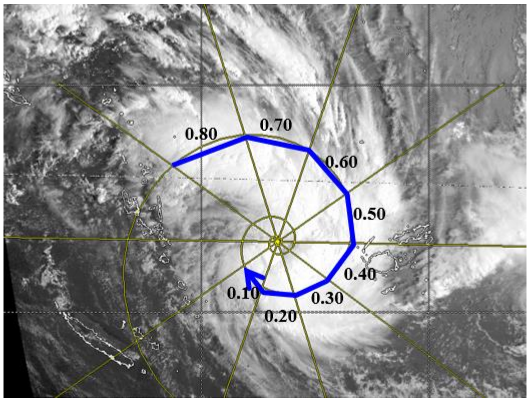
Assignment, tropical cyclones

1) Using the curved band pattern from the Dvorak technique, what is the approximate T number and intensity for this Southern Hemisphere tropical cyclone (10 pts)?



2) Given an environmental pressure p_{env}=1013 mb, central pressure p_c=950 mb, radius of maximum winds r_{max}=25 km, and a storm speed c of 5 ms^{-1} at landfall in the Florida panhandle, using the third column of coefficients, what is p_c 12 hours after landfall (15 pts)?

TABLE 5. Decay constant a, regression parameters (RMW, km; translation speed c, m s^{-1}; and Δp_o, mb; a_0 is the intercept and a_1 is the slope). The largest value of r^2 for each region is in boldface.

		$a = a_0 + a_1 \Delta p_o$				$a = a_0 + a_1 \Delta p_o/\mathrm{RMW}$				$a = a_0 + a_1 \Delta p_o c/\mathrm{RMW}$			
Landfall region	N	a_1	a_0	r^2	σ_ε	a_1	a_0	r^2	σ_ε	a_1	a_0	r^2	σ_ε
Gulf Coast	26	0.00068	0.0244	0.2683	0.0225	0.0120	0.0400	0.4839	0.0189	0.00181	0.0414	**0.5884**	0.0169
Florida Peninsula	13	0.00116	−0.0213	0.3149	0.0325	0.0172	0.0115	0.7442	0.0120	0.00167	0.0225	**0.8378**	0.0158
Atlantic Coast	19	0.00080	0.0110	0.3660	0.0156	0.0245	0.0286	0.2499	0.0170	0.00153	0.0364	**0.3921**	0.0153
Mid-Atlantic Coast	13	0.00074	0.0128	0.3212	0.0174	0.0290	0.0213	0.3776	0.0166	0.00156	0.0370	**0.4206**	0.0161
New England Coast	6	0.00099	0.0034	**0.5471**	0.0114	0.0100	0.0470	0.0287	0.0167	0.00184	0.0304	0.2621	0.0146

3) Estimate the Integrated Kinetic Energy (IKE) of a mature tropical cyclone using:

$$IKE = \int_0^z \int_0^{2\pi} \int_0^{r_{env}} \rho v_t^2(r) r \, dr \, d\theta \, dz$$

where v_t is the tangential winds, ρ is density, r is radius, θ is the azimuthal angle, and z is height. The radius representing the environment of the storm is r_{env}. Assume the following azimuthally averaged v_t profile:

$$v_t(r) = \begin{cases} V_{max} \dfrac{r}{r_{max}}, if\ 0 \le r \le r_{max} \\ V_{max} \dfrac{r_{max}}{r}, if\ r_{max} \le r \le r_{env} \end{cases}$$

which is known as a *Rankine vortex*. V_{max} is the maximum wind of the tropical cyclone located at the radius of maximum winds r_{max}.

Assume the z=15 km, ρ=0.6 kg m^{-3}, r_{env}=1000 km, V_{max}= 50 ms^{-1}, and r_{max}=30 km. For simplicity, ignore v_t's vertical variation. Answer the following:

a) Plot v_t as a function of radius. Using a spreadsheet is recommended, but hand plots are okay (10 pts).
b) Using calculus, write the expression for IKE (3 pts). Show all steps

c) Using the analytical expression, or using a summation technique on a spreadsheet as an alternative, compute IKE in Joules (3 pts).

d) The kilowatt-hour is a unit of energy equivalent to one kilowatt (1 kW) of power sustained for one hour. Convert IKE to kilowatt hours (kW-h). Note that 1 J=2.778X10^{-7} kW-h. If you don't know c, show the calculation steps for full credit (3 pts)

e) If you use 1000 kW-h per month, if the entire hurricane's energy could be converted to electricity, how many years could it power your house? If you don't know c, show the calculation steps for full credit (3 pts)

f) Assuming the population in metro Jackson is 300,000 people and each uses 1000 kW-h, how many years could an entire hurricane power the whole city at 100% efficiency? If you don't know c, show the calculation steps for full credit (3 pts)

g) In reality, at a single point, power $P = \frac{DE}{Dt}$, and for a wind turbine, is limited by the length of the blade and the gear efficiency, typically a "power coefficient" µ of 0.4. At a particular point, the available power from a wind turbine is $P = \frac{1}{2}\mu\rho A V^3$. Assume a wind turbine has blades 52 m long, and hence an area A of $\pi 52^2 = 8495$ m². When the wind turbine is in the eyewall, how much power can the wind turbine generate in kilowatts (3 pts)?

4) If the 850-mb wind is 10 knots from 307 deg, and the 200-mb wind is 25 knots from 160 deg, what is the 850- to 200-mb wind shear in ms^{-1}? Is this favorable for tropical cyclones? (15 pts) Denote direction as ϕ, convert to radians (multiply by $\frac{\pi}{180}$), and note that:

$$u = -\left|\vec{V}\right| \sin\phi$$
$$v = -\left|\vec{V}\right| \cos\phi$$
$$\left|\vec{V}\right| = (u^2 + v^2)^{1/2}$$

5) Eyewall buoyancy exercises. Profile 1 has a 500-mb temperature of -7°C in the standard tropical atmosphere. Suppose Profile 2 is a developing tropical cyclone will have a 500-mb temperature of -4°C near the eyewall. Compute the buoyancy ($T_{parcel} - T_{env}$) at 500 mb using a SkewT (3 pts each)
   a) SST sensitivity, standard tropical atmosphere (Profile 1), relevance to genesis
      i. For an air parcel lifted from 1013 mb, RH=100%, surface temperature of 27°C _____
      ii. For an air parcel lifted from 1013 mb, RH=100%, surface temperature of 29°C _____
   b) pressure sensitivity, eyewall environment (Profile 2), relevance to air-sea interaction process
      i. For an air parcel lifted from 1013 mb, RH=100%, surface temperature of 29°C _____
      ii. For an air parcel lifted from 960 mb, RH=100%, surface temperature of 29°C _____
   c) eyewall environment (Profile 2), relevance to moving over colder water
      i. For an air parcel lifted from 960 mb, RH=100%, surface temperature of 24.5°C _____
      ii. For an air parcel lifted from 960 mb, RH=100%, surface temperature of 22°C _____
   d) eyewall environment (Profile 2), relevance to moving over land
      i. For an air parcel lifted from 960 mb, RH=70%, surface temperature of 24.5°C _____
      ii. For an air parcel lifted from 960 mb, RH=50%, surface temperature of 24.5°C _____

6) Equivalent potential temperature exercise (3 pts each). From Question 5b:

i. For an air parcel lifted from 1013 mb, RH=100%, compute θ_e from the conventional equation. Show calculations below:

ii. For an air parcel lifted from 1013 mb, RH=100%, compute θ_e from Bolton's formulation. Show calculations below:

iii. For an air parcel lifted from 960 mb, RH=100%, compute θ_e from Bolton's formulation. Show calculations below: