

5. Solar Dimming

A recent joint study published in Nature's Scientific Reports shows India's sunlight hours are shrinking due to pollution and cloud buildup threatening the country's solar energy ambitions.

Solar Dimming

1. Definition – Solar dimming refers to the observed decrease in solar radiation reaching the Earth's surface over time. It is a phenomenon where the intensity of sunlight at the ground level reduces due to both natural and anthropogenic factors. Solar dimming has significant implications for energy generation, agriculture, and climate systems.

2. Causes of Solar Dimming

A. Anthropogenic Aerosols – Emissions from industrial activities, vehicular exhaust, and biomass burning release fine particulate matter into the atmosphere. Aerosols act as cloud condensation nuclei, forming smaller and more numerous cloud droplets (Twomey Effect), which increase cloud reflectivity and duration. Types of aerosols –

Primary aerosols – Directly emitted particles like dust, sea salt, and soot.

Secondary aerosols – Formed in the atmosphere via chemical reactions of gases such as SO₂, NO_x, and VOCs, producing sulfates, nitrates, and organic aerosols.

B. Persistent Cloud Cover – Extended periods of cloudiness, especially during the monsoon season, reduce the penetration of sunlight. Clouds scatter and absorb incoming solar radiation, contributing to dimming effects.

C. Urban Haze and Humidity – High urban pollution levels (haze, smoke, smog) and elevated humidity lead to scattering and absorption of sunlight. Urban centers in Northern India experience pronounced solar dimming due to industrial clusters and dense populations.

Key Findings from Indian Studies

Decline in Sunshine Hours – North Indian plains lost about 13.1 hours of sunshine per year on average over the last three decades.

Twomey Effect – Increased aerosols lead to more numerous, smaller cloud droplets, enhancing cloud albedo and keeping skies overcast longer.

Primary Factor – The rise in aerosol concentration from human activity is identified as the main driver of long-term solar dimming.

Implications of Solar Dimming

A. Renewable Energy – Reduced sunlight directly impacts solar power generation, potentially causing up to a 7% decline in output. Poses challenges to India's 2030 clean energy goals and ambitious solar capacity targets.

B. Agriculture – Photosynthesis-dependent crops like rice and wheat are affected by reduced solar radiation. Dimming sunlight can lead to lower crop yields, threatening food security in high-density agricultural regions.

C. Environment and Climate – Solar dimming indirectly influences glacial melting in the Himalayas by altering regional energy balances and hydrological cycles. Impacts ecosystems, water availability, and regional climate patterns, highlighting the link between air pollution and climate change.

Incoming Solar Radiation (Insolation)

1. Definition – Insolation is the solar energy received per unit area on the Earth's surface, primarily in the form of shortwave radiation. It is the primary driver of atmospheric processes, climate patterns, and energy balance on Earth.

2. Magnitude and Variability – At the top of the atmosphere, Earth receives approximately 1.94 calories/cm²/minute. Insolation varies seasonally due to Earth's elliptical orbit –

- Perihelion (closest to Sun)** – January 3 – slightly higher solar intensity.
- Aphelion (farthest from Sun)** – July 4 – slightly lower solar intensity.

Insolation is also influenced by –

- Distribution of land and water (albedo differences).
- Atmospheric circulation and transparency.

3. Angle of solar rays relative to the surface.

Factors Affecting Insolation

Factor	Impact on Insolation
Earth's rotation	Determines day and night cycle, affecting duration of solar exposure.
Solar declination & angle of incidence	Higher angles → more concentrated rays; lower angles → diffuse energy.
Length of the day	Longer days in summer provide higher cumulative insolation.
Atmospheric transparency	Clouds, aerosols, dust, and pollution scatter or absorb sunlight, reducing ground-level insolation.
Topography and land configuration	Mountains, slopes, and surface albedo influence how much sunlight reaches a location.

Significance – Insolation is crucial for climate systems, weather forecasting, agriculture, and renewable energy planning. Reduction in surface solar radiation (solar dimming) alters regional temperature patterns, crop productivity, and solar power potential. Understanding insolation dynamics helps in mitigation strategies for air pollution, renewable energy planning, and climate adaptation.

Source – [https - //timesofindia.indiatimes.com/city/pune/india-getting-cloudier-with-steady-drop-in-sunshine-hours-across-most-regions-finds-study/articleshow/124397258.cms](https://timesofindia.indiatimes.com/city/pune/india-getting-cloudier-with-steady-drop-in-sunshine-hours-across-most-regions-finds-study/articleshow/124397258.cms)