

Cloud Seeding - Techniques and Limitations

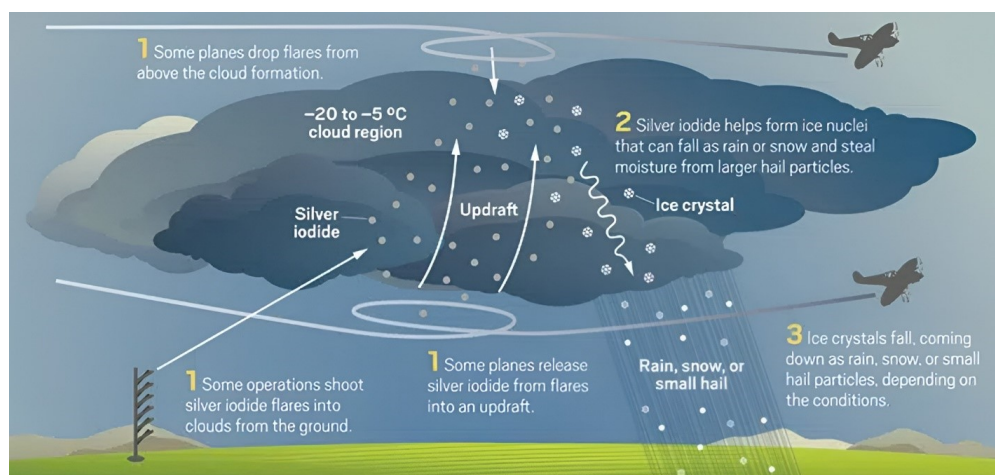
Mains: GS I - Geography

Why in News?

Recently, The Government of the National Capital Territory Delhi carried out cloud seeding and artificial rain to reduce air pollution, it is necessary to understand how this works and if it is effective at all.

What is cloud seeding?

- **Cloud seeding** - It is a weather modification technique that aims to enhance precipitation by dispersing specific chemicals into existing clouds.
- These chemicals act as artificial condensation nuclei, around which moisture can accumulate to form larger water droplets or ice crystals, eventually resulting in rainfall.



- **Agents used** - The process typically uses agents such as
 - **Silver iodide** - It mimics the crystalline structure of ice.
 - **Potassium iodide** - It acts as an alternative nucleating material.
 - **Dry ice** (solid carbon dioxide) - It is used to cool the surrounding air rapidly.
 - **Sodium chloride** (common salt) - It is particularly effective in promoting droplet formation in warmer clouds.
- **Dispersal of agents** - Cloud seeding is most commonly conducted using aircraft that disperse the seeding agents directly into the targeted cloud systems.
- In some cases, ground-based generators are used when wind conditions can effectively carry the aerosols upward into the cloud layer.
- In some cases, even drones are used.

What are the primary requirement for artificial rain?

- **Scientific preconditions**– For cloud seeding to be successful, specific requirements must be met
 - Moisture-rich clouds, particularly cumulus and nimbostratus types, are essential.
 - The presence of super-cooled water droplets within the clouds, favourable wind patterns, and suitable humidity levels are crucial for achieving the desired outcome.
- Cloud seeding is not effective in dry conditions or when the sky is clear, as it cannot create clouds but can only enhance existing ones.
- The presence of existing moisture-laden clouds that have not yet produced rainfall is a prerequisite for cloud seeding.
- This process enhances the natural potential of such clouds to generate precipitation but cannot create rain in clear skies.
- Accurate forecasting of cloud availability is therefore critical.
- **Sufficient moisture** - The target clouds must contain an adequate amount of water vapour and liquid water to be condensed into precipitation.
- In some cases, a cloud's moisture content must be at least 50 per cent.
- **Cloud characteristics** - Clouds targeted for seeding must have sufficient vertical thickness.
 - **For example**, some cloud-seeding projects require clouds to be at least 1 kilometre thick.
 - For cold cloud seeding, the cloud must contain “supercooled” liquid water, which is water that remains a liquid despite having a temperature below freezing. The cloud must be at least -20°C to -7°C .
 - For warm cloud seeding, the cloud temperature must be above freezing.
- **Favourable winds** - The wind conditions must be suitable for the project.
 - Wind direction must transport the seeding material toward the intended area.
 - Wind speed must not be so high that it prevents clouds from growing tall or blows the seeding agents away from the target zone.
- **Vertical air currents** - Clouds with strong vertical updrafts are considered ideal because they help disperse the seeding agents and promote cloud development.

What are the monsoon relevance and limitations?

- **Relevance**
 - **Monsoon provides an Ideal condition** - The Indian monsoon season often provides ideal conditions for cloud seeding, as it brings abundant moisture and widespread cloud cover.
 - This period can be beneficial for targeting rain-deficient zones within the larger monsoon system.
- **Limitations**
 - **Natural rainfall** - It complicates the ability to measure the specific impact of cloud seeding interventions.
 - **Atmospheric variations** - Weather variability and shifting atmospheric conditions can further delay or reduce the effectiveness of seeding efforts.
 - **Flooding** - There is also a potential risk of excessive rainfall or local flooding if

seeding is not carefully managed.

What are the applications in key areas?

- **Temporary relief** - It can provide temporary relief during severe droughts by augmenting rainfall, especially for agriculture and rural water security.
- **Emergency intervention** - It may also serve as an emergency air-quality intervention during episodes of extreme pollution, when artificial rain can help wash suspended pollutants out of the air.
- **Stabilisation of agriculture** - Furthermore, it can support agricultural stabilisation in rain-fed areas during delayed or weak monsoons by supplementing natural rainfall.

What are the limitations of cloud seeding?

- **Environmental risks** - There are environmental risks associated with the use of chemical agents, which can potentially contaminate soil and water bodies and impact biodiversity.
- Long-term exposure may also affect soil fertility and groundwater quality.
- **Limited effectiveness** - The technique has limited efficacy because it cannot induce rainfall in the absence of suitable clouds or sufficient moisture.
- **Ethical and legal concerns** - These concerns also arise, particularly regarding the manipulation of weather systems and the potential impact on rainfall patterns in neighbouring regions.
- **Undermine long term solutions** - Focusing on cloud seeding as a pollution-control strategy may distract from essential, long-term reforms in air-quality management and sustainable urban planning.
- **Region based challenges** - The practical possibility of cloud seeding in region of Delhi and Indo-Gangetic plains are
 - **Extreme pollution events** - They typically occur during the winter months, when atmospheric conditions lack the high humidity required for successful seeding.
 - Even when clouds are present, they are often part of larger synoptic weather systems that already bring natural rainfall, thereby reducing the marginal benefit of artificial rain.
 - When cloud seeding does produce rainfall, the effects are usually short-lived, lasting from a few hours to a couple of days.
 - **Unintended consequences** - Diverting rainfall from neighbouring areas, raises both ethical and geopolitical concerns.

What is the status of cloud seeding experiment in India?

- **Initiatives by states** - States such as Tamil Nadu, Karnataka, Maharashtra, and Andhra Pradesh have undertaken cloud seeding operations to augment rainfall in water-scarce regions.

India has been experimenting with cloud seeding, commonly known as artificial rain, since the 1950s, primarily as a drought management tool.

- **Expansion of the experiment** - In recent times, interest in cloud seeding has expanded beyond drought relief to include its potential as an emergency measure for improving air quality, particularly in highly polluted urban areas such as Delhi.
- **Delayed plans** - Successive governments in Delhi have explored the idea of inducing artificial rain to improve ambient air quality.
- However, the plan has repeatedly faced setbacks due to delays in obtaining inter-agency clearances, unfavourable meteorological conditions, and the unavailability of suitable clouds.
- **Revival of the experiment** - In 2025, the initiative was revived, with the Delhi government signing a Memorandum of Understanding (MoU) with IIT Kanpur to conduct five cloud-seeding trials in northwest Delhi.
- The project, approved by 23 departments, including the Directorate General of Civil Aviation (DGCA), aims to explore whether artificial rain can be a viable solution to tackle rising pollution levels during the winter.
- IIT-Kanpur will deploy its own aircraft for the operation

What should be done?

- **Ensure scientific validation** - Cloud seeding must be backed by real-time scientific validation using satellite data, Doppler radar tracking, and high-resolution meteorological modelling.
- **Develop SOPs** - Standard operating procedures (SOPs) should be developed for the execution, monitoring, and post-event assessment of all cloud seeding operations to ensure accountability and measure outcomes effectively.
- **Establish regulatory framework** - Regulatory frameworks must be established to ensure environmental safety, ethical governance, and transparent application of weather modification technologies.
- **Develop long term solutions** - Cloud seeding offers a scientifically plausible yet highly conditional solution for inducing rainfall and managing air pollution.
- It should be viewed as a supplementary intervention within a broader emergency response framework, rather than as a primary strategy.
- These micro-meteorological interventions require thorough scientific investigation, robust risk assessments, and careful interstate coordination before implementation.
- **Comprehensive analysis** - Any decision to employ cloud seeding must be grounded in comprehensive meteorological analysis, transparent decision-making processes, and a clear understanding of the trade-offs involved.

What lies ahead?

- In the short term, cloud seeding should be considered only as an emergency measure, particularly when air quality indices exceed hazardous levels or during extreme droughts
- India's long-term focus must remain on sustainable air quality solutions, improved urban planning, and climate-resilient development pathways.

Reference

[Down To Earth| Cloud Seeding](#)



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