PLANETARY BOUNDARY LAYER: EXERCISE USING OBSERVATIONS

Introduction

In this exercise, observations of surface fluxes and other near-surface fields are used to estimate characteristics of the planetary boundary layer on a sunny, late-summer day in Iowa.

Goals

1. Use observations to estimate the growth of boundary layer turbulence

2. Compare behavior with experience.

3. Use observations to estimate the surface drag coefficient.

4. Learn how to make and apply plausible estimates for fluxes and other fields in the boundary layer, based in part on our boundary-layer theory

Procedure

1. Observations on 22 August 2008 show that the sun was shining more or less throughout the day.

a. What expectation from these observations might we have about the character of the planetary boundary layer?

2. TKE generation

b. With heating of the surface occurring, what process, and thus what term in the TKE equation, will be generating turbulence kinetic energy?

The surface sensible heat flux is the turbulent, boundary-layer heat flux just above the surface. We can use the relationship between energy flux and temperature flux

$$Flux[W\ -m^{-2}] = \rho C_p(\overline{w'\theta'}) \quad , \qquad (1)$$

where the eddy temperature flux, $(\overline{w'\theta'})$, has units of K-m/s, to estimate $(\overline{w'\theta'})$ at the surface. Guided by the ideal gas law,

c. what value should we use for ρC_p ?

We need a representative value of $(\overline{w'\theta'})$ for the boundary layer.

d. Knowing (1) whether this is a stable or unstable boundary layer and (2) the behavior of the surface sensible heat flux throughout the day , what might be a plausible estimate for $(\overline{w'\theta'})$ *in the middle of the PBL?*

e. What would be a plausible estimate for potential temperature in the middle of the PBL?

From all this information,
f. what is the rate of TKE generation?

3. Strength of boundary layer turbulence

We can assume the rate of TKE generation is representative of the rate throughout the day.
g. What then is the TKE at mid-day? What does this imply for a wind speed in the turbulence?

4. Surface drag coefficient

We can approximate surface wind fluxes from the closure relationships

$$(\overline{w'u'}) = -C_D\left|\vec{V}\right|u \quad , \qquad (\overline{w'v'}) = -C_D\left|\vec{V}\right|v \qquad (2)$$

where C_D is the drag coefficient. Let's estimate C_D from the observations.

We can assume we have rotated our axes so that the momentum and wind fluxes are in the u direction. The observed momentum flux is related the wind flux by

$$\vec{M}[kg/(m-s^2)] = \rho(\overline{w'u'}) \quad . \qquad (3)$$

Estimate the surface wind speed from observations (i.e., orient the u-v axes so that u is parallel to the flow). Using (2) and (3),
h. what is the drag coefficient, C_D?