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EXAMINATION IN FY3201 ATMOSPHERIC PHYSICS AND CLIMATE CHANGE

Faculty for Natural Sciences and Technology
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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
Approved calculators are permitted

You may take:

Molar mass of water vapour	~18 kg/kmole		g=9.8 m s^{-2} and constant in z	
Molar mass of dry air	~29 kg/kmole		1 hPa = 10^2 Pa =10^2 N m^{-2}	
273 K = 0 ºC			Scale Height, H=R·T/g	
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}
	$\gamma = C_p / C_v$	$\kappa = R_d / C_p$	$R_d=C_p - C_v$	Γ_{da}=9.8 K/km

Answer all 5 questions (and good luck!):

1) Atmospheric structure (20 %):

a) At the beach, where both the ocean and the land can be taken to lie at a height of 0 meters, the Sun has warmed up the air-mass over the land to a uniform temperature of 25ºC. The air-mass over the ocean still has a uniform temperature of 15 ºC. If the air pressure at the surface is 1000 hPa, determine the air pressure of the layers 2 km above the ocean and the land, respectively. Assume dry air. (15%)

b) In which direction does the wind blow at a height of 2 km? (3%)

c) In reality a flow pattern will be set up between the land and sea at the surface. Sketch this pattern with arrows that show the local wind direction. (2%)

2) Atmospheric thermodynamics (20 %)

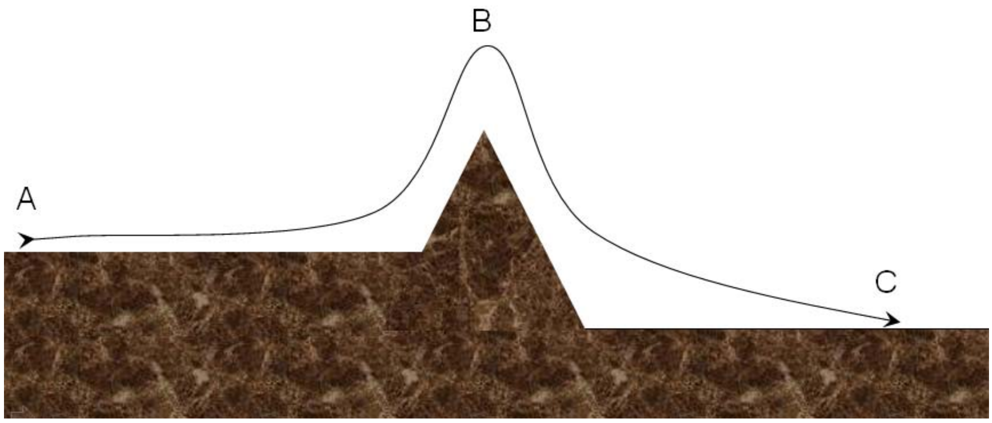
An air-packet begins at a height of 500 m (point A in the figure below) where the air pressure is 940 hPa and the temperature is 15^{o}C, and is carried up the mountain to point B where the air pressure is 800 hPa. Afterwards, the air packet comes down the other side of the mountain to point C where the air pressure is 1000 hPa. Assume dry air and that the air packet undergoes adiabatic expansion and compression.

a) Determine the potential temperature at point A. (5%)

b) Determine the temperature at points B and C, respectively. (11%)

c) If the air packet had contained water vapour which just began to condense at point B, would the air packets temperature be warmer or colder than a dry air packet at points B and C, respectively. Assume that both the dry and moist air packets had the same temperature at point A. (2%)

d) If the air packet had contained water vapour which began to rain out on the mountain top, would the air packet's temperature be warmer or colder than a dry air packet at points B and C, respectively. Assume that both the dry and moist air packets had the same temperature at point A. (2%)



3) Radiation and scattering (20 %)

a) A volcanic ash cloud is 400 m thick and consists of 1 μm (10^{-6} m) diameter particles which have a uniform density of $1x10^{9}$ m^{-3}. A parallel beam of solar radiation with a wavelength of 1 μm hits the ash cloud at a zenith angle of 0^{o}. The bean is scattered with Mie scattering which has a scattering cross section which is 4 times larger than the particle's cross-sectional area. Calculate the cloud layer's optical depth. (8 %)

b) What is the cloud layer's transmission in percent? (8 %)

c) Would the cloud layer's transmission be expected to increase or decrease for wavelengths at 10 μm where the Earth radiates its thermal emission? Why? (2 %)

d) On these grounds, would the ash cloud be expected to warm or cool the Earth? Explain. (2 %)

4) Climate and models (20 %)

a) What are the most important optical properties of a gas that allow it to create a greenhouse effect? (5 %)
b) Describe briefly the difference between numerical grid models and spectral models (5 %)
c) What is meant by a radiative equilibrium temperature? (5 %)
d) Give two examples of processes which are of such small scales that they can not be directly solved in models and must be parameterized. (5 %)

5) Atmospheric stability (20 %)

a) Under what conditions is a dry atmosphere stable against vertical motion and why? (10 %)

b) How does water vapour in the atmosphere influence this stability? (10 %)