מבוא לדינמיקה של האטמוספירה – שעורי בית 2: מועד הגשה: בשיעור של ה- 7/11
פתרו את שאלות 1, 2, 7, 10, ו-12 מפרק 4 בספר של מרשל ופלאם:

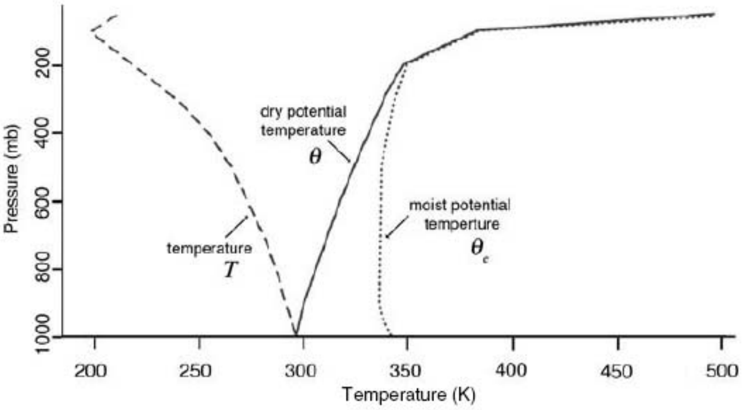
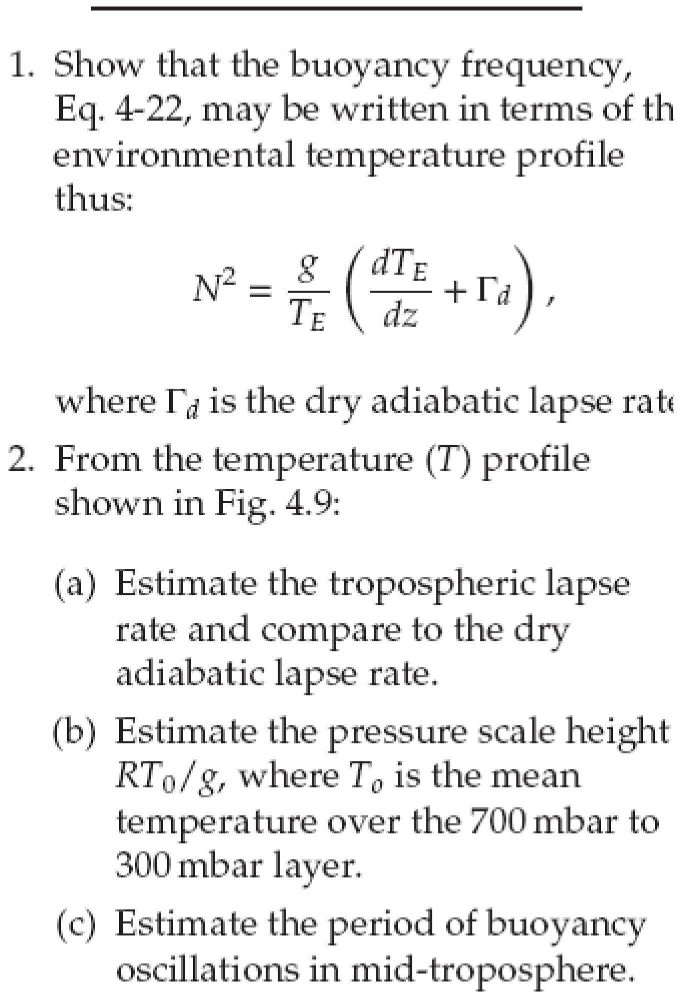


FIGURE 4.9. Climatological atmospheric temperature T (dashed), potential temperature θ (solid), and moist potential temperature θ_e (dotted) as a function of pressure, averaged over the tropical belt ±30°



1. Show that the buoyancy frequency, Eq. 4-22, may be written in terms of th environmental temperature profile thus:

$$N^2 = \frac{g}{T_E}\left(\frac{dT_E}{dz} + \Gamma_d\right),$$

   where Γ_d is the dry adiabatic lapse rat

2. From the temperature (T) profile shown in Fig. 4.9:

   (a) Estimate the tropospheric lapse rate and compare to the dry adiabatic lapse rate.

   (b) Estimate the pressure scale height RT_0/g, where T_o is the mean temperature over the 700 mbar to 300 mbar layer.

   (c) Estimate the period of buoyancy oscillations in mid-troposphere.

7. Assume the atmosphere is in hydrostatic balance and isothermal with temperature 280 K. Determine the potential temperature at altitudes of 5 km, 10 km, and 20 km above the surface. If an air parcel was moved adiabatically from 10 km to 5 km, what would its temperature be on arrival?

10. In Section 3.3 we showed that the pressure of an isothermal atmosphere varies exponentially with height. Consider now an atmosphere with uniform *potential temperature*. Find how pressure varies with height, and show in particular that such an atmosphere has a discrete top (where $p \to 0$) at altitude $RT_o/\left(\kappa g\right)$, where R, κ, and g have their usual meanings, and T_o is the temperature at 1000 mbar pressure.

12. Observations show that, over the Sahara, air continuously subsides (hence the Saharan climate). Consider an air parcel subsiding in this region, where the environmental temperature T_e decreases with altitude at the constant rate of $7\,\mathrm{K\,km^{-1}}$.

    (a) Suppose the air parcel leaves height z with the environmental temperature. Assuming the displacement to be adiabatic, show that, after a time δt, the parcel is warmer than its environment by an amount $w\Lambda_e\delta t$, where w is the subsidence velocity and

    $$\Lambda_e = \frac{dT_e}{dz} + \frac{g}{c_p}\,,$$

    where c_p is the specific heat at constant pressure.

    (b) Suppose now that the displacement is not adiabatic, but that the parcel cools radiatively at such a rate that its temperature is *always the same as* its environment (so the circulation is in equilibrium). Show that the radiative rate of energy loss per unit volume must be

$\rho c_p w \Lambda_e$, and hence that the net radiative loss to space per unit horizontal area must be

$$\int_0^\infty \rho c_p w \Lambda_e \, dz = \frac{c_p}{g} \int_0^{p_s} w \Lambda_e \, dp \ ,$$

where p_s is surface pressure and ρ is the air density.

(c) Radiative measurements show that, over the Sahara, energy is being lost to space at a net, annually-averaged rate of 20 W m^{-2}. Estimate the vertically-averaged (and annually-averaged) subsidence velocity.