

GLOBAL DIMMING: ITS CAUSES, IMPACTS AND SOME POSSIBLE CONTROL MEASURES

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Received: October 2016 Revised accepted: October 2016

ABSTRACT

Sun is the source of all energy available on earth. The amount of solar radiation reaching the earth's surface gradually declines, termed as "Global dimming". Changes in pan evaporation, diurnal temperature range (DTR) and transmissivity of the earth's atmosphere support the incidence of global dimming. Global dimming is mainly caused by increased amount of particles (aerosols) in the air which can be determined by the aerosol optical depth (AOD), increased cloud thickness and cloud cover due to sea ice melting and changes in the land use. The albedo (short wave reflectivity) of the earth is increased by non-BC (black carbon) aerosols such as sulfate, nitrates and organics in atmospheric brown clouds (ABCs) which result in an increased amount of reflected radiation to the space. Albedo of the cloud is also increased as the non-BC aerosols nucleate cloud drops which is known as "cloud-albedo-effect". Volcanic eruptions and desertification also add large amount of aerosols and dusts respectively in the earth's atmosphere. Global dimming results in some ecological problems viz. changes in hydrological cycle, rainfall pattern and rate of photosynthesis. It sometimes causes drought, failure of monsoon and decrease or absence of seasonal rainfall in northern latitudes. Solar radiation controls photosynthesis by controlling the opening and closure of stomata and by maintaining CO₂ concentration. Nevertheless, global dimming also harms human health indirectly. Thus actions could be taken to control this phenomenon due to its direct and indirect impacts on global ecosystem. By cultivating photo insensitive crop varieties we can minimize the adverse effects of global dimming on photosynthesis. Air pollution can be controlled by using some alternative fuels and strictly regulating the emissions from industries thereby lowering the aerosols content in the atmosphere and by these we can escape from the ill effects of global dimming.

Keywords: Aerosol optical depth, agricultural productivity, black carbon, global dimming, pan evaporation

INTRODUCTION

Sun is the ultimate source of all energies available on the Earth and solar energy is the primary factor for photosynthesis in green plants and survival of all living entities in the biosphere of the Earth. Solar radiation or global radiation has two components namely direct solar radiation and diffused solar radiation or sky radiation. Changes in any component of solar radiation significantly influence the global ecosystem. Many long terms independent researches mainly indicate that there is a gradual decline in the global radiation both in direct and diffused components, termed as global dimming, also known as solar dimming. Several studies show the reduction in the insolation, measured mainly by thermopile pyranometer. Global dimming has occurred since 1950. Dimming has been estimated for the period 1950-1980 as compared with earth's solar radiation budget. The reduction in the surface radiation varies by location and this is more prominent in large urbanized areas. Global dimming is caused by some natural and anthropogenic reasons and it results in some environmental and ecological problems which will be discussed later in this paper. Gradual reduction in global irradiance or emittance may lead to climate change which affects the Earth's life.

DIRECT EVIDENCES OF GLOBAL DIMMING

Over the land surface decreased insolation has been observed for the period 1958-1985 (Stanhill and Moreshet, 1992). Significant reduction in the solar radiation was observed over a large area of Africa, Asia, Europe and North America during 1964-1993 (Gilgen et al., 1998). In the polar region, dimming had also taken place (Stanhill, 2005). Over India, dimming was observed during the period 1981-2004 (Padma Kumari et al., 2007).

INDIRECT EVIDENCE OF GLOBAL DIMMING

Occurrence of global dimming is supported by significant changes in the diurnal temperature, pan evaporation and the transmissivity of the Earth's atmosphere. Earth's surface becomes heated by absorbing solar radiation and atmosphere becomes heated mainly by the convection of heat energy from earth's surface into the atmosphere and that's why diurnal temperature range is a measure of solar radiation reaching the earth's surface (Bristow and Campbell, 1984, Thornton and Running, 1999). Aircraft contrails are one of the major potent global dimming causing material and an increased diurnal temperature variation can be observed if the concentration of the aircraft contrails is reduced in the atmosphere which was observed during the three days after 11th September, 2001 attacks in United States when the civil air traffic was almost shutdown.

Solar energy is the main driving force for transforming water from liquid to vapour state. So reduction in the solar radiation decreases the supply of energy for evaporation and thus lowers the amount of pan evaporation. Long time research works have shown the reduction in the pan evaporation in some parts of India (Chattopadhyay and Hulme, 1997), Australia (Roderick and Farquhar, 2004) and China (Thomas, 2000).

Increased amount of particulate matter suspended in the atmosphere increases the amount of reflected solar radiation to the space. This suspended materials cause smog (mixture of smoke and fog) in the large industrialized areas and thus the transmissivity of the atmosphere at those areas is decreased by which the insolation is obstructed from reaching the Earth's surface. Thus reduced transmissivity of the Earth's atmosphere is an indirect measure of reduced solar radiation.

CAUSES OF GLOBAL DIMMING

Global dimming is believed to have caused by a number of reasons viz. increased aerosol load in earth's atmosphere, increased cloud thickness and cloud cover etc. There are many types of sub micron sized particulate matter suspended in the air such as dusts, sulfates, nitrates, organics etc., termed as aerosols, which are emitted from industries and vehicles and reflect the incoming solar radiation back to the space. Due to many anthropogenic activities aerosol load in the Earth's atmosphere has increased. So the amount of reflected radiation is also increased and consequently the global irradiance has reduced. It has been observed that dimming is also a consequence of black carbon (mixture of elemental carbon and organic carbon compounds formed during fossil fuel combustion, bio-gas burning, burning of wood etc. which mixes with other particles in the air and forms the atmospheric brown clouds) over a large area on the earth's surface. Atmospheric brown clouds cause reduction in irradiance by scattering the insolation. Black carbon causes heating of the atmosphere by absorbing direct solar radiation as a result of which surface dimming is occurred. One of the most important sources of aerosols in the air is the aircraft contrails also known as vapour trails which cause dimming by reflecting the insolation. Due to increasing population, industrialization, urbanization the concentration of aerosols is gradually raised which is determined by the aerosol optical depth. It has been observed that dimming is more prominent in highly populated and

industrialized areas as compared to the sparsely populated areas mainly due to the fact that the aerosols concentration in the densely populated and industrialized areas are far more than these in other areas.

Volcanic eruptions add large amount of particles (ash) mainly sulfates in the atmosphere. Volcanic ashes reflect incoming solar radiation and thus after large volcanic eruptions temperature decrease over the earth's surface has been noticed. Desertification increases the dust load in the air and increasing number of dust storms carries a large amount of airborne particles across the continents. Incoming solar radiation is scattered and reflected by the dust particles present in the atmosphere as a result of which albedo (short wave reflectivity) of the earth's atmosphere is increased which is a major cause of global dimming.

Global dimming is also caused by reflection of incoming solar radiation to the space by the clouds. The particles having the potentiality to reflect a large amount of insolation serve as the condensation nuclei for the formation of cloud drops. As the concentration of aerosols in the atmosphere is increased day by day the particle content in the clouds is also raised which makes the clouds more reflective i.e. albedo of the clouds is increased which is known as "cloud-albedo effect". Different types of high altitude clouds like cirrus, cirro stratus, cirro cumulus are mainly composed of ice crystals having the highest albedo. Due to increased sea-ice melting and exposing open ocean cloud cover and cloud thickness is increased and thus the amount of ice crystal in the cloud is also raised in the upper altitude. So the albedo of the clouds is increased. Thus the amount of reflected radiation is increased and thereby insolation is declined.

IMPACTS OF GLOBAL DIMMING

Global dimming interferes with the global hydrological cycle. The mid-latitude zone in the northern hemisphere is the major urbanized and industrialized zone in the world. ABCs are observed over these areas. Due to induced absorption and scattering of insolation the clouds become brighter (IPCC, 2007) which results in less precipitation from the clouds. So rainfall amount is reduced. This also affects the fresh water availability on Earth's surface adversely. Due to global dimming the land and sea surface temperature is changed and consequently the regional circulation patterns are disrupted. As for example global dimming exerts a cooling effect over the higher latitudes in the extra tropical areas in the northern hemisphere and due to the cooling effect the low pressure belt cannot be too strong to pull the monsoon current up to its northern latitude. This results in lowering or absence of seasonal rainfall in those areas and this causes droughts which cause a great threat to the irrigation resources. Global dimming leads to a less amount of evaporation, thereby less cloud and rainfall. On the other hand, due to less precipitation from the ABCs the pollutants remain in the atmosphere and later form acid rain which is a great threat to the global ecosystem.

Global dimming is harmful for agricultural productions. Solar radiation controls the opening and closure of stomata in plant. Lesser insolation may results in partial closure of the stomata and thus photosynthesis and respiration are hampered and net assimilation rate is also affected. Due to partial opening or closure of stomata transpiration is lowered as a result of which temperature of the plant canopy is raised and plants become stressed. Besides diffused radiation constitute a major portion in the photosynthetically active radiation (PAR) wave band (400-700 nm). So photosynthesis and thereby agricultural productions are adversely affected due to the reduction in the diffused component of the global radiation. Carbon assimilation by plants is also hampered in reduced light intensities and thus global dimming affects carbon cycle.

Global dimming has a positive impact also. It reduces rate of evaporation and thus chance of water stress is decreased in the crop field. Thus in the areas where water is the limiting factor for plant growth, global dimming exerts a beneficial effect.

Solar radiation is an important source of renewable energy. If the intensity of the incoming solar radiation is decreased, the power generated on the solar panel is affected. Thus global dimming adversely affects the proper harvesting of solar energy.

SOME POSSIBLE CONTROL MEASURES OF GLOBAL DIMMING

To control global dimming we have to reduce the increasing aerosol concentration in the atmosphere. By using renewable energies, alternative fuels (bio-fuels), public transportation and by strictly regulating the industrial emissions we can control the increase in the aerosols content in the air.

We may go for cultivating photo insensitive crop varieties so that the reduced intensities of solar radiation cannot harm the crop production. In the areas where global dimming causes lowering of seasonal rainfall, drought tolerant crop varieties can be cultivated. Irrigation resources should also be improved by enhancing the water harvesting to minimize the harmful effects of global dimming on food production.

CONCLUSION

Though global dimming may be referred to as a counterpoint to global warming, it is a great danger to the earth's environment. It is caused mainly by increasing aerosol content in the atmosphere and consequently it affects the global hydrological cycle and food security. Global dimming is an emerging problem in the field of climate change and there is a great scope in future for research for finding the causes and mitigation strategies.

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