Environmental Studies
FACT SHEET

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Feedback Mechanisms in Global Climate

Is the temperature of our lower atmosphere (troposphere) increasing as a result of human activity? Many scientists would answer: yes, definitely, and many are worried that now that we have upset the balance of global temperatures, things are going to get much worse. But not all scientists would agree. Some argue that, whilst temperatures may have increased slightly over the last century, this is just a short-term fluctuation and not evidence of a long-term trend. Such scientists also point to the checks and balances that operate in the global climate system. They believe that, even if global temperature has increased, the system will respond in ways that bring it back down again (the Gaia hypothesis).

This Factsheet will look at the processes that may make things worse and those that may bring temperatures back down again. This is a synoptic topic i.e. to understand what is going on will require an ability to pull information from several GCSE, AS and A2 topics together.

Positive and negative feedback

It is easy to confuse these two terms. Imagine that the average temperature of the lower atmosphere on Earth is 13°C.

If something changes the Earth's temperature (e.g. increases it to 14°C or decreases it to 12°C) then:

- **Positive feedback** will reinforce the change in the direction that it has started to go. So, if the temperature increases, positive feedback will push it even further up and so on.
- **Negative feedback** will work against the change, pulling it back to where it started. So if the temperature increases, negative feedback forces will pull it back down again.

To summarise, positive feedback makes a system move even faster away from equilibrium and negative feedback tries to bring a system back into equilibrium.

What are the positive and negative feedback forces that operate in global climate?

Remember: CO, CO_2, CH_4, CFCs, NO_x and water vapour are greenhouse gases. Greenhouse gases stop or slow the release of longwave radiation emitted from the surface of the earth. This trapped heat warms the lower part of the atmosphere – the troposphere.

Photosynthesis: plants use CO_2, release O_2
Respiration: uses O_2, releases CO_2
Decomposition – releases CO_2 and, if anaerobic, CH_4 (methane)
Albedo = ratio of reflected light to incident light (the higher the albedo, the more reflective the surface, the lower the albedo, the more energy it will absorb and the more it will heat up.

The following flow diagrams summarise the key processes. Shorthand notation has been used because it is faster to use this when revising.

Key:
↑ = increase ↓ = decrease CO_2 = carbon dioxide CH_4 = methane WV = water vapour NO_x = a combined term for NO (nitrogen monoxide), N_2O (dinitrogen oxide) and NO_2 (nitrogen dioxide)
t^o = temperature evap = evaporation alb = albedo rops = rate of photosynthesis rod = rate of decomposition ror = rate of respiration

Positive Feedback

1. ↑ t^o ⟶ ↑ rod ⟶ ↑ $[CO_2]$, ↑ $[CH_4]$

Since CO_2 and CH_4 are greenhouse gases, the temperature will go up even more so we can draw arrows and a + sign to show this:

2. ↑ t^o ⟶ ↑ rod ⟶ ↑ $[CO_2]$, ↑ $[CH_4]$ ⟲ (+)

This is positive feedback i.e a change away from the equilibrium has stimulated other processes that have then pushed the system even further out of equilibrium

3. ↑ t^o → ↑ ice + snow melt → ↓ albedo → ↑ absorption of solar radiation ⟲ (+)

The most important positive feedback mechanism is considered to be the one involving water vapour, a powerful greenhouse gas

↑ t^o → ↑ evaporation → ↑ water vapour ⟲ (+)

Negative Feedback

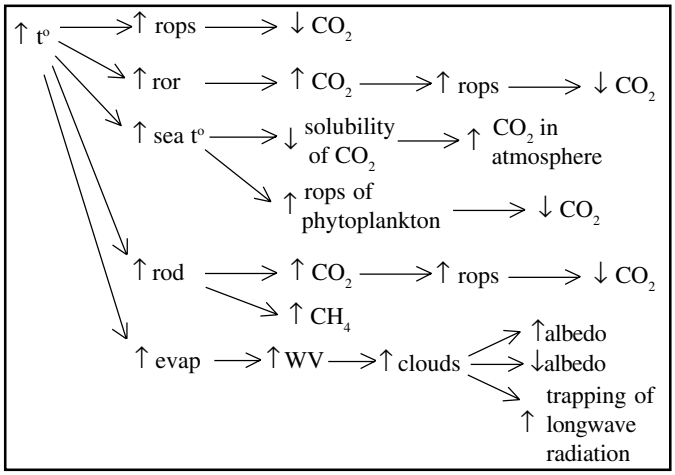
1. ↑ t^o ⟶ ↑ rop ⟶ ↓ CO_2

Since CO_2 is a greenhouse gas a reduction in its concentration will mean less longwave radiation is trapped in the troposphere and temperature will go down so we can draw an arrow thus:

2. ↑ t^o ⟶ ↑ rop ⟶ ↓ CO_2 ⟲ (-)

The above effects are on the A2 specification and you must learn them. But you could be asked to apply your knowledge to more complicated scenarios

Make sure you can explain each of the following steps and that you understand whether each is an example of positive or negative feedback or both!



Clouds

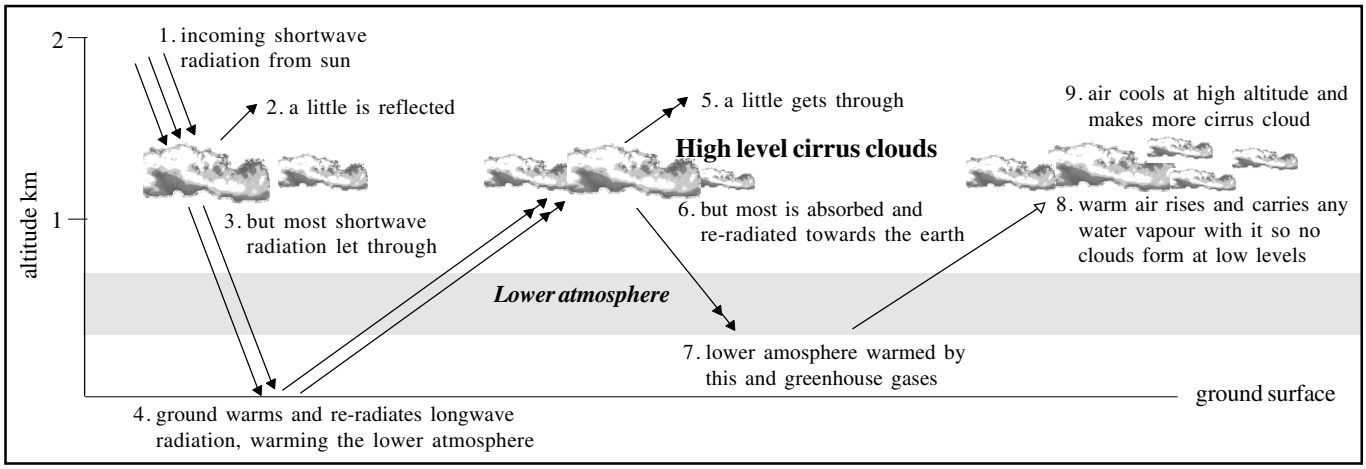
Clouds affect the temperature of the troposphere in several ways:

1. They reflect incoming shortwave radiation back out to space i.e. they help to keep the troposphere **cool**.
2. They also absorb outgoing longwave radiation and reradiate heat back towards the ground – thus helping to **warm** the troposphere

Which of the two processes dominates depends on factors such as cloud ice particle composition, cloud cover and cloud location and is the subject of much research by NASA.

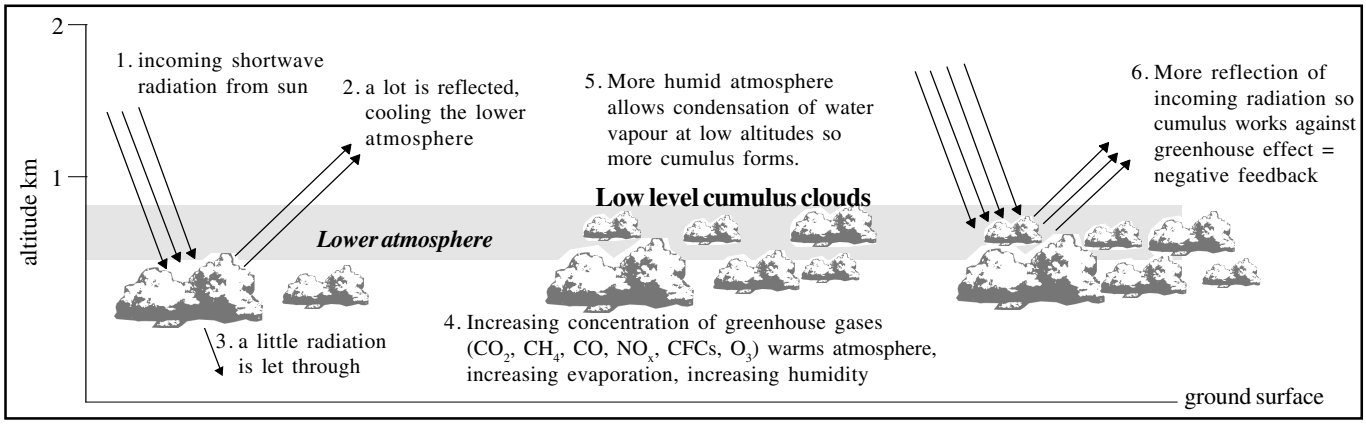
However, in general: high altitude cirrus clouds reflect some incoming shortwave radiation back out to space but they let most through and this radiation is then able to reach the earth's surface. However, these clouds are very efficient at trapping in reradiated longwave radiation, so their **net** effect is to warm the troposphere. Remember that the temperature of the lower atmosphere is increasing anyway as a result of the concentration of greenhouse gases. Warm air near to the ground rises upwards, carrying water vapour with it and this reduces the amount of low-level cloud that forms. Eventually the water condenses at high altitude, forming more cirrus. Hence cirrus cloud leads to greater warming which leads to more cirrus which leads to more warming – producing positive feedback (Fig 1.)

Fig 1. The positive feedback effect of cirrus cloud



Low level cumulus cloud reflects a lot of the incoming shortwave radiation back out to space and this cools the troposphere and the earth's surface. As the greenhouse gases warm the lower atmosphere, evaporation and transpiration increase, thus the humidity of the lower atmosphere increases. Condensation of this moisture at low level can produce thick layers of cumulus cloud. This cumulus cloud reflects more and more of the incoming radiation, thus acting against the effect of the greenhouse gases – negative feedback (Fig 2.)

Fig 2. The negative feedback effect of cumulus cloud



No-one knows the net effect.Hundreds of scientific studies & models are ongoing and scientists are simply unsure of whether the net effect will be more cooling or more warming or whether the changes to cumulus and cirrus will cancel each other out.

Further information

www.giss.nasa.gov Goddard institute for space studies – excellent accounts of cloud research

Global change data and information system www.globalchange.gov

Scroll down on the Home page to the excellent "Ask Dr Global Change" section

IPCC report: Climate Change 2001

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