International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

# Probable Effects of Solar Diameter Variations on Earth System Processes

**Uzmah Bilkees[1], Rajeev Kumar Singh[2]**

Department of Physics, Bhagwant University, Sikar Road, Ajmer-305004, Rajasthan, India

**Abstract:** ***Earth system processes (ESP) are an interconnected group of processes in which continuous changes are characterized through which material or energy flows. There is a remarkable difference between ESP on blue planet and other planetary neighbours as it shows cycling of matter comprehensively. The exclusive thermodynamic state of the blue planet i.e., Earth is a kind of special case thermodynamic equilibrium (TE) sustained with the help of these cyclic activities.In this study, we want to emphasize what are the probable effects of the solar diameter variations on the ESP. The Earth as known to us is a systemin a steady state with non-equilibrium. Energybalance in it is maintained by the solar radiation absorptionand terrestrial radiationemissionback into space. While looking at the equations and the data about the processes of variation of solar diameter, we can infer that the amount of irradiance on the surface of the Earth will also be affected.As it clear that the free energy degrading processes subsequently lower temperatures on the Earth. So we presume that the Earth system processes too will have an impact due to solar mass erosion and diameter variation.***

**Keywords:** Earth system science; Earth system processes (ESP); Sun; thermodynamic equilibrium (TE); Irradiance

## 1. Introduction

On the Earth, if numerous activities like burning of the biomass, downhill flow of water and mixing of the matter in different environmental systemswould go on without regulation; there would be homogeneity in the matter because of uniform mixing. Similarly, all the water will get assembled in the oceans and debris will loiter from all biomass on burning. With this scenario, all the processes would create “dead-earth state” devoid of any gradients to drive fluxes[1]. So, the absence of free energy will not be able to support life on the Earth. These are not the exclusive observations corresponding to these phenomenons, because there aremany processes in a similar direction in the Earth system albeit through time. Many of these examples including above three special cases are irreversible and happen spontaneously. Thermodynamics helps in understanding and quantifying the direction of the energy through the2nd law of thermodynamics. Extant understandable version of this law explains the direction in computable terms by making use of entropy as a measure for the absence of gradients and free energy[2]. A state of thermodynamic equilibrium (TE) is created with mitigating gradients and free energy sources. This situation creates a condition with maximum entropy of the system as well as surroundings. So, in such a state,mixing of the matter occurs finely and free energy doesn’t remain available tocarry out chemical reactions or to perform the physical work. The Earth system from these aspects doesn’t look like a “dead state” and appears to be a violation to the 2nd law of thermodynamics as well as the general trend of the systems. Queries that arise are what are the imaginable reasonsabout the Earth system that makes it possible to maintain itfar away from the final “dead state” of TE? Certain processes are to take place to generate gradients and sources of free energy in such a way thatdoes not violate the second law to avert such a ‘dead’ state of Earth. In order to keep these processesperforming physical and chemical work there is a need to create gradients to keep global cycling of matter going on in case of separation of matter, to yield wood out of ashes orto move water up-hill. The processes could be viewed and splittedinto two different ways in such a living state of the Earth system.One thatperforms the work continuously and creates free energy and another one that is irreversible ones that continuously produce entropy by dissipating it[1].

The ultimate driving force for the sustenance and operation of the dynamic state of earth systems processes comes from the absorption of solar radiation andsubsequent emission of terrestrial radiation towards space. This solar radiation provides the photochemical energy to perform photosynthesis, which in turn provides the major source of free energy to determine the fate of biogeochemical cycles within the Earth system. While consuming free energy the heat created iseventuallyemitted inlongwave radiation form into the space. The atmospherenon-saturated with vapour and with composition around 21% reactive oxygen provides the reflection of this state far from TE.This idea of an atmospheric composition which is far from TE ultimately construed as a signature of extensive life on the Earth and therefore led to theorigination of the controversial Gaia hypothesis[3, 4].

Without taking entropy exchange between the Earth system and space into consideration sustenance of such a state awayfrom TE is not possible. So this concept and trend far from TE can be associatedwith the proposedthermodynamic concept of maximum entropy production(MEP), which explains that the thermodynamic processesin non-equilibrium systemattain such steadystates when their degree of entropy production aremagnified and maximised[3]. In simple words, this implies thatthe subsequent thermodynamic state isprobablyaway from TE to the maximumextent. Seemingly non-equilibrium thermodynamics (NET) and the MEP principle might provide the foundation for the completeunderstanding of the nascent state of environmentaland ecological systems that are far from TE.

We are predicting that variation of solar diameter be it so small changes the solar intensity which would ultimately change thedynamic state of the earth and the earth systems processes. It has beenseen that while looking at the coronal mass ejection (CME) data[5]and astronomical studies the amount irradiance on the surface of the Earth will be affected. This in turn will affect the free energy degrading processes within the Earth system to maintain the MEP state.

## 2. Materials and Methods

All the data that has been used in this paper has been downloaded from extant literature resources of NASA, ESA and other international observatories. SOHO, a project between ESA and NASA has been used to archive dataregarding the solar irradance variability. The data availed was analysed in Microsoft Excel and by other platforms to draw the inferences of its significance in the Earth system processes.

## 3. Results and Discussion

**Solar diameter variations**

Solar diameter measurement variations have a contentious history with highly erraticstudies not in outright values but temporally as well. If we look at direct radius measurements from the seventeenth century to the present era there is a difference of more than two arcsec which continueeven in recent instantaneous measurements. On the specific issue of variability of intensity, the results are also not near to absolute.Specific variability has been seen with 1000(mas amplitude)in phase with solar activity to 200 (mas amplitude) inout ofphase to no significantchange[6].Precise anddurable measurements of the radius of the Sun arecertainlytough task filled with technical glitches in the stability and calibration of instruments. These variabilities have beenovercome by Solar Disk Sextant (SDS) design challenges by depending onbeam splitting wedge. The time dependent behaviour of the photospheric radius of the sun is a key limitation on solar structure models especially with regard to the evolution,locationand geometry of subsurface magnetic fields. Owing to diameter variations,it might have significant consequences regarding the effects of solar variability on climate change[7, 10, and 11]. It is pertinent to take more strides to authorize or explain the predictable changes reported in this paper to further improve the precisescale of the radius and to establish its temporal behaviour. This might require aseries of observations in longterm evaluations which are properly calibrated either from space or space like environments.

**Temperature on the surface of the Sun**

The different ways have been devised to calculate the temperature on the surface of the Sun. If we look at the method of using Stefan-Boltzmann constant (Equation-I) to calculate the surface temperature of the Sunis made:

$$T = (P/\sigma A)^{1/4} = (S4\pi D^2/\sigma 4\pi R^2)^{1/4} = (SD^2/\sigma R^2)^{1/4} = 5775.8\ K) \quad (I)$$

Where,

$\sigma = 5.67 \times 10^{-8}\, W/m^2K^4$ i.e., Stefan-Boltzmann constant

$S = 1367\ W/m^2$ (solar constant)

$D = 1.496 * 1011m$ (Earth-Sun average distance)

$R = 6.963 * 108m$ (radius of the Sun)

From this equation-1, it is clear that is there are mass shedding processes like nuclear fusion and solar wind processes are non-stoppable and occur continuously in the sun. There are likely chances that it might have an effect on the diameter of the sun. So it will affect the surface temperature of the Sun and there by the amount of Irradiance that comes in the Earth system. As this system of calculating the temperature vary as well.

The spectral density emitted by a black body (Sun) in the range of electromagnetic radiation with in thermal equilibrium at a particular temperature predicts spectral radiance of the body in different frequencies, also known as Planck's law. The Planck's law shows the amount of wavelength emitted by a perfect black body via predictions from experimental curve as well as the theoretical curves. These fitting curvesare predictedby these calculations for the sun's surface temperature at around 5800K[8]. Let's see how the work is performed by Earth system processes onfree energy sourcedegradingto produce entropy. Forinstance, the friction reduces the circulation in the atmospheric surface.Continuous input of work is required to maintain a steady-state circulation.Thework for driving this atmospheric circulation is gainedfrom the temperature gradient between equator and poles. The relegation of the energy and production of entropy is formed with the associated transport of heat from warmer to colder regions. The global hydrological cyclein the atmosphere is driven by the energy transformationsconnected with evaporation of water from warmer surface into the water unsaturated atmosphere and itssubsequent condensationat a cooler temperature. The life too requiresfree energy sources to create and maintain complex organisms. The threeparticular examples are highly interactive and do not operate in isolation.Condensation of water is frequently created by the ascending motion in the atmosphere which leads to cloud formation. There is high correlation among the humongous formsof precipitation and uplift. These cited examples compriseconversions of different forms of energy which are directed by the lawsof thermodynamics. It asks a scientific query on whether the thermodynamics can provide us with meaningful insights about the operation of the dynamic earth system at a macroscopicor planetary scale and the how it maintains its steady-state. The foundation of the classical thermodynamics relies on the 1$^{st}$and 2$^{nd}$law of thermodynamics. Total energy of an isolated system remains conserved is conveyed by 1$^{st}$law and the entropy of an isolated system keeps on increasing is stated by the 2$^{nd}$law. Entropy production formulation via 2$^{nd}$law dictates that the free energy of an isolated system with the passage of time is unceasinglydowngraded by diabatic processes.

Consequentially it leads to an equilibrium state of MEP. In statistical interpretationdirection togreater entropy can also be construed as a shift towards more probable states.

Most systems thoughare not isolated and trade-off matter andenergy with in their environment. For example earth exchanges its energy with the surroundings by radiation of different wavelengths. Systems which are in non-equilibrium and not isolated state also find applicability of the interpretations from classical thermodynamics. However when exchanging energy with dissimilar entropy or massfrom end to endin the system frontier, these systems uphold states which does not symbolize thermodynamic equilibrium. For these systems, 2$^{nd}$law of thermodynamics takes the form of continuity equation. In such situationtotal change of system entropy is determined from the local surge in entropy within system and the entropy flux conjunction, which is net flux of entropy across the system boundary:

$$\frac{ds}{dt} = \frac{ds_1}{dt} + \frac{ds_E}{dt} \qquad \text{(II)}$$

With no change of the internal entropy 'S' of the system in steady state, the production of entropy within the system σ leads to the increased balances in the net flux of entropy acrossthe system boundary. The second law in this situation then states that a non-equilibrium system can maintain a state of low entropy by neglect high entropy fluxes out of the system.

**Solar Temperature Effect on the Entropy Production of Earth's Climate System**

Earth is considered as system in non-equilibrium and a steady state condition. When the absorption of solar radiation is balanced by the emission of terrestrial radiation, energy balancecreated at the planetary scaleis given by the following equation,

$$I_o\,(1\text{-}\alpha P)\text{-}\sigma_B T_R{}^4{}_{=}0 \qquad \text{(III)}$$

$I_{o,}$is the net-flux of solar radiation, σ is the Stefan-Boltzmann constant, α being the planetary albedo and $T_R$is effective radiative temperature[9]. With the use of extant values for the earth, one obtains a net radiative temperature of $T_R$= 255 K

The passage of the flux of energy via earth system is subsequently downgraded to lower temperatures which lead to entropy production(Figure 1).

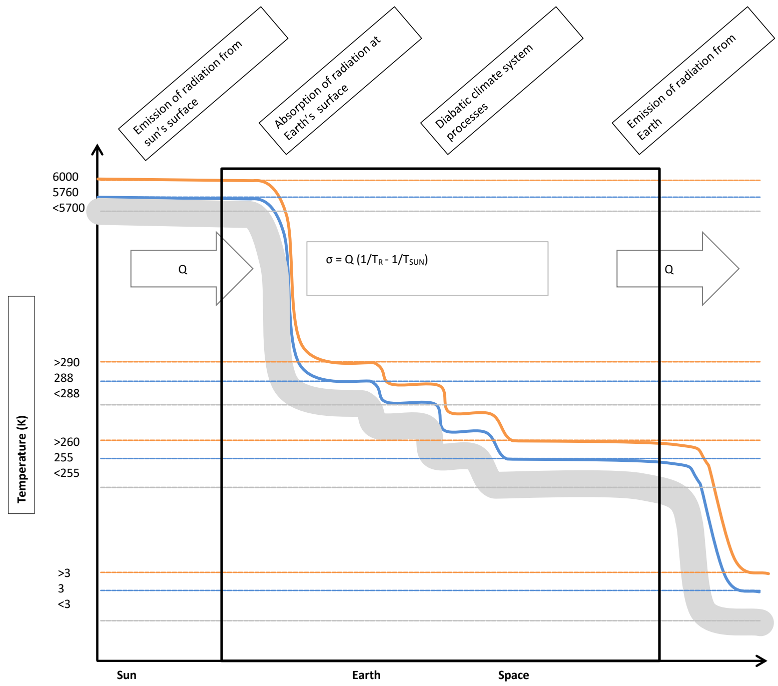


**Figure 1**: Free energy degradation by processes within the Earth system to subsequently lower temperatures shown by schematic diagram. Orange Yellow color represents the free energy status when surface temperature of the sun as 6000 K, Blue color represents the free energy status when surface temperature of the sun as 5760 K, Dark grey band represents with further decrease in the surface temperature of the sun <5700 due to decrease in the diameter of the sun owing to processes of nuclear fusion, solar wind and certain other unrecognised processes

A high radiative temperature of the Sun (~$T_{SUN}$ $_{=}$5760)emitted by solar radiation represents a flux of low entropy. It consists of a flux of photons of high energy. The energyemitted is concertedon reasonably few photons each having a huge amount of energy. While solar radiation is absorbed at the surface of the earth at a surface temperature of roughly $T_S$= 288 K, the amount of entropyproductionis:

$$\sigma RAD = Q\,(1/TS - 1/TSUN) \qquad \text{(IV)}$$

Extent of radiation absorbed is'Q'. Additionalconversions of the energy occur at subsequently lower temperatures. Forinstance, energy reductionfrom the surface at a temperature $T_S$occurs through latent heat flux and is released to the atmosphere at a $T_A$(lower temperature), which leads to entropy production in the amount of:

$$\sigma LH = QLH(1/TA - 1/TS) \qquad \text{(V)}$$

In same way these phenomenons likethe absorption of terrestrial radiation in the atmosphere, the sensible heat flux and the transport of heat from warmer towards colder regions by the atmosphere and oceans also add to the entropyproduction. Eventually the absorbed solar radiation is re-emitted back into space as terrestrial radiation at unevenlyradiative temperature ($T_R$). In contrast to solar radiation, this radiation is emitted from the earth at a much inferior temperature. This represents a flux of photons of less energy and high entropy. The overall entropy production of the Earth system can be projected from the difference of entropy fluxes across the Earth-space boundary:

$$\sigma_{TOT} = I_o(1\text{-}\alpha P)(1/T_R\text{-}1/T_{SUN}) = 900mWm^{-2}K^{-1} \qquad \text{(VI)}$$

We predict here that all these calculations will vary significantly if there is a variation in the diameter of the sun.

As explained that change in diameter be it small leads to small change in the surface temperature of the sun. We have observed with technological advances corrections in the sun's surface temperature has been observed which varies from 6000 K to 5760 K. We assume that if due to solar processes like nuclear fusion, solar wind processes and solar flares masses are lost which leave negligible effect but not zero on the sun's size. Accordingly we have taken into account that these changes will be observed down to earth system processes which relay wholly on the solar irradiance phenomena's. To make it understandable visually we have encompassed all the possible changes in the pictorial form in the figure 1.

## 4. Other events on the Surface of the Sun that might change Irradiance

The surface of the sun releases the energy in the form of photons, energetic particles, and magnetic fields. All of these have a determinate impact on theearth or space near to earth. It is well known that the sun's radiant energy is the primary source of the energy to the earth.The radiation is measured as whole is called the Total Solar Irradiance (TSI) and the spectral irradiance when measured as a function of wavelength. The importantsources of space weather are solar eruptions which include CMEs and flares, fast Solar wind and solar energetic particles (SEPs). All these are the representation of the energetic phenomenons occurring on the sun. Closed magnetic field structuresnormally found in active regions and quiescent filament regions are considered to origins of flares and CMEs on the sun.Fast solar wind on the other hand originates on the sun's open field regions and iswell-known ascoronal holes. The energetic particles are associated with the flares,CMEs, and fast solar wind but the energetic particles accompanying with CMEs are the most intense. Theseenergetic phenomenons are significant for heliosphere and contribute considerably to combative space weatheras well as the climate of the Earth[12].

## 5. Conclusion

Earths system processes rely on the dynamic interaction with solar activities carried in the sun. Temporal behaviour of photospheric radius of the sun is a key constraint to model the different process that occur on the earth right from climate including temperature and humidity balance and MEP models which also relay the solar irradance. So the radius variations in the sun might have significant consequences regarding the effects of solar variability on climate change. For a better understanding and prediction of the earth system dynamics MEP is an interesting idea as well as highly relevant. Importance of studying the sun with state of art technologies is very important to have thorough understanding of its interconnecting dynamics with the Earth. For the same purpose organizations like NASA, ISRO, ESA, NOAA, CNES and other well-known agencies are developing missions to understand the Sun properly. Some of the active missions to study the sun are the Deep Space Climate Observatory (DSCOVR), PICARD,Advanced Composition Explorer (ACE), Solar Monitoring Observatory (SOLAR/SMO),Solar Terrestrial Relations Observatory (STEREO), Solar Dynamics Observatory (SDO),Solar and Heliospheric Observatory (SOHO), Hinode (Sunrise),Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) and Global Geospace Geoscience (GGS) WIND. Missions planned by different organizations for the future are Solar Orbiter, Solar Probe Plus,Aditya-1 and Solar Sentinels. All these missions have one thing in common to study the Sun and some of these are specific for the purpose of Sun-Earth dynamics and effects on the life on Earth. With the meagre data available regarding the dollar diameter and variables of the sun, we can't fully understand and extrapolate the changing effects on the process that are subject to solar irradiance. Hopefully, with all these missions in progress we might develop a beautiful understanding of the Sun's chemical composition, changing features, CME, solar flares, solar winds, nuclear fusion and diameter variation. All these phenomena's will ultimately provide us better knowhow of the Earth system processes.

## 6. Acknowledgement

I thank Mr. Mohd Saleem Darin helping me framing the idea and acquiring the relevant data from observatories and the papers regarding the idea.

## References

[1] Kleidon, A. (2010). A basic introduction to the thermodynamics of the Earth system far from equilibrium and maximum entropy production. *Phil. Trans. R. Soc. B.* 365: 1303-1315.
[2] Iqbal, N., Masood, T. and Demir, N. (2015). Entropy change and phase transitions in an expanding Universe. *Astron. Nachr*.336: 1025-1032.
[3] Kleidon, A. (2004). Beyond Gaia: thermodynamics of life and earth system functioning. *Clim. Change.* 66: 271–319.
[4] Lovelock, J. E. and Margulis, L. (1974). Atmospheric homeostasis by and for the biosphere: the Gaia hypothesis. *Tellus*. 26: 2-10.
[5] Uzmah, B. and Singh, R.K. (2018). Solar intensity variation due to coronal mass ejection over a long range time period. *International Journal of Science and Research*.7:11.
[6] Djafer, D., Thuillier, G., Sofia, S., Egidi, A. 2008. Processing Method Effects on Solar Diameter Measurements: Use of Data Gathered by the Solar Disk Sextant. *Solar Physics*. 247: 2:225.
[7] Rozelot, J. P. and Damiani, C. (2012). Rights and wrongs of the temporal solar radius variability. *European Physical Journal H.* 37, 709–743.
[8] Planck, M. (1914). The Theory of Heat Radiation. Masius, M. (transl.) (2nd ed.). *P. Blakiston's Son & Co*.
[9] Kleidon A., Zehe E., Ehret U., Scherer U. (2014). Earth System Dynamics Beyond the Second Law: Maximum Power Limits, Dissipative Structures, and Planetary Interactions. In: Dewar R., Lineweaver C., Niven R., Regenauer-Lieb K. (eds) Beyond the Second Law. Understanding Complex Systems. Springer, Berlin, Heidelberg
[10] Rozelot, J.P., Kosovichev, A.G., Kilcik, A. (2016). A brief history of the solar diameter measurements: a critical quality assessment of the existing data. *arXiv*. 1609.02710.

[11] Rozelot, J.P., Kosovichev, A.G., Kilcik, A. (2018). How big is the Sun: Solar diameter changes over time.*arXiv*.1804.06930.
[12] Tsuda, T. Shepherd, M., Gopalswamy, N. (2015). Advancing the understanding of the Sun-Earth interaction—the Climate and Weather of the Sun–Earth System (CAWSES) II program. *Progress in Earth and Planetary Science*. 2:28.