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Analysis of 2016-18 Geo-space

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Introduction

Since the discovery of the solar activity periodicity, attempts have been made to find a connection between the solar cycle and the terrestrial climate. However, the results are ambiguous. For different periods and locations, both positive and negative correlations have been found between solar activity parameters and meteorological elements like surface air temperature, sea level pressure, precipitation, etc. 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 ionospheric 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 ionospheric conductivity and expanding the auroral zone. 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 [1].

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 substorms, 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.

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.

Data and methods

Geomagnetic indices are a measure of geomagnetic activity occurring over short periods of time. They are useful for studies of upper atmospheric physics, solar terrestrial relationships or removal of disturbed-time magnetic variations when studying the Earth's deep interior. They have been constructed in order to study the response of the Earth's ionosphere and magnetosphere to changes in solar activity [2].

Solar activity can be measured through a number of indices or combinations of indices, such as sunspot number WN and radio flux F10.7 that vary with the electromagnetic output of the Sun, and interplanetary magnetic field strength B and solar wind speed **v** at Earth's distance that are measures of solar wind properties.

Kp has been continuously calculated since 1932 by the GFZ in Potsdam. 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.

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 auroral 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.

The intensity of a geomagnetic storm is commonly defined by the **minimum *Dst* value**, 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 (Gonzalez et al. 1994) and superintense or extreme if Dst reaches less than _250 nT (Echer et al. 2008). The Dst index, which was introduced as a measurement of the ring current encircling the Earth (Dessler & Parker 1959; Sckopke 1966), 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 [3,4].

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**).

The Quasi-Biennial Oscillation

One of the main problems in solar-climatic influences is the instability of the relations found. Different authors have reported both positive and negative correlations between solar activity and surface air temperature. Data from individual meteorological stations with long measurement records show that the sign of the correlation changes regularly in consecutive centennial solar cycles and seems determined by the North-South asymmetry of solar activity: the correlation is positive when the Northern solar hemisphere is the more active one, and negative when more active is the Southern solar hemisphere. On the other hand, the sign of the correlation between solar activity and different climatic elements reveals a similar dependence on the phase of the quasibiennial oscillation of stratospheric winds **(QBO).** QBO signals have been identified in a number of geophysical parameters, e.g. sea level pressure, ozone distribution, Earth's rotation, and its existence has been shown in solar activity parameters as sunspot numbers, solar radio flux at 10.7 cm, green coronal activity, solar neutrino flux, etc.

The weather we experience on Earth typically occurs in the troposphere, the lowest layer of the atmosphere. But the stratosphere, which envelops the planet just above the troposphere, is home to winds of its own. In a new study, *Newman et al.* report an anomalous interruption in an otherwise reliable stratospheric wind pattern known as the quasi-biennial oscillation.

Each cycle of the quasi-biennial oscillation begins with strong westerly winds that flow through the stratosphere in a belt around the equator. Over the course of about 1 year, these winds gradually weaken and descend in altitude to the lower stratosphere as easterly winds replace them. These easterly winds slowly sink and weaken, too, as westerly winds return. The cycle repeats roughly once every 28 months.

Since 1953, scientists have observed equatorial winds by instruments known as radiosondes, which are carried skyward by weather balloons. The quasi-biennial oscillation was discovered in the early 1960s. Although the timing of each cycle has sometimes varied by a few months, the pattern as a whole has remained uninterrupted—until now.

Using radiosonde data from several equatorial locations around the world, the scientists discovered that the quasi-biennial oscillation began to deviate from its usual pattern in late 2015. At that time, westerly winds were descending in altitude and should have continued to sink and weaken as easterlies replaced them. Instead, the westerly winds shifted upward and seemed to cut off the descent of high-altitude easterlies before they could begin their usual dominance. Additional easterly winds developed at lower altitudes in the stratosphere, beneath the rising westerlies. However, by June, the westerlies appeared to have resumed their normal descent.

The North Atlantic Oscillation

Many variations in the weather in the European and North Atlantic regions are linked with changes in the North Atlantic Oscillation **(NAO).** The NAO is measured using a south-minus-north index of atmospheric surface pressure variation across the North Atlantic and is closely connected with changes in the North Atlantic atmospheric polar jet stream and wider changes in atmospheric circulation. The physical, human, and biological impacts of NAO changes extend well beyond weather and climate, with major economic, social, and environmental effects. The NAO index based on barometric pressure records extends as far back as 1850. A greater than normal pressure difference between the Azores and Iceland is a positive NAO, and a weaker than normal pressure difference is a negative NAO. During the winter months, a positive NAO is associated with warmer and wetter conditions across northwest Europe and cooler and drier conditions across southern Europe as the stronger pressure gradient between the Azores and Iceland drives the storm tracks poleward. The opposite is generally true for negative NAO conditions as the weaker pressure gradient generally results in southward-shifted storm tracks, and sea-level pressure (SLP) reversal will typically result in more easterly conditions.

The prominent increase in the NAO between the 1960s and 1990s was thought to be related to human-induced greenhouse gas forcing. However, since then this trend has reversed, with a significant decrease in the summer NAO since the 1990s and a striking increase in variability of the winter—especially December—NAO that has resulted in four of the six highest and two of the five lowest NAO Decembers occurring during 2004–2015 in the 116-year record.These NAO changes are related to an increasing trend in the Greenland Blocking Index (GBI; equals high pressure over Greenland) in summer and a significantly more variable GBI in December. Such NAO and related jet stream and blocking changes are not generally present in the current generation of global climate models. Several plausible climate forcings and feedbacks, including changes in the sun's energy output and the Arctic amplification of global warming with accompanying reductions in sea ice, may help explain the recent NAO changes.

The solar impact on the NAO-like circulation anomalies is primarily originate from the stratosphere as a result of the variability of solar ultraviolet irradiance (Haigh 1994), with possible contributions from the presence of solar wind driven high energy particles (Andersson *et al* 2014, Seppal¨a¨ and Clilverd 2014). These anomalies drive temperature and circulation anomalies in the upper stratosphere (Frame and Gray 2010) that can be transferred downward to the surface through wave-mean flow interactions (Kodera and Kuroda 2002, Lu *et al* 2017a), ultimately projecting onto the NAO-like pattern.

The lower troposphere and the stratosphere is known to be sensitive to changes in solar radiation. The lower troposphere is heated due to adsorption of visible light, while heating of the stratosphere is caused by ozone adsorbing ultraviolet radiation (Kodera & Kuroda 2002). Variations in the spectral solar irradiance affect the production and destruction of ozone. Studies show that spectral changes may result in increased or decre- ased ozone in the atmosphere (Haigh et al. 2010). The Ozone production in the stratosphere increases during solar maximum and decreases during solar minimum (Rind et al. 2008). The variation in total solar irradiance during the 11 year cycle is approximately 0.1 %. The variations of solar irradiance in the ultraviolet wavelength (200 – 250 nm) are considerably larger, with a range from 4– 8 % between solar minimum and solar maximum.

According to observations of the spatial structures of the NAO, they vary during the different phases of the 11-year solar cycle (Kodera 2002). These observations show that the NAO has a larger hemispherical structure, extending to the stratosphere during solar maxi-mum. During solar minimum the spatial structure is instead restricted to the eastern Atlantic and the troposphere (Kodera 2002). Periods with many sunspots and faculae correspond with periods with higher irradiance in the visual spectrum and even stronger response in the ultraviolet, which acts on the ozone level. It is also proposed that galactic cosmic rays can act as cloud condensation nuclei, which may link variations in the cloud coverage to solar activity, since more cosmic rays penetrate the Earth's magnetic field when the solar activity is low and resulted in the following- lower magnetic field strength means few sunspots, fewer sunspots means less solar wind, less solar wind means more galactic cosmic rays, more galactic cosmic rays means more low level cloud formation, more low level clouds means more sunlight reflected back into space, which in turn means less heating of the Earth's surface and atmosphere.

As energetic particles are injected into the inner magnetosphere on the night side, they are influenced by forces due to curvature and gradient of the magnetic field. Because of these forces, protons drift westward from midnight toward dusk and electrons drift eastward from midnight toward dawn, comprising the net effects as a ring current encircling the Earth westward. A geomagnetic storm is nothing but an enhancement of this ring current.

The solar cycle 24 is a relatively weak cycle (Tan2011; Basu 2013). The birth of solar cycle 24 was remarkable in that the Sun emerged from an extremely deep minimum. The maximum phase of cycle 24 is of particular interest because of the sunspot number was rather small (roughly half of the cycle-23 peak). The weak solar cycle resulted in milder space weather, but there were other complications such as longer-living space debris due to the reduced atmospheric drag.

The primary link between a geomagnetic storm and a CME is the out of the ecliptic component (Bz) of the interplanetary magnetic field (Gonzalez et al., 1994; Zhang et al., 2007;Echer 2008a,b, 2013). Echer et al. (2008a) conclusively showed that for all 90 major (Dst < -100 nT) storms that occurred during cycle 23, it was the Bz component that was responsible for the storms (some people have thought that it was possible that the IMF By component was also important). When Bz is negative (south pointing), then the CME field reconnects with Earth's magnetic field (Dungey, 1961) causing the geomagnetic storm. While the Bz component is negligible in the quiet solar wind, CMEs contain Bz by virtue of their flux rope structure. Fast CMEs drive shocks, so the compressed sheath field between the flux rope and the shock can also contain Bz (Tsurutani et al., 1988). Thus both the flux rope and sheath can be source of Bz and hence cause geomagnetic storms. One of the common indicators of the strength of geomagnetic storms is the Dst index (expressed in nT), which is computed as the horizontal component of Earth's magnetic field measured at several equatorial stations (now a SYM-H index is available which is essentially a one min resolution Dst index). The southward magnetic component of ICMEs (and their upstream sheaths) creates magnetic storms, which are enhancements in the Earth's outer radiation belts.

The magnitude is measured by ground based magnetometers near the equator giving the Dst and SYM-H indices. CMEs/magnetic storms also cause severe ionospheric effects

SABER instrument is onboarded on NASA's TIMED satellite. SABER monitors infrared emissions from carbon dioxide (CO_2) 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.

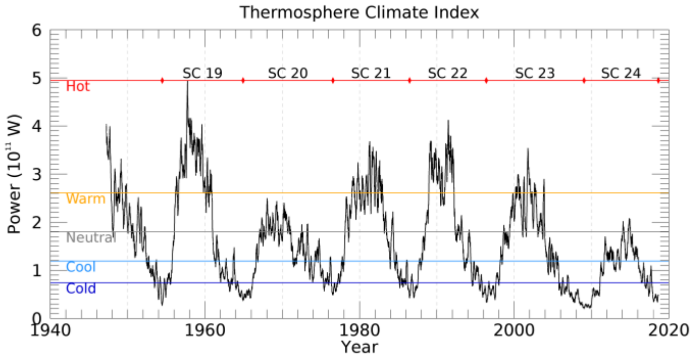

Fig.1. The historical record of Thermosphere Climate Index [9].

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 [6,7,8].

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

Date	Temp. (C)	Precipitation	Wind (m/sec)	Geo. magn. index
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
03.11.18	+10	Rain. Mist.	3	G1-
23.10.18	+17	Rain, showers	10	G1
25-26.10.18	+13	Rain, showers	17	G1
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
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
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

20.04.18	+13	Rain showers	16	G1
14-15-16.04.18	+10	Rain.	8	G1
11.04.18	+15	-	4	G1
12-13.04.18	+17	Thunderstorm	7	G1
23.03.18	+10	Rain. Fog	7	G1
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
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
28.01.18	+1	Rain, snow slight.fog.	4	G1
19.01.18	+5	Rain, Mist, snowflakes.	15	G1
14.01.18	+2	Rain and snow	4	G1

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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(CMEs), მზის ენერგეტიკული ნაწილაკები (SEPs) წარმოქმნიან კოსმოსურ ამინდს გეო-სივრცეში. მათ შეუძლიათ წარმოქმნან შემდეგი ზემოქმედებები: საფრენი აპარატების ელეტრობის ცვლილება, ვან ალენის რადიაციული ღვედის წანაცვლება, დაგეგმილი კოსმოსური ტრაექტორიის შეცვლა, გაშვების ტრაექტორიის შეცდომები, რადარული შეცდომები, რადიო ტალღების გავრცელების ანომალიები, ელექტროენერგიის ბლოკირება, ნავთობისა და გაზის მილსადენის კოროზია, ელექტროშოკის საშიშროება, ელექტრო ხანძარი, გულ-სისხლძარღვთა დაავადებების გამწვავება და საგზაო შემთხვევები. მზე, დედამიწის ორბიტაზე მოძრაობასთან ერთად, მართავს მზე- დედამიწის გარემოს ცვლილებებს.

dst, kp, aa გეომაგნიტური ინდექსები და შტორმამდე და შტორმის შემდეგ 3 დღის მეტეოროლოგიური პარამეტრების (ტემპერატურა, ნალექების, წნევის) დაკვირვების მონაცემები გამოიყენება კორელაციური ანალიზისთვის. ასევე გაანალიზდება ექსტრემალური მეტეოროლოგიური პარამეტრების სეზონური ცვლილებების კავშირი NAO-QBO-მზის-გეოაქტიურობასთან დაკავშირებით.

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Analysis of 2016-18 Geo-space /M. Tatishvili, Z. Khvedelidze, I. Samkharadze, A. Palavandishvili/ Scientific Reviewed Proceedings of the IHM, GTU - 2019 - vol.127 - pp.60-66. Georg.; Abst.: Georg., Eng., Rus. Changes in Earth's climate have been the focal point of recent research in the solar–terrestrial physics and special emphasis has been placed on the coupling between the troposphere, middle atmosphere, near Earth Geospace (mesosphere, thermosphere, ionosphere, and magnetosphere), and solar activity. Solar transients; Solar Flares, Coronal Mass Ejections, Solar Energetic Particles are the drivers of the Space Weather Effect in Geo-Space. Huge energy increases the ionosphere temperature and causes large-scale ion drifts and neutral winds. They can produce the following affects on the Earth: electrostatic spacecraft charging, shifting of the Van Allen radiation belt, space track errors, launch trajectory, radar errors, radio propagation anomalies, electrical power blackouts, oil and gas pipeline corrosion, communication landline and equipment damage, electrical shock hazard, electrical fires, heart attacks, and traffic accidents. The Sun, together with the Earth's motion along its orbit, govern changes in the solar–terrestrial environment. Geomagnetic indices dst, kp, aa and meteorological parameter (temperature, precipitation, pressure) observation data and pre and after storm 3 days are used for correlation analysis. Also seasonal changes in extreme meteorological parameters will be analyzed in connection with NAO-QBO-Solar-Geoactivity.

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Анализ Гео-пространства 2016-18 /М.Р. Татишвили, З.В. Хведелидзе, И.Н. Самхарадзе, А.М. Палавандишвили/ Науч. Реф. Сб. Труд. ИГМ ГТУ - 2019. вып.127 - с.60-66. Груз.; Рез.: Груз., Англ., Рус. Изменения климата Земли были центром недавних исследований в области солнечно-земной физики, и особое внимание было уделено связи между тропосферой, средней атмосферой, околоземным пространством (мезосфера, термосфера, ионосфера и магнитосфера) и солнечной энергией. Солнечные процессы; Солнечные вспышки, выбросы корональной массы, солнечные энергетические частицы являются движущими силами эффекта космической погоды в геопространстве. Огромная энергия повышает температуру ионосферы и вызывает масштабные дрейфы ионов и нейтральные ветры. Они могут оказывать следующие воздействия на Землю: заряд электростатического космического корабля, смещение радиационного пояса Ван Аллена, ошибки космической навигации, траектория запуска, радиолокационные ошибки, аномалии распространения радиосигнала, отключение электроэнергии, коррозия нефте- и газопроводов, наземная линия связи и оборудование повреждения, опасность поражения электрическим током, электрические пожары, сердечные приступы и дорожно-транспортные происшествия. Солнце вместе с движением Земли вдоль своей орбиты управляет изменениями в солнечно-земной среде. Геомагнитные индексы dst, kp, aa и данные наблюдений за метеорологическими параметрами (температура, осадки, давление) и до и после шторма через 3 дня используются для корреляционного анализа. Также будут проанализированы сезонные изменения экстремальных метеорологических параметров в связи с NAO-QBO солнечной геоактивностью.