ATMS 410 – Radar Meteorology | Homework #1
Due: 15 September 2008 | Beam propagation

The purpose of this assignment is to (1) familiarize yourself with the MATLAB programming environment, which we will use for many assignments for the remainder of the course, and (2) explore variations in radar beam propagation under a variety of atmospheric conditions.

Doviak and Zrnic (1993) provide a complete expression for the propagation of the radar beam above the earth's surface *h* with slant range *r*:

$$h = \sqrt{r^2 + (k_e R_e)^2 + 2rk_e R_e \sin E} - k_e R_e + H_0,$$

where $R_e$ is the earth's radius, *E* is the elevation angle of the antenna, and $H_0$ is the height of the antenna above the surface.

$$k_e = \frac{1}{1 + R_e\left(\frac{dn}{dh}\right)},$$ where *dn/dh* is the vertical gradient in the index of refraction. For standard refraction, $k_e$ is assumed to be 4/3. The index of refraction can be calculated as:

$$n = 1 + 7.76\times10^{-5}\ \text{K hPa}^{-1}\left(\frac{P_d}{T}\right) - 5.6\times10^{-6}\ \text{K hPa}^{-1}\left(\frac{e}{T}\right) + 0.375\ \text{K}^2\text{hPa}^{-1}\left(\frac{e}{T^2}\right),$$

where $P_d$ is the dry atmospheric pressure, *T* is the temperature, and *e* is the water vapor pressure. One formula (Bolton 1980) to convert dewpoint (in °C) to water vapor pressure (in hPa) is:

$$e = 6.112\exp\left(\frac{17.67T_d}{T_d + 243.5}\right).$$

The half power beam radius *a* is given by the half power beam width $\phi_0$ at range *r*:

$$a = r\phi_0 / 2.$$

Please answer the following questions for homework: (Be sure to hand in all work including modified source code for your assignment)

Two radars (with beam width 1.0°) are looking at a storm equidistant from both radars (slant range = 75 km) on the dryline in West Texas. Assume both radars are sited at the same elevation (250 m), but the atmosphere has different atmospheric conditions on either side of the dryline. Assume that the conditions on either side of the dryline are homogeneous, and temperature and dewpoint vary linearly with height. Also, assume that the radars and the storm form a straight line oriented east-west on the map.

On the surface (970 hPa) on the east side of the dryline: T=30°C, Dewpoint=27°C, at 500 hPa (5600 m), T=-10°C, Dewpoint=-10°C.
On the surface (970 hPa) on the west side of the dryline: T=35°C, Dewpoint=-10°C, at 500 hPa (5600 m), T=-10°C, Dewpoint=-10°C.

I have given you the source code, which you will modify for the assignment. Be sure to read over the code and try to figure out what it is doing before you modify it.

(a) Using MATLAB, calculate *dn*/*dh* and $k_e$ for the two atmospheric conditions listed above.

(b) Which of these conditions is closest to standard atmospheric refraction ($k_e = 4/3$)? How can you tell?

(c) Using MATLAB, calculate and plot the beam height of both of these radars as a function of range (from 0 to 200 km) for 0.5°, 1.5°, and 2.5° elevation angles using the $k_e$ values obtained in (a) as well as for the $k_e = 4/3$ case. Discuss the differences in beam height from those assumed for standard refraction.

(d) Assume a mesocyclone with rotation is located at heights between 300 m and 1250 m. Assuming forecasters can't see data from both radars, can both offices see the rotation signature of potentially tornadic storm? Why or why not?