MODERN METHODS AND BIG DATA TO STUDY DANGEROUS HYDROMETEOROLOGICAL EVENTS

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Abstract

The article discusses the atmospheric processes that cause dangerous hydrometeorological events. Georgia is a mountainous country with complex topography and a variety of climatic zones. It is prone to all kinds of dangerous hydrometeorological disasters, including heavy rain, hail, thunderstorms, flooding and landslides. It is especially important to investigate the processes that cause these catastrophic events using new data. This has become possible since the launch of the Earth Observing System programme, which provides a wealth of new satellite data that allows us to reanalyze these physical processes. Many methods have been employed to study their spatiotemporal characteristics, including numerical modelling, statistical analysis, analytical solutions, big data and machine learning. NASA THEMIS satellite data makes it possible to apply quantum physics to explain atmospheric processes. These results could be used in future studies and incorporated into early warning systems.

Keywords: Big Data, natural hydrometeorological disasters, Earth Observing System, weather numerical modeling, geo-magnetic index, photon exchange

I. Introduction

Meteorological and hydrological hazards are those resulting from the state and behavior of the Earth's atmosphere, its interaction with the land and oceans, the weather and climate it produces, and the resulting distribution of water resources. According to EM-DAT, from 1979 to 2019, 50% of all recorded disasters (including technological and 'complex' disasters), 56% of deaths and 75% of economic losses are attributed to weather, climate and water-related hazards. Some of the most devastating hazards include tropical cyclones, drought, reverie floods, and heatwaves. These hazards are observed, monitored, and forecasted by the national meteorological and hydrological services of each country [1].

Understanding of the natural environment is increasingly important to respond to the climate change negative impacts and anthropogenic pressures on finite natural resources, and their impacts on water, energy and food security, infrastructure, human health, natural hazards. This is also a major cross-disciplinary challenge involving almost all scientific fields

In 2013, the UK government announced large-scale investment in Big Data infrastructure for science, particularly in the environmental sector starting funding for a program called CEMS (Climate and Environmental Monitoring from Space). This allowed for the creation of larger databases to cope with the upcoming Big Data revolution and to allow research partner organizations to work with more data and produce more results. With a specific focus on climate change and planetary monitoring, CEMS storage removed the need to download enormous data sets while reducing the cost of access. Along with Cloud data, this is now the standard globally for some of the world's top research institutes

II. Study area, material and methods

Environmental data comes from a wide variety of sources and this is increasingly rapidly with new innovations in data capture:

1. Large volumes of data are collected via remote sensing, typically from satellite sensing or aircraft-borne sensing devices, including an increasing use of drones. This includes passive sensing, such as photography or infrared imagery, and active sensing, e.g., RADAR/LIDAR. The increasing availability of open satellite data is a major trend in earth and environmental sciences. For example, the EU Copernicus program and the associated Sentinel missions, or NASA's Earth Observing System satellites, LandSat archive are regularly mined for data for a variety of applications [4].

2. Other data are collected via earth monitoring systems, which consist of a range of sensor technologies measuring various physical entities. Namely weather stations and monitoring systems

3. Model output is also a significant generator of environmental data with results from previous model runs often stored for subsequent analysis

The local circulation systems developed on the background of synoptical processes play significant role in the spatial-temporal distribution of weather determining parameters. The study of all those phenomena includes both the mathematical modeling and separate analysis of microphysical processes, important for precipitation formation, temperature and wind field distribution, also the processing of long-term observation series of those climatic parameters.

One of most important precipitation formation microphysical process – coagulation described by the integral-differential equations has been analytically solved considering income of cloud particles. The results evidently showed redistribution of ice crystals and rain drops in cloud dispersive medium. To investigate solid and liquid precipitation formation following analytical model has been created using the kinetic coalescence equation system for spatial heterogeneous Coachy type task that has the following type [5,6,11]

$$\frac{\partial n1(v,t)}{\partial t} = -n_1(V,t)\int_0^{\infty}\sigma_{11}(V,U)n_1(U,t)dU - n_1(V,t)\int_0^{\infty}\sigma_{12}(V,U)n_2(U,t)dU + \\ + \frac{1}{2}\int_0^{V}\sigma_{11}(V-U,U)n_1(V-U,t)n_1(U,t)dU + \frac{M}{1-LN2(0)t}n_1(V,t) \quad (1)$$

$$\frac{\partial n2(V,t)}{\partial t} = -n_2(V,t)\int_0^{\infty}\sigma_{21}(V,U)n_1(U,t)dU + \int_0^{V}\sigma_{21}(V-U,U)n_2(V-U,t)n_1(U,t)dU + \\ + LN_2(t)n_2(V,t) \quad (2)$$

With following initial conditions: $n_1(V,t)=n_1(V,0)$; $n_2(V,t)=n_2(V,0)$ when $t=0$, n_1 refers to water drops (rain) and n_2-ice crystals (hail) and the distribution function has following type

$$n_i(V,t) = \frac{4N_i^3(0)}{W_i^2(0)}V\exp(-\frac{2N_i(0)}{W_i(0)}V), i = 1,2$$

The solution gives expressions for rain and hail concentrations, water and ice content and is able to identify dangerous size hail grains spectrum.

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The mathematical modeling contain several local weather nonstationary mesoscale model to describe atmospheric processes [9] operational thermohydrodynamical convective cloud model [8,9,10], global forecasting model (WRF) [6], analytical model for microphysical processes (coalescence) [10], the newly proposed study of variation character of meteorological parameters [8,9] (temperature, precipitation, pressure) depending on the geo-magnetic short-time disturbances [16]. Numerical forecasting models based on complete hydrothermodynamical equations give possibility to detail involve physical factors describing atmospheric phenomena that greatly influenced or sometimes define atmospheric circulation processes

For short-term operational forecasting the use of confined area models became available in several national meteorological services. The range of those models is quite diverse from which special attention deserve regional mesoscale models also atmosphere dynamical models with artificial boundaries where model variables are defined from coarse value grid from global model outputs. Such models can describe real weather conditions invisible for global models that form in atmosphere small-scale processes [7].

Numerical forecasting models based on complete hydrothermodynamical equations give possibility detail involve physical factors describing atmospheric phenomena that greatly influenced or sometimes define atmospheric circulation processes. The consideration of those factors in numerical models provides improvement forecasting quality. Realization of weather forecasting issue on confined area is characterized by definite difficulties. Such is the formulation of boundary conditions on the borders of forecasting area. The lack of meteorological data on region borders influenced researches to seek problem solution different ways. By using telescopization or embedded grid method became one of the most effective mean for this [6, 7]. Except boundary conditions telescopization method gives possibility to solve those main issues that are essential for weather forecasting on confined area. Specifically reducing spatial grid step on target area in such way that didn't increase model realization time, also detail describe region orographic features, realize interconnection between largescale, regional and mesoscale meteorological processes using bilateral and unilateral interaction of solutions from different grids.

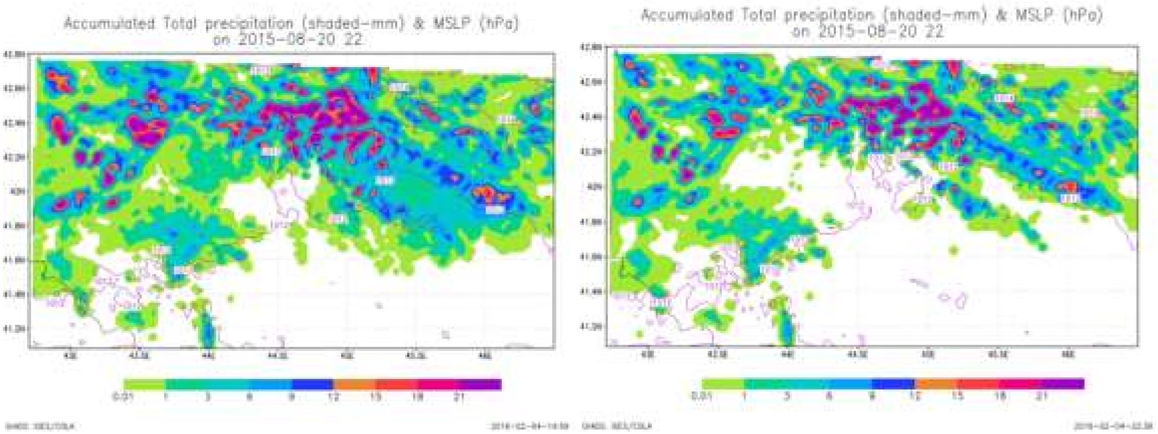


Figure 1: *Forecasted 2.2km resolution gridded precipitation on August 20, 2015 [11].*

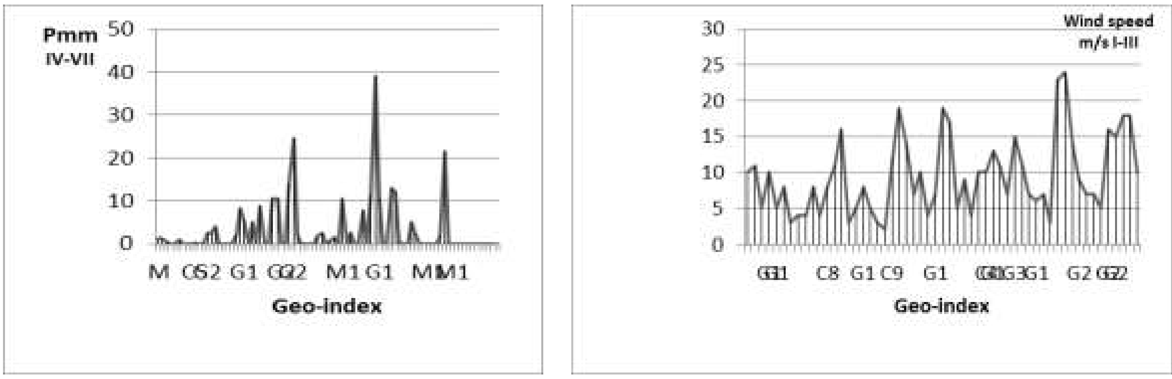
Another one is the operational one-dimensional thermohydrodynamical convective cloud model created for research of natural and artificial precipitation formation and can be used in weather modification [7]. In model for crystallization and melting processes have been introduced new parameterization schemes. The model inputs are radio probe data and outputs vertical development of meteorological parameters till cloud dissipation.

Weather research and forecasting model (WRF) is weather numerical forecasting and atmosphere simulation system created as for research as operational application. The model is elaborated USA National Center for Atmosphere Research (NCAR), Mesoscale and Microscale Meteorological Division (MMM), NOAA, NCEP, ESRL, AFWA, Naval Research Laboratory, CAPS, and etc. It is used in following fields: real-time numerical forecasting, data assimilation, physical parameterization research, regional climatic simulations and etc [3, 6,7,11]. ARW provides introduction of higher spatial-temporal resolution horizontal grid that focuses on target sub-region and significantly increases model resolution (from 15km to 2km) [7.11].

III. Results and discussion

Despite all above listed approaches the origin and nature of most of atmospheric phenomena are still unknown. The climatic observations often show quasi periodic variations similar to solar activity cycles over a wide range of time scale. However, the detailed mechanism and the extent of the influence of solar activity on climate change have not been clearly understood, several possible mechanisms are proposed; such as the forcing through total and spectral irradiance, solar wind and the galactic cosmic rays [2, 15]. The Earth Observation System (EOS) program is designed to examine the role of Earth-Sun connection in wide-scale global processes in order to determine the function of the Earth as a single system. The one of natural reason of global climate change 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 2014-19-year period meteorological elements (wind, pressure, temperature, precipitation) for Georgian region using meteorological observation and NASA's Solar Dynamics Observatory and NOAA Space Weather Prediction Center data [13, 14] has been conducted [2, 15,16]. 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.



(a) (b)

Figure 2: *Precipitation and geo-index correlation in 2017 (IV-VII months) (a)and wind speed and geo-index correlation in 2017 (I-III) (b)for Tbilisi.*

The analysis has been conducted for current, pre and aftershock 3 and 5 days. For meteorological parameters current day is crucial and 3, 5-day time lapse is reliable for circulation processes. 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

IV. Conclusion

The Vere River tragedy on 13 June, 2015 is clear evidence of how meteorological disaster triggered geo-hazard. On this day, flash-flood on Vere River flooded part of Tbilisi city, destroyed buildings, infrastructure, Zoo, many Zoo habitats and 18 humans were dead. After analyzing satellite data and synoptical situation it became clear what happened. During several days from 9 to 14 June 2 MEV high energy electrons penetrate atmosphere [12, 15]. The abundant amounts of electrons create stable clusters in lower atmosphere resisting precipitation infall. After they became so massive that couldn't resist gravitation the great amount of rain water has been fallen out from clouds, causing flooding.

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 as during geomagnetic activity great amount of charged particles and photons penetrate atmosphere.

The most of water properties are preconditioned by the fact that three component atoms aren't placed on one line. Negative charge prevailed on oxygen atoms part and positive on hydrogen. Thus water molecule is electrically polarized. Among atoms and molecules acts force that always has attractive character. It is intermolecular dispersive or Van-Deer-Vaalse force [6,12]. It is only one of the expressions of electromagnetic force. It acts among electrically neutral systems such as dipole or quadruple. In dipoles force reduces by r^4 inverse proportional and in quadruple by r^{-6}. It is not temperature dependent and it s nature is quantum. By increasing dipole number their interaction increases.

$$U(r) = -\tfrac{2}{3c^2}\sum_n r_n^{-1}\left|d_n\right|^2 \omega_n^2 \exp\left(\tfrac{\Gamma_n r}{c}\right)\cos\tfrac{\omega_n r}{c} \tag{3}$$

During cristalization and condensation the some portion of latent heat may be trasformed in characterized radiation. The transformation energy is distributed between existed and new energetic levels. They are called as phase radiation and is depended on medium optical properties. The cloud medium may be imagined as unity of clusters that are on different energetic levels, interacting through energy emition-absorbtion. According to this Earth surrounding environment is one of possible renewable energy source [16], the use of which gives chanse on transition into new energy transportation means.

CONFLICT OF INTEREST.

Authors declare that they do not have any conflict of interest.

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