Assignment 3
GEOG 321 / Knox

Wind and turbulence

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Preamble: In this exercise you will use a 30-min data-set measured above an extensively flat cotton field near Kettleman City, CA, USA[1]. The actual day / time is selected based on your student number (please follow instructions on webpage). On the webpage, you will be provided with two tables:

https://geog321.github.io/assignment3/

Table 1 lists horizontal wind speeds $\overline{u}$ measured with cup-anemometers installed at six heights on a profile tower averaged over 30 minutes. Screen-level air temperature is also provided.

Table 2 contains longitudinal wind u, lateral wind v and vertical wind w measured every second over the same 30 minutes by a fast-response anemometer located at 6.4 m height.

For all questions assume neutral conditions and $z_d = 0$. Assume a pressure of 100 kPa.

Instructions: Please return your answers including all calculations, graphs and discussions in a well-structured report (either word or PDF). Note that if you knit an html file, please go to 'print', then 'Save as PDF'. Label the report document with your name, your student number, the course and year. Upload your answers to myCourses by Wednesday, March 21, 2024, 11:59 pm. Marks are indicated in square brackets. In total there are 50 marks.

[1] http://www.eol.ucar.edu/rtf/projects/ebex2000/

1. Estimate z_0 graphically from all measured values of the wind profile in Table 1. You can either use a spreadsheet/software (e.g. R) or the semi-logarithmic paper provided on Canvas.

   Note: If you solve this question using a semi-logarithmic paper, use a ruler and your graphical judgement (subjective) to create the best fit through the points. [6]

2. Based on the slope of the curve in Question 1, calculate the friction velocity u_*.[4]

3. Estimate the surface shear stress τ_0 from the result in Question 2 and with help of Appendix A3 (p. 392 ff.) in T. R. Oke, 'Boundary Layer Climates available on Canvas. [2]

4. Estimate the eddy diffusivities for momentum K_M using the wind gradients $\Delta\overline{u}$ in Table 1 between (a) $z = 0.95$ and 1.55 m, (b) $z = 1.55$ and 2.35 m, (c) $z = 2.35$ and 3.72 m, (d) $z = 3.72$ and 6.15 m, and (e) $z = 6.15$ and 9.05 m. How does K_M change with height? Explain why. [6]

5. From the values in Table 1, calculate the aerodynamic resistance of the momentum flux r_{a_M} for the layer from the surface to 9.05 m. [2]

6. From the turbulence data provided in Table 2, calculate $\overline{u}$, $\overline{v}$, and $\overline{w}$ † [4]

7. From the data in Table 2 calculate $\overline{u'^2}$, $\overline{v'^2}$, and $\overline{w'^2}$. Name those parameters. [4].

8. From the data in Table 2 calculate the turbulence intensities I_u, I_v, and I_w. [2].

9. From the data in Table 2 calculate the mean turbulent kinetic energy per unit mass $\overline{e}$. What is the ratio of $\overline{e}$ to the mean kinetic energy per unit mass? [2].

10. Which of the three wind components, u, v or w, contains most turbulent kinetic energy per unit mass. Speculate about the shape of the eddies [2].

11. From the data in Table 2 calculate (a) $\overline{u'v'}$ and (b) $\overline{u'w'}$ [4]

12. Calculate r_{uv} and r_{uw} †. Discuss your results. [3]

13. Plot a scatter graph of u' (x-axis) vs. w' (y-axis). Comment your graph and discuss if it looks like you expected. † [6]

14. Using your result in question 11 (b), calculate the friction velocity u_* based on the high-frequency data and compare it to your answer in question 2. † [3].

    To answer questions marked by a † it is highly recommended to use R (or other programming language) or Excel. See the course web-page for help documents on how to use the most common graph software (e.g. Excel) or R. If you still do not have access to a computer and/or appropriate software, you can use only values recorded at a full minute (i.e. every 60th value) of the high-frequency wind data to solve questions 6 to 12 and speculate about the impact this approach has on your calculations.