

Introduction to Computers and Engineering Problem Solving 1.00 / 1.001 Fall 2005

Problem Set 7

Due: 11AM, Friday November 4, 2005

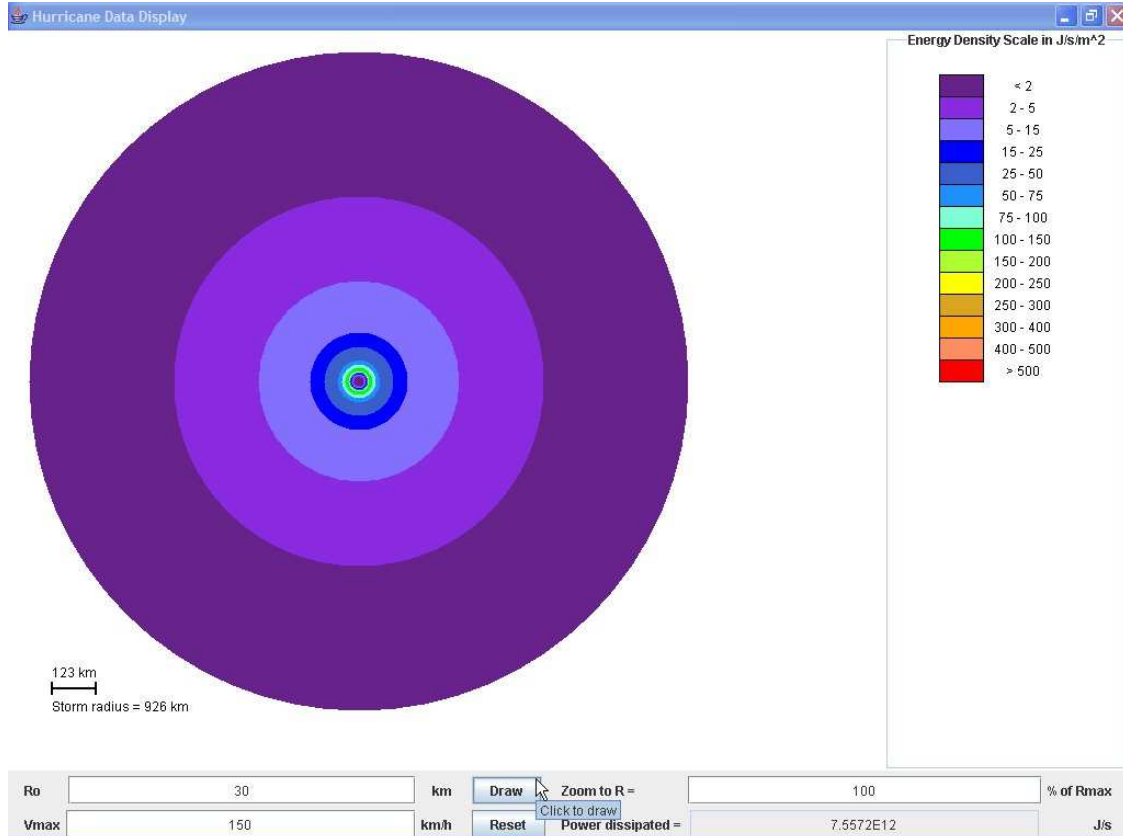
Hurricane Power [100 points]

Introduction

Hurricanes and tropical storms are large scale, low pressure tropical weather disturbances which are accompanied by strong winds and heavy rains. These storms are one focus of current meteorological research which aims to model the hurricane, including the energy dissipated.

In this problem set, you will calculate and display the power dissipated by a hurricane in a GUI like the one shown below. The equations below are part of an actual meteorological model and may be used to approximate a hurricane's power dissipation

Figure 1: Example of a GUI for modeling hurricane power



First, the model states that the velocity v at radius R is

$$v = \begin{cases} v_{\max} \left(\frac{R}{R_o} \right)^2 & , R \leq R_o \\ v_{\max} \sqrt{\frac{R_o}{R}} & , R > R_o \end{cases}$$

Equation 1

where v_{\max} is the maximum wind speed of the storm in meters per second (ms^{-1}) and R_o is the radius at which v_{\max} occurs (“radius of maximum winds”) in meters. R_o is typically twice the radius of the eye. The wind speed and radius of maximum winds must not be less than 62 kilometers per hour (kmph) and 20 kilometers (km), respectively.

Then find the rate of energy dissipation per unit area or “power density” at a given radius. The power density D at a radius R is

$$D = \gamma \rho_{AIR} v^3$$

Equation 2

where v is calculated from Equation 1 using R , γ is the drag coefficient, ρ_{AIR} is the density of air and $\gamma \rho_{AIR} = 2 \times 10^{-3} \text{ J} \cdot \text{s}^2 \cdot \text{m}^{-5}$.

Next, estimate E_{RING} which is the power dissipated over an annular ring bounded by an inner radius, R_1 , and an outer radius, R_2 . E_{RING} is

$$E_{RING} = \frac{\pi}{3} \left[2 \left(\frac{D_2 - D_1}{R_2 - R_1} \right) (R_2^3 - R_1^3) + 3 \left(\frac{R_2 D_1 - R_1 D_2}{R_2 - R_1} \right) (R_2^2 - R_1^2) \right]$$

Equation 3

D_1 is D (See Equation 2) calculated at R_1 and, similarly, D_2 is D calculated at R_2 .

Finally, calculate the total power dissipated by the storm, E_{STORM} , as

$$E_{STORM} = \sum_{\text{all rings}} E_{RING}$$

Equation 4

where E_{RING} is calculated from Equation 3.

You must also plot the power density pattern of the hurricane over its entire area. This plot should appear to be a series of concentric colored rings, as shown in Figure 1. Each color corresponds to a particular power density and is valid for the areas shown. The color scheme is up to you, as is the precise implementation of the GUI.

Assignment

Implement the scheme outlined above. You may find the following suggestions helpful.

1. First design the GUI. The user should input the radius of maximum winds and the maximum wind speed. Make sure that your GUI has fields to accommodate these inputs. Note that calculation should be attempted only if the values contained in the fields are numeric. Make sure that the user knows when the inputs are not numeric. The GUI should also include:
 - a. A button that causes the energy density to be plotted and that also causes the total power dissipation to be calculated.
 - b. A button that resets the GUI to its initial state.
 - c. A field to display the energy dissipated by the storm. Users should not be able to edit this field.
 - d. A field to allow users to enter a ratio that makes the plot zoom in towards the center of the storm. This feature is necessary because the rings near the center are close together and difficult on a large plot. As you zoom, you may ignore power densities outside the region required by the user. Make sure that no plotting takes place if the user enters text, a ratio larger than 100% or a ratio equal to zero or less in this field.
 - e. A scale showing the energy density that each color/pattern in the plot represents. The following energy bounds were used in Figure 1: <2, 2 – 5, 5– 15, 15 – 25, 25 – 50, 50 – 75, 75 – 100, 100 – 150, 150 – 200, 200 – 250, 250 – 300, 300 – 400, 400 – 500, >500.
 - f. A plot of the energy density. Think about how you will draw this – What will you draw on? What items will you draw?, etc. Make sure the user can estimate distances on your plot.
2. Create a class that implements only the required calculations. You will probably find it helpful to create a method for each equation. Values in calculations should be in base SI units (meters, seconds, etc) during calculations. However, when talking about hurricanes, most people use kilometers and kilometers per hour to refer to distances and speed. Assume that user input is in kilometers/kilometers per hour for the relevant fields and that the user is aware of the units required. Below are helpful facts and suggestions for additional useful calculations.
 - a. To convert kilometers to meters, simply multiply by 1000.
 - b. To convert kilometers per hour to meters per second, multiply by 5 and divide by 18. (Same as multiplying by 1000 and dividing by 3600.)
 - c. Assume that the air would be moving at 27 kmph (7.5 ms^{-1}) if there were no storm. Use this value as the wind speed at the edge of the storm and determine the overall radius of the storm. This value will be useful for other calculations. You should implement your strategy in a method.
 - d. Implement methods that may be used to find other pertinent information, like the energy density over a range of radii, or the total power dissipated by the storm. To decide what methods may be useful, consider what information the GUI needs to correctly display all the required information. Think about the types that should be returned by each method. Don't forget that helper methods might be useful.
3. Complete the GUI by handling any important events appropriately.

You can demonstrate that your code works correctly by using a maximum velocity of 150 kmph and a radius of maximum winds of 30 km. The power dissipated should be $7.5572 \times 10^{12} \text{ Js}^{-1}$. Note that for the same radius of maximum winds and an increase in maximum wind speed to 200 kmph, the power dissipation increases to $2.5099 \times 10^{13} \text{ Js}^{-1}$. This value is more than twice New York City's peak summer power consumption!

Turn In

- Turn in **electronic** copies of **all source code** (. java files). No printed copies are required.
- Place a **comment** with your full name, MIT server username, tutorial section, TA's name, and assignment number at the beginning of all . java files in your solution.
- Remember to **comment your code**. Points will be taken off for insufficient comments.
- Place all of the files in your solution into a **single zip file**. Submit this single zip file under the appropriate section and problem set number.
- Your solution is **due at 11AM**. Your uploaded files should have a time stamp of no later than 11AM on the due date.
- **Do not** turn in compiled byte code (. class files) or backup source code (. java~ files).

Penalties

- **30% off** If you turn in your problem set **after 11AM on Friday** but **before 11AM on the following Monday**.
- **No Credit** If you turn in your problem set **after 11AM on the following Monday**.