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Clouds: How They Warm or Cool the Planet, and Two Ways to Engineer Them

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Clouds: How They Warm or Cool the Planet, and Two Ways to Engineer Them

Height and thickness together decide whether a cloud warms or cools the Earth. **High thin clouds mostly warm. Low thick clouds mostly cool. Two geoengineering ideas try to use this.**



Low stratocumulus clouds over Lordship Recreation Ground, Haringey, London. Thick low clouds like these reflect sunlight strongly and cool the surface. Photo by Acabashi, CC BY-SA 4.0, via Wikimedia Commons.

At a Glance

Four facts to hold on to.

01
High clouds

Thin cirrus: net warming.

02
Low clouds

Thick stratocumulus: net cooling.

03
Two ideas

Cirrus thinning and stratospheric aerosol injection.

04
Big caution

Neither removes CO2.

Albedo effectA cloud reflects sunlight back to space. This cools.
Infrared effectA cloud traps heat leaving Earth. This warms.
CirrusA thin, icy cloud high in the sky.
AerosolA tiny particle suspended in air.

What High and Low Clouds Actually Do

Must Know

High clouds warm. Low clouds cool

- **High clouds** like cirrus are thin. Most sunlight passes through them.

- They reflect little sunlight. But they absorb and re-emit outgoing infrared heat.
- That trapping effect wins, so **high clouds warm**.
- **Low clouds** are thick. They reflect incoming sunlight strongly.
- So **low clouds cool** the surface.
- A common exam claim says high clouds cool and low clouds warm. That is the reverse of the real effect.
- Sources: IPCC AR6 clouds chapter and NASA Earth Observatory on clouds.

> **Quick check 1.** High clouds like cirrus produce a net warming effect on Earth, despite being thin and pale. *(True or False?)* See answer ↓

> **Quick check 2.** Low clouds produce a net warming effect, the same as high clouds. *(True or False?)* See answer ↓

Two Effects Every Cloud Has

Good to Know

The solar effect, the infrared effect, and height as the tiebreaker

- Every cloud reflects some sunlight back to space. This is the cooling (albedo) effect.
- Every cloud also absorbs and re-emits heat rising from the surface. This is the warming effect.
- Each cloud has both effects at once.

- For thin high clouds, the infrared warming wins.
- For thick low clouds, the sunlight reflection wins.

Feature	High cirrus	Low stratocumulus
Thickness	Thin and wispy	Thick and dense
Reflects sunlight	Little	A lot
Traps outgoing heat	Strongly	Less decisively
Net effect	Warming	Cooling

> **Quick check 3.** Every cloud produces only one effect on temperature, either warming or cooling, never both. *(True or False?)* See answer ↓

Exam Edge

Previous Year Questions

Three recent questions tested this topic.

Quick check 4. UPSC's 2022 question confirmed that low clouds cause net warming, matching the statement given. *(True or False?)*

See answer ↓

Quick check 5. Thin, feathery, ice-crystal clouds forming between 6,000 and 10,000 metres are called cirrus clouds. *(True or False?)*

See answer ↓



Cirrus uncinus clouds, the high wispy clouds that cirrus thinning proposals target, near IIT Mandi, Himachal Pradesh. Photo by Adarsh Patel, CC BY-SA 4.0, via Wikimedia Commons.

Two Geoengineering Proposals

Good to Know

Cirrus cloud thinning, and stratospheric aerosol injection

- **Cirrus cloud thinning:** seed high cirrus with ice-nucleating particles so the clouds thin out.
- Thinner cirrus lets more heat escape to space. This targets the high-cloud warming effect.
- **Stratospheric aerosol injection:** release sulphate aerosols high in the stratosphere.
- The particles reflect sunlight back to space. This copies the cooling after a big volcanic eruption.
- Both are proposed to reduce global warming. Neither is meant to control rainfall, cyclones or solar wind.

The volcano model, and what can go wrong

- Aerosol injection is modelled on eruptions such as **Mount Pinatubo in 1991**.
- Pinatubo cooled global temperatures for about a year.
- More stratospheric aerosol can reduce ice-crystal formation. That can thin cirrus as a side effect.
- Over-seeding can backfire. Too many particles can make thicker cirrus that trap more heat.
- Sources: USGS Pinatubo volume and IPCC AR6 clouds chapter.

Quick check 6. Cirrus cloud thinning and stratospheric aerosol injection are both proposed specifically to reduce global warming. *(True or False?)* See answer ↓

Quick check 7. Adding more ice-nucleating particles to seed cirrus always thins them further, with no risk of the opposite effect. *(True or False?)* See answer ↓

Why Scientists Stay Cautious

Great to Know

Ozone risk, and no fix for the cause

- Particles in the stratosphere may deplete ozone. That works against another environmental goal.
- Neither technique removes carbon dioxide.
- Both only mask warming while emissions continue.
- The cooling effect would need maintaining for a long time.
- Source: WMO/UNEP ozone assessment 2022.

Intuition gets it backwards

- It feels natural to think thick dark clouds trap heat and thin wispy ones let it out.
- The physics runs the other way.
- High and low clouds pull in opposite directions.
- Predicting how total cloud cover will change in a warming world is still a hard modelling problem.

- These ideas sit beside geological carbon sequestration in the wider climate toolkit.

Exam traps

- High clouds warm. Low clouds cool. Do not swap them.
- Every cloud has both effects. Height and thickness decide the winner.
- Pinatubo is the model for aerosol injection, not cirrus thinning.
- Aerosol injection does not remove CO2.

Think it through: why does cloud colour or thickness fail to predict warming or cooling?

Intuition treats a cloud as one blanket. A thick dark cloud seems to trap more heat. But each cloud runs two effects at once. It reflects sunlight, which cools. It traps outgoing infrared, which warms. A thin cirrus reflects little but still traps heat, so it warms. A thick low cloud reflects a lot, so it cools. That is why scientists target cirrus for thinning. It is also why they stay cautious. Neither idea removes CO2, and each has its own backfire risk.

Quick check 8. Stratospheric aerosol injection removes carbon dioxide from the atmosphere, addressing the root cause of warming. *(True or False?)* See answer ↓

Quick check 9. Stratospheric aerosol injection is modelled on volcanic eruptions like Mount Pinatubo, which cooled global temperatures for about a year. *(True or False?)* See answer ↓

Quick Q&A

Which clouds warm?

High thin clouds like cirrus.

Which clouds cool?

Low thick clouds.

What does aerosol injection copy?

A big volcanic eruption such as Pinatubo.

What can over-seeding cirrus cause?

Thicker cirrus that trap more heat.

Does either idea remove CO2?

No.

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1. Stratospheric sulphate aerosol injection is designed to mimic which natural event?

A. An ocean current shift

B. An ozone hole

C. A major volcanic eruption

D. A solar flare

See answer ↓

2. What is the main goal of cirrus cloud thinning?

A. Letting more outgoing heat escape to space

B. Blocking harmful UV rays

C. Increasing regional rainfall

D. Cooling ocean surfaces directly

See answer ↓

3. What is a documented risk of over-seeding cirrus clouds with ice-nucleating particles?

A. It permanently repairs the ozone layer

B. It can produce thicker clouds that trap more heat

C. It causes instant global cooling

D. There is no known risk

See answer ↓

4. Both cirrus cloud thinning and stratospheric aerosol injection are proposed mainly to address what?

A. Ozone depletion

B. Global warming

C. Acid rain

D. Deforestation

See answer ↓

Answer Key

1. **C.** Injecting sulphate aerosols into the stratosphere copies the cooling effect seen after major volcanic eruptions like Mount Pinatubo in 1991. ↑ Q1
2. **A.** Cirrus cloud thinning aims to thin high clouds so more outgoing infrared heat can escape into space, reducing warming. ↑ Q2
3. **B.** Too many ice-nucleating particles can backfire, producing thicker cirrus clouds that trap more heat instead of thinning them. ↑ Q3
4. **B.** Both geoengineering techniques are proposed specifically in the context of reducing global warming. ↑ Q4

Quick-check answers

1. **True.** ↑ 1
2. **False.** ↑ 2
3. **False.** ↑ 3
4. **False.** ↑ 4
5. **True.** ↑ 5
6. **True.** ↑ 6
7. **False.** ↑ 7
8. **False.** ↑ 8
9. **True.** ↑ 9

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