MO405 Tentamen – June 29, 2010 ?

Openboek-tentamen: no

A few remarks before you start:

Read each problem carefully
Formulate your answers precisely
Use clear handwriting

Succes!

Exercise 1

a. Consider the atmosphere as a homogeneous and isothermal layer. The combined atmosphere-surface albedo is α. The air is transparant for shortwave radiation and has a longwave absorptivity A. Make a scetch of in- and outgoing radiative fluxes at the top-of-atmosphere and the surface. Derive an expression for the surface temperature.

b. After a storm the air contains large amounts of desert dust. Dust scatters sunlight and also acts as a grey body. Adapt the scetch you made in a) for the dusty atmosphere, and derive an expression for the radiative forcing at the surface due to the dust aerosol.

c. Does the surface temperature increase or decrease as a result of this forcing?

Exercise 2

Consider an air parcel with seasalt particles (NaCl). The size distribution is bimodal, with particles of 0.05 μm radius and of 0.1 μm radius in a ratio 9:1. The total particle concentration is 200 cm^{-3}. The ambient temperature is 10° C. The molecular mass M, density ρ and ion yield ν for NaCl are 58.5 g/mole, 2.165 g/cm^3 and 2, respectively.

a. Calculate the supersaturation needed to activate both particles. Also calculate the droplet size at the point of activation.

b. After activation a cloud is formed of 500 m thickness and an average liquid water content of 0.5 g/m^3. Calculate the average radius and the cloud optical thickness of the cloud in case i) the updraft velocity is relatively large and all particles become activated, and ii) the updraft velocity is relatively small and only the large particles are activated.

c. Do you expect significant rain formation for cases i) and ii)? Why (not)?

Exercise 3

(Keep your answers brief and to-the-point!)

a. Explain: the single scattering albedo for aerosol that contains sulfate and soot is smaller than that of pure sulfate particles.

b. Explain: The acidity of rain in the Netherlands is lower than can be expected from the concentrations of sulfate and nitrate in rain water.

c. Explain: Due to the Wegener-Bergeron-Findeisen process a supercooled cloud can transform into an ice cloud within 30 minutes.

d. Explain: A hurricane is an example of a natural moist Carnot cycle.

e. Give the chemical pathway that starts with gaseous SO$_2$ and NH$_3$ and leads to formation of ammonium sulfate, (NH$_4$)$_2$SO$_4$, in the droplet phase.

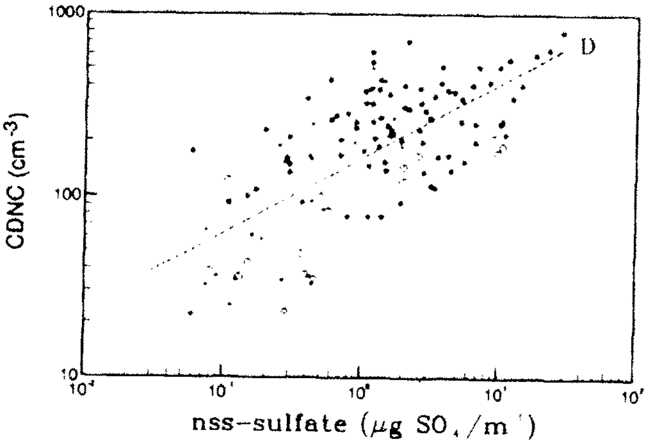
Exercise 4

a. On a cold morning, with an ambient temperature of 0°C and a relative humidity of 30%, you breath out air of 35°C and a relative humidity of 80%. Mixing occurs isobarically between the outside air and your breath, with mass fractions f and $1-f$, respectively. Find expressions (using f and the initial temperature and water vapor pressure in each parcel) for the water vapor pressure and for the saturation water vapor pressure of the mixture.

b. The expressions found under a) can be used to determine if the mixture is saturated. This is difficult to solve analytically, but can you estimate by trial and error in what range of f the mixture is saturated?

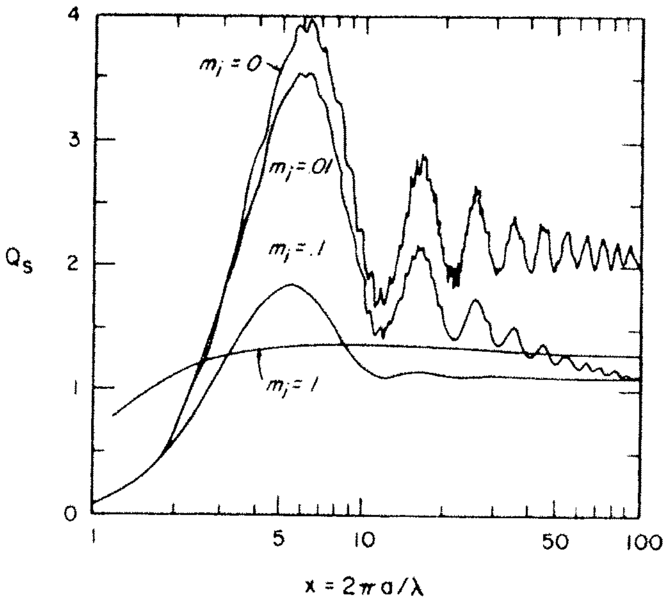
Exercise 5

In early first indirect aerosol effect studies, climate models used an empirical function to approximate the influence of aerosol on cloud drop activation. An example is the relation between aerosol sulfate mass and the cloud droplet number concentration (CDNC) as used by Boucher and Lohmann (1995):



The points refer to individual atmospheric measurements of sulfate mass and CDNC, and the dashed line is the resulting fit that is used in the climate model. Briefly discuss the advantages and disadvantages of such an approach, in terms of computational efficiency and in terms of the representation of relevant dynamical, (micro-)physical and chemical processes.

Constants and equations



Heat capacity air at constant volume/pressure:	717 / 1004 $J^{-1}\,K^{-1}\,kg^{-1}$
Diffusion coefficient for water vapor:	$D = 2.21 \times 10^{-5}\ m^2\,s^{-1}$
Thermal conductivity coefficient:	$K = 2.40 \times 10^{-2}\ J\,m^{-1}\,s^{-1}\,K^{-1}$
Latent heat of evaporation/condensation:	$L = 2500$ J/g
Molecular mass of water / air:	18 / 29 g/mole
Avogadro number:	$6.022\ 10^{23}$ molec/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 density of water:	$\rho_w = 10^6\ g\,m^{-3}$
Stefan-Boltzmann constant:	$\sigma = 5.67 \times 10^{-8}$
Surface tension of water:	$\sigma = 0.075\ N\,m^{-1}$

Clausius Clapeyron: $e_{s,liq}(T) = 10^{\left(9.4041 - \frac{2354}{T}\right)}$ $e_{s,ice}(T) = 10^{\left(10.55 - \frac{2667}{T}\right)}$

Kelvin/Raoult term: $A = \dfrac{2\sigma M_w}{RT\rho_w}$ $B = \dfrac{3 v m_s M_w}{4\pi\rho_w M_s}$

Condensational growth rate of cloud drops:

$$r\frac{dr}{dt} = \frac{(S-1) - \frac{A}{r} + \frac{B}{r^3}}{\left[\left(\frac{L}{R_v T} - 1\right)\frac{L\rho_l}{KT} + \frac{\rho_L R_v T}{De_s(T)}\right]}$$

Collection equation:

$$\frac{dR}{dt} = \frac{\pi}{3}\int_0^R \left(\frac{R+r}{R}\right)^2 \left[u(R) - u(r)\right] n(r) r^3 E(R,r)\,dr$$

P (hPa) – z (m) relation in a standard atmosphere:

$$p = 1013.25 * \left(1 - 2.256 * 10^{-5} * z\right)^{5.256}$$