Geostrophic and Cyclostrophic Flow

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Radial Inflow Experiment

- The phenomenon to be studied here is hurricanes.
- The model to be used in simulating hurricanes is the radial inflow experiment
- Then more theory and other interesting principles will be studied from this. i.e. Rossby number, conservation of angular momentum and balance of forces (namely Coriolis, centrifugal and pressure gradient)

Experiment

- Performed the experiment 3 times with varying the velocities i.e. 5 rpm, 10 rpm and 15 rpm.
- Particles released at varying radii on the surface of water in the bucket.
- Particle tracking software helps us to know how the particle's distance from the center of rotating frame varies with time.

Apparatus Setup

Data Manipulation

- Converted the (X,Y) pixel coordinates to cartesian by x = X – xcenter and y = -(Y – ycenter)
- Calculated radii from center by taking the square root of x^2 + y^2.
- Calculated theta by taking the arctan of (y/x)
- Computed delta thetas and delta times and generate a table on excel and had all these on columns

Rossby Number, Ro

- Ratio of Inertial to Coriolis Force.

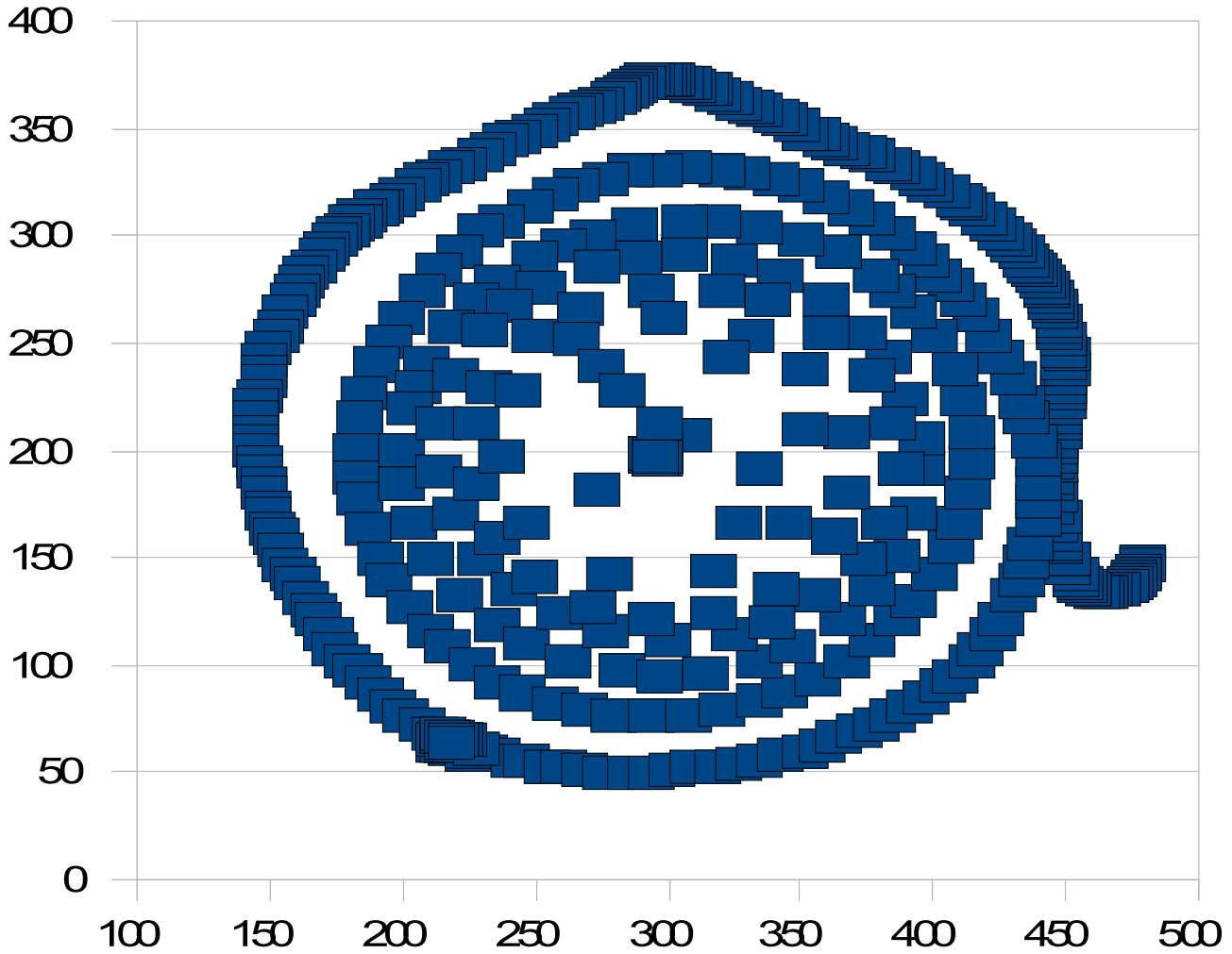
Given by, $Ro = V_\Theta / (2\Omega r)$ from the momentum equation ($g\, \partial h / \partial r = fV_\Theta + (V_\Theta)^2 / r$)

$\Omega = 2\pi / T$, where T is the period for 5 rpm,

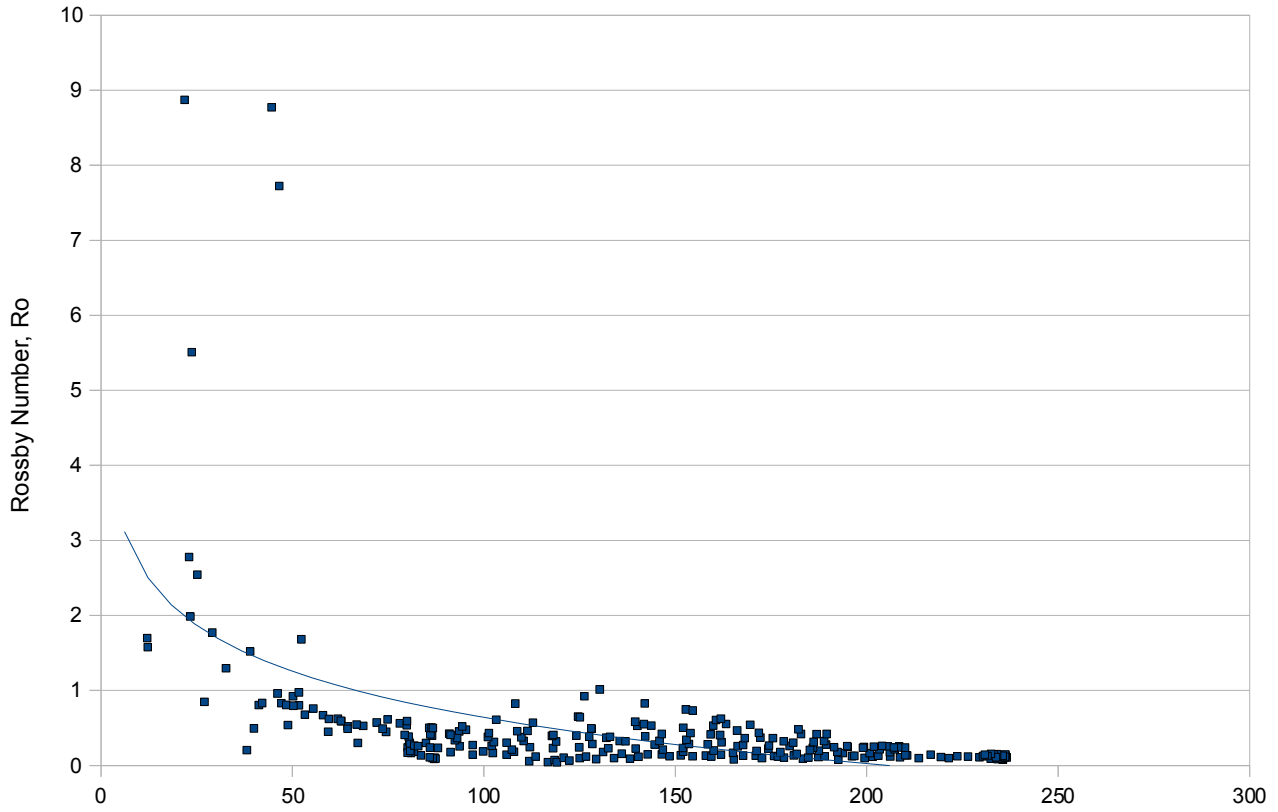
T = 12 s, 6 s for 10 rpm and 4 s for 15 rpm.

$V_\Theta = r\, \Delta\Theta / \Delta t$ for sufficiently small Δt since we know that $V_\Theta = r\, \partial\Theta / \partial t$

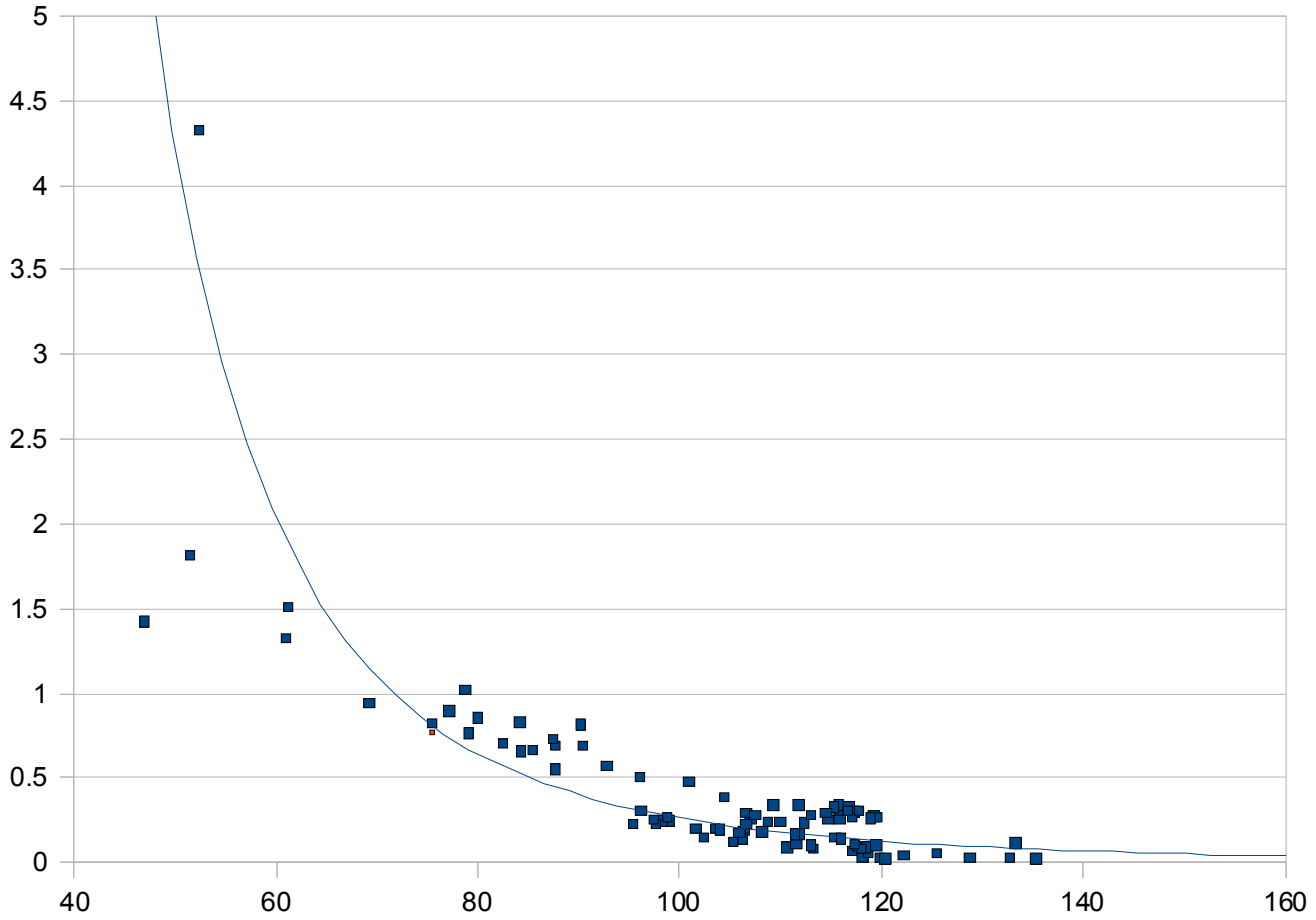
Trajectories of particles when bucket rotated at 5 rpm



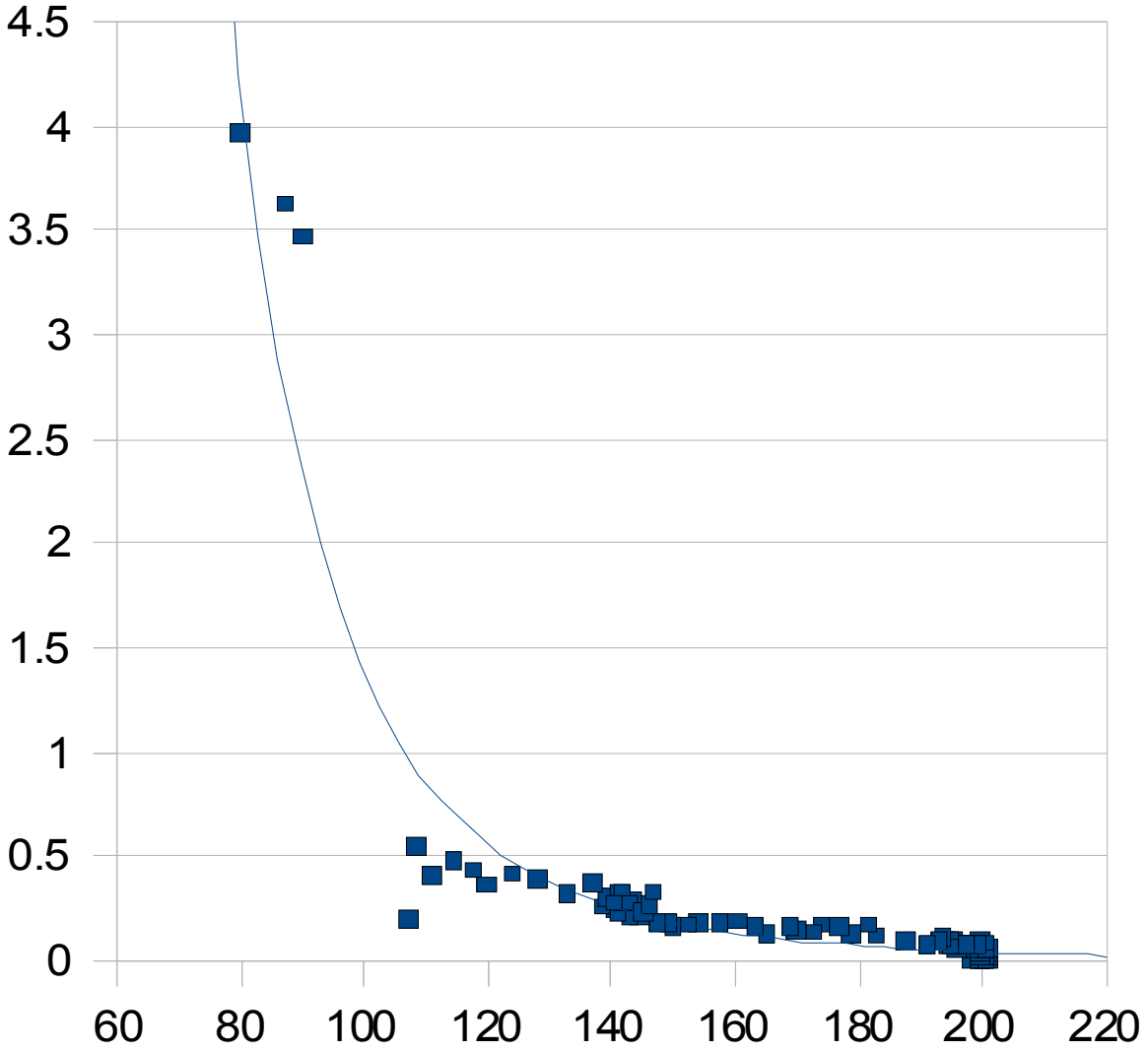
Rossby Number against r Plot (5 rpm)



Rossby Number against r plot (10 rpm)



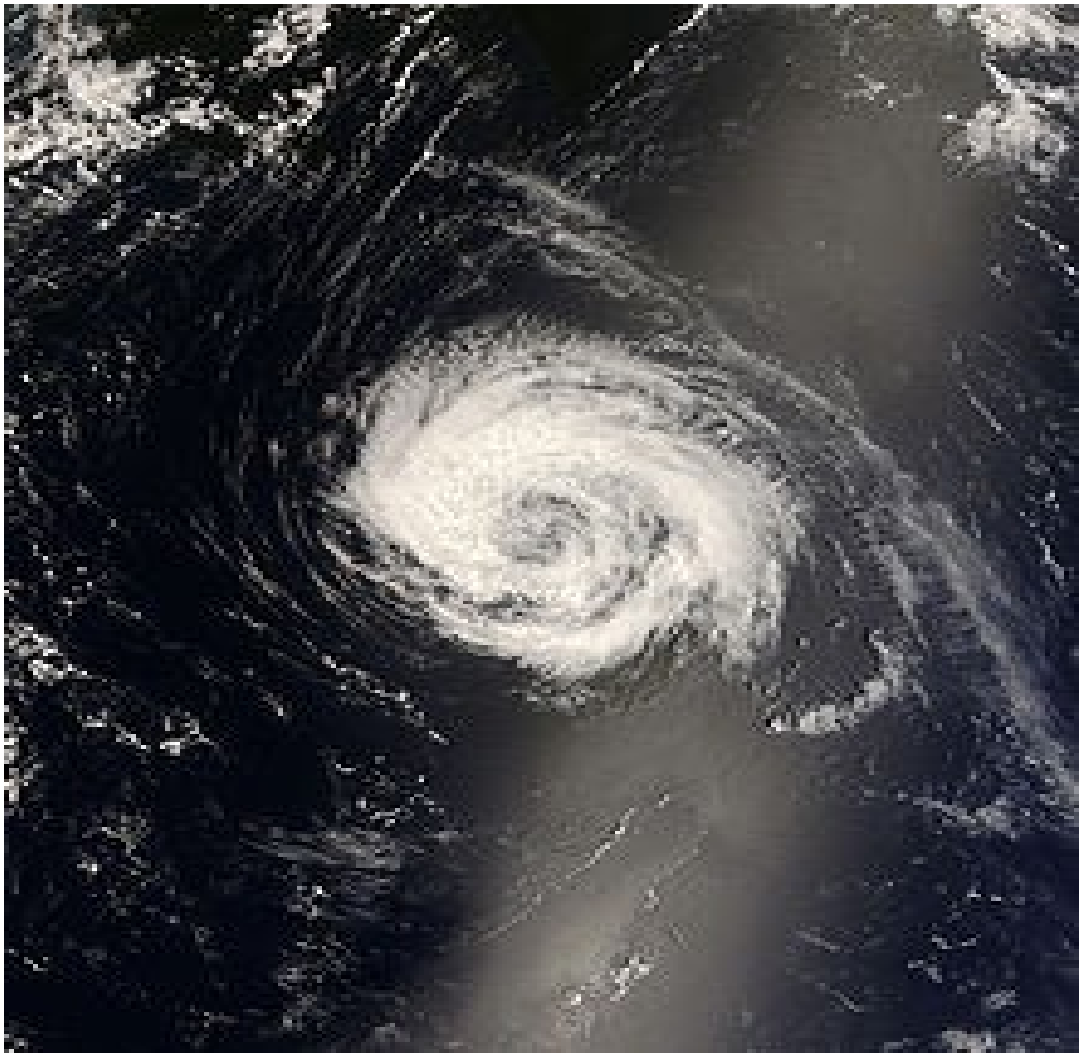
Rossby Number against r plot (15 rpm)



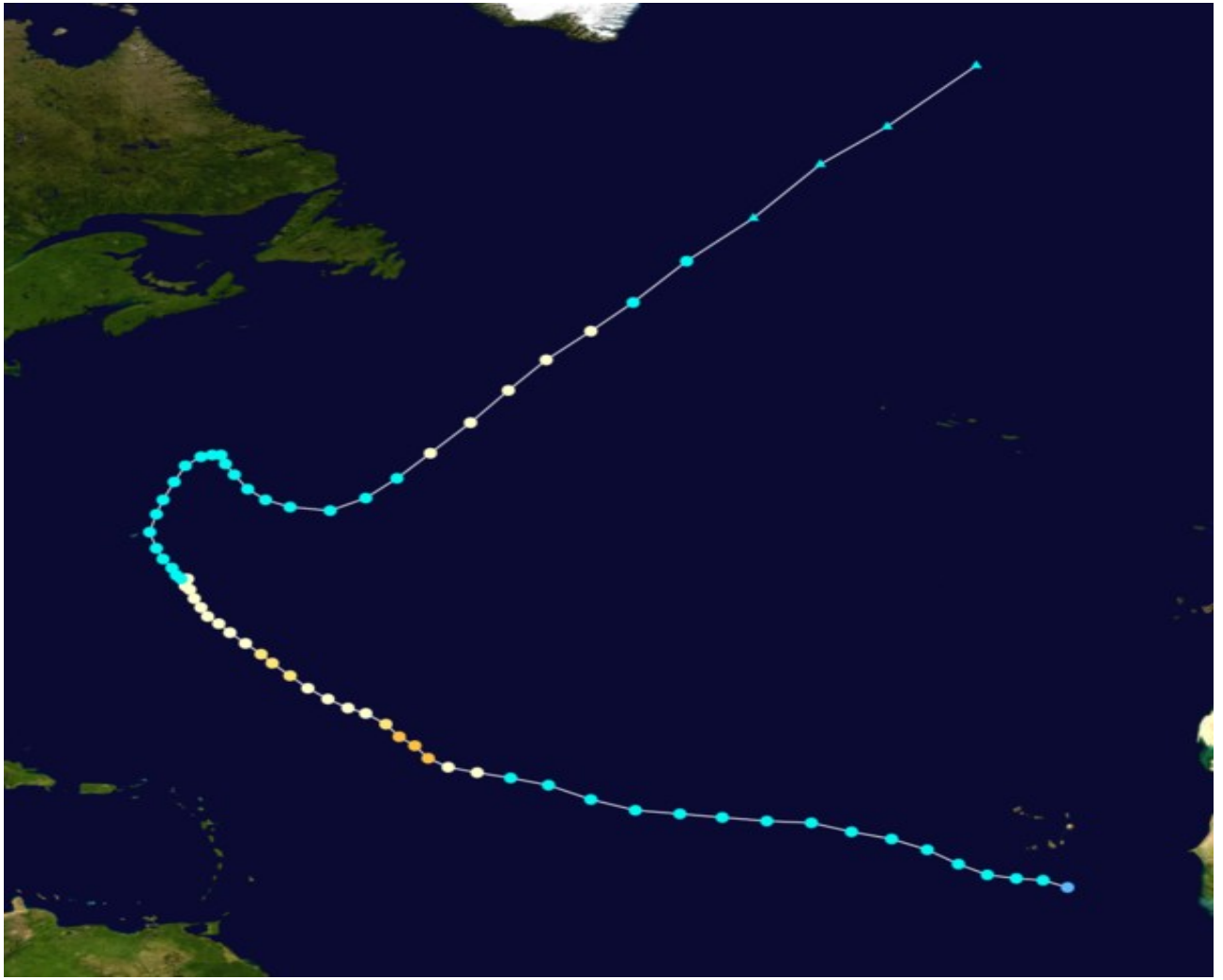
Hurricane Bertha

- Formed July 3. 2008 and dissipated July 20, 2008
- Developed as a tropical wave that emerged off the coast of Africa in July 1, 2008
- Speed – 125 mph
- Areas affected – Bermuda, New Jersey, Delaware, North Carolina and Iceland

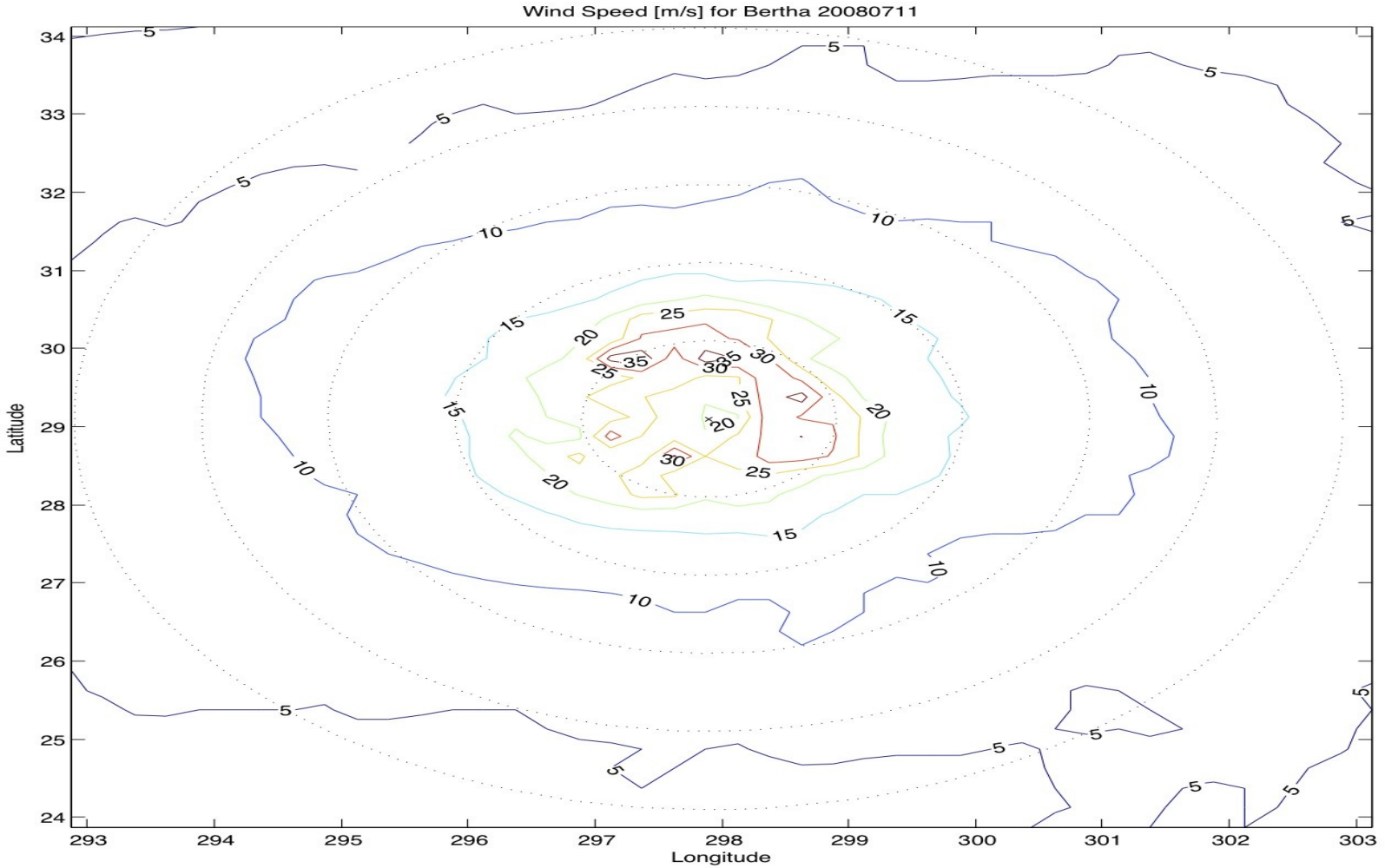
Image of Bertha near Bermuda



Path followed by Hurricane Bertha



Wind Speed at Various Latitudes



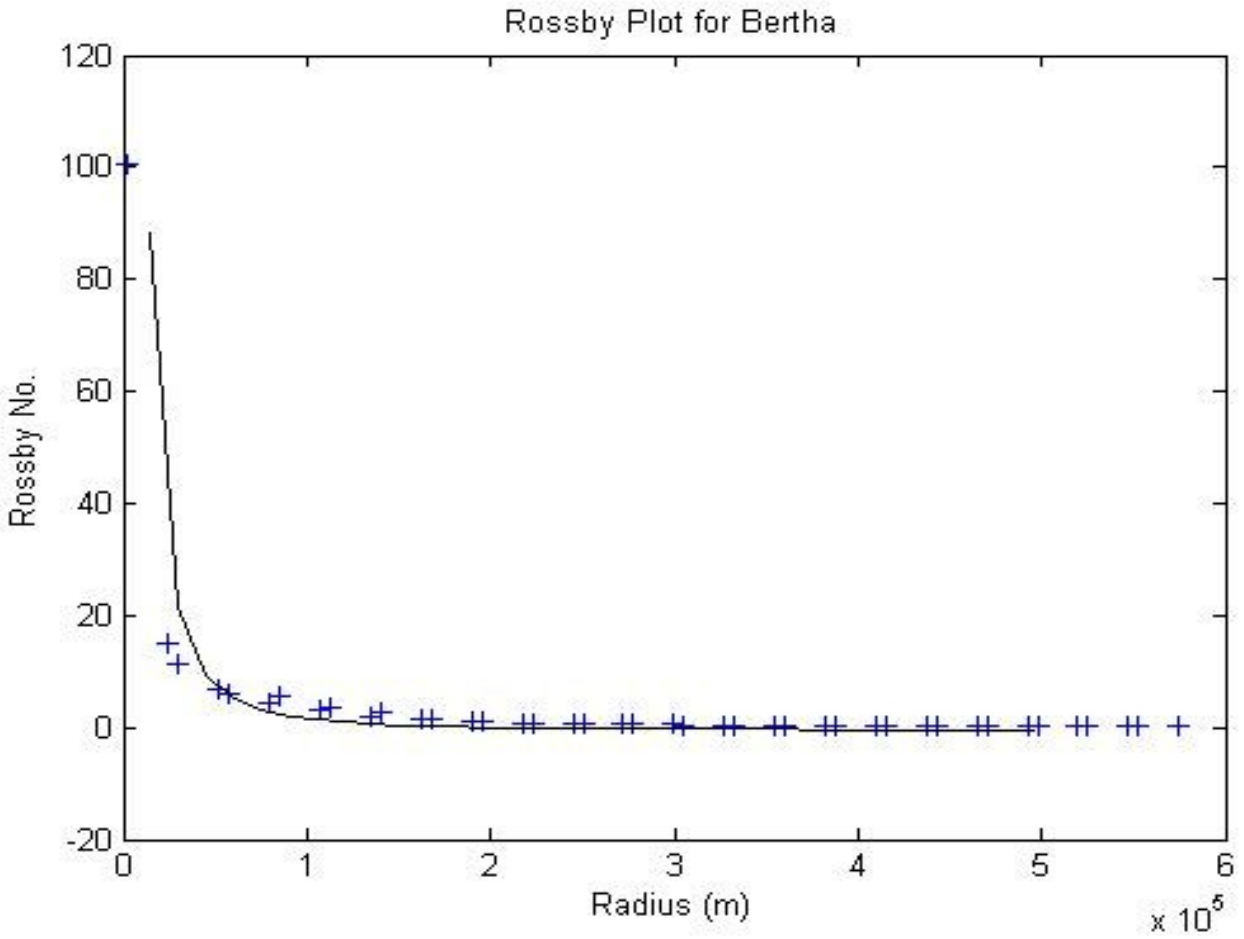
Data Manipulation 2

- From the wind speed contours above, I got the velocities from the various latitudes. From one latitude to the next, you gain 110KM.
- Rossby Number here is given by $V_\theta / (2\Omega r \sin\phi)$
- $fr = 2\Omega r \sin\phi$
- Here since we are on global scale, T = 24 hrs.
- Below is a data and the Rossby Number against radius plot

Data for Bertha's Rossby Plot

Radius (m)	Wind speed (m/s)	fr	Ro
0	20	0	Inf
110000	35	8	4.38
220000	14	16.48	0.85
330000	9	25.43	0.35
440000	6	34.85	0.17
550000	2.5	44.72	0.06

Ro for both southward and northward directions for Bertha



Link between balance of forces and Rossby Number

- If Ro <<1, then we have geostrophic balance and this happens far away from the center and pressure gradient balances with coriolis force
- If Ro >>1, then we have cyclostrophic balance which happens near the center and pressure gradient is balanced by centripetal force.
- The Rossby Number plots that we have seen today show how Ro grows large as we get near r = 0.