Atm Sci 547 Bretherton

Homework 4 solutions

The results below are from the Matlab script `hw4.m` on the class web page. Consider a uniformly stratified lower troposphere with a vertically uniform geostrophic wind of 10 m s^{-1}, a Coriolis parameter f = 10^{-4} s^{-1}, a potential temperature $\theta^{+}(z) = 290 + 0.01z$, where z is height in m, a surface pressure of 1000 mb, and zero humidity. Take the air density = 1.2 kg m^{-3} and $c_p = 10^3$ J kg^{-1} K^{-1}. At time $t = 0$ the wind is geostrophic at all heights. Starting at time $t = 0$, radiative cooling induces a downward surface heat flux $H_0 = -10$ W m^{-2} and a surface drag producing a friction velocity $u_* = 0.2$ m s^{-1}. This induces a stable boundary layer to form near the surface.

1. Surface buoyancy flux $B_0 = gH_0/\rho_0 c_p\theta_0$ = -2.8 x 10^{-4} m^2s^{-3};
   Obukhov length $L = u_*^3/kB_0$ = 71 m.

2. Fig. 2.1 and 2.2 show the desired plots. The PBL height (where K_h goes to zero) quickly evolves to between 50 – 100 m, so a λ of 5-10 m is a reasonable choice.

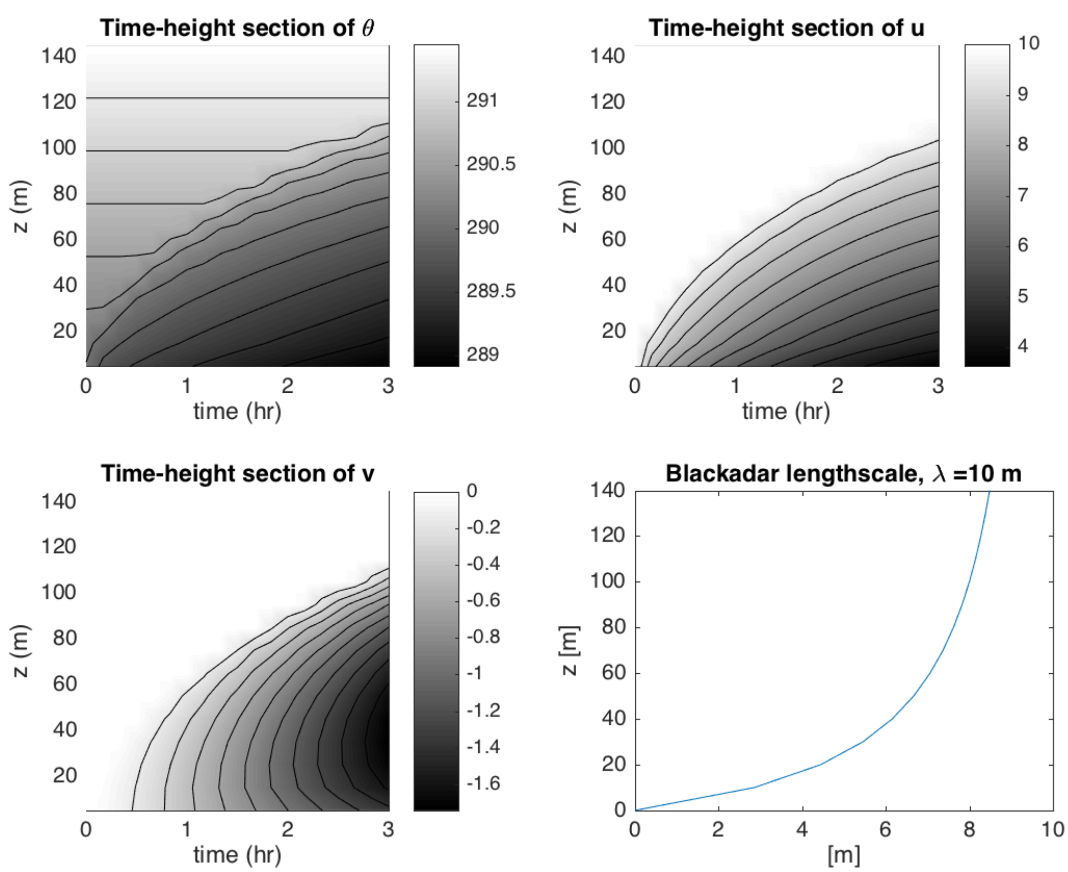

Fig. 2.1: Time-hieght sections and profile of turbulent lengthscale.

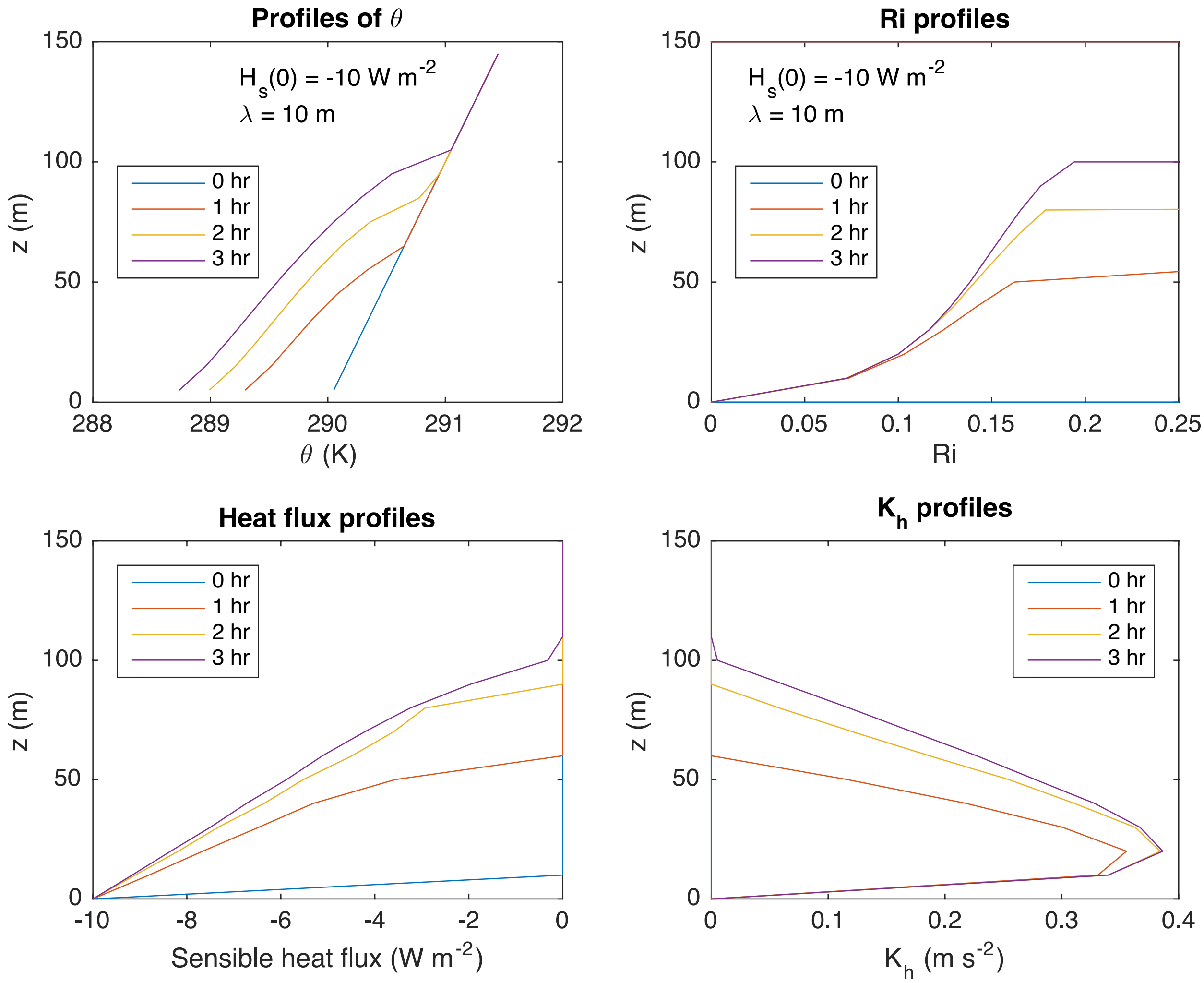

Fig. 2.2: Hourly profiles of selected variables The diffusivity peaks low in the BL, and the stratification is slightly stronger near the BL top. Much of the BL has 0.1 < Ri < 0.2.

3. Compare Fig. 3.1 with Fig. 2.2.. The diffusivities are a bit smaller, but changes are not large.

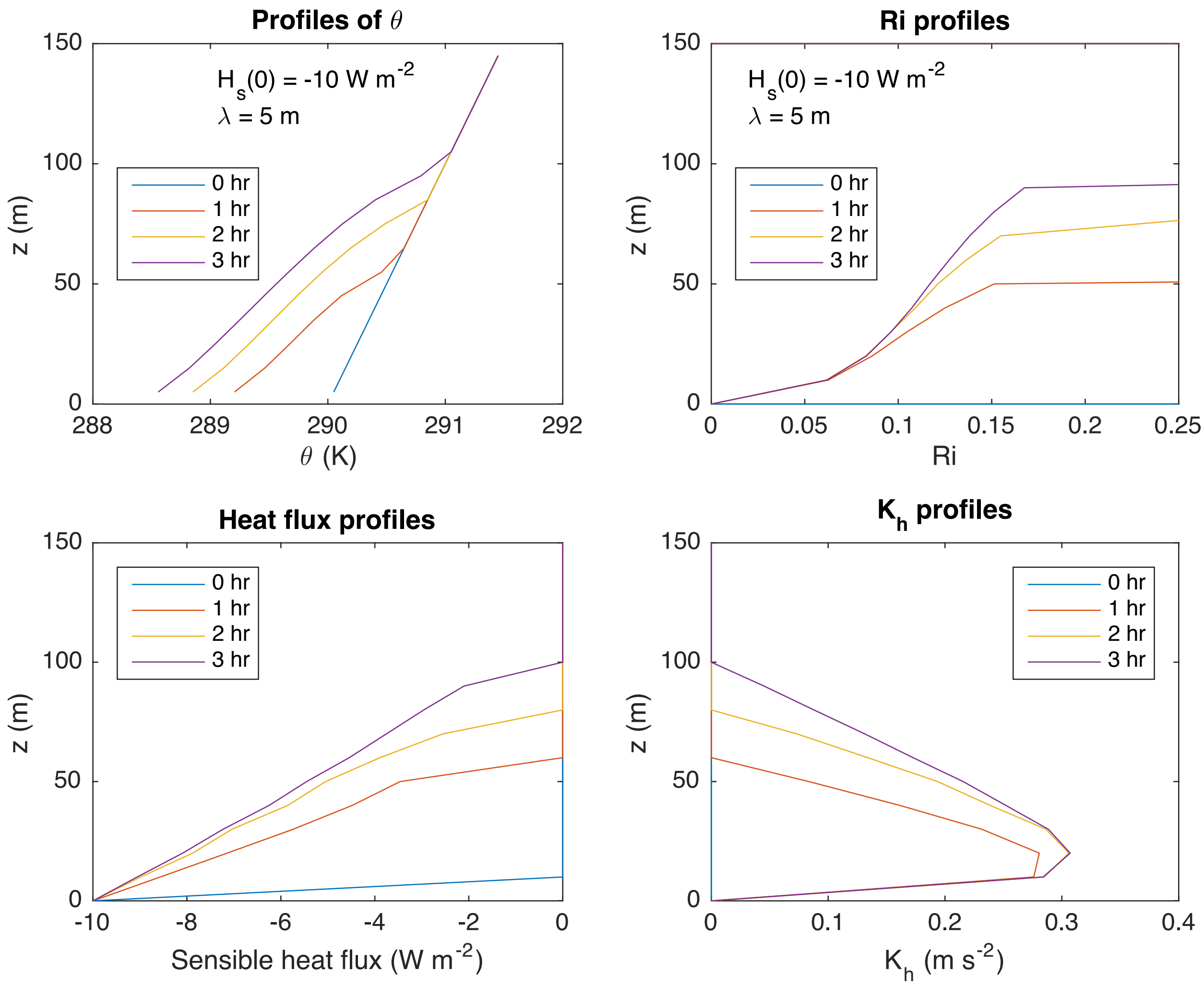

Fig. 3.1: Like Fig. 2.2 but with λ = 5

4. Compare Fig. 4.1 with Fig. 3.1. The PBLstays shallower and cools faster due to the larger turbulent loss of heat into the ground. The Obukhov length (28 m) and turbulent diffusitivies are substantially smaller.

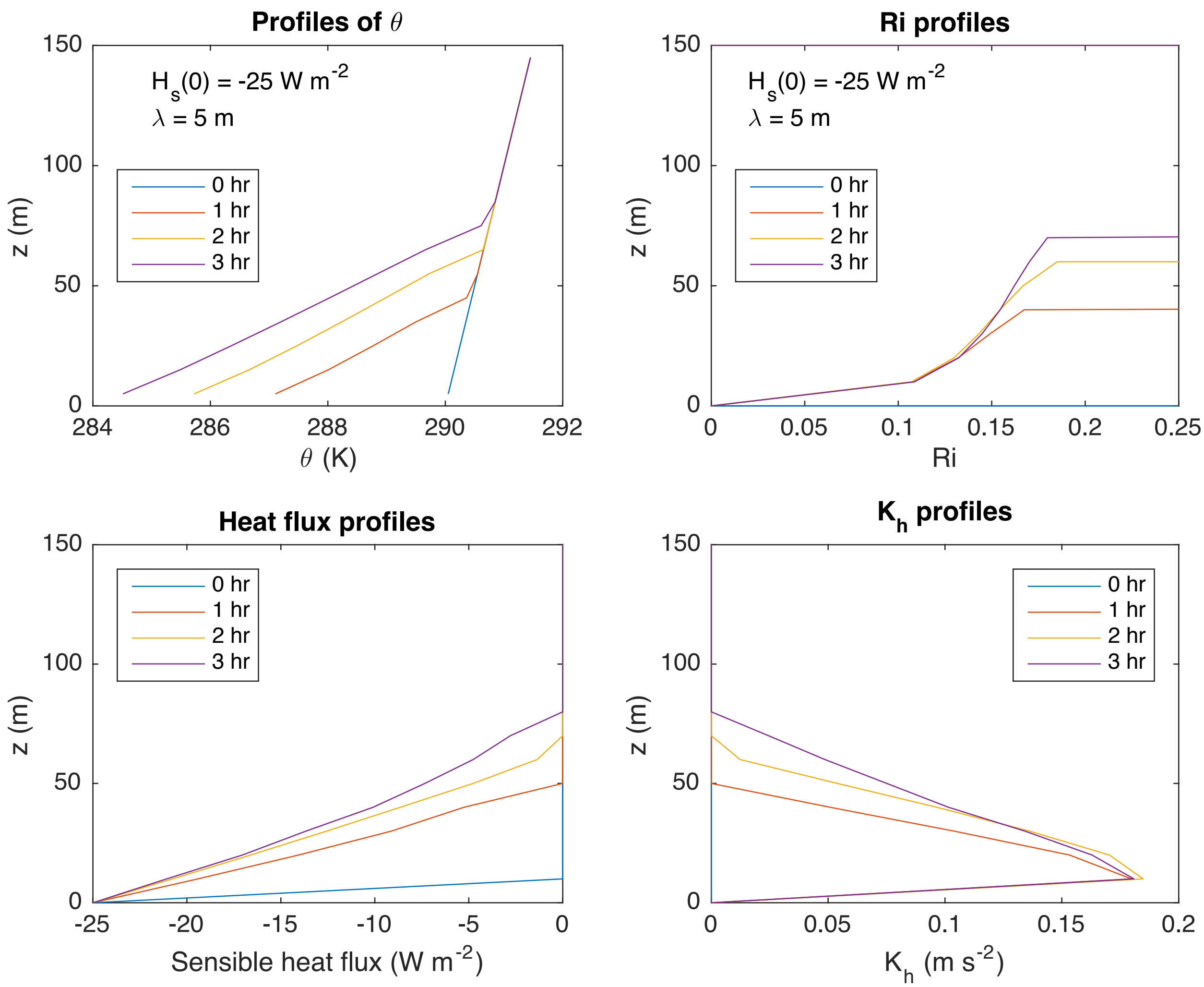

Fig.4.1: Like Fig. 3.2 but with surface downward heat flux of 25 W m^{-2}