Problem Set #1

CONVECTIVE CLOUDS AND STORMS

METR 6223

Fall 2021

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Handed out: Tuesday, 7 Sept. 2021

Due: Tuesday, 14 Sept. 2021

1. (Problem 1.1 on p. 13 of Emanuel’s text)

Determine the total buoyancy force acting on a sample of air of dimensions 10^6 m^3 with a uniform temperature of 28^0 C, immersed in air with a uniform temperature of 0^0 C. Assume that the pressure is 1000 hPa. Also, determine the force per unit mass acting on the sample.

2. (Problem 1.2 on p. 13 of Emanuel’s text)

Suppose that the buoyancy acceleration acting on the sample in the previous problem is maintained at a fixed value. Determine the velocity of the sample at altitudes of 1, 2, 3, 4, and 5 km, if it starts from rest at z = 0 km. Neglect vertical perturbation-pressure gradients.

3. Calculate the pressure variable π at 100 mb increments from 1000 mb to 100 mb.

4. This is a problem designed to calculate the acceleration due to the buoyancy force using temperature and pressure as thermodynamic variables and to compare it to calculations of the acceleration due to the buoyancy force using potential temperature and the Exner function as thermodynamic variables: Suppose that a bubble of air is 5^0 C warmer than its environment and that its pressure is 1 hPa higher than that of the environment.

(a) What is the buoyancy force in terms of pressure and temperature at 850 hPa? at 500 hPa? at 300 hPa? The temperature in the environment at 850, 500, and 300 hPa is 20^0 C, -10^0 C, and -35^0 C, respectively.

(b) What is the buoyancy force in terms of potential temperature at the three pressure levels in (a)?

(c) For (b) at 500 hPa, what is the vertical gradient of Exner function if the buoyant bubble is squashed vertically so that it is extremely shallow and extremely wide?

5. Suppose that an air parcel inside a convective cloud at 500 hPa is 5ºC warmer than its environment, which is -9ºC. What must the liquid water mixing ratio be (g kg^{-1}) inside the cloud in order to completely negate the thermal buoyancy?