

Exercise 4: Sensitivity Analysis of Wind Strength

The strength of wind over the ground can be expressed as a function of roughness of the surface and the speed of the wind measured at any height within the surface layer above the ground. It can be expressed as:

$$U_z = \frac{U_*}{\kappa} \ln\left(\frac{Z}{Z_0}\right)$$

where: U_* = Shear Velocity (m/s)
 U = Wind Velocity (m/s) at height Z
 Z = Height (m) of measured wind velocity
 Z_0 = Aerodynamic Roughness Height (m)
 κ = 0.4 (constant)

1. Use the dataset below to write a script that calculates U_* for a series of environments. Note that Z_0 represents the roughness of a surface and therefore should not change for the same environment. The exception is if the surface changes, such as when a vegetated surface leafs in summer. The windspeed measurements are from weather stations that all have the wind sensors at a height of 10m. Plot your values of U_* as a function of windspeed grouped by surface type.

| | Grass | Grass | Desert | Desert | Urban | Urban | Airfield | Airfield |
|--------------------------|-------|-------|--------|--------|-------|-------|----------|----------|
| U (m/s) | 10.0 | 3.0 | 20 | 10 | 10 | 5 | 10 | 20 |
| Z₀ (m) | 0.01 | 0.01 | 0.001 | 0.001 | 0.01 | 0.01 | 0.0001 | 0.0001 |

2. Perform a univariate sensitivity analysis of U_* to U and Z_0 . That is, calculate and plot U_* as a function of U over a reasonable range of values for U (e.g., from 0 m/s to 20 m/s at a $Z = 10$ m) while holding Z_0 at a constant value (use $Z_0 = 0.01$; this is 1 cm so like a grass field). Now, plot U_* as a function of Z_0 over a reasonable range of values for Z_0 (e.g., from 0.0001 to 1 m) while holding U at a constant value (such as 10 m/s).
3. Since U_* is a function of two variables, we should evaluate its bivariate sensitivity. Using `meshgrid`, create "grids" of U and Z_0 (you need to have values of U and Z_0 over the entire grid - and that's what the function `meshgrid` does). Now, calculate U_* over this grid and plot as a (labeled) filled contour map (using `contourf`). Discuss the bivariate sensitivity of U_* to U and Z_0 . Also, discuss your choice of `colormap`.