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MICROCIRCULATION AND HEAT UNIQUENESS OF TBILISI

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Abstract. *Atmospheric processes are highly heterogeneous and anisotropic in space and time. This study examines the climate adaptation strategies. These processes are irregular everywhere, especially in such difficult physical terrain as the TransCaucasus and Georgia in particular. One of such areas is the well-known Tbilisi hollow, which is characterized by a long-standing thermal inversion layer that keeps warm air close to the relief and strengthens heat waves. Extreme heat is a hazard that is capable of causing economic problems and potentially high mortality rates. In order to investigate heat waves, NEA 1991-2020 hydrometeorological observation and ERA5 reanalysis data are used. The results are important for the early warning system and stakeholders.*

Key words*: Daily temperature, heat wave, microcirculation process, Discomfort index*

1. Introduction

Atmospheric processes are highly heterogeneous and anisotropic in space and time. The main reason for this is Solar energy uneven distribution to the Earth's surface. In the lower layers of the atmosphere, the heat regime is provided by the long-wave radiation reflected from the Earth's surface. The heterogeneous surface causes the rays to be reflected at different angles, which in turn causes an uneven distribution of the heat field. Uneven heat field causes an uneven distribution of atmospheric pressure and the formation of permanent "barrier centers". These centers provide air masses motion mainly from west to east ("leading" flow) with approximately 8-12 m/sec velocity and other zonal flows. These processes are irregular everywhere, especially in such difficult physical terrain as the Trans Caucasus and Georgia in particular [1]. There are several microregions in the territory of Georgia whose climatic conditions sharply differ from the climate, with changes in climatic parameters and impacts on weather conditions in the outer region [13]. Change in the microrelief of the Earth's surface, even on a small scale, causes local circulation of the air flow [1,2]. One such area is the well-known Tbilisi hollow [3], which is characterized by long long-standing thermal inversion layer that keeps warm air close to the relief and strengthens heat waves. This traps heat near the Earth's surface. It is usually possible to forecast heat waves, thus allowing the authorities to issue a warning in advance.

In the *Glossary of Meteorology* heat wave is defined as "A period of abnormally and uncomfortably hot and usually humid weather [4]. Typically, HW lasts two or more days. Heat waves have become more frequent and more intense over land, across almost every area on Earth, since the 1950s, with the increase in frequency and duration being caused by climate change. Heat waves form when a high-pressure area in the upper atmosphere strengthens and remains over a region for several days up to several weeks. Heat waves have an impact on the economy. They can reduce labor productivity, disrupt agricultural and industrial processes, and damage infrastructure. Severe heat waves have caused catastrophic crop failures and thousands of deaths from hyperthermia. They have increased the risk of wildfires in areas with drought. They can lead to widespread electricity outages because more air conditioning is used. A heat wave counts as extreme weather. It poses a danger to human health because heat and sunlight overwhelm the thermoregulation in humans.

2. Methodology

There is no universally accepted definition for heatwaves; they are generally considered to be periods of unusually hot weather, lasting for at least several days, and having a negative impact on human health. Also, in Georgia, no formal definition of a heatwave exists. Instead, historical data have been used to develop a heat index, which takes both temperature and relative humidity into consideration, and is an indicator of thermal comfort of the population. Heatwaves are known to be especially problematic in cities, partly due to the positive relationship between population density and perceived heat stress, and partly due to the urban heat island effect, which is prevalent in areas with high settlement density and sparse vegetation. This effect is amplified during extremely warm days. In order to investigate heat waves, NEA 1991-2020 hydrometeorological observation and ERA5 reanalysis data are used.

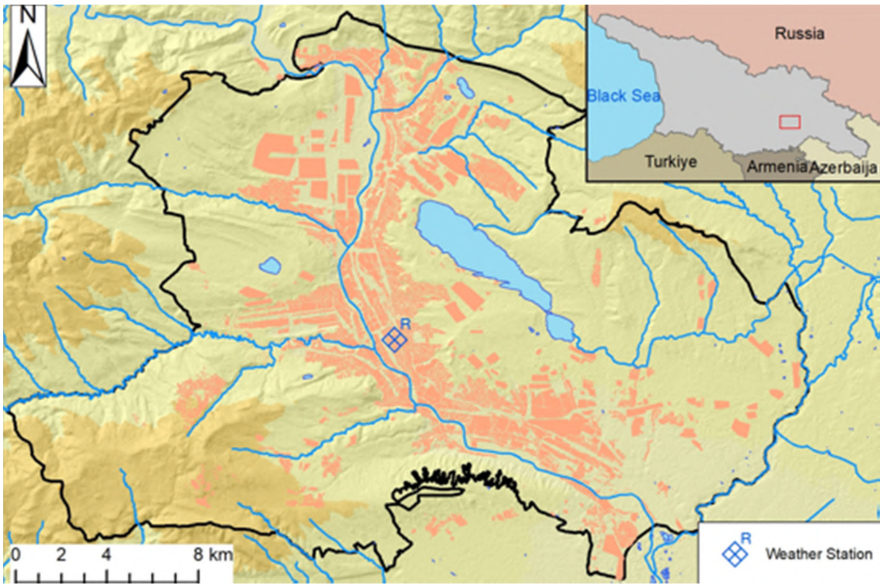

Fig.1. Location of Tbilisi meteorological station.

3. Discussion

The Caucasus Region has been affected by an increasing number of heat waves during the last decades, which have had negative impacts on human health, agriculture, and natural ecosystems. In Tbilisi during the 1991-2020-year period, 2018 was especially hot. The amount mounted 144 days, and reached its highest value of 41^0 in July 2018. Consecutive hot days reached up to 70 °C in 2018 and 120 °C in 2019, accompanied by low humidity [8,9]. July is on average the warmest month of the year, and the average high temperature is 29.9 °C. The city broke its all-time temperature record on July 4th, 2017, by 0.1°C [10,11]. The previous record had been achieved on August 1st, 2000 on when Tbilisi recorded a temperature of 40.4°C. The days with different heat wave thresholds are shown in Figure 2. This helps to identify most warmest year in the selected period.

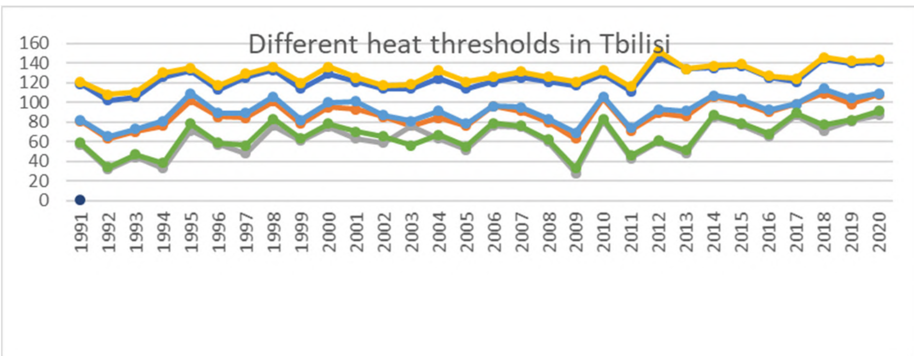

Fig. 2. Heat waves with different thresholds for the 1991-2020 period in Tbilisi

Another important index is the consecutive heat wave day number, which shows the total number of hot and dry days.

For selected years, such exceptional was 22010, 2020 years 115 and 120 days correspondingly.

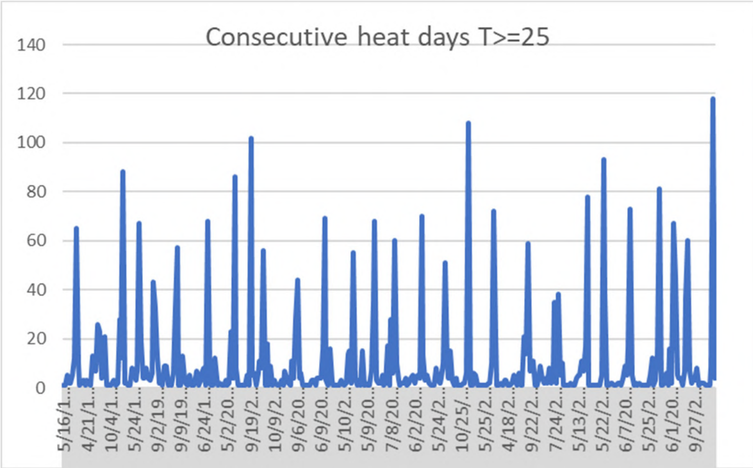

Fig. 3. Consecutive days when T_{max} was equal to/more than 250 °C

The Discomfort Index (DI) method is a method used to identify the level of thermal comfort in an area. It measures how much discomfort a person feels with a given air temperature and relative humidity. The higher the relative humidity and the air temperature, the greater the discomfort index. Conversely, the lower the temperature and humidity, the lower the discomfort index. To calculate the DI hourly temperature and relative humidity, ERA5 reanalysis 2018 26 June-09 July data are used. The calculated values are too high.

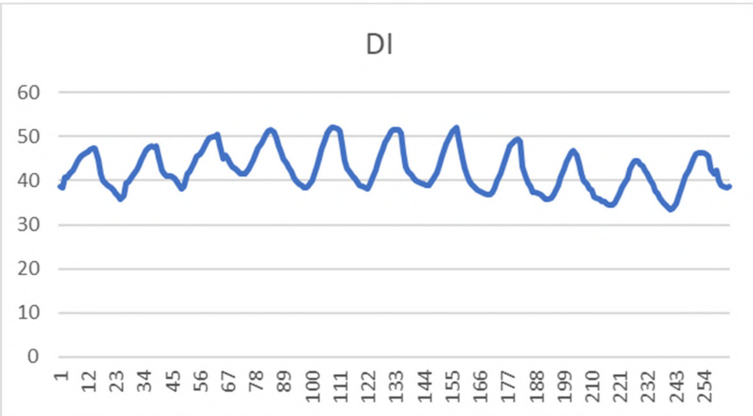

Fig.4. Discomfort Index for Tbilisi during 2018, 26 June-09 July.

While the Discomfort Index is a useful tool for gauging comfort levels, it is not directly designed to predict health risks. High values on the index can indicate conditions that might lead to heat-related illnesses if proper precautions are not taken, such as staying hydrated and avoiding excessive exposure to heat.

The environmental problems faced by the city of Tbilisi are the increase in air temperature and humidity, and the problem of air pollution. It became essential to carry out environmental engineering to solve these problems. The environmental engineering recommendations include intensifying Green Open Space, planting road shade trees, implementing green facades (vertical gardens), implementing a roof garden, and improving people's behavior.

4. Conclusions

The existence of hollows over terrain significantly complicates weather prediction [5,6]. The latent heating in a large complex of deep moist convection often produces a cyclonic vortex. These vortices can then initiate additional convection the next day. When steady wind flows around an isolated obstacle, such as a mountain or a mountainous island, atmospheric vortex streets (AVSs) can be generated on the leeward side of the obstacle under favorable meteorological conditions. The AVS pattern exhibits a double row of counterrotating vortex pairs shedding alternately and resembles the classic von Karman vortex street; these types of vortex streets have significant weather and climate implications. Atmospheric vortex streets may modulate cloud and wind patterns over downstream regions and are an additional reason for forecasting uncertainty. To avoid all these complications together with numerical weather predictions, another model must be run: the microscale model, which depicts local atmospheric disturbance [10,6,13]. This coupling became essential, as Georgia is a country with great tourism potential, including winter sports tourism. Detailed information on the wind stream velocity can aid in safe paragliding sport and rescue missions. Additionally, research outcomes may be important for early warning systems and implementing Nature-Based Solutions (NBS).

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