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EXAMINATION IN FY3201 ATMOSPHERIC PHYSICS AND CLIMATE CHANGE

Faculty for Natural Sciences and Technology
5 June 2012
Time: 09:00-13:00

Number of pages: 3

Permitted help sources: 1 side of an A5 sheet with printed or handwritten formulas permitted
Bi-lingual dictionary permitted
All calculators permitted

You may take:

Molar mass of water vapour: ~18 kg/kmole
Molar mass of dry air: ~29 kg/kmole
273 K = 0 ^oC
Latent heat of vaporization water: $L_v=2.5\text{x}10^6$ J· kg^{-1}
Gas constant for water vapour: $R_v=461$ J·K^{-1}·kg^{-1}
Values for dry air: $C_p=1004$ J·K^{-1}·kg^{-1} $C_v=718$ J·K^{-1}·kg^{-1} $R_d=287$ J·K^{-1}·kg^{-1}
$\gamma = C_p / C_v$ $\kappa = R_d / C_p$ $R_d=C_p - C_v$ $\Gamma_{da}=9.8$ K/km

g=9.8 m s^{-2} and constant in z
1 hPa = 10^2 Pa =10^2 N m^{-2}
Scale Height: H=R·T/g

$$\int \frac{dx}{a+b\cdot x} = \frac{1}{b}\ln(a+b\cdot x) \qquad \int \frac{dx}{(a+b\cdot x)^2} = \frac{-1}{b\cdot(a+b\cdot x)} \qquad \int \frac{dx}{(a+b\cdot x)^3} = \frac{-1}{2b\cdot(a+b\cdot x)^2}$$

Answer all questions (and good luck!):

1) **(25%)** On Venus, the atmosphere consists of 95% CO_2 and 5% N_2. The gravitational acceleration 8.9 m s^{-2}, and the atmospheric pressure at the surface is 9000 kPa (1hPa = 0.1 kPa).

a) What is the mean molar mass and gas constant for the Venus atmosphere? (Take the atomic weights of C, O and N to be 12, 16 and 14, respectively) (7 %)

b) If the atmospheric temperature as a function of altitude is given by the expression:

$$T = T_o - \Sigma\cdot z, \qquad \text{where } \Sigma= 9.4 \text{ K}\cdot\text{km}^{-1} \text{ and } T_o= 735 \text{ K}$$

at what altitude on Venus is the pressure the same as the surface pressure on Earth (1000 hPa)? (15 %)

c) What is the temperature at the altitude where the pressure is 1000 hPa? What planet has these conditions at the surface? (3%)

2) **(25%)** If there is no scattering, a parallel beam from the sun at zenith angle ϕ is absorbed in the atmosphere according to the equation:

$$-\frac{dI_\lambda}{I_\lambda} = -k_\lambda \cdot \rho(z) \cdot \sec(\phi) \cdot dz$$

a) Given an isothermal atmosphere with constant scale height, H, what is the optical depth, τ_λ, at height, z? (8%)

b) Take the sun directly overhead ($\phi=0$), the surface density ρ_o= 1 kg·m^{-3}, the scale height H=10 km and the absorption coefficient k_λ=0.001 m^2·kg^{-1}. Calculate the optical depth at height levels of 40, 30, 20 and 10 km. (4%)

c) Calculate the transmission and absorption of the atmosphere at the height levels 40, 30, 20 and 10 km. (5%)

d) Between which two neighbouring height levels, 40, 30, 20 and 10 km, does the absorption change the most? How is this maximum change related to the optical depth? (5%)

e) When the sun moves off zenith ($\phi>0$), does the maximum in the change of absorption move up or down? (3%)

3) **(25 %)** An air parcel at a pressure of 900 hPa has a temperature of 20°C.

a) How do we define the lifting condensation level (LCL)? If the air parcel is lifted to the LCL and has a temperature of 13°C there, what is the atmospheric pressure there? (5%)

b) The water vapour saturation pressure at temperature T is given by:

$$e_s = 6.112\,hPa \cdot \exp\left[\frac{L_v}{R_v}\left(\frac{1}{273K} - \frac{1}{T}\right)\right]$$

Given that the water vapour mass mixing ratio, μ, of the parcel is constant before condensation occurs, what is the relative humidity of this air parcel before lifting? (12%)

c) If the environmental (atmospheric) temperature decreased adiabatically with height, where would the atmosphere be unstable with respect to vertical motion? Why? (3%)

d) What mass mixing ratio of water must condense during its ascent in order to change the parcel air temperature by 10 K? (Assume the atmospheric mass is the mass of dry air.) (5%)

4) Short Answers (25 %)

a) Explain how the Föhn or Chinook wind comes about. (4%)

b) Describe three types of optical scatter in the atmosphere with regards to wavelength, particle size and asymmetry factor. (4%)

c) What are cloud condensation nuclei (CCN), and why are they needed in order to condense water vapour in the atmosphere? (4%)

d) If the greenhouse effect produces a warming in the troposphere, why is there a net 2 K/day radiative cooling in the upper troposphere? (5%)

e) In atmospheric models, how does one treat physical or chemical processes that have a scale size smaller than the model grid size? (4 %)

f) If an atmospheric absorption line is saturated, describe what happens to the absorption if we continue to increase the absorber density? (4%)