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Rainfall and Temperature Variations over Burkina Faso: Possible Influence of Geomagnetic Activity, Solar Activity and Associated Energies from 1975 to 2020

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Abstract

This study investigates climatic parameters (rainfall, and temperature) over Burkina Faso and the possible role of solar activity and its induced energies. Through morphological investigations, we analyzed solar activity indices (sunspot number, IMF, PC index, Cosmic rays) over the last three solar cycles (1975-2020). Results about interplanetary heating show that joule heating is well correlated with the dynamic pressure of the solar plasma. Climate parameters (rainfall, Temperature) variabilities are modulated by disturbances in solar activity: 1) quiet solar characterized by a drop in solar plasma's parameters is associated with important cloud cover and consequently bring important rainfall which chills terrestrial atmosphere, 2) active solar characterized by important input energy is associated with weak incident cosmic ray consequently with low cloudiness which brings warming. Thus, the possible natural link can be suggested between solar activity and climatic parameters even if it is not the only factor of global warming.

Keywords

Temperature, Rainfall, Solar Activity, Geomagnetic Activity, Climate, Burkina Faso

1. Introduction

The variability of the Sun's activity has been the subject of several studies in recent decades [1]-[8]. These studies have significantly increased our understanding of the space environment and our knowledge of the basic sciences. We have also learned to use our space environment for a wide variety of applications, including navigation, communication, and day-to-day weather forecasting. These applications have profoundly improved the way our society operates and everyday life over the past two decades. Our thirst for knowledge about the phenomena governing the space environment has also enabled us to understand that the Earth and its environment are subject to various external influences, mainly that of the ultimate energy source on Earth: the Sun is not simply a source of energy with constant radiation, but a variable star, whose activity greatly influences the Earth's climate. This study, in connection with studies already carried out [9] [10] [11] [12] aims to further explore the links between geomagnetic activity, solar activity, associated energies, and climatic variability. Section 2 presents data and methodology. Section 3 presents and discusses our findings and Section 4 summarises the particularities observed.

2. Data and Methodology

In this study, several data were used: 1) temperatures and rainfall values from 1975 to 2020 obtained from the Burkina Faso meteorological department. These values are used to represent the temporal variations of the climatic parameters, 2) the daily values of the new sunspot number [13] are taken from http://www.sidc.be/silso/, 3) the solar wind speed, the PCI index, and the interplanetary magnetic field (IMF) are taken from https://omniweb.gsfc.nasa.gov/form/dx1.html. These parameters have been analyzed in previous work [7] [14]. The PCI index indicates magnetic activity in the Polar Regions [14]. Hourly cosmic rays data were obtained from the Thule Neutron Monitor Station (76.5˚N, 68.5˚W, 26.0 m) with a geomagnetic cut-off rigidity of 1.0 GV. All these data will be used for morphological studies of solar activity indices and climatic parameters.

3. Results and Discussions

Figure 1 and **Figure 2** show the profiles of variation of two climatic parameters: rainfall (mm^3) and temperatures (˚C) superimposed with the sunspots number from 1975 to 2020. **Figure 1** shows that the level of precipitation varies with the solar cycle and that the most important precipitations are recorded at the descending and minima phases of each cycle. **Figure 2** shows a gradual increase in temperature since 1975. From these two figures, we it is easy to notice that the most important rainfalls are accompanied by fluctuations in the temperature profile and the highest values of temperatures occur around when Sun gets its minimum activity. Similar observations have been made by [10]. **Figure 3** shows a good correlation between the sunspot numbers (Rz) and the interplanetary magnetic field (IMF). The feature of this figure is the highlighting of the existence of two peaks in the IMF variations during a given sunspot cycle. The first peak appears during maximum phase of the solar cycle, while the second takes

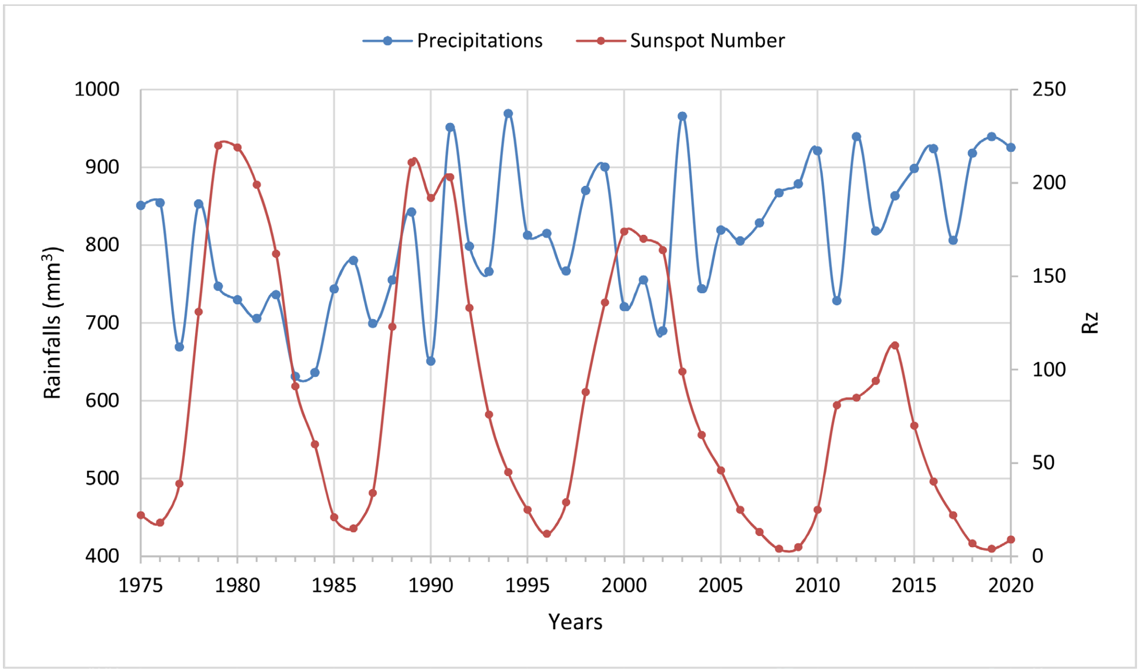

Figure 1. Profiles of rainfalls and sunspot number.

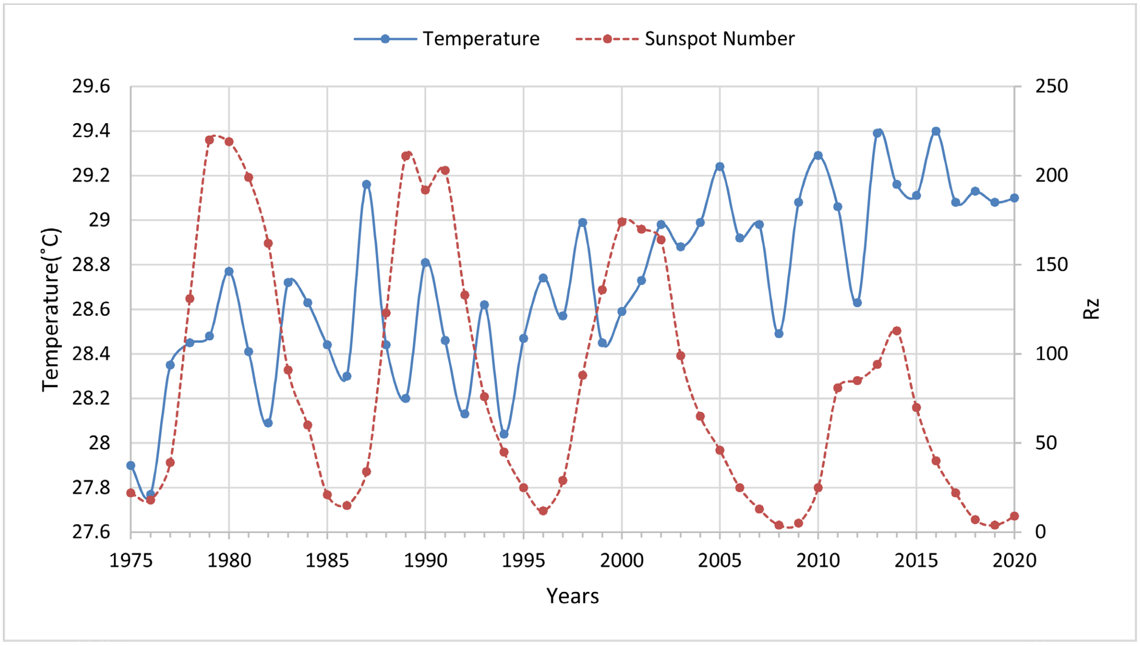

Figure 2. Profiles of temperatures and sunspot number.

place during the descending phase of the cycle as exposed by [15] [7]. These two peaks are the expression of the two components of the solar magnetic field (dipolar field, and toroidal one) widely analyzed by [15] [16]. **Figure 4** superimposes the temporal profiles of the solar wind speed and the IMF. This figure shows a close correlation between these two parameters of the solar plasma highlighting the phenomenon of solar dynamo. Referring to the work reported by [6] [17] on geomagnetic activity where it has been established that the intensity

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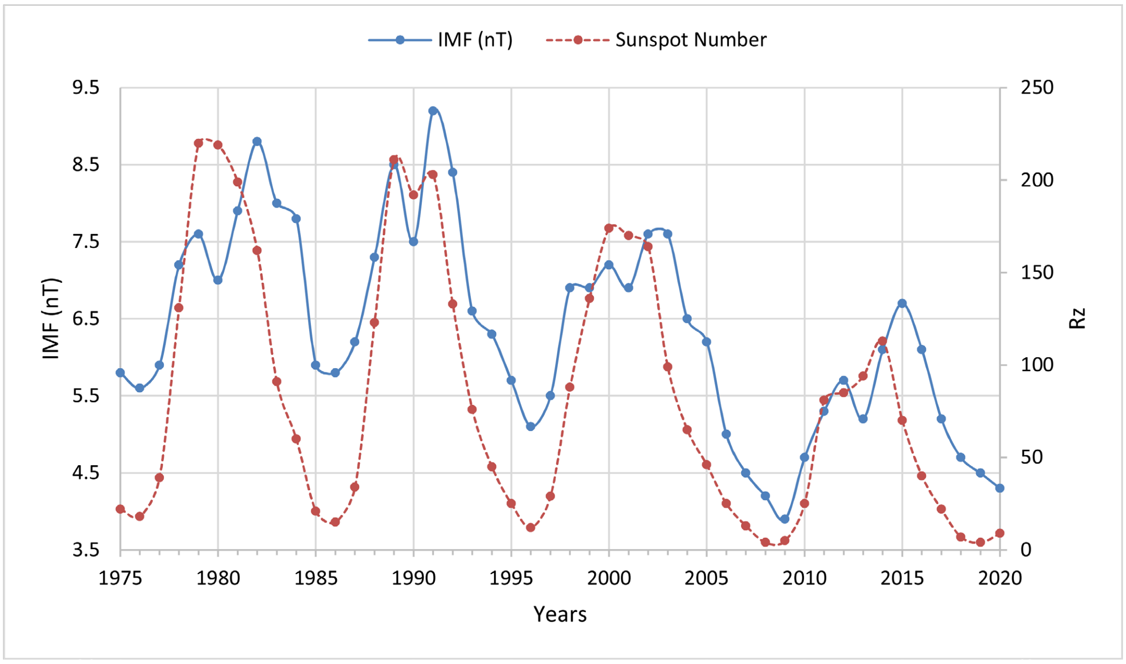

Figure 3. Profiles of interplanetary magnetic field (IMF) and sunspot number (Rz).

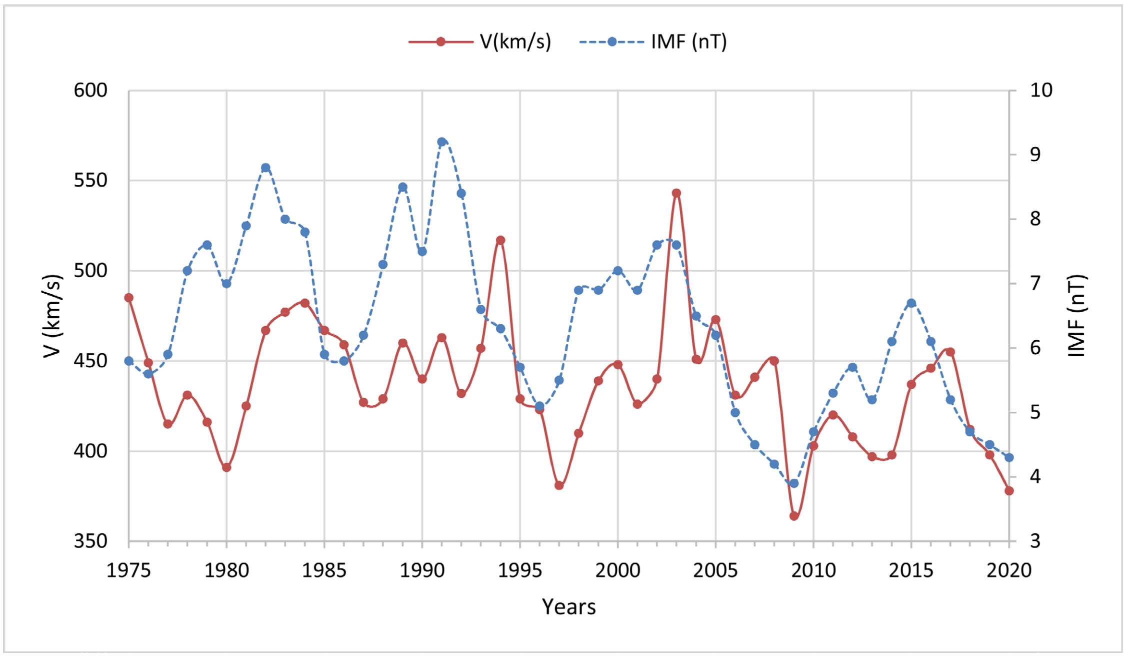

Figure 4. Profiles of solar wind speed (V) and interplanetary magnetic field (IMF).

of the interplanetary magnetic field (IMF) has doubled over the last century with a significant increase in the activity of the Sun, we can think that the temperature variations are related to the evolution of the interplanetary magnetic field and solar activity as stated by Solheim *et al.* [1] [10].

Figure 5 presents the variations of the PC index and IMF. A very good correlation between the interplanetary magnetic field and the PC index can be remarked. **Figure 6** shows the profiles of PC index and sunspots number. From

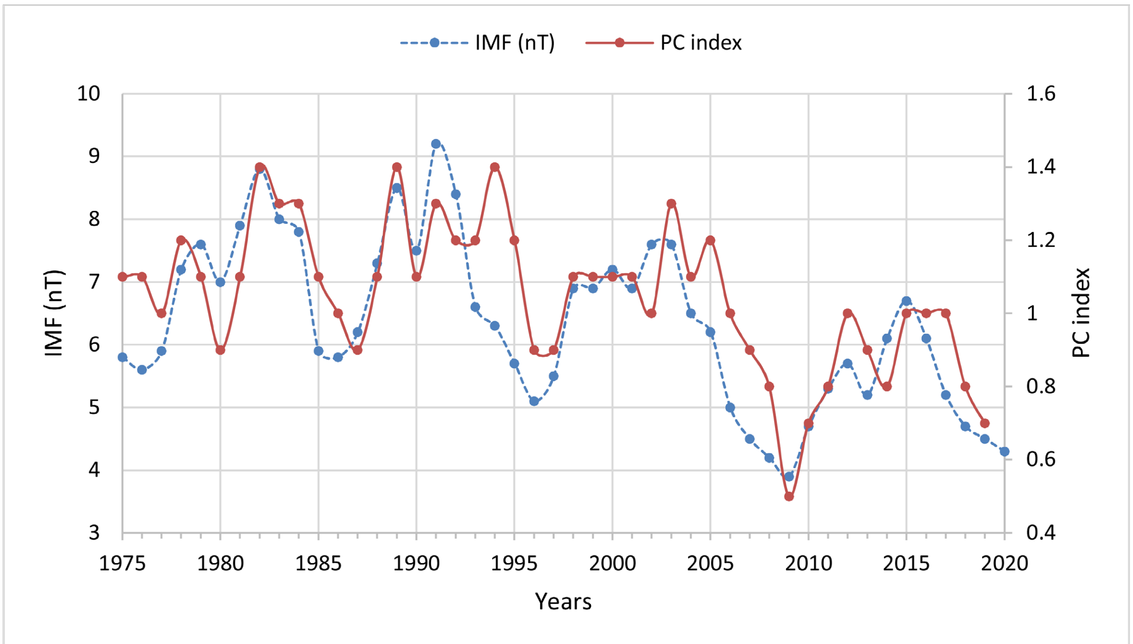

Figure 5. Profiles of interplanetary magnetic field (IMF) and PC index.

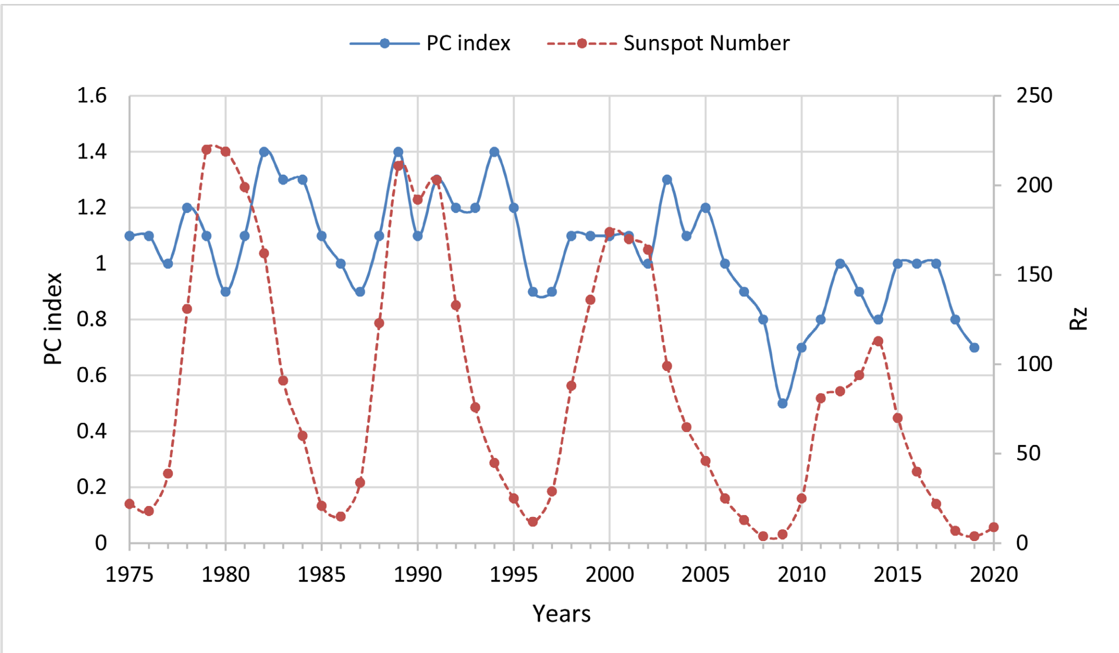

Figure 6. Profiles of PC index and sunspot number.

this figure, one can see that the highest peaks in the profile of the PCI occur more often during the descending phase of the solar cycle a few times around the maximum of solar cycle. These peaks could be associated to the fast wind flowing from coronal holes and to the coronal mass ejections (CMEs) characteristics of these two phases of a cycle [7].

Figure 7 superposes solar wind energy and joule heating over the last three sunspots cycles. It shows that the effect of joule heating in the interplanetary medium is closely related to the energy from the solar plasma carried by the solar wind (correlation coefficient 0.66). Figure 8 shows that precipitation (rainfalls) and joule heating have similar evolutions: precipitations are important when the joule heating is high. Figure 9 shows that the highest temperatures are recorded when the heating is less. Taking into account the good correlation existing between the joule effect and the energy of the solar wind shown in Figure 7,

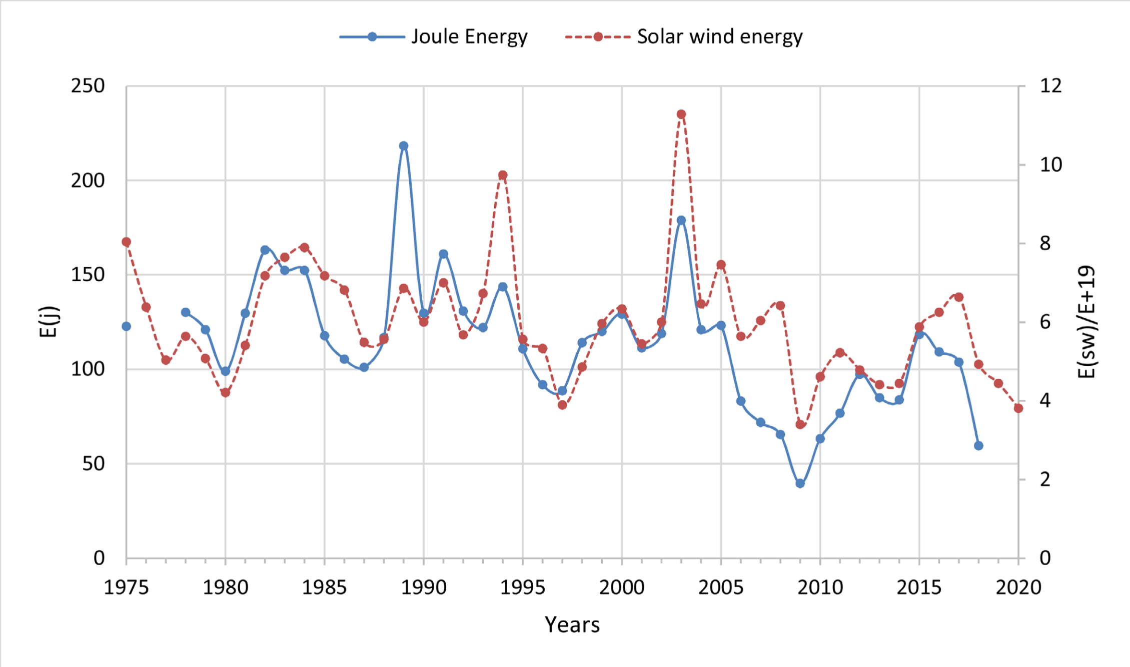

Figure 7. Profiles of solar wind energy and joule heating.

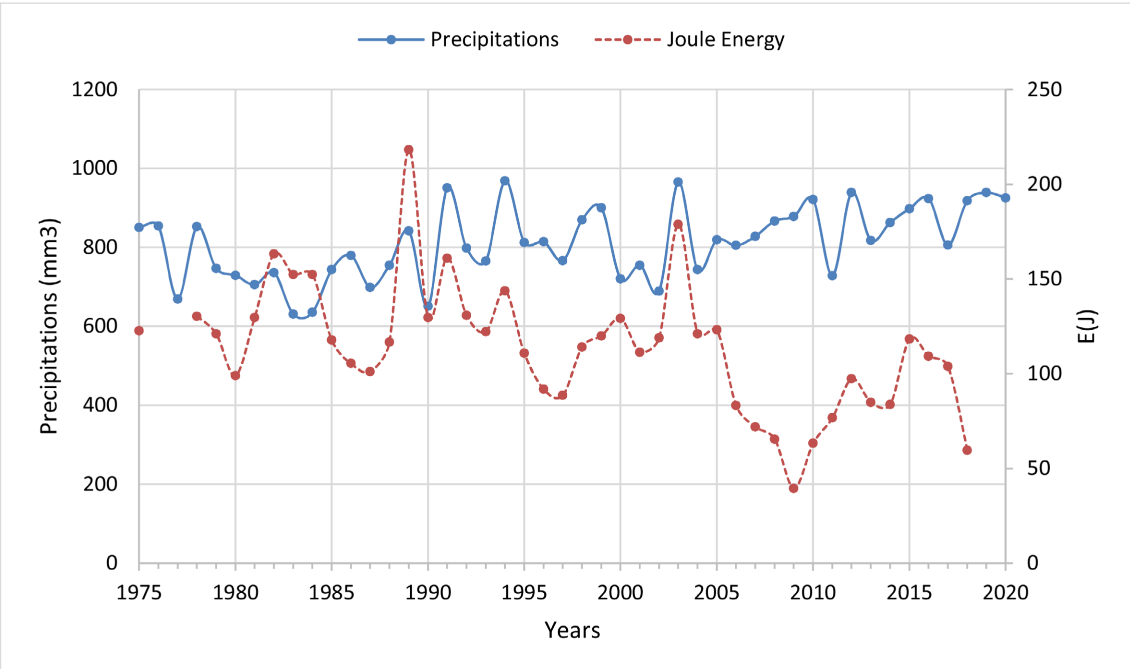

Figure 8. Profiles of precipitations and joule energy.

it appears clearly that the same observations as those in **Figure 8** and **Figure 9** will be made by superimposing the precipitation and the temperature on the solar wind energy.

Figure 10 shows the variations of cosmic rays during the last four the solar cycles. From this figure we can see that sunspots number and cosmic rays are anti-correlated (correlation index 0.8): the rate of cosmic rays is high when sunspot number is low. The propagation, modulation of cosmic rays as well as

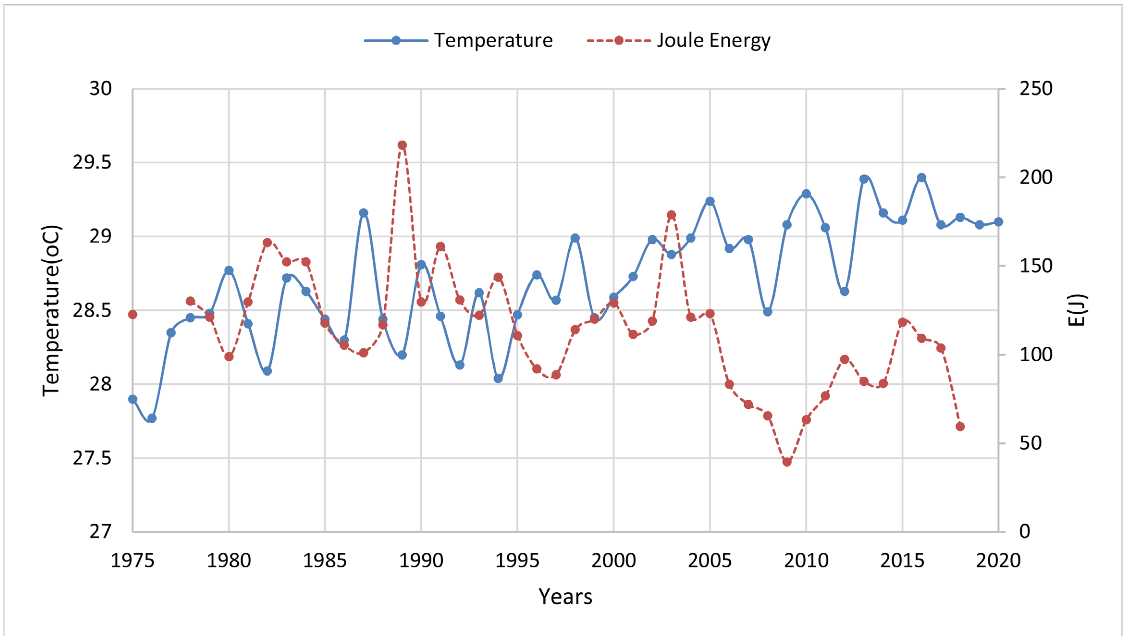

Figure 9. Profiles of temperature and joule energy.

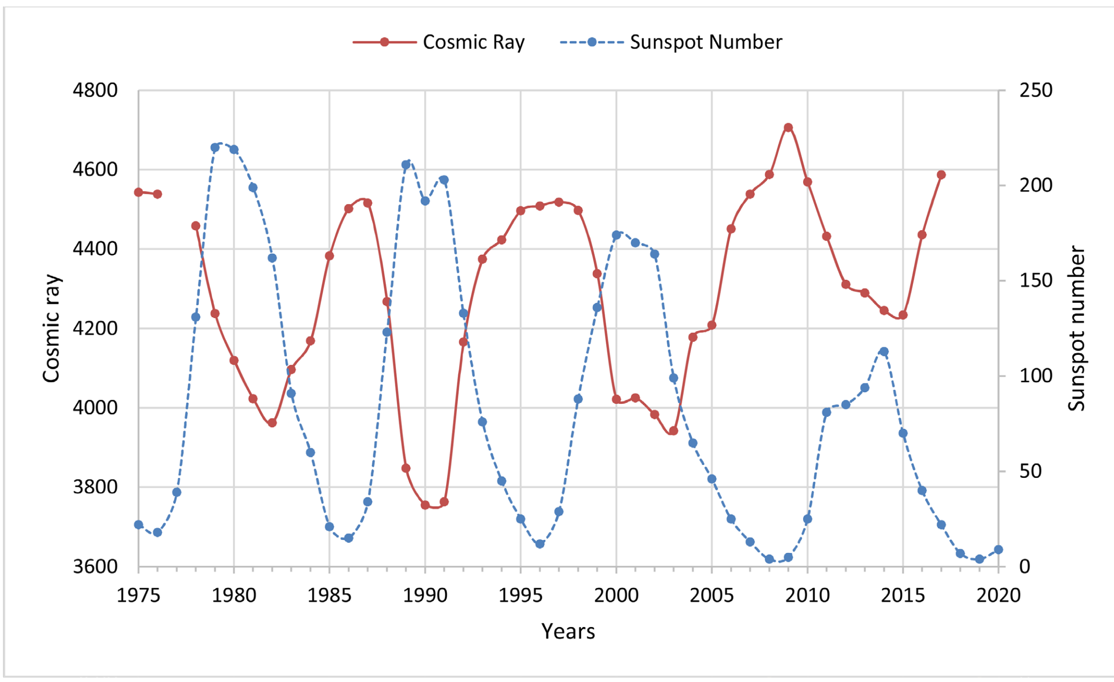

Figure 10. Profiles of cosmic ray and sunspot number.

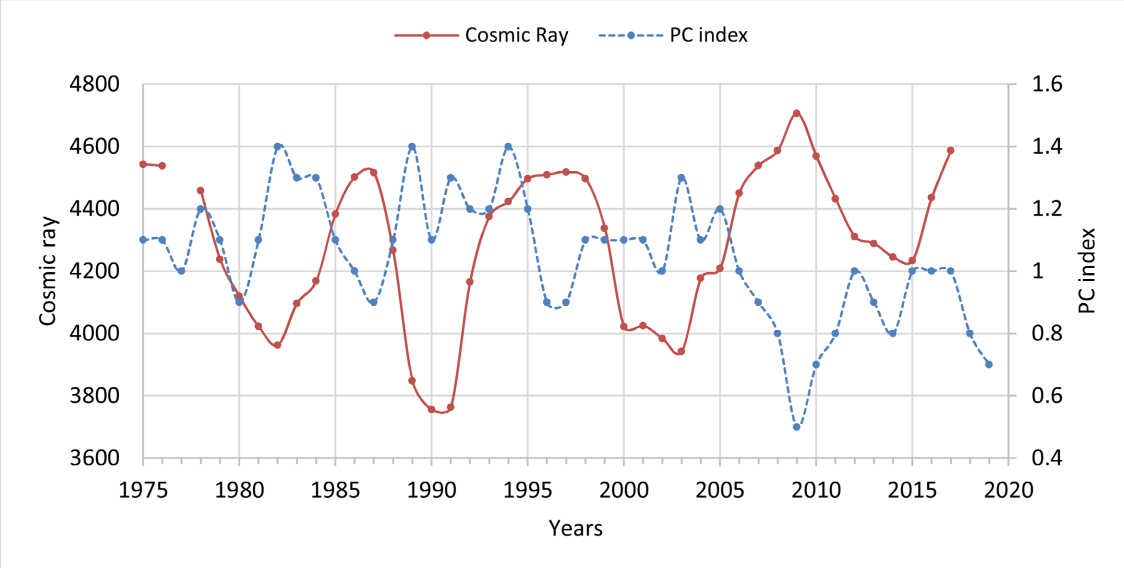

Figure 11. Profiles of PC index and cosmic ray.

their interaction with geomagnetic fields frozen in the solar wind and in coronal mass ejections accompanied by interplanetary shock waves are determined in the heliosphere [18].

Figure 11 shows the profile of cosmic ray versus PC index. One can see that geomagnetic activity is high when cosmic rays rate is low. From these two figures we can say that a decrease in solar and geomagnetic activity leads to an increase in cosmic rays in the Earth's atmosphere. Similar results were shown by [11]. In addition, their study allowed them to find a good correlative relationship between the flux of cosmic rays and the low cloud cover from 1983 to 1995 and the high cloud cover from 1995 to 2009. Cosmic rays may provide a link through which activity influences climate [19].

With a global overview and general analysis of the different figures according to different phases of solar cycle, we can underline important observations: at the solar minimum where calm activity is dominant, the flux of cosmic rays is high, precipitation is high and temperatures are low. This period is characterized by high solar plasma' density, and slow winds coming from the equatorial region of the Sun. During the solar maximum phase, the flux of cosmic rays decreases, precipitation and temperatures fluctuate due to changes in the magnetic field (dynamo effect). During this phase, coronal mass ejections are the most important events and dissipate a large amount of energy in the interplanetary medium. During the rising and decreasing phases where recurrent activity is predominant, cosmic ray flux increase (**Figure 10**), temperatures increase (**Figure 2**) and rainfalls decrease (**Figure 1**). Fast winds from coronal holes and the effects of the disturbing magnetic field characterize these phases of the cycle: quiet Sun causes significant cloud cover while the active Sun induces less cloud cover. **Figure 7** shows clearly that the energy dissipated in the interplanetary medium is closely related to that carried by the solar wind. From the correlations established between the energies of the solar wind, the joule heating, and the climatic parameters (rainfalls and temperatures), it appears that the activity of the Sun constitutes an important mainspring of the terrestrial climate as suggested by [2] [9] [10].

4. Conclusion

Earth's environment is dependent on solar activity. The morphological study of the parameters of the solar wind, the polar cap index (PCI), and the flux of cosmic rays, allowed us to point out interesting results on the effects induced by the agitation of the Sun in the Earth's atmosphere. Thus the level and the energy or thermal gradient of the Earth's atmosphere is a function of the joule heating and the energy the solar wind carries. These two types of solar energy are well correlated. Joule heating is important around the maximum and the descending phase of the solar cycle where high stream solar wind speeds are important. Just as the energy level in the atmosphere is a function of the agitation of our star, the variability in climatic parameters (heating or cooling) are: intense solar activity is linked to weak cloud cover; similarly, a calm Sun is associated with significant cloud cover leading to precipitation and cooling of the Earth's atmosphere ("active sun = few clouds; calm sun = many clouds"). These findings are a step toward understanding the possible role of Sun activity on climate change for future meteorological phenomenon forecasting even if the physical mechanism is still very poorly quantified.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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