

In beginning our discussion of clouds, we need to introduce the concept of forcing and feedback. According to the Intergovernmental Panel on Climate Change, climate forcing is an influence that a climate factor has in altering the balance in the earth system. Carbon dioxide, as discussed in an earlier lecture, is an example of a positive climate forcing agent. An increase in carbon dioxide warms the Earth's surface temperature.

Conversely, a negative forcing tends to cool. Aerosols are one example of a negative forcing agent. Forcing is generally expressed in watts per meter squared. A forcing is idealized as occurring at a specific position in the atmosphere. This is commonly taken as the boundary between the troposphere and stratosphere, a layer called the tropopause.

Climate feedback, on the other hand, is a process that is initiated by direct climate change. These processes can take place in the atmosphere, the ocean, or on the Earth's surface. Climate feedbacks can increase-- that is to say they are positive-- or decrease-- that is to say they are negative, the magnitude of the direct climate change.

There are several examples of climate feedback. These include water vapor, ice, albedo, clouds, surface evaporation, and biogeochemical feedbacks. We will go into depth on some of these with an emphasis on clouds during this lecture. Feedbacks can be perhaps most easily understood for the case of water vapor. An increase in temperature due to the direct climate change of greenhouse gases can lead to a higher concentration of water vapor because warmer air can hold more of this species. Water vapor is itself an infrared absorber. And this is therefore considered a positive feedback.

Cloud effects are more difficult to characterize. In the case of clouds, there are several direct changes, one being the addition of aerosols. Aerosols themselves can impact climate by absorbing or scattering solar and terrestrial radiation. As we learned in the last lecture, the dominant process is scattering of solar energy. And thus, we would say that aerosols are a negative forcing agent.

By interacting with atmospheric conditions including gases, such as water vapor, and ambient temperature, which may change due to direct forcing agents, aerosols can nucleate clouds. This would be termed a negative feedback since clouds tend to scatter more solar energy than they trap terrestrial radiation. Clouds are often called an indirect aerosol effect.

In conclusion, we can see that the climate system is not simply an added set of direct forcings, but instead can be visualized by the flow chart shown here, where forcings can perturb and lead to responses which then modify original forcing agents. Indeed, initial changes in forcing can be both natural, such as solar processes, the Earth's orbit, and volcanoes, or, as we've concentrated on, anthropogenic, such as the emissions created by fossil fuel burning, industrial processes, and land use changes.