EXAM 1 **ATMOS 410** **Due October 15, 2004**

100 points

A. Electromagnetic Waves and Propagation:

1. Suppose that a NEXRAD radar antenna is on a pedestal 50 meters above the ground and is pointed directly at the horizon (elevation angle of 0 degrees). The wavelength of the radar is 10.7 cm. On a particular day, engineers are amazed to find that the beam of the radar remains exactly 50 meters above the ground out to its maximum unambiguous range of 150 km! Answer the following questions about this unusual event. (18 points)

    a. Define the index of refraction.

    b. What atmospheric properties does the index of refraction depend on?

    c. Suppose the index of refraction at the earth's surface was 1.0003 and decreased linearly with height. What must the value of the index of refraction be at an altitude of 1 km for the situation described?

    d. Assume the atmosphere is dry, the pressure at the earth's surface is 1000 mb and the pressure at 1 km is 900 mb. What must the temperature be at the surface and at 1 km for the beam to take this path?

    e. What is the pulse repetition frequency of this radar?

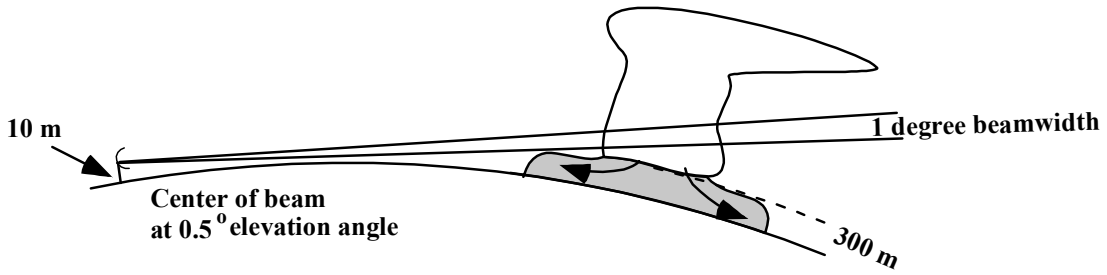
2. Assume that in a particular rainfall, the concentration of raindrops is 1 drop per cubic meter. Within a particular pulse volume, all of the drops are exactly 3 mm in horizontal dimension and have axis ratios (vertical/horizontal) of 0.85. You can assume that although the drops are not actually spherical, they are sufficiently spherical that Rayleigh scattering can be assumed. (11 points)

    a. Suppose that the radar transmits waves at horizontal polarization. What is the radar reflectivity factor in this pulse volume (in dBZ)?

    b. Suppose that the radar transmits waves at vertical polarization. What is the radar reflectivity factor in this pulse volume (in dBZ)? (use the simple vertical and horizontal dimensions to calculate the reflectivity factor.

    c. What characteristic of an electromagnetic wave is associated with the polarization direction?

3. a. In Homework 1, we used the equation $\frac{d^2h}{ds^2} = \frac{1}{r} + \frac{dn}{dh}$ to deduce ray paths. Refer to the diagram below. Suppose that the outflow from a thunderstorm downburst is 300 meters deep. Suppose further that a radar with a 1° beamwidth is located on a pedestal 10 meters above the earth's surface with its antenna pointed so that the center of the beam is exactly 0.5° above the horizon. How far away does the radar have to be from the thunderstorm before it can no longer detect any part of the outflow circulation? (You may assume that dn/dh is constant and has a value of -4×10^{-8} m^{-1} and that the radius of the earth is 6.37×10^6 m). (10 pts)

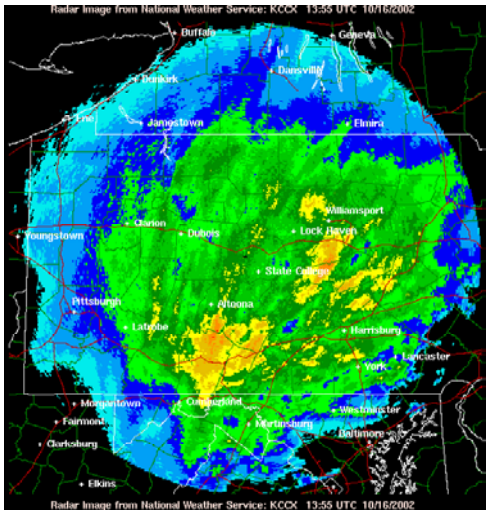


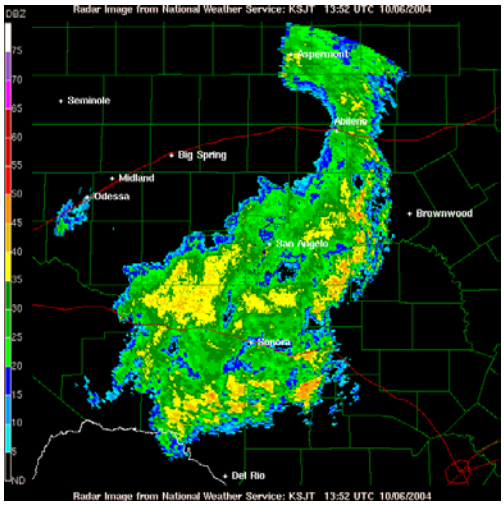
B. Fundamentals of radar

4. The National Weather Service asks you to choose the pulse repetition frequency and wavelength for its new generation radar "WOWRAD". What factors influence the selection of the PRF and λ. (Answer with a list of factors and no more than a sentence or two explaining each point on the list. Extra credit for any Doppler considerations since Doppler is not part of exam). (10 points)

5. Suppose a building were blocking a radar beam. However, on the radar screen, echo appears behind the building even through no electromagnetic energy is illuminating this area. Explain how the echo behind the building comes about. (5 points)

C. Radar displays





6. Shown above are two standard displays of radar data from the National Weather Service during a stratiform rain event in Pennsylvania and a convective event in Texas. Answer the following questions about these displays. (15 points)

    a. What type of display is this?
    b. What parameter is displayed in color on this image?
    c. What would the typical range of this parameter be for stratiform rain?
    d. What would the typical range of this parameter be for convective rain?
    e. What is the precise definition of this parameter?
    f. The stratiform rain has areas where this parameter has high values equivalent to values in the convective rain. Physically, what is causing the high values in each case?

D. The radar equation

7. When deriving the radar equation for weather targets, we made the assumption that the scattering of electromagnetic energy satisfied the Rayleigh Approximation. (6 pts)

    g. What is the Rayleigh Approximation?

    h. What specific assumption about the electric field must be made for the Rayleigh Approximation to be valid?

8. Assume a widespread stratiform rain is viewed in PPI mode with a K band radar. What assumptions made in deriving the weather radar equation are violated above, within, and below the bright band? (9 pts)

9. A mosquito flying across the center of a radar beam will have its internal temperature raised 4°C if it is irradiated by 1000 watts/m^2, causing it to have heart failure. Assuming that the radar emits a peak power of 1 megawatt, and the maximum gain of the radar is 40 db, within what radius from the radar will the poor mosquito be cooked? (6)

E. Relation of Z to other meteorological quantities.

10. Meteorologists use Z/R relationships to estimate rainfall. Based on Homework 2 and our general discussions in class, write a short summary of problems affecting the use and application of Z/R relationships. (10)