NS-255B

Tentamen Klimaat, straling en thermodynamica – 2 februari 2010

Openboek-tentamen: nee

Enkele opmerkingen vooraf:

- formuleer je antwoord nauwkeurig
- let op spel- en taalfouten
- denk aan de eenheden
- schrijf duidelijk en vermijd doorhalingen
- constanten en formules op de laatste pagina
- succes!

Exercise 1

A particular method to measure the concentration of aerosol particles brings the particles in a saturated environment where they grow out to droplets with a radius of 10 μm. Laser light with a wavelength of 0.5 μm is directed through the container, that has a path length of 50 cm.

a) Calculate the size parameter. Which scattering regime applies?

b) Calculate the optical thickness for a particle concentration of 1000 cm^{-3}.

c) What percentage of the incoming light is transmitted?

Exercise 2

An air parcel at the surface (p=1000 hPa) has a temperature of 24°C and a dewpoint temperature of 16°C.

a) Calculate the relative humidity and the specific humidity of the air.

b) The parcel ascends. At which altitude does it reach saturation? Can this altitude be characterized as the LCL (lifting condensation level)? And as the LFC (level of free convection)?

c) The parcel continues to an altitude of 3 km (p=700 hPa). What is the final temperature and the mass mixing ratio of the liquid water?

Exercise 3

Consider the atmosphere of the Earth as a single isothermal and well-mixed layer over a reflective surface. The atmosphere does not absorb solar radiation, the combined albedo of the surface and the atmosphere is α, and the absorptivity of the atmosphere for infrared radiation is A.

a) Draw a diagram of the surface/atmosphere system and the relevant up- and downwelling radiative fluxes. Assume equilibrium and derive an expression for the surface temperature. Calculate the temperature of the surface and of the atmosphere for α=0.3 and A=0.8.

b) Then dust enters the atmosphere. Dust reflects solar radiation and acts as grey body in the infrared. The albedo increases by α', and the absorptivity by A'. Show that the surface temperature does not change because of dust when α'/A' equals 0.583.

Exercise 4

a) Give the four reactions that make up the Chapman cycle. Indicate which reactions lead to warming of the stratosphere. How does absorption of photons in the UV region by ozone influence radiative transfer through the atmosphere for wavelengths 0.21, 0.28 and 0.35 μm?

b) In the upper part of the stratospheric ozone layer the concentration of ozone molecules can be approximated by: $n=n_0p^{3/2}$, with p being the atmospheric pressure. Derive an expression for the optical thickness for absorption of UV radiation by ozone, as function of p. The zenith angle is 0°, and assume a constant temperature and absorption cross section with altitude. You will need the hydrostatic equation $dp=g\rho dz$.

c) *For bonus points:* Use your result for b) and give an expression for the pressure level where ozone absorption of UV (i.e., dI/dp) maximizes. Show that this corresponds with an optical thickness of 1/3.

Exercise 5

Large quantities of soot aerosol (Dutch: roet) are found in the boundary layer and lower troposphere over the Indian Ocean. The pollution orginates for a large part from biofuel burning in southeast Asia. Consider a layer of soot with a thickness of 2 km. Absorption of sunlight by the soot causes a daily average positive radiative forcing of the atmosphere of 28 W/m^2.

a) Calculate the heating rate of the atmosphere in K/day, assuming a total daylength of 12 hrs and an air density of 1 kg/m^3.

b) What would be the consequence of this warming for the stability of the atmosphere, for the atmospheric circulation and for precipitation?

Constants and equations

Heat capacity air at constant volume/pressure:	717 / 1004 $J^{-1}\ K^{-1}\ kg^{-1}$
Latent heat of evaporation/condensation:	L = 2500 J/g
Molecular mass of water / air:	18 / 29 g/mole
Gas constant:	R = 8.314 J $mole^{-1}\ K^{-1}$
Specific gas constant for water vapor:	R_v = 462 J $kg^{-1}\ K^{-1}$
Specific gas constant for air:	R_a = 287 J $kg^{-1}\ K^{-1}$
Specific density of water:	$\rho_w = 10^6$ g m^{-3}
Stefan-Boltzmann constant:	$\sigma = 5.67*10^{-8}$ W $m^{-2}\ K^{-4}$
Solar constant:	S = 1368 W m^{-2}

Clausius Clapeyron: $$e_s(T) = 10^{\left(9.4041 - \frac{2354}{T}\right)}$$