International Scientific Journal
Journal of Environmental Science
http://environment.scientific-journal.com/

Dependence of meteorological parameters on geomagnetic storms in Georgia

Marika Tatishvili, Tengiz Tsintsadze, Inga Samkharadze, Ana Palvandishvili
Institute of Hydrometeorology of Georgian Technical University, Tbilisi, Georgia
marika.tatishvili@yahoo.com

Abstract— The renewable solar, wind and bio energies became more and more actual and applicable in the World. Many studies have been devoted to study their application ways and develop equipments and devices to produce energy supply. The research of their possible energy potential is crucial for energy sector and state economics that are preconditions for sustainable development. The application of wind energy is important for Georgia. However the wind phenomenon is still under persistent scientific investigation its nature is still unknown. There are many reasons of its genesis. After NASA's Earth Observation Mission program many new data has been gathered that clarify many phenomena from different point of view. The real drivers of climate are the Sun's insulation (light and heat), its magnetic flux, and the relative position and orientation of the Earth to the Sun.

Geomagnetic storm is a major disturbance of Earth's magnetosphere that occurs when there is a very efficient exchange of energy from the solar wind into the space environment surrounding Earth. These storms result from variations in the solar wind that produces major changes in the currents, plasmas, and fields in 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.

The correlation between geomagnetic storms and meteorological elements (wind, pressure, temperature) for Georgian region using meteorological observation and NASA's Solar Dynamics Observatory and NOAA Space Weather Prediction Center data has been conducted. The results show that there exist dependence between weather parameters and income radiation. Especially important is wind parameter variability investigation. Such research hasn't been carried out yet in Georgia and is important for space weather researches..

Key words: Wind energy, wind velocity, disturbed atmosphere, geomagnetic storm, geomagnetic indices.

Introduction

The complex relief of Georgian territory has definite influence on air masses motion in atmosphere lower layers. Mainly west and eastern atmospheric processes prevailed over Georgian territory. Current geodynamics and orographic properties of Georgia play an important role in formation of weather various patterns. Such complex relief conditions the formation and evolution of various scaled circulation systems and heterogeneous spatial distribution of meteorological elements. This is verified by the fact, that such important parameter as wind annual distribution has diverse type, with sharply expressed spatial inhomogeneities.

The wind is one of most important meteorological element used both in science and energetic industry. However its origin and nature isn't well understood yet. Wind direction and value in atmosphere surface layer is depending on local geographic conditions. Meteorological observation 1960-2017 data is used to carry out investigation.

Particularly wind is air masses horizontal and vertical motion caused by temperature and pressure gradient. Due to Earth motion wind is enforced by Coriolis force. In middle latitudes dominate motion caused by pressure gradient, parallel to isobars. The influence of friction and orography on air masses motion is important, as they resist motion and force it to replace toward low pressure area. Wind direction and velocity at atmosphere surface layer depends on local geographical conditions.

Except Gori there are a lot of windy regions in Georgia such as: Kutaisi, Tbilisi and Telavi, the notable is that those regions have different thermal and dynamical conditions. Wind observation 50 year period (1960-2014) data for Kutaisi have been processed and divided by 5m/sec interval gradation beyond 15m/sec. It may be concluded that 1 gradation wind occurs mainly in February-March and second gradation occurs mainly in January-March.

Data and methods

In order to investigate wind field parameters over Georgian territory the 1984-2014 observation data from meteorological stations were used [1]. Wind maximal velocity variability by month has sinusoidal character; wind maximal values were detected in February-March and minimal in July (Fig.1, 2,3)

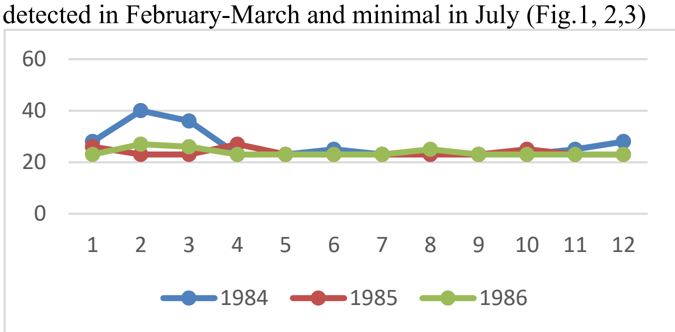

Fig.1. Wind maximal velocity distribution by years (1984-86)

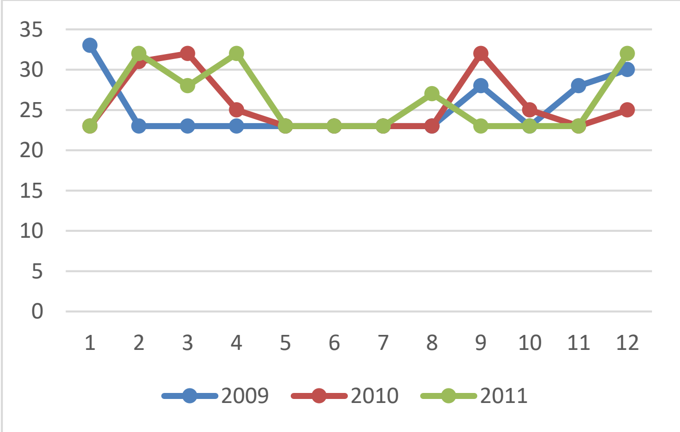

Fig.2. Wind maximal velocity distribution by years (2009-11)

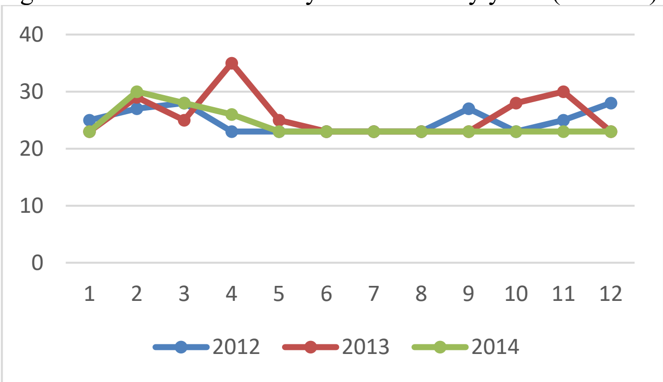

Fig.3. Wind maximal velocity distribution by years (2012-2014)

To understand wind extreme velocity character 1984-2014 year data had been treated and results are presented on

To understand wind extreme velocity character 1984-2014 year data had been treated and results are presented on Fig.6. The wind velocity has sinusoidal character and its maximal value reaches 40m/sec. It is remarkable that wind extremes lower threshold for last years has been increased [2,3].

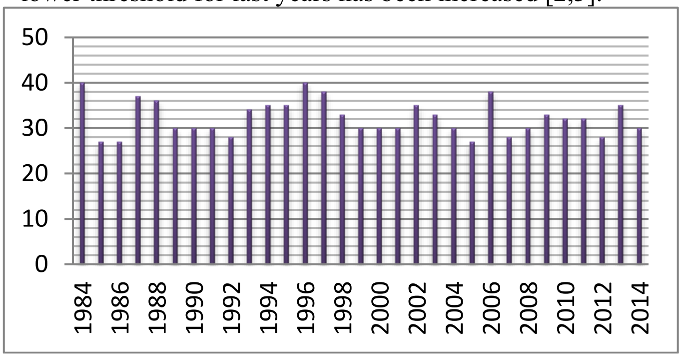

Fig.6. Wind maximal velocity (>25m/sec) distribution for Kutaisi region (1984-2014)

To understand wind nature and its origin it is necessary to identify weather and climate driven natural factors. The Sun is the source of the energy that causes the motion of the atmosphere and thereby controls weather and climate. Any change in the energy from the Sun received at the Earth's surface will therefore affect climate. During stable conditions there has to be a balance between the energy received from the Sun and the energy that the Earth radiates back into Space. This energy is mainly radiated in the form of long wave radiation corresponding to the mean temperature of the Earth.

The effects of the radiation and particles that stream out from the Sun would be quite deadly for the inhabitants of Earth if not for two protective features. The first one is Earth's atmosphere, which blocks out the x-rays and most of the ultraviolet radiation. When x-ray or ultraviolet photons encounter the atmosphere they hit molecules and are absorbed, causing the molecules to become ***ionized***; photons are re-emitted but at much longer (and less biologically destructive) wavelengths. The second protective mechanism is the Earth's magnetic field. This protects living organisms from the charged particles that reach the planet steadily as part of the solar wind and the much greater bursts that arrive following mass ejections from the Sun. When charged particles encounter a magnetic field, they generally wrap around the field lines. Only when the path of the particle is parallel to the field can it travel without deflection. If the particle has any motion across the field lines it will be deflected into a circular or spiral path by the Lorentz Force. Most charged particles in the solar wind are deflected by the Earth's magnetic field at a location called the Magnetopause, about 10 Earth radii above the Earth on the day side. Inside the Magnetopause, the Earth's magnetic field has the dominant effect on particle motion, and outside, the solar wind's magnetic field has control (www.spaceweather.gov).

Since the early 1900's scientists have suspected that both the auroras and the variations in the Earth's magnetic field must be caused by some kind of currents which flow in the upper atmosphere. Today we know that there are many currents which flow in the magnetosphere caused by the very complicated interplay between the solar wind and Earth's magnetic field. Although these currents are only partially understood at present, the one that has been studied most extensively is the Birkeland current, which is associated with the auroras. When the solar wind encounters the Earth's magnetic field about 50,000 km above Earth, an electromotive force (EMF) of about 100,000 volts is generated. This applied EMF is distributed throughout the magnetosphere and Earth's upper atmosphere, much as the voltage from a electric utility generator is distributed around a power grid. A portion of the solar-wind-generated EMF, perhaps 10,000 volts, accelerates electrons down magnetic field lines into the ionosphere at altitudes of about 100 km. These electrons first travel horizontally and then back up to the upper atmosphere to form a closed circuit. Although this circuit has many similarities to a simple circuit with wires and a battery, it is also very complex since it occurs in three-dimensional space and varies wildly in time as the solar-wind intensity changes. It is the high-speed electrons near the bottom of this current loop which collide with molecules and atoms of the atmosphere that produce the auroras. The strongest Auroral emission comes from altitudes of about 100 km. As with any simple circuit, energy is dissipated as the electrons flow around the loop. Some of this energy shows up as the light of the auroras, but most of it becomes thermal energy—heating the atmosphere. Another important result of the Birkeland current is that, like any current loop, it produces a magnetic field. This field extends down to the Earth's surface where it adds to the geomagnetic field, causing it to fluctuate. These fluctuations in magnetic field can then induce currents in the Earth's surface, or in conductors like power lines or pipelines. All of this is determined by the behavior of the solar wind reaching Earth, which in turn is determined by the events taking place on the Sun. It also means that many of our electronic systems on Earth may become disrupted or even damaged. Our sun produces high-energy solar cosmic rays (protons and ions) in Solar Proton Events (SPEs). These particles generally have energies in the range of 10 MeV to 100 MeV [4]. Very energetic SPE events are also capable of generating near-relativistic protons in the order of 20 GeV.4 Table 3 gives the arrival time of the protons based on energy level after the solar flare first becomes visible on the Earth. In general, SPEs take from hour to minutes to reach Earth depending on their energy. High-energy protons in SPEs produce ultraviolet auroras, invisible to the human eye, when they collide with Earth's atmosphere. These reactions produce NOx byproducts that eventually settle on the planet's surface. The nitrates from large SPEs are detectable in the ice cores. The observations show that a massive SPE can also produce a short-lived major magnetic spike on Earth. Protons in SPEs and CMEs have energy spectrums ranging from around 10 KeV to above 20 GeV. However, solar events producing protons with energies above 1 GeV are rare. Due to geomagnetic shielding solar energetic particles with energies less than 100 MeV can only reach the Earth's atmosphere over Polar Regions where they lose their energy in collision with atoms in the atmosphere creating a cosmic ray shower of particles. If the particles have energies greater than 500 MeV, the cosmic ray shower can penetrate to the planet's surface

The complex coupling of the solar wind and the geomagnetic field produces many effects near Earth. Earth is embedded in the outer atmosphere of the Sun and therefore is affected by events which occur in the surface layers and coronal regions of the Sun. Terrestrial effects are the result of three general types of conditions on the Sun: eruptive flares, disappearing filaments and coronal holes facing Earth [3].

Mid-latitude coronal holes (usually occurring during the phase of solar activity following solar maximum) are sources of high-speed solar wind streams, which buffet Earth in synchronism with the 27-day solar rotation. Previously the cause of these recurring geomagnetic storms was unknown, so the regions were called M-regions, M for mysterious. Non-recurrent major storms and large geomagnetic storms are almost always associated with coronal mass ejections (CMEs) and with the shock waves associated with CMEs.

Several centuries ago, the disruptive effects of the Sun were totally unnoticed by humans. But as technology developed that utilized currents, conductors, and eventually electromagnetic waves, the disruptive effects of the Sun became evident. Early telegraph systems in the 1800s were subject to mysterious currents that seemed to be generated spontaneously.

When an intense surge of solar wind reaches Earth, there are many changes which occur in the magnetosphere. The day side of the magnetosphere is compressed closer to the surface of Earth and the geomagnetic field fluctuates wildly. This type of event is generally called a geomagnetic storm. During a geomagnetic storm the high-latitude currents which occur in the ionosphere change rapidly, in response to changes in the solar wind. These currents produce their own magnetic fields which combine with Earth's magnetic field. At ground level, the result is a changing magnetic field which induces currents in any conductors that are present.

When a mass of plasma is ejected from the Sun, the plasma travels outward in the solar wind. These plasma bursts have their own magnetic fields which are carried along with the plasma. How these fields are oriented when they arrive at Earth determines whether magnetic reconnection will occur. When the direction of the solar wind field is opposite the direction of Earth's field, magnetic reconnection occurs, and the geomagnetosphere essentially becomes a part of the solar magnetic field. In this condition, Earth is much more prone to the effects of the solar wind. Solar wind particles can enter the magnetosphere more easily, and those already within the magnetosphere are energized. Changes in solar wind magnetic fields cause wild fluctuations in the magnetospheric fields. In response to these fluctuations, in accordance with Lenz's Law, massive currents flow throughout the magnetosphere. It is these high altitude currents that induce voltages at ground level. If the magnetic field of the solar wind is in the same direction as the Earth's field, then magnetic reconnection does not occur and the magnetosphere is much more separated and protected from the solar wind [6]. The Sun-Earth environment has variables, which are changing on regular basis due to starbursts. These variables are the Kp, proton flux and E-flux. Sudden changes in these parameters may abruptly influence the environment of the Earth. If an E-flux hike is responsible for global warming, then an E flux lowering may lead to snowfall, thunderstorms and erratic rainfall. The effect of earth directed CME would not only trigger the earthquake, but affect the whole environment of the Earth, including the destruction of ozone layers leading to climate change.

The effect of Earth directed Coronal Mass Ejections (CME) from the Sun reveals a sensational impact on the atmosphere and geosphere. It has been observed that there is a close relationship between Kp values (Planetary Indices) and particle flux (Electron flux and Proton Flux) with the CME. The response of the magnetosphere to interplanetary shocks or pressure pulses can result in sudden injections of energetic particles into the inner magnetosphere. Solar active regions usually reach kilogauss values in their magnetic field. When the earth directed CME glances along the magnetic shield, local disturbances in the atmosphere of the Earth have been noticed. Cyclic changes of the general atmosphere circulation are of prime interest as are the transformation and recurrence of circulation forms, which characterize planetary wave dynamics. The changes of the atmospheric pressure in geomagnetically and electronically excited cases (including the solar activity effect) in comparison to the variations in geomagnetically and electronically quiet cases.

Conclusion

In order to identify connection between geomagnetic activity and synoptic and circulation processes 2015-17 warm period (III-IX months) various synoptic and geomagnetic indices daily data (http://SunSpotWatch.com) have been studied for Georgian conditions.

Table 1. Geomagnetic activity indices and meteorological elements daily data for 2015-17 warm period in Georgia [4].

Geostorms		Insignificant cloudiness (700 hpa)		Showers. Thunderstorm	
Geo. magn. index	Geomagn storm type	Number of events	Circulation processes	Number of events	Circulation processes
K4	Active	10	South-west wave	20	South-east wave South-west wave High pressure area High pressure area (1 event)
K5	Minor storm	25	South-west wave	10	South-east wave South-west wave
K6	Moderate storm	23	High pressure area (8 event)	8	South-east wave South-west wave
K7	Strong storm	4	High pressure area (3 event)	3	South-west wave
K8	Severe storm	1	High pressure area	-	

It is ascertained that during all magnetic storms south-west or south-east wave processes have been formed and strong storms create high pressure areas. Depending on the synoptic situation wave processes leads the formation of thunderstorm and heavy showers. In addition, through geomagnetic storms the direction of circulation processes may drastically be changed.

The NOAA Space Environment Services Center (SESC) in Boulder is one of the world centers that make forecasts of solar and geomagnetic activity. Daily predictions are issued for the likelihood of solar flares, proton flares, x-ray events and magnetic storms. Longer-range forecasts are also made so that the launches of manned spaceflights can be planned with more safety. The SESC is a worldwide nerve center for about 1400 data streams, including x-ray and particle flux data from the GOES satellites, H_ images and magnetograms from observatories around the world, measurements of the geomagnetic field at many locations, and 10.7-cm radio levels from several radio telescopes. Each day the features of the solar disk are mapped by hand so that the evolution of active regions, coronal holes, filaments, and neutral lines may be carefully studied. Forecasters attempt to consider all of this information when making their daily forecasts of solar effects on Earth [6]. At the present time, these forecasts are not very reliable; major flares are sometimes not forecast and predictions that are made often do not come true. Even though forecasters have a large amount of data to work with, the physics of the Sun, the magnetosphere, and the interplanetary medium is not well understood. At the present time, many partial mathematical models have been developed, but there is no comprehensive model of the Solar-Terrestrial environment.

In most cases, the ability to predict the behavior of nature comes from a mathematical model. For example, the motion of an object falling in a gravitational field can be modeled using the mathematical expression $v = g \_ t$. Earth weather forecasters have been trying for the last 30 years to construct a mathematical model of the global weather using the very complex equations of fluid dynamics to describe the circulation of the oceans and atmosphere. Even with the best supercomputers to run these models, it has proven impossible to precisely model Earth weather. Modeling the solar-terrestrial environment is vastly more complex. The physics necessary to do this includes not only fluid dynamics but also Maxwell's equations. This combination is known as magnetohydrodynamics (MHD) , and at the present time the equations of MHD cannot be completely solved analytically. Numerical solutions exist which involve the use of a computer in a "trial and error" fashion. Numerical solutions, however, can give incorrect results and at best are an approximation. There is some suspicion that we have not yet developed the physics necessary to fully understand the Sun, where strong magnetic fields are erupting and plasmas swirl at ultra-high temperatures. The issue needs further investigation applying quantum filed theory that is more suitable for description of photon-photon or photon-charged particle interaction [7]. 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.

References

1. Climatic and agro-climatic atlas of Georgia. Georgian Technical University. 2014

2. M.Tatishvili, D.Demetrashvili, I.Mkurnalidze Weather forecasting modeling in Georgia Proceedings of International Scientific Conference Dedicated to Academician I.Prangishvili 85 Anniversary "Information

and Computer Technologies, Modeling, Control" Georgian Technical University. 2015

3. Marika Tatishvili, Inga Samkharadze. Local disturbances and wind field distribution modeling in Georgia. International Scientific Journal. Journal of Environmental Science. vol.6. 2018

4. The connection of geomagnetic activity and weatherformation in Georgian region Marika Tatishvili, Zurab Khvedelidze, Irine Mkurnalidze, Inga Samkharadze, Khatuna Kokosadze. International Scientific Conference MODERN PROBLEMS OF ECOLOGY Proceedings - Vol. VI. 2018

5. M.Tatishvili, N.Bolashvili, I.Mkurnalidze. Climate and causes of its variability. Transactions of Institute of Hydrometeorology, v. 119, 2013. pp. 38-43.

6. www.spaceweather.gov

7. M.Tatishvili. Energy Transformation in Clouds According Quantum Principles. International Scientific Journal. Journal of Environmental Science. vol 3. ISBN- 13: 978-1499721980; ISBN -10: 1499721986 2014. pp. 7-9. Vienna, Austria