Cloud Seeding

For Prelims: **Cloud Seeding and Types**, Artificial Rain, Convective Clouds

For Mains: Application of Cloud Seeding and Concerns, Atmospheric Circulation, Water Resources

Source: TH

Why in News?

Cloud seeding, a groundbreaking technique to enhance rainfall, has taken centre stage in a recent study published in the ***journal Bulletin of the American Meteorological Society***, conducted by the **Indian Institute of Tropical Meteorology, Pune.**

- The study unveils the potential of cloud seeding to boost precipitation in water-scarce regions, offering hope for tackling drought **conditions.**

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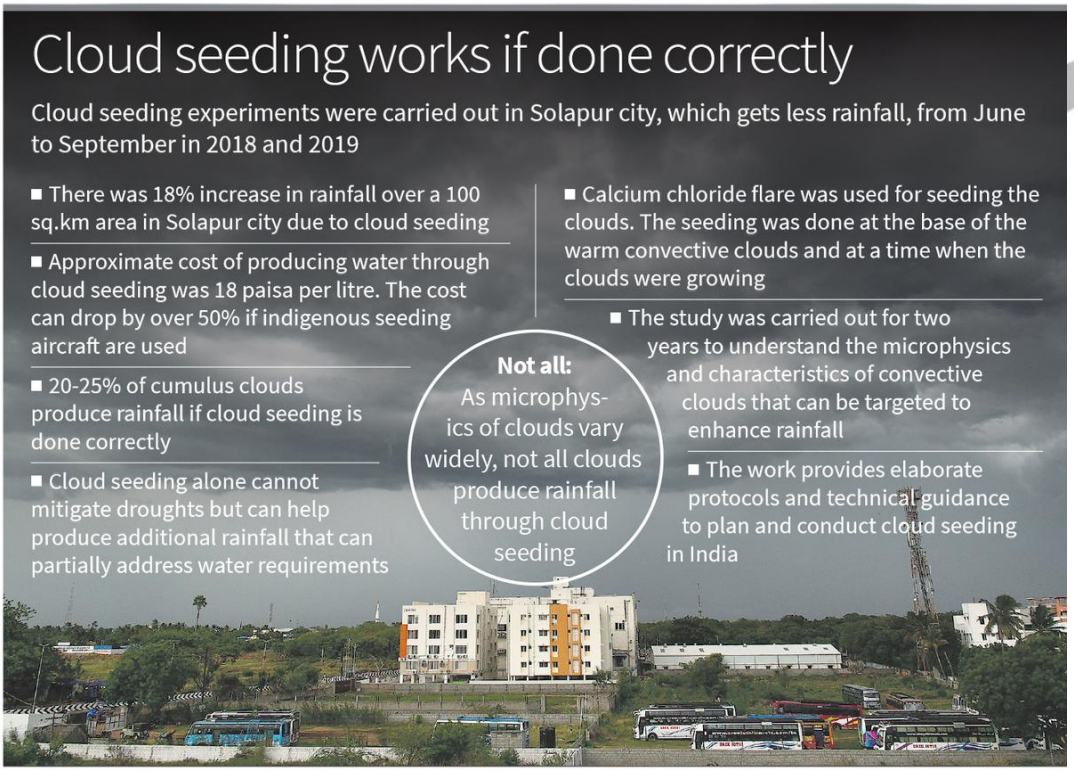


What are the Key Highlights of the Study?

- **CAIPEEX Phase-4 Investigation:**

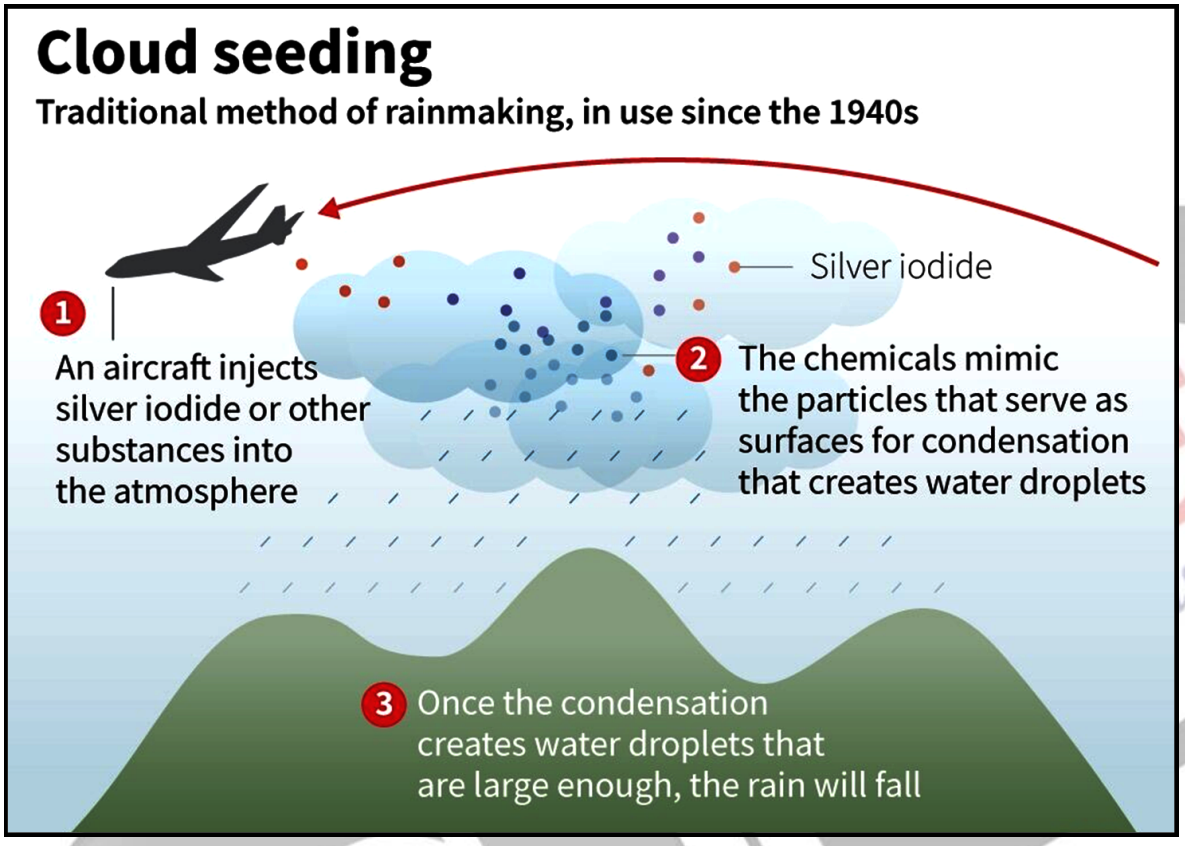
    - The Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX phase-4) was a two-year study in Solapur (Maharashtra), conducted during the 2018 and 2019 summer monsoons.
    - Its primary objective was to assess the **effectiveness of hygroscopic seeding in deep convective clouds** and develop a cloud seeding protocol.
        - Researchers used calcium chloride flares for cloud seeding.
            - A cloud seeding flare releases these particles when triggered. The seeding was done at the base of the warm convective clouds and at a time when the clouds were in their growing stage so that the seed particles could enter the clouds with minimum dispersion.
    - The experiment employed **two aircraft for cloud parameter study and cloud seeding.**
- **Cloud Seeding's Effectiveness:**
    - Cloud seeding is proven effective for **enhancing rainfall under suitable conditions.**
    - A random seeding experiment selected 276 convective clouds, with 150 clouds subjected to seeding and 122 unseeded.
        - Specific cloud characteristics, including liquid **water content and vertical motion,** were used to identify clouds with potential for rainfall.
        - Targeted convective clouds were typically over one kilometer deep and likely to evolve into deep cumulus clouds.
- **Benefits:**
    - **Cost-Benefit Ratio:**
        - The approximate **cost of producing water through cloud seeding was 18 paisa per liter** during the research experiment.
        - Using indigenous seeding aircraft could reduce costs by more than 50%.
    - **Managing Drought Conditions:**
        - Cloud seeding alone cannot fully mitigate droughts but can contribute to an **18% increase in rainfall, partially addressing water requirements.**
        - Undertaking cloud seeding as part of catchment-scale projects could help in drought management.
    - **Practical Applications:**
        - Cloud seeding can significantly benefit regions like Solapur which falls on the **leeward side of the** Western Ghats and hence gets low rainfall.
        - Additional water through cloud seeding has the potential to alleviate water scarcity issues in such areas.
- **Microphysics and Cloud Characteristics:**
    - The two-year study aimed to understand the **microphysics and characteristics of convective clouds** suitable for enhancing rainfall.
        - It provides comprehensive protocols and technical guidance for planning and conducting cloud seeding in India.
- **Cloud Variability:**
    - Not all cumulus clouds respond to cloud seeding; **approximately 20-25% can produce rainfall** if seeding is executed correctly.
    - Cloud microphysics varies widely, leading to varied results with cloud seeding.

Convective Clouds

- **Convective clouds** are clouds that form when **warm, humid air rises** through cooler air in the atmosphere.
    - The warm air is less dense than the surrounding air, so it rises. This process is called **convection.**
    - Convective clouds are also known as **cumuliform clouds.** They look like stacks of cotton balls.
- There are two types of convective clouds: **Cumulus clouds and cumulonimbus clouds.**
    - Cumulus clouds are fluffy, white clouds with a flat base and a rounded top. Cumulus clouds can develop into cumulonimbus clouds, which are associated with thunderstorms.
    - Cirrocumulus Clouds are high-altitude clouds that appear as small, white, and fluffy cloud patches. They often have a wavy or honeycomb-like pattern.

What is Cloud Seeding?

- **About:**
  - It is the process of **artificially generating rain** by implanting clouds with particles such as silver iodide crystals.
  - Cloud seeding uses planes to spray clouds with chemicals to condense smaller particles into larger rain droplets.



- **Cloud Seeding Methods:**
  - **Static Cloud Seeding:**
    - This method involves **introducing ice nuclei, such as silver iodide or dry ice, into cold clouds** that have supercooled liquid water droplets.
    - The ice nuclei can trigger the formation of ice crystals or snowflakes, which can grow at the expense of the liquid droplets and fall as precipitation.
  - **Dynamic Cloud Seeding:**
    - Dynamic cloud seeding is a method of inducing rain by **boosting vertical air currents.**
      - The process is considered more complex than static cloud seeding because it depends on a sequence of events working properly.
  - **Hygroscopic Cloud Seeding:**
    - This method involves spraying fine particles of hygroscopic materials, such as **salts through flares** or explosives into the base of warm clouds.
    - The particles can act as cloud condensation nuclei and increase the number and size of the cloud droplets, which can enhance the reflectivity and stability of the clouds.
- **Applications:**
  - Cloud seeding is done to enhance **winter snowfall and increase mountain snowpack**, which can supplement the natural water supply for communities in the surrounding area.
  - Cloud seeding can also be done to prevent hailstorms, dissipate fog, induce rainfall in drought-prone regions, or reduce air pollution.
- **Challenges:**

- Cloud seeding requires the presence of **moisture-filled clouds**, which are not always available or predictable.
- Cloud seeding does not occur during times when **additional precipitation would be problematic,** such as times of high flood risk or busy holiday travel periods.
- Cloud seeding may have negative effects on the environment and health, such as altering the natural water cycle, contaminating the soil and water with chemicals, or affecting the local climate.