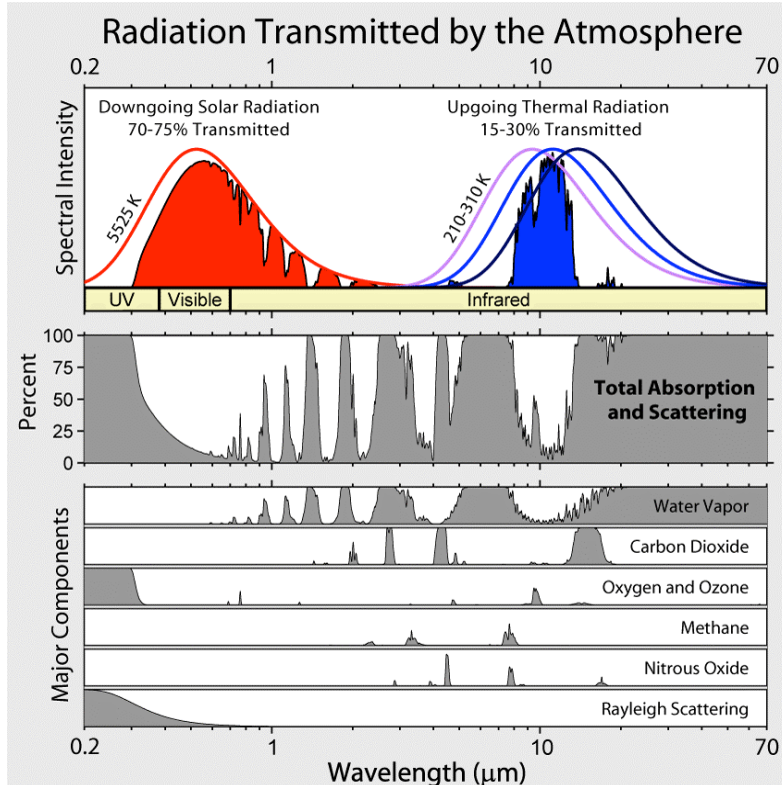


Climate Dynamics (test 1, 18 April 2011, 9:00-12:00)

In this test the symbols, if not explained, have their usual meaning.

Answers may be given Dutch

Problem 1



Absorption bands in the Earth's atmosphere and the effect that this has on both Solar radiation and upwelling thermal radiation. Individual absorption spectra for important atmospheric constituents plus Rayleigh scattering are shown in the lower panel.

(a) The figure above shows the absorption of individual constituents of the atmosphere. Which of these constituents is a so-called “greenhouse-gas”?

(b) Where in the spectrum is the so-called “atmospheric window”?

Problem 2

What kind of climate would we in The Netherlands have if the *obliquity* were equal to zero?

Problem 3

The vertical dependence of the density, ρ_v , of water vapour in the atmosphere can reasonably accurately be approximated by the following formula.

$$\rho_v = \rho_{g,v} \exp\left(\frac{-z}{H_v}\right)$$

Here $\rho_{g,v}$ is the density of water vapour at $z=0$ (the ground) and H_v is the so-called “scale height”. During the Indian summer monsoon a typical value of $\rho_{g,v}$ is 0.024 kg m^{-3} . A typical value of H_v is 3000 m.

(a) How much precipitable water in the form of water vapour per square metre is contained in the atmosphere under such circumstances?

(b) Where does all this water vapour come from?

Problem 4

Give a short (about half a page) review of the influence of clouds on the climate on Earth

Problem 5

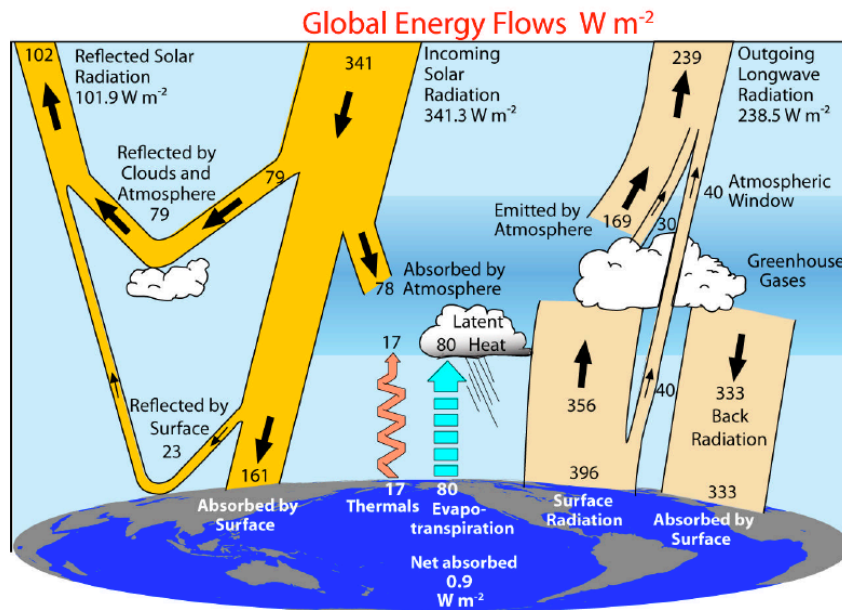
Carbon dioxide is the most important absorber of long wave radiation in the stratosphere, while ozone is the most important absorber of short wave radiation. Most of the stratospheric *short* wave heating occurs in the upper 10 hPa of the atmosphere. The value of the *long* wave optical path, τ_{strat} , of the upper 10 hPa (1000 Pa) of the atmosphere due to this effect can be estimated as follows.

$$\tau_{\text{strat}} = q_{\text{CO}_2} \sigma_{\text{CO}_2} \Delta p / g.$$

For the long wave absorption cross-section of carbon dioxide we may assume that $\sigma_{\text{CO}_2} = 0.3 \text{ m}^2 \text{ kg}^{-1}$. The specific concentration, q_{CO_2} , of carbon dioxide can be estimated to be equal to 400 ppmv.

- Is the upper 10 hPa of the atmosphere optically thin or optically thick to transmission of long wave radiation?
- What is the net long wave emission coefficient of the upper 10 hPa of the atmosphere?
- Estimate the annual mean and global mean radiative equilibrium temperature of the upper 10 hPa of the atmosphere, assuming that 1% of the incoming Solar flux is absorbed in this layer.
- Will the temperature of the upper 10 hPa decrease or increase with increasing CO_2 -concentration?

Problem 6



Earth's annual average energy balance between 2000-2004. Numbers are energy fluxes in W m^{-2} .

All questions below relate to the figure above.

- Is the Earth's surface in radiative equilibrium?
- Calculate the planetary albedo.
- Calculate the cloud albedo, assuming that the cloud fraction is 0.6.
- Name two constituents in the atmosphere that take care of about half the absorption of 78 W m^{-2} of the incoming Solar radiation.