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Global Dimming: A Hot Climate Topic

Global dimming, also referred to as solar dimming, is a new buzz word in the scientific community. Coined by researcher Gerald Stanhill, the term refers to indications that diminished amounts of sunlight are reaching Earth's surface. This is happening, not because the sun itself is dimming, but because solar radiation cannot penetrate pollution and thicker clouds.

The phenomenon was first revealed in 1985 through research by geographer Atsumu Ohmura of the Swiss Federal Institute of Technology. Ohmura was studying climate and atmospheric radiation and was analyzing historical solar radiation levels. He was surprised to find that levels of incoming solar radiation declined overall by as much 10% in the 1960s through the 1980s. Some regions in Asia, Europe, the former Soviet Union, and the United States saw a larger decline, and sunlight levels in densely populated, highly polluted Hong Kong dropped by 37%. These results contradicted the logic and evidence of global warming. If Earth is getting hotter, how can incoming sunlight be decreasing? Ohmura was shocked by the results, and when he published his findings the science world largely ignored them. A few other researchers, including Stanhill, published papers in the 1990s that supported diminishing sunlight levels. Still, only recently did the solar dimming effect attract the notice of the global change scientific community.

Stanhill and his colleague, Shabtai Cohen of The Agricultural Research Organization of Israel, proved in 2001 that the solar dimming phenomenon is real, with the average amount of solar radiation reaching Earth's surface decreasing by 0.23-0.32% each year from 1958 to 1992. These results finally gained the attention of climate researchers, although some attributed the results to inaccurate instrumentation.

Global Warming and Solar Dimming

In contrast to solar dimming, the world is very familiar with the concept of global warming. Greenhouse gases such as water vapor and carbon monoxide trap longwave heat energy that otherwise would radiate from Earth's surface out to space. The trapping effect contributes to the warming of the planet. Solar dimming works in the opposite way, preventing a fraction of the sun's

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heating rays from reaching the surface and warming Earth. Researcher James Hansen of the National Aeronautics and Space Administration (NASA) estimates that the cooling effect of solar dimming is about half as large as the greenhouse gas warming effect.

One method used to quantify solar irradiation involves measuring the rate at which water evaporates from a pan placed in sunlight. Each day the water level is measured. Any rainfall is subtracted to determine how much water evaporated the prior day. If the climate is warming, increased evaporation is expected. In contrast, researchers have found that less water is evaporating in this measurement. For years, researchers were at a loss to explain this mystery; solar dimming may be the explanation.

Aerosol Effects on Solar Radiation

General consensus points to a long-term trend of decreasing amounts of solar radiation reaching Earth's surface. The cause is thought to be increased pollution, which is also being blamed for global warming. Aerosols such as sulfates and black carbon (soot) can affect the heat balance of the planet. Whereas sulfate aerosols are produced by the combustion of fossil fuels, black carbon (soot) is produced by incomplete combustion of coal, biomass (wood, field residue, cow dung, etc.), and diesel fuel.

Aerosol particles can cool the climate in two ways. Directly, sulfate aerosols reflect incoming solar radiation back to space. Indirectly, aerosols can increase the reflectivity of clouds by providing more nuclei on which water vapor can condense and form tiny cloud droplets. With more droplets to take up available water vapor, the droplets stay smaller and lighter in weight, and they fall less readily from the cloud as rain. The result is optically thicker clouds and decreased rainfall.

Aerosols also contribute to climate warming. Soot particles absorb solar radiation rather than reflecting it; thus, they warm the atmosphere and counter the cooling effects of reflective sulfate aerosols. By warming the atmosphere, soot can inhibit cloud formation and thus allow more sunlight to reach and warm the surface. Research indicates that soot stays

Solar radiation is measured with an instrument called a radiometer. Several different types of radiometers are available, each with a specific measurement capability. Radiometers are very sensitive and require much care. They are susceptible to calibration drift and need to be monitored and maintained carefully to preserve the accuracy of data they collect over time. The ARM Climate Research Facility (ACRF) maintains a Radiometer Calibration Facility (RCF) at its SGP central site to guarantee that its more than 100 radiometric instruments are calibrated accurately and efficiently. The RCF can calibrate up to 100 radiometers simultaneously. It compares the instruments annually to the World Radiometric Reference of the World Meteorological Organization, which is the standard for radiometers. In addition to proper calibration, cleaning and maintenance of the instruments is crucial for the collection of accurate data products. ACRF prides itself on its calibration and maintenance standards, which other researchers may not have the resources to attain. ACRF has invested in the RCF and adopted strict maintenance schedules to generate the most accurate long-term solar radiation data available to the scientific community.

The ARM Climate Research Facility Radiometer Calibration Facility at the SGP central site (ARM photo).

in the atmosphere for only about two weeks, a much shorter time than the life spans of other aerosols and greenhouse gases such as methane or carbon dioxide. Reducing the amount of black carbon soot being produced would have positive effects in a short period.

The individual characteristics of real aerosols, which often contain both sulfate and soot, complicate global warming. The interactions and climate feedbacks of aerosols are very intricate, complicated, and controversial. The contribution of aerosols to global warming and cooling is not a new topic; aerosols have been included in global climate models for quite some time. However, researchers have recently focused new attention on their effect on climate change, particularly global warming.

NREL Pyrheliometer Comparisons

The World Meteorological Organization in 1977 established the World Radiometric Reference (WRR) as the international standard for solar irradiance measurements. To provide accurate, reliable measurements, a radiometer must have its calibration traceable to the WRR standard.

Every five years the World Radiation Center/Physikalisch-Meteorologisches Observatorium Davos in Davos, Switzerland hosts the International Pyrheliometer Comparison (IPC). Participants bring their instruments to the IPC and receive the transferred WRR standard. The National Renewable Energy Laboratory (NREL) participates in the IPC as the representative for the U.S. Department of Energy. NREL maintains a select group of absolute cavity radiometers having calibrations directly traceable to the WRR standard.

Each year NREL hosts the NREL Pyrheliometer Comparisons at its Solar Radiation Research Laboratory (SRRL) in Golden, Colorado. Radiometer owners are invited to participate in the comparisons so that the WRR standard can be transferred to their reference radiometers for use in their calibration activities. ARM Climate Research Facility (ACRF) personnel and radiometers travel to NREL to participate in the annual comparisons and calibrate all ACRF reference radiometers against the WRR traceable standard. Acquiring the WRR standard is necessary to generate accurate, reliable long-term data for ACRF users.

Instruments used during the NREL Pyrheliometer Comparison at SRRL in Golden, Colorado included the Transfer Standard Group (left) and solar trackers (right). (SRRL photo).

Solar Dimming on a Regional Scale

Sunlight levels around the globe are decreasing unevenly. Less polluted areas generally have little or no dimming, but the way global dimming works is not well understood. Some areas with clean air experience dimming as well. In a 1999 field project called The Indian Ocean Experiment (INDOEX), researchers found the air over the Indian Ocean to be much more polluted than expected. Their measurements of solar radiation under the pollution cloud were 10% lower than measurements taken in clean air. NASA satellite images have revealed widespread pollution clouds downwind of Africa, South America, North America, and Europe. Although the dimming is referred to as "global," research shows that it is a regional problem.

At the ARM SGP site, values of solar radiation reaching the surface have increased, supporting the theory that global dimming is a regional phenomenon caused mainly by pollution. Because scientists don't believe that they have a good understanding of solar dimming, more research and data collection are necessary. Solar dimming remains a very controversial topic that is attracting increased scientific attention. Accurate, long-term measurements of solar radiation values are needed. The ARM SGP site and its vast array of solar radiation and energy flux systems will provide accurate, long-term data to contribute to scientific understanding of solar dimming.

To provide more research capability for the global scientific community, the scientific infrastructure and data archive established through the Department of Energy's Atmospheric Radiation Measurement (ARM) Program are now being made available for use by scientists worldwide through the ARM Climate Research Facility.