1 |
| 15.08.18 | +23 | - | 5 | G1 |
| 16.08.18 | +25 | - | 5 | G1 |
| 17.08.18 | +26 | Rain, showers | 4 | G1 |
| 23-24.07.18 | +26 | Rain, showers Thunderstorm | 7 | G1 |
| 06.07.18 | +25 | Thunderstorm | 13 | C |
| 07.07.18 | +24 | Rain, showers. | 12 | C |
| 09.07.18 | +28 | - | 4 | C |
| 27.06.18 | +28 | - | 5 | G1  |
| 28.06.18 | +30 | - | 6 | G1  |
| 22.06.18 | +26 | - | 4 | M |
| 23.06.18 | +23 | Thunderstorm, moderate. | 8 | C |
| 24.06.18 | +26 | Thunderstorm, moderate. | 9 | C |
| 17,18,19,20.06.18 | +22 | Rain, showers ,Thunderstorm | 10 | C |
| 01.06.18 | +19 | Thunderstorm | 14 | G1  |
| 02.06.18 | +19 | Rain, showers ,Thunderstorm | 9 | G2  |
| 17.05.18 | +21 |  Rain, showers | 5 | G1  |
| 19.05.18 | +21 | Rain, showers | 6 | G1 |
| 14.05.18 | +19 | Thunderstorm | 9 | G2 |
| 06.05.18 | +23 | Thunderstorm | 6 | G2 |
| 07.05.18 | +23 | - | 6 | G2 |
| 20.04.18 | +13 | Rain showers | 16 | G1 |
| 21.04.18 | +12 | - | 12 | G1 |
| 22.04.18 | +13 | - | 11 | G1 |
| 20.04.18 | +13 | - | 16 | G2 |
| 19.04.18 | +14 | - | 14 | G2 |
| 14-15-16.04.18 | +10 | Rain. | 8 | G1 |
| 11.04.18 | +15 | - | 4 | G1 |
| 12-13.04.18 | +17 | Thunderstorm | 7 | G1 |
| 10.04.18 | +13 | - | 5 | G1 |
| 09.04.18 | +14 | - | 5 | G1 |
| 08.04.18 | +13 | - | 5 | G1 |
| 23.03.18 | +10 | Rain. Fog | 7 | G1 |
| 22.03.18 | +10 | - | 9 | G1 |
| 20.03.18 | +14 | - | 5 | G2 |
| 17-18.03.18 | +10 | Rain showers. | 11 | G1; G2 |
| 13.03.18 | +4 | Mist | 6 | G1  |
| 08-09-10.03.18 | +10 | Rain showers | 24 | G1  |
| 03.03.18 | +6 | Mist | 4 | G1  |
| 27.02.18 | +5 | Rain. | 5 | G1  |
| 26.02.18 | +7 | Rain shower,slight. | 14 | G1  |
| 19.02.18 | +6 | Mist, fog,  | 8 | G1  |
| 18.02.18 | +4 | Rain | 2 | G1  |
| 17.02.18 | +5 | - | 4 | G1  |
| 15.02.18 | +5 | - | 3 | G1  |
| 14.02.18 | +6 | Rain, Mist. | 8 | G1  |
| 12.02.18 | +6 | Mist | 14 | C1.5 |
| 10.02.18 | +6 | Mist, fog. Rain showers | 5 | C4 |
| 08.02.18 | +6 | Mist | 3 | C8 |
| 04.02.18 | +5 | - | 6 |  B, C |
| 30.01.18 | +2 | - | 12 | G1 |
| 28.01.18 | +1 | Rain, snow slight.fog. | 4 | G1 |
| 22.01.18 | +5 | - | 6 | B9 |
| 20.01.18 | +7 | - | 17 | G1 |
| 19.01.18 | +5 | Rain, Mist, snowflakes. | 15 | G1 |
| 14.01.18 | +2 | Rain and snow | 4 | G1 |

**Conclusion**

In addition from analyzing of historical records of meteorological observations and geomagnetic activity this correlation became more obvious. Many dangerous hydrometeorological event (flood, landslide) occurred over Georgian territory has driven by this activity, as the result of intensification of precipitation amount. Even hail processes intensification are the result of increasing atmosphere electricity and thunderstorm activity, that are produced by high energy charged particles intrusion into upper atmosphere.

It is not fully clear the physical mechanism of this correlation and the issue needs further investigation applying quantum filed theory that is more suitable for description of photon-photon or photon-charged particle interaction [10]. But it may be assumed that for weather forecasting the only existed numerical weather models aren’t sufficient and they have to be enhanced by electromagnetic models to make forecasting more precise.

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