METR 130: Assignment 4 (Spring 2011)
Due Date: May 12, 2011

Question 1

A common equation for the height of the convective internal boundary layer (CIBL) as a function of distance downwind of its edge (x = 0) is as follows:

$$h_{CIBL}^2 = 2.8\alpha x, \quad \text{where}$$

$$\alpha = \frac{\left(H_{s,0} / \rho c_p \right)}{U_m \gamma_\theta}$$

Here, U_m is the mean wind speed within the CIBL and γ_θ is the potential temperature lapse rate (K per meter) of the elevated stable layer capping the CIBL. All other symbols have standard definitions.

Apply this equation to CIBL development within a sea breeze flow over the Los Angeles Air Basin. Specifically, check that the above equation gives a reasonable prediction of the CIBL depth at El Monte. Assume the sea breeze blows onshore along a line between Long Beach on the coast towards El Monte inland. Use the paper of Wakimoto and McElroy (1986), posted on the course website, to determine values for various inputs required in the above equation and check your calculated CIBL depth at El Monte against what was observed at this location.

Question 2

Consider a marine boundary layer (MBL) advected over an area of relatively colder sea surface temperature. The potential temperature profile of the upwind MBL can be approximated as dry adiabatic in the lowest 500 meters. The sea surface potential temperatures of the areas of relatively warm (upwind) and cold (downwind) SSTs are 15 and 10 degrees Celsius, respectively. For the upwind MBL, a stratocumulus cloud base exists at 500 meters extending upward to the base of the elevated temperature inversion capping the upwind MBL. The wind speed over the lowest 500 meters of the upwind MBL is fairly uniform with depth at a value of 5 m/s (except, of course, very close to surface and in the surface layer, where U = 0 at the surface and a log-law surface layer wind speed profile exists).

a. Illustrate the situation in a diagram, indicating vertical profiles of potential temperature, specific humidity and wind speed, any internal boundary layers that develop, expected values for various boundary layer depths, cloud layers, etc …

b. A common equation for the height of the stable internal boundary layer (SIBL) is as follows:

$$h_{SIBL}^2 = 0.004\alpha x, \quad \text{where}$$

$$\alpha = \frac{U_m^2}{g\Delta\theta / \theta_{avg}}$$

Here, U_m is the mean wind speed within the SIBL and $\Delta\theta$ is the potential temperature difference from the top of the SIBL to the surface. All other symbols have standard definitions.

Using this equation, calculate the depth of the SIBL at 20 kilometers downwind of the point where the SST changes. Assume for the sake of calculation that U_m maintains the same value as in the upwind MBL.

c. Assuming that MO theory applies within the SIBL at 20 kilometers downwind, calculate the potential temperature at two levels: z = 50 and z =100 meters.

d. Assume the near-surface specific humidity within the upwind MBL is 9 g/kg and varies linearly with height to the base of the cloud layer at 500 meters. If this layer simply advects over the colder surface, and assuming the calculated values of potential temperature from part 'c', what would be the relative humidity at z = 50 and z = 100 meters at a distance 20 kilometers downwind of the edge of the SIBL? Would advection fog form?