Research Article

ISSN 2766-2624

Advances in Earth and Environmental Science

Is Global Warming the Result of Earth's Clouds Having Lower Albedo Due to Declining Solar Activity Over the Past Few Decades?

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Submitted: 12 Mar 2026; **Accepted:** 17 Mar 2026; **Published:** 27 Mar 2026

Citation: N. P. (2026). Is Global Warming the Result of Earth's Clouds Having Lower Albedo Due to Declining Solar Activity Over the Past Few Decades?. *Adv Earth & Env Sci; 7*(1):1-20. DOI : https://doi.org/10.47485/2766-2624.1091

Abstract

The now widely accepted paradigm identifies greenhouse gases as the source of global warming, a significant share of which is anthropogenic, stemming from the extraction and burning of fossil fuels and intensive agricultural production. The hope is that humanity can limit this biosphere-threatening process by regulating these activities. This article argues that processes on the Sun have partly or entirely caused global warming in the Earth's atmosphere over the past 100 years. Global warming is likely a consequence of streams of positively charged, high-energy particles emitted by the Sun, mainly during the "rise" phase of solar activity, when phenomena on the Sun's surface are associated with a growing magnetic field. Part of this high-energy radiation reaches the Earth. It penetrates deep into the Earth's atmosphere, increasing the concentration of ions that serve as condensation nuclei around which water vapor forms droplets. Condensation nuclei increase cloudiness in the lower atmosphere. The upper surfaces of clouds and fog partly reflect solar electromagnetic radiation, returning energy to space, which leads to a decrease in surface temperature and, hence, in the temperature of the ground air heated by the surface. When solar activity decreases, as observed over the last 100 years, the reverse process occurs: the high-energy fluxes of corpuscular radiation decrease, the ionization of the Earth's atmosphere decreases, cloudiness decreases, and more solar electromagnetic radiation reaches the Earth's surface, increasing the temperature. An additional argument for the presence of high-energy radiation that penetrates deep into the Earth's atmosphere and even reaches the Earth's surface is the high, statistically significant correlation between the fluxes of such radiation recorded by the GOES series satellites in geostationary orbit (36,000 km above the Earth's surface) and human mortality from the deadliest diseases. The bad news is that if the described mechanism is the leading cause of global warming, there is not much humanity can do to protect itself and the biosphere. Humanity's efforts (the International Energy Agency estimates global clean energy investment at USD 2 trillion for 2024) should be redirected to increasing the planet's reflectance of solar electromagnetic radiation.

Keywords: Global warming, Climate change, Solar cycle, Ionizing radiation, Satellite data.

Introduction

In the Synthesis Report, "CLIMATE CHANGE 2023," Summary for Policymakers, in the first chapter, "A. Current Status and Trends, Observed Warming and its Causes," the authors from the Intergovernmental Panel on Climate Change (IPCC) state: "Human activities, mainly through emissions of greenhouse gases, have unequivocally caused global warming, with the global surface temperature reaching 1.1° C above 1850-1900 in 2011-2020. (Intergovernmental Panel On Climate Change [IPPC], 2023).

In modern times, the thesis quoted above has become the dominant scientific paradigm about global warming.

In the present work, the author argues that global warming over the last 100 years has been partially or entirely caused by changes in high-energy, positively charged corpuscular radiation emitted mainly during the "rise" phase of the 11-year solar activity cycle. Deep in the Earth's atmosphere, this radiation increases air ionization and, as a result, cloudiness. Solar activity has gradually decreased in recent cycles, reducing the amount of emitted ionizing radiation and leading to reduced cloudiness. Less cloudiness means more solar electromagnetic radiation reaches the Earth's surface, resulting in higher surface temperature.

Materials and Methods

In connection with the described study, three types of data were collected and processed, obtained from reliable sources – globally recognized databases of NOAA, NASA, EUROSTAT, and the US National Center for Health Statistics – 1. data on the surface temperature, 2. on the solar corpuscular radiation with high energy reaching the Earth's orbit, and 3. mortality in the human population from causes, mainly diseases, supposedly dependent on said solar radiation. The joint study of the three data types allowed a conclusion to be drawn about the cause of an invisible chain of interconnected phenomena, to which, in the author's opinion, global warming is also connected.

Temperature Data

Meteorological stations have operated in Bulgaria since the last quarter of the 19th century. The temperature data for the Stara Zagora station (latitude/longitude 42.42°N/25.64°E, elevation 168 m) are analyzed below. The station was selected for its proximity to major sources of greenhouse gases and its long-term, accurate temperature reporting – an almost continuous series spanning 126 years [data from the National Meteorological Institute, Branch Stara Zagora]. The station is located within Stara Zagora (population 125,732 as of 2021). With its heavy traffic, developed industry, and domestic combustion (continental climate with heating in winter and cooling in summer), the city is a significant source of greenhouse gases. In the vicinity of the station, about 40 km southeast, is the "Maritsa-Iztok" energy complex, a major source of greenhouse gas emissions. The complex covers an area of 240 km^2, consists of a coal mine and four thermal power plants around it with a total capacity of 3 GW, and has been operating since 1977. The ground-level air temperature data for the other stations from the rest of the world used in the study are from the NOAA website, National Climatic Data Center, in the Global Historical Climatology Network Daily (GHCNd) database (NOAA, n.d). The database includes thousands of climate stations, but temperature data were retrieved only for stations whose range of continuous annual temperatures spans the last completed solar cycle 24 (till 2018) and at least four solar cycles back in time. The total number of stations included in the study was 872.

The number of tropical cyclones depends on the degree of ocean warming. Data on North Atlantic tropical storms were obtained from (Colorado State University [CSU], 2024).

Data on global temperature anomalies for the land surface were obtained from (NOAA, 2024). The global land surface temperature anomaly is calculated annually as the difference (in K) between the annual mean global land surface air temperature and the global mean land surface air temperature for the hundred-year interval, 1901-2000.

Solar Activity Data

The solar substance is in a plasma state – a mixture of positively charged particles (protons and alpha particles) and negatively charged particles (electrons). Rising from deep within the Sun to its surface (convection), heated plasma flows export energy that leaves the Sun in the form of electromagnetic radiation. The solar magnetic field changes cyclically with a period of about 22 years. This change is observable because, during phases of field growth (solar activity), regions of increased magnetic field on the Sun's visible surface (photosphere) exhibit reduced convection, making them cooler, emitting less radiation, and, from a great distance, appearing darker (sunspots). Along with the appearance of spots during the Sun's active phase, solar mass ejections (SME), explosive processes with increased radiation brightness (flares), etc., occur. Within a 22-year cycle, solar activity changes twice for about 11 years (solar cycle). Solar activity has been monitored regularly through the Sun Spots Number (SSN, Solar Index) for over two and a half centuries. Each cycle is assigned a number. The Sun is currently nearing the maximum of its 25th cycle. Within the solar cycle, solar activity increases for several years ("rise" phase), reaches a maximum, and then decreases ("fall" phase) to a minimum (Figure 1). Manifestations of solar activity during a specific cycle are related to the magnitude of the SSN at the cycle's maximum. Across cycles, the maximum SSN varies; over the last seven cycles (from the 18th, since the mid-1950s) to the 24th, the number of sunspots at cycle maxima has declined. SSN data were obtained from the sites (SSN, 2015; SSN, n.d).

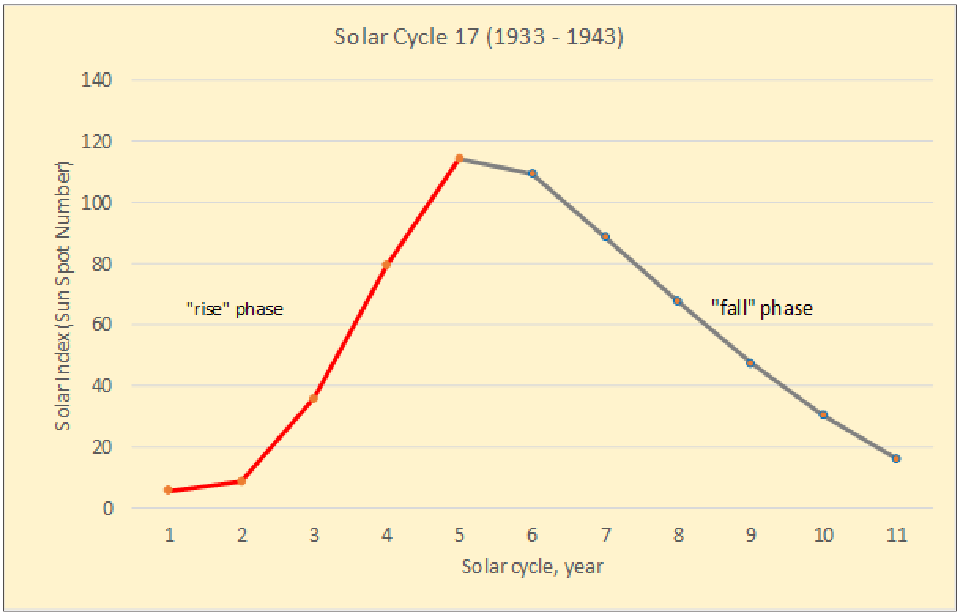

Figure 1: A solar activity cycle, illustrated by solar cycle 17 (chosen for its typical shape). During the first phase of the cycle, solar activity increases and reaches a maximum (the highest number of sunspots). Then, during the second phase, activity decreases to a minimum before the next cycle begins.

Solar Corpuscular Radiation Data

Satellite data on corpuscular radiation – protons and alpha particles recorded by the satellites of the two series SMS (Synchronous Meteorological Satellites) and GOES (Geostationary Operational Environmental Satellites) were obtained from a NOAA site (NOAA, n.d).

The SMS and GOES series satellites fly in geostationary orbit (above the Earth's equator) at an altitude of 36,000 kilometers, completing one orbit every 24 hours. They "hang" over a specific point on the Earth's surface and are not shaded by the Earth at their circumference around it.

Data on alpha-particle and proton fluxes (unit: (number of particles).$cm^{-2}.s^{-1}.sr^{-1}.MeV^{-1}$) with energies in the range 3.8 – 21.3 MeV (detectors' channels A1 and A2) were used. The fluxes were recorded by the satellite high-energy particle detectors:

1. Energetic Particles Sensor (EPS),
2. Energetic Proton, Electron, and Alpha Detector (EPEAD), and
3. High Energy Proton and Alpha Particles (HEPAD). The data are available at 5-minute intervals, with up to 25 instrument reports per interval.

The frequency of solar fluxes of positively charged particles is higher during the "rise" phase of solar activity cycles.

Day and Night Cloud Data

Cloud data are recorded by the MODIS (Moderate Resolution Imaging Spectroradiometer) instruments on board the satellites EOS AM-1 (Earth Observing System, "Terra"), in orbit since December 1999, and EOS PM-1 ("Aqua"), in orbit since May 2002, flying in a sun-synchronous orbit 700 km above the Earth's surface. Data on the relative fraction of monthly mean daytime and nighttime cloud cover during the 24th solar cycle (2009 to 2018) were obtained from the NASA GIOVANNI database (GIOVANNI, n.d).

Mortality Data by Place and Cause of Death

The analysis below is based on authoritative health data sources – EUROSTAT (EUROSTAT, 2023). and the US National Center for Health Statistics (NCHS) (Centers for Diseases Control and Prevention [CDC], 2023).

The parameter annual mortality rate – number of deaths per 100,000 inhabitants – was used as a mortality characteristic in the study. EUROSTAT offers free access to data on mortality rates by cause for the countries of the European Union, the European Economic Area, and the candidate countries for membership in the union. Geographically, these countries are located in Europe and the Mediterranean. Data are grouped by NUTS (Nomenclature Des Unités Territoriales Statistiques in French, the Nomenclature of Territorial Units for Statistics). Mortality data from the EUROSTAT shortlist, which groups mortality rates by cause of death into 92 categories, mostly diseases, were used in the study. The groups are related to the International Classification of Diseases (ICD-10) classes. The shortlist contains mortality data for EU countries (NUTS-1) and EU regions (NUTS-2, smaller areas of the larger NUTS-1 countries). Currently (2024), the shortlist includes mortality rate data for the period 2011–2020. Annual mortality rate data were extracted for 377 European regions (NUTS-2) separately from each of the shortlist groups for the interval 2011 – 2019 (the last pre-pandemic year).

In NCHS, each death is coded as a numerical row with many parameters, particularly the cause of death and year of death, compressed into millions of cases per year. Specialized software was developed to extract the necessary information.

Data Processing

For each of the hundreds of meteorological stations on the surface of the planet with sufficient length of annual mean temperature data (the 24th solar cycle and no fewer than four consecutive solar cycles back in time, from 1933 to 2018), mean surface air temperatures were calculated for the years of the solar activity phase "rise" (Figure 1). When the temperature data series for a given station was 5 consecutive solar cycles, the correlation coefficient was calculated from those 5 cycles. When the series was longer than five solar cycles, the maximum correlation coefficient calculated for each length after the fifth cycle was taken as the result. For example, for a station with a temperature data length of eight solar cycles, the correlation coefficients were calculated for series lengths of five, six, seven, and eight cycles. The maximum and the length of the data series for that maximum were chosen.

The typical length of consecutive temperature data for the stations included in the study was six solar cycles. The maximum length was eight cycles. The mean temperatures obtained for each station were compared with the corresponding series of mean SSNs for the "rise" phase of the same cycles.

Correlation analysis Lakin (1990) was used to process the data. The correlation coefficient indicates the degree of association (a causal relationship) between two variable processes. If the processes change synchronously in the same direction, they are positively correlated. The processes are negatively (inversely) correlated if they change in opposite directions. The greater the correlation coefficient (which ranges from -1.000 to 1.000), the stronger the correlation. A correlation coefficient close to 0.000 indicates a lack of connection between the two processes. The correlation coefficient between the two series of values: 1. mean temperatures and 2. mean SSNs was calculated to assess whether there is a causal relationship between solar activity phenomena and surface air thermal changes for a given station.

In mathematical statistics, the level of statistical significance (Lakin, 1990) is a parameter that indicates the reliability of the calculated correlation coefficient. The smaller the value of this parameter, the more reliably the correlation coefficient is established, i.e., the more reliably a cause-and-effect relationship has been established.

The correlation coefficient and the level of statistical significance are related. For example, for the eight solar cycles (the maximum consecutive data length for temperature), a minimum correlation coefficient of 0.708 (or -0.708 for a negative correlation) corresponds to a statistical significance level of 0.05; a minimum correlation coefficient of 0.835 (or -0.835) corresponds to a statistical significance level of 0.01; and a minimum correlation coefficient of 0.925 (or -0.925) corresponds to a statistical significance level of 0.001 (Lakin,1990).

In scientific studies, a statistical significance level of 0.05 or less is accepted as a criterion for the reliability of the correlation coefficient. Correlation coefficients with a significance level less than 0.05 are considered highly reliable. That is, a causal relationship between ground air temperature and SSN can be considered reliably established if their correlation coefficient is at least 0.708 for data spanning eight solar cycles.

The *coefficient of determination*, which indicates how much variation in the independent variable (in this case, mean SSN) explains variation in the dependent variable (in this case, surface air temperature), can be calculated using regression analysis. If the coefficient of determination is 1.000, the dependence between two processes is deterministic – the process effect depends only on the process cause. If the dependence is deterministic, no other cause independent of the first intervenes in the process effect. An example of a deterministic process is the change in the magnitude of the electric current through a given wire – the effect depends on a single cause – the change in voltage between the two ends of the wire. Suppose the dependence between two variables is linear and the coefficient of determination is close to unity. In that case, the dependence is close to deterministic; the effect is influenced by only one cause, and no independent cause affects the effect. In particular, if the variation in surface air temperature is a linear consequence of solar activity and the dependence has a coefficient of determination close to unity, only solar activity intervenes in the variation of surface air temperature. No other cause, independent of solar activity, intervenes, particularly greenhouse gases in the air. Of course, the hypothetical possibility remains that solar activity is related to the emission of greenhouse gases. Still, such a hypothesis should explain why their concentration has increased despite the decreasing trend of solar activity in the last few decades.

Results

Of the stations included in the study, 812 (93%) showed a negative correlation between temperature and SSN during the "rise" phase (Figure 1) of the last five solar cycles. Of these, 321 stations had statistically significant correlations (significance level at least 0.05). Of these, 163 stations had statistically significant correlations less than -0.900 (significance level at least 0.05). Most often, the maximum statistically significant negative correlations were obtained in six consecutive cycles (171 cases). The number of statistically significant negative correlations decreased quickly as the length of the cycle series increased, reaching a length of up to 8 cycles.

The phenomenon is observable worldwide (Figure 2). Figure 2 shows the change in the global land temperature anomaly (the difference between the global annual temperature and the global average land temperature for the hundred years 1901-2000 (NOAA, 2024). over the last six cycles of solar activity "rise" phases.

The figure shows that the inverse correlation with SSN discussed above for the "rise" phases of the last six solar cycles also holds for the global surface air temperature over the entire landmass of the planet, but the correlation is statistically insignificant. The figure also shows that for the last four cycles of solar activity – from the 21st to the 24th – the negative correlation of -0.958 becomes statistically significant at the 0.05 level.

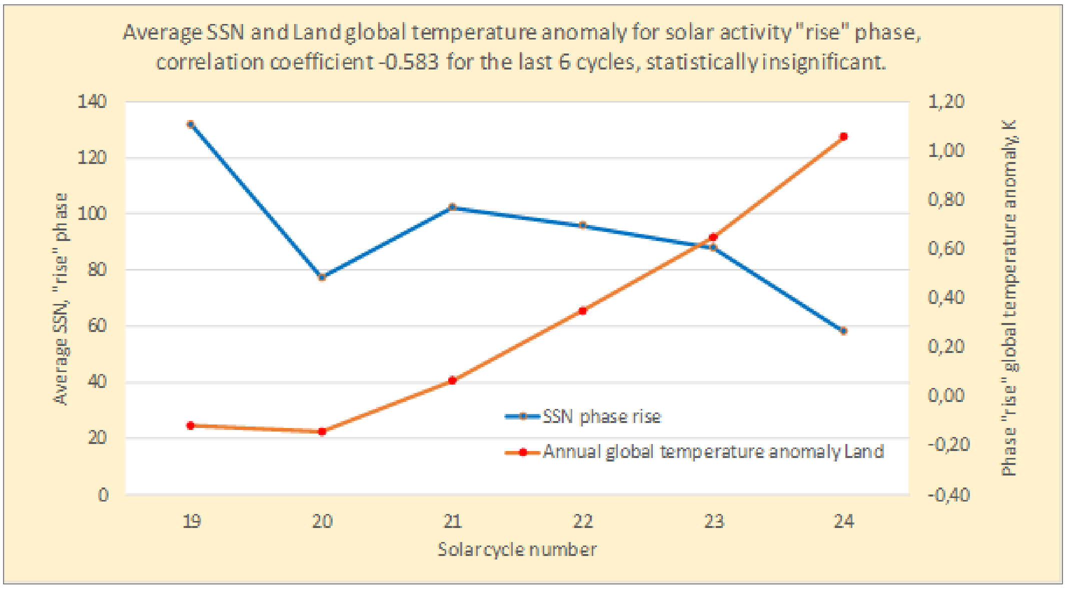

Figure 2: For the surface air temperature anomaly on land, there is also an inverse relationship with SSN during the "rise" phase of the last six cycles of solar activity, i.e., the phenomenon discussed above applies to all land on the planet.

Sufficiently long temperature data are available mainly for Europe (Figure 3). Figure 3 shows, on a Google Earth map, the locations of stations included in the study, with very high, statistically significant correlations ranging from -0.900 to -1.000 in Europe and Africa. There are also stations for which this phenomenon is barely noticeable or not observed.

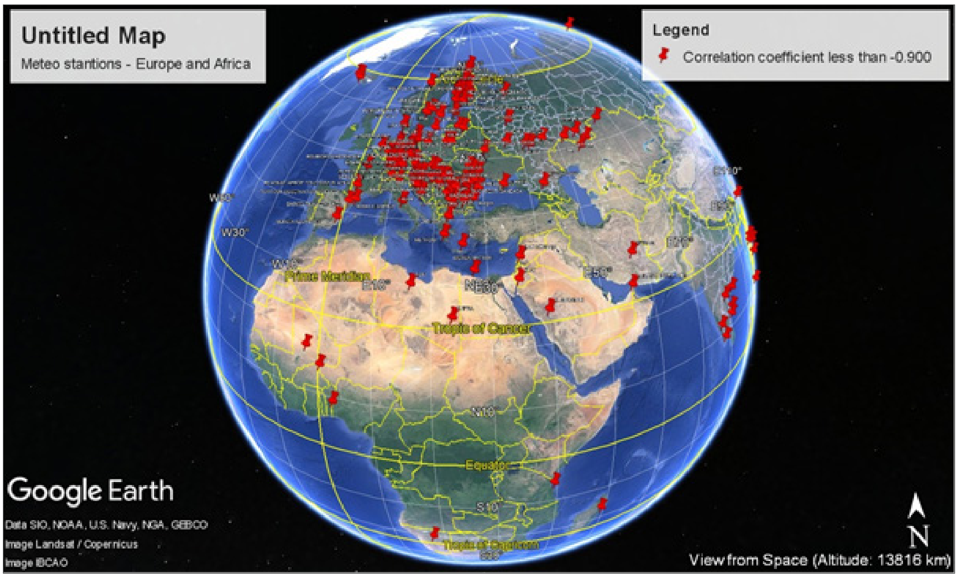

Figure 3: Stations with correlation coefficients below -0.900 between surface air temperature and SSN during the "rise" phase of the solar cycles.

The examples below are for the Stara Zagora meteorological station in Bulgaria, located near the power source of carbon dioxide air pollution – the energy complex "Maritsa-Iztok". The station has a long, accurate operational history and records of surface air temperature data for 126 years. Figure 4 shows the relationship between the average annual surface air temperature measured at the Stara Zagora station during the "rise" phases of solar activity cycles 17 to 24 (the cycles have a total duration of 86 years) and the average annual SSNs for the "rise" phases of the same cycles. A high, negative, statistically significant correlation between the two data series indicates a causal relationship between temperature changes in the Stara Zagora region and solar activity. As solar activity increases within a particular cycle, temperature decreases. Due to a decreasing trend in SSN values over the last five cycles and their negative correlation with temperature, surface air temperature in the Stara Zagora region has been increasing in recent years.

This phenomenon is observed at each station in the meteorological network in Bulgaria. Air temperature data for some of these stations are included in the GHCNd database (NOAA, n.d).

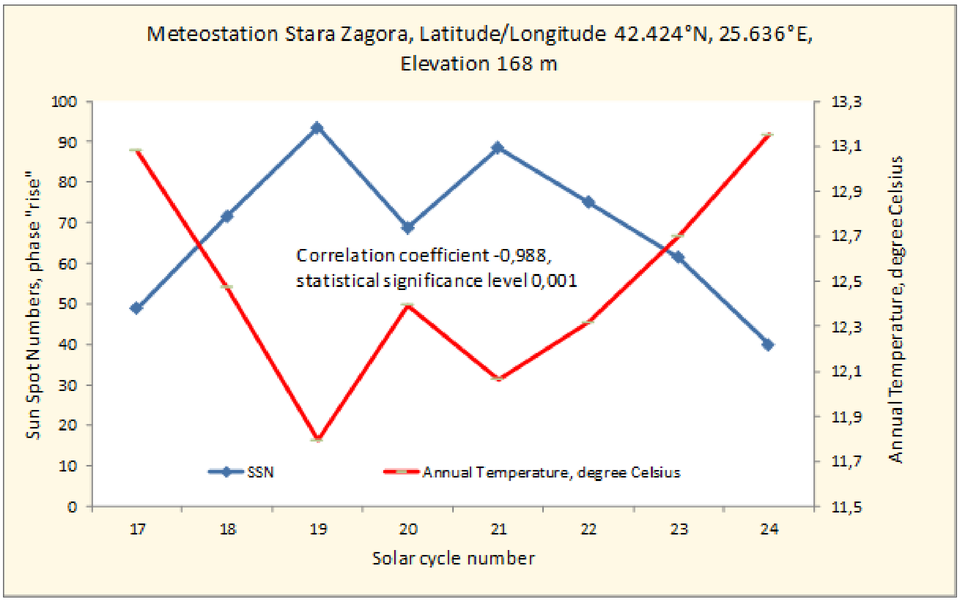

Figure 4: There is a statistically significant negative correlation between the mean surface air temperature at the weather station STARA ZAGORA, BULGARIA, and the mean number of sunspots during the "rise" phase of the last eight solar activity cycles.

By definition, relative air humidity is inversely correlated with air temperature. If the described dependence between SSN in the “rise” phase and temperature is an observable fact, a positive correlation should be observed between SSN in the “rise” phase and the relative surface air humidity measured over the years during the “rise” phases of the SSN. Figure 5 shows the time dependence of the average values of SSN during the “rise” phase and their corresponding average values of relative air humidity obtained from the same weather station in Stara Zagora. The existence of a high, statistically significant positive correlation between relative air humidity and SSN in the “rise” phase is independent confirmation of an inverse relationship between air temperature and SSN in the “rise” phase.

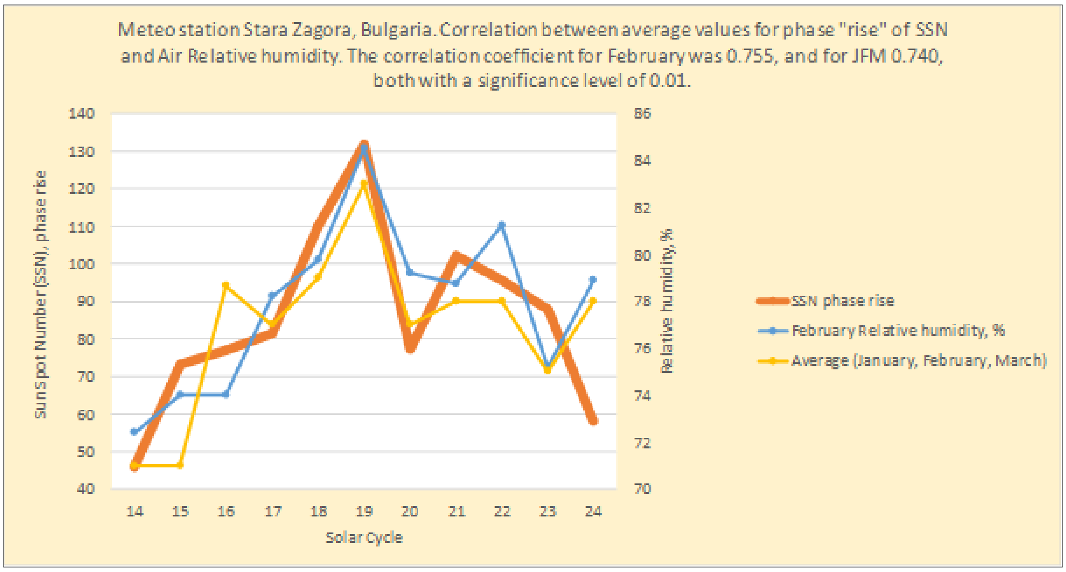

Figure 5: There is a statistically significant positive correlation between SSN during the “rise” phase and the relative air humidity measured over the years at the meteorological station Stara Zagora, Bulgaria, during the “rise” phases of the SSN.

The dependence between solar activity and air humidity implies a dependence between solar activity and precipitation as well. Figure 6 shows two time-dependent curves over the year (annual courses). One curve is the yearly precipitation trend (in l/m^2) for the Stara Zagora weather station, by month, averaged over the years 1899 – 2023. The other curve is the annual trend of the correlation coefficient between the precipitation at the Stara Zagora weather station and SSN, monthly averaged for the years with a “rise” phase in the last seven solar cycles 18 – 24. Between the two dependencies, there is a statistically significant correlation with a correlation coefficient of 0.731, significant at the 0.01 level.

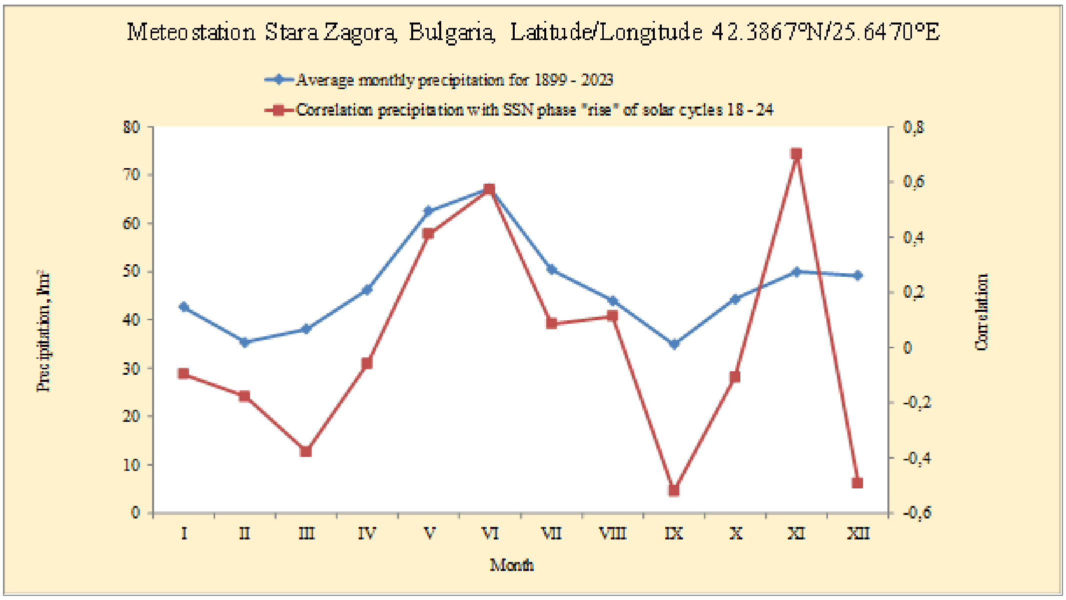

Figure 6: There is a statistically significant correlation between the annual course of precipitation and the correlation coefficient for the “rise” phase of the solar activity cycle across the last seven cycles.

There is no correlation between the change in surface air temperature in the Stara Zagora region and the SSN during the "fall" phase of the solar cycles included in the study (Figure 7). The temperature change during the "fall" phase is below 0.5°C, while during the "rise" phase it is almost 3 times higher – by 1.4°C.

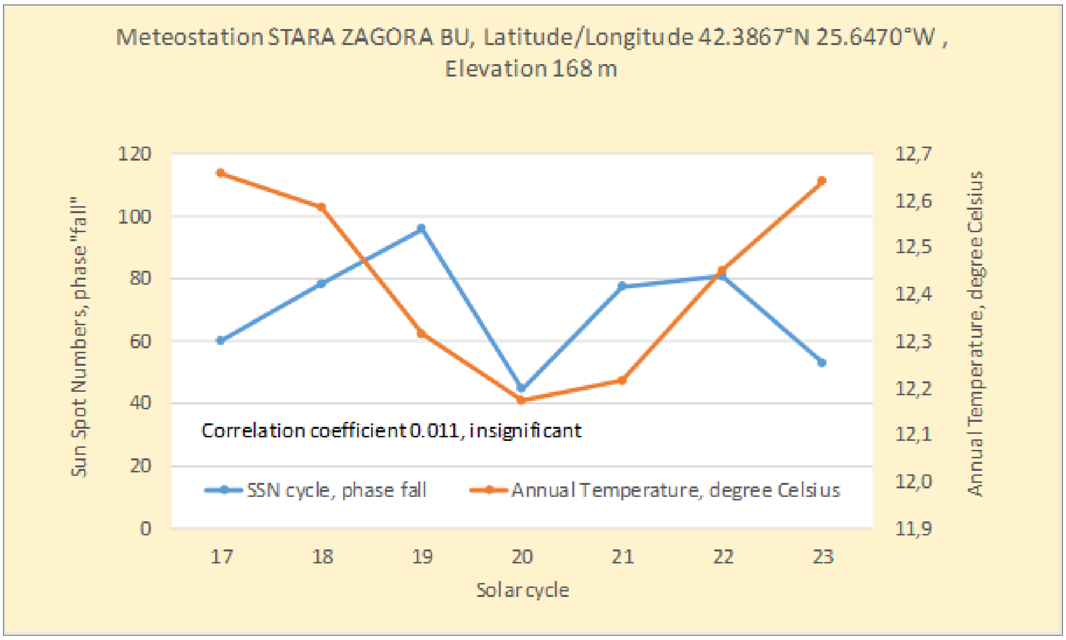

Figure 7: There is no statistically significant correlation between the mean surface air temperature at the weather station STARA ZAGORA, BULGARIA, and the mean number of sunspots during the "fall" phase of the last seven solar activity cycles.

It can be summarized that over the last several decades, the surface air temperature in the Stara Zagora region has been increasing during the "rise" phase of the solar cycles because:

- it is negatively correlated with SSN during the same phase,
- SSN has been decreasing over the past few solar cycles.

Figure 8 shows the dependence of the surface air temperature for the Stara Zagora region on the SSN for the phase "rise" of the solar cycles included in the study. The dependence is linear, with a high coefficient of determination $R^2 = 0.9771$ (maximum value of 1.000). According to the explanation above, the surface temperature shows an almost deterministic linear dependence on a single cause – solar activity, as characterized by SSN. The obtained result rejects the hypothesis of a temperature dependence of the concentration of greenhouse gases, at least in the region of Stara Zagora. This conclusion is particularly impressive, as it was drawn for the Stara Zagora region, where the air should contain more carbon dioxide from the burning coal at the above-mentioned "Maritsa-Iztok" energy complex. Since in a region with a power source of greenhouse gases, their influence on the rising air temperature is negligible, the conclusion is that solar activity is the dominant, if not the only, cause of the global increase in air temperature in the last few decades.

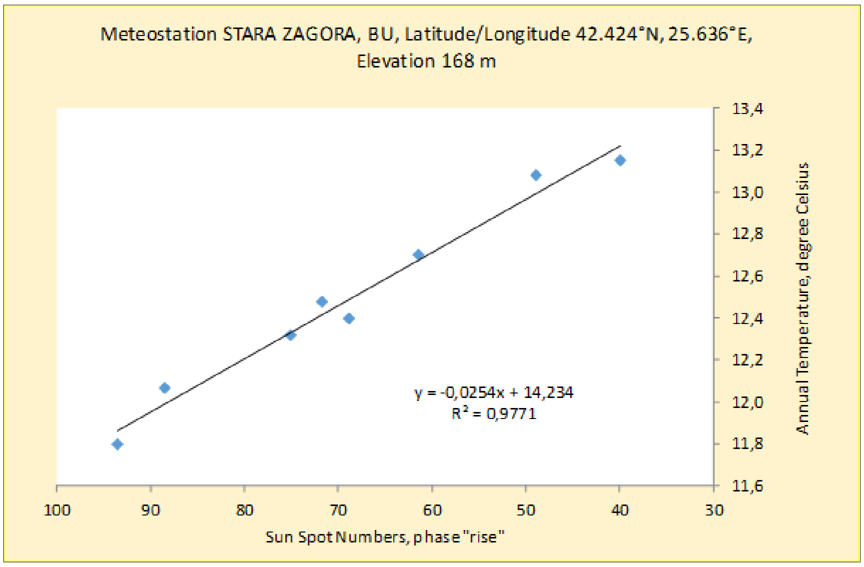

Figure 8: There is a linear relationship with a very high coefficient of determination between surface air temperature in the region of STARA ZAGORA, BULGARIA, and the number of sunspots, both calculated for the "rise" phase of the solar cycles included in the study.

The phenomenon described is also observed at other weather stations worldwide, with varying degrees of manifestation. Examples from a subset of the dozens of stations in Europe where the phenomenon is observable are shown in Figures 9, 10, 11, and 12.

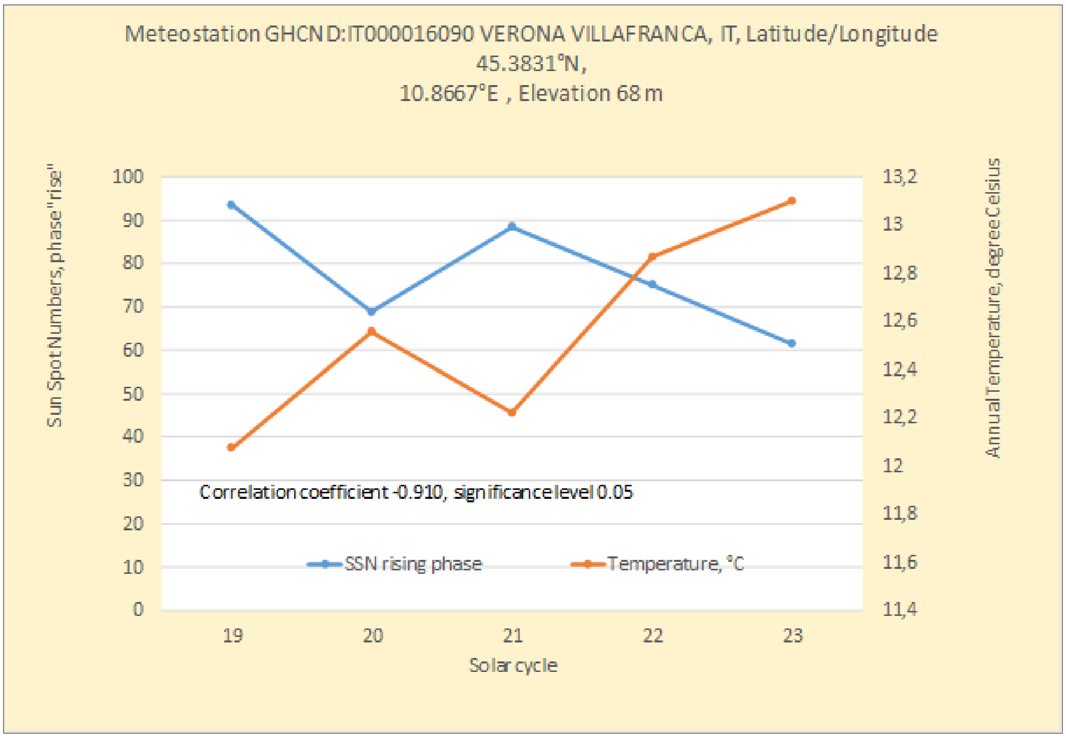

Figure 9: A statistically significant negative correlation exists between the mean surface air temperature at weather station VERONA VILLAFRANKA, ITALY, and the mean sunspot number during the "rise" phase of the five solar activity cycles (for which data are available).

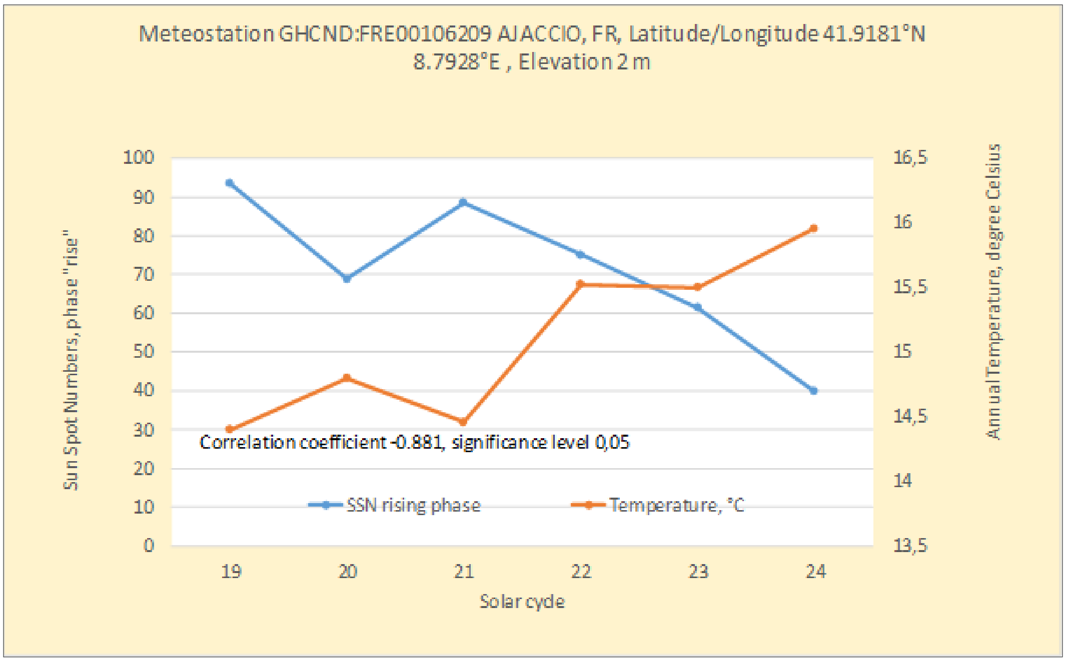

Figure 10: A statistically significant negative correlation exists between the mean surface air temperature at weather station AJACCIO, Corsica, FRANCE, and the mean sunspot number during the "rise" phase of the six solar activity cycles (for which data are available).

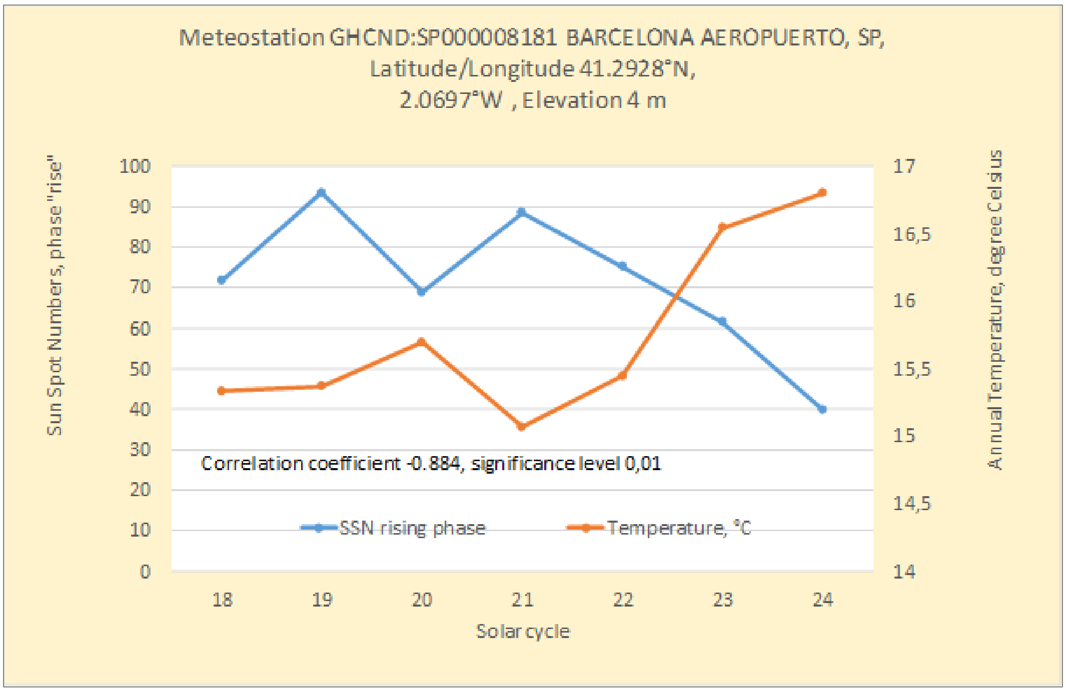

Figure 11: There is a statistically significant negative correlation between the mean surface air temperature at weather station BARCELONA AEROPUERTO, SPAIN, and the mean sunspot number during the "rise" phase of the seven solar cycles for which data are available.

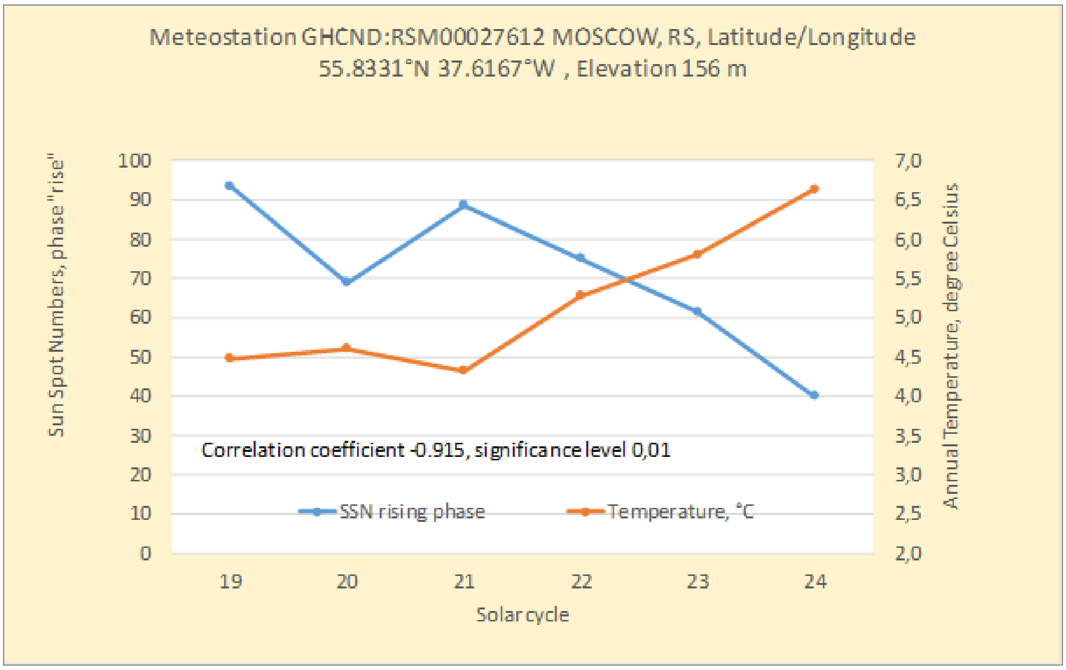

Figure 12: A statistically significant negative correlation exists between the mean surface air temperature at the MOSCOW, RUSSIA, weather station and the mean sunspot number during the "rise" phase of the six solar activity cycles (for which data are available).

The number of tropical cyclones depends on the degree of ocean warming. Figure 13 shows the change in the number of named Atlantic tropical cyclones (wind speed above 61 km/h) and solar activity during the „rise" phase, with a correlation coefficient of -0.934, statistically significant at the 0.05 level (Colorado State University [CSU], 2024). The dependence indicates that increasing ocean temperature is associated with decreasing solar activity during the last few cycles.

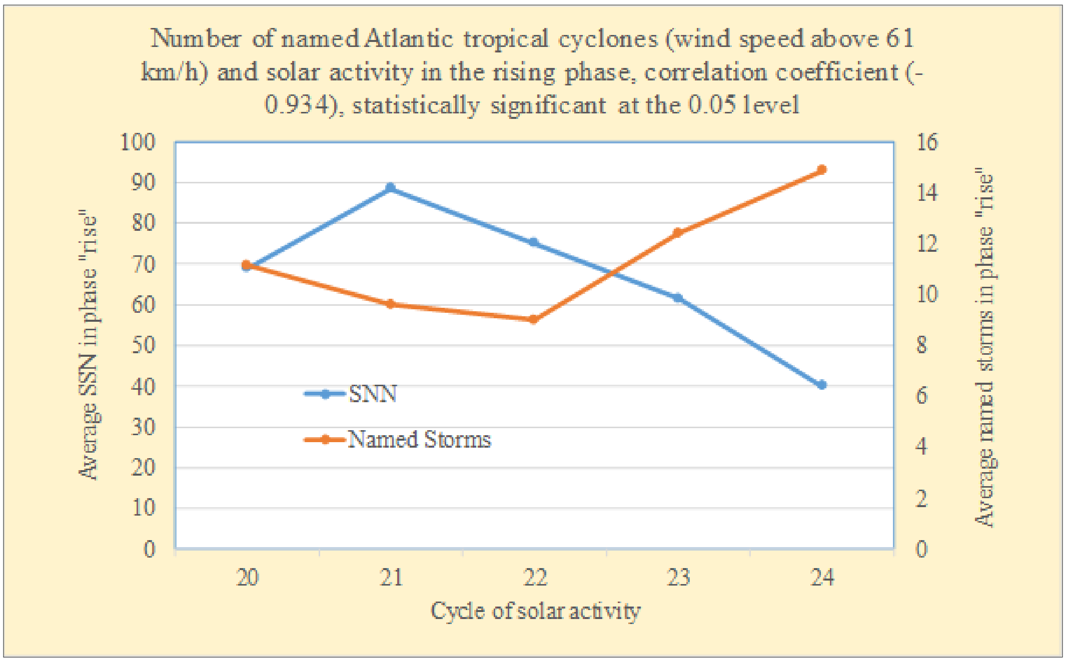

Figure 13: The increasing ocean temperature is associated with the decreasing solar activity over the last few cycles.

During a cycle with a high SSN maximum, a reduced emission of electromagnetic radiation from the solar photosphere should be expected because the many sunspots are darker than the average brightness. As a result, less solar energy would reach the Earth's surface. The reduced solar energy would explain the lower temperature of the ground air during the "rise" phase of the solar cycle, as electromagnetic radiation absorbed by the Earth's surface supplies the energy converted into heat for the ground air. However, this effect is not observed because the accompanying sunspot areas (faculae) are brighter than the average brightness of the photosphere. The increased brightness of the faculae completely compensates for the decreased brightness of the photosphere in the sunspot region.

Average monthly data on the flux of solar electromagnetic radiation reaching the Earth's surface since 1980 have been obtained for the area bounded by the reference coordinates 20°E, 40°N, 30°E, and 50°N, covering part of the Balkans, where the above-described negative correlation between the number of sunspots and the temperature of the surface air during the "rise" phase of the solar cycles is clearly expressed (GIOVANNI, n.d). The data cover the last four solar cycles – a total of 7 phases of solar activity of both types – "rise" and "fall" – with values between 212 $W.m^{-2}$ and 220 $W.m^{-2}$. The comparison between the average fluxes of electromagnetic radiation during the two phases showed no statistically significant difference. There are also no statistically significant correlations between changes in flux and changes in air temperatures in each phase, i.e., the conclusion is that the described phenomenon is not related to changes in the Sun's electromagnetic radiation.

For two areas with high correlation coefficients between SSN and surface air temperature – the Balkans and the Western Mediterranean – data on the relative cloud cover of the sky, separately for daytime and nighttime, were obtained from the onboard MODIS (Moderate Resolution Imaging Spectroradiometer) instruments on the "Terra" and "Aqua" satellites (GIOVANNI, n.d). The data set covers only the last complete solar cycle 24 (the planned life of the satellites was 6 years; "Terra" has been operating for more than 25 years, and "Aqua" – 22 years). The short length of the data series makes the difference between daytime cloudiness for the two phases of the solar cycle – "rise" and "fall" – statistically insignificant. For both areas – the Balkans and the Western Mediterranean – during the "rise" phase of the solar activity cycle, the daily cloud fraction is higher than during the "fall" phase, according to data from both satellites. The difference reaches 1.5% cloud fraction (Figure 14). Increased daytime cloud shading during the "rise" phase reasonably explains the decrease in surface temperature during that phase. The increased cloudiness may be due to a higher number of condensation nuclei in the atmosphere at the condensation level where clouds form. Condensation, and thus cloud formation, depends on the presence of ions, which at a height of a few kilometers are the only condensation nuclei around which water vapor forms droplets and, as a result, clouds.

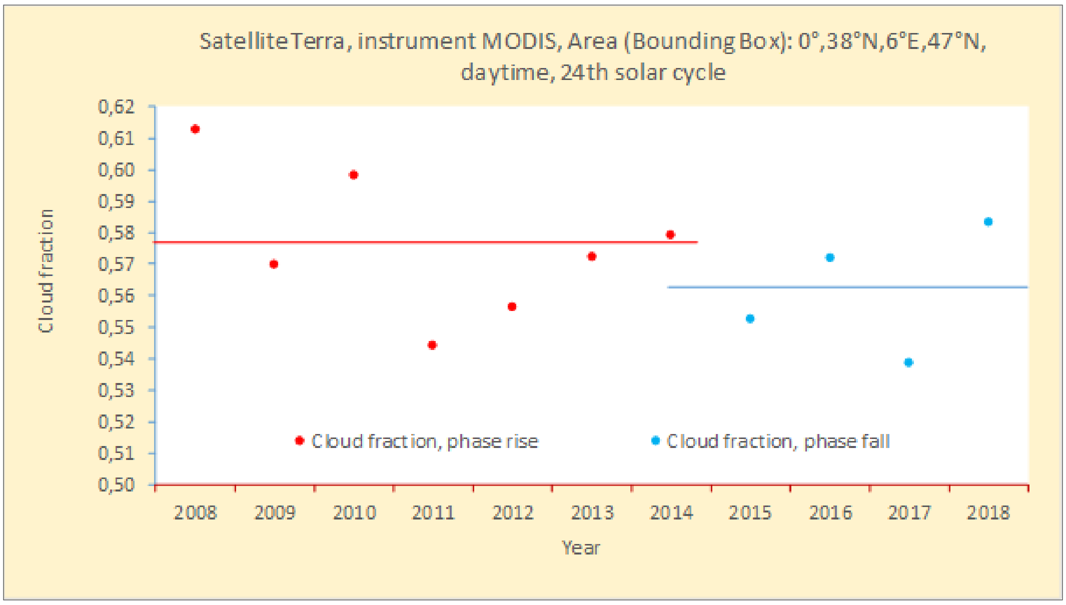

Figure 14: Daytime cloudiness over the western Mediterranean is about 1.5% higher during the "rise" phase of the solar cycle than during the "fall" phase.

GOES series satellite data show that high-energy, positively charged particles – hydrogen and helium nuclei (protons and alpha particles), capable of ionizing the air – arrive from the Sun to the Earth (NOAA, n.d). Most often, these particles do not penetrate deep into the Earth's atmosphere to the ground-level troposphere, where clouds form, due to the deflecting effect of the Earth's magnetic field and energy losses from collisions with particles in the Earth's atmosphere.

However, a study shows that positively charged, high-energy solar particles, i.e., with a high ionization potential, probably penetrate the atmosphere and even reach the Earth's surface (Takuchev, 2019; Takuchev, 2020; Takuchev, 2021; Takuchev, 2021; Takuchev, 2021; Takuchev, 2022; Takuchev, 2023; Takuchev, 2023; Takuchev, 2023; Takuchev, 2023; Takuchev, 2023; Takuchev, 2023; Takuchev, 2023; Takuchev, 2024). The study reveals a statistically significant positive correlation between fluxes of positively charged solar particles registered by GOES satellites and human mortality, a phenomenon that could be explained by these particles penetrating the atmosphere to the Earth's surface. The most affected are the inhabitants of Europe and the Mediterranean.

Figure 15 shows, with blue isolines, the distribution of mortality for the group cause "All causes of death (A00-Y89) excluding S00-T98" from the EUROSTAT shortlist in 2012 – the year with the highest mortality in the studied interval from 2011 to 2019. The map was created using data for 377 NUTS-2 regions in Europe and the Mediterranean. A region with increased mortality stands out in Eastern Europe, with a maximum in the Central Balkans.

Red isolines show the distribution of the impact index of the annual flux of solar alpha radiation, recorded by the GOES series satellites for the studied interval, 2011 – 2019, on mortality in each of the NUTS-2 regions. The index was calculated as a weighted sum of the number of statistically significant correlations for the studied interval between annual mortality by cause groups and the yearly flux of solar alpha radiation for each region separately. The number of correlations is divided into three groups depending on their levels of statistical significance – most significant ($p < 0.001$), medium significance ($0.001 \leq p < 0.01$), and least significant ($0.01 \leq p < 0.05$). In the weighted sum, the weighting factor for the most significant group is 3, for the intermediate 2, and for the least significant 1. For individual NUTS-2 regions, the impact index varies from 0 to 30. The impact index reaches the maximum value of 30 for the region "Yugozapadna i yuzhna tsentralna Bulgaria" (Balkans). Two areas of maximum impact stand out – the Balkans and the Western Mediterranean. While in the Western Mediterranean this does not lead to a significant increase in mortality, in the Balkans there is a marked coincidence between mortality and solar alpha radiation recorded by the GOES satellites.

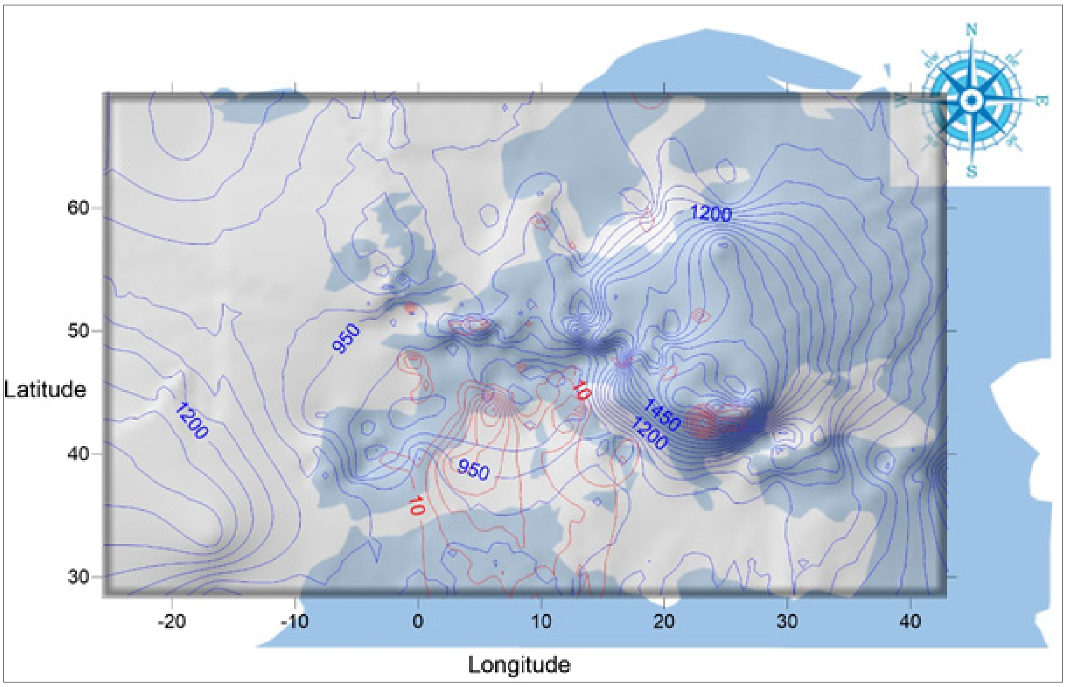

Figure 15: The main areas of solar alpha radiation's influence on mortality in Europe and the Mediterranean are the Balkans and, to a lesser extent, the Western Mediterranean. (Software Surfer 10).

Figures 16, 17, and 18 show examples of strong correlations, indicating a cause-and-effect relationship between the annual mortality from some of the deadliest causes listed in the EUROSTAT shortlist and the annual flux of solar alpha radiation.

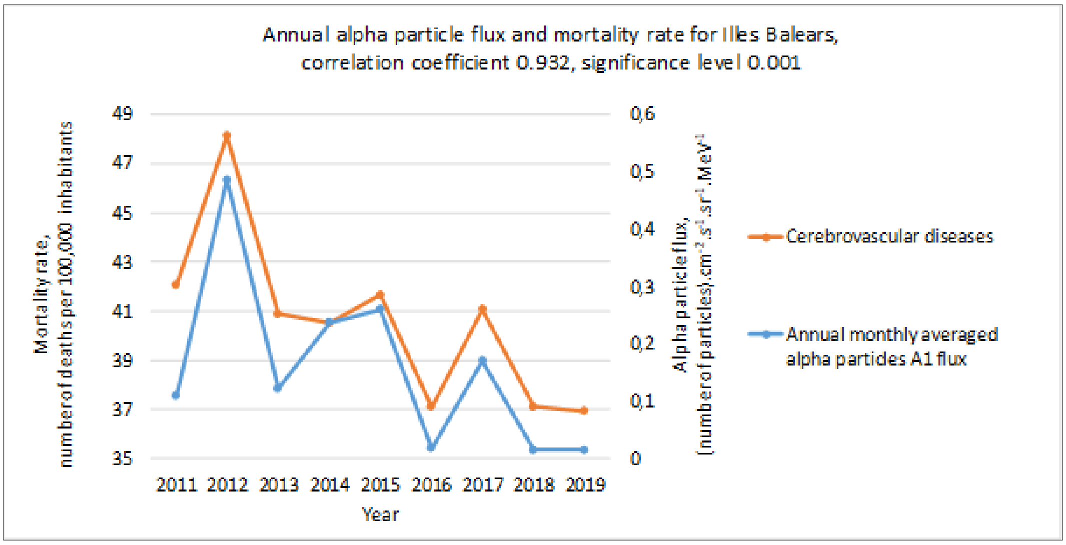

Figure 16: There is a statistically significant correlation between the annual flux of high-energy solar alpha particles and cerebrovascular disease mortality in the Western Mediterranean, indicating that there is a very likely causal relationship between the two phenomena.

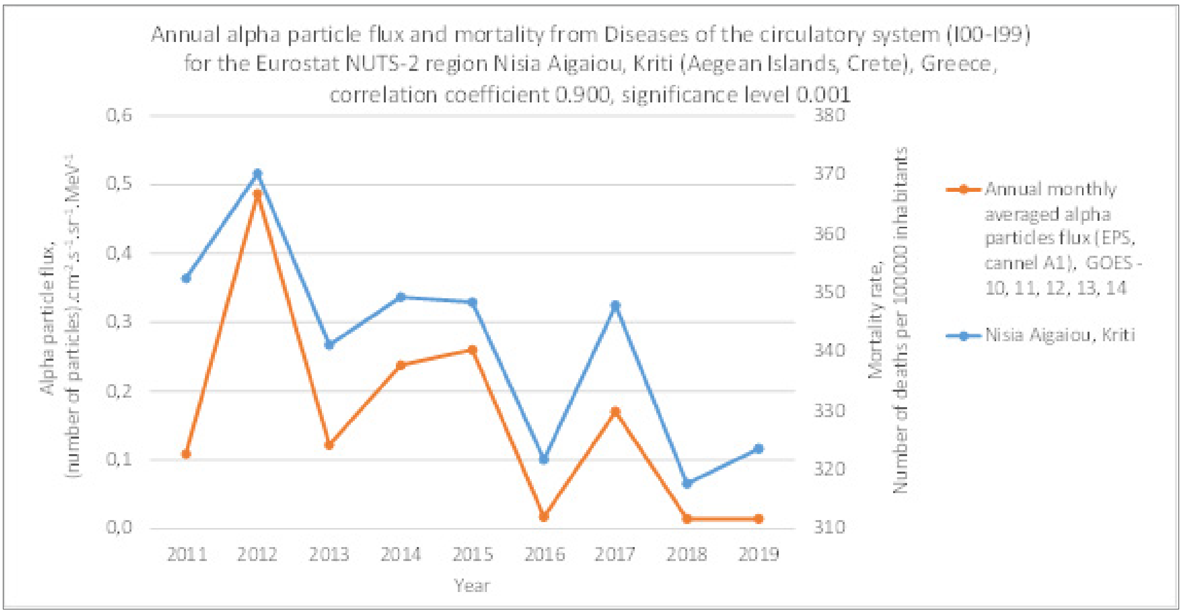

Figure 17: There is a high, statistically significant correlation between the annual flux of high-energy solar alpha particles and mortality from circulatory system diseases in the Aegean Islands and Crete, Greece, indicating that a causal relationship between the two phenomena is very likely.

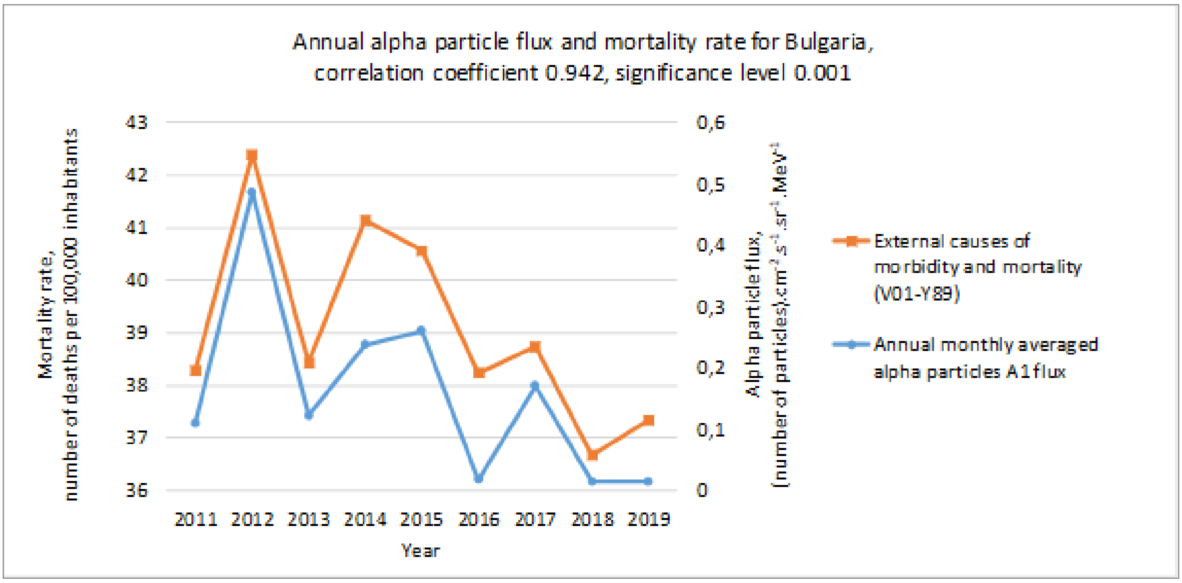

Figure 18: There is a statistically significant correlation between the annual flux of high-energy solar alpha particles and mortality from external causes of death in Bulgaria. That is, there is very likely a causal relationship between the two phenomena.

Further arguments are presented below in support of the hypothesis that the cause of death in the listed cases is streams of (so far unrecorded) solar alpha particles with very high energy, allowing them to penetrate to the Earth's surface and, therefore, to pass through the atmosphere, ionizing it and increasing condensation nuclei and associated cloudiness.

A hypothetical mechanism explaining the described human mortality from the impact of invading high-energy solar alpha particles (Takuchev, 2019; Takuchev, 2020; Takuchev, 2021; Takuchev, 2021; Takuchev, 2021; Takuchev, 2022; Takuchev, 2023; Takuchev, 2023; Takuchev, 2023; Takuchev, 2023; Takuchev, 2023; Takuchev, 2023; Takuchev, 2023; Takuchev, 2024).

1. An observed phenomenon – in the statistics of several countries located mainly in the 30°N – 50°N band, mortality from certain diseases, primarily those of the circulatory system, is strongly correlated with flows of positively charged particles with energies of the order of 4 – 21 MeV, as recorded by the SMS and GOES series satellites in Earth orbit. The recorded alpha particle flows are mostly pulses lasting a few minutes to a few days.
2. Proposed hypothesis – positively charged particles with high energy penetrate the Earth's atmosphere and reach the Earth's surface, damaging human health, primarily the circulatory system, and causing death, mainly in older adults with an already damaged circulatory system.

3. As the average altitude of the affected countries increases, particle flux-correlated mortality shows an increasing trend (Takuchev, 2021; Takuchev, 2023). This is probably due to a more intense positively charged particle flux penetrating the thinner atmosphere over the mountainous regions of Earth's surface – an argument favoring the hypothesis.
4. The source of the flows of positively charged particles is the Sun – mortality increases with observable processes on the Sun's photosphere – from SME and flares directed to Earth (phenomena on the solar surface that could be observed with other astronomical means) (Takuchev, 2021; Takuchev, 2023). The Alpha Magnetic Spectrometer (AMS-02) on the International Space Station measures cosmic rays, excluding those of solar origin (when shielded from the Sun by the station's solar panels). In particular, it measures the flow of 3He and 4He (alpha particles) in cosmic rays. The measurements show (Space Science Data Center [SSDC], n.d). an increasing annual flux of alpha particles in cosmic rays for the interval of years from 2011 to 2017 (last available data), while the flux of GOES-registered (solar?) alpha particles for the same interval of years is decreasing (Figures 16, 17, and 18). Indirect evidence for the Sun as a source of high-energy alpha particles is that this assumption convincingly explains the downstream processes that ultimately lead to death.
5. High-energy alpha particles are positively charged solar particles capable of penetrating the Earth's atmosphere to the surface. Calculators PSTAR (National Institute of Standards and Technology [NLST], n.d). and ASTAR (NLST, n.d). compute the penetration parameters of protons and alpha particles, respectively, in various substances, particularly in air. Calculations using data for a homogeneous atmosphere – an atmospheric model with constant density, temperature, and pressure decreasing with height (Takuchev, 2021) – show that only particles with energy above 2.4 GeV for protons and over 6.2 GeV for alpha particles can penetrate the Earth's atmosphere to the surface. GOES satellites have not registered protons above 0.7 GeV. However, alpha particle fluxes with energy above 3.4 GeV have been recorded, and those above 6.2 GeV are hypothesized (Takuchev, 2021; Takuchev, 2023; Takuchev, 2023). i.e., the particles that reach the Earth's surface are probably high-energy alpha particles. Only registered alpha particle fluxes with a sufficiently high magnitude, at least (hundreds of particles).$cm^{-2}.s^{-1}.sr^{-1}.MeV^{-1}$, are correlated with the mortality of the Earth's surface.
6. It is assumed that the alpha particles recorded by the satellites were emitted simultaneously with the hypothetical fast alpha particles in a common explosive process on the solar surface. It can be calculated that particles with an energy of 7 GeV take 8.87 min to reach the Earth's surface from the Sun's surface, while particles registered by satellites with energies of 5 – 10 MeV take about 2 hours. The registered alpha particles do not have enough energy to penetrate the atmosphere, unlike the hypothetical fast alpha particles that reach the Earth's surface in minutes from the center of the solar disk. However, the registered alpha particles indicate that two hours earlier, the Earth's surface was irradiated with fast alpha particles.
7. Although alpha particle streams irradiate the entire illuminated part of the atmosphere, penetration of fast alpha particles to the surface occurs only in a limited area of the surface (death spot), where two conditions favoring penetration are combined:

- The Sun is culminating over the center of the death spot – the path through the atmosphere of the invading positively charged particles to the point of observation is shortest at the moment of the Sun's maximum rise above the horizon (the culmination of the Sun). The point of registration is the point on the Earth's surface where the solar disk is at its culmination at the moment of alpha particle flux registration by satellites. Its longitude can be determined from the GOES satellite registration time tag (hours and minutes), and its latitude from the date of registration. The approximate center of the death spot can be calculated – the Earth's angular velocity is 15° per hour. Therefore, the death spot center is approximately 30° east of the registration point. Examples of USA mortality are shown in Figures 19 and 20.
- At the center of the death spot, a coincidence occurs – the direction of the geomagnetic vector aligns with the direction of the alpha particle intrusion – so the alpha particle's motion is not deflected by the magnetic force. Such a coincidence occurs twice a year for latitudes in the band from 28°N to 48°N (Takuchev, 2021). For latitudes outside this band, such a coincidence is impossible. Fast alpha particles do not reach the Earth's surface (but can still ionize the air), which explains why no correlation is observed between alpha radiation fluxes and mortality from circulatory system diseases in countries near the North Pole.

US Medical Statistics provides free access to the world's most complete mortality information for US citizens, particularly on each death. In some recent periods, US mortality statistics have also collected data on an individual's date of death. Daily death data, in sync with the temporal specificity of the flows of high-energy alpha particles recorded by the satellites, enabled tracking the rapid changes in the number of deaths in the United States.

Examples of USA Ischemic Heart Diseases (IHD) mortality are shown in Figures 19 and 20.

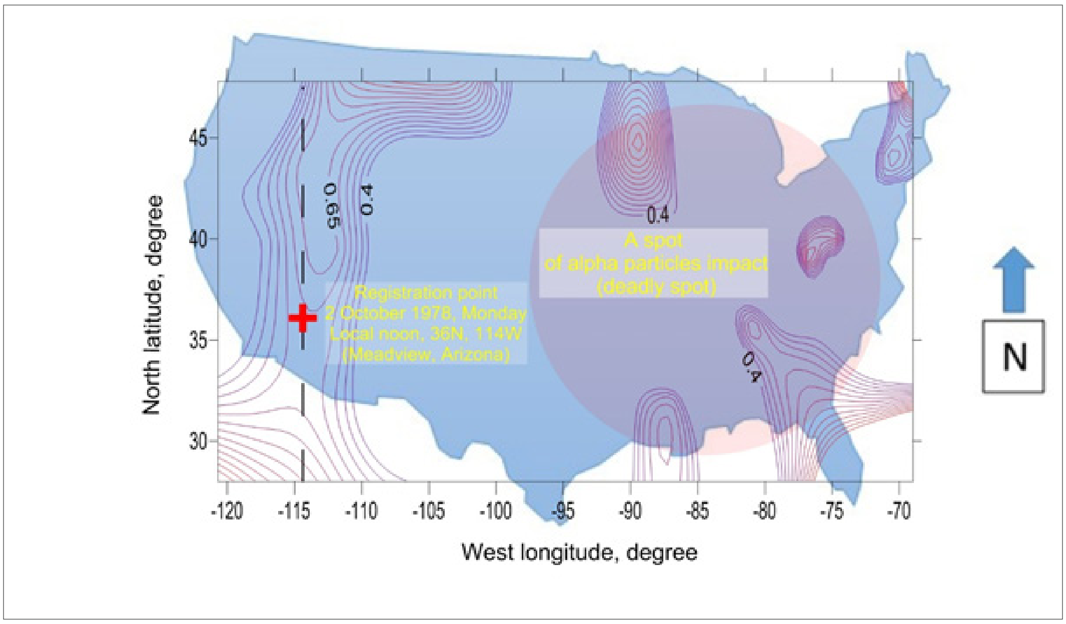

Figure 19: Registration point (red cross) of alpha radiation flux on October 2, 1978, in the western USA, and the dead spot in the eastern US, tentatively denoted by a circle centered 30° east of the registration point.

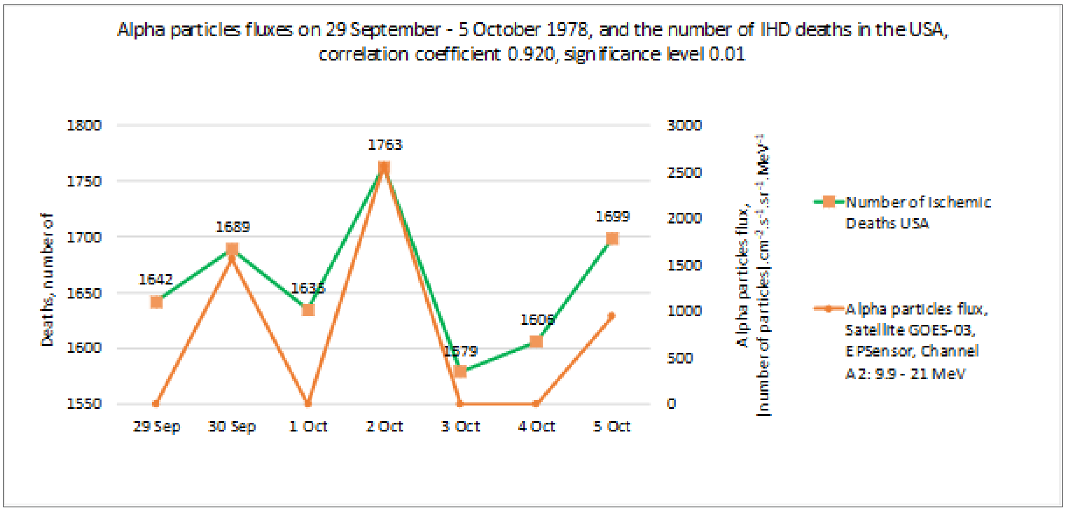

Figure 20: There is a statistically significant correlation between alpha particle fluxes on September 29 and October 2, 1978, and the daily number of ischemic heart disease deaths in the USA.

The isolines outline areas (states) with high correlation coefficients between the alpha particle flux and IHD deaths.

The described hypothesis also explains the positive correlation between solar activity and precipitation, as shown in Figure 6. The positive correlation between solar activity and precipitation is highest in May-June when:

1. The Sun is at its upper culmination (at noon), i.e., the atmosphere is thinnest for incoming streams of ionizing solar particles. For Stara Zagora, the maximum culmination is 66.12° on June 21 (Astronomical Calendar, 2023).
2. The direction of the intruding particles is close to the inclination of the geomagnetic induction. For Stara Zagora, the geomagnetic induction is directed from south to north, entering the Earth's surface at an angle of 58.72° (Takuchev, 2021; Astronomical Calendar, 2023). The coincidence of the upper solar culmination for Stara Zagora with the inclination of the geomagnetic vector occurs on May 4 (Astronomical Calendar, 2023; Intermagnet, 2018). When the direction of particle invasion coincides with the inclination of the magnetic induction vector, the particles are not acted upon by a force deflecting their direction of motion. They penetrate the atmosphere and ionize atmospheric gases, contributing to local precipitation.

The positive correlation between solar activity and November precipitation (Figure 6), which peaks around solar lower culmination (midnight), can be explained by fluxes of ionizing solar particles impinging at the same latitude at the appropriate angle. During the day, positively charged particles emitted by the Sun in late autumn fall obliquely to the Earth's surface (long path through the atmosphere) and at a significant angle relative to the inclination of the geomagnetic vector, which is constant at the point of observation (58.72° for Stara Zagora). The combination of these conditions prevents the positive solar particles from penetrating deep into the atmosphere and affecting cloudiness during the day. Some of the solar particles from the November streams pass along the Earth and are swirled by the Earth's magnetic field in the opposite direction, entering the night side of the Earth's atmosphere. The return stream arrives at midnight (lower solar culmination) for specific locations on the Earth's surface. If, for a particular point, the geomagnetic induction inclination coincides with the lower solar culmination, similar to during the day at local noon, favorable conditions are created for the penetration of solar particles deep into the atmosphere above this point of the Earth's surface, i.e., conditions are created for increased nighttime cloudiness and precipitation above that point. The coincidence of the lower solar culmination for Stara Zagora with the inclination of the geomagnetic vector occurs on November 8th (latitude for Stara Zagora (42.42°) - solar declination on November 8th (-16.3°) = Inclination of the geomagnetic vector (58.72°) (Astronomical Calendar, 2023). Combined with the low temperature at November midnight, favorable conditions for Increased condensation and cloudiness are created. These conditions explain the strong positive correlation with November precipitation. Increased nighttime cloudiness also helps trap longwave radiation emitted from the Earth's surface in the lower atmosphere, raising its temperature and contributing to global warming.

Conclusion

A strong negative correlation was observed between the average Sun Spot Number during the "rise" phase of the 11-year solar activity cycle and the annual average Earth's surface temperature, based on data from several meteorological stations, mainly in Europe. As solar activity has decreased over the last 70 years – the last few solar cycles up to the 24th have had a monotonically decreasing number of sunspots – this negative correlation with temperature results in a rising surface air temperature. Once initiated as a result of declining solar activity over the past few decades, the global warming process has the potential to be self-sustaining, with more water evaporating into the surface atmosphere and the warmer atmosphere retaining it longer. Because water vapor is a major greenhouse gas, this can further increase global warming. As discussed above, the contribution of other greenhouse gases in the Earth's atmosphere to this process is small or negligible.

If solar alpha particles contribute to mortality on the Earth's surface, then along their path to the surface they also create an increased concentration of ions (condensation nuclei) in the lower troposphere. Fluxes of solar alpha particles are more frequent during the „rise" phase of solar activity (Figure 21).

The phenomenon decreases and even shows a trend toward a positive correlation at high mountain stations, i.e., it affects the lower layers of the troposphere below the high peaks. As a result of increased low cloud cover, the reflection from the upper surfaces of the clouds and the fogs beneath them increases. Due to an increased number of condensation nuclei, daytime cloudiness increases (the illuminated part of the atmosphere irradiated by solar ionizing radiation), increasing the reflection of solar electromagnetic radiation from the upper surfaces of the clouds back into space. Due to increased shading from additional cloud cover, less electromagnetic solar radiation reaches the Earth's surface during the day. The Earth's surface absorbs less electromagnetic radiation and heats less, i.e., the ground air temperature is lower. From the 19th to the 24th cycle, solar activity decreases. To the extent that the frequency of solar alpha particle fluxes is related to solar activity, especially during the "rise" phase, high-energy alpha radiation fluxes also decrease in frequency and intensity. As a result, daytime cloud cover decreases, and more electromagnetic radiation reaches the Earth's surface, raising the temperature of the Earth's surface and surface air in the last decades of declining solar activity.

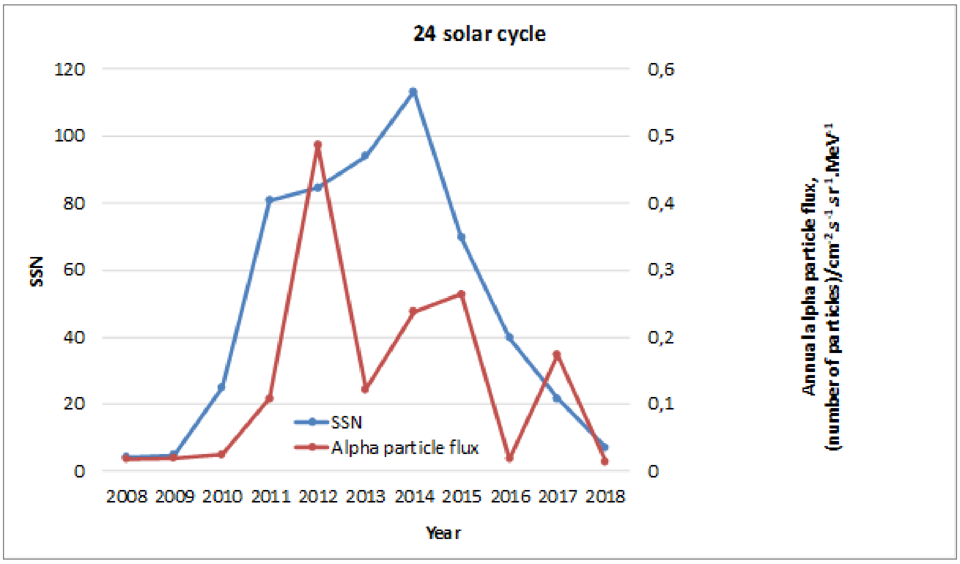

Figure 21: The annual alpha particle flux is about 20% higher during the "rise" phase than during the "fall" phase of the last complete (24th) cycle of solar activity.

Discussion

At the moment, the dominant explanation for the global warming of surface air in the last few decades is the burning of fossil fuels. It is widely accepted that global warming is caused by human activity. This idea offers hope for a possible solution to the problem if drastic measures are taken worldwide to limit the use of fossil fuels.

In the exposition above, a more pessimistic conclusion was drawn, namely that solar activity is the leading cause of the rising temperature. This conclusion removes the hope that humanity can take measures to deal with the problem. Measures can be taken to adapt to the inevitable changes imposed by nature. To the extent that the level of development of human civilization does not allow it to influence the processes of the Sun, the efforts of humanity must be redirected from efforts to reduce greenhouse gases to measures to increase the reflectivity of the planet – a measure that would act to lower the planetary temperature regardless of the cause of global warming (e.g., by dispersing light-reflecting aerosols into the stratosphere).

Some circumstances surrounding the described phenomenon – the inverse relationship between temperature and the "rise" phase of solar activity – remain unclear:

1. The described phenomenon is unevenly distributed across the Earth's surface (Figure 3). A likely reason for this uneven distribution is the historically determined uneven distribution of meteorological stations on land – they are most densely located in Europe. The later commissioning of a large part of the stations and the earlier cessation of their activities – before 2018 – make the data series too short and/or incomparable with the data from European stations.
2. The phenomenon is not constant over time – it is observed only in data from the last 90 years and at stations where the inverse relationship between temperature and solar activity during the "rise" phase is strongly emphasized. Figure 22 shows the change in the moving average of SSN, with a window of five solar cycles, as a function of solar cycle number. The resulting curve is quasi-cyclical, with two maxima and two minima. The approximate period (between the two maxima) is 130 years. The figure also shows the moving average, with a window of five solar cycles, of the correlations between temperatures and SSN for the "rise" phase at three stations in Central Europe with long data series. A sharp change in the signs of the correlations from positive to negative around the "rise" phase of solar cycle 15 (1913 – 1917) is noticeable in the region of the increase toward the second maximum of the SSN moving average curve. The length of the temperature data series is insufficient to trace temperature behavior around the first maximum. Suppose the hypothesis proposed above to explain increasing cloudiness during the "rise" phase is correct after the 15th cycle, with the years of the rising phase. In that case, does the emission of high-energy positively charged particles from the Sun begin during the "rise" phase of the 15th solar activity cycle a hundred years ago?

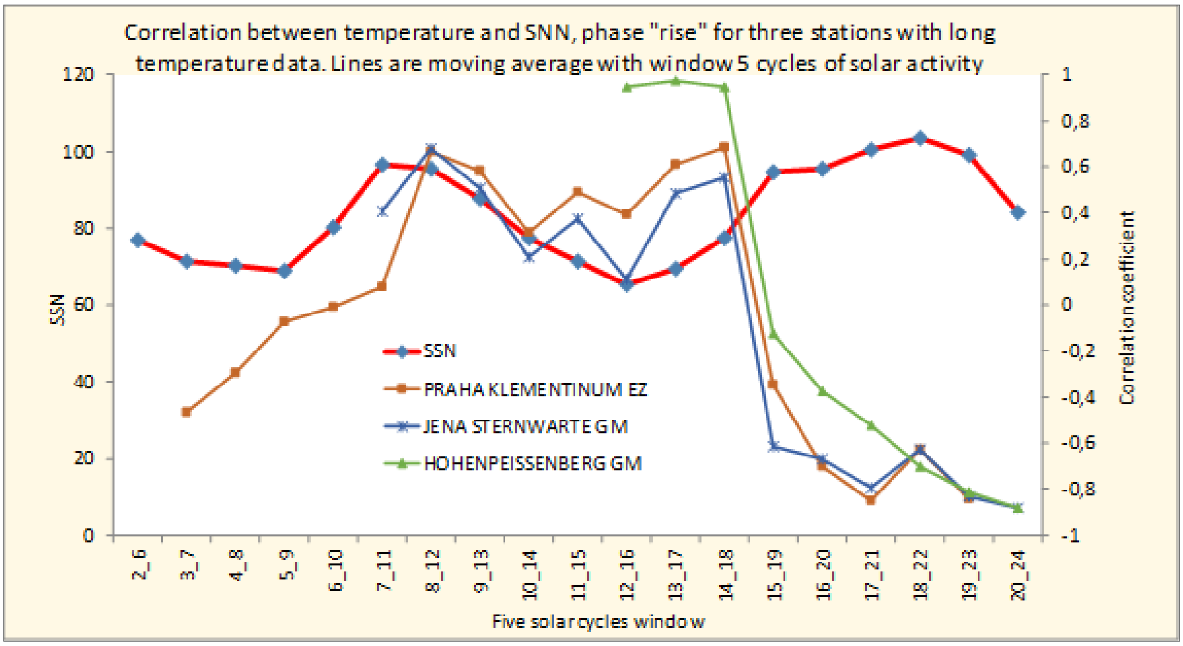

Figure 22: The temperature at three stations with long data series in Central Europe is inversely correlated with SSN only over the last 110 years (from the 15th solar cycle) (NOAA, n.d).

For the stations shown in Figure 22, which have long observation series, the precipitation correlation coefficient with the SSN also changes to a positive sign during the "rising" phase after the 15th cycle of solar activity, when, according to the proposed hypothesis, cloudiness during the "rising" phase increases (Figure 23).

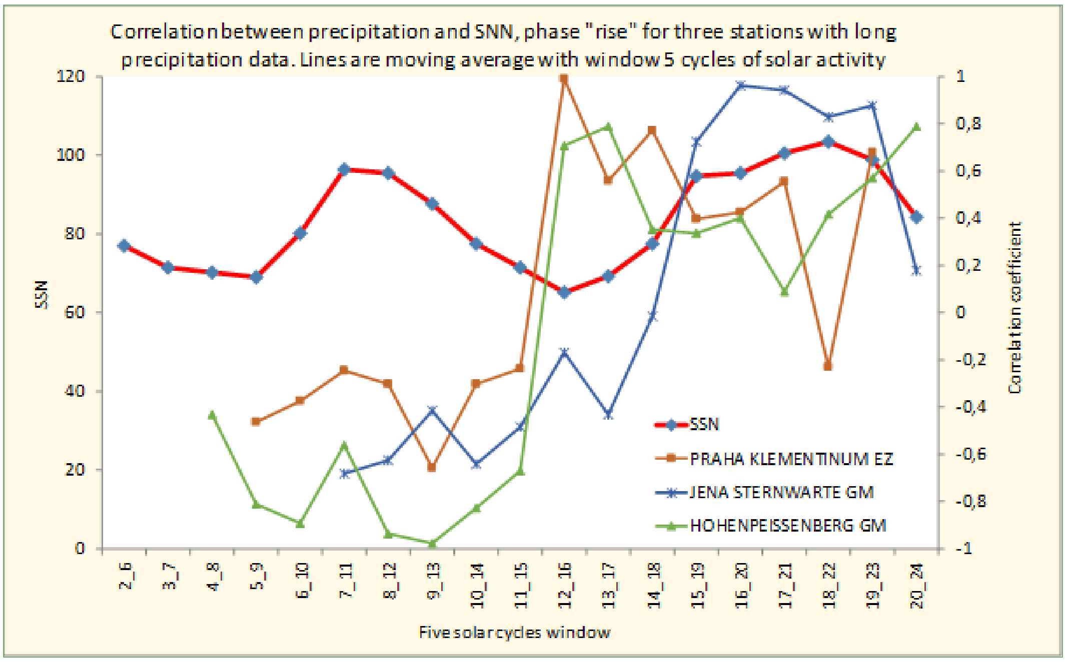

Figure 23: The correlation coefficient between precipitation amount and SSN during the "rising" phase of solar activity cycles becomes positive after the 15th cycle (NOAA, n.d).

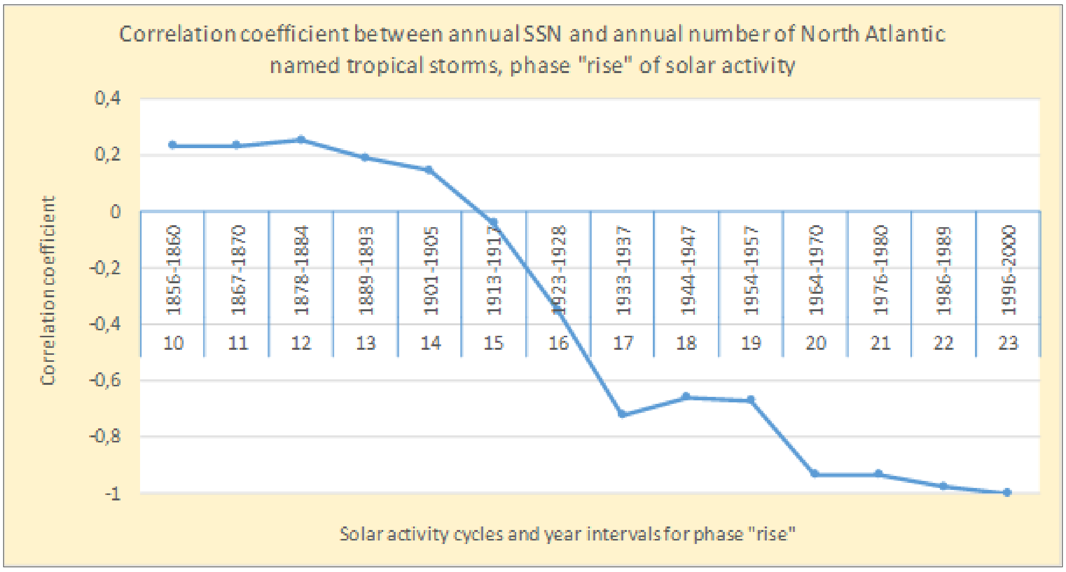

Figure 24: The correlation coefficient between the number of named tropical storms in the North Atlantic and the SSN during the "rising" phase of solar activity cycles turns negative after the 15th cycle (Colorado State University [CSU], 2024).

The frequency and intensity of tropical storms depend on the warmth of the ocean waters. Figure 24 shows the dependence of the number of named tropical storms (wind speeds over 61 km/h, 33 knots) in the North Atlantic Ocean (the ocean with the most extended series of temperature data) on the "rising" phase of the solar activity cycles. The correlation coefficient between the number of named tropical storms and the SSN of the "rising" phases of the solar activity cycles becomes negative after the 15th cycle. Within the framework of the hypothesis presented above, during the "rising" phase of the 15th cycle and afterward, cloudiness becomes dependent on the phase "rise" of solar cyclicity.

What can be expected in the future? We, as humanity, can do nothing about the solar processes leading to global warming. It is possible that the solar processes associated with global warming are cyclical, as seen in the SSN curve in Figures 22 and 23. Short-term temperature changes of a few tens of years have also occurred in the recent past – for example, from the middle of the 17th century, temperatures were lower for about 70 years compared with previous years. This period is known as the "Little Ice Age" and is supposedly associated with changes in solar activity. The continued increase in global temperature, regardless of its cause, risks triggering an uncontrollable melting of the polar and Greenland ice sheets due to the absorption of more heat by the ever-larger areas of ocean and land freed from ice – i.e., a so-called positive feedback between the decreasing ice areas reflecting light to space and the heat absorbed by the planet.

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