Nick Lorenz

March 25 Lecture Summary

The main goals of this lecture were to:

- Introduce the planetary boundary layer
- Introduce the notion of turbulence
- See how turbulence affects fluid motion in the planetary boundary layer

We began by defining the planetary boundary layer (PBL) as the portion of the atmosphere where the effects of momentum, moisture, and heat transfer from the earth's surface are most strongly felt. The area above the PBL is known as the free atmosphere where there is no interaction with the surface. The PBL can be as shallow as 30 meters when it is stably stratified or as deep as 3 kilometers when it is highly convective. We defined the typical PBL depth to be 1 kilometer.

There is turbulence in the PBL, for example when a parcel that gets lifted is warmer than the environment, it will rise until it reaches equilibrium with the environment. For mass continuity to hold, there needs to be some sinking to balance out the rising parcel which results in a typically small scale circulation, therefore turbulence. To see how this turbulence affects our equations of motion we had to look at Reynolds averaging: $a = \bar{a} + a'$, which simply says that the total value of a variable (*a*) is the sum of the average value ($\bar{a}$) and the fluctuating component a'. The average of the product of two variables, *a* and *b* is

$$\overline{ab} = \bar{a}\bar{b} + \overline{a'b'}$$

where the second term of the RHS is known as the covariance of *a* and *b*. The covariance term is non-zero when the two variables have a relationship with each other so that they co-vary. Some other identities with Reynolds averaging are

$$\overline{a'} = 0;\ \bar{a} = \bar{\bar{a}} + \overline{a'};\ \bar{\bar{a}} = \bar{a};\ \overline{a'\bar{b}} = 0$$

We utilized the Boussinesq approximation ($\rho = \rho_0$ except when multiplied by gravity) for our momentum, thermodynamic energy and mass continuity equations, and the only term that did not deal with constant density was the buoyancy term in the vertical momentum equation: $g\frac{\theta}{\theta_0}$ where θ is the deviation from the horizontal average and θ_0 is the horizontal average. Combining the Boussinesq approximation with the Reynolds averaging concept, our horizontal momentum equation becomes

$$\frac{\bar{D}\bar{u}}{Dt} = -\frac{1}{\rho_0}\frac{\partial\bar{p}}{\partial x} + f\bar{v} + \overline{F_{r_x}} - \left(\frac{\partial}{\partial x}\left(\overline{u'^2}\right) + \frac{\partial}{\partial y}\left(\overline{u'v'}\right) + \frac{\partial}{\partial z}\left(\overline{u'w'}\right)\right)$$

which states that the average time rate of change of the average zonal velocity is the sum of the average PGF, the average Coriolis force, the average frictional force, and the turbulent fluxes which are the terms inside the parentheses.