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Long Term Trends in Climate Variability of Caucasus Region

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ABSTRACT

Over the period 1855–1996 was observed a long-term increase trend of solar activity, that leads to temperature rise. In the Caucasus region it is also observed a warming trend. The main goal of this study is to identify contribution of the Sun on climate variability of Caucasus Mountains and long term prediction of future climate trend in the region for sustainable development.

Key words: climate change, solar activity.

1. Introduction

Solar radiation is the major source of heat for the Earth. The sun provides light and warmth. In fact 99. 97% of energy budget of the earth arrives from the Sun [1]. This energy to the atmosphere is the primary driver of the Earth's weather.

Its motions through the sky cause day and night, the passage of the seasons, and earth's varied climates. The added hours of daylight are one reason why summer is warmer than winter. Another reason that's even more important: the angle of the mid-day sun.

Global atmospheric circulation strongly affected by the amount of solar radiation received at Earth. That amount changes based on the Earth's albedo, that is how much radiation is reflected back from the Earth's surface and clouds. The amount of radiation given off by the Sun is changing with solar activity like sunspots and total solar irradiance.

A reconstruction of total solar irradiance since 1610 to the present estimated by various authors an increase in the total solar irradiance since the Maunder Minimum of about 1.3 W/m² [2]. This is a huge amount of energy, taking into account the Earth's total land mass.

Currently, our civilization consumes around 17.7 Terawatts of power taken from all sources of energy, namely oil, coal, natural gas and alternative energies. Every second the Earth's surface receives about 100 times more energy from the Sun.

During the period 1855-1996 was observed an increase in temperature in the Northern Hemisphere. The averaged sunspot number risen about 40% and temperature change on – 4%-10%.

The atmosphere in temperate regions continues to receive more heat than it gives up to space, a situation that lasts a month or more, depending on the latitude.

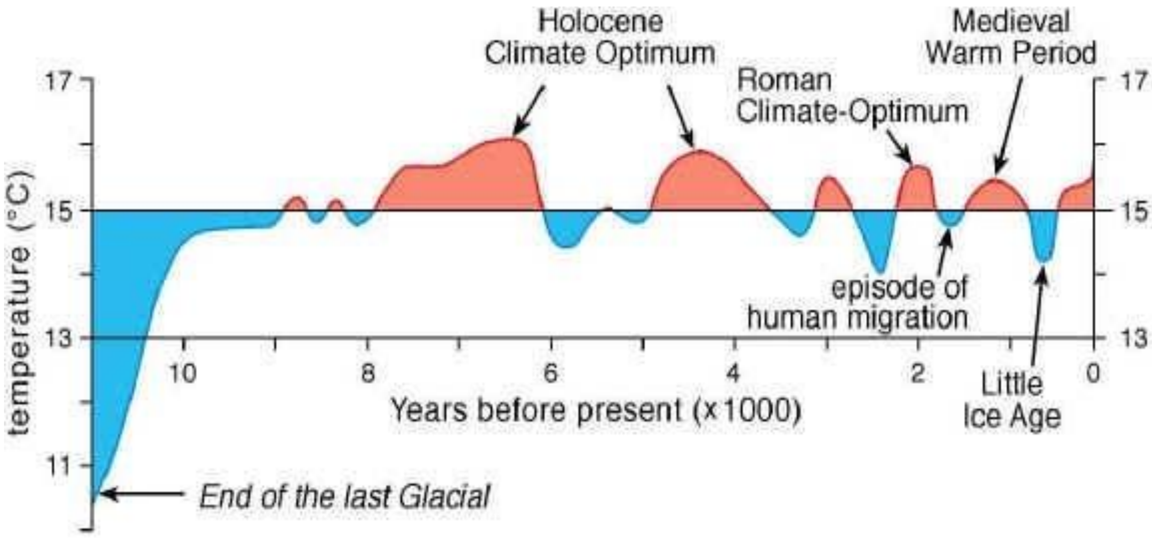
Climate of the Earth's has been changed over the 4, 5 billion years of the Earth's geological history. There have been periods of warming and there have been ice ages.

The Holocene Climate Optimum was a warm period during roughly the interval 9,000 to 5,000 years Before Present. The Holocene Climate Optimum warm event consisted of increases of up to 4 °C.

The Medieval Warm Period or Medieval Climate Optimum is generally thought to have occurred from about 950–1250.

The Little Ice Age was a period of cooling that occurred after the Medieval Warm Period (Fig. 1). Global warming has happened repeatedly over time: periodical cooling cycles alternated with warming.

The modern Warm Period has been occurred in the period 1880 to 2012, as can be seen from Fig. 2 [3].



Average near-surface temperatures of the northern hemispere during the past 11.000 years (after Dansgaard et al., 1969, and Schönwiese, 1995)

Fig. 1. Holocene climate variability over the period of 11.000 years

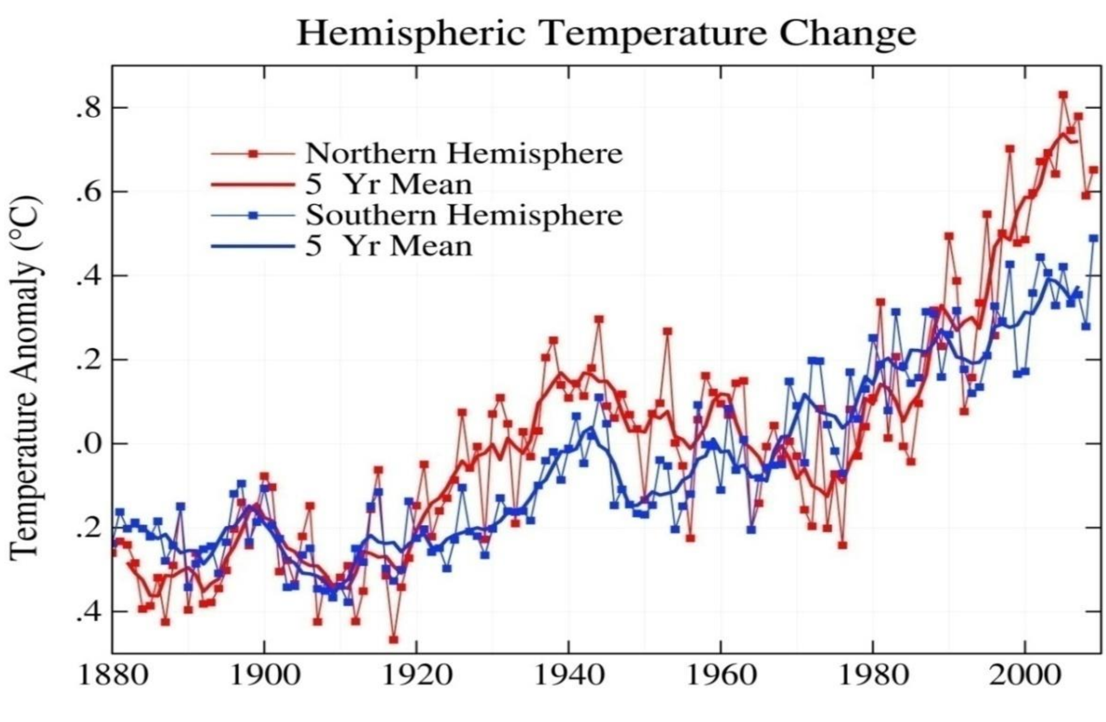
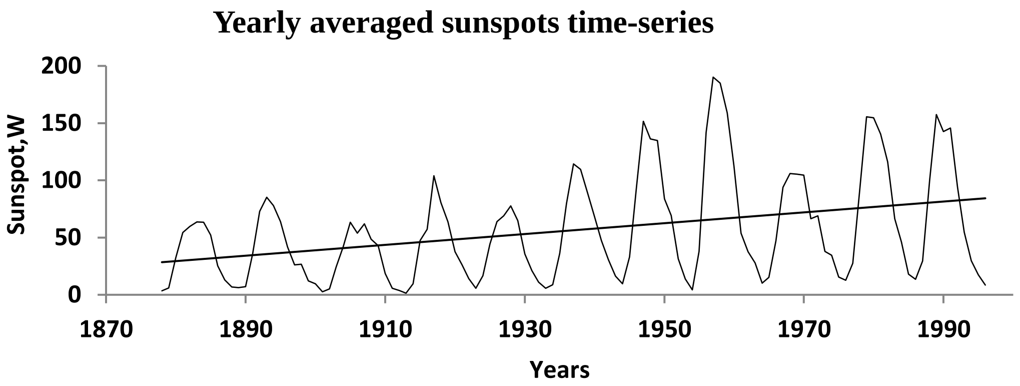


Fig. 2. Temperature change (NASA/GISS) http://www.giss.nasa.gov/research/news/20100121/

2. Background

Climate variability in the Caucasus region has to be considered in the context of global climate change. Common global climate change experience shows heterogeneous effect across regions of the world. Climate change and associated impacts differs from region to region around the globe. Anticipated effects include warming global temperature, rising sea levels, changing precipitation, and expansion of deserts in the subtropics.

Increase of solar activity in the last time has led to increase of air temperature, atmospheric carbon dioxide and global sea level (Fig. 3 - 7).



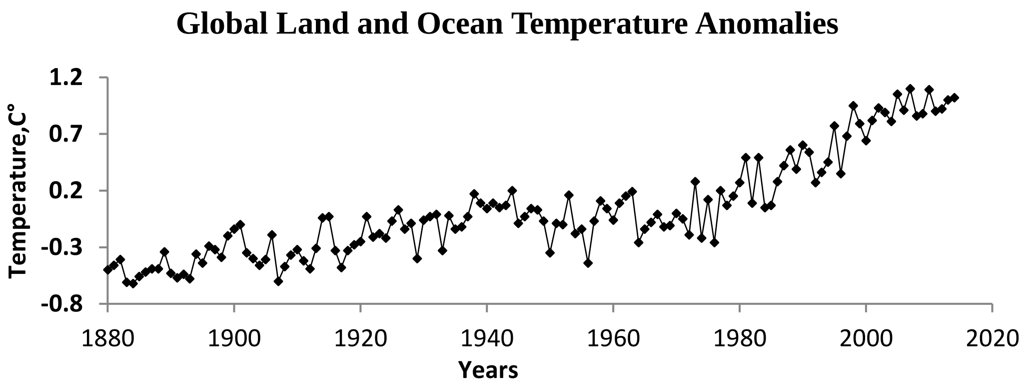


Fig. 3. Long-term increase trend of solar activity and temperature anomaly over the period 1880–1996.

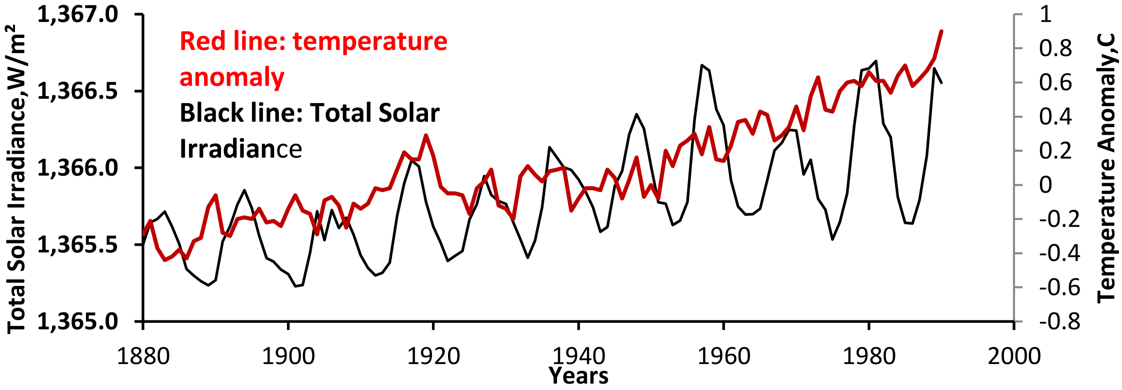
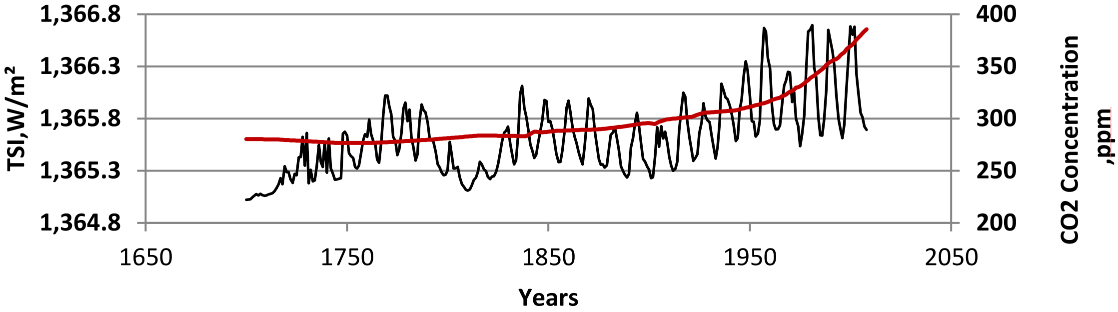


Fig. 4. Temperature Anomaly Data of NOAA's National Centers for Environmental Information (NCEI) and Total Solar Irradiance over the period of 1880-2008.



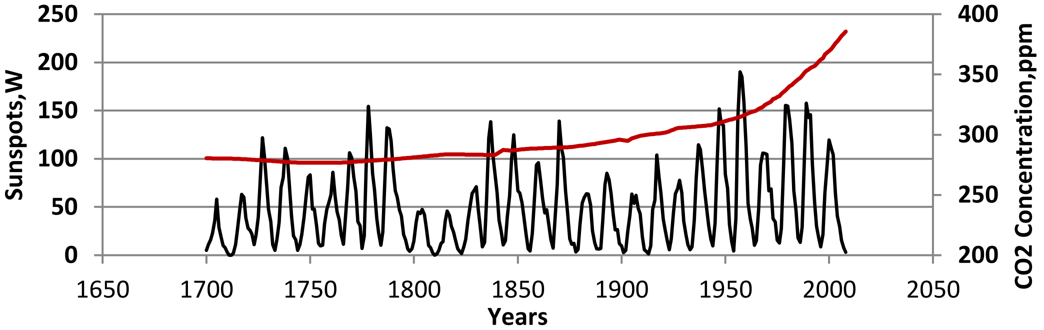


Fig. 5. The atmospheric carbon dioxide and solar activity (red line CO_2 concentration).

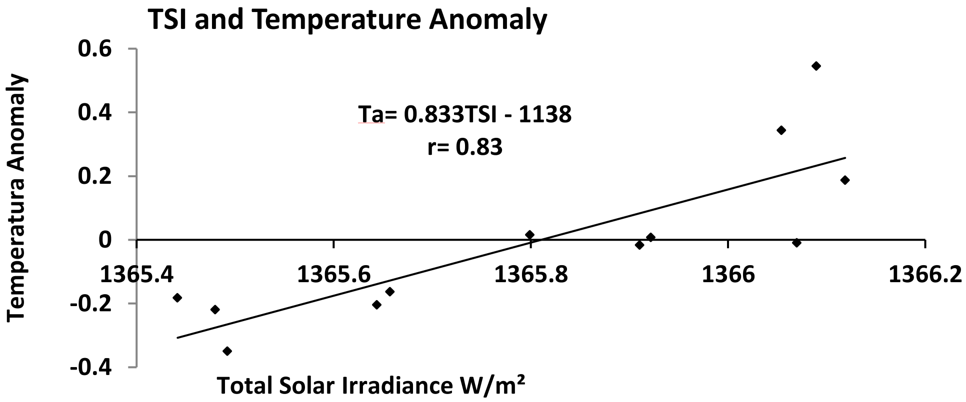


Fig. 6. Temperature Anomaly Data and solar activity.

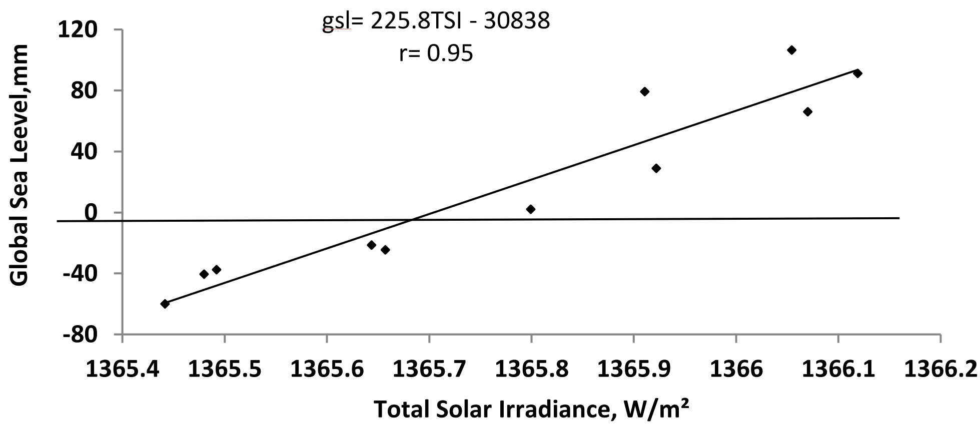


Fig. 7. Global Sea Level (gsl) in dependence from TSI over observed period 1878-2008.

3. Long term trends in climate variability of Caucasus region

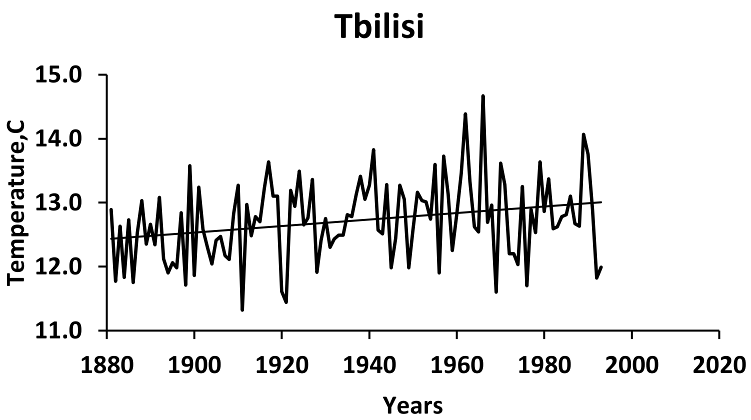
The Caucasus is a region located between the Black and Caspian Seas. The Greater Caucasus range moderates local climate by serving as a barrier against cold air from the north. Lesser Caucasus Mountains partially protect the region from the influence of dry and hot air masses from the south as well [4].

Regional climates in the Caucasus region are largely influenced by distance from the Black and Caspian Seas and the orography of the Greater and Lesser Caucasus. The prevailing west winds from the Black Sea loose most of their moisture when crossing the Surami ridge that connects the Greater with the Lesser Caucasus as a result of orographic lift. Dry winds descend into the Kura valley which therefore has a more arid character with warm to hot and dry summers and cold winters. Climate change is ambiguous here - warming in eastern Georgia and cooling in the west [5,6].

Mountains receive less solar radiation than adjacent foothills and plains located a short distance away. Winds blowing against mountains force some of the air to rise, and clouds form from the moisture in the air as it cools.

Smoothed Total Solar Irradiance (TSI) values were compared with smoothed weather parameters over the same period. Our calculations show that temperature change in the region closely depends on Total Solar Irradiance (TSI). For example temperature in Tbilisi over the period 1878-1996 can be written as:

$$T= 0.73TSI – 980.2 \qquad r=0.83 \qquad (1)$$



a

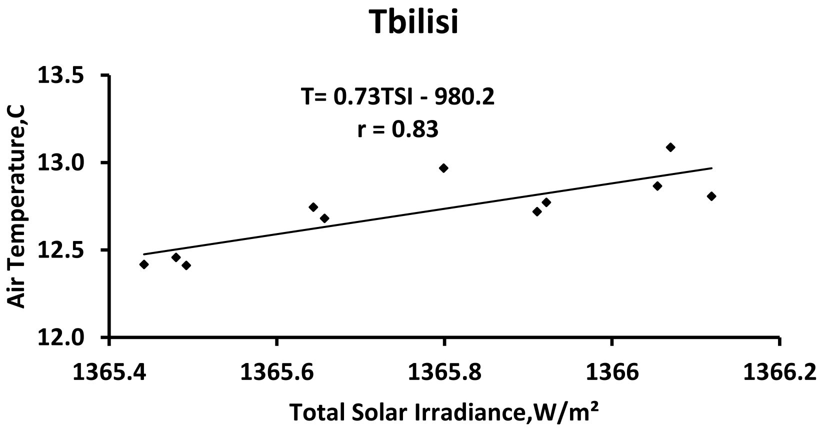


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Fig. 8. Air temperature time series (a) in Tbilisi over the period 1881-1996 and relationship of temperature from solar irradiance (b).

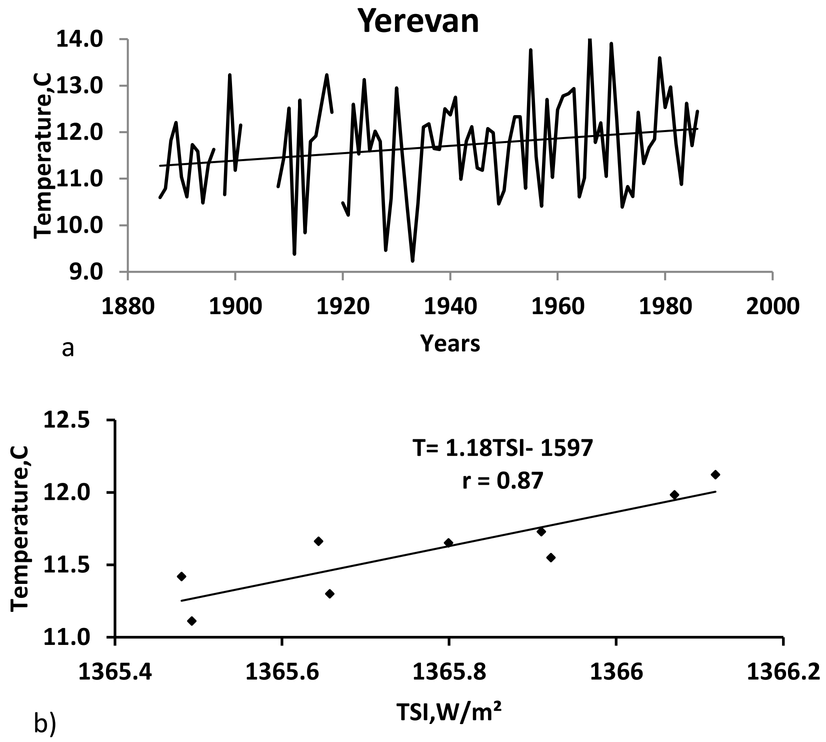


Fig. 9. Air temperature time series (a) in Yerevan over the period 1890-2008 and relationship of temperature from solar irradiance (b).

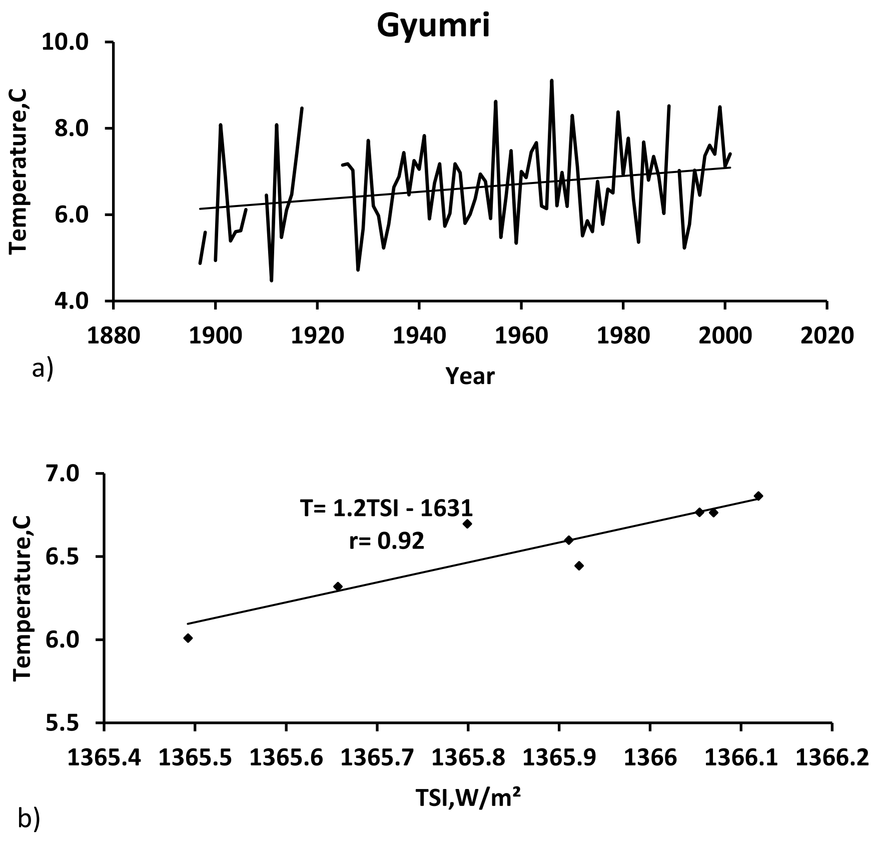


Fig. 10. Air temperature time series (a) in Gyumri over the period 1902-2001 and relationship of temperature from solar irradiance (b).

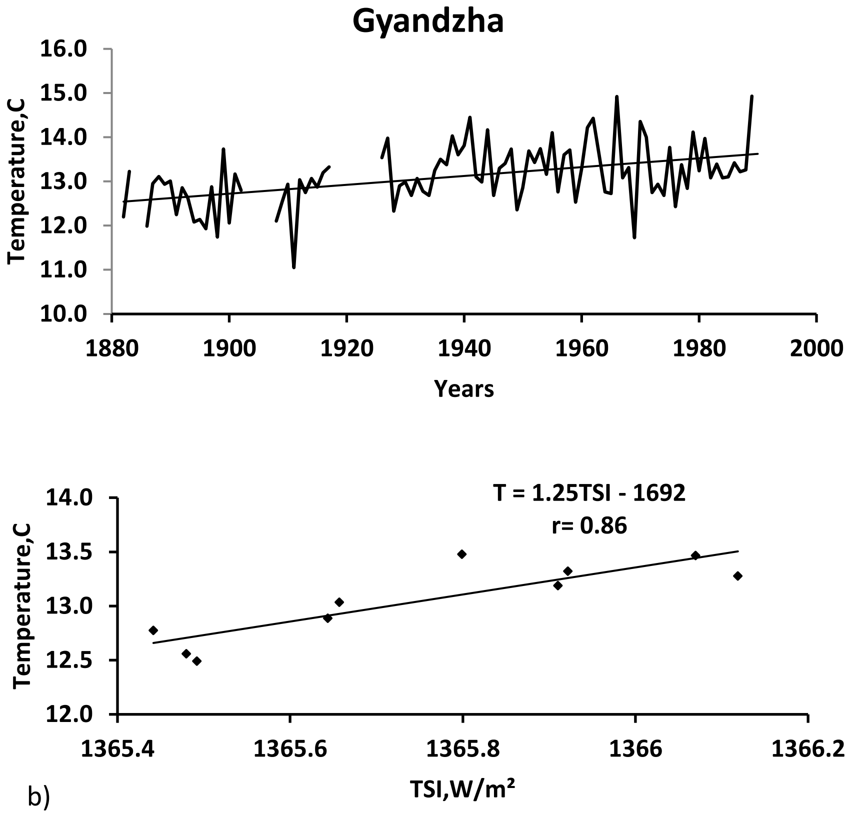


Fig. 11. Air temperature time series (a) in Gyandzha (Kirovobad) over the period 1882-1996 and relationship of temperature from solar irradiance (b).

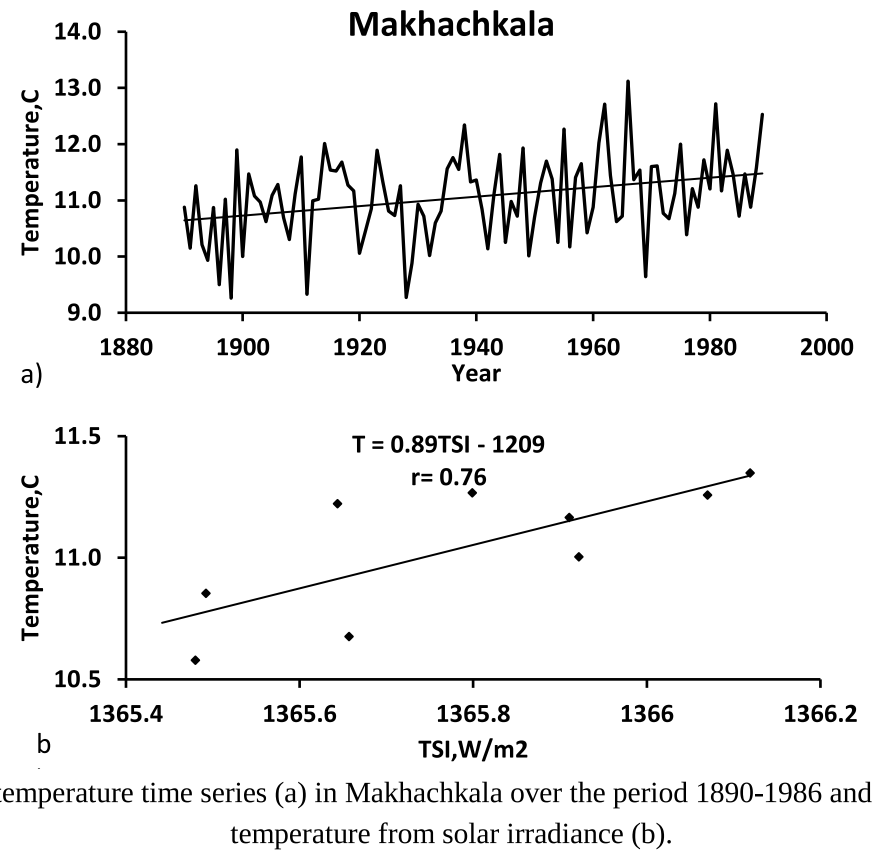


Fig. 12. Air temperature time series (a) in Makhachkala over the period 1890-1986 and relationship of temperature from solar irradiance (b).

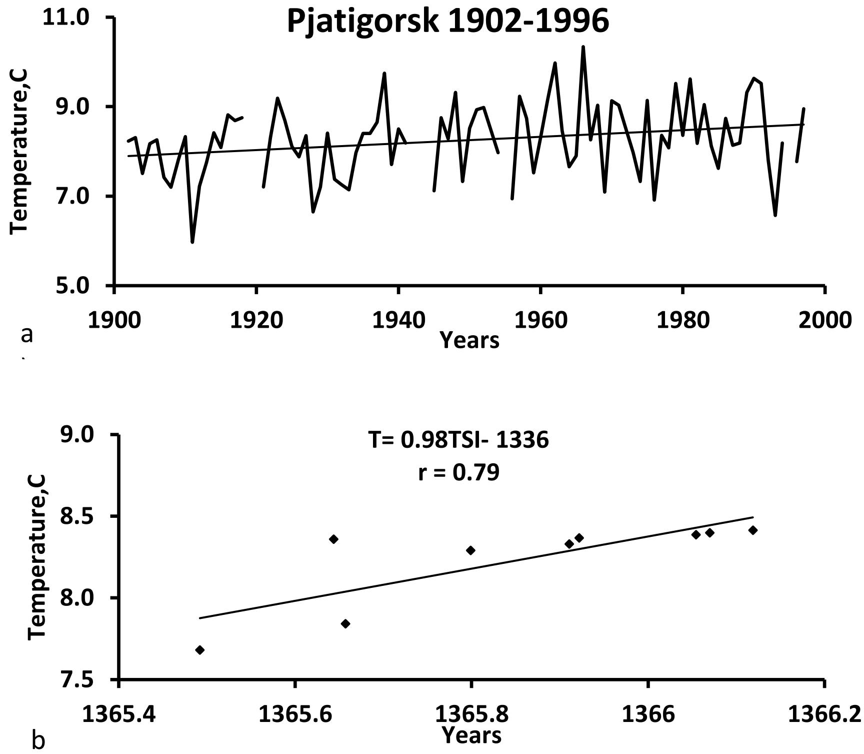


Fig. 13. Air temperature time series (a) in Piatigorsk over the period 1902-1996 and relationship of temperature from solar irradiance (b).

Temperatures are increasing over entire region and the annual mean amount of precipitation is tending to decrease.

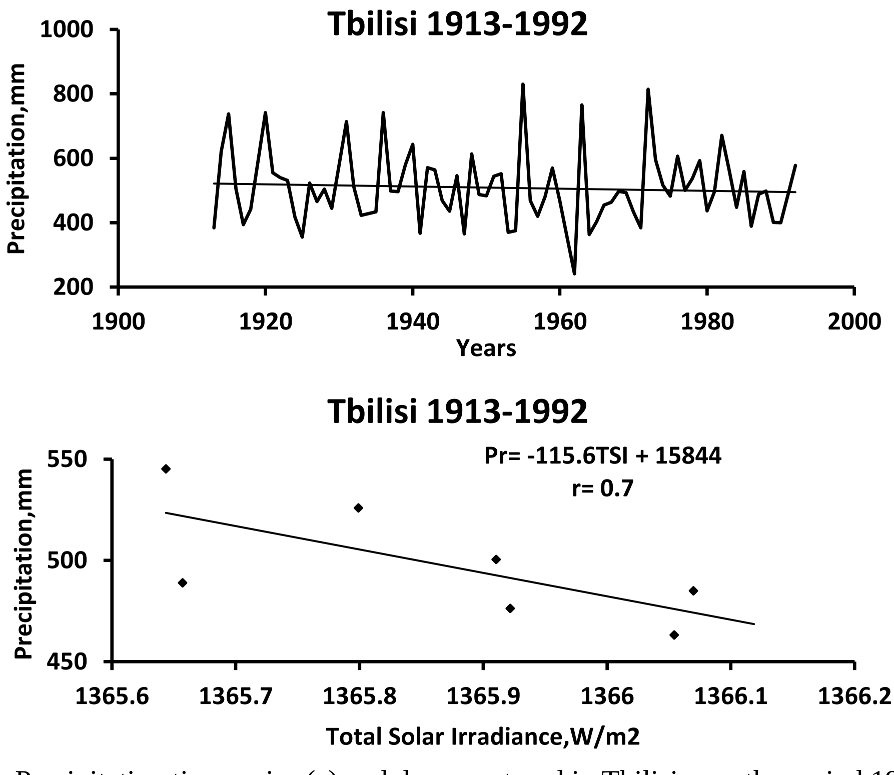
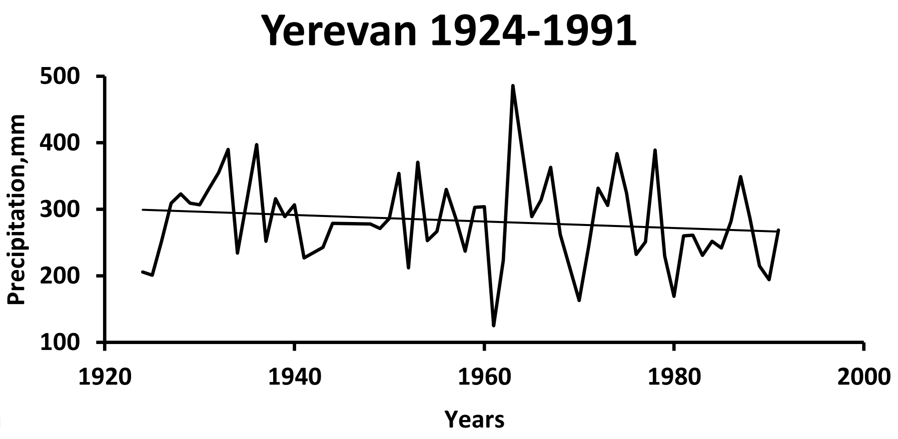
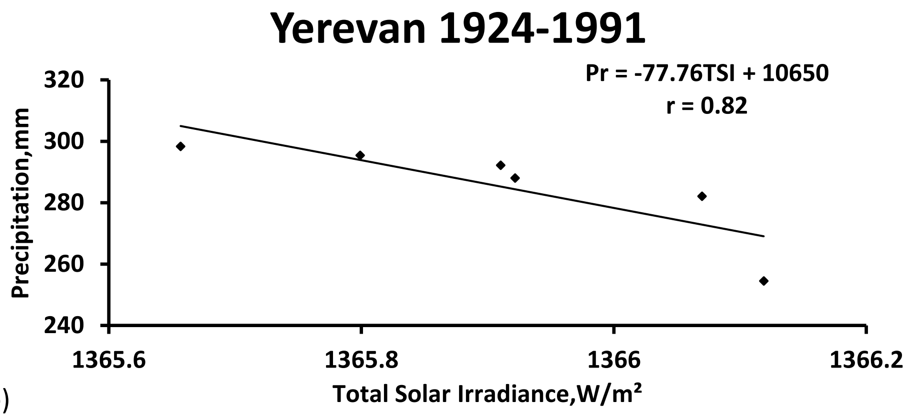


Figure 14. Precipitation time series (a) and decrease trend in Tbilisi over the period 1913-1992 in dependence from solar irradiance (b).

The same trend shows time series of Yerevan and Makhachkala station precipitation (Fig. 15).



a



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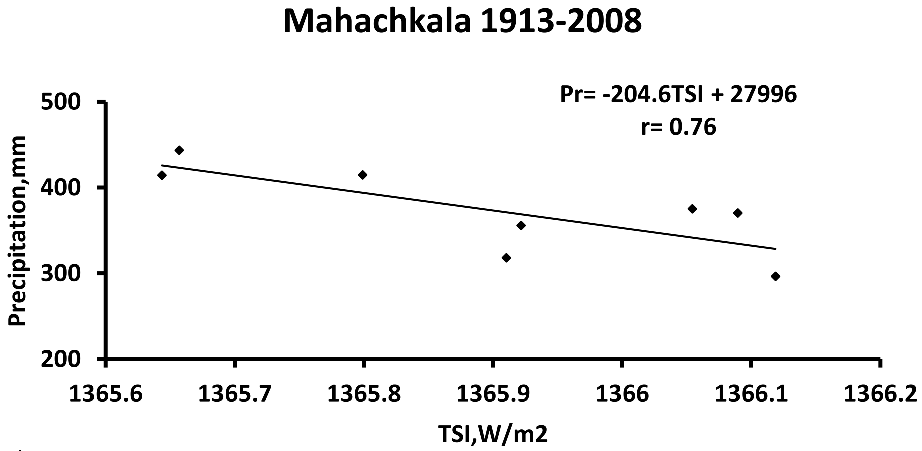

c)

Fig. 15. Precipitation time series (a) and decrease trend in Yerevan (b) over the period 1924-1991 and Makhachkala (c) over the period 1913-2008 in dependence from solar irradiance.

This precipitation trend is typical for rain shadow located on the side of a mountain range that is protected from the prevailing winds [7]. The mountains block the passage of rain-producing weather systems and cast a "shadow" of dryness behind them. Wind and moist air is drawn by the prevailing winds towards the top of the mountains, where it condenses and precipitates before it crosses the top.

Table 1

Comparison of Caucasus weather stations altitudes show different temperature change.

Weather station	Altitude	Observed period	Air °C increase
Gumri	1523 m	1902-1996	0.70
Yerevan	907 m	1890-1996	0.70
Tbilisi	490 m	1878-1996	0.45
Kirovobad	408 m	1878-1996	0.50
Makhachkala	32 m	1890-1986	0.78
Pjatigorsk	538m	1902-1996	0.70

Temperature change in Tbilisi points out good correlation with temperature variability in Geneva (Switzerland) altitude 420 m, although temperature increase over the same period 1878-1996 more high - 1.7 °C (Fig. 17).This can be explained more intensive prevailing west winds from the Atlantic Ocean, that more weak in the Caucasus region.

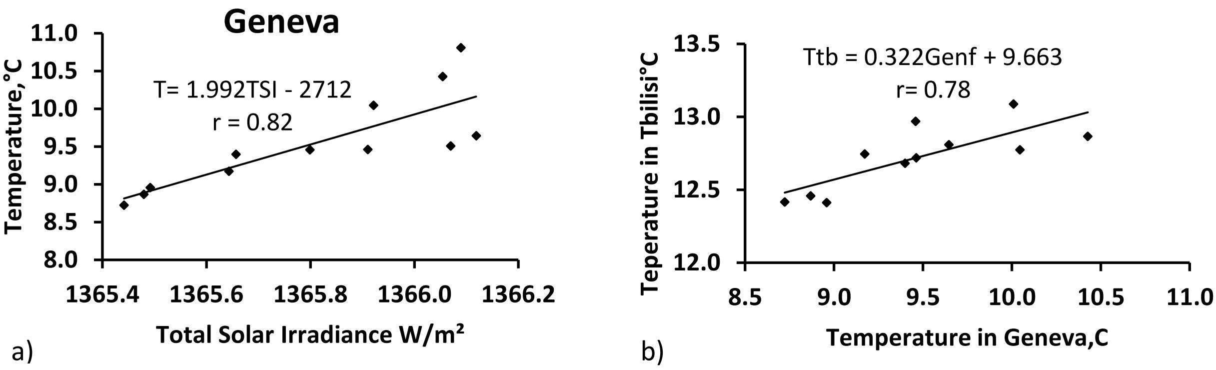

Fig. 16. Dependence of air temperature in Geneva from Total Solar Activity (a) and air temperature in Tbilisi (Ttb) from temperature in Geneva (Genf) over the period 1878-1996.

Moderate temperature increase trend in the Caucasus region can be connected with mountainous topography. The southern slopes of the Caucasus Mountain Range receive more solar irradiance.

Amount of Total Solar Irradiance on the different slopes varies in mountain disposition south/north - ratio -1.62, south/east- ratio 1.54, south /west ratio -1.56 [8]. In the Northern hemisphere, south-facing slopes receive more direct sunlight and have a warmer climate than those facing north.

Conclusion

More sunspots deliver more energy to the atmosphere, by way of increased brightness of the Sun and solar wind what tend to warm the Earth. Solar activity affects the Earth in many ways, some which we are still coming to understand.

In accordance with National Geophysical Data Center (NGDC) forecasting the solar cycles 24 and 25 will be very weak: averaged sunspot numbers W-35 for the solar cycle 24 and for the solar cycle 25 less than W-35 , NGDC (2009). Total Solar Irradiance will equal -1365,48. (23 cycle -1366,09).

This actually will lead to a decrease of the temperature on 0.5-0. 7 C in both averaged solar cycles, in Geneva will decrease to 1.5 C. Temperature of air will be lower in the Northern Hemisphere. Precipitation rate in Caucasus will be more in average on 100-150 mm in dependence from location.

The World Ocean level also will be lower, due to more snow and glacier accumulation on continents.

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კლიმატის ცვალებადობის მრავალწლიური ტრენდები კავკასიის რეგიონში

ბ. ნურტაევი, ლ. ნურტაევი

რეზიუმე

1855-1996 წლებში დაიკვირვებოდა მზის აქტივობის მატების გრძელვადიანი ტრენდი, რაც იწვევდა ტემპერატურის მატებას. კავკასიის რეგიონში ასევე დაიკვირვება დათბობის ტენდენცია. ამ გამოკვლევის მთავარი მიზანია - მზის წვლილის განსაზღვრა კავკასიის მთების კლიმატის ცვლილებაში და მომავალი კლიმატური ტენდენციის გრძელვადიანი პროგნოზირება რეგიონში მისი მდგრადი განვითარებისათვის.

Долговременные тренды изменчивости климата в Кавказском регионе

Б.С. Нуртаев, Л. Нуртаев

Резюме

В период 1855-1996 гг. наблюдался долгосрочный тренд роста солнечной активности, что приводило к повышению температуры. В Кавказском регионе также наблюдается тенденция к потеплению. Основная цель этого исследования - определить вклад Солнца в изменчивость климата гор Кавказа и долгосрочное прогнозирование будущей климатической тенденции в регионе для устойчивого развития.