

Environmental Effect of a Solar Eclipse



What Happens, When the Solar Radiation Changes?

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1 When Solar Radiation Changes

The climate of the Earth is highly influenced by the radiation of the Sun. In a short period—some million years—it has no change, just small variations occur. Any little change in the solar radiation has an effect on the Earth. In this section we will study a couple of examples about this problem, due to natural circumstances in the celestial space, higher atmosphere (volcanic aerosols) or anthropogenic processes [1–4].

[AQ1]

1.1 Ice Ages, Glacial, Interglacial Periods

We have evidence of climate changes in the history of the Earth, about “ice ages” and warmer periods. In the present we live in an interglacial period of an ice age, started 33.5 million years ago. Interglacial period means a warmer period within an ice age, glacial period means a cooler period. We know 6–7 great ice ages from the history of Earth, with several glacial and interglacial periods [5].

There are several—sometimes not fully understood—reasons why ice ages and glacial, interglacial periods occur, like atmospheric composition, tectonic plate motion, volcanism, orbit and obliquity of the Earth, large meteorites, etc. One of them is Milutin Milanković’s theory, presumed that glacial periods are influenced by astronomical reasons. These changes influence the solar radiation touching the Earth’s surface at a given geographical latitude [1, 6]. Periods based on this theory (approximately 100,000 years) were clearly detectable at 140 million-year-old (Jurassic period) limestone layers from sea animals, whose life was influenced by the climate change [7].

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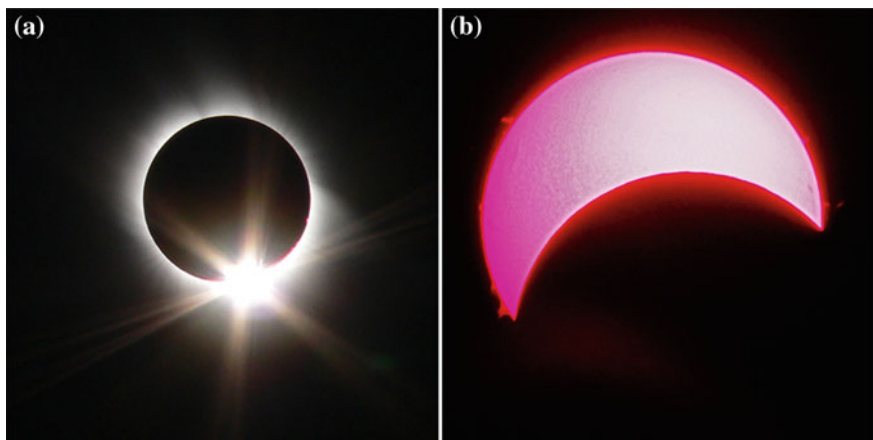


Fig. 1 **a** Total solar eclipse with diamond ring effect from Turkey, 29th March, 2006 (Photo by Z. Mitre). **b** Partial solar eclipse through hydrogen-alpha telescope from Hungary, 20th March, 2015. We can recognize some solar prominences (from sunspots) all around the edge of the Sun (Photo by Z. Mitre)

1.2 Sunspot Cycles, Clouds, Climate

Sunspots are dark, temporary, colder areas on the photosphere of the Sun, with intense magnetic activity. Most solar flares, prominences and corona mass ejections originate from around sunspot groups, these ejections cause geomagnetic storms on the Earth (Fig. 1b). Their number on the Sun varies in a period of 11 years, it is called solar cycle or solar magnetic activity cycle.

There is also a longer-period trend in the activity of the Sun. These are the great minimum and maximum periods, which last for decades. Of course these long periods also contain the 11-years cycles. The average number of sunspots is lower during the minimum periods, and higher during the maximum periods [4].

There is a hypothesis, which says the solar cycles have an effect to the Earth's climate through the cloud formation [2, 4]. Cosmic rays from the universe help the chemical reactions to produce aerosol for cloud formation. Stronger magnetic activity of the Sun during sunspot maximum reflects more cosmic rays than in sunspot minimum. A decrease in cosmic radiation reaching the Earth results in less clouds in the atmosphere, and thus more solar radiation reaches the surface [8].

From the 13th century till the 18th century there was a long colder period ("Little Ice Age"), when the solar activity was lower, than now. During this period more cosmic rays reached the Earth, more clouds formed, less solar radiation touched the ground. There was a period during the 10th century with intensive solar activity, less cosmic rays reached the Earth. Climate of the Earth was warmer, for example the Vikings reached Greenland this time, which was really green, with more vegetation diversity and less ice than now [9].

1.3 Volcanic Aerosols in the Atmosphere

It seems the Little Ice Age has another reason too, related to the volcanic activity, and influenced the climate more than the sunspot minimum. When a volcano erupts, a huge amount of ash rises to the higher atmosphere and covers the whole Earth. The ash cloud blocks the solar radiation, temperature decreases [10].

This is not the only one period when volcanic eruption influenced the temperature decrease. During the 6th century, around 535/536 AD there was a significant global temperature decrease. There are descriptions about low temperature, snow during the summer, crop failures, dense dry fog, drought, epidemics. Byzantine historian Procopius described that the Sun gave its light without brightness, like *the Sun in eclipse*. Many scientific evidence validate the volcano eruption theory, based on tree ring analysis, ice cores from Greenland, Antarctica with higher sulfate amount than usual [11].

1.4 Global Dimming

The global dimming is a problem of anthropogenic origin, similar to the natural phenomena we studied above. We produce artificial dust from engines, power plants, it spreads in the higher atmosphere, reduces the amount of solar light reaching the ground, but helps the cloud formation. Global dimming has cooling effects [12].

Air traffic also adds to the global dimming problem, producing contrails, which become clouds and appear many times over territories where naturally no cloud formation would occur. After the terror attack against the United States of America in 2001 September, all of the aircrafts were grounded for 3 days. Climatologist recognized, that, as there were no contrails above the USA, there was an observable increase in temperature during this period [13].

Global dimming influences the weather as well. Due to the reduced sunlight, the monsoon has reduced force. There are ongoing research about the effects on the agriculture [12, 14, 15].

2 Solar Eclipse and Environment

The solar eclipse is an ideal phenomenon to study and analyze, what happens when the solar radiation decreases. As the Moon moves in front of the solar disc, the lunar shadow causes changes in the environment, including but not limited to the temperature and light decrease (Fig. 1a).

Diameter of the shadow depends on the distance of the Moon from the Earth, as it has elliptical orbit. Partial eclipse is, when the Moon covers a certain percent of the solar disc and total coverage does not happen. This is a more frequent phenomena,

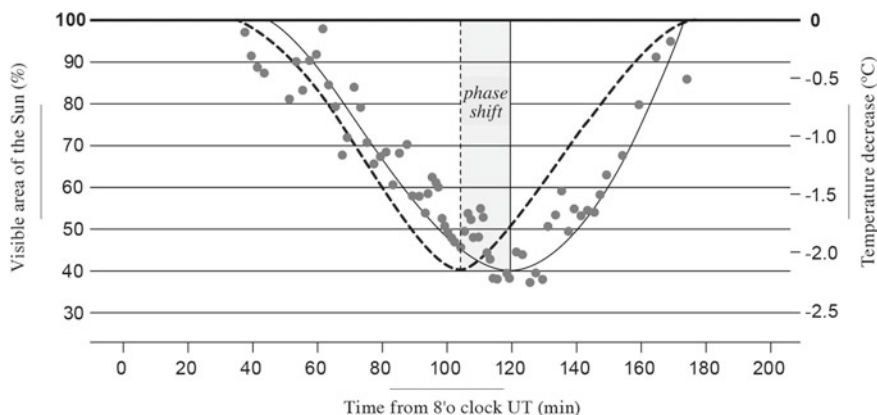


Fig. 2 Visible area of the Sun in percent and temperature decrease from professional measurement as a function of time during 03.20.2015. Data from measurements of students with home thermometers are represented by dots (Edited by Z. Mitre)

because it is observable from several parts of the Earth, while the diameter of the track of totality usually 100–200 km of a total solar eclipse.

In the last 15 years we observed several solar eclipses, both partial and total ones, from several parts of the world. All examinations showed the same results, like light and temperature decrease. In 2009, we recorded data from the total solar eclipse in Shanghai with different heights above the ground. We experienced that the higher we measure the temperature, the less decrease we observe. Based on multiple observations, it seems, temperature decrease is observable up to a height of 20–25 m above the ground. In 1999, during the “great” total solar eclipse in Hungary, we made observations 48, 82, 112 m above the ground, and no temperature decrease was experienced.

All of the temperature decreases at both total and partial solar eclipses has a shift in time from the phase of solar eclipse, due to the convection in the air. This delay is influenced by the local conditions. For example in 2006, Turkey, the temperature still decreased for 15 min after the end of the total phase of the eclipse, then it began to increase again [16–18].

Our latest examination shows that different land covers influence the degree of temperature decrease and the delay from the phase of the eclipse. On the 20th March 2015, we executed a widespread observation project, as there was a partial solar eclipse with a maximum coverage of 60% above Hungary. We had five measurement stations in areas not so far from each other, with different vegetation. Areas with dense vegetation (bushes, trees, park) has only 10–11 min delay and less decrease in temperature (-1.1°C). Highest temperature decrease (-2.1°C) happened in a city parking zone with dark asphalt coverage with a shift of 14–16 min [19] (Fig. 2).

High school students were involved into the experimental measure above. Parallel with our professional temperature measurements, they measured the temperature at

all of the observation stations with their own home thermometers, and made description of their subjective point of view about the environmental changes (what they feel on their own skin, birds, animal's behavior, etc.).

The inquiry-based learning is a good way to demonstrate the students the effects of the solar radiation decrease included but not limited to the microclimate. After the phenomena we discussed the data experienced and kept lessons about the usage of their observation regarding climate change as well. This is a good way of motivation for students to collect more information about the climate change problem and discuss about the possible solutions [19].

Latest researches try to apply a more precise theoretical model, based on meteorological and physical theories, to the solar radiation decrease and temperature change during a solar eclipse. In the last three years we have also improved our former analysis method, included but not limited to the theoretical model of the solar radiation change [19]. It seems a small coverage already induces temperature decrease, so a little decrease of the solar light has observable effects. That is why it is important to make detailed observations of partial eclipses with several percent of maximum coverages, to analyze the environment reactions to the solar radiation change with different amounts.

3 Conclusions

Solar eclipses are good "reality experiments" about the environmental reaction of the solar radiation change. It can decrease by natural processes, like sunspot cycles or volcanic aerosols, etc., and anthropogenic influences, like air pollution. Measurements show, that land coverage has an influence on the microclimate. These examinations can help the civil engineering of urban territories to design cities with good microclimate.

Global dimming could be a problem for the future, as, apparently, the fossil fuel emission, air traffic, etc. have an observable role in it. We saw, that small amount of solar radiation decrease has an effect on the environment both in light and temperature, which reduce the efficiency of solar energy production as well.

With inquiry-based learning, we can start discussions about the climate change problem in schools, involve high school students in experiments related to solar eclipses. The changes we experience in light, temperature, vegetation, fauna, etc. have useful information for several type of lessons to discuss about this problem.

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