aus: IPCC-Bericht **1995**, WG1,
Seite 58, .pdf-Seite 72

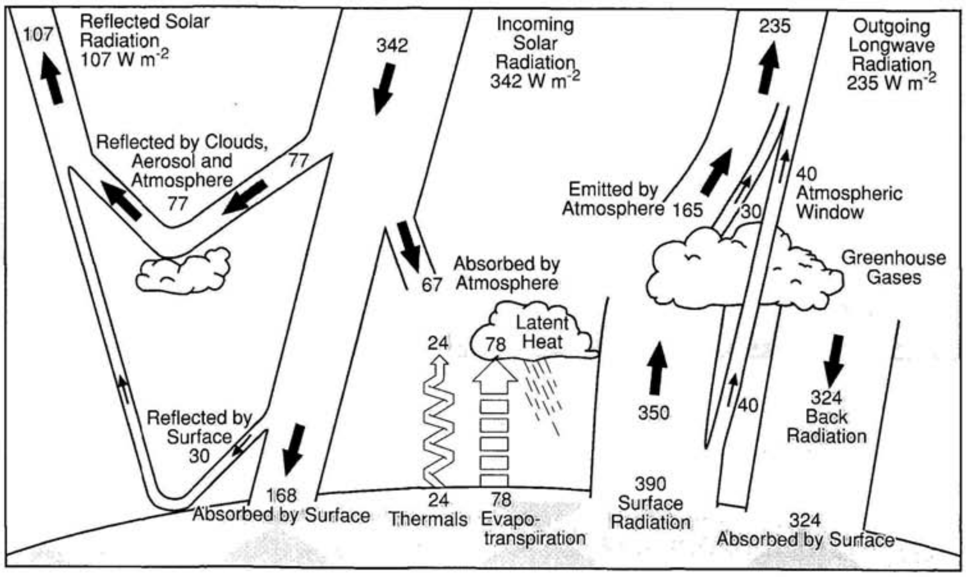


Figure 1.3: The Earth's radiation and energy balance. The net incoming solar radiation of 342 Wm^{-2} is partially reflected by clouds and the atmosphere, or at the surface, but 49% is absorbed by the surface. Some of that heat is returned to the atmosphere as sensible heating and most as evapotranspiration that is realised as latent heat in precipitation. The rest is radiated as thermal infrared radiation and most of that is absorbed by the atmosphere which in turn emits radiation both up and down, producing a greenhouse effect, as the radiation lost to space comes from cloud tops and parts of the atmosphere much colder than the surface. The partitioning of the annual global mean energy budget and the accuracy of the values are given in Kiehl and Trenberth (1996).

radiation from areas where there is no cloud and which is present in the part of the spectrum known as the atmospheric "window" (Figure 1.3). The bulk of the radiation, however, is intercepted and absorbed by the atmosphere which in turn emits radiation both up and down. The emissions to space occur either from the tops of clouds at different atmospheric levels (which are almost always colder than the surface), or by gases present in the atmosphere which absorb and emit infrared radiation. Most of the atmosphere consists of nitrogen and oxygen (99% of dry air) which are transparent to infrared radiation. It is the water vapour, which varies in amount from 0 to about 2%, carbon dioxide and some other minor gases present in the atmosphere in much smaller quantities which absorb some of the thermal radiation leaving the surface and emit radiation from much higher and colder levels out to space. These radiatively active gases (see Chapter 2 for details) are known as greenhouse gases because they act as a partial blanket for the thermal radiation from the surface and enable it to be substantially warmer than it would otherwise be, analogous to the effects of a greenhouse. This blanketing is known as the natural greenhouse effect.

Clouds also absorb and emit thermal radiation and have a blanketing effect similar to that of the greenhouse gases. But clouds are also bright reflectors of solar radiation and thus also act to cool the surface. While on average there is strong cancellation between the two opposing effects of short-wave and long-wave cloud radiative forcing (Chapter 4) the net global effect of clouds in our current climate, as determined by space-based measurements, is a small cooling of the surface.

1.2.3 Mars and Venus

Similar greenhouse effects also occur on our nearest planetary neighbours, Mars and Venus. Mars is smaller than the Earth and possesses, by Earth's standards, a very thin atmosphere (the pressure at the Martian surface is less than 1% of that on Earth) consisting almost entirely of carbon dioxide which contributes a small but significant greenhouse effect. The planet Venus, by contrast, has a

Gelb-Markierung nachträglich hinzugefügt

Quelle:
www.ipcc.ch/ipccreports/sar/wg_I/ipcc_sar_wg_I_full_report.pdf#page=72

aus: IPCC-Bericht **2001**, WG1, Chapter 1,
Seite 90, .pdf-Seite 6

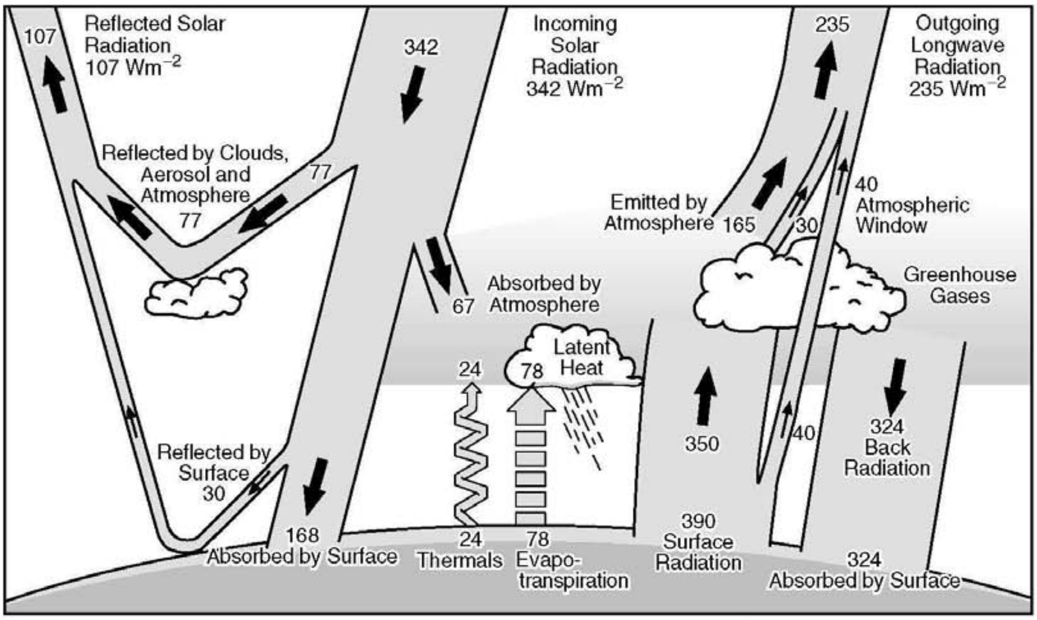


Figure 1.2: The Earth's annual and global mean energy balance. Of the incoming solar radiation, 49% (168 Wm^{-2}) is absorbed by the surface. That heat is returned to the atmosphere as sensible heat, as evapotranspiration (latent heat) and as thermal infrared radiation. Most of this radiation is absorbed by the atmosphere, which in turn emits radiation both up and down. The radiation lost to space comes from cloud tops and atmospheric regions much colder than the surface. This causes a greenhouse effect. Source: Kiehl and Trenberth, 1997: Earth's Annual Global Mean Energy Budget, *Bull. Am. Met. Soc.* 78, 197-208.

and clouds, except in a transparent part of the spectrum called the "atmospheric window", as shown in Figure 1.2. They emit in turn infrared radiation in all directions including downward to the Earth's surface. Thus greenhouse gases trap heat within the atmosphere. This mechanism is called the natural greenhouse effect. The net result is an upward transfer of infrared radiation from warmer levels near the Earth's surface to colder levels at higher altitudes. The infrared radiation is effectively radiated back into space from an altitude with a temperature of, on average, –19°C, in balance with the incoming radiation, whereas the Earth's surface is kept at a much higher temperature of on average 14°C. This effective emission temperature of –19°C corresponds in mid-latitudes with a height of approximately 5 km. Note that it is essential for the greenhouse effect that the temperature of the lower atmosphere is not constant (isothermal) but decreases with height. The natural greenhouse effect is part of the energy balance of the Earth, as can be seen schematically in Figure 1.2.

Clouds also play an important role in the Earth's energy balance and in particular in the natural greenhouse effect. Clouds absorb and emit infrared radiation and thus contribute to warming the Earth's surface, just like the greenhouse gases. On the other hand, most clouds are bright reflectors of solar radiation and tend to cool the climate system. The net average effect of the Earth's cloud cover in the present climate is a slight cooling: the reflection of radiation more than compensates for the greenhouse effect of clouds. However this effect is highly variable, depending on height, type and optical properties of clouds.

This introduction to the global energy balance and the natural greenhouse effect is entirely in terms of the global mean and in radiative terms. However, for a full understanding of the greenhouse effect and of its impact on the climate system, dynamical feedbacks and energy transfer processes should also be taken into account. Chapter 7 presents a more detailed analysis and assessment.

Radiative forcing and forcing variability

In an equilibrium climate state the average net radiation at the top of the atmosphere is zero. A change in either the solar radiation or the infrared radiation changes the net radiation. The corresponding imbalance is called "radiative forcing". In practice, for this purpose, the top of the troposphere (the tropopause) is taken as the top of the atmosphere, because the stratosphere adjusts in a matter of months to changes in the radiative balance, whereas the surface-troposphere system adjusts much more slowly, owing principally to the large thermal inertia of the oceans. The radiative forcing of the surface troposphere system is then the change in net irradiance at the tropopause after allowing for stratospheric temperatures to re-adjust to radiative equilibrium, but with surface and tropospheric temperatures and state held

Gelb-Markierung nachträglich hinzugefügt

Quelle:
www.grida.no/climate/ipcc_tar/wg1/pdf/TAR-01.pdf#page=6

aus: IPCC-Bericht **2007**, WG1,
Seite 96, .pdf-Seite 96

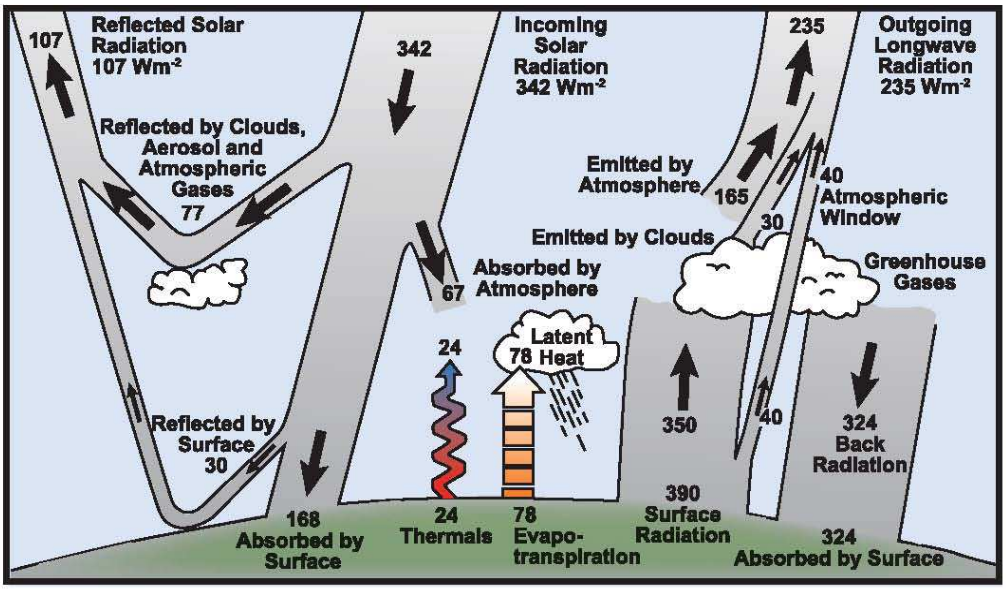
Frequently Asked Question 1.1

What Factors Determine Earth's Climate?

The climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living things. The atmospheric component of the climate system most obviously characterises climate; climate is often defined as 'average weather'. Climate is usually described in terms of the mean and variability of temperature, precipitation and wind over a period of time, ranging from months to millions of years (the classical period is 30 years). The climate system evolves in time under the influence of its own internal dynamics and due to changes in external factors that affect climate (called 'forcings'). External forcings include natural phenomena such as volcanic eruptions and solar variations, as well as human-induced changes in atmospheric composition. Solar radiation powers the climate system. There are three fundamental ways to change the radiation balance of the Earth: 1) by changing the incoming solar radiation (e.g., by changes in Earth's orbit or in the Sun itself); 2) by changing the fraction of solar radiation that is reflected (called 'albedo'; e.g., by changes in cloud cover, atmospheric particles or vegetation); and 3) by altering the longwave radiation from Earth back towards space (e.g., by changing greenhouse gas concentrations). Climate, in turn, responds directly to such changes, as well as indirectly, through a variety of feedback mechanisms.

The amount of energy reaching the top of Earth's atmosphere each second on a surface area of one square metre facing the Sun during daytime is about 1,370 Watts, and the amount of energy per square metre per second averaged over the entire planet is one-quarter of this (see Figure 1). About 30% of the sunlight that reaches the top of the atmosphere is reflected back to space. Roughly two-thirds of this reflectivity is due to clouds and small particles in the atmosphere known as 'aerosols'. Light-coloured areas of Earth's surface – mainly snow, ice and deserts – reflect the remaining one-third of the sunlight. The most dramatic change in aerosol-produced reflectivity comes when major volcanic eruptions eject material very high into the atmosphere. Rain typically

(continued)



FAQ 1.1, Figure 1. *Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. Source: Kiehl and Trenberth (1997).*

Gelb-Markierung nachträglich hinzugefügt

Quelle:
www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4_wg1_full_report.pdf#page=96