Homework 2

In the first problem, we look at the thermal, moisture, and wind structures of the atmosphere and their effects on atmospheric stability. In the second problem, we calculate plume rise height in a stable atmosphere and inspect the effect of latent heat release from condensation of water.

1. Temperature profiles at day and night (10 points)

(a) In daytime, temperature decreases with altitude at 6.5 K/km. If the surface temperature is 288 K, show the vertical profiles of T and θ from the surface to 2-km altitude. (The surface pressure is 1000 hPa.)

(b) At night, a temperature inversion forms in the lowest 500 m. Temperature increases with altitude at 3 K/km. Show the vertical profiles of T and θ from the surface to 500 m (assuming the temperature at 500 m is the same as in daytime).

(c) Now consider that the relative humidity is 70%. Add virtual temperature at the surface in the two previous figures and comment on how the effect of moisture differs between night and day. (Hint: Saturation vapor pressure can be estimated with

$e_s = 6.112\exp(\frac{17.67T}{T+243.5})$, where e_s is in mb and T is in °C.)

(d) In order to destabilize the surface layer, how high the wind speeds at 10 m need to be at day and night?

2. Power plant plume (10 points)

The ambient temperature profile is isothermal at T = 5°C. The power plant plume emitted at 825 hPa has an initial temperature of 25 °C and H_2O vapor mixing ratio of 15 g kg^{-1}.

(a) If the plume is dry, how high can the plume reach above 825 hPa?

(b) Consider that the heat absorption per kg of air in the plume is approximately $C_p\Delta\theta$. How high can the moist plume reach if all the water in the parcel condenses? (Use the specific latent heat of $2.5\text{x}10^6$ J kg^{-1} for water condensation.) A more careful calculation would show that the plume can only reach an altitude much lower than calculated here. Discussion the season for the overestimate in this calculation.

(c) Calculate the initial relative humidity of the plume. (Hint: Saturation vapor pressure can be estimated with $e_s = 6.112\exp(\frac{17.67T}{T+243.5})$, where e_s is in hPa and T is in °C.)

(d) Calculate the altitude above 825 hPa, at which cloud droplets begin to form in the plume.