GEO2310 Meteorology — Exercise 13.03.24
Planetary Boundary Layer, Part 1

1 Turbulence and Static Stability

(a) What are characteristics of turbulence?

(b) Which mechanisms create or destroy turbulence?

(c) Explain the terms "static stability" and "lapse rate". Draw three vertical profiles representing stable, neutral and unstable conditions. What do we know about the lapse rates under these conditions?

(d) What is potential temperature? Write down the equation and explain how it is connected to static stability.

2 Statistical Description of Turbulence

(a) What is Reynolds decomposition? Why do we describe turbulence statistically?

(b) Describe the concept of Kolmogorovs energy cascade and draw (schematically) the corresponding energy spectrum.

(c) Turbulence intensity can be described by using the variance, e.g. $\sigma_u^2, \sigma_v^2, \sigma_w^2$ corresponding to the variance of streamwise, crosswise and vertical wind speed. Use them, to define the terms "stationary", "homogeneous" and "isotropic" turbulence. How can you interprete these three flow characteristics?

(d) What is turbulent kinetic energy (TKE)? Write down the TKE equation and explain the terms. Which terms are sources or sinks of TKE?

3 Turbulence Closures and Logarithmic Wind Profile

(a) What is a parametrization? Why (and when) do we need to parametrize turbulence?

(b) An example for a first-order closure is given by:

$$\overline{w'\theta'} = -K_H \frac{\partial \overline{\theta}}{\partial z} \tag{1}$$

Explain both sides of the equation and how they are connected (e.g., with a sketch). What does K_H represent? Why is it called first-order closure?

(c) Sketch and explain the logarithmic wind profile. Write down the equation and name all variables.