

Predictive Analytics of Climate Trends

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Abstract

The accumulation of data in the weather observation will be continued steadily to infinity. To perform weather predictions, a huge amount of data needs to be processed and assimilated to create of acceptable models. This paper presents a method of estimating a long term (more than 100 years) temperature and precipitation sets for predicting of a future trends. The method uses average solar cycle length as a uniform sampling basis for assessment of weather features. Long-term observation of climatic variables shows that in the theory of weather chaos exists a certain order. The order is expressed as a long-term increasing temperature trends and in rising of ocean levels. Here we demonstrate how the proposed approach can be highly effective in varied large-scale applications involving regional temperature trends in Caucasus region.

Key words: climate variability, precipitation, uniform sampling, solar cycle, attractor, Total Solar Irradiance, time series, sets.

Introduction

Predictive analytics encompasses a variety of statistical techniques from data mining, predictive modeling, and machine learning, and that analyze current and historical facts to make predictions about future or otherwise unknown events.

The Earth's climate has changed many times over geological history.

The last 3 million years have been characterized by cycles of glacials and interglacials within a gradually deepening ice age. Currently, the Earth is in an interglacial period, beginning about 20,000 years ago (Petit et al, 1999). Climate has changed when the planet received more or less the Sun's energy. Paleoclimatology, or the study of past climates, can help place this warming in the context of natural climate variability. The Earth warmed by roughly 0.6°C during the 20th century, the temperature changes have occurred over the past 100 to 150 years.

However, air-temperature reconstructions may underestimate pre-instrumental temperatures including warmth during Medieval and Roman times. The Roman Warm Period peaked around 150 AD at 2° C warmer than today (Scheidel et al, 2012a).

Dendrochronological evidence from wood found at the Parthenon shows variability of climate in the 5th century BC resembling the modern pattern of variation (Scheidel et al, 2012b).

It is believed, that current period of warming is occurring more rapidly than many past events.

In fact, reliable instrumental records are available only for the last 150 years. Earlier records exist for a few stations and in this paper we considered also time series with more than 250 years. We here address these issues by developing of big data processing, time series and application of attractors in data processing.

The study is based on two fundamental cores principles underlying geosciences:

1. The global climate is regulated by how much energy the Earth receives from the Sun.
2. The Doctrine of Uniformity –the assumption, that the same natural laws and processes that operate in our present-day scientific observations have always operated in the universe in the past and apply everywhere in the universe.

The Earth atmosphere is an open energy system receiving energy from the sun. The first law of thermodynamics, states that energy can neither be created nor destroyed; energy can only be transferred or changed from one form to another. 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 (Taylor, 2005a). This energy to the atmosphere is the primary driver of the Earth's weather.

A reconstruction of total solar irradiance since 1843 to the present estimated an increase in the total solar irradiance of about 0,8 W/m². This is a huge amount of energy, taking into account the Earth's total land mass.

The goal of this study is to reveal the general underlying process which generates or allows such a variations in climate and precipitation trends in Caucasus region.

1.Method

Annual air temperature or rainfall data, in mathematical sense, represents a set of natural numbers and can be described as:

$$T = \{t_0, t_1, t_2, t_i, \dots\}; \tag{1}$$

-where t_0, t_i -averaged yearly air temperature in °C.

In accordance with concept of the Earth's energy budget and notion of sets (mathematic), every member of air temperature "T" or rainfall "P" set is also a member of set solar activity presented as Total Solar Irradiance "TSI" (Nurtaev, 2019), then "T" is said to be a subset of "TSI" (Fig. 1).

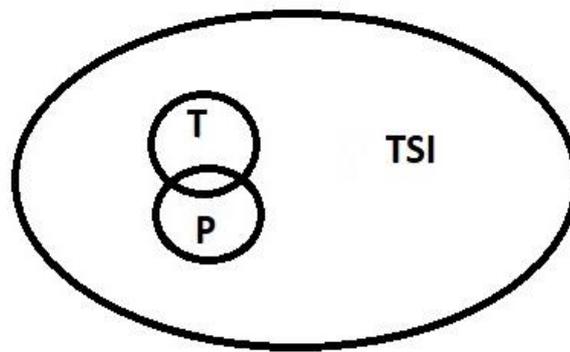


Fig. 1. Air temperature (T) and precipitation (P) are subsets of solar activity, $T \subset TSI, P \subset TSI$.

$$TSI = \{tsi_0, tsi_1, tsi_2, tsi_3, tsi_i, \dots\}; \tag{2}$$

-where $tsi_1, tsi_2, \dots, tsi_i$ - measured Total Solar Irradiance in W/m².

Each value of tsi_i predetermines the corresponding value of air temperature t_i . The conversion of meteorological time series into numerical sets allows working with them as with mathematical objects.

For discovery of relationship a set of data points plotted on an x and y axis to represent two sets of variables is created. An independent variable "tsi" is plotted along the horizontal axis. The measured air temperature or dependent variable t is plotted along the vertical axis.

We tested a relationship between temperature and solar activity "tsi" over the period 1760-2009 on an example of the Basel weather station, a longest time series of observations (HISTALP data, 2013). The generally positive relationship between the two variables can be easily discernible from the cloud formed by 250 points (Fig.2a).

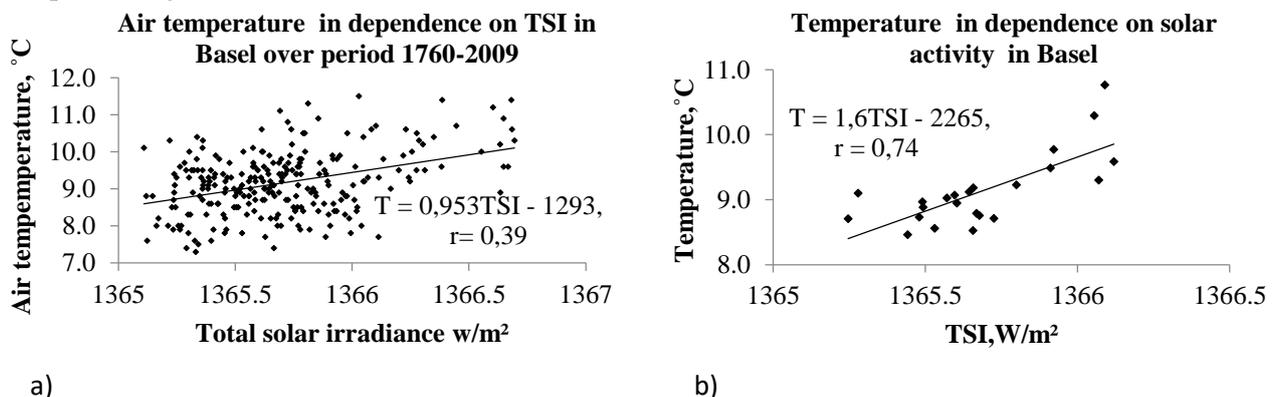


Fig.2. Yearly averaged air temperature in Basel in dependence from Total Solar Irradiance (a) and averaged in solar cycles (b).

In accordance with concept of the Earth's energy balance and sets theory (Figure 1) –every change of sun output- “tsi”, leads to change of subset air temperature “t”. This means, that every change in average annual solar energy leads to a change in average air temperature

To enhance the trend in the graph, we used an global attractor (Nurtaev, 2019), expressed in the length of the solar cycle.

Observation period for meteorological objects was divided on 11 years solar cycles time intervals for air temperature and solar activity. It was calculated for every such interval averaged Total Solar Irradiance and air temperature Nurtaev (2015):

$$TSI = \frac{1}{n} \sum_{i=0}^n tsi_i; \quad (3)$$

$$T^{\circ} = \frac{1}{n} \sum_{i=0}^n t_i; \quad (4)$$

where TSI– averaged Total Solar Irradiance for one solar cycle with length n = 11 years; T° – averaged air temperature for one solar cycle °C, i - solar cycles 1 to current 24.

This averaging allows avoiding a cyclic variability of Total Solar Irradiance as well air temperature and leads to uniform sampling both parameters in the same time interval. Solar minima and maxima are the two extremes of the Sun's 11-year activity cycle. Averaging over 11 years as a rule gives a smoothing effect and reveals a climate trend at centennial timescales, which are more than two centuries in our test case study in Basel weather station Fig.2 (b).

2. Climate trends in Caucasus region.

The climate change in Caucasus region and its effects on the environment, ecology, and economy in the 20th century close connected with global climate trends. Over the period 1855–1996 was observed a long-term increase trend of global surface temperature. During this period also was observed an increase in solar activity in the Northern Hemisphere. The average global temperature on Earth has increased by about 0.8° Celsius. The averaged TSI analysis reveals that input of solar energy in Earth atmosphere also increased on 0, 8 W/m² (Fig. 3).

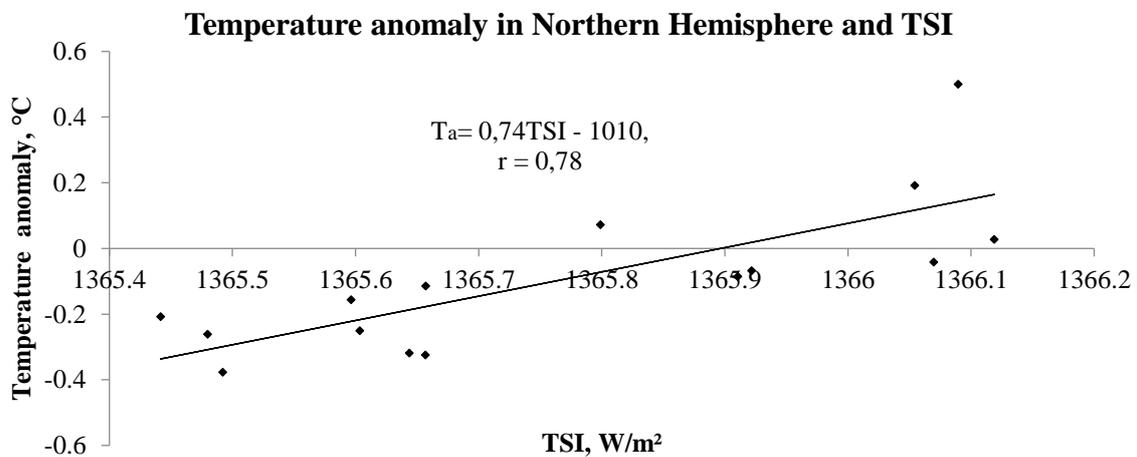


Fig.3. Dependence of air temperature anomaly in Northern Hemisphere from solar activity over the period 1843-2008.

The temperature trends in capitals of Caucasus region were presented in our previous study (Nurtaev, 2016).

Temperature in Yerevan has following trend:

$$T = 1.18TSI - 1597, r = 0.87 \quad (5)$$

Temperature in Tbilisi has following trend:

$$T = 0.73TSI - 980.2, r = 0.83 \quad (6)$$

This study is based on the World Bank Data for Caucasian countries and Turkey, Climate Change Knowledge Portal, World Bank Group, 2019).

Yearly averaged air temperature data in the Armenia country are presented in Fig. 4.

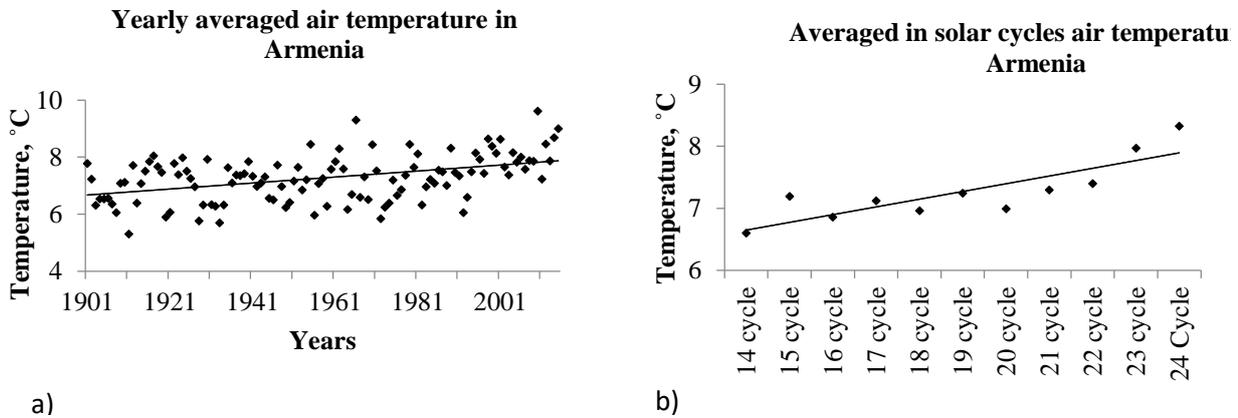


Fig.4.Long term air temperature data sets in Armenia country (a) and averaged in solar cycles (b).

The graph in Fig.4a presents the point cloud or noisy data with weak trend. In the graph in Fig.4b we divided this dimension of the scatter plot into uneven intervals of averaged solar cycle's lengths. Simple visual inspection reveals already a strong trend- 0, 84.

Among the factors that increase the temperature, the main driving force is solar activity. Average annual solar radiation arriving at the top of the Earth's atmosphere is roughly 1365 W/m².

So we compared two variables TSI and air temperature observed in Armenia divided in non-equal segments (length of solar cycles).

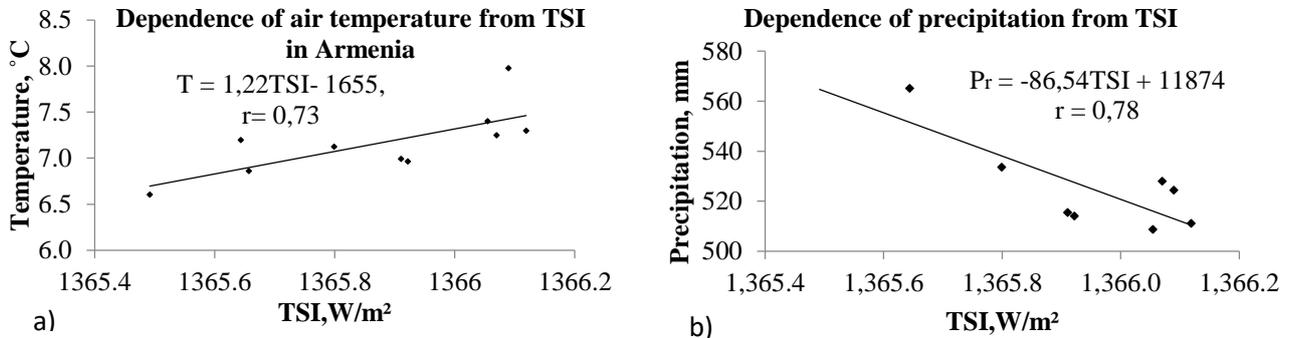


Fig. 5. Dependence of air temperature (a) and precipitation (b) from TSI in Armenia over the period 1902-2008.

The same analyses of datasets were applied for other countries of the Caucasus region and near located Turkey, Fig. 6,7,8.

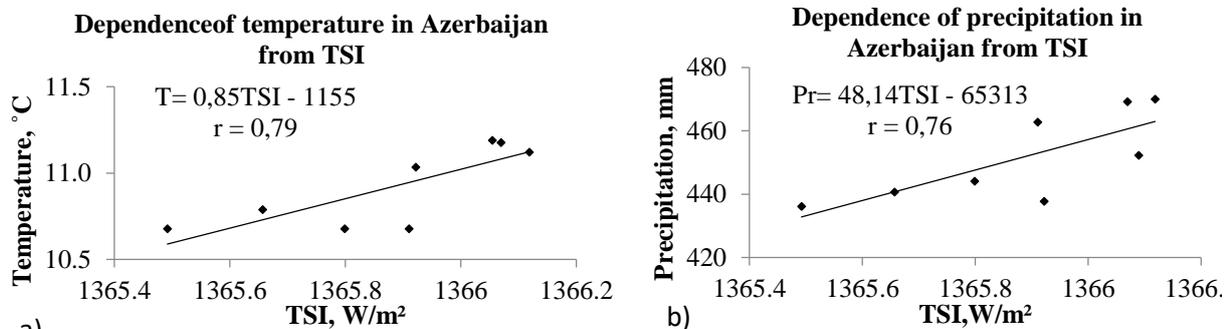


Fig. 6. Dependence of air temperature (a) and precipitation (b) from TSI in Azerbaijan over the period 1902-2008.

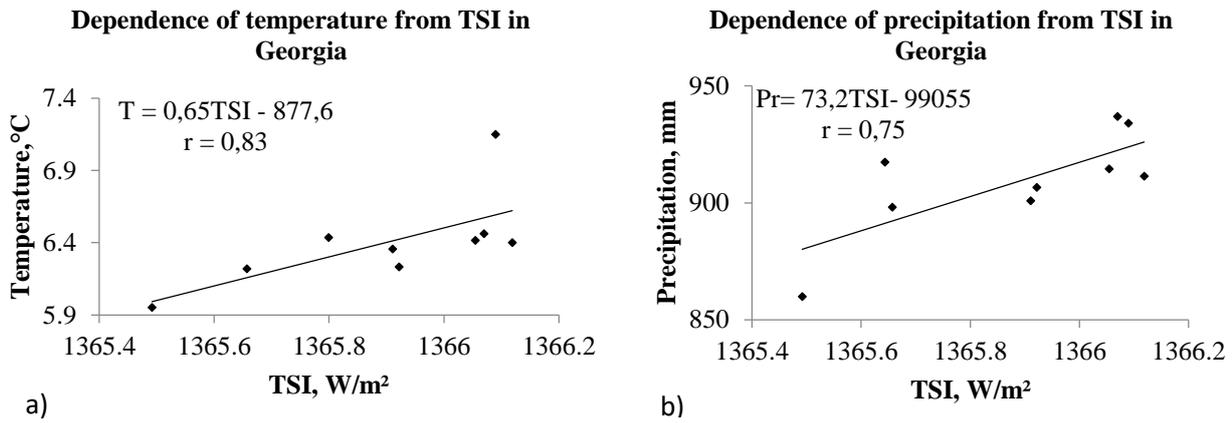


Fig. 7. Dependence of air temperature (a) and precipitation (b) from TSI in Georgia over the period 1902-2008.

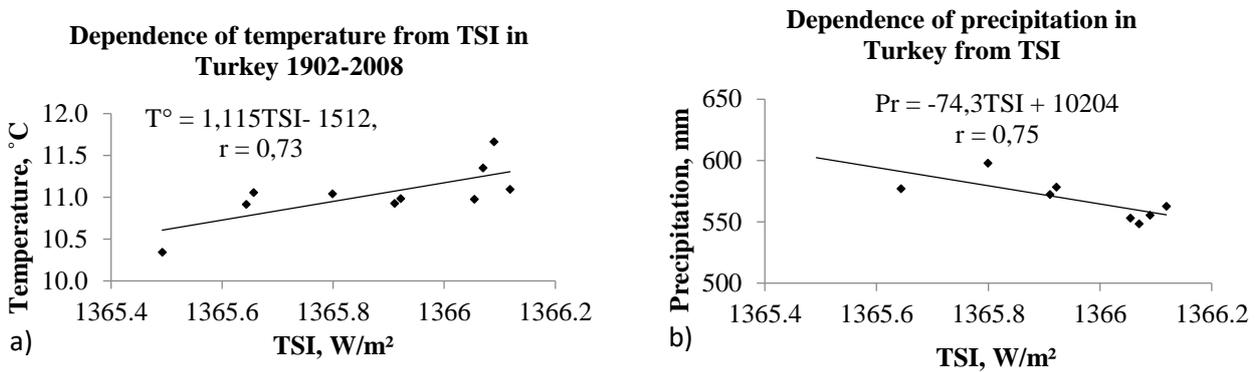


Fig. 8. Dependence of air temperature (a) and precipitation (b) from TSI in Turkey over the period 1902-2008.

3. Discussion

Despite a long term observation of weather variable, a significant part of the observed data is rarely used.

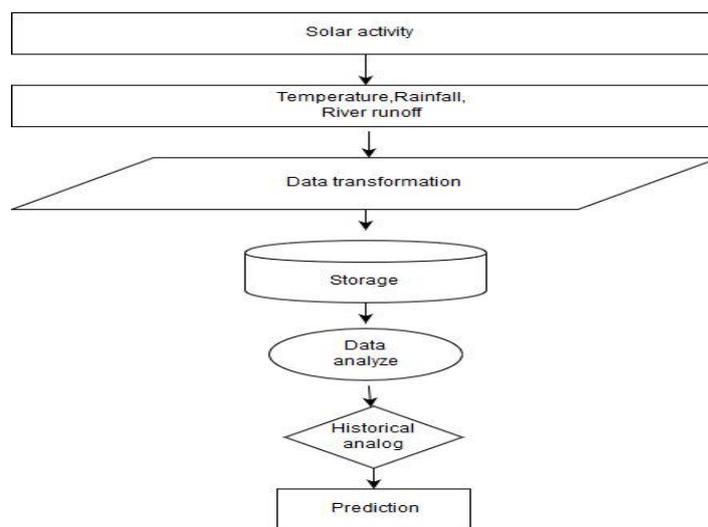


Fig. 9. Scheme of predictive analytics for climate trend forecasting.

The World Meteorological Organization defines a climate normal period as a period of at least 30 years. The current climatological standard normal period (1981–2010) at the time of writing (WMO, 2017) be used for these datasets to allow comparison among different data forms on a consistent basis. Climate normals are used implicitly or explicitly, as a prediction of the conditions most likely to be experienced in a given location

Here, we find that use of global attractor as solar cycle averaging for climate variables may be a productive way to predict future climate trends for the Caucasus countries.

Importantly, direct effects of study, to perform a meteorological data as mathematical numerals and work with these as an object of mathematics. (Mathematical object is an abstract object arising in mathematics). Figure 9 presents a hierarchical scheme of predictive analytics for climate trends application.

Here we demonstrate how the same approach can be highly effective for one station as well as in large-scale applications on country level, where climate conditions vary over a wide range from mountains to valleys and coastal zones.

It is clear of course, that relationship for one station is higher than for country. For example-Yerevan station- $r=0,83$ (5) and for all Armenia country, $r=0,73$ (Fig.5)

4. Conclusion

Proposed method of averaging of weather variables in solar cycles allows us reveal with high probability the averaged temperature in the next averaged solar cycle. Bringing all weather parameters together in solar intervals alleviates to assess relationships between all pair of variables and see the trend for next 11 years.

NASA's forecast for the next solar cycle (25) reveals it will be the weakest of the last 200 years, TSI = 1365.5 W/m² (National Geophysical Data Center (NGDC) forecasting, 2009). Temperature in all studied countries of Caucasus region will be decreased on 0, 5-0,6 °C in the next averaged solar cycle.

Solar cycle 25 is the upcoming and 25th solar cycle since 1755, when extensive recording of solar sunspot activity began. It is expected to begin in late 2019 and continue through 2030.

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კლიმატური ტენდენციების პროგნოზული ანალიტიკა

ბ. ნურტაევი

რეზიუმე

ამინდზე დაკვირვებების მონაცემების დაგროვება მოხდება უსასრულოდ. ამინდის პროგნოზის შესასრულებლად საჭიროა დიდი რაოდენობის მონაცემების დამუშავება და ათვისება მისაღები მოდელების შესაქმნელად.

მოცემულ სტატიაში წარმოდგენილია ტემპერატურისა და ნალექების ნაკრებების გრძელვადიანი (100 წელზე მეტი) შეფასების მეთოდი მომავალი ტენდენციების პროგნოზირებისათვის. მეთოდი იყენებს მზის ციკლების საშუალო ხანგრძლივობას როგორც ამონაკრების ერთიან საფუძველს ამინდის მახასიათებლების შეფასებისათვის. კლიმატურ ცვლადებზე მრავალწლიანი დაკვირვებები გვიჩვენებს, რომ ამინდის ქაოსის თეორიაში არსებობს გარკვეული წესრიგი. ეს წესრიგი ვლინდება ტემპერატურული ტრენდების მრავალწლიან ზრდაში და ოკეანის დონის მომატებაში. აქ ჩვენ დემონსტრაციას ვაკეთებთ, როგორ შეიძლება შემოთავაზებული მიდგომა იყოს ძალზე ეფექტური სხვადასხვა დიდმასშტაბიანი გამოყენების დროს, რომლებიც მოიცავენ კავკასიის რეგიონში ტემპერატურულ ტრენდს

Прогнозная аналитика климатических тенденций

Б. Нуртаев

Резюме

Накопление данных в наблюдениях за погодой будет продолжаться до бесконечности. Для выполнения прогнозов погоды необходимо обработать и усвоить огромное количество данных для создания приемлемых моделей.

В данной статье представлен метод оценки долгосрочных (более 100 лет) наборов температуры и осадков для прогнозирования будущих тенденций. Метод использует среднюю продолжительность солнечного цикла в качестве единой основы выборки для оценки характеристик погоды. Многолетние наблюдения за климатическими переменными показывают, что в теории погодного хаоса существует определенный порядок. Порядок выражается в долгосрочном повышении температурных трендов и повышении уровня океана. Здесь мы демонстрируем, как предлагаемый подход может быть очень эффективным в различных крупномасштабных применениях, включающих региональные тренды температуры в Кавказском регионе.