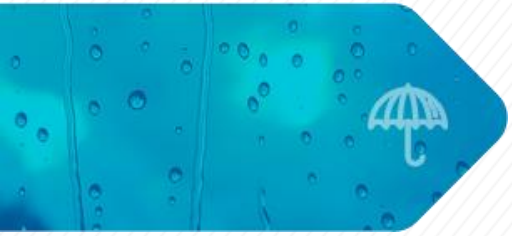
Introduction to Meteorology

39 Climate system feedback and interaction (1)

Introduction

The Earth climate system is in a delicate balance between incoming and outgoing energy. If this balance is broken, even slightly, climate can undergo a series of complicated changes. A remakable disturbance is the global warming attributed to the emission of carbon dioxide by human activity. The radiative forcing due to an increase in greenhouse gases may cause a temperature increase of less than 0.5 degree for 100 years. However, the actual global temperature has risen more than 0.5 degree. This is due to the feedback within the climate systems. The water vapor-temperature positive feedback is a typical example. Increase in atmospheric temperature allows more water vapor to evaporate into the atmosphere and again strengthens the greenhouse effect.

Contents



1. Climate system feedback

Learning objectives

1. Explain the concept of climate system feedback.

Learning Activities

1. Climate system feedback

Climate systems have feedbacks that amplify the temperature increase, such as the water vapor –temperature feedback (positive feedback). Conversely, there are also feedbacks that tend to weaken the temperature increase (negative feedback)

Learning Activities

1. Climate system feedback

1) Negative feedback and positive feedback

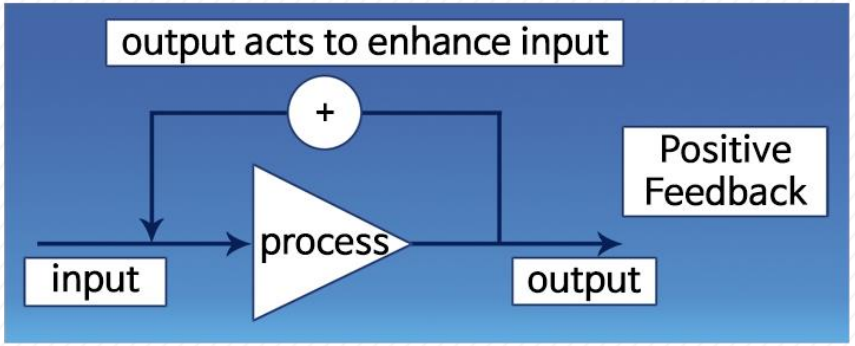
Some feedbacks reinforce the initial change (positive feedback) as shown in the figure, while some weaken the initial changes (negative feedback).

The Earth's climate system has both positive and negative feedbacks. All feedback mechanisms work simultaneously but with the different timescale.

Some feedbacks occur instantaneously, while others take place over thousands of years. Sometimes it is unclear whether the two variables are positively or negatively correlated.

Let's look at a case where the atmosphere slowly warms up as an example of positive feedback in the climate system. As the temperature increases, the amount of water vapor that the atmosphere can contain might increase, which would increase the surface evaporation and water vapor in the atmosphere. The temperature will be further increased by the greenhouse effect.

Another positive feedback is the case in which the atmosphere has been cooled over hundreds or thousands of years. In this case, high-latitude is covered with snow and ice. Snow and ice reflect the light, which eventually reduces the solar radiation and cools the atmosphere.



〈Positive feedback〉

Learning Activities

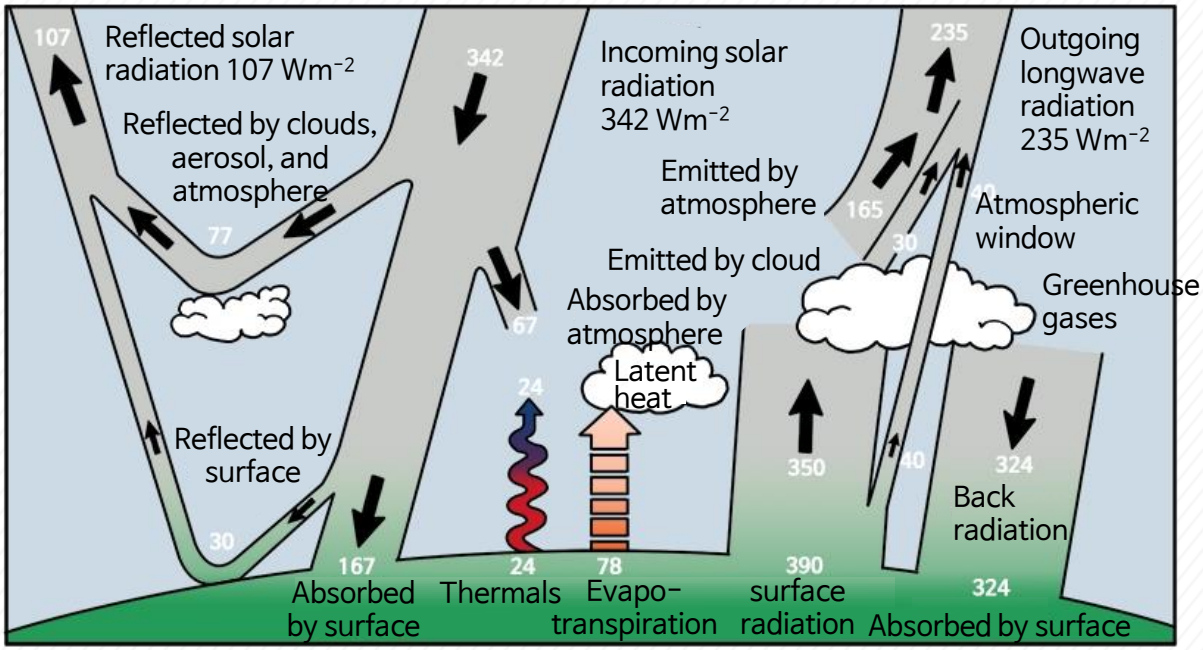
1. Climate system feedback

This figure shows global energy balance. The climate of the earth is maintained through a complex balance between the energy transfer processes.

The increase in carbon dioxide primarily affects changes in the energy balance associated with the greenhouse gas, which in turn leads to secondary changes in the energy balance.

For example, the increase in energy reaching the surface (back radiation) induces a change in the surface, such as sea ice decrease or vegetation increase, which affect the energy balance.

A better understanding of these feedback mechanisms is necessary to predict the future climate change more accurately.



〈The Earth's annual global mean energy budget〉

※ Source: Kiehl and Trenberth (1997)

Summary

1. Climate system feedback

Feedback theory:

The Earth climate system is in a delicate balance between incoming and outgoing energy. If this balance is broken, even slightly, climate can undergo a series of complicated changes.

- Positive feedback
  - Mechanisms that reinforce the initial change.
- Negative feedback
  - Mechanisms that weaken the initial change.