Atm Sci 547 Bretherton Due Thursday, 10 May, 2018

Homework Set 4

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. What are the surface buoyancy flux and the Obukhov lengh?

2. Implement the local first-order closure discussed in the Lecture 8 notes, with Monin-Obukhov stability factors and a Blackadar lengthscale with an asymptotic lengthscale of λ = 10 m. Discretize using a vertical grid spacing of Δz =10 m and as many vertical layers as you need to encompass the development of the boundary layer. It is natural to compute the turbulent fluxes at layer interfaces $k\Delta z$, k = 0, 1,2,…, and the u, v, θ at layer centers $(k+0.5)\Delta z$. You can set this up as a system of coupled ODEs which you can solve using a Python or Matlab ODE solver. An example of how to do this for a different case (a dry convetive boundary layer heated from below) is given in the homework section of the class web page.

   Calculate and plot the time-height evolution of the BL θ, and wind profiles up until t = 3 hours. Plot hourly profiles of Ri, turbulent heat flux, and eddy heat diffusivity. Comment on whether the choice of λ was appropriate (i. e. is λ comparable to 10% of the PBL height?)

3. If you set λ = 5 m how does the solution change?

4. If you also set $H_0 = -25$ W m^{-2} (stronger surface cooling) what happens?