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RESEARCH ARTICLE

Solar Magnetic Field Change and Its Impact on Earth's Global Warming

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Abstract

The now generally accepted paradigm attributes the Earth's global warming to greenhouse gases, a significant portion of which is anthropogenic, primarily from the extraction and burning of fossil fuels and intensive agricultural practices. The hope is that it is within humanity's ability to limit this biosphere-threatening process by regulating the mentioned activities. This article argues that processes on the Sun have partly or entirely caused global warming in the Earth's atmosphere over the past 70 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 the phenomena on the Sun's surface are associated with the growing magnetic field. Part of the flow of high-energy radiation reaches the Earth. It penetrates deep into the Earth's atmosphere, creating an increased content of ions that serve as condensation nuclei around which water vapor forms drops. Condensation nuclei increase cloudiness in the lower atmosphere. The upper surface of clouds and fog partly reflects electromagnetic solar radiation into space. It does not reach the Earth's surface, which leads to a decrease in the temperature of the surface and, hence, in the temperature of the ground air heated by the surface. When the solar activity decreases, as observed in the last 70 years, the reverse process occurs – the high-energy fluxes of corpuscular radiation decrease, the ionization of the air in the Earth's atmosphere decreases, the 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 3 trillion for 2024) should be redirected towards increasing the planet's reflectance of solar electromagnetic radiation.

Keywords: Global Warming, Climate Change, Solar Cycle, Ionizing Radiation, Satellite Data.

1. 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) claim: "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. [1]" 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 70 years has been partially or

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entirely caused by changes in high-energy, positive corpuscular radiation, which is 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, resulting in a decrease in emitted ionizing radiation, which in turn leads to reduced cloudiness. Less cloudiness means more solar electromagnetic radiation reaching the Earth's surface and higher surface temperature.

2. 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 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. for 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 as to the cause of an invisible chain of interconnected phenomena, to which, in the author's opinion, global warming is also connected.

2.1 Temperature Data

Meteorological stations have worked 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) is analyzed below. The choice of the station is based on its proximity to major sources of greenhouse gases and the long-term, accurate reporting of temperature data at the station, with an almost continuous series of temperature data spanning 126 years [data from the National Meteorological Institute, Branch Stara Zagora]. The station is located within Stara Zagora (with a population of 125,732 as of 2021). With its intensive traffic, developed industry, and domestic combustion (resulting from a continental climate that necessitates heating in winter and cooling in summer), the city is a significant contributor to greenhouse gas emissions. In the vicinity of the station, about 40 km southeast of it, is located a power source of greenhouse gases emitting into the air – the "Maritsa-Iztok" energy complex. The complex spans an area of 240 km², comprising a coal mine and four thermal power plants surrounding it, with a total capacity of 3 GW, and has been operational since 1977. The ground air temperature data for the other stations from the rest of the world used in the study are sourced from the NOAA website, specifically the National Climatic Data Center, in the Global Historical Climatology Network Daily (GHCNd) database [2]. 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 (until 2018) and at least four solar cycles prior. The total number of included stations in the study was 872.

The number of tropical cyclones depends on the degree of warming of the ocean water. Data on North Atlantic tropical storms were obtained from [3].

Data on global temperature anomalies for land surface were obtained from [4]. Global land surface temperature anomaly is calculated by year 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.

2.2 Solar Activity Data

The solar substance is in a plasma state – a mixture of particles with a positive charge (protons and alpha particles) and a negative charge (electrons). Rising from deep to the Sun's surface (convection), heated flows of plasma 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. Its change is observable because, in phases of field growth (solar activity), areas of increased magnetic field on the visible surface of the Sun (photosphere) have reduced convection, as a result of which they are cooler, emit less radiation, and from a great distance they appear darker (sunspots). Along with the appearance of spots during the active phase of the Sun, 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 of its cycles gets 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 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 maximum of the cycle. For different cycles, the maximum SSN varies; for the last five cycles (from the 18th to the 23rd, since the mid-1950s), there has been a decline in the number of sunspots at the maxima of the cycles. SSN data were obtained from the sites [5, 6].

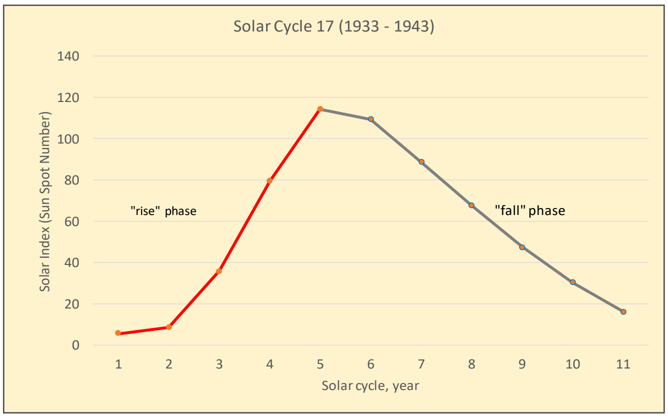

Figure 1. *A solar activity cycle in the example of solar cycle 17 (chosen for its typical shape). During the first phase of the cycle, solar activity increases and reaches a maximum (the largest number of sunspots). Then, during the second phase, the activity decreases to a minimum before the start of the next cycle.*

2.3 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 an NOAA site [7].

The SMS and GOES series satellites fly in geostationary orbit (above the Earth's equator) at 36,000 kilometers above the Earth's surface, making one lap in 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 of 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 averaged over a 5-minute interval, during which there are up to 25 reports of the instrument.

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

2.4 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 (from 2009 to 2018) were obtained from the NASA GIOVANNI database [8].

2.5 Mortality Data by Place and Cause of Death

The analysis below is based on the authoritative sources of health data – EUROSTAT [9] and the US National Center for Health Statistics (NCHS) [10].

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 from causes in 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 causes 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 includes mortality data for EU countries (NUTS-1) and EU regions (NUTS-2, which are smaller areas within 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 for each of the shortlisted groups for the period 2011–2019 (the last pre-pandemic year).

In NCHS, each death is coded with a numerical row, including various parameters, particularly the cause of death and year of death, among others, with millions of cases processed annually. Specialized software was developed to extract the necessary information.

2.6 Data Processing

For each of the hundreds of meteorological stations on the surface of the planet with sufficient length of annual mean temperature data (24th solar cycle and no less than four consecutive solar cycles back in time (from 1933 to 2018)), mean surface air temperatures were calculated for the years of solar activity phase "rise" (Figure 1). When the length of the temperature data series for a given station was five consecutive solar cycles, the correlation coefficient was calculated from the data for the five 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 the maximum of these coefficients were chosen.

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

Correlation analysis [11] was used for data processing. The correlation coefficient indicates the degree of connection (a causal relationship) between two variable processes. If the processes are changing synchronously in the same direction, they are positively correlated, to a greater extent, the closer the correlation coefficient is to +1.000. The processes are negatively (inversely) correlated if they are synchronously changing in opposite directions, to a greater extent, the closer to -1.000 the correlation coefficient is. 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 the solar activity phenomena and surface air thermal changes for a given station.

In mathematical statistics, the level of statistical significance [11] is a parameter indicating the degree of reliability of the calculated correlation coefficient. The smaller the number 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 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 [11].

In scientific studies, a level of statistical significance of no more than 0.05 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, indicating a causal relationship between ground air temperature and SSN can be reliably established if their correlation coefficient is no less than 0.708 for data encompassing eight solar cycles.

The coefficient of determination, which indicates the extent to which the variation in the independent variable (in this case, mean SSN) explains the variation in the dependent variable (in this case, surface air temperature), can be calculated using the statistical method of 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, there is no other cause independent of the first to intervene 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 value of 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 of the surface air temperature is a linear consequence of the solar activity and the dependence has a coefficient of determination close to unity, only the solar activity intervenes in the variation of the surface air temperature. No other cause, independent from 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 with the decreasing trend of solar activity in the last few decades.

3. Results

Of the stations included in the study, 812, i.e., 93%, had 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, maximum statistically significant negative correlations were obtained in six continuous cycles (171 cases). The number of statistically significant negative correlations quickly decreases with the increase in length of the series of cycles, reaching a length of up to 8 cycles.

The phenomenon is observable worldwide (Figure 2). Figure 2 shows the change in global land temperature anomaly (the difference between the global annual temperature and the global average land temperature for the hundred years 1901-2000 [4]) for the last six cycles of solar activity "rise" phases.

The figure shows that the above-discussed inverse correlation with SSN 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 mentioned negative correlation of -0.958 becomes statistically significant at the significance level of 0.05.

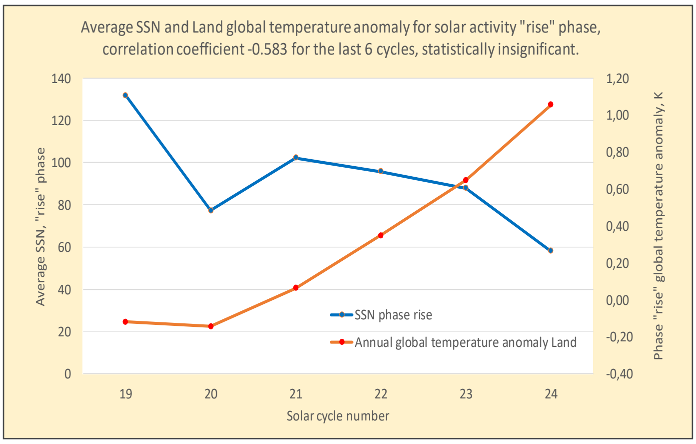

Figure 2. *For the surface air temperature anomaly on land, there is also an inverse relationship with SSN for the "rise" phase of the last six cycles of solar activity, i.e., the phenomenon discussed above covers all land on the planet.*

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

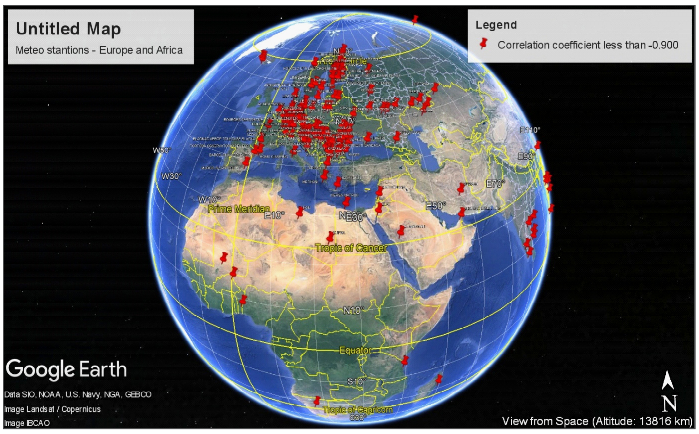

Figure 3. *The stations with correlation coefficients below -0.900 between surface air temperature and SSN for the phase "rise" of the solar cycles.*

Iztok”. The meteorological station has a long and accurate operational history, with records of surface air temperature data dating back 126 years. Figure 4 shows the relationship between the average value of the annual surface air temperatures measured at the Stara Zagora station, averaged for the phase “rise” of solar activity cycles with numbers from 17 to 24 (the cycles have a total duration of 86 years), and the average value of the annual SSNs for the “rise” phases for the same cycles of solar activity. A high negative statistically significant correlation between the two data series indicates a causal relationship between the two phenomena – temperature changes in the Stara Zagora region and solar activity. As solar activity increases within a particular cycle, the temperature decreases. Due to the decreasing trend in SSN values over the last five cycles and their negative correlation with temperature, the surface air temperature for the Stara Zagora region has been increasing in recent years.

This phenomenon is observed at each station of the meteorological set in Bulgaria. Air temperature data for some of them are included in the GHCNd database [2].

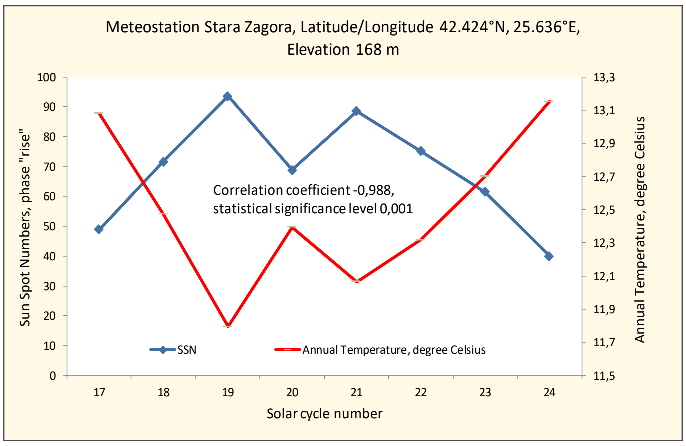

Figure 4. *There is a highly statistically significant negative correlation between the mean surface air temperature for the weather station STARA ZAGORA, BULGARIA, and the mean value of the number of sunspots during the phase “rise” of the last eight solar activity cycles.*

Relative air humidity is inversely correlated with air temperature by definition, i.e., 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 dependence on time of the average values of SSN during the “rice” phase and their corresponding average values of the relative humidity of the air obtained from the same weather station of Stara Zagora. The existence of a high, statistically significant positive correlation between the relative humidity of the air and the SSN in the “rise” phase is an independent confirmation of an inverse relationship between the air temperature and the SSN in the “rise” phase.

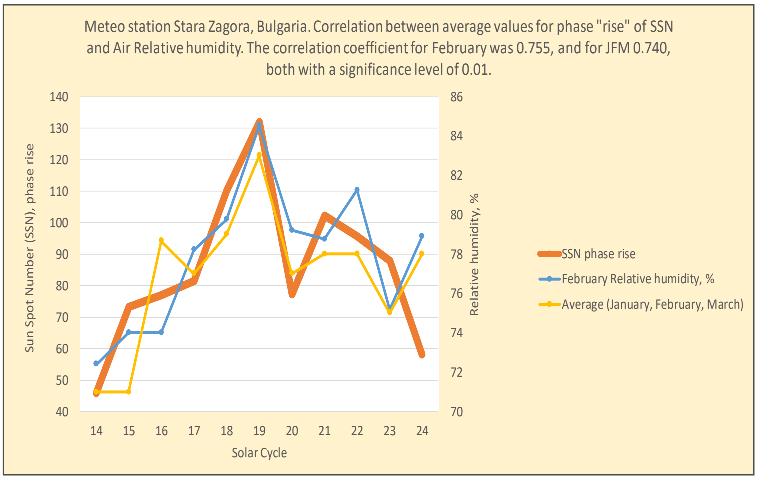

Figure 5. *There is a statistically significant positive correlation between SSN in the “rise” phase and the relative air humidity measured over the years during the “rise” phases of the SSN in the meteorological station Stara Zagora, Bulgaria.*

The existence of a dependence between solar activity and air humidity implies the existence of a dependence between solar activity and precipitation, too. Figure 6 shows two time dependencies (curves) during the year (annual courses). One curve represents the yearly precipitation trend in mm (= l/m²) for the Stara Zagora weather station in the city of Stara Zagora, by month, averaged over the period from 1899 to 2023. The other curve represents the annual trend of the correlation coefficient between 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, a statistically significant correlation exists with a correlation coefficient of 0.731, which is statistically significant at the 0.01 level.

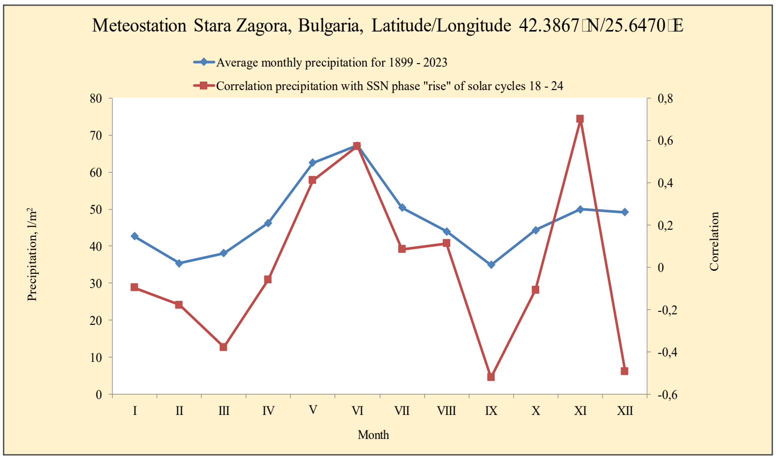

Figure 6. *There is a statistically significant correlation between the annual course of precipitation and its correlation coefficient for the "rise" phase of the solar activity cycle for the last seven cycles.*

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

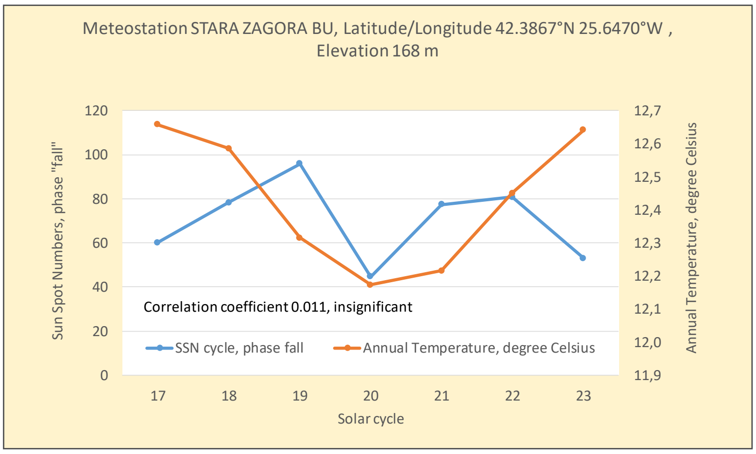

Figure 7. *There is no statistically significant correlation between the mean surface air temperature for the weather station STARA ZAGORA, BULGARIA, and the mean number of sunspots during the phase "fall" of the last seven solar activity cycles.*

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

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

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 has an almost deterministic linear dependence due to a single cause – the solar activity characterized by SSN. The obtained result rejects the hypothesis of temperature dependence on the concentration of greenhouse gases, at least for the region of Stara Zagora. This conclusion is particularly impressive, as it was made for the Stara

Zagora region, where the air should contain more carbon dioxide released from the burning coal in 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.

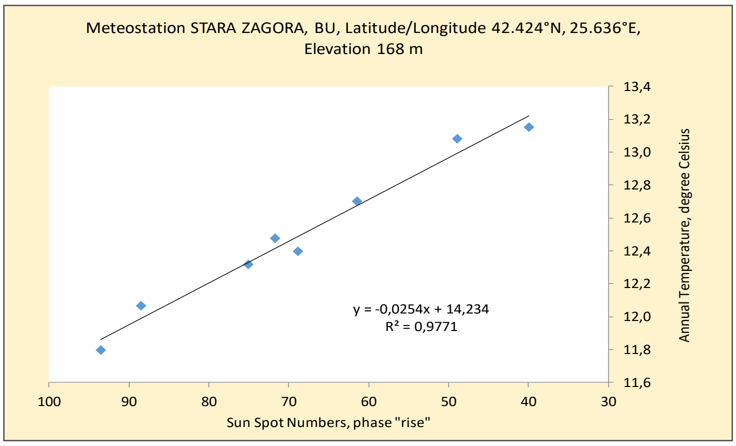

Figure 8. *There is a linear relationship with a very high coefficient of determination between surface air temperature in the region of STARA ZAGORA, BULGARIA, and the number of sunspots, both calculated for the phase "rise" of the solar cycles included in the study.*

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

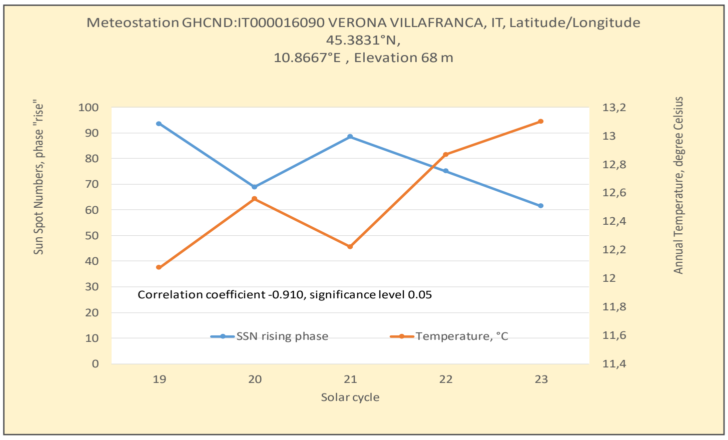

Figure 9. *A high statistically significant negative correlation exists between the mean surface air temperature for weather station VERONA VILLAFRANKA, ITALY, and the mean sunspot number during the phase "rise" of the five solar activity cycles (for which data are available).*

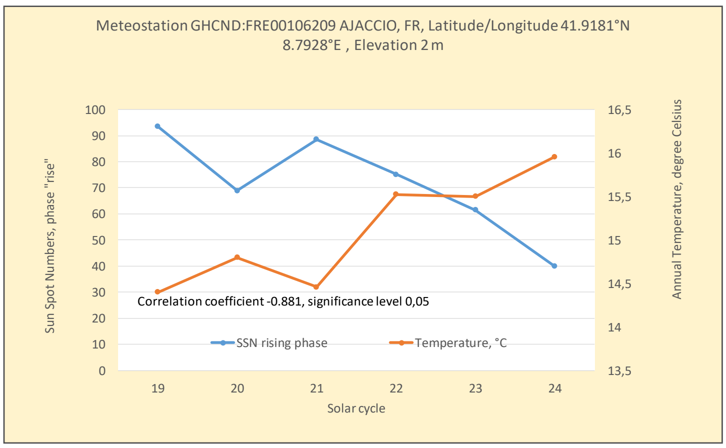

Figure 10. *A high statistically significant negative correlation exists between the mean surface air temperature for weather station AJACCIO, Corsica, FRANCE, and the mean sunspot number during the phase "rise" of the six solar activity cycles (for which data are available).*

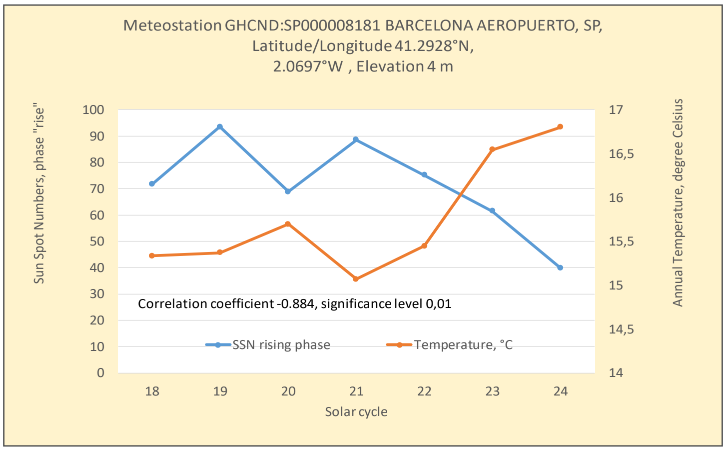

Figure 11. *There is a high statistically significant negative correlation between the mean surface air temperature for weather station BARCELONA AEROPUERTO, SPAIN, and the mean sunspot number during the phase “rise” of the seven cycles of solar activity (for which data are available).*

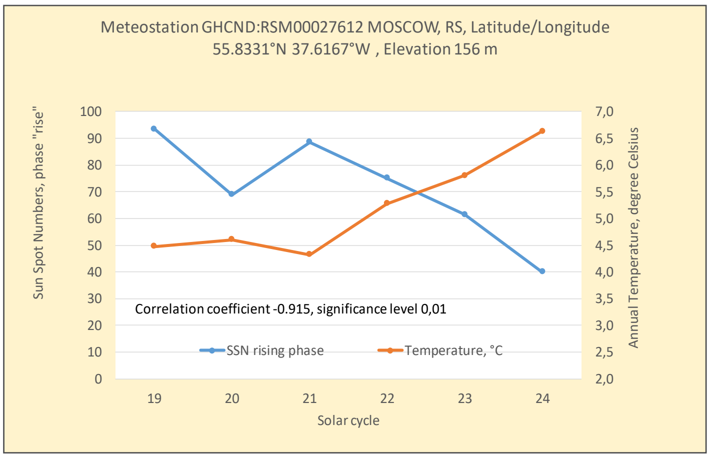

Figure 12. *A highly statistically significant negative correlation exists between the mean surface air temperature for weather station MOSCOW, RUSSIA, and the mean sunspot number during the phase “rise” of the six solar activity cycles (for which data are available).*

The number of tropical cyclones depends on the degree of warming of the ocean water. Figure 13 shows the change in the number of named Atlantic tropical cyclones (wind speed above 61 km/h) and solar activity in the „rise“ phase, with a correlation coefficient (-0.934), statistically significant at the 0.05 level [3]. The dependence indicates that increasing ocean temperatures are related to decreasing solar activity over the last few cycles.

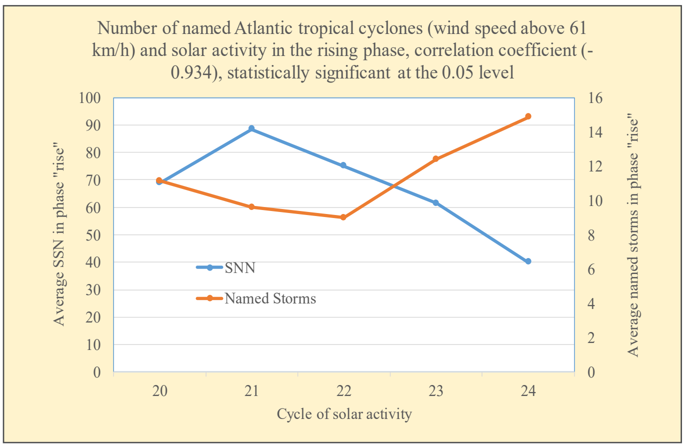

Figure 13. *The increasing ocean temperature depends on the decreasing solar activity over the last few cycles.*

During a cycle with a high SSN maximum, a reduced emission of electromagnetic radiation from the solar photosphere should be expected due to the many sunspots darker than the average brightness. As a result, less solar energy would reach the Earth’s surface. The decreasing 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. Such an effect is not observed due to the accompanying sunspot areas (faculae), which 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 with reference coordinates 20°E, 40°N, 30°E, and 50°N, covering part of the Balkans, where the above-described phenomenon of 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 [8]. The data covers the last four solar cycles, encompassing a total of 7 phases of solar activity of both types – "rise" and "fall" – with values ranging between 212 W/m² and 220 W/m². The comparison between the average fluxes of electromagnetic radiation during the two phases showed no statistically significant difference between the fluxes. There are also no statistically significant correlations between the change in flows and the change in air temperatures in each phase, i.e., it follows the conclusion that the described phenomenon is not related to changes in the Sun's electromagnetic radiation.

Data on the relative fraction of clouds covering the sky, separately for daytime and nighttime cloudiness, for two areas with high correlation coefficients between SSN and surface air temperature – the Balkans and the Western Mediterranean – were obtained from the onboard MODIS (or Moderate Resolution Imaging Spectroradiometer) instruments on the "Terra" and "Aqua" satellites [8]. The data set covers only the last complete solar cycle 24 (the planned life of the mentioned satellites was 6 years; "Terra" has been operating for more than 25 years, and "Aqua" for 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 studied areas – the Balkans and the Western Mediterranean – during the "rise" phase of the solar activity cycle, the daily cloud fraction is higher than that of the "fall" phase, according to data from both satellites. The difference reaches 1.5% cloud fraction (Figure 14). Increasing cloud shading during the daytime during the "rise" phase reasonably explains this phase's decrease in surface temperature. The increased cloudiness may be due to the increased number of condensation nuclei in the atmosphere at the condensation level where the clouds form. Condensation and, as a result, the formation of clouds depend 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.

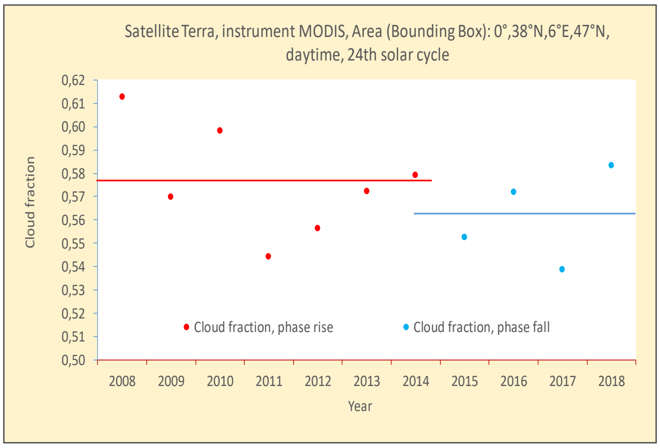

Figure 14. *Daytime cloudiness over the western Mediterranean is about 1.5% more during the phase "rise" of the solar cycle than during the "fall" phase.*

The GOES series satellite data show that the positively charged particles with high energy – hydrogen and helium nuclei (protons and alpha particles), capable of ionizing the air, arrive from the Sun to the Earth [7]. Most often, these particles do not penetrate deep into the Earth's atmosphere to the ground layer troposphere, where clouds are formed, due to the deflecting effect of the Earth's magnetic field and the energy losses in the collisions with the particles of 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 [12 – 25]. The study reveals a highly positive, statistically significant correlation between fluxes of positively charged solar particles registered by GOES satellites and human mortality, a phenomenon that could be explained by the penetration of the particles through 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 by the group cause "All causes of death (A00-Y89) excluding S00-T98" of EUROSTAT shortlist in 2012, the year with the highest mortality for the studied interval years 2011 – 2019. The map was made from data for 377 NUTS-2 regions in Europe and the Mediterranean. A region with increased mortality stands out over Eastern Europe, with a maximum over the Central Balkans.

Red isolines indicate the distribution of the impact index for the annual flux of solar alpha radiation, as recorded by the GOES series satellites, for the studied interval of years 2011–2019, in relation to 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 of years between annual mortality rates by cause groups and the yearly flux of solar alpha radiation for each region separately. The number of correlations is divided into three groups based on their levels of statistical significance: most significant, with a p-value of less than 0.001; medium significance, with a p-value between 0.001 and 0.01; and least significant, with a p-value between 0.01 and 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. And 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.

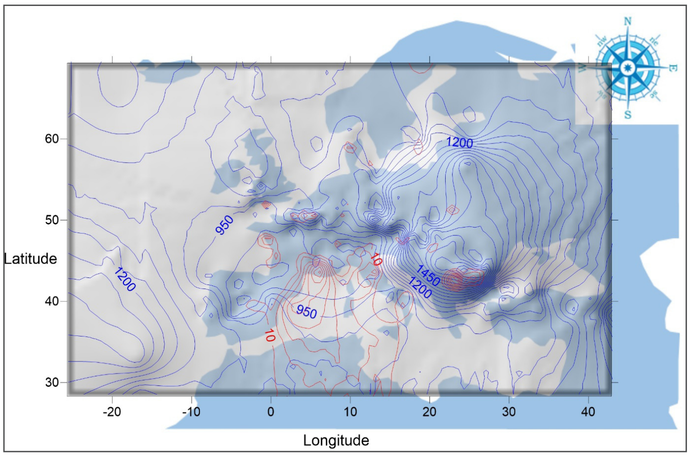

Figure 15. *The main areas of influence of solar alpha radiation on mortality in Europe and the Mediterranean are the Balkans and, to a lesser extent, the Western Mediterranean. (Software Surfer 10).*

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

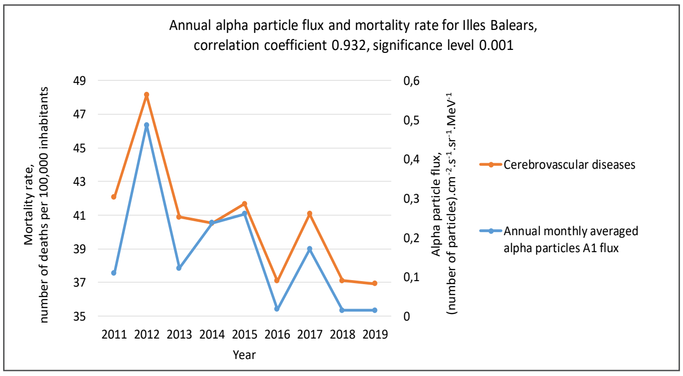

Figure 16. *There is a highly statistically significant correlation between the annual flux of high-energy solar alpha particles and cerebrovascular disease mortality in the Western Mediterranean, i.e., it is very likely that there is a causal relationship between the two phenomena.*

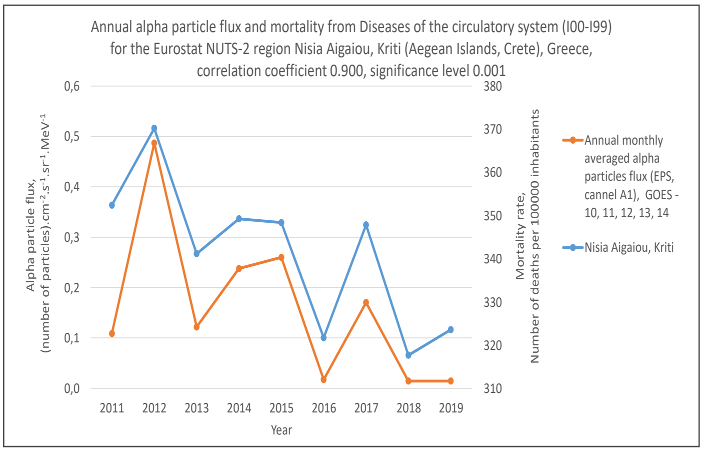

Figure 17. *Between the annual flux of high-energy solar alpha particles and mortality from circulatory system diseases in the Aegean Islands and Crete, Greece, there is a high statistically significant correlation, i.e., it is very likely that there is a causal relationship between the two phenomena.*

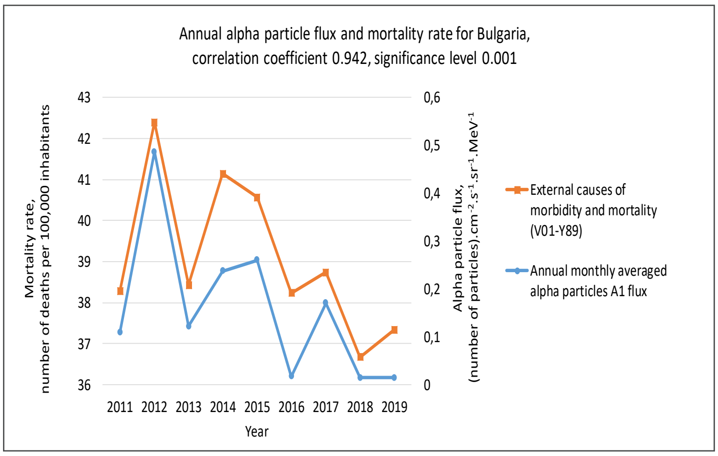

Figure 18. *There is a high statistically significant correlation between the annual flux of solar alpha particles with high energy and the mortality from external causes of death in Bulgaria. I.e., there is very likely a causal relationship between the two phenomena.*

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 and with ionization within it to increase condensation nuclei and associated cloudiness.

3.1 A Hypothetical Mechanism Explaining Human Mortality with the Impact of Invading High-Energy Solar Alpha Particles [12 - 25]

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 an energy of the order of 4 – 21 MeV, recorded by the SMS and GOES series satellites in Earth orbit. The recorded alpha particle flows are mostly pulses that last 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, where they damage human health, to the greatest extent, the human circulatory system, causing death, mainly in older adults with an already damaged circulatory system.
3. As the average altitude of the affected countries increases, the particle flux-correlated mortality shows an increasing trend [15, 21]. It is probably due to the more intense positively charged particle flux penetrating the thinner atmosphere over the mountainous region 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 (phenomenon on the solar surface that could be observed with other astronomical means) [15, 21]. 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 [26] 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. Positively charged solar particles capable of penetrating the Earth's atmosphere to the Earth's surface are high-energy alpha particles. Calculators PSTAR [27] and ASTAR [28] calculate the penetration parameters of protons, respectively, alpha particles in different substances, in particular in air. Calculations with data for a homogeneous atmosphere – an atmospheric model with constant density, temperature, and pressure decreasing with height [15] show that only particles whose energy is above 2.4 GeV for protons and over 6.2 GeV for alpha particles can penetrate the Earth's atmosphere to the surface. There are no registered protons above 0.7 GeV by GOES satellites. Still, there are registered alpha particle fluxes with energy above 3.4 GeV, hypothetically also those with energy above 6.2 GeV [15, 21, and 22], i.e., the particles that penetrate the Earth's surface are probably high-energy alpha particles. Only registered fluxes of alpha particles with a high enough magnitude of at least (hundreds of particles).$cm^{-2}.s^{-1}.sr^{-1}.MeV^{-1}$ is 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 need 8.87 min to reach the Earth's surface from the Sun's surface, and particles registered from satellites with energies of 5 – 10 MeV travel about 2 hours. The registered alpha particles do not have enough power to penetrate the atmosphere, unlike the hypothetical fast alpha particles that reach the surface of the Earth in minutes from the center of the Sun's disk. However, the registered alpha particles indicate that two hours earlier, there was an irradiation of the Earth's surface 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), for which two conditions favoring penetration are combined

a. The Sun is culminating for the center of the death spot – the path through the atmosphere of the invading positively charged particles to the point of observation is the shortest at the moment of the maximum rise of the Sun above the horizon (the culmination of the Sun). The point of registration is a point on the Earth's surface where the solar disk is at its culmination at that moment of the alpha particle flux registration by satellites. Its longitude can be determined from the data (time tag) for the hours and minutes of the GOES satellite registration. 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.

b. For the center of the death spot, a coincidence is in effect – the direction of the geomagnetic vector coincides with the direction of the alpha particle intrusion – then the alpha particle movement is not affected by the deflecting magnetic force. Such a coincidence occurs twice a year for latitudes in the band from 28°N to 48°N [15]. 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. For some intervals in the recent past, 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 high-energy alpha particle flows recorded by the satellites, made it possible to track the rapid changes in the number of deaths in the United States.

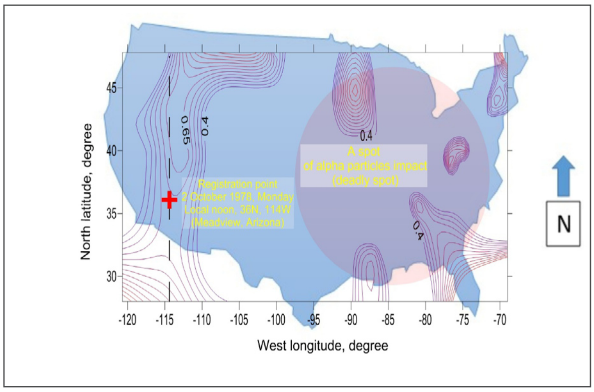

Figure 19. *Registration point (red cross) of alpha radiation flux from October 2, 1978, in the western USA, and the dead spot in the eastern US, tentatively denoted by a circle centered 30° eastward from the registration point.*

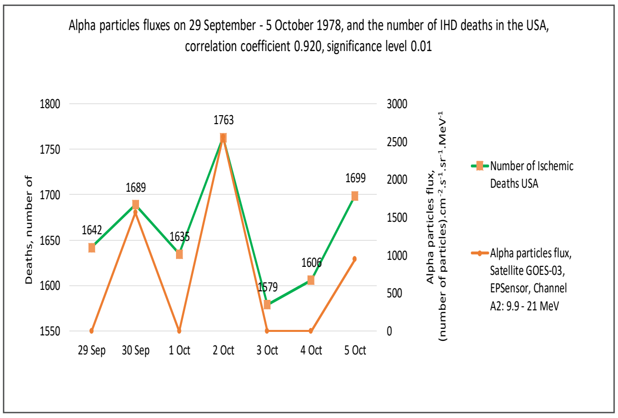

Figure 20. *There is a high statistically significant correlation between alpha particle fluxes on September 29 and October 2, 1978, and the daily number of ischemic heart disease deaths in the USA.*

The 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 maximal in May-June when:

1. The Sun is at its upper culmination (at noon), i.e., the atmosphere is the thinnest for intruding streams of ionizing solar particles. For Stara Zagora, the maximum culmination is 66.12° on June 21, [29].
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° [15, 29]. The coincidence of the upper solar culmination for Stara Zagora, with the inclination of the geomagnetic vector, is on May 4 [29, 30]. 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 the local precipitation.

The positive correlation between solar activity and precipitation in November, coinciding with the November precipitation maximum (Figure 4), can be explained by fluxes of ionizing solar particles impinging on the same latitude at the appropriate angle around solar lower culmination (midnight). During the day, positively charged particles emitted by the Sun in the late autumn fall obliquely to the Earth's surface (long path through the atmosphere) and at a significant angle deviation to the inclination of the geomagnetic vector, which is constant at the point of observation (58.72° for Stara Zagora). The combination of both conditions prevents positive solar particles from penetrating deeply into the atmosphere and affecting cloudiness during the day. Some of the solar particles of 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, similarly 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 is on November 8th (latitude for Stara Zagora (42.42°) – solar declination on November 8th (-16.3°) = Inclination of the geomagnetic vector (58.72°) [29]. Combined with the low temperature at November midnight, favorable conditions for increased condensation and cloudiness are created. These conditions explain the high positive correlation with precipitation in November. Increased cloudiness at night also helps to trap longwave radiation from the Earth's surface in the lower atmosphere, which increases its temperature and contributes to global warming.

4. Conclusion

A high negative correlation between the average Sun Spot Number in phase "rise" in the 11-year solar activity cycle and the annual average Earth's surface temperature was observed in the 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. Their 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. This occurs because the warmer atmosphere retains more water than the surface atmosphere, and water vapor is a major greenhouse gas that can exacerbate 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 cause part of the mortality on the Earth's surface, then on 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 of change towards a positive correlation for high mountain stations, i.e., it affects the low layers of the troposphere, below the high peaks, for which, as a result of the increased low cloud cover, the reflection from the upper surface of the clouds and the fogs below them increases. As a result of the increased number of condensation nuclei, daytime cloudiness is increased (the illuminated part of the atmosphere irradiated by solar ionizing radiation), increasing the reflection of solar electromagnetic radiation from the upper surface 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., lower ground air temperature. From the 19th to the 24th cycle, solar activity decreases (Figures 16, 17, and 18). 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.

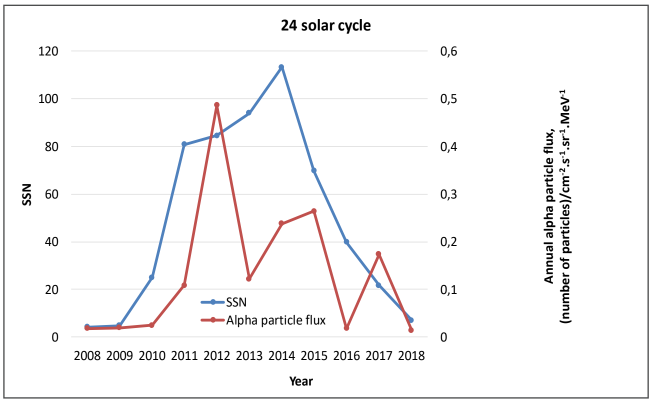

Figure 21. *The annual alpha particle flux is about 20% higher in magnitude during the phase "rise" than the phase "fall" of the last complete (24th) cycle of solar activity.*

5. Discussion

Currently, the prevailing theory for the cause of surface air warming over the last few decades is the burning of fossil fuels; it is widely accepted that human activity is a significant contributor to global warming. This idea offers hope for a possible solution to the problem if drastic measures are taken globally to limit the use of fossil fuels.

In the exposition above, the more pessimistic conclusion was drawn that solar activity is the leading cause of the rising temperature.This conclusion undermines the hope that humanity can take measures to address 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 in the direction of lowering the planetary temperature regardless of the cause of global warming (e.g., by dispersing light-reflecting aerosols into the stratosphere?).

Some circumstances in connection with the described phenomenon – the inverse relationship between temperature and solar activity "rise" phase, remain unclear.

1. The described phenomenon is unevenly distributed over the Earth's surface (Figure 3). A likely reason for the observed uneven distribution of the phenomenon 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, makes 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 the data for the last 90 years and for the stations for which the inverse relationship between temperature and solar activity "rise" phase is strongly emphasized. Figure 22 shows the change in the moving average of SSN with a window of five solar cycles, depending on the solar cycle number. The resulting curve is quasi-cyclical with two maxima and minima. The approximate period (between the two maxima) is 130 years. The moving average with a window of five solar cycles on the correlations of temperatures with SSN for the phase "rise" is also shown in the figure for three stations in Central Europe with a long data series. The sharp change in the signs of the correlations from positive to negative around the solar activity cycle 15 "rise" phase (1913 – 1917) is noticeable in the region of the increase of the second maximum of the curve with the moving average of SSN. The length of the series of temperature data is insufficient to trace the behavior of temperatures around the first maximum. The hypothesis proposed above to explain increasing cloudiness during the "rise" phase is correct after the 15th cycle. In that case, did the emission of high-energy positively charged particles from the Sun begin during the "rise" phase of the 15^{th} solar activity cycle a hundred years ago?

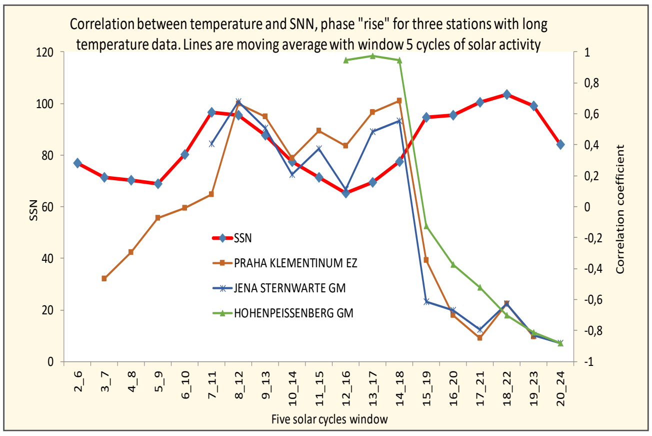

Figure 22. *The temperature at three stations with long data series in Central Europe is inversely correlated with SSN only during the last 90 years (from the 15th solar cycle) [31].*

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

The frequency and strength 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) for the North Atlantic Ocean (the ocean with the most extensive 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 15^{th} cycle.

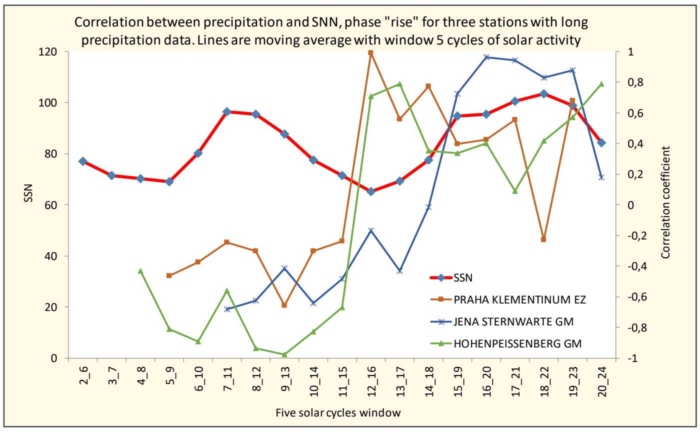

Figure 23. *The correlation coefficient between precipitation amount and SSN during the "rising" phase of solar activity cycles becomes positive after the 15th cycle [31].*

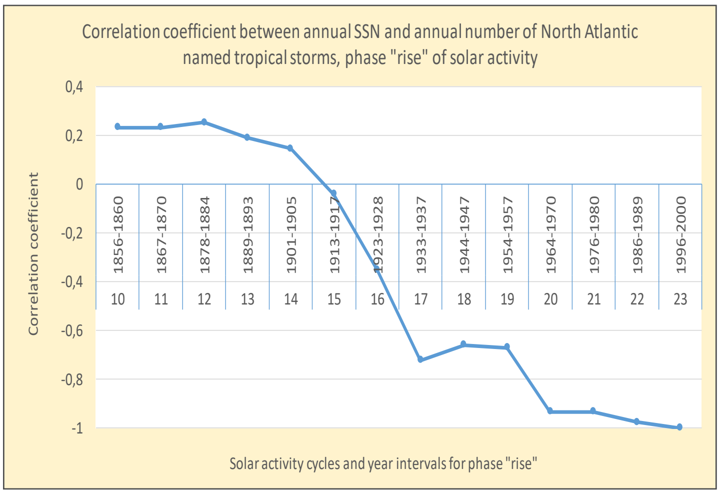

Figure 24. *The correlation coefficient between the number of named tropical storms in the North Atlantic and the SSN during the "rising" phase of solar activity cycles becomes negative after the 15th cycle [3].*

Within the framework of the hypothesis presented above, during the "rising" phase of the 15th cycle and after that, 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 not excluded that the solar processes associated with global warming are cyclical, as seen from the SSN curve in Figures 22 and 23. Changes in temperature with a short-term nature, lasting a few tens of years, have also occurred in recent times – for example, from the middle of the 17th century, temperatures were lowered for about 70 years compared to previous years. The time interval 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 process of the Polar and Greenland ice sheets due to the absorption of more heat from the ever-larger areas of ocean and land freed from the ice – i.e., so-called positive feedback between the decreasing ice areas reflecting light to space and the heat absorbed by the planet.

6. References

1. "CLIMATE CHANGE 2023" https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf.
2. NOAA National Climatic Data Center.https://www.ncdc.noaa.gov/cdo-web/datatools/selectlocation.
3. Colorado State University, CSU Tropical Weather & Climate Research, Forecast Archive https://tropical.colostate.edu/archive.html#data, retrieved on November 15, 2024.
4. NOAA National Centers for Environmental Information, Climate at a Glance: Global Time Series, published January 2024, retrieved on January 29, 2024 from https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series.
5. SSN, Royal Observatory of Belgium, Brussels http://www.sidc.be/silso/datafiles#total .
6. SSN, NOAA https://ngdc.noaa.gov/stp/space-weather/solar-data/solar-indices/sunspot-numbers/american/ .

7. Data from GOES satellites. Available: https://www.ncei.noaa.gov/data/goes-space-environment-monitor/access/avg/.
8. GIOVANNI, NASA https://giovanni.gsfc.nasa.gov/giovanni.
9. EUROSTAT, European short list of deaths by cause, death rate by NUTS 2 region of residence Statistics | Eurostat (europa.eu) 10/10/2023.
10. Centers for Diseases Control and Prevention (CDC), USA, National Center for Health Statistics (NCHS), Scientific Data Documentation, Detailed Mortality File, 1962-1992 https://wonder.cdc.gov/wonder/sci_data/mort/detailed/type_txt/DetailedMortality1962-1992.asp last visited on 20. III.2023.
11. Lakin G.F. 1990. Biometrics. Moscow. Higher School Publishing House. 208-214. (In Russian).
12. Nikolay Takuchev. 2019. Solar corpuscular radiation and mortality from various forms of ischemic heart disease in Bulgaria for the interval 2005 – 2015. AIP Conference Proceedings 2075, 130005 (2019); 13005-1 – 13005-6, https://doi.org/10.1063/1.5091290 Published Online: February 26 2019.
13. Takuchev N. 2020 Ischemic Heart Diseases Mortality for Bulgaria Partly Depends on Solar Corpuscular Radiation? ES Journal of Cardiology Volume 1 Issue 2: 1010. Published Online: June 3 2020, https://escientificlibrary.com/cardiology/Article/ESJC-V1-1010.pdf.
14. Nikolay Takuchev. 2021. How Ischemic Heart Diseases Mortality Depends on Solar Corpuscular Radiation: A Case from Bulgaria. Chapter in: Challenges in Disease and Health Research Vol. 8. Book Publisher International. ISBN-13 (15) 978-93-91215-98-9 (Print) 978-93-91215-06-4 (eBook).
15. Nikolay Takuchev. 2021. Does the Angel of Death Sometimes Use Solar Alpha Particles to Take Our Souls? Book Publisher International. FIRST EDITION 2021 ISBN 978-93-91215-36-1 (Print) ISBN 978-93-91215-44-6 (eBook) DOI: 10.9734/bpi/mono/978-93-91215-36-1.
16. Nikolay Takuchev, 2021. Solar Corpuscular Fluxes of Alpha Particles and Mortality from Ischemic Heart Disease in Bulgaria. In: Proceedings of a scientific conference "RADIATION SAFETY IN THE MODERN WORLD", November 17-18, 2021, Veliko Tarnovo, Bulgaria. DOI 10.34660/INF.2021.13.75.010 (In Bulgarian).
17. Nikolay Takuchev 2022 The Solar Alpha Particles Invading Earth and Ischemic Heart Diseases – the Worldwide Killer Number One, Connected? London Journal of Research in Science: Natural and Formal © 2022 London Journals Press Volume 22 | Issue 5 | Compilation 1.0 Classification: DDC Code: 616.12003 LCC Code: RC681 LJP Copyright ID: 925684 Print ISSN: 2631-8490 Online ISSN: 2631-8504, 43-51.
18. Nikolay Takuchev. 2023. The High-Energy Positive Solar Particles Invading the Earth with Contribution to the Mortality from Ischemic Heart Diseases? SCIREA Journal of Physics. ISSN: 2706-8862. http://www.scirea.org/journal/Physics. February 26, 2023. Volume 8, Issue 2, April 2023. https://doi.org/10.54647/physics140528.
19. Nikolay Takuchev. 2023. Alpha particle fluxes and ischemic heart disease mortality study for Bulgaria and Los Angeles, California, USA. J Mod Appl Phy Vol 6 No June 2 2023. 1 – 10. DOI: 10.37532/puljmap.2023.6(2);01-06.
20. Nikolay Takuchev. 2023. Solar Alpha Particles and Death from Ischemic Heart Disease. Journal of Current Medical Research and Opinion CMRO 06 (06), 1615-1625 (2023) DOI: https://doi.org/10.52845/CMRO/2023/6-6-2.
21. Takuchev N. Space threat to the USA – increase in mortality from ischemic heart disease due to high-energy alpha particles entering Earth's orbit. J Mod Appl Phys. 2023; 6(3):1-13.
22. Nikolay Takuchev. 2023. Solar Alpha Particles and Death from Ischemic Heart Disease. Int J Complement Alt Med. (International Journal of Complementary & Alternative Medicine) 2023;16(4):228–232.
23. Takuchev N. Humanity is subject to a deadly cosmic impact – is non-human intelligent intervention also possible? J Mod Appl Phys. 2023; 6(3):1-11.
24. Takuchev N. High Energy Solar Alpha Particles are Dangerous for the People on the Earth's Surface. J. Phys. Astron.2023;11(8):368.
25. Takuchev N. Space Alpha Particle Fluxes towards the Earth's Surface Increase Human Mortality – Examples from the Balkans and Greece. Open J of Astro 2024, 2(1): 000105. DOI: 10.23880/oaja-16000105.
26. Cosmic Ray Data Base (CRDB), charged cosmic rays. https://tools.ssdc.asi.it/CosmicRays/ .
27. PSTAR. Available: https://physics.nist.gov/PhysRefData/Star/Text/PSTAR.html.
28. ASTAR. Available: https://physics.nist.gov/PhysRefData/Star/Text/ASTAR.html.
29. ASTRONOMICAL CALENDAR 2023. BAS, Institute of Astronomy with National Astronomical

Observatory, ISSN 0861–1270, Paradigma Publishing House, 2022 (In Bulgarian).

30. Data on the geomagnetic field. Available: http://www.intermagnet.org/data-donnee/dataplot-eng.php?type=xyz last visited on 14.8.2018.

31. NOAA National Climatic Data Center http://www.ncdc.noaa.gov/cdo-web/datatools/selectlocation.