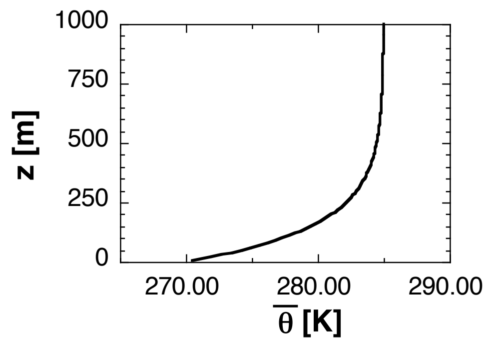
Problem Set 4
Due: 10 October 2016

Returning to this problem:
In the apple orchards of central Washington, some farmers have large fans (actually propellers) deployed in their fields to inhibit frost formation. Frost is typically a threat on clear nights with little or no wind, and the surface and air just above it cool due to radiation to space. The figure shows a profile of potential temperature $\overline{\theta}(z)$ for such a situation.



When turned on, the fans create turbulence, which affects the mixing coefficients K_m and K_h. Suppose the average eddy size (or mixing length) with the fans off is 10 cm, but with the fans on it is larger.

Challenge: How big should we make the propeller so that enough warm (high potential temperature) air is pulled downward by PBL turbulence to counterbalance the radiative cooling?

Further Assumptions:
(1) Radiative cooling is 1 K/hour at every level in the lowest 100 m.
(2) Vertical turbulent heat flux $\overline{w'\theta'} = 0$ at surface.
(3) Horizontal wind speed is 1 m/s at 100 m and 0 m/s at the surface.
(4) Mixing length is essentially the diameter of the spinning propeller.

(a) Using your $\overline{w'\theta'}$ from the previous problem set, and estimating $d\theta/dz$ from the figure, what must be the value of K_h to give the needed $\overline{w'\theta'}$?

(b) Using the vertical shear of the wind speed in assumption (3), the mixing length hypothesis, and assumption (4), what is the diameter of the propeller?