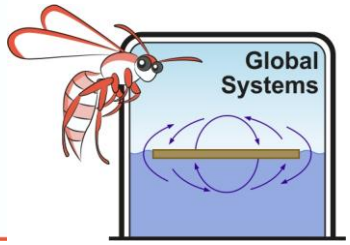


Permafrost Feedback Loops - Teacher Notes

Permafrost is frozen rock, soil and organic materials. It occurs at high altitudes and high latitudes and acts as a long-term carbon sink. Permafrost can vary in thickness from 1 meter to 1,500 meters. It occupies 25% of the land in the Northern Hemisphere occurring in a belt of land stretching from Siberia to China and in North America. In the Southern Hemisphere it is found in Antarctica, the Antarctic mountains and in the Andes Mountains. Ground must remain frozen for two consecutive years to be classified as true permafrost. Presently most of the permafrost has remained continuously frozen since the last Ice Age. More shallow permafrost was added during cold periods about 6,000 years ago and about 400 years ago.

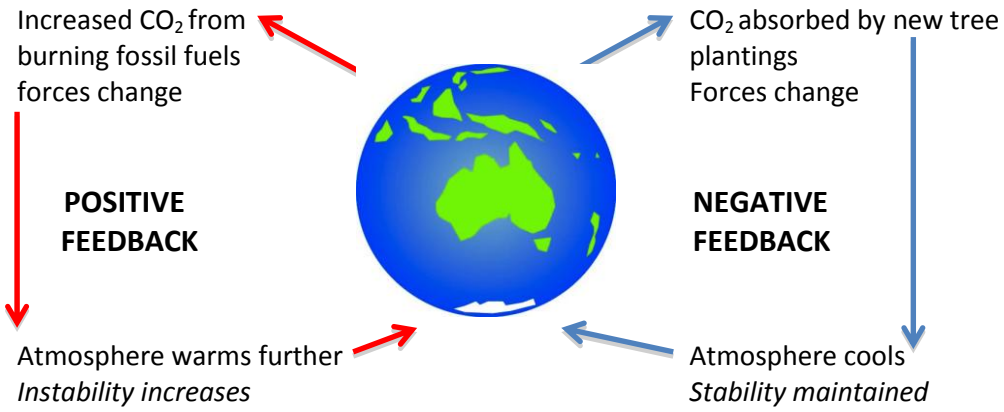
Permafrost can be used as a proxy thermometer as it melts and freezes response to changes in air temperature. Canadian studies have suggested that there is a distinct time lag between atmospheric warming and melting due to the great depth of permafrost.

Current changes to permafrost and climate change

There are two major problems that will occur if global warming forces permafrost melting:

1. The release of increased volumes of stored methane and carbon dioxide into the atmosphere. These are “greenhouse gasses” and will cause increased melting.
2. Movement of the soil causing disruption of infrastructure such as pipelines, roads and building stability and of increased erosion and changes in water table and geomorphology.

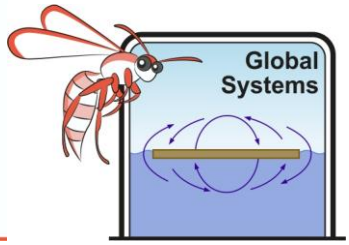
Feedback loops and climate change



Climate is the result of many systems working together. To be stable, systems need to be self-regulating. Feedback loops permit systems to modify their response to change (forcing factors) to return to stable conditions.

Positive feedback amplifies the effect of the forcing factor. E.g. If a child cries from fear shouting at them will only increase the fear and crying. Increased temperatures will melt permafrost and release methane and carbon dioxide. These are “greenhouse gasses and will cause further heating of the atmosphere. The system becomes increasingly unstable.

Negative feedback reduces the effect of the forcing factor helping the system to return to normal. E.g. If a child cries from hunger, giving them food means they will no longer be hungry and will no longer cry. If the atmosphere is becoming warmer due to increased carbon dioxide, planting trees will absorb some of the forcing carbon dioxide, will reduce temperature rise and will work towards returning the system to stability.



Permafrost Feedback Loops - Teacher Notes

Feedback loops

To be stable, systems need to be self-regulating. Feedback loops permit systems to modify their response to change (forcing factors) to return to stable conditions. Human beings depend on feedback loops to keep our bodies balanced and healthy.

A negative feedback loop reduces the effect of change and helps maintain balance within our bodies.

A positive feedback loop increases the effect of the change and produces instability.

Feedback scenarios

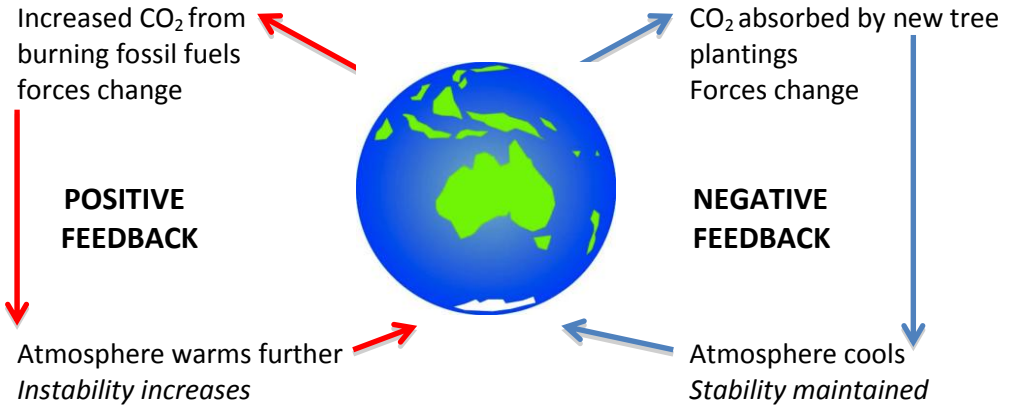
Which of the following feedback loops are positive and which are negative?

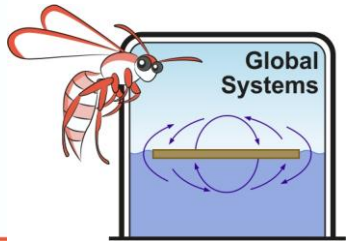
1. A student eats a whole bag of salty chips and becomes thirsty as a result. They drink two glasses of water and no longer feel thirsty. Negative feedback as the student is no longer thirsty.

2. Beer contains chemicals (diuretics), which make people thirsty. At home a teacher drinks two glasses of beer because they feel hot and thirsty. After twenty minutes they feel even thirstier and drink more beer. Positive feedback as they originally felt thirsty and now feel even thirstier.

3. Late for class, students run the last 200m very quickly. They arrive outside the door gasping for breath, however four deep breaths bring them back to normal and they calmly walk through the door. Negative feedback as the student is no longer gasping.

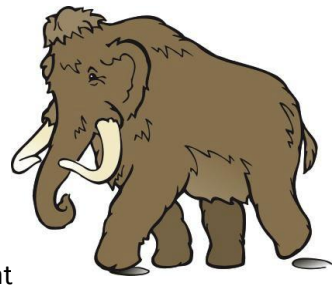
Like our bodies, climate stability is the result of many systems working together. Feedback loops can maintain a stable climate system. Human generated changes can produce ***forcing factors***, which can destroy balance. Burning fossil fuels pumps unusually high amounts of carbon dioxide into the atmosphere.





Permafrost Feedback Loops - Teacher Notes

The effect of climate change warming on permafrost



Permafrost is frozen soil, rock and organic materials. It occurs at high altitudes and high latitudes (near the poles). The ground must remain frozen for over two years. Most of our present permafrost has remained unmelted since the last Ice Age. Bacteria in the soil decompose organic matter producing methane and carbon dioxide as a by-product. These gasses are held within an ice matrix as clathrates. Permafrost acts as a long-term carbon sink. The bodies of woolly mammoths have been found in perfect condition in permafrost in Siberia. Studies in Canada suggest that permafrost areas are decreasing. If our climate warms due to increasing levels of greenhouse gasses, more soil will defrost and these gasses will dissolve into water and diffuse into the atmosphere to join other greenhouse gasses.

Will this increase in aerosol gasses result in positive or negative feedback? This is a positive feedback loop as the end result is that the initial stimulus is increased and system stability will not be maintained.

Write a flow chart (loop) or draw a labelled diagram describing the sequence of events that may be precipitated when permafrost starts to melt. Name the sinks and releasing factors for methane.

Initial sink permafrost soil
Releasing factor warming atmosphere
Leading to melting of permafrost soils
Leading to greenhouse gasses released into atmosphere (sink)
Leading to increased greenhouse gas levels in atmosphere
Leading to further warming of atmosphere (reinforcement or strengthening of original stimulus and the cycle continues.

Methane has a relatively short residence in the atmosphere. It only remains for about 10 years before it breaks down to form carbon dioxide and water. It is however twenty times more effective in heat retention than carbon dioxide.

Describe two forcing factors leading to global warming that occur when permafrost melts and methane levels in the atmosphere rise.

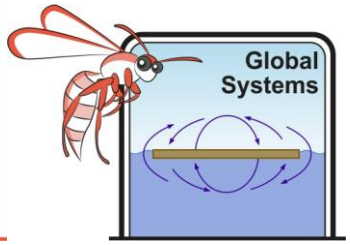
1. Methane is a greenhouse gas and will cause warming for about 10 years
2. When methane degrades/breaks down it forms carbon dioxide, which is also a greenhouse gas although it is ten times less effective.

Individual carbon dioxide molecules only remain in the atmosphere a few days before they dissolve into the ocean. To maintain equivalence of partial pressure however, for every molecule that is absorbed by the ocean, it releases one into the atmosphere to maintain balance.

If melting permafrost releases 12 molecules of carbon dioxide into the atmosphere:
How many molecules will be almost immediately absorbed into the sea? 12

After a short time how many molecules will remain in the sea? Six molecules as this will balance six molecules returning to the atmosphere.

What effect will these molecules of carbon dioxide have on the pH/acidity or alkalinity of the sea?
It will become more acid



What effect might this change have on sea organisms which have carbonate shells or skeletons?
They will dissolve

Methane has a relatively short residence in the atmosphere. It only remains for about 10 years before it breaks down to form carbon dioxide and water. It is however twenty times more effective in heat retention than carbon dioxide. Reducing the amount of methane released into the atmosphere would produce a rapid reduction of temperature.

Interesting fact **Methane clathrates in the ocean**

Methane clathrates are also held under great pressure in ocean deeps. Warming will decrease water pressure and release these reserves. Geologists have suggested that one of the factors causing major extinctions such as the "Great Dying" between Permian and Triassic times was exacerbated by the release of methane clathrates from the sea. Enormous volcanic basaltic rock outpourings from vents built up the Siberian Traps. Volcanic activity would have been accompanied by venting of huge volumes of carbon dioxide forcing global warming. Warm seas could no longer retain methane and it would have entered the atmosphere causing further lethal global warming. This was the greatest extinction of all time. 96% of all marine species died and 70% of all terrestrial species. It was the only known mass extinction of insects.

Evidence for this theory lies with the rocks deposited at this time. The ratio of ^{13}C to ^{12}C indicates that methane from bacterial breakdown produced a very high proportion of the carbon found in the rocks.